Experimental program on neutrinos and axions at LSC and CERN

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(on behalf of Julio Morales)
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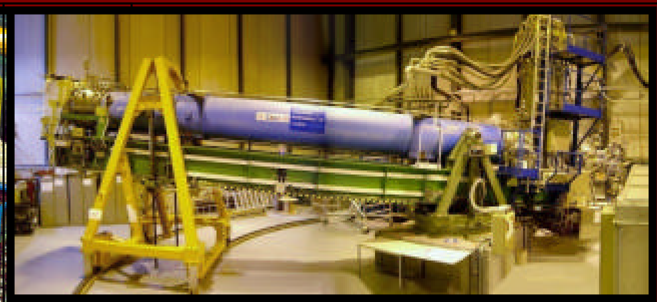
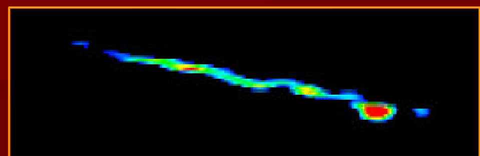
Spanish Particle Physics Panel Meeting, Madrid, May 26th, 2008



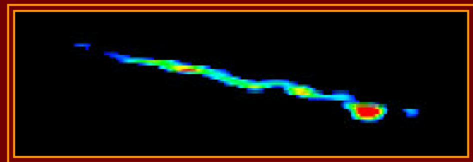


Overall structure of project

continuation of the present lines of work:

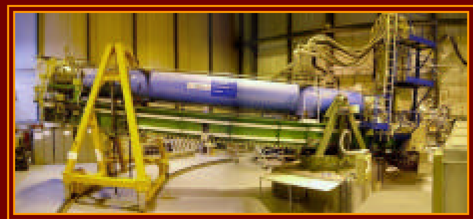
ββ at LSC

1. Participation in **BiPo & SuperNEMO** experiment at *Laboratorio Subterráneo de Canfranc* (LSC)
2. Development of new techniques on TPCs (Micromegas) for ββ decay searches. In connection with **NEXT**.



axions at CERN

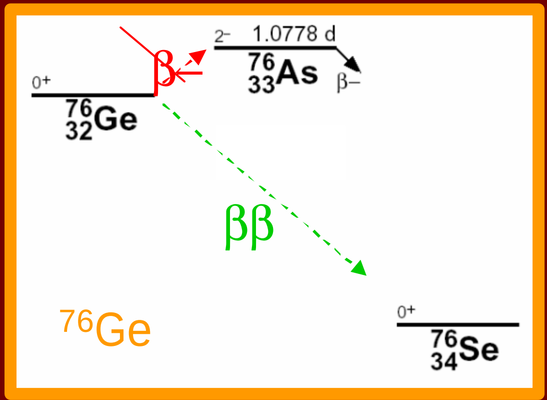
3. Participation in **CAST** experiment at CERN

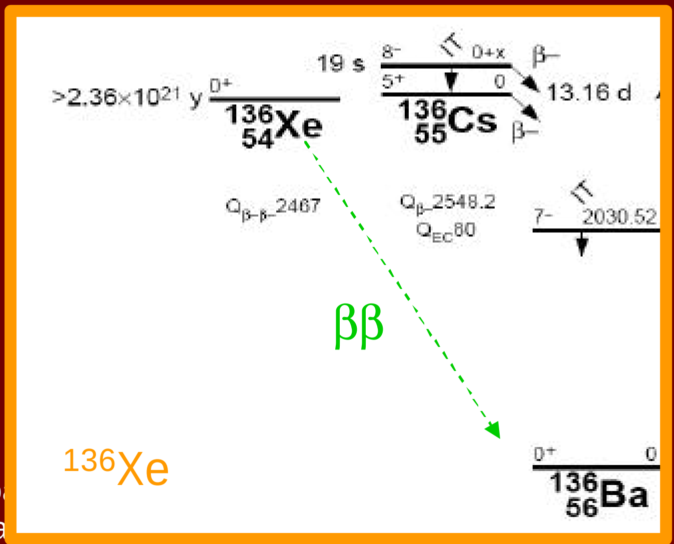


ββ at LSC

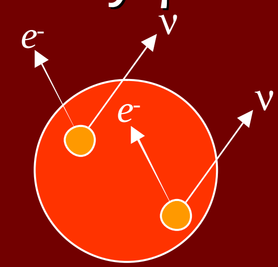
Neutrinoless Double Beta ($0\nu\beta\beta$)

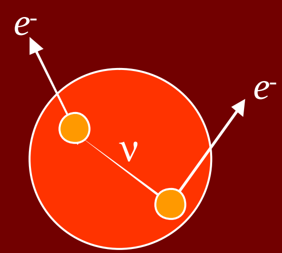
- $\beta\beta$ decay is relevant when the nucleus cannot decay β.





- ✓ With emission of 2 ν ($2\nu\beta\beta$). Standard process, observed in a number of isotopes.
- ✓ With no neutrino ($0\nu\beta\beta$). Only possible if neutrino is massive and Majorana. Not yet seen(*).

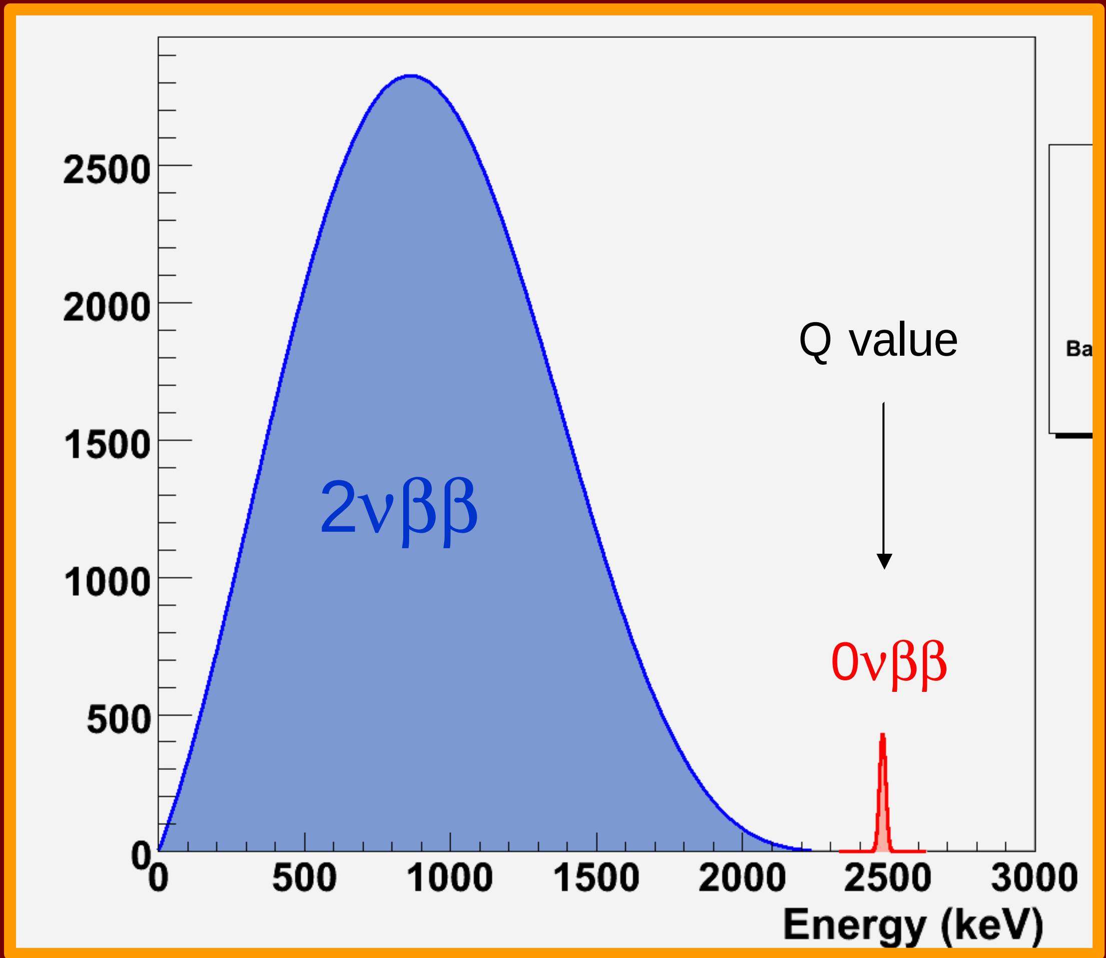


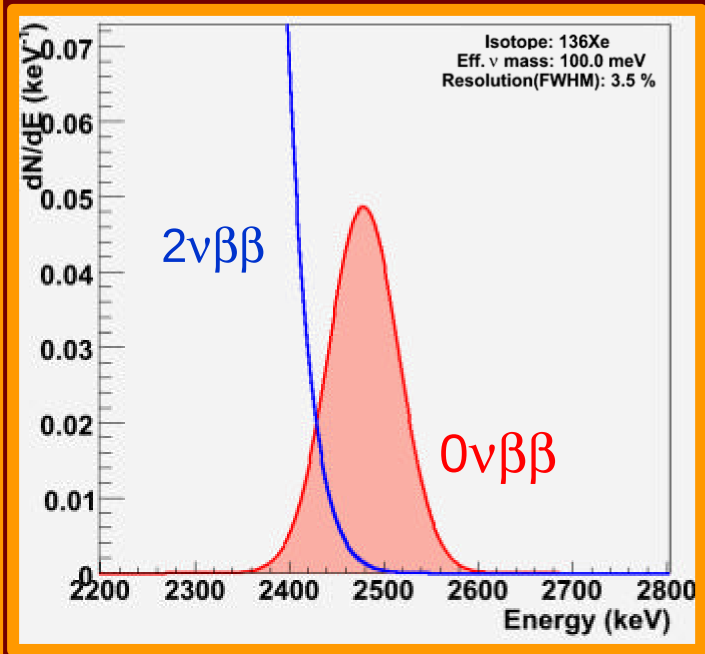


- Precious information on neutrino properties (mass scale, Majorana/Dirac nature,…)

Neutrinoless Double Beta ($0\nu\beta\beta$)

- "Visible" energy (i.e. the 2 e^-) spectrum:





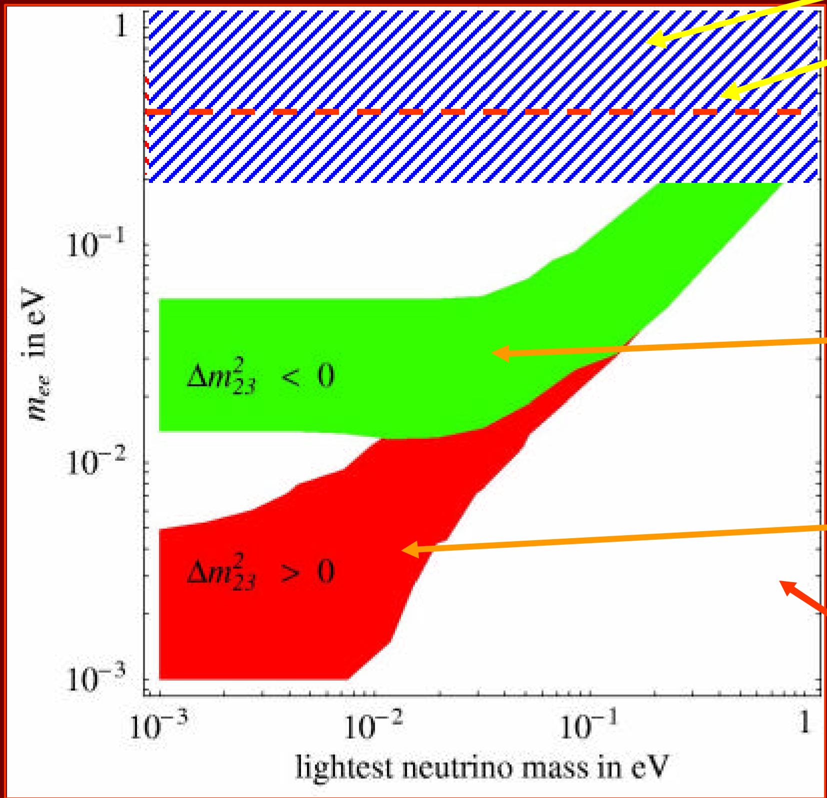
- Energy resolution very important. **Only way to distinguish between both processes**

Neutrino mass scale and 0νββ

- IGEX (^{76}Ge) @ LSC $<m_\nu> < 0.33 - 1.35$ eV PRD65(02)092007
- NEMO-3 (^{100}Mo) @ LSM $<m_\nu> < 0.6 - 1.3$ eV PRL95(05)182302 & talk @ TAUP07
  expected next summer $< 0.3 - 0.7$ eV
- CUORICINO (^{130}Te) @ LNGS $<m_\nu> < 0.2 - 1.1$ eV PRL95(05)142501

Region being explored by present experiments

claimed evidence (0.2-0.6 eV)
PLB586(04)092007



"quasi" degeneracy
$m_1 » m_2 » m_3$

Inverse hierarchy
$Dm^2_{12} = Dm^2_{atm}$

Direct hierarchy
$Dm^2_{12} = Dm^2_{sol}$

Cosmologically disfavoured Region

ApPEC reccomendations

...about SuperNEMO and future ββ experiments...

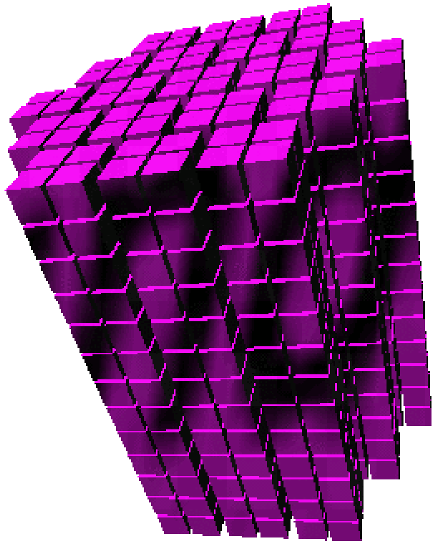
The European detectors which are expected to start operation within the next 5 years are GERDA, CUORE, Super-NEMO and possibly COBRA (mass range 50-100 meV). With these detectors, Europe will be in the best position to improve sensitivity and maintain its leadership in this field and clearly prove or disprove the mentioned claim.

