



Particle and Astroparticle Physics in Spain

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Past (2000-2003) HEP Spanish Committee chairman

IFIC-Universitat de València & CSIC

12th Workshop on Electronics for LHC and Future Experiments

Valencia 25-29 september 2006

SPAIN

A total of 44,4 M hab. (8,75% foreign residents)

GNP 900.000 M€

R&D 9.000 M€ (~1%)

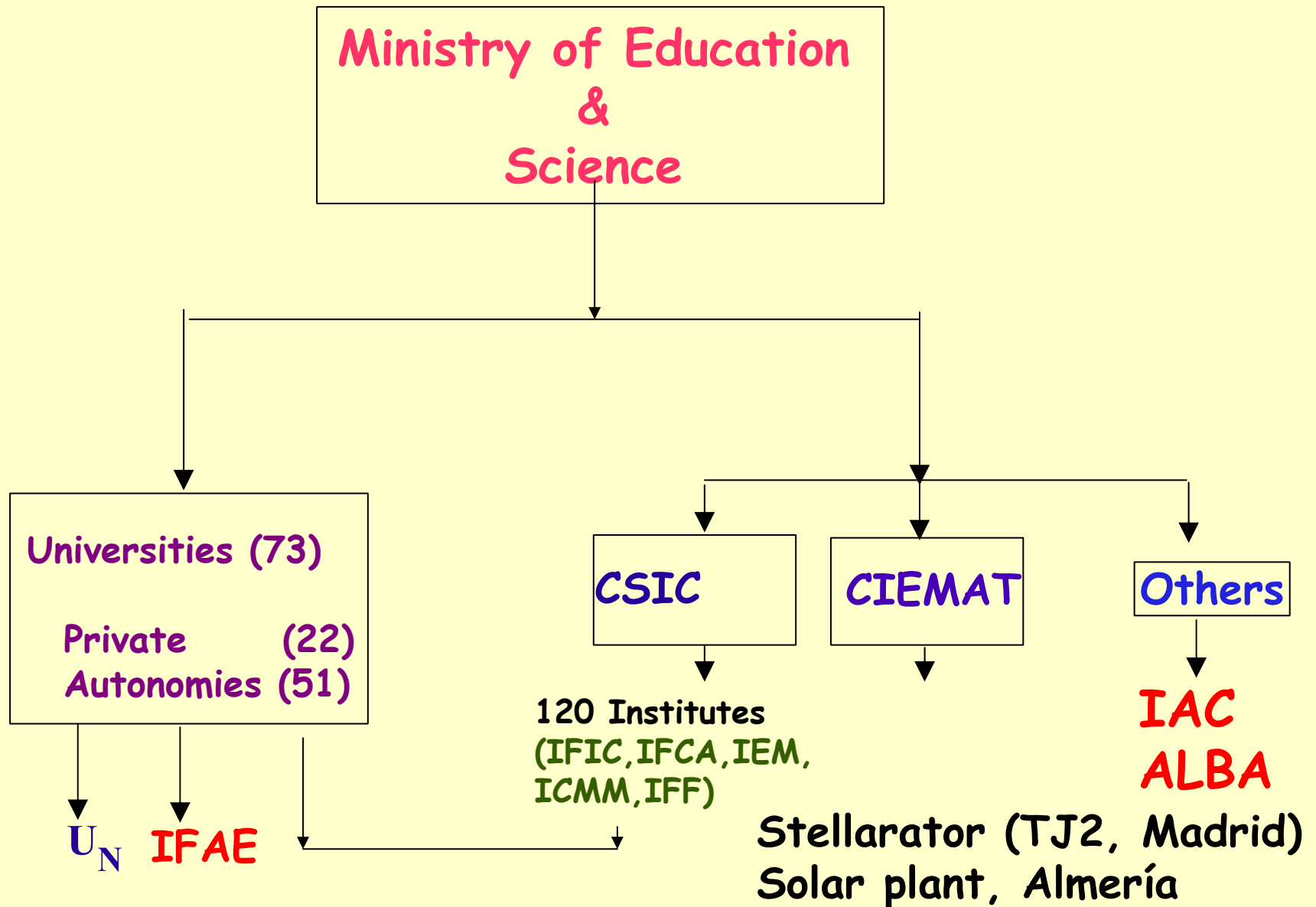
CERN Contribution ~80 MCHF (~8%)

to be compared (G 20%)
(UK 17%)
(F 15%)
(I 12%)

Research groups in Spain



Research institutions in Spain



Particle & Astroparticle physics in the Vth National Plan (2004-2007)

One of the 23 National R&D Programs

Basic research: Astronomy & Astrophysics,
Particle Physics,
Physics,
etc...

Priorities of the National Program

1. Particle Physics (CERN).

- Quarks & Leptons, Neutrino, Hadrons, Theory.

2. Astroparticle physics & Cosmology.

3. Experimental Nuclear Physics (N-TOF, ISOLDE, GSI).

4. GRID Technologies .

5. Detectors and Accelerators Technologies.

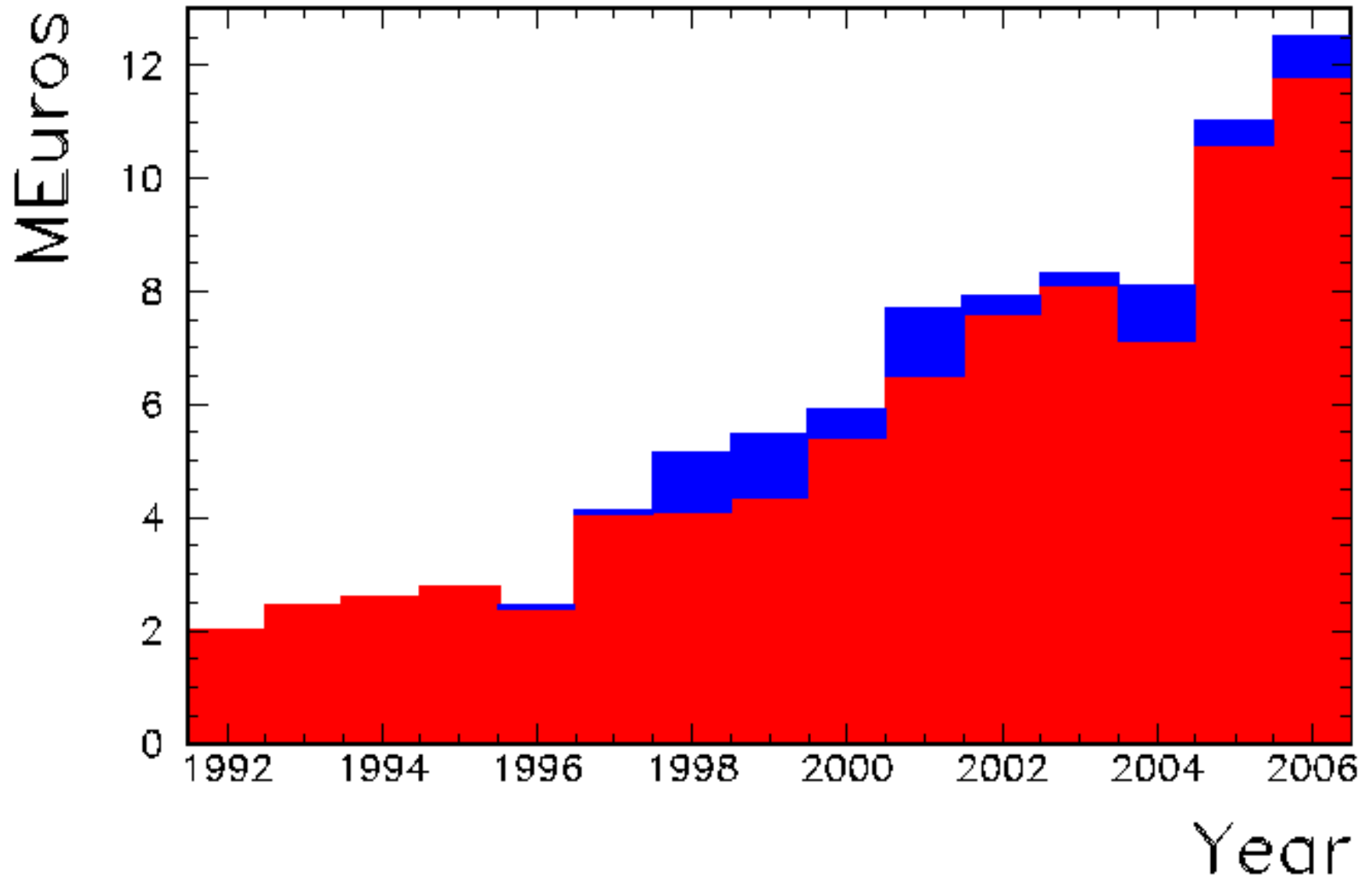
National Program of Particle Physics (2006)

A total of ~ 60 research projects

About 400 researchers, 62 technicians, 212 fellows & st.
11,8 M€ 2006 budget

1. Theory	11.7 %
2. LHC (ATLAS, CMS, LHC-b)	24.4 %
3. GRID (ATLAS, CMS, LHC-b)	21.2 %
4. HERA (Zeus) CDF, BABAR	5.9 %
5. Nuclear+ISOLDE (Dirac, +Legnaro, Ganil, GSI)	9.7 %
6. Astroparticles(Auger, Canfranc, Magic, Antares, Icarus)	20.7 %
7. Technologies & Applications.....	6.1 %

Particle physics funding



6 questions* defining Particle physics

1. Which are the ultimate matter constituents?
2. Which are the forces that bind or break them?
3. By which mechanism do constituents get their masses ? Does the **Higgs boson** exist?
4. What is the nature of **neutrinos** ?
5. Is supersymmetry a valid theory?
6. Are there any hints of a *GUT* theory ?

*"Science is the art of replacing unimportant questions that can be answered by important ones which cannot" Edward B. Ferguson Jr. 1976.

The Standard Model

Generation: I II III

Leptones

ν_e	e
---------	-----

ν_μ	μ
-----------	-------

ν_τ	τ
------------	--------

Quarks

u	u	u
d	d	d

c	c	c
s	s	s

t	t	t
b	b	b

Bosones
“Gauge”

Z^0	W^+	γ
	W^-	

	g	

Higgs

Graviton



Spanish contributions to the LHC

ATLAS	IFIC-Valencia	TiCal	315 submodules (50% of EB) 1500 PMs ROD
	IFIC-Valencia	STC	200 silicon modules (+IMB)
	Barcelona IFAE		315 submodules
		TiCal	65 modules (1 Extended Barrel)
	Madrid UAM		Forward LAr Calorimeter
CMS	CIEMAT		Chambers MB2 (70) Electronics
	IFCA Santander		Alignment
	Madrid UAM		Trigger, Electronics
LHCb	USC		Si Tracker
	UB-URL		RICH (PM, Electronics)
LCG	All groups		



FABRICADO POR
MANUFACTURED BY

Grupo
felguera, s.a.



felguera
construcciones
mecánicas, s.a.

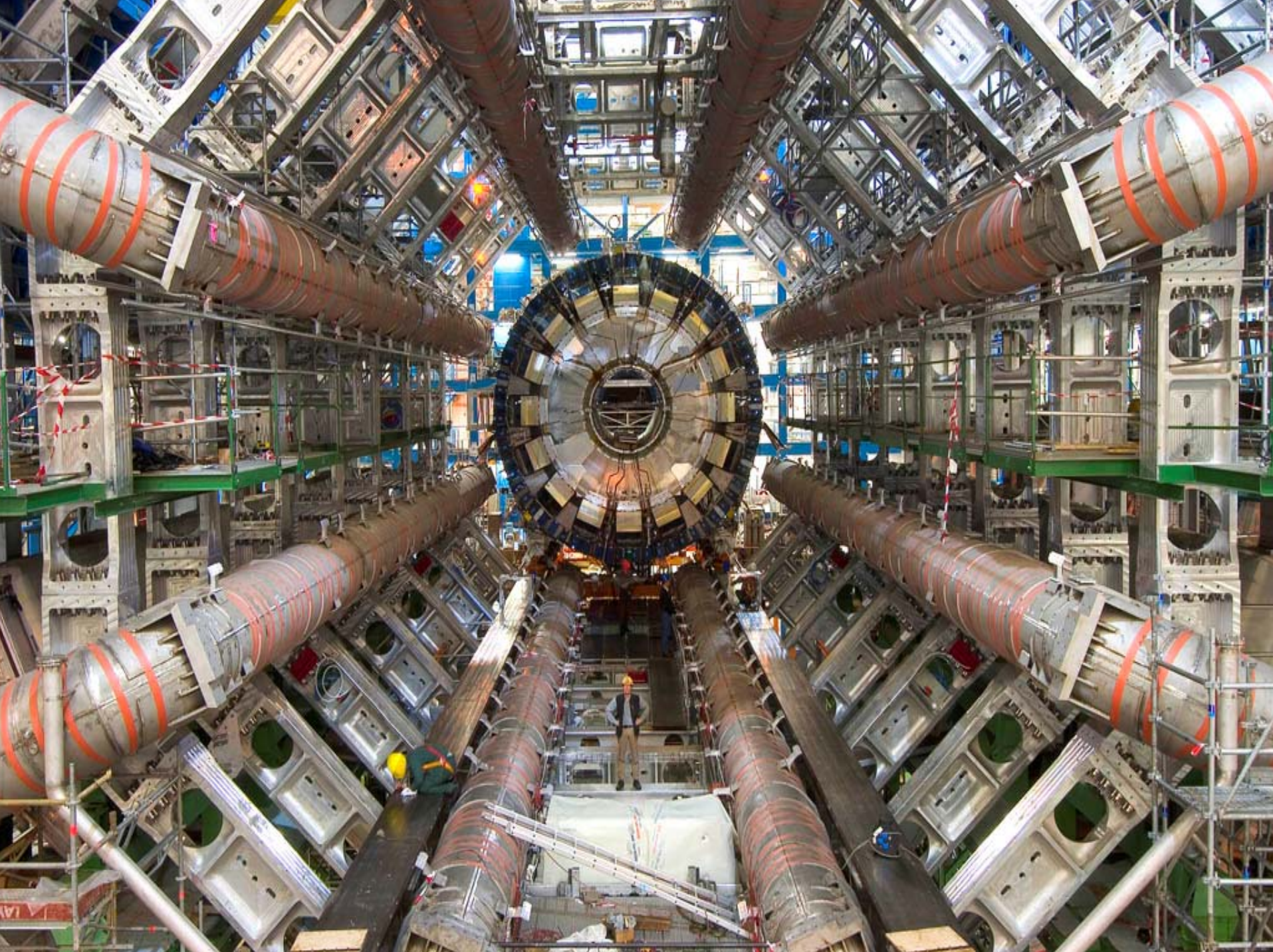
LANOVEDO, ASTURIAS - ESPAÑA
1994

IEA
ITA

INSTITUTO DE ENGENHARIA E INVESTIGACAO TECNICA
Braga

Barba

Barba



Experimental projects at IFIC

Particle & Astroparticle

- LHC-ATLAS:
 - TiCal
 - SCT
 - GRID computing
 - Software
- K2K
- Antares
- B-Factory/BaBar
- LEP/Delphi
- Accelerator Physics
- Detector R&D

Nuclear Physics

- γ -Spectroscopy
 - nTOF
 - ISOLDE
 - FAIR, ALBA
- Nuclear Reactions
 - Hades
 - TAPS
- Integral

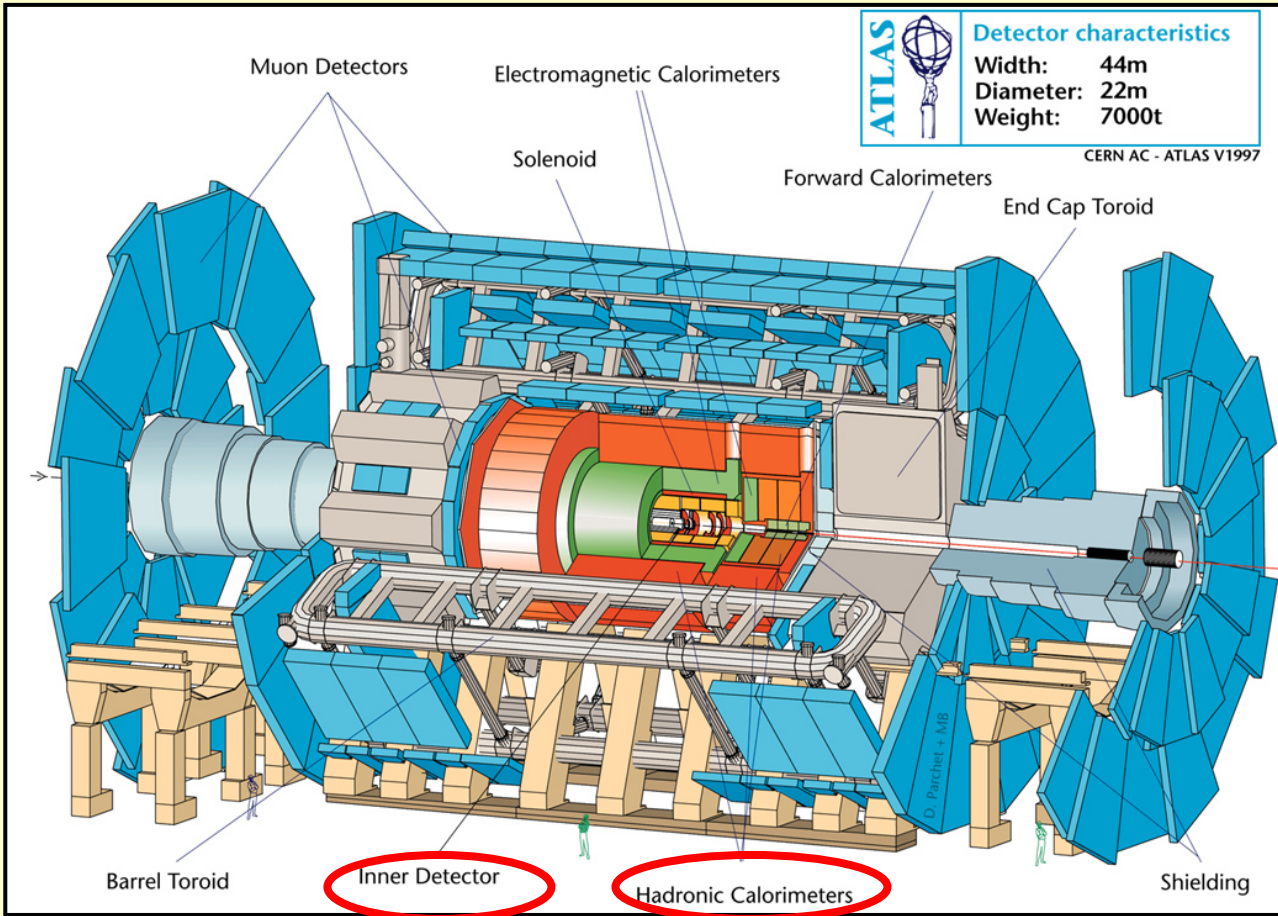
Medical Applications

- Nuclear Medicine
- CIMA



LHC-ATLAS

Detector subsystems



Software and Simulation

Inner Detector Alignment
B-tagging techniques
Higgs in MSSM and Top quark production

LHC Accelerator Physics:

Luminosity and Fwd Physics with ATLAS:

