Study of the performance of the HEPD apparatus for the CSES mission

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THE CSES MISSION

**CSES: China Seismo-Electromagnetic Satellite**

- Space mission with different goals
- Collaboration China National Space Administration (CNSA) - Italian Space Agency (ASI)
- Developed by:
  - China Earthquake Administration (CEA)
  - Italian National Institute for Nuclear Physics (INFN)
  - Chinese and Italian Universities

- 98° inclination Sun synchronous circular orbit
- Altitude ~500 km
- Expected lifetime ~5 years
- Launch scheduled for the first half of 2017
THE CSES MISSION

CSES: China Seismo-Electromagnetic Satellite

Several instruments on board:
- a Search-Coil Magnetometer, a High-Precision Magnetometer and Electric Field Detector for measuring the *magnetic and electric fields*
- a Plasma Analyser Package and a Langmuir Probe for *measurements of local plasma disturbances*
- a GNSS Occultation Receiver and a three frequency (VHF/UHF) Transmitter for the *study of profile disturbance of plasma*
- the High-Energy Particle Package and High-Energy Particle Detector for the *measurement of the flux and spectrum of energetic particles*
THE HEPD DETECTOR

HEPD: High Energy Particle Detector

The High-Energy Particle Detector (HEPD) is developed by the Italian members of the CSES mission.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy range</td>
<td>Electron: 3-100 MeV</td>
</tr>
<tr>
<td></td>
<td>Proton: 30-200 MeV</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>&lt;8° @ 5 MeV</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>&lt;10% @ 5 MeV</td>
</tr>
<tr>
<td>Particle Identification</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Maximum Omni-directional Flux</td>
<td>$10^7$ cm$^{-2}$s$^{-1}$sr$^{-1}$ (accepted by trigger before pre-scaling)</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>-10 °C - +35 °C</td>
</tr>
<tr>
<td>Mass (including electronics)</td>
<td>&lt;43 kg</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>&lt;43 W</td>
</tr>
<tr>
<td>Scientific Data Bus</td>
<td>RS-422</td>
</tr>
<tr>
<td>Data Handling Bus</td>
<td>CAN 2.0</td>
</tr>
<tr>
<td>Operation mode</td>
<td>Event by Event</td>
</tr>
<tr>
<td>Life span</td>
<td>&gt;5 Years</td>
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</table>
THE HEPD DETECTOR

- The **tracker**, made of two planes of double-side silicon micro-strip sensors; each tracker plane includes 3 ladders made of 2 modules.
- The **trigger system**, made of one layer of plastic scintillator, divided into 6 segments; different trigger combinations can be used.
- The **range calorimeter**, which consists of two parts:
  - The first part is made with 16 plastic scintillator planes, 1cm thick.
  - The bottom part of the calorimeter consists of a layer with 9 LYSO crystals.
- The **veto system**, five plastic scintillator counters, 5 mm thick.
- The **electronics sub-system**.
EXPECTED RATE

Expected rate of cosmic rays along the satellite orbit

Data from PAMELA experiment

Period: July, 7th – November, 30th 2006 (142 Days)
December 13th: Solar flares is excluded
Latitude: [-60°;+60°]
Altitude: [490 – 520] km
Geometric factor PAMELA/HEPD ~ 6
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Different trigger masks depending on the orbital zone!
TRIGGER CONFIGURATIONS

Different trigger masks depending on the orbital zone!

1. T1 & P1
2. T1 & P1 & P2
3. T1 & P1 & P2 & P3
4. T1 & (P1 || P2)
5. (T1,3 || T1,4) & (P1)
6. T1 & (P1 || P2) & (P16 || P15)
7. T1 & (P1 || P2) & P17
MC SIMULATION

ELECTRONS 1-200 MeV
$10^9$ Events

PROTONS 10-500 MeV
$10^9$ Events
TRIGGER CONFIGURATIONS

Different trigger masks depending on the orbital zone!

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2. T1 & P1 & P2
3. T1 & P1 & P2 & P3
4. T1 & (P1 || P2)
5. (T1,3 || T1,4) & (P1)
6. T1 & (P1 || P2) & (P16 || P15)
7. T1 & (P1 || P2) & P17

Each of these configurations have to be considered:
• without veto
• with lateral veto
• with the whole veto (lateral+bottom)
Estimates of the electron discrimination power against protons

$dE$ vs $E$ method for discriminating electrons against protons

~45 @ 200 MeV
**ELECTRON/PROTON DISCRIMINATION**

- **dE vs E** method for discriminating electrons against protons
  
  - **dE**: is the particle energy loss within the two layers of the silicon tracker
  - **E**: is the energy released in the whole detector.

  ![Graph showing dE vs E for electron and proton distributions](image)

  - Electron and proton distributions are very different
  - Proton contamination into electron sample is negligible
### ELE - ENERGY RESOLUTION

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Graph 1</th>
<th>Graph 2</th>
<th>Graph 3</th>
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<tbody>
<tr>
<td>3</td>
<td><img src="image1.png" alt="Graph 1" /></td>
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<td><img src="image3.png" alt="Graph 3" /></td>
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ENERGY RESOLUTION

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Energy range | Electron: 3-100 MeV
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Angular resolution | <8° @ 5 MeV
Energy resolution | <10% @ 5 MeV
Particle Identification | >90%
THE QUALIFICATION MODEL

4 HEPD versions must be produced:

- Electrical Model, EM (2014)
- Structural and Thermal Model, STM (2015)
- Qualification Model, QM (2016)
- Flight Model (FM) (under construction)

Front view: The trigger system with its six segments is visible

The bottom part of the HEPD QM calorimeter. The 9 LYSO crystals are shown

Side view: The 16 plastic scintillator planes can be seen. The PMTs are at the corners of each calorimeter plane
Beam test @BTF of the "Laboratori Nazionali di Frascati" of INFN

- Electrons and positrons from 30 to 150 MeV

Electrons 30 MeV
~10⁴ events

The HEPD QM during the beam test at the BTF.
TEST BEAM @BTF

Beam test @BTF of the "Laboratori Nazionali di Frascati" of INFN
- Electrons and positrons from 30 to 150 MeV

Electrons 30 MeV
~10^4 events
CONCLUSIONS

- Trigger configurations have been chosen according to the available bandwidth for the data transfer
  - It is changed depending on the orbital zones crossed by the satellite
- Requests on energy resolution and electron/proton discrimination have been answered
- HEPD Qualification Model has been tested
  - Beam test @BTF of the "Laboratori Nazionali di Frascati" of INFN
    Data under study
- HEPD Flight Model under construction
  - Delivery on September/October 2016