

To the Graduate Council:

I am submitting herewith a dissertation written by Youssef Mohamad Charara entitled "Characterization of the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) Detector." I have examined the final paper copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Nuclear Engineering.

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Characterization of the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) Detector

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Youssef Mohamad Charara
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Dedication

For my uncle,

Youssef Mohamad Kamah

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I would like to first thank Dr. Larry Townsend, my major advisor, for all his support and guidance through the years. Dr. Townsend has been the greatest academic advisor and a wonderful fatherly figure who taught me how to make simple analogies out of complex theories by making them “intuitively obvious to the casual observer” as well as how to “carefully choose the ditch you are willing to die in” when making daily life decisions.

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ABSTRACT

In order to be able to pave the way for future lunar manned missions, proper studies for the radiation environment of the Moon and its impact on humans are necessary. For this reason, the Lunar Reconnaissance Orbiter (LRO) spacecraft is scheduled to be launched in April 2009. It will carry several instruments with various objectives, one of which is the Cosmic Ray Telescope for the Effects of Radiations (CRaTER) detector, which will characterize the lunar radiation environment and its impacts on human tissue by measuring the radiation Linear Energy Transfer (LET) in A-150 Tissue Equivalent Plastic. To properly support CRaTER's mission, advance knowledge of the detector's response to the lunar radiation environment is necessary. The goal of this dissertation is to characterize CRaTER's response to ground based calibrations, Galactic Cosmic Rays (GCRs), and Solar Particle Events (SPEs) by building a Linear Energy Transfer (LET) database using three-dimensional Monte Carlo methods. This is the first database suitable for supporting CRaTER's mission, by comparing what will be measured in space with Monte Carlo codes based models.

1. INTRODUCTION

In order to fulfill the President's vision for space exploration and return to the moon by 2018, NASA has formulated a series of robotic missions to pave the way for the eventual permanent human presence on the moon.

The Lunar Reconnaissance Orbiter (LRO), first in the series of NASA's Lunar Precursor Robotic Program (LPRP), is to be launched in April 2009.

One of the instruments LRO will carry is the Cosmic Ray Telescope for the Effects of Radiation (CRaTER), which will characterize the lunar radiation environment and its impact of humans by directly measuring the Linear Energy Transfer (LET) in A-150 Tissue Equivalent Plastic.

In order to be able to better understand the LET response of CRaTER, it is necessary to first have a "picture" of the detector's response, especially since CRaTER will be exposed to a mixture of charged particles that originate from various sources, and have various energies and therefore various LETs.

This dissertation serves as an analysis of the detector's response that will help guide the CRaTER science team to be able to have a reference database. In addition, once measurements are obtained, it will be necessary to validate prediction models used in most three dimensional Monte Carlo codes.

1.1. Justification and Originality

Unlike Earth, the moon has neither an atmosphere nor a geomagnetic field that could be used to shield astronauts and spacecraft electronic components from the harsh space radiation environment, which includes very energetic galactic cosmic rays (GCRs) that are able to limit an astronaut's effective career, and in the case of solar particle events (SPEs), be lethal. For that reason, a better and more accurate understanding of the lunar radiation environment is required.

Currently, a number of satellites provide energy spectra for the various elements that constitute the cosmic ray spectrum.

The Advanced Composition Explorer (ACE) has the Cosmic Ray Isotope Spectrometer (CRIS) onboard, which provides energy spectra for elements between Lithium and Zinc between 50 and 500 MeV/nucleon.

The High Energy Astrophysics Observatory-3 (HEAO-3) measures energy spectra for elements between Boron and Nickel for the high energy range between 500 and 35000 MeV/nucleon among other detectors that provide spectra for protons and helium for various energy ranges. A summary of the existing instruments is listed in table 1.

Table 1. Summary of Existing Instruments [1]

Data Source	Elements	Energy Range	Time Period
ACE CRIS Expt	$3 \leq Z \leq 30$	$\sim 50\text{--}500$ MeV/nuc	1997–present
HEAO-3 Danish-French Expt	$5 \leq Z \leq 28$	$\sim 800\text{--}35000$ MeV/nuc	1979–1981
IMP-8 GSFC Expt	H, He	$\sim 100\text{--}300$ MeV/nuc	1973–2004
STS-091 AMS Expt	H, He	$\sim 200\text{--}20000$ MeV/nuc	1998
balloons BESS Expt	H, He	$\sim 200\text{--}50000$ MeV/nuc	1993–present (multiple flights)

Indirect Measurements

Data Source	Elements	Energy Range	Time Period
Neutron Monitors e.g. Climax	total	>3 GV $\gtrsim 2000$ MeV/nuc (p)	1951–present

However, none of the existing instruments are able to directly quantify the most biologically important element of space exploration research, which is to determine whether man can be safely sent into deep space.

A valuable quantity that can be used to examine the question of the biological risk for a manned mission is the measured Linear Energy Transfer (LET) of charged particles in the deep space environment.

For this purpose a collaboration involving research personnel from Boston University, Massachusetts Institute of Technology, The University of Tennessee, The Aerospace Corporation, Air Force Research Laboratory, and the National Space Weather Prediction Center successfully developed a sensor system called the Cosmic Ray Telescope for the Effects of Radiation (CRaTER).

In the early design stage, the University of Tennessee was involved in determining the best geometrical configuration of the detector by calculating LET of various elements that one could encounter in the lunar environment.

The objectives of the CRaTER detector on the Lunar Reconnaissance Orbiter (LRO) are “to characterize the lunar radiation environment and its biological impact on humans as well as to investigate shielding capabilities and validation of other deep-space radiation mitigation strategies involving materials.”

CRaTER will directly measure linear energy transfer (LET) spectra, thereby providing a direct link between the ambient environment and its biological impact on future human missions to the Moon.

In addition, the LET data could be used for benchmarking existing cross section models used in particle transport codes since most of the existing cross section databases are calculated and the uncertainties associated with the calculations are quite large.

1.2. Goal of Dissertation

The goal of this work is to predict and analyze CRaTER’s response in advance to various scenarios, which is done for the first time.

The new and innovative features of this work are:

1. A benchmark study of HETC-HEDS against proton calibrations performed at the Massachusetts General Hospital (MGH) Proton Therapy Center and heavy ion calibrations performed at the Brookhaven National Laboratory (BNL) to validate the code.

2. A complete database is developed for all relevant GCR elements with their corresponding energies by the use of Monte Carlo methods to characterize CRaTER's response for 2009, which is the time CRaTER will be orbiting the Moon. This database will serve as a prediction of the expected GCR environment during the LRO/CRaTER mission to be compared and validated with the measured CRaTER data
3. Simulations of various large historical solar particle events to evaluate CRaTER's response to similar events. The events are those of the September, October, and November of 1989, October 2003 (Halloween) event, and a prediction for a worst case scenario for the year 2009

1.3. Outline of dissertation

Chapter I has been an introduction to the problem and existing databases. Chapter II serves as a review of the lunar radiation environment and space radiation interaction processes. Chapter III describes the Lunar Reconnaissance Orbiter (LRO) mission in general, and describes the CRaTER detector in detail. Chapter IV describes the Monte Carlo code used in this work, HETC-HEDS; the methodology used to obtain the results for the benchmark study; calculation of the LET spectra for the GCR elements; calculation of the LET spectra of the solar particle events (SPEs); and finally discusses the results obtained. Chapter V discusses the conclusions, and suggestions for future work.

2. LUNAR RADIATION ENVIRONMENT

The Lunar surface is under constant bombardment by radiations that include a variety of charged particles as well as photons and neutrons with energy range that extends to GeVs as depicted in figure 1 [2].

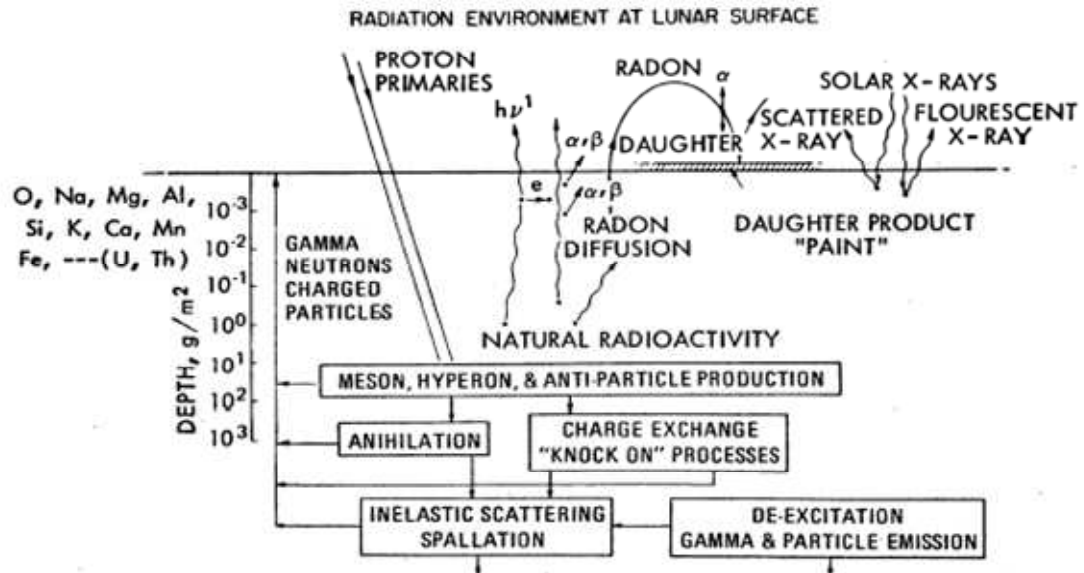


Figure 1. The Lunar Surface Radiation Environment [2]

This environment limits an astronaut's career since the radiation exposure limits make it impossible for an astronaut to spend extended periods of time on the lunar surface without proper shielding [3].

NASA has developed Permissible Exposure Limits (PELs) for 30 day, annual, and career exposures as listed in table 2 [4].

Table 2. Dose Limits for Short-Term and Career for Various Organs [4]

<i>Organ</i>	<i>30 day limit</i>	<i>1 Year Limit</i>	<i>Career</i>
Lens*	1000 mGy-Eq	2000 mGy-Eq	4000 mGy-Eq
Skin	1500	3000	4000
BFO	250	500	Not applicable
Heart**	250	500	1000
CNS***	500	1000	1500
CNS*** (Z$\geq$10)	-	100 mGy	250 mGy

*Lens limits are intended to prevent early (< 5 yr) severe cataracts (e.g., from a solar particle event). An additional cataract risk exists at lower doses from cosmic rays for sub-clinical cataracts, which may progress to severe types after long latency (> 5 yr) and are not preventable by existing mitigation measures; however, they are deemed an acceptable risk to the program.

**Heart doses calculated as average over heart muscle and adjacent arteries.

***CNS limits should be calculated at the hippocampus.

The main sources of radiations on the lunar surface are the galactic cosmic rays (GCRs) that originate from deep space and include elements up to Uranium, and solar energetic particles (SEPs) that originate from solar particle events (SPEs) mainly associated with coronal mass ejections (CMEs).

2.1. Galactic Cosmic Rays

The origin of galactic cosmic rays is unknown, but it is speculated that they originate from supernovas. Because the particles come from outside the galaxy, particle fluxes outside Earth's magnetosphere are isotropic over the entire energy range. The GCR flux is composed of approximately 85 % H, 14 % He, and 1 % heavier ions, and for the heavy ion portion, only elements up to Iron are of concern because the fluence for

elements with charge $Z > 26$ drops significantly in the GCR spectrum. Figure 2 shows the flux of the galactic cosmic ray spectrum as a function of charge (Z) as measured by the various existing detectors. It can be noted that for particles heavier than Iron, the flux drops significantly making the heavier elements of insignificant concern.

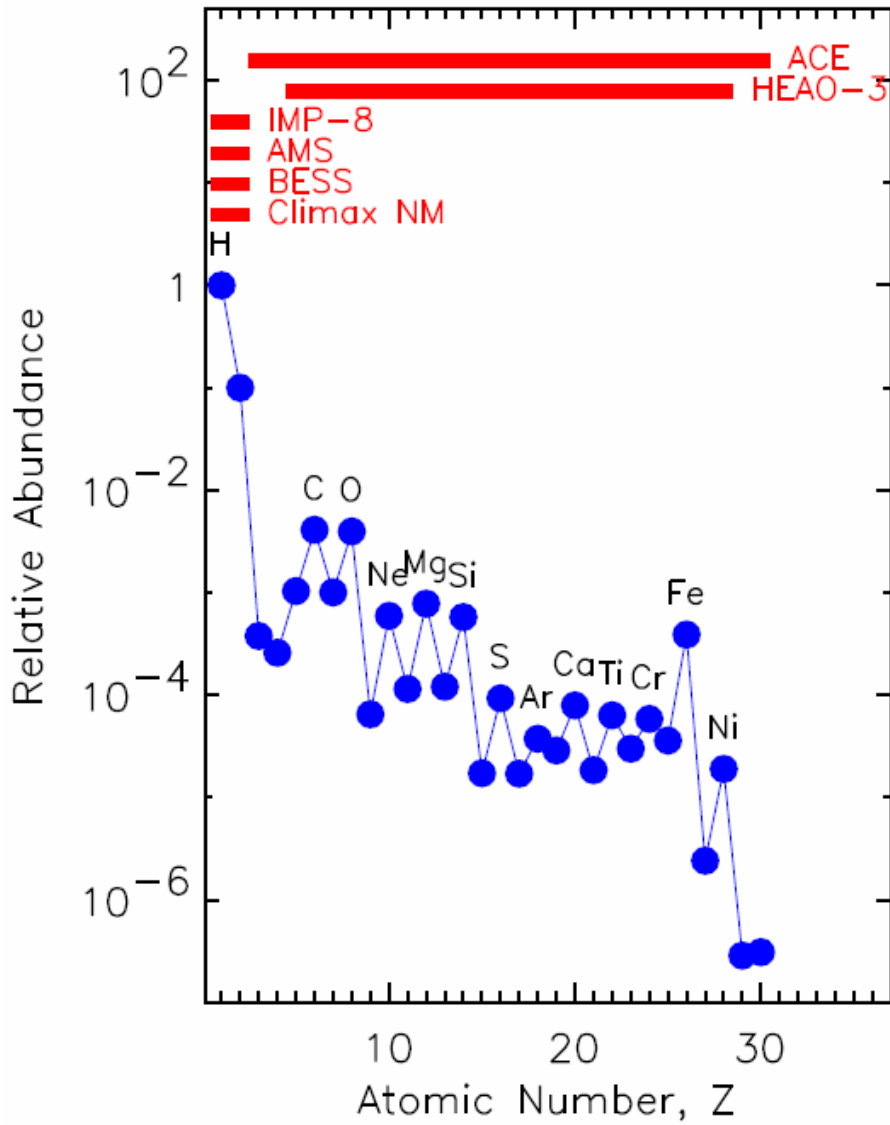


Figure 2. GCR Fluence as a Function of Charge (Z) [1]

One of the problems associated with Galactic Cosmic Rays is their dosimetry. Because very limited data exists on the damage they can cause, the biological impacts on humans are relatively unknown. Heavier particles are generally more harmful because they have a higher Linear Energy Transfer (LET) than protons. Figure 3 shows the relative dose for each of the galactic cosmic ray spectrum components along with their intensities [3].

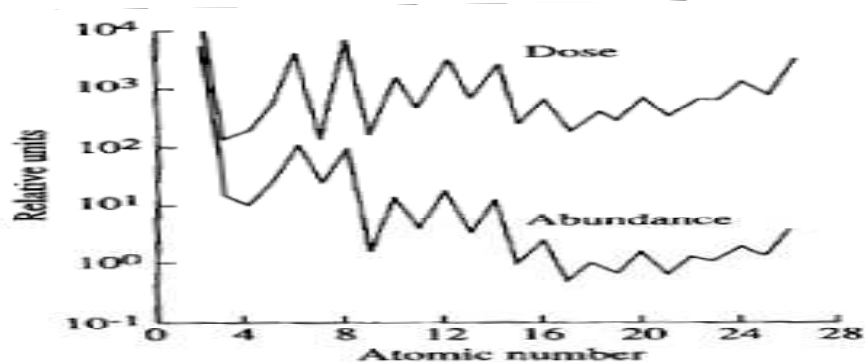


Figure 3. Relative Dose and Relative Intensities for the Galactic Cosmic Ray Spectrum [3]

The flux of particles in the GCR spectrum is dependent on the solar activity. The flux is highest during solar minimum, and lowest during solar maximum. This is due to the deflection of low energy ions by magnetic fields associated with solar wind plasma, which is strong during solar maximums periods.

Figure 4 compares the energies as a function of flux for the 1977 solar minimum and the 1959 solar maximum for major elements in free space [3].

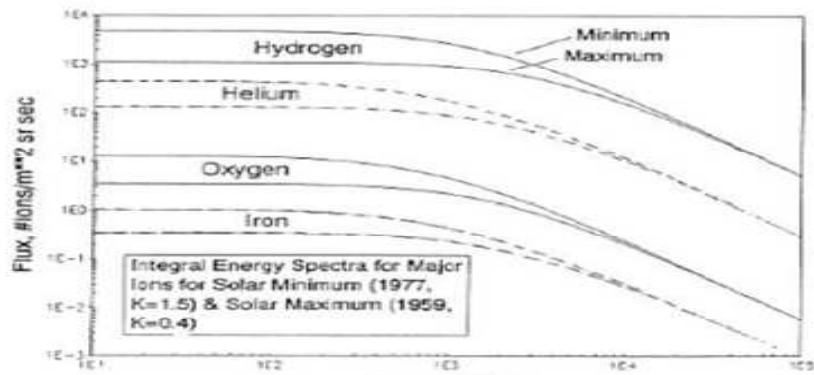


Figure 4. Free-Space GCR Integral Spectra for Solar Maximum and Solar Minimum [3]

Over the 11 year solar cycle, the GCR environment varies by approximately a factor of 2. Figure 5 depicts such variations for various elements between the 1977 solar minimum and the 1990 solar maximum [5].

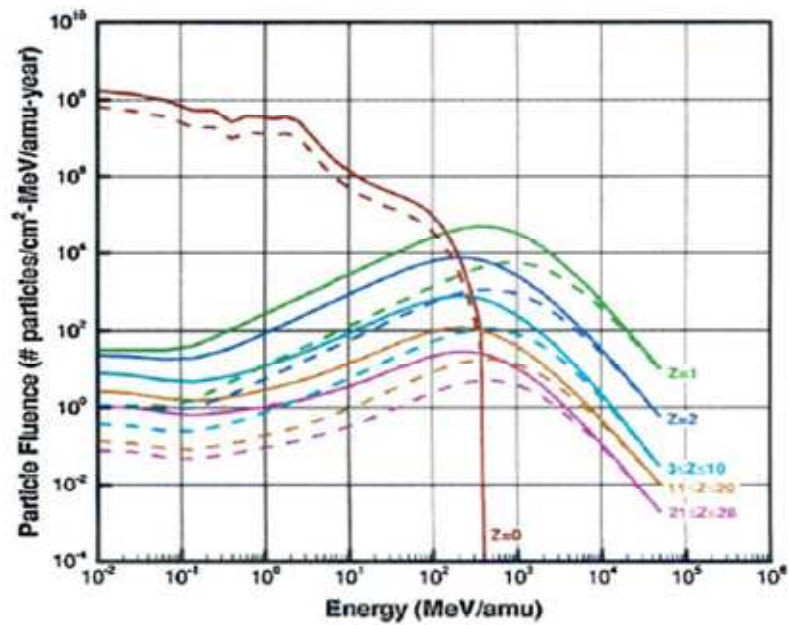


Figure 5. Lunar Surface Induced GCR Environment during the 1977 Solar Minimum (full lines) and the 1990 Solar Maximum (dashed lines) [5]

2.2. Solar Energetic Particles

Periodically, the sun is seen to eject significant amounts of protons, alpha particles, and a few heavier elements. Such events are called solar particle events and could last on the order of days and sometimes even weeks. According to the National Space Weather Prediction Center, an SPE is declared in progress when the rate of protons with energies greater than or equal to 10 MeV exceeds 10 particles/cm²-sec-ster for more than fifteen minutes [6]. Also, an energetic SPE is declared when particles with energies greater than or equal to 100 MeV exceed 1 particle/cm²-sec-ster [7].

The main constituents of their spectra are protons, which have an energy range that extends to the order of TeVs. In the past, several large events were observed during which, if an astronaut had been on surface of the moon shielded by only a space suit, the dose could have been lethal [3]. Figure 6 compares the integral proton fluences for several large SPEs.

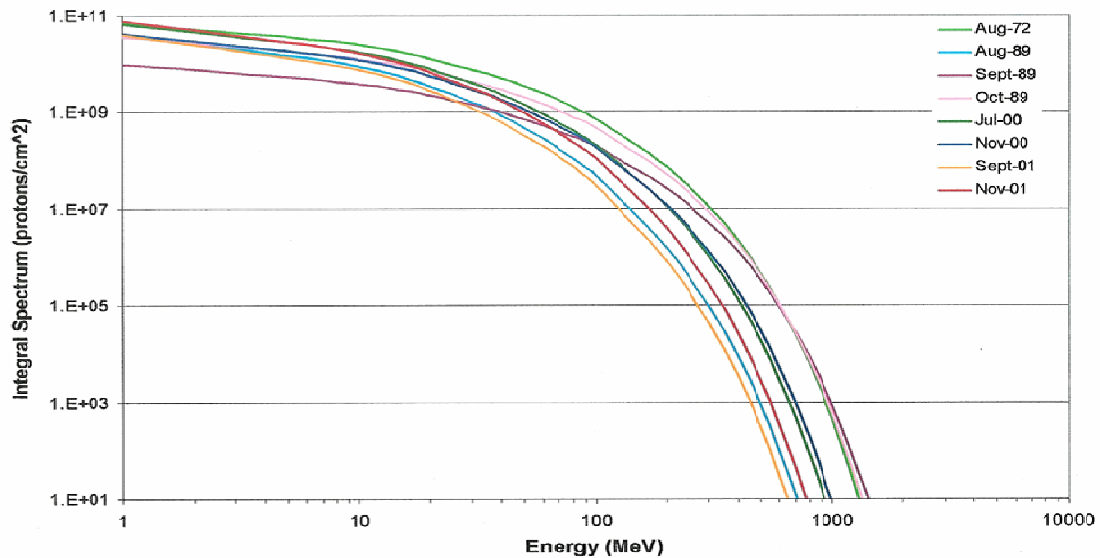


Figure 6. SPE Integral Spectrum versus Energy for Several Large SPEs [8]

2.3. Space Radiation Interaction

The energetic particles in space consist mainly of atomic constituents covering a very broad energy spectrum and flux values as shown in figure 7 [3].

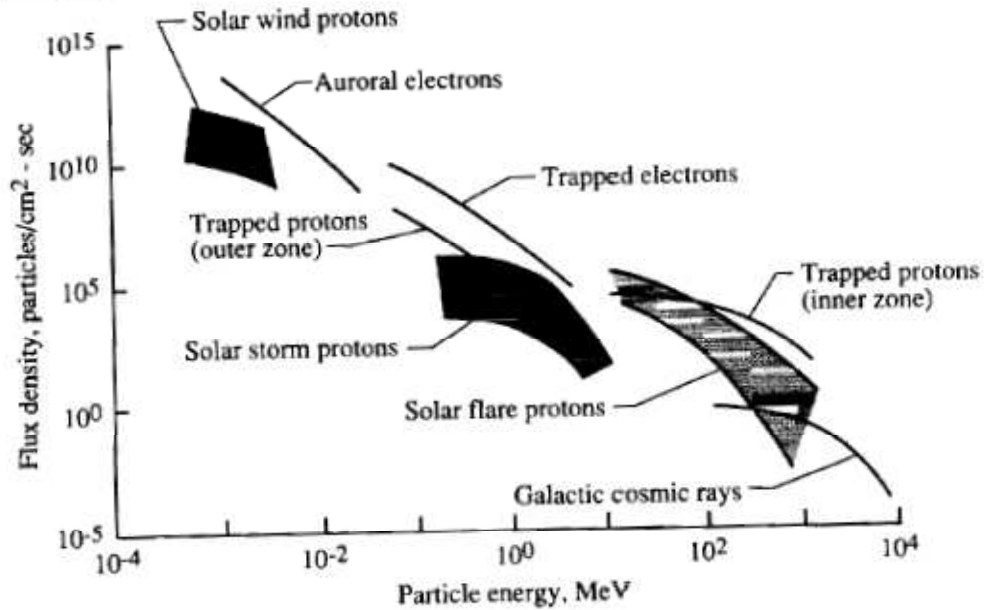


Figure 7. Space Radiation Environment [3]

The structure of the electron clouds contains only 0.05 % of the mass but occupies most of the space within the material. Embedded within these electron clouds are the atomic nuclei whose dimensions are 10^{-5} times smaller than the complete atom but contain 99.95 percent of the mass of the atom. Clearly, an energetic particle passing through such material will mainly interact with the electrons in the cloud and seldom strike a nucleus.

The two dominant means of energy loss for charged particles is through excitation and ionization. That is, a collision between an incoming particle and the orbital electrons,

which results in a small amount of energy transfer, and causes the electron to either jump to a higher orbit in the case of excitation, or be completely ejected from the atom in the case of ionization. However, the occasional interaction with the nucleus is still of importance because of the large amount of energy transferred in the process that will cause new energetic particles to be produced. Several processes can cause generation of secondary particles including direct knockout of nuclear constituents, resonant excitation followed by particle emissions, and coherent effects with the nucleus. Such events are dependent on energy, particle type, and material composition [3].

2.4. Measures of Exposure

The amount of energy deposited in material is expressed in units of joules per kilogram, which is also known as Gray [4]. This unit represents the quantity of radiation dose, D , which is defined as the mean energy imparted (absorbed) per unit mass dE/dm .

$$D = \frac{dE}{dm} \quad (1)$$

Where

dE is the mean energy imparted in the material

dm is the mass of the material absorbing the energy

The same absorbed dose delivered by different types of radiation may result in different degrees of biological damage to body tissues. The total energy deposited is not the only factor which determines the extent of the damage. The equivalent dose, $H_{T,R}$ was introduced to take into account the dependence of the harmful biological effects on the type of radiation being absorbed. The equivalent dose is therefore a measure of the risk

associated with an exposure to ionizing radiation. Risks due to exposures to different radiation types can be directly compared when in terms of equivalent dose [4].

The unit of equivalent dose is the sievert (Sv) and is defined for a given type of radiation by the relationship:

$$H_{T,R} = w_R D_{T,R} \quad (2)$$

The radiation weighting factor w_R is a dimensionless number which depends on the way in which the energy of the radiation is distributed along its path through the tissue.

The rate of deposition of energy per unit pathlength along the track is known as the Linear Energy Transfer (LET) of the radiation and has units of KeV/ μ measured in water.

Radiation with a high LET (such as heavy charged sub-atomic particles) is more likely than radiation with a low LET (such as x-rays or beta particles) to damage the small structures in tissue such as DNA molecules. This is because the higher energy from high LET radiation is absorbed in a small volume surrounding the trail of dense ionization produced by this radiation. The radiation weighting factor is directly related to the LET of the radiation as is shown in figure 8. The radiation weighting factors are used to correct for differences in the biological damage to tissue caused by chronic exposure to different radiations [4]. The radiation weighting factors for various radiations are shown in table 3.

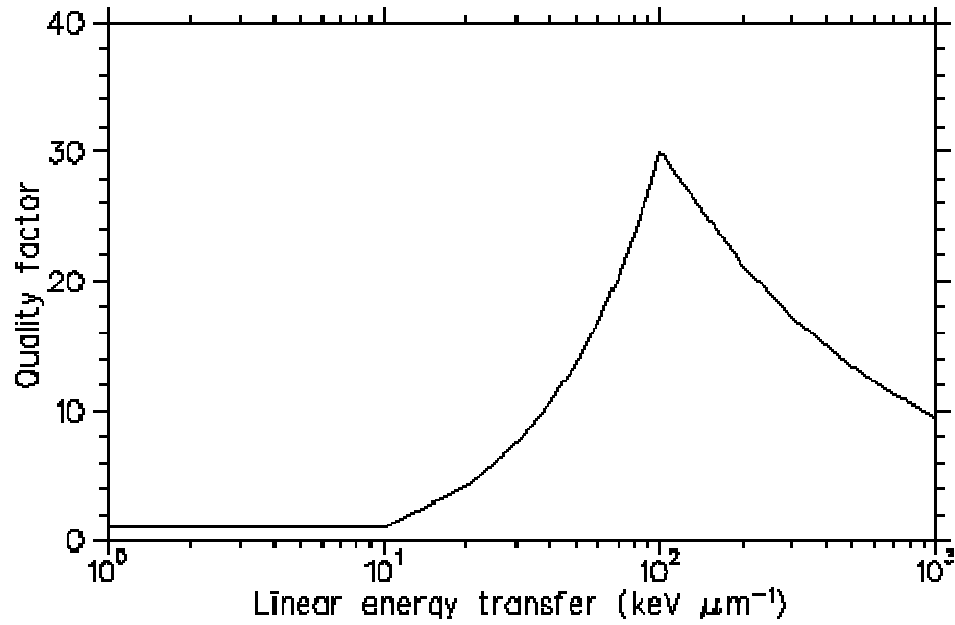


Figure 8. Correspondence between LET and Radiation Weighting Factor [4]

Table 3. Radiation Weighting Factors [4]

Type	Energy range	Radiation weighting factor, w_R
Photons	all	1
Electrons/muons	all	1
Neutrons	$< 10 \text{ keV}$	5
	$10 \text{ keV to } 100 \text{ keV}$	10
	$100 \text{ keV to } 2 \text{ MeV}$	20
	$2 \text{ MeV to } 20 \text{ MeV}$	10
	$> 20 \text{ MeV}$	5
Protons (not recoil protons)	$> 2 \text{ MeV}$	5
Alpha particles	all	20
Fission fragments	all	20
Heavy nuclei	all	20

When radiation consists of components with different w_R , then the equivalent dose, H_T , is given by summing all contributions:

$$H_T = \sum w_R D_{T,R} \quad (3)$$

Where

w_R is the radiation weighting factor

$D_{T,R}$ is the dose deposited into particular tissue by particular radiation type R

Since different tissues of the body respond differently to radiation, the probability for stochastic effects that results from a given equivalent dose will generally depend upon the particular tissue or organ irradiated. To take such differences into account, the effective dose E is introduced [4], which represents the risk for all stochastic effects for an irradiated individual, and is defined as the sum of the weighted equivalent doses over all tissues:

$$E = \sum w_T H_T \quad (4)$$

Where

w_T is the tissue weighting factor

H_T is the equivalent dose deposited in a particular tissue

NASA imposes short-term and career dose limits, which have distinct purposes. Short-term limits are intended to prevent the occurrence of any clinically significant health risk, and career limits are intended to limit the increased risk of cancer induction and mortality to an acceptable level.

Early radiation effects are deterministic in nature and occur only above dose thresholds, usually after a significant fraction of cell loss in tissues. Recent studies suggests that cataract risks from space radiation are linear with GCR dose [9], with no apparent threshold, and caused by genetic damage leading to aberrant cellular differentiation of lens epithelial cells [10, 11].

Late effects, such as cancer, are stochastic in nature and some level of risk is incurred even at low doses. Currently, NASA uses the Risk of Exposure Induced Death (REID) quantity as basis for dose limits. Table 4 shows sample career effective dose limits for the future lunar missions using the REID criteria of a 3 % limit [12]. Also shown are calculations of the average life-loss expected if a cancer fatality would occur that are estimated from human data for low LET radiation exposure.

Table 4. Sample Career Dose Limits corresponding to a REID of 3% [12]

<i>Age, yr</i>	<i>Career effective dose limits in units of Sievert (mSv) for 1-year missions (Ave Life Loss).</i>	
	Males	Females
25	520 (15.7)	370 (15.9)
30	620 (15.4)	470 (15.7)
35	720 (15.0)	550 (15.3)
40	800 (14.2)	620 (14.7)
45	950 (13.5)	750 (14.0)
50	1150 (12.5)	920 (13.2)
55	1470 (11.5)	1120 (12.2)

3. THE LRO MISSION

In order to pave the way for a permanent stay on the moon and be able to travel to Mars and beyond, NASA's Vision for Space Exploration resulted in developing the Lunar Reconnaissance Orbiter (LRO) spacecraft that will carry several exploratory instruments to ease a near future return to the moon. [13].

Scheduled to be launched by April 24, 2009 on an Atlas V401 rocket, transfer to the Moon will take approximately four days where LRO will be placed at a 50 km altitude to orbit the moon for a 1-year mission after which a transition to a science phase will take place.

The scientific phase will include extracting processed data sets to help better understanding the lunar environment allowing an easier and safer human return to the Moon and for future human exploration of the solar system.

The data sets will be deposited into the Planetary Data System (PDS), which will be accessible to the public, six months after the completion of the primary mission.

These data sets will include invaluable information for supporting the extension of human presence in the solar system that will help identify sites with favorable terrain, environment, as well as data such as day-night temperature maps, and the moon's UV albedo. The CRaTER Data Level definitions are listed in table 5.

Table 5. CRaTER Data Level Definitions [13]

Data Level	Description
Level 0	Unprocessed instrument data (pulse height at each detector, plus secondary science) and housekeeping data.
Level 1	Depacketed science data, at 1-s resolution. Ancillary data pulled in (spacecraft attitude, calibration files, etc.)
Level 2	Pulse heights converted into energy deposited in each detector. Calculation of Si LET
Level 3	Data organized by particle environment (GCR, foreshock, magnetotail). SEP-associated events identified and extracted.
Level 4	Calculation of incident energies from modeling/calibration curves and TEP LET spectra

As shown in figure 9, LRO will carry the following instruments:

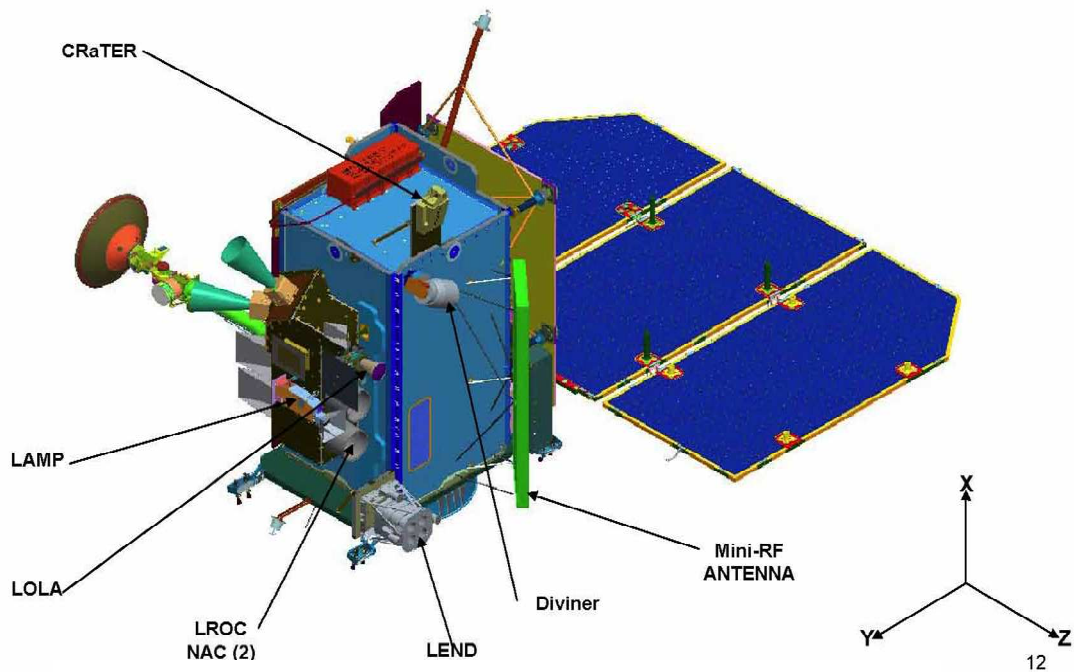


Figure 9. The Lunar Reconnaissance Orbiter (LRO) Concept [13]

3.1. Cosmic Ray Telescope for the Effects of Radiation (CRaTER)

The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) will characterize the lunar radiation environment and determine its potential biological impacts as well as test models of radiation effects and shielding.

Diviner Lunar Radiometer Experiment

The Diviner Lunar Radiometer (DLRE) will provide orbital thermal mapping at 500 meters scale measurements, giving detailed information about surface and subsurface temperatures (identifying cold traps and potential ice deposits), as well as rock abundances and hazards and ice stability

Lyman Alpha Mapping Project

The Lyman Alpha Mapping Project (LAMP) will map the entire lunar surface in the far ultraviolet. LAMP will search for surface ice and frost in the polar regions and provide images of permanently shadowed regions illuminated only by starlight.

Lunar Exploration Neutron Detector

The Lunar Exploration Neutron Detector (LEND) will create high resolution hydrogen distribution maps in the upper 1 m of the Moon crust at 10 Km scales, and provide information about the lunar radiation environment. LEND can be used to search for evidence of water ice on the Moon's surface, and will provide space radiation environment measurements useful for future human exploration.

Lunar Orbiter Laser Altimeter

The Lunar Orbiter Laser Altimeter (LOLA) will measure landing site slopes, lunar

surface roughness, and generate a high resolution 3D map of the Moon. LOLA will also identify the Moon's permanently illuminated and permanently shadowed areas by analyzing lunar surface elevations.

Lunar Reconnaissance Orbiter Camera

The Lunar Reconnaissance Orbiter Camera (LROC) will retrieve high resolution black and white images of the lunar surface, capturing images of the lunar poles with resolutions down to 1m, and will image the lunar surface in color and ultraviolet. These images will provide knowledge of polar illumination conditions, identify potential resources hazards, and enable safe landing site selection.

Mini-RF

The mini-RF is a technology demonstration of an advanced single aperture radar (SAR) capable of measurements in X-band and S-band. Mini-RF will demonstrate new lightweight SAR, communication technologies and locate potential water-ice.

CRaTER Detector

In order to achieve the objective of implementing a sustained, safe, and affordable human and robotic program to search for evidence of life, understand the history of the solar system, and prepare for future human exploration as envisioned by the President's Space Exploration Policy Directive, the following set of goals have been set by the CRaTER's investigation team:

- Develop a novel instrument that is low-cost and simple to measure the Linear Energy Transfer spectra and its time variation in the lunar orbit
- Measure the LET spectra of galactic and solar cosmic rays to model their impact for a long term presence on the lunar surface
- Investigate the effect of shielding by measuring LET spectra behind different amounts and types of materials
- Benchmark model predictions of LET spectra with CRaTER's measurements using available data

The scope of this proposal is to achieve the last goal. The CRaTER concept is shown in figure 10.

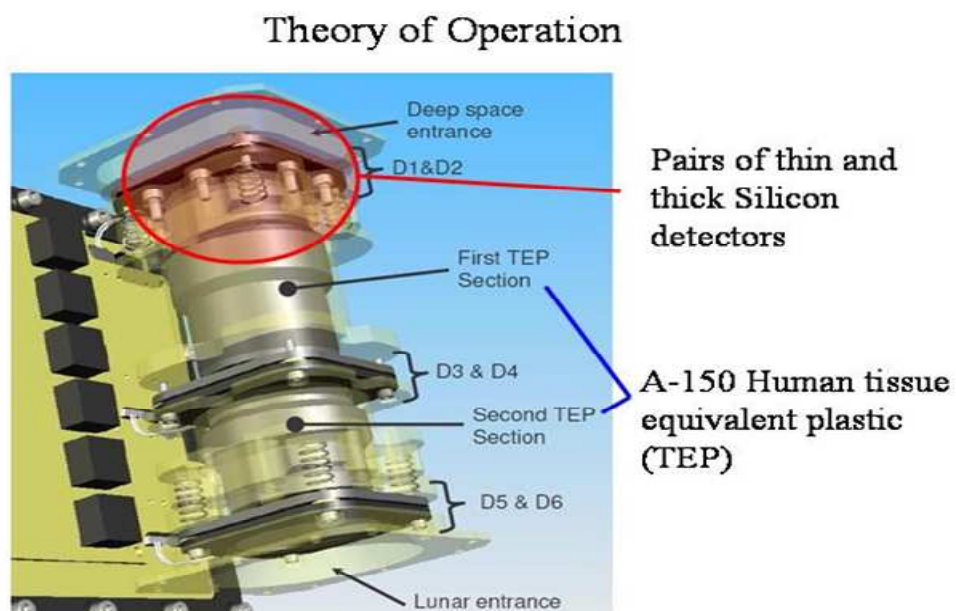


Figure 10. The CRaTER Detector Concept [14]

3.1.a. CRaTER Technology

The technology associated with developing the CRaTER instrument is based on existing technology that has long been used by NASA to existing instruments that have been operating flawlessly. The CRaTER instrument consists of an integrated sensor and electronics box with simple electronic and mechanical interfaces to the spacecraft.

The CRaTER sensor front-end design, analog electronics, and digital processing unit are based on standard technologies that have been developed for other NASA flight programs. Figure 11 depicts the different components of the CRaTER assembly.

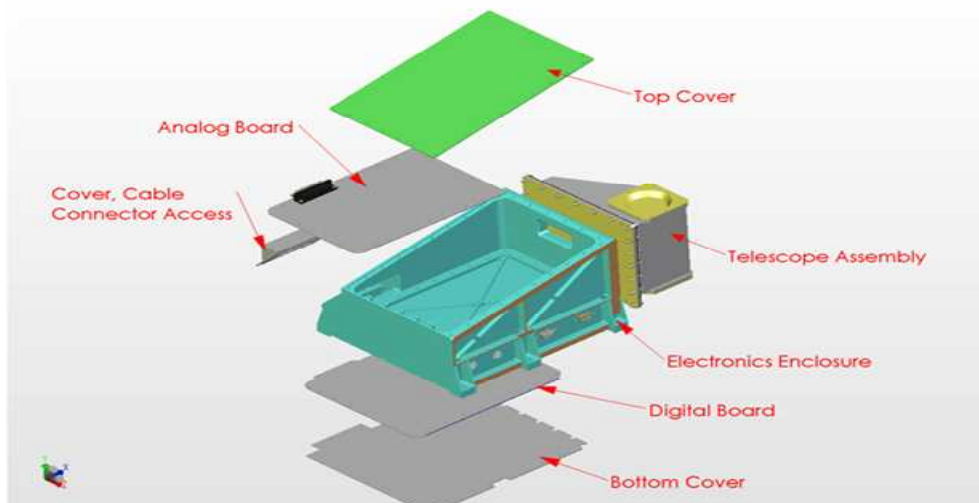


Figure 11. The CRaTER Detector Assembly [13]

The detector stack consists of six silicon detectors divided into three pairs. Each pair consists of a thin detector (140 μ m) and a thick detector (1mm).

Solid state detectors use semiconducting crystals (in CRaTER's case, silicon) with n-type (electron-rich, electron conducting) and p-type (electron-deficient, hole conducting) sectors.

When a reversed bias voltage is applied at the p-type side, the unbonded electrons in the semiconductor are pushed away from the voltage source, while the holes are pulled towards it. This leaves a neutral area void of charge and current at the junction of the sectors, called the depletion region. As incoming radiation (e.g. protons) collide with the depletion region, electron-hole pairs are formed in the material (where a once bonded electron is freed from its atom, leaving a hole). The electron and the hole respond to the applied voltage, and a small current is created. This current can be detected and later analyzed.

A cold environment greatly reduces the transmission of thermal signals. In addition, the solid state of the semiconducting material makes it easier to detect those signals attributable to freed electrons. Figure 12 shows the plot of the electronic, nuclear and total stopping power for protons in silicon as a function of proton energy [14].

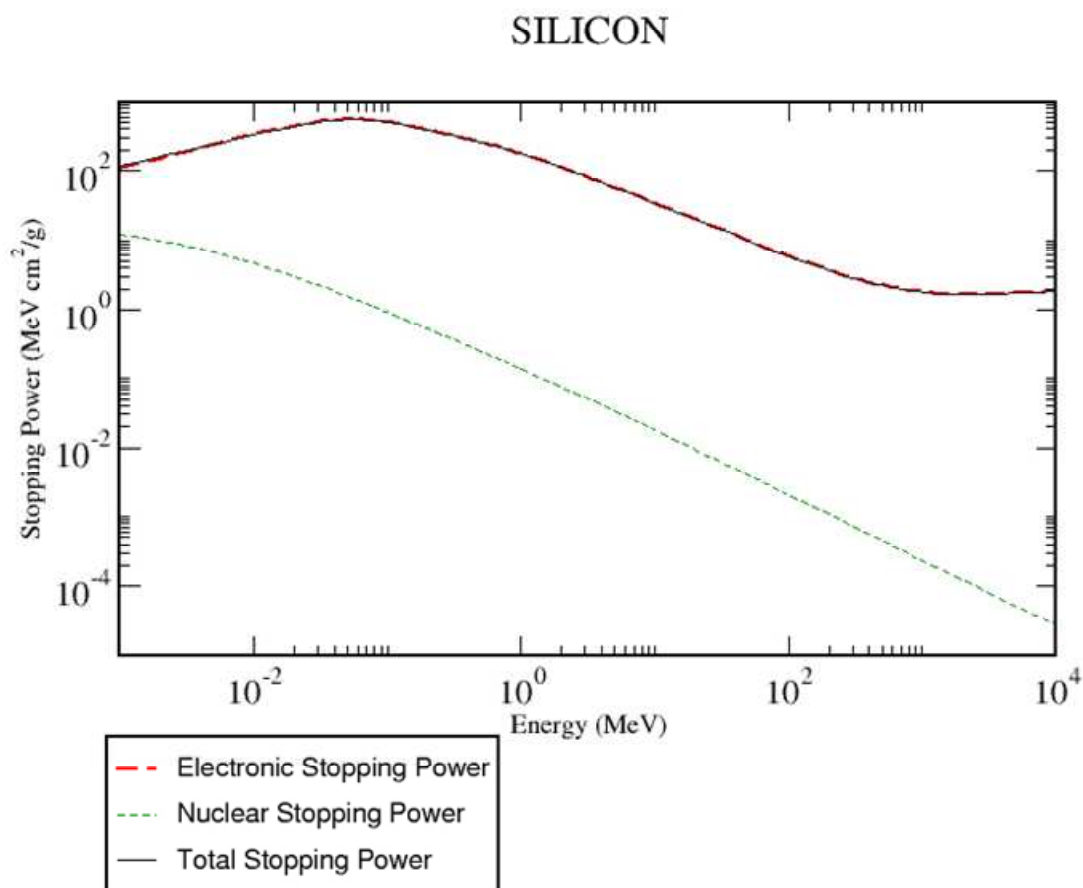


Figure 12. Stopping Power of Protons in Silicon [14]

Sandwiched between each pair of detectors is a section of A-150 tissue-equivalent plastic (TEP).

Tissue equivalent plastic (or TEP) is a plastic recipe designed to simulate human tissue. It includes hydrogen and nitrogen percentages-by-composition that are similar to that found in human skin and muscle. Scientists can use the atomic-level effects that radiation has on the TEP to deduce what sort of similar effects may occur in humans. It has a density of 1.127 g/cm^3 and composition by weight as listed in table 6.

Table 6. Atomic composition of A-150 by weight

Atomic Number	Fraction by weight
1	0.101327
6	0.775501
7	0.035057
8	0.052316
9	0.017422
20	0.018378

Figure 13 shows the plot of the electronic, nuclear and total stopping power for protons in A-150 Tissue Equivalent Plastic as a function of proton energy [14].

