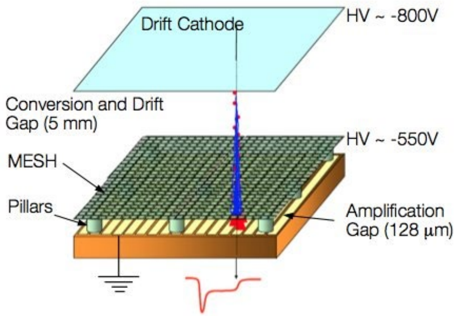
IAXO/TREX Detector R&D Activities

Instrumentation for the future of particle, nuclear and astroparticle physics and medical applications in Spain

CAPA Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

The MicroMegaS concept



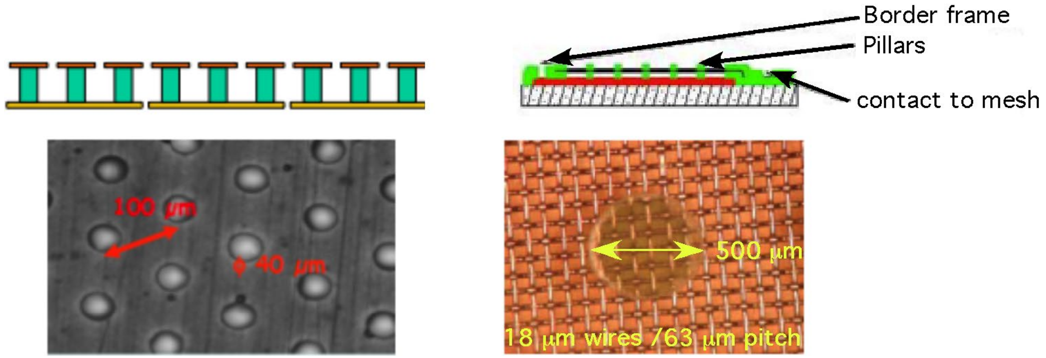
Classic: a mesh is suspended (pillars) over the anode strips or pads, G. Charpak + I. Giomataris

Bulk:

- metallic woven mesh on a Printed Circuit Board (PCB),
- more robust and no dead space

Microbulk:

- the mesh, the pillars, and the readout structure are produced in one single structure.
- Invented by in 2006 by I.Giomataris (CEA Saclay) and R. de Oliveira (CERN)
- more homogeneous amplification gap, better radiopurity and energy resolution



Side view sketch and mesh top view picture of a standard 50 µm micro-bulk (left) and a 128 µm bulk-micromegas (right)

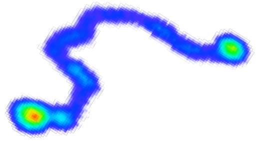
	bulk	micro-bulk
Standard amplification gap	128 μm	50 μm
Other possible amplification gaps	(64)-100-150-194 μm	(12.5)-25 μm
Standard Mesh pitch	63 μm	100 μm
Standard Mesh openings	45 μm	40 μm
Standard maximum size	50x150 cm^2	10x10 cm^2
R&D maximum size	100x200 cm^2	30x30 cm^2
Best FWHM 5.9 keV resolution	19%	11%
Currently in use in experiments	T2K/TPC	Axion CAST experiment, nTOF
Current R&D programs	ILC/TPC, ILC/DHCAL, SLHC/Muon chambers upgrade, CLAS12 spectrometer, ...	NEXT, MIMAC, ...

Comparison of some bulk and micro-bulk specifications and performances.

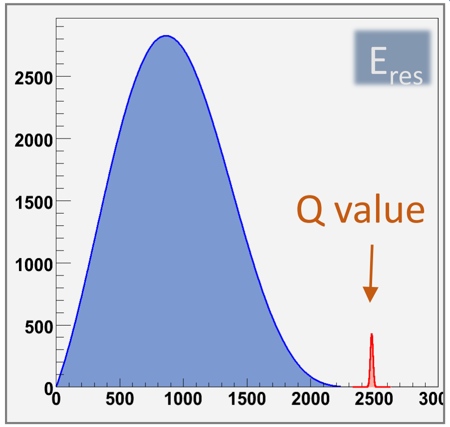
A. Delbart el al, Micromegas for charge readout of double phase Liquid Argon TPCs, Journal of Physics: Conference Series 308 (2011) 012017

