SLS Booster Radiation Environment

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The 200 km LET (Linear Energy Transfer) and particle flux environments SLS-SPEC-159 Cross-Program Design Specification for Natural Environments (DSNE) were obtained using the Cosmic Ray Effects on Microelectrons 96 (CREME96[1]). In this section, DSNE Tables 3.2.13-1 – 3 are reproduced using the technical notes provided in the DSNE.

For the LET and flux, the GTRN routine is ran using the following options:

- 1.C.a. & 1.C.b. 200 km circular orbit
- 1.C.c. 51.6 degrees orbit inclination
- 1.C.g. Effective L-shell range: $2.4 \leqslant L \leqslant 2.55$
- 2. Stormy magnetic weather conditions

2.1 Linear Energy Transfer (LET)

To compute the LET, the LETSPEC routine is used setting the following parameters:

- 2. and 3. $Z = 1$ to 92
- 4. particles > 0.1 MeV/nuc
- 5. Silicon target material

Integral LET due to solar particle events (SPEs) and galactic cosmic rays (GCRs) are both computed as shown in Figure 1. Agreement in both the SPE and GCR integral LET spectra show that the CREME96 inputs were interpreted correctly.

[1] https://creme.isde.vanderbilt.edu/

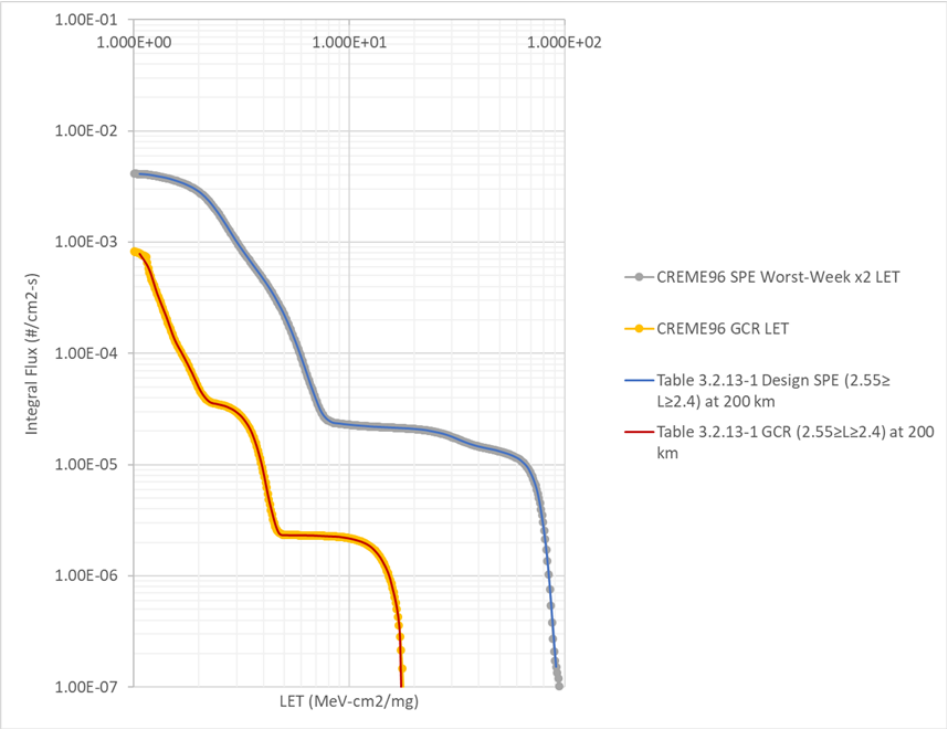


Figure 1: Output generated from CREME96 LETSPEC are plotted against DSNE Table 3.2.13-1 for SPEs and GCRs.

2.2 Differential Flux

The differential flux for both SPEs and GCRs are computed using the FLUX routine with the following options set:

SPE

- 1. and 2. $Z = 1$ to 92
- 2.a. CREME96
- 3.b. Worst Week
- 4. Inside Earth's Magnetosphere

GCR

- 1. and 2. $Z = 1$ to 92
- 2.a. CREME96
- 3.b. Solar Minimum (Cosmic-Ray Maximum)
- 4. Inside Earth's Magnetosphere

The differential flux output from CREME96 is plotted against Table 3.2.13-2 in Figure 2 and shows perfect agreement. Note that there is a factor of 2x on the SPEs from CREME96 to DSNE. According to the technical notes in DSNE, "The x2 multiplier of the 1989 event is needed to simulate a 'worst case' SPE exposure at the high 97% probability level..."

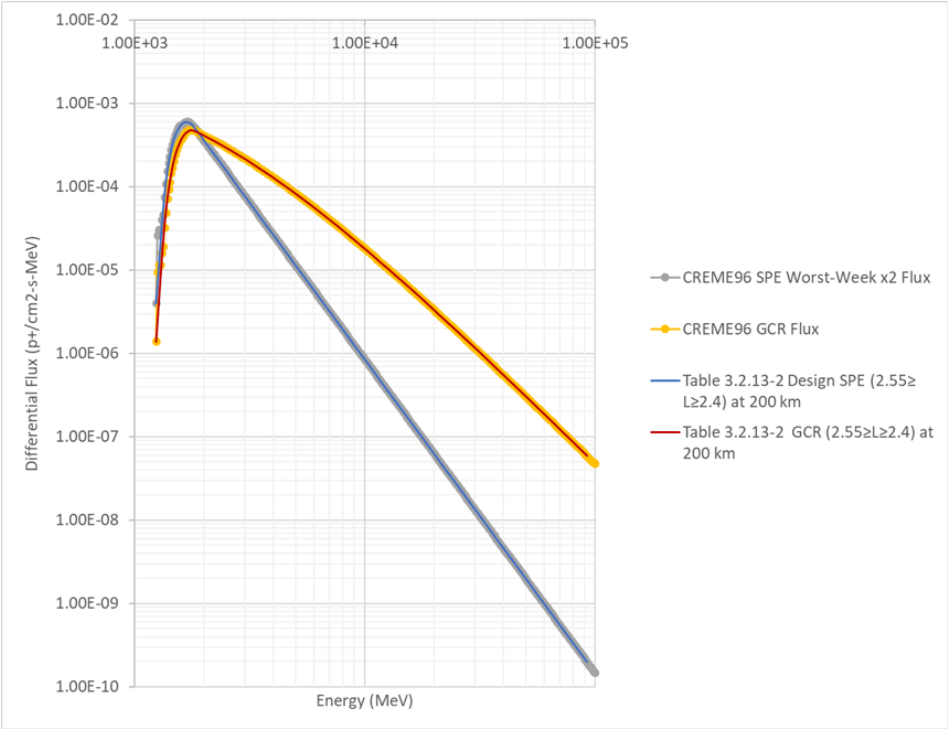


Figure 2: Output generated from CREME96 FLUX are plotted against DSNE Table 3.2.13-2 for SPEs and GCRs.

2.3 Integral Flux

The integral flux for both the SPEs and GRCs are derived from the differential flux output. Since the flux spectra have power-law-like features, the best way to approximate the differential flux is to interpolate using a power-law fit between data points (x_i, y_i), i.e.

$$y(x) = y_i \left(\frac{x}{x_i} \right)^{b_i}, \text{ for } x_i \leqslant x \leqslant x_{i+1}, \tag{1}$$

where

$$b_i = \frac{\log(y_{i+1}/y_i)}{\log(x_{i+1}/x_i)}. \tag{2}$$

The integral flux ($> x$) can then be computed by integrating from some x to infinity

$$Y(> x) = \int_x^\infty dx' y(x'). \tag{3}$$

Inserting Equation (1) for $y(x)$, the integral flux becomes

$$Y(> x_n) = \sum_{i=n}^{N-1} \frac{y_i x_i}{b_i + 1} \left[\left(\frac{x_{i+1}}{x_i} \right)^{b_i+1} - 1 \right]. \tag{4}$$

Applying Equation (4) to the differential fluxes shown in Section 2.2, the integral fluxes are derived and compared with DSNE Table 3.2.13-3 in Figure 3. The comparison again shows perfect agreement and also give merit to the power-law interpolation method outlined above.

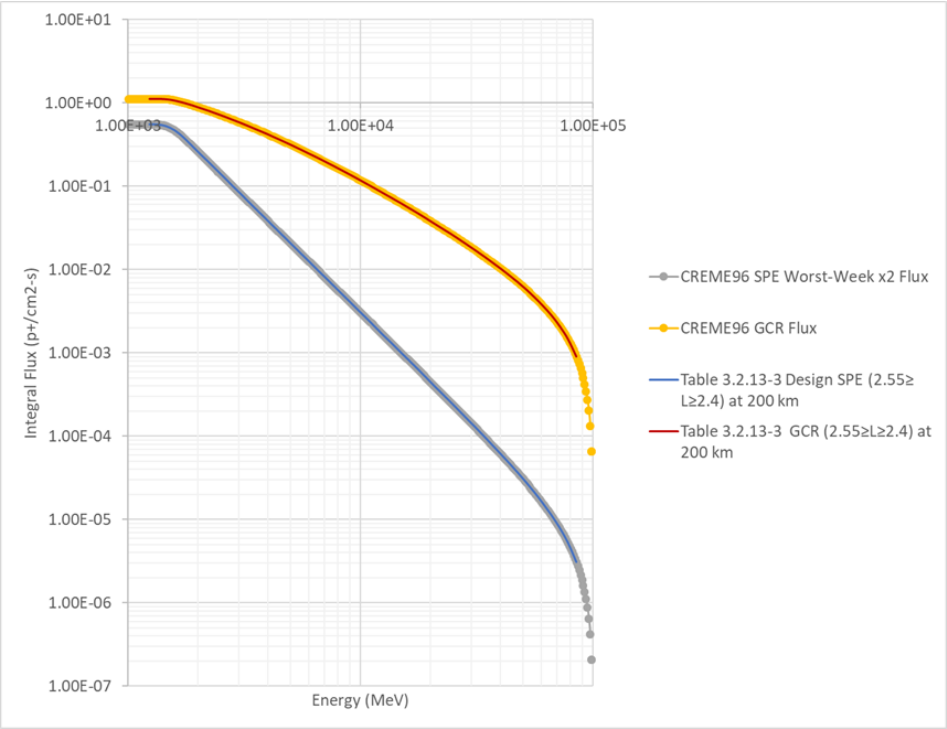


Figure 3: Output generated from CREME96 FLUX and converted to integral fluxes using Equation (4) are plotted against DSNE Table 3.2.13-3 for SPEs and GCRs.

3 Updated 50 km Environment

In this section, the methods used to derive the DSNE tables for the 200 km environments will be used to compute the new 50 km environments. The assumptions that went into the parameters used for the 50 km environments are discussed in Section 3.1. Following in Section 4, the integral LET spectra, differential fluxes, and integral fluxes generated for the 50 km environments are compared to the DSNE 200 km environments.

3.1 Assumptions

Information about the 3-DOF DAC-1 BOLE separation was given by Patrick Montgomery on 2/2/2021. The trajectory was optimized to produce maximum loads, so a lower separation altitude is achieved. There also was no dispersion in launch azimuth. The specific data provided is as follows:

3.1.1 BOLE Separation Location

- Altitude (ft): 1.47769768×10^5 to 1.56331111×10^5 (or 45.04 km to 47.65 km)
- Geodetic Latitude (deg): 28.63679 to 28.63769
- Longitude (deg): 279.844269 to 279.892322
- Inclination (deg): 28.48989 to 28.49106

3.1.2 LC-39b Location

In order to include dispersion in launch azimuth, the downrange distance is computed assuming a launch location from KSC launch complex 39b.

- Geodetic Latitude (deg): 28.627623
- Longitude (deg): 279.378890.

3.1.3 Downrange Distance and Initial Bearing

Given the latitude and longitude (ϕ, λ) of the starting and ending location, a downrange distance can be computed[2] using

$$D = 2r_E \arcsin(\sqrt{a}), \tag{5}$$

where $r_E = 6371$ km (Earth's radius), and

$$a = \sin^2(\Delta\phi/2) + \cos\phi_1 \cos\phi_2 \sin^2(\Delta\lambda/2), \tag{6}$$

for $\Delta\phi = \phi_1 - \phi_2$ and $\Delta\lambda = \lambda_1 - \lambda_2$.

