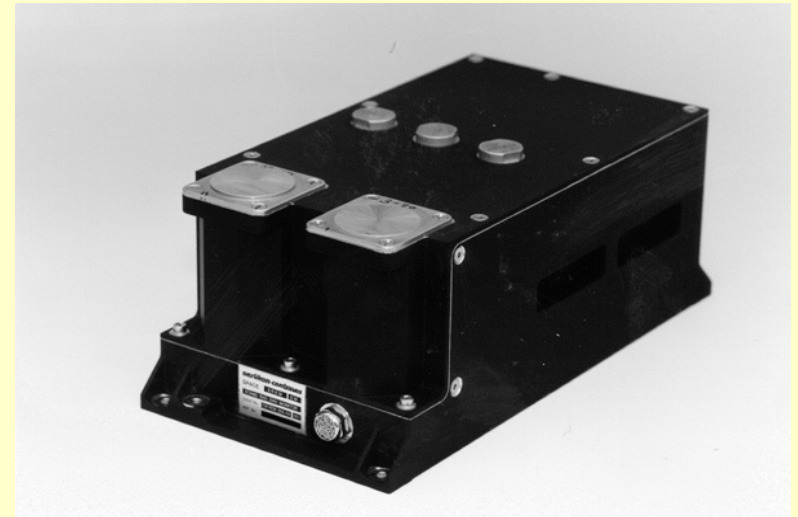


Standard Radiation Environment Monitor SREM

Characteristics

1. Online radiation monitoring and scientific data accumulation
2. Coarse spectroscopy of protons and electrons
3. Alarm flags for hyper and under activity
4. 3 Silicon Detectors in Al/Ta shielding
5. Directional sensitivity/telescope
6. Fast discriminators coupled with 15 scalers
7. Count rates >100 kiloevents/sec
8. Integrated dead time correction (3 scalers)
9. Energy threshold: 10 MeV p^+ , 0.5 MeV e^-
10. Mass: 2.5 kg
11. Dimensions: 96x122x217 mm³
12. Power consumption: ≈ 2 W
13. Temperatures: -20 to +55°C (o)
14. In-orbit operation time 10 years



*Designed and manufactured
by Contraves Space AG
in cooperation with PSI/ESA*

*10 SREM units fabricated
and 2 are already flying*

Calibration Procedure

GOALS

- ï Key performances verification
- ï Response function determination
- ï Computer model testing
- ï Proper understanding for space collected data

STEPS

- ï Two tests with radioactive sources $^{60}\text{Co}/^{90}\text{Sr}$
- ï Proton response calibrations in PIF
- ï Linearity and sensitivity
- ï Dead time and pile-ups
- ï Total sensitive area
- ï Long term stability

Facilities

1. Calibrated radioactive sources:

- i Gamma rays ^{60}Co ; $\langle E \rangle = 1.25 \text{ MeV}$
- i Electrons ^{90}Sr ; $E_{\text{max}} = 2.28 \text{ MeV}$

Point-like sources placed on detector heads (and sides)

2. Protons from PIF/PSI - Proton Irradiation Facility:

- i Initial energies - $E_{\text{low}} = 60 \text{ MeV}$, $E_{\text{high}} = 300 \text{ MeV}$
- i E_{low} used at 0° , E_{high} used for angular distributions
- i Flat beam field, on-line monitoring
- i low dose (below 3 rad)

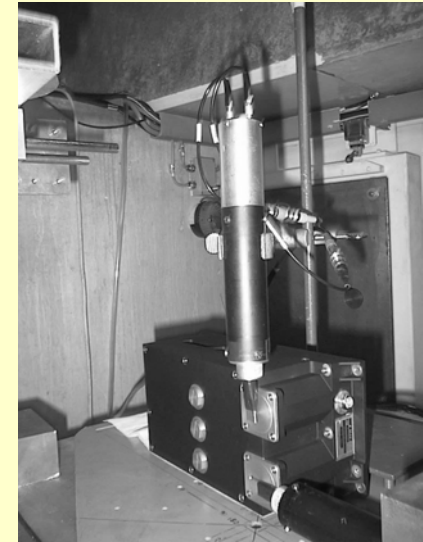
Full energy range: 6 - 300 MeV
 Full angular range: $0^\circ \leq \theta \leq 180^\circ$, $0^\circ \leq \phi < 360^\circ$
 Full flux range: $0 < F < 2 \times 10^5 \text{ p/cm}^2/\text{sec}$

Energy set for comparison:

12, 18, 24, 28, 32, 36, 42, 50, 60, 70, 100, 150, 300 MeV

3. EGSE from CS AG and from PSI for protons

remote operation from control room $\approx 40\text{m}$



*SREM unit placed on the angular stage
 (and two plastic detectors in front - up)*

Modeling

Mass model constructed using GEANT code

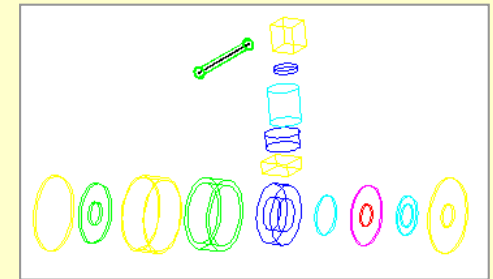
- ï Exact description of Si-detectors and housing
- ï Simplified printed boards, cables, connectors
- ï About 350 volumes/shapes introduced

Extensions for comparison with calibration data

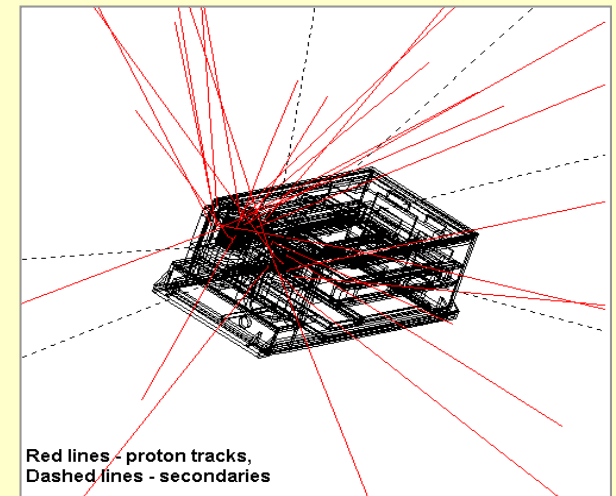
- ï Single elements and geometry of PIF introduced
- ï Beam profiles and energy degrading included
- ï Realistic flux normalization using plastics
- ï Comparison with sources takes into account source geometry, position and activity for both e^- and γ

Steps

- ï Introducing individual parameters and corrections
- ï Computations and comparison (more fine tuning)
- ï Full response function calculations



Detector, Contact and Cable ñ expanded view



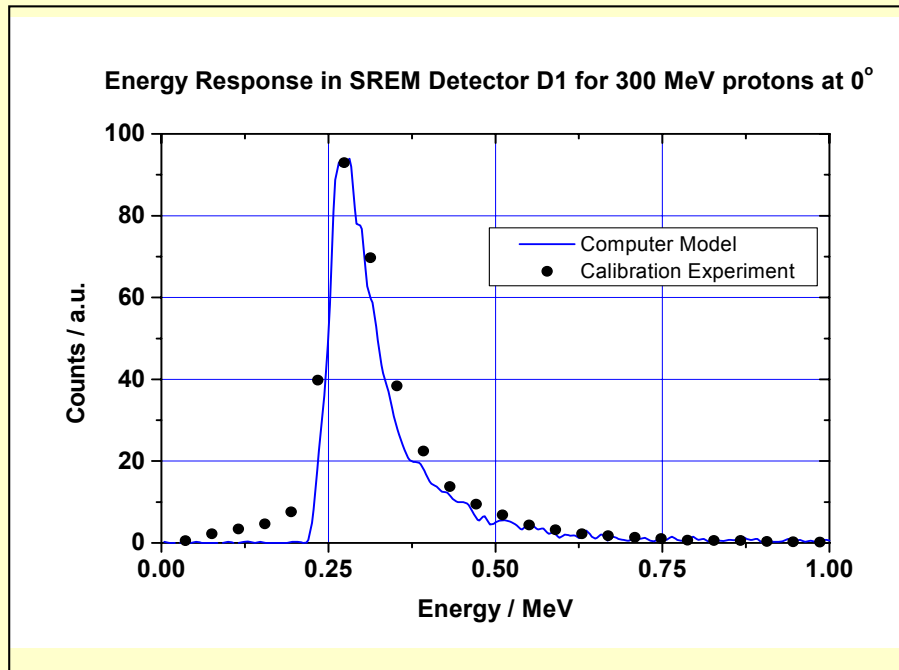
Red lines - proton tracks,
Dashed lines - secondaries

Linearity

Minimum Sensitivity:

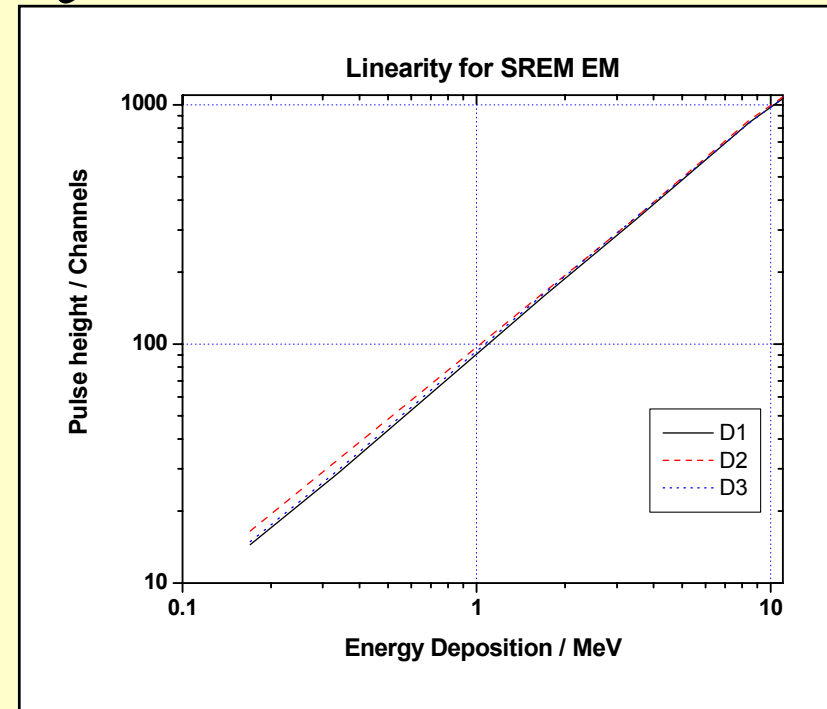
Low energy threshold for detectors: 0.5 MIP

(Minimum Ionizing Particle Energy) - 79.1 keV in 500 μm Si



Energy resolution of the analogue channel:

In agreement with calculations



Linearity Region:

Confirmed to be in a range:

Ω - 30 MIPs (0.079 $\tilde{n}$ 4.75 MeV)

