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Geant4 Use at JPL

Insoo Jun

on behalf of Natural Space Environments Group
Jet Propulsion Laboratory, California Institute of Technology

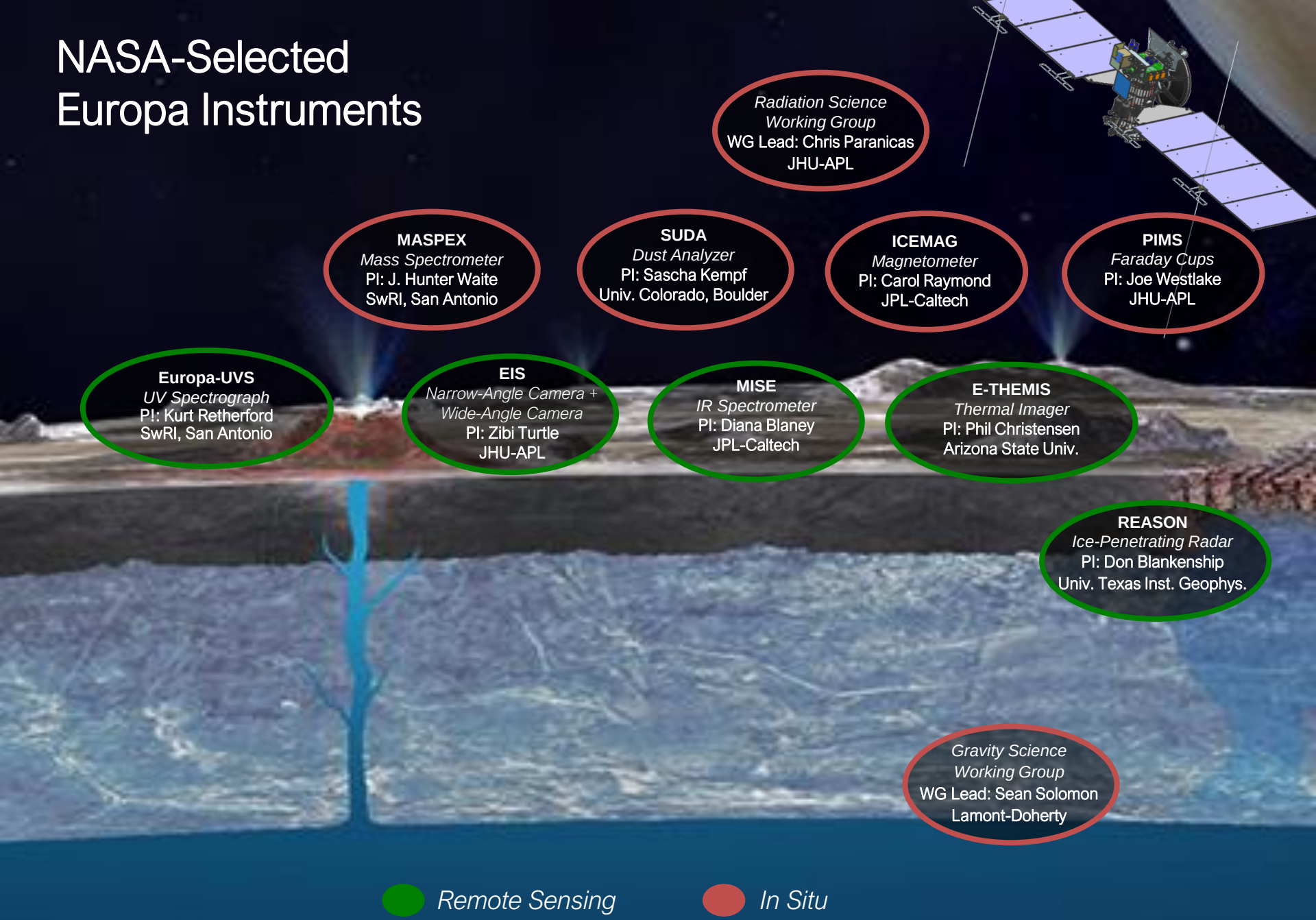
2017 Geant4 Space User's Workshop

At the University of Surrey

General Geant4 Usage at JPL

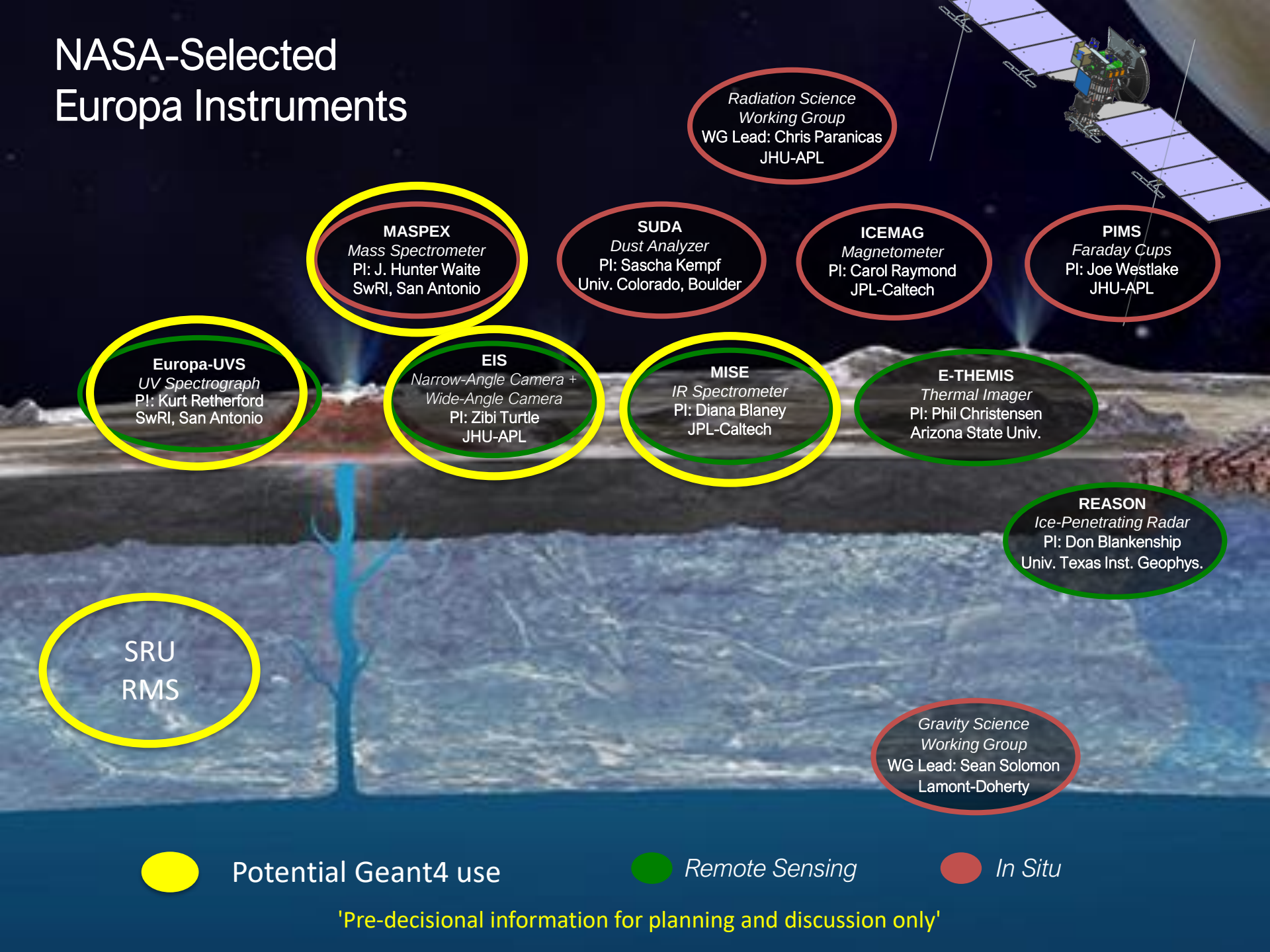
- Mission support
- Instrument design for proposed missions with high radiation environment
  - Europa Clipper Mission
  - Io Volcanic Observer
- For the last year or so, our Geant4 usage has been focused on simulating transients in imagers
  - e.g., fireflies in CCD

