Abstract—In this paper, we describe the new architecture and main characteristics of the High Energy Particle Detector (HEPD) for the second Chinese Seismo Electromagnetic Satellite (CSES). We present the characteristics of the detector and electronics, highlighting the improvements with respect to HEPD-01, the first instrument currently flying on board CSES-01 launched on February 2, 2018. The two CSES satellites will form the basis for the construction of the satellite constellation planned for the future. The HEPD-02 instrument, developed by the Italian "Limadou" collaboration, consists of the following subsystems: detector, electronics, power supplies and mechanics. The detector comprises the following subsystems: a Tracker, a Trigger, an Energy and Veto detector; the electronic subsystem consists of the following boards: Trigger, the Tracker Data Acquisition (T-DAQ) and the Data Processing and Control Unit (DPCU). HEPD-02 will be able to work in different configurations depending on the orbital position, in order to manage the different particle fluxes encountered in space.

Index Terms—Astrophysics, Low earth orbit satellites, Space technology, Earth Observing System

I. INTRODUCTION

THE High Energy Particle Detector (HEPD) is designed to provide good energy (at least 10% at E~5 MeV) and angular resolutions (at least 8° at E > 5 MeV) for electrons in the energy range 3 to 100 MeV and for protons in the energy range 30 to 200 MeV. We present the characteristics of the detector and electronics, highlighting the improvements with respect to HEPD-01 [1] [2], the first instrument currently flying on board CSES-01, launched on February 2, 2018.

II. THE DETECTOR ARCHITECTURE AND SYSTEM DESCRIPTION

The detector has an architecture based on (Fig. 1.): a tracker, a trigger plane made of two crossed layers of five scintillator counters and a range calorimeter. The range calorimeter is composed of a tower of 12 scintillator counters, a matrix of inorganic scintillators and a veto system made of five thick scintillators that surrounds the calorimeter. The HEPD-02 comprises four subsystems: Detector subsystem (DEC), Electronics subsystem (ELS), Power Supply Subsystem (PWS), Mechanical subsystem (MEC).

A. Mechanical Subsystem (MEC)

The detector mechanical structure includes five panels and a baseplate for coupling to the satellite, a mechanical box for the electronic subsystem and the mechanics for anchoring the tracker and calorimeter. The baseplate has the task of disposing the heat generated by the electronics; in addition, the other parts of the mechanical sub-system are fixed on it.

B. Detector Subsystem (DEC)

The Detector subsystem DEC consists of: tracker Detector, Trigger Detector, Energy Detector and Veto Detector.

Fig. 1. HEPD-02 architecture.

For the new tracker we are opting for a solution based on a CMOS pixel sensor. Respect to HEPD-01, this technology
reduces systematic uncertainties on tracking, giving a single-hit resolution up to 6 times better and do not suffer from multi-hit degeneracy.

The Trigger Detector (Fig. 2) consists of two thin plastic scintillator planes read out by PMTs of dimensions 200x180x2 mm³ segmented in 5 counters (dimensions 200x30x2 mm³ each excluding mechanics); each counter is covered with reflective coating and read out by PMTs (Hamamatsu R9880-210) through light-guides connected, one on each side. The segmented trigger layer, in coincidence with one or more planes of the calorimeter, provides the HEPD trigger signal.

The Energy Detector is a calorimeter consisting of 12 scintillator planes and a 3 x 3 matrix of inorganic crystals on the bottom of the tower. Each plastic scintillator plane is covered with diffusing coating and measures 150x150x10 mm³ (excluding mechanics). It is read out by two PMTs (Hamamatsu R9880-210) located on opposite corners. The inorganic crystal plane measures 150 x 150 x 40 mm³ and consists of a matrix of 3 x 3 blocks; each block of dimensions 48 x 48 x 40 mm³ (excluding mechanics) is covered by diffusing coating and read out by PMT (Hamamatsu R9880-210) located on the bottom face. The Veto Detector consists of five plastic scintillator planes (four lateral and one at the bottom of the instrument), each covered with diffusing coating and read out by two PMTs (Hamamatsu R9880-210) located on opposite corners.

C. Electronic Subsystem (ELS)

The ELS subsystem contains the necessary electronics for management and acquisition of signals from the DETECTOR subsystem, system and HOUSEKEEPING management, satellite interface management and power supply management. The ELS consists of the following modules: Trigger, T-DAQ, DPCU, LV-PS and HV-PS. Each module has its own dedicated mechanics that allows anchoring to the HEPD-02 baseplate and heat dissipation. The communication and power electrical interconnection between the various modules is carried out using custom harness made using Glenair microD connector and Glenair Ambestrand braided EMI shield.

III. ELECTRONIC SUBSYSTEM IN DETAIL

Most of the improvements of HEPD-02 compared to HEPD-01 concerns electronics. With regard to Front-end electronics, attention was paid to improve the PMTs signal management. While with regard to system management, it was decided to replace the previous architecture based on an DSP ADSP2189 and an ACTEL FPGA Flashpro3 with a board based on Xilinx SoC. The design of the two high and low voltage power supply has also been reviewed and improved. All the electronic sub-systems have been designed using a HOT/COLD redundancy and the communications between the various modules of which it is composed is carried out by means of the SPACEWIRE LITE protocol.

A. DPCU (Data Processing and Control Unit)

The HEPD-01 CPU board is replaced by the DPCU in HEPD-02. This board has a Xilinx Zynq 7000 Series SoC FPGA unit as its central unit, flanked by a small FPGA Proasic3 MICROSEMI. The board includes the memory necessary for processing and the provisional data storing. Zynq has the task of managing the TC/TM interface from the satellite based on the CAN protocol and the transfer of scientific data packets on the dedicated channel. ProAsic3, given its inherent radiation tolerance, has the task of: acting as a watchdog, selecting the boot device for the Zynq and possibly acting as an external Scrubber for the Zynq programming memory.

B. Trigger

The trigger board is responsible for generating and distributing the system trigger as well as for PMT signals acquisition and processing. In the new board, in order to improve the management of PMT signals and the generation of triggers, the EASIROC based architecture [2] [3] is reviewed with one based on CITIROC.

C. T-DAQ (Tracker-DataAquisition)

The T-DAQ board, starting from the trigger received, has the task of starting the acquisition of the pixel tracer signals and pre-packing the data obtained and sending them to the DPCU for the creation of event/RUN data packets.

D. LV-PS (LowVoltage-PowerSupply)

The LV-PS module is based on a HOT/COLD architecture and has the task of generating all the secondary power supplies needed for all the ELS modules. The module also manages the wired ON/OFF telecommands (TCs) received from satellite and send the wired telemetry (TM). The module also has the task of monitoring and managing all the overcurrent situations on the output power lines. The power supply telemetry data are sent to the DPCU to be sent to the ground.

E. HV-PS (HighVoltage-PowerSupply)

The HV-PS module has the task of generating and managing the high voltage (HV) power supplies required for PMTs. The architecture of the module foresees a HOT/COLD redundancy and the HV generation is carried out by means of step-up DC/DC managed by the control board present in the module itself. The control board receives the configuration from the DPCU and sends back the high voltage telemetry data.

REFERENCES