SREM Batch Calibration at PSI

Proton Calibration Test Report for Rosetta SREM

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Calibration Date

The whole proton calibration was done during the weekend 9-11 December 2000, using the PSI Proton Irradiation Facility.

Participants

The following personal was present during performing of the tests:

PSI Test Physicist: W.Hajdas

Test Equipment

1. SREM unit (CS AG)
2. EGSE (CS AG)
3. Connection cables (PSI)
4. ^{60}Co Source, PSI Nr. 238
   Certificate 265883 Amersham Buchler GmbH & Co KG
   Activity 435 kBq with the reference day 1st March 1997.
5. Two Plastic Detectors (1 cm^2 area)
6. Two Ionization Chambers
7. Measurement electronics
8. Data Acquisition System PC
9. Beam Setup and Control PC
10. Beam Optics Control Equipment / wire chamber, readout electronics etc
11. Proton Irradiation Facility equipment: degrader, holder, XY-table etc.

Measurement Configuration

SREM unit was tested in the PSI PKC2 area and the data were transferred on-line to the CS AG EGSE operated from the measurement room - PIF barrack in Nucleon Area.

Experimental setup and arrangement details are shown on the photographs and sketch below.

Firstly the, the SREM was place horizontally on the angular stage on top of the XY table.

For the calibration measurements, the SREM position varied depending on the angles between SREM and incoming proton beam.