NASA-Selected Europa Instruments



'Pre-decisional information for planning and discussion only'

NASA-Selected Europa Instruments



'Pre-decisional information for planning and discussion only'

Characterization of the Response to Radiation of the APIC Camera

NASA's New Frontiers Homesteader Program

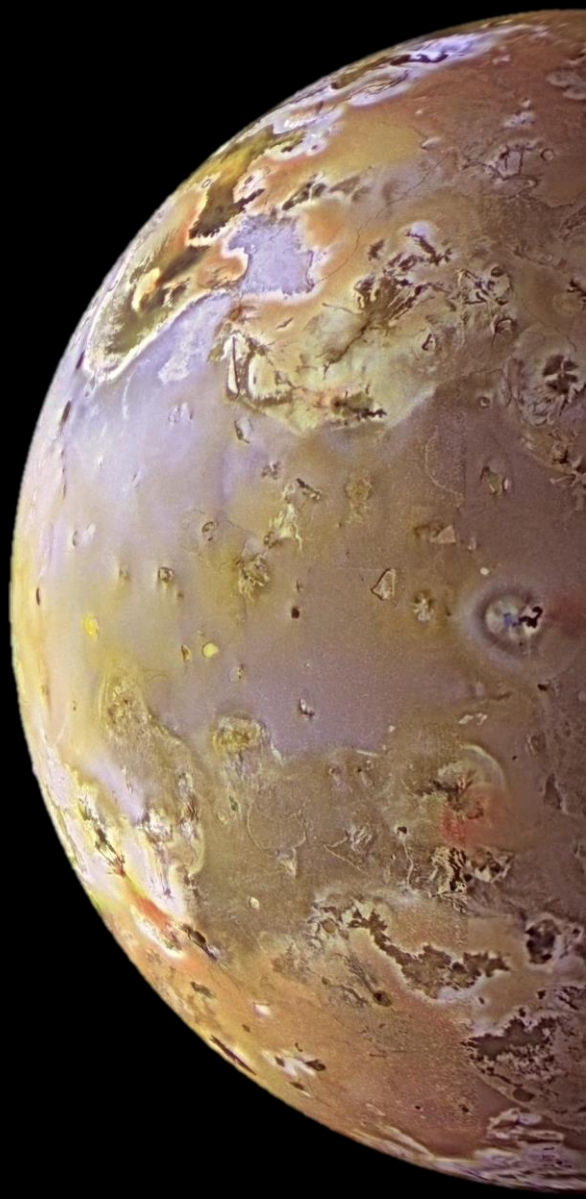
Maria de Soria-Santacruz Pich, Insoo Jun, Ed Riedel, Wousik Kim, and Ryan Park

Motivation

- The main science goal of the Advanced Pointing Imaging Camera (APIC) is to measure the tidal deformation of Io's surface from images taken from multiple spacecraft flybys. APIC is part of NASA's New Frontiers Homesteader Program.

