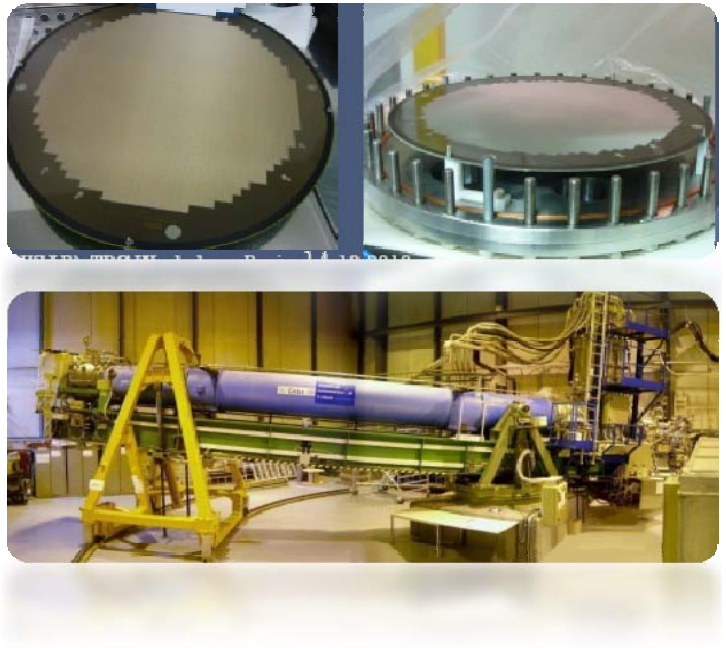
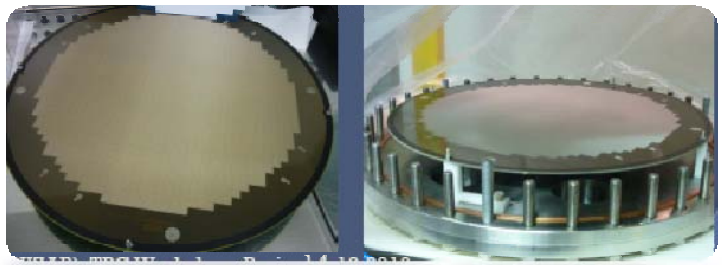
Status of R&D on Micromegas for low background applications: the T-REX project

Igor G Irastorza
Universidad de Zaragoza
CYGNUS 2011, Aussois, France
7-10 June 2011



Outline

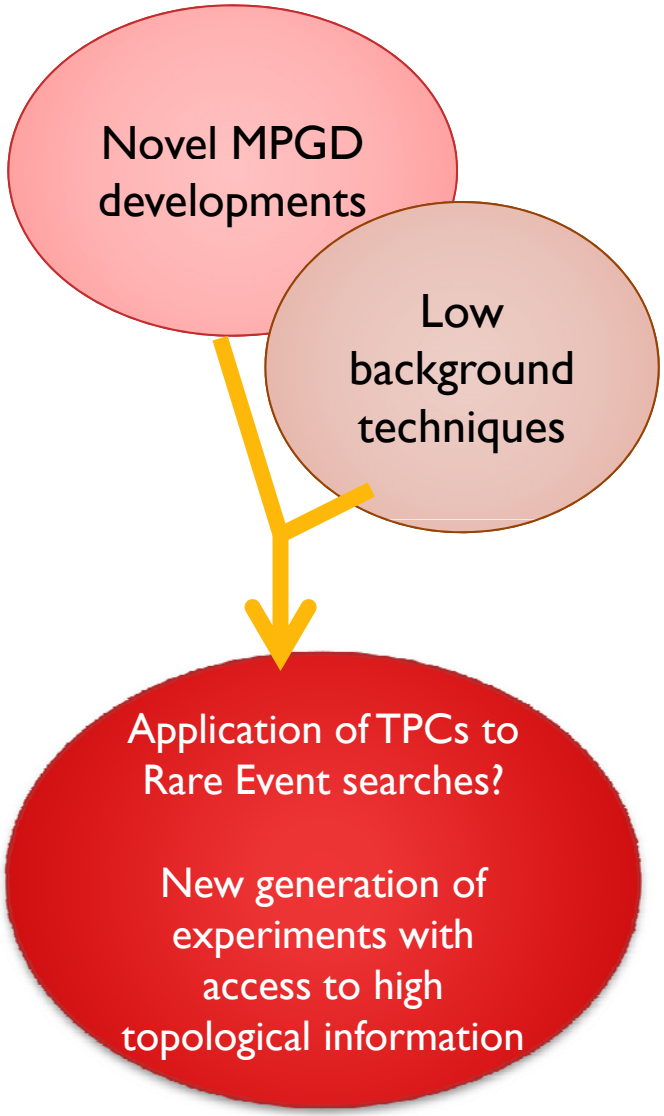
- MM readouts for rare events:
  - generic motivation
  - T-REX project
- MM readouts for axion searches (→ CAST)
- MM readout for double beta decay (→ NEXT)
- Generic results: radiopurity



- **U. Zaragoza:** J. Castel, S. Cebrian, T. Dafni, J. Galán*, J. A. García, H. Gómez, J. Gracia, D. C. Herrera, I. G. Irastorza, G. Luzón, A. Rodríguez, L. Seguí, A. Tomás, J. A. Villar
- **CEA/Saclay:** E. Ferrer-Ribas, I. Giomataris, F.J. Iguaz, J. P. Mols, T. Papaevangelou.
- **CERN**: R. de Oliveira, A. Teixeira
- **CAST** collaboration
- **NEXT** collaboration

T-REX project

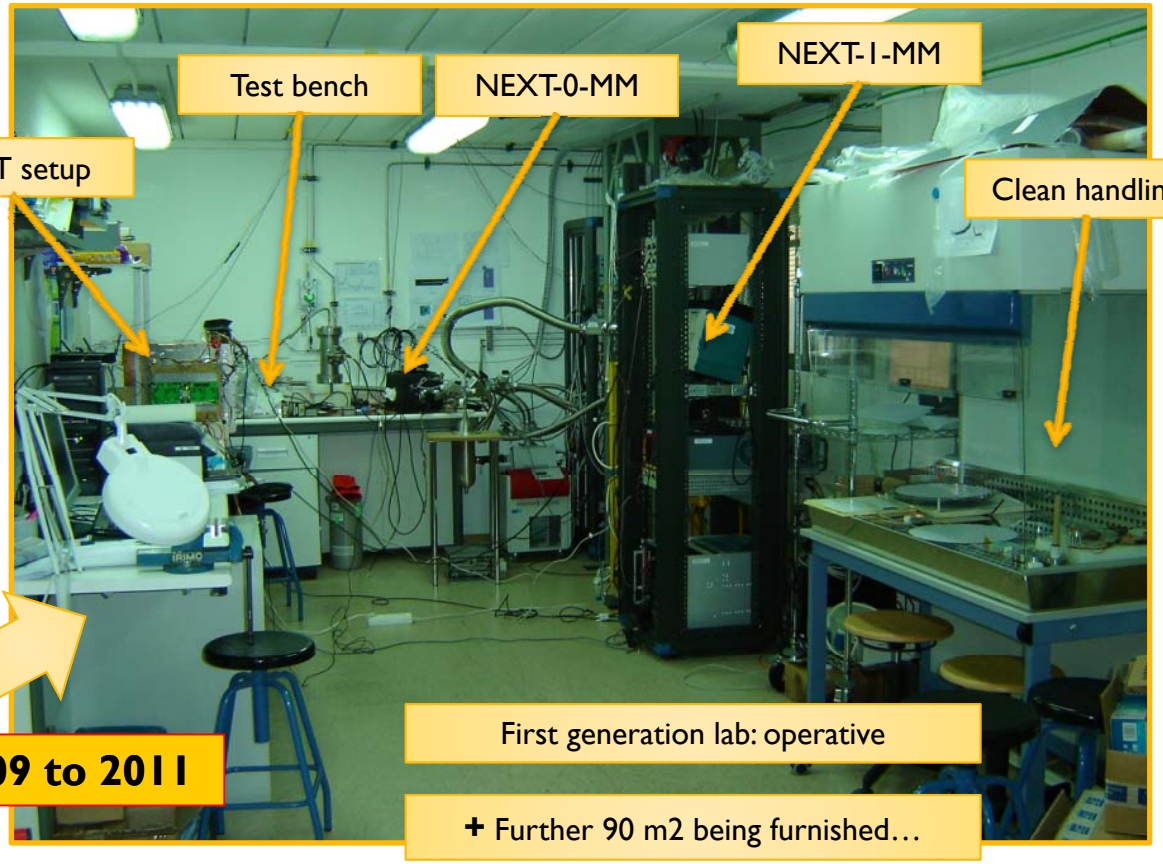
- Gas TPCs offer high potential for rare event through signal topology.
  - Example: direcionality of WIMPs!
- But, complex detector to reach high masses
- Novel readout techniques based on MPGD
- T-REX to merge MPGDs (=Micromegas) + low background expertise.
- Focus on exploratory R&D and small scale prototyping
- ERC St-G funded. IDEAS program.



