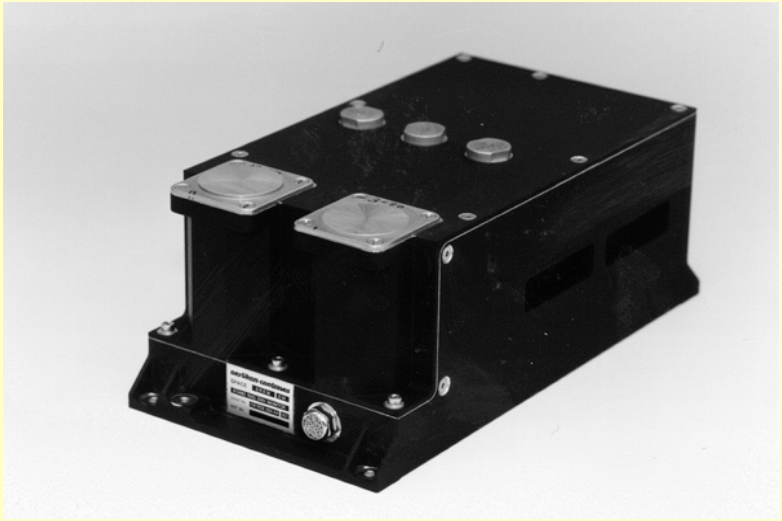
Standard Radiation Environment Monitor SREM

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 mm^3
12. Power consumption: ≈ 2W
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

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

STEPS

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

Facilities

1. Calibrated radioactive sources:

- Gamma rays ^{60}Co ; <E>=1.25 MeV
- Electrons ^{90}Sr ; E_{max}=2.28 MeV

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

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

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

Full energy range:	6 - 300 MeV
Full angular range:	$0^o \leq \theta \leq 180^o$, $0^o \leq \phi < 360^o$
Full flux range:	$0 < F < 2\Sigma 10^5$ p/cm²/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 ñ 40m

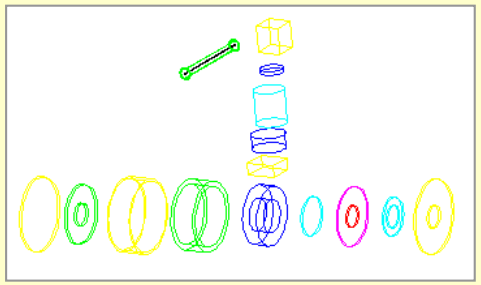
SREM unit placed on the angular stage

(and two plastic detectors in front - up)

Modeling

Mass model constructed using GEANT code

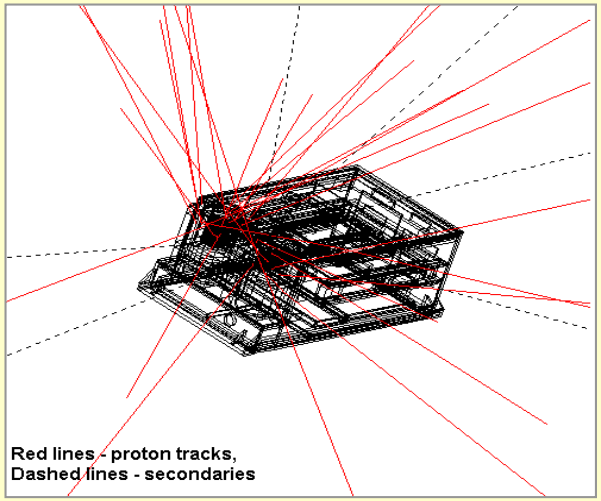
- Exact description of Si-detectors and housing
- Simplified printed boards, cables, connectors
- About 350 volumes/shapes introduced



Detector, Contact and Cable ñ expanded view

Extensions for comparison with calibration data

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



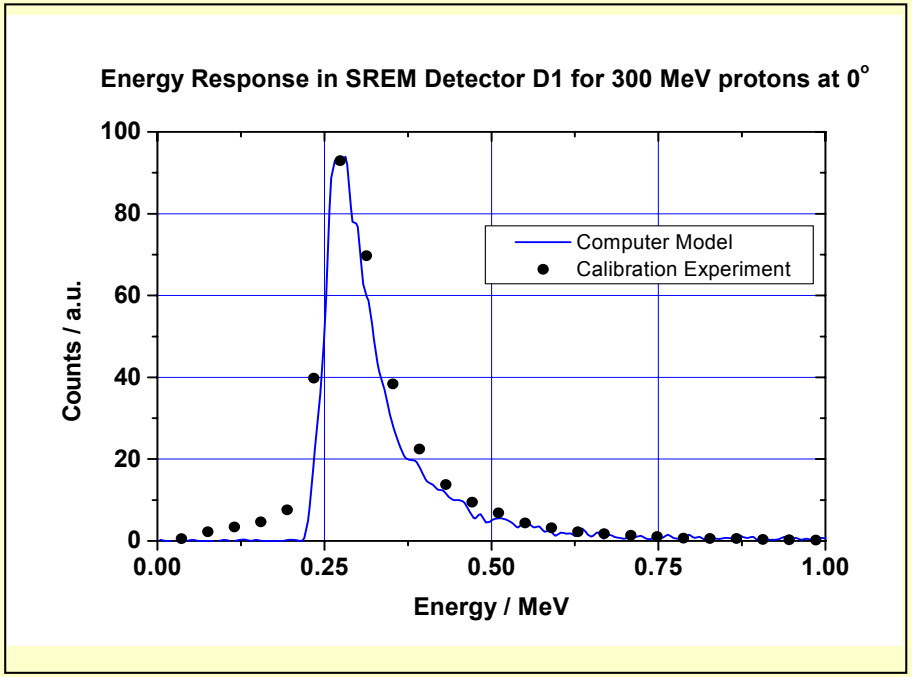
Steps

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

Linearity

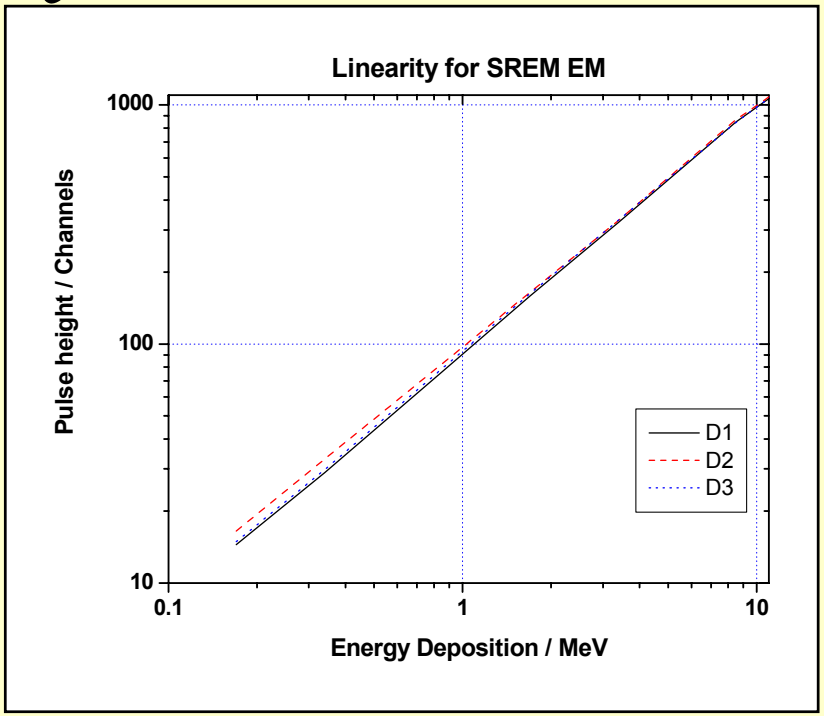
Minimum Sensitivity:

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 ñ 4.75 MeV)

Fulfils specifications for all p and e channels

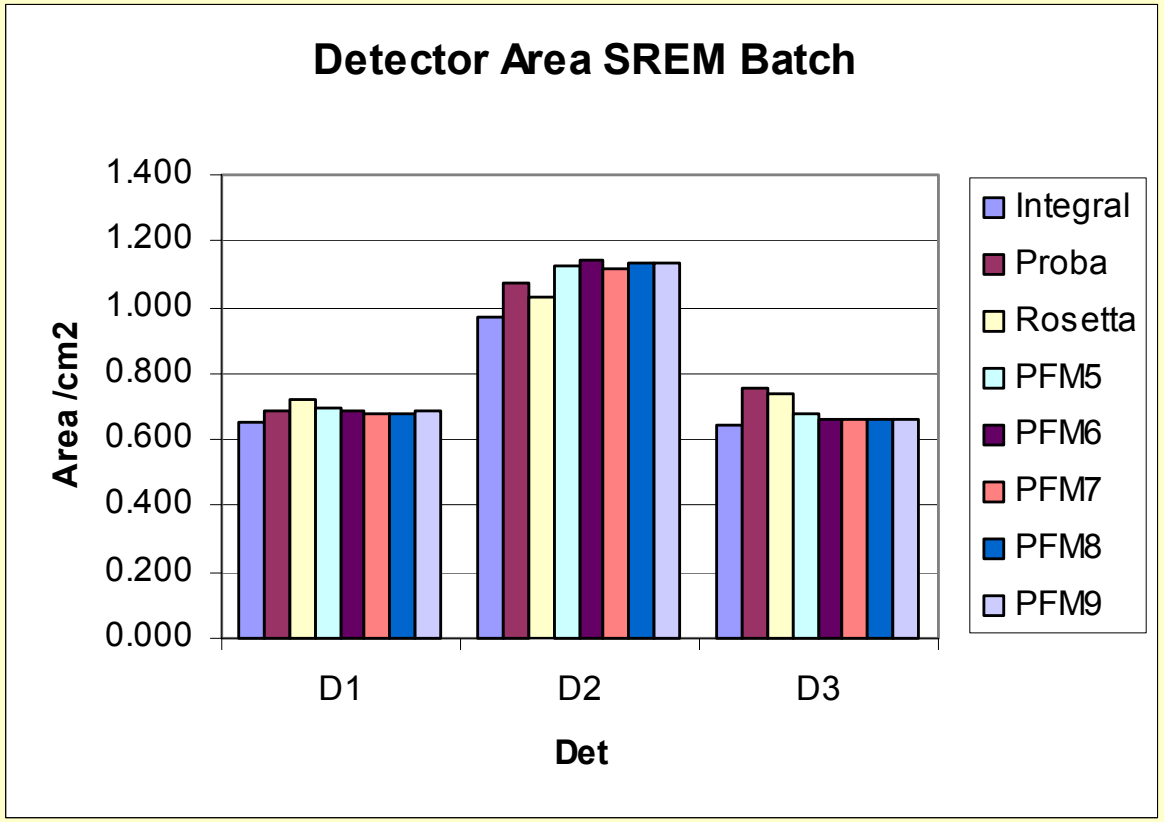
Measured for two SREMs and
indirectly verified for all 10 units

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 <A>= 0.69 cm^2
D2 <A>= 1.09 cm^2
D3 <A>= 0.68 cm^2

(Error for single detector < 0.01cm^2)