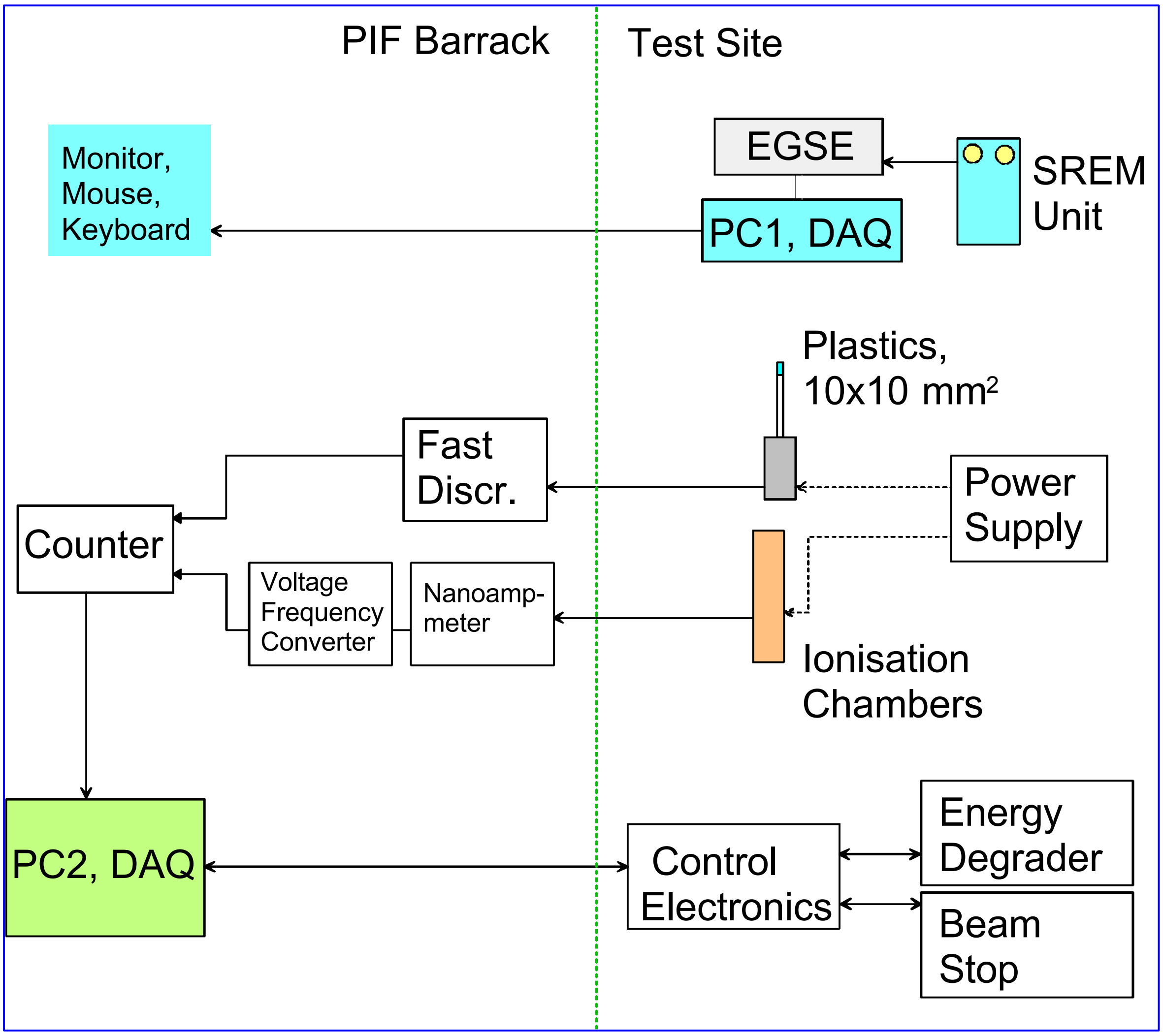


Figure 1: Data acquisition and measurement set-up for SREM proton tests.

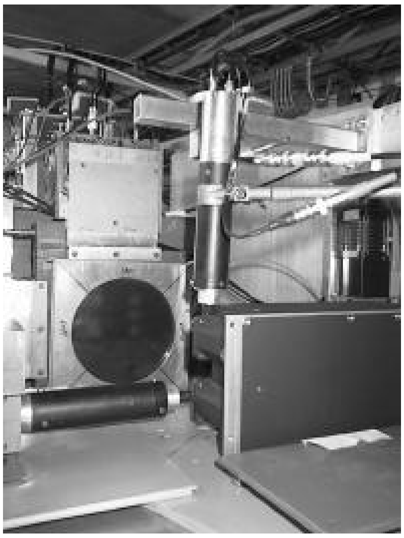


Photo: SREM unit, plastic detectors and ionization chamber during PIF calibrations.

Photo: SREM unit placed on the angular stage during calibration runs at PIF.

Photo: SREM unit placed on the angular stage with two plastic detectors in front.

Calibration Procedure Summary

The proton calibrations steps for the PROBA SREM unit are summarized in the Test Flow Table below.

Test Flow Summary Table

No	Procedure	Remark
1	PIF Preparation	Beam line, test site, electronics, software
2	SREM SFT, ^{60}Co and Cosmics check	Test readiness proof of SREM & EGSE
3	Test arrangement in the PIF test area	Test site check of SREM, EGSE & PIF
4	Setup for E_0=60 MeV proton beam	
5	Energy range measurement	
6	Proton flux normalization measurement	Proton intensity at SREM position
7	SREM Low energy response at 0°	Using degrader, Energies (0-60 MeV)
8	SREM Thresholds determination	Using degrader, Energies (0-60 MeV)
9	Setup for E_0=300 MeV proton beam	
10	Energy range verification	
11	Proton flux normalization measurement	Proton intensity at SREM position
12	SREM Detector area measurement	E_0= 300 MeV, flat beam
13	SREM Dead-time determination	E_0= 300 MeV, adjustable intensity
14	Full response calibration / set of energies and angles	E_0=300 MeV, using degrader; 12 angular positions, 5 energies

Test Flow and Results Step by Step

1. Short Functional Test

As the Rosetta SREM cannot be switched on using autostart mode and requires ON/OFF commands, the CS AG EGSE had to be provided for proton calibrations. The short test and 100 sec long data accumulation run were completed succesfully –see Table below. Higher than usually values in the low energy scalers during the test are due to increased low energy gamma background in the nucleon area.

Table: Short test accumulation file

Group	0
File	0
ST	1152
StartTime	883
StopTime	1882
TC1	995
S12	232
S13	7
S14	0
S15	0
TC2	885
S25	0
C1	0
C2	0
C3	0
C4	0
TC3	801
S32	206
S33	0
S34	0
PL1	0
PL2	1
PL3	0

2. Initial Check and Alignment in Experimental Area

The SREM was setup in the test area facing the beam at the angle of 0 deg. It was mounted on the PIF XY-Table and connected with the EGSE located below the table. The EGSE and SREM were operated from the PIF Measurement Barrack using 40 m long connection cable for monitor, mouse and keyboard extention. The SREM distance from the downstream Ionization Chamber was equal to 27.5 cm. It was the distance where the rotation axis of the turntable stage was located. After the alignment and functional test, the SREM was removed out of the beam for the beam preparation and 60 MeV energy setup.

3. Beam Set-up and Energy Calibration – E_0=60 MeV

Two plastic detectors were mounted at the place of the SREM – one 3 cm above and another one 3 cm below the beam axis. It corresponded to positions of the two SREM detector heads. The beam was setup to 60 MeV, centered and flattened. Relative measurements of the plastic and ionization chamber responses were performed for degrader thickness changed from 0 to 16 mm. Each degrader position corresponds to single proton energy at the plastic/SREM location. From the range-energy curve, the initial proton energy value at the SREM location was verified to be 60.0 MeV.

