The electronics of the HEPD of the CSES experiment

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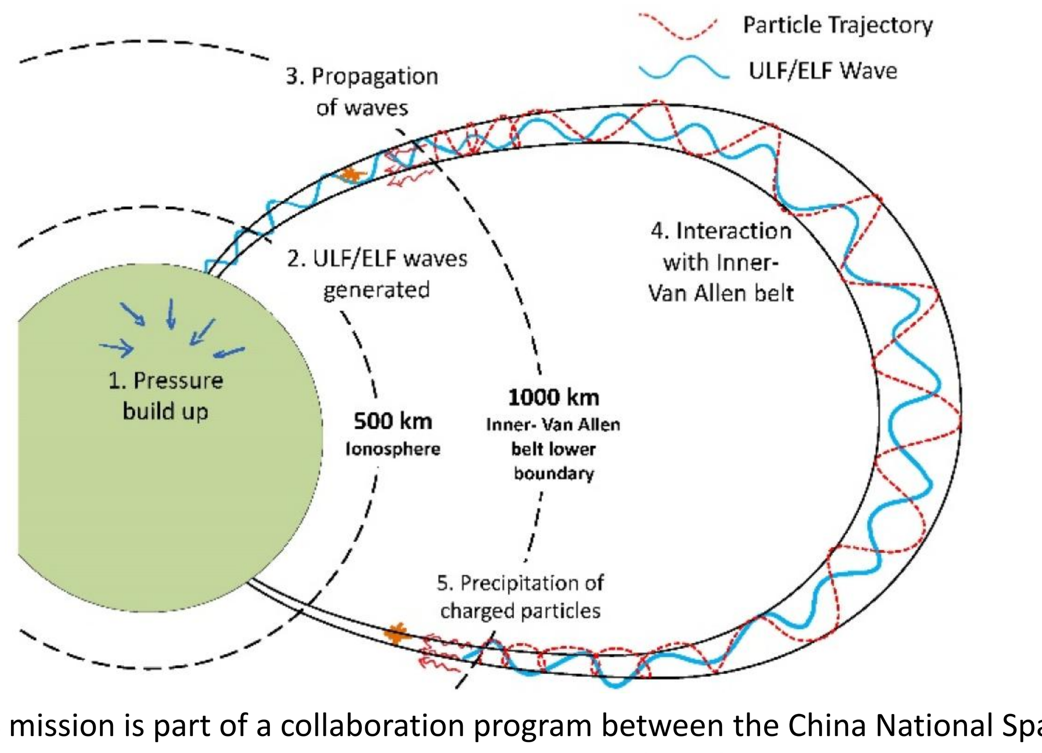
ABSTRACT: The China Seismo Electromagnetic Satellite (CSES) aims to contribute to the monitoring of earthquakes from space. This space mission, lead by a Chinese-Italian collaboration, will study phenomena of electromagnetic nature and their correlation with the geophysical activity. The satellite will be launched in 2017 and will host several instruments onboard: two magnetometers, an electrical field detector, a plasma analyzer, a Langmiur probe and the High Energy Particle Detector (HEPD).

The HEPD, built by the Italian collaboration, will study the temporal stability of the inner Van Allen radiation belts, investigating precipitation of trapped particles induced by magnetospheric, ionosferic and tropospheric electromagnetic emissions, as well as by seismo-electromagnetic disturbances. It consists of two layers of plastic scintillators for trigger and a calorimeter. The direction of the incident particle is provided by two planes of double-side silicon microstrip detectors. HEPD is capable of separating electrons and protons and identify nuclei up to Iron. The HEPD will study the low energy component of cosmic rays too. The HEPD comprises the following subsystems: detector, electronics, power supply and mechanics. The electronics can be divided in three blocks: silicon detector, scintillator detectors (trigger, energy and veto detectors) and global control and data managing.

