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Review of Nuclear Physics Experiments for Space Radiation

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Abstract

Human space flight requires protecting astronauts from the harmful effects of space radiation. The availability of measured nuclear cross section data needed for these studies is reviewed in the present paper. The energy range of interest for radiation protection is approximately 100 MeV/n to 10 GeV/n. The majority of data are for projectile fragmentation partial and total cross sections, including both charge changing and isotopic cross sections. The cross section data are organized into categories which include charge changing, elemental, isotopic for total, single and double differential with respect to momentum, energy and angle. Gaps in the data relevant to space radiation protection are discussed and recommendations for future experiments are made.

1 Introduction

The space radiation environment is comprised of energetic particles produced from three sources. Firstly, solar particle events (SPE) consist primarily of protons emitted from the Sun during coronal mass ejections (CME) and solar flares. Very large SPEs are rare, but can potentially inflict a lethal radiation dose to astronauts. SPEs can also affect the stability of electronic devices. Energies can reach up to the GeV region. Secondly, galactic cosmic rays (GCR) consist of protons and heavier nuclei emitted from supernovae within the Milky Way Galaxy and are accelerated to the vicinity of the Solar system and elsewhere. GCR particles have energies from 10 A MeV to the ZeV region (Zetta eV = 10^{21} eV). The peak of the spectrum is in the hundreds of MeV to GeV range, which is most important region for space radiation. Thirdly, the geomagnetically trapped particles consist of protons and electrons confined by the magnetic field of Earth. There are two regions called the inner and outer Van Allen radiation belts. Protons and electrons are found in both belts, with the most important being inner belt protons with energies up to a few 100 MeV and beyond, and outer belt electrons with energies up to a few 100 keV and beyond.

It is important to have an accurate knowledge of the particle spectrum at various places in the Solar system where a particular mission will take place. The spectrum is modified when particles impinge on a medium. For instance, the spectrum of particles is modified after traversal through a spacecraft wall, due to the atomic and nuclear reactions that take place. Knowledge of the spectrum on the other side of the medium enables one to determine the accumulated radiation dose that an astronaut receives. Transport codes are used in studies of cosmic rays propagating through various media. If the cosmic ray spectrum incident on top of the Earth's atmosphere is known, then the cosmic ray spectrum observed on the ground can be deduced by transporting through the atmosphere. Similarly, knowing the cosmic ray spectrum incident on a spacecraft allows one to deduce the radiation environment inside the vehicle [Wilson91]. Essential ingredients to transport codes are the atomic, nuclear and particle interaction cross sections. For space radiation purposes, the nuclear cross sections, which describe nuclear interactions and break up are increasingly important as the primary radiation is slowed or stopped in the medium.

The purpose of this paper is to review the data available for nuclear cross sections, with the aim of identifying gaps in the data and recommending future measurements. The focus is on data needed for space radiation, although this report can be useful for other areas such as heavy ion beam therapy. Neutrons projectiles and fragments are not specifically considered in the present work, in order to keep the paper to a reasonable length. However, some neutron projectiles, represented by $Z_P = 0$, occur in the database and on the plots displayed herein. A detailed discussion of neutrons can be found in the book by Nakamura and Heilbronn [Nakamura07]. In the present work, a database has been constructed which compiles the results of all published nuclear physics experiments relevant to space radiation. It consists of about 50,000 entries. Information regarding the types of cross sections measured, journal references, projectile energy, mass numbers, and projectile, target and fragment charge, is included in the database.

1.1 Reactions and cross sections

Table 1 contains a list of symbols used throughout this document. Reaction and cross section notation is summarized in Tables 2 and 3.

1.1.1 Inclusive cross section

The inclusive cross section results when only specified particles are measured. An inclusive reaction is typically denoted as

$$P + T \to F + X \,, \tag{1}$$

where the projectile P and the target T make up the initial state. The final state consists of the measured projectile fragment F and the outgoing particles X, which may or may not be measured. The isotopic notation for an inclusive nuclear reaction is given by

$$^{A_P}Z_P + {}^{A_T}Z_T \to {}^{A_F}Z_F + X \,. \tag{2}$$

where Z refers to the nuclear charge or element. The total nucleon number is defined as $A \equiv Z + N$, where N is the neutron number.

In contrast, an exclusive cross section results when all outgoing particles are assumed to have been detected. An inclusive cross section is the sum of all exclusive cross sections. Theorists typically calculate and sum exclusive processes to obtain the inclusive cross section. However, experimentally it is difficult to measure every exclusive process. It is easier to measure a particular fragment F, which is the inclusive process. Thus, in a simplified way of speaking, exclusive cross sections are easier for theorists to calculate, but more difficult for experimentalists to measure. In contrast, inclusive cross sections are more difficult for theorists to calculate, but easier for experimentalists to measure. More stringent tests of theoretical models can be achieved by comparing theory and experiment for exclusive reactions. Comparing theoretical models to inclusive cross section measurements results in less precise tests of theoretical models.

1.1.2 Charge changing cross section

The charge changing cross section [Westfall79, Webber90a], denoted by $\sigma_{\Delta Z \geq 1}$, is often defined to be the cross section for removing at least one charge from the projectile. The mass changing cross section, $\sigma_{\Delta A \geq 1}$, is defined [Westfall79, Webber90a] to be the cross section for removing at least one nucleon from the projectile. The charge changing cross section is for production of a fragment with a charge different from the projectile. This can refer to a specific fragment or to the total charge changing cross section, which is the cross section for a reaction where the projectile nucleus is not observed in the reaction products. For example, if the projectile nucleus is a ^{12}C projectile, then ^{12}C nuclei are not observed in the reaction products. The terms "total charge changing" and "charge changing" are often used interchangeably. See Table 3 for explanations of cross section notation. In the present work, charge changing cross sections are represented by figures with a light blue background, as shown in Figure 1. In terms of testing theoretical models, the fragment production cross section, which refers to production of a specific element, is a more stringent test than the charge changing cross section.

One way to calculate charge changing cross sections is the following. The total absorption cross section, σ_{abs}, is first calculated for a given projectile and target combination. Next, the cross section for single neutron removal, two neutron removal, three neutron removal, etc. are calculated for the projectile-target system of interest until all neutrons are removed. The charge changing cross section, σ_{cc}, is then computed by subtracting the sum of the neutron removal cross sections from σ_{abs}. More explicitly,

$$\sigma_{cc} = \sigma_{abs} - \sigma_{1n} - \sigma_{2n} - \sigma_{3n} ... - \sigma_{Nn} = \sigma_{abs} - \sum_{j=1}^{N} \sigma_{jn}, \quad (3)$$

where σ_{jn} is the cross section for removing j neutrons from the projectile and N is the number of neutrons in the projectile.

1.1.3 Fragment production (elemental) cross section

Fragment production (or fragmentation or partial charge changing or elemental) cross sections quantify the probability for production of fragments with a given charge. Charge changing cross sections are more easily measured than fragment production (elemental) cross sections. A theorist might first calculate the fragment production cross sections and then sum them to obtain the charge changing cross section. For intermediate to heavy projectiles, most measurements are of fragments in excess of one third of the projectile charge. For heavier projectiles, it is difficult for an experimentalist to accurately identify individual light fragments against the background produced by multiple charged fragments from intermediate to heavy reacting nuclei. The projectile fragment production cross section is for production of a fragment with a given charge. An example is the reaction

$$^{12}\mathrm{C} + {}^{27}\mathrm{Al} \rightarrow \mathrm{Z}_{\mathrm{F}}^{3+} + \mathrm{X}\ , \tag{4}$$

where the cross section is for production of a fragment $\mathrm{Z_F}$, with charge 3. A projectile fragment production cross section is also referred to as a partial fragmentation, partial charge changing, fragmentation, or elemental cross section. The elemental fragmentation cross section, which is listed as $\sigma(\mathrm{Z_F})$ in Table 3, is the cross section for the production of a specific element. In the present work, elemental cross sections are represented by figures shaded in yellow background, as in Figure 2.

Data points comprise many separate, and sometimes overlapping measurements. In a few cases, such as the experimental measurements of Gutbrod et al. [Gutbrod76], light fragments were measured but not heavy fragments. Typically, experiments can be optimized to measure either low Z or high Z fragments, but not both. Most experimental measurements are of fragment production near the beam axis, which is where kinematics dictate that most fragments will be emitted. Therefore, experimental cross section data require correction factors. In addition to corrections for secondary interactions and multiple scattering in the target and detectors, corrections for fragments emitted outside of the detector acceptance rely on assumptions about fragment transverse momentum distributions. Correction methods are specific to each experimental setup and these details should be taken into account when comparing models to data.

In many on-axis experiments, only small corrections are needed to obtain the charge-changing cross sections and fragment cross sections for $\mathrm{Z_F} > \mathrm{Z_{beam}}/2$. This is an important point; in many experiments, total corrections for these cross sections are on the order of 10%, and are not a significant issue. This is the point of doing the experiments on-axis; they are relatively simple and accurate.

1.1.4 Isotopic cross section

The isotopic cross section describes the production of a fragment with a given charge and mass. An example is the reaction

$$^{12}\mathrm{C} + {}^{27}\mathrm{Al} \rightarrow {}^{7}\mathrm{Li} + \mathrm{X}\ . \tag{5}$$

Compared to fragment production (elemental) or charge changing cross sections, isotopic cross sections provide the most stringent test of theoretical models. Isotopic cross sections are more difficult to measure experimentally, because one must identify each separate isotope. In the present work, isotopic cross sections are represented by figures shaded in pink background, as in Figures 3 - 5. Measured isotopic cross sections include inclusive, exclusive, total and differential cross sections with respect to both momentum and angle. The data were measured primarily for investigations of basic nuclear physics or cosmic ray propagation. These aims dictated the choice of energies, collision systems and observables.

1.1.5 Differential cross section

The previous discussions have been concerned with total cross sections, which are related to the total number of particles detected. Angular or energy information has not yet been considered. Differential cross sections are measured as a function of one or more variables, such as fragment energy E, momentum p, or emission angle θ. For example, the single differential cross section, $\frac{d\sigma}{dp}$, is a cross section measured as a function of the single variable p. A double differential cross section, such as $\frac{d\sigma}{dEd\theta}$, is with respect to two variables. Instead of momentum (or energy) and angle, other variables for the double differential cross section are equivalent. Common choices are the longitudinal (z) and transverse ($\perp$) components of momentum,

$$p_z \equiv p\cos\theta \tag{6}$$

$$p_\perp \equiv p\sin\theta. \tag{7}$$

Another commonly used kinematic pair is rapidity and transverse momentum, where rapidity is defined as

$$y \equiv \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right), \tag{8}$$

with

$$E = m_\perp \cosh y \tag{9}$$

$$p_z = m_\perp \sinh y. \tag{10}$$

The transverse mass is defined as

$$m_\perp^2 \equiv m^2 + p_\perp^2 = E^2 - p_z^2, \tag{11}$$

where m is the mass of the fragment.

In summary, the following pairs of kinematic variables are equivalent, (p, θ), $(p_z, p_\perp)$ and $(y, p_\perp)$. Also, use of p is equivalent to E or T, where T is the fragment kinetic energy. The solid angle Ω is equivalent to θ. Kinematic variables are summarized in Table 4. Note that many authors use the symbol E for kinetic energy. In this paper, E describes total energy and T represents kinetic energy. For differential cross sections (usually plotted on a vertical axis), the distinction does not matter because $dE = dT$. However, the horizontal axis on a differential cross section plot is usually the kinetic energy T where the distinction does matter, because $E \neq T$.

A theorist would first calculate a double differential cross section, and then integrate over energy or angle to get a single differential cross section. To obtain a total cross section, the double differential cross section is integrated twice. It is easier for an experimentalist to measure total cross sections. Measurements involving energy or angle are more complicated. For example, it is difficult to measure a double differential cross section because count rates must be obtained for a range of energy at a variety of angles. Furthermore, such experiments must, by definition, be capable of resolving different fragment energies, which implies a more complicated detection scheme than is used in most on-axis experiments. The most stringent test of a theory is comparing a double differential cross section calculation to experiment, and the least stringent test is comparing a total cross section calculation to experiment.

Single differential cross sections are measured with respect to a single observable as the dependent variable. Most measurements were undertaken to elucidate basic nuclear physics issues such as whether bulk nuclear matter exhibits thermodynamic or hydrodynamic behavior. However, angular and momentum distribution data can also be used to differentiate between models and to estimate two and three dimensional dose distributions at depths in materials. The fact that there is only one dependent variable in single differential cross sections does not imply that the data was integrated over all other observables. Consequently, it is important to consider details presented in the literature for each data set. For example, a differential cross section with respect to laboratory angle, $\frac{d\sigma}{d\theta}$ or $\frac{d\sigma}{d\Omega}$, may have a specific acceptance in fragment momentum or energy, as opposed to including all fragment momenta or energies. Differential cross sections with respect to momentum, $\frac{d\sigma}{dp}$, are generally quoted at one or more specific angles or angular acceptances. Acceptances in many cases depend sensitively on model dependent momentum distributions.

Angular distribution cross sections are generally quoted as a function of solid angle Ω, in units of mb/sr. Although, in some cases [Kidd88], acceptance corrections are applied and the tabulated result is quoted as a differential cross section (in mb) at a specific angle. When comparing to models, experimental details must be taken into account. Most angular distributions are published as cross sections with respect to momentum, or as double differential cross sections, as discussed below.

Transverse, $\frac{d\sigma}{dp_\perp}$, and longitudinal, $\frac{d\sigma}{dp_z}$, momentum distributions yield information on the detailed dynamics of nucleus-nucleus collisions, including both initial and final state interactions. Momentum distribution widths are a sensitive test of models and an essential tool for extrapolating from limited angular data. Double differential cross sections measured as a function of both fragment energy (or momentum) and angle are also a stringent test of models. In addition, they provide more detailed information on dose distributions than simple angular distributions integrated over all fragment energies or energy spectra taken at a single angle. However, as seen later, the data are limited.

1.2 Light ion reactions

An important subset of reactions are the light ion reactions represented by

$$\mathrm{A_P} + \mathrm{A_T} \rightarrow \mathrm{L_F} + \mathrm{X}, \tag{12}$$

where $\mathrm{L_F}$ is defined to be a charged fragment with $\mathrm{Z_F} \leq 2$. Thus, a light ion reaction has a light fragment present in the final state, whether in combination with a heavy fragment or not. Inclusive data for light fragments produced by heavy projectiles are very limited, due to the difficulty of separating light fragments from the background generated by multifragmentation. Almost all of the heavy projectile data include only measured fragments with a minimum charge, which is approximately one half that of the projectile. Now consider the different types of cross sections.

1.2.1 Light ion total cross sections

The data [Lindstrom75] for protons emitted near the beam axis are primarily for 1.05 and 2.1 GeV/n ^{12}C, and 2.1 GeV/n ^{16}O. Lindstrom et al. [Lindstrom75] measured ^{1,2,3}H and ^{3,4,6}He in a 12.5 sr cone around 0°. Note that these are actually differential cross section measurements at 0° and not total cross sections, as is often assumed. Neverthless, as the authors state, the forward cross section accounts for 70% - 100% of the total cross section, except for light ions. Measurements of ^{3,4,6}He production have also been made by Kobayashi et al. [Kobayashi88] and Korejwo et al. [Korejwo00, Korejwo02]. Projectile energies are between 790 and 2100 MeV/n, except for data taken by Korejwo et al. [Korejwo00, Korejwo02] for He isotope production from the reaction $^{12}\mathrm{C} + {}^{1}\mathrm{H}$ at 2.69 and 3.66 GeV/n.

1.2.2 Light ion angular differential cross sections

Cross sections for elastic and quasielastic alpha particle scattering at $\theta_{\mathrm{lab}} = 17^{\circ}, 26^{\circ}$ and 45° were reported in reference [Gooding61]. Reference [Poskanzer75] contains plotted angular distributions for ^{3}He and ^{4}He at $\theta_{\mathrm{lab}} = 20^{\circ} - 120^{\circ}$ from 1.05 GeV/n ^{4}He and ^{16}O ions. The most extensive data set is reference [Nagamiya81]. It includes data for ^{1,2,3}H and ^{3,4}He (as well as π^{+} and π^{-}) produced at $\theta_{\mathrm{lab}} = 10^{\circ} - 145^{\circ}$ for 800 and 2100 MeV/n ^{12}C, ^{20}Ne and ^{40}Ar beams. Total inclusive cross sections as a function of angle, as well as double and triple differential cross sections, are tabulated.

1.2.3 Light ion momentum distributions, $\frac{d\sigma}{dp_z}$, $\frac{d\sigma}{dp_\perp}$

The momentum distribution centers and widths for p, d, t and ^{3,4,6}He produced in 1.05 and 2.1 GeV/n ^{12}C and 2.1 GeV/n ^{16}O are tabulated in reference [Greiner75]. Nagamiya [Nagamiya81] has detailed contour plots of proton (and pion) production cross sections in the momentum rapidity plane for 800 MeV/n $^{40}\mathrm{Ar} + \mathrm{KCl}$ and Pb.

1.2.4 Light ion double differential cross sections

Most of the double differential cross section data are for light fragments. Heavy fragment double differential cross sections measurements are rare. There may be a need for some limited sets of angular measurements to verify the assumption [Wilson91] that all of the projectile fragments heavier than He travel in the incident beam direction with essentially no angular spread.

2 Survey of measurements for space radiation

The experimental data that are available for space radiation studies will now be analyzed. Projectile nuclei from H to Ni are the most important with energies up to about 10 GeV/n, although data up to 100 GeV/n would be useful in calibrating theoretical models. Also, heavier nuclei, up to U, can be useful for studies of space electronics. Thus, the broadest region of interest includes the entire periodic table up to 100 GeV/n.

The majority of data referenced in this paper are for projectile fragmentation total cross sections. In addition, charge changing, mass changing, elemental and isotopic cross sections are included. In this report, a fragment is defined as a charged nuclear fragment with a mass and charge that is different from the primary beam particle. In certain special cases (for example, ^{12}C break up into three α particles), an exclusive total fragment production cross section, in which all fragments of a given charge are accounted for, requires a detector arrangement covering 4π steradian in solid angle. No such exclusive measurements have been made in the target, projectile or energy regimes relevant to space radiation studies, although there have been measurements at several different angles. The most extensive and detailed fragment production total cross section data of this type are from survey measurements for astrophysics and space radiation protection applications. For example, see references [Webber90, Webber90a, Webber90b, Webber90c, Webber98, Webber98b], [Cummings90], [Chen94], [Knott96], [Knott97], and also [Zeitlin97], [Zeitlin01], [Zeitlin07], [Zeitlin07a], [Zeitlin08]. In many cases, experimental data includes isotopic cross sections, which will be discussed in the next section. In order to elucidate the knowledge gaps, the data are grouped into several different categories. Note that there is some overlap and some data points appear in more than one grouping.

The energy range of greatest interest for GCR studies is approximately 100 MeV/n to 10 GeV/n. For particle energies less than about 100 MeV/n, energy deposition is dominated by atomic interactions with the target, and nuclear reactions are less important. (Note however, that secondary neutrons produced from these fragments can penetrate through the spacecraft or habitat.) For lunar surface sorties, they can be an issue. Lower energy ions are also of interest for heavy ion therapy. The small number of GCR ions, substantially more energetic than 10 GeV/n, contribute relatively little to radiation dose.

Figures 1 - 68 identify all the cross section measurements relevant to space radiation. Each symbol on each plot represents on or more cross section measurement. Actual cross section values are not provided, because the intent is to identify gaps in the available cross section data relevant for space exploration. The kinetic energy (T) regions are typically broken down into four regions, namely below the pion threshold at 280 MeV/n, then up to 3 GeV/n, then up to 15 GeV/n and finally above 15 GeV/n. The cut-offs at 3 GeV/n and 15 GeV/n were chosen to overlap experiments performed at the Berkeley Bevalac and the Brookhaven Alternating Gradient Synchrotron (AGS) with typical beam energies of 2.1 GeV/n and 14.6 GeV/n, respectively. Henceforth, these energy regions will be defined as follows:

Below the pion threshold: $T < 280$ MeV/n
Low energy: 280 MeV/n $\leq T < 3$ GeV/n
Medium energy: 3 GeV/n $\leq T < 15$ GeV/n
High energy: $T \geq 15$ GeV/n

The projectiles of most interest for space radiation are those from H to Ni. Henceforth, projectiles, targets and fragments will be defined in terms of charge Z as follows:

Light: Z = 1, 2 (H, He isotopes)
Medium-Light: Z = 3 − 9 (Li − F)
Medium: Z = 10 − 19 (Ne − K)
Heavy: Z = 20 − 30 (Ca − Zn)
Very Heavy: Z > 30 (heavier than Zn)

Light to heavy projectiles are of most interest for space radiation. Light projectiles are very abundant and highly penetrating. Light fragments are also highly penetrating. Figures 1 - 62 plot the experimental measurements as a function of projectile charge and target charge. The database contains information on projectile charges ranging across the entire periodic table, however Figures 1 - 62 only show projectile charges up to 30. This cut-off was selected since it is the range of interest for space radiation, and makes it easier to read the projectile charge on the plots.

The galactic cosmic ray spectrum shows local peaks in abundance [Simpson83], relative to their near neighbors, for the following six nuclei: ${}_1$H, ${}_2$He, ${}_6$C, ${}_8$O, ${}_{14}$Si, ${}_{26}$Fe, where charge numbers are indicated as lower case. This is not to say, for example, that ${}_{26}$Fe has a higher abundance than ${}_{10}$Ne for instance. Rather, these six nuclei are most important in terms of contribution to dose in unshielded deep space [Wilson91]. (Note that Mg is just as important as Si. Given that they are close in mass number and have similar shell structure, only Si is emphasized. Even though C and O are similar in mass number, O is doubly magic and C is not. Therefore, both C and O are considered because they have quite different shell structure.)

While it is important to understand the physical interactions of all nuclei up to Ni, it is important to always have these six nuclei represented in any set of projectile measurements. The recommendations presented herein will focus on these six nuclei. Recall that the nuclear magic numbers are 2, 8, 20, 28, 50, 82 and 126, which correspond to fully closed nucleon shells. This is analagous to electron closed shells for inert gases. Nuclei with magic proton numbers are $_2$He, $_8$O, $_{20}$Ca, $_{28}$Ni, $_{50}$Sn and $_{82}$Pb. Note that the naturally occuring isotopes, $^4_2$He, $^{16}_8$O, $^{40}_{20}$Ca, $^{208}_{82}$Pb, are doubly magic (magic numbers of both protons and neutrons). The naturally occurring isotopes of Ni and Sn are $^{59}_{28}$Ni and $^{119}_{50}$Sn, whereas the doubly magic isotopes are $^{56}_{28}$Ni and $^{100}_{50}$Sn. Even though C and O possess similar proton numbers, it is important to have both represented in the experimental data, because one is (doubly) magic and the other is not.

2.1 Targets

Alloys made up primarily of aluminum (Z=13) are the typical material used for spacecraft structures. However, low Z materials have been shown to provide better space radiation protection [Wilson91]. Therefore, targets with Z $\leq$ 13 are of special interest for space radiation. Experimentally, it is rather simple to use a variety of targets. Such data are useful for testing theoretical models. ***In all of the recommendations for future experiments presented below, a range of targets across the periodic table is recommended, unless otherwise noted.*** Note that emulsion targets, which include AgBr [Hyde71], are represented in the database with an average target charge of 41.

Hydrogen targets are of particular interest to cosmic ray transport and space radiation shielding, since hydrogenous materials have highly favorable properties for shielding against charged nuclei [Wilson91]. Figures 1 - 62 show plots of projectile charge versus target charge. As mentioned earlier, the database contains projectile charges across the entire periodic table. However, only projectile charges up to 30 are shown in the plots, for ease in identifying projectiles. The entire range of target charges up to 100 will always be shown. Each symbol on the plots is centered on the projectile charge / target charge value it represents. For example, the symbols that just touch the horizontal axis in Figure 1 represent measurements using H targets with a target charge of 1. Thus, H targets are easily read from the plots. Note that H target cross sections can be obtained in principle using inverse collisions of protons onto heavy targets. However, extracting elemental and isotopic cross sections can be especially challenging. Therefore, it is preferred that hydrogen targets be used for these cross section measurements.

2.2 Charge changing measurements

Charge changing total cross section measurements are shown in Figure 1. Of course, no charge changing measurements exist for H projectiles, because they do not break up into smaller nuclear fragments. Differential cross sections also do not exist, because charge changing involves many fragments. There are obvious gaps below the pion threshold and above 3 GeV/n. The principal gaps are at low and high energies for heavy projectiles (Z = 20 - 30). In particular, there are no data for Fe projectiles at the lowest and highest energies. In addition, there are only a few measurements for light projectiles.

H targets are well represented for low energy, but are poorly represented at all other energies. Exceptions occur for C and Si projectiles below the pion threshold and for O and Si projectiles at medium and high energy. At high energy, there are measurements for S projectiles, but Si is not represented,

Charge changing measurement recommendations are summarized in Table 5. Of course, H projectiles are not considered for charge changing measurements. He projectiles will not be considered either, because the only fragment is H, and this will be considered separately in the H fragments discussion. Although charge changing cross sections have been useful in providing the first tests of theoretical models, further charge changing experiments augment the extensive comparisons between theoretical models and measurements that have been performed to date [Zeitlin11].

2.3 Hydrogen fragment measurements

Hydrogen fragment measurements are shown in Figures 2 - 19. Recommendations are summarized in Table 6 and are discussed in detail below. Elemental energy differential and momentum differential cross section data are not plotted because no data are currently available.

2.3.1 Total cross sections

Total cross sections for elemental H fragments are shown in Figure 2. Total cross sections for isotopic H fragments are shown in Figures 3, 4 and 5. For elemental fragments at low energy, there are a series of measurements for C, Ne and Fe projectiles on a variety of targets. The most serious lack of data is for He and Si projectiles. At low energy, there are measurements for Ne projectiles. These cannot take the place of new O measurements because O is doubly magic, as explained previously. C and O projectile data are also available. However, Si and Fe projectiles are not represented.

Isotopic data can be summed to obtain elemental data. ***Filling in the gaps for isotopic data would supersede the need for filling in gaps in elemental data. Isotopic data provide tests of coalescence models that are used for light ion production modeling***. At medium energy, there is only one elemental measurement, but there are more isotopic measurements, especially for He projectiles. Heavier projectiles are missing. Recommendations for future measurements are summarized in Table 6.

2.3.2 Differential cross sections

Available differential cross sections for elemental and isotopic H fragments are shown in Figures 6 - 19. It can be seen that dE and dΩ data are very sparse, with most of the available data being for H projectiles. At low energy, for ^{1,2,3}H fragments there are parallel momentum data for C and O projectiles on a variety of targets. However, with only parallel momentum measurements, an angular distribution must be assumed in order to extract dE information. For light fragments, the angular information is important. Assumptions cannot be made about the angular distribution because light fragments are scattered over a larger range of angles. Therefore, these parallel momentum distributions, by themselves, are of limited usefulness.

The most complete set of data are double differential cross sections for H isotopes. H projectiles are well represented, except for medium energy deuteron and triton production and at high energy. ***He projectile data are available at low energy, but not at medium energy***. Given that most measurements are double differential, it is worthwhile to continue them to complement existing data sets, since double differential cross sections are the most precise test of theoretical models. Consequently, additional single differential cross section measurements are not recommended. At low energy, He projectiles on several targets are represented, as well as heavier projectiles. At low energy, O measurements on H and a few other light targets would be useful. Fe projectiles are missing. At medium energy there are no data except for H projectiles. Therefore, ***a full set of medium energy measurements are recommended***. Recommendations are summarized in Table 6.

2.4 Helium fragment measurements

Helium fragment measurements are shown in Figures 20 - 38. Recommendations are discussed in detail below and are summarized in Table 7. Elemental momentum differential cross section data are not plotted because no data are currently available.

2.4.1 Total cross sections

Total cross sections for elemental He fragments are shown in Figure 20. Total cross sections for isotopic He fragments are shown in Figures 21, 22 and 23. For elemental fragments at low energy, there are a series of measurements for C, Ne and Fe projectiles on a variety of targets. The most serious lack of data is for He and Si projectiles. For ^{3,4,6}He isotopic fragments at low energy, there are some He projectile measurements on low Z targets. C and O projectile data are also available. However, Si and Fe projectiles are not represented. Filling in the gaps for isotopic data would supersede the need for filling in gaps in elemental data. At medium energy, there are only a couple of elemental measurements, but there are some isotopic measurements. Heavier projectiles are missing. Recommendations for total cross section measurements are summarized in Table 7.

2.4.2 Differential cross sections

Available differential cross sections for elemental and isotopic He fragments are shown in Figures 24 - 38. For He, the situation is similar to that previously found for H fragments;

the data are very sparse. Most of the available data are for H projectiles, with an exception at low energy. For ^{3,4,6}He fragments, there are parallel momentum data for C and O projectiles on a variety of targets. At medium energy, there are transverse momentum distributions for Si projectiles producing ^{6}He fragments. As with H fragments, these parallel momentum distributions, by themselves, are of limited usefulness. Again, as with H fragments, the most complete set of data are for double differential cross sections. For the reasons quoted previously for H fragments, ***it is recommended that double differential cross section measurements be pursued instead of single differential measurements***. These recommendations are summarized in Table 7.

2.5 Medium-light ($Z_F = 3 - 9$) fragment measurements

Medium-light fragment measurements are shown in Figures 39 - 48. Recommendations are discussed in detail below and are summarized in Table 8. H and He projectiles are not considered herein because projectile fragmentation will not produce medium-light fragments.

2.5.1 Total cross sections

Total cross sections for elemental and isotopic medium-light fragments are shown in Figures 39 and 40. At low energy, elemental cross sections are well represented and there is a reasonable representation of isotopic measurements. The data seems sufficient, so no new measurements are recommended. At medium energy, there is a lack of elemental and isotopic cross section data for C and Fe projectiles and isotopic data for O projectiles. At high energy, the elemental S measurements will suffice, instead of new elemental Si measurements. Recommendations are summarized in Table 8.

2.5.2 Differential cross sections

For non-light fragments there remain discrepancies in the codes when compared to large and small acceptance zero degree data, owing circumstantially to incorrect transverse momentum assumptions in the code. Therefore, a range of double differential cross section measurements for medium-light fragments is being made for C, O, Si and Fe. (He projectiles will not produce medium-light fragments except in pick-up reactions.) A full range of measurements is recommended, as shown in Table 8.

2.6 Medium ($Z_F = 10 - 19$) fragment measurements

Medium fragment measurements are shown in Figures 49 - 57. Recommendations are discussed in detail below and are summarized in Table 9. Projectiles with $Z \leq 10$ are not considered herein, because projectile fragmentation will not produce medium fragments.

Elemental momentum differential cross section data are not plotted because of the lack of available data.

2.6.1 Total cross sections

Total cross sections for elemental and isotopic medium fragments are shown in Figures 49 and 50. Low energy elemental cross sections are well represented and there is a reasonable representation of isotopic measurements. The data seems sufficient, therefore no new measurements are recommended. At medium energy, there is a lack of elemental and isotopic cross sections for Fe projectiles. At medium energy, medium fragment total cross sections should be measured for Fe projectiles. At high energy, the elemental S measurements will suffice, instead of new elemental Si data. Recommendations are summarized in Table 9.

2.6.2 Differential cross sections

Figures 51 - 57 show that existing differential cross section measurements for medium fragments are even more sparse than for medium-light fragments. A range of double differential cross section measurements for medium fragments is being recommended for Si and Fe projectiles. (He, C and O projectiles will not produce medium fragments except in pick-up reactions.) Recommendations are shown in Table 9.

2.7 Heavy ($Z_F = 20 - 30$) fragment measurements

Heavy fragment measurements are shown in Figures 58 - 62. Recommendations are discussed in detail below and are summarized in Table 10. Projectiles with $Z \leq 20$ are not considered, because projectile fragmentation will not produce heavy fragments. Elemental energy differential, isotopic energy differential, elemental angular differential, elemental momentum differential cross sections and isotopic momentum differential cross sections are not plotted because of the lack of available data.

2.7.1 Total cross sections

Total cross sections for elemental and isotopic heavy fragments are shown in Figures 58 and 59. Low energy elemental cross sections are well represented and there is a reasonable representation of isotopic measurements. The data seems sufficient, so no new measurements are recommended. At medium energy, there is a lack of elemental and isotopic cross sections for Fe projectiles. At medium energy, heavy fragment total cross sections should be measured for Fe projectiles. Recommendations are summarized in Table 10.

2.7.2 Differential cross sections

Figures 60 - 62 show that existing measurements for heavy projectiles are extremely sparse. $Z_F = 20 - 30$ fragments produced by Fe projectiles are expected to continue with approximately the same trajectory as the projectile. Nevertheless, this should be checked. These fragments will be produced from H, He, C, O and Si projectiles only for pick-up, but not fragmentation reactions. Fe projectiles will produce heavy fragments in fragmentation reactions. Therefore, a range of experiments is being recommended for Fe projectiles.

2.8 Hydrogen targets

Figure 63 shows all cross sections plotted as a function of projectile charge and energy for H targets, which shows that ***there are significant gaps for most projectiles below the pion threshold and at medium and high energy. It is recommended that an extensive set of measurements on H targets be performed.***

2.9 Isotopic data for ^{4}He, ^{12}C, ^{16}O, ^{28}Si, ^{56}Fe projectiles

The information being presented in the elemental cross section figures, such as Figures 2 and 20, represents points in a multi-dimensional space. Each individual plot in Figure 2, for example, consists of the 2-dimensional space of (Z_P, Z_T). With the four plots of Figure 20 each representing different kinetic energy T regions, the space is 3-dimensional, namely (Z_P, Z_T, T). Figures 2 and 20 contain this 3-dimensional information for particular elemental fragments Z_F, expanding the space to the 4-dimensions of (Z_P, Z_T, T, Z_F). The space is further expanded when considering isotopic fragments, such as Figures 3, 4 and 5, with the 5-dimensional space being (Z_P, Z_T, T, Z_F, A_F). Finally, the different cross section types, such as σ, $\frac{d\sigma}{dE}$, $\frac{d\sigma}{d\Omega}$, etc., expand to a 6-dimensional space consisting of (Z_P, Z_T, T, Z_F, A_F, Σ_i), where Σ_i denotes the different types of cross sections. The entire collection of plots in this paper represent a single plot in this 6-dimensional space, and judicious choices have been made in presenting the 2-dimensional slices of this 6-dimensional space. In Figures 1 - 62, the 2-dimensional slices have been (Z_P, Z_T), with other dimensions represented as separate plots. Figure 63 presents a (Z_P, T) slice for H ($Z_T = 1$) targets.

A 2-dimensional slice of interest is the plane (Z_F, A_F) for each of the six important GCR nuclei ^{1}H, ^{4}He, ^{12}C, ^{16}O, ^{28}Si and ^{56}Fe shown in Figures 64 - 68. The question is: Are all important isotopic fragments measured for the six important GCR nuclei? (^{1}H projectiles are not of interest, because they do not fragment (apart from charge changing into neutrons), although they can undergo pick-up reactions.)

Consider Figure 64, which shows (Z_F, A_F) total cross sections for ^{4}He projectiles at a variety of energies. One clearly sees the isotopic fragments ^{1,2,3}H and ^{3}He, which are precisely the important fragments for which one wants cross section data. (^{4}He fragments do not represent a fragmentation reaction and ^{6}He fragments involve a two neutron pickup with a low cross section. Therefore, these two fragments are of considerably less importance for ^{4}He projectiles.) However, this information for ^{1,2,3}H and ^{3}He fragments is already contained in Figures 3, 4, 5 and 21, which actually convey more information because the target charge Z_T is also represented. Therefore, Figure 64 is redundant, but is included in order to clarify the discussion. The other isotopic fragment cross sections of Figures 65 - 68 are not redundant, and are of interest because the information has not been captured in previous figures which only cover a range of fragment charges, such as $Z_F = 3 - 9$, $Z_F = 10 - 19$ or $Z_F = 20 - 30$. Clearly, the information referring to ^{1,2,3}H or ^{3,4,6}He fragments in Figures 64 - 68 is redundant since it has been displayed previously. *Careful examination of Figures 3 - 5 and Figures 21 - 23 will reveal consistency with* ^{1,2,3}H *and* ^{3,4,6}He *isotope information displayed in Figures 64 - 68. Equivalently, the recommendations for* ^{1,2,3}H *and* ^{3,4,6}He *isotope measurements in Tables 6 and 7 are consistent with all the Figures 3 - 5, 21 - 23 and 64 - 68. In checking these consistencies, the target information needs to be carefully considered.*

Therefore, focus has been placed on only non-light fragments in Figures 65 - 68. Consider the ^{12}C projectile data in Figure 65. Fragment data are well represented in all energy regimes, except high energy. Consider the ^{16}O projectile data in Figure 66. Data are well represented at low energy, but there are major gaps below the pion threshold and at intermediate and high energy. Consider the ^{28}Si projectile data in Figure 67. There are major gaps at all energies. Consider the ^{56}Fe projectile data in Figure 68. The low energy region is well represented with major gaps at all other energies. The corresponding new measurement recommendations are summarized in Table 11.

Appendices 1 and 2 describe inverse kinematics and relations between cross sections. Table 12 summarizes all the measurements.

3 Conclusions

A database has been created which contains information on all nuclear physics experiments, relevant to space radiation protection, that have been performed to date. However, neutrons are not considered. This paper has focused on the nuclei prominent in the galactic cosmic ray spectrum, namely H, He, C, O, Si and Fe. Recommendations have been made for charge changing, elemental and isotopic measurements. These recommendations have been summarized in Tables 5 - 10. Isotopic cross sections are the most difficult to measure, but provide the best test of theoretical models and are the preferred measurement type. Overall, there are a surprisingly large number of gaps in the experimental data concerning the important galactic cosmic ray nuclei mentioned above. This represents a significant gap in validating theoretical models.

Finally, a prioritized list of experimental measurements is now presented. The experiments are summarized in the Tables, which are listed in priority order below. Within the tables themselves, double differential cross sections are a higher priority than total cross sections.

1. Finish analysis of existing data
2. Complete the set of measurements listed in Table 7
3. Complete the set of measurements listed in Table 6
4. Complete the set of measurements listed in Table 11
5. Complete the set of measurements listed in Table 8
6. Complete the set of measurements listed in Table 9
7. Complete the set of measurements listed in Table 10
8. Complete the set of measurements listed in Table 5

The reasoning for this priority order has already been discussed in the text, but some of the reasons are worth repeating here. The light ions of H and He are especially important due to their high penetrating power and their large angular spread from the beam. Therefore, double differential cross sections for light ions are especially important, which is why the experiments listed in Tables 7 and 6 are of high priority. As previously discussed, the projectiles of H, He, C, O, Si, Fe are particularly prominent and it is important to have an accurate knowledge of all the fragments produced from these projectiles. This is why Table 11 is next on the priority list. The measurements listed in Tables 8, 9, 10 are in that order because lighter fragments undergo more deflection than heavier fragments, making measurements of double differential cross sections more important for light fragments than for heavier ones. Finally, completion of the experiments listed in Table 5 would provide a nearly complete set (from a space radiation perspective) of charge changing cross section measurements.

4 Appendix 1: Inverse kinematics

If one has, for example, cross section data for the reaction $^4\mathrm{He}+^{12}\mathrm{C}$, then this same data will, of course, suffice for the reaction $^{12}\mathrm{C}+^4\mathrm{He}$. However, the projectile energies will be different in each case. The use of such inverse kinematics greatly reduces the need to perform separate experiments. A brief review of inverse kinematics is presented here.

The notation is as follows. Subscripts will refer to the projectile or target nuclei, and sub-subscripts will refer to the projectile or target reference frame. For example, the quantity $E_{\mathrm{T_P}}$ refers to the total energy of the target as measured in the projectile frame. The quantity $T_{\mathrm{P_T}}$ refers to the kinetic energy of the projectile as measured in the target frame. The symbol $x_{\mathrm{P_P}}$ refers the quantity x of the projectile as measured in the projectile frame. Mass m always refers to rest mass and so is independent of the frame. Thus, m_P and m_T refer to the projectile and target rest mass (as measured in any frame). Finally, the notation $(x)_\mathrm{P}$ or $(x)_\mathrm{T}$ denotes the quantity in parenthesis as measured in the projectile or target frames, respectively.

The square of the projectile and target 4-momenta as measured in the projectile frame is equal to the square of the projectile and target 4-momenta as measured in the target frame,

$$\begin{aligned}(\tilde{p}_\mathrm{P}+\tilde{p}_\mathrm{T})^2_\mathrm{P} &= (\tilde{p}_\mathrm{P}+\tilde{p}_\mathrm{T})^2_\mathrm{T} \\ m_\mathrm{P}^2+m_\mathrm{T}^2+(2\tilde{p}_\mathrm{P}\cdot\tilde{p}_\mathrm{T})_\mathrm{P} &= m_\mathrm{P}^2+m_\mathrm{T}^2+(2\tilde{p}_\mathrm{P}\cdot\tilde{p}_\mathrm{T})_\mathrm{T}. \end{aligned} \tag{13}$$

The 4-vector scalar product (also invariant) is

$$\tilde{p}_1\cdot\tilde{p}_1 \equiv E_1E_2-\mathbf{p}_1\cdot\mathbf{p}_2. \tag{14}$$

Note also that

$$\begin{aligned}\mathbf{p}_{\mathrm{P_P}} &\equiv 0 \qquad \Rightarrow \quad E_{\mathrm{P_P}}=m_\mathrm{P} \\ \mathbf{p}_{\mathrm{T_T}} &\equiv 0 \qquad \Rightarrow \quad E_{\mathrm{T_T}}=m_\mathrm{T}. \end{aligned} \tag{15}$$

Equation (13) reduces to

$$m_\mathrm{P}E_{\mathrm{T_P}} = m_\mathrm{T}E_{\mathrm{P_T}} \tag{16}$$

or

$$E_{\mathrm{T_P}} = \frac{m_\mathrm{T}}{m_\mathrm{P}}E_{\mathrm{P_T}}. \tag{17}$$

This formula shows how to convert from the energy of the projectile as measured in the target frame to the energy of the target as measured in the projectile frame. It is easily shown that a similar formula holds for the kinetic energies,

$$T_{\mathrm{T_P}} = \frac{m_\mathrm{T}}{m_\mathrm{P}}T_{\mathrm{P_T}}. \tag{18}$$

Consider the reaction $p +^{12}$ C. Assuming that the mass of ^{12}C is roughly 12 times the mass of the proton, gives

$$T_{p\mathrm{C}} = \frac{1}{12} T_{\mathrm{C}_p}, \tag{19}$$

which says that the kinetic energy of the proton in the C frame is $\frac{1}{12}$ times the kinetic energy of the C in the proton frame. That is, the kinetic energy of the projectile in the reaction $p +^{12}$ C is $\frac{1}{12}$ times the kinetic energy of the projectile in the $^{12}\mathrm{C} + \mathrm{p}$ reaction. Here, the kinetic energy is measured in MeV and not MeV/n. Note that for the special case of a nucleon-nucleus reaction, if the kinetic energy is measured in MeV/n then there is no mass conversion factor. That is, for example, if the kinetic energy of the nucleus is 1000 MeV/n in a nucleus-nucleon reaction then the inverse kinematic kinetic energy of the nucleon in the nucleon-nucleus reaction will also be 1000 MeV/n (which for the case of a nucleon is 1000 MeV). Thus, for nucleon-nucleus reactions, inverse kinematics is trivial when measuring in units of MeV/n. Finally, one can easily show that equation (18) implies that the speed of the projectile in the target frame is the same as the speed of the target in the projectile frame, as it should be. Each observer sees the other one moving at the same speed,

$$\beta_{\mathrm{T_P}} = \beta_{\mathrm{P_T}}. \tag{20}$$

5 Appendix 2: Relations between cross sections

It is important to note that the charge changing cross section is *not* simply the sum of the elemental cross sections, i.e.

$$\sigma(\mathrm{cc}) \neq \sum_{\mathrm{Z_F}} \sigma(\mathrm{Z_F}).$$

Similarly, the elemental cross section is *not* simply the sum of the isotopic cross sections, i.e.

$$\sigma(\mathrm{Z_F}) \neq \sum_{\mathrm{A_F}} \sigma(\mathrm{A_F}).$$

To see this, consider the following reaction.

$$\mathrm{Be} + \mathrm{T} \to \mathrm{F} + \mathrm{T},$$

where T represents the target and F represents the fragments. Rewrite this reaction in terms of nuclear charge denoted by numbers, i.e.

$$\begin{aligned} 4 + \mathrm{T} &\to 31 + \mathrm{T} \\ &\to 22 + \mathrm{T} \\ &\to 211 + \mathrm{T} \\ &\to 111 + \mathrm{T} \end{aligned}$$

where, for example, the notation $4 + \mathrm{T} \to 31 + \mathrm{T}$ means $4 + \mathrm{T} \to 3 + 1 + \mathrm{T}$ which is the reaction $\mathrm{Be} + \mathrm{T} \to \mathrm{Li} + \mathrm{H} + \mathrm{T}$.

The cross section for producing $\mathrm{Z_F} = 1, 2, 3$ (H,He,Li) contains the following terms,

$$\begin{aligned} \sigma(3) &\sim |\langle 31|t|i\rangle|^2 \\ \sigma(2) &\sim |\langle 22|t|i\rangle + \langle 211|t|i\rangle|^2 \\ \sigma(1) &\sim |\langle 31|t|i\rangle + \langle 211|t|i\rangle + \langle 111|t|i\rangle|^2, \end{aligned}$$

where transition operator t matrix elements are denoted as $\langle f|t|i\rangle$. The initial state is $|i\rangle \equiv |4 + \mathrm{T}\rangle$ and the T state is suppressed (not written explicitly) in the final states $\langle f|$. Statistical weighting factors due to different possible arrangements of the final states are not written explicitly. For example, there would be a factor of 3! outside the $\langle 111|t|i\rangle$ term.

The charge changing cross section contains the following terms

$$\sigma(\mathrm{cc}) \sim |\langle 31|t|i\rangle + \langle 22|t|i\rangle + \langle 211|t|i\rangle + \langle 111|t|i\rangle|^2.$$

Even if one ignores all the cross terms resulting from expanding the modulus squared $|x|^2$, such as $\langle 31|t|i\rangle\langle 22|t|i\rangle$, it is evident that

$$\sum_{\mathrm{Z_F}} \sigma(\mathrm{Z_F}) > \sigma(\mathrm{cc}),$$

where $\sum_{\mathrm{Z_F}} \sigma(\mathrm{Z_F}) = \sigma(3) + \sigma(2) + \sigma(1)$. This is because

$$\begin{aligned} |\langle 31|t|i\rangle|^2 + |\langle 22|t|i\rangle + \langle 211|t|i\rangle|^2 + |\langle 31|t|i\rangle + \langle 211|t|i\rangle + \langle 111|t|i\rangle|^2 \\ > |\langle 31|t|i\rangle + \langle 22|t|i\rangle + \langle 211|t|i\rangle + \langle 111|t|i\rangle|^2, \end{aligned}$$

assuming that minus signs don't occur in cross terms such that significant cancellations occur. A similar argument also shows that

$$\sum_{\mathrm{A_F}} \sigma(\mathrm{A_F}) > \sigma(\mathrm{Z_F}).$$

Table 1: Symbols

Symbol	Meaning
n	Neutron
p	Proton
d	Deuteron
t	Triton
h	Helion
α	Alpha particle
Z	Proton number
N	Neutron number
A	Nucleon number (A $\equiv$ Z+N)
A_P	Nucleon number of projectile
A_T	Nucleon number of target
A_F	Nucleon number of fragment
H	Heavy ion ($A > 4$)
L	Light ion ($A \leq 4$)
P	Projectile
T	Target
F	Fragments (Defined as projectile nuclei that have lost one of more nucleons. However, a projectile nucleus in the final state is not classified as a fragment.)
X	Unspecified reaction product
H_P	Heavy ion projectile
H_T	Heavy ion target
H_F	Heavy ion fragment
L_P	Light ion projectile
L_T	Light ion target
L_F	Light ion fragment
^{A}Z	Isotope
$^{A_P}Z_P$	Projectile isotope
$^{A_T}Z_T$	Target isotope
$^{A_F}Z_F$	Fragment isotope
MeV/n	Kinetic energy in units of MeV per nucleon e.g. 100 MeV/n for ^{12}C implies a nuclear kinetic energy of 1200 MeV
GeV/n	Kinetic energy in units of GeV per nucleon

Table 2: Reaction notation.

Symbol	Explanation
$\mathrm{P} + \mathrm{T} \rightarrow \mathrm{F} + \mathrm{X}$	Notation for an inclusive nuclear reaction. The projectile appears first on the left hand side, and the target appears second. The projectile fragment F appears first on the right hand side.
${}^{A_P}Z_P + {}^{A_T}Z_T \rightarrow {}^{A_F}Z_F + X$	Isotopic notation for an inclusive nuclear reaction.

Table 3: Cross section definitions. Several names are listed for $\sigma(\mathrm{Z_F})$, in accordance with literature conventions.

Symbol	Names	Explanations
$\mathrm{Z_F}$	Fragment proton number	
σ	Total cross section	
$\sigma_{\Delta Z \geq 1}$	*Total* charge changing cross section Charge changing cross section	Cross section for a reaction where the projectile nucleus is not observed in the reaction products.
$\sigma(\mathrm{Z_F})$	*Partial* charge changing cross section Projectile fragmentation cross section Fragmentation cross section Fragment production cross section Partial fragmentation cross section Elemental fragmentation cross section	
$\sigma(^{\mathrm{A_F}}\mathrm{Z_F})$	Isotopic cross section	

Table 4: Kinematic variables (with $c \equiv 1$).

Variable	Meaning
T	Kinetic energy
E	Total energy, $E = T + m$
$p \equiv \|\mathbf{p}\|$	Magnitude of 3-momentum, as in $E^2 = \mathbf{p}^2 + m^2$
θ	Angle
Ω	Solid angle
p_z	Longitudinal 3-momentum
$p_\perp$	Transverse (perpendicular) 3-momentum
y	Rapidity
$\tilde{p}$	4-momentum, $\tilde{p}^2 = E^2 - \mathbf{p}^2 = m^2$

Table 5: ***Charge changing total cross section measurement recommendations***. A range of targets is needed. The notation (T) indicates that only a few additional targets are required. The notation, "$< \pi$ threshold" signifies projectile energies below the pion threshold. As explained in the text, H and He projectiles are not considered for charge changing measurements.

Cross section	$< \pi$ threshold projectile	Low energy projectile	Medium energy projectile	High energy projectile
σ	O,Fe	–	C,Fe(T)	C,Fe

Table 6: ***H elemental and ^{1,2,3}H isotopic fragment measurement recommendations***. "All" projectiles signifies He, C, O, Si, Fe. Projectiles needed for *only* H targets are listed with (H). Projectiles needed for a range of targets, *except* H, are listed with ($\not{H}$). No parentheses indicates that a range of targets, including H, is needed. The notation (T) means that only a few additional targets are required. H projectiles are not considered.

Cross section	Fragment	Below π threshold projectile	Low energy projectile	Medium energy projectile	High energy projectile
σ	H	All	He,O,Si,Fe(T)	All	All
	^{1,2,3}H	He(T),C,O(H),Si,Fe	He($\not{H}$),O(T),Si,Fe	He(H),C($\not{H}$),O,Si,Fe	All
dEdΩ	H	All	All	All	All
	^{1,2,3}H	He(H),C,O(H),Si,Fe	O,Si,Fe	All	All

Table 7: ***He elemental and ^{3,4,6}He isotopic fragment measurement recommendations***. "All" projectiles signifies He, C, O, Si, Fe. Projectiles needed for *only* H targets are listed with (H). Projectiles needed for a range of targets, *except* H are listed with ($\not{H}$). No parentheses indicates that a range of targets, including H, is needed. The notation (T) indicates that only a few additional targets are required.

Cross section	Fragment	Below π threshold projectile	Low energy projectile	Medium energy projectile	High energy projectile
σ	He	All	He,O,Si,Fe(T)	All	All
	^{3}He	He(T),C,O(H),Si,Fe	He($\not{H}$),O(T),Si,Fe	He(H),C($\not{H}$),O,Si,Fe	All
	^{4}He	He(T),C,O(H),Si($\not{H}$),Fe	He,Si($\not{H}$),Fe	He,C($\not{H}$),O,Si,Fe	All
	^{6}He	All	He,O(T),Si,Fe	He,C($\not{H}$),O,Si(H),Fe	All
dEdΩ	He	All	All	All	All
	^{3}He	He(H),C,O(H),Si,Fe	O,Si,Fe	All	All
	^{4}He	He(H),C,O(H),Si,Fe	O,Si,Fe	All	All
	^{6}He	All	He,O,Si,Fe	All	All

Table 8: ***Medium-light ($\mathbf{Z_F}$=3 - 9) elemental and isotopic fragment measurement recommendations***. A complete measurement set for C, O, Si and Fe projectiles would be required to fill this gap. Projectiles needed for *only* H targets are listed with (H). Projectiles needed for a range of targets, *except* H, are listed with ($\not\mathrm{H}$). No parentheses indicates that a range of targets, including H, is needed. H and He projectiles are not considered, because projectile fragmentation will not produce medium-light fragments.

Cross section	Fragment	Below π threshold projectile	Low energy projectile	Medium energy projectile	High energy projectile
σ	Elemental	C(T),O,Fe	–	C($\not\mathrm{H}$),O(H),Fe	C,Fe
	Isotopic	C(H),O,Si,Fe	Fe($\not\mathrm{H}$)	C($\not\mathrm{H}$),O,Si(H),Fe	C,O,Si,Fe
dEdΩ	Elemental	C,O,Si,Fe	C,O,Si,Fe	C,O,Si,Fe	C,O,Si,Fe
	Isotopic	C,O,Si,Fe	C,O,Si,Fe	C,O,Si,Fe	C,O,Si,Fe

Table 9: ***Medium ($\mathbf{Z_F}$=10 - 19) elemental and isotopic fragment measurement recommendations***. Projectiles needed for *only* H targets are listed with (H). Projectiles needed for a range of targets, *except* H, are listed with ($\not\mathrm{H}$). No parentheses indicates that a range of targets, including H, is needed. Projectiles with Z $\leq$ 10 are not considered, because projectile fragmentation will not produce medium fragments.

Cross section	Fragment	Below π threshold projectile	Low energy projectile	Medium energy projectile	High energy projectile
σ	Elemental	Fe	–	Fe	Fe
	Isotopic	Si($\not\mathrm{H}$),Fe	–	Fe	Fe($\not\mathrm{H}$)
dEdΩ	Elemental	Si,Fe	Si,Fe	Si,Fe	Si,Fe
	Isotopic	Si,Fe	Si,Fe	Si,Fe	Si,Fe

Table 10: ***Heavy (Z_F=20 - 30) elemental and isotopic fragment measurement recommendations***. Projectiles needed for *only* H targets are listed with (H). Projectiles needed for a range of targets, *except*, H are listed with ($\not{H}$). No parentheses indicates that a range of targets, including H, is needed. Projectiles with Z $\leq$ 20 are not considered, because projectile fragmentation will not produce heavy fragments.

Cross section	Fragment	Below π threshold projectile	Low energy projectile	Medium energy projectile	High energy projectile
σ	Elemental	Fe	–	Fe	Fe
	Isotopic	Fe	–	Fe	Fe($\not{H}$)
dEdΩ	Elemental	Fe	Fe	Fe	Fe
	Isotopic	Fe	Fe	Fe	Fe

Table 11: ***Non-light ($Z_F \geq 3$) isotopic fragment total cross section measurement recommendations for ^{12}C, ^{16}O, ^{28}Si, ^{56}Fe projectiles***. Fragment recommendations are listed in terms of fragment charge Z_F. Measurements should be made for as many fragment masses A_F as possible, on a variety of targets.

Projectile	Below π threshold projectile	Low energy projectile	Medium energy projectile	High energy projectile
^{12}C	–	–	–	$Z_F = 1 - 6$
^{16}O	$Z_F = 3 - 8$	–	$Z_F = 3 - 8$	$Z_F = 3 - 8$
^{28}Si	$Z_F = 3 - 14$	$Z_F = 3 - 7$	$Z_F = 3 - 14$	$Z_F = 3 - 14$
^{56}Fe	$Z_F = 3 - 26$	–	$Z_F = 3 - 26$	$Z_F = 3 - 17, 19,$ 20,22,25,26

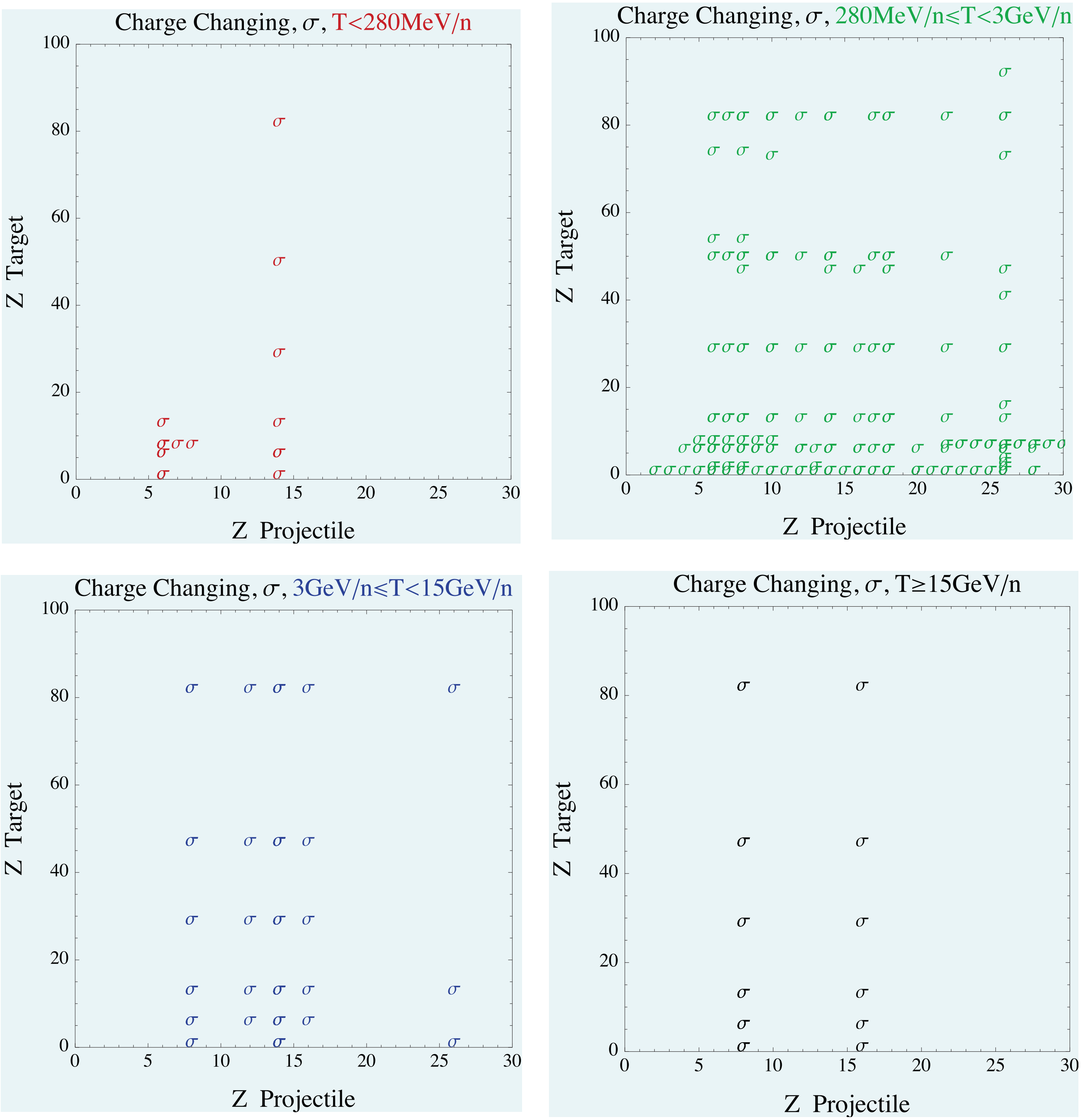


Figure 1: Charge changing total cross sections.