4. Low Energy Response / Threshold Measurements

The SREM was repositioned on the turntable stage of the XY-table and exposed to protons of varied energies. The proton incoming angle was equal to Θ=0° – front irradiation. The degrader values varied from 0 to 4 mm in steps of 1 mm and from 4 to 16 mm in steps of 0.333 mm of Al. All data with measurement results is attached below for integer degrader values. The measurements were performed using 10 sec long time intervals for each data point. The beam was subsequently switched off and new degrader value was set. The flux normalization data were collected simultaneously – split beam scaler signal and two plastic beam flux scalers were saved for data analysis purposes. As one can see in the Figure below, the response shows distinct features for each degrader and energy value. It is as expected in calculations and it will allow to determine particle spectra in space. One also extracted from this data set the SREM energy thresholds.

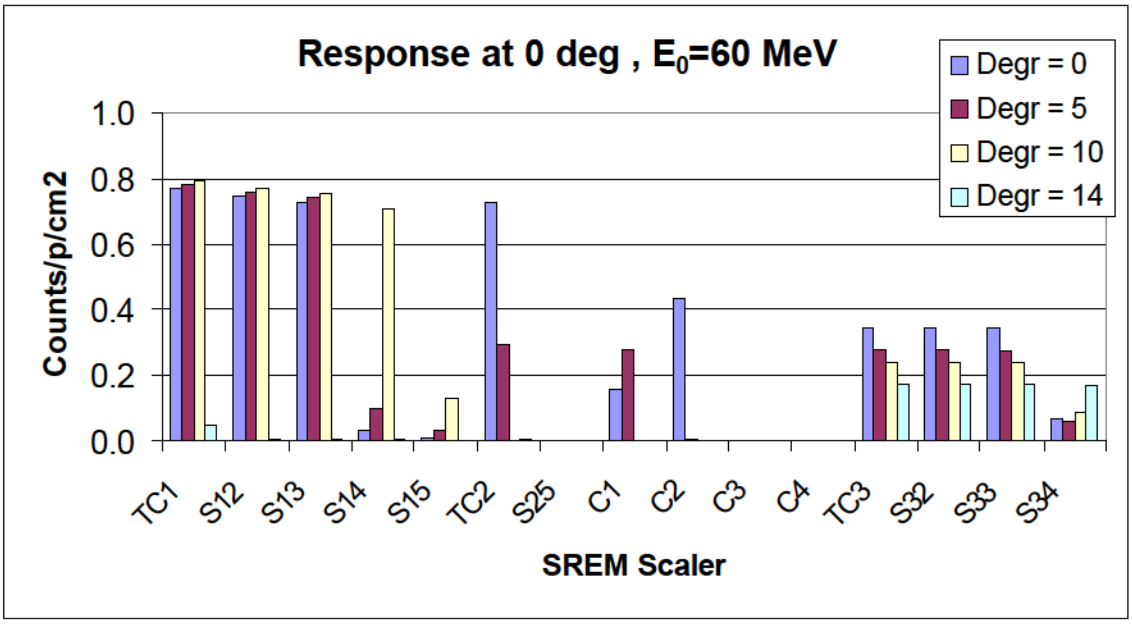


Figure 2. Normalized response of the SREM for 60 MeV protons at Θ=0° and different Al degreder thickness.

Threshold values measured for SREM detectors D1, D2, D3 are:

D1: Threshold (mm Al) = 12.25, Energy threshold = 22.5 MeV
D2: Threshold (mm Al) = 5.72, Energy threshold = 45.7 MeV
D3: Threshold (mm Al) = 14.29, Energy threshold = 9.40 MeV

Above values agree within experimental errors with threshold values specified for the SREM unit. If however a corrections were to be used for the computer model calculations the following modifications will apply:

Volume	Dimension (mm)/(change)	Position (cm)/(old)
D1 APL5	0.266 / (+0.166)	9.3383 / (9.3300)
D2 TAB1	1.131 / (+0.900)	6.9950 / (6.9950)
D3 AP35	0.085 / (-0.090)	9.3330 / (9.3375)

The 0 deg response data together with normalized flux measurement will be used to calculate theoretical response for further verification of the SREM characteristics and obtaining fine tuned final response function. An example of the low energy data used for response measurement and threshold determination is shown in the Figure below.