T-REX: infraestructure

- New gas detector lab at UNIZAR

From 2009 to 2011



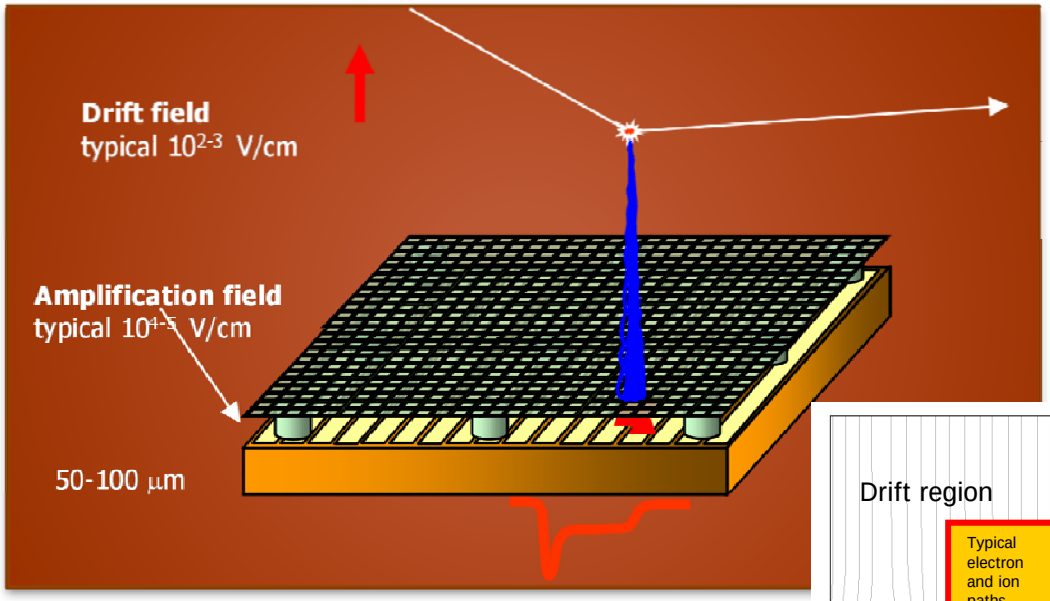
First generation lab: operative

+ Further 90 m2 being furnished…

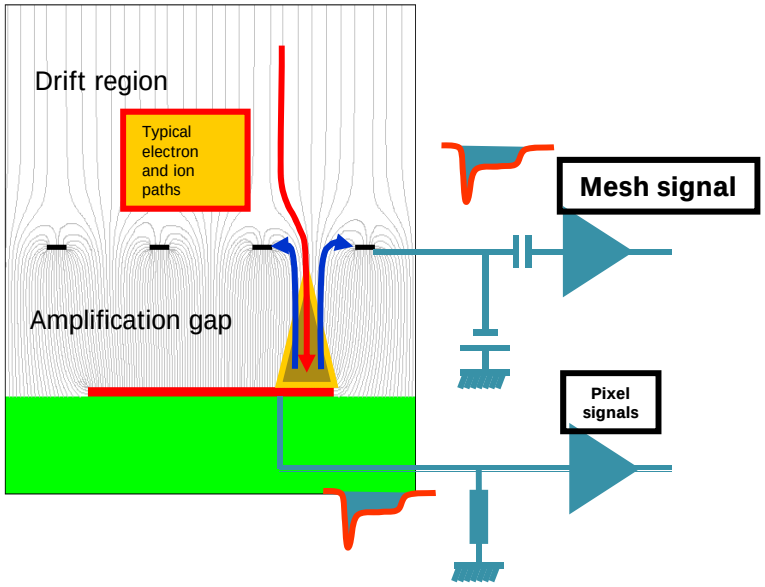
+ R&D space underground @ Canfranc

Micromegas readouts

- Giomataris, Charpak (96)

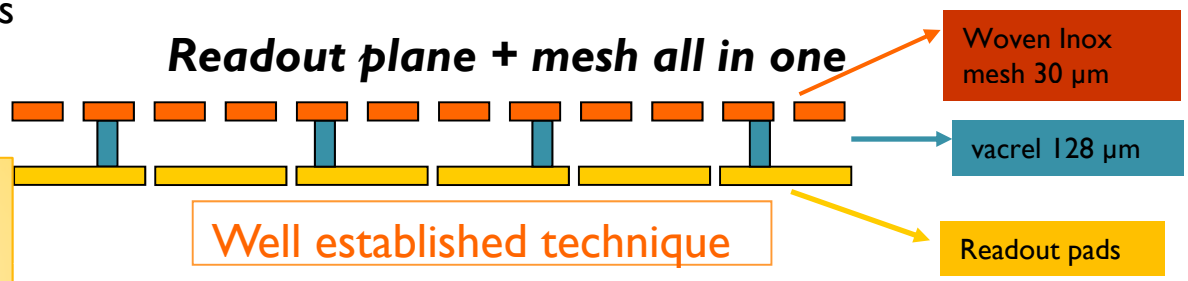


Simplicity
Granularity
Homogeneity
Large areas
…



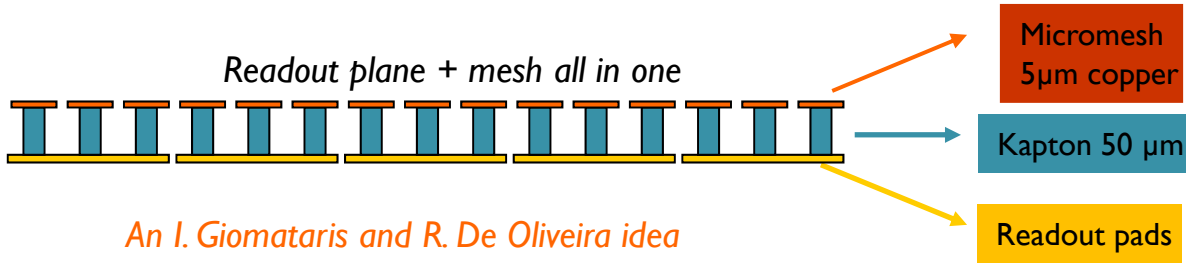
Micromegas readouts

- Bulk & microbulk techniques developed for all-in-one fabrication
  - Ease of operation
  - Large areas
- BULK



• **BULK**
Robust
Mature
Very large areas available (2 m2)

- MICROBULK



• **MICROBULK**
Higher homogeneity
Light weight, radiopure

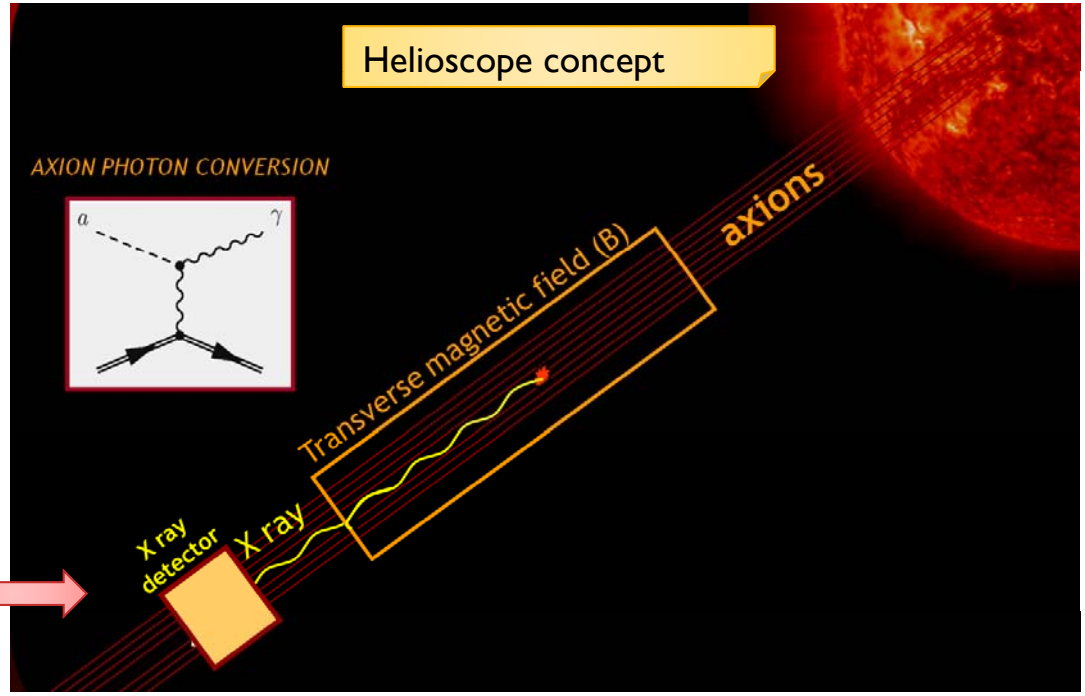
See for details:
JINST 5 (2010) P02001

Solar Axions: CAST

- Axions: hypothetical particles solving the strong CP problem, and possible dark matter candidates.
- Produced by the Sun by photon-to-axion conversion of the solar plasma photons
- Detectable via "helioscope concept" proposed by Sikivie

Background of x-ray detectors, one of the parameters driving the sensitivity

Low background x-ray detection → experimental challenge



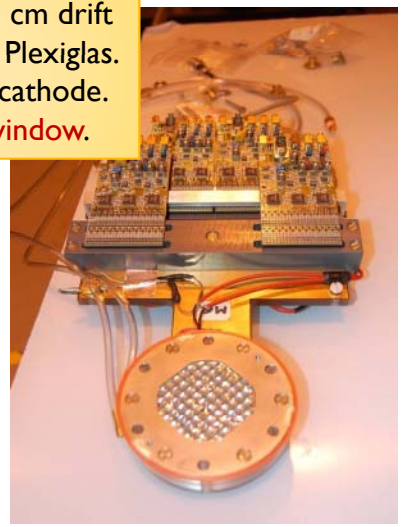
CAST experiment @ CERN

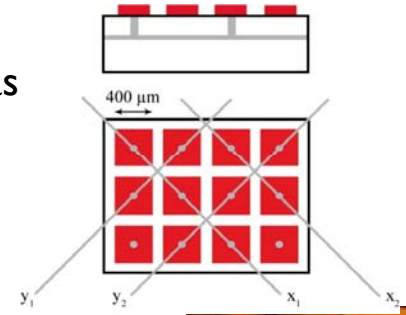
- Decommissioned LHC test magnet (L=10m, B=9 T)
- Moving platform ±8°V ±40°H (to allow up to 50 days / year of alignment)
- 4 magnet bores to look for X rays
- 3 X rays detector prototypes being used.
- X ray Focusing System to increase signal/noise ratio.

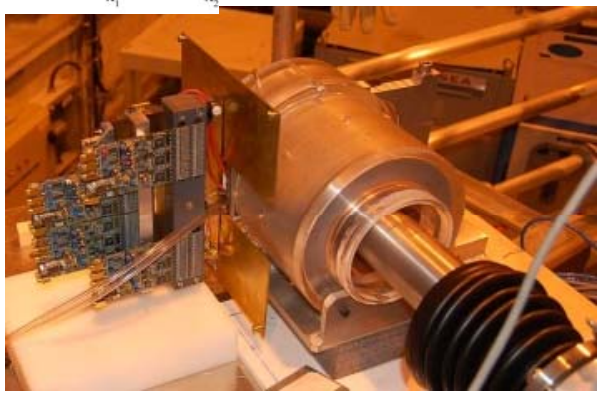
Low background x-ray detection

- CAST microbulk Micromegas exploit 3 strategies:
  - Low intrinsic radioactivity:
    - Light mass
    - Clean materials (copper, plexiglas
  - Signal topology → offline discrimination
    - 2D readout pattern
    - Time information from mesh pulse
  - Shielding
    - 2.5 cm arqueological lead
    - 0.5 cm inner copper
    - Clean inner atmospere by N2 flushing.

The chamber, 3 cm drift length, made of Plexiglas. Stainless steel cathode. 4 μm mylar window.





