

GRUPPO DI ASTROPARTICELLE E ASTROFISICA

**Prof. R. Battiston, Prof. M. Busso,
Prof. L. Gammaitoni, Prof. B. Bertucci, Prof. M. Pauluzzi,
Dr. G. Tosti, Dr. E. Fiandrini, Dr. C. Cecchi
15 t.d., Ass. Ric. Dott.**

1) Astro-particelle

Raggi Cosmici-AMS

Onde Gravitazionali-VIRGO

Applicazioni sismiche-CSES (Cina)

2) Astrofisica alte energie-FERMI

3) Astrofisica stellare e nucleare-IRAIT

Con il supporto e in collaborazione con

- Sezione INFN di Perugia**
- INAF – Progetto Antartide**
- Laboratorio SERMS (Polo di Terni)**

Standard Model of FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is included on this chart because it is one of the fundamental interactions even though not part of the "Standard Model."

FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c ²	Electric charge	Flavor	Approx. Mass GeV/c ²	Electric charge
ν_e electron neutrino	$<1 \times 10^{-8}$	0	u up	0.003	2/3
e electron	0.000511	-1	d down	0.006	-1/3
ν_μ muon neutrino	<0.0002	0	c charm	1.3	2/3
μ muon	0.106	-1	s strange	0.1	-1/3
ν_τ tau neutrino	<0.02	0	t top	175	2/3
τ tau	1.7771	-1	b bottom	4.3	-1/3

Spin is the intrinsic angular momentum of particles. Spin is given in units of $\hbar$, which is the quantum unit of angular momentum, where $\hbar = h/2\pi = 6.58 \times 10^{-25}$ GeV s $\approx 1.05 \times 10^{-34}$ J s.

Electric charges are given in units of the proton's charge. In SI units the electric charge of the proton is 1.60×10^{-19} coulombs.

The **energy** unit of particle physics is the electronvolt (eV), the energy gained by one electron in crossing a potential difference of one volt. **Masses** are given in GeV/c² (remember $E = mc^2$), where $1 \text{ GeV} = 10^9 \text{ eV} = 1.60 \times 10^{-10}$ joule. The mass of the proton is $0.938 \text{ GeV}/c^2 = 1.67 \times 10^{-27} \text{ kg}$.

BOSONS

force carriers
spin = 0, 1, 2, ...

Unified Electroweak spin = 1			Strong (color) spin = 1		
Name	Mass GeV/c ²	Electric charge	Name	Mass GeV/c ²	Electric charge
γ photon	0	0	g gluon	0	0
W^-	80.4	-1			
W^+	80.4	+1			
Z^0	91.187	0			

Color Charge

Each quark carries one of three types of "strong charge," also called "color charge." These charges have nothing to do with the colors of visible light. There are eight possible types of color charge for gluons. Just as electrically-charged particles interact by exchanging photons, in strong interactions color-charged particles interact by exchanging gluons. Leptons, photons, and W and Z bosons have no strong interactions and hence no color charge.

Quarks Confined in Mesons and Baryons

One cannot isolate quarks and gluons; they are confined in color-neutral particles called **hadrons**. This confinement (binding) results from multiple exchanges of gluons among the color-charged constituents. As color-charged particles (quarks and gluons) move apart, the energy in the color-force field between them increases. This energy eventually is converted into additional quark-antiquark pairs (see figure below). The quarks and antiquarks then combine into hadrons; these are the particles seen to emerge. Two types of hadrons have been observed in nature: **mesons** $q\bar{q}$ and **baryons** qqq .

Residual Strong Interaction

The strong binding of color-neutral protons and neutrons to form nuclei is due to residual strong interactions between their color-charged constituents. It is similar to the residual electric interaction that binds electrically neutral atoms to form molecules. It can also be viewed as the exchange of mesons between the hadrons.

PROPERTIES OF THE INTERACTIONS

Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$					
Baryons are fermionic hadrons. There are about 120 types of baryons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c ²	Spin
p	proton	uud	1	0.938	1/2
$\bar{p}$	anti-proton	$\bar{u}\bar{u}\bar{d}$	-1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	-1	1.672	3/2

Matter and Antimatter

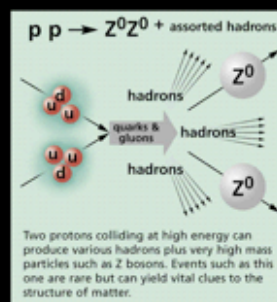
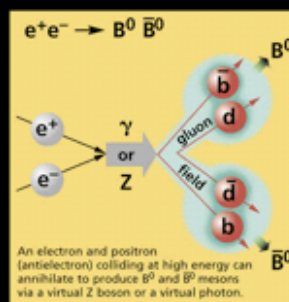
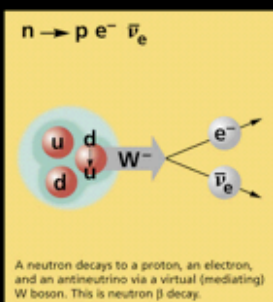
For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or - charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g., Z^0 , γ , and $\eta_c = c\bar{c}$, but not $K^0 = d\bar{s}$) are their own antiparticles.

Figures

These diagrams are an artist's conception of physical processes. They are not exact and have no meaningful scale. Green shaded areas represent the cloud of gluons or the gluon field, and red lines the quark paths.

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic	Strong	
				Fundamental	Residual
Acts on:	Mass - Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at:					
	10^{-41}	0.8	1	25	Not applicable to quarks
	10^{-41}	10^{-4}	1	60	
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

Mesons $q\bar{q}$					
Mesons are bosonic hadrons. There are about 140 types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c ²	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	-1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2.980	0



The Particle Adventure

Visit the award-winning web feature *The Particle Adventure* at <http://ParticleAdventure.org>

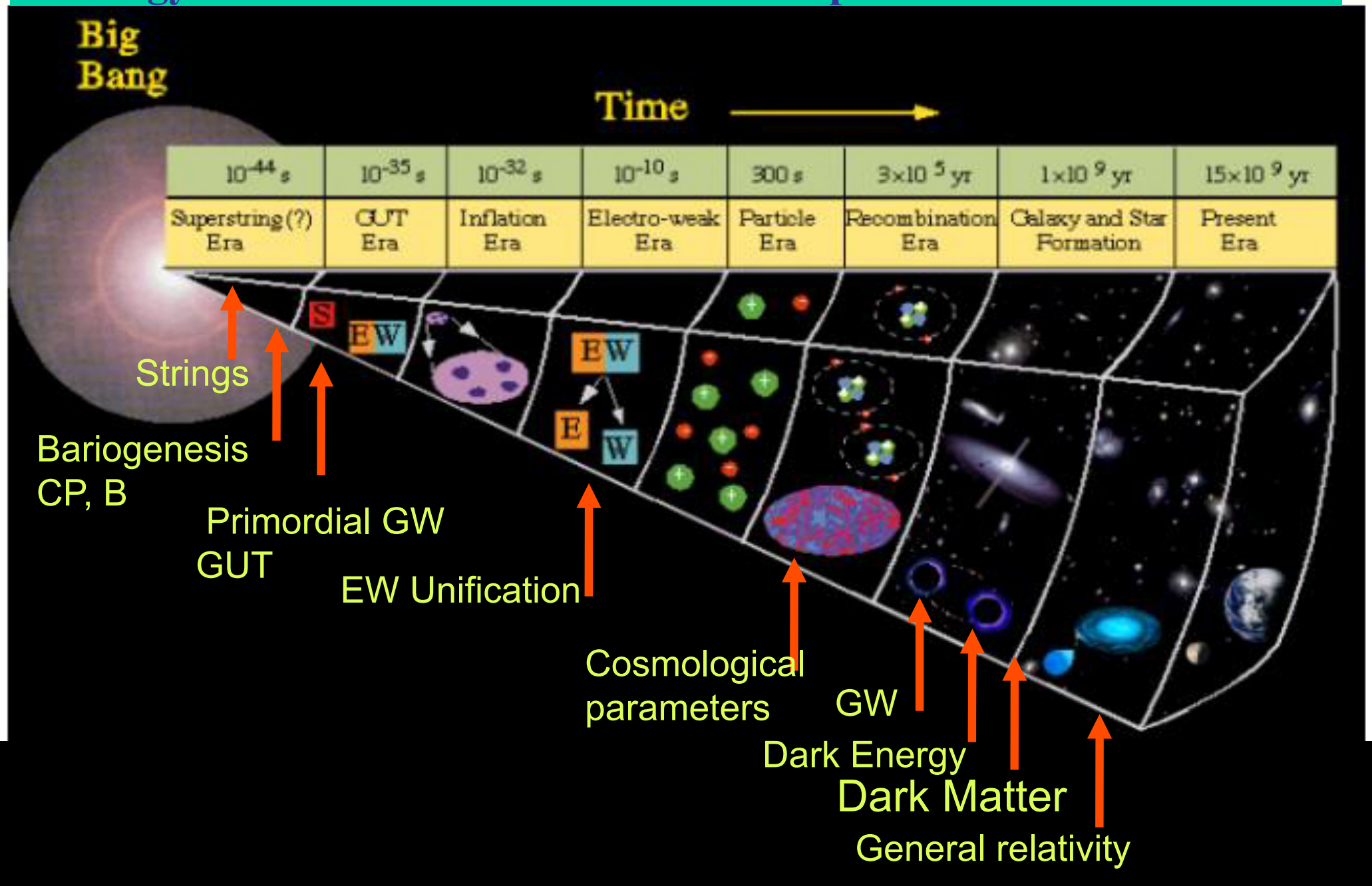
This chart has been made possible by the generous support of:

U.S. Department of Energy
U.S. National Science Foundation
Lawrence Berkeley National Laboratory
Stanford Linear Accelerator Center
American Physical Society, Division of Particles and Fields
BURLE INDUSTRIES, INC.

©2000 Contemporary Physics Education Project. CPEP is a non-profit organization of teachers, physicists, and educators. Send mail to: CPEP, MS 50-308, Lawrence Berkeley National Laboratory, Berkeley, CA, 94720. For information on charts, text materials, hands-on classroom activities, and workshops, see:

<http://CPEPweb.org>

Cosmos is the “ultimate” laboratory to study fundamental physics, up to energy scales unreachable with the most powerful accelerators.....



