# Particle and Astroparticle Physics in Spain

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## Particle and Astroparticle Physics in Spain

Antonio Ferrer
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)

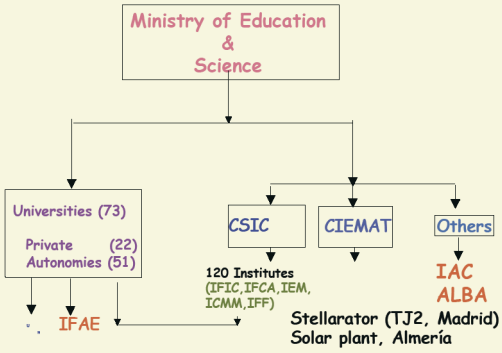
GNP 900.000 M€
R&D 9.000 M€ (~1%)

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

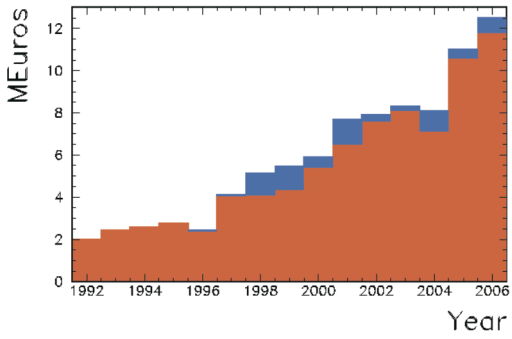
1. Particle Physics (CERN).
   - Quarks & Leptons, Neutrino, Hadrons, Theory.
2. Astroparticle physics & Cosmology.
3. Experimental Nuclear Physics (N-TOF, ISOLDE,GSI).
4. GRID Technologies .
5. Detectors and Accelerators Tecnologies.

## 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

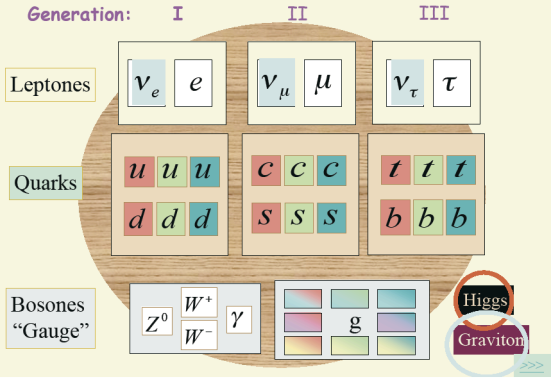



## 6 questions* defining Particle physics

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 ?

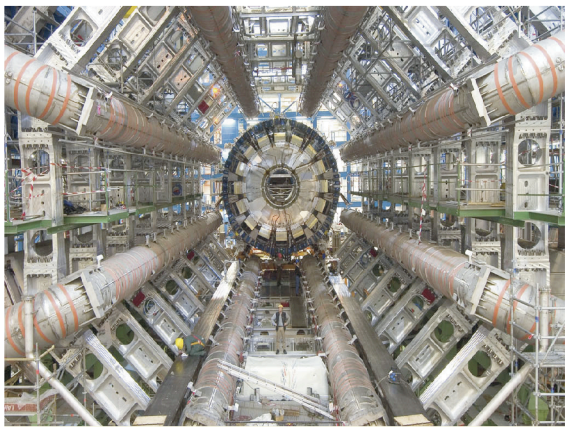
*"Science is the art of replacing unimportant questions that can be answered by important ones which cannot" Edward B. Ferguson Jr. 1976.

## The Standard Model




## 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 | | |

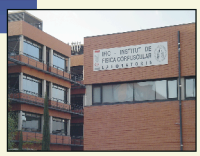


# Experimental projects at IFIC

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

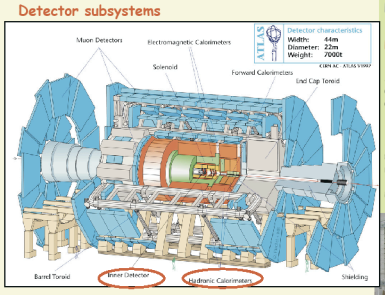
**Nuclear Physics**
- γ–Spectroscopy
  - nTOF
  - ISOLDE
  - FAIR, ALBA
- Nuclear Reactions
  - Hades
  - TAPS
- Integral

