RUAG Aerospace Defence Technology

PAUL SCHERRER INSTITUT PSI

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Nos creare scientia hodie ad cras

Radiation Hard Electron Monitor RADEM

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Radiation Hard Electron Monitor - RADEM

Compact, light instrument for exploration of Jupiter radiation environment

Mass < 1 kg; Volume < 1 dm^3, Power < 1 W

Electron detector

Spectral range 100 keV – 20 (40) MeV

peak flux 10^9 e/cm^2/s

Proton and heavy ion detector

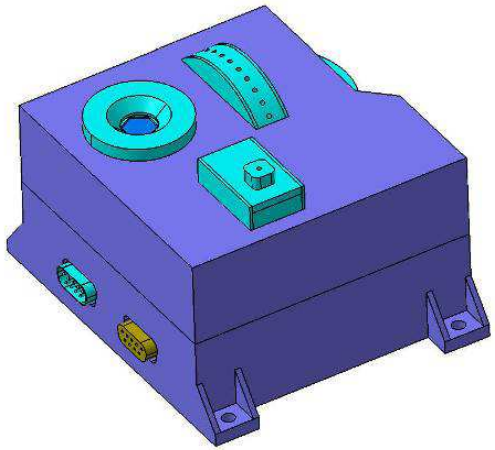
Spectral range 2 MeV – 200 MeV

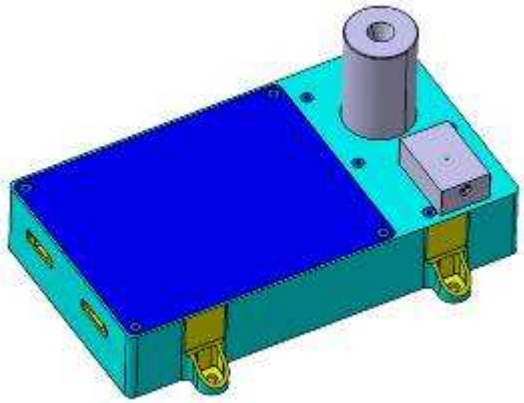
peak flux 10^8 p/cm^2/s

Radiation hard

dose determination and alarm function

Particle separation





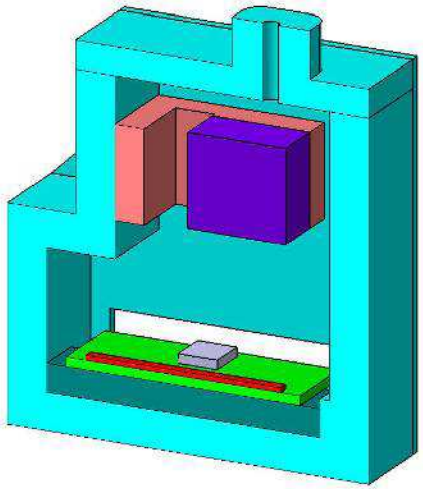
Electron Spectrometer - concept

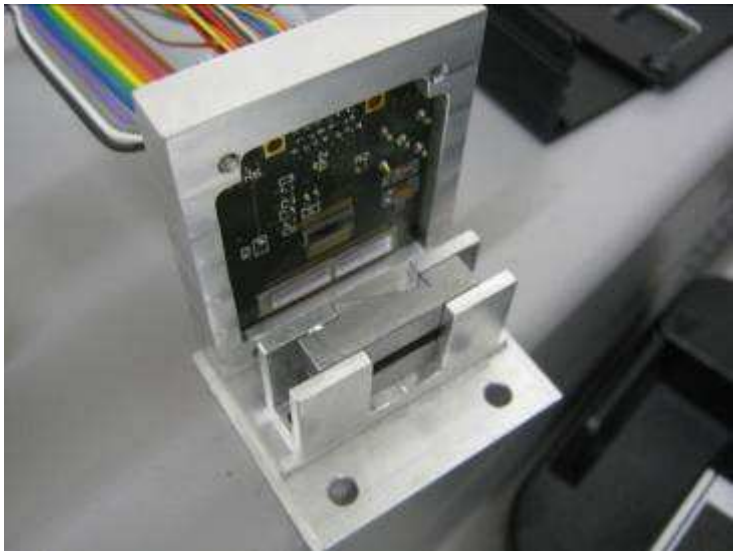
Magnetic Spectrometer based on permanent magnets

Energy range from 100 keV to 20 MeV (40 MeV option)

Energy resolution - 8 bins evenly spaced on log-scale

Si-microstrip as energy sensor





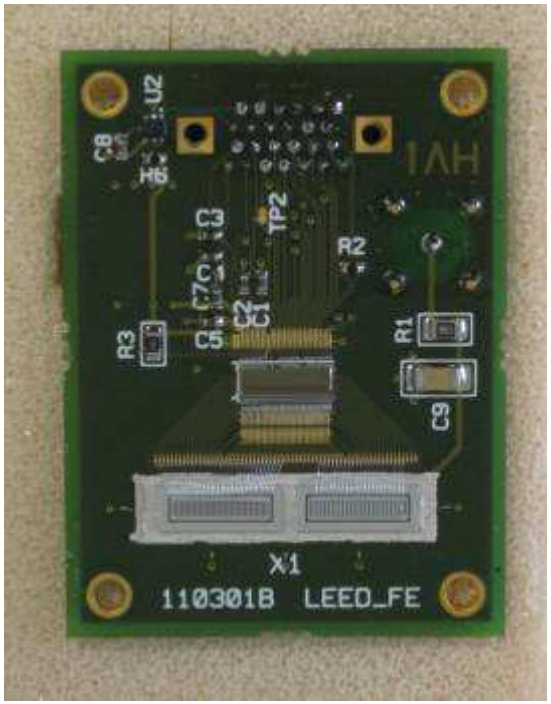
Electron Spectrometer - technology

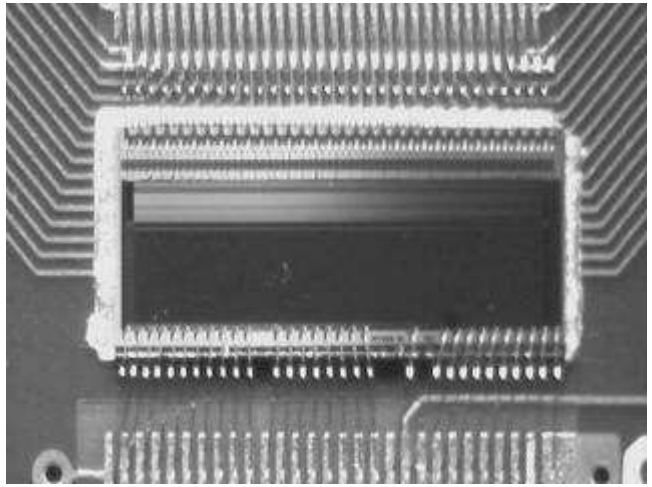
Magnetic field enclosed inside and shaped field for optimal resolution

Fast readout ASIC based on radiation hard technology

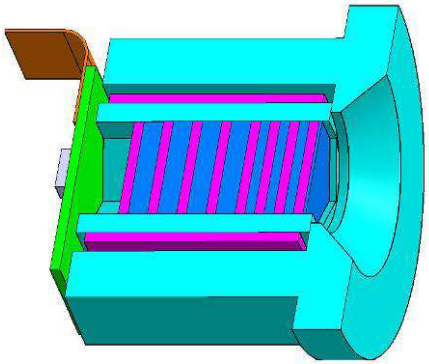
Si-microstrip bonded directly to ASIC (low noise)

