15th Topical Seminar on Innovative Particle and Radiation Detector

Beam tests of a prototype of the Radiation Hard Electron Monitor to be flown in the JUICE mission

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IPRD15 14-17 October 2019 Siena, Italy

Jupiter Icy Moons Explorer

Cosmic Vision
ESA next L-class Mission

What are the conditions for planet formation and emergence of life?

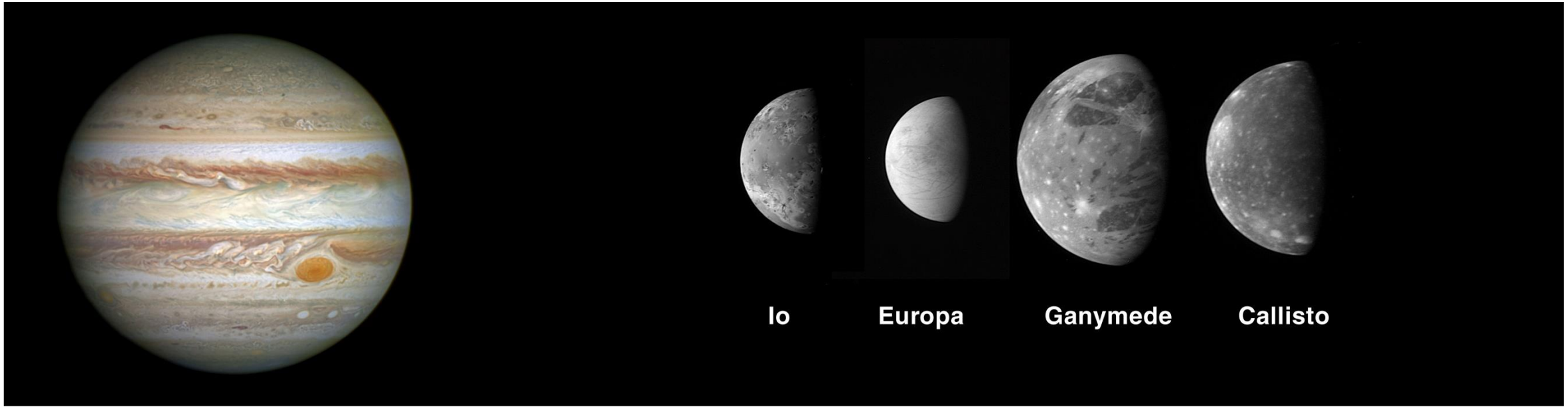
- Emergence of habitable worlds around gas giants

How does the Solar System work?

- Jupiter system as an archetype for gas giants

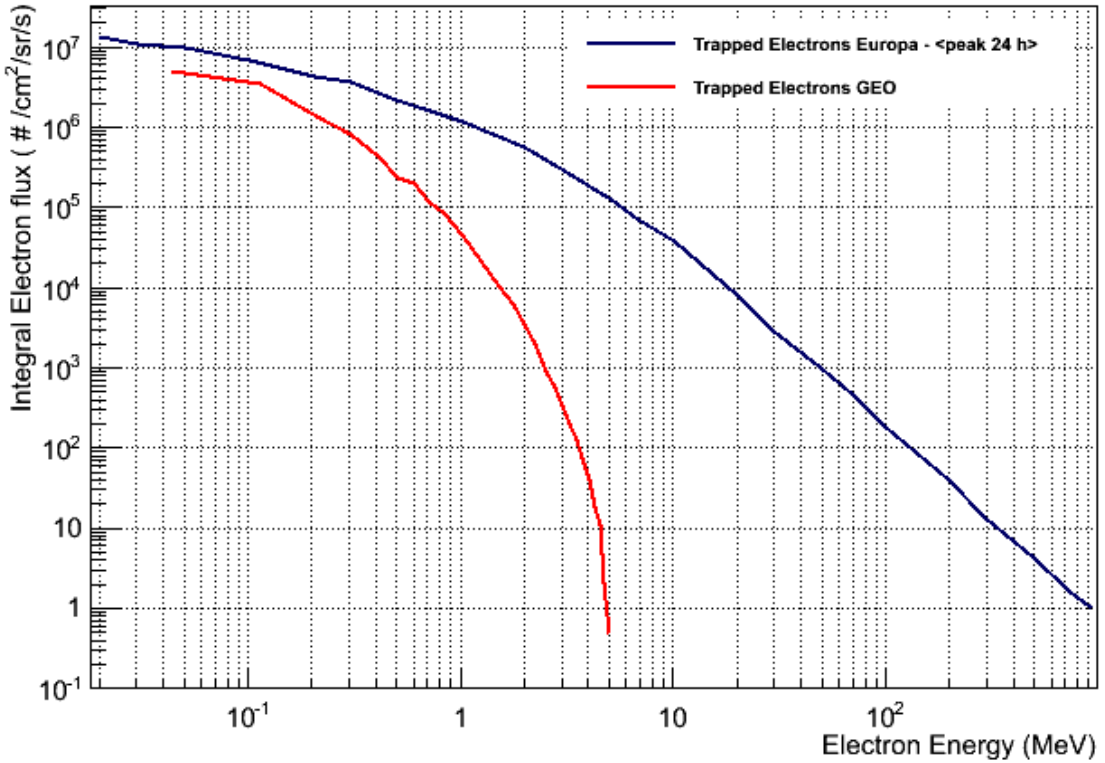
Launch in 2022

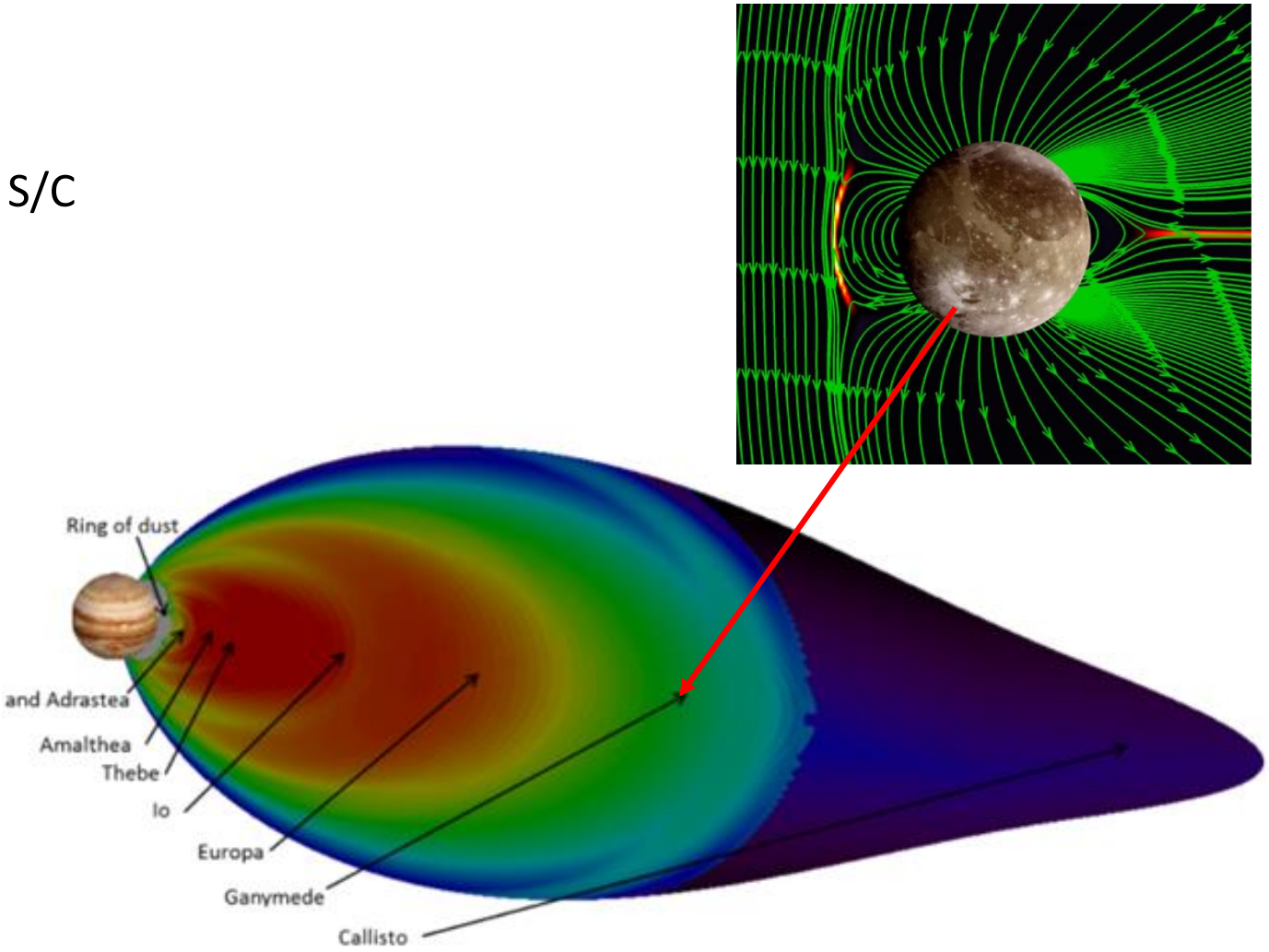
Arrival in 2030



Jovian Trapped Particles

- ❑ Different source than the Van Allen belts – Io
  - Jupiter is a large accelerator
  - Large fluxes of electrons with E>10 MeV
- ❑ Only long-term measurements made by Galileo S/C
  - Electron data up to 11 MeV
  - Long-term proton data up to 1.25 MeV