[2] E.g., see https://www.movable-type.co.uk/scripts/latlong.html

The initial bearing from the launch point can also be calculated using

$$\tan\theta_{i(1,2)} = \frac{\sin\Delta\lambda\cos\phi_2}{\cos\phi_1\sin\phi_2 - \sin\phi_1\cos\phi_2\cos\Delta\lambda}. \tag{7}$$

Therefore, from the initial separation data, the bearing and downrange distance is the following:

- **Nominal bearing** (deg, from N CCW): -88.48 to -88.71 (i.e., almost strictly due East)
- **Downrange distance** (km): 45.4 to 50.1.

The range of valid bearings from KSC LC-39b are $-35°$ to $-120°$, where the worst-case[3] would be $-35°$ (most northerly direction), giving an orbital inclination of $57°$.

3.1.4 Magnetic Epoch and L-Shell

A magnetic epoch must be selected in order to convert geodetic latitude and longitude to magnetic latitude and longitude. The magnetic latitude and separation altitude are used to compute the L-shell. In DSNE, it is implicitly assumed that the magnetic epoch is 1980, driven by the assumptions built into CREME96. However, a magnetic epoch of 2020 is also used in the analysis for the lower bound[4] on the L-shell.

The L-shell can be computed by

$$L = \frac{1 + \frac{h}{R_E}}{\cos(\phi_{\text{geomagnetic}})}, \tag{8}$$

were h is the spacecraft altitude, $R_E = 6371$ km, and $\phi_{\text{geomagnetic}}$ is the geomagnetic latitude.

If a most-northerly(southerly) launch azimuth case is assumed, the magnetic latitude for different magnetic epochs is given in Table 1.

Table 1: The magnetic latitudes at BOLE separation for magnetic epochs of 1980 & 2020 and bounding cases for launch azimuths ($65°$ to $-30°$).

	1980 epoch	2020 epoch
Most-northerly	$39.83°$	$38.14°$
Most-southerly	$39.23°$	$37.54°$

L-Shell Sensitivity: The L-shell sensitivity, or dL, is affected by magnetic epoch, launch azimuth, and separation altitude, summarized below:

[3] Worst-case in terms of a larger L-shell value, giving less magnetic field protection from space radiation.

[4] Currently, the magnetic south pole (near the geographic north pole) has been migrating towards the Asian continent, hence putting KSC at a lower L-shell over several decades.

- Magnetic epoch: Magnetic latitude difference of $1.69°$ ($dL \approx 0.08$ or 72% of total dL)
- Launch azimuth: Magnetic latitude difference of $0.60°$ ($dL \approx 0.03$ or 27% of total dL)
- Altitude at separation: Altitude difference of 5 km ($dL \approx 0.0013$ or 1% of total dL)

Therefore, the choice of magnetic epoch drives the range of the L-shell compared to the launch azimuth range and range in separation altitude.

3.1.5 L-Shell Range

Given the analysis in Section 3.1.4, the L-shell range used in deriving the new 50 km environments is:

- From 1.60174 (most southerly launch azimuth, 2020 magnetic epoch, and separation altitude of 45 km)
- To 1.70896 (most northerly launch azimuth, 1980 magnetic epoch, and separation altitude of 50 km).

The difference from using a separation altitude of 47.65 km vs. 50 km changes the L-shell value only in the last two significant figures.

3.2 GTRN, FLUX, and LETSPEC Options for 50 km Environments

The options used in the GTRN routine for the 50 km environments (as a best guess worst-case) are as follows:

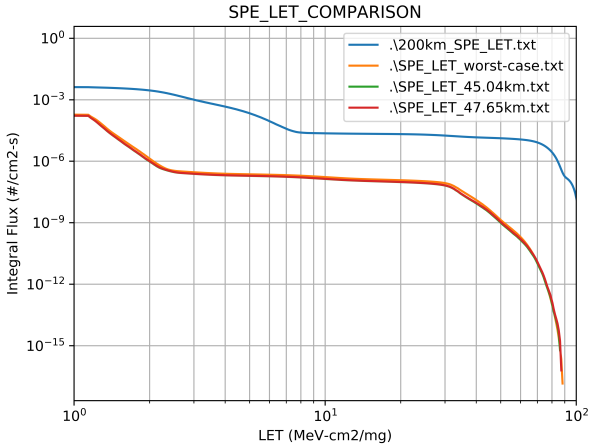
- 1.C.a. & 1.C.b. 50 km circular orbit
- 1.C.c. 57 degrees orbit inclination
- 1.C.g. Effective L-shell range: $1.60174 \leqslant L \leqslant 1.70896$
- 2. Stormy magnetic weather conditions.

Options for the FLUX and LETSPEC routines are the same as in Sections 2.2 and 2.1, respectively.

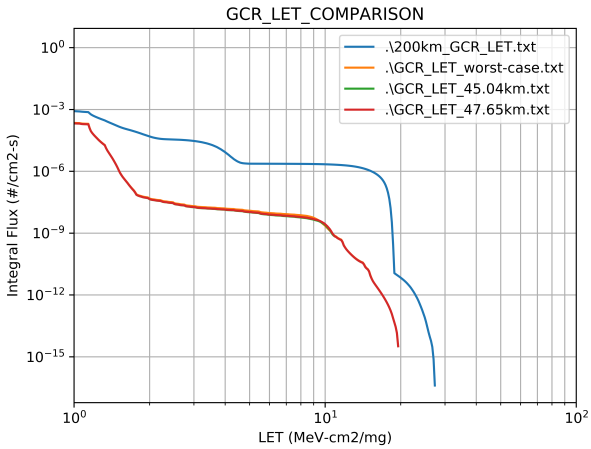
4 Comparison of 50 km and 200 km Environments

4.1 Linear Energy Transfer (LET)

The high resolution tables for the SPE and GCR LET spectra are given in Appendix B, Listings 5 and 6. For a lower resolution table (that would conform to what is in DSNE), see Table 2.



(a) Comparing different SPE LET BOLE environments with 200 km DSNE environment.



(b) Comparing different GCR LET BOLE environments with 200 km DSNE environment.

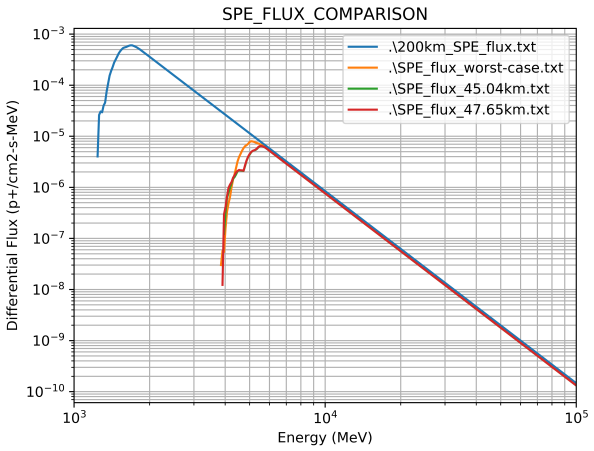
Figure 4: Comparison of integral LET fluxes between 50 km and 200 km environments.

Table 2: 50 km Integral LET Flux as Shown in Figure 4, worst-case lines.

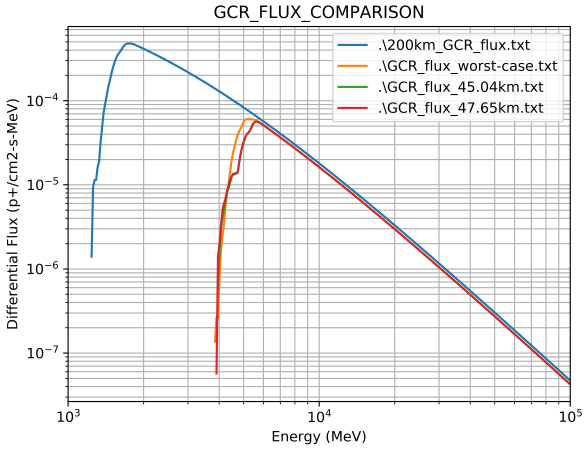
	Design SPE	GCR
LET (MeV-cm^2/mg)	Integral Flux (#/cm^2-s)	Integral Flux (#/cm^2-s)
1.00E+00	1.86E-04	2.23E-04
1.10E+00	1.84E-04	2.04E-04
1.20E+00	1.24E-04	5.81E-05
1.31E+00	5.31E-05	2.04E-05
1.44E+00	2.19E-05	3.32E-06
1.58E+00	1.01E-05	4.63E-07
1.73E+00	4.73E-06	1.21E-07
1.89E+00	2.19E-06	5.80E-08
2.07E+00	9.77E-07	4.33E-08
2.27E+00	4.92E-07	3.53E-08
2.49E+00	3.46E-07	3.04E-08
2.73E+00	3.11E-07	2.44E-08
2.99E+00	2.90E-07	2.03E-08
3.27E+00	2.71E-07	1.82E-08
3.58E+00	2.56E-07	1.71E-08
3.92E+00	2.45E-07	1.58E-08
4.30E+00	2.38E-07	1.47E-08
4.71E+00	2.32E-07	1.33E-08
5.16E+00	2.27E-07	1.16E-08
5.65E+00	2.22E-07	1.00E-08
6.19E+00	2.17E-07	9.19E-09
6.78E+00	2.10E-07	8.47E-09
7.43E+00	2.03E-07	7.90E-09
8.14E+00	1.93E-07	7.17E-09
8.91E+00	1.82E-07	5.79E-09
9.76E+00	1.71E-07	2.92E-09
1.07E+01	1.59E-07	9.12E-10
1.17E+01	1.49E-07	3.93E-10
1.28E+01	1.40E-07	8.18E-11
1.41E+01	1.34E-07	3.83E-11
1.54E+01	1.29E-07	5.54E-12
1.69E+01	1.25E-07	1.04E-12
1.85E+01	1.21E-07	1.10E-13
2.02E+01	1.17E-07	0.00E+00
2.22E+01	1.13E-07	0.00E+00
2.43E+01	1.07E-07	0.00E+00
2.66E+01	1.00E-07	0.00E+00
2.91E+01	9.00E-08	0.00E+00
3.19E+01	6.84E-08	0.00E+00
3.50E+01	3.58E-08	0.00E+00
3.83E+01	1.79E-08	0.00E+00
4.20E+01	8.48E-09	0.00E+00
4.60E+01	3.46E-09	0.00E+00
5.04E+01	1.27E-09	0.00E+00
5.52E+01	5.07E-10	0.00E+00
6.04E+01	1.82E-10	0.00E+00
6.62E+01	4.21E-11	0.00E+00
7.25E+01	4.54E-12	0.00E+00
7.94E+01	1.54E-13	0.00E+00
8.70E+01	2.84E-16	0.00E+00

4.2 Differential Flux

High resolution tables shown in Appendix B in Listings 3 and 4. The low resolution data is shown in Table 3.



(a) Comparing different differential SPE flux BOLE environments with 200 km DSNE environment.



(b) Comparing different differential GCR flux BOLE environments with 200 km DSNE environment.

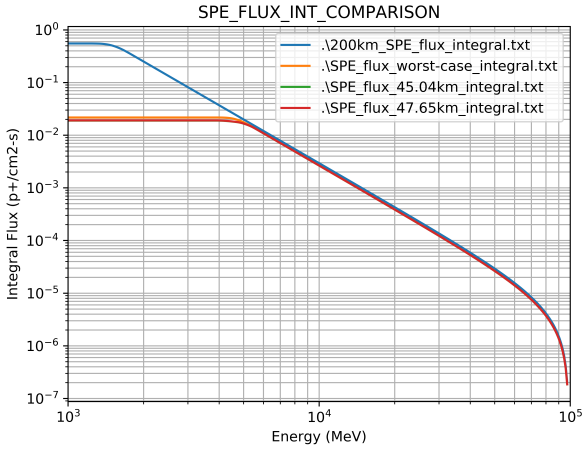
Figure 5: Comparison of differential fluxes between 50 km and 200 km environments.

Table 3: 50 km Differential Flux as Shown in Figure 5, worst-case lines.