Fulfills specifications for all p and e channels

Measured for two SREMs and
indirectly verified for all 10 units

Sensitive Area

Measured during calibration

Exposures at 0° and 300 MeV

Low intensity, flat beam

Consistency within < 10%

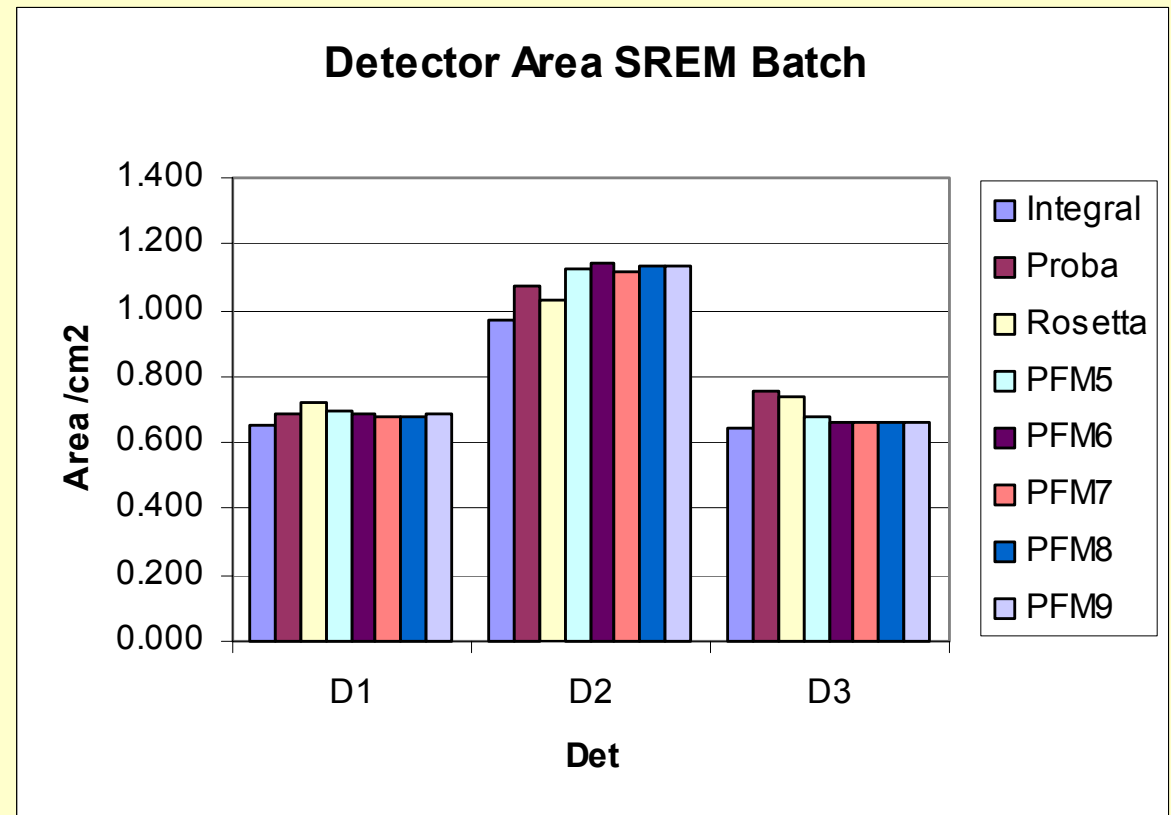
*Differs from nominal values
(connected with det. technology)*

D1 $\langle A \rangle = 0.69 \text{ cm}^2$

D2 $\langle A \rangle = 1.09 \text{ cm}^2$

D3 $\langle A \rangle = 0.68 \text{ cm}^2$

(Error for single detector < 0.01 cm²)



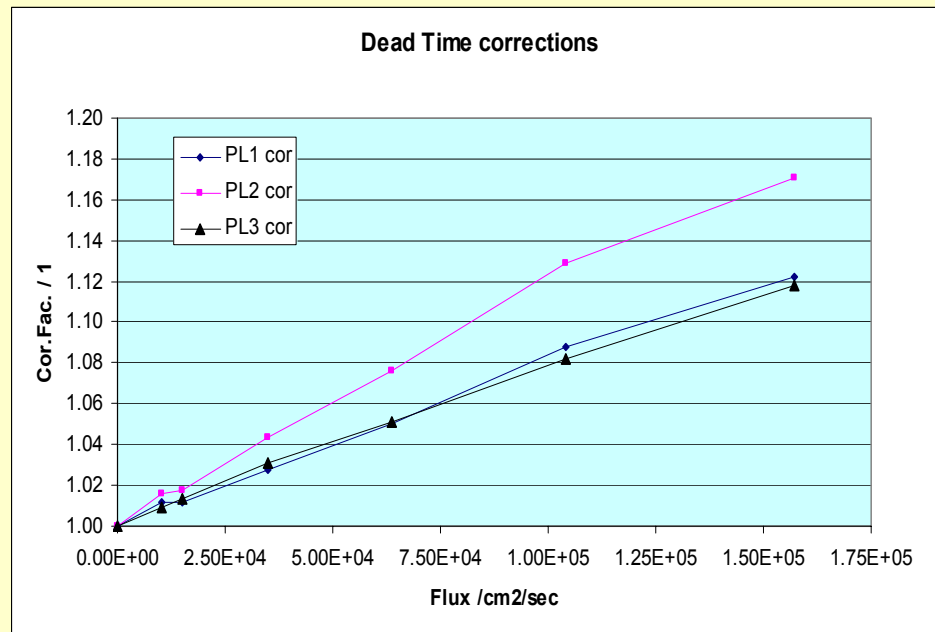
Dead-time and Pile-ups

Measured using DT and TC scalers

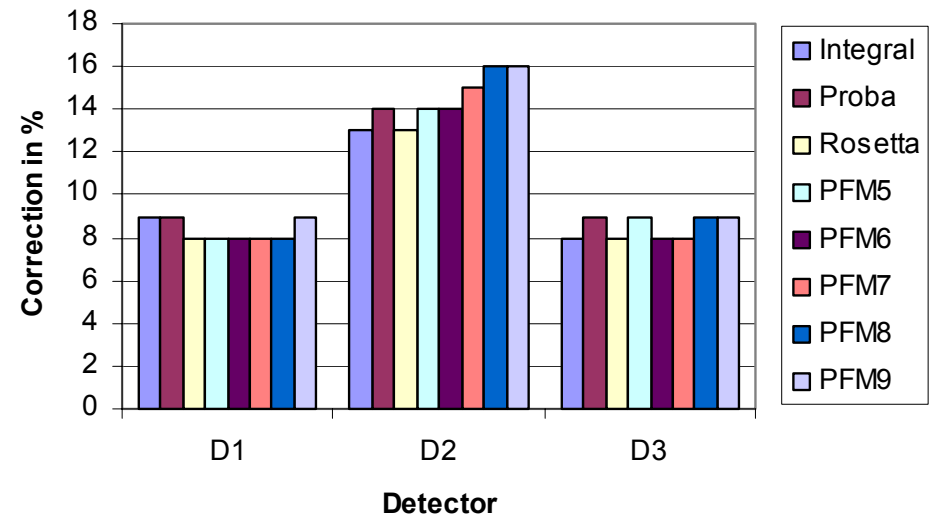
Exposures at 0 and 300 MeV

Intensity from 10^3 to 1.5×10^5 /cm²/s

Normalization to fast plastic detector



Deadtime at 1E5 p/cm²/sec SREM batch



DT corrections smaller than required:
20% maximum at 10^5 /cm²/s

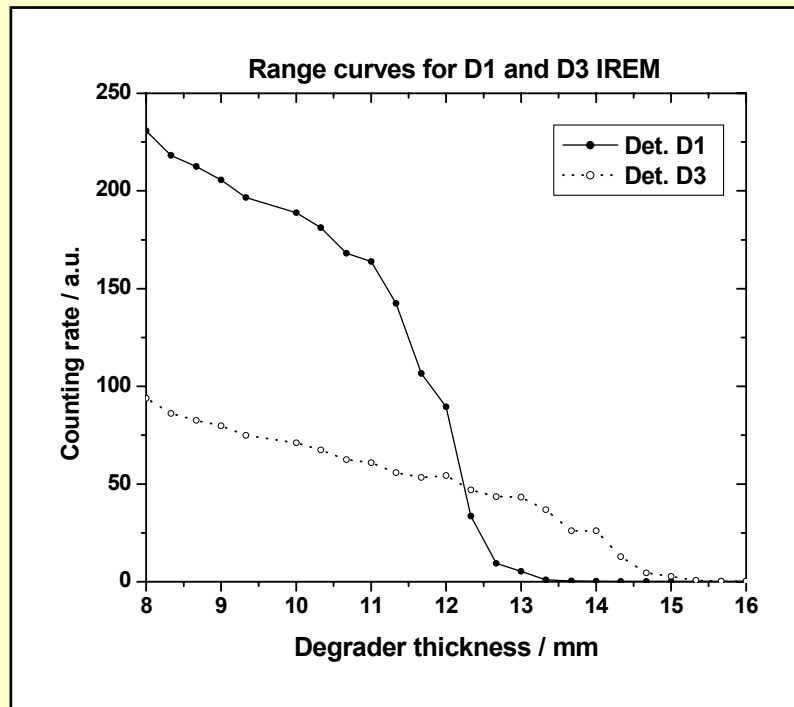
Only a few percent pile-ups for realistic
space environment (at higher energies)

Low energy threshold

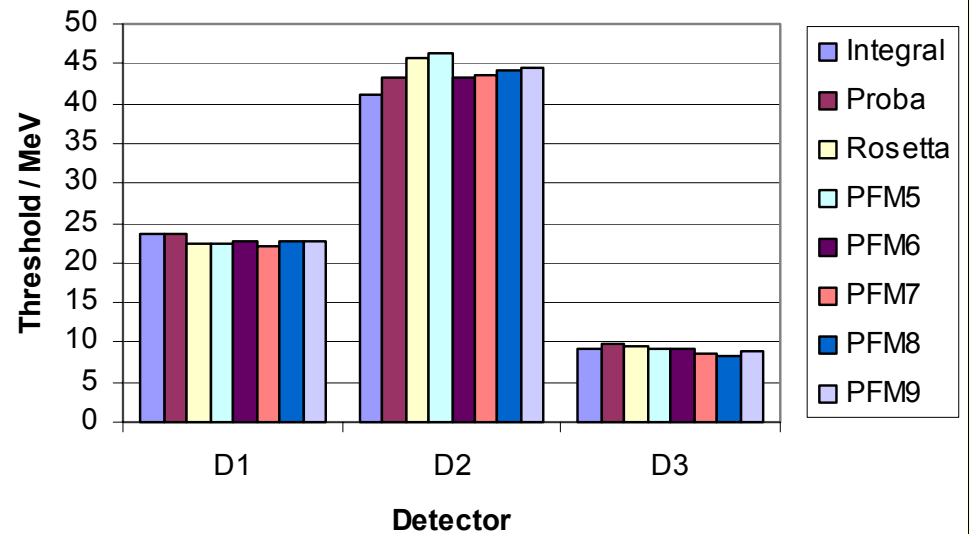
Measured using TC scalers and ICs

Exposures at $\Theta=0^\circ$ and $E_0 = 60$ MeV

Degrader steps 0.33 mm Al



Energy Threshold SREM Batch



Threshold fit for each detector
Result within 5-10% with specs.

