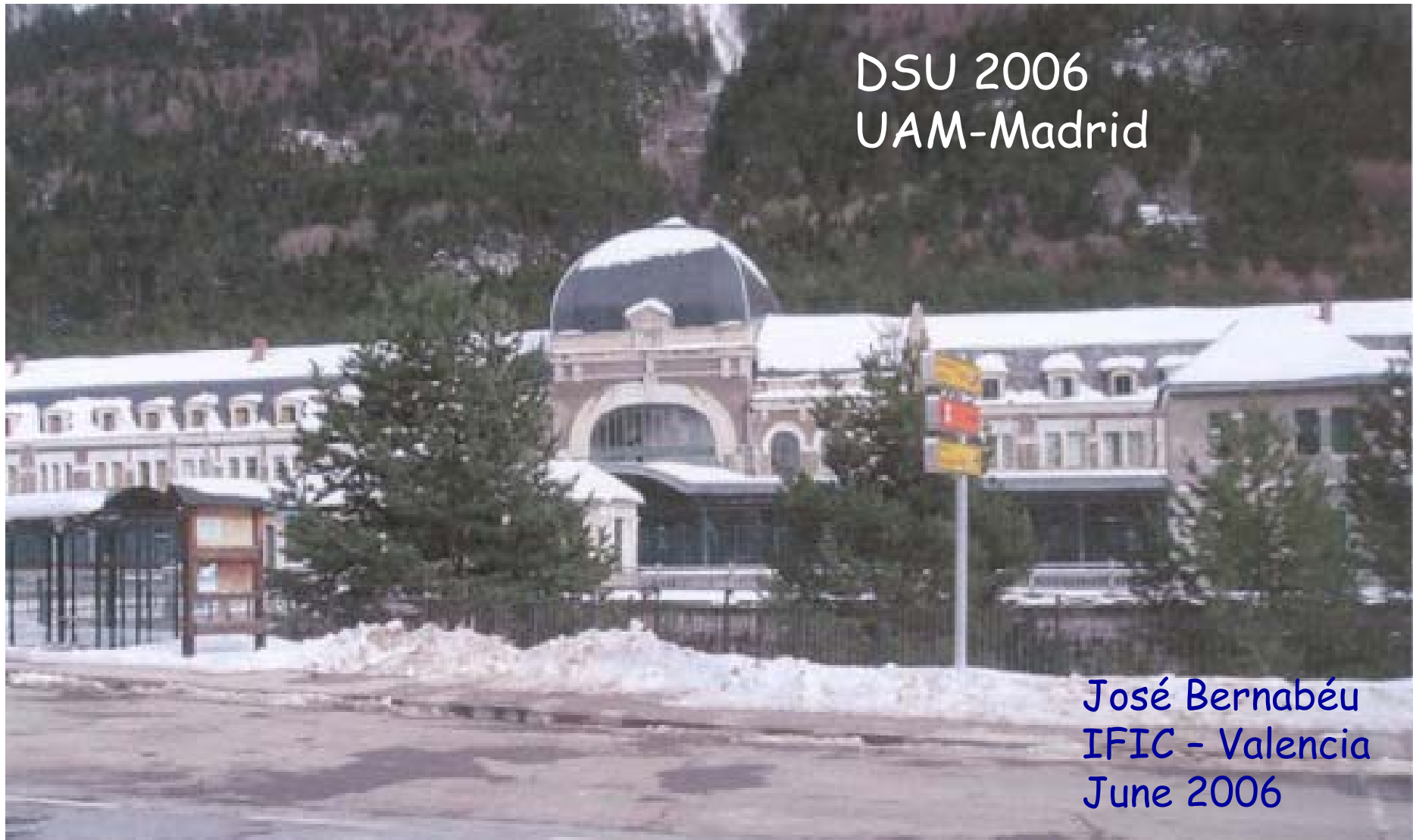


# Canfranc

## Underground Laboratory (LSC)



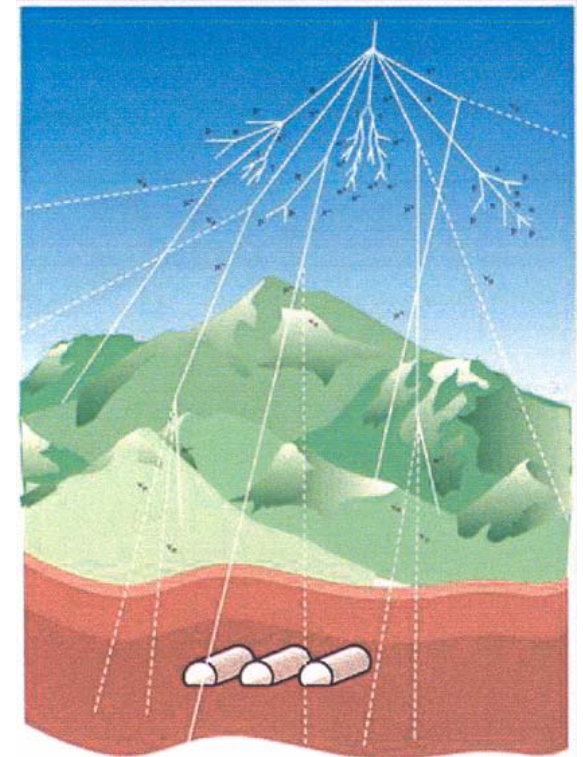
- 
- Underground Physics
  - Need of Underground Space
  - The New LSC was inaugurated
    - Main Hall
    - Ultralow Background Lab.
    - Services and Offices
  - Complementary Facilities
  - Management of LSC
  - Consortium MEC-DGA-UZ
  - Expressions of Interest
  - Conclusions

# Underground Physics

- Physics in Underground Labs. developed during last 20 years with discoveries of great scientific impact. Why underground?
- This allows the screening of cosmic rays coming from space (one muon per  $\text{cm}^2$  per minute in the earth surface). Only under big rock thickness one may study certain fundamental processes.
- The detectors are made with the extreme radio purity materials and isolated from the radioactive environment.
- NEUTRINO PHYSICS

-Neutrino Nature: Dirac or Majorana?  $\beta\beta 0\nu$  decay mediated by Majorana neutrino mass  $\langle m_\nu \rangle = \sum_k U_{ek}^2 m_k$ , sensitive to CP Violating Majorana phases.

-To reach the level of  $10^{-2}$  eV or less, one needs target masses near one ton and drastic background reduction → Worldwide International Collaborations.



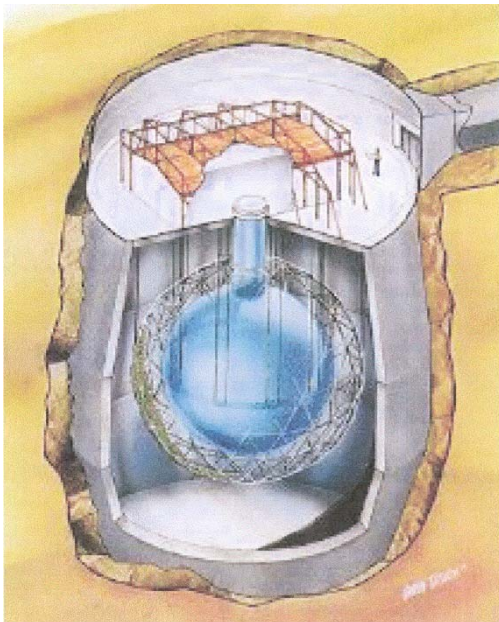
# Underground Physics

- $\beta\beta 0\nu$  would be a signal of  $\Delta L=2$  interactions at high energy scales. Experimentally,  ${}^AZ \rightarrow {}^A(Z+2) + e + e$  gives a peak in the sum of electron energies.

- The solar neutrino problem was solved by SNO by comparing neutral current (total  $\nu$  flux) and charged current ( $\nu_e$  flux) detections by deuterium. SNO is sensitive to  ${}^8\text{B}$  neutrinos and Borexino will be more sensitive to  ${}^7\text{Be}$  neutrinos in the energy region where the MSW effect in the Sun is most important.

- To complete the picture, a direct detection experiment is recommended for low energy pp neutrinos with few percent precision:

- Definitive proof of the MSW mechanism
- Measurement of Sun luminosity from neutrinos
- One needs a few kiloton detector.

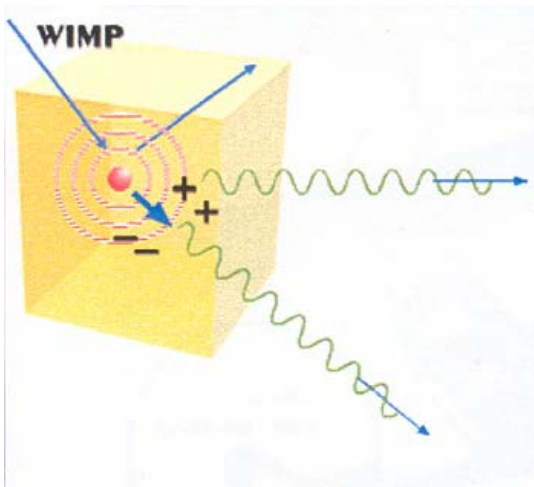




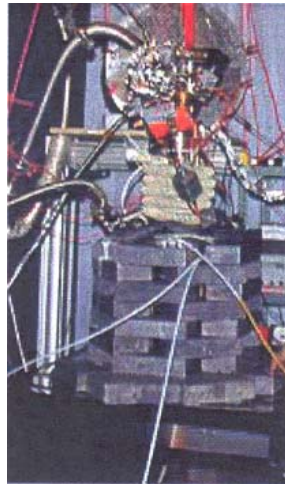
# Underground Physics

- DARK MATTER

- Recent cosmological observations say that 95% of the matter-energy content of the Universe is unknown to us. Baryonic matter accounts for 5% (1% is visible as stars, clouds and other objects)
- 70% is dark energy (we don't know what we are talking about)
- 25% is non-baryonic dark matter and most of it has to be cold: these particles are WIMPs with a very weak interaction with matter, of the order of one particle per day and per kilogram of the detector.



