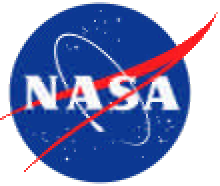


Proton-Induced Transients and Charge Collection Mechanisms in a LWIR HgCdTe Focal Plane Array

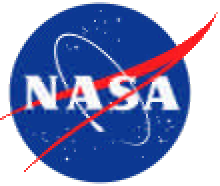
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- **Air Force Research Laboratory**
- **NASA Goddard Space Flight Center**
- **SGT, Inc.**
- **P,R&T, Inc.**



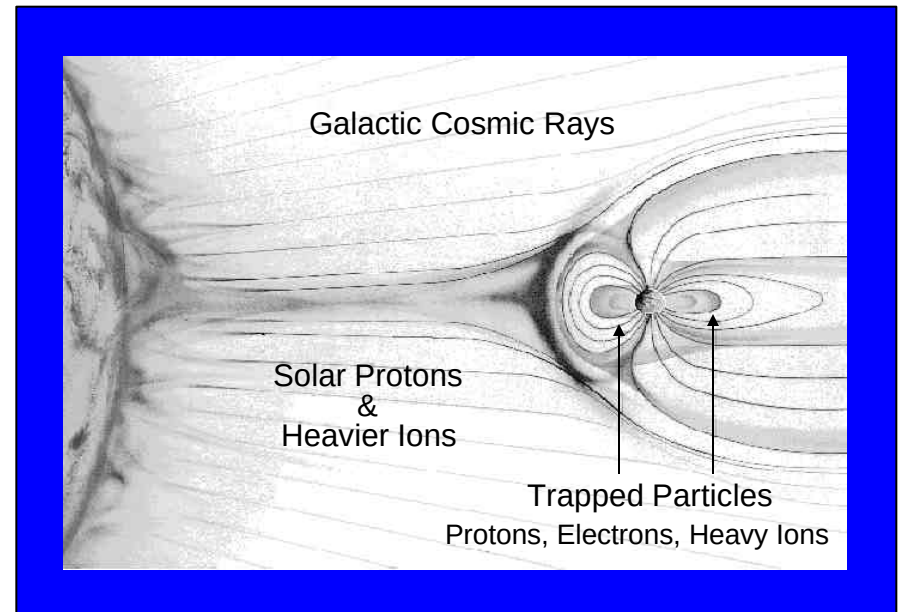
Outline

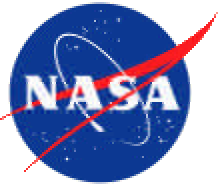
- **Introduction**
- **Device Description**
 - 256 x 256 LWIR HgCdTe array
- **Data Analysis & Results**
- **Charge Collection Modeling**
- **Summary**



Introduction

- **The Problem: Low noise performance of IR detectors is required, even in the presence of charged particles.**
 - galactic cosmic rays, trapped protons & solar energetic particles
 - Particle induced transients identified as an important source of noise on ESA's ISO satellite
 - Also observed on NICMOS Instrument on NASA's Hubble Space Telescope



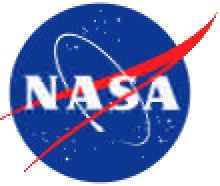


Introduction, cont.