MPDGs for rare event searches: a long experience

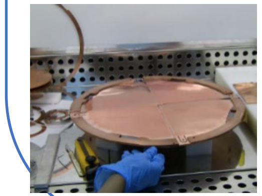
Neutrinoless double beta decay

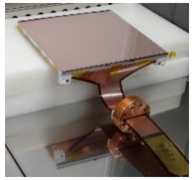


A signal event:
- 1 two blob track
- Around Q energy

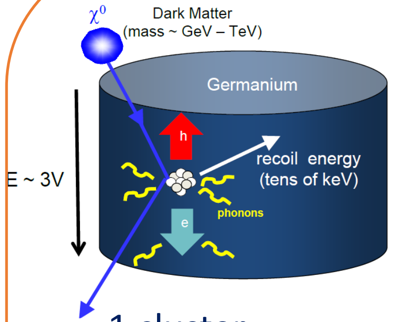


TREX-BB

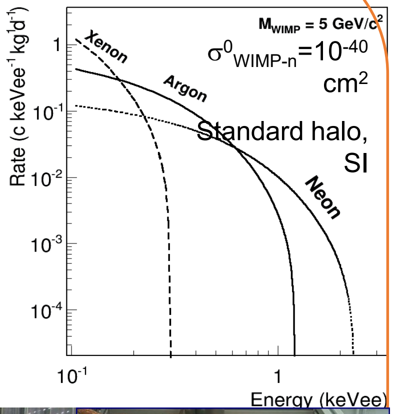


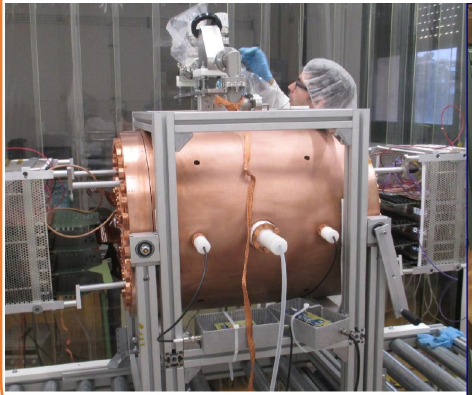


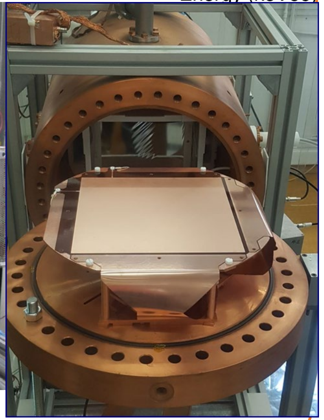
WIMPs



1 cluster
Low energy

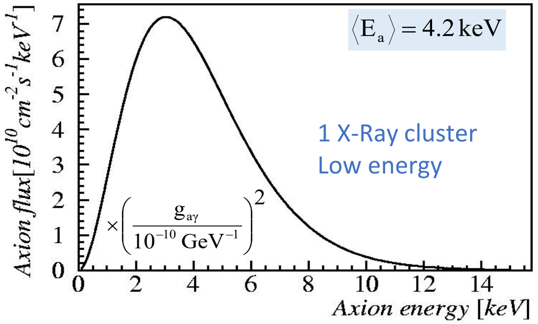






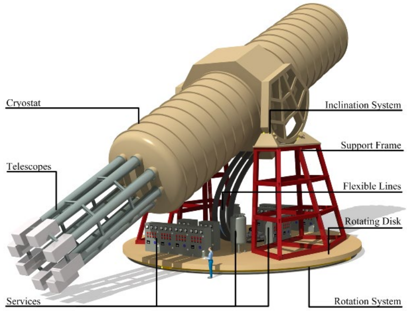
TREXDM

Solar Axions



CAST

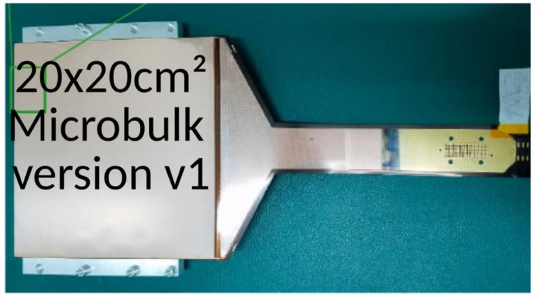
IAXO

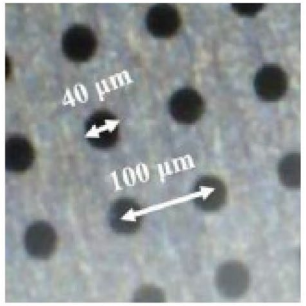


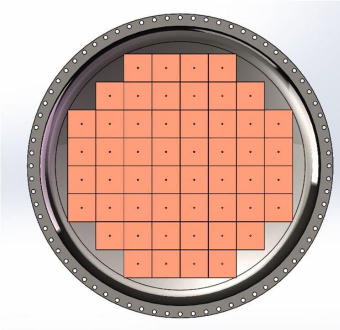
TREX-BB

H=34 cm, D=30 cm
1152- 8x8 mm2 pixels


field cage (left) and the field cage with the Cirlex screen insulator

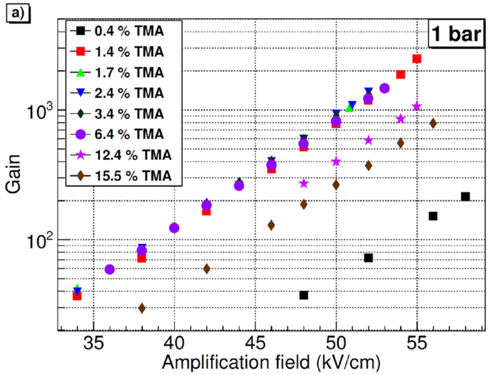


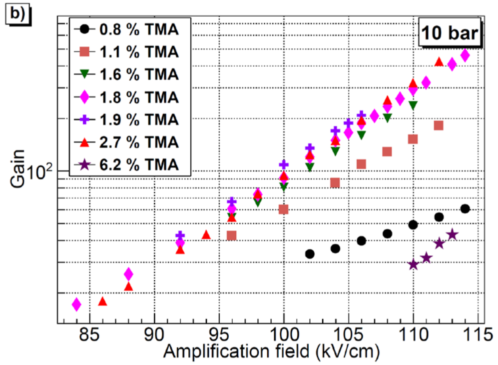




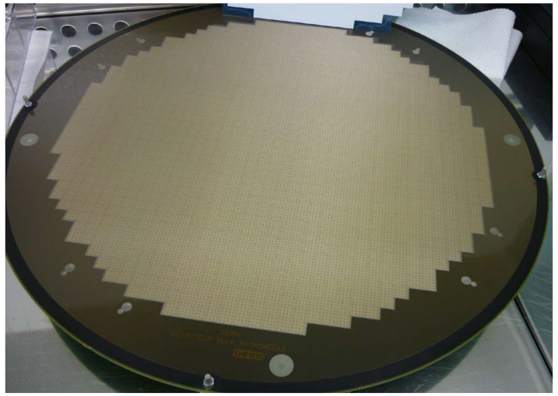
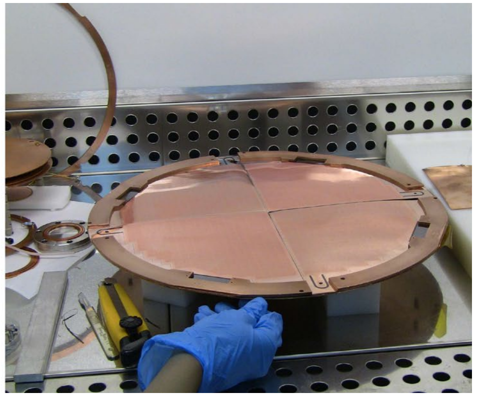
- MMs fabricated at CERN: Kapton and copper with a thickness of about 0.2 mm.
- 64 readout strips in each side (X and Y) with 3 mm piches.

