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CubeSat compatible instrumentation for monitoring the radiation environment

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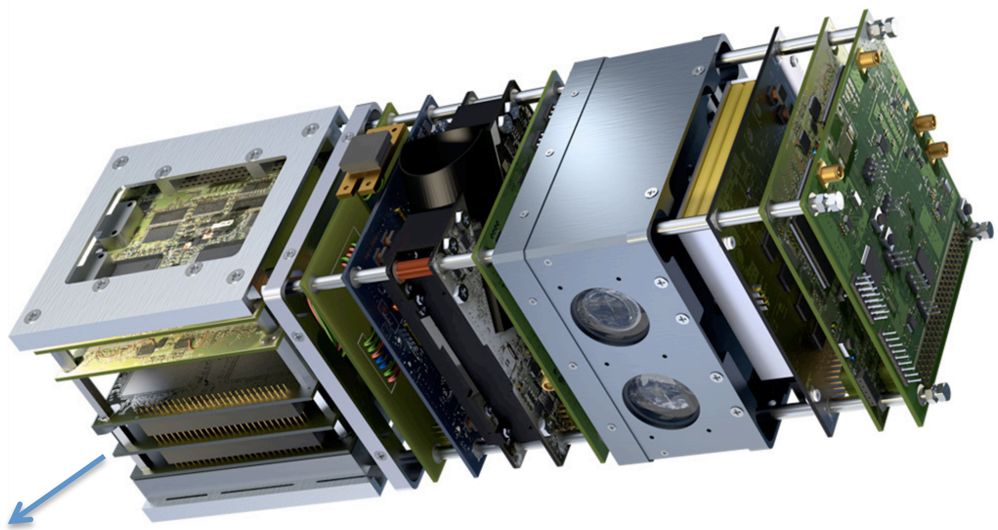
RADMON

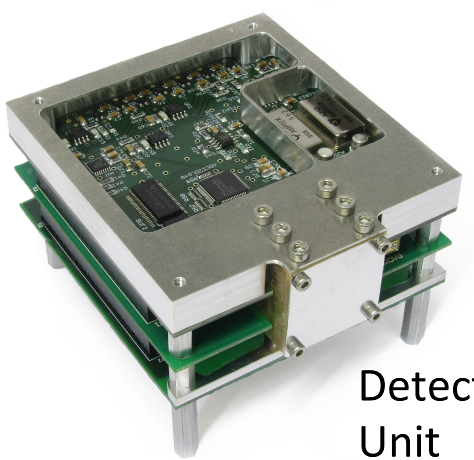
Radiation Monitor for a CubeSat

RADMON: Energetic particles @ LEO

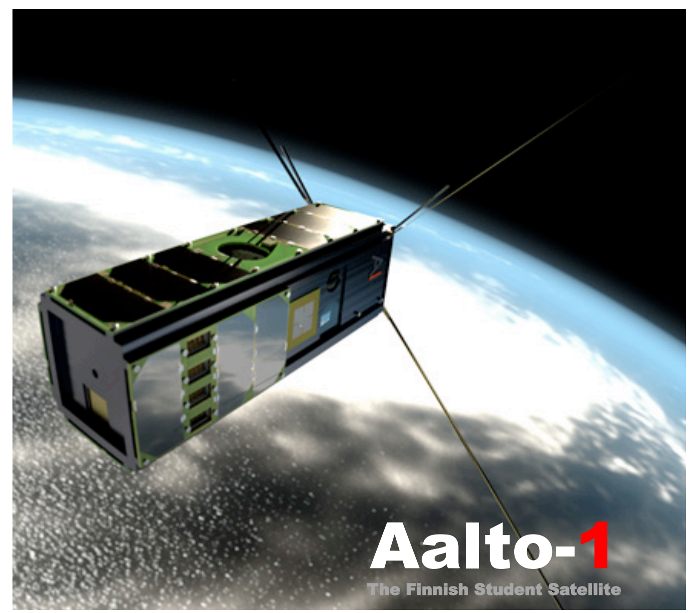
RADMON
Mass: 0.4 kg
Power: 1 W
Volume: 0.4 U



