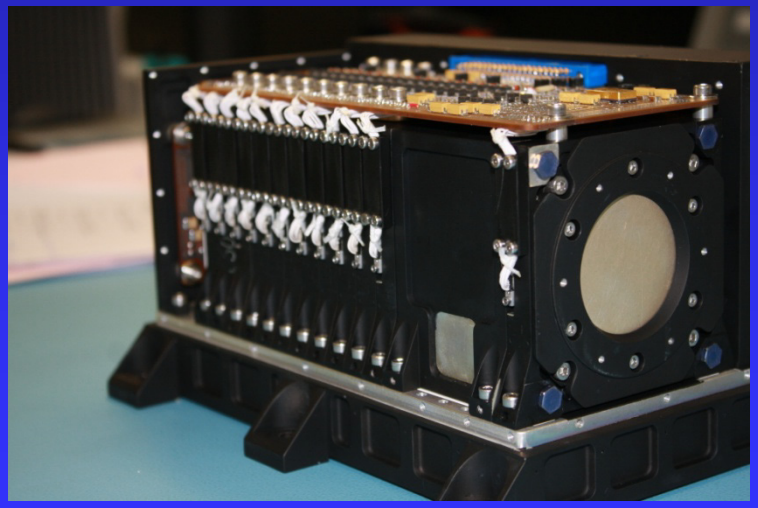
The Energetic Particle Telescope (EPT) functional validation

M. Cyamukungu, S. Benck, J. Cabrera, Gh. Grégoire, S. Bonnewijn, J. Maes, E. Van Ransbeeck, G. Creve, J. De Saedeleer, B. Desoete, C. Semaille, E. Valtonen, R. Punkkinen, P. Nieminen, A. Menicucci, A. Zadeh, G. Santin, W. Hajdas and I. Britvitch

Outline:

- EPT setup
- Energy channels
- Calibration
- Function validation
- Conclusion



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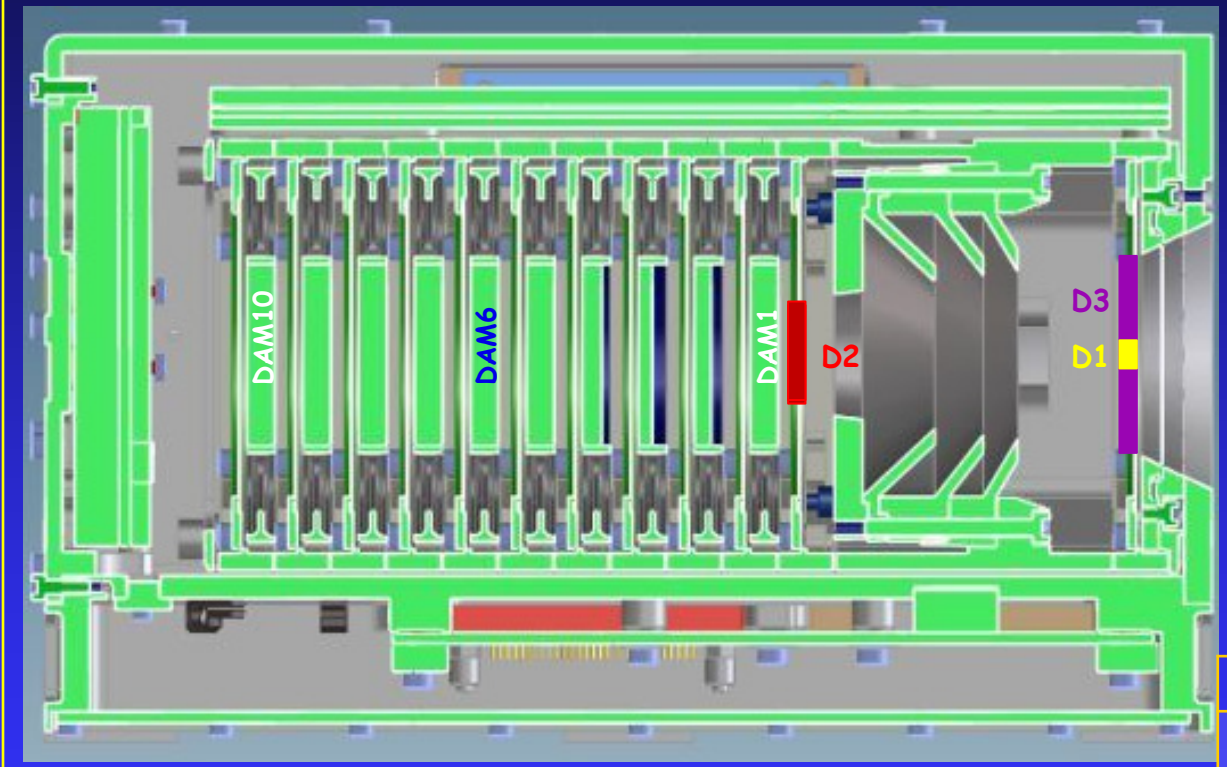
EPT functional validation

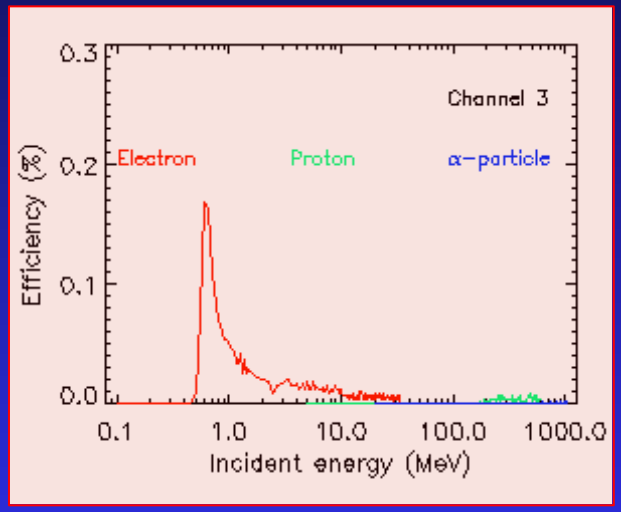


Particles are recorded by the EPT if and only if they hit D1 and D2 or D3 and D2. D1 has priority over D3.

