the T-REX project: Micromegas readouts for Rare Event Searches

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Outline

T-REX: MM readouts for rare event searches
MM for axion searches: CAST
MM for $\beta\beta$ searches: NEXT
Radiopurity Measurements
Conclusions

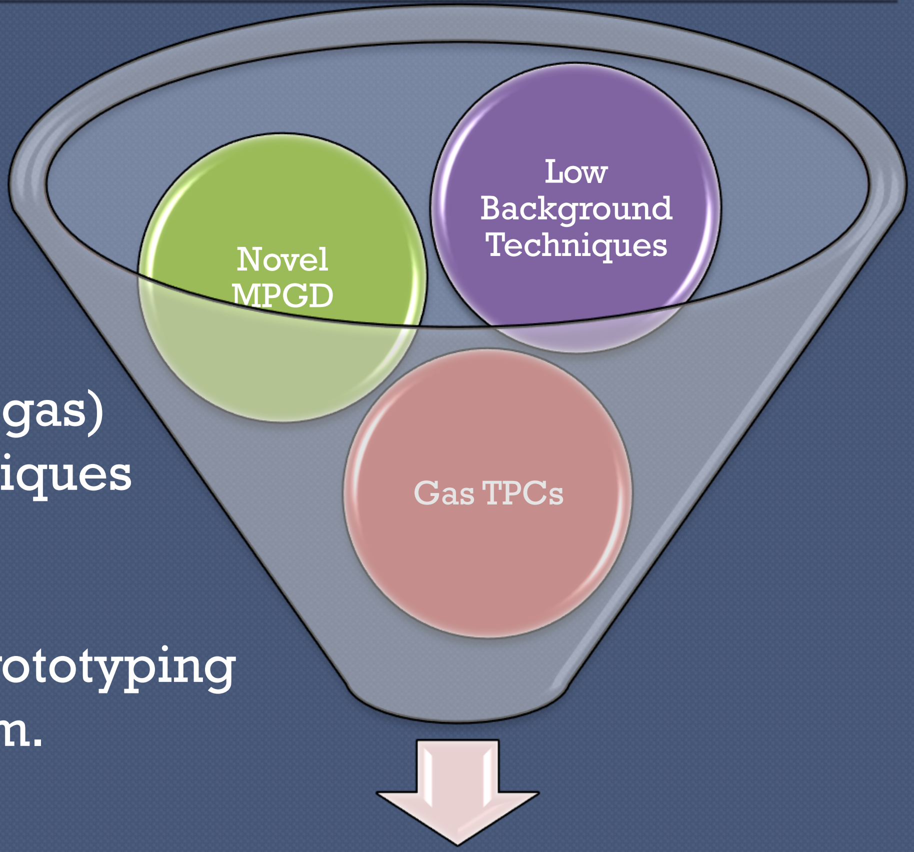
T-REX

Rare Event Searches:
topology can be the key

Gas TPCs can do it

T-REX: merge MPGDs (Micromegas)
+ low background techniques

Focus on R&D and small scale prototyping
ERC St-G funded. IDEAS program.

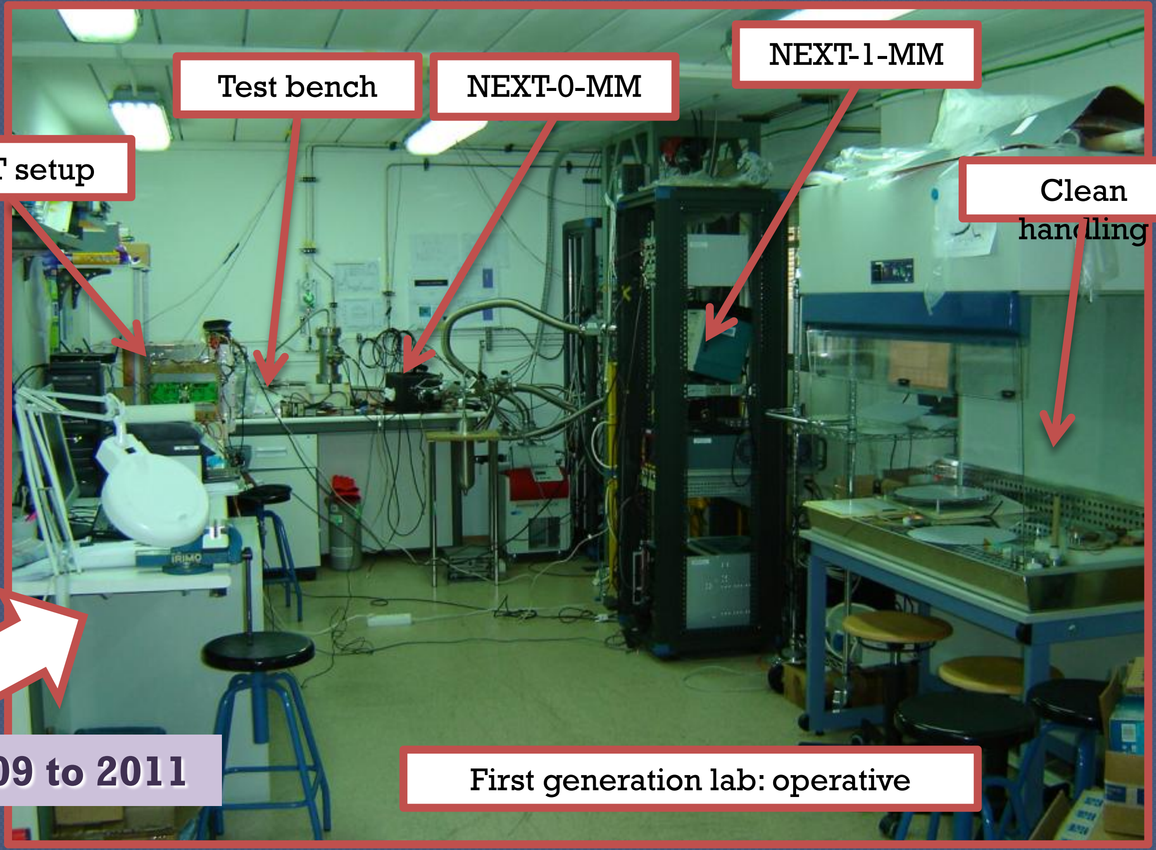


New Generation of Rare Event Searches

T-REX: infrastructure

New gas detector lab at UNIZAR

From 2009 to 2011



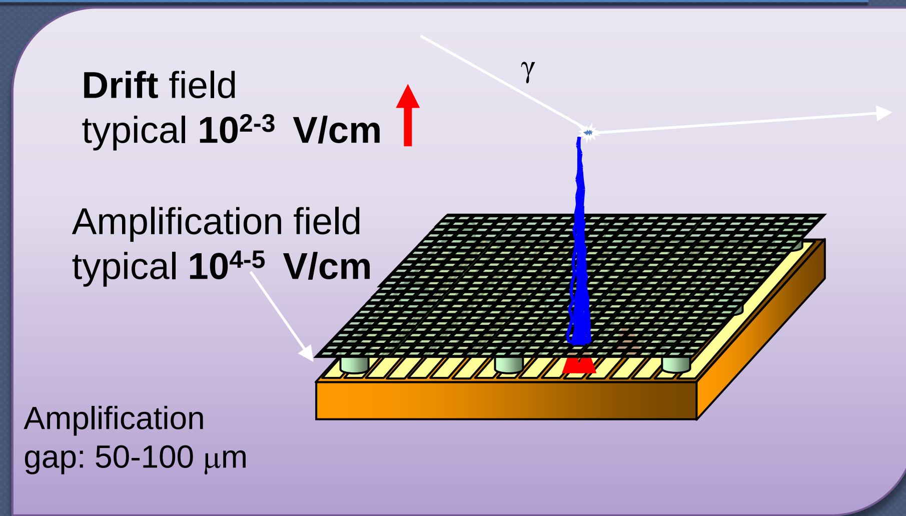
Further 90 m² being furnished…

Micromegas

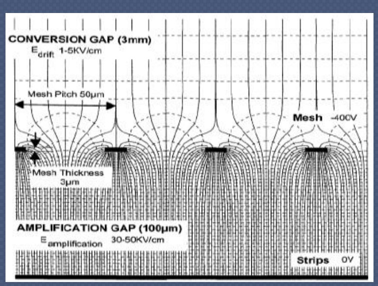
Two-region gaseous detector:

Conversion region
- Primary ionization
- Charge drift

Amplification region
- Charge multiplication
- Readout layout
  - Strips (1or 2 D)
  - Pixels

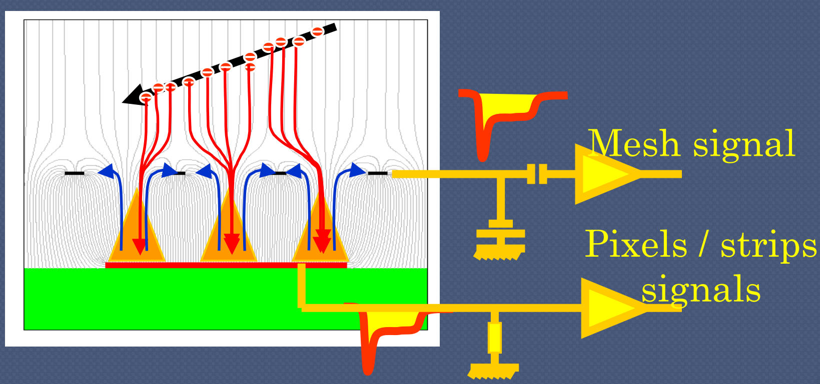


Separated by a Micromesh:
Very strong and uniform electric field



Giomataris et al. (1996)

Advantages:
- Simplicity
- Granularity
- Homogeneity
- Large areas
- …



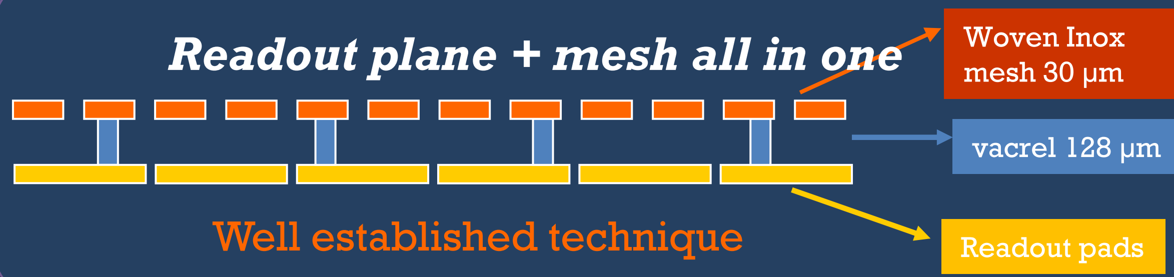
Micromegas

Bulk & microbulk techniques developped for all-in-one fabrication

- Ease of operation
- Large areas

BULK
Robust
Mature
Very large areas available (2 m^2)