- The signal is induced by coherent nuclear recoil which manifests either by light or charge or heat.
- For liquid argon detector, the signal could be scintillation light produced from excited molecular states, being effective down to the keV recoil energy → one ton detector would provide much better sensitivity.

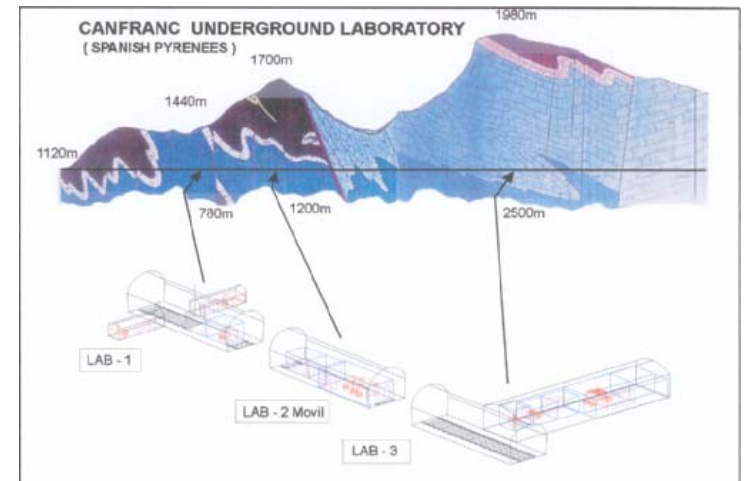


# Need of Underground Space

- Existing facilities in the EU, grouped in the ILIAS Network:
  - LNGS: INFN Lab. with site in Gran Sasso Tunnel under the Apeninos
  - LSC: Conceived by Angel Morales in 1985 under the Spanish Pyrenees

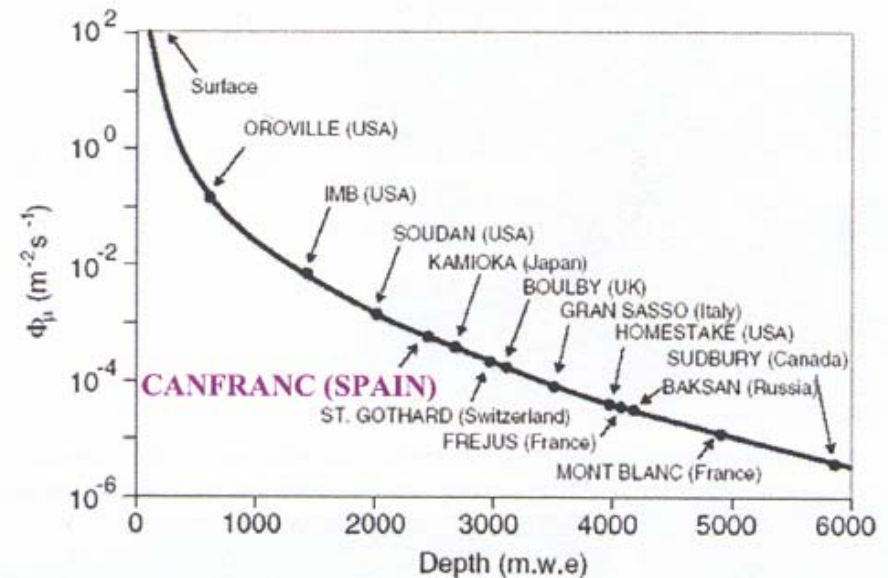
The past underground facilities were inside the (unused) railway tunnel and had LAB-1 and LAB-3 as working laboratories. In LAB-3 the muon flux is  $2 \times 10^{-3} \text{ m}^{-2} \text{ s}^{-1}$ , that of neutrons is  $(3,8 \pm 0,4) \times 10^{-2} \text{ m}^{-2} \text{ s}^{-1}$  and that of gammas is  $200 \text{ m}^{-2} \text{ s}^{-1}$ . Radon activity is variable around  $50\text{-}100 \text{ Bq m}^{-3}$ . The scientific program included dark matter search (ANAIS, IGEX-DM, ROSEBUD) and  $\beta\beta 0\nu$  (IGEX- $2\beta$ )

  - LSM: French Lab. belonging to IN2P3 (CNRS) and DSM (CEA), with site in the Frejus Tunnel in the Highway connecting Lyon with Torino.
  - Boulby Mine Underground Facility, near Sheffield: dark matter collaboration in UK



# Need of Underground Space

- At present, there is an increasing interest in the Underground Physics described before with a series of proposals, letters of intent or conceptual designs at different levels of development. The present restrictions in the available underground space and the corresponding infrastructures are the most important limitations to the development of the field, including the creativity of the community of physicists.
- Furthermore, the existing advances were made possible due to a certain redundancy in some of these delicate experiments, using experimental techniques either complementary or different: think of the examples of solar neutrinos.
- The good environmental conditions of Canfranc Lab. justified the project for the new facility which is now inaugurated: it contains two experimental halls.



# The new LSC

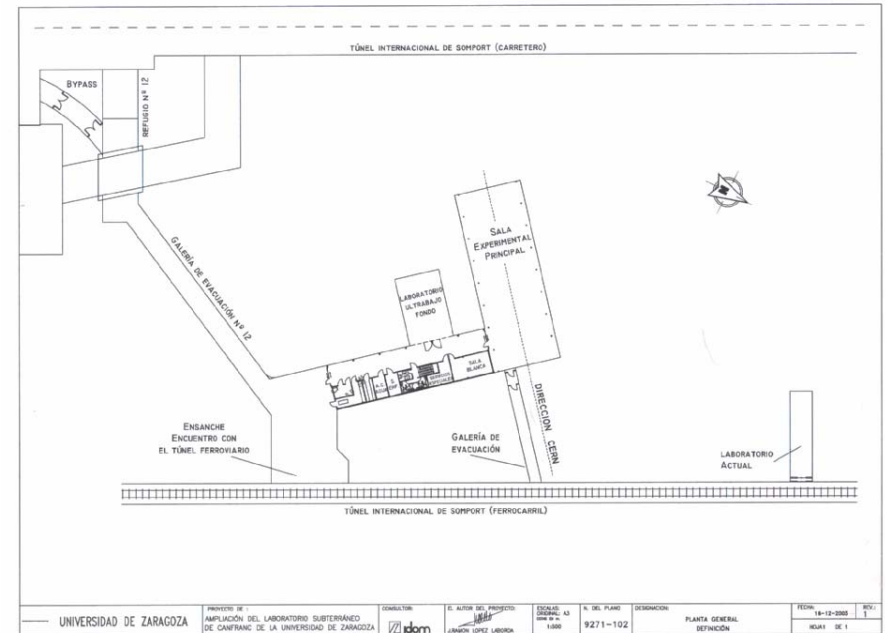
- The Main Hall has  $40 \times 15 \times 12 \text{ m}^3$  and it is oriented towards CERN
- A smaller Hall of  $150 \text{ m}^2$  of surface and 8 m height constitutes the ultralow background Lab. for dark matter studies and other needs.
- In the access corridor, one has a White Hall, offices and workshops for more than  $1000 \text{ m}^2$ .





# Complementary Facilities

- Besides the laboratory, the work already made contemplates the basic infrastructure of ventilation, electric power and safety. All these works inside the Lab. were finished in November 2005.
- As seen in the plan, the access to the facilities is extraordinarily easy. The geologic conditions, the absence of underground water, etc., are positive too and make LSC a very good candidate for future terrestrial neutrino experiments with further excavations.
- The new LSC has to have service structures in the surface: general ones like electric, hydraulic, ventilation, experimental setup, safety, administration, etc., as well as those directly related to experiments as computing, networks, mechanical workshops, storage, offices, residences, etc.



# Complementary Facilities

- A definite Project is being settled by the authorities of the Ministry of Education and Science to have appropriate installations outside the Lab.
- As external facilities, one contemplates the store and workshops, mechanical as well as electronic, the deposits for cryogenic liquids and two buildings for general services. This will be the main external reference and the official site of the Lab.



Laboratorio Subterráneo  
de Canfranc

Septiembre 2004

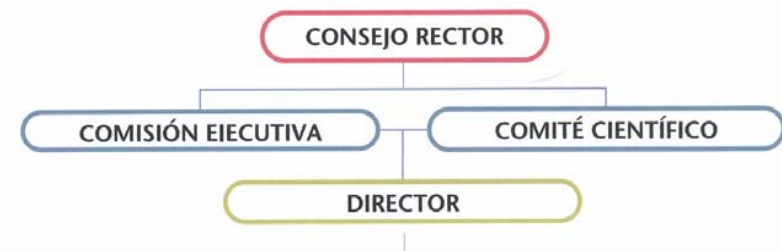
José Bernabeu  
Alessandro Bettini\*  
Domènec Espriu  
José Angel Villar

The two buildings will be the one to the left restored and a new one to be built nearby.



# Management of LSC

- The new LSC should have a simplified structure adapted to the legal environment of Spain. The administrative structure is that of the Consortium (see later)
- The management of LSC contemplates:
  1. The Government bodies of the Consortium
  2. The Scientific Advisory Committee
  3. Two or more Associate Directors for specific responsibilities.
- The LSC will have its own budget and staff depending on the Directorate. The members of the Lab. with equal duties and rights in agreement with their qualification, will be not only the proper staff of the Lab., but also the attached personnel from the University of Zaragoza or other Institutions, as well as attached fellows. The present group of Zaragoza is associated to the new Laboratory.