$$D1 E_{thr} = 22.8 \pm 0.5 \text{ MeV}$$

$$D2 E_{thr} = 44.0 \pm 1.6 \text{ MeV}$$

$$D3 E_{thr} = 9.1 \pm 0.4 \text{ MeV}$$

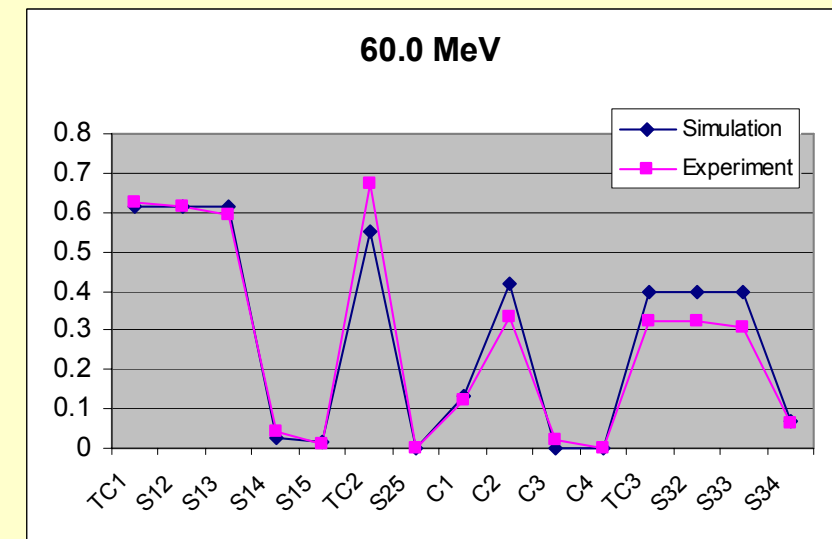
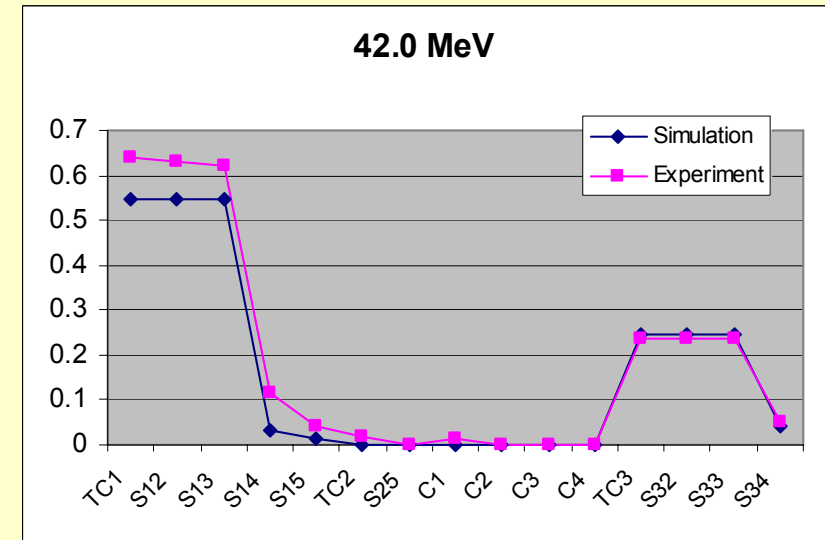
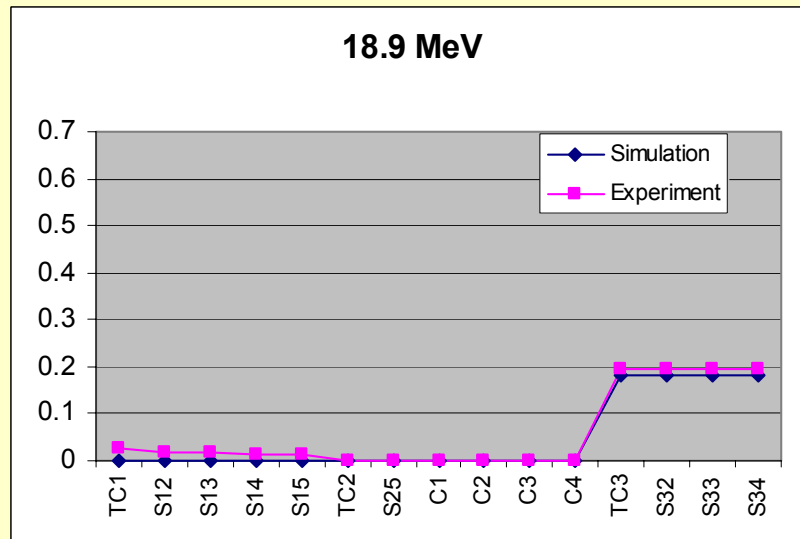
Relatively large scatter of results

I. Low energy response at 0°

Example: Comparison of PROBA results

Calculations include beam and facility features

*In general agreement is very good
but closer to thresholds $\tilde{n}$ bigger deviations*



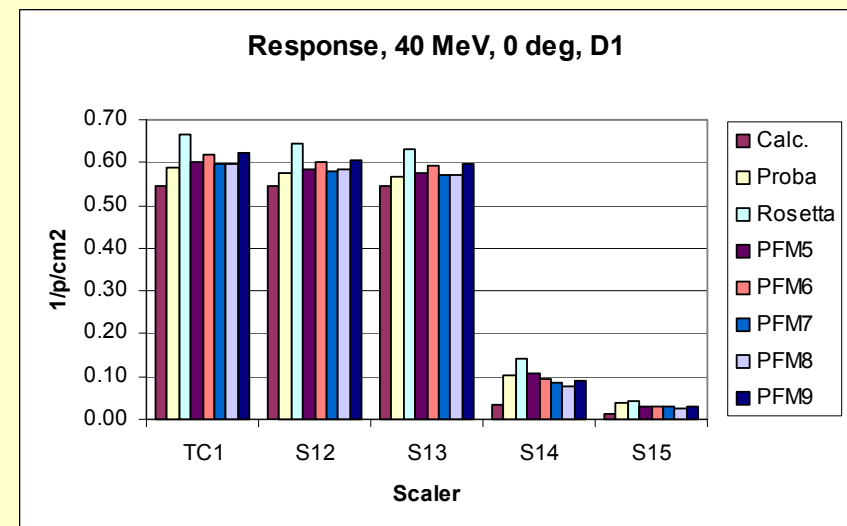
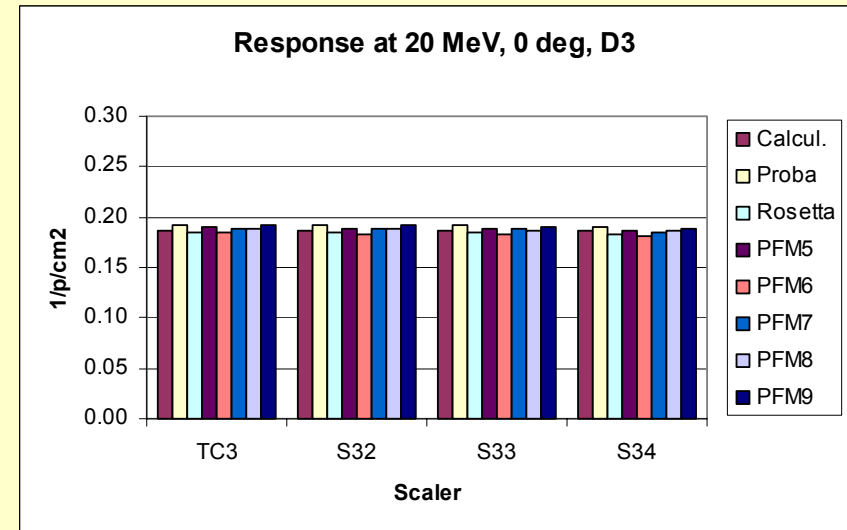
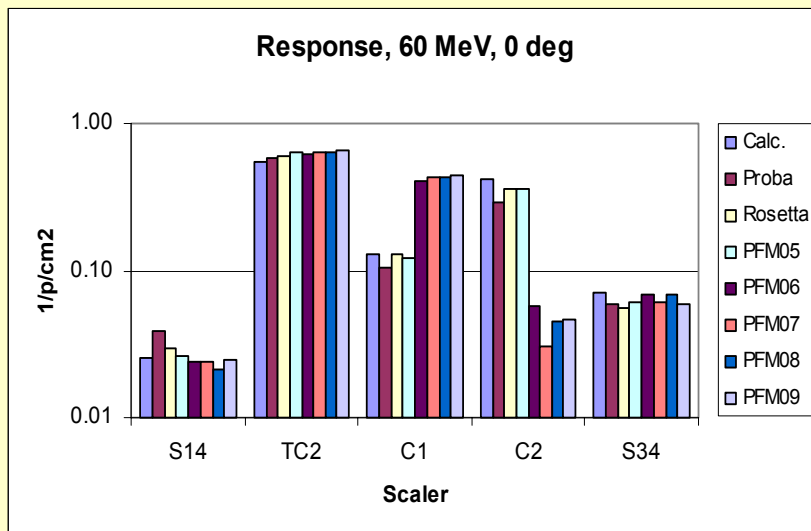
II. Low energy response at 0°

Comparison for SREMs PFM3 to PFM9:

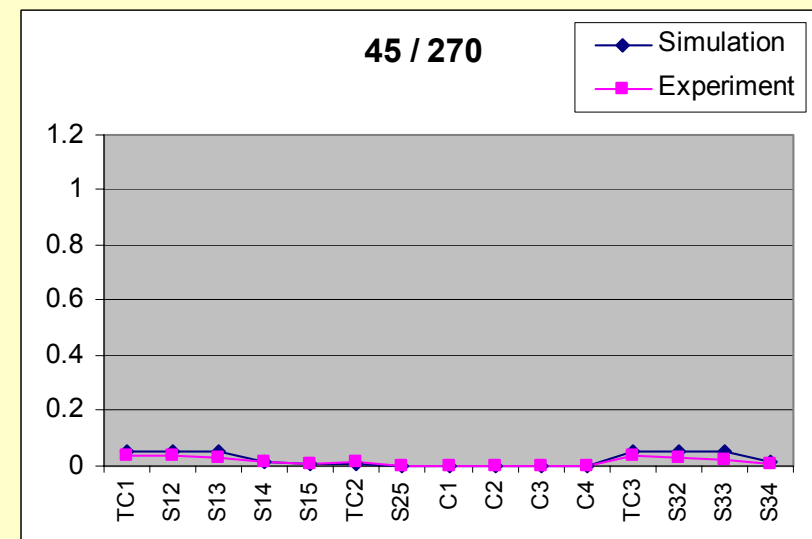
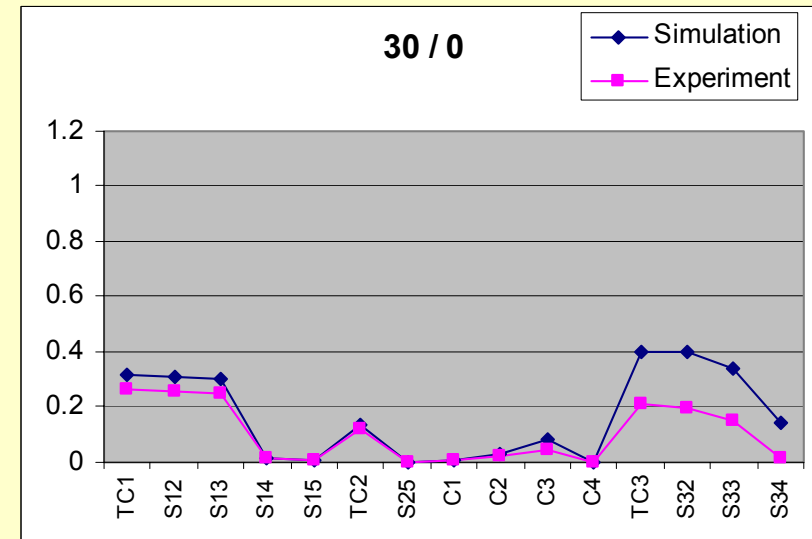
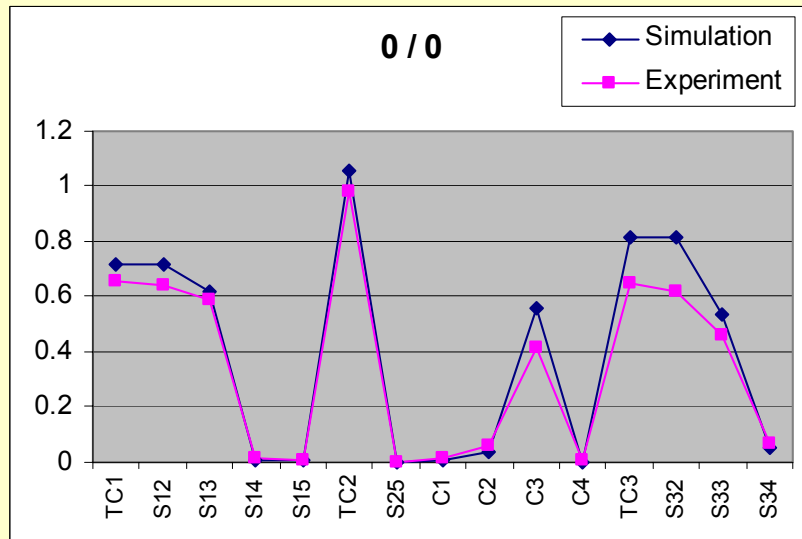
Agreement generally very good !