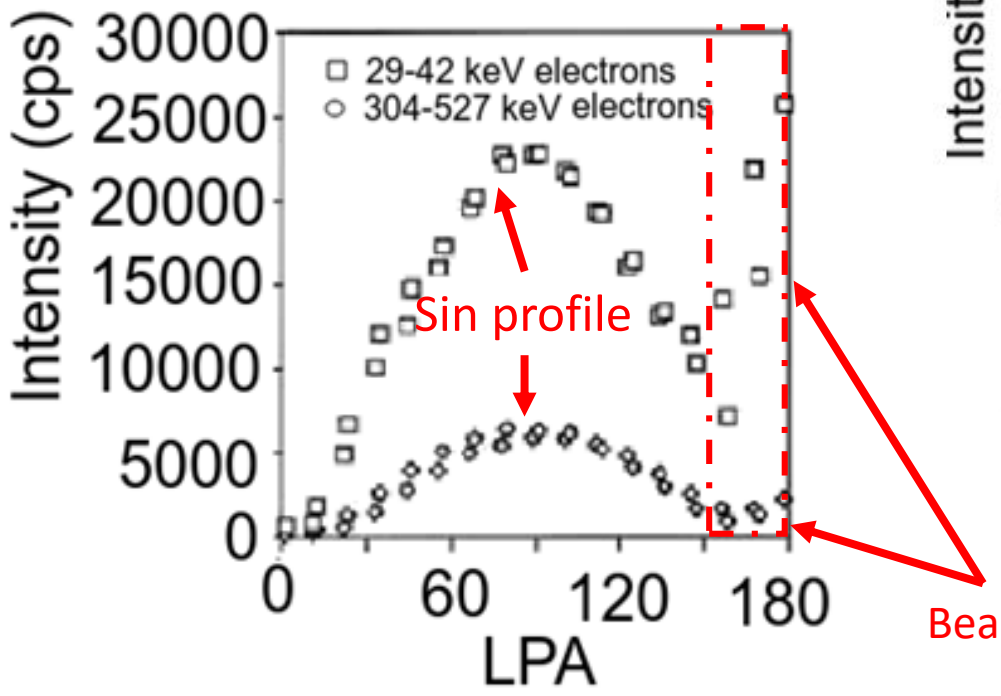


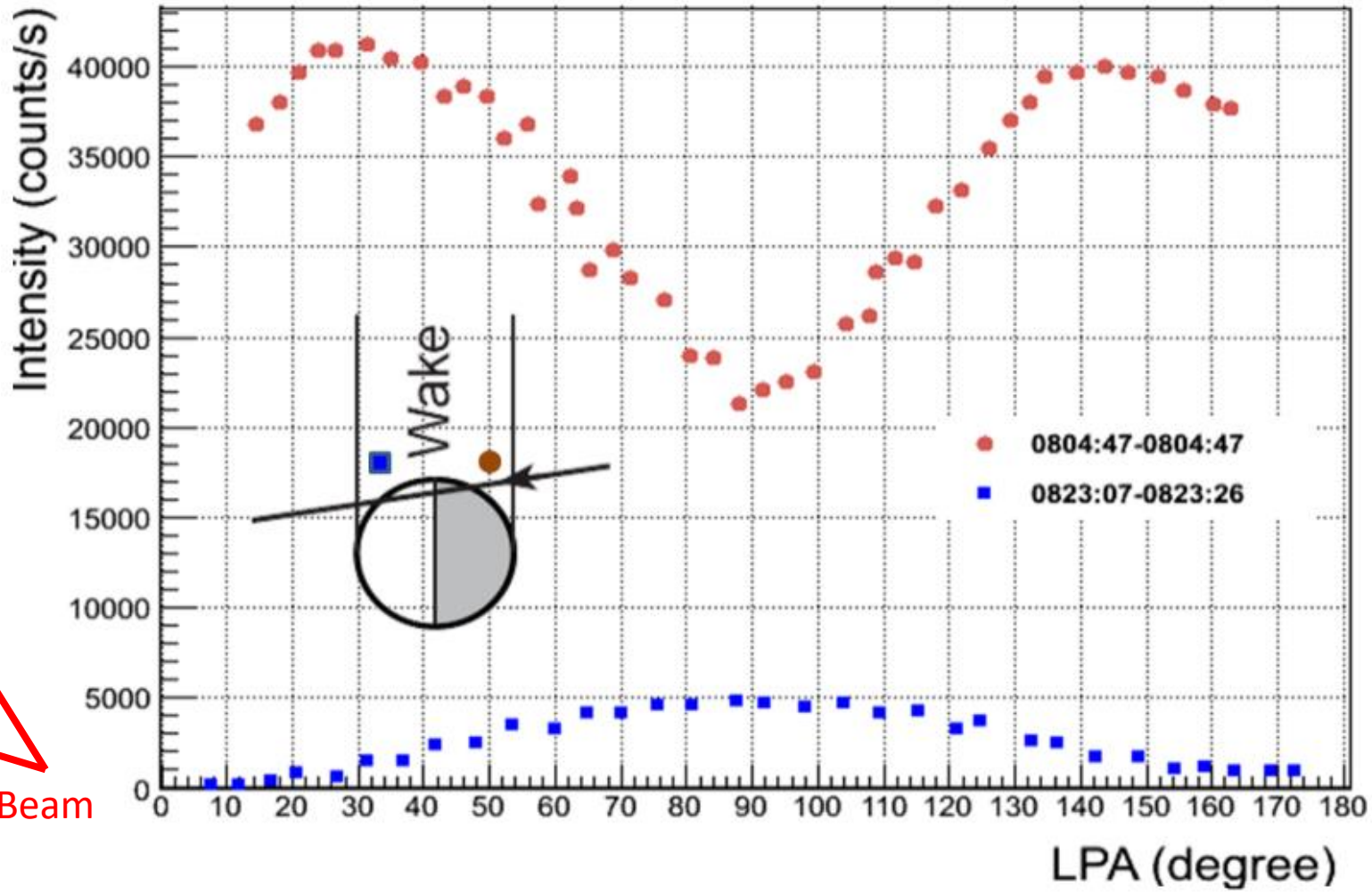


Credit: S. Bourdarie @ 2014 NSREC course

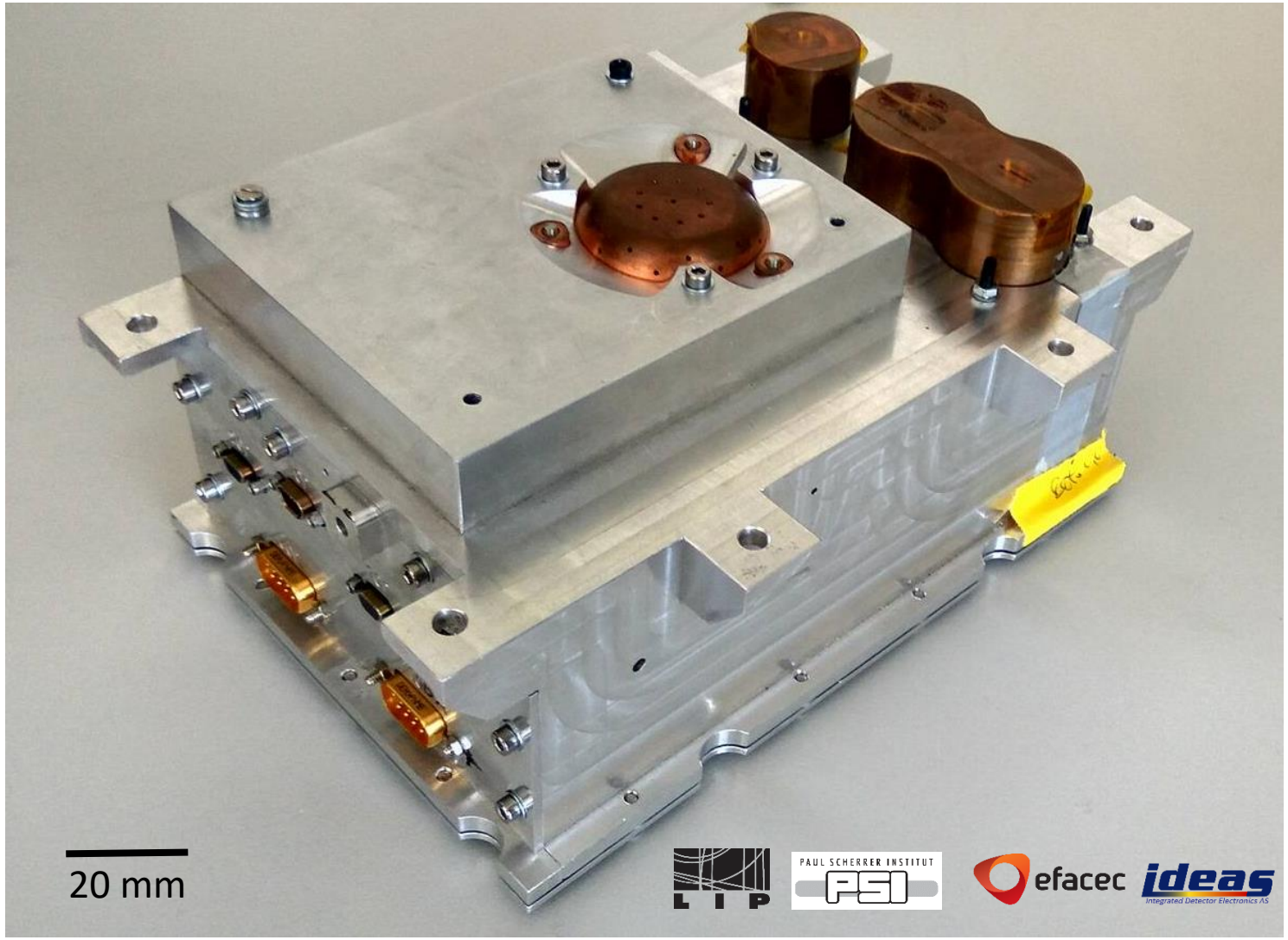
Ganymede – Angular Variability

- Spatial dependent angular variability
- Consequence of particle dynamics
- Implications in RHA