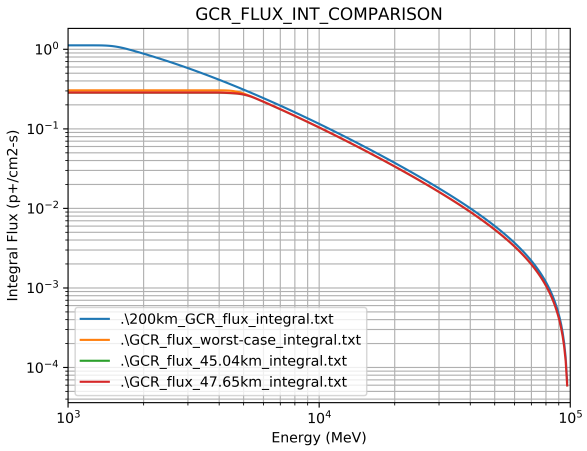
	Design SPE	GCR
Energy (MeV)	Differential Flux (p+/cm^2-s-MeV)	Differential Flux (p+/cm^2-s-MeV)
3.90E+03	5.50E-08	2.56E-07
4.17E+03	5.99E-07	3.17E-06
4.45E+03	2.77E-06	1.66E-05
4.75E+03	6.00E-06	4.01E-05
5.08E+03	7.97E-06	5.95E-05
5.42E+03	7.19E-06	6.00E-05
5.79E+03	5.92E-06	5.50E-05
6.19E+03	4.63E-06	4.78E-05
6.61E+03	3.61E-06	4.14E-05
7.06E+03	2.82E-06	3.58E-05
7.55E+03	2.20E-06	3.09E-05
8.06E+03	1.72E-06	2.66E-05
8.61E+03	1.34E-06	2.29E-05
9.20E+03	1.04E-06	1.97E-05
9.83E+03	8.15E-07	1.68E-05
1.05E+04	6.35E-07	1.44E-05
1.12E+04	4.96E-07	1.23E-05
1.20E+04	3.87E-07	1.05E-05
1.28E+04	3.02E-07	8.96E-06
1.37E+04	2.35E-07	7.62E-06
1.46E+04	1.84E-07	6.48E-06
1.56E+04	1.43E-07	5.50E-06
1.67E+04	1.12E-07	4.67E-06
1.78E+04	8.72E-08	3.95E-06
1.90E+04	6.80E-08	3.35E-06
2.03E+04	5.31E-08	2.83E-06
2.17E+04	4.14E-08	2.39E-06
2.32E+04	3.23E-08	2.02E-06
2.48E+04	2.52E-08	1.70E-06
2.64E+04	1.97E-08	1.44E-06
2.82E+04	1.53E-08	1.21E-06
3.02E+04	1.20E-08	1.02E-06
3.22E+04	9.34E-09	8.57E-07
3.44E+04	7.29E-09	7.21E-07
3.68E+04	5.69E-09	6.06E-07
3.93E+04	4.44E-09	5.09E-07
4.20E+04	3.46E-09	4.27E-07
4.48E+04	2.70E-09	3.59E-07
4.79E+04	2.11E-09	3.01E-07
5.12E+04	1.64E-09	2.52E-07
5.47E+04	1.28E-09	2.12E-07
5.84E+04	1.00E-09	1.77E-07
6.24E+04	7.80E-10	1.48E-07
6.66E+04	6.09E-10	1.24E-07
7.12E+04	4.75E-10	1.04E-07
7.60E+04	3.71E-10	8.71E-08
8.12E+04	2.89E-10	7.29E-08
8.68E+04	2.26E-10	6.10E-08
9.27E+04	1.76E-10	5.10E-08
9.90E+04	1.37E-10	4.27E-08

4.3 Integral Flux

High resolution tables are omitted from the appendix since they can be derived from Listings 3 and 4 by applying Equation (4). The low resolution data is shown in Table 4.



(a) Comparing different integral SPE flux BOLE environments with 200 km DSNE environment.



(b) Comparing different integral GCR flux BOLE environments with 200 km DSNE environment.

Figure 6: Comparison of integral fluxes between 50 km and 200 km environments.

Table 4: 50 km Integral Flux as Shown in Figure 6, worst-case lines.

	Design SPE	GCR
Energy (MeV)	Integral Flux (p+/cm^2-s)	Integral Flux (p+/cm^2-s)
3.50E+03	2.17E-02	3.05E-01
3.74E+03	2.17E-02	3.05E-01
4.00E+03	2.16E-02	3.04E-01
4.28E+03	2.14E-02	3.03E-01
4.58E+03	2.04E-02	2.97E-01
4.90E+03	1.84E-02	2.83E-01
5.24E+03	1.57E-02	2.63E-01
5.61E+03	1.31E-02	2.41E-01
6.00E+03	1.09E-02	2.20E-01
6.42E+03	9.04E-03	2.00E-01
6.87E+03	7.50E-03	1.82E-01
7.34E+03	6.23E-03	1.65E-01
7.86E+03	5.17E-03	1.50E-01
8.40E+03	4.29E-03	1.36E-01
8.99E+03	3.56E-03	1.23E-01
9.61E+03	2.96E-03	1.11E-01
1.03E+04	2.46E-03	9.98E-02
1.10E+04	2.04E-03	8.99E-02
1.18E+04	1.69E-03	8.09E-02
1.26E+04	1.40E-03	7.27E-02
1.35E+04	1.16E-03	6.53E-02
1.44E+04	9.66E-04	5.85E-02
1.54E+04	8.01E-04	5.24E-02
1.65E+04	6.64E-04	4.68E-02
1.76E+04	5.51E-04	4.18E-02
1.89E+04	4.56E-04	3.73E-02
2.02E+04	3.78E-04	3.32E-02
2.16E+04	3.13E-04	2.95E-02
2.31E+04	2.59E-04	2.62E-02
2.47E+04	2.14E-04	2.32E-02
2.64E+04	1.77E-04	2.05E-02
2.83E+04	1.46E-04	1.81E-02
3.02E+04	1.21E-04	1.59E-02
3.23E+04	9.93E-05	1.40E-02
3.46E+04	8.17E-05	1.22E-02
3.70E+04	6.70E-05	1.07E-02
3.96E+04	5.48E-05	9.26E-03
4.23E+04	4.47E-05	8.00E-03
4.53E+04	3.63E-05	6.88E-03
4.84E+04	2.93E-05	5.87E-03
5.18E+04	2.35E-05	4.97E-03
5.54E+04	1.87E-05	4.17E-03
5.93E+04	1.47E-05	3.45E-03
6.34E+04	1.14E-05	2.80E-03
6.78E+04	8.67E-06	2.23E-03
7.26E+04	6.39E-06	1.72E-03
7.76E+04	4.49E-06	1.26E-03
8.30E+04	2.91E-06	8.53E-04
8.88E+04	1.60E-06	4.89E-04
9.50E+04	5.14E-07	1.63E-04

5 Results

In general, both the SPE and GCR fluxes[5] were reduced by flying in an altitude of 50 km vs. 200 km, which is to be expected. The peak SPE and GCR fluxes shifted from 1.7×10^3 MeV to 5.1×10^3 MeV (see Figure 5). The shifted peak is due to the lower L-shell the 50 km environment is in, requiring particles with higher rigidity, and hence more energy.

The overall integral SPE flux reduced by a factor of 25x whereas the overall integral GCR flux reduced by a factor of 3.7x (see Figure 6). Since the SPE energy spectrum occurs at much lower energies compared to the GCRs, it is expected that more of the SPEs would be shielded by the Earth's magnetic field compared to the GCRs.

At 1 LET (MeV-cm^2/mg), the SPE LET flux reduced by a factor of 22x while the GCR LET flux reduced by a factor of 3.7x. However, at 10 LET (MeV-cm^2/mg), the SPE LET flux reduced by a factor of 137x and the GCR LET flux reduced by a factor of 965x. Therefore, it is clear to see that the 50 km environments are much more benign compared with the 200 km environments that are in DSNE.

[5] Differences in fluxes due to heavy ions were not studied in this analysis.

A Raw CREME96 Output for Integral LET

Listing 1: 50 km worst case SPE integral LET.

```
14 Booster_50km_worst_case_worst_week_LET.LET                                                210
    5
%Created by CREME96:LETSPEC_DRIVER Version  210 on  20210318 at 121049.0
%ZMIN =  1 ZMAX = 92 LETMIN = 1.00E+00 LETMAX = 1.10E+05 MeV-cm2/g LBINS =
   1002
%EMINCUT = 1.00E-01 MeV/nuc
%TARGET MATERIAL = SILICON
%Input File to LETSPEC_DRIVER: Booster_50km_worst_case_worst_week.flx
%Created by CREME96:FLUX_DRIVER Version  210 on  20210318 at 120824.4
%ZMIN =  1 ZMAX = 92
%IMODE  =   2 WORST-WEEK SOLAR ENERGETIC PARTICLE MODEL
%ITRANS =   1 INSIDE MAGNETOSPHERE/NO TRAPPED FLUXES
%INPUT GEOMAGNETIC TRANSMISSION FILE: Booster_50km_worst_case.gt1
%Created by CREME96:GTRANS_DRIVER Version  210 on  20210318 at 120634.3
%Incl =  57.000 deg  Apo = 0.5000E+02 Peri = 0.5000E+02 km   0.00   0.00
   0.00
%ISTORM = 1 IPRECALC = 0  Grid Epoch = 1980.0   L Bin: 0.1602E+01 0.1709E+01
 1.0000E+00  1.1000E+05   1002      1     92  SILICON                                210
    5

 8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00
 8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00
 8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00
 8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00
 8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00
 8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00
 8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00  8.7670E+00
 8.7670E+00  8.7670E+00  8.7670E+00  8.6588E+00  7.2476E+00  5.0224E+00
 3.4655E+00  2.4476E+00  1.7633E+00  1.2896E+00  9.5834E-01  7.2363E-01
 5.5640E-01  4.3677E-01  3.5093E-01  2.8938E-01  2.4530E-01  2.1384E-01
 1.9143E-01  1.7550E-01  1.6431E-01  1.5645E-01  1.5097E-01  1.4719E-01
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 1.4126E-01  1.2918E-01  9.4673E-02  8.9177E-02  8.6825E-02  8.5462E-02
 8.4605E-02  8.4038E-02  8.3652E-02  8.3385E-02  8.3197E-02  8.3064E-02
 8.2969E-02  8.2901E-02  8.2852E-02  8.2817E-02  8.2792E-02  8.2774E-02
 8.2762E-02  8.2753E-02  8.2747E-02  8.2742E-02  8.2739E-02  8.2737E-02
```

49	8.2736E−02	8.2735E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
50	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
51	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
52	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
53	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
54	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
55	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
56	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
57	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
58	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
59	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
60	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
61	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
62	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
63	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
64	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
65	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
66	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
67	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
68	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
69	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
70	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
71	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
72	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
73	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
74	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
75	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02
76	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2734E−02	8.2469E−02
77	8.2060E−02	8.1944E−02	8.1891E−02	8.1859E−02	8.1837E−02	8.1825E−02
78	8.1818E−02	8.1814E−02	8.1812E−02	8.1810E−02	8.1809E−02	8.1808E−02
79	8.1808E−02	8.1808E−02	8.1807E−02	8.1807E−02	8.1807E−02	8.1807E−02
80	8.1807E−02	8.1807E−02	8.1807E−02	8.1807E−02	8.1807E−02	8.1807E−02
81	8.1807E−02	8.1807E−02	8.1675E−02	8.1584E−02	8.1545E−02	8.1522E−02
82	8.1510E−02	8.1504E−02	8.1502E−02	8.1501E−02	8.1500E−02	8.1500E−02
83	8.1500E−02	8.1499E−02	8.1499E−02	8.1499E−02	8.1499E−02	8.1499E−02
84	8.1499E−02	8.1499E−02	8.1499E−02	8.1499E−02	8.1499E−02	8.1499E−02
85	8.1499E−02	8.0548E−02	7.9603E−02	7.9199E−02	7.8994E−02	7.8910E−02
86	7.8880E−02	7.8866E−02	7.8857E−02	7.8852E−02	7.8848E−02	7.8845E−02
87	7.8843E−02	7.8841E−02	7.8840E−02	7.8840E−02	7.8839E−02	7.8839E−02
88	7.8839E−02	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02
89	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02
90	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02	7.8838E−02
91	7.8838E−02	7.8838E−02	7.8838E−02	7.8809E−02	7.8552E−02	7.8455E−02
92	7.8421E−02	7.8409E−02	7.8403E−02	7.8400E−02	7.8398E−02	7.8396E−02
93	7.8395E−02	7.8395E−02	7.8394E−02	7.8394E−02	7.8393E−02	7.8393E−02
94	7.8393E−02	7.8393E−02	7.8380E−02	7.8362E−02	7.8357E−02	7.8355E−02
95	7.8354E−02	7.8354E−02	7.8353E−02	7.8353E−02	7.8353E−02	7.8353E−02
96	7.8353E−02	7.8353E−02	7.8353E−02	7.8353E−02	7.8353E−02	7.8230E−02
97	7.7990E−02	7.7912E−02	7.7888E−02	7.7880E−02	7.7876E−02	7.7874E−02
98	7.7872E−02	7.7871E−02	7.7870E−02	7.7869E−02	7.7869E−02	7.7868E−02
99	7.7868E−02	7.7853E−02	7.7829E−02	7.7816E−02	7.7809E−02	7.7806E−02
100	7.7805E−02	7.7804E−02	7.7804E−02	7.7804E−02	7.7804E−02	7.7804E−02
101	7.7804E−02	7.7804E−02	7.7433E−02	7.6982E−02	7.6736E−02	7.6571E−02
102	7.6440E−02	7.6326E−02	7.6224E−02	7.6134E−02	7.6061E−02	7.6004E−02
103	7.5964E−02	7.5939E−02	7.5922E−02	7.5912E−02	7.5905E−02	7.5901E−02
104	7.5898E−02	7.5896E−02	7.5895E−02	7.5895E−02	7.5894E−02	7.5894E−02
105	7.5894E−02	7.5826E−02	7.5681E−02	7.5575E−02	7.5479E−02	7.5395E−02