Particle	Energy
Electrons:	200 keV – 10 MeV
Protons:	4 MeV – 300 MeV
a-particles:	16 MeV – 1 GeV
Heavier ions:	All collected in 19 chan.
Resolution:	Typically 10% in energy

The EPT mechanical assembly and mainly digital electronics lead to straightforward energy range and channel definition (limited post-processing of data).

Electrons:



« Reconfigured » Electron channels in Low Energy Section (LES) being defined based on an Artificial Neural Network approach.
The design of the ANN is made easier due to non-contamination and sharp energy thresholds for « primary » channels.

Electrons are efficiently detected in 19 specific channels (1 – 19):

Particle	Channel																			
	Low Energy Section (LES)									*High Energy Section (HES)*										
Electron	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Proton	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
He	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
Heavy ion	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76

Protons:

Energy (MeV)	ch29	ch30	ch31	ch32	ch33	ch34	ch35	ch36	ch37	ch38
20	98.7546	0.006	0	0	0	0	0	0	0	0
28.6	79.9614	19.1928	0.0002	0	0	0	0	0	0	0
45	1.1698	98.15	0.0248	0.0006	0	0	0	0	0	0
60.6		58.0438	40.5578	0.001	0	0	0	0	0	0
76	0.0894	3.097	95.6618	0.0302	0	0	0	0	0	0
91.4			52.6542	43.318	0.0014	0	0	0	0	0
105	0.0044	2.5308	4.258	91.848	0.0264	2E-04	0	0	0	0
140	0.0006	2.1784	3.4214	5.8226	86.5872	0.042	0	0	0	0
154.4					44.5668	41.73	0	0	0	0
167	0.0008	1.6348	2.6264	4.5142	5.4614	80.92	0.03	2E-04	0	0
180.4						37.17	44	0.002	0	0
190	0.0002	0.9884	1.6288	3.1806	3.4454	5.742	75.9	0.025	2E-04	0
202.4							58.3	18.33	0.002	0
213	0	0.4762	0.8284	1.769	1.9296	3.714	5.8	70.28	0.025	0
225	0	0.3232	0.5428	1.274	1.3538	2.941	4.74	48.54	22.63	0.0032
229.8									60.25	0.0084

Protons are efficiently detected in 19 specific channels (20 – 38):

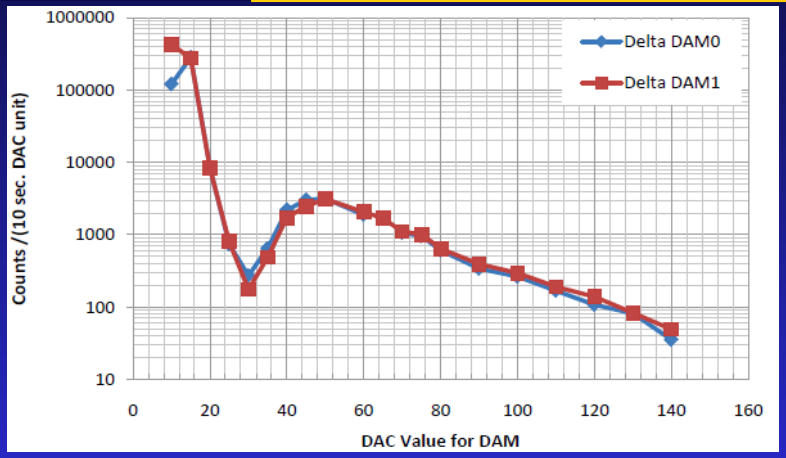
Proton channels in High Energy Section

29	11.8 – 29
30	29 – 61
31	61 – 91
32	91 – 125
33	125 – 154
34	154 – 180
35	179 – 202
36	202 – 225
37	225 – 245
38	>245

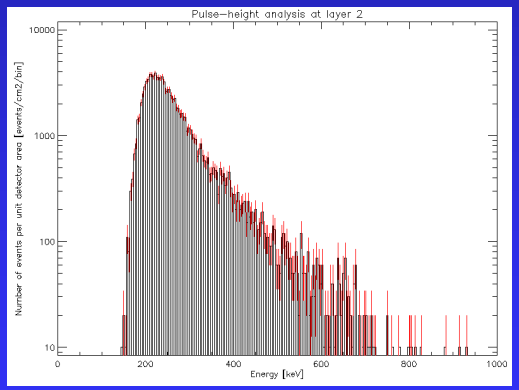
Particle	Channel																		
	Low Energy Section (LES)									*High Energy Section (HES)*									
Electron	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Proton	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
He	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
Heavy ion	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76

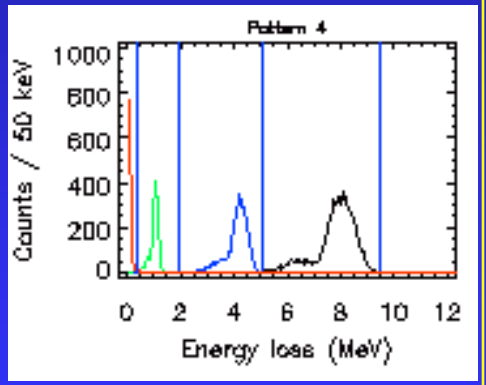
Calibration of sensors and energy channels:

- Differential method used to calibrate (EQM) DAM using 230 MeV protons ===➔ 11 DAC units/50 keV;



