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The HEPD apparatus for the CSES mission

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The HEPD apparatus for the CSES mission

Beatrice Panico[1]
INFN Napoli, I-80126 Naples, Italy
E-mail: bpanico@na.infn.it

G. Osteria, F. Perfetto, V. Scotti
INFN Napoli, I-80126 Naples, Italy

P. Cipollone, C. De Donato, C. De Santis, L. Marcelli, G. Masciantonio, M. Mergè, F. Palma, P. Picozza, A. Sotgiu, R. Sparvoli
INFN Sezione di Roma Tor Vergata, I-00173 Rome, Italy

A. Contin, C. Guadalini, G. Laurenti, M. Lolli, F. Palmonari, L. Patrizii, M. Pozzato
INFN Sezione di Bologna, I-40127 Bologna, Italy

M. Ricci, B. Spataro
INFN Frascati National Laboratories, I-00044 Frascati - RM, Italy

W.J. Burger, R. Battiston, F.M. Follega, R. Iuppa, I. Lazzizzera, C. Manea, I. Rashevskaya, E. Ricci, V. Vitale
INFN Sezione di Trento, I-38123 Povo - TN, Italy

G. Ambrosi, M. Ionica, M. Sposito
INFN Perugia, I-06123 Perugia, Italy

S. Bartocci, L. Conti
International Telematic University UNINETTUNO, I-00186 Roma, Italy

G. Castellini, L. Pacini, S.B. Ricciarini
IFAC-CNR, I-50019 Sesto Fiorentino - FI, Italy

Abstract. The High-Energy Particle Detector (HEPD) is one of the payloads of the CSES space mission. The HEPD is built by the Italian Limadou collaboration and has different goals. It will study the temporal stability of the inner Van Allen radiation belts, the precipitation of trapped particles in the atmosphere and the low energy component of the cosmic rays (5 - 100

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MeV for electrons and 15 - 300 MeV for protons). It has been tested at the Beam Test Facility of the INFN National Laboratory of Frascati, for electrons, and at the Proton Cyclotron of Trento, for protons. Here is presented a study of the performance of the apparatus to separate electrons and protons and identify nuclei up to iron.

1. The High-Energy Particle Detector

The China Seismo Electromagnetic Satellite (CSES) is a space mission dedicated to the monitoring of the perturbations originated by electromagnetic emissions in the atmosphere, ionosphere, magnetosphere and in the Van Allen belts. The launch is scheduled for the first half of 2018 and the expected lifetime is 5 years.

The High-Energy Particle Detector (HEPD) is one of the payloads of the CSES space mission. It is developed by the Italian Collaboration Limadou to study protons and electrons in the energy range [3-200] MeV [2] requiring a good energy resolution and particle identification.

It is composed by different instruments [3]. At the top of the detector a tracker provides the direction of the incident particle; it is made of two planes of double-side silicon micro-strip sensors, each one is divided into 6 pads. The trigger plane consists of one layer of plastic scintillator divided into 6 segments. The calorimeter is divided into 2 parts: the upper calorimeter, composed by 16 plastic scintillators with dimensions (15x15x1) cm^3 and the lower calorimeter, a layer composed of 9 LYSO cubes. The combined signal given by the first calorimeter plane and the trigger plane provides the main trigger of the experiment. On the sides and bottom of the instrument there is a veto system, made by scintillator planes 5 mm thick.

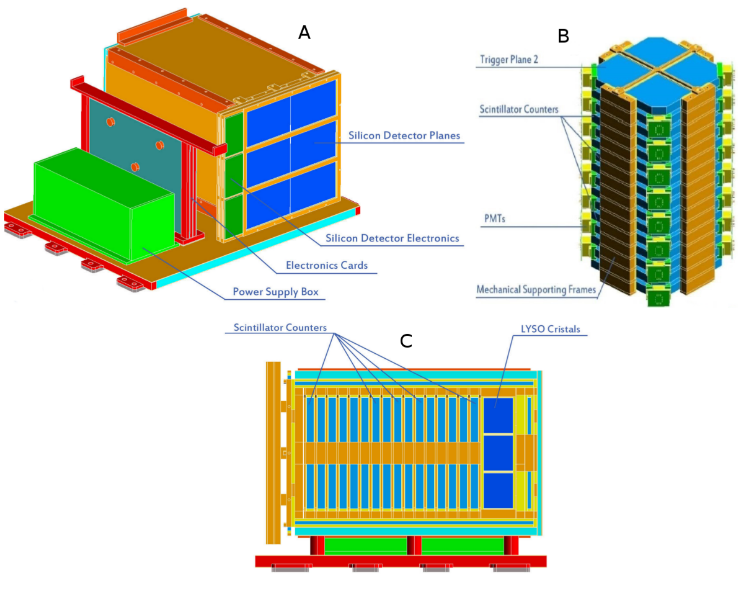

Figure 1. View of the HEPD electronic box and detectors.

