



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of Technology

Space Radiation Effect Experiments for Jovian mission

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Europa Clipper Mission Concept - Mission to a Jupiter's Icy Moon

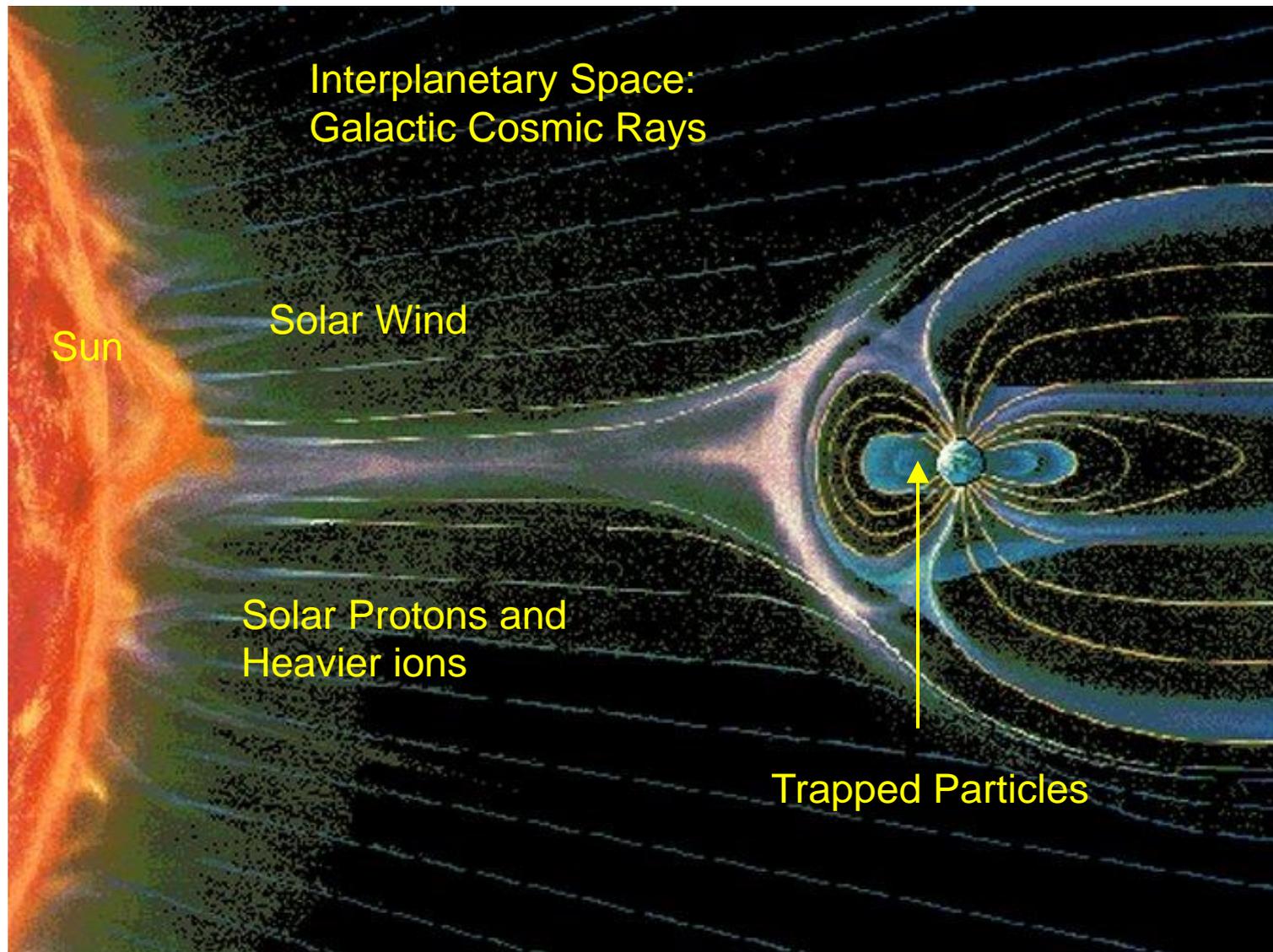
The Europa Clipper

Proposed Launch: 2022