- Energy-ADC value calibration of S1, S2 and S3 sensors carried-out using 230 MeV protons ===➔ 10 ADC units/100 keV;





- In-flight calibration of S1, S2 and S3 sensors possible using the maximum energy deposited by 10 – 12 MeV protons;

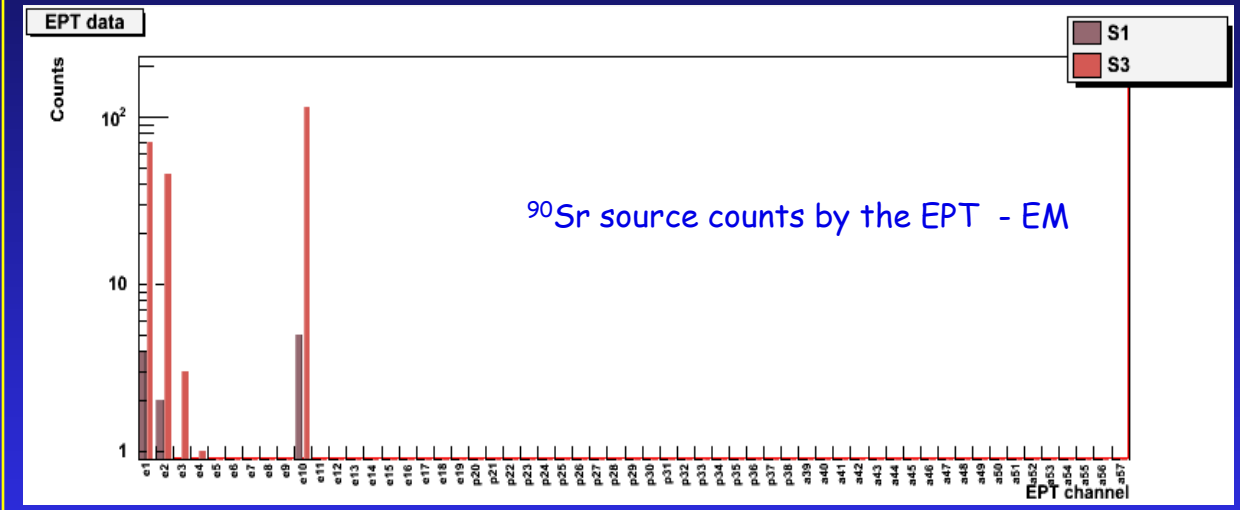
- Channel calibration based on intensive GEANT4 simulations (intrisic detection efficiency calculations) and in-beam validations.

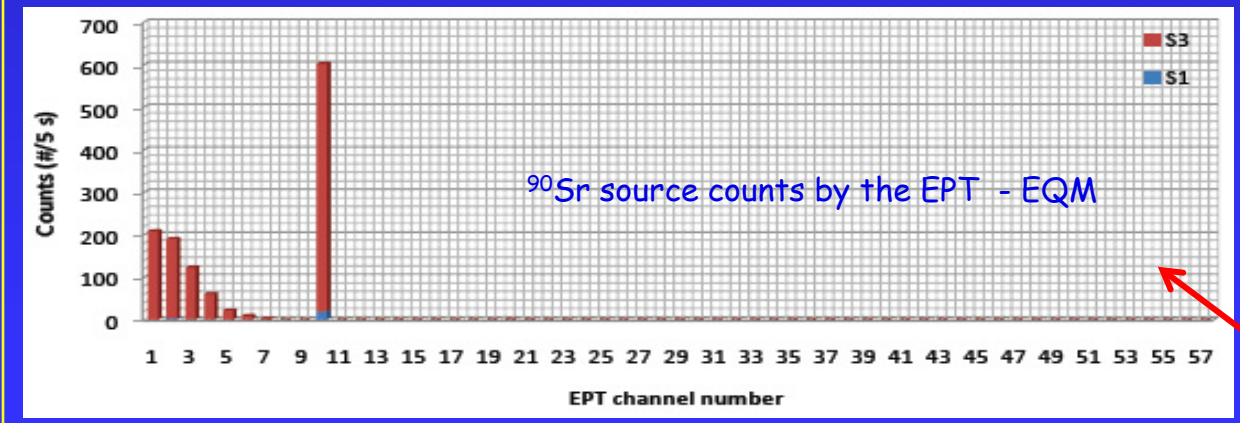
EPT functional validation

EPT functionalities validated based on steadily improved procedure applied to the breadboard, the EM and the EQM:

- Validation of the particle classification algorithm;
- Validation of the design of the EPT channels ;
- Measurement of the maximum count rate of the S3 detector to establish the saturation conditions;
- Validation of the FOV angle definition;
- Etc...

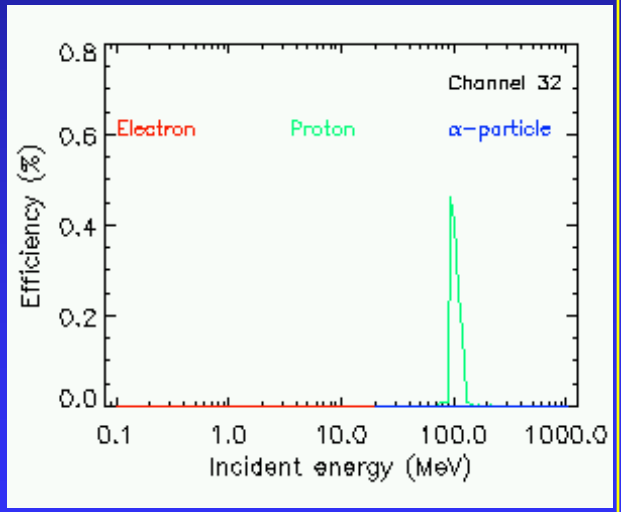
Particle identification - Contamination issue:





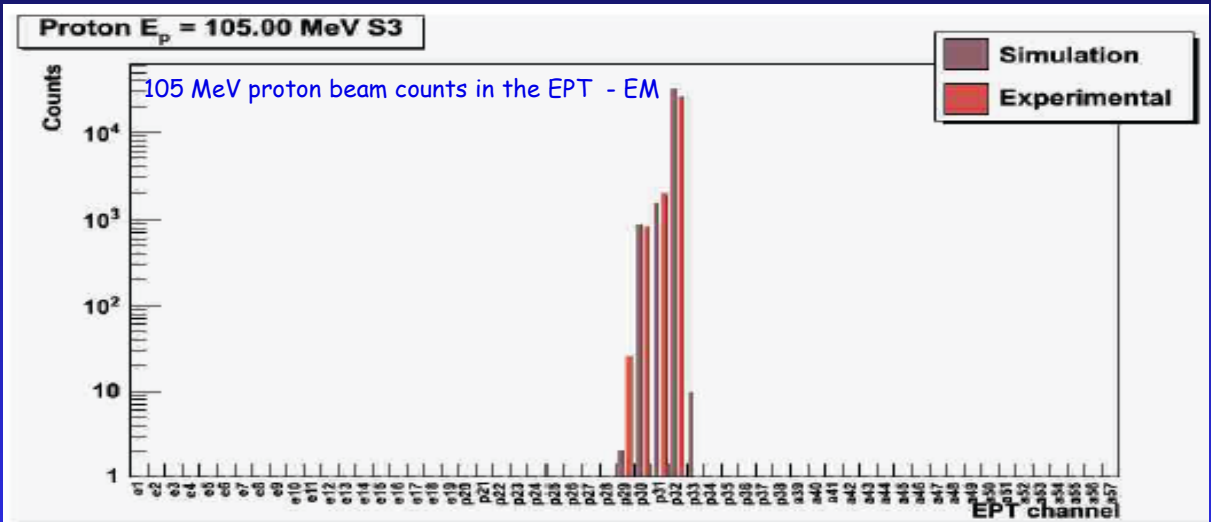
No contamination of proton nor α-particle channels by electrons.

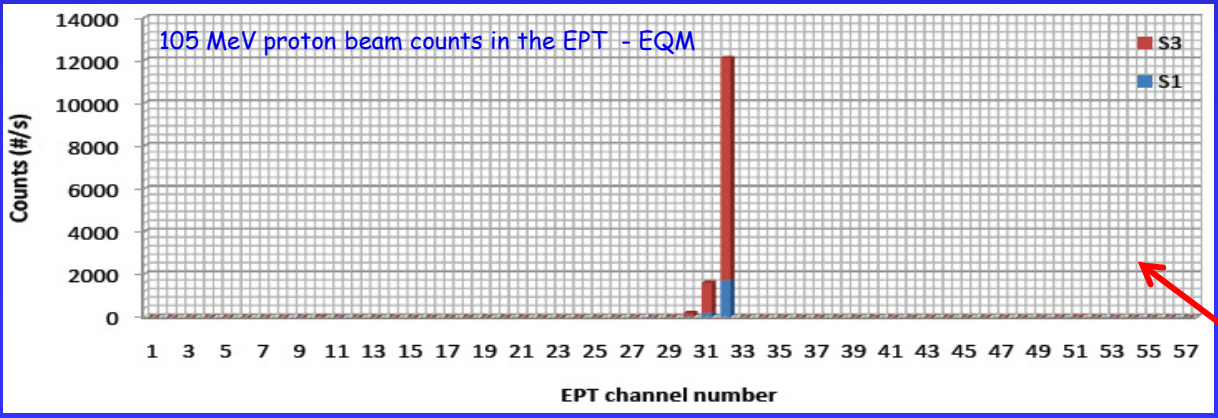
Efficiency evaluation by GEANT4 and tuning at design time allowed to avoid contamination.



With linear spacing of low energy channels.

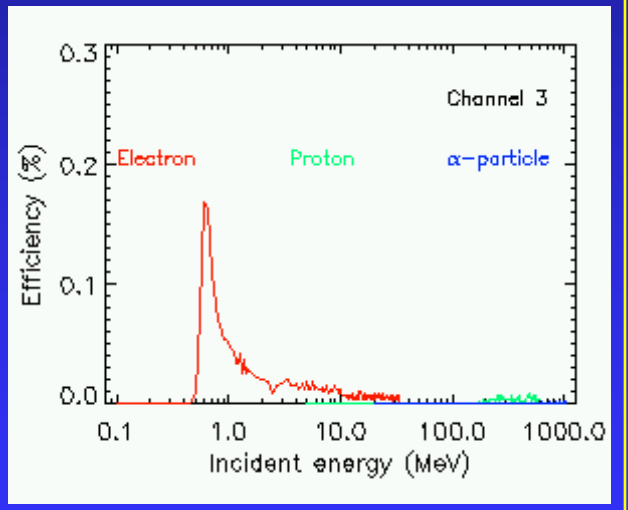
Particle identification - Contamination issue (ctd):