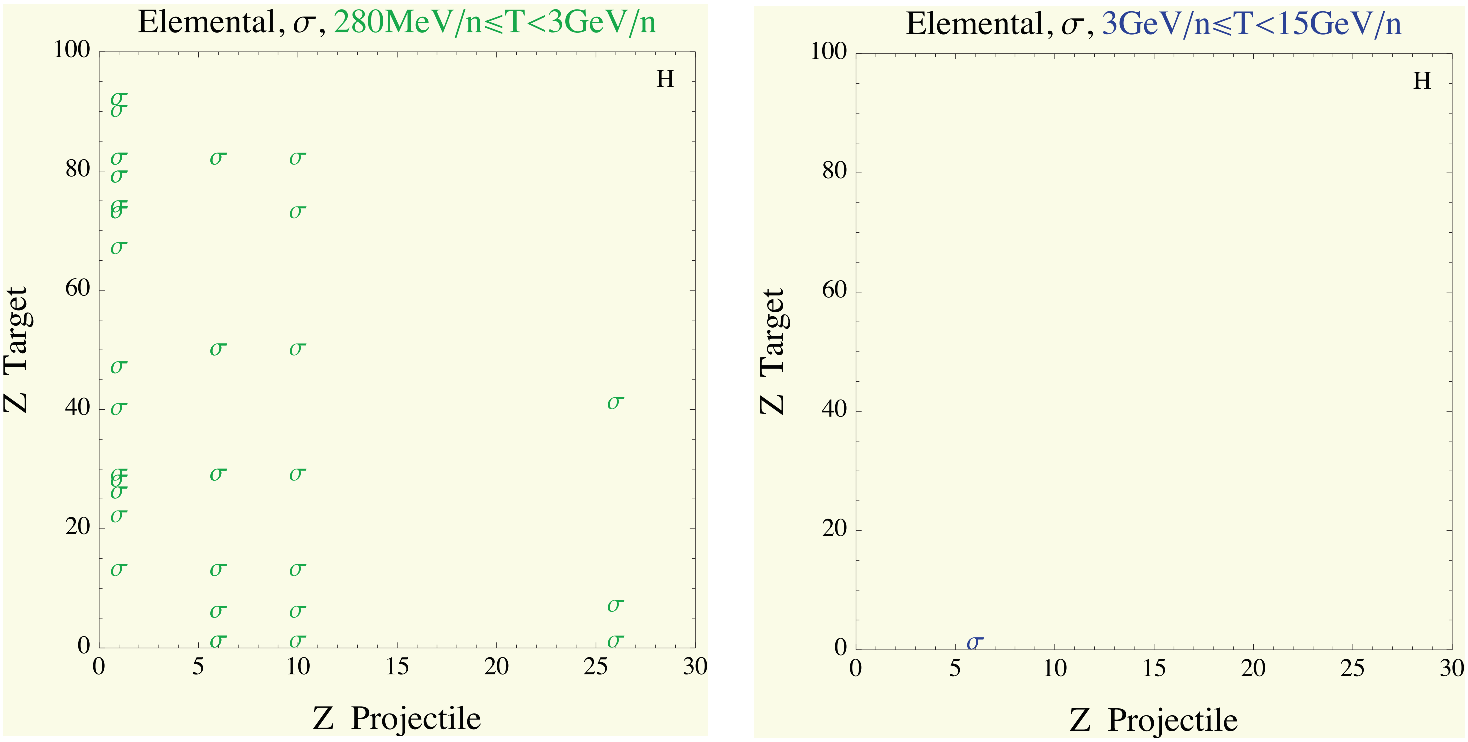


Figure 2: Elemental total cross sections for H fragments.

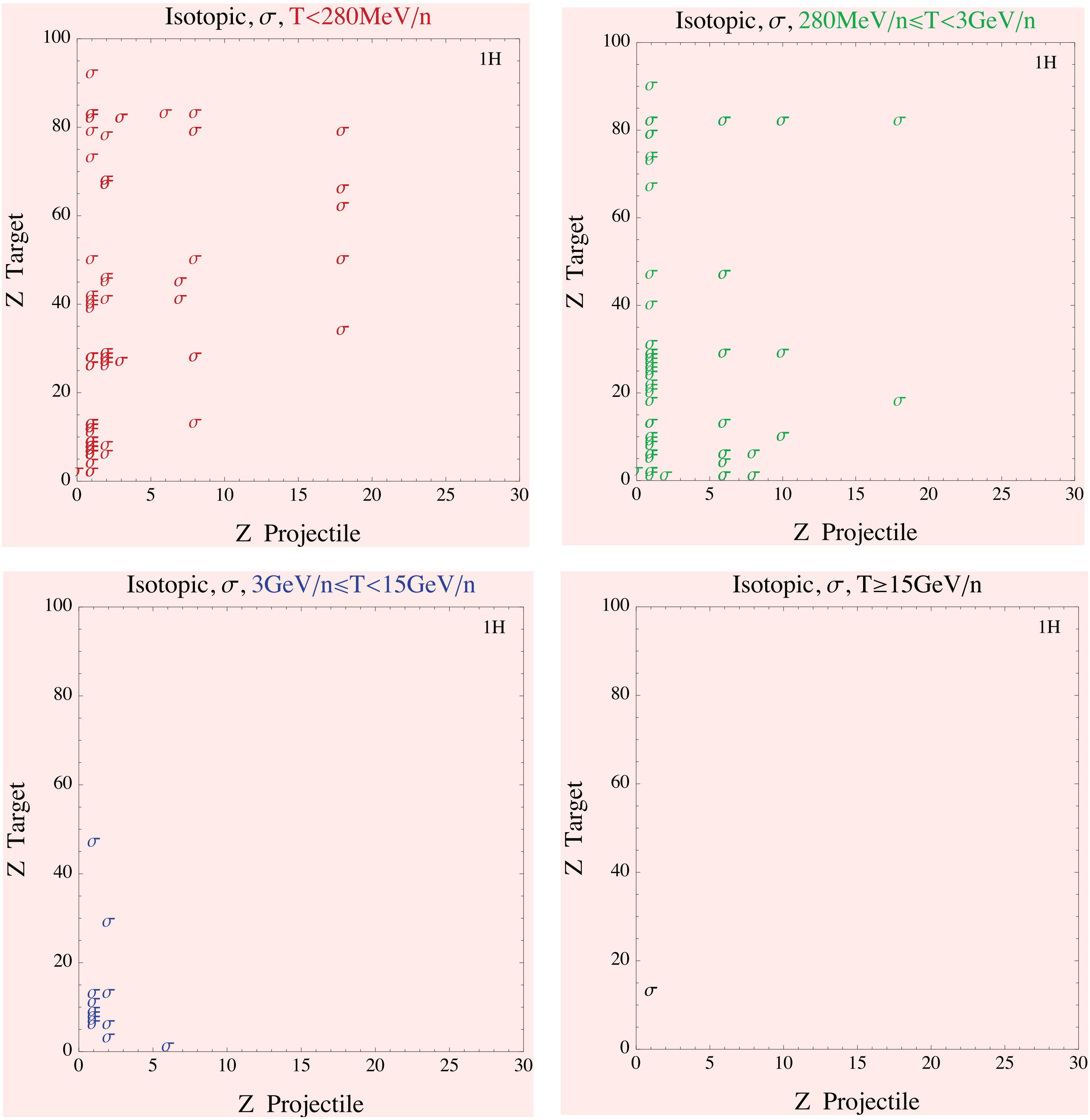


Figure 3: Isotopic total cross sections for ^{1}H fragments.

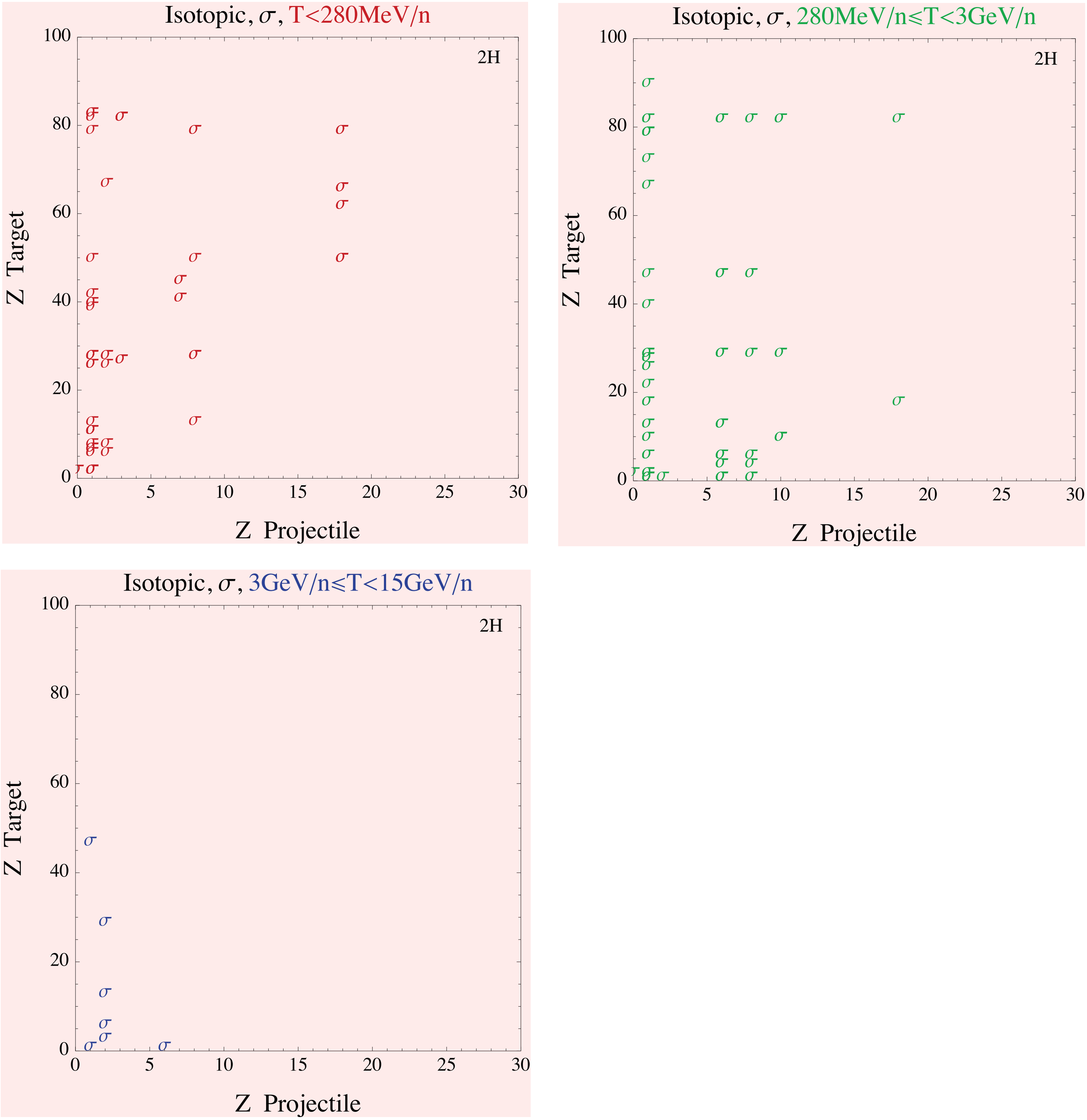


Figure 4: Isotopic total cross sections for ^{2}H fragments.

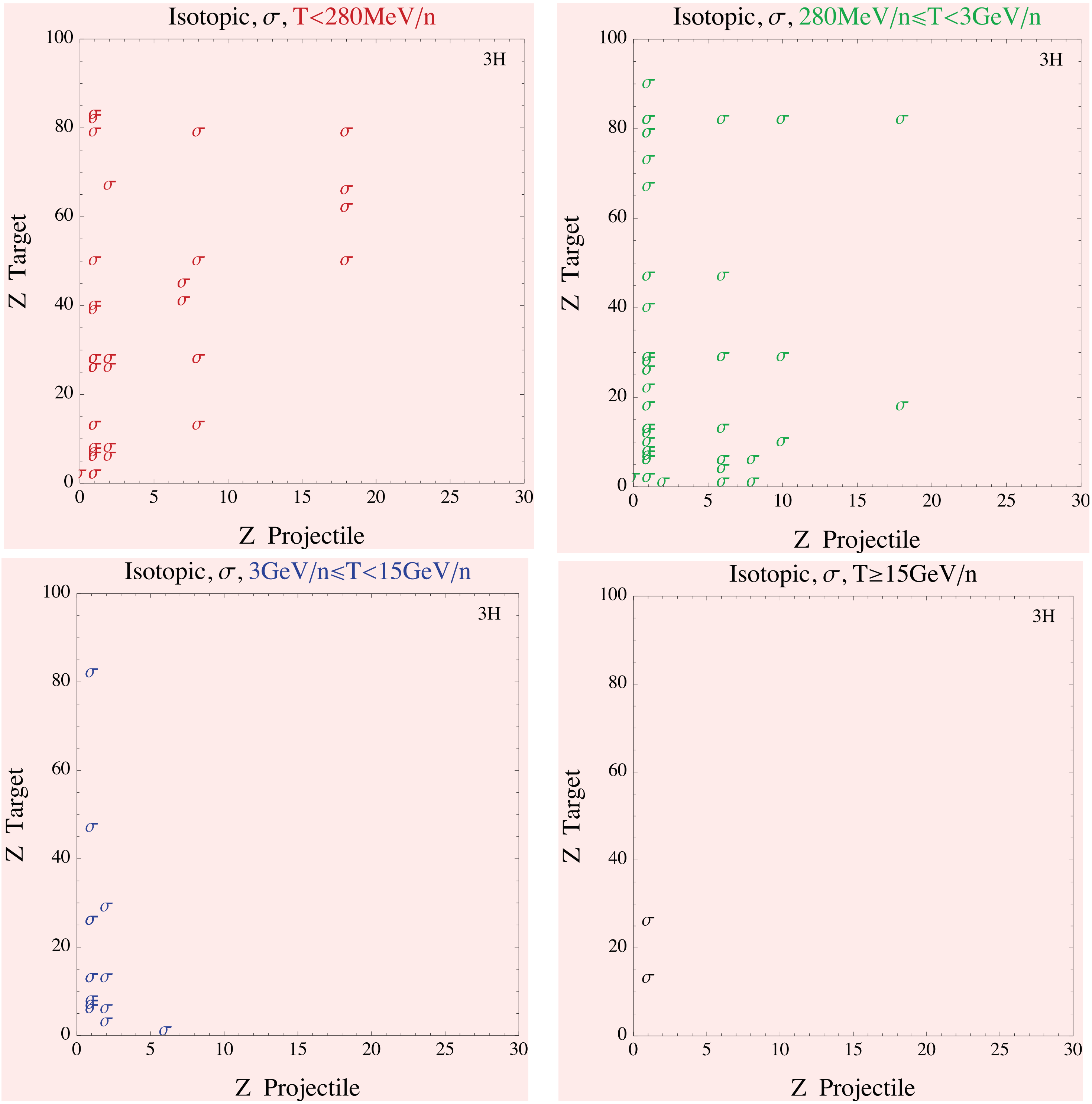


Figure 5: Isotopic total cross sections for ^{3}H fragments.

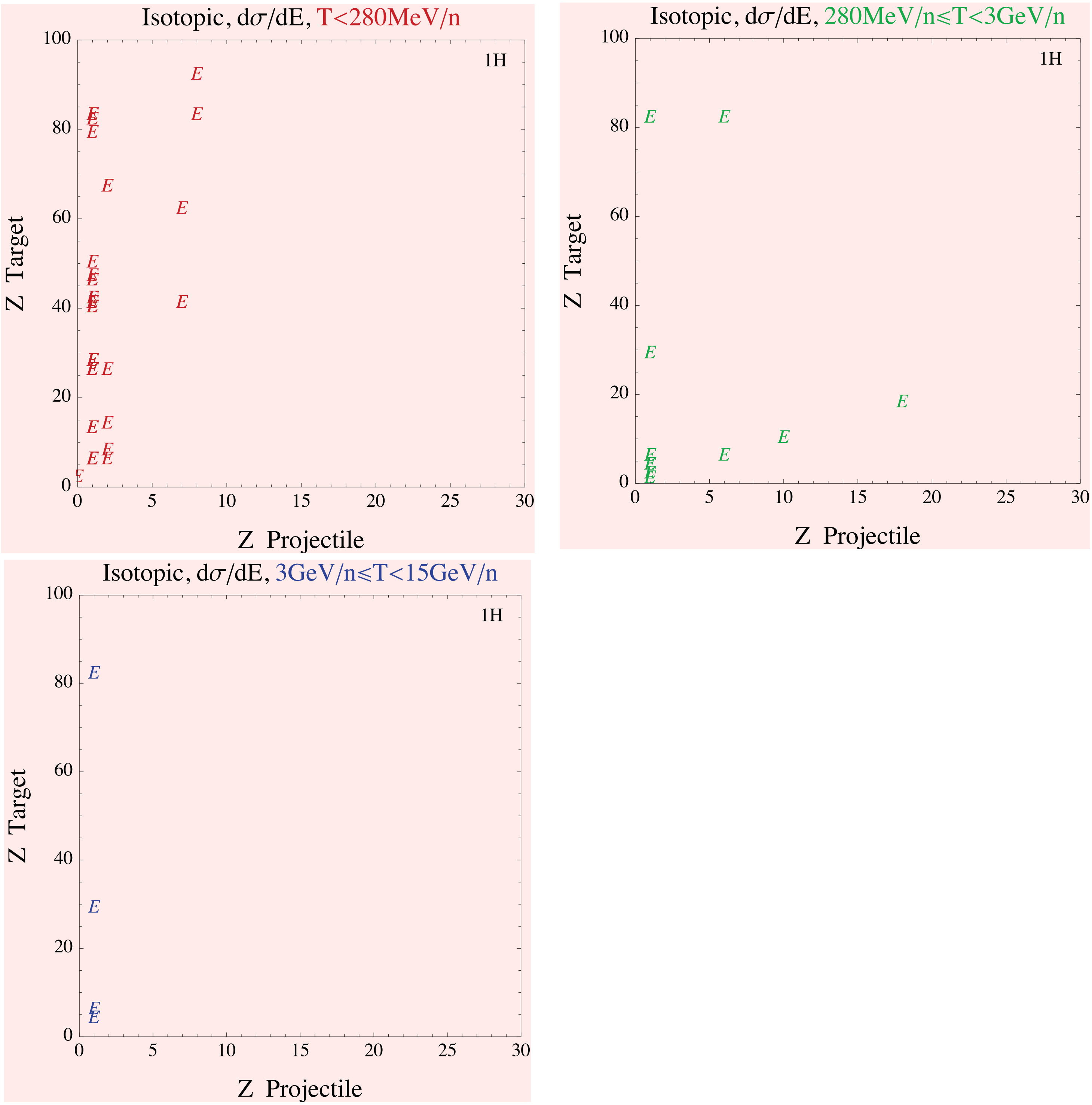


Figure 6: Isotopic energy differential cross sections for ^{1}H fragments.

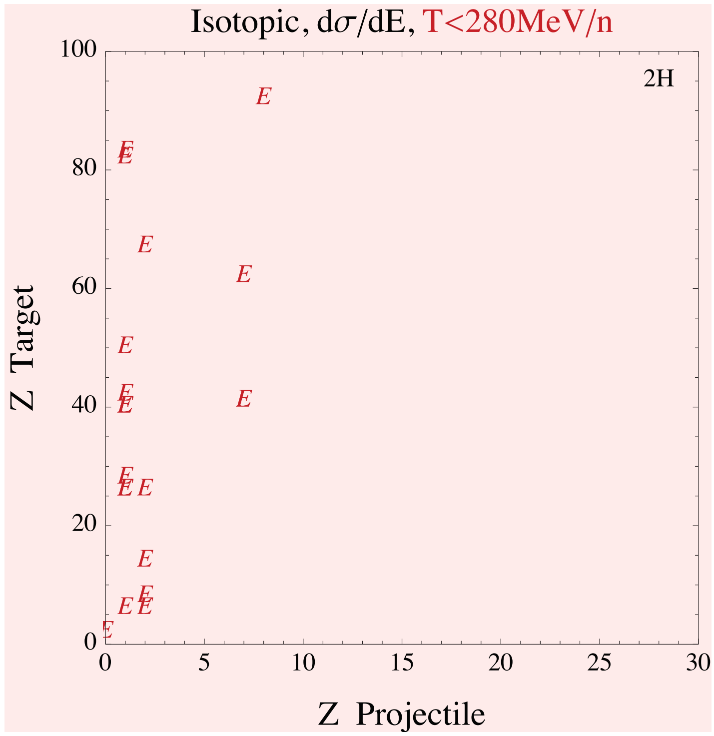


Figure 7: Isotopic energy differential cross sections for ^{2}H fragments.

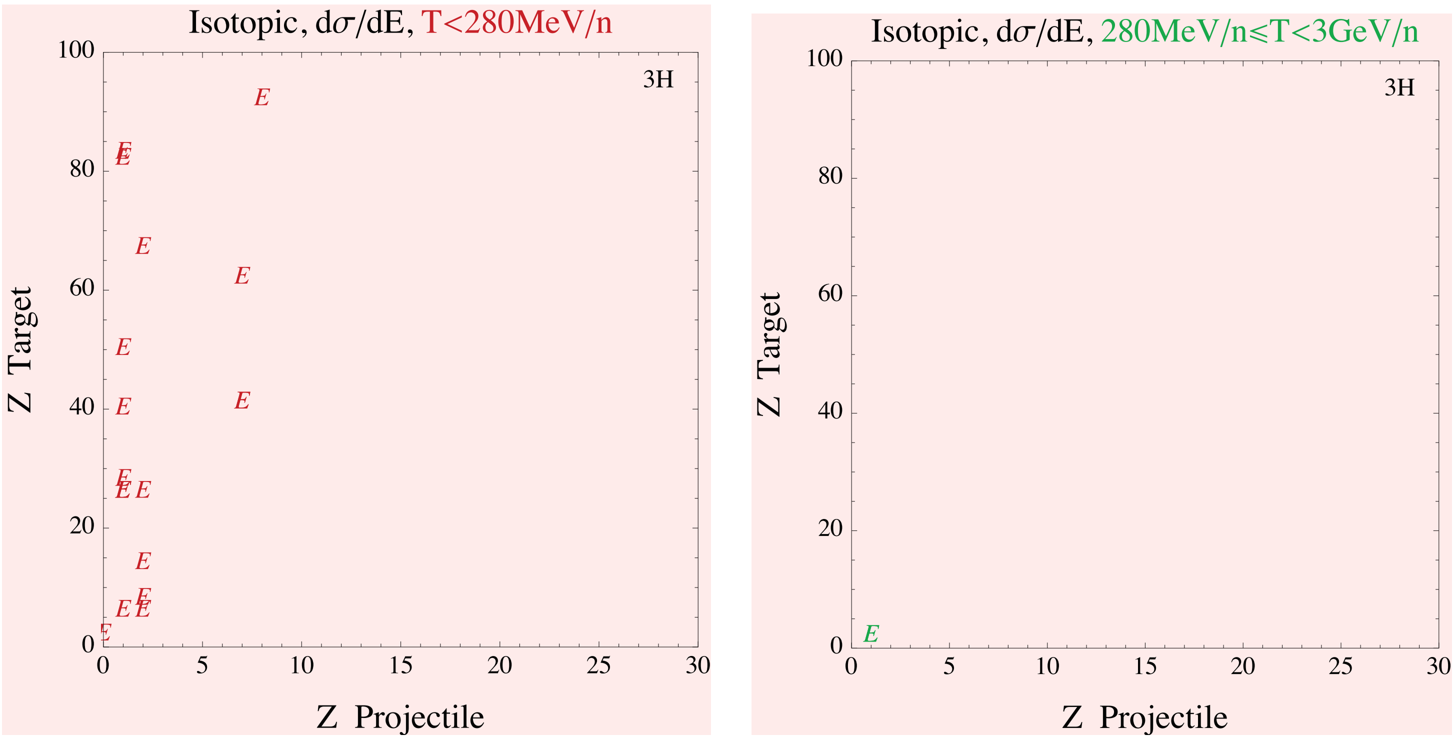


Figure 8: Isotopic energy differential cross sections for ^{3}H fragments.

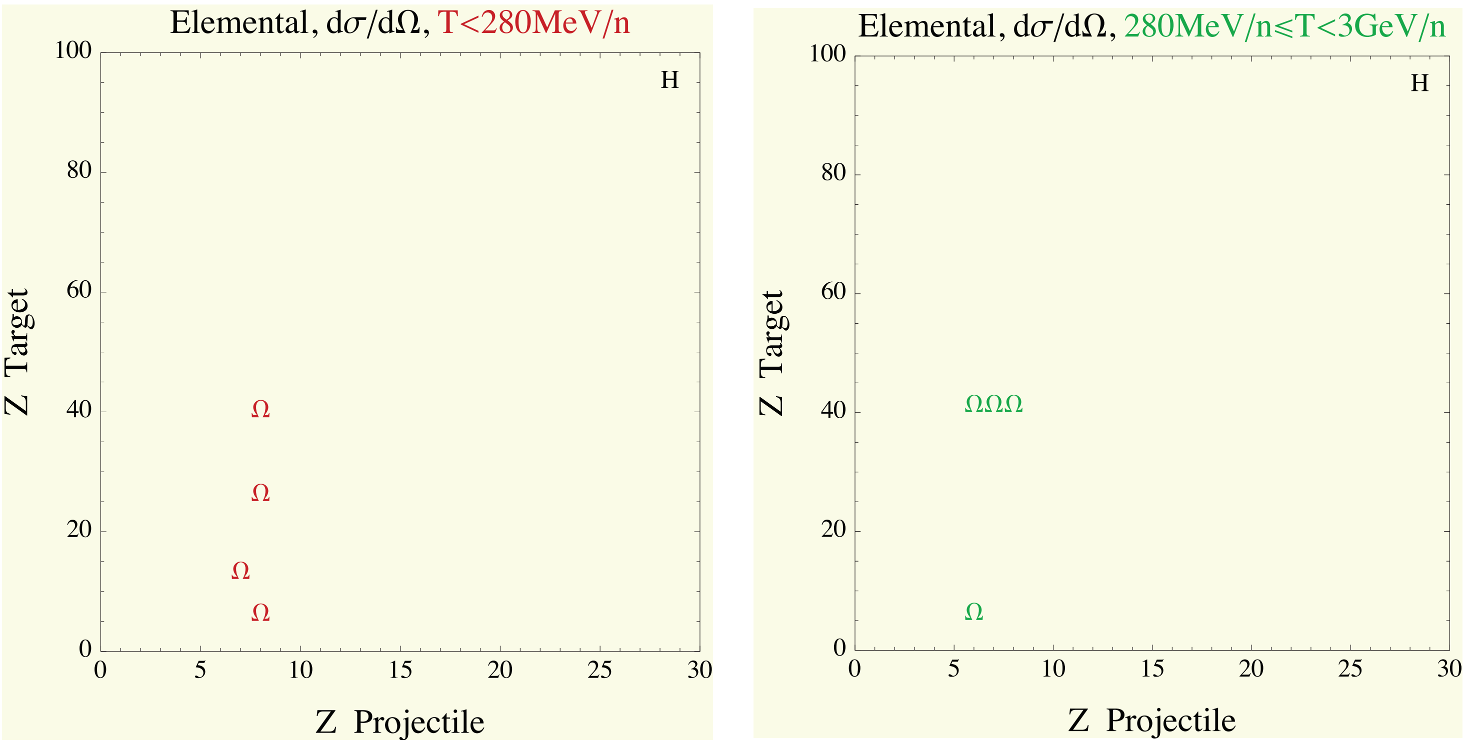


Figure 9: Elemental angular differential cross sections for H fragments.

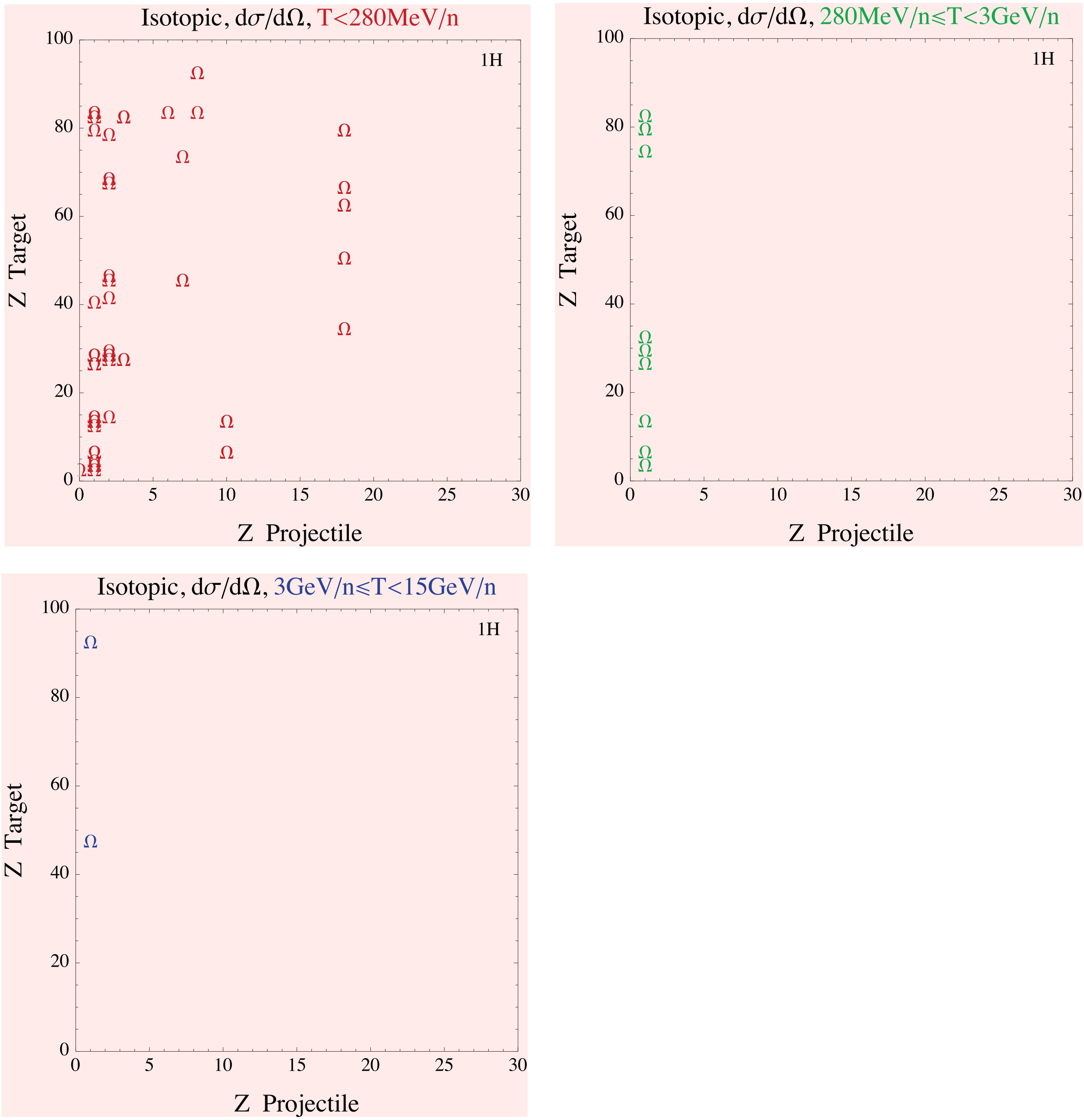


Figure 10: Isotopic angular differential cross sections for ^{1}H fragments.

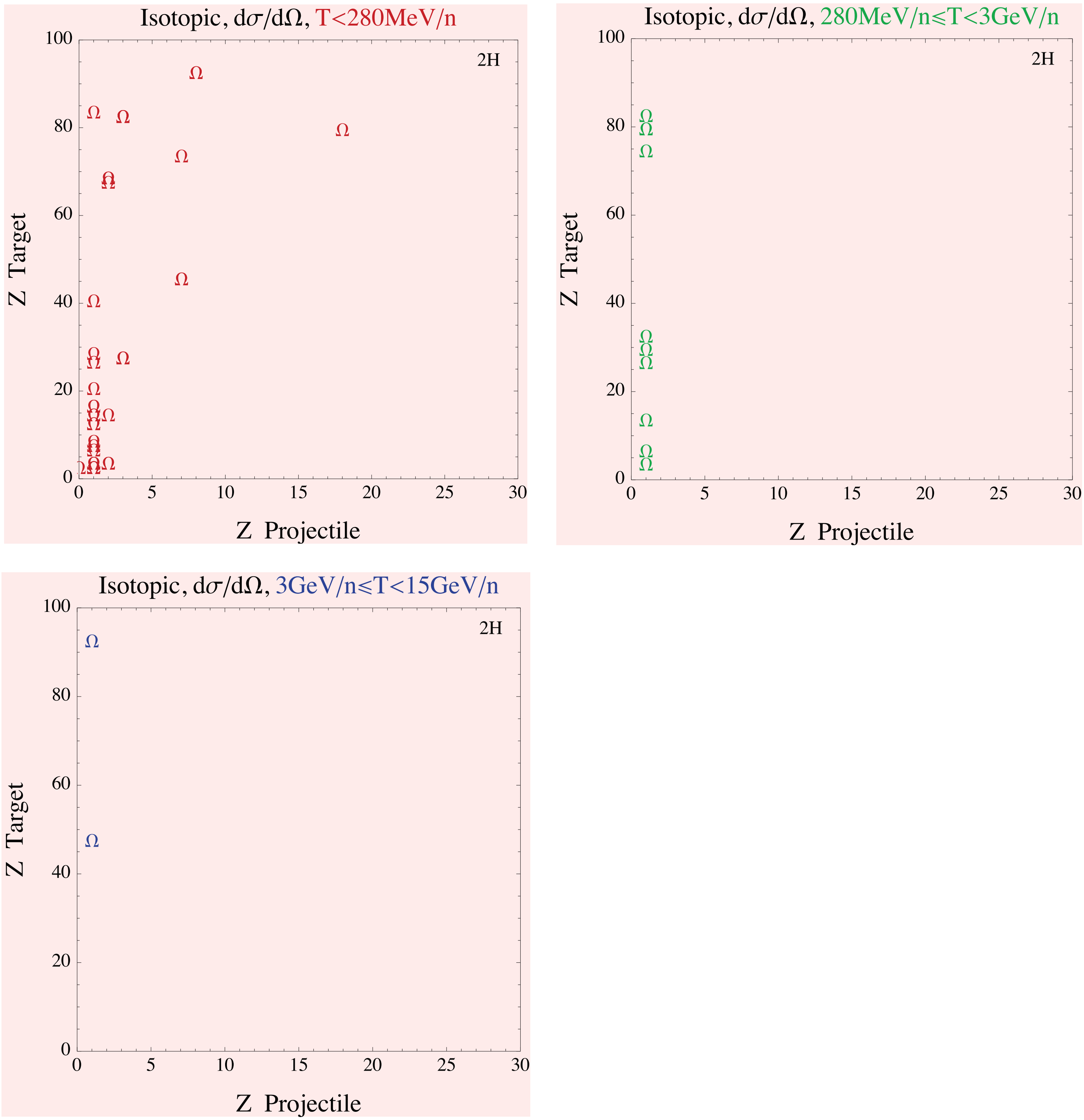


Figure 11: Isotopic angular differential cross sections for ^{2}H fragments.

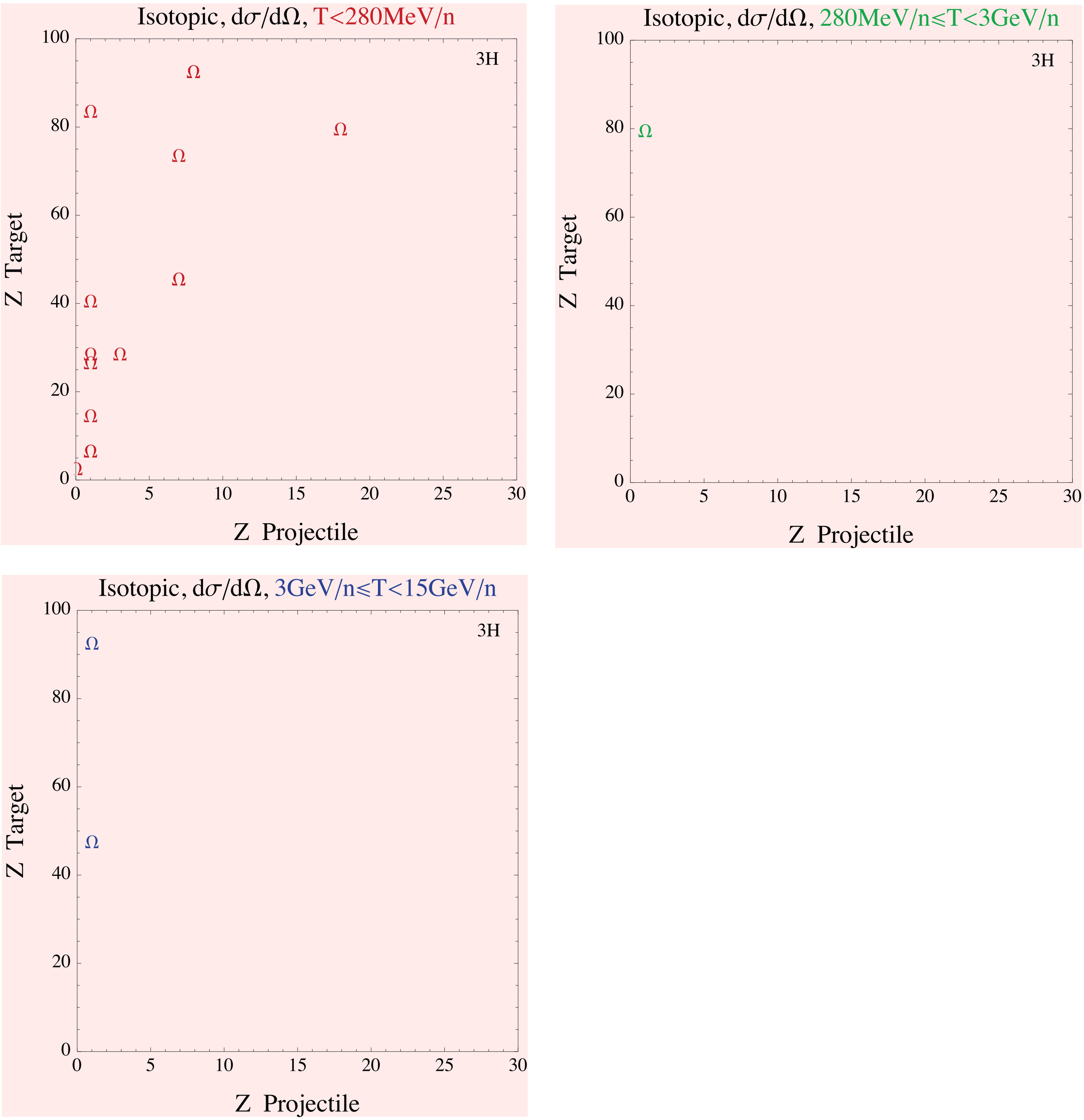


Figure 12: Isotopic angular differential cross sections for ^{3}H fragments.

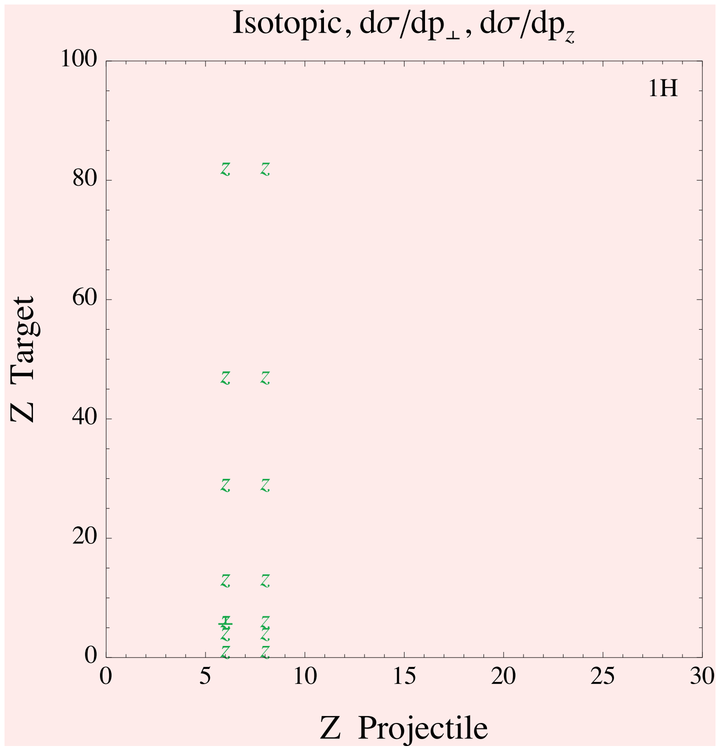


Figure 13: Isotopic momentum differential cross sections for ^{1}H fragments covering all energies.

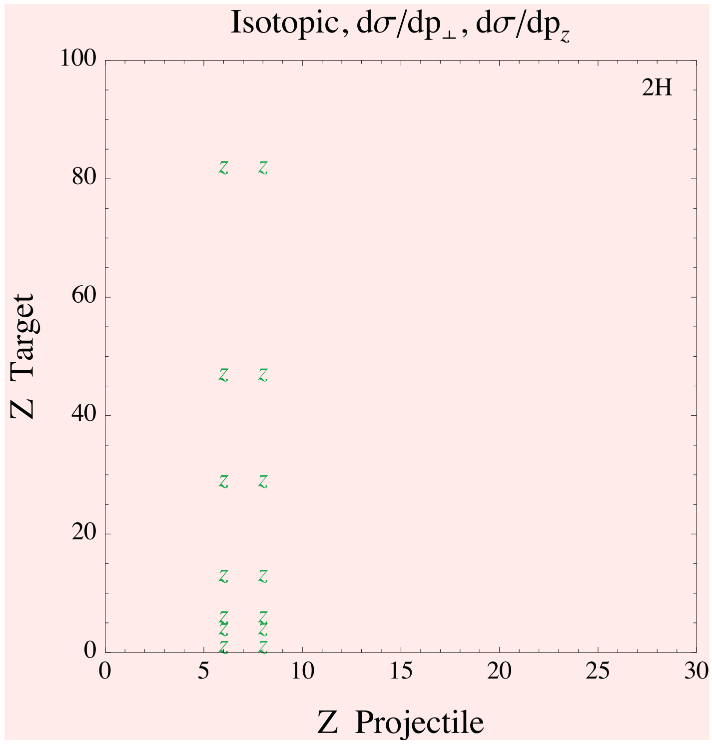


Figure 14: Isotopic momentum differential cross sections for ^{2}H fragments covering all energies.

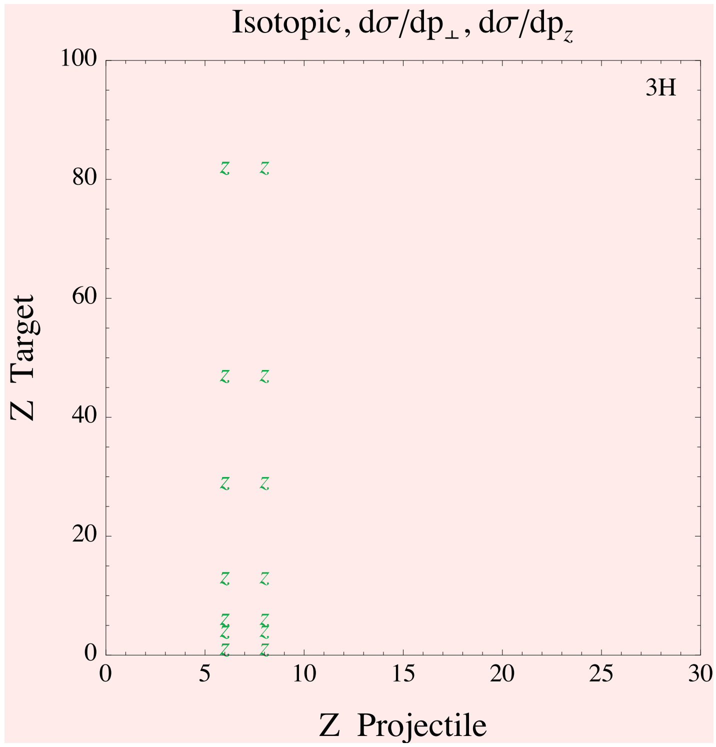


Figure 15: Isotopic momentum differential cross sections for ^{3}H fragments covering all energies.

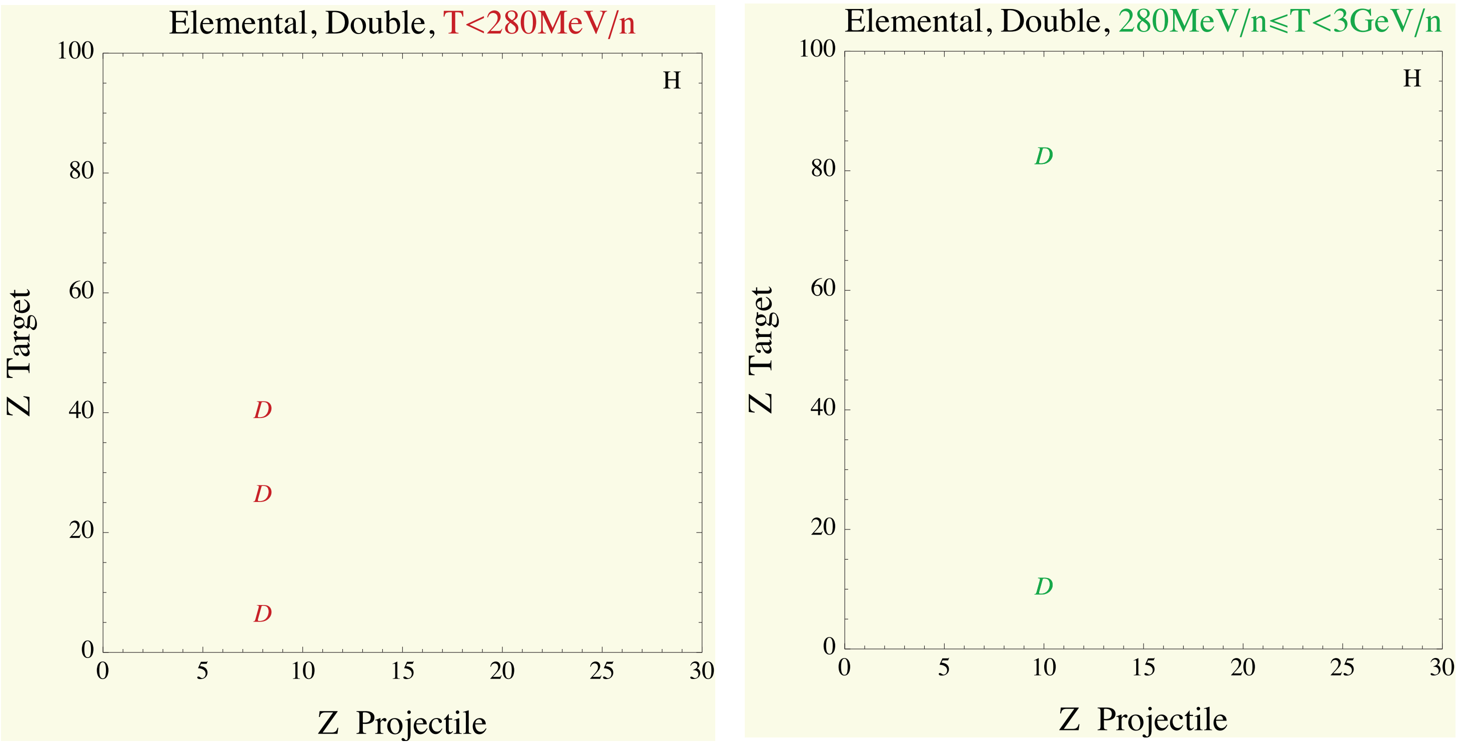


Figure 16: Elemental double differential cross sections for H fragments.

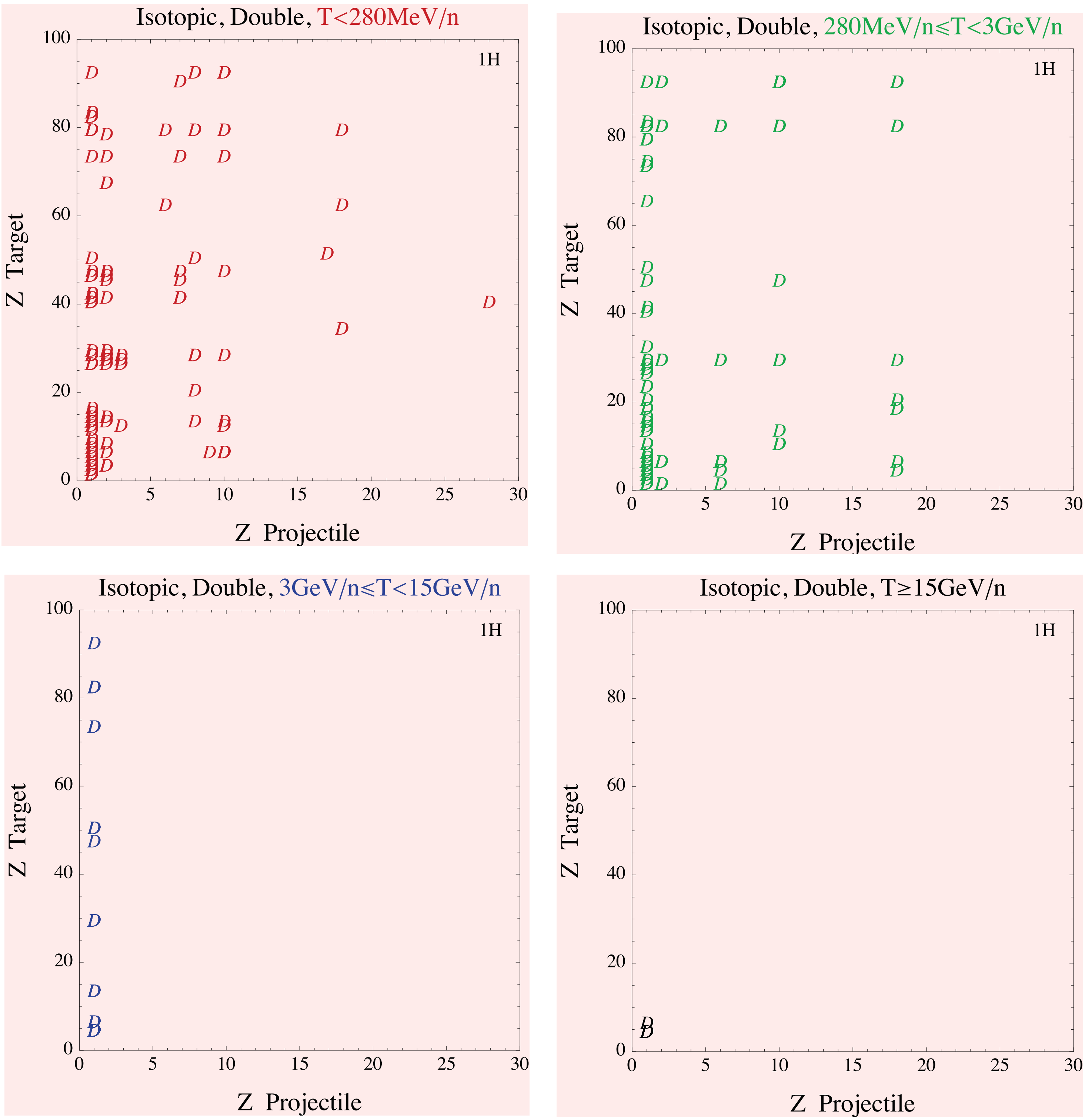
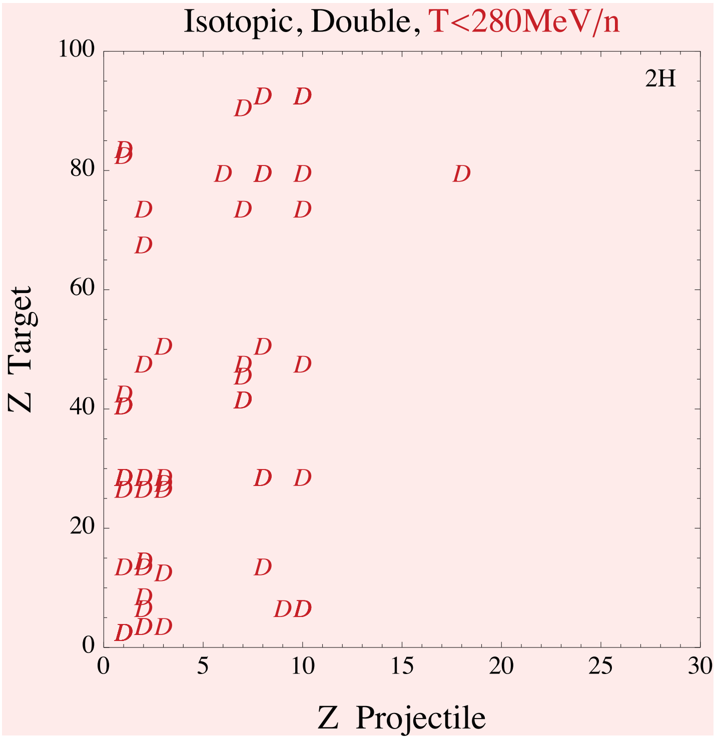
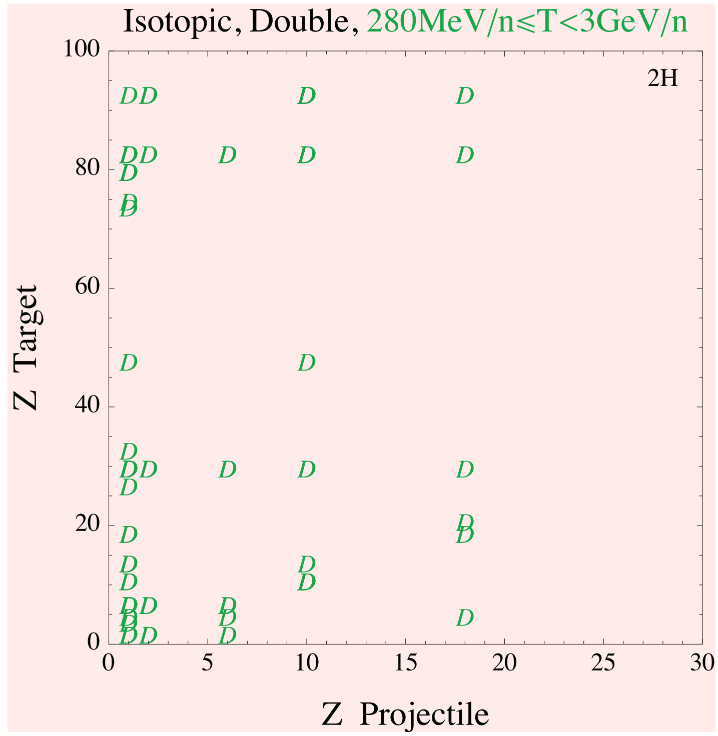


Figure 17: Isotopic double differential cross sections for ^{1}H fragments.





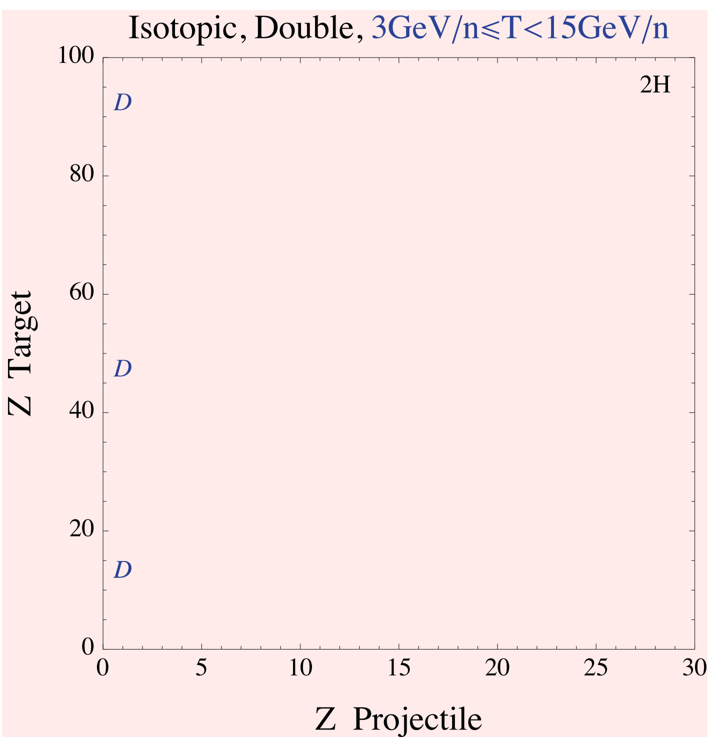


Figure 18: Isotopic double differential cross sections for ^{2}H fragments.

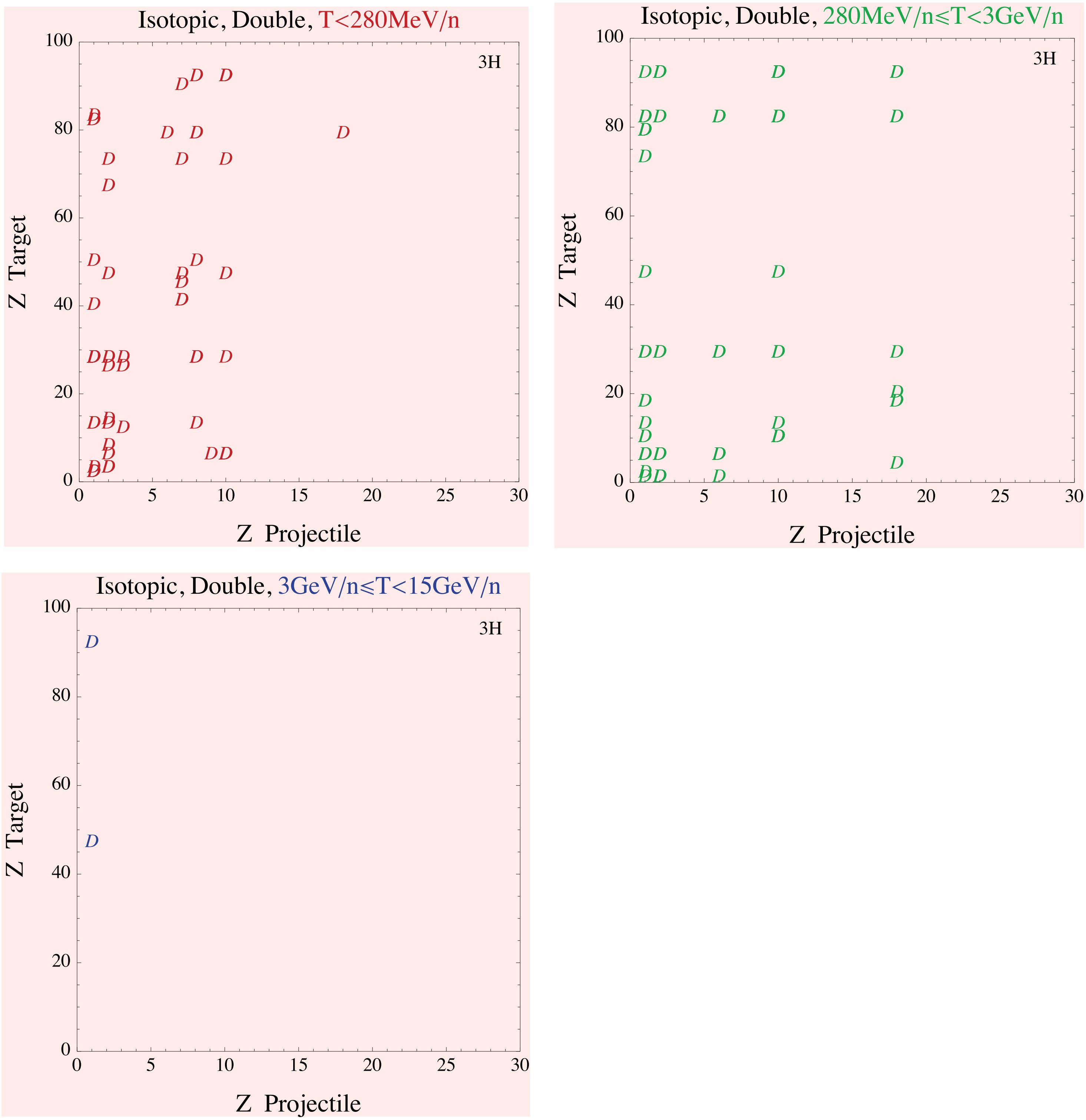


Figure 19: Isotopic double differential cross sections for ^{3}H fragments.

