Micromegas for Dark Matter searches:
CAST/IAXO & TREX-DM experiments

Universidad Zaragoza

European Research Council

StG-2009: T-REX

J.G. Garza* for the CAST & IAXO collaborations & TREXDM group.

Outline

- Micromegas in the search of Dark Matter: axions and WIMPs.
- Low background x-ray detection in CAST.
- TREX-DM prototype and characterization.
- Prospects for axions and light-WIMPs.

MPGD 2015 – 15^{th} October 2015

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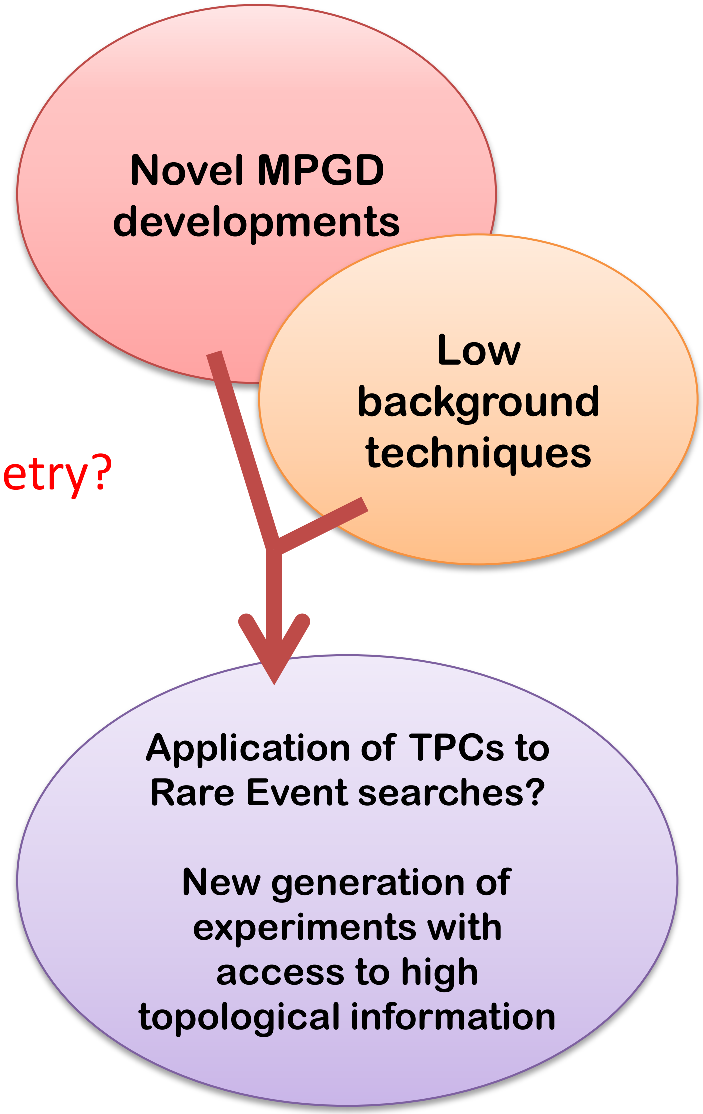
Traditionally…
Gas TPCs offer high potential for rare event through signal topology.

But…
- Relatively complex detectors. Radiopurity?
- Widely used for tracking, but what about calorimetry?
- Gas → low density → Scaling-up?



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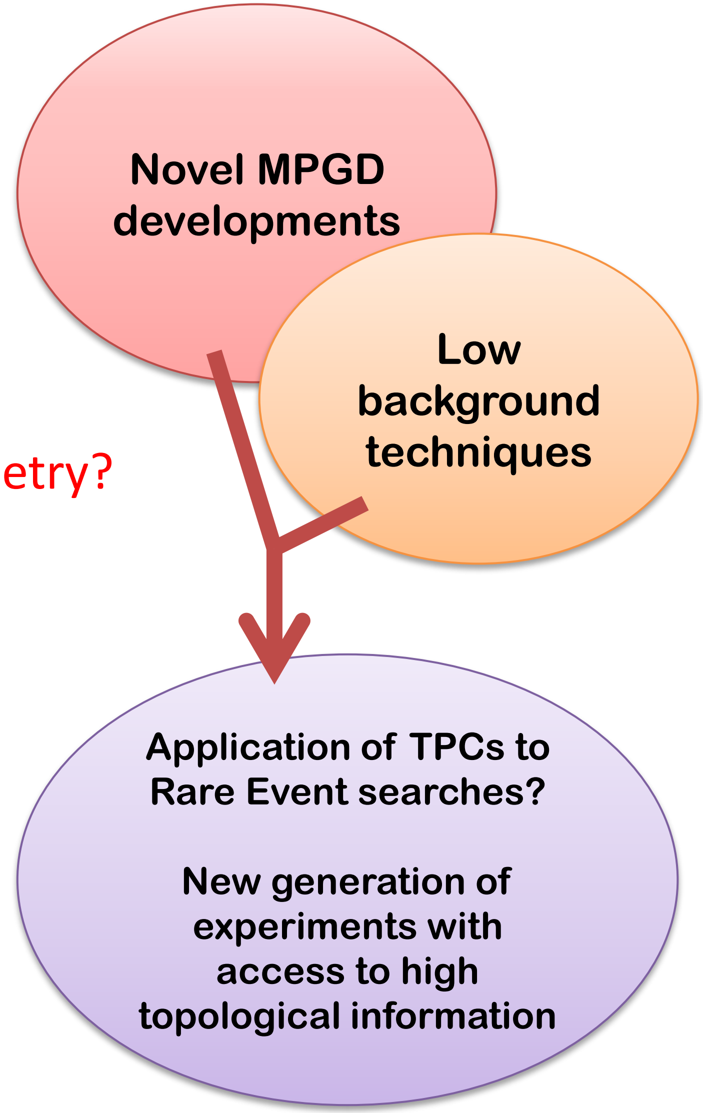


Claim: modern TPCs equipped with MPGD may override traditional prejudices of TPCs: radiopurity, scaling-up, robustness, simplicity,…

a conceptually complex detector, but a relatively simple implementation.

Merge MPGDs (=Micromegas) + low background expertise.

Dark Matter

Two most compelling particle candidates:

Axions

(Solve strong- CP)
(strings)

WIMPs

(SUSY)
(strings)

Application of Micromegas to the search of:

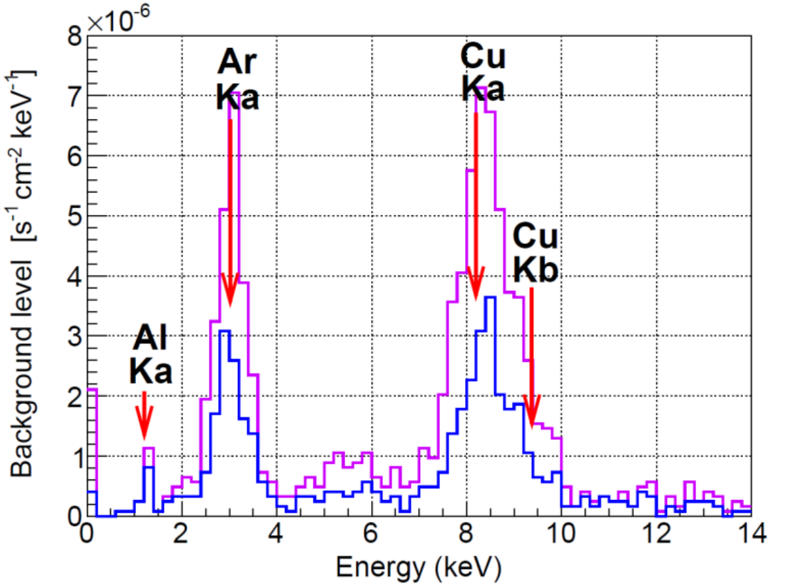
- Solar axions: expected signal is an x-ray 1-7 keV → Low background is crucial.
- Low mass WIMPs (<10 GeV): nuclear recoil of extremely low energy → Low energy threshold is crucial.

MICROMEGAS can provide both low-threshold and low-background.

A Micromegas TPC for Dark Matter detection

It is a consolidated technology…

… as good performance is systematically obtained.



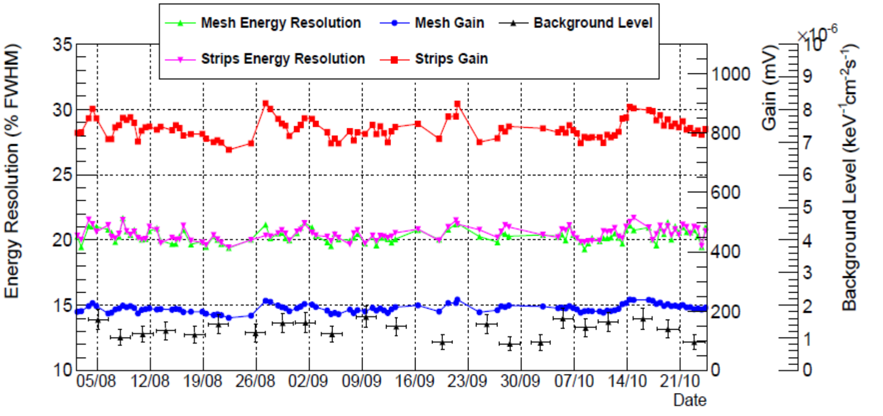
Background spectrum in a CAST-MM detector

A Micromegas TPC for Dark Matter detection

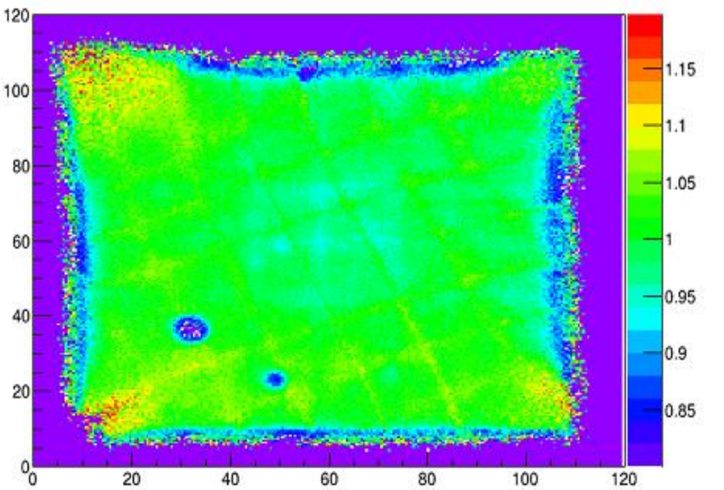
It is stable over long running periods…

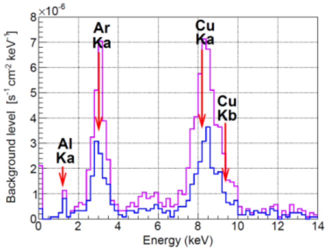
… and the gain is uniform over the detector surface.