A-150 TISSUE-EQUIVALENT PLASTIC

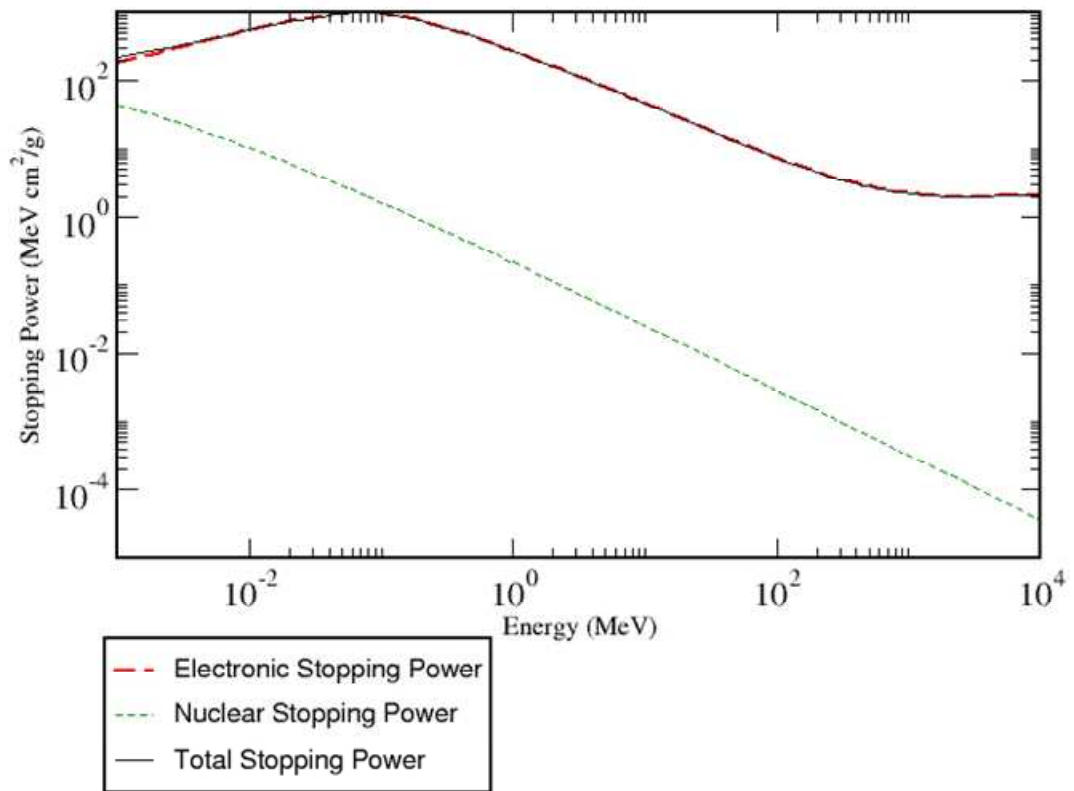


Figure 13. Stopping Power of Protons in A-150 [14]

Starting with the zenith end of the detector stack, which faces out into space, and working toward the nadir end, which faces the lunar surface, there is a silicon detector pair (D1-D2), then 5.4 cm of A-150 TEP, then another detector pair (D3-D4), followed by 2.7 cm of A-150 TEP, and the final detector pair (D5-D6).

Figure 14 shows the configuration of the CRaTER detector. Table 7 lists the characteristics of the CRaTER detector.

CRaTER Telescope Configuration

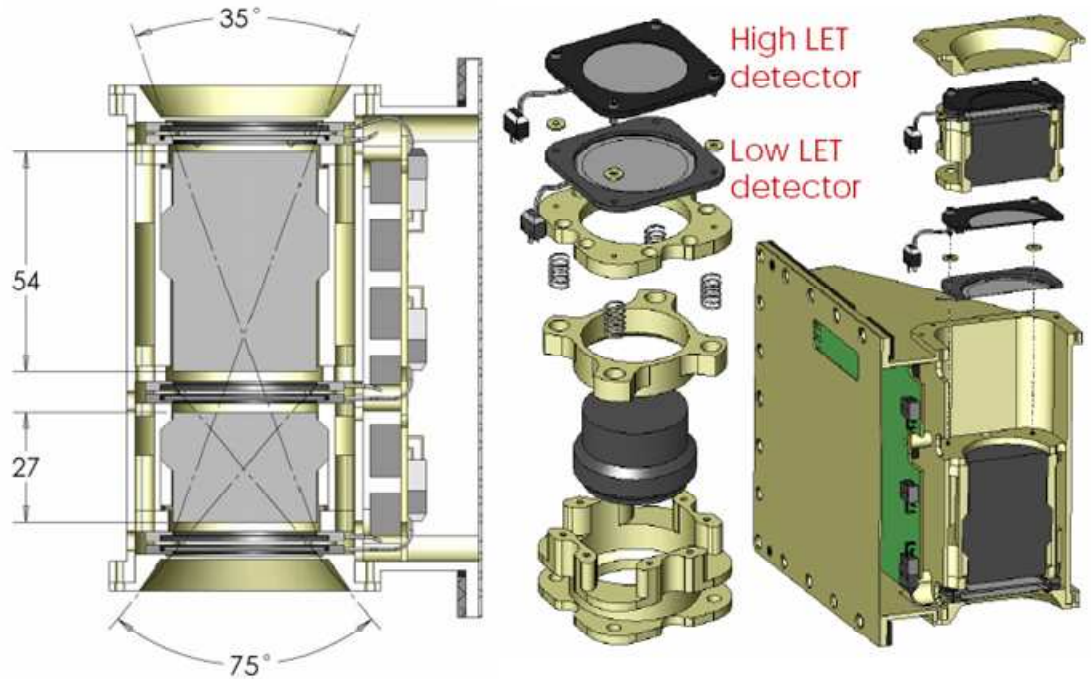


Figure 14. The CRaTER Telescope Configuration [14]

Table 7. Characteristics of The CRaTER Detector [14]

Low LET detectors	9.6 cm ² circular, 1000 microns thick. 0.2 MeV threshold
High LET detectors	9.6 cm ² circular, 140 microns thick. 2 MeV threshold
TEP absorber 1	5.4 cm cylinder
TEP absorber 2	2.7 cm cylinder
Zenith FOV	35 degrees, 6-detector coincidence
Nadir FOV	75 degrees, for D3D4D5D6 coincidence
Geometry factor	0.1 cm ² sr (D1D2 events)
LET range	0.2 - 7 MeV/micron (Si)
Incident particle energy range	>20 MeV (H) >87 MeV/nucleon (Fe)

In principle, the detector operates as follows:

1) An energetic charged particle from space enters the telescope at the top through D1.

The particle deposits energy in the components through ionization of the detector components. Nuclear interactions produce numerous energetic secondary particles, which also deposit energy.

2) Primary and secondary particles interact with one or more detectors. Thin detectors respond to high LET particles. Thick detectors respond to low LET particles.

3) Detectors with sufficient energy deposition cross the trigger threshold.

4) Digital logic compares coincidences with an event mask of desirable events.

5) Pulse height analysis (PHA) is conducted on every detector to measure energy deposition.

Once the LRO mission begins, LET measurements in the TEP sections will be obtained using

$$LET = \frac{dE}{dx} = \frac{E_0 - E_f}{L} \quad (5)$$

Where

E_0 and E_f are the energies of the particles as measured by the silicon detectors at either end of each TEP section

L is the length of the TEP material.

The detectors map as follows:

- Thin detectors (D1, D3, D5) map 0 –300 MeV.
- Thick detectors (D2, D4, D6) map 0 -100 MeV.

There are 4096 channels in the instrument. This results in 73.3 keV/bin for thin (140 μ m) and 24.4 keV/bin for thick (1000 μ m) detectors [14].

4. CHARACTERIZATION OF CRATER

To properly support CRaTER's mission, knowledge of the detector's response to the lunar radiation environment is necessary in advance. For this reason, the research presented herein is to characterize CRaTER's probable response to various scenarios.

Three CRaTER models were built, one Engineering Model (EM), and two Flight Models: Flight Model 1 (FM1) that will be launched into lunar orbit, and Flight Model 2 (FM2), which is a back up instrument. Figure 15 shows the dimensions of all three models.

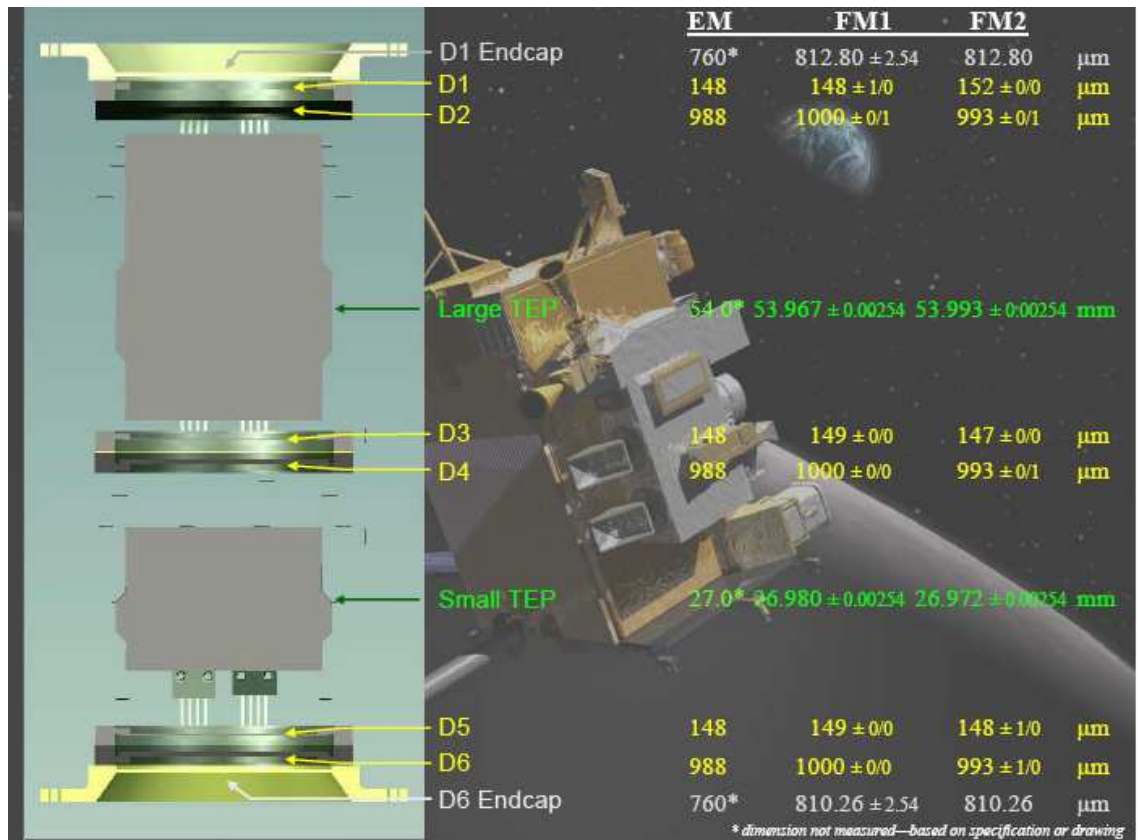


Figure 15. Engineering and Flight Models Dimensions [15]

The EM was used for calibration purposes, and the model was used for comparisons with ground based experiments.

For the GCR and SPE predictions, the FM1, which will be launched into space, was modeled.

4.1. HETC-HEDS

The High Energy Transport Code for Human Exploration and Development in Space (HETC-HEDS) was the Monte Carlo three dimensional code used in this work.

HETC-HEDS simulates particle cascades by using Monte Carlo methods to compute the trajectories of the primary particle and all the secondary particles produced in nuclear collisions [16]. The particles considered by HETC-HEDS (protons, neutrons, π^+ , π^- , μ^+ , or μ^- , light ions and heavy ions) can be arbitrarily distributed in angle, energy, and space. Each particle in the cascade is followed until it disappears by escaping from the boundaries of the system, undergoes a nuclear collision or absorption, comes to rest due to energy losses from ionization and excitation of atomic electrons in the target medium, or, in the case of pions and muons, decays. Neutrons produced below a specified cutoff, usually 20 MeV, and photons produced in the cascade from π^0 decays or from deexcitation are not transported. Information regarding the neutrons and photons is stored for transport by other codes such as MORSE [17], MCNP [18], and EGS [19]. HETC-HEDS provides a complete history file of all cascades so that analyses of specific problems can be performed.

The energy losses of protons, light and heavy ions, charged pions, and muons due to the excitation and ionization of target atomic electrons are treated using the Bethe stopping power formula [20] based on the continuous slowing-down approximation.

Bethe derived the following expression for the stopping power for a charged particle:

$$-\frac{dE}{dx} = \frac{4\pi k_0^2 Z^2 e^4 n}{mc^2 \beta^2} \left[\ln \frac{2mc^2 \beta^2}{I(1 - \beta^2)} - \beta^2 \right] \quad (6)$$

Where

$$k_0 = 8.99 \times 10^9 \text{ N.m}^2.\text{C}^{-2}$$

Z = effective charge of the heavy particle

e = magnitude of the electron charge

n = number of electrons per unit volume in the medium

m = electron rest mass

c = speed of light in vacuum

$\beta = v/c$ = speed of the particle relative to c

I = mean excitation energy of the medium

The assumption in this work is that the unrestricted stopping power (dE/dx) is equal to LET_∞ . The term unrestricted refers to the amount of energy lost by particles without restricting the amount of energy lost to a particular cutoff values.

One could note from equation (6) that LET_∞ depends on two variables, Z and β . The dependence on Z translates into an increase in the LET_∞ value for particles traversing a medium as the Z of the incident particle increases, whereas the dependence on β translates into an increase in the LET_∞ as the speed of the incident particle decreases.

Note that as the atomic number of the target medium increases, n increases and thus, LET_{∞} also increases.

Range straggling is taken into account. Range-energy tables for each material in the system are computed for protons. These same tables are used for nuclei with mass numbers $A > 1$, and for charged pions and muons by making use of scaling relations. HETC-HEDS currently allows multiple Coulomb scattering only for the primary charged particles.

Pion production is based on the isobar model of Sternheimer and Lindenbaum [21]. Only single- and double-pion production in nucleon-hydrogen collisions and single-pion production in pion-nucleon collisions are accounted for. This model is used for energies up to 3.5 GeV for neutrons and protons and up to 2.5 GeV for charged pions. Nonelastic nucleon collisions and charged-pion collisions with hydrogen nuclei at energies above 3.5 GeV and 2.5 GeV, respectively, are treated by using the calculational methods of Ref. [22]. Special provisions are made to insure that energy and nucleons are conserved for each collision. Efforts are underway, but not yet completed, to incorporate pion production channels for collisions involving light and heavy ions. Charged-pion decay is taken into account using the known pion lifetime. The neutrino produced in the decay is ignored. The neutral pion is assumed to decay into two photons at its point of origin. HETC-HEDS does not transport neutral pions. However, the energy, direction, and spatial location of the neutral pions produced are included as part of the output. Muon decay in flight is taken into account using the

known muon lifetime. Muons that come to rest are assumed to decay immediately. No information about the electrons, positrons, or neutrinos produced from muon decay is calculated.

Elastic collisions of protons and pions with all nuclei other than hydrogen are neglected at all energies. Elastic collisions of light and heavy ions with target nuclei are treated using cross sections obtained from an optical potential model derived from quantum multiple scattering theory. The angular dependence is obtained using a Fraunhofer approximation. Details are provided in Ref. [23]. Elastic collisions by neutrons with nuclei other than hydrogen at energies above the neutron cutoff energy (usually 20 MeV) is optional, and if the option is chosen, requires the input of elastic scattering cross section data (σ_s and $d\sigma_s/d\Omega$).

The intranuclear-cascade evaporation concept of particle-nucleus interaction, as modeled by Bertini [24], is used to model the particle-nucleus collisions below 3.5 GeV for nucleons and below 2.5 GeV for charged pions. Following the intranuclear-cascade, the residual excitation energy is treated using an evaporation model [25]. The particles allowed to evaporate are protons, neutrons, d, ^3H , ^3He , and α . An extrapolation model determines the energy, angle, and multiplicity of the products from inelastic nucleon-nucleus and pion-nucleus collisions at higher energies (3-15 GeV) [26]. Heavy ion interactions are modeled using the new event generator. In this event generator, nucleus-nucleus collision total cross sections are based upon an optical potential approximation of a nucleus-nucleus multiple scattering formalism [27, 28]. Nucleus-nucleus reaction cross sections are described using the parameterization due to Tripathi

[29]. Breakup of light ions ($Z < 2$) is divided into 3 pieces, which are (1) deuteron breakup, (2) alpha fragmentation, and (3) ^3H and ^3He breakup. Finally, breakup of heavy ions ($Z > 2$) is described using the semi-empirical fragmentation model NUCFRG2 developed at NASA Langley Research Center [30-31].

4.2. Comparison with ground-based calibrations

The first part of this research was to perform a benchmarking study of simulations by comparing them against calibrations performed in various facilities to validate the use of the HETC-HEDS code and to better understand the detector's response.

Calibration of CRaTER has been carried out at Massachusetts General Hospital Proton Therapy Facility (MGH) using various Proton beam energies, and at Brookhaven National Laboratory (BNL) using various heavy ion beams.

Once all beam corrections were implemented into HETC-HEDS, the calibration procedure was mimicked, simulated, and compared with experiment.

4.2.a. Comparisons with proton beams

Proton beam experiments were carried out at the Massachusetts General Hospital (MGH) Proton Therapy Center. The EM was exposed to various proton energies at various exposure rates. Representative results for energies of 115, 117, and 200 MeV impinging on the zenith side of CRaTER are presented in the next section.

4.2.a.i. 115 MeV Proton Beam

Results for the 115 MeV proton beam are shown in figures 16 through 21. The results show energy deposition comparisons of responses for all six detectors between

calibration data and HETC-HEDS simulations. The x-axis is channel number and y-axis is the number of counts.

Responses of the thin detectors (detectors one, three, and five) are in a fair agreement, but it was difficult to obtain a better agreement because those detectors are very thin, and not much energy is deposited in each.

Detectors two and four (thick detectors) have a much better agreement especially that the peaks match. The reason for detector six's discrepancy is because a proton with an energy of 115 MeV has a range that is equal to the thickness of the detector. Thus, the Bragg peak occurs in detector six, and the agreement is not expected to be very good. This is because of the statistical behavior of particles where not all particles will stop exactly in the same place, and therefore will not have the same range (Range Straggling).

4.2.a.ii. 117 MeV Proton Beam

Comparisons for the 117 MeV proton beam are depicted in figures 22 through 27. The comparisons are in a very good agreement for the first five detectors (1 through 5) where the peaks match almost perfectly. The reason for the discrepancy for detector six's response is the same reason mentioned for the 115 MeV beam comparison.

4.2.a.iii. 200 MeV Proton Beam

Comparisons for the 200 MeV proton beam are depicted in figures 28 through 33.

Now that the range of the 200 MeV proton is more than the total thickness of CRaTER, the agreement is almost perfect for all six detectors.

