Open-Source Code for Simulating Proton Transmission Through Thin Radiation Shields

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Introduction

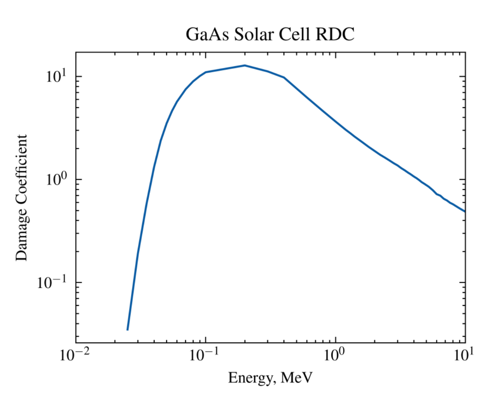
Space Based Solar Power (SBSP) demands lightweight (<50 g/m²), efficient (20%), low-cost (<$1/W), and radiation hard (15 yr. at geostationary) solar cells. With typical solar cell coverglass weighing 130 g/m², it is important for us to be able to model the performance of thin radiation shields.

Two standard tools for modeling solar cell radiation shields are EQFlux and MC-SCREAM. EQFlux is insufficient for SBSP because its analytic proton-range calculations underestimate the number of low-energy protons transmitted to the solar cell.[1] MC-SCREAM uses accurate Monte-Carlo calculations to simulate proton transmission but its critical MULASSIS component, which calculates the slowed proton spectrum, is not readily available, and its use of the non-ionizing-energy-loss diverges from experimental damage estimates at low proton-energies.[2]

To overcome these limitations we wrote, and share, a code for Monte-Carlo proton transmission and damage calculations. As written, it reads proton spectra prepared by SPENVIS, uses TRIM to calculate how the protons transmission spectrum through a radiation shield, and then uses the empirical relative damage coefficient (RDC) method of EQFlux to determine the effective radiation dose.[3]

Method Comparison

EQFlux Pros:



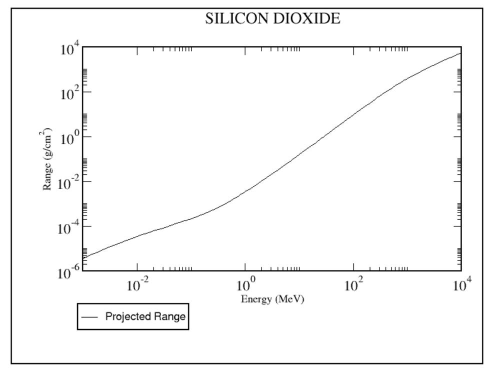
Experimental Damage

MC-SCREAM Pros:

GEANT4
A SIMULATION TOOLKIT

Modern scattering calculations

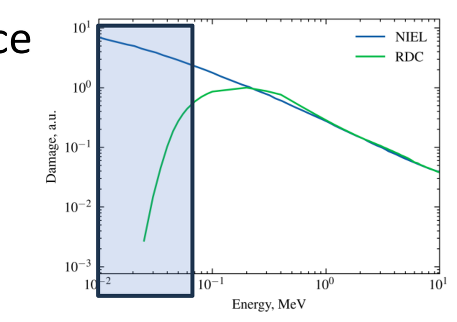
EQFlux Cons:



Simple proton range models[4]

MC-SCREAM Cons:

Divergence of low-energy proton damage

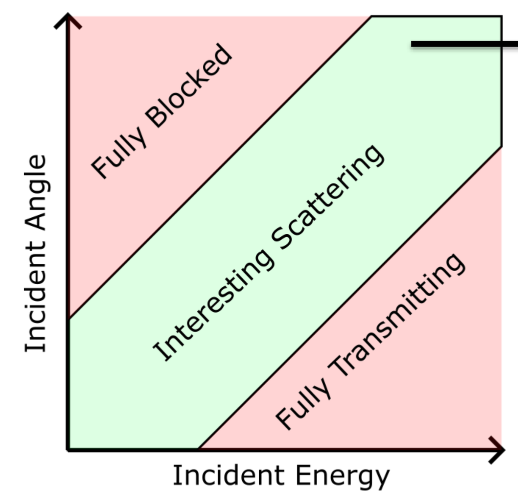


Geographic restrictions on source-code

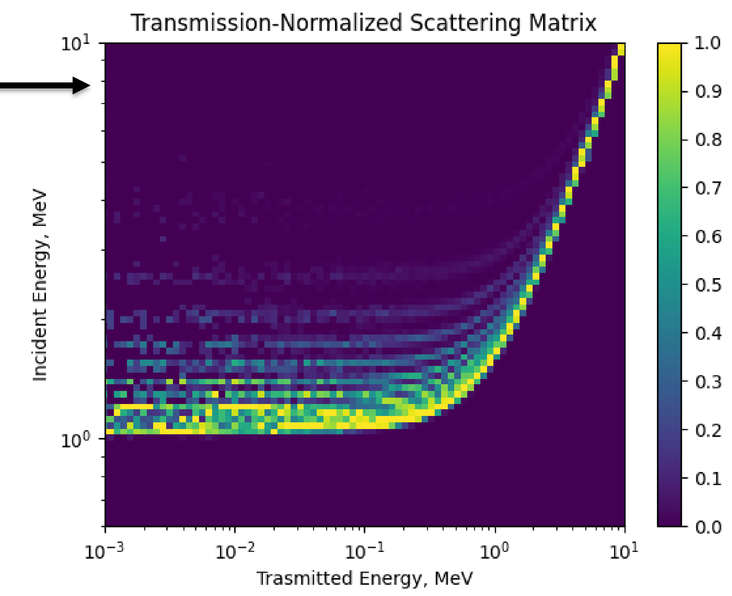
Method

Goal: combine the pros of EQFlux and MC-SCREAM

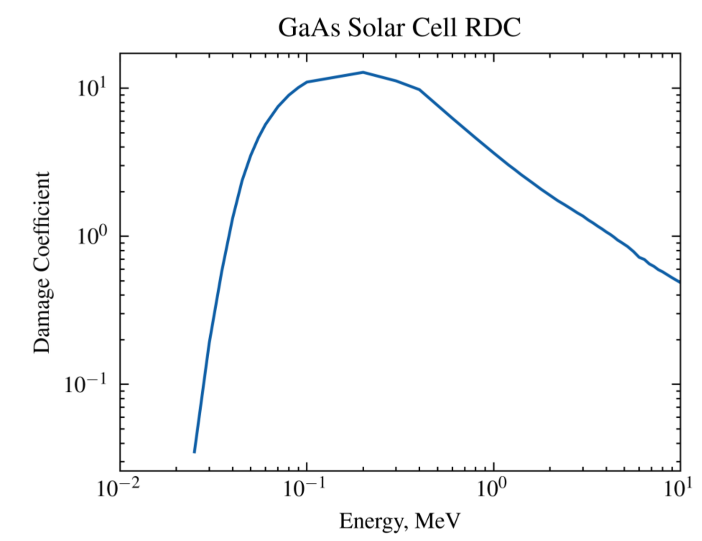
Efficiently find worthwhile simulations



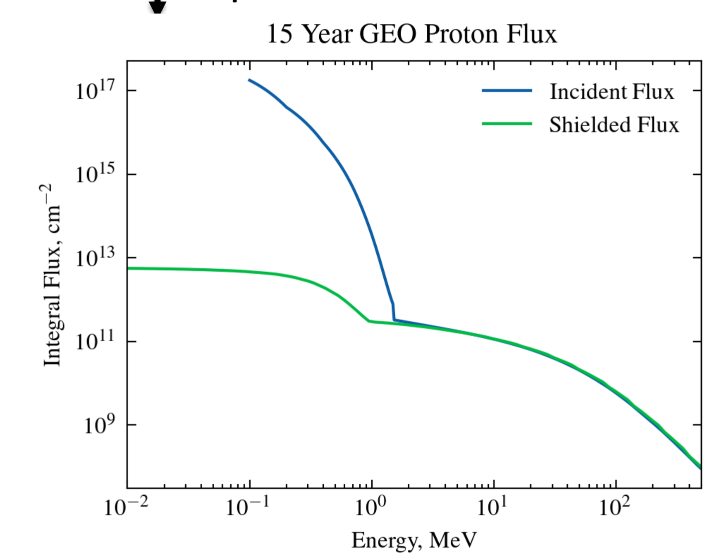
Calculate interesting matrix elements in detail



Use experimental damage data



Determine slowed proton spectra[5]