106	7.5324E−02	7.5267E−02	7.5224E−02	7.5193E−02	7.5171E−02	7.5156E−02
107	7.5146E−02	7.5139E−02	7.5135E−02	7.5132E−02	7.5131E−02	7.5130E−02
108	7.5129E−02	7.5128E−02	7.5128E−02	7.5128E−02	7.5125E−02	7.5123E−02
109	7.5121E−02	7.5118E−02	7.5116E−02	7.5114E−02	7.5112E−02	7.5109E−02
110	7.5107E−02	7.5105E−02	7.5103E−02	7.5102E−02	7.5100E−02	7.5099E−02
111	7.5098E−02	7.5097E−02	7.5097E−02	7.5096E−02	7.5049E−02	7.4980E−02
112	7.4925E−02	7.4868E−02	7.4811E−02	7.4753E−02	7.4698E−02	7.4650E−02
113	7.4609E−02	7.4573E−02	7.4547E−02	7.4527E−02	7.4514E−02	7.4504E−02
114	7.4498E−02	7.4494E−02	7.4488E−02	7.4452E−02	7.4426E−02	7.4405E−02
115	7.4386E−02	7.4368E−02	7.4350E−02	7.4333E−02	7.4316E−02	7.4297E−02
116	7.4281E−02	7.4267E−02	7.4256E−02	7.4246E−02	7.4238E−02	7.4231E−02
117	7.4110E−02	7.4003E−02	7.3923E−02	7.3850E−02	7.3781E−02	7.3713E−02
118	7.3647E−02	7.3552E−02	7.3455E−02	7.3375E−02	7.3306E−02	7.3245E−02
119	7.3191E−02	7.3135E−02	6.6072E−02	5.9826E−02	5.5118E−02	5.0818E−02
120	4.6701E−02	4.2619E−02	3.8613E−02	3.4629E−02	3.0929E−02	2.7468E−02
121	2.4462E−02	2.1742E−02	1.9317E−02	1.7011E−02	1.5046E−02	1.3411E−02
122	1.1980E−02	1.0776E−02	9.7150E−03	8.7951E−03	7.9590E−03	7.2269E−03
123	6.5527E−03	5.9520E−03	5.4094E−03	4.9002E−03	4.4319E−03	4.0129E−03
124	3.6408E−03	3.2998E−03	2.9949E−03	2.7185E−03	2.4663E−03	2.2407E−03
125	2.0328E−03	1.8509E−03	1.6857E−03	1.5346E−03	1.3879E−03	1.2588E−03
126	1.1432E−03	1.0304E−03	9.3110E−04	8.4657E−04	7.6001E−04	6.8865E−04
127	6.2005E−04	5.5765E−04	5.0500E−04	4.5297E−04	4.1192E−04	3.7017E−04
128	3.3817E−04	3.0529E−04	2.8087E−04	2.5620E−04	2.3620E−04	2.1727E−04
129	2.0111E−04	1.8786E−04	1.7530E−04	1.6594E−04	1.5731E−04	1.5117E−04
130	1.4608E−04	1.4163E−04	1.3832E−04	1.3536E−04	1.3292E−04	1.3094E−04
131	1.2925E−04	1.2785E−04	1.2653E−04	1.2526E−04	1.2403E−04	1.2289E−04
132	1.2168E−04	1.2053E−04	1.1939E−04	1.1830E−04	1.1723E−04	1.1619E−04
133	1.1517E−04	1.1417E−04	1.1316E−04	1.1218E−04	1.1125E−04	1.1032E−04
134	1.0943E−04	1.0856E−04	1.0771E−04	1.0688E−04	1.0609E−04	1.0530E−04
135	1.0456E−04	1.0383E−04	1.0313E−04	1.0246E−04	1.0180E−04	1.0117E−04
136	1.0058E−04	9.9993E−05	9.9430E−05	9.8906E−05	9.8386E−05	9.7900E−05
137	9.7427E−05	9.6990E−05	9.6563E−05	9.6147E−05	9.5758E−05	9.5388E−05
138	9.5035E−05	9.4705E−05	9.4394E−05	9.4053E−05	9.3744E−05	9.3444E−05
139	9.3176E−05	9.2915E−05	9.2662E−05	9.2421E−05	9.2132E−05	9.1869E−05
140	9.1632E−05	9.1391E−05	9.1160E−05	9.0933E−05	9.0684E−05	9.0422E−05
141	9.0177E−05	8.9944E−05	8.9707E−05	8.9473E−05	8.9232E−05	8.8956E−05
142	8.8698E−05	8.8442E−05	8.8182E−05	8.7919E−05	8.7651E−05	8.7374E−05
143	8.7093E−05	8.6816E−05	8.6524E−05	8.6233E−05	8.5932E−05	8.5618E−05
144	8.5301E−05	8.4980E−05	8.4651E−05	8.4312E−05	8.3965E−05	8.3613E−05
145	8.3252E−05	8.2881E−05	8.2501E−05	8.2109E−05	8.1707E−05	8.1297E−05
146	8.0870E−05	8.0443E−05	8.0006E−05	7.9546E−05	7.9080E−05	7.8614E−05
147	7.8126E−05	7.7633E−05	7.7125E−05	7.6610E−05	7.6088E−05	7.5550E−05
148	7.5026E−05	7.4442E−05	7.3906E−05	7.3329E−05	7.2751E−05	7.2186E−05
149	7.1590E−05	7.0998E−05	7.0401E−05	6.9804E−05	6.9198E−05	6.8606E−05
150	6.7998E−05	6.7408E−05	6.6797E−05	6.6203E−05	6.5600E−05	6.5015E−05
151	6.4434E−05	6.3851E−05	6.3287E−05	6.2705E−05	6.2166E−05	6.1609E−05
152	6.1087E−05	6.0571E−05	6.0076E−05	5.9582E−05	5.9099E−05	5.8623E−05
153	5.8165E−05	5.7724E−05	5.7286E−05	5.6878E−05	5.6482E−05	5.6094E−05
154	5.5732E−05	5.5381E−05	5.5032E−05	5.4705E−05	5.4393E−05	5.4072E−05
155	5.3773E−05	5.3498E−05	5.3215E−05	5.2945E−05	5.2697E−05	5.2449E−05
156	5.2200E−05	5.1963E−05	5.1736E−05	5.1510E−05	5.1285E−05	5.1070E−05
157	5.0865E−05	5.0657E−05	5.0454E−05	5.0252E−05	5.0054E−05	4.9859E−05
158	4.9660E−05	4.9465E−05	4.9268E−05	4.9078E−05	4.8879E−05	4.8687E−05
159	4.8492E−05	4.8296E−05	4.8099E−05	4.7896E−05	4.7698E−05	4.7491E−05
160	4.7287E−05	4.7074E−05	4.6866E−05	4.6650E−05	4.6433E−05	4.6209E−05
161	4.5986E−05	4.5754E−05	4.5521E−05	4.5279E−05	4.5033E−05	4.4790E−05
162	4.4526E−05	4.4272E−05	4.4009E−05	4.3728E−05	4.3456E−05	4.3163E−05

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 4.2868E-05  4.2565E-05  4.2248E-05  4.1930E-05  4.1593E-05  4.1251E-05
 4.0889E-05  4.0522E-05  4.0127E-05  3.9725E-05  3.9300E-05  3.8849E-05
 3.8385E-05  3.7883E-05  3.7338E-05  3.6766E-05  3.6143E-05  3.5462E-05
 3.4710E-05  3.3877E-05  3.2939E-05  3.1894E-05  3.0714E-05  2.9367E-05
 2.7785E-05  2.6077E-05  2.4452E-05  2.2530E-05  2.0724E-05  1.9222E-05
 1.7459E-05  1.5816E-05  1.4462E-05  1.3234E-05  1.2120E-05  1.1064E-05
 1.0145E-05  9.3097E-06  8.4972E-06  7.8152E-06  7.1313E-06  6.5247E-06
 5.9796E-06  5.4063E-06  4.9334E-06  4.4973E-06  4.0625E-06  3.6770E-06
 3.3394E-06  3.0241E-06  2.6962E-06  2.4284E-06  2.1778E-06  1.9302E-06
 1.7127E-06  1.5214E-06  1.3352E-06  1.1853E-06  1.0429E-06  9.1569E-07
 8.0629E-07  7.0320E-07  6.2233E-07  5.4443E-07  4.8160E-07  4.2546E-07
 3.8013E-07  3.3721E-07  3.0119E-07  2.6745E-07  2.3910E-07  2.1320E-07
 1.8975E-07  1.6741E-07  1.4873E-07  1.3168E-07  1.1610E-07  1.0063E-07
 8.8020E-08  7.6375E-08  6.5344E-08  5.6031E-08  4.7504E-08  3.9560E-08
 3.2889E-08  2.6677E-08  2.1913E-08  1.7512E-08  1.3889E-08  1.0977E-08
 8.4935E-09  6.3543E-09  4.7338E-09  3.5154E-09  2.5674E-09  1.8406E-09
 1.2957E-09  8.8832E-10  5.9195E-10  3.9170E-10  2.5237E-10  1.6007E-10
 1.0003E-10  5.8494E-11  3.3128E-11  1.8683E-11  9.8686E-12  4.9447E-12
 2.3797E-12  9.4333E-13  2.8423E-13  8.5922E-14  5.6218E-15  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
```

Listing 2: 50 km worst case GCR integral LET.