Jovian Orbit Insertion: 2025





Space Radiation Environment





Jupiter's Magnetosphere

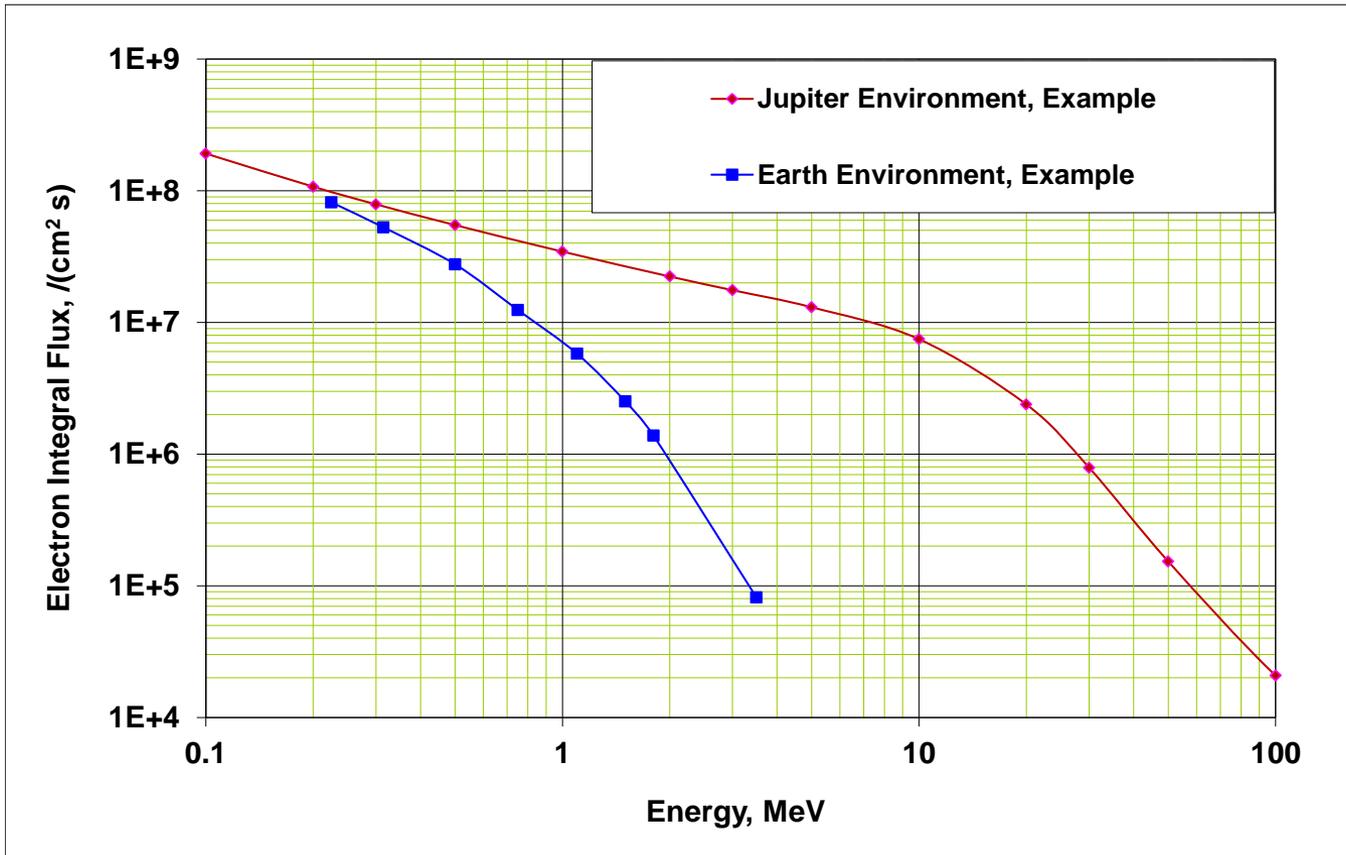
	Earth	Jupiter
Equatorial radius (km)	6.38×10^3	7.14×10^4
Magnetic moment (G-cm ³)	8.1×10^{25}	1.59×10^{30}
Rotation period (hr)	24.0	10.0
Aphelion/perihelion (AU)	1.01/0.98	5.45/4.95

