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

Paul Marshall[1], John E. Hubbs[2], Douglas C. Arrington[2], Robert A Reed[3], George Gee[4], Jim C. Pickel[5], Rudolfo A. Ramos[2], and Cheryl J. Marshall[3]

- GSFC Radiation Effects Consultant
- Air Force Research Laboratory
- NASA Goddard Space Flight Center
- SGT, Inc.
- P,R&T, Inc.

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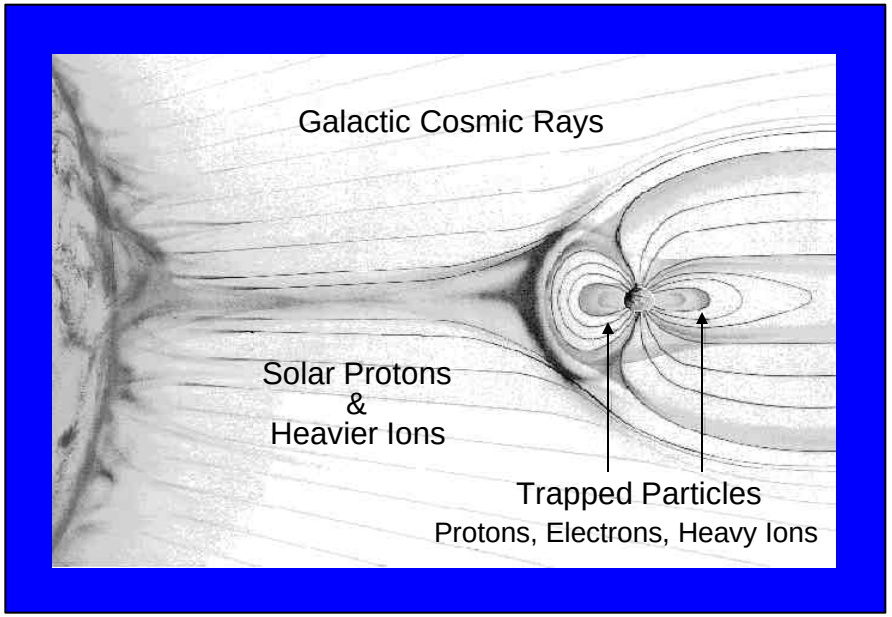
Outline

- **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**



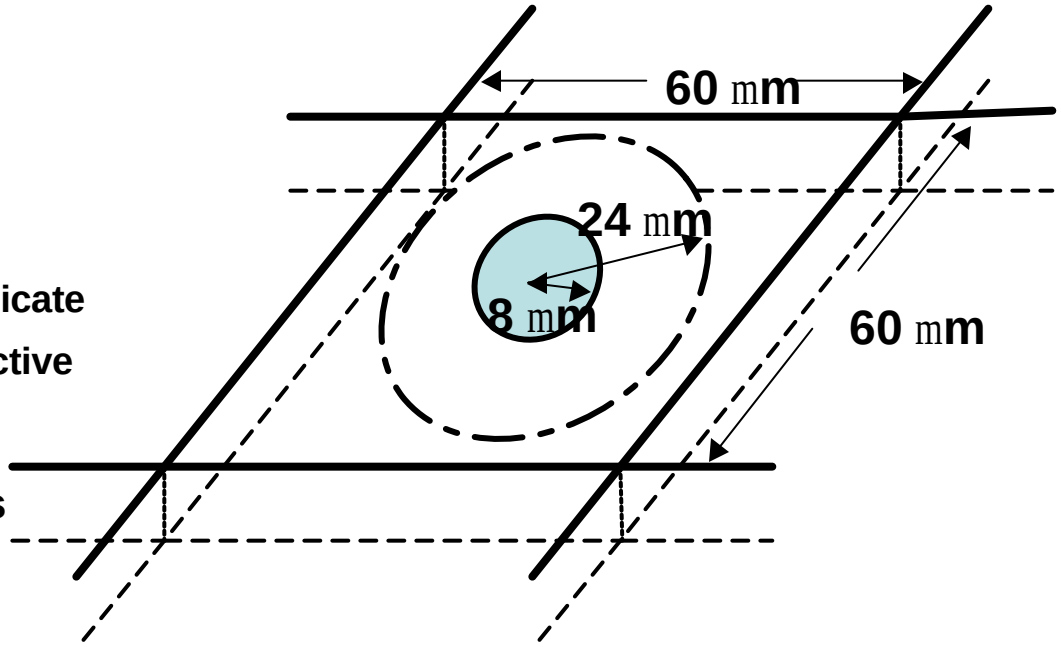
Introduction, cont.

