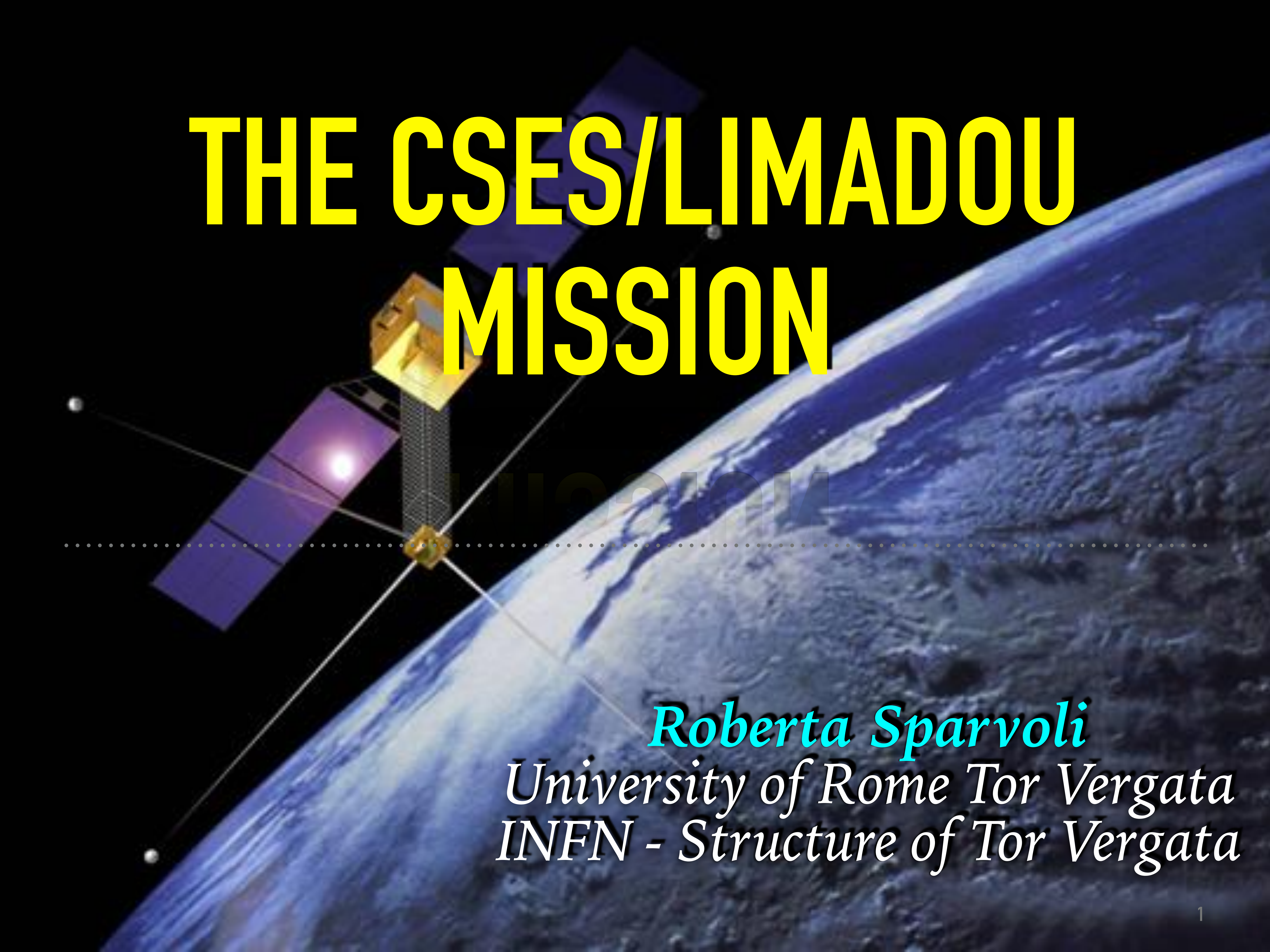


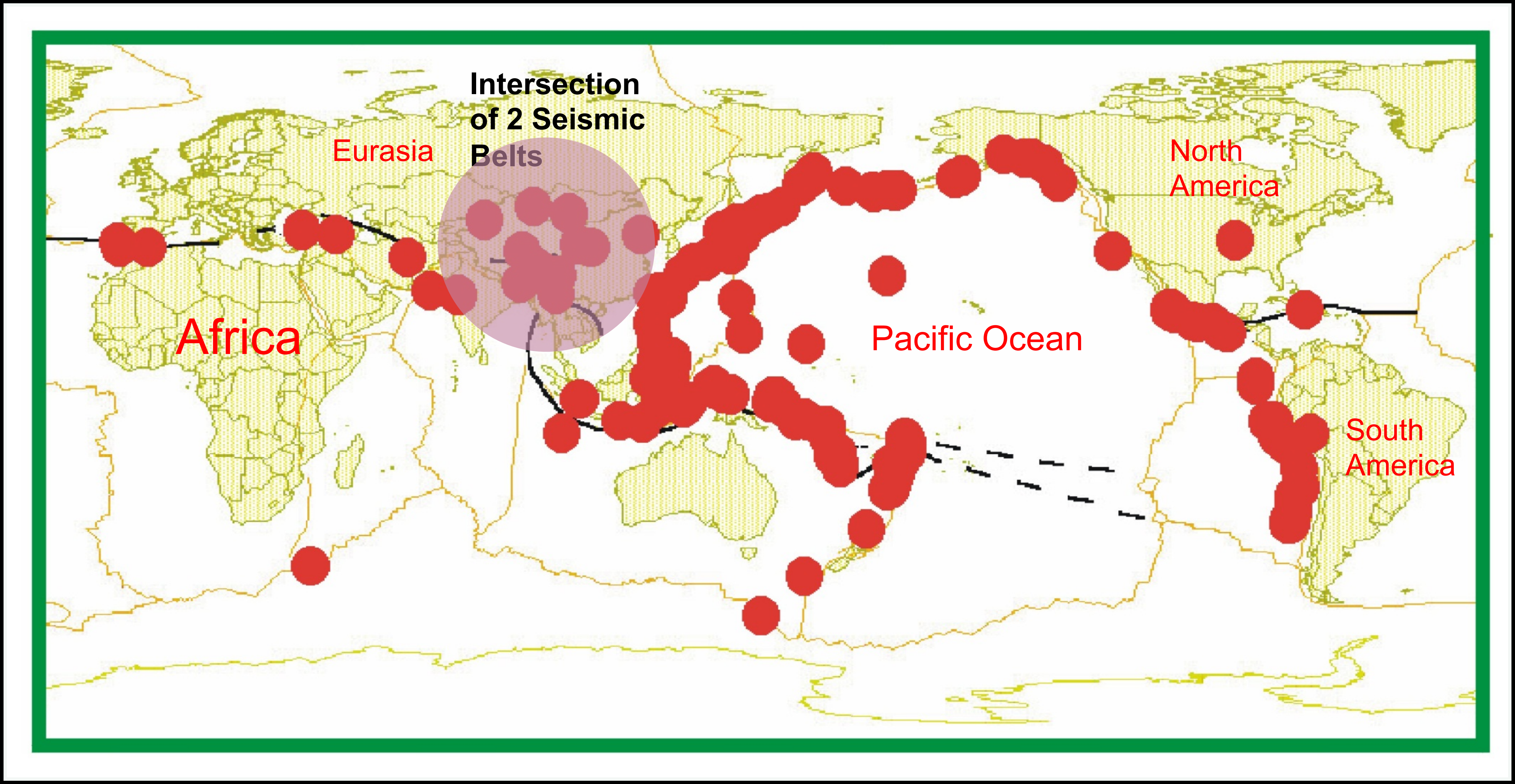
THE CSES/LIMADOU MISSION

Roberta Sparvoli
University of Rome Tor Vergata
INFN - Structure of Tor Vergata

CSES COLLABORATION

- **China**
  - China National Space Administration (CNSA)
  - China Earthquake Administration (CEA)
  - China Aerospace Science and Technology Corporation (CASC)
  - China Academy of Space Technology (CAST)
  - DFH Satellite Co., Ltd
  - Chinese scientific Institutes (Lanzhou LIP, NSSC, CAS, ..)
- **Italy**
  - Italian Space Agency (ASI)
  - Italian National Institute of Nuclear Physics (INFN)
  - Italian National Institute of Astrophysics and Planetology (INAF)
  - Italian National Institute of Geophysics and Vulcanology (INGV)
  - Italian Universities

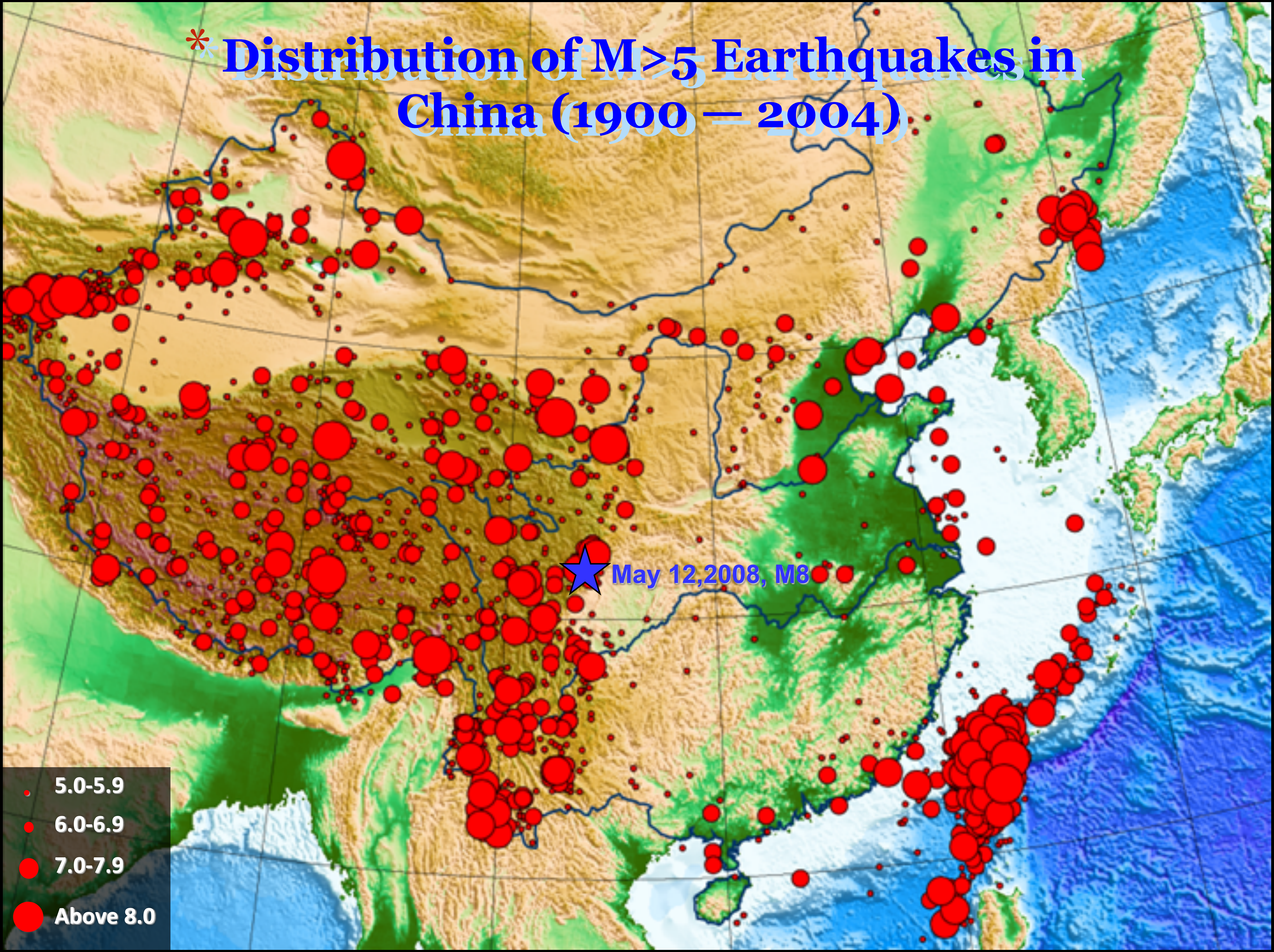
BACKGROUND OF THE CSES SATELLITE



Earthquake prevention and disaster mitigation is one of the common goals of human-being in the world.

China is one of the earthquake-prone countries in the world, with very heavy disasters.

* Distribution of M>5 Earthquakes in China (1900 – 2004)



1976 – TANGSHAN LARGE EARTHQUAKE

The largest earthquake of XX century as for deaths

2008 – SICHUAN EARTHQUAKE

The country was completely destroyed

DIFFICULTIES IN EQ PREDICTIONS

Earthquakes are **a very complex phenomenon**, with a l**ong preparation phase,** that involve measurable changes of physical parameters over huge surfaces with large energy releases.

Worldwide on each day there are

2 Earthquakes with M > 5

Every two days there is

1 Earthquake with M > 6

Despite huge efforts and the deployment of large seismic networks, **ground based, short term earthquakes forecast efforts** have been so far unsuccessful.

HELP FROM SPACE-BASED OBSERVATIONS

In the recent years, (Chinese) seismologists started to pay attention to the development of space observation techniques in earthquake science.

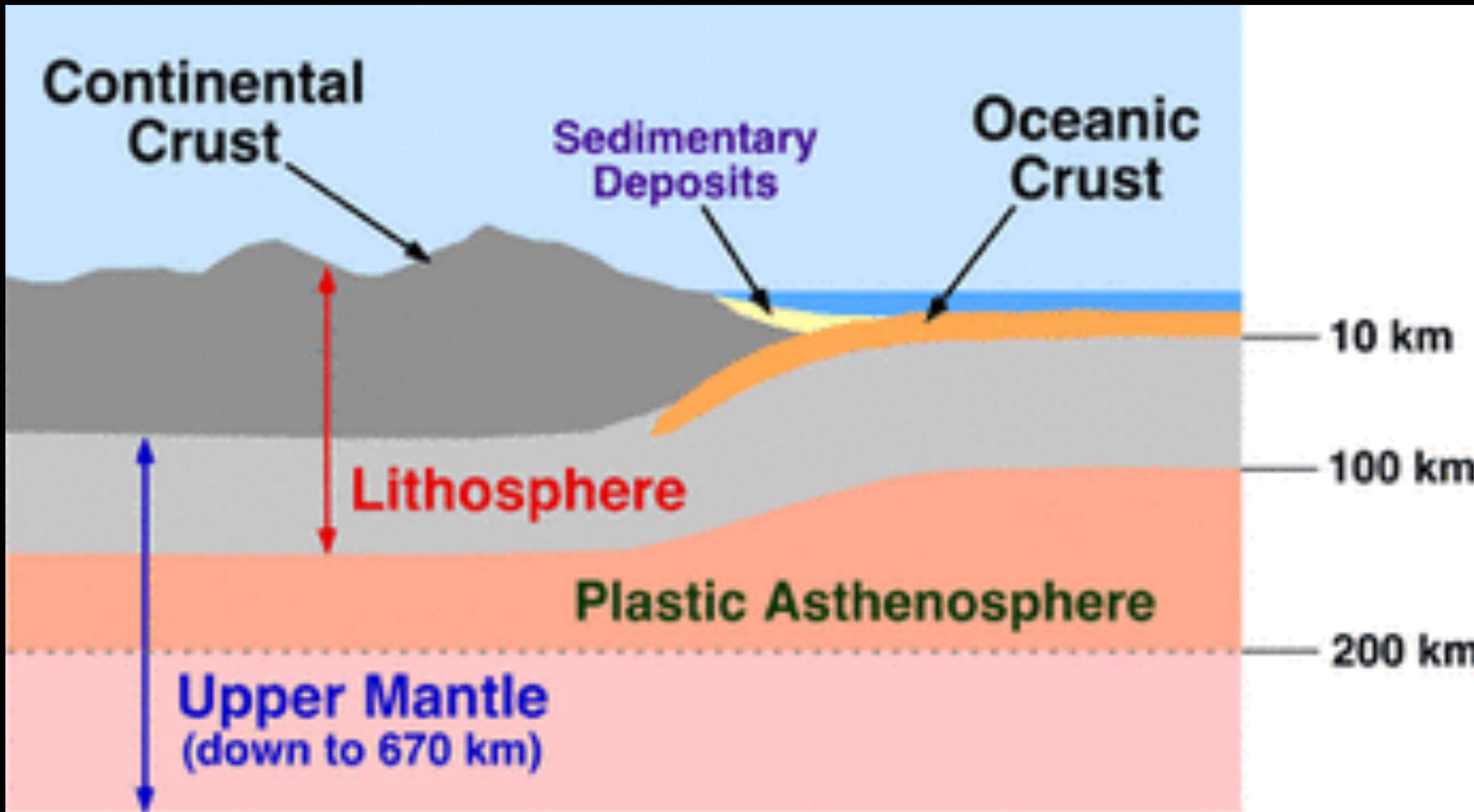
- **Global coverage:** Easily cover regions where ground stations are difficult to build. Ground areas;
- **More opportunity for case studies:** According to statistics, the practical opportunities of researchers for earthquake case studies would increase 25 times w.r.t. the ground based observation;
- **Simultaneous observations:** It is possible to host on the same satellite different high-precision detection instruments.

WHAT DO WE DETECT FROM SPACE FROM AN EARTHQUAKE?

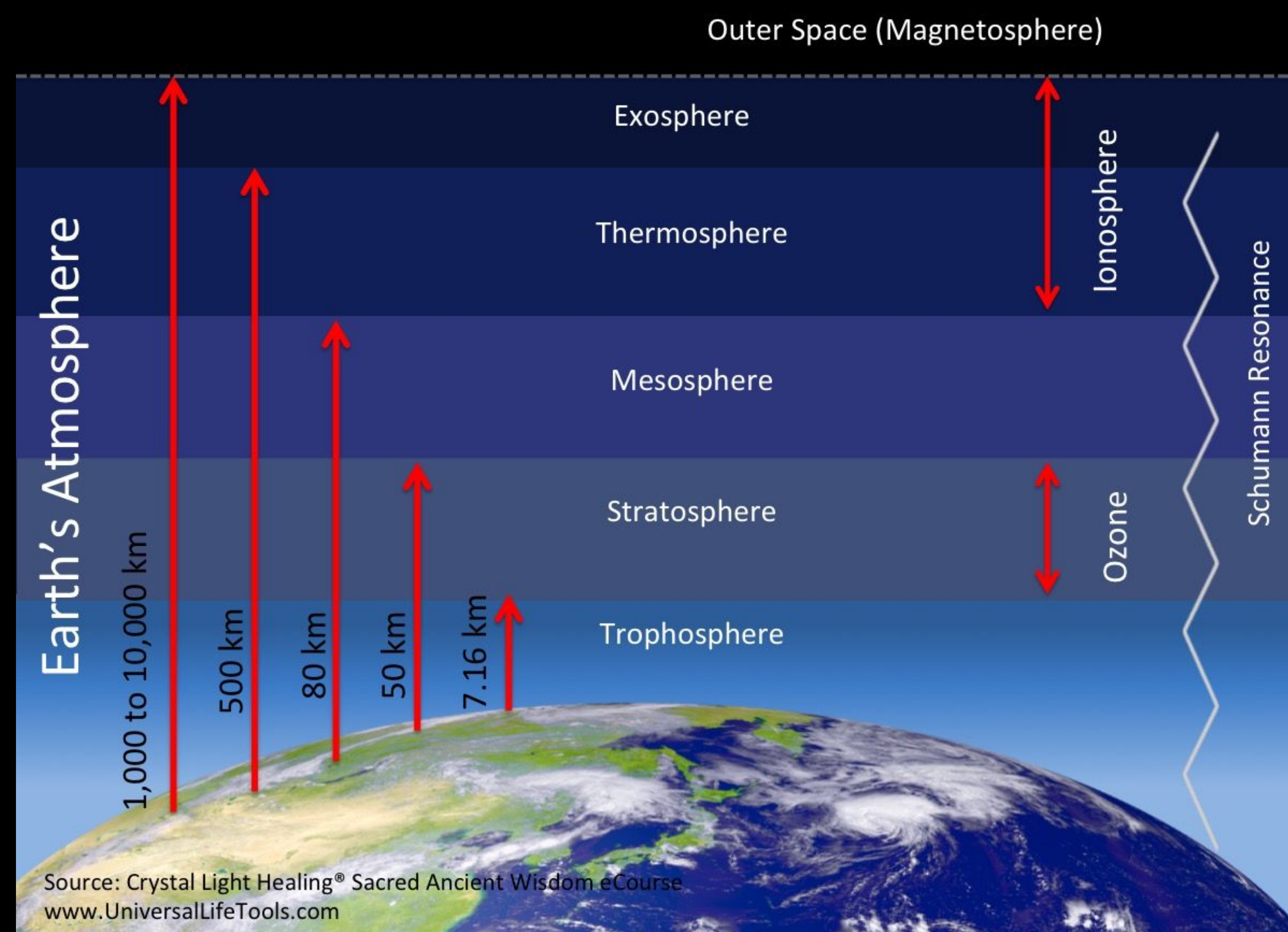
- LEO satellite observation seem to confirm the fact that **earthquakes produce modification of the physical parameters of the ionosphere and magnetosphere** such as:
  - changes of the **electric and magnetic fields** (Molchanov 1993, Parrot 1994)
  - changes of the ionospheric **plasma temperature and density** (Parrot & Mogilevsky 1994, Parrot 1994, Chmyrev 1997)
  - precipitation of particles from the Van Allen belts (Aleksandrin 2002)

When? from a few minutes up to several hours prior to an earthquake of moderate or strong magnitude (M > 4.0)

COUPLING MECHANISM



*From the upper layers of the Earth (**lithosphere**), the disturbance must travel towards the space, reaching the **ionosphere** and the outer space (**magnetosphere**)*

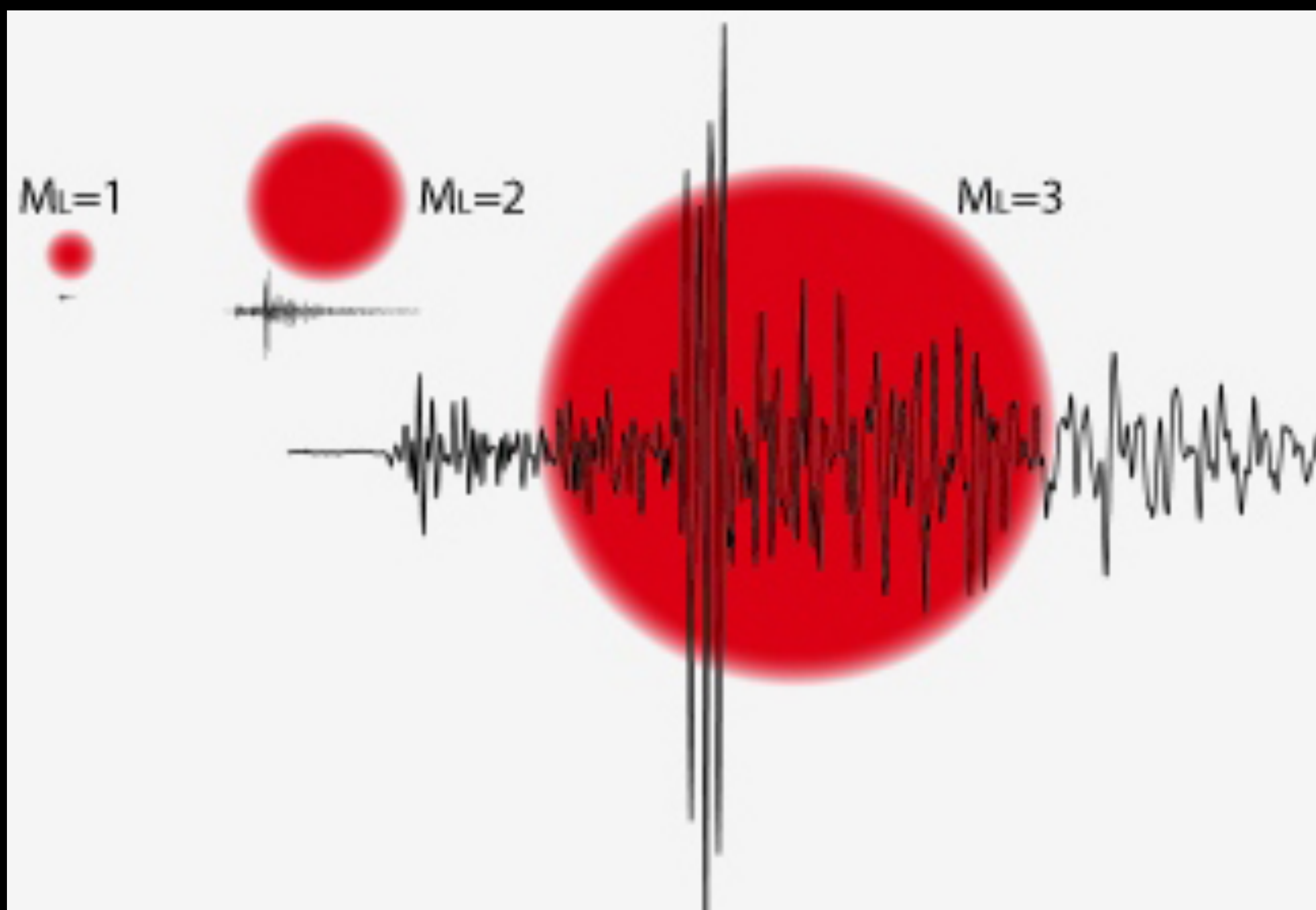


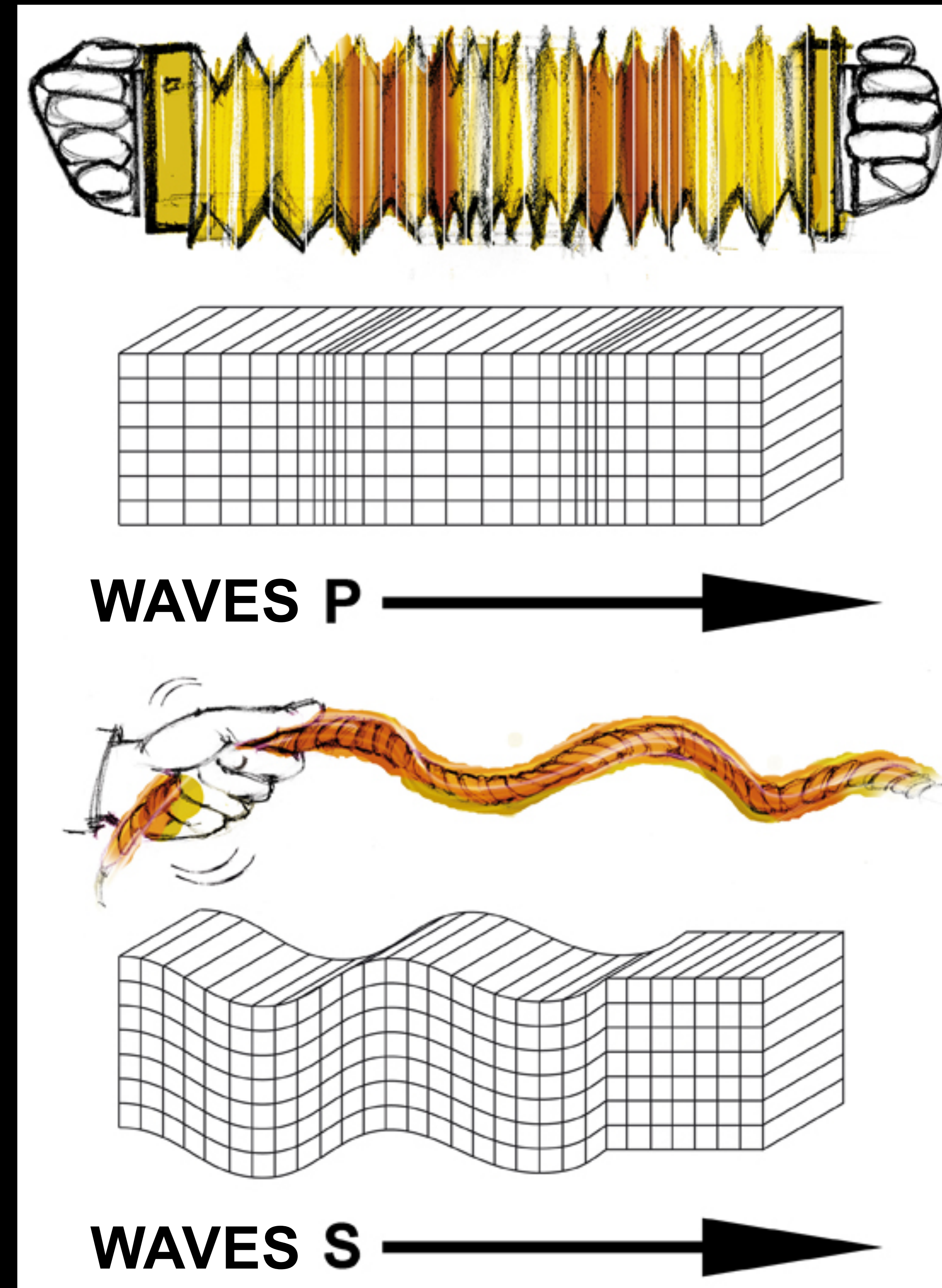
EARTHQUAKE MECHANISM

- The rocks that form the Earth's crust are continually subject to **gigantic efforts**, which are the result of **slow movements** between the large plates in which the most superficial layer of the Earth is divided (the lithosphere).
- When the effort **exceeds the resistance limit of the rocks**, they suddenly **break and release an enormous amount of energy that propagates, in the form of seismic waves,** from the hypocenter in all directions, generating the earthquake.
- The “size” of an earthquake is measured by the **Magnitude Ms**, related to the energy release E (in erg) by the following formula

$$log\, E = 1.56\, M_s + 11.8.$$

An earthquake one unit greater in Magnitude releases 30 times more energy!