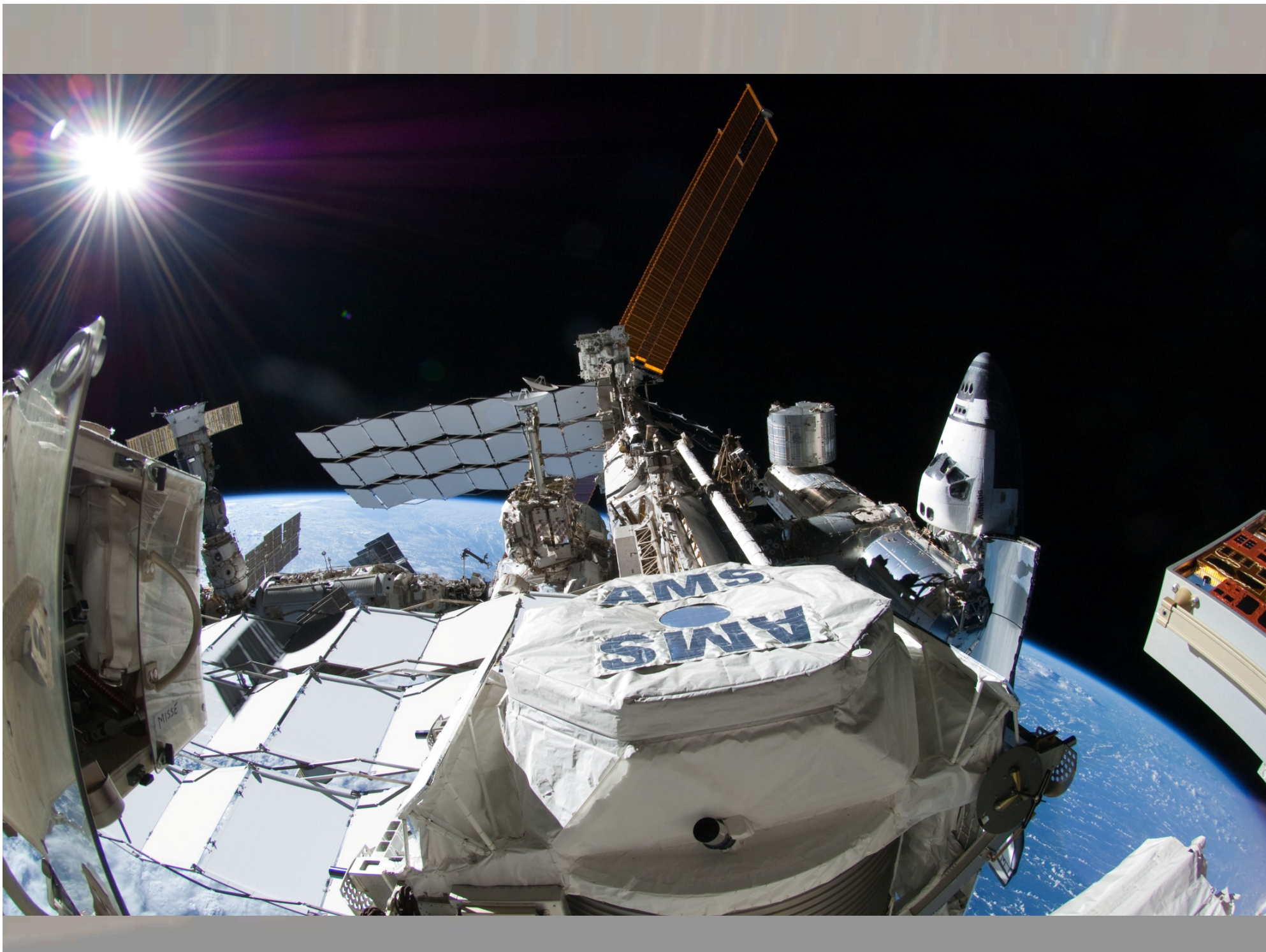
Gruppo AMS Perugia

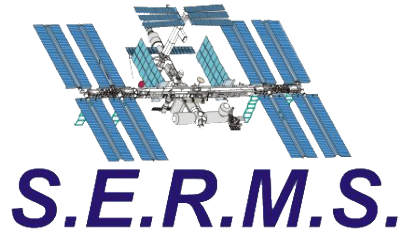


Launch of AMS-02 on STS-134

May 16th 27th, 2011 @ 08:56 AM

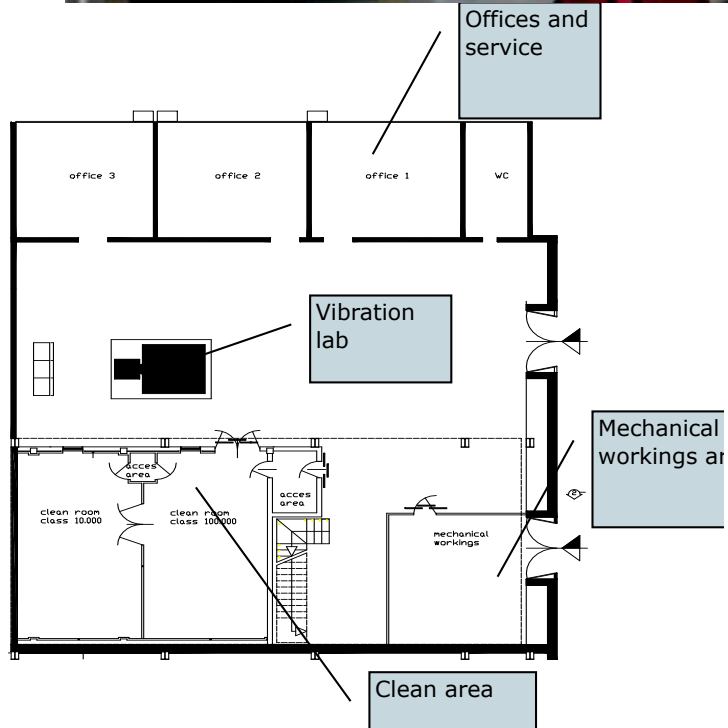




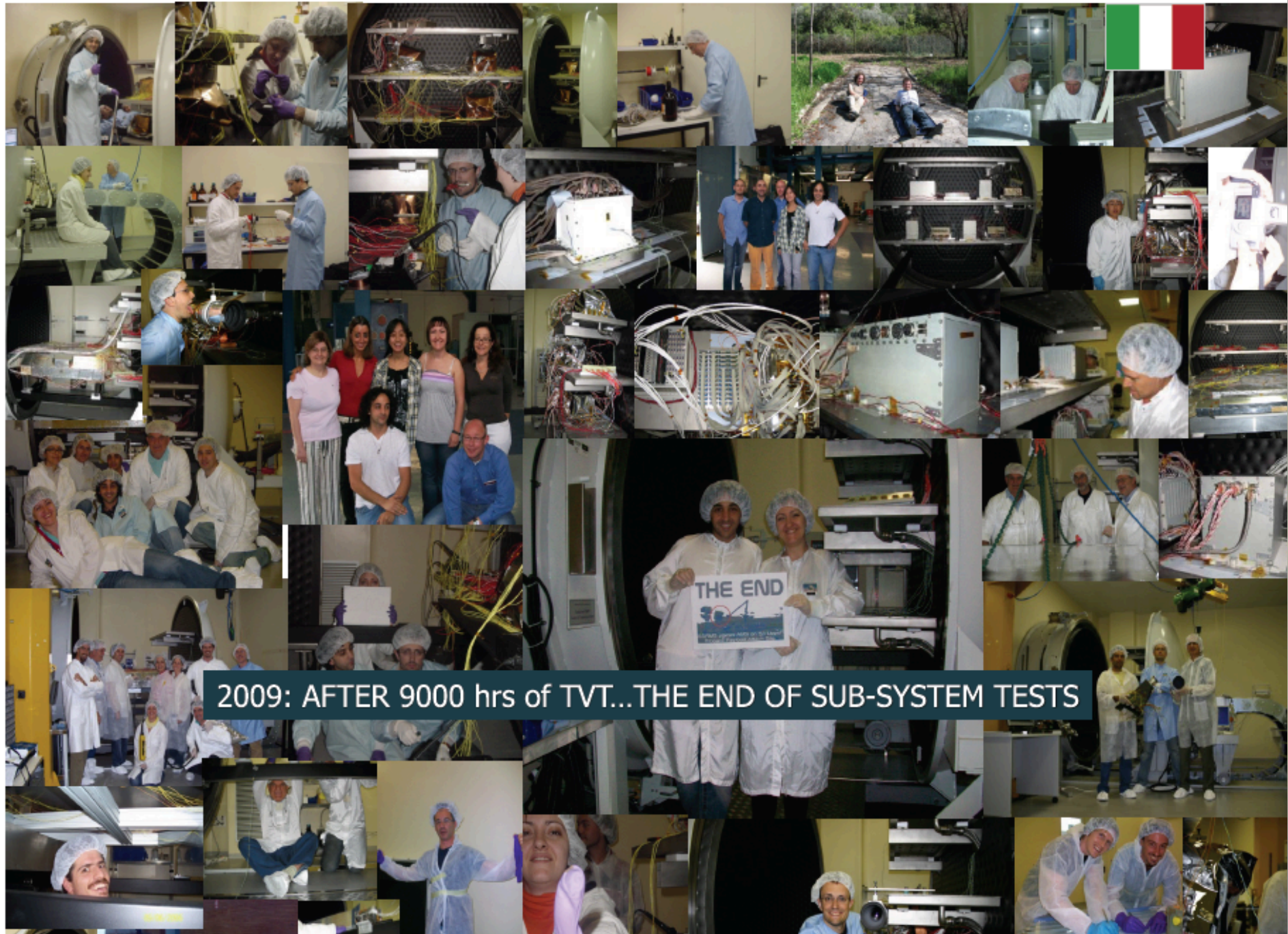


Laboratorio SERMS

Polo Universitario di Terni

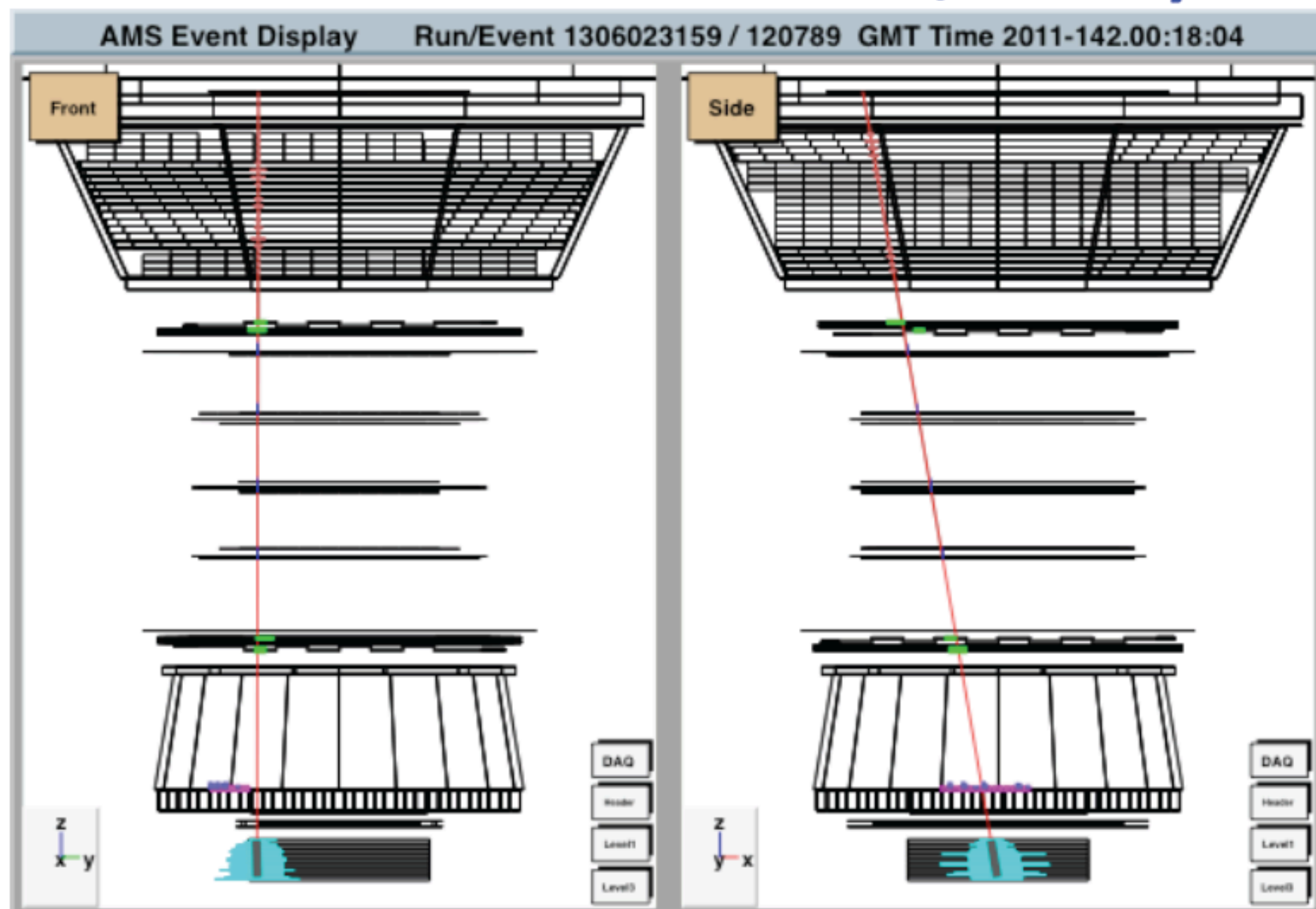


- Su una superficie complessiva di » 500 m²:
- Shaker + slipping table
- Clean Rooms:
 - M5.5 (9x4x3.5m³)
 - M6.5 (9x5x3.5 m³)
- Camere termiche
- Simulatore Spaziale (camera TVT)