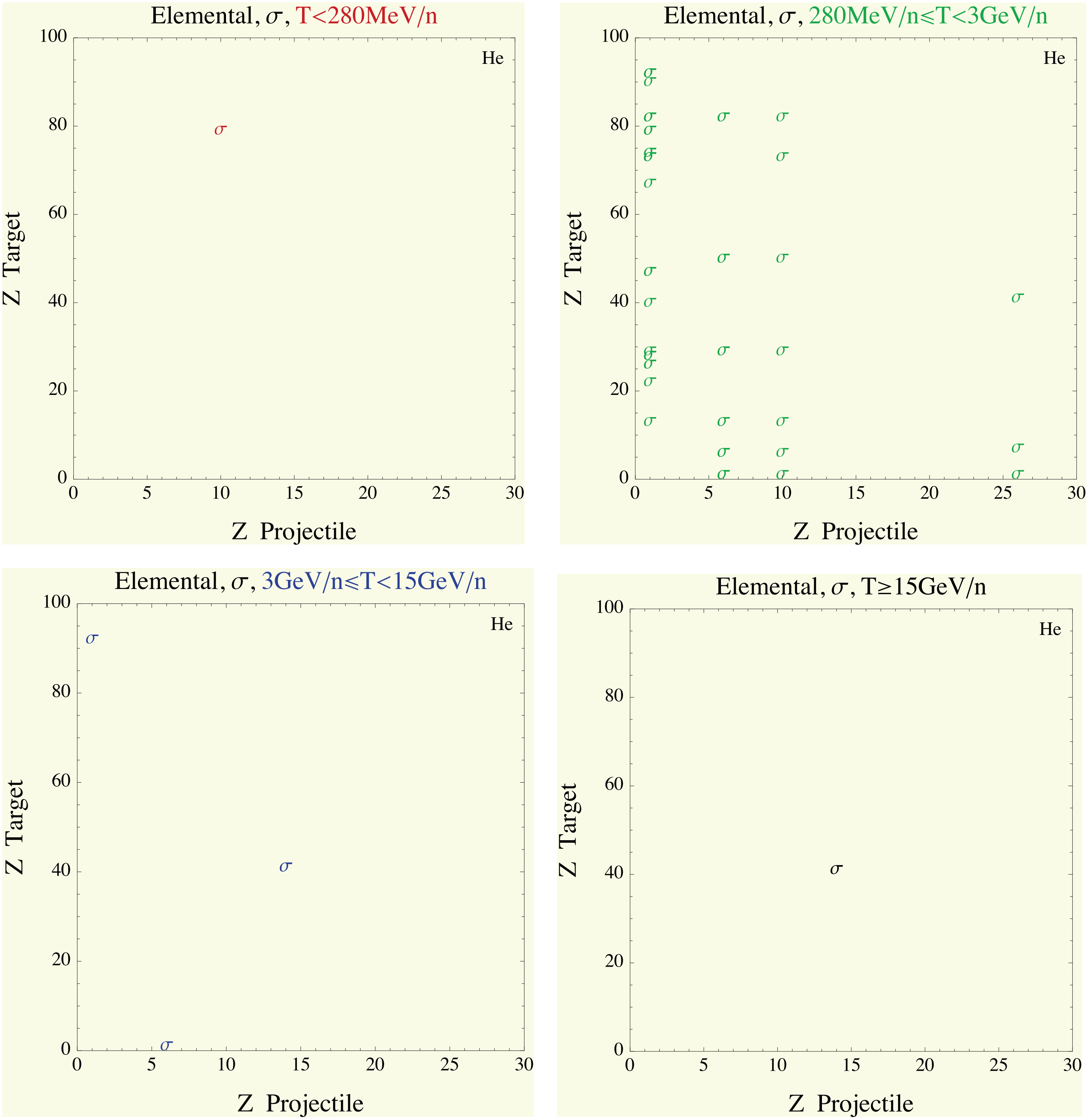


Figure 20: Elemental total cross sections for He fragments.

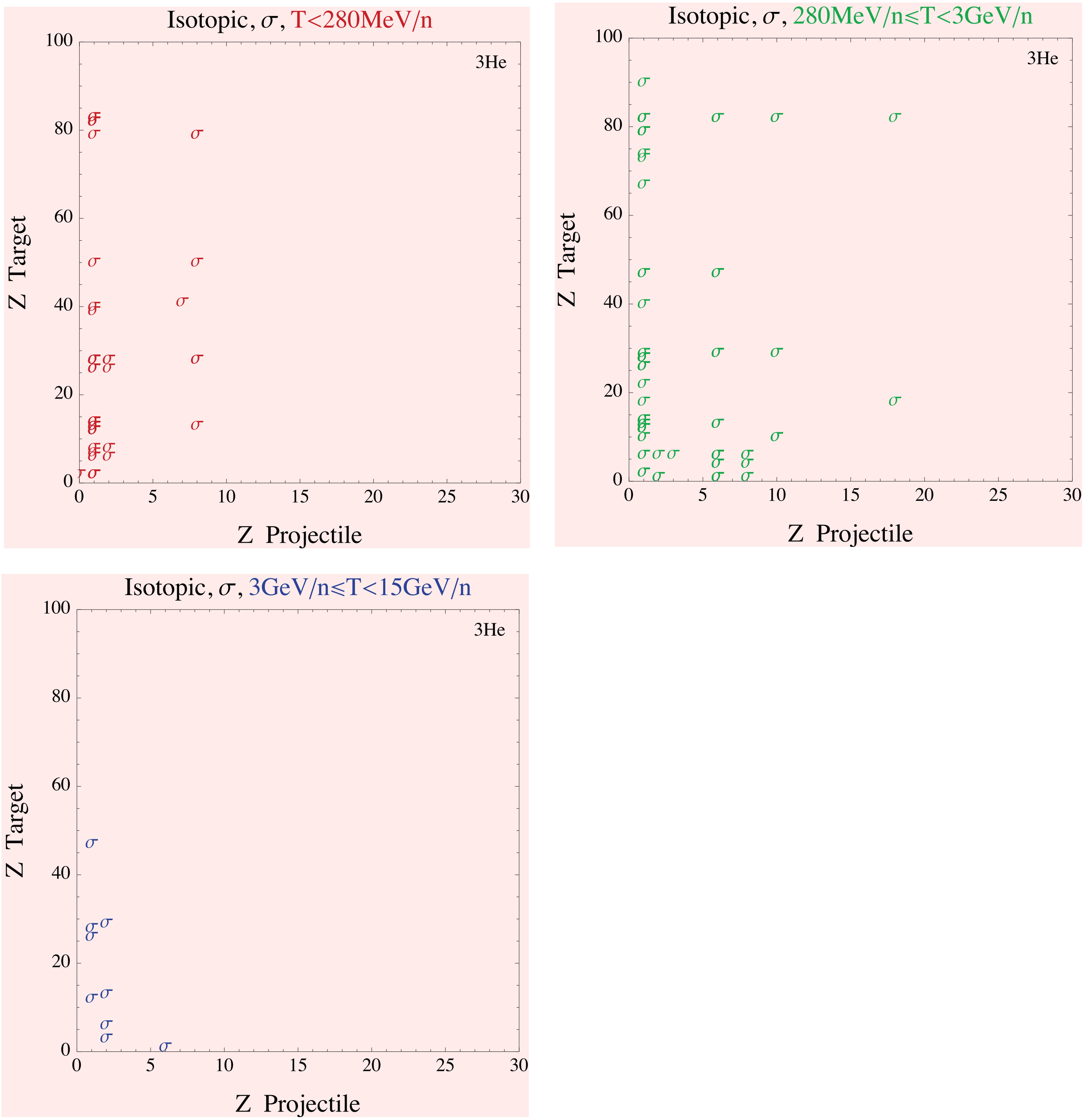


Figure 21: Isotopic total cross sections for ^{3}He fragments.

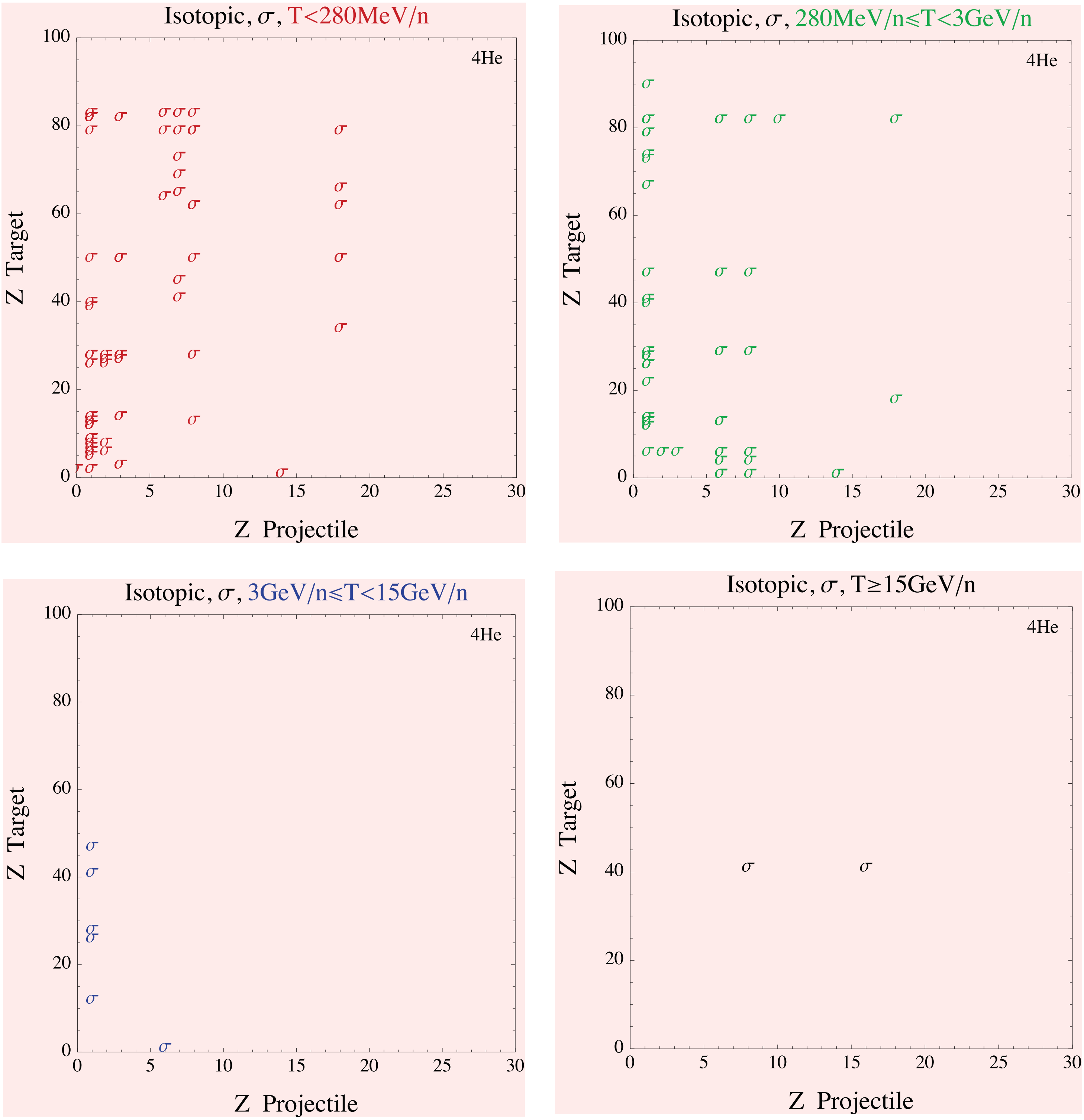


Figure 22: Isotopic total cross sections for ^{4}He fragments.

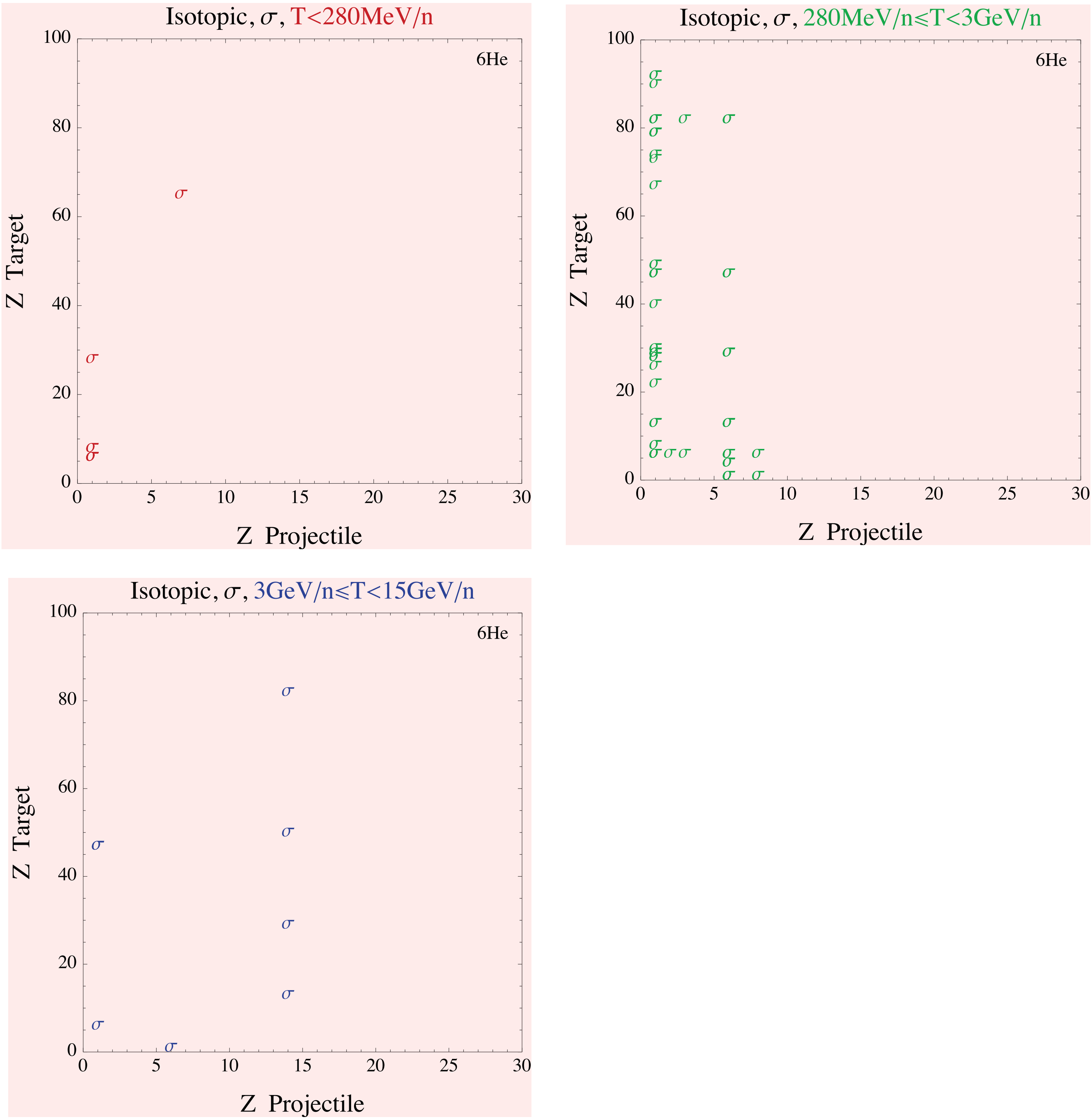


Figure 23: Isotopic total cross sections for ^{6}He fragments.

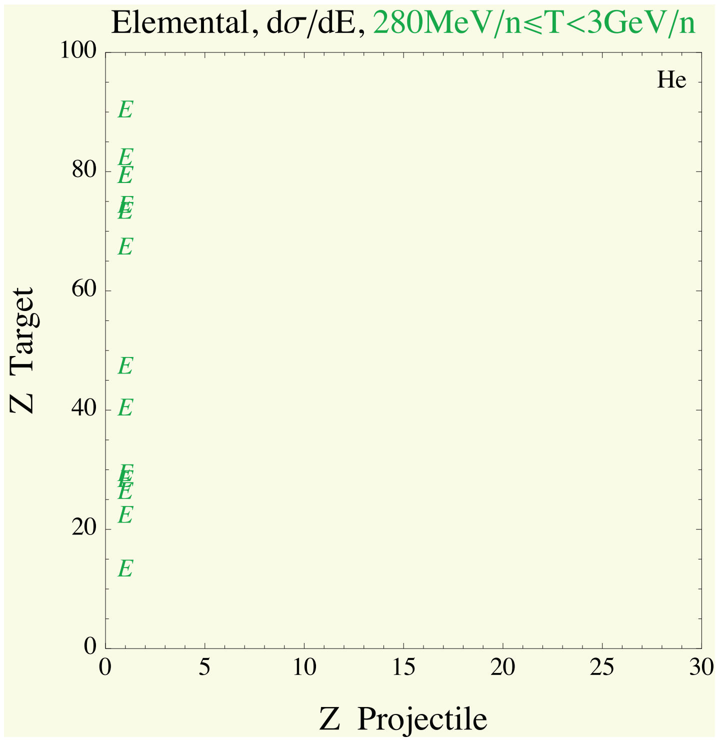


Figure 24: Elemental energy differential cross sections for He fragments.

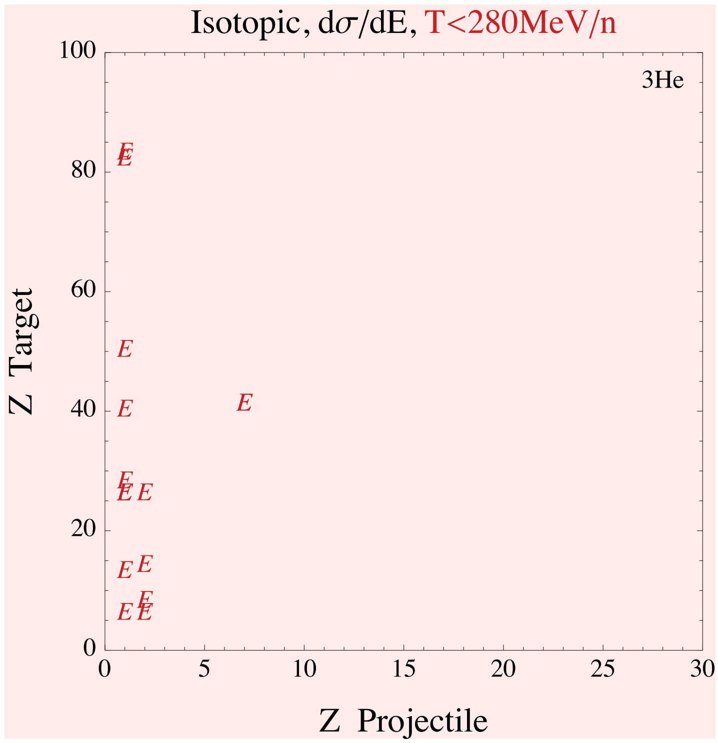


Figure 25: Isotopic energy differential cross sections for ^{3}He fragments.

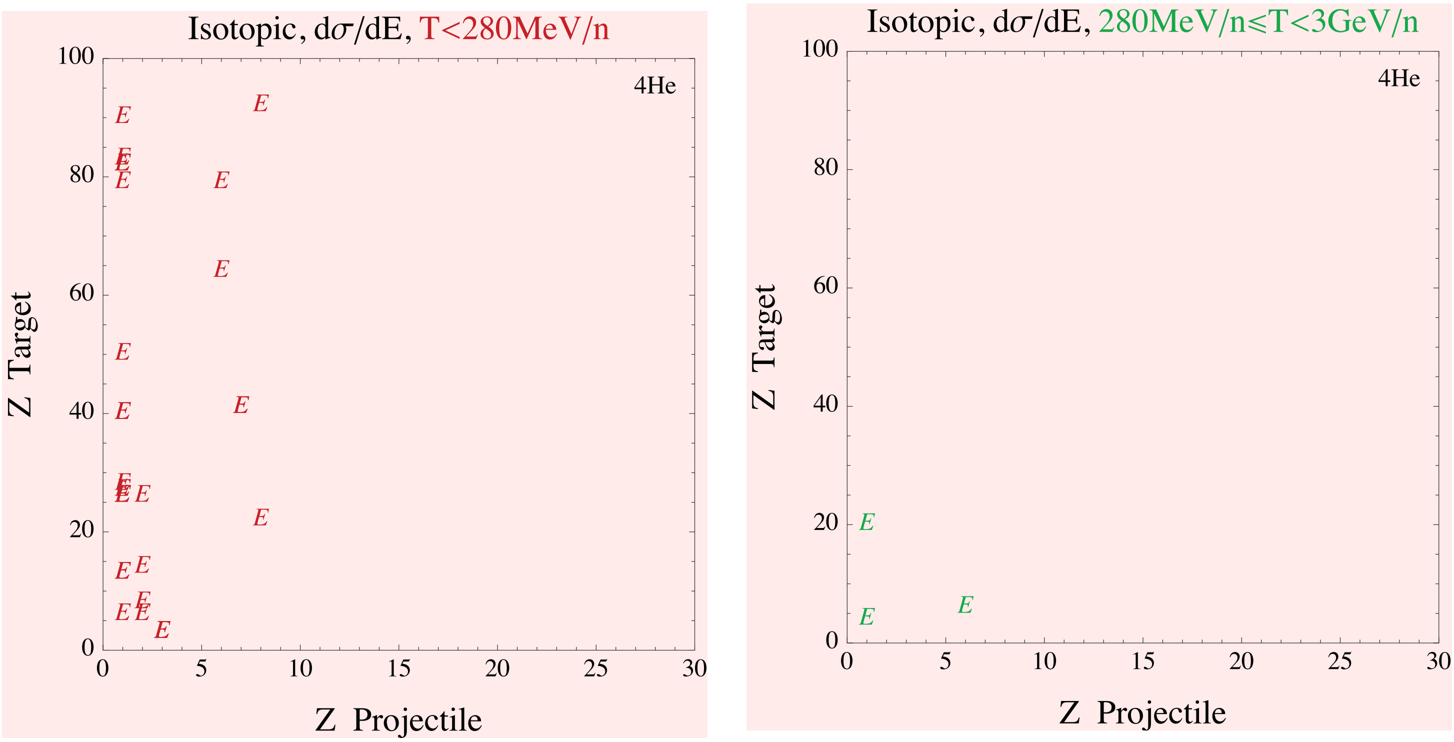


Figure 26: Isotopic energy differential cross sections for ^{4}He fragments.

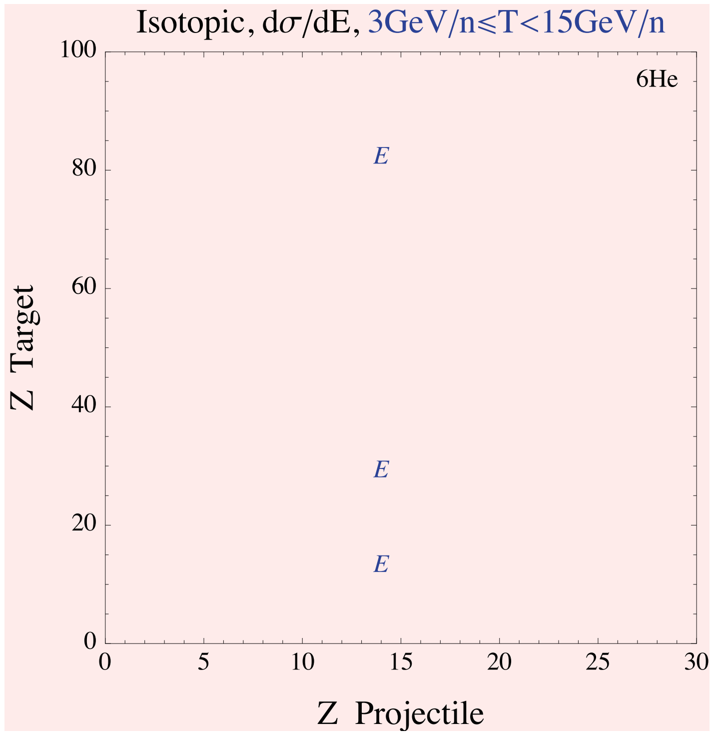


Figure 27: Isotopic energy differential cross sections for ^{6}He fragments.

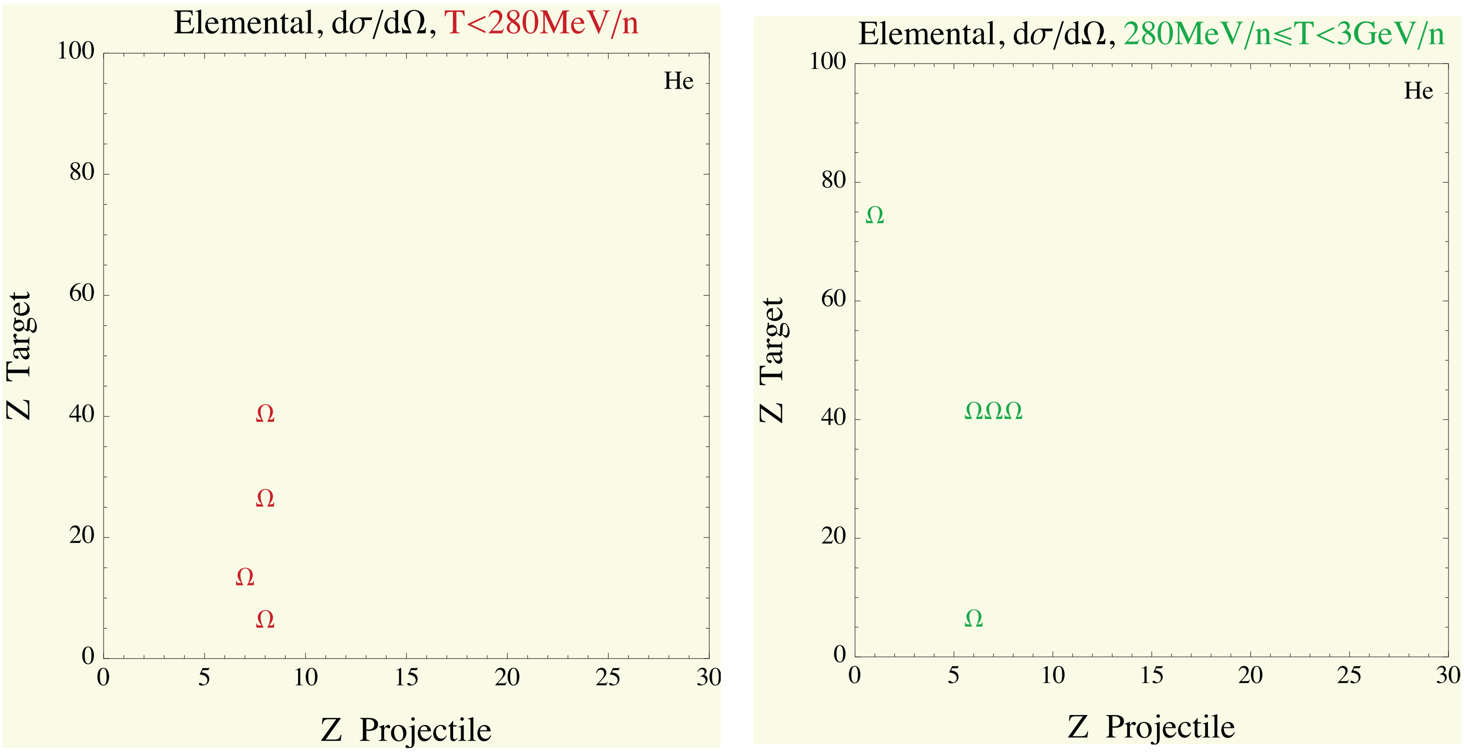


Figure 28: Elemental angular differential cross sections for He fragments.

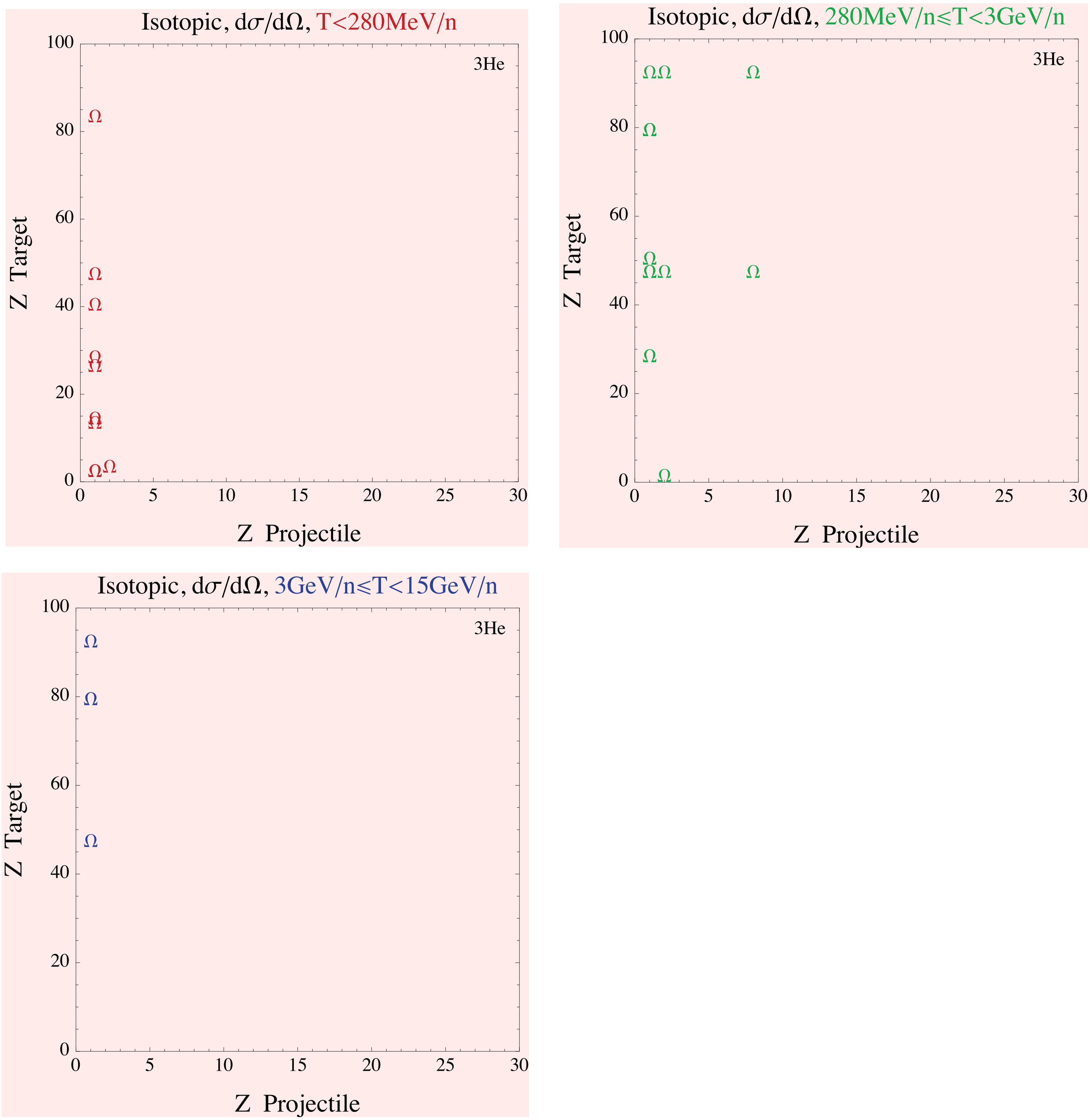


Figure 29: Isotopic angular differential cross sections for ^{3}He fragments.

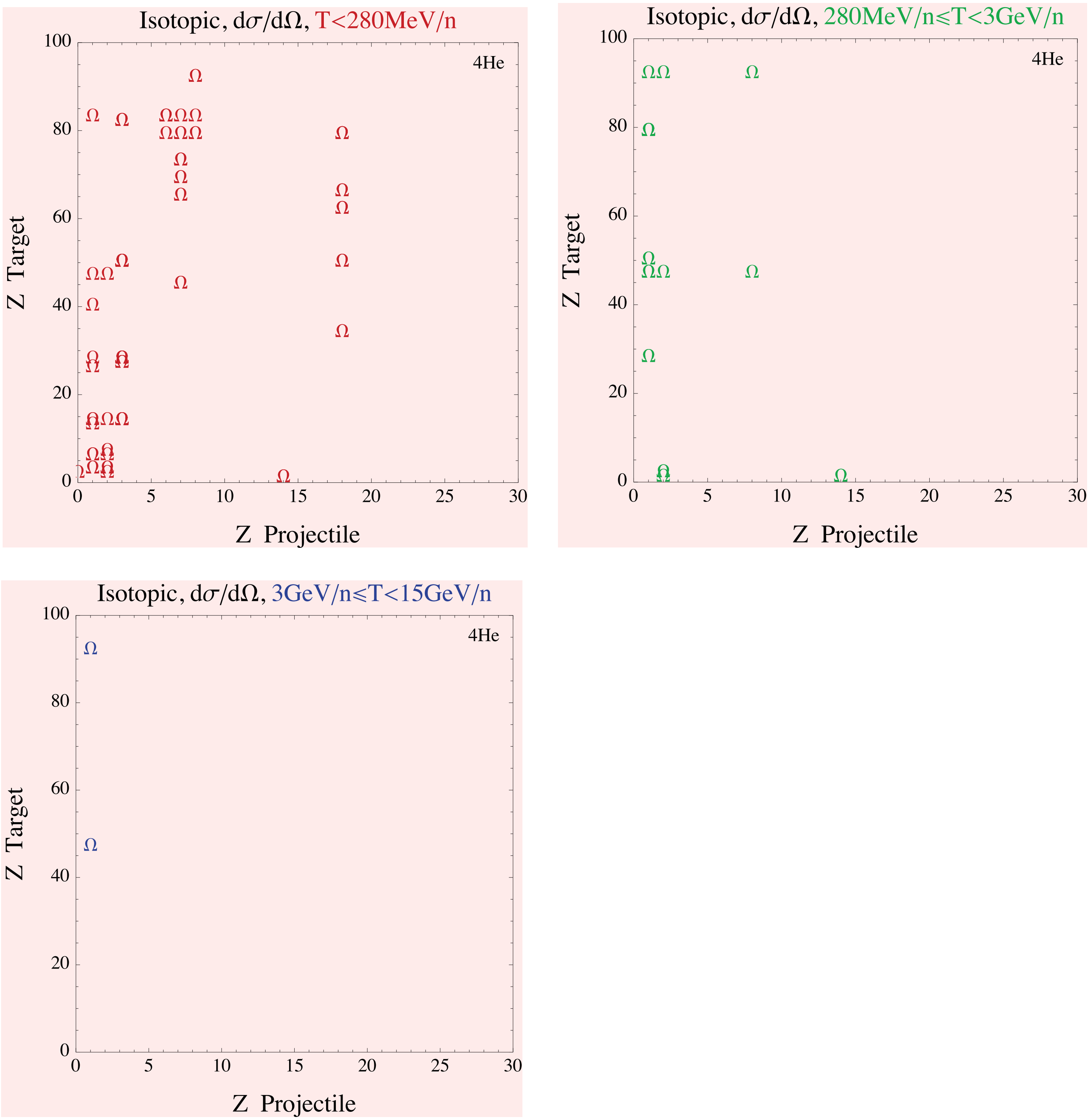
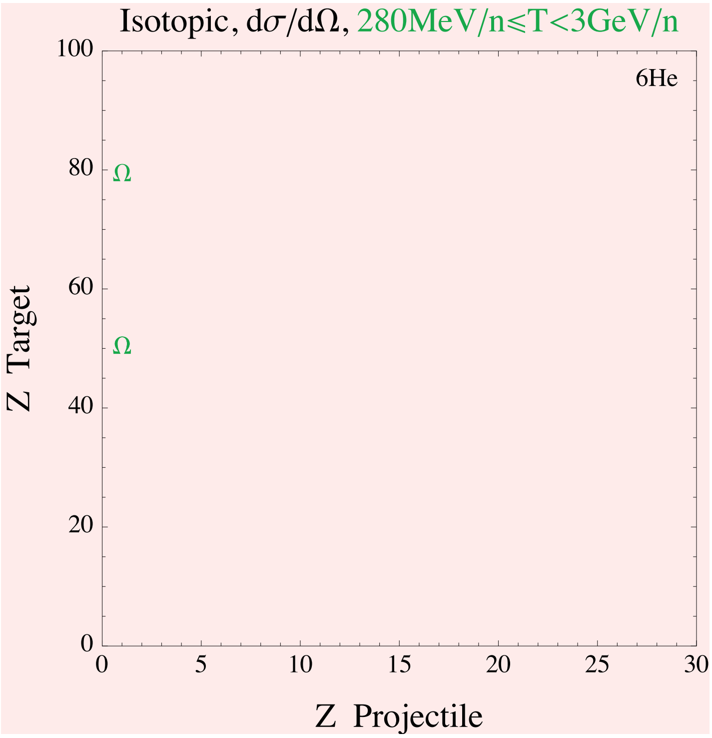


Figure 30: Isotopic angular differential cross sections for ^{4}He fragments.



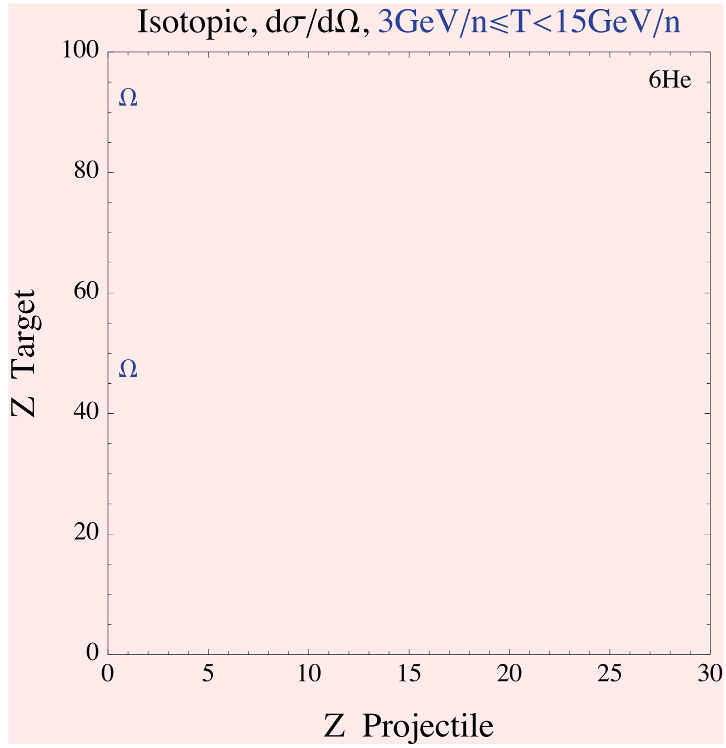


Figure 31: Isotopic angular differential cross sections for ^{6}He fragments.

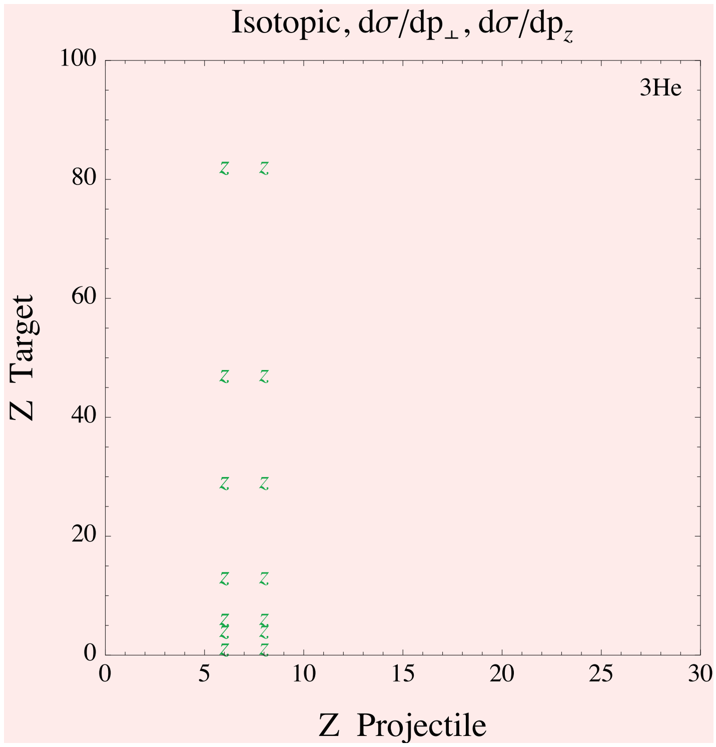


Figure 32: Isotopic momentum differential cross sections for ^{3}He fragments covering all energies.

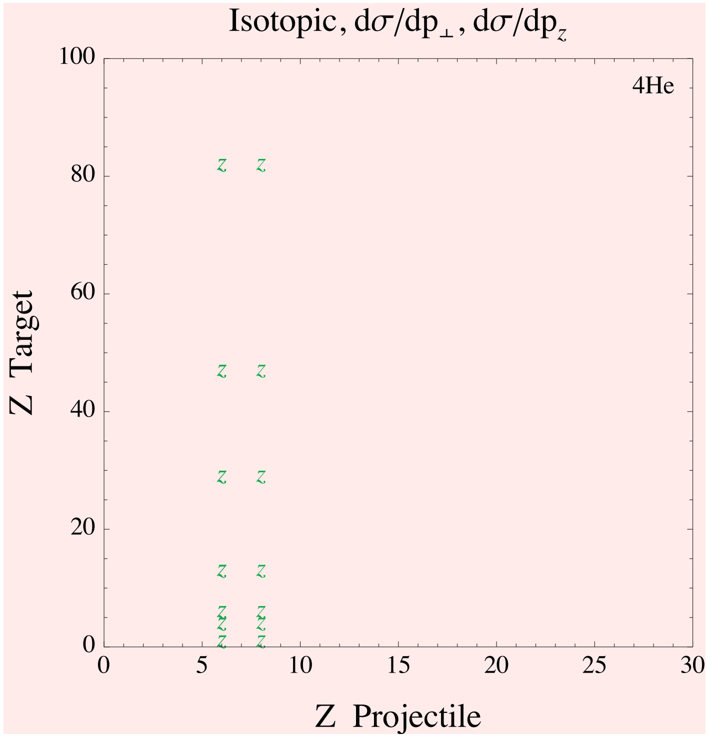


Figure 33: Isotopic momentum differential cross sections for ^{4}He fragments covering all energies.

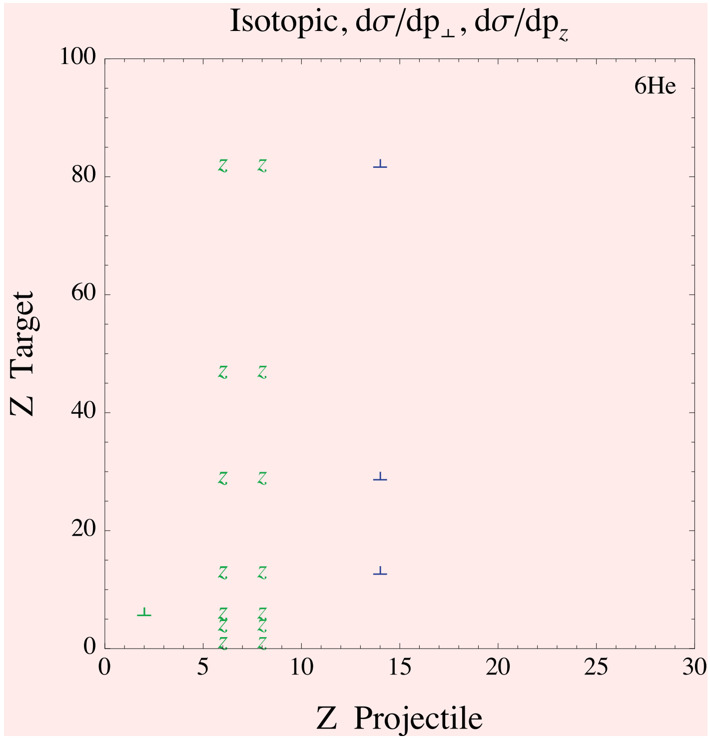


Figure 34: Isotopic momentum differential cross sections for ^{6}He fragments covering all energies.

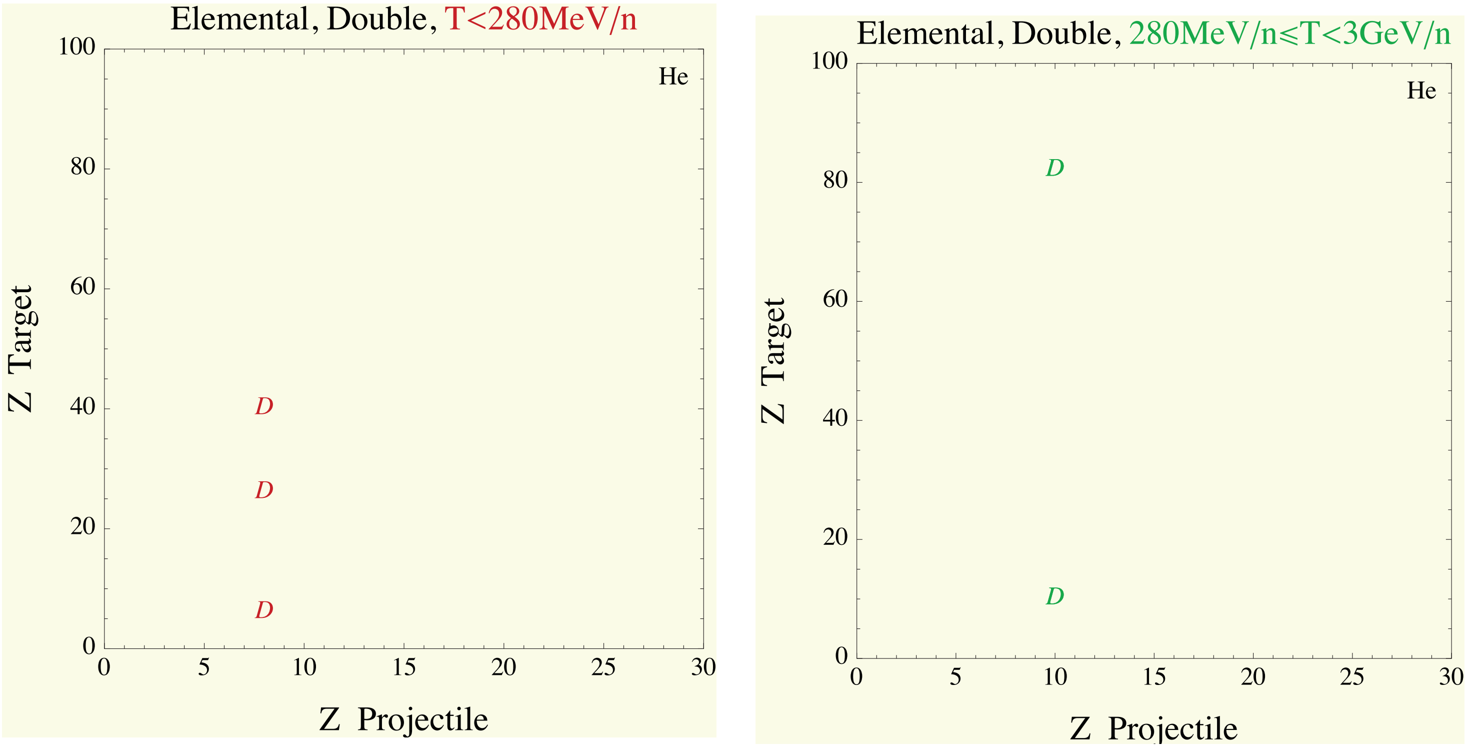


Figure 35: Elemental double differential cross sections for He fragments.

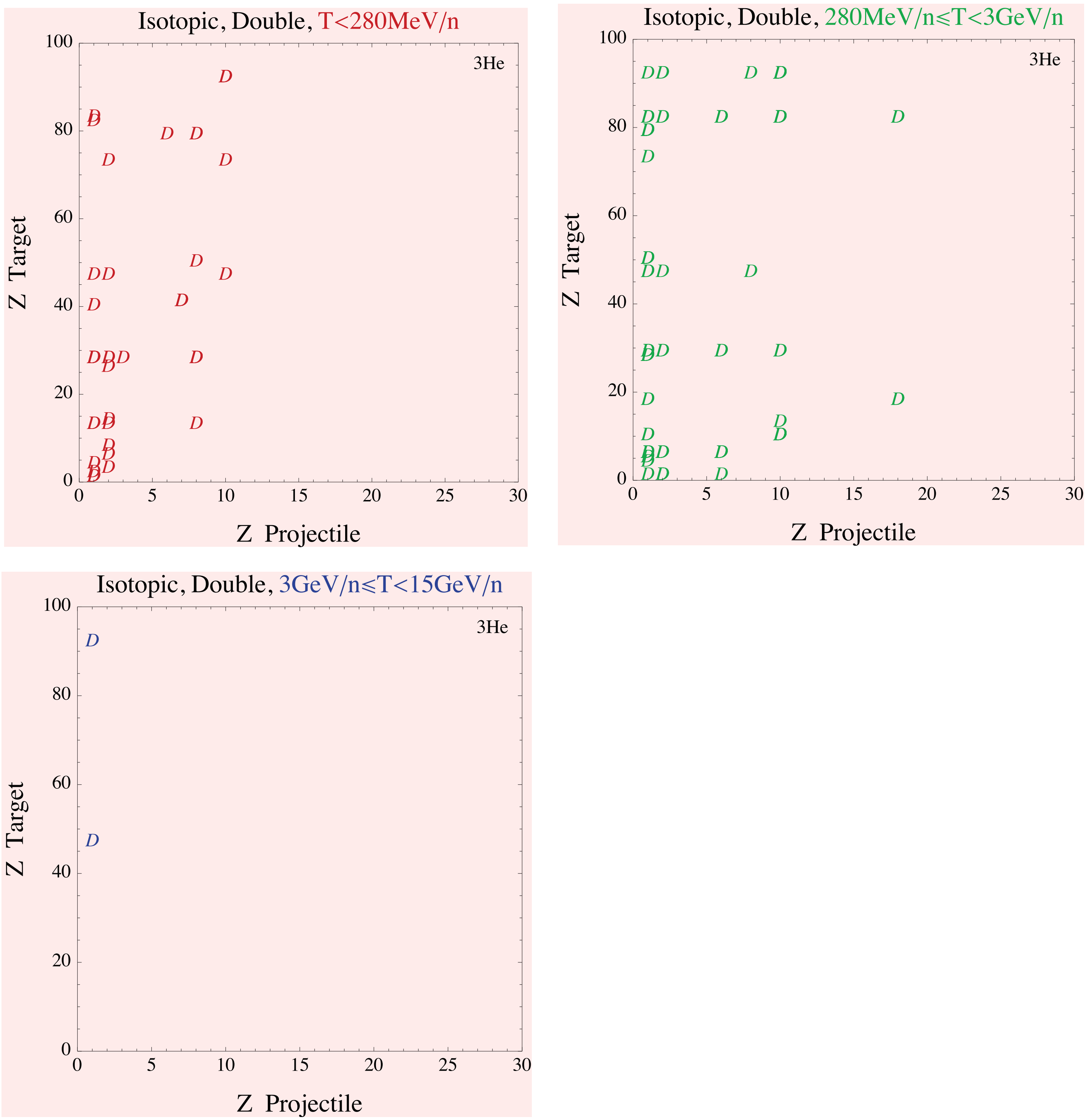


Figure 36: Isotopic double differential cross sections for ^{3}He fragments.

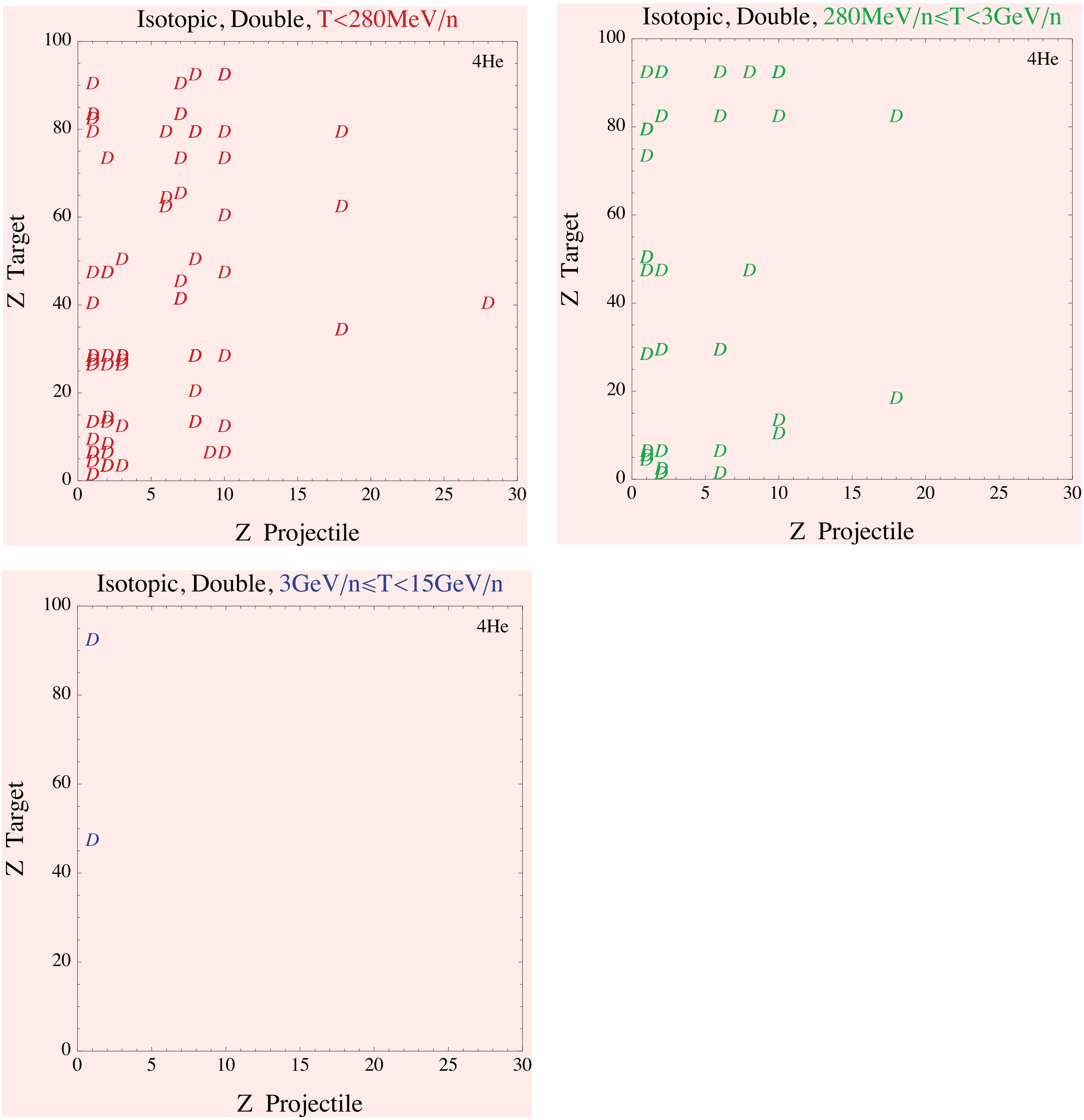


Figure 37: Isotopic double differential cross sections for ^{4}He fragments.

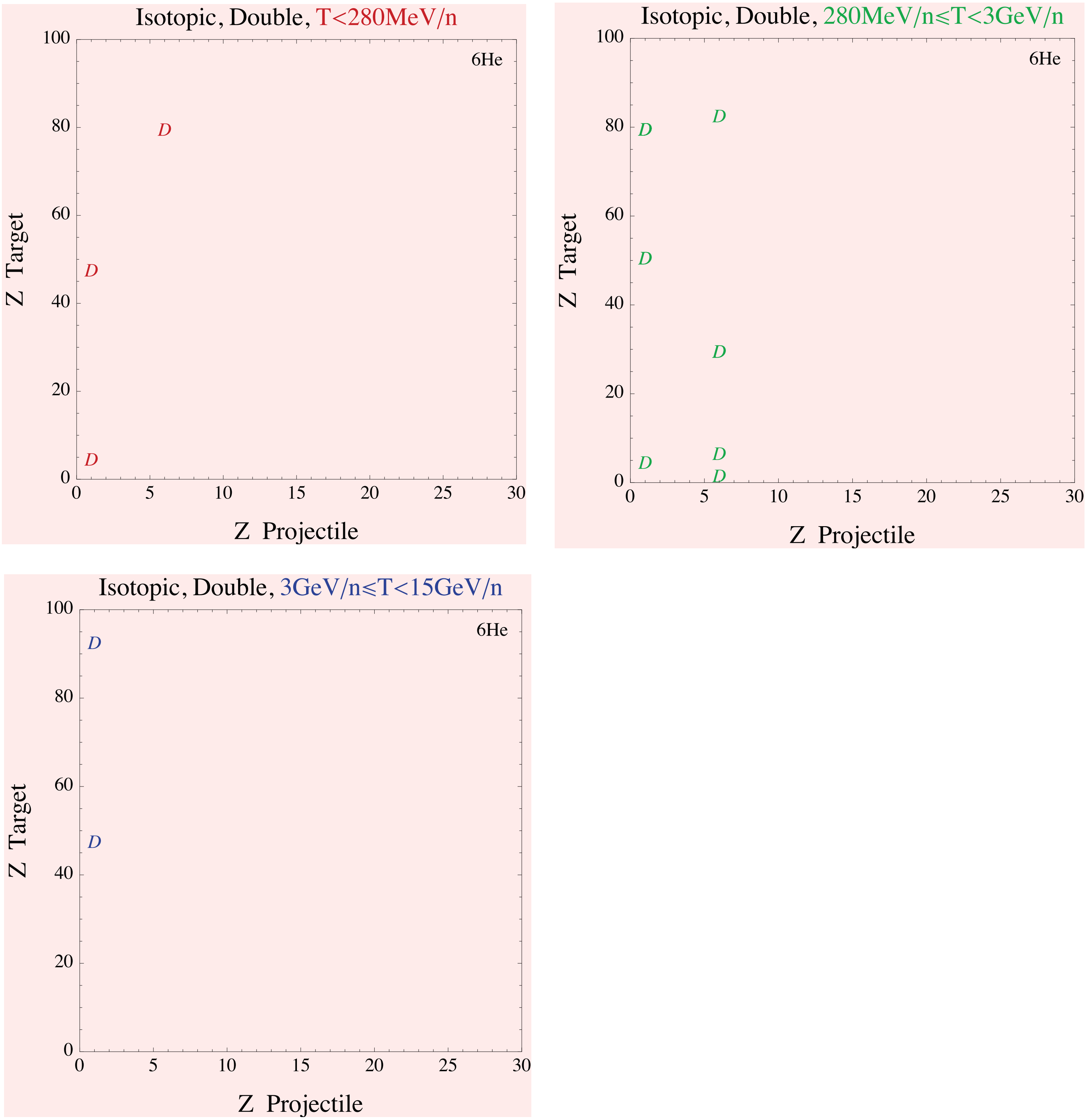


Figure 38: Isotopic double differential cross sections for ^{6}He fragments.

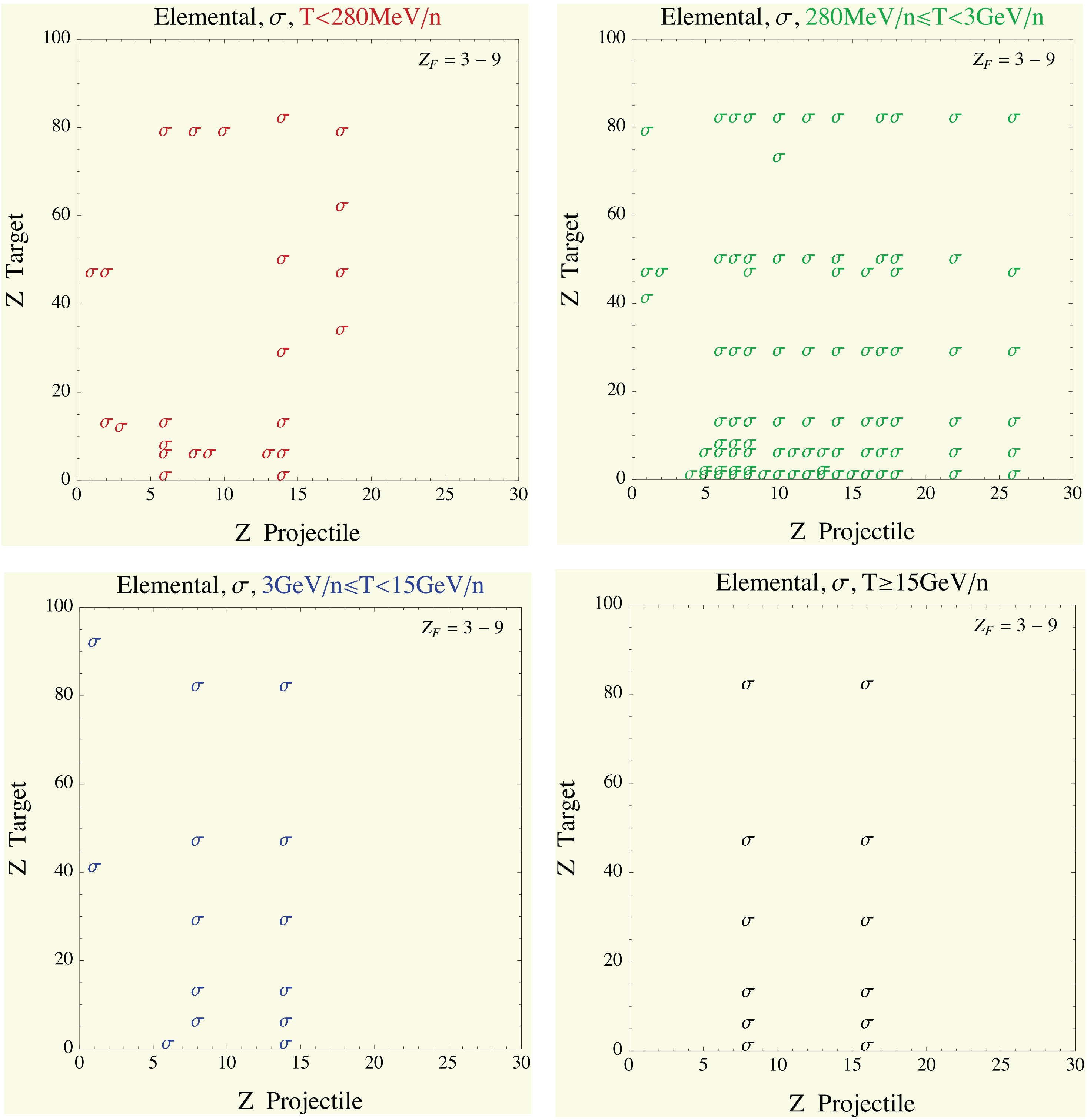


Figure 39: Elemental total cross sections for Z = 3 − 9 fragments.