Sufficient shielding for background suppression





Proton Telescope - concept

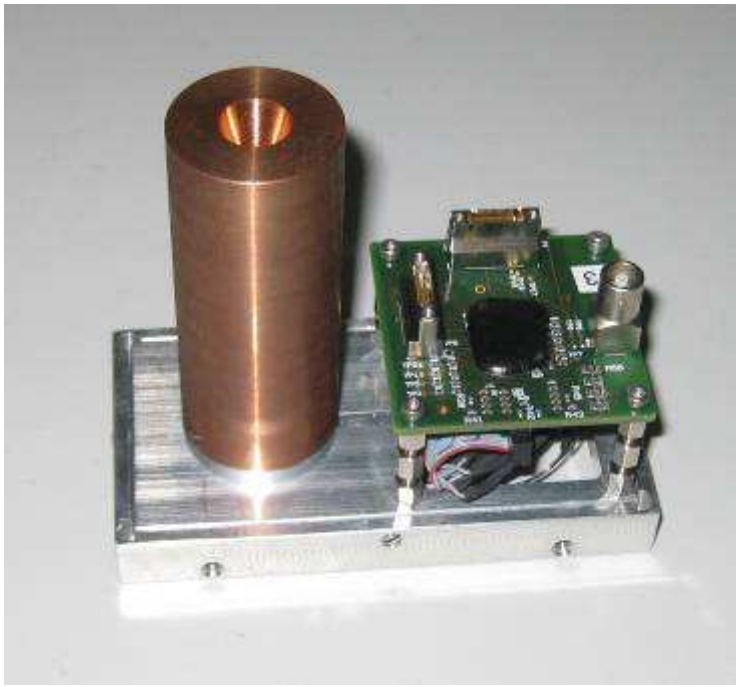


Arranged as particle telescope of 8 Si-detectors

Energy range 2 MeV – 200+ MeV

Energy resolution – 8 bins equally spaced on log-scale

Fully depleted Si-diodes as sensors



Proton Telescope - technology

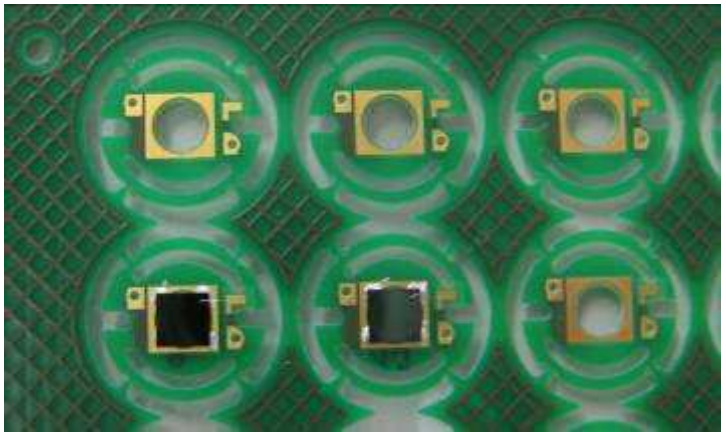
Range shifters (energy degraders) for energy threshold

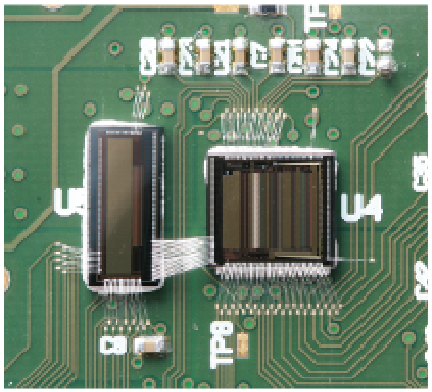
Fast, low power, radiation hard readout ASIC (A/D) with short distance to detectors

Digital spectral unfolding concept for fast data taking

Backup readout with analogue channel for verification

Variable threshold / coincidences for heavy ion detection





Mass Model for Monte Carlo Simulations

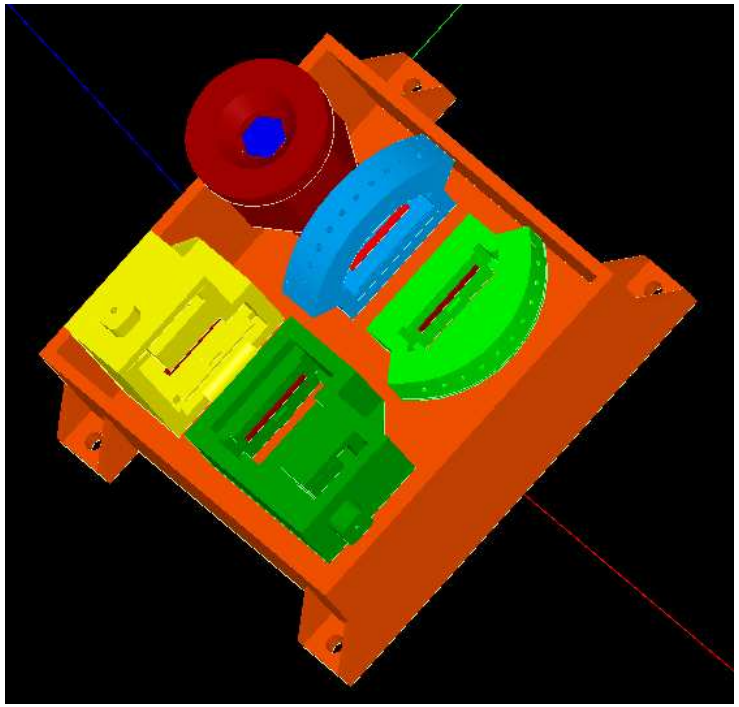
Full mass model constructed with GIANT and GRAS

Input based on BB and Lab DM CAD drawings

Lab responses with protons and electrons computed

Responses for Jupiter environment simulated

Results used for optimization of both detector units



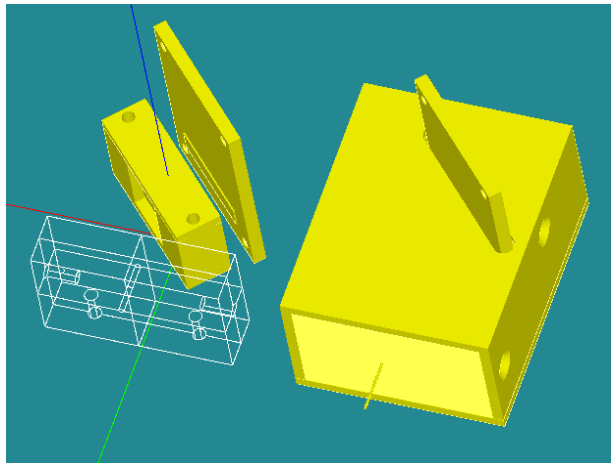
Simulations of Spectrometer Response – Simple Case

