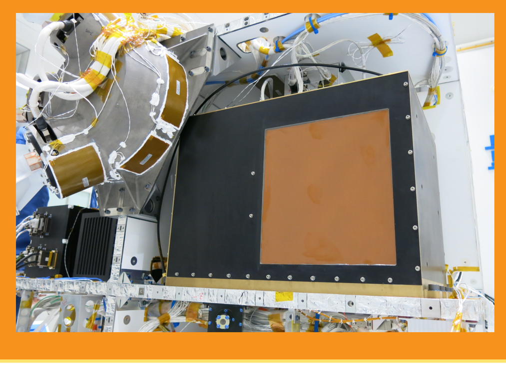

Measurement of the re-entrant lepton spectrum with the High-Energy Particle Detector on board CSES-01

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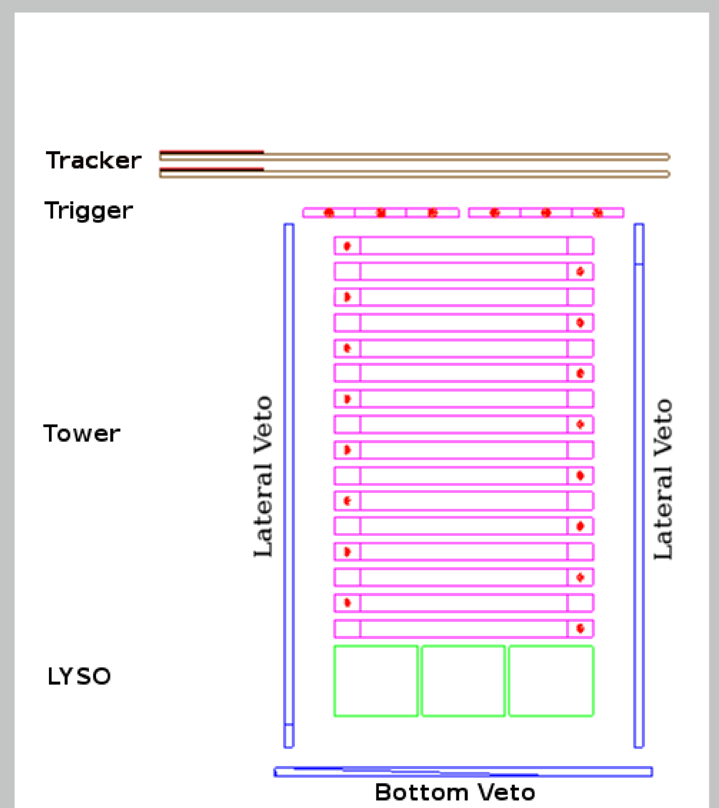
Introduction

High-energy galactic particles can penetrate the Earth's magnetic field and interact in atmosphere leading to the production of charged secondary particles. Some of these secondaries move in the upward direction along the field line (the so-called splash albedo) and, if their rigidity is higher than the geomagnetic cut-off, they can escape to the interplanetary space. Otherwise, if these particles have a rigidity below the geomagnetic cut-off, they spiral along the field line and re-enter in the opposite hemisphere with a downward direction (re-entrant albedo). CSES-01 (China Seismo-Electromagnetic Satellite) is the first of a series of scientific space missions dedicated to monitoring electromagnetic fields and waves, plasma and particle perturbations of the atmosphere, ionosphere, and magnetosphere. Currently, the CSES-01 satellite is in orbit since February 2nd, 2018 equipped with nine instruments, among them the Italian High-Energy Particle Detector (HEPD-01). For most of its acquisition time along CSES-01 orbits, HEPD-01 collects particles with energy below the local geomagnetic cutoff, thus being perfectly suited for the study of the albedo component. Due to the detector structure and its pointing direction towards the Zenith, only the downwards component (i.e. the re-entrant) can be observed.