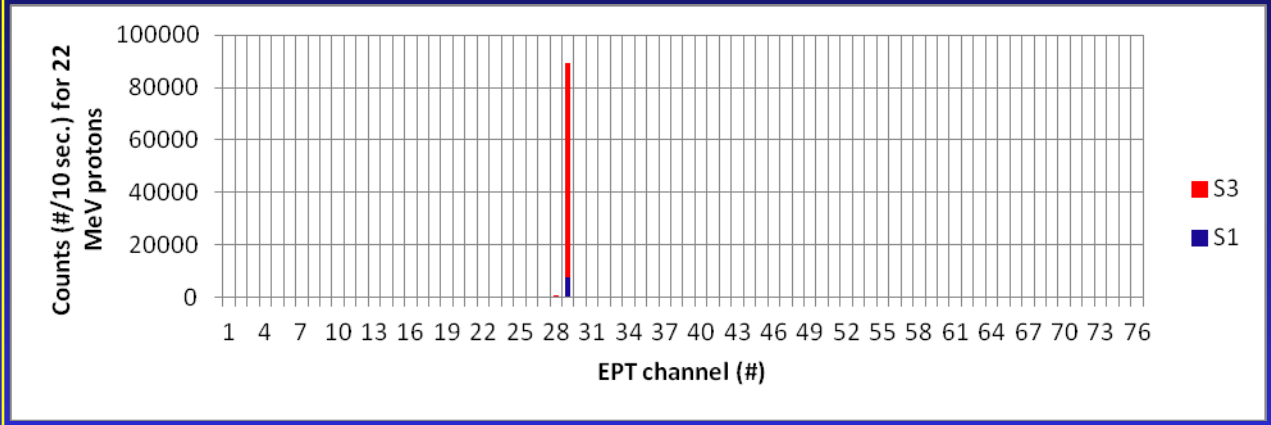
No contamination of electron nor α-particle channels by proton beam.

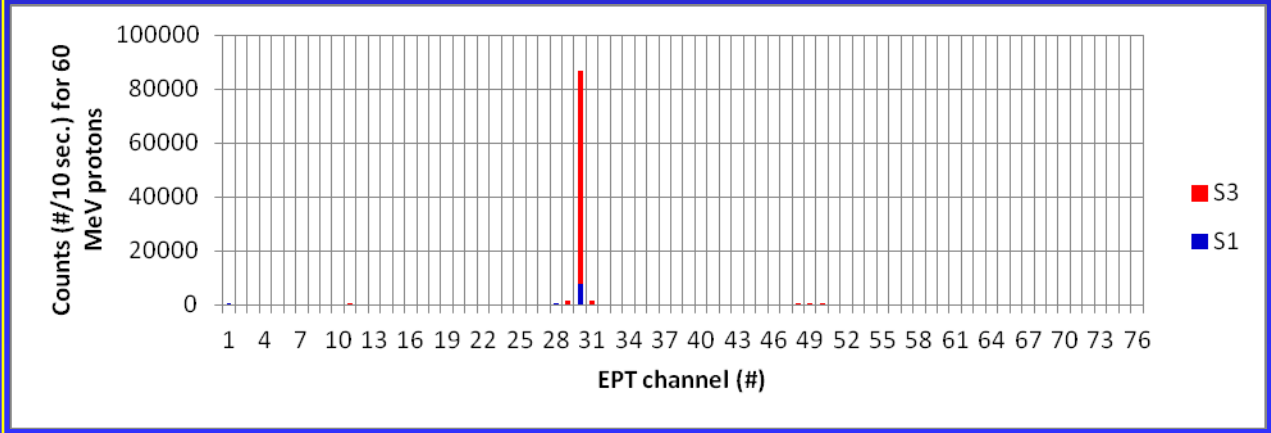
Efficiency evaluation by GEANT4 and tuning at design time allowed to avoid contamination:



Incident intensity is 12800 p/(s cm^2) through a 1 cm diameter collimator.

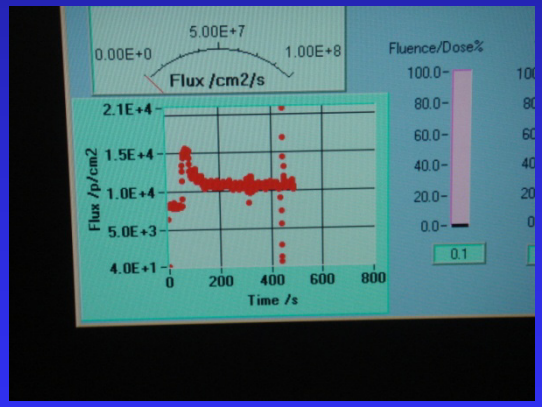
Validation of the design of the EPT EQM channels :





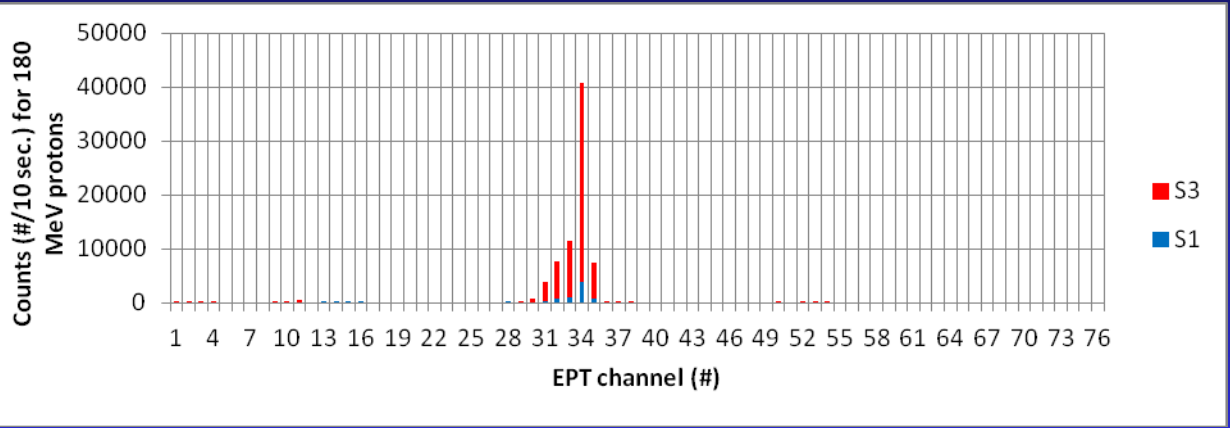
No contamination of electron nor α-particle channels by proton beam.