- **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**

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

LWIR HgCdTe Array Description

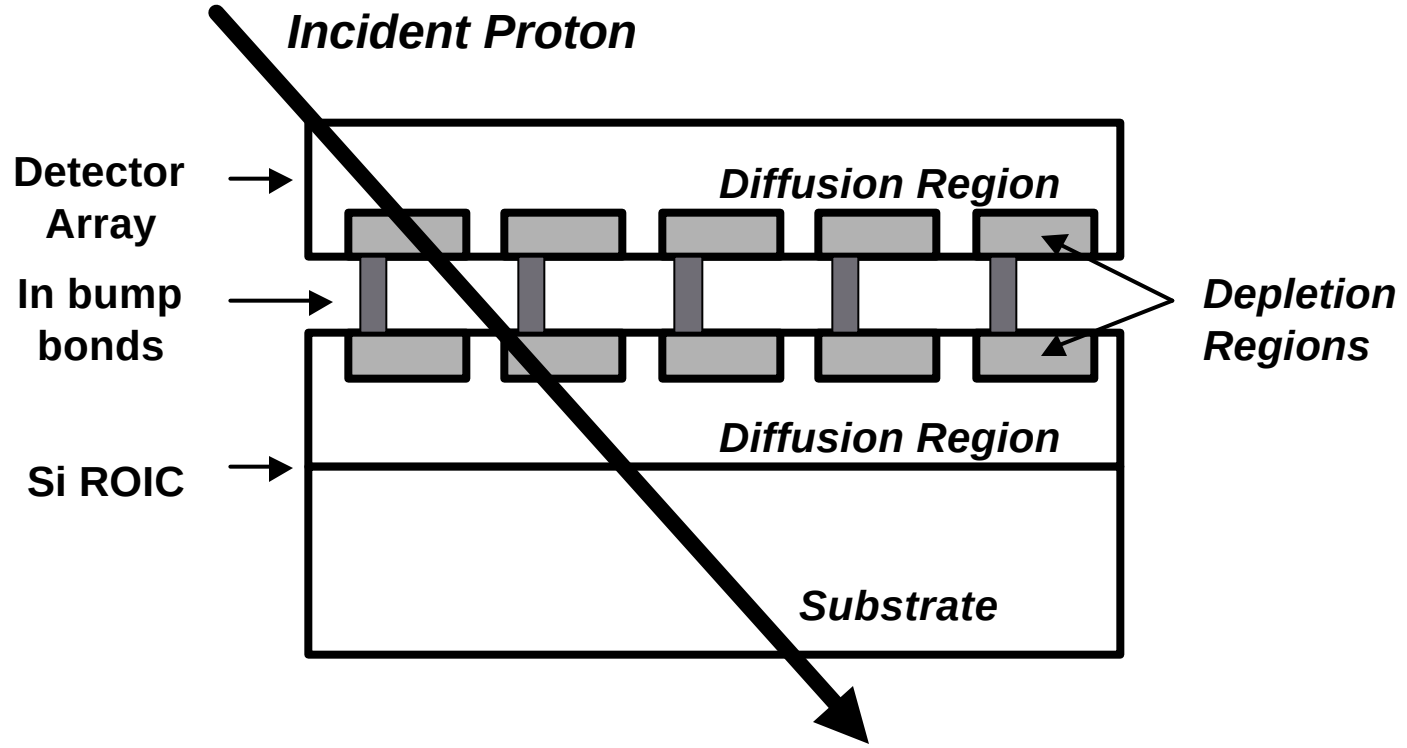
- **256 x 256 pixel array**
  - **Epitaxially grown multi-layer planarized heterojunction structure**
  - **Cutoff wavelength ~14 μm**
  - **Pixel pitch is 60 μm**
  - **Unit cell utilizes a central implanted diode for drift induce charge collection**
    - **Optical measurements indicate lateral collection 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 μV/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.**