*Again - far from thresholds $\tilde{n}$ better
(see e.g. S14 at 40 and 60 MeV)*

*Jump from PFM06 in coincidence scalers
(see C1,C2 from PFM06) $\tilde{n}$ fit of thresholds?*



Angular distributions



Example: PROBA results at 100 MeV
 Angle pairs $(\Theta, \varphi) = (0, 0), (30, 0), (45, 270)$

Agreement is pretty good

Response quickly decreases with angle

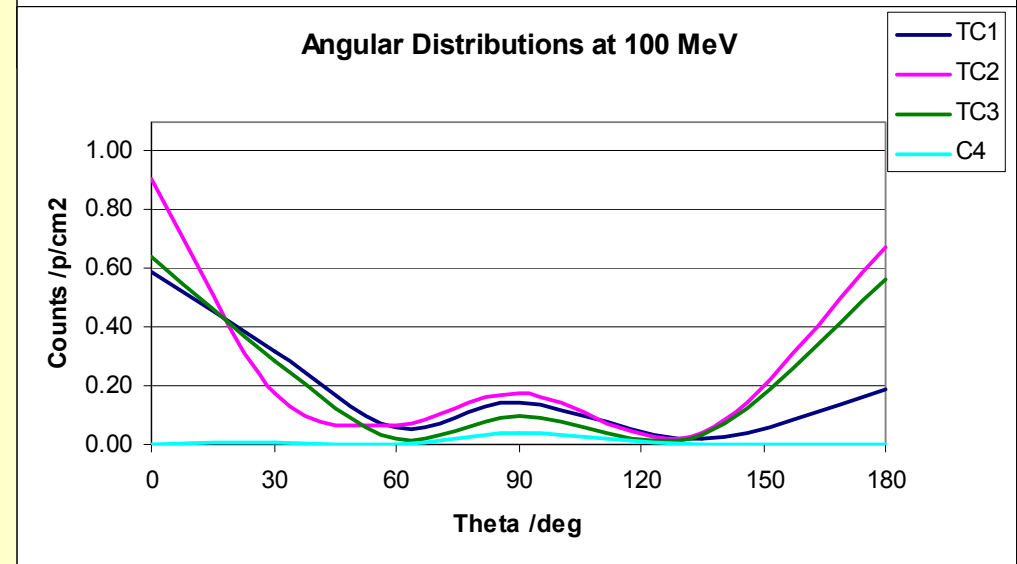
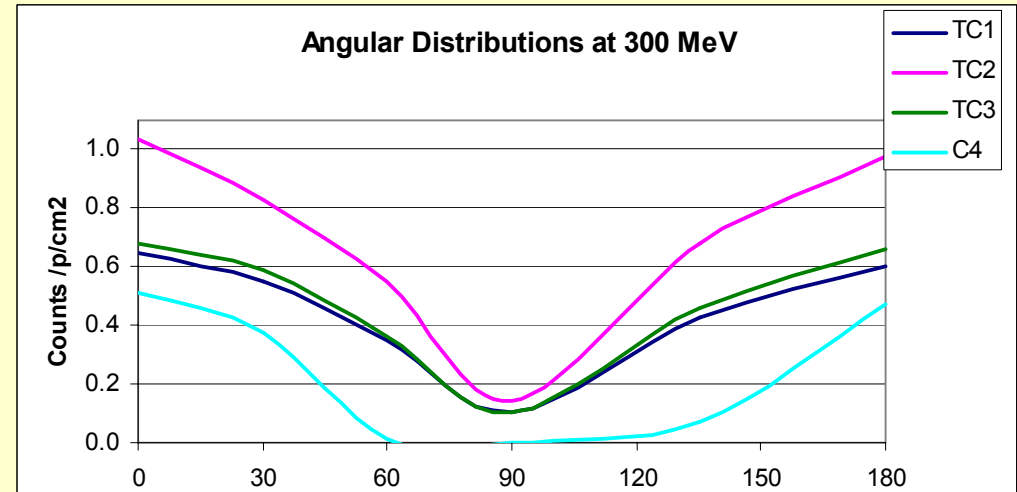
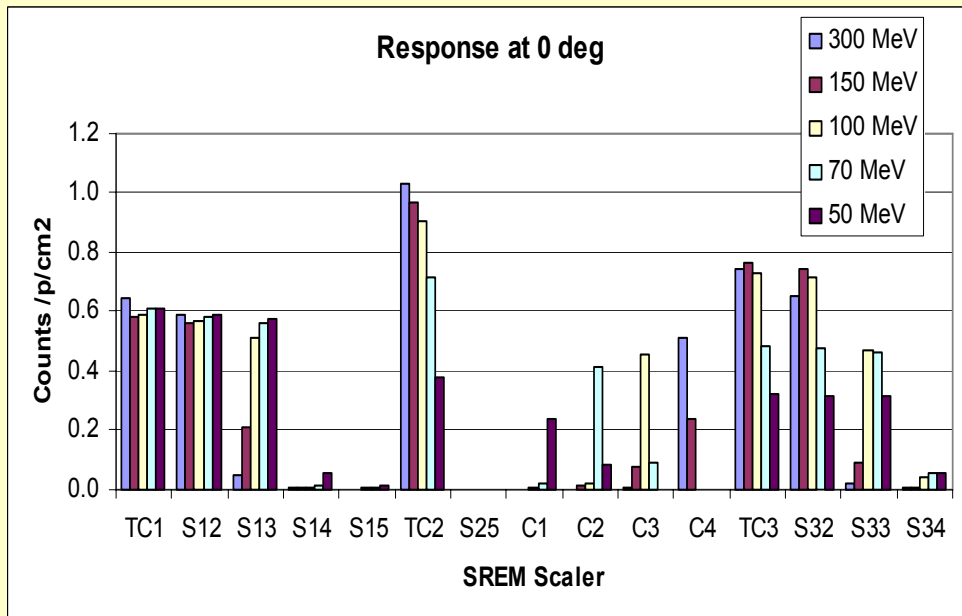
High energy response vs. angle

Example: PFM05

(selected angles & scalers)

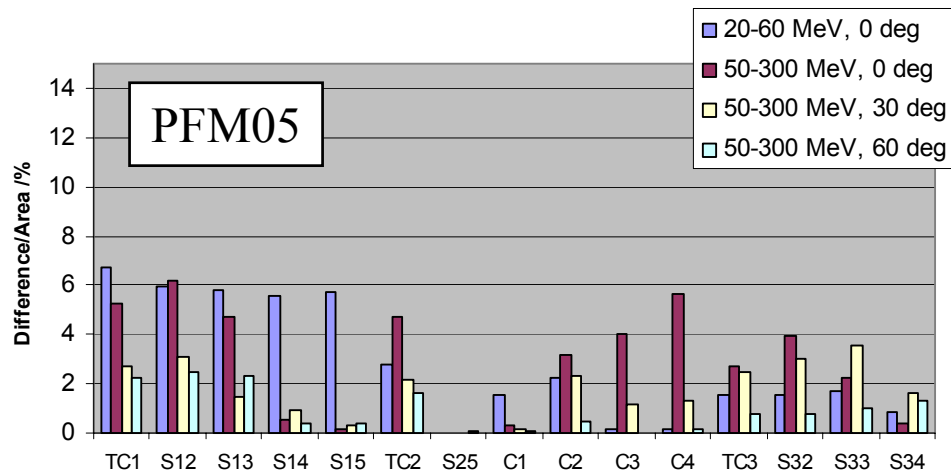
Strong energy dependence even at 0°

High angular sensitivity even at high E

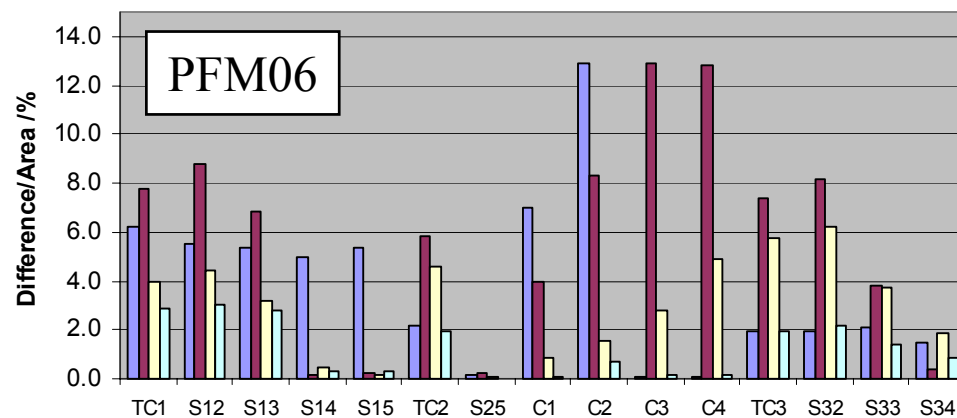
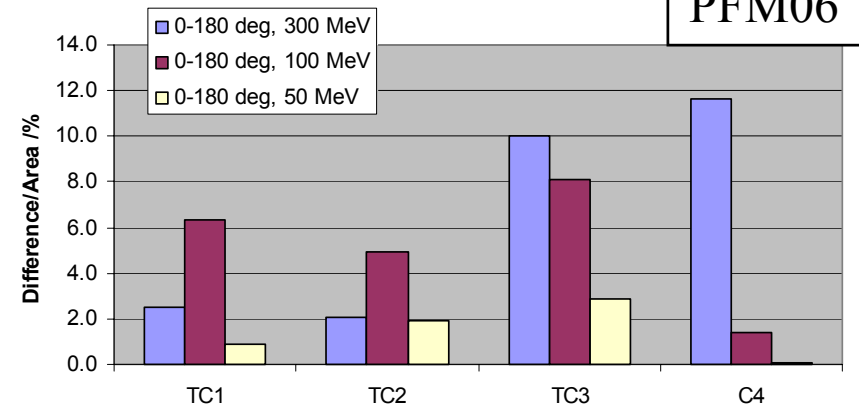


