PROCEEDINGS OF SCIENCE

The High Energy Particle Detector for the second China Seismo-Electromagnetic Satellite

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The CSES (China Seismo-Electromagnetic Satellite) is a multi-instrumental scientific space program devoted to study the near-Earth electromagnetic, plasma and particle environment to understand the seismo-associated disturbances in the ionosphere-magnetosphere transition zone. In particular, the mission aims at confirming the existence of possible temporal correlations between the occurrence of medium and large magnitude earthquakes and the observation in space of electromagnetic perturbations, plasma variations and precipitation of bursts of high-energy charged particles from the inner Van Allen belt.

The second satellite (CSES-02) is currently under development and its launch is expected by the beginning of 2023. One of the instruments on board the satellites is a particle detector (HEPD-02, High-energy Particle Detector). This high-precision particle detector measures electrons in the energy range between 3 and 100 MeV, protons between 30 and 200 MeV, as well as light nuclei in the MeV energy window.

The HEPD-02 detector will be composed of a tracker made of Monolithic Active Pixel Sensors, a double layer of crossed plastic scintillators for trigger and a calorimeter. The calorimeter will be constituted by a tower of plastic scintillator and two-segmented planes of inorganic LYSO crystals. The calorimeter is surrounded by five scintillator planes used as a veto system.

This contribution describes the new architecture and the main characteristics of HEPD-02, with a focus on the choices made to meet the challenging scientific objectives of the mission.

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1. Introduction

The China Seismo Electromagnetic Satellite is a space mission developed to monitor earthquake-related electromagnetic field and particles in the Ionosphere [1].

The objectives of CSES are to study seismo-ionospheric perturbations of

- electromagnetic field
- plasma
- particles
- and their correlation with geophysical activity.

The CSES mission aims at monitoring earthquake-related electromagnetic field and particles in the ionosphere building a constellation of multi-instrument payload [2]. Among the instruments onboard, there is the High Energy Detector, built by the Italian CSES-Limadou Collaboration.

The first satellite of the constellation has been launched on February, 2nd 2018 and has been operational since then.

This paper describes the main characteristics of HEPD-02, paying particular attention to the improvements and upgrades with respect to the HEPD-01.

2. The High Energy Particle Detector

The HEPD has been designed to measure:

- Seismo-induced perturbations of the inner Van Allen belt
- Galactic and solar particles
- Solar physics [3]

In order to meet these scientific goals, the HEPD is composed of several detectors:

- Trigger: 2 crossed layers of segmented plastic scintillators (T1 and T2 in Figure 1)
- Tracker: 3 layers of ALPIDE CMOS pixel chips placed after the first trigger plane to limit the effect of multiple scattering on the direction measurement. Each MAPS layer measures (x,y) and combining the three layers it is possible to track in 3d space.
- Calorimeter: made up by 12 layers of 10 mm thick plastic scintillator (EJ-200) planes and 2 crossed layers segmented into 3 bars of LYSO crystals, which have higher light yeld and allow to improve the range of the calorimeter. The LYSO cristals are slower compared to the plastic scintillator, in order to perform a better measure of the signal of the LYSO, the read-out chips of the signals coming from PMT have been updated in HEPD-02.
- Veto system: made of four 4 lateral and one bottom planes of 8 mm thick plastic scintillators surrounding the calorimeter. The Veto completely contains the calorimeter.

All the scintillators are read out by two Hamamatsu R9880-210 PMT building up to the total of 64 channels. A schematic view of the instrument is shown in Fig. 1. The tracker and the trigger have been improved since HEPD-01, hence they are described in more detail in the following sections.

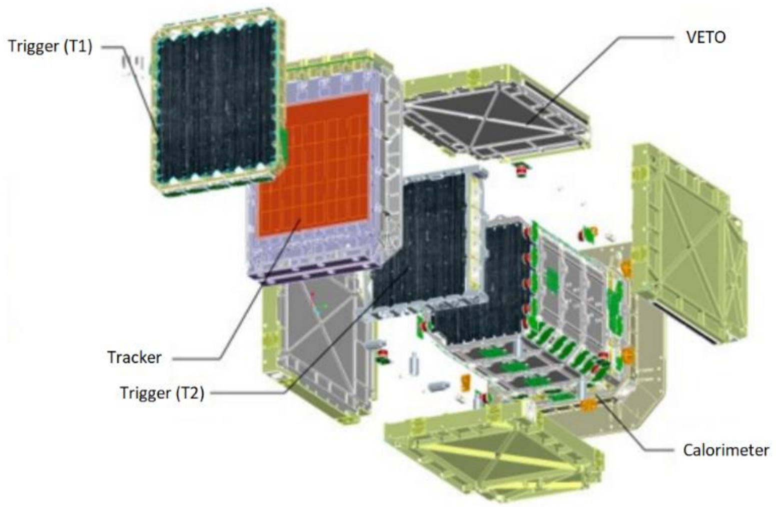

Figure 1. A schematic view of the detector design of the HEPD-02.

2.1 The trigger

The trigger system has been designed to cope with the increased fluxes of polar orbits [4], for this reason it is 2 crossed layers of segmented scintillator planes EJ-200.

In addition, to match the tracking modules the first plane is segmented into 5 counters read out by light-guides connected to PMTs. These photomultipliers are coupled to the paddle via light guides, designed in order to match both the shape of the scintillator bar and the aperture of the phototube to optimize the light collection. The first plane (T1 in Figure 1) is 2 mm thick to minimize multiple scattering and allow a low threshold.

The second plane (T2 in Figure 1) is segmented into 4 ticker layers to give a good measure of the energy loss of charged particles. All counters are covered with a reflective coating and read out by two PMTs placed on opposite sides or corner of the scintillators to improve the uniformity of light collection.

2.2 The tracker

The tracker is the most innovative component of the HEPD-02 compared to HEPD-01. In fact, for the second satellite, the tracker is constituted by 3 planes of ALPIDE CMOS pixel chips [5], developed for the ALICE experiment at LHC, which will be used in space for the first time, demonstrating how knowledge from high-energy physics can be successfully transferred to other fields of science and technology.

Each sensitive plane is composed of 5 independent tracking modules. The pixel detector allows to reduce systematic uncertainties on tracking: single-hit resolution up to six times better and without multi-hit degeneracy. Every plane has 10 ALPIDE sensors organised in two rows (15 x 150 mm^2 each). Control and read-out based on ultra-thin (180 nm) flexible printed circuits. A prototype of the tracker is shown in Figure 2.

Figure 2. A prototype of the tracker of HEPD-02.

In adapting the ALPIDE CMOS pixel chips several challenges for use in space had to be addressed:

- Light support (Carbon Fiber Reinforced Plastics staves) to avoid multiple scattering
- Support must withstand launch acceleration and vibration
- Heat dissipation and material outgassing in vacuum
- Limited power budget

3. Conclusions

At the moment, the design of the instrument is in advanced stage of development. The qualification models for both the mechanics and the electronics of the various subsystems are under production.

HEPD-02 detector design, simulation, mechanical and thermal design as well as subsystems interfaces and communication protocol are finalized.

Testing of prototypes (tracker, PMTs, trigger) are in progress and everything is on track for a launch in 2023.

References

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