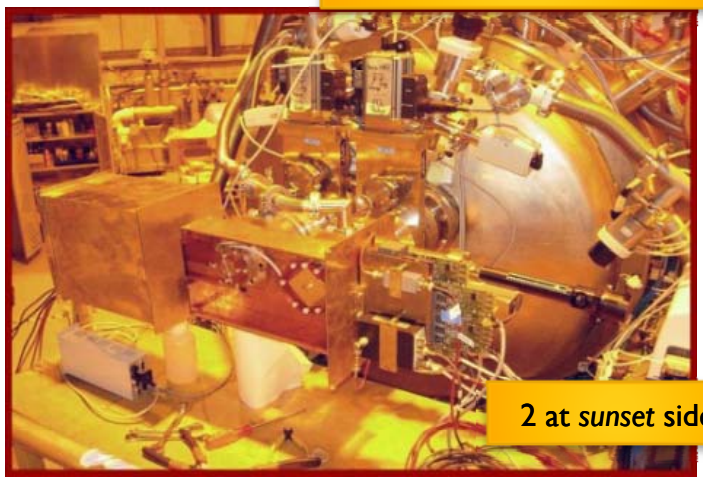


Current detectors in CAST

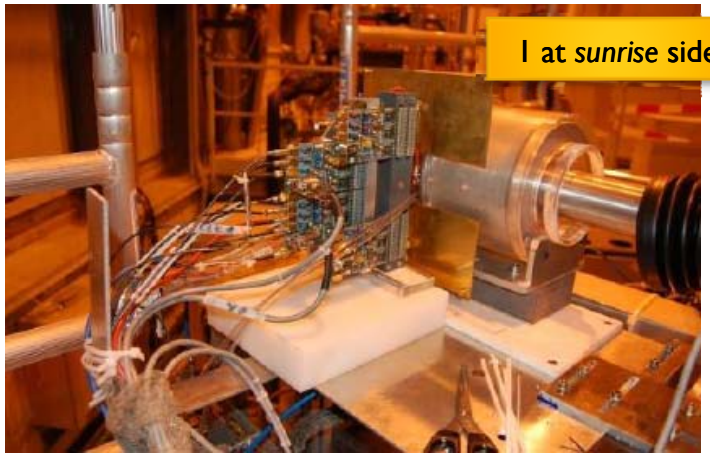
- 3 low background Micromegas currently installed and taking data at CAST
  - Sunset side: since 2008 2 microbulks replace the former MWPC TPC
  - Sunrise side: since 2008 microbulk technology used, improved shielding,…

Recent results published in
2009 NIMA604 15-19
2009 JPCS179 012015
2010 JINST 5 P01009
2010 JINST 5 P02001
2011 NIM A 628 172-176
…and presented at
Blois 2010
Vienna Instrumentation 2010
EXRS2010, Coimbra
TPC-Paris 2010
Moriond2010

3 MMs at CAST



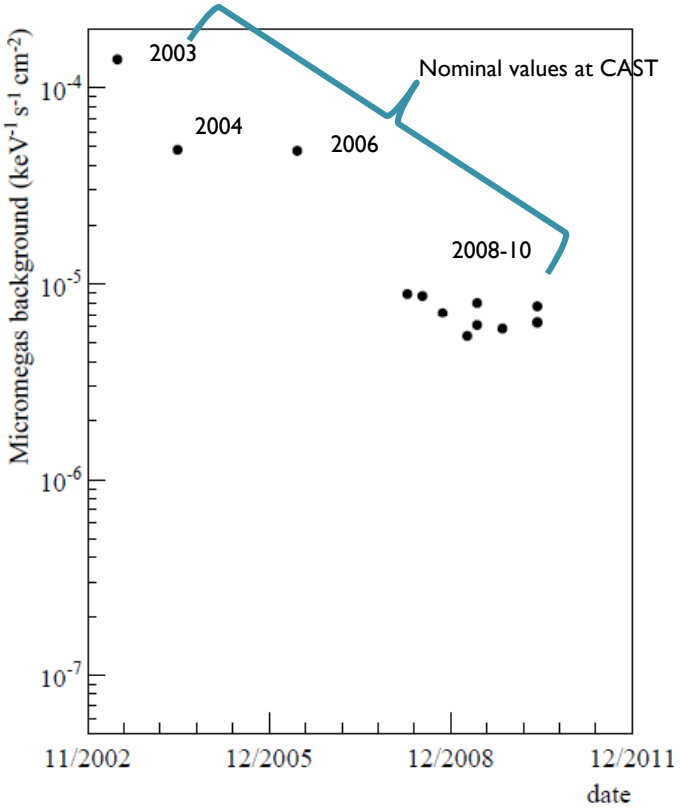
2 at *sunset* side



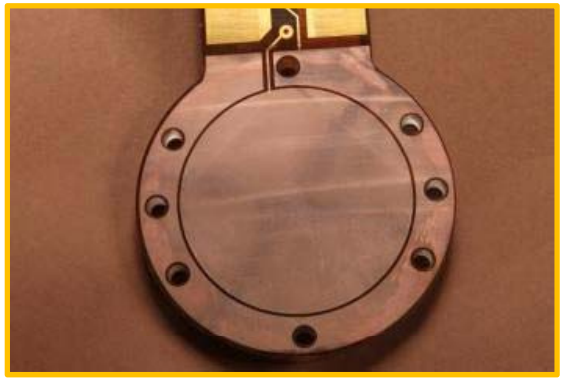
1 at *sunrise* side

MM experience at CAST

History of background improvement of Micromegas detectors at CAST

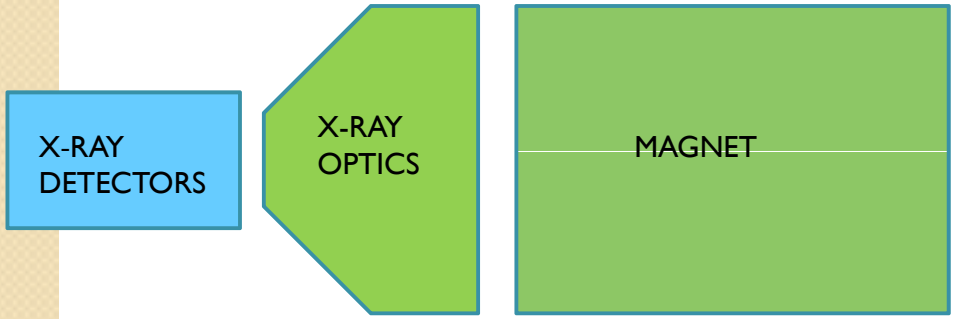


- Latest Micromegas: x20 improved background
  - Shielding
  - Radiopurity. New manufacturing technique (microbulk readouts)
  - More powerful offline cuts
- Long term operation experience
- Reliability, stability



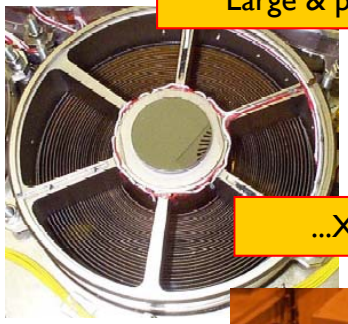
Towards a new generation axion heliocope (NGAH)

- CAST is established as a reference result in experimental axion physics
- No other technique can realistically improve CAST in a wide mass range.
- Next step in the field → new generation axion helioscope
- CAST has shown the way to improve the helioscope technique…

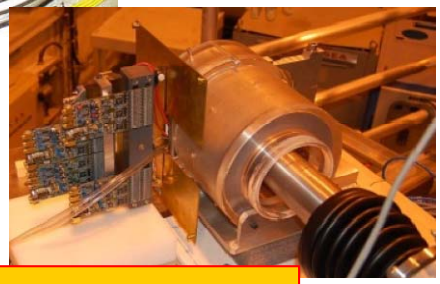


Ingredients of a successful helioscope

Large & powerful magnet...

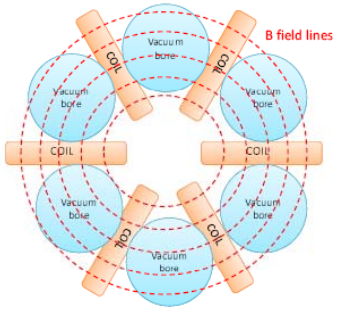


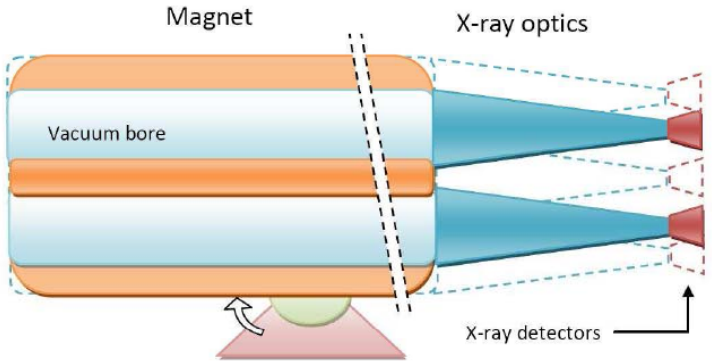
...X-ray optics,...