# Scientific Policy Committee

- The MEC has followed a methodology, to start with the management of the LSC, of appointing a SPC with the following tasks:
  - To define the International Character of the Lab. and the corresponding Programming as such from the very beginning.
  - To promote International Collaborations with experiments to be installed in this Facility.
  - To propose to the Consortium Bodies the Directorate of the Lab., with the control of the quality of the installations in the overall Facility.

## UNDERGROUND LABORATORY OF CANFRANC SCIENTIFIC POLICY COMMITTEE

- Chairman: Prof. Jose Bernabeu (IFIC, Spain)
- Secretary: Prof. Domenec Espriu (PP Programme)
- Members:
  - Prof. Frank Avignone (South Carolina, US)
  - Prof. Eugenio Coccia (Director of LNGS, Italy)
  - Prof. Enrique Fernandez (IFAE, UAB, Spain)
  - Prof. Concepcion Gonzalez-Garcia (SB, US)
  - Prof. Rafael Rebolo (IAC, Spain)
  - Prof. Michel Spiro (Director of IN2P3, France)
  - Prof. David Wark (Rutherford Lab., UK)







# The LSC starts officially

---

- On Monday 27 March 2006, the LSC was inaugurated by
  - The Minister of Education and Science
  - The President of the Aragon Government
  - The Rector of the University of Zaragozaand they proceeded to the signature of the agreement for LSC.
- The SPC, in its meeting of 10 March 2006, recommended to the Consortium parties the appointment of the Directorate Team formed by:
  - Professor Sandro Bettini, as Director General
  - Professor Julio Morales, as Associate Director
  - Professor Jose Angel Villar, as Associate Director

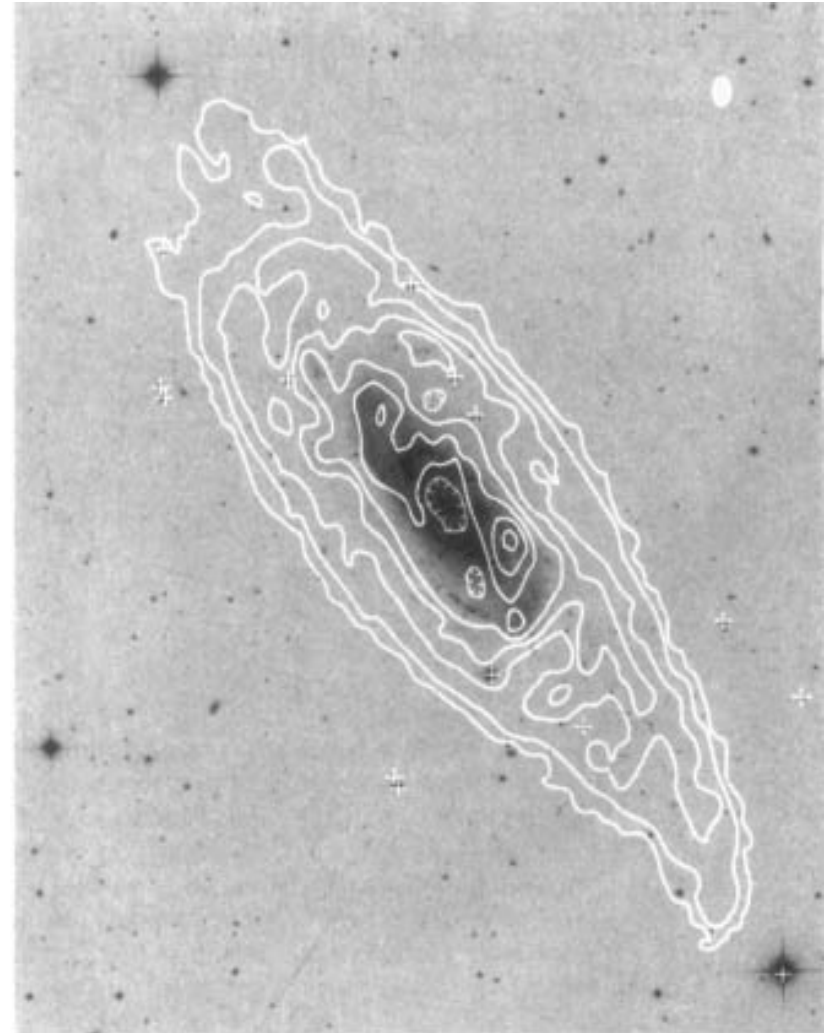
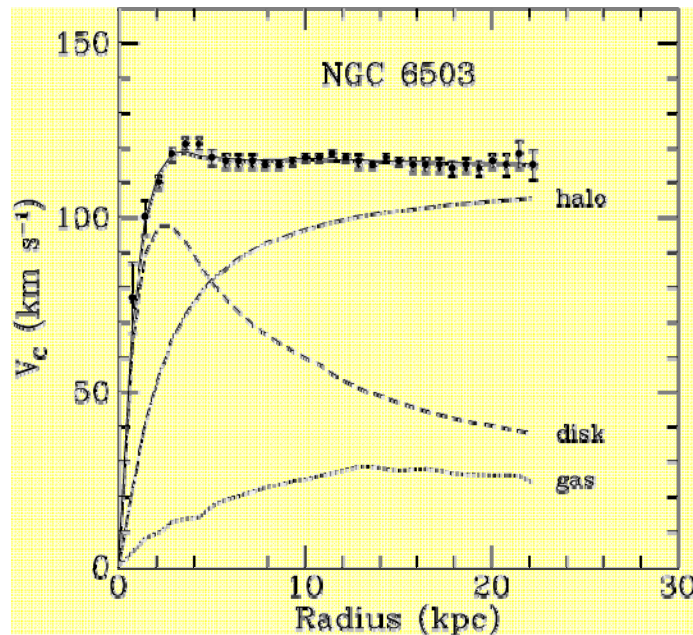
This Team was selected among the candidates that had applied in an International Call announced since November 2005.

- The SPC, in the same meeting, decided to proceed with the Expressions of Interest that were presented by International Collaborations in the framework of an International Call announced since July 2005. The experiments to be defended orally in an OPEN SESSION next July 6th in Canfranc and installed in the LSC are grouped in three categories :
  - Dark Matter Searches    - Double Beta Decay    - Gravitation

<http://www.unizar.es/lsc>

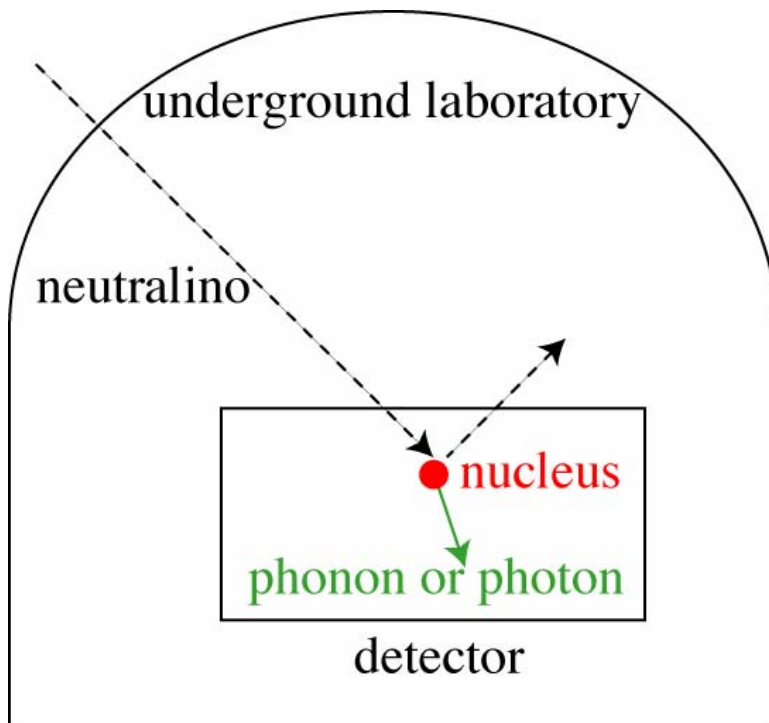
# Galactic Dark Matter

- Observe galaxy rotation curve using Doppler shifts in 21 cm line from hyperfine splitting

