Characterisation of a Scintillator-based Detector for Radiation Monitoring in Low Earth Orbit

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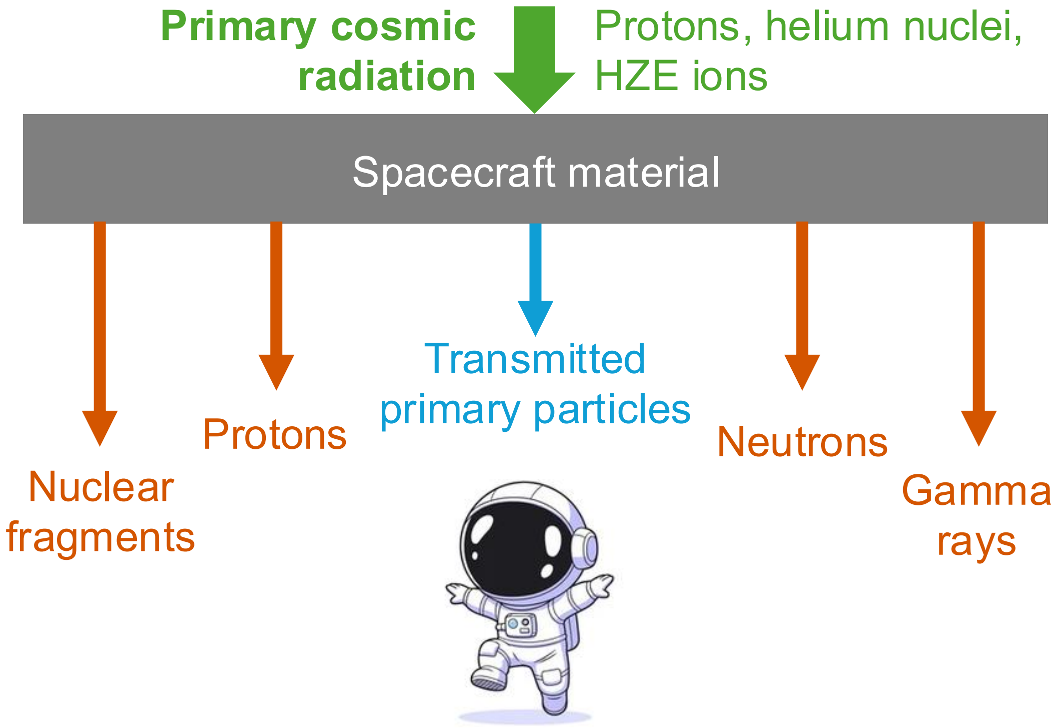
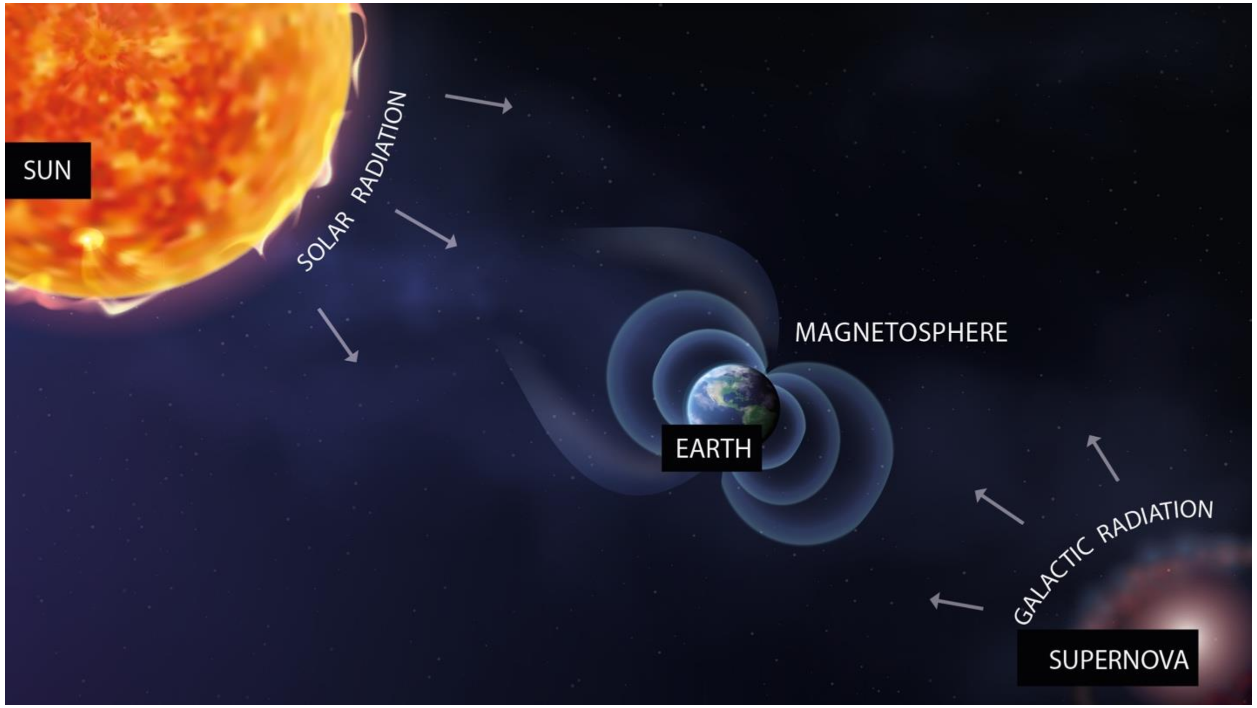
Radiation Environment in LEO

Primary Cosmic Radiation

- Galactic Cosmic Rays (GCR)
- Solar Energetic Particles (SEP)
- Trapped Particles





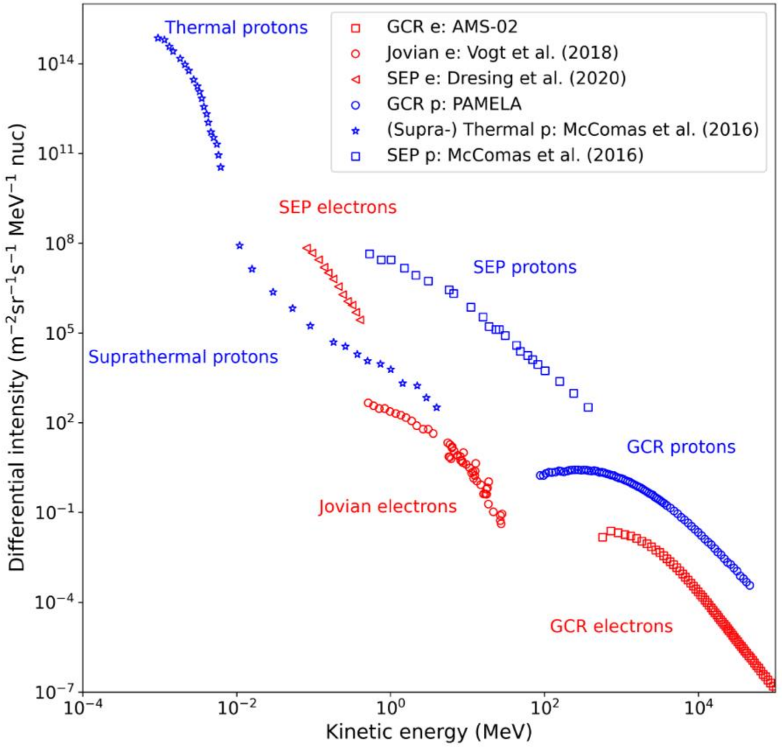
Secondary Cosmic Radiation

- Produced in spacecraft materials
- <u>Neutrons</u>, protons, gamma rays, muons, electrons and nuclear fragments

Why the LEO radiation field is variable

The primary field changes with source population, geomagnetic location and space weather.

Energetic particle distributions near Earth

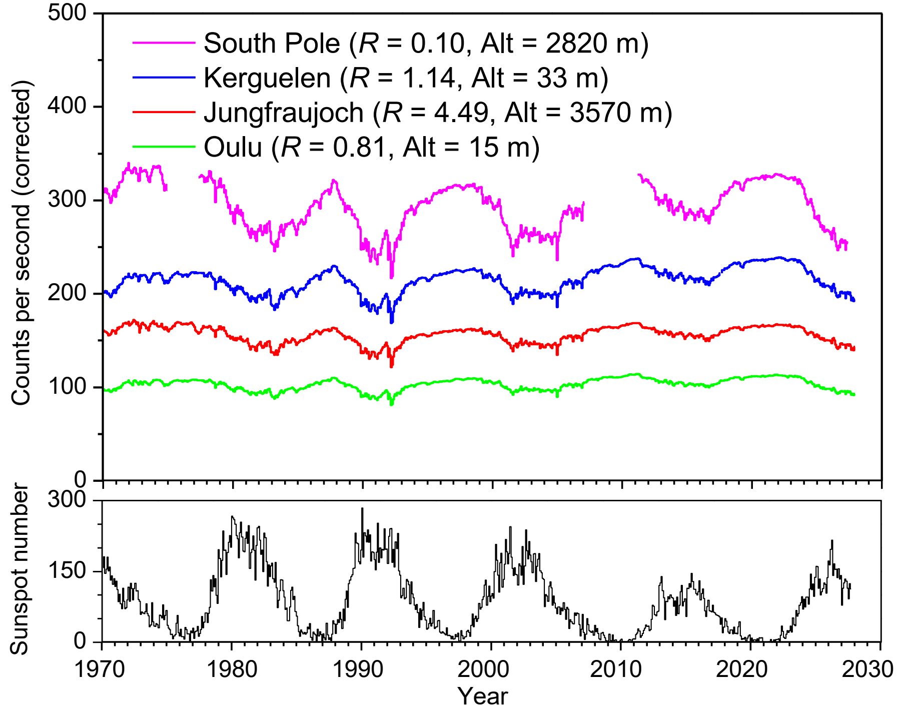


Geomagnetic shielding controls which particles reach low Earth orbit.

