Probabilistic Modeling for Solar Energetic Particle Events

Fifth Gait Technologies, The Next Step

Space Environment Engineering and Science Applications Workshop (SEESAW)

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Overview

- New data base of Solar Energetic Particle (SEP) episodes for protons and helium
- Short and Long mission approaches for probabilistic modeling
- Examples of the peak flux and episode-integrated fluence probabilistic models

Data base of SEP Episodes

- An episode is one or more events that overlap.
  - Flux doesn't return to background in between events
- Episode-Integrated Fluence Proton Data base
  - GME on IMP-8 and EPS on GOES
  - Normalized using isotropic periods of flux and Rodriguez et al. [2014]
  - Redistributed the GOES fluence in GME channels

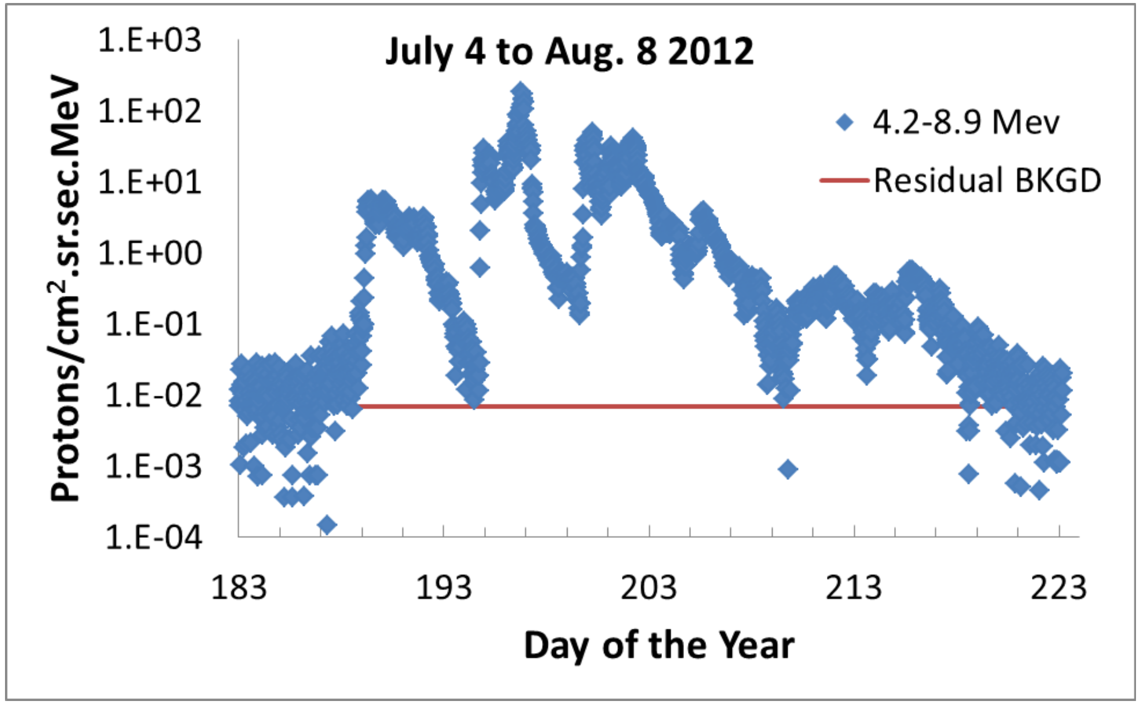

Image from [Robinson, 2015]

