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Detection of hydrogen and helium with SOHO/EPHIN*

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Abstract. A Monte Carlo simulation code based on GEANT 3.21 has been used to follow the SOHO (Solar and Heliospheric Observatory)/EPHIN (Electron, Proton and Helium Instrument) response to the detection of hydrogen and helium nuclei. The geometrical factor dependence on the energy has been evaluated and the contamination of the EPHIN channels has been obtained.

1 Introduction

A Monte Carlo simulation on the SOHO/EPHIN instrument was carried out making use of GEANT 3.21, developed at CERN (Brun, R. et al. , 1993). Proton, deuterium, ^{3}He and ^{4}He nuclei have been simulated. The energy of the incident particle has been obtained randomly from several power law energy distributions with spectral index between -5 and 1. Angular and incidence position have been selected randomly according to an isotropic flow of particles hitting uniformly on a circular surface, located on the acceptance window of the sensor.

Figure 1 shows a sketch of the sensor parts introduced in the simulation. Only three different geometries have been used, solid cylinders, tubes and policones with revolution symmetry around the sensor axis. Kapton and Titanium sheets protect the sensor aperture window from cosmic dust and Sunlight. EPHIN sensor has six sensitive solid-state cylindrical detectors (A-E) for energy measurement and F is acting as veto detector (Müller-Mellin et al. , 1995). All of them surrounded by a tube with variable section of scintillator NE104 to detect particles escaping from the sensor.

Actually, we have carried out twelve simulations, three for each isotope, with different energy distributions; flat energy spectrum, lineal energy spectrum and a power law with spectral index $\gamma = -2$. It has been simulated $5 \cdot 10^7$ protons, deuterons, ^{3}He and ^{4}He in the energy range 1-81 MeV/n and with 90° aperture angle.

All over this work, instrumental data obtained from Monte Carlo simulation and flight data used individually or combined are described. All these instrumental characteristics should be used to improve the experimental data analysis.

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2 Energy measurement

Particle identification is one of the main instrumental topics of the EPHIN sensor. It may be achieved from the integration of Bethe-Bloch's equation (Seamster et al. , 1977), from an empiric relationship for the stopping power (Goulding et al. , 1964) or based on some kind of intermediate solution. Particle identification involves three physical parameters: total energy, energy lost by the ion in a detector of known thickness, and the path of the particle in this detector. These magnitudes are affected by several uncertainties: the threshold energy of the detectors, electronics saturation, coincidence system shortcoming, detector resolution, nuclear interactions and insensitive zones.

Table 1. Average relative difference between measured and real energy for total, parallel and central incidence.

	Total	Parallel	Central
^{1}H	0.11	0.024	0.004
^{2}H	0.11	0.021	0.004
^{3}He	0.10	0.020	0.003
^{4}He	0.12	0.026	0.008

Figure 2 shows the simulation of the amount of energy not detected by EPHIN. It has been obtained by the sustraction of the measured energy to the real energy of the particle. The upper plot of Figure 2 shows a zoom of the peak that appears in the low energy region. As can be seen the difference in the energy determination is less than 200 keV, although a significative number of particles have larger differences. The mean value of the energy differences is 7.7 MeV that can

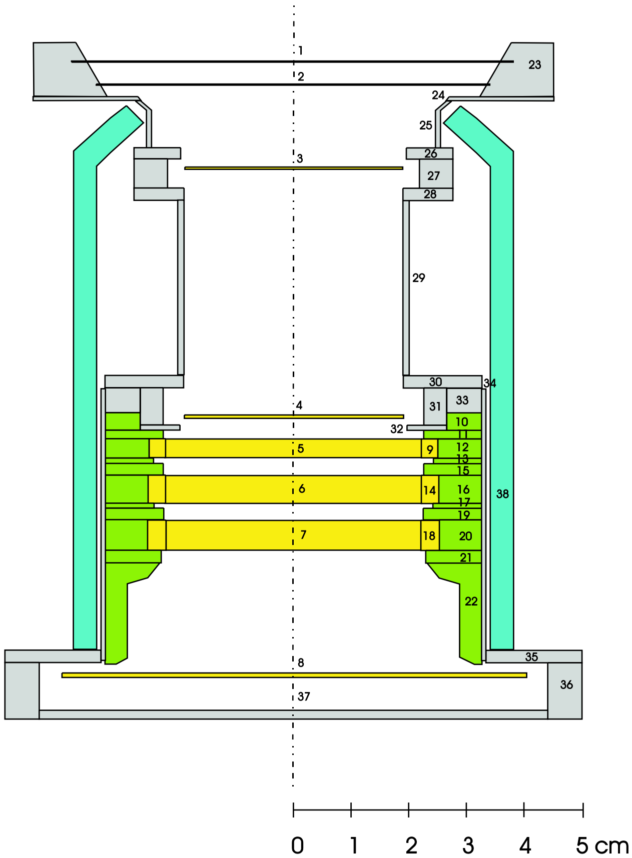

Fig. 1. EPHIN sketch showing the 38 sections introduced in the Monte Carlo simulation.