Drawing of the readout plane, which consists of 52 MMs with an active area of 20x20 cm2.





Dependency of the gas gain on amplification field for different TMA concentrations at 1 (a) and 10 (b) bar.

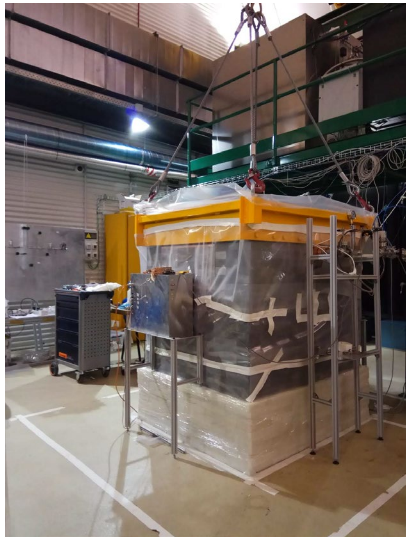
Bulk (left) and Microbulk (right) Micromegas used for instrumenting the readout plane of the TPC

- Technical solutions for scaling-up via tessellation
- Different gas mixtures have been tested (Xe+TMA)

TREX-DM (TPC for Rare Event eXperiments-Dark Matter)

A Micromegas TPC for Dark Matter detection at Laboratorio Subterráneo de Canfranc

- ~20 l of pressurized gas (~0.16 kg Ne at 10 b)
- Equipped with novel micromesh gas structures (microbulk Micromegas) readouts and new AGET-based electronics.
- **Goals:** low energy threshold (< 1 keV) and low background level (~1 (keV kg day)$^{-1}$).
- NOT focused in directionality → operation at high pressure.
- Potential to be sensitive to low mass WIMPs (0.1-10 GeV/c2) beyond current bounds
- It has been in commissioning stage at LSC → moved to a new placement → to be restarted in September?



H=0.5 m, D=0.5 m
Central cathode

Readout planes: MicroMegaS

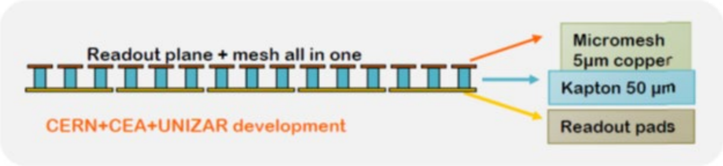
A reliable detector largely used at CAST offering advantages for rare event detection:

Topological information: to discriminate backgrounds from expected signal by dark matter

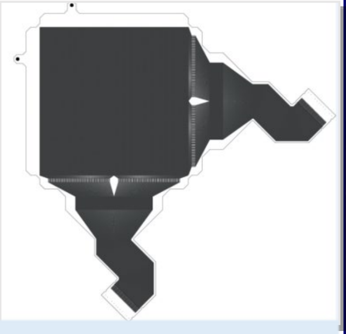
- few microns track → point-like event
- Fiducial cuts →electron events from walls

Low intrinsic radioactivity: made out of kapton and copper, potentially very clean

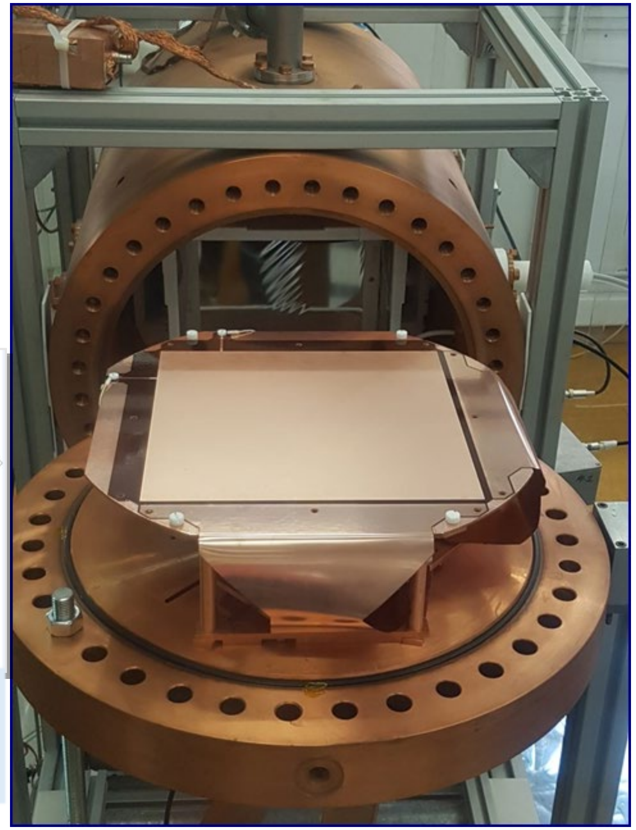
Scaling-up



Microbulk technology → more homogeneus and radiopure



25 x 25 cm^2
TREX-DM fabricated at CERN



Strips
256 X strips, 256 Y strips,
~1 mm pitch → Tracking
Sampling rate 50 MHz, 512 samples, window 10.2 µs
Expected event rate: ~10 Hz

Mesh
Preamplifier + amplifier → Spectrum
(redundant information)