- We studied APIC's transient noise (or "fireflies") response and compared it to the camera requirements. Tests and simulations were performed to retire all radiation risks.

- In this presentation we will show:
  - **One example of firefly beam-Line tests of detector**



Firefly Beam-Line Tests of Detector

TESTS OVERVIEW:

- We performed "firefly" electron and proton beam tests of the CMOSIS CMV20000 detector. The detector was mounted on a prototype driving board.
- Electron beam tests were performed at Brookhaven National Laboratory on April 2016:
  - Tests in vacuum with 45 MeV electron beam operated at 1.5 Hz
  - The exposure time was 300 ms at 3 fps
  - Total of 33 runs in different configurations: Two shielding materials (Al and W-Cu) with different thicknesses, four beam charges, two orientations
- Proton beam tests happened at the UC Davis Crocker Nuclear Laboratory on June 2016:
  - Tests in air with 64 MeV proton beam
  - The exposure time was 50 ms at 1 fps
  - Total of 29 runs in different configurations: Two shielding materials (Al and W-Cu) of different thicknesses, three flux levels, two orientations

Simulation

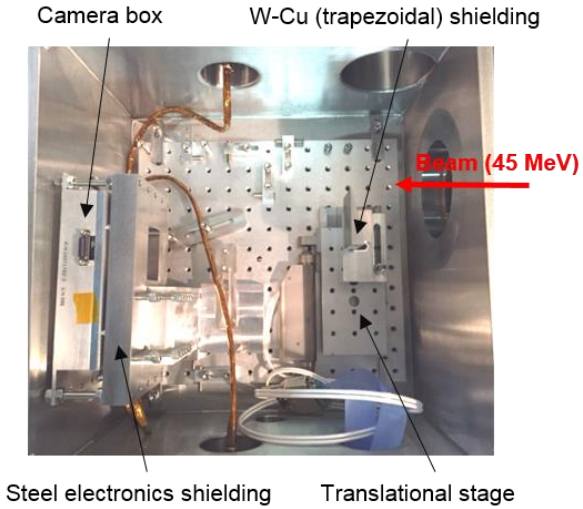
- We performed Monte Carlo radiation transport simulations using the Geant4 code of the experimental setup, and compared experimental and simulation results
- The purpose of the tests was to benchmark radiation transport simulations with mono-energetic beams <u>to gain confidence on the predictive capability of the tool(s)</u> so that we can use them to design a camera capable of surviving the mission expected environment and satisfying instrument requirements without performing typically expensive and time-consuming tests in an actual space-like environment

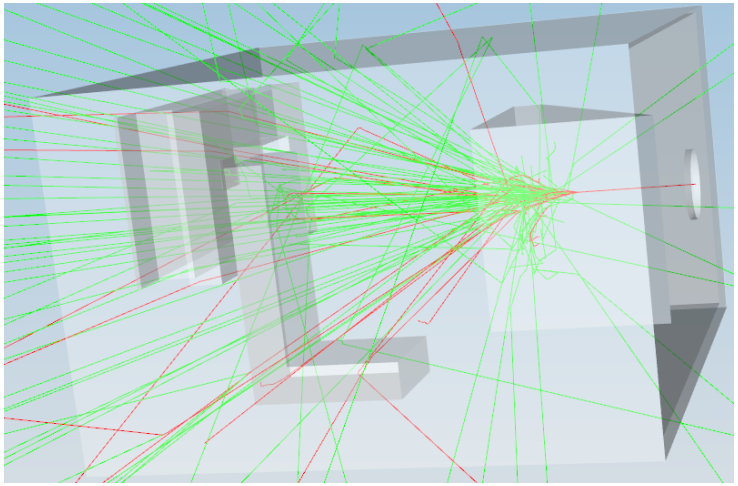
- Developed detailed CAD model of experimental setup using SolidWorks and assigned materials using FASTRAD
- GDML input to Geant4 was carefully debugged
- Detector simulated as: Coverglass (SiO_2, 0.7 mm) + vacuum gap (1.03 mm) + sensitive target (Si, studied the sensitivity to thickness) + substrate (Si, 0.72 mm)
- Included additional components to the board to study their secondary generation, but the effect was found to be negligible
- Performed checks with simplified geometries as well as using TIGER