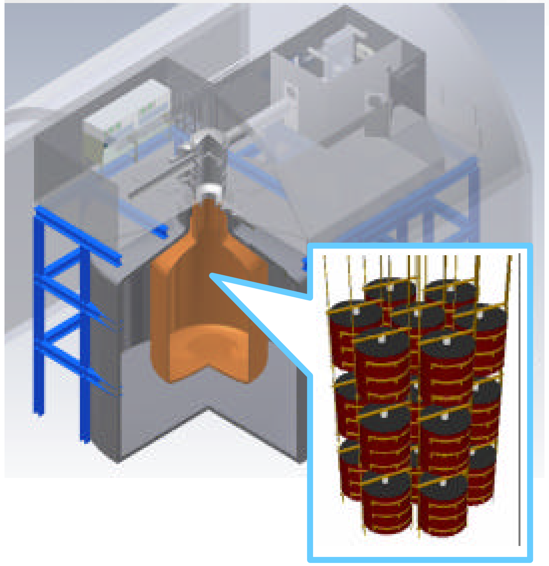
Only even larger, future-generation detectors, with an active mass of order one ton, good resolution and very low background, can cover the second possible mass range (inverted mass hierarchy) and reach the level of 20-50 meV. Different nuclear isotopes and different experimental techniques are needed to establish the effect and extract a neutrino mass value. We recommend a strong participation of Europeans in the future-generation detectors with a sensitivity down to 20 meV. Decisions on these detectors are due by the beginning of the next decade.

*ASPERA Roadmap, phase I, October 2006.

Current generation ββ experiments

- Source = target





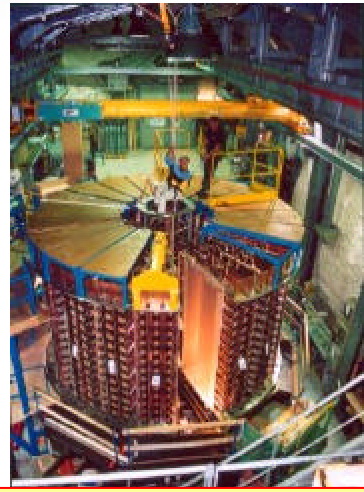
CUORICINO/CUORE

GERDA

- Good E resolution
- Good scaling-up
- BUT, modest background discri.

→strong requirements on radiopurity and shielding

- Source ? target

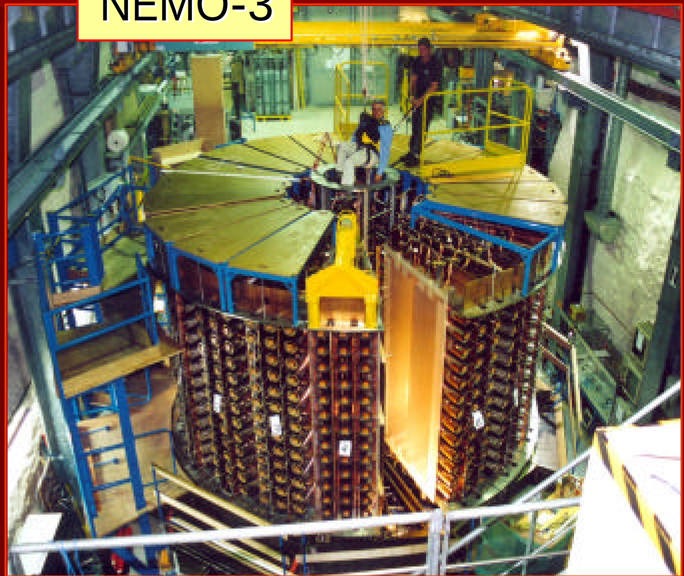


NEMO/SUPERNEMO

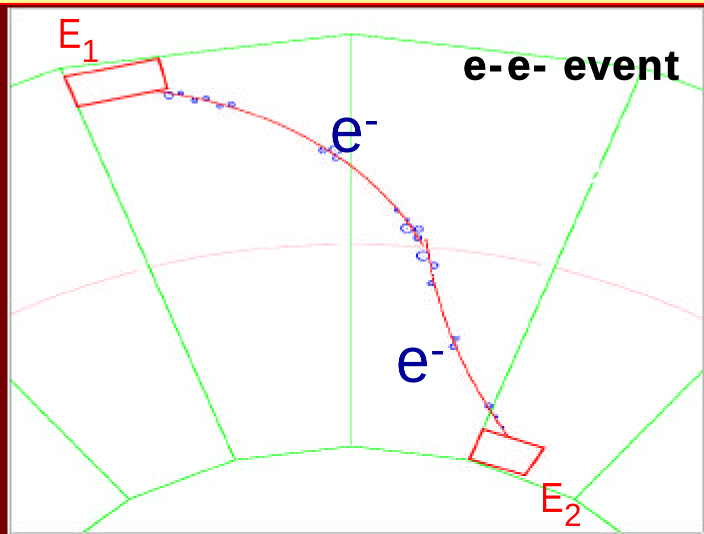
- Event topology information
- BUT, moderate energy resolution and difficult scaling up

Nemo-3 / SuperNemo

NEMO-3



measurement of all kinematic parameters: individual energies and angular distribution



- **Running at Modane underground laboratory since 2003**
- **Tracking detector: drift chamber (6180 Geiger cell)**
- **Calorimeter (1940 plastic scintillators– Low radioactive PMTs)**
- **Magnetic field for charge identification**

SuperNEMO

NEMO-3		SuperNEMO
^{100}Mo	Isotope	150Nd or 82Se
7 kg	Isotope mass M	100-200 kg
8%	Efficiency ε	~30 %
208Tl: < 20 μBq/kg **214Bi: < 300 μBq/kg**	Foil contamination ^{208}Tl and ^{214}Bi	**208Tl: < 2 μBq/kg** **214Bi: < 10 μBq/kg**
12% @ 3 MeV	E resolution (FWHM)	4% @ 3 MeV
$T_{1/2}(\beta\beta0\nu) > 2 \times 10^{24}$ y $<m_\nu> < 0.3 – 1.3$ eV	Sensitivity	$T_{1/2}(\beta\beta0\nu) > 2 \times 10^{26}$ y $<m_\nu> < 40 - 110$ meV

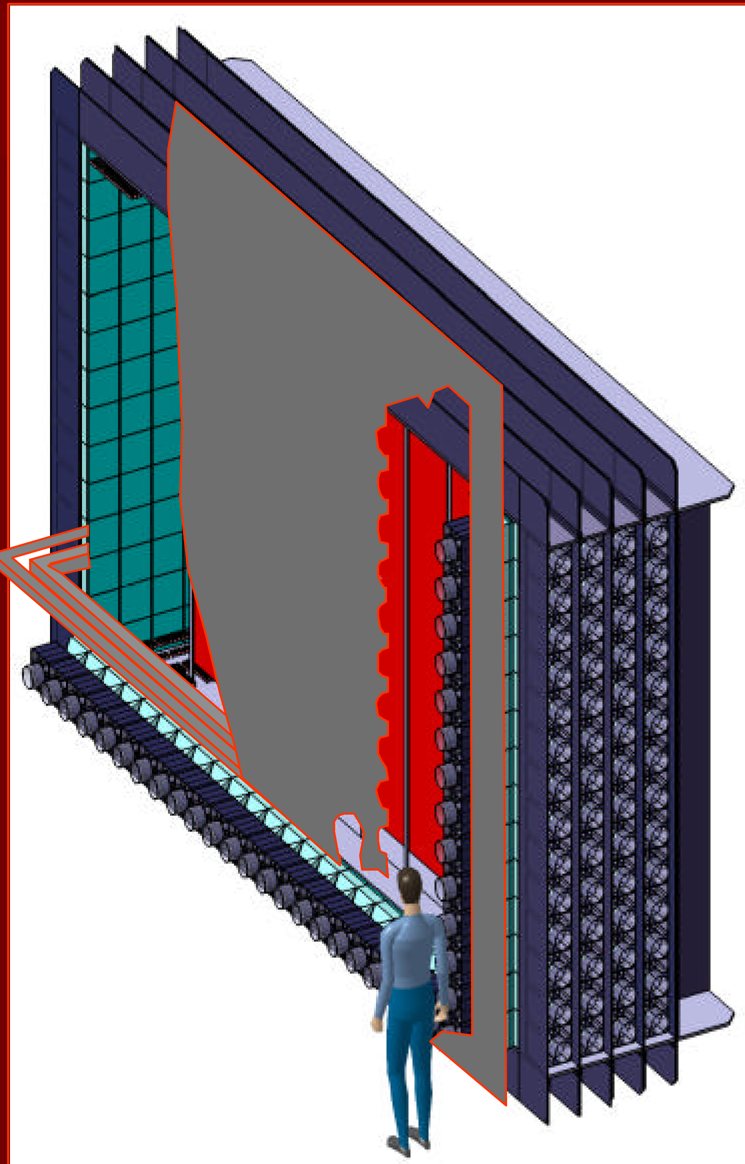
$$T_{1/2}(\beta\beta0\nu) > \ln 2 \times \frac{N_A}{\mathbf{A}} \times \frac{\mathbf{M} \times \varepsilon \times \mathbf{T_{obs}}}{\mathbf{N_{90}}}$$

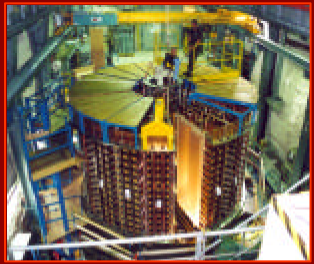
SuperNEMO

- Planar and modular design
  ~100 kg of enriched isotopes
  (20 modules x 5 kg)

- 1 module →

  – Source (40 mg/cm2) 4 x 3 m2
  – Tracking : drift chamber ~3000 cells in Geiger mode
  – Calorimeter: scintillators + PM
    - ~1 000 PM if scint. blocks
    - ~ 100 PM if scint. bars





Latest work status (@ Zaragoza)

- Zaragoza is mainly involved in:
  - Radiopurity:
    - new DAQs of Ge detectors being designed and mounted.
    - Final installation must wait for LSC to be re-opened.
    - Database being designed to coordinate radiopurity measurements in SN and gather results.
  - BiPo:
    - Participation in BiPo1 tests done before LSC closure
    - Participation in BiPo2 tests at Orsay.
    - Participation in analysis software for both designs
  - Radon:
    - Setup using decommissioned TPC being mounted in Zaragoza.

BiPo

- **Goal:** to measure ultra-low levels of ^{208}Tl and ^{214}Bi in thin 2β source foils
  - *Sensitivity:* in **10 m2 foils (40 mg/cm2) in 1 month** to measure activities

    A(^{208}Tl)<2 μBq/kg
    A(^{214}Bi)<10 μBq/kg

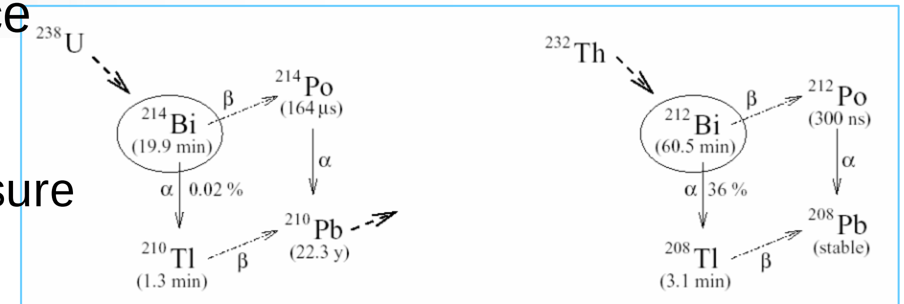
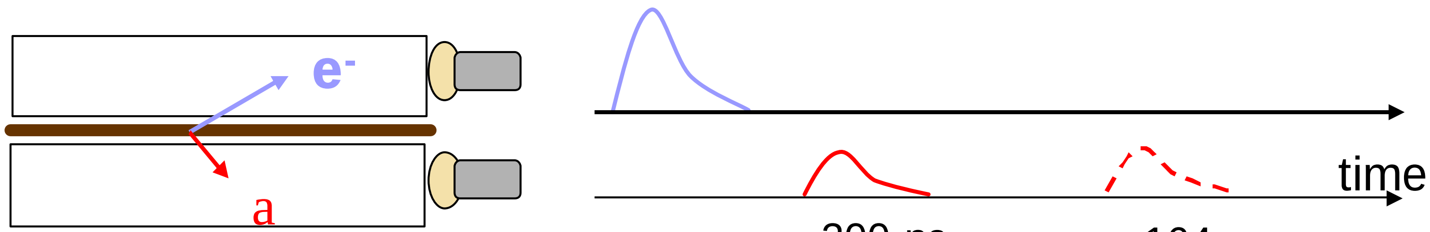


FIGURE 1. BiPo processes for ^{214}Bi and ^{208}Tl.

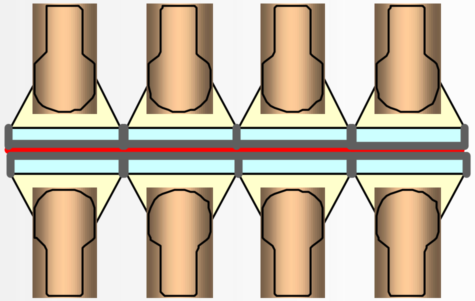
- **Method:** using a sandwich of two plastic scintillators, to register BiPo events (= delayed coincidence between e- and α)



~300 ns
for ^{212}Bi (^{208}Tl)

~ 164 ms
for ^{214}Bi

BiPo Prototypes



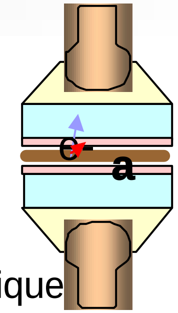
➢ **BiPo-1:** direct readout

• 2 capsules operated at Canfranc in 2007

• method validated with standard aluminum foil (known activity)

• 20 capsuled presently running at Modane

• achieved sensitivity: A(^{208}Tl)$<2\mu$Bq/m^2



Phoswich technique

? b/a discrimination

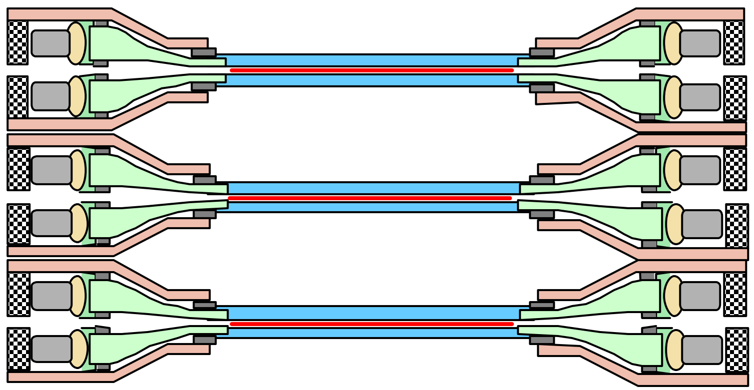
Development at IFIC

➢ **BiPo-2:** multilayers scintillators plates with lateral readout

? Spatial resolution

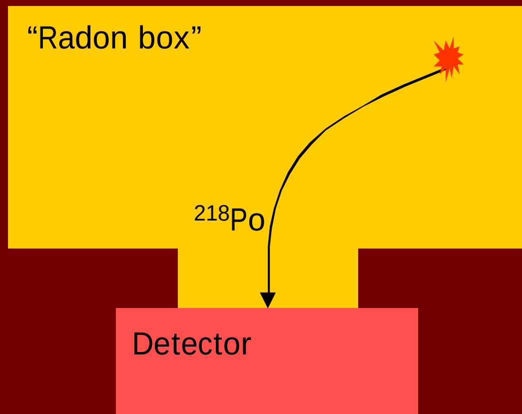
• Detector ready at Orsay

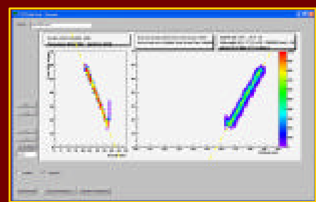
• Measurement at Modane in next months

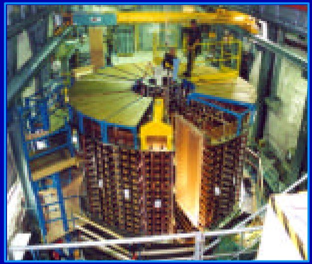


Radon Control

- Radon-free air factory:
  - experience in Modane: from 20 to 0.1 Bq/m3 (in the detector´s surrounding air) (~2 mBq/m3 inside NEMO3)
  - Similar one (50% larger) will be built in Canfranc
- Measure very low concentrations of Rn in gases (down to 1 mBq/m3 if possible):
  - New idea being tested in Zaragoza







Specific objectives (1)

1.1. Radiopurity of materials:

- Set-up measuremnt benches at Canfranc and use them to measure samples for BiPo and SuperNemo.
- Coordination of radiopurity resources of the collaboration.