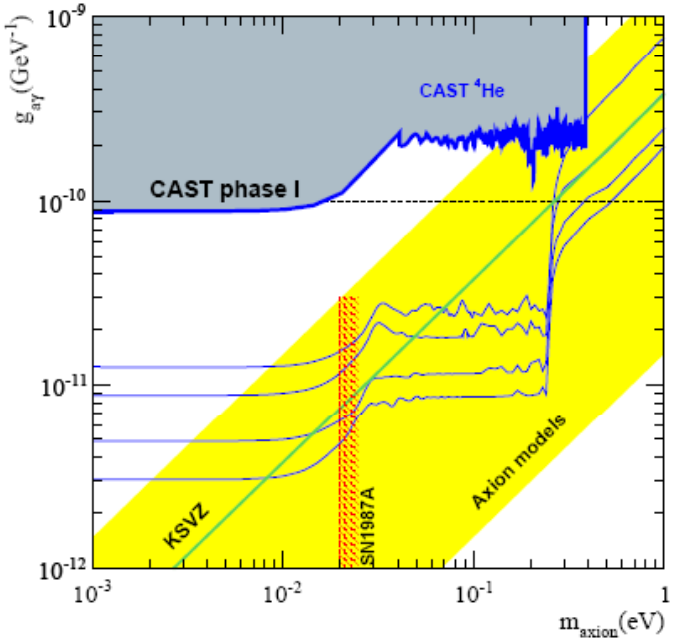
...and low background detectors

NGAH





- New larger toroidal magnet
- New optics based on novel plastic-substrate techniques
- X-ray detectors based on latest R&D on microbulks
- Sensitivity of 1 to 1.5 orders of magnitude beyond CAST achievable.
- Working group in CAST (and beyond) assessing this…

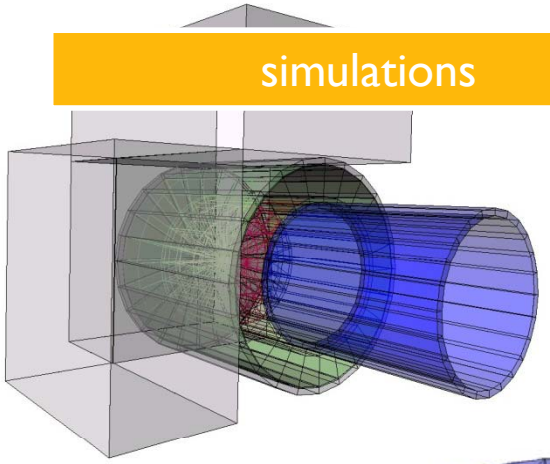


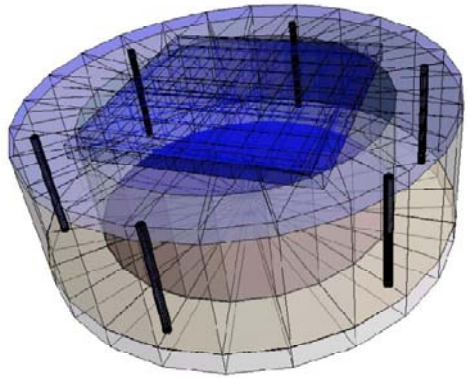
I G Irastorza et al. *Towards a new generation axion helioscope arxiv:1103.5334*
Accepted for publication in JCAP

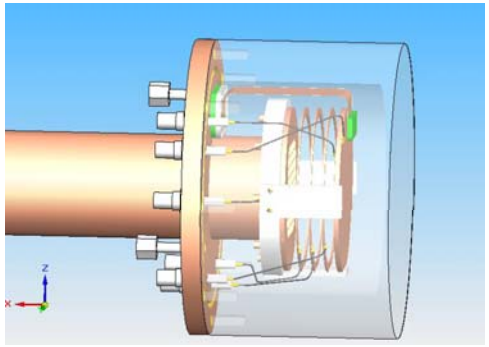
An ultralow-b MM for the NGAH

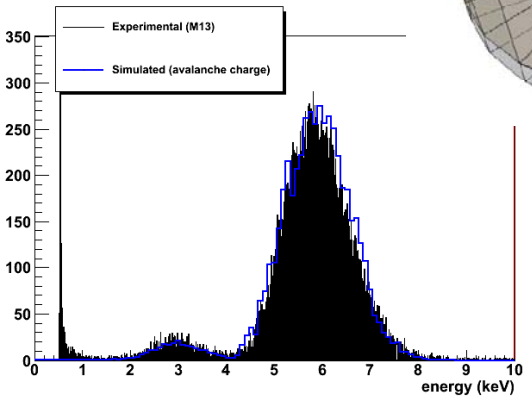
- **Goal:** at least 10^{-7} c/keV/cm^2/s, down to 10^{-8} c/keV/cm^2/s if possible.
- **Work ongoing:**
  - Experimental tests with current detectors at CERN, Saclay & Zaragoza
  - Especially: underground setup at Canfranc Lab
  - Simulation works to build up a background model
  - Design a new detector with improvements implemented

simulations





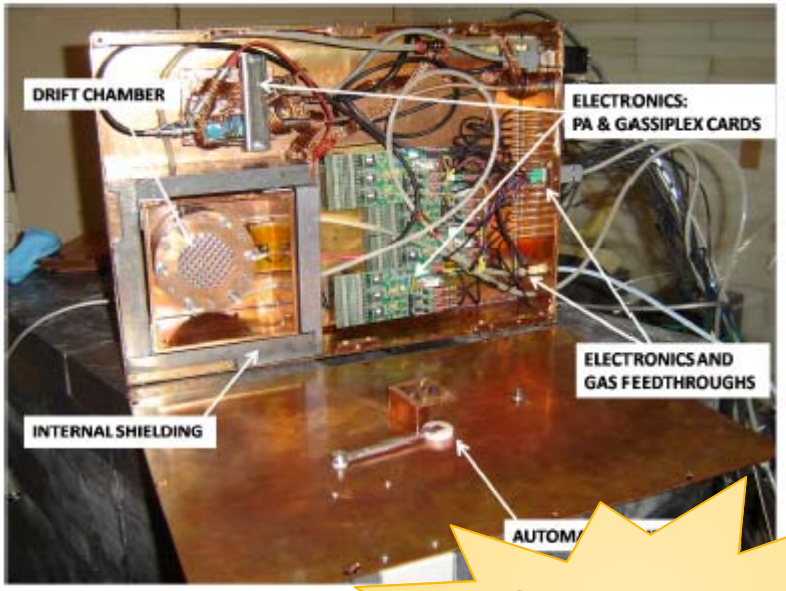


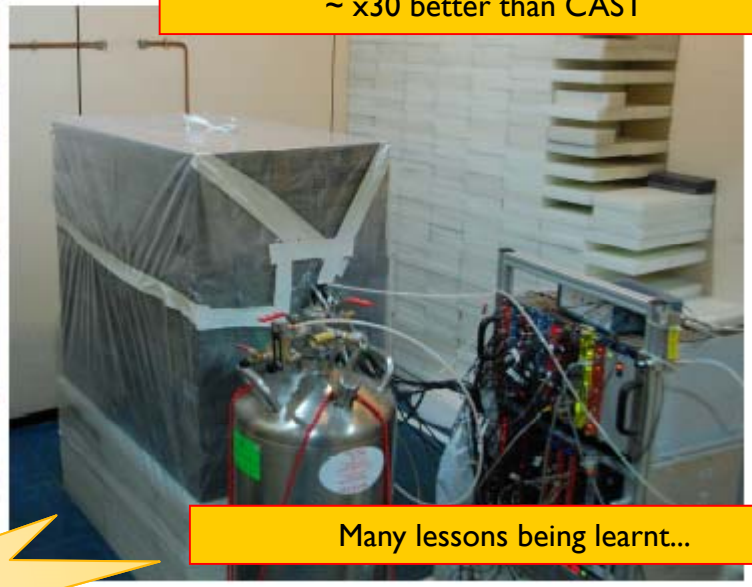


Tests at Canfranc

- CAST replica taking data in Canfranc. Goals:
  - Study background limitations under controlled conditions
  - Tests solutions for improvement.
  - Compare to simulations

Backgrounds around 2x10-7 c/keV/s/cm2
with improved shielding
~ x30 better than CAST



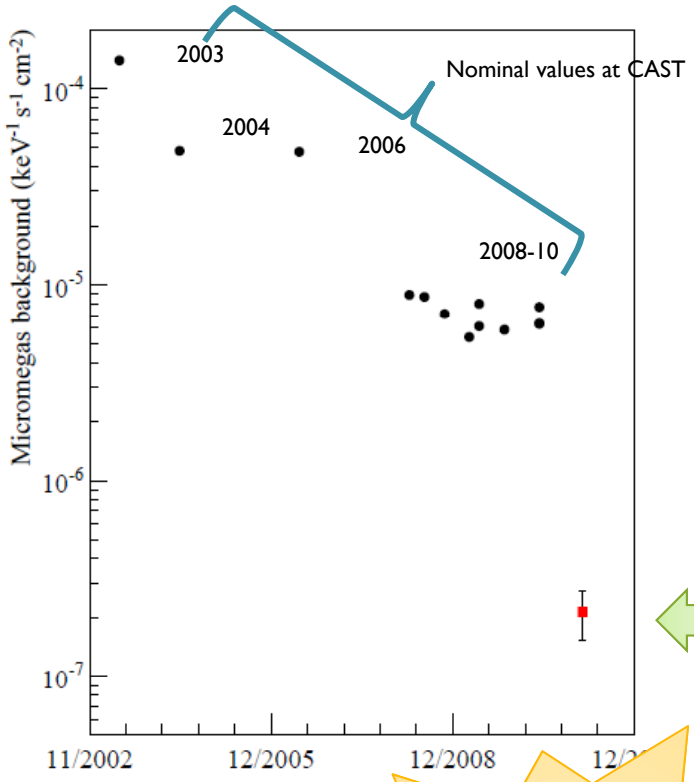


Many lessons being learnt...

See next talk
by J. Galán

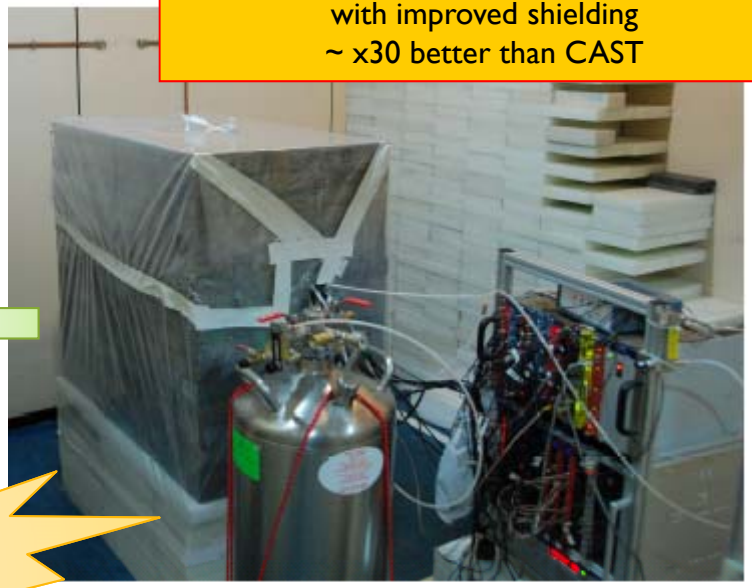
New detectors

History of background improvement of Micromegas detectors at CAST



- Tests in controlled conditions underground at Canfranc:
  - Better shielding coverage
  - Thicker shielding