Optics design & Beam Dynamics simulation for an absolute Luminosity determination

LHC Injector (SPS)

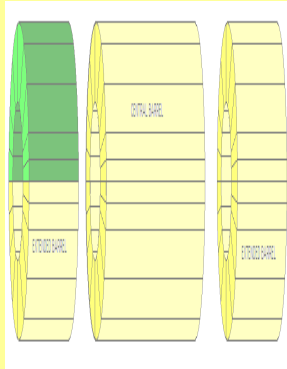
Optics design, modelling of machine, study of non-linear resonance driving terms, localisation of sources of non-linearity



ATLAS-TiCal

Submodules Construction

315 iron submodules assembled (900 kg each),
half extended barrel



Photomultipliers Testbench

1750 (17.5%) of the Tilecal photomultipliers tested
in test bench labview

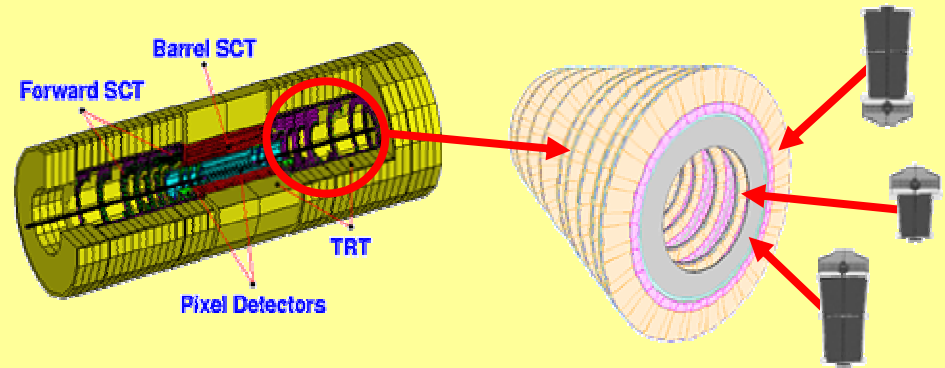
Read Out Driver (ROD)

Design, assembly, test and commissioning of the
32 ROD electronic boards to calculate energy,
time and quality information of the
more than 10.000 channels

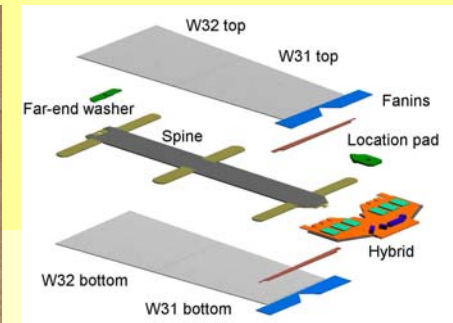
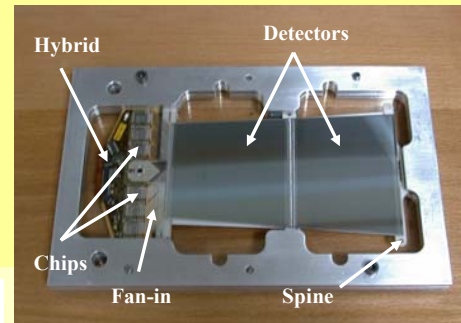


ATLAS-SCT

Characterization, assembly, metrology, bonding and
test of 220 modules with 4 silicon wafers each and
its corresponding read out electronics of the Atlas
Forward Tracker



Forward outer module

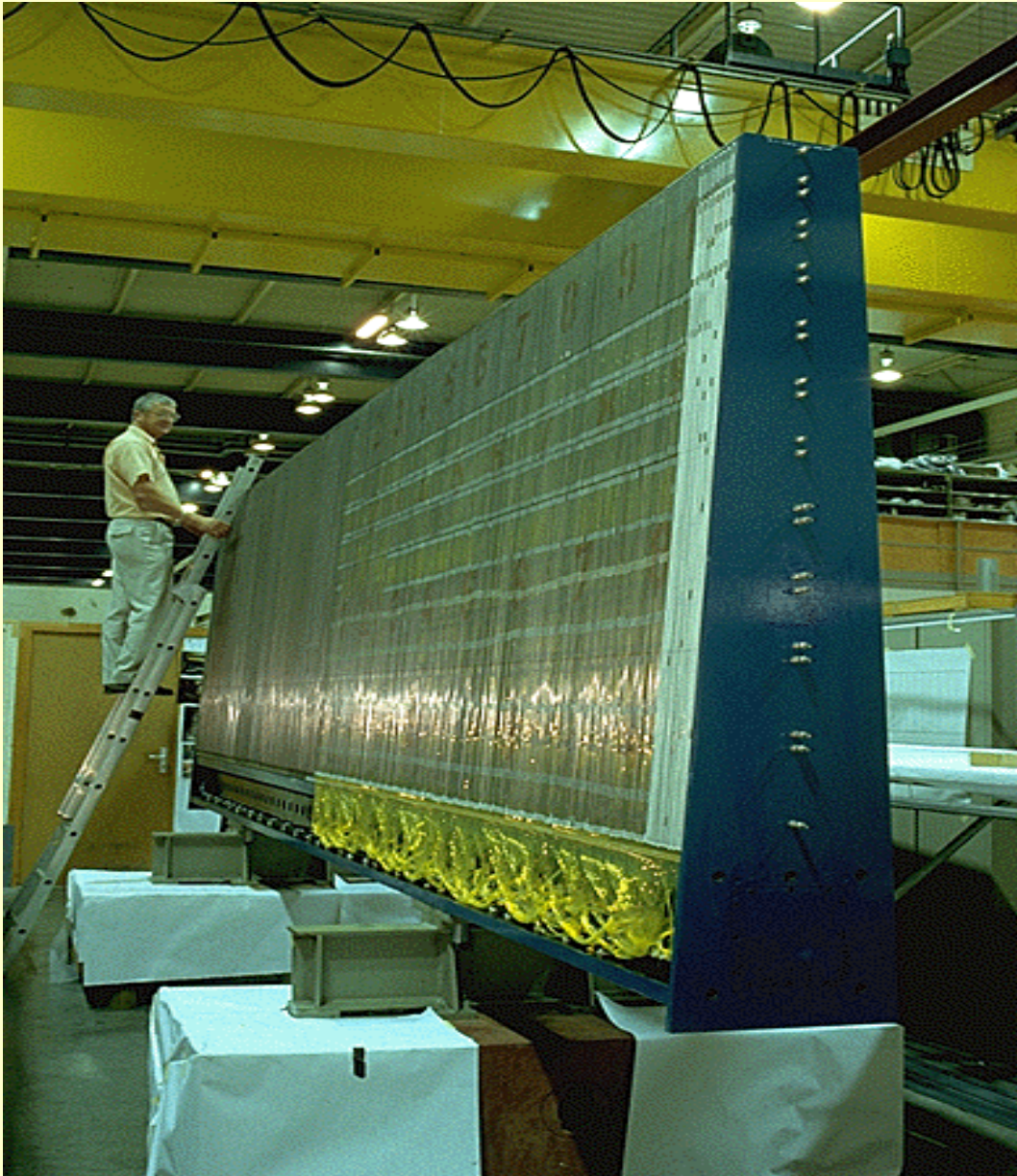


TileCal Submodule





TileCal Module

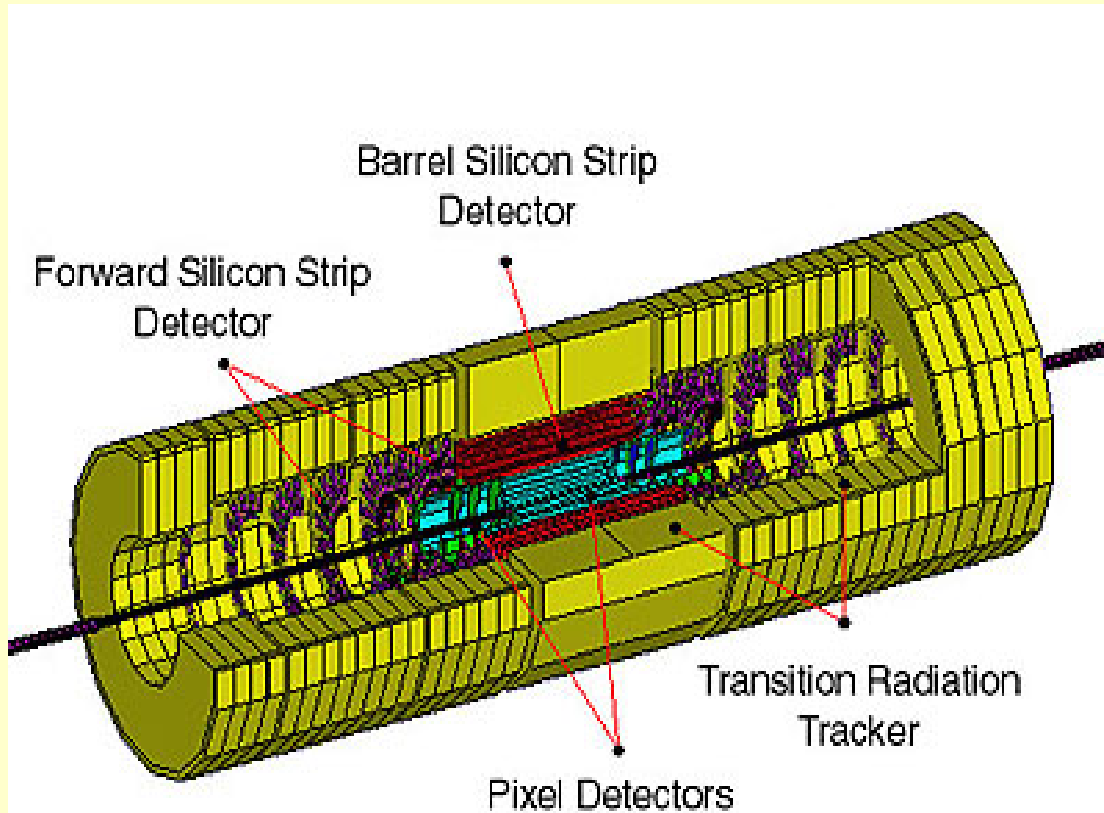


Spain built 1 EB
= 64 modules
640 Tons

50% submodules in
Valencia (IFIC)
50% submodules in
Barcelona (IFAE)

Extended Barrel mounted
and instrumented in IFAE

SCT (Silicon inner tracker)



Inner Tracker



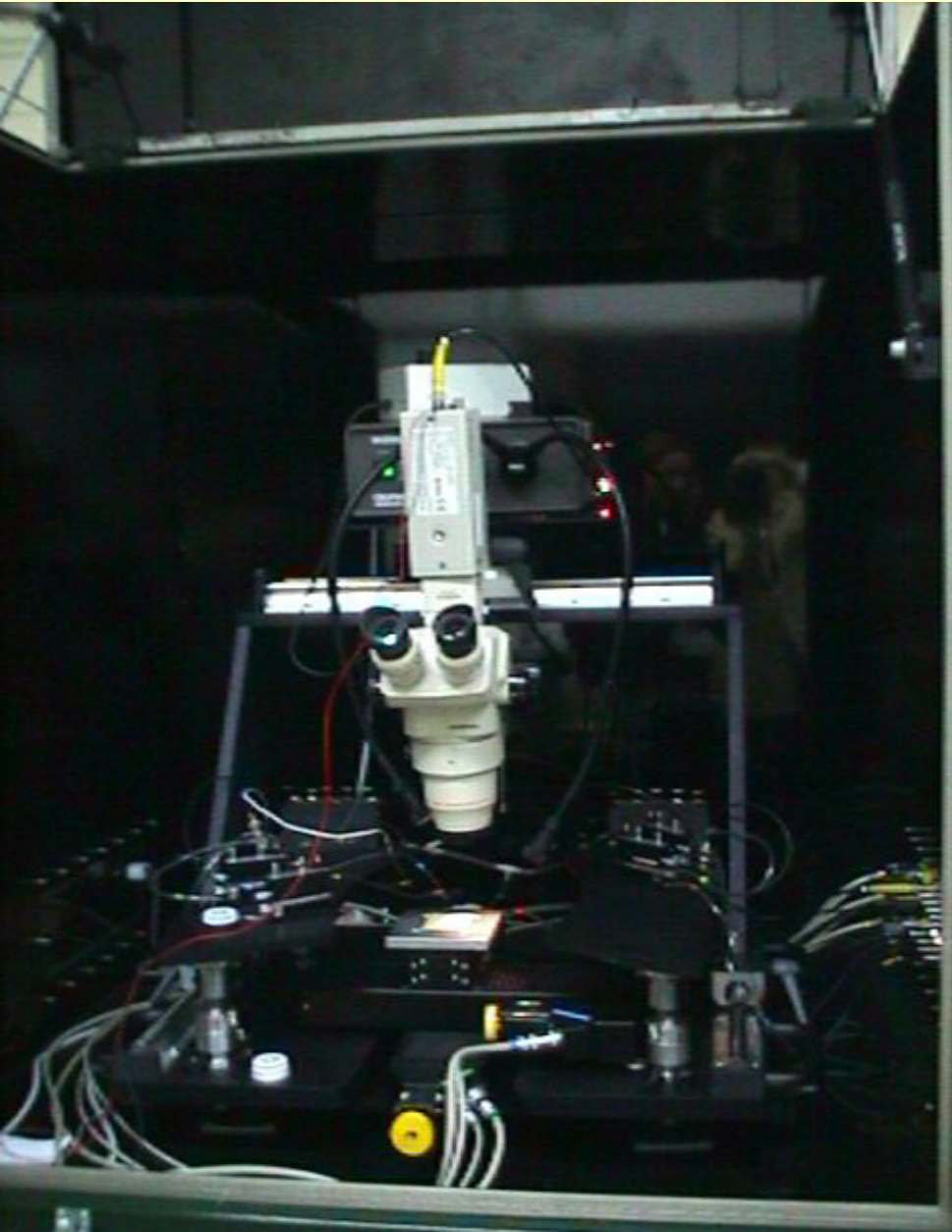
IFIC - Valencia
CNM-Barcelona

2 Wheels

200 modules

Test, Microbonding,
Mount

IFIC, SCT clean room



IFIC, clean room (SCT)



ATLAS-GRID

GRID Infraestructure at IFIC



➤ 134 PC's en 6 racks

➤ CPU:

➤ 67 Athlon K7 @ 1.2 GHz

➤ 67 Athlon K7 @ 1.4 GHz

➤ RAM: 1 Gbytes

➤ HD: 40 Gbytes (~2 Gbytes Linux RH 7.3)

➤ NIC: FastEthernet (100 Mps)

➤ 8 Intel servers

➤ CPU:

➤ High availability GRID center for ATLAS (Tier 2)

➤ Production of simulated data. Data Challenges

➤ Distributed analysis facility

➤ Support for 20 physics analysis (common effort of spanish groups in ATLAS)

➤ R&D in GRID technologies and e-Science



➤ 8 disc servers (8 TBytes),

➤ Robot de cintas 140 TBytes

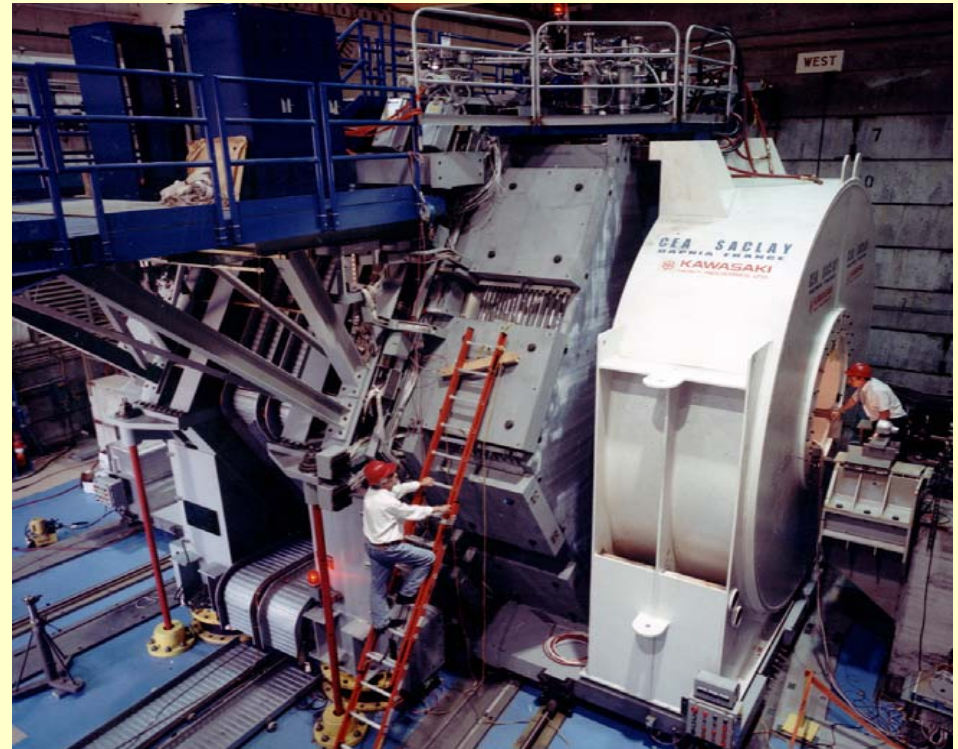
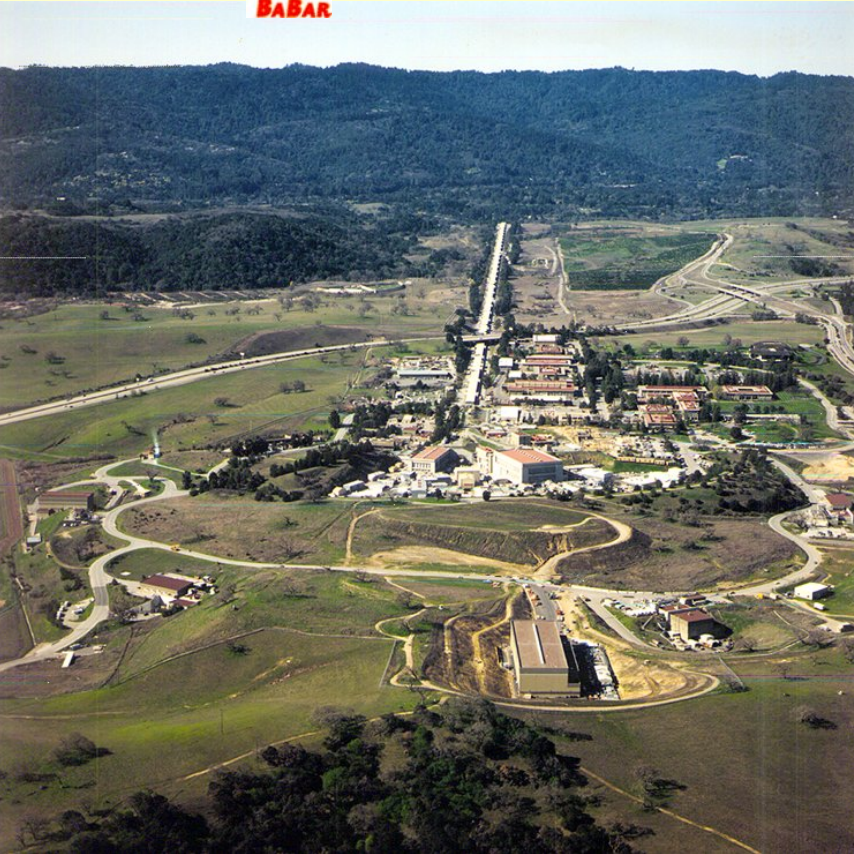
➤ STK L700e

➤ 700 slots

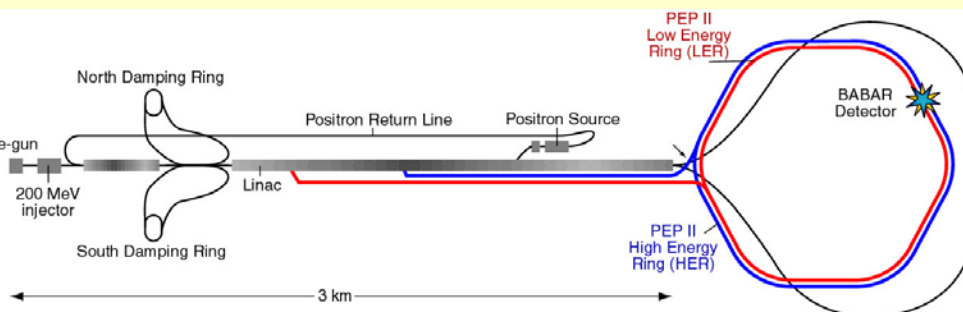
➤ 4 x drives HP LT02 (200 GB nativo, 400 GB comp.)



