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THE CHARGED PARTICLE DETECTOR (CPD): Data Analysis Methodology

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1. Introduction

So far, the space radiation physicists have used simulation tools (like the CERN software GEANT) mainly to plan in-beam calibrations of detectors or to validate in-beam calibration results. Some others have to resort to Monte-Carlo tools to correct the so called "energy dependent geometrical factor" for "background signals" originating from outside the formal field of view of the detector. In many cases the simulation tools are used to evaluate the "contamination" of detector channels by undesirable type of particles. The method devised for the analysis of the Charged Particle Detector data was developed to deal with complex detection systems where a detector must be considered as a set of shielding material and sensors interacting with all the types of particles present in its environment. Rather than to evaluate the geometrical factor of two detector surfaces (generally, the detector aperture and the sensitive element), we compute the geometrical factor of the detector interface with the incident radiation and we describe the transfer from the interface to the sensor using the energy dependent intrinsic detection efficiency.

A Monte-Carlo simulation of an in-beam calibration of a simple detector (the LIULIN dosimeter) and a complex detector (the CPD) will be shown in Section 2. It illustrates the level of reliability reached by the GEANT software. In Section 3, isotropic proton fluxes obtained by use of the intrinsic efficiency method are presented (CRRES Proton Switches) along with its necessary extension to measurements of anisotropic fluxes along the OERSTED orbit (CPD). A concluding Section 4 summarises the contents of the final OERSTED/CPD charged particle model.

2. Numerical calibration with GEANT 3.21

a) The LIULIN dosimeter

The LIULIN detector is made of a 300m thick silicon sensor behind a 0.2 mm aluminum window. It is linked to a pulse height multichannel analyser (256 channels) which stores up to 1000 spectra of the energy lost in the sensor. Figure 1 shows the results of the LIULIN in-beam calibration as compared to the simulation prediction.

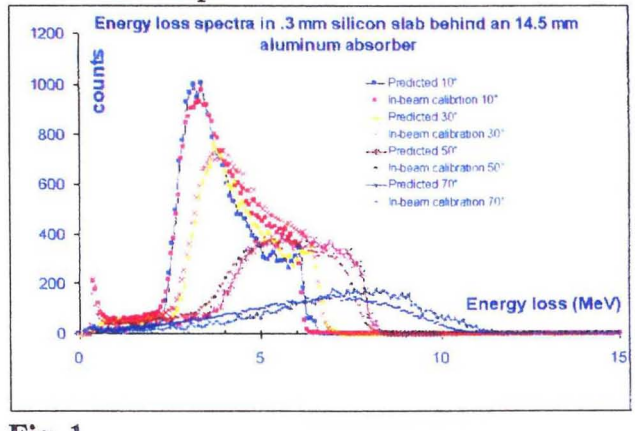


Fig. 1

b) Simulated response of the CPD

The CPD modules have been optimized to reduce the delta ray production. But such a setup shown in

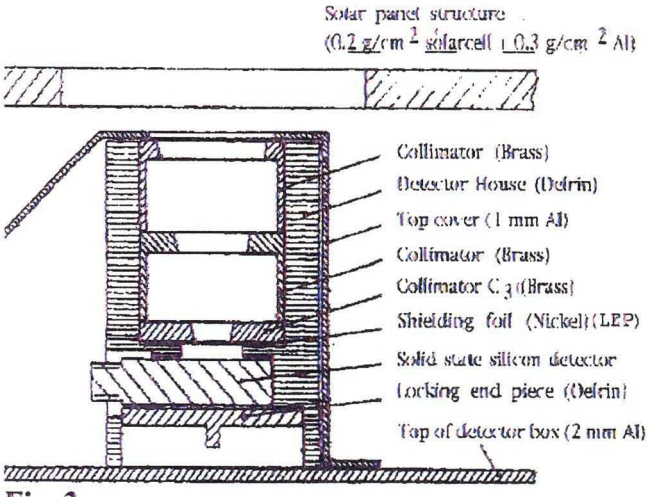


Fig. 2

Figure 2 leads to rather complex energy loss spectra, even from a mono-energetic particle beam. This is illustrated in Figure 3 which shows several peaks in response to a mono-energetic 200 MeV α - particle beam.