IAXO-D0: the Micromegas prototype at Unizar

IAXO detector prototype

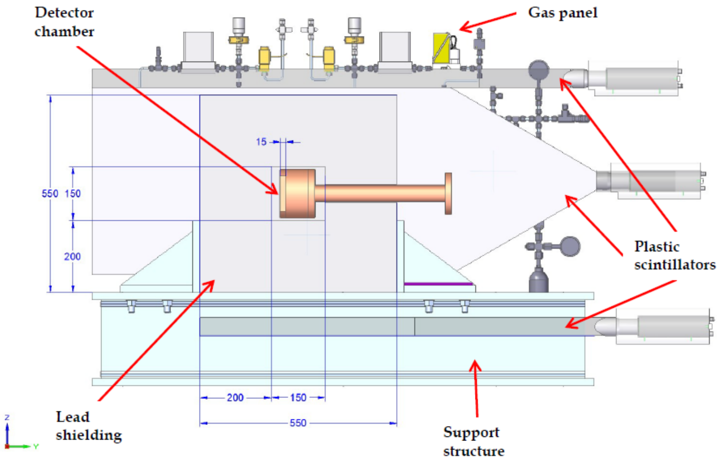
- Ar or Xe+ quencher, 1.4 bar, 3cm drift
- Shielding, material screening

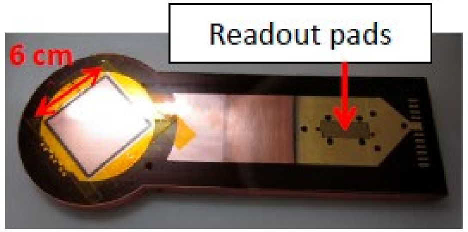
Goals

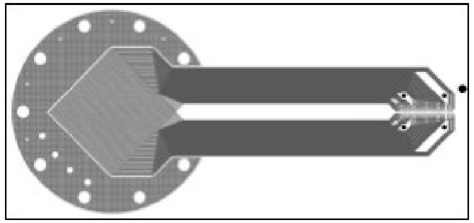
- Background level: 10^{-7}-10^{-8} counts keV^{-1} cm^{-2} s^{-1}
- Energy threshold: ~0.1 keV

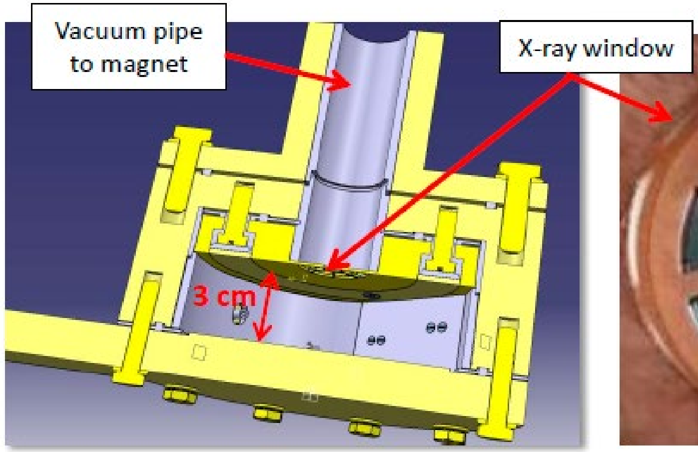
Micromegas detector

- Same design as CAST XRT-MM detector: excellent performance features
- AFTER→AGET-based electronics: auto-trigger for every readout channel