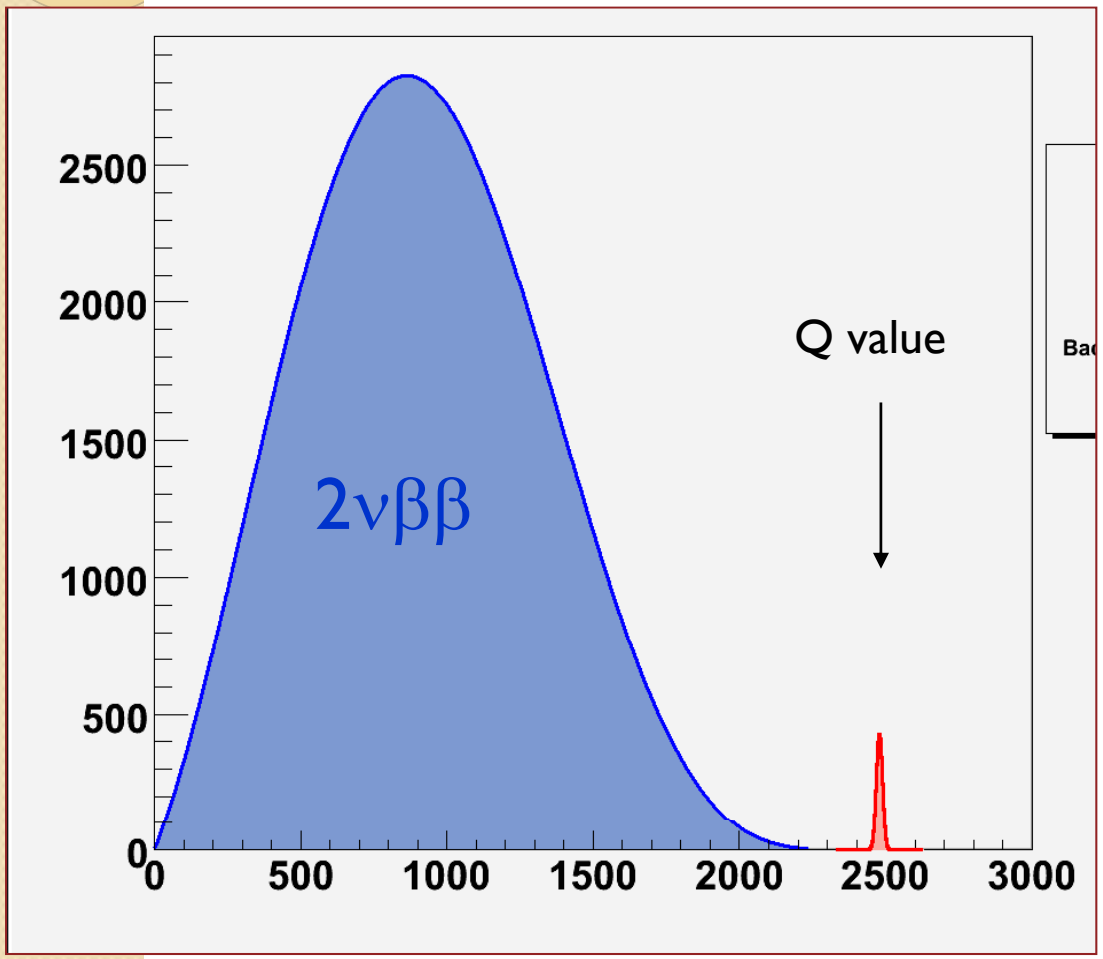
Backgrounds around 2x10-7 c/keV/s/cm2
with improved shielding
~ x30 better than CAST

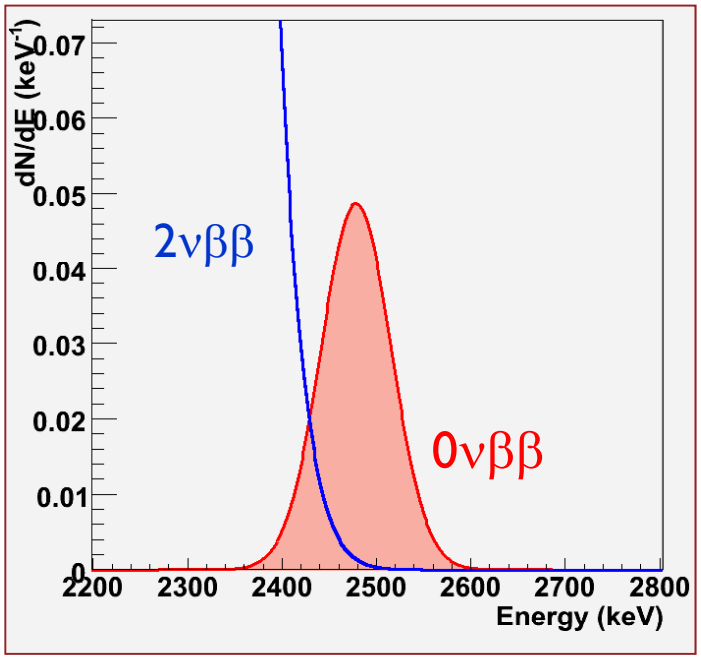


See next talk
by J. Galán

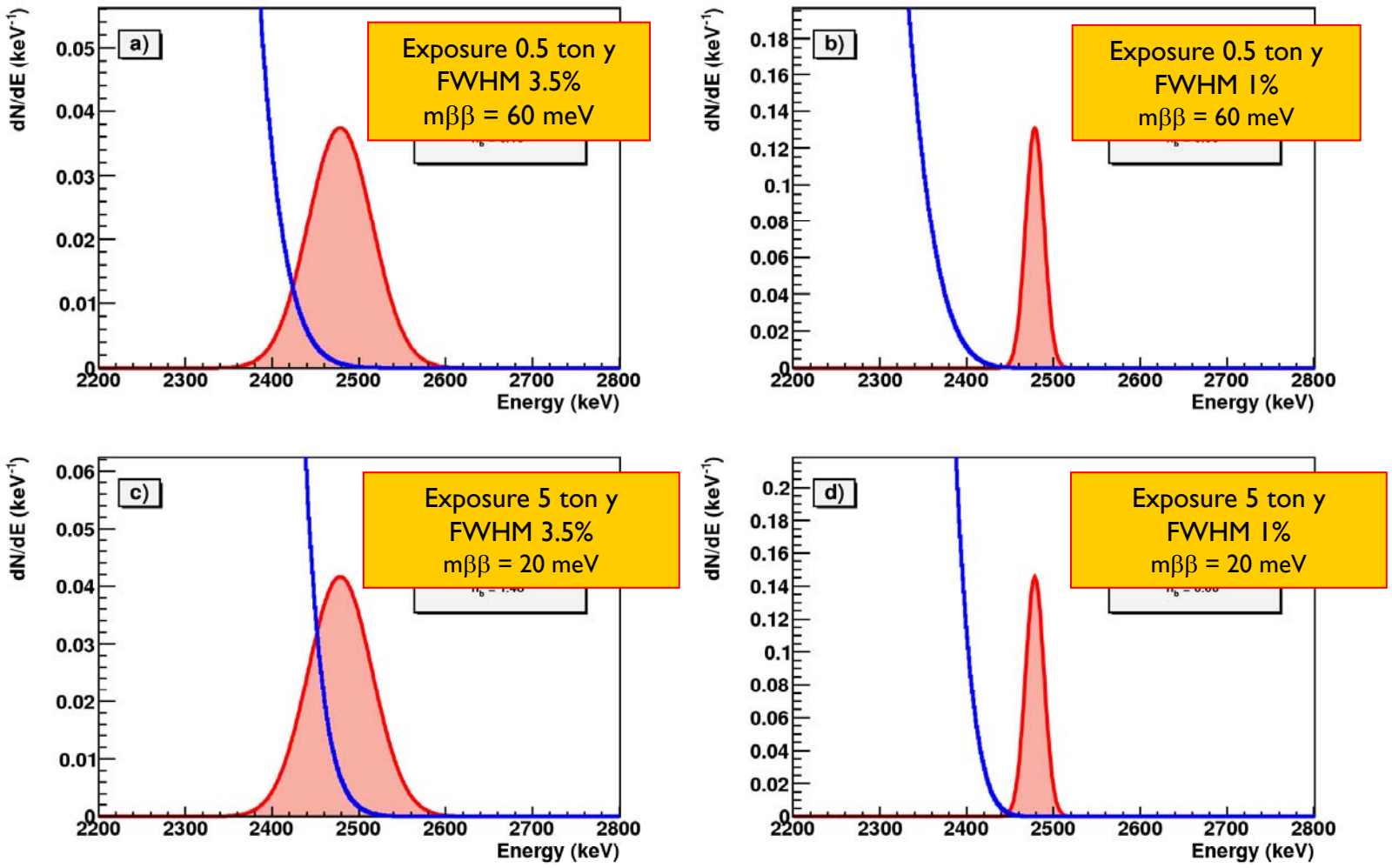
MM readouts for ββ

- Energy resolution is the only way to distinguish 0ν from 2ν.





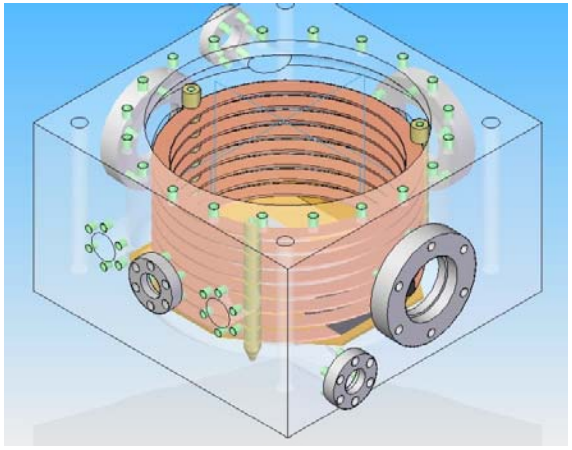
The role of E resolution @ the ton scale

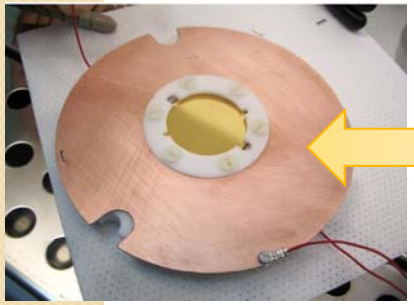


Energy resolution with MMs

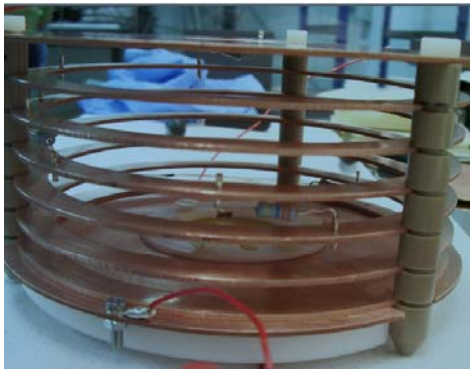
- Goal: tests small microbulk readouts in diverse conditions of high pressure Xe
  - All stain-less steel
  - UHV specs. bakeable
  - Low outgassing materials
  - 2 liter volume
  - Max P 12 bar
  - 6 cm drift