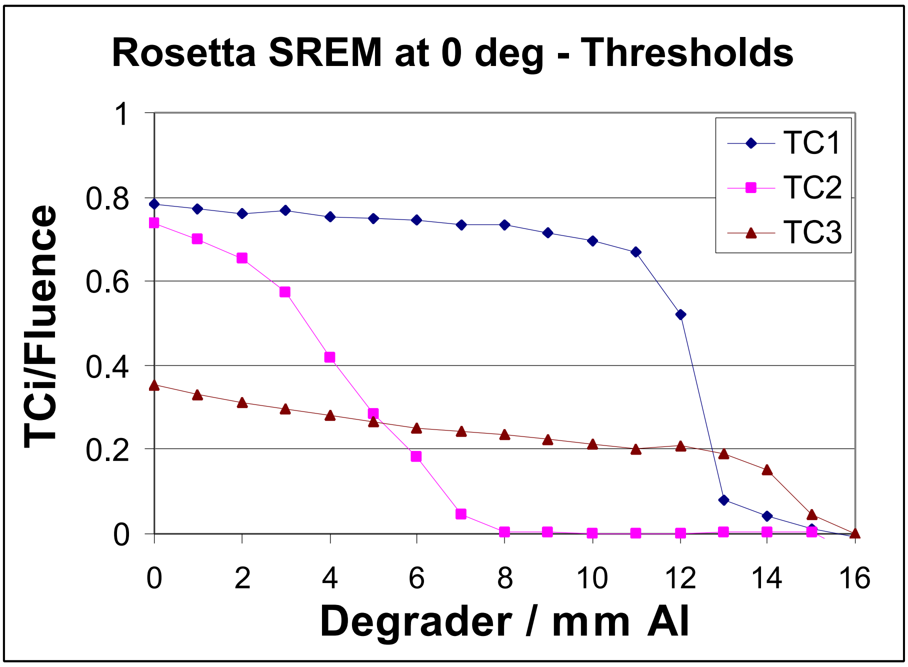


Figure 3: Response curves for SREM scalers TC1, TC2 and TC3 as function of the degrader (proton energy) used to determine low energy thresholds (raw data).

Table: Raw data used for low energy threshold determination.

Degrader [mm]	Fluence [p/cm^2]	TC1 [counts]	TC2 [counts]	TC3 [counts]
0	76971	60189	56769	27102
1	73964	56976	51605	24371
2	72160	54653	47219	22377
3	65809	50470	37809	19510
4	63113	47319	26403	17797
5	56080	41862	15996	14888
6	55615	41342	10264	13999
7	51577	37754	2499	12543
8	46379	33907	277	10911
9	45619	32554	228	10327
10	40414	28019	140	8552
11	35939	23917	166	7320
12	29527	15292	154	6155
13	25006	2108	190	4829
14	19863	947	227	3035
15	7635	201	162	416
16	498	113	134	124
background	356	114	141	96

5. Beam Set-up and Energy Calibration – E_0=300 MeV

Two plastic detectors were mounted at the place of the SREM – one 3 cm above and another one 3 cm below the beam axis. It corresponded to positions of the two SREM detector heads. The beam was setup to 300 MeV, centered and flattened. Relative measurements of the plastic and ionization chamber responses were performed for degrader thickness changed from 220 to 247 mm – range measurement and for degrader values equal to 0, 167, 205, 222, 231 mm. Each of the latest degrader position corresponds to single proton energy at the plastic/SREM location – 300, 150, 100, 71, 50.8 MeV. From the range-energy curve, the initial proton energy value at the SREM location was confirmed to be equal to 300 MeV.

6. Detector Area Determination

Area measurement was performed for the SREM unit positioned at 0 deg. Two plastic detectors (1 cm^2 active area each) were placed directly in front of the SREM detector heads. In enabled protons entering the SREM detectors to come through plastic detector at first. The beam intensity was set below 10'000 p/cm^2/sec to keep dead time corrections small and beam profiles were flat. The measurement was done using 300 MeV protons due to their high range and low divergence. Results were collected using 10 sec long time intervals for each data point. The beam was subsequently switched off and the measurement was repeated. The flux normalization data were collected simultaneously – two plastic detectors scalers were saved for data analysis purposes. The detector areas have deadtime corrections taken into account. The results are presented below.