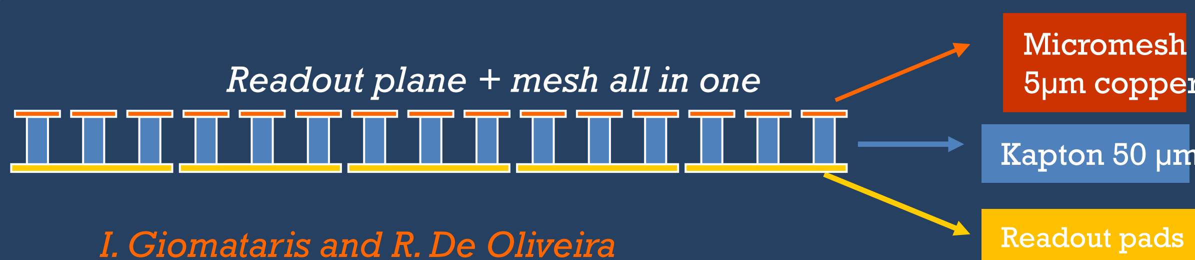
Readout plane + mesh all in one



Well established technique

MICROBULK
Higher homogeneity
Light weight, radiopure

Readout plane + mesh all in one



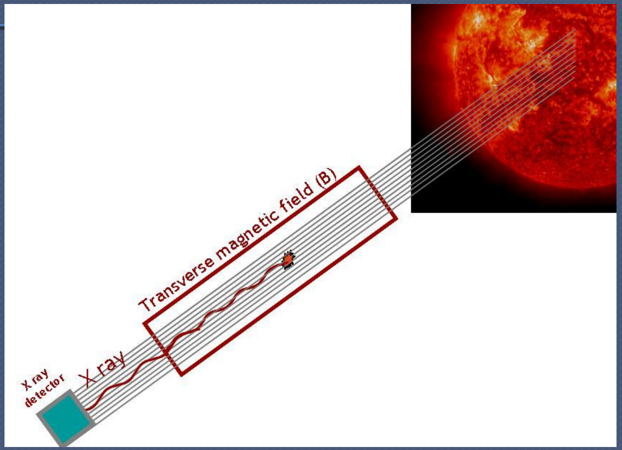
I. Giomataris and R. De Oliveira

See also 2010 JINST 5 P02001

μM for axion searches: CAST

S. Aune et al., 2009 NIMA604 15-19
2009 JPCS179 012015
J. Galán et al., 2010 JINST 5 P01009
S. Andriamonje et al., 2010 JINST 5 P02001
T. Dafni et al., 2011 NIM A 628 172-176
presented at:
Blois 2010, Vienna Instrumentation 2010, EXRS2010, TPC Symposium 2010, Moriond2010

CAST experiment @ CERN



Axions: hypotetical 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" (Sikivie, 83)

very low background X-ray detectors are necessary
CAST uses
•3 microbulk micromegas
•a CCD-X-ray focusing device system

Microbulks in CAST

2 microbulks at SUNSET

1 microbulk at SUNRISE

Low intrinsic radioactivity:

- Light mass, clean materials (copper, plexiglass,…)

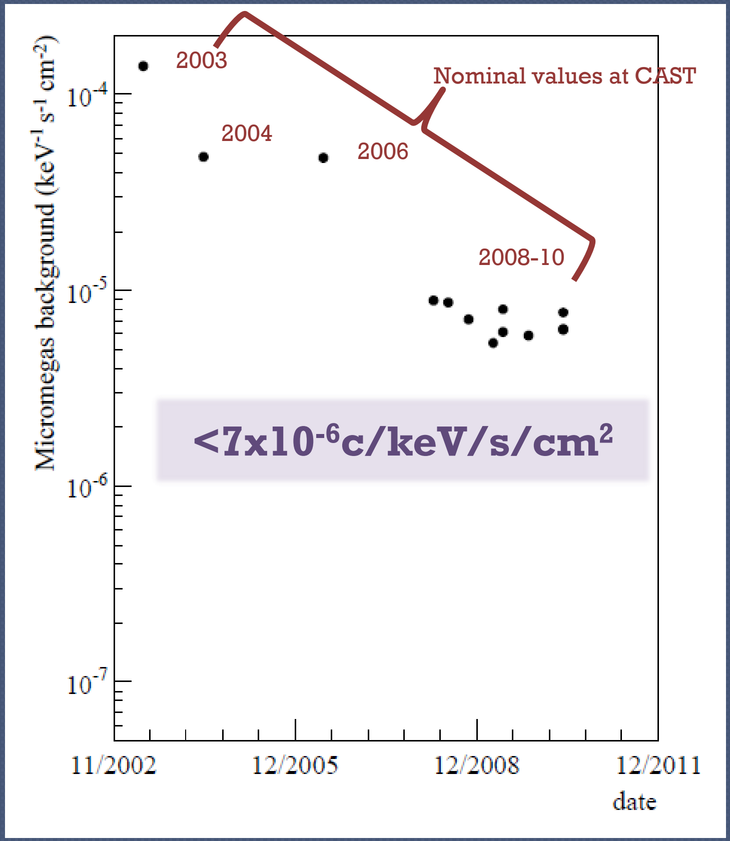
Signal topology → offline analysis

- 2D readout pattern, Time information

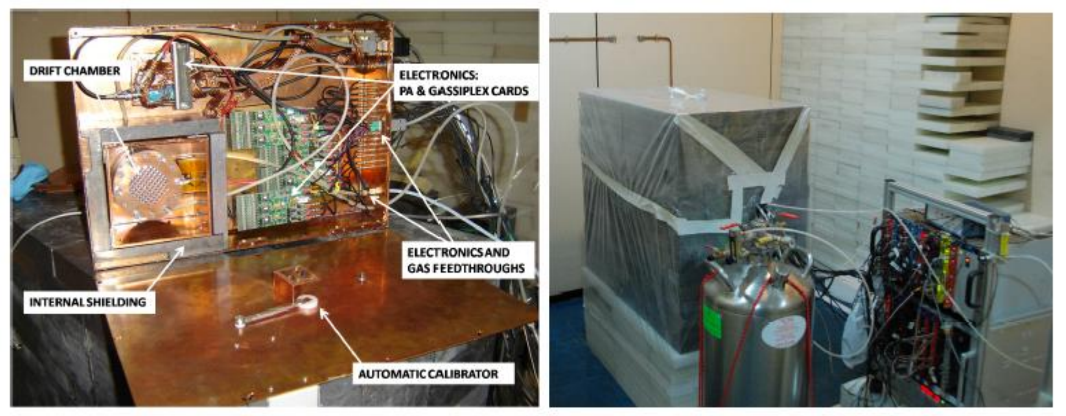
Shielding

- archeological lead, inner Cu, N_2 flushing.

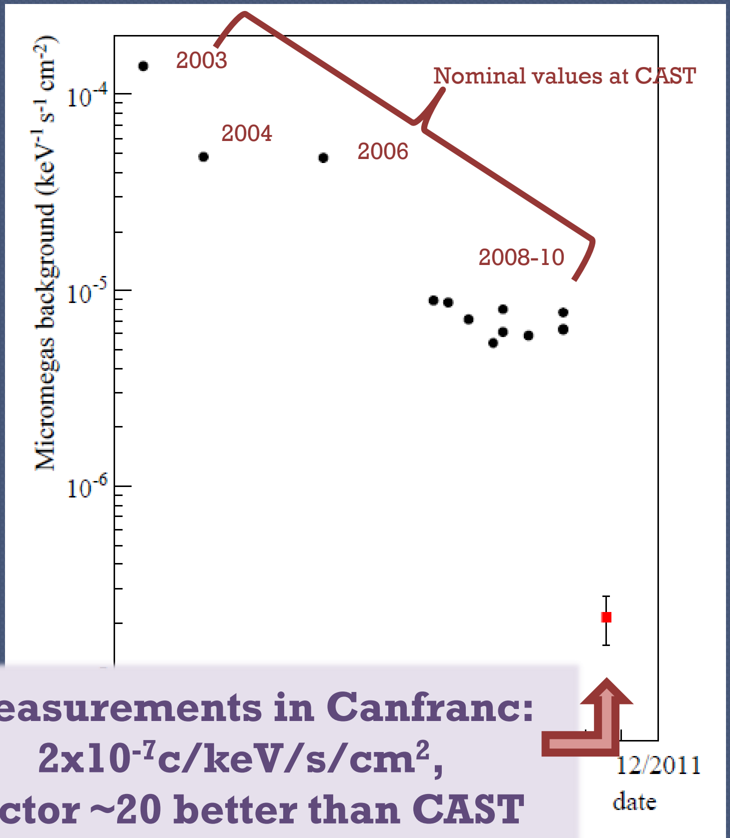
Background Level history at CAST



Microbulks in Zgz and Canfranc



Background Level history at CAST



Measurements in Canfranc: $2x10^{-7}$c/keV/s/cm^2, factor ~20 better than CAST

Going Underground (Laboratorio Subterraneo de Canfranc):

- << cosmics
- Stable environmental conditions
- Better and thicker shielding
- Simulation works to build a background model

Goal: to design a new detector with improvements implemented

μM for ββ searches: NEXT

F.J.Iguaz et al. J. Phys.: Conf Series 179 (2009) 012007
T. Dafni et al., NIM A 608 (2009) 259-266
A. Tomas et al., 2009 JINST 4 P11016
S. Cebrian et al., JCAP (2010) 010

Presented in:
Vienna Instrumentation 2010, IDM2010 (Montpellier), Neutrino2010 (Athens), ICHEP2010 (Paris), TPCSymposium 2010(Paris)

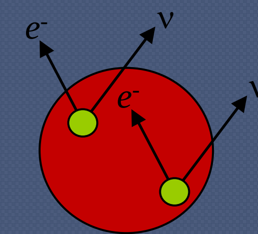
MM readouts for ββ

Neutrinoless double beta decay would provide important information:

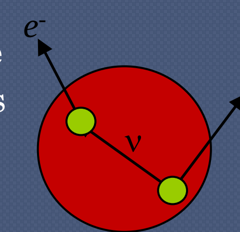
✓on the neutrino nature (Majorana or Dirac)

✓on the neutrino mass scale

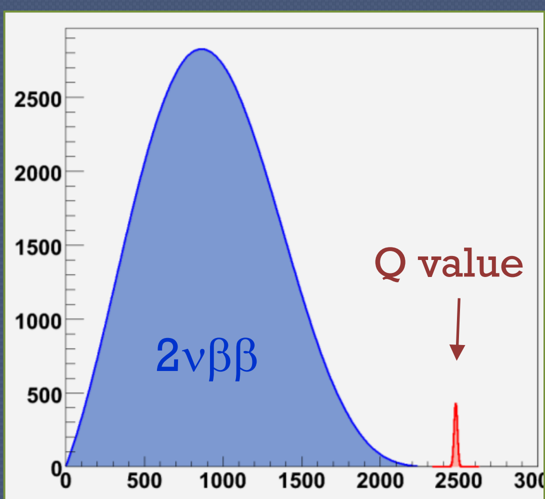
2νββ: Standard process, observed in about 10 isotopes so far