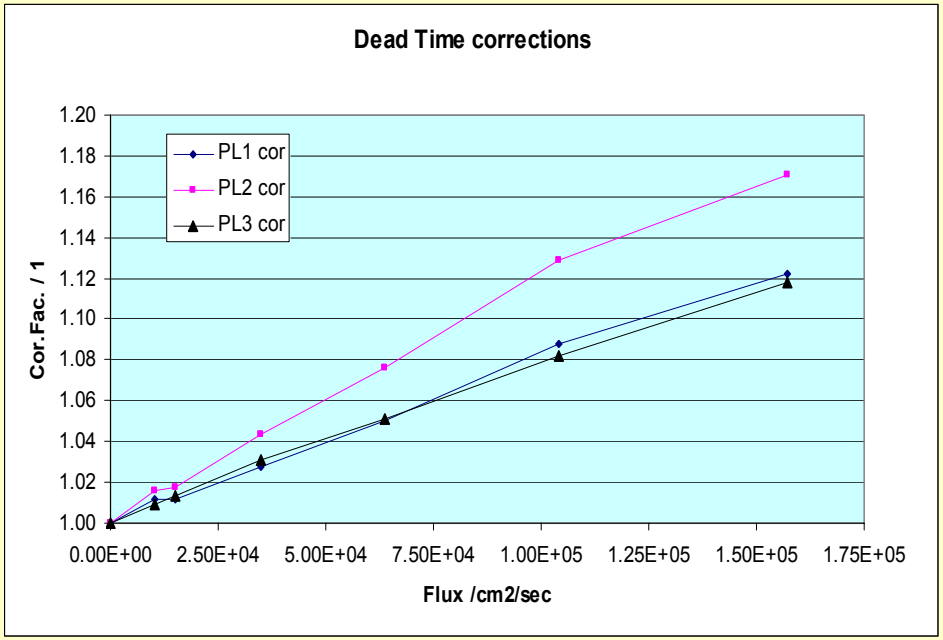
Dead-time and Pile-ups

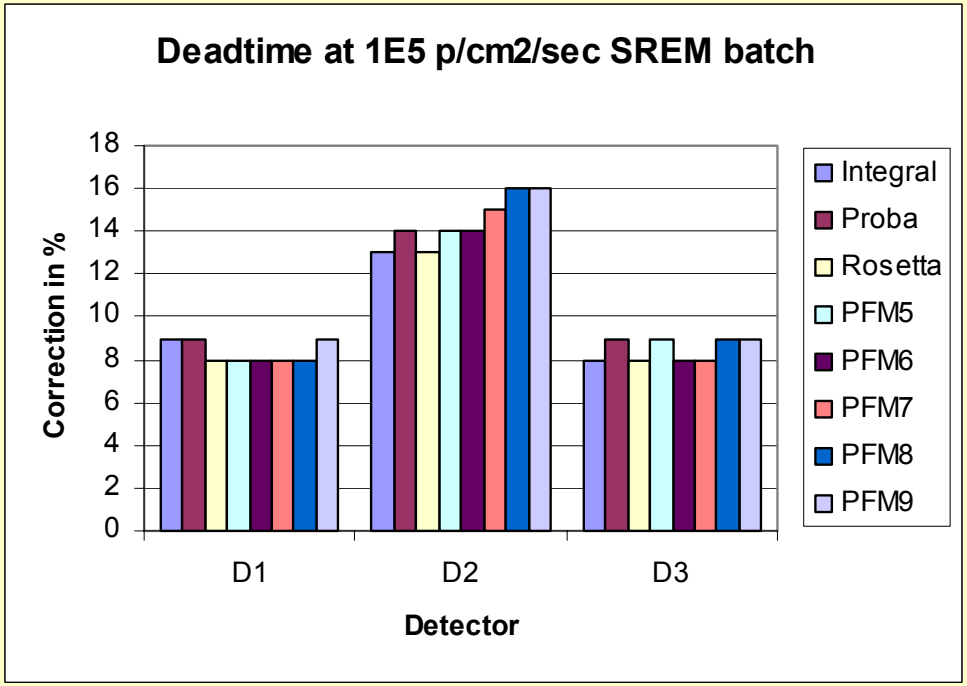
Measured using DT and TC scalers

Exposures at 0∞and 300 MeV

Intensity from 10^3 to $1.5ï10^5$ /cm^2/s

Normalization to fast plastic detector





DT corrections smaller than required:
20% maximum at 10^5 /cm^2/s

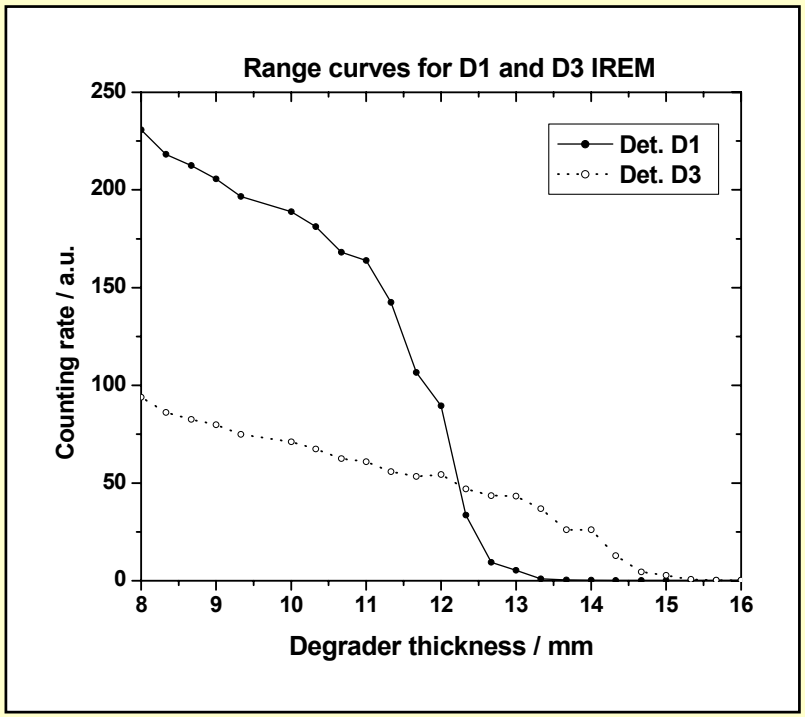
Only a few percent pile-ups for realistic space environment (at higher energies)

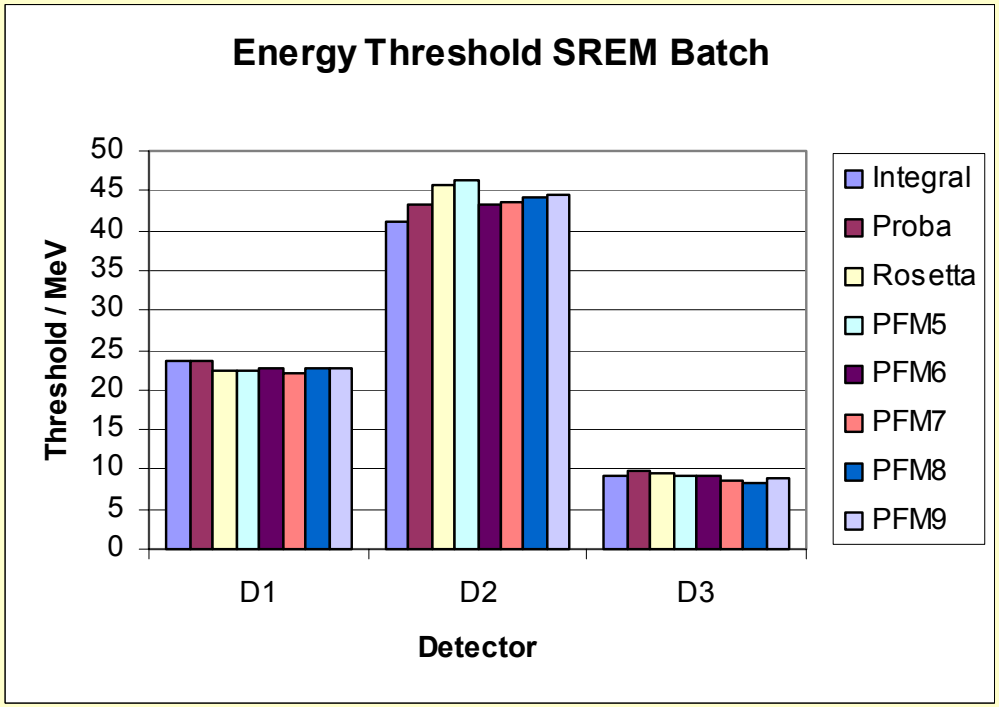
Low energy threshold

Measured using TC scalers and ICs

Exposures at Θ=0∞and E_0 = 60 MeV

Degrader steps 0.33 mm Al





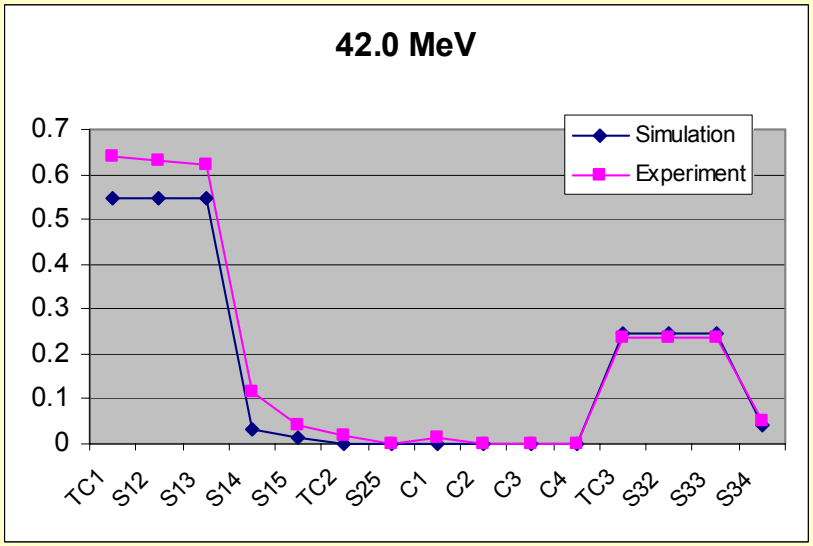
Threshold fit for each detector
Result within 5-10% with specs.
D1 E_{thr} = 22.8 ± 0.5 MeV
D2 E_{thr} = 44.0 ± 1.6 MeV
D3 E_{thr} = 9.1 ± 0.4 MeV
Relatively large scatter of results