BaBar: Asymmetric B-Factory at SLAC



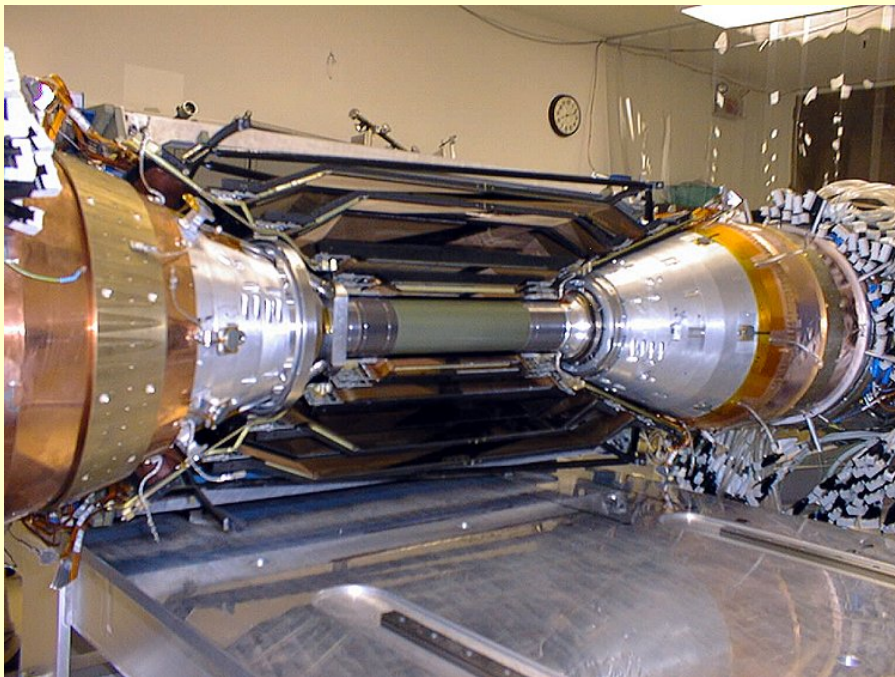
- Very rich B, charm and tau physics program
- Search for CP Violation in B meson decays and test at this low energy scale the SM
- **CP violation established in 2001**
- **Direct CP violation established in August 2004**
- Try to open windows on new Physics
- Since 1999, recorded ~260 M BB pairs. ~4-8 times more by end of decade





BaBar: Asymmetric B-Factory at SLAC

Silicon Vertex Tracker (SVT) reconstruction software



Feasibility studies to use and increase IFIC computing resource for official Monte Carlo productions (also being negotiated)

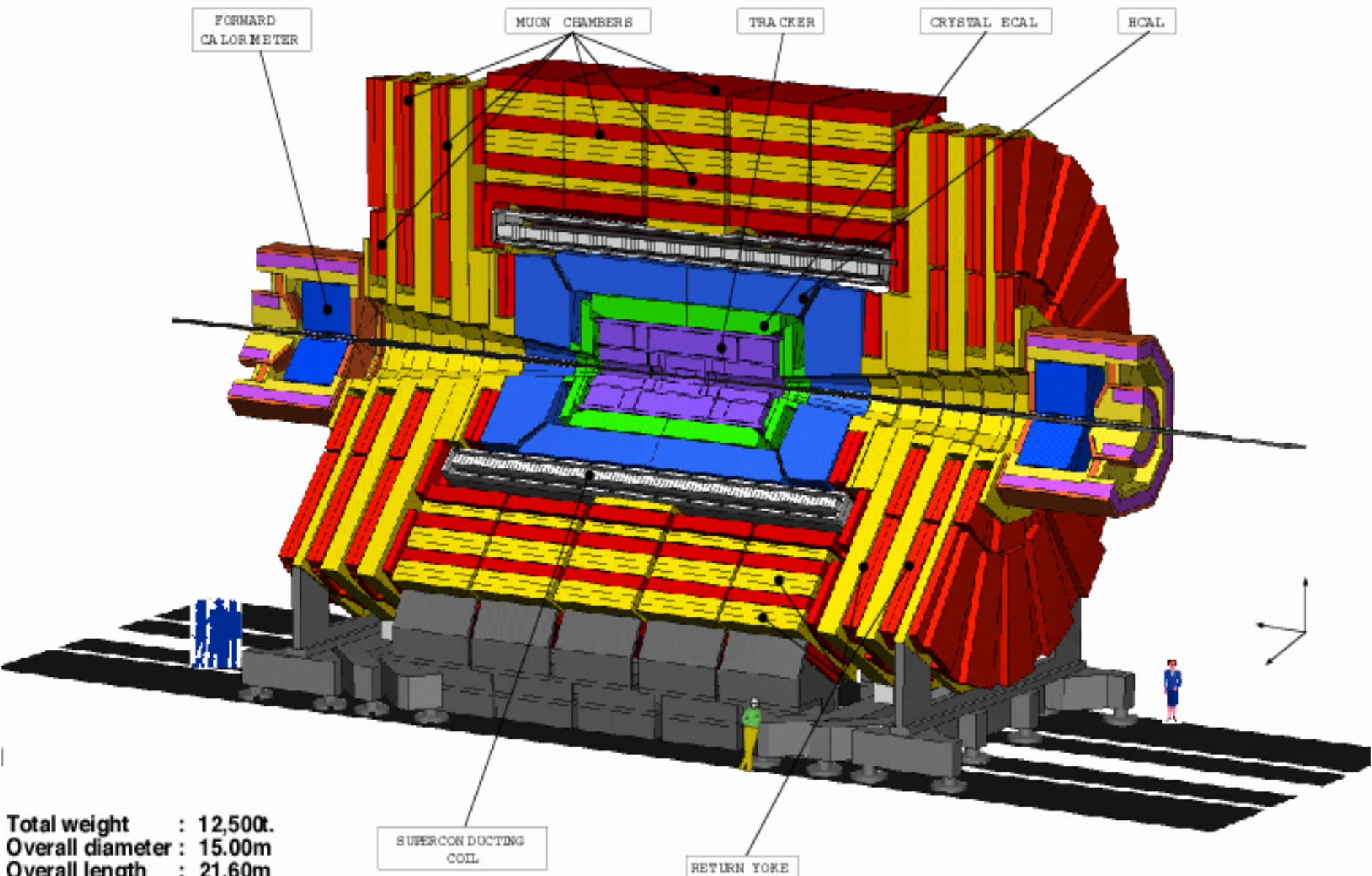
BaBar/PEP-II Long Term Planning Task Force. Evaluation of Physics impact of increased PEP-II luminosity and possible BaBar detector upgrades (DOE report)



- CP violation measurements of the 3rd CKM weak angle γ in $B^- \rightarrow D_0^* K^-$ decays
- Precision CP Violation measurements with charmonium events and mixing studies with fully reconstructed hadronic decays
- Detailed studies of Quantum Mechanics of the BB System at the $Y(4S)$: simultaneous and precision test of all discrete symmetries, as a probe for New Physics

CMS

A Compact Solenoidal Detector for LHC



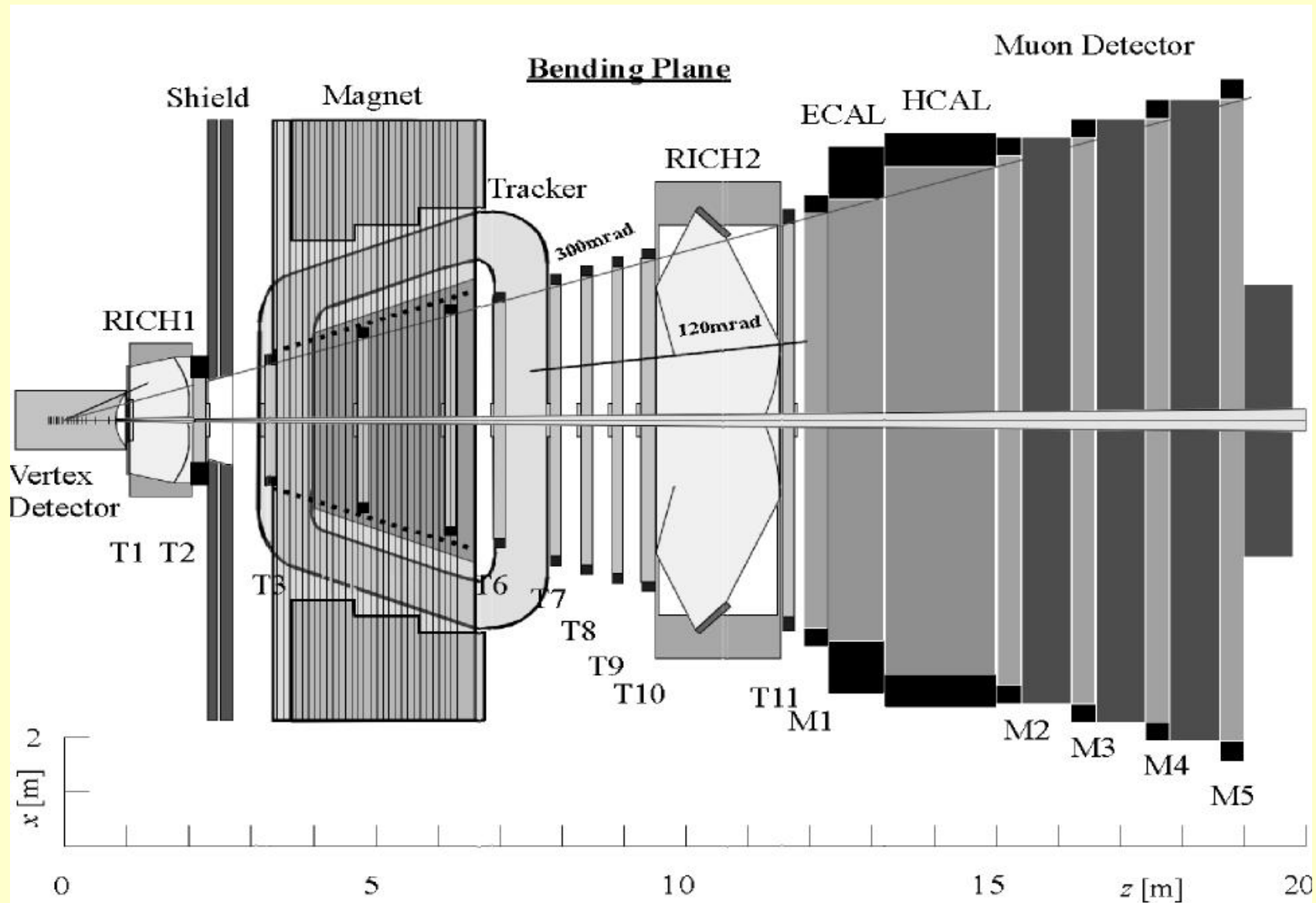
Muon chambers construction at CIEMAT



First MB2 Chamber Assembled at CIEMAT



El espectrómetro LHCb



6 questions* defining Astroparticle physics

1. What is the Universe made of ?
2. Do protons have a finite life time ?
3. What are the properties of neutrinos ? What is their role in cosmic evolution ?
4. What do neutrinos tell us about the interior of Sun and Earth, and about Supernova explosions ?
5. What is the origin of cosmic rays ? What is the view of the sky at extreme energies ?
6. What is the nature of gravity ? Can we detect gravitational waves ? What will they tell us about violent cosmic processes ?

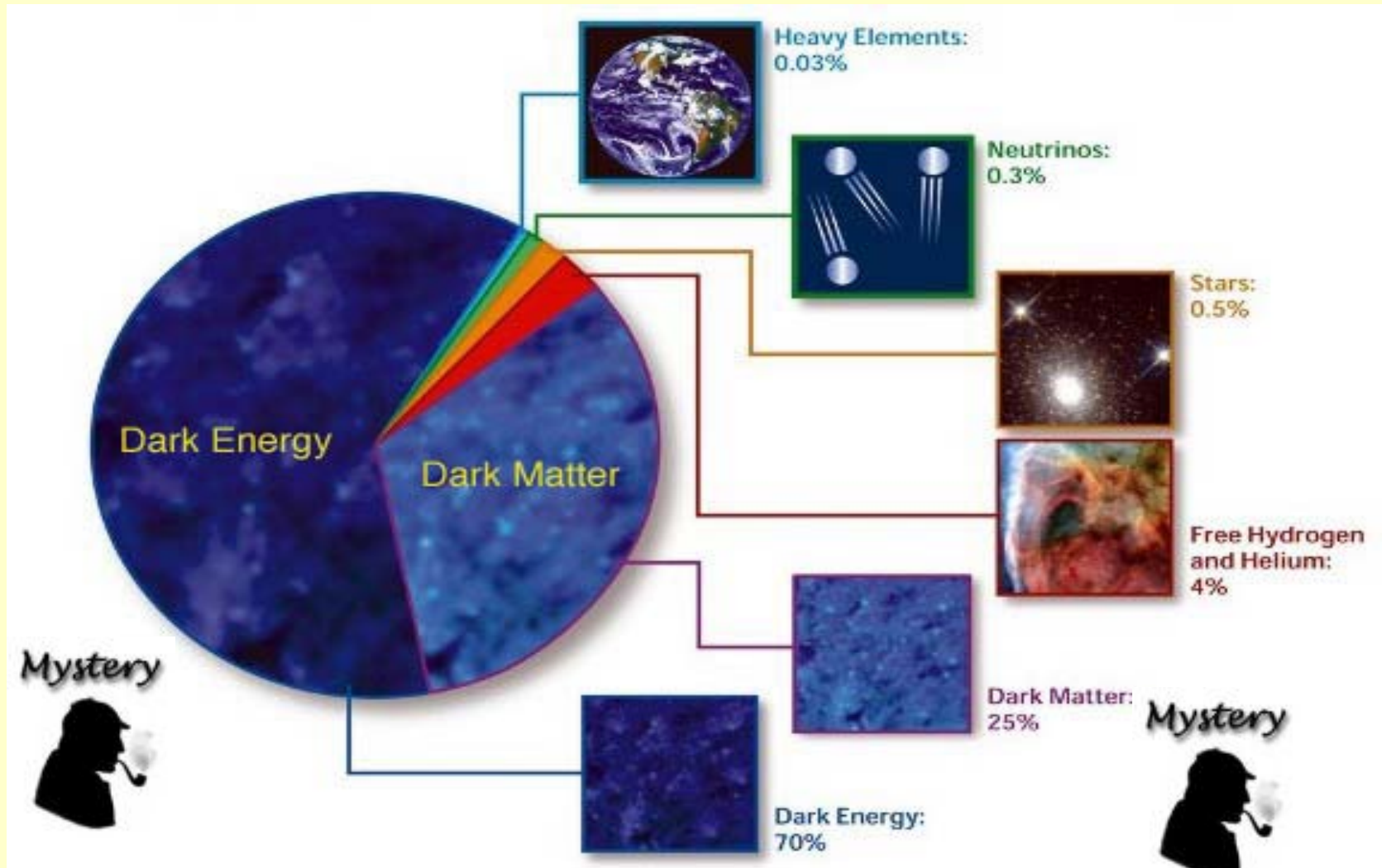
*"Science is the art of replacing unimportant questions that can be answered by important ones which cannot" Edward B. Ferguson Jr. 1976.

Astroparticles (+ neutrinos) in Spain

1. LSC CANFRANC & CAST
UZ
2. MAGIC
IFAE - UAB - UCM
3. ANTARES
IFIC
4. AMS
CIEMAT
5. AUGER
USC-UCM-UAH
6. K2K
IFAE+IFIC
7. ICARUS
UGR - CIEMAT
8. CHOOZ
CIEMAT

What is the Universe made of?

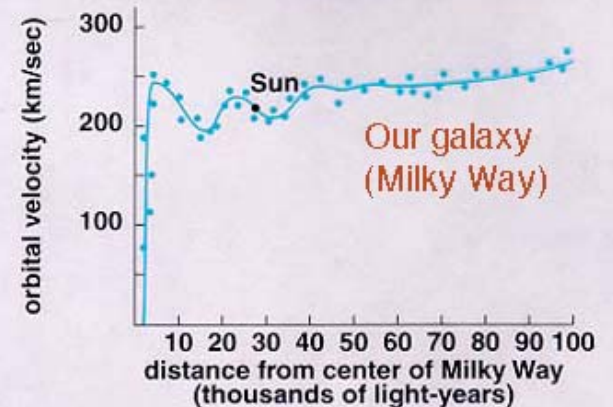
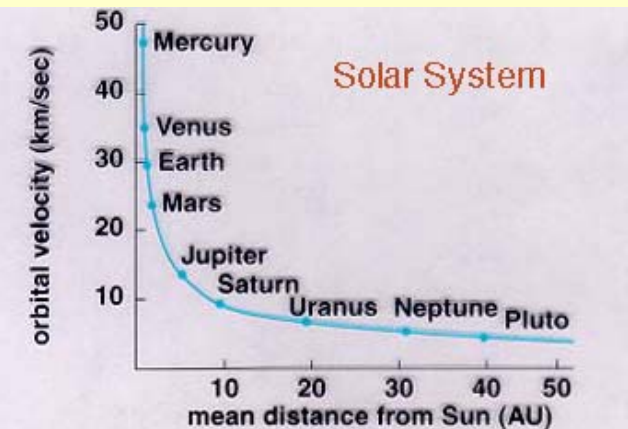
Stars and planets account only for a small fraction of the Universe!