Particle populations dominate different energy ranges.

Solar activity can change the field rapidly.

Ground Neutron Monitor data 1970 - 2026



The radiation field is mixed, energy dependent and time dependent.

The dosimetry problem

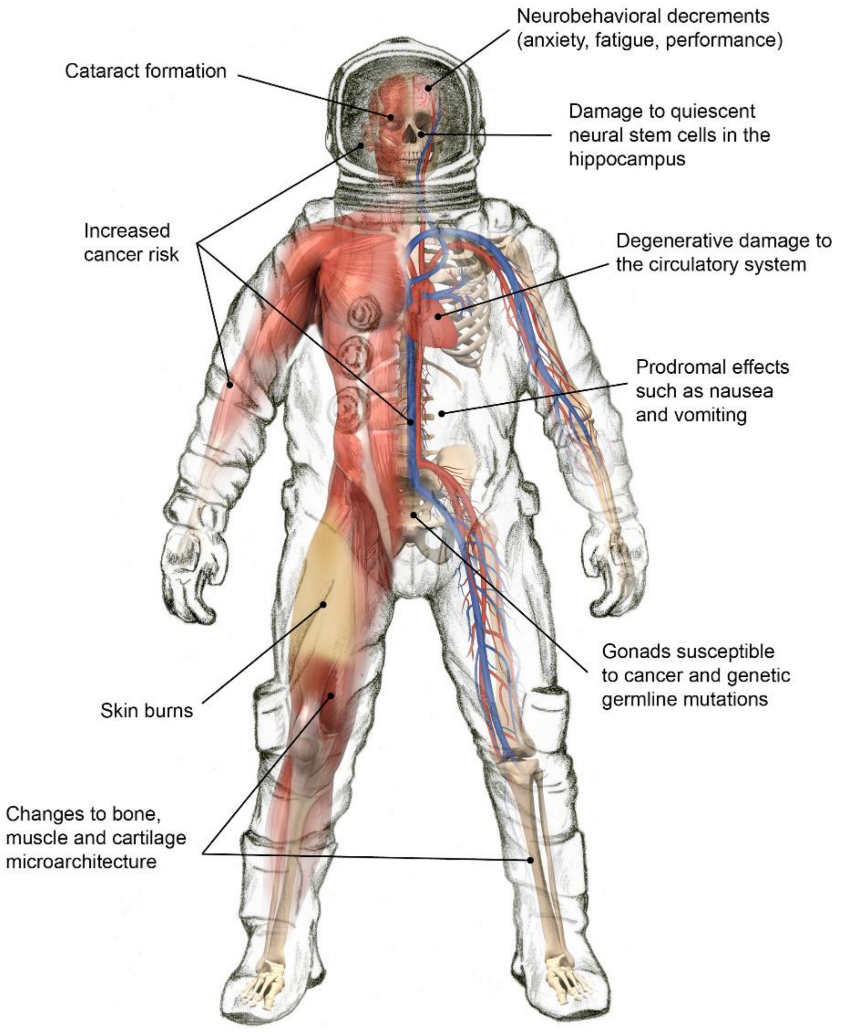
Astronaut risk depends on dose, particle type and how the field changes during a mission.

Health Risk

- Biological effects depend on the total dose and radiation quality.
- Current health-risk models have high uncertainty, so on-board measurement is essential.

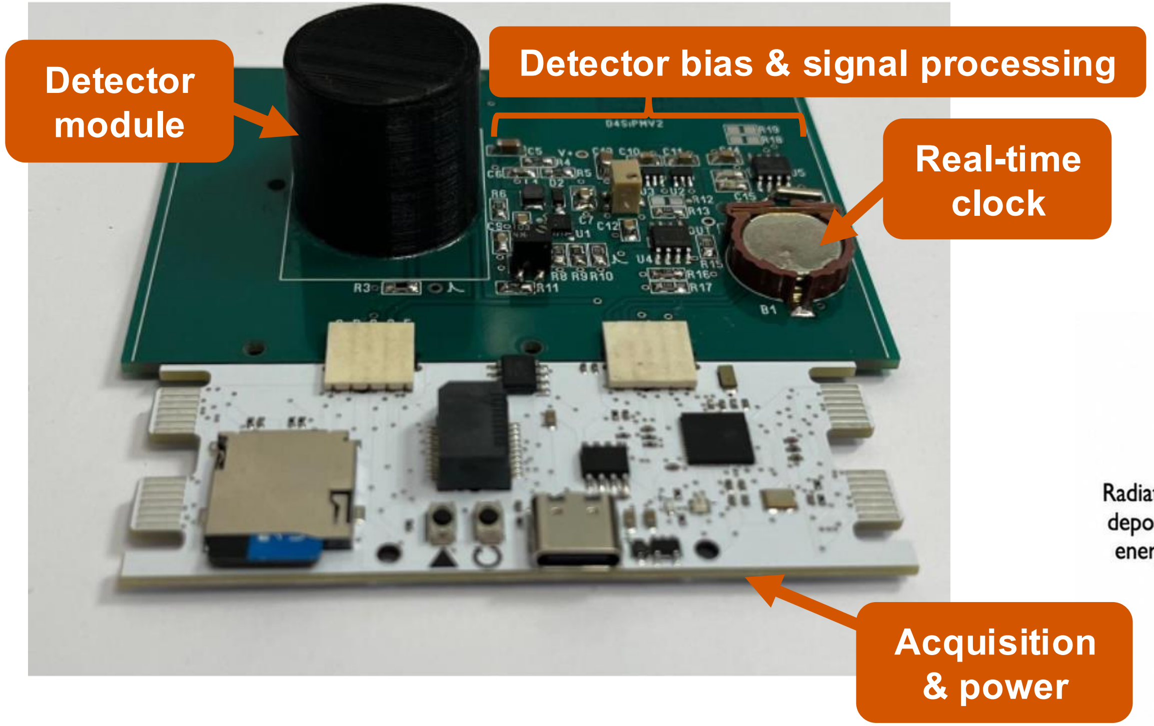
Measurement Challenge

- Space instruments must be compact, low-power and robust.
- Mixed fields make a single “dose” measurement difficult to interpret.



n-lab compact detector solution

A compact flight detector with threshold-based event readout.

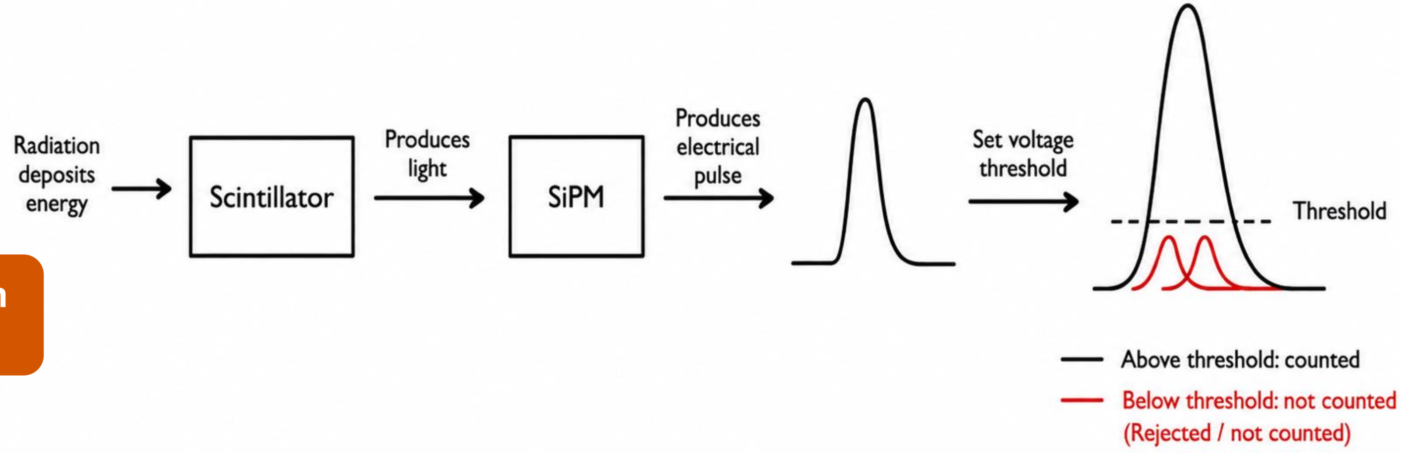


20 mm plastic scintillator + silicon photomultiplier

Compact, robust and low power for flight deployment

MaxIQ xChip core readout

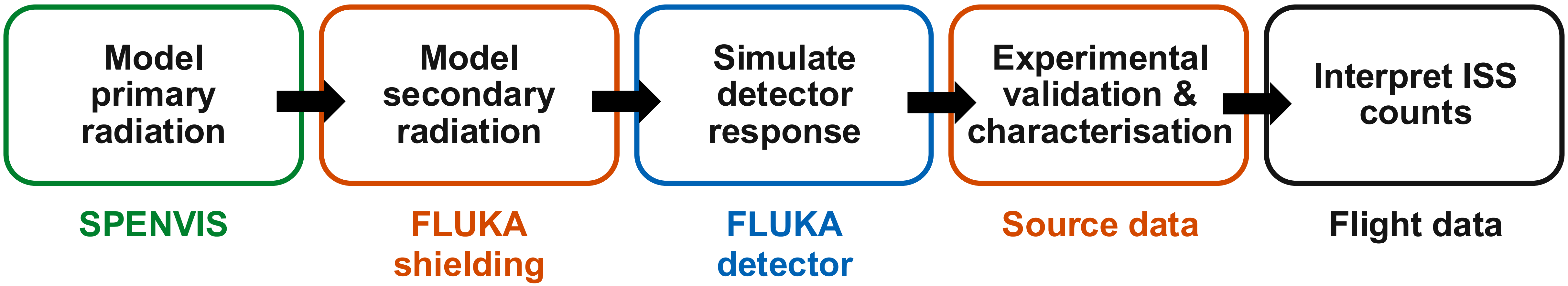
Logs timestamped events whose pulse height exceeds a set voltage threshold.