RADEM



Requirements:

- ❑ Measure electron flux
  - Spectral range 300 keV – 40 MeV
  - Peak Flux 10^9 e/cm^2/s
  - Electron Directional Distribution
- ❑ Measure proton flux
  - Spectral range 5 MeV– 250 MeV
  - Peak Flux 10^8 p/cm^2/s
- ❑ Measure Heavy Ion population
  - From Helium to Oxygen
- ❑ Dose determination
- ❑ Low mass (~3 kg currently)
- ❑ Low power

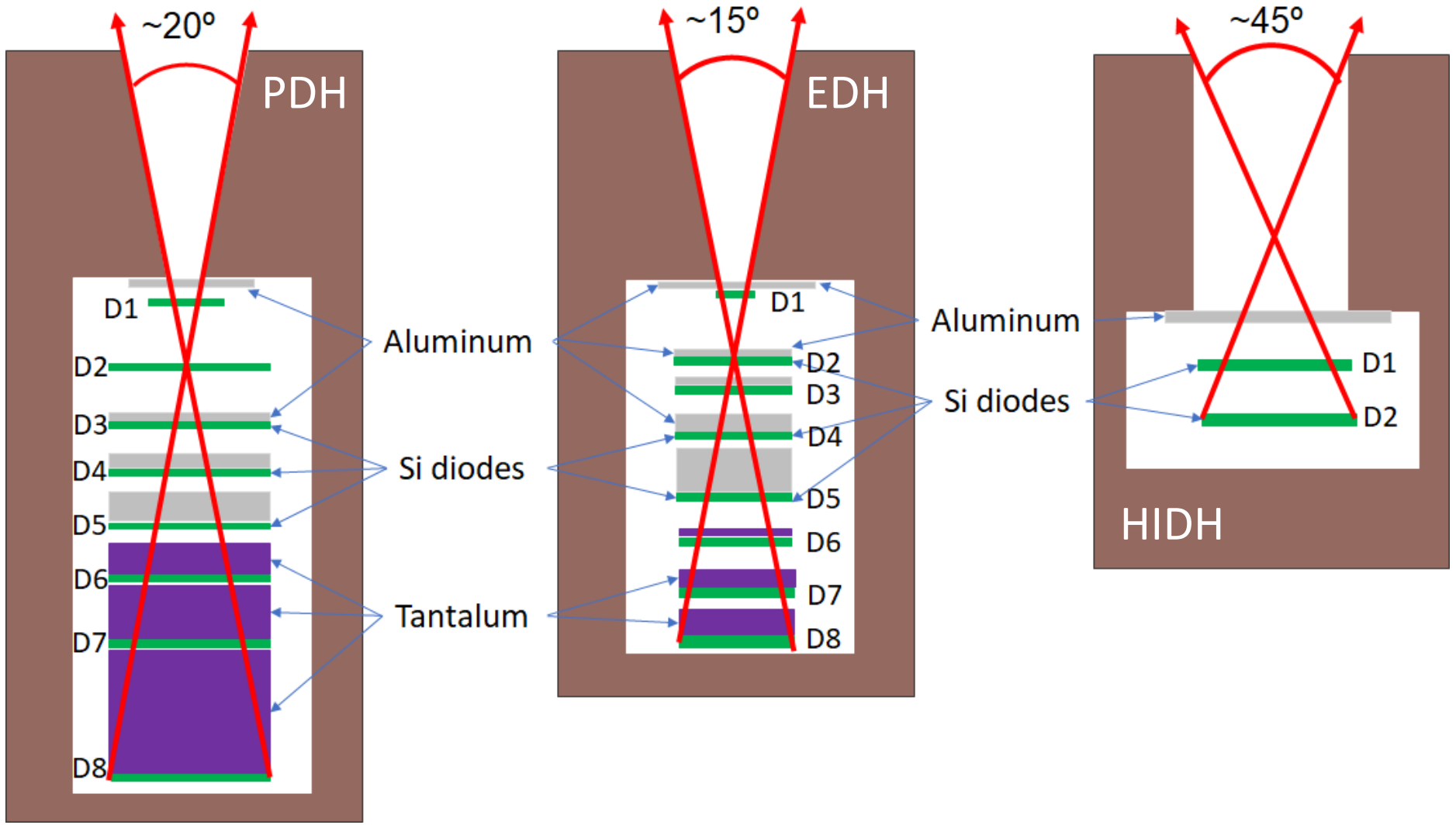
RADEM – Detectors

Traditional Stack Detectors
SREM, MFS, BERM..

Copper Collimator

Al/Ta Absorbers
+
Silicon PIN-diodes

Energy bins (MeV)	
PDH	EDH
4-7	0.35-0.5
7-12.5	0.5-1.25
12.5-20	1.25-2
20-35	2-4
35-50	4-7
50-80	7-17.5
80-125	17.5-35
>125	>35

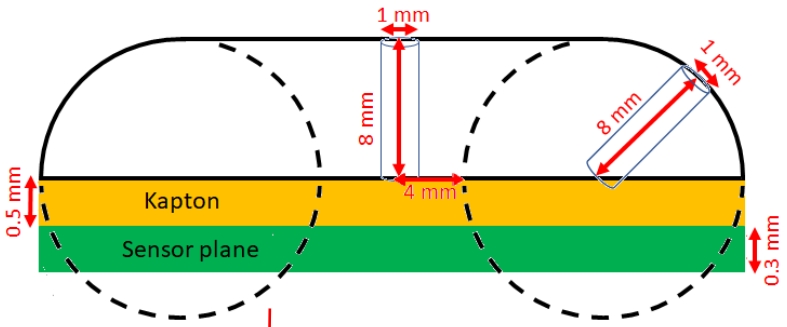


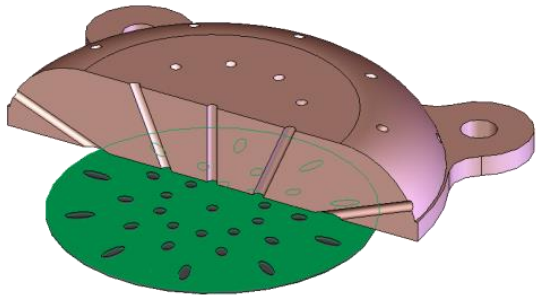
RADEM – Detectors

New concept (M. Pinto et al, DOI: 10.1109/TNS.2019.2900398)

Copper Collimator

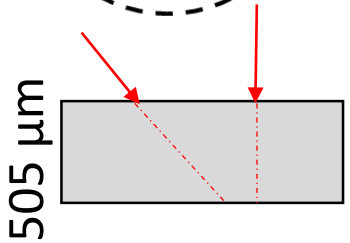
- ❑ 28 holes (directions)
  - Diameter: 1mm
  - Length: 8mm





Single 505 µm Kapton absorber

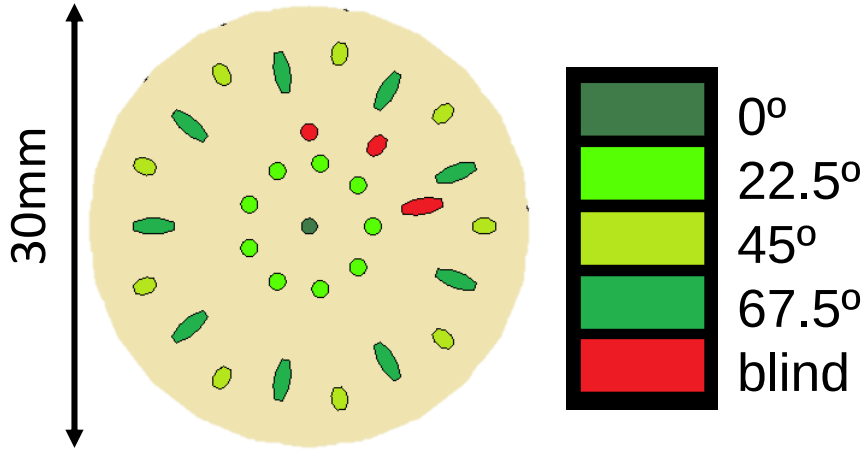
- ❑ Different energy thresholds



Zenith Angle	0 deg	22.5 deg	45 deg	67.5 deg
Electrons	0.3 MeV	0.3 MeV	0.35 MeV	0.5 MeV
Protons	7 MeV	7 MeV	8.5 MeV	12.5 MeV

Detection Plane (instrumented PIN diode):