<u>Sensitive area values measured for SREM detectors D1, D2, D3 are:</u>

D1 area = 0.723 ± 0.006 cm^2
D2 area = 1.031 ± 0.006 cm^2
D3 area = 0.736 ± 0.006 cm^2

Table: Area measurement experimental data.

nr	Fluence (D1/D2)	Fluence (D3)	D1/TC1	D2/TC2	D3/TC3	PL1	PL2	PL3	beam
1	2181950	2149446	1548162	2183937	1555442	1868	2747	1878	ON
2	2137580	2111317	1519390	2147343	1534454	1745	2682	1839	ON
3	12607	9698	9263	13191	13009	0	0	0	OFF

7. Dead Time Measurement

Dead time measurement was done using the same set-up as for detector area determination. The proton flux however was varied up to $5 \bullet 10^5$ p/cm^2/sec. The data is included in the table below. Measurements were done using 10 sec long time intervals.

The beam was subsequently switched off and new flux value was set. The flux normalization data were collected simultaneously – two plastic detectors and main beam current scalers were saved for data analysis purposes. For particle fluxes below $1.\bullet 10^5$ $p/cm^2/sec$ the dead time pulser correction is linear and does not exceed 20% as it is defined in detector specifications – see Figures below. For higher fluxes, the correction becomes non-linear and one should use TCi scaler values and a non-linear fit results from the calibration data.

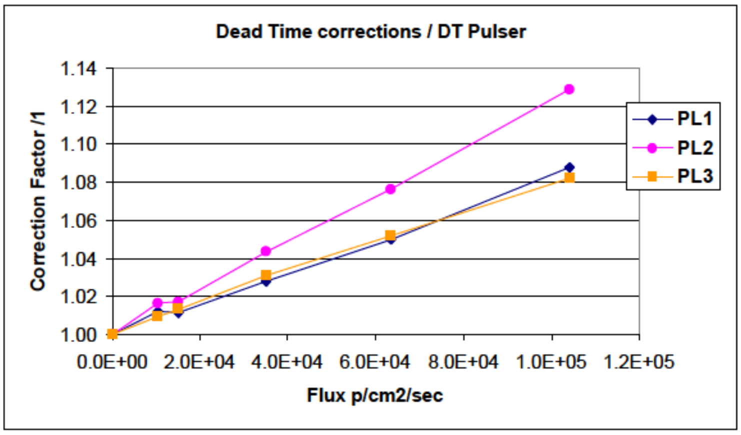


Figure 4. Deadtime corection factors from PLi scalers.

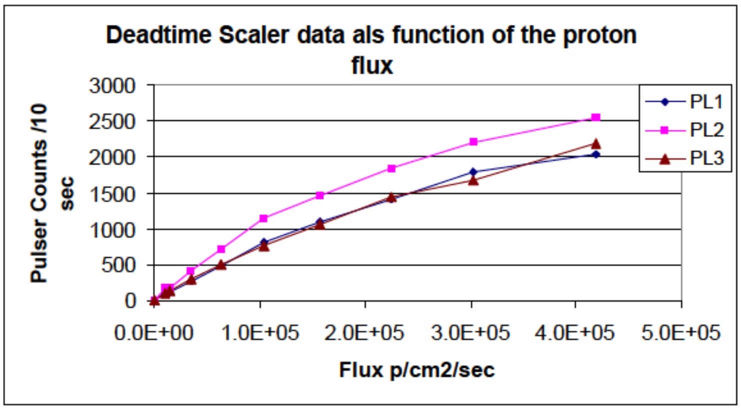


Figure 5. Nonlinear dependence of the deadtime scalers for higher particle fluxes.

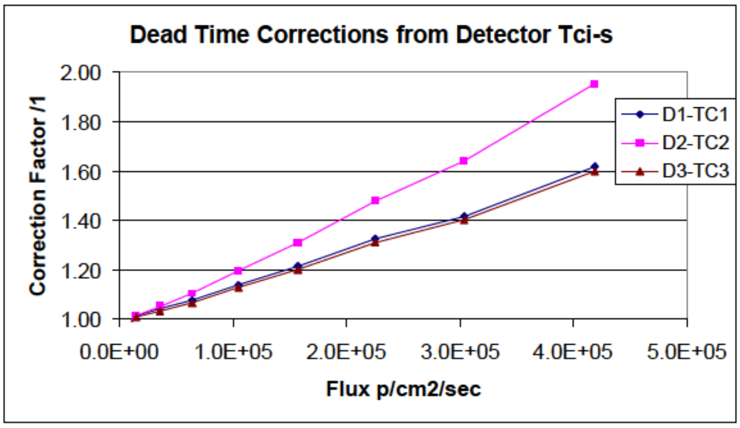


Figure 6. Deadtime corrections als function of the proton flux taken from TCi scalers.