Firefly Beam-Line Tests of Detector

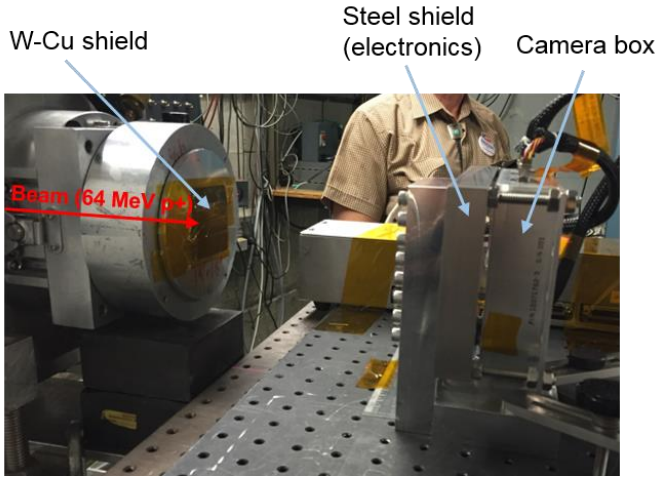
Jet Propulsion Laboratory
California Institute of Technology

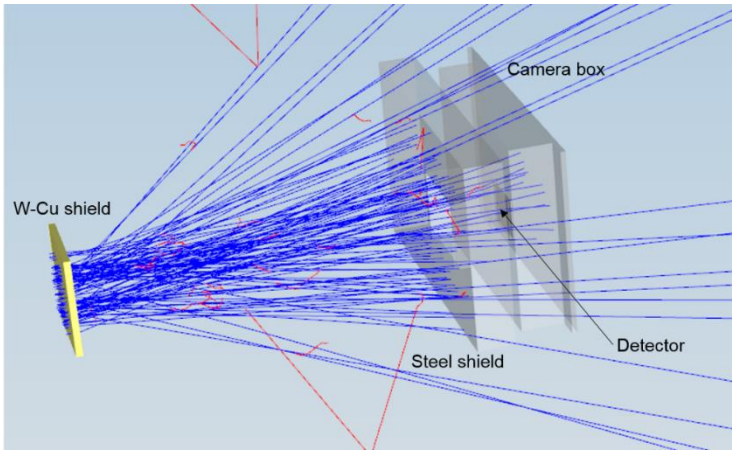
BNL Electron Beam-Line Tests and Simulations





UC Davis Proton Beam-Line Tests and Simulations

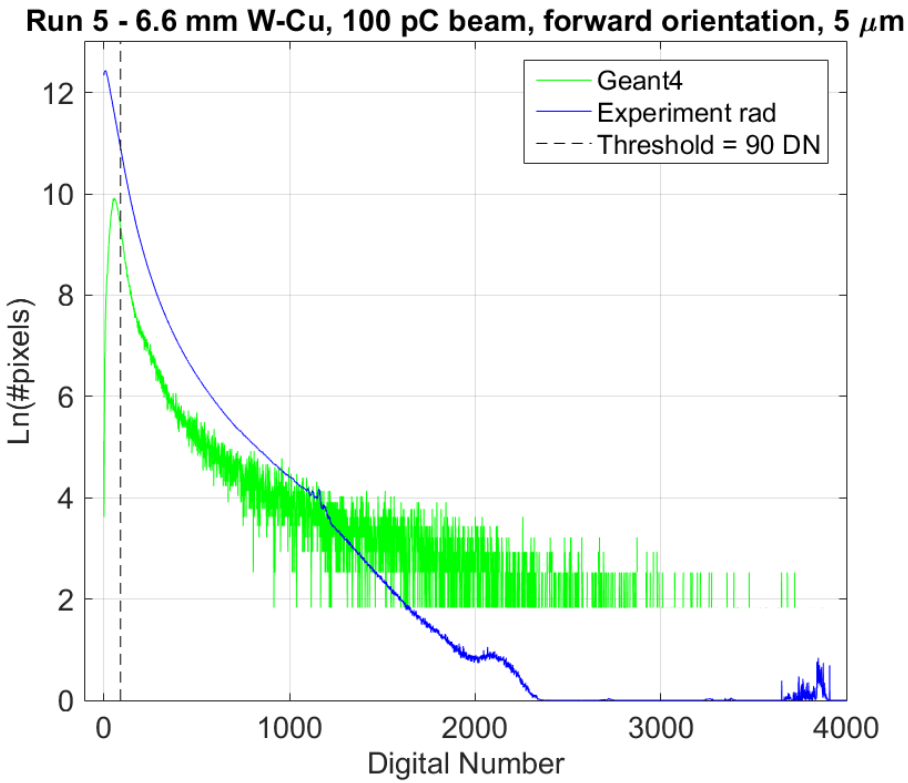




Firefly Beam-Line Tests of Detector

- Discrepancies were observed between test and simulation results:
  - The detector response presents an unexpected behavior with increasing beam flux in the experimental data
  - Significant discrepancies observed for high-Z shielding materials (tungsten) compared to aluminum shielding
  - Discrepancies at low Digital Numbers corresponding to secondary generation

- Separate test and simulation benchmarking efforts are currently in place to understand the issues above



Worst-case discrepancy between test and simulations (W-Cu shield at 100 pC)

Lessons-Learned

- Testing is important to understand the detector behavior when irradiated and the capability of radiation transport tools

- Simulation of detector behavior also requires deep understanding of how the tool(s) treats radiation transport, especially when secondary particles are important (e.g., thick shield)

- Good knowledge of the detector's geometrical/material makeup, driving electronics, sources of potential dark noise, and operation is essential to correctly interpret firefly test and simulation results

Using the Galileo Solid-State Instrument (SSI) as a Sensor for the High-Energy Electron Environment

