SCHOOL OF ENGINEERING

VANDERBILT UNIVERSITY

Distribution of Proton-Induced Transients in Silicon Focal Plane Arrays

Presented by Nathaniel Dodds[1]

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Outline

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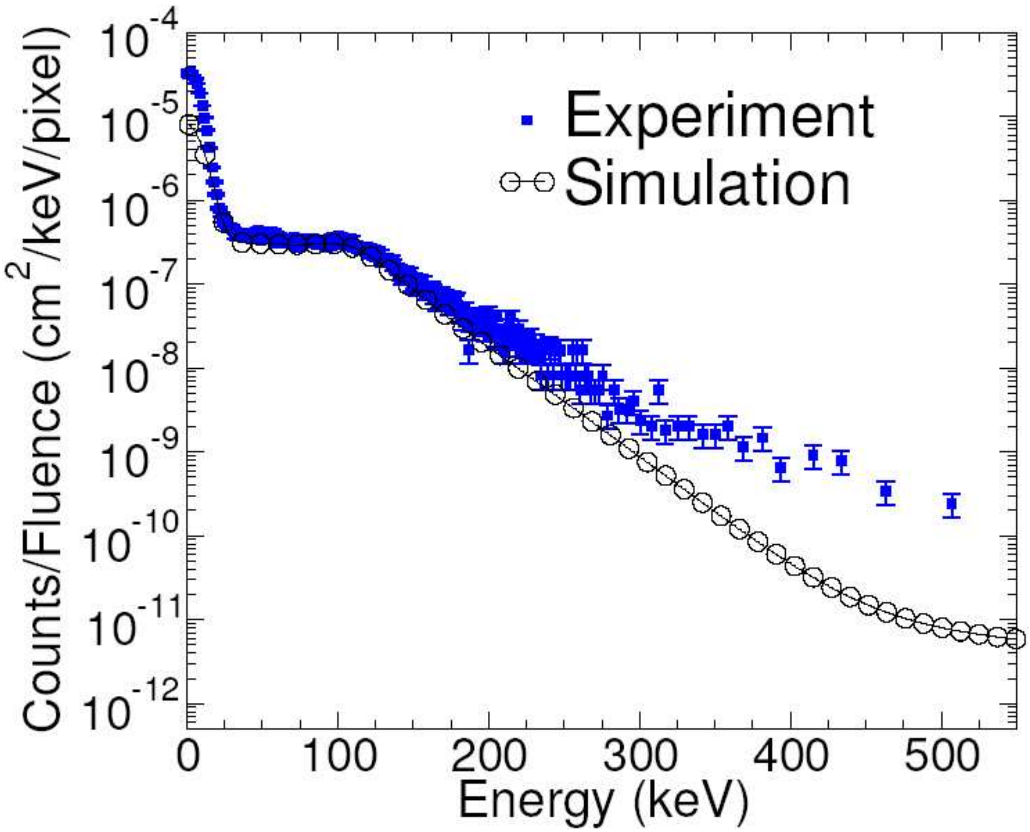
- Experimental Setup
- Modeling Description
- Results
  - Direct ionization dominates event rates
  - Path length and constant dE/dx method does not capture full distribution
- Conclusions



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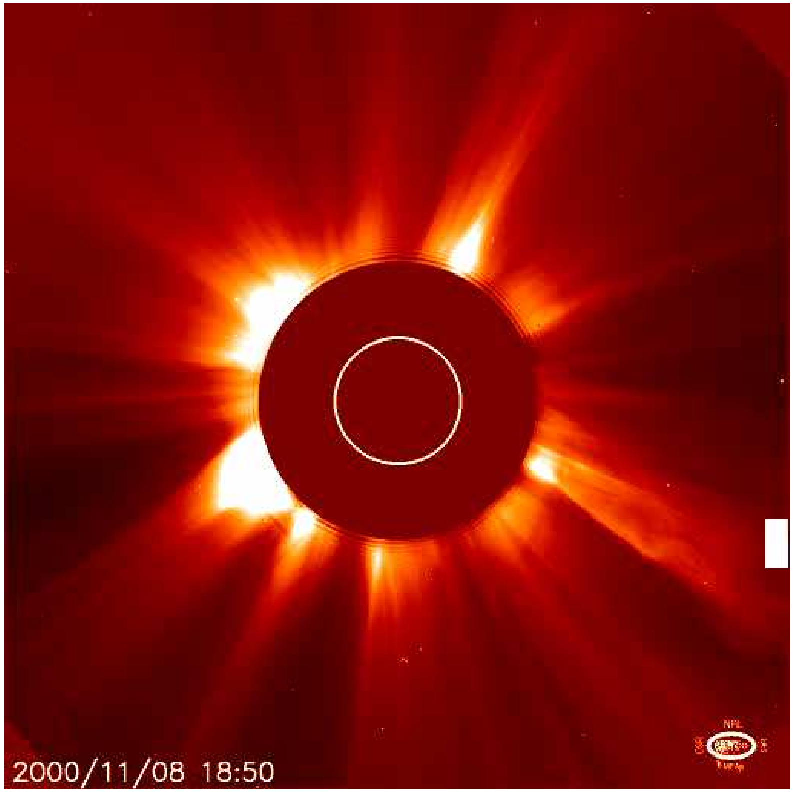
Motivation