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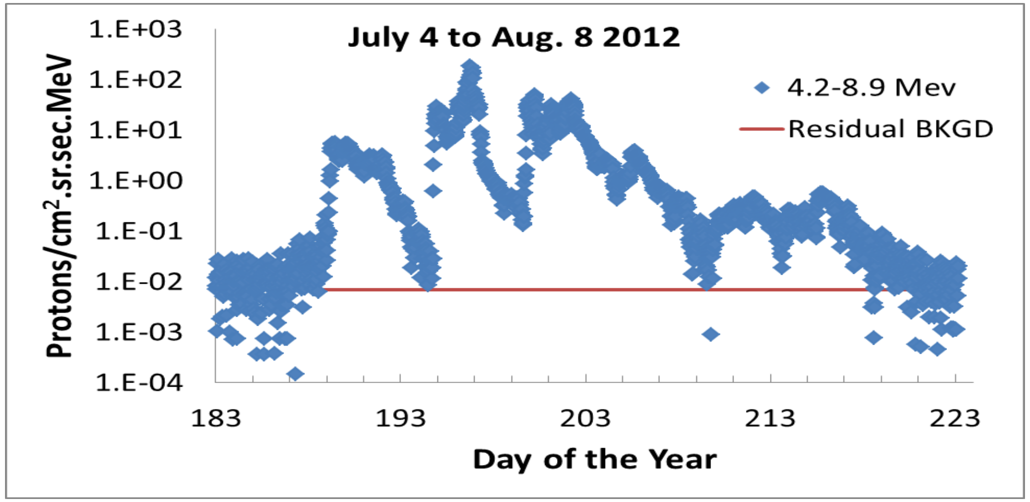
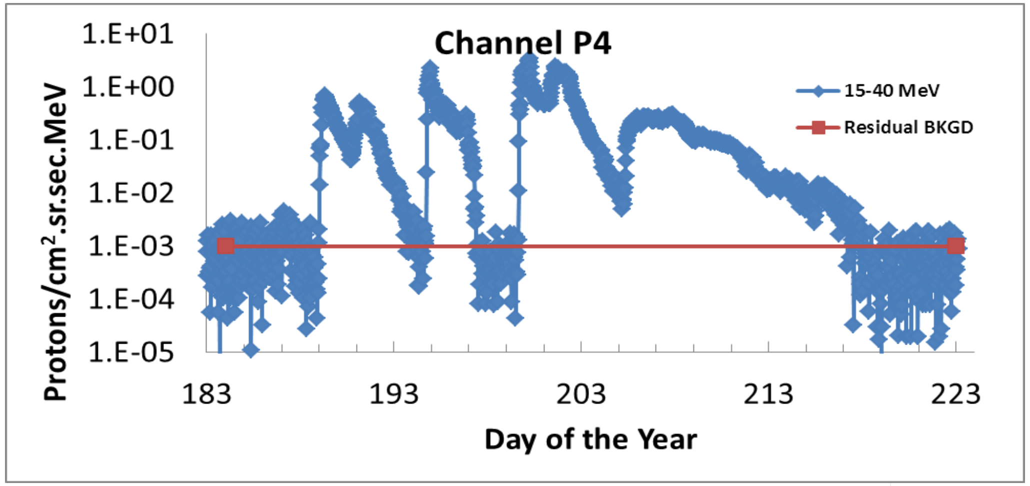
Data Base of SEP Peak Fluxes

- Peak Flux Data Base
  - Proton
    - EPS on GOES
    - Normalized using periods of isotropic flux and Rodriguez et al. [2014]
  - Helium
    - Solar Energetic Particle Environment Modeling (SEPEM) system [Crosby et al., 2015]





Images from [Robinson, 2015]

Probabilistic Modeling

For long missions: [Xapsos et al., 1998]

The probability of no event with a flux $\geq \phi$ occuring in T years:

$$F_T(M) = \sum_n \frac{(\mu T)^n}{n!} \exp(-\mu T)\,[P(M)]^n$$

Where $M = \log(\phi)$

This can be simplified to :

$$F_T(M) = exp\{-\mu T[1 - P(M)]\}$$

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Long Missions: [Xapsos et al., 1998]

$$F_T(M) = exp\{-\mu T[1 - P(M)]\}$$

- Cumulative distributions built from data bases.
- Episodes per year
- User-specified mission start date, duration, and confidence level