Geant4 Space User's Workshop

April 2017

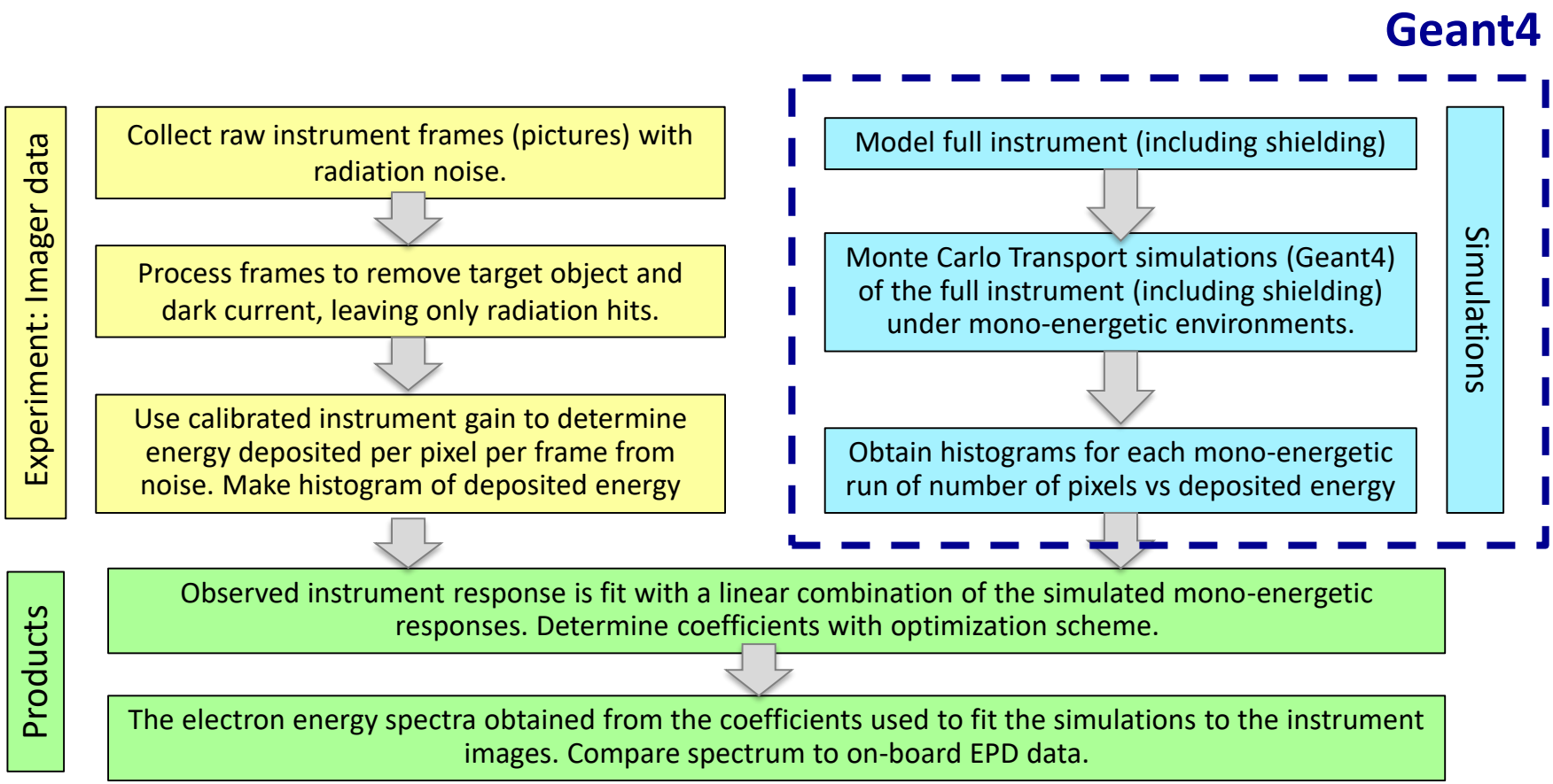
A. Carlton, MIT

Project Overview

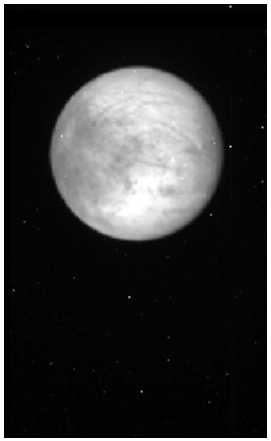
- Developing a method to use CCD imagers to sense the high-energy (>1 MeV electron) environment by comparing detector noise to charged particle transport simulations
- Supporting a graduate student thesis (A. Carlton, MIT)