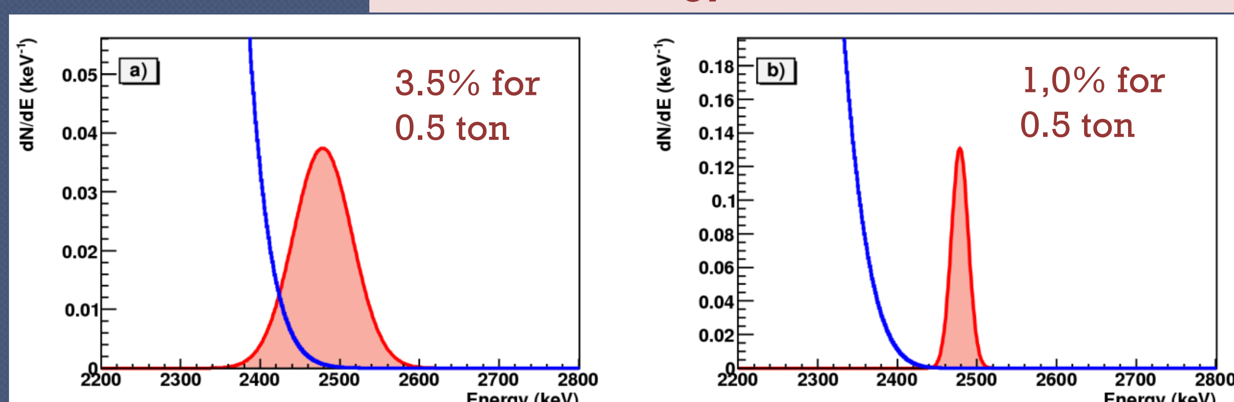
0νββ: Only possible if the neutrino has a mass and is Majorana particle. Yet to be seen



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



The role of Energy Resolution at the ton scale



NEXT

A high-pressure, 100kg gaseous Xe TPC to look for the $0\nu\beta\beta$ decay of ^{136}Xe

Project Baseline:

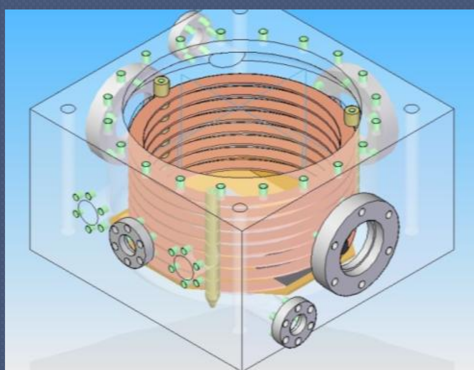
An electroluminescence TPC where the energy is measured with PMTs and the topology is given by SiPM.

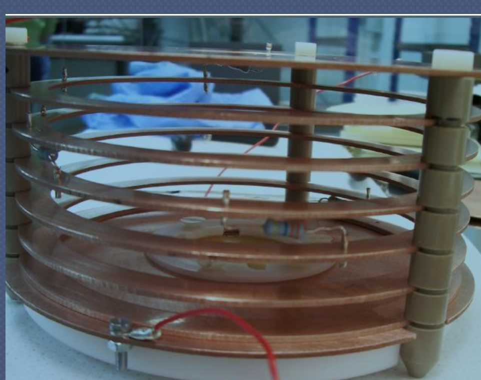
Parallel study:

- Equip the detector with Microbulk Micromegas and perform the energy and topology measurement through the charge collection

Advances on the R&D related to this option

NEXT-0-MM Setup





NEXT-0-MM

Stainless Steel
UHV specs. bakeable
Low outgassing materials
2 liter volume
Max P 12 bar
6 cm drift

Field Cage

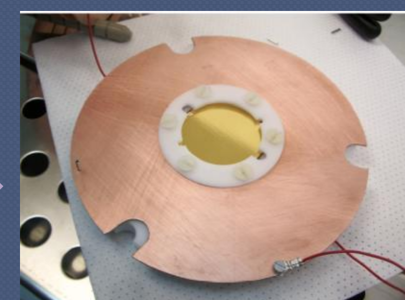
6 copper rings
3 Peek columns
6 resistors of 10MΩ

Goal: tests small microbulk readouts in diverse conditions of high pressure Xe

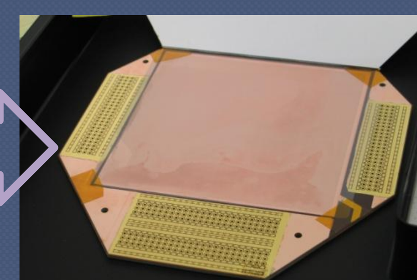
Microbulk Micromegas

50 μm gap

Ø 35 mm

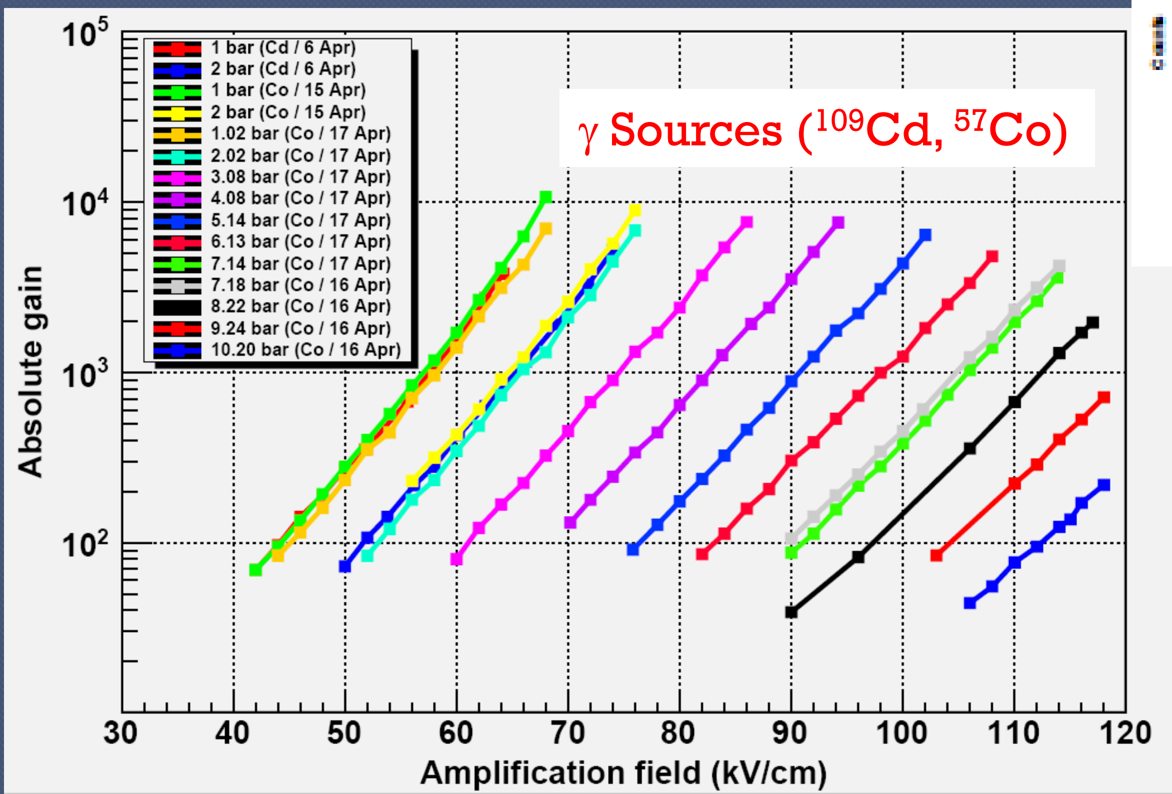


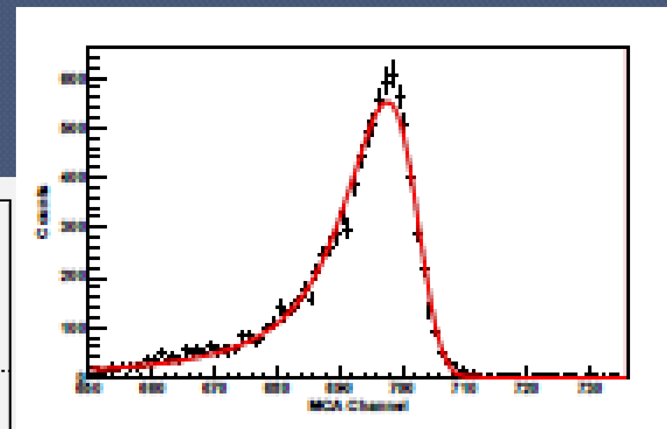
$10x10\ cm^2$
Pixelized anode
12x12 pixels