Energy- and particle-dependent response is obtained through calibration and radiation-transport modelling.

Aim and process

Predict and validate the response of a compact scintillator detector
in the LEO radiation environment.



The aim is not only to record counts, but to make those counts physically interpretable.

Primary radiation modelling with SPENVIS

SPENVIS was used to define the incident primary radiation field for a representative ISS-like orbit.

Orbit definition

Representative ISS-like orbit
400 km circular altitude
51.6° inclination
42-day duration

Orbit propagation: drag and solar radiation pressure neglected

Radiation components

Trapped protons/electrons: AE9/AP9
GCR: ISO 15390 with magnetic shielding
SEP: ESP/PSYCHIC

Output

Differential particle flux vs energy
Primary field for transport modelling

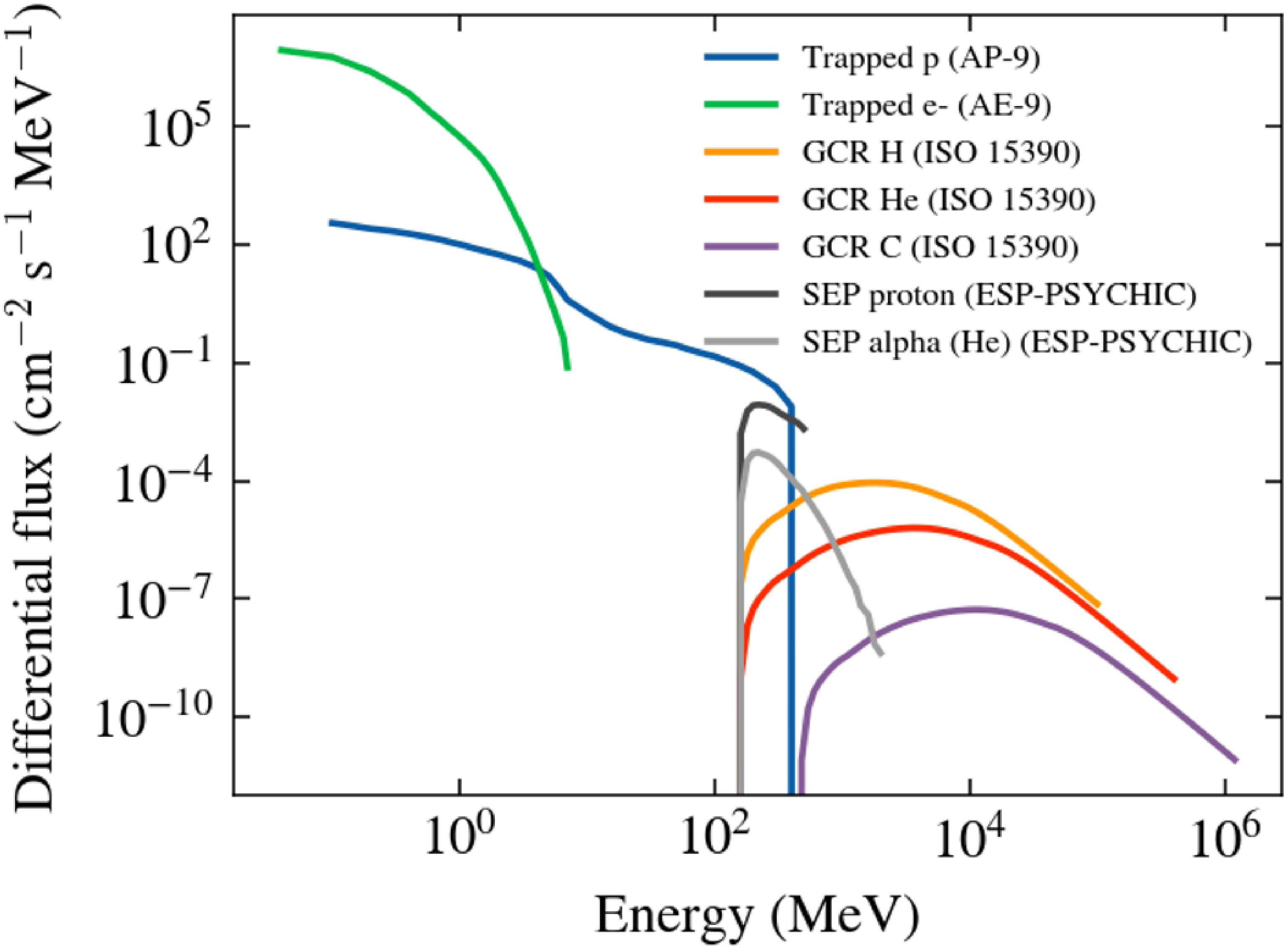
Primary radiation model → incident field for FLUKA

SPENVIS
The Space Environment Information System

SPENVIS output: incident particle spectra

Primary spectra for an ISS-like orbit.

- **Trapped particles** dominate the low-energy region.
- **SEP and GCR components** extend the field to higher energies.
- **Heavy ions** reach high energies, but a with much lower flux.



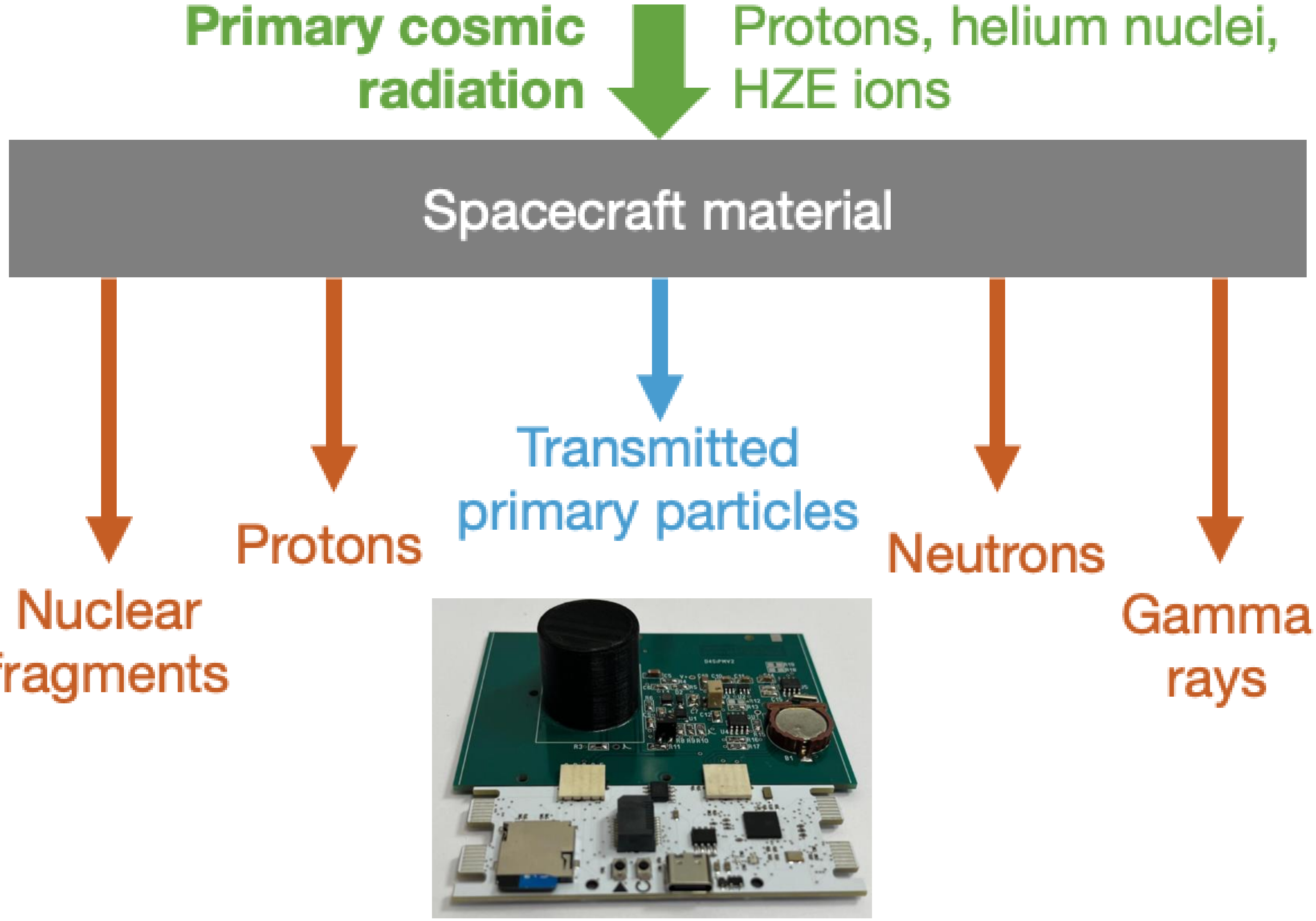
From primary to secondary radiation

The detector is inside spacecraft material, so shielding changes the field.