- Proton events contribute to device noise floor
- Better understanding of how radiation-induced energy deposition occurs will improve prediction techniques
- Accurate modeling helps predict on-orbit response



http://sohowww.nascom.nasa.gov/gallery/Movies/flares.html

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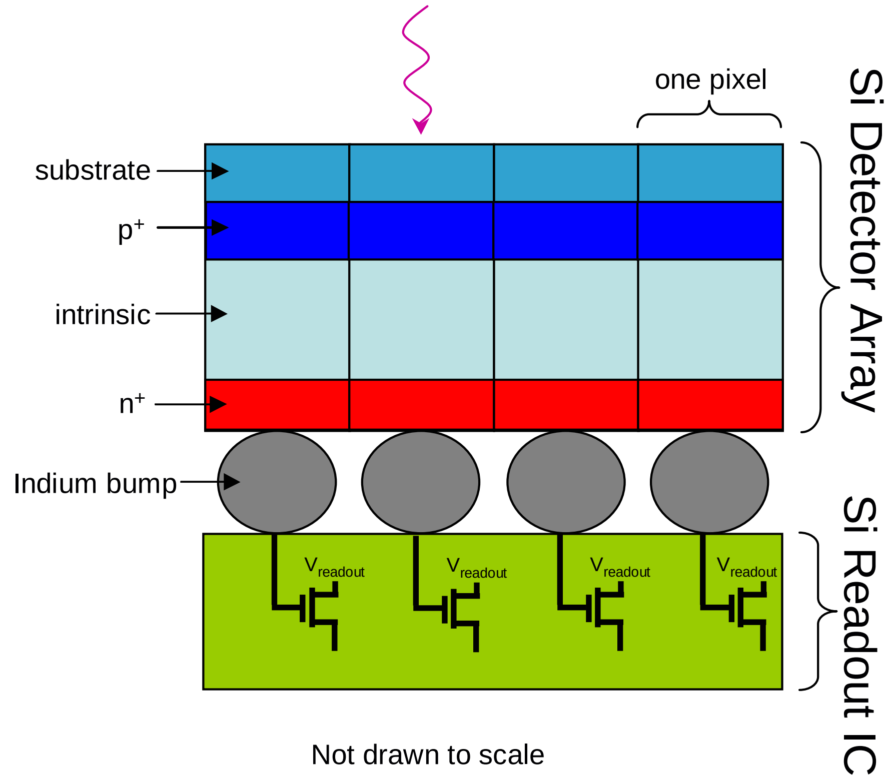
Experimental Setup

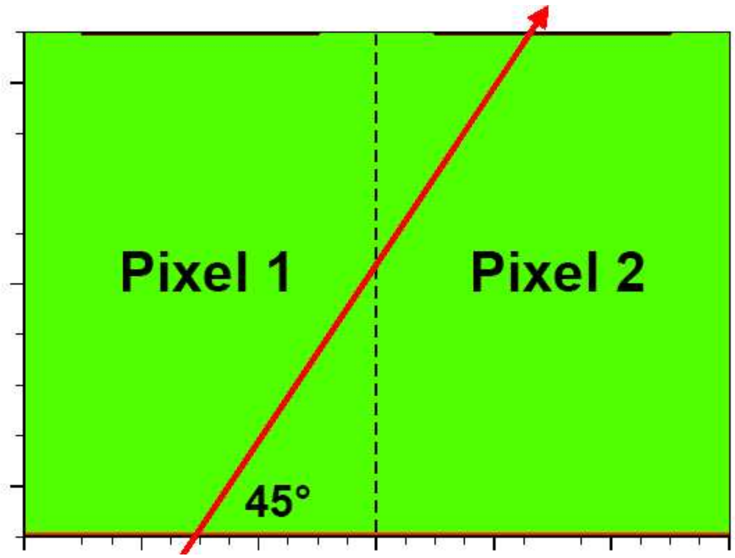
- Back side hybrid FPA consisting of a silicon p-i-n 128 × 128 detector array with hardened CMOS readout integrated circuit (ROIC)
- Full radiometric characterizations were performed
  - Dark current, noise, responsivity, and sensitivity
- Biased to 15 V resulting in full depletion
- Irradiated with 63 MeV protons at 45°
- Exposed at 233 K

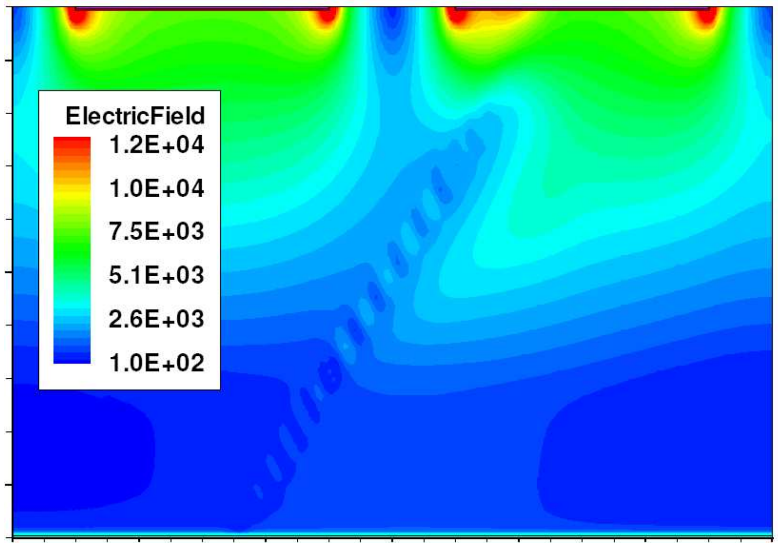
Hybrid FPA Cross section

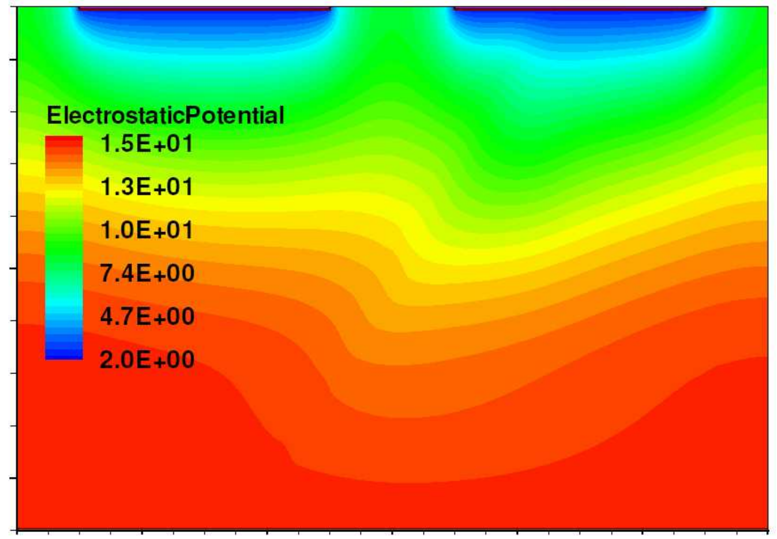


Not drawn to scale

TCAD Simulations







- TCAD simulations revealed rectangular parallelepiped (RPP) assumption was sufficient to estimate device response to radiation