```
 14 Booster_50km_worst_case_GCR_LET.LET                                 210
     5
%Created by CREME96:LETSPEC_DRIVER Version  210 on  20210318 at 121114.4
%ZMIN =  1 ZMAX = 92 LETMIN = 1.00E+00 LETMAX = 1.10E+05 MeV-cm2/g LBINS =
    1002
%EMINCUT = 1.00E-01 MeV/nuc
%TARGET MATERIAL = SILICON
%Input File to LETSPEC_DRIVER: Booster_50km_worst_case_GCR.flx
%Created by CREME96:FLUX_DRIVER Version  210 on  20210318 at 120916.8
%ZMIN =  1 ZMAX = 92
%IMODE  =   0 SOLAR-QUIET MODE: YEAR =  1977.0000
%ITRANS =   1 INSIDE MAGNETOSPHERE/NO TRAPPED FLUXES
%INPUT GEOMAGNETIC TRANSMISSION FILE: Booster_50km_worst_case.gt1
%Created by CREME96:GTRANS_DRIVER Version  210 on  20210318 at 120634.3
%Incl =  57.000 deg  Apo = 0.5000E+02 Peri = 0.5000E+02 km   0.00   0.00
    0.00
%ISTORM = 1 IPRECALC = 0  Grid Epoch = 1980.0   L Bin: 0.1602E+01 0.1709E+01
%Relative dwell time = 0.3899E-01
 1.0000E+00  1.1000E+05   1002      1     92  SILICON                   210
     5

 2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02
 2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02
 2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02
 2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02
 2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02
 2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02
 2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02  2.8661E+02
 2.8661E+02  2.8661E+02  2.8661E+02  2.8539E+02  2.6622E+02  2.2927E+02
 1.9682E+02  1.7051E+02  1.4895E+02  1.3099E+02  1.1600E+02  1.0342E+02
 9.2864E+01  8.3998E+01  7.6557E+01  7.0328E+01  6.5128E+01  6.0810E+01
 5.7231E+01  5.4271E+01  5.1850E+01  4.9870E+01  4.8261E+01  4.6965E+01
```

29	4.5923E+01	4.5092E+01	4.4437E+01	4.4204E+01	4.4204E+01	4.4204E+01
30	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
31	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
32	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
33	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
34	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
35	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
36	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
37	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
38	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
39	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
40	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
41	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
42	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
43	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
44	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01	4.4204E+01
45	4.4204E+01	3.9349E+01	2.4113E+01	1.9282E+01	1.6192E+01	1.3903E+01
46	1.2119E+01	1.0689E+01	9.5213E+00	8.5617E+00	7.7656E+00	7.1042E+00
47	6.5536E+00	6.0950E+00	5.7132E+00	5.3960E+00	5.1331E+00	4.9154E+00
48	4.7368E+00	4.5899E+00	4.4703E+00	4.3731E+00	4.2947E+00	4.2315E+00
49	4.1812E+00	4.1413E+00	4.1131E+00	4.1094E+00	4.1094E+00	4.1094E+00
50	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00
51	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00
52	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00
53	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00
54	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00
55	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00
56	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.1094E+00	4.0868E+00
57	3.9981E+00	3.9651E+00	3.9502E+00	3.9400E+00	3.9321E+00	3.9257E+00
58	3.9204E+00	3.9161E+00	3.9125E+00	3.9095E+00	3.9070E+00	3.9049E+00
59	3.9031E+00	3.9016E+00	3.9004E+00	3.8994E+00	3.8985E+00	3.8978E+00
60	3.8973E+00	3.8968E+00	3.8964E+00	3.8961E+00	3.8959E+00	3.8957E+00
61	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00
62	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00
63	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00
64	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00	3.8955E+00
65	3.8955E+00	3.8639E+00	3.8203E+00	3.8073E+00	3.8002E+00	3.7949E+00
66	3.7909E+00	3.7877E+00	3.7851E+00	3.7830E+00	3.7813E+00	3.7799E+00
67	3.7788E+00	3.7778E+00	3.7771E+00	3.7764E+00	3.7759E+00	3.7755E+00
68	3.7752E+00	3.7749E+00	3.7747E+00	3.7746E+00	3.7744E+00	3.7743E+00
69	3.7742E+00	3.7742E+00	3.7741E+00	3.7741E+00	3.7741E+00	3.7741E+00
70	3.7741E+00	3.7741E+00	3.7741E+00	3.7741E+00	3.7741E+00	3.7741E+00
71	3.7741E+00	3.7741E+00	3.7741E+00	3.7637E+00	3.6140E+00	3.5579E+00
72	3.5342E+00	3.5180E+00	3.5058E+00	3.4964E+00	3.4889E+00	3.4830E+00
73	3.4783E+00	3.4744E+00	3.4713E+00	3.4688E+00	3.4668E+00	3.4651E+00
74	3.4638E+00	3.4628E+00	3.4619E+00	3.4612E+00	3.4607E+00	3.4603E+00
75	3.4600E+00	3.4597E+00	3.4595E+00	3.4594E+00	3.4593E+00	3.4593E+00
76	3.4593E+00	3.4593E+00	3.4593E+00	3.4593E+00	3.4593E+00	3.2203E+00
77	2.8705E+00	2.7546E+00	2.6760E+00	2.6170E+00	2.5706E+00	2.5332E+00
78	2.5027E+00	2.4776E+00	2.4567E+00	2.4394E+00	2.4250E+00	2.4129E+00
79	2.4029E+00	2.3947E+00	2.3878E+00	2.3821E+00	2.3775E+00	2.3737E+00
80	2.3706E+00	2.3681E+00	2.3660E+00	2.3644E+00	2.3631E+00	2.3621E+00
81	2.3615E+00	2.3615E+00	2.2488E+00	2.1926E+00	2.1674E+00	2.1498E+00
82	2.1366E+00	2.1263E+00	2.1181E+00	2.1115E+00	2.1061E+00	2.1017E+00
83	2.0981E+00	2.0952E+00	2.0928E+00	2.0908E+00	2.0892E+00	2.0879E+00
84	2.0869E+00	2.0860E+00	2.0854E+00	2.0848E+00	2.0844E+00	2.0841E+00
85	2.0838E+00	1.7358E+00	1.4824E+00	1.3799E+00	1.3074E+00	1.2517E+00

86	1.2075E+00	1.1715E+00	1.1419E+00	1.1173E+00	1.0968E+00	1.0797E+00
87	1.0653E+00	1.0533E+00	1.0433E+00	1.0349E+00	1.0279E+00	1.0221E+00
88	1.0174E+00	1.0135E+00	1.0102E+00	1.0040E+00	9.9240E−01	9.8806E−01
89	9.8518E−01	9.8301E−01	9.8179E−01	9.8115E−01	9.8064E−01	9.8023E−01
90	9.7991E−01	9.7964E−01	9.7943E−01	9.7926E−01	9.7912E−01	9.7901E−01
91	9.7892E−01	9.7885E−01	9.7879E−01	9.6966E−01	8.9850E−01	8.7446E−01
92	8.6055E−01	8.5041E−01	8.4256E−01	8.3631E−01	8.3122E−01	8.2705E−01
93	8.2360E−01	8.2074E−01	8.1836E−01	8.1638E−01	8.1473E−01	8.1337E−01
94	8.1223E−01	8.1130E−01	8.0152E−01	7.8985E−01	7.8606E−01	7.8351E−01
95	7.8160E−01	7.8011E−01	7.7893E−01	7.7799E−01	7.7724E−01	7.7672E−01
96	7.7630E−01	7.7596E−01	7.7568E−01	7.7545E−01	7.7527E−01	7.2686E−01
97	6.5148E−01	6.2706E−01	6.1054E−01	5.9807E−01	5.8821E−01	5.8025E−01
98	5.7372E−01	5.6831E−01	5.6380E−01	5.6005E−01	5.5692E−01	5.5430E−01
99	5.5211E−01	5.3951E−01	5.2587E−01	5.2080E−01	5.1720E−01	5.1442E−01
100	5.1221E−01	5.1044E−01	5.0900E−01	5.0783E−01	5.0687E−01	5.0609E−01
101	5.0552E−01	5.0515E−01	4.4929E−01	4.0869E−01	3.9203E−01	3.8012E−01
102	3.7095E−01	3.6360E−01	3.5759E−01	3.5263E−01	3.4849E−01	3.4502E−01
103	3.4211E−01	3.3966E−01	3.3503E−01	3.3155E−01	3.2949E−01	3.2787E−01
104	3.2656E−01	3.2548E−01	3.2461E−01	3.2389E−01	3.2330E−01	3.2283E−01
105	3.2244E−01	3.1423E−01	3.0349E−01	2.9981E−01	2.9731E−01	2.9542E−01
106	2.9392E−01	2.9271E−01	2.9171E−01	2.9089E−01	2.9020E−01	2.8944E−01
107	2.8553E−01	2.8388E−01	2.8296E−01	2.8228E−01	2.8175E−01	2.8133E−01
108	2.8098E−01	2.8071E−01	2.8048E−01	2.7965E−01	2.7148E−01	2.6815E−01
109	2.6673E−01	2.6576E−01	2.6504E−01	2.6448E−01	2.6404E−01	2.6368E−01
110	2.6339E−01	2.5968E−01	2.5605E−01	2.5481E−01	2.5398E−01	2.5335E−01
111	2.5287E−01	2.5249E−01	2.5219E−01	2.5195E−01	2.4251E−01	2.3481E−01
112	2.3183E−01	2.2973E−01	2.2814E−01	2.2688E−01	2.2586E−01	2.2504E−01
113	2.2389E−01	2.2087E−01	2.1965E−01	2.1888E−01	2.1829E−01	2.1782E−01
114	2.1744E−01	2.1713E−01	2.1607E−01	2.0763E−01	2.0449E−01	2.0308E−01
115	2.0209E−01	2.0134E−01	2.0075E−01	2.0029E−01	1.9873E−01	1.9451E−01
116	1.9308E−01	1.9232E−01	1.9176E−01	1.9132E−01	1.9098E−01	1.9069E−01
117	1.8253E−01	1.7820E−01	1.7652E−01	1.7537E−01	1.7450E−01	1.7382E−01
118	1.7327E−01	1.6849E−01	1.6441E−01	1.6292E−01	1.6191E−01	1.6112E−01
119	1.6050E−01	1.5990E−01	1.0200E−01	7.1024E−02	5.8245E−02	4.9141E−02
120	4.2063E−02	3.6345E−02	3.1534E−02	2.7227E−02	2.3830E−02	2.1016E−02
121	1.8653E−02	1.6671E−02	1.4989E−02	1.0747E−02	8.1834E−03	6.5796E−03
122	5.3094E−03	4.2770E−03	3.4361E−03	2.7119E−03	2.1141E−03	1.6343E−03
123	1.2418E−03	9.2050E−04	6.8675E−04	5.4543E−04	4.3932E−04	3.6649E−04
124	3.0737E−04	2.5851E−04	2.1786E−04	1.8049E−04	1.5148E−04	1.2832E−04
125	1.0951E−04	9.4137E−05	7.7866E−05	6.1212E−05	5.6402E−05	5.3490E−05
126	5.1199E−05	4.9292E−05	4.7168E−05	4.5647E−05	4.4563E−05	4.3688E−05
127	4.2964E−05	3.9581E−05	3.6727E−05	3.5505E−05	3.4789E−05	3.4235E−05
128	3.3348E−05	3.2498E−05	3.2033E−05	3.1689E−05	3.1414E−05	2.9872E−05
129	2.8358E−05	2.7739E−05	2.7352E−05	2.7061E−05	2.6280E−05	2.5760E−05
130	2.5476E−05	2.5267E−05	2.4733E−05	2.2647E−05	2.1762E−05	2.1322E−05
131	2.1006E−05	2.0489E−05	1.9952E−05	1.9678E−05	1.9479E−05	1.9141E−05
132	1.7937E−05	1.7409E−05	1.7130E−05	1.6922E−05	1.6589E−05	1.6339E−05
133	1.6188E−05	1.6071E−05	1.5666E−05	1.5146E−05	1.4938E−05	1.4805E−05
134	1.4673E−05	1.4531E−05	1.4442E−05	1.4377E−05	1.4247E−05	1.4010E−05
135	1.3909E−05	1.3846E−05	1.3752E−05	1.3617E−05	1.3553E−05	1.3510E−05
136	1.3295E−05	1.3017E−05	1.2913E−05	1.2849E−05	1.2712E−05	1.2613E−05
137	1.2559E−05	1.2480E−05	1.2172E−05	1.2029E−05	1.1957E−05	1.1874E−05
138	1.1782E−05	1.1731E−05	1.1676E−05	1.1325E−05	1.1135E−05	1.1047E−05
139	1.0953E−05	1.0849E−05	1.0791E−05	1.0685E−05	1.0250E−05	1.0033E−05
140	9.9275E−06	9.7919E−06	9.6924E−06	9.6317E−06	9.4749E−06	9.2804E−06
141	9.1916E−06	9.1194E−06	9.0359E−06	8.9867E−06	8.8208E−06	8.3278E−06
142	8.1115E−06	7.9960E−06	7.8830E−06	7.8098E−06	7.7280E−06	7.5600E−06

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7.4740E-06  7.4142E-06  7.3458E-06  7.3031E-06  7.2293E-06  7.0996E-06
7.0417E-06  6.9993E-06  6.9615E-06  6.9361E-06  6.8131E-06  6.7114E-06
6.6653E-06  6.6147E-06  6.5817E-06  6.5268E-06  6.4118E-06  6.3598E-06
6.3122E-06  6.2693E-06  6.2311E-06  6.1073E-06  6.0360E-06  5.9746E-06
5.9043E-06  5.8480E-06  5.7389E-06  5.6537E-06  5.5687E-06  5.4795E-06
5.3708E-06  5.1914E-06  5.0327E-06  4.8480E-06  4.6761E-06  4.4471E-06
4.1695E-06  3.8914E-06  3.6085E-06  3.3238E-06  2.9966E-06  2.6674E-06
2.3640E-06  2.1037E-06  1.8731E-06  1.5971E-06  1.3868E-06  1.1986E-06
1.0439E-06  8.9469E-07  7.2660E-07  6.4722E-07  5.8162E-07  5.3835E-07
4.7452E-07  4.3710E-07  4.0548E-07  3.8076E-07  3.0398E-07  2.0661E-07
1.6181E-07  1.3200E-07  1.1147E-07  9.5485E-08  8.2435E-08  7.1695E-08
6.2787E-08  5.5373E-08  4.9204E-08  4.4103E-08  3.9974E-08  3.6548E-08
3.3793E-08  3.1530E-08  2.9803E-08  2.4768E-08  1.8889E-08  1.5880E-08
1.4122E-08  1.1337E-08  7.2386E-09  5.0405E-09  3.7350E-09  2.9959E-09
2.4477E-09  2.0091E-09  1.6465E-09  1.3454E-09  1.0939E-09  8.8428E-10
7.0953E-10  5.6435E-10  4.4382E-10  3.4416E-10  2.6199E-10  1.9456E-10
1.3949E-10  9.4711E-11  5.8598E-11  3.6624E-11  2.2632E-11  1.1388E-11
2.5699E-12  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
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0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
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0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
```