The usual "geometrical factor" method is no longer valid for such non-ideally collimated sensors.

3. The intrinsic efficiency of particle detectors

a) The Proton Switches

A Proton Switch (PS) is made of a 3mm x 3mm x 3mm cubic silicon detector shielded by a spherical dome. The electronic unit sets a detection threshold corresponding to an energy deposit of 5 MeV. It also sorts to specific bins the particles which deposit more than 7 MeV into the sensors. This allows 2 channels for each PS.

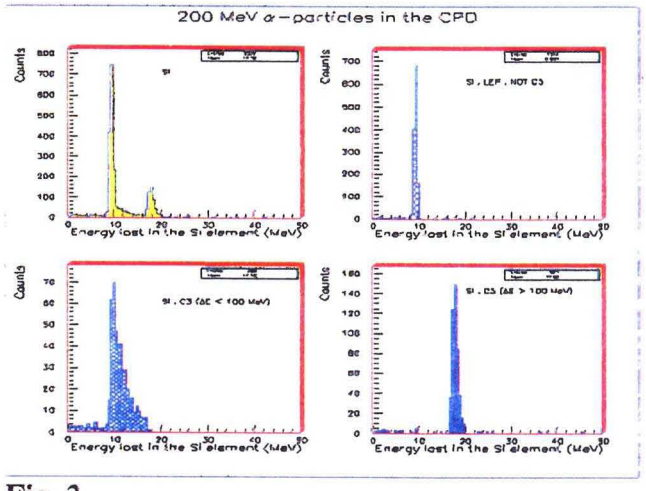


Fig. 3

Two such PS detectors were accommodated on the CRRES satellite flown on July 25, 1990.

Figure 4 depicts the PS mechanical assembly . The intrinsic detection efficiencies of channel 2L for protons, electrons and α - particles are shown in Figure 5. The proton fluxes are obtained by least-square fits of the counting rates N_{ji} (which depends on the geometrical factor G, the efficiency p_{ji} and the proton differential spectrum $J_d(E)$) expressed as:

$$N_{ji} = G \int_{E_{th}}^{E_u} p_{ji}(E) J_d(E) dE$$

The results are shown in Figure 6 along with their comparison to the predictions made by use of CRRESPRO (proton fluxes measured by the PROTEL instrument onboard CRRES) and AP8 models.