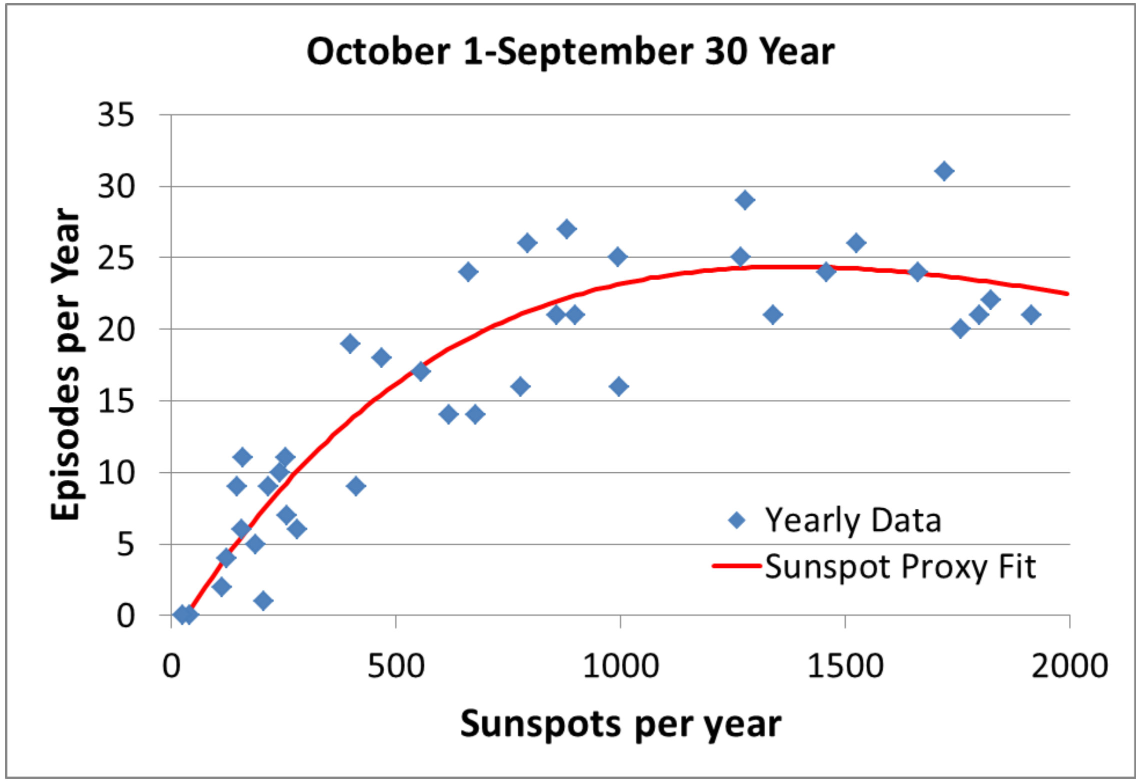

Image from [Robinson, 2015]

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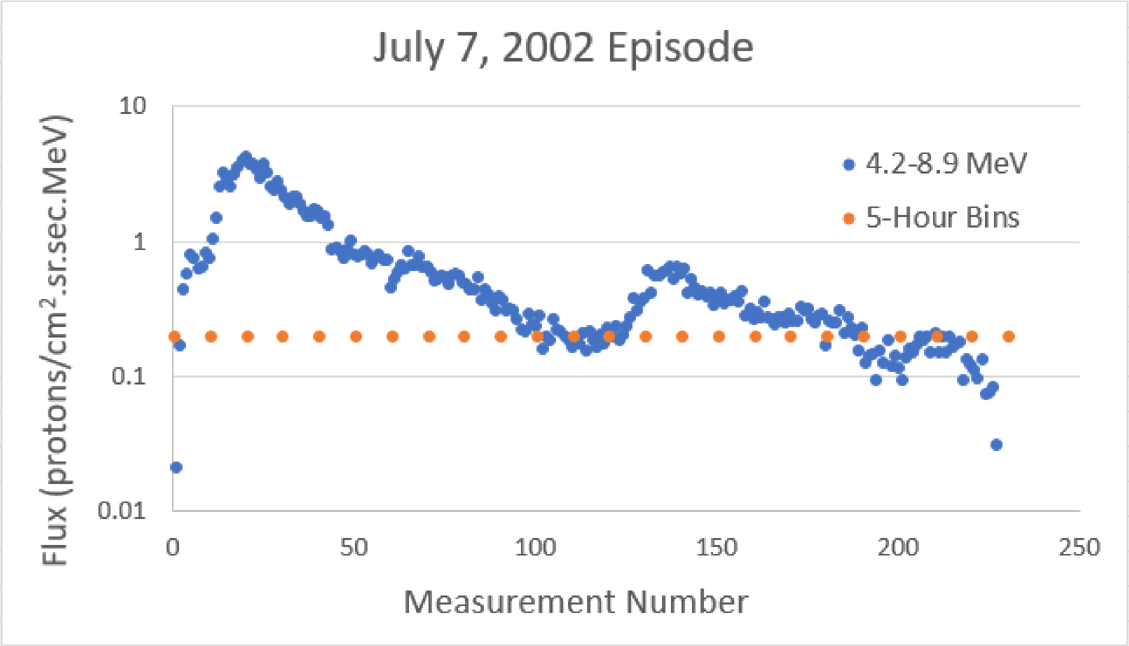

Short Mission:

- Chronological list of flux measurements
  - Remove measurement at BKGD
- Mission length used to group data
  - Maximum flux taken to build a custom cumulative distribution
- Confidence Level used to determine if flux is above BKGD