ML=1
ML=2
ML=3


WAVES P
WAVES S

EARTHQUAKE PRECURSORS: ELECTROMAGNETIC WAVES

- The fracturing of the rock is preceded by accumulation of deformation in the fault zone.

- The strain increase is accompanied by other natural phenomena in the vicinity of the preparing fracture which are the so-called earthquake precursors.

- These precursors include the **seismogenic electromagnetic emissions (SEMES)** that are one of the *most significant earthquake precursors and can be studied with both ground based and spacecraft experiments.*

SEMES DISTURBANCES AS SEISMIC PRECURSORS

During their propagation through the solid crust, the higher frequency content of the seismic EME waves **are attenuated** and only the **VLF/ULF/ELF (Very/Ultra/Extremely Low Frequency. Band: 0 - 500 Hz) waves are supposed to reach the Earth's surface and propagate further into** the near Earth space.

—> detected as perturbation of EM signals in the ionosphere in a specific frequency band!

The interaction of these EMEs with the ionospheric environment can cause different kinds of perturbations, in the plasma component as well as in the electromagnetic field and trapped particles in the Van Allen radiation belts.

HOW DO SEMES ORIGINATE?

The most reliable models describing EME generation mechanisms invoke effects as **piezoelectricity, piezomagnetism and electrokinetic effects.**

- **Piezoelectricity** is a property that arises from the crystal anisotropy of the material. A piezoelectric substance shows an electromagnetic response against mechanical stimulations on electric polarization caused by deformation of the crystal lattices.

- **Piezomagnetism** consists of the magnetization of a material obtained by applying a stress to the crystal.

- The **electrokinetic phenomena** are related to the existence of a double layer formed at a solid liquid interface where the ions are held to the solid and a mobile layer extending into the liquid. The difference of the electrical potential between the solid-liquid interface and the bulk of the liquid is the so-called electrokinetic potential.

BACKGROUND

- **The Sun**: generates (regular and irregular) variations of the ionosphere parameters by impulsive events as solar Coronal Mass Ejections (CME) and solar flares.

- **Natural non-seismic activity:** lightning, volcanic eruptions;

- **Anthropogenic activity:** ground-based transmitters are used for radionavigation and communications and their strongest interaction region is around the geomagnetic equator. Also the broadcasting stations, at HF frequencies, make use of powerful transmitters which can heat the ionosphere and change its temperature and density.

PARTICLE BURSTS AS SEISMIC PRECURSORS

Correlations between **short-term variations (bursts) of high-energy charged particle fluxes** in near-Earth space and seismic activity have been at first pointed out on the basis of results obtained from several satellite measurements (dedicated to CR physics) in the 80-90s:

- MARIA and MARIA-2 (Salyut 7 and MIR orbital stations) —> electrons 20 - 200 MeV
- ELECTRON (Intercosmos and Meteor 3 satellite) —> electrons < 30 MeV
- GAMMA-1 (on GAMMA satellite) —> electrons >50 MeV
- PET (SAMPEX satellite) —> electrons 4 - 15 MeV

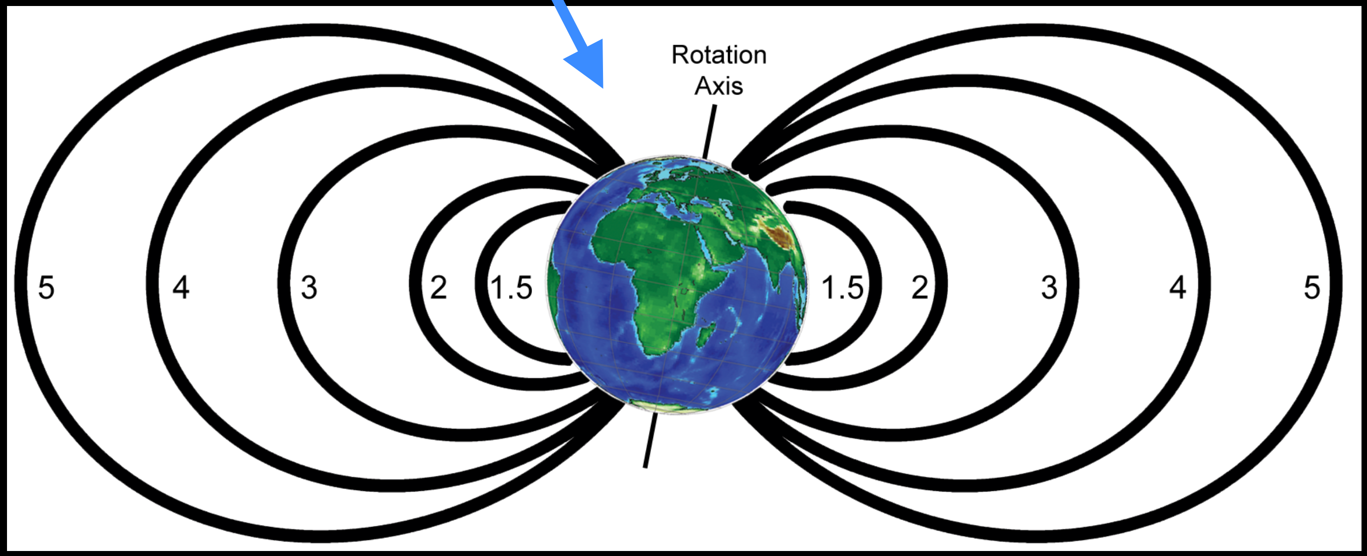
EARTH'S MAGNETIC FIELD: L-SHELL AND B

Originated by **electric currents running inside the Earth core**. To a first approximation it is a **dipolar field**.

To describe the field, also in not-dipole approximation, usually the **McIlwain coordinates (B,L) are used.**

A point P in the space is defined by:

L-shell: distance (in R_E) of the field line passing for P, measured on the equatorial plane.
A measure of "**equatorial radius**".



B: magnetic field intensity in P.
A measure of "**latitude**".

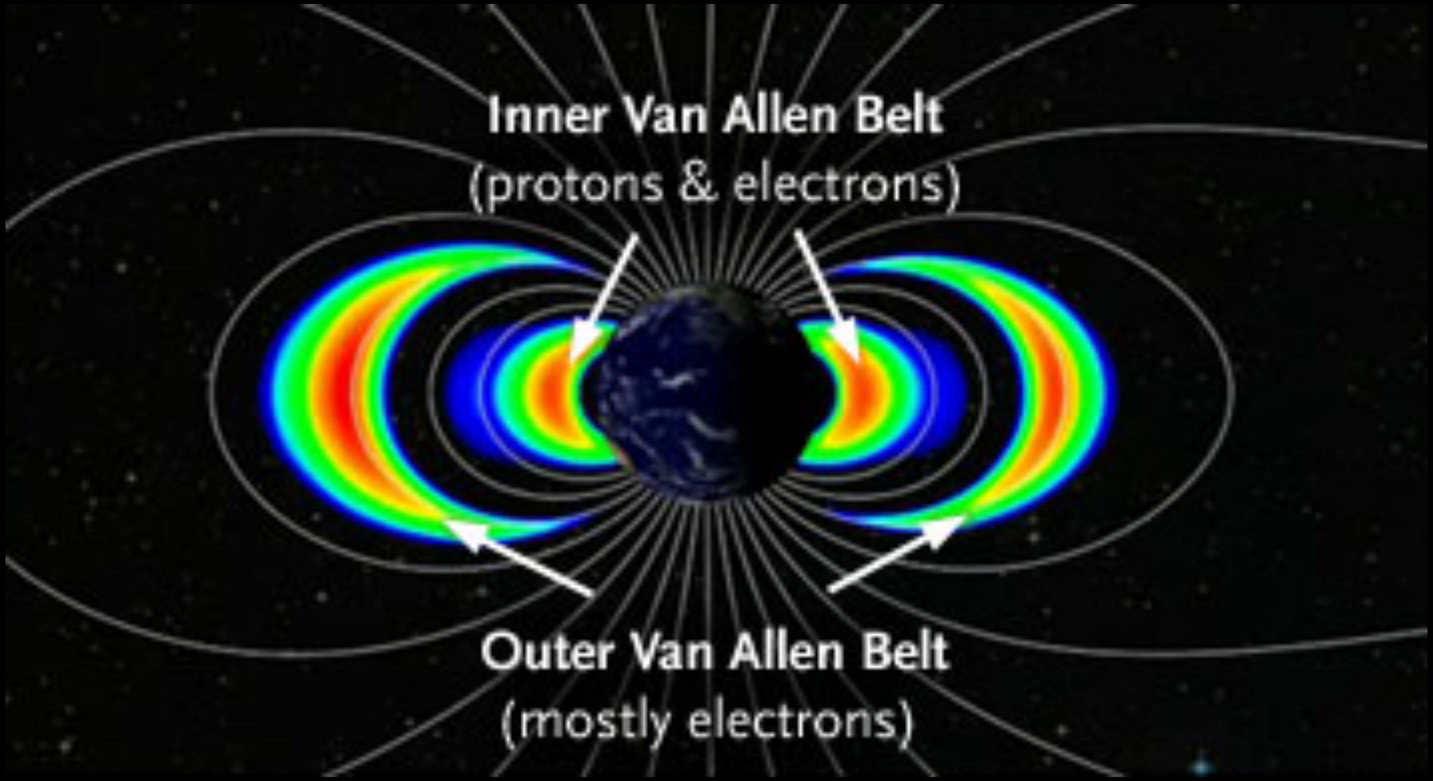
PARTICLE BURSTS AS SEISMIC PRECURSORS

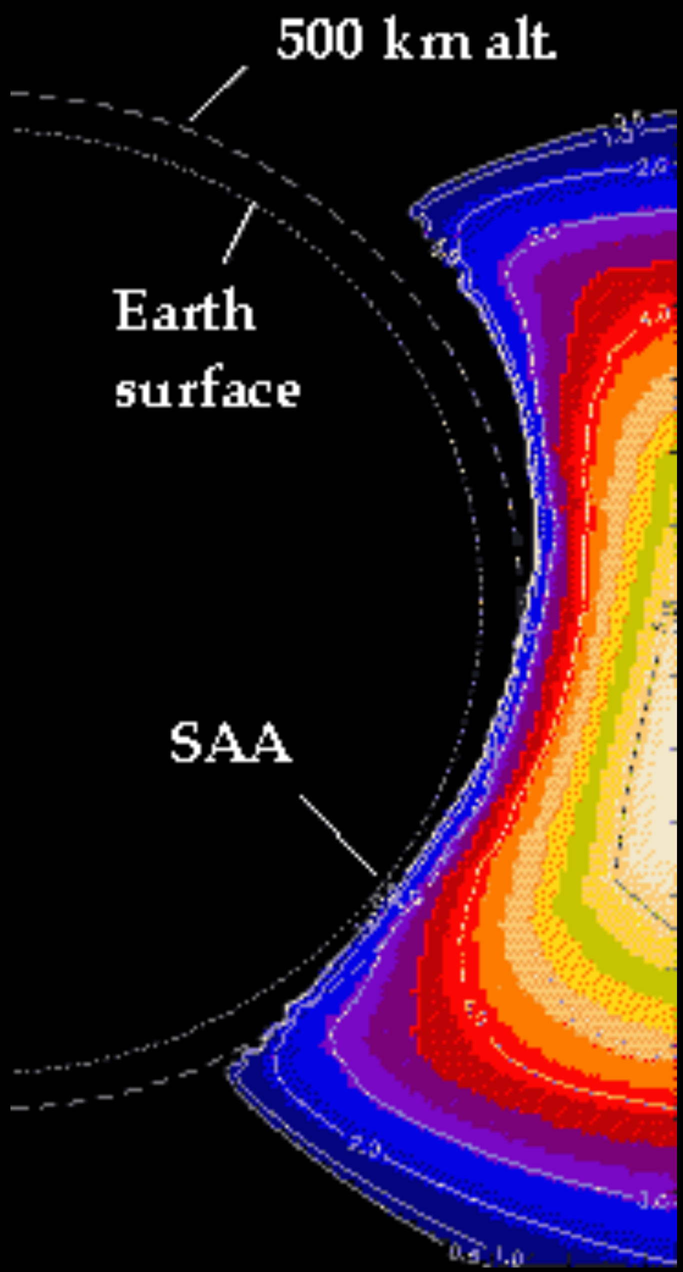
- The particles constituting the burst are low energy particles trapped in the **Van Allen Belts**.

- These belts are zones of energetic charged particles, most of which originate from the solar wind, that are **captured by the Earth's magnetic field.**

- **Two such belts (inner and outer)** surround the earth, extending from an altitude of about 1000 to 65000 km above the surface: Electrons (1 MeV < E < 50 MeV) and ions (10 eV < E < 1 GeV

VAN ALLEN BELTS





Above South America, about 200 - 300 kilometers off the coast of Brazil, and extending over much of South America, the nearby portion of the Van Allen Belt forms what is called the **South Atlantic Anomaly**. This is an area of **enhanced radiation** caused by the offset and tilt of the geomagnetic axis with respect to the Earth's rotation axis, which brings part of the radiation belt to **lower altitudes**.

MOTION OF TRAPPED PARTICLES

Combination of 3 periodic motions:

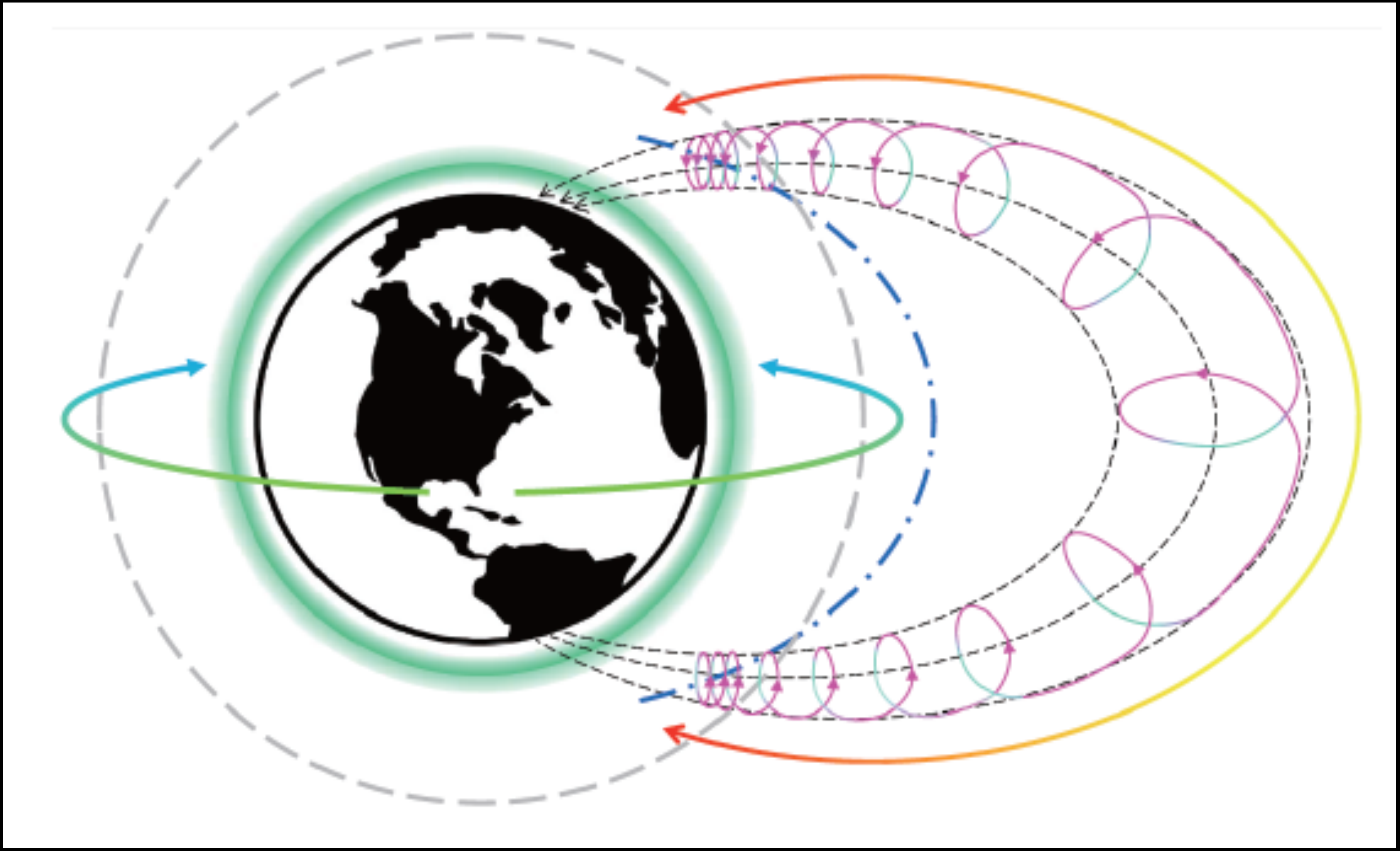
***Gyration**: a helix around the field line;

***Bounce**: oscillation around the equatorial plane between almost symmetrical **mirror points**. Only small oscillations are possible, the mirror point cannot hit the Earth surface.

Pitch-angle a_0: angle between vec(p) and vec(B) at the equator.

Condition for trapping: $|\sin a_0| \geq R_0^{-5/4} (4 R_0-3)^{-1/4}$;

***Drift:** longitudinal. It is due to dishomogeneity of the field and variations of the gyroradius. Positive particles drift westward, negative eastward.



*Death: distortions in the magnetic field (also due to solar activity) bring particles to jump to different field lines which go down to dense atmosphere. Collisions. Also collisions among themselves.

MODEL FOR VAN ALLEN PARTICLE PRECIPITATION

A possible **model to explain the precipitation of particles trapped in the Van Allen belts is this** (Molchanov et al. 1992, Aleshina et al. 1992, Galper at al. 1997, 2000):

1. The ULF seismic electromagnetic wave **propagates upward in the magnetosphere;**
2. It is **captured by a magnetic field tube;**
3. It **propagates as Alfven wave along the field line** and begins to **interact with particles**;
4. The **pitch angle's particle changes** creating a particle precipitation.
5. Precipitated particles **drift around the Earth along the L-shell** corresponding to the epicenter earthquake location. A satellite passing the disturbed L-shell can detect such a particle burst.

A PRELIMINARY ANALYSIS

Alexandrin et al. (2002) analyzed data from the different instruments (**all electrons in the MeV region**), studying the temporal correlation between bursts and strong earthquakes.

Burst selection (T_{PB}):

- Couting rate of the burst 4 sigmas over the background
- Equatorial regions
- No SAA

Correlation (T_{EQ}):

- A set of earthquakes with M>4 from the CNSS (Council of the National Seismic System) catalogue in an interval +- 12 h around the burst detection

$$\Delta_T = T_{EQ} - T_{PB}$$

A PRELIMINARY ANALYSIS

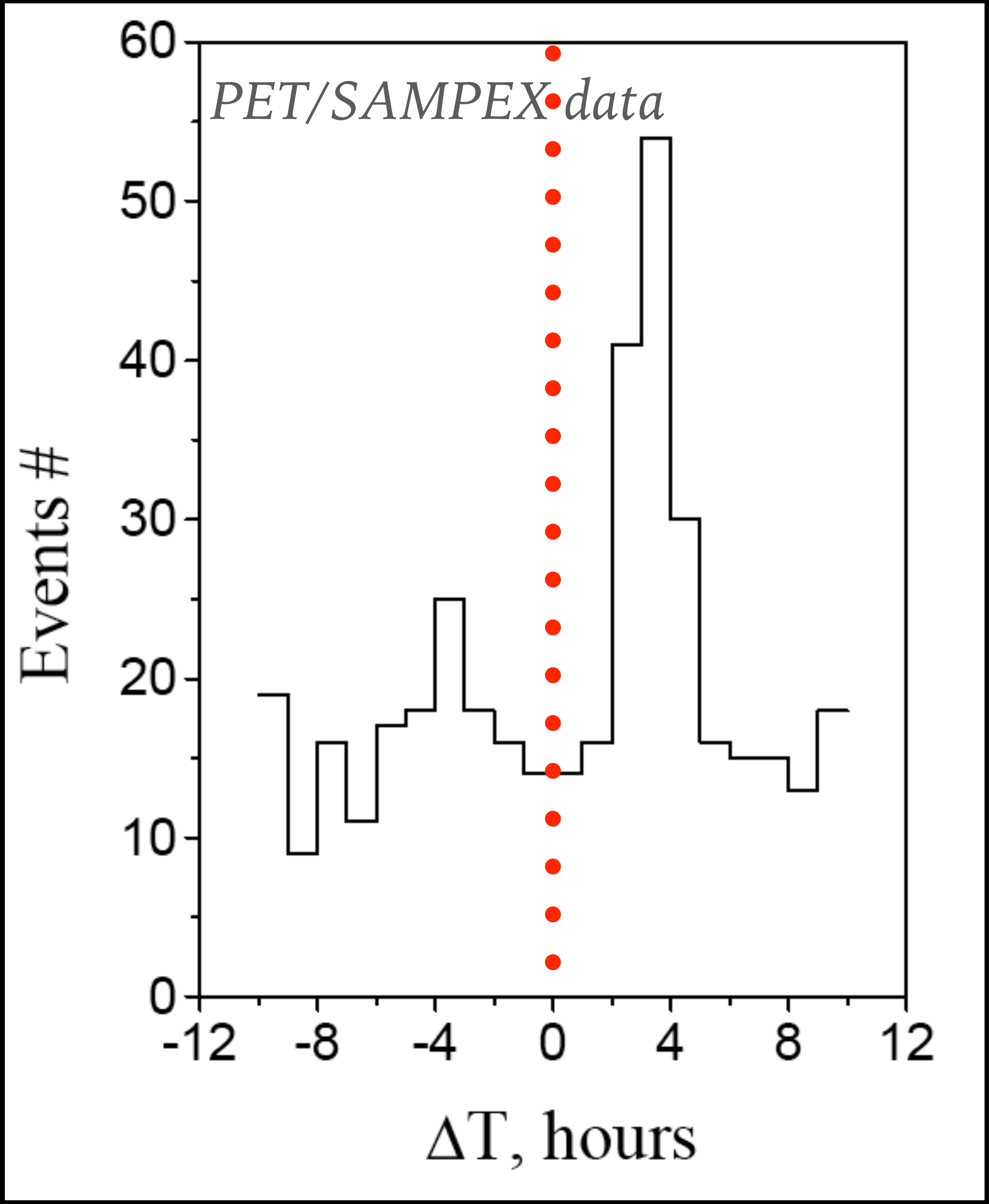
Selection on L-shell:

- L-shell of the PB;
- L-shell of the EQ as derived by the model (the L-shell where the EME is captured by the magnetic line, 300 km up the epicenter in the model)

$$\Delta L = L_{EQ} - L_{PB}$$

The plot of ΔT with the ΔL cut (0.2, 0.1, 0.05) brings interesting results:

A PRELIMINARY ANALYSIS



For all instruments (MIR, METEOR, GAMMA-1, PET) the results look similar.

The **positive value** of all the peaks (2-5 hours) means that the particle bursts **could be a short term earthquake precursor.**

The shape of the pick changes if hardening/ releasing the requests on M and L-shell.