Long term stability



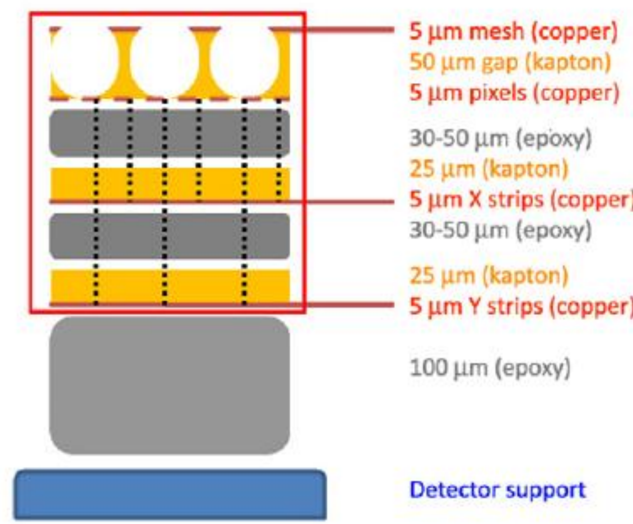
Uniformity of gain



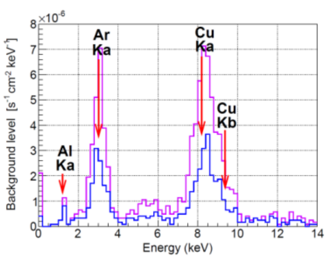


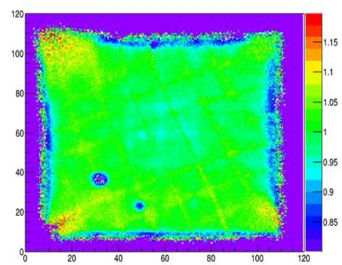
A Micromegas TPC for Dark Matter detection

It is intrisically radiopure as only made of kapton & copper…



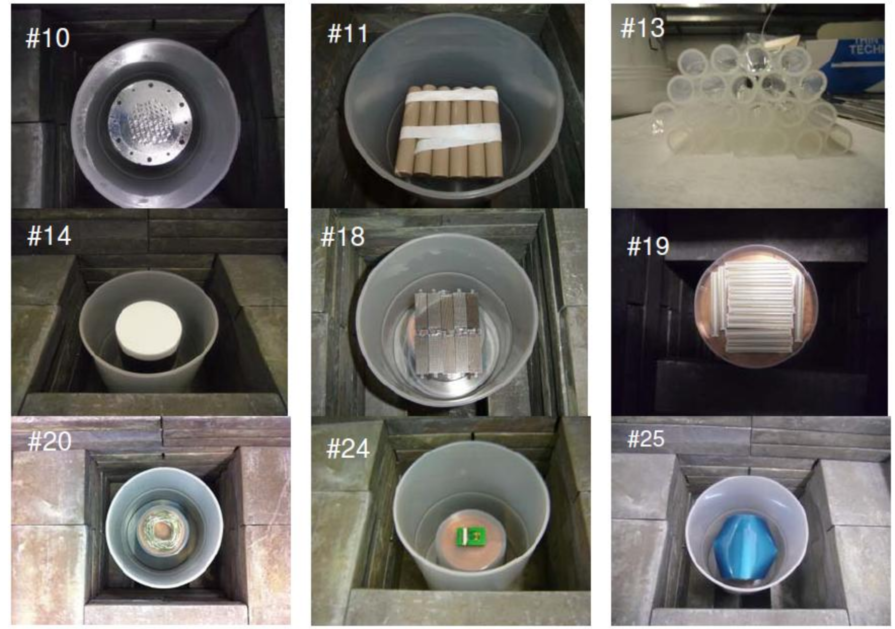
S. Cebrian *et al., Astr . Part.* **34** (2011) 354



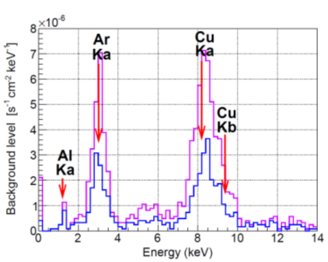


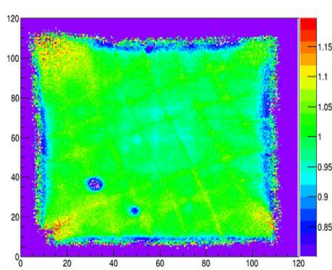
A Micromegas TPC for Dark Matter detection

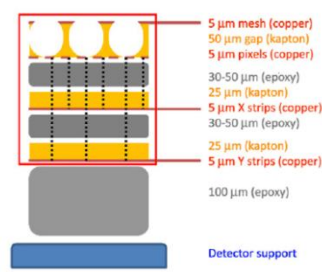
… and radiopurity control techniques can be applied for the rest of the components/materials.



F. Aznar *et al.*, *JINST* **8** (2013) C11012



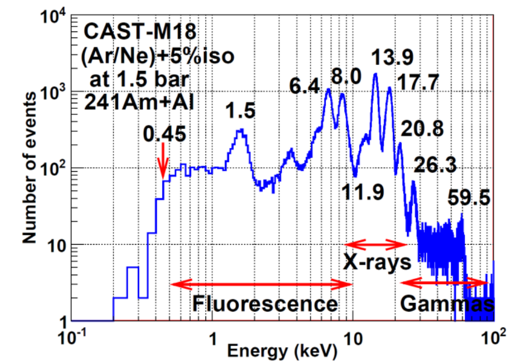


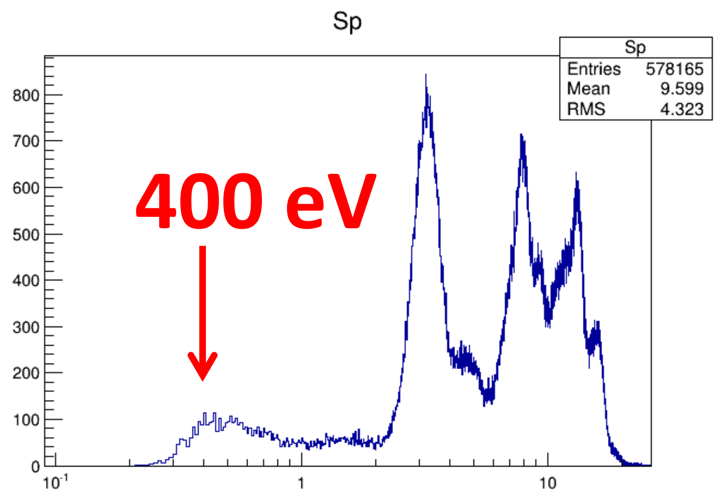


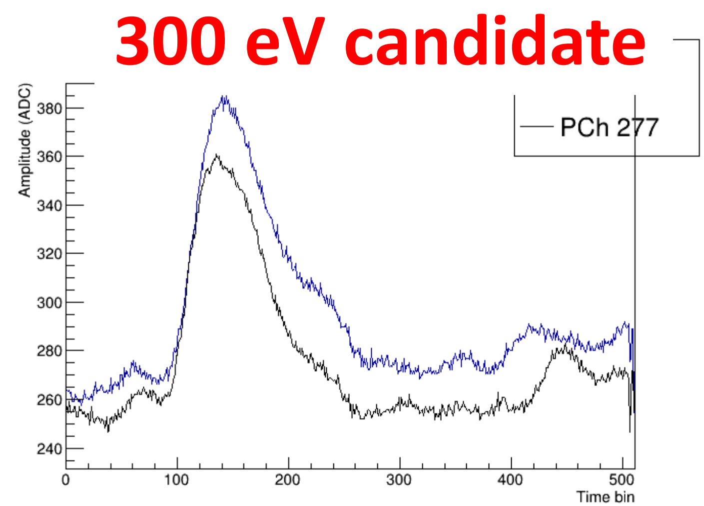
A Micromegas TPC for Dark Matter detection

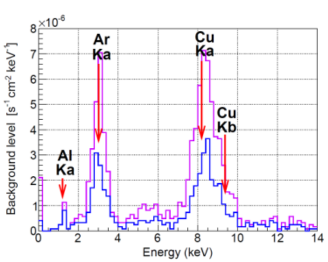
*A low energy threshold (**< 200 eV**) is feasible due to charge-amplification and auto-trigger electronics (GET)*

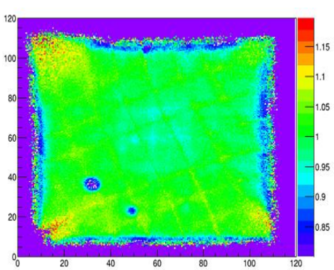
S. Aune et al., JINST **9** (2014) P01001.

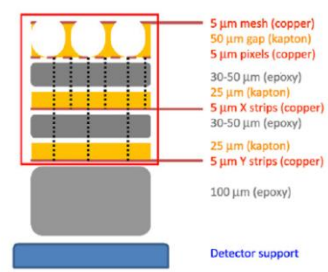


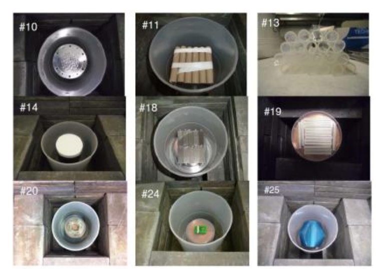






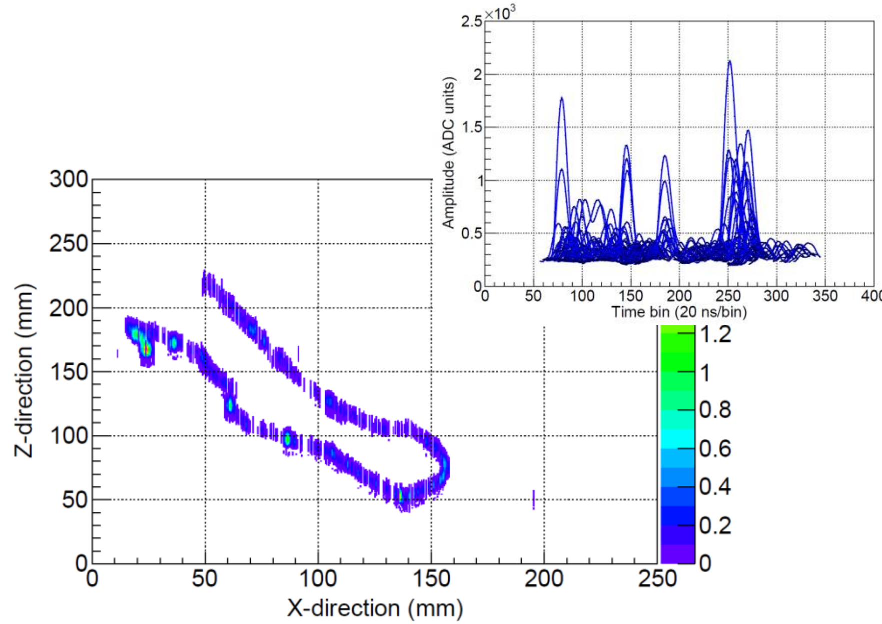


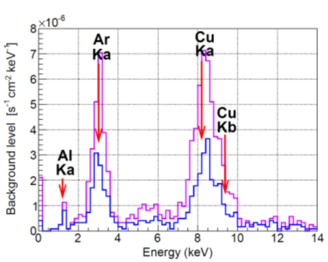


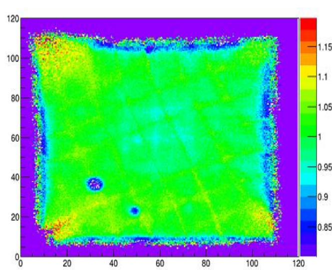


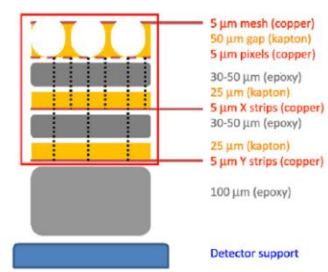
A Micromegas TPC for Dark Matter detection

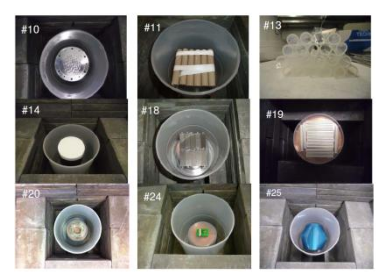
A rich topological information is available due to highly granular readout.