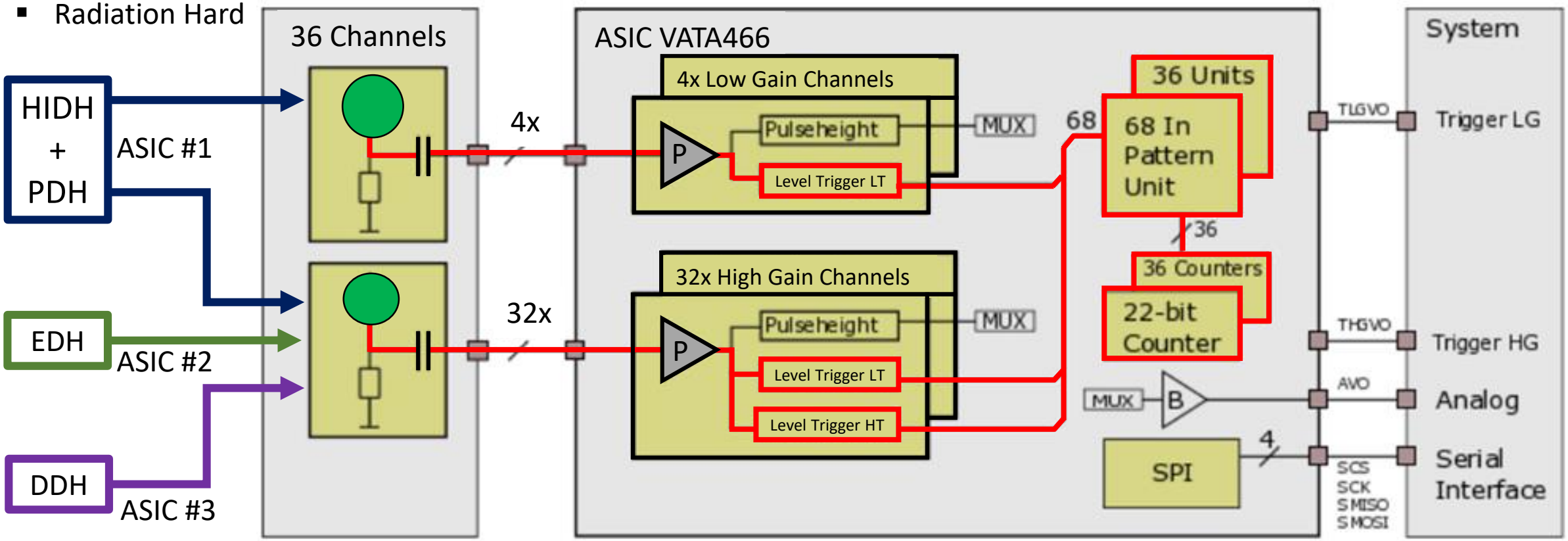
- ❑ 31 Silicon sensors (300 µm thick)
  - 4 zenithal directions
  - 9 azimuthal directions
  - 3 blind sensors



RADEM – Readout

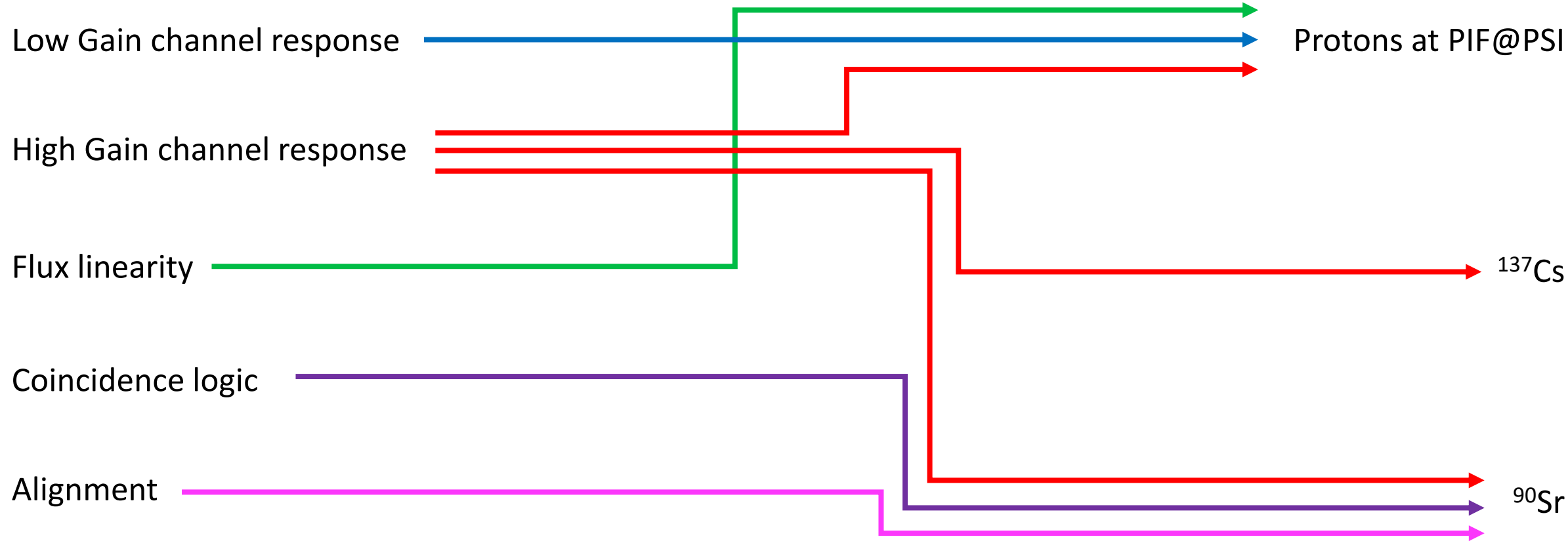
ASIC VATA 466 – developed specifically for RADEM

- 1 MHz max count rate / channel
- Programable logic
- Radiation Hard



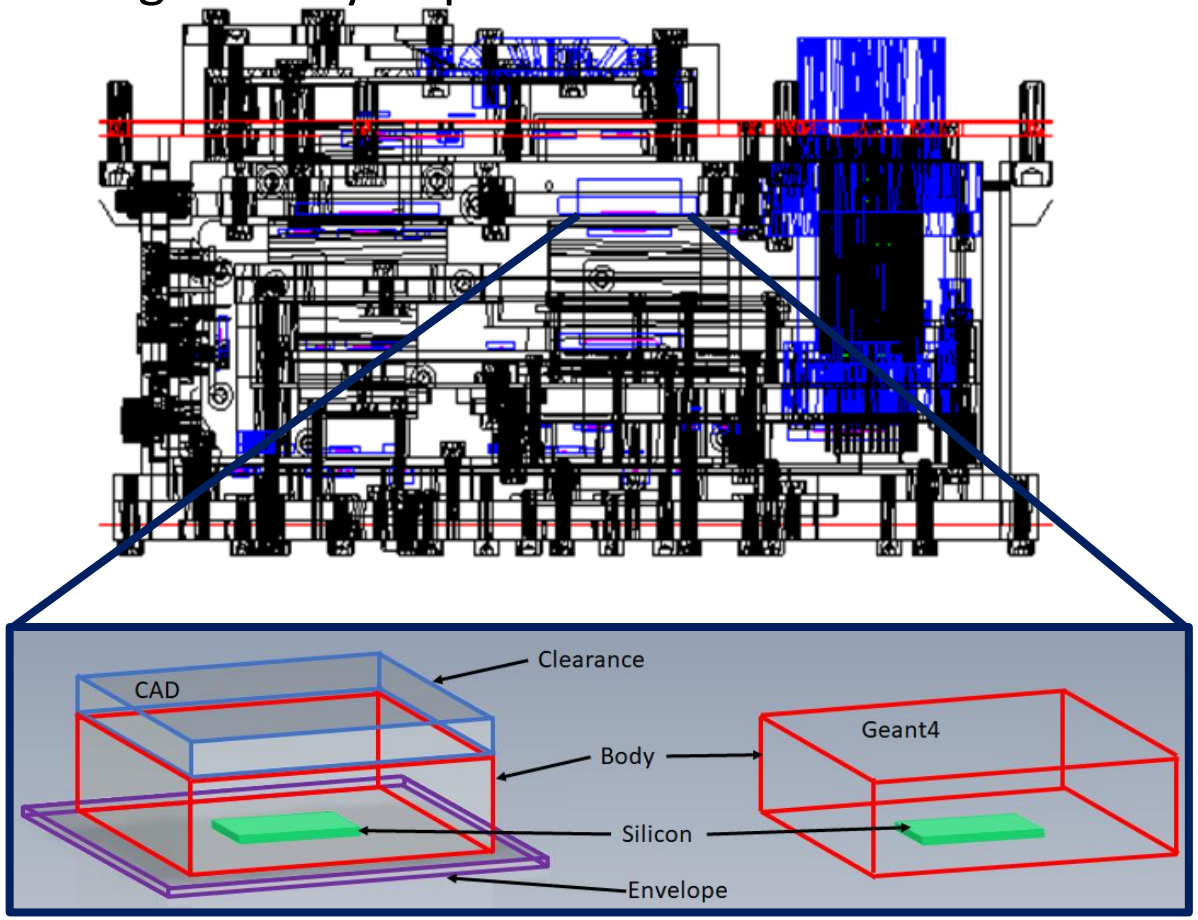
Tests

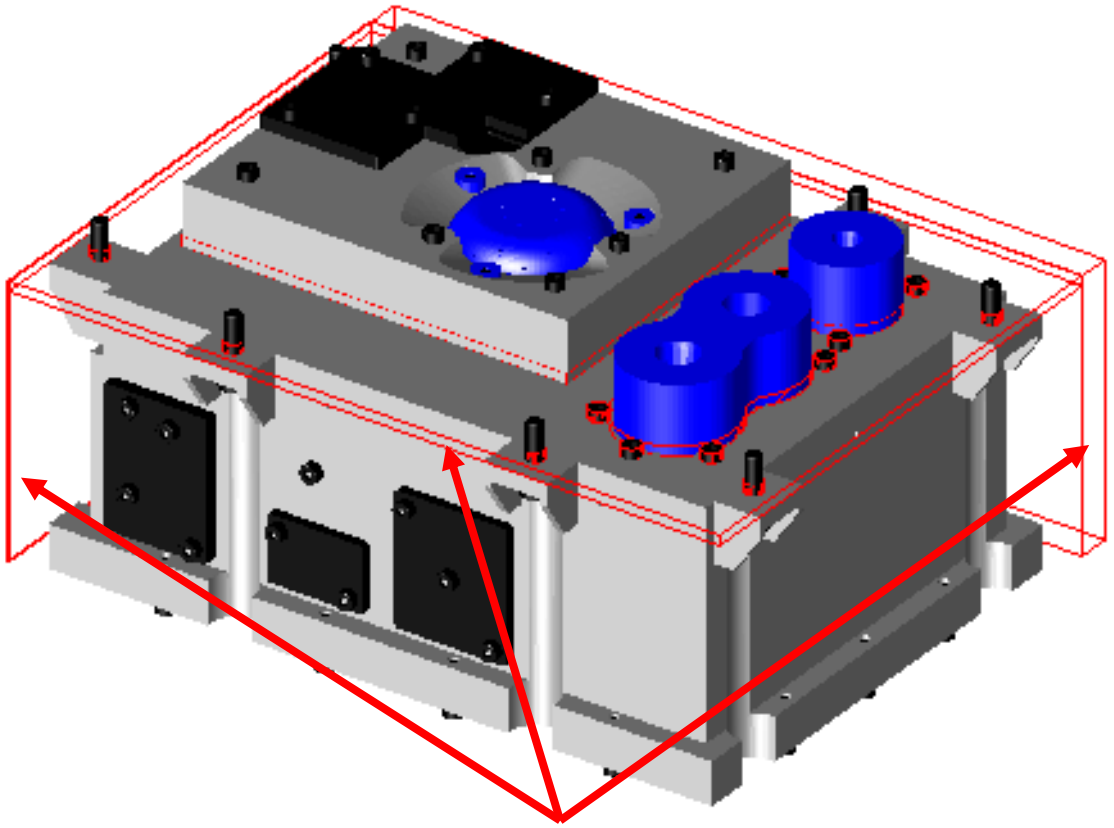
Test RADEM Engineering Model under different radiation conditions at PSI
Test detector response
Test full functionality of the readout – All detectors use the same readout chip
Geant4 simulations compared with experimental results