B Processed CREME96 Flux and LET Data

Listing 3: SPE differential flux in units of p+/cm^2-s-MeV as a function of energy in MeV. Note, values with zero flux are omitted.

```
3849.5909565252637 3.003865231656417e-08
3903.0902315631893 5.701865002559331e-08
3957.3330070046322 5.4135924606659315e-08
4012.3296155662606 1.5648147343824614e-07
4068.090533562524 3.308474055348483e-07
4124.626382901348 4.825486315913922e-07
```

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4181.947933107477  6.506866704115179e−07
4240.06610337394  9.99654782372272e−07
4298.991964642105  1.4062774027117063e−06
4358.736741710519  1.7963878120638725e−06
4419.311815373194  2.387786345916844e−06
4480.7287245874595  3.209953709731907e−06
4542.999168672099  3.911659844837724e−06
4606.1350095358775  4.507054484546061e−06
4670.148273937197  5.210771238950175e−06
4735.051155774997  5.852410122519354e−06
4800.856018411652  6.386732201041906e−06
4867.575397027993  6.6739994332861565e−06
4935.2220010112105  7.087181699086287e−06
5003.808716375796  7.696399346470418e−06
5073.348608218278  7.972608172574033e−06
5143.8549232059095  7.900477205247612e−06
5215.341092100118  7.746916156340143e−06
5287.820732314845  7.507652459842744e−06
5361.307650510617  7.3189055732150686e−06
5435.815845224494  7.167355143605897e−06
5511.359509536735  6.929599411582222e−06
5587.953033774356  6.7207463319715725e−06
5665.61100825243  6.411864942270624e−06
5744.348226053355  6.099716296209942e−06
5824.17968584476  5.82325614269404e−06
5905.12059473669  5.5287004154934615e−06
5987.186371178312  5.248973005617826e−06
6070.392647895075  4.983319930830273e−06
6154.755274866495  4.731238536306228e−06
6240.290322345519  4.4919748398088295e−06
6327.014083919647  4.264774859101216e−06
6414.943079614811  4.049135939358812e−06
6504.0940590421615  3.8443040983447585e−06
6594.484004588822  3.649776681234478e−06
6686.130134652754  3.4650510332033982e−06
6779.049906922799  3.2898758268392316e−06
6873.261021704094  3.123497079905116e−06
6968.78142528991  2.9654121375764774e−06
7065.629313380139  2.815369672441029e−06
7163.823134547507  2.673118357086483e−06
7263.381593751727  2.5379042092759784e−06
7364.3236559027355  2.409450768855999e−06
7466.6685494731955  2.2875821066379437e−06
7570.435770161459  2.1718709660209245e−06
7675.645084605177  2.0619906213689676e−06
7782.316534146764  1.9576897452697866e−06
7890.470438651029  1.8586667448286364e−06
8000.127400375862  1.7646451598920011e−06
8111.308307896872  1.6753736630475935e−06
8224.034340086333  1.5906260596243552e−06
8338.326970147675  1.510176154951228e−06
8454.207969705787  1.4337977543571528e−06
8571.69941295444  1.3612646631710717e−06
8690.823680861058  1.2924009522043833e−06
8811.603465430217  1.227030692268487e−06
8934.061774026108  1.1649528214335527e−06
9058.221933755356  1.1060416759934368e−06
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9184.107595910458  1.0500710612770813e−06
9311.742740475276  9.969655790607993e−07
9441.151680692832  9.465241674147615e−07
9572.359067696898  8.986462953740531e−07
9705.38989520764  8.532062992325305e−07
9840.269504292832  8.100282498015922e−07
9977.023588194927  7.690618815987813e−07
10115.67819722552  7.301563981767254e−07
10256.25974372752  6.932364013117382e−07
10398.795007106608  6.581510945564472e−07
10543.311138932282  6.248753451696242e−07
10689.835668110107  5.932583567038965e−07
10838.396506125651  5.632498636768069e−07
10989.021952361272  5.347493351234403e−07
11141.740699487027  5.077065055613392e−07
11296.581838926179  4.820208440255892e−07
11453.574866396988  4.5764208503373235e−07
11612.749687531192  4.344948303620828e−07
11774.13662357091  4.1250368178695415e−07
11937.766417144358  3.91643506567118e−07
12103.670238122208  3.718389064788879e−07
12271.879689554951  3.5303961603980655e−07
12442.426813693159  3.351702370261879e−07
12615.344098091025  3.1820563669680296e−07
12790.664481795127  3.021206823104232e−07
12968.42136161878  2.868399756433625e−07
13148.64859850402  2.7233838395439196e−07
13331.380523971564  2.585405090198256e−07
13516.651946660839  2.4547399685501494e−07
13704.498158960478  2.3305590941390522e−07
13894.954943731389  2.212686537776363e−07
14088.058581122814  2.1007453083436514e−07
14283.84585548357  1.9944840784286302e−07
14482.354062368882  1.893601255136555e−07
14683.62101564501  1.797820378313909e−07
14887.685054692352  1.7068649878071776e−07
15094.58505170861  1.6205340216865303e−07
15304.360419113784  1.5385510197984509e−07
15517.051117057608  1.460740052954339e−07
15732.69766103181  1.386849793741907e−07
15951.341129587669  1.3166791802313255e−07
16173.023172161324  1.2500774159752218e−07
16397.78601700733  1.1868434390437663e−07
16625.67247924299  1.126826452989587e−07
16856.725969003943  1.0698253958828538e−07
17090.99049971364  1.0156894712761944e−07
17328.510696467205  9.643181482046941e−08
17569.33180453234  9.155354974797518e−08
17813.499697967836  8.692409881364525e−08
18061.060888362415  8.252586909861956e−08
18312.06253369443  7.835132078052943e−08
18566.552447315302  7.438788748876055e−08
18824.579107057205  7.062551612682142e−08
19086.191664467897  6.705415359822054e−08
19351.43995417332  6.366123353234357e−08
19620.374503370906  6.044172938094475e−08
19893.04654145421  5.7383074773409726e−08
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20169.508009771867  5.448024316149275e-08
20449.81157152182  5.172569472282523e-08
20734.01062178298  4.9109376360915644e-08
21022.159297686794  4.66237482533954e-08
21314.31248872947  4.4266297126141615e-08
21610.525847228237  4.2026969882662816e-08
21910.85579892224  3.990073997471324e-08
22215.35955372141  3.788258085404716e-08
22524.095116604058  3.5967465972418824e-08
22837.121298666603  3.4147855507459615e-08
23154.497728326147  3.2418722910923793e-08
23476.284862679473  3.078006818281136e-08
23802.54399901916  2.9221838226630822e-08
24133.337286510483  2.774403304238218e-08
24468.727738029847  2.63416260818197e-08
24808.7792421685  2.500883681446076e-08
25153.55657540231  2.3743654621007082e-08
25503.125414431415  2.254256091768663e-08
25857.552348690613  2.1402288448139683e-08
26216.904893034392  2.031982128341878e-08
26581.251500597446  1.9291892167164202e-08
26950.661575834725  1.8315987825253066e-08
27325.205487741892  1.738959498356251e-08
27704.954583260303  1.6509949040557367e-08
28089.981200867736  1.5674788049527057e-08
28480.35868435799  1.4881850063760995e-08
28876.161396812553  1.412912446396088e-08
29277.46473476558  1.341434930341613e-08
29684.345142566675  1.2735765290240733e-08
30096.880126942287  1.2091613132548684e-08
30515.148271760496  1.147988221104168e-08
30939.22925299995  1.0899315888658285e-08
31369.203853927873  1.0347903546100205e-08
31805.153980487972  9.824388546306001e-09
32247.162676903234  9.327514252214239e-09
32695.31414149451  8.855772699351196e-09
33149.693742719995  8.407655923243148e-09
33610.38803543657  7.982409941653234e-09
34077.484777388156  7.57852679010773e-09
34551.072945922184  7.195252486369775e-09
35031.24275493945  6.831330393377933e-09
35518.08567207842  6.485755201483056e-09
36011.6944361395  6.1577729284482815e-09
36512.16307475026  5.846126937212175e-09
37019.58692227738  5.550565900362447e-09
37534.06263798633  5.269581853425376e-09
38055.688224454505  5.003174796400961e-09
38584.56304623956  4.750088092227767e-09
39120.78784880712  4.509819086081219e-09
39664.4647777224  4.281613795724457e-09
40215.69739810724  4.064969566332905e-09
40774.590714368904  3.859383743081989e-09
41341.25119020179  3.6641023437348477e-09
41915.78676886829  3.4788740408791935e-09
42498.30689376034  3.302944852278165e-09
43088.92252924794  3.135812123107188e-09
43687.74618181609  2.9772245259539754e-09
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44294.89192149689  2.8266794059939524e−09
44910.475403598066  2.6836741084025447e−09
45534.61389073484  2.5479573057674655e−09
46167.42627516664  2.419001210522912e−09
46809.03310144558  2.2966298934802825e−09
47459.55658937835  2.180466363521146e−09
48119.12065730856  2.0701587622683014e−09
48787.85094572127  1.965430629568232e−09
49465.87484117702  1.8660306380086507e−09
50153.321500576916  1.7716320619535848e−09
50850.321875766596  1.6820087067319752e−09
51557.0087384804  1.5969343776727636e−09
52273.51670563398  1.5161577473636629e−09
52999.982264966595  1.4394526211336143e−09
53736.54380104148  1.3666430697940175e−09
54483.34162160639  1.2975028986738132e−09
55240.51798432056  1.2318813113256297e−09
56008.217123854134  1.1695772458196368e−09
56786.58527936256  1.110414772967234e−09
57575.770722344656  1.0542430963210483e−09
58375.92378488591  1.0009114194337081e−09
59187.19688829625  9.502689458578405e−10
60009.744572143805  9.022151446285312e−10
60843.72352369419  8.565740865571786e−10
61689.2926077569  8.132452406788682e−10
62546.61289694847  7.721029432874563e−10
63415.84770237424  7.33046663418028e−10
64297.16260473853  6.959758701056684e−10
65190.72548588514  6.607648996442341e−10
66096.70656077818  6.273383538100387e−10
67015.27840992535  5.955957016381674e−10
67946.61601225386  5.654866776461627e−10
68890.89677844117  5.368856181278813e−10
69848.30058471099  5.097171248596367e−10
70819.00980709694  4.839309323589717e−10
71803.20935618442  4.594516424022001e−10
72801.08671233321  4.362038567656356e−10
73812.83196139157  4.141373099668209e−10
74838.63783090533  3.932017365232985e−10
75878.69972683015  3.7329660547015355e−10
76933.21577075552  3.544219168073861e−10
78002.38683764367  3.365022723113099e−10
79086.41659409564  3.194874064994676e−10
80185.5115371464  3.033270538894017e−10
81299.88103360188  2.879709489986548e−10
82429.73735991989  2.7339395908599813e−10
83575.29574264813  2.5957095141020305e−10
84736.77439942134  2.464441206664435e−10
85914.39458053098  2.3397828101699917e−10
87108.38061106988  2.221432731723957e−10
88318.95993366533  2.1090642456903572e−10
89546.36315180332  2.0023757591744478e−10
90790.82407375761  1.9010908120227129e−10
92052.5797571265  1.8049329440816366e−10
93331.8705539914  1.7136256951977028e−10
94628.94015670012  1.6269428706998533e−10
95944.03564428937  1.5446331431758006e−10
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97277.40752954928  1.4665205834369441e−10
98629.30980674532  1.3923287313297675e−10
100000.0  1.3220324541130424e−10
```

Listing 4: GCR differential flux in units of p+/cm^2-s-MeV as a function of energy in MeV. Note, values with zero flux are omitted.