Analog Board
Digital Board
PSU Board



Detector
Unit



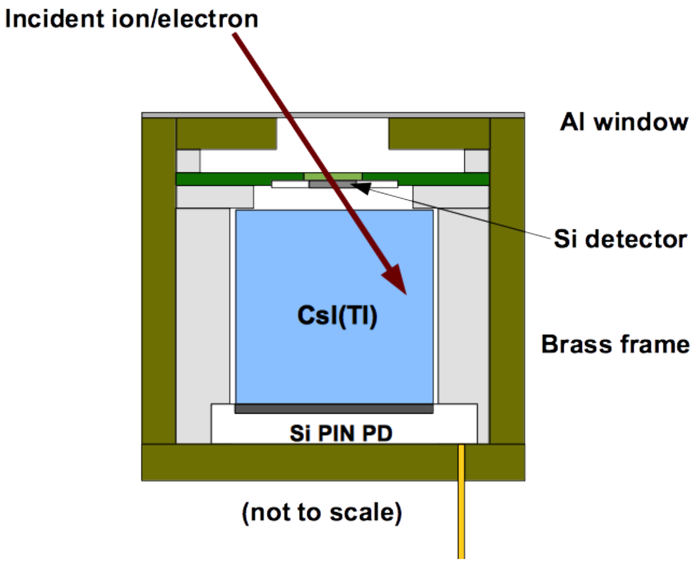
Aalto-1
The Finnish Student Satellite

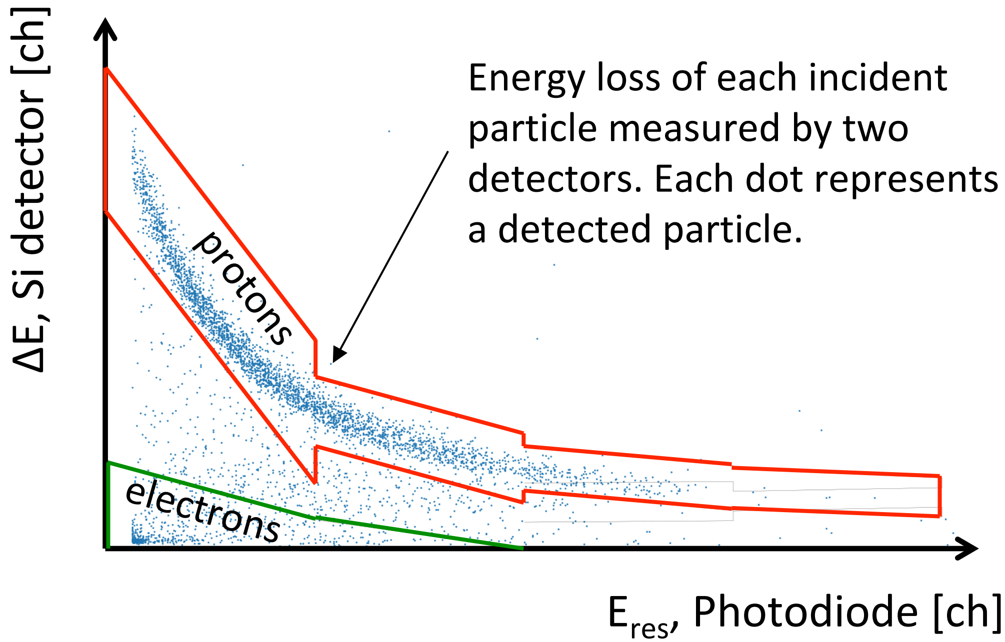
Turun yliopisto
University of Turku

RADMON measurement principle: ΔE vs E_{res} method

ΔE @ constant E_{res} gives the species