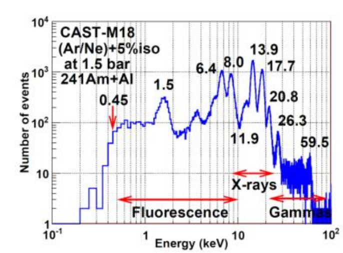






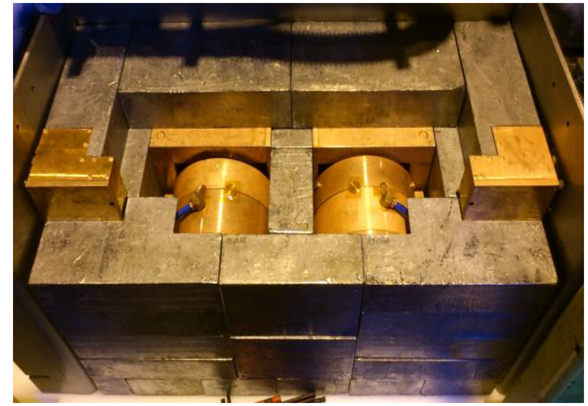


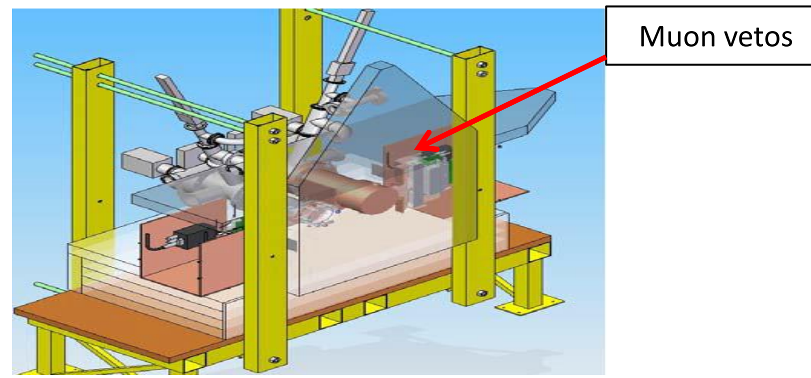


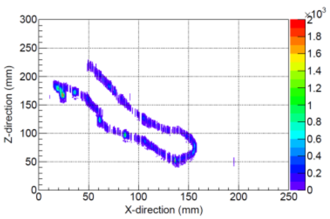


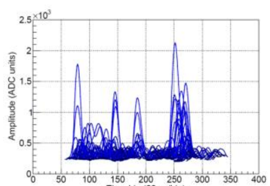
A Micromegas TPC for Dark Matter detection

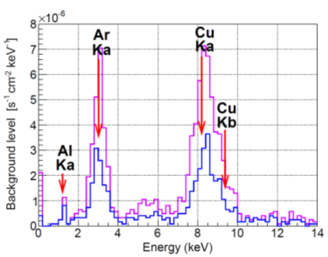
Shielding techniques (passive and active) from low background experiments are also applied.

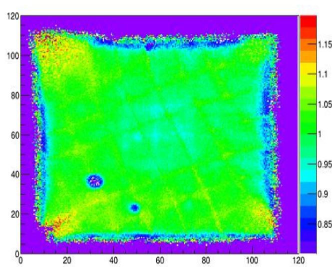


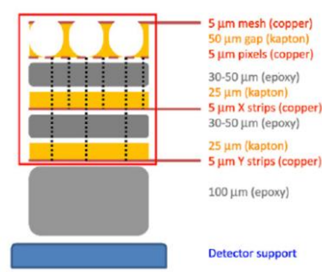


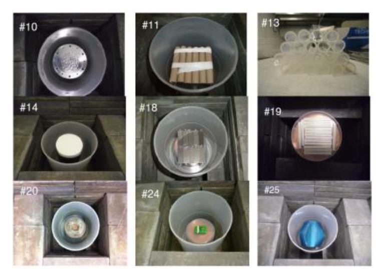


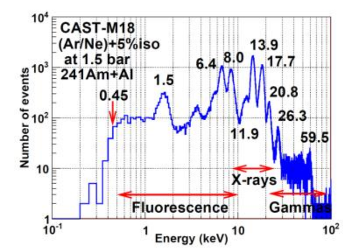








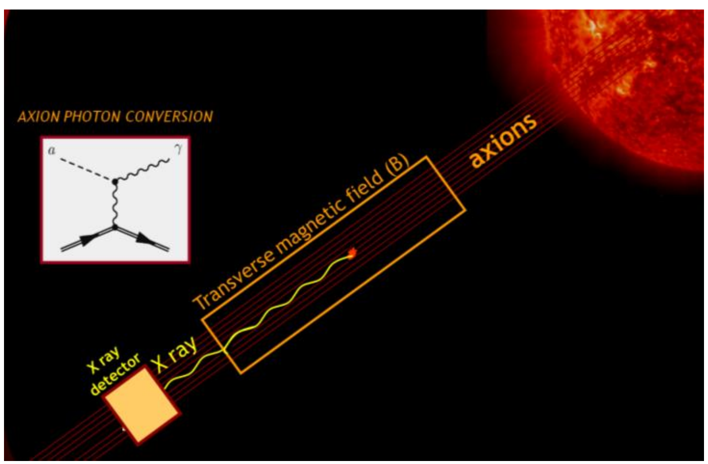




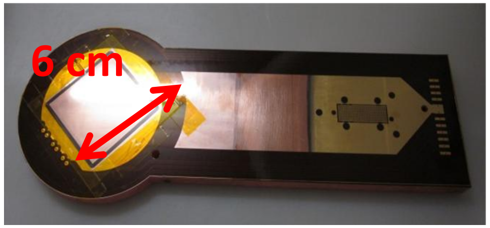
Solar axions: CAST @ CERN

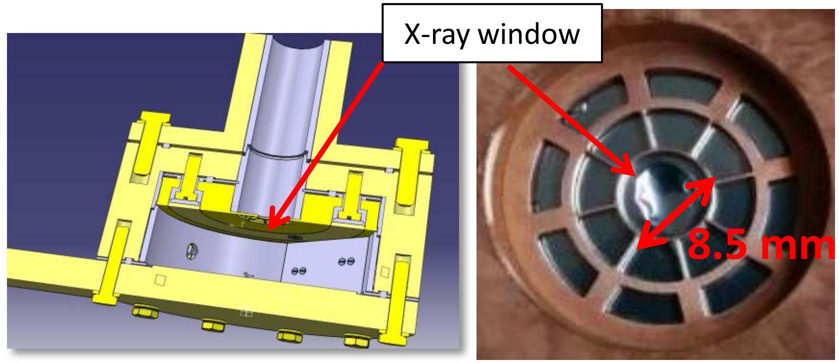
Micromegas used as x-ray detectors:

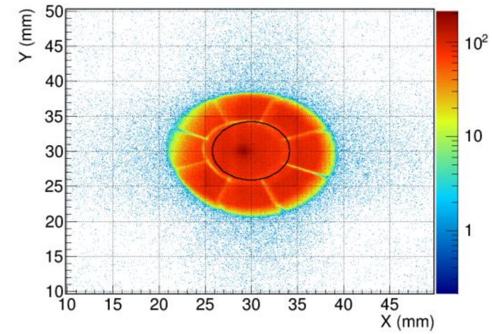
Background of x-ray detectors, one of the parameters driving the sensitivity.



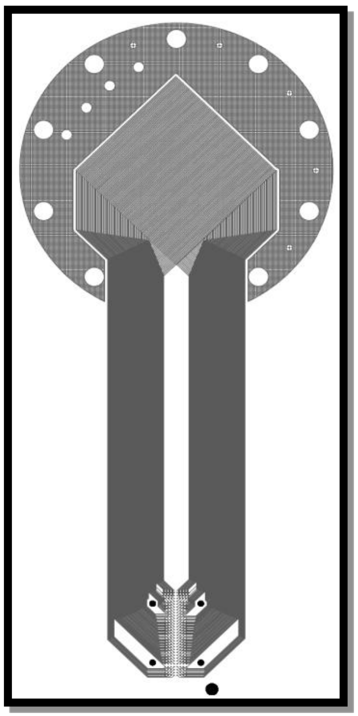
Micromegas in CAST

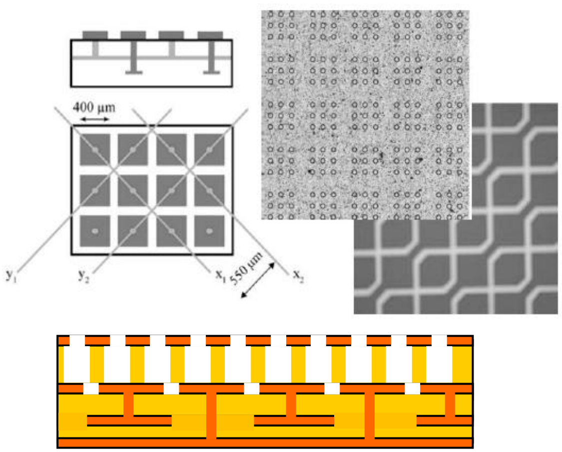






Readout plane



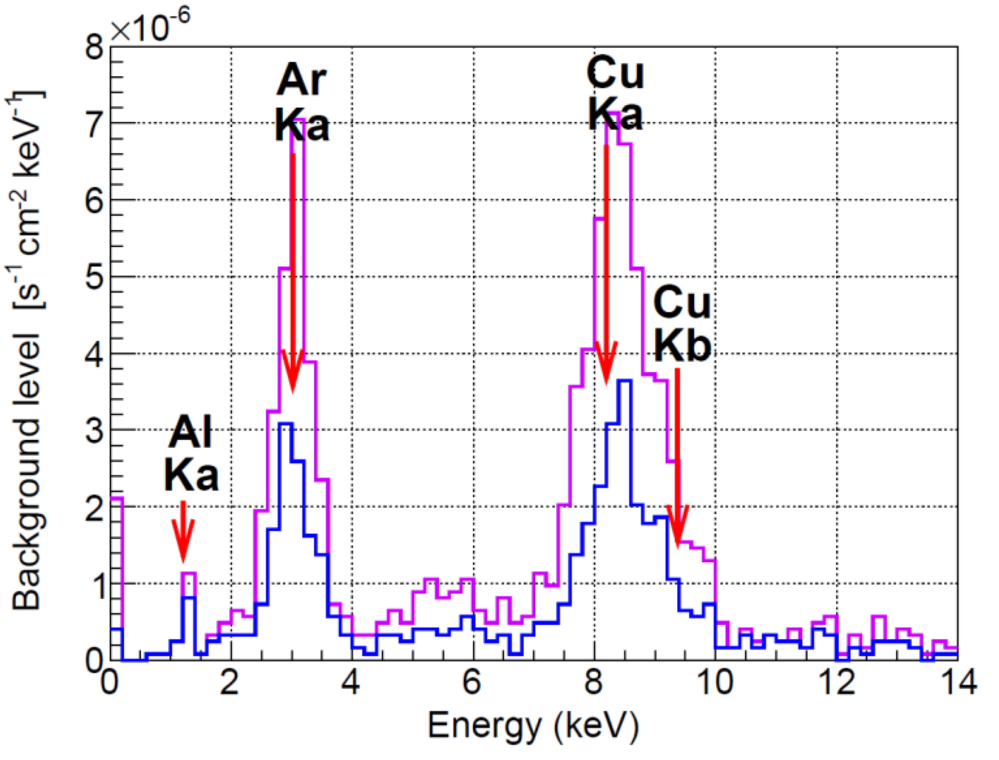


Mesh 5 μm of copper
Holes 30 μm diameter
Pitch 100 μm
Pads of 400 μm
Thickness 80 μm

CAST-MM Features

- Active area: 6x6 cm^2 (120x120 strips) microbulk produced at CERN workshop.
- Gas: Ar + 2%iC$_2$H$_4$ at 1.4 bar.
- Conversion region: 3 cm (100 V/cm).
- Amplification gap: 50 μm (10^4 V/cm).
- X-ray window: 4 μm aluminized mylar.
- AFTER-based readout electronics.