Approach

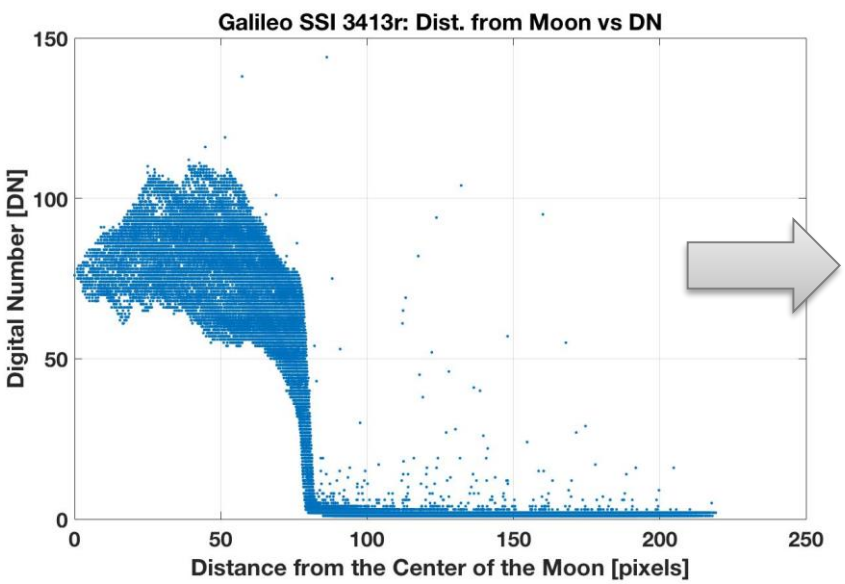
- Use Galileo spacecraft Solid-State Imager (SSI) data
  - Galileo has an energetic particle detector for validation

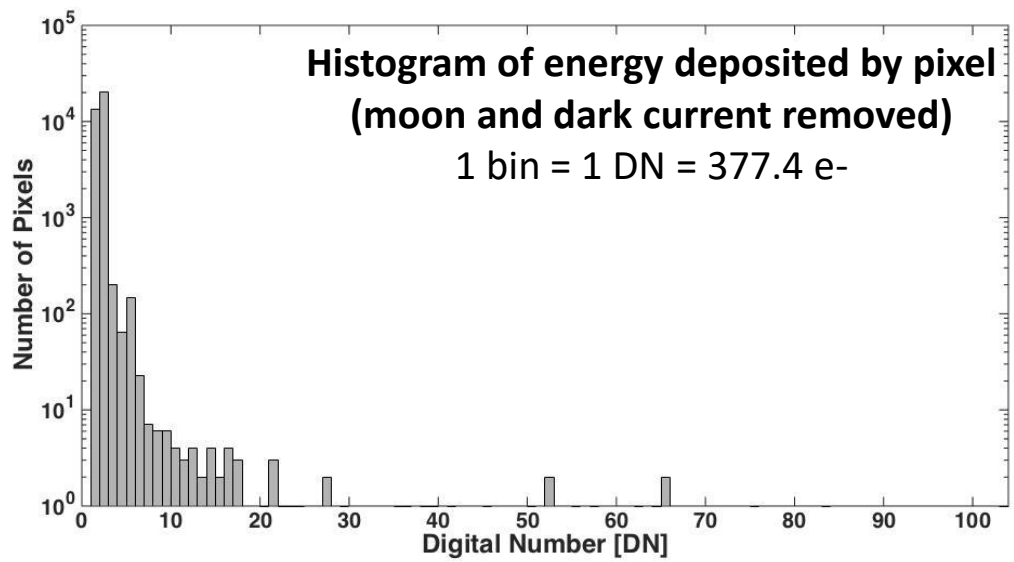


Energy Deposited in SSI Flight Data

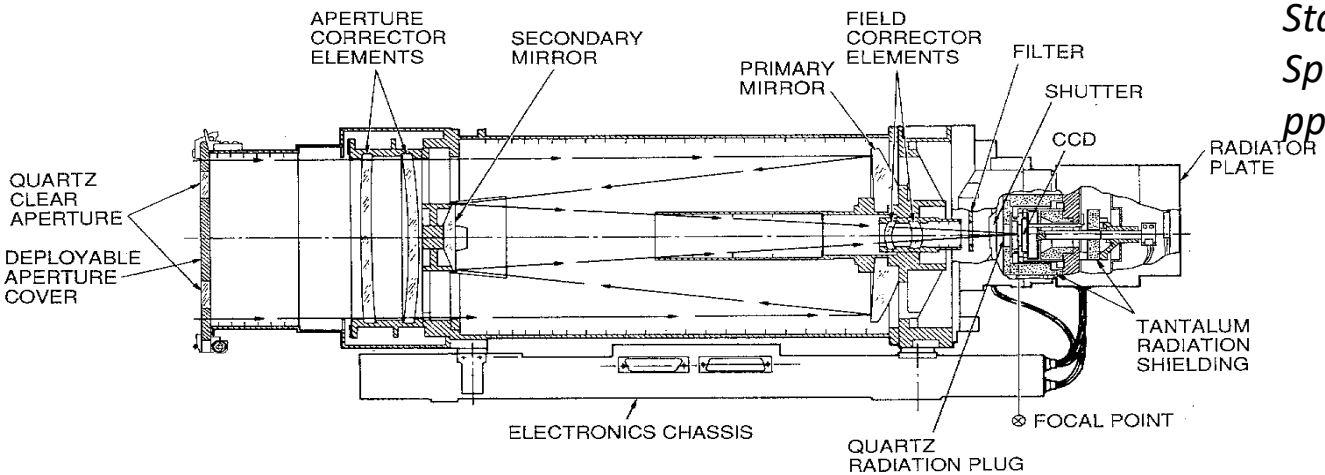


Original Galileo SSI Image
Orbit: 33
Target: Europa
Image Time: 18-Jan-2002 15:16:32
Duration: 195.83 ms + 8.667 s
Fills 400 x 240 pixels





Use of Geant4: Modeling Geometry



Belton et al., "The Galileo Solid-State Imaging Experiment," Space Science Reviews, Vol. 60, pp. 413-455, 1992.