Table: Deadtime measurement data.

Nr	PL10.2	PL10.1	Flux	TC1	TC2	TC3	PL1	PL2	PL3
0	1261	970	0	926	1319	1301	0	0	0
2	102926	102616	1.03E+04	74701	106848	76146	118	159	94
1	147407	153529	1.50E+04	105152	149928	111739	114	169	132
3	359352	342326	3.51E+04	249440	351524	243905	271	418	297
4	655443	615555	6.35E+04	440767	610798	424276	476	711	489
5	1078473	1006681	1.04E+05	685841	928870	656166	805	1139	757
6	1631639	1511411	1.57E+05	972472	1283505	924773	1088	1456	1057
7	2336114	2157571	2.25E+05	1274644	1630140	1211691	1404	1832	1450
8	3157107	2902456	3.03E+05	1610823	1981548	1525268	1792	2200	1672
9	4363437	4004942	4.18E+05	1952099	2302147	1845999	2042	2558	2184

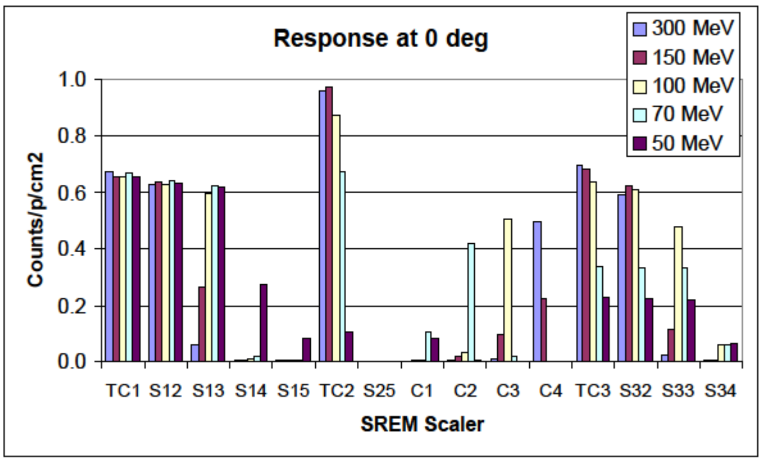
8. Full Response Calibration – Set of Energies and Angles

For full response measurement, the plastic detectors were removed. The SREM was placed on the axis of the turntable stage on the XY-table. The beam flux was monitored using two ionization chambers previously normalized to the plastic detectors. The following values of energies and proton incoming angles were set-up for response measurements:

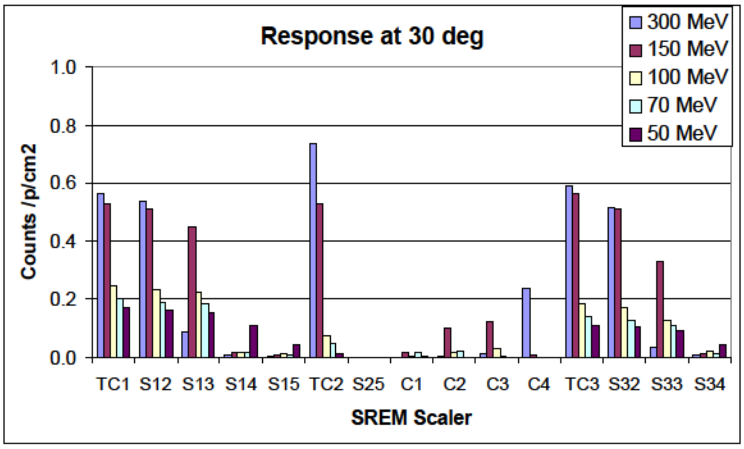
Table: Angle and energy settings for angular distribution response measurement.

Nr	Θ	φ	Energies
[1]	[deg]	[deg]	[MeV]
1	0	0	50.8, 71., 100, 150., 300.
2	30	0	50.8, 71., 100, 150., 300.
3	60	0	50.8, 71., 100, 150., 300.
4	90	0	50.8, 71., 100, 150., 300.
5	45	180	50.8, 71., 100, 150., 300.
6	180	0	50.8, 71., 100, 150., 300.
7	135	180	50.8, 71., 100, 150., 300.
8	135	0	50.8, 71., 100, 150., 300.
9	30	90	50.8, 71., 100, 150., 300.
10	60	90	50.8, 71., 100, 150., 300.
11	45	270	50.8, 71., 100, 150., 300.
12	90	270	50.8, 71., 100, 150., 300.