Efficiency evaluation by GEANT4 and tuning at design time allowed to avoid contamination:



22 and 60 MeV protons detected in Channel 29 (12 – 29 MeV) and 30 (29 – 61 MeV), respectively.

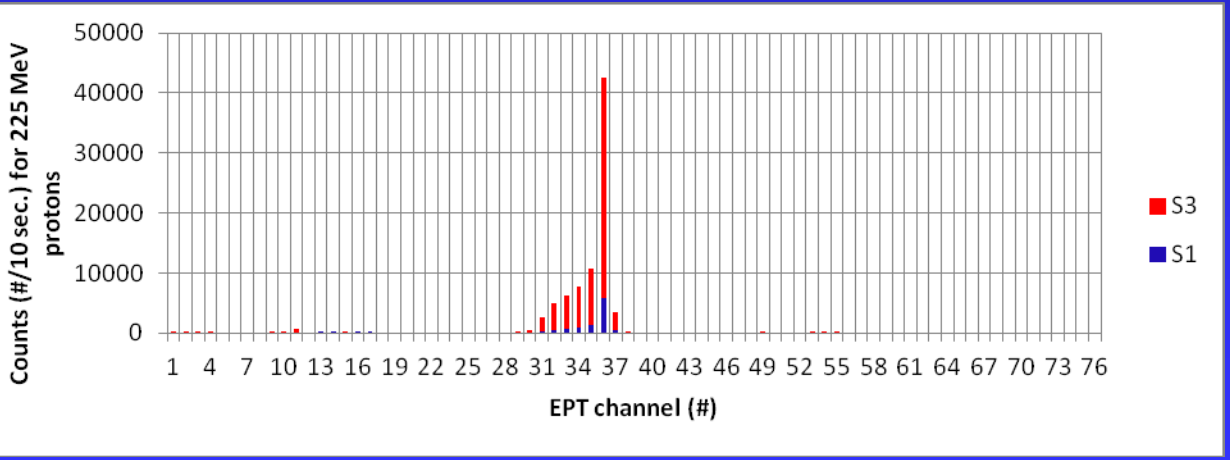
Validation of the design of the EPT EQM channels (ctd):



No contamination of electron nor α-particle channels by proton beam.

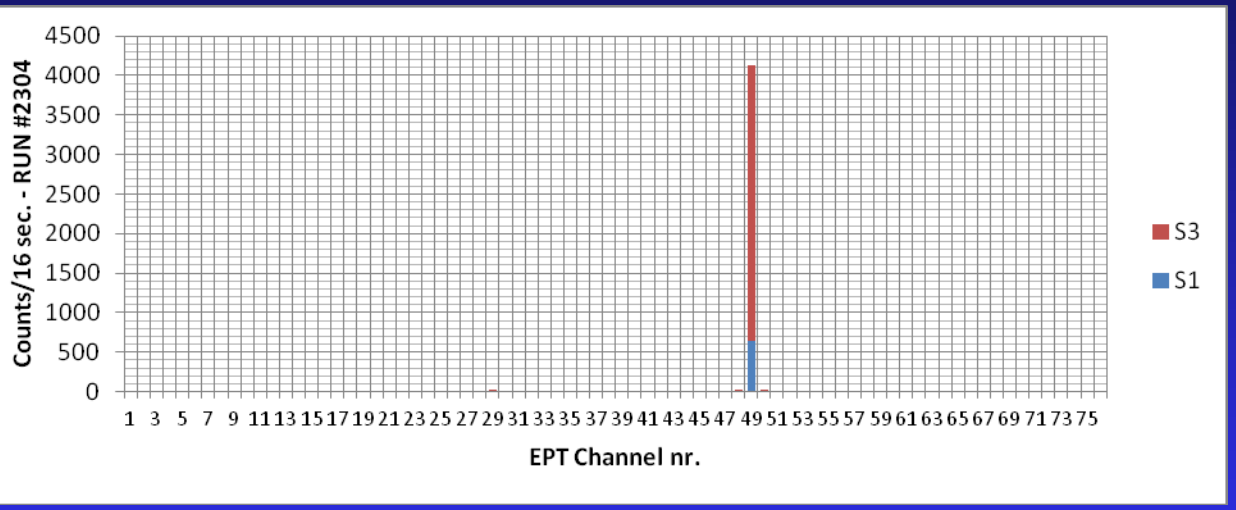
Efficiency evaluation by GEANT4 and tuning at design time allowed to avoid contamination:

180 MeV protons mainly detected in Channel 34 (154 - 180 MeV).



225 MeV protons mainly detected in Channel 36 (202 - 225 MeV).

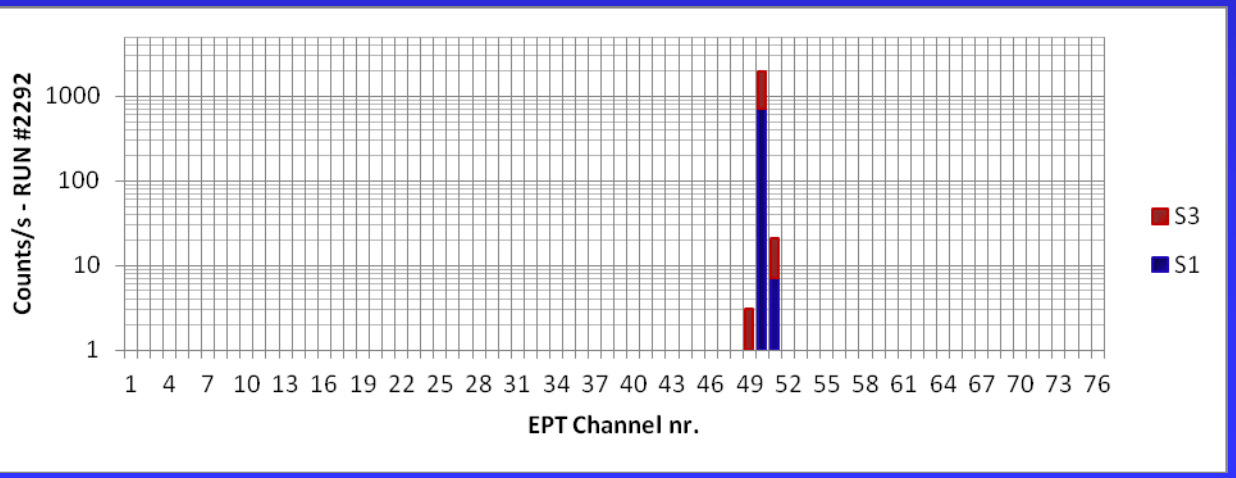
Validation of the design of the EPT EM channels - α-particles :



No contamination of electron neither proton channels by α-particle beam.

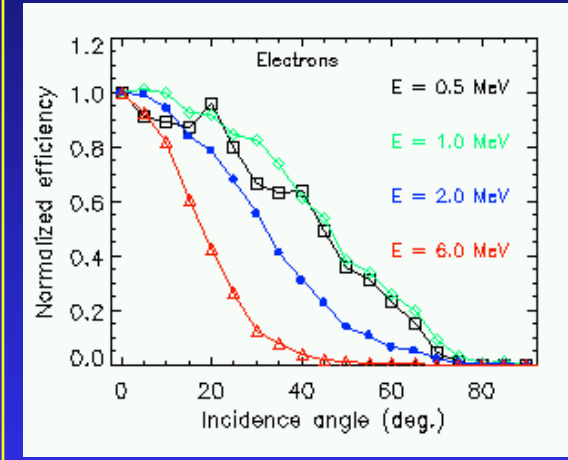
Efficiency evaluation by GEANT4 and tuning at design time allowed to avoid contamination:

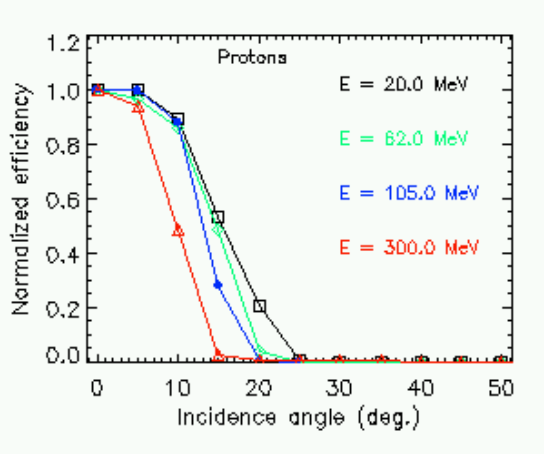
201 MeV α-particles detected in Channel 49 (115 – 239 MeV).

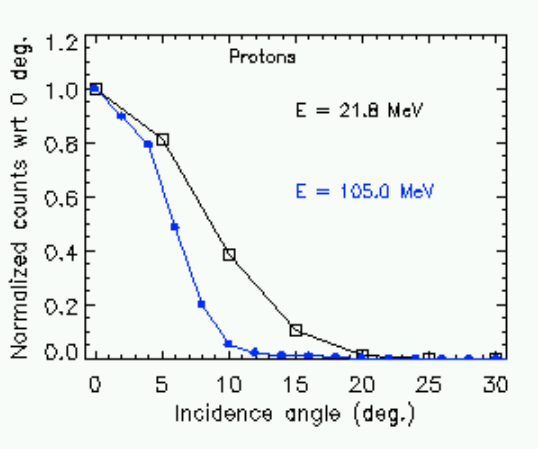


351 MeV α-particles detected in Channel 50 (239 - 360 MeV).

Field Of View angle:





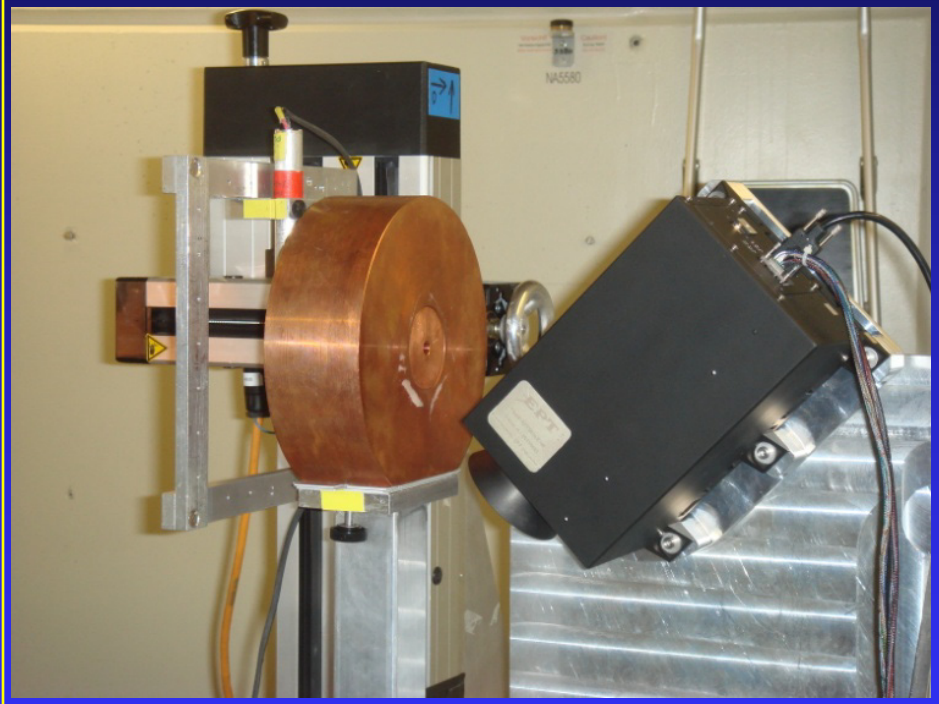


GEANT4 evaluation of the intrinsic detection efficiency variation as a function of incidence angle for electrons and protons coming from the EPT aperture. F.O.V angle for protons is well approximated by its geometrically-defined counterpart.