2009: AFTER 9000 hrs of TVT...THE END OF SUB-SYSTEM TESTS

AMS data on ISS Electron 240 GeV, 22 May



CERN POCC fully operational



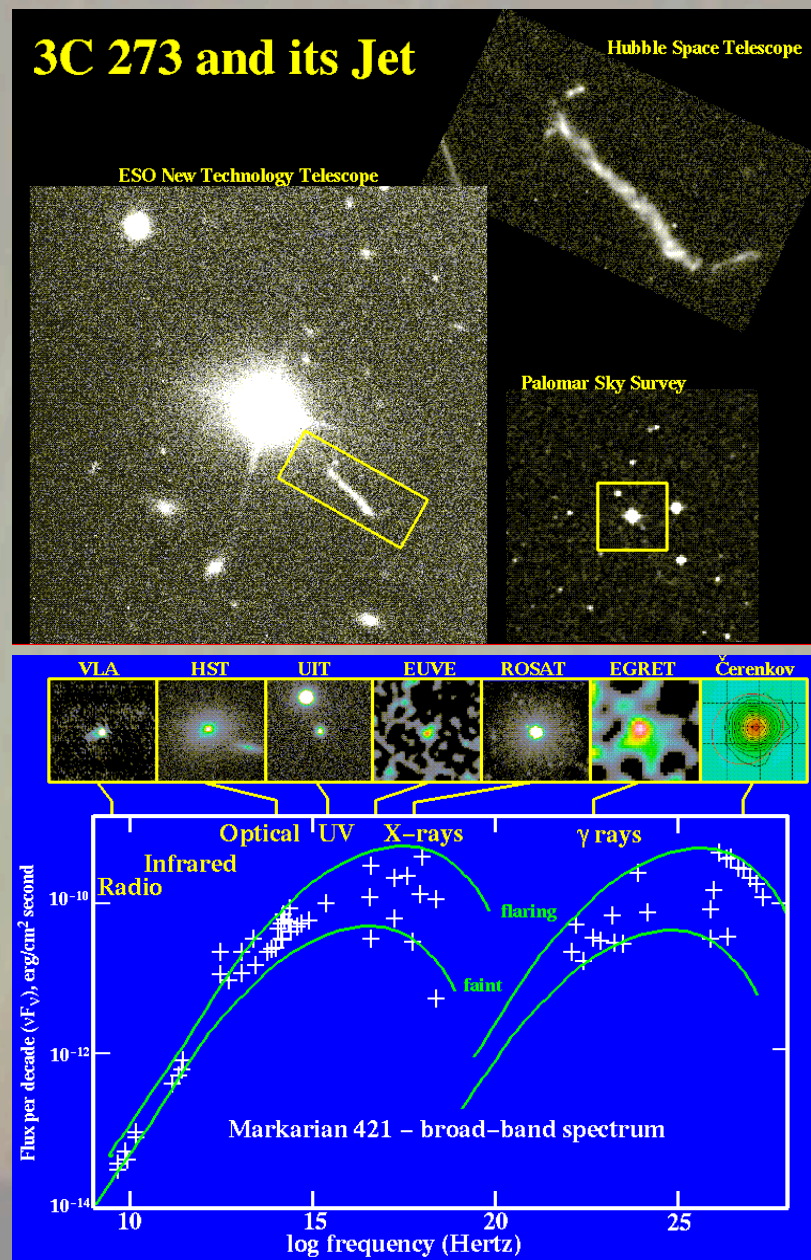
Astrofisica all'energie dei MeV-GeV: Fermi-LAT

Contributi alla scienza con Fermi:

- Cataloghi generale delle sorgenti
- Cataloghi delle sorgenti extragalattiche
- Studio della variabilità temporale e spettrale delle sorgenti extragalattiche (AGN)
- Studi Multifrequenza di AGN

Altri contributi:

- Software per rilevazione di flaring sources su tempi scale di 6 ore, un giorno, una settimana
- Coordinamento di varie attività della Collaborazione Fermi-LAT



Fermi Large Area Telescope 2FGL catalog

1873 sorgenti

○ AGN ⊗ AGN-Blazar

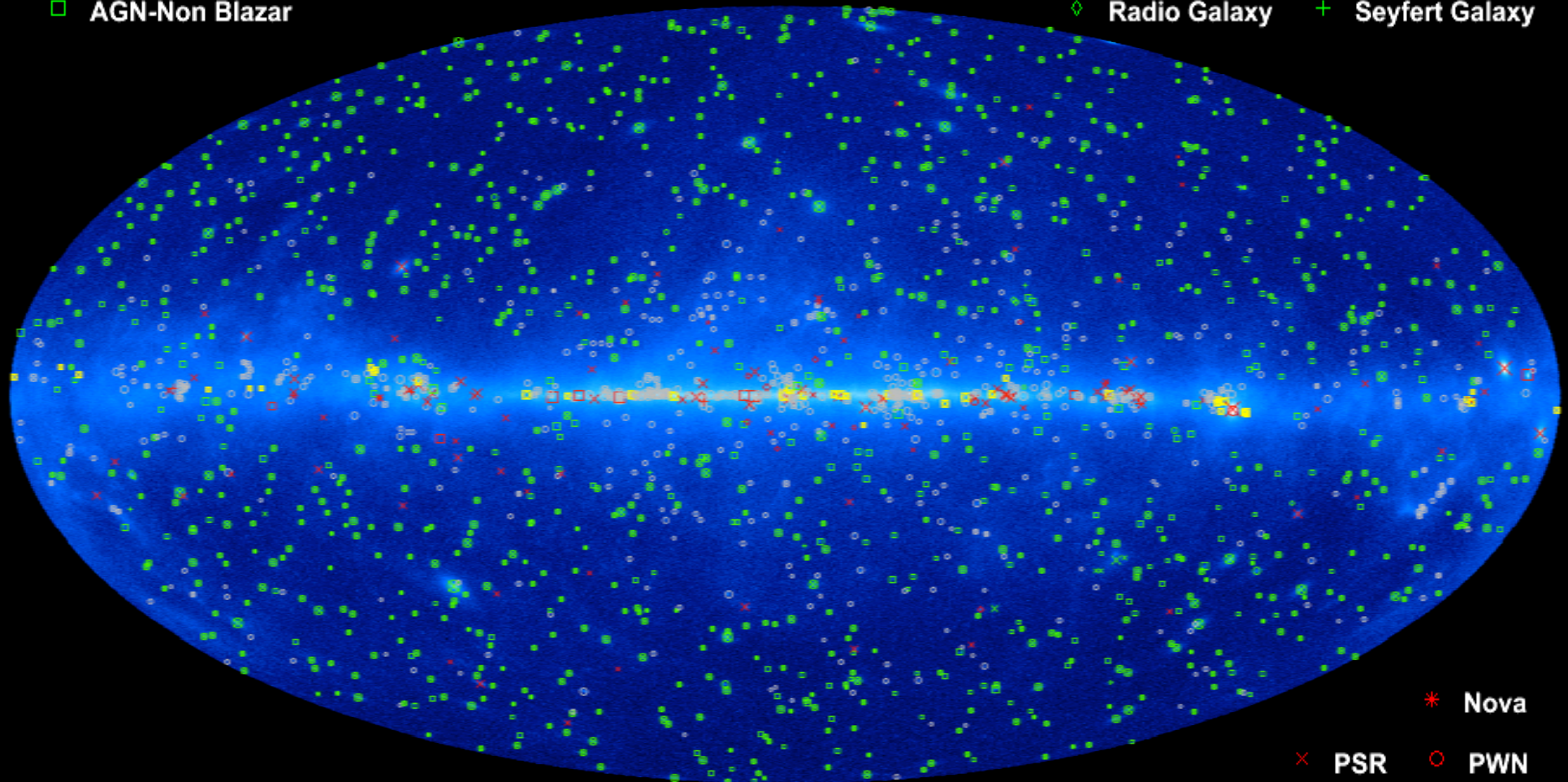
□ AGN-Non Blazar

× Galaxy

* Starburst Galaxy

◇ Radio Galaxy

+ Seyfert Galaxy



○ Unassociated

□ Possible Association with SNR and PWN

* Nova

× PSR

○ PWN

⊗ PSR w/PWN

□ SNR

◇ Globular Cluster

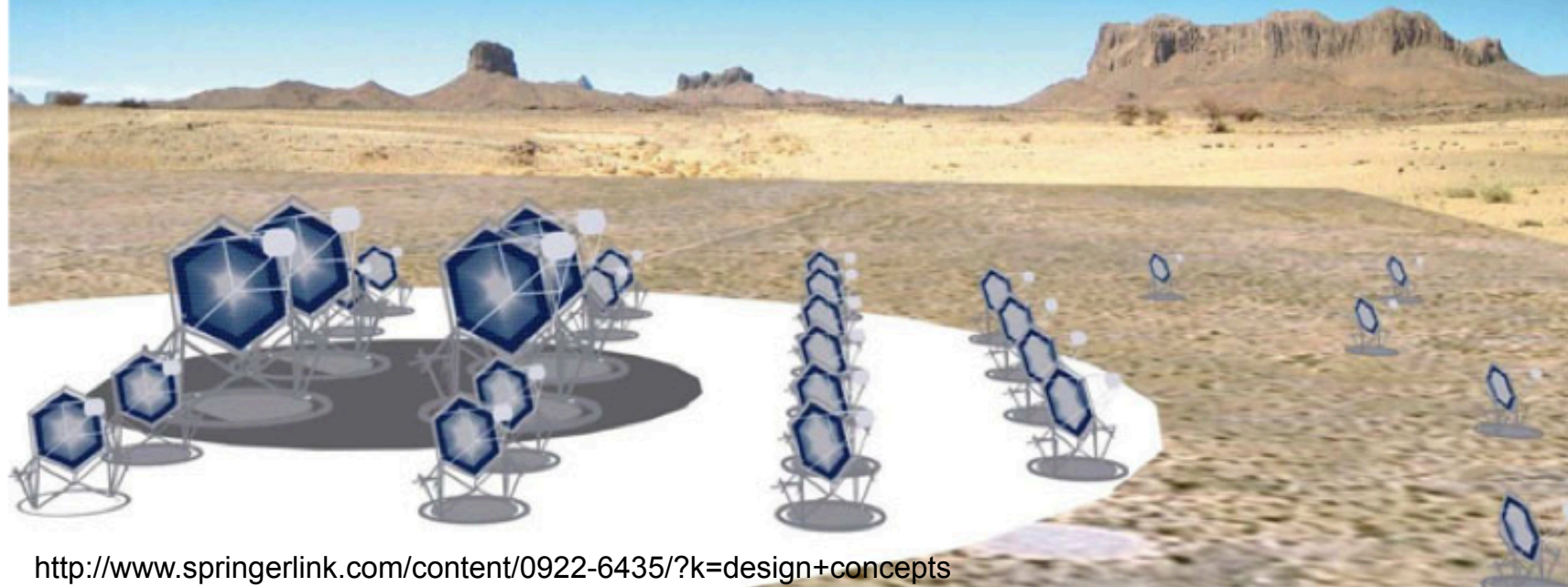
+ HMB

Credit: Fermi Large Area Telescope Collaboration

Astrofisica all'energie dei TeV: CTA

<http://www.cta-observatory.org>

The CTA Consortium consists of over 500 scientists working in 25 countries: Argentina, Armenia, Austria, Brazil, Bulgaria, Croatia, Czech Republic, Finland, France, Germany, Greece, India, Ireland, Italy, Japan, Namibia, Netherlands, Poland, Slovenia, South Africa, Spain, Sweden, Switzerland, the UK, and the USA.