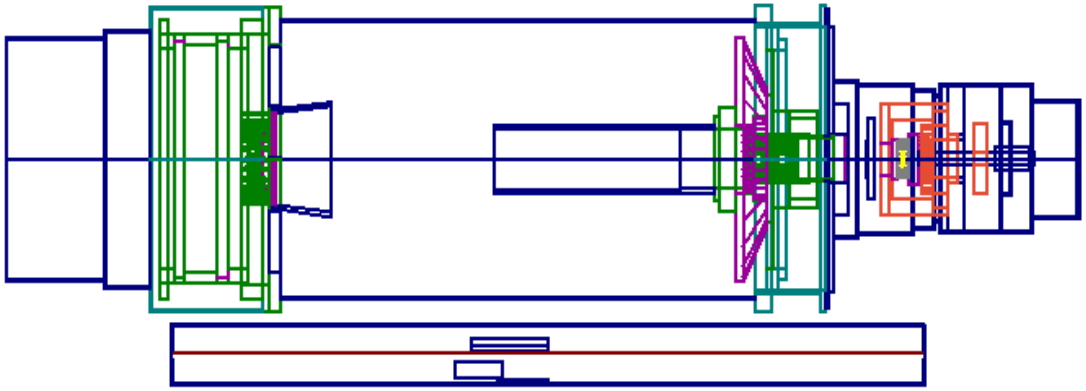
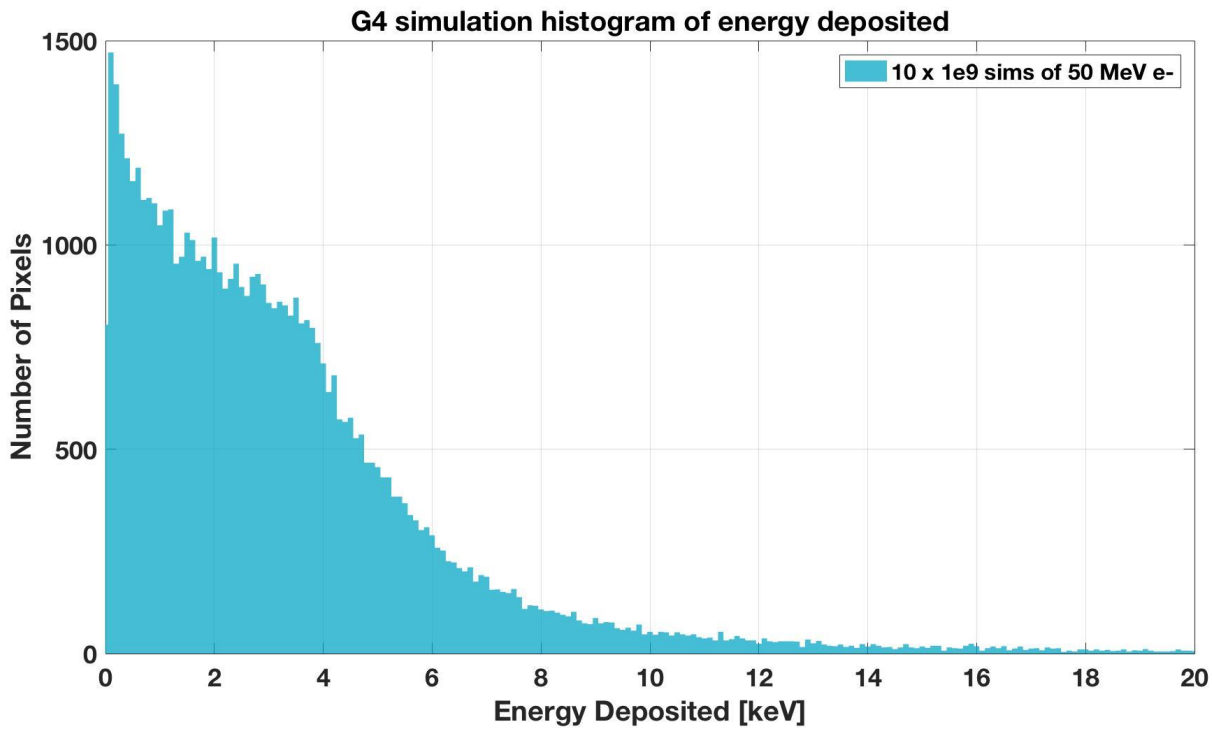


Image credit: A. Carlton

Detector construction in Geant4 of SSI geometry, visualization in HepRep.