DEMETER MISSION

DEMETER: Detection of Electro-Magnetic Emissions Transmitted from Earthquake Region

—> First mission throughly dedicated to ionospheric perturbances wrt earthquakes or human activities.

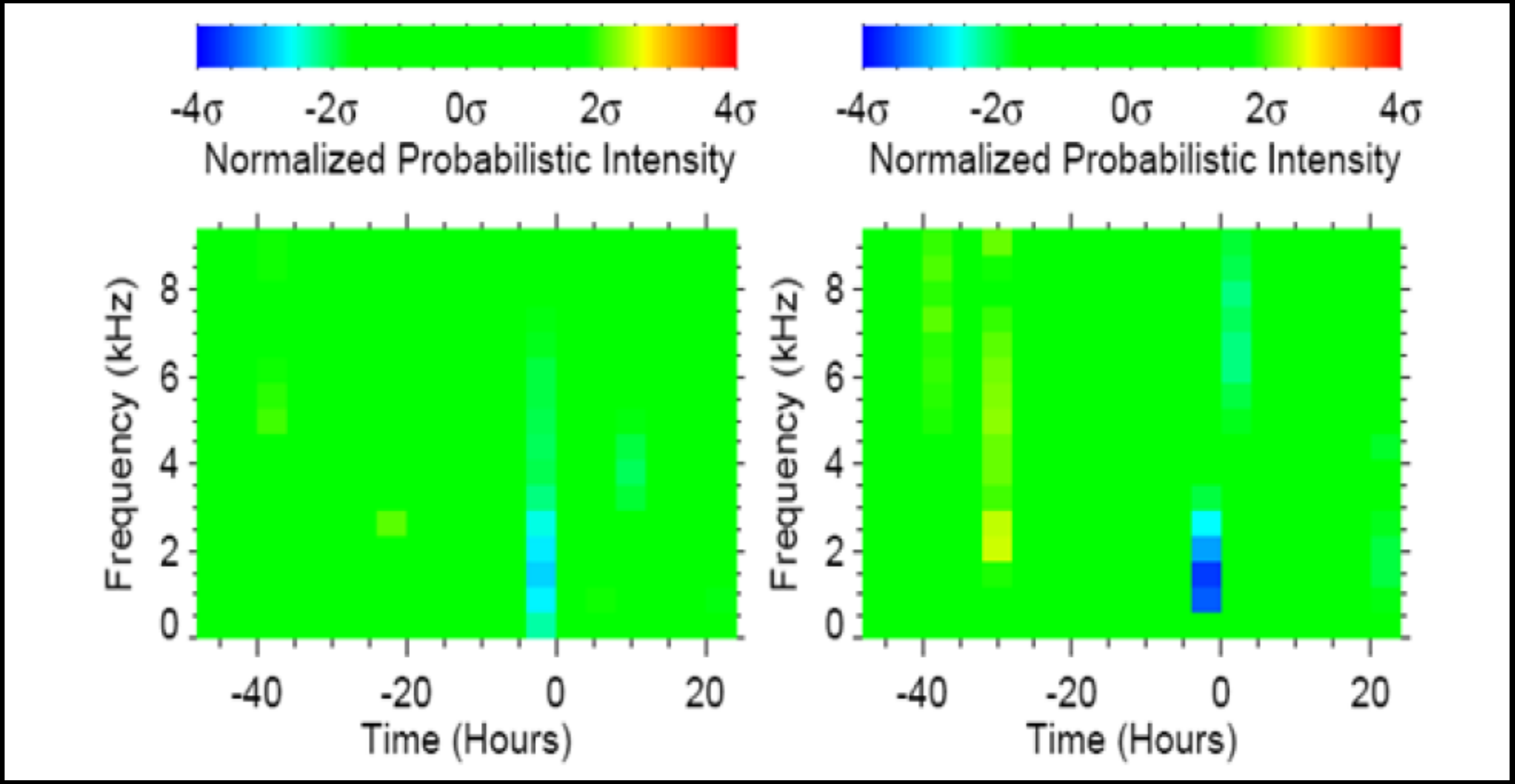
Mission by CNES-CNRS, which flew between June 2004 and December 2010.

The micro-satellite (110 kg) had a polar orbit and 700 km altitude. The satellite housed several scientic payloads: an electric field detector (ICE), a magnetic field detector (IMSC), a plasma analyser (IAP), two Langmuir probes (ISL) and a particle detector (IDP) for electrons between 70 keV and 0.8 MeV.

DEMETER ANALYSYS

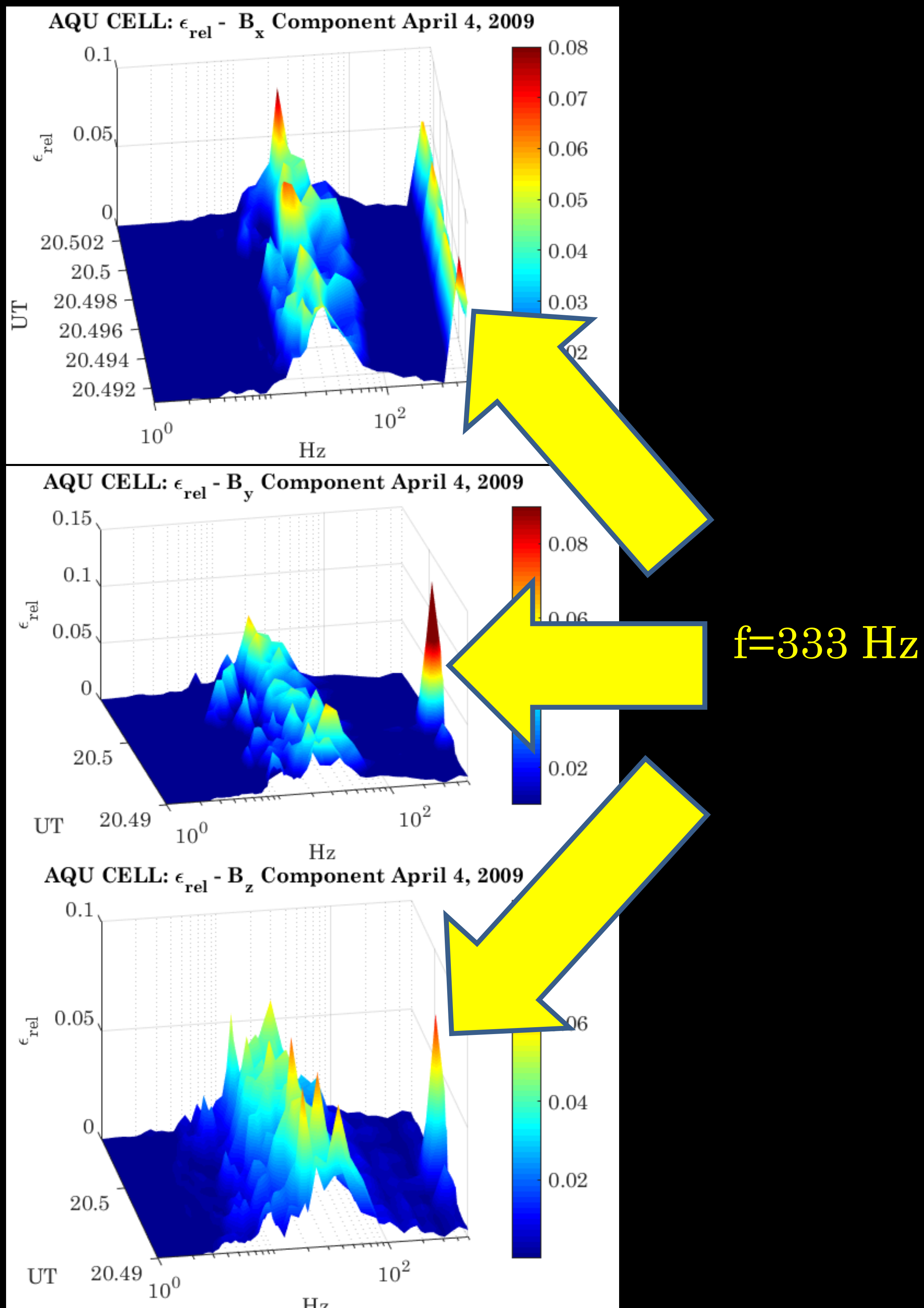
Several papers published show **examples of perturbations of ionospheric parameters in relation with earthquakes.**

- One of the most important results is the statistical analysis of the intensity of waves measured by the Demeter electric antennas as a function of the seismic activity.



The electric field measured during night time for earthquakes with M> 4.8 (left) and > 5 (right) and with a depth less than 40 km. The figures show a decrease of the wave intensity in a frequency range between 1 and 2 kHz which starts a few hours before the earthquakes (t=0).

DEMETER: A POST ANALYSYS FOR L'AQUILA EQ (04.04.2009)



Lately, an analysis of the full electric and magnetic DEMETER dataset (Bertello et al. 2018), evaluated the instrumental and environmental background over L'Aquila seismic region, finds an EMEs with a peculiar frequency of 333Hz two days before the 6.3 Mw earthquake.

Authors explain this EMEs as the consequence of a horizontal current system flowing at ground, switched on by an anomalous ground impedance generated by the fault-break.

UNCLEAR RESULTS FOR PB CORRELATION FROM DEMETER

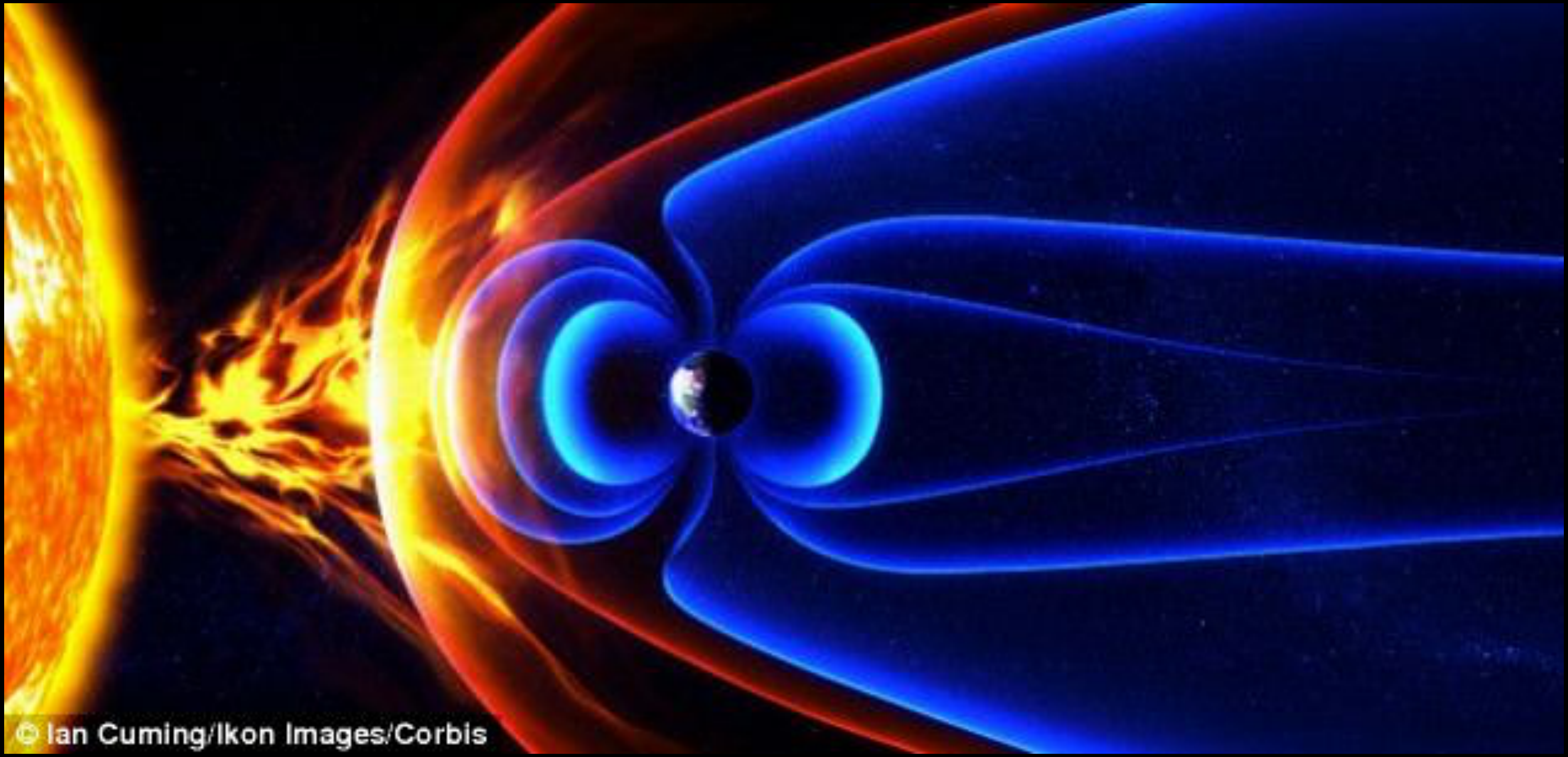
No clear evidence of temporal correlation between PB with earthquakes was observed for h<18 hrs(Buzzi, 2008).

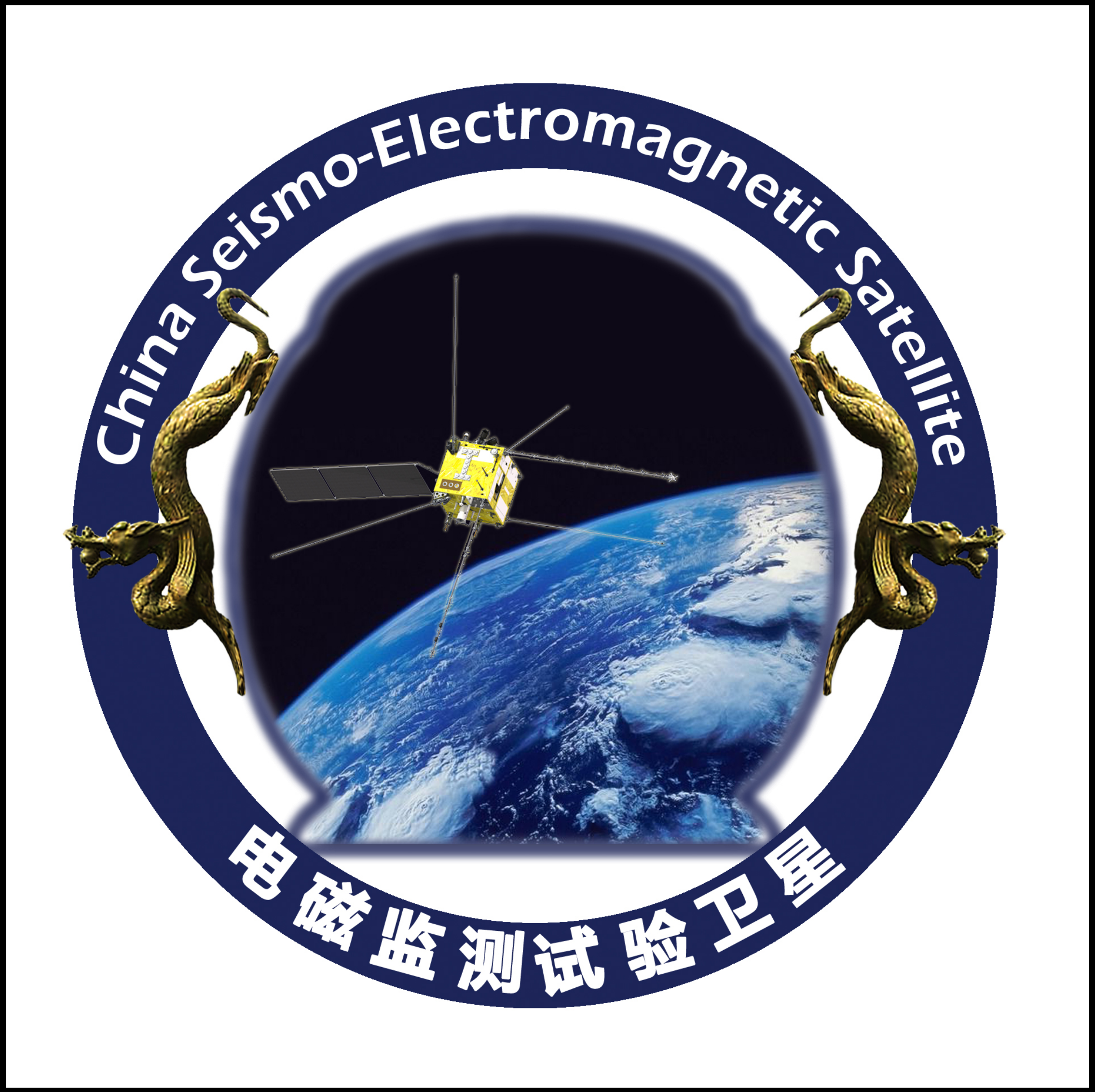
The possible explanations for the absence of such correlation between the PBs measured by DEMETER and earthquake occurrences can be related to different factors such as:

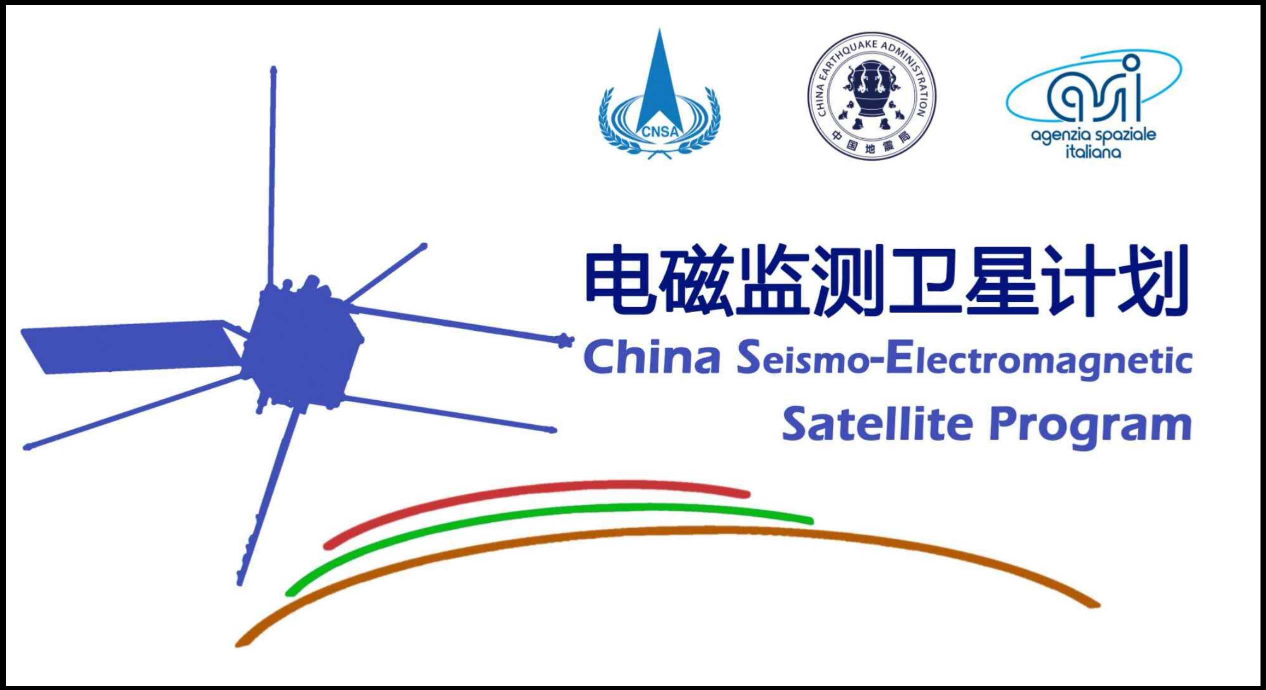
- **the orientation**: the particle detector direction, due to the satellite orientation, was always perpendicular to the magnetic field lines in such a way that the IDP detects mainly trapped particles (pitch angle close to 90);
- **the low-energy range of the detected particles** (between 70 keV and 0.8 MeV, signicantly lower than the range measured by the MARIA, ELECTRON, GAMMA-1 or SAMPEX-PET);
- **the poor statistics** due to the small geometric factor.

A post-analysis (Zhang 2013) has seen instead interesting correlations with 6 M>7 earthquakes for longer time-intervals.

THE "CHINA SEISMO-ELECTROMAGNETIC SATELLITE"



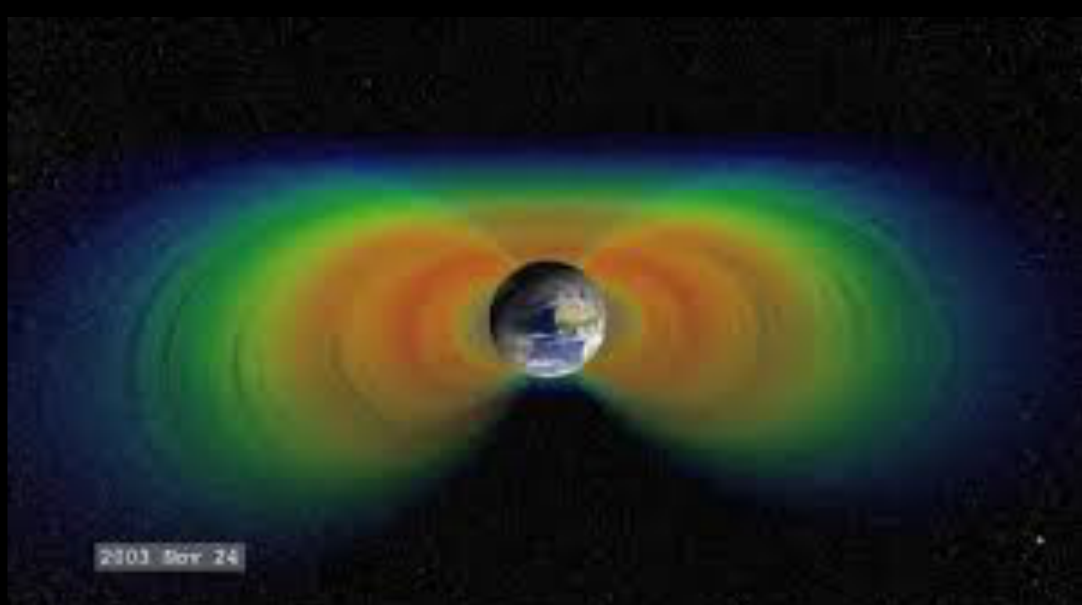

China Seismo-Electromagnetic Satellite
电磁监测试验卫星


CNSA
agenzia spaziale italiana
电磁监测卫星计划
China Seismo-Electromagnetic
Satellite Program

OBJECTIVES OF THE "CHINA SEISMO-ELECTROMAGNETIC SATELLITE"

EQ monitor

study of the lithosphere-atmosphere-ionosphere coupling



SpaceWeather monitor

study of the radiation environment in the magnetosphere

SPACE WEATHER

Space weather is a branch of space physics concerned with the **time varying conditions within the Solar System**, emphasizing **the space surrounding the Earth and the magnetosphere.**

Space weather is influenced by the **solar wind and the interplanetary magnetic field (IMF) carried by the solar wind plasma**.

Coronal mass ejections (CMEs) and their associated shock waves are also important drivers of space weather as they can compress the magnetosphere and trigger geomagnetic storms.

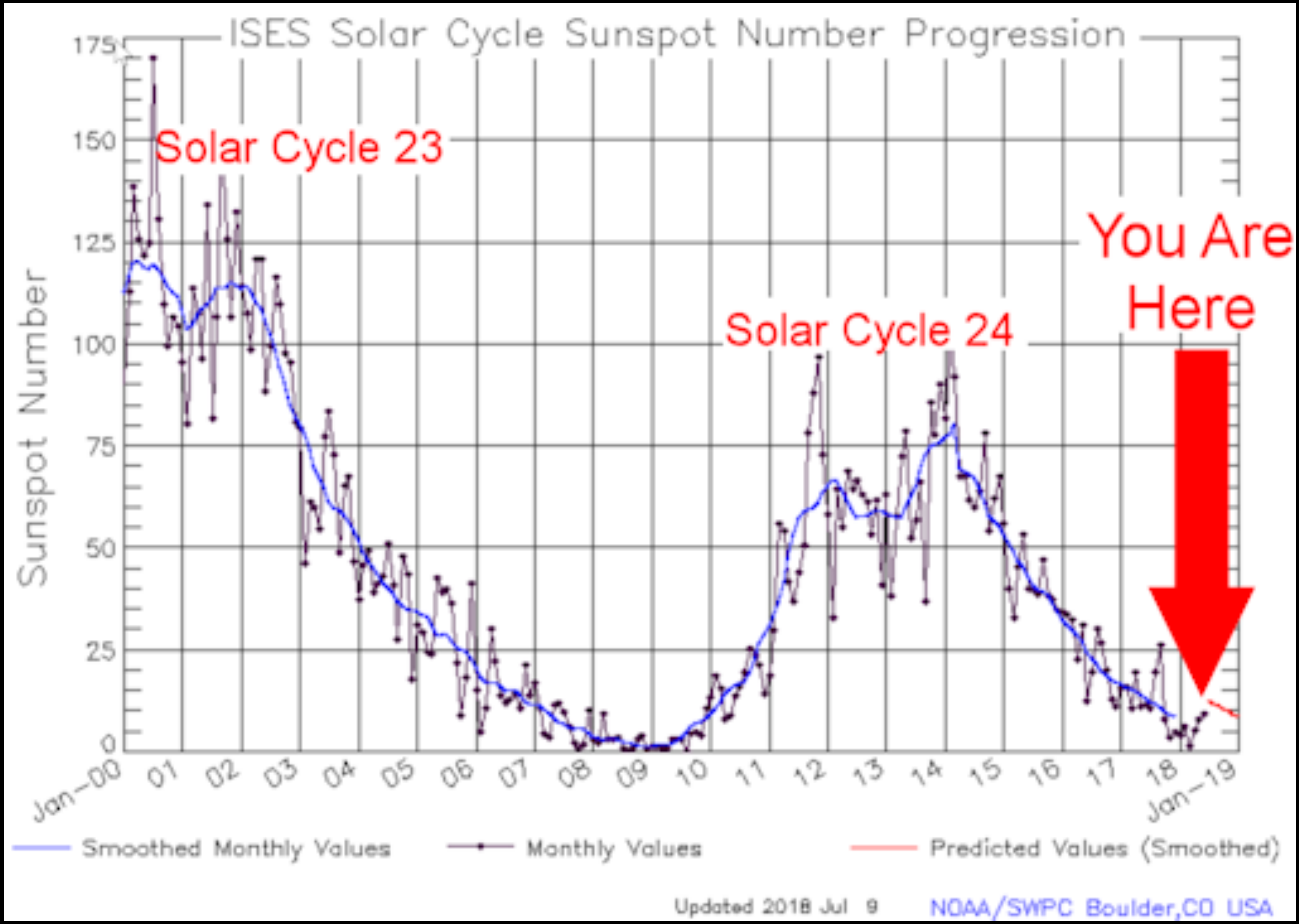
Solar energetic particles (SEP) accelerated by coronal mass ejections or solar flares can trigger solar particle events (SPEs), a strong impact space weather event.