Proof of existence of « dark matter »

Rotational curves

(velocity of peripheral stars,
too large)

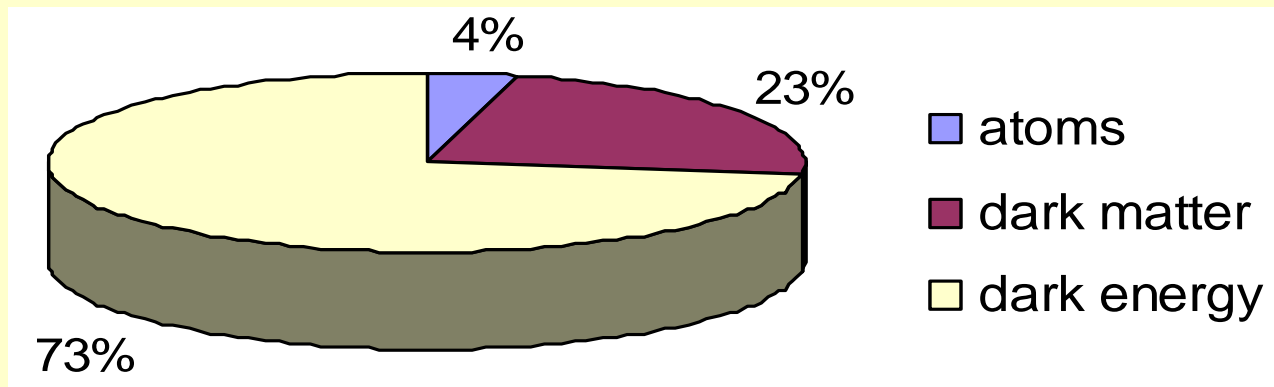
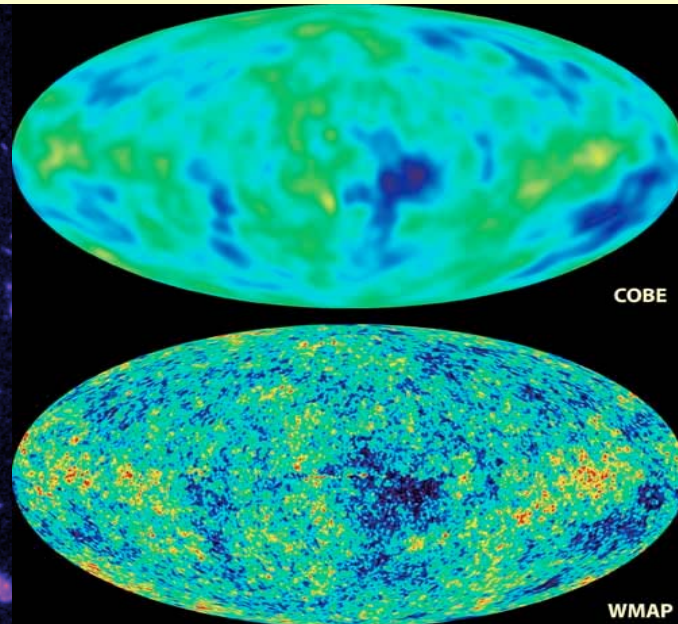
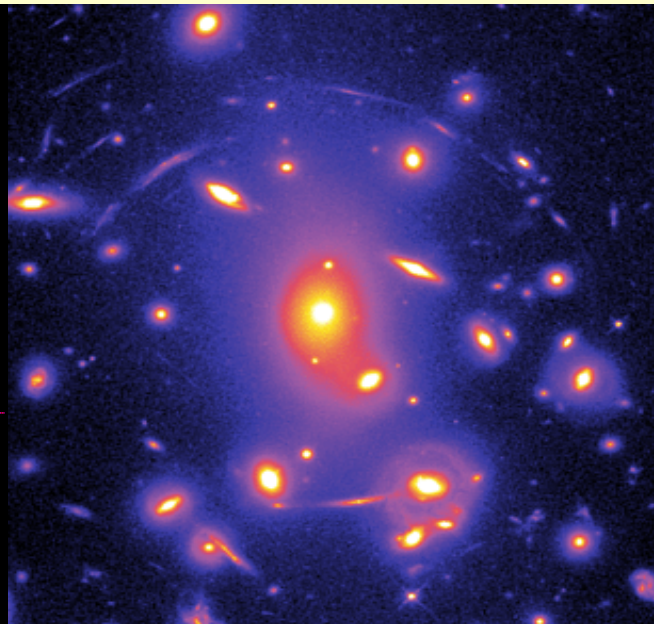
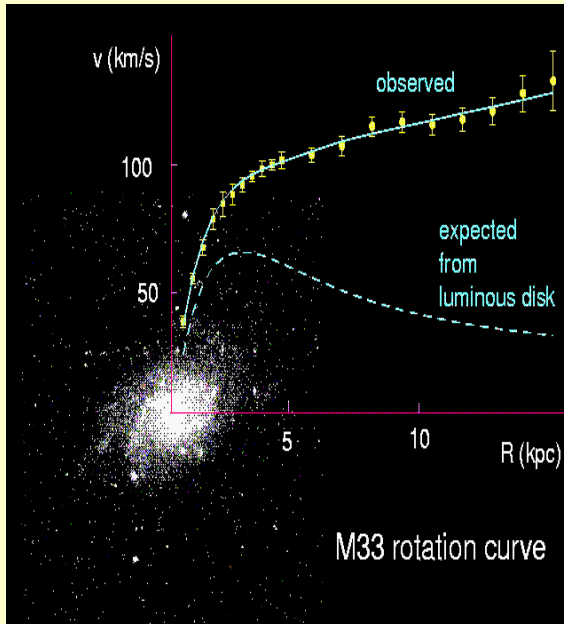


Dark Matter

Rotational light curves

Gravitational lensing

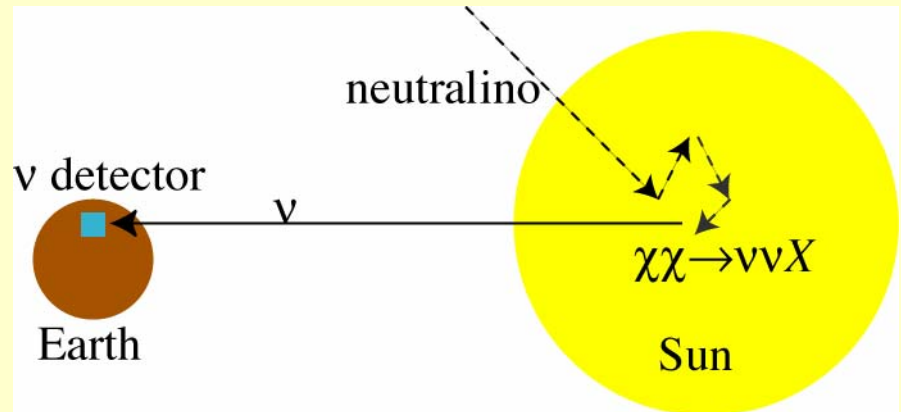
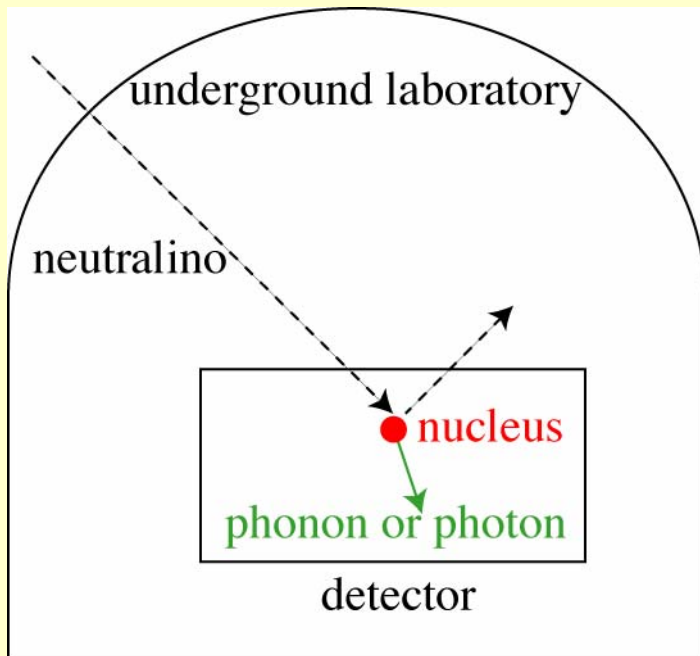
Temperature fluctuations



Detection of Dark Matter


- Direct detection
- CDMS-II, Cuore, DAMA, ANAIS, etc

- Indirect detection
- SuperK, AMANDA, ICECUBE, Antares, etc



complementary techniques are getting into the interesting region of parameter space

European Underground Labs



IUS
Institute of Underground
Science in Boulby mine,

Pyhäsalmi Mine

(plans...)



LSM
LABORATOIRE SOUTERRAIN de MODANE

Laboratoire Souterrain
de Modane, France



LNGS

Laboratori Nazionali del
Gran Sasso, Italy

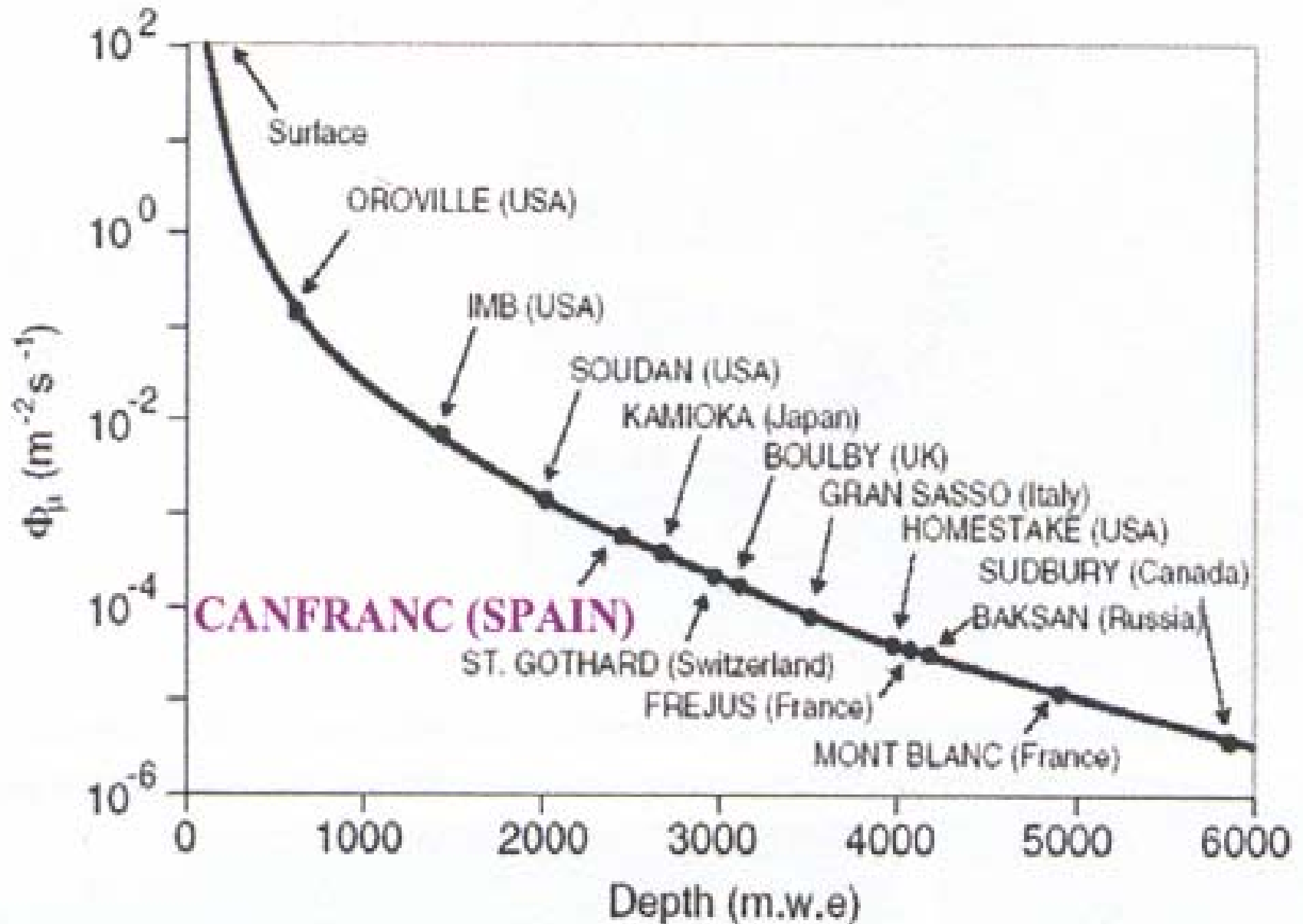


LSC

Laboratorio Subterraneo
de Canfranc, Spain

Baksan

Underground Laboratories





THE CANFRANC UNDERGROUND LABORATORY

PHYSICS RESEARCH PROGRAM STATUS, RESULTS AND PROSPECTS



**Laboratory of Nuclear and High Energy Physics
University of Zaragoza**

L S C LABORATORIO SUBTERRÁNEO DE CANFRANC

CANFRANC UNDERGROUND ASTROPARTICLE LABORATORY

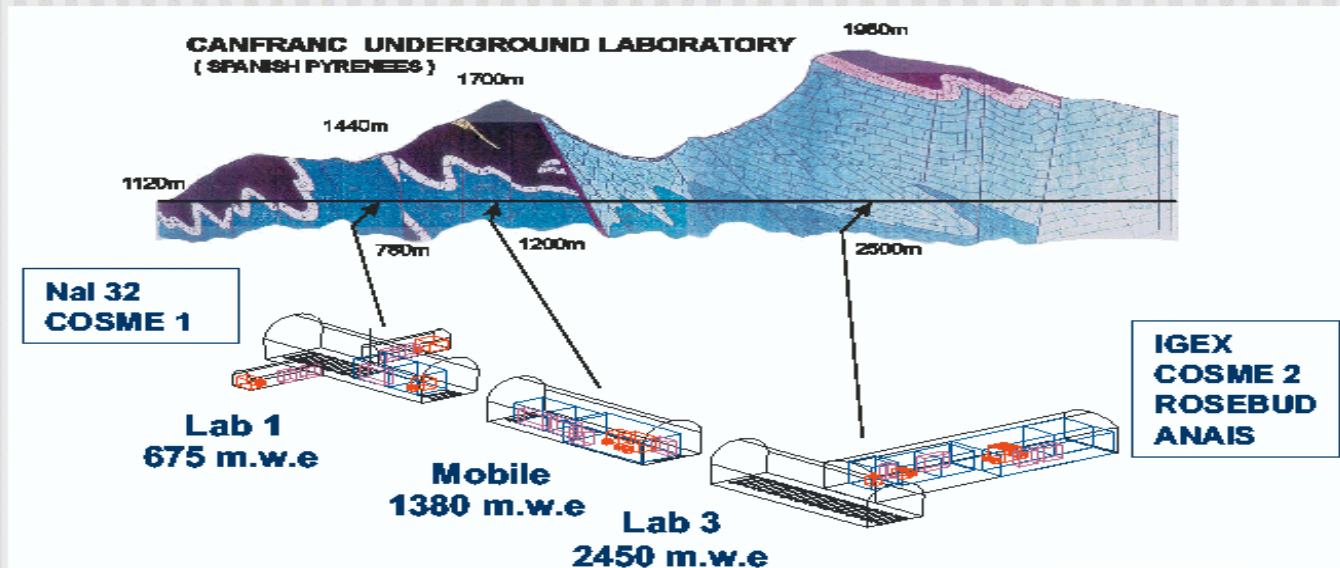
SPAIN



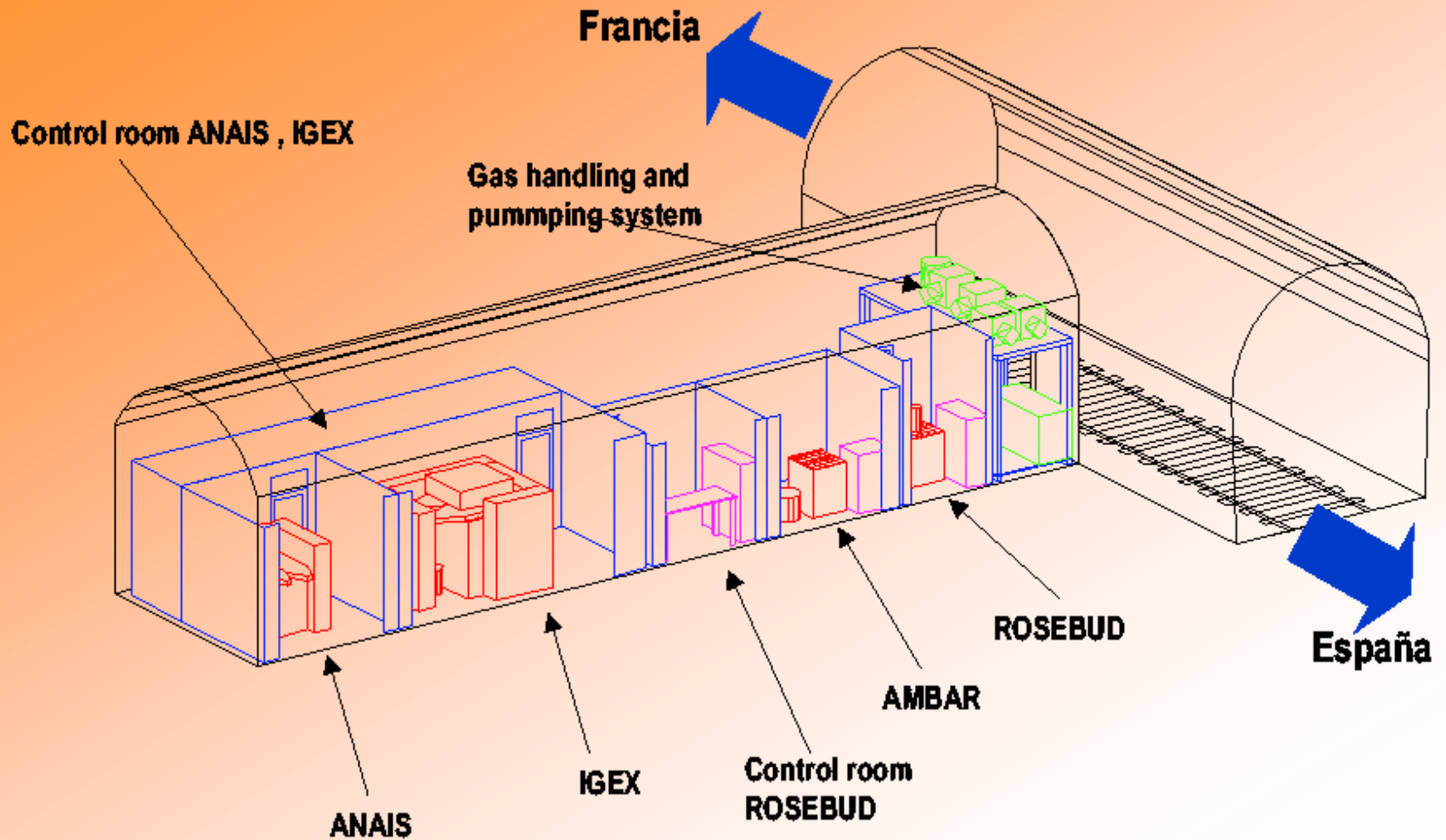
Spanish Pyrenees



Railway tunnel (not in use)