Batch Comparison - Summary

Mean square deviation between calculations and data
relative to detector area



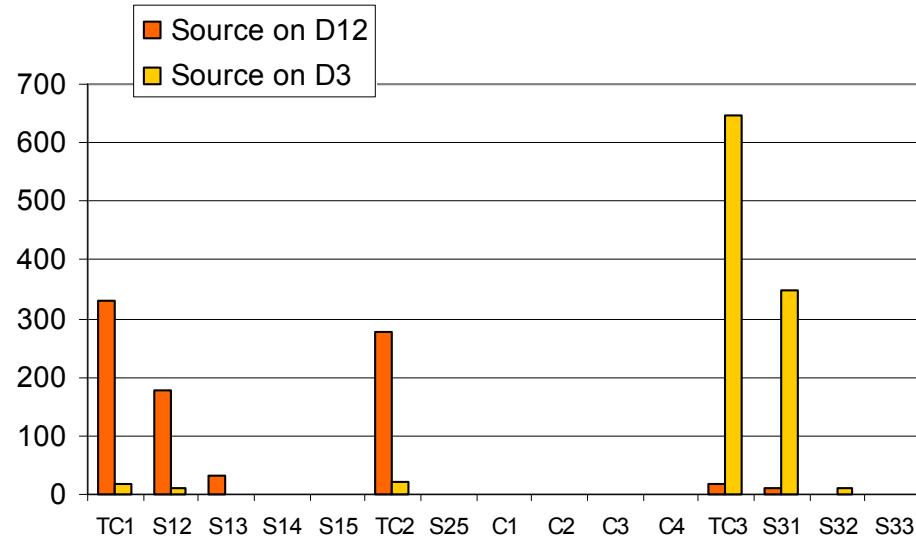
Angular distribution mean relative square deviation
between calculations and data



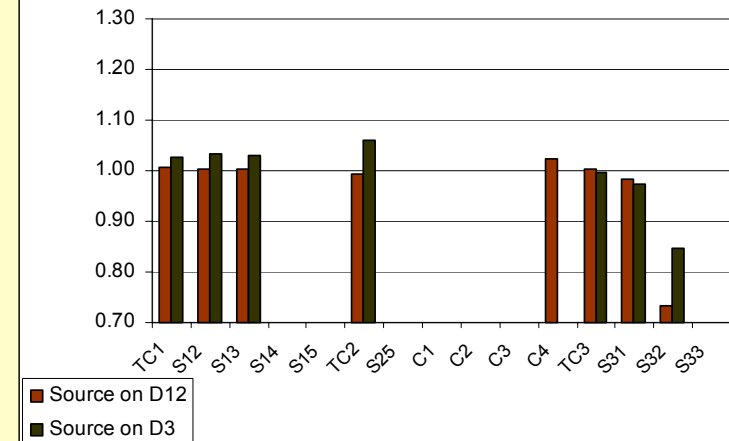
1. Calibration results generally successful
2. In average, agreement better than 10%
3. Some coincidence channels differ more
4. *Using response for typical mass model*
5. *Corrections for area and thresholds fits*

Gamma Responses

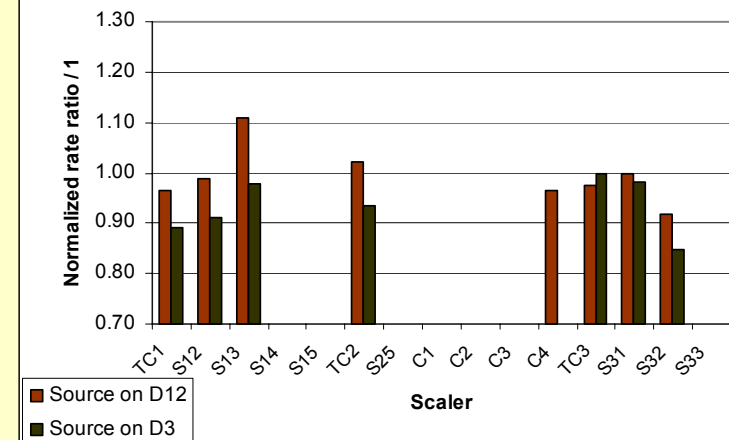
60Co data normalized to 1000 kBq source activity



60Co data comparison with 1st check - ratio



60Co data comparison with SREM Proba - ratio

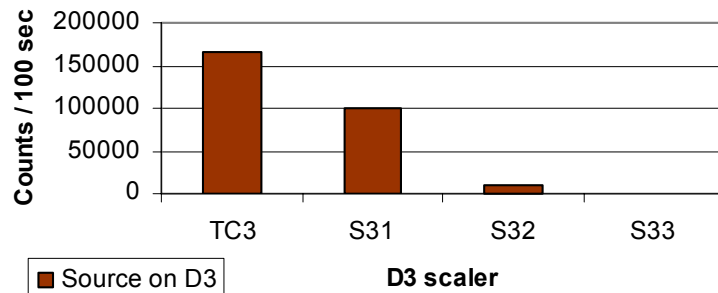


- Two test routinely performed,
- Only half of scalers can be tested with ^{60}Co
- Very sensitive to any changes in threshold sensitive area and Contact changes.

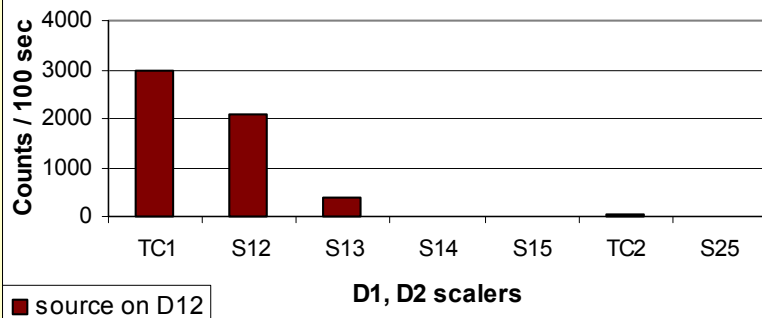
All SREMs up to PFM09 similar

Electron Responses

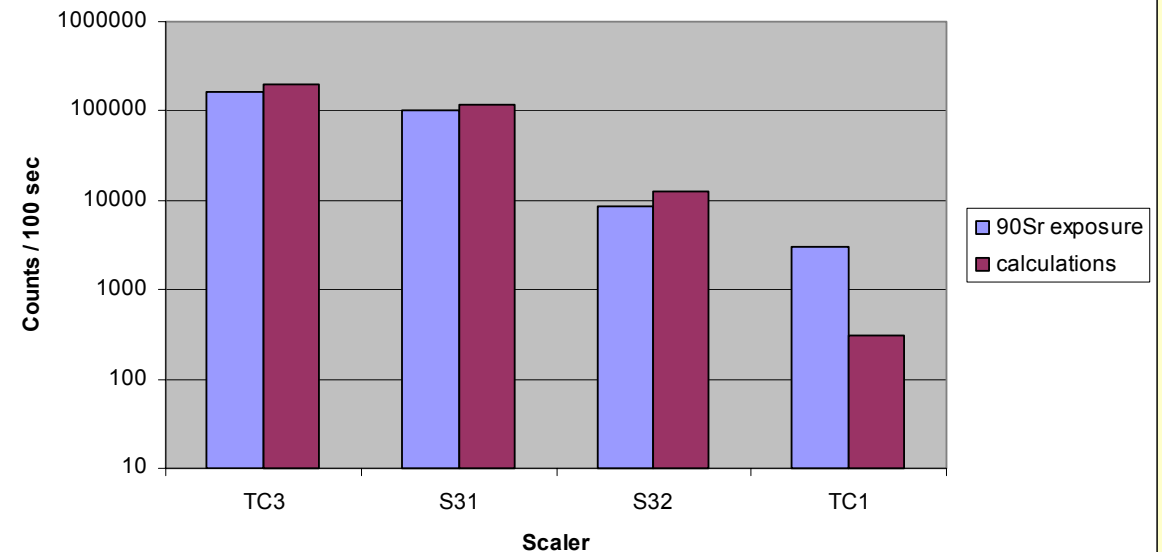
90Sr electron source test



90 Sr electron source test



Comparison with calculations



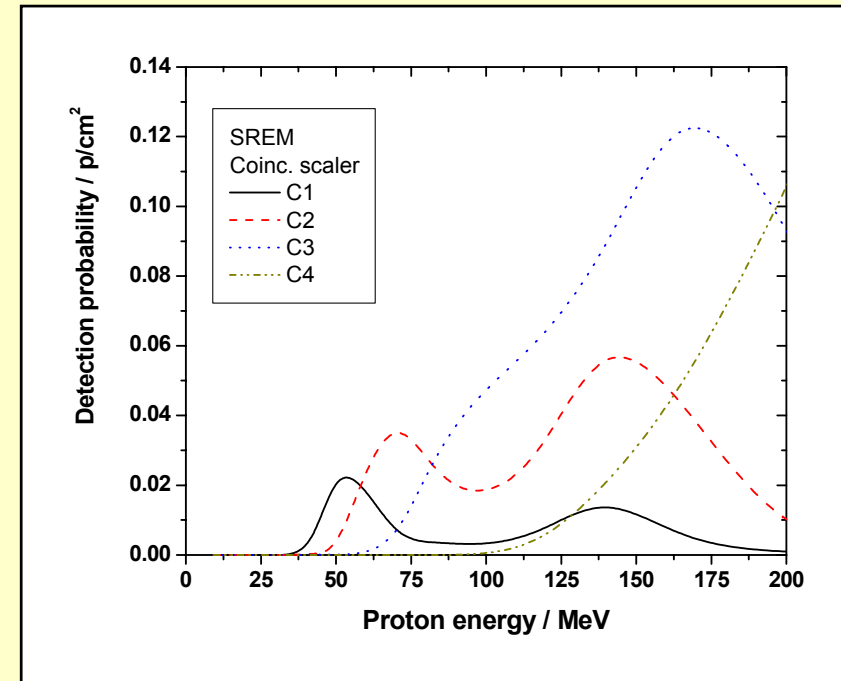
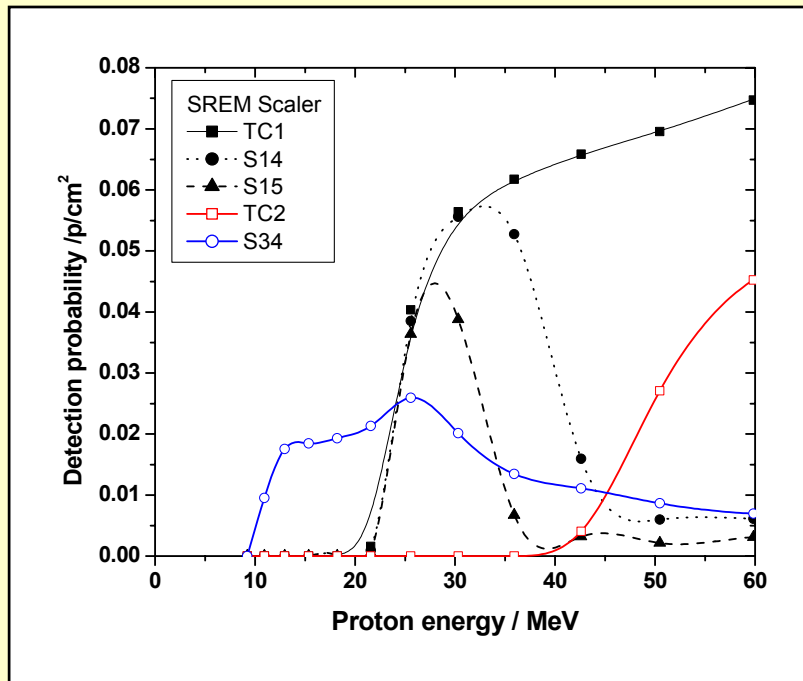
Good agreement already for
calculations with no free parameters