A variety of physical phenomena are associated with space weather, including geomagnetic storms, energization of the Van Allen radiation belts, ionospheric disturbances and scintillation of satellite-to-ground radio signals and long-range radar signals, aurora, and geomagnetically induced currents at Earth's surface.

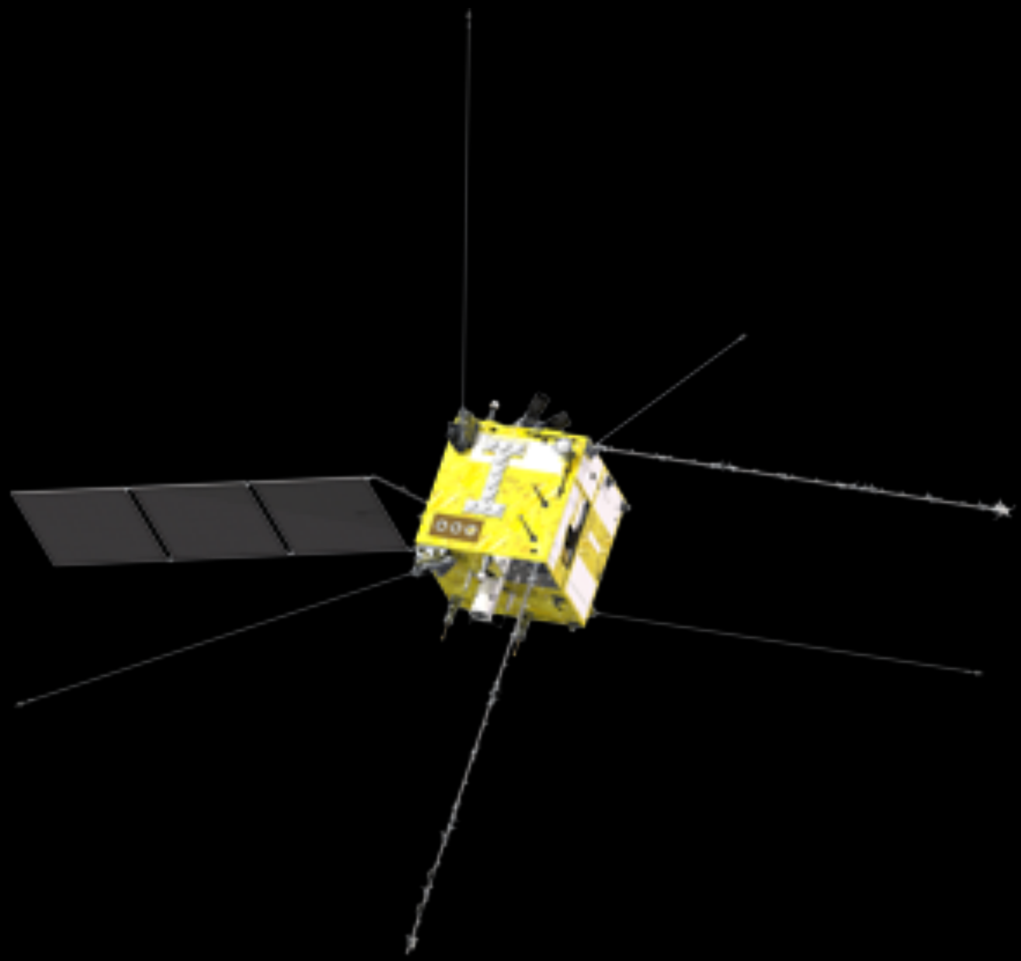
EFFECTS OF THE SPACE WEATHER

- Spacecraft electronics
- Spacecraft orbit changes
- Safety of humans in space and in commercial aviation
- Long-distance radio signals
- Ground-induced electric fields
- Terrestrial weather

CSES IN THE CURRENT SOLAR CYCLE



CSES PLATFORM AND ORBIT



CSES satellite on the CAST platform

Platform

- CAST-2000 baseline
- Earth oriented 3-axis stabilization system
- Total Mass: 730 kg
- Dimensions: 1.4 m^3
- Peak Power Consumption: ~900 W
- X-Band Data Transmission,120 Mbs
- Design Life-span: 5 Years

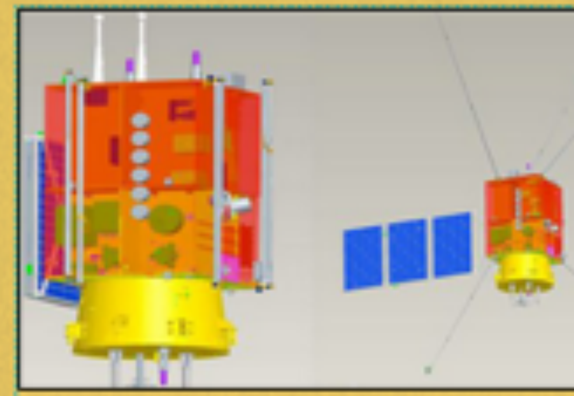
Orbit

- Circular Sun Synchronous Orbit
- Altitude: 506.9 km
- Inclination: 97.4 °
- Orbit period/min. 97

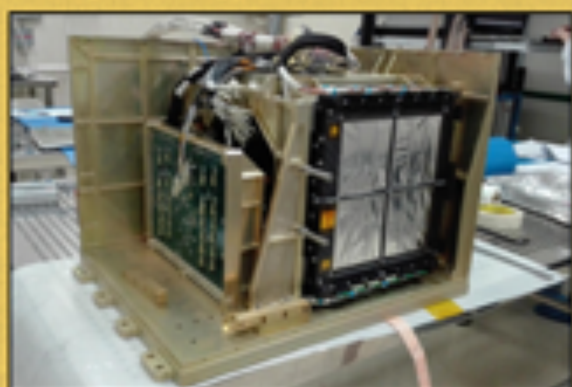
INSTRUMENTS ONBOARD

Measurements	Instruments
Measurement of the electrical and magnetic fields and their perturbations in ionosphere	Search-Coil Magnetometer
	Fluxgate Magnetometer
	Electrical Field Detector
Measurement of the disturbance of plasma in ionosphere	Plasma analizer
	Langmuir probe
Measurement of the flux and energy spectrum of the particles in the radiation belts	Two High Energy Particle Detector - Electrons - Protons
Measurement of the profile of electronic content	GPS Occultation Receiver
	Tri-frequency transmitter

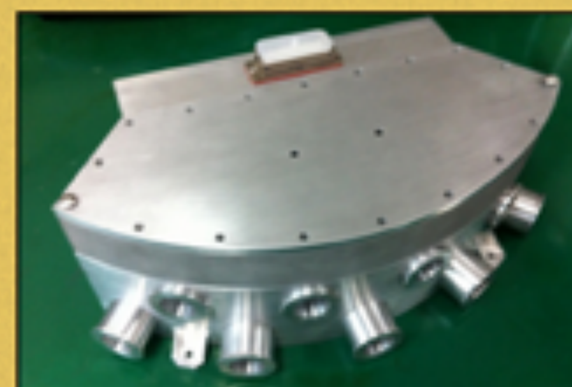
The Satellite



High-Energy Particle Detector

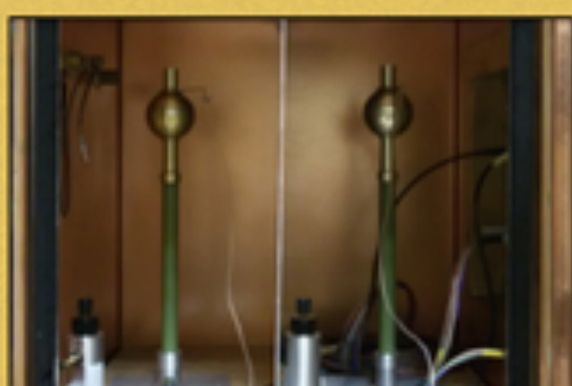


High-Energy Particle Package

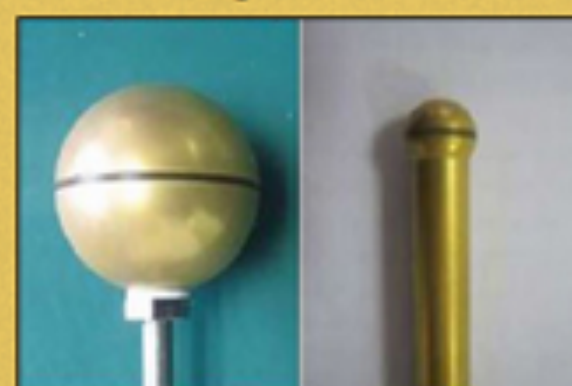


Search-Coil Magnetometer

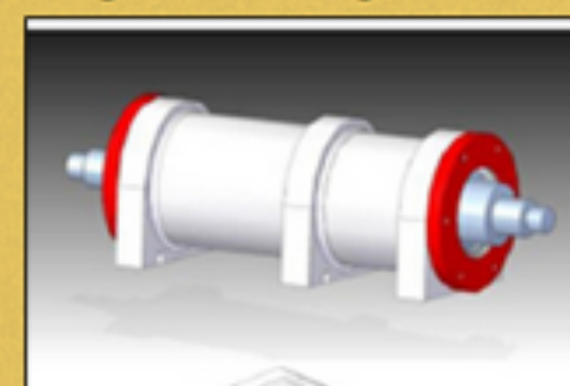
Electric Field Detector



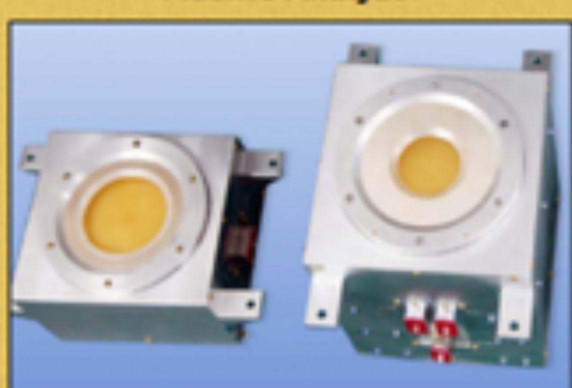
Langmuir Probe



High-Precision Magnetometer

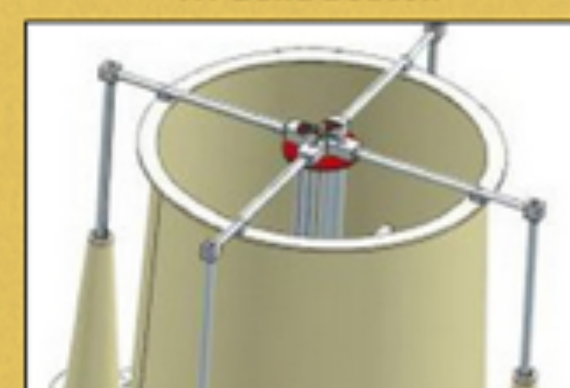


Plasma Analyzer

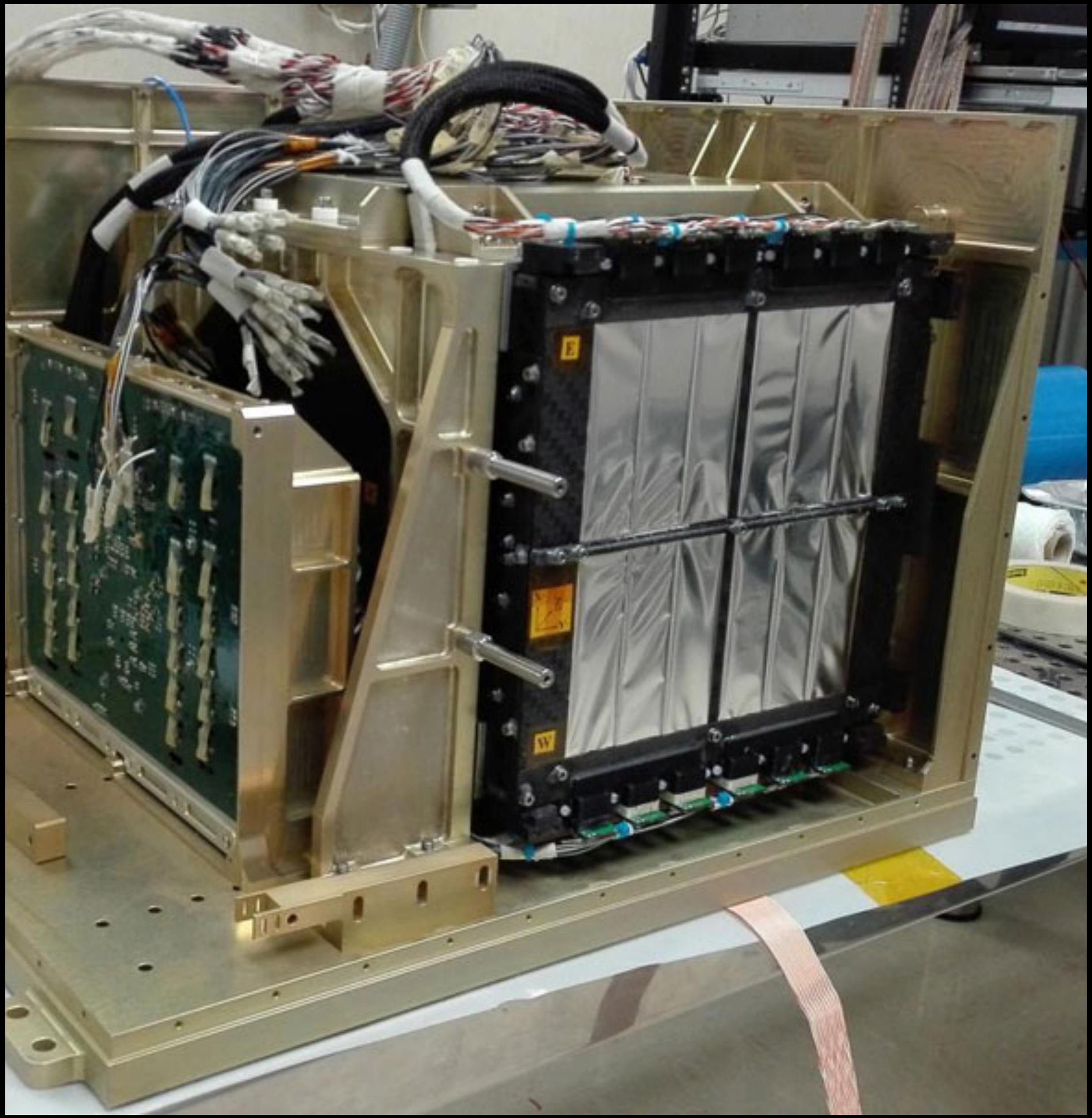


GNSS Occultation Receiver

Tri-Band Beacon



ITALIAN CONTRIBUTION: HEPD



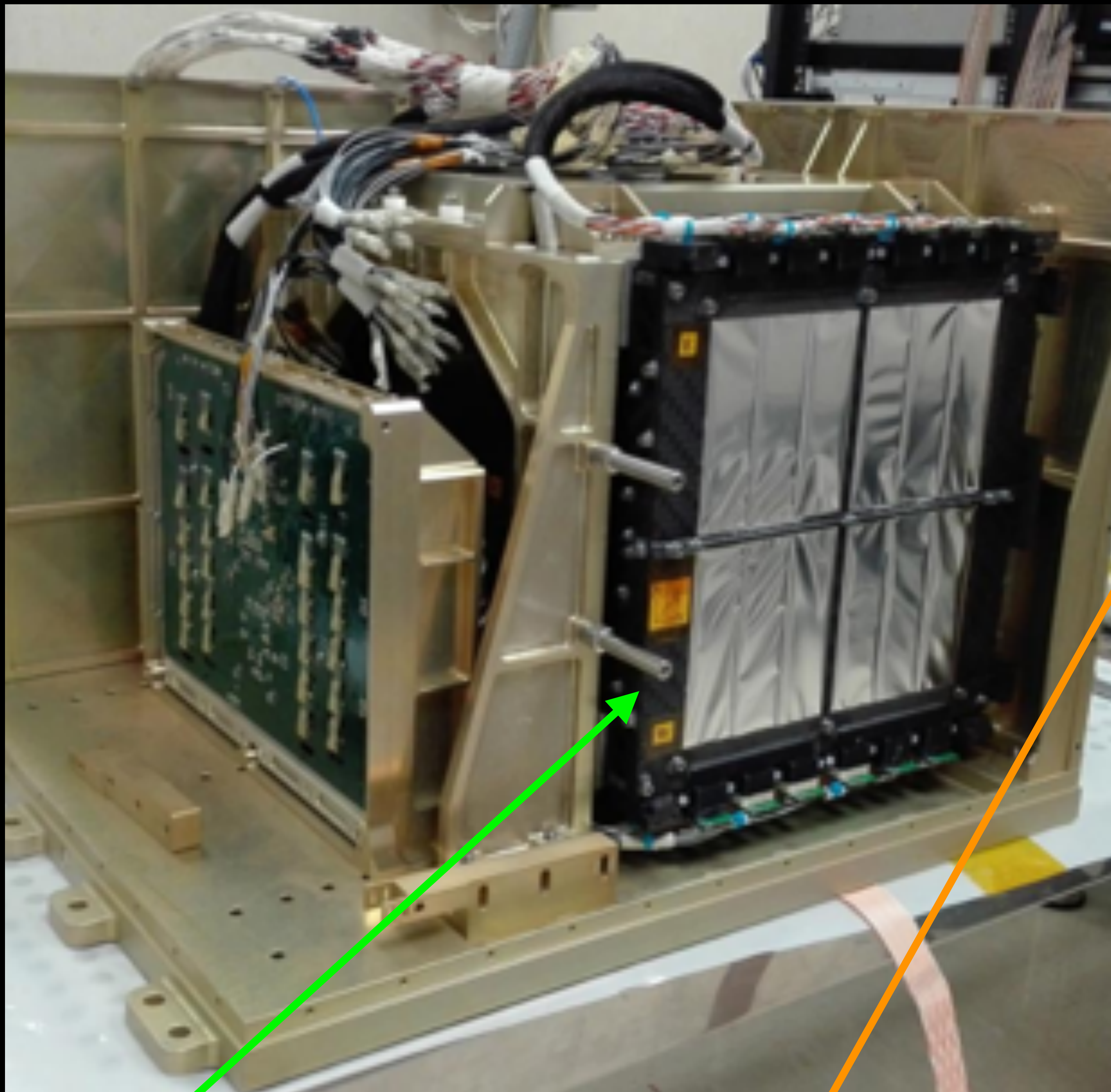
The High Energy Particle Detector HEPD assembled in Italy clean rooms

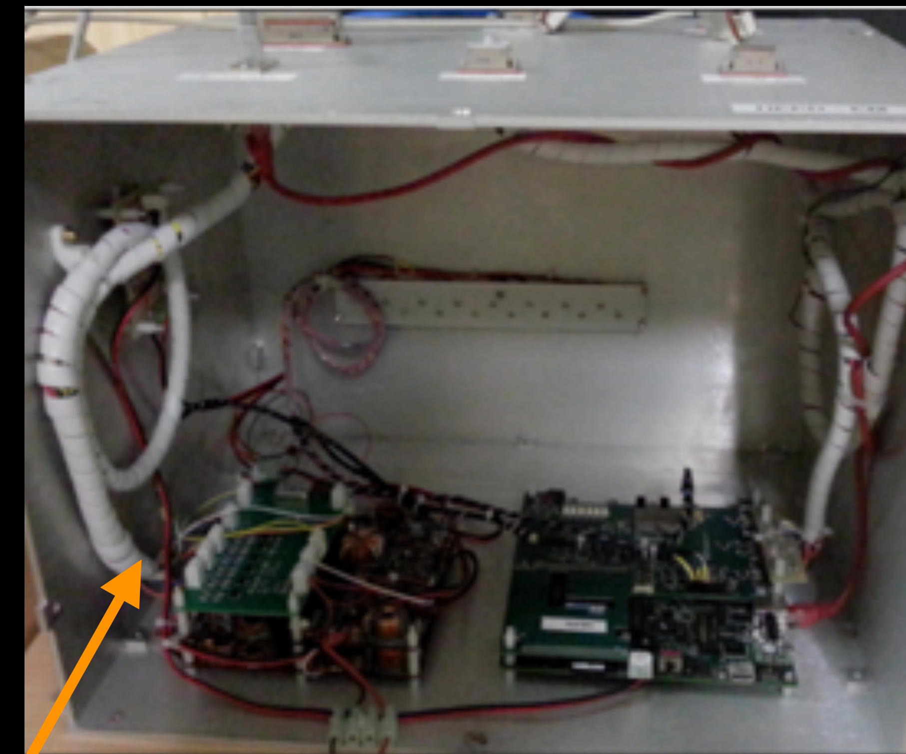
- Two planes of **double-side silicon microstrip detectors** which provide the direction of the incident particle;
- Two layers of **plastic scintillators for trigger** (one thin segmented counter S1 and one deep counter S2);
- Calorimeter made of:
  - **15 layers of plastic scintillator planes** (15 × 15 × 1 cm^3) read out by PMTs;
  - **a 3 × 3 matrix of inorganic scintillator LYSO** (15 × 15 × 4 cm^3) read out by PMTs;
- The calorimeter volume is surrounded by 5 mm thick **plastic scintillator veto planes**

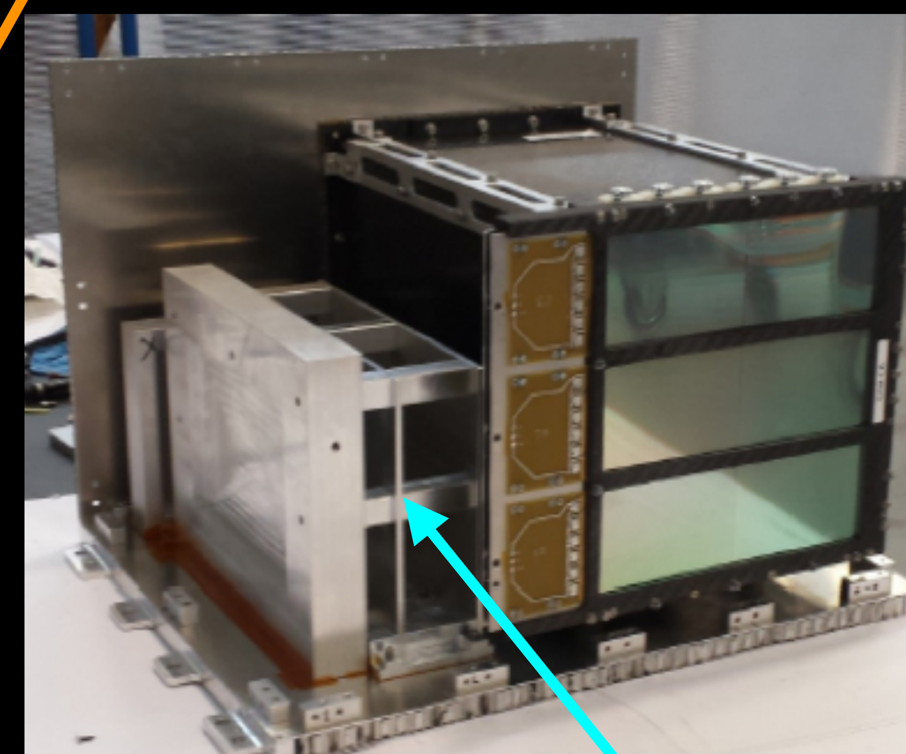
HEPD SPECIFICATIONS

- Energy range
  - Electrons: 3 MeV~100 MeV
  - Protons: 30 MeV~200 MeV
- Angular resolution <8°@ 5 MeV
- Energy resolution <10% @ 5 MeV
- Particle Identification >90%
- Mass ≤ 44 kg
- Power Consumption ≤ 27 W
  (Power budget ≤ 43 W)
- GF electrons: 370-40 cm^2 sr
- GF protons: 430 -60 cm^2sr

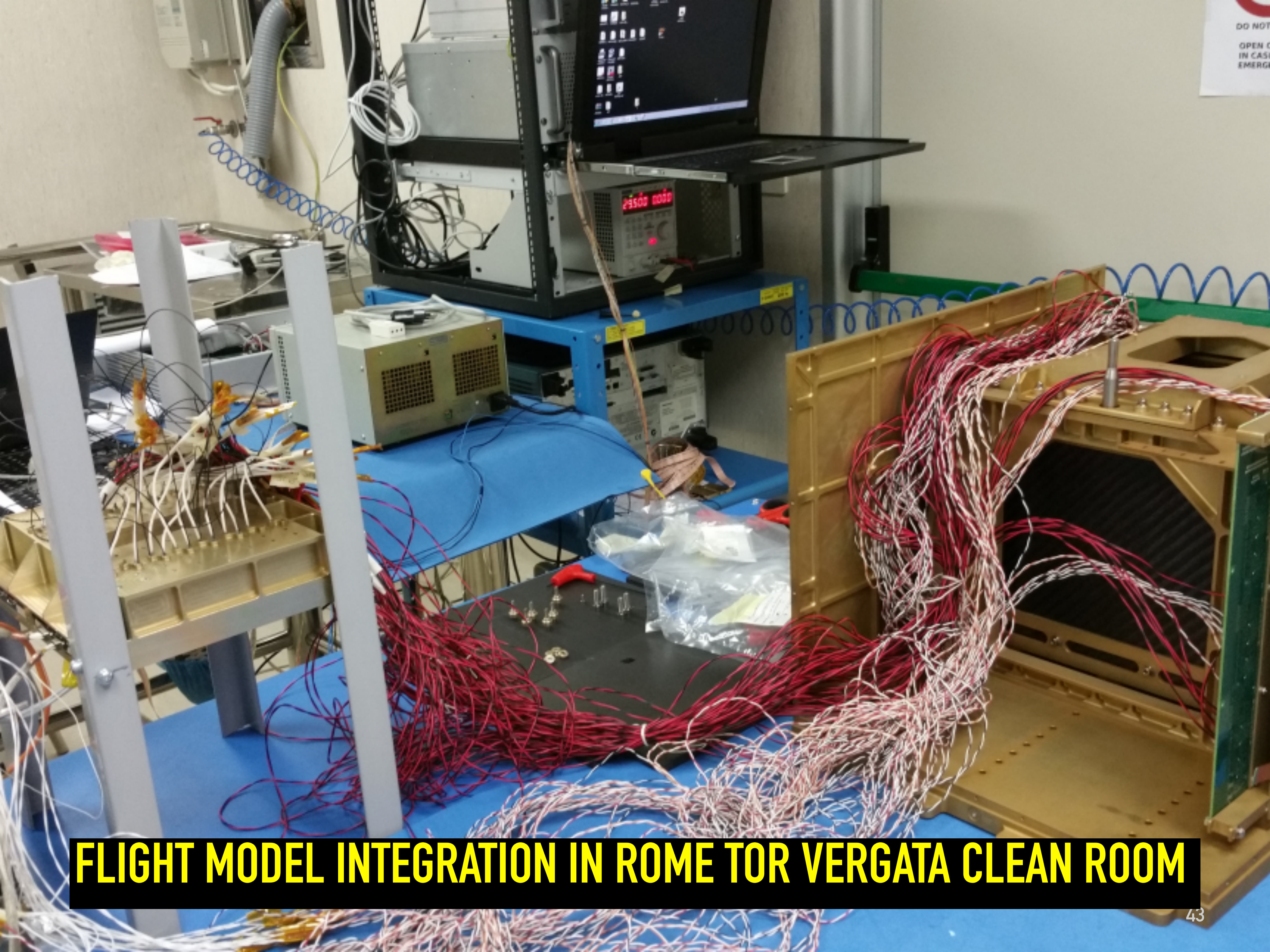
Geometrical factor at least 30 times bigger than DEMETER