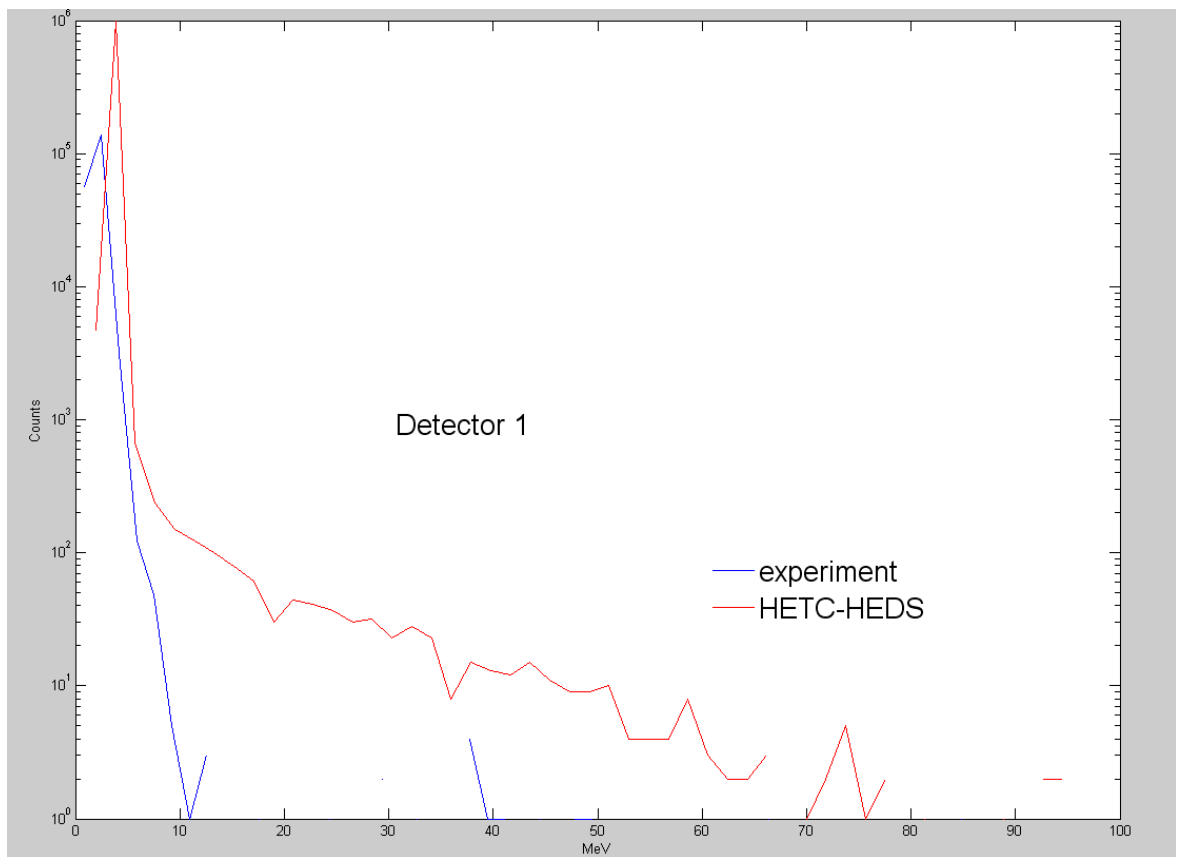


Figure 16. Detector 1 Response for 115 MeV Proton Beam

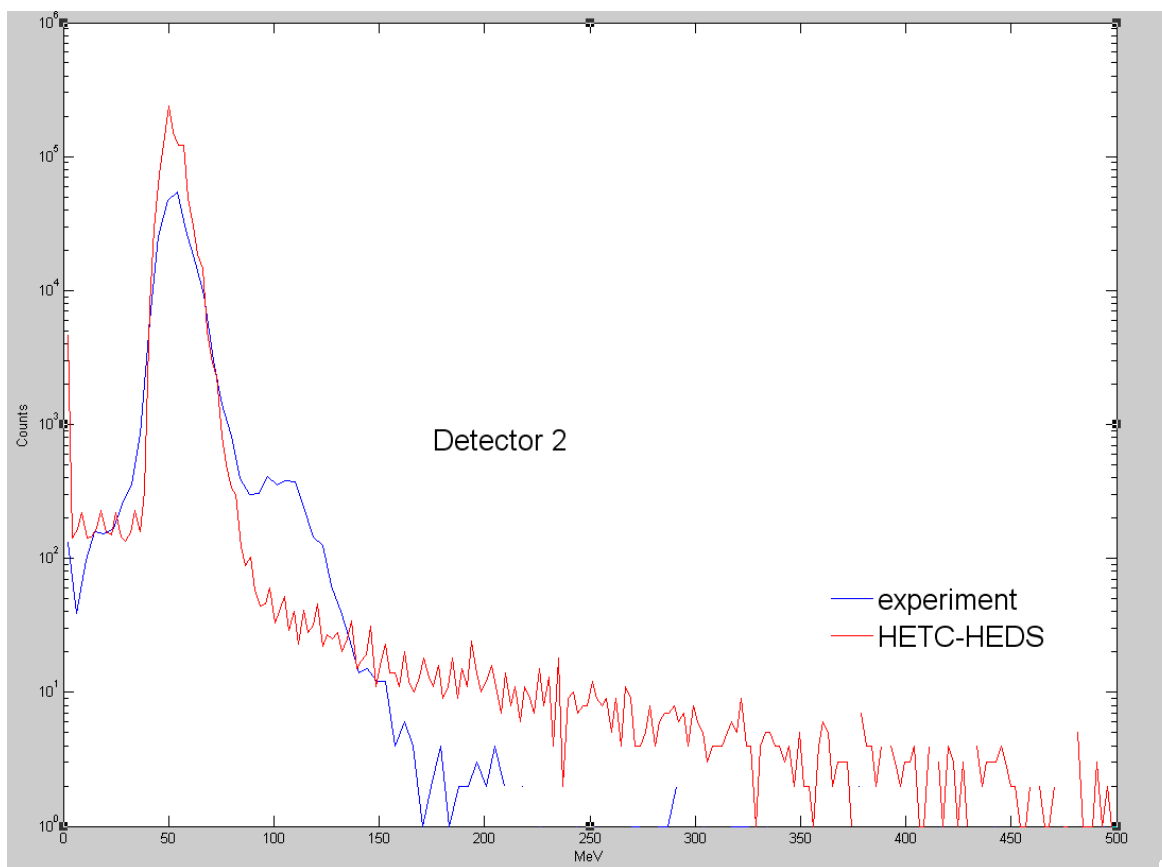


Figure 17. Detector 2 Response for 115 MeV Proton Beam

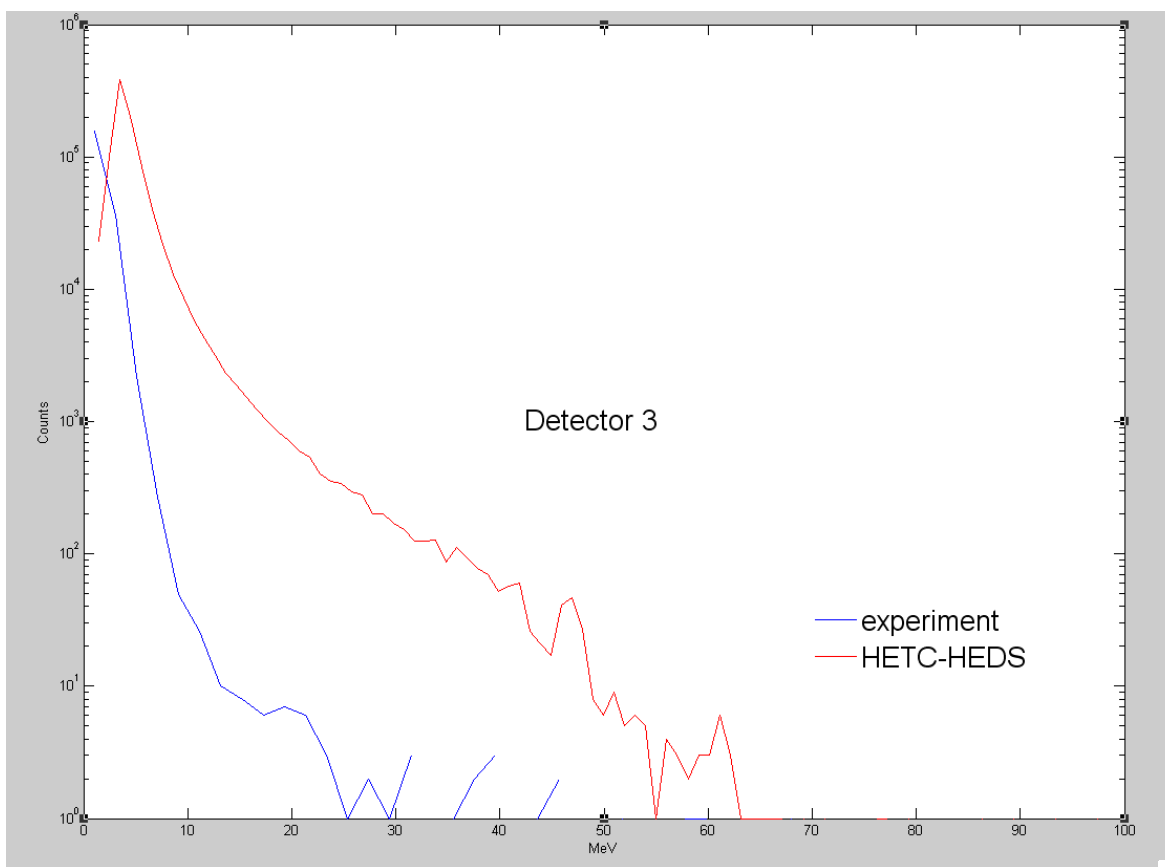


Figure 18. Detector 3 response for 115 MeV Proton Beam

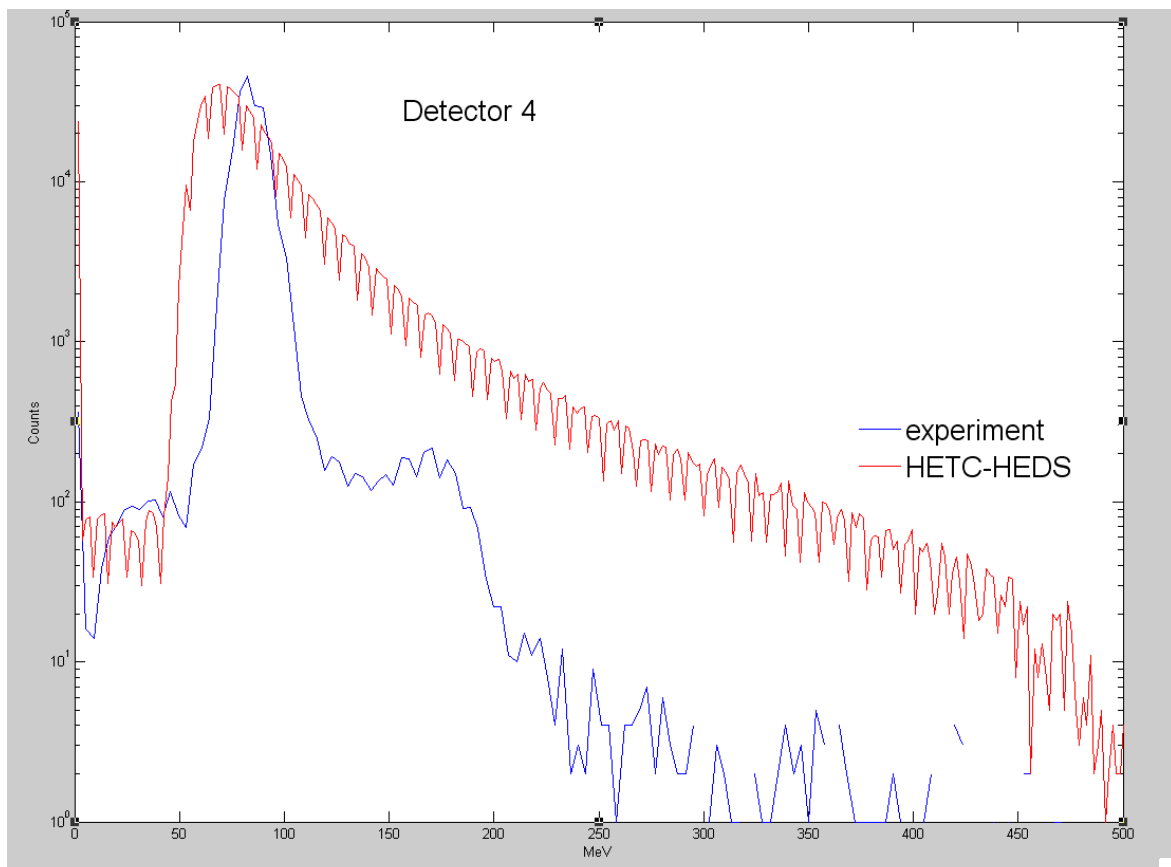


Figure 19. Detector 4 Response for 115 MeV Proton Beam

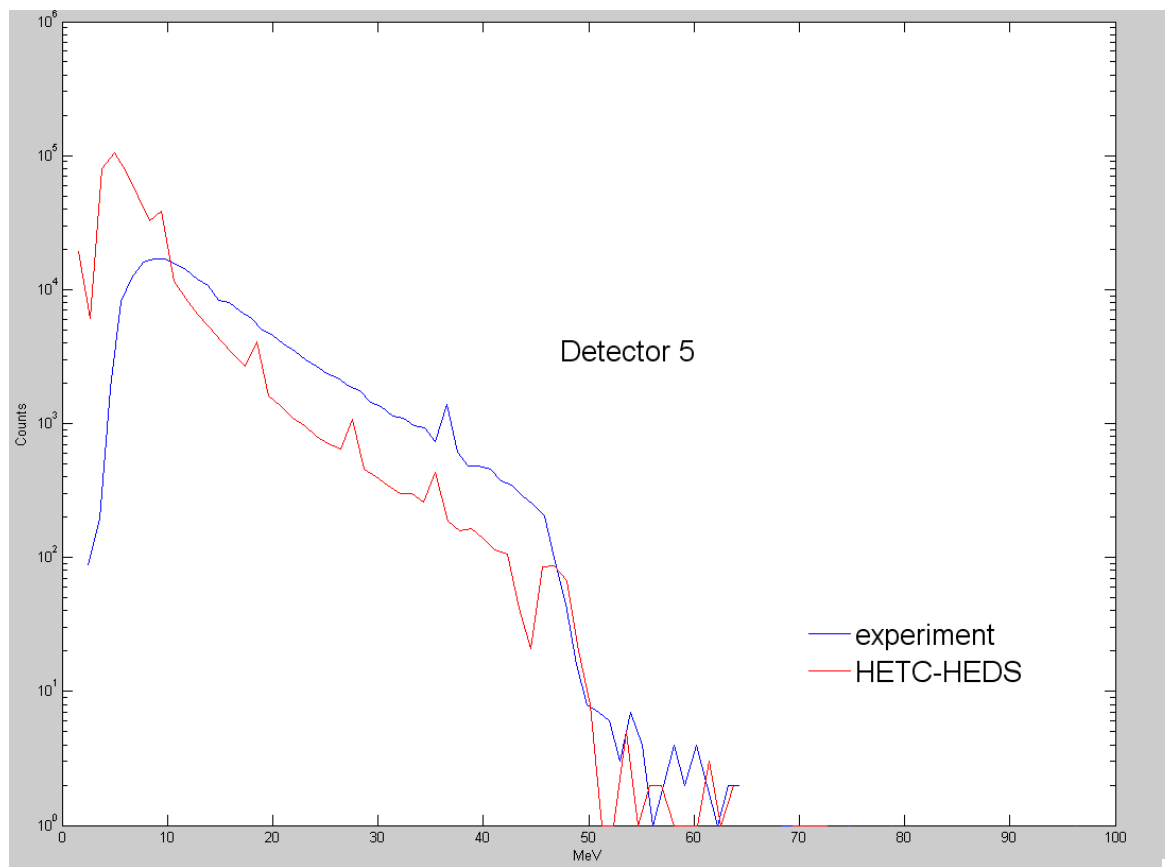


Figure 20. Detector 5 Response for 115 MeV Proton Beam

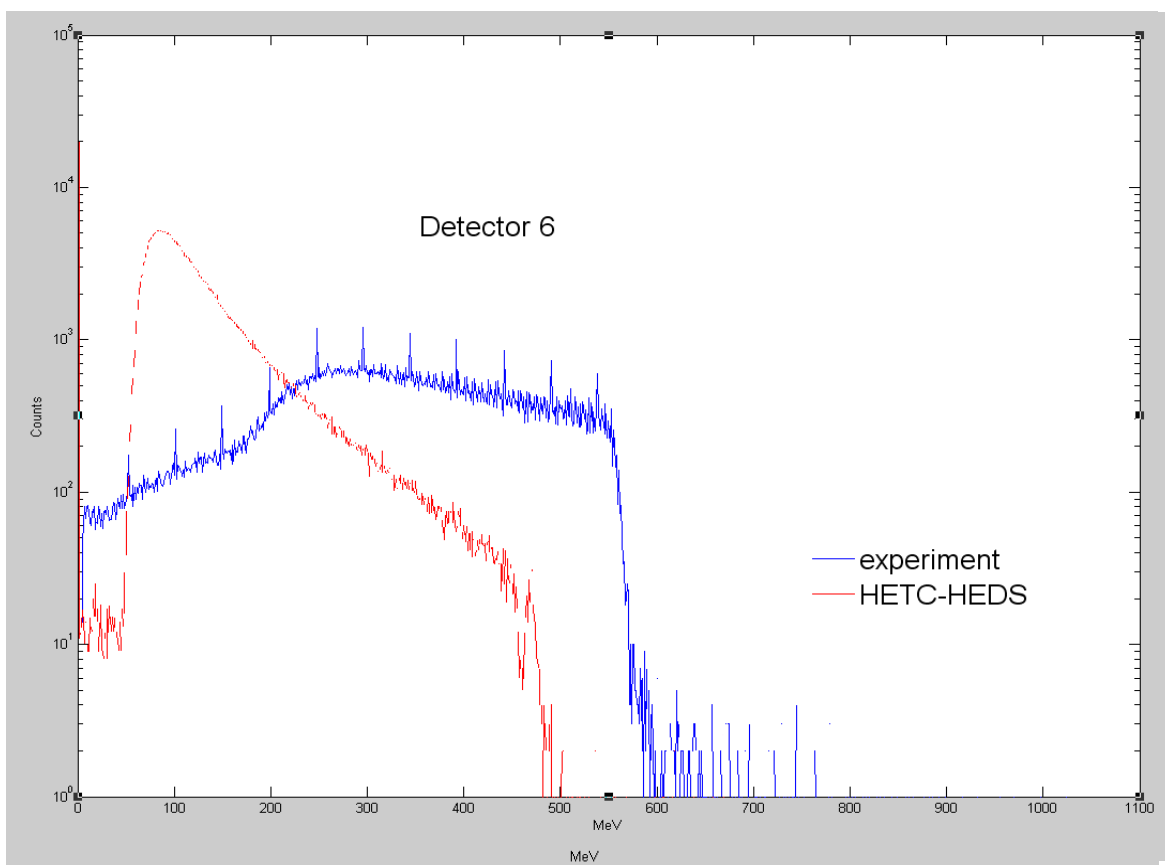


Figure 21. Detector 6 Response for 115 MeV Proton Beam

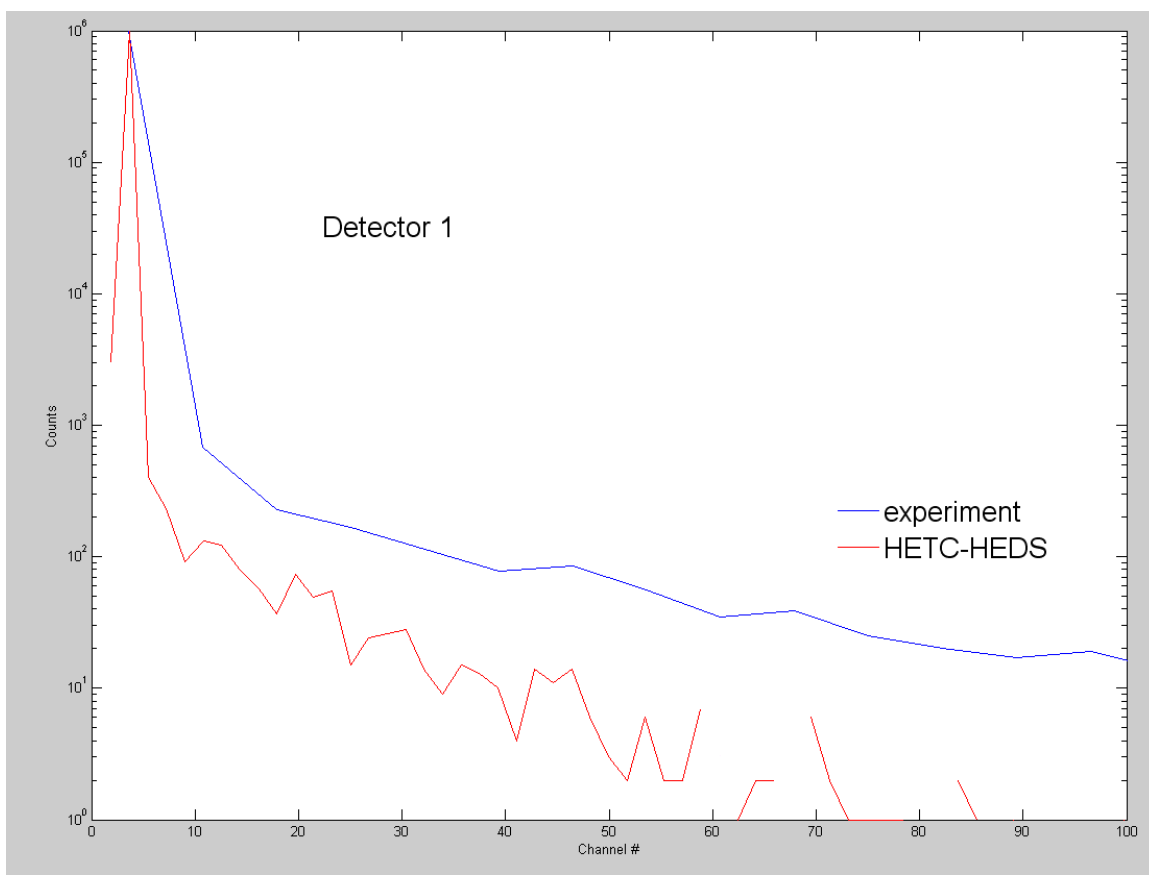


Figure 22. Detector 1 Response for 117 MeV Proton Beam

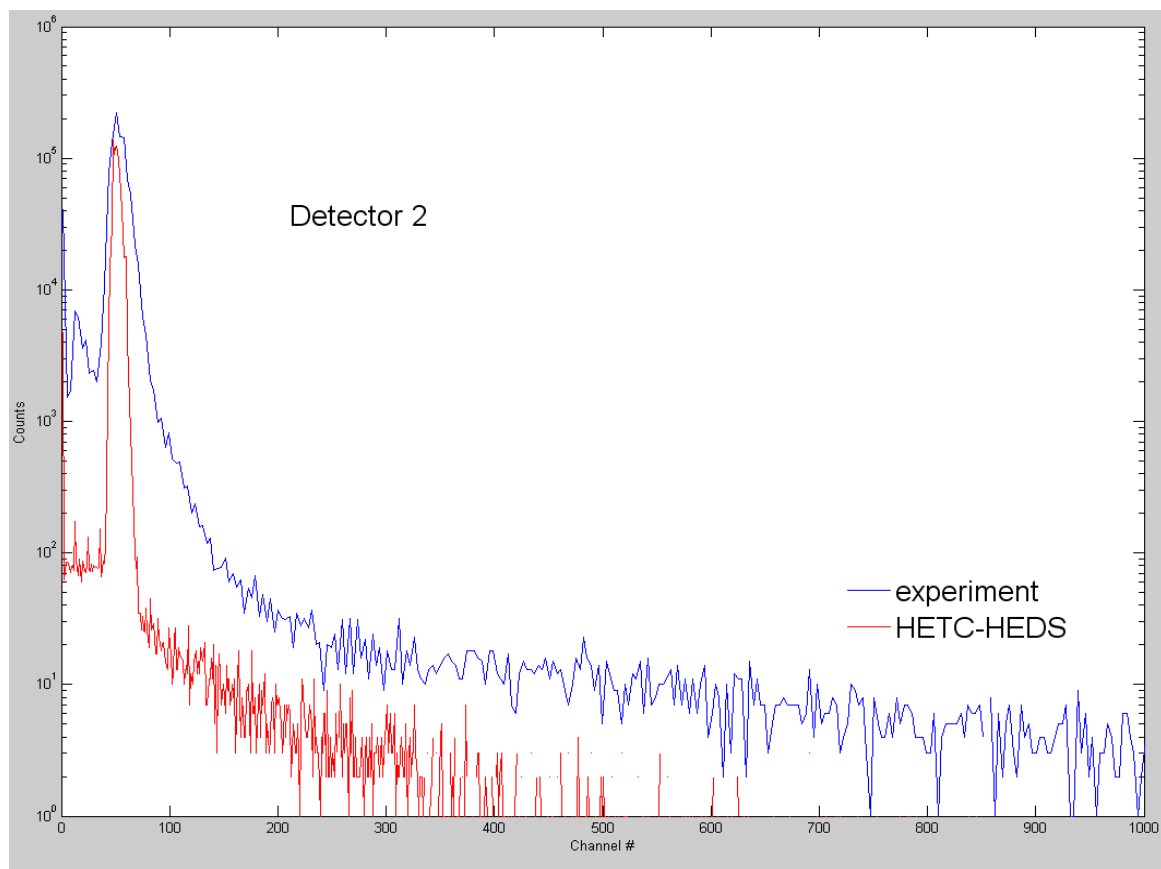


Figure 23. Detector 2 Response for 117 MeV Proton Beam

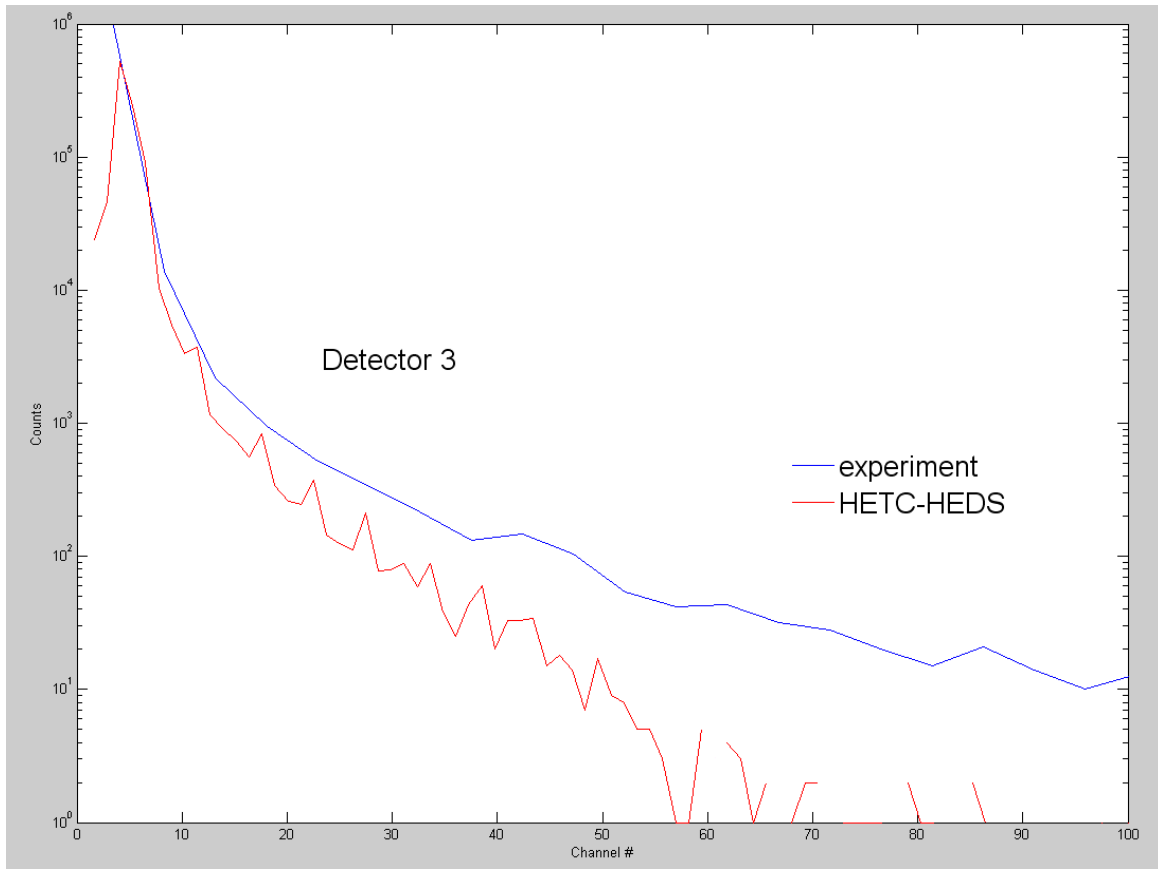


Figure 24. Detector 3 Response for 117 MeV Proton Beam

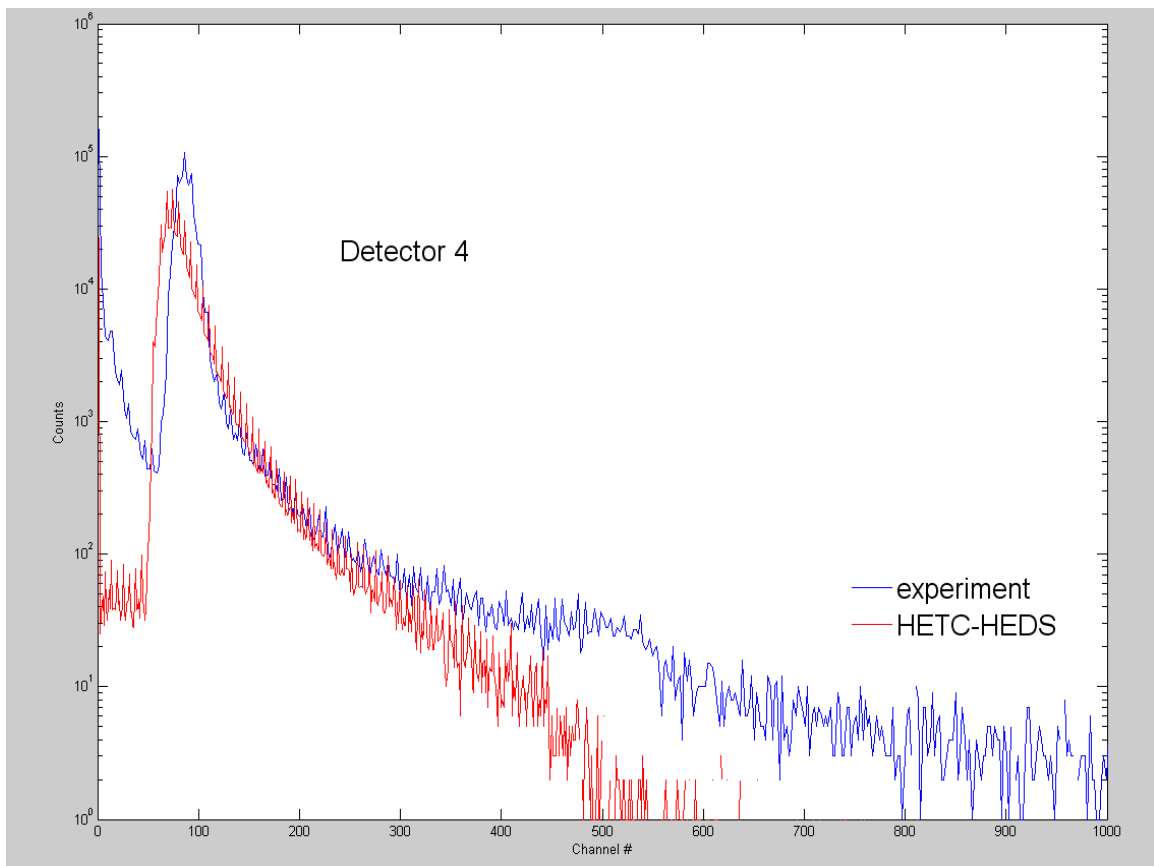


Figure 25. Detector 4 Response for 117 MeV Proton Beam

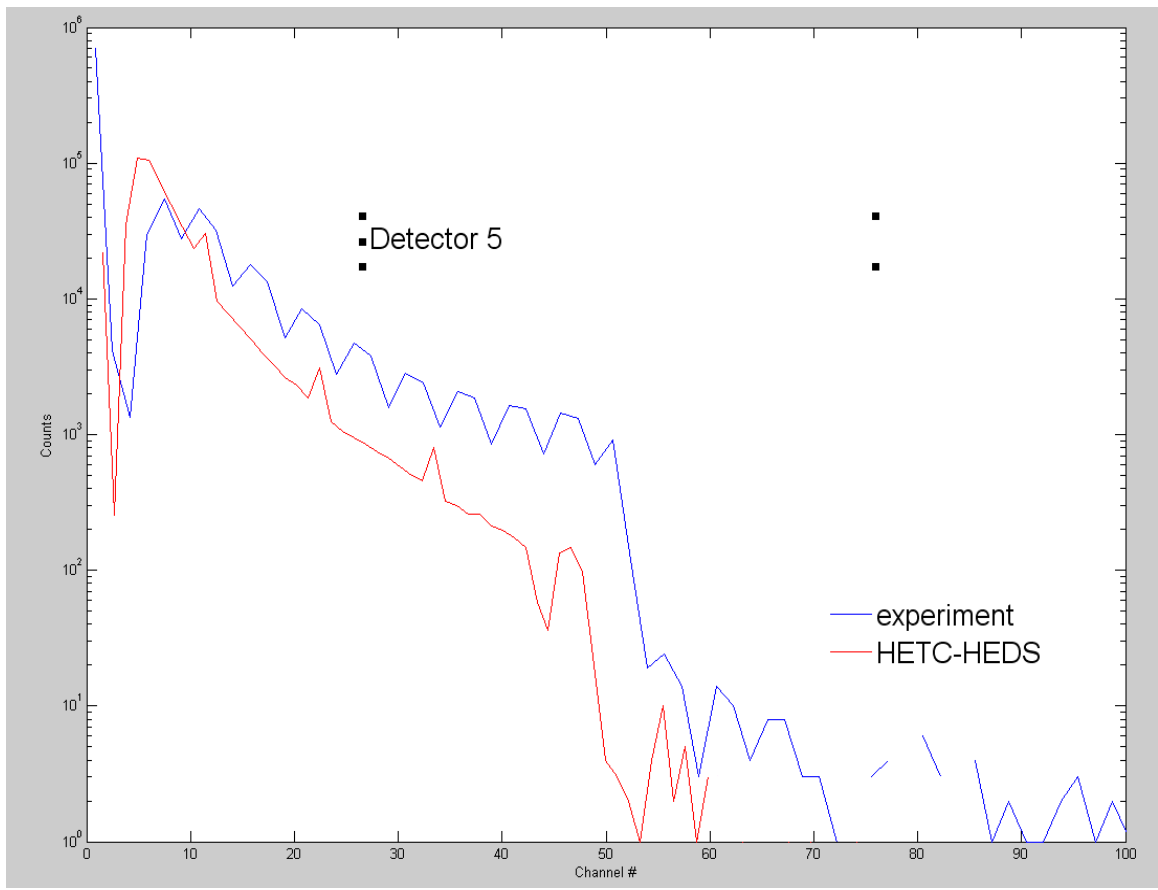


Figure 26. Detector 5 Response for 117 MeV Proton Beam

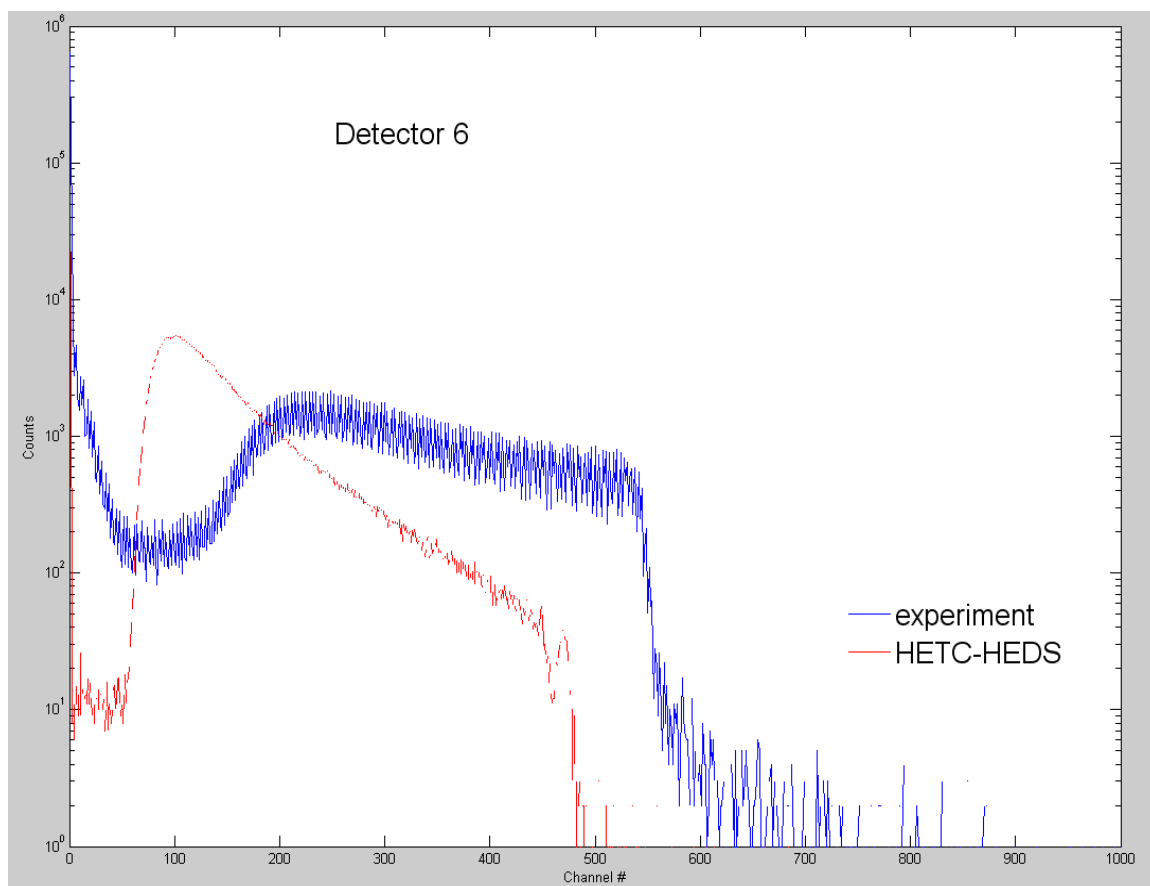


Figure 27. Detector 6 Response for 117 MeV Proton Beam

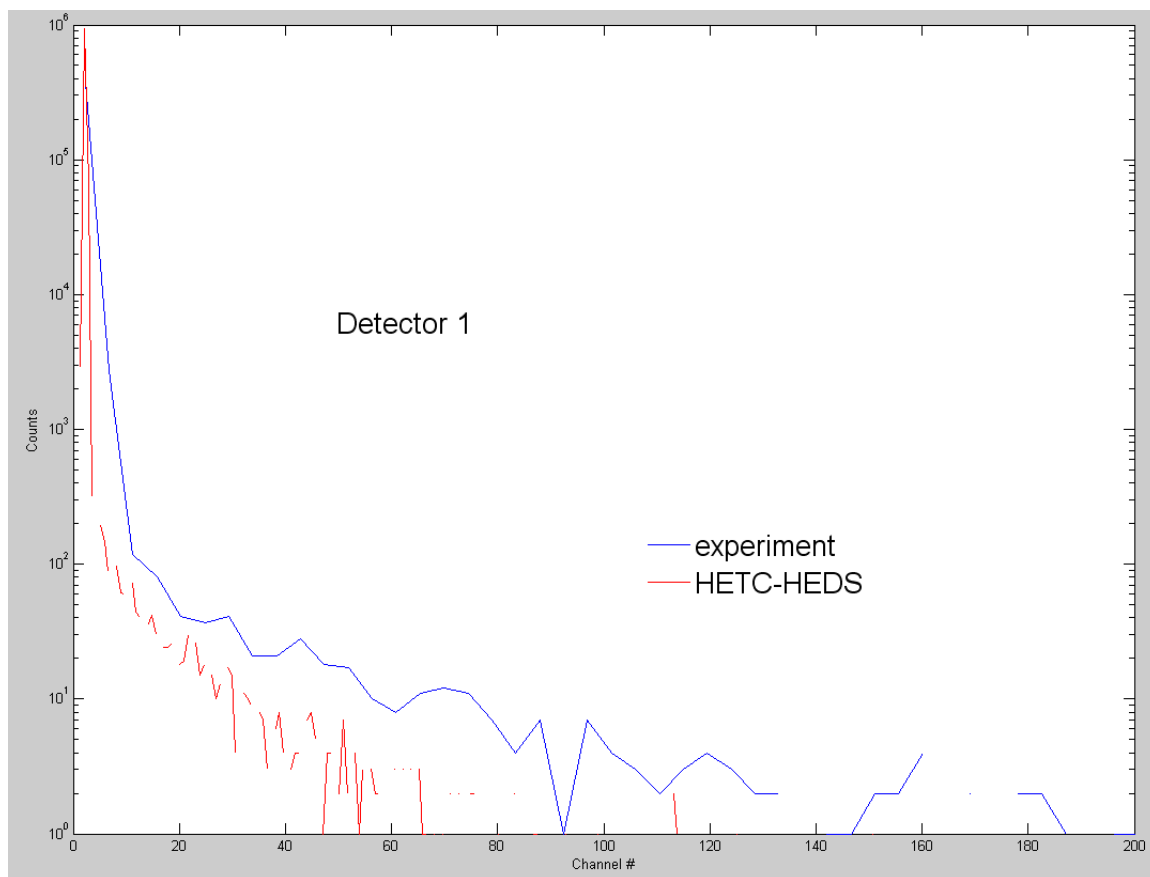


Figure 28. Detector 1 Response for 200 MeV Proton Beam

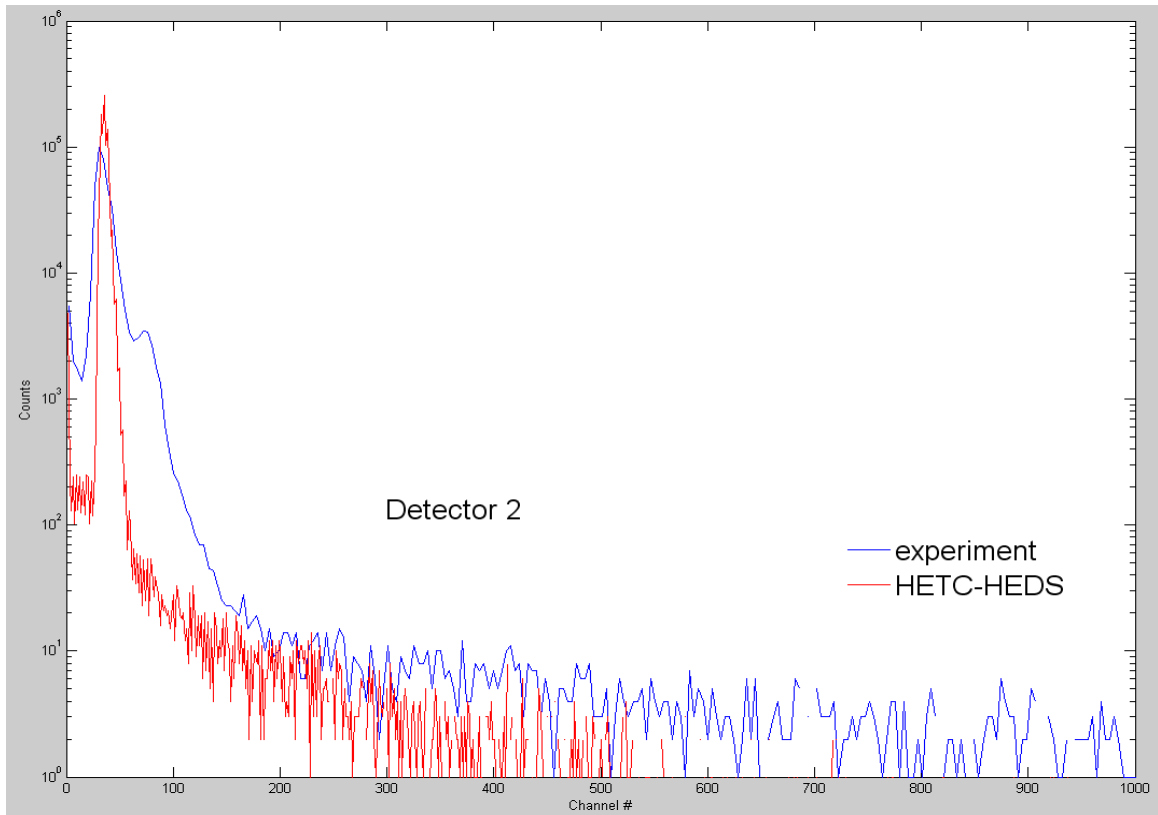


Figure 29. Detector 2 Response for 200 MeV Proton Beam

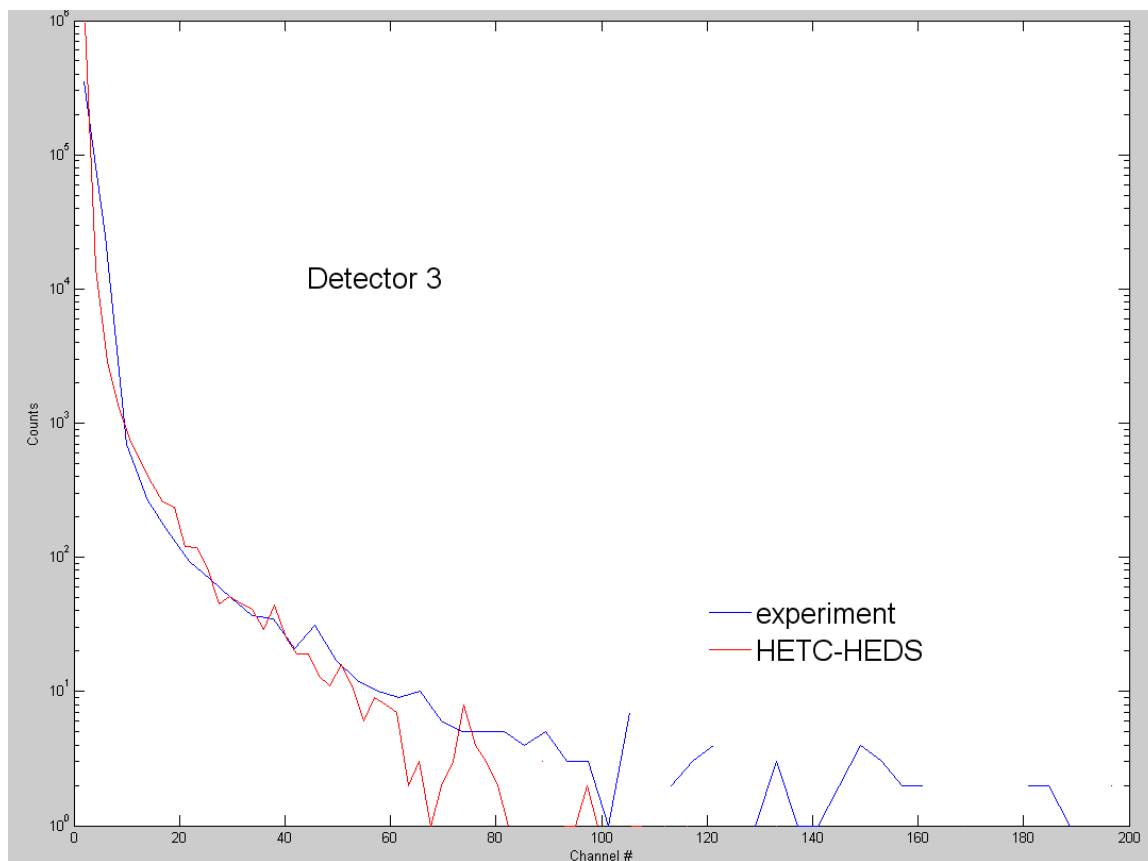


Figure 30. Detector 3 Response for 200 MeV Proton Beam

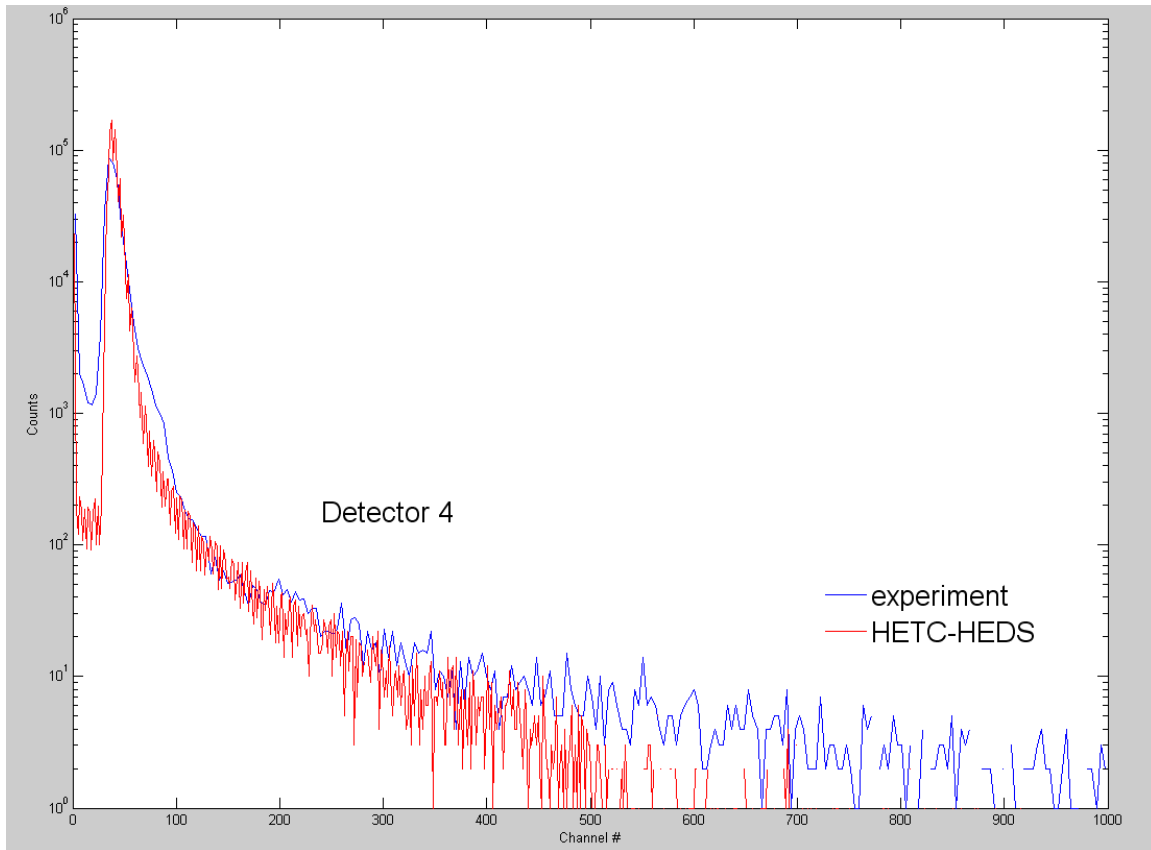


Figure 31. Detector 4 Response for 200 MeV Proton Beam

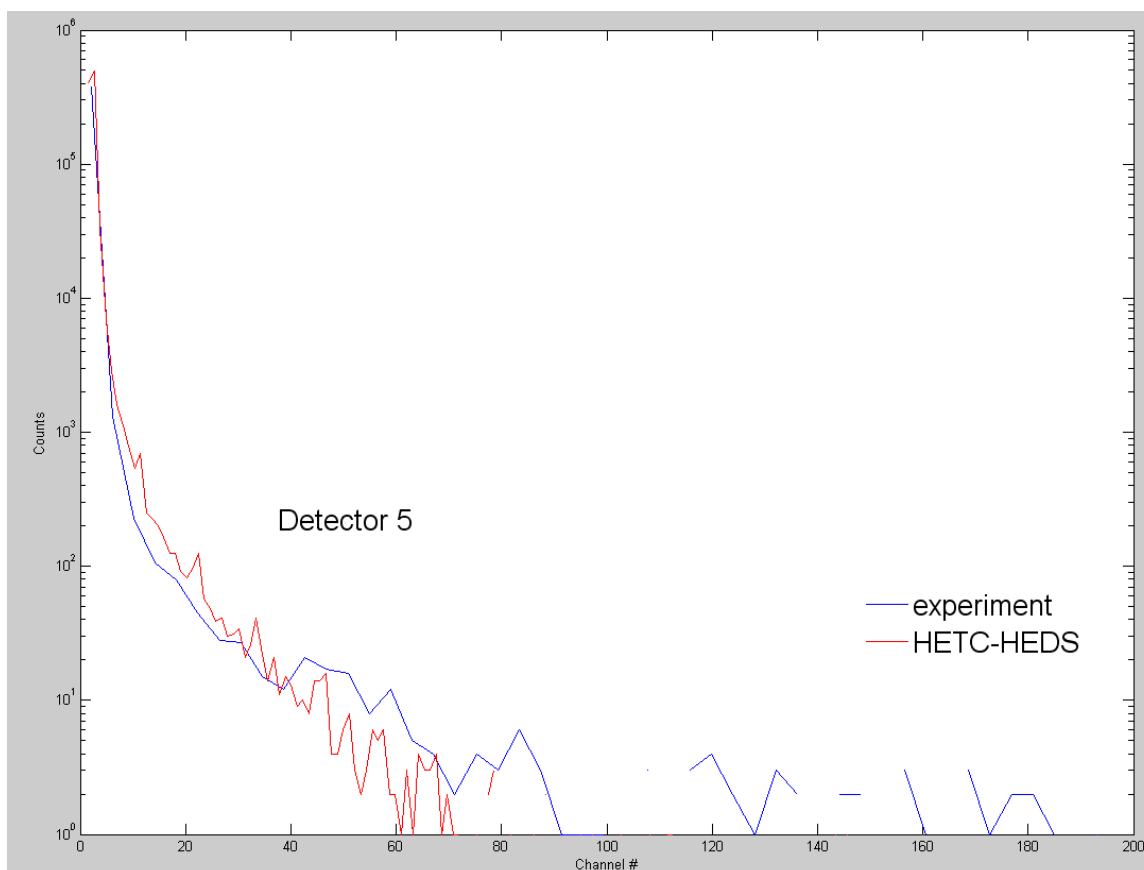


Figure 32. Detector 5 Response for 200 MeV Proton Beam

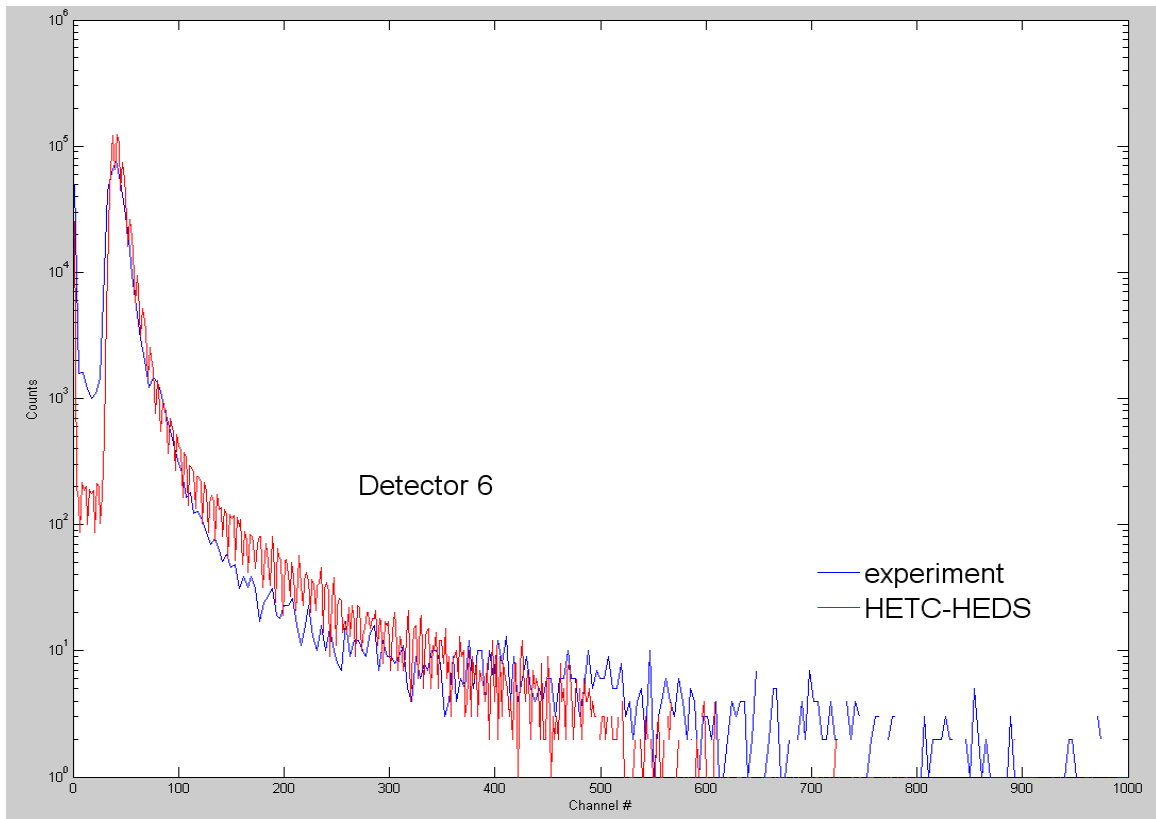


Figure 33. Detector 6 Response for 200 MeV Proton Beam

4.2.b. 600 MeV/nucleon Silicon Beam

The comparisons for a 600 MeV/nucleon silicon beam are depicted in figures 34 through 39. The calibration runs were carried out at the Brookhaven National Laboratory (BNL). Because silicon is a much heavier element than hydrogen, its Linear Energy Transfer (LET) is much higher. It can be clearly seen that the energy deposited in each of the detectors is much higher than energy deposited by the previous proton calibration runs. In this case, projectile and target fragmentation cross sections become very important. It could be seen in the comparison among the thin detectors that the predictions obtained with HETC-HEDS are somewhat shifted to the right. (higher channel numbers). The problem with benchmarking heavy ion calibration runs lies in taking into account all beam corrections when simulating the runs with HETC-HEDS. These could vary from an unknown dead layer thickness in the silicon detectors, spread in momentum of the primary beam, and exact energy impinging the target (CRaTER). So the shift in the peaks in the thin detectors case could be a result of either an actual thicker dimension of the detector than reported, or smaller primary beam energy than reported. This shift in energy deposition could also be seen in the case of the thicker detectors response. For the silicon comparison, the energy was assumed to be 600 MeV/nucleon and the spread in momentum was assumed to be 3 percent. The peaks seen in the figures correspond to the fragments from either the projectile or the target that in turn will mostly deposit their energy locally inside the particular detector being compared (peaks one through thirteen). In conclusion, comparisons for the 600 MeV/nucleon silicon calibration is in fair agreement with the HETC-HEDS simulation.

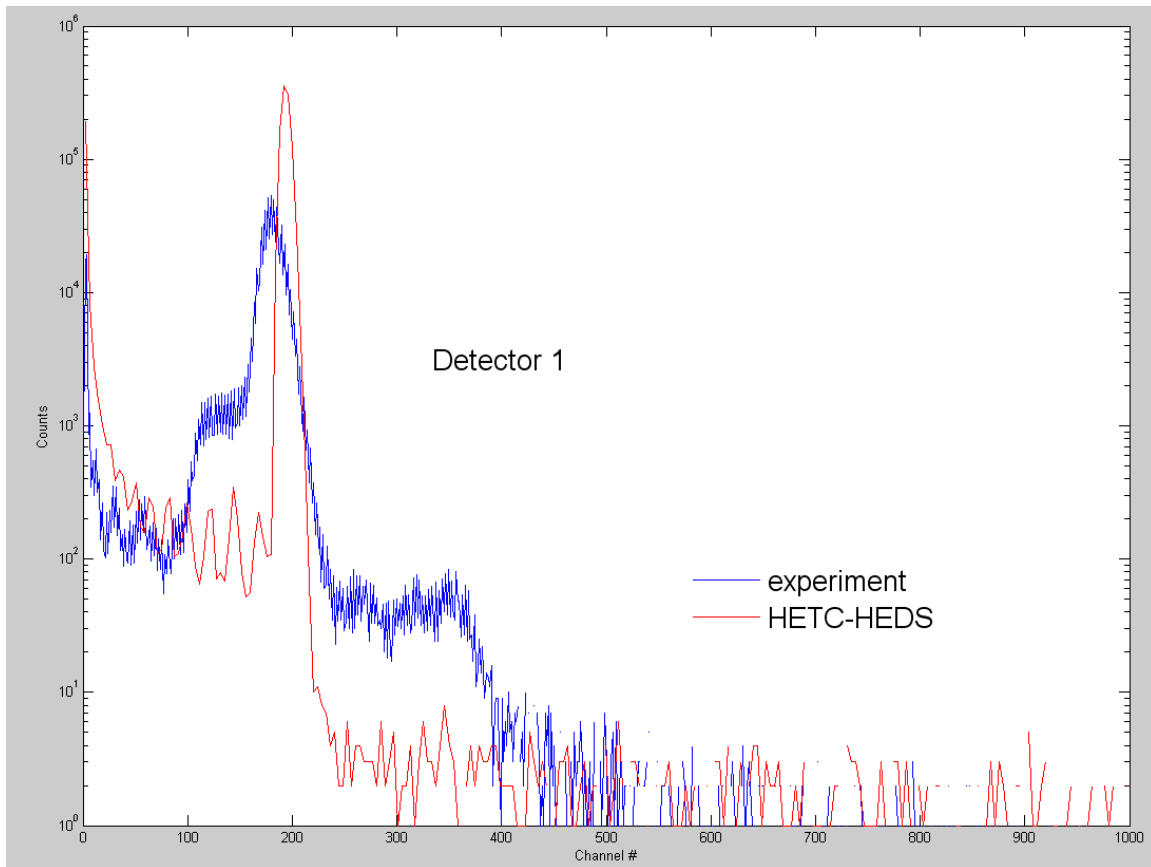


Figure 34. Detector 1 Response for 600 MeV/nucleon Si Beam

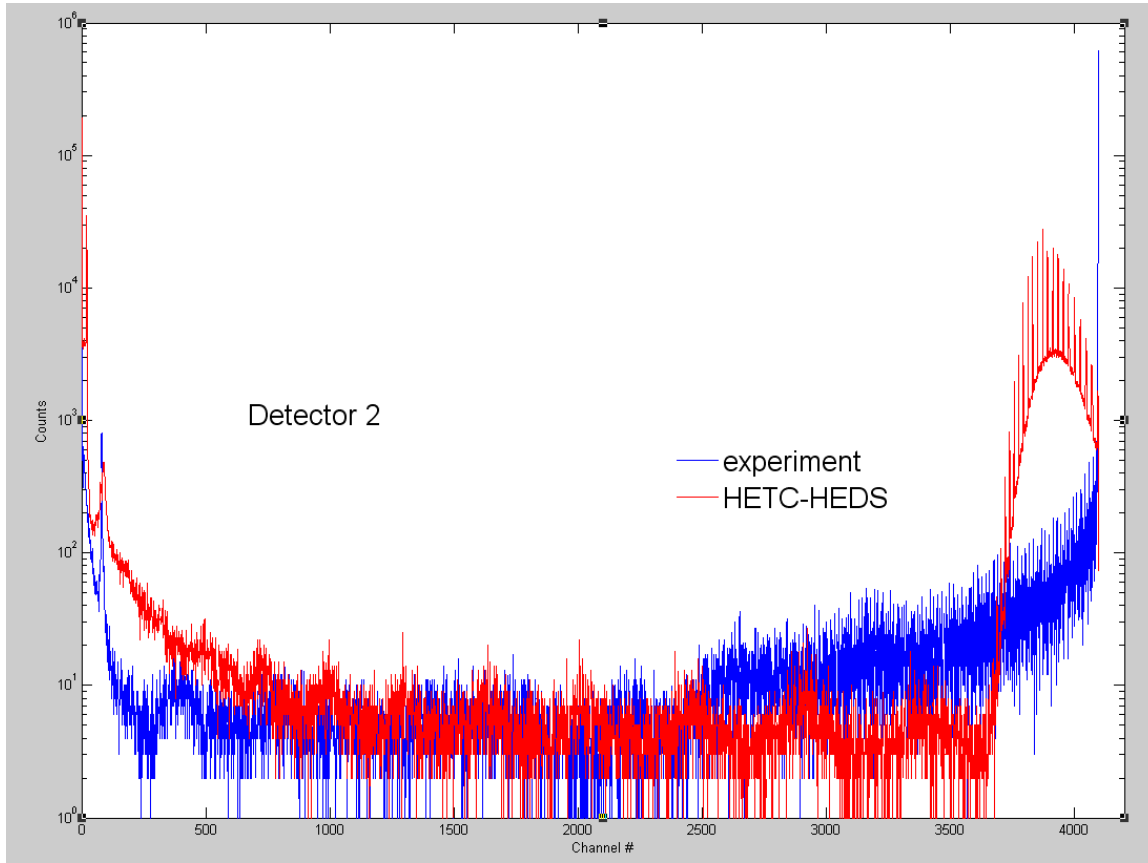


Figure 35. Detector 2 Response for 600 MeV/nucleon Si Beam

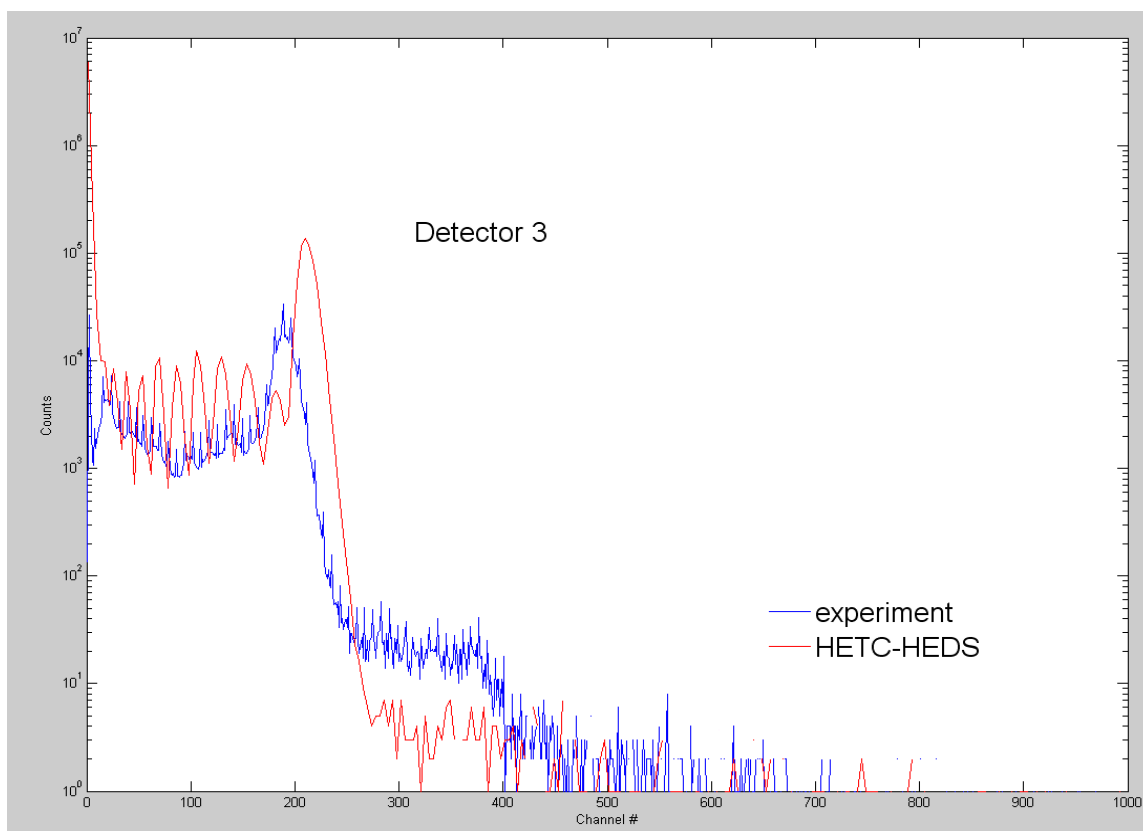


Figure 36. Detector 3 Response for 600 MeV/nucleon Si Beam

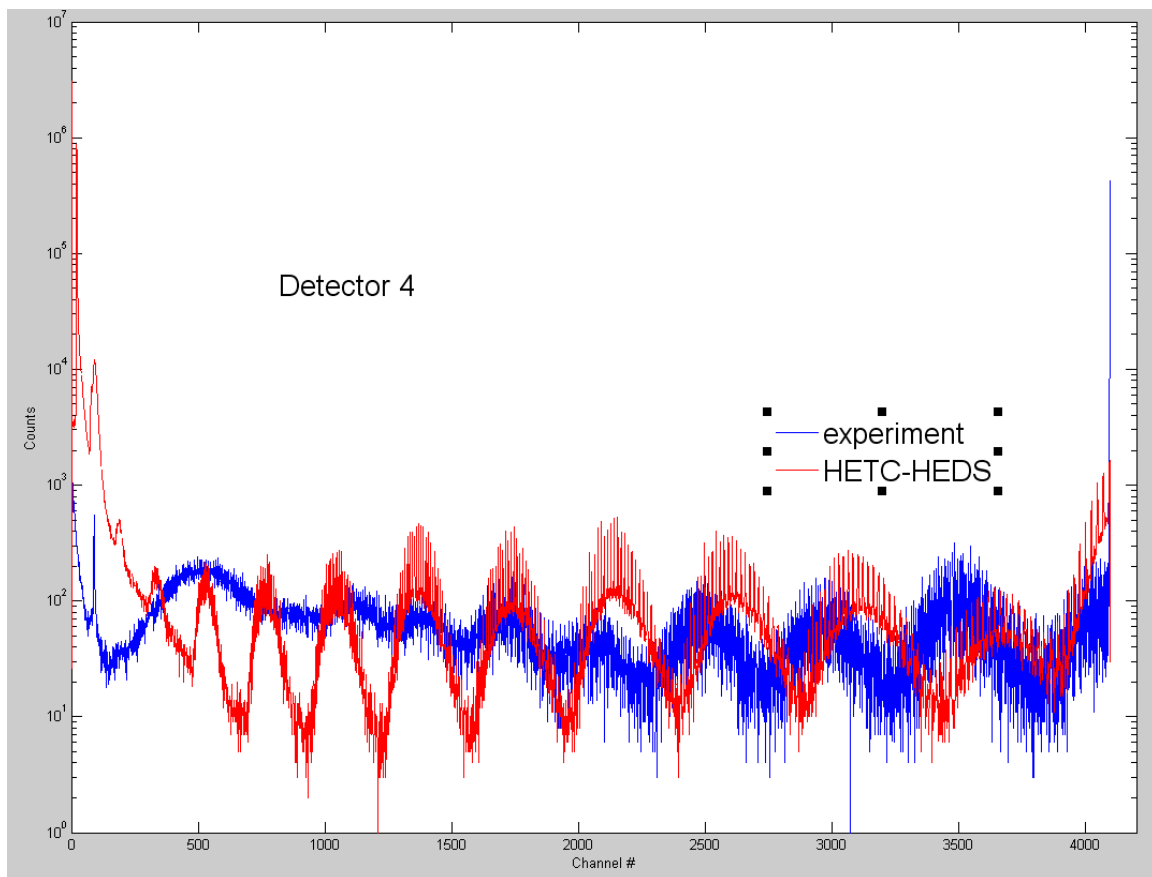


Figure 37. Detector 4 Response for 600 MeV/nucleon Si Beam

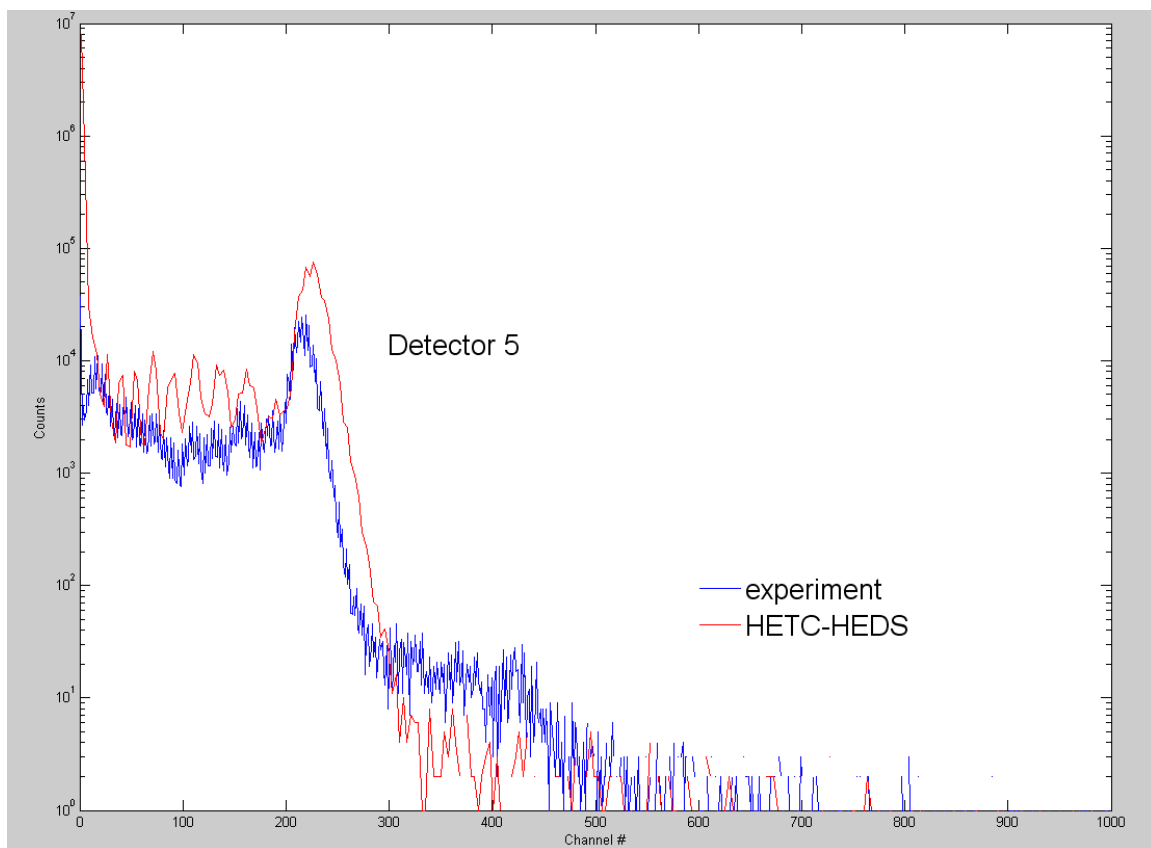


Figure 38. Detector 5 Response for 600 MeV/nucleon Si Beam

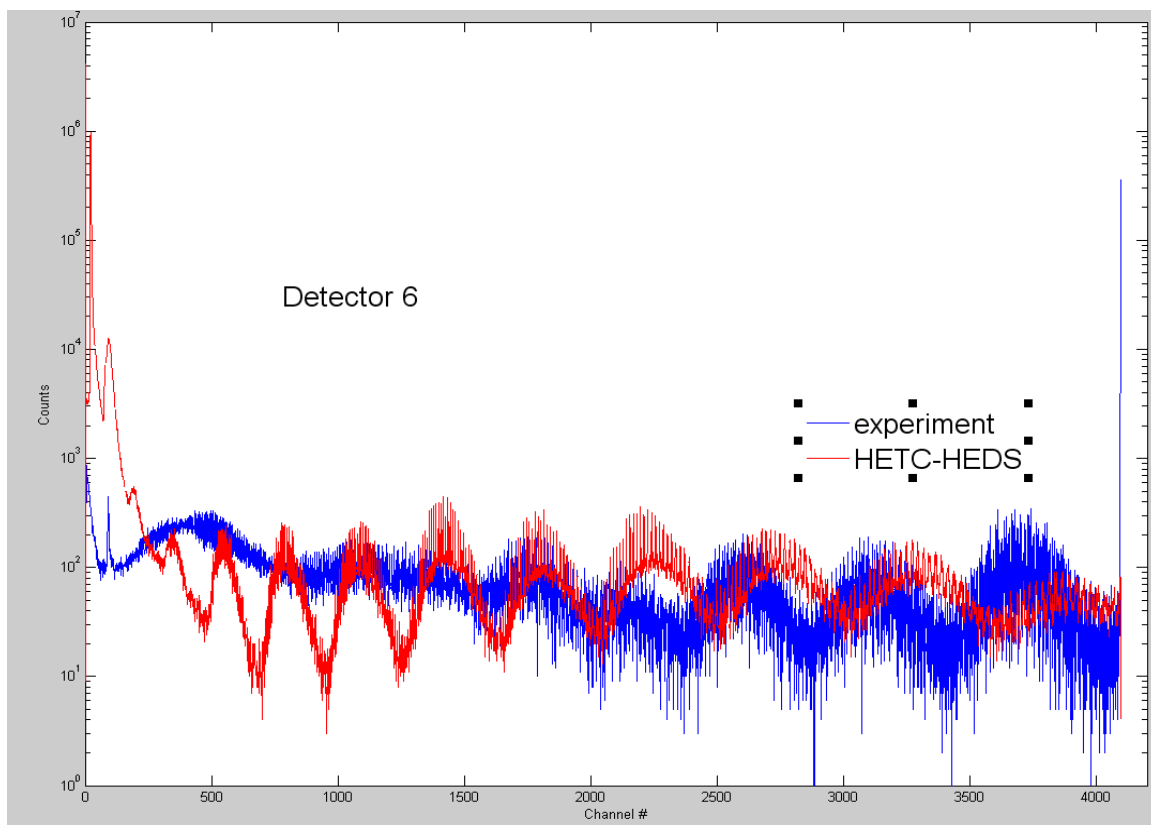


Figure 39. Detector 6 Response for 600 MeV/nucleon Si Beam

4.2.c. 650 MeV/nucleon Iron Beam

Comparisons for the 650 MeV/nucleon Iron beam are depicted in figures 40 through 45

Overall the HETC-HEDS simulations are in fair agreement for all detectors.