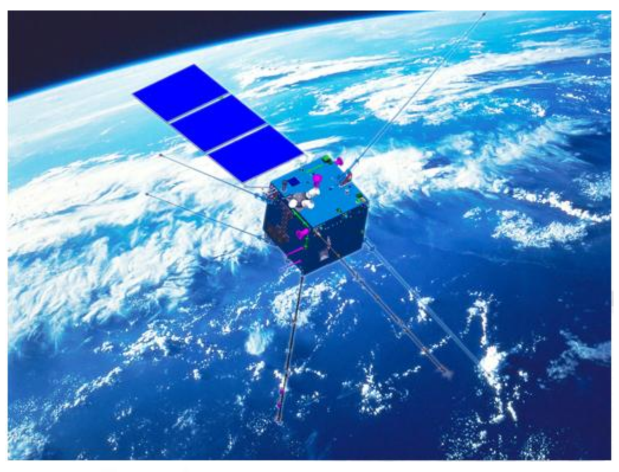
CSES-Limadou mission

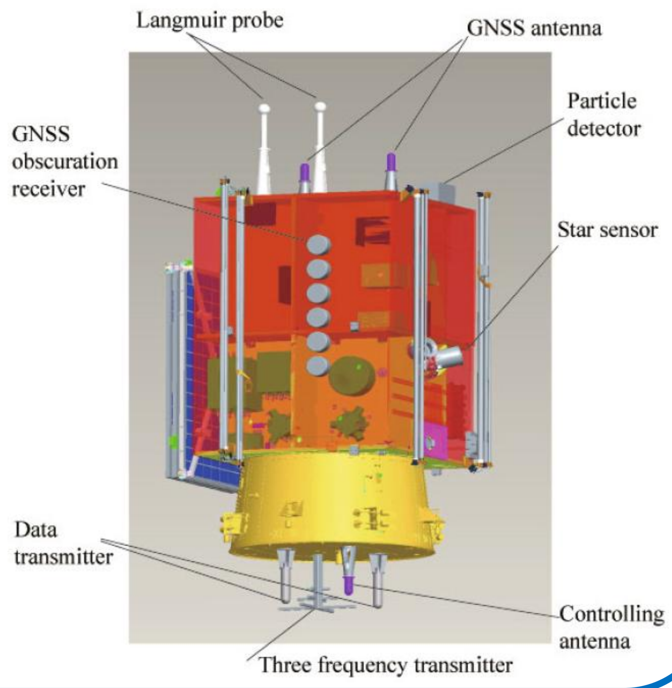


CSES is a scientific mission dedicated to monitoring electromagnetic, plasma and particles perturbations of atmosphere, ionosphere, magnetosphere and Van Allen belts induced by natural sources and anthropocentric emitters and to study their correlations with the occurrence of seismic events. CSES mission will investigate the structure and the dynamic of the topside ionosphere, the coupling mechanisms with the lower and higher plasma layers and the temporal variations of the geomagnetic field, in quiet and disturbed conditions.

Among the possible anomalies generated by a seismic event, bursts of Van Allen belt electron fluxes in the magnetosphere have been repeatedly reported in literature by various experiments, though a statistical significance was always difficult to claim [1, 2, 3]. A recent study [4] presented a new search for correlation between the precipitation of low energy electrons (E > 0.3 MeV) trapped within the Van Allen Belts and earthquakes with magnitude above 5 Richter scale. The authors used 13 years of electron data measured by the NOAA POES 15, 16, 17 and 18 satellites corresponding to about 18 thousands M>5 earthquakes registered in the NEIC catalog of the U.S. Geological Survey, and found a correlation peak with significance of 5.7 standard deviations.

In order to establish a firm correlation between the lithosphere and the magnetosphere, the CSES satellite aims at measuring such particle bursts, by means of a particle detector sensitive to sudden bursts and capable of separating electrons from protons, the High Energy Particle Detector (HEPD). CSES is sensitive to all radiation, not only that coming inside the Earth's magnetosphere. The high inclination orbit of the satellite allows the telescope to detect particles of different nature during its revolution: galactic cosmic rays - which are modulated by the solar activity at low energies and also solar energetic particles associated to transient phenomena such as Solar Flares or Coronal Mass Ejections.