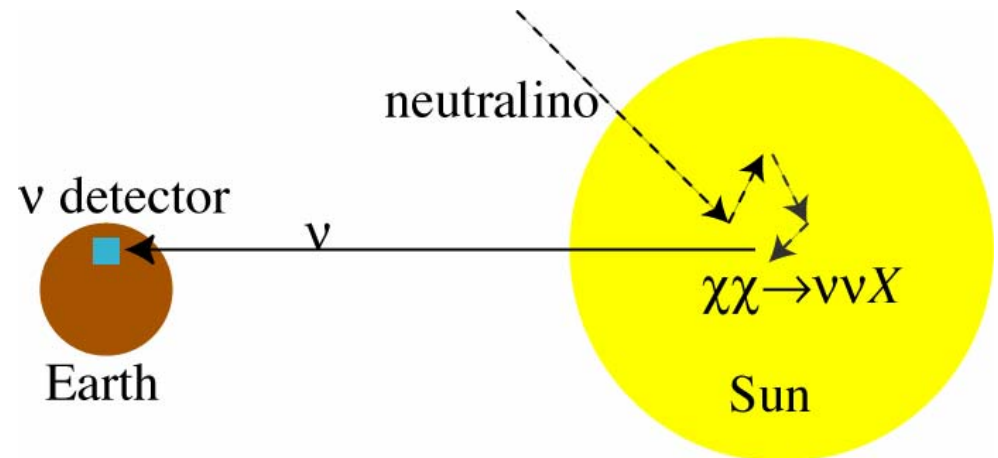


# Detection of Dark Matter

- Direct detection
- **CDMS-II**, Edelweiss, DAMA, GENIUS, etc



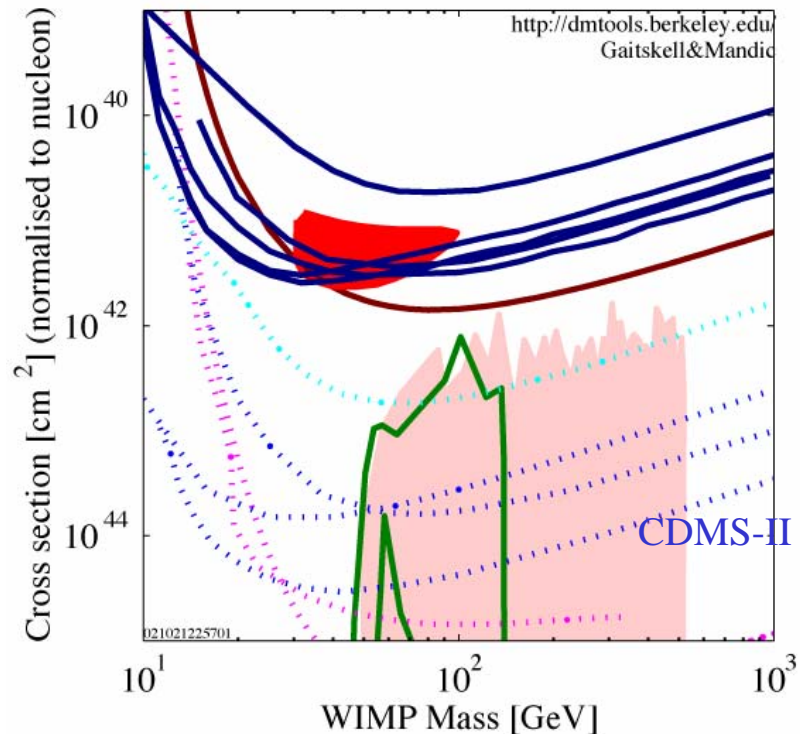
- Indirect detection
- **SuperK, AMANDA, ICECUBE, Antares, etc**



complementary techniques are getting into the interesting region of parameter space

# Particle Dark Matter

- Stable, TeV-scale particle, electrically neutral, only weakly interacting
- No such candidate in the Standard Model
- Lightest Supersymmetric Particle (LSP): superpartner of a gauge boson in most models
- LSP a perfect candidate for WIMP  
But there are many other possibilities (techni-baryons, gravitino, axino, invisible axion, WIMPZILLAS, etc)



Detect Dark Matter to see *it is there*.

Produce Dark Matter in accelerator experiments to see *what it is*.