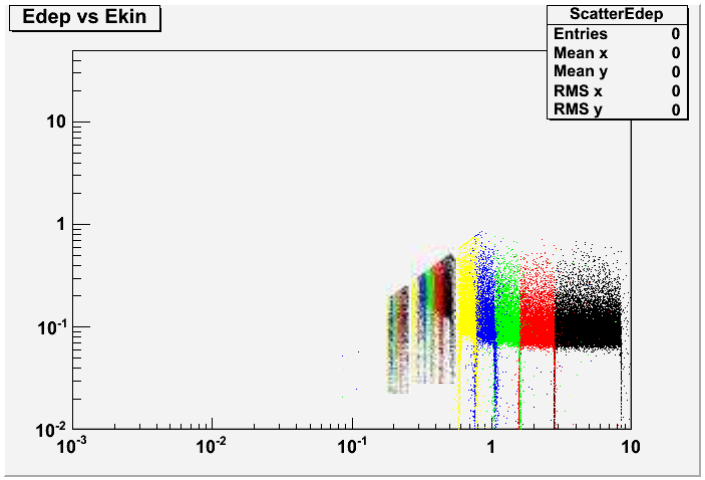
Simulations performed with electrons and protons

Initial study with narrow electron beam directly from the top

Very good energy resolution and spatial separation

No side penetration





Simulations of Spectrometer Response – Realistic Case

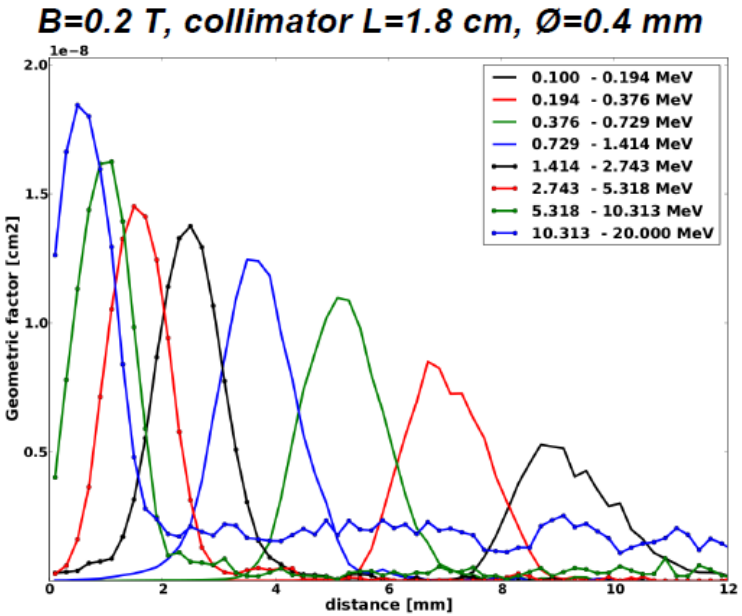
Simulations performed with electrons and protons

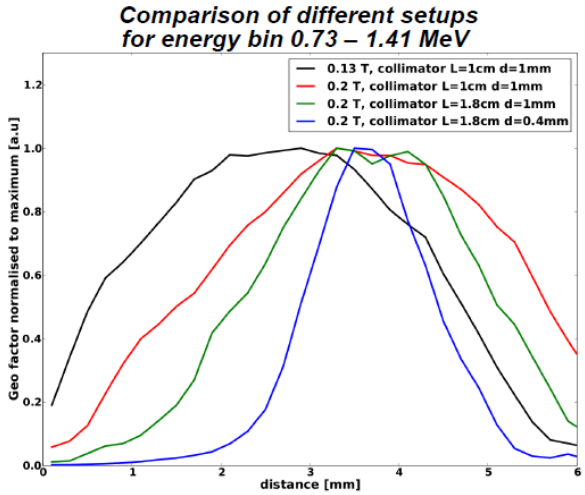
Response from front and all direction determined

Specifications for electrons are kept

Two folded simulations to save computing time: narrow and wide

Optimization of detector performed (back to parallel design)





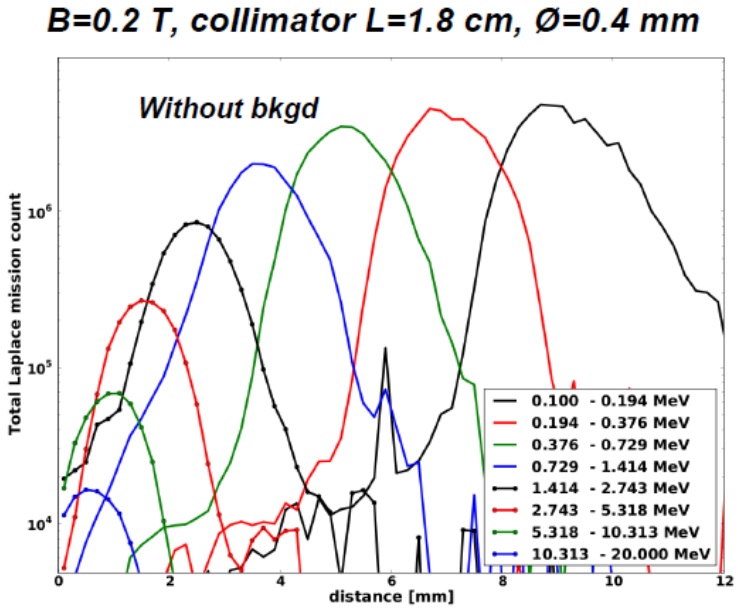
Spectrometer Response – Electrons in Jupiter Environment

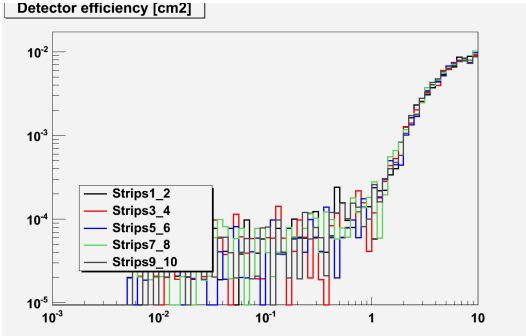
Modeling with Jupiter environment performed

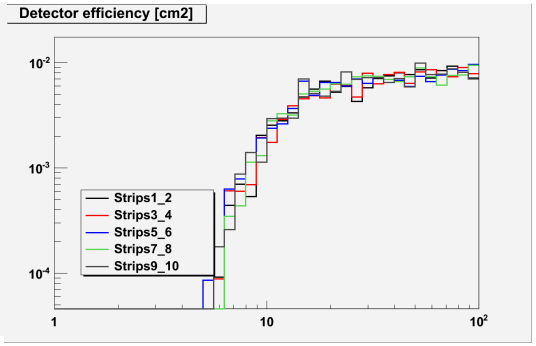
Power low electron spectra pose serious problem for RADEM (and the mission)

Side electron background needs extra shielding and further MC
- easy penetration at high energies
(- less troubles with protons)

Increasing S/N ratio needs improved collimator entrance







Spectrometer Response – Protons in Jupiter Environment

Discrimination of protons possible with energy loss thresholds

Small side shielding works sufficiently well

Extra detection of protons as backup

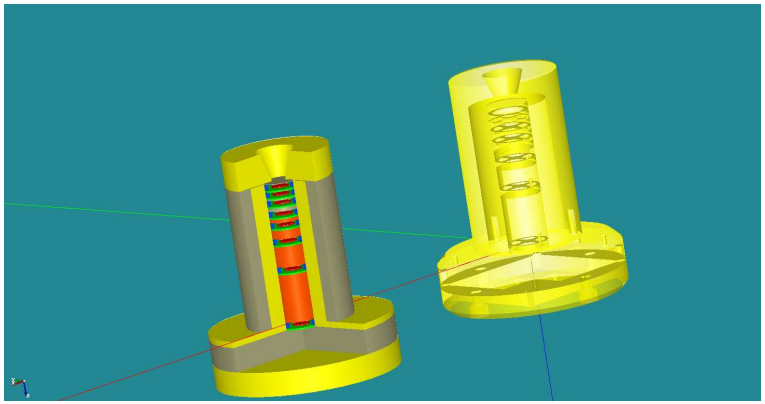
Simulations of Telescope Response – Simple Case