SPENVIS defines the incident field

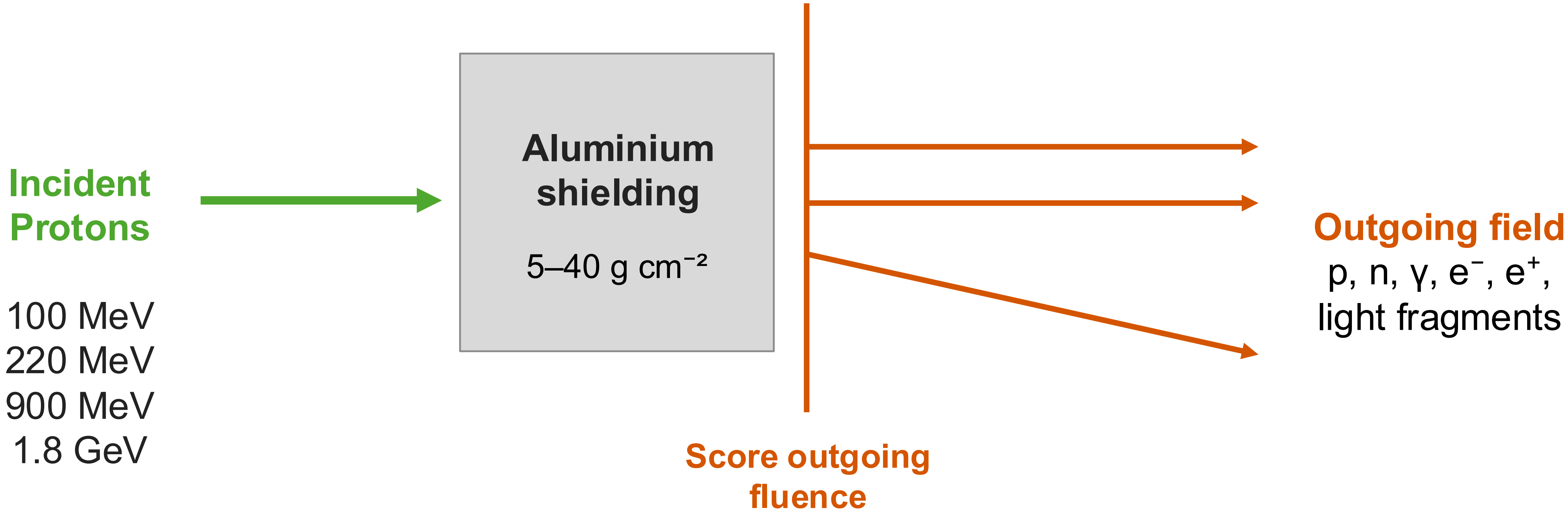
Model interactions

Estimate transmitted and secondary radiation



Secondary radiation modelling with FLUKA

Controlled monoenergetic studies isolate how energy and aluminium thickness affect the outgoing field.



Monoenergetic first, before full SPENVIS-weighted spectra.

These results describe the field exiting shielding, NOT yet the detector response.

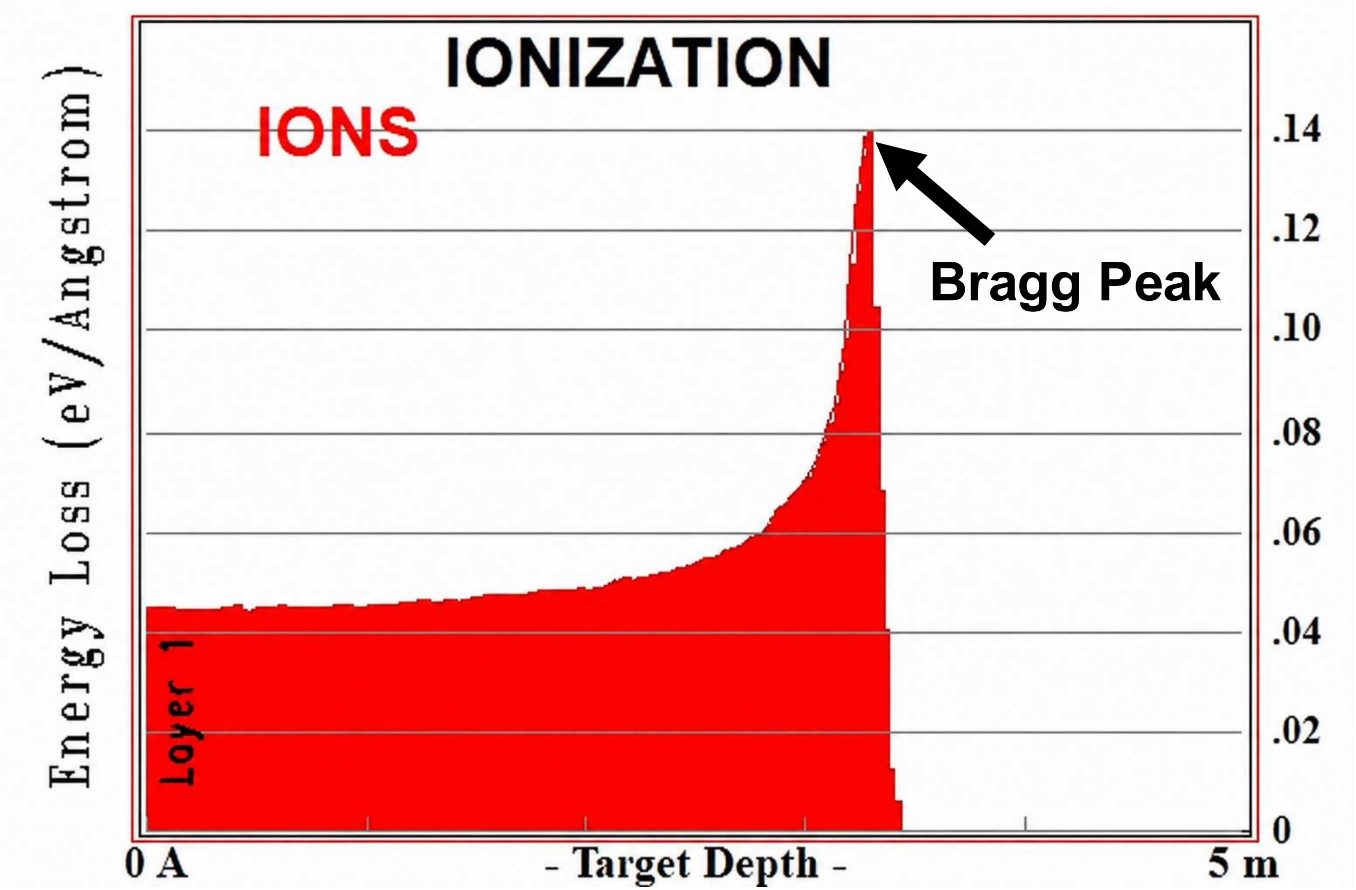
Proton transport through aluminium

Proton transmission is governed by range, not simple exponential attenuation.

- Protons lose energy along their path through material.
- The energy loss increases as the proton slows down, producing the Bragg peak.
- For 1.8 GeV protons, range is 892 g cm^{-2}.