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2. MonteCarlo Simulation

A Monte Carlo simulation based on Geant4 toolkit was developed in order to evaluate the HEPD performances [4].
In Fig. 1 different views of the simulated detectors have been showed: in Fig. 1A there are the HEPD box and the electronic box; in Fig. 1B the 16 scintillator planes are showed; in Fig. 1C can be seen the detectors that composed HEPD.

The simulation has been used to study the trigger mask efficiency, the energy resolution of the calorimeter and the electron/proton discrimination. To study the energy resolution of the detector samples of protons and electrons at fixed energies have been simulated. The simulated energy range is [3-150] MeV for electrons and [30-200] MeV for protons.

In Fig. 4 the energy deposited in each detector layer is reported for electron beams of different initial energy.

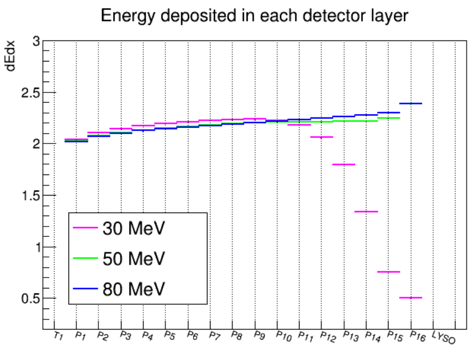

Figure 2. Profile of the energy released by electrons with different energies into the calorimeter for each layer.

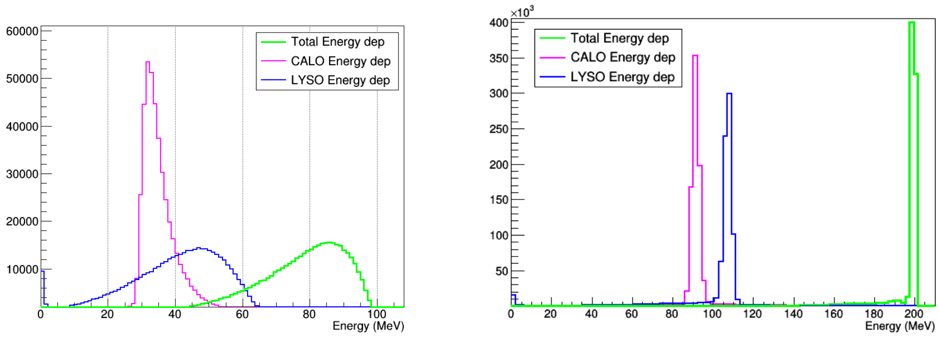

Figure 3. Energy loss into the upper and lower part of the calorimeter for electrons (left) and protons (right).

In Fig. 3(left) the energy losses of electrons with energy E=100 MeV into the upper and lower calorimeter are reported. The green line represents the total energy released by the particle; the magenta line represents the energy deposited into the upper calorimeter, while the blue line is the energy released into the Lyso cristals. In Fig. 3 the same plots are reported for a beam of protons with energy E=200 MeV.

In Fig. 4 the energy resolution of the HEPD calorimeter is reported. Only events completely contained into the calorimeter have been considered. According to the initial requests, the energy resolution has to be $< 10\%$ at 5 MeV. For both electrons and protons results are in good agreement with them. The energy losses inside the material of the mechanical structures are responsible of the low energy tails observed in the distributions. Due to the LYSO crystals at the end of the calorimeter, protons are fully contained for energies between [150 - 250] MeV.

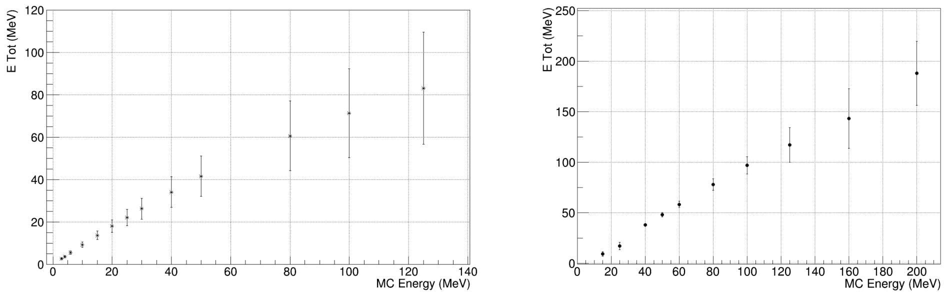

Figure 4. Energy resolution for the calorimeter for electrons (left) and protons (right).