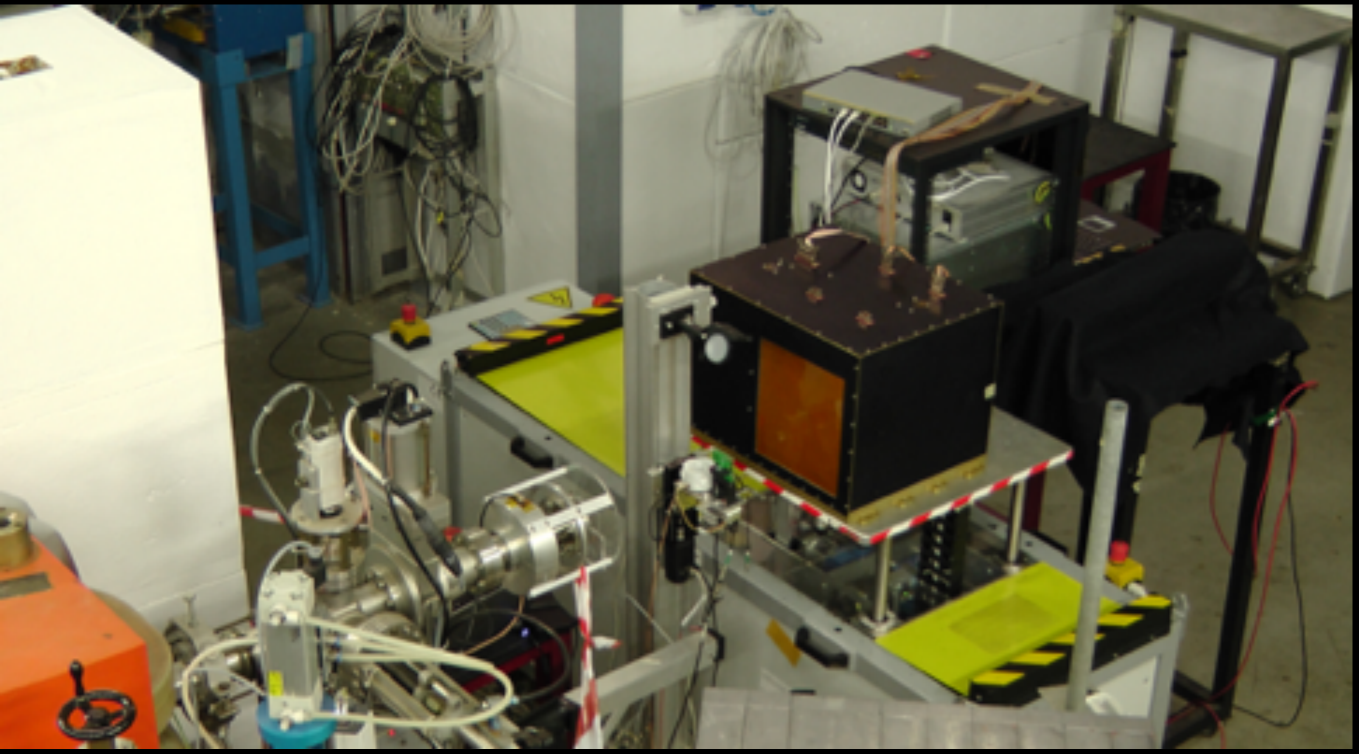
Qualification Model, *Electrical Model* and *Structural&Thermal Model* of HEPD



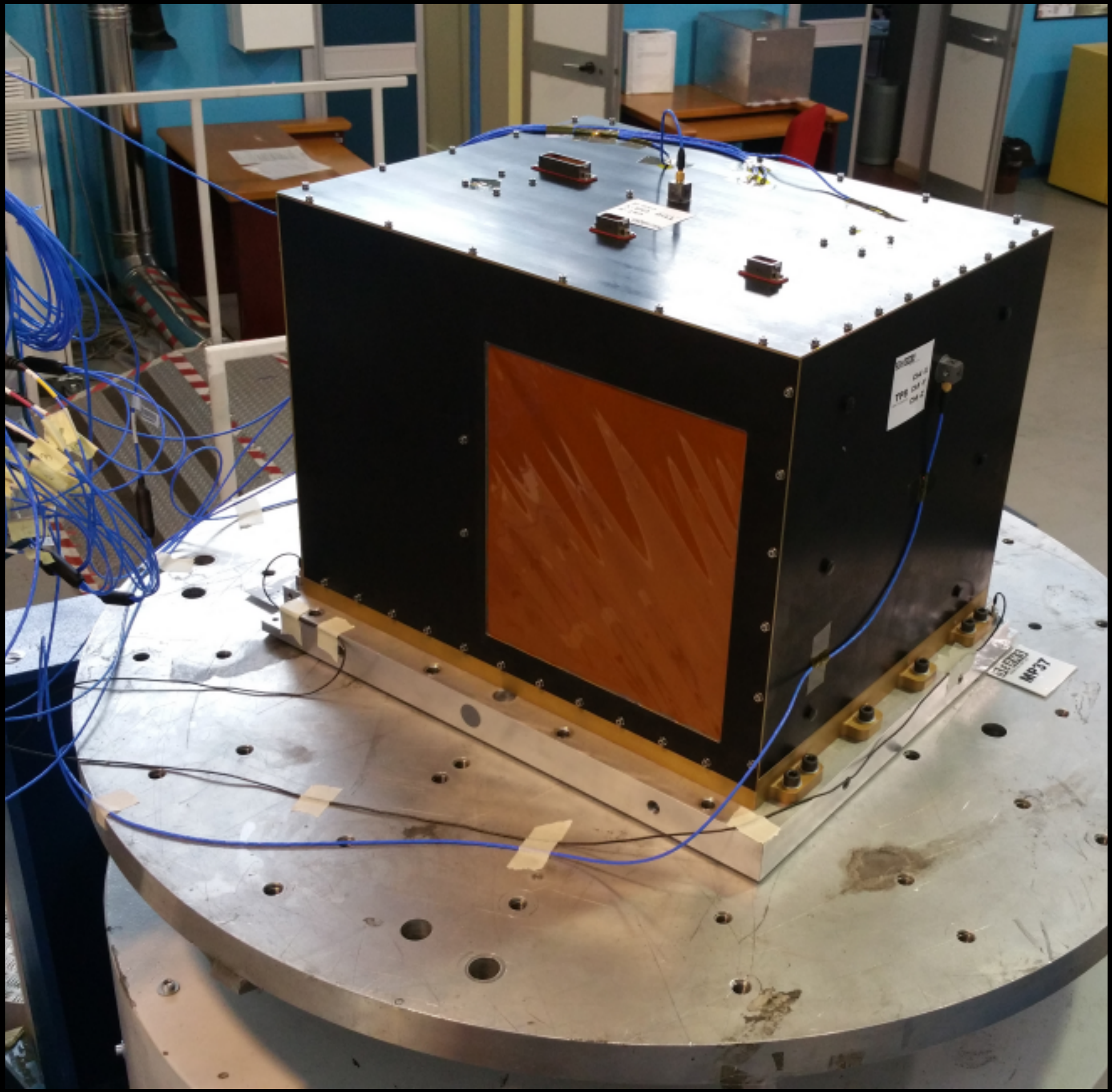
FLIGHT MODEL INTEGRATION IN ROME TOR VERGATA CLEAN ROOM

FLIGHT MODEL READY TO DELIVER TO CHINA

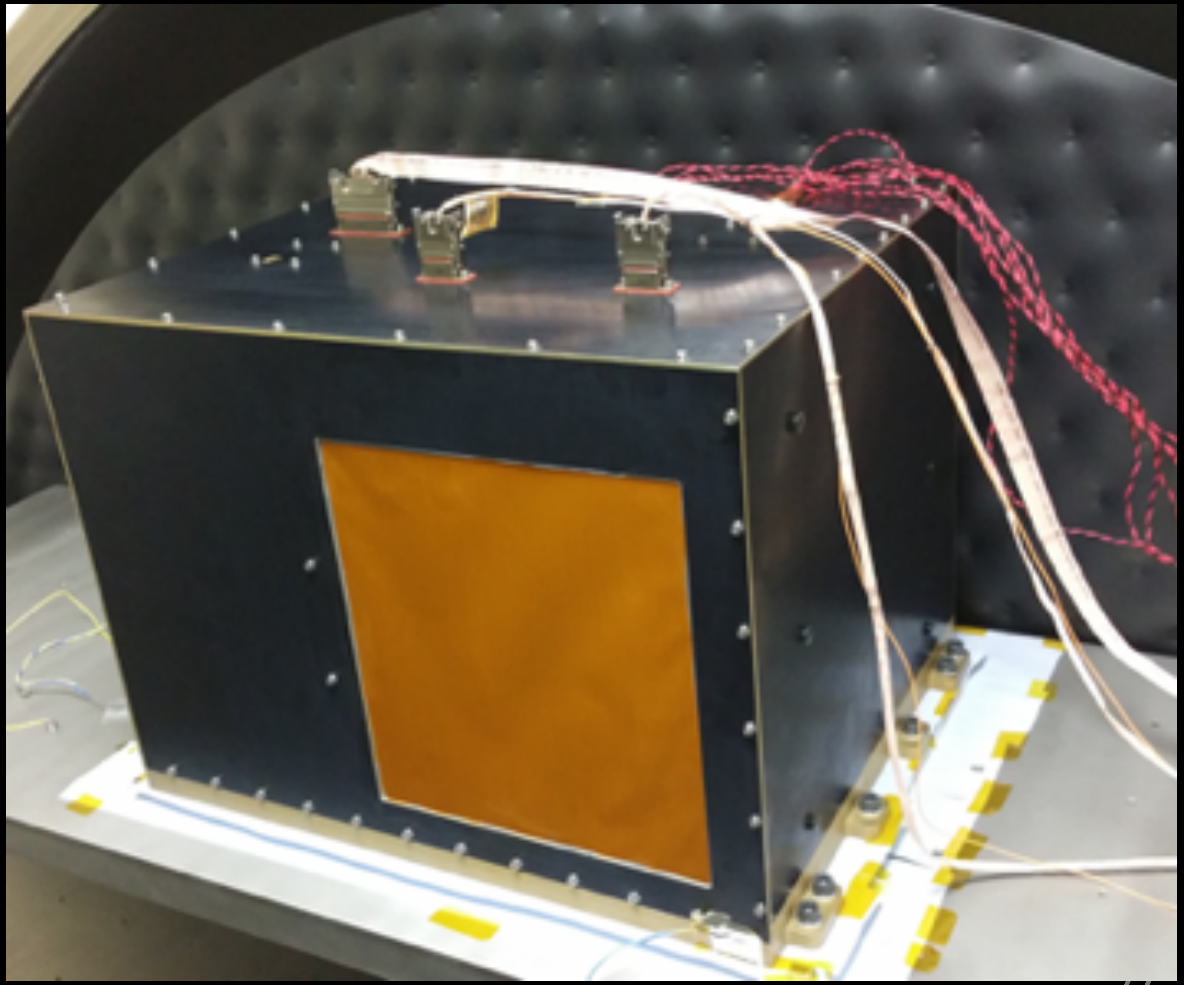
HEPD BEAM TESTS



- Electron Beam Test @ BTF, Frascati, 3rd-5th October 2016
  - Energy: 30 MeV, 45 MeV, 60 MeV, 120 MeV
- Proton Beam Test @ APSS Proton Therapy, Trento, 8th-12th November 2016
  - Energy: 37 MeV, 51 MeV, 70 MeV, 100 MeV, 125 MeV, 175 MeV, 202 MeV, 228 MeV

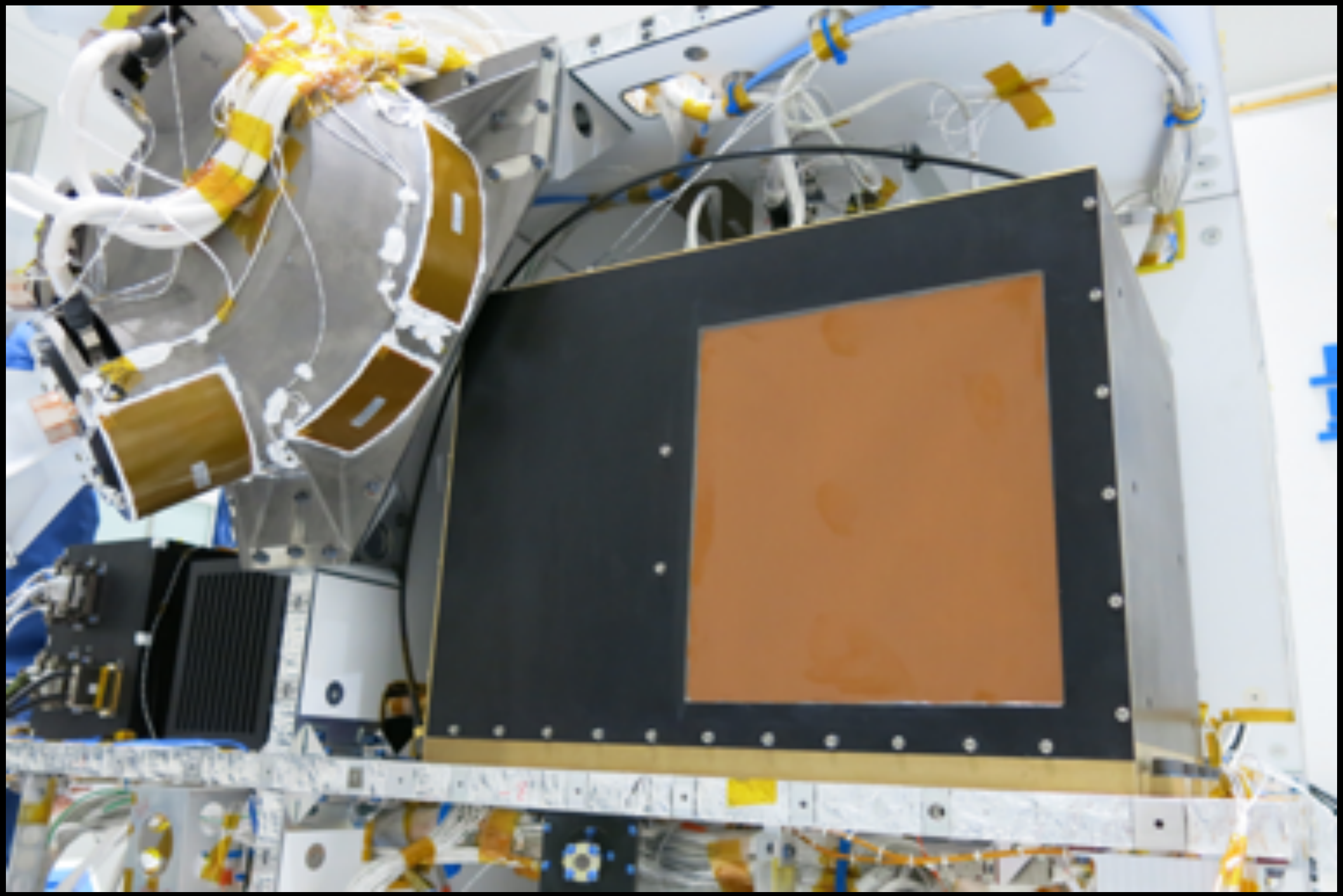


VIBRATION TEST
(October 2016)

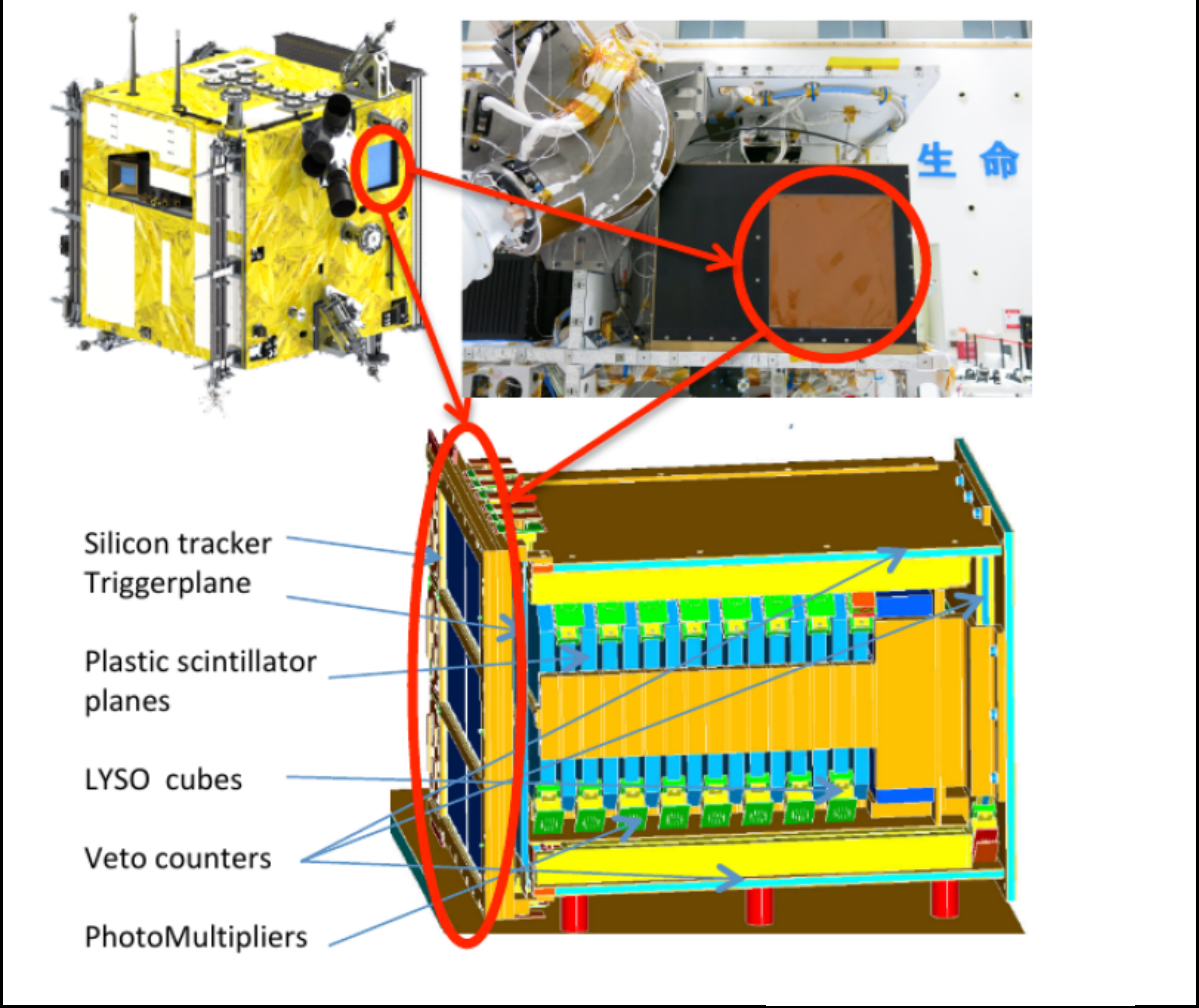


THERMAL-VACUUM TEST
(November 2016)

HEPD TESTING ACTIVITIES IN BEIJING



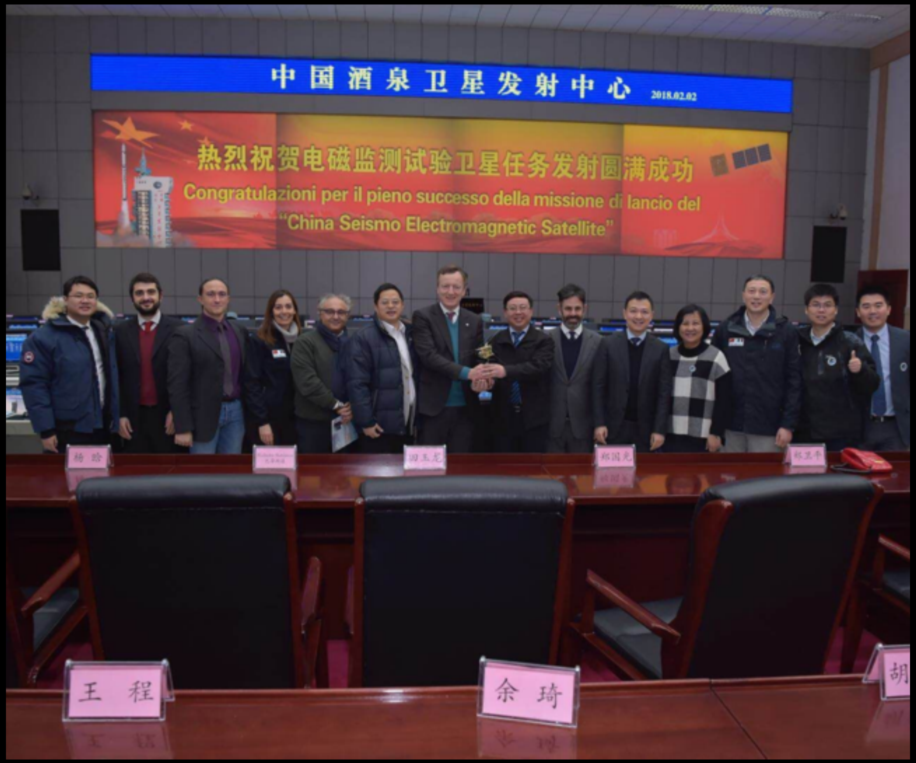
- <u>**January 2017**</u>: Assembly and Integration Verification;
- <u>**February 2017:**</u> Sine (0.75 g) & Random (2.37 GRMS) Vibration Test;
- <u>**March 2017:**</u> HEPD command & control software upgrade;
- <u>**April 2017:**</u> Thermal Balance & Thermal Vacuum Test (4 cycles, -10 °C - +40 °C);
- <u>**December 2017**</u>: Pre-Lauch Site Transfer Functional Test;
- <u>**25th December 2017:**</u> CSES transfer to Jiuquan Satellite Launch Center (JSLC).


生 命
Silicon tracker
Triggerplane
Plastic scintillator planes
LYSO cubes
Veto counters
PhotoMultipliers

CSES LAUNCH

- Jiuquan Satellite Launch Center (JSLC): 40° 57’ 29.2” N - 100° 17’ 28.7” E
- Functional test and atmospheric muon acquisitions (7-8 January 2018)
- All instruments compliant to satellite requirements before launch

Launch 2nd February 2018 15:51:04

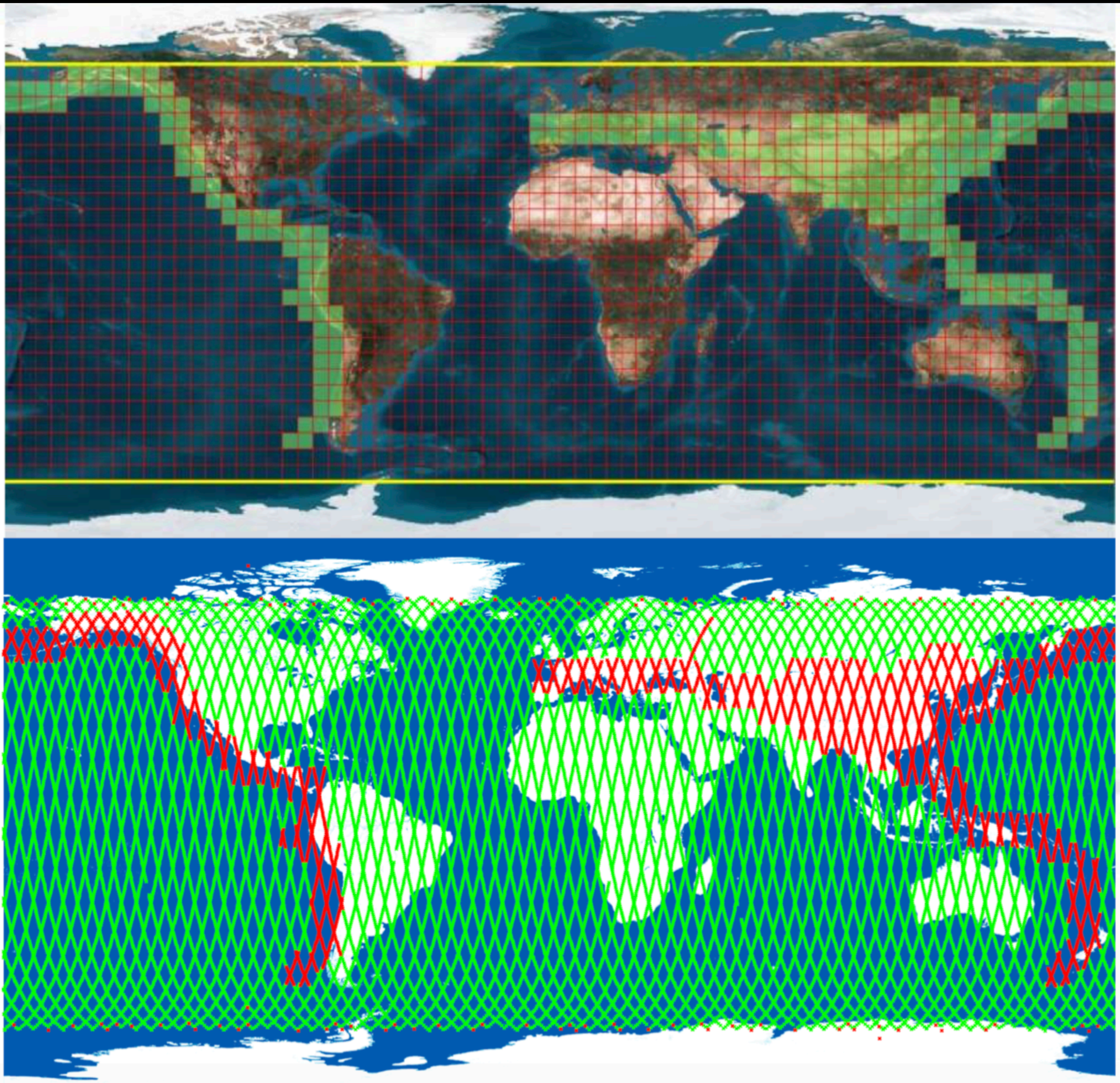


Chinese and Italian delegations after the successful launch.