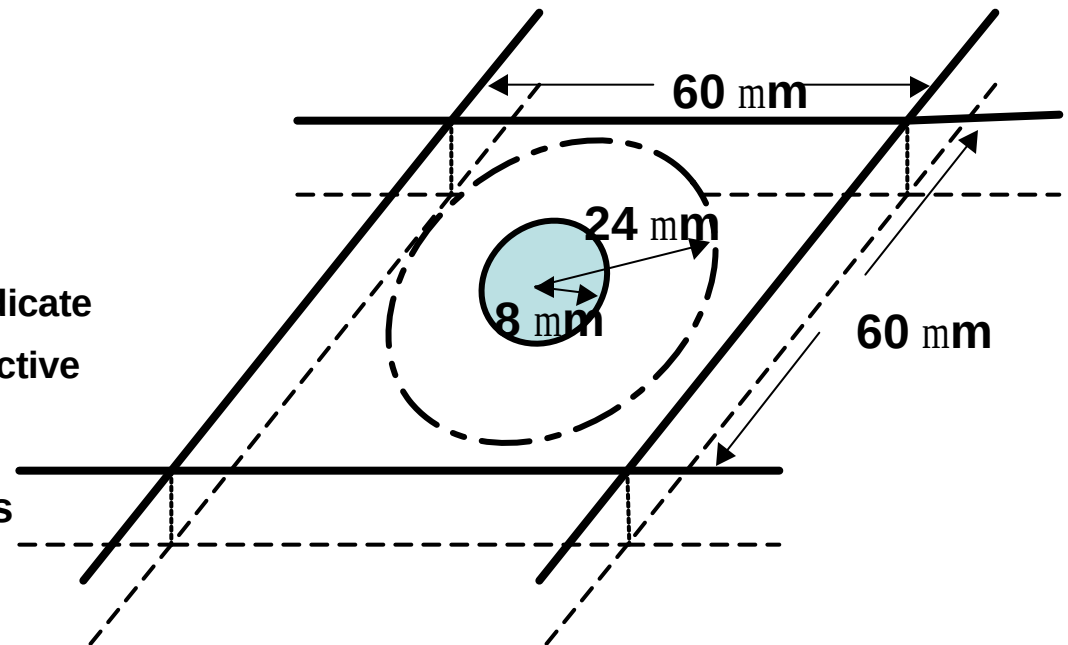
- Tools to analyse particle-induced transients have been developed by Pickel et al.¹
 - To date, comparisons of model have been made to flight data for a HgCdTe array exposed to trapped protons, and to a Si array exposed to laboratory protons.
- We report ground based proton transient measurements in a modern LWIR HgCdTe array operating under cryogenic conditions.
 - Demonstration of charge collection mechanisms
 - Provide benchmarks for modeling tools

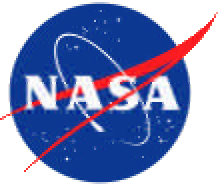
¹Pickel et al., "Radiation-Induced Charge Collection in Infrared Detector Arrays," *IEEE Trans. Nucl. Sci.*, Vol. 49, p. 3822, Dec. 2002.



LWIR HgCdTe Array Description

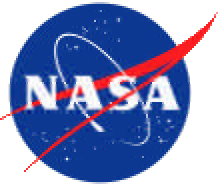
- **256 x 256 pixel array**
 - Epitaxially grown multi-layer planarized heterojunction structure
 - Cutoff wavelength ~14 μm
 - Pixel pitch is 60 μm
 - Unit cell utilizes a central implanted diode for drift induce charge collection
 - Optical measurements indicate lateral collection with effective diffusion length of 16 μm
 - QE is 54% with no coatings
 - Pre-rad pixel dark current <0.05 pA