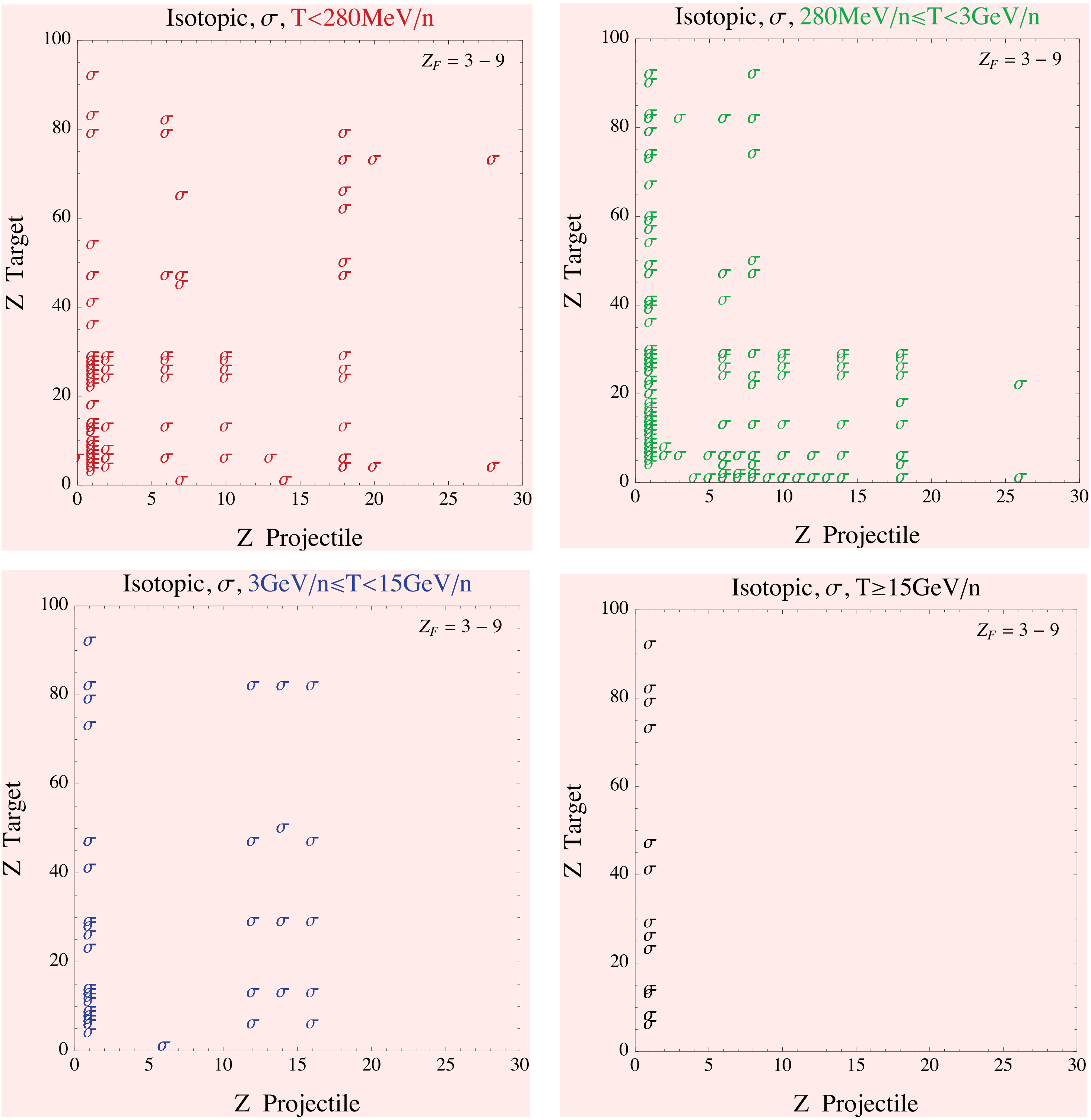


Figure 40: Isotopic total cross sections for Z = 3 − 9 fragments.

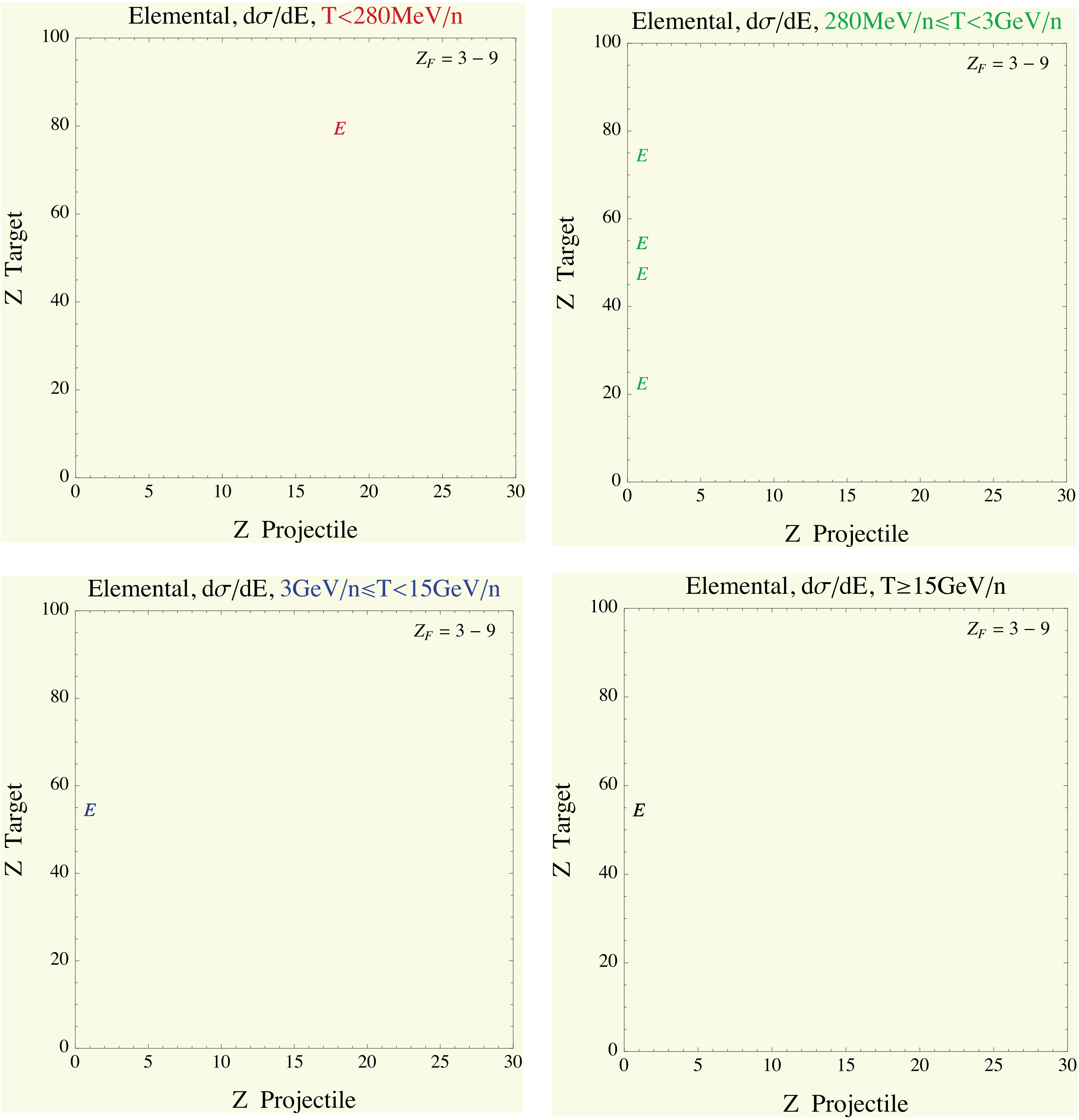


Figure 41: Elemental energy differential cross sections for $Z = 3 - 9$ fragments.

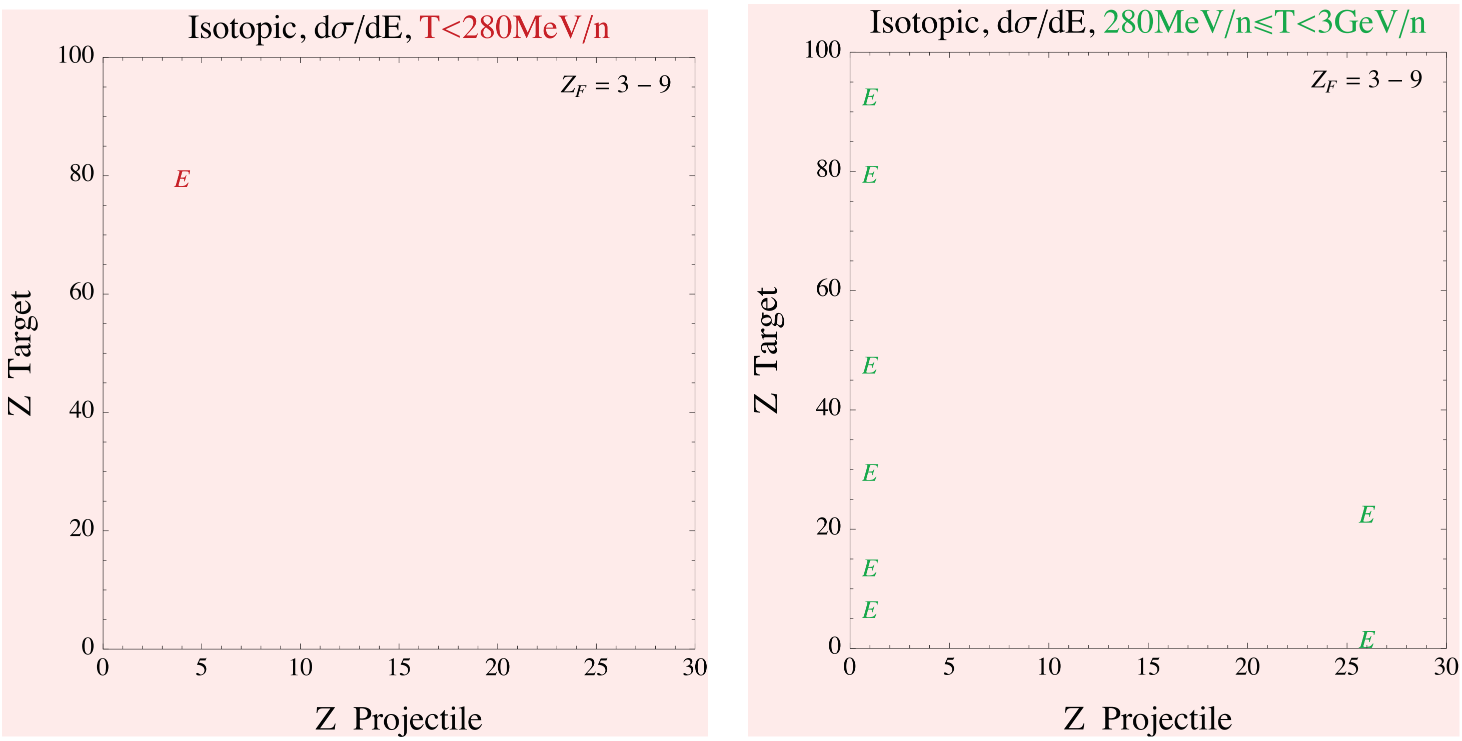


Figure 42: Isotopic energy differential cross sections for Z = 3 − 9 fragments.

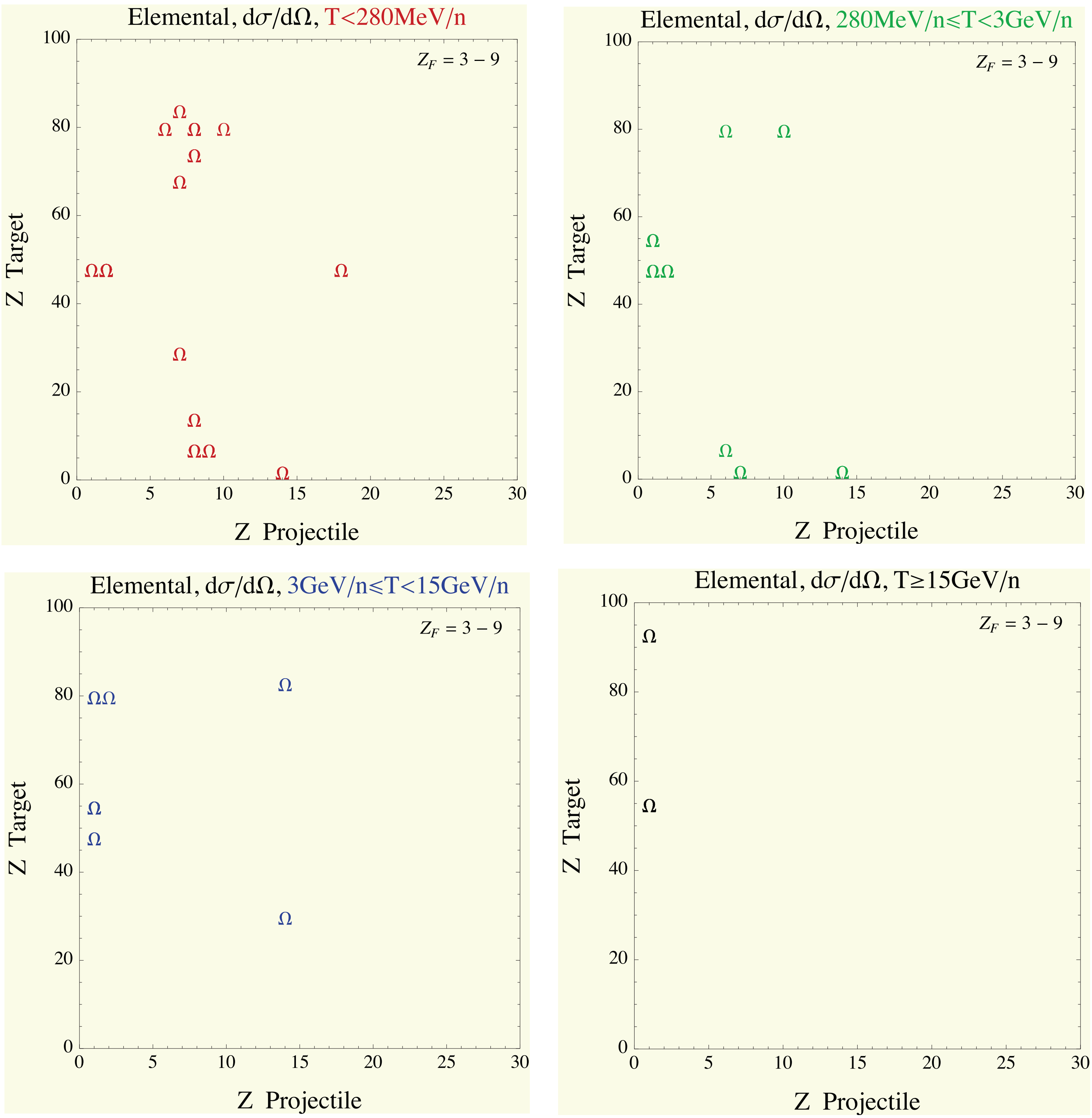
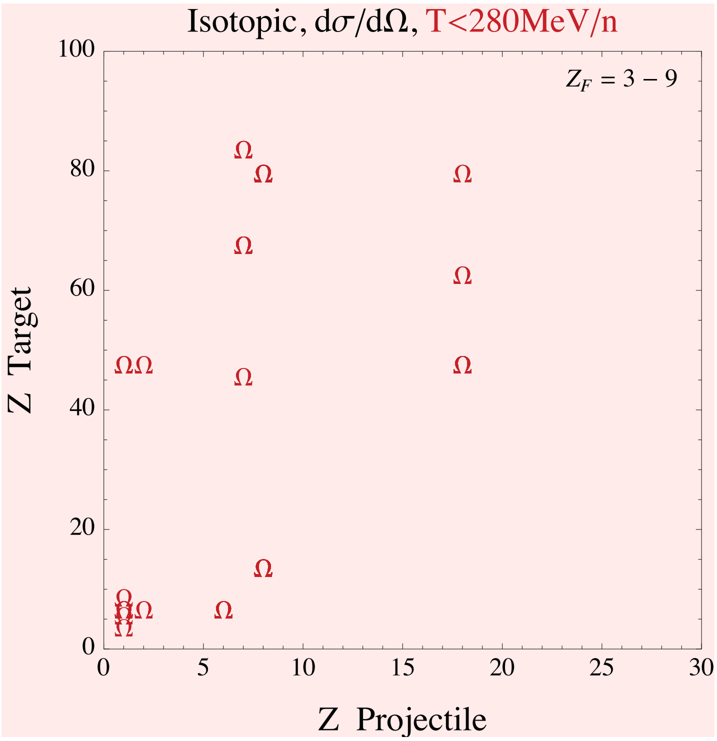
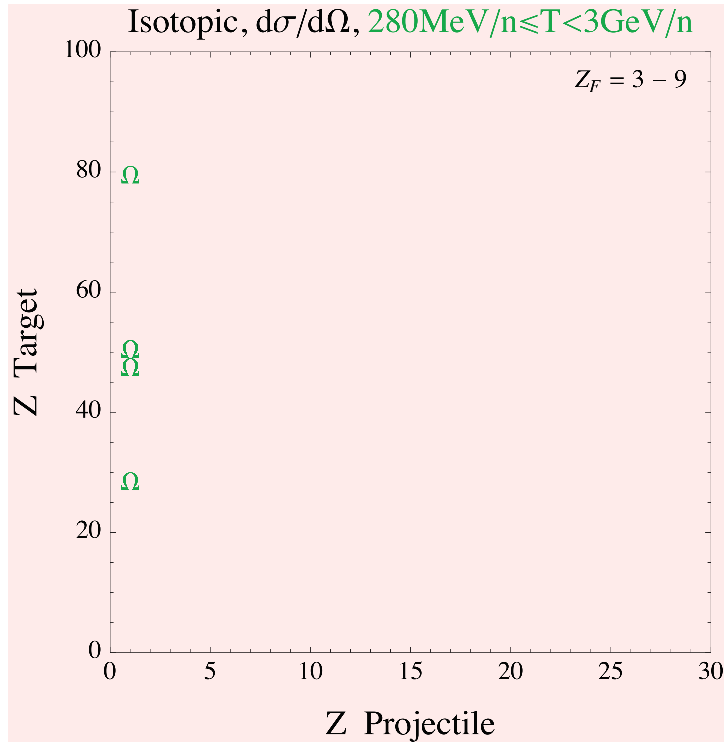


Figure 43: Elemental angular differential cross sections for Z = 3 − 9 fragments.





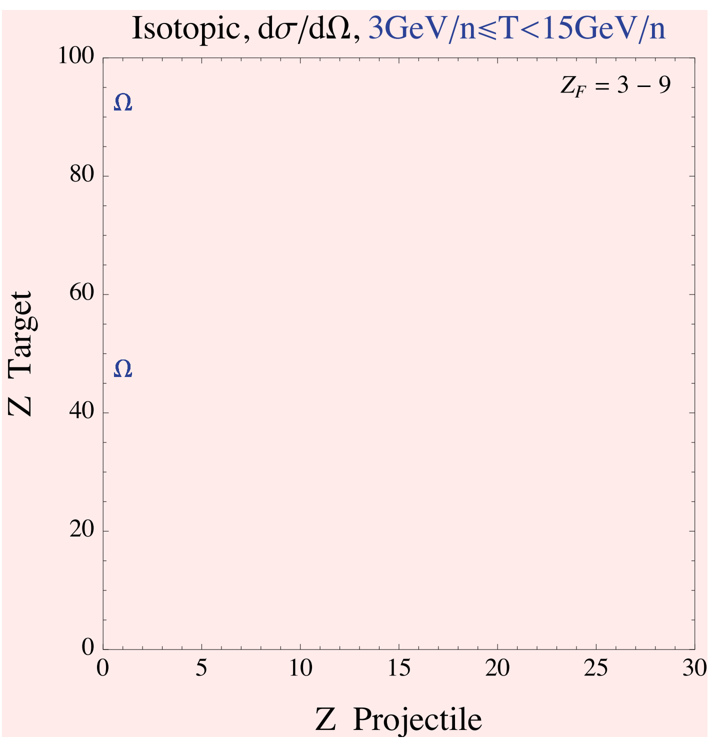


Figure 44: Isotopic angular differential cross sections for Z = 3 − 9 fragments.

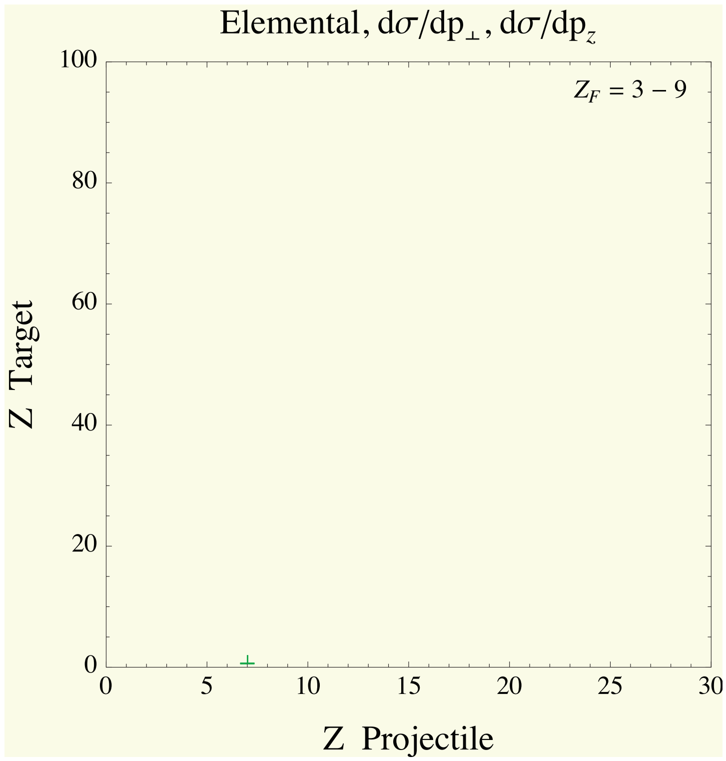


Figure 45: Elemental momentum differential cross sections for Z = 3 − 9 fragments covering all energies.

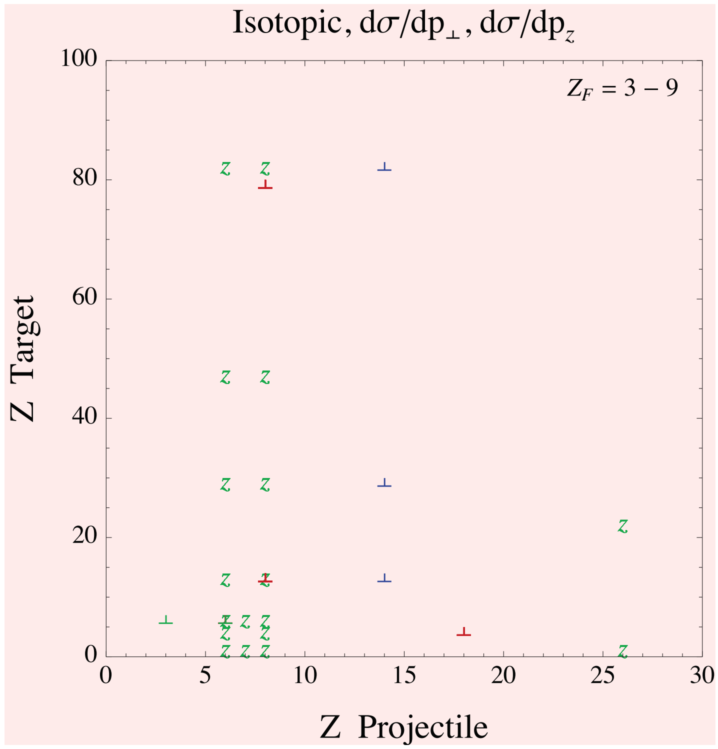


Figure 46: Isotopic momentum differential cross sections for Z $= 3-9$ fragments covering all energies.

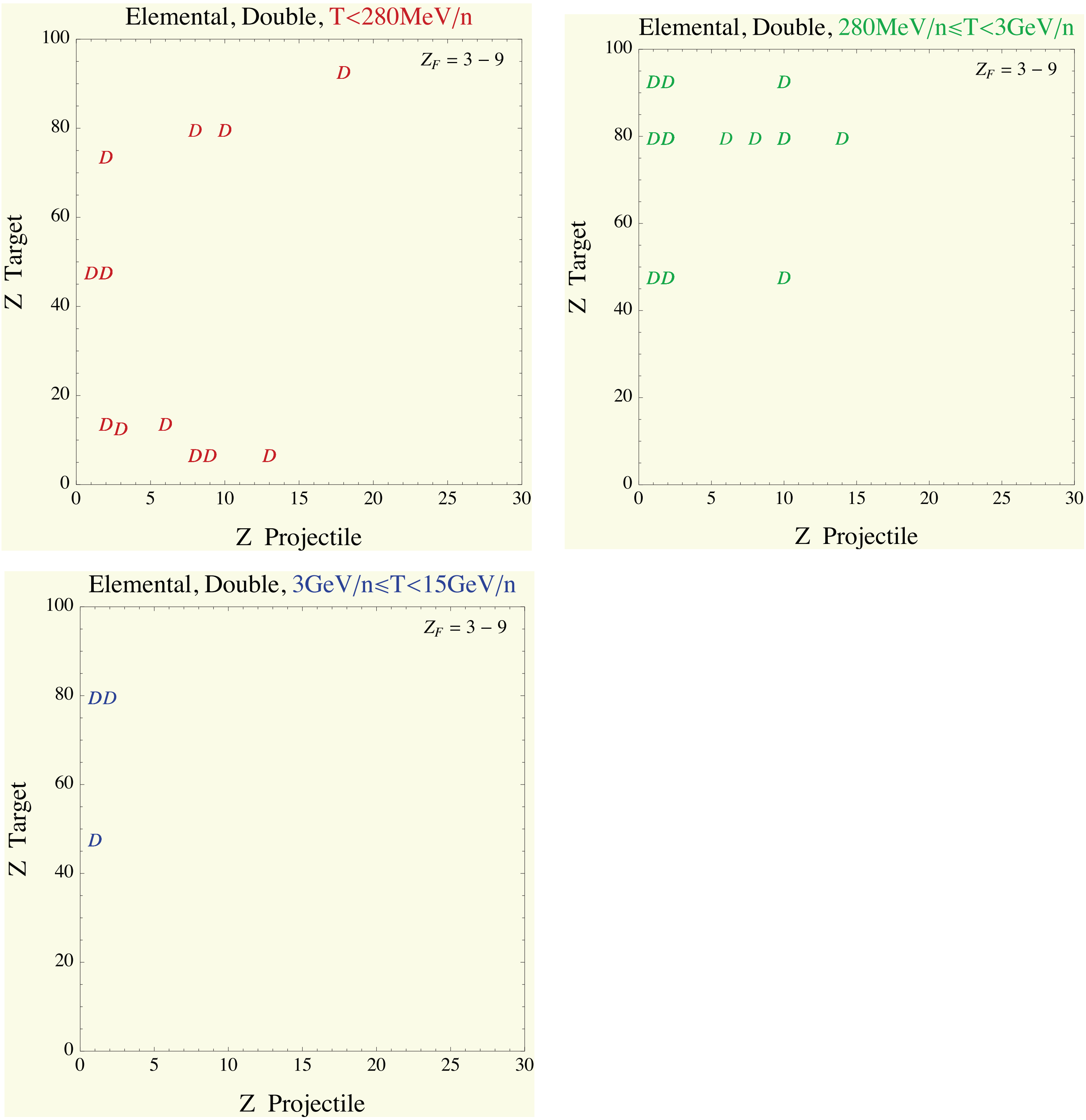


Figure 47: Elemental double differential cross sections for $Z = 3 - 9$ fragments.

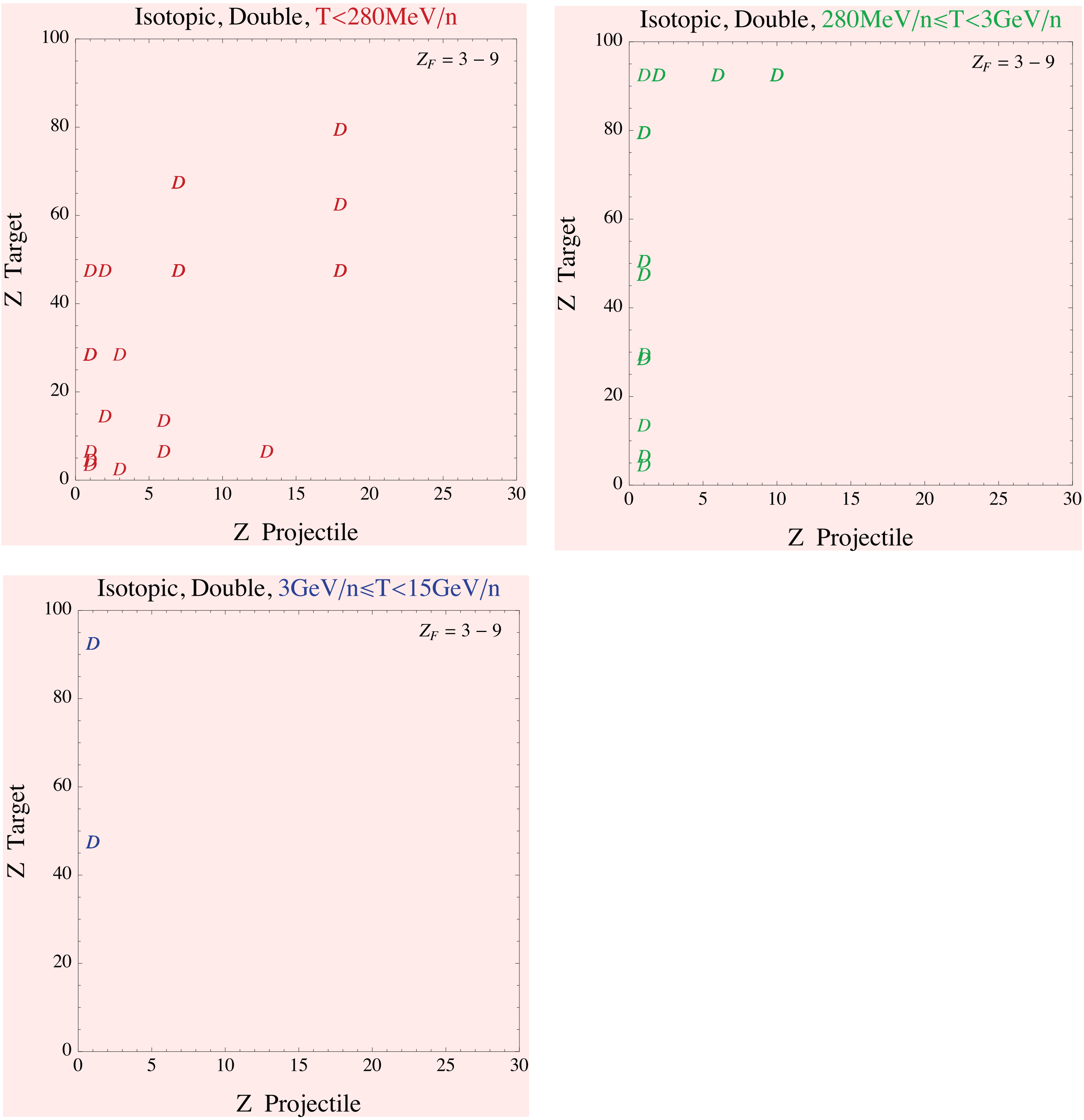


Figure 48: Isotopic double differential cross sections for $Z = 3 - 9$ fragments.

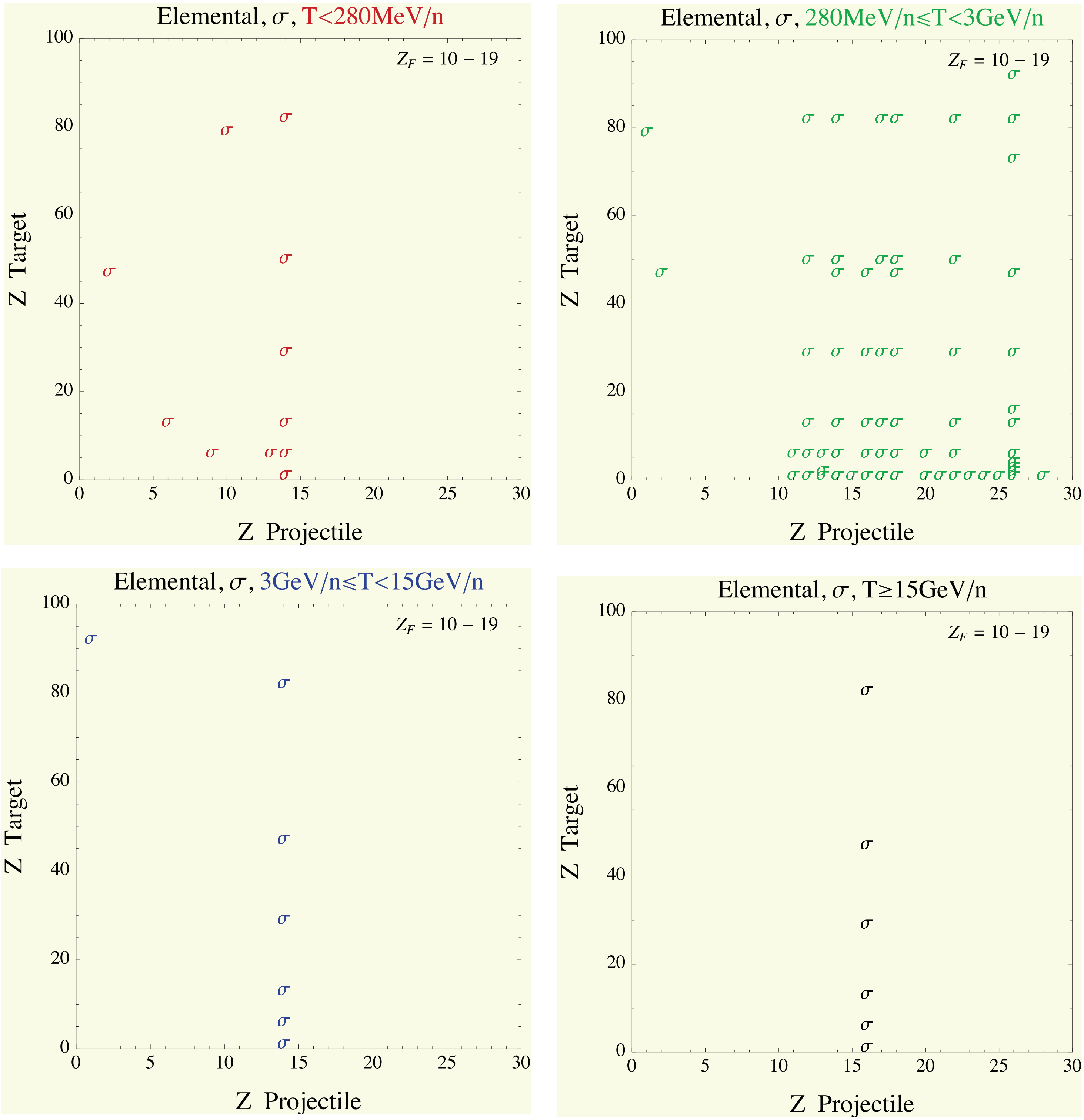


Figure 49: Elemental total cross sections for Z = 10 − 19 fragments.

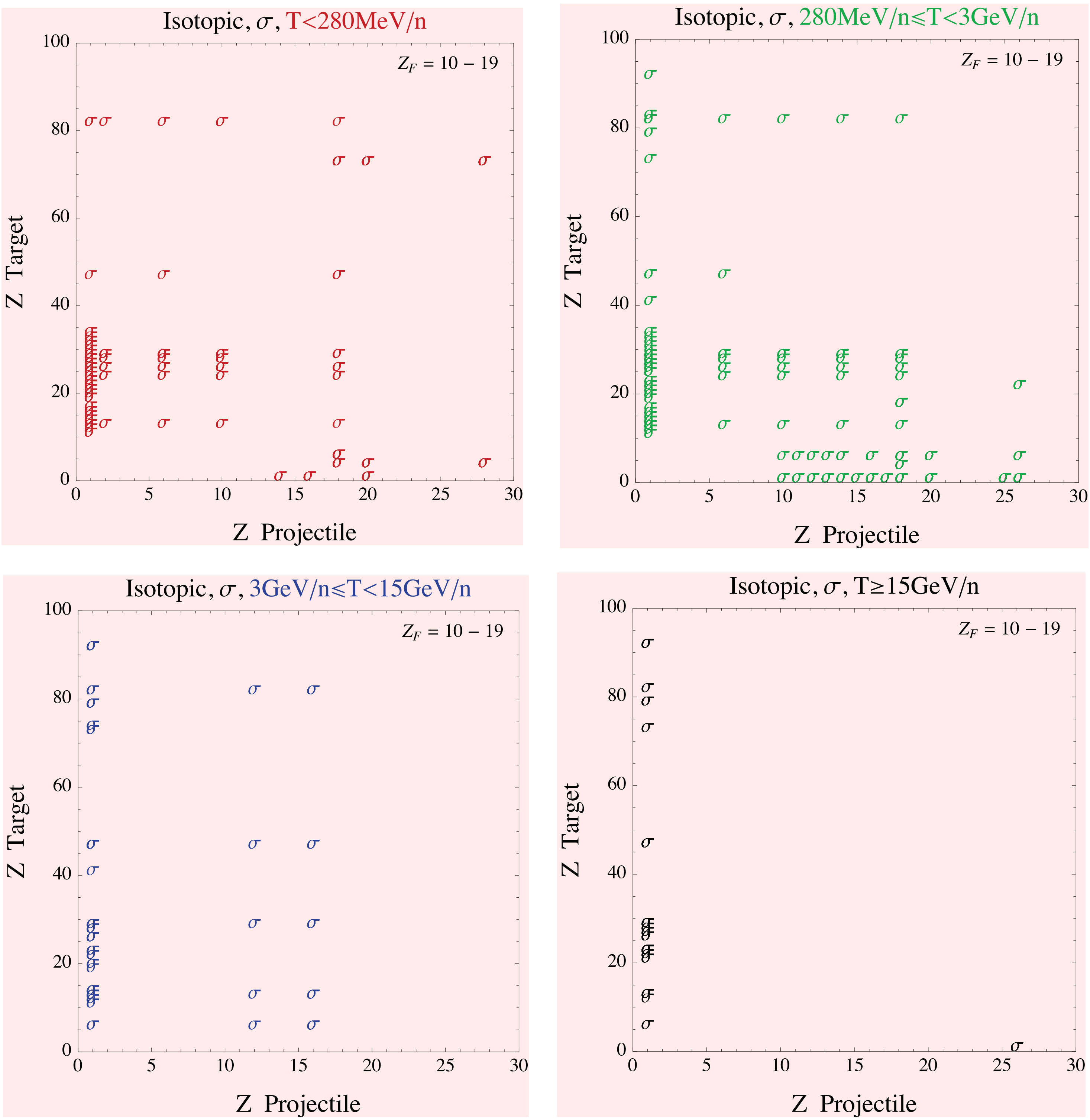


Figure 50: Isotopic total cross sections for Z = 10 − 19 fragments.

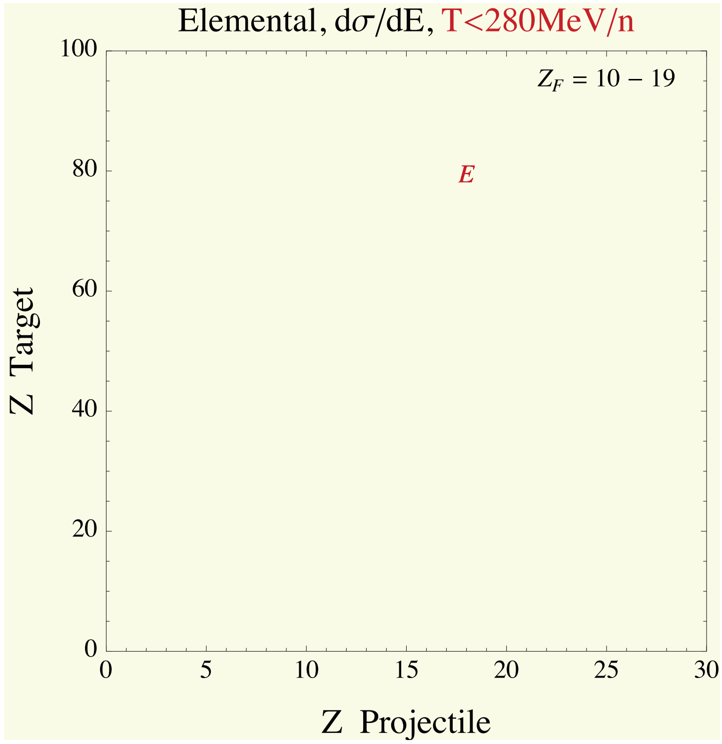


Figure 51: Elemental energy differential cross sections for Z = 10 − 19 fragments.

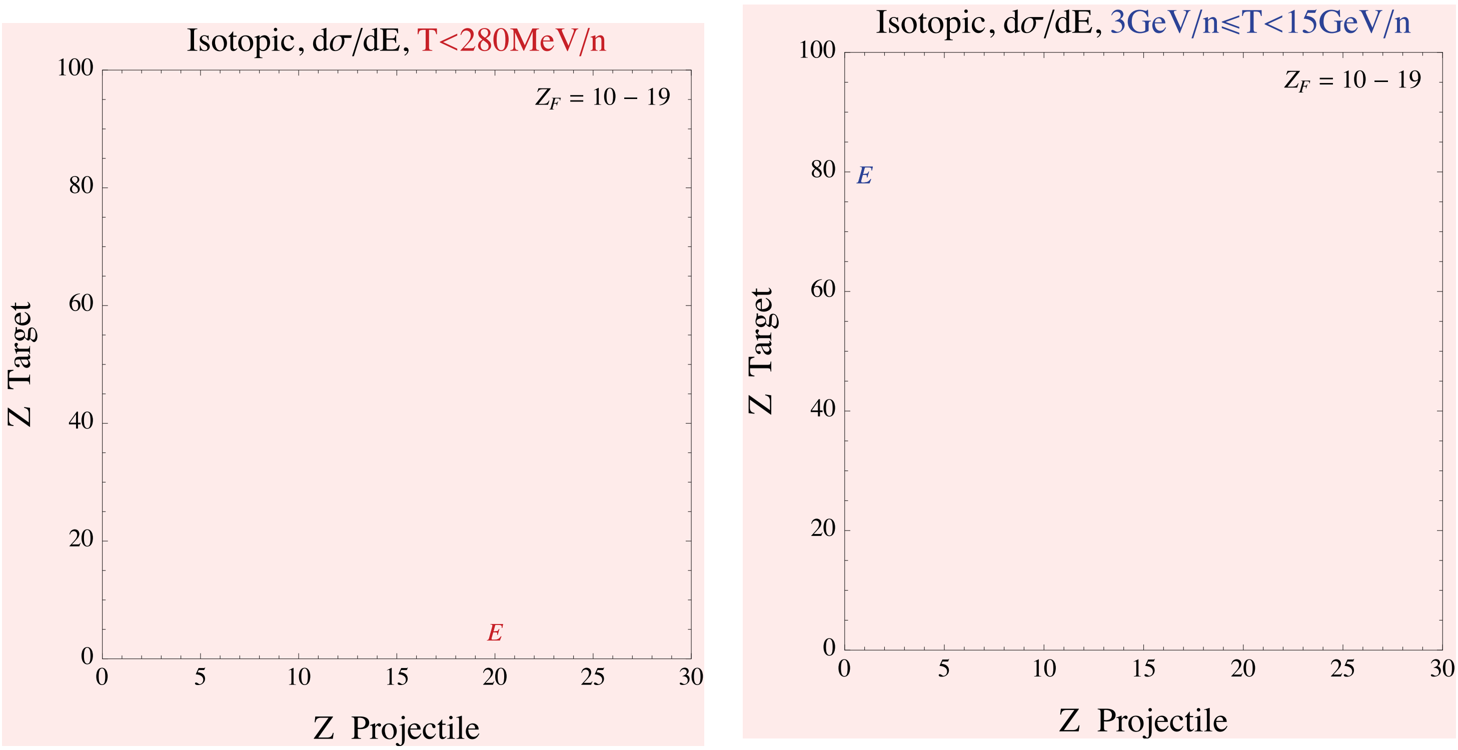


Figure 52: Isotopic energy differential cross sections for Z = 10 − 19 fragments.

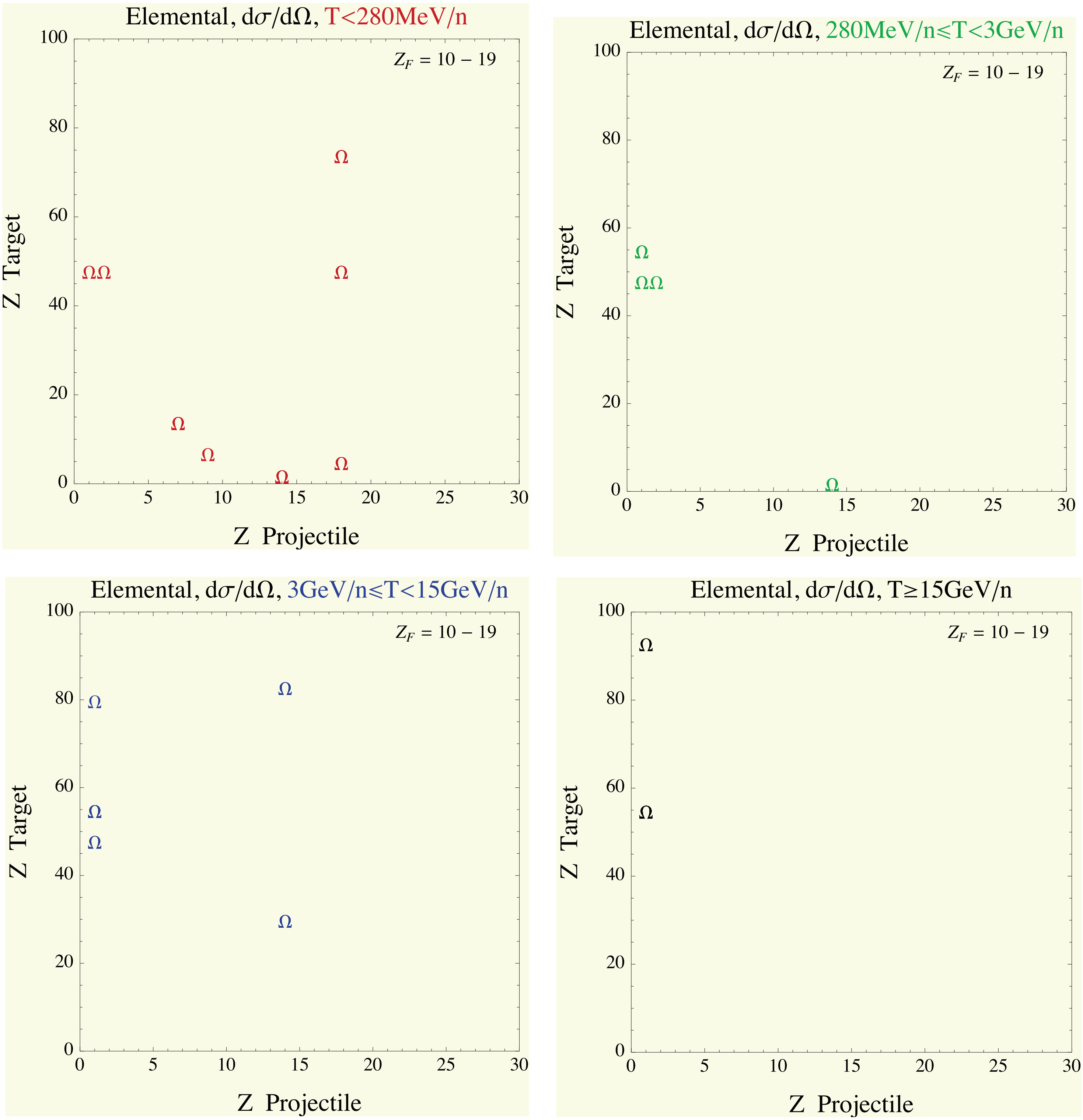


Figure 53: Elemental angular differential cross sections for Z = 10 − 19 fragments.

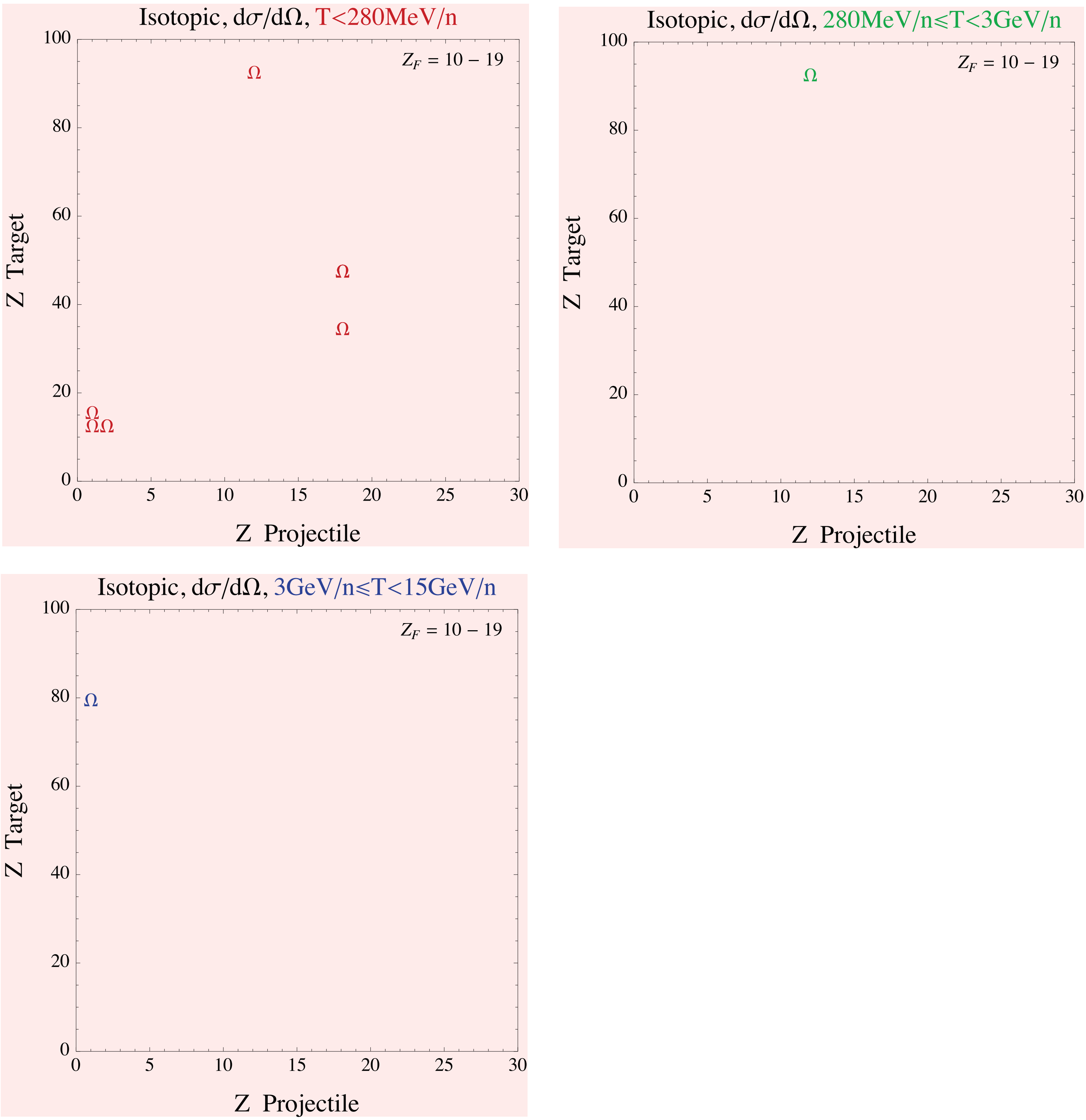


Figure 54: Isotopic angular differential cross sections for Z = 10 − 19 fragments.

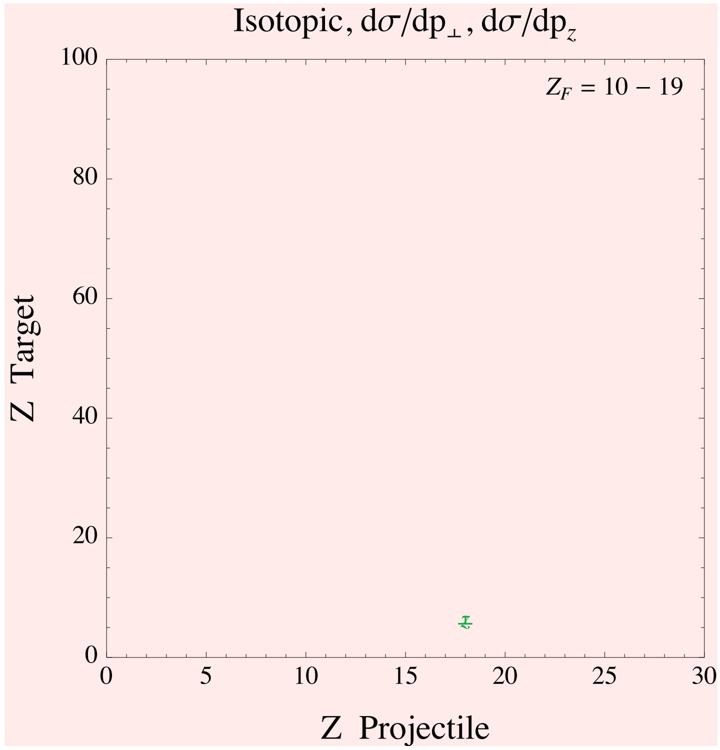


Figure 55: Isotopic momentum differential cross sections for Z = 10 − 19 fragments covering all energies.

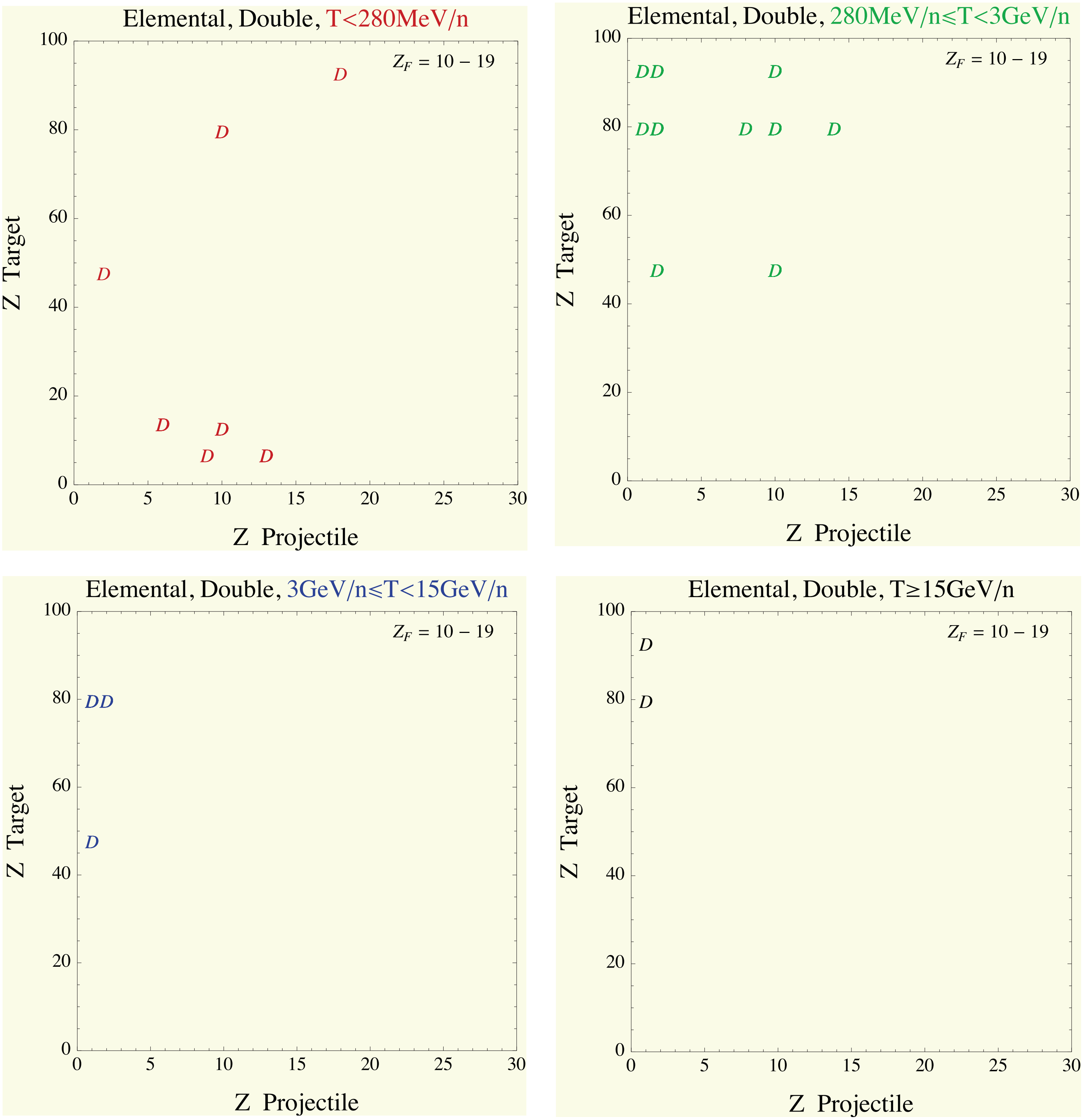


Figure 56: Elemental double differential cross sections for $Z = 10 - 19$ fragments.

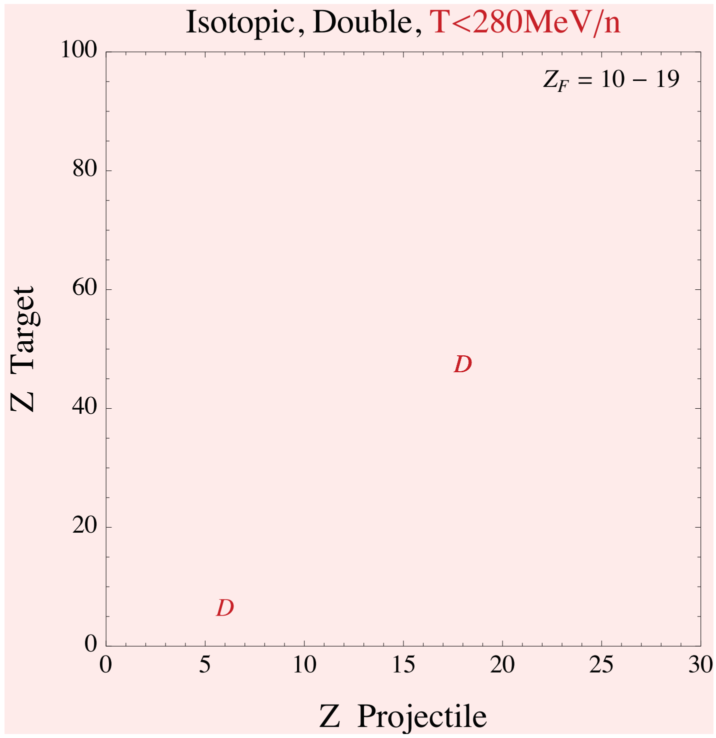


Figure 57: Isotopic double differential cross sections for Z = 10 − 19 fragments.