$\Delta E + E_{res}$ gives the energy





RADMON Mass: 0.4 kg
RADMON Power: 1 W
RADMON Volume: 0.4 U

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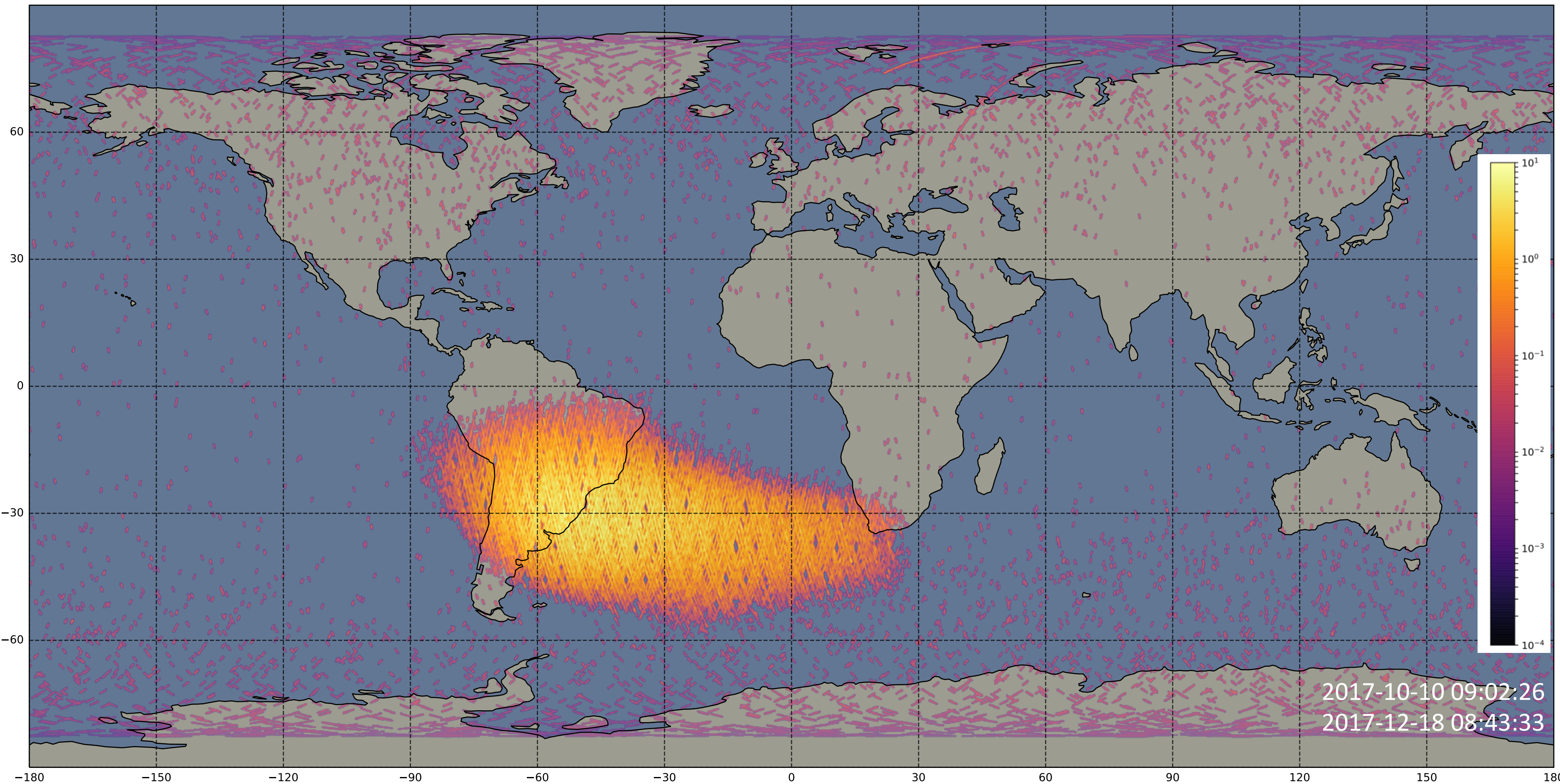
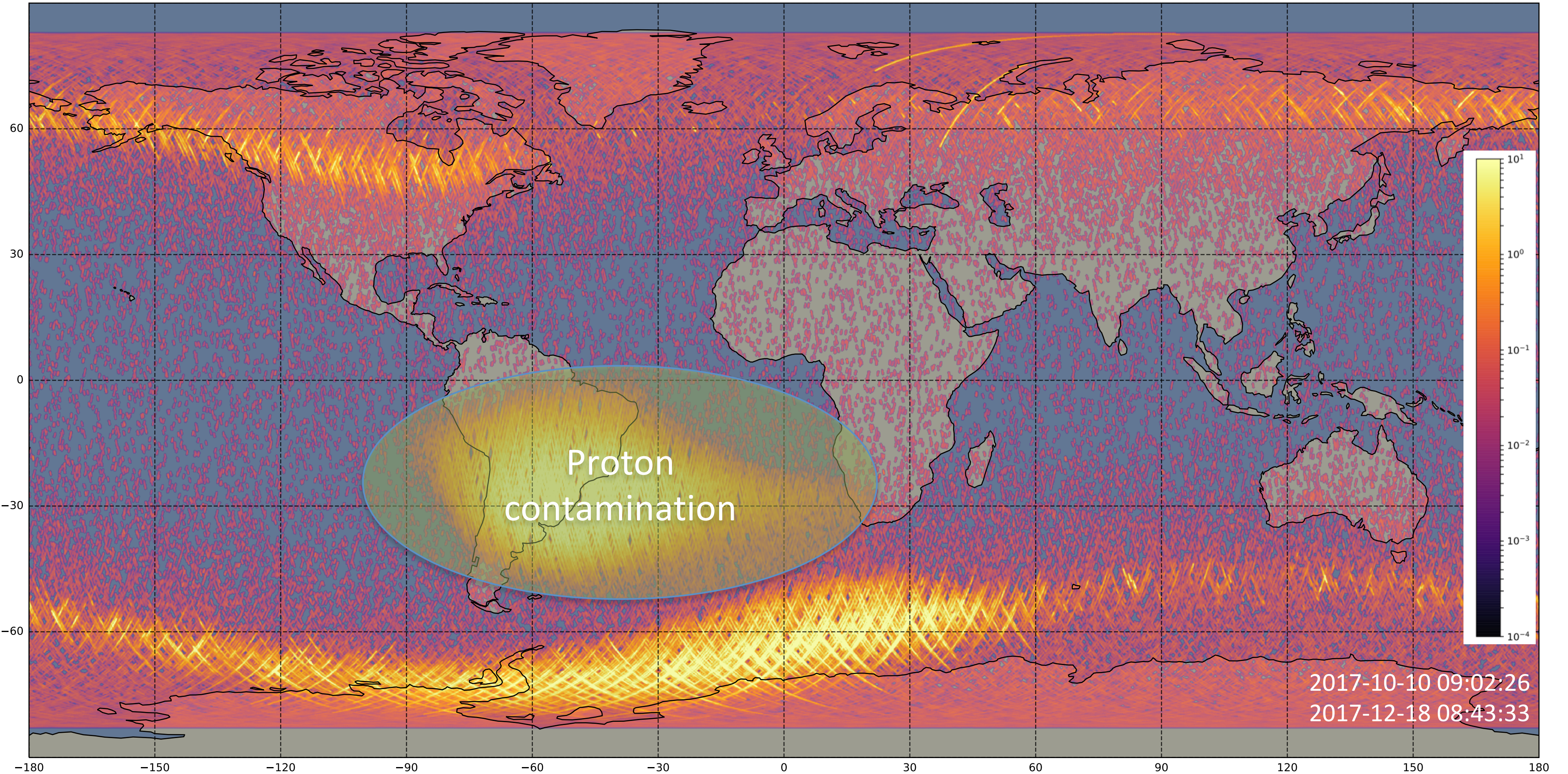
Energetic (>10 MeV) protons