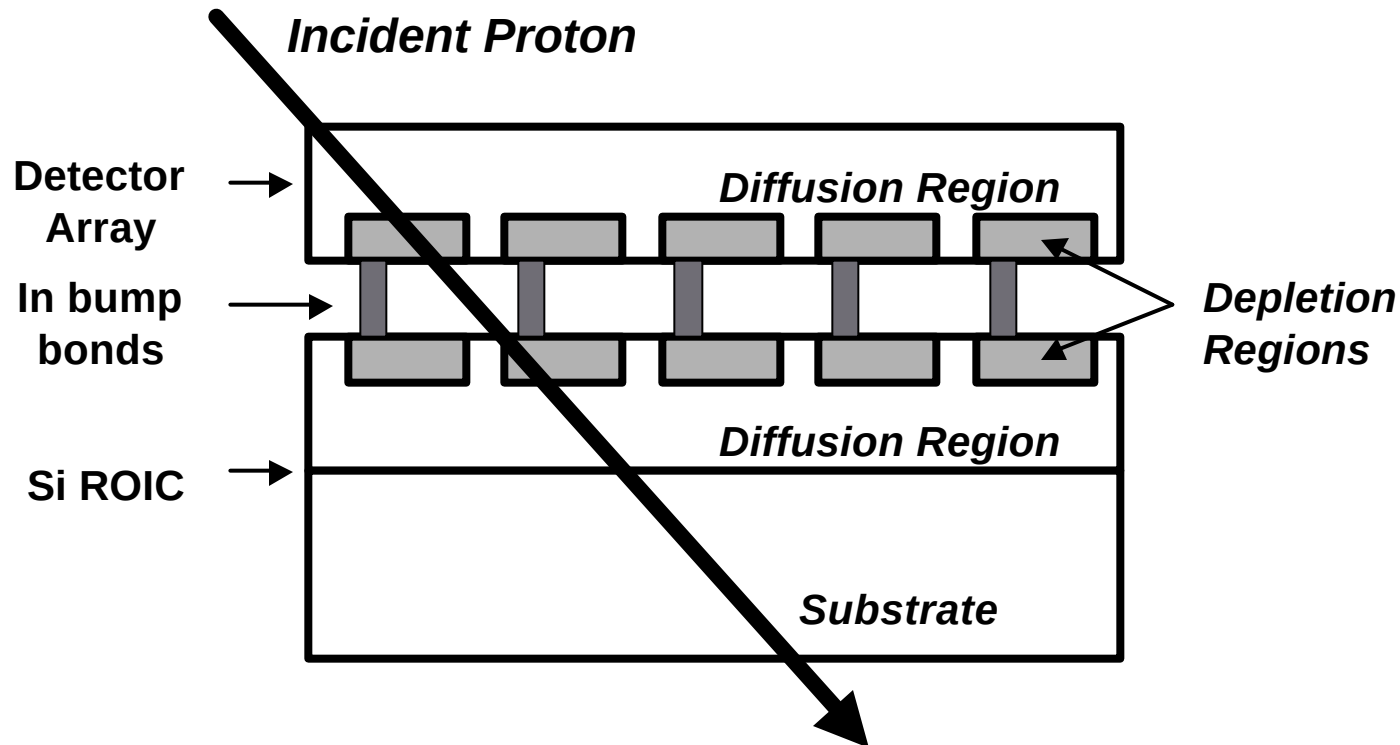


LWIR HgCdTe Array Description, cont.

- **Detector array is bump bonded to CMOS readout integrated circuit (ROIC)**
 - **ROIC provides snapshot readout with 100 Hz frame rate**
 - **ROIC includes**
 - **analog and digital test modes**
 - **analog and digital monitor points**
 - **Threshold shifts of representative FETs**
 - **Node voltages**
 - **Clock lines**
 - **Measured conversion gain is 0.82 mV/electron**

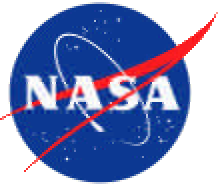


Experimental Approach



- **30 and 63 MeV protons incident at 45°**
 - Dewar modified to permit both proton irradiation with minimal energy loss and full radiometric capabilities.
- **The transient response of the bare ROIC also measured.**

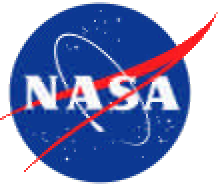
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Experimental Approach, cont.

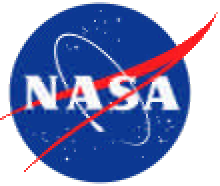
- **Data acquired at 40K using full frames readouts under low illumination (pixel dark currents <0.05 pA)**
- **Two readout timing conditions compared:**
 - **100% starring efficiency with integration occurring during readout.**
 - **50% starring efficiency with an interleave-then-integrate scheme with slightly elevated read noise**
- **Integration time is 39.54 ms for both readout methods.**
- **Each run consisted of a series of clear frames followed by sequences of multiple frames (either 87 or 40).**
 - **Clear frames allow baseline subtractions**
- **Measurements for >2 orders of magnitude in beam flux acquired**
 - **All fluxes low enough to provide sparse proton strikes**