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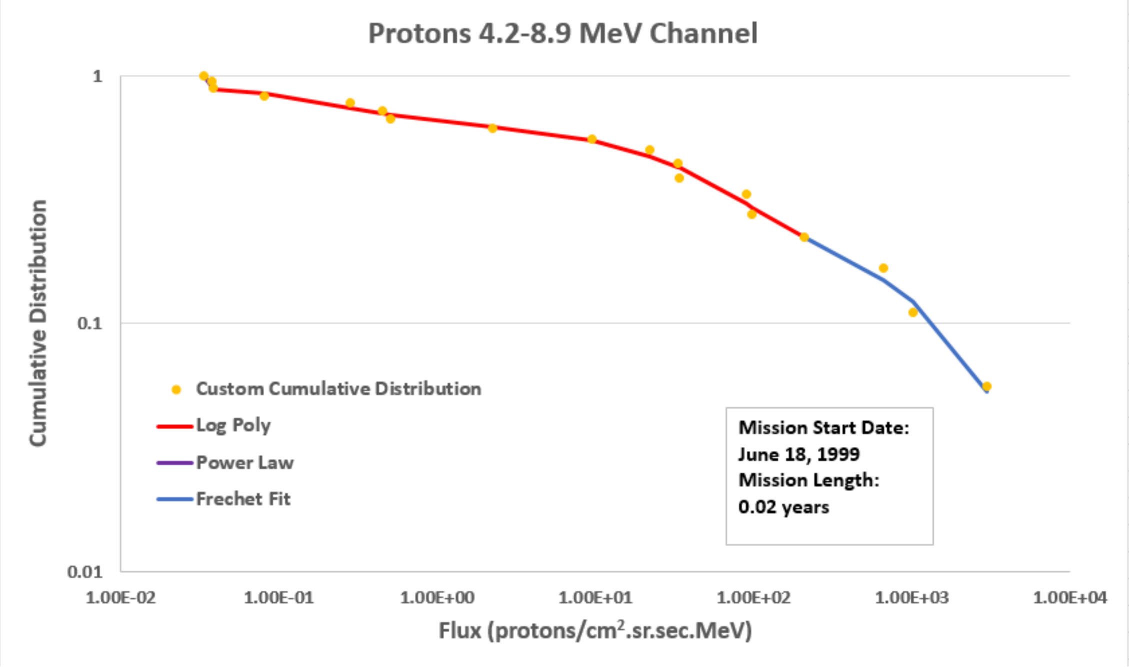
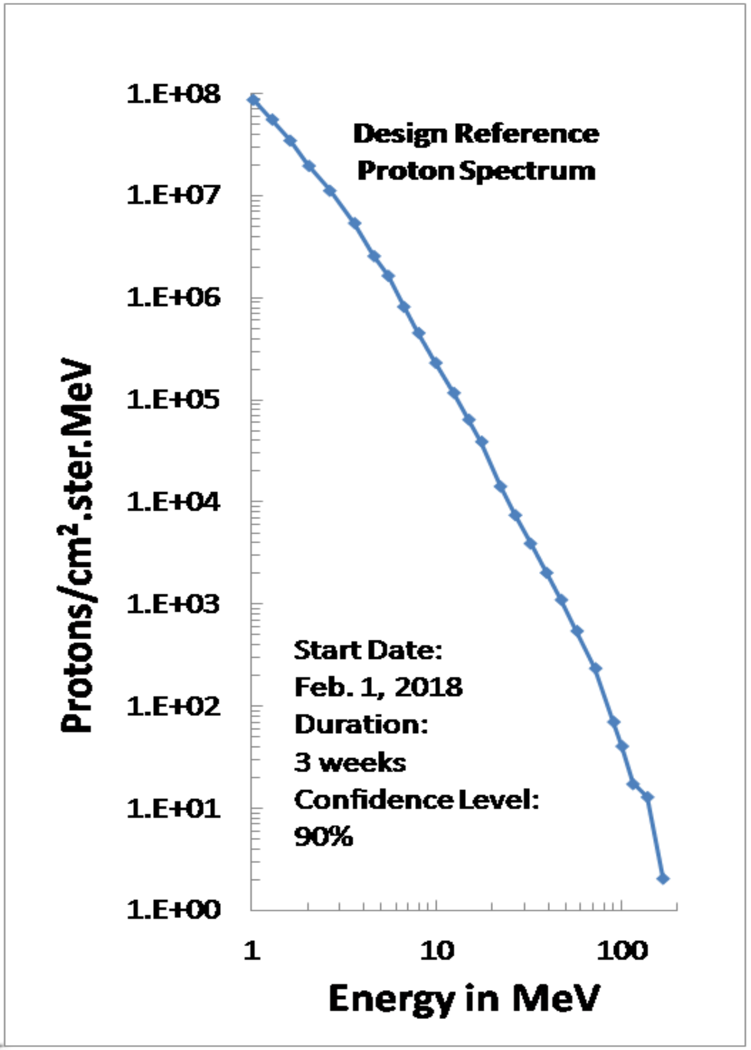
Probabilistic Modeling