Inner-belt protons observed in SAA at a stable rate [not much orbit-to-orbit variations]

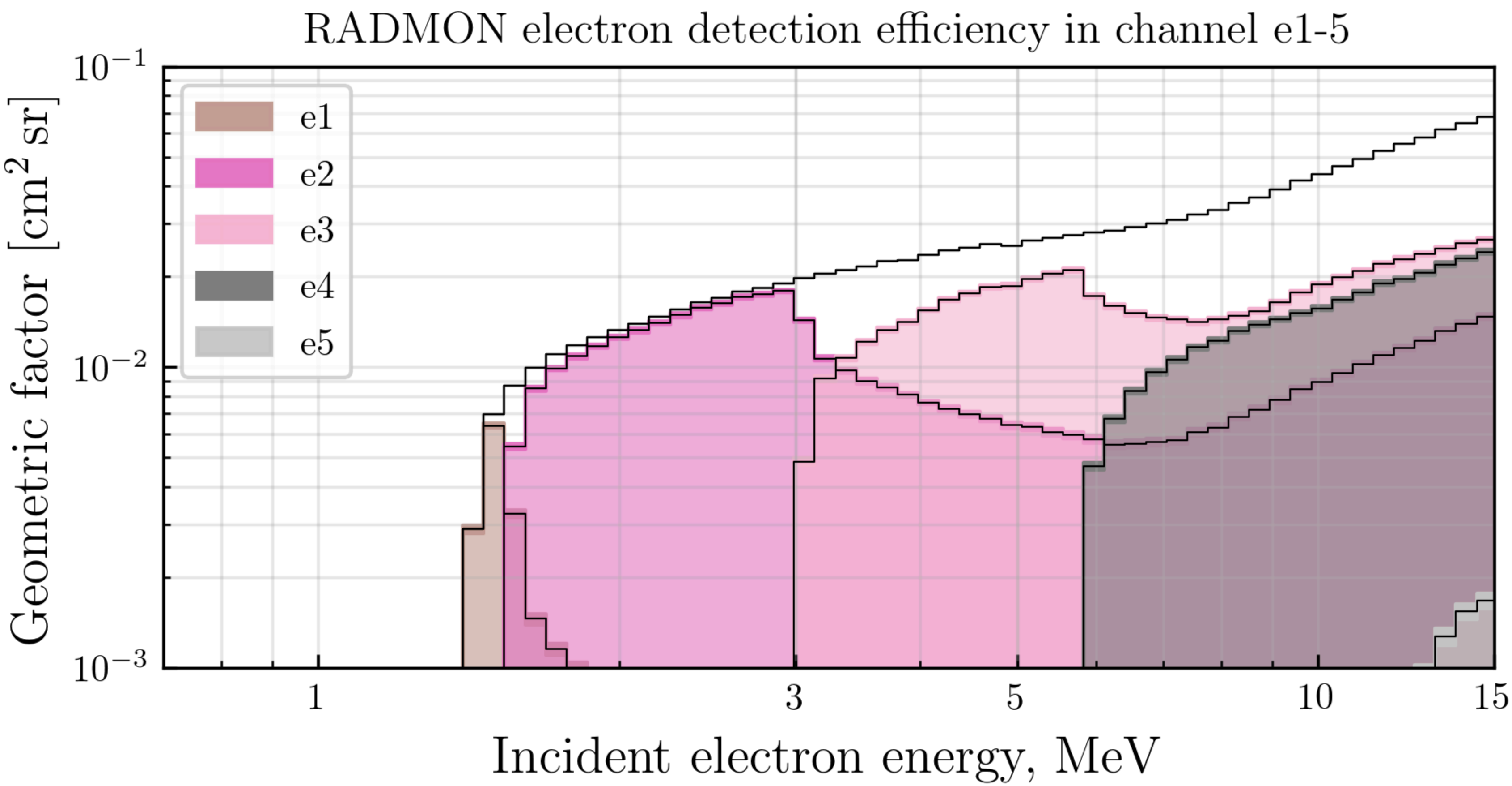
Fig. A. Punkkinen

Relativistic (>1.5 MeV) electrons

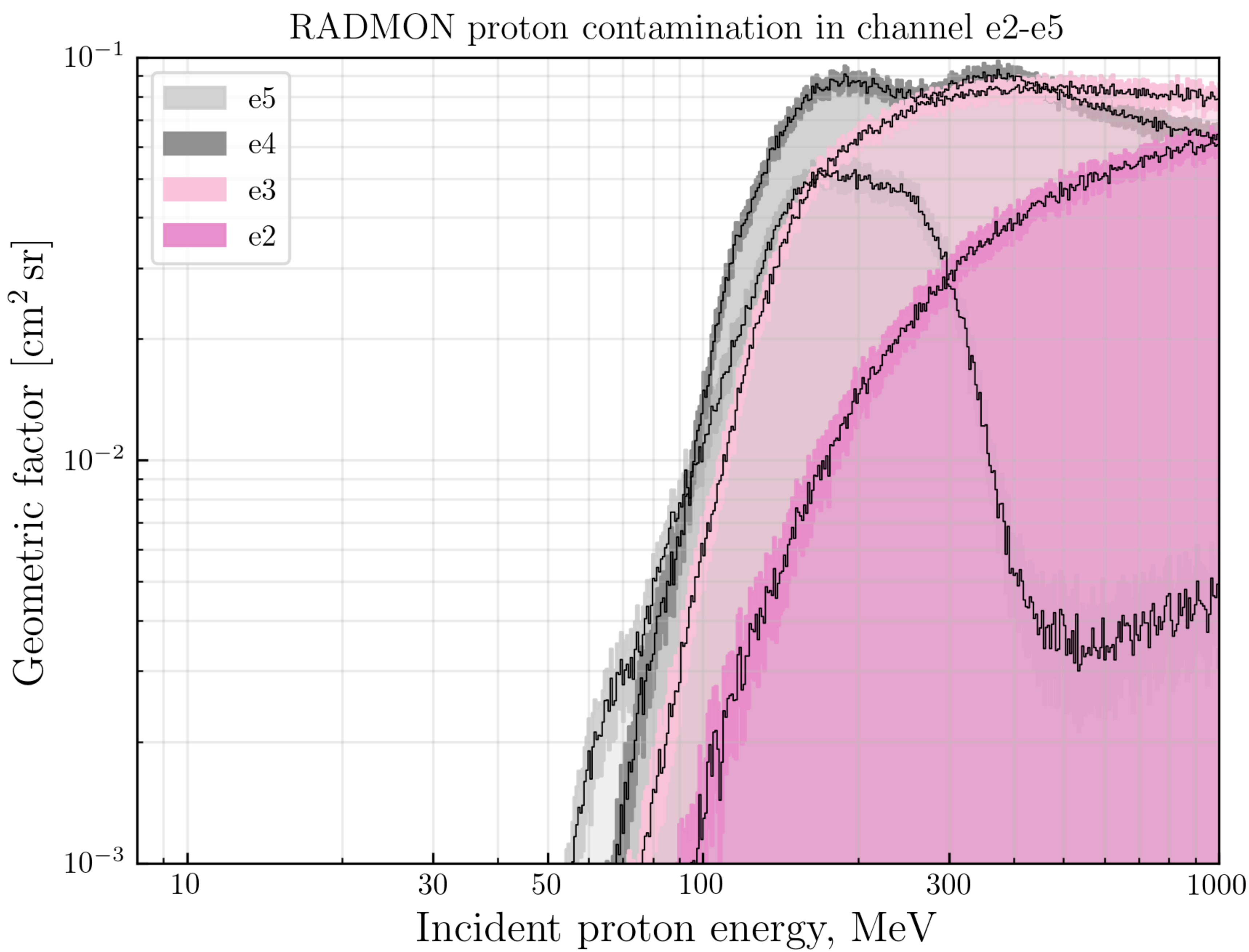


Inner-belt electrons observed in SAA at a stable rate
Outer-belt electrons observed at higher latitudes more variable
Quasi-trapped electron flux increases with longitude from trapped region

