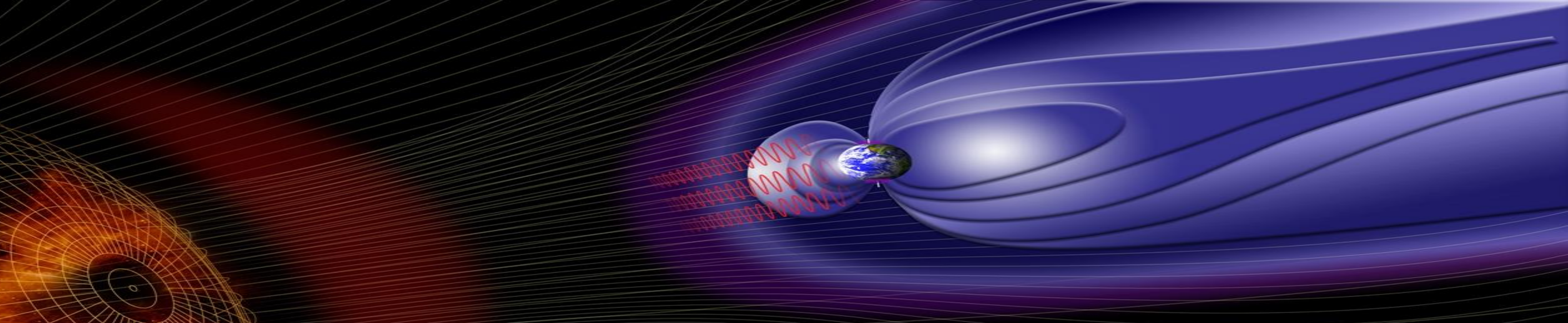
CRIS 2016
10th Cosmic Ray International Seminar



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

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The CSES Mission

The ***China Seismo-Electromagnetic Satellite (CSES)***, is a space mission dedicated to the monitoring of the perturbations originated by electromagnetic emissions (e.m.) in the atmosphere, ionosphere, magnetosphere and in the Van Allen belts [1]. The satellite is based on the Chinese CAST2000 platform. It is a 3-axis attitude stabilized satellite and will be placed in a 97,4° inclination Sun-synchronous circular orbit, at an altitude of ~ 500 km. The launch is scheduled for the first half of 2017 and the expected lifetime is 5 years.

CSES hosts several instruments on board:

1. a Search-Coil Magnetometer, a High Precision Magnetometer and Electric Field Detector for measuring the magnetic and electric fields;
2. a Plasma Analyser Package and a Langmuir Probe for measurements of local plasma disturbances;
3. a GNSS Occultation Receiver and a three frequency (VHF/UHF) Transmitter for the study of profile disturbance of plasma;
4. the High-Energy Particle Package and High-Energy Particle Detector (HEPD) for the measurement of the flux and spectrum of energetic particles.

The CSES mission will investigate the structure and the dynamic of the topside ionosphere, will monitor electric and magnetic field and high energy particle fluctuations, searching for their correlations with the geophysical activity, in order to contribute to the monitoring of earthquakes from space.
CSES will also complement the cosmic ray measurements in an energy range up to few hundreds of MeV, below the one which has been studied so far by current cosmic ray space missions and will contribute to the study of the solar-terrestrial environment with the observation of Coronal Mass Ejections (CMEs).

