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 Sunsynchronous circular orbit
- Altitude ~500 km
- Expected lifetime ~5 years
- Launch scheduled for 2017, August
**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 – LIMADOU 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>$10^7 \text{ cm}^{-2}\text{s}^{-1}\text{sr}^{-1}$ (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>
</tr>
</tbody>
</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

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
THE HEPD MODELS

4 HEPD versions must be produced:

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

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
~10^4 events

The HEPD FM during the beam test at the BTF

Preliminary
TEST BEAM @BTF

The HEPD FM during the beam test at the BTF
**TEST BEAM @BTF**

Electrons 30 MeV

Total ADC counters vs. number of hit Calo counters

Hit channels for beam centered in position T4
**TEST BEAM @BTF**

Total charge measured in the Calo ($\sum_i P_i$)

\[ \chi^2 / \text{ndf} = 66.05 / 9 \]
- Constant: $64.7 \pm 14.6$
- Mean: $2533 \pm 7.9$
- Sigma: $395.4 \pm 5.1$

Sigma/Peak: 0.111

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**Electrons 30 MeV**

Event selection:
- No Lateral Veto hit
- No Bottom veto hit
- More than 12 crossed planes

Total charge measured in the Calo for different impact point of the beam

\[ \chi^2 / \text{ndf} = 30.34 / 21 \]
- Constant: $228.7 \pm 5.7$
- Mean: $7357 \pm 6.6$
- Sigma: $1133 \pm 21.5$

Sigma/Peak: 0.154

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B. Panico – EPS/HEP 05-12 July 2017, Venice
Electrons 30 – 120 MeV

Event selection:
NoLateral Veto hit
No Bottom veto hit
More than 12 crossed planes

Counts are normalized to the LYSO central cristal
**TEST BEAM @BTF**

**Electrons 30 – 120 MeV**

Event selection:
- NoLateral Veto hit
- No Bottom veto hit
- More than 12 crossed planes

**UPPER Calo**

- Signal/Peak
  - Y-axis: 0.16 to 0.02
  - X-axis: 40 to 120 MeV

**LYSO**

- ADC events (LYSO peak)
  - Y-axis: 0 to 400
  - X-axis: Energy loss (MeV)

TEST BEAM @Trento

Beam test @Proton Cyclotron of Trento

- Protons from 51 to 300 MeV

Number of hit Calo planes

The HEPD FM during the beam test at Trento
TEST BEAM @Trento

Energy loss in the Calo

37 MeV
Sigma/peak 0.11

51 MeV
Sigma/peak 0.09

70 MeV
Sigma/peak 0.08

100 MeV
Sigma/peak 0.08

125 MeV
Sigma/peak 0.07

154 MeV
Sigma/peak 0.07

174 MeV
Sigma/peak 0.09

228 MeV
Sigma/peak 0.08
TEST BEAMS

Fully contained protons

Not contained protons

B. Panico – EPS/HEP 05-12 July 2017, Venice
Energy loss in the LYSO

154 MeV
Sigma/peak 0.33

174 MeV
Sigma/peak 0.09

228 MeV
Sigma/peak 0.05

Energy resolution for fully contained 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 Flight Model has been tested

  ✓ Beam test @BTF of the "Laboratori Nazionali di Frascati" of INFN
  ✓ Beam test @Proton Cyclotron of Trento
      Data under study

✓ HEPD Flight on August, 16th 2017