3. Test beams

The HEPD project involved the construction of 4 detector versions: the Electrical Model (EM), the Structural and Thermal Model, the Qualification Model (QM) and the Flight Model (FM). In May 2017, The FM was tested at the Beam Test Facility (BTF) of the Laboratori Nazionali di Frascati of INFN with an electron/positron beam with energy between 30 and 120 MeV [5].

Test beam results are important to understand the behaviour of the instrument and to calibrate the PMTs used to read each plane. In Fig. 5 the numbers of counts on the trigger paddle hit by an electron beam of 30 MeV has been showed. It can be clearly seen the signal induced by 1, 2, and 3 contemporary particles.

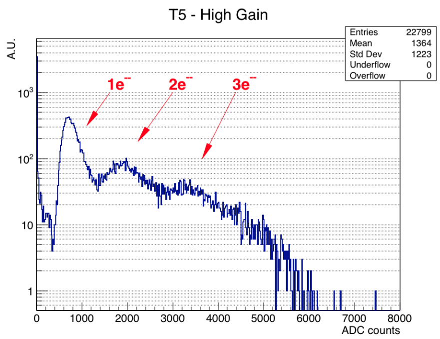

Figure 5. Energy released by electrons with 30 MeV on one paddle of the trigger plane.

Fig. 6 (left) represents the number of planes that give a signal for two electron beams with different energies. The blue plot is referred to electrons with energy equal to 30 MeV; the green plot is referred electrons with energy equal to 45 MeV. The dEdx for minimum ionizing particles in plastic scintillator is $\sim$2 MeV/cm, indeed electrons with energy equal or greater than 45 MeV cross the 16 planes stopping in lyso cristals. Results are in a good agreement with expectations.

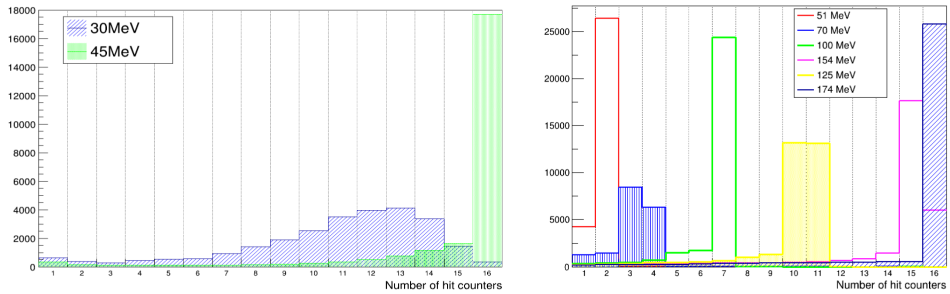

Figure 6. Right: Fired calorimeter plane by electrons with 30/45 MeV. Left: Fired calorimeter plane for proton beams with energies [50-170] MeV.

In October 2017, the FM was tested at the Proton Cyclotron of Trento with proton beams with energy included into the range [70-200] MeV. In Fig. 6 (right) the number of hit planes for proton beams with different energies is reported. Differently from electrons, the plane where protons lose all the energy can be clearly identified, allowing a good estimation of the energy loss in the calorimeter.

The correlation between test beam data and simulation results allows the calibration of the instrument with a good precision.

This is also reported in Fig. 7, where the total counts obtained in the upper calorimeter are reported as a function of the beam energy. Electrons lose a constant quantity of energy into the upper calorimeter, stopping into the LYSO crystal. For protons, instead, there is a good linearity between the primary particle energy and the obtained signal.

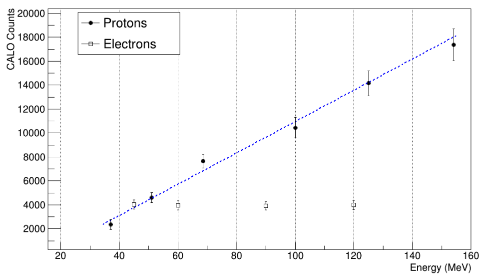

Figure 7. Total counts read into the calorimeter for electrons and protons with different energies.

4. Conclusions and acknowledgements

In this paper the performances of the HEPD detector have been described. Some results obtained at the test beams are reported. We would like to thank the Beam Test Facility at 'Laboratori Nazionali di Frascati' and the Proton Cyclotron of Trento for the possibility to test the detector.

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