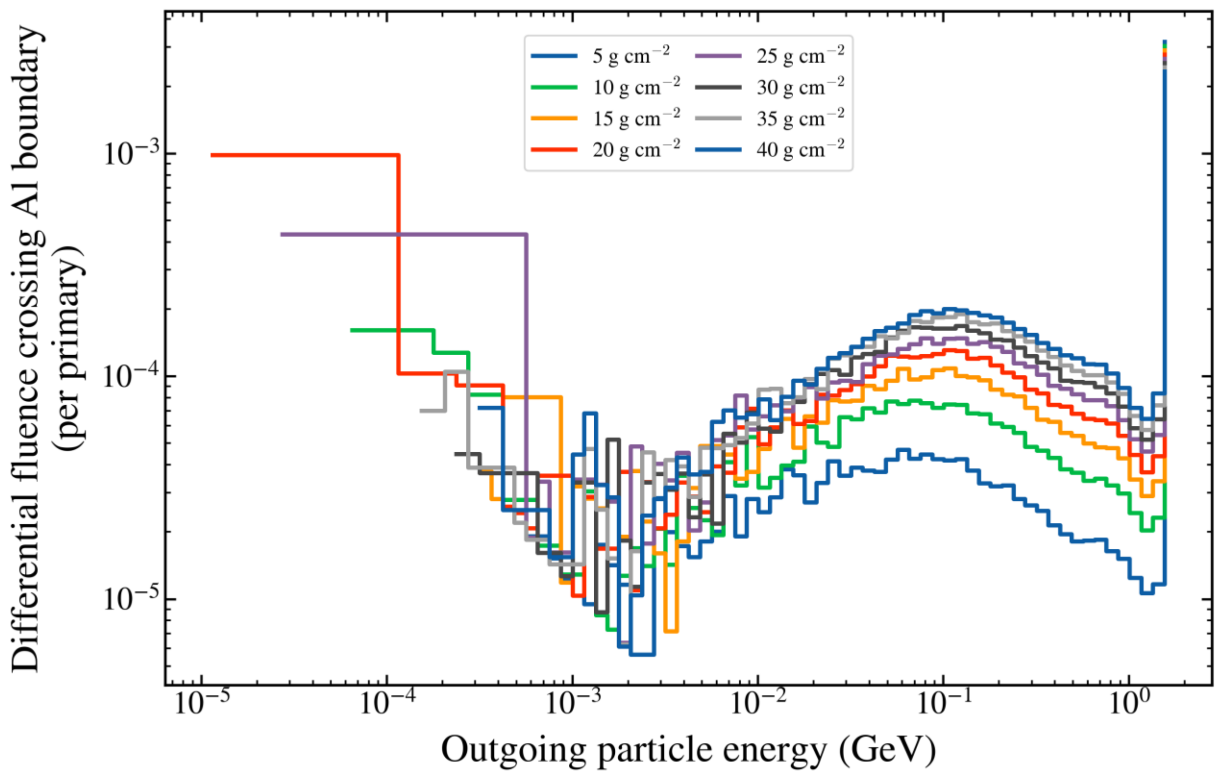
Range > thickness: primaries transmit

Thickness > range: primaries stop

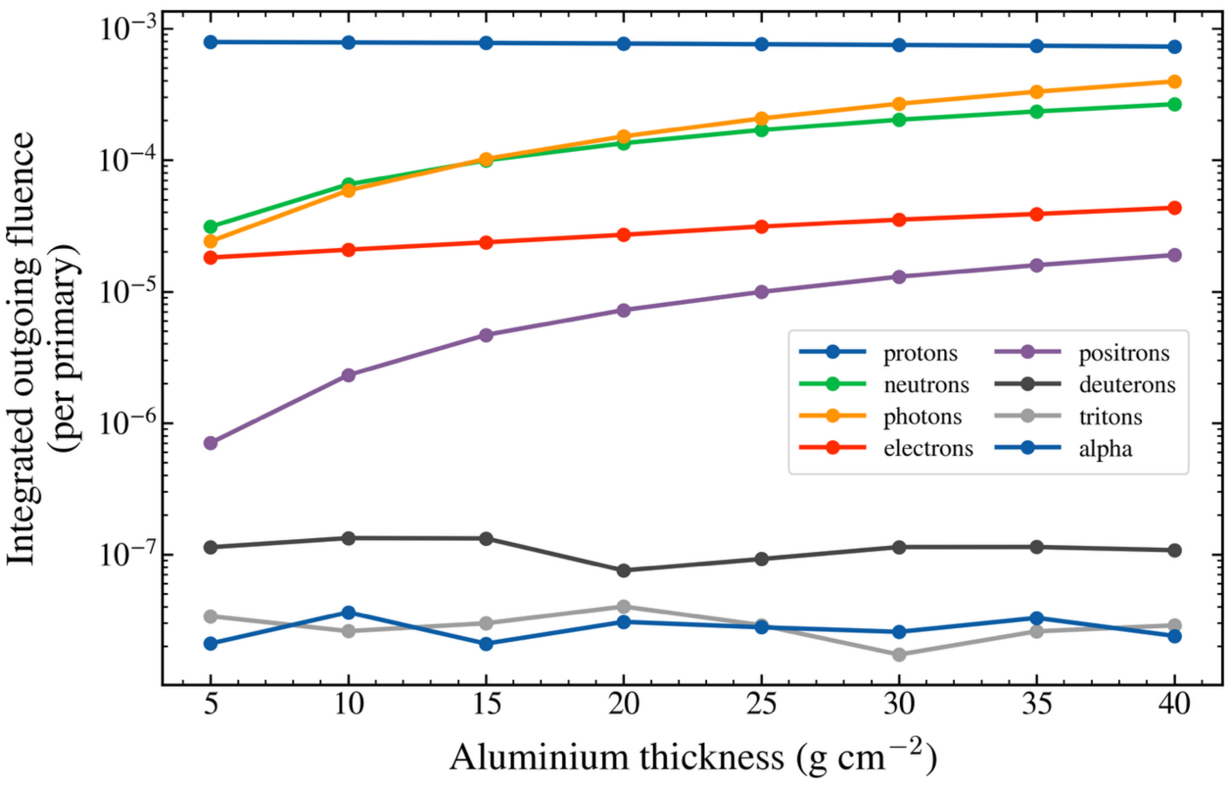


Preliminary results: 1.8 GeV protons

At 1.8 GeV, the proton range is much larger than the aluminium thicknesses studied, so primary protons transmit while secondaries build up.



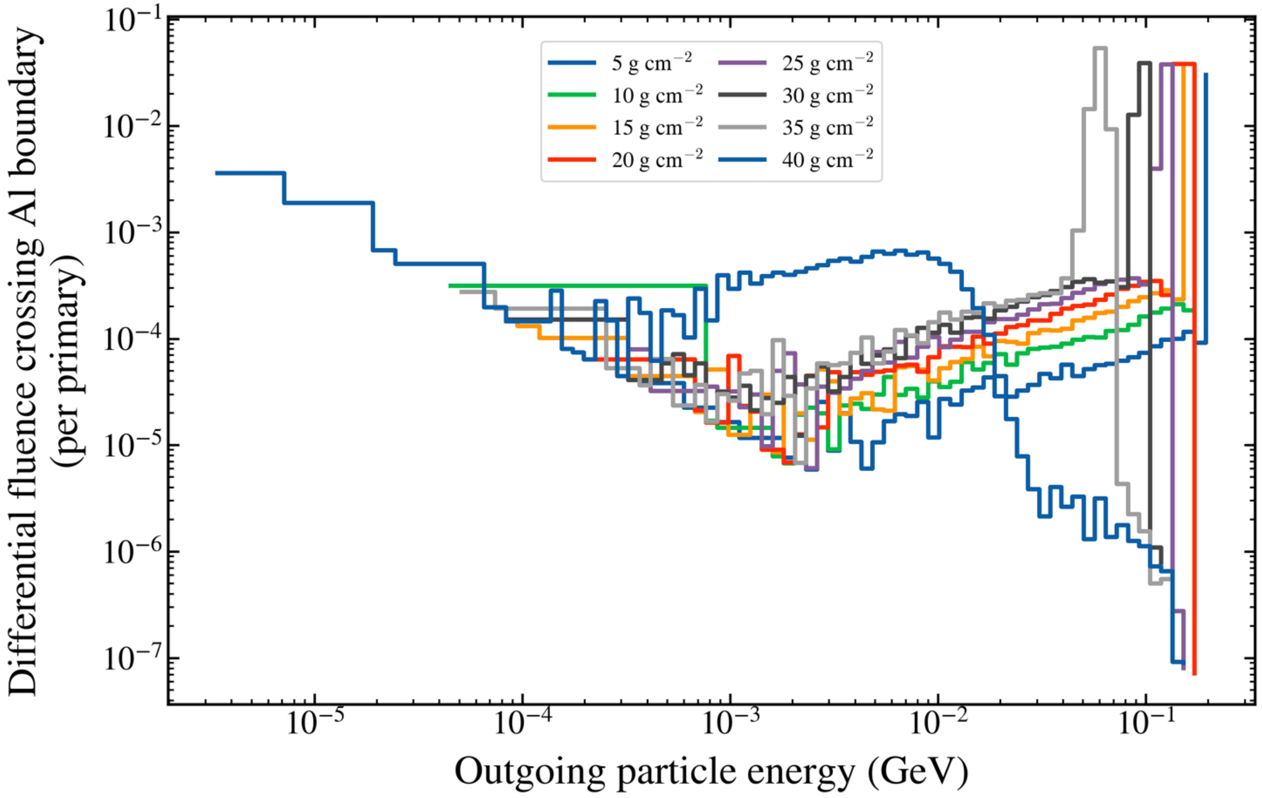
Transmitted proton component remains strong across the thickness range.