Canfranc Underground Laboratory



International Somport road tunnel





Laboratorio Subterráneo de Canfranc



ICARUS in LNGS Hall B

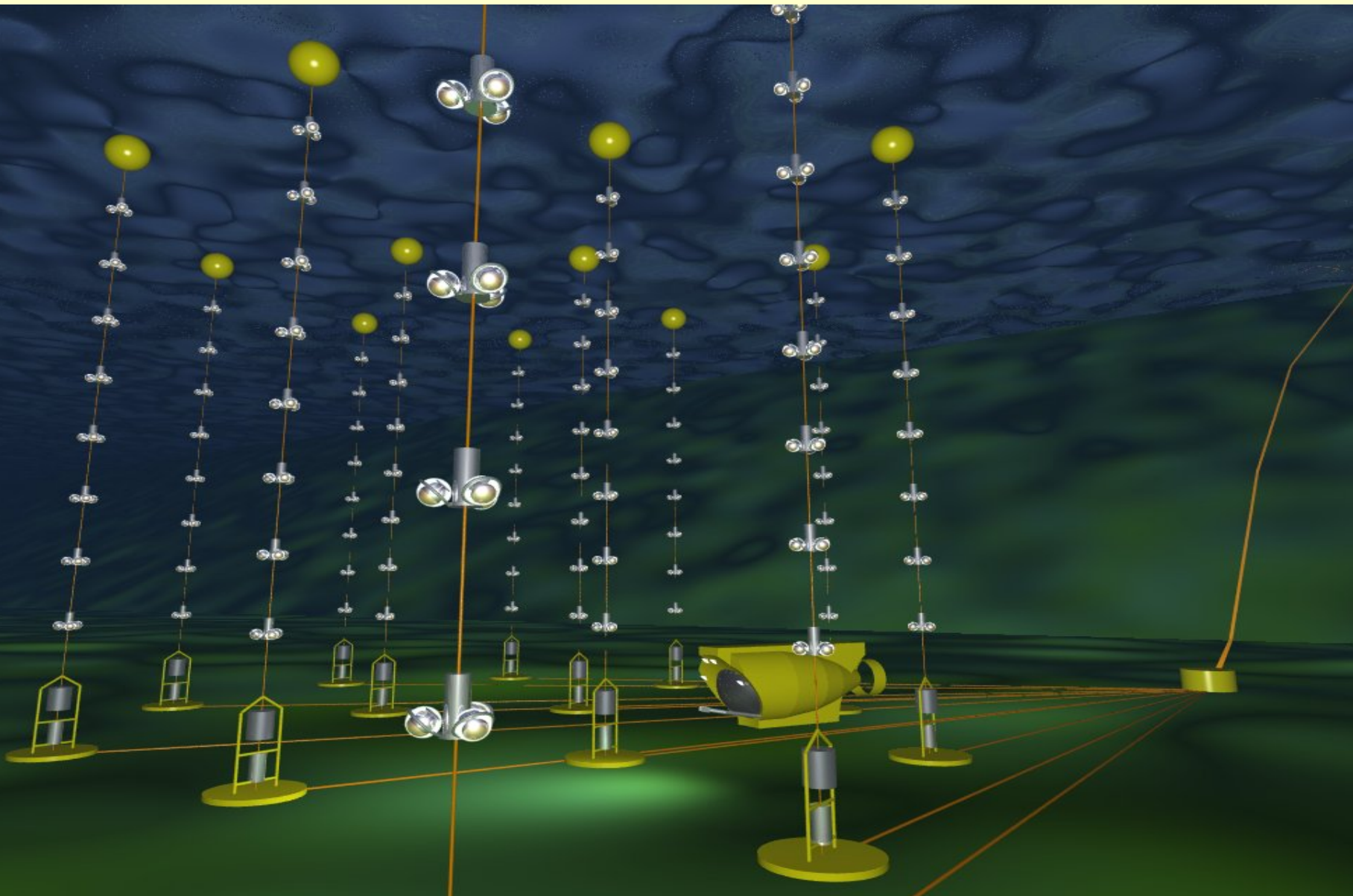


Origin & properties of Cosmic Rays

1. Neutrinos (Antares)
2. Gamma rays (Magic)
3. Charged particles (Auger)
4. Antimatter? (AMS)

*"Science is the art of replacing unimportant questions that can be answered by important ones which cannot" Edward B. Ferguson Jr. 1976.

ANTARES 0.1 km² detector

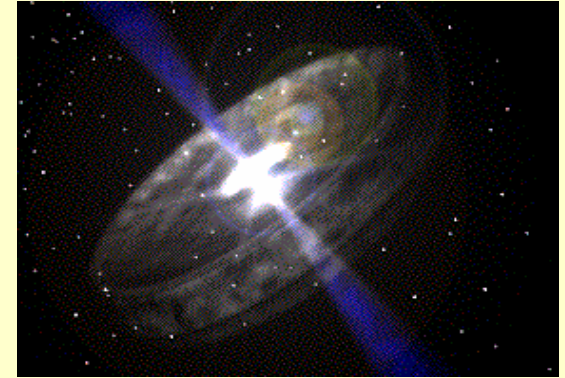
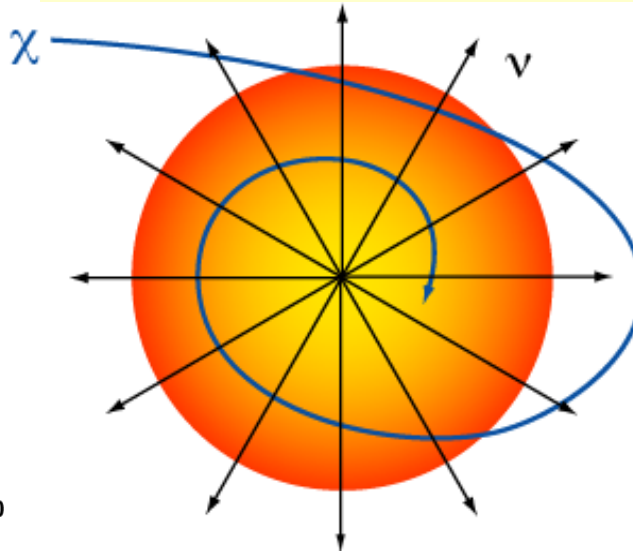
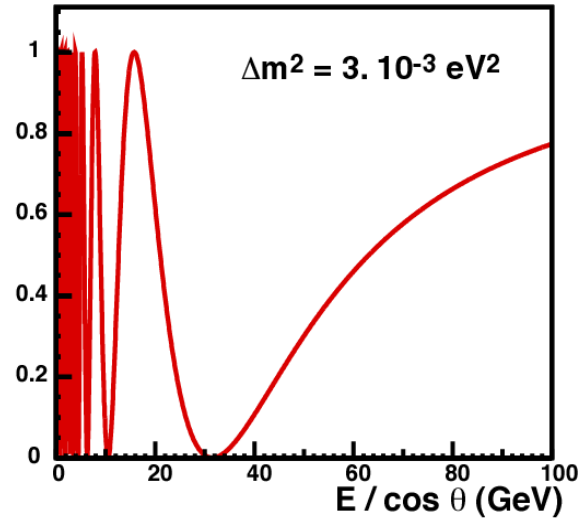


ANTARES



Photomultiplier
to detect
Cherenkov light

ANTARES



Low Energy

$$10 \text{ GeV} < E_\nu < 100 \text{ GeV}$$

ν oscillations

(Observation of first oscillation minimum)

Medium Energy

$$10 \text{ GeV} < E_\nu < 1 \text{ TeV}$$

Neutralino search

Self-annihilation at center of Earth, Sun, Galaxy

$$\chi\chi \rightarrow X \rightarrow \nu$$

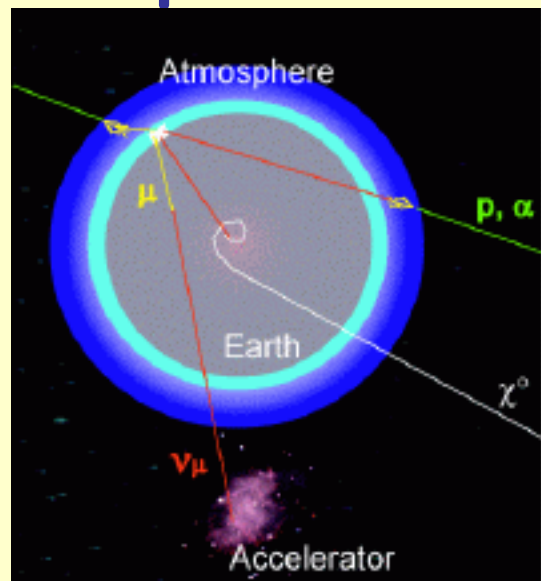
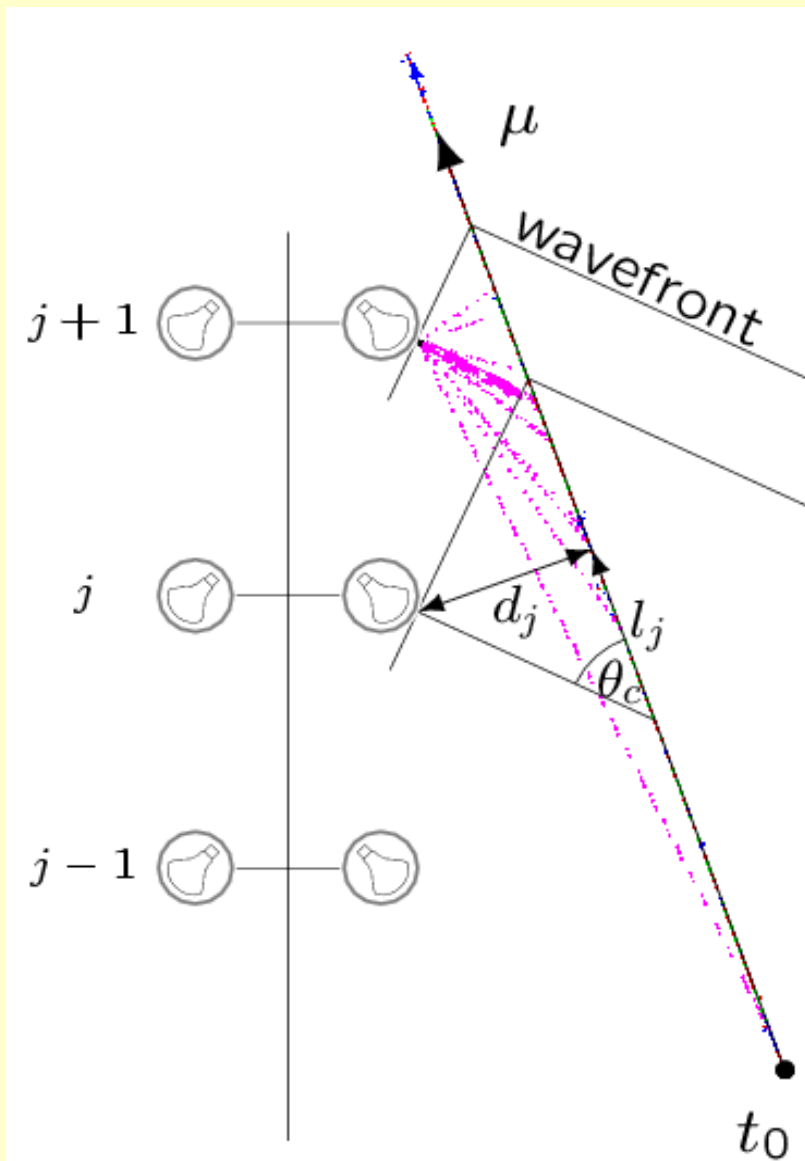
High Energy

$$E_\nu > 1 \text{ TeV}$$

ν from (extra-) galactic sources

SN remnants, AGN, GRB, ...

Detection principle



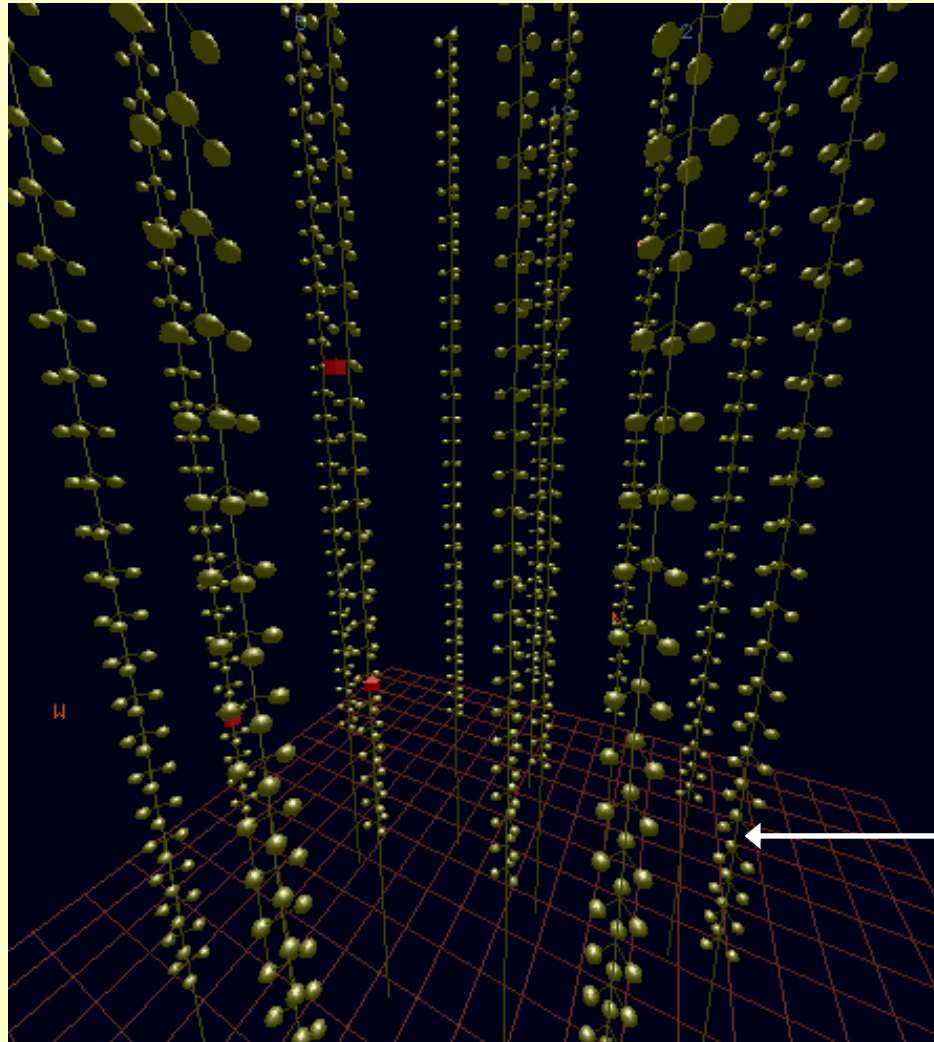
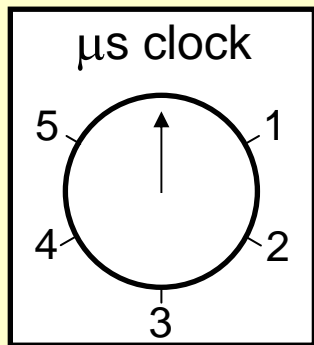
$$c(t_j - t_0) = l_j + d_j \tan(\theta_c)$$

medium
properties

$$\left. \begin{array}{l} \delta x = 20 \text{ cm} \\ \delta t = 1 \text{ ns} \end{array} \right\} \delta\theta = 0.2 \text{ deg.}$$

$$\nu_\mu + N \rightarrow \mu + X$$

Neutrino detection (ANTARES)