- Jupiter is roughly 10 times the size of the Earth while its magnetic moment is 20,000 times larger.
- As the magnetic field at the equator is proportional to the magnetic moment divided by the cube of the radial distance, the Jovian magnetic field is proportionally **20 times** larger than the Earth's.

*The energy and flux levels of **trapped** particles in the Jovian system can be much higher than those at the Earth or in the interplanetary space*

Space Radiation Effect Experiments

- The Jovian radiation environment is dominated by high-energy electrons.
- It is very critical to do experiments at a facility with high energy electron beams with an energy of 50 – 100 MeV to simulate the space radiation effects at Jupiter.
- We like to do experiments on Europa Clipper spacecraft's subsystems and payloads (instruments) at AFT.





Space Radiation Effects

- **Total Ionizing Dose (TID)**
 - Cumulative long term damage effect from ionizing energy deposition mainly due to protons and electrons
- **Displacement Damage Dose (DDD)**
 - Cumulative long term damage effect from non-ionizing energy deposition mainly due to protons, electrons, and neutrons
- **Single Event Effects (SEE)**
 - Event caused by a single charged particle (heavy ions and/or protons) traversing the active volume of microelectronic devices
- **Transient or Secondary radiation**
 - Transient noises on sensors from energetic particles
- **Charging (Surface and Internal)**
 - Electrons deposit charges in material which induces electrostatic discharge



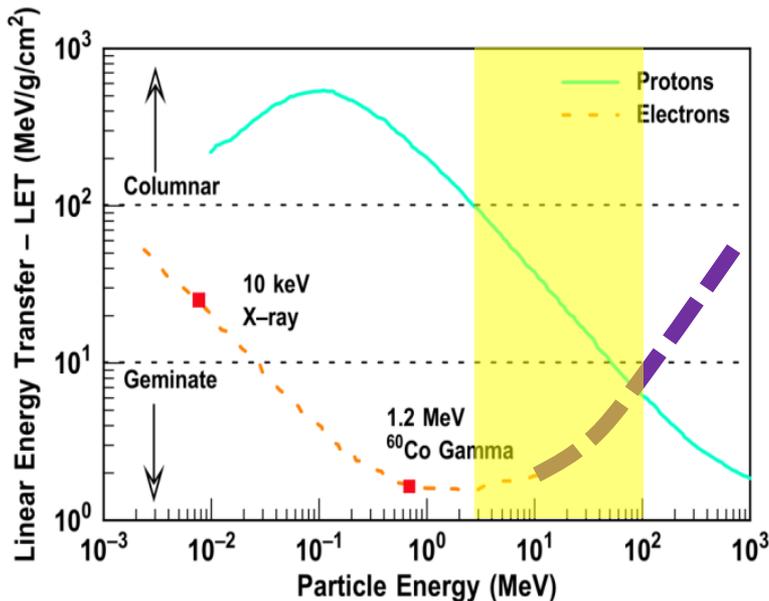
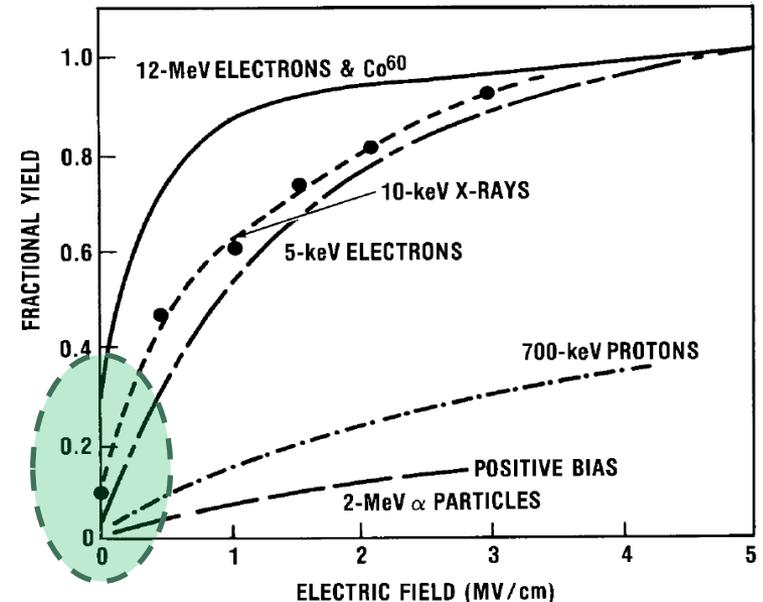
Proposed Space Radiation Effect Experiments