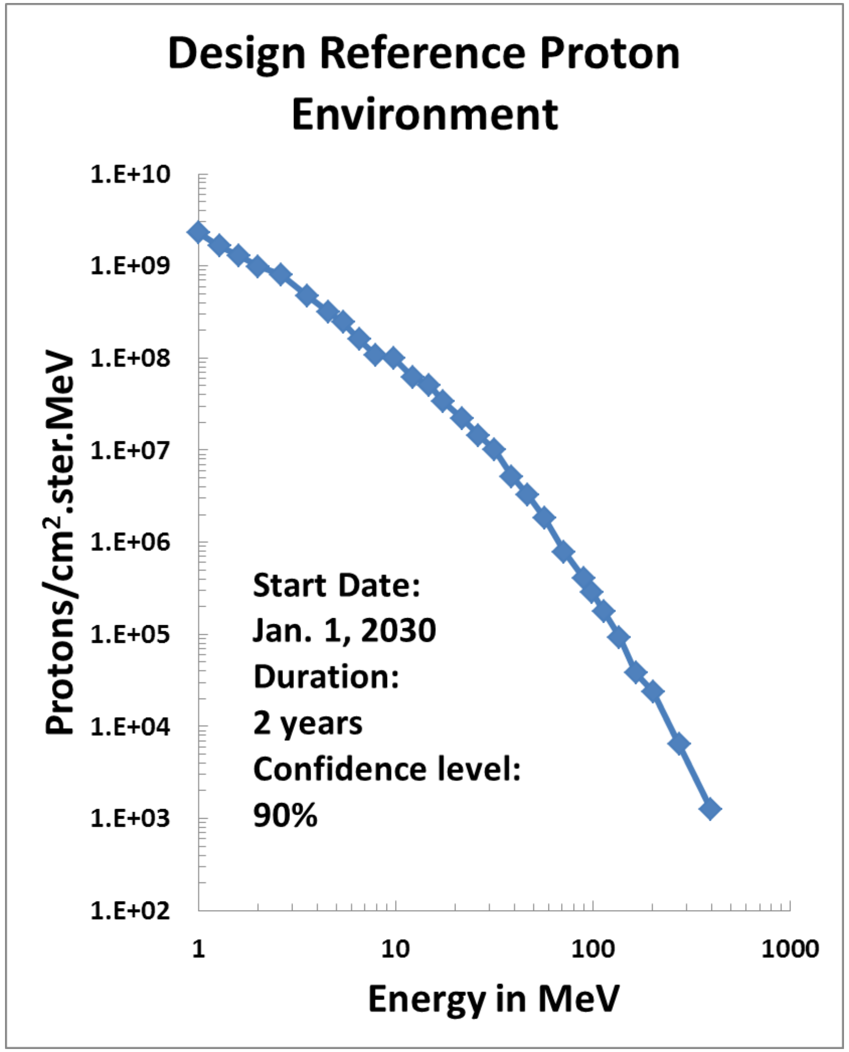


Short Mission:

- If under 1000 groups, use 3 fits [Robinson, 2015]:
  - Power Law
  - Logarithmic Polynomial
  - Fréchet Distribution
- If over 1000 groups, use the custom distribution
- Linear interpolation used between values in distribution

Episode-Integrated Fluence Model





Images from
[Robinson, 2015]