Background level at CAST

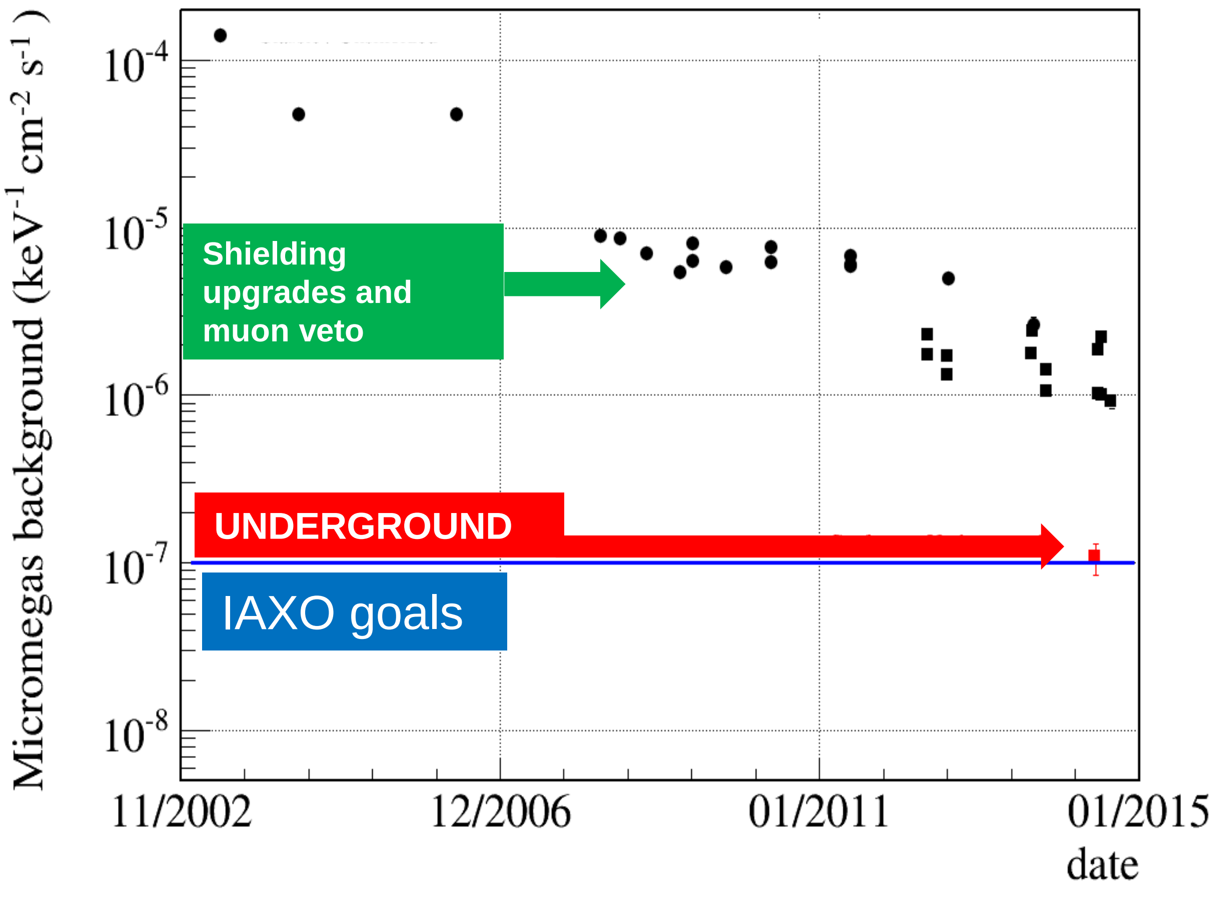


Background spectrum characteristic of:

Cu-K_α (8 keV) + escape peak (5 keV) + Ar-K_α (3 keV) + Al-K_α (1.5 keV).

Further background reduction requires indentifying the origin of these events.

Micromegas Background evolution at CAST



JINST 8 (2013) C12042

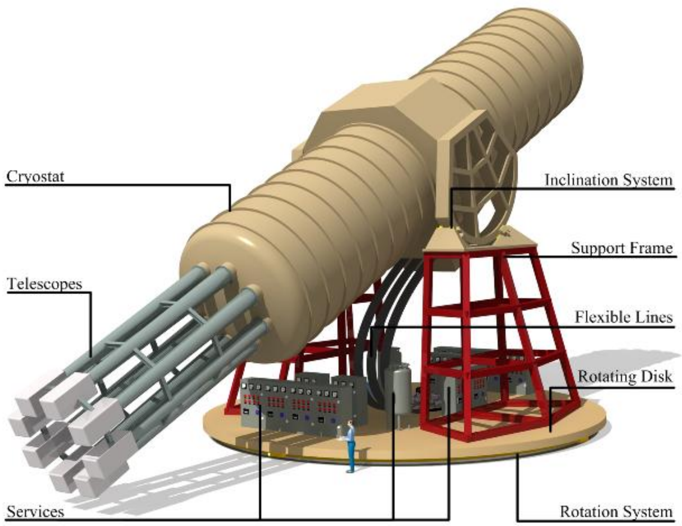
JINST 9 (2014) P01001

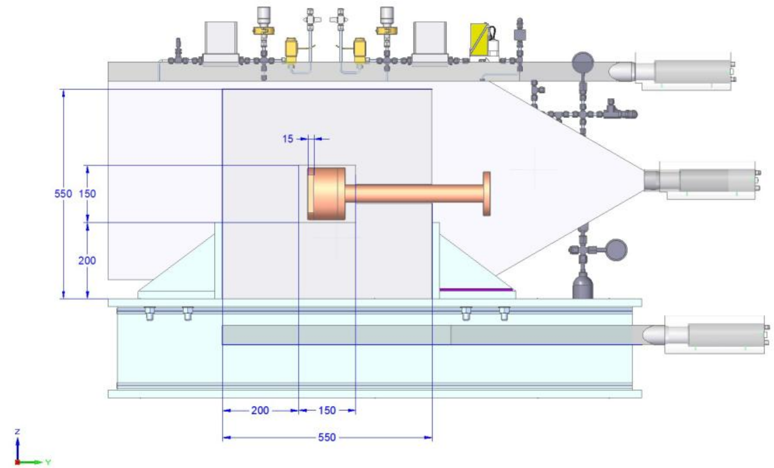
Best background in CAST (surface) : 8 x 10^{-7} c/keV/cm^2/s

Best background in LSC (underground): ~1 x 10^{-7} c/keV/cm^2/s

IAXO Prospects

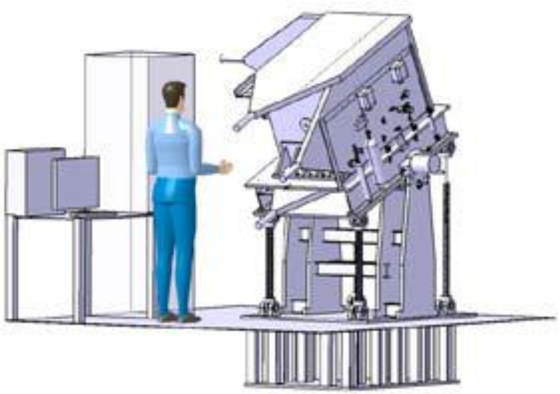
J. A. García *et al., AxionWIMP 2015*





Micromegas is the baseline technology.

As part of IAXO TDR, IAXO-D0 is being commissioned.



Goal for IAXO: 10^{-7} - 10^{-8} c/keV/cm^2/s

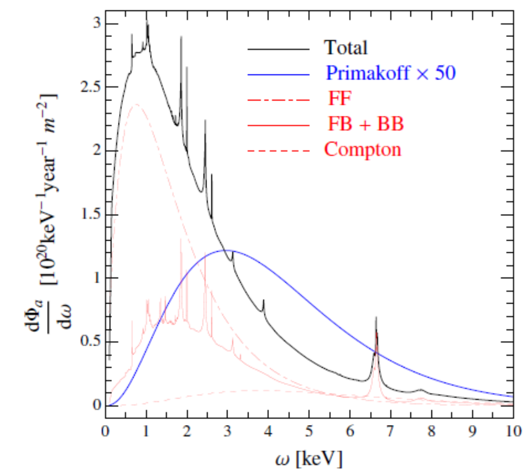
IAXO-D0 prototype:

- Improved veto coverage.
- Different target gas (to get rid of Ar-39 & flourescences).
- Improved shielding & radiopurity.
- Set-up to test other technologies (for example, InGrid, see poster by C. Krieger)

Prospects: Lowering the energy threshold

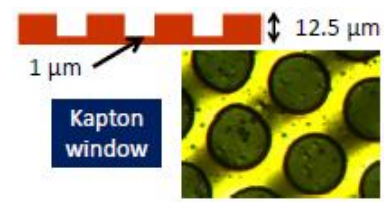
Motivation:

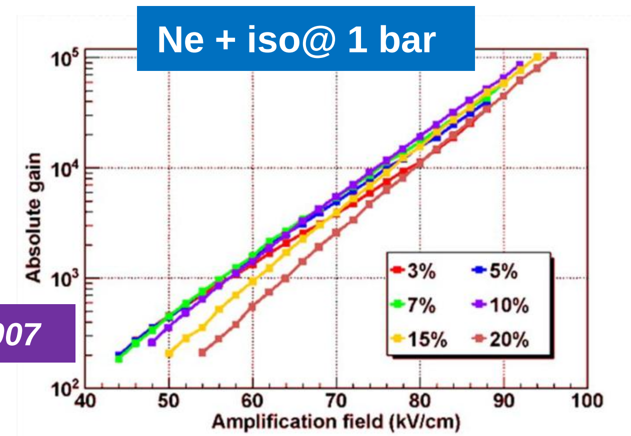
- New physics at sub-keV energies.
- Other searches: paraphotons, chamaleons, etc.



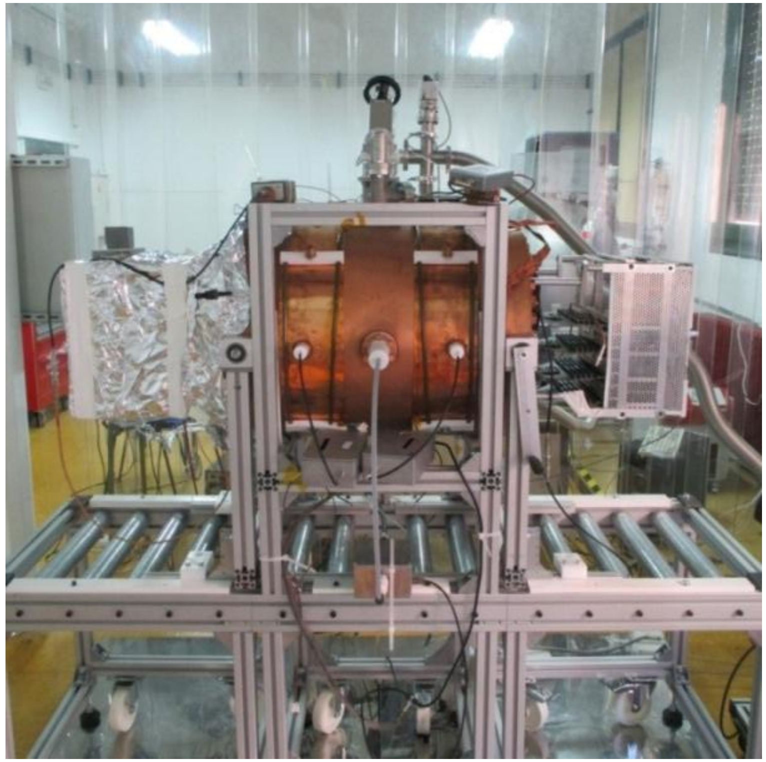
Low threshold R&D lines:

- More transparent x-ray windows.
- New gas mixtures with higher gain (Neon?).
- Auto-trigger electronics (AGET)
- Resistive microbulk (higher gain?)