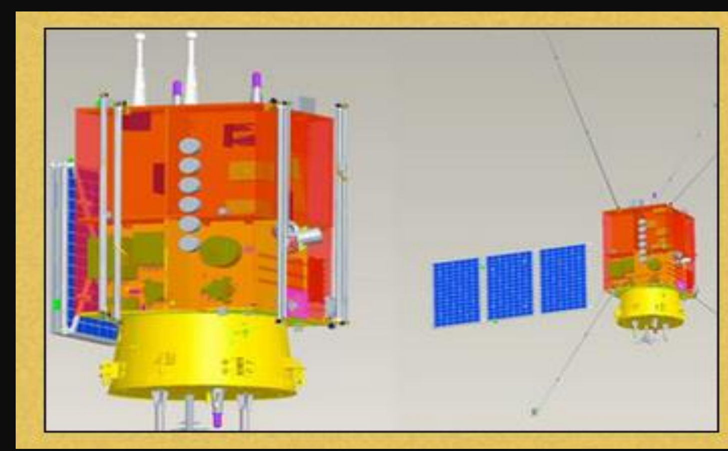


Fig.1: Sketch of the CSES satellite

HEPD

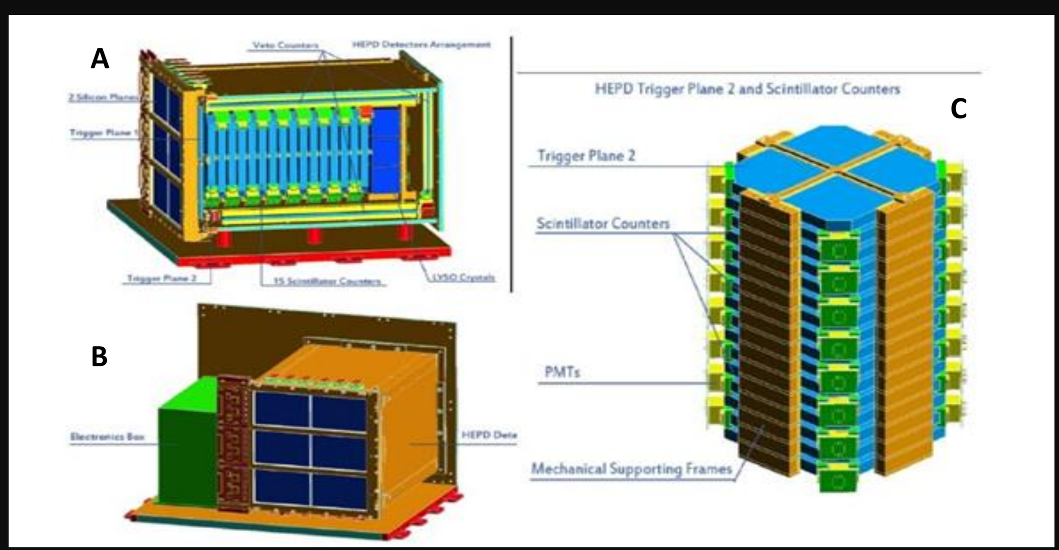


Fig.2: An illustration of the main components of the HEPD: A) Side view with the position of sub-detectors; B) The electronic box; C) The plastic counters of the calorimeter.

The ***High-Energy Particle Detector (HEPD)*** is one of the payloads of the CSES space mission.
The HEPD is built by the Italian collaboration and has different goals. It will study the temporal stability of the inner Van Allen radiation belts, the precipitation of trapped particles in the atmosphere and the low energy component of the cosmic rays (5 - 100 MeV for electrons and 15 - 300 MeV for protons).

The HEPD components are:
- a ***tracker***, made of two planes of double-side silicon micro-strip sensors, at the top of the instrument, to provide the direction of the incident particle;
- the ***trigger system***, e.g. two layers of plastic scintillators read by PMTs, an upper thin one divided into 6 segments;
- a ***calorimeter***, composed by 16 plastic scintillators (15x15x1) cm^3 and a layer (15x15x4) cm^3 of 9 LYSO cubes, all of which read by PMTs;
- a scintillator ***veto system***, 5 mm thick, at sides and at the bottom of the instrument;
- the ***power supply and electronics***, which are inserted in a box placed at one side of the detector.

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
Data Handling Bus	CAN 2.0
Operation mode	Event by Event
Life span	> 5 Years

Fig.3: HEPD main design parameters.

Expected rates

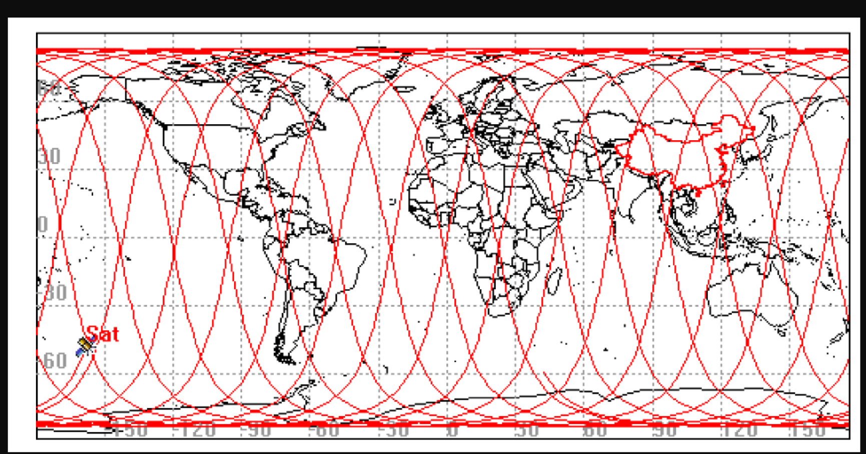


Fig.4: 1-day HEPD orbits

Due to the small amount of signal fluctuation in the electromagnetic component of cosmic rays which occurs during an earthquake, it is very important to have a valuation of the expected background.