All SREMs behave in a similar way

Full Response Matrix - Protons

Discriminator levels are set to select proton energy

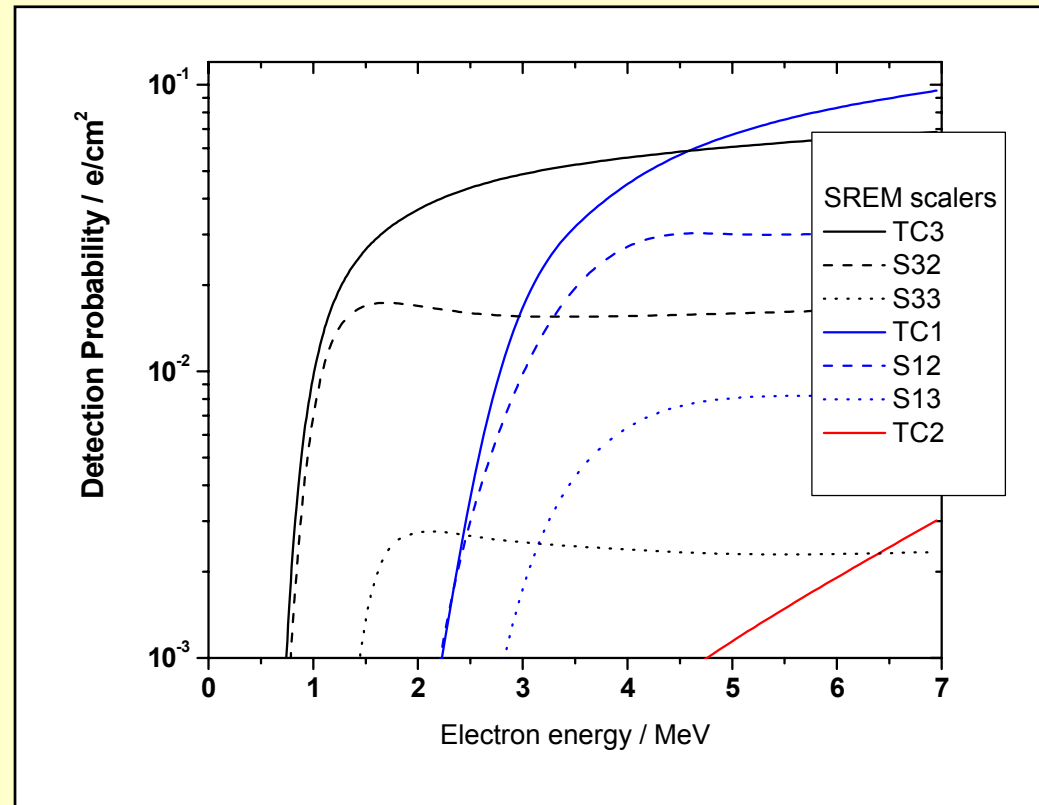
The range extends from 8 MeV



Single channels cover lower energies

Coincidence channels are sensitive to higher energies

Full Response Matrix - Electrons

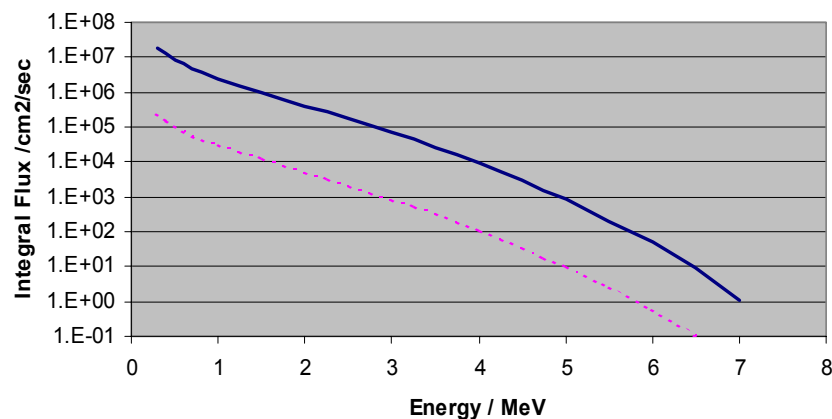


Discriminator allow to select electron energy

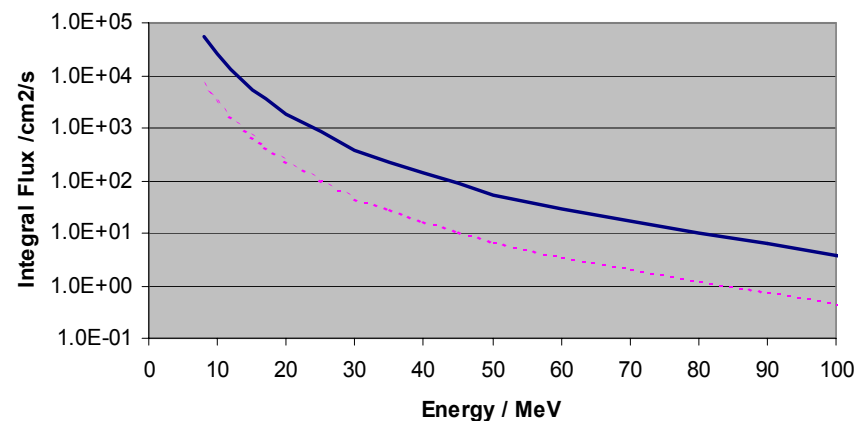
The range extends from 0.6 MeV

Typical Responses

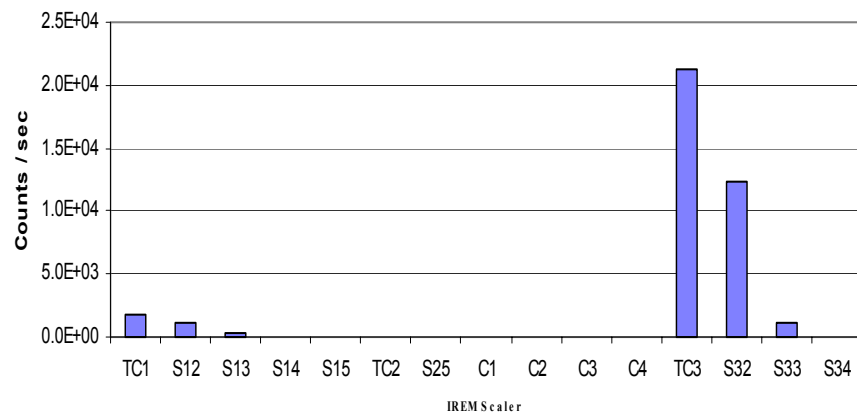
Electron Belt Spectrum



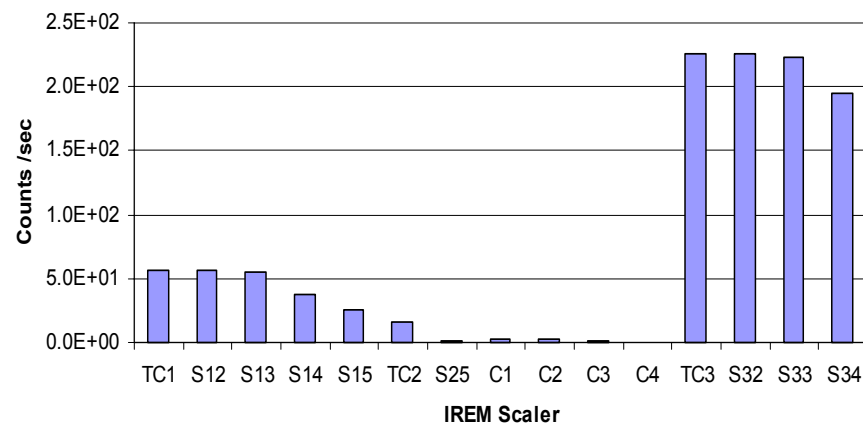
Proton Belt Spectra



Counting Rate in Electron Belt

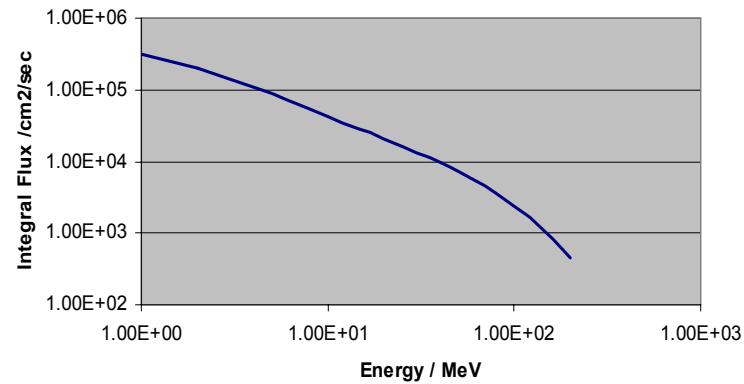


Counting Rate in Proton Belt

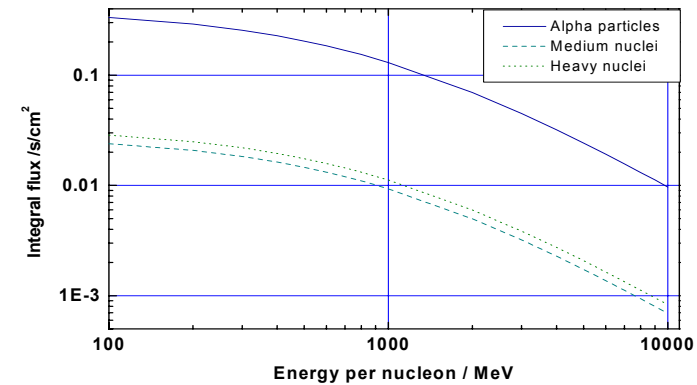


Detection Limits

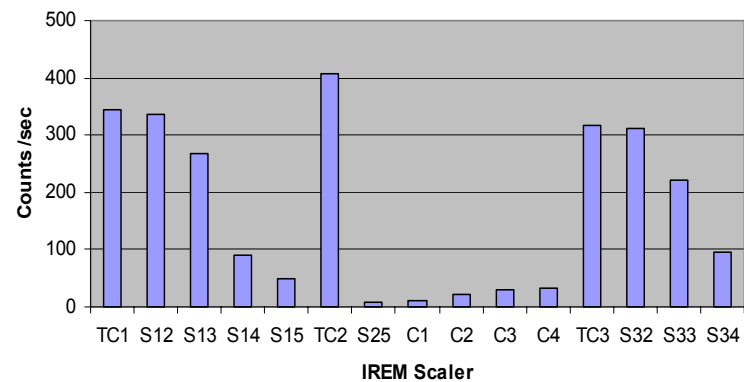
Example of Solar Protons



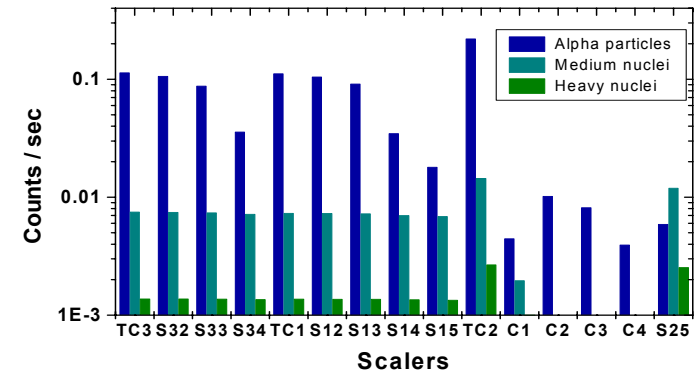
Galactic Cosmic Rays integral fluxes used in simulations