```
3849.5909565252637  1.3643308576009754e−07
3903.0902315631893  2.657410393818534e−07
3957.3330070046322  2.5886723465579897e−07
4012.3296155662606  7.67654448089973e−07
4068.090533562524  1.664792778990303e−06
4124.626382901348  2.4904033283537008e−06
4181.947933107477  3.4440651942774185e−06
4240.06610337394  5.425530512749573e−06
4298.991964642105  7.825707300092175e−06
4358.736741710519  1.024837789083448e−05
4419.311815373194  1.3963751026675913e−05
4480.7287245874595  1.924037004764533e−05
4542.999168672099  2.4028157251716173e−05
4606.1350095358775  2.837235157310014e−05
4670.148273937197  3.360875820810361e−05
4735.051155774997  3.867300556569035e−05
4800.856018411652  4.3233341461641295e−05
4867.575397027993  4.6275659787377646e−05
4935.2220010112105  5.033082758463135e−05
5003.808716375796  5.597312799047862e−05
5073.348608218278  5.937107460460135e−05
5143.8549232059095  6.0240667451115e−05
5215.341092100118  6.047314530748064e−05
5287.820732314845  5.9991853312950683e−05
5361.307650510617  5.986241969562279e−05
5435.815845224494  5.999813649825787e−05
5511.359509536735  5.933211885569683e−05
5587.953033774356  5.888224278770278e−05
5665.61100825243  5.747732255301742e−05
5744.348226053355  5.593919878981985e−05
5824.17968584476  5.463103960886506e−05
5905.12059473669  5.305396009676299e−05
5987.186371178312  5.151709297062686e−05
6070.392647895075  5.002043823045668e−05
6154.755274866495  4.856273923919102e−05
6240.290322345519  4.7142739359768434e−05
6327.014083919647  4.576169522925036e−05
6414.943079614811  4.4415836936452495e−05
6504.0940590421615  4.310516448137483e−05
6594.484004588822  4.183093450107881e−05
6686.130134652754  4.0589377084380126e−05
6779.049906922799  3.938174886834021e−05
6873.261021704094  3.820679321589763e−05
6968.78142528991  3.706325348999094e−05
7065.629313380139  3.5952386327681594e−05
7163.823134547507  3.487042181778527e−05
7263.381593751727  3.3818616597363405e−05
7364.3236559027355  3.279571402935457e−05
7466.6685494731955  3.180171411375876e−05
7570.435770161459  3.08341035764531e−05
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7675.645084605177  2.9895395691560468e−05
7782.316534146764  2.898182054789656e−05
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45534.61389073484  3.51305456895025e−07
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Listing 5: SPE integral LET flux in units of #/cm^2-s as a function of LET in units of MeV-cm^2/mg. Note, values with zero LET are omitted.

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25.221762473591717  1.0453461059260821e−07
25.51595265984783  1.0367507084258605e−07
25.813574321829726  1.0276526561010644e−07
26.114667484753074  1.0184289400701249e−07
26.419272640693364  1.008501507284781e−07
26.72743075403119  9.983981453108364e−08
27.03918326696159  9.87716730288631e−08
27.354572105067156  9.76381863994479e−08
27.67363968295643  9.647202720643536e−08
27.996428909967744  9.521036359675371e−08
28.322983195940157  9.384062919978855e−08
28.653346457051203  9.240303640150587e−08
28.98756312172272  9.083726662295671e−08
29.325678136596064  8.9125726945281e−08
29.667736972576513  8.723574480488137e−08
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34.89742709279601  3.634697036497247e−08
35.30447559256046  3.326066974208586e−08
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36.98070533703408  2.3397828101699918e−08
37.41205348736163  2.1355792876866552e−08
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38.28990239042371  1.7922911752435913e−08
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47.17790734881422  2.6210935827430363e−09
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48.284905504606854  2.0264277925303313e−09
48.848107436217795  1.767334363203474e−09
49.41787863440305  1.5640858848868288e−09
49.994295724012055  1.368301830715113e−09
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54.22192714154886  6.009238427786557e−10
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64.52385313783347  6.704661377585193e-11
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69.98013699493397  1.189733704285069e-11
70.79639515922064  8.835163851543647e-12
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73.30274086269873  3.256449281005036e-12
74.15775434599756  2.232591668829508e-12
75.02274082686823  1.4877326170339824e-12
75.89781663175737  9.844494739288976e-13
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77.67870831944572  4.022997888480945e-13
78.58476370286961  2.514028105108696e-13
79.50138744376981  1.4701145654326 51e-13
80.42870281295511  8.325974514249813e-14
81.36683451908213  4.6955500437614483e-14
82.31590872542702  2.4802497008972987e-14
83.27605306685165  1.242738655536436e-14
84.24739666696932  5.980838430198105e-15
85.23007015550937  2.3708468783286874e-15
86.22420568588417  7.143479039438615e-16
87.22993695296257  2.1594553918539376e-16
88.24739921104906  1.4129124463960878e-17
```

Listing 6: GCR integral LET flux in units of #/cm^2-s as a function of LET in units of MeV-cm^2/mg. Note, values with zero LET are omitted.

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0.001  0.36016474817814825
0.001011664140702465  0.36016474817814825
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0.0010474792421170211  0.36016474817814825
0.0010596971873799857  0.36016474817814825
0.0010720576444755924  0.36016474817814825
0.0010845622756819092  0.36016474817814825
0.0010972127626660488  0.36016474817814825
0.0011100108067103262  0.36016474817814825
0.0011229581289410524  0.36016474817814825
0.0011360564705599977  0.36016474817814825
0.0011493075930785557  0.36016474817814825
0.0011627132785546356  0.36016474817814825
0.0011762753298323217  0.36016474817814825
0.0011899955707843244  0.36016474817814825
0.0012038758465572632  0.36016474817814825
0.0012179180238198067  0.36016474817814825
0.0012321239910137091  0.36016474817814825
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0.0013056783277806303  0.36016474817814825
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0.0013363151996161047  0.36016474817814825
0.0013519021681272698  0.36016474817814825
0.001367670945232274  0.36016474817814825
0.001383623651572137  0.36016474817814825
0.0013997624325233328  0.36016474817814825
0.00141608945848631  0.36016474817814825
0.0014326069251773721  0.36016474817814825
0.0014493170539239672  0.36016474817814825
0.0014662220919634185  0.36016474817814825
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0.0015006260162363897  0.36016474817814825
0.001518129529231551  0.36016474817814825
0.001535837205665075  0.36016474817814825
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0.0015718746021883782  0.36016474817814825
0.001590209168714935  0.36016474817814825
0.0016087575922051761  0.36016474817814825
0.0016275223671168165  0.36016474817814825
0.0016465060170032762  0.36016474817814825
0.001665711094853058  0.36016474817814825
0.0016851401834330816  0.3586316509631964
0.001704795895636023  0.33454191849546994
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0.0017447977952225946  0.24733130643181722
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0.0017857383127250295  0.18717609030087987
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0.002052362602066165  0.06515663163545231
0.0020763016482291423  0.06266849025380919
0.0021005199227948474  0.06064656122195881
0.0021250206827226575  0.05901795959033786
0.0021498072229615833  0.05770854377232163
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1.310703827177994  2.0949396451198173e-05
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1.438120967254931  3.4078740469080643e-06
1.454895412564157  2.6566564115816722e-06
1.4718655173636774  2.0537219495047196e-06
1.4890335638533132  1.5604919028911218e-06
1.506401860852792  1.1567344150517618e-06
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1.6337866302979671  2.737709502044289e-07
1.6528433474315682  2.268104232185687e-07
1.6721223447951443  1.9035538206631275e-07
1.69162621509657  1.6125166772345688e-07
1.7113575812854358  1.376143245978473e-07
1.7313190969057788  1.1829604305239293e-07
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1.7719433457346414  7.692126780461536e-08
```

```
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1.8777233796716797  5.927305691380934e−08
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1.921782907429377  5.599951736876878e−08
1.944198853661227  5.489995994001235e−08
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```

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12.577492055177073  1.0359087615946984e−10
12.724197692192789  9.009459411964808e−11
12.872614524400527  7.890047117637694e−11
```

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17.40251548500365  5.577206606064888e-13
17.605500874197553  4.3248421106378524e-13
17.810853913531556  3.2922634372559596e-13
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18.441396712794997  1.1901735272565715e-13
18.656499758803008  7.363641852602188e-14
18.874111797005227  4.6023075738029035e-14
19.09426209263954  2.844020997441768e-14
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19.542296227907357  3.229431584184164e-15
```

C Python Conversion Scripts

Listing 7: Python routine to plot processed raw CREME96 output.

```
import sys
import numpy as np
from numpy import vectorize # https://stackoverflow.com/questions/8036878/function-of-numpy-array-with-if-statement
import matplotlib.pyplot as plt

# python .\plot_CREME96.py 4 FLUX SPE_FLUX_COMPARISON .\200km_SPE_flux.txt .\SPE_flux_worst-case.txt .\SPE_flux_45.04km.txt .\SPE_flux_47.65km.txt
# python .\plot_CREME96.py 4 FLUX GCR_FLUX_COMPARISON .\200km_GCR_flux.txt .\GCR_flux_worst-case.txt .\GCR_flux_45.04km.txt .\GCR_flux_47.65km.txt
# python .\plot_CREME96.py 8 FLUX FLUX_COMPARISON .\200km_SPE_flux.txt .\SPE_flux_worst-case.txt .\SPE_flux_45.04km.txt .\SPE_flux_47.65km.txt .\200km_GCR_flux.txt .\GCR_flux_worst-case.txt .\GCR_flux_45.04km.txt .\GCR_flux_47.65km.txt
```

```
9
10  # python .\plot_CREME96.py 4 LET SPE_LET_COMPARISON .\200km_SPE_LET.txt .\
        SPE_LET_worst-case.txt .\SPE_LET_45.04km.txt .\SPE_LET_47.65km.txt
11  # python .\plot_CREME96.py 4 LET GCR_LET_COMPARISON .\200km_GCR_LET.txt .\
        GCR_LET_worst-case.txt .\GCR_LET_45.04km.txt .\GCR_LET_47.65km.txt
12  # python .\plot_CREME96.py 8 LET LET_COMPARISON .\200km_SPE_LET.txt .\
        SPE_LET_worst-case.txt .\SPE_LET_45.04km.txt .\SPE_LET_47.65km.txt .\200
        km_GCR_LET.txt .\GCR_LET_worst-case.txt .\GCR_LET_45.04km.txt .\
        GCR_LET_47.65km.txt
13
14  # python .\plot_CREME96.py 4 FLUX_INT SPE_FLUX_INT_COMPARISON .\200
        km_SPE_flux_integral.txt .\SPE_flux_worst-case_integral.txt .\SPE_flux_45
        .04km_integral.txt .\SPE_flux_47.65km_integral.txt
15  # python .\plot_CREME96.py 4 FLUX_INT GCR_FLUX_INT_COMPARISON .\200
        km_GCR_flux_integral.txt .\GCR_flux_worst-case_integral.txt .\GCR_flux_45
        .04km_integral.txt .\GCR_flux_47.65km_integral.txt
16  # python .\plot_CREME96.py 8 FLUX_INT FLUX_INT_COMPARISON .\200
        km_SPE_flux_integral.txt .\SPE_flux_worst-case_integral.txt .\SPE_flux_45
        .04km_integral.txt .\SPE_flux_47.65km_integral.txt .\200
        km_GCR_flux_integral.txt .\GCR_flux_worst-case_integral.txt .\GCR_flux_45
        .04km_integral.txt .\GCR_flux_47.65km_integral.txt
17
18  Nfiles = int(sys.argv[1])
19  plotType = sys.argv[2] # options are [FLUX, FLUX_INT, LET]
20  plotTitle = sys.argv[3]
21
22  xLabel = ''
23  yLabel = ''
24
25  xmin = 0.0
26  xmax = 1.0
27
28  # convert from CREAM96 units to DSNE units
29  if plotType == 'FLUX':
30          xLabel = 'Energy (MeV)'
31          yLabel = 'Differential Flux (p+/cm2-s-MeV)'
32          xmin   = 1.E3
33          xmax   = 1.E5
34
35  if plotType == 'FLUX_INT':
36          xLabel = 'Energy (MeV)'
37          yLabel = 'Integral Flux (p+/cm2-s)'
38          xmin   = 1.E3
39          xmax   = 1.E5
40
41  if plotType == 'LET':
42          xLabel = 'LET (MeV-cm2/mg)'
43          yLabel = 'Integral Flux (#/cm2-s)'
44          xmin   = 1.E0
45          xmax   = 1.E2
46
47
48  for i in range(0, Nfiles):
49
50          filename = sys.argv[4 + i]
51
52          x,y = np.loadtxt(filename, unpack=True)
```

```

        data_masked = np.ma.masked_where(y == 0.0, y)

        #print(data_masked)

        #print(np.shape(E), np.shape(data))

        plt.loglog(x, data_masked, label=filename)
        plt.grid(b=True, which='both') # https://stackoverflow.com/questions/9127434/how-to-create-major-and-minor-gridlines-with-different-linestyles-in-python
## plt.xscale('symlog')
## plt.yscale('symlog')

plt.title(plotTitle)
plt.xlabel(xLabel)
plt.ylabel(yLabel)
plt.xlim(xmin, xmax)
plt.legend()
plt.savefig(plotTitle + ".png", dpi=800)
plt.show()
```

Listing 8: Python routine to read raw CREME96 output and save as processed output.