**Medical Applications**
- Nuclear Medicine
- CIMA



## LHC-ATLAS

Detector subsystems




**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


**Software and Simulation**

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

## ATLAS-TiCal

**Submodules Construction**

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

**Photomultipliers Testbench**

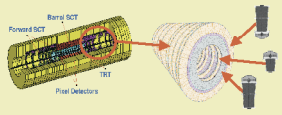
**1750 (17.5%) of the Tilecal photomultipliers** tes in test bench labview

**Read Out Driver (ROD)**

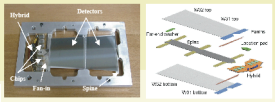
Design, assembly, test and commissioning of the 32 ROD electronic boards to calculate energy, time and quality information of the more than 10.000 channels

## 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

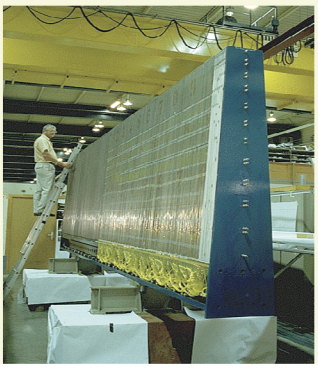



**Forward outer module**




## TileCal Submodule

## *TileCal* Module

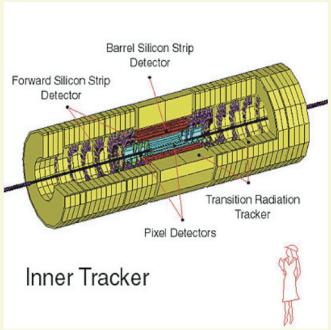


Spain built 1 EB
= 64 modules
640 Tons

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

Extended Barrel mounted and instrumented in IFAE

## SCT (Silicon inner tracker)



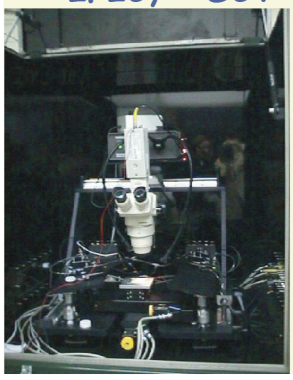

IFIC - Valencia
CNM-Barcelona

2 Wheels

200 modules

Test, Microbonding, Mount

## IFIC, SCT clean room



## IFIC, clean room (SCT)

## ATLAS-GRID

### GRID Infraestructure at IFIC

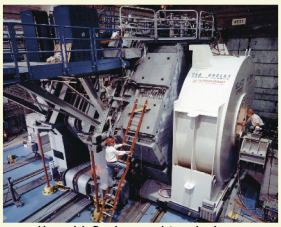
- High availability GRID center for ATLAS (Tier 2)
  - Production of simulated data. Data Challenges
  - Distributed analysis facility
  - Support for 20 physics analysis (common effort of spanish groups in ATLAS)
  - R&D in GRID technologies and e-Science

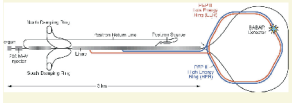
- 8 Intel servers
- CPU:

- 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 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

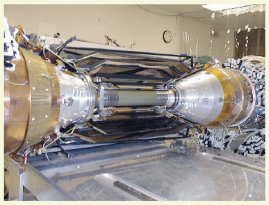
Try to open windows on new Physics

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

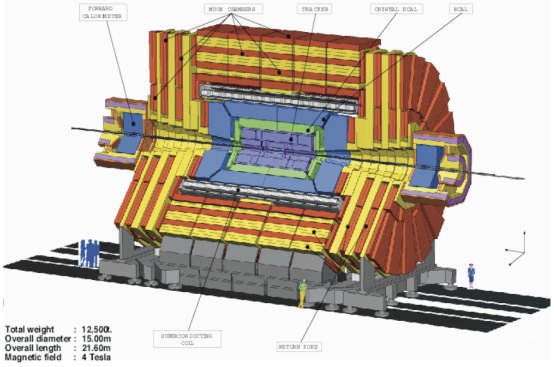
Feasibility studies to use and increase IFIC computing resource for official Monte Carlo productions (also being negociated)



