Reconstructing Solar Particle Event Spectra from Absorbed Dose Measurements

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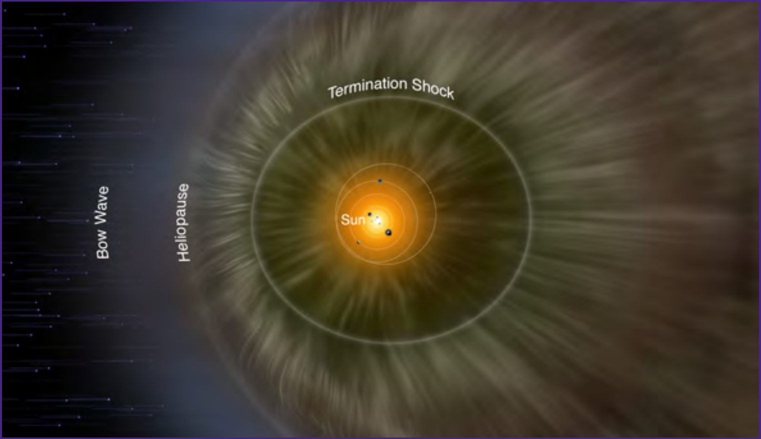
Outline

Credit: NASA

Introduction

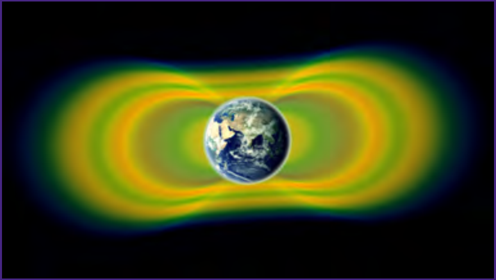
Space Radiation Environment



Credit: NASA/IBEX/Adler Planetarium

Introduction

Space Radiation Environment



Credit: NASA/Van Allen Probes/GSFC

Credit: NASA/GSFC/SDO

Introduction

Space Radiation Environment

- Human impacts
  - Cancer risk
  - CNS and cardiovascular effects
  - Acute Radiation Syndrome (ARS)
- Electronics impacts
  - Single event upsets (SEUs)
  - Single event latchups (SELs)
  - Total ionizing dose (TID)
  - Displacement damage (DD)

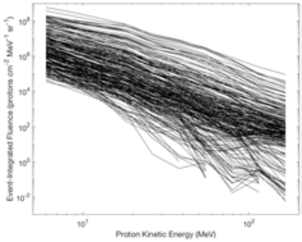
Credit: NASA

Credit: NASA

Introduction

Solar Particle Events (SPEs)

- Associated with flares and CMEs
- Difficult to predict occurrence
- Intensity and spectrum variation
- Monitoring
  - Near Earth
  - Elsewhere in heliosphere

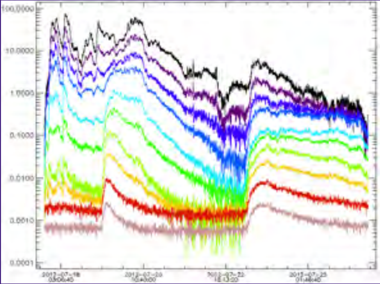


SPE fluence spectra from 1974-2013

Introduction

SPE Monitoring

- Monitoring Near Earth
  - Coverage since 1974
  - SMS, GOES, IMP-8, ACE
  - ISS crew protection
  - Satellite operations

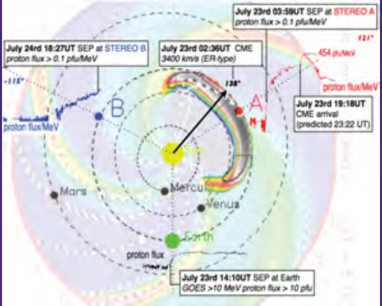


July 2012 SPE Time Profile (ESA SEPEM)

Introduction

SPE Monitoring

- Monitoring Away from Earth
  - Parker Spiral
  - Diffusion across field lines
  - SPE propagation
  - Modeling not mature
- *In-situ monitoring needed*



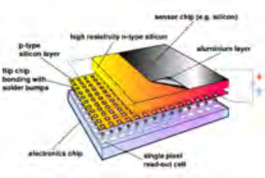
July 23, 2012 CME (Credit: NASA/STEREO)