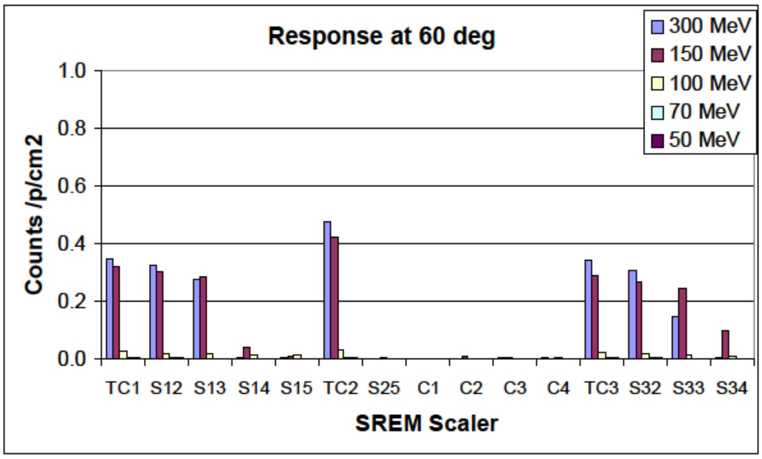
Measurements were performed using 10 sec long time intervals for each data point. The beam was subsequently switched off and new energy value was set. The flux normalization data were collected simultaneously – two calibrated ionization chambers and main beam current scalers were saved for data analysis purposes. The data is included in the appendix. Figures below present a SREM response at different Θ (polar) angles. Note how sensitivity depends on the front collimator opening.



Figures 7: SREM scaler response for different energies and Θ = 0°.

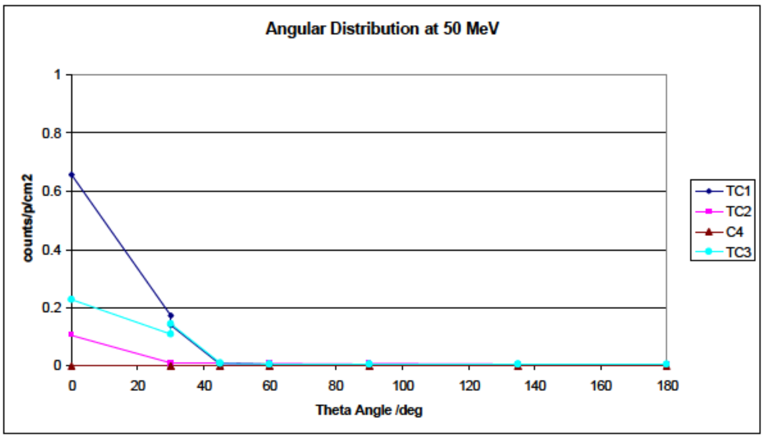


Figures 8: SREM scaler response for different energies and Θ = 30°.

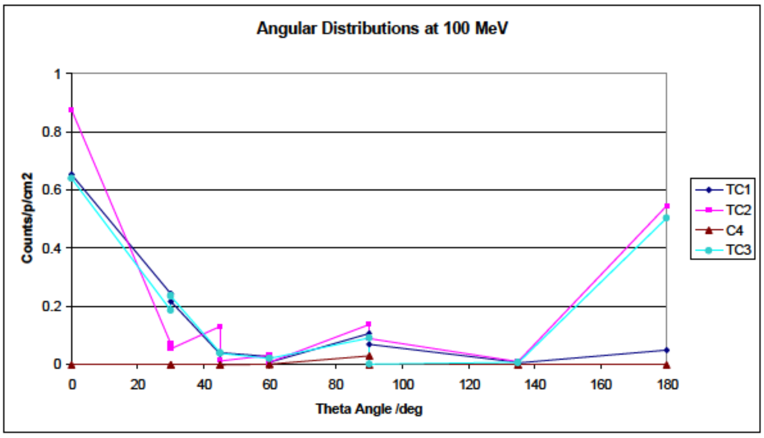


Figures 9: SREM scaler response for different energies and Θ = 60°.