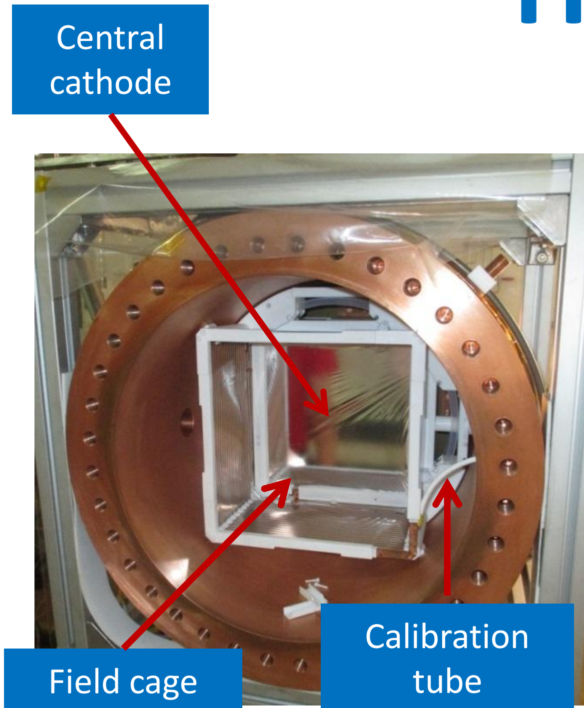
JINST 7 (2012) P04007

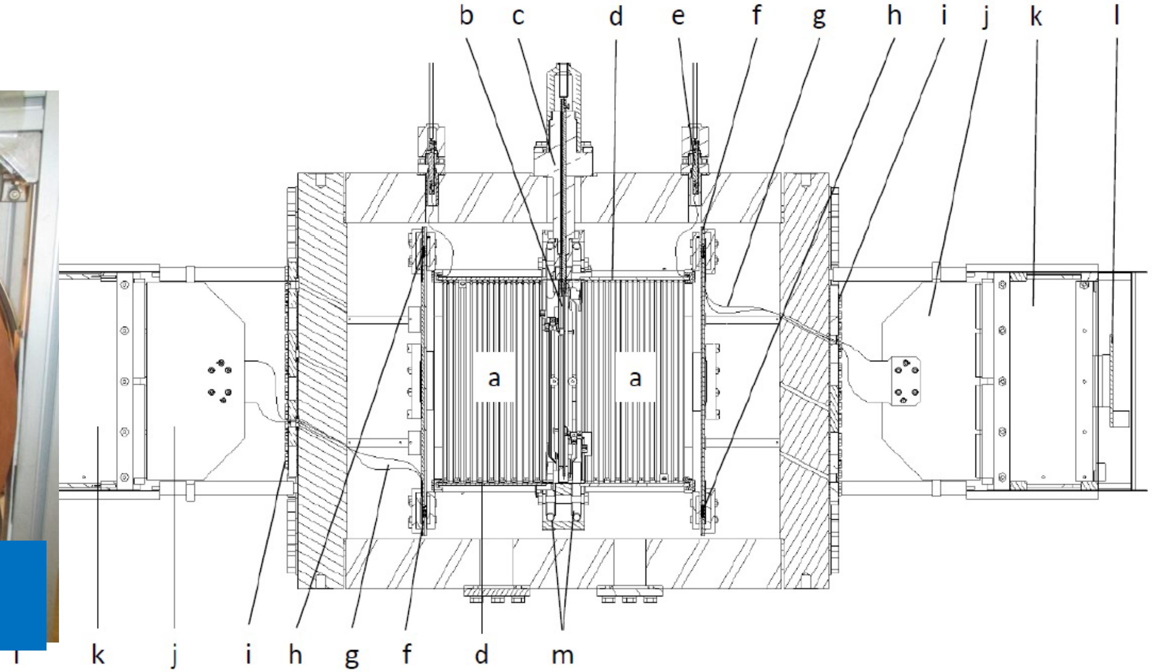


TREX-DM ia a gaseous Micromegas-based TPC for low mass WIMPs.

A scaled-up version of Micromegas for axion research, but with a 10^3 times larger active mass.

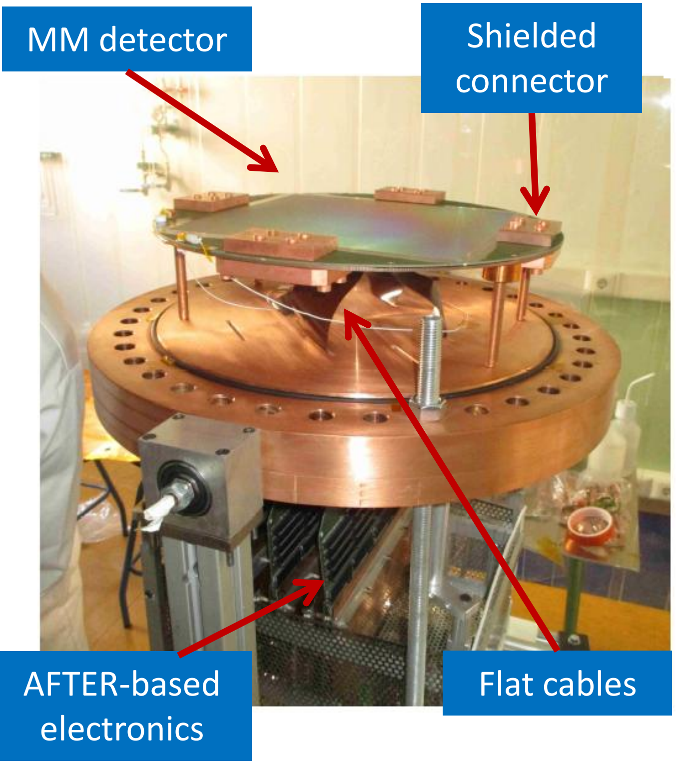
TREX-DM

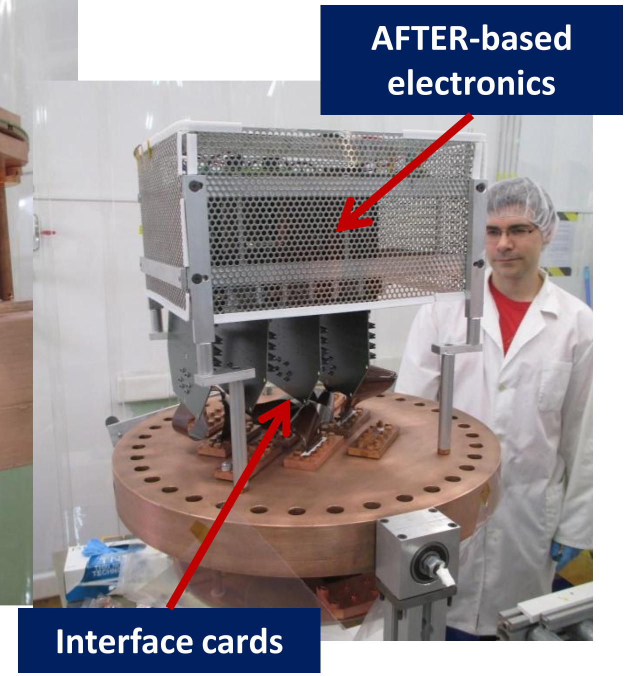




- Symmetric TPC with two active volumes: 19 cm x 20 cm x 20 cm.
- Flexibility in the choice of target gas and pressure.
- **Experimental strength:** intrinsic charge amplification with Micromegas, potential **low energy threshold** (~ 100 eV) and **low background** (1 keV^{-1} kg^{-1} day^{-1}) despite not very effective electron/nulear recoil discrimination.

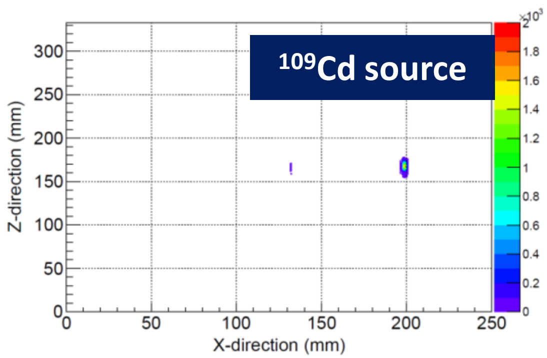
TREX-DM

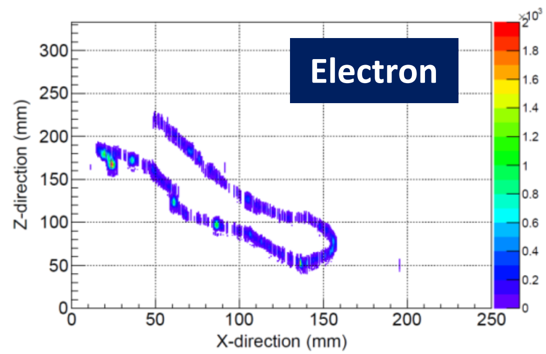


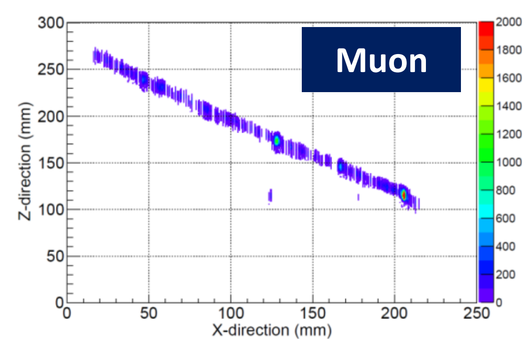


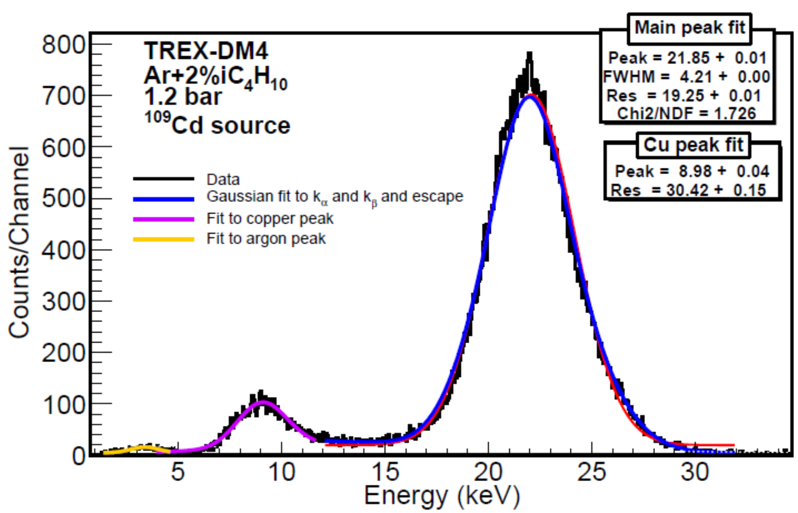
- 20 x 20 cm^2 bulk MM detectors. 432x432 strips, 0.6 mm pitch, 128 µm gap.
- Signals extracted by flat cables + feedthroughs.
- Sampling-ADC electronics record strip signals with external (mesh) trigger. Possible upgrade to auto-trigger electronics → lower threholds expected.
- Special care in grounding for a low energy threshold : all HV lines have a dedicated filter, strips signals shielded by a ground layer, FE electronic cards inside a Faraday cage.

Two bulk Micromegas have been characterized in Ar + 2% iC_4H_{10} up to 10 bar.