Congratulations in Chinese and Italian!

COMMISSIONING PHASE – FEBRUARY 2018 – JULY 2018

- **Working Mode**
  Operates perfectly
  Matching ground
  design.

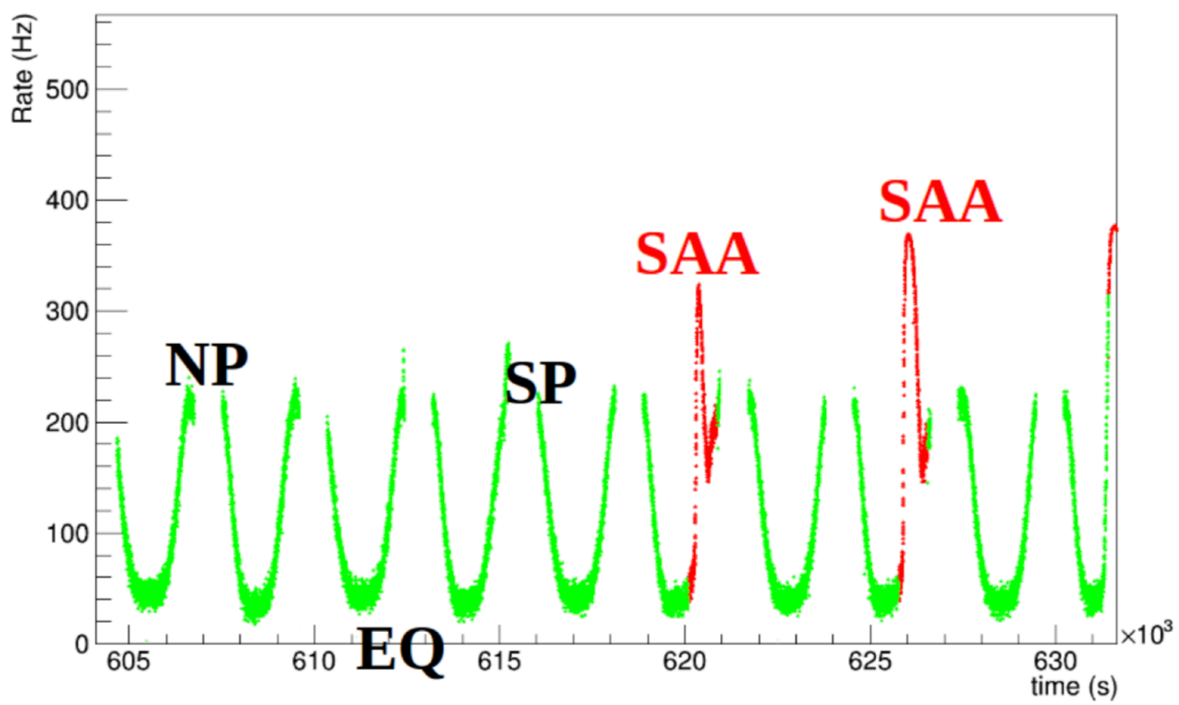


- ➢ **Payload Working Zone Covers -65~ +65.**
- ➢ **Burst Mode Covers Seismic Belt and China Mainland.**

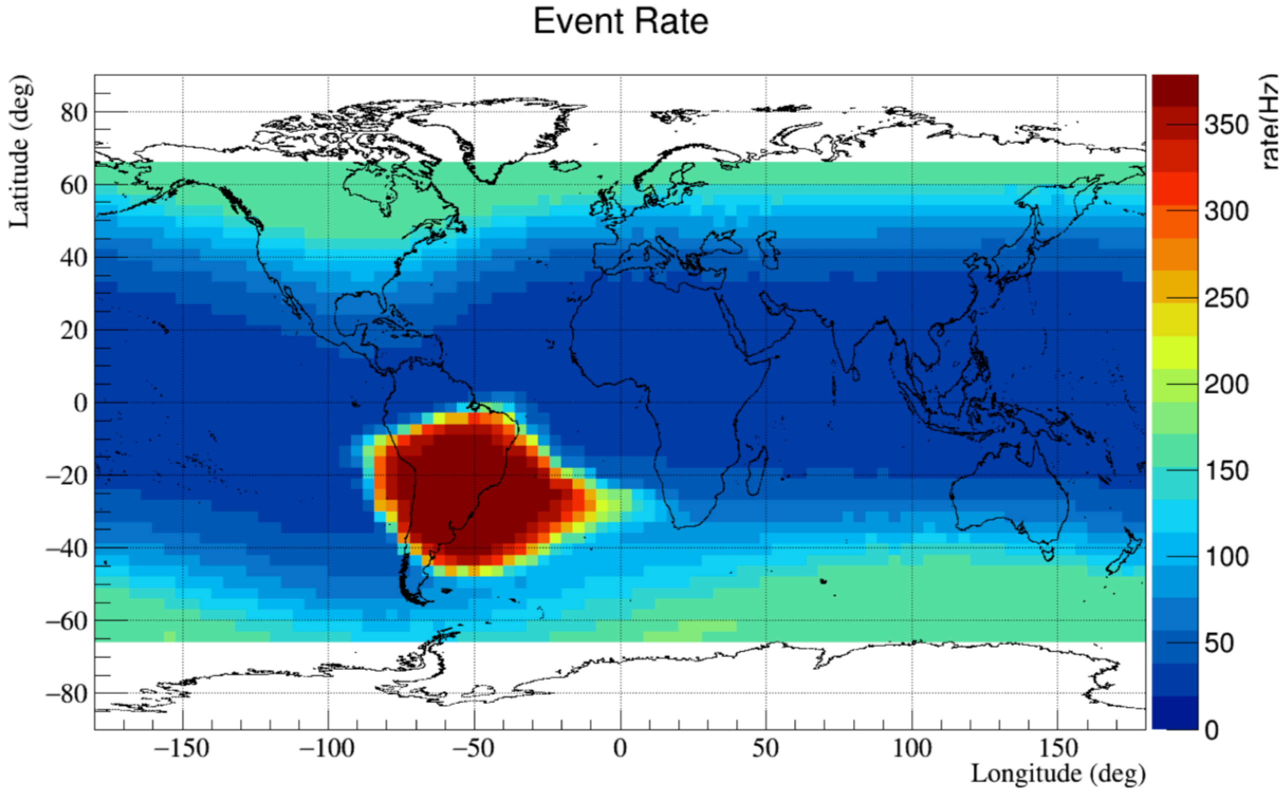
COMMISSIONING PHASE FOR HEPD

During the commissioning phase the HEPD has been tested in different configurations in order to:

- study the trigger rates along the orbit in different trigger configurations;
- study to define the optimal trigger thresholds in flight;
- perform an in-flight calibration to be compared with beam test results.

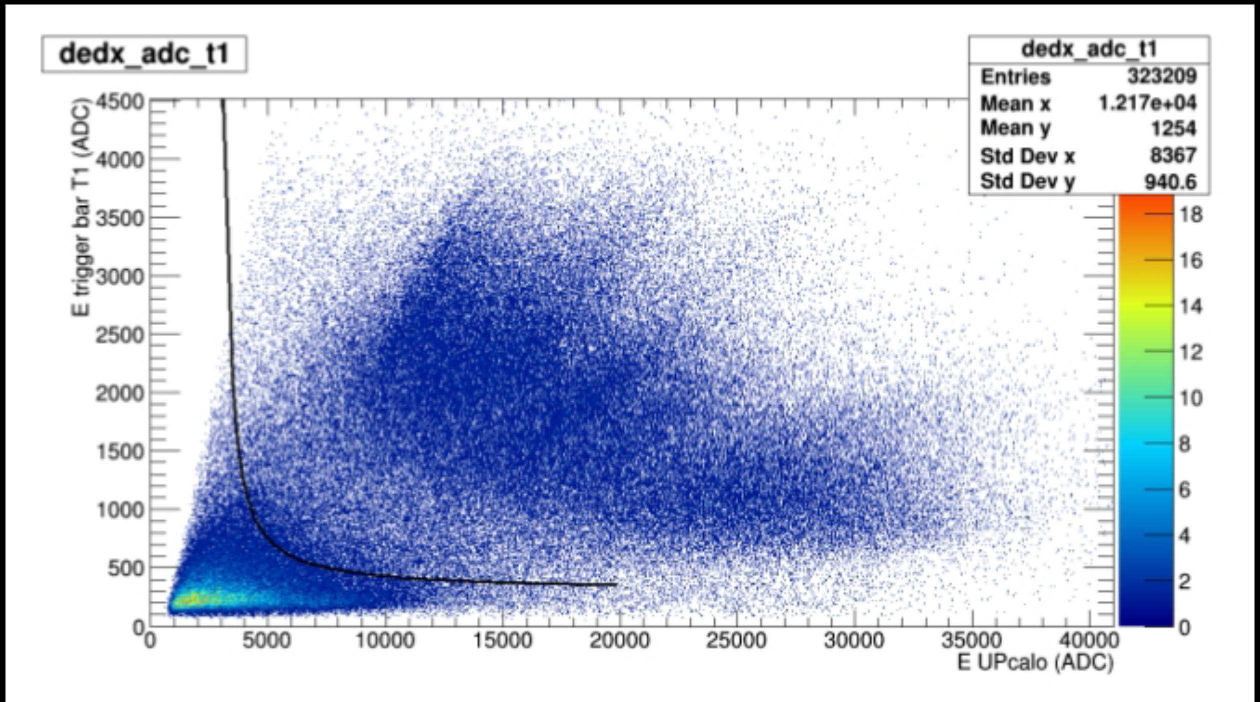


Event trigger rate as a function of time



Event trigger rate map (all particles) measured in a given trigger configuration (~ 1 month of acquisition)

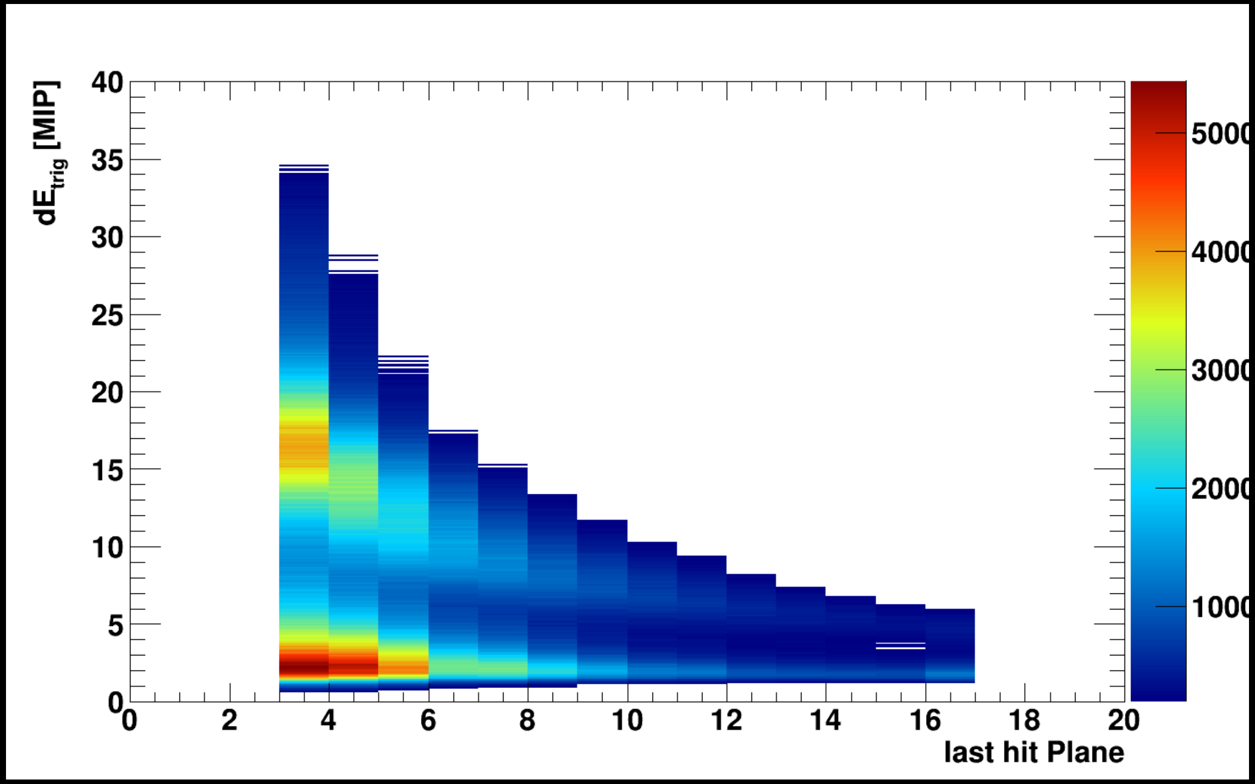
PARTICLE IDENTIFICATION: PROTONS AND ELECTRONS



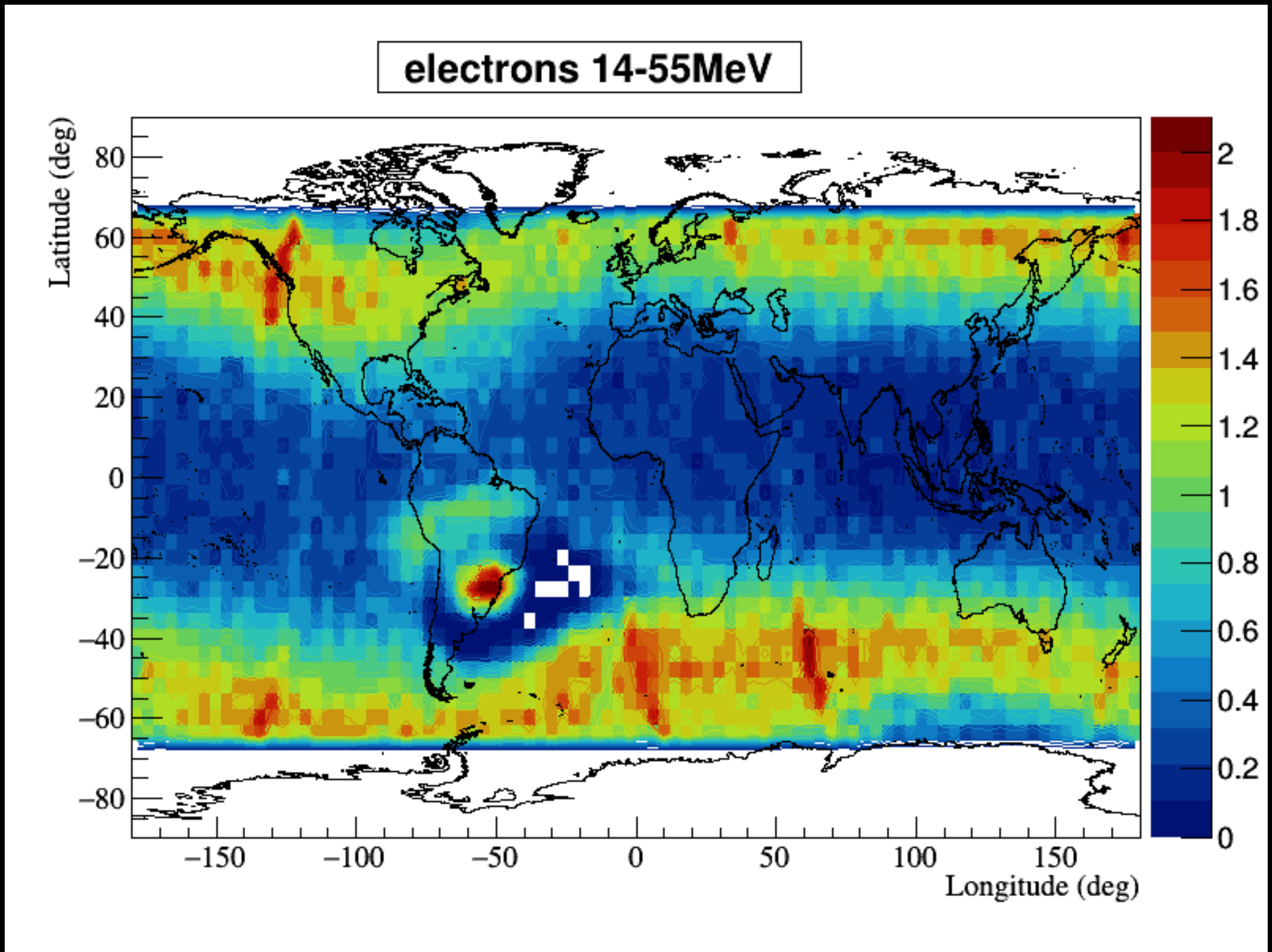
A first level of particle recognitions basedon the energy deposited in the calorimeter and in the trigger planes.

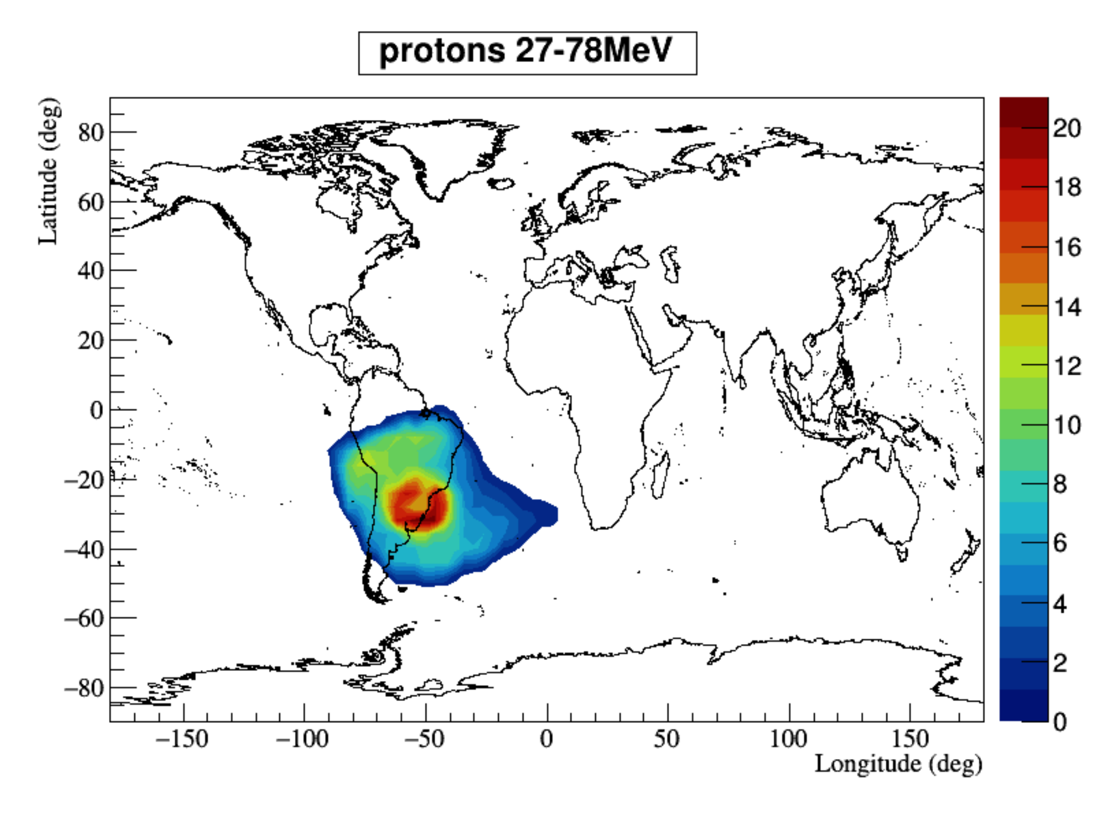
2 **tight** cut defined to select **electrons or** protons

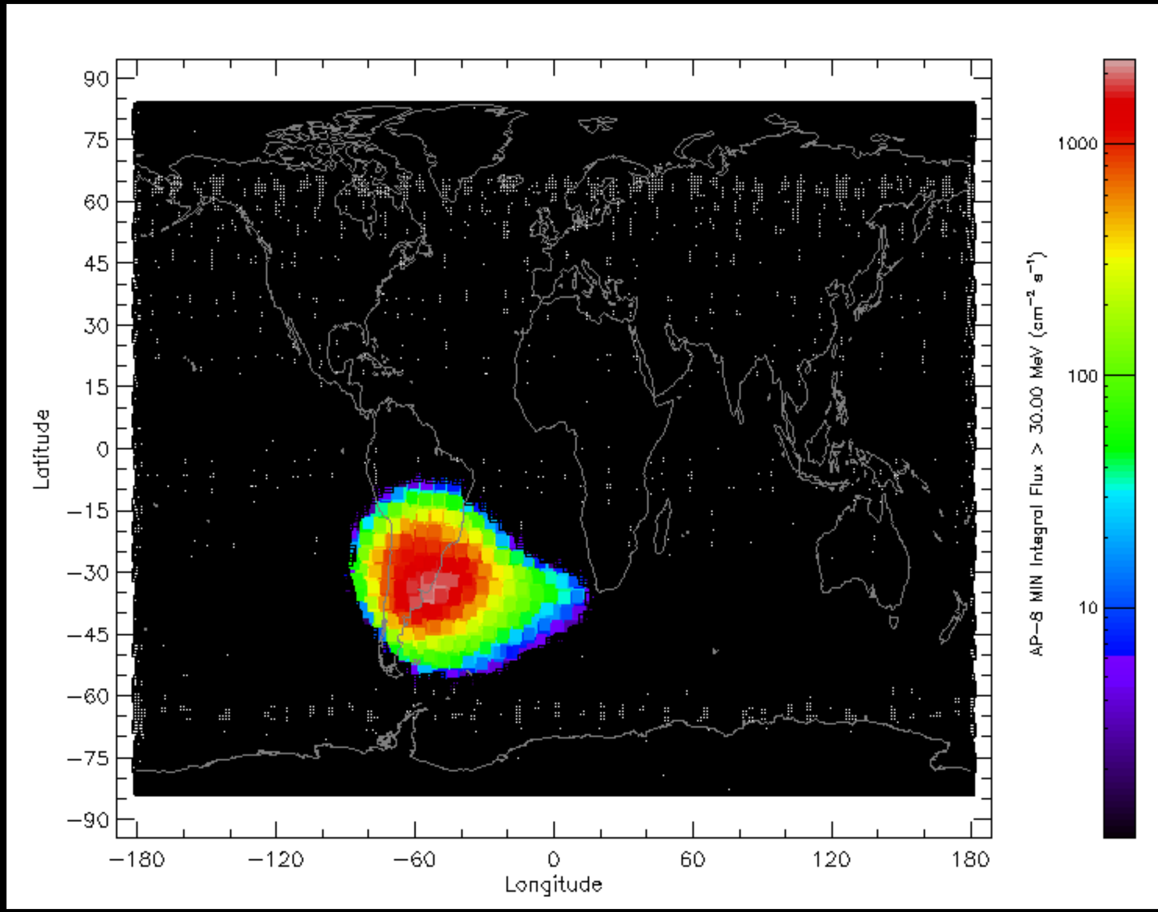
Optimization in progress with range information included.