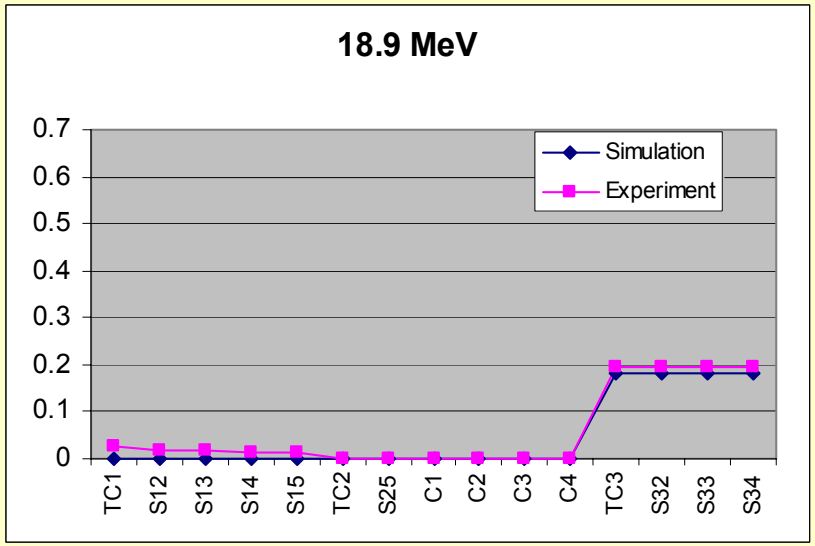
I. Low energy response at 0°

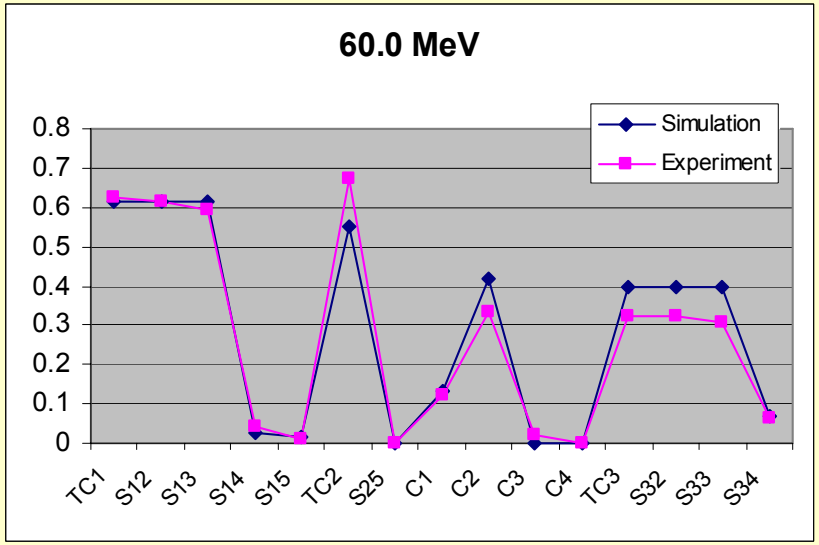
Example: Comparison of PROBA results

Calculations include beam and facility features

In general agreement is very good
but closer to thresholds ñ bigger deviations







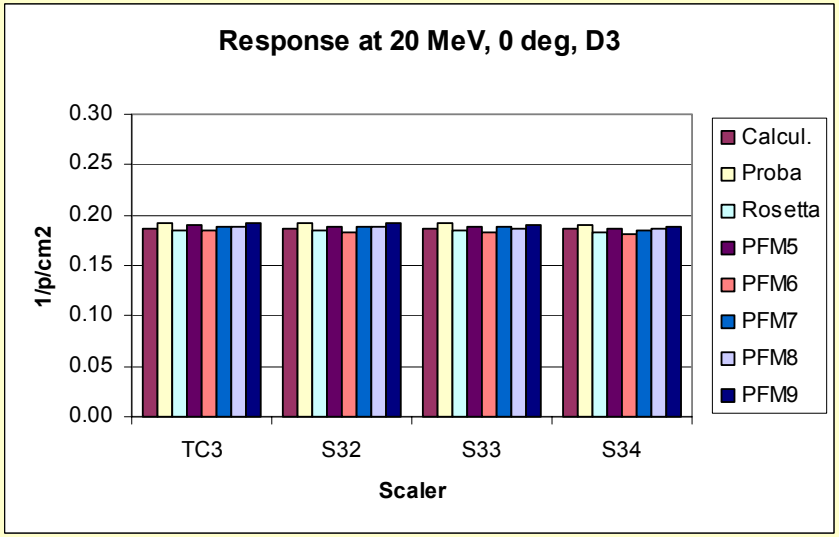
II. Low energy response at 0°

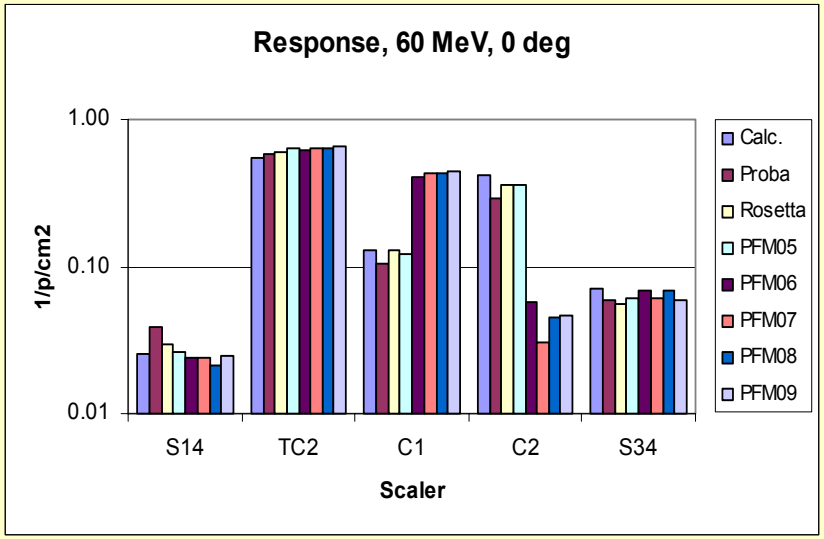
Comparison for SREMs PFM3 to PFM9:

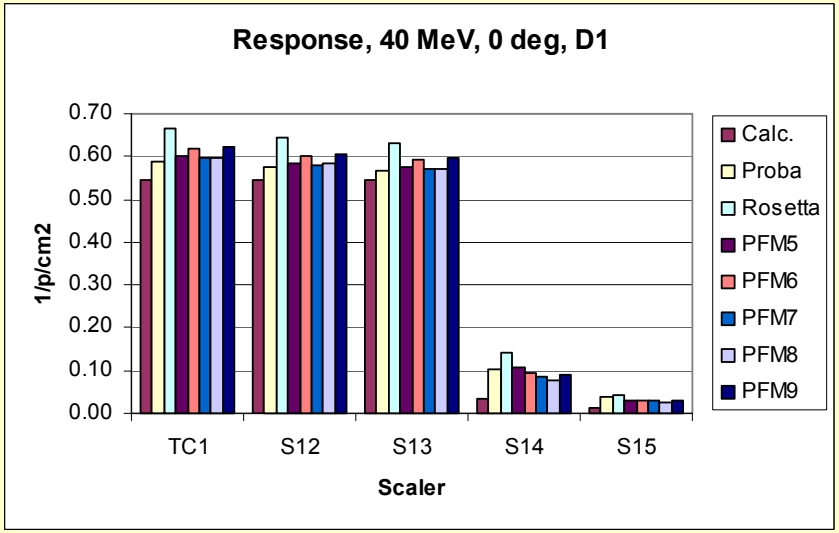
Agreement generally very good !

Again - far from thresholds ñ better
(see e.g. S14 at 40 and 60 MeV)

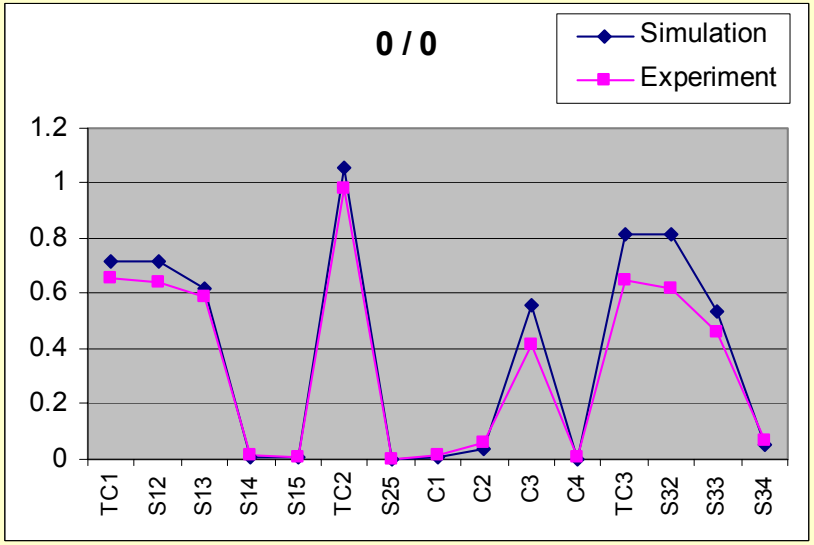
Jump from PFM06 in coincidence scalers
(see C1,C2 from PFM06) ñ fit of thresholds?

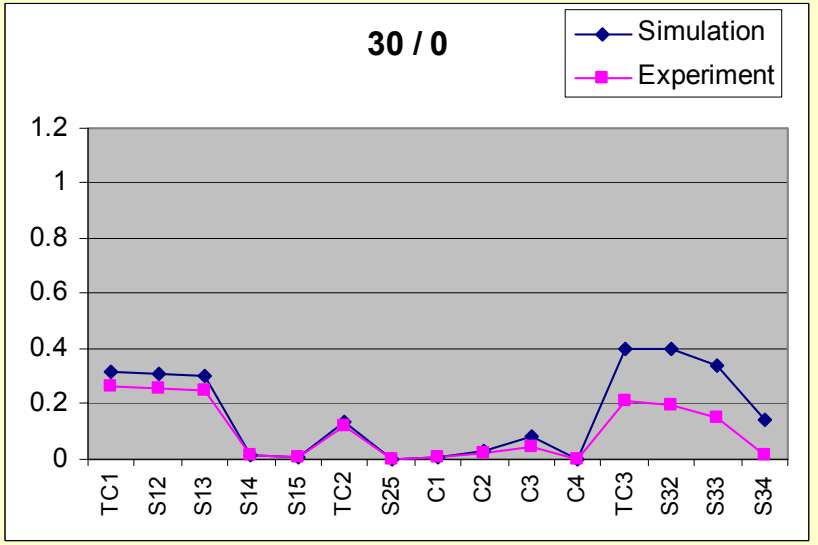


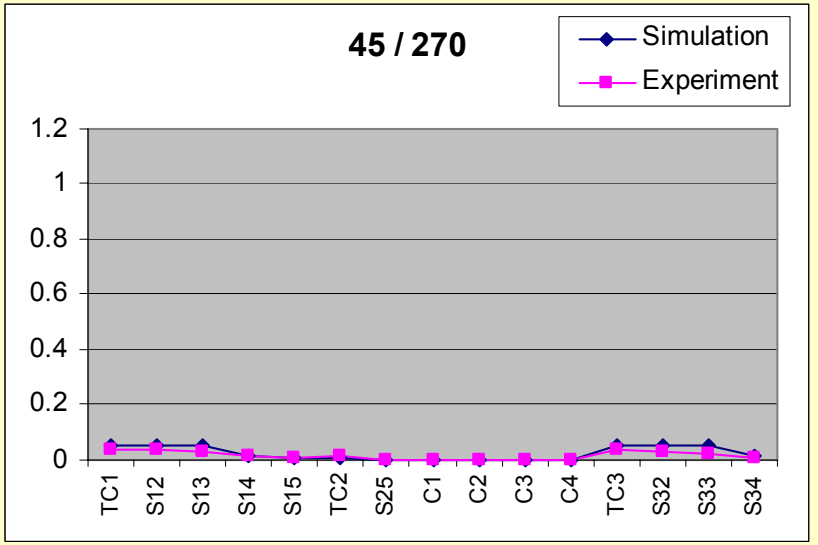




Angular distributions







Example: PROBA results at 100 MeV

Angle pairs (Θ,φ)=(0,0),(30,0),(45,270)