GUIMesh

Full geometry imported from STEP as tessellated solids via GDML with GUIMesh





Spacecraft described as Aluminum shielding equivalent

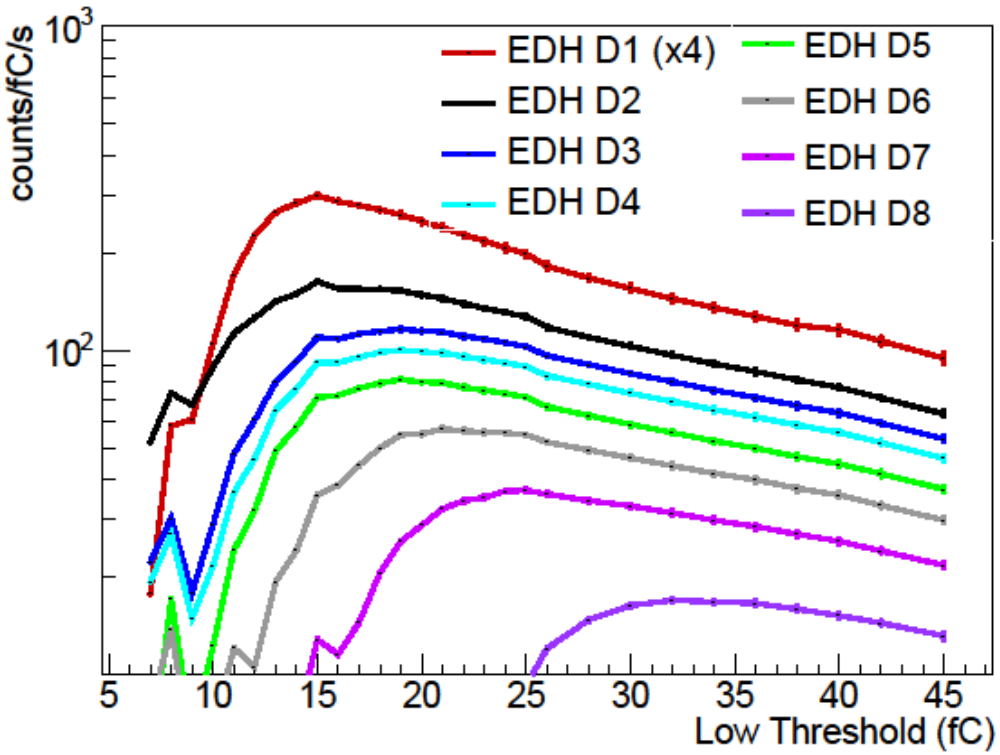
M. Pinto et al, DOI: https://doi.org/10.1016/j.cpc.2019.01.024
Code: https://github.com/MPintoSpace/GUIMesh

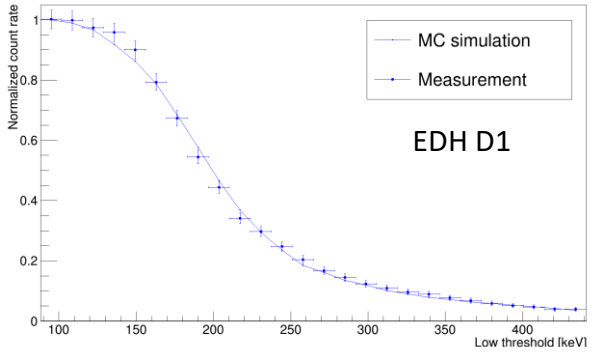
High Gain channels

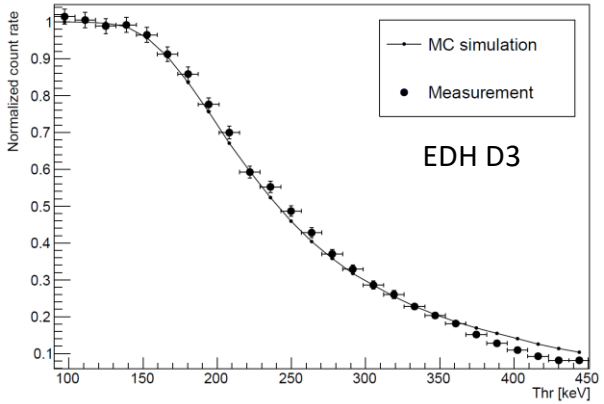
EDH; PDH and DDH connected to High-Gain channels

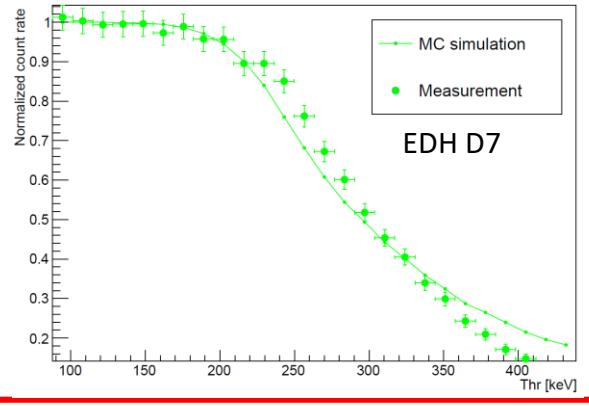
All EDH trackers tested at the same time