Differences in calculated versus measured energy depositions are caused by the same reasons mentioned in the case of the 600 MeV/nucleon silicon beam calibrations. In addition, because of the possibility of having a fragmentation event that could result in producing many fragments, a Monte Carlo analysis will be difficult to be compared with an actual calibration run. The reason for that is that HETC-HEDS will follow each of the fragments separately and look at their contribution in energy deposition. On the other hand, in the case of the calibration run, it would be virtually impossible to be able to detect all fragments and taking their energy deposition contribution into account.

This is because a silicon detector has a certain dead time in which the detector will not respond to additional particles. This time period is not short enough so that the detector is able detect all fragments separately. The only major discrepancy is in detector five in which one would expect an overestimation with HETC-HEDS, which is not the case.

Again, in the case of iron, beam corrections become even more difficult to quantify because an incident iron particle produces more fragments than an incident silicon particle for example, and hence the comparison is not very good. In this case, the energy was assumed to be 650 MeV/nucleon and the spread in momentum was assumed to be 3 %.

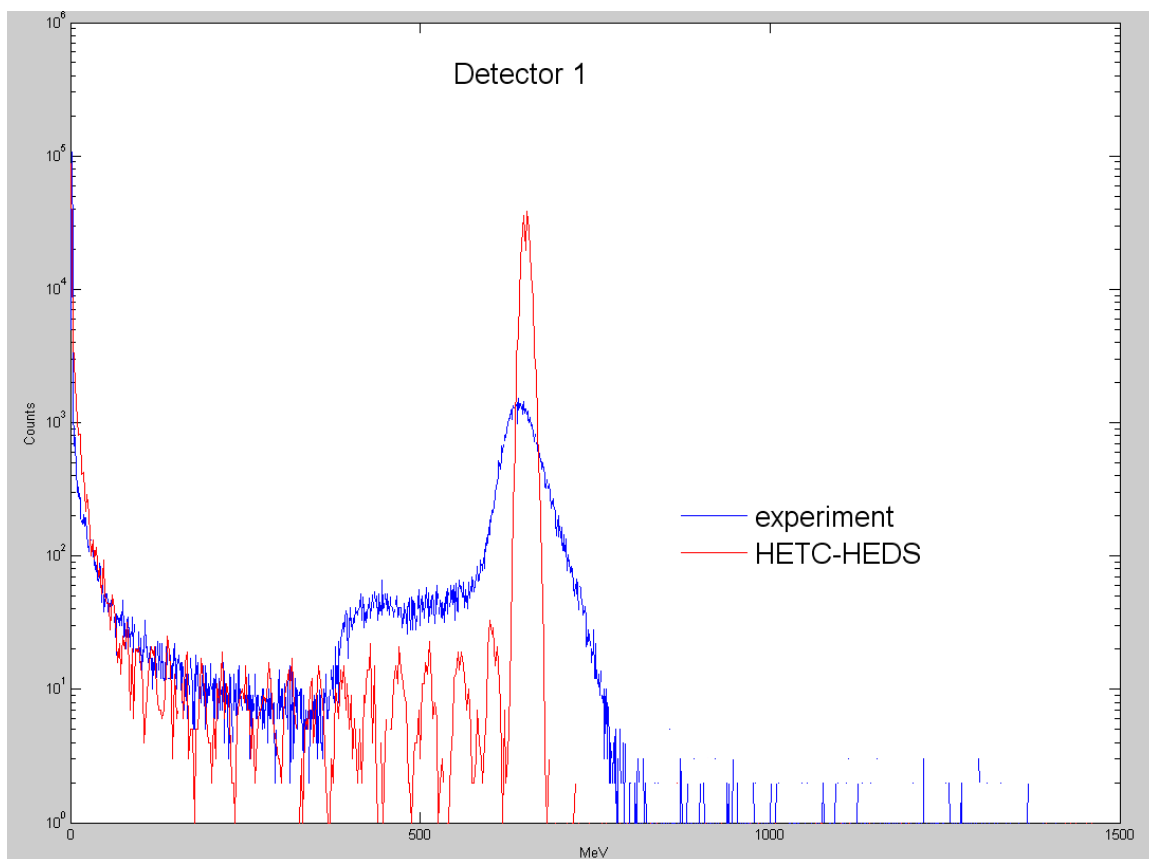


Figure 40. Detector 1 Response for 650 MeV/nucleon Fe Beam

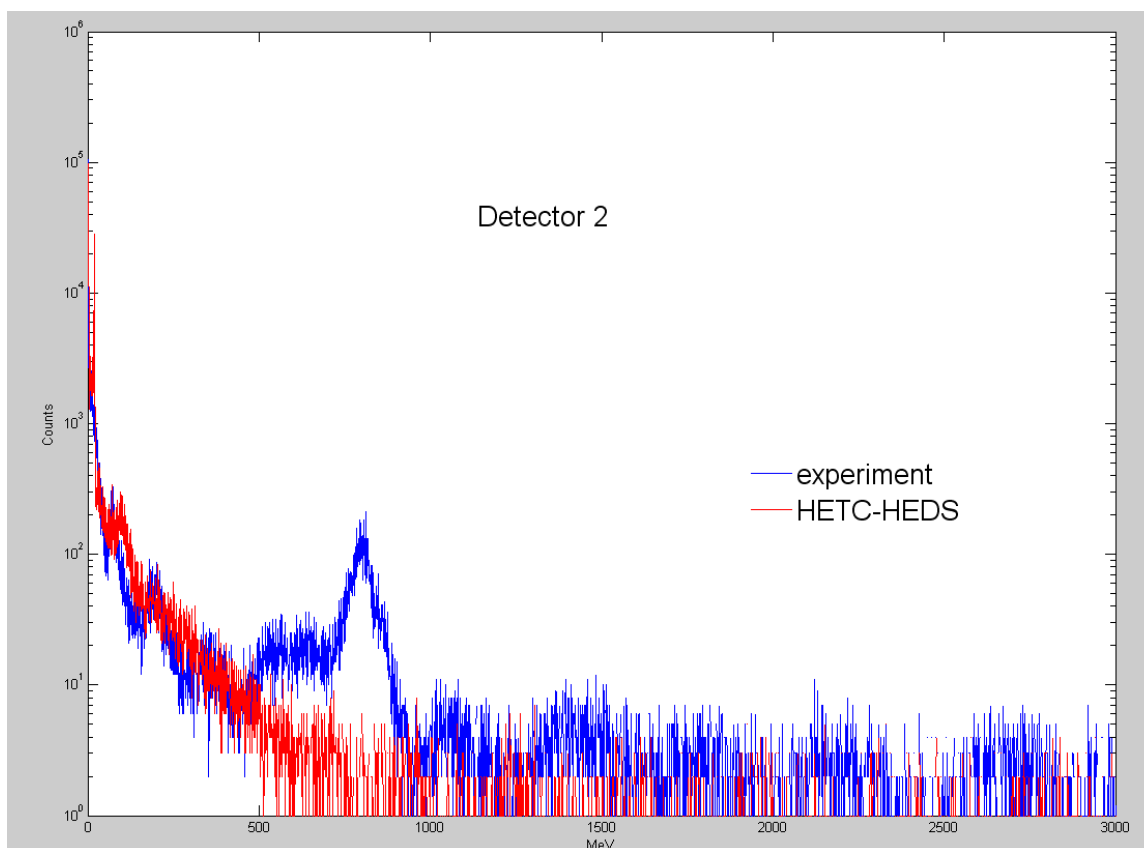


Figure 41. Detector 2 Response for 650 MeV/nucleon Fe Beam

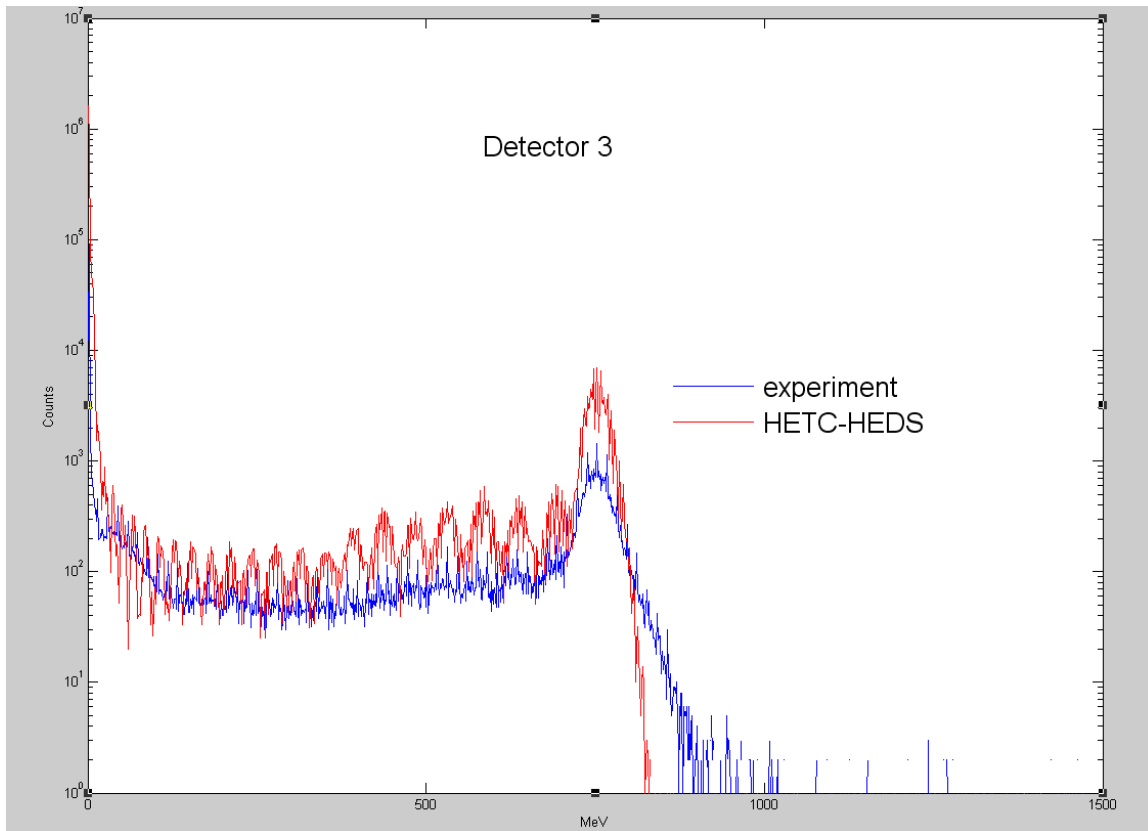


Figure 42. Detector 3 Response for 650 MeV/nucleon Fe Beam

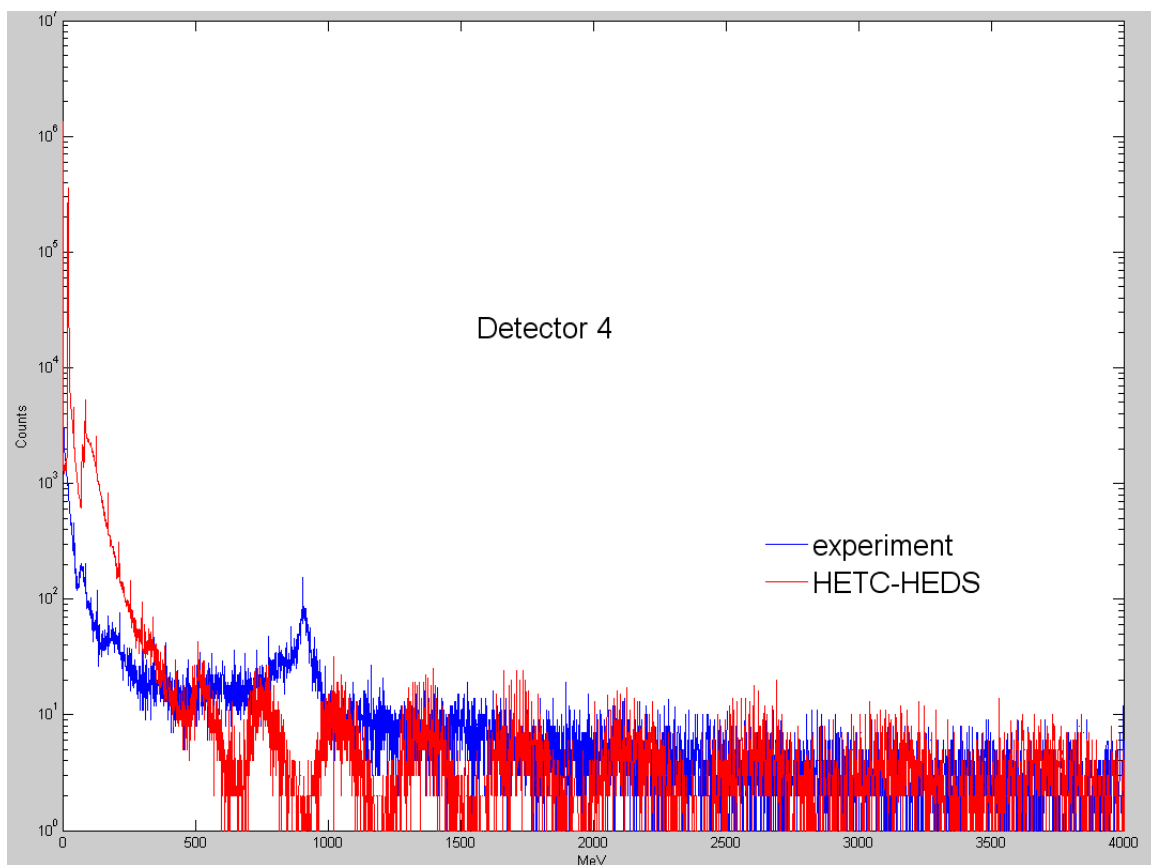


Figure 43. Detector 4 Response for 650 MeV/nucleon Fe Beam

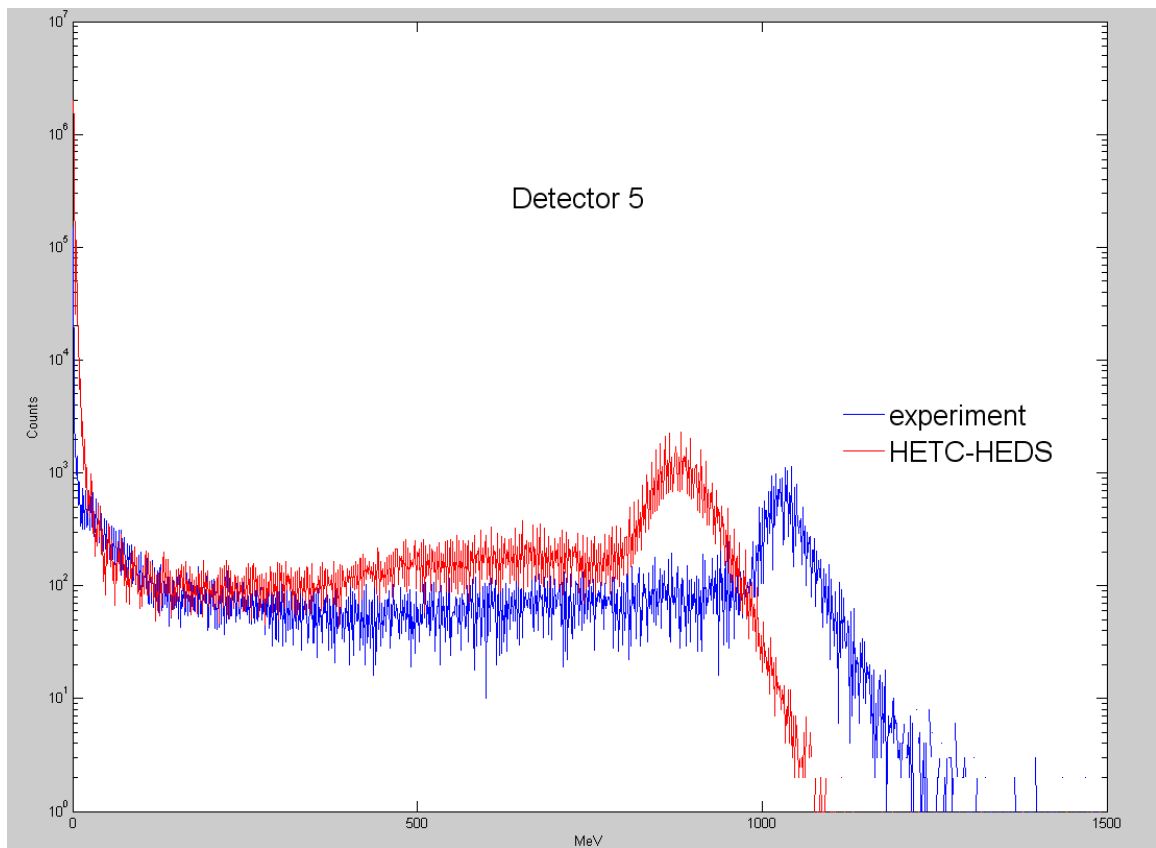


Figure 44. Detector 5 Response for 650 MeV/nucleon Fe Beam

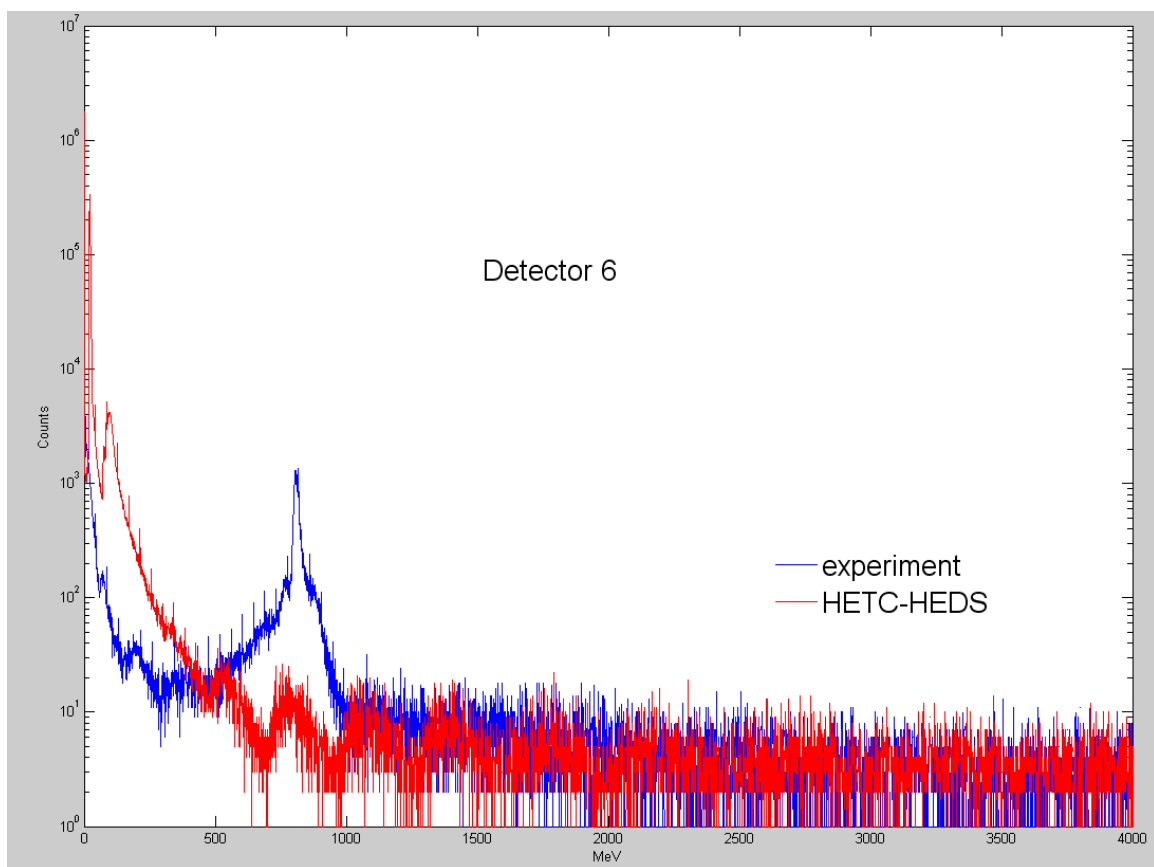


Figure 45. Detector 6 Response for 650 MeV/nucleon Fe Beam

4.3. CRaTER's Response to the GCR spectrum

To better understand the lunar galactic cosmic ray environment and its impacts on humans, it is necessary to characterize CRaTER's LET response to the galactic cosmic rays spectrum one might be exposed to on the Moon. This will be accomplished by building an LET data base that will include simulations of all the relevant components of the GCR spectrum with their corresponding energies.

The Flight Model 1 CRaTER configuration was modeled using HETC-HEDS where simulations of all the energies that constitute each of the elements of the GCR spectrum were made.

Starting with 20 MeV per nucleon energy, particles with charges between $1 \leq Z \leq 26$ were simulated since particles with $Z > 26$ have a very low fluence and are not significant in their contribution to dose or dose equivalent received by astronauts.

Then data of total energy deposited per path length of material by any particle produced, whether it is a primary beam particle or a secondary particle generated from a fragmentation event from the projectile or the target was used to obtain an average LET using the following equation:

$$AverageLET = \sum_{i=1}^n \frac{(E_{initial} - E_{final})_i}{n} * \frac{1}{L} \quad (7)$$

Where

i denotes the primary particle

n denotes the number of primary particles

L is the length of the material of interest

E_{initial} denotes the initial energy of the particle as before interacting in the material

E_{final} denotes the final energy of the particle after interacting in the material and is defined as:

$$E_{\text{final}} = E_i^f + \sum_{m=1}^{k_i} E_m \quad (8)$$

Where m is the first fragment of particle i

k_i is the k^{th} fragment of particle i

E_m is the energy of fragment m

In all the calculations, the number of primary particles, n, followed was one hundred thousand particles, which resulted in statistical errors of less than three percent. Once the averaged LET was obtained, the LET was multiplied by the GCR flux as predicted for the year 2009 by the Badwar-O'Neill GCR environmental model.

By doing so, a precursor data base is made available to be compared with CRaTER's flight data and benchmarked with the models used in HETC-HEDS.

4.3.a. BADWHAR O'NEILL Model

The fluxes of the GCR energy spectrum were obtained using the Badhwar-O'Neill interplanetary galactic cosmic ray model. In the early 1990's Badhwar and O'Neill developed a GCR model based on balloon and satellite data from 1954 to 1992. Since August 1997, the Cosmic-Ray Isotope Spectrometer (CRIS) on the Advanced

Composition Explorer (ACE) has provided significantly more accurate GCR energy spectra due to its much larger collection power with a geometric factor of about 250 cm²-sr. The original Badhwar – O’Neill Model, updated with the new ACE data, provides interplanetary mission planners with highly accurate GCR environment data for radiation protection for astronauts and radiation hardness assurance for electronic equipment [32].

This model accurately accounts for solar modulation of each relevant element (hydrogen to nickel) by propagating the assumed Local Interplanetary Spectrum (LIS) of each element through the heliosphere by solving the Fokker – Planck diffusion, convection, energy loss boundary value problem. A single value of the deceleration parameter, $\Phi(t)$, describes the level of solar cycle modulation and determines the GCR energy spectrum for all of the elements at a given distance from the sun.

The intensity and energy of galactic cosmic rays entering the heliosphere is lowered as they are scattered by irregularities in the interplanetary magnetic field embedded in the solar wind. Parker (1965) showed that the steady-state, spherically symmetric Fokker-Planck equation accurately accounts for diffusion, convection, and adiabatic deceleration of these particles. The Fokker-Planck equation is readily solved numerically to propagate the Local Interstellar Spectrum (LIS) for each element to a given distance from the sun.

A single diffusion coefficient, $K(r, t)$, describes the effect of the sun's magnetic field on particles entering the heliosphere.

$$K(r, t) = \frac{\left(\frac{K_0}{V_{sw}} \right) \beta P \left[\frac{r}{r_0} \right]^2}{\Phi(t)} \quad (9)$$

where V_{sw} is the constant solar wind speed (400 km/s), r is distance from the sun in Astronomical Units (distance between Earth and Sun (A.U.)) , t is time in years, k_0 is constant, β is particle speed relative to the speed of light, P is particle rigidity in MV.

Figure 46 shows the change in modulation parameter $\Phi(t)$ of solar cycle 23 for various elements of the GCR spectrum.

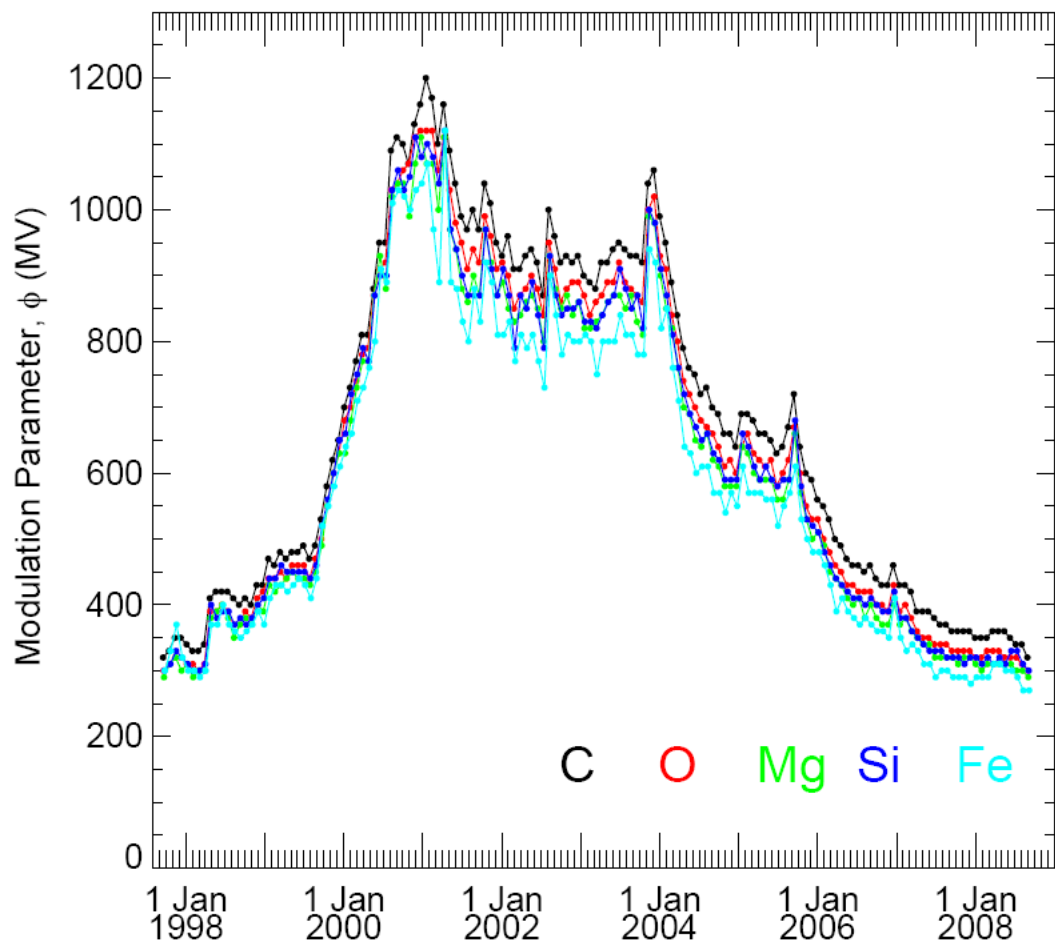


Figure 46. Change of Modulation Parameter $\Phi(t)$ of Solar cycle 23

The model generates GCR energy spectra (flux in #ions/m**2/sr/s/MeV/n versus energy in MeV/n) from 1.0 to 10^{12} MeV/n for elements (Z=1 to 28) by propagating an input Local Interstellar Spectrum (LIS) to 1 AU by solving the Fokker–Planck equation for given $\Phi(t)$ (the solar modulation parameter which describes the current state of the sun's ability to modulate cosmic rays).

The model allows user to enter the element charge and $\Phi(t)$.

The output contains the modulated GCR spectrum for the element and $\Phi(t)$ entered.

The disadvantage of the Badwhar-O'Neill model is that the lowest value that can be used as input for the solar modulation parameter $\Phi(t)$ is 450 MV. This will not be a problem since CRaTER will be launched into lunar orbit near minimum solar activity and the value of Φ during the one year period of data collection will have an average of about 450 MV.

The units of the generated flux were (flux in #ions/m**2/sr/s/MeV/n), so a factor of 10^{-4} was multiplied by the flux to convert the units to cm^2 .

Also, all particles were assumed to be entering CRaTER from the 35° Zenith field of view which faces out to space. To take that into account, the flux was also multiplied by a factor of 0.29 to rid the denominator of the steradian unit (sr). The following equation was used:

$$\text{Steradian} = 2\pi(1 - \cos(0.5 * 35^\circ)) = 0.29 \quad (10)$$

4.3.b. Average LET Spectra

Before representing the LET spectra for the GCR elements, it is worthwhile to discuss the change in average LET as a function of energy for the some representative elements. Figures 47 and 48 show the LET spectra (keV/micron) for the GCR elements as a function of energy (MeV/nucleon) in both Tissue Equivalent Plastic sections TEP1 and TEP2.

As one would expect, the two figures show the increase in LET as a function of energy as well as atomic number Z . For each of the elements, the Bragg peak occurs at an energy that increases with atomic number Z , which explains the shift of the Bragg peaks as Z increases.

Furthermore, it can also be seen that LET values are higher in TEP2 for some elements, since the Bragg peak becomes more pronounced as the energy of the primary beam decreases and the particles travel through the various elements of the detector and lose energy. As such, when the energy of a particle decreases to a particular threshold, the electron capture cross section becomes important. In this case, the nucleus will rid itself of its excess energy by capturing an atomic electron. Then, the excess energy is transferred to the electron, ejecting it from the atom. Hence, the rapid increase in energy transfer.

LET in TEP 1

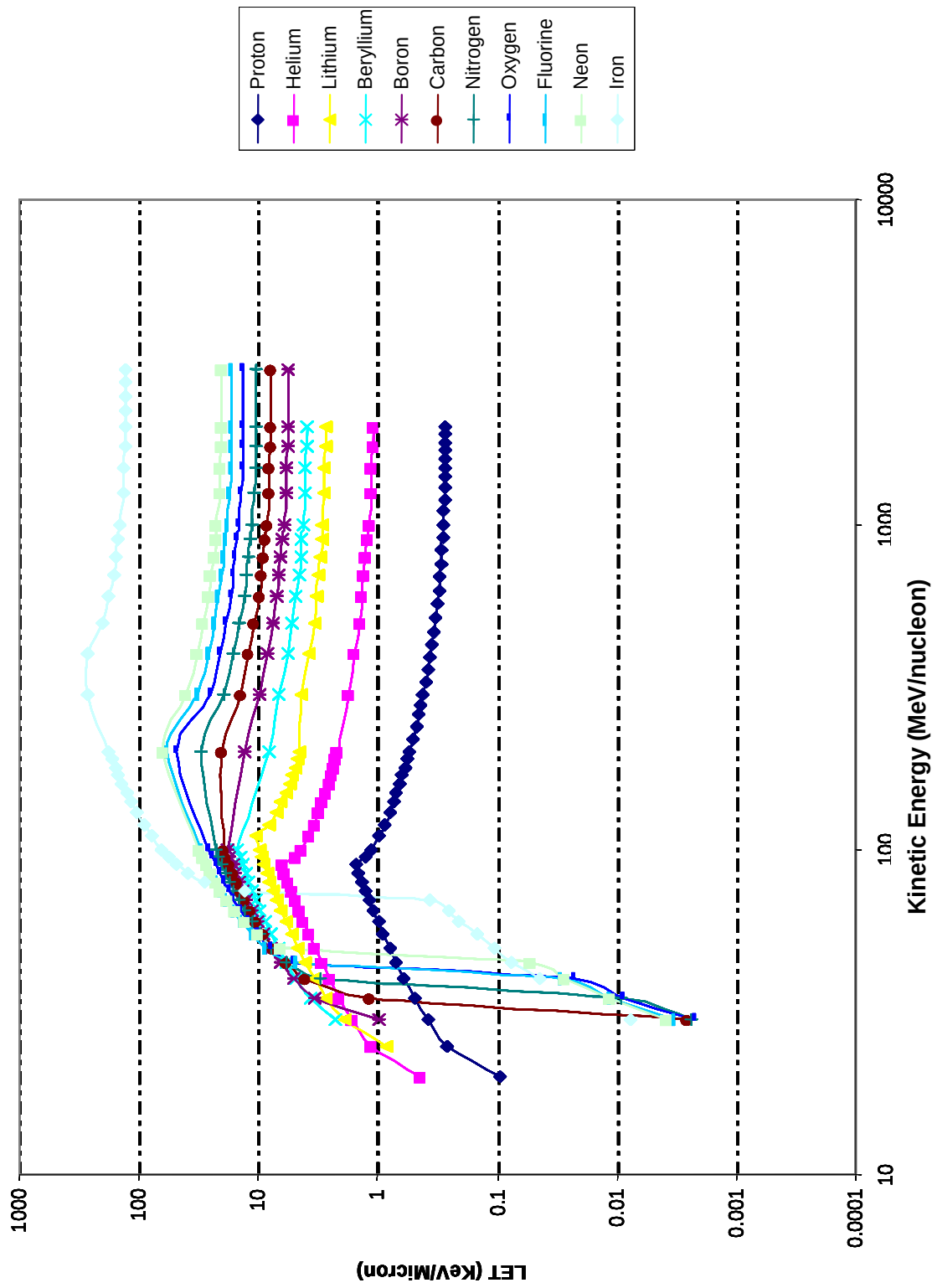


Figure 47. Average LET Spectrum in TEP 1

LET in TEP2

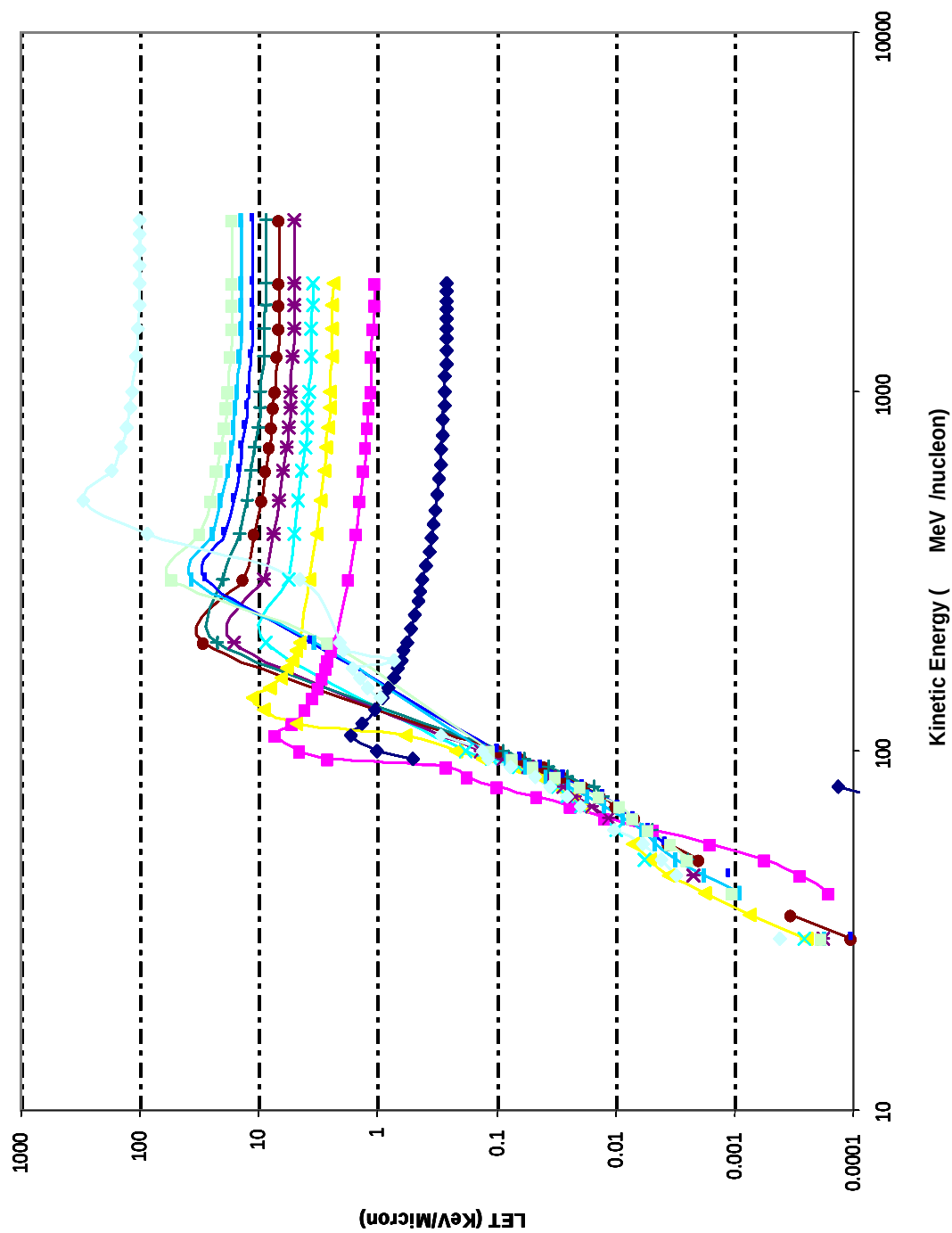


Figure 48. Average LET Spectrum in TEP 2

4.3.c. LET GCR spectra prediction for 2009

Figures 49 and 50 show the predicted LET spectra (keV/micron/s) for the year 2009 as a function of energy (MeV/nucleon) for elements that have the highest fluxes in the GCR environment. Despite the fact that elements with higher Z, i.e. iron, have higher LET values than TEP (the target in this case), figures 49 and 50 show that the highest value of LET is that of protons. This is because protons constitute about eighty five percent of the GCR spectrum and therefore will have higher energy deposition values than iron. The same argument could be made about oxygen, which has higher flux values than iron does for example. The values in LET values are higher for TEP2 than they are for TEP1. The increase in the Bragg peak as a function of Z is also a property of those spectra. The values of LET are represented per second, which makes it as simple as multiplying the LET values by a duration of time in seconds spent in space to obtain a cumulative LET value. Since the purpose of this work was to create a database with lookup tables of LET values for the various GCR elements, it would best to represent the values in table format, which will make it easy for one to interpolate between calculated LET values to obtain the LET for a desired energy of a particular element. Values of LET spectra for all GCR elements, proton through iron, are represented in tables 9 through 34 in the appendix. Because CRaTER does not differentiate between particle species, Figure 51 shows a prediction for the cumulative LET spectrum for elements hydrogen to iron as a function of energy per nucleon.

As expected, LET in TEP1 is higher than that in TEP2 in the low energy range. The reason is because most particles will deposit their energies completely in TEP1 before

they can reach TEP2. However, it is clear from the figure that the difference in LET values between TEP1 and TEP2 becomes smaller as energy increases, and eventually LET is virtually the same in the high energy region.

LET spectrum in TEP 1

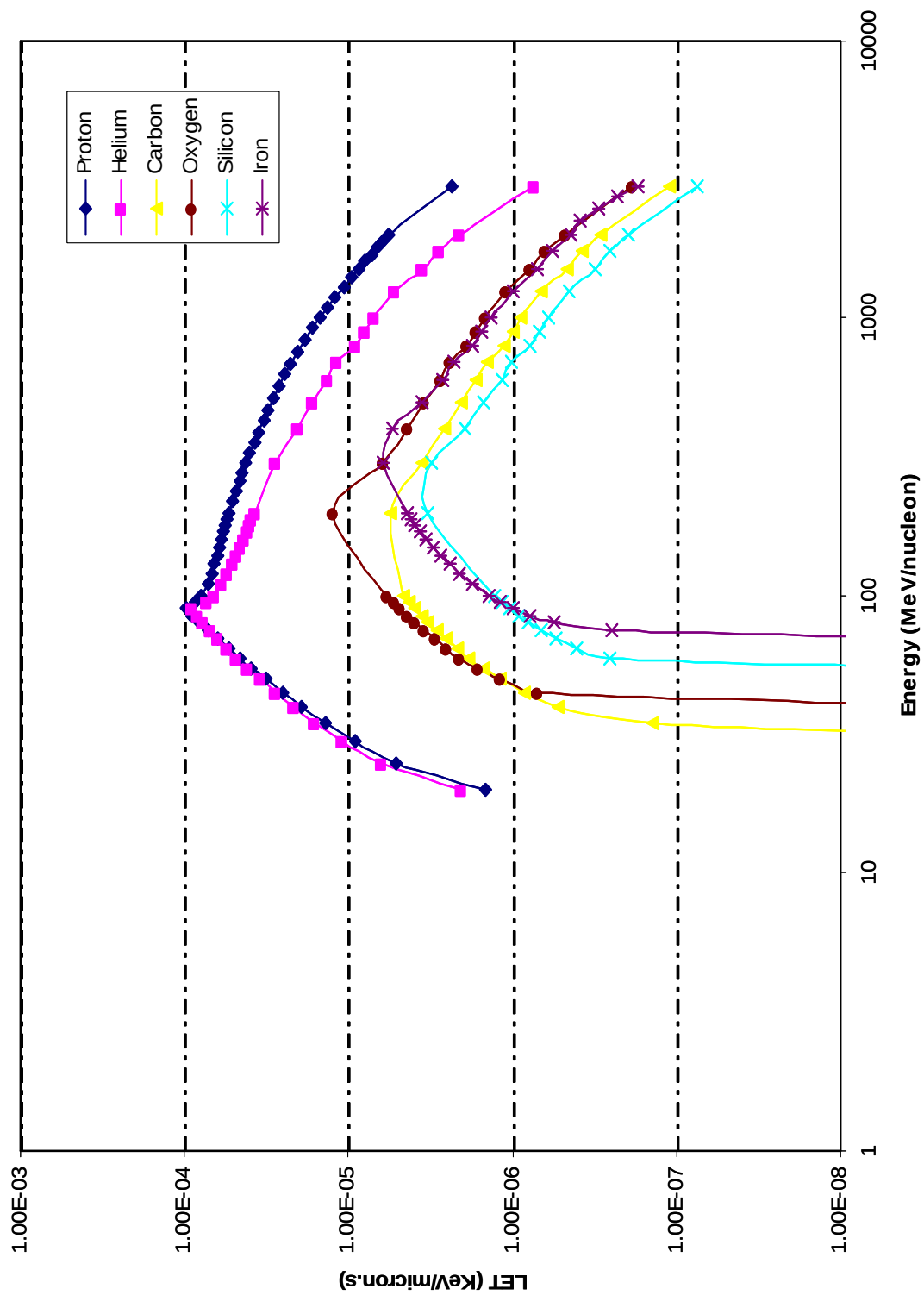


Figure 49. Predictions of the LET Spectrum in TEP1 for 2009

LET spectrum in TEP 2

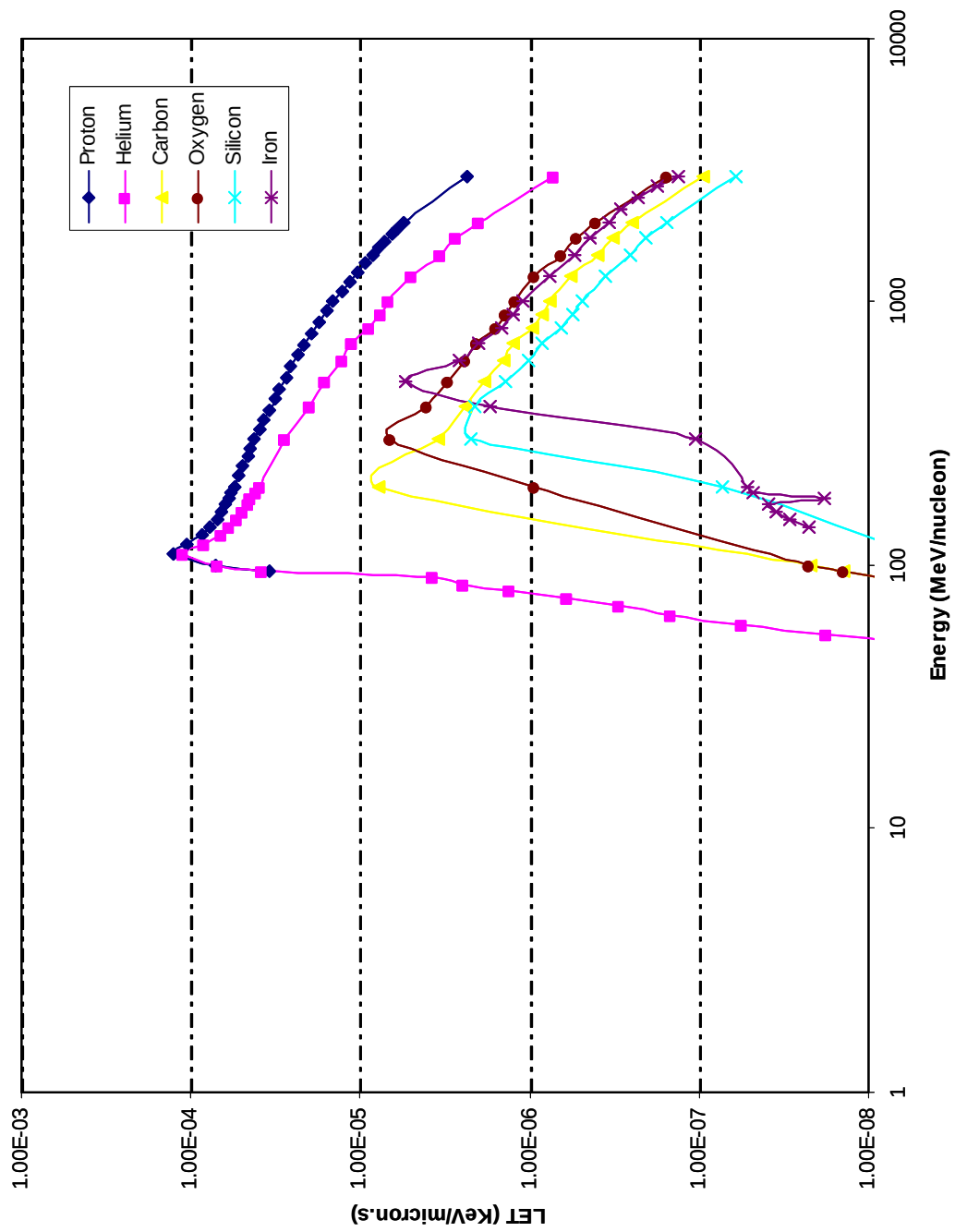


Figure 50. Predictions of the LET Spectrum in TEP2 for 2009

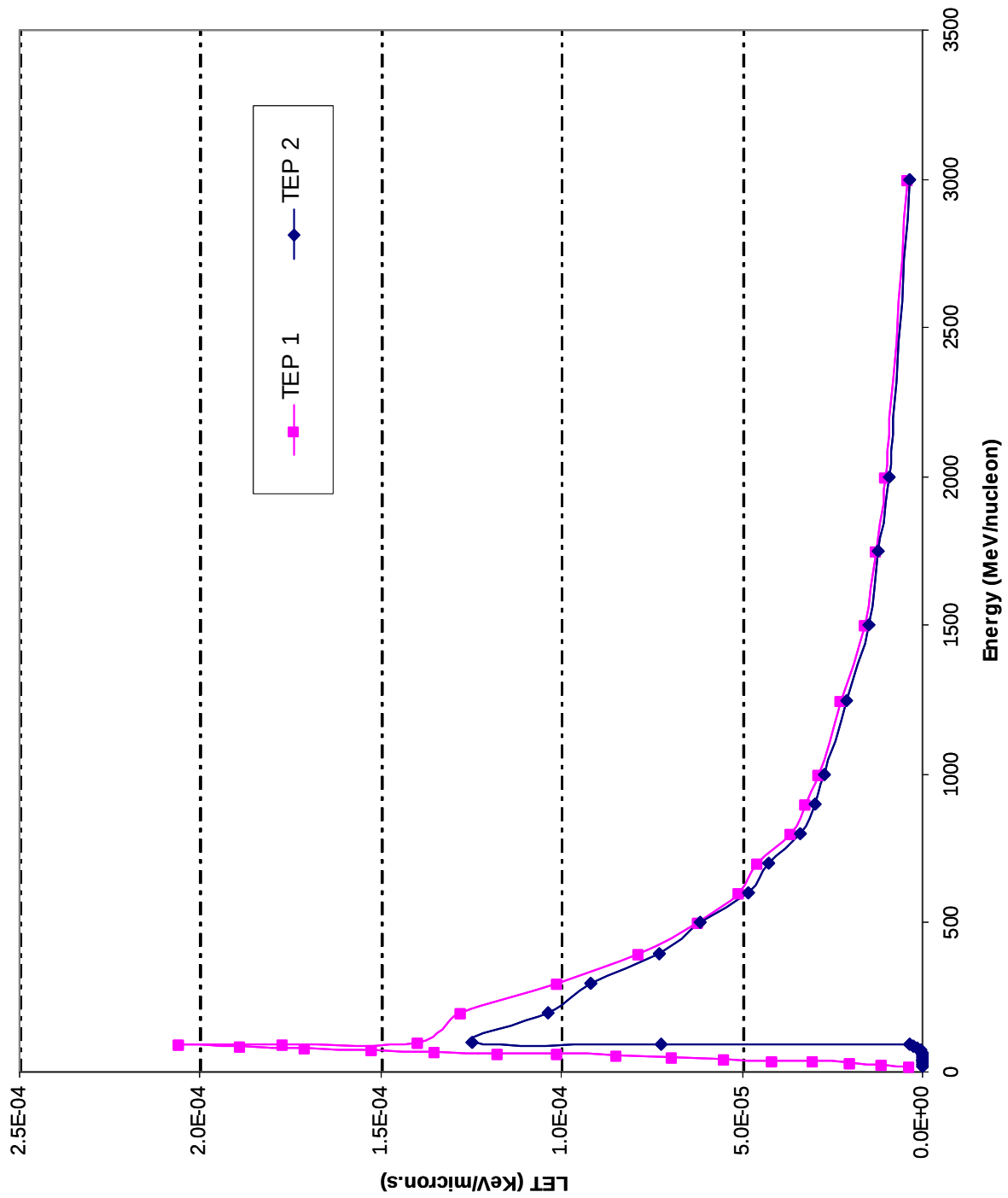


Figure 51. Prediction of The Cumulative LET Spectrum For 2009

4.4. CRaTER's Response to Solar Particle Events

The last scenarios included in this work are predictions for various large solar particle events. The events selected are those of September, October, and November 1989, the October 2003 (Halloween) event, and a prediction for an assumed worse case scenario 2009 event when CRaTER is in lunar orbit. The latter was calculated by simply assuming the event to be the largest event that occurred in November of 1997, the beginning of solar cycle 23 since CRaTER will be orbiting the Moon in the beginning of solar cycle 24.