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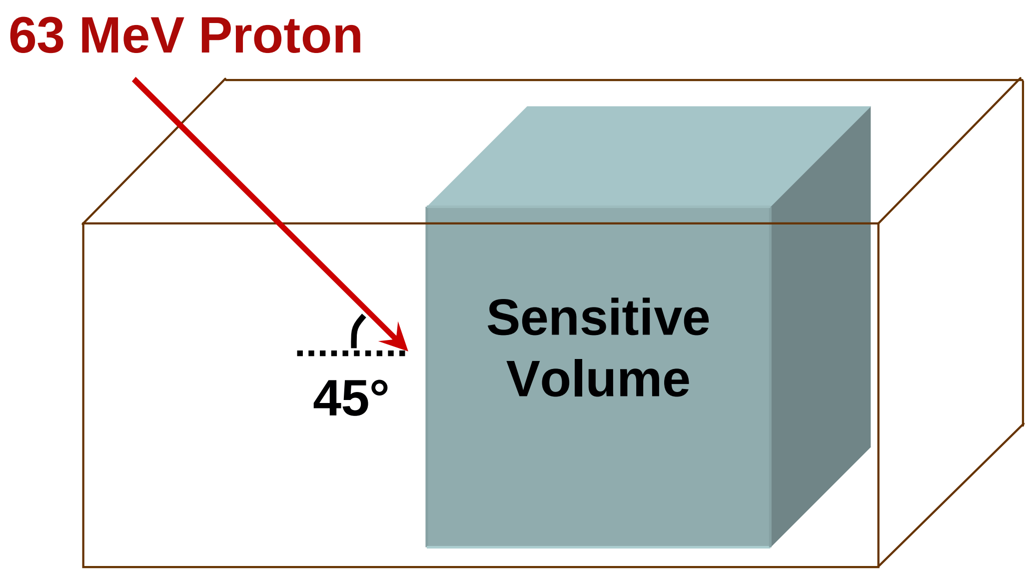
Monte Carlo Simulations

- MRED (Monte Carlo Radiative Energy Deposition), a Geant4 based tool, used for simulation
- Sensitive volume equal in size to one pixel



Pile Up

- Accounts for the probability of multiple hits on a single pixel
- Based on a measure of the mean number of hits per pixel during a single integration time