Counting Rate Example - Solar Events (trend only)

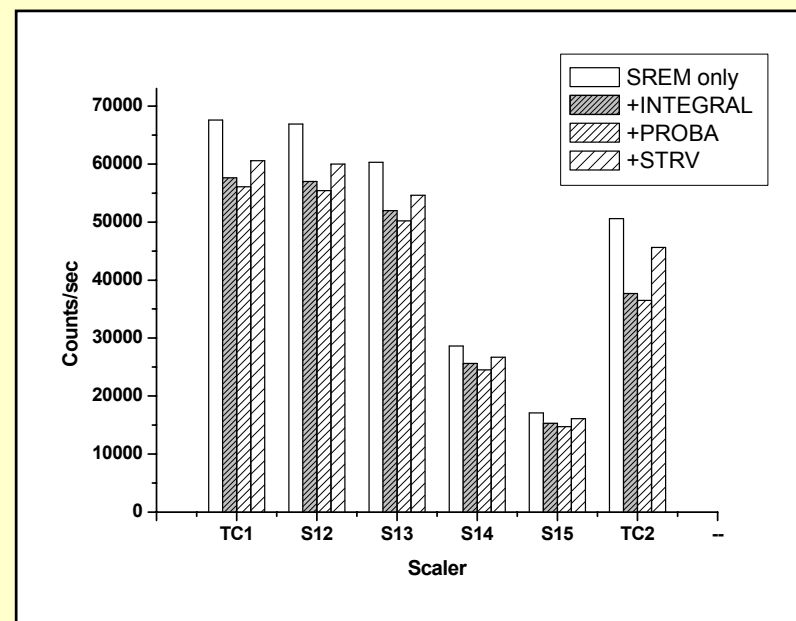
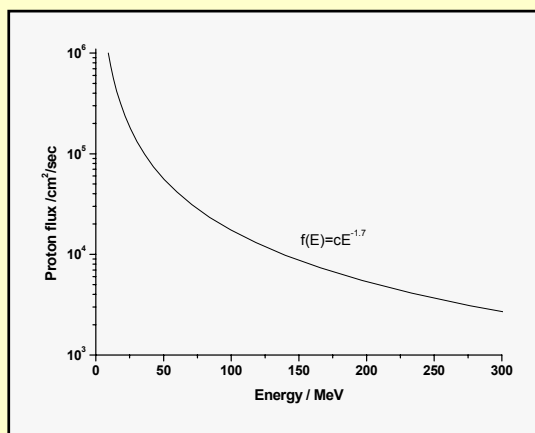
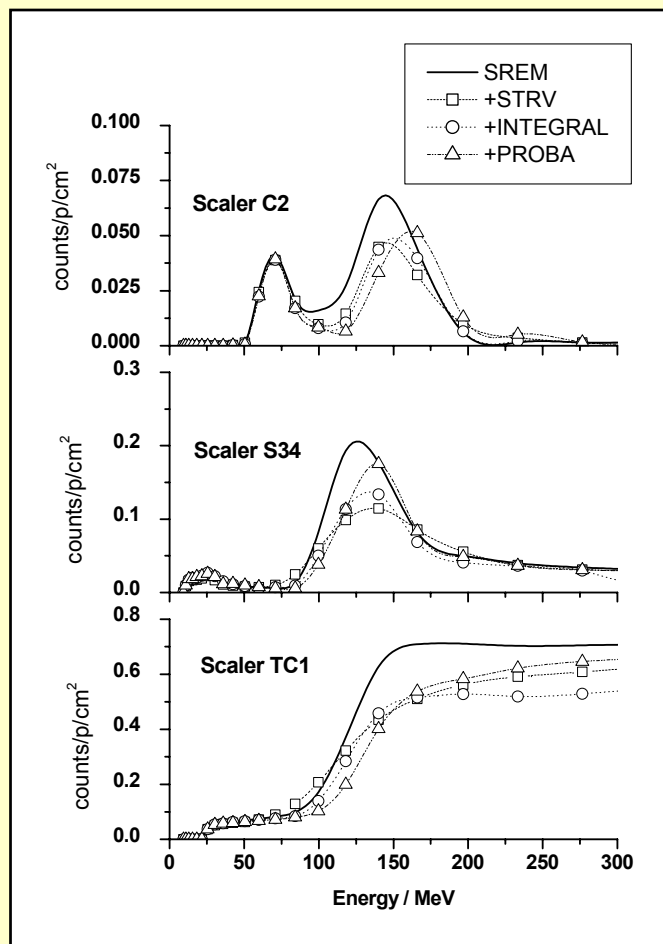


Galactic Cosmic Rays background in SREM counters

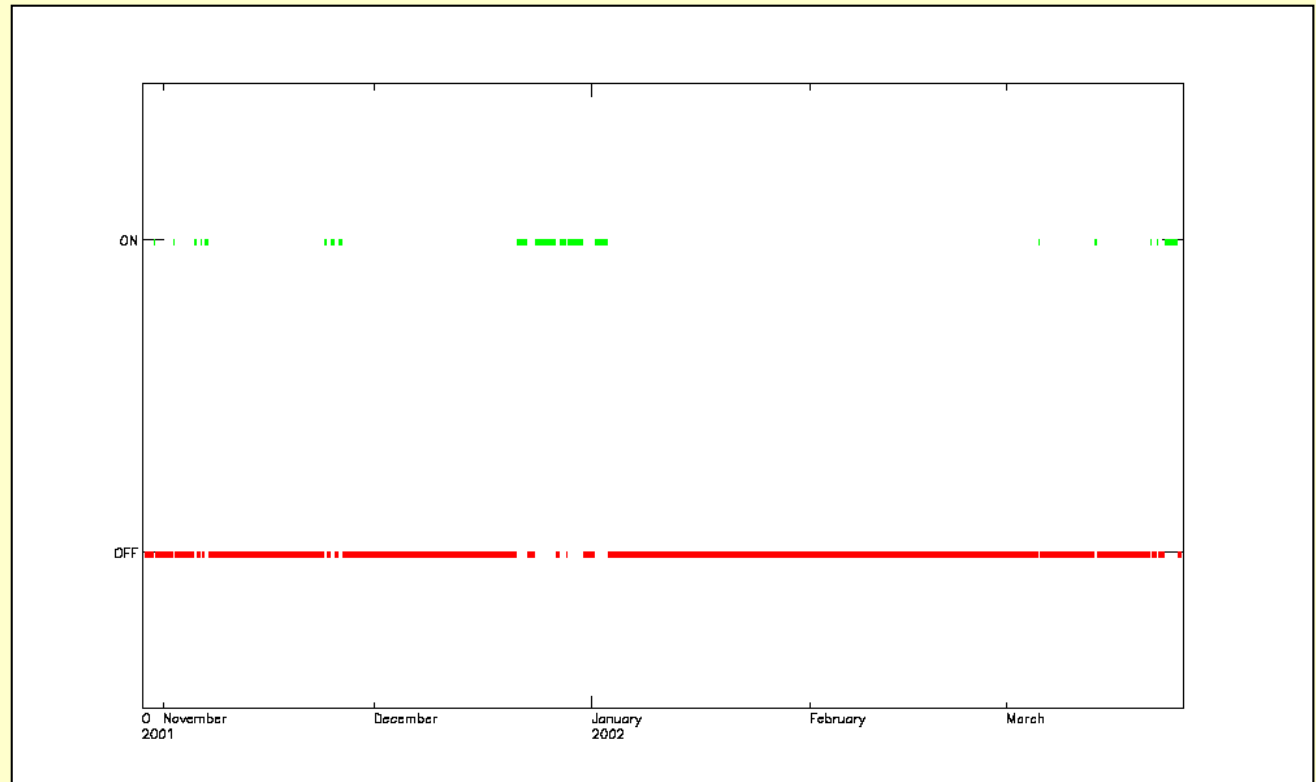
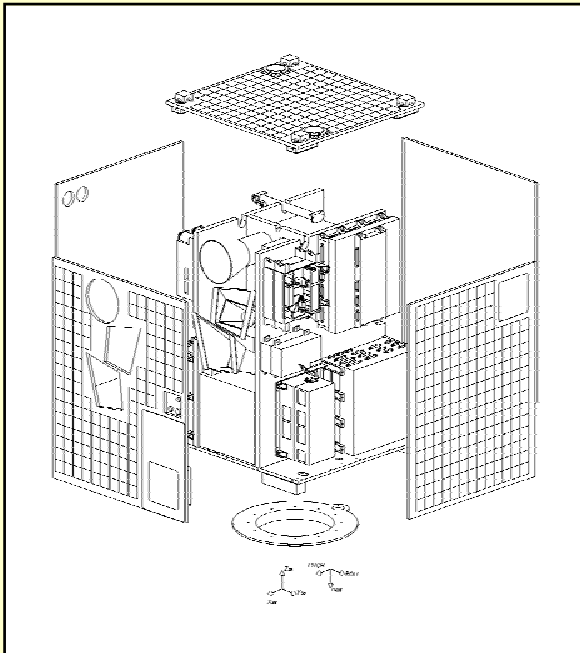


Response with Satellite

Only high energy proton sensitivity changes but responses for typical space spectra differ little

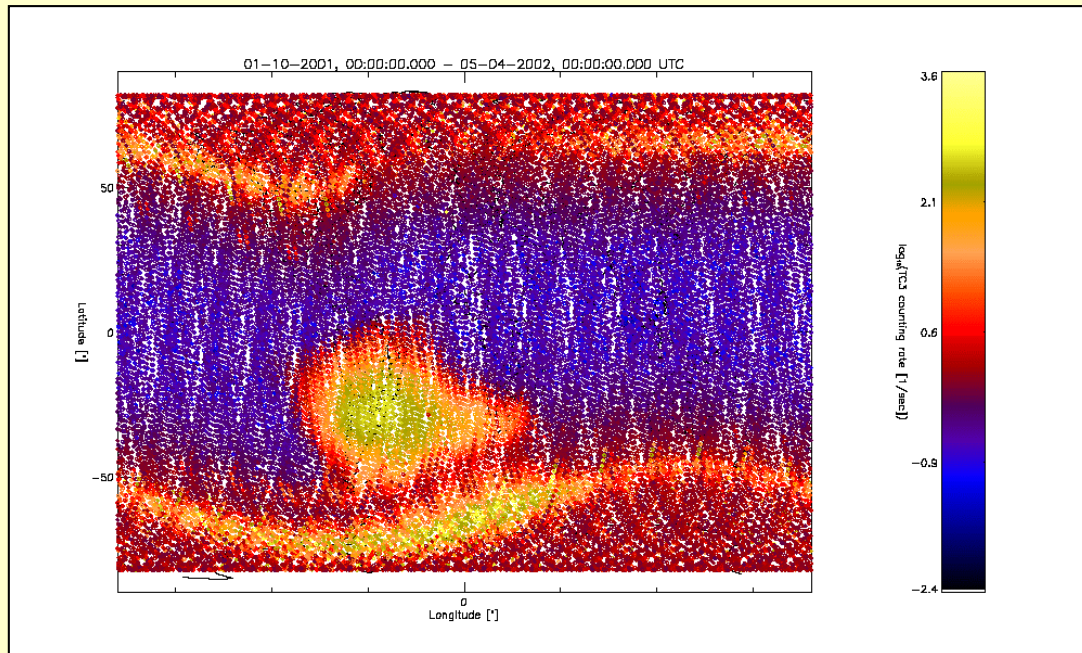


PROBA with SREM Onboard



Until now only limited data available (*SREM mostly OFF*)
due to satellite tiny power budget and restricted planning