SKY RATE MAPS





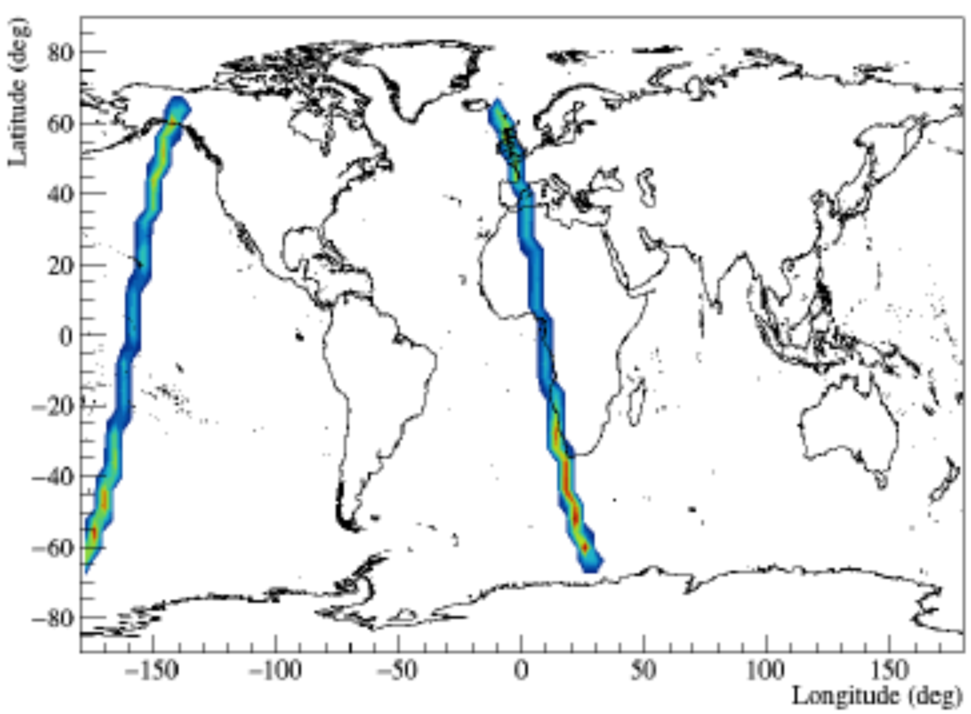


Comparison of sky rate maps with the expectations from ***models of trapped particles*** *(SPENVIS AP9 model)*

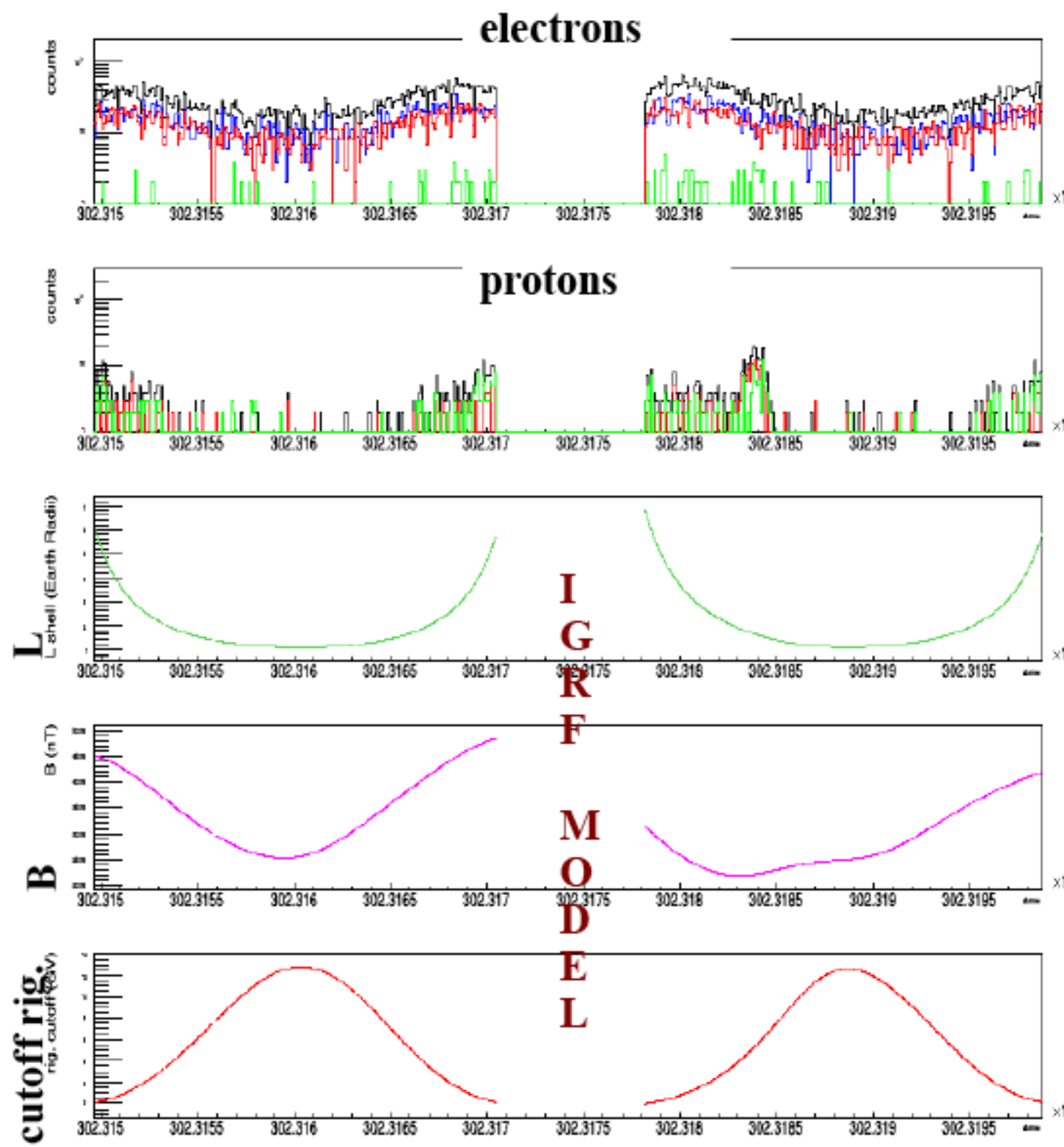
PARTICLE RATES FOR DIFFERENT TYPES OF ORBIT: NO SAA

- e^- all energies
- e^- < 14 MeV
- 14 MeV < e^- < 55 MeV
- 55 MeV ≤ e^- < 100 MeV

- p^+ all energies
- 27 MeV< p^+ <78 MeV
- 78 MeV< p^+ <220MeV



Coarse binning due to low statistics



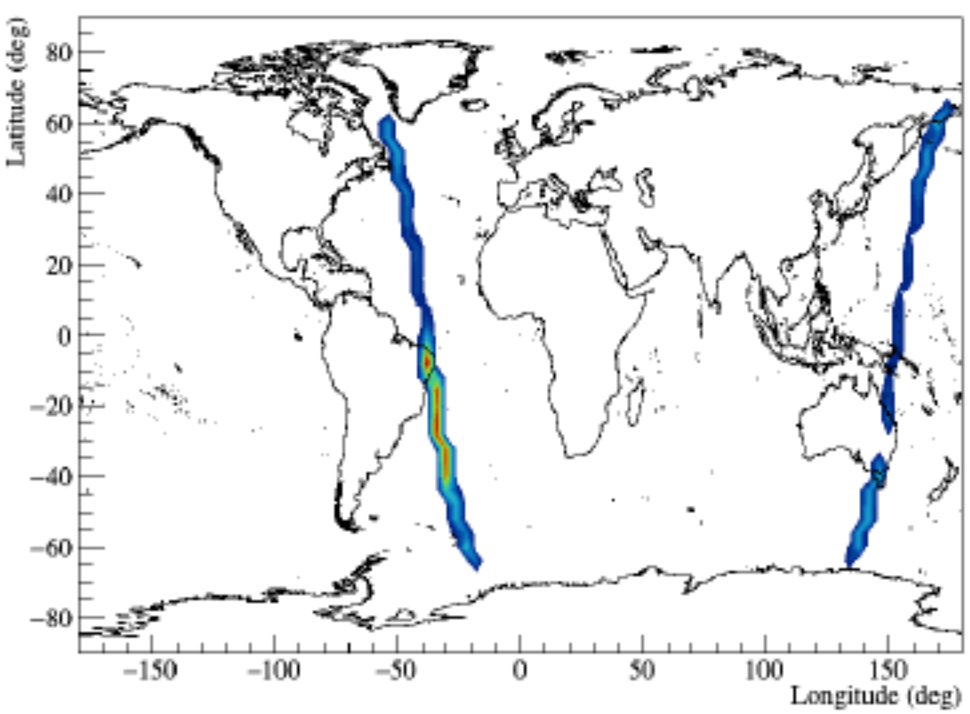
2018-08-01 00:22

2018-08-01 01:44

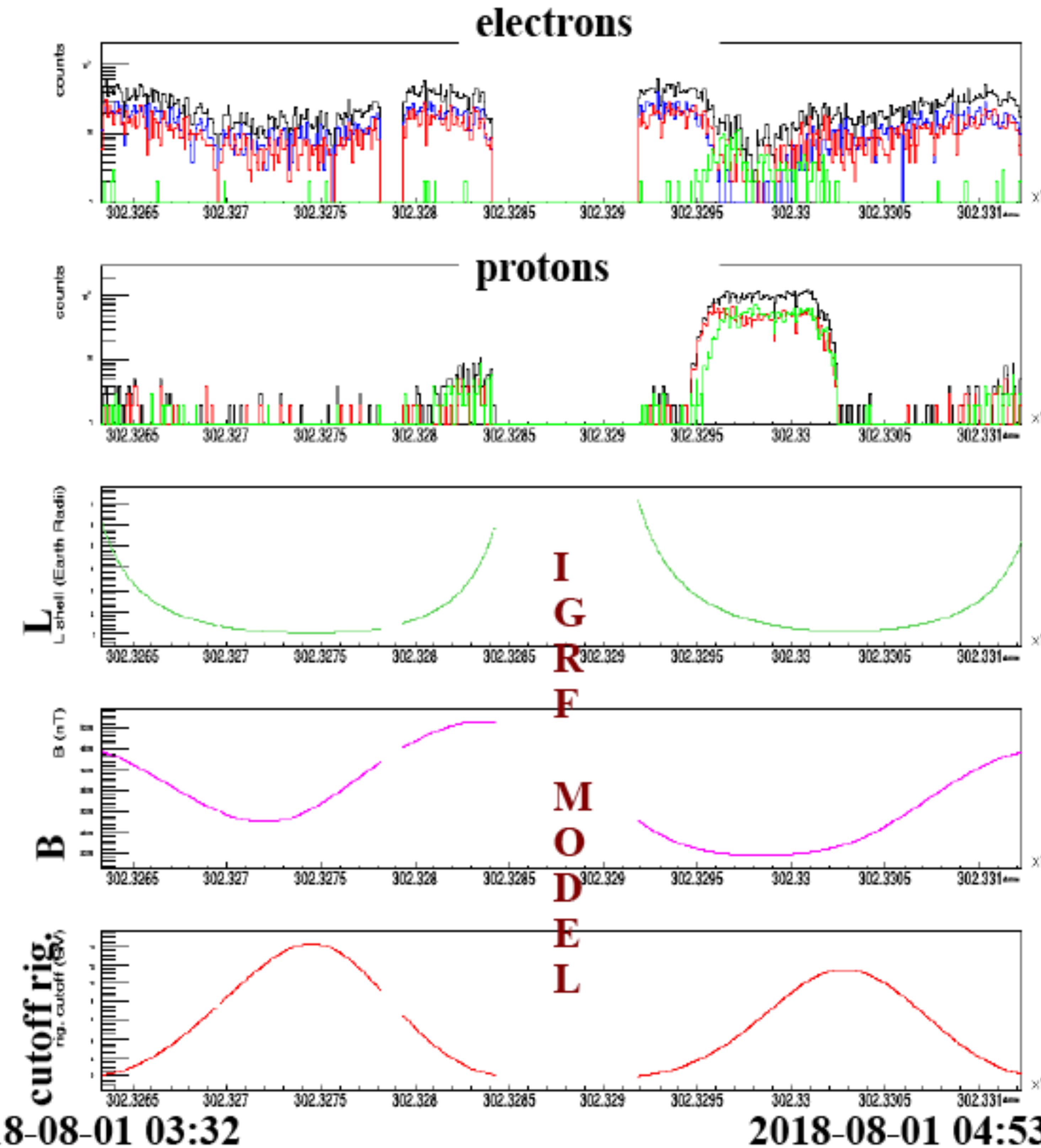
PARTICLE RATES FOR DIFFERENT TYPES OF ORBIT: WITH SAA

- e^- all energies
- e^- < 14 MeV
- 14 MeV < e^- < 55 MeV
- 55 MeV ≤ e^- < 100 MeV

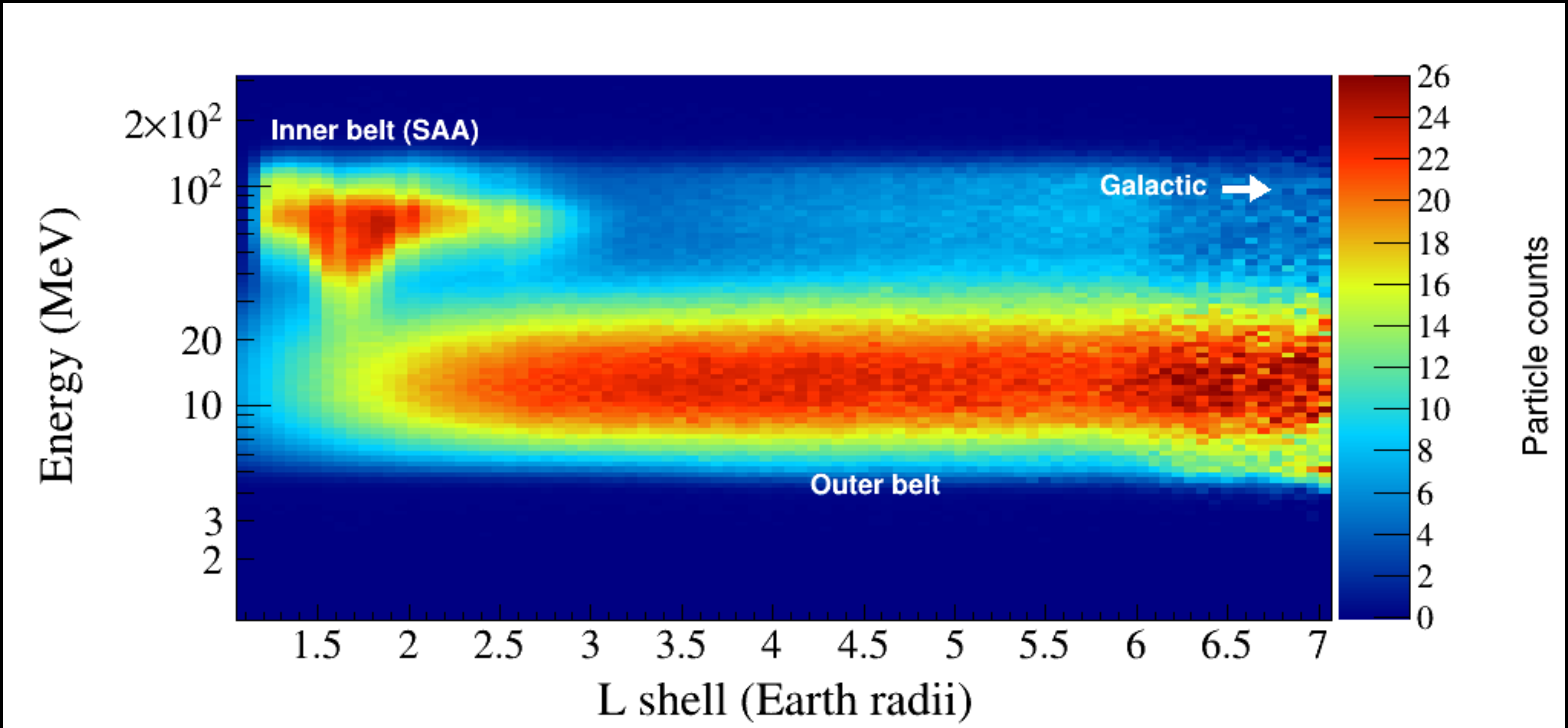
- p^+ all energies
- 27 MeV< p^+ <78 MeV
- 78 MeV< p^+ <220MeV



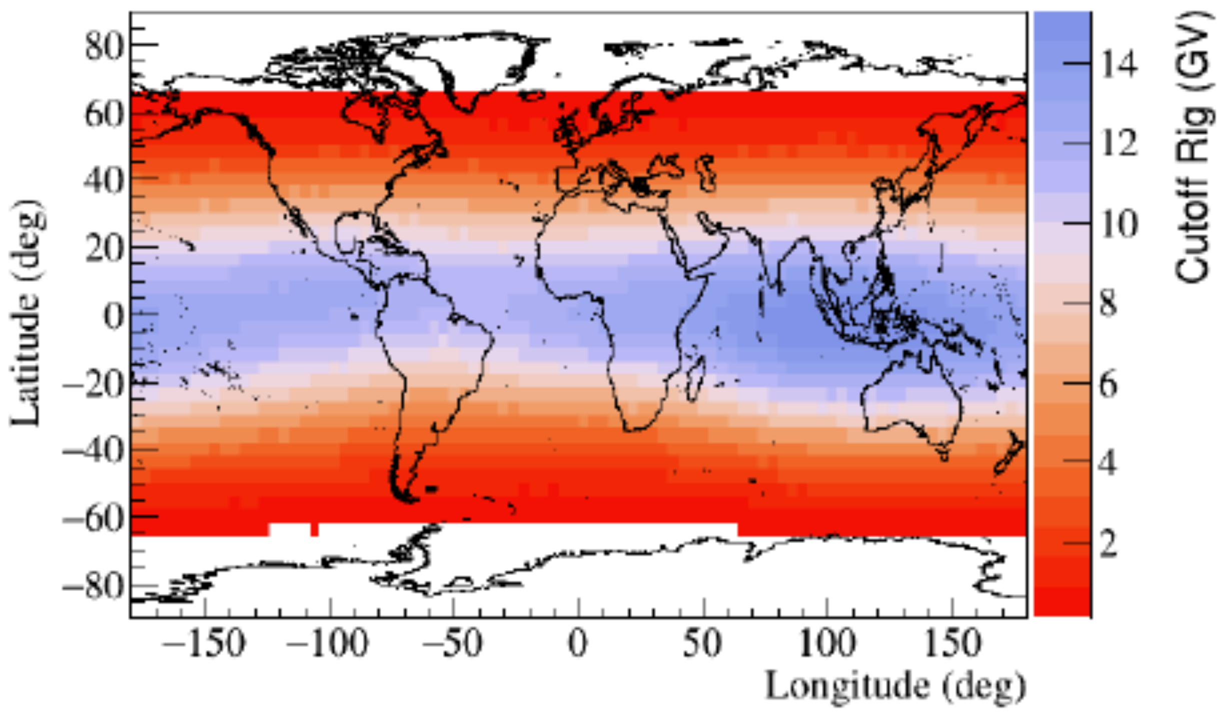
Coarse binning due to low statistics



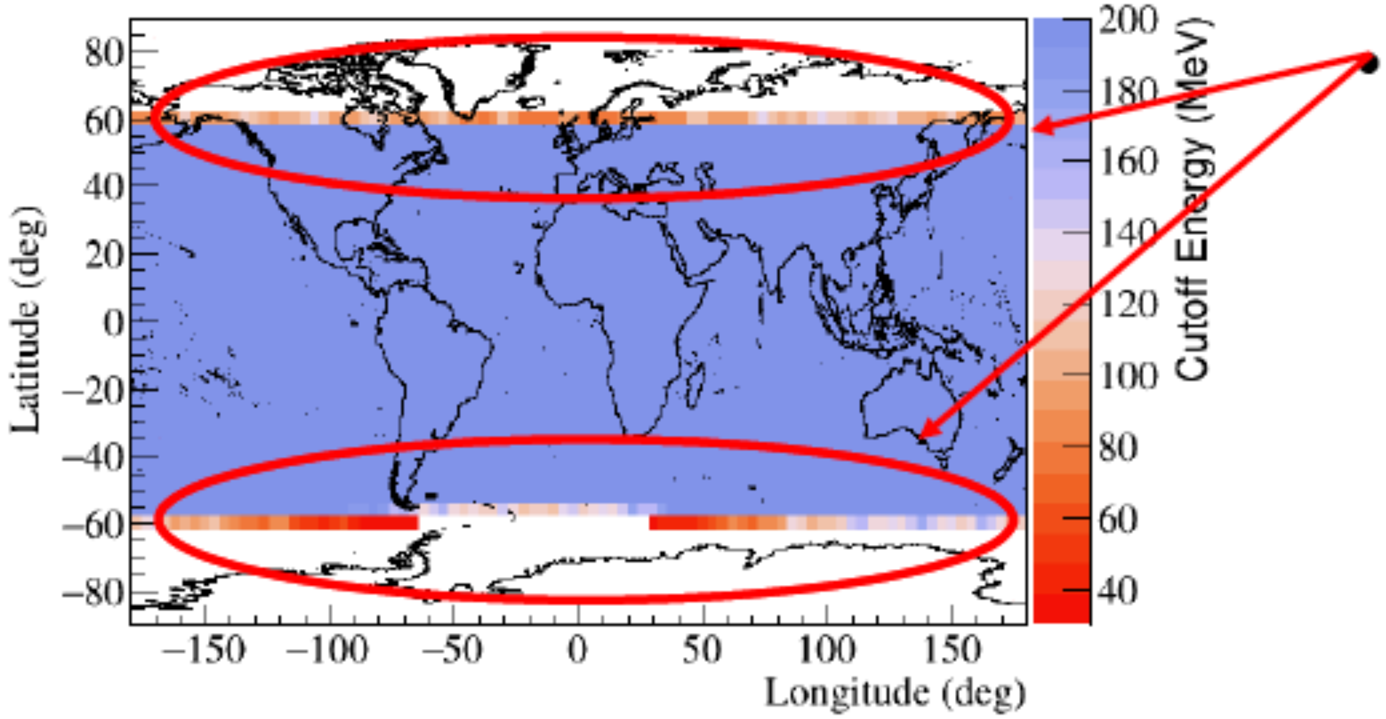
PARTICLE POPULATIONS



MAP OF HEPD GALACTIC PROTONS

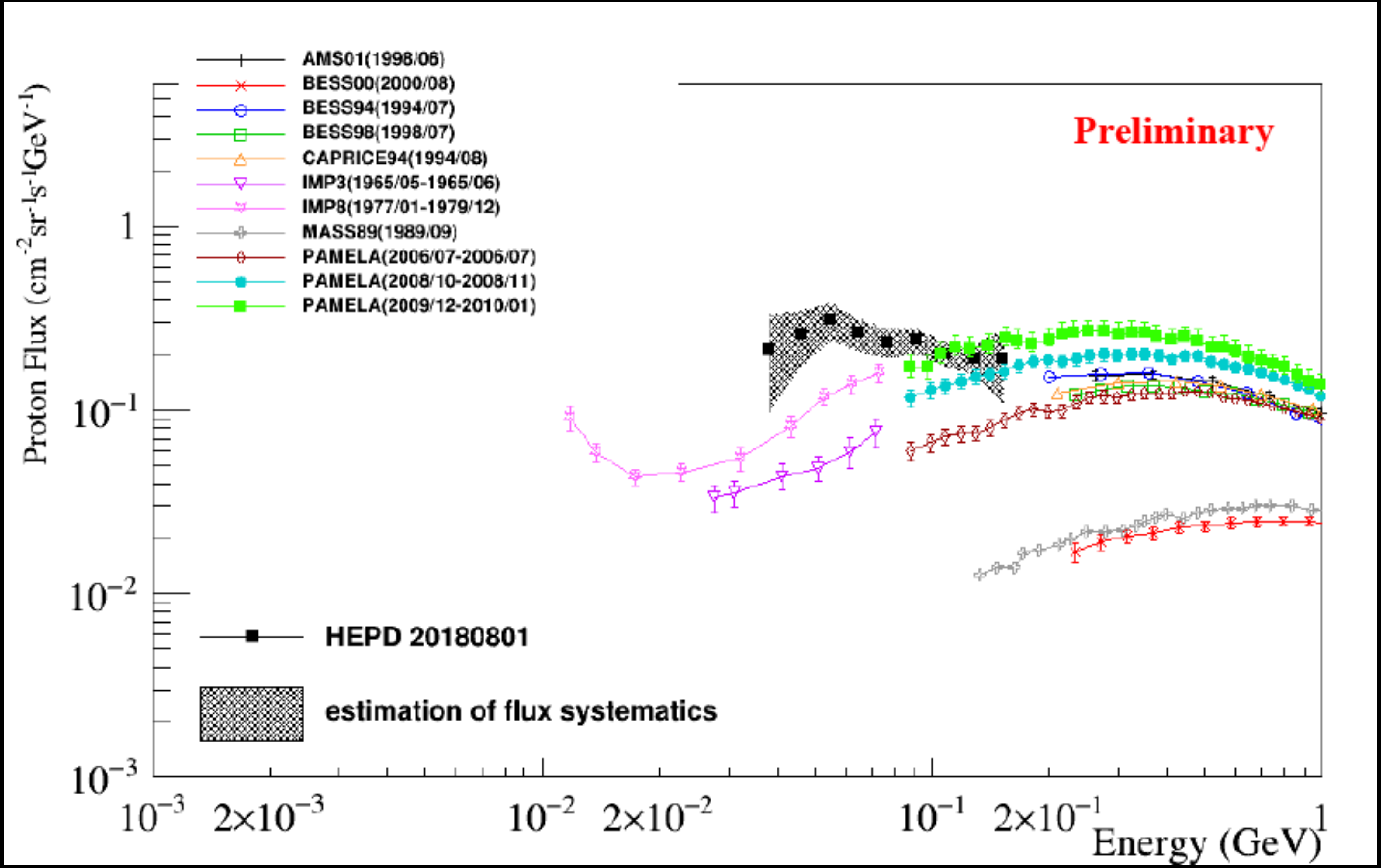


- HEPD proton energy range (30 – 300 MeV) is above cutoff rigidity at polar regions



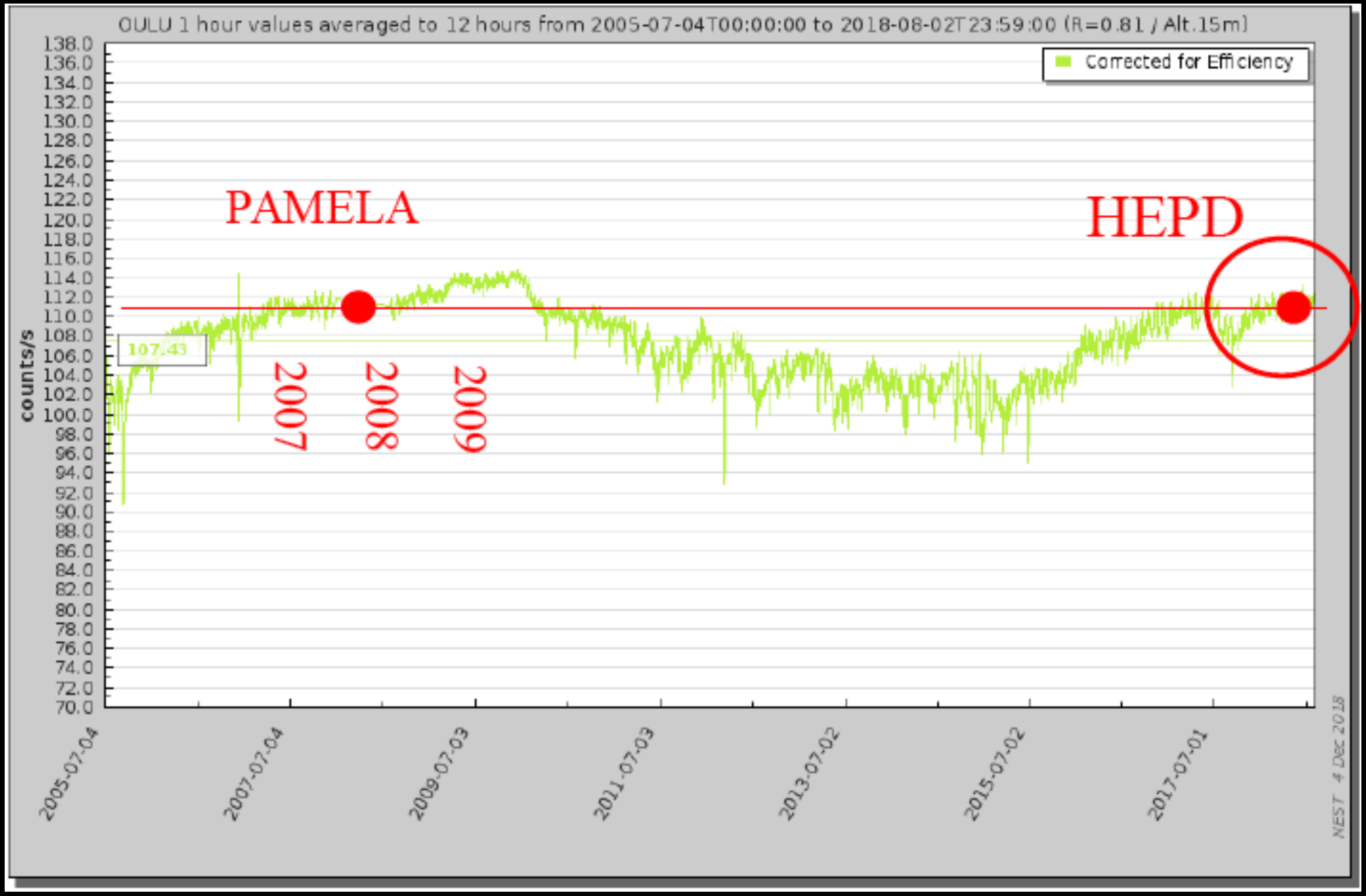
- HEPD is capable to measure the lowest galactic particles (i.e. 35-45 MeV) for ~6% of the orbit