Events / Pixel → μ

Simulation → σ

Experiment → ϕ, τ

$$\mu = \sigma \times \phi \times \tau$$

σ = Integral cross section
Φ = Flux
τ = Integration time

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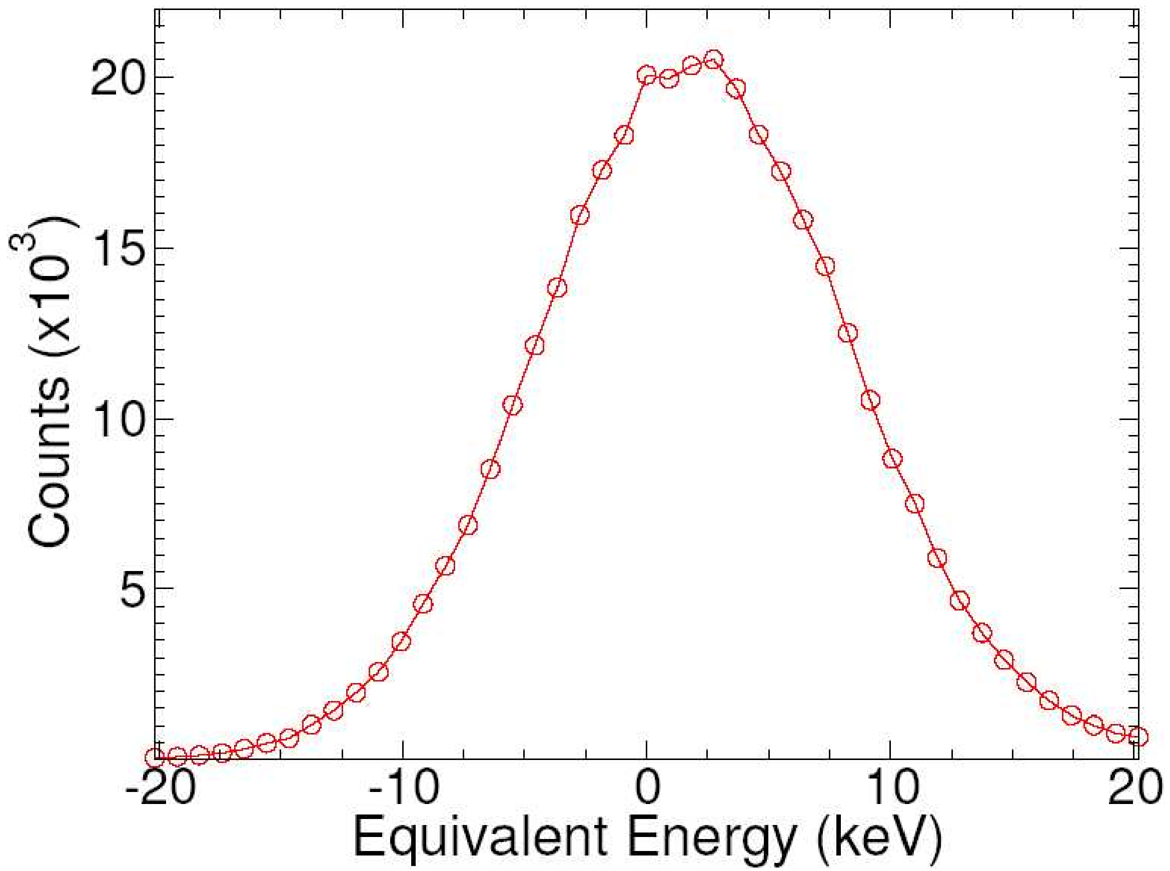
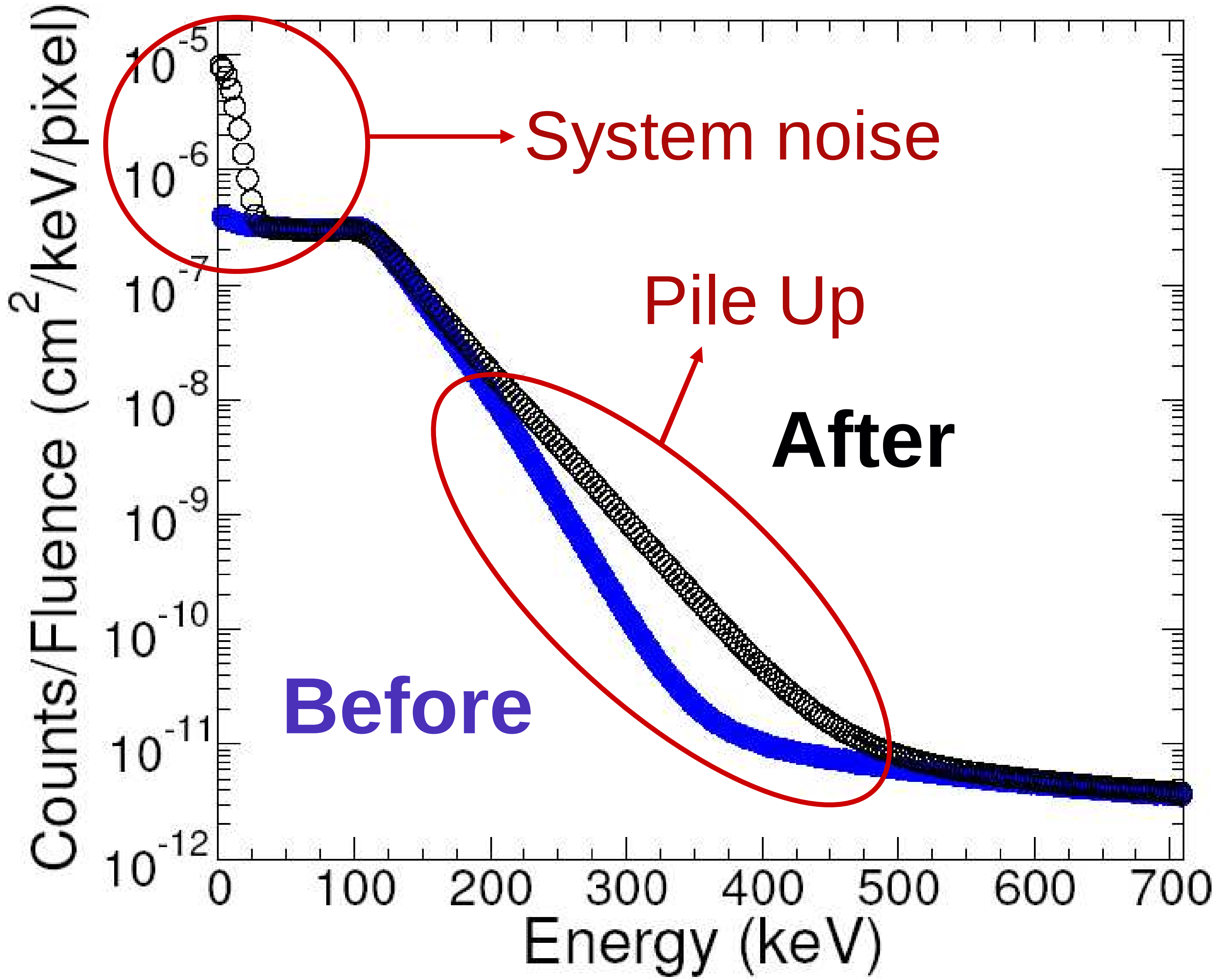
Non Radiation Noise

- Broadening at zero region shows amount of system noise present
- Gaussian convolution used to apply noise to simulation