1.2. BiPo: Participation (as host group) in the construction, installation and operation of the BiPo detector in the LSC.

- Construction/installation (2009-2010), commissioning (2010-2011), operation (2011 onwards).

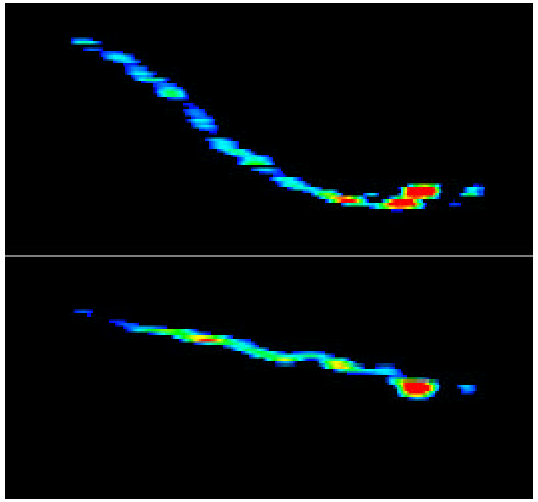
1.3. Radon: Study of the problem of radon:

- Installation of the radon-free air factory (down to few mBq/m3) in Canfranc (presumably during 2009)
- Experimentation towards the measurement of very low quantities of Radon in air.

Gas TPCs for Double Beta?

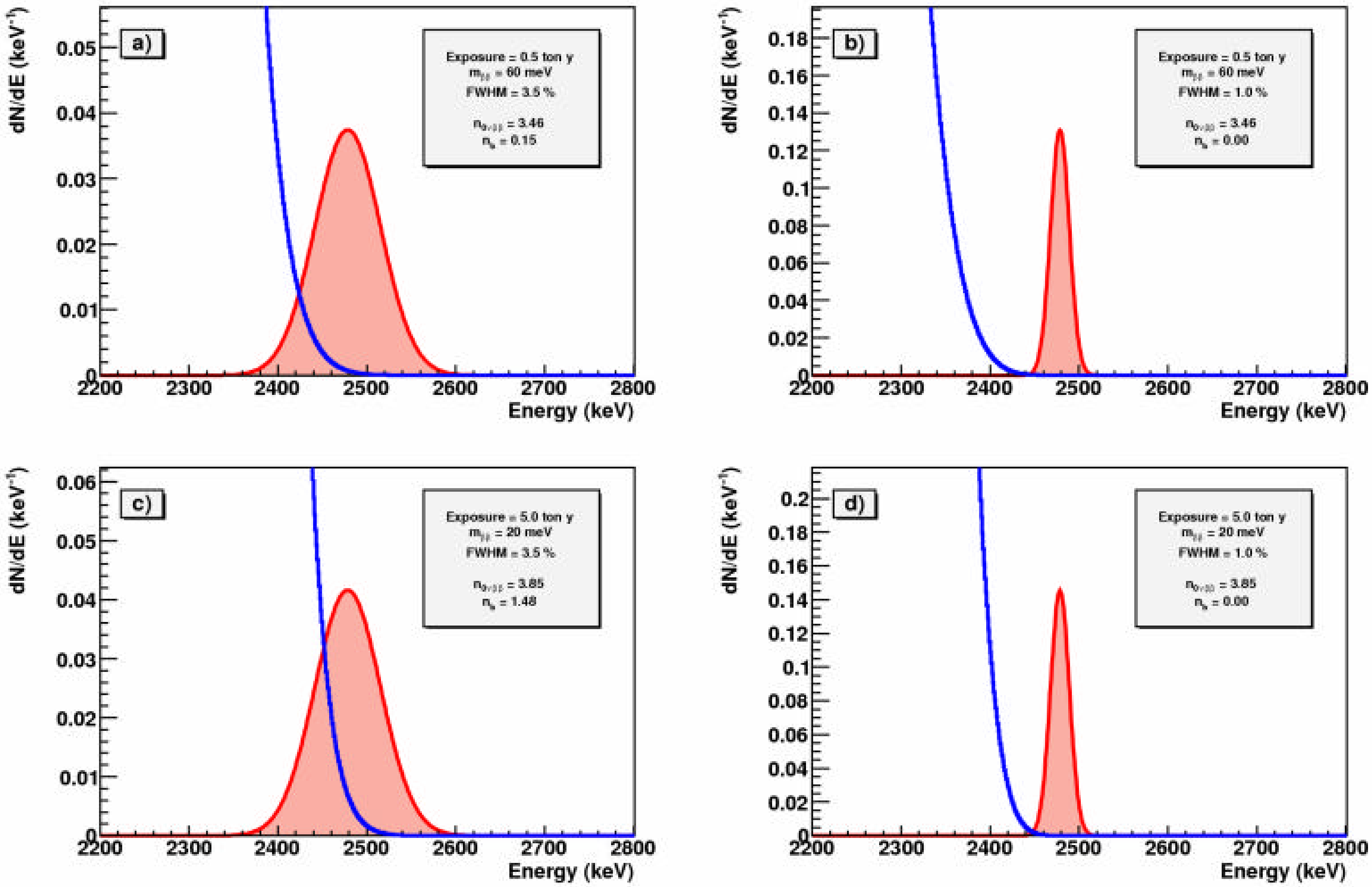
- Without topological signature (GERDA, CUORE, EXO...) external background will limit sensitivity. SuperNEMO will reach a limit (~100kg) due to poor energy resolution
- **What technology to go to >1 ton detectors and probe inverted/normal neutrino hierarchy?**

- Gas TPCs offer in principle the advantages of both approaches: topological signature & scaling-up
- Gothard TPC in the 90´s
- Not presently comtemplated in present projects (EXO: liquid TPC)
- **Why?** *traditionally* bad resolution, instability, complexity...



870 keV e- in the MUNU TPC

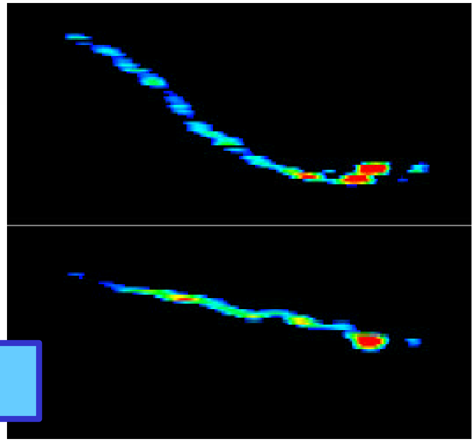
The role of E resolution @ the ton scale



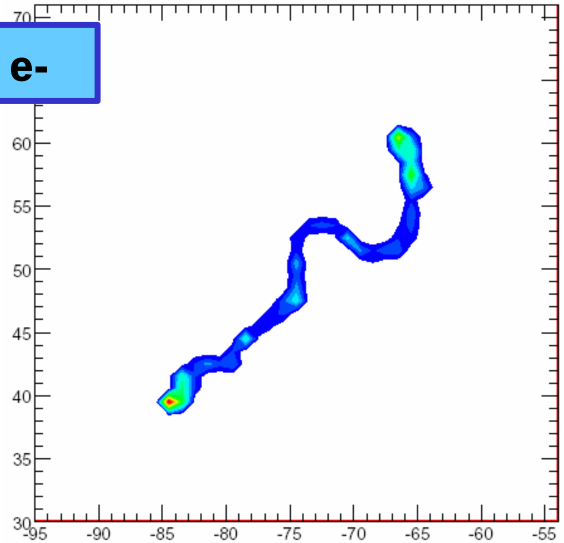
The topological signature

- A gas TPC have access to the "image" of the event.
- 1 e^- events and 2 e^- events have different topologies. This can be used to reject gamma background (1 e^-)
- Gothard demostrated that this can be done. They achieved a 96.5% efficiency in rejecting single e^- events. We may do better.
- **A gas TPC would have an extra handle to reduce background by a factor of at least 10^2 (most probably more).**

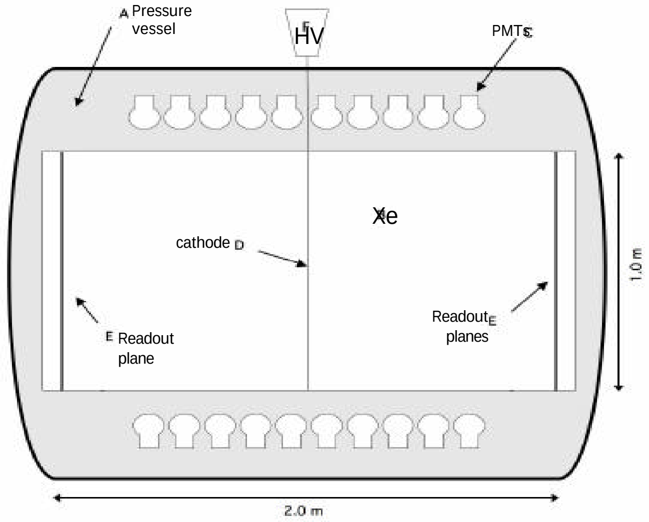
1 e-



2 e-



A new initiative: NEXT



- A **N**eutrino **E**xperiment with a gas **X**e **T**PC may:

1. Have all advantages of a Xe monolithic detector (like EXO)
2. Outdo Liquid Xe by getting topological info
3. Override tradicional limitation of gas TPCs (Gothard) by applying the latest developments on TPC readouts

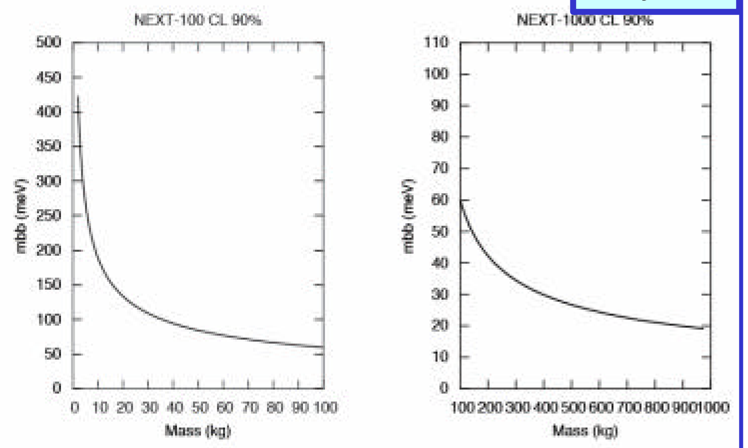
- Competitive option for the next (ton scale) generation of experiments

Initiative pushed by spanish groups *(Barcelona, Ciemat, Santiago, Valencia, Zaragoza)* for R&D phase + prototype construction in Canfranc. Interest and support by other groups. Especially *Saclay (Y. Giomataris), Berkeley (D. Nygren), Canadian groups*, ...

A new initiative: NEXT

- A sensitivity down to 60 eV (for NEXT-100) and 20 eV (for NEXT-1000) is a priori reachable:

10 years



Of course, IF

- Low enough resolution is achieved (~1% FWHM)
- Low enough backgroung after topology cuts (i.e. not background limited)

- We believe this is possible after last developments on TPC

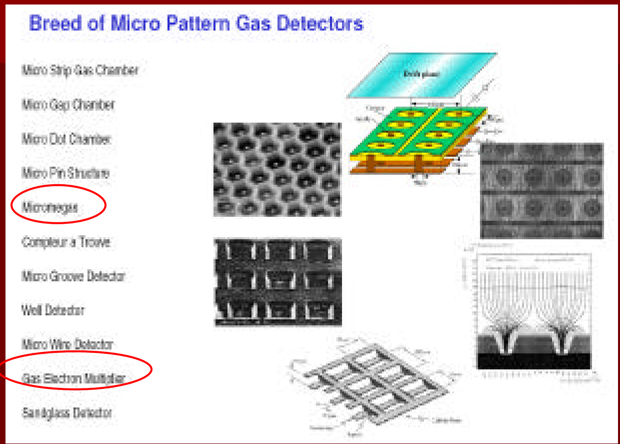
- A dedicated R&D is needed now to demonstrate these issues (as well as other technical ones)

NEXT R&D

- Energy resolution and gas mixture
  - Demonstrate in Xe
  - Role of quencher. Compromise with scintillation signal.
- T0 measurement (UV light)
- Software: simulations, topology information, backgrounds
- Mechanics (high P issues)
- Background
  - Needed radiopurity measurement program
  - Needed shielding? Active/pasive? Selfshielding?
- Readout type and design, which is best for NEXT, implications to radiopurity

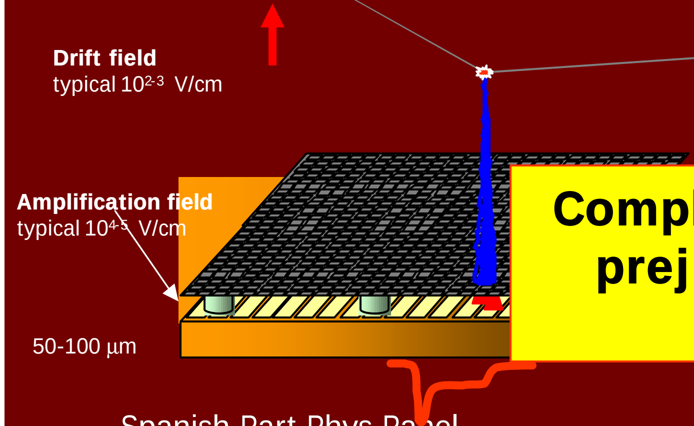
MPGD detectors: Micromegas

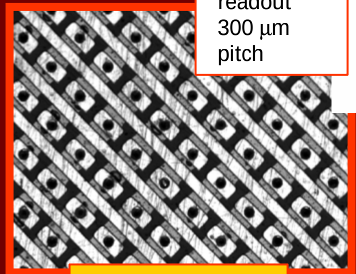
seminal idea is atributed to Oed (88)