<http://www.springerlink.com/content/0922-6435/?k=design+concepts>

Principali temi scientifici di CTA

- 1 - Origine dei raggi cosmici e loro ruolo nell'Universo
- 2 - Studio dei fenomeni di accelerazione di particelle nelle vicinanze di Buchi neri
- 3 - Materia oscura e Nuova Fisica (beyond the Standard Model)

Fase preparatoria partita nel 2010 - Prima Luce: 2017

*Esperimento Virgo (Cascina) per la ricerca
delle onde gravitazionali*





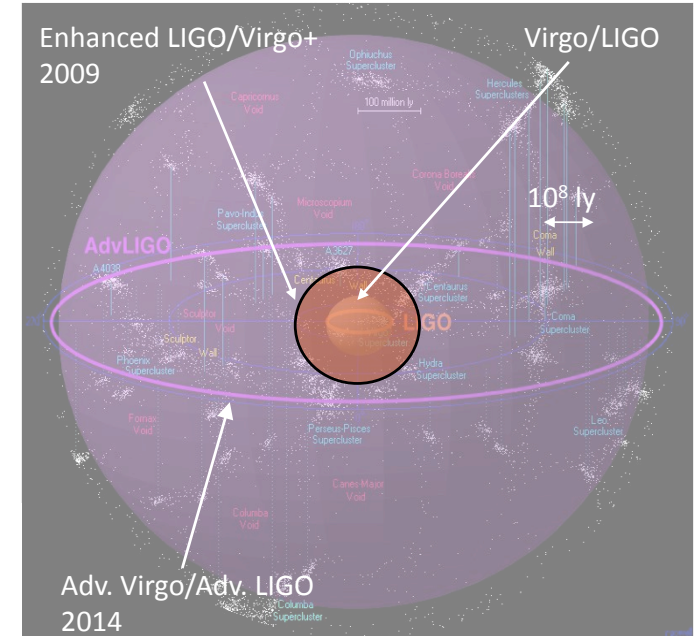
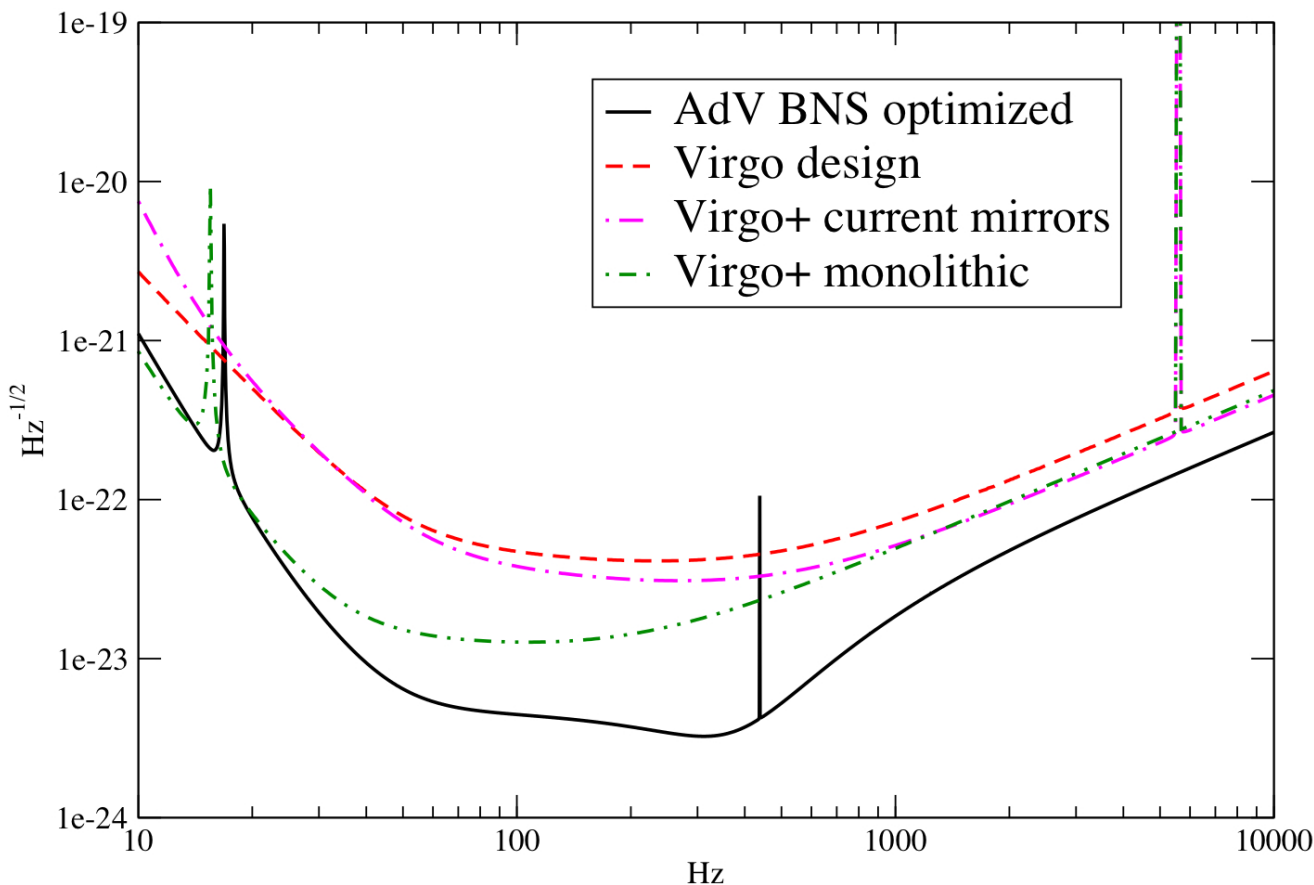
ADVANCED VIRGO (AdV)

2009-2014

Project approved by the
CSN2-INFN

Reviewed by CCS –INFN
Class Ranking A

We will explore a Universe volume 1000 times
larger than VIRGO



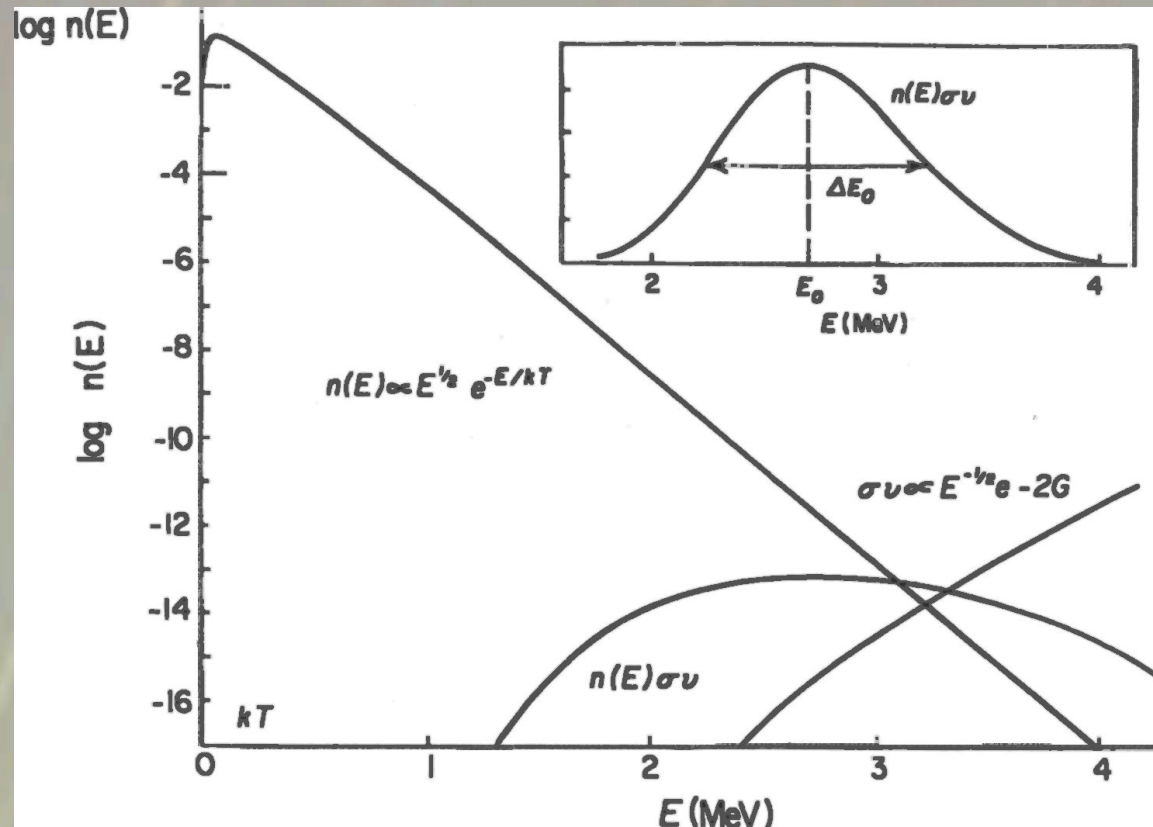
Credit: R.Powell, B.Berger

- **GOALS:**
 - ☐ Sensitivity: about 10x better than Virgo
 - ☐ Timeline: be back online with Adv LIGO

Attività di Astrofisica Nucleare e Stellare

1. Sviluppo di modelli di evoluzione e nucleosintesi stellare
2. Modelli idrodinamici e magneto-idrodinamici delle fasi evolutive finali delle stelle,
4. Astronomia infrarossa (e sviluppo tecnologico collegato) in Antartide,