Post Processing Results



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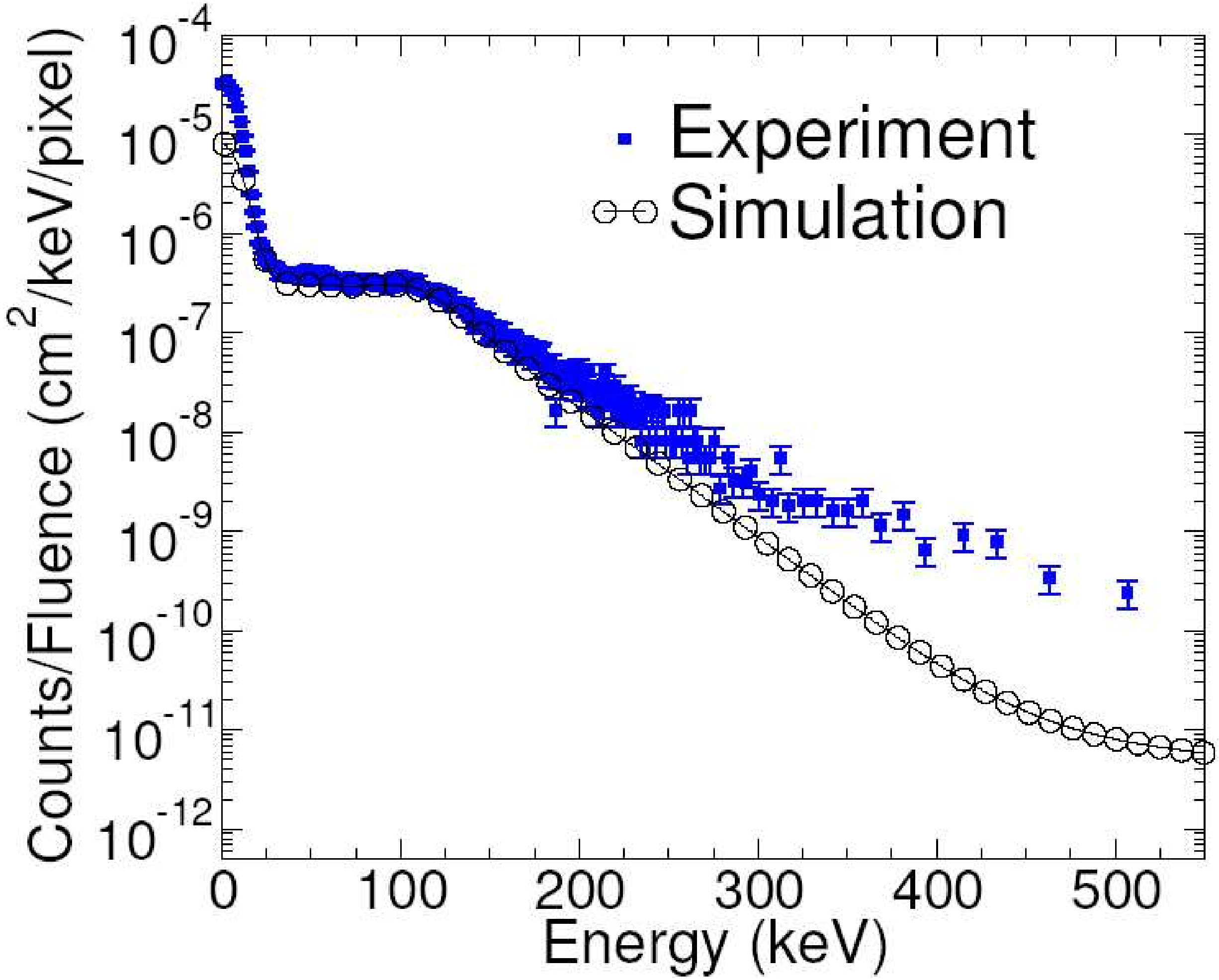
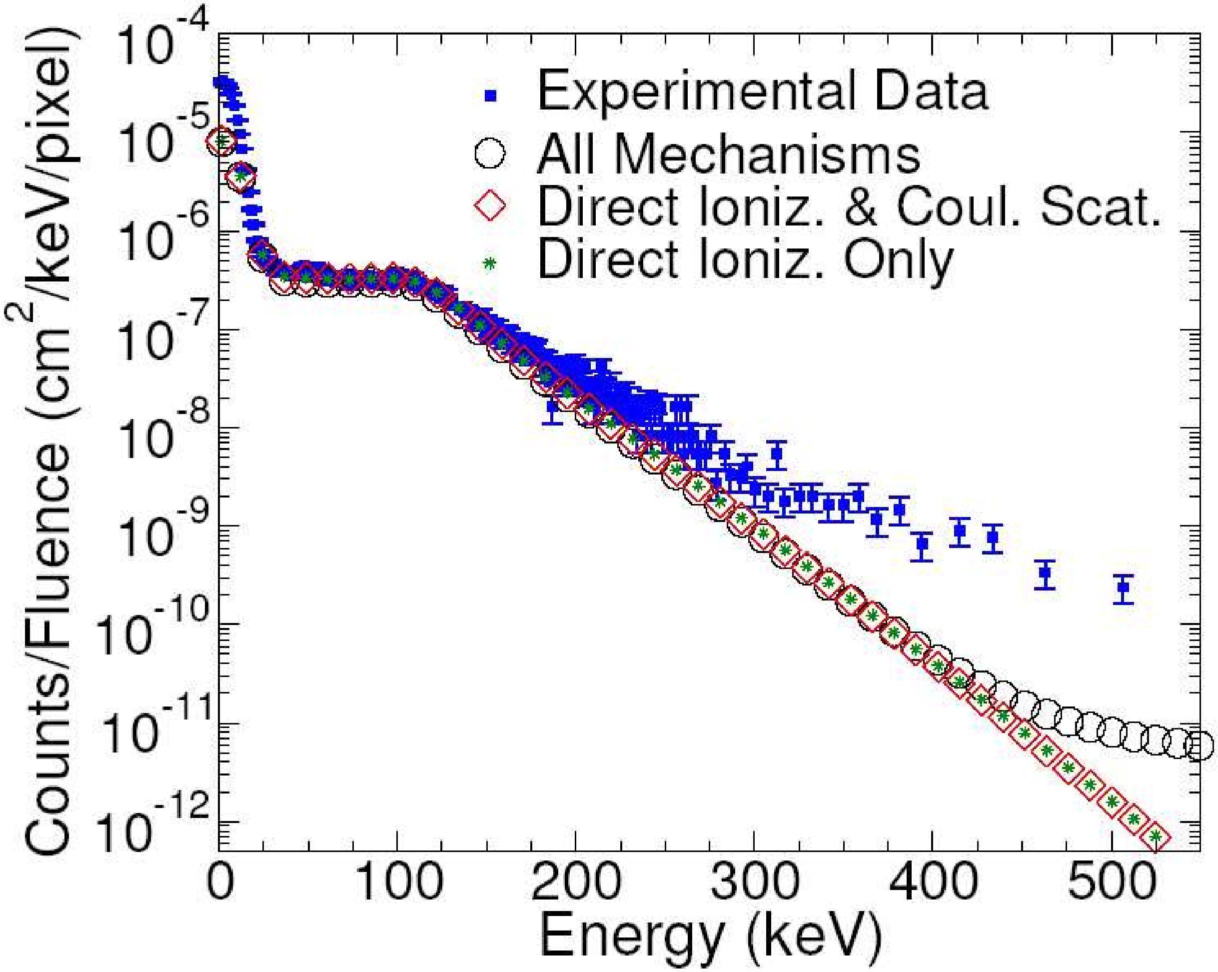
Results