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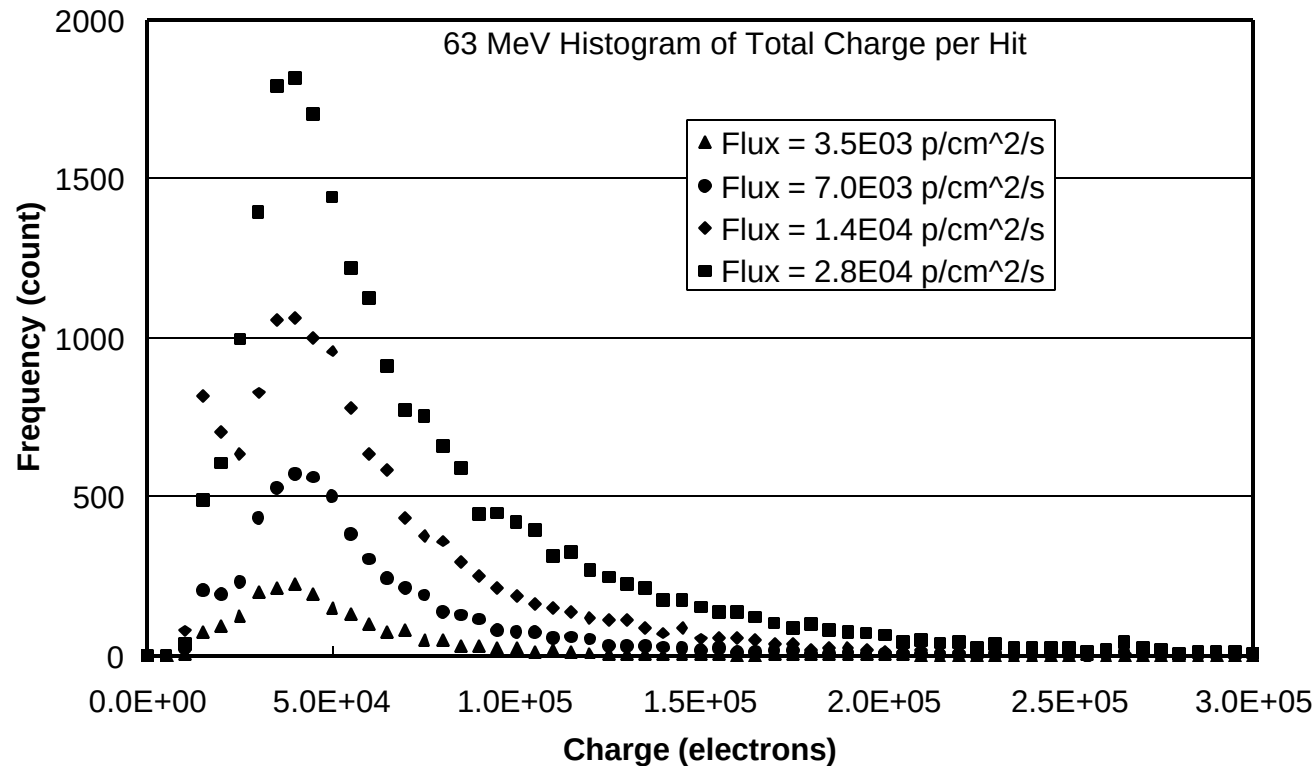


Data Analysis

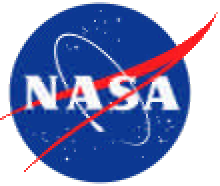
- **Considerable effort required to validate proton-struck pixels versus erratic pixels and normal pixels against a background of random noise.**
 - **The large number of data and clear frames were essential.**
 - **See paper for details.**