The CSES mission is part of a collaboration program between the China National Space Administration (CNSA) and the Italian Space Agency (ASI), and developed by China Earthquake Administration (CEA) and Italian National Institute for Nuclear Physics (INFN), together with several Chinese and Italian Universities and research Institutes.

CSES is the first satellite of a space monitoring system proposed in order to investigate the topside ionosphere - with the most advanced techniques and equipment - and designed in order to gather world-wide data of the near-Earth electromagnetic environment. The observations will contribute to provide an observations sharing service for international cooperation and the scientific community.

The satellite will be placed at a 98° Sun-synchronous circular orbit at an altitude about 500 km, the launch is scheduled in the first half of 2017 with an expected lifetime of 5 years. The satellite mass is about 730 kg and the peak power consumption is about 900 W.

The High Energy Particle Detector

The HEPD comprises the following subsystems: detector, electronics, power supply and mechanics. The HEPD detector is contained in an aluminum box, while the electronics cards are placed outside the detector fixed on the base plate by means of a dedicated supporting structure. The outside surface is covered with aluminized polyimide layer to assure a good thermal insulation.

The detector consists of three components:

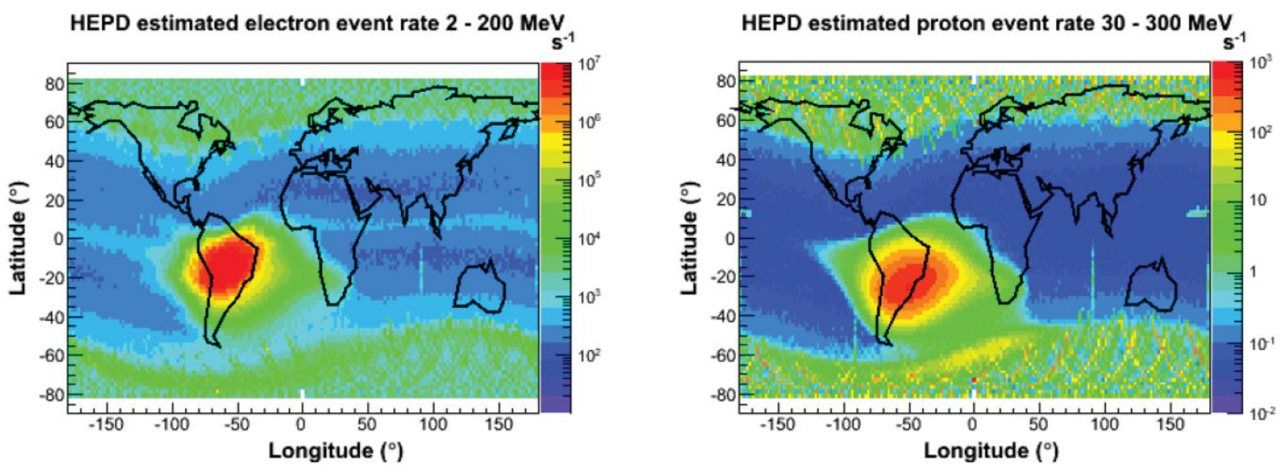
- **Silicon planes: two planes of double-side silicon micro-strip detectors are placed on the top of the detector in order to track the direction of the incident particle limiting the effect of Coulomb multiple scattering on the direction measurement**
- **Trigger: two layers of plastic scintillators, one thin segmented counter and one deep counter**
- **Calorimeter: a tower of 15 layers of plastic scintillator planes followed by a 3x3 matrix of an inorganic scintillator LYSO**

The calorimeter volume is surrounded by 5 mm thick plastic scintillator veto planes. All the scintillators are read out by photomultiplier tubes (PMTs).