This will establish a reference measure for the CRaTER team in case such events occur when CRaTER is in lunar orbit.

4.4.a. Solar Particle Event (SPE) Data

The Geostationary Operational Environmental Satellite (GOES) program was designed to operate in geostationary orbit, 35,790 km (22,240 statute miles) above the Earth, and thereby remaining stationary (with respect to a point on the ground).

The advanced GOES I-M spacecraft continuously views the continental United States, neighboring environs of the Pacific and Atlantic Oceans, and Central, South America and southern Canada. The three-axis, body-stabilized spacecraft design enables the sensors to "stare" at the Earth and thus more frequently image clouds, monitor Earth's surface temperature and water vapor fields, and sound the atmosphere for its vertical thermal and vapor structures. Thus the evolution of atmospheric phenomena can be followed, ensuring real-time coverage of short-lived dynamic events, especially severe

local storms and tropical cyclones—two meteorological events that directly affect public safety, protection of property, and ultimately, economic health and development. The main mission is carried out by the primary payload instruments, the Imager and the Sounder. The Imager is a multi-channel instrument that senses infrared radiant energy and visible reflected solar energy from the Earth's surface and atmosphere. The Sounder provides data for vertical atmospheric temperature and moisture profiles, surface and cloud top temperature, and ozone distribution.

Other instruments on board the spacecraft are the ground-based meteorological platform data collection and relay, and the space environment monitor (SEM). The latter consists of a magnetometer, an X-ray sensor, a high energy proton and alpha detector, and an energetic particle sensor, all used for in-situ surveying of the near-Earth space environment [33].

4.4.b. Space Environment Monitor (SEM)

The Space Environment Monitor (SEM) measures the effect of the Sun on the near-Earth solar-terrestrial electromagnetic environment, providing real-time data to the Space Environment Services Center (SESC). The SESC, as the nation's "space weather" service, receives, monitors, and interprets a wide variety of solar-terrestrial data, and issues reports, alerts and forecasts for special events such as solar flares or geomagnetic storms.

The SEM subsystem consists of four instruments used for in situ measurements and monitoring of the near-earth (geostationary altitude) space environment and for

observing the solar X-ray output. An energetic particles sensor (EPS) and high energy proton and alpha detector (HEPAD) monitor the incident flux density of protons, alpha particles, and electrons over an extensive range of energies. Solar output is monitored by an X-ray sensor (XRS) mounted on an X-ray positioning platform, fixed on the solar array yoke. Two redundant three-axis magnetometers, mounted on a deployed 3-meter boom, operate one at a time to monitor Earth's geomagnetic field strength in the vicinity of the spacecraft. The SEM instruments are capable of ground command-selectable, in-flight calibration for monitoring on-orbit performance and ensuring proper operation [34].

4.4.c. Energetic Particles Sensor (EPS)

The EPS performs three integral measurements (at geostationary orbit) of electrons from 0.6 to more than 4.0 megaelectronvolts (MeV), a seven-channel differential analysis of protons from 0.8 to 500 MeV, and a six-channel differential analysis of alpha particles from 4 to 500 MeV per nucleon. The EPS also provides all the support required by the HEPAD, which extends the EPS energy ranges to greater than 700 MeV for protons and to greater than 3400 MeV per nucleon for alphas. The EPS and HEPAD are housed within the spacecraft main body and view the space environment through apertures.

The EPS unit consists of a telescope subassembly, a dome subassembly and signal analyzer unit/data processing unit (SAU/DPU); the latter unit provides the final amplification of the telescope and dome output signals. These components are housed

on a separate panel, mounted on the spacecraft's south equipment panel, providing a clear field of view towards the west.

The telescope uses two silicon surface barrier detectors that output charge pulses to charge sensitive preamplifiers within the telescope, converting them into voltage pulses; this preconditions the signals sent to the SAU/DPU. These detectors sense low energy protons in the range of 0.8 to 15 MeV and alpha particles in the range of 4 to 60 MeV. The two detectors, surrounded by tungsten shielding, are arranged in a telescope configuration: a 50- μm , 100- mm^2 front detector and a 500- μm , 200- mm^2 rear detector. Tungsten collimators define the field of view of 70° and eliminate detector edge effects. Sweeping magnets exclude electrons below about 100 kilo-electron-volts (keV), while a 0.145-mil aluminum foil excludes light. The outer surface of the front solid-state detector is covered with 130 $\mu\text{g}/\text{cm}^2$ of aluminum, rendering it light tight. The dome employs three sets of two 1500- μm , 25- mm^2 , silicon surface barrier detectors, each with different thickness moderators covering the respective pairs' independent fields of view, thus providing three different energy thresholds. As in the telescope, the solid state detector output charge pulses are passed through charge sensitive preamplifiers, converting them into voltage pulses before being routed to the SAU/DPU. After processing, the output of the detector pairs [35].

4.4.d. High Energy Proton and Alpha Detector (HEPAD)

The HEPAD senses incident flux of high energy protons (350 to greater than 700 MeV) and alphas (640 to greater than 850 MeV/nucleon). The unit consists of a telescope subassembly with two silicon surface barrier detectors, a Cerenkov radiator, and a photomultiplier tube (PMT), all arranged in a telescope configuration, and a signal analyzer subassembly. The Cerenkov radiator and PMT provide directional (front/rear incidence) discrimination and energy selection. The solid-state detectors differentiate between minimum ionizing protons and alpha particles and are shielded from protons below 70 MeV and electrons below 15 MeV by aluminum and tungsten barriers.

The signal analyzer subassembly contains all the amplification and processing electronics required to sort the accepted telescope events into particular particle types and energy levels and to transmit data to the EPS SAU/DPU on 11 data lines (4 proton, 2 alpha, and 5 single channels). The five single channels are required to correct proton and alpha channel data. PMT operating voltage is changeable upon ground command to compensate for aging effects; turn-on detection circuitry ensures that the PMT voltage always initializes at the lowest value. In-flight calibration capability is also included.

The SAU/DPU multiplexes all of the EPS/HEPAD particle data (27 channels) and accumulates the results in compression counters. Outputs of these compression counters are transferred serially to spacecraft telemetry in an 80- channel sub-multiplexed data stream. The SAU/DPU also processes timing signals from the spacecraft telemetry unit, housekeeping telemetry, in-flight calibration, and control commands to the EPS/HEPAD subsystem. Upon ground command, the SAU/DPU in-flight calibration

circuitry generates a sequence of amplitude modulated test pulses that are applied to the charge-sensitive preamplifier inputs to determine the stability of amplification chains and threshold discriminators [33].

In this work, the GOES satellite data was chosen to use as the input proton spectra. The data is binned into seven energy channels as follows:

Table 8. GOES Satellite Energy Channels

Channel	Energy (MeV)
1	E>1 MeV
2	E>5 MeV
3	E>10 MeV
4	E>30 MeV
5	E>50 MeV
6	E>60 MeV
7	E>100 MeV

The differential flux data obtained from GOES was averaged over five minute time intervals having units of ions/cm²/second/steradian. As stated previously, CRaTER has a 35° field of view (FOV), so the same factor of 0.29 was multiplied by the GOES data. After doing so, the data was fitted using Nonlinear Least Square techniques to interpolate fluxes between energies between 20 and 100 MeV, and to extrapolate fluxes between energies of 100 and 3000 MeV. Once that was completed, the LET spectra for the various events were calculated. It would be necessary first to show the differences in the integral spectra of the events analyzed in this work. Figure 51 shows the differences in the spectra between all events.

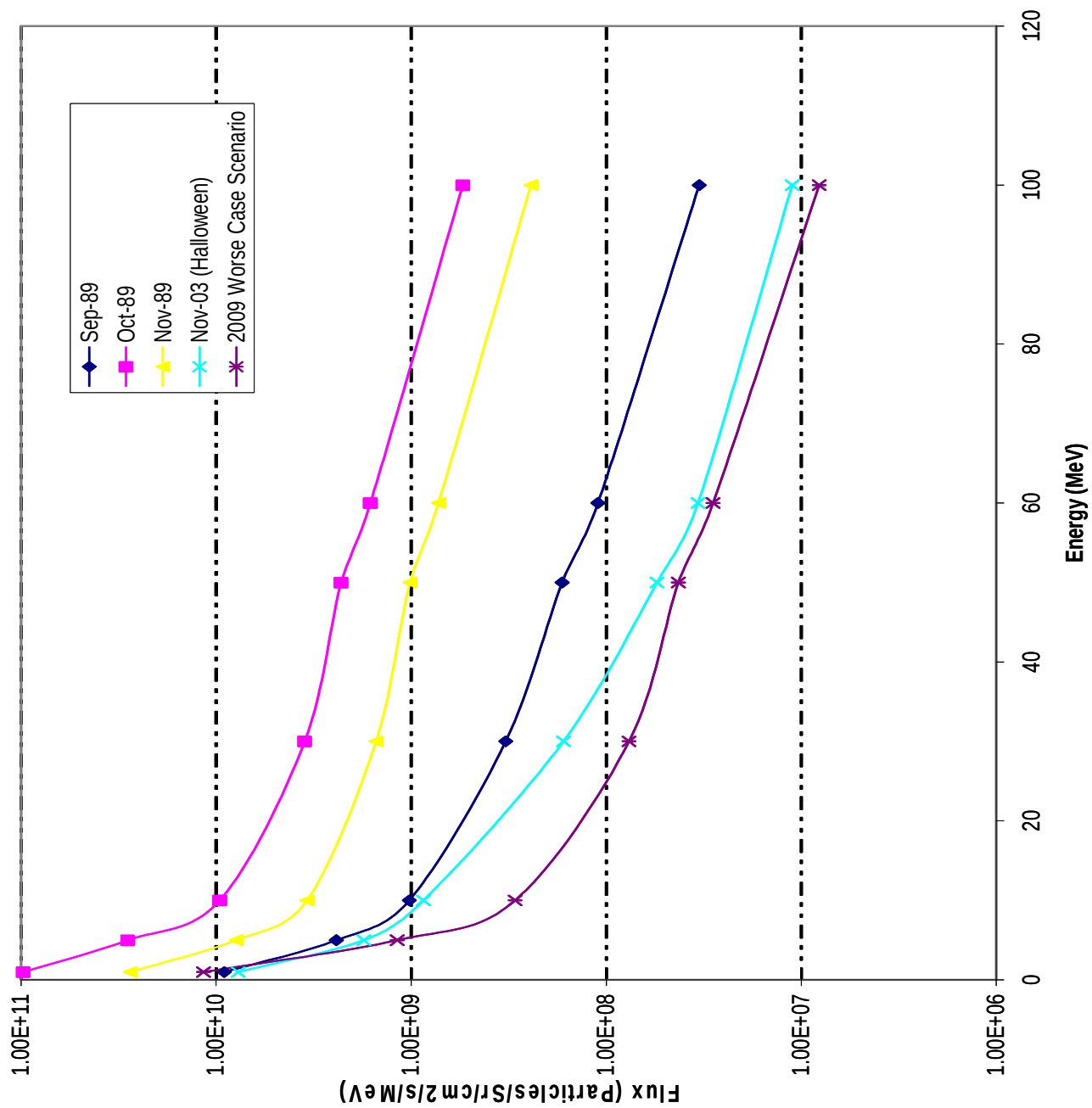


Figure 52. Comparison of the Integral Fluxes of the Solar Particle Events

To put things into perspective, the LET spectrum of the particular event was calculated using the following equation:

$$LET = \left(\frac{E_{deposited}}{L} * SPE \right)_i \quad (11)$$

Where

$E_{deposited}$ is the energy deposited by the particle with energy i

L is the length of the medium the particle is traversing

SPE is the flux of energy i

The LET was then plotted against energy and time to obtain a three dimensional plot.

4.4.e. 1989 Events

The reason why the 1989 events were chosen for this work was because of the variation of the events in the months of September, October, and November.

All plots are LET spectra as a function of energy and time. The colors represent the magnitudes of the LET where the color blue represent the lowest LET while the color red represents the highest LET. The units for LET on the x-axis are exponential of LET (KeV/micron/second), the units of energy on the y-axis are MeV, and the units of time on the z-axis are seconds. Figures 52 and 53 represent the prediction of CRaTER's response in TEP1 and TEP2 for the September 1989 event. The spectrum for this particular event was the hardest of solar cycle 23, meaning that this event had the

highest percentage of high energy protons relative to the total number of protons of the event when comparing it with other events. The event has a sudden rise in LET that remains almost linear until the end of the event. In comparison, the LET in TEP2 is lower than that in TEP1. This is expected since a big portion of particles in this event have low energy and will attenuate and lose their energy before getting to TEP2.

Figures 54 and 55 present the prediction of CRaTER's response in TEP1 and TEP2 for the October 1989 event. This event was quite different than that of the September 1989. This difference could be observed in the behavior of the LET spectrum as a function of energy and time. The LET spectrum has three different rises, which could be seen as the three different peaks in LET values. In some instances, this event had almost double the values of LET as compared to the previous event, which translates to having fluxes twice as large as there are in the previous event

Figures 56 and 57 present the prediction of CRaTER's response in TEP1 and TEP2 for the November 1989 event. The November 1989 event has many rises, but the major difference between it and the previous two events is its hardness (soft event spectrum) except at the beginning of the event. This is noticeable when looking at the intensity of the LET in TEP2, which remains virtually unchanged for that specific period of time.

4.4.f. 2003 Event (Halloween)

Figure 58 presents the prediction of CRaTER's LET response in TEP1 and figure 59 is a rotated view (to better illustrate LET variation with time) of the same LET spectrum for the October 2003 event. Figure 60 represent the prediction of CRaTER's LET response in TEP2 and figure 61 is a rotated view of the same LET spectrum for the October 2003 event.

As stated previously, the importance of predicting CRaTER's response to SPEs is to be able to determine the significance of those events to the safety of astronauts. When the event has a hard spectrum, this means that more sophisticated means of shielding will be required. This does not indicate, however, that more shielding will take care of the problem since as particles lose energy, their LET becomes higher because their velocities become lower, so more shielding might actually do more harm than good.

This is the case for the October 2003 event, also known as the Halloween event, since it occurred at the end of October close to Halloween. This event had its major significance at the beginning where multiple rises in LET at energies up to 3000 MeV occurred within a very short period of time. Had an astronaut been present in space without proper shielding, the doses received could have been mission threatening or lethal [36].

4.4.g. 2009 Worse Case Scenario

The final Solar Particle Event study included in this research is a prediction of a worse case scenario event that might occur when CRaTER is in lunar orbit. This event was assumed to be the same event that occurred in November of 1997, around the same stage in the previous solar cycle (cycle 23) as when CRaTER will be in space.

Figure 62 represents the prediction of CRaTER's LET response in TEP1 and figure 63 is a rotated view of the same LET spectrum for a 2009 event. Figure 64 represent the prediction of CRaTER's LET response in TEP2 and figure 65 is a rotated view of the same LET spectrum for the 2009 event.

The LET spectrum of this event is similar to that of the Halloween event in it having a hard spectrum, but there are fewer LET peaks than there were in the Halloween event.

Because the data for the SPE predictions are large, the data is attached in a CD-ROM with this work.

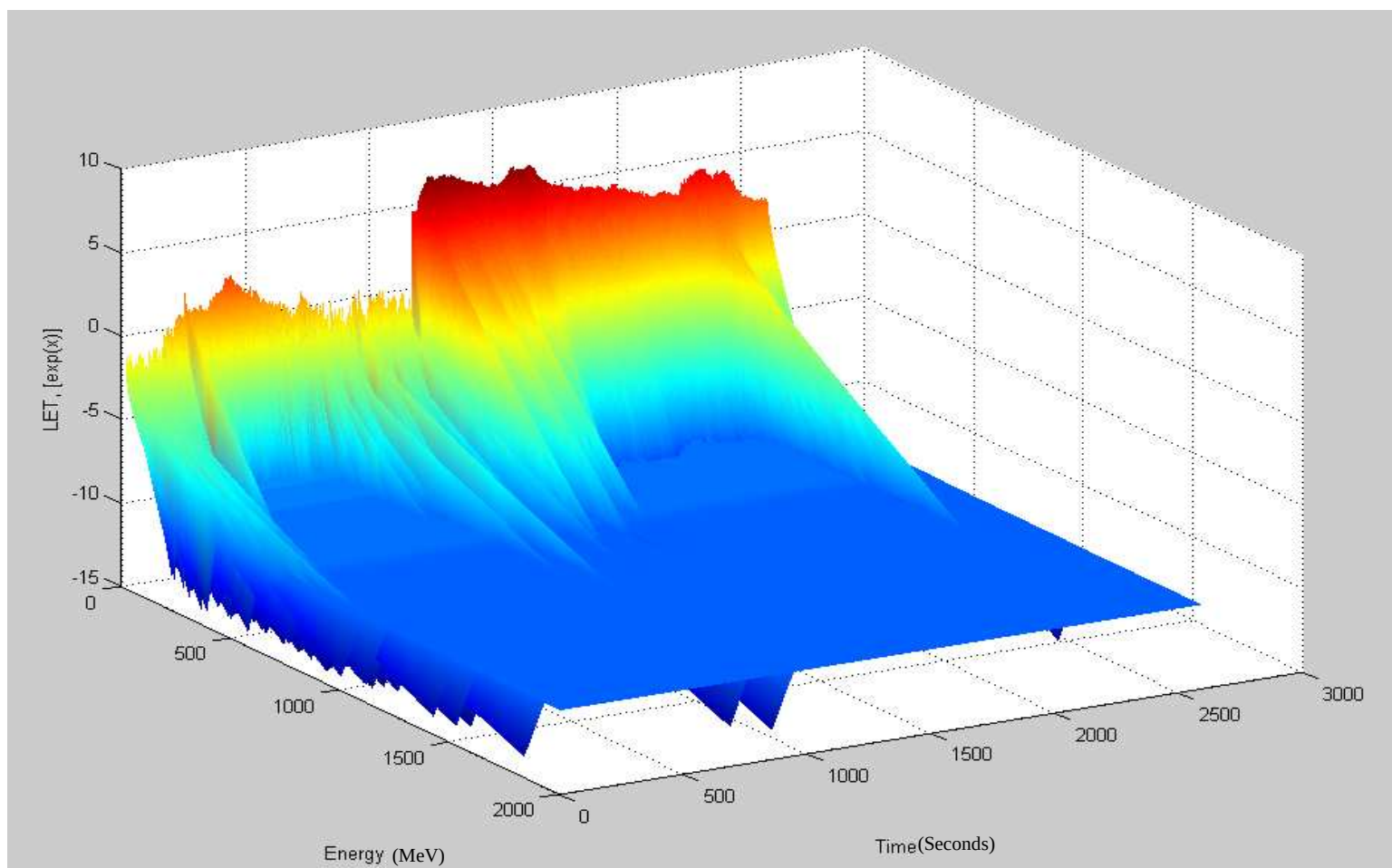


Figure 53. Prediction of LET Spectrum in TEP 1 for September 1989 SPE

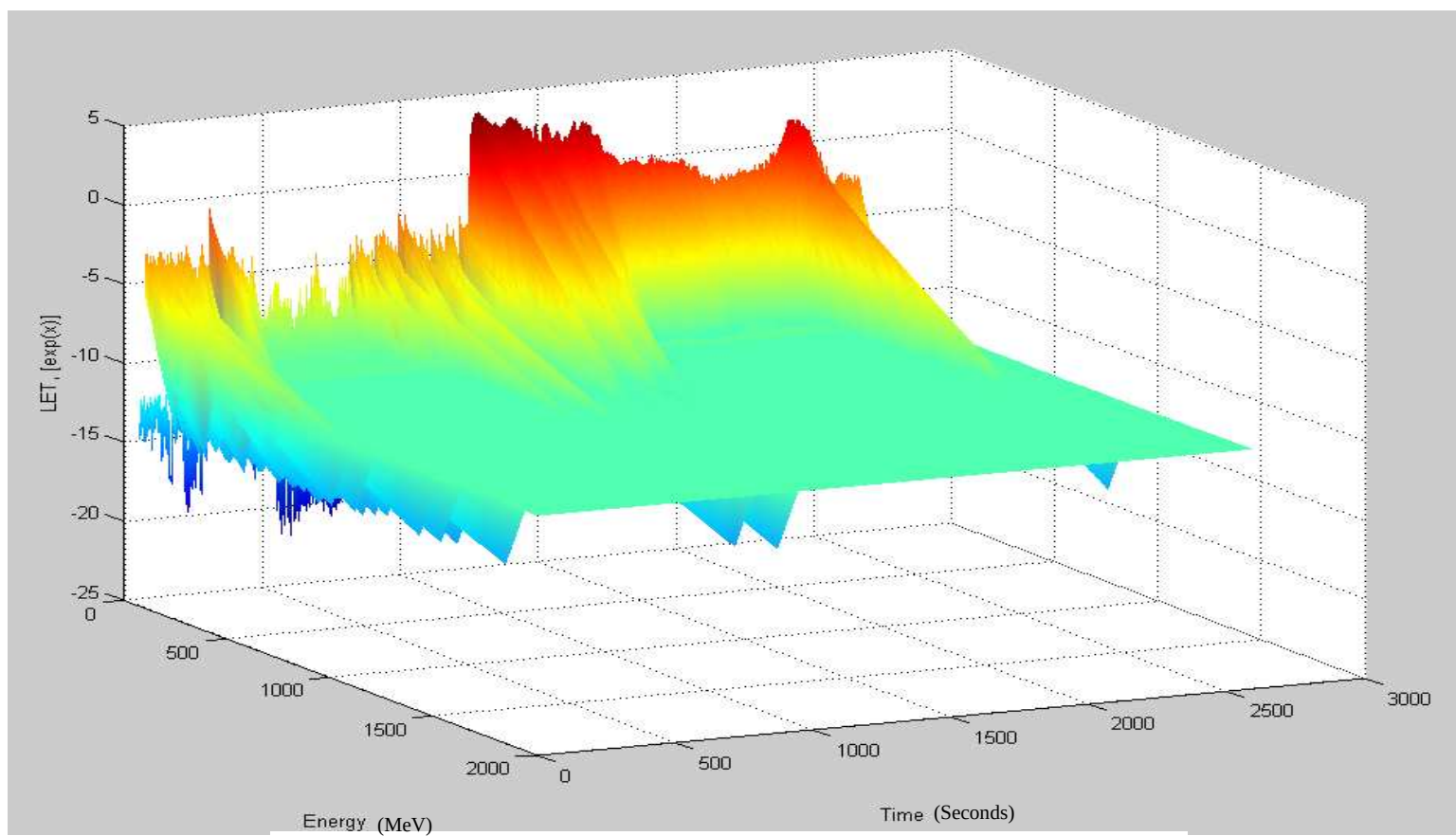


Figure 54. Prediction of LET Spectrum in TEP 2 for September 1989 SPE

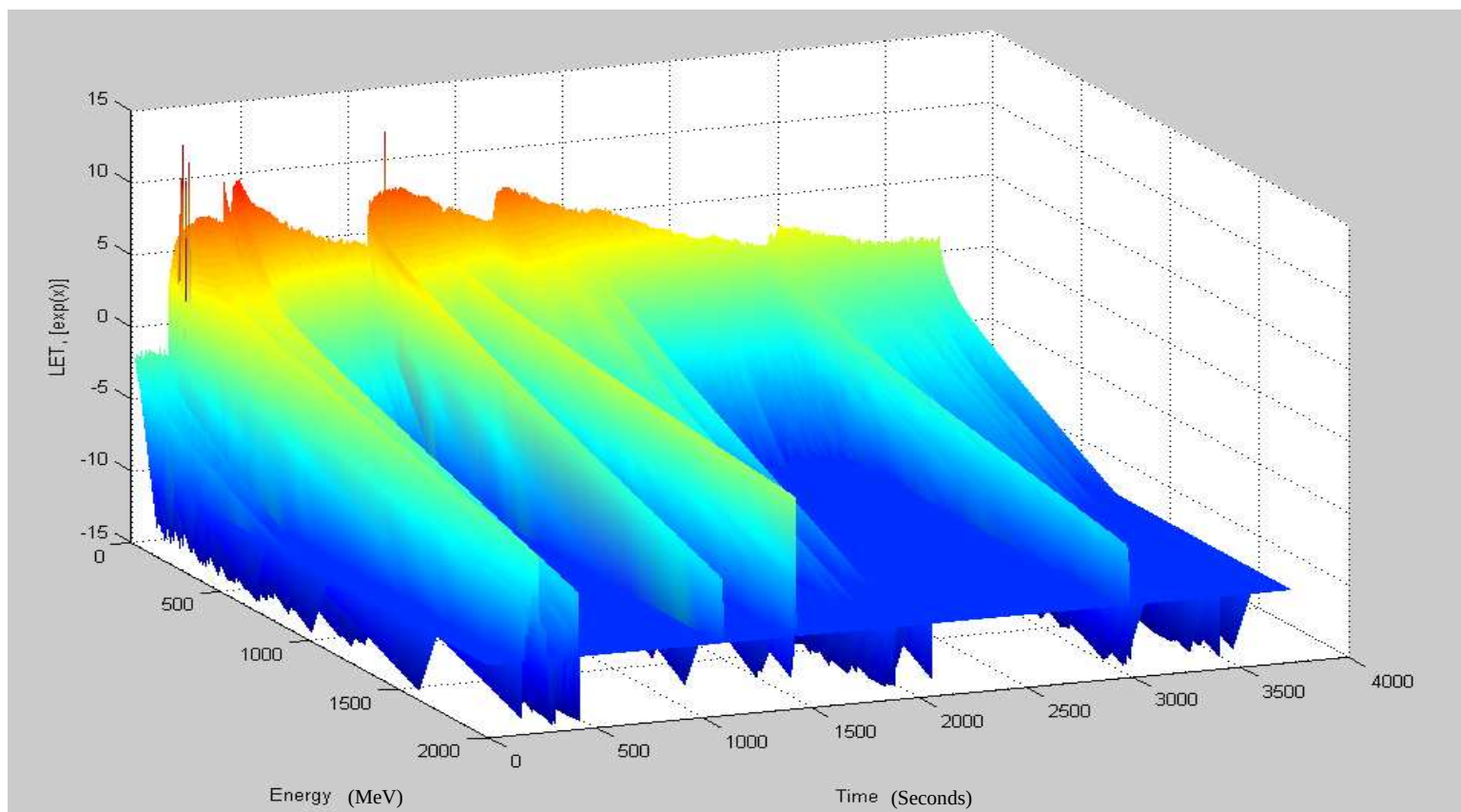


Figure 55. Prediction of LET Spectrum in TEP 1 for October 1989 SPE

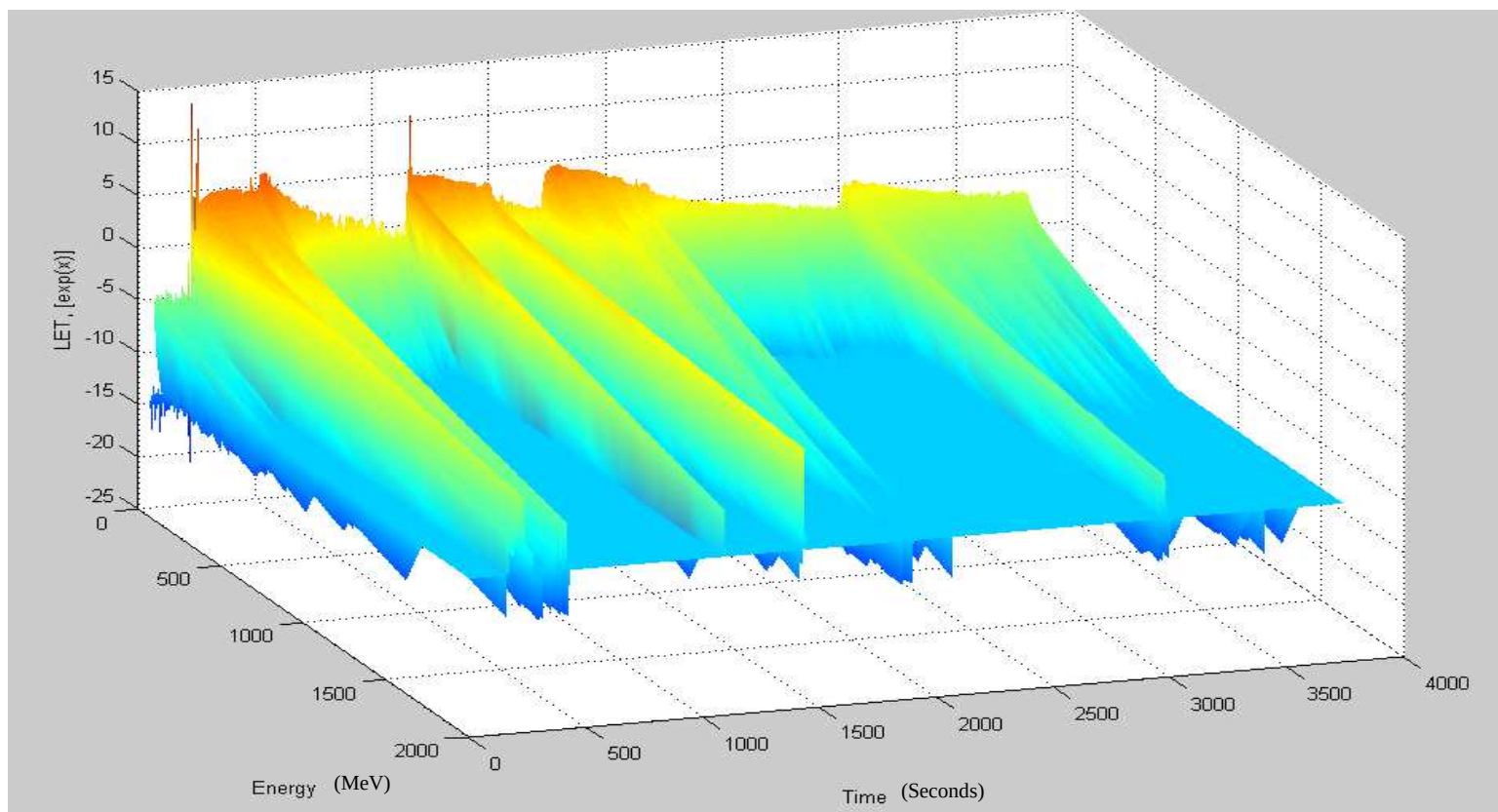


Figure 56. Prediction of LET Spectrum in TEP 2 for October 1989 SPE

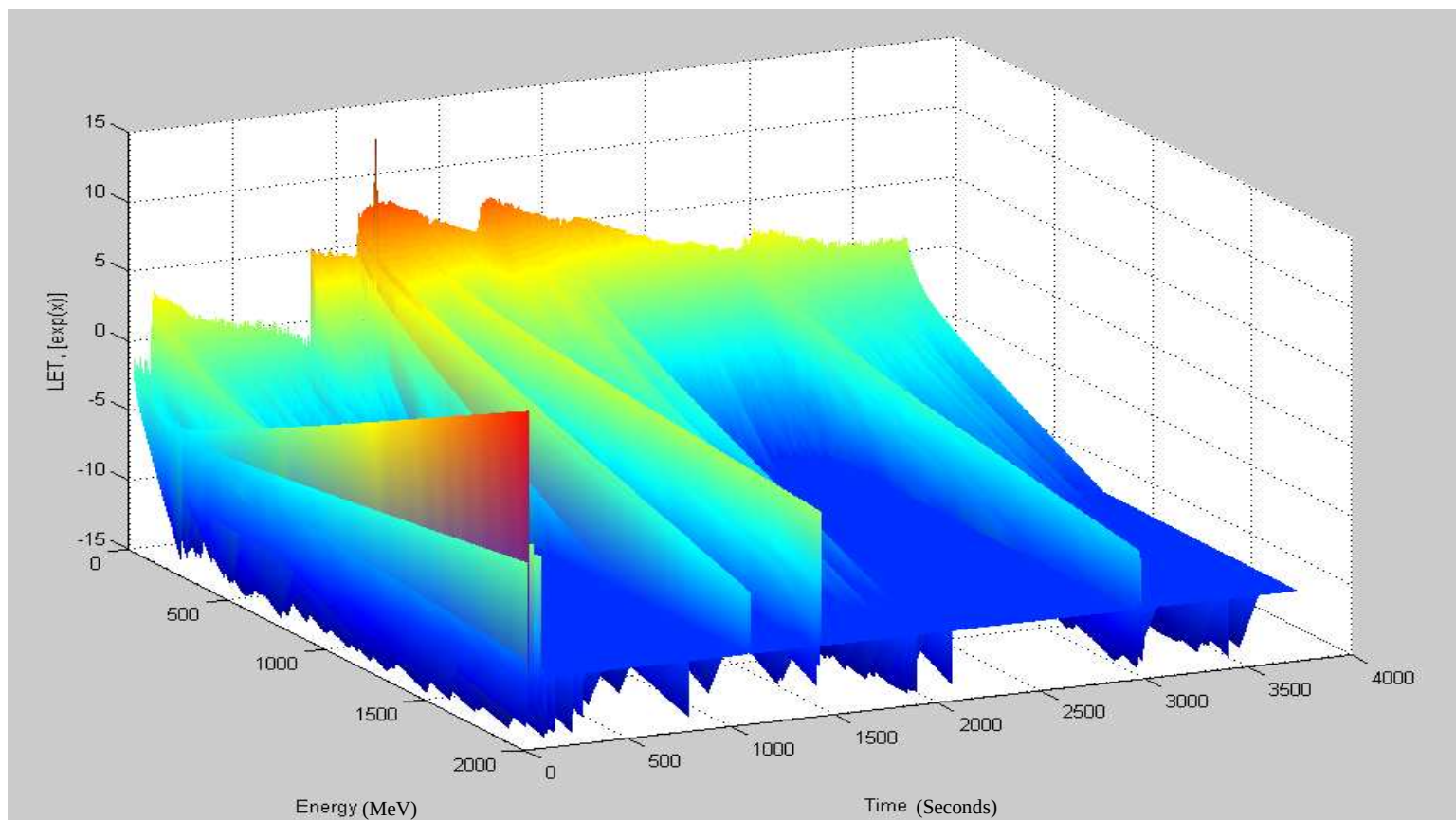


Figure 57. Prediction of LET Spectrum in TEP 1 for November 1989 SPE

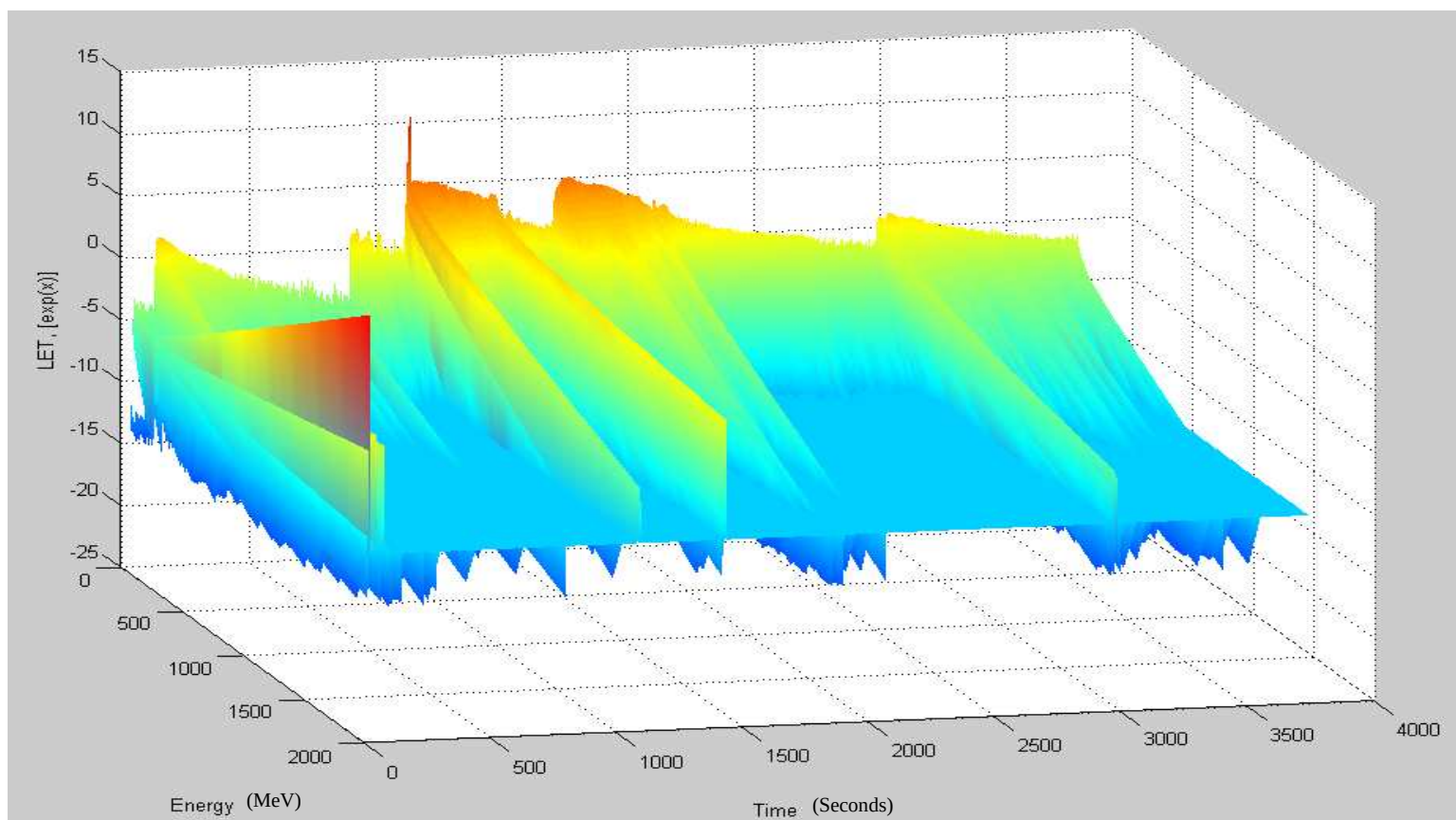


Figure 58. Prediction of LET Spectrum in TEP 2 for November 1989 SPE

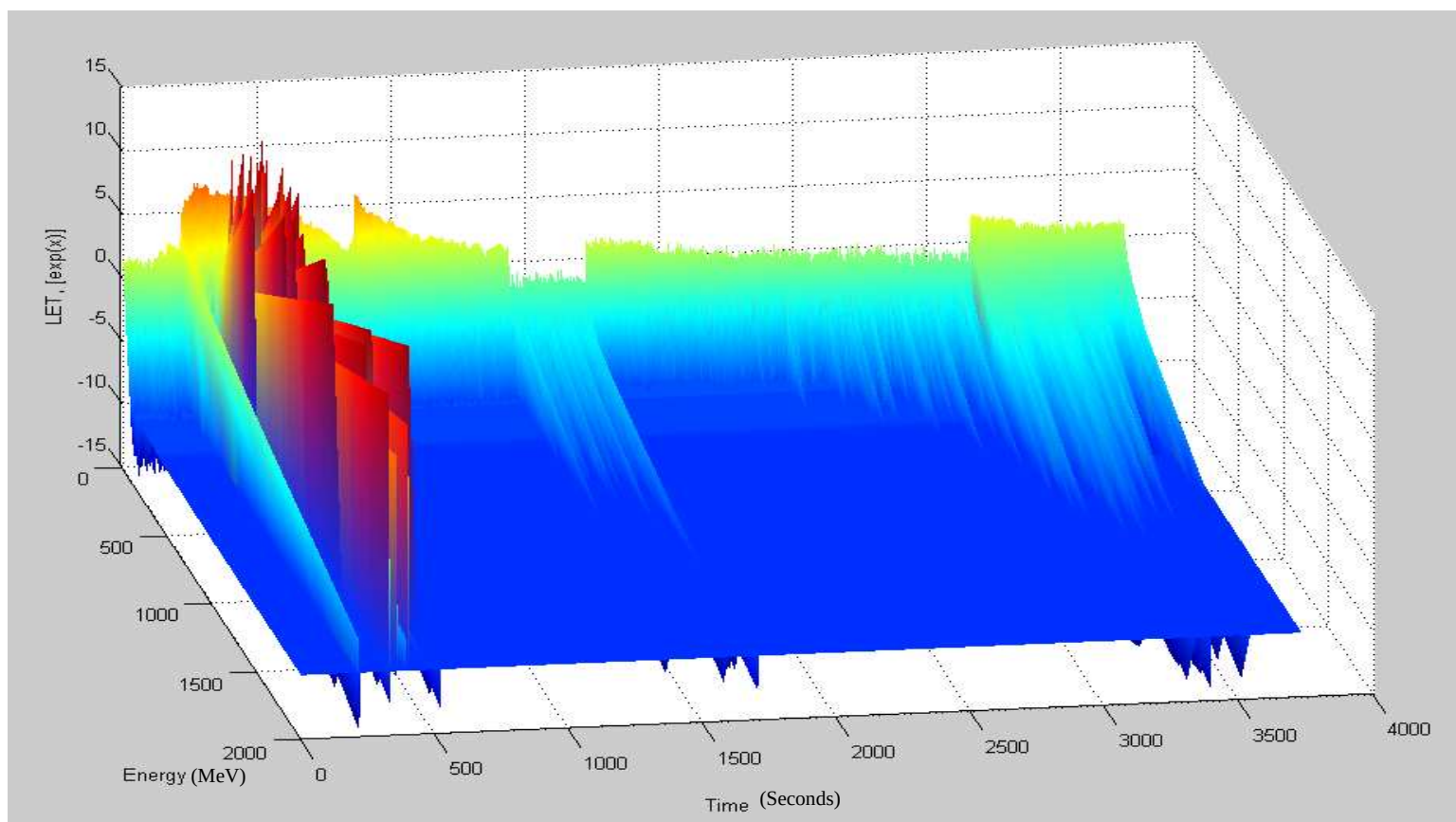


Figure 59. Prediction of LET Spectrum in TEP 1 for Halloween 2003 SPE

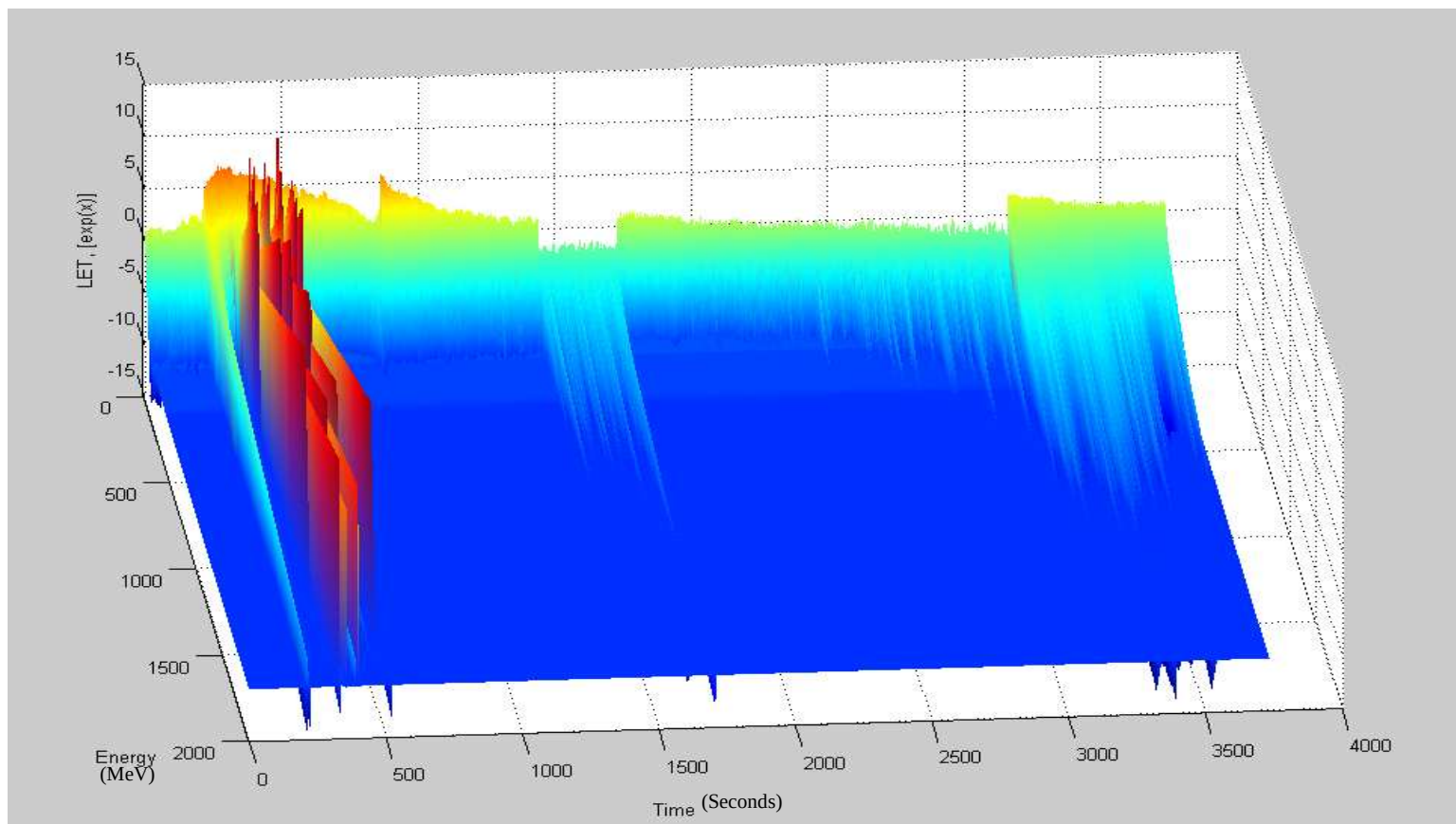


Figure 60. Prediction of LET Spectrum in TEP 1 for Halloween SPE (Rotated View)