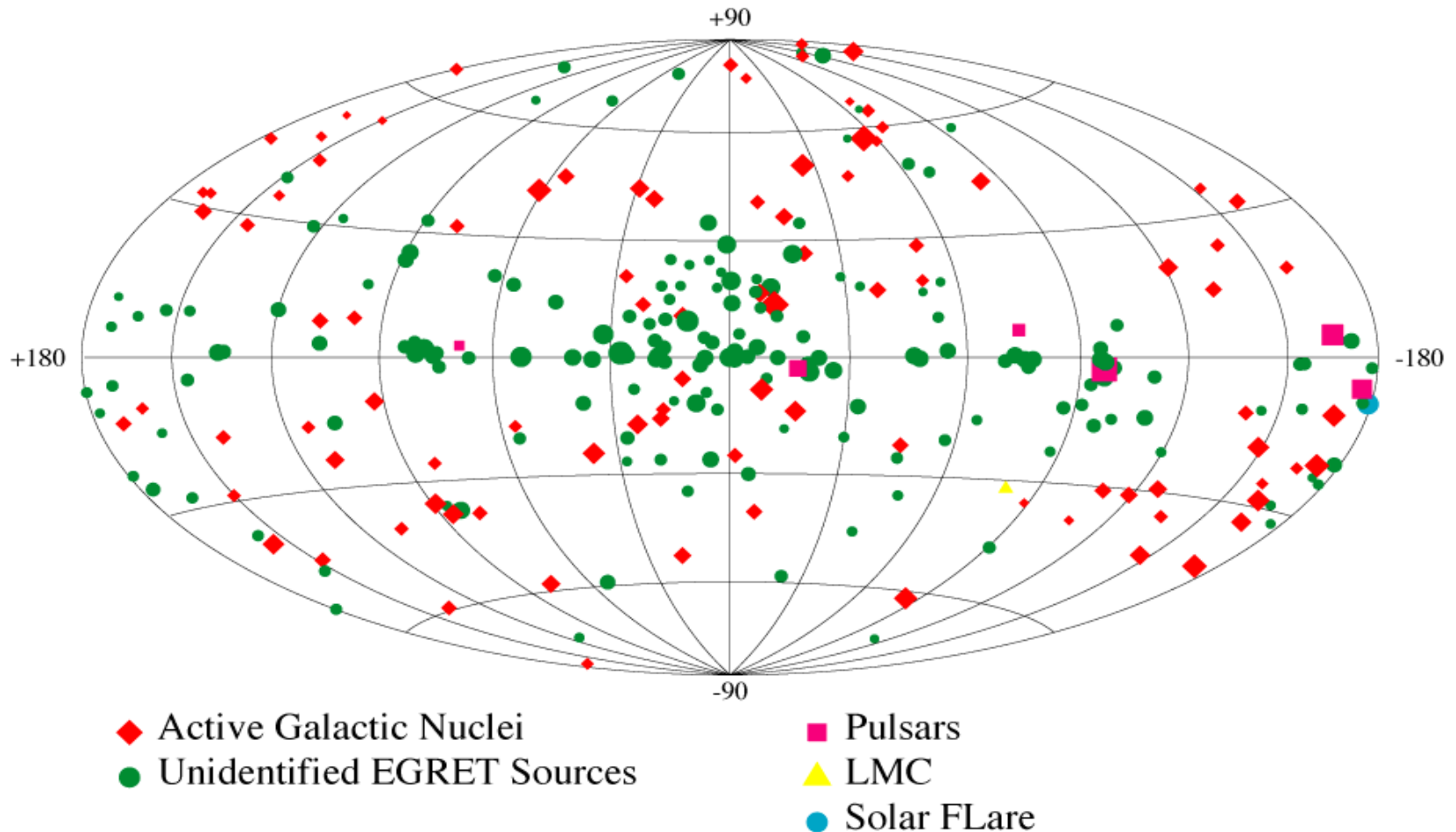
~100 kHz

~1 ν / hour

Gamma-ray galactic sources

Third EGRET Catalog

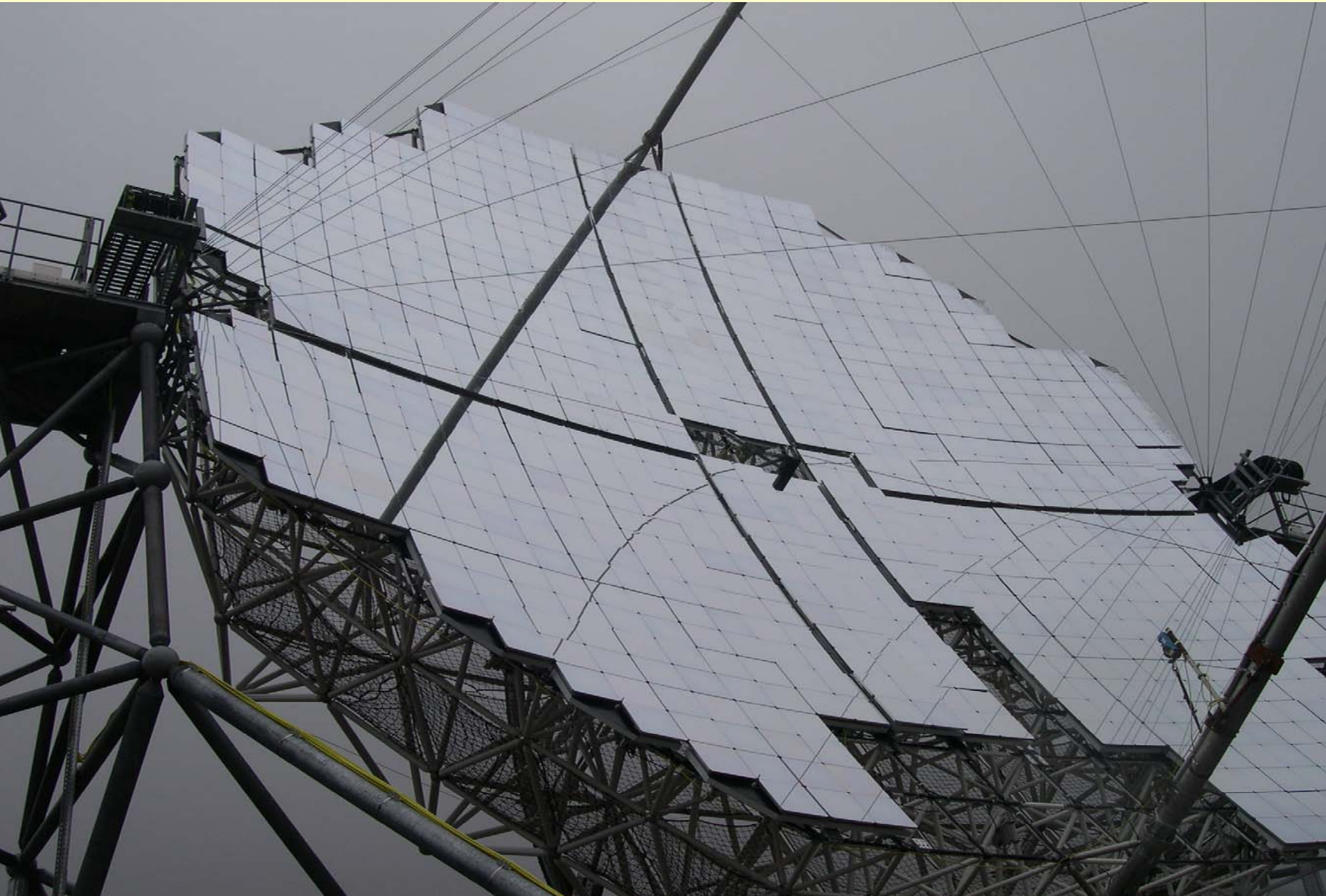
$E > 100 \text{ MeV}$



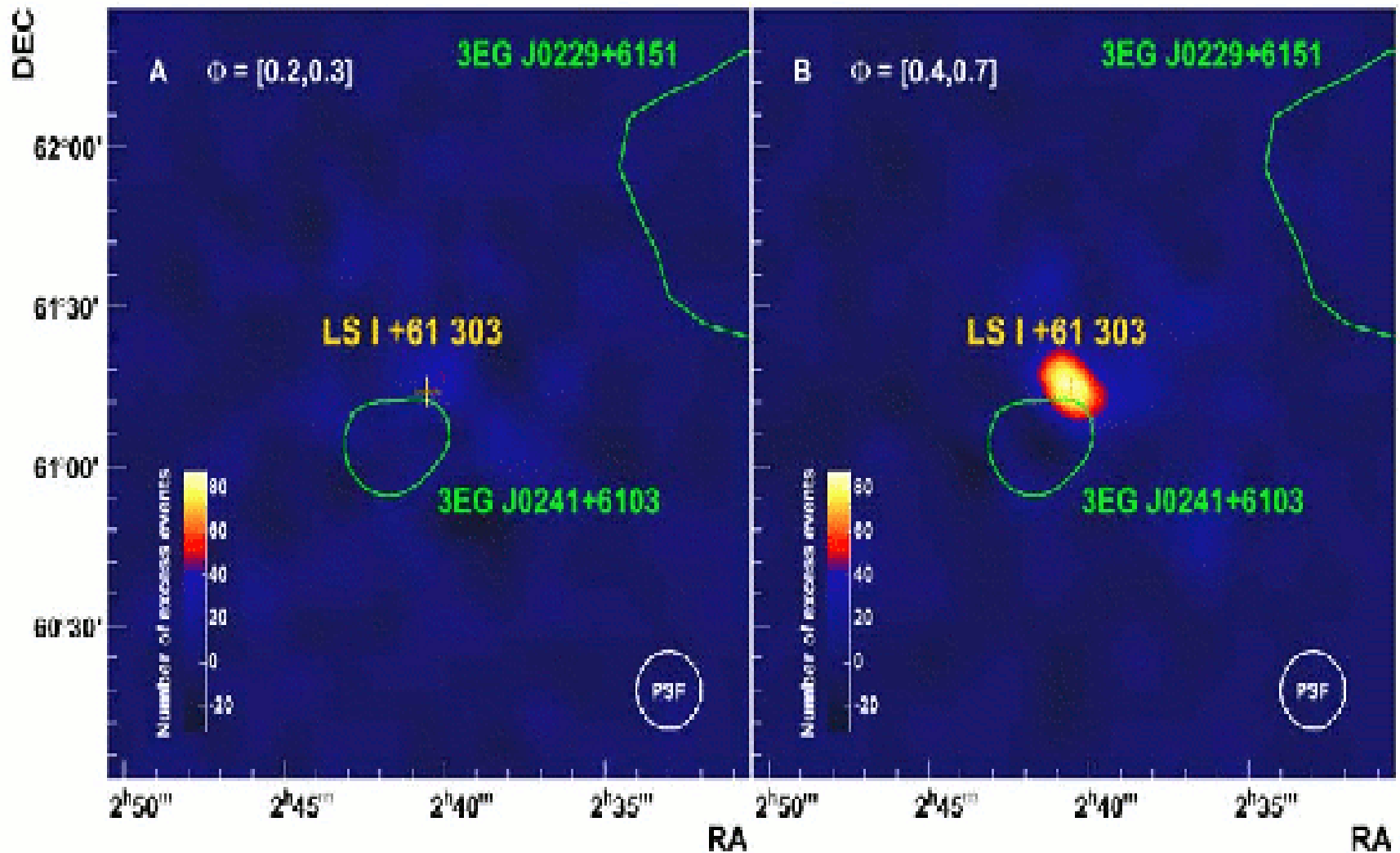
El Roque de los Muchachos (MAGIC)



Magic, the inauguration day



Microquasar (MAGIC)



AUGER

Purpose: Detect & discover the origin of cosmic rays with

$$E > 10^{19} \text{ eV}$$

2 deployments (each cost 50 M\$)

In each hemisphere:

1600 detectors (surface) + 30 fluorescence telescopes in

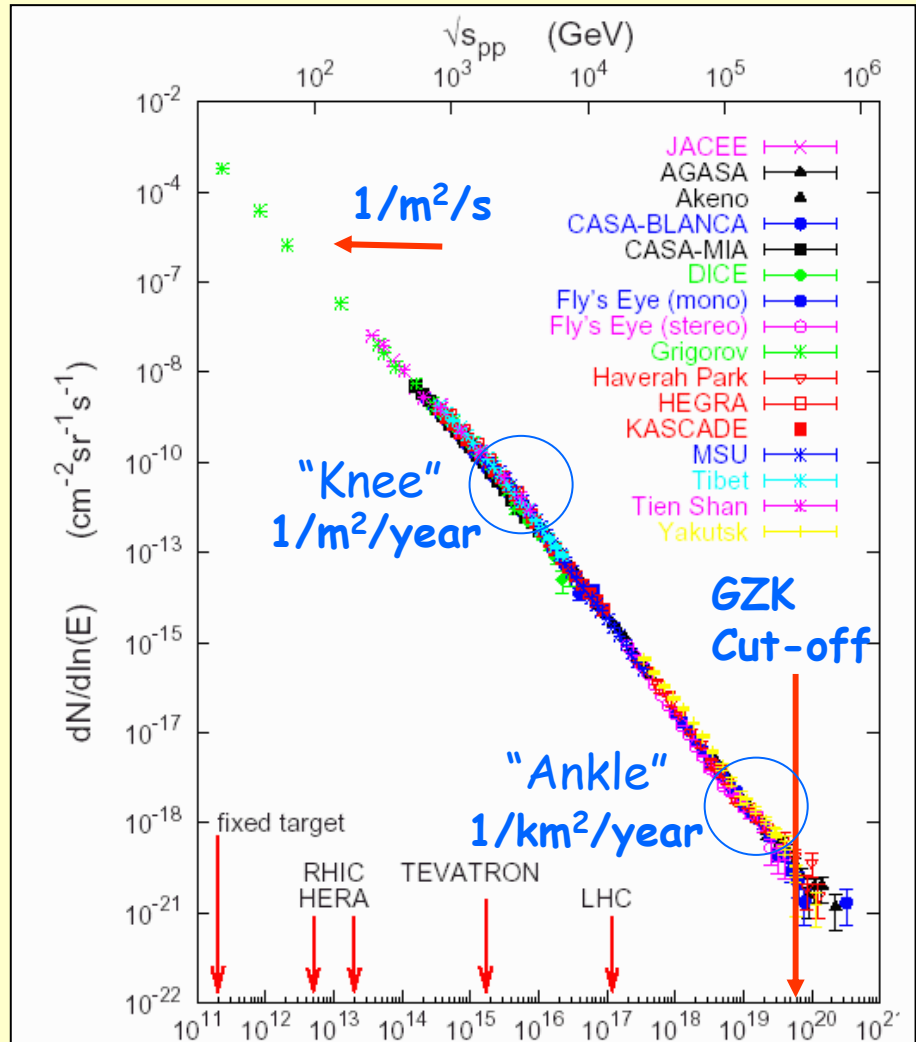
3000 km²

South: Provincia de Mendoza, Argentina

North: ?

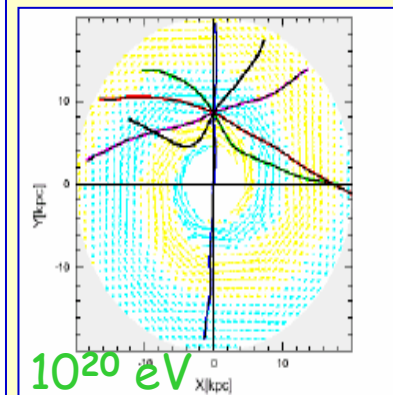
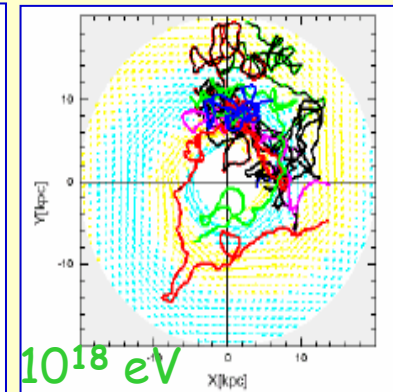
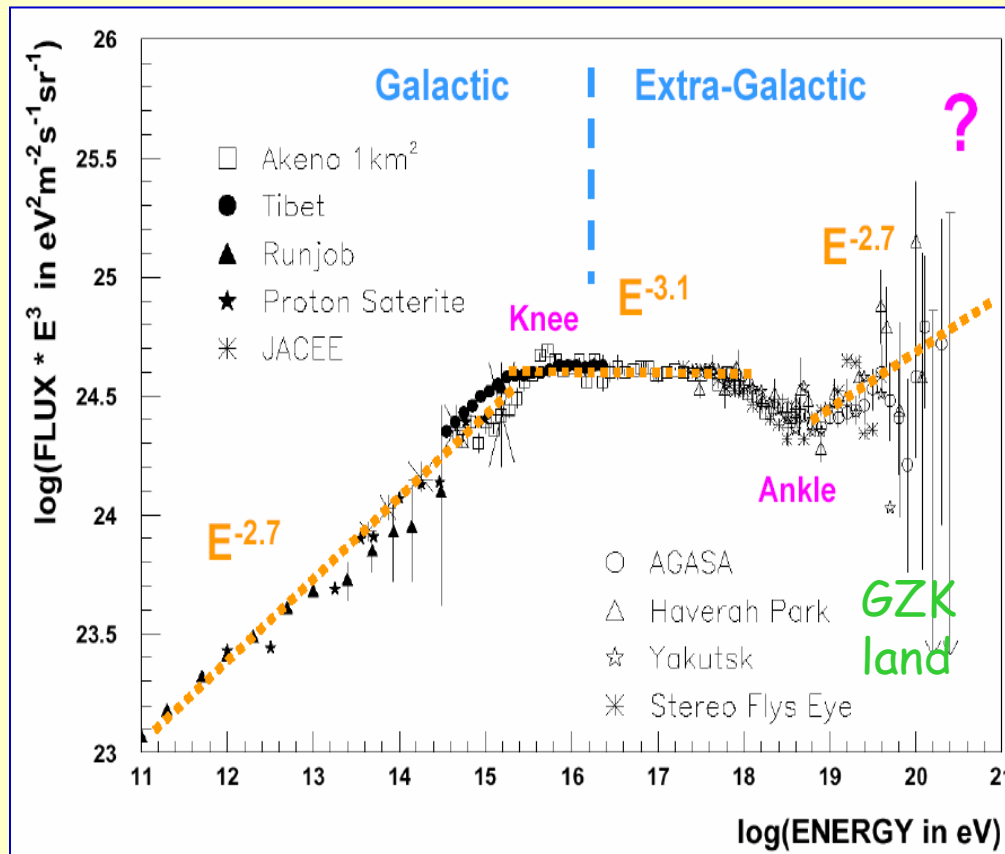
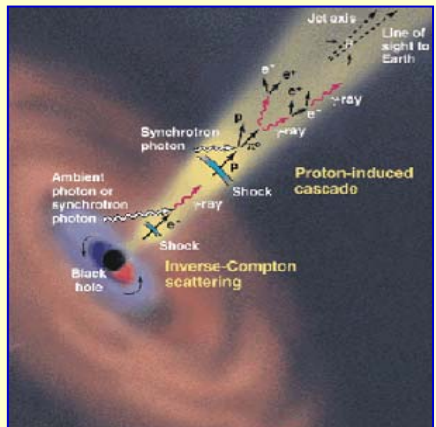
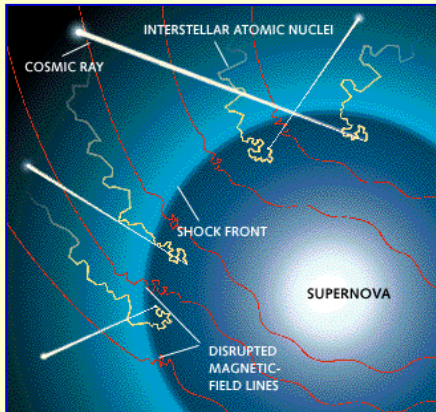
Cosmic Rays Spectrum

- High energy cosmic rays consist of protons, nuclei, gammas,...
- Measured flux extends to $s^{1/2} \sim 400$ TeV
- Highest energy particles are extremely rare
- Supernova shock fronts can accelerate particles upto 10^{15} eV
- Above $\sim 10^{15}$ eV, presumably acceleration is in AGNs (?)
- How do UHECR protons evade the GZK cut-off at $\sim 7 \times 10^{19}$ eV (if source is >100 Mps away)?
- UHECR manifest themselves as extended air showers (EAS) --an indirect way of measuring CRs

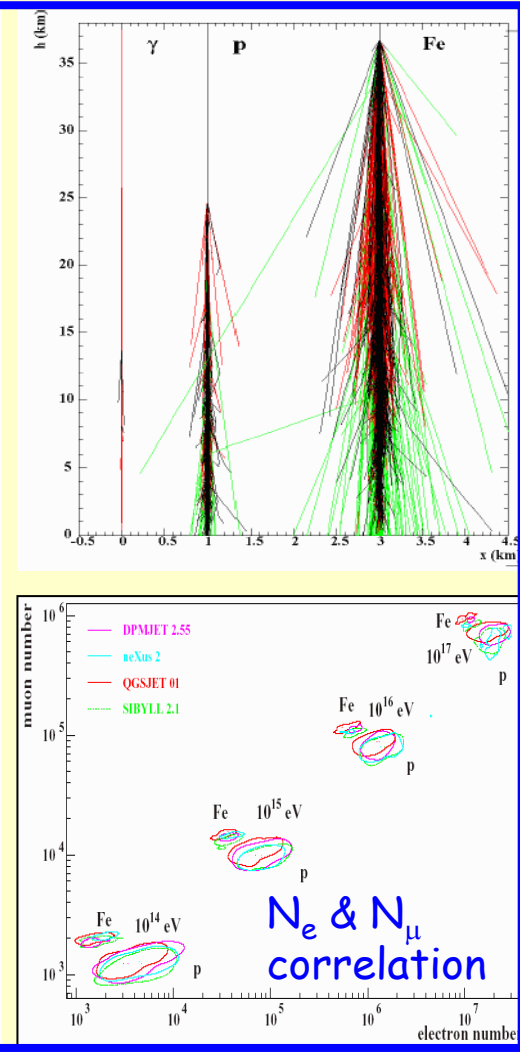
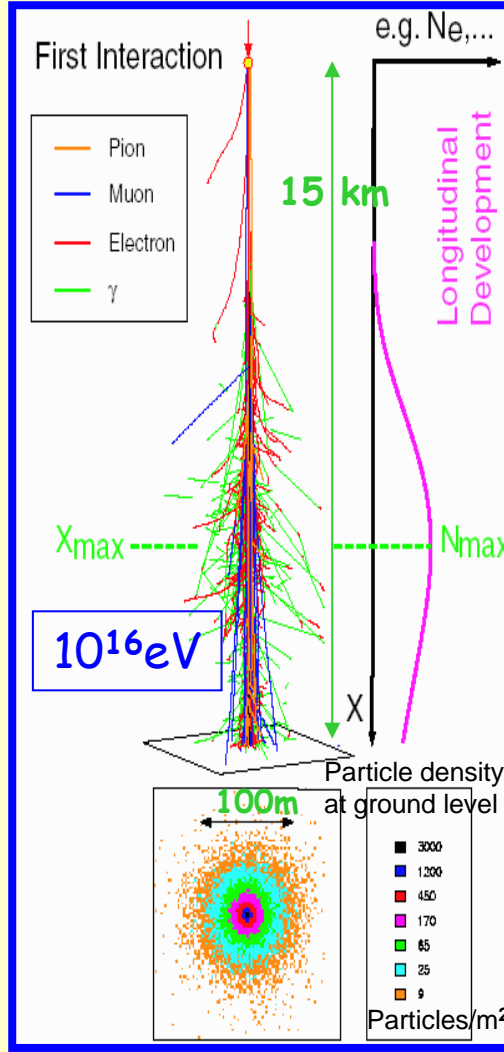


Mysteries of the Spectrum

- Protons are trapped in our Galaxy (μG B-fields) up to $\sim 10^{17} - 10^{18} \text{ eV}$
- Protons can travel straight above $\sim 10^{20} \text{ eV}$
- Supernova shockwave acceleration up to $\sim 10^{15} \text{ eV}$
- Above the knee the acceleration mechanism is essentially unknown: active galaxies, massive black holes systems, gamma ray bursts ?