Introduction
SPE Monitoring

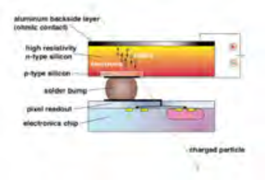

Credit: NASA


Credit: NASA


Credit: NASA



Credit: CERN/Medipix



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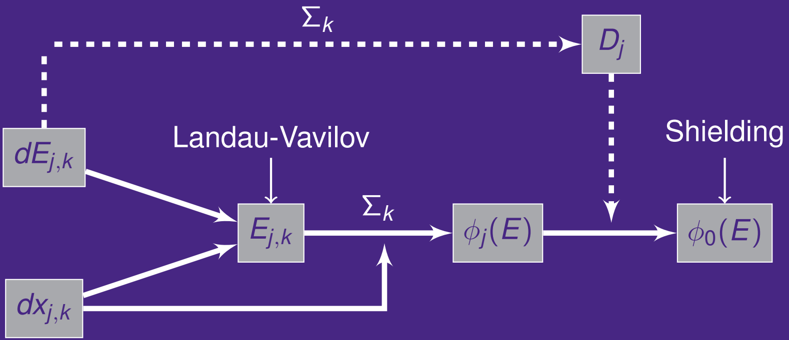
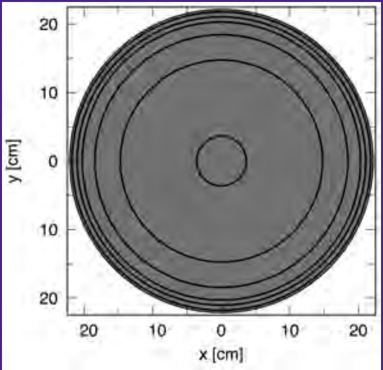
Introduction
SPE Monitoring



Description of the Actual Work

Simulation Geometry

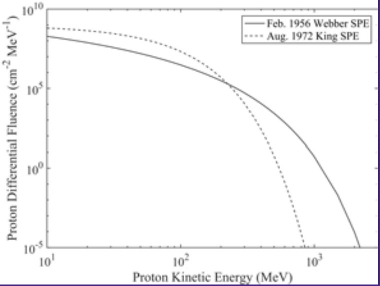
- Aluminum sphere
  - Radius 60 g cm^{-2}
  - Vehicle approximation
- Silicon detectors
  - Spherical shells (1 mm)
  - 1, 3, 5, 10, 20, 50 g cm^{-2}
- Isotropic, uniform irradiation



Description of the Actual Work

PHITS Settings

- PHITS version 2.88
- Monoenergetic protons
  - 10 MeV to 2.5 GeV
- Straggling neglected
- PHITS event generator
- Particle-specific energy cuts
  - HCP: 1 keV/n
  - Neutrons: 10^{-4} eV
  - Photons: 1 keV
  - e^- & e^+: 100 keV



Description of the Actual Work

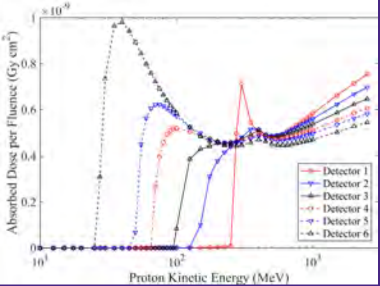
SPE Spectrum Constraints

Equality	Inequality	Lower Bound
$D_j = \sum_{i=1}^{46} R_{i,j}\phi_i$	$-\frac{\phi_i}{\Delta E_i} + \frac{\phi_{i+1}}{\Delta E_{i+1}} \leqslant 0$	$\phi_i \geqslant 0$

Results

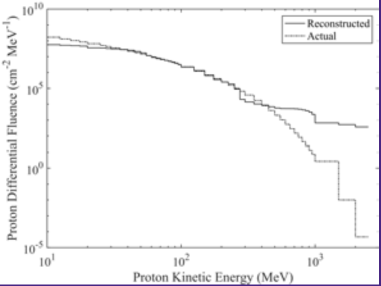
Absorbed Dose Response Functions

- All errors $<6\%$, most $<1\%$
- Threshold energy required to reach detector
- Detector 1 is most point-like
- Secondary production effects

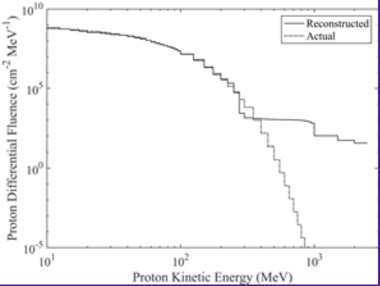


Results

Reconstructed SPE Spectra



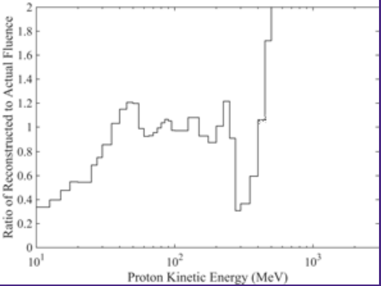
February 1956 Webber SPE



August 1972 King SPE

Results

Bin Fluence Ratios



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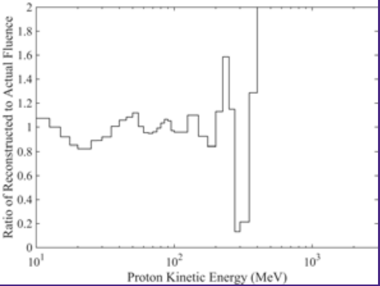

August 1972 King SPE

Results

Significance

- First to investigate proposed method
- Relevant to NASA's exploration radiation monitoring strategy
- Simplified geometry/specific environments
  - Reasonable agreement between 30 and 200 MeV
  - Roll-over in fluence spectrum for most SPEs
  - Large errors at lower and higher energies
  - Anticipate heavy dependence on local detector shielding

- Consider library of SPEs
- Characterize error in dosimetry
- Apply nonlinear optimization techniques
- Reconstruct proton flux spectrum as a function of time
- Optimize coefficients for functional forms instead of bin fluence
- Optimize placement of detectors within spacecraft
- Combine with more detailed information provided by HERA