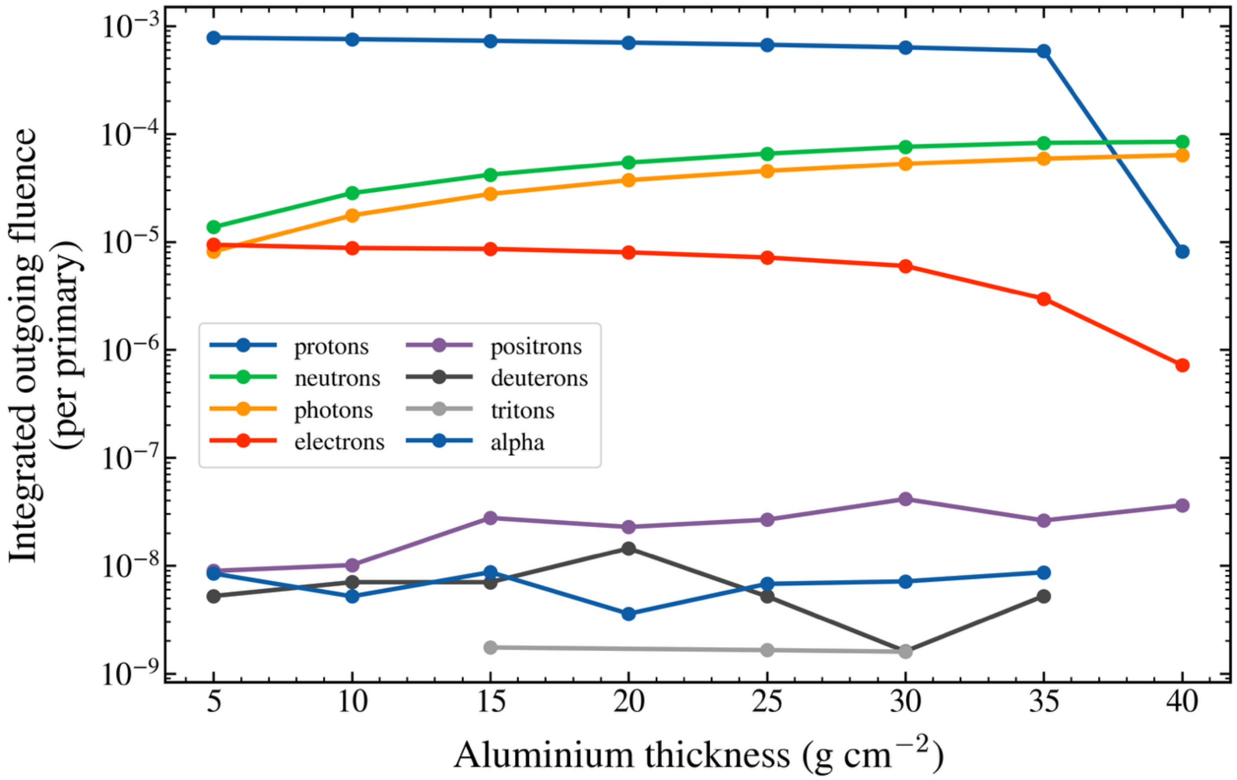


Neutrons, photons and electrons increase as more aluminium is added.

Energy dependence of the shielding response

At 220 MeV, the proton range is comparable to the 5–40 g cm⁻² thickness range studied.





Primary proton transmission drops near the stopping range.

Secondary production is lower than for 1.8 GeV and changes as primaries slow down.

Planned detector-response modelling

The next simulation step converts outgoing fields into predicted above-threshold counts.

Simulation prediction

- Score energy deposition in scintillator
- Apply operating threshold

Laboratory validation

- Known gamma and neutron sources
- Compare measured vs predicted counts

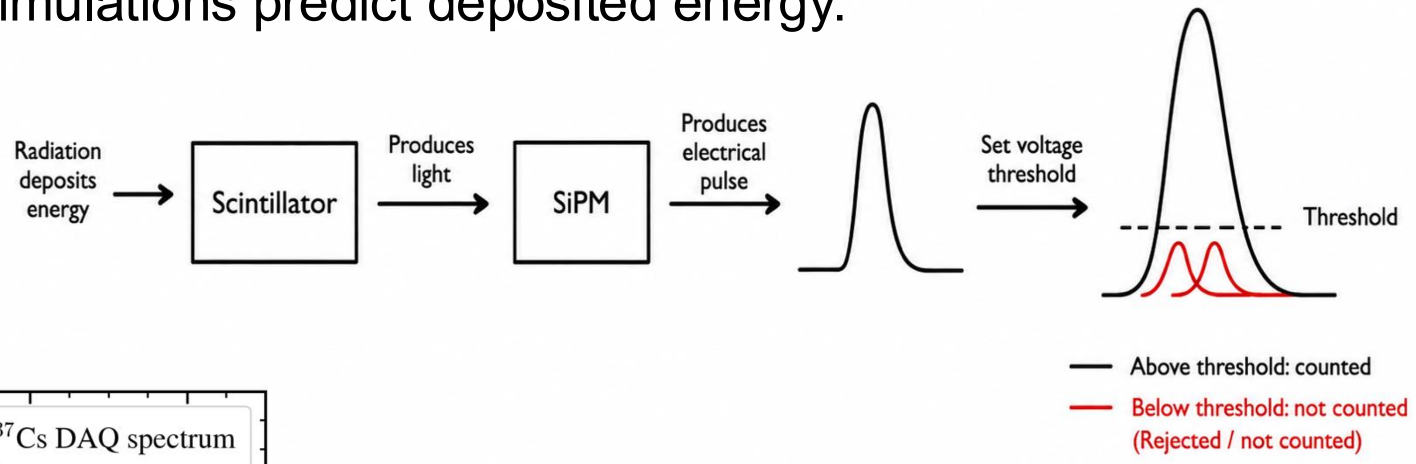
Flight interpretation

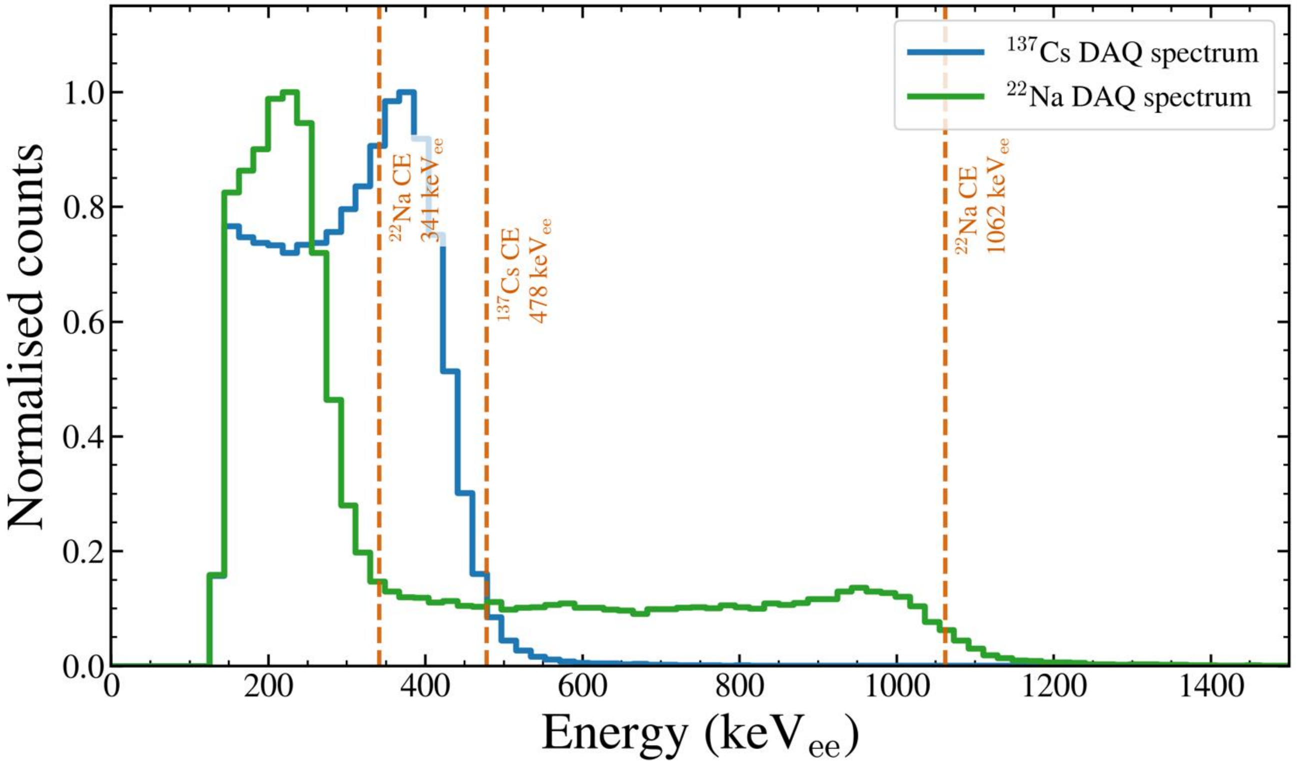
- Use validated model on ISS count rates
- Earthbound twin supports comparisons

Why calibration is needed

The detector threshold is a voltage, but simulations predict deposited energy.

Need a relationship between energy and voltage.