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

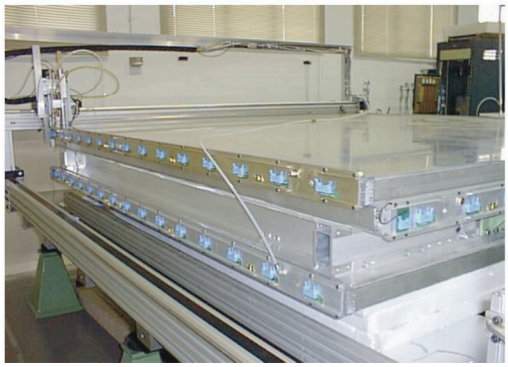
- CP violation measurements of the 3rd CKM weak angle $\gamma$ in $B^- \to D_0^{(*)}K^-$ decays
- Precision CP Violation measurements with charmonium events and mixing studies with fully reconstructed hadronic decays
- Detailed studies of Quantum Mechanics of the BB System at the $\Upsilon(4S)$: simultaneous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

## CMS
## A Compact Solenoidal Detector for LHC

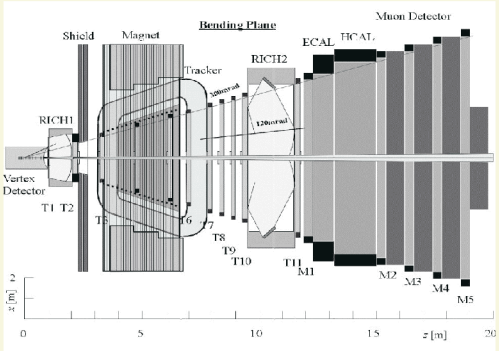



## Muon chambers construction at CIEMAT

## 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 ?

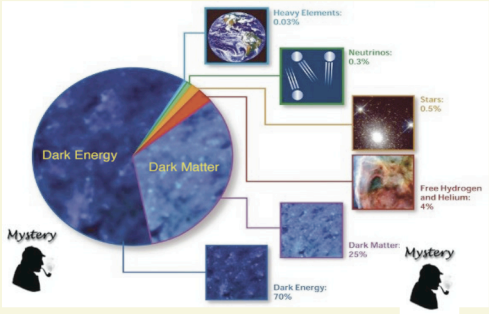
*"Science is the art of replacing unimportant questions that can be answered by important ones which cannot" Edward B. Ferguson Jr. 1976.

# 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?

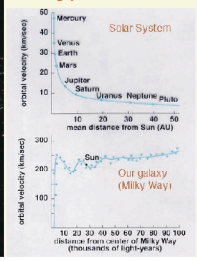
Stars and planets account only for a small fraction of the Universe!



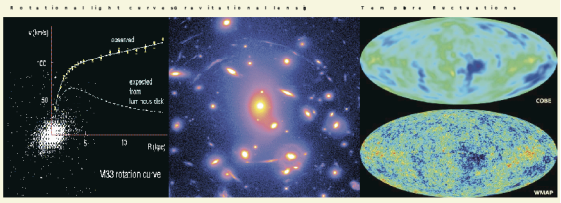

# Proof of existence of « dark matter»

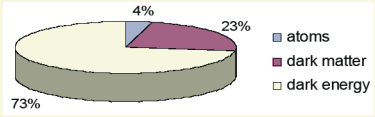
Rotational curves

(velocity of peripheral stars, too large)



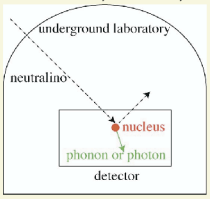

# Dark Matter



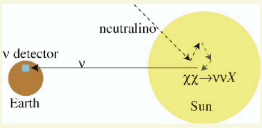




# Detection of Dark Matter

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

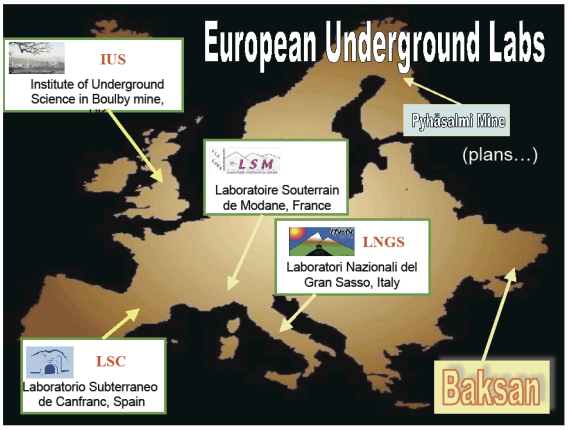



- Indirect detection
- SuperK, AMANDA, ICECUBE, Antares, etc

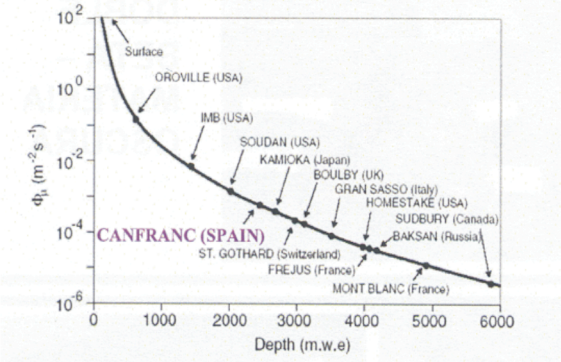



complementary techniques are getting into the interesting region of parameter space