1a. Le reazioni nucleari nelle stelle e la nucleosintesi

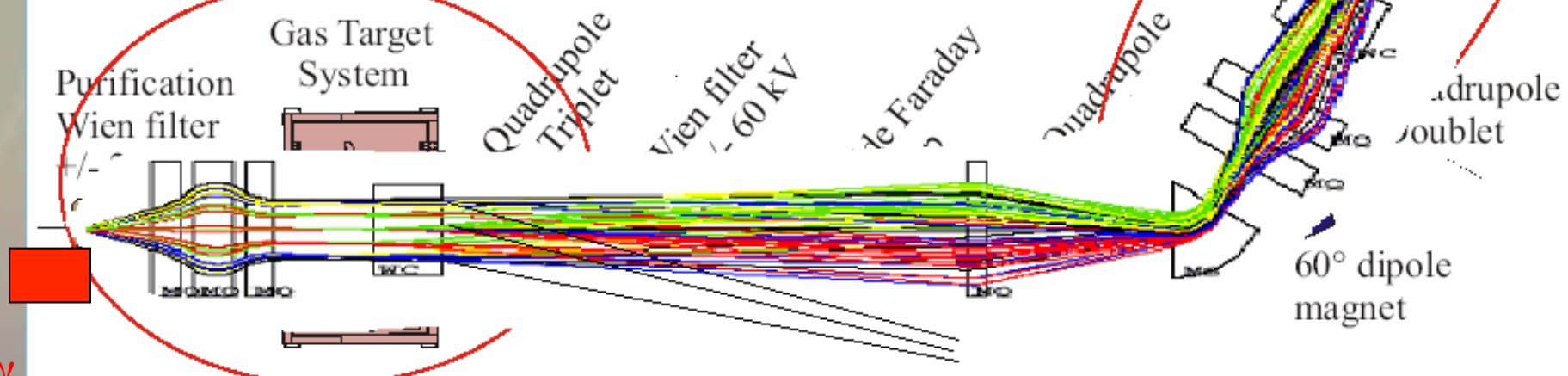
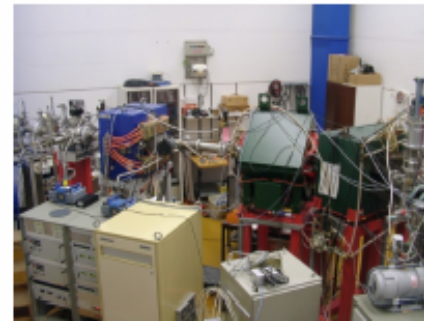
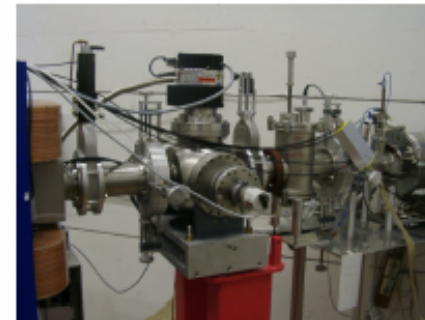
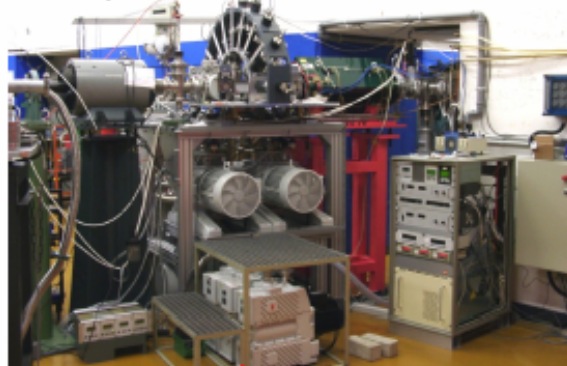


Le reazioni avvengono a bassa energia, dove domina la barriera coulombiana. La loro probabilità dipende dal prodotto tra l'efficienza dell'effetto tunnel quantistico (1) moltiplicata per la distribuzione di Maxwell del gas stellare (2). Esso è apprezzabile solo in un piccolo intervallo di energia (finestra di Gamow: 3). Misure a queste energie basse richiedono laboratori underground (Gran Sasso) o tecniche particolari per eliminare il fondo dei raggi cosmici.

1b. Esempio: Accelerator Mass Spectrometry

ERNA Separator (Napoli-Perugia)

Spettrometro di massa associato ad un Tandem per riconoscere i nuclei prodotti.



2a. Mescolamenti magnetici e nucleosintesi

Busso et al. (2007) and Nordhaus et al. (2008) suggested that magnetic buoyancy provides mixing of newly produced elements to the stellar surface, accounting for the isotopic anomalies in red giant stars.

Starting from MHD stellar models:

Navier-Stokes equations

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \quad (1)$$

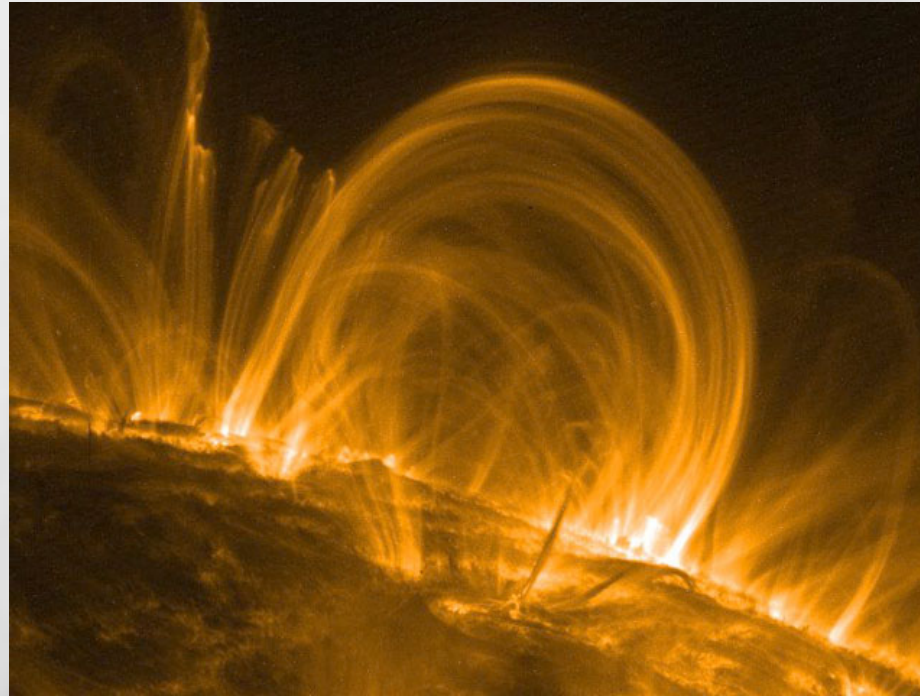
$$\frac{\partial \epsilon}{\partial t} + \vec{v} \cdot \nabla \epsilon + \frac{p}{\rho} \nabla \cdot \vec{v} - \frac{1}{\rho} \nabla \cdot (K \nabla T) + \frac{j^2}{\rho \sigma} = 0 \quad (2)$$

$$\frac{\partial \vec{v}}{\partial t} + \vec{v} \cdot \nabla \vec{v} + \frac{1}{\rho} \nabla p - \vec{F} - \frac{1}{\rho c} \vec{j} \times \vec{B} - \nu \nabla^2 \vec{v} = 0 \quad (3)$$

$$\frac{\partial \vec{B}}{\partial t} - \nabla \times (\vec{v} \times \vec{B}) - \lambda \nabla^2 \vec{B} = 0 \quad (4)$$

explain how mag. fields sample nucleosynthesis products inside a star carrying them to the surface.

2b. COMMON EMERGING MAGNETIZED STRUCTURES: THE SOLAR Ω -SHAPED LOOPS (SOLAR CORONA)



Similar “conveyor belts” can explain the appearance of new elements at the surface of evolved stars

THE ASTROPHYSICAL JOURNAL, 671:802–810, 2007 December 10

© 2007. The American Astronomical Society. All rights reserved. Printed in U.S.A.

CAN EXTRA MIXING IN RGB AND AGB STARS BE ATTRIBUTED TO MAGNETIC MECHANISMS?

MAURIZIO BUSSO,¹ GERALD J. WASSERBURG,² KENNETH M. NOLLETT,³ AND ANDREA CALANDRA¹

Received 2007 May 31; accepted 2007 August 20

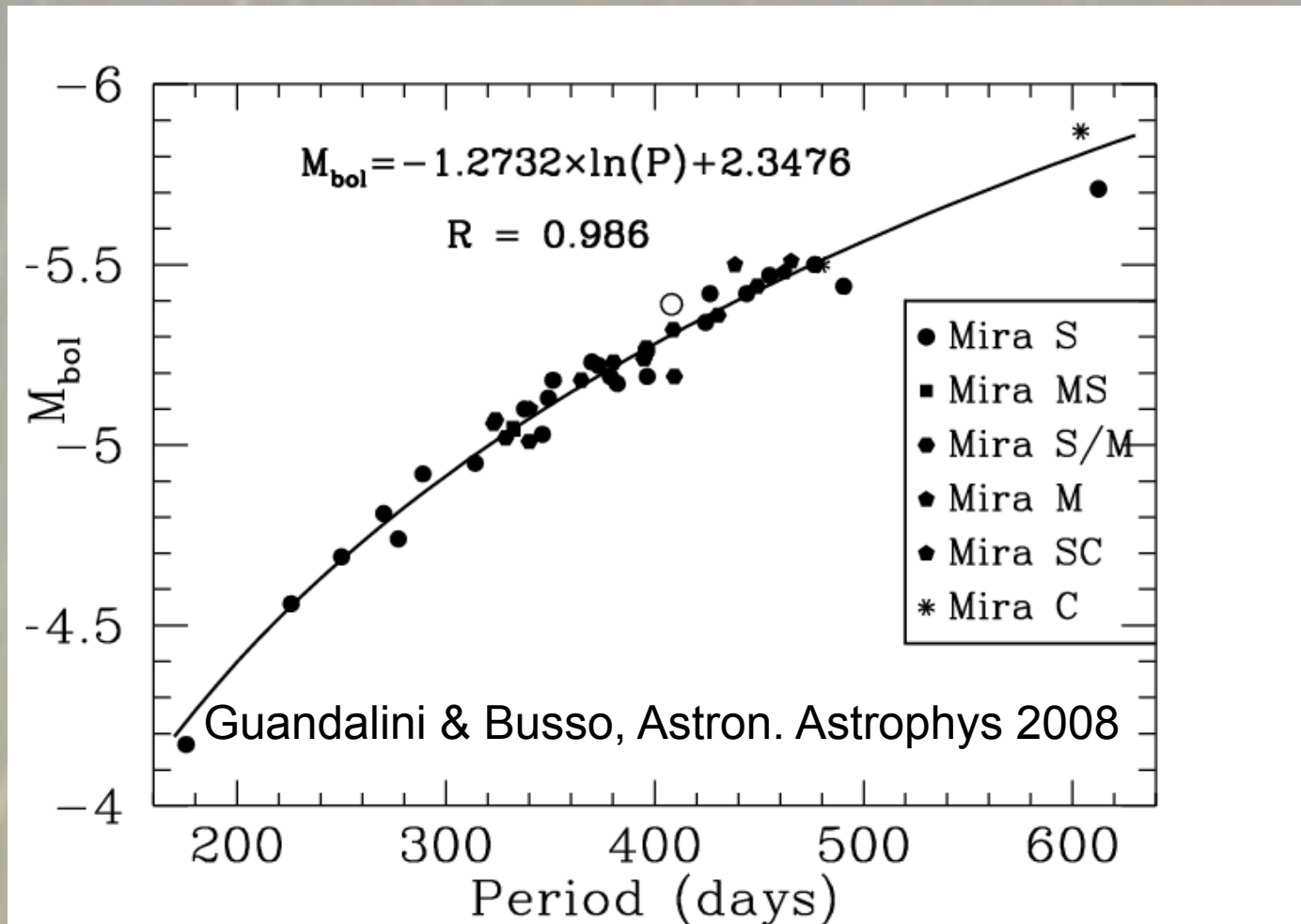
3a. The IRAIT Project at Dome C

(The Dome and the telescope inside it).