# ZEPLIN III: two phase liquid xenon detectors with high background rejection capability

## Electron recoils (background):

primary scintillation

+

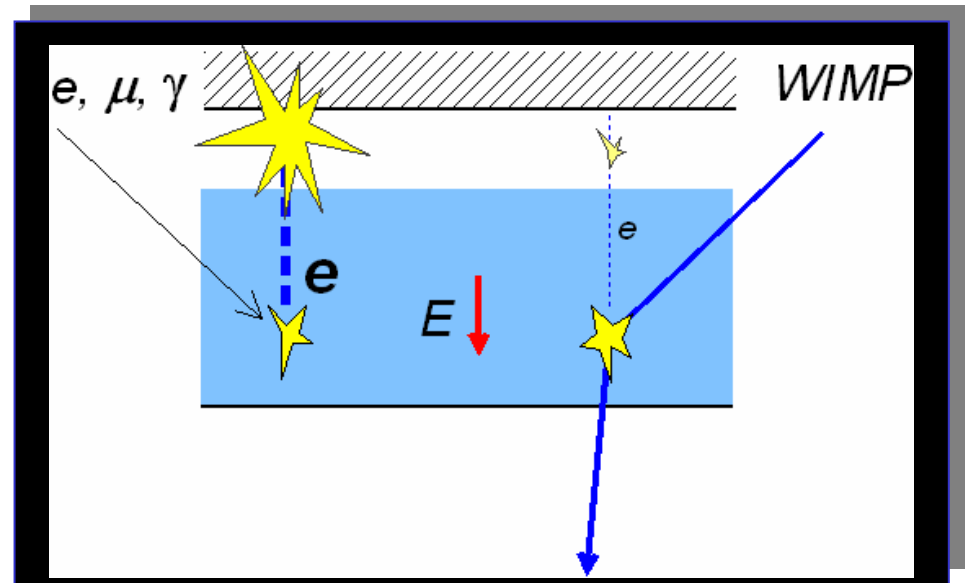
**strong** secondary scintillation

## Nuclear recoils:

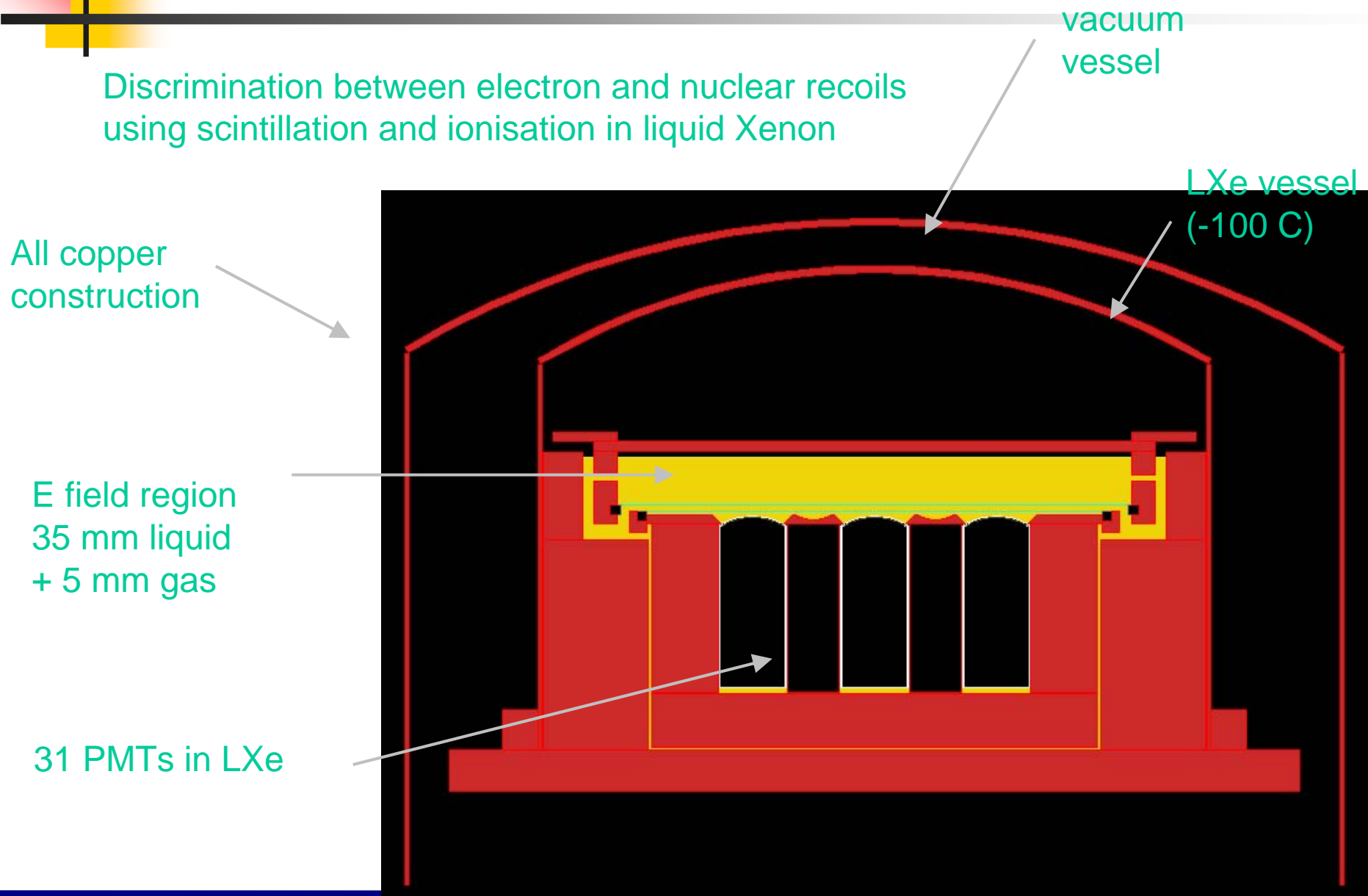
primary scintillation

+

**weak** secondary scintillation



# ***ZEPLIN III: 2-Phase Xenon WIMP Detector***



# ZEPLIN III: Technical drawing

**LXe chamber**

**Fiducial volume of LXe**

$m \approx 15$  kg

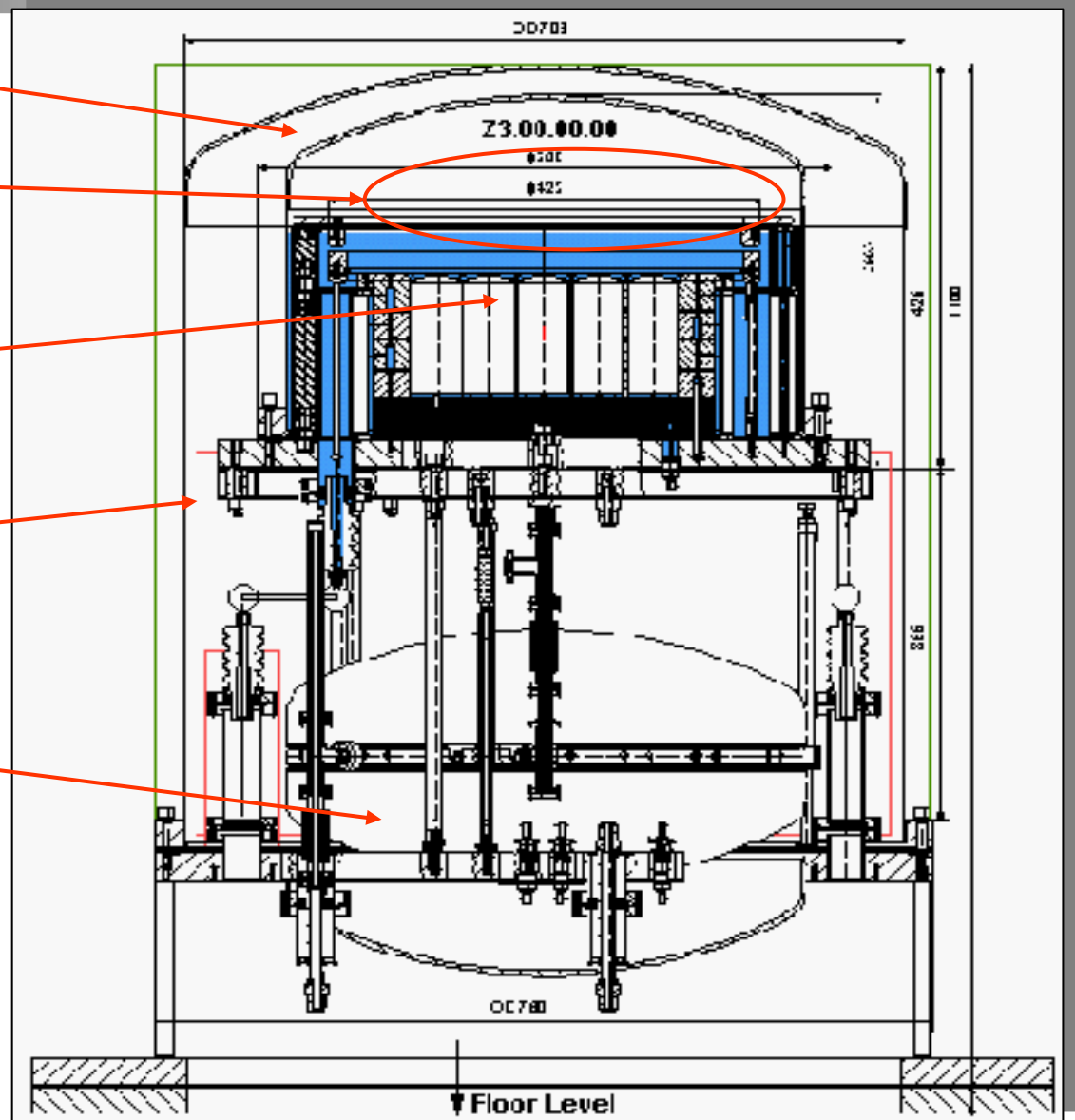
**31 PMTs (2-inch)**

**Vacuum jacket**

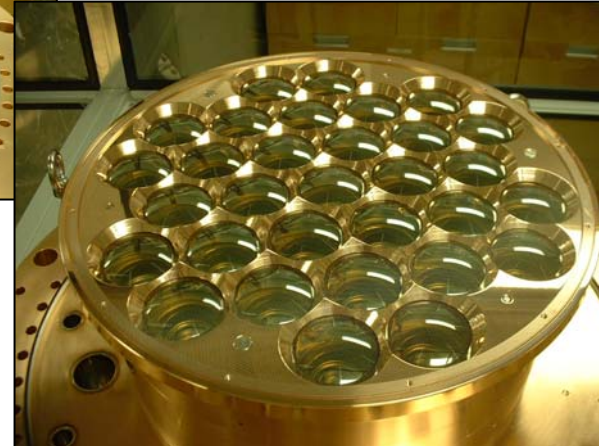
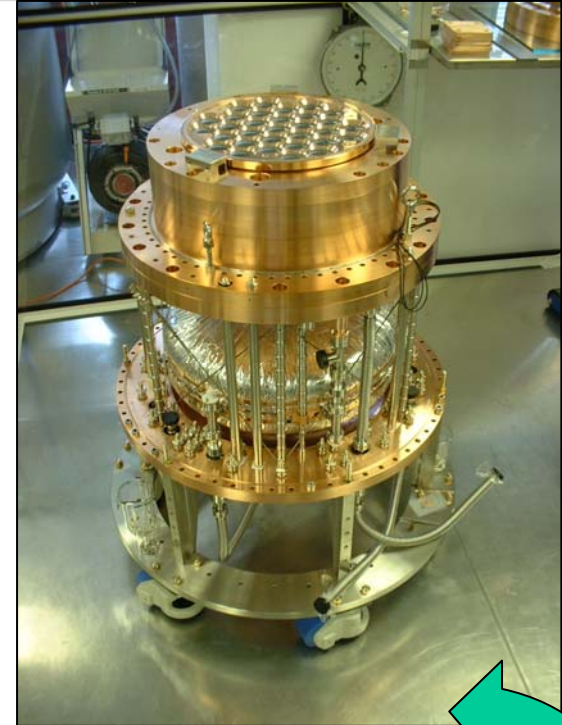
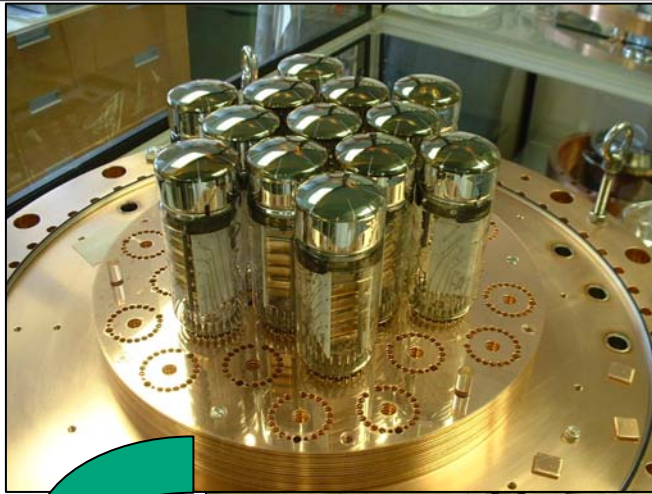
**Liquid nitrogen tank**

(enough to run about 42 hours without refill)

All metallic parts – OFHC Copper

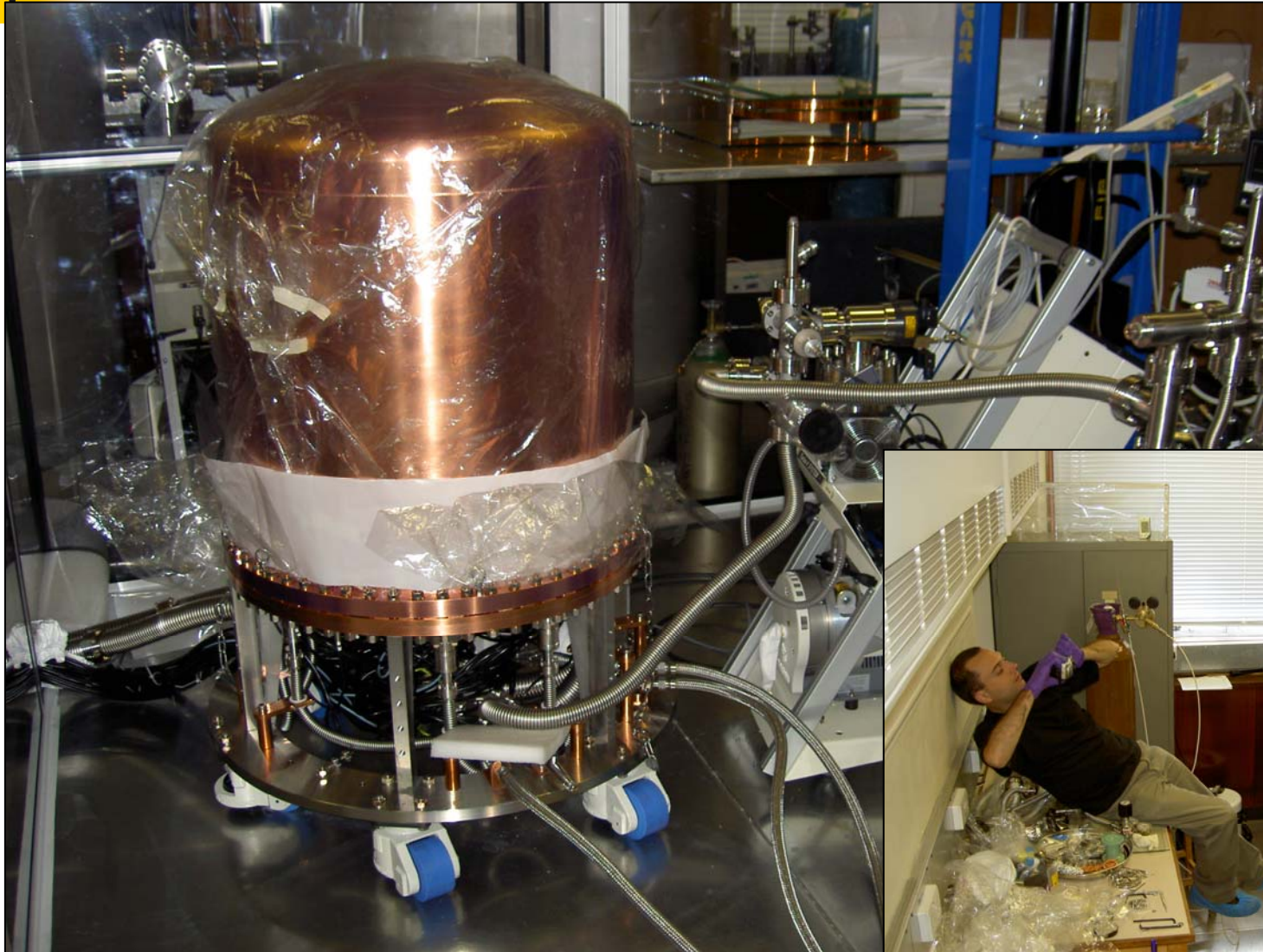


# ZEPLIN III: will it work all together ?





# ZEPLIN III: it is real !



## *The expansion of the noble liquids technique...*

Experiment	Target	Readout type	Mass	What for ?	Where ?
ICARUS	Ar	Ionization+ Scintillation	600 ton	$\nu$ physics + proton decay	LNGS
WARP	Ar	1ry+2 <sup>nd</sup> ry light	0.1 ton	DM	LNGS
ArDM	Ar	Ionization+ Scintillation	1 ton	DM	Canfranc
DEAP	Ar	Scintillation	1 ton	DM	Canada
T2K-LAr	Ar	Ionization+ Scintillation	100 ton	$\nu$ beam	Japan
FLARE	Ar	Ionization	15-50 kton	$\nu$ beam	USA
GLACIER	Ar	Ionization+ Scintillation (+Cerenkov?)	1-10-100 kton	$\nu$ astrophysics + beam +proton decay	EU ?