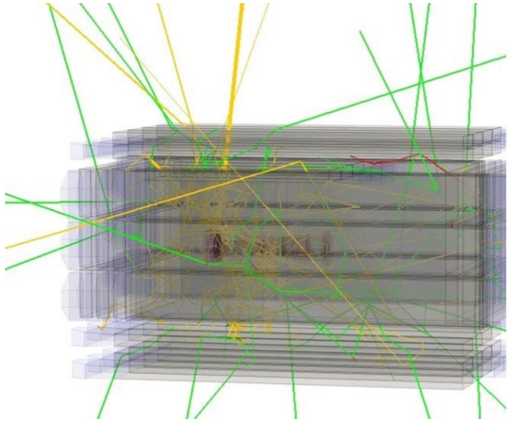


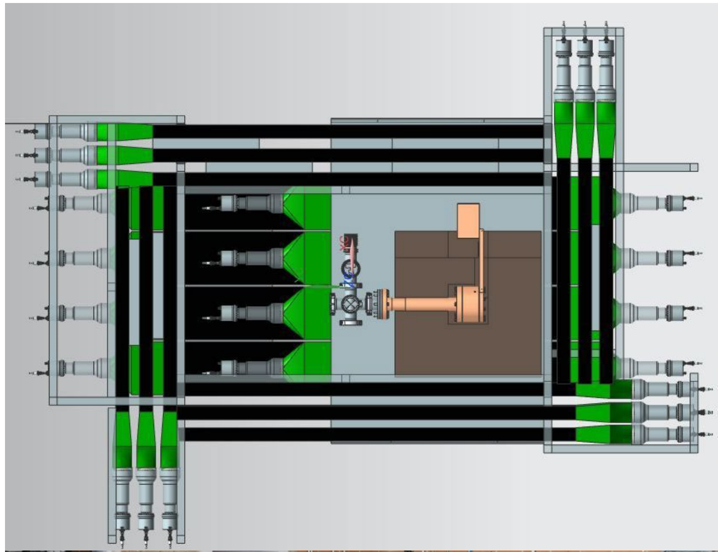


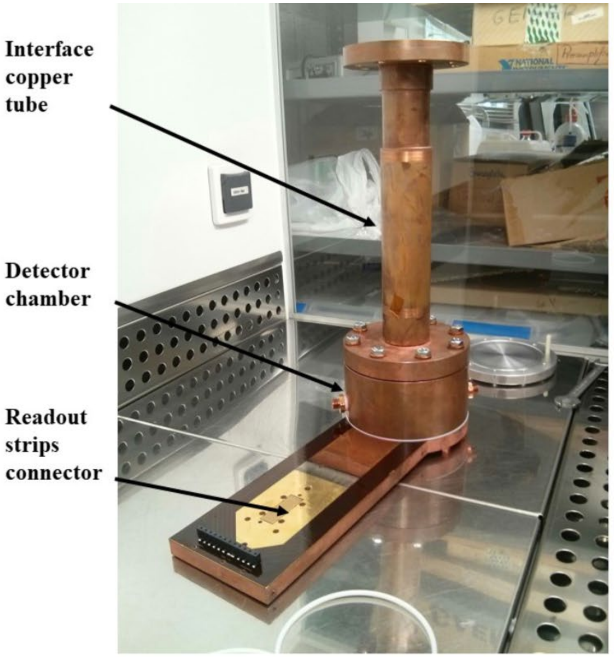
6cm x 6cm, 2x 104 strips, 0.475mm width, 0.5mm pitch

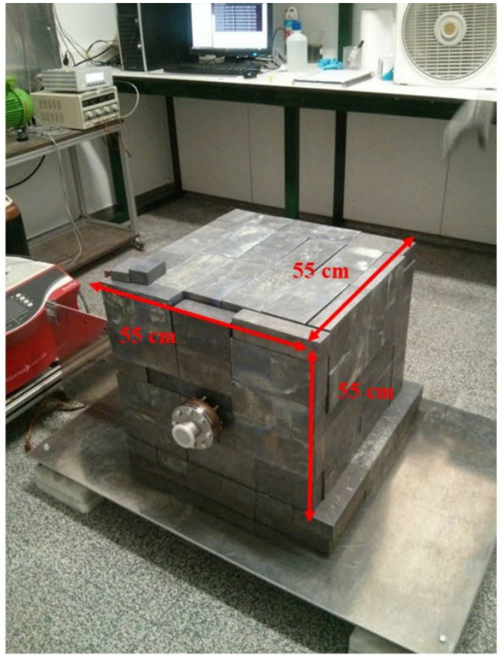
IAXO-D0: the Micromegas prototype at Unizar

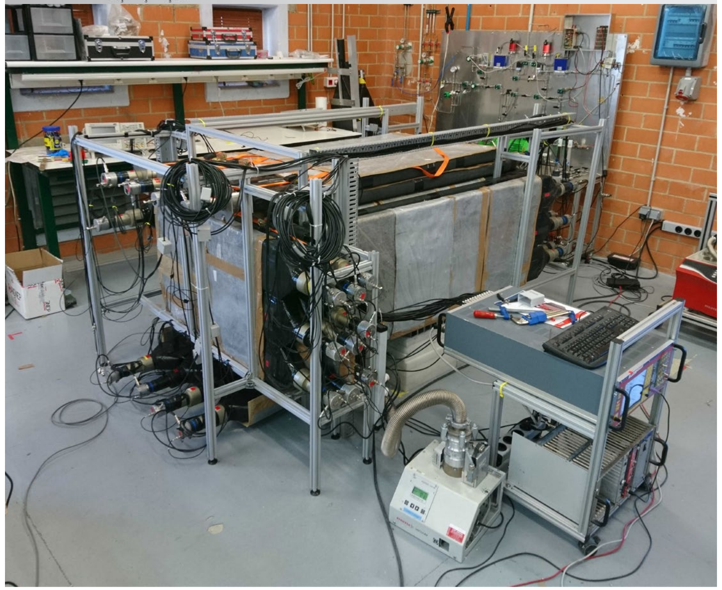
- Setup to study background levels
- Xe-Ne mixture
- Multi-layer veto system → reduce background induced by cosmic muons and neutrons
  - Detector equipped with 57 veto panels
  - 4 π coverage with 3 layers
  - Cadmium sheets placed between the layers











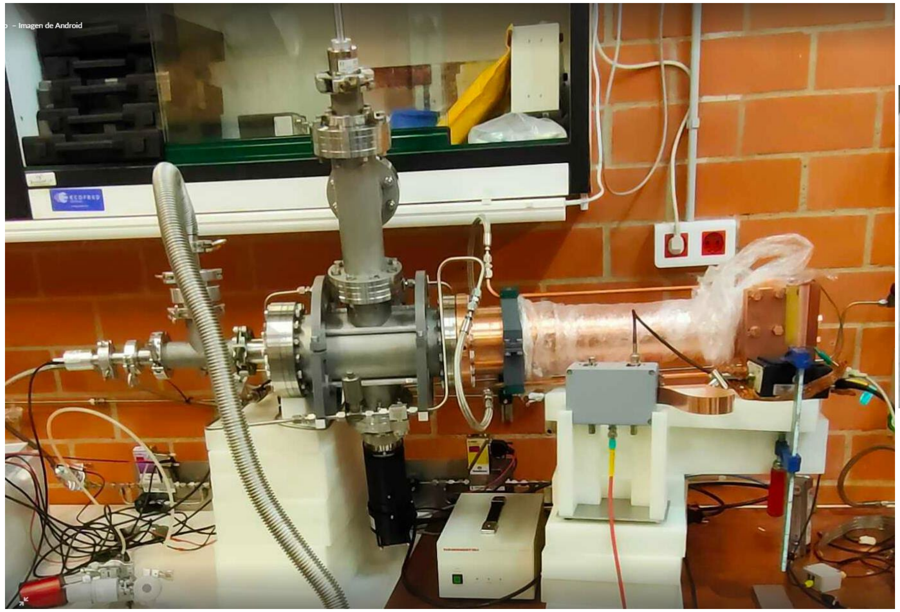
IAXO-D1 at IAXO-LAB (UNIZAR)