Progetto installato alla base di Dome C sull'altipiano antratico.
Dall'anno prossimo, usato per imaging infrarosso di stelle evolute.
Vari key-projects. Il più ambizioso: studiare nell'infrarosso stelle evolue variabili, facendone un nuovo criterio per determinatre le distanze cosmologiche (dalla relazione tra la loro luminosità e il loro periodo)

3b. Period-Luminosity Relations



**A NEW GROUP OF STANDARD CANDLES
FOR OLD STELLAR POPULATIONS**
(Selected in infrared from space and Antarctica)

DIDATTICA:

TESI in Fisica di Base:

Astrofisica nucleare, Fisica Astroparticellare e delle Alte Energie

TESI TRIENNALI DI: 2-3 tesi all' anno in media

TESI SPECIALISTICHE: 2-3 tesi all' anno in media

DOTTORATO : 2 dottorandi per ciclo in media

TESI in Fisica Applicata ed in Ingegneria Gestionale e dei Materiali
Tecniche e tecnologie spaziali e per l'energia rinnovabile

TESI TRIENNALI DI: 5 tesi all' anno in media

TESI SPECIALISTICHE: 2 tesi all' anno in media

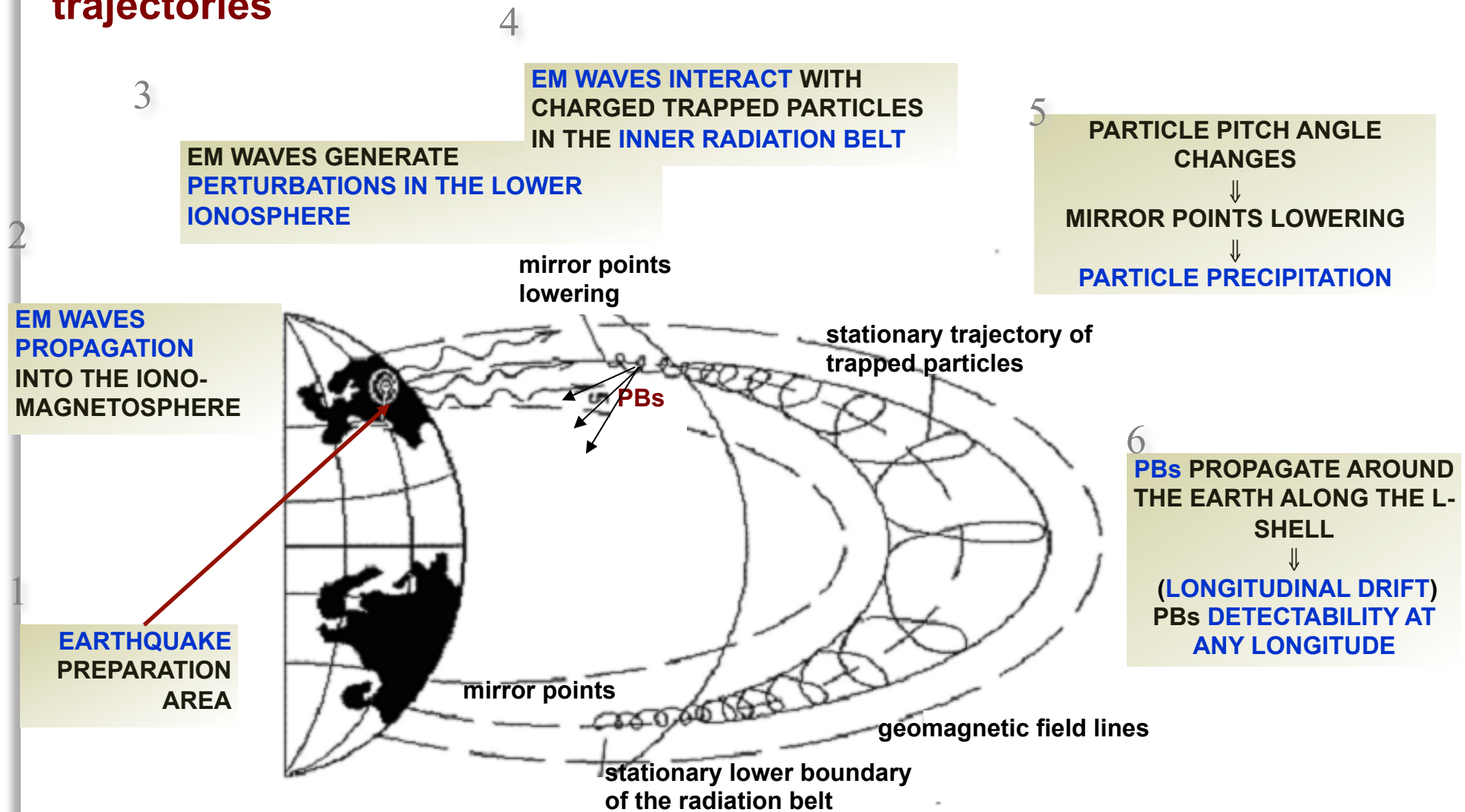
DOTTORATO : 1 dottorandi per ciclo in media

Fisica multidisciplinare

- Interazione Magnetosfera – Ionosfera-Litosfera
- Studio delle correlazioni tra le perturbazioni tra i disturbi delle fasce di Van Allen e le attività sismiche

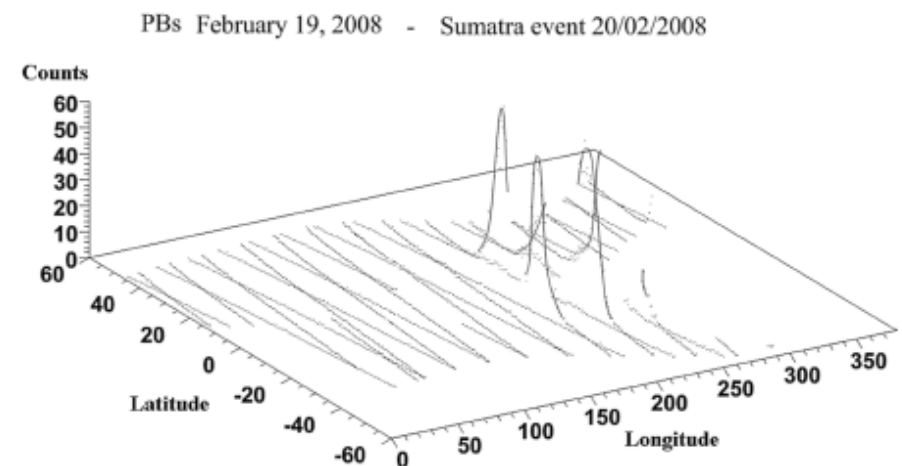
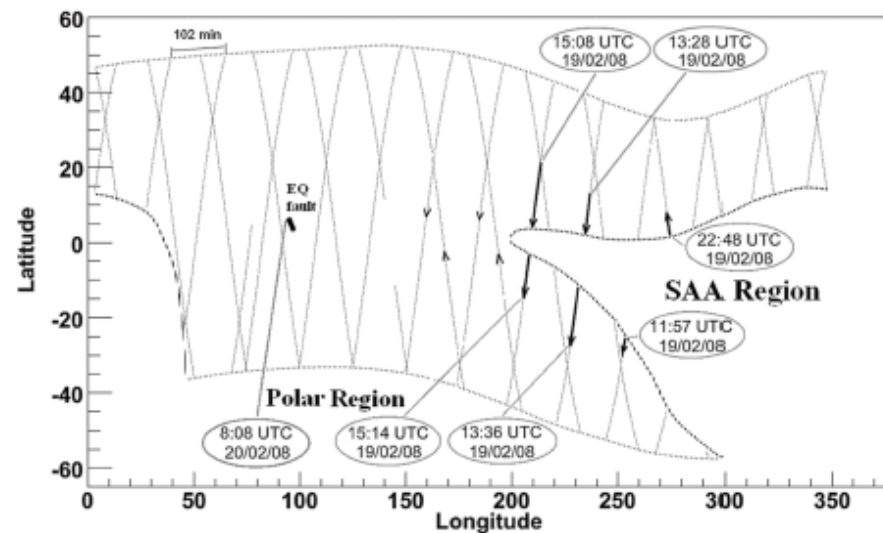
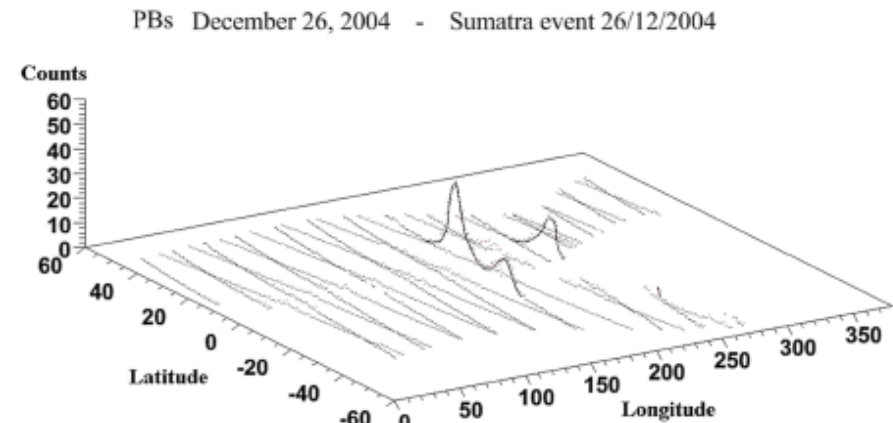
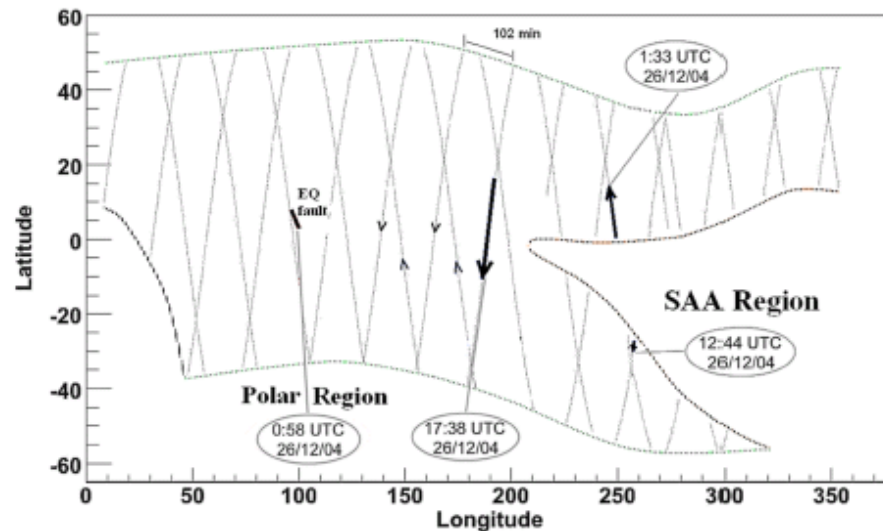
A Possible Representation of the Phenomenology

Schematic representation in a meridian plane of the trapped particle trajectories