# European Underground Labs

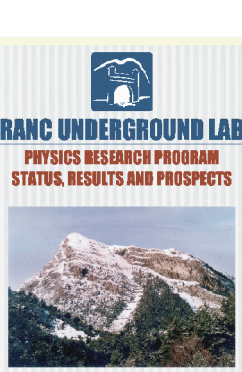


## Underground Laboratories




# THE CANFRANC UNDERGROUND LABORATORY

**PHYSICS RESEARCH PROGRAM**
**STATUS, RESULTS AND PROSPECTS**

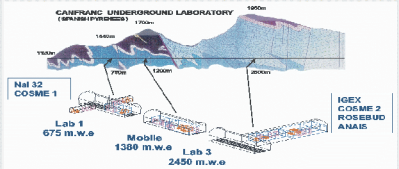


Laboratory of Nuclear and High Energy Physics
University of Zaragoza

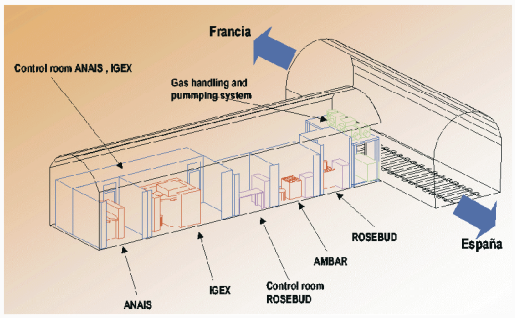
## LSC LABORATORIO SUBTERRÁNEO DE CANFRANC

CANFRANC UNDERGROUND ASTROPARTICLE LABORATORY






## Canfranc Underground Laboratory





Laboratorio Subterráneo de Canfra

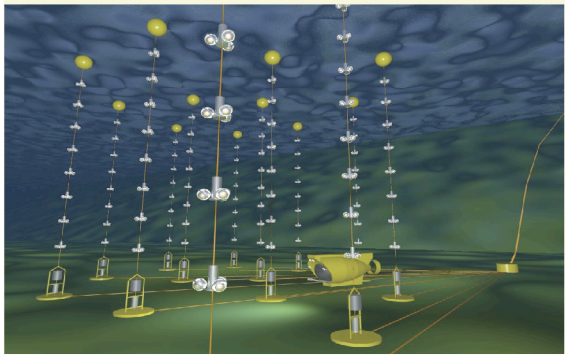
## ICARUS in LNGS Hall B

## 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.

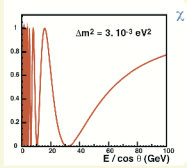
## ANTARES 0.1 km$^2$ detector

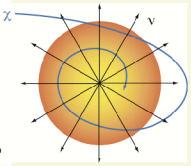


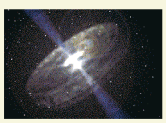
## ANTARES

Photomultiplier to detect Cherenkov light

## ANTARES

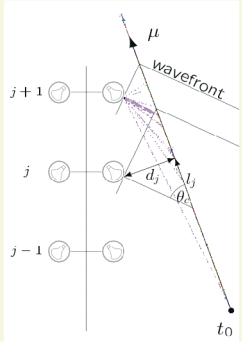


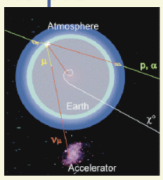



| Low Energy | Medium Energy | High Energy |
|---|---|---|
| ν oscillations (Observation of first oscillation minimum) | Neutralino search Self-annihilation at center of Earth, Sun, Galaxy $\chi\chi \rightarrow \ell \rightarrow \nu$ | ν from (extra-) galactic sources SN remnants, AGN, GRB, … |

## Detection principle




$\cos\theta_c = \frac{1}{n} + \frac{c\,\delta t}{d_j}$

medium properties

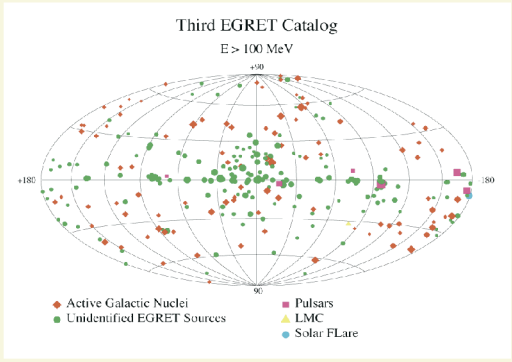
$\delta_x$ = 20 cm

$\delta\theta$ = 0.2 deg.