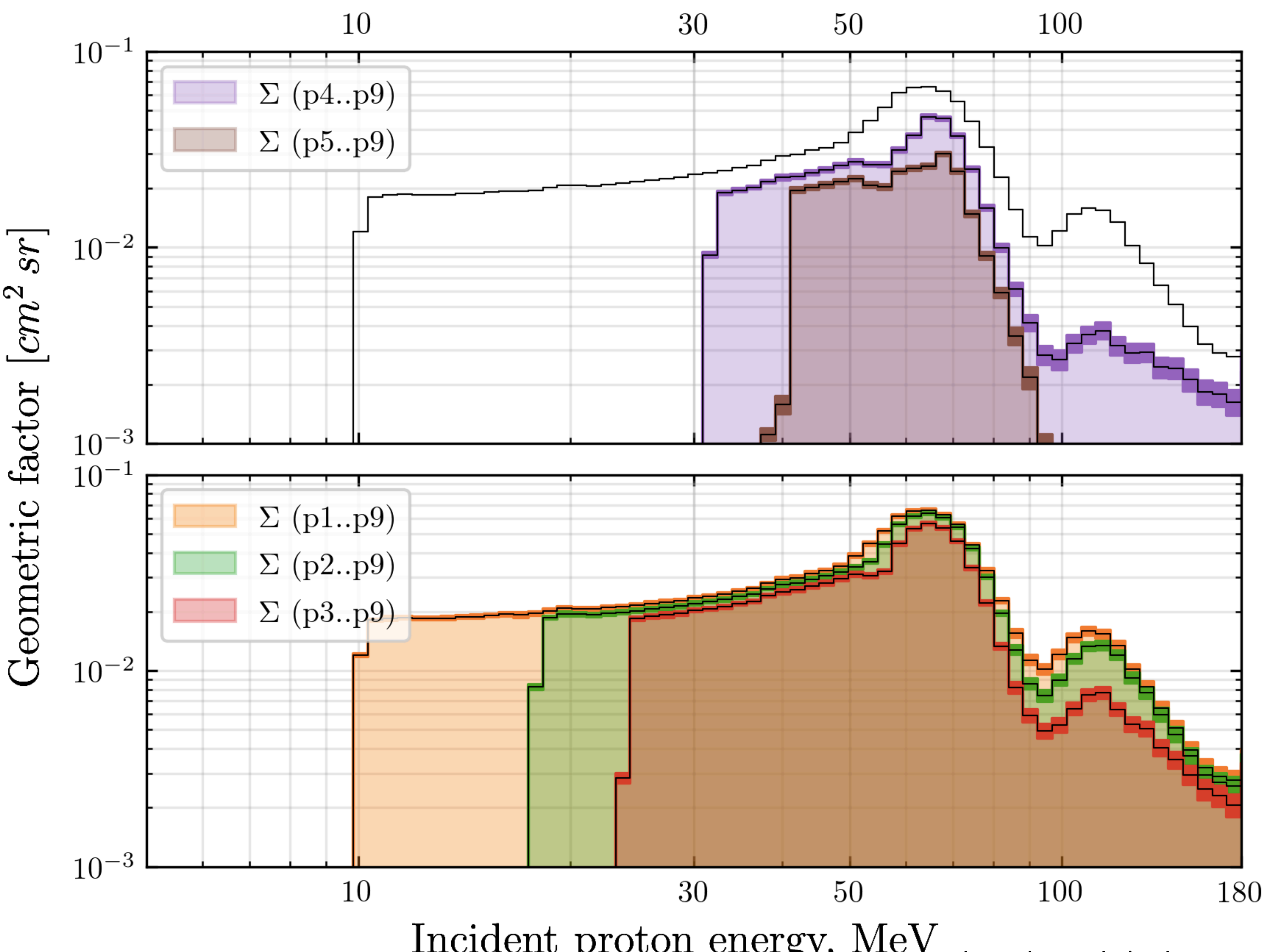
Fig. A. Punkkinen



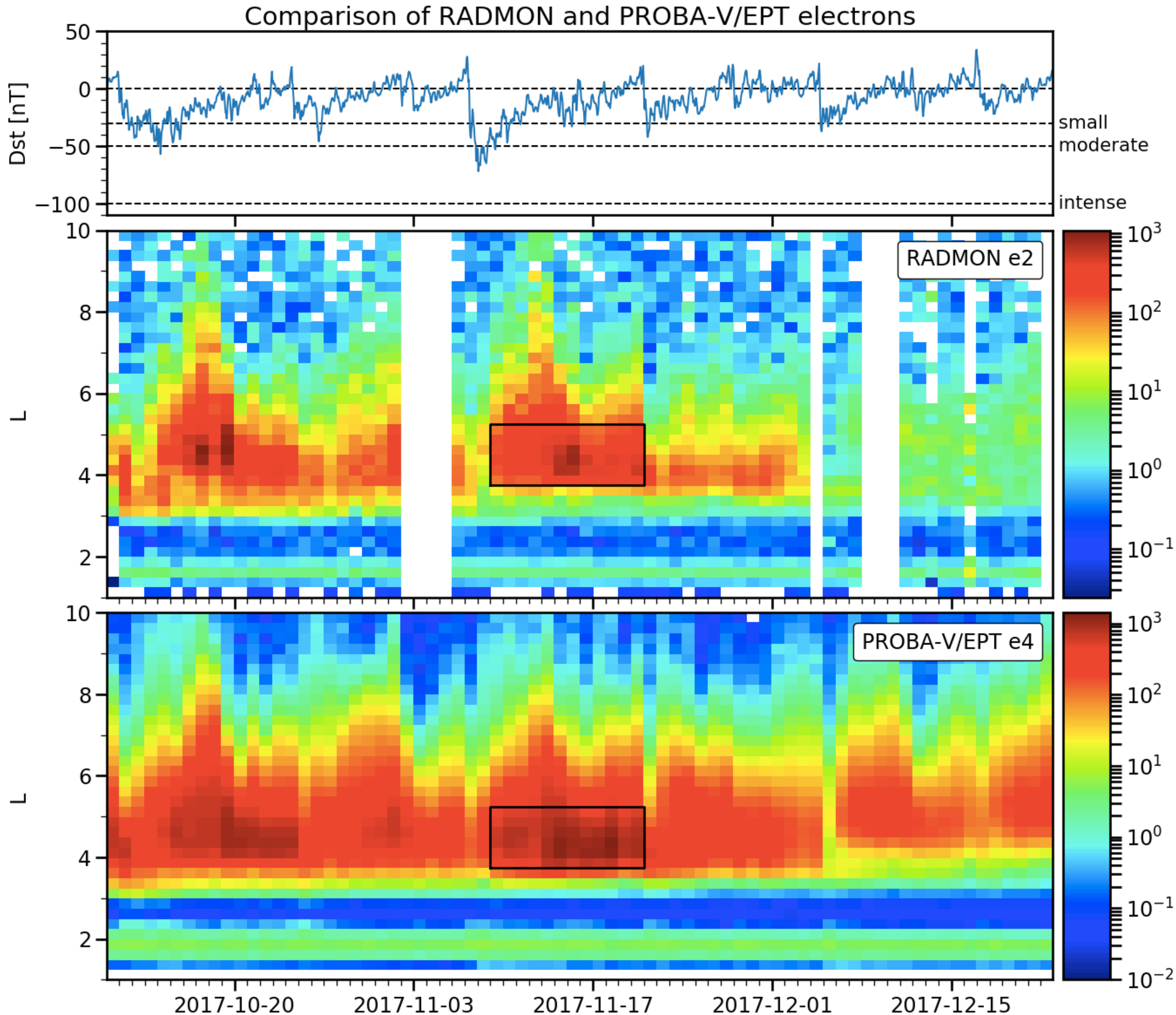
Oleynik et al. (submitted)