MICROMEGAS

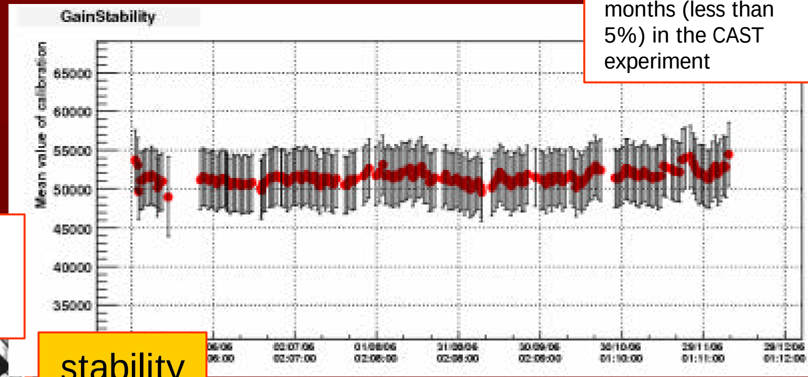
Giomataris, Charpak (96)





CAST readout 300 µm pitch

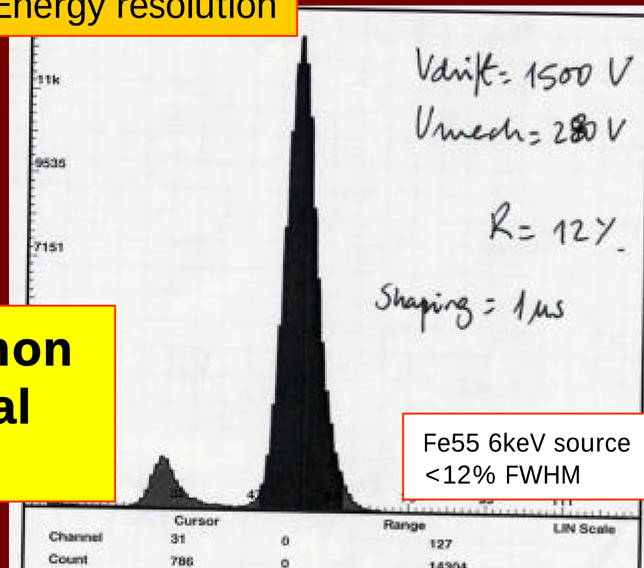
granularity



Gain stability over 7 months (less than 5%) in the CAST experiment

stability

Energy resolution

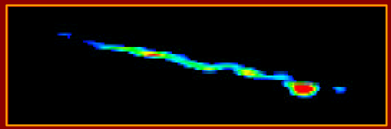


Fe55 6keV source <12% FWHM

Ease of construction

technique

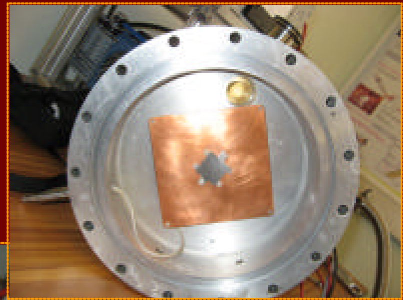
Completely overrides common prejudices on conventional multiwire TPCs

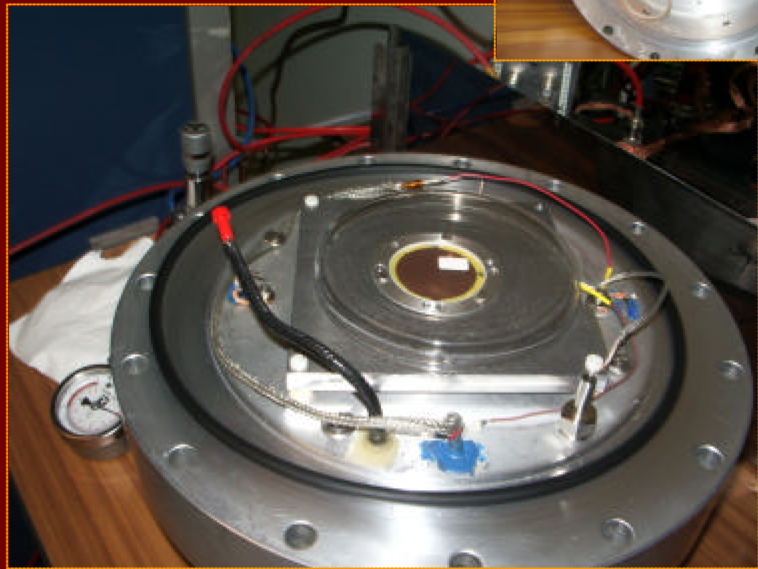


Latest work status (@ Zaragoza)

- Zaragoza-Saclay specific collaboration: Zaragoza team has set up a system of high pressure TPC in Saclay lab
  - Energy resolution of Micromegas in Ar
  - System recently upgraded with recirculation
  - Xenon measurements in a few days
- New “gas detector lab” created in Zaragoza:
  - Basic infraestructure being installed
  - Test bench for developing TPC readouts (Micromegas): gas, mixer, chamber, electronics, clean air cabin, ...
- Process of transferring Micromegas manufacturing know-how to local centers ongoing.
  - Links with local expert groups created: Instituto de Nanotecnología de Aragón e Ikerlan Centro Tecnológico de Vitoria.
  - First Micromegas entirely built in Spain just finished (to be tested in Zaragoza very soon)
- Software:
  - Background simulations in progress
  - $\beta\beta$ event Identification algorithm already created. Being optimized.

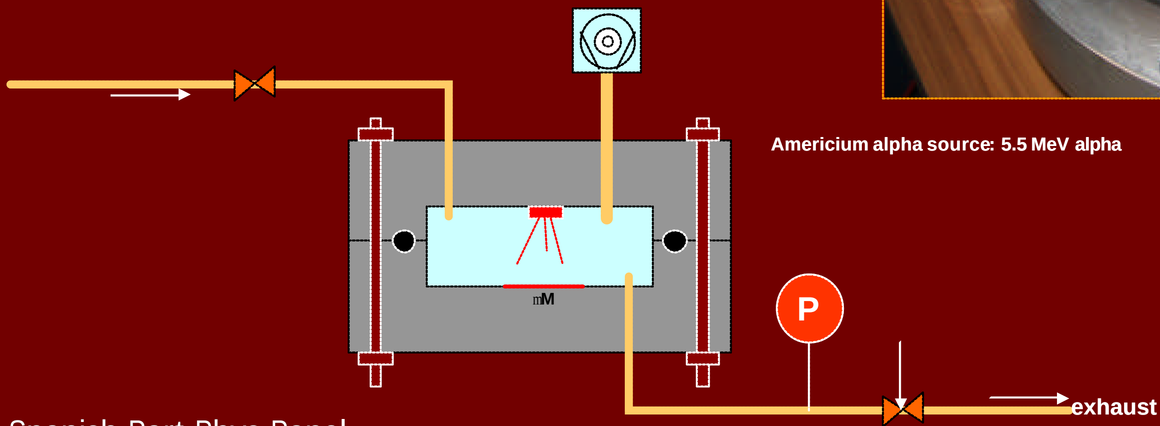
High energy resolution in Micromegas: ongoing tests





- Measurement of E resolution at high energies:
  - High pressure Ar+Isob small setup, read by new generation Micromegas readout (*microbulk*) non-pixelized anode

- Mixtures testes: Ar + Iso 2%, Ar + Iso 5%
- Pressures tested: from 1 to 5 bar



Energy resolution Measurements

- Energy resolution tested with Am alphas source (5.5 MeV)
- Best resolution obtained:

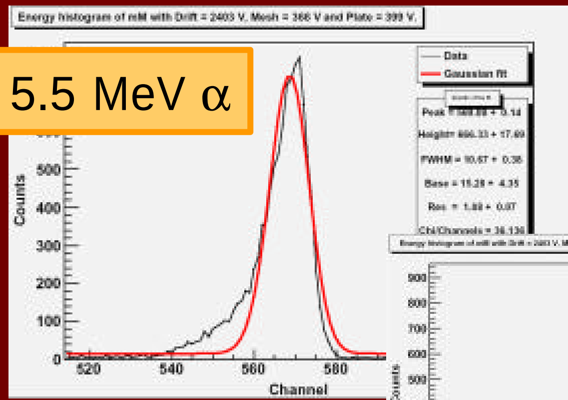
1.5 – 2 % (FWHM)

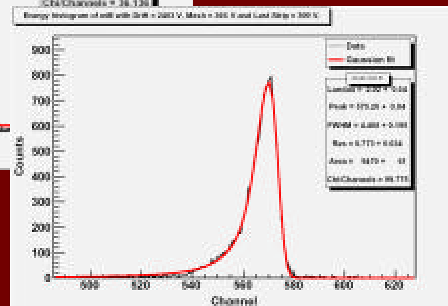
in a wide range of parameters (mesh and drift V, P, etc…)

- Landau deconvolution analysis indicate possible intrinsic Micromegas energy resolution of **0.7 % FWHM**.

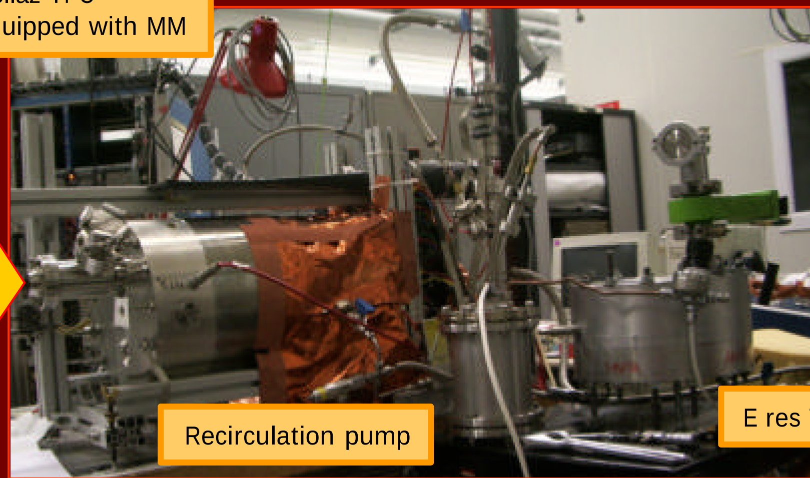
- Setup upgraded recently for same measurement in Xe (recirculation system). Mesaurements to be done in the next days.

Am 5.5 MeV α





Hellaz TPC
Equipped with MM



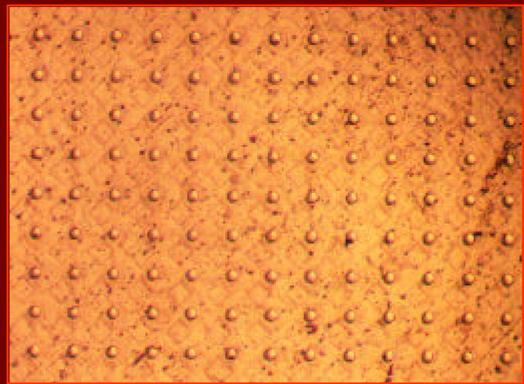
Recirculation pump

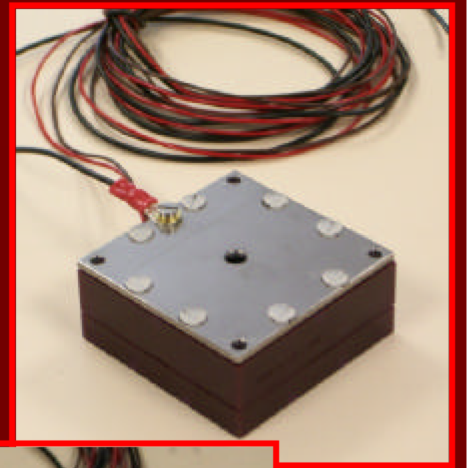
E res TPC

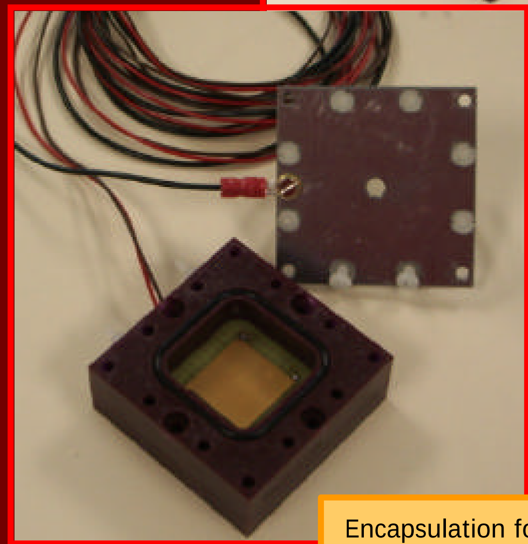
First series of Micromegas “made in Spain”

- Design by Zaragoza and built at Ikerlan facilities in Vitoria.
- Both PCB and microfabrication techniques are being used.
- Just arrived to Zaragoza for testing next days.