$\delta_t$ = 1 ns

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

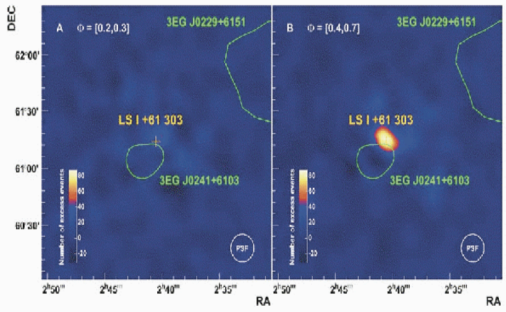
## Gamma-ray galactic sources




## El Roque de los Muchachos (MAGIC)

## Magic, the inauguration day

## Microquasar (MAGIC)




## AUGER

Purpose: Detect & discover the origin of cosmic rays with

$E > 10^{19}$ eV

2 deployments (each cost 50 M$)

In each hemisphere:

1600 detectors (surface) + 30 fluorescence telescopes in

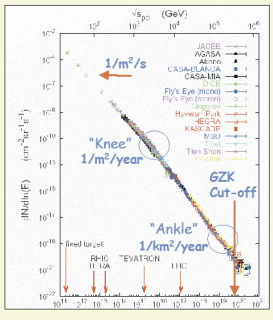
3000 $km^2$

South: Provincia de Mendoza, Argentina

North: ?