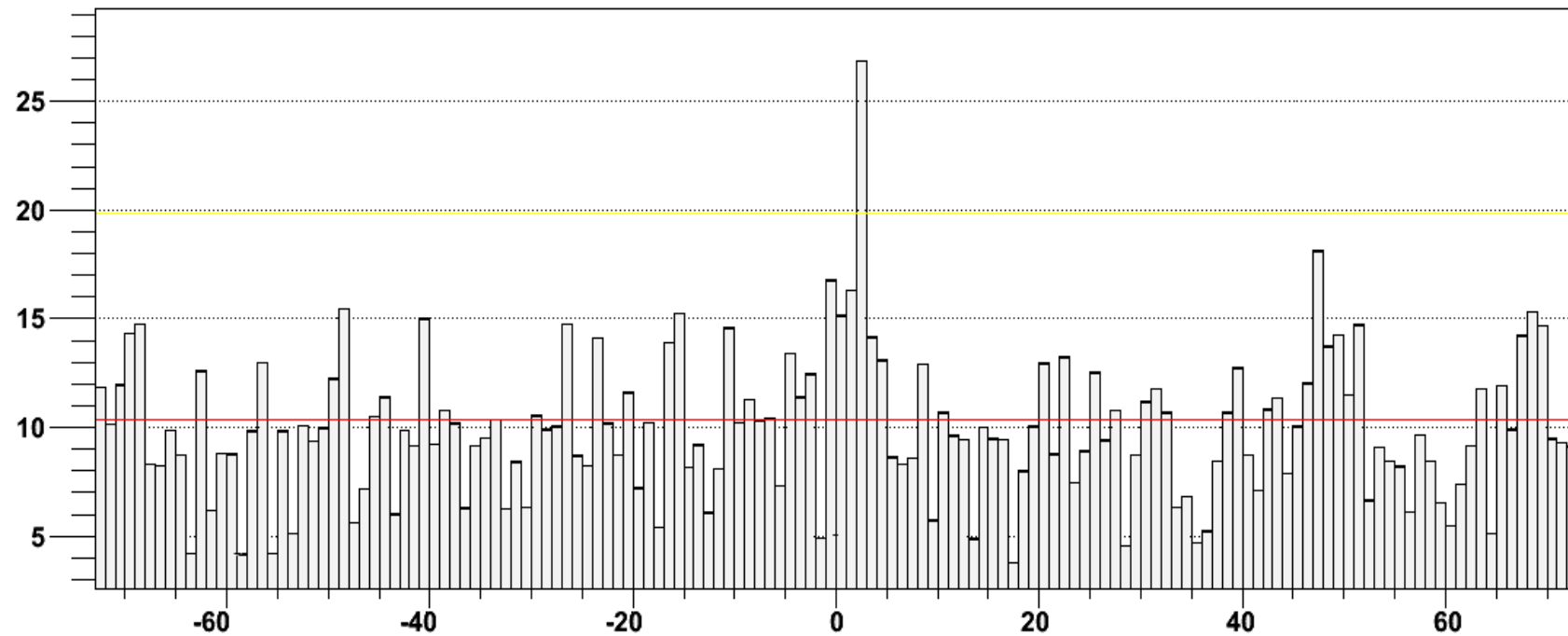


Examples of Particle Bursts

(Fidani and Battiston, NHESS, 8, 1277-1291, 2008)



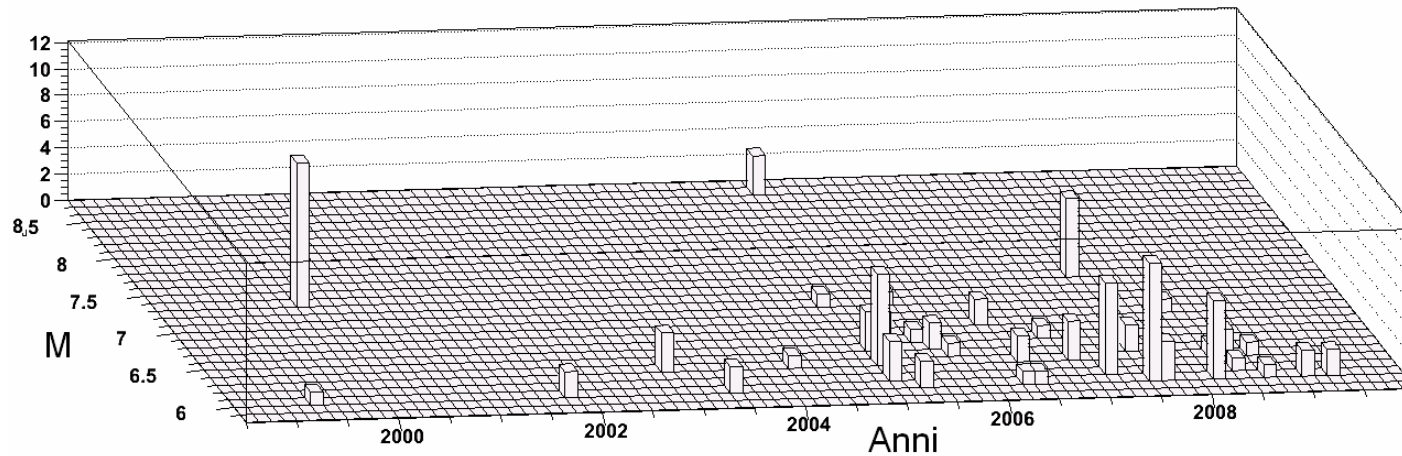
PB correlations 3 days (1800 km)



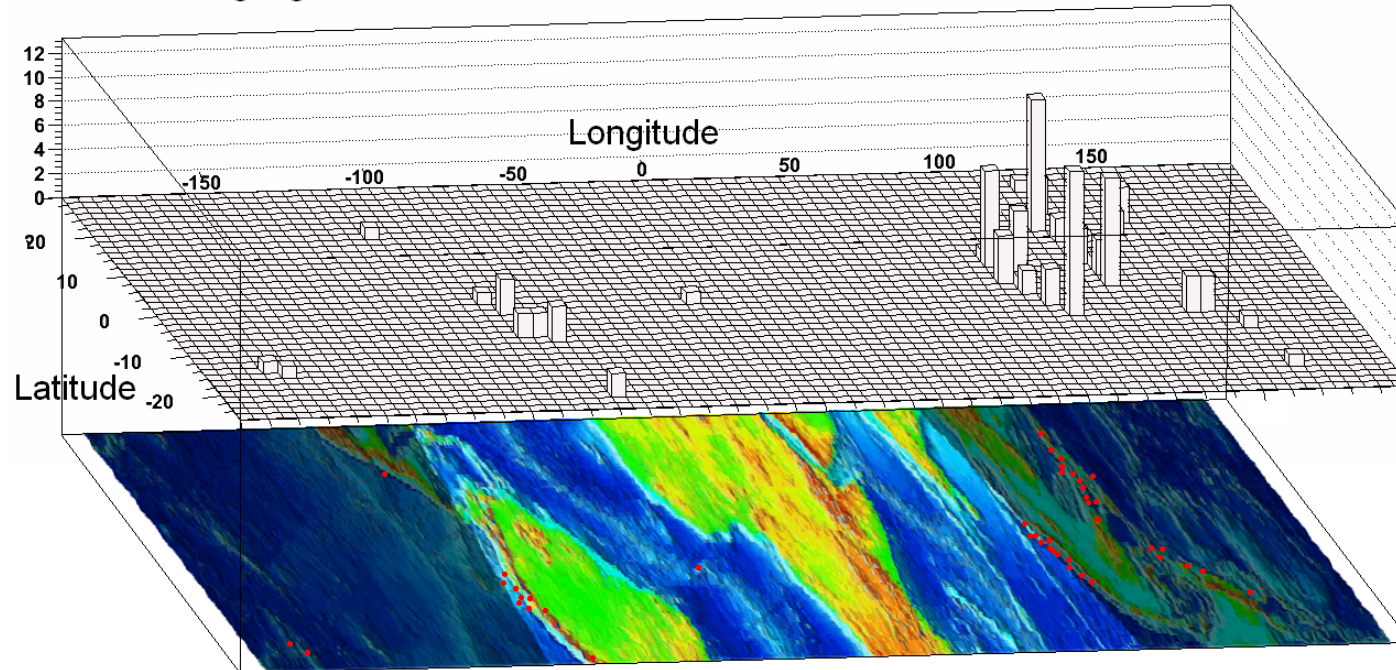
Average in red
3 sigmas in yellow

Their magnitude ad positions

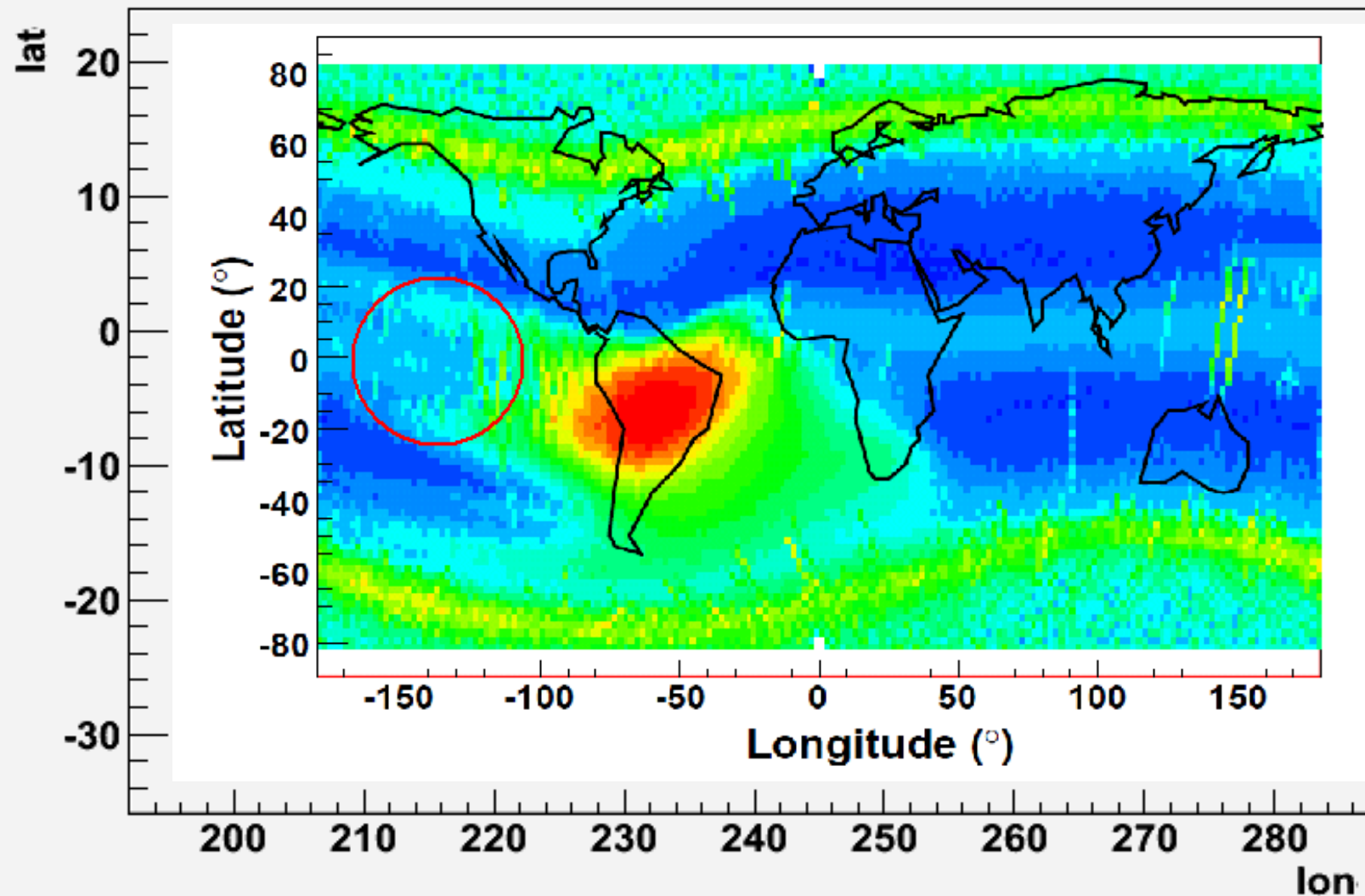
Magnitudo dei terremoti che contribuiscono alla correlazione 2-3 ore