Experimental data comparable to Geant4 simulation

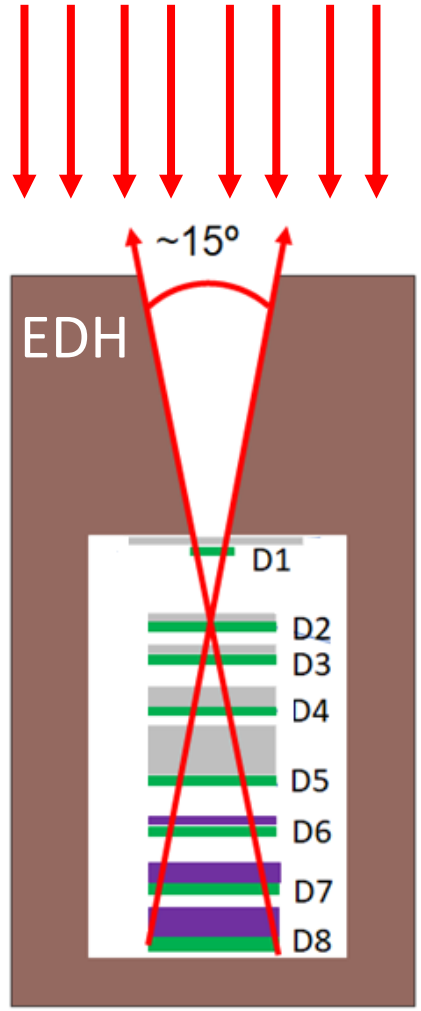








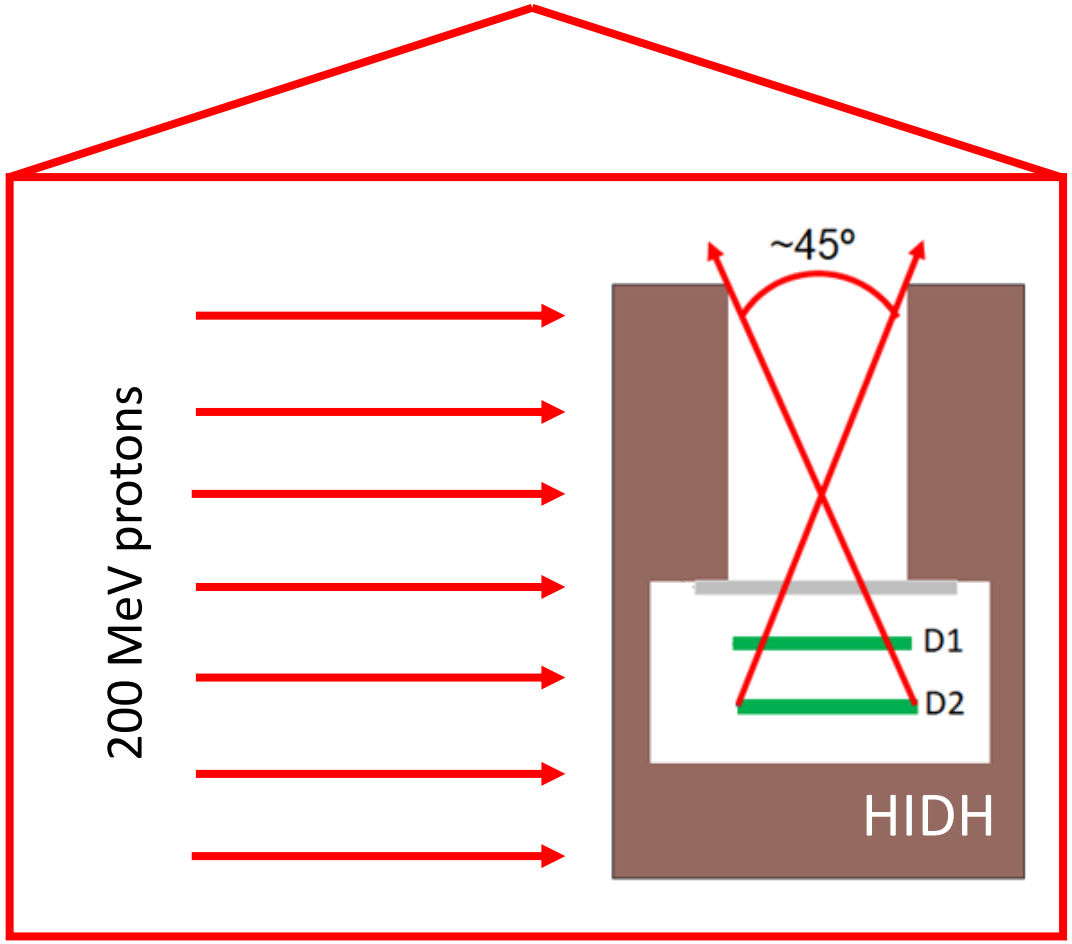
100 MeV protons



Low Gain channels

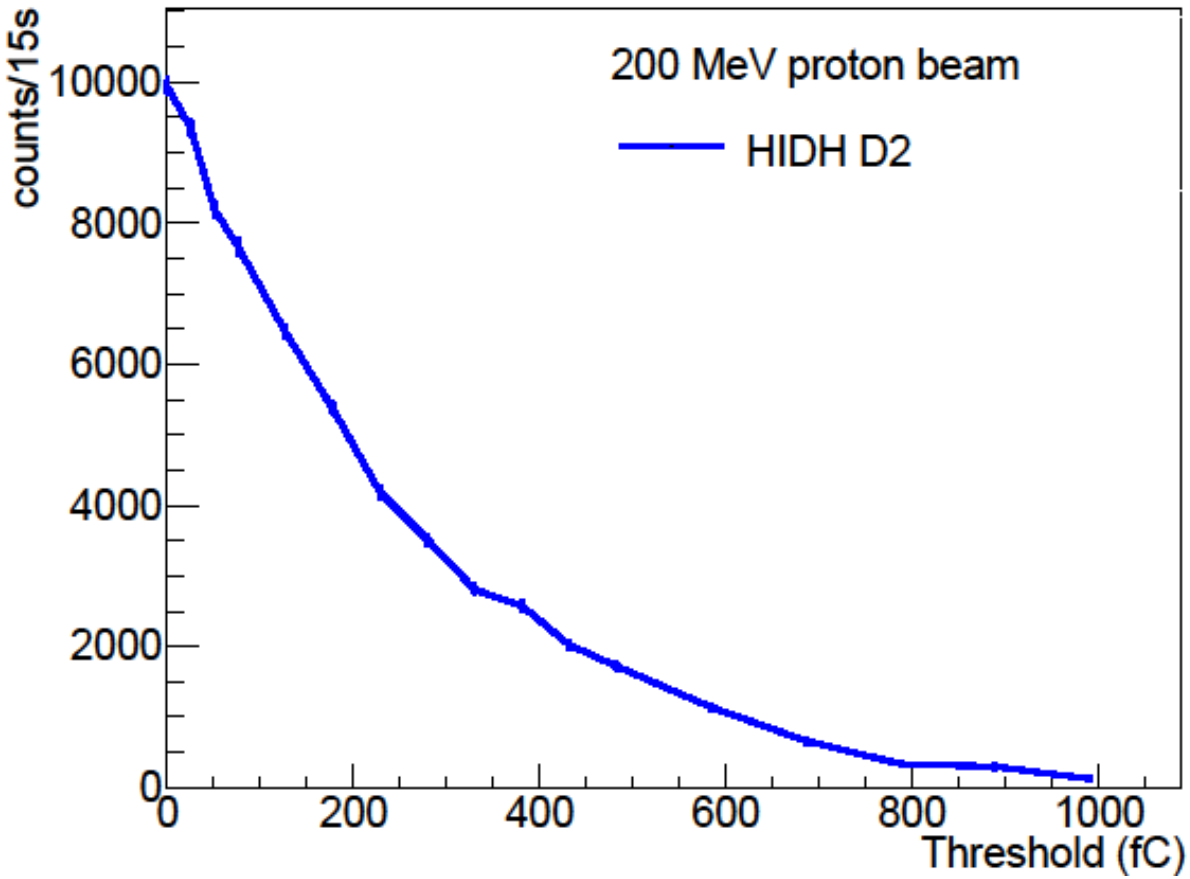
Only the HIDH is connected to LG channels

Proton beam directed sideways - difficult to center



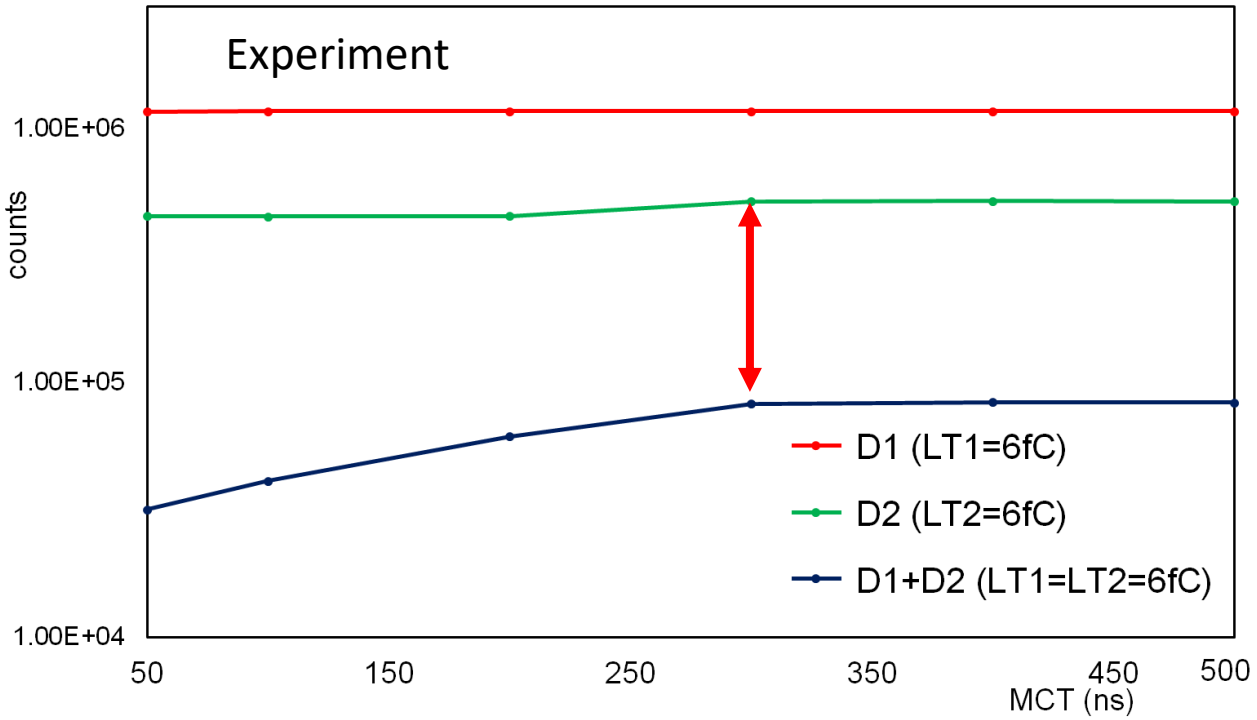
Not enough energy deposited to reach plateau