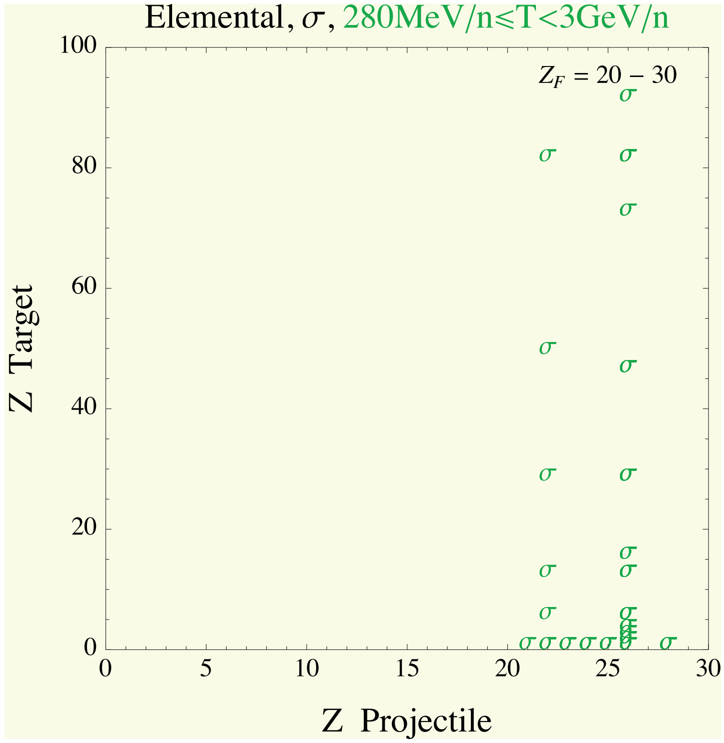


Figure 58: Elemental total cross sections for Z = 20 − 30 fragments.

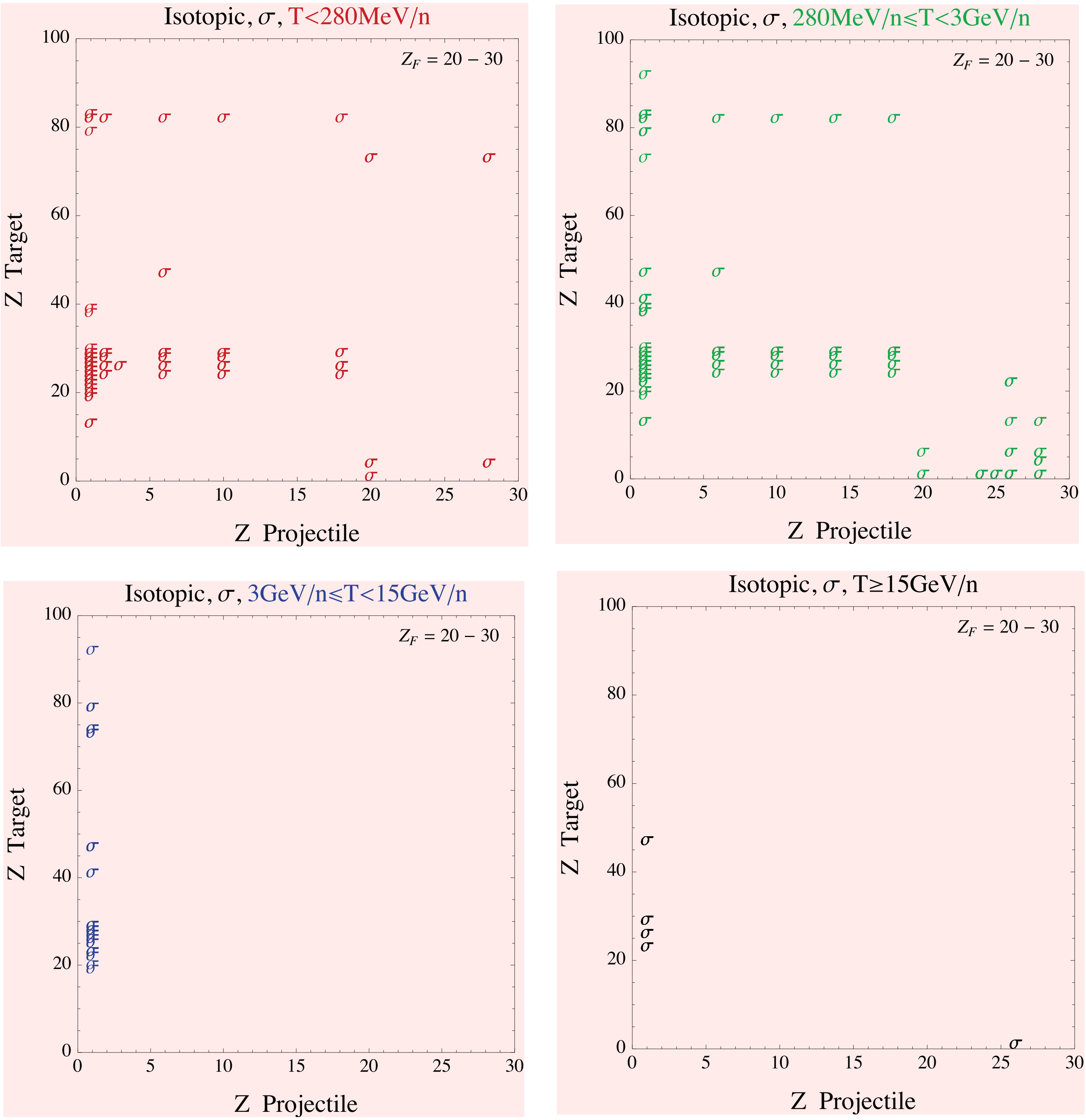


Figure 59: Isotopic total cross sections for Z = 20 − 30 fragments.

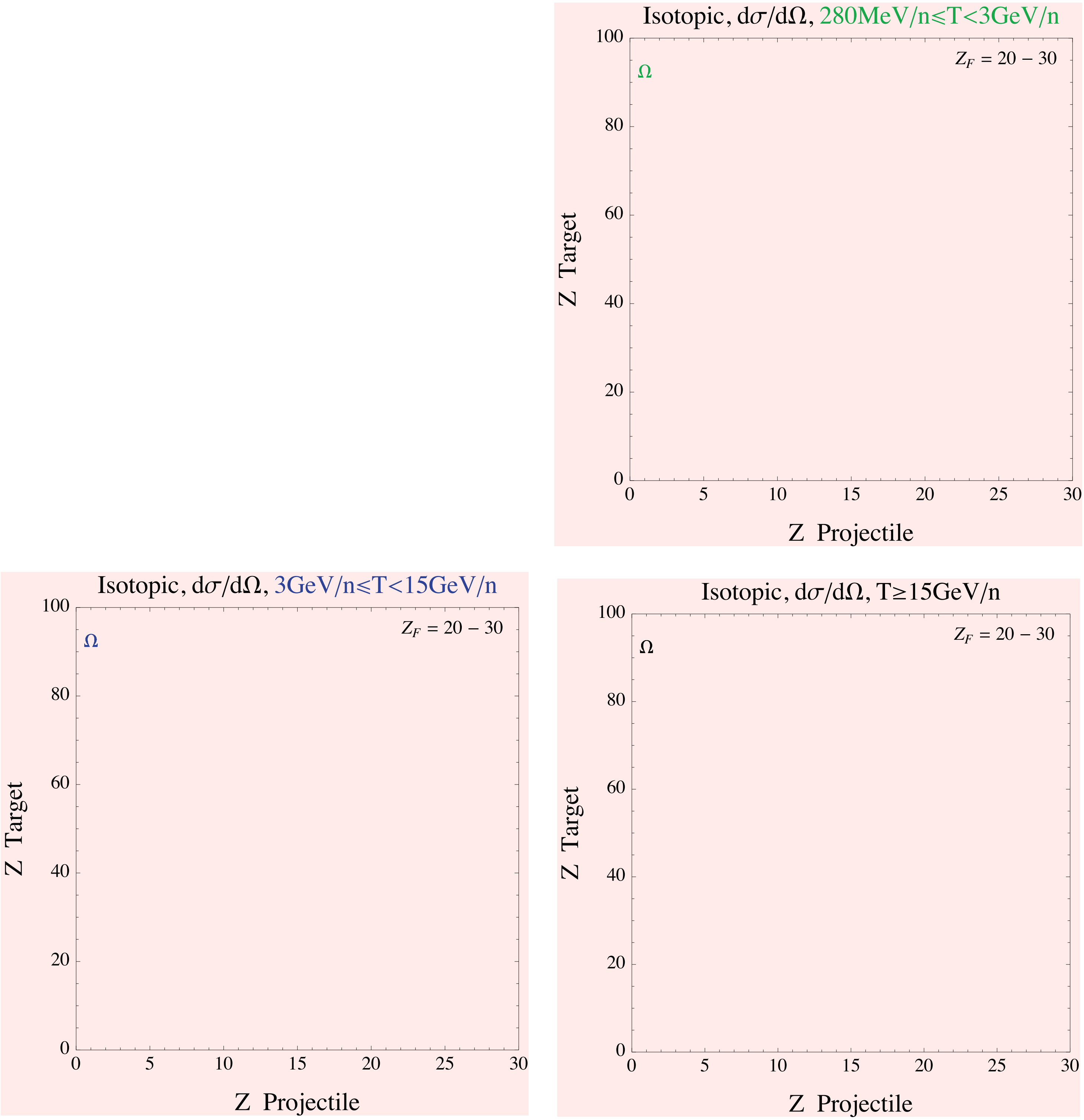


Figure 60: Isotopic angular differential cross sections for Z $= 20 - 30$ fragments.

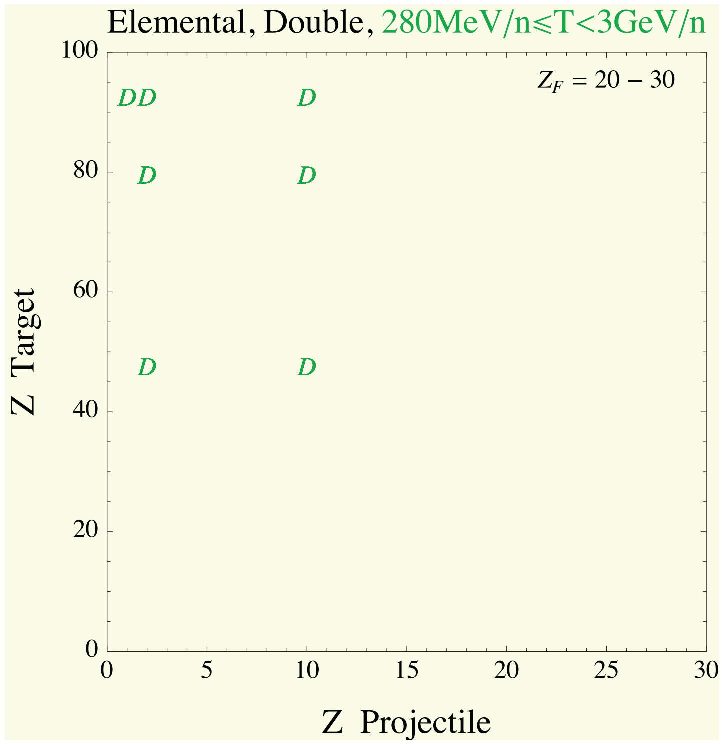


Figure 61: Elemental double differential cross sections for $Z = 20 - 30$ fragments.

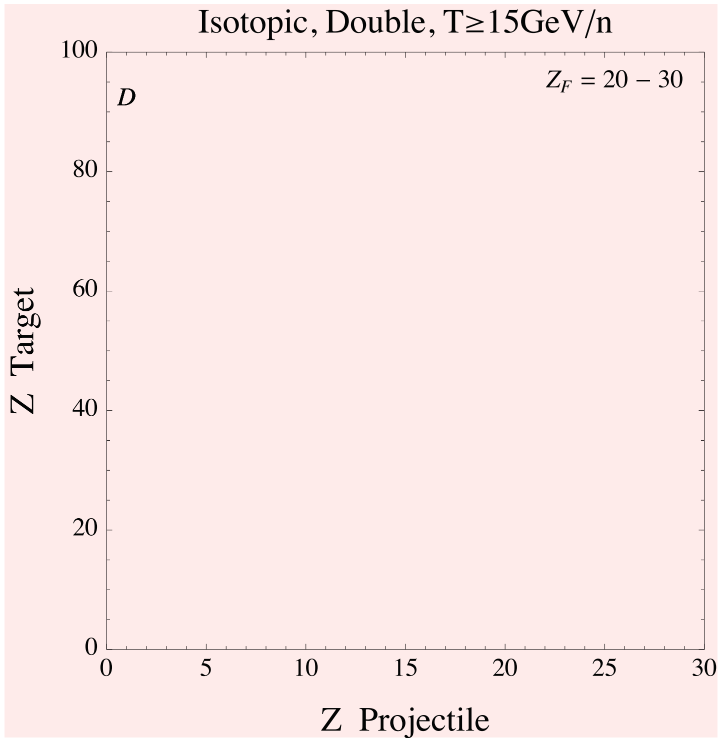


Figure 62: Isotopic double differential cross sections for Z = 20 − 30 fragments.

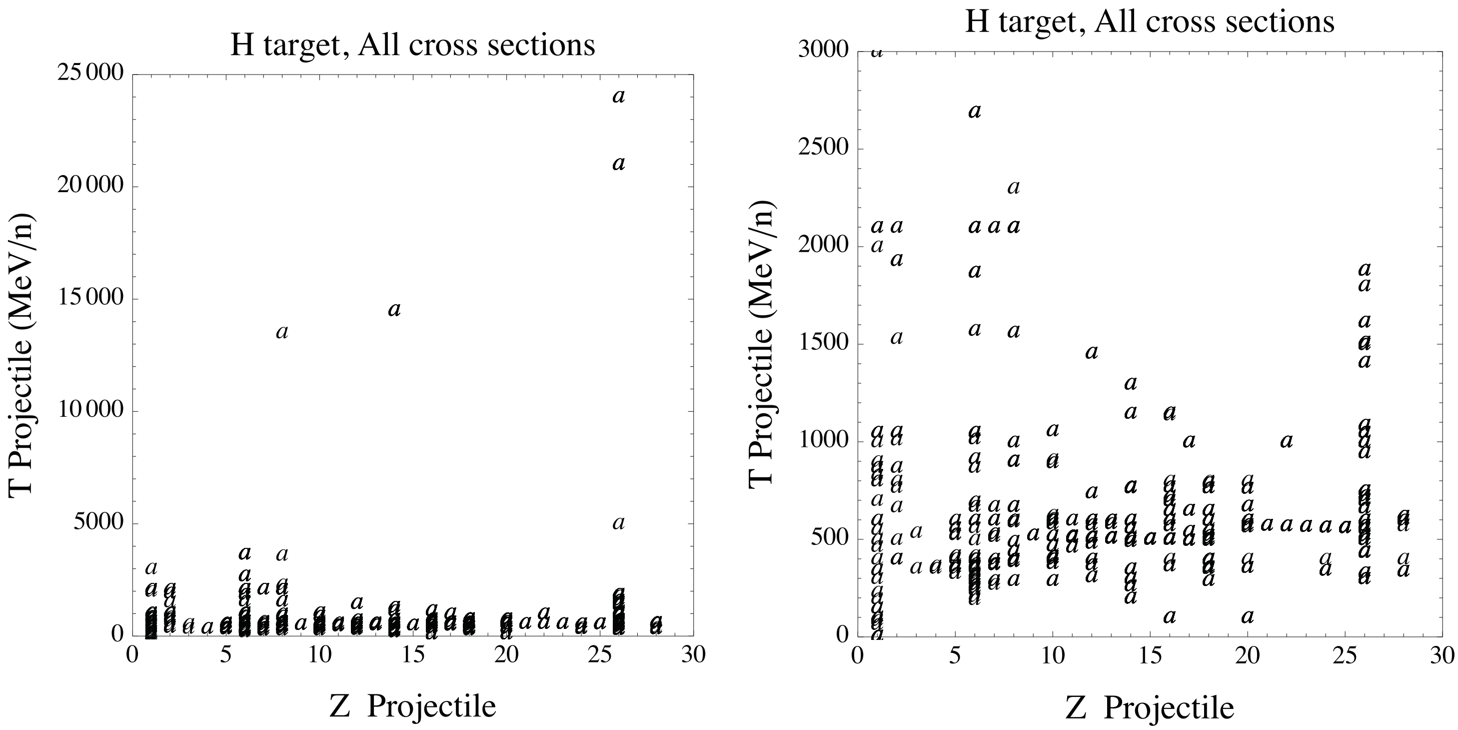


Figure 63: All cross sections for H targets. The right hand panel is the same as the left panel, except zooming in to energies less than 3 GeV/n.

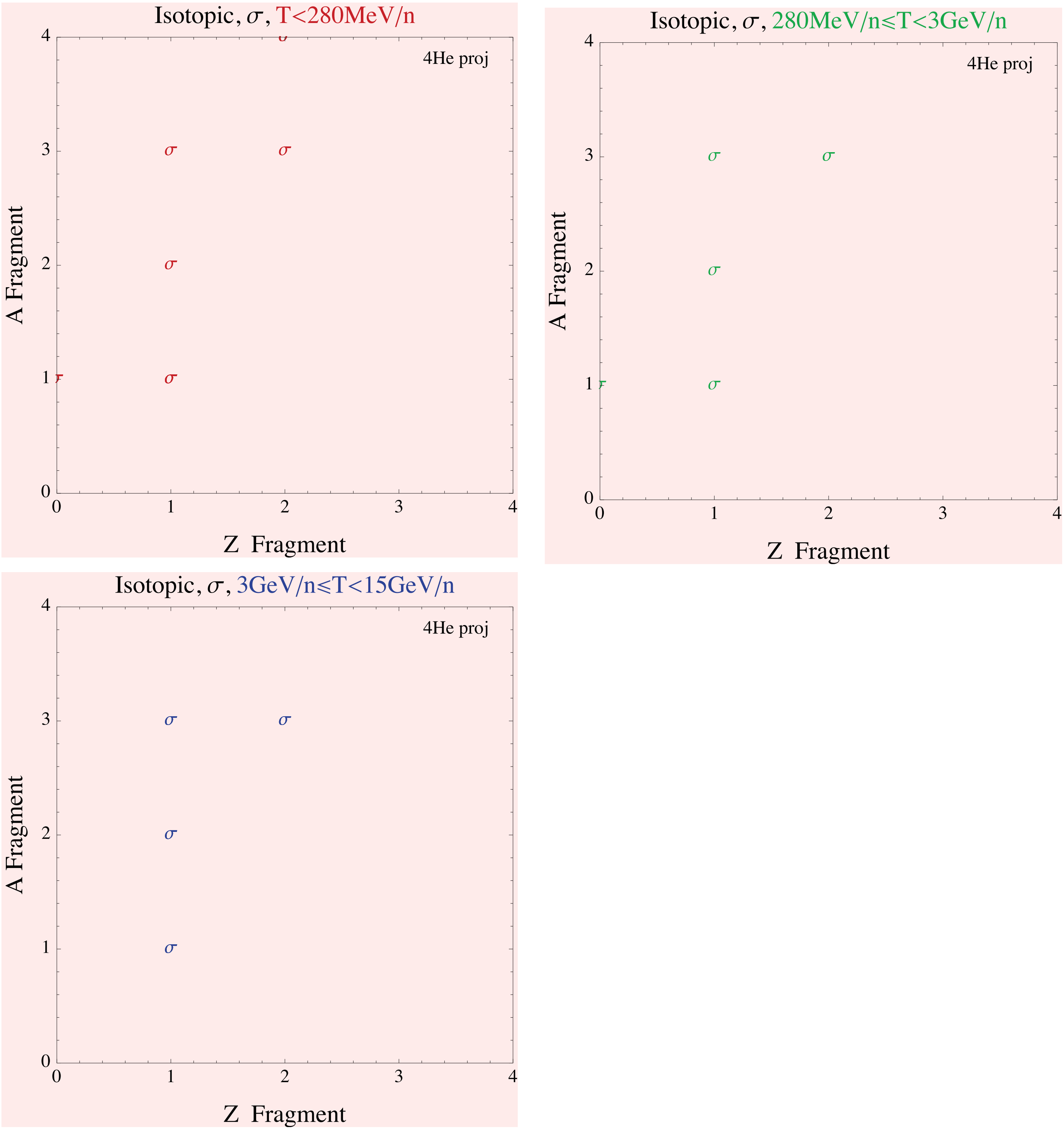


Figure 64: Isotopic total cross sections for ^{4}He projectiles.

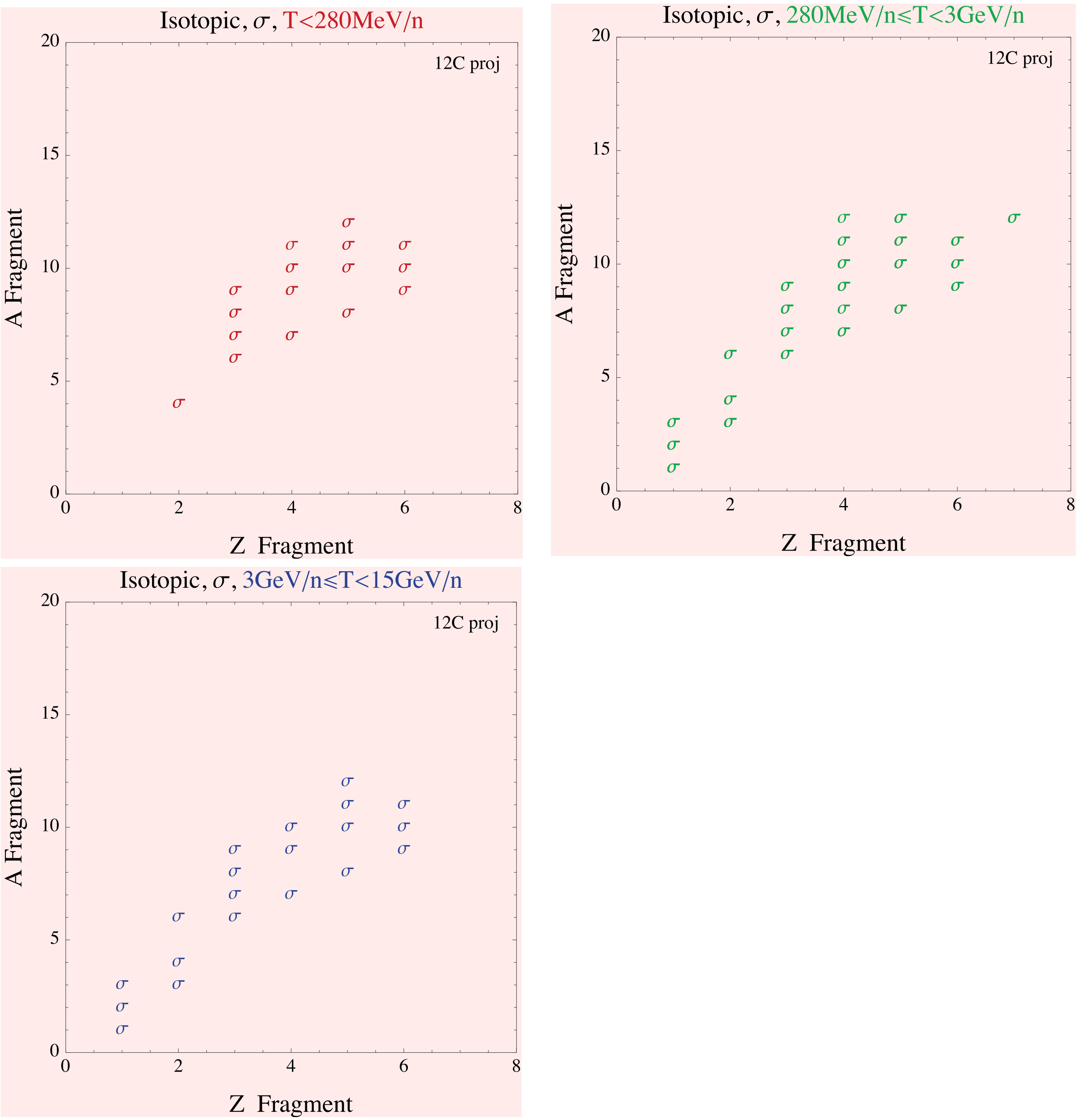


Figure 65: Isotopic total cross sections for ^{12}C projectiles.

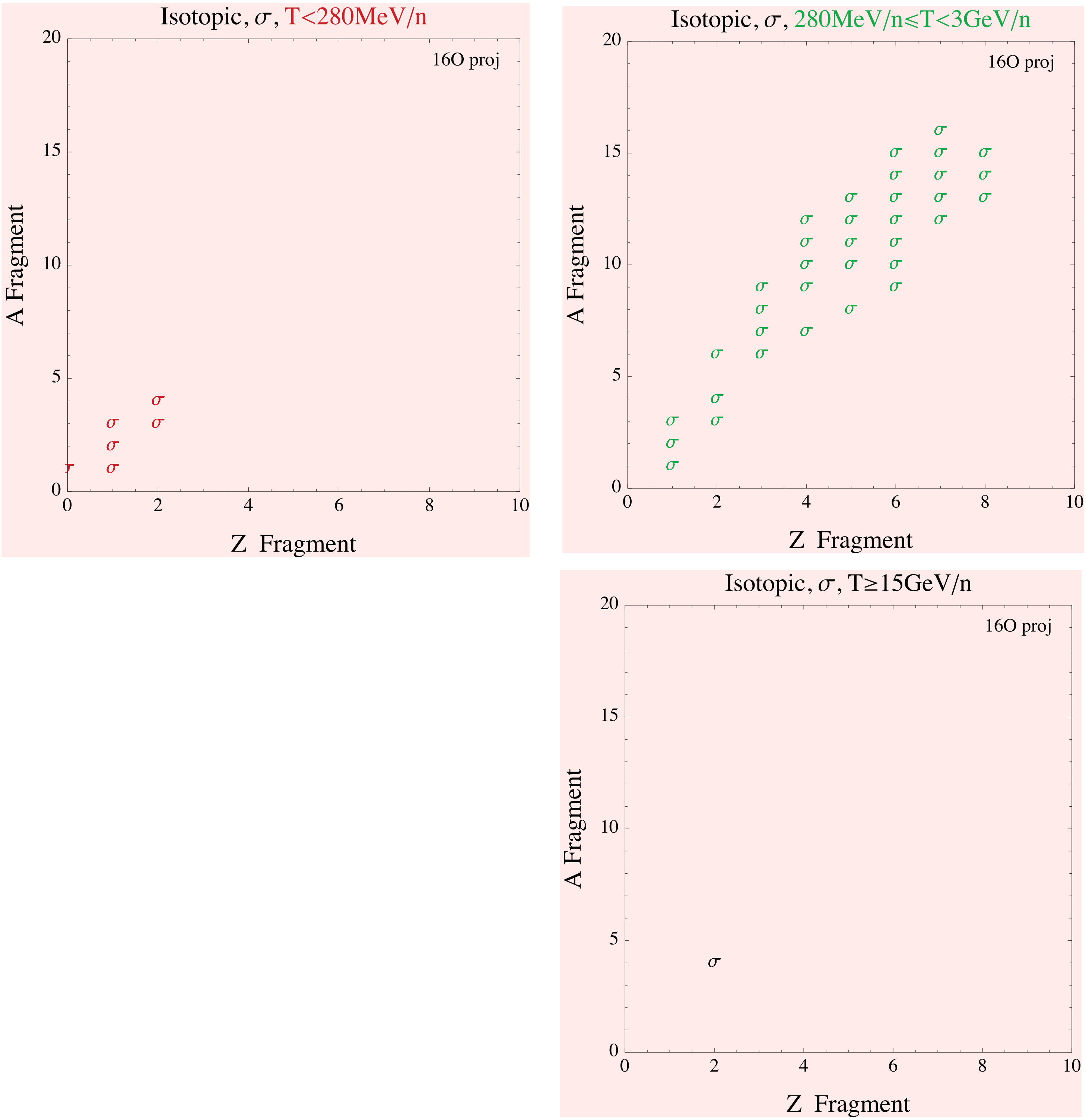


Figure 66: Isotopic total cross sections for ^{16}O projectiles.

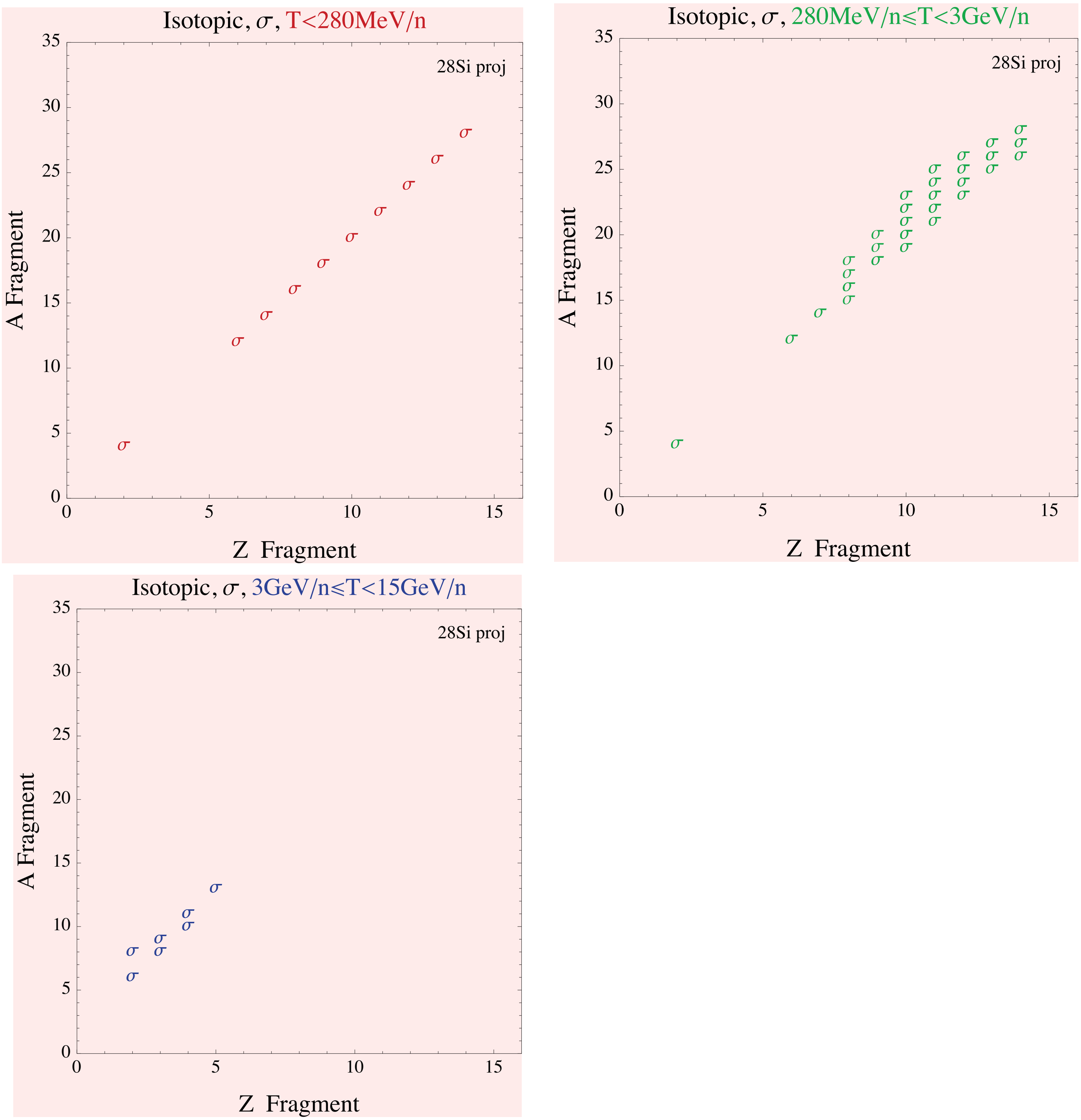


Figure 67: Isotopic total cross sections for ^{28}Si projectiles.

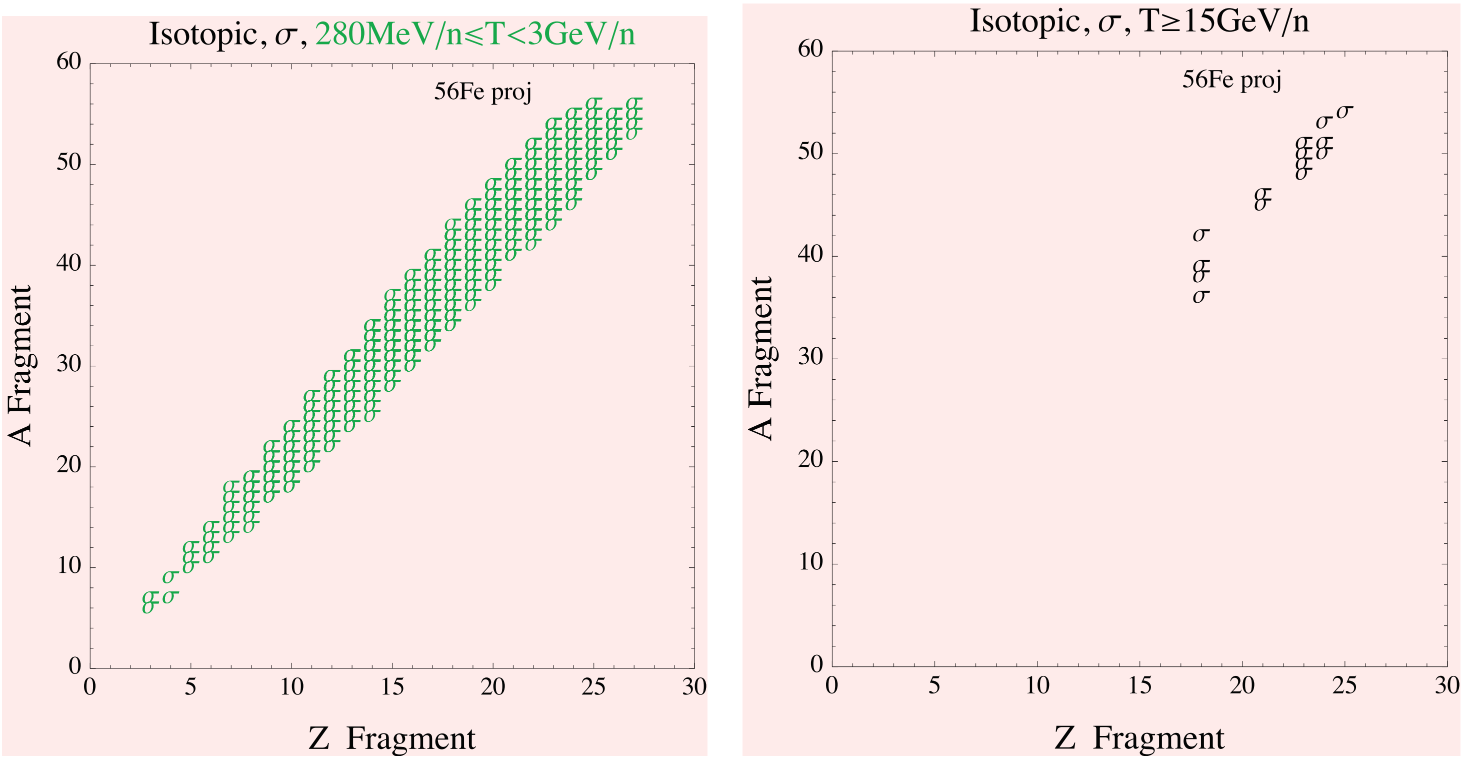


Figure 68: Isotopic total cross sections for ^{56}Fe projectiles.

Table 12: Data Reference. Assume reactions are inclusive unless stated as exclusive (excl) under the Type column. Kinetic energy numbers with or without a decimal point are in units of GeV/n or MeV/n respectively. Abbreviations are as follows: cc = charge changing, elem = elemental, iso = isotopic, inel = inelastic, mult = multiplicity, ex = exclusive, emd = electromagnetic dissociation, inv kin = inverse kinematics, corr = correlations, fiss = fission, pol = polarization, imf = intermediate mass fragments, triple = triple differential cross section, quad = quadruple differential cross section. Also rev = review and means that data from other sources are reviewed in the reference. This table is continued in the following pages.

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Abdurakhimov81]	^{4}He	4.5	Li,C,Al,Cu	$^{1-3}$H,^{3}He	iso	σ	
[Abe87]	^{3}He	9,15	^{12}C	n,^{14}O	iso	dΩ	ex
[Abe87a]	^{3}He	8,15	^{26}Mg	n,^{28}Si	iso	dΩ	ex
[Abramov10]	^{12}C	300	Be	^{1,2}H	iso	$E\frac{d^3\sigma}{d^3p}$	
[Aksinenko80]	^{4}He,^{12}C	3.66	Li,C,Ne,Al Cu,Zn,Pb		inel	σ	mult
[Aladashvili81]	^{4}He	1.93	^{1}H	n, $^{1-3}$H,^{3}He,π	iso	σ	ex
[Alard75]	^{1}H	600	C,Al,Fe,Au^{9}Be,^{40}Ca	$^{1-3}$H,^{3,4}He	iso	σ, dE, dEdΩ	
[Alexakhin00]	^{14}N	52	Ag	$^{1-3}$H	iso	dEdΩ	mult
[Alexander63]	^{1}H	0.5 – 6.2	^{238}U	^{67}Cu,^{90,93,99}Mo,^{111}Ag $^{121,123-125,130,132,133-135}$I ^{112}Pd,^{132,134}Te	iso	σ	
[Alvarez10]	^{238}U	1.0	Be	^{A}Pt – ^{A}Fr	iso	σ	
[Anderson83]	^{1,2}H,^{4}He,^{12}C	400,1.05,2.1	H,C,Cu,Pb	^{1,2,3}H,^{3,4,6,8}He	iso	dpdΩ	
[Anikina83]	^{20}Ne	3.3	C,Al,Cu,Pb		inel	σ	
[Apollonio10]	^{1}H	2.2,4.1,7.1 8.0,11.1	Be,C,Al,Cu Sn,Ta,Pb	^{1}H	iso	dpdΩ	
[Armbruster04]	^{238}U	1.0	^{1}H	^{A}N – ^{A}U	iso	σ	
[Asano85]	^{1}H	500	Ta,W,Au	^{A}Co – ^{A}Hg	iso	σ	
[Asano88]	^{1}H	12.0	Ta,W,Au	^{A}Na – ^{A}Pt	iso	σ	
[Auble83]	^{16}O	52,100,147	Al,Ni,Sn,Au	^{1,2,3}H,^{3,4}He	iso	σ, dEdΩ	
[Audouin06]	^{208}Pb	500	^{1}H	^{A}Tm – ^{A}Bi	iso	σ	
[Austin62]	n,^{1}H	120,153	^{12}C	^{11}B,^{11}C	iso	σ	ex

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Avan84]	^{1}H	200	^{6}Li,^{27}Al,^{58}Ni,^{197}Au	^{1}H	iso	dEdΩ	
[Avdeyev02]	^{4}He,^{12}C	3.65,1.87	Au	C	elem	dΩ, dEdΩ	mult
[Awes79]	^{16}O	20	^{238}U	$^{1-3}$H,^{4}He	iso	dE, dΩ	
[Awes80]	^{16}O	20	^{238}U	$^{1-3}$H	iso	dEdΩ	
[Awes81]	^{16}O	20	^{238}U	$^{1-3}$H,^{4}He	iso	dE, dΩ, dEdΩ	
[Badala93]	^{16}O	94	Al,Ni,Au	^{4}He	iso		
[Badran01]	^{7}Li	$1-13$	^{56}Fe	$^{1-3}$H,^{4}He,^{52,54}Mn $^{56-58,60}$Co,^{60,61}Cu	iso	σ,dEdΩ	
[Baker58]	^{1}H	$1.0-3.0$	C,Al,Cu,Ag,Au	^{7}Be	iso	σ	
[Banaigs87]	^{4}He	1.53	^{2}H,^{3,4}He	^{4}He	iso	$d\Omega$, dpdΩ	
[Bandyopadhyay02]	^{7}Li,^{19}F	7,5	^{12}C,^{24}Mg	$^{1-3}$H,^{4}He	iso	dEdΩ	
[Barrette95]	^{28}Si	13.7	Al,Cu,Sn,Pb	^{6,8}He,^{8,9}Li,^{10,11}Be,^{13}B	iso	σ, dE, dp$_{\perp}$	w(p$_{\perp}$)
[Barrette00]	^{197}Au	10.6	^{197}Au	^{2,3}H,^{3,4}He	iso	dpdy	mult
[Bastid90]	^{20}Ne	400,800	NaF,Pb	H,He	elem	dpdΩ	
[Basu07]	^{16}O	5	^{40}Ca	^{1}H, ^{4}He	iso	dEdΩ	
[Batzel54]	^{1}H	$10-33$	Mg,Al	^{22}Na	iso	σ	
[Bazin90]	^{86}Kr	44	^{27}Al,^{103}Rh ^{197}Au	^{12}C,^{16}O,^{23}Na,$^{19-25}$Ne $^{40-47}$Ca,^{A}Zn $-$ ^{A}Sr	iso	dp,yield	
[Beck76]	^{1}H	558	Be,C,Al,Fe Cu,Ge,W,Pb	^{1,2}H	iso	dΩ,dEdΩ	
[Beene81]	^{16}O	$7-11$	^{154}Sm	n,^{4}He	iso	σ	mult,ex
[Benenson67]	^{1}H	43,52	^{12}C	^{1}H,^{10}C	iso	dΩ	ex
[Benioff60]	^{1}H	5.7	Be,C,N,O F,Na,Al	^{3}H,^{7}Be,^{11}C,^{13}N, ^{14,15}O,^{18}F,^{24}Ne,^{22}Na,^{27}Mg	iso	σ	ex

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Benlliure98]	^{238}U	750	^{208}Pb	$^{62-71}$Zn,$^{66-73}$Ga,$^{67-76}$Ge,$^{69-77}$As	iso	σ	
				$^{71-79}$Se,$^{75-81}$Br,$^{75-84}$Kr,$^{77-86}$Rb			
				$^{80-90}$Sr,$^{82-93}$Y,$^{84-93}$Zr,$^{87-97}$Nb			
				$^{89-100}$Mo,$^{91-102}$Tc,$^{91-105}$Ru,$^{95-107}$Rh			
				$^{97-107}$Pd,$^{100-111}$Ag,$^{102-114}$Cd,$^{104-116}$In			
				$^{107-118}$Sn,$^{109-121}$Sb,$^{111-124}$Te,$^{114-126}$I			
[Benlliure99]	^{197}Au	950	Be	$^{192-195}$Ir,$^{190-194}$Os,$^{189-194}$Re,	iso	σ	
				$^{187-192}$W,$^{185-189}$Ta,$^{184-188}$Hf			
[Benlliure01]	^{197}Au	800	H	$^{38-42}$Ar,$^{40-44}$K,$^{42-47}$Ca,$^{44-49}$Sc, $^{46-52}$Ti, $^{48-54}$V	iso	σ	
				$^{50-57}$Cr,$^{52-59}$Mn,$^{54-61}$Fe,$^{57-64}$Co,$^{59-66}$Ni,$^{61-68}$Cu			
				$^{63-71}$Zn,$^{65-75}$Ga,$^{68-77}$Ge,$^{70-80}$As,$^{72-82}$Se,$^{74-84}$Br			
				$^{77-87}$Kr,$^{79-89}$Rb,$^{81-91}$Sr,$^{84-94}$Y,$^{87-96}$Zr,$^{89-99}$Nb			
				$^{91-101}$Mo,$^{93-104}$Tc,$^{96-106}$Ru,$^{98-108}$Rh, $^{100-110}$Pd			
				$^{102-112}$Ag,$^{105-114}$Cd, $^{107-116}$In,$^{109-119}$Sn,$^{111-121}$Sb			
				$^{114-123}$Te, $^{118-125}$I, $^{120-127}$Xe,$^{125-130}$Cs			
[Benlliure02]	^{197}Au	800	^{1}H	Ca – Xe	elem	σ	
				$^{42-47}$Ca, $^{46-52}$Ti,$^{53-59}$Mn,$^{57-64}$Co	iso	σ	
				$^{61-67}$Cu,$^{65-75}$Ga,$^{70-80}$As,$^{74-83}$Br			
				$^{78-89}$Rb,$^{84-94}$Y,$^{89-99}$Nb,$^{93-104}$Tc			
				$^{98-108}$Rh,$^{105-112}$Ag,$^{107-116}$In,$^{111-121}$Sb			
				$^{156-177}$Lu,$^{159-178}$Hf,$^{160-182}$Ta,$^{163-185}$W			
				$^{164-186}$Re,$^{169-191}$Os,$^{168-193}$Ir,$^{173-196}$Pt			
				$^{174-196}$Au			
[Benlliure10]	^{208}Pb,^{238}U	1.0	Be	^{A}Yb – ^{A}Fr	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Bernas65]	^{1}H	44 − 25.0	^{12}C,^{16}O	^{6}He,^{6,7}Li,^{7}Be	iso	σ	
[Bernas67]	^{1}H	20 − 10.0	^{12}C	$^{6-9}$Li,^{7,10}Be,^{10}B,^{10,11}	iso	σ	rev
	^{1}H	1 − 10.0	^{14}N	^{6,8,9}Li,^{7,11}Be,^{10,11}B, $^{10-12}$C,^{13}N,^{14,15}O			
	^{1}H	10 − 10.0	^{16}O	^{6,7,9}Li,^{7}Be,^{10}B ^{10,11,14}C,^{13}N,^{15}O			
	^{1}H	20 − 5.7	^{12}C,^{16}O,^{14}N ^{19}F,^{23}Na	n,^{1}H,^{11}C,^{13}N,^{15}O,^{22}Na			(p,pn),ex
	^{1}H	150	^{12}C	n,^{1,3}H,^{4}He,$^{6-9}$Li,^{7,8,10}Be ^{10,11}B,$^{10-12}$C			ex
	^{1}H	150	^{14}N	n,^{1}H,^{4}He,^{6,8,9}Li,^{7,10}Be ^{10}B,$^{10-12}$C,^{13}N,^{13,14}O			ex
	^{1}H	150	^{16}O	n,^{1}H,^{4}He,^{6,7,9}Li,^{7,9,12}Be ^{13}N,^{14,15}O			ex
	^{1}H	150	^{7}Li,^{9}Be,^{10,11}B,^{13}C ^{18}O,^{19,20}F	n,^{1}H,^{4}He,^{8}Li,^{7}Be,^{13,17}N ^{14,15}O,^{17,18}F,^{19}Ne			ex
[Bernas97]	^{238}U	750	Be	^{A}Ca − ^{A}Pd	iso	σ	
[Bernas03]	^{238}U	1.0	^{1}H	^{A}Ni − ^{A}Eu	elem,iso	σ	
[Bernas06]	^{238}U	1.0	^{1}H	^{A}Gd − ^{A}Re	iso	σ	
[Bertrand73]	^{1}H	30 − 60	^{12}C,^{27}Al,^{54,56}Fe ^{120}Sn,^{197}Au,^{209}Bi	$^{1-3}$H,^{3,4}He	iso	dE, dΩ, dEdΩ, σ	
[Bertrand74]	^{4}He	15	^{12}C,^{16}O,^{54}Fe	$^{1-3}$H,^{3,4}He	iso	σ,dE,dEdΩ	
[Bhattacharya91]	^{4}He	15	Al	Li − O	elem	σ, dEdΩ	
[Bhattacharya95]	^{7}Li	5	Mg	Be − F	elem	σ, dEdΩ	
[Bhattacharya96]	^{19}F	5	^{12}C	Li − Na	elem	σ, dΩ, dθ, dEdΩ	
[Billerey81]	^{14}N	7	^{27}Al	H,He,Mg,Al,Si,P,S,Cl	elem	dΩ_1dΩ_2	ex
[Binns87]	^{56}Fe,^{84}Kr ^{132}Xe,^{165}Ho ^{197}Au	1.0 − 1.7	H, C, CH_2, Al	Sn − Pt	cc,elem	σ	
[Bizard77]	^{4}He	1.01	^{1}H	^{3}He	iso	σ, dΩ, dpdΩ	
[Blank94]	^{58}Ni	585	Be	$^{40-44}$Sc,$^{40-46}$Ti,$^{43-48}$V $^{43-49}$Cr,$^{47-52}$Mn,$^{46-54}$Fe $^{50-56}$Co,$^{50-57}$Ni	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Bloch88]	^{14}N	20,35	Ag	n,$^{6-8}$Li,$^{7-10}$Be,^{10,11}B	iso	σ, dEdΩ	mult,ex
[Bobchenko79]	^{1}H	$4.2-8.1$	Be,B,C,F,Mg,Al S,Ca,Ti,V,Fe,Cu Nb,Cd,Sn,Ta,Pb,U		total inel	σ	
[Bogatin76]	^{1}H	660	^{10,11}B,^{58,64}Ni,^{112,124}Sn	^{3,4}He	iso	dEdΩ	
	^{1}H	$200-20.0$	Al,Fe,Pb	^{3}H,^{7}Be	iso	σ	rev
[Boger94]	^{86}Kr	$6-9$	^{63}Cu	H $-$ Cr	elem	σ, dΩ, dEdΩ	
				^{4}He	iso	dΩ, dEdΩ	ex
[Bolshakova09]	^{1}H	7.1,8.0	Be	^{1}H	iso	dpdΩ	
[Bolshakova09a]	^{1}H	$2.2-14.1$	Be	^{1}H	iso	dpdΩ	
[Bolshakova09b]	^{1}H	$2.2-14.1$	Ta	^{1,2}H	iso	dpdΩ	
[Bolshakova10]	^{1}H	$2.2-14.1$	Cu	^{1,2}H	iso	dpdΩ	
[Bolshakova10a]	^{1}H	$2.2-14.1$	Pb	^{1,2}H	iso	dpdΩ	
[Brechtmann86]	^{56}Fe	1.7	Ag	O $-$ Mn	elem	σ	
[Brechtmann88]	^{32}S	720	H,C	C $-$ P	cc,elem	σ	
[Brechtmann88a]	^{32}S	700,1.2,200.0	H,C,Al, Cu,Ag,Pb	O $-$ Mn	cc,elem	σ	emd
[Brechtmann88b]	^{16}O	60.0,200.0	H,C,Al Cu,Ag,Pb	C,N	cc,elem	σ	emd
[Brechtmann89]	^{28}Si	14.5	H,C,Al Cu,Ag,Pb	C $-$ Al	cc,elem	σ	emd
[Britt61]	C,O	7,9,11	Au,Bi	^{1}H,^{4}He	iso	σ, dE, dΩ	
[Brohm95]	^{46,47}Ti,$^{48-51}$V $^{49-53}$Cr,$^{50-56}$Mn $^{51-58}$Fe $^{54-55,57-60}$Co $^{56,59-63}$Ni ^{61,62,65}Cu ^{63,64,67,68}Zn ^{69,70}Ga ^{72,73}Ge,^{74,75}As ^{76,77}Se	$500-750$	CH_2		cc	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Bubak07]	^{1}H	2.5	Au	C − Al	elem	σ, dEdΩ	
				$^{1-3}$H,^{3,4,6}He,$^{6-9}$Li ^{7,9,10}Be,$^{10-12}$B	iso	σ, dEdΩ	
[Budzanowski08]	^{1}H	1.2,1.9,2.5	Au	$^{1-3}$H,^{3,4,6}He,$^{6-9}$Li ^{7,9,10}Be,$^{10-12}$B	iso	dEdΩ, σ	
[Budzanowski09]	^{1}H	175	Ni	$^{1-3}$H,^{3,4}He,^{6,7}Li ^{7,9}Be,^{10,11}B	iso	dEdΩ, σ	
[Budzanowski09a]	^{1}H	10 − 3.0	Ni	$^{1-3}$H,$^{3-6}$He,$^{6-8}$Li,$^{7-10}$Be ^{10,11}B,^{12}C,^{14}N,^{21,22}Ne,^{26}Al ^{36}Cl,^{36,38}Ar,^{44,46}Sc,^{44}Ti ^{48}V,^{48,51}Cr,^{52,54}Mn,$^{55-57}$Co ^{56,57}Ni	iso	σ	rev
[Budzanowski10]	^{1}H	1.2,1.9,2.5	Ni,Au	$^{1-3}$H,^{3,4}He,$^{6-8}$Li,^{7,9,10}Be,^{11}B	iso	dEdΩ, σ	
[Caamano04]	^{36}Ar	1.05	^{9}Be	^{12,13}N,$^{13-16}$O,^{17,18}F $^{17-20}$Ne,$^{20-22}$Na,$^{20-23}$Mg $^{22-25}$Al,$^{24-27}$Si,$^{27-29}$P $^{29-31}$S, $^{31-33}$Cl,^{33,34}Ar	iso	σ	w(p_z)
[Caretto58]	^{1}H	1.0 − 6.0	Cu,Ag,Ta Au,Pb,U	^{24}Na,^{18}F	iso	σ	
[Casarejos06]	^{238}U	1.0	^{2}H	^{A}Ce − ^{A}Np	iso	σ	
[Caskey88]	^{14}N	35	^{165}Ho	$^{6-9}$Li,^{7,9,10}Be $^{10-13}$B,$^{10-15}$C	iso	dΩ, dEdΩ dpdΩ	w(p)
[Charvet87]	^{84}Kr	35	^{93}Nb	H,He	elem	dE	
[Chen94]	^{4}He,^{22}Ne,^{26}Mg,^{32}S ^{40}Ca,^{52}Cr,^{58}Ni	400 − 900	H		cc	σ	
[Chen94a]	^{12}C	20	Ag	^{43}K,^{48}Sc,^{48}V,^{52}Mn,^{52}Fe,^{55}Co ^{57}Ni,^{62}Zn,^{67}Ga,^{71}As,^{87}Y,^{89}Zr, ^{93}Mo,^{95}Tc,^{97}Ru,^{99}Rh,^{100,101}Pd ^{105,106}Ag,^{107}Cd,^{109,111}In,^{113}Sn	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Cheshire74]	^{12}C,^{16}O	2.1	CsI,W		cc	σ	
[Chiba91]	^{1}H	831	H,C	n	iso	dEdΩ	ex
[Chrien80]	^{1}H	800	Li,^{6}Li,^{12}C,^{27}Al ^{40}Ca,^{51}V,^{90}Zr,Pb	^{1}H	iso	dEdΩ	
[Christie93]	^{139}La	1.2	H,C	Fe $-$ Ba	cc,elem	σ	w(p$_\perp$)
			Pb		cc	σ	
[Chulkov00]	^{14}Be,$^{10-19}$B,$^{12-20}$C $^{14-23}$N,$^{16-24}$O,$^{18-27}$F	930	C		cc	σ	n removal
[Clerc95]	^{208}Pb	1.0	Cu	$^{199-207}$Pb,$^{196-207}$Tl	iso	σ	
	^{238}U	950	Cu	$^{230-237}$U,$^{227-237}$Pa	iso	σ	
[Cline76]	^{1}H	590	Al,Fe, Ni,Cu	^{A}Be,^{A}O,^{A}F, ^{A}Na ^{A}Al,^{A}Cl $-$ ^{A}K,^{A}Sc ^{A}V $-$ ^{A}Zn	iso	σ	
[Cocconi61]	^{1}H	8.0 $-$ 24.0	Be	^{1}H	iso	dpdΩ	
[Cordell81]	^{1}H	600	^{27}Al,^{181}Ta	^{1}H	iso	dEdΩ	
nnn[Courtenay-Wright50]	^{1,2}H	10 $-$ 340	C,N,Ne Ar,Kr,Xe	^{8}Li	iso	σ	
[Cowley80]	^{1}H	100	^{58}Ni	^{1}H	iso	dEdΩ	ex
[Cowley98]	^{1}H	392	^{40}Ca	^{1}H	iso	dEdΩ	ex
[Cowley00]	^{1}H	392	^{40}Ca	^{1}H	iso	dEdΩ	ex
[Crandall56]	^{1,2}H,^{2,3}He	43 $-$ 350	^{12}C,^{27}Al	^{3}He,^{11}C,^{24}Na	iso	σ	ex

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Cumming58]	^{1}H	350 – 4.0	^{12}C	^{11}C	iso	σ	ex
[Cumming62]	^{1}H	28.0	C,Al	^{A}Be – ^{A}Mg	iso	σ	
[Cumming62a]	^{1}H	2.0 – 28.0	^{12}C	^{11}C	iso	σ	ex
[Cumming63]	^{1}H	30 – 28.0	C,Al	^{7}Be,^{11}C,^{24}Na,^{18}F	iso	σ	rev
[Cumming76]	^{1}H	28.0	Cu	^{7}Be,^{22,24}Na,^{28}Mg,	iso	σ	
	^{12}C	2.1		^{38}S,^{34,38,39}Cl,^{37,39,41,42}Ar			
				^{42,43}K,^{47}Ca,^{43,44,47,48}Sc,^{48}V			
				^{48,49,51}Cr,^{52,54,46}Mn,^{52,59}Fe			
				^{55,56,58,60,61}Co,^{56,57,65}Ni			
				^{60,61,64}Cu,^{62,63,65}Zn,^{66,67}Ga			
[Cumming78]	^{40}Ar	2.0	Cu	^{7}Be,^{22,24}Na,^{28}Mg	iso	σ	
				^{37,39}Ar			
				^{42,43}K, $^{43,44,46-48}$Sc			
				^{48}V,^{48,51}Cr,^{52,54,46}Mn			
				^{52,59}Fe,$^{55-58,60}$Co,^{56,57}Ni			
				^{61,64}Cu,^{62,65}Zn,^{66,67}Ga			
[Cummings90]	^{56}Fe,^{139}La	500 – 1.6	H,C,CH_2	Ne – Mn, Co	elem	σ	$\Delta Z = +1$
	^{165}Ho,^{197}Au		C,Al,Cu,Pb	Tc – Pt, Hg			
[Currie56]	^{1}H	450,2.05	C,N,O,Mg,Al	^{3}H	iso	σ	
			Fe,Ni,Ag,Pb				
[Currie59]	^{1}H	120 – 6.2	C,N,O,Mg,Al,Fe,Ni,Ag,Pb	^{3}H	iso	σ	rev
[D'Auria68]	^{4}He	2 – 6	^{59}Co	n,^{1}H,^{4}He	iso	σ,dEdΩ	rev,reac
[Deak90]	^{14}N	35	Ag	n,^{6,7}Li,$^{7-10}$Be	iso	dEdΩ	ex
				$^{10-12}$B, $^{11-13}$C,^{14,15}N			
[de Jong98]	^{208}Pb	1.0	Cu	^{A}Pr – ^{A}Bi	iso	σ	
[De Lellis11]	^{12}C	313	emulsion	^{8}Be	iso	σ	
[Devins69]	^{1}H	30	^{7}Li	$^{1-3}$H,^{4,5}He,^{5,6}Li	iso	dΩ, dEdΩ	ex
[Dey09]	^{20}Ne	8,9,10	^{12}C,^{27}Al	$^{1-3}$H,^{4}He,Ne,Na,Mg,Al	iso	dΩ, dEdΩ	ex
[Dittrich90]	^{1}H	50 – 20.0	O,Mg,Al,Si,Mn,Fe,Ni	^{10}Be,^{26}Al	iso	σ	rev
[Doering78]	^{4}He	180	Al,Ag,Ta	^{1,2,3}H,^{3,4}He	iso	dEdΩ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Dostrovsky61]	^{1}H	940,1.84,2.9	Cu,Zn,Ag,In,Au,Pb,U	^{6}He,^{8}Li,^{7}Be,^{13}N	iso	σ	
[Dostrovsky65]	^{1}H	1.0,2.8	B − F,Na − Si,S	^{1}H,^{9}Li,^{16}C,^{17}N	iso	σ	ex
			Ca,Ti,Ni,Cu				
			Nb,Ag,La,Pr				
			Nd,Ta,W,Pb,U				
[Dudkin90]	^{56}Fe	1.8	H,CNO,AgBr	H,He	elem,cc	σ	mult
[Dufauquez06]	^{1}H	27,63	Al,Si	$^{1-3}$H,^{3,4}He	iso	dΩ, dEdΩ	
	^{4}He	6,11,15	Si	n,$^{1-3}$H,^{3,4}He,^{6}Li,^{7}Be	iso	dΩ, dEdΩ	ex,mult
[Duisebayev03]	^{1}H	30	^{90,92}Zr,^{92}Mo	^{1,2}H	iso	σ, dE, dEdΩ	
[Duisebayev05]	^{1}H	30	^{56}Fe	^{1}H,^{4}He	iso	σ,dE	
[Edge69]	^{1}H	1.0,2.0,3.0	Be,C,Cu,Pb	^{1}H	iso	dE, dEdΩ	
[Ellegaard85]	^{3}He	500,667,767	^{1}H	^{3}H	iso	dEdΩ	ex Δ^{++}
[El Nadi64]	^{1}H,^{3}He	2,19	^{14}N	^{2}H,^{4}He	iso	$d\Omega$	
[El Nadi02]	^{28}Si	3.7,14.6,200.0	Emulsion	He	elem	σ	rev,mult
[Engelage86]	^{12}C	2.1	^{12}C	3 × ^{4}He	iso,ex	dE	w(p$_z$)
							w(p$_\perp$)
[English73]	^{1}H	11.5,300.0	Ag	^{7}Be,^{24}Na,^{28}Mg,^{44,47,48}Sc	iso	σ	
				^{48}V,^{52}Mn,^{67}Ga,^{69}Ge			
				^{74}As,^{73}Se,^{76,77}Br,^{83,84}Rb			
				^{87}Y,^{86,89}Zr,^{90}Nb,^{95,96}Tc			
				^{97}Ru,^{101,103}Rh,^{106}Ag			
[English74]	^{1}H	300.0	Ag	^{7}Be,^{22,24}Na,^{28}Mg,^{38}Cl	iso	σ	
				^{41}Ar,^{A}Sc − ^{A}Ag			
[English74a]	^{1}H	11.5	Ag	^{7}Be,^{22,24}Na,^{38}Cl,^{41}Ar	iso	σ	
				$^{44,46-48}$Sc,^{48}V, ^{A}Mn − ^{A}Co			
				^{A}Cu − ^{A}Ga,^{A}As − ^{A}Br			
				^{A}Rb − ^{A}Nb,^{A}Tc − ^{A}Ag			
[Enke99]	^{1}H	1.2,1.8	Fe,Ni,Ag,Ta	n, $^{2-3}$H,^{3,4}He	elem,iso	dΩ, dE, σ	mult
			W,Au,Pb,U				