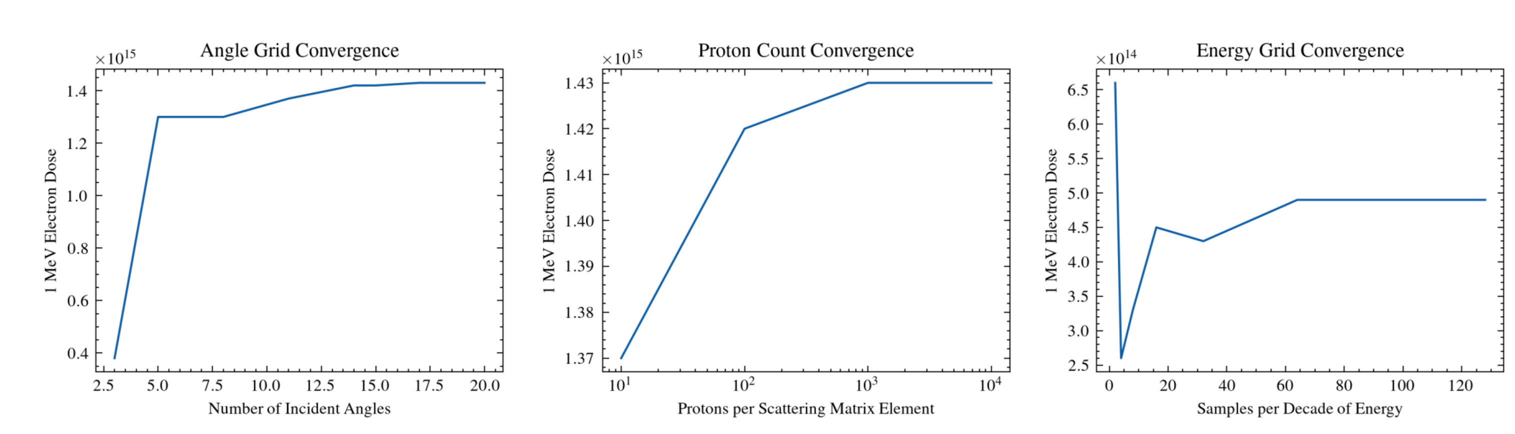


Integrate

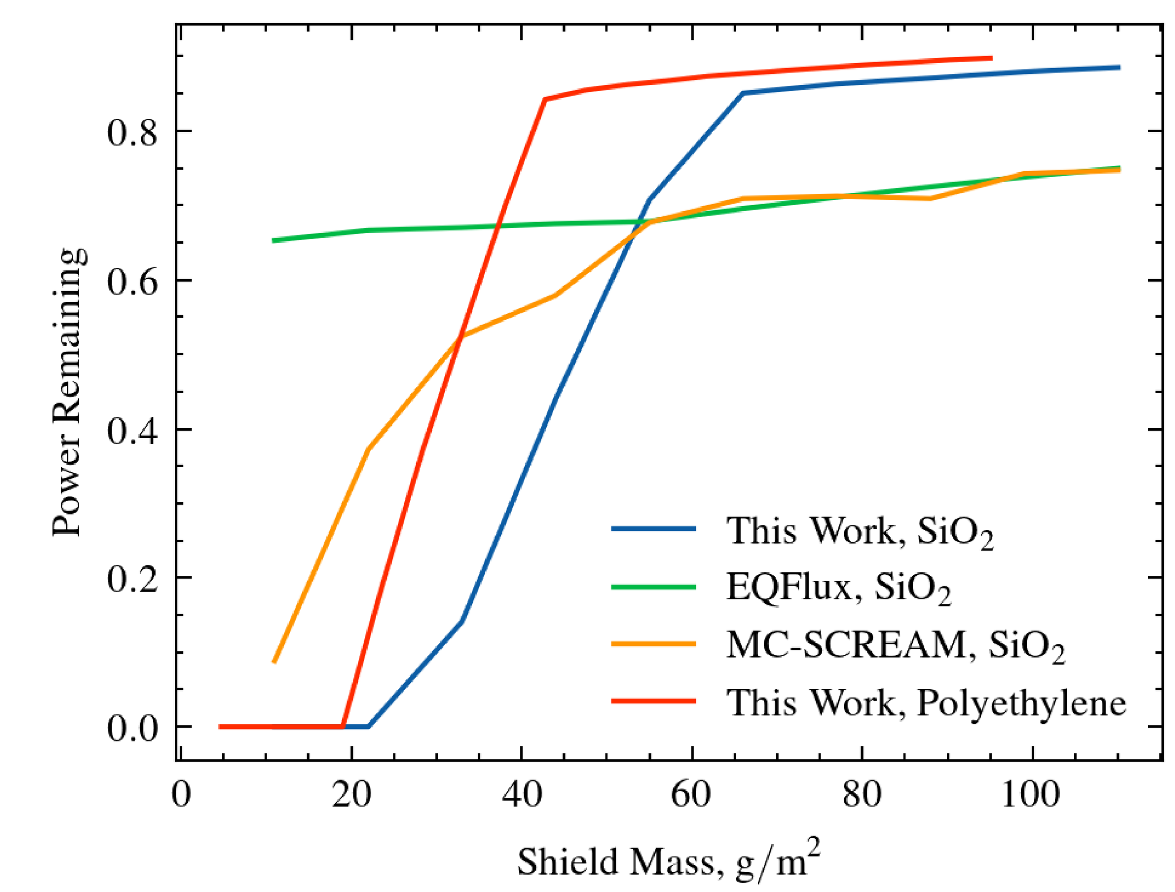
$4.7 * 10^{16}$ 1 MeV e^-

GitHub with Code

Convergence Behavior



Results



- We predict more degradation for thin shield than EQFlux or MC-SCREAM
- We predict less degradation for thick shield than EQFlux or MC-SCREAM

Discussion

- Hydrogen-rich polymers as the bulk of shielding may reduce shielding mass by 50%
- 35 g/m² of polyethylene could reduce the dose to $1 * 10^{16}$ 1 MeV e^-, which is compatible with SBSP targets with InP solar cells

Future Work

- Identify source of disagreement between our model and EQFlux and MC-SCREAM for thicker radiation shields
- Careful measurements of low-energy proton damage to devices are needed to validate possibility of thin proton shields

References

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