Extended Air Showers

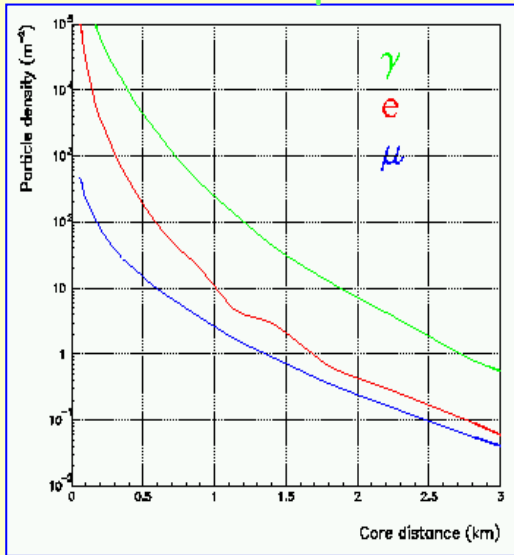


There are many ways of detecting cosmic rays

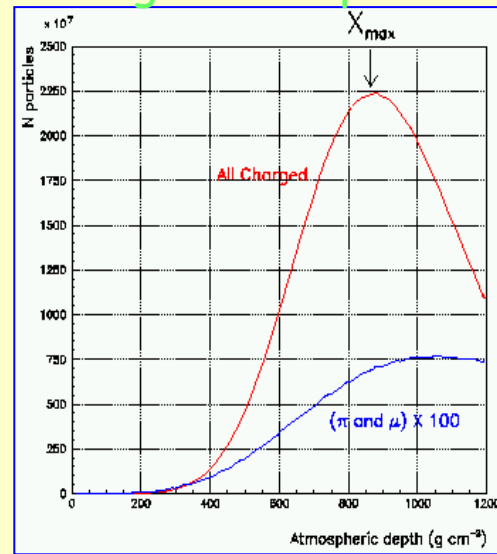
EAS properties can be used to estimate the mass & energy of the incident particle using MC

The Atmosphere as a Calorimeter

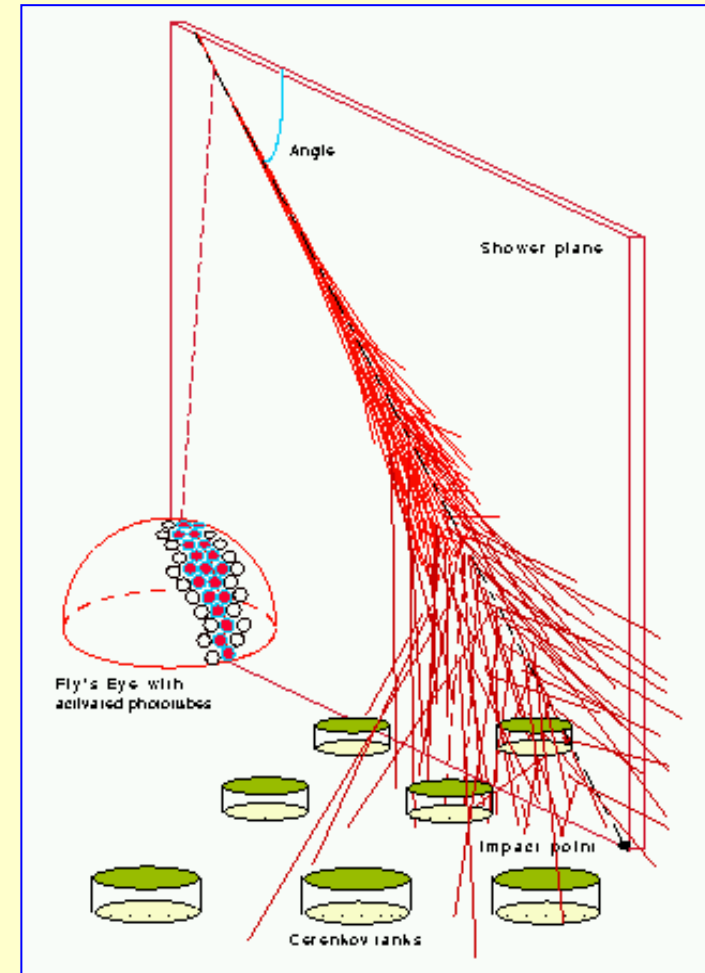
Transverse profile



Longitudinal profile

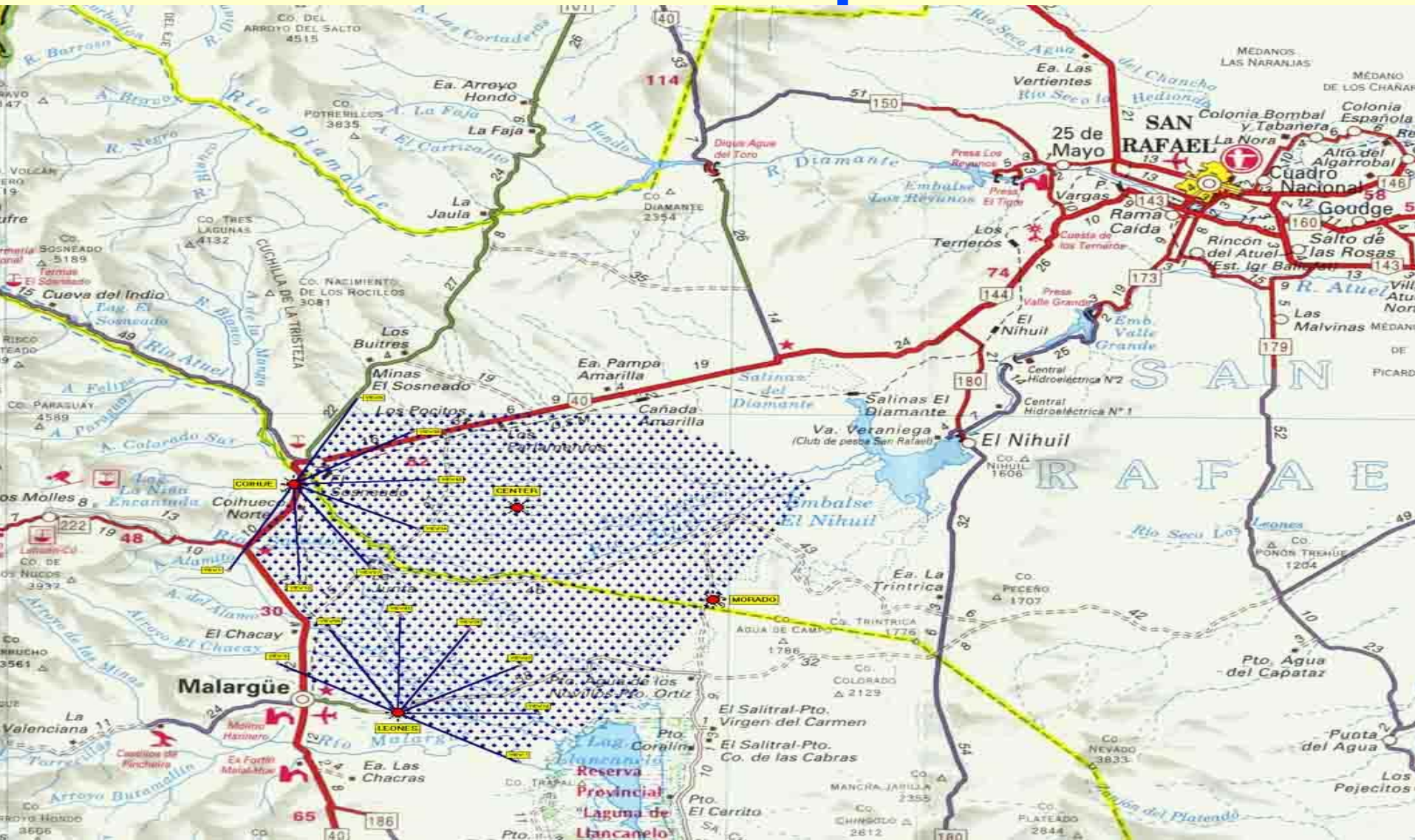


- Fluorescence Detectors
 - Atmosphere is sensing calorimeter
 - Measure the longitudinal distribution
- Ground Arrays
 - Technique developed in the 50's
 - Measure the lateral distribution at ground

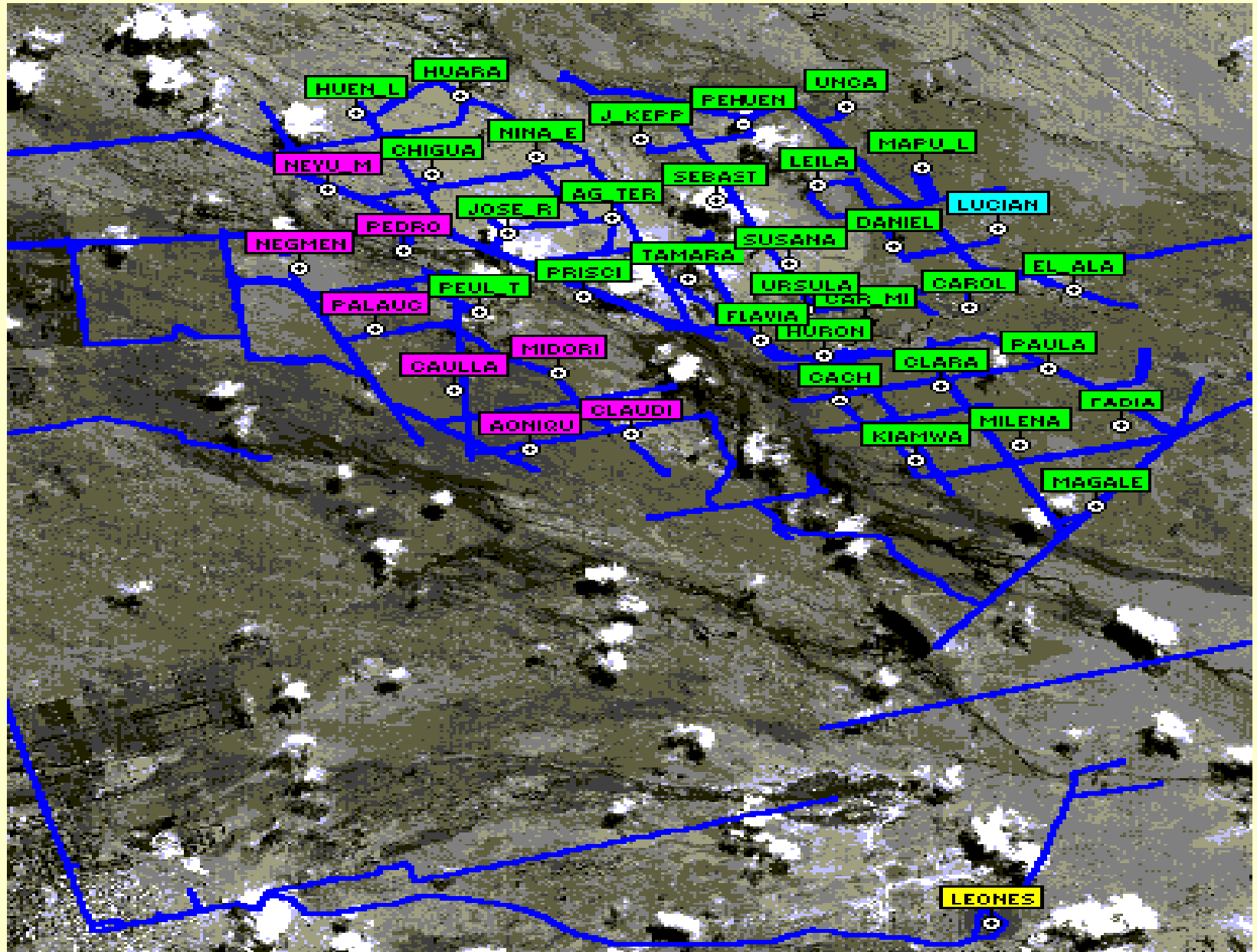


Auger - Measuring transverse and Longitudinal shower profiles

Auger observatory in the south Hemisphere



AUGER



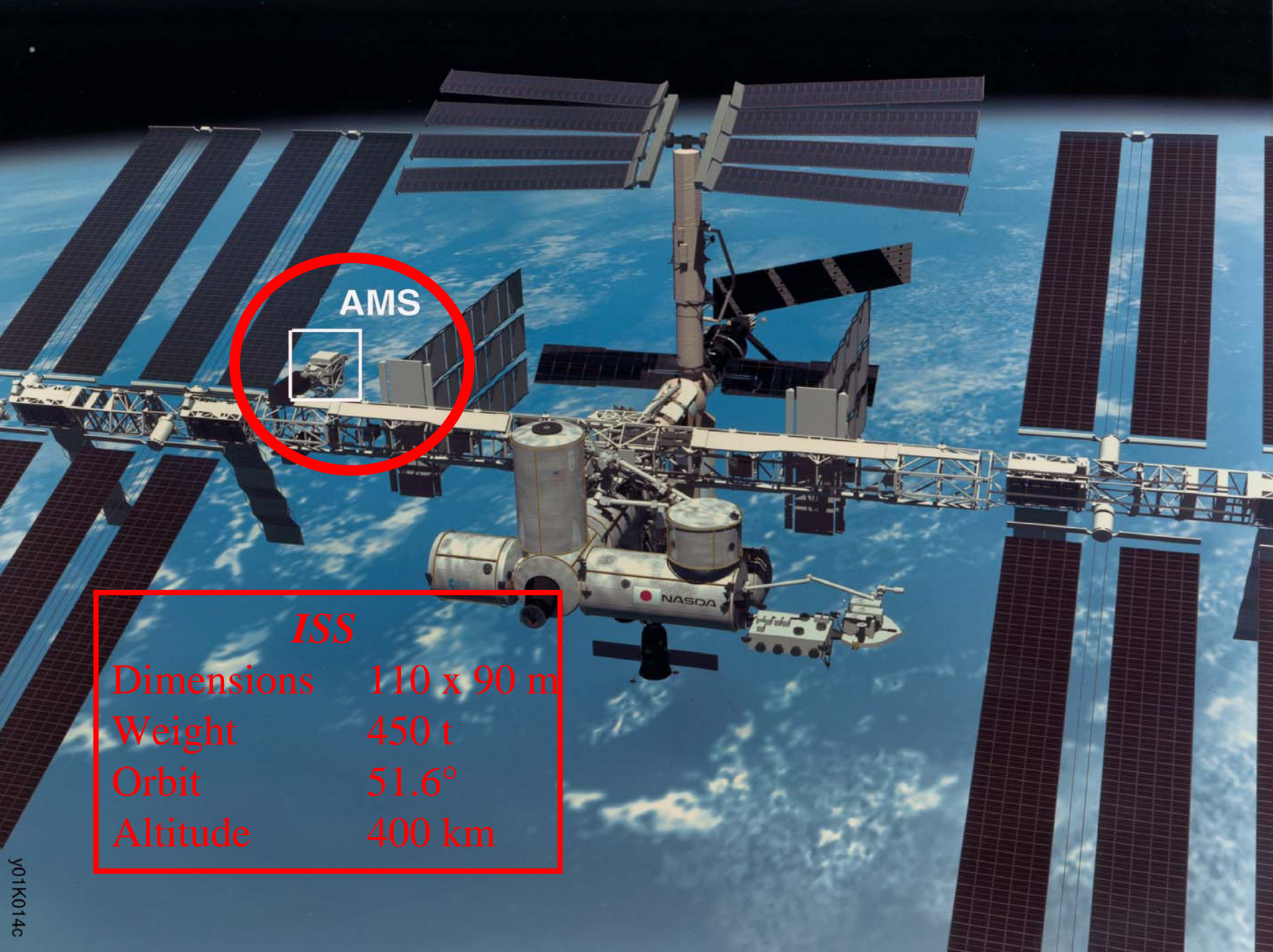
AUGER



Spanish
Contribution:

Solar panels
(1000) at
surface
detectors
(Cerenkov)

Shower
simulation



AMS

ISS

Dimensions 110 x 90 m

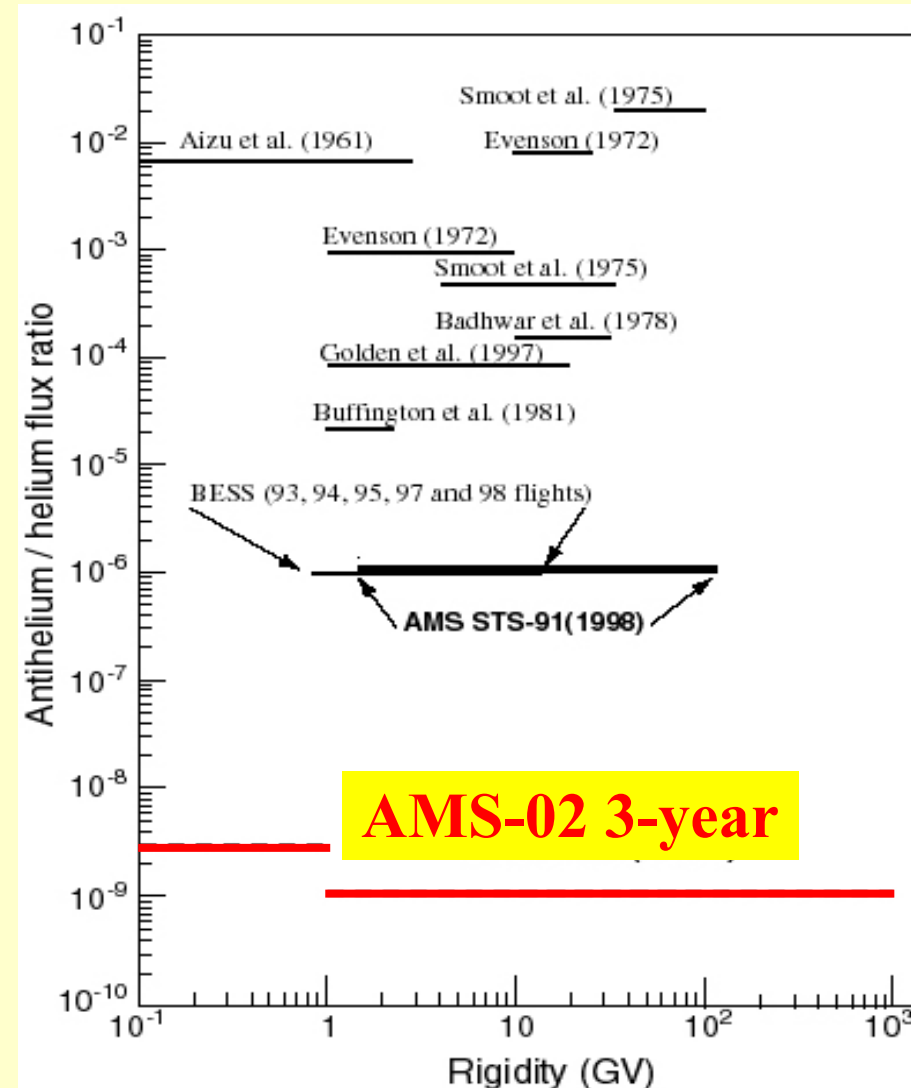
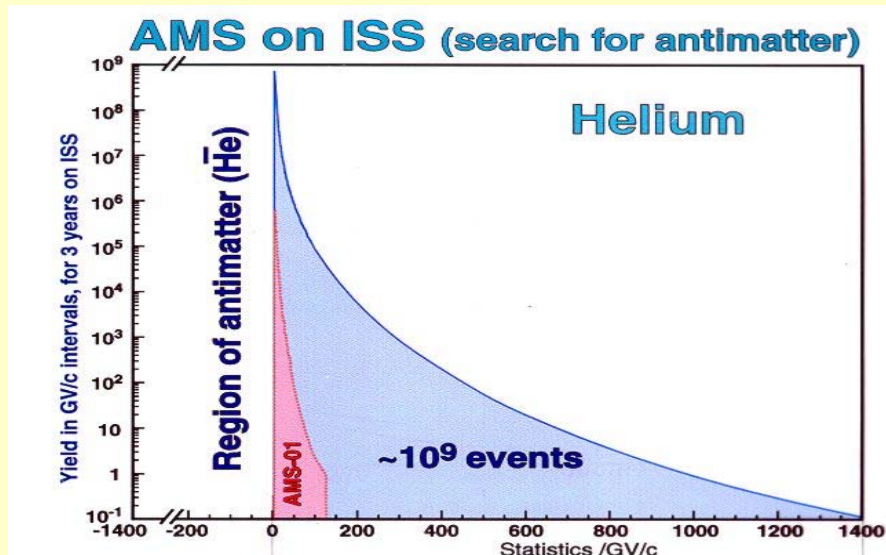
Weight 450 t