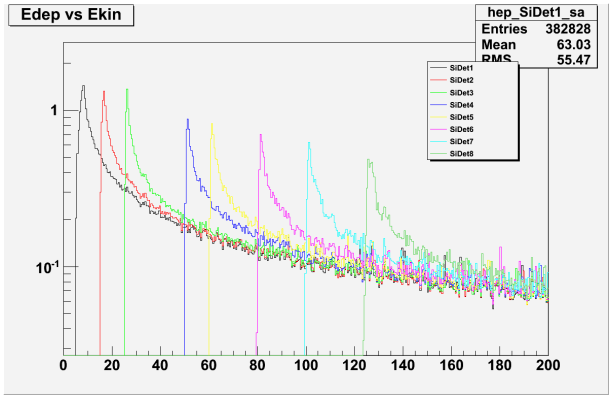
Simulations performed with protons and electrons

Initial case with parallel proton beam from the top

Ideal case with very good performance for the requirements

Clear spectral deconvolution with very good energy resolution





Simulations of Telescope Response – Realistic Case

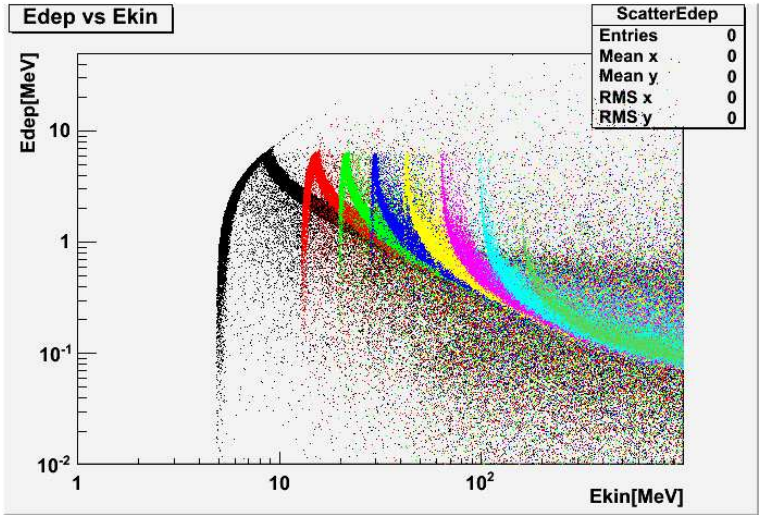
Response from front and all direction determined

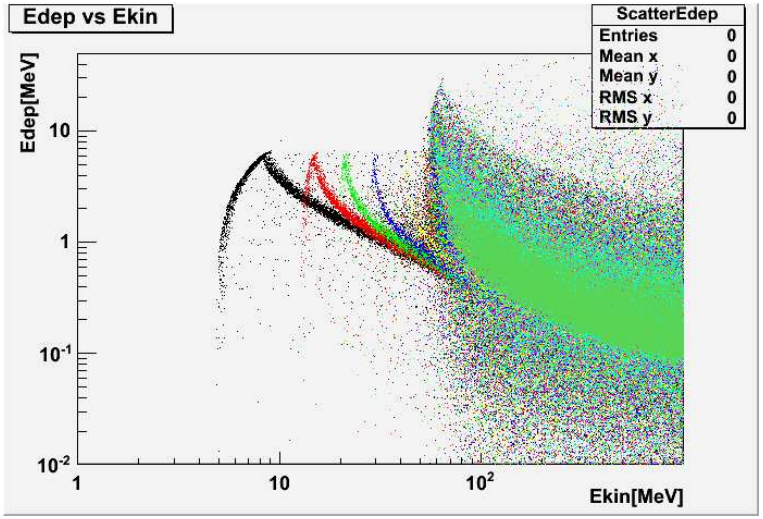
Energy resolution worse but all specifications for protons kept

A need for variable threshold to assure good particle discrimination

Present shielding sufficient for blocking part of side protons

Applying coincidences allows for clear response matrix and spectral unfolding





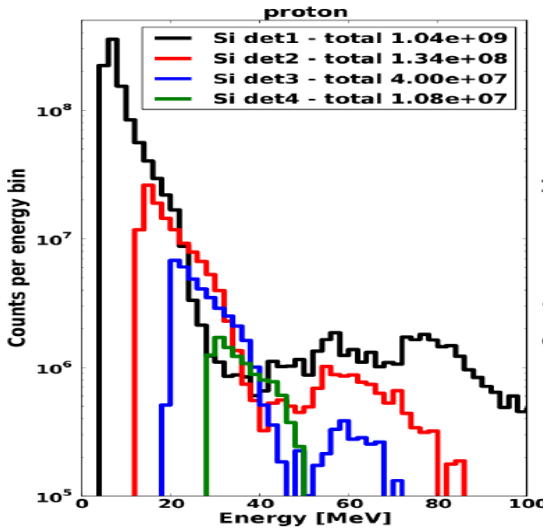
Telescope Response – Protons in Jupiter Environment

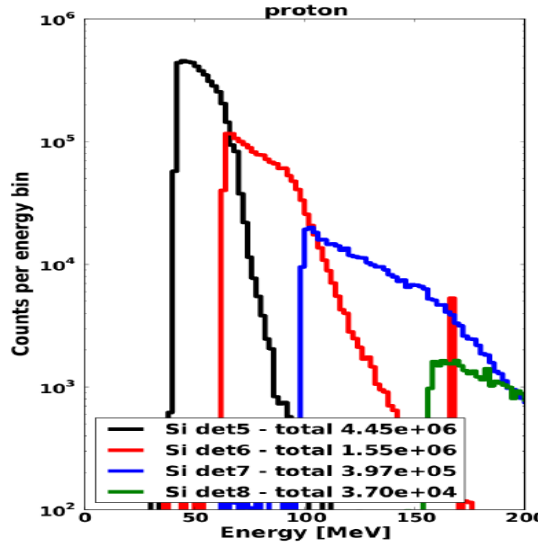
Response from front and all direction determined

Modeling with Jupiter environment performed

In case of no other background sources the telescope provides good results

Quality of measurements is related to background suppression level





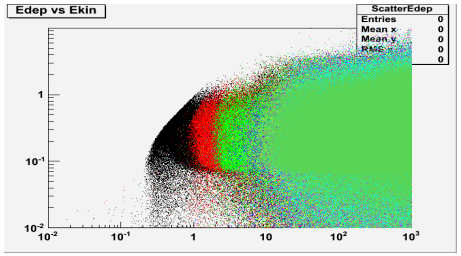
Telescope Response – Electrons in Jupiter Environment