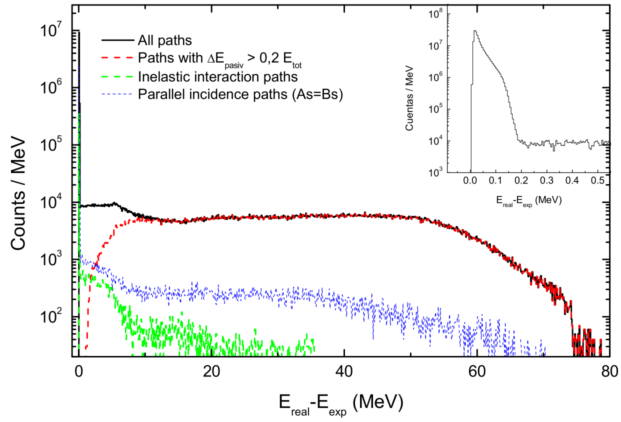

Fig. 2. Number of particles versus difference between real and measured energy.

be reduced to 1.3 MeV if parallel incidence is required. If only the central sector of the A and B detectors is selected, deviations in the energy determination has mean value of 0.1 MeV. Although the number of detected particles is reduced in a factor of nearly 30.

Table 1 shows the average relative differences between measured and real energy, for total, parallel and central incidence. It can be observed as averaged values of the energy measurement defect are about 11 % for total acceptance, but only $\sim$ 2 % and 0.4 % for parallel and central acceptances.

3 Energy range of detection

EPHIN instrument was designed to measure Hydrogen and Helium ions between 4 and 50 MeV/n. Before proceeding to the study of the data provided by the EPHIN sensor, it is necessary to delimit with accuracy the energy range where particle detection is effective. The analysis has to be carried out separately for each isotope, since significative differences can be obtained for each one. Energy range have been obtained from Monte Carlo simulation for protons, deuterons, ^{3}He and ^{4}He nuclei. The Monte Carlo simulation of the EPHIN response to each isotope has been performed with an isotropic and uniformly distributed particles flow in the energy range 1-81 MeV/n. The detection energy ranges have been estimated as the intervals where the lost particles are lower than 50 %.

Figure 3 shows the detection energy ranges for protons, deuterons, ^{3}He and ^{4}He. It can be observed how the energy ranges are 4.4-55.5 MeV, 2.9-37.3 MeV/n, 5.1-64.7 MeV/n and 4.3-55.2 MeV/n respectively.

4 Geometrical factors from Monte Carlo simulation

Geometrical factors permit to obtain the real incident flux in the sensor, from counting rates of the coincidence system. Accurated determination of geometrical factors gives more reliable flux data extracted from on flight counting rates. Geometrical factors obtained from Monte Carlo simulation turn out to be of great importance. Figure 4 shows dependence of geometrical factors on the energy for protons, deuterons, ^{3}He and ^{4}He, obtained from the Monte Carlo simulation with uniformly distributed energy spectra. With power-law energy spectra the simulated geometrical factors obtained.

Table 2. Geometrical factors in cm^{2}sr calculated by Monte Carlo simulation for total, parallel and central particle incidence.

	Total	Parallel	Central
P4	4.56	1.05	0.17
P8	4.71	1.04	0.18
P25	4.17	1.01	0.17
P41	3.27	0.94	0.16
H4	4.53	1.00	0.17
H8	4.64	1.04	0.18
H25	4.18	1.00	0.17
H41	3.29	0.94	0.16

Table 2 shows geometrical factors of 8 coincidence channels from simulation for parallel, central and total incidence. These geometrical factors have been obtained with the measured energy of the simulated particles and selecting this par-

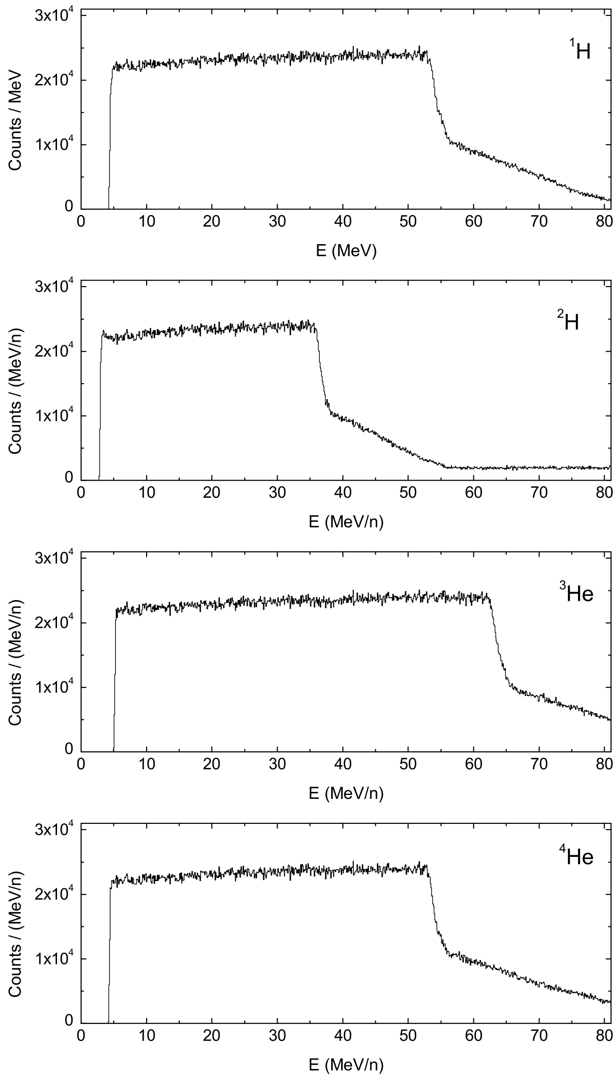

Fig. 3. Energy intervals obtained for protons, deuterons, ^{3}He and ^{4}He.