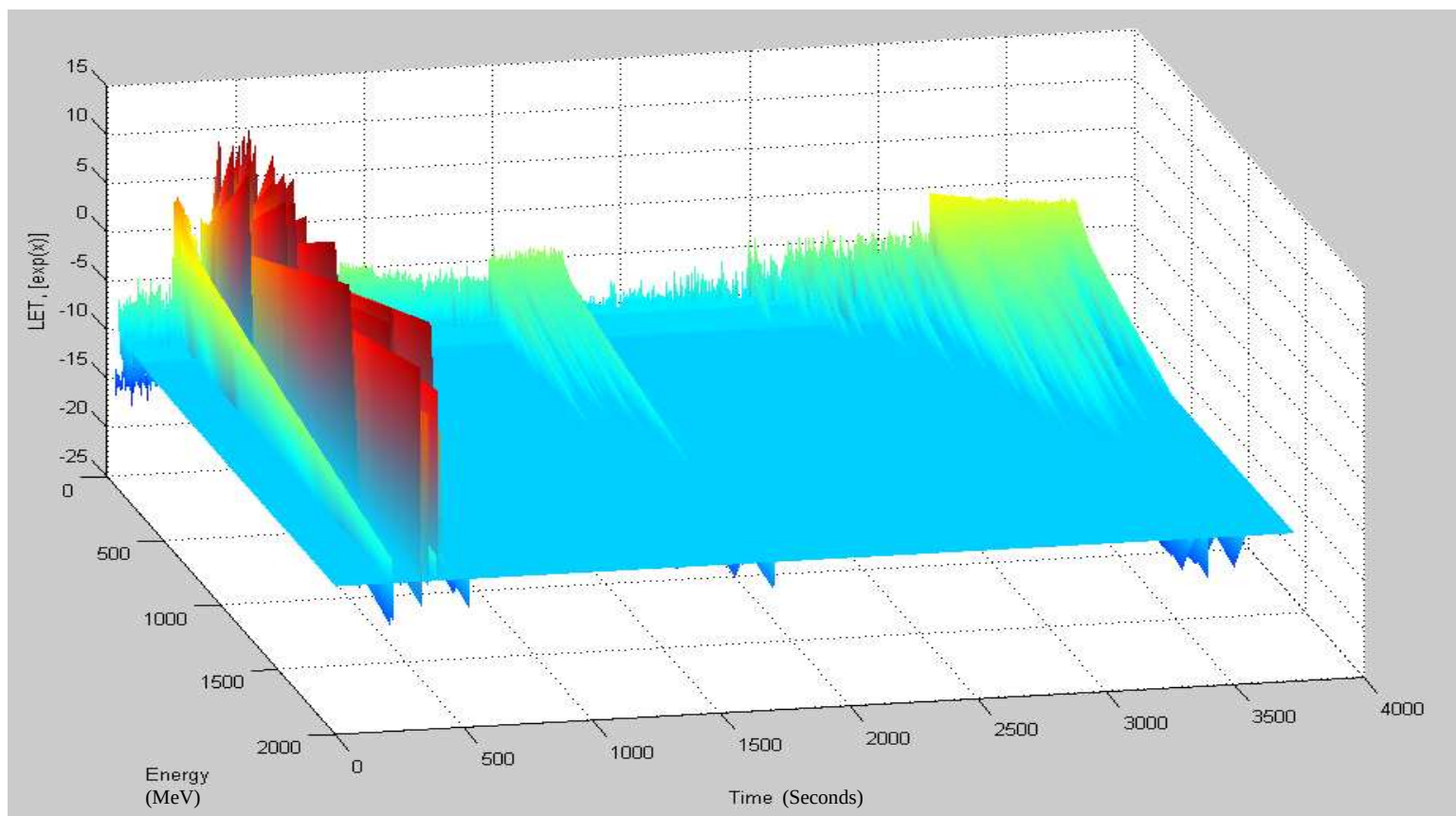


Figure 61. Prediction of LET Spectrum in TEP 2 for Halloween 2003 SPE

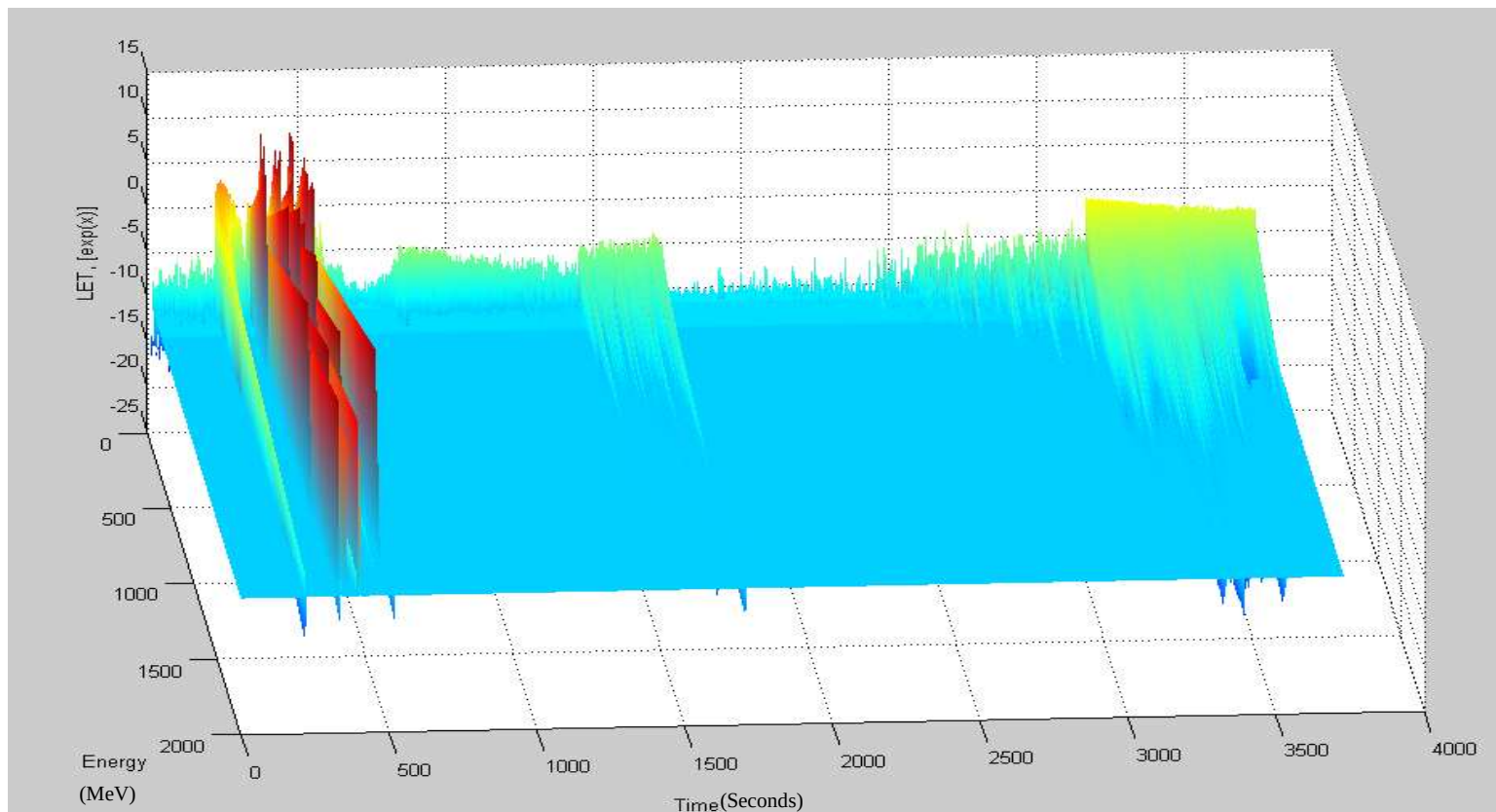


Figure 62. Prediction of LET Spectrum in TEP 2 for Halloween SPF (Rotated View)

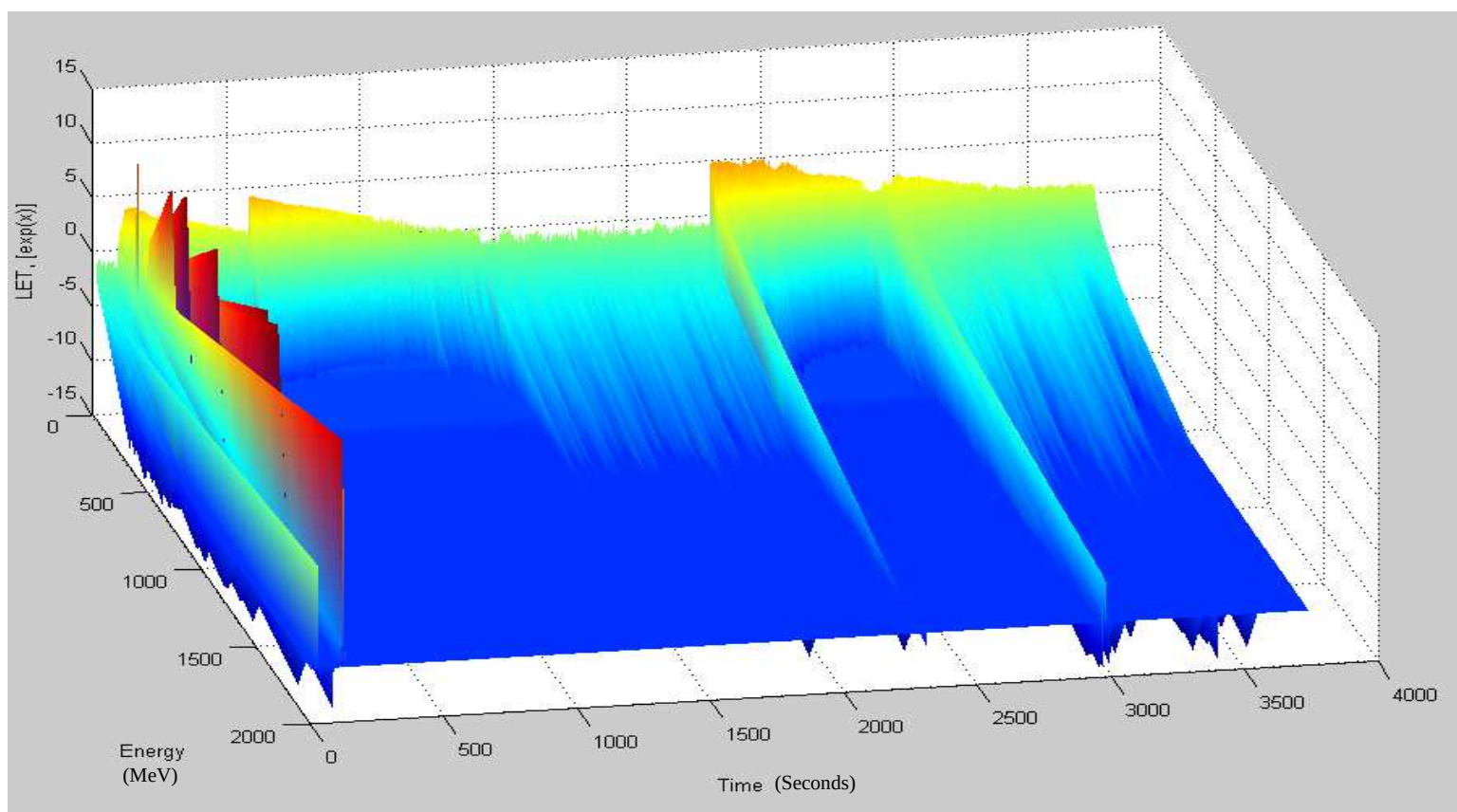


Figure 63. Prediction of LET Spectrum in TEP 1 for 2009 Worst Case Scenario SPE

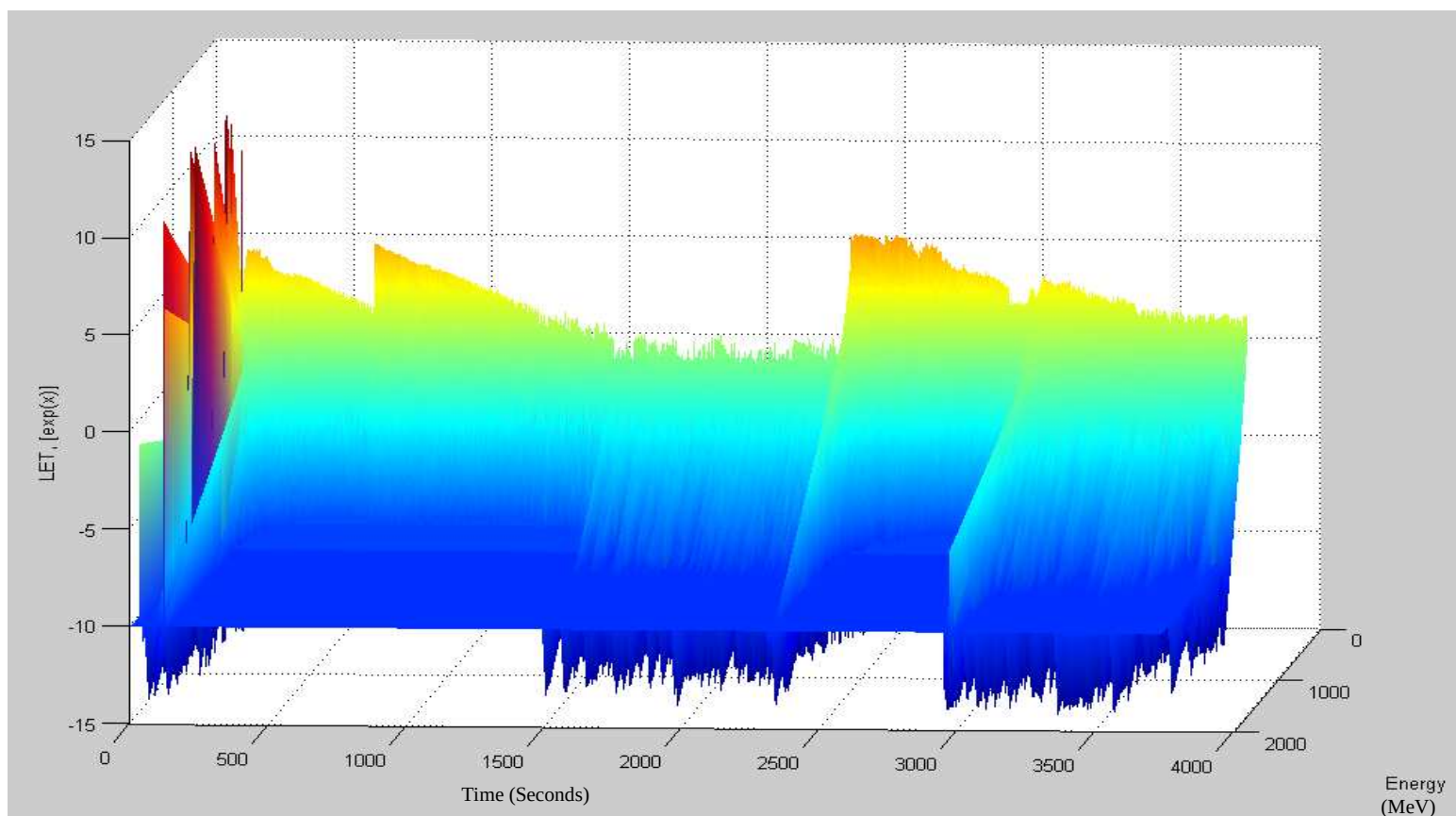


Figure 64. Prediction of LET Spectrum in TEP 1 for 2009 Worst Case Scenario SPE (Rotated View)

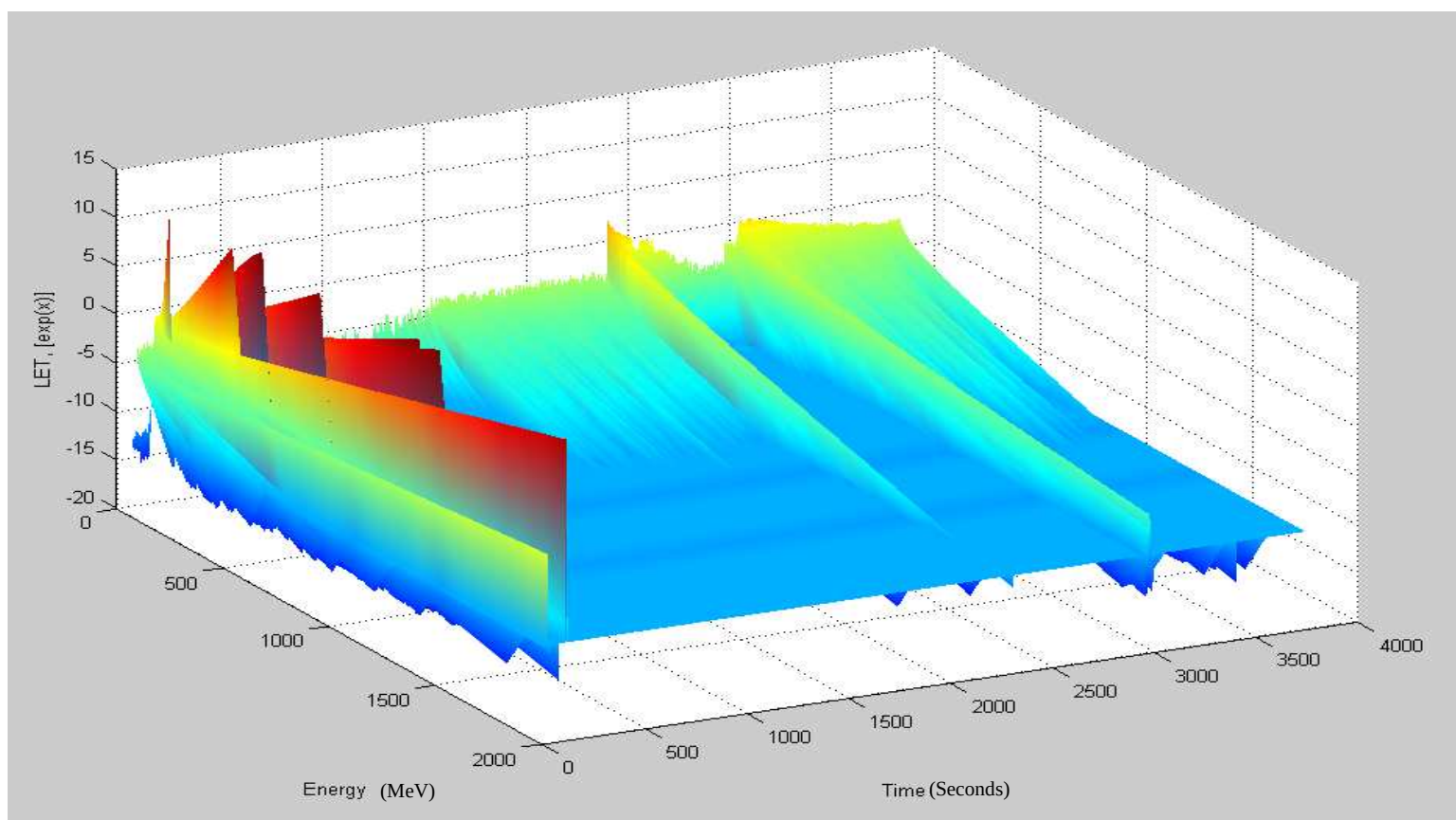


Figure 65. Prediction of LET Spectrum in TEP 2 for 2009 Worst Case Scenario SPE

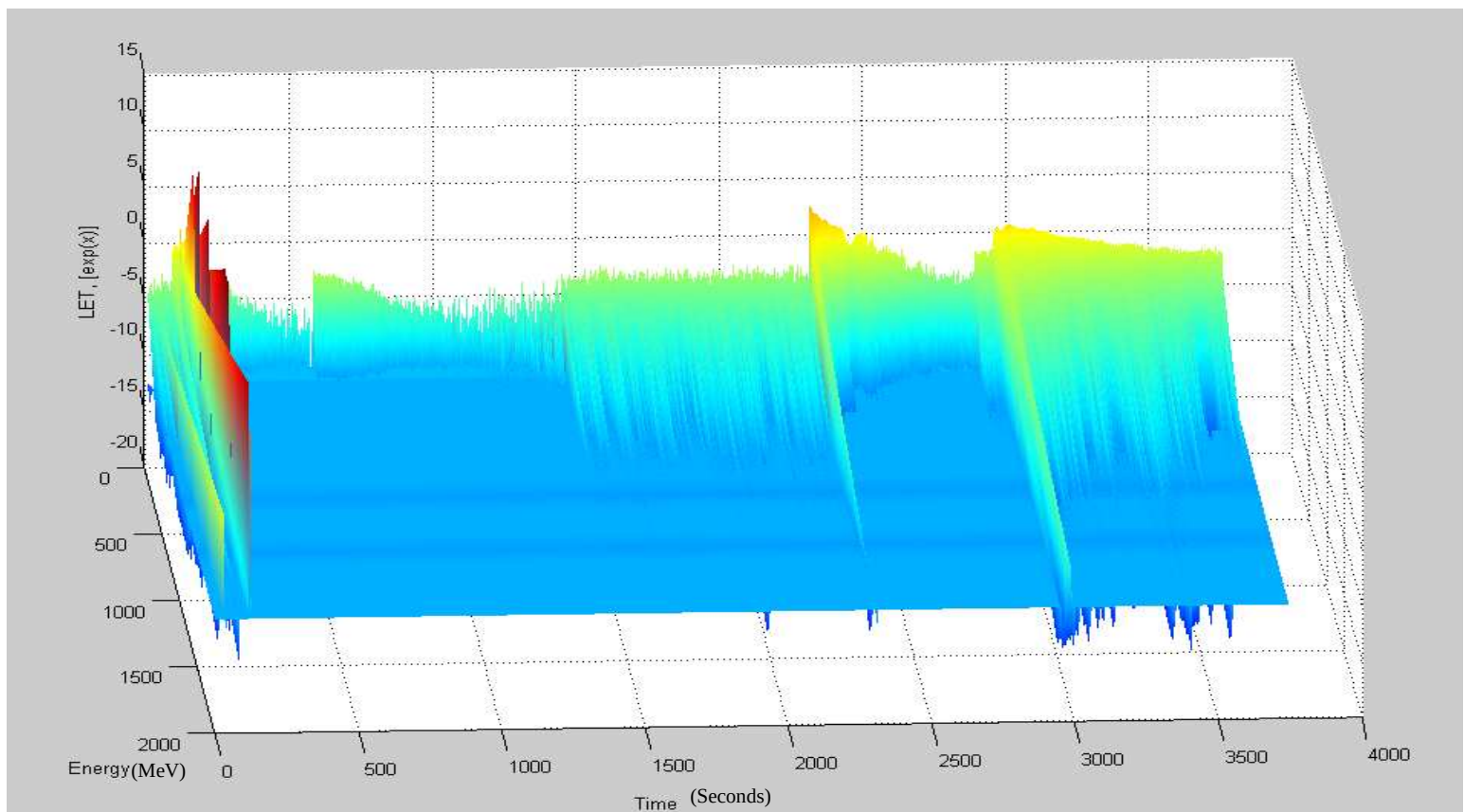


Figure 66. Prediction of LET Spectrum in TEP 2 for 2009 Worst Case Scenario SPF (Rotated View)

5. CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

In conclusion, the code HETC-HEDS was compared against proton, silicon, and iron calibration data and validated for use to predict CRaTER's response to the GCR environment and SPEs. The comparisons were in fair agreement for the proton beam calibrations. At the lower energies (115 and 117 MeV) the agreement in detectors five and six had some discrepancies caused mainly by range and energy straggling. If the exact beam energy and momentum spread were known, the agreement could have been better. At the higher energies however, the agreement was better since energy and range straggling effects are not as pronounced as in the lower beam energy cases.

The comparisons for the silicon and iron beam calibrations were in a good agreement, but more calibration beam corrections need to be incorporated into HETC-HEDS in order to have better agreement. Those corrections might include better values for the dead layer thicknesses of the silicon detectors, knowledge of exact beam energies, and a better approximation of the percent spread in the beam momentum.

A complete LET data base for GCR elements proton up to iron was developed for use by the CRaTER team for future comparisons with real time data obtained with CRaTER when it is flown into lunar orbit. Furthermore, the comparisons will help determine the accuracy of existing models and databases used in transport codes.

CRaTER's response to historical large Solar Particle Events as well as a prediction for a worse case scenario of the year 2009 was developed to present a picture of what might be expected in case CRaTER was exposed to such events when orbiting the Moon.

There is still much work to do. Once the actual data from CRaTER are obtained, it will be very important to do a direct comparison with what has been presented in this work.

Finally, it would be interesting to do a study on the spatial and energy distributions in TEP for the secondary particles produced such as secondary protons and neutrons to decide their significance in dosimetry especially those of secondary neutrons that could be produced by heavy particles such as iron and are able to deposit much of their energies in volumes outside of the target of interest.

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APPENDIX

Table 9. GCR LET data for protons (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	9.5E-05	1.3E-04	1.5E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	9.1E-05	1.0E-04	5.1E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	9.2E-05	9.8E-05	9.2E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	9.2E-05	9.7E-05	1.4E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	9.3E-05	9.7E-05	1.9E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	9.5E-05	9.7E-05	2.5E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50	9.6E-05	9.8E-05	3.2E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
55	9.7E-05	9.8E-05	3.9E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
60	9.8E-05	9.9E-05	4.6E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
65	9.8E-05	9.9E-05	5.4E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
70	9.8E-05	1.0E-04	6.3E-05	1.9E-08	7.9E-09	0.0E+00	0.0E+00	0.0E+00
75	9.9E-05	1.0E-04	7.2E-05	1.9E-08	1.4E-08	3.6E-09	1.2E-09	3.8E-09
80	9.9E-05	1.0E-04	8.1E-05	3.9E-08	2.4E-08	7.9E-09	2.8E-09	8.4E-09
85	9.9E-05	1.0E-04	9.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
90	9.9E-05	9.9E-05	9.9E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
95	9.8E-05	9.9E-05	8.6E-05	2.8E-04	3.1E-04	3.4E-05	2.4E-08	1.4E-08
100	9.8E-05	9.9E-05	7.9E-05	2.0E-04	2.1E-04	7.1E-05	5.7E-09	0.0E+00
110	9.7E-05	9.8E-05	7.2E-05	1.5E-04	1.6E-04	1.3E-04	0.0E+00	0.0E+00
120	9.7E-05	9.7E-05	6.9E-05	1.4E-04	1.4E-04	1.1E-04	2.5E-04	2.6E-04
130	9.5E-05	9.6E-05	6.5E-05	1.2E-04	1.2E-04	8.6E-05	1.7E-04	1.7E-04
140	9.4E-05	9.5E-05	6.3E-05	1.2E-04	1.2E-04	7.7E-05	1.4E-04	1.4E-04
150	9.3E-05	9.3E-05	6.1E-05	1.1E-04	1.1E-04	7.0E-05	1.2E-04	1.2E-04
160	9.2E-05	9.2E-05	5.9E-05	1.1E-04	1.1E-04	6.6E-05	1.1E-04	1.1E-04
170	9.0E-05	9.0E-05	5.7E-05	1.0E-04	1.0E-04	6.3E-05	1.1E-04	1.1E-04
180	8.8E-05	8.9E-05	5.6E-05	9.8E-05	9.8E-05	6.0E-05	1.0E-04	1.0E-04
190	8.7E-05	8.7E-05	5.5E-05	9.5E-05	9.5E-05	5.8E-05	9.8E-05	9.7E-05
200	8.5E-05	8.5E-05	5.3E-05	9.2E-05	9.2E-05	5.6E-05	9.3E-05	9.3E-05
220	8.2E-05	8.3E-05	5.0E-05	8.7E-05	8.7E-05	5.2E-05	8.6E-05	8.7E-05
240	7.9E-05	8.0E-05	4.8E-05	8.3E-05	8.3E-05	4.9E-05	8.1E-05	8.2E-05
260	7.6E-05	7.7E-05	4.6E-05	7.9E-05	7.9E-05	4.6E-05	7.6E-05	7.8E-05
280	7.4E-05	7.4E-05	4.4E-05	7.5E-05	7.5E-05	4.4E-05	7.3E-05	7.3E-05

300	7.0E-05	7.1E-05	4.2E-05	7.2E-05	7.2E-05	4.2E-05	7.0E-05	7.0E-05
330	6.6E-05	6.7E-05	4.0E-05	6.7E-05	6.8E-05	3.9E-05	6.5E-05	6.5E-05
360	6.4E-05	6.4E-05	3.8E-05	6.3E-05	6.4E-05	3.7E-05	6.0E-05	6.1E-05
390	6.0E-05	6.0E-05	3.6E-05	6.0E-05	6.1E-05	3.5E-05	5.8E-05	5.8E-05
430	5.6E-05	5.6E-05	3.3E-05	5.6E-05	5.7E-05	3.2E-05	5.4E-05	5.4E-05
470	5.3E-05	5.3E-05	3.1E-05	5.2E-05	5.3E-05	3.0E-05	4.9E-05	5.0E-05
520	4.8E-05	4.9E-05	2.9E-05	4.8E-05	4.9E-05	2.8E-05	4.6E-05	4.6E-05
570	4.5E-05	4.5E-05	2.7E-05	4.5E-05	4.6E-05	2.6E-05	4.4E-05	4.3E-05
630	4.1E-05	4.1E-05	2.4E-05	4.1E-05	4.2E-05	2.4E-05	3.9E-05	4.0E-05
690	3.8E-05	3.8E-05	2.3E-05	3.8E-05	3.9E-05	2.2E-05	3.5E-05	3.7E-05
760	3.5E-05	3.5E-05	2.0E-05	3.5E-05	3.6E-05	2.0E-05	3.4E-05	3.3E-05
840	3.1E-05	3.1E-05	1.8E-05	3.1E-05	3.3E-05	1.8E-05	2.9E-05	3.0E-05
920	2.8E-05	2.8E-05	1.7E-05	2.8E-05	3.0E-05	1.6E-05	2.7E-05	2.7E-05
1000	2.6E-05	2.6E-05	1.5E-05	2.5E-05	2.7E-05	1.5E-05	2.5E-05	2.5E-05
1100	2.3E-05	2.3E-05	1.3E-05	2.3E-05	2.4E-05	1.3E-05	2.2E-05	2.3E-05
1200	2.0E-05	2.1E-05	1.2E-05	2.0E-05	2.2E-05	1.2E-05	1.9E-05	2.0E-05
1300	1.8E-05	1.8E-05	1.1E-05	1.8E-05	2.0E-05	1.0E-05	1.8E-05	1.8E-05
1400	1.6E-05	1.7E-05	9.7E-06	1.6E-05	1.8E-05	9.4E-06	1.6E-05	1.7E-05
1500	1.5E-05	1.5E-05	8.7E-06	1.5E-05	1.6E-05	8.5E-06	1.4E-05	1.5E-05
1600	1.4E-05	1.4E-05	8.0E-06	1.3E-05	1.5E-05	7.8E-06	1.4E-05	1.4E-05
1700	1.3E-05	1.3E-05	7.2E-06	1.2E-05	1.4E-05	7.1E-06	1.2E-05	1.3E-05
1800	1.1E-05	1.2E-05	6.7E-06	1.2E-05	1.3E-05	6.5E-06	1.2E-05	1.2E-05
1900	1.1E-05	1.1E-05	6.1E-06	1.0E-05	1.2E-05	6.0E-06	1.0E-05	1.1E-05
2000	9.6E-06	9.9E-06	5.7E-06	9.9E-06	1.1E-05	5.6E-06	9.3E-06	1.0E-05
3000	4.0E-06	4.2E-06	2.4E-06	4.2E-06	4.8E-06	2.3E-06	4.3E-06	4.4E-06

Table 10. GCR LET data for helium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	1.1E-04	1.5E-04	2.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	1.0E-04	1.2E-04	6.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	1.0E-04	1.1E-04	1.1E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	1.0E-04	1.1E-04	1.6E-05	1.2E-09	8.3E-10	0.0E+00	0.0E+00	0.0E+00
40	1.0E-04	1.0E-04	2.2E-05	3.5E-09	3.7E-09	1.4E-09	4.2E-09	3.8E-09
45	1.0E-04	1.0E-04	2.8E-05	8.9E-09	4.8E-09	2.6E-09	0.0E+00	0.0E+00
50	9.9E-05	1.0E-04	3.4E-05	2.5E-08	2.1E-08	5.6E-09	0.0E+00	0.0E+00
55	9.8E-05	1.0E-04	4.1E-05	1.1E-07	8.2E-08	1.8E-08	1.2E-08	1.2E-08
60	9.7E-05	9.8E-05	4.8E-05	3.5E-07	3.0E-07	5.6E-08	0.0E+00	0.0E+00
65	9.5E-05	9.6E-05	5.5E-05	5.9E-07	5.5E-07	1.5E-07	5.1E-08	4.2E-08
70	9.6E-05	9.8E-05	6.3E-05	1.2E-06	1.0E-06	3.0E-07	1.0E-07	8.6E-08
75	9.4E-05	9.5E-05	7.0E-05	2.8E-06	2.6E-06	6.1E-07	3.5E-07	3.5E-07
80	9.3E-05	9.4E-05	7.7E-05	5.5E-06	5.3E-06	1.3E-06	6.8E-07	6.4E-07
85	9.2E-05	9.3E-05	8.4E-05	8.3E-06	8.0E-06	2.4E-06	1.1E-06	1.1E-06
90	9.0E-05	9.1E-05	9.1E-05	1.0E-05	1.1E-05	3.8E-06	2.3E-06	2.2E-06
95	8.8E-05	8.8E-05	7.3E-05	2.3E-04	2.6E-04	3.8E-05	4.5E-06	4.0E-06
100	8.7E-05	8.7E-05	6.6E-05	1.7E-04	1.8E-04	6.9E-05	6.2E-06	6.1E-06
110	8.4E-05	8.4E-05	5.9E-05	1.3E-04	1.3E-04	1.1E-04	1.1E-05	1.1E-05
120	8.1E-05	8.1E-05	5.5E-05	1.1E-04	1.1E-04	8.4E-05	2.0E-04	2.1E-04
130	7.9E-05	7.8E-05	5.1E-05	9.8E-05	1.0E-04	6.7E-05	1.3E-04	1.3E-04
140	7.7E-05	7.6E-05	4.8E-05	9.0E-05	9.2E-05	5.9E-05	1.1E-04	1.1E-04
150	7.6E-05	7.4E-05	4.6E-05	8.3E-05	8.5E-05	5.3E-05	9.6E-05	9.8E-05
160	7.2E-05	7.2E-05	4.3E-05	7.7E-05	8.1E-05	4.9E-05	8.5E-05	8.8E-05
170	7.2E-05	7.2E-05	4.2E-05	7.2E-05	7.7E-05	4.6E-05	7.9E-05	8.2E-05
180	7.2E-05	7.1E-05	4.1E-05	7.1E-05	7.5E-05	4.4E-05	7.9E-05	7.8E-05
190	6.9E-05	6.9E-05	3.9E-05	6.8E-05	7.2E-05	4.2E-05	7.2E-05	7.4E-05
200	6.7E-05	6.7E-05	3.7E-05	6.6E-05	7.1E-05	4.0E-05	6.9E-05	7.0E-05
300	5.0E-05	5.1E-05	2.8E-05	4.6E-05	4.9E-05	2.8E-05	4.7E-05	5.0E-05
400	4.0E-05	3.8E-05	2.1E-05	3.3E-05	3.8E-05	2.0E-05	3.5E-05	3.7E-05
500	3.2E-05	3.1E-05	1.7E-05	2.6E-05	2.9E-05	1.6E-05	2.8E-05	3.0E-05
600	2.7E-05	2.6E-05	1.3E-05	2.1E-05	2.6E-05	1.3E-05	2.4E-05	2.6E-05
700	2.4E-05	2.3E-05	1.2E-05	1.9E-05	2.4E-05	1.1E-05	2.0E-05	2.3E-05
800	1.8E-05	1.8E-05	9.1E-06	1.5E-05	1.8E-05	8.8E-06	1.6E-05	1.7E-05
900	1.6E-05	1.6E-05	7.9E-06	1.2E-05	1.6E-05	7.6E-06	1.4E-05	1.5E-05
1000	1.4E-05	1.4E-05	7.0E-06	1.1E-05	1.4E-05	6.8E-06	1.2E-05	1.4E-05
1250	1.1E-05	1.0E-05	5.2E-06	8.5E-06	1.0E-05	5.1E-06	9.3E-06	1.0E-05

1500	7.1E-06	7.2E-06	3.5E-06	5.5E-06	7.2E-06	3.4E-06	6.5E-06	6.8E-06
1750	5.6E-06	5.6E-06	2.8E-06	4.6E-06	5.7E-06	2.7E-06	5.0E-06	5.4E-06
2000	4.2E-06	4.3E-06	2.1E-06	3.4E-06	4.1E-06	2.0E-06	3.6E-06	4.1E-06
3000	1.4E-06	1.5E-06	7.4E-07	1.2E-06	1.4E-06	7.2E-07	1.2E-06	1.4E-06

Table 11. GCR LET data for lithium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	4.2E-07	3.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	3.5E-07	4.8E-07	6.5E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	3.3E-07	3.9E-07	1.7E-08	1.1E-11	3.9E-12	2.3E-12	0.0E+00	0.0E+00
35	3.3E-07	3.6E-07	2.9E-08	1.6E-11	1.1E-11	7.7E-12	0.0E+00	0.0E+00
40	3.2E-07	3.4E-07	4.1E-08	2.9E-11	2.8E-11	2.1E-11	0.0E+00	0.0E+00
45	3.2E-07	3.3E-07	5.4E-08	8.3E-11	6.4E-11	4.7E-11	5.6E-11	4.2E-11
50	3.1E-07	3.3E-07	6.7E-08	1.6E-10	1.2E-10	7.4E-11	1.0E-10	7.3E-11
55	3.1E-07	3.2E-07	8.2E-08	2.2E-10	2.0E-10	1.1E-10	1.2E-10	1.1E-10
60	3.1E-07	3.2E-07	9.7E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
65	3.1E-07	3.1E-07	1.1E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
70	3.0E-07	3.1E-07	1.3E-07	7.7E-10	6.9E-10	3.5E-10	3.9E-10	3.4E-10
75	3.0E-07	3.0E-07	1.4E-07	1.0E-09	8.8E-10	4.4E-10	5.1E-10	4.9E-10
80	3.0E-07	3.0E-07	1.6E-07	1.7E-09	1.6E-09	6.3E-10	7.1E-10	6.5E-10
85	2.9E-07	3.0E-07	1.8E-07	3.6E-09	3.2E-09	8.9E-10	8.6E-10	8.1E-10
90	2.9E-07	2.9E-07	1.9E-07	7.5E-09	7.0E-09	1.5E-09	9.7E-10	9.1E-10
95	2.9E-07	2.9E-07	2.1E-07	1.2E-08	1.2E-08	2.8E-09	1.5E-09	1.3E-09
100	2.8E-07	2.9E-07	2.2E-07	2.0E-08	1.8E-08	4.9E-09	1.9E-09	1.7E-09
110	2.8E-07	2.8E-07	2.5E-07	6.6E-08	6.1E-08	1.4E-08	8.1E-09	7.5E-09
120	2.7E-07	2.7E-07	2.0E-07	5.8E-07	6.3E-07	1.2E-07	1.8E-08	1.7E-08
130	2.6E-07	2.7E-07	1.8E-07	3.9E-07	4.0E-07	2.3E-07	4.2E-08	3.9E-08
140	2.6E-07	2.6E-07	1.7E-07	3.3E-07	3.3E-07	3.0E-07	8.9E-08	8.5E-08
150	2.5E-07	2.5E-07	1.6E-07	2.9E-07	2.9E-07	2.2E-07	5.0E-07	5.4E-07
160	2.5E-07	2.5E-07	1.5E-07	2.7E-07	2.7E-07	1.8E-07	3.5E-07	3.5E-07
170	2.4E-07	2.4E-07	1.4E-07	2.5E-07	2.5E-07	1.6E-07	2.9E-07	2.9E-07
180	2.4E-07	2.4E-07	1.4E-07	2.4E-07	2.4E-07	1.5E-07	2.6E-07	2.6E-07
190	2.7E-07	2.7E-07	1.3E-07	2.2E-07	2.3E-07	1.4E-07	2.4E-07	2.4E-07
200	2.6E-07	2.6E-07	1.3E-07	2.1E-07	2.2E-07	1.3E-07	2.2E-07	2.2E-07
300	2.3E-07	2.4E-07	1.3E-07	1.9E-07	2.2E-07	1.1E-07	1.8E-07	1.8E-07
400	1.9E-07	1.9E-07	9.9E-08	1.4E-07	1.7E-07	8.7E-08	1.4E-07	1.4E-07
500	1.7E-07	1.7E-07	8.3E-08	1.2E-07	1.5E-07	7.3E-08	1.1E-07	1.2E-07
600	1.4E-07	1.4E-07	7.0E-08	9.6E-08	1.2E-07	6.1E-08	9.8E-08	1.0E-07
700	1.2E-07	1.3E-07	6.3E-08	8.7E-08	1.1E-07	5.5E-08	8.7E-08	9.3E-08
800	1.1E-07	1.1E-07	5.2E-08	7.1E-08	9.1E-08	4.5E-08	7.3E-08	7.7E-08

900	9.2E-08	9.7E-08	4.6E-08	6.2E-08	8.2E-08	4.0E-08	6.7E-08	7.2E-08
1000	8.7E-08	8.8E-08	4.2E-08	5.8E-08	7.2E-08	3.6E-08	6.0E-08	6.2E-08
1250	7.1E-08	7.1E-08	3.3E-08	4.6E-08	5.9E-08	2.9E-08	5.0E-08	4.9E-08
1500	5.0E-08	5.3E-08	2.4E-08	3.2E-08	4.3E-08	2.1E-08	3.6E-08	3.7E-08
1750	4.1E-08	4.2E-08	2.0E-08	2.6E-08	3.5E-08	1.7E-08	2.9E-08	3.1E-08
2000	3.2E-08	3.3E-08	1.5E-08	2.2E-08	2.7E-08	1.3E-08	2.1E-08	2.3E-08
3000	1.3E-08	1.3E-08	6.2E-09	8.5E-09	1.1E-08	5.4E-09	8.3E-09	1.0E-08

Table 12. GCR LET data for beryllium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	4.4E-07	2.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	3.4E-07	5.8E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	3.2E-07	3.8E-07	1.1E-08	3.6E-12	2.9E-12	1.2E-12	0.0E+00	0.0E+00
35	3.1E-07	3.4E-07	2.0E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	3.0E-07	3.2E-07	2.9E-08	2.7E-11	1.8E-11	0.0E+00	0.0E+00	0.0E+00
45	2.9E-07	3.1E-07	4.0E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50	2.9E-07	3.0E-07	5.1E-08	8.0E-11	6.8E-11	4.3E-11	3.8E-11	3.4E-11
55	2.9E-07	3.0E-07	6.2E-08	1.5E-10	1.1E-10	0.0E+00	0.0E+00	0.0E+00
60	2.9E-07	2.9E-07	7.4E-08	2.0E-10	1.7E-10	8.3E-11	0.0E+00	0.0E+00
65	2.8E-07	2.9E-07	8.7E-08	3.0E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00
70	2.8E-07	2.9E-07	9.9E-08	4.0E-10	3.5E-10	1.9E-10	2.0E-10	1.7E-10
75	2.8E-07	2.8E-07	1.1E-07	6.4E-10	5.4E-10	2.6E-10	2.8E-10	2.4E-10
80	2.8E-07	2.8E-07	1.3E-07	8.7E-10	7.8E-10	3.3E-10	3.3E-10	3.2E-10
85	2.7E-07	2.8E-07	1.4E-07	1.8E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00
90	2.7E-07	2.8E-07	1.5E-07	3.3E-09	3.0E-09	7.5E-10	0.0E+00	0.0E+00
95	2.7E-07	2.7E-07	1.7E-07	5.2E-09	4.9E-09	1.3E-09	7.2E-10	6.3E-10
100	2.7E-07	2.7E-07	1.8E-07	8.0E-09	7.4E-09	2.2E-09	9.6E-10	9.2E-10
200	2.2E-07	2.2E-07	1.3E-07	2.2E-07	2.2E-07	1.4E-07	2.4E-07	2.4E-07
300	2.1E-07	2.1E-07	1.1E-07	1.7E-07	2.0E-07	9.2E-08	1.7E-07	1.7E-07
400	1.7E-07	1.7E-07	8.7E-08	1.3E-07	1.6E-07	7.8E-08	1.4E-07	1.4E-07
500	1.5E-07	1.5E-07	7.3E-08	1.1E-07	1.3E-07	6.5E-08	1.1E-07	1.2E-07
600	1.2E-07	1.3E-07	6.1E-08	9.1E-08	1.1E-07	5.5E-08	9.3E-08	1.0E-07
700	1.1E-07	1.2E-07	5.4E-08	8.2E-08	1.0E-07	4.8E-08	8.6E-08	9.1E-08
800	9.3E-08	9.4E-08	4.4E-08	6.7E-08	8.3E-08	4.0E-08	6.8E-08	7.3E-08
900	8.4E-08	8.5E-08	4.0E-08	5.9E-08	7.7E-08	3.5E-08	6.4E-08	6.9E-08
1000	7.5E-08	7.6E-08	3.6E-08	5.3E-08	6.8E-08	3.2E-08	5.7E-08	5.9E-08
1250	5.9E-08	6.1E-08	2.8E-08	4.3E-08	5.4E-08	2.5E-08	4.5E-08	4.8E-08
1500	4.3E-08	4.4E-08	2.0E-08	3.0E-08	3.9E-08	1.8E-08	3.5E-08	3.5E-08
1750	3.6E-08	3.6E-08	1.7E-08	2.6E-08	3.2E-08	1.5E-08	2.6E-08	2.8E-08
2000	2.6E-08	2.8E-08	1.3E-08	1.9E-08	2.5E-08	1.2E-08	2.2E-08	2.2E-08
3000	1.1E-08	1.1E-08	5.2E-09	7.9E-09	1.0E-08	4.7E-09	8.9E-09	9.0E-09