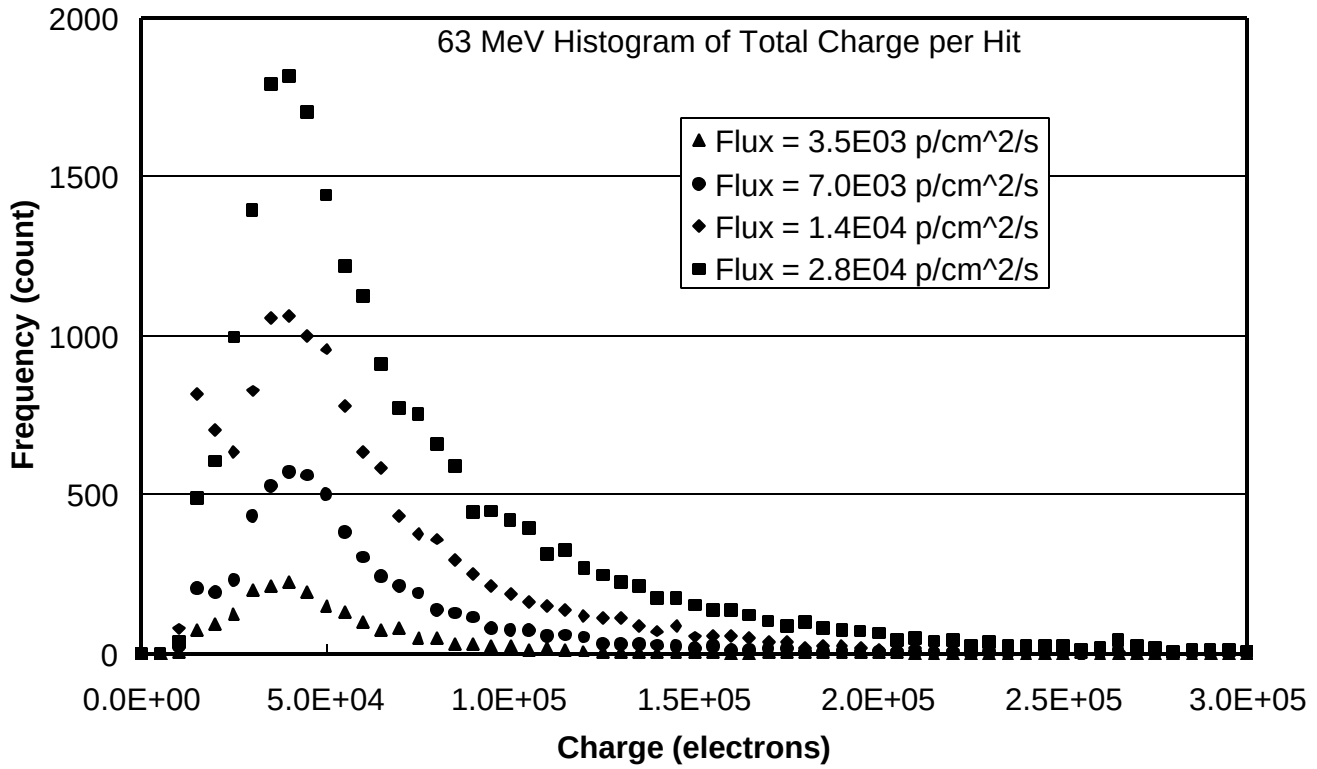
Experimental Approach, cont.