Posizione geografica dei terremoti che contribuiscono alla correlazione 2-3 ore



Correlated Particle Bursts



Experimental search for Wave-Particle Interaction and Seismo-Particle Correlation Phenomena

The China Seismo Electromagnetic Satellite

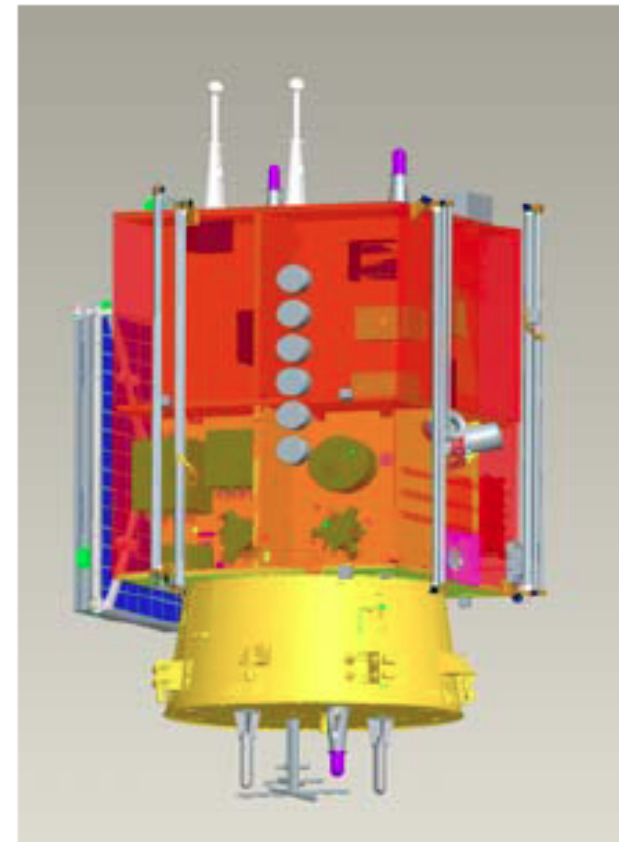
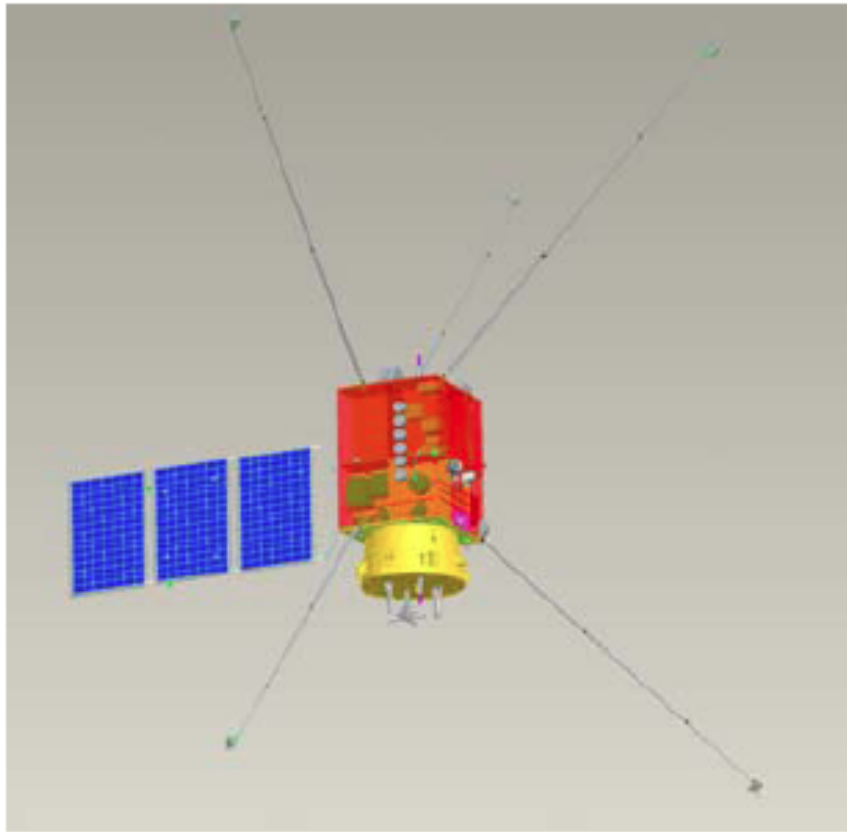


CONSULTA DELLE FONDAZIONI
DELLE CASSE DI RISPARMIO UMBRE



The design of the platform

CSES : China Seismo Electromagnetic Satellite



1 Collaboration on Payloads and their main specifications 载荷及其主要参数

(a) The Energetic Particle detector : 高能粒子探测器

(b) Electric Field Detector: 电场仪

- Frequency range: DC~3.5MHz
 - Sample Rate: 100 Hz (DC~10Hz)
 - ≥ 5 kHz (10Hz~2kHz)
 - ≥ 50 kHz (2kHz~20kHz)
 - ≥ 10 MHz (20kHz~3.5MHz)
 - Resolution: $1\mu\text{V/m}$
 - Sensitivity:
 - $10\mu\text{V}\cdot\text{m}^{-1}\cdot\text{Hz}^{-1/2}@100\text{Hz}$;
 - $1\mu\text{V}\cdot\text{m}^{-1}\cdot\text{Hz}^{-1/2}@10\text{kHz}$;
 - $0.5\mu\text{V}\cdot\text{m}^{-1}\cdot\text{Hz}^{-1/2}@500\text{kHz}$
 - Dynamic Range: 120dB (DC~20kHz); $\geq 90\text{dB}$ (20kHz~3.5MHz)
 - Operating temperature:
 - For the electrical Box (Inside Satellite): $-10\text{ }^{\circ}\text{C}\sim+45\text{ }^{\circ}\text{C}$
 - For the inside the probe (Outside satellite): $-30\text{ }^{\circ}\text{C}\sim+60\text{ }^{\circ}\text{C}$
 - Mass: $< 10\text{ kg}$ (including electronics)
 - Total Power Consumption : $\leq 10\text{ W}$
- (c) Booms 电场仪伸杆
- Length: 5 meters
 - Mass of the sensor : $< 1\text{ kg}$



Participation to CSES to search for earthquake phenomena from SPACE

2010-2020

China: satellite, launch, 6 detectors

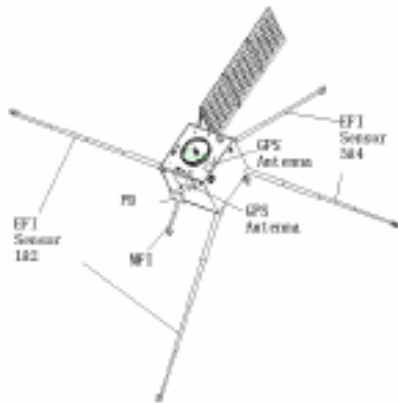
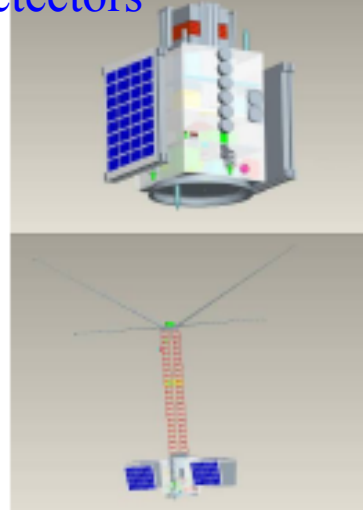
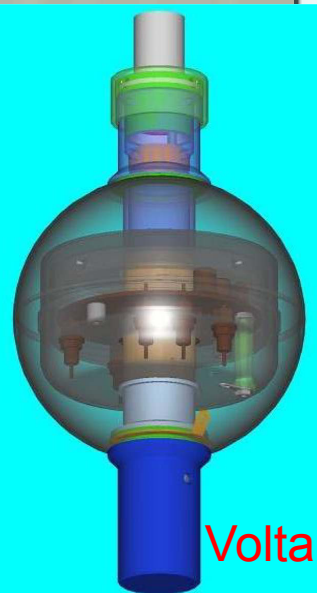
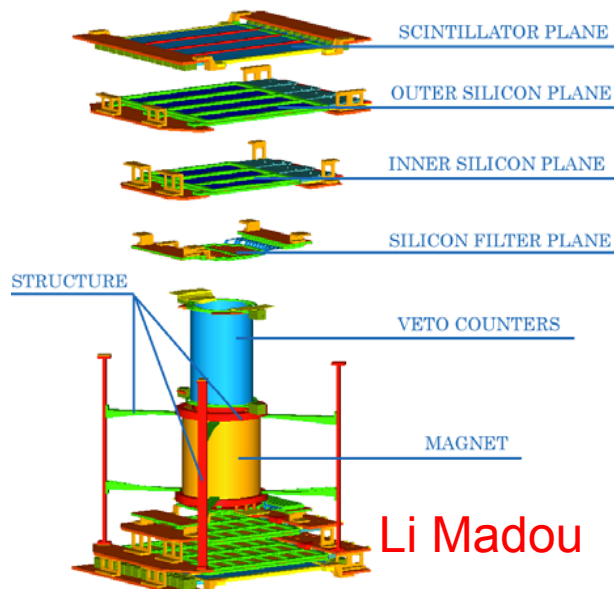


Fig. 3- Layout esterno di CSES



Italy : particle and electric field detectors



ENDORSEMENT

On behalf of the group of China Seismo-Electromagnetic Satellite (CSES), we're honourable to express that CSES working group is very interested in China-Italy cooperation of earthquake satellite based on the framework of China-Italy Bilateral Space Meeting. We hope this cooperation go through with prove of China National Space Administration (CNSA) and Italian Space Agency (ASI).

The main items of this cooperation are available to carry Italian scientific payloads on board CSES and joint research on relevant models and data analysis. The payloads would be composed of a particle detector, a search coil magnetometer and a flux-gate magnetometer.

According to the draft design of CSES, the main specifications of the instruments are as following:

(1) Search-Coil magnetometer:

- (a) 3 components
- (b) Frequency range : 10Hz ~ 20 kHz
- (c) Sensitivity: $5 \times 10^{-5} \text{ nT} \cdot \text{Hz}^{-1/2} @ 2\text{kHz}$
- (d) Dynamic range: >90dB.

(2) Fluxgate magnetometer

- (a) Frequency Range: DC~10Hz
- (b) Sampling Rate: 30Hz
- (c) Measurement Range: $\pm 65000 \text{ nT}$
- (d) Dynamic Range: $\pm 2500 \text{ nT}$
- (e) Precision: 0.1nT
- (f) Noise: $\leq 100 \text{ pT RMS}$

(3) Energetic Particle Detector

- (a) Direction measurement of high energy particles
 - i. Flux of high energy electrons ($\geq 200 \text{ KeV}$)
 - ii. Flux of high energy protons (1.5MeV~200MeV)
- (b) Energy spectrum measurement of high energy electrons and protons
 - i. Energy range of electron: 0.4MeV~10MeV (8 energy channels)
 - ii. Energy range of Proton: 3MeV~300MeV (8 energy channels)

The specifications might be modified with progress of the CSES project.

This endorsement is specially prepared for Opportunity Missions of ASI.

Xuhui SHEN

Chief researcher of the project of CSES

Xinjian SHAN

Coordinator for the China-Italy cooperation of CSES

Xuhui Shen
Xinjian Shan OCT 26. 2007