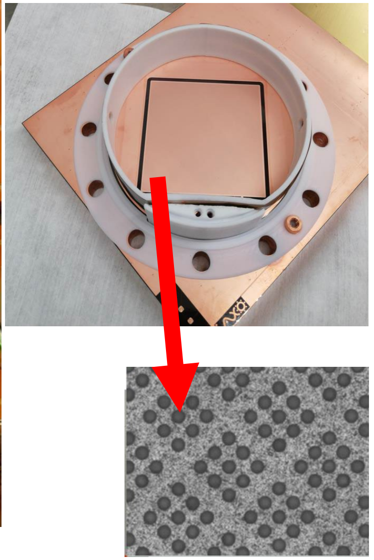
Filter combination:

- Ti target + 40 μm Ti filter →4.5 keV peak
- Cu target + 50 μm Ni filter →8 keV peak
- Small hole with 100 μm Al filter →1.5 keV peak

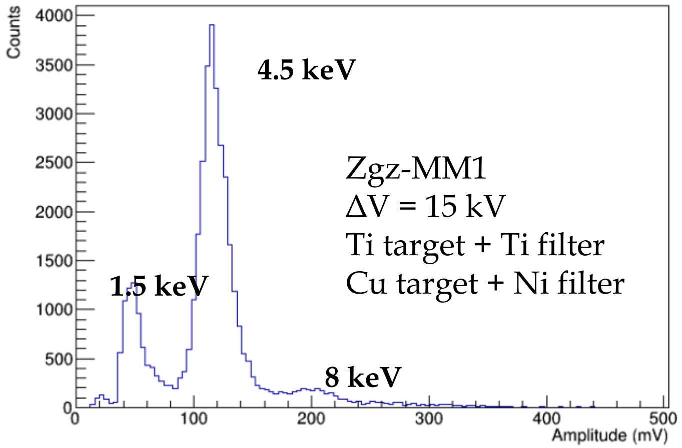
MMs- test setup

- Performance
- Gas mixtures (Ar+Iso, Xe-Ne-Iso, …)
- Pressures

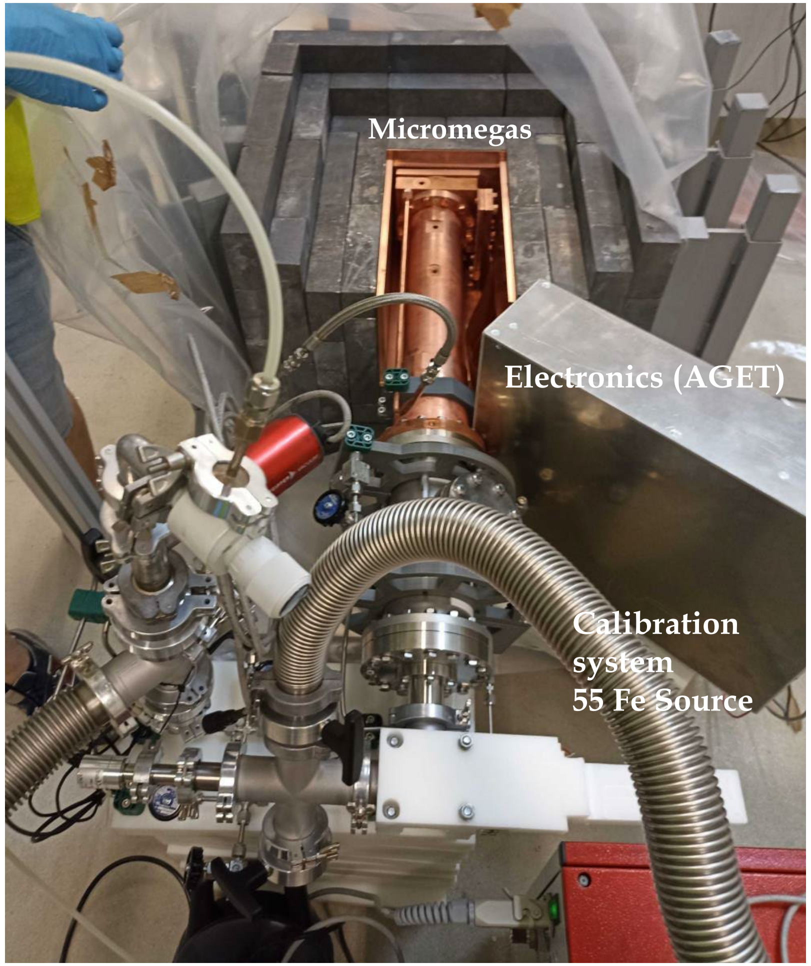




- Gas mixture Ar+ISO (1%) @ 1.1 bar
- Mesh signal via Tektronix oscilloscope → Preamplified and amplified signal recorded.
- Strips signals using FEMINOS + AGET electronics
- Slow control commissioning (Gas system + vacuum system)