- **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**

Data Analysis

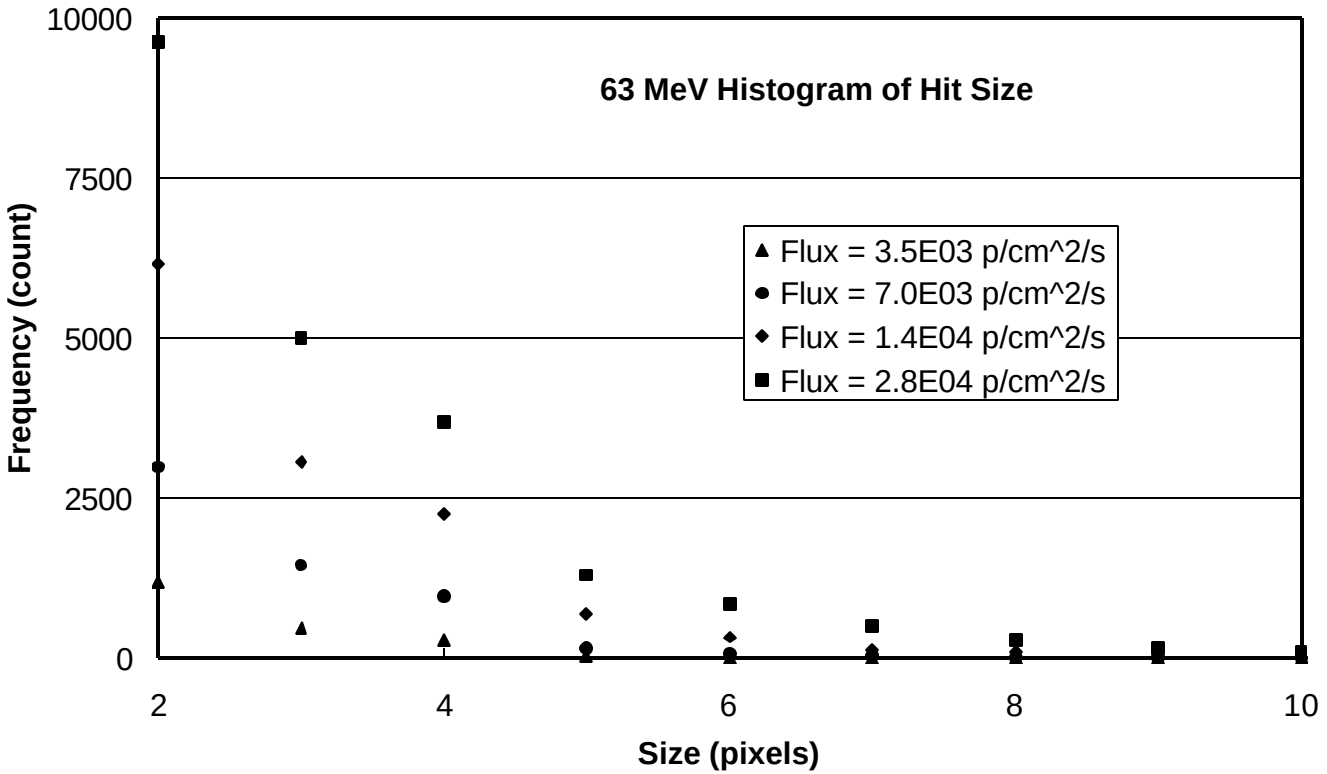
- **Considerable effort required to validate proton-struck pixels versus erratic pixels and normal pixels against a background of random noise.**
  - **The large number of data and clear frames were essential.**
  - **See paper for details.**