# ArDM (Argon Dark Matter)

<http://neutrino.ethz.ch/ArDM>

- ETH Zurich (A.Rubbia)
- Univ. of Zurich (C.Amsler)
- Univ. de Granada (A.Bueno)
- CIEMAT Madryt
- IPJ (T.Kozłowski, P.Majakowski, E.Rondio)
- Univ. of Sheffield (N.Spooner)

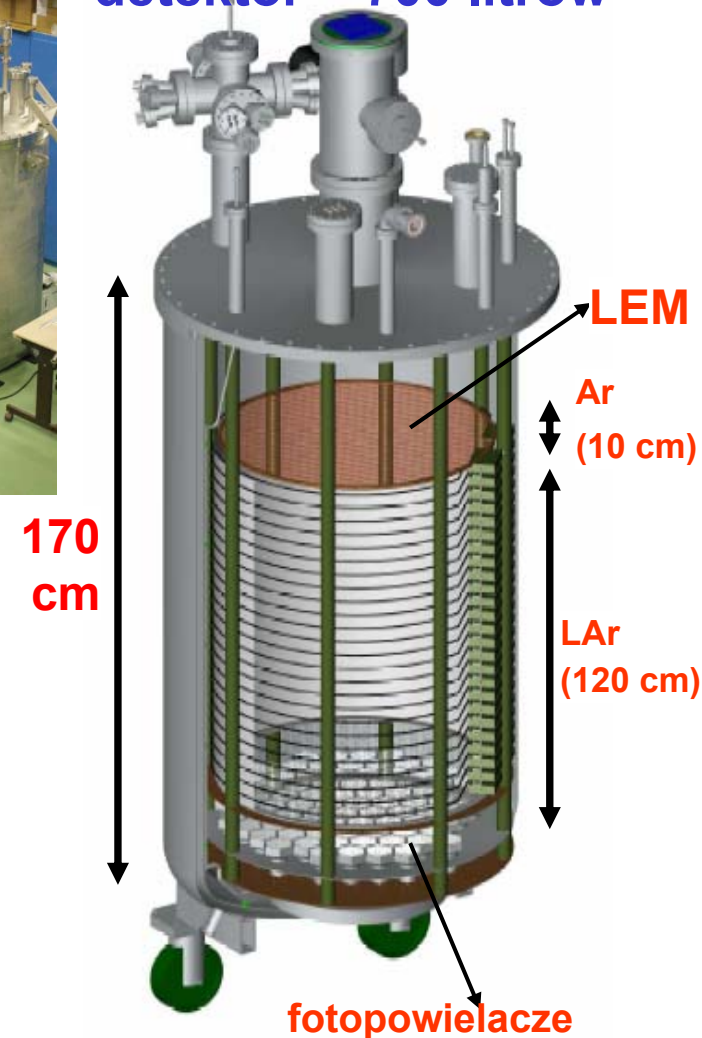
## ZASADA DZIAŁANIA:



mierzymy energię jąder odrzutu [30-100 keV] z elastycznego rozpraszania WIMP-ów ( $\chi$ )



detektor ~ 700 litrów





# ANAIS

- **Instituciones**

Universidad de Zaragoza (UZ)

- **Localización**

Laboratorio subterráneo de Canfranc

- **Descripción**

ANAIS es un experimento destinado a la búsqueda de efectos de modulación anual en la señal de WIMPs con 10 centelleadores de NaI (107 kg). Con el fin de mejorar los dos factores que determinan la sensibilidad de este tipo de experimentos (el umbral de energías y el fondo radioactivo en sus proximidades) se ha puesto en marcha en el Laboratorio Subterráneo de Canfranc un prototipo con un único detector sobre el que se están realizando diversas modificaciones: se ha instalado una nueva base externa de teflón en el fotomultiplicador, se va a sustituir éste por otros de ultrabajo fondo radioactivo situados fuera del blindaje interno, etc. Al igual que para el experimento completo, el detector se ha instalado en un blindaje que consiste (de dentro a fuera) en 30 cm de plomo de baja actividad, 2 mm de cadmio y 40 cm de polietileno y agua borada. Además, una bolsa de PVC mantenida a sobrepresión por la inyección de N<sub>2</sub> gas evita la entrada de radón y se han dispuesto vetos anti-muones cubriendo la parte superior del dispositivo.

- La adquisición mediante un osciloscopio digital de los pulsos de los sucesos ha permitido discriminar el ruido a través del análisis de la forma de los mismos, reduciendo el umbral de energía del detector hasta 4 keV. También va a implementarse un sistema de control para garantizar la necesaria estabilidad de las condiciones ambientales: temperaturas, niveles de radón, ganancia, ...



# AN AIS



Detalle del experimento  
prototipo con un único cristal de  
10.7 kg



Depósitos de  
agua borada  
cerrando el  
blindaje del  
prototipo



Blindaje de plomo (30 cm) del experimento  
prototipo con un único cristal de 10.7 kg

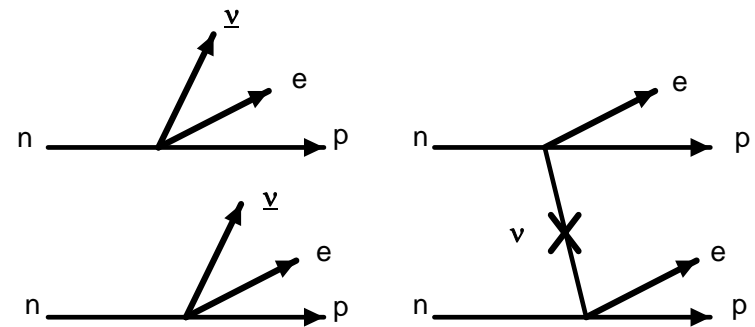
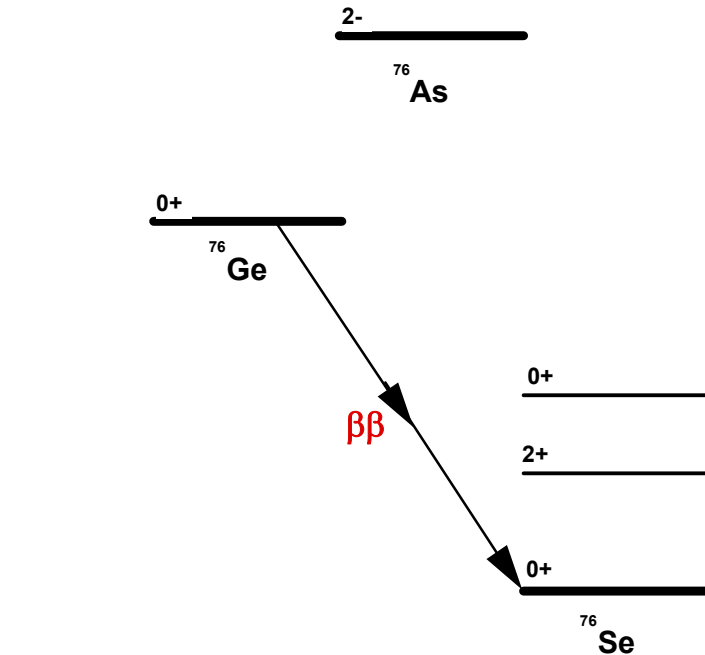


Láminas de cadmio y  
polietileno en el blindaje del  
prototipo

# Double beta decay

- Large number of even-even nuclei undergo double-beta decay, but not single-beta decay
- Standard Model process of  $2\nu\beta\beta$  is also allowed of course
- Enrichment procedure in place for about 10 isotopes
- You do not search for peaks in unknown places: you always know where to look
- Q value of the decay is well known (difference in energy between two isotopes)

$$| \langle m_\nu \rangle | = \left| c_3^2 c_2^2 m_1 + s_3^2 c_2^2 e^{i\phi_2} m_2 + s_2^2 e^{i\phi_3} m_3 \right|$$