Views under microscope







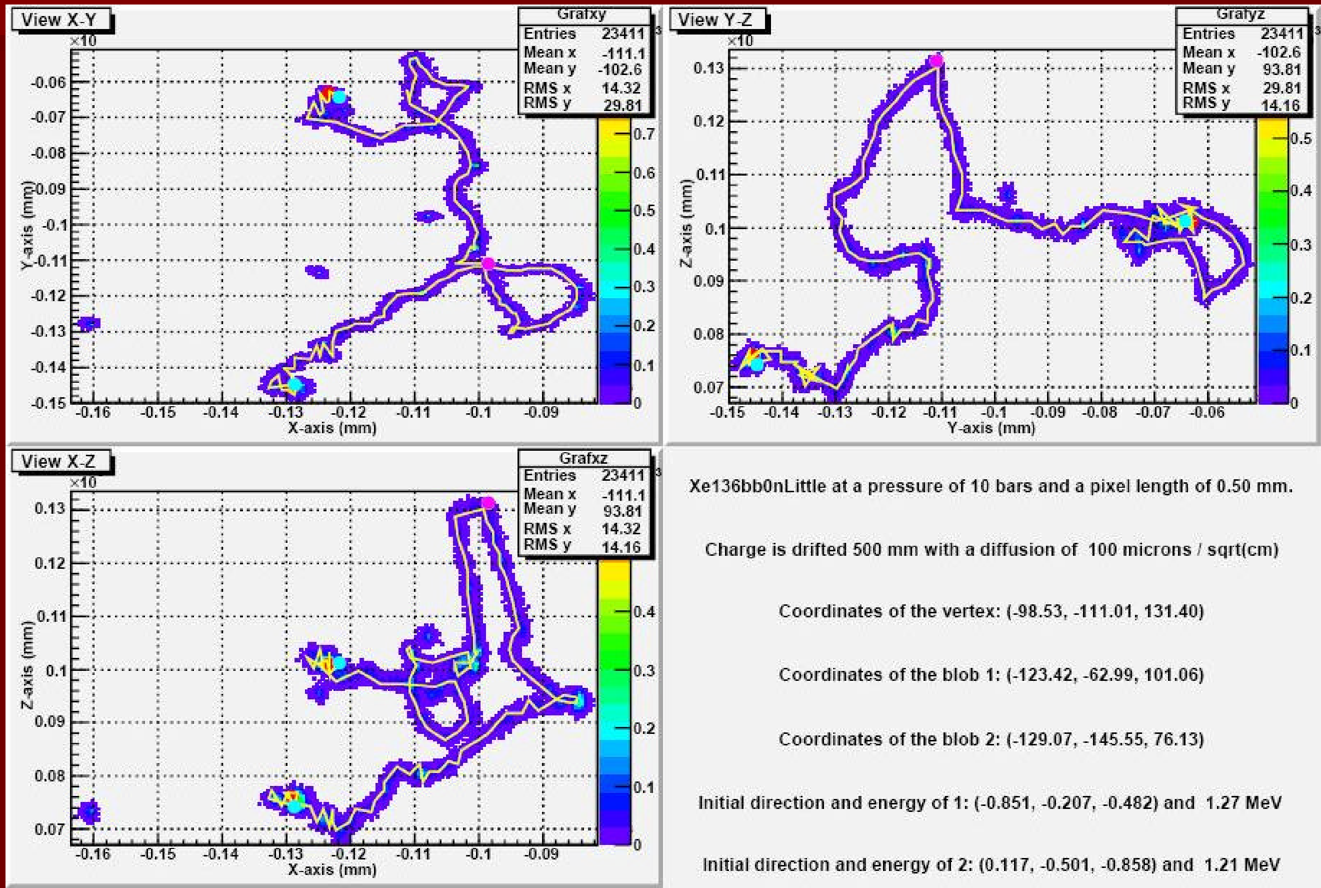
Encapsulation for tests

ββ simulations

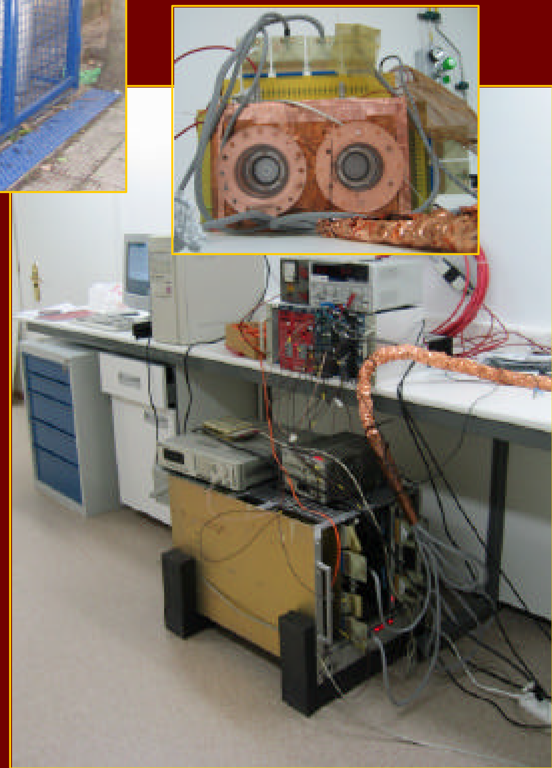
- Simulated ββ event.
- "Blob" finding algorithm.

- Very preliminarily: factor of 100 in 1 e- rejection achieved in simulations

- Much optimization pending (and experimental validation)



New “gas detector lab” in Zaragoza



Expresion of Interest to Canfranc

Expression of Interest to the Canfranc Scientific Committee

NEXT: A proposed Neutrino Experiment with a Xenon TPC

F. Nova, F. Grañena, T. Lux, F. Sánchez,
Institut de Física d'Altes Energies, IFAE, Barcelona, Spain

D. Nygren
Lawrence Berkeley Laboratory, Berkeley, USA

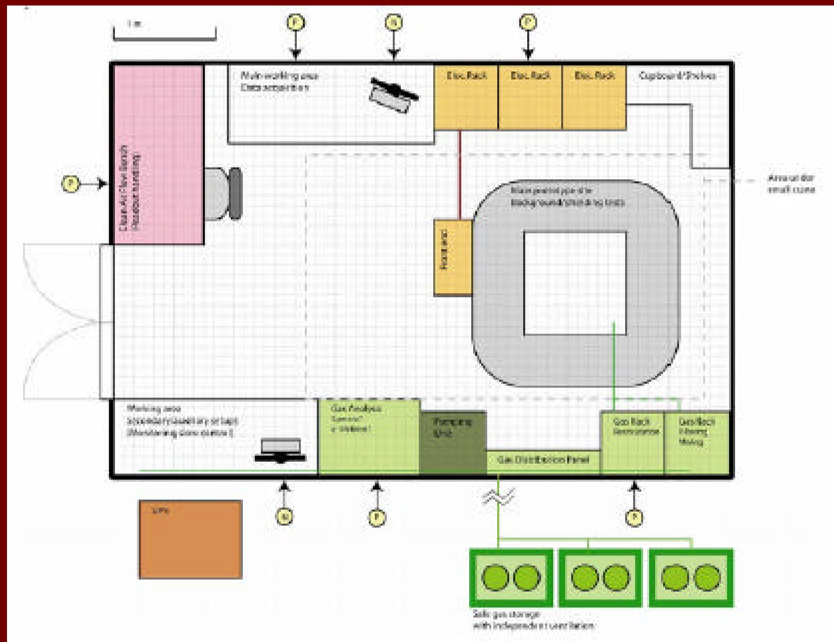
I. Giomataris, E. Ferrer-Ribas
CEA/Saclay, Paris, France

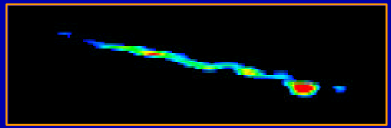
M. Ball, J. Catala, A. Cervera, J. Díaz, A. Gil, J. J. Gómez-Cadenas,
C. Hansen, J. Martín-Albo, F. Monrabal, L. Monfregola,
J. Muñoz-Vidal, P. Novella, M. Sorel, N. Yahlali
Instituto de Física Corpuscular, IFIC, CSIC - U. Valencia, Spain

R. Bravo, R. Palma, J. L. Pérez, R. Ripoll
U. Politécnica de Valencia, Spain

J. M. Carmona, S. Cebrián, Th. Dafni , J. Galn, H. Gómez,
F. J. Iguaz, I. G. Irastorza, G. Luzón, J. Morales,
A. Rodríguez, J. Ruz, A. Tomás, J. A. Villar
U. Zaragoza, Spain

- Footprint of 30 m2 area requested to LSC to perform R&D and operate the prototype





Specific objectives (2)

2.1. Simulation study of ββ event phenomenology in gas. Detector effects. Background. Discrimination by topology.

2.2. Construction of test setup (in Zaragoza and later in Canfranc) to prove feasibility. Measure and study:

- Energy resolution
- Operation at high energy (~5 bars?)
- Study T0 issue (scintillation, ion feedback,...)
- Gas mixture (role of quencher)
- Event topology

2.3. Construction of a middle scale demonstrator (few kg Xenon) for underground operation

- Background issues underground
- Electronics

2.4. Evaluation of results, and assessment towards a conceptual design for a large scale TPC for ββ. Letter of intent or experimental proposal to Canfranc.

axions
at CERN

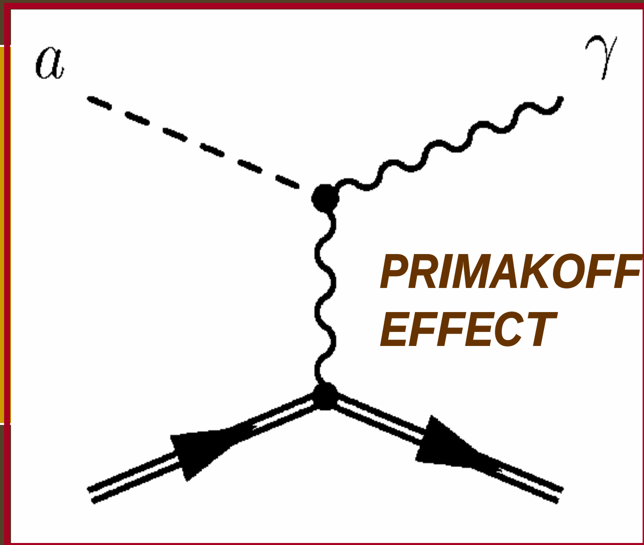
AXION motivation

$$\mathcal{L}_{CP} = \theta \frac{\alpha_s}{8\pi} G\tilde{G}$$

- **Strong CP problem:** why strong interactions seem not to violate CP?
  - CP violating term in QCD is not forbidden. But neutron electric dipole moment not observed.
- Natural answer if Peccei-Quinn mechanism exist.
  - New U(1) global symmetry → spontaneously broken.

$$\frac{\alpha_s}{8\pi f_a} a G\tilde{G}$$

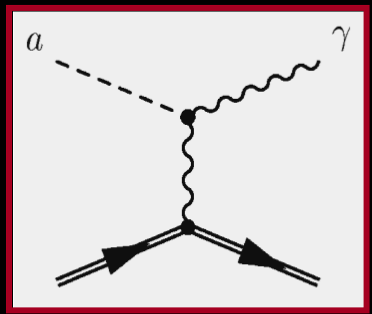
- As a result, new pseudoscalar, neutral and very light particle is predicted, **the axion.**
- It couples to the photon in every model.

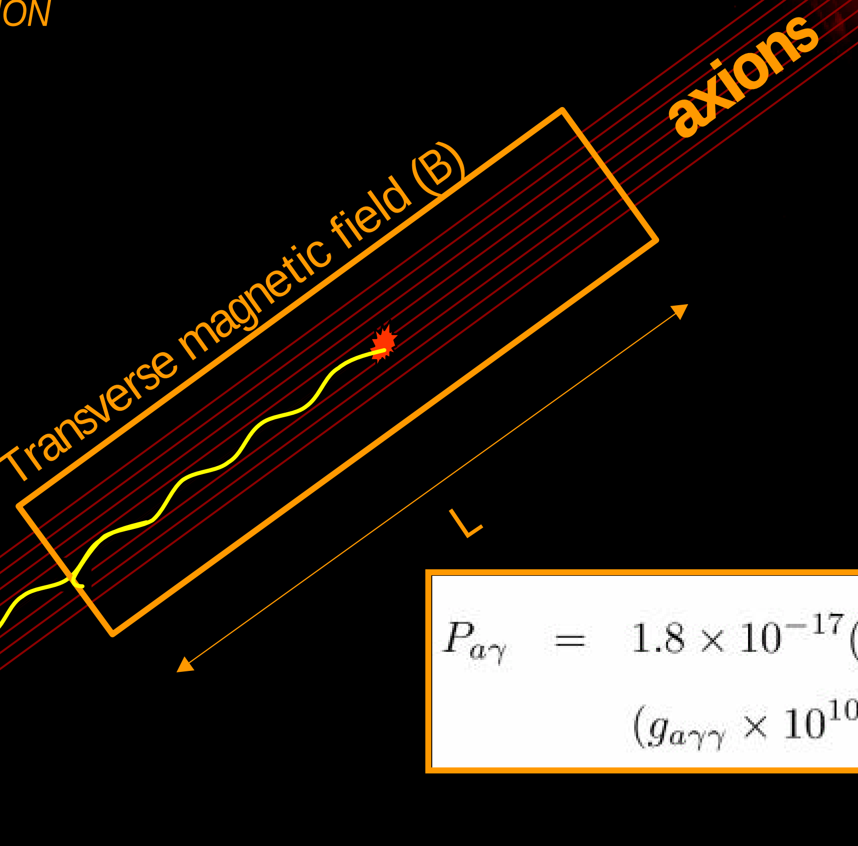


CAST principle

- Axion helioscope [Sikivie, PRL 51 (87)]

AXION PHOTON CONVERSION





$$P_{a\gamma} = 1.8\times 10^{-17}\left(\frac{B}{8.4T}\right)^2\left(\frac{L}{10m}\right)^2 \left(g_{a\gamma\gamma}\times 10^{10}GeV^{-1}\right)^2 \underbrace{|\mathcal{M}|^2}_{\textit{COHERENCE}\ \ 1},$$

ApPEC reccomendations

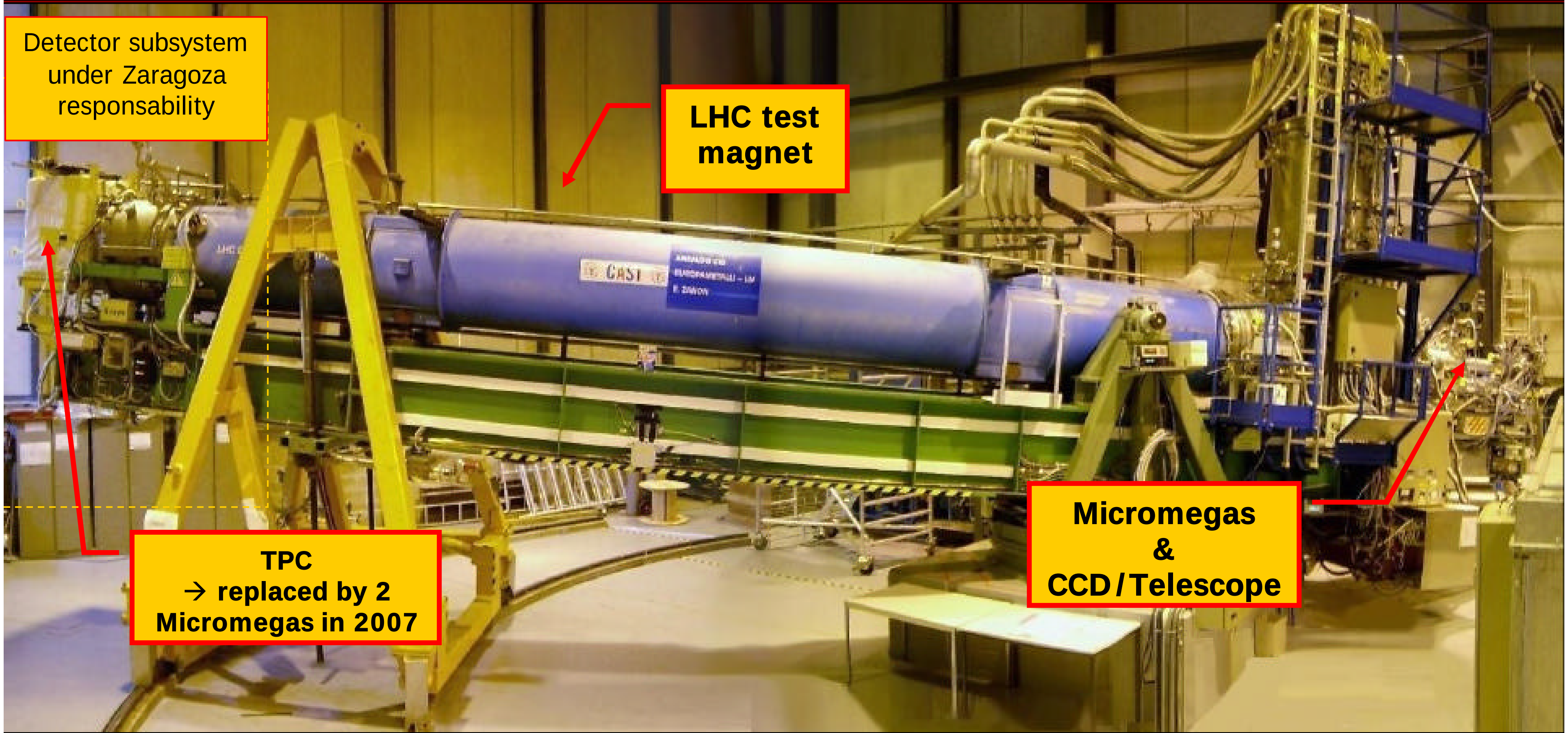
...about CAST...

pursued in the USA and Japan. In Europe, a search for solar axions is performed with the CAST experiment at CERN. This search covers a range of axion parameters which would correspond to a hot dark matter particle, similar to neutrinos. Therefore, CAST is complementary to the US and Japanese efforts.