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Peak Flux Model

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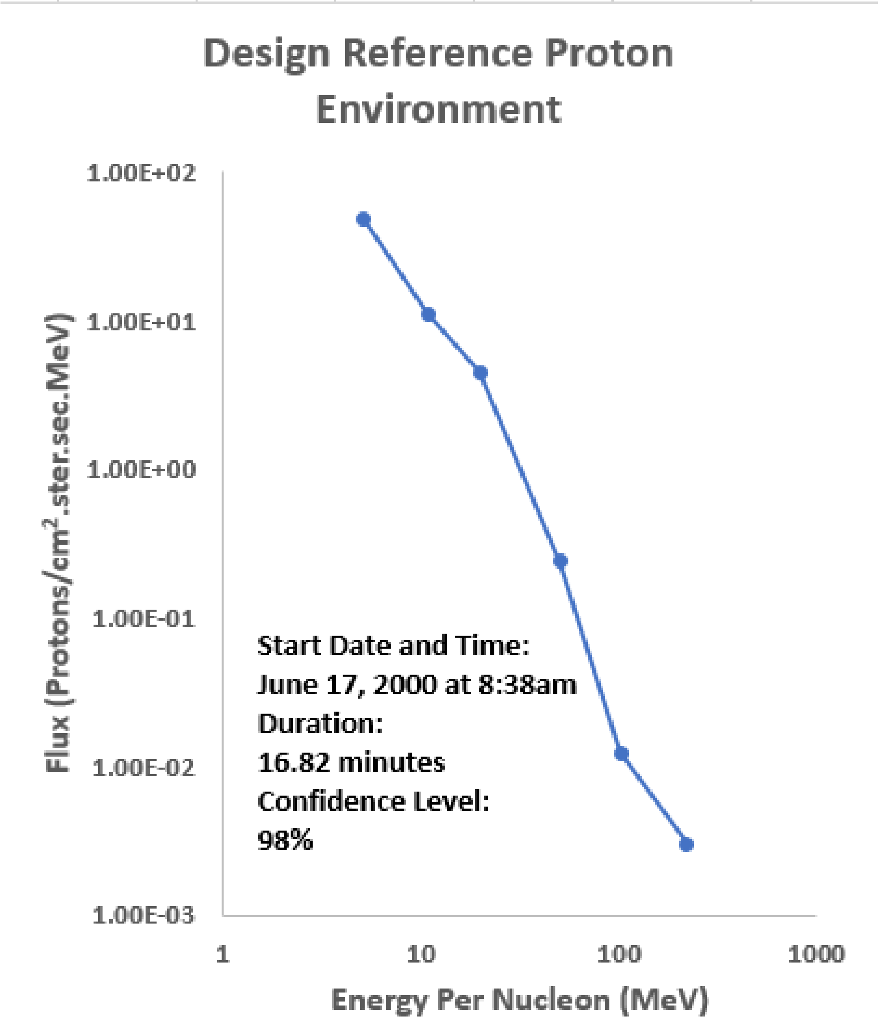