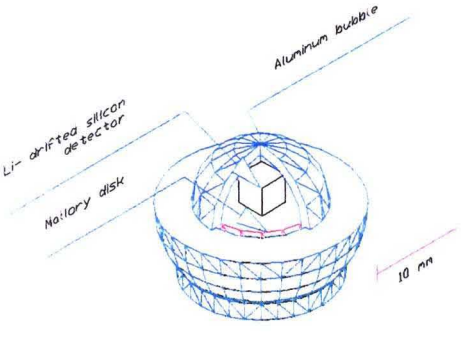


Fig. 4

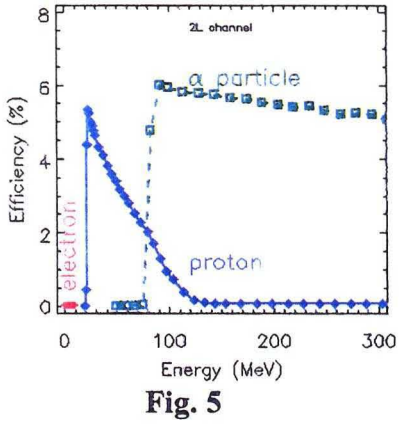


Fig. 5

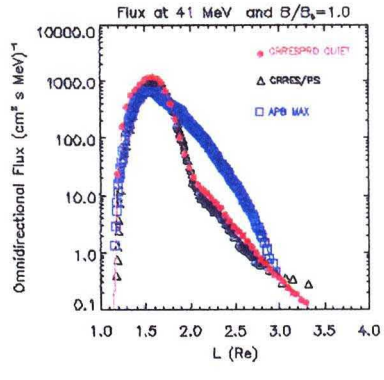
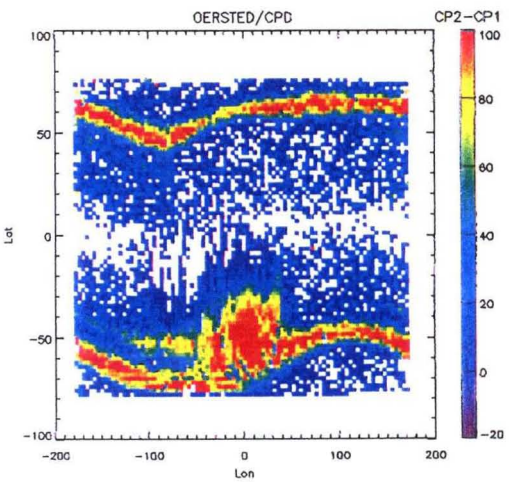


Fig. 6

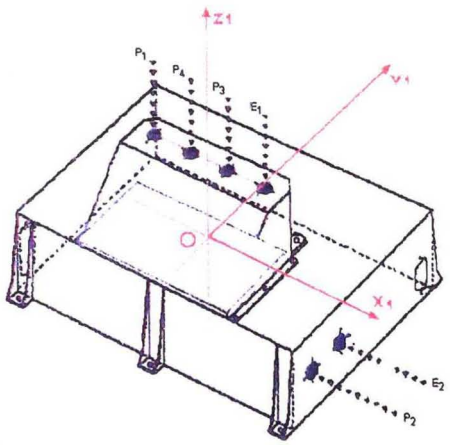
b) The Charged Particle Detector

The particle flux along the OERSTED satellite are very anisotropic as shown in Figure 7a (Figure 7b shows the orientation of the CPD modules relatively to each other).
The counting rate (CR) of each CPD bin (which depends on the field of view solid angle dω, the angular dependent efficiency ε(E,ω) and the angular dependent flux $\phi_d(E,\omega)$) is given by the formula:

$$CR = \int_{\Omega} d\omega \int_{E_{min}}^{E_{max}} \varepsilon(E,\omega)\phi_d(E,\omega)dE$$



a)



b)

Fig. 7

Angular dependent particle fluxes will be obtained by least-square fit of the flux model to the observed counting rates. The angular dependent efficiencies are under evaluation and Figure 8 shows the results for electrons (red), protons (blue) and α-particles directed towards the detector symmetry axis (Z1).

4. Conclusion: the OERSTED/CPD particle flux model

The method presented herein is based on a precise characterization of the CPD. It allows us to determine angular dependent energy spectra of electrons and protons. However, the lack of specific bins dedicated to α-particles may result in high uncertainties on the measured α-particles fluxes.