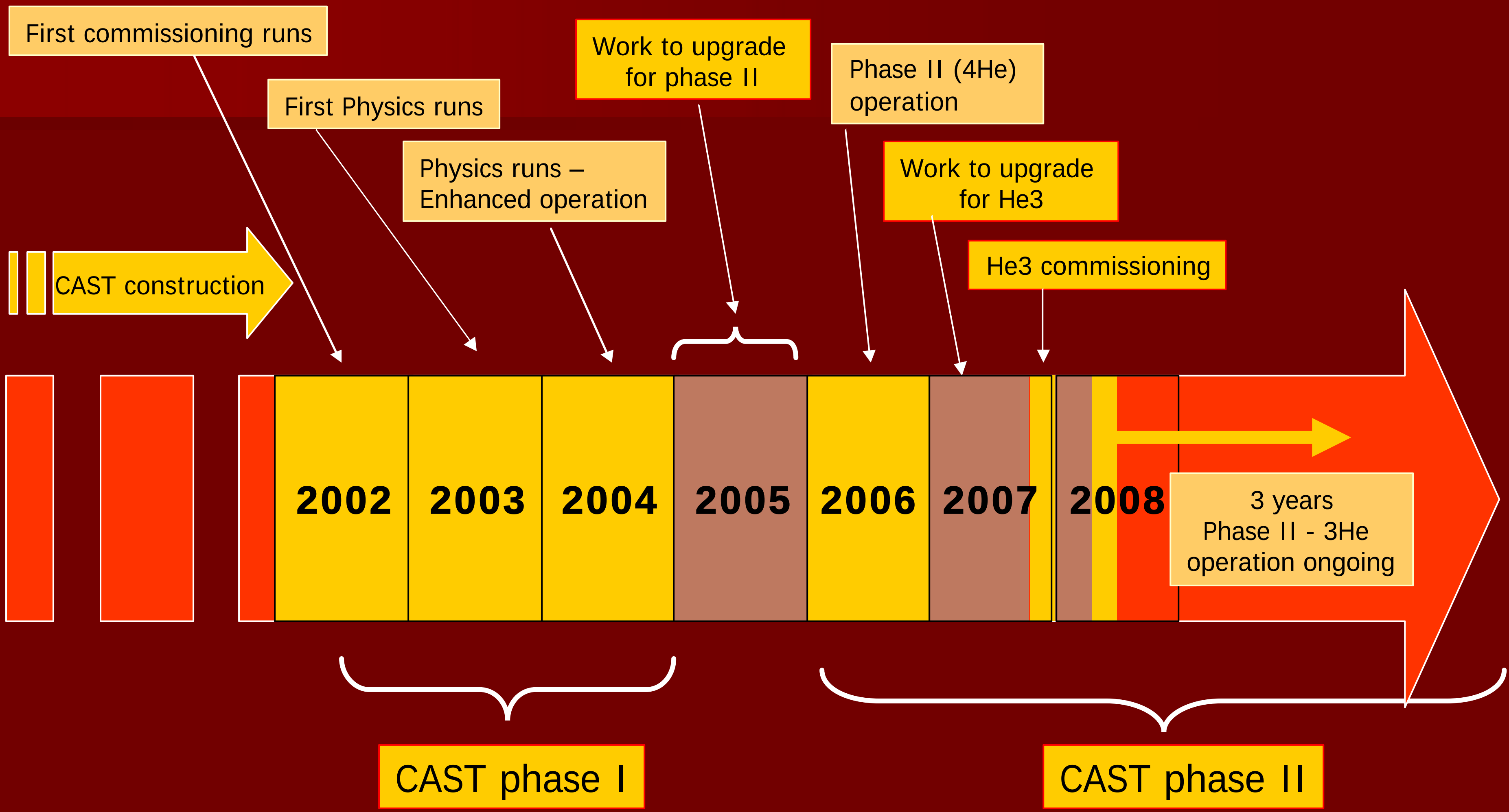
The CAST experiment should be continued to cover the full range of axion masses that is accessible by this technique.

*ASPERA Roadmap, phase I, October 2006.

CAST setup overview



CAST history

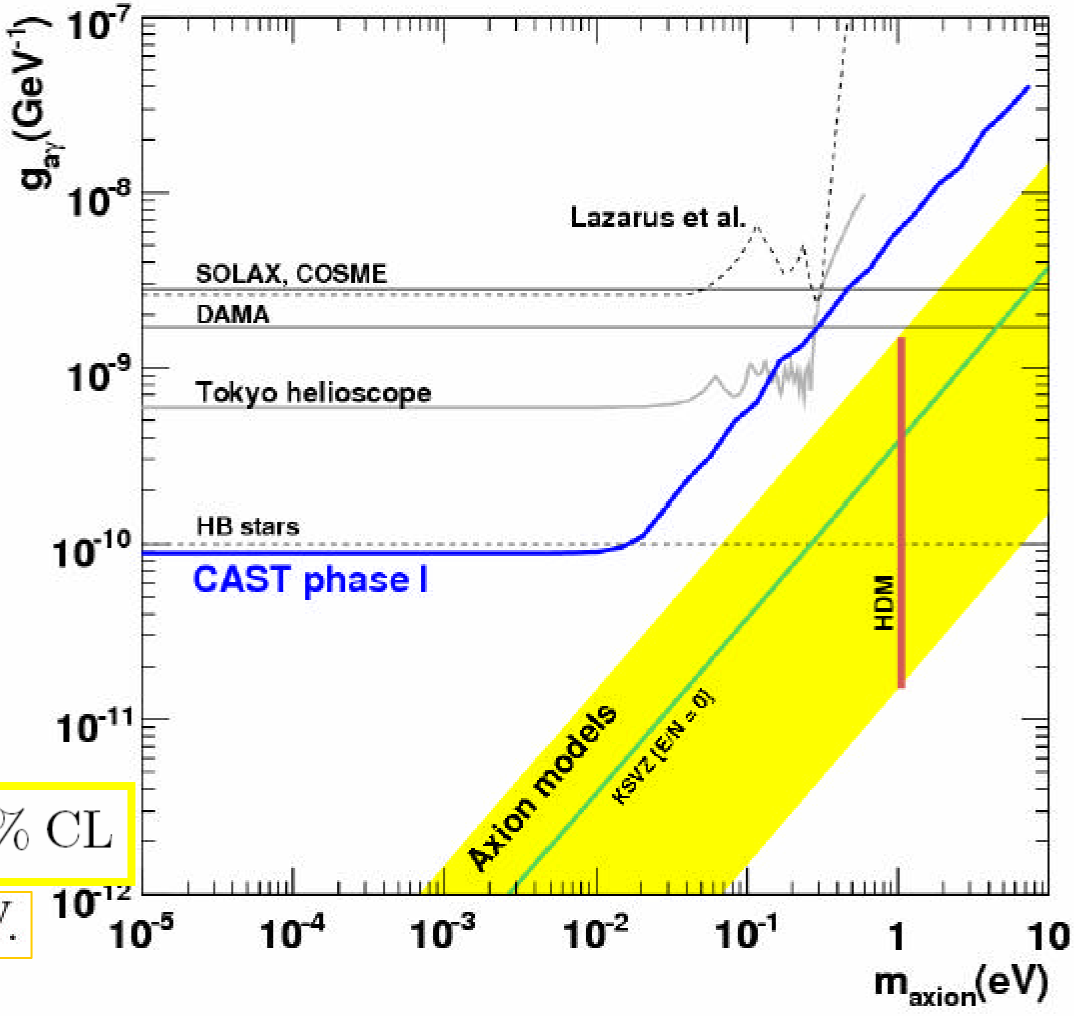


Phase I final result

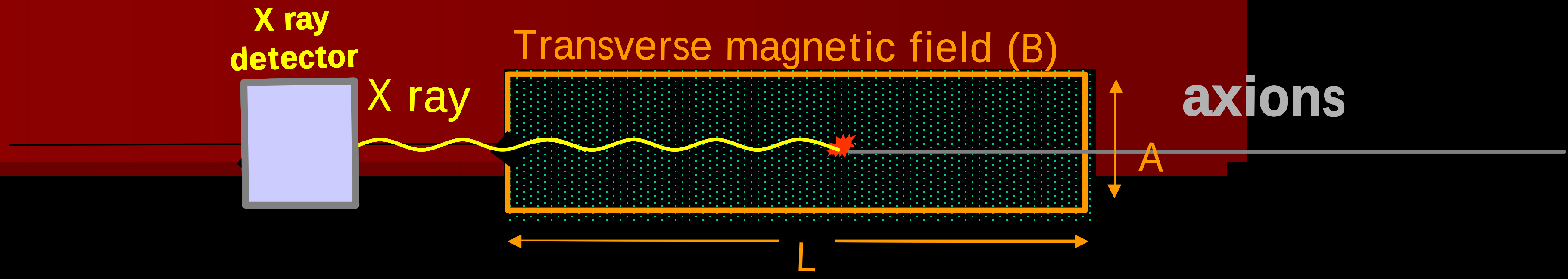
- New exclusion plot, including all phase I data improves last 2003 result
- Factor of 7 improvement beyond previous experimental searches.
- It goes beyond astrophysical limit of globular clusters for coherence masses
- **Published JCAP 0702:010,2007**

$$g_{a\gamma} < 8.8 \times 10^{-11}\,\mathrm{GeV}^{-1} \text{ at } 95\%\ \mathrm{CL}$$

for $m_a < 0.02$ eV.



CAST phase II – principle of detection



Extending the coherence to higher axion masses...

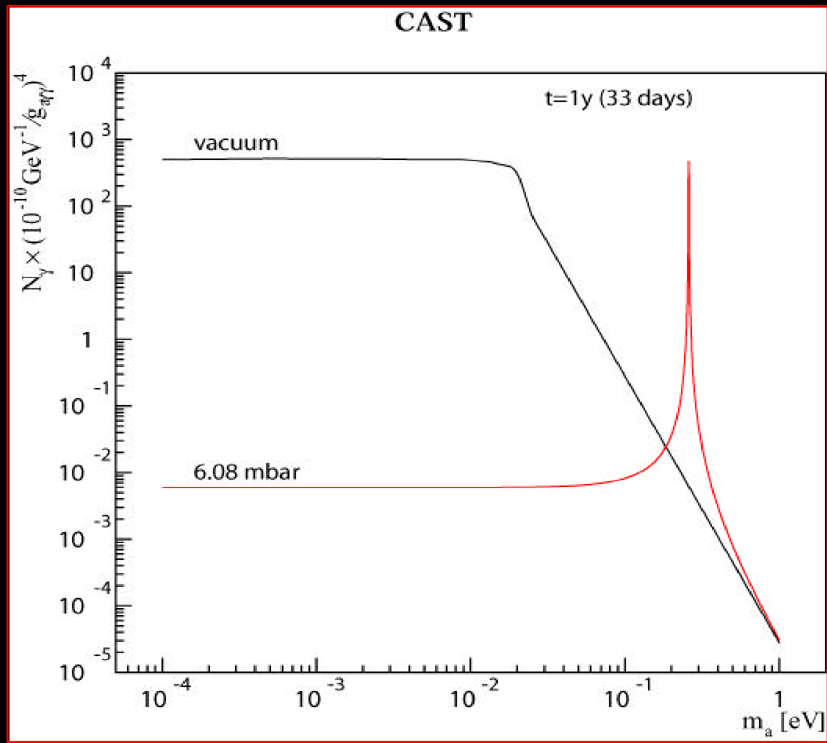
•Coherence condition (qL << 1) is recovered for a narrow mass range around m_γ

$$|q| = \frac{m_a^2 - m_\gamma^2}{2E}$$

$$m_\gamma \approx \sqrt{\frac{4\pi\alpha N_e}{m_e}} = 28.9\sqrt{\frac{Z}{A}\rho} \quad \mathrm{eV}$$