- Good agreement below 300 keV
- Differences past 300 keV due to
  - Simplification of structure
  - Known error in nuclear reaction models, see R.A. Reed, *et. al.*, TNS 2007
  - Charge sharing between pixels

Reaction Mechanisms

- Direct ionization is dominant mechanism below 450 keV
- Coulomb scattering does not contribute significantly here



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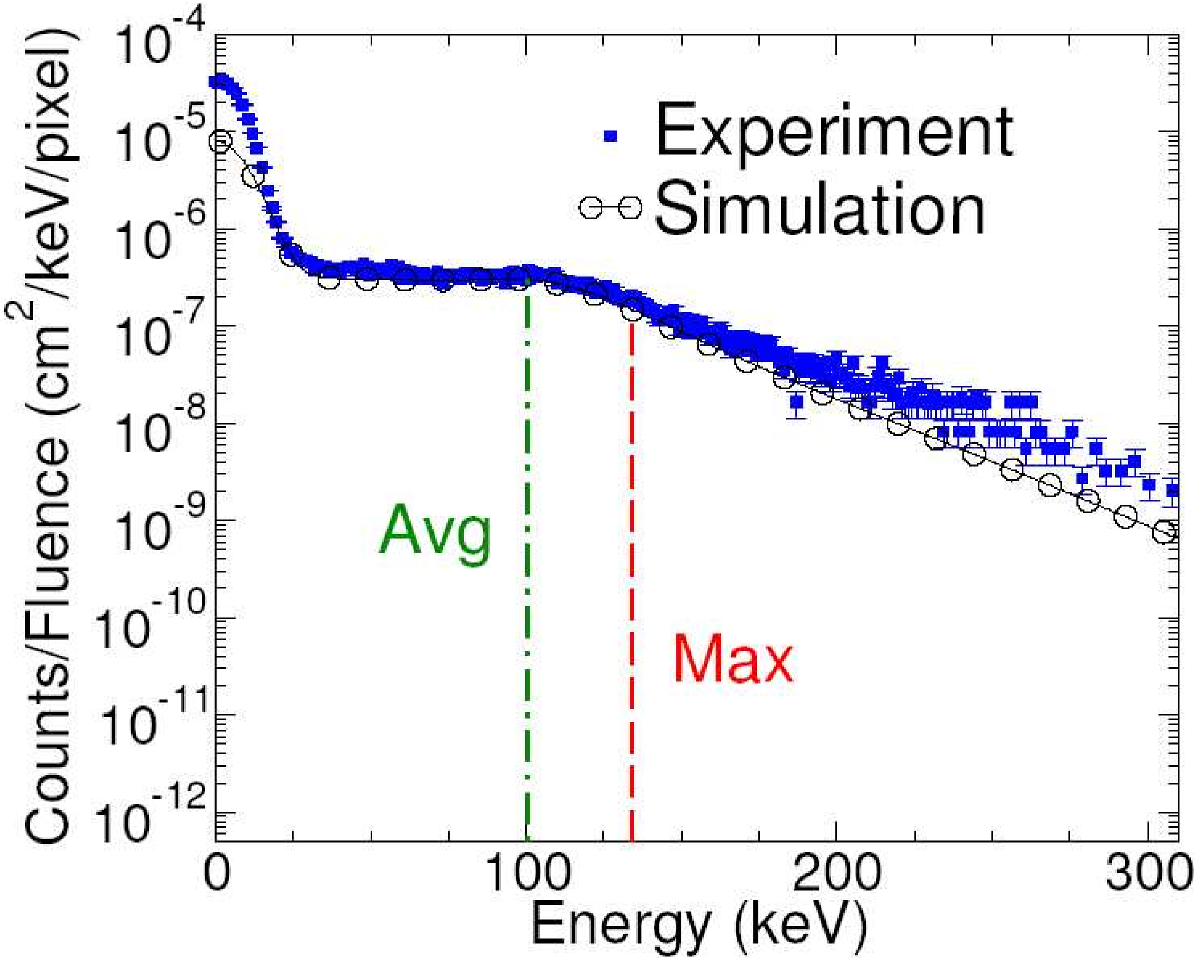
Constant dE/dx and Path Length Distribution Calculation

Energy Deposited = dE/dx × Path Length



- Fluctuation of dE/dx is not considered
- Variation in distribution comes from path length only in this type of calculation