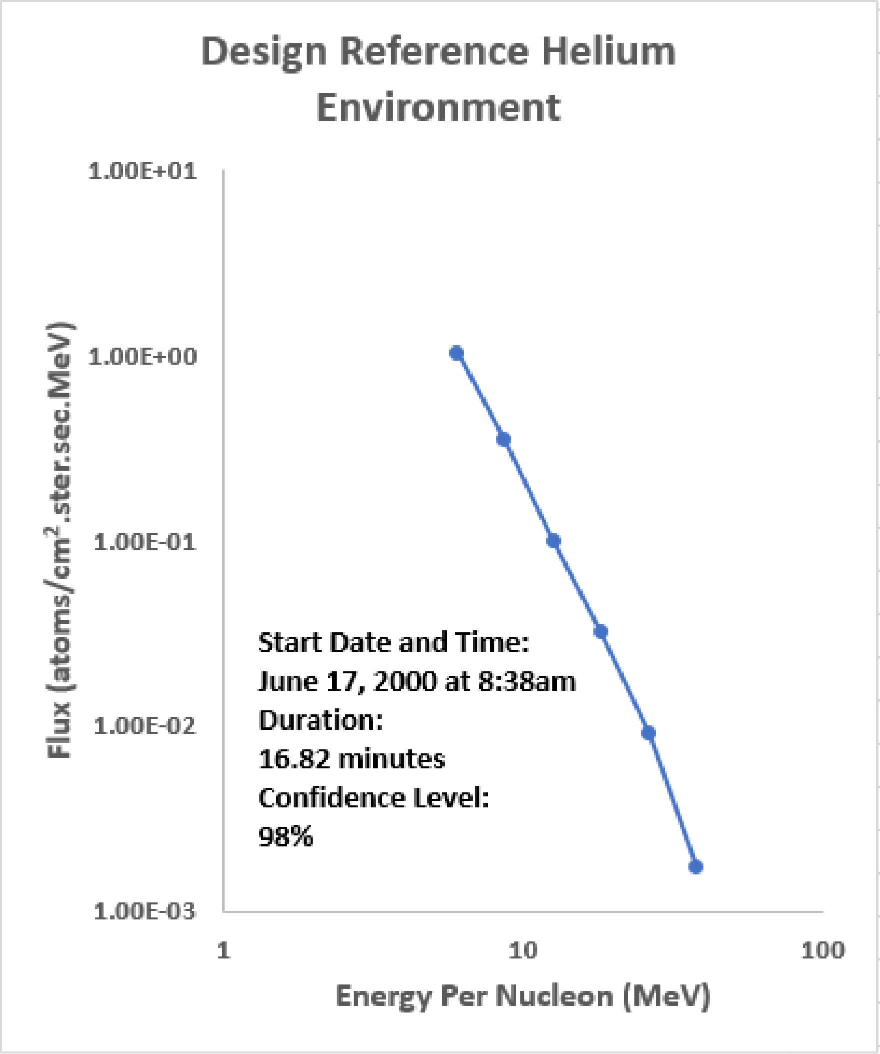

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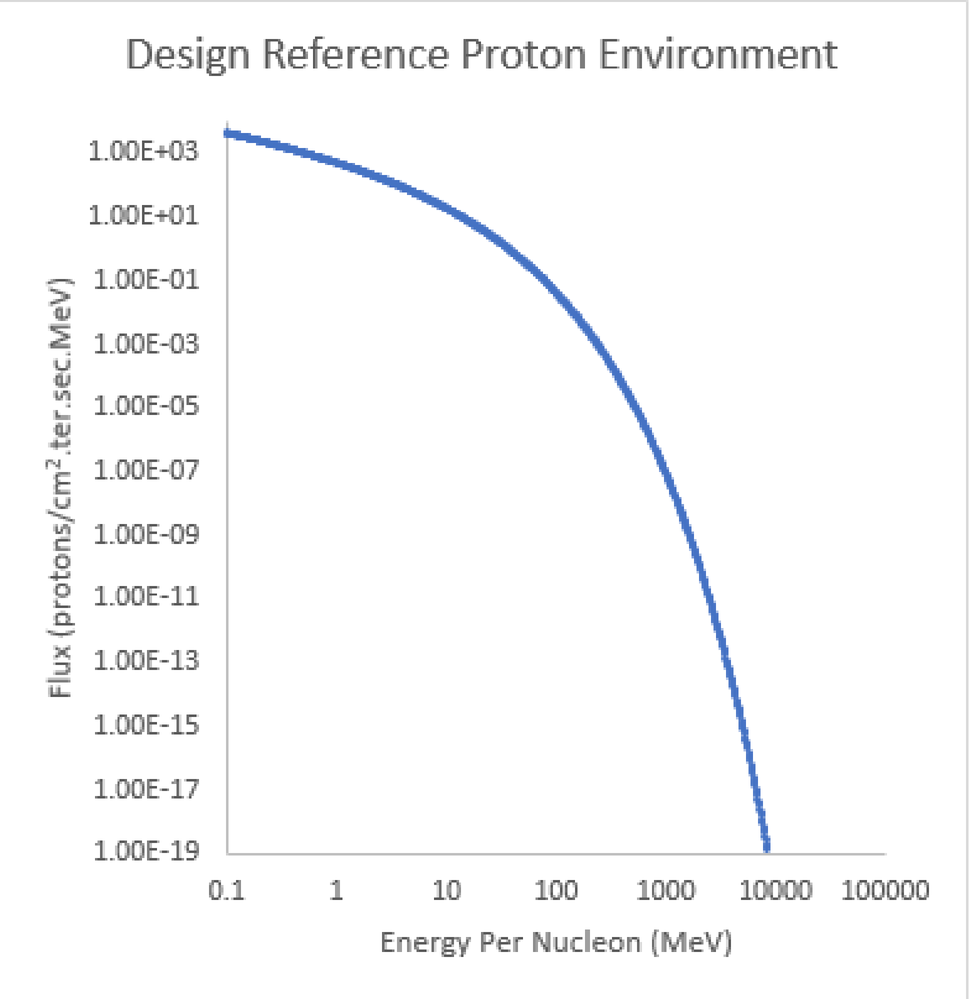
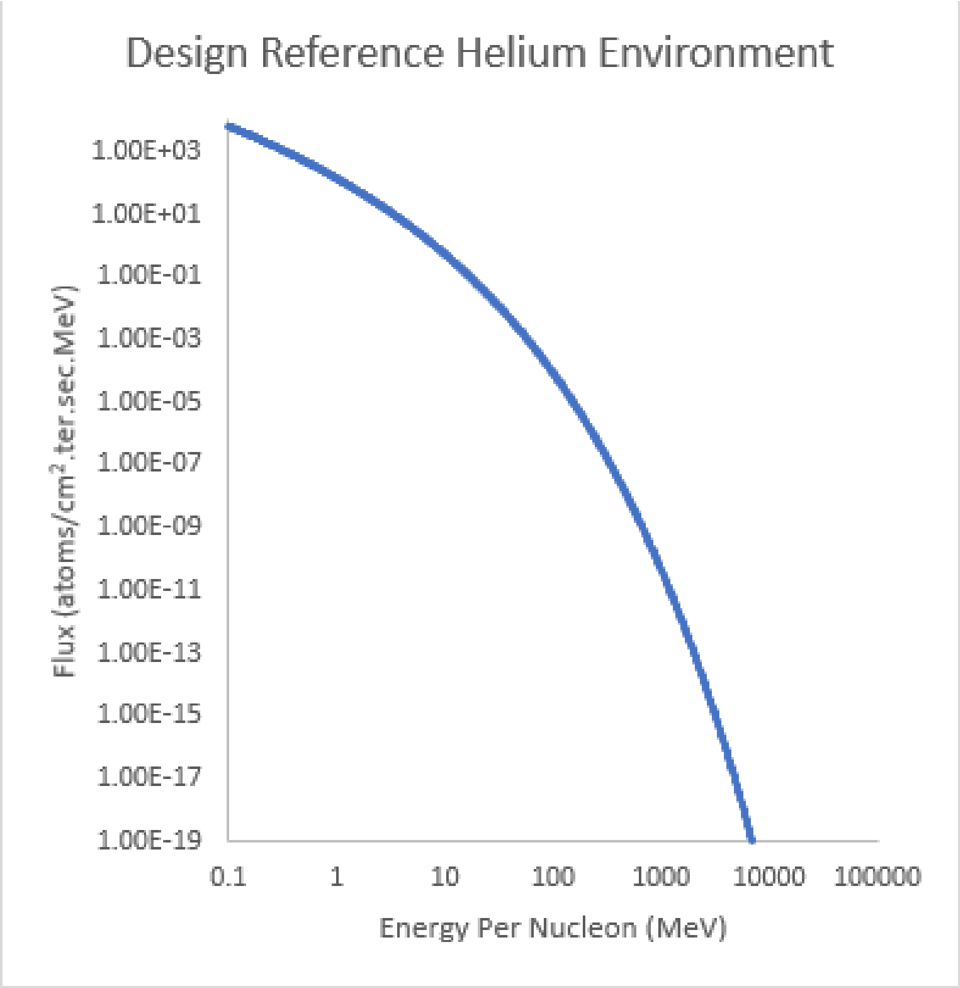
Peak Flux Model in CREME96 Energy Channels