Since CSES crosses different orbital zones, the background expectation must be expressed as a function of the coordinates of the satellite.
In Fig. 5 the expected rates for different bins of latitude and longitude are shown. The altitude range considered is similar to that of CSES. The rates have been calculated starting from the real counters given by the PAMELA experiment, with a scale factor which takes into account the different geometry factor.

Also the configuration of trigger mask has to change as a function of orbital zone. There have been many studies about these configurations.

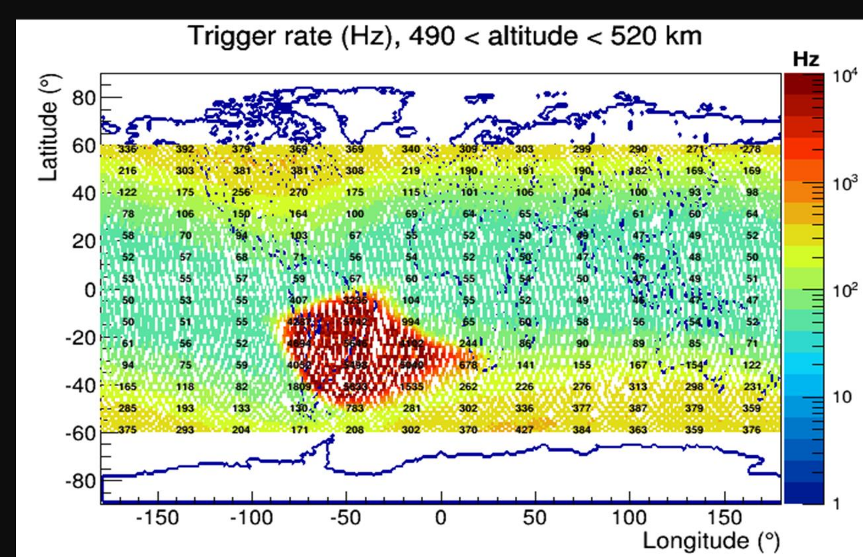


Fig.5: Expected trigger rate for HEPD

MC Simulation

Geant4 simulated system:
- silicon tracker;
- trigger plane;
- calorimeter planes;
- veto systems;
- mechanical structure;
- the top HEPD box and the front satellite wall

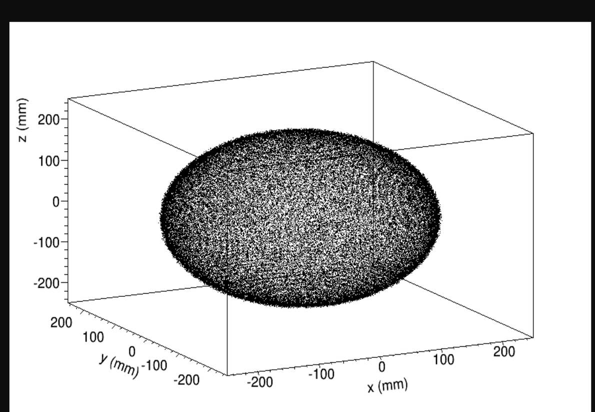
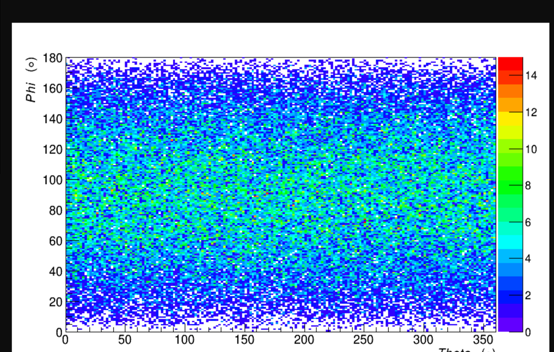


Fig. 6: Simulated homogeneous spherical surface around HEPD
Fig. 7: Angular distribution for the simulated events



10^9 events have been uniformly generated on a spherical surface around HEPD, defined as in Fig. 6.
The corresponding angular distribution for θ and φ is reported in Fig.7.
The simulation have been used to study the trigger masks efficiency, the energy resolution of the calorimeter and the electron/proton discrimination.

Electrons 1-200 MeV
Spectrum $E^{-\gamma}$, γ=2.2
Protons 10-500 MeV
Spectrum $E^{-\gamma}$, γ=2.2

Electron/Proton discrimination

Since, at these energies protons are slow and not relativistic within the HEPD operational range, the *dE vs E* method for discriminating electrons against protons can be used.