Histograms of Integrated Charge



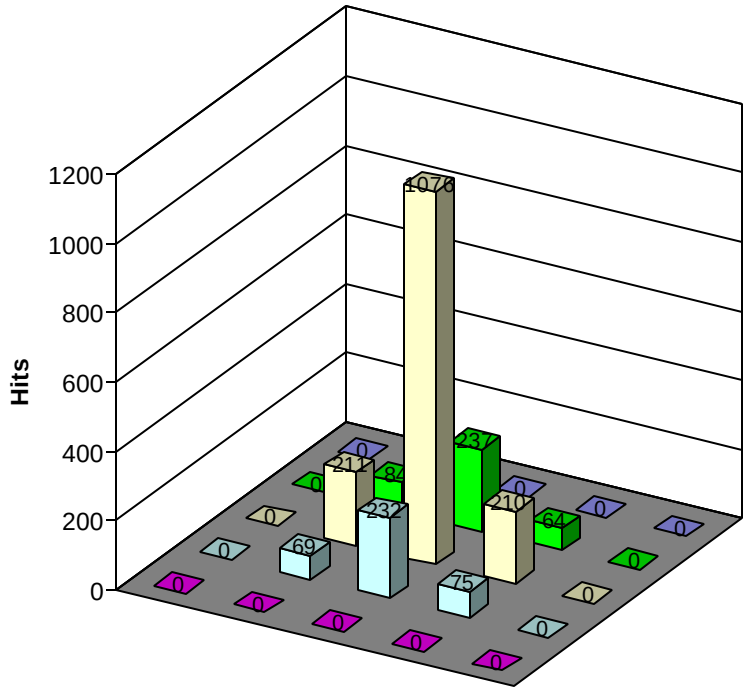
- **Total charge is integrated over struck pixel and nearest neighbors (if their charge exceeds the noise floor).**

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

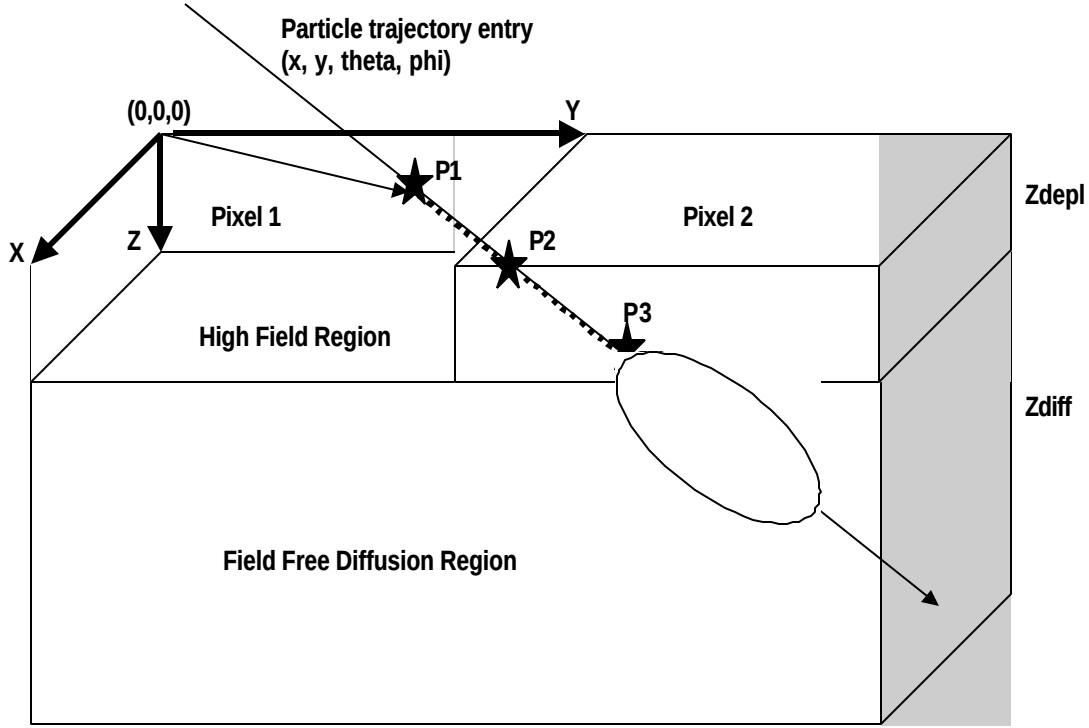


- **>1000 30 MeV proton hits are correlated to the central pixel and averages taken to reveal the relative number of pixels affected.**
- **High degree of symmetry, with pixels sharing a boundary being most affected. (Beam trajectory effects are absent.)**

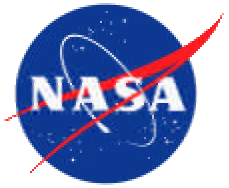
Charge Collection Modeling

- **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.**