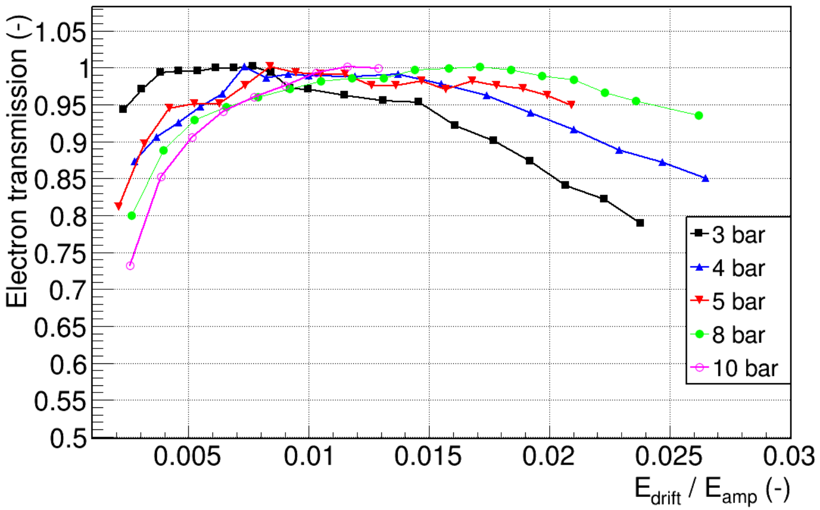


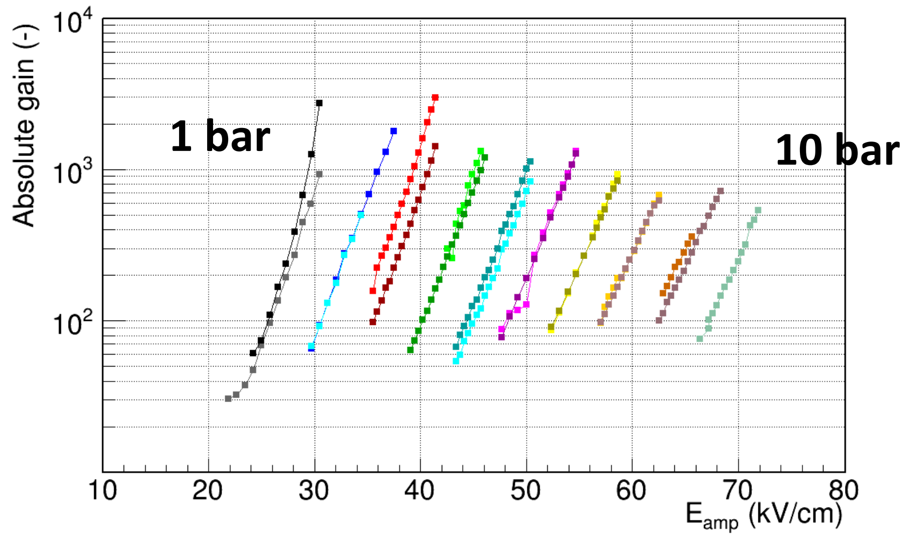




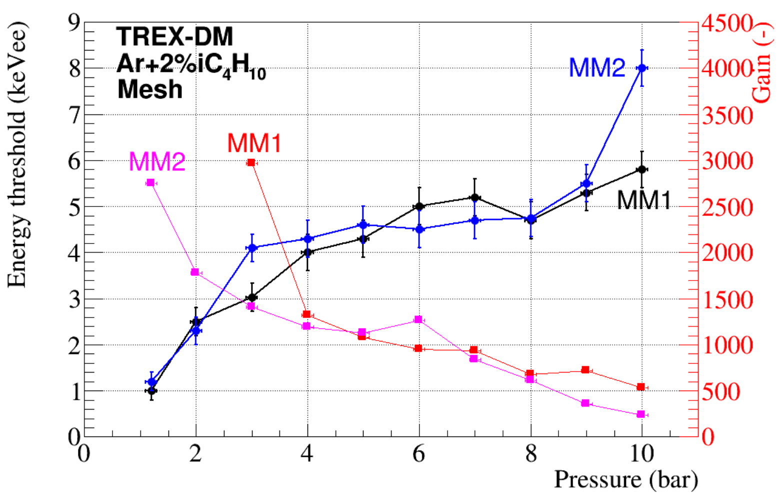


BULK Characterization



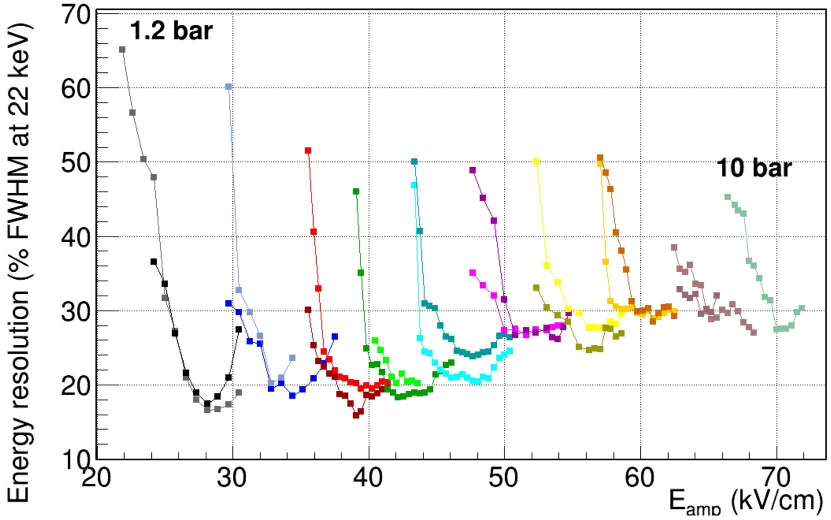


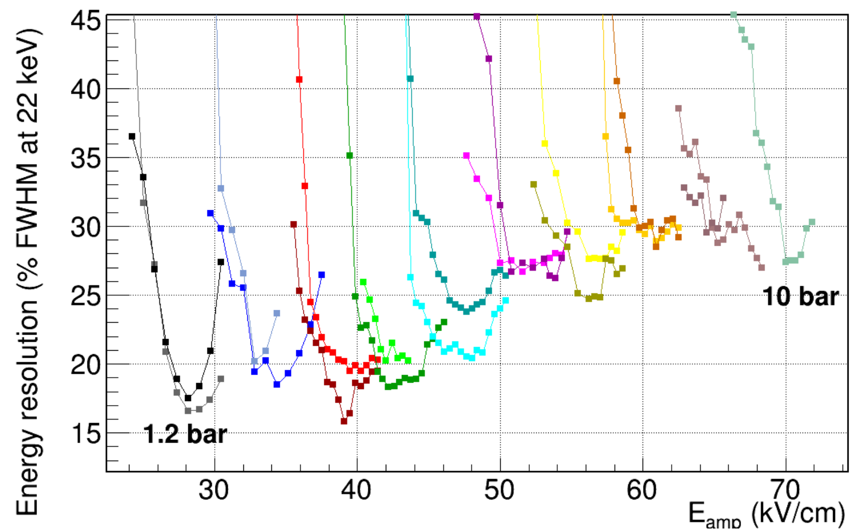
- Detectors characterized in Ar+2%iso up to 10 bar.
- Large electron transmission plateau at all preasures.
- Degradation of performance with pressure:
  - **Gain:** 3 x 10^3 (1.2 bar) -> 5 x 10^2 (10 bar).
  - **Threshold:** 1.0 keV -> 6.0 keV.
  - **Resolution:** 16% FWHM -> 27% FWHM.
- Uniformity of gain: fluctuations < 10%.



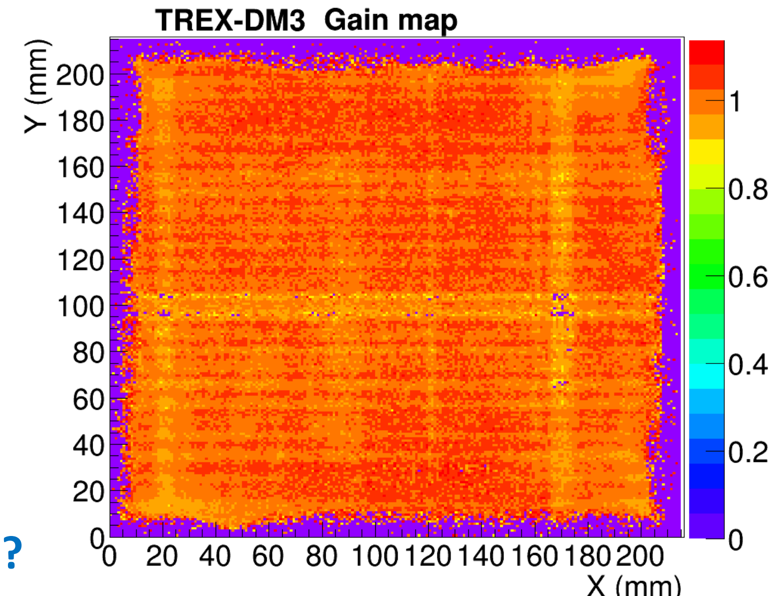
To be improved by increasing the fraction of quencher ?

BULK Characterization





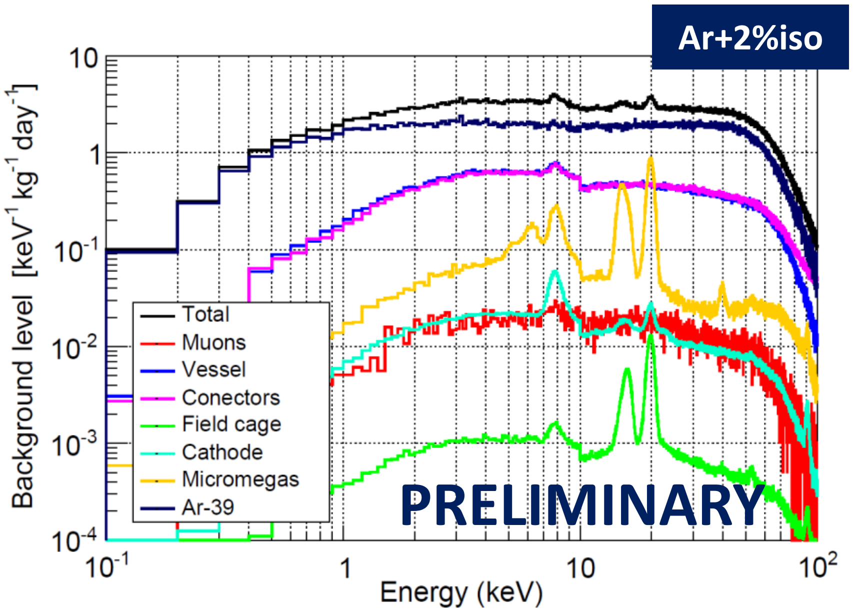
- Detectors characterized in Ar+2%iso up to 10 bar.
- Large electron transmission plateau at all preasures.
- Degradation of performance with pressure:
  - **Gain:** 3 x 10^3 (1.2 bar) -> 5 x 10^2 (10 bar).
  - **Threshold:** 1.0 keV -> 6.0 keV.
  - **Resolution:** 16% FWHM -> 27% FWHM.
- Uniformity of gain: fluctuations < 10%.

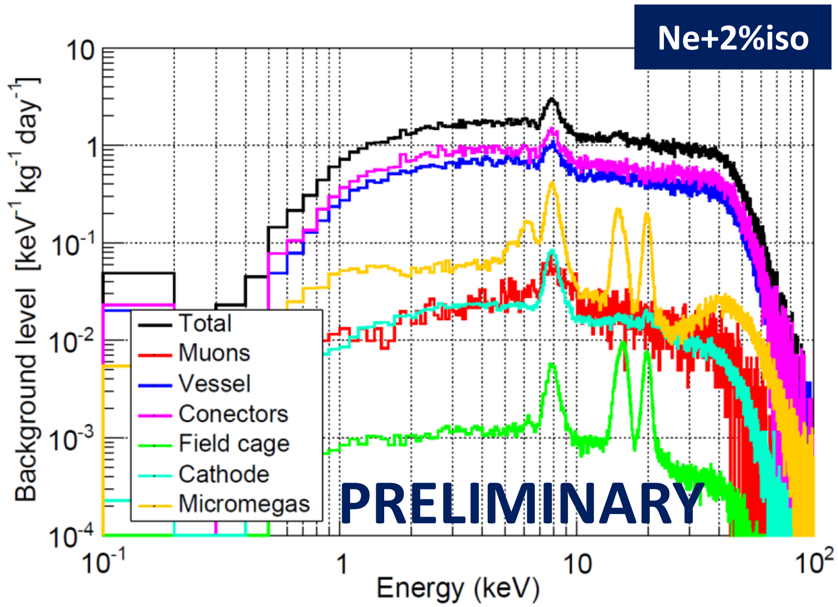


To be improved by increasing the fraction of quencher ?