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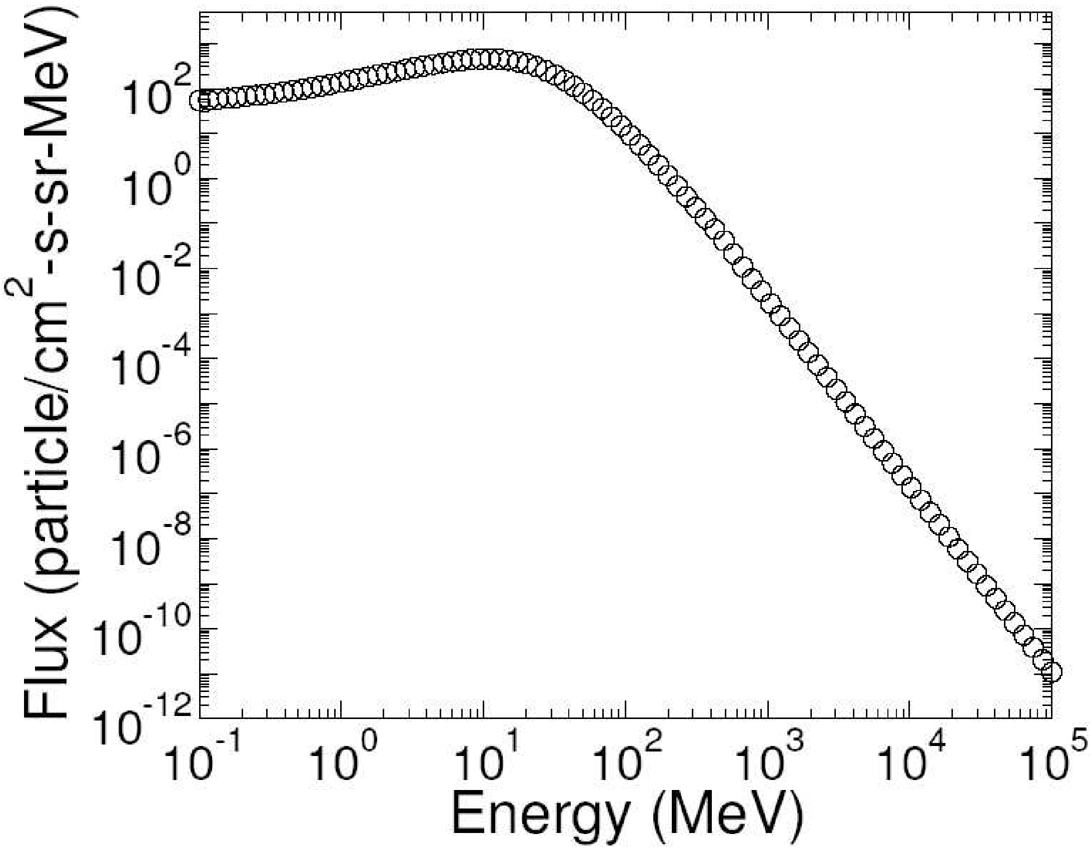
Implications for Space

- Proton environment from CREME96
- Geosynchronous orbit, worst week



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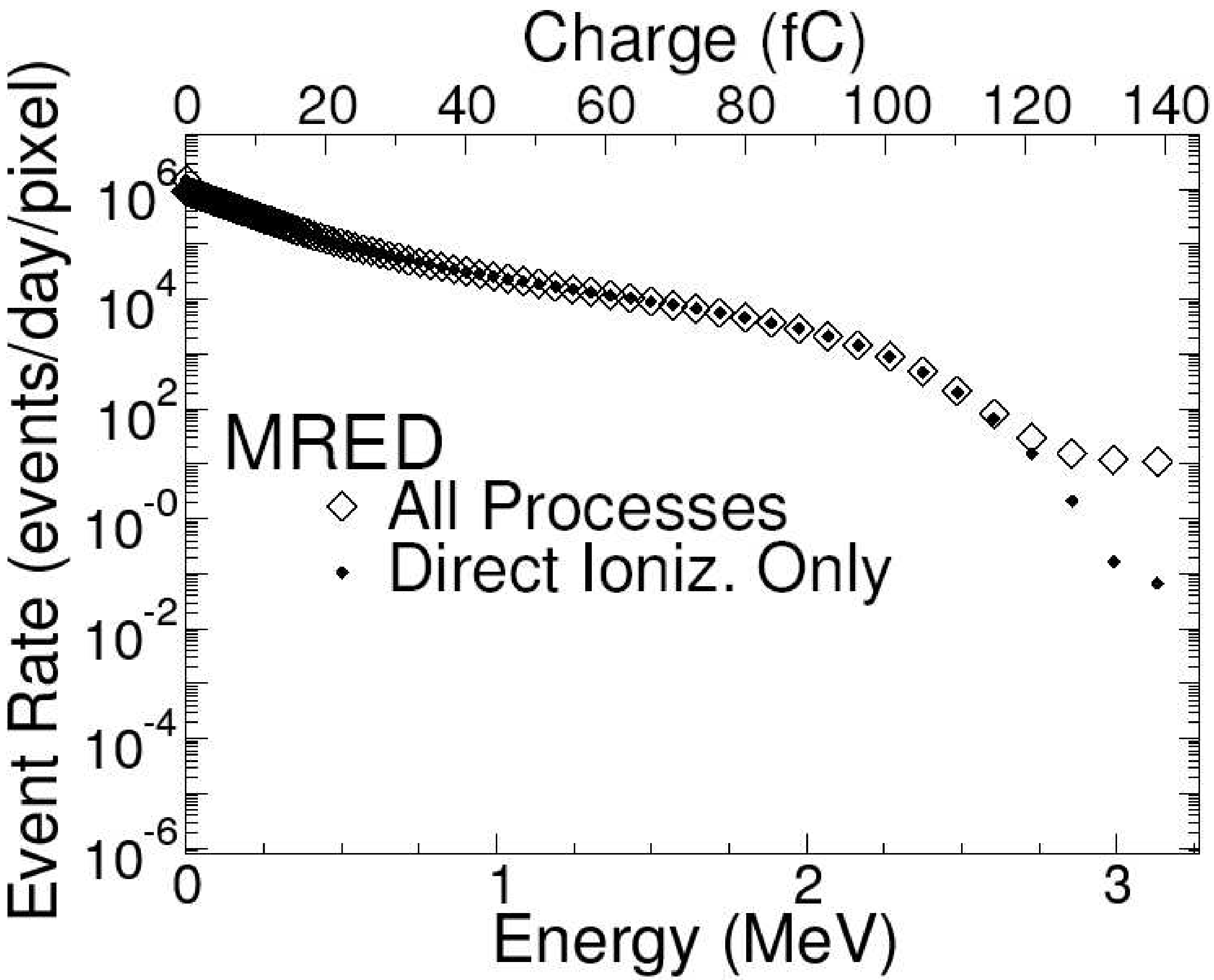
Implications for Space