Table 13. GCR LET data for boron (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	7.6E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	3.4E-06	3.1E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	2.9E-06	4.4E-06	2.4E-08	1.4E-11	1.3E-11	4.6E-12	0.0E+00	0.0E+00
35	2.7E-06	3.2E-06	9.9E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	2.6E-06	2.9E-06	1.6E-07	6.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	2.5E-06	2.7E-06	2.3E-07	1.5E-10	1.2E-10	7.8E-11	7.2E-11	7.2E-11
50	2.4E-06	2.6E-06	3.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
55	2.4E-06	2.5E-06	3.7E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
60	2.3E-06	2.4E-06	4.5E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
65	2.3E-06	2.4E-06	5.2E-07	1.2E-09	1.0E-09	5.2E-10	5.4E-10	4.4E-10
70	2.3E-06	2.3E-06	6.0E-07	1.7E-09	1.5E-09	7.7E-10	0.0E+00	0.0E+00
75	2.2E-06	2.3E-06	6.8E-07	2.7E-09	2.4E-09	1.1E-09	1.1E-09	9.9E-10
80	2.2E-06	2.2E-06	7.6E-07	3.9E-09	3.8E-09	1.4E-09	1.4E-09	1.2E-09
85	2.1E-06	2.2E-06	8.3E-07	7.0E-09	6.3E-09	1.9E-09	1.7E-09	1.6E-09
90	2.1E-06	2.1E-06	9.1E-07	1.2E-08	1.1E-08	3.0E-09	2.2E-09	2.1E-09
95	2.1E-06	2.1E-06	9.9E-07	1.9E-08	1.8E-08	4.9E-09	2.9E-09	2.7E-09
100	2.0E-06	2.1E-06	1.1E-06	2.7E-08	2.6E-08	7.9E-09	4.2E-09	3.8E-09
200	1.5E-06	1.5E-06	9.0E-07	1.6E-06	1.6E-06	1.1E-06	2.2E-06	2.2E-06
300	1.2E-06	1.2E-06	6.2E-07	9.9E-07	1.1E-06	5.8E-07	9.5E-07	9.6E-07
400	9.0E-07	9.1E-07	4.7E-07	7.4E-07	8.4E-07	4.2E-07	7.2E-07	7.4E-07
500	7.3E-07	7.4E-07	3.7E-07	5.8E-07	6.8E-07	3.3E-07	5.8E-07	5.9E-07
600	6.0E-07	6.0E-07	3.0E-07	4.5E-07	5.4E-07	2.6E-07	4.5E-07	4.8E-07
700	5.2E-07	5.2E-07	2.6E-07	3.9E-07	4.7E-07	2.3E-07	4.1E-07	4.2E-07
800	4.1E-07	4.1E-07	2.0E-07	3.1E-07	3.7E-07	1.8E-07	3.1E-07	3.3E-07
900	3.5E-07	3.6E-07	1.8E-07	2.7E-07	3.2E-07	1.5E-07	2.9E-07	2.9E-07
1000	3.2E-07	3.2E-07	1.5E-07	2.4E-07	2.9E-07	1.4E-07	2.4E-07	2.5E-07
1250	2.4E-07	2.4E-07	1.2E-07	1.8E-07	2.2E-07	1.0E-07	1.9E-07	1.9E-07
1500	1.7E-07	1.7E-07	7.9E-08	1.2E-07	1.5E-07	6.9E-08	1.3E-07	1.3E-07
1750	1.3E-07	1.4E-07	6.3E-08	9.6E-08	1.2E-07	5.5E-08	1.0E-07	1.1E-07
2000	1.0E-07	1.0E-07	4.8E-08	7.2E-08	9.1E-08	4.2E-08	7.7E-08	7.8E-08
3000	3.6E-08	3.6E-08	1.7E-08	2.7E-08	3.3E-08	1.5E-08	2.8E-08	2.9E-08

Table 14. GCR LET data for carbon (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	2.9E-05	6.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	1.9E-05	2.0E-05	2.7E-10	5.5E-11	1.5E-11	1.1E-11	0.0E+00	0.0E+00
35	1.7E-05	2.6E-05	1.4E-07	1.3E-10	1.6E-10	4.0E-11	0.0E+00	0.0E+00
40	1.6E-05	1.9E-05	5.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	1.5E-05	1.7E-05	8.5E-07	5.2E-10	4.8E-10	0.0E+00	0.0E+00	0.0E+00
50	1.5E-05	1.6E-05	1.2E-06	1.2E-09	8.3E-10	3.2E-10	0.0E+00	0.0E+00
55	1.4E-05	1.5E-05	1.5E-06	1.6E-09	1.1E-09	6.1E-10	6.1E-10	5.2E-10
60	1.4E-05	1.5E-05	1.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
65	1.4E-05	1.4E-05	2.2E-06	2.9E-09	2.7E-09	1.3E-09	1.3E-09	1.1E-09
70	1.3E-05	1.4E-05	2.5E-06	4.8E-09	4.1E-09	1.9E-09	2.0E-09	1.6E-09
75	1.3E-05	1.4E-05	2.9E-06	8.1E-09	6.6E-09	2.7E-09	2.6E-09	2.3E-09
80	1.3E-05	1.3E-05	3.3E-06	1.3E-08	1.2E-08	3.9E-09	3.6E-09	3.4E-09
85	1.3E-05	1.3E-05	3.6E-06	2.1E-08	1.9E-08	5.9E-09	5.0E-09	4.8E-09
90	1.2E-05	1.3E-05	4.0E-06	3.8E-08	3.1E-08	9.0E-09	6.0E-09	5.4E-09
95	1.2E-05	1.2E-05	4.3E-06	5.1E-08	4.8E-08	1.4E-08	8.4E-09	7.8E-09
100	1.2E-05	1.2E-05	4.7E-06	7.5E-08	7.2E-08	2.2E-08	1.3E-08	1.1E-08
200	8.4E-06	8.4E-06	5.5E-06	1.1E-05	1.2E-05	7.9E-06	1.1E-06	1.1E-06
300	6.5E-06	6.5E-06	3.6E-06	5.8E-06	5.9E-06	3.5E-06	5.9E-06	6.0E-06
400	4.9E-06	4.9E-06	2.6E-06	4.2E-06	4.7E-06	2.4E-06	4.1E-06	4.2E-06
500	4.0E-06	4.0E-06	2.1E-06	3.2E-06	3.7E-06	1.8E-06	3.2E-06	3.3E-06
600	3.2E-06	3.2E-06	1.6E-06	2.5E-06	2.9E-06	1.4E-06	2.6E-06	2.6E-06
700	2.9E-06	2.8E-06	1.4E-06	2.2E-06	2.5E-06	1.3E-06	2.2E-06	2.3E-06
800	2.2E-06	2.3E-06	1.1E-06	1.7E-06	2.0E-06	9.8E-07	1.8E-06	1.7E-06
900	2.0E-06	2.0E-06	9.9E-07	1.5E-06	1.8E-06	8.6E-07	1.6E-06	1.6E-06
1000	1.8E-06	1.8E-06	8.8E-07	1.3E-06	1.6E-06	7.6E-07	1.4E-06	1.4E-06
1250	1.4E-06	1.4E-06	6.6E-07	1.0E-06	1.2E-06	5.7E-07	1.1E-06	1.1E-06
1500	9.3E-07	9.5E-07	4.7E-07	7.1E-07	8.5E-07	4.0E-07	7.6E-07	7.4E-07
1750	7.8E-07	7.7E-07	3.8E-07	5.8E-07	6.9E-07	3.2E-07	6.0E-07	6.0E-07
2000	5.9E-07	6.0E-07	2.9E-07	4.4E-07	5.2E-07	2.5E-07	4.6E-07	4.7E-07
3000	2.3E-07	2.3E-07	1.1E-07	1.7E-07	2.0E-07	9.5E-08	1.8E-07	1.8E-07

Table 15. GCR LET data for nitrogen (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	1.2E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	7.2E-06	4.6E-06	5.9E-11	6.8E-12	1.2E-11	2.3E-12	4.1E-12	4.7E-12
35	5.9E-06	8.5E-06	2.6E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	5.4E-06	7.3E-06	9.7E-08	6.8E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	5.1E-06	6.1E-06	2.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50	4.9E-06	5.5E-06	3.0E-07	2.2E-10	1.6E-10	9.2E-11	7.7E-11	6.9E-11
55	4.7E-06	5.2E-06	3.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
60	4.6E-06	5.0E-06	4.9E-07	4.5E-10	4.3E-10	2.2E-10	2.3E-10	2.0E-10
65	4.5E-06	4.8E-06	5.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
70	4.4E-06	4.6E-06	6.9E-07	1.1E-09	9.6E-10	0.0E+00	0.0E+00	0.0E+00
75	4.3E-06	4.5E-06	7.9E-07	1.7E-09	1.5E-09	6.3E-10	5.3E-10	5.4E-10
80	4.3E-06	4.4E-06	8.9E-07	2.9E-09	2.6E-09	7.9E-10	0.0E+00	0.0E+00
85	4.2E-06	4.3E-06	1.0E-06	4.9E-09	4.4E-09	1.4E-09	1.2E-09	1.1E-09
90	4.1E-06	4.2E-06	1.1E-06	7.3E-09	6.8E-09	2.0E-09	1.6E-09	1.4E-09
95	4.0E-06	4.1E-06	1.2E-06	1.1E-08	1.1E-08	3.3E-09	2.2E-09	2.0E-09
100	3.9E-06	4.0E-06	1.3E-06	1.7E-08	1.6E-08	5.1E-09	3.2E-09	2.8E-09
200	2.8E-06	2.8E-06	2.0E-06	5.0E-06	5.3E-06	1.5E-06	2.3E-07	2.3E-07
300	2.1E-06	2.1E-06	1.2E-06	2.0E-06	2.1E-06	1.3E-06	2.2E-06	2.2E-06
400	1.6E-06	1.6E-06	8.9E-07	1.4E-06	1.5E-06	8.1E-07	1.3E-06	1.3E-06
500	1.3E-06	1.3E-06	7.0E-07	1.1E-06	1.2E-06	6.2E-07	1.1E-06	1.1E-06
600	1.1E-06	1.1E-06	5.6E-07	8.5E-07	9.7E-07	4.8E-07	8.3E-07	8.4E-07
700	9.3E-07	9.5E-07	4.8E-07	7.4E-07	8.7E-07	4.2E-07	7.4E-07	7.4E-07
800	7.4E-07	7.4E-07	3.8E-07	5.7E-07	6.5E-07	3.2E-07	5.6E-07	5.8E-07
900	6.5E-07	6.5E-07	3.3E-07	5.0E-07	5.7E-07	2.8E-07	5.1E-07	5.0E-07
1000	5.8E-07	5.8E-07	2.9E-07	4.4E-07	5.1E-07	2.5E-07	4.5E-07	4.5E-07
1250	4.3E-07	4.4E-07	2.2E-07	3.3E-07	3.7E-07	1.8E-07	3.3E-07	3.3E-07
1500	3.0E-07	3.1E-07	1.5E-07	2.3E-07	2.7E-07	1.3E-07	2.3E-07	2.4E-07
1750	2.4E-07	2.5E-07	1.2E-07	1.8E-07	2.2E-07	1.0E-07	2.0E-07	1.9E-07
2000	1.8E-07	1.8E-07	9.1E-08	1.4E-07	1.6E-07	7.7E-08	1.4E-07	1.4E-07
3000	6.9E-08	6.9E-08	3.4E-08	5.1E-08	6.0E-08	2.9E-08	5.3E-08	5.4E-08

Table 16. GCR LET data for oxygen (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	4.6E-05	1.5E-05	2.2E-10	1.6E-11	1.5E-11	1.0E-11	3.2E-12	3.6E-12
35	3.4E-05	3.4E-05	1.0E-09	1.3E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	3.0E-05	5.3E-05	2.9E-09	1.8E-10	1.9E-10	0.0E+00	0.0E+00	0.0E+00
45	2.8E-05	3.5E-05	7.1E-07	3.3E-10	3.4E-10	1.5E-10	1.1E-10	1.2E-10
50	2.6E-05	3.1E-05	1.2E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
55	2.5E-05	2.8E-05	1.6E-06	1.4E-09	1.1E-09	6.1E-10	4.7E-10	4.6E-10
60	2.4E-05	2.7E-05	2.1E-06	1.8E-09	1.7E-09	9.1E-10	7.1E-10	7.3E-10
65	2.4E-05	2.5E-05	2.5E-06	3.3E-09	3.0E-09	1.3E-09	1.3E-09	1.2E-09
70	2.3E-05	2.5E-05	3.0E-06	3.7E-09	3.4E-09	1.8E-09	1.9E-09	1.4E-09
75	2.3E-05	2.4E-05	3.5E-06	6.9E-09	6.0E-09	2.5E-09	2.4E-09	2.2E-09
80	2.2E-05	2.3E-05	3.9E-06	1.2E-08	1.0E-08	3.9E-09	3.5E-09	3.1E-09
85	2.2E-05	2.2E-05	4.4E-06	2.1E-08	1.8E-08	5.7E-09	4.7E-09	0.0E+00
90	2.1E-05	2.2E-05	4.9E-06	3.1E-08	2.9E-08	9.0E-09	7.2E-09	6.4E-09
95	2.1E-05	2.1E-05	5.3E-06	5.1E-08	4.9E-08	1.4E-08	9.1E-09	8.3E-09
100	2.0E-05	2.1E-05	5.8E-06	7.4E-08	7.2E-08	2.2E-08	1.3E-08	1.3E-08
200	1.4E-05	1.4E-05	1.3E-05	3.7E-06	3.4E-06	9.5E-07	8.6E-07	8.5E-07
300	1.1E-05	1.1E-05	6.2E-06	1.1E-05	1.1E-05	6.7E-06	1.2E-05	1.2E-05
400	8.0E-06	8.0E-06	4.4E-06	6.9E-06	7.1E-06	4.1E-06	6.7E-06	6.8E-06
500	6.5E-06	6.5E-06	3.5E-06	5.4E-06	6.0E-06	3.0E-06	5.3E-06	5.3E-06
600	5.2E-06	5.3E-06	2.8E-06	4.2E-06	4.7E-06	2.4E-06	4.2E-06	4.2E-06
700	4.7E-06	4.7E-06	2.4E-06	3.7E-06	4.1E-06	2.1E-06	3.6E-06	3.6E-06
800	3.7E-06	3.7E-06	1.9E-06	2.9E-06	3.2E-06	1.6E-06	2.8E-06	2.8E-06
900	3.2E-06	3.2E-06	1.7E-06	2.5E-06	2.8E-06	1.4E-06	2.5E-06	2.5E-06
1000	2.9E-06	2.9E-06	1.5E-06	2.2E-06	2.5E-06	1.2E-06	2.2E-06	2.2E-06
1250	2.2E-06	2.2E-06	1.1E-06	1.7E-06	1.9E-06	9.3E-07	1.6E-06	1.7E-06
1500	1.5E-06	1.6E-06	7.8E-07	1.2E-06	1.3E-06	6.5E-07	1.2E-06	1.2E-06
1750	1.3E-06	1.3E-06	6.3E-07	9.5E-07	1.1E-06	5.3E-07	9.1E-07	9.7E-07
2000	9.6E-07	9.7E-07	4.8E-07	7.3E-07	8.5E-07	4.0E-07	7.1E-07	7.4E-07
3000	3.8E-07	3.8E-07	1.9E-07	2.8E-07	3.2E-07	1.6E-07	2.9E-07	2.8E-07

Table 17. GCR LET data for fluorine (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	9.0E-07	1.6E-07	4.3E-12	3.6E-13	3.6E-13	2.2E-13	0.0E+00	0.0E+00
35	5.9E-07	4.9E-07	1.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	5.1E-07	8.0E-07	4.8E-11	3.1E-12	2.9E-12	1.5E-12	7.9E-13	9.4E-13
45	4.7E-07	6.3E-07	9.1E-09	8.0E-12	7.6E-12	3.3E-12	4.0E-12	2.6E-12
50	4.5E-07	5.4E-07	1.7E-08	1.6E-11	1.3E-11	6.2E-12	6.0E-12	3.9E-12
55	4.3E-07	4.9E-07	2.5E-08	2.2E-11	1.8E-11	1.0E-11	7.8E-12	6.2E-12
60	4.2E-07	4.6E-07	3.2E-08	2.7E-11	2.5E-11	1.4E-11	1.6E-11	1.4E-11
65	4.1E-07	4.4E-07	4.0E-08	4.5E-11	4.2E-11	2.1E-11	2.3E-11	1.9E-11
70	4.0E-07	4.3E-07	4.8E-08	6.1E-11	6.1E-11	3.2E-11	3.1E-11	2.5E-11
75	4.0E-07	4.2E-07	5.6E-08	1.2E-10	1.1E-10	4.7E-11	4.4E-11	4.1E-11
80	3.9E-07	4.1E-07	6.4E-08	2.1E-10	2.0E-10	7.0E-11	6.4E-11	6.3E-11
85	3.8E-07	4.0E-07	7.2E-08	3.4E-10	3.2E-10	1.1E-10	9.7E-11	9.0E-11
90	3.8E-07	3.9E-07	8.0E-08	5.4E-10	5.1E-10	1.7E-10	1.4E-10	1.4E-10
95	3.7E-07	3.8E-07	8.8E-08	8.3E-10	8.1E-10	2.6E-10	2.0E-10	1.9E-10
100	3.7E-07	3.7E-07	9.7E-08	1.3E-09	1.2E-09	4.0E-10	2.7E-10	2.6E-10
200	2.8E-07	2.8E-07	2.3E-07	5.3E-08	4.9E-08	1.3E-08	1.3E-08	1.3E-08
300	2.2E-07	2.2E-07	1.3E-07	2.2E-07	2.2E-07	1.4E-07	2.7E-07	2.8E-07
400	1.7E-07	1.7E-07	9.5E-08	1.5E-07	1.5E-07	8.9E-08	1.5E-07	1.5E-07
500	1.4E-07	1.4E-07	7.6E-08	1.2E-07	1.2E-07	6.7E-08	1.1E-07	1.1E-07
600	1.2E-07	1.2E-07	6.2E-08	9.5E-08	1.0E-07	5.3E-08	8.9E-08	9.1E-08
700	1.0E-07	1.0E-07	5.4E-08	8.2E-08	9.0E-08	4.6E-08	8.1E-08	7.9E-08
800	8.4E-08	8.4E-08	4.3E-08	6.5E-08	7.2E-08	3.6E-08	6.0E-08	6.2E-08
900	7.4E-08	7.4E-08	3.8E-08	5.7E-08	6.3E-08	3.2E-08	5.6E-08	5.5E-08
1000	6.6E-08	6.7E-08	3.4E-08	5.0E-08	5.6E-08	2.8E-08	4.9E-08	4.9E-08
1250	5.1E-08	5.1E-08	2.6E-08	3.8E-08	4.3E-08	2.1E-08	3.6E-08	3.8E-08
1500	3.6E-08	3.6E-08	1.8E-08	2.7E-08	3.0E-08	1.5E-08	2.6E-08	2.7E-08
1750	2.9E-08	2.9E-08	1.5E-08	2.2E-08	2.5E-08	1.2E-08	2.1E-08	2.2E-08
2000	2.3E-08	2.3E-08	1.1E-08	1.7E-08	1.9E-08	9.4E-09	1.7E-08	1.7E-08
3000	8.7E-09	8.7E-09	4.4E-09	6.6E-09	7.4E-09	3.6E-09	6.4E-09	6.5E-09

Table 18. GCR LET data for neon (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	1.2E-05	3.0E-09	5.6E-11	4.6E-12	4.8E-12	2.7E-12	0.0E+00	0.0E+00
35	9.8E-06	4.3E-06	1.9E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	7.7E-06	8.2E-06	5.1E-10	3.3E-11	2.6E-11	1.9E-11	0.0E+00	0.0E+00
45	6.8E-06	1.2E-05	1.1E-09	7.5E-11	5.0E-11	0.0E+00	0.0E+00	0.0E+00
50	6.4E-06	8.3E-06	1.4E-07	1.2E-10	8.9E-11	5.5E-11	5.6E-11	4.0E-11
55	6.0E-06	7.2E-06	2.4E-07	2.2E-10	1.8E-10	8.1E-11	6.9E-11	5.8E-11
60	5.8E-06	6.6E-06	3.3E-07	3.1E-10	2.7E-10	1.3E-10	1.3E-10	8.8E-11
65	5.6E-06	6.2E-06	4.1E-07	4.6E-10	4.0E-10	1.9E-10	1.9E-10	1.6E-10
70	5.4E-06	5.9E-06	5.0E-07	6.3E-10	5.7E-10	2.6E-10	2.4E-10	2.2E-10
75	5.3E-06	5.6E-06	5.9E-07	1.0E-09	9.5E-10	3.9E-10	4.0E-10	3.3E-10
80	5.1E-06	5.4E-06	6.8E-07	1.9E-09	1.7E-09	5.9E-10	5.0E-10	4.8E-10
85	5.0E-06	5.3E-06	7.7E-07	3.3E-09	3.2E-09	9.6E-10	8.1E-10	7.5E-10
90	4.9E-06	5.1E-06	8.5E-07	5.3E-09	5.0E-09	1.5E-09	0.0E+00	0.0E+00
95	4.8E-06	5.0E-06	9.4E-07	7.9E-09	7.5E-09	2.4E-09	1.6E-09	1.5E-09
100	4.7E-06	4.8E-06	1.0E-06	1.2E-08	1.2E-08	3.7E-09	2.3E-09	2.1E-09
200	3.2E-06	3.3E-06	2.4E-06	2.9E-07	2.8E-07	1.0E-07	1.1E-07	1.1E-07
300	2.4E-06	2.4E-06	1.4E-06	2.6E-06	2.6E-06	1.9E-06	4.8E-06	5.2E-06
400	1.8E-06	1.8E-06	9.9E-07	1.6E-06	1.6E-06	9.4E-07	1.6E-06	1.6E-06
500	1.4E-06	1.4E-06	7.7E-07	1.2E-06	1.2E-06	6.9E-07	1.1E-06	1.1E-06
600	1.2E-06	1.2E-06	6.1E-07	9.2E-07	9.8E-07	5.2E-07	8.6E-07	8.5E-07
700	1.0E-06	1.0E-06	5.3E-07	8.0E-07	8.6E-07	4.4E-07	7.6E-07	7.7E-07
800	8.1E-07	8.1E-07	4.1E-07	6.2E-07	6.7E-07	3.4E-07	6.0E-07	5.9E-07
900	7.1E-07	7.1E-07	3.6E-07	5.4E-07	5.9E-07	3.0E-07	4.9E-07	5.1E-07
1000	6.3E-07	6.3E-07	3.2E-07	4.8E-07	5.2E-07	2.6E-07	4.4E-07	4.5E-07
1250	4.8E-07	4.8E-07	2.4E-07	3.6E-07	3.9E-07	2.0E-07	3.4E-07	3.4E-07
1500	3.4E-07	3.4E-07	1.7E-07	2.5E-07	2.7E-07	1.4E-07	2.4E-07	2.4E-07
1750	2.7E-07	2.7E-07	1.4E-07	2.0E-07	2.2E-07	1.1E-07	1.9E-07	1.9E-07
2000	2.1E-07	2.1E-07	1.0E-07	1.5E-07	1.7E-07	8.5E-08	1.4E-07	1.5E-07
3000	8.2E-08	8.1E-08	4.0E-08	6.0E-08	6.7E-08	3.3E-08	5.8E-08	5.7E-08

Table 19. GCR LET data for sodium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	1.1E-06	6.5E-10	1.4E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	2.6E-06	8.3E-07	4.7E-11	5.1E-12	4.4E-12	1.7E-12	0.0E+00	0.0E+00
40	1.9E-06	1.8E-06	1.1E-10	9.5E-12	8.4E-12	3.8E-12	3.9E-12	2.3E-12
45	1.7E-06	2.6E-06	2.3E-10	1.6E-11	1.3E-11	6.6E-12	6.6E-12	6.1E-12
50	1.6E-06	2.1E-06	2.7E-08	1.8E-11	1.7E-11	1.2E-11	1.2E-11	1.3E-11
55	1.5E-06	1.8E-06	5.0E-08	4.9E-11	3.7E-11	1.9E-11	1.9E-11	1.6E-11
60	1.4E-06	1.6E-06	7.1E-08	5.9E-11	5.2E-11	3.1E-11	3.2E-11	2.6E-11
65	1.3E-06	1.5E-06	9.1E-08	9.4E-11	7.7E-11	4.5E-11	5.0E-11	4.0E-11
70	1.3E-06	1.4E-06	1.1E-07	1.6E-10	1.4E-10	6.8E-11	7.3E-11	6.4E-11
75	1.3E-06	1.4E-06	1.3E-07	2.1E-10	1.9E-10	9.8E-11	1.0E-10	8.3E-11
80	1.2E-06	1.3E-06	1.5E-07	4.3E-10	3.8E-10	1.3E-10	1.3E-10	1.2E-10
85	1.2E-06	1.3E-06	1.7E-07	7.5E-10	7.1E-10	2.2E-10	1.7E-10	1.7E-10
90	1.2E-06	1.2E-06	1.9E-07	1.1E-09	1.1E-09	3.4E-10	2.5E-10	2.5E-10
95	1.1E-06	1.2E-06	2.1E-07	1.7E-09	1.6E-09	5.3E-10	3.4E-10	3.3E-10
100	1.1E-06	1.2E-06	2.3E-07	2.4E-09	2.3E-09	7.9E-10	5.4E-10	5.0E-10
200	7.7E-07	7.7E-07	5.4E-07	4.6E-08	4.4E-08	1.7E-08	2.1E-08	2.1E-08
300	5.6E-07	5.7E-07	3.5E-07	6.4E-07	6.5E-07	5.8E-07	4.8E-06	2.3E-07
400	4.2E-07	4.2E-07	2.3E-07	3.8E-07	3.8E-07	2.3E-07	3.9E-07	3.9E-07
500	3.4E-07	3.4E-07	1.8E-07	2.8E-07	2.9E-07	1.6E-07	2.7E-07	2.7E-07
600	2.7E-07	2.7E-07	1.4E-07	2.2E-07	2.2E-07	1.2E-07	2.0E-07	2.0E-07
700	2.4E-07	2.4E-07	1.2E-07	1.9E-07	2.0E-07	1.1E-07	1.7E-07	1.7E-07
800	1.9E-07	1.9E-07	9.7E-08	1.5E-07	1.5E-07	8.1E-08	1.4E-07	1.4E-07
900	1.7E-07	1.7E-07	8.5E-08	1.3E-07	1.4E-07	7.0E-08	1.2E-07	1.2E-07
1000	1.5E-07	1.5E-07	7.5E-08	1.1E-07	1.2E-07	6.2E-08	1.0E-07	1.0E-07
1250	1.1E-07	1.1E-07	5.7E-08	8.5E-08	9.1E-08	4.7E-08	7.9E-08	8.0E-08
1500	7.9E-08	7.9E-08	4.0E-08	5.9E-08	6.3E-08	3.3E-08	5.5E-08	5.6E-08
1750	6.4E-08	6.4E-08	3.2E-08	4.8E-08	5.2E-08	2.6E-08	4.6E-08	4.5E-08
2000	4.9E-08	4.9E-08	2.5E-08	3.7E-08	4.0E-08	2.0E-08	3.5E-08	3.4E-08
3000	1.9E-08	1.9E-08	9.5E-09	1.4E-08	1.5E-08	7.8E-09	1.3E-08	1.3E-08

Table 20. GCR LET data for magnesium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	6.0E-09	3.5E-09	8.2E-11	1.8E-11	6.2E-12	3.9E-12	1.5E-12	2.0E-12
35	3.4E-05	1.3E-06	3.0E-10	3.7E-11	3.8E-11	1.3E-11	0.0E+00	0.0E+00
40	1.8E-05	1.0E-05	7.5E-10	2.9E-11	3.8E-11	3.0E-11	0.0E+00	0.0E+00
45	1.5E-05	1.7E-05	1.4E-09	1.3E-10	1.0E-10	5.0E-11	4.5E-11	4.1E-11
50	1.3E-05	2.3E-05	2.7E-09	1.5E-10	1.1E-10	8.2E-11	8.7E-11	7.9E-11
55	1.2E-05	1.6E-05	2.6E-07	2.5E-10	2.0E-10	1.2E-10	0.0E+00	0.0E+00
60	1.2E-05	1.4E-05	4.3E-07	3.2E-10	3.3E-10	1.7E-10	1.8E-10	1.7E-10
65	1.1E-05	1.3E-05	5.8E-07	5.9E-10	5.2E-10	2.6E-10	2.3E-10	2.3E-10
70	1.1E-05	1.2E-05	7.3E-07	8.0E-10	7.2E-10	3.6E-10	4.0E-10	3.6E-10
75	1.0E-05	1.1E-05	8.8E-07	1.2E-09	1.2E-09	0.0E+00	0.0E+00	0.0E+00
80	1.0E-05	1.1E-05	1.0E-06	2.3E-09	2.2E-09	0.0E+00	0.0E+00	0.0E+00
85	9.9E-06	1.0E-05	1.2E-06	4.5E-09	4.3E-09	1.2E-09	9.4E-10	9.3E-10
90	9.6E-06	1.0E-05	1.3E-06	7.6E-09	7.1E-09	2.1E-09	1.5E-09	1.4E-09
95	9.4E-06	9.8E-06	1.5E-06	9.8E-09	9.3E-09	3.2E-09	2.0E-09	2.0E-09
100	9.2E-06	9.6E-06	1.6E-06	1.5E-08	1.4E-08	4.8E-09	3.2E-09	3.2E-09
200	6.3E-06	6.3E-06	3.9E-06	2.5E-07	2.4E-07	1.1E-07	1.4E-07	1.4E-07
300	4.6E-06	4.6E-06	2.9E-06	5.8E-06	5.9E-06	3.8E-06	8.5E-07	8.1E-07
400	3.4E-06	3.4E-06	1.9E-06	3.2E-06	3.2E-06	1.9E-06	3.4E-06	3.4E-06
500	2.8E-06	2.8E-06	1.5E-06	2.3E-06	2.4E-06	1.4E-06	2.2E-06	2.2E-06
600	2.2E-06	2.2E-06	1.2E-06	1.8E-06	1.8E-06	1.0E-06	1.6E-06	1.6E-06
700	1.9E-06	2.0E-06	1.0E-06	1.5E-06	1.6E-06	8.5E-07	1.4E-06	1.4E-06
800	1.5E-06	1.5E-06	7.9E-07	1.2E-06	1.2E-06	6.5E-07	1.1E-06	1.1E-06
900	1.4E-06	1.4E-06	6.9E-07	1.0E-06	1.1E-06	5.6E-07	9.2E-07	9.4E-07
1000	1.2E-06	1.2E-06	6.1E-07	9.0E-07	9.6E-07	5.0E-07	8.1E-07	8.5E-07
1250	9.2E-07	9.1E-07	4.6E-07	6.8E-07	7.2E-07	3.7E-07	6.3E-07	6.2E-07
1500	6.4E-07	6.4E-07	3.2E-07	4.8E-07	5.1E-07	2.6E-07	4.3E-07	4.4E-07
1750	5.2E-07	5.2E-07	2.6E-07	3.8E-07	4.1E-07	2.1E-07	3.6E-07	3.6E-07
2000	4.0E-07	4.0E-07	2.0E-07	2.9E-07	3.1E-07	1.6E-07	2.7E-07	2.8E-07
3000	1.5E-07	1.5E-07	7.6E-08	1.1E-07	1.2E-07	6.2E-08	1.0E-07	1.0E-07

Table 21. GCR LET data for aluminum (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	7.5E-10	4.8E-10	1.3E-11	1.2E-12	8.1E-13	6.2E-13	3.3E-13	2.1E-13
35	5.4E-06	1.8E-09	5.1E-11	4.1E-12	1.6E-12	0.0E+00	0.0E+00	0.0E+00
40	2.9E-06	1.4E-06	1.1E-10	9.7E-12	8.4E-12	0.0E+00	0.0E+00	0.0E+00
45	2.4E-06	2.4E-06	2.1E-10	1.9E-11	1.5E-11	7.1E-12	3.7E-12	3.0E-12
50	2.1E-06	3.5E-06	3.9E-10	3.3E-11	2.4E-11	0.0E+00	0.0E+00	0.0E+00
55	2.0E-06	2.7E-06	3.3E-08	4.6E-11	4.0E-11	1.8E-11	0.0E+00	0.0E+00
60	1.9E-06	2.3E-06	6.1E-08	6.6E-11	6.1E-11	3.0E-11	3.0E-11	2.5E-11
65	1.8E-06	2.1E-06	8.6E-08	1.1E-10	9.5E-11	4.6E-11	4.3E-11	4.2E-11
70	1.8E-06	2.0E-06	1.1E-07	1.4E-10	1.3E-10	6.5E-11	5.5E-11	5.4E-11
75	1.7E-06	1.9E-06	1.3E-07	2.4E-10	2.2E-10	9.5E-11	9.4E-11	9.0E-11
80	1.7E-06	1.8E-06	1.6E-07	4.8E-10	4.3E-10	1.4E-10	1.3E-10	1.2E-10
85	1.6E-06	1.7E-06	1.8E-07	7.8E-10	7.4E-10	2.3E-10	1.8E-10	1.8E-10
90	1.6E-06	1.7E-06	2.0E-07	1.2E-09	1.1E-09	3.6E-10	2.7E-10	2.5E-10
95	1.5E-06	1.6E-06	2.3E-07	1.7E-09	1.5E-09	5.5E-10	3.9E-10	3.7E-10
100	1.5E-06	1.6E-06	2.5E-07	2.3E-09	2.2E-09	8.0E-10	6.3E-10	5.8E-10
200	1.1E-06	1.1E-06	6.5E-07	3.4E-08	3.3E-08	1.6E-08	2.1E-08	2.1E-08
300	8.2E-07	8.3E-07	5.3E-07	1.1E-06	1.1E-06	5.8E-07	0.0E+00	0.0E+00
400	6.3E-07	6.3E-07	3.6E-07	5.9E-07	5.9E-07	3.6E-07	6.4E-07	6.5E-07
500	5.1E-07	5.1E-07	2.8E-07	4.3E-07	4.4E-07	2.5E-07	4.1E-07	4.2E-07
600	4.1E-07	4.1E-07	2.2E-07	3.3E-07	3.4E-07	1.9E-07	3.1E-07	3.1E-07
700	3.6E-07	3.6E-07	1.9E-07	2.8E-07	2.9E-07	1.6E-07	2.6E-07	2.6E-07
800	2.9E-07	2.9E-07	1.5E-07	2.2E-07	2.3E-07	1.2E-07	2.0E-07	2.0E-07
900	2.5E-07	2.6E-07	1.3E-07	1.9E-07	2.0E-07	1.1E-07	1.7E-07	1.8E-07
1000	2.3E-07	2.3E-07	1.2E-07	1.7E-07	1.8E-07	9.4E-08	1.6E-07	1.6E-07
1250	1.7E-07	1.7E-07	8.7E-08	1.3E-07	1.4E-07	7.0E-08	1.2E-07	1.2E-07
1500	1.2E-07	1.2E-07	6.1E-08	9.0E-08	9.4E-08	4.9E-08	8.2E-08	8.3E-08
1750	9.8E-08	9.8E-08	4.9E-08	7.2E-08	7.7E-08	4.0E-08	6.7E-08	6.7E-08
2000	7.5E-08	7.5E-08	3.7E-08	5.5E-08	5.8E-08	3.0E-08	4.9E-08	5.1E-08
3000	2.9E-08	2.9E-08	1.4E-08	2.1E-08	2.2E-08	1.1E-08	1.9E-08	1.9E-08

Table 22. GCR LET data for silicon (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	2.9E-09	2.4E-09	6.6E-11	8.1E-12	2.3E-12	2.7E-12	1.7E-12	1.6E-12
35	1.4E-08	7.5E-09	2.2E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	2.3E-05	5.0E-06	5.2E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	1.6E-05	1.2E-05	1.0E-09	5.9E-11	5.3E-11	3.4E-11	0.0E+00	0.0E+00
50	1.4E-05	1.8E-05	1.8E-09	1.2E-10	1.1E-10	5.6E-11	4.6E-11	3.6E-11
55	1.3E-05	2.3E-05	3.2E-09	1.8E-10	1.4E-10	0.0E+00	0.0E+00	0.0E+00
60	1.2E-05	1.6E-05	2.5E-07	3.3E-10	2.8E-10	1.2E-10	1.2E-10	1.1E-10
65	1.1E-05	1.4E-05	4.0E-07	3.7E-10	3.5E-10	2.0E-10	0.0E+00	0.0E+00
70	1.1E-05	1.3E-05	5.4E-07	7.6E-10	6.4E-10	2.7E-10	2.8E-10	2.1E-10
75	1.0E-05	1.2E-05	6.7E-07	9.9E-10	8.8E-10	4.0E-10	4.3E-10	3.9E-10
80	1.0E-05	1.1E-05	8.0E-07	1.8E-09	1.6E-09	5.7E-10	5.1E-10	5.2E-10
85	9.9E-06	1.1E-05	9.3E-07	3.8E-09	3.6E-09	9.8E-10	7.9E-10	7.7E-10
90	9.6E-06	1.0E-05	1.1E-06	5.5E-09	5.1E-09	1.6E-09	1.1E-09	1.0E-09
95	9.3E-06	9.9E-06	1.2E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
100	9.1E-06	9.6E-06	1.3E-06	1.0E-08	9.8E-09	3.6E-09	2.5E-09	2.4E-09
200	6.2E-06	6.3E-06	3.3E-06	1.5E-07	1.5E-07	7.2E-08	1.0E-07	1.0E-07
300	4.6E-06	4.6E-06	3.1E-06	7.5E-06	7.9E-06	2.2E-06	3.9E-07	3.7E-07
400	3.4E-06	3.4E-06	1.9E-06	3.3E-06	3.3E-06	2.1E-06	4.0E-06	4.0E-06
500	2.7E-06	2.7E-06	1.5E-06	2.3E-06	2.4E-06	1.4E-06	2.3E-06	2.3E-06
600	2.2E-06	2.2E-06	1.2E-06	1.8E-06	1.8E-06	1.0E-06	1.7E-06	1.7E-06
700	1.9E-06	1.9E-06	1.0E-06	1.5E-06	1.5E-06	8.5E-07	1.4E-06	1.4E-06
800	1.5E-06	1.5E-06	7.8E-07	1.2E-06	1.2E-06	6.5E-07	1.0E-06	1.1E-06
900	1.3E-06	1.3E-06	6.8E-07	1.0E-06	1.1E-06	5.6E-07	9.1E-07	9.1E-07
1000	1.2E-06	1.2E-06	6.0E-07	8.9E-07	9.2E-07	4.9E-07	8.0E-07	8.1E-07
1250	9.0E-07	9.0E-07	4.5E-07	6.7E-07	6.9E-07	3.6E-07	6.0E-07	6.0E-07
1500	6.3E-07	6.3E-07	3.2E-07	4.7E-07	4.9E-07	2.5E-07	4.2E-07	4.2E-07
1750	5.1E-07	5.1E-07	2.6E-07	3.8E-07	3.9E-07	2.1E-07	3.4E-07	3.4E-07
2000	3.9E-07	3.9E-07	2.0E-07	2.9E-07	3.0E-07	1.6E-07	2.7E-07	2.6E-07
3000	1.5E-07	1.5E-07	7.5E-08	1.1E-07	1.2E-07	6.0E-08	1.0E-07	1.0E-07

Table 23. GCR LET data for phosphorus (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	6.2E-11	5.6E-11	1.6E-12	2.4E-13	7.6E-14	0.0E+00	0.0E+00	0.0E+00
35	3.0E-10	1.5E-10	5.4E-12	6.7E-13	2.7E-13	0.0E+00	0.0E+00	0.0E+00
40	6.4E-07	9.3E-08	1.2E-11	1.3E-12	4.1E-13	0.0E+00	0.0E+00	0.0E+00
45	4.3E-07	2.7E-07	2.5E-11	2.0E-12	1.4E-12	9.9E-13	1.4E-12	8.2E-13
50	3.7E-07	4.2E-07	4.4E-11	4.1E-12	2.9E-12	1.7E-12	0.0E+00	0.0E+00
55	3.4E-07	5.7E-07	7.1E-11	4.3E-12	3.6E-12	2.3E-12	0.0E+00	0.0E+00
60	3.2E-07	4.3E-07	5.6E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
65	3.1E-07	3.7E-07	9.7E-09	1.2E-11	1.1E-11	5.4E-12	4.7E-12	4.6E-12
70	3.0E-07	3.4E-07	1.3E-08	1.7E-11	1.6E-11	8.7E-12	7.9E-12	7.0E-12
75	2.9E-07	3.2E-07	1.7E-08	2.6E-11	2.4E-11	1.1E-11	1.1E-11	1.1E-11
80	2.8E-07	3.1E-07	2.1E-08	4.7E-11	4.2E-11	1.6E-11	1.5E-11	1.3E-11
85	2.8E-07	3.0E-07	2.4E-08	1.0E-10	9.7E-11	2.6E-11	2.1E-11	1.9E-11
90	2.7E-07	2.9E-07	2.8E-08	1.5E-10	1.5E-10	4.2E-11	2.8E-11	2.6E-11
95	2.7E-07	2.8E-07	3.2E-08	2.1E-10	1.9E-10	6.5E-11	4.0E-11	3.7E-11
100	2.6E-07	2.8E-07	3.6E-08	2.8E-10	2.7E-10	9.5E-11	6.5E-11	6.2E-11
200	2.1E-07	2.1E-07	1.1E-07	4.4E-09	4.4E-09	2.2E-09	3.2E-09	3.1E-09
300	1.7E-07	1.7E-07	1.2E-07	3.2E-07	3.4E-07	6.4E-08	1.1E-08	1.0E-08
400	1.4E-07	1.4E-07	7.9E-08	1.3E-07	1.4E-07	8.8E-08	1.7E-07	1.8E-07
500	1.1E-07	1.1E-07	6.2E-08	9.8E-08	9.9E-08	5.8E-08	9.7E-08	9.7E-08
600	9.5E-08	9.4E-08	5.0E-08	7.7E-08	7.8E-08	4.4E-08	7.2E-08	7.1E-08
700	8.5E-08	8.4E-08	4.4E-08	6.6E-08	6.7E-08	3.7E-08	6.0E-08	6.0E-08
800	6.8E-08	6.8E-08	3.5E-08	5.2E-08	5.3E-08	2.9E-08	4.7E-08	4.7E-08
900	6.1E-08	6.1E-08	3.1E-08	4.6E-08	4.7E-08	2.5E-08	4.1E-08	4.1E-08
1000	5.4E-08	5.4E-08	2.8E-08	4.1E-08	4.2E-08	2.2E-08	3.6E-08	3.6E-08
1250	4.2E-08	4.2E-08	2.1E-08	3.1E-08	3.2E-08	1.7E-08	2.8E-08	2.8E-08
1500	3.0E-08	3.0E-08	1.5E-08	2.2E-08	2.3E-08	1.2E-08	1.9E-08	2.0E-08
1750	2.4E-08	2.4E-08	1.2E-08	1.8E-08	1.8E-08	9.6E-09	1.6E-08	1.6E-08
2000	1.8E-08	1.8E-08	9.2E-09	1.3E-08	1.4E-08	7.3E-09	1.2E-08	1.2E-08
3000	7.0E-09	7.0E-09	3.4E-09	5.1E-09	5.3E-09	2.7E-09	4.7E-09	4.6E-09

Table 24. GCR LET data for sulfur (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	3.9E-10	3.4E-10	9.3E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	1.7E-09	9.2E-10	3.5E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	5.9E-06	2.3E-09	8.9E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	3.5E-06	1.4E-06	1.5E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50	2.8E-06	2.4E-06	2.5E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
55	2.5E-06	3.4E-06	4.2E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
60	2.3E-06	3.7E-06	1.4E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
65	2.2E-06	2.9E-06	4.9E-08	6.6E-11	5.9E-11	3.0E-11	0.0E+00	0.0E+00
70	2.1E-06	2.5E-06	7.4E-08	9.6E-11	8.9E-11	4.4E-11	4.5E-11	4.4E-11
75	2.0E-06	2.3E-06	9.8E-08	1.5E-10	1.4E-10	6.2E-11	5.9E-11	5.9E-11
80	2.0E-06	2.2E-06	1.2E-07	2.8E-10	2.6E-10	8.3E-11	8.9E-11	7.3E-11
85	1.9E-06	2.1E-06	1.4E-07	5.5E-10	5.2E-10	1.3E-10	1.1E-10	2.5E-11
90	1.9E-06	2.0E-06	1.7E-07	8.9E-10	8.5E-10	2.5E-10	1.4E-10	1.4E-10
95	1.8E-06	2.0E-06	1.9E-07	1.2E-09	1.1E-09	3.9E-10	2.1E-10	1.9E-10
100	1.8E-06	1.9E-06	2.1E-07	1.6E-09	1.5E-09	5.7E-10	3.7E-10	3.6E-10
200	1.3E-06	1.3E-06	6.2E-07	2.3E-08	2.3E-08	1.2E-08	1.7E-08	1.7E-08
300	1.0E-06	1.0E-06	8.3E-07	4.2E-07	3.7E-07	7.7E-08	4.7E-08	4.6E-08
400	7.9E-07	7.9E-07	4.6E-07	8.1E-07	8.2E-07	5.9E-07	1.4E-06	1.6E-06
500	6.5E-07	6.5E-07	3.6E-07	5.7E-07	5.8E-07	3.4E-07	5.8E-07	5.8E-07
600	5.4E-07	5.4E-07	2.8E-07	4.4E-07	4.4E-07	2.5E-07	4.1E-07	4.1E-07
700	4.8E-07	4.8E-07	2.5E-07	3.7E-07	3.8E-07	2.1E-07	3.4E-07	3.4E-07
800	3.8E-07	3.8E-07	2.0E-07	2.9E-07	3.0E-07	1.6E-07	2.6E-07	2.6E-07
900	3.4E-07	3.4E-07	1.7E-07	2.5E-07	2.6E-07	1.4E-07	2.3E-07	2.3E-07
1000	3.0E-07	3.0E-07	1.5E-07	2.3E-07	2.3E-07	1.2E-07	2.0E-07	2.0E-07
1250	2.3E-07	2.3E-07	1.2E-07	1.7E-07	1.7E-07	9.2E-08	1.5E-07	1.5E-07
1500	1.7E-07	1.7E-07	8.3E-08	1.2E-07	1.3E-07	6.5E-08	1.1E-07	1.1E-07
1750	1.4E-07	1.4E-07	6.7E-08	9.8E-08	1.0E-07	5.3E-08	8.6E-08	8.8E-08
2000	1.0E-07	1.0E-07	5.2E-08	7.6E-08	7.9E-08	4.1E-08	6.8E-08	6.8E-08
3000	4.1E-08	4.1E-08	2.0E-08	3.0E-08	3.1E-08	1.6E-08	2.6E-08	2.7E-08