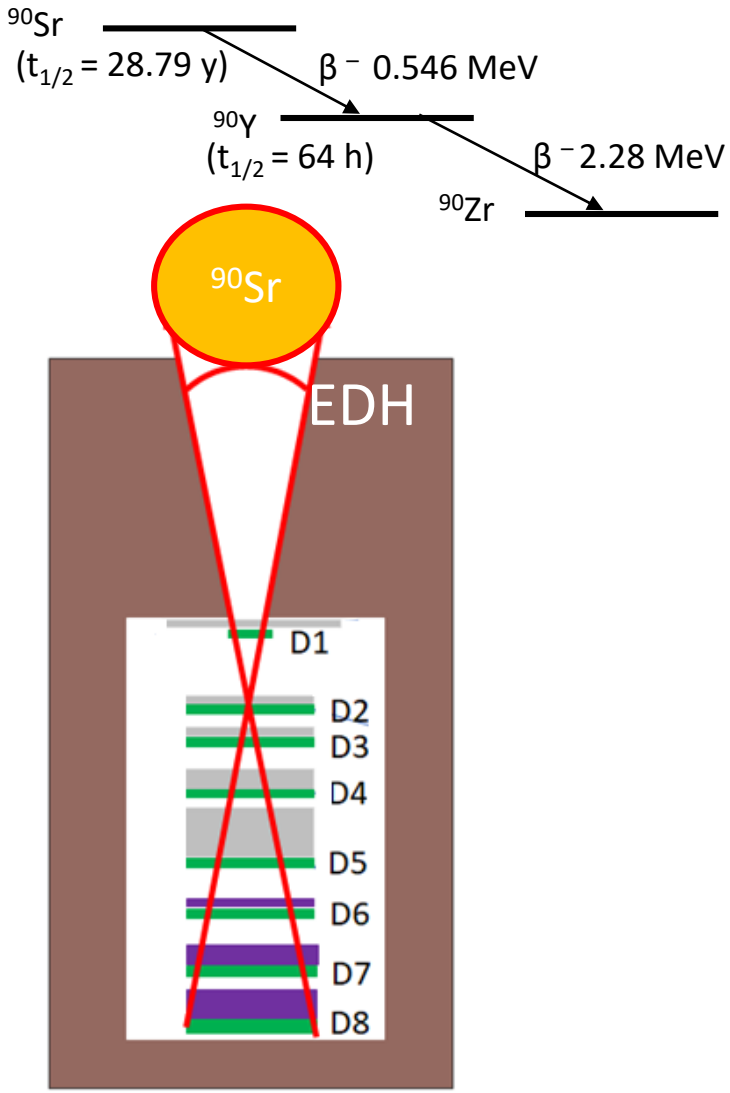
<u>Clear response to radiation</u>



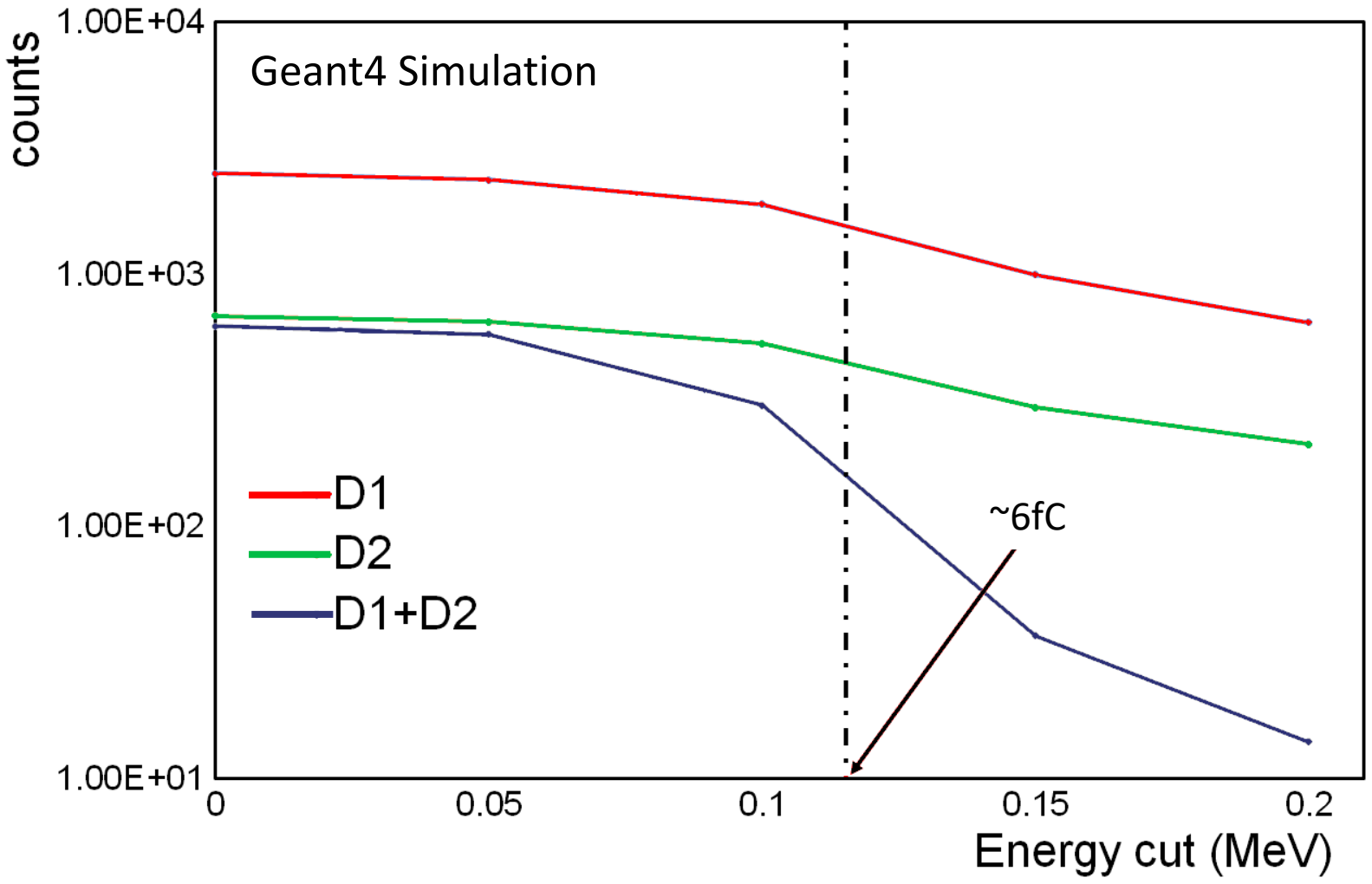
Coincidence Logic (1)

- Coincidence are critical for stack detectors
  - Determines particle energy
- Fully programmable - including Mono-stable coincidence time
- Tests done with ^{90}Sr on top of the EDH





Coincidence Logic (2)



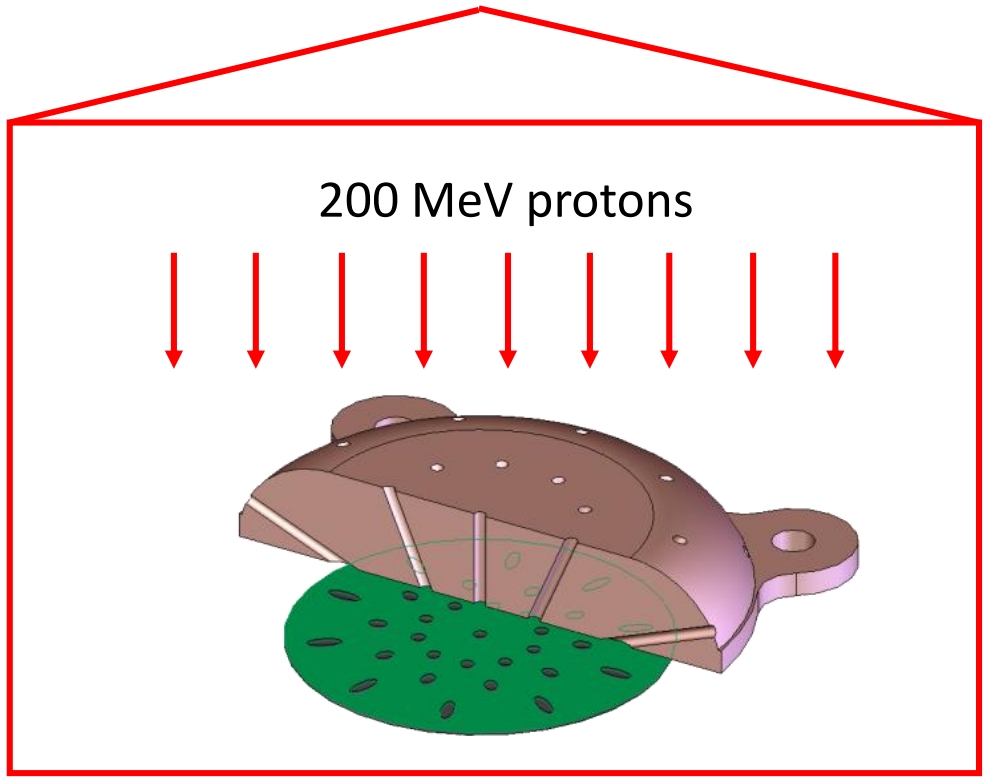
Discrepancy due to energy cut → Coincidence logic shown to work