Agreement is pretty good

Response quickly decreases with angle

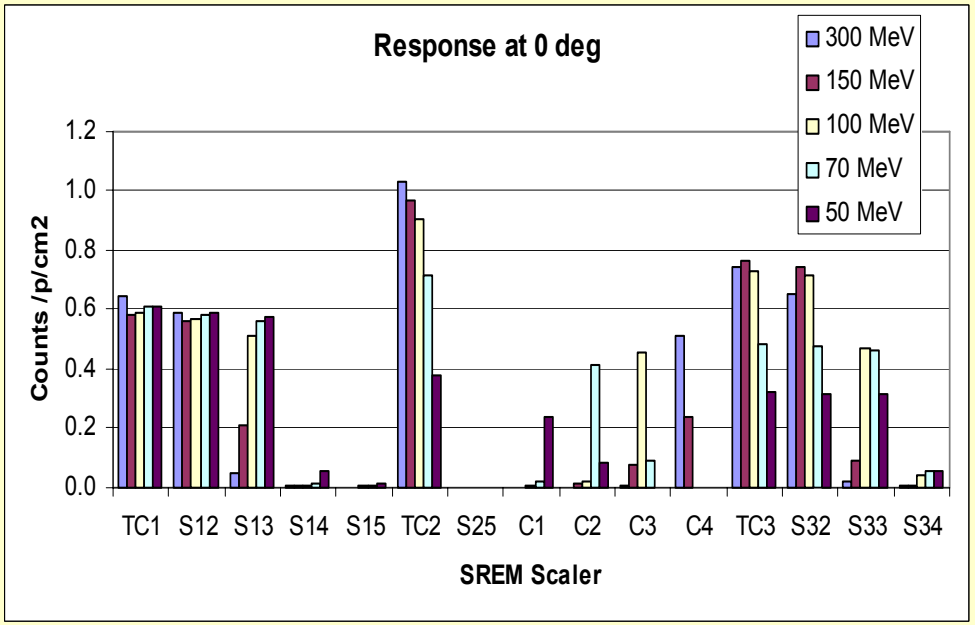
High energy response vs. angle

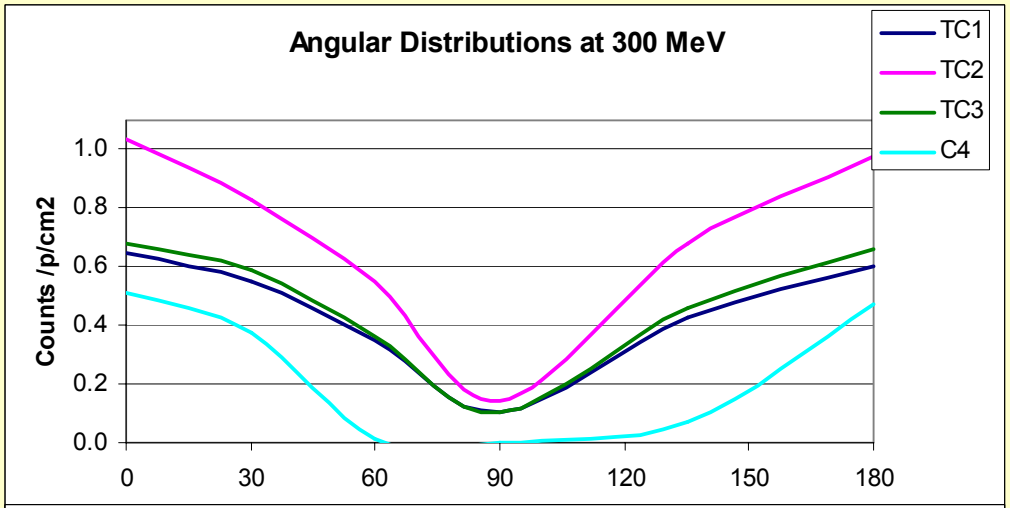
Example: PFM05

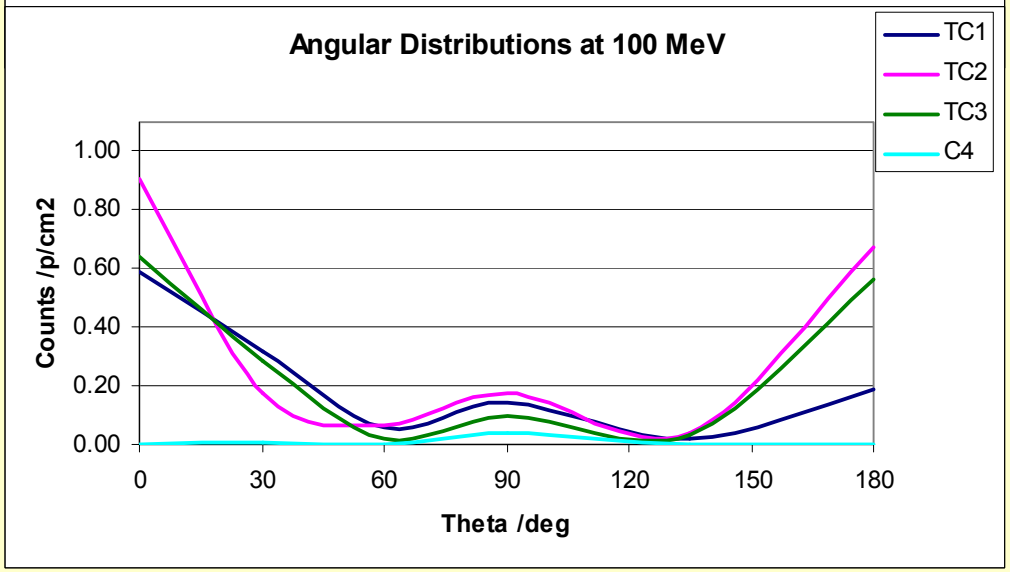
(selected angles & scalers)