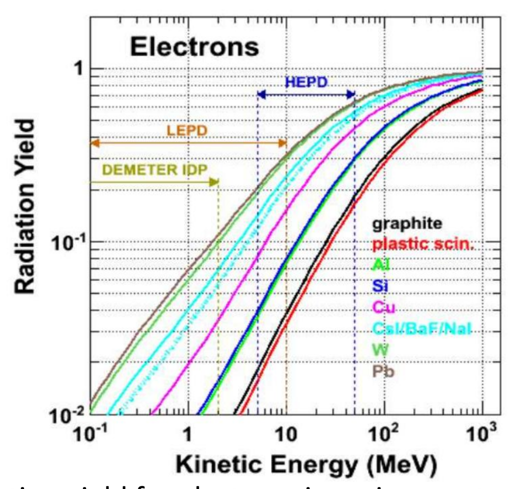
The good energy-loss measurement of the silicon track, combined with the energy resolution of the scintillators and calorimeter, allows identifying electrons with acceptable proton background levels (10^{-5} – 10^{-3}).

Italian groups are developing the Electrical, Mechanical&Thermal, Qualification (QM) and Flight Models (FM) of the HEPD

The HEPD will measure electrons, protons and light nuclei along CSES orbit.

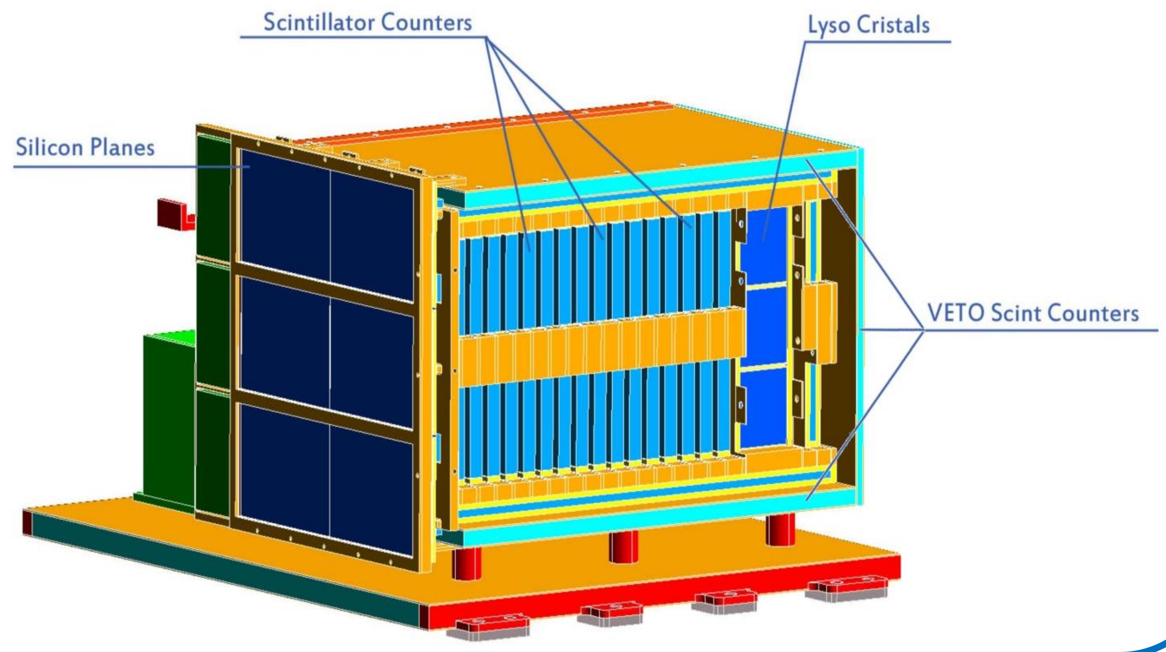


Expected count rates for electrons and protons along the CSES orbit.