NEXT-0-MM @ UNIZAR



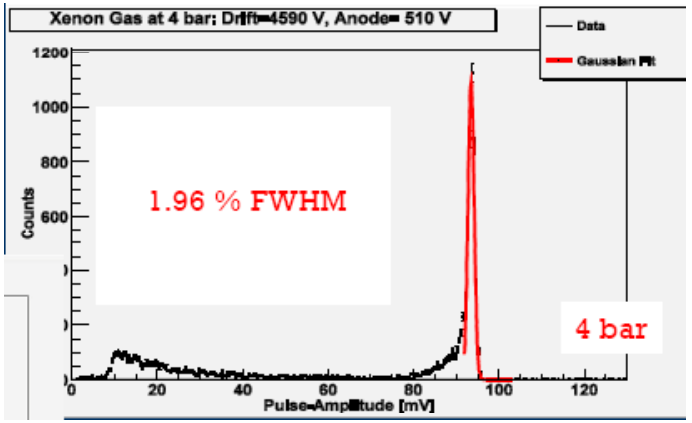


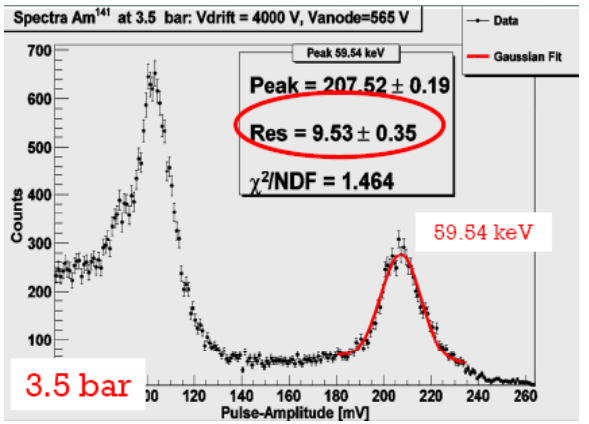
Ø 35 mm
50 μm gap
microbulk



Current results

- Microbulk are able to work at **pure high pressure Xe** !!
- Gains ~100
- ^{241}Am 5.5 MeV alphas:
  - ΔE ~ 2% FWHM for 2 to 5 bar
- With low energy gammas:
  - ΔE ~ 1.2% FWHM equivalent at 2.5 MeV for 2 bar, 2% for 5 bar
- Better results are conceivable after further ongoing R&D
  - MM geometry improvements
  - Use of quenchers
- To be confirmed with long e- tracks → larger prototype commissioning



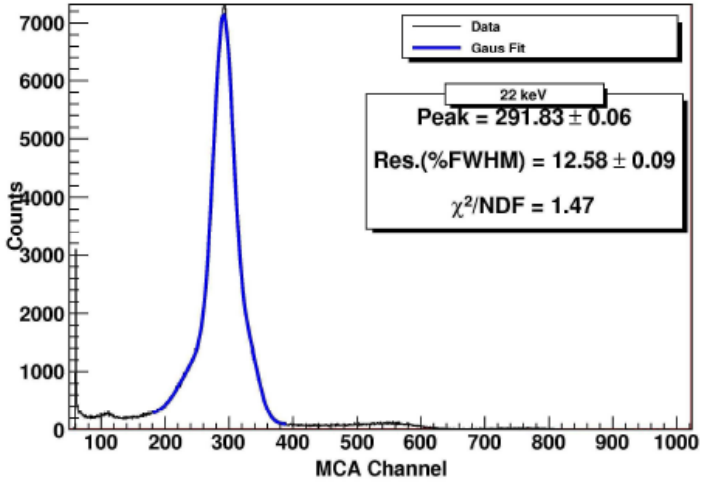


Publications R&D MMs doble beta:
NIM A 608 (2009) 259
JCAP 10 (2010) 010

Talks/proceedings in conferences:
Vienna Instrumentation 2010
IDM2010, Montpellier
Neutrino2010, Atenas
ICHEP2010 , Paris
TPC-Paris 2010

Current results: Xe-mixtures

- Systematic study of Xe-TMA with Micromegas ongoing.
- Very first results very promising:
  - High gains achievable (>10^3)
  - Much higher gains than pure Xe at same voltage (Penning effect)
  - 1% resolution seems to be at hand
  - More work ongoing
- Data with Xe-Ne also taken:
  - Higher gains than pure Xe
  - Energy resolution probably better, at least the same (not conclusive)



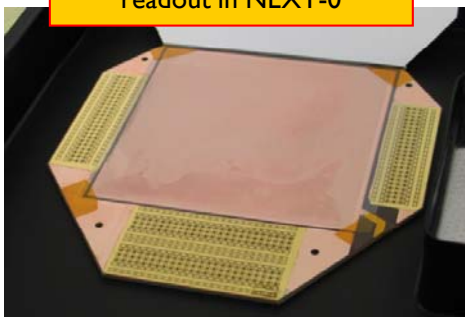
Xe-TMA 2.5%
4 bar
12.5% FWHM
@ 22 keV Cd source

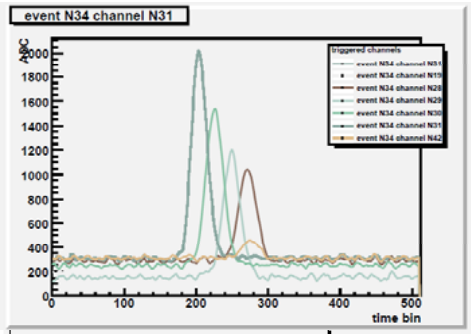
Extrapolates to 1.2 % FWHM at Qββ
First data ever taken with MM in this gas, to our knowledge

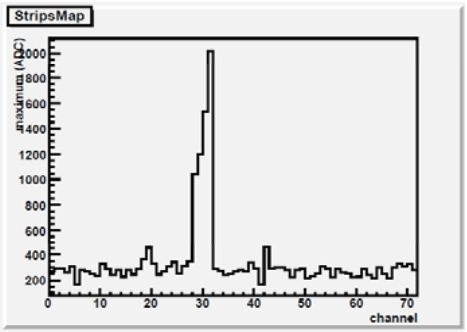
Alpha tracks

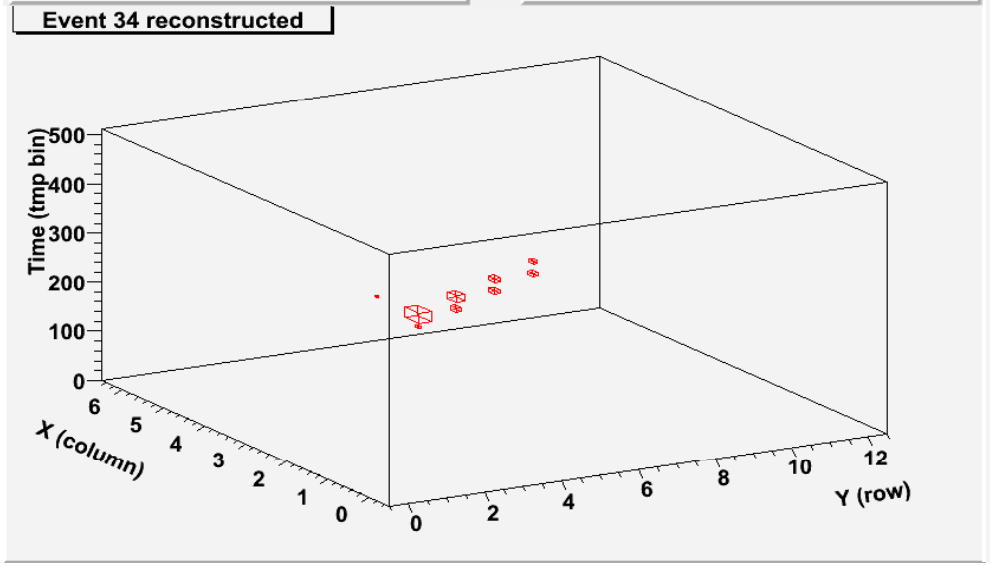
Ar- 2% Isobutane @1bar
reduced T2K electronics version

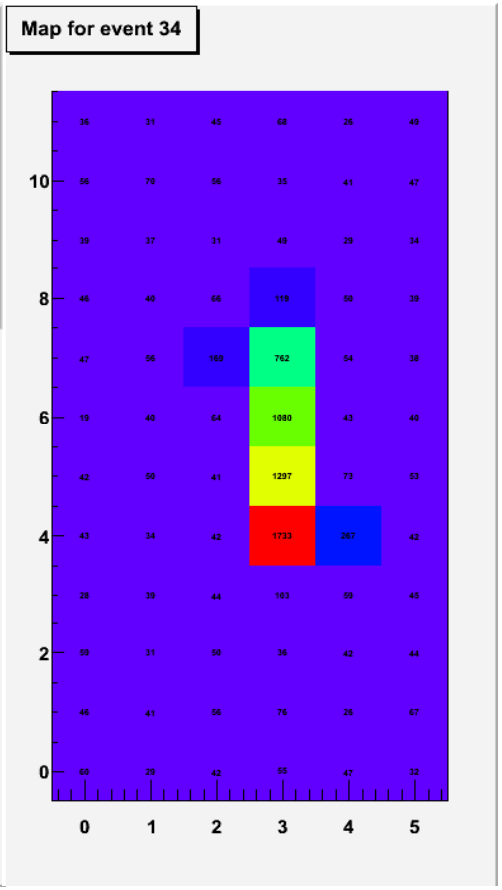
With 0.8 cm side 120 pixel readout in NEXT-0