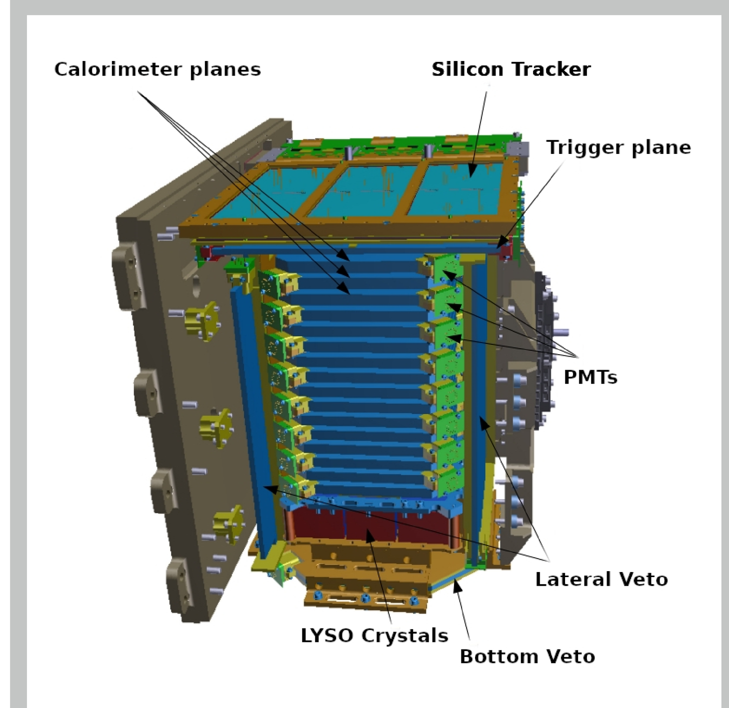
HEPD-01

The High-Energy Particle Detector (HEPD-01) is one of the payloads installed onboard the CSES-01 satellite. It is devoted to the measurements of electrons (3-100 MeV) and protons (30-250 MeV) fluxes and their variations. The detector includes the following set of sub-detectors (in descending order from the top to the bottom side of the instrument):

- the tracker plane - made of two layers of double-sided silicon strip sensors - for the reconstruction of the incoming particle direction
- the trigger plane - made of a segmented layer of 6 plastic scintillator bars - for the generation of the trigger pulse
- the calorimeter - made of a plastic scintillator tower (16 planes) plus a final layer of LYSO inorganic crystals - for the measurement of the energy deposition
- a veto system - made of 5 plastic scintillator planes - for the rejection of particles not fully contained inside the calorimeter



(a)



(b)

Figure 1:(a) A scheme of the HEPD-01 detector, as implemented in the Geant 4 software used for the detector simulations. (b) Computer-aided design of the HEPD-01 detector, including the mechanical structures and a satellite wall.

The trigger plane, as well as the calorimeter and the veto system, are read-out by Photo-Multipliers Tubes.

HEPD-01 is acquiring data since the CSES-01 launch (February 2018), in the latitude region between $\simeq -65^\circ$ and $\simeq +65^\circ$. During the polar passages, it's switched off because of satellite attitude operations.

Analysis

Events in HEPD-01 are recorded when a particle deposits a signal above the threshold in both the segmented trigger plane (T) and the first two planes of the plastic scintillator tower (P1 and P2). Further selections are then applied offline to clean the lepton sample as much as possible and to select the re-entrant albedo component.

These selections include:

- the containment, to ensures a proper reconstruction of the deposited energy;
- a trigger multiplicity equals 1, to reject multi-particle events;
- plane continuity. A continuous release of signal inside the scintillator tower is requested;
- to discriminate electrons and positrons from protons, ionization energy losses inside each calorimeter plane are required to be compatible with the expectation for a singly charged minimum ionizing particle (mip)(see Fig. 2);
- $1.1 <$ L-shell < 1.2 and B > 23000 nT (see Fig. 3). Being the cutoff in this region always higher than 8 GeV, all the contained leptons acquired in this region must be secondaries produced in the atmosphere. With the request of no signal on the bottom veto plane, splash albedo particles with an upward direction are removed.

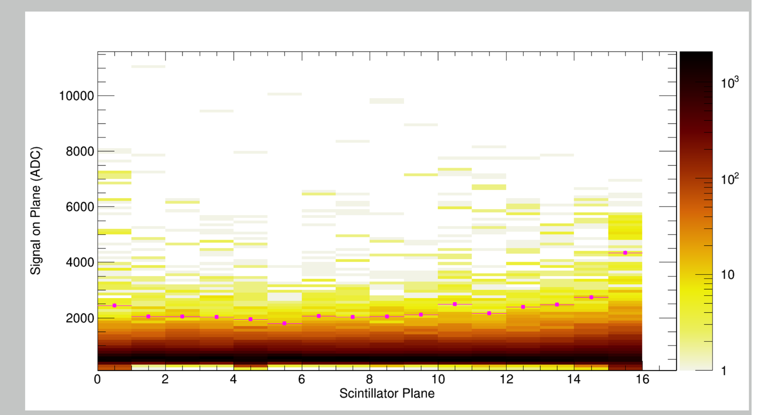


Figure 2:MC Signal distribution on each plane for electrons stopped in P16.