Flux

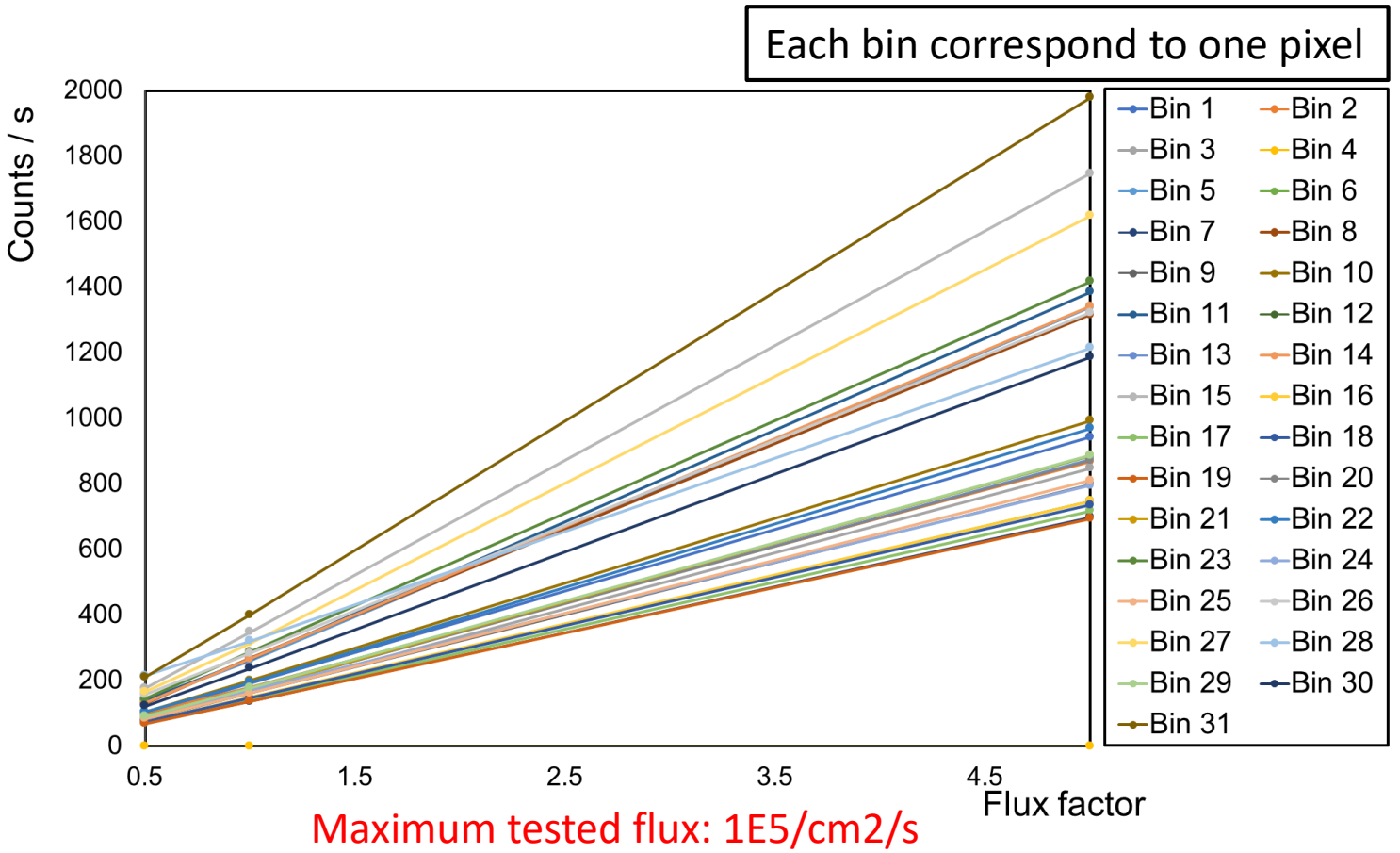
RADEM will operate under high fluxes

DDH allows to test 31 channels at the same time

Collimator proton cutoff ~70 MeV



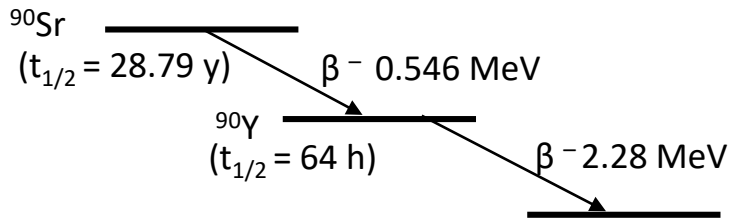
Linear response was observed in all channels



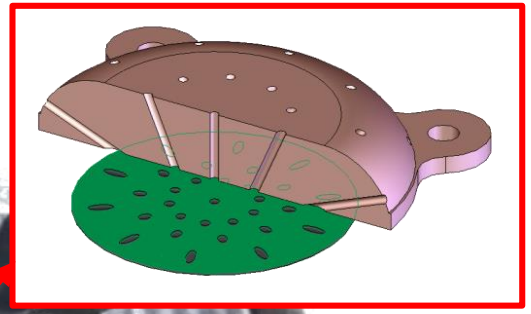
Maximum tested flux: 1E5/cm2/s

Alignment (1)

- Alignment is especially critical for DDH
  - Sensitivity to each direction
  - Hard to test



Directionality Detector



- Preliminary setup
  - ^{90}Sr source
  - RADEM
  - XY scan

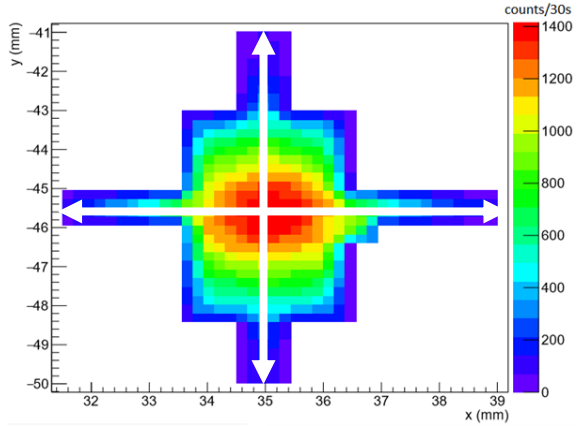
- Only a subset sensors measured
  - Mechanical constraints
  - Noise issues

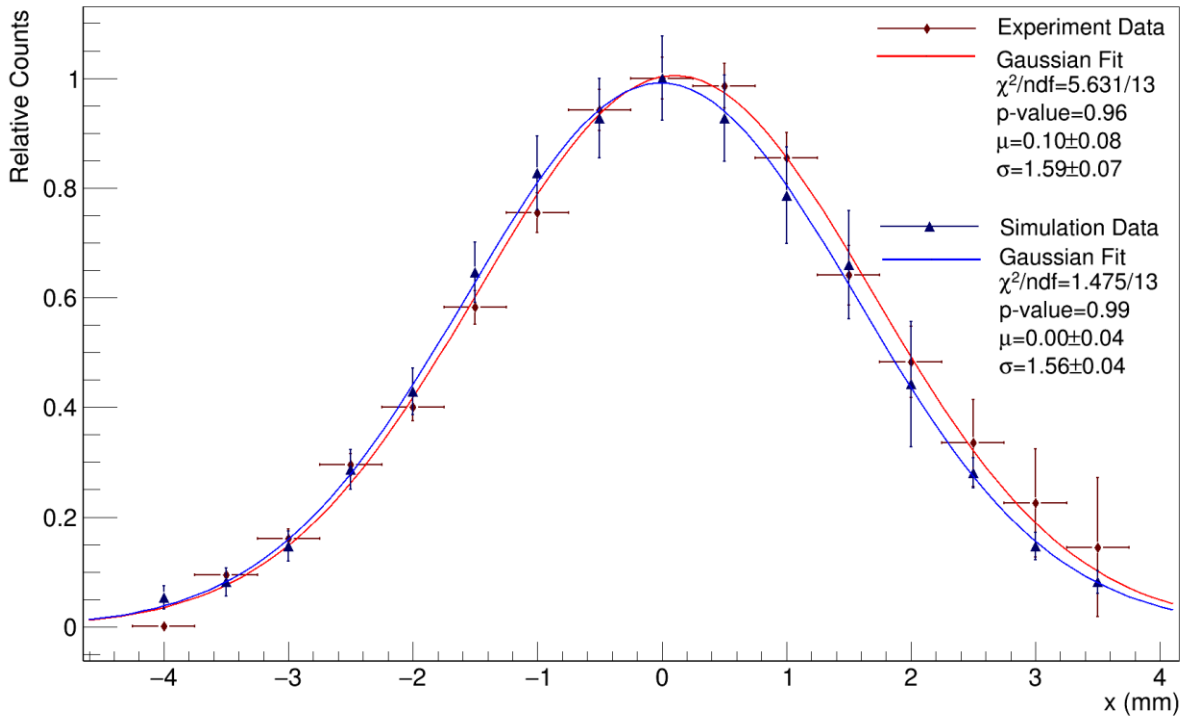
Alignment (2)

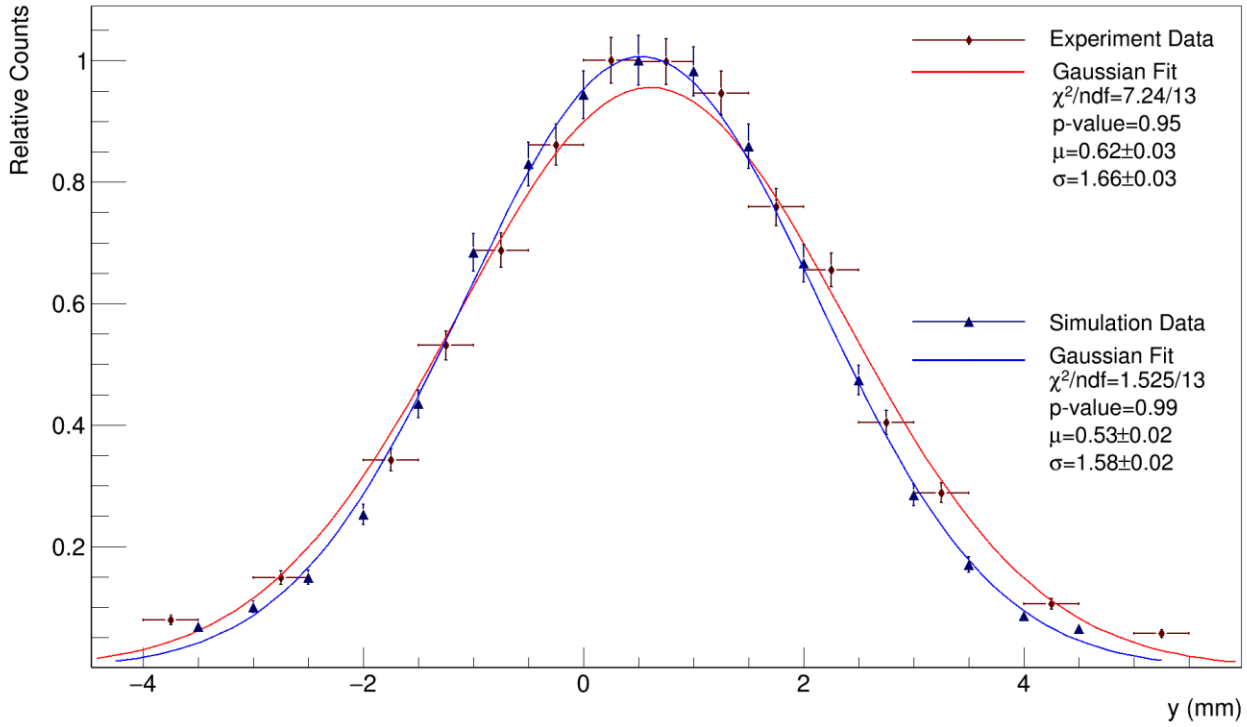
Results for central diode scan follow Gaussian distribution

Results agree very well with Geant4 simulations

Good alignment between collimator and sensor plane







Conclusions / Current Status

Engineering Model:

Radiation tests and integration with spacecraft approved

- All detectors performed as expected
- Readout fully functional
- Alignment showed good results

Engineering Qualification Model:

Stress tests only – no radiation tests

ProtoFlight Model :

Calibration will take place in 2020

Thank you!