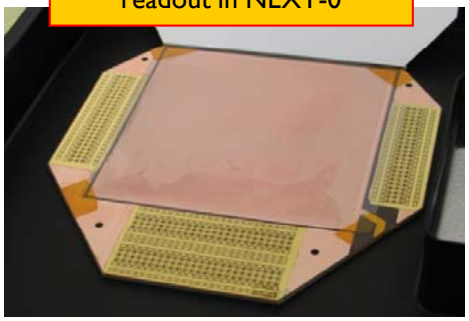


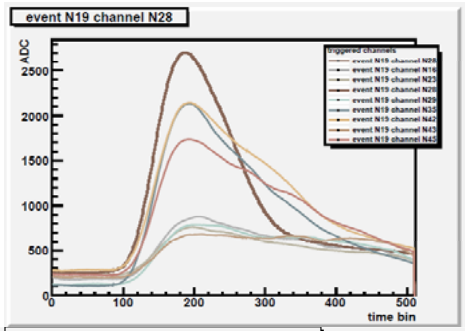


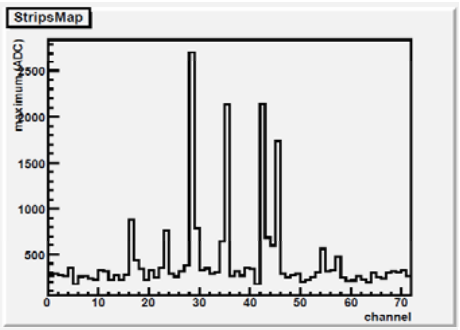
Alpha tracks

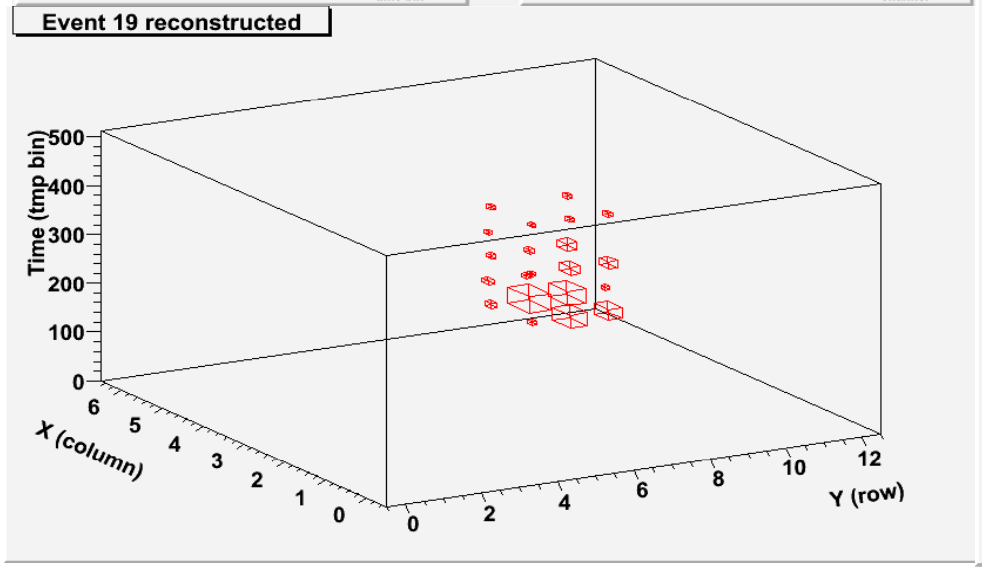
Pure Ar @1.23 bar
reduced T2K electronics version

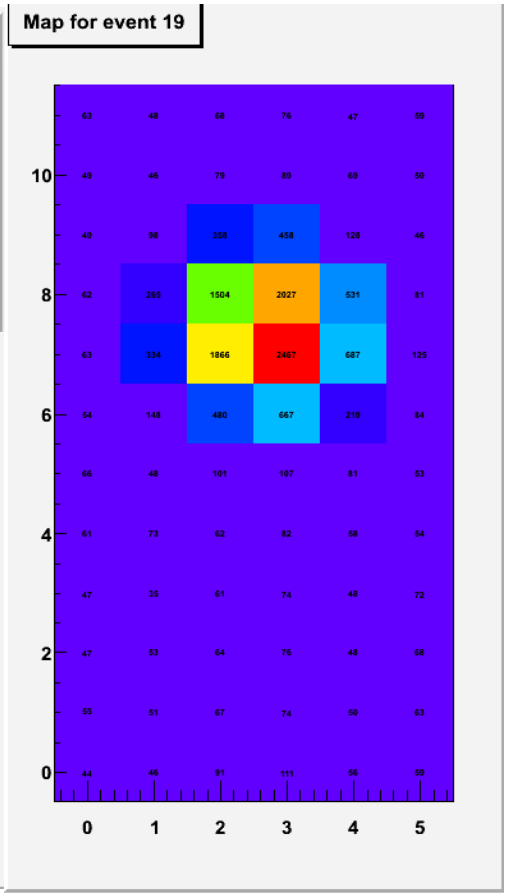
With 0.8 cm side 120 pixel readout in NEXT-0











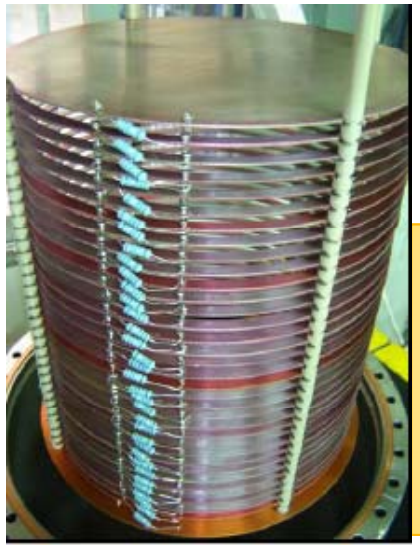
NEXT-1-MM

- Prototype of medium size (1 kg Xe @ 10 bar)
- **Goal:** test microbulk readouts in realistic conditions (e- tracks fully contained)
  - Inner Volume of 74 litres (600mm height, Ø 396mm)
  - Tested for operation at high pressure (15 bar)
  - Steel structure to manipulate the parts of the vessel with a crane
  - Using the same gas system as for NEXT-0
  - Heating and insulation systems

NEXT-1-MM

Field Cage

35 cm drift height
34 rings
Inner ring Ø 28cm
Outer ring Ø 30cm
4 PEEK columns
35 resistors
70 PEEK screws



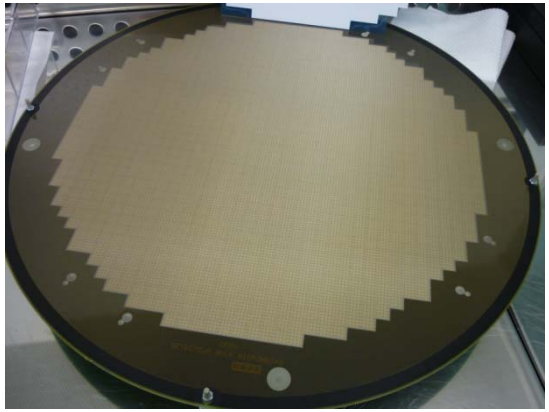
330 MΩ total resistivity
For drift fields of ~ kV/cm
need to supply 35kV

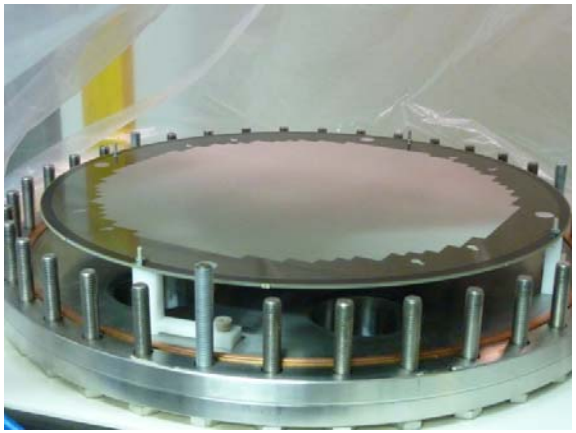
Special HHV FT
are studied

Cirlex foil between field cage and vessel walls

Bulk Micromegas

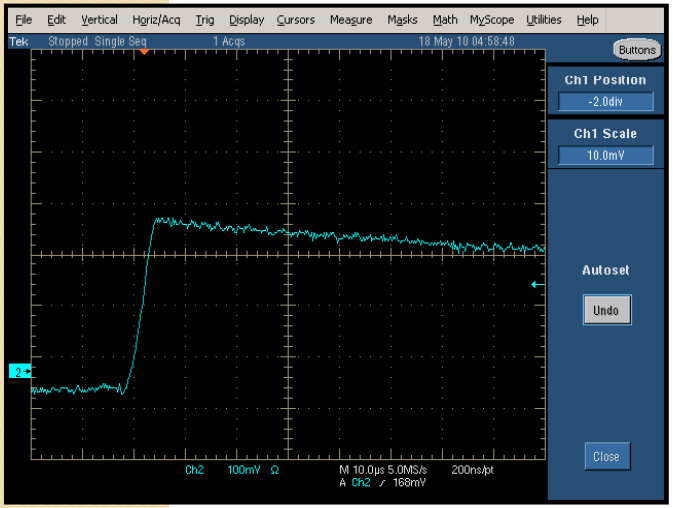
Active region Ø ~30cm
1252 pixels
independently read