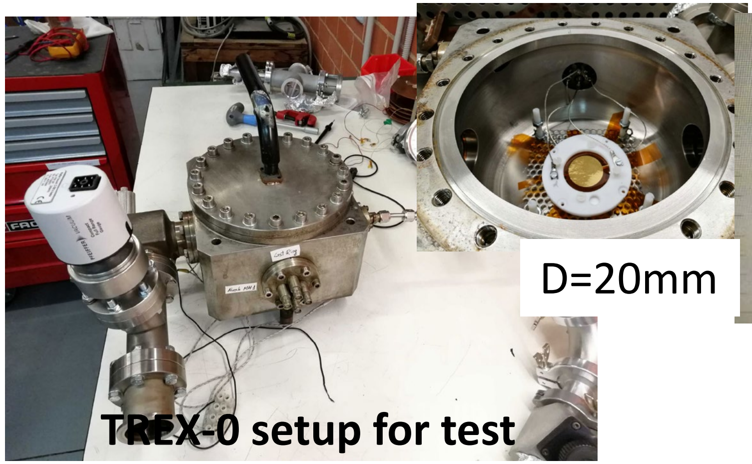


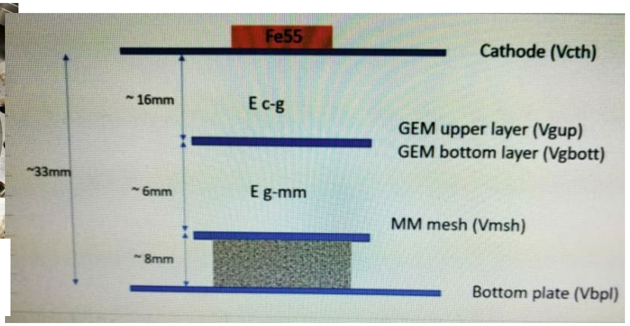
IAXO-D1 at LSC



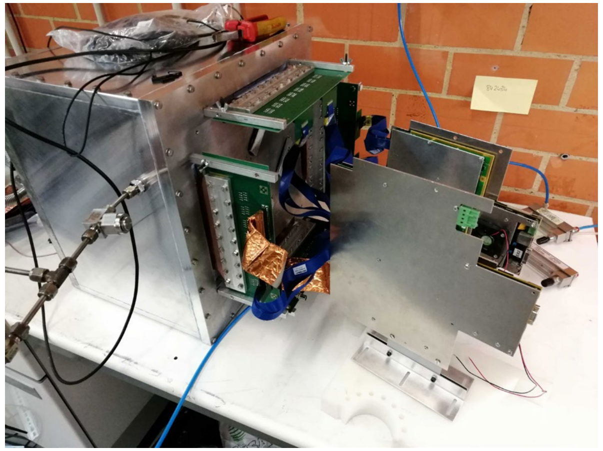
- Gas system and electronics already installed.
- System under commissioning to be ready

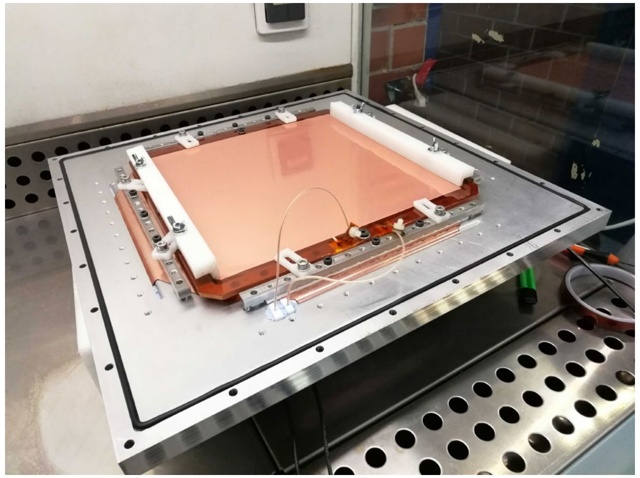
MMs-GEM Test





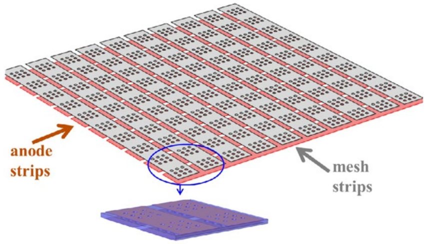
25 x 25 cm2

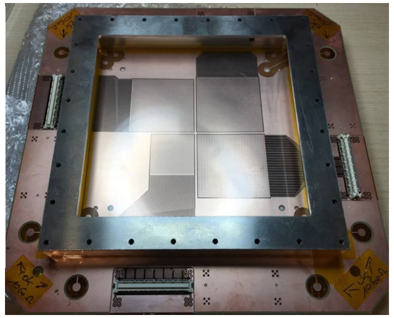




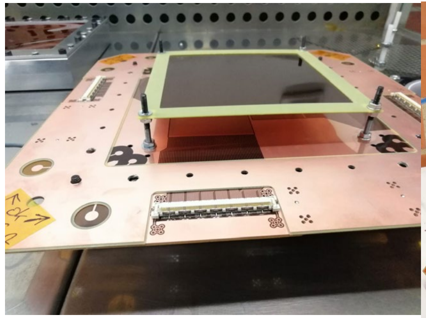
- First test: amplification factor higher than 80 in Ar+2%iso
- To be tested (gas mixtures and pressures)
- Promising results to achieve lower energy threshold

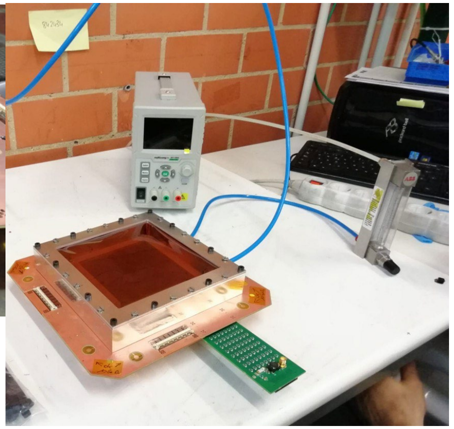
Segmented mesh





4x4 cm2



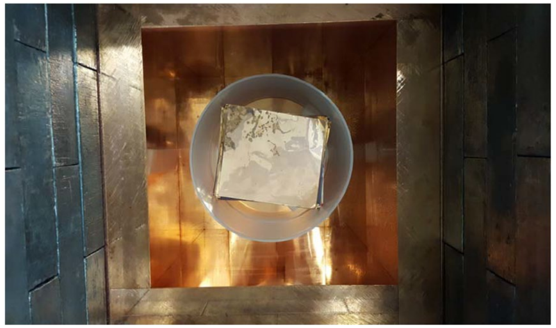


Setup ready for testing

- Simpler construction process
- Less material budget
- Real XY readout structure→ better resolution