Background model

F.J. Iguaz *et al.*, *TAUP 2015*





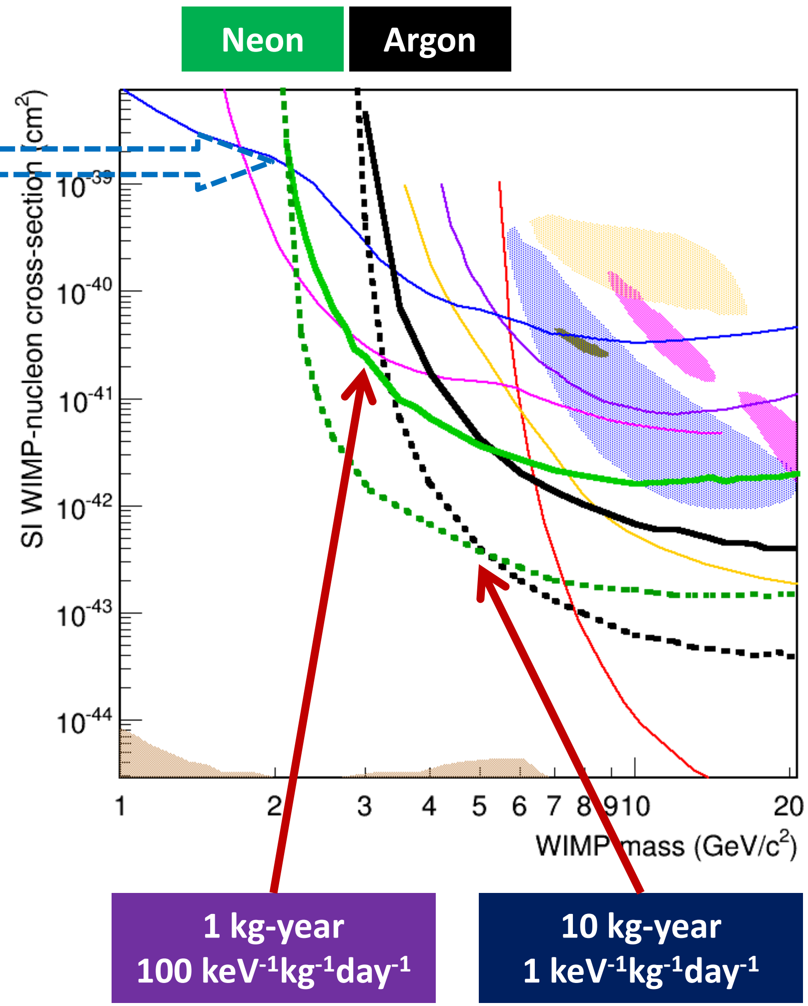
- Main contributions: ^{39}**Ar** (for argon based), **electrical connectors** and **vessel**.
- ^{39}**Ar** contribution will be **2 x 10^2 keV^{-1} kg^{-1} day^{-1}** if argon comes from **surface** sources.

Summary of background levels:

- **Argon @ 10 bar**: ***3.09 keV^{-1} kg^{-1} day^{-1}***.
- **Neon @ 10 bar: *1.38 keV^{-1} kg^{-1} day^{-1}***.

TREX-DM Prospects

*Supposing a **0.4 keVee** energy threshold & that this background model is valid*



2012-16: Proof of concept.

- Design, construction & comissioning.
- Test bulk MM in argon- & neon mixtures at high pressure.
- Study dependence of the energy threshold with pressure.

2016-17: Radiopure version for a physics at LSC.

- Installation of radiopure components.
- Modification for thick lead shielding.

Challenges for near-term future:

- **Low energy threshold** at high pressures.
- **Quenching factor** must be measured.

Conclusions

- Micromegas are a competitive option for the detection of rare processes because low-background and low-threshold are feasible.

- Micromegas successfully operated in CAST for years with record sensitivity limits in axion-photon coupling and are the base technology for IAXO.

- TREX-DM is a project under commissioning that can achieve very high sensitivity to light WIMPs.

(*) jgraciag@unizar.es

StG-2009: T-REX

Thanks for your attention!

Dark Matter

Two most compelling particle candidates:

Axions

(Solve strong- CP)
(strings)

Different detection techniques depending on the axion origin (Lab, Sun, Galaxy halo), most of them based on axion-photon coupling.

In helioscopes, axions are converted to x-rays (1-10 keV) in an intense magnetic field → **Low background x-ray detectors are crucial.**

WIMPs

(SUSY)
(strings)

WIMP-nucleon scattering searches done in underground detectors looking for ionization, heat and scintillation.

Mainstream experiments: very large target masses & extremely low backgrounds provided by the electron/nuclear recoil discrimination → however this sets large energy thresholds and less sensitivity to light WIMPs.

Low threshold detectors are crucial to search low mass WIMPs.

MICROMEGAS can provide both low-threshold and low-background.

Background Model based on:

- In-situ measurements at CAST.
- Surface tests at Zaragoza.
- Canfranc Underground Laboratory (LSC): Upgrade CAST-MM replica.
- Geant4 Montecarlo simulations of CAST-MM.

Contribution	Background Level ($c/keV^{-1}/cm^2/s^{-1}$)	Technique	FINAL Background Level ($c/keV^{-1}/cm^2/s^{-1}$)
Gamma flux	$\sim 7 \times 10^{-5}$	Lead/copper shield	**Negligible**
Radon	$\sim 8 \times 10^{-7}$	N_2 flux	**Negligible**
Muons	$\sim 2 \times 10^{-6}$	Active veto	**$\sim 7 \times 10^{-7}$**

Underground (CAST-LSC) lower limit:

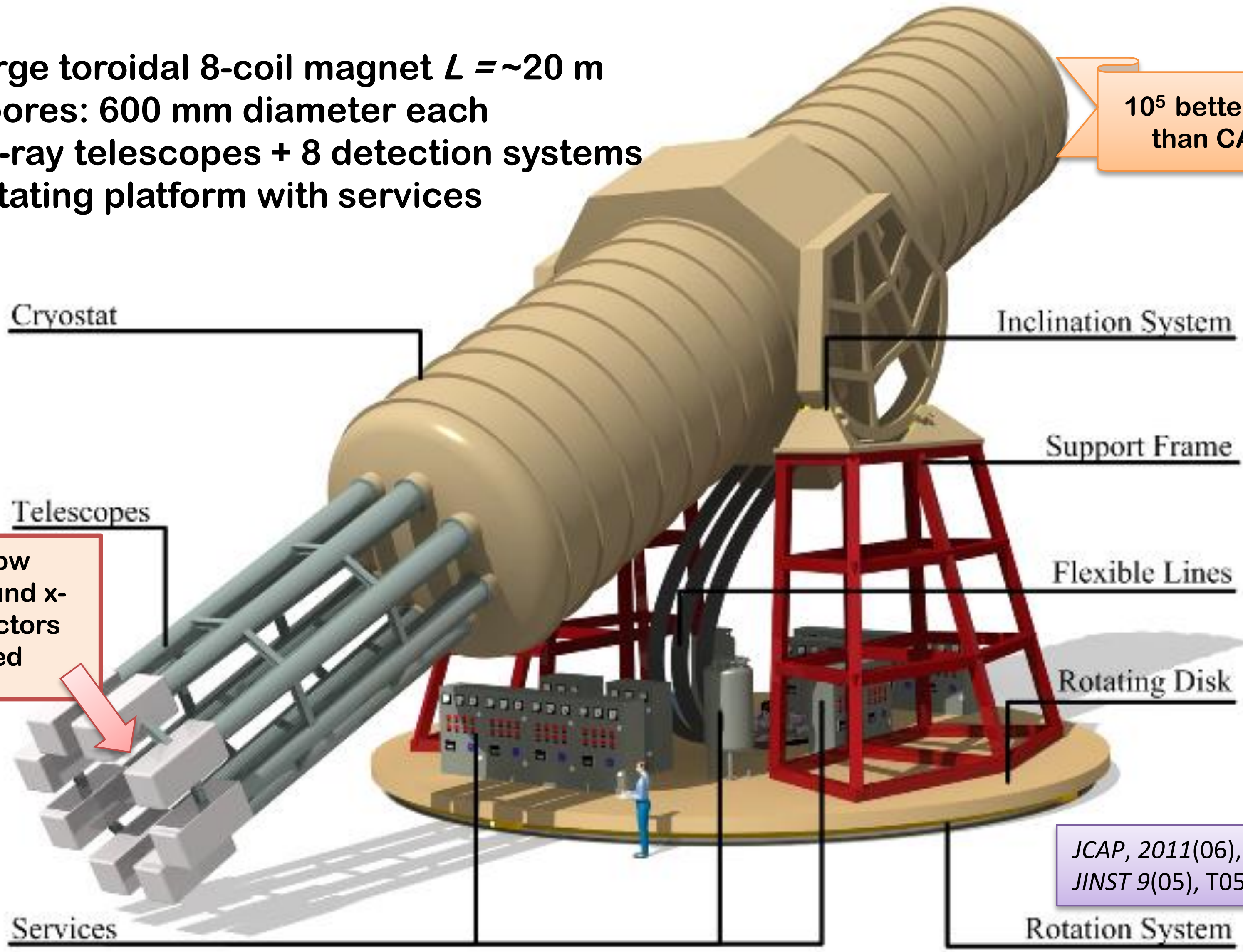
- ❑ Background: $\sim 1 \times 10^{-7}$ $c/keV^{-1}/cm^2/s^{-1}$.
- ❑ Origin: **^{39}Ar radio-activity? Neutrons ? Cosmic ativation ??**

- R&D activity to reduce the dominant contributions to background (main IAXO-Micromegas TDR activity).

IAXO: International Axion Observatory

- Large toroidal 8-coil magnet *L* =~20 m
- 8 bores: 600 mm diameter each
- 8 x-ray telescopes + 8 detection systems
- Rotating platform with services