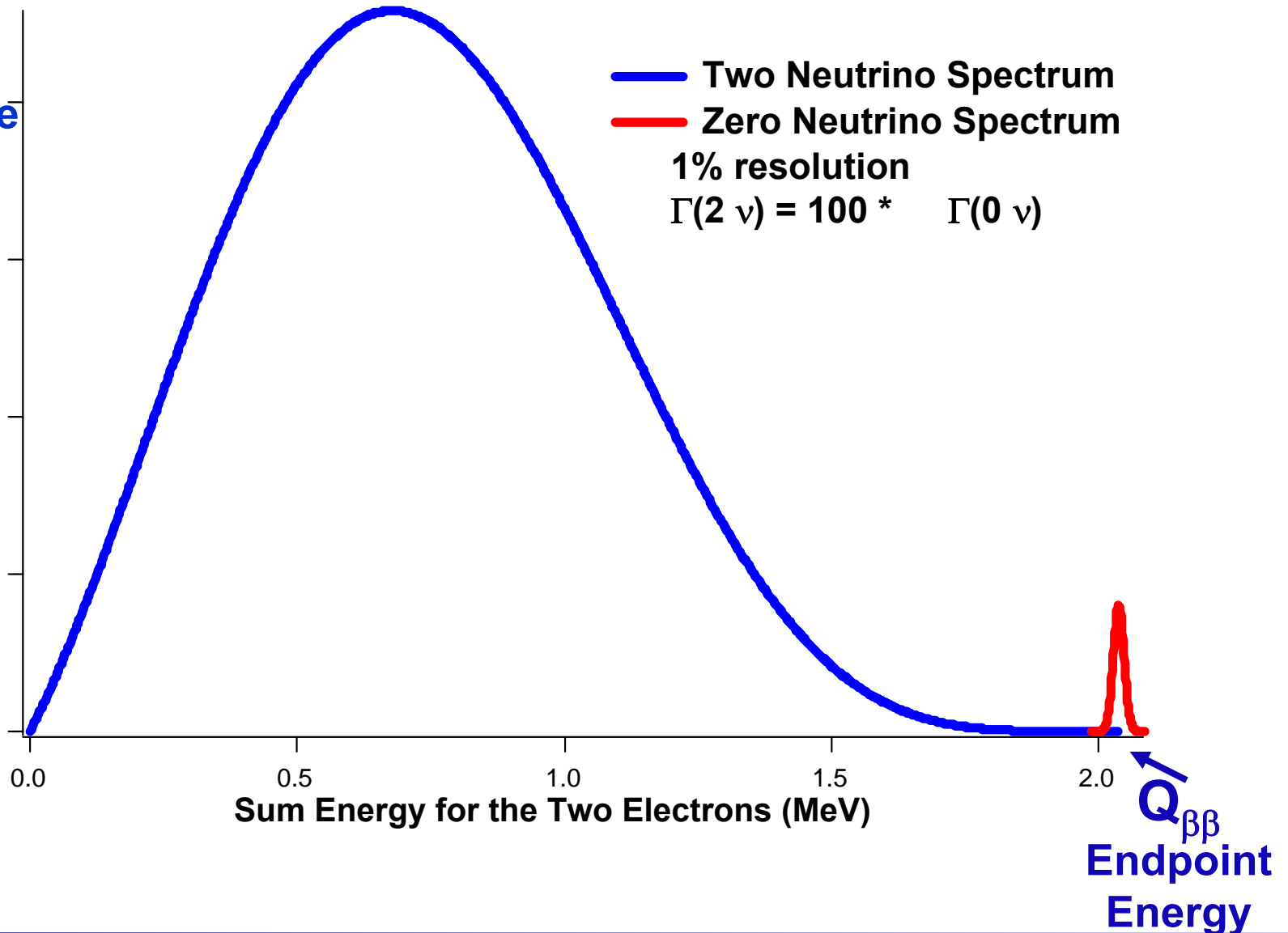


$2\nu\beta\beta$

$0\nu\beta\beta$

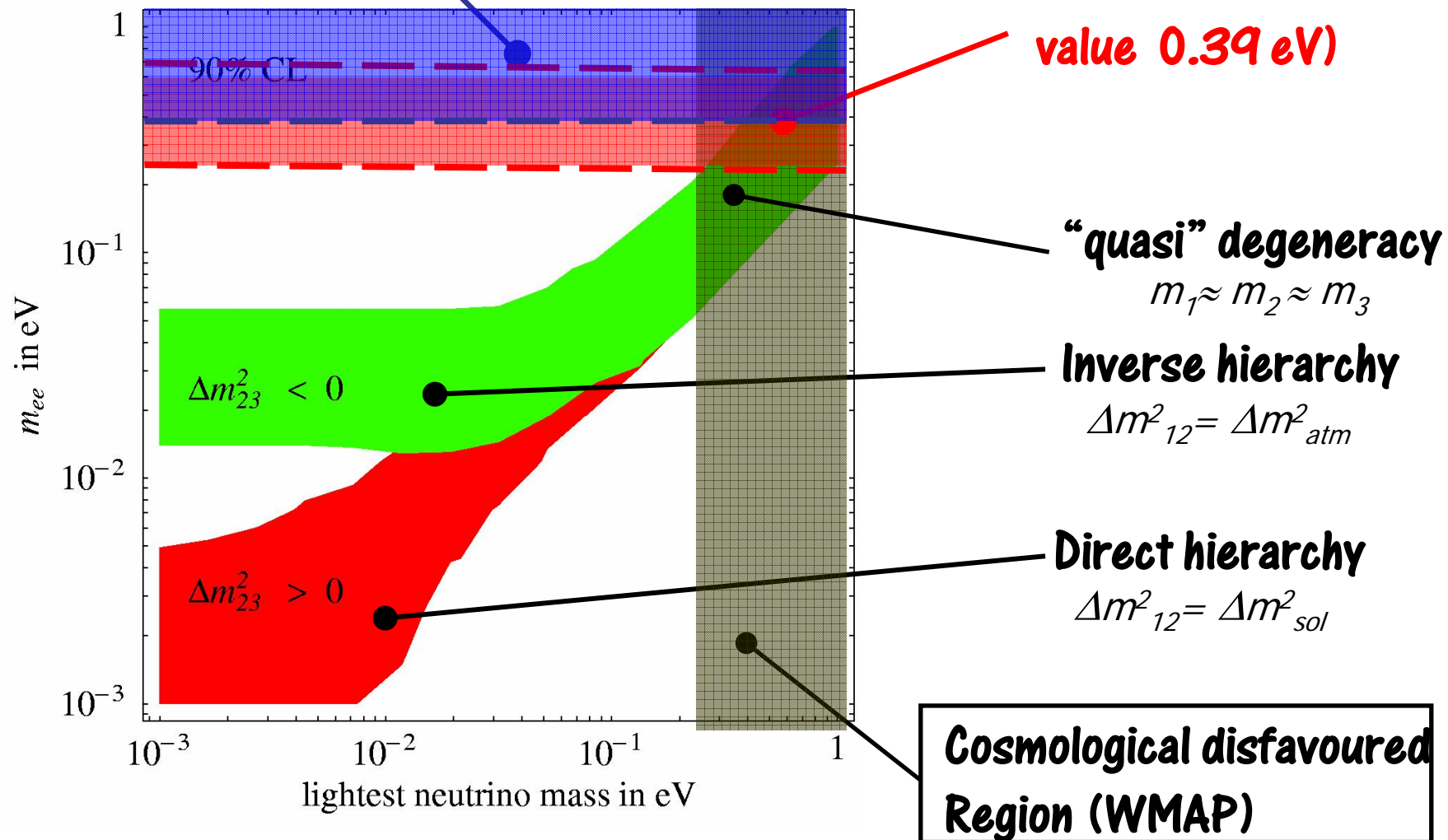
# Double beta decay

<sup>76</sup>Ge example



Present Cuoricino/NEMO-III region

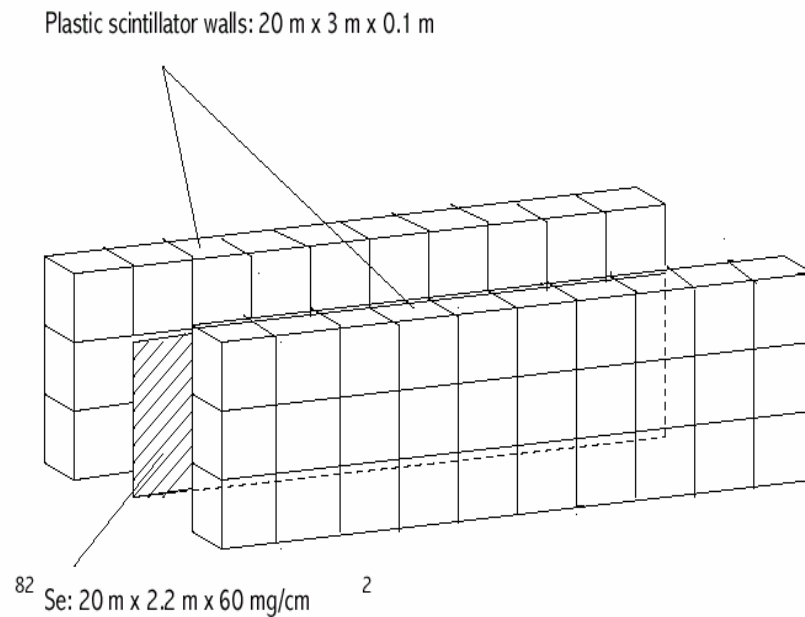
Possible evidence (best value 0.39 eV)





# Super-NEMO and Bi-Po

- Based on NEMO-III technology, SM only background
- study Se, Nd, Mo, low SM background
- Design study started 2005