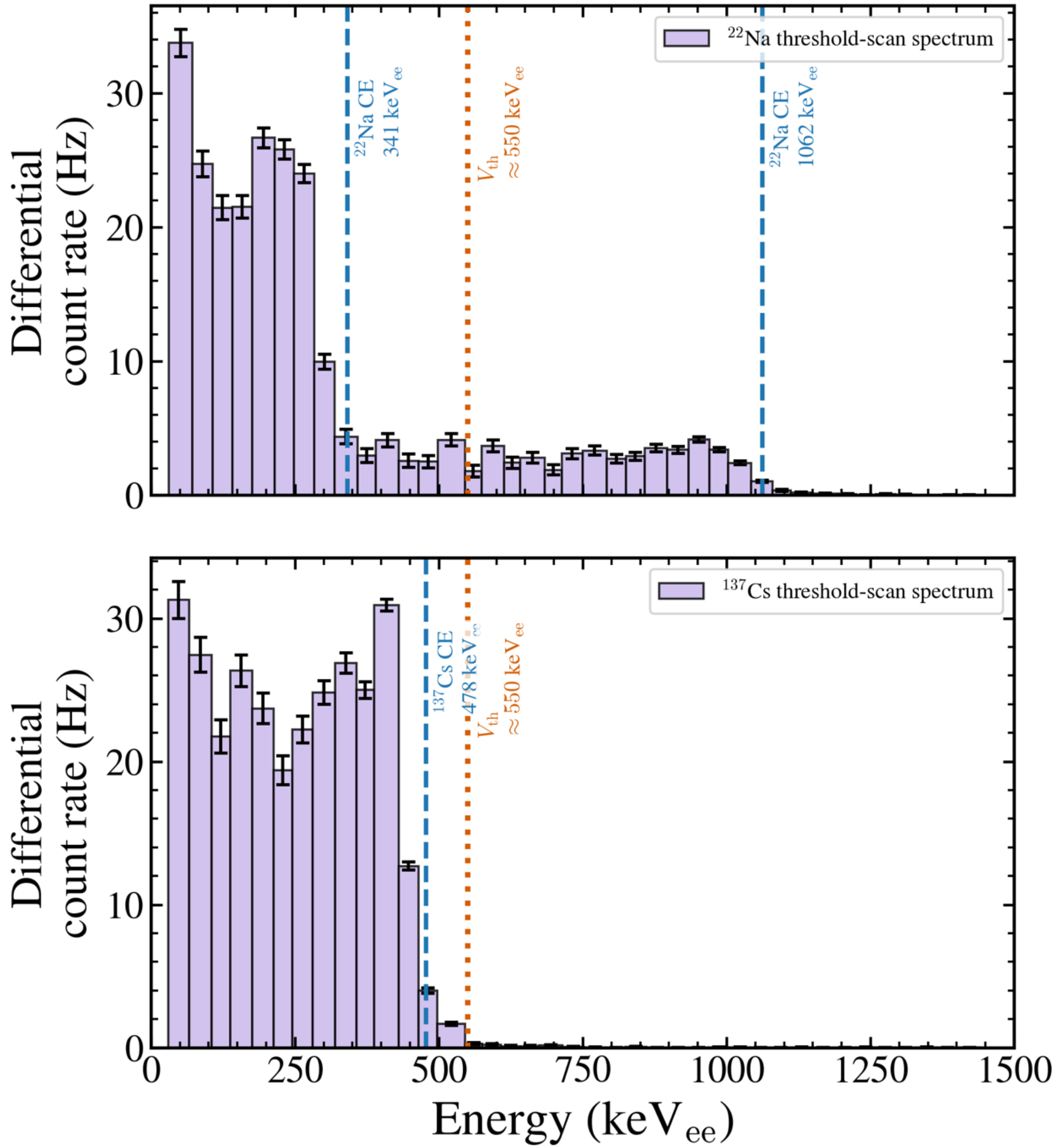


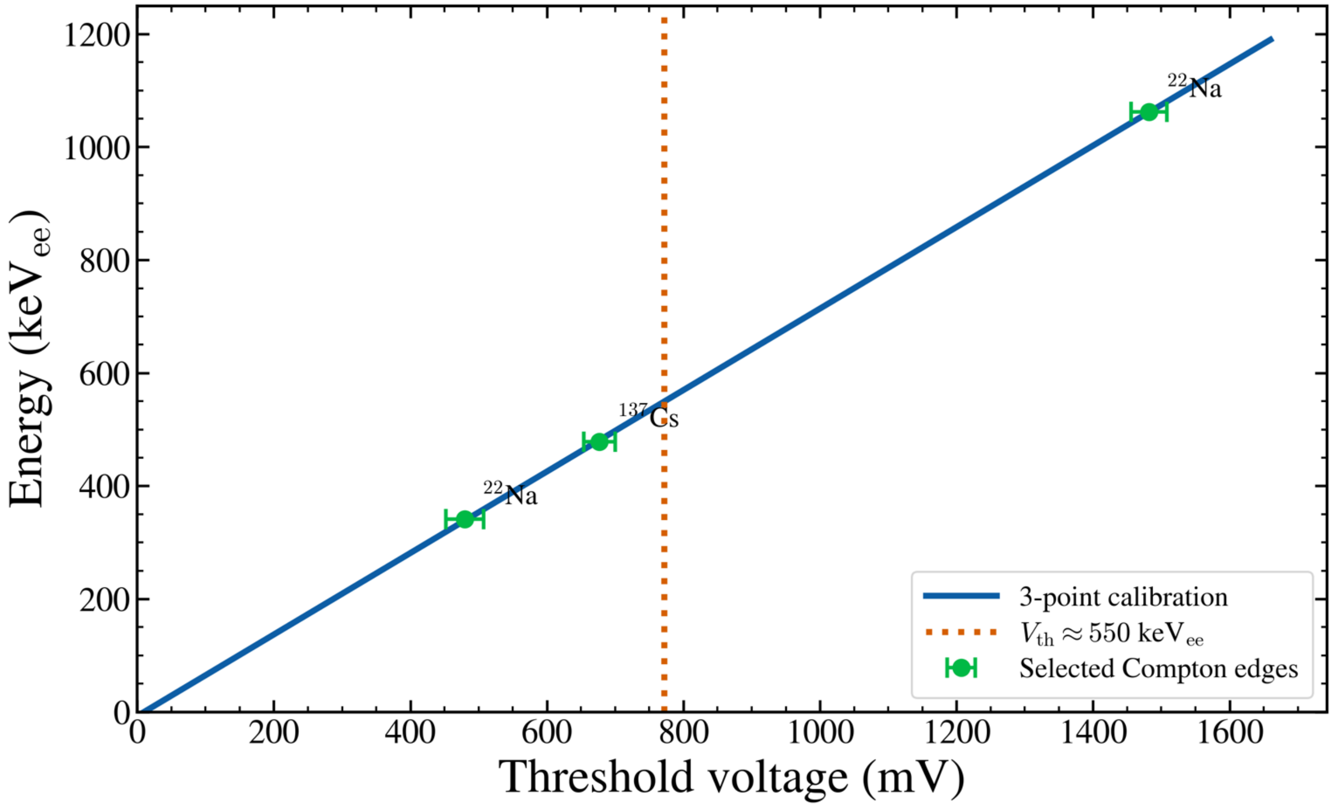


- **V_{th} scanned in ~50 mV steps**
- **Adjacent count-rate differences reconstruct a differential pulse-height spectrum**
- **^{137}Cs and ^{22}Na Compton edges relate V_{th} to deposited energy in keV_{ee}**

Threshold scan and voltage-to-energy calibration

Changing the trigger threshold maps the detector response versus deposited energy.