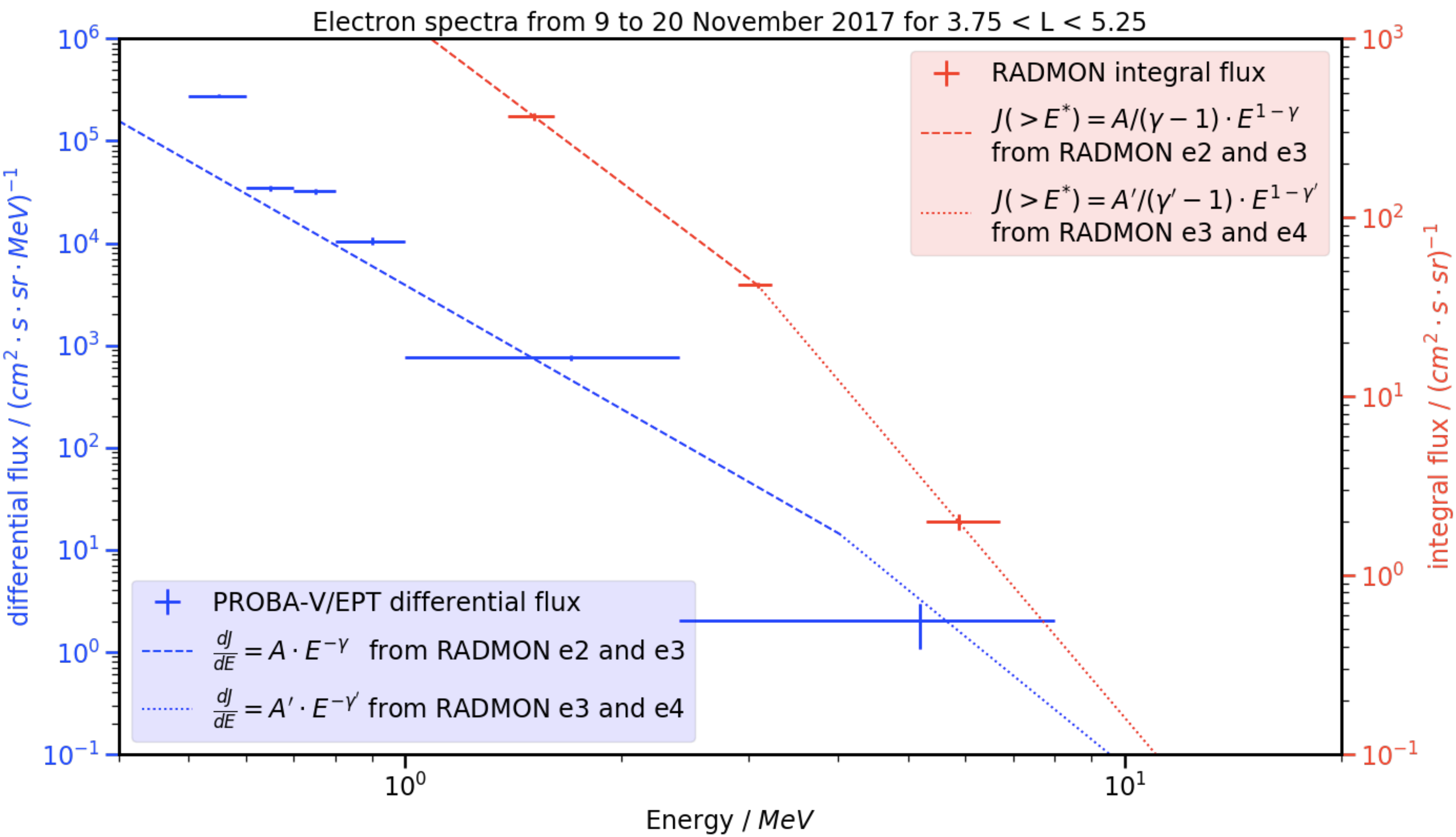
RADMON proton contamination in channel e2-e5
e5
e4
e3
e2
Geometric factor [cm² sr]
10^{-1}
10^{-2}
10^{-3}
10
30
50
100
300
1000
Incident proton energy, MeV



Oleynik et al. (submitted)



Gieseler et al. (submitted)



Gieseler et al. (submitted)

Summary / RADMON

- Despite its low-cost, low-power and low-mass, RADMON is a very capable instrument concept
- FPGA-based signal processing allows several improvements for future models without changes in hardware
  - Better electron/proton separation
  - Extension of proton energy range to 250 MeV
- Sensitivity can also be improved ten-fold by increasing the size of the sensors with marginal mass increase
- Dynamic range of counting can be further improved by changing the scintillator material (to, e.g., LYSO)
  - Power consumption will increase, though
- Mass and size can be somewhat reduced by redesigning electronics
- Next version developed for constellation mission (see Huovelin et al. on Thursday)

Particle Telescope (PATE)

Particle Telescope aboard FORESAIL-1 mission

- Mass 1.2 kg
- Power 2.5 W
- Size 1.4 U
- Telemetry 1.3 kbit/s

Measures electrons and protons

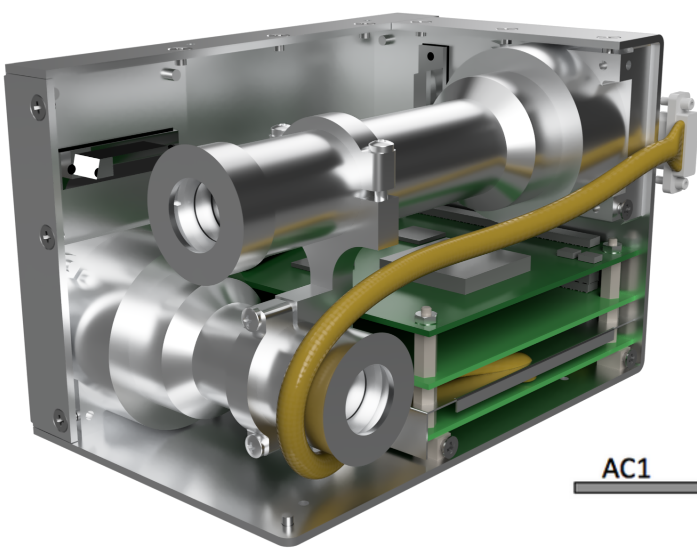
- Electron energy range: 80–800 keV
- Proton energy range: 0.3–10 MeV