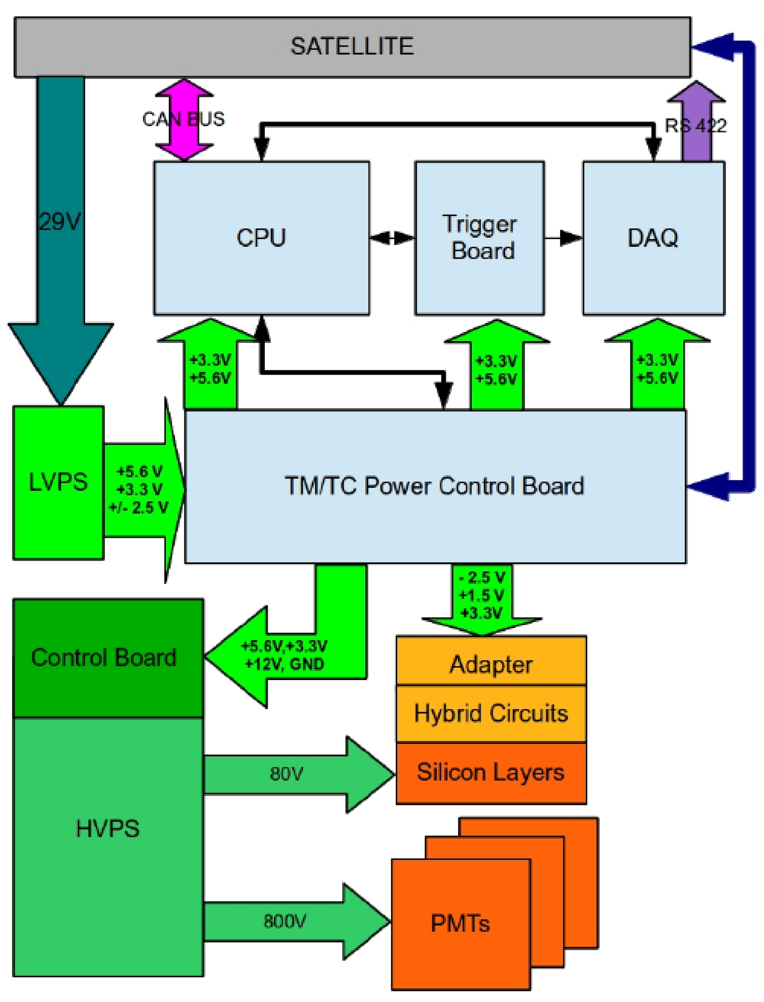


The radiation yield for electrons in various materials from NIST.

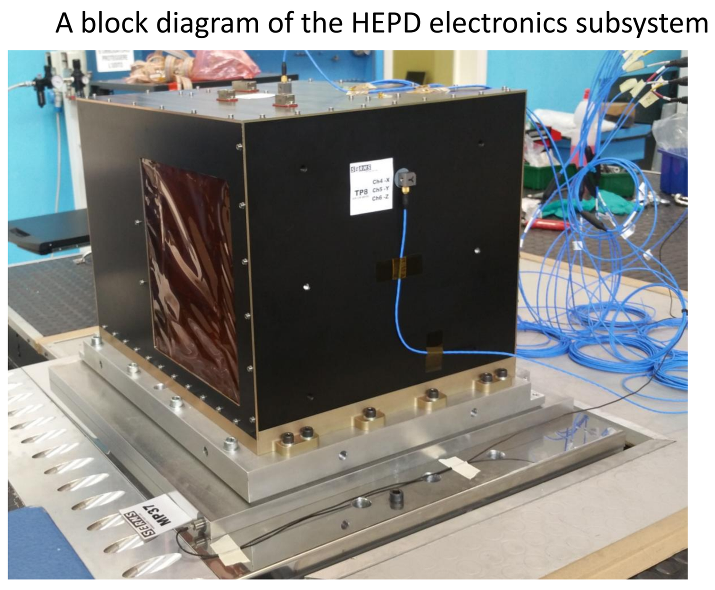
Parameter	Value
Energy range	Electron: 3-100 MeV
	Proton: 30-200 MeV
Angular resolution	<8°@ 5 MeV
Energy resolution	<10% @ 5 MeV
Particle Identification	>90%
Maximum Omni-directional Flux	10^7 $cm^{-2}s^{-1}sr^{-1}$ (accepted by trigger before pre-scaling)
Operating temperature	-10 °C - + 35 °C
Mass (including electronics)	< 43 kg
Power Consumption	< 43 W
Scientific Data Bus	RS-422