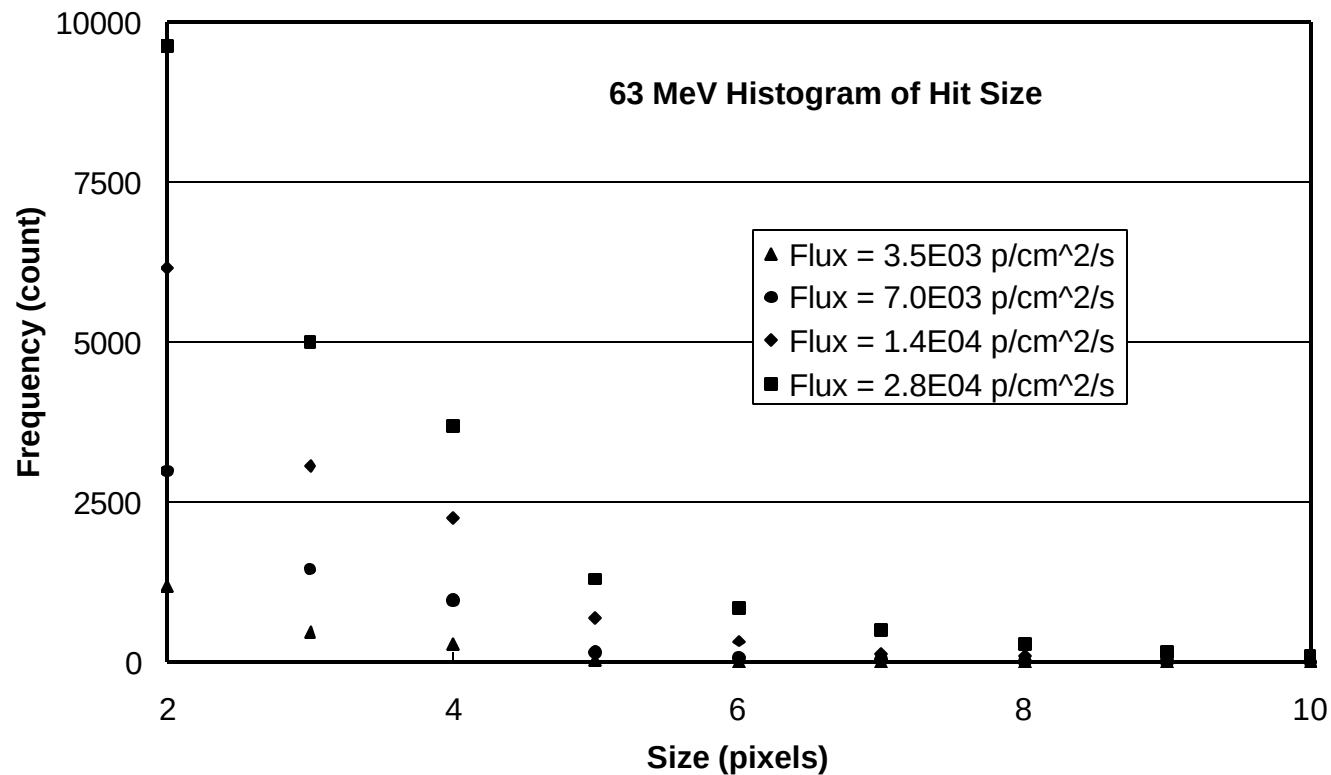
Histograms of Integrated Charge



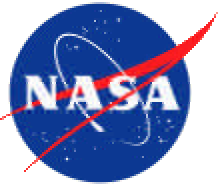
- Total charge is integrated over struck pixel and nearest neighbors (if their charge exceeds the noise floor).



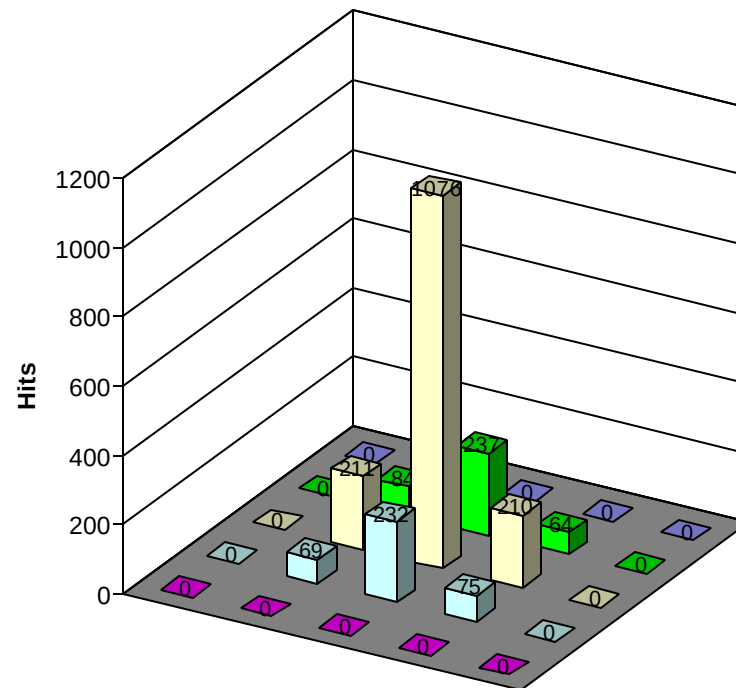
Histograms of Number of Pixels Affected



- No single pixels hits!
- Charge diffusion in field free regions of the detector array result in charge collection over several pixels (crosstalk).