NEXT-0-MM
Tests in Argon-Isobutane

Example of results in Ar-2% Isobutane up to 10 bar





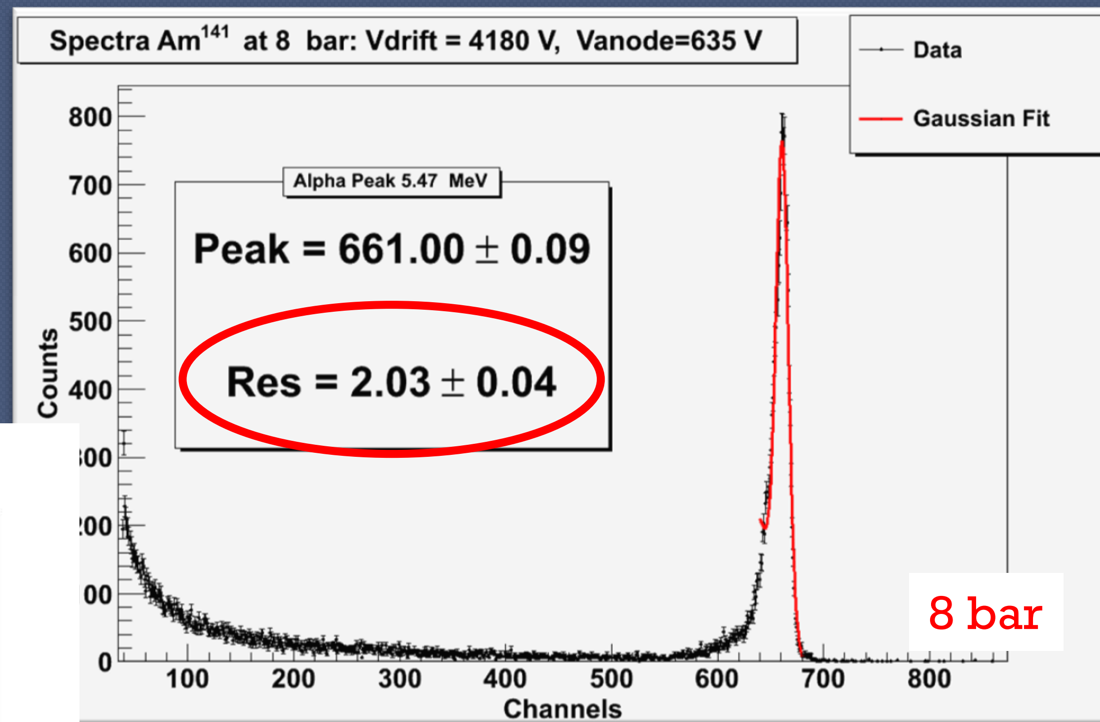
5.5 MV α de ^{241}Am

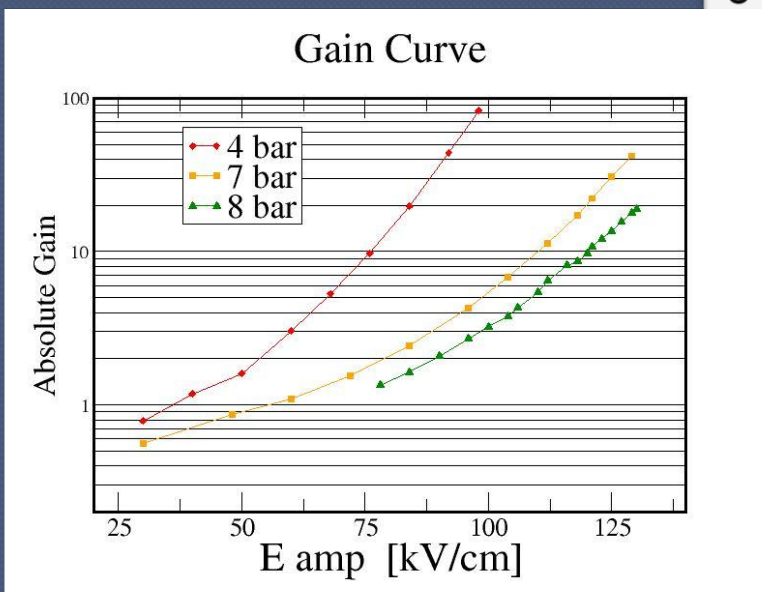
0.7% (FWHM) at 4.75 bar

NEXT-0-MM
Tests with α in Pure Argon

Using an ^{241}Am source

Tests performed in high pressures, reaching 8 bar.

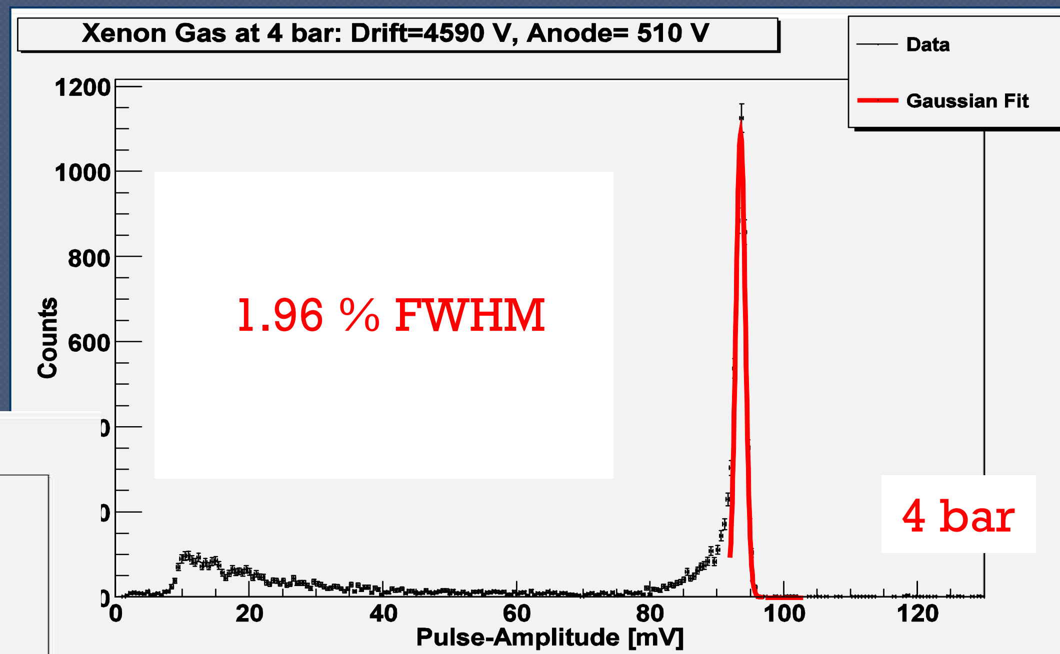


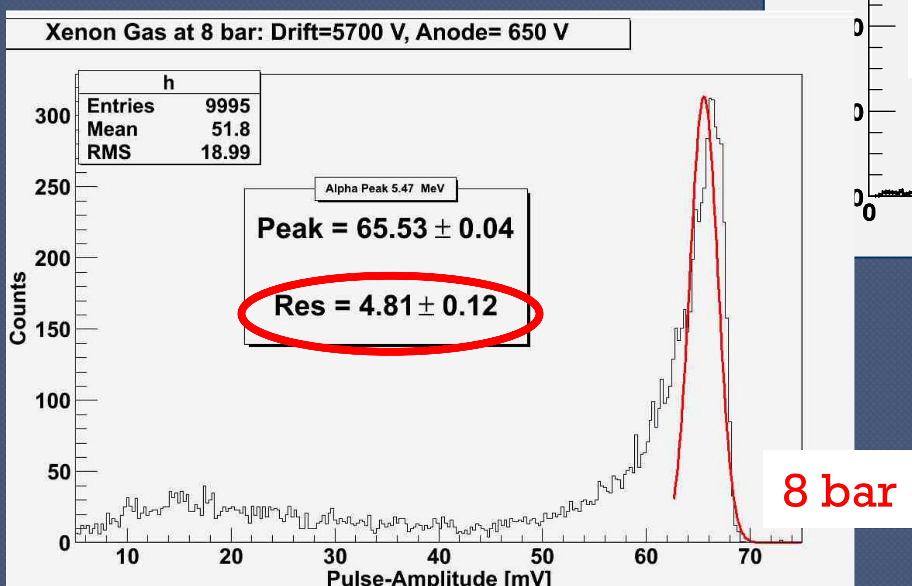


NEXT-0-MM
Tests with α in Pure Xenon

^{241} Am source

Examples at 4 and 8 bar





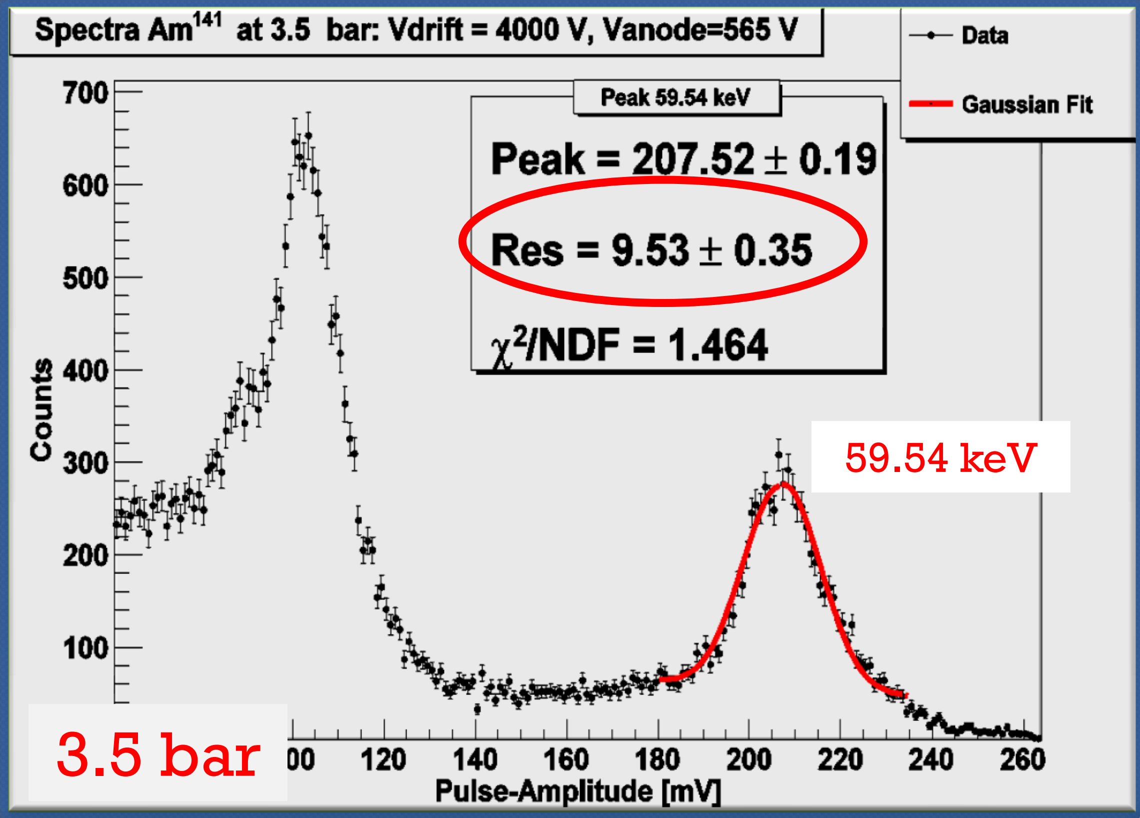
At higher pressures resolution worsens because of Attachment