Orbit 51.6°

Altitude 400 km

AMS-02 sensitivity to Antimatter

In 3 years AMS
Will detect 10^9 He
with $E \lesssim 1$ TeV

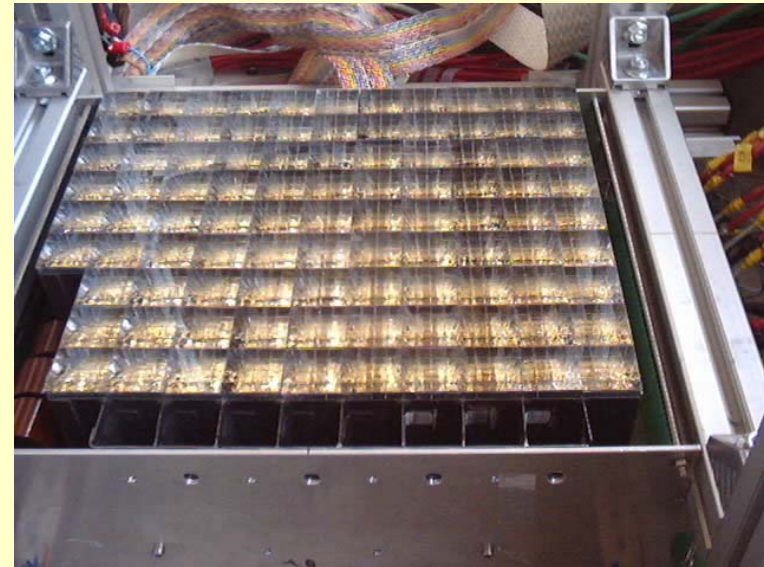
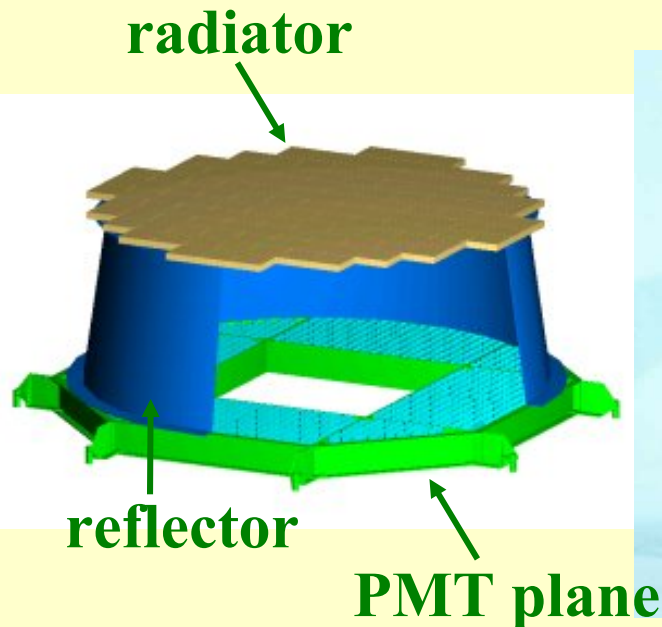


AMS-02 Ring Imaging Cerenkov Counter

3 cm silica aerogel ($n=1.05$) radiator

680 multianode (4x4) PMTs

$\sigma(\beta)/\beta = 0.1\% @ \beta = 1$ (protons)



The Neutrino mass

Experimental detection of neutrino oscillations



Neutrinos have got mass

How large is $m(\nu_e)$, what is the mass hierarchy?

1. Tritium β -decay

$$m(\nu_e)^2 = -0,6 \pm 2,2 \pm 2,1 \text{ eV}^2 \quad \text{Mainz}$$

$$P \ m(\nu_e) \leq 2,3 \text{ eV} \ (95\%)$$

2. $0\nu\beta\beta$ -decay

$$\langle m(\nu_e) \rangle \gg 0,4 \text{ eV} \quad \text{to be confirmed}$$

3. ν -Oscillations

$$7,3 \times 10^{-5} \text{ eV}^2 < \Delta m_{12}^2 < 9,3 \times 10^{-5} \text{ eV}^2 \quad \text{solar}$$

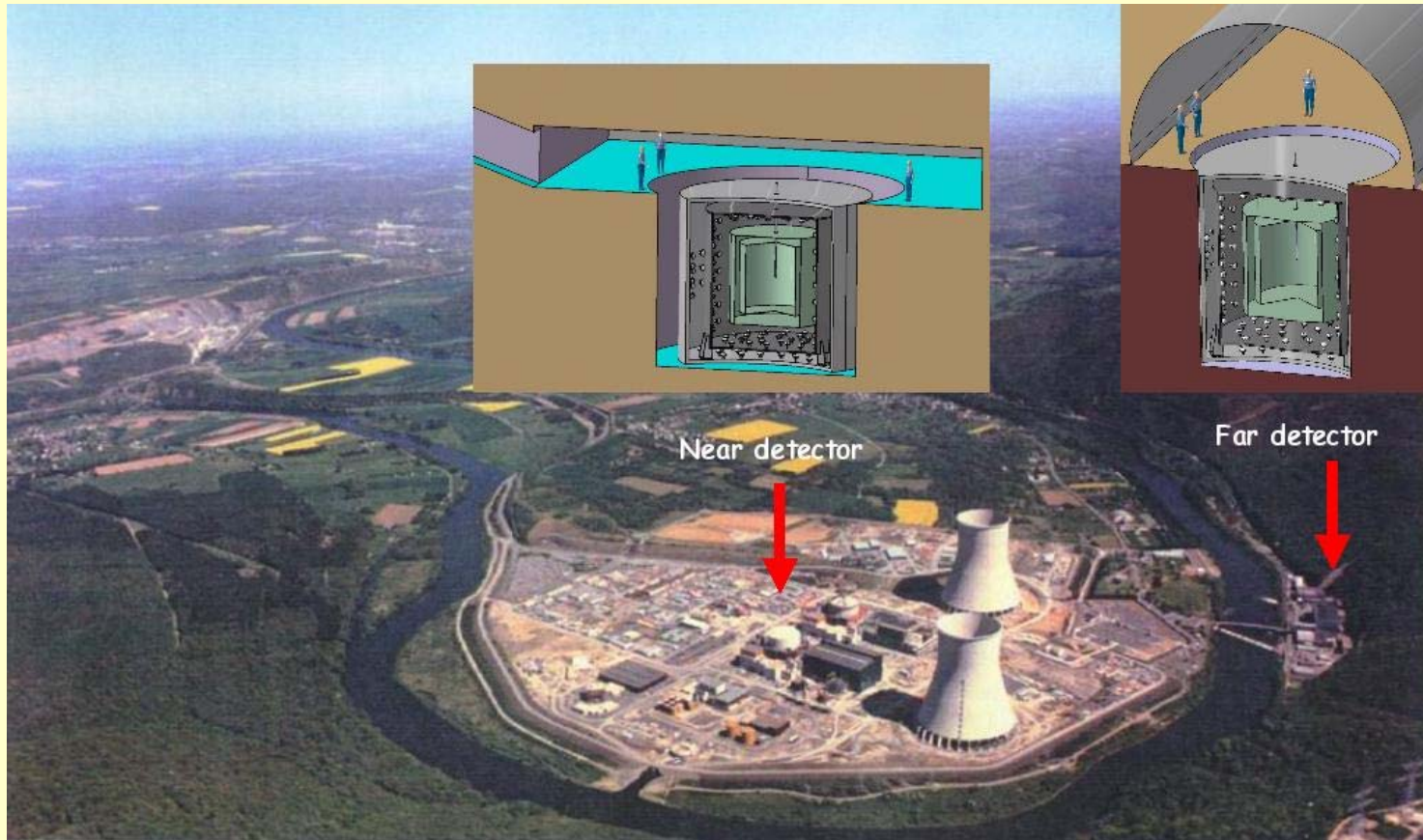
$$1,6 \times 10^{-3} \text{ eV}^2 < \Delta m_{23}^2 < 3,6 \times 10^{-3} \text{ eV}^2 \quad \text{atm.}$$

\Rightarrow There is a ν with $m_{\nu_i} \geq 0,009 \text{ eV}$ and one with $m_{\nu_j} \geq 0,05 \text{ eV}$

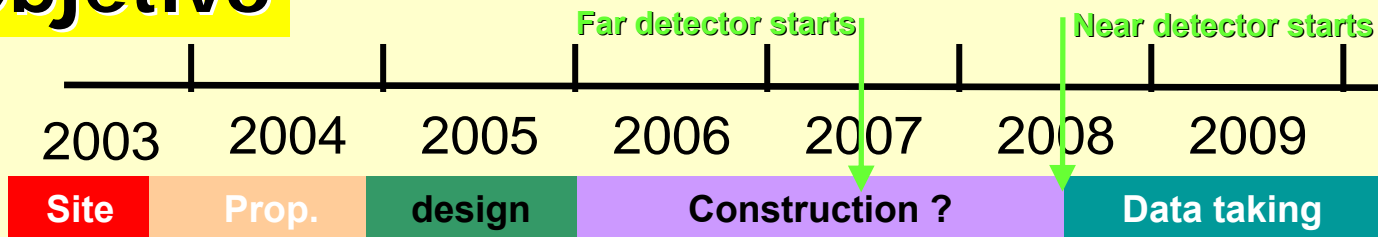
4. Cosmology

$$\sum m_{\nu_i} \leq 0,7 \text{ eV}$$

Double-CHOOZ (France)



Objetivo



in 2009
 $\sin^2(2\theta_{13}) < 0.05$

in 2011
 $\sin^2(2\theta_{13}) < 0.025$

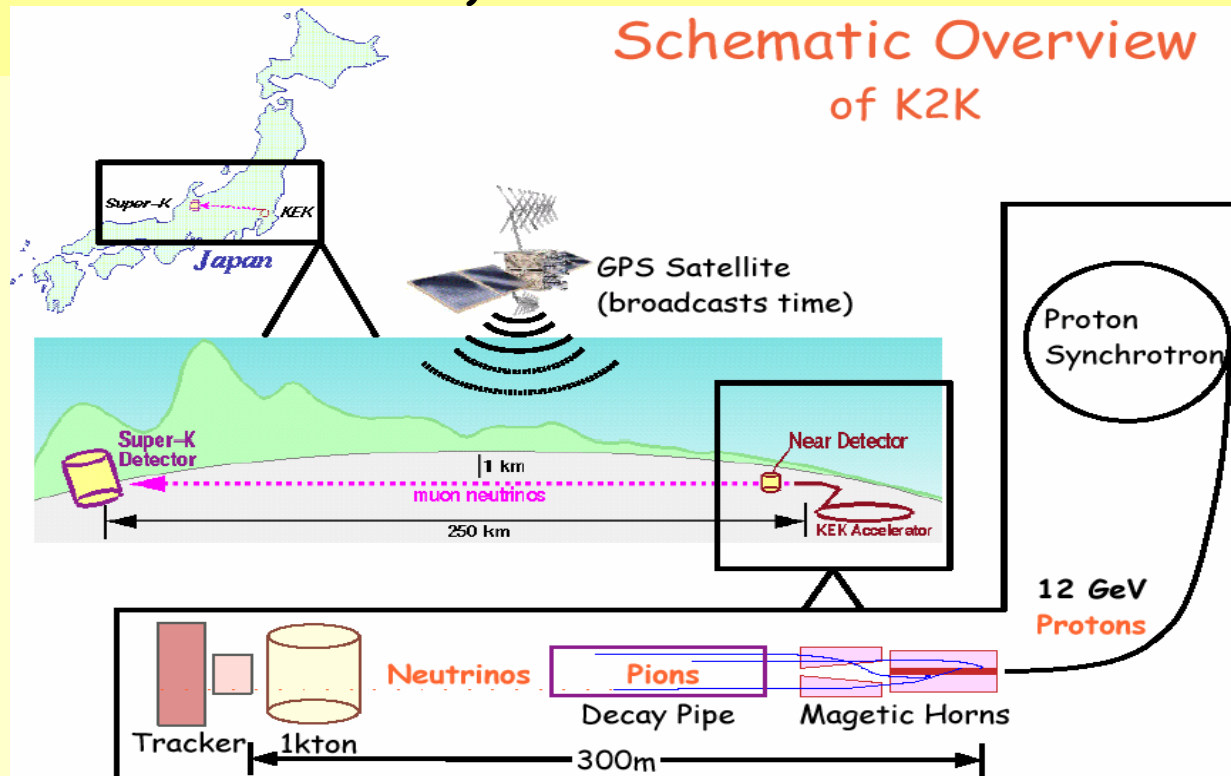
Neutrino Oscillations-K2K

KEK to SuperKamiokande:

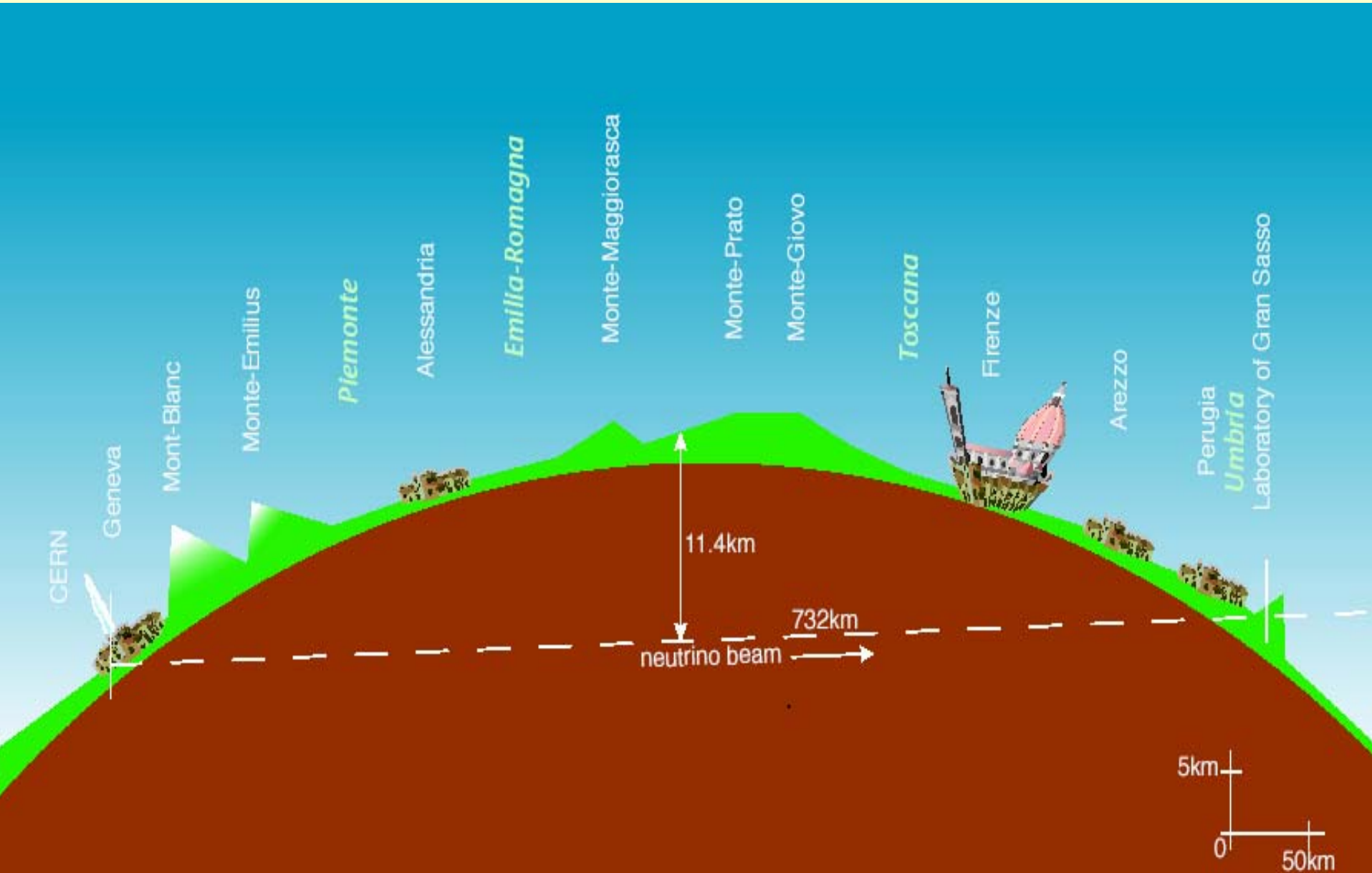
- Confirm the evidence of oscillations observed by Super-Kamiokande
- Measure the disappearance of muonic neutrinos in a beam that is produced in KEK and detected in Super-Kamiokande

Two major contributions:

- Extrapolation of the neutrino flux measured in the near detector to the far detector (from Harp data)
- Contribution to the reconstruction of the new SciBar detector (in collaboration with IFAE)



CERN neutrinos to Gran Sasso (CNGS)



Conclusions

1. Spain is very active in Particle & Astroparticle physics and in a continuous growth.
2. We are deeply involved in the CERN program, and more modestly with DESY, Fermilab, SLAC, KEK programs.
3. There are two important infrastructures for Astroparticle Physics: the Canfranc underground lab and El Roque de los Muchachos observatory.
4. My best wishes for a very nice workshop !