Strong energy dependence even at 0∞

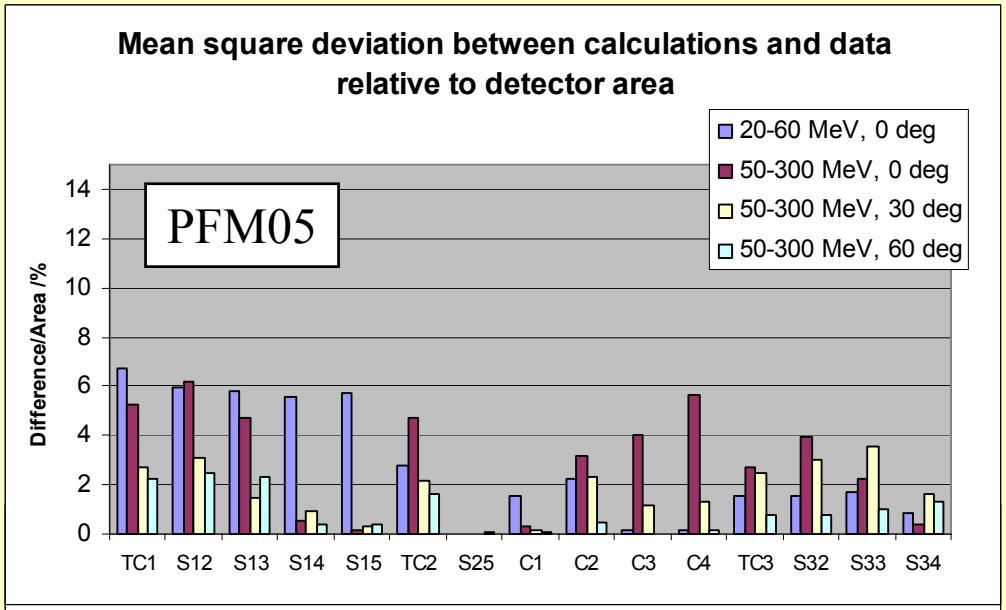
High angular sensitivity even at high E

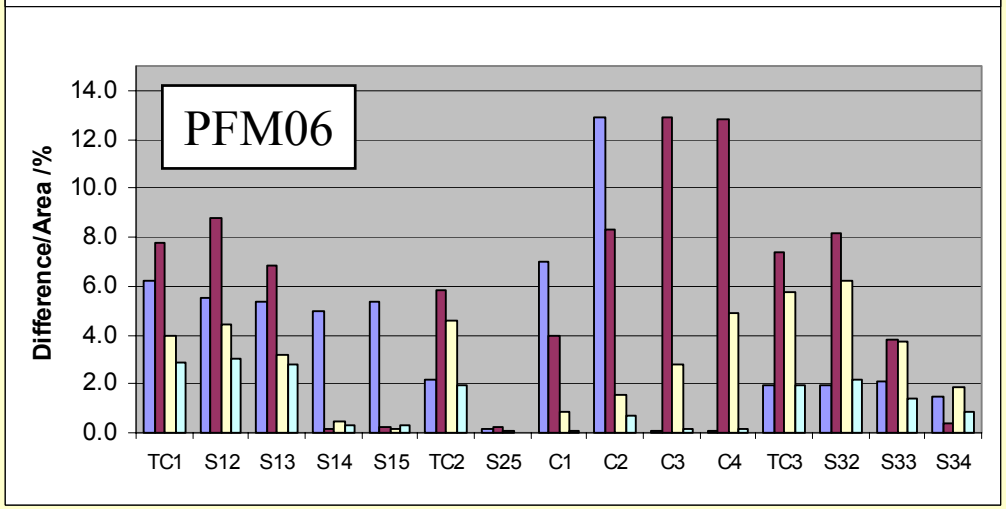


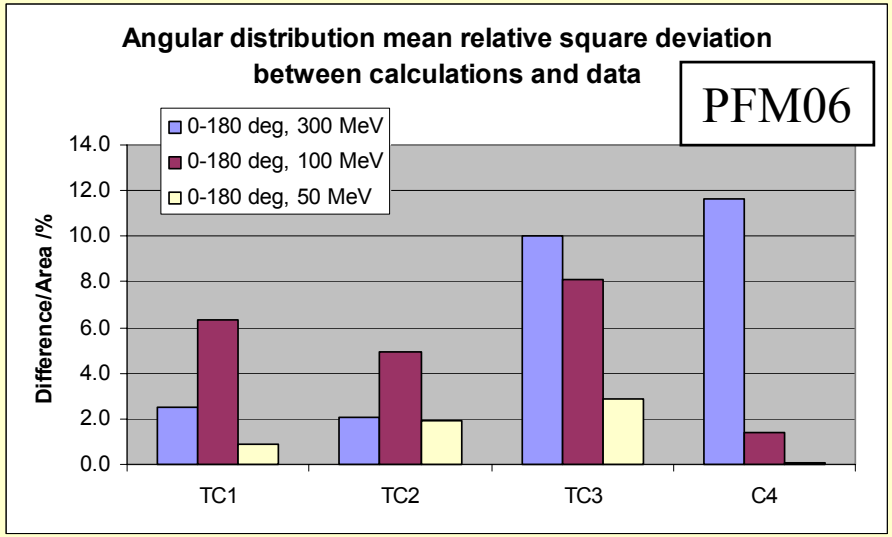




Batch Comparison - Summary

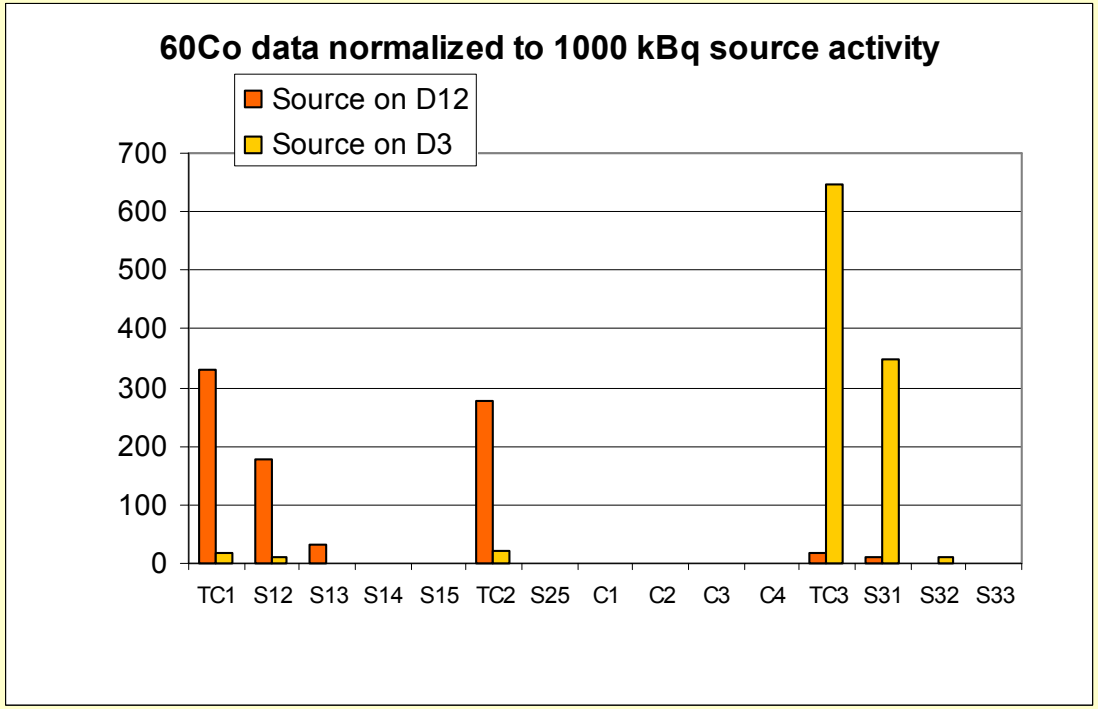


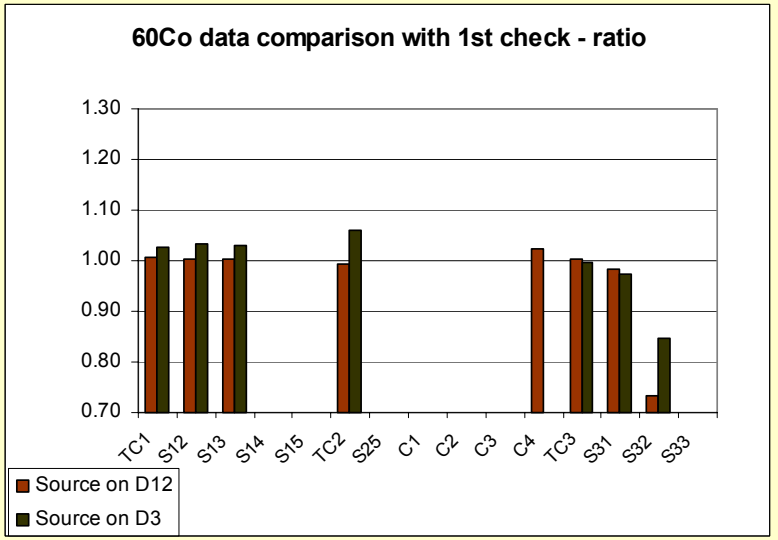


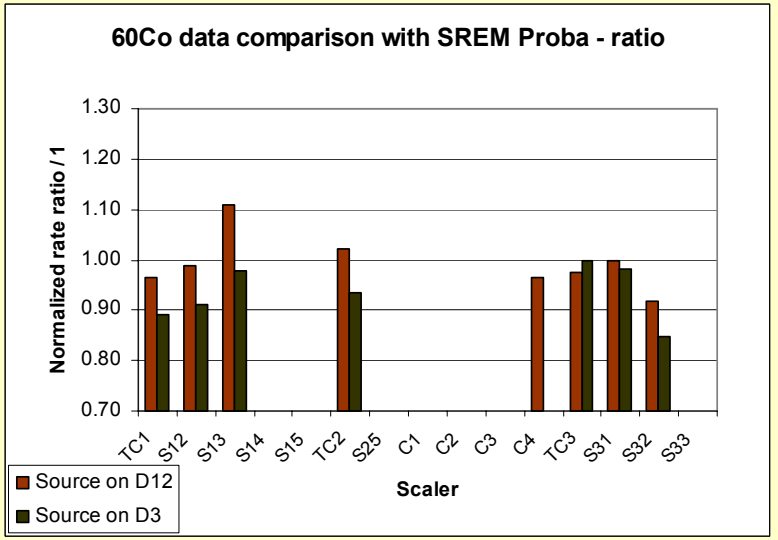


1. **Calibration results generally successful**
2. **In average, agreement better than 10%**
3. **Some coincidence channels differ more**
4. ***Using response for typical mass model***
5. ***Corrections for area and thresholds fits***

Gamma Responses



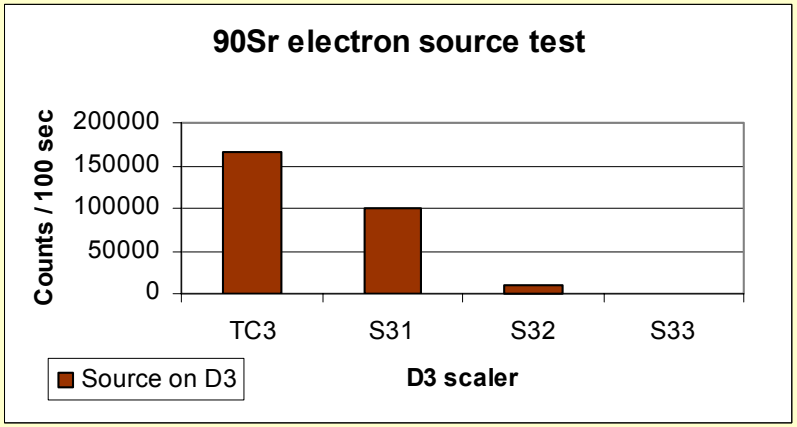


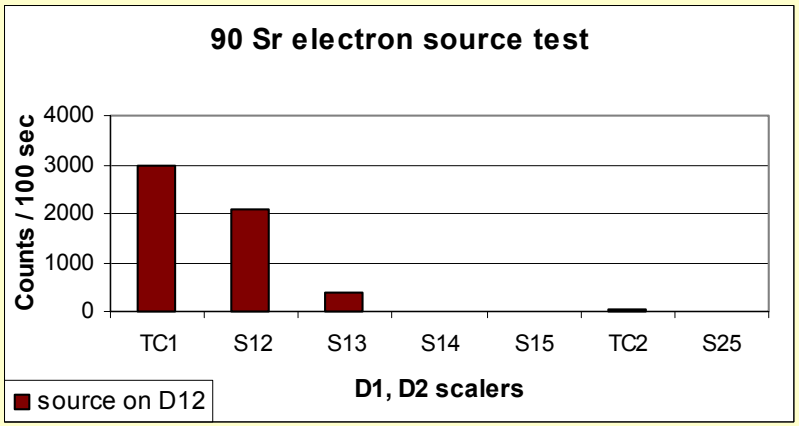


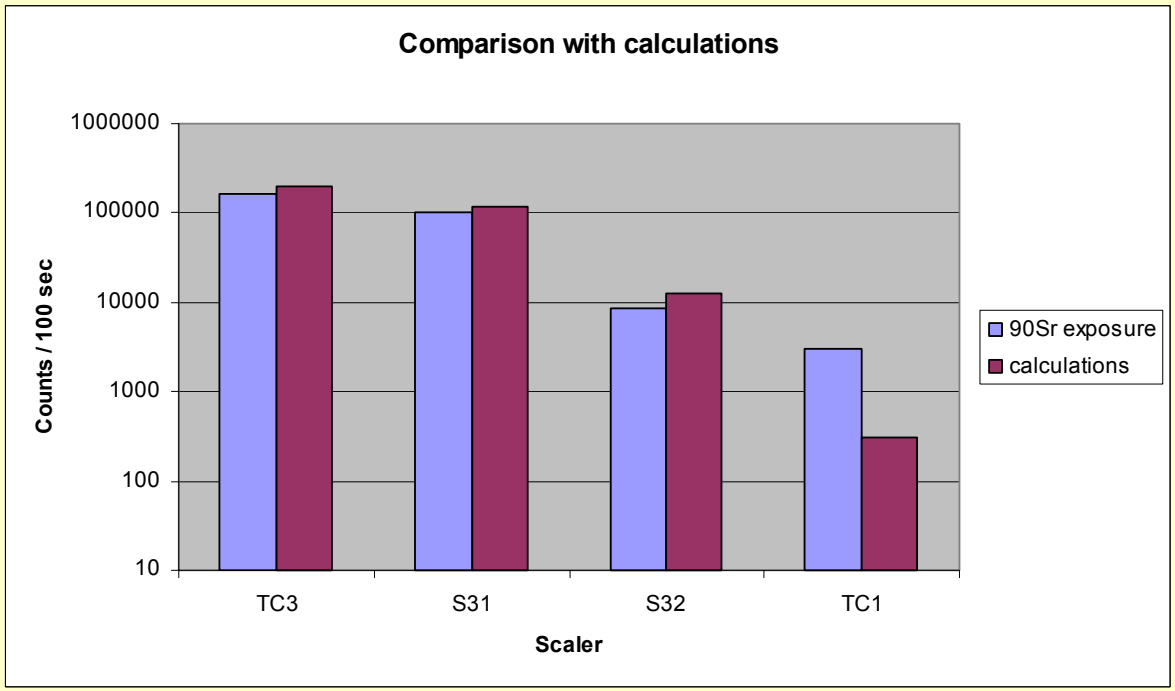
- Two test routinely performed,
- Only half of scalers can be tested with ^{60}Co
- Very sensitive to any changes in threshold sensitive area and Contact changes.

All SREMs up to PFM09 similar

Electron Responses







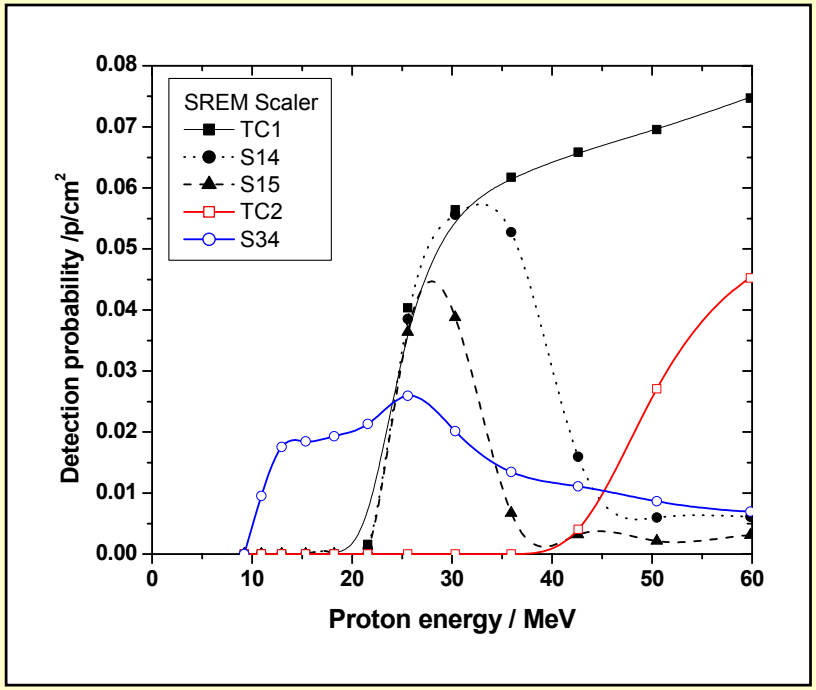
Good agreement already for calculations with no free parameters