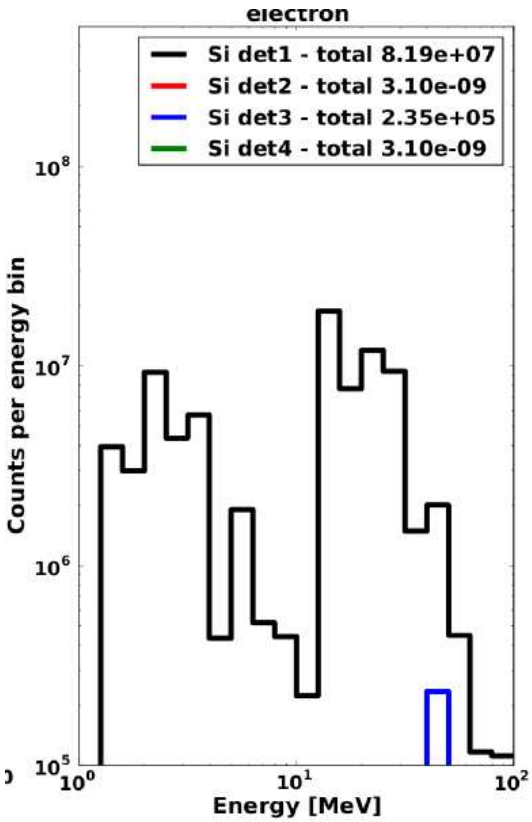
Modeling with Jupiter environment performed

Response from the front and all directions computed

Basic shielding and spacecraft mantel (8 mm) included into simulations

Electron discrimination using threshold and coincidences possible





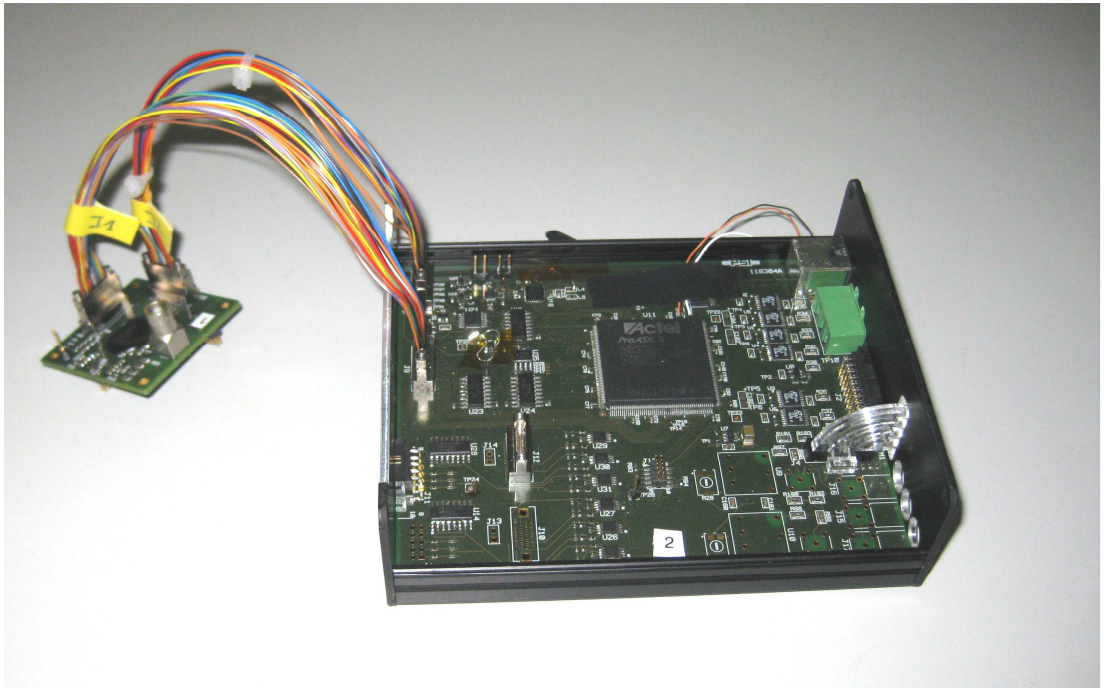
Laboratory Measurements with EGSE

Laboratory DM models for electron spectrometer and telescope as well as dedicated EGSE used

The same EGSE serves for both instruments

EGSE uses dedicated FPGA to facilitate communication and data taking

It delivers power to frontend electronics and high voltage bias for detectors

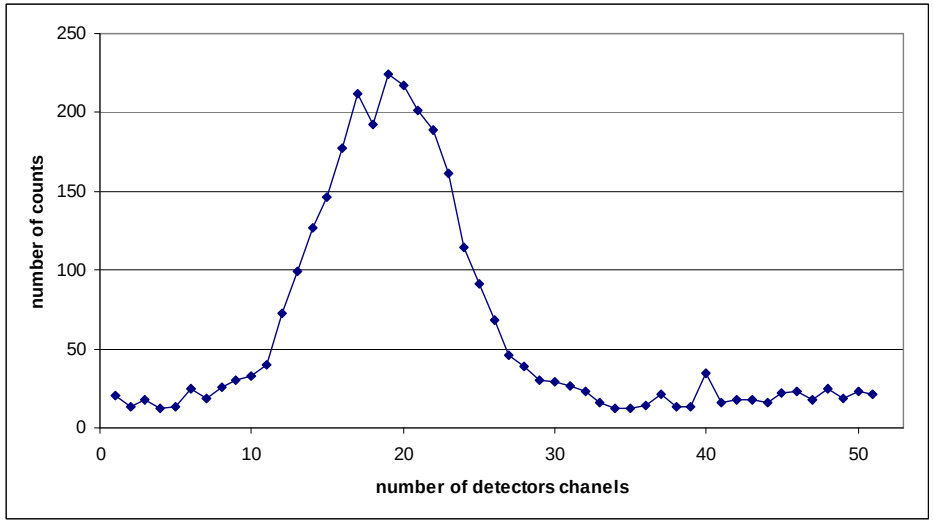


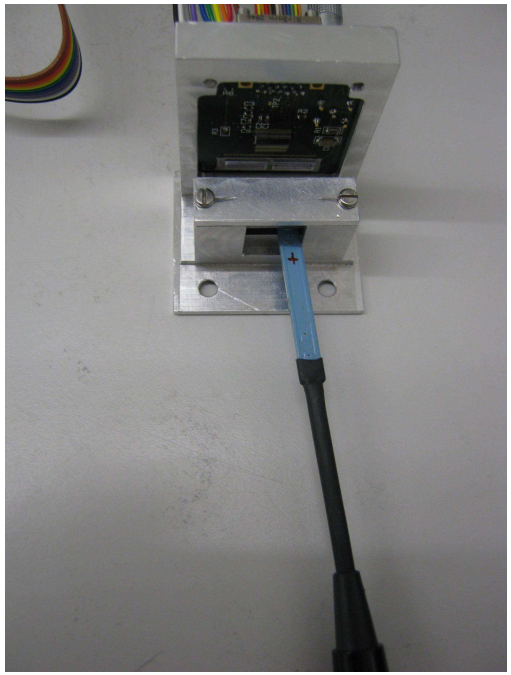
Electron Spectrometer – Laboratory Test Data