Future Work

Episode-Integrated Fluence Model:

- Extend model to include 2014-2016 proton data.

Peak Flux Model:

- Create data bases for heavier elements and include Z=3-92 in model. Use measured elemental ratios to scale distributions.
- Integration into Space Ionizing Radiation Environments and Effects ($SIRE^2$) toolkit [Fisher et al., 2017].
  - GUI based toolkit based on Cosmic Ray Effects on Micro-Electronics, 1996 version (CRÈME96)

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References

- Robinson, Z. D., "New probabilistic model for episode integrated fluences of protons using episodes from 1973-2013." University of Alabama in Huntsville, 2015.
- Rodriguez, J. V., J. C. Krosschell, and J. C. Green, "Intercalibration of GOES 8-15 solar proton detectors," Space Weather, Vol. 12, Iss. 1, 2012, 92–109.
- Crosby, N., D. Heynderickx, P. Jiggens, A. Aran, B. Sanahuja, P. Truscott, F. Lei, C. Jacobs, S. Poedts, S. Gabriel, I. Sandberg, A. Glover, and A. Hilgers, "SEPEM: A tool for statistical modeling the solar energetic particle environment," Space Weather, Vol. 13, Iss. 7, 2015, pp. 406–426.
- Xapsos, M. A., G. P. Summers, and E. A. Burke, "Probability model for peak fluxes of solar proton events," IEEE Transactions on Nuclear Science, Vol. 45, Iss. 6, 1998, pp. 2948–2953.
- Fisher, J. H., J. H. Adams Jr., J. H. Nonnast, Z. D. Robinson, R. Reed, R. Weller, B. Sierawski, and K. Waren, "Space Ionizing Radiation Environment (SIRE) Model Computer Demonstration," Journal of Radiation Effects, Research, and Engineering, Vol. 35, Iss. 1, 2017, pp. 50–55.