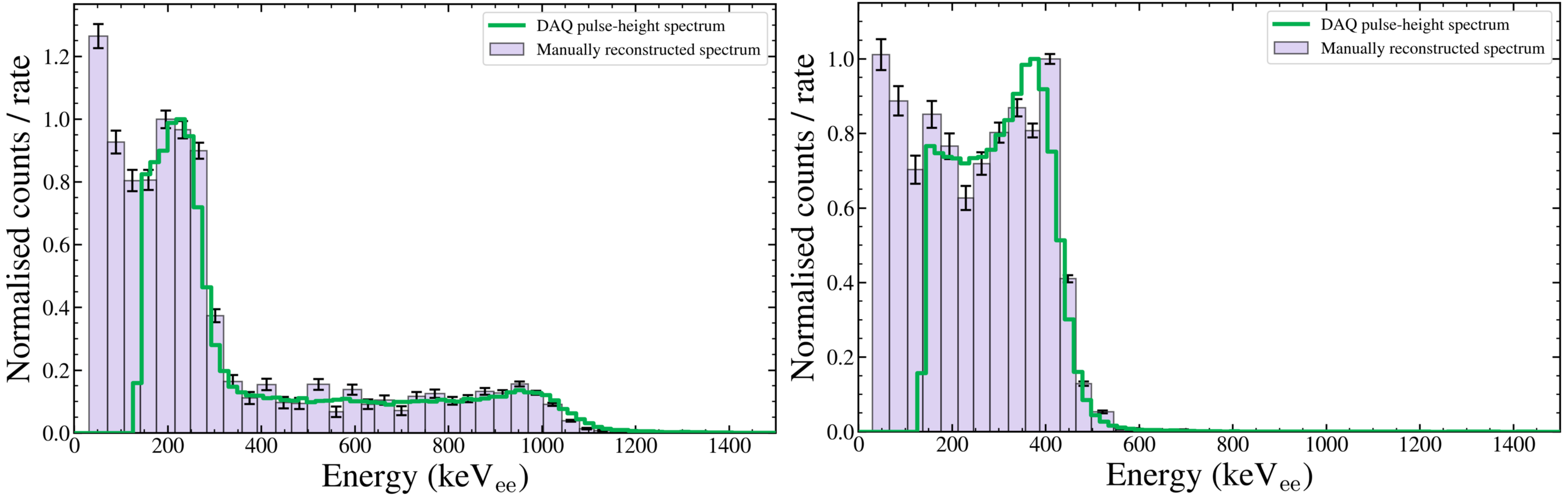




Chosen threshold: 772 mV ≈ 550 keV$_{ee}$

Threshold spectra compared with DAQ spectra

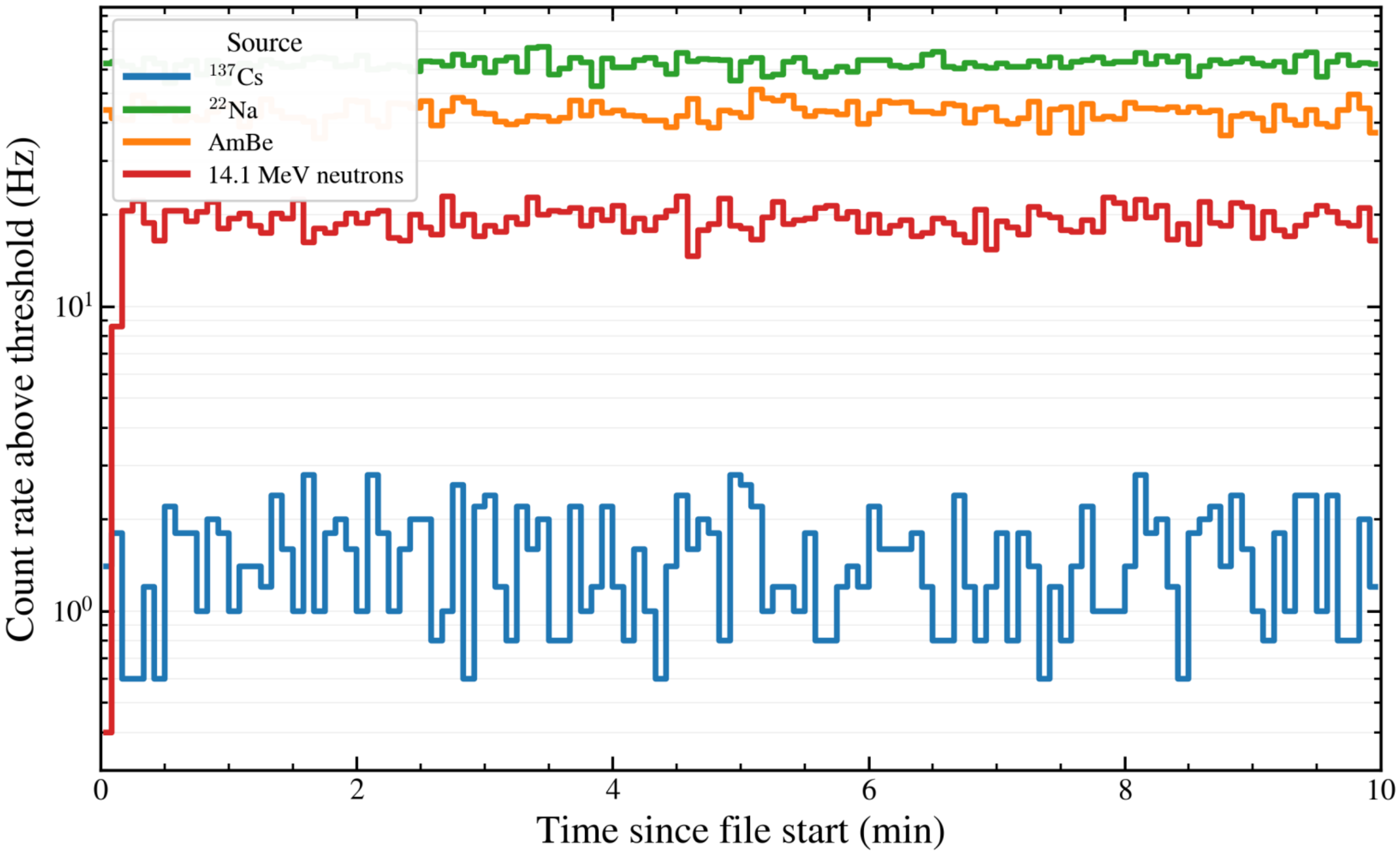
The reconstructed threshold spectra are checked against direct pulse-height measurements.



Main spectral shape and fall-off are reproduced after energy alignment and normalisation.

Source-response measurements for validation

Known gamma and neutron sources provide test cases for detector-response simulations.



Source	Radiation type	Relative to threshold
^{137}Cs	γ	Below
^{22}Na	γ	Above
AmBe	n/γ	Above
14.1 MeV neutrons	n/γ	Above

AmBe and 14.1 MeV neutron measurements provide validation cases for detector-response simulations.

UCT n-lab detector to fly on NASA Mission NG-25 to ISS

launch expected December 2026

- Cargo flight to International Space Station
- Space-X Falcon 9 rocket
- Cygnus XL cargo spacecraft (Northrop Grumman)
- Cape Canaveral Space Launch Complex 40
- Cargo payload 5000 kg
- Our detector <100 g ☺

n lab
n lab innovation
MAXIQ.SPACE
VOYAGER

NASA SPACEX NORTHROP GRUMMAN

NG-24 launch 11 April 2026

From the lab to the ISS

The flight detector has been sent off for its journey towards ISS deployment.

Flight detector

Will measure count rates in the real ISS radiation environment.

→

Earthbound twin

Continues lab calibration and source-response tests.

Progress and next steps

Calibration plus radiation-transport modelling make compact ISS measurements physically interpretable.

Progress so far

- ISS-like primary spectra modelled with SPENVIS.
- FLUKA shielding simulations completed for monoenergetic protons.
- Threshold calibrated using 137-Cs and 22-Na.
- Gamma and neutron source-response measurements performed.

Next steps

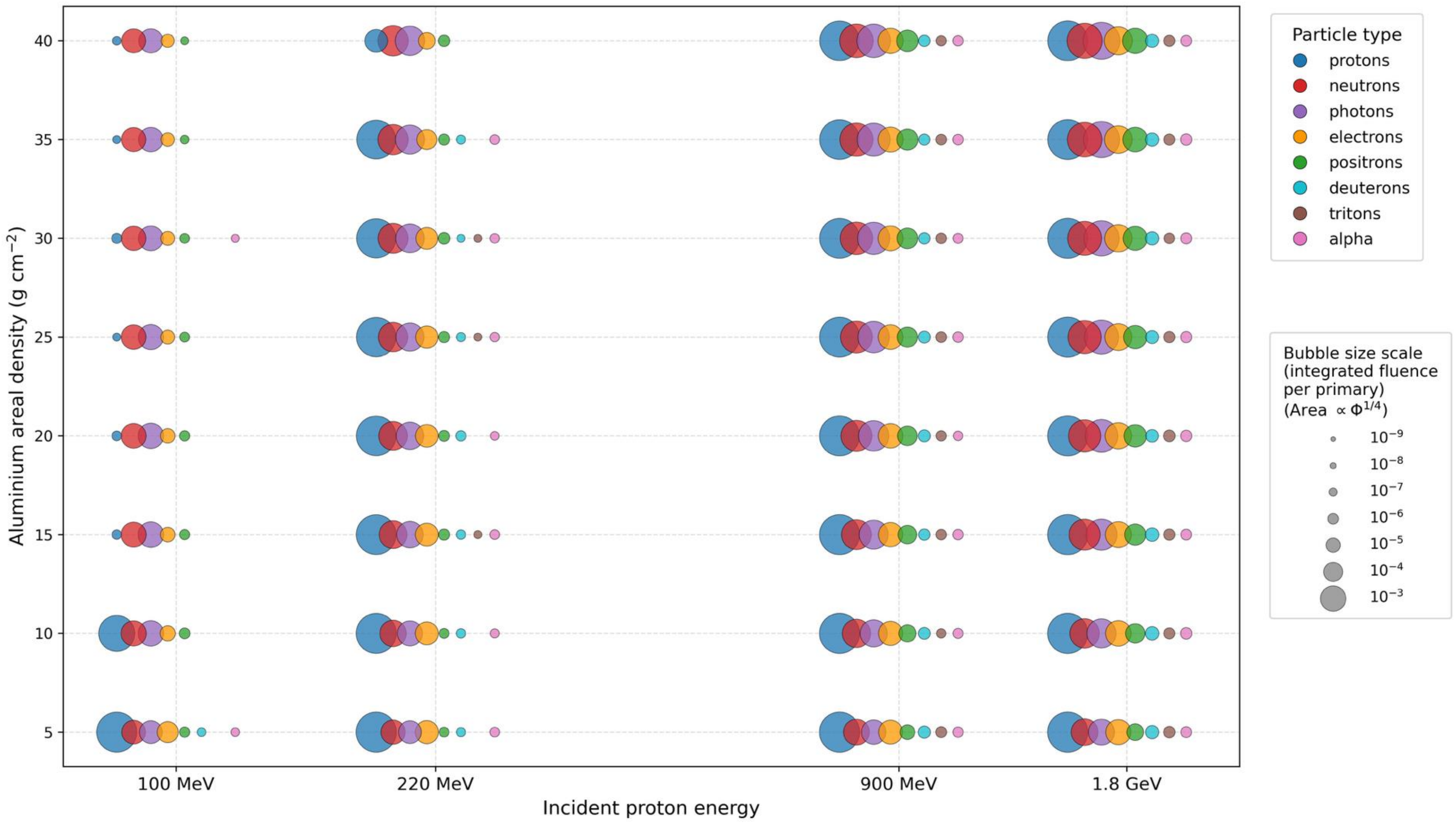
- Use broad SPENVIS-weighted FLUKA spectra.
- Include alpha particles and heavier primary species.
- Simulate detector response directly.
- Compare predicted counts with lab and ISS data.

Final message

This work links space-environment modelling, radiation-transport simulations and laboratory detector characterisation to make compact ISS radiation measurements physically interpretable.

Summary of Stage 1 monoenergetic protons

Integrated outgoing fluence across incident proton energy and aluminium areal density.



- Bubble area represents integrated outgoing fluence per primary.
- Higher energies produce broader mixed fields.
- Low-energy protons attenuate more strongly.

Power-source stability check

No obvious power-source dependence in the above-threshold count rate.