The electronics



A block diagram of the HEPD electronics subsystem



The QM of the HEPD during vibration test at SERMS

The electronics can be divided in three blocks:

- Silicon detector
- Scintillator detectors
- Global control and data managing.

Each detector block includes power chain for bias distribution and a data acquisition processing chain. The main Power Supply provides the low voltages to the detector electronics and the high bias voltages for PMTs and silicon modules.

The system is composed by front-end electronics and four boards:

• Data Acquisition (DAQ) Board: manages the scientific data of detector. The board manages the following functionalities:

- Acquisition of Trigger signal from PMT/Trigger board
- Management of hybrid circuits on the silicon planes
- Acquisition of silicon planes data
- Computing of PMTs data & Silicon planes data
- Data compression
- Transmission of scientific data on the scientific data link

• Trigger Board: manages the analog signals coming from the PMTs and to generate the trigger signals needed by the other boards. The main functions of the boards are:

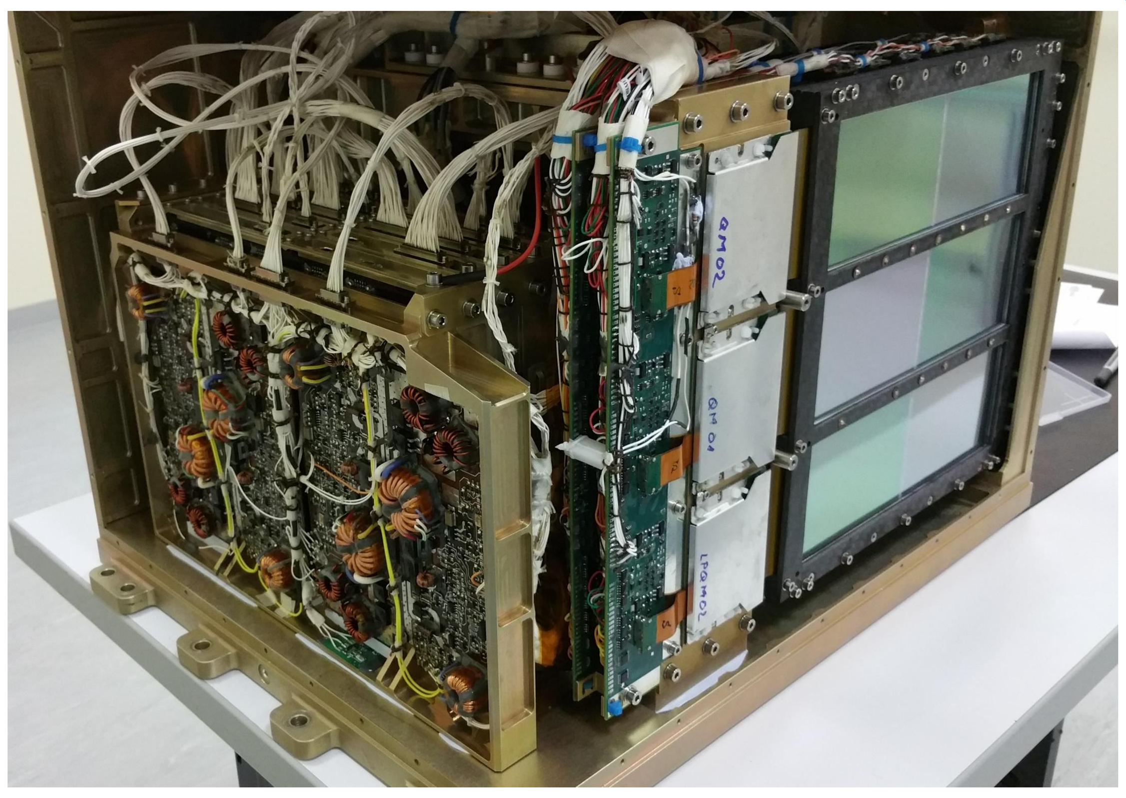
- To acquire the PMTs analog signal using EASIROC Integrated Circuits
- To convert the EASIROC readout signals into digital signals
- To allow the DAQ board to read the EASIROC digital output
- To allow the CPU to configure the EASIROC
- To generate and transmit "slow" event trigger signals manipulating the "fast" trigger signals coming from EASIROC
- To allow the CPU to configure the "slow" trigger generation algorithm