NEXT-0-MM
Measurements with γ in Pure Xenon

^{241}Am source upside down

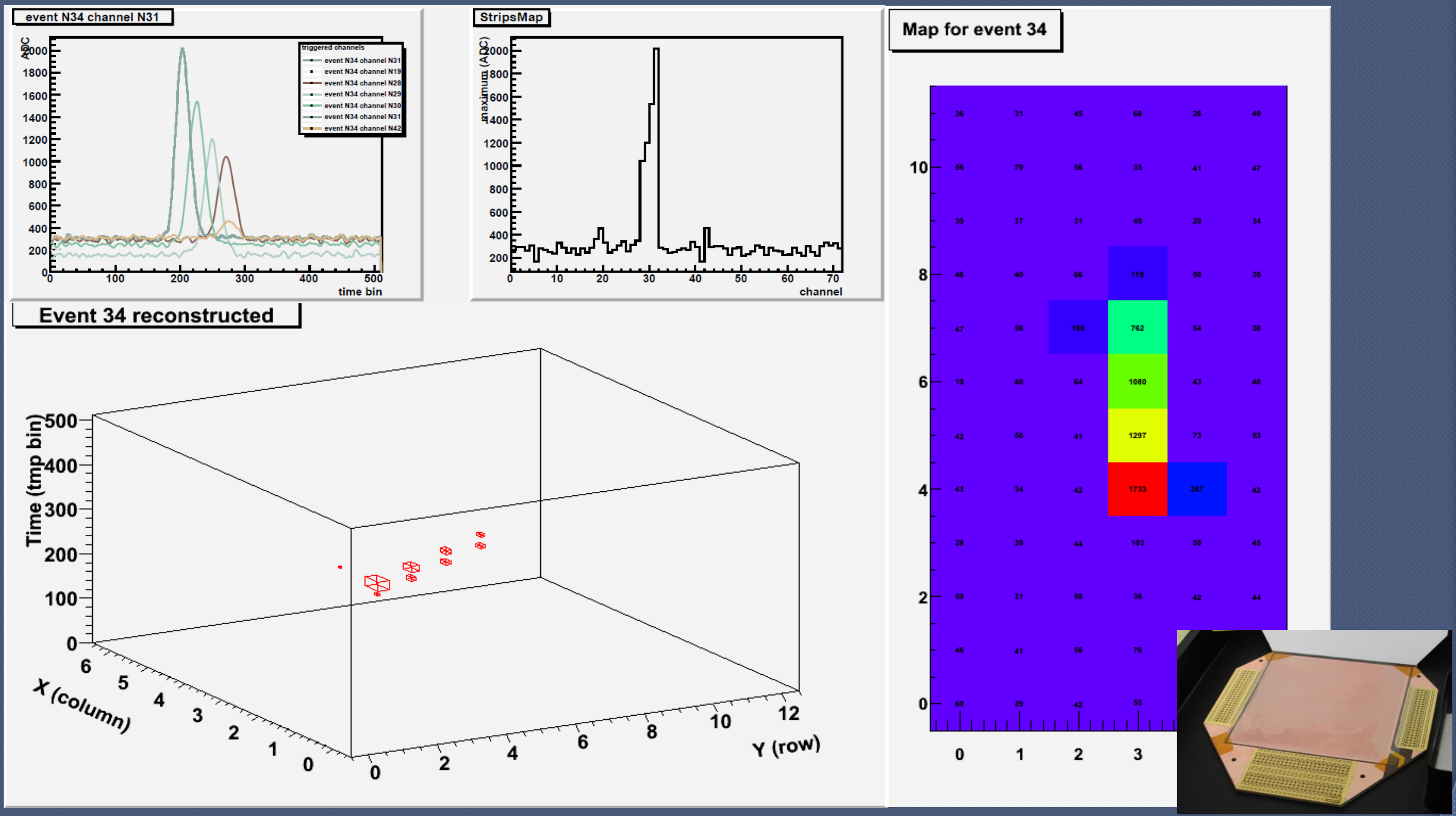
blocks the α allows the 59.54 keV γ

Example taken at 3.5 bar



NEXT-0-MM
α tracks in Ar-Iso

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

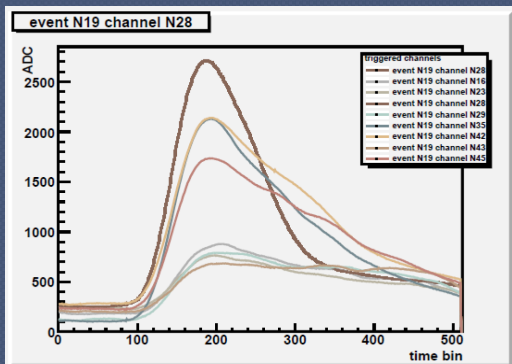


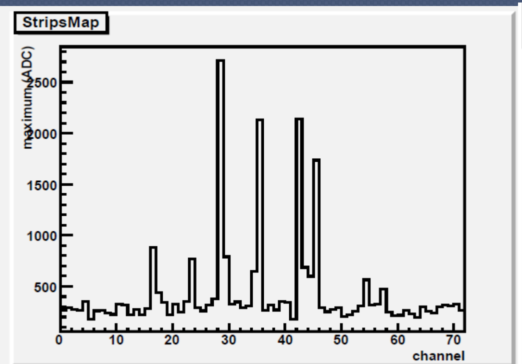
NEXT-0-MM

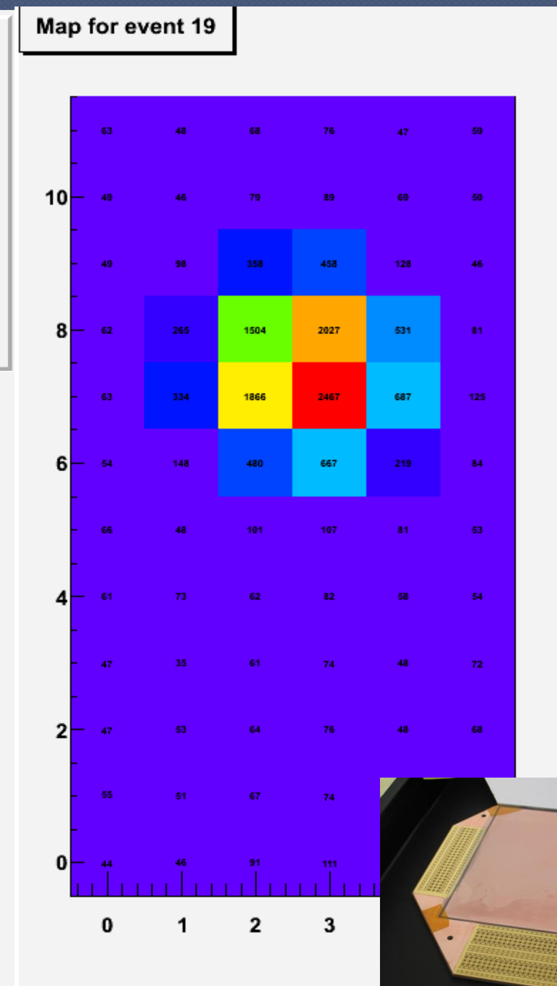
α tracks in pure Ar

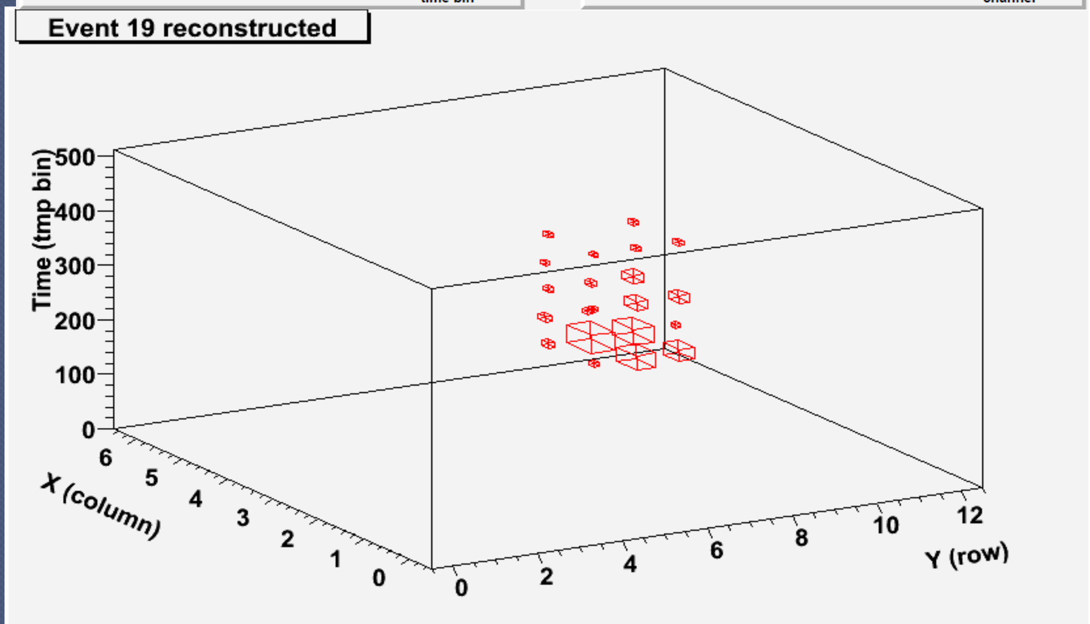
Pure Ar @1.23 bar

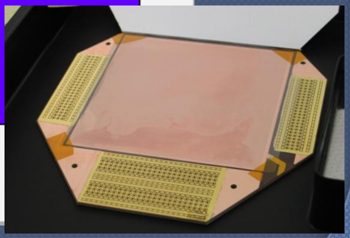
reduced T2K electronics version









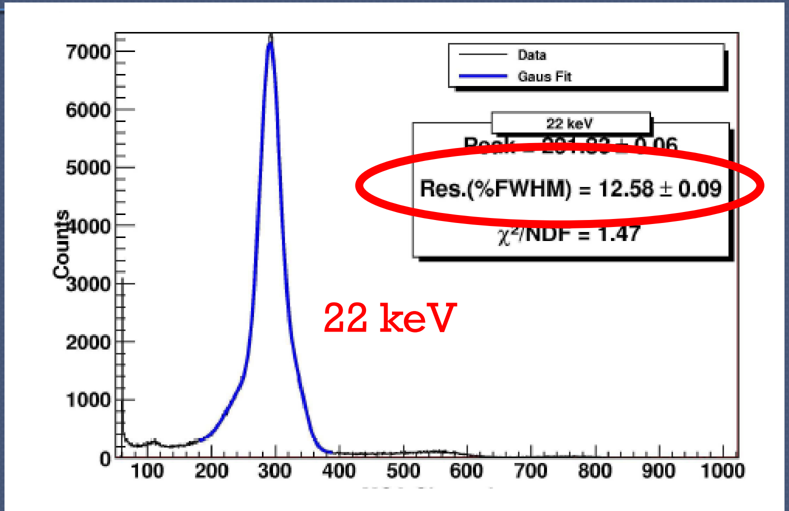


NEXT-0-MM
Xe-mixtures

Systematic study of Xe-TMA with Micromegas ongoing.