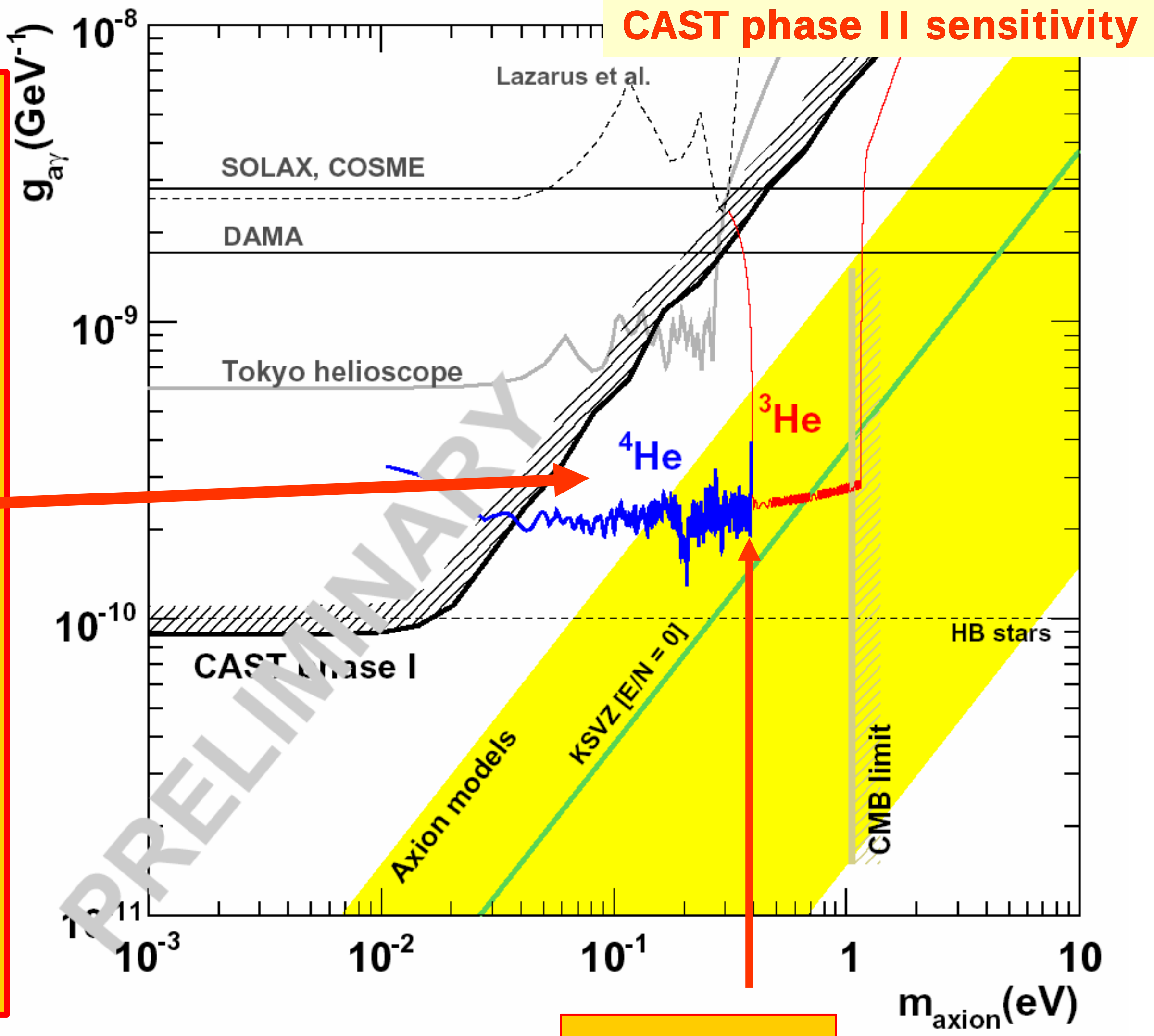
N_e: number of electrons/cm^3

ρ: gas density (g/cm^3)

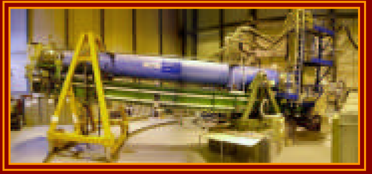


Phase II operation (^{4}He and ^{3}He)

- Data taking with 4He performed all along 2006
- ~160 density steps performed, reaching ~13 mbar (~0.39 eV)
- Exclusion plot obtained after analysis (preliminary)
  - QCD axion models region is entered !!.
- Analysis being finalised: 4He paper in preparation
- ^{3}He phase recently started (shown expected sensitivity)



~13 mbar
~0.39 eV

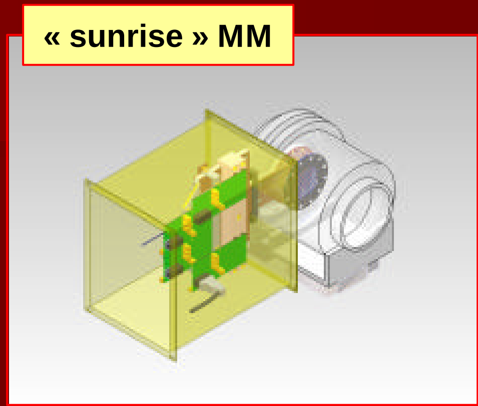


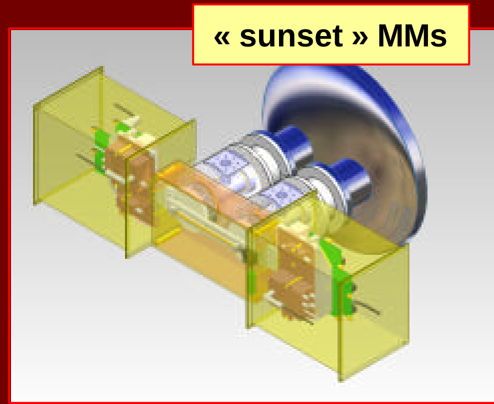
Latest work status (@ Zaragoza)

- Participation in He3 data taking:
  - Zaragoza group is the one taking a larger fraction of data taking shifts
  - Run coordination
- Responsabilities on overall experiment:
  - Shift coordination (until June)
  - Analysis coordination
- Analysis of TPC data from the He4 phase being finalised for inclusion in paper in preparation.
- New detectors for CAST:
  - TPC replaced last year by 2 new Micromegas detectors built in collaboration with Saclay and Athens.
  - TPC setup (shielding, calibrator, diff. Pumping, etc…) adapted to the new detectors.
  - Software for analysis of new detectors in preparation (first version already operational)

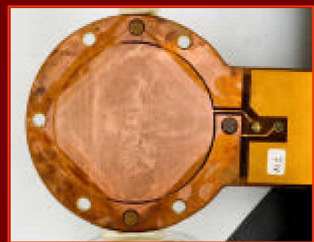
New detectors for CAST

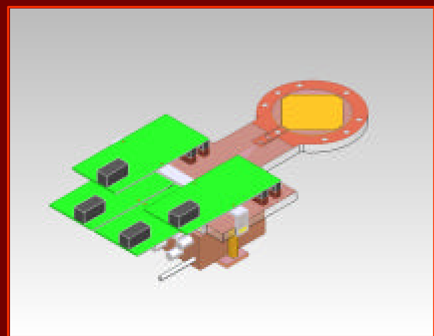
- At the sunset side, replace conventional multiwire TPC.
- At the sunrise side, replace old un-shielded MM, with a more optimized design (very small space), able to accommodate shield and a possible X-ray focusing device.
- Higher efficiency.
- Lower background (shielding)
- Robustness

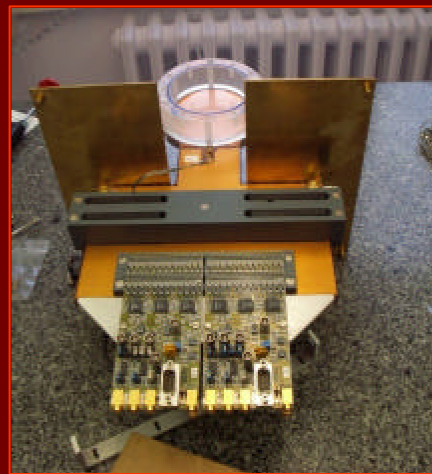




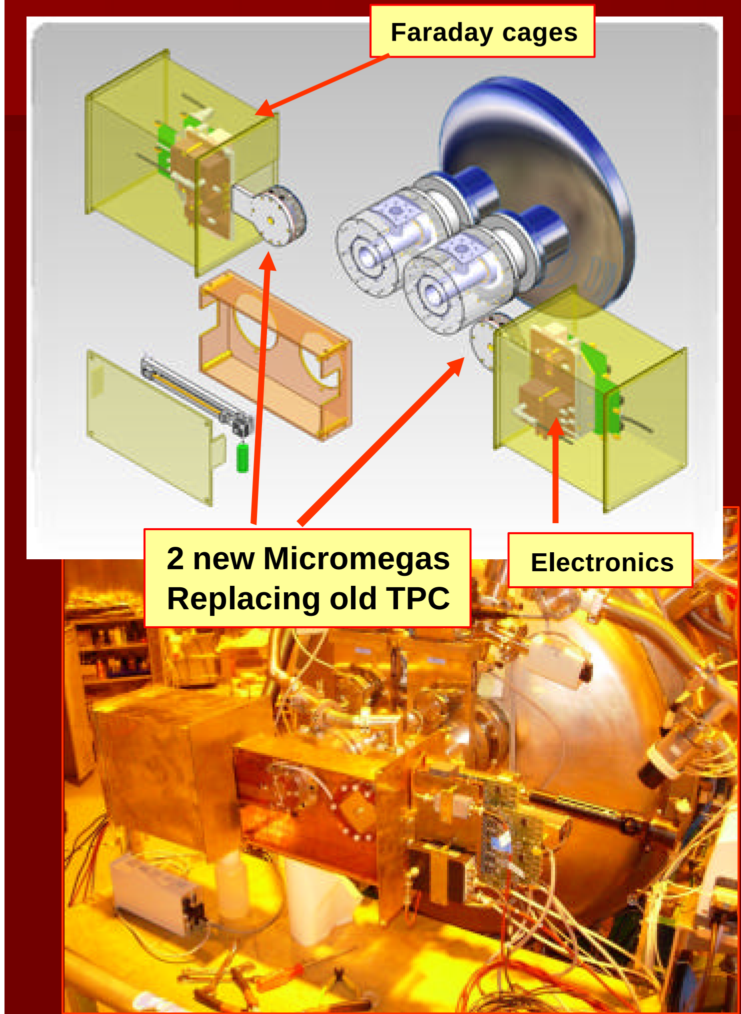
- NEW DESIGN:
  - Microbulk technology
  - 106 × 106 strips, 0.5 mm pitch
  - Compact construction to fit with shielding
  - Very good energy resolution
  - Same mechanics for both sunset and sunrise

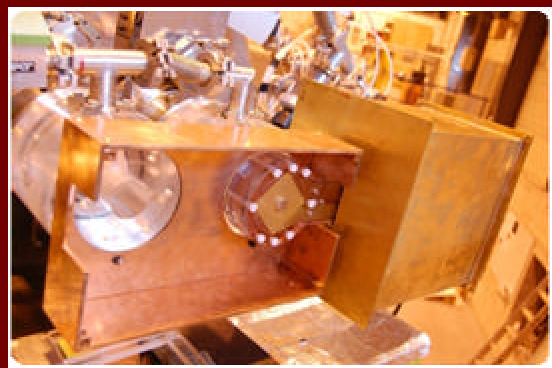






New “sunset” CAST Micromegas

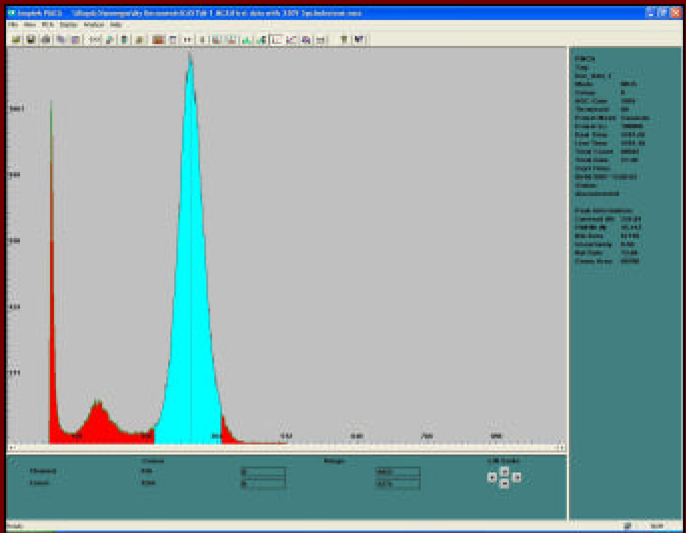


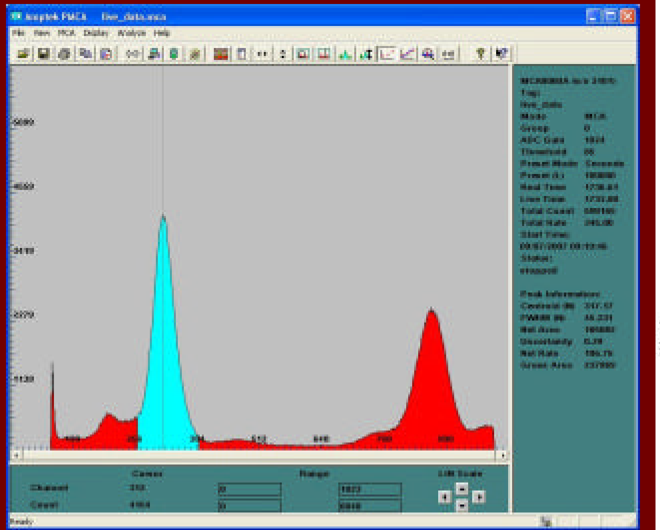


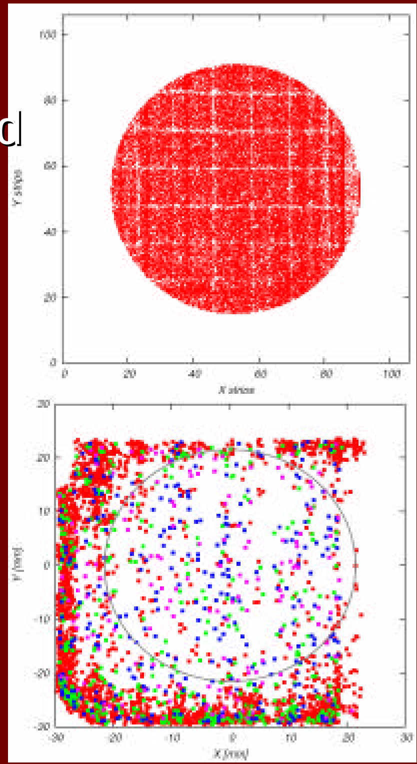
- TPC shielding and setup adapted to the new detectors…

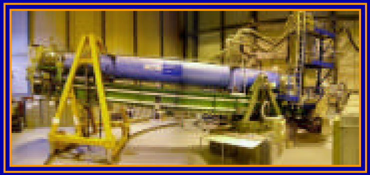
First data with new detectors

- Energy resolution:
  - @ 5.9 keV~13% FWHM
  - @ 8 keV~14% FWHM
- 2D hit maps:
  - Calibration
  - background









Specific objectives (3)

3.1. Participation in the CAST collaboration. Contribution to the **general operation and maintenance** of the experiment as a whole.

1. Common fund.
2. Shift & run coordination quota.
3. Collaboration meetings, analysis coordination, etc...
4. Specific contributions to other detector subsystem expected from Zaragoza, especially **detector background simulations**, shielding design and construction and generic assistance in low background issues.