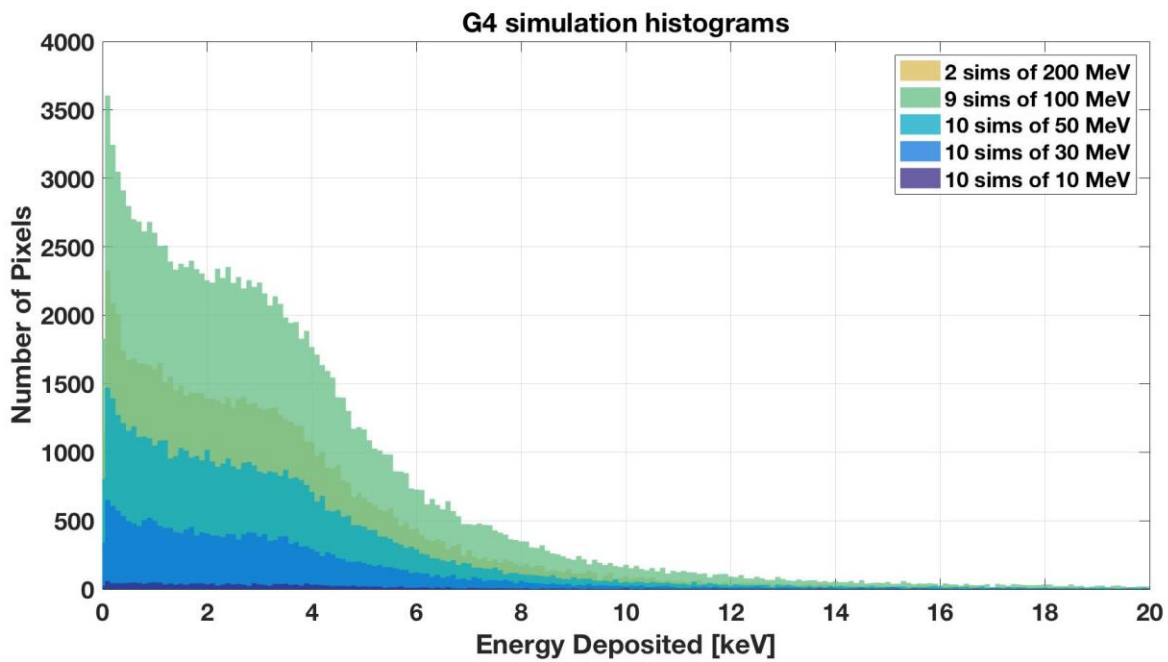
10 Geant4 simulations of 1E9 50 MeV electrons

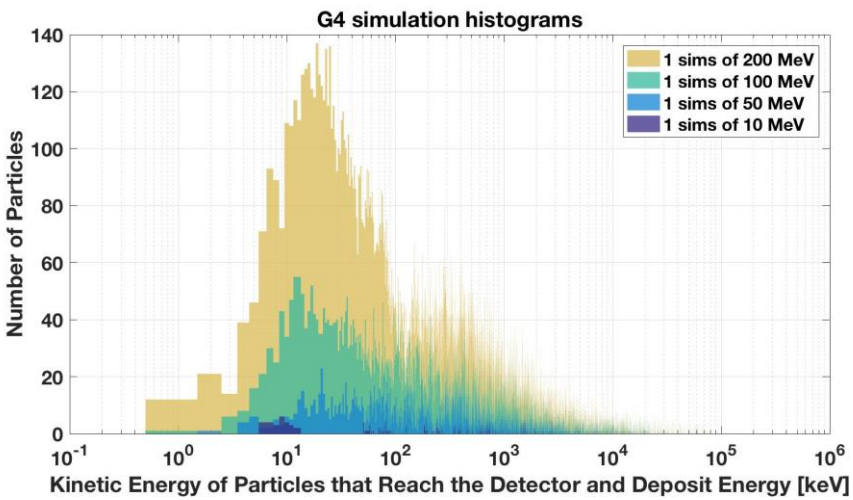
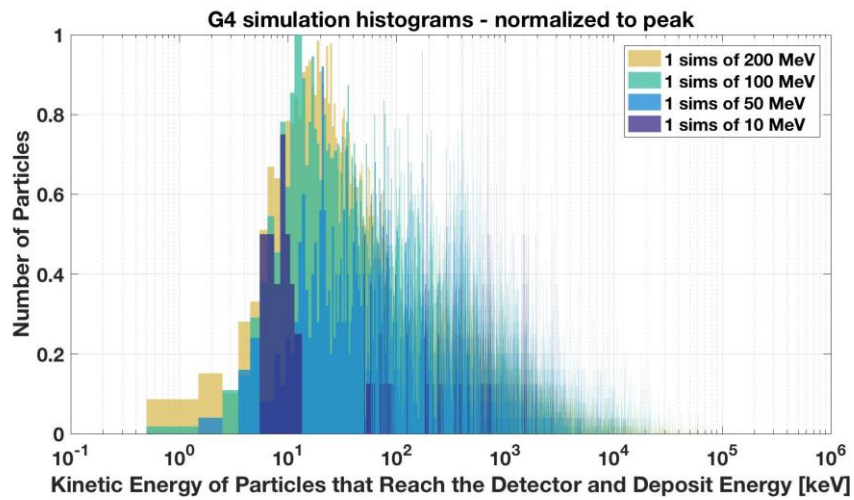
- Example of building a histogram from Geant4 simulation results: energy deposited on the detector



Mono-energetic Simulations with SSI

- In order to build a set of basis functions for fitting the flight data, our goal is to distinguish the shapes of the energy deposition curves from mono-energetic simulations.



Findings to date

- Most energy depositions are due to ~10 keV to ~1 MeV electrons, no matter what the incident electron energy
- Start to see a lot more energy depositions for 50 MeV than for 10 MeV
  - May be able to determine an integral channel from the SSI somewhere between 10 and 50 MeV