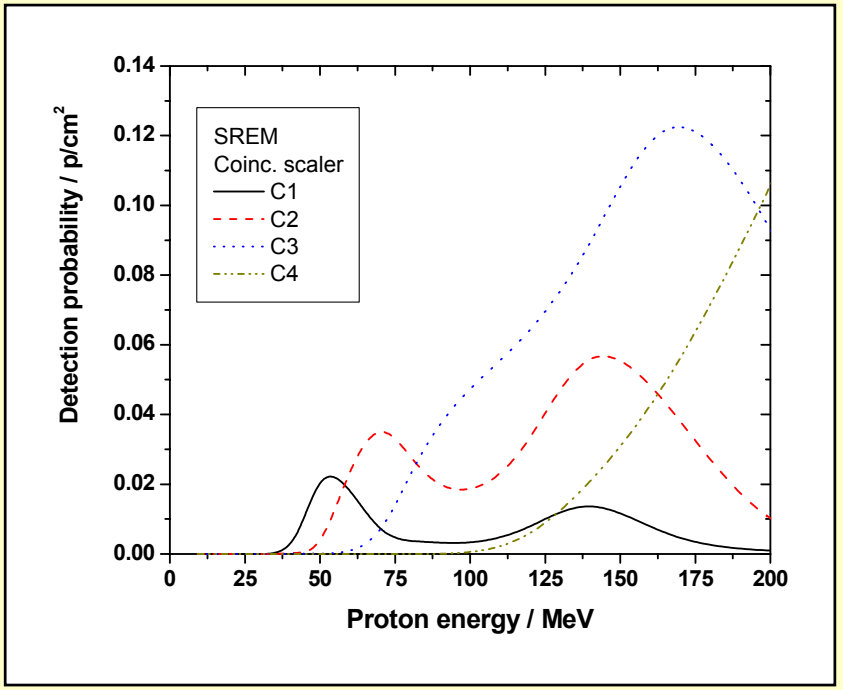
All SREMs behave in a similar way

Full Response Matrix - Protons

Discriminator levels are set to select proton energy

The range extends from 8 MeV

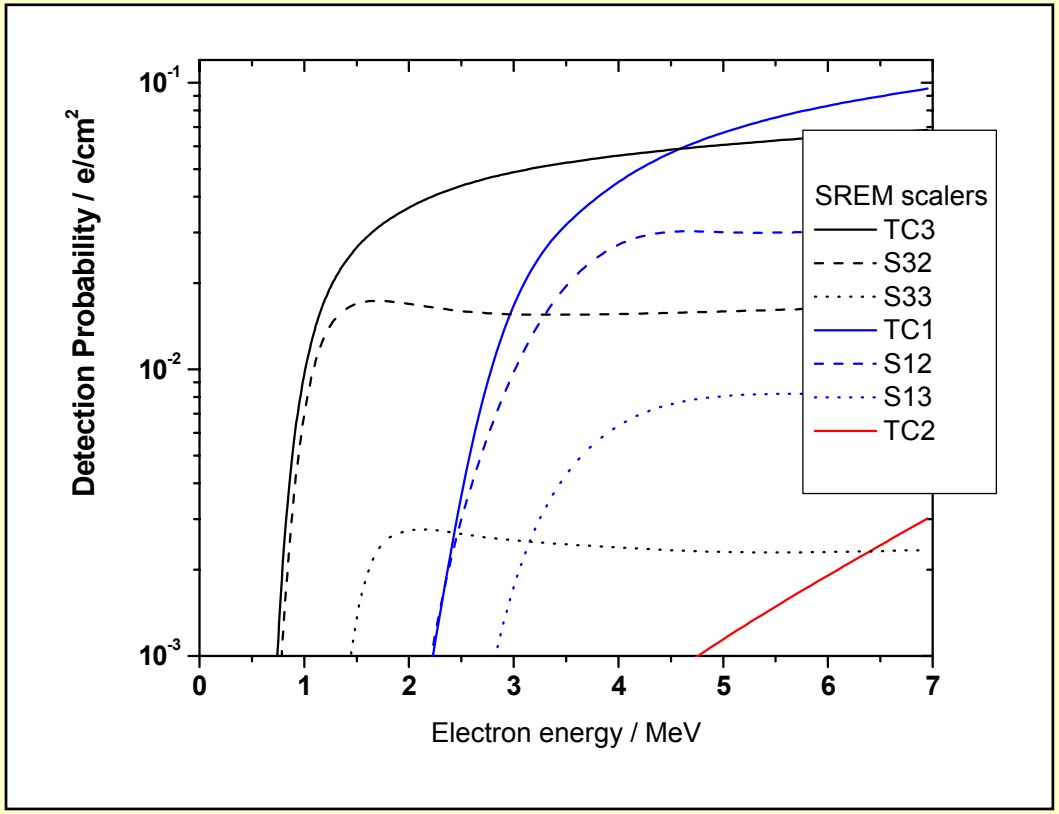




Single channels cover lower energies

Coincidence channels are sensitive to higher energies

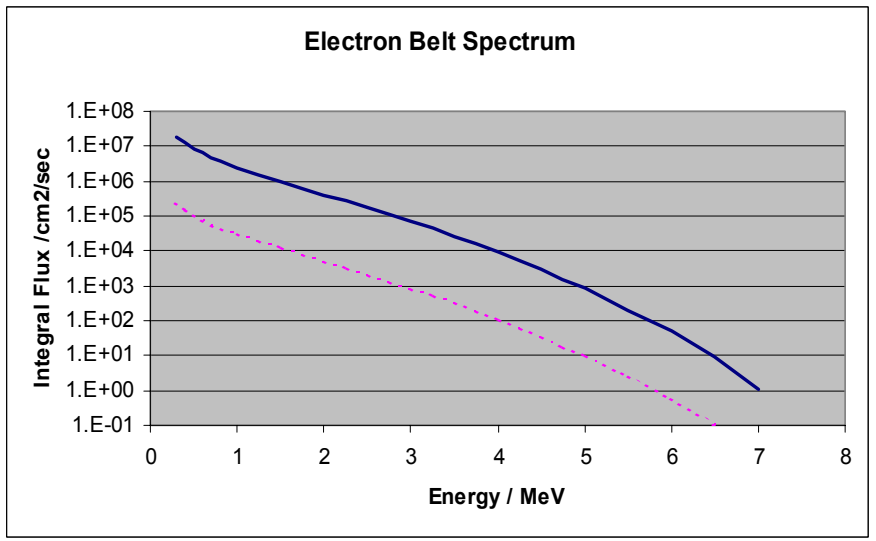
Full Response Matrix - Electrons

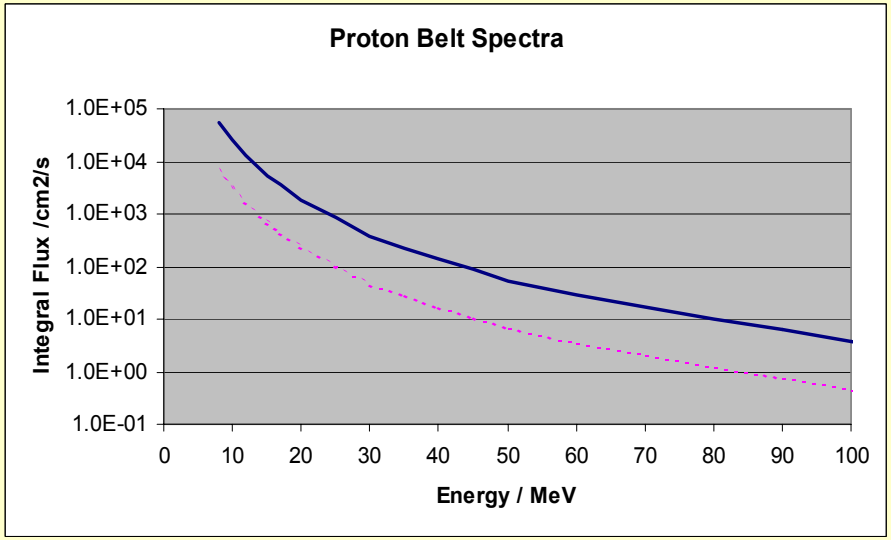


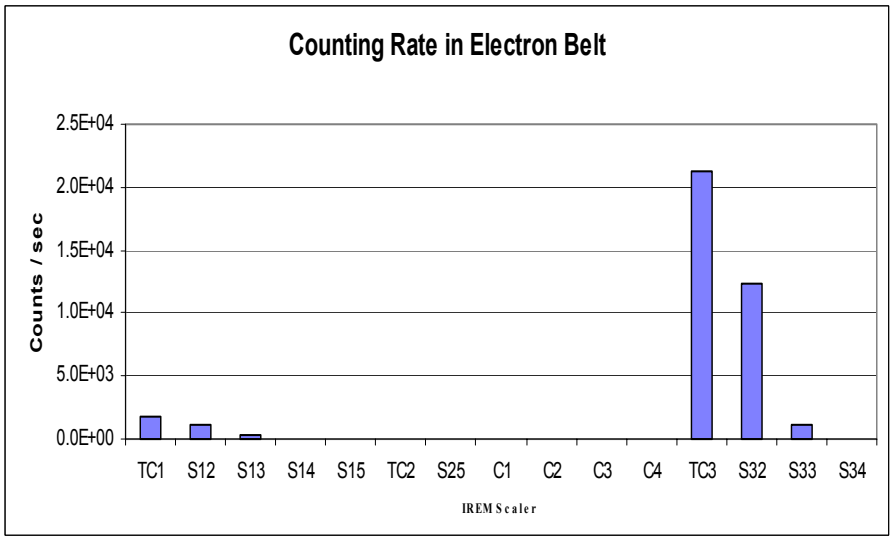
Discriminator allow to select electron energy