ticles with a ΔE-E method similar to those used with on flight data. By this procedure, the geometrical factors include uncertainties correction in the total energy determination of the particle.

The geometrical factor for parallel incidence shows a constant value of approximately 1.02 cm^{2}sr being energy independent, and nearly the same for all the isotope and the spectral form evaluated.

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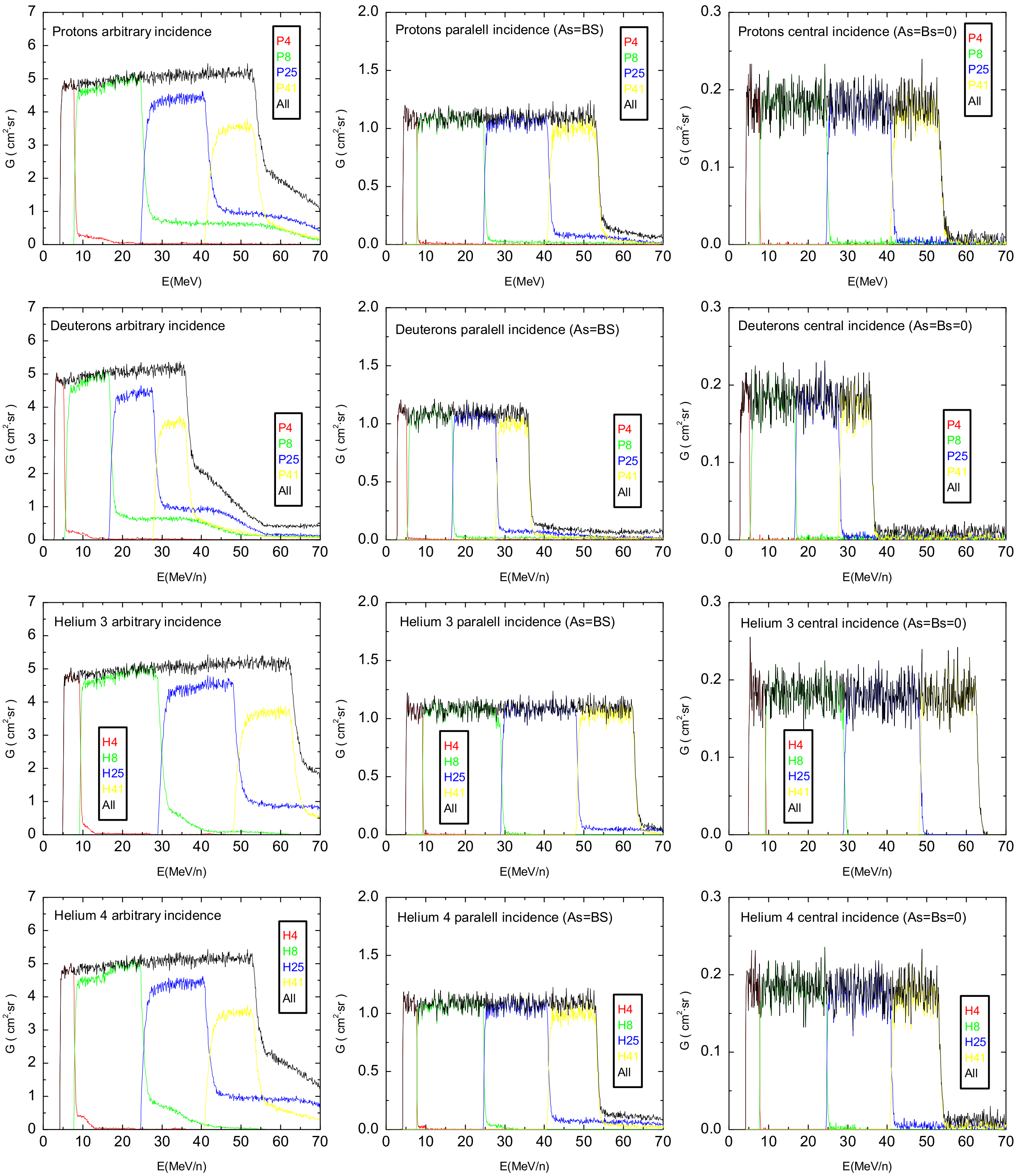

Fig. 4. Dependence on the energy of geometrical factors for protons, deuterons, ^{3}He and ^{4}He in cm^{2}sr.