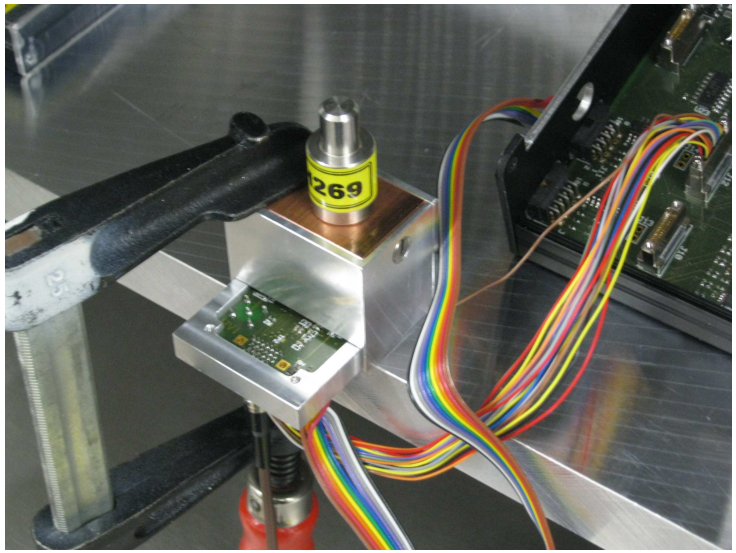
Counting rate tests with strong electron source

Threshold scanning

Optimization of dynamic range

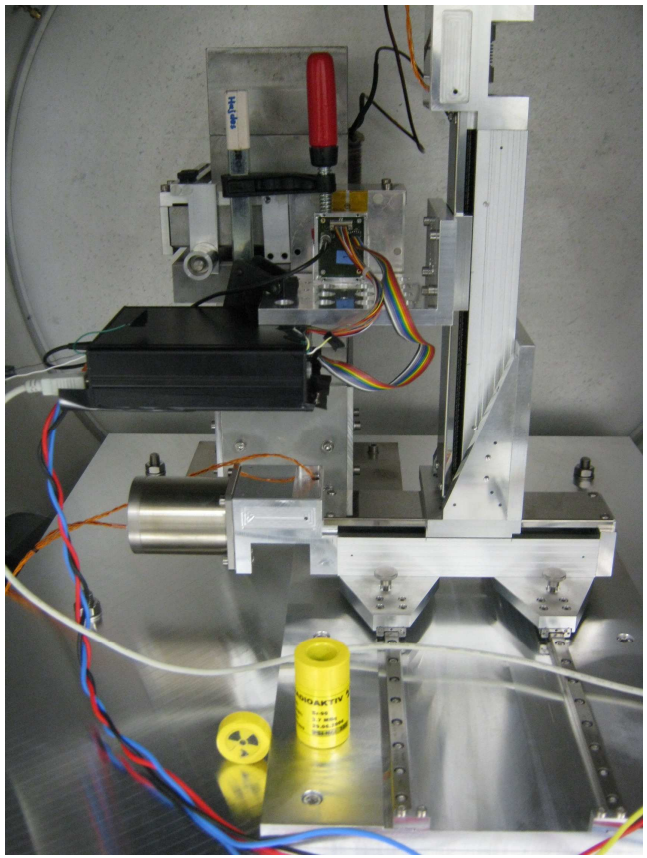


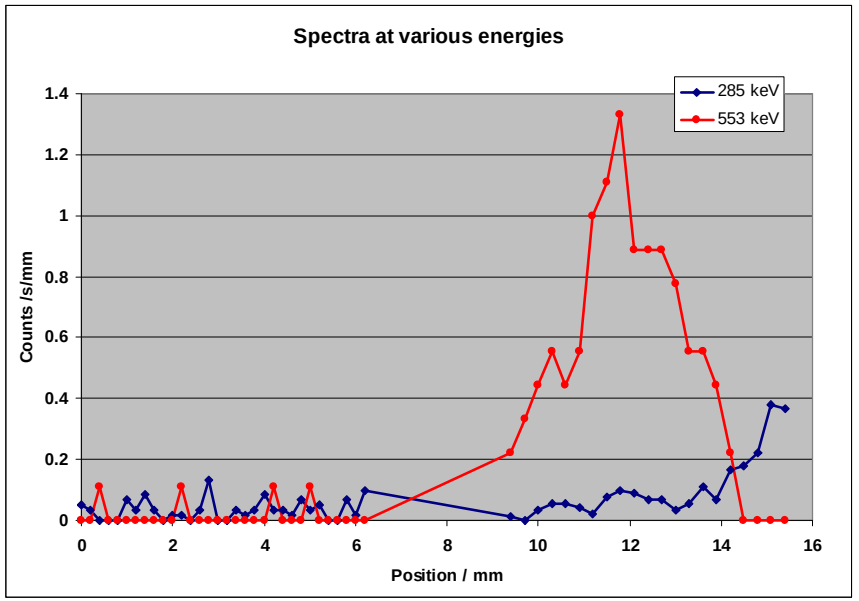


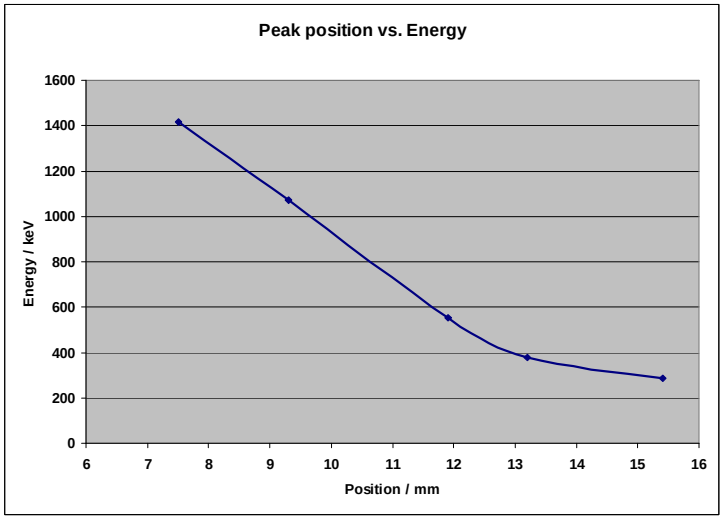


Electron Spectrometer – Data from Monochromator

- Spectrometric tests with PSI electron monochromator
- ^{90}Sr beta source (37 MBq)
- Test at various energies