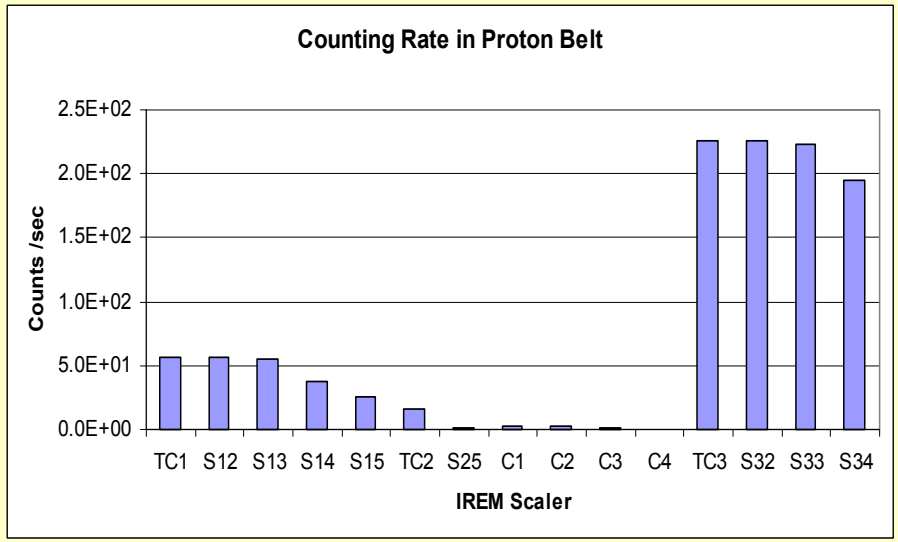
The range extends from 0.6 MeV

Typical Responses

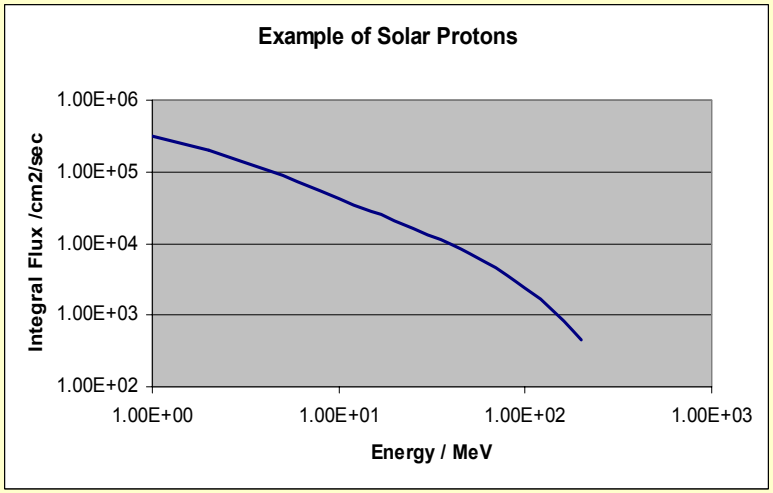


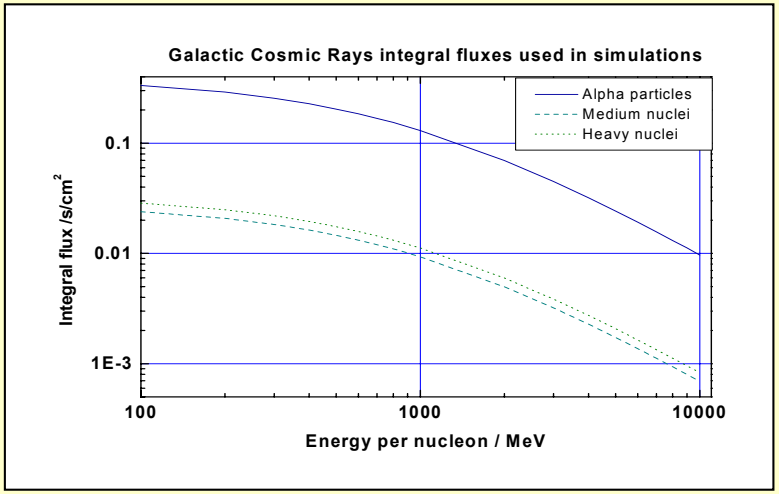


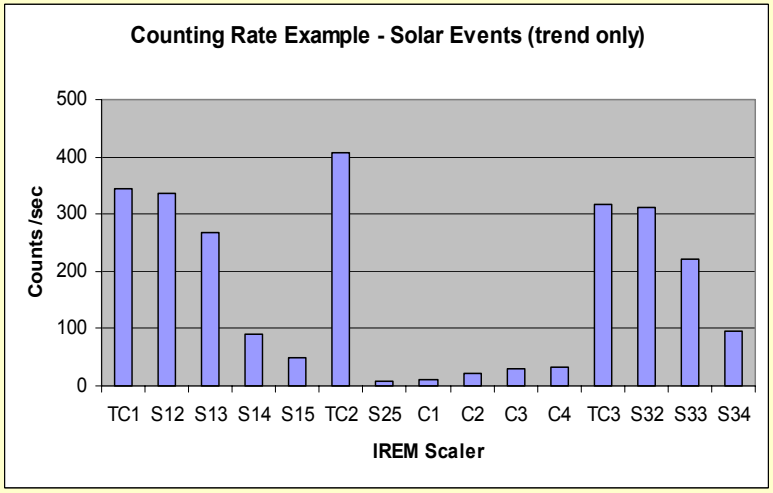


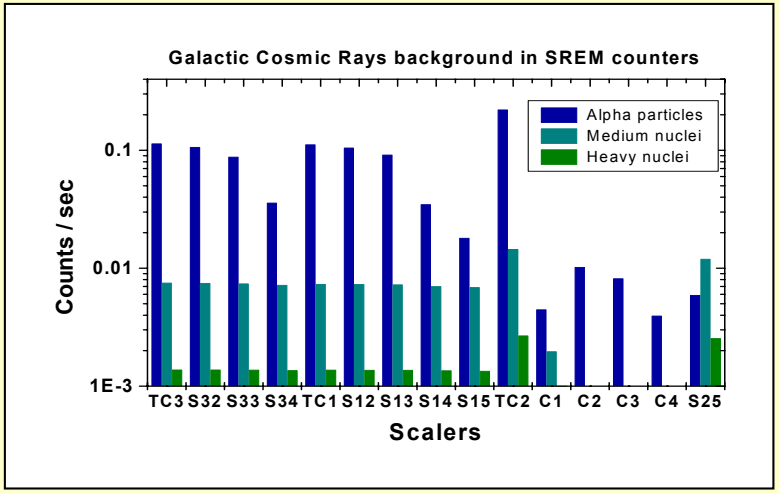


Detection Limits

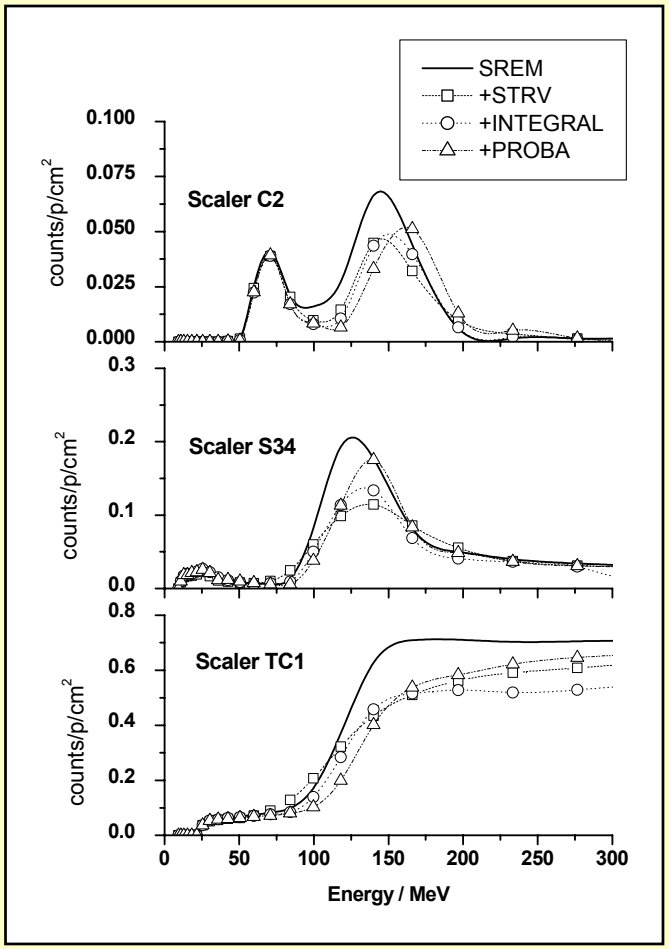




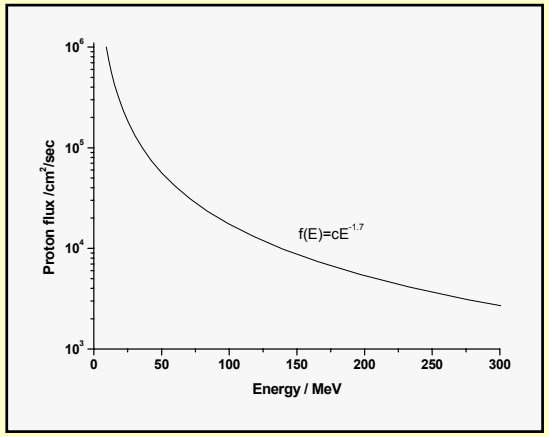


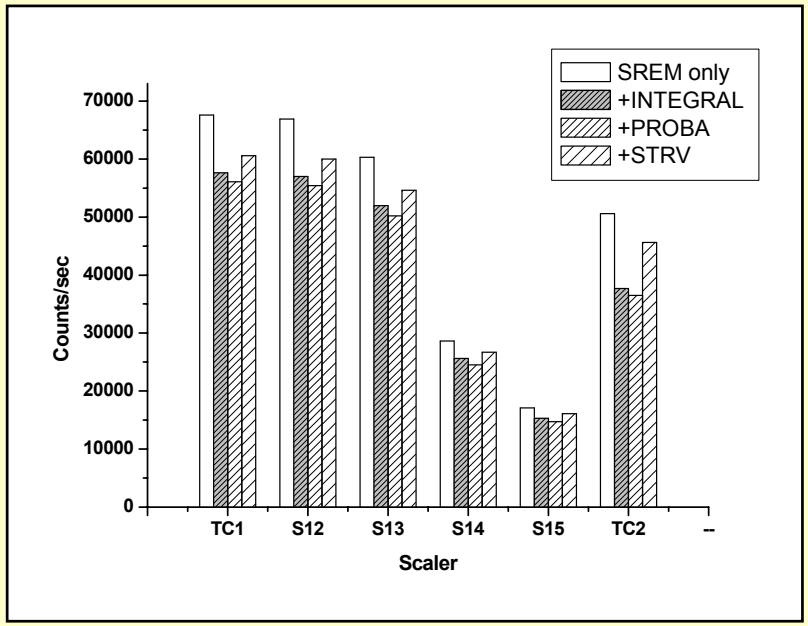


Response with Satellite

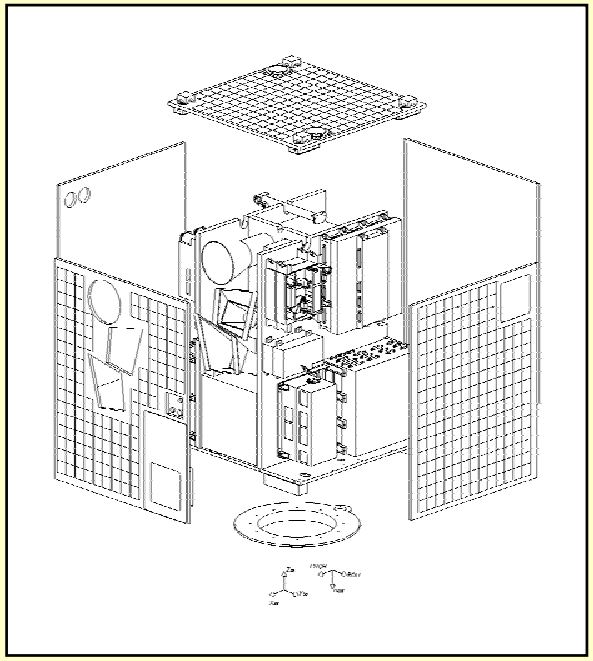


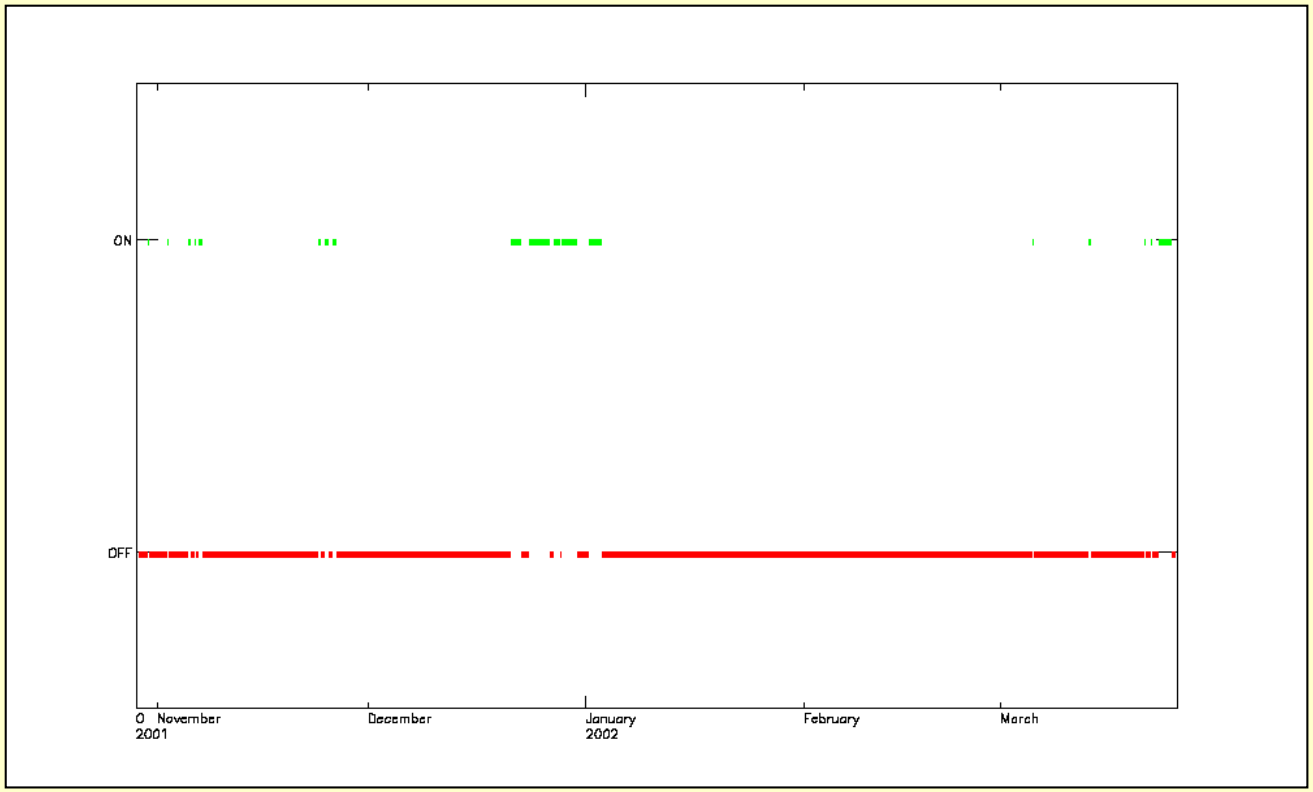
Only high energy proton sensitivity changes but responses for typical space spectra differ little