1. (1 week) Comparison of the **total ionizing dose (TID)** charge yield with different environments.
 - Co-60 vs. high energy electron
2. (1 week) The experiment of the effective **displacement damage dose (DDD)** due to high energy electrons.
 - Normally electron contribution to displacement damage is small.
 - However, at Jupiter, electron will be a major contributor of displacement damage on, for example, solar panel due to its high energy and abundance.
3. (1 week) **Transient Noise** evaluations of the instruments with sensors (imaging sensors and mass spectrometer) at high energy electron environments
4. (1 week) Basic shielding effectiveness test
 - Typically we rely on Monte Carlo simulation for shielding design, however verification of the simulation for the high energy electron is lacking.
 - Electron transmission experiments for various shielding thicknesses for different materials.

Charge Yield (TID effect)

Comparison between electron and Co-60

- Fact:** The effect on device is proportional to TID and (fractional) charge yield.
- Status:** Total Ionizing Dose tests have been done using Co-60 source.
- Question:** is Co-60 testing representative of the wide energy spectrum of electron at Europa?
- Objectives:** to bound electron *charge yield* under low field conditions for bipolar technologies



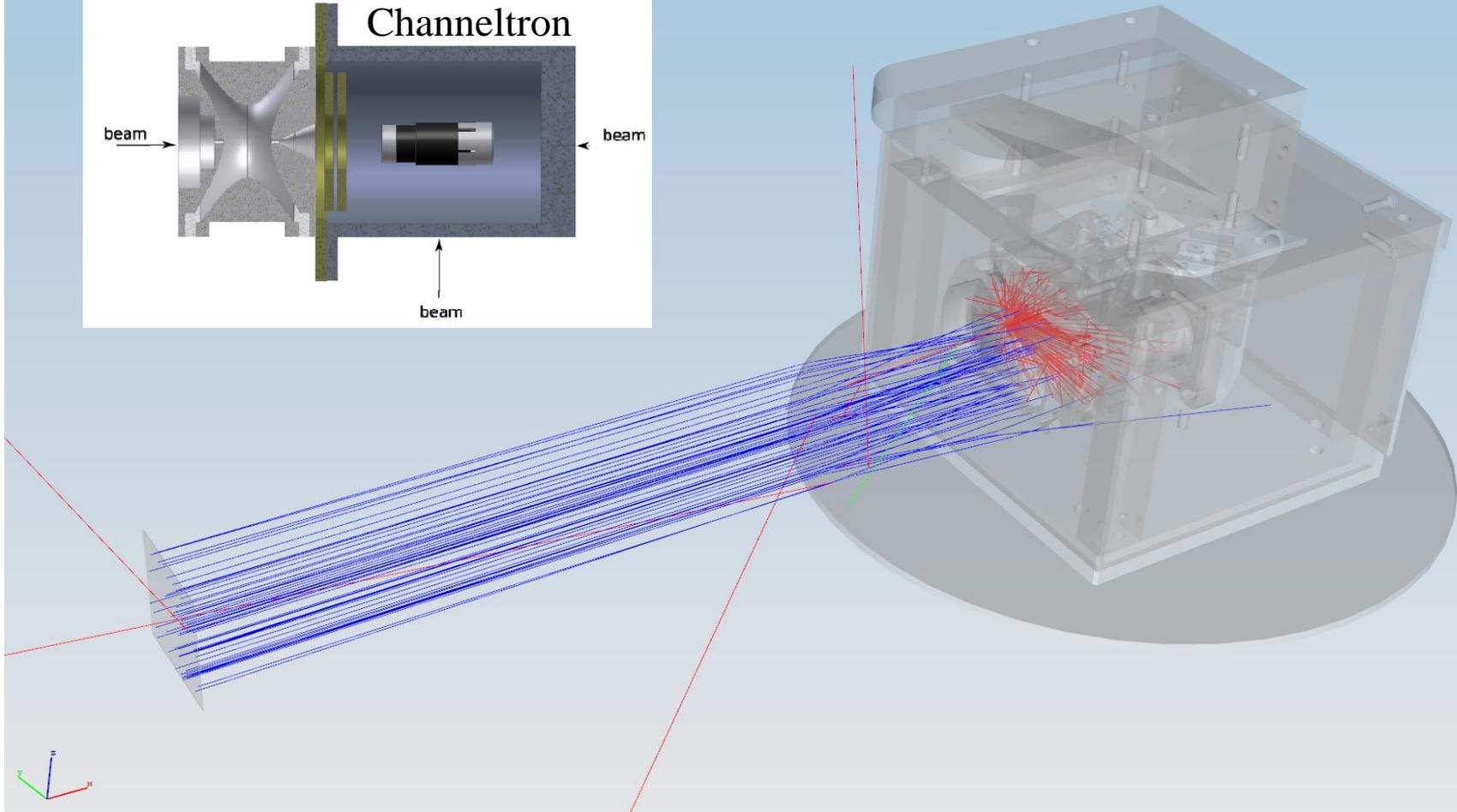
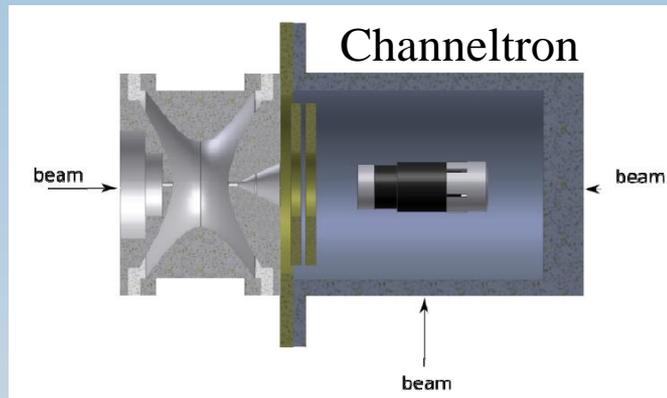
Degradation and ELDRS (Enhanced Low Dose Rate Sensitivity) is affected by Charge Yield

- The charge yield process for high energy electron is unknown
- Experiments at high energy facilities are needed.