Fig. 9: Electron and proton spectra from [2]

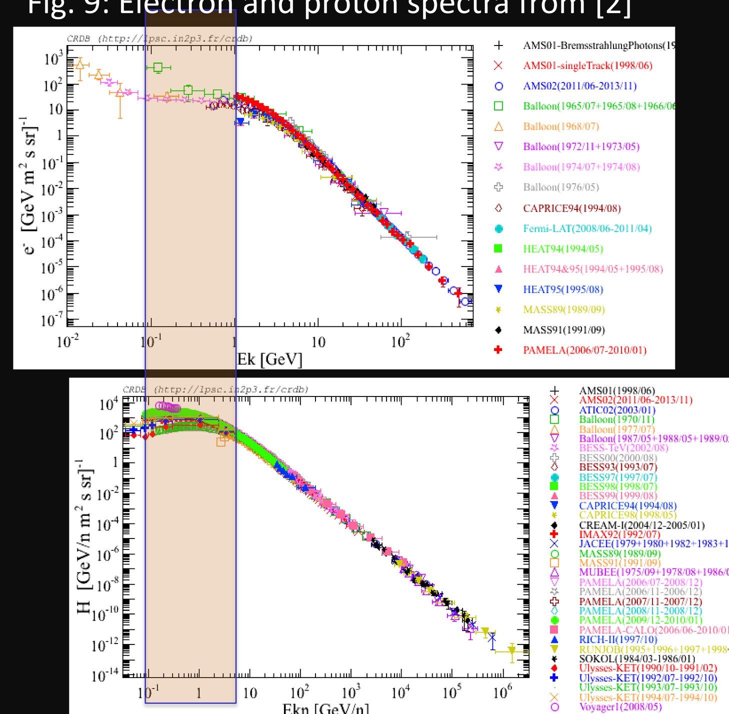
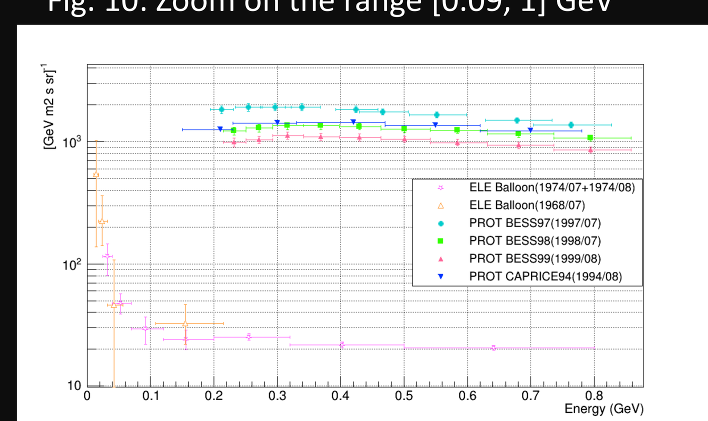


Fig. 10: Zoom on the range [0.09, 1] GeV



To normalize the simulated proton and electron spectra, the results in [2] have been used.
The normalization factor is chosen at 200 MeV, where proton spectrum is ~45 times greater than the electron spectrum

In Fig. 8 the Energy resolution of the HEPD calorimeter is reported. Both for electrons than for protons it is in good agreement with the initial requests.