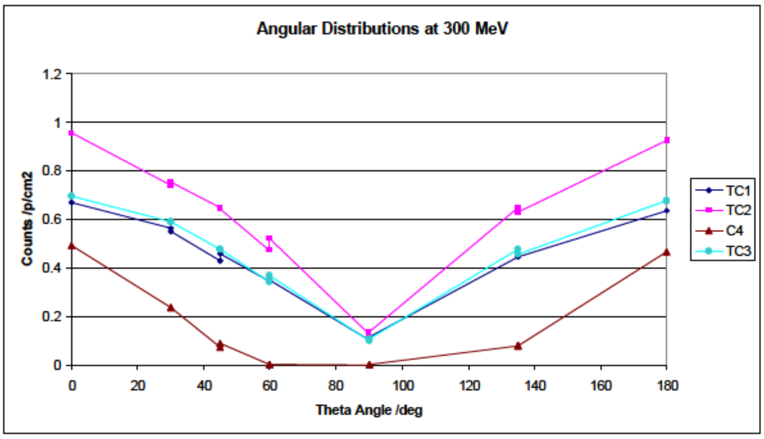
The figures below show angular distribution over the whole range of polar angle Θ presented for different energies and azimuth ϕ angles. As one can see the side shielding protects SREM detectors very effectively againts low energy protons. For higher energies the angular distribution as very symmetric. Both features agrees with theoretical predictions.



Figures 10: Angular response of TC1, TC2, TC3 and C4 scalers at 50 MeV.



Figures 11: Angular response of TC1, TC2, TC3 and C4 scalers at 100 MeV.



Figures 12: Angular response of TC1, TC2, TC3 and C4 scalers at 300 MeV.

Two figures below demonstrate the SREM response dependence for azimuthal angles ϕ=0° and 90° at the same polar angle Θ=60°. Data is presented for 300 and 100 MeV.

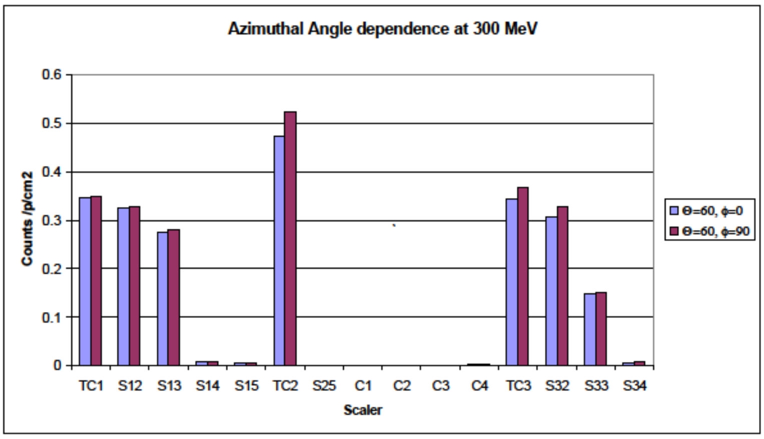


Figure 13. SREM response in function of the azimuthal angle ϕ at 300 MeV (Θ=60°).

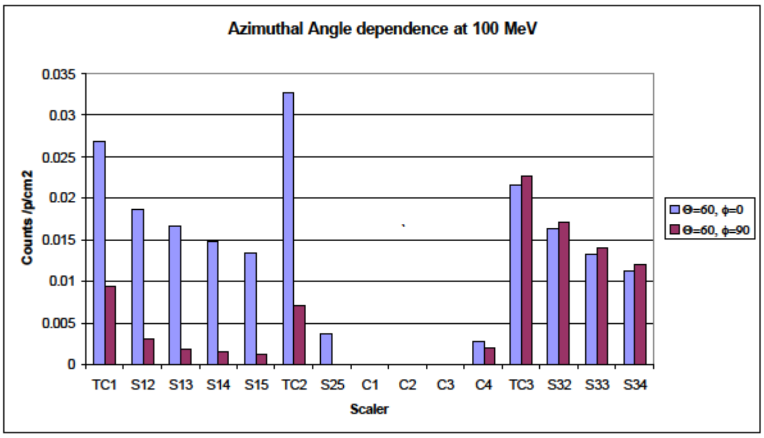


Figure 14. SREM response in function of the azimuthal angle ϕ at 100 MeV (Θ=60°).

The response at 300 is almost identical as expected for strongly penetrating high energy protons. In contrary, for 100 MeV protons the shielding stops most of them and different irradiation geometry makes the responses dissimilar.

9. SREM removal and activation control

After measurements SREM was deposited safely for further control activation control. Ca. 24 hours after the test no activation was present any more. The total dose deposited in the SREM during calibration is estimated to be much less than 50 rad.

10. Response function verification and calculation

First analysis of the SREM response results does not show any major discrepances. Fine tuning of the response may be performed due to area and threshold corrections. If required, the measured data are to be compared with Monte Carlo simulations run for the corrected values. It will allow to replace a standard response function calculated for arbitrary (however close to typical) values of SREM detector and threshold parameters.