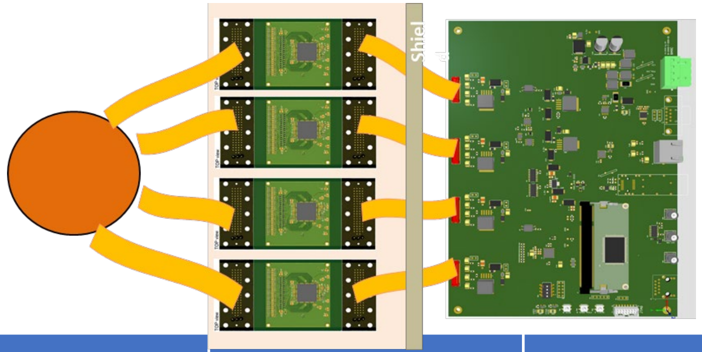
Radiopurity control

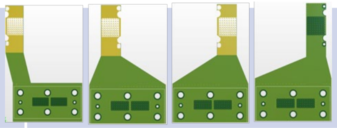
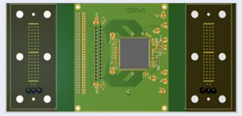
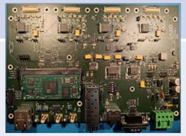
Radiopurity measurements using Ge detectors performed in the LSC or techniques as ICPMS to select materials and to help in the MMs fabrication process



Testing radon emanation of commercial and home-made moisture filters

Radiopure electronics



		Radiopure
Limandes Micromegas-FEC		Yes
Front End Card (FEC)	 x4	PCB → yes Components → no
Limandes FEC-BEC	 x4	Part
Back End Card (BEC)		No

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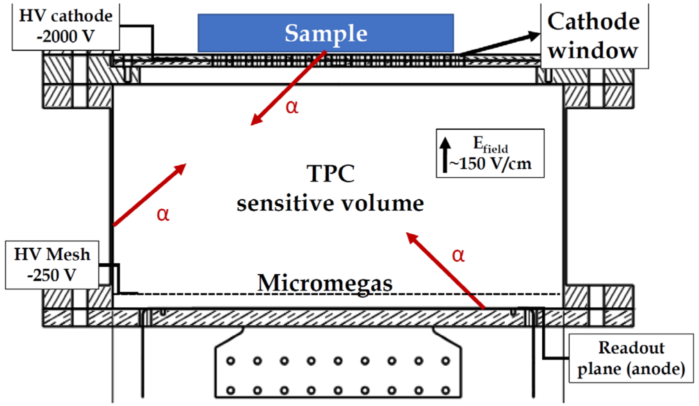
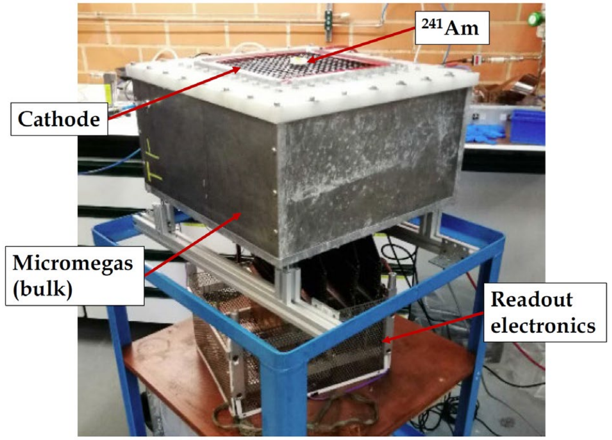
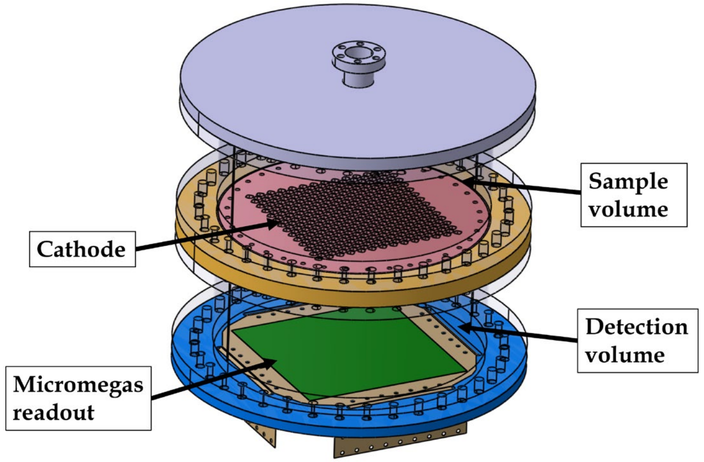
AlphaCAMM: surface radiopurity control

AlphaCAMM working principle







Site measurements

HENSA
High Efficiency Neutron Spectrometry Array

EM Noise control

ITAINNOVA
INSTITUTO TECNOLÓGICO DE ARAGÓN

Conclusions

Decades of experience on gaseous detectors

- Experiments: CAST, TREX-BB, TREX-DM, IAXO
- Laboratory setups for detector characterization and gas studies.
- Experience on radiopurity control (including radon and material emanation), radiopure electronics (ICCUB), shielding design, and site characterization (HENSA).
- EM noise studies (ITA INNOVA, Aragón)
- Access to the LSC underground laboratory.
- Part of the RD51 collaboration and active contributors since its creation

People (FTE) in detector R&D: 2 engineers +1 technician, 4.25 Ph-students, 2.5 post-doc researchers, 1.5 senior researchers

Open detector challenges being addressed: Mostly encompassed by the DRDT 1.4 of the ECFA roadmap. More specifically:

- Improve the radiopurity of detectors of this type in order to reduce their intrinsic background
- Improve the energy threshold of detection (by improving operational gain and/or EM noise)
- Improve general robustness of detector, technical design choices, novel gas mixtures and operation points, etc. to facilitate future implementations: scaling-up to larger detector sizes, handling large readout granularity, etc.