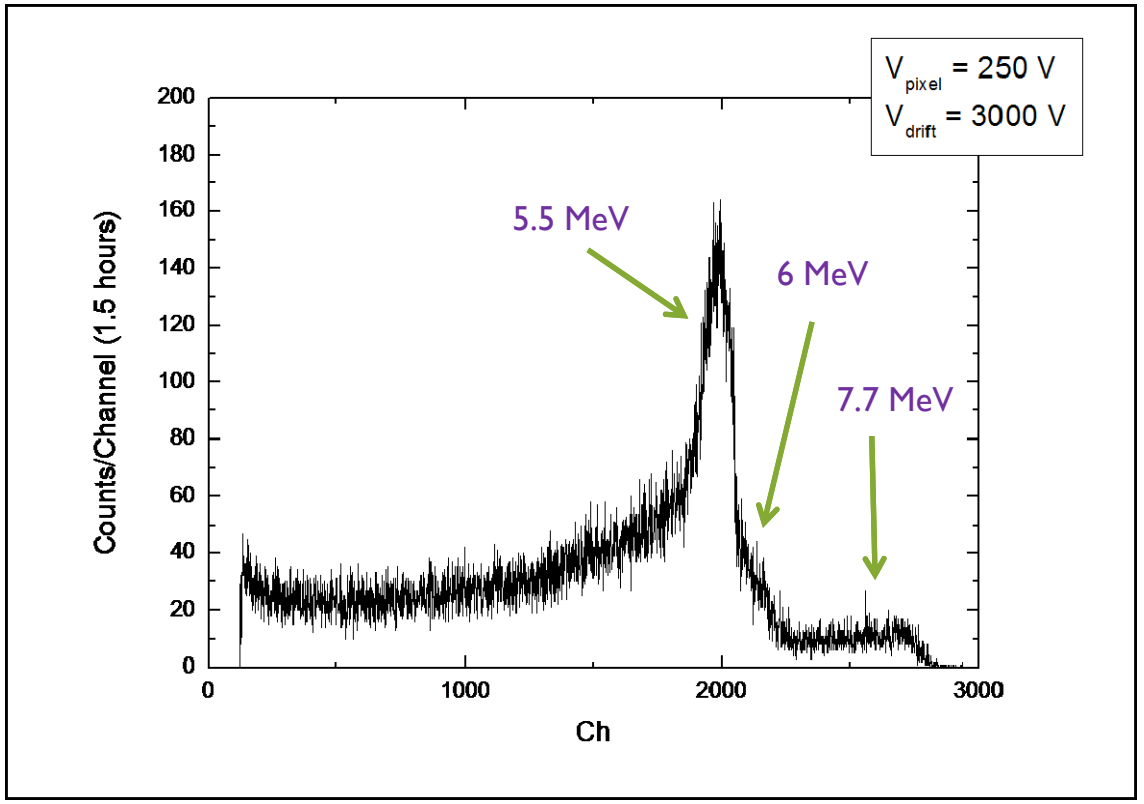




First events

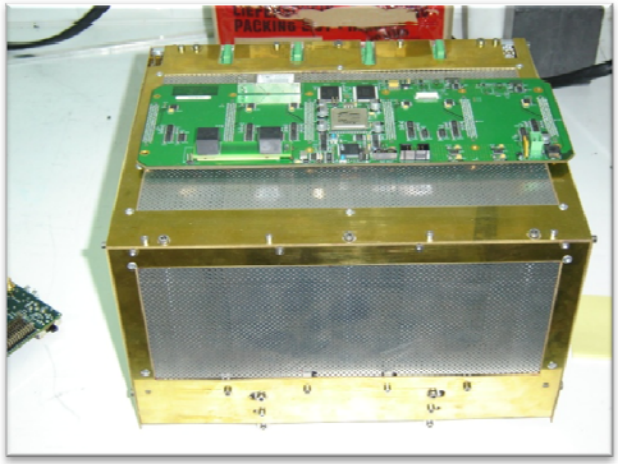
- Rn222 diffused in Ar+2%Isob
- Mesh-only read
- All volume active

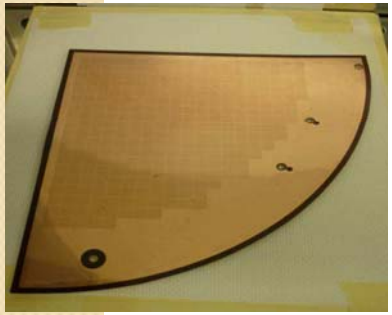




First events

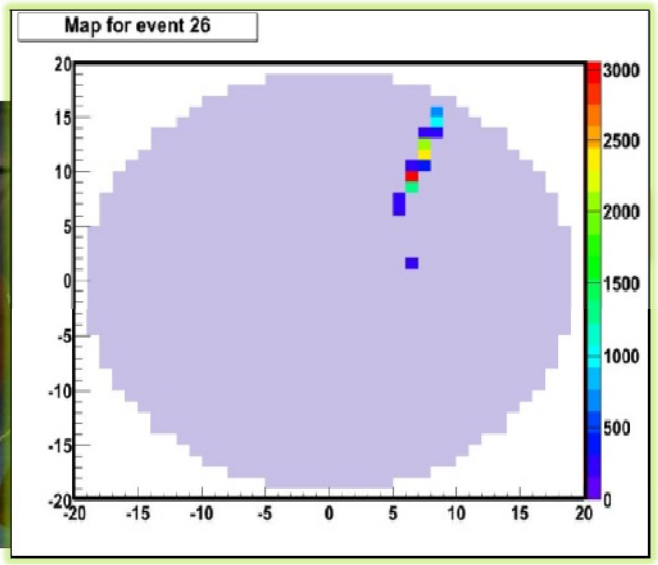
- First alpha tracks in Ar with AFTER-based DAQ
- Now installing microbulk readout



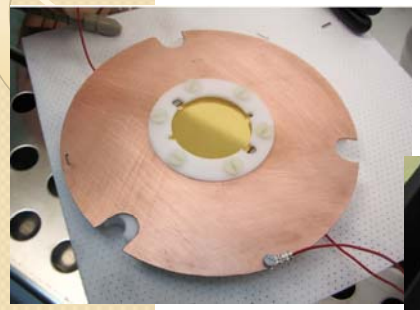


Readout microbulk
In 4 sectors

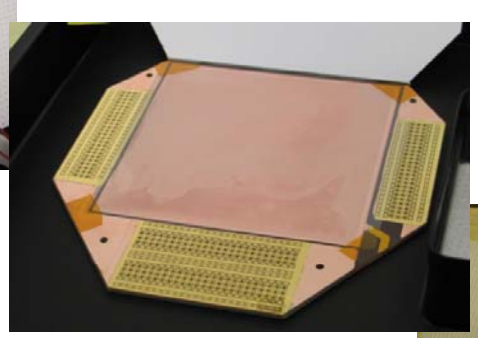
First tracks



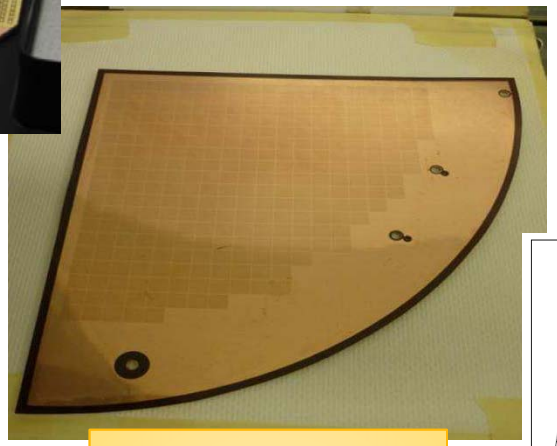
Microbulk scaling-up



3 cm

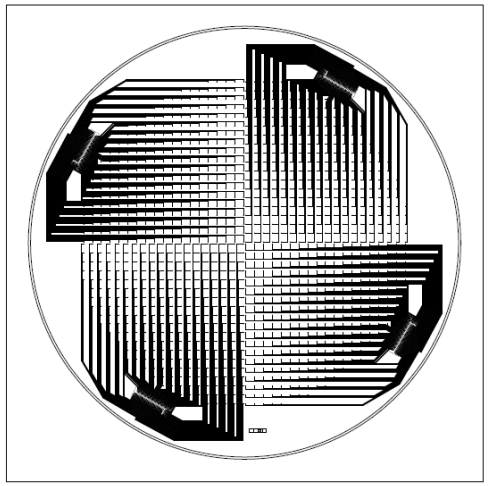


10 x 10 cm^2
12 x 12 Pixels



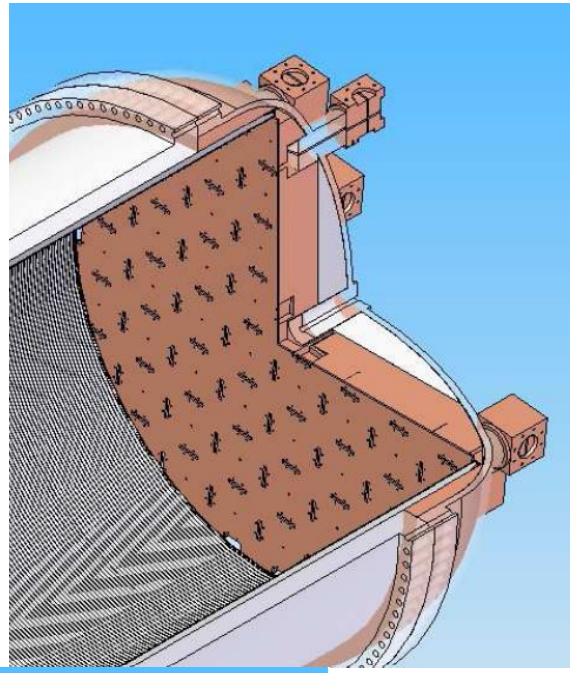
15 cm radius
300 Pixels
Largest microbulk up to now

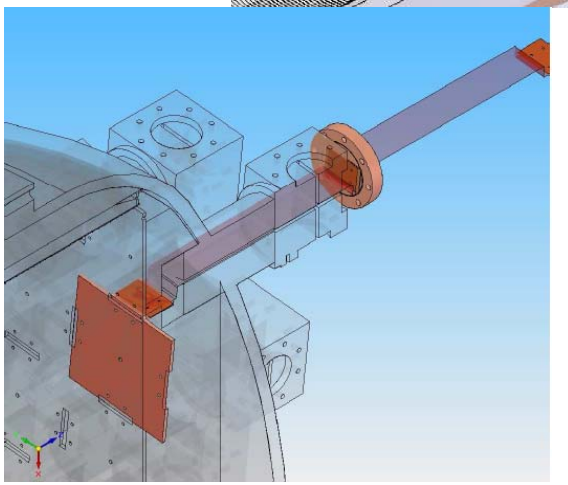
Work ongoing to fabricate 30 cm radius microbulk



Microbulk scaling-up

- Design concepts developed to build larger areas of microbulk readouts
  - Mosaic of modules
  - Dead-zone less
  - Extraction of signals





Radiopurity of microbulks

- Microbulks are made mostly of copper & kapton → potentially very radiopure
- Radioactivity of several samples measured at HPGe at Canfranc
  - 2 samples of raw material (double clad kapton foil)
  - 2 samples detached from old CAST detectors
- Very low levels → compatible with sensitivity of measurement
- Further work ongoing

HPGe detector at Canfranc

See details in Astropart. Phys. (2011) 34, 354

Results (in μBq/cm²)	^{232}Th	^{235}U	^{238}U	^{40}K	^{60}Co
Microbulk mM	<9.3	<13.9	26.3±13.9	57.3±24.8	<3.1*
Kapton-Cu foil	<4.6*	<3.1*	<10.8	<7.7*	<1.6*
Cu-Kapton-Cu foil	<4.6*	<3.1*	<10.8	<7.7*	<1.6*

Conclusions

- Microbulk Micromegas large interest for Rare Events. T-REX project.
- Case for axion searches:
  - CAST at CERN
  - Future helioscope
  - Details of R&D with detector at Canfranc (→next talk)
- Case for $\beta\beta$ searches
  - Prototypes to develop microbulk readouts for NEXT. Energy resolution…
- Microbulk radiopurity