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Enqvist99]	^{238}U	1.0	Pb	^{A}H $-$ ^{A}Bi	iso	σ	
[Enqvist01]	^{208}Pb	1.0	^{1}H	^{A}Ti $-$ ^{A}Te,^{A}Pm $-$ ^{A}Pb	iso	σ	
[Enqvist02]	^{208}Pb	1.0	^{2}H	^{A}Ti $-$ ^{A}Pb	iso	σ	
[Erb76]	^{12}C		^{12}C	^{4}He,^{20}Ne	iso	dEdΩ	ex
[Eyal73]	^{16}O	8,10	^{197}Au	C	elem	dEdΩ	
	^{12}C,^{16}O	8,10	^{197}Au	Li,Be,B,C,N	elem	σ, dΩ	
	^{12}C,^{16}O	8,10	^{197}Au	$^{202-205}$Po,$^{198-203}$Bi,$^{196-203}$Pb	iso	σ	
				$^{195-201}$Tl,^{195,197}Hg,$^{192-199}$Au			
[Fernandez05]	^{208}Pb	500	^{1}H	^{A}V $-$ ^{A}Ba	iso	σ	
[Fink87]	^{1}H	$41 - 600$	Ti,Fe,Ni	^{41}Ca	iso	σ	
[Fink90]	^{1}H	$40 - 200$	Ti	^{42,43}K,$^{44,46-48}$Sc,^{48}V,^{41}Ca	iso	σ	
[Fink00]	^{1}H	$20 - 3.0$	K,Ca,Ti,Fe	^{36}Cl	iso	σ	
[Fireman55]	^{1}H	2.2	N,O	n,^{3}H	iso	σ	
[Flesch99]	^{56}Fe	700	H,C,Al,Cu,Ag,Pb	C $-$ Cr	elem	σ	
[Flesch01]	^{28}Si	490	CH_2,C,Al	C $-$ Al	cc,elem	σ	
			Cu,Ag,Pb				
[Fohr11]	^{112}Sn	1.0	^{112}Sn	^{A}Ne $-$ ^{A}Sn	iso	σ	
	^{124}Sn	1.0	^{124}Sn	^{A}Ne $-$ ^{A}Sn	iso	σ	
[Fontes71]	^{1}H	150,600	^{12}C	^{6,7}Li,^{7,9,10}Be	iso	σ	
	^{4}He	$100 - 137$	^{12}C	^{6,7}Li,^{7,9,10}Be	iso	σ	
[Fontes77]	^{1}H	41,49,150,600,25.0	^{12}C	^{7}Be,^{10,11}B	iso	σ	
	^{4}He	$100 - 160$	^{12}C	^{7}Be,^{10,11}B	iso	σ	
[Fortney80]	^{1}H	800,3.0,11.5,400.0	^{238}U	$^{44,46-48}$Sc	iso	$d\Omega$	
[Fortney80a]	^{1}H	400.0	^{238}U	$^{44,46-48}$Sc	iso	dEdΩ	
[Fortsch88]	^{1}H	90,200	^{12}C	^{1}H	iso	dEdΩ	
[Fortsch91]	^{1}H	$100 - 200$	^{58}Ni	^{1}H	iso	dEdΩ, dE, σ	
[Fortsch07]	^{12}C,^{27}Al	13	^{12}C,^{27}Al	^{7,9}Be,	iso	dEdΩ	
				B $-$ Si	elem	dEdΩ	
[Frankel81]	^{40}Ar	100	U	B $-$ Ne	elem	dEdΩ	
[Frascaria75]	^{1}H	156	^{4}He	^{1,2,3}H	iso	dEdΩ	ex

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Friedlander54]	^{1}H	2.2	Cu	$^{A}Be - {}^{A}Zn$	iso	σ	
[Friedlander55]	^{1}H	$400 - 3.0$	Al	n,^{1}H,^{7}Be,^{11}C ^{13}N,^{15}O,^{18}F,^{22}Na	iso	σ	ex
[Friese93]	^{136}Xe	760	Al	^{116}Rh,^{119}Pd,^{122}Ag,^{124}Cd ^{127}In,$^{129,130,132}Sn$ $^{132,133}Sb$,$^{134,135}Te$,^{136}I	iso	σ	
[Fukuda84]	^{14}N	9,11,15	^{93}Nb	^{1-3}H,$^{3,4}He$	iso	σ, dEdΩ	
[Fukuda84a]	^{14}N	15	^{232}Th	^{1-3}H,^{4}He	iso	dEdΩ	
[Fulmer81]	^{16}O	13	^{12}C,^{56}Fe,^{91}Zr	He,He	elem	dΩ, dEdΩ	
[Furukawa71]	^{1}H	$5 - 50$	Si,Al,Mg	^{22}Na,^{26}Al	iso	σ	
[Galin74]	^{40}Ar	4,5	Se	^{1}H,^{4}He,Li	iso,elem	σ, dΩ, dEdΩ	
[Galin74a]	^{14}N	6,9	^{103}Rh	^{1-3}H,^{4}He	iso	σ, dΩ, dEdΩ	
[Gazzaly78]	^{40}Ar	1.8	Be,Cu	^{1-3}H	iso	$dpd\Omega$	
[Geaga80]	^{1}H,^{12}C,^{40}Ar	1.05,2.1,4.89,7.71,400.0	C,Al	^{1}H	iso	dpdΩ	
[Geer95]	^{197}Au	10.6	H, C, CH_2, Al Cu,Sn,Pb	Sn − Pt, Hg	cc,elem	σ	emd
[Goldhaber78]	^{12}C	2.1	Be	^{10}Be	iso	dp_z	$w(p_z)$
	^{4}He,^{20}Ne	250,400,1.05,2.1	C,U	^{1-3}H,$^{3,4}He$	type	dpdΩ	
[Golovchenko01]	^{12}C	32 - 102	CH_2	B	cc,elem	σ	
[Golovchenko02]	^{12}C	112 - 254	C, CH_2, H_2O	Be,B	cc,elem	σ	
[Gonthier80]	^{16}O	19	Ti	^{4}He	iso	dE	
[Gooding60]	^{1}H	153	^{12}C	^{11}B	iso	σ	ex
[Gooding61]	^{4}He	229	He,C	$2 \times {}^{4}He$	iso,ex	dΩ	
[Gosset77]	^{4}He,^{12}C,^{20}Ne	250,400,2.1	Al,U	^{1-3}H,$^{3,4}He$,^{7}Li,$^{7,9,10}Be$ ^{10}B,^{12}C,^{14}N,^{16}O	iso	dEdΩ	mult
[Gradsztajn65]	^{1}H	156	^{12}C	^{6}He,^{6-9}Li,$^{9,10}Be$ $^{10,11}B$,$^{10,11}C$	iso	σ	
[Graulich00]	^{1}H	1	^{18}F	^{1}H,$^{4}He$$^{15}O$	iso	dEdΩ	
[Green80]	^{1}H	$100 - 100.0$	Ag	$^{3,4}He$,$^{6,7}Li$,^{7-10}Be,B,C,N O,F,Ne,Na^{11}C,^{24}Na,^{32}P	elem,iso	σ, dΩ, dEdΩ	rev
[Green87]	^{1}H	190,300	Be,Ag	^{1-3}H,$^{3,4,6}He$,$^{6,7}Li$,^{7}Be	iso	dEdΩ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Greiner75]	$^{12}C,^{16}O$	1.05,2.1	Be, CH_2, C, Al	$^{1-3}H,^{3-6}He,^{6-9}Li$	iso	dp_z	$w(p_z)$
			Cu,Ag,Pb	$^{7-11}Be,^{8-13}B,^{9-15}C$			
				$^{12-16}N,^{13-15}O$			
[Griffiths69]	^{1}H	30,50	$^{3,4}He$	n, $^{1,2}H,^{3}He$	iso	σ, dΩ, dEdΩ	ex
[Guertin05]	^{1}H	63	^{208}Pb	n, $^{1-3}H,^{3,4}He$	iso	σ, dE, dEdΩ	
[Gupta99]	^{7}Li	6	^{58}Ni	$^{1-3}H,^{3,4}He,^{7}Li$	iso	dΩ, dEdΩ	$\frac{d^3\sigma}{dE_\alpha d\Omega_\alpha d\Omega_t}$
[Gutbrod76]	$^{4}He,^{20}Ne$	250,400,2.1	U	$^{1,2,3}H,^{3,4}He$	iso	dEdΩ	
[Harada99]	^{1}H	14,18,26	^{12}C	$^{1}H,^{4}He,^{8}Be$	iso	dEdΩ	ex
[Hautala02]	^{1}H	197	C,Ca,Pb	n	iso	dEdΩ	pol
[He94]	^{197}Au	2250.0	C,Al,Fe,Cu,Sn,Pb	Yb − Pt	cc,elem	σ	
[Heckman72]	^{14}N	2.1	H,C	$^{6,7}Li,^{7,9}Be,^{8,10-12}B$	iso	dΩ (0°)	
				$^{9-13}C,^{12,13}N$			
[Heckman78]	$^{12}C,^{14}N,^{16}O$	2.1	Emulsion	H,He	elem	dΩ	
	$^{12}C,^{14}N,^{16}O$	2.1	Emulsion	$^{1-3}H,^{3,4}He$	iso		w(p),mult
[Heilbronn91]	^{14}N	35	Ag	$^{6,7}Li,^{9,10}Be,^{11,12}B,^{12-14}C$	iso	dEdΩ	
[Henzlova08]	$^{124,136}Xe$	1.0	Pb	$^{A}Ne - {}^{A}Ba$	iso	σ	
[Herbach06]	^{1}H	1.2	Al,Ti,Fe,Ni,Cu,Zr,Ag	$^{1-3}H,^{3-6}He,^{6-9}Li$	elem,iso	σ, dE	mult
						dΩ, dEdΩ	
			Ho,Ta,W,Au,Pb,Th,U	$^{7,9,10}Be$			
[Heydegger76]	^{1}H	82 − 800	Mg, Al, SiO_2	$^{7}Be,^{22}Na,^{28}Mg$	iso	σ	
[Hicks56]	^{1}H	32 − 350	^{27}Al	^{24}Na	iso	σ	ex
[Hintz52]	^{1}H	10 − 150	$^{12}C,^{27}Al,^{11}B,^{34}S$	n, $^{1}H,^{18}F,^{22,24}Na$	iso	σ	ex
				$^{11}C,^{34}Cl$			
[Hirzebruch92]	^{16}O	900,2.3	H,C,Al,Cu	C,N	cc,elem	σ	emd
		3.6,13.5	Ag,Pb,CH_2				
			CR-39(CHO$_7$)				
[Hirzebruch95]	^{197}Au	10.0	H,C,Al,Cu,Ag,Pb	Os,Ir,Pt,Hg	cc,elem	σ	emd
[Honda60]	^{1}H	300 − 800	C,Fe	$^{7}Be,^{22}Na,^{26}Al,^{34,36,38}Cl$	iso	σ	
				$^{42,43}K,^{52,54}Mn$			
[Honda64]	^{1}H	730	Fe	$^{7,10}Be,^{22}Na,^{26}Al,^{32}Si$	iso	σ	
				$^{34,36,38,39}Cl,^{42}Ar$			
				$^{40,42,43}K,^{45}Ca,^{46}Sc$			
				$^{44}Ti,^{52,54}Mn$			

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Horvath94]	^{36}Ar	35	Ag	$^{9-11}$Be,$^{8,11-13}$B,$^{11-15}$C,$^{12-16}$N $^{15-19}$O,$^{17-21}$F,$^{19-22}$Ne	iso	$\sigma, d\Omega, dEd\Omega$	
[Horwitz60]	^{1}H	2.0 – 6.0	^{12}C	^{11}C	iso	σ	ex
[Hsi99]	^{1}H	831 – 13.7	^{197}Au	C,^{3,4} He	elem,iso	$dE, dEd\Omega$	
[Hudis68]	^{1}H	3.0 – 30.0	C,Ag,Ta,Au,Pb,U	^{7}Be,^{22,24}Na	iso	σ	
[Hudis68a]	^{1}H	1.0,2.0,3.0	Cu,Ag,Au,U	^{24}Ne,^{24}Na	iso	σ	
[Hudis70]	^{1}H	3.0,29.0	Cu,Ag,Au,U	$^{20-22}$Ne,$^{36-39,42}$Ar $^{76-86}$Kr,$^{122-136}$Xe	iso	σ	
[Husain73]	^{1}H	3.0,29.0	V	^{A}Be – ^{A}Cr	iso	σ	
[Hyde71]	^{1}H	1.0 – 30.0	Ag,Emulsion	$^{1-3}$H,^{3,4,6}He,$^{6-9}$Li, $^{7-10}$Be,$^{9-13}$B $^{11-14}$C,^{14,15}N,^{18}F, $^{20-22,24}$Ne,^{22,24}Na	iso	$\sigma, dEd\Omega, d\Omega$	rev
[Iancu05]	^{36,40}Ar	318 – 361	H,C,Al Cu,Ag,Pb	N – Cl	cc,elem	σ	
[Ieiri89]	^{2}H	33	^{58}Ni	^{1}H	iso	$dEd\Omega$	pol
[Inamura79]	^{14}N	7	^{159}Tb	n,^{4}He	iso	$dEd\Omega$	
[Iwamoto10]	^{1}H	300,392	^{16}O,^{51}V,^{159}Tb,^{181}Ta ^{197}Au,^{208}Pb,^{209}Bi	^{1}H	iso	$dEd\Omega$	
[Jacak83]	^{40}Ar	Au	42,92,137	^{10}Be A = 1 – 14	iso	$dEd\Omega$ σ	
[Jaderstrom08]	^{28}Si	200,300	^{1,2}H	^{4}He,^{12}C,^{14}N,^{16}O,^{18}F ^{20}Ne,^{22}Na,^{26}Al,^{28}Si	elem,iso	$\sigma, dp, d\Omega$	
[Jaros78]	^{1,2}H,^{4}He,^{12}C	870,2.1	^{1,2}H,He,C		tot,inel	σ	
[Jilany04]	^{24}Mg	Emulsion	3.7				mult
[Junghans98]	^{208}Pb,^{238}U	1.0,950	Cu	^{A}W – ^{A}U	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Kadkin98]	^{3}He	32	^{58,64}Ni	$^{1-3}$H,^{3,4}He	iso	σ, dEdΩ	
[Karnaukhov03]	^{1}H,^{4}He,^{12}C	4.0,8.1,14.6,22.4	Au	He − Mg	elem	yield	
[Katcoff59]	^{1}H	2.2	C,Al,Cu,Ag,Au,U	^{8}Li	iso	dE, dEdΩ	
[Katcoff68]	^{1}H	3.0,29.0	Ag	^{A}He − ^{A}Ag	iso	σ	
[Kaufman80]	^{1}H	200 − 20.0	^{197}Au	^{A}Na − ^{A}Au	iso	σ	
[Kavaloski63]	^{1}H	40	^{12}C,^{16}O,^{24,25}Mg	^{2}H	iso	$d\Omega$	
					^{32,34}S,^{40}Ca		
[Kiang89]	^{1}H	35	^{24}Mg	n,^{24}Al	iso	dΩ	ex
[Kidd88]	^{12}C	250	C	$^{6-8}$Li,$^{7,9-11}$Be $^{8,10-12}$B,^{10,11}C	iso	σ, dθ, dp$_\perp$	w(p$_z$) w(p$_\perp$)
[Kim94]	^{12}C	135	Cu	^{22,24}Na,^{27,28}Mg,^{29}Al ^{34,38,39}Cl,^{41}Ar,$^{42-44}$K ^{47}Ca,$^{43,44,46-48}$Sc ^{48}V,^{48,49,51}Cr ^{52,54,56}Mn,^{52,53,59}Fe $^{55-58,60-62}$Co,^{57}Ni ^{60,61,64}Cu,^{62,63,65}Zn	iso	σ	
[Kim02]	^{1}H	10 − 1.0	C,O	^{10}Be,^{14}C	iso	σ	
[Kin05]	^{1}H	300,392	^{12}C,^{27}Al,^{93}Nb	^{1}H	iso	dEdΩ	
[Knott96]	^{22}Ne,^{26}Mg,^{32}S ^{36,40}Ar,^{40}Ca ^{52}Cr,^{58}Ni	338 − 894	H	B − Co	elem	σ	
[Knott97]	^{36,40}Ar	352 − 765	H	$^{17-21}$F,$^{19-23}$Ne $^{21-25}$Na, $^{22-28}$Mg $^{25-30}$Al,$^{26-32}$Si $^{29-35}$P,$^{31-37}$S $^{33-39}$Cl	iso	σ	
[Kobayashi88]	^{6,8}He,^{11}Li	790	C,Pb	^{3,4,6,8}He,$^{6-9}$Li	iso	σ, dp$_\perp$	w(p$_\perp$) emd

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Korejwo00]	^{12}C	3.66	H	H,He,Li,Be,B,C	elem	σ	
				$^{1-3}$H,^{3,4,6}He,$^{6-9}$Li	iso	σ	
				^{7,9,10}Be,$^{8,10-12}$B,$^{9-11}$C			
[Korejwo02]	^{12}C	1.87,2.69	H	^{3,4,6}He,$^{6-9}$Li	iso	σ	
				^{7,9,10}Be,$^{8,10-12}$B,$^{9-11}$C			
[Korteling70]	^{1}H	100,200,300	Na – Se	^{22,24}Na	iso	σ	
[Korteling70a]	^{1}H	300,400	^{23}Na,$^{24-26}$Mg,^{27}Al	^{18}F,^{22,24}Na	iso	σ	
			$^{28-30}$Si,^{31}P,$^{32-34}$S				
[Kox87]	^{12}C,^{16}O,^{20}Ne	9 – 300	^{12}C,^{27}Al,^{40}Ca		reac	σ	
			^{54,56,57}Fe,^{89}Y				
			^{64,66,68}Zn, Ag				
[Kreutz93]	^{197}Au	600	C,Al,Cu,Pb	He – Pt	cc,elem	σ	
					type	σ	
[Kundu08]	^{16}O	15,16,18,20	^{12}C	Li,Be,B	elem	σ, dΩ, dEdΩ	
[Kwiatkowski86]	^{3}He	66	Ag	Li – Al	elem	dEdΩ, σ	
[Lafleur66]	^{1}H	30 – 4.0	O,Al	^{7}Be	iso	σ	rev
	^{1}H	30 – 85	O, Al, Ti – Cu	^{7}Be	iso	σ	
			Ag, Au, Pb				
[La Tessa07]	^{40}Ar	400	H,C,Al,Cu,Sn,Pb	Ne – Ar	elem	σ	
[Lee Aamodt52]	^{1}H	18 – 340	^{12}C	^{11}C	iso	σ	ex
[Leistenschneider02]	$^{17-21}$O	557-635	C	$^{11-16}$C,$^{13-19}$N,$^{16-20}$O	iso	σ	
[Lemaire79]	^{12}C,^{20}Ne,^{40}Ar	400,800,2.1	C,KCl,NaF,Pb		reac	σ	
				^{2,3}H, ^{3}He,	iso	dpdΩ	
[Lestringuez71]	^{1}H,^{4}He	600,220	C	^{7,9,10}Be	iso	σ	
[Letourneau02]	^{1}H	2.5	Au	$^{1-3}$H,^{3,4,6}He,^{6,7}Li	iso	dEdΩ, dΩ, σ	mult
[Lewandowski80]	^{1}H	72	^{27}Al,^{59}Co,^{90}Zr	^{4}He	iso	dE, dEdΩ	
			^{197}Au,^{208}Pb,^{232}Th				
[Leya98]	^{1}H	13 – 1.6	Mg,Al,Si	^{3,4}He,$^{20-22}$Ne	iso	σ	
[Leya05]	^{1}H	44 – 2.6	Pb	^{3,4}He,^{21,22}Ne,^{36,38}Ar	iso	σ	
				$^{78,80-86}$Kr,$^{124,126,128-134}$Xe			

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Liang97]	$^{12}C,^{35}Cl,^{60}Ni,$	6,12	$^{144}Sm,^{121}Sb,^{96}Zr,$	$^{1}H,^{4}He$	iso	$\sigma, dEd\Omega$	mult
[Lindner56]	^{1}H	$100-340$	$^{238}U,^{232}Th$	$^{A}Bi-{}^{A}Np$	iso	σ	
[Lindsay62]	^{1}H	$27-32$	$Mg,^{27}Al$	^{7}Be	iso	σ	
[Lindstrom75]	$^{12}C,^{16}O$	1.05,2.1	H, Be, CH_2, C	$^{1-3}H,\ ^{3,4,6}He,\ ^{6-9}Li$	iso	σ	
			Al,Cu,Ag,Pb	$^{7-12}Be,\ ^{8,10-13}B,\ ^{9-15}C$			
				$^{12-16}N,\ ^{13-15}O$			
[Logan80]	^{40}Ar	9	^{197}Au	$^{1-3}H,^{4}He$	iso	$d\Omega, dEd\Omega$	
[Logan80a]	^{40}Ar	5,7,9	$^{116}Sn,^{154}Sm,^{164}Dy,^{197}Au$	$^{1}H,^{4}He$	iso	$\sigma, d\Omega, dEd\Omega$	fission,ex
[Loveland77]	^{12}C	2.1	U	$A=22-210$	mass	σ	
[Loveland77a]	^{12}C	2.1	Au,Pb	$A=22-210$	mass	σ	
[Lukyanov09]	^{72}Zn	95	Be	$^{47}Ca,^{54}V,^{62}Co$	iso	dp	
	$^{64,68}Ni,^{69}Cu$	95	Be	$^{35-40}Cl,^{36-42}Ar,^{39-45}K$	iso	σ	
	^{72}Zn			$^{41-48}Ca,^{46-51}Sc,^{45-54}Ti$			
				$^{48-56}V,^{50-58}Cr,^{52-60}Mn$			
				$^{55-62}Fe,^{57-64}Co,^{59-65}Ni$			
				$^{64-68}Cu,^{67-69}Zn$			
[Machner84]	^{1}H	62,200,558	^{27}Al	^{1}H	iso	$dEd\Omega$	
[Marcinkowski98]	^{1}H,n	18,20,26,27	^{93}Nb	^{1}H,n	iso	$dE, dEd\Omega$	
[Marquez51]	^{1}H	335	Be,C,Al,Cu,Ag,Au	$^{7}Be,^{11}C,^{18}F,^{22,24}Na$	iso	σ	
[Marquez52]	^{1}H	335,420	O,F,Al,Cl,Cu,Ag,Au	$^{7}Be,^{11}C,^{13}N,\ ^{22,24}Na,^{18}F$	iso	σ	
[Matsuoka83]	^{2}H	28	$^{58}Ni,^{90}Zr$	^{1}H	iso	$dEd\Omega$	
[Meadows51]	^{1}H	$4-95$	$^{24-26}Mg$	$n,^{1}H,^{22}Na$	iso	σ	ex
[Merchel00]	^{1}H	$17-2.6$	Fe,Ni	$^{53}Mn,^{60}Fe$	iso	σ	
[Meyer72]	$n,^{1}H$	$30-300$	^{4}He	$n,^{1-3}H,^{3}He$	iso	σ	ex
[Meyer80]	$^{1}H,\ ^{4}He,\ ^{20}Ne$	400,1.05,2.1	Ag,Au,U	$He-Fe$	elem	$dEd\Omega$	mult,corr
	$^{4}He,\ ^{20}Ne$	400,1.05,2.1	U			σ	fiss
[McGill84]	^{1}H	800	$^{1,2}H,^{12}C,^{40}Ca,^{208}Pb$	^{1}H	iso	$\sigma, dpd\Omega$	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Michel79]	^{1}H	12 – 45	V,Fe,Co	^{A}Sc,^{A}V,^{A}Cr,^{A}Mn ^{A}Fe,^{A}Co,^{A}Ni	iso	σ	
[Michel85]	^{1}H	10 – 200	Al,V,Mn,Co	^{22,24}Na,^{43}K,^{47}Ca,$^{44,46-48}$Sc ^{48}V,^{48,51}Cr,^{52,54}Mn,$^{55-58}$Co	iso	σ	rev
[Michel95]	^{1}H	800 – 2.6	C – Si, Ca – Co	^{A}He – ^{A}Zn	iso	σ	
	^{1}H	20 – 5.0	Mg,Al,Si,V,Mn,Fe,Ni,Cu	^{A}He,^{A}Be,^{A}Ne,^{A}Na,^{A}Sc ^{A}V,^{A}Cr,^{A}Co	iso	σ	rev
[Michel96]	^{1}H	20 – 3.0	O,Si,Al,Fe	^{10}Be,^{26}Al	iso	σ	
[Michel97]	^{1}H	10 – 3.0	Al,Fe,Co,Sr,Y,Zr,Nb,Au	^{7}Be,^{22,24}Na,^{A}Sc ^{A}Mn – ^{A}Co,^{A}Zn ^{A}Ge – ^{A}Ru,^{A}Lu ^{A}Hf,^{A}Re – ^{A}Hg	iso	σ	rev
[Mills92]	^{1}H	10 – 200	Cu	^{46,48}Sc,^{48}V,^{48,49,51}Cr ^{52,54,56}Mn,^{52,59}Fe $^{55-58,60}$Co,^{56,57}Ni ^{60,61,64}Cu,^{62,63,65}Zn	iso	σ	
[Miura87]	^{2}H	12.5	^{31}P	n,^{32}S	iso	dΩ	ex
[Mocko06]	^{40,48}Ca,^{58,64}Ni	140	^{9}Be,^{181}Ta	^{A}B – ^{A}Cu	iso	σ, dp	
[Mocko07]	^{86}Kr	64	^{9}Be,^{181}Ta	^{A}Mn – ^{A}Kr	iso	σ, dp	
[Momota02]	^{40}Ar	90	^{9}Be	$^{6,8-11}$Be, $^{10-15}$B, $^{11-18}$C $^{13-21}$N, $^{15-24}$O, $^{18-26}$F $^{19-29}$Ne, $^{21-31}$Na, $^{23-34}$Mg $^{25-36}$Al, $^{27-38}$Si, $^{29-39}$P	iso dp$_{\perp}$ ($^{16-21}$N)	σ	w(p$_{\perp}$)
	^{16}O	290	^{12}C	^{7}Li,$^{7,9-11}$Be,$^{8,11-13}$B $^{9-11,13}$C,^{12,13,15}N,$^{13-15}$O	iso	σ	
[Morita82]	^{12}C	250,1.0	^{197}Au,^{238}U	^{43}K, ^{72}As,^{89,97}Zr,^{90}Nb, ^{99}Mo,^{97}Ru,^{123,133}I,^{145}Eu, ^{149}Gd,^{152}Tb,^{155}Dy	iso	$d\theta$	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Motobayashi84]	^{3}He	33	^{165}Ho,^{166,167}Er	n,$^{1-3}$H	iso	σ, dE, dΩ, dEdΩ	ex
	^{3}He	30 − 100	^{165}Ho,^{166,167}Er	n,^{1}H	iso	σ	
[Mougey81]	^{12}C	86	C,Ag,Au	$^{6-9}$Li,^{7,9,10}Be	iso	σ	
				$^{8,10-12}$B,$^{9-11}$C	dEdΩ(^{7}Be,^{10} B)		
[Murakami03]	^{1}H,^{4}He,^{16}O	290 − 12.0	Au	O − Si	elem	dEdΩ	
	^{20}Ne,^{28}Si						
[Murphy83]	^{9}Be	27	Au	^{6,7}Li	iso	dE	w(p)
[Mustapha99]	^{197}Au	800	H	$^{135-145}$Pm,$^{135-147}$Sm	iso	σ	
				$^{143-148}$Eu,$^{144-152}$Gd			
				$^{145-154}$Tb,$^{146-157}$Dy			
				$^{149-160}$Ho,$^{150-167}$Er			
				$^{152-166}$Tm,$^{155-170}$Yb			
				$^{152-173}$Lu,$^{160-191}$Hf			
				$^{162-180}$Ta,$^{165-183}$W			
				$^{167-191}$Re,$^{169-200}$Os			
				$^{173-193}$Ir,$^{170-196}$Pt			
				$^{178-196}$Au,$^{182-196}$Hg			
[Nagamiya79]	^{12}C,^{20}Ne,^{40}Ar	800	C,NaF,KCl,Pb	^{1}H	iso	dpdΩ	corr
[Nagamiya80]	^{40}Ar	800	Pb	^{1}H	iso	dpdΩ	mult
[Nagamiya81]	^{1}H,^{12}C,^{20}Ne,^{40}Ar	400,800,2.1	C,NaF, KCl	^{1,2,3}H,^{3,4}He	iso	σ, dpdΩ	
			Cu,Pb				
[Nakayama07]	^{7}Li	51	^{4}He	^{7}Be	iso	dEdΩ	
[Napolitani04]	^{56}Fe	1.0	H,Ti	^{A}Li − ^{A}Co	iso	σ, dE, dp_z	
[Napolitani07]	^{136}Xe	1.0	^{1}H	^{A}Li − ^{A}Ba	iso	σ	
[Natowitz81]	^{20}Ne	43	Ni,Ag,Ta	$^{1-3}$H,^{3,4}He	iso	dEdΩ	w(p)
[Newton62]	^{1}H	150	^{7}Li	^{1}H	iso	dΩ	
[Nicholls72]	^{1}H	141	^{4}He	n,$^{1-3}$H,^{3,4}He	iso,inel,elas	σ, dE, dEdΩ	ex
[Nilsen95]	^{84}Kr,^{109}Ag	444 − 1.47	H, Li, C, CH_2	Cr − Ag	cc,elem	σ	
			Al,Cu,Sn,Pb				

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Nomura78]	^{14}N	6,7	^{209}Bi	n,^{4}He	iso	σ	
[Notani07]	^{40}Ar	100	Be,Ta	^{30}Mg,^{36}Al	iso	dpdΩ	
				$A = 6 - 39$	mass		w(p)
				$^{6-8}$Li,$^{9-11}$Be,$^{10-14}$B $^{12-17}$C,$^{13-20}$N,$^{15-24}$O, $^{17-26}$F,$^{19-28}$Ne, $^{21-31}$Na $^{23-33}$Mg,$^{24-35}$Al, $^{26-36}$Si $^{29-37}$P,$^{30-37}$S,$^{33-36}$Cl $^{35-38}$Ar,$^{37-41}$K	iso	σ	
[Ogilvie91]	^{197}Au	600	C,Al,Cu	Li $-$ P	elem	σ	mult
[Ohnuma86]	^{1}H	35	^{13}C	n,^{13}N	iso	dΩ	ex
[Ohnuma87]	^{1}H	35,40	^{12}C,^{16}O	n,^{12}N,^{16}F	iso	dΩ	ex
[Okihana97]	^{4}He	30	^{6}Li	^{2}H,$^{3-5}$He	iso	dΩ, dEdΩ	ex
[Okumusoglu74]	^{2}H	6	^{1}H	n,^{1}H	iso	dEdΩ	ex
[Olson81]	^{18}O	1.7	Be,C,Al,Ti,Cu Sn,W,Pb,U	^{6,7}Li,^{10}Be,^{10,12}B $^{12-15}$C,$^{14-17}$N ^{16,17}O,^{18}F	iso	σ	emd
[Olson83]	^{12}C,^{16}O	1.05,2.1	H,Be,C,Al Cu,Ag,Pb	$^{1-3}$H,^{3,4,6}He,$^{6-9}$Li $^{7,9-11}$Be,$^{8,10-13}$B $^{9-15}$C,$^{12-16}$N $^{13-15}$O	iso	σ	emd
[Ozawa00]	^{40}Ar	1.0	Be	$^{11-19}$B,$^{13-22}$C,$^{14-23}$N,$^{16-24}$O,$^{18-29}$F	iso	σ	
[Pakou03]	^{6}Li	1,2	^{28}Si	^{4}He	iso	σ, dΩ	
[Pakou05]	^{7}Li	1,2	^{28}Si	^{4}He	iso	σ, dΩ	
[Parikh60]	^{1}H	$50 - 950$	^{12}C	^{11}C	iso	σ	ex
[Parikh60a]	^{1}H	$100 - 1.0$	^{27}Al,^{12}C	^{7}Be,^{11}C,^{18}F,^{24}Na	iso	σ	
[Pate61]	^{1}H	$680 - 1.8$	^{235,238}U,^{232}Th	^{A}Ac $-$ ^{A}Np	iso	σ	
[Perdrisat69]	^{1}H	600	^{2}H,^{4}He	n,^{1,3}H	iso	dE, dEdΩ	ex
[Pereira07]	^{238}U	1.0	^{2}H	^{A}V $-$ ^{A}Tm	iso	σ	
[Perron76]	^{1}H	600,21.0	Fe	$^{7-10}$Be,^{22}Na,^{45,46}Sc,$^{48-51}$V $^{50-54}$Cr,$^{53-55}$Mn,^{56}Co	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Pfaff95]	^{86}Kr	70	Al	$^{68-76}$As,$^{69-78}$Se,$^{76-80}$Br,$^{73-82}$Kr $^{75-85}$Rb,$^{79-85}$Sr,$^{81-85}$Y	iso	σ	w(p$_z$)
[Pfaff96]	^{78}Kr	75	^{58}Ni	$61-67$Zn,$^{62-70}$Ga,$^{64-71}$Ge $^{66-73}$As,$^{68-74}$Se,$^{70-75}$Br, $^{72-76}$Kr,$^{74-79}$Rb,$^{77-80}$Sr	iso	σ	
[Pfeiffer73]	^{6,7}Li	2,3,4	^{58}Ni,^{118}Sn	^{2}H,^{4}He	iso	σ, dΩ	
[Pfutzner95]	^{56,58}Ni,^{52}Fe	$470-635$	Be,Al	$^{54-57}$Ni,$^{50-52}$Fe	iso,emd	σ	
[Poppe63]	^{2}H	$2-6$	^{1,3}H	n	iso	dEdΩ	
[Porile64]	^{1}H	29.0	Cu,Fe,Ti	^{22,24}Na,^{42,43}K	iso	σ	
[Porile89]	^{1}H	$1.6-18.1$	Xe	Be,C,O,N,F	elem	dE	
				Li − Si	elem	dΩ	
[Poskanzer71]	^{1}H	5.5	U	$^{1-3}$H,^{3,4,6}He,$^{6-9}$Li,^{7,9,10}Be $^{10-13}$B,$^{11-15}$C,$^{14-17}$N	elem,iso	dEdΩ, dΩ, σ	
[Poskanzer75]	^{1}H,^{4}He,^{16}O	1.05,2.7	Ag,U	^{3,4}He	iso	dEdΩ, dθ	
[Price91]	^{28}Si	14.5	Cu,Pb	O − Si	cc,elem,emd	σ, $d\Omega$	
[Prout02]	^{1}H	197	^{2}H,^{3,4}He	n	iso	dΩ, dEdΩ	pol
[Pugh73]	^{1}H	65,85,100	^{2}H,^{3,4}He	n,^{1,2}H	iso	dEdΩ	ex
[Radin74]	^{4}He	230	^{9}Be,^{12}C,^{16}O,^{27}Al	^{7}Be,^{11}C,^{13}N,^{15}O,^{18}F	iso	σ	
[Raisbeck72]	^{1}H,^{4}He	150,220,600	^{12}C	^{6,7}Li	iso	σ	
[Raisbeck74]	^{1}H	150,600	N,Mg,Si	^{7,10}Be	iso	σ	
[Raisbeck75]	^{4}He	700	C,O	^{7,9,10}Be	iso	σ	
[Raisbeck75a]	^{1}H	1,2,3,23	Si,Mg,Fe,Ni	^{7}Be,^{22}Na	iso	σ	
[Ramaty69]	^{1}H	$20-9.0$	H,He,C,N,O	n,$^{1-3}$H,^{3,4}He,π	iso	σ, $d\Omega$	rev
[Rayudu63]	^{1}H	$130-400$	Fe,Ni	^{7}Be,^{32}P,^{48}V,^{51}Cr ^{52,54}Mn,^{56}Co	iso	σ	
[Reeder65]	^{1}H	2.2	^{14,15}N,^{16,18}O	^{9}Li,^{7}Be	iso	σ	
[Reedy87]	^{1}H	$20-10.0$	Al,Si	^{26}Al	iso	σ	
[Reedy07]	^{1}H	$5-10.0$	C,O,Mg,Al,Si Fe,Ni,K,Ca,Ti,Cr	^{10}Be,^{14}C,^{26}Al ^{36}Cl,^{41}Ca,^{53}Mn	iso	σ	rev

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Regnier79]	^{1}H	80 − 24.0	Sc,Ti,V,Fe,Co,Ni,Cu	^{36,38,39,42}Ar	iso	σ	
[Reinhold98]	^{129}Xe	790	Al	$^{85-93}$Zr,$^{86-96}$Nb,$^{88-98}$Mo, $^{90-100}$Tc,$^{92-103}$Ru,$^{94-112}$Rh $^{96-114}$Pd,$^{101-117}$Ag,$^{100-119}$Cd $^{102-122}$In,$^{102-124}$Sn,$^{108-127}$Sb $^{110-128}$Te,$^{113-124}$I,$^{115-126}$Xe $^{118-129}$Cs	iso	σ	w(p$_z$)
[Reisdorf10]	^{40}Ca,^{96}Ru ^{197}Au,^{58}Ni ^{96}Zr,^{129}Xe	400 − 1.9	^{40}Ca,^{96}Ru ^{197}Au,^{58}Ni ^{96}Zr,^{129}Xe	$^{1-3}$H,^{3,4}He	iso	dy	mult
[Rejmund01]	^{197}Au	800	^{1}H	$^{131-142}$Nd,$^{133-144}$Pm,$^{134-147}$Sm $^{139-148}$Eu,$^{141-152}$Gd,$^{144-153}$Tb $^{147-157}$Dy,$^{148-159}$Ho,$^{150-166}$Er $^{153-169}$Tm,$^{155-171}$Yb,$^{156-174}$Lu $^{159-176}$Hf,$^{162-182}$Ta,$^{164-186}$W $^{166-186}$Re ,$^{169-191}$Os,$^{171-193}$Ir $^{175-196}$Pt,$^{174-196}$Au,$^{178-196}$Hg	iso	σ	
[Remington86]	^{14}N	35	Ni,Ho	n	iso	σ, dEdΩ	ex,mult
				Li,Be,B,C	elem	$d\Omega$	ex
[Remsberg63]	^{1}H	370	^{45}Sc,^{50,52}Cr,^{55}Mn,^{56}Fe ^{58}Ni,^{59}Co,^{65}Cu,^{69,71}Ga	n,^{1}H,^{51,52}Mn,^{49}Cr $^{55-57}$Co,^{65,66,68}Ga	iso	σ	
[Remsberg75]	^{1}H	28.0	Au,U	C,N,O,F,Ne,Na,Mg	elem	dΩ, dEdΩ	
[Renberg71]	^{1}H	220 − 570	H,Be,B,C,O,Na,Al,Fe I,Cu,Ge,Sn,Pb		reac	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Ricciardi06]	^{238}U	1.0	H	$^{15-17}$N,$^{16-19}$O,$^{19-21}$F $^{20-24}$Ne,$^{23-26}$Na,$^{24-30}$Mg $^{27-31}$Al,$^{28-32}$Si,$^{31-35}$P $^{33-38}$S,$^{35-40}$Cl,$^{37-42}$Ar $^{39-46}$K,$^{41-48}$Ca,$^{46-54}$Sc $^{46-54}$Ti,$^{48-54}$V,$^{48-58}$Cr $^{52-61}$Mn,$^{53-63}$Fe,$^{56-66}$Co $^{58-73}$Ni,$^{60-76}$Cu,$^{62-77}$Zn $^{64-81}$Ga,$^{67-84}$Ge,$^{69-85}$As $^{71-88}$Se,$^{73-94}$Br,$^{75-95}$Kr $^{78-98}$Rb	iso	σ	
[Richter92]	^{1}H	100,120,150,200	^{58}Ni,^{100}Mo,^{197}Au	^{1}H	iso	dEdΩ	
[Ridikas00]	^{2}H	50	^{9}Be,^{12}C,^{13}Al,^{58}Ni,^{93}Nb ^{181}Ta,^{208}Pb,^{238}U	^{1}H	iso	σ, dΩ dEdΩ	mult
[Roeder06]	^{48}Ca,^{40,42}S	100	^{2}H	$^{31-33}$Al,$^{33-36}$Si,$^{36-39}$P,$^{38-41}$S ^{39,40,42}Cl,^{42,44,45}Ar,$^{44-48}$K ^{46,47}Ca,^{48}Sc	iso	σ	
[Rosenfeld56]	^{1}H	$50-900$	^{12}C	^{11}C	iso	σ	ex
[Rowland58]	^{1}H	1.0,1.9,2.85	C,Al,Cu,Ag,Pb	^{6}He	iso	σ	
[Roy81]	^{1}H	500	^{4}He,Ni,Ta	^{1}H	iso	dEdΩ	
[Rudy75]	^{12}C,^{1}H	2.1,300.0	Ag	^{7}Be,^{24}Na,^{28}Mg ^{42,43}K,$^{44,46-48}$Sc,^{48}V ^{52}Mn,^{66}Ga,^{69}Ge ^{74}As,^{73,75}Se,^{76,77}Br ^{79}Kr	iso	σ	
[Samanta92]	^{4}He	13	^{6}Li	^{2}H,^{4}He	iso	dΩ, dEdΩ	
[Sampsonidis95]	^{16}O,^{24}Mg ^{32}S	3.65	C,Al,Cu,Ag,Pb	C,N,O,F,Ne Na,Mg,Al,Si,P	cc,iso	σ	
[Sandoval80]	^{1}H,^{4}He ^{20}Ne,^{18}Ar	$241-2.1$	Al,Ca,Ag,U	$^{1-3}$H	iso	dEdΩ	mult

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Scampoli05]	^{56}Fe	1.0,5.0	CH_2, C, Al, Pb		cc	σ	
[Schaeffer59]	^{1}H	$160-6.0$	Fe	^{3}H,^{3,4}He,^{21}Ne,$^{36-39}$Ar	iso	σ	
[Schall96]	^{19,20}Ne,^{18}F ^{15,16}O	$200-670$	$H_2O, CH_2, O_2C_5H_8$ Al,C,^{14}N,^{12}C,^{10}B	B,C,N	cc,elem	σ	
[Schiekel96]	^{1}H	$50-3.0$	Ca,Ti,Fe,Ni,^{55}Mn,^{59}Co	^{36}Cl	iso	σ	rev
[Schiekel96a]	^{1}H	$200-2.0$	C,N,O,Mg,^{27}Al,Si,Ca Ti,Mn,Fe,Co,Ni,Cu	^{7,10}Be,^{22,24}Na,^{28}Mg ^{26}Al,^{36}Cl,$^{44-48}$Sc ^{48}V, ^{48,51}Cr,^{47}Ca ^{43}K,^{52,54}Mn, ^{59}Fe $^{56-58}$Co,^{56,57}Ni,^{65}Zn	iso	σ	rev
[Schnabel04]	^{1}H	$98-1.6$	Ni	^{41}Ca	iso	σ	
[Schweizer79]	^{4}He	180	Al,Ag,Ta	Li,Be,B,C,N,O	elem	dEdΩ	
[Segel82]	^{1}H	100,164	^{27}Al,^{58,62}Ni,^{208}Pb	$^{1-3}$H,^{3,4}He	iso	σ, dΩ, dEdΩ	
[Sengupta89]	^{16}O,^{32}S	60.0,200.0	Emulsion	^{4}He	iso	σ	mult
[Shibata85]	^{4}He	27	^{165}Ho	^{1}H,n	iso	σ, dE, dEdΩ	ex,mult
[Shyam99]	^{1}H		^{7}Be	^{8}B	iso,emd	σ	
[Signorini03]	^{6}Li	5,6,7	^{208}Pb	^{1,2}H,^{4}He	iso	σ, dΩ	ex
[Singh90]	^{32}S	200.0	Emulsion	He	elem		mult
[Singh91]	^{28}Si	14.5	Emulsion	He	elem		mult
[Singh94]	^{1,2}H,^{4}He,^{12}C ^{16}O,^{22}Ne ^{24}Mg,^{28}Si	4.5	Emulsion		iso	σ	mult
[Singh96]	^{208}Pb	10.6,160.0	Emulsion	H,He	elem		mult
[Singh10]	^{84}Kr	950	H,CNO,AgBr Emulsion	^{4}He	iso	σ	mult
[Singh10a]	^{84}Kr	$500-1.7$	Emulsion	^{4}He	iso	w(p$_\perp$)	mult
[Sisterson97]	^{1}H	$30-5000$	O,Si	^{7,10}Be,^{22}Na,^{26}Al,^{7,10}Be	iso	σ	rev
[Siwek-Wilcznska79]	^{12}C	$8-17$	^{160}Gd	^{4}He	iso	σ	
[Skoski73]	^{14}N	270	H	^{11}C	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Sobotka83]	^{3}He	30	Ag	^{4}He,Li,^{7,9}Be,B,C,N,O,F	elem,iso	$d\Omega, dEd\Omega$	
[Souliotis94]	^{18}O,^{40}Ar	80	^{9}Be,^{27}Al,^{181}Ta	Li – Ar	elem	$d\Omega$	
[Sourkes76]	^{1}H	18 – 48	^{3,4}He		reac	σ	
[Souza09]	^{6}Li	3,4,5	^{59}Co	^{1,2}H,^{4}He	iso	$\sigma, d\Omega, dEd\Omega$	
[Stapleton71]	^{1}H	7.0	O	^{7}Be	iso	σ	
[Steckmeyer89]	^{40}Ar	60	Ag,Au	Li – Cl	elem	$dE, d\Omega$	mult
[Stephan91]	Kr	200	Ar	^{A}Na – ^{A}Rb	iso	$d\Omega$	
[Stevenson81]	^{48}Ca	213	Be	^{20}C,^{27}F	iso	σ	
[Stock80]	^{1}H,^{20}Ne,^{49}Ar	393,1.04,2.1	Ca,U	^{1}H	iso	$dEd\Omega$	mult
[Stolz02]	^{112}Sn	1.015	Be,Cu	$^{75-77}$Sr,$^{76-79}$Y,$^{78-81}$Zr ^{82,83}Nb,$^{83-85}$Mo,^{86,87}Tc $^{87-90}$Ru,$^{90-92}$Rh,$^{91-94}$Pd $^{94-97}$Ag,$^{96-99}$Cd,$^{98-107}$In $^{100-109}$Sn,$^{106-109}$Sb,$^{108-111}$Te	iso	σ	
[Stovall64]	^{1}H	40	C,^{24}Mg,^{54,56}Fe ^{58,56}Ni,^{208}Pb	^{1}H	iso	$d\Omega, dEd\Omega$	
[Strauch56]	^{1}H	96	Li – F,Na – S Cu,Ag,Pb,Bi	^{1}H	iso	$dEd\Omega$	
[Streibel97]	^{197}Au	10.0	C, CH_2, Al Cu,Ag,Pb		cc	σ	emd
[Sugitate82]	^{93}Nb	1	^{14}N	^{1}H	iso	$dEd\Omega$	pol
[Symons79]	^{1}H,^{40}Ar	24.0,205	^{238}U,^{12}C	$^{26-30}$Na	iso	σ	
[Taieb03]	^{238}U	1.0	^{1}H	^{A}W – ^{A}U	iso	σ	inv kin
[Tanaka95]	^{1}H	12.0	Au	Na	elem	$d\Omega, dEd\Omega$	
[Tanihata80]	^{12}C,^{20}Ne,^{40}Ar	400,800	C,NaF, KCl,Pb	^{1}H	iso	dp	mult
[Tanihata81]	^{1}H	800	C,NaF,KCl,Cu,Pb	^{1}H	iso	$dpd\Omega$	
[Tannenwald53]	n	90	^{4}He	n, $^{1-3}$H,^{3,4}He	iso	$\sigma, dE, d\Omega$	ex
[Titarenko98]	^{1}H	10 – 3.0	^{209}Bi	^{A}Co – ^{A}Bi	iso	σ	rev
[Titarenko02]	^{1}H	1.0	^{208}Pb	^{A}Sc – ^{A}Bi	iso	σ	rev
[Titarenko06]	^{1}H	40 – 2.6	^{208,nat}Pb,^{209}Bi	^{7}Be,^{24}Na,^{59}Fe,^{86}Rb ^{101}Rh,^{173}Lu,^{190,192}Ir ^{196}Au,^{199,200}Tl,^{203}Pb	iso	σ	rev

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Titarenko08]	^{1}H	25 − 3.0	^{27}Al	^{22}Na	iso	σ	rev
	^{1}H	300 − 2.6	^{56}Fe	$^{A}Be - ^{A}Co$	iso	σ	rev
[Tokushuku90]	^{1}h	3.2	Al	$^{1,2}H$	iso	$dpd\Omega$	
[Toshito07]	^{12}C	200 − 400	H_2O, CHO_3	Li,Be,B	cc,elem	σ	
[Trockel88]	^{12}C	30,48,84	^{197}Au	$3 \leq Z \leq 16$	imf	σ	
[Tull90]	^{40}Ar	1.65	C,KCl	$^{8-13}B, ^{10-16}C, ^{13-18}N$ $^{14-20}O, ^{17-22}F, ^{19-25}Ne$ $^{21-27}Na, ^{23-30}Mg, ^{25-32}Al$ $^{27-34}Si, ^{29-36}P, ^{31-38}S$ $^{34-40}Cl$	iso elem	$\sigma, dp_z, dp_\perp$	mult w(p_z) w($p_\perp$)
[Tyren57]	^{1}H	185	C	^{1}H	iso	$d\Omega, dEd\Omega$	
[Tyren66]	^{1}H	460	$^{4}He, ^{6,7}Li, ^{9}Be, ^{10,11}B$ $^{12}C, ^{14}N, ^{16}O, ^{27}Al$ $^{28}Si, ^{31}P, ^{32}S, ^{40}Ar$ $^{40}Ca, ^{51}V, ^{59}Co$	^{1}H	iso	$dEd\Omega$	(p,2p)
[Uozumi07]	^{1}H	392	^{12}C	$^{3,4}He, ^{6,7}Li$	iso	$dEd\Omega$	
[Urbon80]	^{1}H	11.5	^{197}Au	^{24}Na	iso	$dE, d\Omega$	
[Utsunomiya80]	^{14}N	6,7,8	$^{159}Tb, ^{169}Tm, ^{181}Ta, ^{197}Au, ^{209}Bi$	$^{1-3}H, ^{4}He$	iso	$\sigma, d\Omega, dEd\Omega$	
[Utsunomiya81]	^{14}N	8	^{209}Bi	^{4}He	iso	$d\Omega, dEd\Omega$	
[Valentin65]	^{1}H	50 − 5.7	$^{7}Li, ^{10,11}B, ^{13}C, ^{14}N,$ $^{19}F, ^{23}NA, ^{48}Ti, ^{51}V, ^{52}Cr$	$n, ^{1}H, ^{15}O, ^{13}N, ^{11}C$	iso	$\sigma, d\Omega$	
[Van Bibber79]	^{16}O	90,120	Al,Au	$^{6-8}Li, ^{7,9,10}Be, ^{8,10-12}B$ $^{10-14}C, ^{13-15}N, ^{15}O$	iso	$d\Omega, dp_\perp$	
[Vaz83]	^{40}Ar	8	Ag,Sm,Au	Be,B,C,N,O,F $^{7}Li, ^{12}C, ^{16}O, ^{1}H, ^{4}He$	elem iso	σ $\sigma, d\Omega, dEd\Omega$	
[Villagrasa07]	^{56}Fe	300,500 750,1.0,1.5	H	$^{16-19}O, ^{17-22}F, ^{18-24}Ne$ $^{20-27}Na, ^{22-29}Mg, ^{24-31}Al$ $^{26-34}Si, ^{28-37}P, ^{30-39}S$ $^{32-41}Cl, ^{34-44}Ar, ^{37-46}K$ $^{38-48}Ca, ^{41-50}Sc, ^{42-52}Ti$ $^{44-54}V, ^{46-55}Cr, ^{49-56}Mn$ $^{51-55}Fe, ^{51-55}Co$	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Viyogi79]	^{40}Ar	213	C	$^{13-20}$O,$^{17-23}$F,$^{18-25}$Ne $^{20-27}$Na,$^{22-30}$Mg $^{24-32}$Al,$^{26-34}$Si $^{29-34}$P,$^{31-38}$S	iso	σ	
[Volnin75]	^{1}H	1.0	^{112,124}Sn,^{58,64}Ni	^{3,4,6}He,$^{6-9}$Li,^{7,9}Be ^{10,11}B,^{12}C	iso	dEdΩ, dΩ	
[Waddington93]	^{197}Au	910,10.6	A=1,5,12,30,60,120,200		cc,pickup	σ	
		910,10.6	H,C,Cu,Pb	Pr – Pt	elem	σ	
[Waddington00]	^{197}Au	920 – 10.6	H,CH_2,C,Al,Cu,Sn,Pb	La – Tl	cc,elem	σ pickup	
[Warner80]	^{6}Li	6 – 8	^{6}Li	^{4}He	iso	dE, σ	ex
[Warner83]	^{6}Li	16	^{6}Li	^{2}H,^{4}He	iso	dEdΩ	triple quad
[Warner92]	^{4}He	11 – 17	^{7}Li	^{3}H,^{4}He	iso	dEdΩ	ex
[Warner92a]	^{4}He	12 – 20	^{6}Li	n,^{1}H,^{4}He	iso	dEdΩ	ex
[Warwick83]	^{1}H,^{4}He ^{20}Ne	250 – 4.9	Au	A = 12 – 140 C - Mg	mass,elem	dEdΩ	mult
[Watanabe87]	^{1}H	18	^{90}Zr,^{93}Nb,^{92,94,96,98,100}Mo ^{106}Pd,Ag	^{1}H	iso	dE, dEdΩ	
[Watanabe90]	^{1}H	12,14,16,18 29,39	^{56}Fe,^{60}Ni,^{98}Mo,^{106}Pd	^{1}H	iso	dE, dEdΩ	
[Watanabe95]	^{1}H,n	14,18,21,26	^{93}Nb,^{98}Mo,^{106}Pd	^{1}H,n	iso	dE, dEdΩ	
[Webb87]	^{12}C	2.1	C	^{11}B + p	exc	$dp_\perp$	
[Webber90]	^{23}Na,$^{24-26}$Mg,^{27}Al ^{28}Si,^{32}S,^{40}Ca,^{56}Fe	600	H	^{21,22}Ne,^{23}Na,^{25,26}Mg ^{26,27}Al,^{29,30}Si,^{31}P	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Webber90a]	^{12}C, ^{14}N, ^{16}O, ^{20}Ne ^{24}Mg, ^{27}Al,^{28}Si, ^{32}S ^{40}Ar, ^{40}Ca, ^{56}Fe, ^{58}Ni	$300 - 1.6$	H,He,C		cc,mc	σ	
[Webber90b]	^{11}B, ^{12}C, ^{14}N, ^{16}O, ^{20}Ne ^{23}Na, ^{24}Mg, ^{27}Al, ^{28}Si ^{32}S,^{40}Ar, ^{40}Ca, ^{56}Fe	$300 - 1.6$	H,He,C	Li – Mn	elem	σ	
[Webber90c]	^{11}B, ^{12}C, ^{14}N, ^{16}O, ^{20}Ne ^{23}Na, ^{24}Mg, ^{27}Al, ^{28}Si ^{32}S,^{40}Ar, ^{40}Ca, ^{56}Fe	600	H,He,C	^{7,9,10}Be, $^{10-12}$B, $^{10-14}$C, $^{12-16}$N $^{14-18}$O, $^{16-21}$F, $^{18-24}$Ne, $^{21-25}$Na $^{22-27}$Mg, $^{24-30}$Al,$^{26-32}$Si, $^{28-35}$P $^{30-38}$S,$^{33-39}$Cl, $^{35-41}$Ar, $^{36-44}$K $^{38-45}$Ca,$^{43-48}$Sc, $^{44-50}$Ti,$^{47-52}$V $^{49-54}$Cr,$^{51-55}$Mn,$^{53-56}$Fe $^{55-57}$Co,^{56,57}Ni	iso	σ	
[Webber98]	^{7}Li, ^{9}Be, ^{11}B, ^{12}C,^{14,15}N ^{16}O,^{20,22}Ne,^{56}Fe, ^{58}Ni	$353 - 620$	H	Li – F, Si – Co	cc,elem	σ	
[Webber98a]	^{9}Be, ^{11}B, ^{12}C,^{14,15}N ^{16}O,^{20,22}Ne,^{56}Fe, ^{58}Ni	$365 - 620$	H	^{7,9,10}Be, ^{10,11}B, $^{10-14}$C, $^{13-16}$N $^{14-20}$O, $^{17-21}$F, $^{18-21}$Ne, $^{32-36}$S $^{34-38}$Cl, $^{36-40}$Ar, $^{39-43}$K, $^{40-45}$Ca $^{43-47}$Sc, $^{44-50}$Ti, $^{47-51}$V, $^{49-54}$Cr $^{51-55}$Mn, $^{53-55}$Fe, $^{55-57}$Co,	iso	σ	
[Webber98b]	^{6}Li, ^{10}B, ^{19}F, ^{21}Ne,^{22,23}Na ^{24,25}Mg, ^{26,27}Al, ^{28,29}Si,^{30,31}P ^{32,33}S, ^{34,37}Cl, ^{36,38}Ar,^{42,44}Ca ^{44,46}Sc, ^{46,48}Ti, ^{48,50}V,^{50,52}Cr ^{52,55}Mn, ^{54,56}Fe ($Z_P = 3, 5, 9 - 18, 20 - 26$)	500-600	H	Li – Mn $^{15-18}$O,$^{17-20}$F,$^{19-23}$Ne $^{21-25}$Na,$^{23-27}$Mg,$^{25-29}$Al $^{27-31}$Si,$^{29-33}$P,$^{31-36}$S $^{33-38}$Cl,$^{36-41}$Ar,$^{39-43}$K $^{40-46}$Ca,$^{43-48}$Sc, $^{45-50}$Ti $^{47-52}$V,$^{49-54}$Cr, $^{51-54}$Mn $^{52-53}$Fe	cc,elem iso	σ σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Weber92]	^{86}Kr	500	Be	$^{53-55}$Sc,$^{56-58}$Ti,^{60,61}V $^{61-64}$Cr,$^{64-66}$Mn,$^{66-69}$Fe $^{69-72}$Co,$^{72-75}$Ni	iso	σ	
[Weber94]	^{86}Kr	500	Be	^{41}K, $^{59-67,70}$Cu,$^{61-70,75-77}$Zn $^{64-72,76-78}$Ga,$^{65-74,79-82}$Ge $^{68-77,80,81,83}$As,$^{70-79,83,84}$Se $^{72-81}$Br, $^{74-84}$Kr	iso	$\sigma, \mathrm{dp_z}$	w($\mathrm{p_z}$)
[Wefel79]	^{14}N	530	H	Li,Be,B,C	elem	$\sigma, \mathrm{d}\Omega, \mathrm{dp}_\perp$	w(p)
[Wesick85]	^{1}H	100,150	^{2}H,^{3,4}He	^{1,2}H	iso	dEdΩ	ex
[West66]	^{4}He	10	^{59}Co,^{58,60,62}Ni,^{63,65}Cu Nb,Rh,Pd,Pt	^{1}H	iso	$\sigma, \mathrm{d}\Omega, \mathrm{dEd}\Omega$	
[Westerberg78]	^{12}C,^{20}Ne	13,9	^{158}Gd,^{150}Nd	n,^{4}He	iso	dE, dEdΩ	mult
[Westfall79]	^{56}Fe	600,1.05,1.88	H,Li,Be,B	Al – Mn	cc,mc,elem	σ	emd
		21.0,24.0	C,S,Cu,Ag Ta,Pb,U	^{36,38,39,42}Ar,^{45,46}Sc,$^{48-51}$V, ^{50,51,53}Cr,^{54}Mn	iso	σ	rev
[Westfall79a]	^{48}Ca	212	Be	$^{14-18}$C,$^{17-22}$N,$^{20-23}$O $^{21-26}$F,$^{24-28}$Ne,$^{27-31}$Na $^{29-34}$Mg,$^{32-36}$Al,$^{35-39}$Si $^{37-42}$P,$^{39-44}$S,$^{41-45}$Cl	iso	σ	
[Westfall82]	^{20}Ne	100,156	Au	^{1,2}H,^{4}He	iso	dEdΩ	
[Westfall84]	^{12}C	35	Au	$^{1-3}$H,^{3,4,6}He	iso	dEdΩ	
[Wickersham57]	^{1}H	28	^{4}He	n,$^{1-3}$H,^{3,4}He	iso	σ, dΩ	ex
[Wilczynski80]	^{14}N	10	^{159}Tb	^{4,6}He,^{6,7}Li,$^{7-10}$Be $^{10-12}$B,$^{11-13}$C	iso	σ	
[Whitfield93]	^{12}C	90	Cu	^{22,24}Na,^{28}Mg,^{34,39}Cl, ^{41}Ar,^{42,43}K,$^{43,44,46-48}$Sc ^{48}V,^{48,49,51}Cr,^{52,54,56}Mn ^{52,59}Fe,$^{55-58,60}$Co ^{56,57,65}Ni,^{60,61,64}Cu ^{62,63,65}Zn	iso	σ	

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Wlazlo00]	^{208}Pb	1.0	H	$^{134-145}$Pm,$^{136-147}$Sm,$^{138-151}$Eu $^{140-154}$Gd,$^{142-157}$Tb,$^{145-160}$Dy $^{147-163}$Ho,$^{149-166}$Er,$^{152-169}$Tm $^{154-172}$Yb,$^{156-175}$Lu,$^{159-178}$Hf $^{161-182}$Ta,$^{163-185}$W,$^{166-188}$Re $^{168-190}$Os ,$^{171-199}$Ir,$^{174-201}$Pt $^{177-205}$Au,$^{180-201}$Hg ,$^{184-207}$Tl $^{188-208}$Pb	iso	σ	
[Wu79]	^{1}H	90,100	^{27}Al,^{58}Ni ^{90}Zr,^{209}Bi	$^{1-3}$H,^{3,4}He	iso	$\sigma, \mathrm{dEd}\Omega, \mathrm{d}\Omega, \mathrm{dE}$	
[Yamada79]	^{14}N	12	^{154}Sm	$^{1-3}$H	iso	dE	
[Yamaguchi06]	^{80}Kr	1.05	Be	$^{64-68}$Ge,$^{66-70}$As,$^{68-72}$Se $^{70-74}$Br,$^{72-76}$Kr,^{74,76,78}Rb	iso	σ	
[Yamaguchi10]	^{28}Si	$90 - 550$	C		cc	σ	
[Yashima03]	^{1}H,He,C,Ne,Ar	100,230	C,Al,Cu	^{11}C,^{7}Be,^{22,24}Na,^{27,28}Mg, ^{29}Al,^{24,38,39}Cl,^{41}Ar,^{42,43}K $^{44,46-48}$Sc,^{48,49,51}Cr,^{54,56}Mn ^{52,59}Fe,$^{55-58,60-62}$Co,^{57,65}Ni ^{60,61,64}Cu,^{62,63,65}Zn	iso	σ	
[Yashima04]	^{1}H,He,Ne,C,Ar,Si	100,230,400,800	Al,Cr,Fe Ni,Cu,Pb	^{7}Be,^{11}C,^{22,24}Na,^{27,28}Mg ^{29}Al,^{34,38,39}Cl,^{41}Ar ^{42,43}K,$^{43,44,46-48}$Sc,^{48,49,51}Cr ^{54,56}Mn,^{52,59}Fe $^{55-58,60-62}$Co,^{57,65}Ni ^{60,61,64}Cu,^{62,63,65}Zn ^{202}Tl,^{201}Pb,^{204,205}Bi	iso	σ	
[Yennello91]	^{3}He	300,1.2	Ag	C	elem	$\mathrm{dEd}\Omega$	mult
[Yennello93]	^{3}He	$160 - 1.2$	Ag,^{197}Au	Li – Na	elem	$\sigma, \mathrm{d}\Omega, \mathrm{dEd}\Omega$	mult

Reference	Projectile	Kinetic Energy	Target	Fragment	Type	Cross Section	Other
[Yiou68]	^{1}H	135 – 19.0	O,Al	n,^{1}H,^{6,7}Li,$^{7-10}$Be ^{10,11}B,^{22}Na	iso	σ	
[Yiou69]	^{1}H	135,600,19.0	O	^{6,7}Li,^{7,9}Be,^{10}B	iso	σ	
[Yokoyama01]	C	180,290	Nb,Pr,Au	A = 60 – 200		σ	
[Yule60]	^{1}H	80 – 500	^{12}C,^{14}N,^{19}F, ^{23}Na,^{27}Al,^{45}Sc ^{54}Fe,^{59}Co,^{58}Ni ^{63,65}Cu,^{64}Zn,^{69}Ga ^{75}As,^{81}Br,^{89}Y ^{100}Ru,^{100}Mo ^{107}Ag,^{127}I,^{133}Cs ^{142}Ce,^{181}Ta ^{197}Au,^{232}Th,^{238}U	$^{A-1}$Target	iso	σ	rev
[Zamani10]	^{2}H	250 – 2.5	Pb		inel	σ	rev
[Zeitlin97]	^{56}Fe	1.05	H,C,Al,Cu,Pb	Mg – Mn	cc,elem	σ	
[Zeitlin01]	^{20}Ne	600	H,C,Al,Cu,Sn,Ta,Pb	H – F	cc,elem	σ	
[Zeitlin07]	^{12}C	290,400	H,C,Al,Cu,Sn,Pb	H – B	cc,elem	σ, dΩ	
[Zeitlin07a]	^{28}Si	263 – 1.16	H,C,Al,Cu,Sn,Pb	C – Al	cc,elem	σ	
[Zeitlin08]	^{35}Cl,^{40}Ar ^{48}Ti	290,400,650,1.0	H,C,Al,Cu,Sn,Pb	B – Sc	cc,elem	σ	
[Zeitlin11]	^{14}N,^{16}O ^{20}Ne,^{24}Mg	290 – 1.0	H,C,Al,Cu,Sn,Pb	Be – Na	cc,elem	σ	
[Zhou10]	n	37	^{209}Bi	n	iso	dΩ	
[Zhu91]	^{3}He	67	Ag	^{1}H	iso	dEdΩ	

References

[Abdurakhimov81] Abdurakhimov, A.K. et al., 1981. A study of pion production in 4.5 (GeV/c)/nucleon ^{4}He interactions with nuclear targets. Nuclear Physics A 362, 376-390.