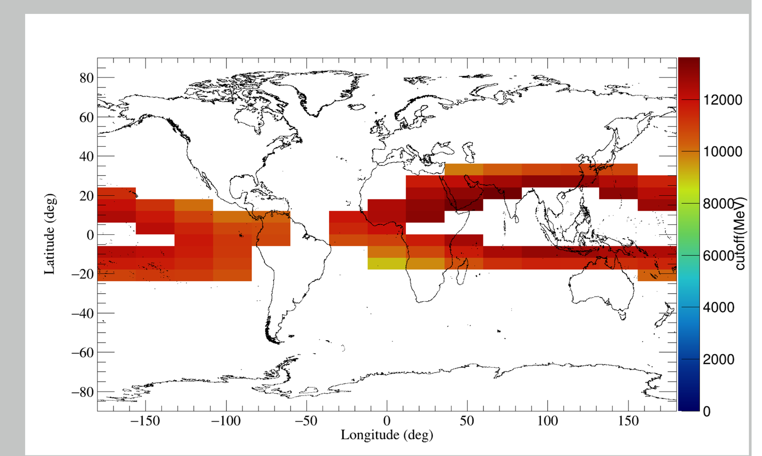


Figure 3:The region corresponding to the selections on L-shell and B.

The geometrical factor of HEPD-01 and all the selection cut efficiencies are evaluated using a Monte Carlo (MC) simulation (Geant4-based software) after applying the same selection criteria used for flight data. The MC software includes the generation, propagation, and collection of the scintillation light produced in the calorimeter and has been tuned with HEPD-01 test beam data. Residual background due to misidentified interacting protons with energy $>\simeq 500 MeV$ has been evaluated with a proton MC simulation reproducing the galactic proton spectrum in the same L-region. This background, mostly due to the inelastic production of leading neutral barions, is less than 5% on the whole energy range and has been included in the systematic uncertainty of the final spectrum.

Results

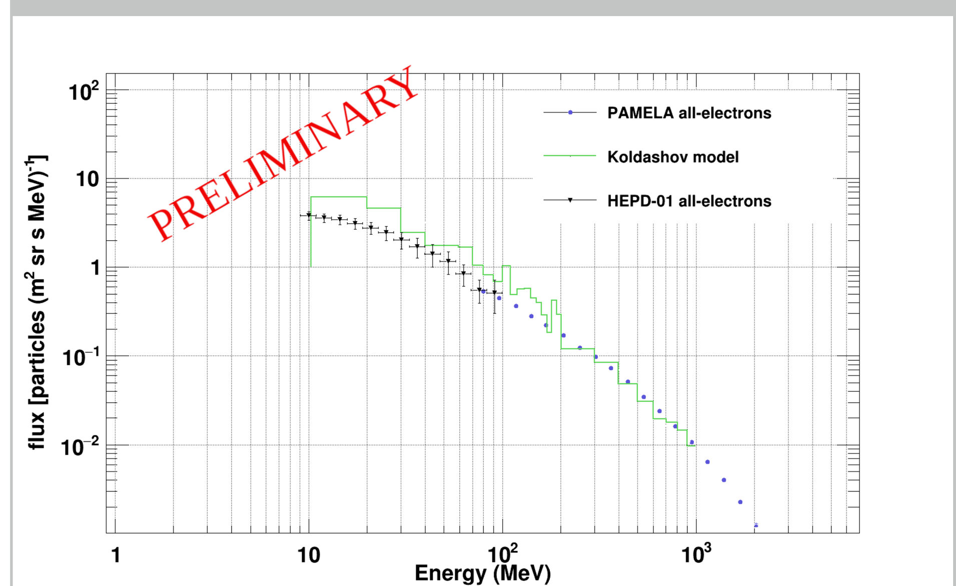


Figure 4:*HEPD-01 re-entrant all-electrons flux.*

The live time is accumulated considering the time spent by the apparatus in one month (August 2018) in the orbital position selected by the aforementioned criteria on L-shell and B.

The preliminary re-entrant all-electrons flux is reported in Fig.4. The resulting spectrum is shown together with PAMELA measurements from[1] (acquired in the same L-shell region), after the sum of the electron and positron components and with a theoretical model[2] used for the calculation of secondary electron and positron fluxes at the top of atmosphere with energy greater than 10 MeV.

The agreement with PAMELA data in the region where the instruments' energy ranges overlap is good, but to finalize the HEPD-01 measurement further studies are required to extend the analyzed time period, to inspect other L-shell regions, and to include the measurement below 10 MeV. HEPD-01 can be precious to provide data below 100 MeV, where there is a lack of recent experimental data, and to help the development of secondary particle production models.

References

[1] O. Adriani, *et al.*, *Measurements of quasi-trapped electron and positron fluxes with PAMELA*, in Journal of Geophysical Research, 114 (2009)

[2] S. V. Koldashov, *et al.*, *Electron and Positron Albedo Spectra with Energy more than 20 MeV*, in International Cosmic Ray Conference 24th, Rome.

For additional information see the proceeding and reference therein.