Electron scattering by the front-shielding foil and S1/S3 sensors increases the F.O.V angle, mainly for the lowest incident energies.

In-beam validation of the EPT-EQM F.O.V angle. Experimental conditions (10 mm diameter collimator, 86 mm EPT-to-collimator distance) affect the angular response, but 22 MeV protons are not detected if incidence angle exceeds 25°.

Field Of View angle (ctd):



Tilted and vertically shifted EPT is not sensitive to off-aperture 230 MeV protons, even when these are focussed on the S2 sensor.

```
PILE-UP INDEX:
0 3 1

S1/S3 - S2 Coincidence:
1 42

TEST COUNTING:
13 1343 405616

13890 68379 97590 88535 63868 34493 9791 13971 35626 33144
98768 71834 96645 44480 68480 96295 46855 52146 51950 100048

ELECTRONS S1:
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ELECTRONS S3:
0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0

PROTONS S1:
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

PROTONS S3:
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ALPHA S1:
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

ALPHA S3:
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

HEAVY IONS S1:
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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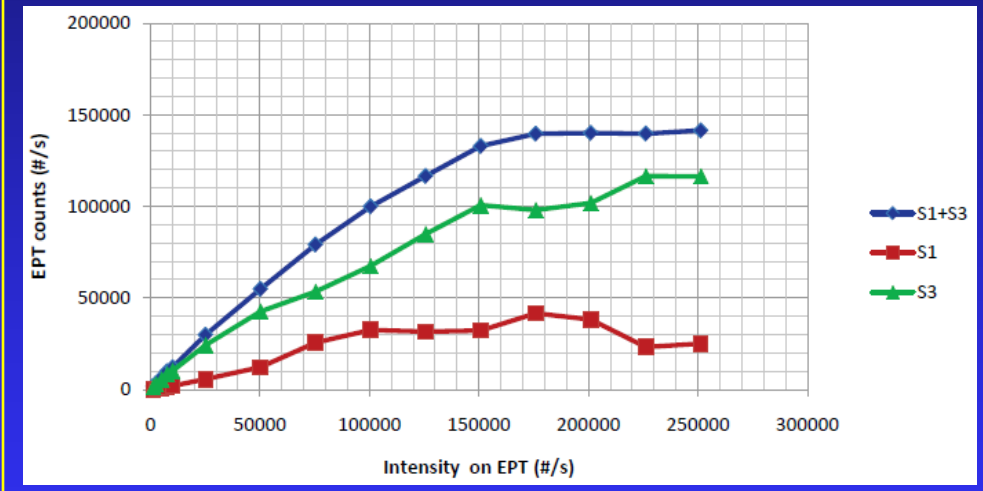
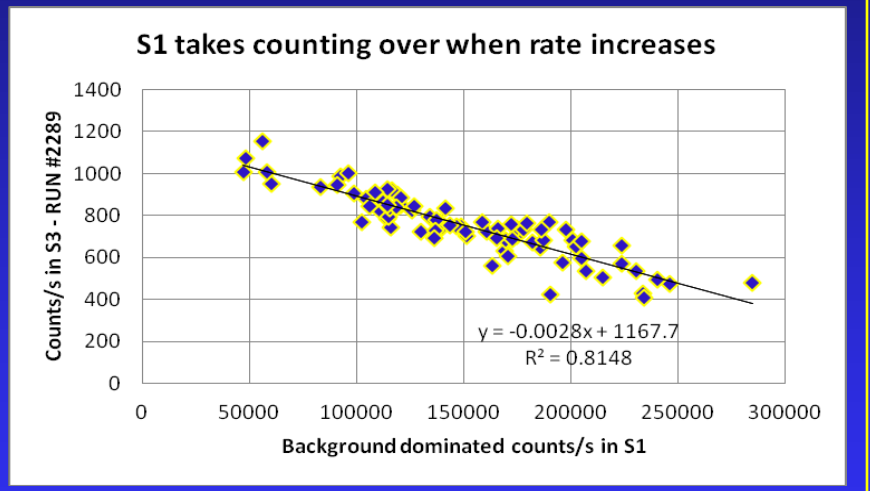
Lot of particles on single sensors

In-beam validation of EQM maximum count rates:





The EPT can readily measure up to 10^7 s^{-1} cm^{-2} fluxes.

Measurements of even higher fluxes can be achieved by accommodating a gold foil as aperture window and by avoiding S1 operation at <100 keV threshold.

As shown during the EPT-EM validation with 351 MeV a-particles and 44 keV S1 threshold, processing activation background in S1 prevents S3 from dealing with useful events!

Status and perspectives:

- ✓ The EPT functions have been validated either on the breadboard, the EM or the EQM using electron, proton or a-particle beams;
- ✓ The experimental results confirm GEANT4 simulation predictions (maybe because the EPT concept is simple and reduces sources of uncertainties);
- ✓ The qualification of the EPT EQM was completed yesterday and the FM is being prepared for flight on board the PROBA-V satellite;
- ✓ The EPT is expected to significantly contribute to providing high quality data for space physics, for radiation modelling and for space weather applications;
- ✓ More flight opportunities are needed to definitely improve the instrument TRL.