Very first results promising:

- High gains achievable (>10^3)
- >> gains than pure Xe at same voltage (Penning effect)
- 1% resolution seems to be at hand
- More work ongoing



4 bar, Xe-TMA 2.4%

Data with Xe-Ne also taken:

- Higher gains than pure Xe
- Energy resolution probably better, at least the same (not conclusive)

Extrapolates to 1.2 % FWHM at Qββ

First data ever taken with MM in this gas, to our knowledge

NEXT-1-MM

Bigger Prototype for ~1kg of Xe (at 10 bar)

test microbulk readouts in realistic conditions

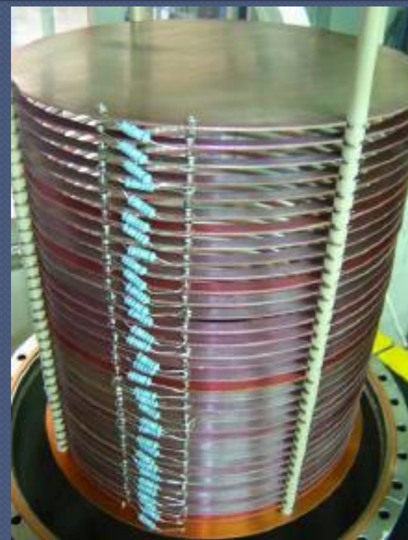
e- tracks fully contained

- Inner Volume of 74 litres (600mm height, Ø 396mm)
- Tested for operation at high pressure (15 bar)
- Steel structure to manipulate the vessel with a crane
- Using the same gas system as for NEXT-0
- Heating and insulation systems

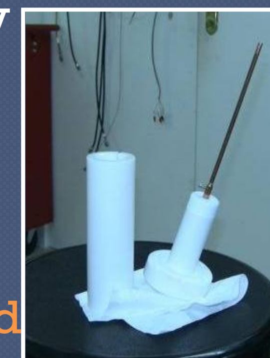
Equipping NEXT-1-MM

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

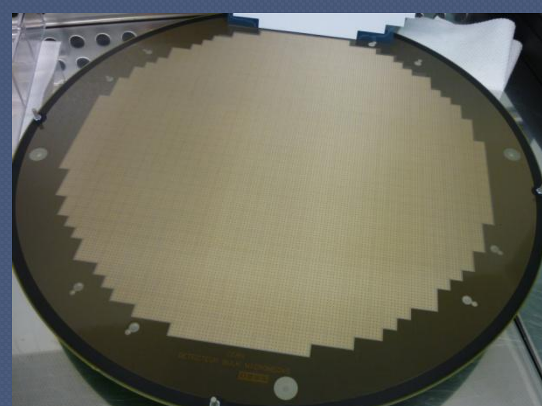


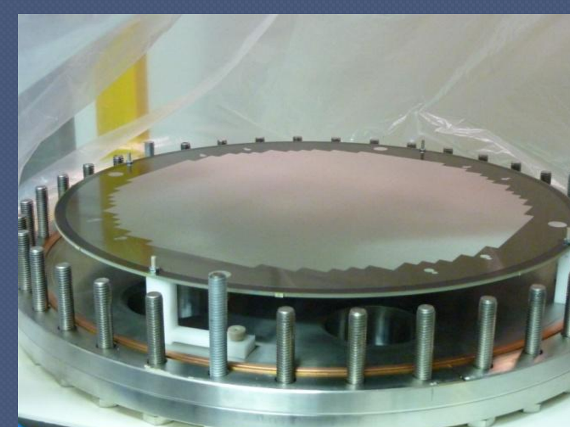
Special HHV FT
  are studied

Cirlex foil between field cage and vessel walls

Bulk Micromegas

Active region Ø ~30cm
1252 pixels
  independently read

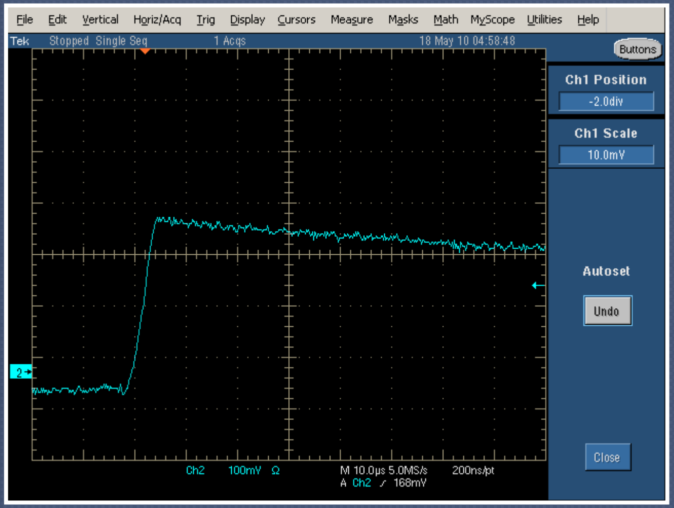




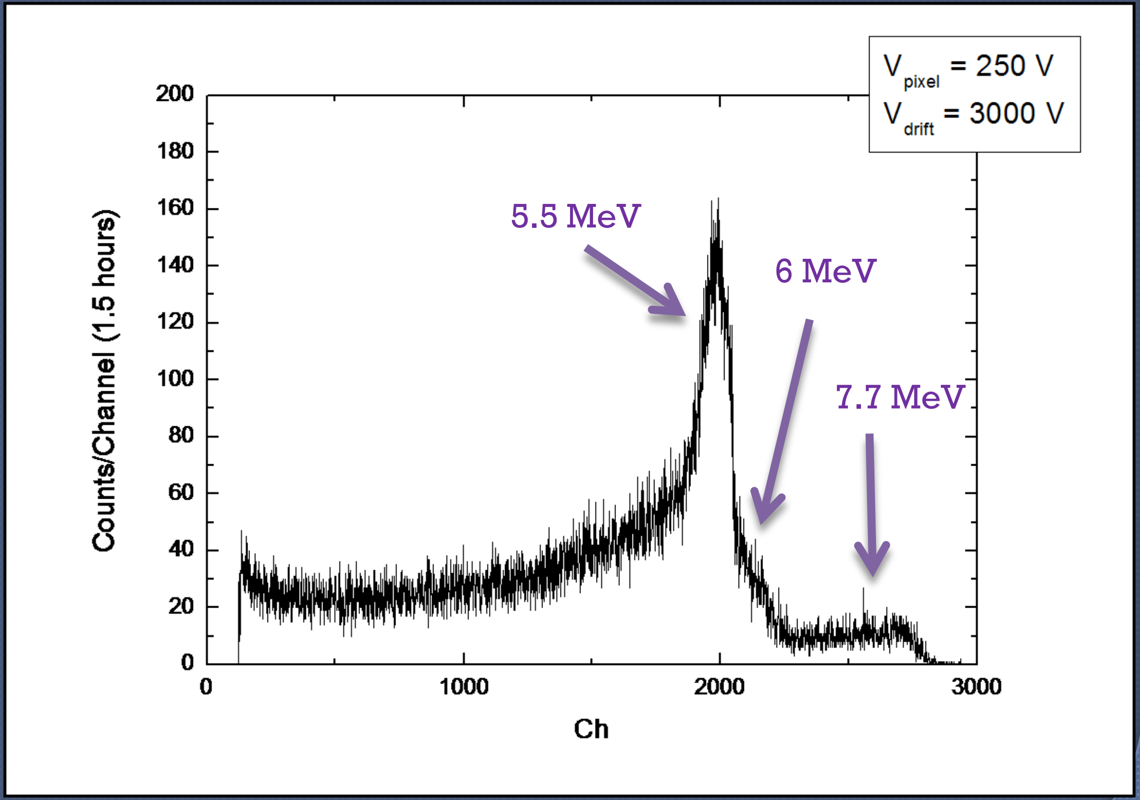
First Tests

Reading the mesh

First pulses
(muons and alpha events)

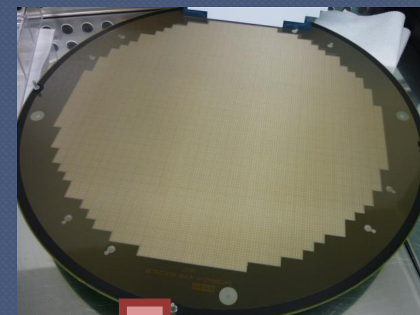


Rn source diffused
in Ar - 2%Iso at 1 bar
All volume active

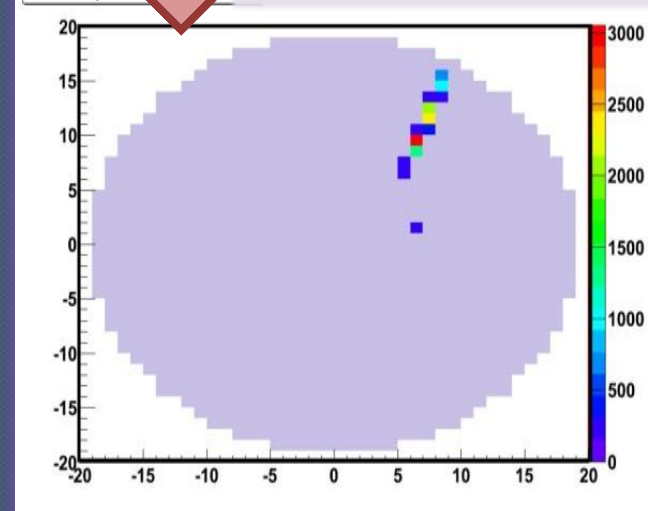


First Pulses

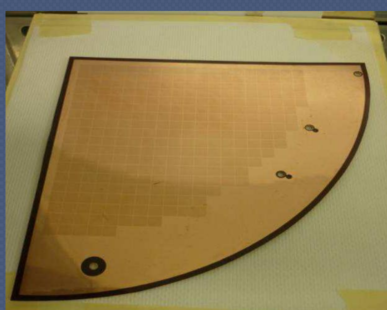
First alpha tracks in Ar
with AFTER-based DAQ
with a Bulk readout