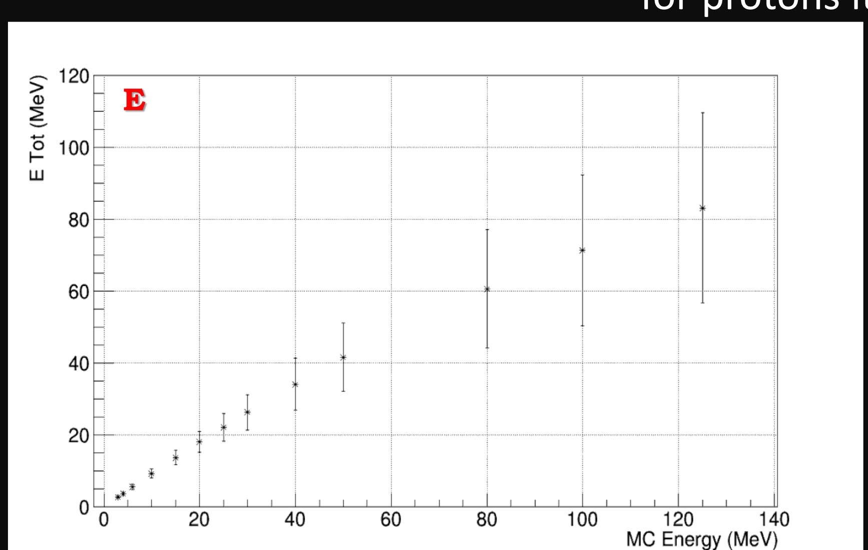
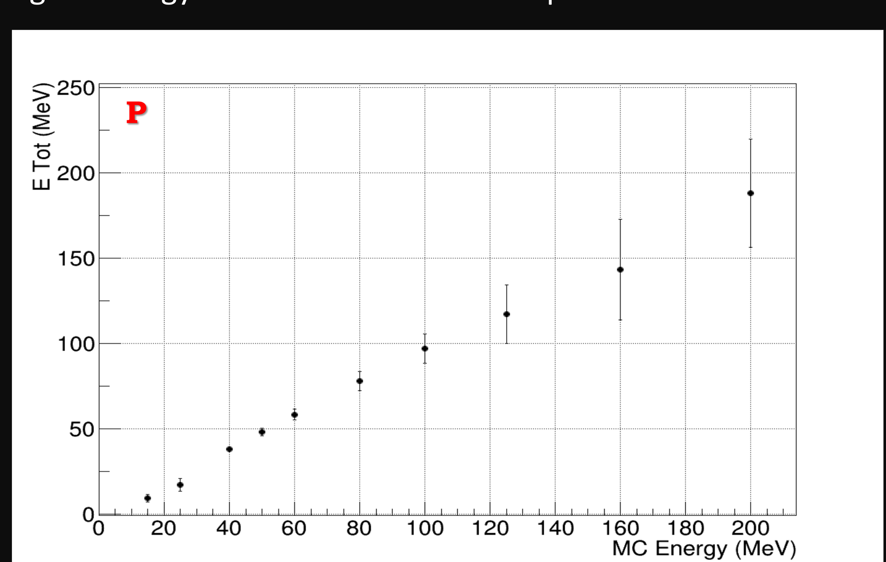
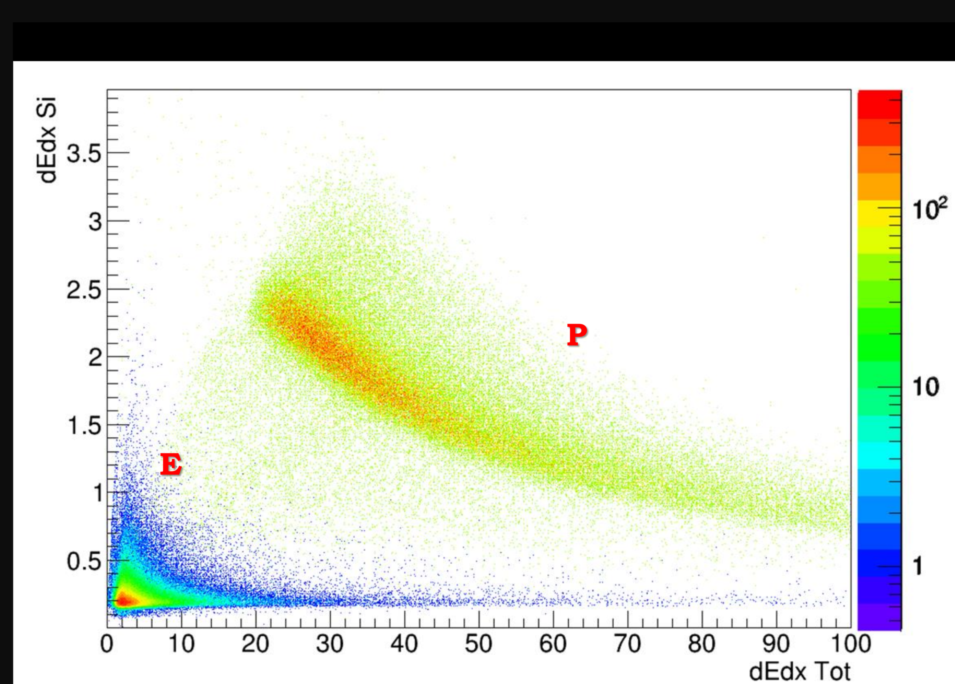


Fig. 8: Energy resolution for simulated protons and electrons





The dE is measured within the two layers of silicon tracker, while the sum of the energy released in the detector provides the E measurement.

The veto system allow to select events completely contained into the calorimeter. Electron and proton distributions are very different and particles lay in separate energy bands.

Fig.11: The dE vs E scatter plot for Monte Carlo simulated electrons and protons.

References
[1] Wang L. et al., Earthq Sci (2015) 28 4, 303
[2] http://lpsc.in2p3.fr/crdb/