[Abe87] Abe, K., Maeda, K., Ishimatsu, T., Kawamura, T., Furukawa, T., Orihara, H., Zafiratos, C.D., 1987. The reaction $^{26}\mathrm{Mg}(^3\mathrm{He,n})^{28}\mathrm{Si}$ at 23 and 45 MeV. Nuclear Physics A 462, 358-366.

[Abe87a] Abe, K., Maeda, K., Ishimatsu, T., Kawamura, T., Furukawa, T., Orihara, H., Ohnuma, H., 1987. The reaction $^{12}\mathrm{C}(^3\mathrm{He,n})^{14}\mathrm{O}$ at 45.5 MeV. Nuclear Physics A 466, 109-118.

[Abramov10] Abramov, B.M., Borodin, Y.A., Bulychev, S.A., Dukhovskoi, I.A., Krutenkova, A.P., Kulikov, V.V., Martem'anov, M.A., Matsuk, M.A., Turdakina, E.N., Khanov, A.I., 2010. Light fragments in (C + Be) interaction at an energy of 300 MeV/nucleon. Bulletin of the Russian Academy of Sciences: Physics 74, 564-566.

[Aksinenko80] Aksinenko, V.D., et al., 1980. Streamer chamber study of the cross sections and multiplicities in nucleus-nucleus interactions at the incident momentum of 4.5 GeV/c per nucleon. Nuclear Physics A 348, 518-534.

[Aladashvili81] Aladashvili, B.S., et al., 1981. Production of deuterons in a $^4\mathrm{He}-\mathrm{p}$ interaction at 8.6 GeV/c. Acta Phys. Slov. 31, 29-37.

[Alard75] Alard, J.P., et al. 1975. Light fragment production in p-Nucleus interactions at 600 MeV. Astrophysical application. Il Nuovo Cimento 30, 320-344.

[Alexakhin00] Alexakhin, V.Y., et al. Proton, deuteron, and triton emission in $^{14}\mathrm{N}$ + Ag interactions at an energy of 52 MeV per nucleon. Physics of Atomic Nuclei 63, 1673-1678.

[Alexander63] Alexander, J.M., Baltzinger, C., Gazdik, M.F., 1963. Cross section and recoil studies of reactions of U^{238} with protons of 0.5 to 6.2 GeV. Physical Review 129, 1826-1834.

[Alvarez10] Alvarez-Pol, H., et al., 2010. Production of new neutron rich isotopes of heavy elements in fragmentation reactions of $^{238}\mathrm{U}$ projectiles at 1 A GeV. Physical Review C 82, 041602.

[Anderson83] Anderson, L., Bruckner, W., Moeller, E., Nagamiya, S., Niessen-Meyer, S., Schroeder, L., Shapiro, G., Steiner, H., 1983. Inclusive particle production at forward angles from collisions of light relativistic nuclei: nuclear fragments. Physical Review C 28, 1224-1245.

[Anikina83] Anikina, M.K., Vardenga, G.L., Golokhvastov, A.I., Kuznetsov, A.A., Lukstyn'sh, Y., Man'yakov, P.K., Okonov, E.O., Khorozov, S.A., 1983. Cross sections for inelastic interaction of neon nuclei with various other nuclei. Soviet Journal of Nuclear Physics 38, 88-89.

[Apollonio10] Apollonio, M., et al., 2010. Measurements of forward proton production with incident protons and charged pions on nuclear targets at the CERN proton synchrotron. Physical Review C 82, 045208.

[Armbruster04] Armbruster, P., et al., 2004. Measurement of a complete set of nuclides, cross sections, and kinetic energies in spallation of ^{238}U 1A GeV with protons. Physical Review Letters 93, 212701.

[Asano85] Asano, Y., Mori, S., Noguchi, M., Sakano, M., Katoh, K., Kondo, K., 1985. Spallation and fission yields in the interactions of tantalum, tingsten and gold with 500 MeV protons. Journal of the Physical Society of Japan 54, 3734-3741.

[Asano88] Asano, Y., Kariya, H., Mori, S., Okano, M., Sakano, M., 1988. Spallation of tantalum, tingsten and gold by 12 GeV protons. Journal of the Physical Society of Japan 57, 2995-3002.

[Auble83] Auble, R.L., et al., 1983. Light ion emission from reactions induced by 0.8 - 2.4 GeV ^{16}O projectiles. Physical Review C 28, 1552-1564.

[Audouin06] Audouin, L., et al., 2006. Evaporation residues produced in spallation of ^{208}Pb by protons at 500 A MeV. Nuclear Physics A 768, 1-21.

[Austin62] Austin, S.M., Salmon, G.L., Clegg, A.B., Foley, K.J., Newton, D., 1962. Reactions Induced in ^{12}C by Nucleons of Energy 120-150 MeV. Proceedings of the Physical Society 80, 383-394.

[Avan84] Avan, M., et al., 1984. Backward emission of energetic protons. Physical Review C 30, 521-526.

[Avdeyev02] Avdeyev, S.P., et al., 2002. Comparative study of multifragmentation of gold nuclei induced by relativistic protons, ^{4}He, and ^{12}C. Nuclear Physics A 709, 392-414.

[Awes79] Awes, T.C., Gelbke, C.K., Back, B.B., Mignerey, A.C., Wolf, K.L., Dyer, P., Breuer, H., Viola, V.E., 1979. Light particle spectra observed in central and peripheral collisions of $^{16}O +^{238} U$ at 20 MeV/nucleon. Physics Letters B 87, 43-46.

[Awes80] Awes, T.C., Gelbke, C.K., Poggi, G., Back, B.B., Glagola, B., Breuer, H., Viola, V.E., Symons, T.J.M., 1980. Coalescence of light particles in the reaction $^{16}O +^{238} U$ at 315 MeV. Physical Review Letters 45, 513-516.

[Awes81] Awes, T.C., , Poggi, G., Gelbke, C.K.Back, B.B., Glagola, B., Breuer, H., Viola, V.E., 1981. Precompound emission of light particles in the reaction $^{16}O +^{238} U$ at 20 MeV/nucleon. Physical Review C 24, 89-110.

[Badala93] Badala, A., Barbera, R., Palmeri, A., Pappalardo, G.S., Riggi, F., 1993. Breakup of the projectile in ^{16}O induced reactions on ^{27}Al, ^{58}Ni, and ^{197}Au targets around 100 MeV/nucleon. Physical Review C, 48, 633-646.

[Badran01] BadranR.I., Parker, D.J., Naqib, I.M., 2001. Complete and incomplete fusion in reactions of $^{7}Li +^{56} Fe$ at E(^{7}Li) = 50 and 68 MeV from analysis of recoil range and light-particle measurements. European Physical Journal A 12, 317-325.

[Baker58] Baker, E., Friedlander, G., Hudis, J., 1958. Formation of Be^7 in interactions of various nuclei with high energy protons. Physical Review 112, 1319-1321.

[Banaigs87] Banaigs, J., et al., 1987. Inelastic scattering of α particles on light nuclei at $P_\alpha = 7.0$ GeV/c. Physical Review C 35, 1416-1424.

[Bandyopadhyay02] Bandyopadhyay, D., Bhattacharya, C., Krishan, K., Bhattacharya, S., Basu, S.K., Chatterjee, A., Kailas, S., Shrivastava, A., Mahata, K., 2002. Light charged particle evaporation from hot ^{31}P nucleus at $E^* = 60$ MeV. arXiv:nucl-ex/0108004v2. nnn

[Barrette95] Barrette, J., et al., 1995. Production of neutron-rich isotopes from the fragmentation of ^{28}Si projectiles at $p_{lab} = 14.6$ GeV/c per nucleon. Physical Review C 52, 956-963.

[Barrette00] Barrette, J., et al., 2000. Light fragment yields from central Au+Au collisions at 11.5A GeV/c. Physical Review C 61, 044906.

[Bastid90] Bastid, N., et al., 1990. Exclusive measurements of light fragment production at forward angles in Ne-Pb and Ne-NaF collisions at E/A = 400 MeV and 800 MeV. Nuclear Physics A 506, 637-654.

[Basu07] Basi, C., Adhikari, S., Ghosh, S.K., Roy, S., Ray, S., Behera, B.R., Datta, S.K., 2007. Reaction mechanisms in $^{16}O + {}^{40}Ca$ at an incident energy of E(^{16}O) = 86 MeV through inclusive measurements of α and proton spectra. Physical Review C 76, 034609.

[Batzel54] Batzel, R.E., Coleman, G.H., 1954. Cross sections for formation of Na^{22} from aluminum and magnesium bombarded with protons. Physical Review 93, 280-282.

[Bazin90] Bazin, D., Guerreau, D., Anne, R., Guillemaud-Mueller, D., Mueller, A.C., Saint-Laurent, M.G., 1990. Zero degree measurements of isotopic distributions in 44

MeV/u ^{86}Kr induced reactions for the production of nuclei far from stability. Nuclear Physics A 515, 349-364.

[Beck76] Beck, S.M., Powell, C.A., 1976. Proton and deuteron double differential cross sections at angles from 10° to 60° from Be, C, Al, Fe, Cu, Ge, W, and Pb under 558 MeV proton irradiation. NASA Technical Note D-8119.

[Beene81] Beene, J.R., Halbert, M.L., Hensley, D.C., Dayras, R.A., Geoffroy Young, K., Sarantites, D.G., Barker, J.H., 1981. Fusion-like reactions of ^{16}O with ^{154}Sm: γ - ray multiplicity versus bombarding energy. Physical Review C 23, 2463-2478.

[Benenson67] Benenson, W., Crawley, G.M., Dreisbach, J.D., Johnson, W.P., 1967. Excited states of ^{10}C from the $^{12}\mathrm{C(p,t)}^{10}$C reaction at $\mathrm{E_p} = 43$ and 52 MeV. Nuclear Physics A, 97, 510-514.

[Benioff60] Benioff, P.A., 1960. Nuclear reactions of low Z elements with 5.7 BeV protons. Physical Review 119, 316-324.

[Benlliure98] Benlliure, J., et al., 1998. Production of medium-weight isotopes by fragmentation in 750 A MeV ^{238}U on ^{208}Pb collisions. European Physical Journal A 2, 193-198.

[Benlliure99] Benlliure, J., Schmidt, K.H., Cortina-Gil, D., Enqvist, T., Farget, F., Heinz, A., Junghans, A.R., Pereira, J., Taieb, J., 1999. Production of neutron-rich isotopes by cold fragmentation in the reaction ^{197}Au + Be at 950 A MeV. Nuclear Physics A 660, 87-100.

[Benlliure01] Benlliure, J., et al., 2001. Isotopic production cross sections of fission residues in ^{197}Au on proton collisions at 800 A MeV. Nuclear Physics A 683, 513-539.

[Benlliure02] Benlliure, J., et al., 2002. Signatures of fission dynamics in highly excited nuclei produced in ^{197}Au (800 A MeV) on proton collisions. Nuclear Physics A 700, 469-491.

[Benlliure10] Benlliure, J., et al., 2010. Extending the north-east limit of the chart of nuclides. aeXiv:1004.0265.

[Bernas65] n Bernas, P., Epherre, M., Gradsztajn, E., Klapisch, R., Yiou, F., 1965. Mass spectrometric determination of Li^6 and Li^7 production in C^{12} and O^{16} by high energy protons. Physics Letters B 15, 147-149.

[Bernas67] Bernas, R., Gradsztajn, E., Reeves, H., Schatzman, 1967. On the nuclsosynthesis of lithium, beryllium and boron. Annals of Physics 44, 426-478.

[Bernas97] Bernas, M., et al., 1997. Discovery and cross section measurement of 58 new fission products in projectile fission of 750 A MeV ^{238}U. Physics Letters B 415, 111-116.

[Bernas03] Bernas, M., et al., 2003. Fission residues produced in the spallation reaction ^{238}U + p at 1 AGeV. Nuclear Physics A 725, 213-253.

[Bernas06] Bernas, M., et al., 2006. Very heavy fission fragments produced in the spallation reaction ^{238}U = p at 1 A GeV. Nuclear Physics A 765, 197-210.

[Bertrand73] Bertrand, F.E., Peelle, R.W., 1973. Complete hydrogen and helium particle spectra from 30 to 60 MeV proton bombardment of nuclei with A = 12 to 209 and comparison with the intranuclear cascade model. Physical Review C 8, 1045-1064.

[Bertrand74] Bertrand, F.E., Peelle, R.W., Kalbach-Cline, C., 1974. Differential cross sections for charged particle emission in reactions of 58 MeV α particles with ^{12}C,^{16} O and ^{54}Fe: Comparison with the exciton model of pre-equilibrium particle emission. Physical Review C 10, 1028-1040.

[Bhattacharya91] Bhattacharya, C. et al. 1991. Heavy fragment emission in alpha-induced reactions on aluminum at 60 MeV. Physical Review C 44, 1049-1056.

[Bhattacharya95] Bhattacharya, C. et al., 1995. Intermediate mass fragments emission in the reaction 47 MeV ^{7}Li + Mg. Physical Review C 52, 798-806.

[Bhattacharya96] Bhattacharya, C., et al., 1996. Intermediate mass fragments emission in the reaction 96 MeV ^{19}F on ^{12}C. Physical Review C 54, 3099-3108.

[Billerey81] Billerey, R., Cerruti, C., Chevarier, A., Chevarier, N., Cheynis, B., Demeyer, A., Namboodiri, M.N., 1981. Preequilibrium emission in the fusion reactions in the system ^{14}N +^{27} Al at 100 MeV. Physical Review Letters 47, 639-642.

[Binns87] Binns, W.R., Garrard, T.L., Israel, M.H., Kertzmann, M.P., Klarmann, J., Stone, E.C., Waddington, C.J., 1987. Systematics of the release of residual nuclei from relativistic nucleus-nucleus interactions. Physical Review C 36, 1870-1885.

[Bizard77] Bizard, G., et al., 1977. ^{3}He production in ^{4}He fragmentation on protons at 6.85 GeV/c. Nuclear Physics A 285, 461-468.

[Blank94] Blank, B., et al., 1994. Production cross sections and the particle stability of proton-rich nuclei from ^{58}Ni fragmentation. Physical Review C 50, 2398-2407.

[Bloch88] Bloch, C., Benenson, W., Galonsky, A.I., Kashy, E., Heltsley, J., Heilbronn, L., Lowe, M., Radtke, R.J., Remington, B., 1988. Neutrons in coincidence with intermediate mass fragments at large angles from ^{14}N + Ag reactions at E/A = 20 and 35 MeV. Physical Review C 37, 2469-2486.

[Bobchenko79] Bobchenko, B.M., et al., 1979. Measurement of total inelastic cross sections for interaction of protons with nuclei in the momentum range from 5 to 9 GeV/c and for interaction of π^- mesons with nuclei in the momentum range from 1.75 to 6.5 GeV/c. Soviet Journal of Nuclear Physics 30, 805-813.

[Bogatin76] Bogatin, V.I., Litvin, V.F., Lozhkin, O.V., Perfilov, N.A., Yakovlev, Y.P., 1976. Isotopic effects in high energy nuclear reactions and isospin correlations of fragmentation cross sections. Nuclear Physics A 260, 446-460.

[Boger94] Boger, J., Alexander, J.M., Elmaani, A., Kox, S., Lacey, R.A., Narayanan, A., Moses, D.J., McMahan, M.A., DeYoung, P.A., Gelderloos, C.J., 1994. Intermediate mass fragments from the reactions 486, 550, 640, and 730 MeV ^{86}Kr + ^{63}Cu. Physical Review C 49, 1597-1602.

[Bolshakova09] Bolshakova, A., et al., 2009. Cross sections of large angle hadron production in proton and pion-nucleus interactions I: beryllium nuclei and beam momenta of +8.9 GeV/c and -8.0 GeV/c. European Physical Journal C 62, 293-317.

[Bolshakova09a] Bolshakova, A., et al., 2009. Cross sections of large angle hadron production in proton and pion-nucleus interactions II: beryllium nuclei and beam momenta of $\pm$3 GeV/c to $\pm$15 GeV/c. European Physical Journal C 62, 697-754.

[Bolshakova09b] Bolshakova, A., et al., 2009. Cross sections of large angle hadron production in proton and pion-nucleus interactions III: tantalum nuclei and beam momenta of $\pm$3 GeV/c to $\pm$15 GeV/c. European Physical Journal C 63, 549-609.

[Bolshakova10] Bolshakova, A., et al., 2010. Cross sections of large angle hadron production in proton and pion-nucleus interactions IV: copper nuclei and beam momenta of $\pm$3 GeV/c to $\pm$15 GeV/c. European Physical Journal C 64, 181-241.

[Bolshakova10a] Bolshakova, A., et al., 2010. Cross sections of large angle hadron production in proton and pion-nucleus interactions V: lead nuclei and beam momenta of $\pm$3 GeV/c to $\pm$15 GeV/c. European Physical Journal C 66, 57-117.

[Brechtmann86] Brechtmann, C., Drechsel, H., Beer, J., Heinrich, W. 1986. Cross sections for the production of fragments with Z $\geq$ 8 by fragmentation of 9 $\leq$ Z $\leq$ 26 nuclei. 13th International Conference on Solid State Nuclear Track Detectors, Rome, 23 - 27 September, 1985. Siegen report Si-85-18. Int. J. Radiat. Appl. Instrum., Part D, Pergamon, Nuclear Tracks 12, 361-364.

[Brechtmann88] Brechtmann, C., Heinrich, W., 1988a. Measurements of elemental fragmentation cross section for relativistic heavy ions using CR39 plastic nuclear track detectors. Nuclear Instruments and Methods in Physics Research B 29, 675-679.

[Brechtmann88a] Brechtmann, C., Heinrich, W., 1988b. Fragmentation cross sections of ^{32}S at 0.7, 1.2 and 200 GeV/nucleon. Zeitschrift für Physik A 331, 463-472.

[Brechtmann88b] Brechtmann, C., Heinrich, W., 1988c. Fragmentation cross sections of ^{16}O at 60 and 200 GeV/nucleon. Zeitschrift für Physik A 330, 407-416.

[Brechtmann89] Brechtmann, C., Heinrich, W., Benton, E.V., 1989. Fragmentation cross sections of ^{28}Si at 14.5 GeV/nucleon. Physical Review C 39, 2222-2226.

[Britt61] Britt, H.C., Quinton, A.R., 1961. Alpha particles and protons emitted in the bombardment of ^{197}Au and ^{209}Bi by ^{12}C,^{14}N and ^{16}O projectiles. Physical Review 124, 877-887.

[Brohm95] Brohm, T., et al., Münzenberg, G., Nickel, F., Pfützner, M., Roeckl, E., Schall, I., Sümmerer, K., Vieira, D.J., Weber, M., 1995. Total charge changing cross sections of stable and neutron deficient secondary projectiles around A=60. Nuclear Physics A 585, 565-576.

[Bubak07] Bubak, A., et al., 2007. Non-equilibrium emission of complex fragments from p + Au collisions at 2.5 GeV proton beam energy. Physical Review C 76, 014618.

[Budzanowski08] Budzanowski, A., et al., 2008. Competition of coalescence and fireball processes in nonequilibrium emission of light charged particles from p + Au collisions. Physical Review C 78, 024603.

[Budzanowski09] Budzanowski, A., et al., 2009. Variation of nonequilibrium processes in p+Ni system with beam energy arXiv:0909.1436.

[Budzanowski09a] Budzanowski, A., et al., 2009. Evidence of Ni break-up from total production cross sections in p + Ni collisions. arXiv0910.1872.

[Budzanowski10] Budzanowski, A., et al., 2010. Comparison of nonequilibrium processes in p + Ni and p + Au collisions at GeV energies. Physical Review C 82, 034605.

[Caamano04] Caamano, M., Cortina-Gil, D., Summerer, K., Benlliure, J., Casarejos, E., Geissel, H., Munzenberg, G., Pereira, J., 2004. Production cross-sections and momentum distributions of fragments from neutron-deficient ^{36}Ar at 1.05 A GeV. Nuclear Physics A 733, 187-199.

[Caretto58] Caretto, A.A., Hudis, J., Friedlander, G., 1958. Production of F^{18} and Na^{24} in irradiation of various targets with protons between 1 and 6 BeV. Physical Review 110, 1130-1133.

[Casarejos06] Casarejos, E., et al., 2006. Isotopic production cross sections of spallation-evaporation residues from reactions of ^{238}U (1 A GeV) with deuterium. Physical Review C 74, 044612.

[Caskey88] Caskey, G., Heilbronn, L., Remington, B., Galonsky, A., Deak, F., Kiss, A., Seres, Z., 1988. Fragment spectra from reactions induced by 35 MeV/nucleon ^{14}N on ^{165}Ho. Physical Review C 37, 969-975.

[Charvet87] Charvet, J.L., et al., 1987. Binary break-up of a high velocity hot source formed in the ^{84}Kr $+^{93}$ Nb reaction at 34.5 MeV/u. Physics Letters B 189, 388-392.

[Chen94] Chen, C.X., et al., 1994. Interactions in hydrogen of relativistic neon to nickel projectiles: Total charge-changing cross sections. Physical Review C 49, 3200-3210.

[Chen94a] Chen, C.X., et al. 1994. Interactions in hydrogen of relativistic neaon to nickel projectiles: Total charge-changing cross sections. Physical Review C 49, 3200-3210.

[Cheshire74] Cheshire, D.L., et al., 1974. Fragmentation cross sections of 2.1 GeV/nucleon ^{12}C and ^{16}) ions. Physical Review C 10, 25-31.

[Chiba91] Chiba, J., et al. 1991. Coincidence measurements of (p,n) reactions at 1.5 GeV/c on C and H in the Δ excitation region. Physical Review Letters 67, 1982-1985.

[Chrien80] Chrien, R.E., Krieger, T.J., Sutters, R.J., May, M., Palevsky, H., Stearns, R.L., Kozlowski, T., Bauer, T., 1980. Proton spectra from 800 MeV protons on selected nuclides. Physical Review C 21, 1014-1029.

[Christie93] Christie, W.B., et al., 1993. Fragmentation of 1.2 GeV per nucleon ^{139}La. Physical Review C 48, 2973-2983.

[Chulkov00] Chulkov, L.V., et al., 2000. Total charge changing cross sections for neutron rich light nuclei. Nuclear Physics A 674, 330-342.

[Clerc95] Clerc, H.G., et al., 1995. The influence of fission on the fragmentation of relativistic ^{208}Pb and ^{238}U projectiles in peripheral collisions. Nuclear Physics A 590, 785-794.

[Cline76] Cline, J.E., Nieschmidt, E.B., 1971. Measurements of spallation cross sections for 590 MeV protons on thin targets of copper, nickel, iron and aluminum. Nuclear Physics A 169, 437-448.

[Cocconi61] Cocconi, G., Diddens, A.N., Lillethun, E., Wetherell, A.M., 1961. Elastic and quasi-elastic collisions of protons with momenta between 9 and 25 GeV/c. Physical Review Letters 6, 231-234.

[Cordell81] Cordell, K.R., Thornton, S.T., Dennis, L.C., Doering, R.R., Parks, R.L., Schweizer, T.C., 1981. Proton inclusive cross sections from 600 MeV proton-nucleus reactions. Nuclear Physics A 352, 485-491.

[Courtenay Wright50] Courtenay Wright S., 1950. Li^8 splinters from nuclear bombardments. Physical Review 79, 838-845.

[Cowley80] Cowley, A.A., Chang, C.C., Holmgren, H.D., 1980. Forward angle proton spectra in the continuum from the $^{58}Ni(p, xp)$ reaction at 100 MeV. Physical Review C 22, 2633-2635.

[Cowley98] Cowley, A.A., et al., 1998. Rescattering in knockout reactions as manifested in $^{40}Ca?(p, p'p'')$ at an incident energy of 392 MeV. Physical Review C 57, 3185-3190.

[Cowley00] Cowley, A.A., Steyn, G.F., Watanabe, Y., Noro, T., Tamura, K., Kawabata, M., Hatanaka, K., Sakaguchi, H., Takeda, H., Itoh, M., 2000. Inclusive reaction $^{40}Ca(p, p'x)$ at an incident energy of 392 MeV. Physical Review C 62, 064604.

[Crandall56] Crandall, W.E., Millburn, G.P., Pyle, R.V., Birnbaum, W., 1956. Physical Review 101, 329-337.

[Cumming58] Cumming, J.B., Friedlander, G., Swartz, C.E., 1958. $C^{12}(p, pn)C^{11}$ cross section at 2 and 3 BeV. Physical Review 111, 1386-1394.

[Cumming62] Cumming, J.B., Friedlander, G., Hudis, J., Poskanzer, A.M., 1962. Spallation of aluminum by 28 GeV protons. Physical Review 127, 950-954.

[Cumming62a] Cumming, J.B., Friedlander, G., Katcoff, S., 1962. $C^{12}(p, pn)C^{11}$ cross section at 28 GeV. Physical Review 125, 2078-2081.

[Cumming63] Cumming, J.B., 1963. Monitor reactions for high energy proton beams. Annual Review of Nuclear Science 13, 261-286.

[Cumming76] Cumming, J.B., Stoenner, R.W., Haustein, P.E., 1976. Spallation of copper by 25 GeV ^{12}C ions and 28 GeV protons. Physical Review C 14, 1554-1563.

[Cumming78] Cumming, J.B., Haustein, P.E., Ruth, T.J., Virtes, G.J., 1978. Spallation of copper by 80 GeV ^{40}Ar ions. Physical Review C 17, 1632-1641.

[Cummings90] Cummings, J.R., Binns, W.R., Garrard, T.L., Israel, M.H., Klarmann, J., Stone, E.C., Waddington, C.J., 1990. Determination of the cross sections for the production of fragments from relativistic nucleus-nucleus interactions. I. Measurements. Physical Review C 42, 2508-2529.

[Currie56] Currie, L.A., Libby, W.F., Wolfgang, R.L., 1956. Tritium production by high energy protons. Physical Review 101, 1557-1563.

[Currie59] Currie, L.A., 1959. Tritium production by 6 BeV protons. Physical Review 114, 878-880.

[D'Auria68] D'Auria, J.M., Fluss, M.J., Kowalski, L., Miller, J.M., 1968. Reaction cross section for low energy alpha particles on ^{59}Co. Physical Review 168, 1224-1227.

[Deak90] Deak, F., Kiss, A., Seres, Z., Galonsky, A., Heilbronn, L., Schelin, H.R., 1990. Light fragments from ^{14}N + Ag collisions at 35 MeV/nucleon. Physical Review C 42, 1029-1035.

[de Jong98] de Jong, M., et al., 1998. Fragmentation cross sections of relativistic ^{208}Pb projectiles. Nuclear Physics A 628, 479-492.

[De Lellis11] De Lellis, G., et al., 2011. Measurement of the fragmentation of Carbon nuclei used in hadron-therapy. Nuclear Physics A 853, 124-134.

[Devins69] Devins, D.W., Bunch, S.M., Forster, H.H., Hokhikian, J., Kim, C.C., 1969. Charged particle reactions from $^7\mathrm{Li} + \mathrm{p}$ at 30 MeV. Nuclear Physics A 126, 261-272.

[Dey09] Dey, A., Bhattacharya, S., Bhattacharya, C., Banerjee, K., Rana, T.K., Kundu, S., Banerjee, S.R., Mukhopadhyay, S., Guptab, D., Saha, R., 2009. Light charged particle emission from hot ^{32}S* formed in $^{20}\mathrm{Ne} +^{12}$ C reaction. European Physical Journal A 41, 39-51.

[Dittrich90] Dittrich, B., Herpers, U., Hofmann, H.J., Wolfli, W., Bodemann, R., Lupke, M., Michel, R., Dragovitsch, P., Filges, D., 1990. AMS measurements of thin-target cross sections for the production of ^{10}Be and ^{26}Al by high energy protons. Nuclear Instruments and Methods in Physics Research B 52, 588-594.

[Doering78] Doering, R.R., Schweizer, T.C., Thornton, S.T., Dennis, L.C., Cordell, K.R., Ziock, K.O.H., Comiso, J.C., 1978. Correlated energy spectra of light fragments from 720-MeV α induced reactions. Physical Review Letters 40, 1433-1435.

[Dostrovsky61] Dostrovsky, I., Fraenkel, Z., Hudis, J., 1961. Physical Review 123, 1452-1458.

[Dostrovsky65] Dostrovsky, I., Davis, R., Poskanzer, A.M., Reeder, P.L., 1965. Cross sections for the production of $\mathrm{Li}^9, \mathrm{C}^{16}$ and N^{17} in irradiations with GeV energy protons. Physical Review 139, B 1513 - B 1524.

[Dudkin90] Dudkin, V.E., Kovalev, E.F., Nefedov, N.A., Antonchik, V.A., Bogdanov, S.D., Ostroumov, V.I., Crawford, H.J., Benton, E.V., 1990. Multiplicities of secondaries in interactions of 1.8 GeV/nucleon ^{56}Fe nuclei with photoemulsion and the cascade evaporation model. Nuclear Physics A 509, 783-799.

[Dufauquez06] Dufauquez, C., El Masri, Y., Roberfroid, V., Cabrera, J., Keutgen, T., Van Mol, J., P. Demetriou, P., Charity, R., 2006. Light charged particle and neutron production in proton and α particle induced reactions on $^{\mathrm{nat}}$Si at energies between 20 and 65 MeV. Nuclear Physics A 773, 24-55.

[Duisebayev03] Duisebayev, A., IsmailoV, K.M., Boztosun, I., 2003. Inclusive spectra of ?(p,xp) and (?p,xd)? reactions on ^{90,92}Zr and ^{92}Mo nuclei at $E_p = 30.3$ MeV. Physical Review C 67, 044608.

[Duisebayev05] Duisebayev, A., IsmailoV, K.M., Boztosun, I., 2005. Inclusive cross sections of ?(p,xp) and (?p,xα)? reactions on ^{56}Fe at $E_p = 29.9$ MeV. Physical Review C 72, 054604.

[Ellegaard85] Ellegaard, C., 1985. The $p(^3\mathrm{He}, t)\Delta^{++}$ reaction. Physics Letters B 154, 110-114.

[Edge69] Edge, R.D., Tompkins, D.H., Glenn, J.W., 1969. Proton production from nuclei bombarded by protons of 1, 2 and 3 BeV. Physical Review 183, 849-853.

[El Nadi64] El Nadi, M., Riad, F., 1964. The structure of three and four nucleon projectiles from stripping reactions. Nuclear Physics 50, 33-40.

[El Nadi02] El-Nadi, M., El-Nagdy, M.S., Ali-Mossa, N., Abdelsalam, A., Abdalla, A.M., Abdel-Halim, S.M., 2002. Multiple fast helium fragments production from ^{28}Si - emulsion interaction at 14.6 A GeV. Journal of Physics G 28, 1251-1258.

[Engelage86] Engelage, J., Baumgartner, M., Greiner, D.E., Lindstrom, P.J., Olson, D.L., Wada, R., Crawford, H.J., Webb, M.L., 1986. A quasi-exclusive measurement of $^{12}\mathrm{C}(^{12}\mathrm{C}, 3\alpha)\mathrm{X}$ at 2.1 GeV/nucleon. Physics Letters B 173, 34-38.

[English73] English, G., Yu, Y.W., Porile, N.T., 1973. Nuclear reactions of silver with 300 GeV protons. Physical Review Letters 31, 244-247.

[English74] English, G., Porile, N.T., Steinberg, E.P., 1974. Nuclear reactions of silver with 11.5 GeV protons. Physical Review C 10, 2268-2280.

[English74a] English, G., Yu, Y.W., Porile, N.T., 1974. Physical Review C 10, 2281-2285.

[Enke99] Enke, M., et al., 1999. Evolution of a spallation reaction: experiment and Monte Carlo simulation. Nuclear Physics A 657, 317-339.

[Enqvist99] Enqvist, T., et al., 1999. Systematic experimental survey on projectile fragmentation and fission induced in collisions of ^{238}U at 1 A GeV with lead. Nuclear Physics A 658, 47-66.

[Enqvist01] Enqvist, T., et al., 2001. Isotopic yields and kinetic energies of primary residues in 1 A GeV $^{208}Pb + p$ reactions. Nuclear Physics A 686, 481-524.

[Enqvist02] Enqvist, T., et al., 2002. Primary-residue production cross sections and kinetic energies in 1 A GeV ^{208}Pb on deuteron reactions. Nuclear Physics A 703, 435-465.

[Erb76] Erb, K.A., Betts, R.R., Hanson, D.L., Sachs, M.W., White, R.L., Tung, P.P., Bromley, D.A., 1976. New resonances in the low energy $^{12}C -^{12} C$ spectrum. Physical Review Letters 37, 670-673.

[Eyal73] Eyal, Y., Beg, K., Logan, D., Miller, J., Zebelman, A., 1973. Behavior of particles transferred in the $^{16} +^{197}$ Au and $^{12}C +^{197}$ Au reactions. Physical Review C 8, 1109-1122.

[Fernandez05] Fernandez-Dominguez, B., et al., 2005. Nuclide cross-sections of fission fragments in the reaction $^{208}Pb + p$ at 500 A MeV. Nuclear Physics A 747, 227-267.

[Fink87] Fink, D., Paul, M., Hollos, G., Theis, S., Vogt, S., Stueck, R., Englert, P., Michel, R., 1987. Measurements of ^{41}Ca spallation cross sections and ^{41}Ca concentrations in the giant meteorite by accelerator mass spectrometry. Nuclear Instruments and Methods in Physics Research B 29, 275-280.

[Fink90] Fink, D., Sisterson, J., Vogt, S., Herzog, G., Klein, J., Middleton, R., Koehler, A., Magliss, A., Production of ^{41}Ca and K, Sc and V short-lived isotopes by the irradiation of Ti with 35 to 150 MeV protons: applications to solar cosmic ray studies. Nuclear Instruments and Methods in Physics Research B 52, 601-607.

[Fink00] Fink, D., Vogt, S., Hotchkis, M., 2000. Cross-sections for ^{36}Cl from Ti at E_p = 35150 MeV:? Applications to in-situ exposure dating. Nuclear Instruments and Methods in Physics Research B 172, 861-866.

[Fireman55] Fireman, E.L., Rowland, F.S., 1955. Tritium and neutron production by 2.2 BeV protons on Nitrogen and Oxygen. Physical Review 97, 780-782.

[Flesch99] Flesch, F., Hirzebruch, S.E., Huntrup, G., Rocher, H., Streibel, T., Winkel, E., Heinrich, W., 1999. Fragmentation cross section measurements of iron projectiles using CR-39 plastic nuclear track detectors. Radiation Measurements 31, 533-536.

[Flesch01] Flesch, F., Iancu, G., Heinrich, W., Yasuda, H., 2001. Projectile fragmentation of silicon ions at 490 A MeV. Radiation Measurements 34, 237-240.

[Fohr11] Fohr, V., et al., 2011. Experimental study of fragmentation products in the reactions $^{112}\mathrm{Sn} +^{112} \mathrm{Sn}$ and $^{124}Sn +^{124} Sn$ at 1 A GeV. arXiv:1106.5368v1 [nucl-ex], 2011.

[Fontes71] Fontes, P., Perron, C., Lestringuez, J., Yiou, F., Bernas, R. 1971. Production cross sections of Lithium and Beryllium isotopes in ^{12}C by high energy protons and alpha particles. Nuclear Physics A 165, 405-414.

[Fontes77] Fontes, P., 1977. ^{10}B and ^{11}B production cross sections in ^{12}C spallation by protons and alpha particles: Application to cosmic ray propagation. Physical Review C 15, 2159-2168.

[Fortney80] Fortney, D.R., Porile, N.T., 1980a. Test of the applicability of the two-step model to the emission of Sc fragments in the interaction of ^{238}U with 400 GeV protons. Physical Review C 22, 670-677.

[Fortney80a] Fortney, D.R., Porile, N.T., 1980b. Angular distributions of Sc fragments from the interaction of ^{238}U with $0.8 - 400$ GeV protons. Physical Review C 21, 2511-2518.

[Fortsch88] Fortsch, S.V., Cowley, A.A., Pilcher, J.V., Whittal, D.M., Lawrie, J.J., Van Staden, J.C., Friedland, E., Continuum yields from $^{12}\mathrm{C(p, p')}$ at incident proton energies of 90 and 200 MeV. Nuclear Physics A 485, 258-270.

[Fortsch91] Fortsch, S.V., Cowley, A.A., Lawrie, J.J., Whittal, D.M., Pilcher, J.V., Smit, F.D., 1991. Continuum protons from $^{58}\mathrm{Ni(p, p')}$ at incident energies between 100 and 200 MeV. Physical Review C 43, 691-700.

[Fortsch07] Fortsch, S.V., et al., 2007. Contributions of complete fusion and break-up fusion to intermediate mass fragment production in the low energy interaction of ^{12}C and ^{27}Al. Nuclear Physics A 797, 1-32.

[Frankel81] Frankel, K.A., Stevenson J.D., 1981. Interactions of 100 MeV/nucleon ^{40}Ar with uranium. Physical Review C 23, 1511-1526.

[Frascaria75] Frascaria, R., Roos, P.G., Morlet, M., Marty, N., Willis, A., Comparat, V., Fujiwara, N., 1975. $^{4}\mathrm{He(p, 2p)}^{3}\mathrm{H}$ and $^{4}\mathrm{He(p, pd)}^{2}\mathrm{H}$ reactions at 156 MeV. Physical Review C 12, 243-250.

[Friedlander54] Friedlander, G., Miller, J.M., Wolfgang, R., Hudis, J., Baker, E., 1954. Nuclear reactions of copper with 2.2 BeV protons. Physical Review 94, 727-728.

[Friedlander55] Friedlander, G., Hudis, J., Wolfgang, R.L., 1955. Disintegration of aluminum by protons in the energy range 0.4 to 3.0 BeV. Physical Review 99, 263-268.

[Friese93] Friese, J., et al., 1993. Production of neutron rich nuclei by fragmentation of 760 AMeV ^{136}Xe. Nuclear Physics A 553, 753-756.

[Fukuda84] Fukuda, T., Ishihara, M., Ogata, H., Miura, I., Shimoda, T., Katori, K., Shimoura, S., Tanaka, M.K., Takada, E., Otsuka, T., 1984. Light particle emission in the reaction $^{93}\mathrm{Nb} +^{14}\mathrm{N}$ at 132, 159 and 208 MeV. Nuclear Physics A 425, 548-572.

[Fukuda84a] Fukuda, T., Nomura, T., Shimoda, T., Katori, K., Shimoura, S., Sueki, K., Ogata, H., 1984. Linear momentum transfer in the reaction $^{232}\mathrm{Th}(^{14}\mathrm{N}, \mathrm{light\ particles})$ at 208 MeV. Nuclear Physics A 429, 193-204.

[Fulmer81] Fulmer, C.B., Ball, J.B., Ferguson, R.L., Robinson, R.L., Wu, J.R., 1981. Light particle emission from reactions of 208 MeV ^{16}O ions with $^{12}\mathrm{C},^{56}\mathrm{Fe}$ and ^{91}Zr. Physics Letters B 100, 305-309.

[Furukawa71] Furukawa, M., Shizuri, K., Komura, K., Sakamoto, K., Tanaka, S., 1971. Production of ^{26}Al and ^{22}Na from proton bombardment of Si, Al and Mg. Nuclear Physics A 174, 539-544.

[Galin74] Galin, J., Gatty, B., Guerreau, D., Rousset, C., Sclotthauer-Voos, U.C., Tarrago, X., 1974. Stufy of charged particles emitted from ^{117}Te compund nuclei. I. Argon induced reactions. Physical Review C 9, 1113-1125.

[Galin74a] Galin, J., Gatty, B., Guerreau, D., Rousset, C., Sclotthauer-Voos, U.C., Tarrago, X., 1974. Stufy of charged particles emitted from ^{117}Te compund nuclei. II. Comparison between $^{40}\mathrm{Ar} +^{77}\mathrm{Se}$ and $^{14}\mathrm{N} +^{103}\mathrm{Rh}$ reactions and determination of critical angular momenta. Physical Review C 9, 1126-1137.

[Gazzaly78] Gazzaly, M.M., et al., 1978. Central collisions with a projectile of 1.8 GeV/nucleon ^{40}Ar. Physics Letters B 79, 325-328.

[Geaga80] Geaga, J.V., Chessin, S.A., Grossiord, J.Y., Harris, J.W., Hendrie, D.L., Schroeder, L.S., Treuhaft, R.N., Van Bibber, K., 1980. Observation of high-momentum protons from limiting fragmentation. Physical Review Letters 45, 1993-1996.

[Geer95] Geer, L.Y., Klarmann, J., Nilsen, B.S., Waddington, C.J., Binns, W.R., Cummings, J.R., Garrard, T.L., 1995. Charge-changing fragmentation of 10.6 GeV/nucleon 197Au nuclei. Physical Review C 52, 334-345.

[Goldhaber78] Goldhaber, A.S., Heckman, H.H., 1978. High energy interactions of nuclei. Annual Review of Nuclear and Particle Science 28, 161-205.

[Golovchenko01] Golovchenko, A.N., Skvarč, J., Yasuda, N., Ilić, R., Tretyakova, S.P., Ogura, K., Murakami, T., 2001. Total charge changing and partial cross section measurements in the reaction of 110 MeV/u ^{12}C with paraffin. Radiation Measurements 34, 297-300.

[Golovchenko02] Golovchenko, A.N., Skvarc, J., Yasuda, N., Giacomelli, M., Tretyakova, S.P., Ilic, R., Bimbot, R., Toulemonde, M., Murakami, T., 2002. Total charge changing and partial cross section measurements in the reactions of $\sim$ 110-250 MeV/nucleon ^{12}C in carbon, paraffin, and water. Physical Review C 66, 014609.

[Gonthier80] Gonthier, P., Ho, H., Namboodirir, M.N., Adler, L., Natowitz, J.B., Simon, S., Hagel, K., Terry, R., Khodai, A., 1980. Limits to the fusion of 310 MeV ^{16}O with Ti. Physical Review Letters 44, 1387-1391.

[Gooding60] Gooding, T.J., Pugh, H.G., 1960. Quasi-elastic scattering of 153 MeV protons by p-state protons in C^{12}, Nuclear Physics 18, 46-64.

[Gooding61] Gooding, T.J., Igo, G., 1961. Scattering of 915 MeV α particles from carbon and helium: Direct evidence for α particle clustering in nuclei. Physical Review Letters 7, 28-30.

[Gosset77] Gosset, J., Gutbrod, H.H., Meyer, W.G., Poskanzer, A.M., Sandoval, A., Stock, R., Westfall, G.D., 1977. Central collisions of relativistic heavy ions. Physical Review C 16, 629-657.

[Gradsztajn65] Gradsztajn, E., Yiou, F., Klapisch, R., Bernas, R. 1965. Intranuclear cascade and Fermi model breakup calculations of the production of Li, Be and B isotopes in C^{12} by 156 MeV protons. Physical Review Letters 14, 436-439.

[Graulich00] Graulich, J.S., et al., 2000. 7.07 MeV resonant state in ^{19}Ne reexamined through a new measurement of the $^{18}\mathrm{F}(?\mathrm{p},\alpha)^{15}$O reaction and $^{18}\mathrm{F}(?\mathrm{p},\mathrm{p})$ scattering. Physical Review C 63, 011302(R).

[Green80] Green, R.E.L., Korteling, R.G., 1980. Fragment production from p + Ag interactions at intermediate energies. Physical Review C 22, 1594-1611.

[Green87] Green, R.E.L., Korteling, R.G., D'Auria, J.M., Jackson, K.P., Helmer, R.L., 1987. Light fragment spectra to upper kinematic limits for 300 MeV proton reactions with Be and Ag. Physical Review C 35, 1341-1352.

[Greiner75] Greiner, D.E., Lindstrom, P.J., Heckman, H.H., Cork, B., Bieser, F.S., 1975. Momentum distributions of isotopes produced by fragmentation of relativistic ^{12}C and ^{16}O projectiles. Physical Review Letters 35, 152-155.

[Griffiths69] Griffiths, R.J., Harbison, S.A., 1969. Measurements of cross sections for nuclear reactions related to the anomalous composition of 3 Centauri A. Astrophysical Journal 158, 711-718.

[Guertin05] Guertin, A., et al., 2005. Neutron and light charged particle productions in proton induced reactions on ^{208}Pb at 62.9 MeV. European Physical Journal A 23, 49-60.

[Gupta99] Gupta, D., Samanta, C., Kanungo, R., Sharan, M.K., Kailas, S., Chatterjee, A., Mahata, K., Shrivastava, A., 1999. Measurement of 42 MeV ^{7}Li projectile breakup on ^{58}Ni target beyond grazing incidence. Nuclear Physics A 646, 161-174.

[Gutbrod76] Gutbrod, H.H., Sandoval, A., Johansen, P.J., Poskanzer, A.M., Gosset, J., Meyer, W.G., Westfall, G.D., Stock, R., 1976. Final state interactions in the production of hydrogen and helium isotopes by relativistic heavy ions on uranium. Physical Review Letters 37, 667-670.

[Harada99] Harada, M., et al., 1999. The $^{12}\mathrm{C}(\mathrm{p},\mathrm{p}'3\alpha)$ breakup reaction induced by 14, 18 and 26 MeV protons. Journal of Nuclear Science and Technology, 36, 313-325.

[Hautala02] Hautala, C., et al., Polarization transfer in quasifree $(\vec{p},\vec{n})$ reactions on C, Ca, and Pb targets at 197 MeV. Physical Review C 65, 034612.

[He94] He, Y.D., Price, P.B., 1994. Nuclear and electromagnetic fragmentation of 2.25 TeV ^{197}Au nuclei. Zeitschrift für Physik A 348, 105-109

[Heckman72] Heckman, H.H., Greiner, D.E., Lindstrom, P.J., Bieser, F.S., 1972. Fragmentation of ^{14}N at 29 GeV: inclusive isotope spectra at 0^{o}. Physical Review Letters 28, 926-929.

[Heckman78] Heckman, H.H., Greiner, D.E., Lindstrom, P.J., Shwe, H., 1978. Fragmentation of ^{4}He, ^{12}C, ^{14}N and ^{16}O nuclei in nuclear emulsion at 2.1 GeV/nucleon. Physical Review C 17, 1735-1747.

[Heckman78] Heckman, H.H., Greiner, D.E., Lindstrom, P.J., Shwe, H., 1978. Fragmentation of ^{4}He, ^{12}C, ^{14}N, and ^{16}O nuclei in nuclear emulsion at 2.1 GeV/nucleon. Physical Review C 17, 1735-1747.

[Heilbronn91] Heilbronn, L., et al., 1991. Production of neutron-unbound states in intermediate-mass fragments from ^{14}N + Ag reactions at E/A = 35 MeV. Physical Review C 43, 2318-2335.

[Henzlova08] Henzlova, D., et al., 2008. Experimental investigation of the residues produced in the ^{136}Xe+Pb and ^{124}Xe+Pb fragmentation reactions at 1 A GeV. Physical Review C 78, 044616.

[Herbach06] Herbach, C.M., et al., 2006. Charged-particle evaporation and pre-equilibrium emission in 1.2 GeC proton induced spallation reactions. Nuclear Physics A 765, 426-463.

[Heydegger76] Heydegger, H.R., Turkevich, A.L., Van Ginnekin, A., Walpole, P.H., 1976. Production of ^{7}Be, ^{22}Na, and ^{28}Mg from Mg, Al, and SiO_2 by protons between 82 and 800 MeV. Physical Review C 14, 1506-1514.

[Hicks56] Hicks, H.G., Stevenson, P.C., Nervik, W.E., 1956. Reaction $Al^{27}(p, 3pn)Na^{24}$. Physical Review 102, 1390-1392.

[Hintz52] Hintz, N.M., Ramsey, N.F., 1952. Excitation functions to 100 MeV. Physical Review 88, 19-27.

[Hirzebruch92] Hirzebruch, S.E., Heinrich, W., Tolstov, K.D., Kovalenko, A.D., Benton. E.V., 1992. Fragmentation cross sections of ^{16}O between 0.9 and 200 GeV/nucleon. Physical Review C 46, 1487-1494.

[Hirzebruch95] Hirzebruch, S.E., Becker, E., Huntrup, G., Streibel, T., Winkel, E., Heinrich, W., 1995. Charge-changing interactions of ^{197}Au at 10 GeV/nucleon in collisions with targets from H to Pb. Physical Review C 51, 2085-2090.

[Honda60] Honda, M., Lal, D., 1960. Some cross sections for the production of radionuclides in the bombardment of C, N, O and Fe by medium energy protons. Physical Review 118, 1618-1625.

[Honda64] Honda, M., Lal, D., 1964. Spallation cross sections for long lived radionuclides in iron and light nuclei. Nuclear Physics 51, 363-368.

[Horvath94] Horvath, A., et al., 1994. Fragment isotope spectra from the ^{36}Ar + Ag reactions at 35 MeV/nucleon. Physical Review C 49, 1012-1015.

[Horwitz60] Horowitz, N., Murray, J.J., 1960. $C^{12}(p, pn)C^{11}$ cross section from 3 to 6 BeV. Physical Review 117, 1361-1363.

[Hsi99] Hsi, W., et al., 1999. Exclusive studies of angular distributions in GeV hadron-induced reactions with ^{197}Au. Physical Review C 60, 034609.

[Hudis68] Hudis, J., Tanaka, S., 1968. Production of ^{7}Be,^{22} Na and ^{24}Na fragments from heavy elements at 3, 10 and 30 GeV. Physical Review 171, 1297-1300.

[Hudis68a] Hudis, J., 1968. Production of neon-24 and sodium-24 in the 1 - 3 GeV proton bombardment of copper, silver, gold and uranium targets. Physical Review 171, 1301-1304.

[Hudis70] Hudis, J., Kirsten, T., Stoenner, R.W., Schaeffer, O.A., 1970. Yields of stable and radioactive rare gas isotopes formed by 3 and 29 GeV proton bombardment of Cu, Ag, Au and U. Physical Review 1, 2019-2030.

[Husain73] Husain, L., Katcoff, S., 1973. Interaction of 3 and 29 GeV protons with vanadium. Physical Review C 7, 2452-2461.

[Hyde71] Hyde, E.K., Butler, G.W., Poskanzer, A.M., 1971. Characteristics of fragments produced in the interaction of 5.5 GeV protons with silver. Physical Review C 4, 1759-1778.

[Iancu05] Iancu, G., Flesch, F., Heinrich, W., 2005. Nuclear fragmentation cross-sections of 400 A MeV ^{36}Ar and ^{40}Ar in collisions with light and heavy target nuclei. Radiation Measurements 39, 525-533.

[Ieiri89] Ieiri, M., et al., 1989. Polarization transfer measurements for the $(\vec{d}, \vec{p}X)$ reaction at E_d = 65 MeV and the reaction mechanism for the protons in the continuum. Nuclear Physics A 504, 477-510.

[Inamura79] Inamura, T., Kojima, T., Nomura, T., Sugitate, T., Utsunomiya, H., 1979. Multiplicity of γ rays following fast α particle emission in the 95 MeV ^{14}N $+^{195}$ Tb reaction. Physics Letters B 84, 71-74.

[Iwamoto10] Iwamoto, H., Imamura, M., Koba, Y., Fukui, Y., Wakabayashi, G., Uozumi, Y., Kin, T., Iwamoto, Y., Hohara, S., Nakano, M., 2010. Proton production double differential cross sections for 300 MeV and 392 MeV proton induced reactions. Physical Review C 82, 034604.

[Jacak83] Jacak, B.V., Westfall, G.D., Gelbke, C.K., Harwood, L.H., Lynch, W.G., Scott, D.K., Stoker, H., Tsang, M.B., 1983. Measurement of complex fragments and clues to entropy production from $42-137$ MeV/nucleon Ar + Au. Physical Review Letters 51, 1846-1849.

[Jaderstrom08] Jaderstrom, H., et al., 2008. 200 and 300 MeV/nucleon nuclear reactions responsible for single-event effects in microelectronics. Physical Review C 77, 044601.

[Jaros78] Jaros, J., et al., 1978. Nucleus-nucleus total cross sections for light nuclei at 1.55 and 2.89 GeV/c per nucleon. Physical Review C 18, 2273-2292.

[Jilany04] Jilany, M.A., 2004. Nuclear fragmentation in interactions of 3.7 A GeV 24Mg projectiles with emulsion targets. Physical Review C 70, 014901.

[Junghans98] Junghans, A.R., de Jong, M., Clerc, H.G., Ignatyuk, A.V., Kudyaev, G.A., Schmidt, K.H., 1998. Projectile fragment yields as a probe for the collective enhancement in the nuclear level density. Nuclear Physics A 629, 635-655.

[Kadkin98] Kadkin, E.P., Kondratyev, S.N., Konobeev, A.Y., Lunev, V.P., Saltikov, L.S., Sklyarenko, V.D., Slyusarenko, L.I., Tokarevsky, V.V., Yurkuts, N.P., 1998. Distinctions between the cross sections for ^{3}He interaction with ^{58}Ni and ^{64}Ni nuclei. Physics of Atomic Nuclei 61, 1459-1471.

[Karnaukhov03] Karnaukhov, V.A., et al., 2003. Critical temperature for the nuclear liquid-gas phase transition. Physical Review C 67, 011601.

[Katcoff59] Katcoff, S., 1995. Energy distributions of Li^{8} fragments emitted from C, Al, Cu, Ag, Au and U bombarded by 2.2 BeV protons. Physical Review 114, 905-911.