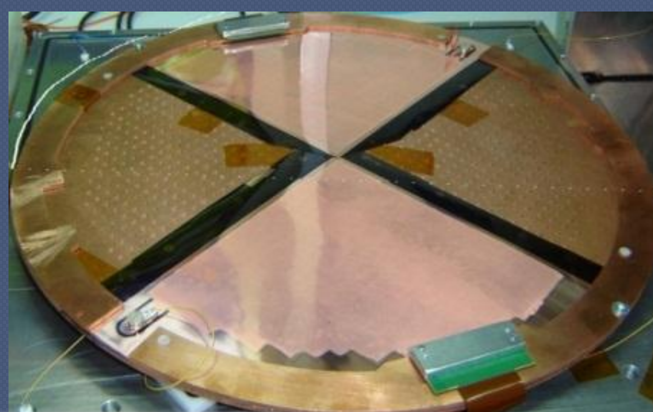


First tracks



Now installing microbulk readout





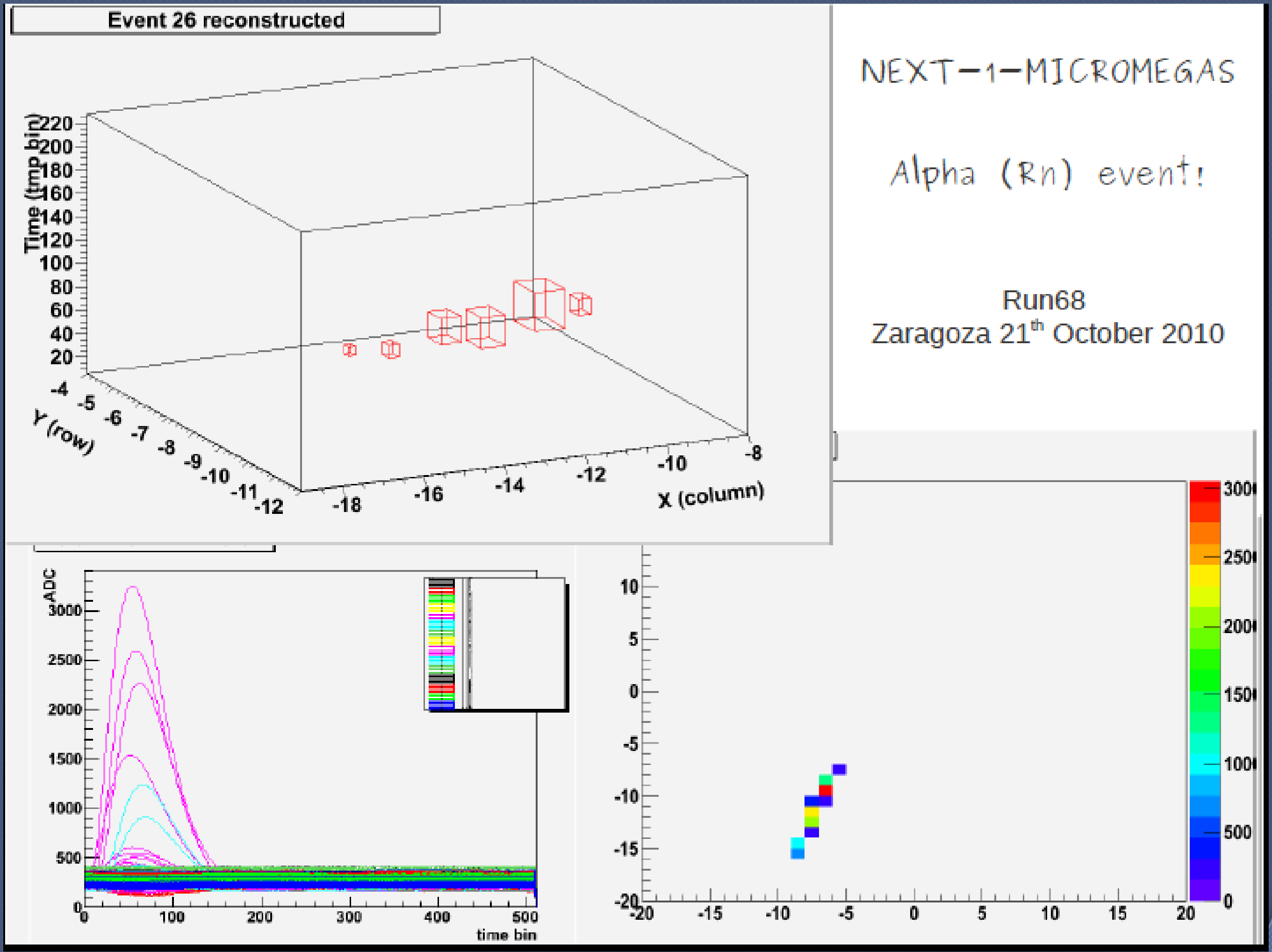
Microbulks in 4 sectors

NEXT-1-MM
Reading the pixels

Ar-2% Isobutane

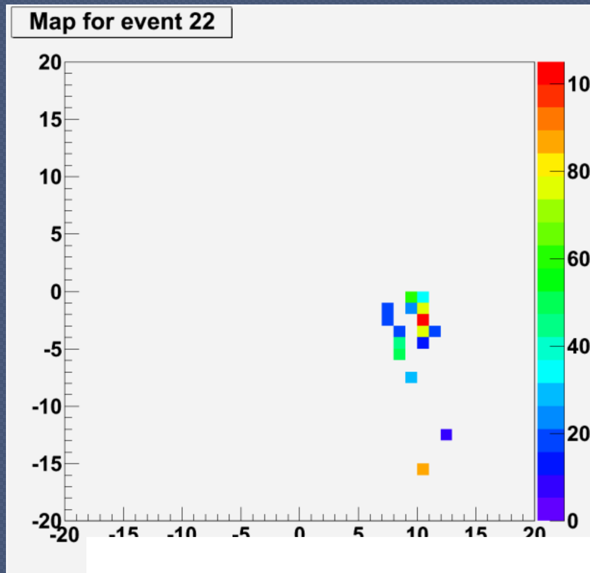
Rn source

1 bar

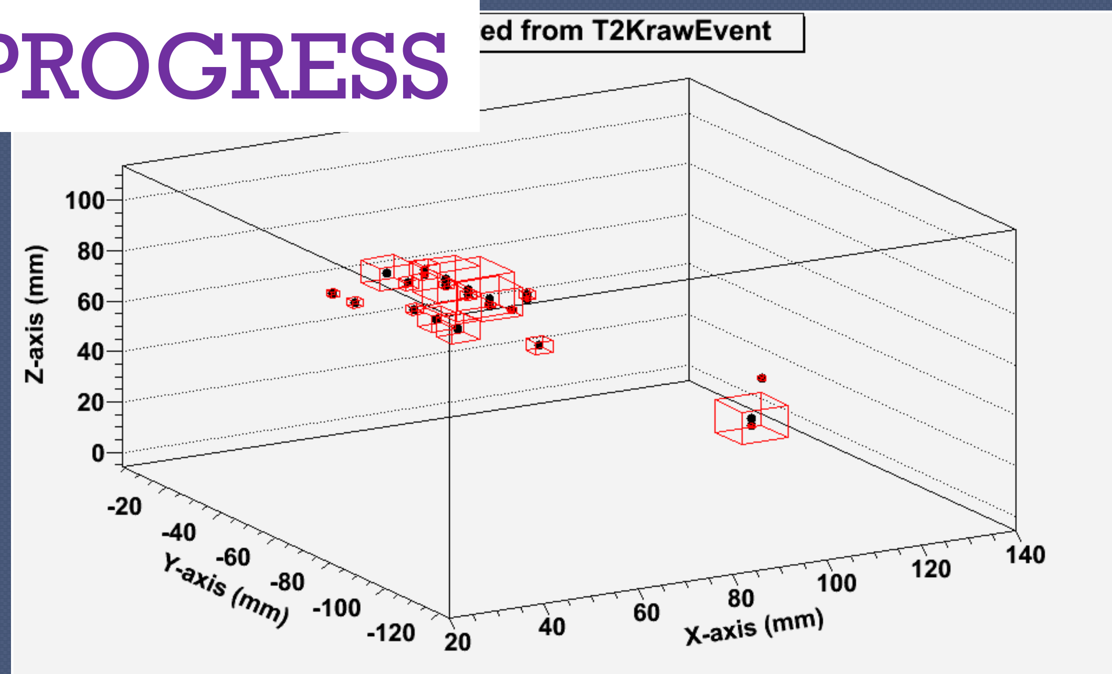


NEXT-1-MM
Reading the pixels

First events in Xe !



WORK IN PROGRESS



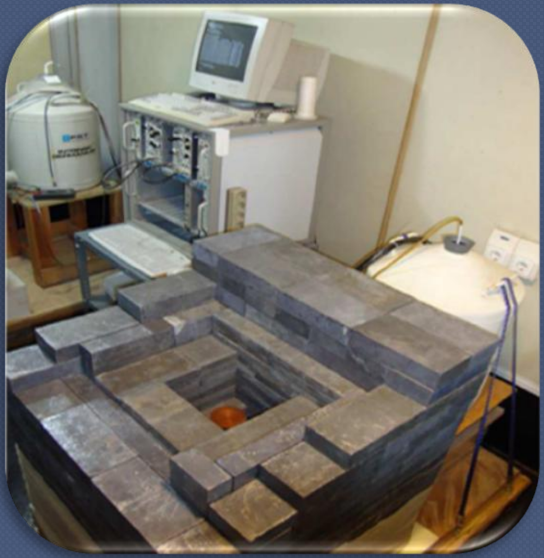
Radiopurity measurements

S. Cebrian et al., Astropart. Phys (2010) doi:10.1016/j.astropartiphys.2010.09.003

Radiopurity measurements

Rare event searches dictate the use of radiopure materials
important parameter for the big-scale experiments
Necessary to know the quantity, nature and origin of the contamination

Microbulks are mostly Cu & Kapton
potentially very radiopure
Several samples measured
with HPGe at Canfranc
- 2 samples of raw material (double clad kapton foil)
- 2 samples detached from old CAST detectors



HPGe detector in Canfranc

Radiopurity measurements results

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*

*Level obtained from the Minimum Detectable Activity of the detector

✓Very low levels of radioactivity, compatible with the sensitivity of the measurement

✓Contamination probably comes from the treatment of the materials used

✓Next steps: identification of the contaminating steps and find alternatives

S. Cebrian et al., Astropart. Phys 34 (2011) 354-359

Summary

The T-REX project

Microbulk Micromegas readouts are of most interest for such applications.

Examples of development within this scope:

✓For axions, in CAST:

- Stability of operation
- Very low backgrounds: $<1x\ 10^{-5}$ c/s/keV/cm^2 in CAST, with potentials to go lower , closing in the intrinsic resolution with measurements in Canfranc at $\sim 2x\ 10^{-7}$ c/s/keV/cm^2

✓ For double beta decay, in NEXT

- Operation at high pressures
- Energy Resolutions of :

  1.96 % (FWHM) at 4 bar of pure Xe for 5.5 MeV α

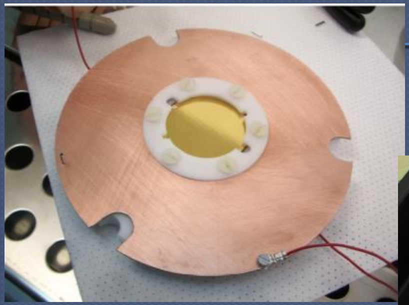
  9.5 % (FWHM) at 3.5 bar of pure Xe for 60keV γ

  2.4%(FWHM) at 3.4 bar of Xe-2.4%TMA for 22kev γ

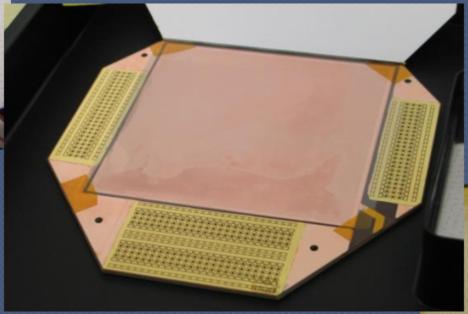
The microbulk planes present very low radioactivity levels