```
import sys
import numpy as np
from numpy import vectorize # https://stackoverflow.com/questions/8036878/function-of-numpy-array-with-if-statement
import matplotlib.pyplot as plt

# python .\read_CREME96_flx.py 1 1 SPE_FLUX .\3_2_13_200km_SPE_worst_week.flx 12 > 200km_SPE_flux.txt
# python .\read_CREME96_flx.py 1 1 GCR_FLUX .\3_2_13_200km_GCR.flx 12 > 200km_GCR_flux.txt
# python .\read_CREME96_flx.py 1 1 SPE_LET .\3_2_13_200km_SPE_worst_week_with_heavies_LET.let 17 > 200km_SPE_LET.txt
# python .\read_CREME96_flx.py 1 1 GCR_LET .\3_2_13_200km_GCR_with_heavies_LET.let 17 > 200km_GCR_LET.txt

# python .\read_CREME96_flx.py 3 0 SPE_FLUX .\Booster_45_04km_SPE_worst_week.flx 12 .\Booster_47_65km_SPE_worst_week.flx 12 .\3_2_13_200km_SPE_worst_week.flx 12
# python .\read_CREME96_flx.py 3 0 GCR_FLUX .\Booster_45_04km_GCR.flx 12 .\Booster_47_65km_GCR.flx 12 .\3_2_13_200km_GCR.flx 12

### 3/18/2021

# python .\read_CREME96_flx.py 1 1 SPE_FLUX .\Booster_50km_worst_case_SPE_worst_week.flx 12 > SPE_flux_worst-case.txt
# python .\read_CREME96_flx.py 1 1 GCR_FLUX .\Booster_50km_worst_case_GCR.flx 12 > GCR_flux_worst-case.txt
# python .\read_CREME96_flx.py 1 1 SPE_LET .\Booster_50km_worst_case_SPE_worst_week_LET.let 17 > SPE_LET_worst-case.txt
# python .\read_CREME96_flx.py 1 1 GCR_LET .\Booster_50km_worst_case_GCR_LET.let 17 > GCR_LET_worst-case.txt

```

```
21 # python .\read_CREME96_flx.py 4 0 SPE_FLUX .\
       Booster_50km_worst_case_SPE_worst_week.flx 12 .\3
       _2_13_200km_SPE_worst_week.flx 12 .\Booster_45_04km_SPE_worst_week.flx 12
        .\Booster_47_65km_SPE_worst_week.flx 12
22 # python .\read_CREME96_flx.py 4 0 GCR_FLUX .\Booster_50km_worst_case_GCR.flx
       12 .\3_2_13_200km_GCR.flx 12 .\Booster_45_04km_GCR.flx 12 .\
       Booster_47_65km_GCR.flx 12
23 # python .\read_CREME96_flx.py 4 0 SPE_LET  .\
       Booster_50km_worst_case_SPE_worst_week_LET.let 17 .\3
       _2_13_200km_SPE_worst_week_with_heavies_LET.let 17
       Booster_47_65km_SPE_worst_week_LET.let 17
       Booster_45_04km_SPE_worst_week_LET.let 17
24 # python .\read_CREME96_flx.py 4 0 GCR_LET  .\Booster_50km_worst_case_GCR_LET.
       let 17 .\3_2_13_200km_GCR_with_heavies_LET.let 17 Booster_47_65km_GCR_LET
       .let 17 Booster_45_04km_GCR_LET.let 17
25
26 Nfiles = int(sys.argv[1])
27 toPrint = int(sys.argv[2])
28 plotType = sys.argv[3] # options are [SPE_FLUX, GCR_FLUX, SPE_LET, GCR_LET]
29
30 xScale = 1.
31 yScale = 1.
32
33 xLabel = ''
34 yLabel = ''
35
36 # convert from CREAM96 units to DSNE units
37 if plotType == 'SPE_FLUX':
38         xScale = 1. # MeV
39         yScale = 4.*np.pi/100.**2 * 2. # convert from p+/m2-s-sr-MeV to p+/cm2
       -s-MeV (2x)
40         xLabel = 'Energy (MeV)'
41         yLabel = 'Differential Flux (p+/cm2-s-MeV) (2x)'
42
43 if plotType == 'GCR_FLUX':
44         xScale == 1. # MeV
45         yScale = 4.*np.pi/100.**2 # convert from p+/m2-s-sr-MeV to p+/cm2-s-
       MeV
46         xLabel = 'Energy (MeV)'
47         yLabel = 'Differential Flux (p+/cm2-s-MeV)'
48
49 if plotType == 'SPE_LET':
50         xScale = 1.E-3 # MeV-cm2/g to MeV-cm2/mg
51         yScale = 4.*np.pi/100.**2 * 2. # convert from #/m2-s-sr to #/cm2-s (x2
       )
52         xLabel = 'LET (MeV-cm2/mg)'
53         yLabel = 'Integral Flux (#/cm2-s) (x2)'
54
55 if plotType == 'GCR_LET':
56         xScale = 1.E-3 # MeV-cm2/g to MeV-cm2/mg
57         yScale = 4.*np.pi/100.**2 # convert from #/m2-s-sr to #/cm2-s
58         xLabel = 'LET (MeV-cm2/mg)'
59         yLabel = 'Integral Flux (#/cm2-s)'
60
61
62 for i in range(0, Nfiles):
63
```

```
        filename = sys.argv[4 + i*2]
        Nheader = int(sys.argv[5 + i*2])

        line = np.loadtxt(filename, skiprows = Nheader-2, max_rows = 1,
    usecols = (0,1,2))

        Emin = line[0]
        Emax = line[1]
        N_E  = int(line[2])

        E = np.logspace(np.log10(Emin), np.log10(Emax), N_E) * xScale

        #print(Emin, Emax, N_E)

        data = np.loadtxt(filename, skiprows = Nheader, max_rows = int(N_E/6))

        data = data.flatten() * yScale



        data_masked = np.ma.masked_where(data == 0.0, data)

        #print(data_masked)

        #print(np.shape(E), np.shape(data))
        if toPrint == 1:
                for i in range(0,N_E):
                        print(E[i], data[i])
        if toPrint == 0:
                plt.loglog(E, data_masked, label=filename)
                plt.grid(b=True, which='both') # https://stackoverflow.com/
    questions/9127434/how-to-create-major-and-minor-gridlines-with-different-
    linestyles-in-python
## plt.xscale('symlog')
## plt.yscale('symlog')
if toPrint == 0:
        plt.xlabel(xLabel)
        plt.ylabel(yLabel)
        plt.legend()
        plt.show()
```

Listing 9: Python routine to read processed CREME96 differential flux output and save as processed integral flux output.

```
import sys
import numpy as np
import matplotlib.pyplot as plt

# python .\convert_differential_to_integral_flux.py .\200km_SPE_flux.txt > 200
    km_SPE_flux_integral.txt
# python .\convert_differential_to_integral_flux.py .\SPE_flux_worst-case.txt
    > SPE_flux_worst-case_integral.txt
# python .\convert_differential_to_integral_flux.py .\SPE_flux_45.04km.txt >
    SPE_flux_45.04km_integral.txt
# python .\convert_differential_to_integral_flux.py .\SPE_flux_47.65km.txt >
    SPE_flux_47.65km_integral.txt

```

```
# python .\convert_differential_to_integral_flux.py .\200km_GCR_flux.txt > 200km_GCR_flux_integral.txt
# python .\convert_differential_to_integral_flux.py .\GCR_flux_worst-case.txt > GCR_flux_worst-case_integral.txt
# python .\convert_differential_to_integral_flux.py .\GCR_flux_45.04km.txt > GCR_flux_45.04km_integral.txt
# python .\convert_differential_to_integral_flux.py .\GCR_flux_47.65km.txt > GCR_flux_47.65km_integral.txt

filename = sys.argv[1]

x,y = np.loadtxt(filename, unpack=True)

N = x.shape[0]

yint = np.zeros(N-1)

for i in range(0, N-1):
        if y[i] > 0. and y[i+1] > 0:
                bi = np.log(y[i+1] / y[i]) / np.log(x[i+1] / x[i])

                yint[i] = y[i] * x[i] / (bi + 1.) * ((x[i+1] / x[i])**(bi + 1.) - 1.)

        if i > 0:
                yint[i] = yint[i] + yint[i-1]

yint = yint[-1] - yint # to make an integral flux > x, not < x

for i in range(0, N-1):
        print(x[i], yint[i])
```

Listing 10: Python routine to sample data at a different resolution with logarithmically spaced abscissa.

```
import sys
import numpy as np
from numpy import vectorize # https://stackoverflow.com/questions/8036878/function-of-numpy-array-with-if-statement
import matplotlib.pyplot as plt


# python .\convert_lower_res_data.py SPE_LET_worst-case.txt 1. 87. 50 > SPE_LET_low-res.txt
# python .\convert_lower_res_data.py GCR_LET_worst-case.txt 1. 87. 50 > GCR_LET_low-res.txt

# python .\convert_lower_res_data.py SPE_flux_worst-case.txt 3900. 1.E5 50 > SPE_flux_low-res.txt
# python .\convert_lower_res_data.py GCR_flux_worst-case.txt 3900. 1.E5 50 > GCR_flux_low-res.txt

# python .\convert_lower_res_data.py SPE_flux_worst-case_integral.txt 3500. 9.5E4 50 > SPE_flux_integral_low-res.txt
# python .\convert_lower_res_data.py GCR_flux_worst-case_integral.txt 3500. 9.5E4 50 > GCR_flux_integral_low-res.txt

```

```
16 def y_power_law(x0, x1, y0, y1, x):
17         return y0 * (x/x0)**(np.log(y1/y0) / np.log(x1/x0))
18
19
20 def get_y(x_vec, y_vec, x):
21         i = 0
22
23         while i < x_vec.size and x > x_vec[i]:
24                 i = i + 1
25
26         i = i - 1
27         if i < 0 or i > x_vec.size - 2:
28                 return 0.
29         else:
30                 return y_power_law(x_vec[i], x_vec[i+1], y_vec[i], y_vec[i+1],
       x)
31
32 vget_y = vectorize(get_y)
33
34
35 filename = sys.argv[1]
36 xmin = float(sys.argv[2])
37 xmax = float(sys.argv[3])
38 Nx   = int(sys.argv[4])
39
40
41 x_data, y_data = np.loadtxt(filename, unpack=True)
42
43 x_low_res = np.logspace(np.log10(xmin), np.log10(xmax), Nx)
44
45 #y_low_res = vget_y(x_data, y_data, x_low_res)
46
47 for i in range(0, Nx):
48         y_low_res = get_y(x_data, y_data, x_low_res[i])
49         print(x_low_res[i], y_low_res)
```