5. Aknowledgements

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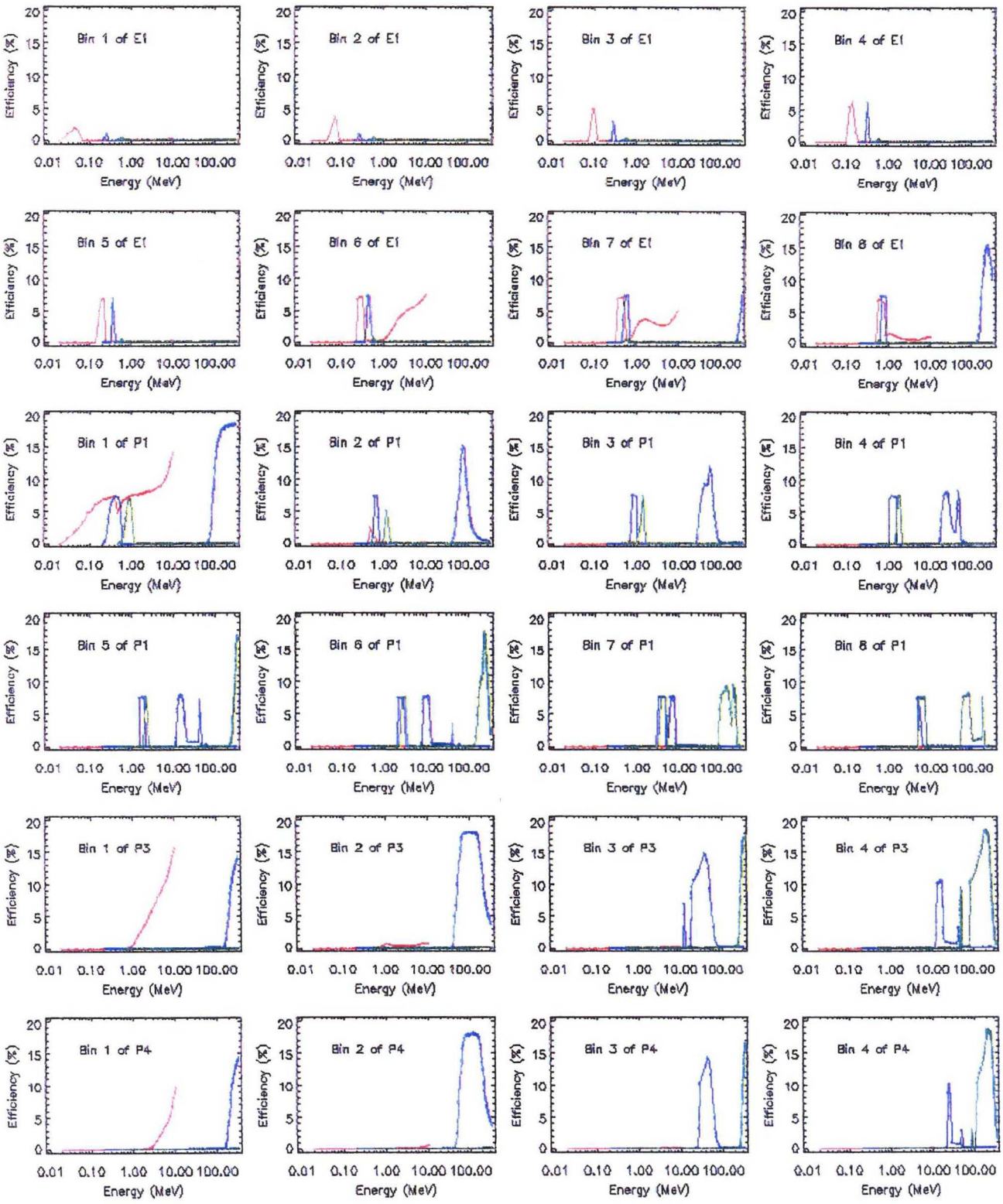
Bin 1 of E1
Bin 2 of E1
Bin 3 of E1
Bin 4 of E1
Bin 5 of E1
Bin 6 of E1
Bin 7 of E1
Bin 8 of E1
Bin 1 of P1
Bin 2 of P1
Bin 3 of P1
Bin 4 of P1
Bin 5 of P1
Bin 6 of P1
Bin 7 of P1
Bin 8 of P1
Bin 1 of P3
Bin 2 of P3
Bin 3 of P3
Bin 4 of P3
Bin 1 of P4
Bin 2 of P4
Bin 3 of P4
Bin 4 of P4
Efficiency (%)
Energy (MeV)
0.01 0.10 1.00 10.00 100.00
0 5 10 15 20

Fig. 8