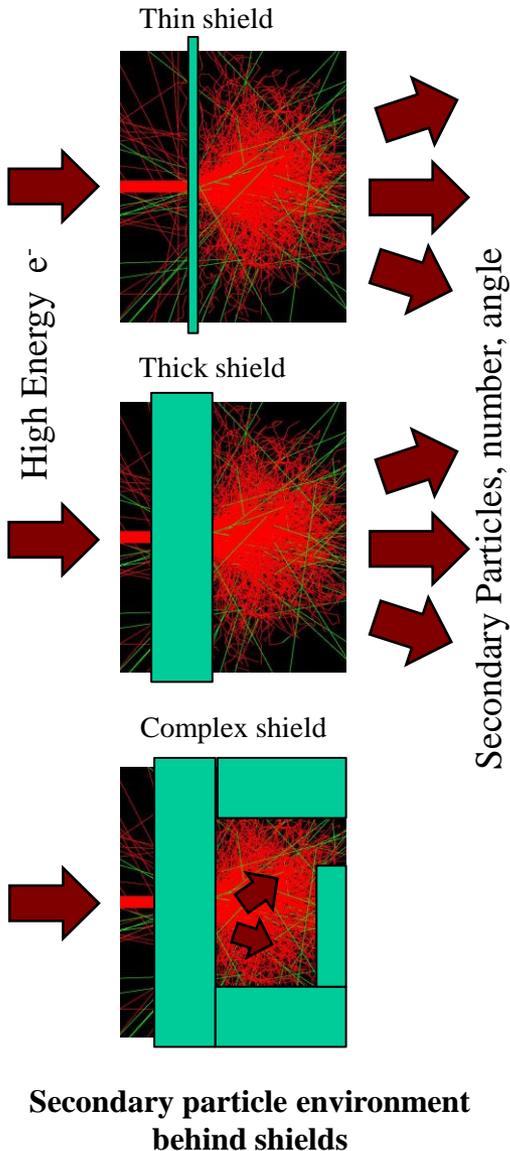


Transition Noise Test for Imaging Instruments

Basically repeating previous experiment but using different instruments with different types of sensors (CCD, CMOS, or Channeltron)



Shielding Benchmarking Test



Objective: Validate physics-based models by experiment.

- The secondary particles behind shields
- Obtaining spectral and angular distribution

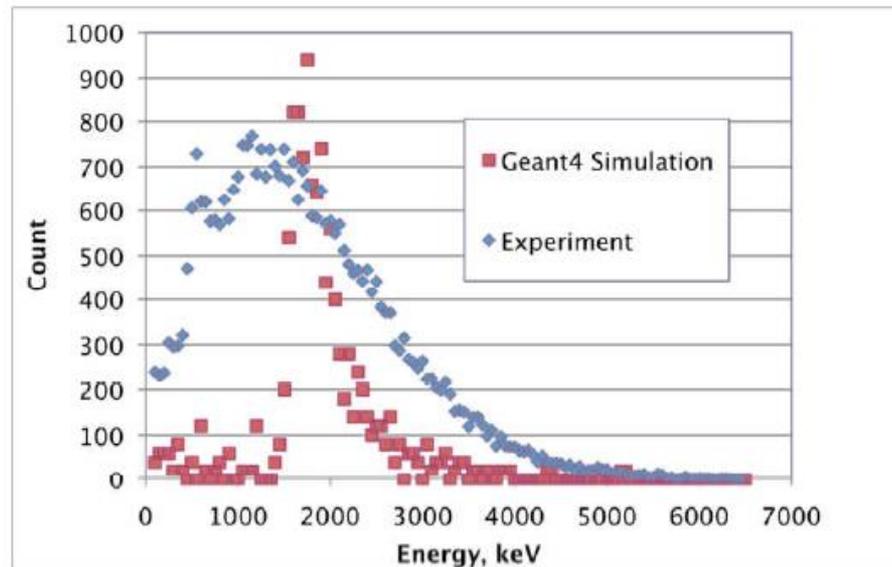
Thin and Thick Slab Shielding

- Develop models and methodology based on Geant4 and MCNPX to describe radiation environment behind the shield
 - Model outputs provide particle type, energy spectrum and deposited energy
- Conduct beam tests at ATF facilities to verify the methodology and models for the interaction of high energy electrons with slab shields
- Energy spectrum measurements for secondary particles (electron and photon)
- Angular distribution from several detector positions.



Challenges

- Low intensity pulse
- Broad pulse width for space-like dose rate
- Simulate the space spectrum
- Angle dependent energy spectrum measurements for secondary particles
- Previous result



Energy deposition spectra on Lithium-drifted Silicon detector.
23 MeV electron beam, Idaho Accelerator Center