3.2. Full responsibility of the **sunset detector system** (former TPC setup, now 2 new Micromegas detectors)

1. Continuous presence at CERN to supervise the operation of the detector
2. Maintenance tasks
3. Data analysis and interpretation

Group

Name	FTE
Jose Manuel CARMONA	50 %
Susana CEBRIAN	50 %
Theopisti DAFNI	100 %
Gloria LUZON	100 %
Igor G. IRASTORZA	100 %
Julio MORALES	100 %
PhD Students:	
Jaime RUZ	100 %
Asunción RODRIGUEZ	100 %
Francisco J. IGUAZ	100 %
Alfredo TOMAS	100 %
Total	9 FTE

- Signataires of the project
  - 4 FTE more than last time's request
- Non signataire manpower:
  - Some technical staff (University, ILIAS contracts)
  - Student at CERN currently payed by Saclay.

Methodology

<table>
<tr><th>Tasks</th><th>Persons</th><th>First Year (*)</th><th>Second Year (*)</th><th>Third Year (*)</th></tr>
<tr><td>WP1 Radiopurity: a) Evaluation and coordination</td><td rowspan="4"><u>JM</u>, <u>SC</u>, JMC, AR, AT, P1</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>b) Setup new infrastructure</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>c) Perform measurements</td><td>| | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>d) Analysis and interpretation</td><td>| | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>WP2 BiPo: a) Development and b) Simulation</td><td rowspan="5"><u>SC</u>, <u>JM</u> , GL, FJI , AR, P1</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>c) Construction/installation tasks</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>| | | | | | | | | | |</td></tr>
<tr><td>d) Analysis</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>e) Final design</td><td>| | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td></tr>
<tr><td>f) Commissioning and operation</td><td>| | | | | | | | | | |</td><td>| | | | | | | | | | |</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>WP3 Software: all subtasks</td><td><u>GL</u>, ThD, FJI, SC, AR, AT</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>WP4: Radon: a) Radon-free air factory</td><td rowspan="4"><u>JMC</u>, <u>JM</u> , GL, ThD, IGI</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>b) Radon measurement</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>c) Simulation tasks</td><td>| | | | | | | | | | |</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>d) Radon progeny</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x|x</td><td>| | | | | | | | | | |</td></tr>
</table>

Requested budget

- Overall break-up

CONCEPTO			Ayuda que se solicita	% total
			EURO	
COSTE DE PERSONAL	CONCEPTO	COSTE IMPUTABLE		
	Costes de personal	152000.0		
	Complementos Salariales	56700.0		
	TOTAL COSTES DE PERSONAL CON CARGO AL PROYECTO		208.700	
COSTE DE EJECUCIÓN	CONCEPTO	COSTE IMPUTABLE		
	Pequeño equipamiento y material bibliográfico (a)	518500.0		
	Material Fungible (b)	275113.0		
	Viajes y Dietas (c)	136093.0		
	Varios (d)	155000.0		
	TOTAL COSTES DE EJECUCIÓN(a+b+c+d)		1.084.706	
TOTAL COSTES DIRECTOS			1.293.406	**100,00%**
TOTAL COSTES INDIRECTOS			271.615	
TOTAL COSTES DIRECTOS (Directos + Indirectos)...			1.565.021	**100,00%**

Equipment break-up

Descripción	Coste Imputable EURO	Justificación de uso
Materiales de blindaje de detectores para CAST	10.000	destinado a la modificación o ampliación del blindaje actual (WP6. CAST @ CERN)
Equipamiento de vacío o sistema de gases para CAST	6.000	destinado a la sustitución de piezas, actualización y mantenimiento en general del sistema actual (WP6. CAST @ CERN)
Equipamiento electrónico e informático para CAST	21.000	destinado a la sustitución actualización de módulos y mantenimiento en general (WP6. CAST @ CERN)
Equipamiento para la medida y monitoraje de la pureza de gases, especialmente trazas de oxígeno y agua	42.000	Necesario para la construcción del banco de pruebas de TPCs en Zaragoza y Canfranc
Material inventariable relacioinado con medida y control de gases (medidores de presión, caudalímetros, mezcladores, etc¿)	20.000	Necesario para la construcción del banco de pruebas de TPCs en Zaragoza y Canfranc (WP5)
Equipamiento para bombeo/sistema de vacio	15.000	WP5. desarrollo de TPCs
Material electrónico inventariable básico (crates VME o NIM, fuentes de baja tensión, medidores, etc.¿)	19.000	WP5. desarrollo de TPCs
Electrónica de adquisición. Módulos digitales comerciales.	15.000	WP5. desarrollo de TPCs
Electrónica de adquisición. Módulos analógicos de bajo ruido (preamplificación, amplificación, etc¿)	25.000	WP5. desarrollo de TPCs
Módulos de alimentación	25.000	(WP5 TPCs)
Electrónica de adquisición especializada para TPCs (tipo flash-ADCs de múltiples canales)	20.000	Necesario para montar prototipos de TPCs con lecturas pixelizadas
Equipamiento para el slow control de prototipos	9.000	Necesario para monitorizar diversos parámetros externos (presiones, temperaturas, etc¿) de los prototipos tanto de CAST como TPCs.
Materiales para la construcción de un detector de radon y electrónica asociada. Fuente de Radón	21.000	(WP4. Estudios de Radon y factoría de aire limpio)
Actualización y refuerzo del cluster de simulación existente (ampliación del número de nodos y de la capacidad de disco)	8.000	(WP3 Software. Simulación. Diseño de prototipos de BiPo)
Equipamiento para el slow control de los prototípos de BiPo	12.000	(WP2 Prototipos de BiPo)
Equipamiento para el desarrollo de distintas opciones de BiPo	18.000	(WP2 Prototipos de BiPo)
Grua y polipastos para el manejo diario de los blindajes de los detectores	12.000	Necesarios mara el manejo diario de los blindajes (abrir, cerrar,...) para la colocación de las muestras a medir
Set fuentes de calibración y campana de preparación de muestras	4.500	(WP1. Medidas de radiopureza en BiPo-SNEMo)
Electrónica para la actualización de los sistemas de adquisición de los detectores existentes	18.000	(WP1. Medidas de radiopureza en BiPo-SNEMo)
Sondas y adaptadores	3.000	Slow control del banco de medidas de radiopureza en BiPo-SNEMO
2 detectores de Ge hiperpuro de 2 Kg y su electrónica asociada	188.000	Nuevos detectores para el banco de medida de radiopureza en LSC (WP1. Medidas de radiopureza en BiPo-SNEMo)
Informática (PCs para la adquisición de espectros y el slow control de la granja de detectores en LSC)	3.000	(WP1. Medidas de radiopureza en BiPo-SNEMo)
Informática (PCs de alto rendimiento para la coordinacion de las medidas de radiopureza)	4.000	Coordinación del WP de medidas de radiopureza de materiales en SuperNEMO: creación y explotación de bases de datos, páginas Web para la distribución de resultados y gestión de solicitudes de medida.
TOTAL	518.500	

Travels and subsistence break-up

Descripción	Coste Imputable EURO	Justificación de uso
Viajes y estancias en el CERN para la ejecución del experimento (Reuniones de la colaboración, Turnos de medida, turnos de apoyo, actuaciones de mantenimiento y asistencia a congresos-presentación de resultados)	66.000	Estimados a partir de los gastos y presencia de los últimos años.
Gastos de viaje a reuniones de coordinación y/o conferencias	8.000	WP5. Desrrollo de las TPCs
Gastos de viaja al LSC y a Saclay para la construcción y la operación de los prototipos de la TPCs	14.400	WP5. Desrrollo de las TPCs
Viajes para la coordinación de la instalación de la factoría de aire limpio (LSC: 4pax/tsemana, 6 semanas,2 días; Praga: 2 viajes a 1500eur)	6.600	WP4 Estudios de Radon
Viajes para la coordinación del grupo de software (LSC: 1pax/trimestre 3 años 2 días; Modane, Orsay, etc 1pax/trimestre 3 años 2 días)	9.000	(WP3 Software. Simulación. Diseño de prototipos de BiPo)
Viajes al LSC para instalación y prueba de prototipos de BiPo (2 personas/mes 2 años un día)	2.400	(WP2 Prototipos de BiPo)
Viajes al LSC para instalación de detectores y blindajes (3pax/semana*4 sem*5dias/viaje)	14.175	(WP1. Medidas de radiopureza en BiPo-SNEMo)
Viajes rutinarios al LSC para realizacion de medidas (0,5pax/semana, 1 día)	8.438	(WP1. Medidas de radiopureza en BiPo-SNEMo)
Viajes de Coordinación del WP medida de radiopureza de SNEMO. Viajes al LSC, Modane, Burdeos, Orsay	7.080	(WP1. Medidas de radiopureza en BiPo-SNEMo)

TOTAL	136.093

Personnel break-up

Perfil	Coste imputable	Justificación de necesidad y tareas que realizará
Doctorado	76.000	P1.- Licenciado o doctor en Físicas, con experiencia en técnicas de bajo fondo y conociendo el personal del Laboratorio Subterráneo de Modane (LSM) y sus instalaciones de radiopureza, para realizar un trabajo activo de protocolización y coordinación, junto con el LSM y el resto de usuarios del banco de medidas de radiopureza a extender y operar en el LSC a lo largo del presente proyecto. Esta persona controlará el flujo de muestras de materiales a medir para todas las actividades del proyecto (SN/BiPo, CAST y desarrollo de TPCs), su evaluación y distribución entre los distintos detectores disponibles. También se encargará de mantener la base de datos con los resultados de las medidas y asegurar el acceso a los mismos a todos los usuarios (como, por ejemplo, los miembros de la colaboración SN)
Doctorado	76.000	P2.- Licenciado o doctor en Físicas, con experiencia en la operación de TPCs en general y/o de planos de lectura Micromegas en particular. Esta persona participará sobre todo en las actividades de desarrollo con este tipo de detectores, especialmente en el montaje y operación del banco de pruebas previsto y los prototipos. Asistirá asimismo en las actividades relacionadas como las tareas de simulación de TPCs, o las tareas de mantenimiento de los detectores Micromegas de CAST, bajo la responsabilidad del grupo.

Complementos Salariales	56.700
TOTAL	208.700

Consumables break-up

Descripción	Coste Imputable EURO	Justificación de uso
Gastos de mantenimiento de los detectores en CAST. Gases para los detectores, pequeñas piezas de remplazo para los calibradores, consumibles informática, gastos en comunicaciones, otro pequeño material e imprevistos	21.000	(WP6. CAST at CERN)
Gastos de los servicios de mecánica de precisión o electrónica	9.000	(WP6. CAST at CERN)
Material electrónico básico (cables, crates, etc.¿)	10.000	Necesario para la construcción del banco de pruebas de TPCs en Zaragoza y Canfranc (WP5 TPCs)
Gases habituales para operación de detectores (bajo caudal durante 3 años) y gases especiales (Xe, ¿).	18.000	Cálculo supuesto 2000 LN de Xe (WP5 TPCs)
Gastos de instalación de sistemas de distribución de gas.	18.000	Necesario para la construcción del banco de pruebas de TPCs en Zaragoza y Canfranc (WP5 TPCs)
Costes del servicio de mecánica de precisión (materia prima y mano de obra)	13.000	Incluye la realización de vasijas de gas para alta presión donde contener las TPCs prototipos (WP5 TPCs)
Costes de producción de nuevos planos de lectura Micromegas usando tecnología de microfabricación	36.000	Exploración de nuevos sistemas de manufacturación de alta precisión (WP5 TPCs)
Costes de producción de nuevos planos de lectura Micromegas usando tecnología de litografía de circuitos impresos	22.000	Planos de lectura para los prototipos de TPCs. Pruebas de planos desde el punto de vista del bajo fondo. (WP5 TPCs)
Materiales para completar los blindajes de los prototipos de BiPo y del detector final (10Tm de plomo, 5 Tm de cobre OFHC mecanizado, 2,5 Tm de plietileno o agua borada)	61.200	Solo se presupuesta la mitad del material necesario. (WP2 Prototipos de BiPo)
Gastos imprevistos	3.000	(WP1. Medidas de radiopureza en BiPo-SNEMo)
Gastos de instalación en el LSC de dos nuevos detectores HPGe	6.000	Gastos de instalación en el LSC de dos nuevos detectores HPGe
Consumo de Nitrógeno liquido	5.913	Estimado para 6 detectores y un consumo medio de 1,5 l/detector (WP1. Medidas de radiopureza en BiPo-SNEMo)
Materiales para las medidas de las muestras	8.000	Elementos para la medida y preparación de las muestras (soportes, marinellis, productos químicos, pequeño material) (WP1. Medidas de radiopureza en BiPo-SNEMo)
Blindaje de 2 nuevos detectores HPGe (Plomo, Cobre OFHC, Polietileno) y gastos de construcción	44.000	Construcción de blindajes para dos nuevos detectores HPGe (WP1. Medidas de radiopureza en BiPo-SNEMo)

TOTAL	275.113

Others break-up

Descripción	Coste Imputable EURO	Justificación de uso
Coste de la factoría de aire libre de radon (confinanciada al 50% por el Laboratorio de Canfranc)	75.000	Necesaria para las operaciones de BiPo y SNEMO en el Laboratorio Subterráneo de Canfranc
Contribución al commond fund de CAST	80.000	Quota en función de los participantes, decidida por la colaboración

TOTAL	155.000

Ongoing project (2008) situation

Funds granted:
263,000 EJECUCIÓN
36000 PERSONAL

Period: 1 year (2008)

Accounting situation at 30th APRIL 2008:

TOTAL EJECUCION				
	ITEM	SALDO	%	DESV%
	SALDOS INICIALES	263,600.00		
	EJECUTADO	51,213.58	19.4	-13.9
	RESTO	212,386.42	80.6	
TOTAL PERSONAL				
	ITEM	SALDO	%	DESV%
	SALDOS INICIALES	36,000.00		
	EJECUTADO	11,904.83	33.1	-0.2
	RESTO	24,095.17	66.9	
TOTAL VIAJES Y DIETAS				
	SALDO INICIAL	42,643.67		
	EJECUTADO	25,183.85	59.1	25.8
	RESTO	17,459.82	40.9	
TOTAL INVENTARIABLE				
	SALDO INICIAL	105,372.08		
	EJECUTADO	21,409.96	20.3	-13.0
	RESTO	83,962.12	79.7	
TOTAL FUNGIBLE				
	SALDO INICIAL	54,699.37		
	EJECUTADO	17,416.41	31.8	-1.5
	RESTO	37,282.96	68.2	
TOTAL OTROS				
	SALDO INICIAL	60,884.88		
	EJECUTADO	2,203.36	3.6	-29.7
	RESTO	58,681.52	96.4	

Break-up “EJECUCION”