Microbulk Micromegas gather all the necessary characteristics

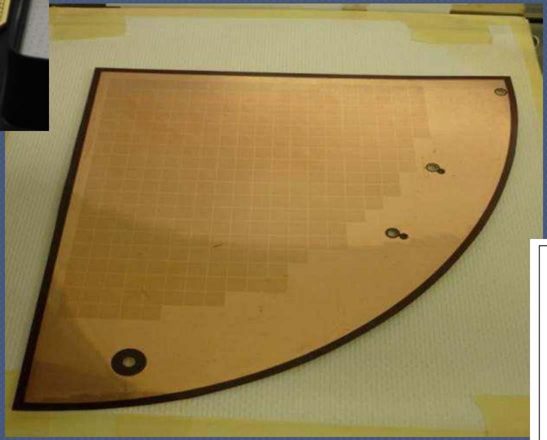
Microbulk scaling-up



3 cm Ø

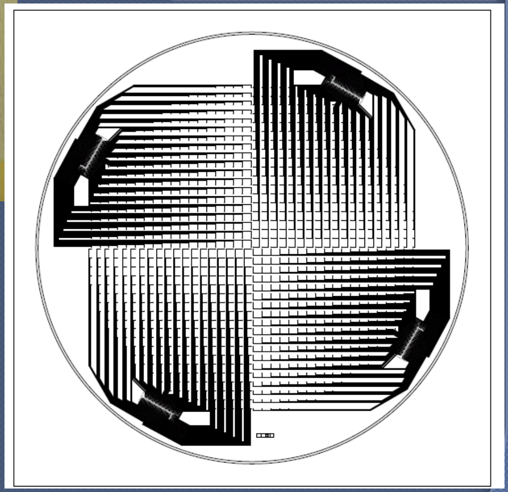


10 x 10cm^2
12 x 12 pixels



15 cm radius
300 pixels
Largest microbulk up to now

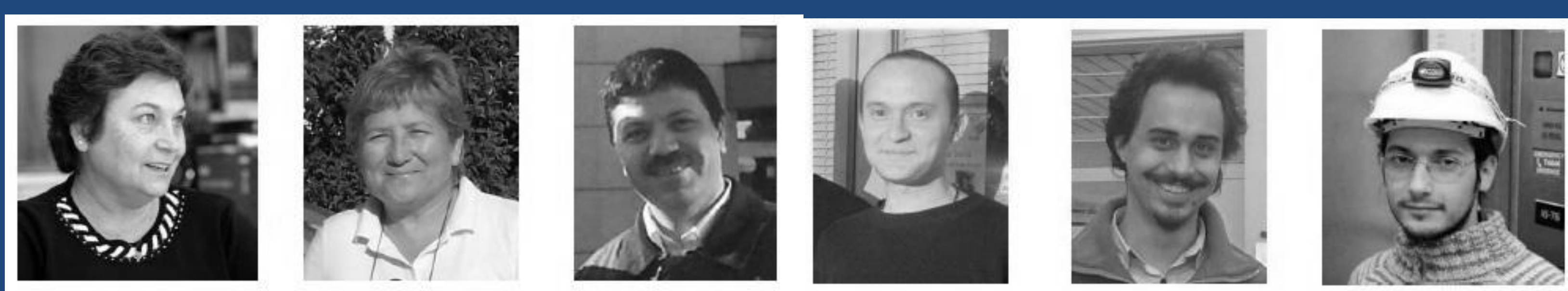
Underway:
30 cm Ø microbulk



TREX: infrastructure

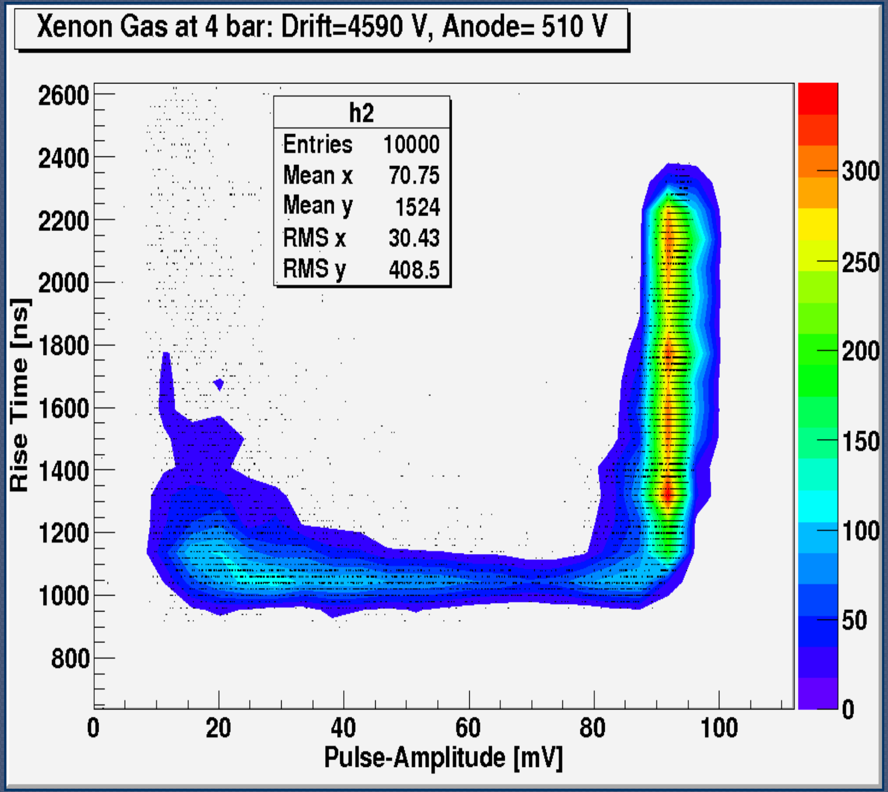
~90 m^2 extra space for the project being equipped…

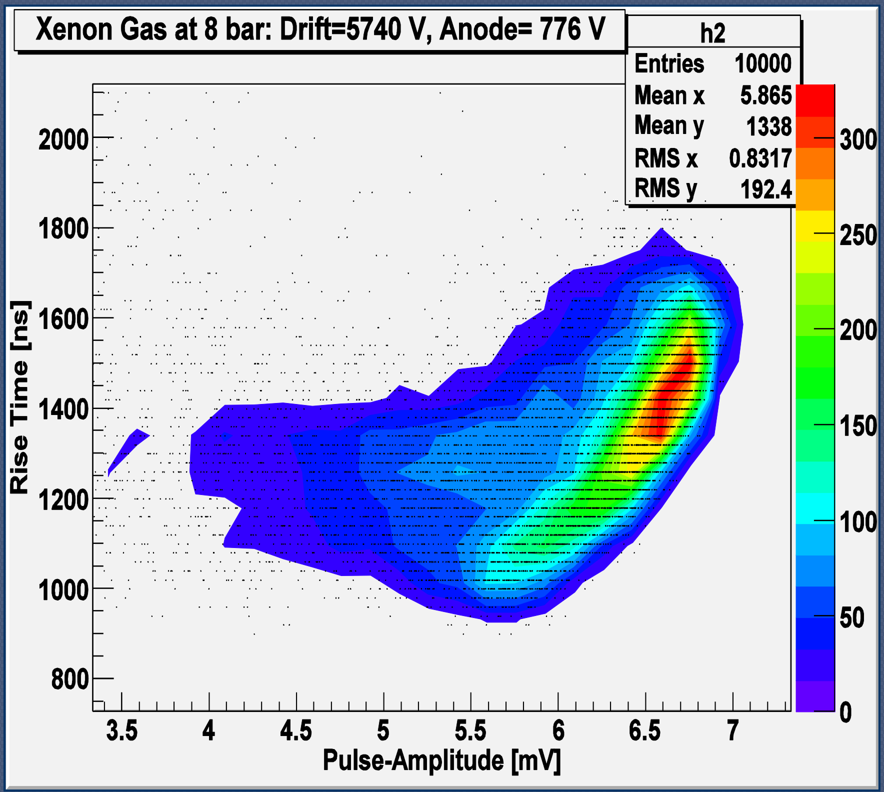
Thank you for your attention



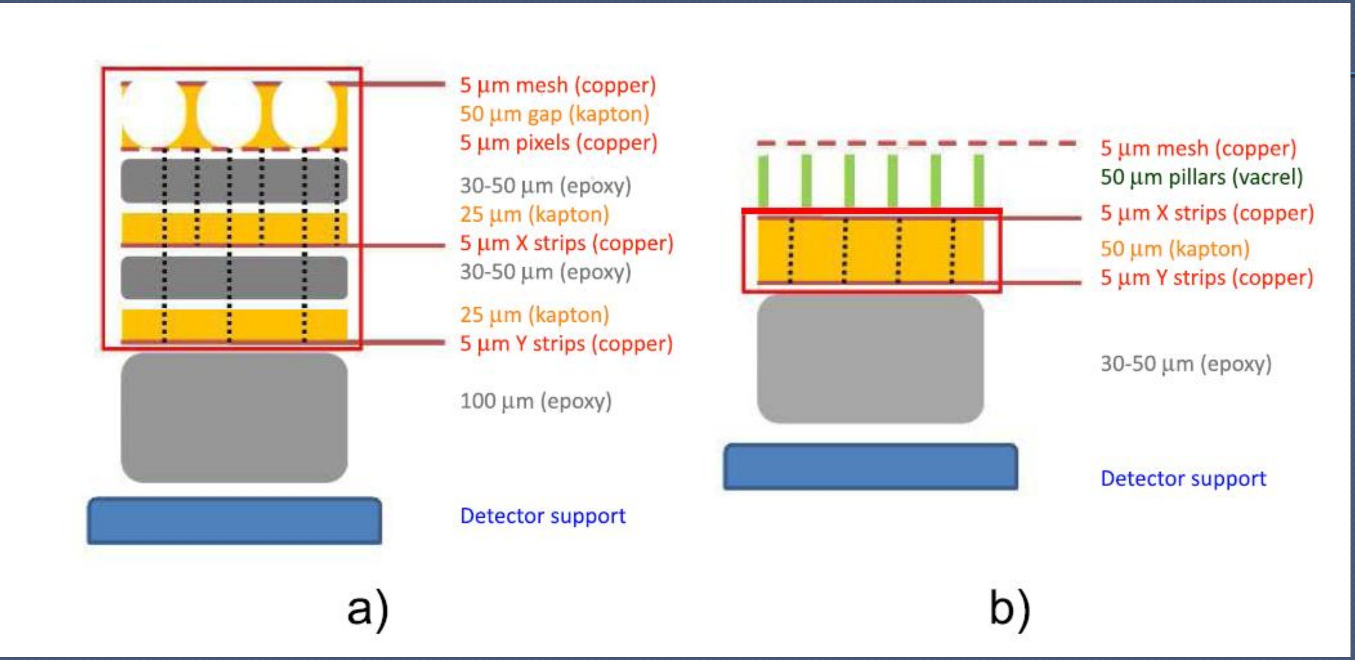
NEXT-0
Tests with α in Pure Xenon

When going to higher pressures the effect of attachment can be clearly seen





Radiopurity measurements



Results (in µBq/cm^2)	^{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*

*Level obtained from the Minimum Detectable Activity of the detector

S. Cebrian et al., Astropart. Phys (2010) doi:10.1016/j.astropartiphys.2010.09.003