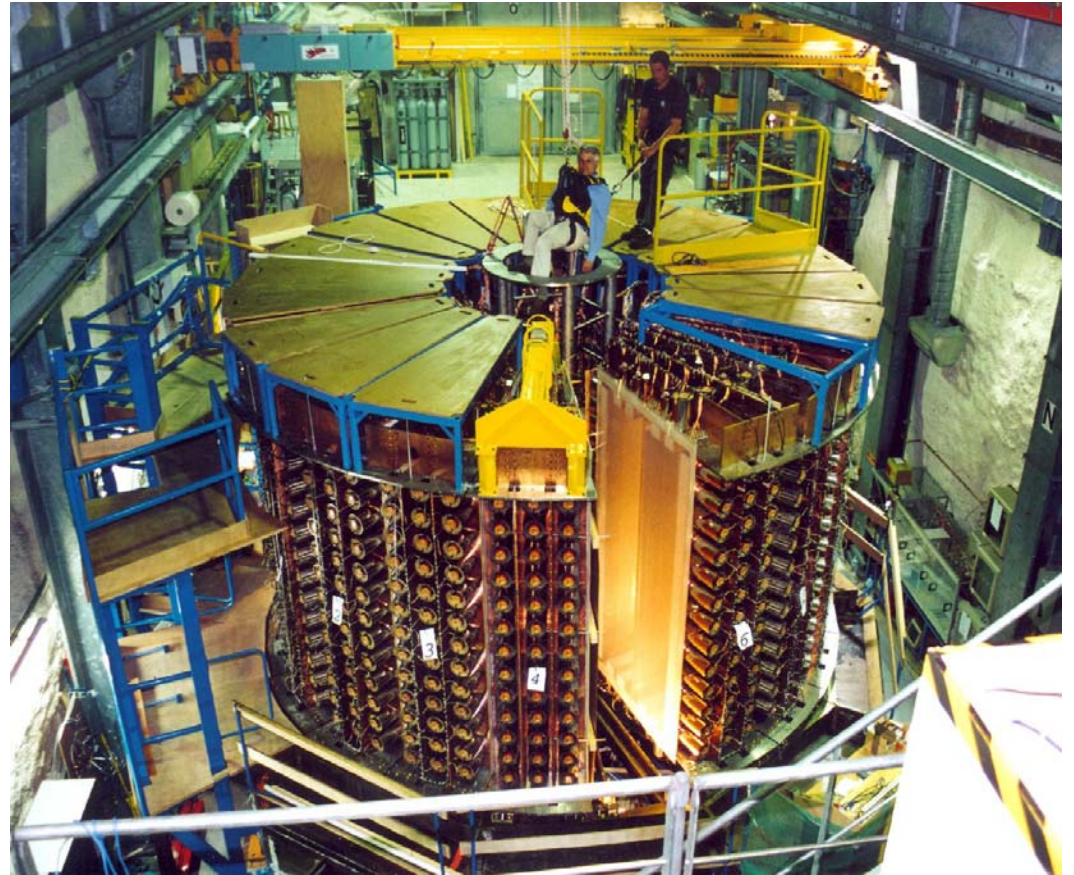
Feasible if:

- a) BG only from  $2\nu\beta\beta$  (NEMO3)
- b)  $\Delta E/E = 10\%$  at 1 MeV (8% has already been demonstrated in recent R&D)

# Bi-Po in Canfranc

NEMO III is installed in Frejus. The prototype Bi-Po (bigger than NEMO III) of SuperNEMO is going to be installed in the new LSC. The International Collaboration contains at present two groups from Valencia, one group from Barcelona and one group from Zaragoza. The Coordinator of the Spanish participation is J. J. Gómez Cadenas.

This tracking detector is complementary to the bolometric GERDA and CUORE, with its capability to measure the single electron energy (in both  $2\nu$  and  $0\nu$  channels) and the angular correlation between both electrons. SuperNEMO will use different isotopes.

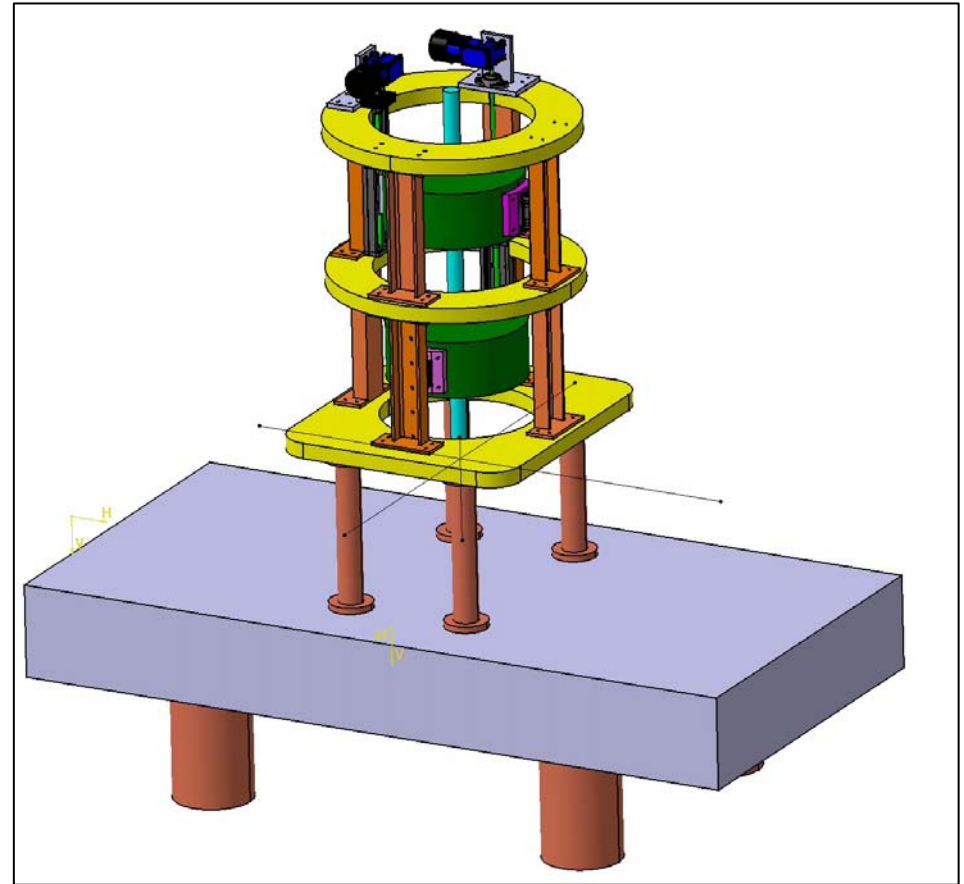


# Gravity Tests

- Torsion Pendulum
- Test of the Equivalence Principle

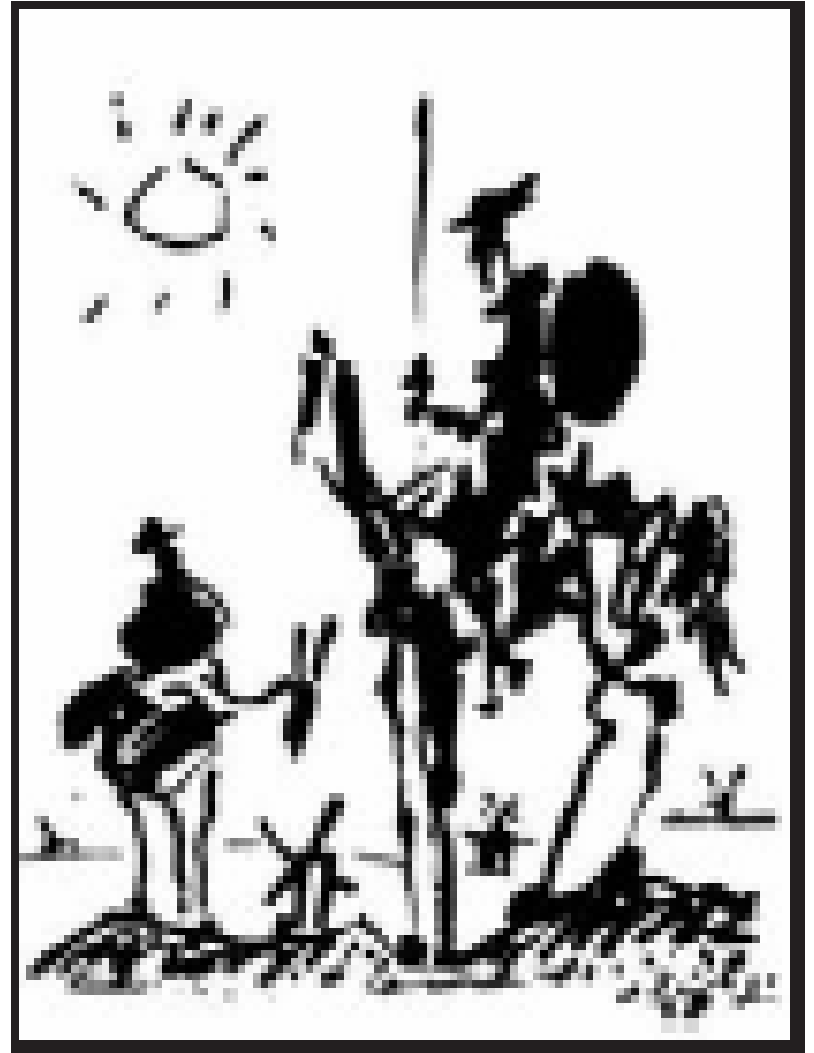
$$m_i = m_g$$

- Precision in the measurement of Newton Constant
- Deviations from the Inverse Square Law at small distances



# Outlook

- Good luck to the new LSC!
- Unique in Spain.
- Crucial for Underground Space in Europe.
- Experiments of unprecedented interest and dimensions for the International Scientific Community.
- New Spanish groups are encouraged to participate in the experiments to be installed in the LSC.





# Rendez-vous

- July 6th, 16:00 in Canfrac
  - OPEN SESSION OF THE SCIENTIFIC POLICY COMMITTEE
  - ORAL PRESENTATIONS OF THE EXPERIMENTS BY SPOKE PERSONS
- July 7th, 9:00 in Canfrac
  - VISIT TO THE LSC AND INSTALATIONS
  - 11:30 CLOSED SESSION



Contact:

[mfatas@unizar.es](mailto:mfatas@unizar.es)

• See you in 'El Tobazo'