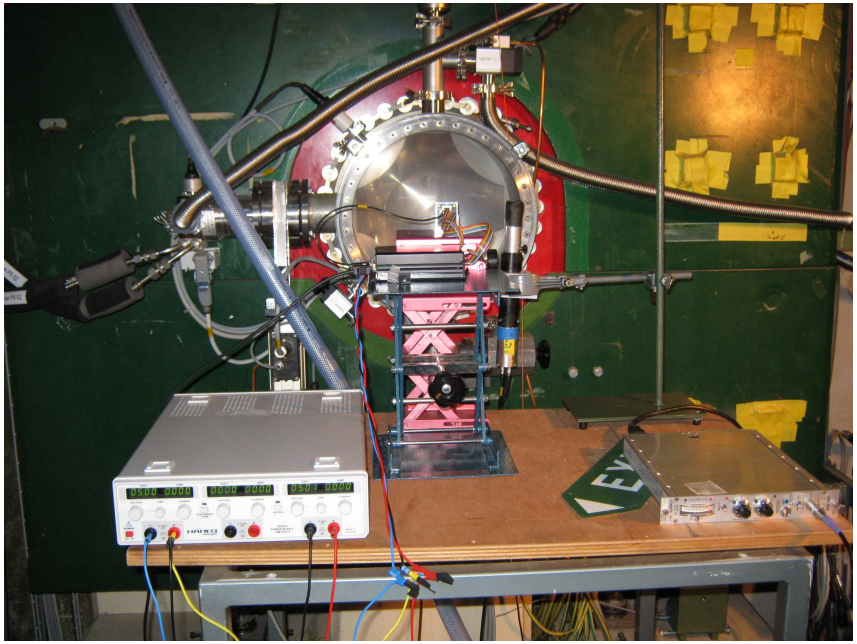


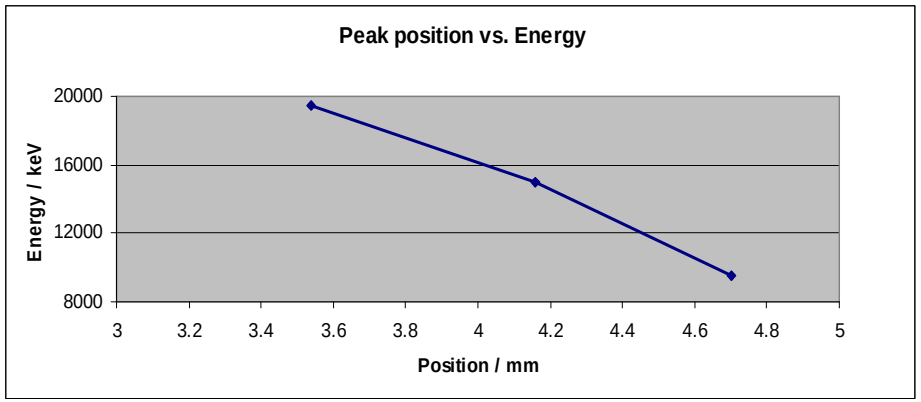


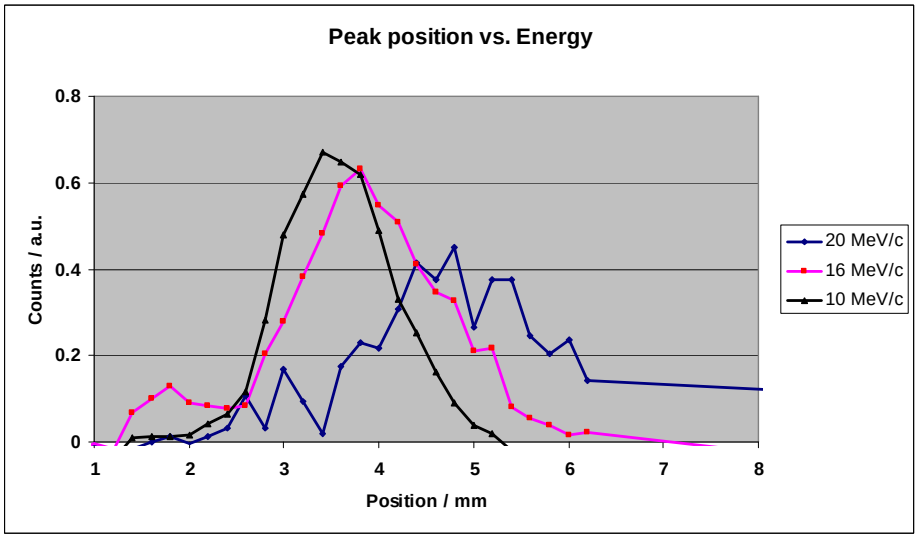


Electron Spectrometer – Data from PiE1 Beamline

- piE1 – particle physics test area at PSI
- Beamline for muon (μ^-, μ^+) experiments
- Setup for momentum p=20 MeV/c
- Other energies: 5 - 40 MeV/c by magnets scaling
- Electron beam not clean – contaminations possible

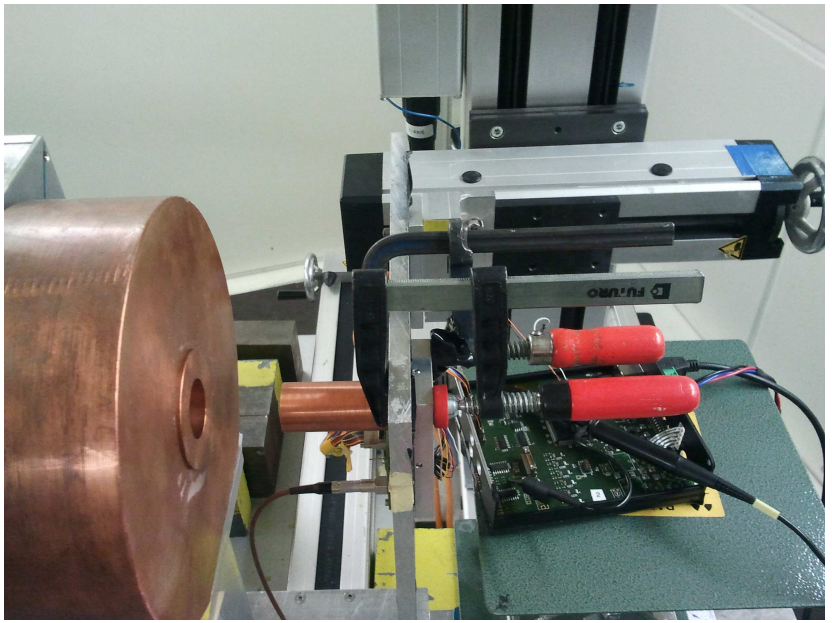


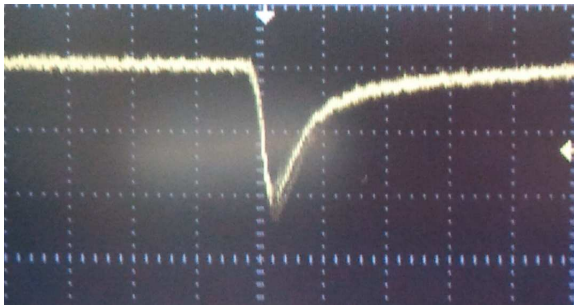


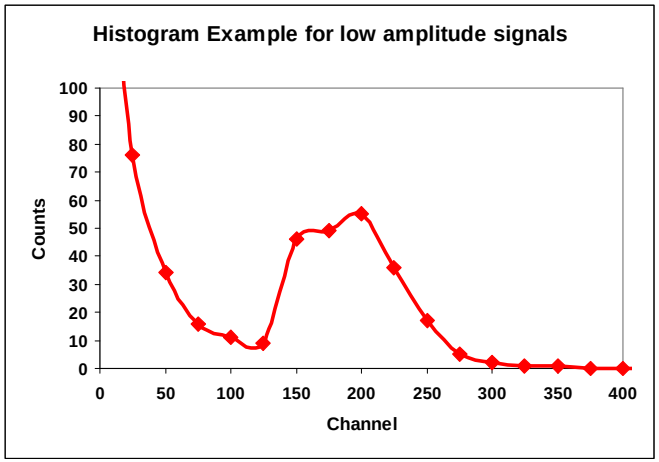


Proton Telescope – Setup at PIF Facility

- Laboratory DM model with EGSE
- Telescope tests with protons at PIF PSI
- Energy range from 5 MeV to 230 MeV
- Low energies with large straggling
- Setup for low intensity fluxes and using of collimators