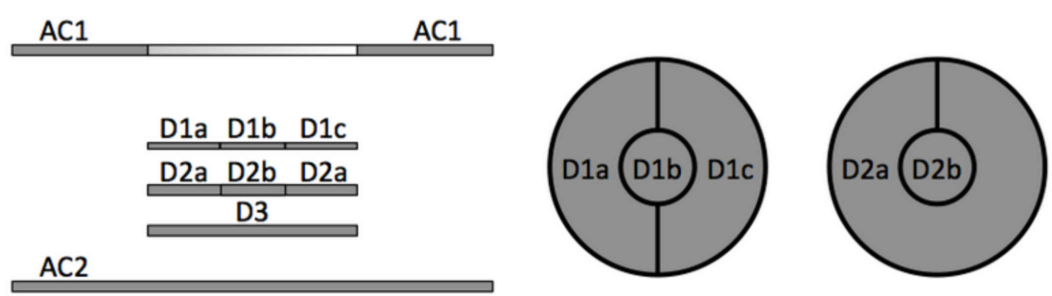
Prototype tested with radioactive sources (alpha and beta)

EQM will be assembled and functionally tested by the end of November

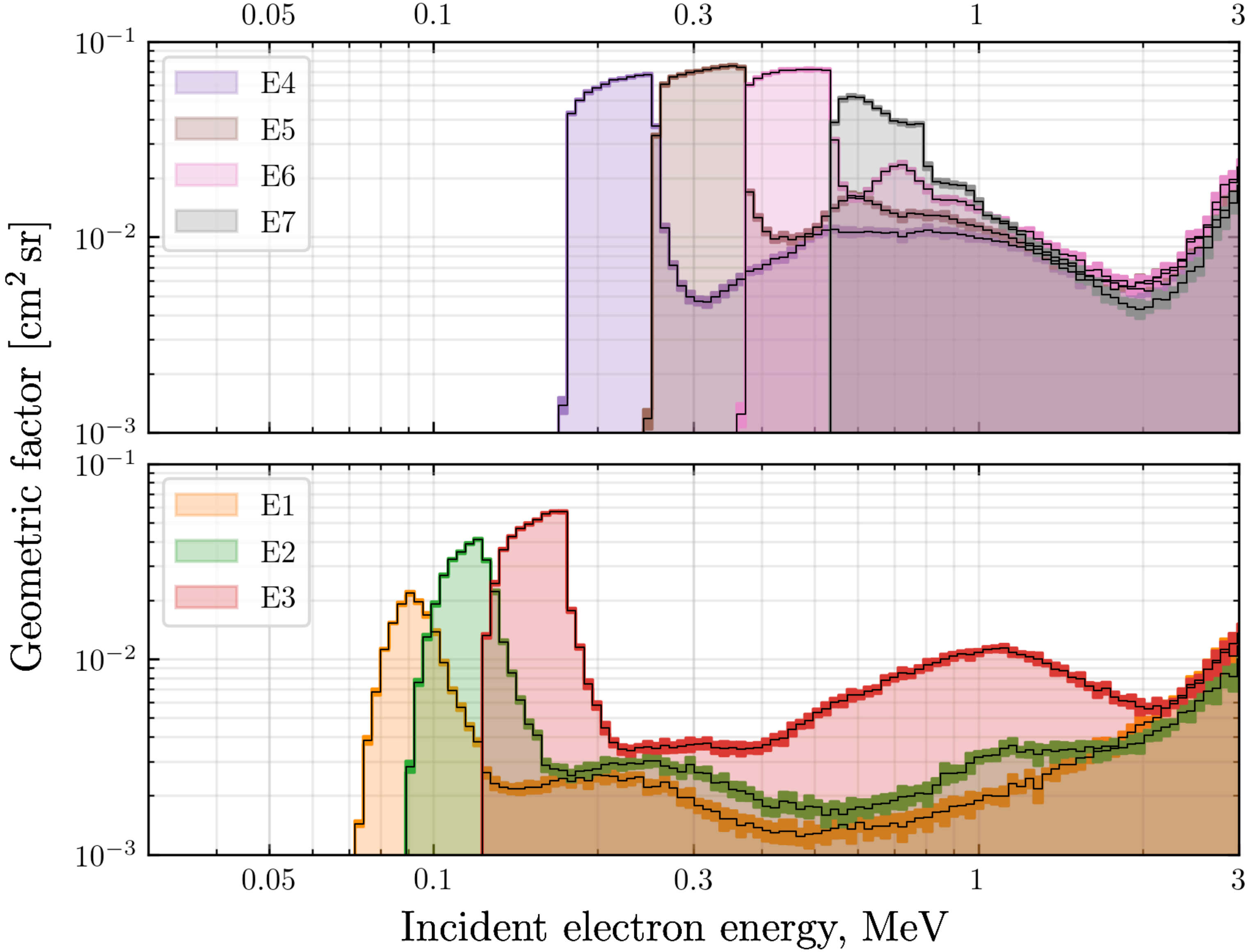
Qualifications: Dec-Jan —> TRL 6

Launch: 2020

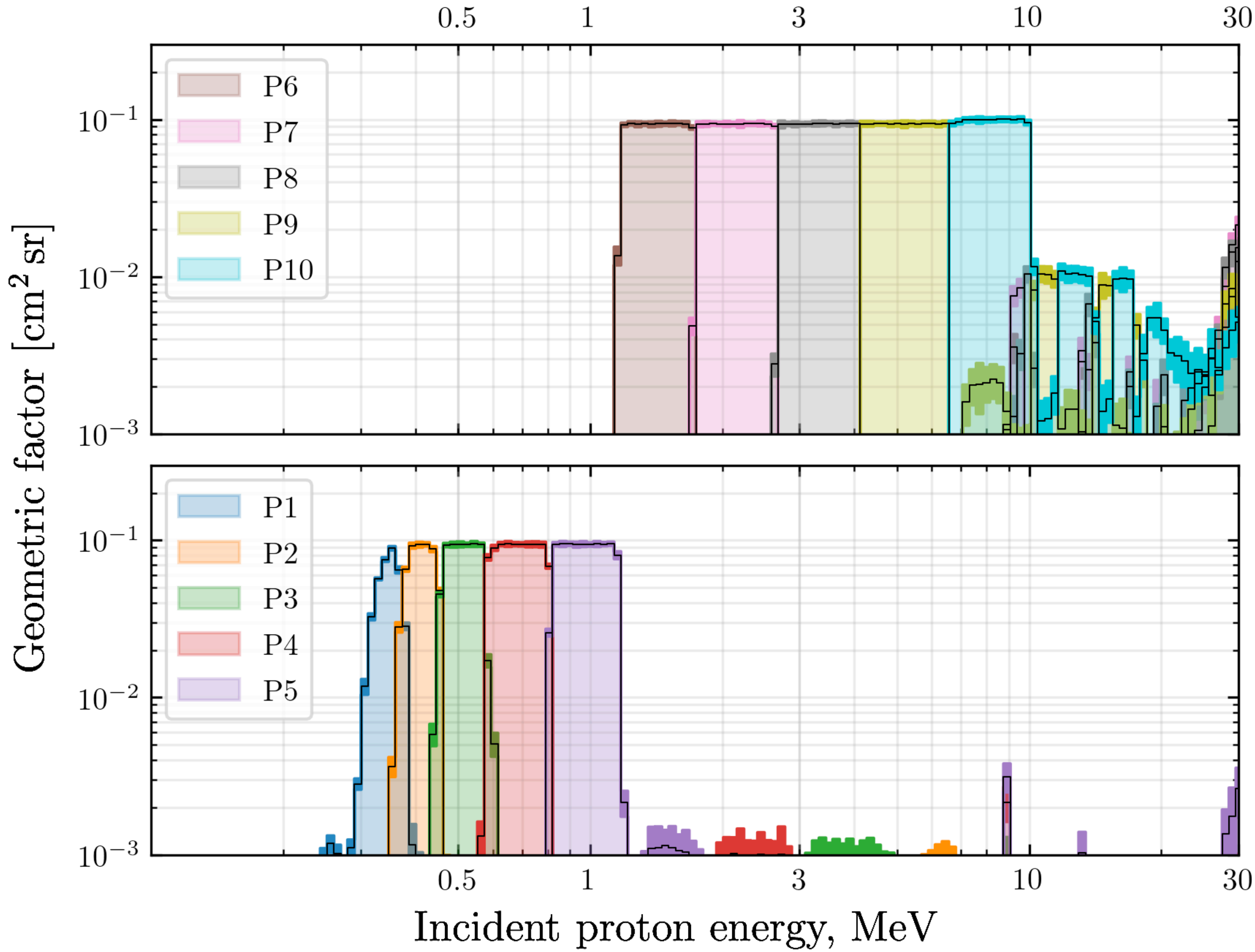




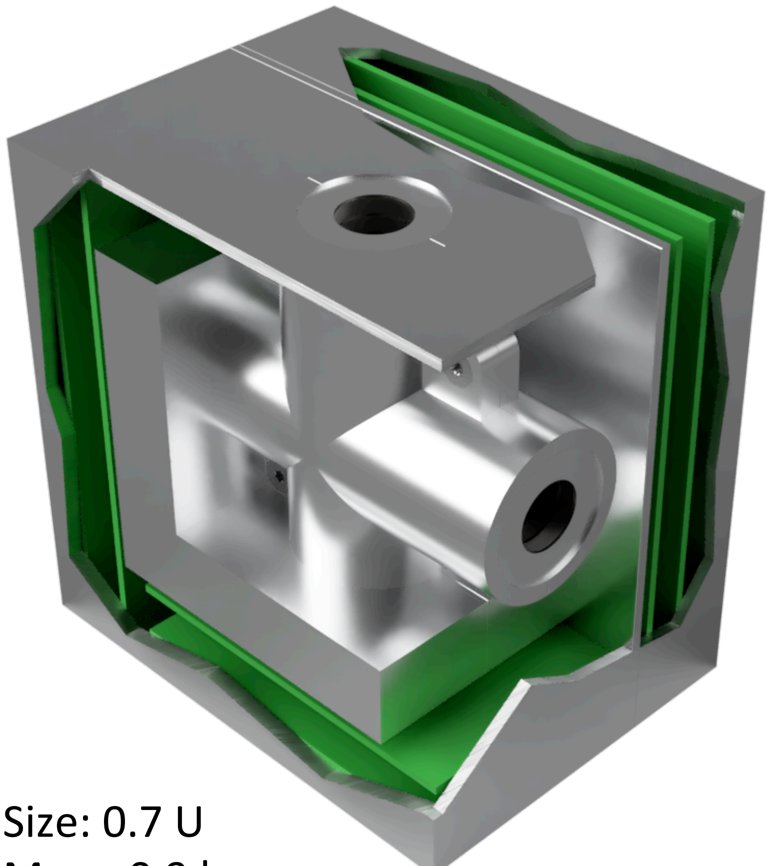
Electron response



Proton response



More compact design



Size: 0.7 U
Mass: 0.9 kg
Power: 2.5 W
Electrons: 0.1–1 MeV, >1 MeV
Protons: 0.4–10 MeV, >10 MeV

Developed in collaboration with Aboa Space Research Oy for a small constellation mission concept (SCOPI).

Summary / PATE

- A high-fidelity particle telescope designed for medium-energy electrons and ions
  - Qualification campaign about to start for the 1.4U device —> TRL 6 to be reached within 3 months
  - Launch on-board a 3-U CubeSat (FORESAIL-1) to polar LEO in 2020 —> TRL 9 within 15 months
- Compact variant for monitoring applications with somewhat higher energy range in preliminary definition phase
  - Representative prototype to be built and tested during 2020 —> TRL 5
  - Lots of heritage from PATE —> swift development cycle

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Conclusions

- University of Turku develops CubeSat compatible instrumentation for high and medium energy particles
  - Protons: 0.3 – 10 MeV and >10 MeV
  - Electrons: 0.08 – 1 MeV and >1 MeV
- High-energy instrumentation is already flying hardware and the first medium energy instrument will fly in 2020
- We collaborate with several Finnish SMEs and can adapt our design quite flexibly to accommodate needs for various space weather missions.

Thank you for your attention!

Instrument for LEO constellation

- Based on Aalto-1/RADMON (TRL 9), but with significant improvements to cover
  - Protons: 10–250 MeV, ten differential channels
  - Electrons: >1 MeV, five integral channels
- Foreseen specs:
  - Mass <500 g
  - Volume <0.5 U
  - Power <1.5 W
  - Dynamic range up to 1 MHz in counting
  - Nominal GF ≥ 0.2 cm^2 sr (increasing with energy)
  - Data rate: configurable

Aalto-1/RADMON