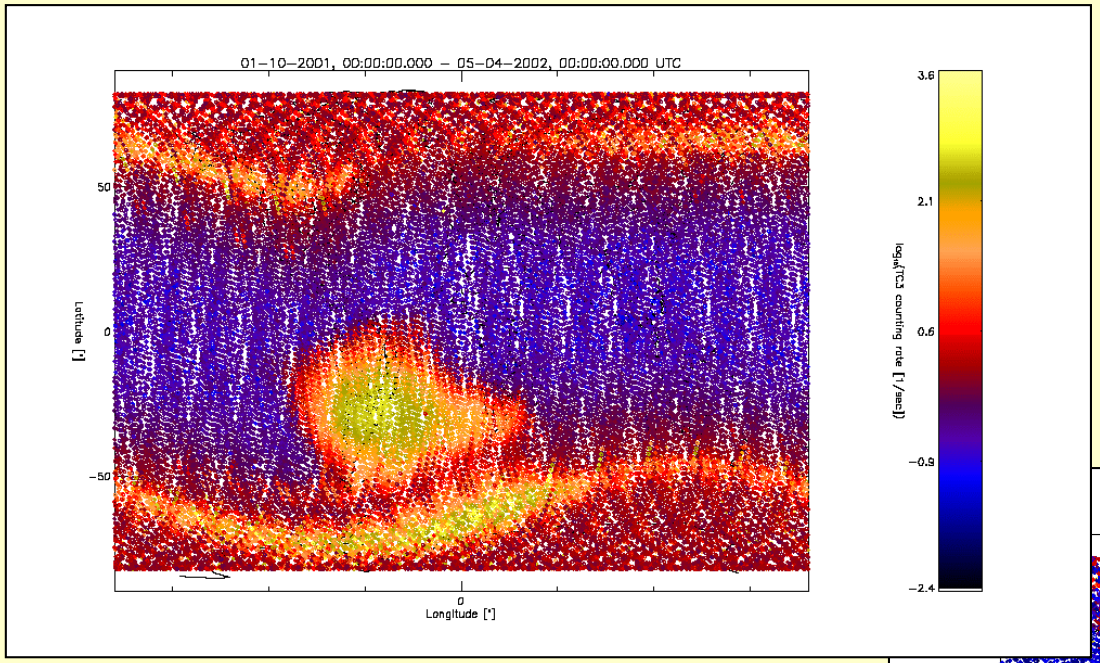
PROBA with SREM Onboard



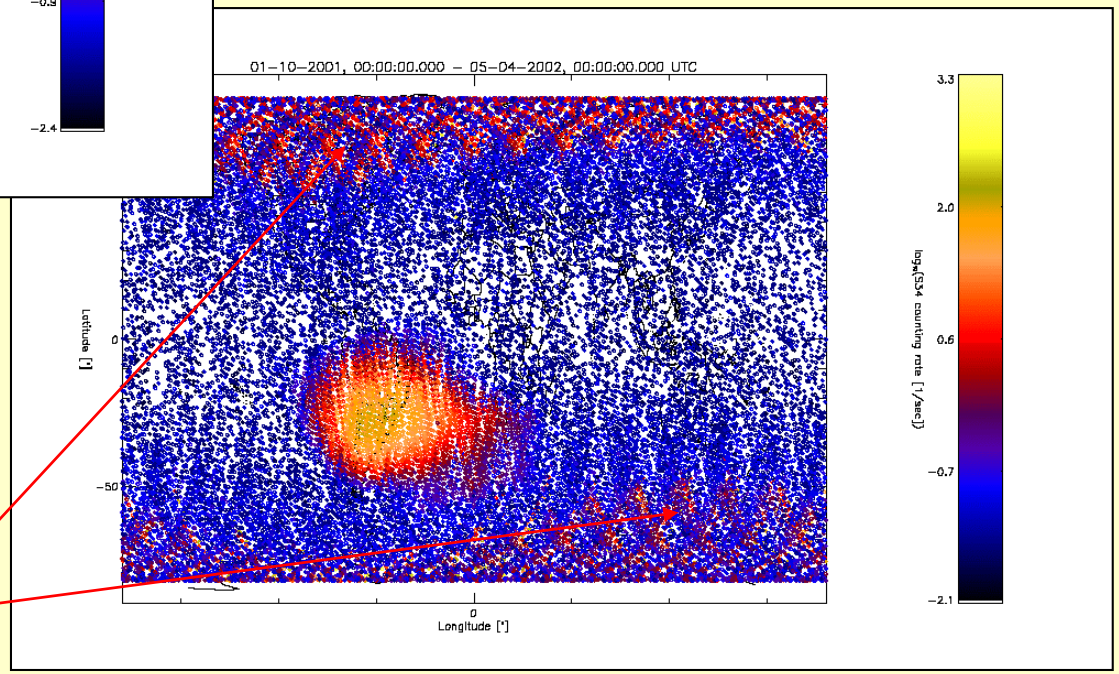


Until now only limited data available (*SREM mostly OFF*)
due to satellite tiny power budget and restricted planning

First Environment Maps



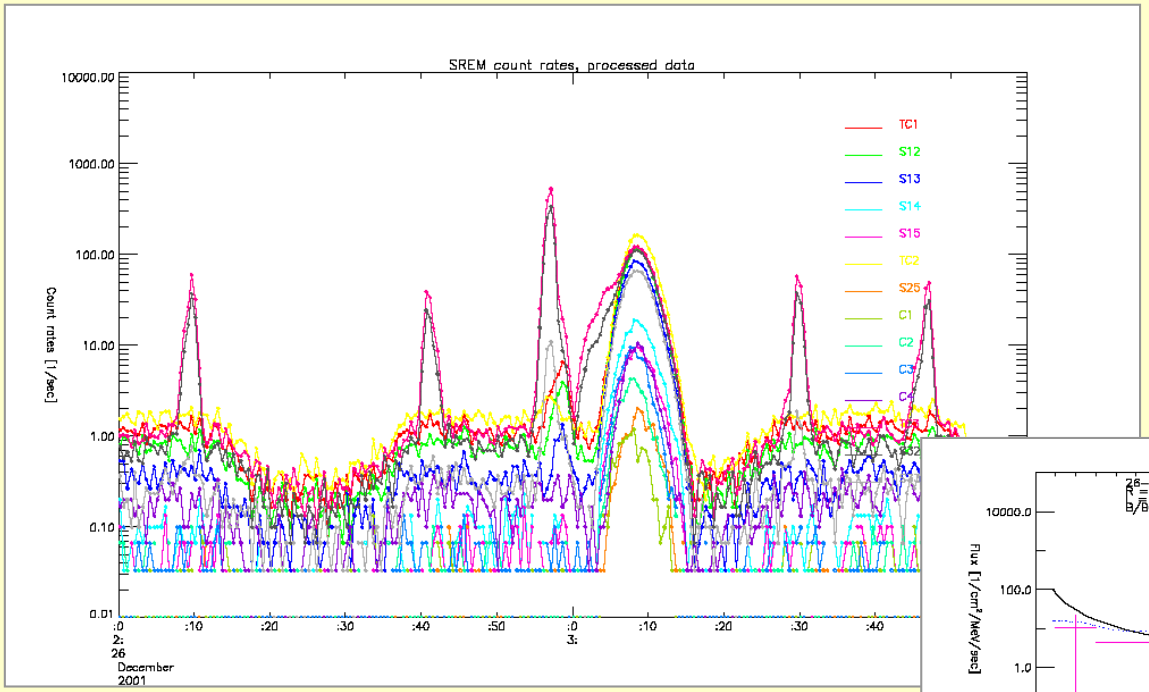
Electrons (E > 0.65 MeV)
and
Protons (E > 9 MeV)



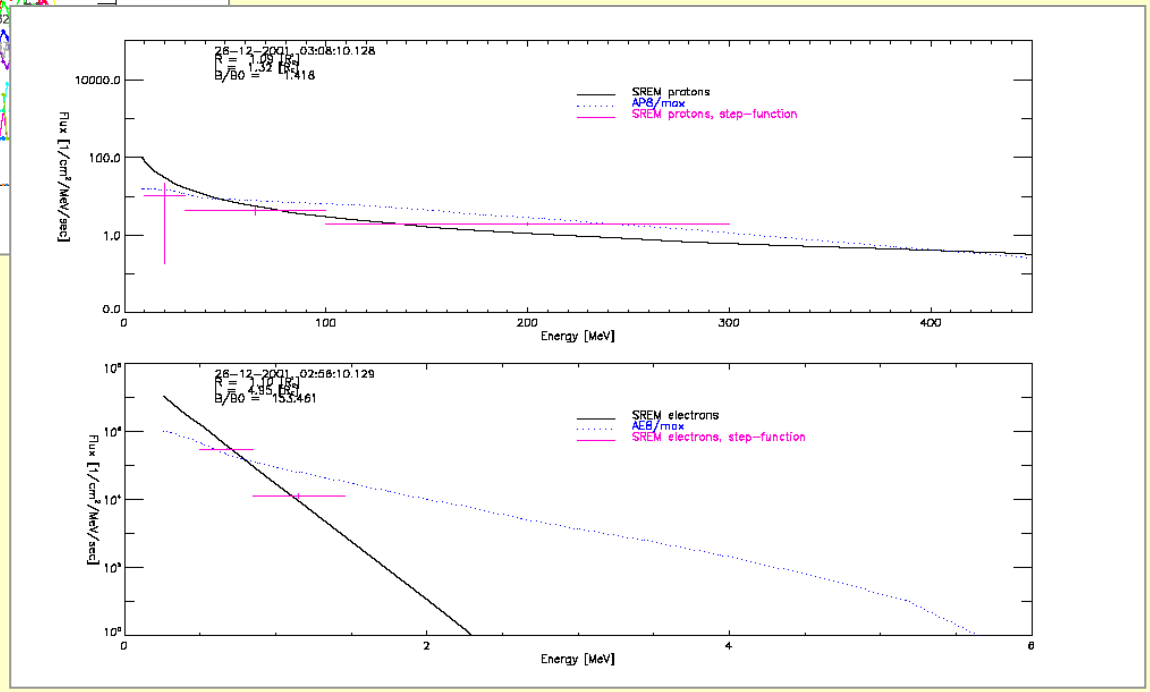
Protons

Solar Protons

First Orbital Data

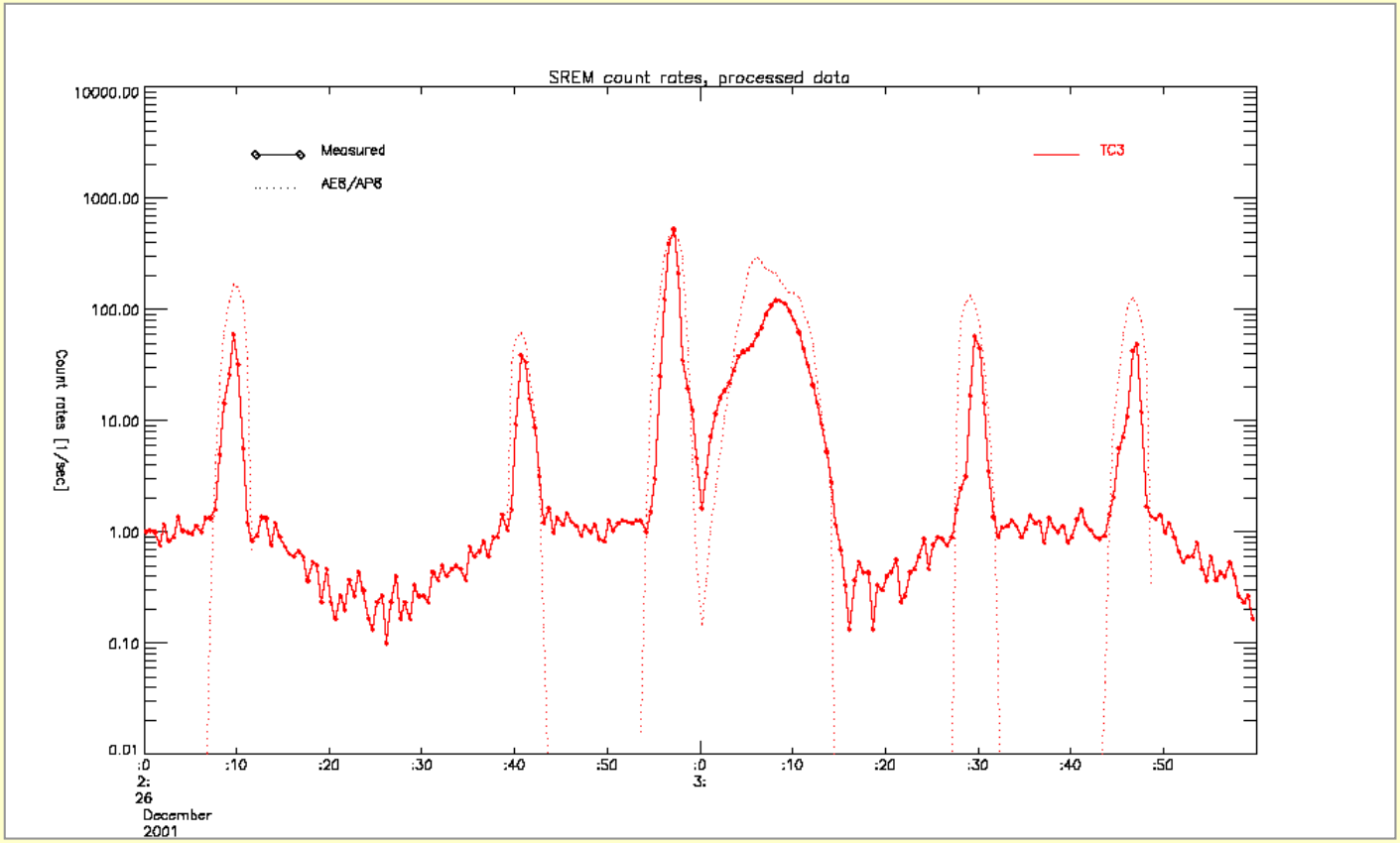


Count rate along the orbit
(all scalers)



PROBA SREM Particle spectra
and AE8/AP8
(Power low 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)