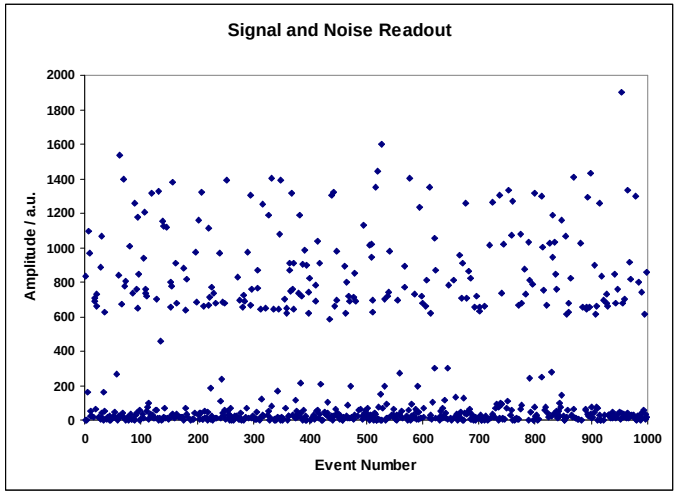


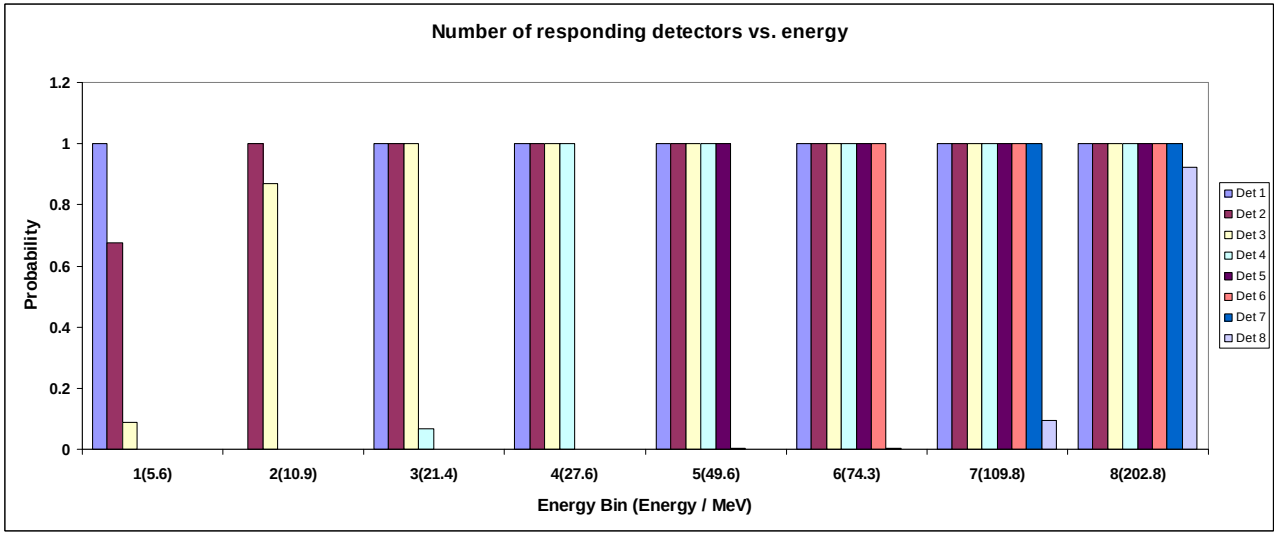




Proton Telescope – Data from PIF proton exposures

- Energy selection for energy bins values
- Both digital patterns and analogue pulses processed
- Both results agrees with predictions
- Optimization of FW and frontend electronics





Test of ASIC for Single Event Latchups

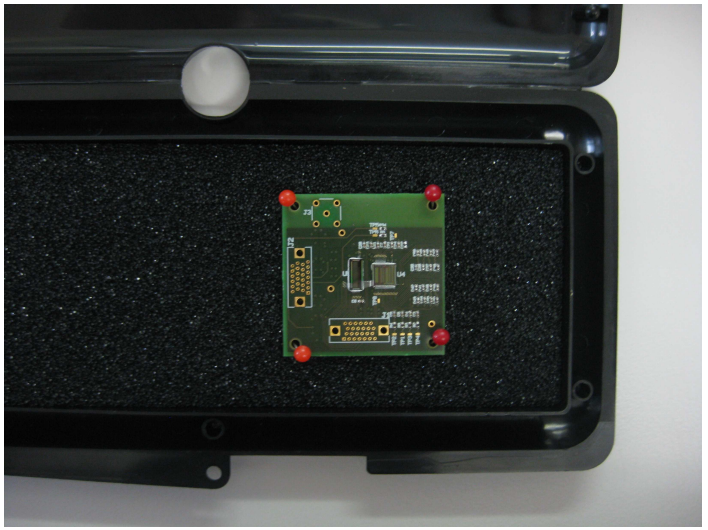
ASIC for HEP-Proton Telescope used for Latch-up SEL tests

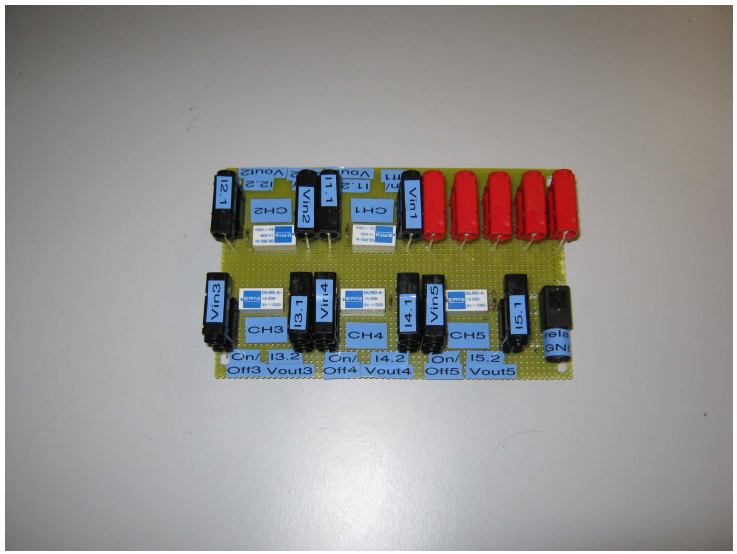
Current selection: VA64TAP3 from Gamma-Medica - will be replaced by new design

ASIC TID Rad-hard, low power, analogue and digital readouts

SEL Test HW and SW provided by PIF Group

Tests with protons up to 50 krad(Si) dose did not show any SEL but some with HI





Current Status and Critical Issues

Breadboard and laboratory DM models constructed

Tests done using realistic electron and proton beams

Computer model constructed for response simulations

Functional requirements verified and optimized

Detector performance improvement potential

Shielding improvements as result of Jupiter particle model based Monte Carlo simulation

Ready for the next development stage

Summary

RADEM - compact and light, low power radiation hard electron monitor for Jupiter mission is under construction

It is designed for detection of electrons (spectrometer) and protons (telescope) with optional ion detection

Its parameters address anticipated radiation environment: high fluxes, particle discrimination, energy resolution

RADEM laboratory DM tests performed using realistic radiation environments verified its requirements and functionality in accordance to SR

Thank You