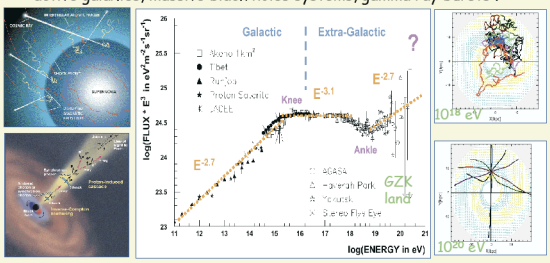
## Cosmic Rays Spectrum

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

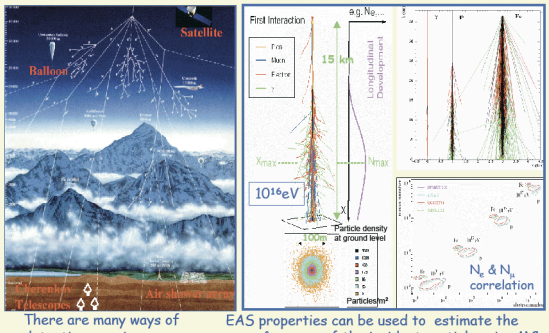


# Misteries of the Spectrum

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



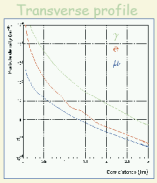

# Extended Air Showers

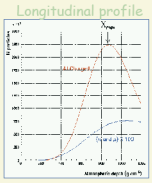


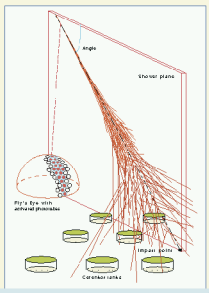

There are many ways of detecting cosmic rays

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

# The Atmosphere as a Calorimeter



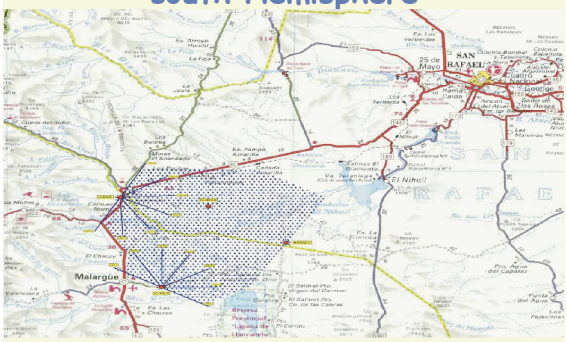



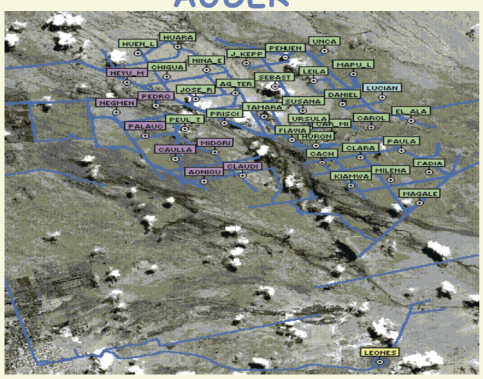

- Fluorescence Detectors
  - Atmosphere is sensing calorimeter
  - Measure the longitudinal distribution
- Ground Arrays
  - Technique developed in the 50's
  - Measure the lateral distribution at ground

Auger - Measuring transverse and Longitudinal shower profiles

# Auger observatory in the south Hemisphere




# AUGER

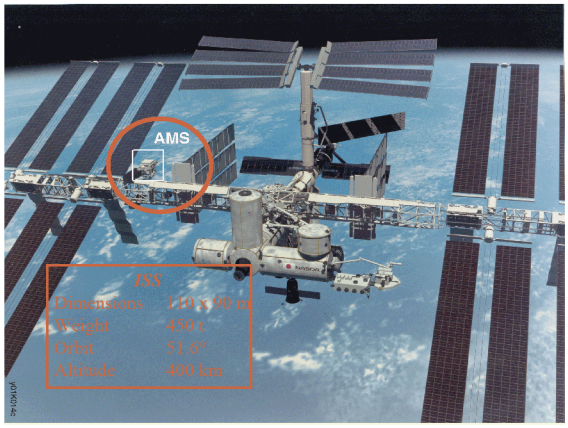



# AUGER

Spanish Contribution:

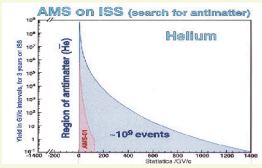
Solar panels (1000) at surface detectors (Cerenkov)

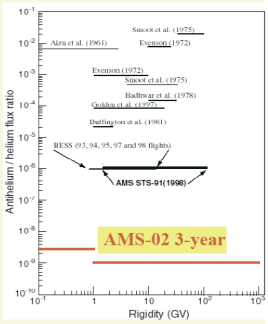
Shower simulation




## AMS-02 sensitivity to Antimatter

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



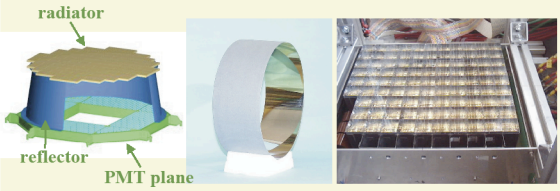




## AMS-02 Ring Imaging Cerenkov Counter

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

⇓

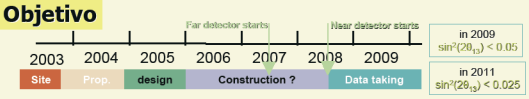
Neutrinos have got mass

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

1. Tritium b-decay
   $m(\nu_e)^2 = -0,6 \pm 2,2 \pm 2,1\ eV^2$ Mainz
   P $m(\nu_e) \leq 2,3eV$ (95%)
2. 0νbb-decay
   $\langle m(\nu_e) \rangle \gg 0,4\ eV$ to be confirmed
3. ν-Oscillations
   $7,3\times10^{-5}eV^2 < \Delta m_{12}^2 < 9.3\times10^{-5}eV^2$ solar
   $1,6\times10^{-3}eV^2 < \Delta m_{23}^2 < 3.6\times10^{-3}eV^2$ atm.
   ⇒ There is a ν with $m_{\nu i} \geq 0,009eV$ and one with $m_{\nu j} \geq 0,05eV$
4. Cosmology
   $\sum m_{\nu i} \leq 0,7eV$

## Double-CHOOZ (France)

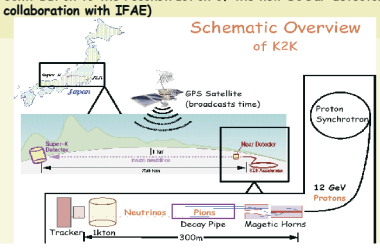

**Objetivo**




## 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)



## 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 infraestructures for Astroparticle Physics: the Canfranc underground lab and El Roque de los Muchachos observatory.

4. My best wishes for a very nice workshop !