PRELIMINARY GCR PROTON FLUX



HEPD can reach a **very low energy range for galactic protons** which cannot be achieved by current space instruments

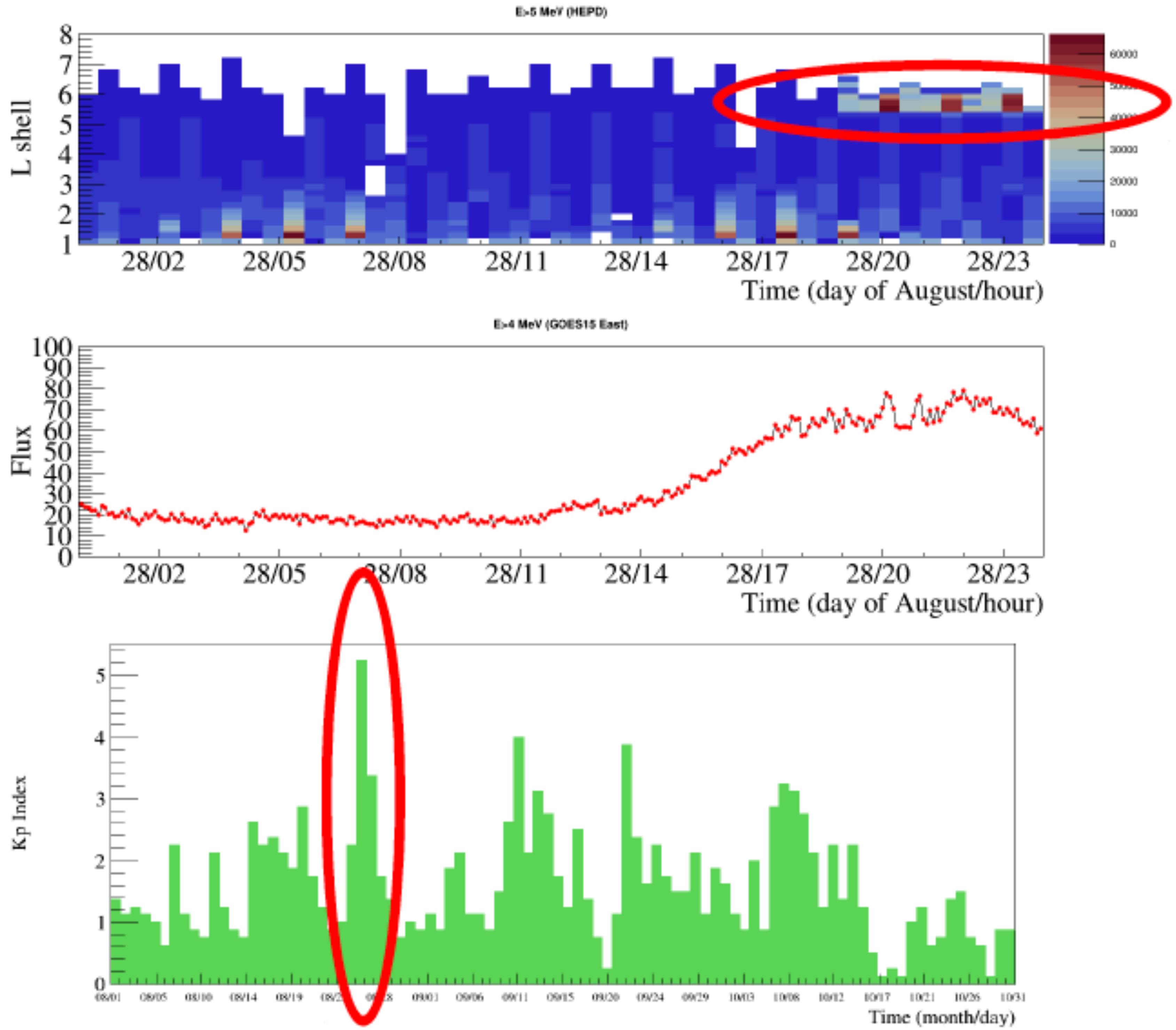
PRELIMINARY GCR PROTON FLUX



Considering the modulation potential and other parameters, we expect HEPD galactic protons to be **almost at the same level of PAMELA 2008 protons**

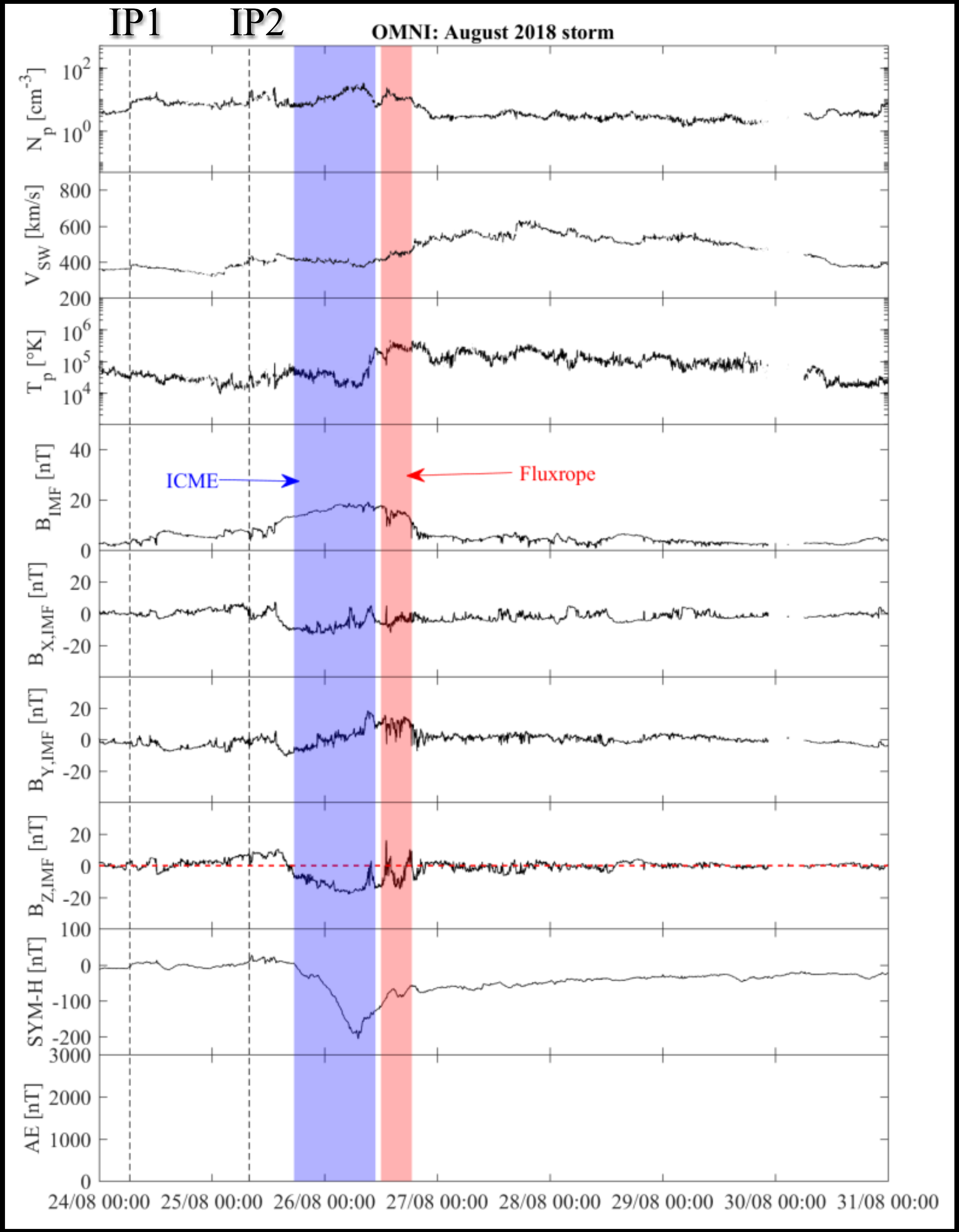
HEPD AND SOLAR PARTICLES

- HEPD registered a rise in particle counts around 1900 UTC of August 28th, after GOES observed a similar rise in electron flux (E>4 MeV)



Moderate geomagnetic storm during August 26th-27th

THE 25TH–26TH AUGUST MAGNETIC STORM



Two Interplanetary Shocks (IP) precede the ICME and a fluxrope:

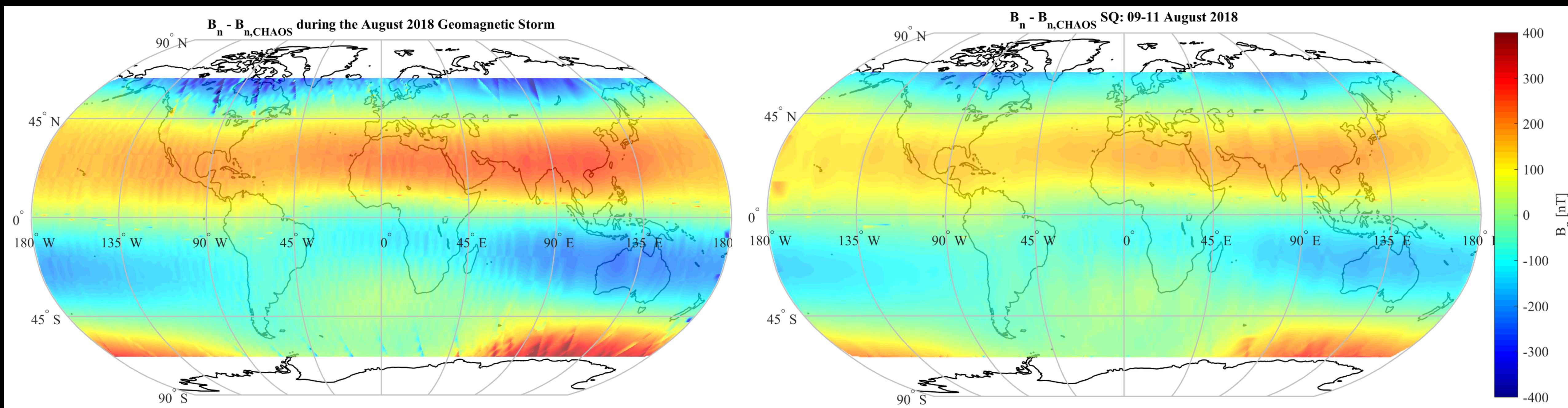
1. IP1: 24/08 at 06:33 UT – Increase of all SW parameters;
2. IP2: 25/08 at 07:58 UT – Increase of all SW parameters;
3. **ICME: 25/08 at 17:31 UT** – Rotation of Bz(IMF) and increase in the SW density and IMF amplitude;
4. Fluxrope: 26/08 at 12:02 UT – Increase in SW density, temperature and IMF amplitude. Rotation of the Bz(IMF).

At ground two Sudden Impulses (SI) and strong geomagnetic storm:

1. Two sudden increases in the Sym-H at 06:33 UT and at 07:58 UT;
2. Main Phase: Sym-H=-202 nT;
3. Recovery phase very long in time (31/08).
4. No AE-index data available.

THE GEOMAGNETIC STORM SEEN BY THE OTHER CSES INSTRUMENTS:

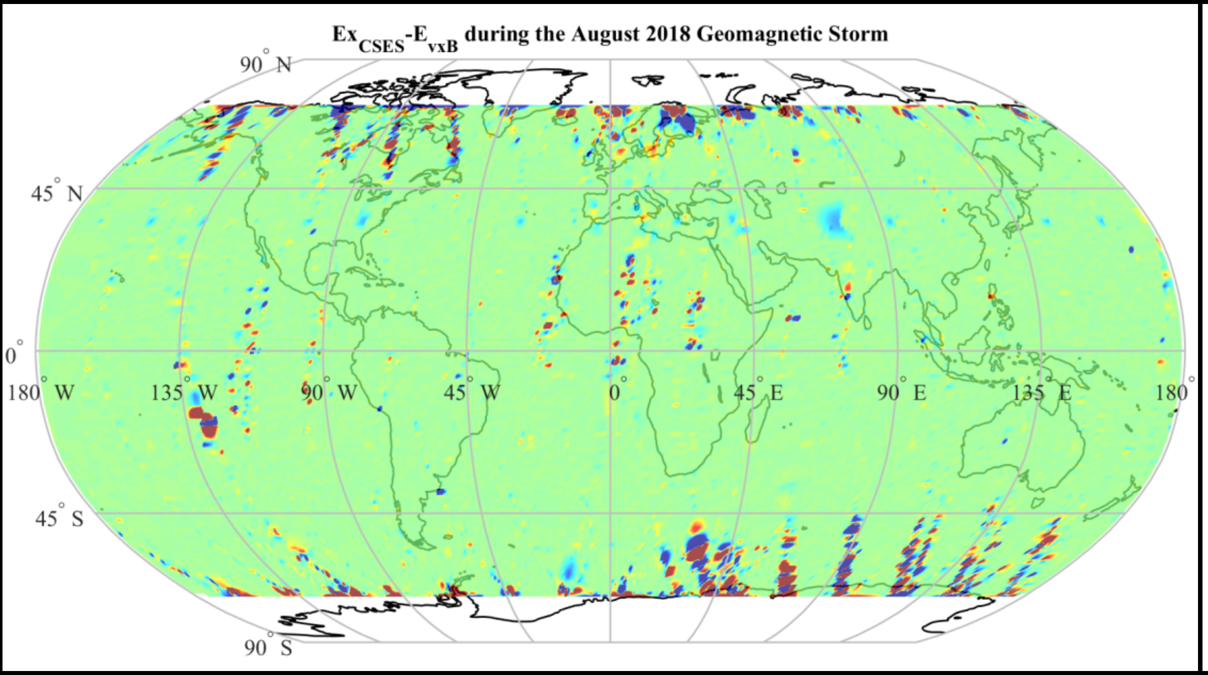
HIGH PRECISION MAGNETOMETER (HPM)

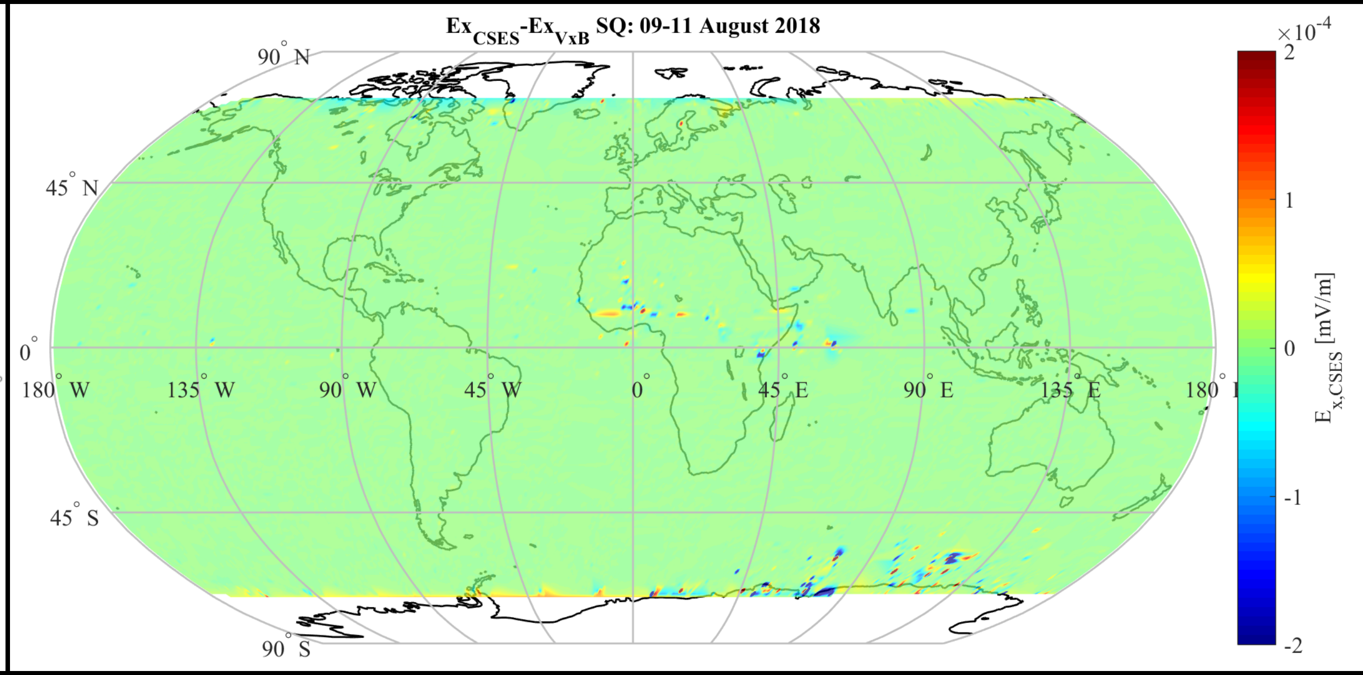


- **Strong increase of the Ring Current** and Ionospheric current activity during the main phase with respect to the Solar Quiet SQ period;
- **Strong increase in the Field aligned current** activity during the main phase with respect to the SQ period.

THE GEOMAGNETIC STORM SEEN BY THE OTHER CSES INSTRUMENTS:

ELECTRIC FIELD DETECTOR (EFD)

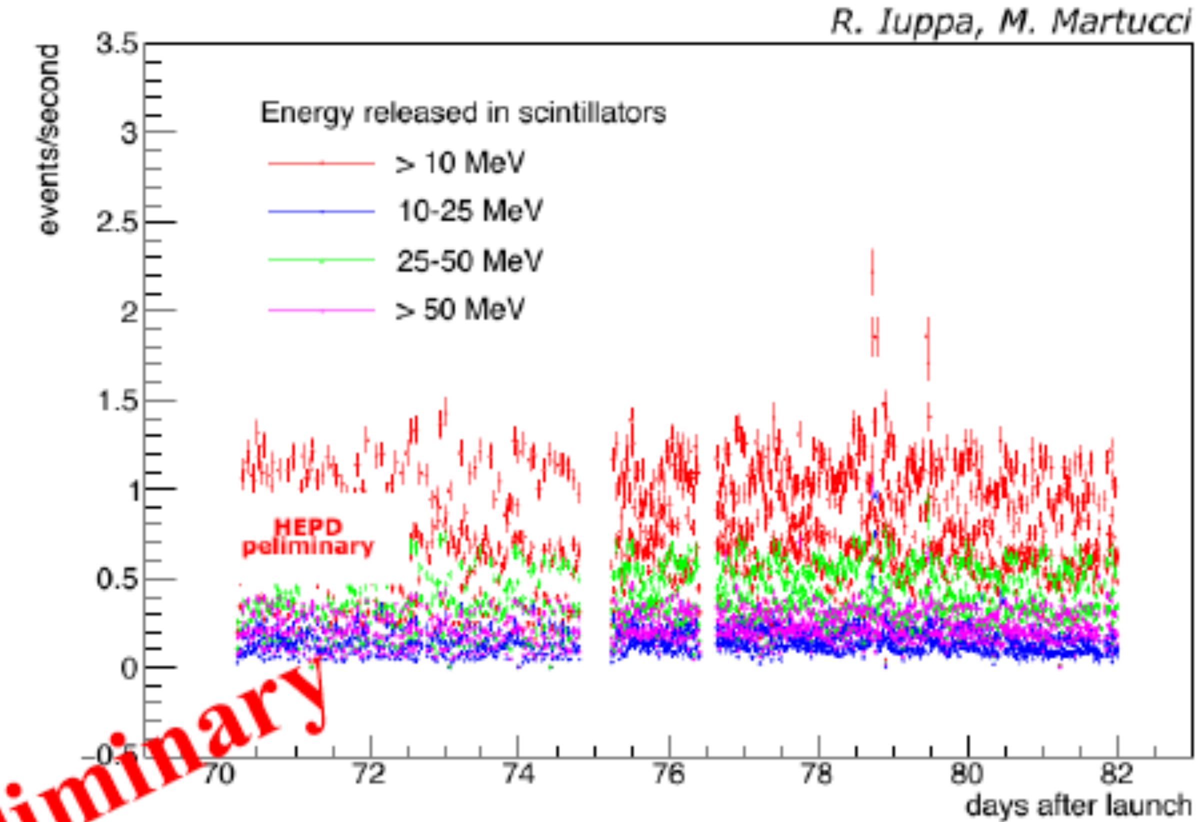


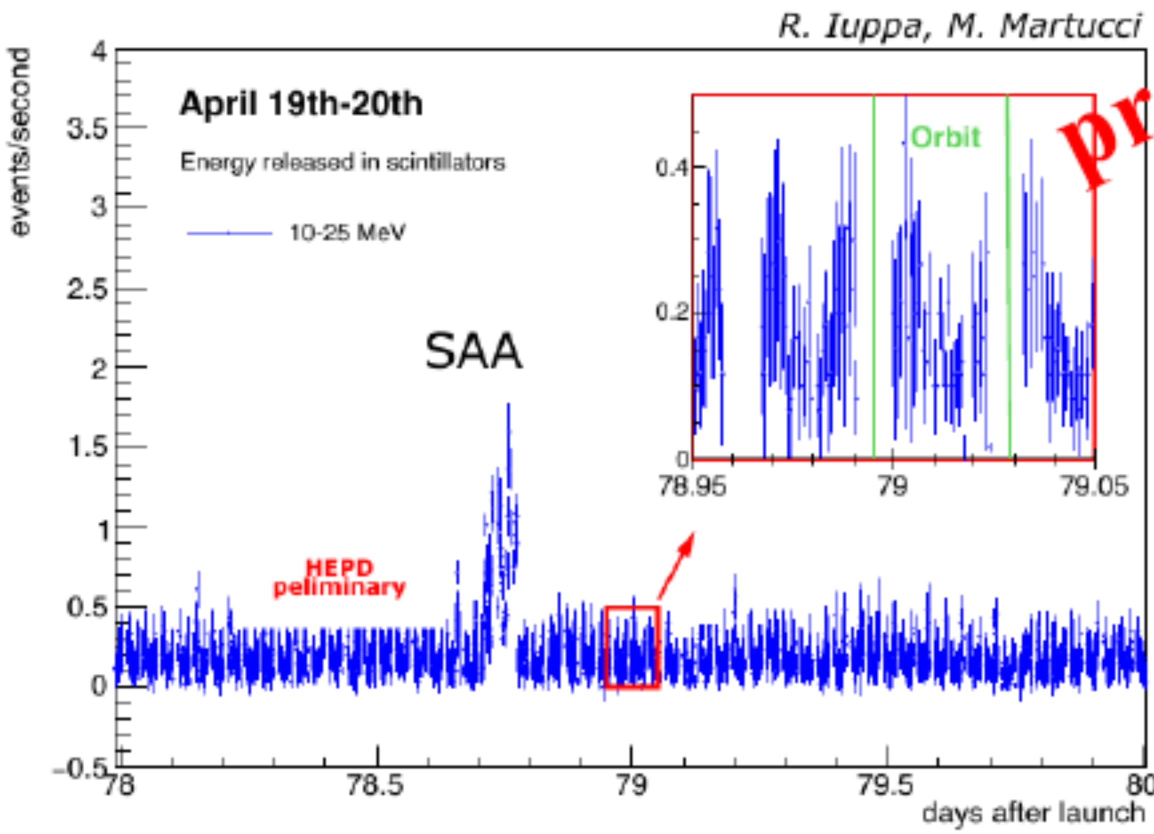


- **Strong increase of the Auroral Electrojet (AEJ) activity** in the north-south direction with respect to the SQ period;
- **Strong increase of the EEJ activity** in the north-south direction with respect to the SQ;

ELECTRONS RATES: SEARCH FOR PARTICLE BURSTS

Electron acquisition rate (tight selection) as a function of time (10 minutes bin). Different periods of data taking appear, due to changes of configurations during commissioning. Energy intervals are well resolved.





Electron acquisition rate (tight selection) on April 19th-20th (1 minute bin). HEPD large area allows to be sensitive to percent level electron flux variation on time scales as short as few seconds.

CSES-2 PROGRAM: LAUNCH IN 2021

- Same CAST-2000 platform with minor improvements
- 2 new instruments onboard
- Full time operational
- Identical orbital plane but 180° phase difference

Italy will build two instruments:

- **HEPD**
- **EFD**

The Chinese and Italian Space Agencies are signing an MoU on 25th Jan 2019

CONCLUSIONS

- Earthquakes observation from space **opens a new window for possible precursors** and hope for disaster forecasting;
- The **CSES/Limadou collaboration** conceived, designed, constructed, qualified and is currently operating the CSES satellite in orbit;
- Huge testing work preceded the launch;
- CSES has **overcome the commissioning phase**, providing good quality data and confirming expectations.
- While the PB (earthquake-focused) analysis is at the beginning, CSES demonstrated to be a powerful Space Weather instrument, with performance even better than other SW satellites (ESA/SWARM), currently flying;
- CSES satellite is the **first of a constellation of "CSES-like" satellites** expected to be launched in the coming years, not only in China;
- The launch of CSES-2 is **planned for the 2021**.