[Katcoff68] Katcoff, S., Fickel, H.R., Wyttenbach, A., 1968. Distribution of radionuclides from the interaction of 3 and 29 GeV protons with silver. Physical Review 166, 1147-1155.

[Kaufman80] Kaufman, S.B., Steinberg, E.P., 1980. Cross section measurements of nuclides formed by the reaction of 0.20 - 6.0 GeV protons with ^{197}Au. Physical Review 22, 167-178.

[Kavaloski63] Kavaloski, C.D., Bassani, G., Hintz, N.M., 1963. (p,d) nuclear structure studies on nuclei between A=12 and A=48. Physical Review 132, 813-822.

[Kiang89] Kiang, G.C., et al., 1989. Spectroscopy of ^{24}Al through the $^{24}\mathrm{Mg(p,n)}^{24}$Al reaction at $\mathrm{E_p} = 35$ MeV. Nuclear Physics A 499, 339-352.

[Kidd88] Kidd, J.M., Lindstrom, P.J., Crawford, H.J., Woods, G., 1988. Fragmentation of carbon ions at 250 MeV/nucleon. Physical Review C 37, 2613-2623.

[Kim94] Kim, Y.K., Kim, J.C., Moon, C.B., Cho, S.Y., Chung, Y.H., Ohkubo, Y., 1994. Heavy ion reactions of Cu with 135 MeV/nucleon ^{12}C. Nuclear Physics A 578, 621-639.

[Kim02] Kim, K.J., Sisterson, J.M., Englert, P.A.J., Caffee, M.W., Reedy, R.C., Vincent, J., Castaneda, C., 2002. Experimental cross-sections for the production of ^{10}Be from natural carbon targets with 40.6 to 500 MeV protons. Nuclear Instruments and Methods in Physics Research B 196, 239-244.

[Kin05] Kin, T., et al., 2005. Proton production cross sections for reactions by 300 and 392 MeV protons on carbon, aluminum, and niobium. Physical Review C 72, 014606.

[Knott96] Knott, C.N., et al., 1996. Interactions of relativistic neon to nickel projectiles in hydrogen, elemental production cross sections. Physical Review C 53, 347-357.

[Knott97] Knott, C.N., et al., 1997. Interactions of relativistic ^{36}Ar and ^{40}Ar nuclei in hydrogen: Isotopic production cross sections. Physical Review C 56, 398-406.

[Kobayashi88] Kobayashi, T., Yamakawa, O., Omata, K., Sugimoto, K., Shimoda, T., Takahashi, N., Tanihata, I., 1988. Projectile fragmentation of the extremely neutron rich nucleus ^{11}Li at 0.79 GeV/nucleon. Physical Review Letters 60, 2599-2602.

[Korejwo00] Korejwo, A., Dzikowski, T., Giller, M., Wdowczyk, J., Perelygin, V.V., Zarubin, A.V., 2000. The measurement of isotopic cross sections of ^{12}C beam fragmentation on liquid hydrogen measured at 3.66 GeV/nucleon. Journal of Physics G 26, 1171-1186.

[Korejwo02] Korejwo, A., Giller, M., Dzikowski, T., Perelygin, V.V., Zarubin, A.V., 2002. Isotopic cross sections of ^{12}C fragmentation on hydrogen measured at 1.87 and 2.69 GeV/nucleon. Journal of Physics G 28, 1199-1208.

[Korteling70] Kortelung, R.G., Caretto, A.A., 1970. Energy dependence of ^{22}Na and ^{24}Na production cross sections with 100 to 400 MeV protons. Physical Review C 1, 1960-1971.

[Korteling70a] Kortelung, R.R., Caretto, A.A., 1970. Production of 18F, 22Na and 24Na from separated isotopes of the light elements with 300 and 400 MeV protons. Physical Review C 1, 193-201.

[Kox87] Kox, S., et al., 1987. Trends of total reaction cross sections for heavy ion collisions in the intermediate energy range. Physical Review C 35, 1678-1691.

[Kreutz93] Kreutz, P., et al., 1993. Charge correlations as a probe of nuclear disassembly. Nuclear Physics A 556, 672-696.

[Kundu08] Kundu, S., Dey, A., Banerjee, K., Rana, T.K., Muhkopadhayay, Gupta, D., Saha, R., Bhattacharya, S., Bhattacharya, C., 2008. Fragment emission studies of the ^{16}O + ^{12}C reaction. Physical Review C 78, 044601.

[Kwiatkowski86] Kwiatkowski, K., Bashkin, J., Karwowski, H., Fatyga, M., Viola, V.E., 1986. Intermediate mass fragment production in the reaction of 200 MeV ^{3}He with Ag. Physics Letters B 171, 41-45.

[Lafleur66] Lafleur, M.S., Porile, N.T., Yaffe, L., 1966. Formation of ^{7}Be in nuclear reactions induced by 85 MeV protons. Canadian Journal of Chemistry 44, 2759-2767.

[La Tessa07] La Tessa, C., Sihver, L., Zeitlin, C., Miller, J., Guetersloh, S., Heilbronn, L., Mancusi, D., Iwata, Y., Murakami, T., 2007a. Test of weak and strong factorization in nucleus-nucleus collisions at several hundred MeV/nucleon. Nuclear Physics A 791, 434-450.

[Lee Aamodt52] Lee Aamodt, R., peterson, V., Phillips, R., 1952. 12C$(\mathrm{p, pn})^{11}$C cross section from threshold to 340 MeV. Physical Review 88, 739-744.

[Leistenschneider02] Leistenschneider, A., et al., 2002. Fragmentation of unstable neutron-rich oxygen beams. Physical Review C 65, 064607.

[Lemaire79] Lemaire, M.C., Nagamiya, S., Schnetzer, S., Steiner, H., Tanihata, I., 1979. Composite particle emission in relativistic heavy ion collisions. Physics Letters B 85, 38-42.

[Lestringuez71] Lestringuez, J., Raisbeck, G.M., Yiou, F., Bernas, R., 1971. Cross sections for the production of berylium isotopes from the 880 MeV alpha particle bombardment of carbon. Physics Letters B 36, 331-333.

[Letourneau02] Letourneau, A., et al., 2002. Composite-particle emission in the reaction p + Au at 2.5 GeV. Nuclear Physics A 712, 133-166.

[Lewandowski80] Lewandowski, Z., Loeffler, E., Wagner, R., Mueller, H.H., Reichart, W., Schober, P., Gadioli, E., Gadioli Erba, E., 1980. Proton induced α and τ emission at 72 MeV. Lettere al Nuovo Cimento 28, 15-20.

[Leya98] Leya, I., Busemann, H., Baur, H., Wieler, R., Gloris, M., Neumann, S., Michel, R., Sudbrock, F., Herpers, U., 1998. Cross sections for the proton-induced production of He and Ne isotopes from magnesium, aluminum, and silicon. Nuclear Instruments and Methods in Physics Research B 145, 449-458.

[Leya05] Leya, I., Wieler, R., David, J.C., Leray, S., Donadille, L., Cignon, J., Michel, R., 2005. Production of noble gas isotopes by proton-induced reactions on lead. Nuclear Instruments and Methods in Physics Research B 229, 1-23.

[Liang97] Liang, J.F., Bierman, J.D., Kelly, M.P., Sonzogni, A.A., Vandenbosch, R., van Schagen, J.P.S., 1997. Dissipative effects in the formation of the ^{156}Er compound nucleus. Physical Review C 56, 908-917.

[Lindner56] Lindner, M., Osborne, R.N., 1956. Nonfission inelastic events in uranium and thorium induced by high energy protons. Physical Review 103, 378-385.

[Lindsay62] Lindsay, R.H., Neuzil, E.F., 1962. (p,^{7}Be) reaction in Al and Mg from 27 to 31.5 MeV. Physical Review 127, 1269-1273.

[Lindstrom75] Lindstrom, P.J., Greiner, D.E., Heckman, H.H., Cork, B., Bieser, F.S. 1975. Isotope production cross sections from the fragmentation of ^{16}O and ^{12}C at relativistic energies. Lawrence Berkeley Laboratory Report LBL-3650.

[Logan80] Logan, D., Delagrange, H., Rivet, M.F., Rajagopalan, M., Alexander, J.M., Kaplan, M., Duek, E., 1980. Light charged particle emission in ^{40}Ar induced reactions: A probe of the very early evolution of the collisions. Physical Review C 22, 1080-1096.

[Logan80a] Logan, D., Rajagopalan, M., Zisman, M.S., Alexander, J.M., Kaplan, M., Kowalski, L., 1980. Rapid energy equilibration and emission of H and He in the reaction of ^{40}Ar with ^{197}Au. Physical Review C 22, 104-121.

[Loveland77] Loveland, W., Otto, R.J., Morrissey, D.J., Seaborg, G.T., 1977a. Large collision residues and nuclear fission in the interaction of 25.2 GeV ^{12}C with Uranium. Physical Review Letters 39, 320-322.

[Loveland77a] Loveland, W., Otto, R.J., Morrissey, D.J., Seaborg, G.T., 1977b. Further studies of large collision residues in relativistic heavy-ion reactions with heavy nuclei. Physics Letters B 69, 284-286.

[Lukyanov09] Lukyanov, S., et al., 2009. Projectile fragmentation of radioactive beams of ^{68}Ni, ^{69}Cu, and ^{72}Zn. Physical Review C 80, 014609.

[Machner84] Machner, H., Protic, D., Riepe, G., Didelez, J.P., Frascaria, N., Gerlic, E., Hourani, E., Morlet, M., 1984. Quasi-free scattering and exciton model analysis at 200 MeV. Physics Letters B 138, 39-42.

[Marcinkowski98] Marcinkowski, A., Mariafiski, B., Moroz, Z., Wojtkowska, J., Demetriou, P., 1998. Nucleon scattering to the continuum in terms of the two fermion theory of multistep direct reactions. Nuclear Physics A 633, 446-458.

[Marquez51] Marquez, L., Perlman, I., 1951. Observations on lithium and beryllium nuclei ejected from heavy nuclei by high energy particles. Physical Review 81, 953-957.

[Marquez52] Marquez, L., 1952. The yield of F^{18} from medium and heavy elements with 420 MeV protons. Physical Review 86, 405-407.

[Matsuoka83] Matsuoka, N., Hatanaka, K., Sakai, H., Saito, T., Hosono, K., Itahashi, T., Shimizu, A., Kondo, M., 1983. Tensor analysing powers of the proton continuum spectra from deuteron breakup at 56 MeV. Nuclear Physics A 408, 99-108.

[McGill84] McGill, J.A., Hoffmann, G.W., Barlett, M.L., Fergerson, R.W., Milner, E.C., Chrien, R.E., Sutter, R.J., Kozlowski, T., Stearns, R.L., 1984. Proton + nucleus inclusive (p, p') scattering at 800 MeV. Physical Review C 29, 204-208.

[Meadows51] Meadows, J.W., Holt, R.B., 1951. Some excitation functions for protons on magnesium. Physical Review 83, 1257.

[Merchel00] Merchel, S., Faestermann, T., Herpers, U., Knie, K., Korschinek, G., Leya, I., Michel, R., Rugel, G., Wallner, C., 2000. Thin and thick target cross sections for the production of 53Mn and 60Fe. Nuclear Instruments and Methods in Physics Research B 172, 806-811.

[Meyer72] Meyer, J.P., 1972. Deuterons and He^3 formation and destruction in proton induced spallation of light nuclei ($Z \leq 8$). Astronomy and Astrophysics Supplement 7, 417-467.

[Meyer80] Meyer, W.G., Gutbrod, H.H., 1980. Correlations between slow and fast fragments in relativistic nuclear collisions. Physical Review C 22, 179-191.

[Michel79] Michel, R., Brinkmann, G., Weigel, H., Herr, W., 1979. Measurement and hybrid model analysis of proton induced reactions with V, Fe and Co. Nuclear Physics A 322, 40-60.

[Michel85] Michel, R., Peiffer, F., Stuck, R., 1985. Measurement and hybrid model analysis of integral excitation fucntions for proton induced reactions on vanadium, manganese and cobalt up to 200 MeV. Nuclear Physics A 441, 617-639.

[Michel95] Michel, R., et al., Nuclide production by proton-induced reactions on elements ($6 \leq Z \leq 29$) in the energy range from 800 to 2600 MeV. Nuclear Instruments and Methods in Physics Research B 103, 183-222.

[Michel96] Michel, R., Leya, I., Borges, L., 1996. Production of cosmogenic nuclides in meteoroids: accelerator experiments and model calculations to decipher the cosmic ray record in extraterrestrial matter. Nuclear Instruments and Methods in Physics Research B 113, 434-444.

[Michel97] Michel, R., et al., 1997. Cross sections for the production of residual nuclides by low and medium-energy protons from the target elements C, N, 0, Mg, Al, Si, Ca, Ti, V, Mn, Fe, Co, Ni, Cu, Sr, Y, Zr, Nb, Ba and Au. Nuclear Instruments and Methods in Physics Research B 129, 153-193.

[Mills92] Mills, S.J., Steyn, G.F., Nortier, F.M., 1992. Experimental and theoretical excitation functions of radionuclides produced in proton bombardment of Copper up to 200 MeV. Appl. Radiat. Isot. nnn 43, 1019-1030.

[Miura87] Miura, K., et al., 1987. The $^{31}P(d,n)^{32}S$ reaction at 25 MeV. Nuclear Physics A 467, 79-92.

[Mocko06] Mocko, M., et al., 2006. Projectile fragmentation of ^{40}Ca, ^{48}Ca, ^{58}Ni, and ^{64}Ni at 140 MeV/nucleon. Physical Review C 74, 054612.

[Mocko07] Mocko, M., et al., 2007. Projectile fragmentation of ^{86}Kr at 64 MeV/nucleon. Physical Review C 76, 014609.

[Momota02] Momota, S., et al., 2002. Production of projectile-like fragments at intermediate energies. Nuclear Physics A 701, 150c-155c.

[Morita82] Morita, Y., Loveland, W., McGaughey, P.L., Seaborg, G.T., 1982. Target fragment angular distributions from the interaction of 3.0 GeV and 12.0 GeV ^{12}C with ^{197}Au and ^{238}U. Physical Review C 26, 511-518.

[Motobayashi84] Motobayashi, T., Ejiri, H., Shibata, T., Okada, K., Sasao, M., Maeda, K., Suzuku, H., 1984. Breakup processes for 100 MeV ^{3}He interacting with ^{165}Ho and ^{166,167}Er nuclei. Nuclear Physics A 413, 290-310.

[Mougey81] Mougey, J., et al., 1981. Projectile fragments from 86 MeV/nucleon ^{12}C induced reactions. Physics Letters B 105, 25-29.

[Murakami03] Murakami, T., et al., 2003. Multifragmentation induced by light heavy-ions with GeV energy. Proceedings of the 10th International Conference on Nuclear Reaction Mechanisms, Edited by Ettore Gadioli, Varenna, Villa Monastero, Italy, 9-13 June 2003, pp. 541-548.

[Murphy83] Murphy, M.J., Stokstad, R.G., 1983. Momentum widths of heavy-ion reaction products at 27.4 MeV/nucleon. Physical Review C 28, 428-431.

[Mustapha99] Mustapha, B., et al., 1999. Study of spallation residues by the reverse kinematics method in the reaction Au + p at 800 A MeV. XXXVII Bormio conference, Italy, January 1999.

[Nagamiya79] Nagamiya, S., Anderson, L., Brckner, W., Chamberlain, O., Lemaire, M.C., Schnetzer, S., Shapiro, G., Steiner, H., Tanihata, I., 1979. Wide-angle high-energy proton spectra by 800 MeV/A C, Ne, and Ar beams. Physics Letters B 81, 147-150.

[Nagamiya80] Nagamiya, S., Lemaire, M.C., Schnetzer, S., Steiner, H., Tanihata, I., 1980. Single-particle spectra associated with high-multiplicity events in 800-MeV/nucleon Ar on KCl and Pb. Physical Review Letters 45, 602-605.

[Nagamiya81] Nagamiya, S., Lemaire, M.C., Moeller, E., Schnetzer, S., Shapiro, G., Steiner, H., Tanihata, I., 1981. Production of pions and light fragments at large angles in high energy nuclear collisions. Physical Review C 24, 971-1009.

[Nakamura07] Nakamura, T., Heilbronn, L., 2007. Handbook on secondary particle production and transport by high energy heavy ions. World Scientific, Singapore.

[Nakayama07] Nakayama, S., et al., 2007. Analog of the giant dipole resonance in ^{4}He. Physical Review C 76, 021305.

[Napolitani04] P. Napolitani, P., Schmidt, K.H., Botvina, A.S., Rejmund, F., Tassan-Got, L., Villagrasa, C., High resolution velocity measurements on fully identified light nuclides produced in 56Fe + hydrogen and 56Fe + titanium systems. 2004. Physical Review C 70, 054607.

[Napolitani07] Napolitani, P., et al., 2007. Measurement of the complete nuclide production and kinetic energies of the system ^{136}Xe + hydrogen at 1 GeV per nucleon. Physical Review C 76, 064609.

[Natowitz81] Natowitz, J.B., Namboodiri, M.N., Adler, L., Schmitt, R.P., Watson, R.L., Simon, S., Berlanger, M., Choudhury, R., 1981. Particle emission at a ^{20}Ne projectile velocity comparable to the Fermi velocity. Physical Review Letters 47, 1114-1117.

[Newton62] Newton, D., Clegg, A.B., Salmon, G.L., Fisher, P.S., Foley, K.J., 1962. The $^{7}\mathrm{Li}(\mathrm{p},\mathrm{p}')$ reaction at 150 MeV. Proceedings of the Physical Society 79, 27-33.

[Nicholls72] Nicholls, J.E., Craig, A., Griffith, T.C., Imrie, D.C., Lush, C.J., Metheringham, A.J., 1972. Inelastic p $-^{4}$ He scattering at 141 MeV. Nuclear Physics A 181, 329-336.

[Nilsen95] Nilsen, B.S., Waddington, C.J., Cummings, J.R., Garrard, T.L., Klarmann, J., 1995. Fragmentation cross sections of relativistic $^{84}_{36}$Kr and $^{109}_{47}$Ag nuclei in targets from hydrogen to lead. Physical Review C 52, 3277-3290.

[Nomura78] nnn

[Notani07] Notani, M., et al., 2007. Projectile fragmentation reactions and production of nuclei near the neutron drip line. Physical Review C 76, 044605.

[Ogilvie91] Ogilvie, C.A., et al., 1991. Rise and fall of multifragment emission. Physical Review Letters 67, 1214-1217.

[Ohnuma86] Ohnuma, H., et al., 1986. A comparative study of the $^{13}\mathrm{C}(\mathrm{p},\mathrm{p}')^{13}\mathrm{C}$ and $^{13}\mathrm{C}(\mathrm{p},\mathrm{n})^{13}\mathrm{N}$ reactions at $\mathrm{E_p}$ = 35 MeV. Nuclear Physics A 456, 61-74.

[Ohnuma87] Ohnuma, H., et al., 1987. $^{12}\mathrm{C}(\mathrm{p},\mathrm{n})^{12}\mathrm{N}$ and $^{16}\mathrm{O}(\mathrm{p},\mathrm{n})^{16}\mathrm{F}$ reactions at $\mathrm{E_p}$ = 35 and 40 MeV: reliability of the information obtained from DWBA analysis of low energy (p,n) data. Nuclear Physics A 467, 61-78.

[Okihana97] Okihana, A., Ushiro, K., Yoshimura, T., Kakigi, S., Sekioka, T., 1997. Quasifree processes in the ^{6}Li breakup reactions by alpha particles. Nuclear Physics A 614, 71-85.

[Okumusoglu74] Okumusoglu, N.T., Blyth, C.O., Dunscombe, P.B., Berovic, N., McKee, J.S.C., 1974. Nucleon exchange and quasi-free scattering in the reaction $^{1}\mathrm{H}(\mathrm{d},\mathrm{pn})\mathrm{p}$ at 12.2 MeV. Nuclear Physics A 231, 391-396.

[Olson81] Olson, D.L., Berman, B.L., Greiner, D.E., Heckman, H.H., Lindstrom, P.J., Westfall, G.D., Crawford, H.J., 1981. Electromagnetic dissociation of relativistic ^{18}O nuclei. Physical Review C 24, 1529-1539.

[Olson83] Olson, D.L., Berman, B.L., Greiner, D.E., Heckman, H.H., Lindstrom, P.J., Crawford, H.J., 1983. Factorization of fragment production cross sections in relativistic heavy ion collisions. Physical Review C 28, 1602-1613.

[Ozawa00] Ozawa, A., et al., 2000. Production cross-sections of light neutron-rich nuclei from ^{40}Ar fragmentation at about 1 GeV/nucleon. Nuclear Physics A 673, 411-422.

[Pakou03] Pakou, A., et al., 2003. α particle production in the reaction $^{6}\mathrm{Li} +^{28}\mathrm{Si}$ at near barrier energies. Physical Review Letters 90, 202701.

[Pakou05] Pakou, A., et al., 2005. α particle production: Direct and compound contribution in the reaction $^{7}\mathrm{Li} +^{28}\mathrm{Si}$ at near-barrier energies. Physical Review C 71, 064602.

[Parikh60] Parikh, V., 1960. Absolute cross section of $^{12}\mathrm{C(p, pn)}^{11}\mathrm{C}$ from 288 to 383 MeV. Nuclear Physics 18, 628-637.

[Parikh60a] Parikh, V., 1960. Cross sections for $\mathrm{Al}^{27}\mathrm{(p, 3pn)Na}^{24}$, $^{27}\mathrm{Al(p, 5p5n)F}^{18}$ and $\mathrm{C}^{12}\mathrm{(p, 3p3n)Be}^{7}$ relative to $\mathrm{C}^{12}\mathrm{(p, pn)C}^{11}$. Nuclear Physics 18, 638-645.

[Pate61] Pate, B.D., Poskanzer, A.M., 1961. Spallation of uranium and thorium nuclei with BeV energy protons. Physical Review 123, 647-654.

[Perdrisat69] Perdrisat, C.F., Swenson, L.W., Gugelot, P.C., Boschitz, E.T., Roberts, W.K., Vincent, J.S., Priest, J.R., 1969. (p,2p) reactions at 600 MeV on Deuterium and Helium-4. Physical Review 187, 1201-1209.

[Pereira07] Pereira, J., 2007. Isotopic production cross sections and recoil velocities of spallation-fission fragments in the reaction ^{238}U (1 A GeV) + d. Physical Review C 75, 014602.

[Perron76] Perron, C., 1976. Cross sections for production of stable and long-lived nuclides by high energy spallation of iron: cosmic ray implications. Physical Review C 14, 1108-1120.

[Pfaff95] Pfaff, R., et al., 1995. Projectilelike fragment momentum distributions from ^{86}Kr + Al at 70 MeV/nucleon. Physical Review C 51, 1348-1355.

[Pfaff96] Pfaff, R., Morrissey, D.J., Benenson, W., Fauerbach, M., Hellstrom, M., Powell, C.F., Sherrill, B.M., Steiner, M., Winger, J.A., 1996. Fragmentation of ^{78}Kr projectiles. Physical Review C 53, 1753-1758.

[Pfeiffer73] Pfeiffer, K.O., Speth, E., Bethge, K., 1973. Break up of ^{6}Li and ^{7}Li on Tin and Nickel nuclei. Nuclear Physics A 206, 545-557.

[Pfutzner95] Pfutzner, M. et al., 1995. One- and two-neutron removal from the radioactive secondary projectiles ^{56}Ni and ^{52}Fe. Nuclear Physics A 587, 229-240.

[Poppe63] Poppe, C.H., Holbrow, C.H., Borchers, R.R., 1963. Neutrons from D + T and D + H, Physical Review 129, 733-739.

[Porile64] Porile, N.T., Tanaka, S., 1964. Formation of sodium and potassium nuclides in the bombardment of light elements with 29 GeV protons. Physical Review 135, B122-B128.

[Porile89] Porile, N.T., 1989. Approach to criticality in the fragmentation of xenon by $1-19$ GeV protons. Physical Review C 39, 1914-1928.

[Poskanzer71] Poskanzer, A.M., Butler, G.W., Hyde, E.K., 1971. Fragment production in the interaction of 5.5 GeV protons with uranium. Physical Review C 3, 882-904.

[Poskanzer75] Poskanzer, A.M., Sextro, R.G., Zebelman, A.M., Gutbrod, H.H., Sandoval, A., Stock, R., 1975. Search for fragment emission from nuclear shock waves. Physical Review Letters 35, 1701-1704.

[Price91] Price, P.B., He, Y.D., 1991. Behavior of nuclear projectile fragments produced in collisions of 14.5 A GeV ^{28}Si with Pb and Cu targets. Physical Review C 43, 835-848.

[Prout02] Prout, D.L., et al., 2002. Polarization transfer in quasifree ? $(\vec{\mathrm{p}},\vec{\mathrm{n}})$ reactions on ^{2}H and ^{3,4}He targets at 197 MeV. Physical Review C 65, 034611.

[Pugh73] Pugh, H.G., Roos, P.G., Cowley, A.A., Cheng, V.K., Woody, R., 1973. The (p,2p) reaction on ^{2}H,^{3}He and ^{4}He. Physics Letters B 46, 192-194.

[Radin74] Radin, J.R., Smith, A.R., Little, N., 1974. Alpha spallation cross sections at 920 MeV (230 MeV/N) in ^{27}Al, ^{16}O, ^{12}C and ^{9}Be and application to cosmic ray transport. Physical Review C 9, 1718-1729.

[Raisbeck72] Raisbeck, G.M., Lestringuez, J., F. Yiou, 1972. Cross sections for ^{6}Li and ^{7}Li production from the bombardment of ^{12}C by 150 and 600 MeV protons and 880 MeV alpha particles. Physical Review C 6, 685-690.

[Raisbeck74] Raisbeck, G.M., Yiou, F., 1974. Cross sections for the spallation production of ^{10}Be in targets of N, Mg and Si and their astrophysical applications. Physical Review C 9, 1385-1395.

[Raisbeck75] Raisbeck, G.M., Yiou, F., 1975. Production cross sections of Be isotopes in C and O targets bombarded by 2.8 GeV α particles: Implications for factorization. Physical Review Letters 35, 155-159.

[Raisbeck75a] Raisbeck, G.M., Yiou, F., Production cross sections for ^{7}Be and ^{22}Na in targets of Si, Mg, Fe and Ni irradiated by 1, 2, 3 and 23 GeV protons. Physical Review C 12, 915-920.

[Ramaty69] Ramaty, R., Lingenfelter, R.E., 1969. Cosmic ray deuterium and helium-3 of secondary origin and the residual modulation of cosmic rays. Astrophysical Journal 155, 587-608.

[Rayudu63] Rayudu, G.V., 1963. Formation cross sections of various radionuclides from Ni, Fe, Si, Mg, O and C for protons of energies between 130 and 400 MeV. Canadian Journal of Chemistry 42, 1149-1154.

[Reeder65] Reeder, P.L., 1965. Cross sections for production of ^{7}Be from light targets by 2.2 GeV protons. Journal of Inorganic and Nuclear Chemistry 27, 1879-1880.

[Reedy87] Reedy, R.C., 1987. Predicting the production rates of cosmogenic nuclides in extraterrestrial matter. Nuclear Instruments and Methods in Physics Research B 29, 251-261.

[Reedy07] Reedy, R.C., 2007 Proton cross sections for producing cosmogenic radionuclides. 38th Lunar and Planetary Science Conference, (Lunar and Planetary Science XXXVIII), March 12-16, 2007, League City, Texas. LPI Contribution No. 1338, p.1192.

[Regnier79] Regnier, S., 1979. Production of argon isotopes by spallation of Sc, Ti, Fe, Co, Ni, and Cu. Physical Review C 20, 1517-1527.

[Reinhold98] Reinhold, J., Friese, J., Korner, H.J., Schneider, R., Zeitelhack, K., Geissel, H., Magel, A., Munzenberg, G., Summerer, K., 1998. Projectile fragmentation of ^{129}Xe at Elab=790A MeV. Physical Review C 58, 247-255.

[Reisdorf10] Reisdorf, W., et al., 2010. Systematics of central heavy ion collisions in the 1A GeV regime. Nuclear Physics A 848, 366-427.

[Rejmund01] Rejmund, F., et al., 2001. Measurement of isotopic cross sections of spallation residues in 800 A MeV ^{197}Au + p collisions. Nuclear Physics A 683, 540-565.

[Remington86] Remington, B.A., et al., 1986. Neutron fragment coincidence measurements in ^{14}N + Ho and ^{14}N + Ni reactions at 35 MeV/nucleon. Physical Review C 34, 1685-1705.

[Remsberg63] Remsberg, L.P. Miller, J.M., 1963. Study of (p,pn) reactions in medium weight nuclei at 370 MeV. Physical Review 130, 2069-2076.

[Remsberg75] Remsberg, L.P., Perry, D.G., 1975. Appearance of novel sideways peaking in light fragment angular distributions from 26 GeV proton irradiation of U and Au. Physical Review Letters 35, 361-363.

[Renberg71] Renberg, P.U., Measday, D.F., Pepin, M., Schwaller, P., Favier, B., Richard-Serre, C., 1971. Reaction cross sections for protons in the energy range $220 - 570$ MeV. Nuclear Physics A 183, 81-104.

[Ricciardi06] Ricciardi, M.V., et al., 2006. Light nuclides produced in the proton induced spallation of ^{238}U at 1 GeV. Physical Review C 73, 014607.

[Richter92] Richter, W.A., Cowley, A.A., Lindsay, R., Lawrie, J.J., Fortsch, S.V., Pilcher, J.V., Bonetti, R., Hodgson, P.E., 1992. hhh Statistical multistep direct calculations for $(\mathrm{p}, \mathrm{p}')$ continuum spectra up to 200 MeV. Physical Review C 46, 1030-1044.

[Ridikas00] Ridikas, D., Mittig, W., Savajols, H., Roussel-Chomaz, P., Fortsch, S.V., Lawrie, J.J., Steyn, G.F., 2000. Inclusive proton production cross sections in (?d,xp)? reactions induced by 100 MeV deuterons. Physical Review C 63, 014610.

[Roeder06] Roeder, B.T., et al., 2006. Production cross sections for heavy-ion fragmentation reactions on a liquid deuterium target at intermediate energies. Physical Review C 74, 034602.

[Rosenfeld56] Rosenfeld, A.H., Swanson, R.A., Warshaw, S.D., 1956. Cross section fo $C^{12}(\mathrm{p}, \mathrm{pn})C^{11}$. Physical Review 103, 413-419.

[Rowland58] Rowland, F.S., Wolfgang, R.L., 1958. Production of He^6 by high energy protons. Physical Review 110, 175-177.

[Roy81] Roy, G., et al., 1981. Inclusive scattering of protons on helium, nickel and tantalum at 500 MeV. Physical Review C 23, 1671-1678.

[Rudy75] Rudy, C.R., Porile, N.T., 1975. Nuclear reactions of silver with 25.2 GeV ^{12}C. Physics Letters B 59, 240-243.

[Samanta92] Samanta, C., Ghosh, S., Lahiri, M., Ray, S., Banerjee, S.R., 1992. Alpha-particle scattering from ^6Li near the α-d breakup threshold. Physical Review C 45, 1757-1766.

[Sampsonidis95] Sampsonidis, D., Papanastassiou, E., Zamani, M., Debeauvais, M., Adloff, J.C., Kulakov, B.A., Krivopustov, M.I., Butsev, V.S., 1995. Fragmentation cross sections of ^{16}O, ^{24}Mg, and ^{32}S projectiles at 3.65 GeV/nucleon. Physical Review C 51, 3304-3308.

[Sandoval80] Sandoval, A., Gutbrod, H.H., Meyer, W.G., Stock, R., Lukner, C., 1980. Spectra of p, d, and t from relativistic nuclear collisions. Physical Review C 21, 1321-1343.

[Scampoli05] Scampoli, P. Durante, M., Grossi, G., Manti, L., Pugliese, M., Gialanella, G., 2005. Fragmentation studies of relativistic iron ions using plastic nuclear track detectors. Advances in Space Research 35, 230-235.

[Schaeffer59] Schaeffer, O.A., Zahringer, J. 1959. High sensitivity mass spectrometric measurement of stable helium and argon isotopes produced by high energy protons in iron. Physical Review 113, 674-678.

[Schall96] Schall, I., et al., 1996. Charge-changing nuclear reactions of relativistic light-ion beams ($5 \leq Z \leq 10$)passing through thick absorbers. Nuclear Instruments and Methods in Physics Research B 117, 221-234.

[Schiekel96] Schiekel, T., Sudbrock, F., Herpers, U., Gloris, M., Leya, I., Micehl, R., Synal, H.A., Suter, M., 1996. On the production of ^{36}Cl by high energy protons in thin targets. Nuclear Instruments and Methods in Physics Research B 113 (1996) 484-489.

[Schiekel96a] Schiekel, T., et al., 1996. Nuclide production by proton induced reactions on elements ($6 \leq Z \leq 29$) in the energy range from 200 MeV to 400 MeV. Nuclear Instruments and Methods in Physics Research B 114, 91-119.

[Schnabel04] Schnabel, C., et al., 2004. Proton induced production cross sections and production rates of ^{41}Ca from Ni. Nuclear Instruments and Methods in Physics Research B 223-224, 812-816.

[Schweizer79] Schweizer, T.C., Doering, R.R., Thornton, S.T., Dennis, L.C., Cordell, K.R., Parks, R.L., 1979. Nuclear fragment production from 720 MeV alpha induced reactions. Physical Review C 19, 1408-1415.

[Segel82] Segel, R.E., Chen, T., Rutledge, L.L., Maher, J.V., Wiggins, J., Singh, P.P., Debevec, P.T., 1982. Inclusive proton reactions at 164 MeV. Physical Review C 26, 2424-2432.

[Sengupta89] Sengupta, K., Singh, G., Jain, P.L., 1989. On the production of helium fragments in ultra-relativistic heavy ion collisions. Physics Letters B 222, 301-305.

[Shibata85] Shibata, T., Maeda, K., Okada, K., Ejiri, H., Sakai, H., Shimizu, A., 1985. The pre-equilibrium process of the $^{165}Ho(\alpha, xnyp)$ reaction at $E_\alpha = 109$ MeV studied by particle-gamma coincidence measurements. Nuclear Physics A 441, 445-460.

[Shyam99] Shyam, R., Thompson, I.J., 1999. Breakup of ^{8}B and the ^{7}Be(p, γ)^{8}B reaction. arXiv:nucl-th/9910027v1.

[Signorini03] Signorini, C., et al., 2003. Exclusive breakup of ^{6}Li by ^{208}Pb at Coulomb barrier energies. Physical Review C 67, 044607.

[Simpson83] Simpson, J.A., 1983. Elemental and isotopic composition of the Galactic cosmic rays. Annual Review of Nuclear and Particle Science 33, 323-381.

[Singh90] Singh, G., Sengupta, K., Jain, P.L., 1990. Mean free paths of multiple helium fragmentsw produced by ^{32}S at 6.4 TeV. Physical Review C 42, 1757-1759.

[Singh91] Singh, G., Ismail, A.Z., Jain, P.L., 1991. Charesctistics of helium fragments produced in ^{28}Si emulsion interactions at 14.5 A GeV. Physical Review C 43, 2417-2421.

[Singh94] Singh, B.K., Ojha, I.D., Tuli, S.K., 1994. Some general characteristics of ^{28}Si-emulsion interactions at 4.5 GeV/c per nucleon. Nuclear Physics A 570, 819-832.

[Singh96] Singh, G., Jain, P.L., Target and projectile fragmentations in ^{208}Pb-emulsion collisions at 160A GeV. Physical Review C 54, 3185-3194.

[Singh10] Singh, M.K., Pathak, R., Singh, V., 2010. Characteristics of alpha projectile fragments emission in interaction of nuclei with emulsion. arXiv:1008.2151v1.

[Singh10a] Singh, M.K., Pathak, R., Singh, V., 2010. Two source emission behavior of projectile fragments alpha in ^{84}Kr interactions at around 1 GeV per nucleon. arXiv:1008.2139v1.

[Sisterson97] Sisterson, J.M., et al., 1997. Measurement of proton production cross sections of ^{10}Be and ^{26}Al from elements found in lunar rocks. Nuclear Instruments and Methods in Physics Research B 123, 324-329.

[Siwek-Wilcznska79] Siwek-Wilcznska, K., du Marchie van Voorthuysen, E.H., van popta, J., Siemssen, R.H., Wilczynski, J., 1979. Incomplete fusion in $^{12}\mathrm{C} +^{160}$ Gd collisions interpreted in terms of a generalized concept of critical angular momentum. Physical Review Letters 42, 1599-1602.

[Skoski73] Skoski, L., Merker, M., Shen, B.S.P., 1973. Absolute cross section for producing ^{11}C from carbon by 270 MeV/nucleon ^{14}N ions. Physical Review Letters 30, 51-54.

[Sobotka83] Sobotka, L.G., Padgett, M.L., Wozniak, G.J., Guarino, G., Pacheco, A.J., Moretto, L.G., Chan, Y., Stokstad, R.G., Tserruya, I., Wald, S., 1983. Compund nucleus decay via the emission of heavy nuclei. Physical Review Letters 51, 2187-2190.

[Souliotis94] Souliotis, G.A., Harkewicz, R., McDonald, K.N., Morrissey, D.J., Chen, Y., Kashy, E., Sherrill, B.M., Orr, N.A., Winger, J.A., 1994. Differential cross sections of projectilelike fragments from ^{18}O and ^{40}Ar at E/A = 80 MeV. Physical Review C 49, 3301-3304.

[Sourkes76] Sourkes, A.M., Houdayer, A., van Oers, W.T.H., Carlson, R.F., Brown, R.E., 1976. Total reaction cross section for protons on ^{3}He and ^{4}He between 18 and 48 MeV. Physical Review C 13, 451-460.

[Souza09] Souza, F.A., et al., 2009. Reaction mechanisms in the ^{6}Li+^{59}Co system. Nuclear Physics A 821, 36-50.

[Stapleton71] Stapleton, G.B., Thomas, R.H., 1971. The production of ^{7}Be by 7 GeV proton interactions with oxygen. Nuclear Physics A 175, 124-128.

[Steckmeyer89] Steckmeyer, J.C., et al., 1989. Transfer reactions and sequential decays of the projectile - like fragments in the 60 MeV/nucleon ^{40}Ar + ^{nat}Ag, ^{197}Au reactions. Nuclear Physics A 500, 372-398.

[Stephan91] Stephan, C., et al., 1991. Peripheral collisions with 200 MeV/nucleon krypton ions. Physics Letters B 262, 6-10.

[Stevenson81] Stevenson, J.D., Price, P.B., 1981. Production of the neutron rich nuclides ^{20}C and ^{27}F by fragmentation of 213 MeV/nucleon ^{48}Ca. Physical Review C 24, 2102-2105.

[Stock80] Stock, R., et al., 1980. Emission patterns in central and peripheral relativistic heavy-ion collisions. Physical Review Letters 44, 1243-1246.

[Stolz02] Stolz, A., 2002. Projectilelike fragmentation of ^{112}Sn at E_{lab} 1 A GeV. Physical Review C 65, 064603.

[Stovall64] Stovall, T., Hintz, N.M., 1964. Inelastic proton scattering at 40 MeV. Physical Review 135, B330-B345.

[Strauch56] Strauch, K., Titus, F., 1956. Inelastic scattering of 96 MeV protons. Physical Review 104, 191-198.

[Streibel97] Streibel, T., Hirzebruch, S.E., Huntrup, G., Rocher, H., Heinrich, W., 1997. Cross sections of ^{197}Au at 10 A GeV and of ^{207}Pb at 158 A GeV. Radiation Measurements 28, 317-322.

[Sugitate82] Sugitate, T., Nomura, T., Ishihara, M., Gono, Y., Utsunomiya, H., Ieki, K., Kohmoto, S., 1982. Polarization of preequilibrium proton emission in the ^{93}Nb +^{14} N reaction. Nuclear Physics A 388, 402-420.

[Symons79] Symons, T.J., Viyogi, Y.P., Westfall, G.D., Doll, P., Greiner, D.E., Faraggi, H., Lindstrom, P.J., Scott, D.K., Crawford, H.J., McParland, C. 1979. Observation of new neutron tich isotopes by fragmentation of 205 MeV/nucleon ^{40}Ar ions. Physical Review Letters 42, 40-43.

[Taieb03] Taieb, J., et al., 2003. Evaporation residues produced in the spallation reaction ^{238}U + p at 1 A GeV. Nuclear Physics A 724, 413-430.

[Tanaka95] Tanaka, K.H., et al. 1995. Energy spectra and angular distribution of intermediate mass fragments emitted in Au/Ag(p,X) reactions with $E_p = 12$ GeV. Nuclear Physics A 583, 581-584.

[Tanihata80] Tanihata, I., Lemaire, M.C., Nagamiya, S., Schnetzer, S., 1980. Two-proton correlation measurements in 800 and 400 MeV/nucleon heavy-ion reactions. Physics Letters B 97, 363-366.

[Tanihata81] Tanihata, I., Nagamiya, S., Schnetzer, S., Steiner, H., 1981. One- and two-proton inclusive spectra in 800 MeV proton-nucleus collisions and the mean free path of protons in nuclei. Physics Letters B 100, 121-125.

[Tannenwald53] Tannenwald, P.E. 1953. Disintegration of helium by 90 MeV neutrons. Physical Review 89, 508-517.

[Titarenko98] Titarenko, Y.E., et al., 1998. Experimental and computer simulation study of the radionuclides produced in thin ^{209}Bi targets by 130 MeV and 1.5 GeV proton induced reactions. Nuclear Instruments and Methods in Physics Research A 414, 73-99.

[Titarenko02] Titarenko, Y.E., et al., 2002. Cross sections for nuclide production in 1 GeV proton irradiated 208Pb. Physical Review C, 65, 064610.

[Titarenko06] Titarenko, Y.E., et al., 2006. Excitation functions of product nuclei from 40 to 2600 MeV proton irradiated $206, 207, 208, \mathrm{natPb}$ and 209Bi. Nuclear Instruments and Methods in Physics Research A 562, 801-805.

[Titarenko08] Titarenko, Y.E., et al., 2008. Cross sections for nuclide production in a ^{56}Fe target irradiated by 300, 500, 750, 1000, 1500, and 2600 MeV protons compared with data on a hydrogen target irradiated by 300, 500, 750, 1000, and 1500 MeV/nucleon ^{56}Fe ions. Physical Review C 78, 034615.

[Tokushuku90] Tokushuku, K., 1990. Analysis of deuteron spectra from hadron-nucleus reactions at several GeV/c with the coalescence model. Physics Letters B 235, 245-249.

[Toshito07] Toshito, T., et al. 2007. Measurements of total and partial charge-changing cross sections for 200 to 400 MeV/nucleon water and polycarbonate. Physical Review C 75, 054606.

[Trockel88] Trockel, R., et al., 1988. Entropy in $^{12}C +^{197}$ Au at intermediate energies. Physical Review C 38, 576-579.

[Tull90] Tull, C.E., 1990. Relativistic heavy ion fragmentation at HISS. Lawrence Berkeley National Laboratory Report LBL 29718.

[Tyren57] Tyren, H., Maris, T.A.J., 1957. Studies of inelastic scattering of 185 MeV protons on Carbon. Nuclear Physics 3, 52-59.

[Tyren66] Tyren, H., Kullander, S., Sundberg, O., Ramachandran, R., Isacsson, P., Berggren, T., 1966. Quasi-free proton proton scattering in light nuclei at 460 MeV. Nuclear Physics 79, 321-373.

[Urbon80] Urbon, J.A., Kaufman, S.B., Henderson, D.J., Steinberg, E.P., 1980. Angular and energy distributions of ^{24}N fragments formed by the reaction of 11.5 GeV protons with ^{197}Au. Physical Review C 21, 1048-1055.

[Uozumi07] Uozumi, Y., et al., 2007. Magnitude factor systematics of Kalbach phenomenology for reactions emitting helium and lithium ions Nuclear Instruments and Methods in Physics Research A 571, 743-747.

[Utsunomiya80] Utsunomiya, H., Nomura, T., Inamura, T., Sugitate, T., Motobayashi, T., 1980. Preequilibrium α particle emission in heavy ion reactions. Nuclear Physics A 334, 127-143.

[Utsunomiya81] Utsunomiya, H., Nomura, T., Inamura, T., Sugitate, T., Ieki, K., Kohmoto, S., 1981. Angular momentum transfer and alignment following preequilibrium α particle emission in the reaction $^{209}Bi +^{14}$ N. Physics Letters B 105, 135-139

[Valentin65] Valentin, L., 1965. Réactions (p,n) et (p,pn) induites à moyenne énergie sur des noyaux légers. Nuclear Physics A 62, 81-102.

[Van Bibber79] Van Bibber, K., et al., 1979. Evidence for orbital dispersion in the fragmentation of ^{16}O at 90 and 120 MeV/nucleon. Physical Review Letters 43, 840-844.

[Vaz83] Vaz, L.C., Logan, D., Alexander, J.M., Duek, E., Guerreau, D., Kowalski, L., Rivet, M.F., Zisman, M.S., 1983. Products of $3 \leq Z \leq 9$ from long lived intermediates in the reactions 336 MeV ^{40}Ar + Ag, ^{154}Sm and Au. Zeitschrift für Physik 311, 89-98.

[Villagrasa07] Villagrasa-Canton, C., et al., 2007. Spallation residues in the reaction ^{56}Fe + p at 0.3A, 0.5A, 0.75A, 1.0A and 1.5A GeV. Physical Review C 75, 044603.

[Viyogi79] Viyogi, Y.P., et al., 1979. Fragmentations of ^{40}Ar at 213 MeV/nucleon. Physical Review Letters 42, 33-36.

[Volnin75] Volvin, E.N., Amalsky, G.M., Seleverstov, D.M., Smirnov, N.N., Vorobyov, A.A., Yakovlev, Y.P., 1075. Fragmentation of nuclei of various nucleon composition in the interaction with 1 GeV protons. Physics Letters B 55, 409-410.

[Waddington93] Waddington, C.J., 1993. Some preliminary results from the new 10.6 GeV/nucleon gold beam at Brookhaven. International Journal of Modern Physics E 2, 739-766.

[Waddington00] Waddington, C.J., Cummings, J.R., Nilsen, B.S., Garrard, T.L., 2000. Fragmentation of relativistic gold by various target nuclei. Physical Review C 61, 024910.

[Warner80] Warner, R.E., Conner, W.T., Ball, G.C., Davies, W.G., Ferguson, A.J., 1980. Mechanism of the ^{6}Li(^{6}Li, $2\alpha)\alpha$ reaction from 36 to 46 MeV. Nuclear Physics A 341, 483-493.

[Warner83] Warner, R.E., Blum, K., Friesel, D., Schwandt, P., Singh, P.P., Galonsky, A., 1983. Multibody final states of the ^{6}Li $+^6$ Li reaction at 97 MeV. Nuclear Physics A 401, 521-530.

[Warner92] Warner, R.E., Okihana, A., Fujiwara, M., Matsuoka, N., Kakigi, S., Hayashi, S., Fukunaga, K., Kasagi, J., Tosaki, M., 1992a. ^{7}Li$(\alpha, 2\alpha)^3$H reaction from 77 to 119 MeV. Physical Review C 45,

[Warner92a] Warner, R.E., Okihana, A., Fujiwara, M, Matsuoka, N., Hayashi, S., Kakigi, S., Fukunaga, K., Kasagi, J., Tosaki, M., Greenfield, M.B., 1992b. Energy dependence of the ^{6}Li$(\alpha, 2\alpha)$pn reaction from 77 to 119 MeV. Physical Review C 46, 616-620.

[Warwick83] Warwick, A.I., et al., 1983. Breakup of spectator residues in relativistic nuclear collisions. Physical Review C 27, 1083-1102.

[Watanabe87] Watanabe, Y., Kumabe, I., Hyakutake, M., Koori, N., Ogawa, K., Orito, K., Akagi, K., Oda, N., 1987. Preequilibrium $(\mathrm{p}, \mathrm{p}')$ spectra for nuclei around neutron number 50. Physical Review C 36, 1325-1334.

[Watanabe90] Watanabe, Y., Kodaka, K., Kubo, Y., Koori, N., Eriguchi, M., Hanada, M., Kumabe, I., 1990. Incident energy dependence of prequilibrium $(\mathrm{p}, \mathrm{p}')$ spectra. Zeitschrift fur Physik A 336, 63-69.

[Watanabe95] Watanabe, Y., et al., 1995. Feshbach-Kerman-Koonin model analysis of preequilibium $(\mathrm{p}, \mathrm{p}')$ and (p,n) reactions at 12 to 26 MeV. Physical Review C 51, 1891-1907.

[Webb87] Webb, M.L., Crawford, H.J., Engelage, J., Baumgartner, M.E., Greiner, D.E., Lindstrom, P.J., Olson, D.L., Wada, R., 1987. Probing the direct step of relativistic heavy ion fragmentation: (^{12}C,^{11}B + p) at 2.1 GeV/nucleon with C and CH_2 targets. Physical Review C 36, 193-202.

[Webber90] Webber, W.R., Soutoul, A., Ferando, P., Gupta, M., 1990. The source charge and isotopic abundances of cosmic rays with Z = 9 - 16: A study using new fragmentation cross sections. Astrophysical Journal 348, 611-620.

[Webber90a] Webber, W.R., Kish, J.C., Schrier, D.A., 1990a. Total charge and mass changing cross sections of relativistic nuclei in hydrogen, helium and carbon targets. Physical Review C 41, 520-532.

[Webber90b] Webber, W.R., Kish, J.C., Schrier, D.A., 1990b. Individual charge changing cross sections of relativistic nuclei in hydrogen, helium and carbon targets. Physical Review C 41, 533-546.

[Webber90c] Webber, W.R., Kish, J.C., Schrier, D.A., 1990c. Individual isotopic fragmentation cross sections of relativistic nuclei in hydrogen, helium and carbon targets. Physical Review C 41, 547-565.

[Webber98] Webber, W.R., Kish, J. C., Rockstroh, J.M., Cassagnou, Y., Legrain, R., Soutoul, A., Testard, O., Tull, C., 1998a. Production cross sections of fragments from beams of 400-650 MeV per nucleon ^{9}Be, ^{11}B, ^{12}C, ^{14}N, ^{15}N, ^{16}O, ^{20}Ne, ^{22}Ne, ^{56}Fe and ^{58}Ni nuclei Interacting in a liquid hydrogen target. I. Charge changing and total cross sections. Astrophysical Journal 508, 940-948.

[Webber98a] Webber, W.R., Kish, J. C., Rockstroh, J.M., Cassagnou, Y., Legrain, R., Soutoul, A., Testard, O., Tull, C., 1998b. Production cross sections of fragments from beams of 400-650 MeV per nucleon ^{9}Be, ^{11}B, ^{12}C, ^{14}N, ^{15}N, ^{16}O, ^{20}Ne, ^{22}Ne, ^{56}Fe and ^{58}Ni nuclei interacting in a liquid hydrogen target. II. Isotopic cross sections of fragments. Astrophysical Journal 508, 949-958.

[Webber98b] Webber, W.R., Soutoul, A., Kish, J.C., Rockstroh, J.M., Cassagnou, Y., Legrain, R., Testard, O., 1998b. Measurement of charge changing and isotopic cross sections at 600 MeV/nucleon from the interactions of 30 separate beams of relativistic nuclei from ^{10}B to ^{55}Mn in a liquid hydrogen target. Physical Review C 58, 3539-3552.

[Weber92] Weber, M., et al., 1992. New neutron rich isotopes in the scandium-to-nickel region, produced by fragmentation of a 500 MeV/u ^{86}Kr beam. Zeitschrift für Physik A 343, 67-71.

[Weber94] Weber, M., et al., 1994. Longitudinal momenta and production cross sections of isotopes formed by fragmentation of a 500 A×MeV ^{86}Kr beam. Nuclear Physics A 578, 659-672.

[Wefel79] Wefel, J.P., Kidd, J.M., 1979. Differential fragmentation cross sections for 7.3 GeV nitrogen ions incident on protons. Physical Review C 19, 1380-1392.

[Wesick85] Wesick, J.S., et al., 1985. ^{2}H, ^{3,4}He$(\vec{p}, p')$ and ^{3,4}He$(\vec{p}, d')$ continuum yields for 100 and 150 MeV protons. Physical Review C 32, 1474-1487.

[West66] West, R.W., 1966. Proton emission in 42 MeV alpha particle bombardments of several elements. Physical Review 141, 1033-1052.

[Westerberg78] Westerberg, L., Sarantites, D.G., Hensley, D.C., Dayras, R.A., Halbert, M.L., Barker, J.H., 1978. Pre-equilibrium particle emission from fusion of ^{12}C+^{158}Gd and ^{20}Ne +^{150} Nd. Physical Review C 18, 796-814.

[Westfall79] Westfall G.D., Wilson, L.W., Lindstrom, P.J., Crawford, H.J., Greiner, D.E., Heckman, H.H., 1979. Fragmentation of relativistic ^{56}Fe. Physical Review C 19, 1309-1323.

[Westfall79a] Westfall, G.D., et al., 1979b. Production of neutron-rich nuclides by fragmentation of 212 MeV/amu ^{48}Ca. Physical Review C 43, 1859-1862.

[Westfall82] Westfall, G.D., et al., 1982. Energy dependence of nuclear matter disassembly in heavy ion collisions. Physics Letters B 116, 118-122.

[Westfall84] Westfall, G.D., et al., 1984. Light particle spectra from 35 MeV/nucleon ^{12}C induced reactions on ^{197}Au. Physical Review C 29, 861-863.

[Whitfield93] Whitfield, J.P., Porile, N.T., 1993. Evolution of the reaction dynamics in the interaction of copper with 15 - 90 MeV/nucleon ^{12}C ions. Physical Review C 47, 1636-1646.

[Wickersham57] Wickersham, A., 1957. Interactions of 28 MeV protons with helium-4, Physical Review 107, 1050-1055.

[Wilczynski80] Wilczynski, J., Siwek-Wilczynski, K., van Driel, J., Gongrijp, S., Hageman, D.C.J.M., Janssens, R.V.F., Lukasiak, J., Siemssen, R.H., 1980. Incomplete fusion reactions in the ^{14}N +^{159} Tb system and a sum-rule model for fusion and incomplete fusion reactions. Physical Review Letters 45, 606-609.

[Wilson91] Wilson, J.W., Townsend, L.W., Schimmerling, W.S., Khandelwal, G.S., Khan, F., Nealy, J.E., Cucinotta, F.A., Simonsen, L.C., Shinn, J.L., Norbury, J.W., 1991. Transport Methods and Interactions for Space Radiations. NASA Reference Publication 1257.

[Wlazlo00] Wlazlo, W., et al., 2000. Cross sections of spallation residues produced in 1 A GeV ^{208}Pb on proton reactions. Physical Review Letters 84, 5736-5739.

[Wu79] Wu, J.R., Chang, C.C., Holmgren, H.D., 1979. Charged particle spectra: 90 MeV protons on ^{27}Al, ^{58}Ni, ^{90}Zr, and ^{209}Bi. Physical Review C 19, 698-713.

[Yamada79] Yamada, H., Zolnowski, D.R., Cala, S.E., Kahler, A.C., Pierce, J., Sugihara, T.T., 1979. Massive transfer accompanying proton, deuteron and triton emission in heavy ion reactions. Physical Review Letters 43, 605-608.

[Yamaguchi06] Yamaguchi, T., et al., 2006. Production cross sections of isotopes formed by fragmentation of $\sim$ 1 A GeV ^{80}Kr beam. Physical Review C 74, 044608.

[Yamaguchi10] Yamaguchi, T., et al., 2010. Energy dependent charge changing cross sections and proton distribution of ^{28}Si. Physical Review C 82, 014609.

[Yashima03] Yashima, H., Uwamino, Y., Iwase, H., Sugita, H., Nakamura, T., Ito, S., Fukumura, A., 2003. Measurement and calculation of radioactivities of spallation products by high energy heavy ions. Radiochim. Acta 91, 689-696. nnn

[Yashima04] Yashima, H., Uwamino, Y., Iwase, H., Sugita, H., Nakamura, T., Ito, S., Fukumura, A., 2004. Cross sections for the production of residual nuclides by high energy heavy ions. Nuclear Instruments and Methods in Physics Research B 226, 243-263.

[Yennello91] Yennello, S.J., et al., 1991. Multifragment emission in reactions induced by 0.90 and 3.6 GeV ^{3}He ion on ^{nat}Ag. Physical Review Letters 67, 671-674.

[Yennello93] Yennello, S.J., et al., 1993. Studies of intermediate mass fragment emission in the ^{3}He + ^{nat}Ag, ^{197}Au reactions between 0.48 and 3.6 GeV. Physical Review C 48, 1092-1105.

[Yiou68] Yiou, F., 1968. Mass spectrometry of lithium, beryllium and boron isotope production in oxygen and carbon targets irradiated by high energy protons. Annales de Physique 3, 169-209.

[Yiou69] Yiou, F., Seide, C., Bernas, R., 1969. Formation cross sections of lithium, beryllium and boron isotopes produced by the spallation of oxygen by high energy protons. Journal of Geophysical Research, Space Physics 74, 2447-2448.

[Yokoyama01] Yokoyama, A., Morimoto, S., Araki, H., Sanada, J., Baba, H., Shinohara, A., Shibata, S., Saito, T., Ohkubo, Y., 2001. Radiochemical study on the mechanism of target fragmentation of Cu, Nb, Pr, and Au targets induced by ^{12}C and ^{40}Ar projectiles. Radiochim. Acta 89, 703-706. nnn

[Yule60] Yule, H.P., Turkevich, A. 1960. Radiochemical studies of the (p,pn) reaction in complex nuclei in the 80-450 MeV range. Physical Review 118, 1591-1598.

[Zamani10] Zamani, M., Stoulos, S., Fragopoulou, M., Krivopustov, M., 2010. Measurement of inelastic cross sections in relativistic deuteron-on-lead reactions. Physical Review C 82, 044605.

[Zeitlin97] Zeitlin, C., Heilbronn, L., Miller, J., Rademacher, S.E., Borak, T., Carter, T.R., Frankel, K.A., Schimmerling, W., Stronach, C.E., 1997. Heavy fragment production cross sections from 1.05 GeV/nucleon ^{56}Fe in C, Al, Cu, Pb, and CH_2 targets. Physical Review C 56, 388-397.

[Zeitlin01] Zeitlin, C., Fukumura, A., Heilbronn, L., Iwata, Y., Miller, J., Murakami, T., 2001. Fragmentation cross sections of 600 MeV/nucleon ^{20}Ne on elemental targets. Physical Review C 64, 024902.

[Zeitlin07] Zeitlin, C., Guetersloh, S., Heilbronn, L., Miller, J., Fukumura, A., Iwata, Y., Murakami, T., 2007a. Fragmentation cross sections of 290 and 400 MeV/nucleon ^{12}C beams on elemental targets. Physical Review C 76, 014911.

[Zeitlin07a] Zeitlin, C., Fukumura, A., Guetersloh, S.B., Heilbronn, L.H., Iwata, Y., Miller, J., Murakami, T., 2007b. Fragmentation cross sections of ^{28}Si at beam energies from 290 A to 1200 A MeV. Nuclear Physics A 784, 341-367.

[Zeitlin08] Zeitlin, C., Guetersloh, S., Heilbronn, L., Miller, J., Fukumura, A., Iwata, Y., Murakami, T., Sihver, L., Mancusi, D., 2008. Fragmentation cross sections of medium-energy ^{35}Cl, ^{40}Ar and ^{48}Ti beams on elemental targets. Physical Review C 77, 034605.

[Zeitlin11] Zeitlin, C., Miller, J., Guetersloh, S., Heilbronn, L., Fukumura, A., Iwata, Y., Murakami, T., Blattnig, S., Norman, R., Mashnik, S., 2011. Fragmentation of ^{14}N, ^{16}O, ^{20}Ne, and ^{24}Mg nuclei at 290 to 1000 MeV/nucleon. Physical Review C 83, 034909.

[Zhou10] Zhou, Z., et al., 2010. Differential cross section for neutron scattering from 209Bi at 37 MeV and the weak particle core coupling. Physical Review C 82, 024601.

[Zhu91] Zhu, F., et al., 1991. Light particle correlations for the ^{3}He + Ag reaction at 200 MeV. Physical Review C 44, R582-R585.

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14. ABSTRACT
Human space flight requires protecting astronauts from the harmful effects of space radiation. The availability of measured nuclear cross section data needed for these studies is reviewed in the present paper. The energy range of interest for radiation protection is approximately 100 MeV/n to 10 GeV/n. The majority of data are for projectile fragmentation partial and total cross sections, including both charge changing and isotopic cross sections. The cross section data are organized into categories which include charge changing, elemental, isotopic for total, single and double differential with respect to momentum, energy and angle. Gaps in the data relevant to space radiation protection are discussed and recommendations for future experiments are made.

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