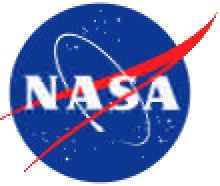


Stacked Line Traces



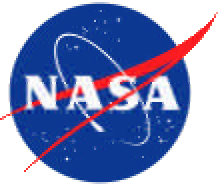
- **>1000 30 MeV proton hits are correlated to the central pixel and averages taken to reveal the relative number of pixels affected.**
- **High degree of symmetry, with pixels sharing a boundary being most affected. (Beam trajectory effects are absent.)**

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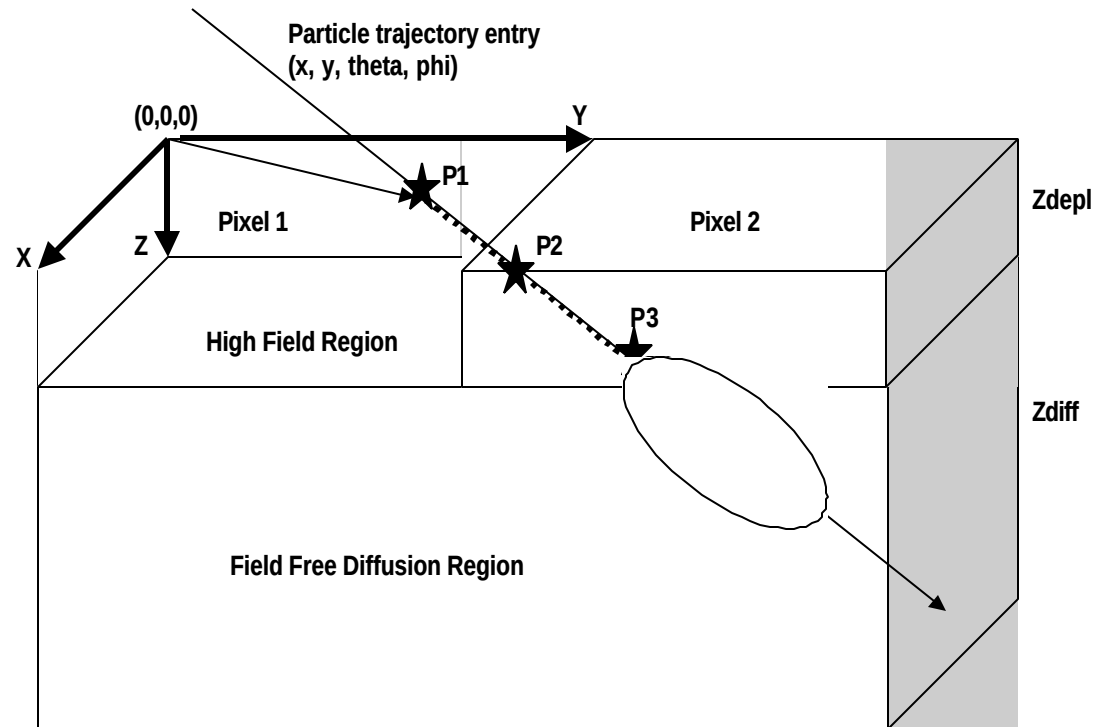


Charge Collection Modeling

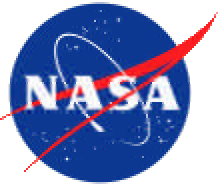
- **Charge collection model incorporates both analytical and Monte Carlo techniques to track ion deposited charge collected by both drift and diffusion.**
 - **We extend the previous model by incorporation of the field free region surrounding the central diode in each pixel.**
 - **Charge generated in field free regions are tracked until recombination, collection or collision with an inactive portion of the device.**
 - **Fidelity of model is strongly dependent on correct treatment of the diffusion characteristics of this device, hence these data provide benchmarking for model.**



Charge Collection Modeling, cont.



- Initial line source of minority carrier distribution based on particle LET and trajectory
- See paper for details and comparison to measured results.



Summary

- **30 and 63 MeV proton transient signatures were characterized for a LWIR HgCdTe array at 40K.**
- **Crosstalk is a significant issue with no single pixel hits observed.**
- **Diffusion in field free regions is the primary mechanism for charge spreading.**
 - **Directional effects due to beam trajectory not seen.**
- **Combine 30 and 63 MeV data will provide stringent test of diffusion modeling.**