- Direct ionization dominates below 2.75 MeV (125 fC)

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Conclusions

- Direct ionization dominates the cross section below 450 keV from incident 63 MeV protons
- Constant dE/dx and path length calculation does not address fluctuations in dE/dx and therefore does not capture the full distribution
- A high fidelity simulation is needed to accurately predict device response

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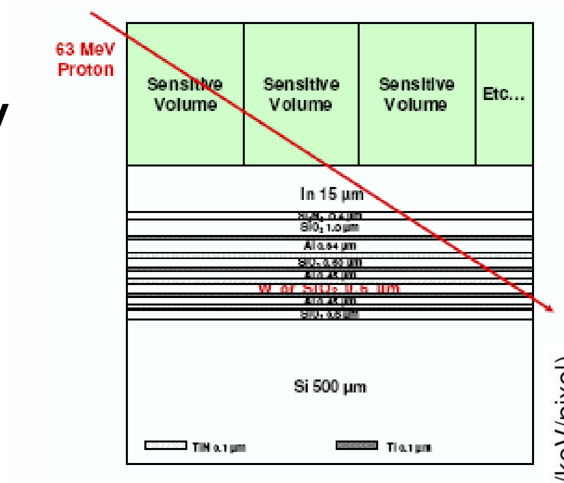
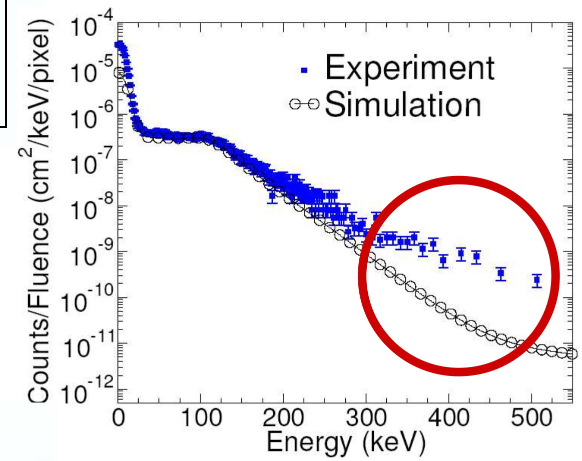
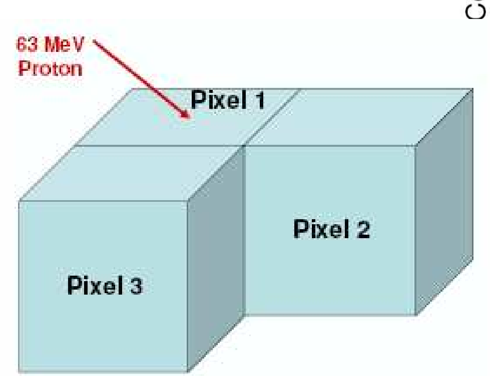
Future Work with Si p-i-n FPA

- Include entire pixel array with underlying indium and ROIC.
- Normal incidence will reduce backscattering
- More ionizing lower energy protons (12 MeV)
- Charge moves along track, but does it move laterally between pixels?

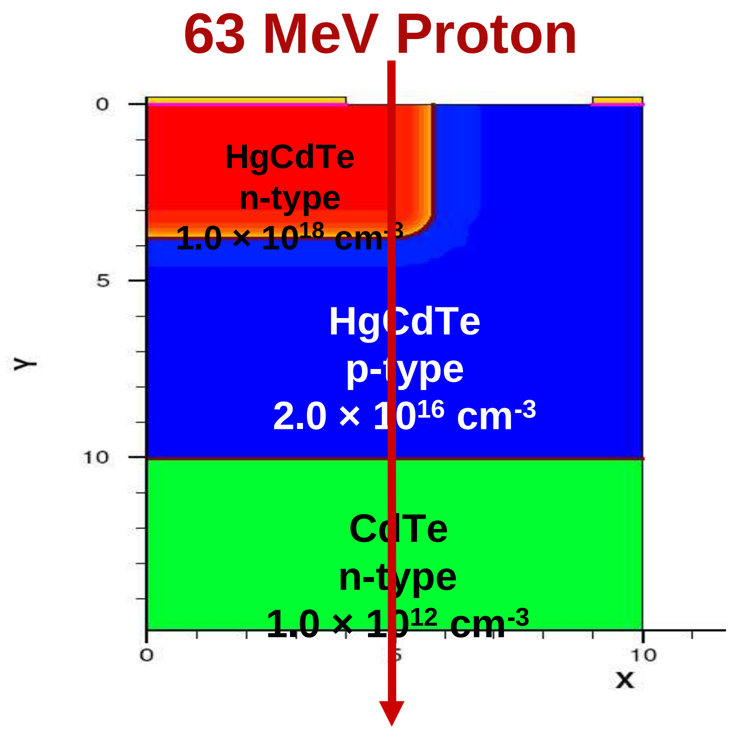


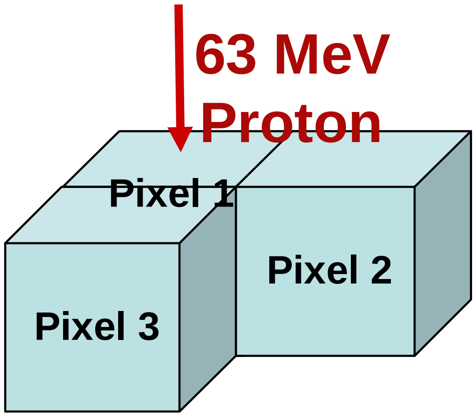




Future Work with HgCdTe FPAs

- Methods developed with Si p-i-n FPAs applied to HgCdTe FPAs
- Crosstalk is more problematic in HgCdTe detectors because they are used at cold temperatures. Charge sharing will be studied.





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