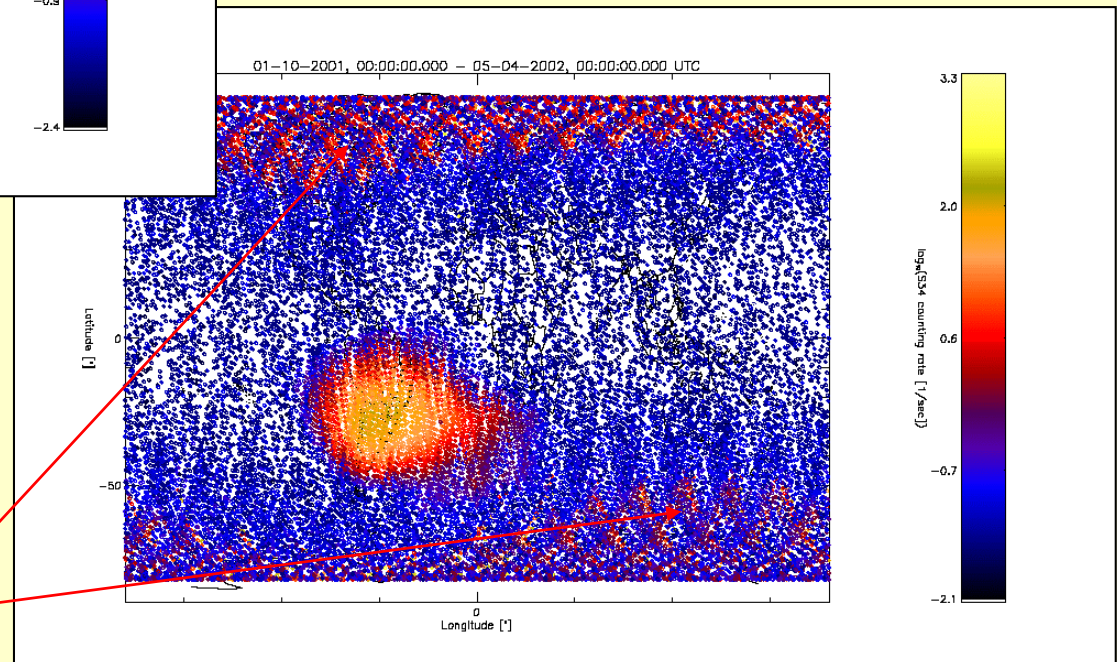
First Environment Maps



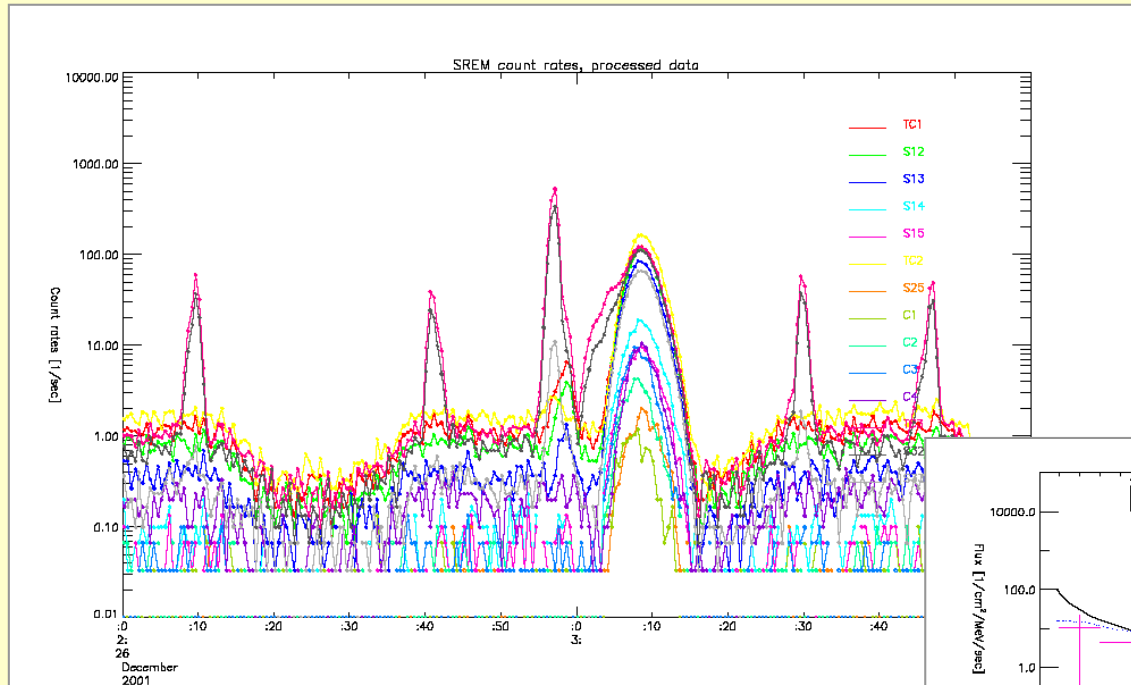
Electrons ($E > 0.65$ MeV)
and
Protons ($E > 9$ MeV)

Protons

Solar Protons

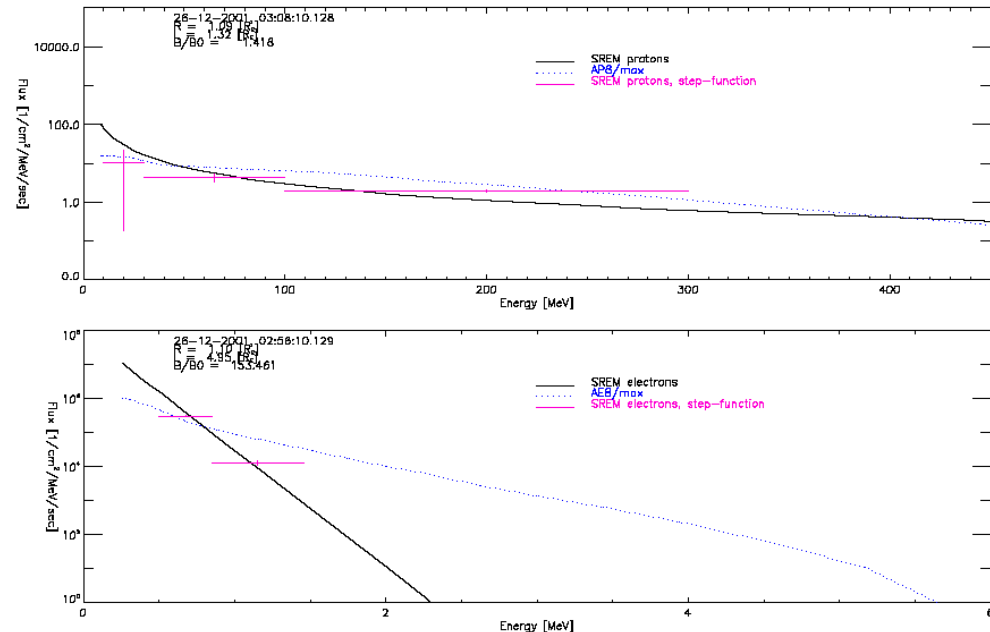


First Orbital Data

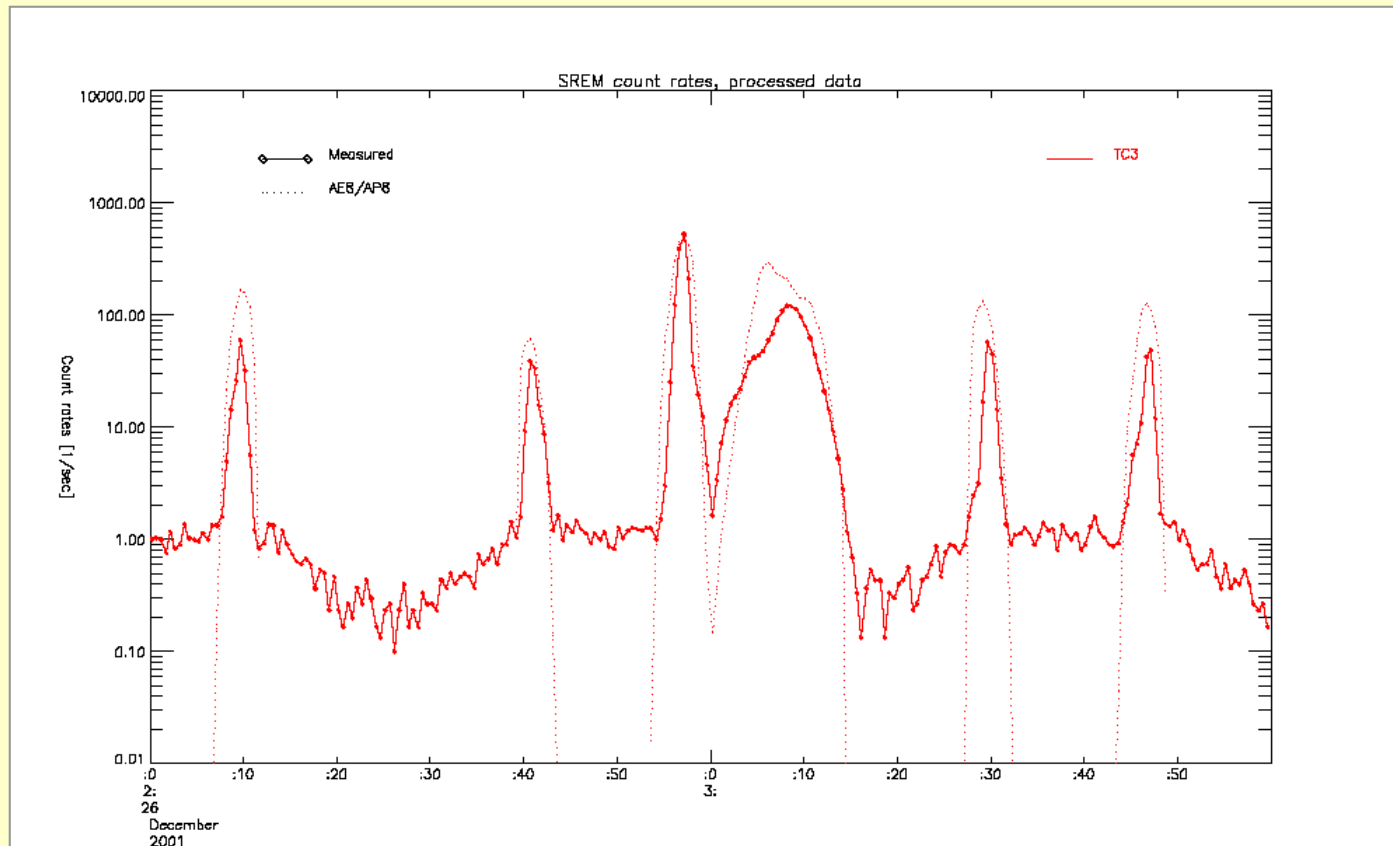


Count rate along the orbit
(all scalers)

PROBA SREM Particle spectra
and AE8/AP8
(Power law and step function fit)



Expected Radiation Environment



PROBA SREM Count rate for TC3
compared with AE8/AP8
($E_p > 9$ MeV, $E_e > 0.7$ MeV)