• CPU Board: controls the detector and communicates with the platform of the satellite via CAN BUS interface. The board manages the following functionalities:

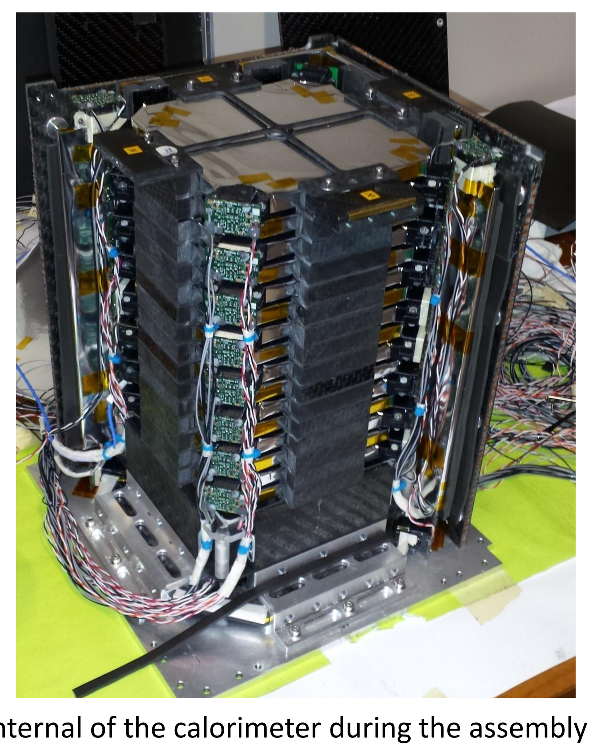
- Communication with Satellite OBDH computer via CAN bus
- Storing of non volatile information
- Management, via internal "slow" control links bus of TM/TC and LVPS control board, Trigger Board and DAQ Board
- Management of system diagnostic routines
- Management of system configuration
- System monitor

• Telemetry/Telecommand board.

All the scintillator detectors transmit signal directly to the Trigger Board before data processing. The Trigger detector provides the fast trigger signals while upper level triggers are implemented in the Trigger Board. The trigger signals of each data processing block are sent to the Trigger Board which controls the ADC acquisition. Afterwards, the ADC data output are sent to the DAQ Board together with Silicon Detector data and processed by a dedicated DSP. The results are written on a DP-RAM waiting to be picked up by the CPU Board.



The electronics and the silicon detector of the HEPD



Internal of the calorimeter during the assembly

All the electronics is designed with embedded "Hot/Cold" redundancy and all the components of the board have been selected capable to withstand a -40°C to +85°C operating range. The maximum data transfer rate from the satellite is 50 GB per day.

The QM of the HEPD has been built, assembled and integrated. The HEPD has been tested at BTF in Frascati (ROMA) at and vibration test have been taken at SERMS (PG).

References

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