Table 25. GCR LET data for chlorine (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	4.9E-11	4.5E-11	1.3E-12	5.0E-14	6.6E-14	8.4E-14	1.7E-13	1.2E-13
35	1.9E-10	1.2E-10	4.7E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	6.9E-07	2.7E-10	1.3E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	5.5E-07	1.8E-07	2.2E-11	1.2E-12	1.3E-12	8.4E-13	0.0E+00	0.0E+00
50	4.3E-07	3.3E-07	3.6E-11	2.8E-12	2.0E-12	1.5E-12	1.5E-12	1.3E-12
55	3.8E-07	4.8E-07	5.8E-11	4.1E-12	3.4E-12	2.0E-12	1.8E-12	1.7E-12
60	3.6E-07	6.4E-07	9.0E-11	6.4E-12	6.0E-12	3.1E-12	2.1E-12	2.8E-12
65	3.4E-07	4.5E-07	6.4E-09	1.1E-11	1.0E-11	4.1E-12	0.0E+00	0.0E+00
70	3.3E-07	4.0E-07	1.0E-08	1.4E-11	1.3E-11	6.7E-12	6.0E-12	6.0E-12
75	3.2E-07	3.7E-07	1.4E-08	2.1E-11	2.0E-11	0.0E+00	0.0E+00	0.0E+00
80	3.1E-07	3.5E-07	1.8E-08	4.0E-11	3.8E-11	0.0E+00	0.0E+00	0.0E+00
85	3.0E-07	3.4E-07	2.2E-08	9.1E-11	8.0E-11	2.1E-11	1.8E-11	1.7E-11
90	3.0E-07	3.3E-07	2.5E-08	1.4E-10	1.4E-10	3.8E-11	2.5E-11	2.3E-11
95	3.0E-07	3.2E-07	2.9E-08	1.9E-10	1.8E-10	6.1E-11	3.5E-11	3.3E-11
100	2.9E-07	3.1E-07	3.3E-08	2.4E-10	2.3E-10	9.0E-11	5.7E-11	5.7E-11
200	2.4E-07	2.5E-07	1.1E-07	3.8E-09	3.8E-09	0.0E+00	0.0E+00	0.0E+00
300	2.0E-07	2.1E-07	1.6E-07	6.7E-08	5.9E-08	1.1E-08	7.6E-09	7.4E-09
400	1.7E-07	1.7E-07	1.0E-07	1.8E-07	1.8E-07	1.4E-07	4.4E-07	7.0E-07
500	1.4E-07	1.4E-07	7.9E-08	1.3E-07	1.3E-07	7.6E-08	1.3E-07	1.3E-07
600	1.2E-07	1.2E-07	6.5E-08	1.0E-07	1.0E-07	5.7E-08	9.4E-08	9.4E-08
700	1.1E-07	1.1E-07	5.7E-08	8.5E-08	8.6E-08	4.8E-08	7.8E-08	7.8E-08
800	8.9E-08	8.9E-08	4.6E-08	6.8E-08	6.9E-08	3.8E-08	6.1E-08	6.1E-08
900	8.0E-08	8.0E-08	4.0E-08	6.0E-08	6.1E-08	3.3E-08	5.3E-08	5.3E-08
1000	7.1E-08	7.1E-08	3.6E-08	5.3E-08	5.4E-08	2.9E-08	4.7E-08	4.7E-08
1250	5.5E-08	5.5E-08	2.8E-08	4.0E-08	4.1E-08	2.2E-08	3.5E-08	3.5E-08
1500	4.0E-08	3.9E-08	2.0E-08	2.9E-08	3.0E-08	1.6E-08	2.5E-08	2.5E-08
1750	3.2E-08	3.2E-08	1.6E-08	2.3E-08	2.4E-08	1.3E-08	2.0E-08	2.1E-08
2000	2.5E-08	2.5E-08	1.2E-08	1.8E-08	1.8E-08	9.6E-09	1.6E-08	1.6E-08
3000	9.3E-09	9.3E-09	4.6E-09	6.7E-09	6.9E-09	3.6E-09	6.0E-09	5.9E-09

Table 26. GCR LET data for argon (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	1.5E-10	1.5E-10	4.4E-12	8.3E-13	6.8E-13	0.0E+00	0.0E+00	0.0E+00
35	5.2E-10	3.6E-10	1.6E-11	1.0E-12	7.9E-13	8.2E-13	0.0E+00	0.0E+00
40	2.4E-06	7.6E-10	3.7E-11	3.6E-12	3.0E-12	0.0E+00	0.0E+00	0.0E+00
45	1.6E-06	5.7E-07	6.7E-11	6.0E-12	5.3E-12	3.0E-12	0.0E+00	0.0E+00
50	1.3E-06	1.0E-06	1.1E-10	1.1E-11	8.9E-12	5.3E-12	0.0E+00	0.0E+00
55	1.1E-06	1.5E-06	1.7E-10	1.6E-11	1.4E-11	7.9E-12	0.0E+00	0.0E+00
60	1.0E-06	1.7E-06	3.9E-09	2.4E-11	2.1E-11	1.1E-11	1.1E-11	9.9E-12
65	9.8E-07	1.3E-06	2.0E-08	3.9E-11	3.3E-11	1.7E-11	1.6E-11	1.5E-11
70	9.4E-07	1.1E-06	3.2E-08	5.8E-11	5.2E-11	2.6E-11	2.2E-11	2.1E-11
75	9.1E-07	1.1E-06	4.3E-08	8.8E-11	7.8E-11	3.6E-11	3.6E-11	3.4E-11
80	8.9E-07	1.0E-06	5.3E-08	1.6E-10	1.5E-10	5.0E-11	5.1E-11	4.8E-11
85	8.7E-07	9.5E-07	6.3E-08	2.7E-10	2.7E-10	7.6E-11	6.2E-11	6.2E-11
90	8.5E-07	9.2E-07	7.4E-08	4.3E-10	4.1E-10	1.2E-10	8.0E-11	7.9E-11
95	8.3E-07	8.9E-07	8.4E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
100	8.2E-07	8.7E-07	9.4E-08	7.3E-10	7.1E-10	2.8E-10	2.2E-10	2.1E-10
200	6.3E-07	6.4E-07	2.9E-07	9.3E-09	9.3E-09	4.9E-09	7.0E-09	7.1E-09
300	5.1E-07	5.1E-07	4.1E-07	1.7E-07	1.4E-07	2.1E-08	1.6E-08	1.6E-08
400	4.0E-07	4.0E-07	2.4E-07	4.2E-07	4.3E-07	3.2E-07	8.5E-07	9.5E-07
500	3.4E-07	3.4E-07	1.9E-07	3.0E-07	3.0E-07	1.8E-07	3.1E-07	3.1E-07
600	2.8E-07	2.8E-07	1.5E-07	2.3E-07	2.3E-07	1.3E-07	2.2E-07	2.2E-07
700	2.5E-07	2.5E-07	1.3E-07	2.0E-07	2.0E-07	1.1E-07	1.8E-07	1.8E-07
800	2.0E-07	2.0E-07	1.0E-07	1.6E-07	1.6E-07	8.7E-08	1.4E-07	1.4E-07
900	1.8E-07	1.8E-07	9.2E-08	1.4E-07	1.4E-07	7.5E-08	1.2E-07	1.2E-07
1000	1.6E-07	1.6E-07	8.2E-08	1.2E-07	1.2E-07	6.6E-08	1.1E-07	1.1E-07
1250	1.2E-07	1.2E-07	6.0E-08	8.8E-08	9.0E-08	4.7E-08	7.7E-08	7.6E-08
1500	8.8E-08	8.8E-08	4.4E-08	6.5E-08	6.6E-08	3.5E-08	5.6E-08	5.7E-08
1750	7.2E-08	7.2E-08	3.6E-08	5.2E-08	5.4E-08	2.8E-08	4.6E-08	4.6E-08
2000	5.5E-08	5.5E-08	2.7E-08	4.0E-08	4.2E-08	2.2E-08	3.5E-08	3.5E-08
3000	2.1E-08	2.1E-08	1.1E-08	1.5E-08	1.6E-08	8.3E-09	1.4E-08	1.4E-08

Table 27. GCR LET data for potassium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	1.1E-10	9.7E-11	2.7E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	3.3E-10	2.3E-10	9.7E-12	1.7E-12	8.3E-13	4.6E-13	6.3E-13	3.8E-13
40	9.2E-07	5.5E-10	2.4E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	1.5E-06	2.8E-07	4.0E-11	2.2E-12	2.0E-12	1.5E-12	1.3E-12	1.2E-12
50	1.1E-06	6.4E-07	7.0E-11	5.3E-12	5.3E-12	2.8E-12	2.3E-12	1.8E-12
55	9.3E-07	9.7E-07	1.1E-10	7.3E-12	6.6E-12	3.8E-12	3.0E-12	3.1E-12
60	8.6E-07	1.3E-06	1.7E-10	1.4E-11	1.1E-11	5.5E-12	5.2E-12	5.2E-12
65	8.1E-07	1.2E-06	8.1E-09	1.9E-11	1.9E-11	8.5E-12	7.9E-12	7.4E-12
70	7.8E-07	9.9E-07	1.8E-08	2.7E-11	2.4E-11	1.3E-11	1.1E-11	1.1E-11
75	7.6E-07	9.0E-07	2.7E-08	4.0E-11	3.7E-11	1.7E-11	1.7E-11	1.6E-11
80	7.4E-07	8.4E-07	3.5E-08	8.3E-11	7.4E-11	2.5E-11	2.5E-11	2.2E-11
85	7.2E-07	8.0E-07	4.3E-08	1.7E-10	1.6E-10	4.0E-11	3.2E-11	2.8E-11
90	7.1E-07	7.7E-07	5.0E-08	2.6E-10	2.5E-10	7.1E-11	4.3E-11	4.2E-11
95	7.0E-07	7.5E-07	5.8E-08	3.5E-10	3.4E-10	1.2E-10	6.5E-11	6.4E-11
100	6.9E-07	7.3E-07	6.6E-08	5.1E-10	4.7E-10	1.8E-10	1.3E-10	1.2E-10
200	5.6E-07	5.6E-07	2.3E-07	6.7E-09	6.6E-09	3.6E-09	5.2E-09	5.2E-09
300	4.6E-07	4.6E-07	3.4E-07	6.5E-08	5.8E-08	1.4E-08	1.2E-08	1.2E-08
400	3.8E-07	3.7E-07	2.3E-07	4.2E-07	4.2E-07	3.1E-07	1.1E-07	9.9E-08
500	3.2E-07	3.1E-07	1.7E-07	2.8E-07	2.8E-07	1.8E-07	3.1E-07	3.1E-07
600	2.6E-07	2.6E-07	1.4E-07	2.2E-07	2.2E-07	1.3E-07	2.1E-07	2.1E-07
700	2.3E-07	2.3E-07	1.2E-07	1.8E-07	1.8E-07	1.0E-07	1.7E-07	1.7E-07
800	1.9E-07	1.9E-07	9.7E-08	1.4E-07	1.4E-07	8.0E-08	1.3E-07	1.3E-07
900	1.7E-07	1.7E-07	8.5E-08	1.2E-07	1.3E-07	6.9E-08	1.1E-07	1.1E-07
1000	1.5E-07	1.5E-07	7.5E-08	1.1E-07	1.1E-07	6.1E-08	9.7E-08	9.6E-08
2000	4.9E-08	4.8E-08	2.4E-08	3.5E-08	3.5E-08	1.9E-08	3.1E-08	3.0E-08
3000	1.8E-08	1.7E-08	8.6E-09	1.2E-08	1.3E-08	6.7E-09	1.1E-08	1.1E-08

Table 28. GCR LET data for calcium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	9.7E-11	9.3E-11	2.7E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	3.3E-10	2.3E-10	9.3E-12	5.5E-13	3.2E-13	4.2E-13	4.0E-13	3.7E-13
40	1.1E-09	4.3E-10	2.1E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	2.2E-06	9.0E-08	3.9E-11	2.3E-12	2.2E-12	1.3E-12	1.1E-12	1.5E-12
50	1.3E-06	5.5E-07	6.7E-11	5.1E-12	3.8E-12	2.4E-12	2.3E-12	1.9E-12
55	1.1E-06	9.1E-07	1.1E-10	6.6E-12	6.0E-12	3.6E-12	3.3E-12	3.2E-12
60	9.9E-07	1.3E-06	1.6E-10	1.4E-11	1.1E-11	5.2E-12	4.2E-12	4.1E-12
65	9.3E-07	1.6E-06	2.5E-10	1.8E-11	1.7E-11	8.3E-12	7.7E-12	7.5E-12
70	8.8E-07	1.2E-06	1.4E-08	2.7E-11	2.4E-11	1.2E-11	1.0E-11	9.6E-12
75	8.5E-07	1.1E-06	2.4E-08	4.0E-11	3.7E-11	1.5E-11	1.7E-11	1.5E-11
80	8.3E-07	9.7E-07	3.3E-08	7.8E-11	7.5E-11	2.3E-11	2.1E-11	2.2E-11
85	8.1E-07	9.2E-07	4.1E-08	1.4E-10	1.3E-10	3.5E-11	2.9E-11	2.6E-11
90	8.0E-07	8.8E-07	4.9E-08	2.4E-10	2.3E-10	6.7E-11	4.0E-11	3.6E-11
95	7.8E-07	8.5E-07	5.7E-08	3.4E-10	3.3E-10	1.1E-10	5.7E-11	5.3E-11
100	7.7E-07	8.2E-07	6.6E-08	4.5E-10	4.4E-10	1.7E-10	1.1E-10	9.9E-11
110	7.5E-07	7.9E-07	8.2E-08	8.3E-10	7.7E-10	3.0E-10	2.9E-10	2.8E-10
120	7.3E-07	7.6E-07	9.9E-08	1.5E-09	1.4E-09	5.4E-10	4.9E-10	4.9E-10
130	7.1E-07	7.3E-07	1.2E-07	2.3E-09	2.2E-09	9.4E-10	8.6E-10	8.4E-10
140	7.0E-07	7.1E-07	1.3E-07	2.8E-09	2.8E-09	1.4E-09	1.4E-09	1.4E-09
150	6.8E-07	6.9E-07	1.5E-07	3.5E-09	3.5E-09	1.8E-09	2.3E-09	0.0E+00
160	6.7E-07	6.8E-07	1.7E-07	4.0E-09	4.0E-09	2.1E-09	2.9E-09	2.8E-09
170	6.6E-07	6.6E-07	1.8E-07	4.6E-09	4.5E-09	2.5E-09	3.4E-09	3.4E-09
180	6.4E-07	6.5E-07	2.0E-07	5.2E-09	5.1E-09	2.8E-09	4.0E-09	4.0E-09
190	6.3E-07	6.4E-07	2.2E-07	5.9E-09	5.9E-09	3.2E-09	4.6E-09	4.5E-09
200	6.2E-07	6.2E-07	2.3E-07	6.7E-09	6.7E-09	3.6E-09	5.1E-09	5.1E-09
300	5.1E-07	5.1E-07	3.5E-07	4.8E-08	4.4E-08	1.2E-08	1.2E-08	1.2E-08
400	4.2E-07	4.1E-07	2.6E-07	5.0E-07	5.1E-07	2.9E-07	7.9E-08	7.5E-08
500	3.5E-07	3.5E-07	1.9E-07	3.2E-07	3.2E-07	2.0E-07	3.7E-07	3.7E-07
600	2.9E-07	2.9E-07	1.6E-07	2.4E-07	2.4E-07	1.4E-07	2.3E-07	2.3E-07
700	2.6E-07	2.6E-07	1.3E-07	2.0E-07	2.0E-07	1.1E-07	1.8E-07	1.8E-07
800	2.1E-07	2.1E-07	1.1E-07	1.6E-07	1.6E-07	8.8E-08	1.4E-07	1.4E-07
900	1.9E-07	1.8E-07	9.4E-08	1.4E-07	1.4E-07	7.6E-08	1.2E-07	1.2E-07
1000	1.7E-07	1.6E-07	8.3E-08	1.2E-07	1.2E-07	6.6E-08	1.1E-07	1.0E-07
1250	1.2E-07	1.2E-07	6.0E-08	8.6E-08	8.8E-08	4.7E-08	7.3E-08	7.3E-08

3000	2.0E-08	1.9E-08	9.4E-09	1.3E-08	1.4E-08	7.2E-09	1.1E-08	1.2E-08
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Table 29. GCR LET data for scandium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	7.0E-11	6.2E-11	2.1E-12	4.2E-13	3.1E-13	1.1E-13	0.0E+00	0.0E+00
35	2.0E-10	1.5E-10	7.1E-12	5.9E-13	5.0E-13	3.3E-13	0.0E+00	0.0E+00
40	7.3E-10	2.8E-10	1.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	1.4E-06	1.2E-07	2.9E-11	2.7E-12	1.8E-12	1.2E-12	1.1E-12	9.3E-13
50	8.9E-07	4.2E-07	4.8E-11	4.2E-12	2.8E-12	1.8E-12	2.0E-12	1.6E-12
55	7.5E-07	6.6E-07	7.2E-11	6.5E-12	5.5E-12	3.0E-12	3.5E-12	2.7E-12
60	6.8E-07	9.0E-07	1.1E-10	1.1E-11	9.4E-12	4.8E-12	4.5E-12	4.1E-12
65	6.3E-07	1.1E-06	1.7E-10	1.5E-11	1.4E-11	6.8E-12	6.6E-12	6.1E-12
70	6.0E-07	8.1E-07	1.1E-08	2.3E-11	2.1E-11	1.1E-11	1.1E-11	9.7E-12
75	5.8E-07	7.1E-07	1.7E-08	3.1E-11	2.9E-11	1.4E-11	1.4E-11	1.3E-11
80	5.6E-07	6.5E-07	2.3E-08	6.0E-11	5.4E-11	1.9E-11	1.9E-11	1.9E-11
85	5.5E-07	6.2E-07	2.9E-08	1.2E-10	1.1E-10	3.1E-11	2.4E-11	2.4E-11
90	5.4E-07	5.9E-07	3.4E-08	1.9E-10	1.8E-10	5.2E-11	3.4E-11	3.4E-11
95	5.2E-07	5.7E-07	4.0E-08	2.6E-10	2.5E-10	8.6E-11	5.2E-11	4.6E-11
100	5.1E-07	5.5E-07	4.5E-08	3.5E-10	3.3E-10	1.3E-10	8.4E-11	7.8E-11
110	5.0E-07	5.2E-07	5.6E-08	6.2E-10	6.0E-10	2.4E-10	2.2E-10	2.2E-10
120	4.8E-07	5.0E-07	6.7E-08	9.8E-10	9.5E-10	3.7E-10	3.4E-10	3.3E-10
130	4.7E-07	4.8E-07	7.8E-08	1.4E-09	1.4E-09	4.0E-10	0.0E+00	0.0E+00
140	4.6E-07	4.6E-07	8.9E-08	1.8E-09	1.8E-09	8.8E-10	9.7E-10	9.3E-10
150	4.4E-07	4.5E-07	9.9E-08	2.2E-09	2.2E-09	1.1E-09	1.4E-09	1.4E-09
160	4.3E-07	4.4E-07	1.1E-07	2.6E-09	2.5E-09	1.4E-09	1.9E-09	1.8E-09
170	4.2E-07	4.2E-07	1.2E-07	2.9E-09	2.9E-09	1.5E-09	2.2E-09	2.1E-09
180	4.3E-07	4.3E-07	1.2E-07	3.0E-09	2.9E-09	1.6E-09	2.2E-09	2.2E-09
190	4.0E-07	4.0E-07	1.4E-07	3.6E-09	3.6E-09	2.0E-09	2.9E-09	2.8E-09
200	3.9E-07	3.9E-07	1.5E-07	4.0E-09	4.0E-09	2.2E-09	3.2E-09	3.1E-09
300	3.1E-07	3.1E-07	2.2E-07	2.1E-08	1.9E-08	5.9E-09	6.9E-09	6.8E-09
400	2.5E-07	2.5E-07	1.5E-07	3.0E-07	3.0E-07	1.8E-07	3.5E-08	3.3E-08
500	2.1E-07	2.1E-07	1.2E-07	1.9E-07	1.9E-07	1.2E-07	2.2E-07	2.2E-07
600	1.7E-07	1.7E-07	9.3E-08	1.4E-07	1.4E-07	8.4E-08	1.4E-07	1.4E-07
700	1.5E-07	1.5E-07	8.0E-08	1.2E-07	1.2E-07	6.9E-08	1.1E-07	1.1E-07
800	1.3E-07	1.2E-07	6.4E-08	9.5E-08	9.5E-08	5.3E-08	8.6E-08	8.4E-08
900	1.1E-07	1.1E-07	5.6E-08	8.3E-08	8.3E-08	4.6E-08	7.3E-08	7.2E-08
1000	9.9E-08	9.8E-08	5.0E-08	7.3E-08	7.3E-08	4.0E-08	6.5E-08	6.4E-08

1250	7.4E-08	7.3E-08	3.7E-08	5.3E-08	5.4E-08	2.9E-08	4.6E-08	4.6E-08
1500	5.5E-08	5.4E-08	2.7E-08	3.9E-08	3.9E-08	2.1E-08	3.4E-08	3.3E-08
1750	4.4E-08	4.4E-08	2.2E-08	3.2E-08	3.2E-08	1.7E-08	2.7E-08	2.7E-08
2000	3.4E-08	3.4E-08	1.7E-08	2.4E-08	2.4E-08	1.3E-08	2.1E-08	2.1E-08
2250	3.0E-08	2.9E-08	1.5E-08	2.1E-08	2.1E-08	1.1E-08	1.8E-08	1.8E-08
2500	2.3E-08	2.3E-08	1.1E-08	1.6E-08	1.6E-08	8.7E-09	1.4E-08	1.4E-08
2750	1.8E-08	1.7E-08	8.6E-09	1.2E-08	1.3E-08	6.7E-09	1.1E-08	1.1E-08
3000	1.3E-08	1.3E-08	6.4E-09	9.2E-09	9.4E-09	5.0E-09	8.0E-09	8.0E-09

Table 30. GCR LET data for titanium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	7.1E-11	6.4E-11	2.2E-12	2.9E-13	3.2E-13	1.4E-13	0.0E+00	0.0E+00
35	1.8E-10	1.4E-10	7.6E-12	5.6E-13	4.0E-13	3.9E-13	5.3E-13	3.6E-13
40	6.9E-10	2.9E-10	1.8E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	1.7E-06	5.5E-08	3.0E-11	2.6E-12	2.0E-12	1.3E-12	1.2E-12	1.1E-12
50	1.0E-06	4.1E-07	5.1E-11	4.9E-12	4.3E-12	2.2E-12	2.3E-12	2.0E-12
55	8.4E-07	6.8E-07	7.6E-11	5.3E-12	5.7E-12	3.3E-12	3.2E-12	2.5E-12
60	7.6E-07	9.4E-07	1.1E-10	1.2E-11	1.1E-11	5.1E-12	5.2E-12	5.1E-12
65	7.0E-07	1.2E-06	1.6E-10	1.5E-11	1.4E-11	7.5E-12	7.9E-12	7.0E-12
70	6.7E-07	9.2E-07	1.0E-08	2.4E-11	2.3E-11	1.2E-11	9.8E-12	9.8E-12
75	6.4E-07	8.0E-07	1.7E-08	3.8E-11	3.4E-11	1.5E-11	1.5E-11	1.4E-11
80	6.2E-07	7.3E-07	2.4E-08	6.6E-11	6.7E-11	0.0E+00	0.0E+00	3.8E-12
85	6.0E-07	6.9E-07	3.0E-08	1.3E-10	1.2E-10	3.2E-11	2.8E-11	2.8E-11
90	5.9E-07	6.5E-07	3.6E-08	1.9E-10	1.8E-10	5.3E-11	3.5E-11	3.4E-11
95	5.8E-07	6.3E-07	4.2E-08	2.6E-10	2.5E-10	8.8E-11	6.1E-11	4.9E-11
100	5.7E-07	6.1E-07	4.8E-08	3.7E-10	3.5E-10	1.3E-10	8.8E-11	8.5E-11
110	5.5E-07	5.7E-07	5.9E-08	6.0E-10	5.8E-10	2.4E-10	2.3E-10	2.2E-10
120	5.3E-07	5.5E-07	7.1E-08	1.0E-09	1.0E-09	3.9E-10	3.9E-10	3.8E-10
130	5.1E-07	5.3E-07	8.3E-08	1.5E-09	1.5E-09	6.5E-10	6.1E-10	6.0E-10
140	5.0E-07	5.1E-07	9.4E-08	1.8E-09	1.8E-09	8.8E-10	9.7E-10	9.4E-10
150	4.9E-07	4.9E-07	1.1E-07	2.2E-09	2.2E-09	1.1E-09	1.5E-09	1.4E-09
160	4.7E-07	4.8E-07	1.2E-07	2.6E-09	2.6E-09	1.4E-09	1.9E-09	1.9E-09
170	4.6E-07	4.7E-07	1.3E-07	2.8E-09	2.8E-09	1.6E-09	2.2E-09	2.2E-09
180	4.5E-07	4.5E-07	1.4E-07	3.3E-09	3.3E-09	1.8E-09	2.5E-09	2.5E-09
190	4.4E-07	4.4E-07	1.5E-07	3.7E-09	3.6E-09	2.0E-09	2.8E-09	2.9E-09
200	4.3E-07	4.3E-07	1.6E-07	4.1E-09	4.1E-09	2.2E-09	3.2E-09	3.2E-09
300	3.4E-07	3.4E-07	2.4E-07	1.7E-08	1.6E-08	5.6E-09	6.9E-09	6.8E-09
400	2.5E-07	2.5E-07	1.4E-07	2.3E-07	2.3E-07	1.5E-07	2.7E-07	2.8E-07
500	2.1E-07	2.1E-07	1.1E-07	1.8E-07	1.8E-07	1.0E-07	1.7E-07	1.7E-07
600	1.9E-07	1.9E-07	1.0E-07	1.6E-07	1.6E-07	9.3E-08	1.5E-07	1.5E-07
700	1.7E-07	1.7E-07	8.9E-08	1.3E-07	1.3E-07	7.6E-08	1.2E-07	1.2E-07
800	1.4E-07	1.3E-07	7.0E-08	1.0E-07	1.0E-07	5.9E-08	9.4E-08	9.3E-08
900	1.2E-07	1.2E-07	6.2E-08	9.1E-08	9.1E-08	5.0E-08	8.0E-08	7.9E-08
1000	1.1E-07	1.1E-07	5.5E-08	8.0E-08	8.0E-08	4.4E-08	7.0E-08	7.0E-08

1250	8.1E-08	8.0E-08	4.0E-08	5.8E-08	5.9E-08	3.2E-08	5.0E-08	5.0E-08
1500	6.0E-08	5.9E-08	3.0E-08	4.3E-08	4.3E-08	2.3E-08	3.7E-08	3.6E-08
1750	4.9E-08	4.8E-08	2.4E-08	3.5E-08	3.5E-08	1.9E-08	3.0E-08	2.9E-08
2000	3.7E-08	3.7E-08	1.8E-08	2.6E-08	2.7E-08	1.4E-08	2.2E-08	2.2E-08
2250	3.3E-08	3.2E-08	1.6E-08	2.3E-08	2.3E-08	1.2E-08	2.0E-08	2.0E-08
2500	2.5E-08	2.5E-08	1.2E-08	1.8E-08	1.8E-08	9.6E-09	1.5E-08	1.5E-08
2750	1.9E-08	1.9E-08	9.4E-09	1.3E-08	1.4E-08	7.3E-09	1.2E-08	1.2E-08
3000	1.4E-08	1.4E-08	7.1E-09	1.0E-08	1.0E-08	5.5E-09	8.7E-09	8.7E-09

Table 31. GCR LET data for vanadium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	7.3E-11	5.5E-11	2.2E-12	2.4E-13	1.8E-13	1.5E-13	0.0E+00	0.0E+00
35	1.9E-10	1.5E-10	8.0E-12	9.3E-13	6.5E-13	4.8E-13	3.8E-13	3.5E-13
40	6.9E-10	3.0E-10	1.9E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	2.0E-06	5.9E-10	3.3E-11	3.0E-12	2.3E-12	1.5E-12	1.8E-12	1.3E-12
50	1.2E-06	4.0E-07	5.2E-11	4.4E-12	3.7E-12	2.2E-12	2.6E-12	2.5E-12
55	9.4E-07	6.9E-07	7.2E-11	7.3E-12	6.2E-12	3.4E-12	3.2E-12	2.6E-12
60	8.4E-07	9.7E-07	1.1E-10	1.3E-11	1.2E-11	5.9E-12	6.1E-12	6.2E-12
65	7.8E-07	1.2E-06	1.7E-10	2.1E-11	1.9E-11	8.7E-12	8.2E-12	7.1E-12
70	7.4E-07	1.1E-06	9.0E-09	2.7E-11	2.5E-11	1.2E-11	1.1E-11	1.1E-11
75	7.1E-07	8.9E-07	1.7E-08	3.7E-11	3.8E-11	1.7E-11	1.7E-11	1.6E-11
80	6.8E-07	8.1E-07	2.4E-08	7.0E-11	6.2E-11	2.3E-11	2.4E-11	2.3E-11
85	6.7E-07	7.6E-07	3.1E-08	1.2E-10	1.2E-10	3.4E-11	3.3E-11	3.2E-11
90	6.5E-07	7.2E-07	3.7E-08	2.0E-10	2.0E-10	5.7E-11	3.9E-11	3.7E-11
95	6.3E-07	6.9E-07	4.3E-08	2.7E-10	2.6E-10	8.8E-11	5.5E-11	5.1E-11
100	6.2E-07	6.7E-07	5.0E-08	3.9E-10	3.7E-10	1.3E-10	9.1E-11	8.5E-11
110	6.0E-07	6.3E-07	6.2E-08	6.2E-10	5.9E-10	2.4E-10	2.2E-10	2.3E-10
120	5.8E-07	6.1E-07	7.5E-08	1.1E-09	1.0E-09	4.0E-10	4.0E-10	3.9E-10
130	5.6E-07	5.8E-07	8.7E-08	1.5E-09	1.5E-09	6.3E-10	6.1E-10	0.0E+00
140	5.5E-07	5.6E-07	1.0E-07	1.9E-09	1.9E-09	9.1E-10	9.8E-10	9.6E-10
150	5.3E-07	5.4E-07	1.1E-07	2.3E-09	2.2E-09	1.2E-09	1.5E-09	1.4E-09
160	5.2E-07	5.3E-07	1.2E-07	2.6E-09	2.6E-09	1.4E-09	1.9E-09	1.9E-09
170	5.1E-07	5.1E-07	1.3E-07	3.0E-09	2.9E-09	1.6E-09	2.3E-09	2.2E-09
180	4.9E-07	5.0E-07	1.5E-07	3.4E-09	3.3E-09	1.8E-09	2.6E-09	2.6E-09
190	4.8E-07	4.9E-07	1.6E-07	3.7E-09	3.7E-09	2.0E-09	2.9E-09	2.9E-09
200	4.7E-07	4.7E-07	1.7E-07	4.1E-09	4.1E-09	2.2E-09	3.3E-09	3.3E-09
300	3.8E-07	3.7E-07	2.5E-07	1.5E-08	1.4E-08	5.3E-09	6.8E-09	6.7E-09
400	3.0E-07	3.0E-07	1.9E-07	3.9E-07	4.0E-07	1.8E-07	2.2E-08	2.1E-08
500	2.5E-07	2.5E-07	1.4E-07	2.3E-07	2.3E-07	1.5E-07	3.0E-07	3.0E-07
600	2.1E-07	2.0E-07	1.1E-07	1.7E-07	1.7E-07	1.0E-07	1.7E-07	1.7E-07
700	1.9E-07	1.8E-07	9.7E-08	1.5E-07	1.5E-07	8.4E-08	1.4E-07	1.3E-07
800	1.5E-07	1.5E-07	7.7E-08	1.1E-07	1.1E-07	6.4E-08	1.0E-07	1.0E-07
900	1.3E-07	1.3E-07	6.8E-08	9.9E-08	9.9E-08	5.5E-08	8.8E-08	8.7E-08
1000	1.2E-07	1.2E-07	6.0E-08	8.8E-08	8.8E-08	4.9E-08	7.7E-08	7.6E-08

1250	8.9E-08	8.7E-08	4.4E-08	6.3E-08	6.4E-08	3.5E-08	5.5E-08	5.5E-08
1500	6.5E-08	6.4E-08	3.2E-08	4.7E-08	4.7E-08	2.5E-08	4.0E-08	4.0E-08
1750	5.3E-08	5.2E-08	2.6E-08	3.8E-08	3.8E-08	2.0E-08	3.2E-08	3.2E-08
2000	4.1E-08	4.0E-08	2.0E-08	2.9E-08	2.9E-08	1.6E-08	2.5E-08	2.5E-08
2250	3.6E-08	3.5E-08	1.7E-08	2.5E-08	2.5E-08	1.4E-08	2.1E-08	2.1E-08
2500	2.7E-08	2.7E-08	1.3E-08	1.9E-08	2.0E-08	1.0E-08	1.6E-08	1.7E-08
2750	2.1E-08	2.1E-08	1.0E-08	1.5E-08	1.5E-08	7.9E-09	1.3E-08	1.3E-08
3000	1.6E-08	1.6E-08	7.7E-09	1.1E-08	1.1E-08	6.0E-09	9.5E-09	9.5E-09

Table 32. GCR LET data for chromium (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	3.1E-10	2.5E-10	9.4E-12	1.5E-12	1.2E-12	6.1E-13	5.1E-13	2.2E-13
35	7.6E-10	5.7E-10	3.2E-11	3.7E-12	2.5E-12	1.6E-12	1.3E-12	1.2E-12
40	2.0E-09	1.1E-09	7.2E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	6.0E-06	2.0E-09	1.3E-10	9.3E-12	7.9E-12	5.6E-12	8.8E-12	4.9E-12
50	5.9E-06	1.3E-06	2.1E-10	1.6E-11	1.4E-11	8.6E-12	1.2E-11	7.9E-12
55	4.5E-06	2.6E-06	3.1E-10	2.9E-11	2.3E-11	1.2E-11	1.3E-11	1.3E-11
60	3.9E-06	3.8E-06	4.6E-10	5.1E-11	4.9E-11	2.3E-11	2.2E-11	2.1E-11
65	3.5E-06	4.9E-06	6.3E-10	7.1E-11	6.9E-11	3.2E-11	3.3E-11	2.6E-11
70	3.3E-06	5.4E-06	1.2E-08	9.6E-11	9.3E-11	4.4E-11	4.0E-11	3.6E-11
75	3.1E-06	4.1E-06	5.6E-08	1.5E-10	1.4E-10	6.2E-11	5.8E-11	5.5E-11
80	3.0E-06	3.7E-06	8.7E-08	2.6E-10	2.3E-10	8.7E-11	1.1E-10	9.8E-11
85	2.9E-06	3.4E-06	1.1E-07	4.9E-10	4.6E-10	1.3E-10	1.1E-10	0.0E+00
90	2.8E-06	3.2E-06	1.4E-07	7.6E-10	7.1E-10	2.0E-10	1.4E-10	1.4E-10
95	2.7E-06	3.0E-06	1.6E-07	1.0E-09	9.7E-10	3.3E-10	2.0E-10	1.9E-10
100	2.6E-06	2.9E-06	1.9E-07	1.4E-09	1.4E-09	5.1E-10	3.1E-10	3.1E-10
110	2.5E-06	2.7E-06	2.4E-07	2.4E-09	2.3E-09	9.4E-10	9.1E-10	8.6E-10
120	2.4E-06	2.5E-06	2.8E-07	3.7E-09	3.6E-09	1.5E-09	1.5E-09	1.5E-09
130	2.3E-06	2.4E-06	3.3E-07	5.6E-09	5.4E-09	2.3E-09	2.2E-09	2.2E-09
140	2.2E-06	2.3E-06	3.7E-07	6.9E-09	6.7E-09	3.3E-09	3.6E-09	3.5E-09
150	2.1E-06	2.2E-06	4.1E-07	8.0E-09	8.0E-09	4.2E-09	5.2E-09	5.2E-09
160	2.1E-06	2.1E-06	4.5E-07	9.4E-09	9.4E-09	5.0E-09	6.7E-09	6.7E-09
170	2.0E-06	2.0E-06	4.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
180	1.9E-06	1.9E-06	5.3E-07	1.2E-08	1.2E-08	6.4E-09	9.2E-09	9.1E-09
190	1.9E-06	2.0E-06	5.4E-07	1.2E-08	1.2E-08	6.5E-09	9.2E-09	9.1E-09
200	1.8E-06	1.8E-06	6.0E-07	1.4E-08	1.4E-08	7.7E-09	1.1E-08	1.1E-08
300	1.4E-06	1.4E-06	8.6E-07	4.3E-08	4.1E-08	1.7E-08	2.2E-08	2.2E-08
400	1.0E-06	1.0E-06	6.6E-07	1.5E-06	1.6E-06	4.9E-07	5.9E-08	5.7E-08
500	8.3E-07	8.2E-07	4.7E-07	7.9E-07	8.0E-07	5.5E-07	1.2E-06	1.2E-06
600	6.8E-07	6.6E-07	3.6E-07	5.7E-07	5.7E-07	3.4E-07	5.7E-07	5.7E-07
700	6.0E-07	5.9E-07	3.1E-07	4.7E-07	4.7E-07	2.7E-07	4.4E-07	4.4E-07
800	4.7E-07	4.6E-07	2.4E-07	3.6E-07	3.6E-07	2.0E-07	3.2E-07	3.2E-07
900	4.1E-07	4.1E-07	2.1E-07	3.1E-07	3.1E-07	1.7E-07	2.7E-07	2.7E-07
1000	3.7E-07	3.6E-07	1.9E-07	2.7E-07	2.7E-07	1.5E-07	2.4E-07	2.3E-07
1250	2.7E-07	2.6E-07	1.3E-07	1.9E-07	1.9E-07	1.0E-07	1.7E-07	1.6E-07

1500	1.9E-07	1.9E-07	9.6E-08	1.4E-07	1.4E-07	7.4E-08	1.2E-07	1.2E-07
1750	1.6E-07	1.5E-07	7.7E-08	1.1E-07	1.1E-07	5.9E-08	9.4E-08	9.3E-08
2000	1.2E-07	1.2E-07	5.8E-08	8.4E-08	8.4E-08	4.5E-08	7.1E-08	7.1E-08
2250	1.0E-07	1.0E-07	5.0E-08	7.2E-08	7.3E-08	3.9E-08	6.1E-08	6.1E-08
2500	7.9E-08	7.8E-08	3.9E-08	5.5E-08	5.6E-08	3.0E-08	4.7E-08	4.7E-08
2750	6.0E-08	5.9E-08	2.9E-08	4.2E-08	4.2E-08	2.3E-08	3.6E-08	3.6E-08
3000	4.5E-08	4.4E-08	2.2E-08	3.1E-08	3.2E-08	1.7E-08	2.7E-08	2.7E-08

Table 33. GCR LET data for manganese (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	2.0E-10	1.7E-10	7.3E-12	6.8E-13	5.8E-13	4.7E-13	3.2E-13	1.9E-13
35	6.3E-10	4.2E-10	2.4E-11	2.1E-12	1.5E-12	1.3E-12	1.6E-12	1.3E-12
40	1.5E-09	8.2E-10	5.2E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	3.7E-06	1.5E-09	1.0E-10	1.0E-11	8.0E-12	4.4E-12	4.5E-12	3.8E-12
50	4.9E-06	8.4E-07	1.5E-10	1.4E-11	1.2E-11	6.6E-12	6.6E-12	6.1E-12
55	5.3E-06	8.9E-07	1.6E-10	1.5E-11	1.3E-11	7.0E-12	7.0E-12	6.5E-12
60	3.1E-06	2.8E-06	3.3E-10	3.8E-11	3.9E-11	1.6E-11	1.4E-11	1.4E-11
65	2.8E-06	3.6E-06	4.6E-10	5.6E-11	5.3E-11	2.5E-11	2.4E-11	2.1E-11
70	2.6E-06	4.5E-06	6.5E-10	7.6E-11	6.9E-11	3.6E-11	3.3E-11	3.0E-11
75	2.4E-06	3.3E-06	3.7E-08	1.1E-10	1.0E-10	5.0E-11	4.9E-11	4.7E-11
80	2.3E-06	2.9E-06	6.1E-08	2.1E-10	1.9E-10	6.8E-11	7.3E-11	6.7E-11
85	2.2E-06	2.6E-06	8.1E-08	3.8E-10	3.5E-10	1.0E-10	9.4E-11	9.2E-11
90	2.1E-06	2.4E-06	1.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
95	2.0E-06	2.3E-06	1.2E-07	8.2E-10	7.8E-10	2.6E-10	1.5E-10	1.4E-10
100	2.0E-06	2.2E-06	1.4E-07	9.9E-10	9.5E-10	3.6E-10	2.5E-10	2.3E-10
110	1.9E-06	2.0E-06	1.7E-07	1.6E-09	1.6E-09	6.4E-10	6.4E-10	6.1E-10
120	1.8E-06	1.9E-06	2.0E-07	2.6E-09	2.5E-09	1.0E-09	1.1E-09	1.1E-09
130	1.7E-06	1.7E-06	2.3E-07	3.7E-09	3.7E-09	1.5E-09	1.5E-09	1.5E-09
140	1.6E-06	1.7E-06	2.6E-07	4.7E-09	4.6E-09	2.2E-09	2.4E-09	2.4E-09
150	1.5E-06	1.6E-06	2.9E-07	5.4E-09	5.4E-09	2.8E-09	3.6E-09	3.4E-09
160	1.5E-06	1.5E-06	3.2E-07	6.3E-09	6.1E-09	3.3E-09	4.6E-09	4.5E-09
170	1.4E-06	1.4E-06	3.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
180	1.4E-06	1.4E-06	3.6E-07	7.6E-09	7.5E-09	4.1E-09	6.0E-09	6.0E-09
190	1.3E-06	1.3E-06	3.9E-07	8.4E-09	8.4E-09	4.6E-09	6.8E-09	6.6E-09
200	1.3E-06	1.3E-06	4.1E-07	9.1E-09	9.1E-09	5.1E-09	7.4E-09	7.4E-09
300	9.1E-07	9.1E-07	5.6E-07	2.5E-08	2.4E-08	1.0E-08	1.4E-08	1.4E-08
400	6.7E-07	6.6E-07	4.4E-07	1.1E-06	1.1E-06	2.7E-07	3.2E-08	3.1E-08
500	5.4E-07	5.3E-07	3.1E-07	5.2E-07	5.2E-07	3.8E-07	9.0E-07	9.7E-07
600	4.3E-07	4.2E-07	2.3E-07	3.6E-07	3.6E-07	2.2E-07	3.7E-07	3.7E-07
700	3.8E-07	3.7E-07	2.0E-07	3.0E-07	3.0E-07	1.7E-07	2.8E-07	2.8E-07
800	3.0E-07	2.9E-07	1.5E-07	2.3E-07	2.3E-07	1.3E-07	2.0E-07	2.0E-07
900	2.6E-07	2.6E-07	1.3E-07	1.9E-07	1.9E-07	1.1E-07	1.7E-07	1.7E-07
1000	2.3E-07	2.3E-07	1.2E-07	1.7E-07	1.7E-07	9.4E-08	1.5E-07	1.5E-07
1250	1.7E-07	1.7E-07	8.4E-08	1.2E-07	1.2E-07	6.6E-08	1.0E-07	1.0E-07

1500	1.2E-07	1.2E-07	6.1E-08	8.7E-08	8.8E-08	4.7E-08	7.4E-08	7.4E-08
1750	1.0E-07	9.8E-08	4.9E-08	7.0E-08	7.1E-08	3.8E-08	6.0E-08	6.0E-08
2000	7.7E-08	7.6E-08	3.7E-08	5.4E-08	5.4E-08	2.9E-08	4.6E-08	4.5E-08
2250	6.7E-08	6.6E-08	3.3E-08	4.6E-08	4.7E-08	2.5E-08	4.0E-08	3.9E-08
2500	5.2E-08	5.1E-08	2.5E-08	3.6E-08	3.6E-08	1.9E-08	3.1E-08	3.1E-08
2750	4.0E-08	3.9E-08	1.9E-08	2.7E-08	2.8E-08	1.5E-08	2.3E-08	2.3E-08
3000	3.0E-08	3.0E-08	1.5E-08	2.1E-08	2.1E-08	1.1E-08	1.8E-08	1.8E-08

Table 34. GCR LET data for iron (KeV/micron/s)

Energy	D1	D2	TEP1	D3	D4	TEP2	D5	D6
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	2.5E-09	1.9E-09	7.5E-11	9.3E-12	5.1E-12	4.0E-12	2.5E-12	8.5E-13
35	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	1.5E-08	8.2E-09	5.5E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	5.0E-08	1.5E-08	1.1E-09	8.8E-11	7.8E-11	4.3E-11	5.2E-11	3.7E-11
50	6.9E-05	4.0E-06	1.6E-09	1.6E-10	1.3E-10	6.0E-11	7.1E-11	5.3E-11
55	4.4E-05	1.7E-05	2.3E-09	2.1E-10	2.0E-10	9.3E-11	1.2E-10	9.5E-11
60	3.6E-05	2.7E-05	3.5E-09	4.0E-10	3.8E-10	1.7E-10	1.6E-10	1.4E-10
65	3.2E-05	3.7E-05	4.4E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
70	3.0E-05	4.6E-05	6.7E-09	8.2E-10	7.6E-10	3.6E-10	3.3E-10	2.9E-10
75	2.8E-05	4.1E-05	2.5E-07	1.1E-09	1.1E-09	4.8E-10	4.8E-10	4.7E-10
80	2.7E-05	3.4E-05	5.5E-07	2.0E-09	1.9E-09	6.9E-10	6.8E-10	6.4E-10
85	2.5E-05	3.1E-05	7.9E-07	3.5E-09	3.3E-09	9.6E-10	8.5E-10	8.4E-10
90	2.4E-05	2.8E-05	1.0E-06	5.6E-09	5.3E-09	1.6E-09	1.1E-09	1.1E-09
95	2.3E-05	2.6E-05	1.2E-06	7.7E-09	7.5E-09	2.5E-09	1.6E-09	1.5E-09
100	2.3E-05	2.5E-05	1.4E-06	1.0E-08	9.7E-09	2.9E-09	0.0E+00	0.0E+00
110	2.1E-05	2.3E-05	1.8E-06	1.7E-08	1.7E-08	6.5E-09	5.9E-09	5.7E-09
120	2.0E-05	2.1E-05	2.1E-06	2.7E-08	2.7E-08	0.0E+00	0.0E+00	0.0E+00
130	1.9E-05	2.0E-05	2.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
140	1.8E-05	1.9E-05	2.8E-06	4.7E-08	4.6E-08	2.2E-08	2.5E-08	2.4E-08
150	1.8E-05	1.8E-05	3.1E-06	5.6E-08	5.6E-08	2.9E-08	3.6E-08	3.5E-08
160	1.7E-05	1.7E-05	3.4E-06	6.5E-08	6.5E-08	3.5E-08	4.7E-08	4.7E-08
170	1.6E-05	1.6E-05	3.6E-06	7.2E-08	7.2E-08	3.9E-08	5.5E-08	5.5E-08
180	1.6E-05	1.6E-05	3.9E-06	8.1E-08	8.1E-08	1.8E-08	0.0E+00	0.0E+00
190	1.5E-05	1.5E-05	4.2E-06	8.8E-08	8.7E-08	4.8E-08	7.0E-08	7.0E-08
200	1.4E-05	1.5E-05	4.4E-06	9.6E-08	9.4E-08	5.2E-08	7.6E-08	7.6E-08
300	1.1E-05	1.0E-05	6.1E-06	2.4E-07	2.4E-07	1.1E-07	1.4E-07	1.4E-07
400	7.7E-06	7.7E-06	5.3E-06	1.7E-05	1.9E-05	1.7E-06	3.1E-07	3.0E-07
500	6.2E-06	6.2E-06	3.6E-06	6.2E-06	6.2E-06	5.4E-06	4.6E-06	4.1E-06
600	5.0E-06	4.9E-06	2.7E-06	4.2E-06	4.3E-06	2.6E-06	4.5E-06	4.5E-06
700	4.4E-06	4.3E-06	2.3E-06	3.5E-06	3.5E-06	2.0E-06	3.3E-06	3.3E-06
800	3.5E-06	3.4E-06	1.8E-06	2.6E-06	2.6E-06	1.5E-06	2.4E-06	2.4E-06
900	3.0E-06	3.0E-06	1.5E-06	2.3E-06	2.3E-06	1.3E-06	2.0E-06	2.0E-06
1000	2.7E-06	2.7E-06	1.4E-06	2.0E-06	2.0E-06	1.1E-06	1.7E-06	1.7E-06
1250	2.0E-06	2.0E-06	9.8E-07	1.4E-06	1.4E-06	7.6E-07	1.2E-06	1.2E-06

1500	1.5E-06	1.4E-06	7.1E-07	1.0E-06	1.0E-06	5.5E-07	8.6E-07	8.6E-07
1750	1.2E-06	1.2E-06	5.8E-07	8.2E-07	8.3E-07	4.4E-07	6.9E-07	6.9E-07
2000	9.1E-07	8.9E-07	4.4E-07	6.3E-07	6.3E-07	3.4E-07	5.3E-07	5.3E-07
2250	7.9E-07	7.8E-07	3.8E-07	5.5E-07	5.5E-07	2.9E-07	4.6E-07	4.6E-07
2500	6.1E-07	6.0E-07	3.0E-07	4.2E-07	4.3E-07	2.3E-07	3.6E-07	3.6E-07
2750	4.7E-07	4.6E-07	2.3E-07	3.2E-07	3.3E-07	1.7E-07	2.8E-07	2.8E-07
3000	3.6E-07	3.5E-07	1.7E-07	2.5E-07	2.5E-07	1.3E-07	2.1E-07	2.1E-07

VITA

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