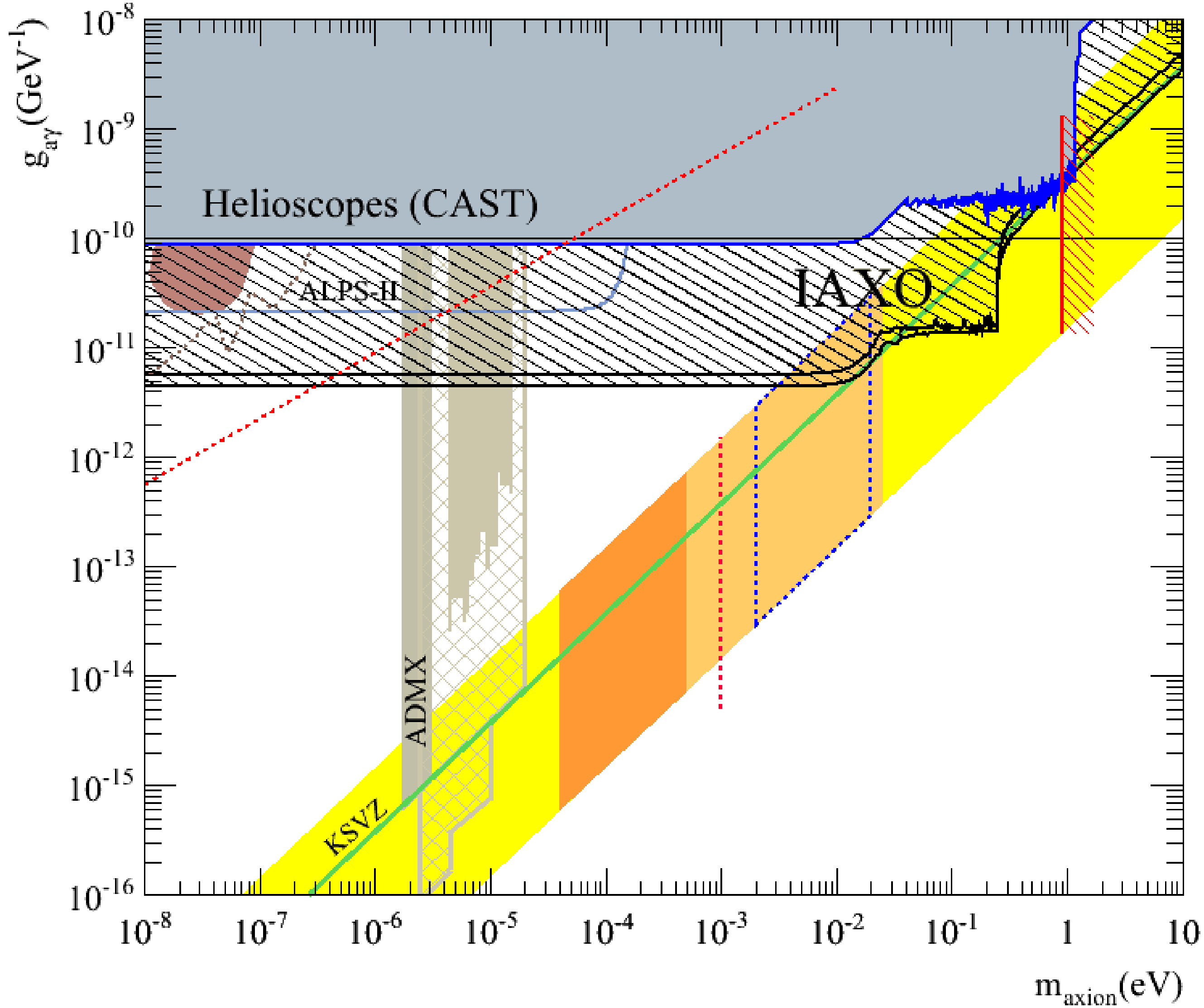
10^5 better SNR than CAST

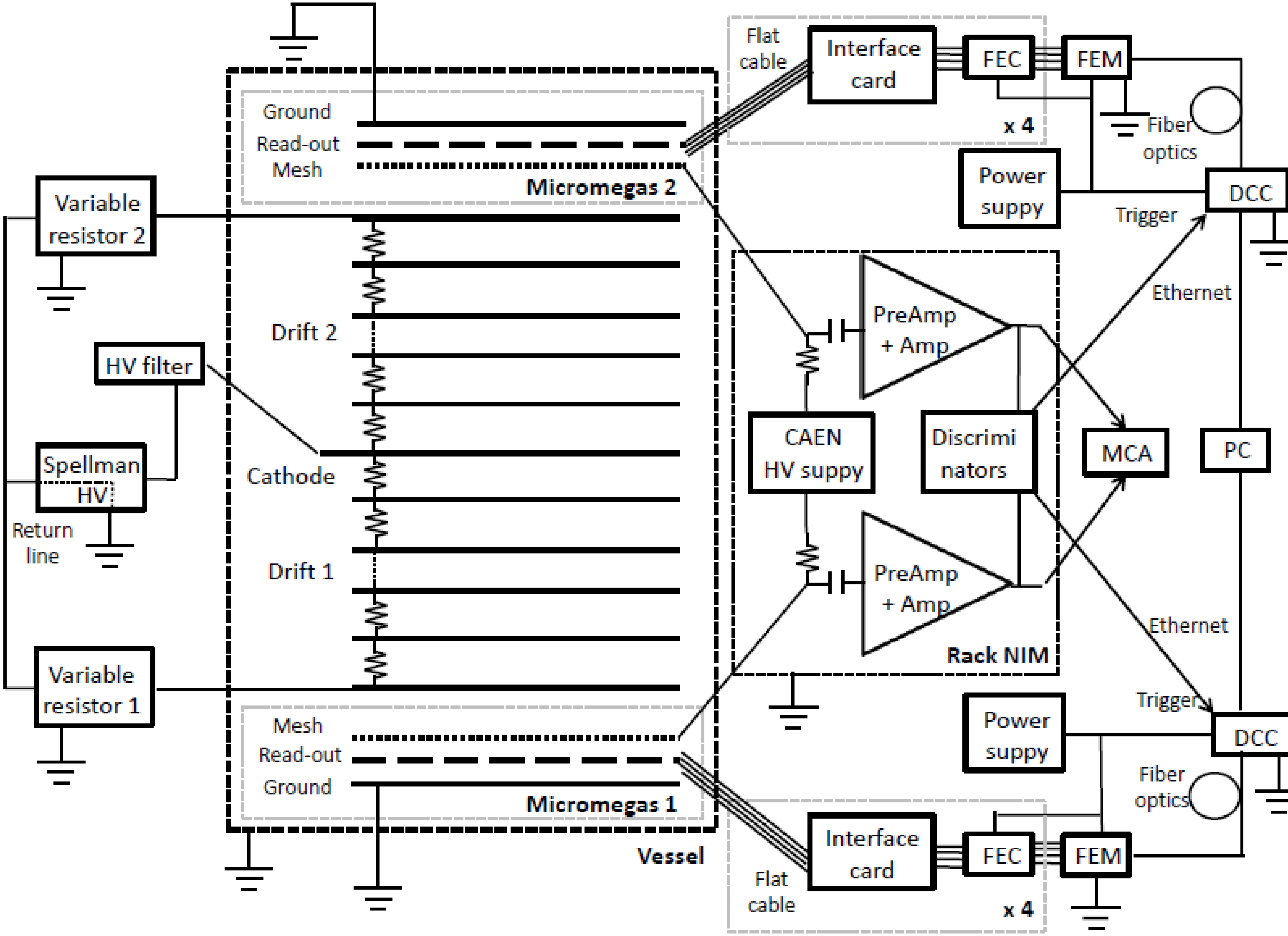


Very low background x-ray detectors needed

JCAP, *2011*(06), 013–013
JINST 9(05), T05002–T05002

IAXO Prospects



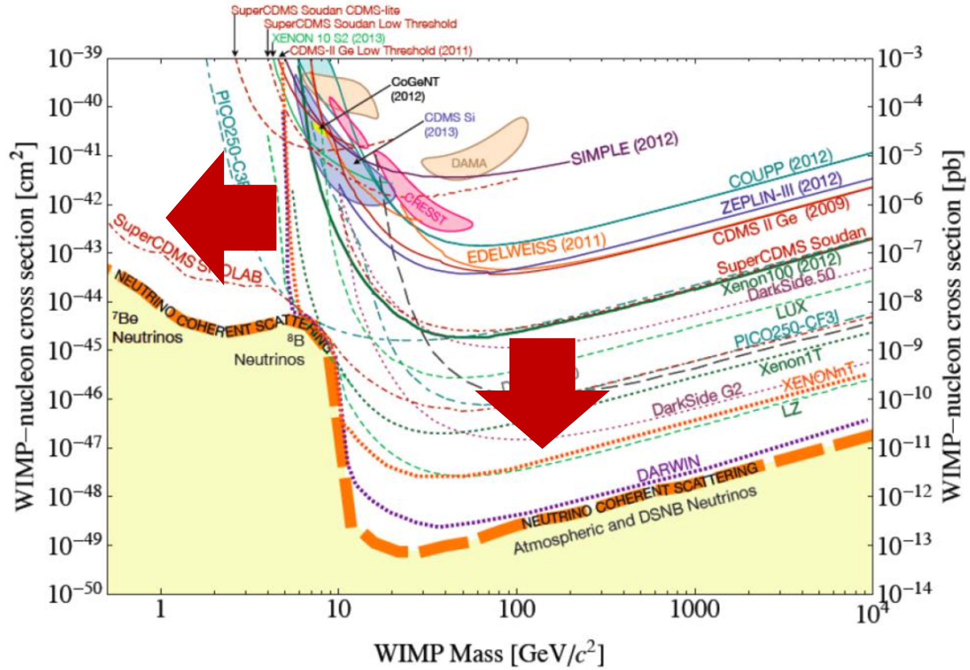


Ground
Read-out
Mesh
Micromegas 2
Flat cable
Interface card
FEC
FEM
x 4
Fiber optics
Power suppy
DCC
Trigger
Variable resistor 2
HV filter
Drift 2
Cathode
Spellman HV
Return line
Drift 1
Variable resistor 1
PreAmp + Amp
CAEN HV suppy
Discrimi nators
MCA
PC
Ethernet
PreAmp + Amp
Rack NIM
Ethernet
Trigger
Power suppy
DCC
Fiber optics
Mesh
Read-out
Ground
Micromegas 1
Vessel
Interface card
FEC
FEM
Flat cable
x 4

Motivation: low mass WIMP detection

Leading Dark Matter experiments focused on ~50-200 GeV WIMPs

- Heavy target nuclei (A^2 - coherence).
- Low background levels:
  - Electron/nuclear recoil discrimination -> high effective threshold -> less sensitive to low WIMP masses.



What happens if mass <10 GeV?

- Very low energy deposits, typically below threshold → exclusions based on the high velocity tail of the distribution (the most uncertain).
- A robust detection or exclusion must imply that a substantial fraction (order 50%) of the WIMP spectrum is over the experimental threshold.
  → light target nuclei.
  → sub-keV detection threshold.

Many experimental efforts in this direction: mainstream experiments bypassing their nuclear/electron discrimination, and new experiments specifically focused in the low-mass range.

TREX-DM: a gaseous Micromegas based-TPC for low mass WIMPs

Flexibility in the choice of target gas and pressure.

Operate 300 g of light nuclei (Ar, Ne) with a **low background level** (~1 keV^{-1} kg^{-1} day^{-1}).

NOT focused in directionality like MIMAC & DRIFT & DMTPC -> **operation at high pressure**.

Electron/nuclear discrimination less effective.

Experimental stregth: Intrinsic charge amplification with Micromegas, potential **low energy threshold** (< 1 keV).

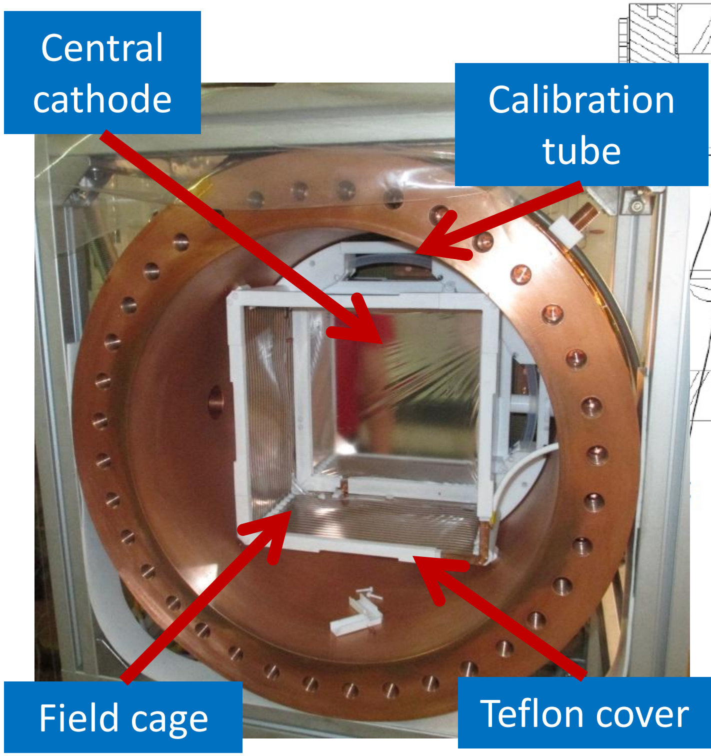
TREX-DM: a MM-TPC for low mass WIMPs

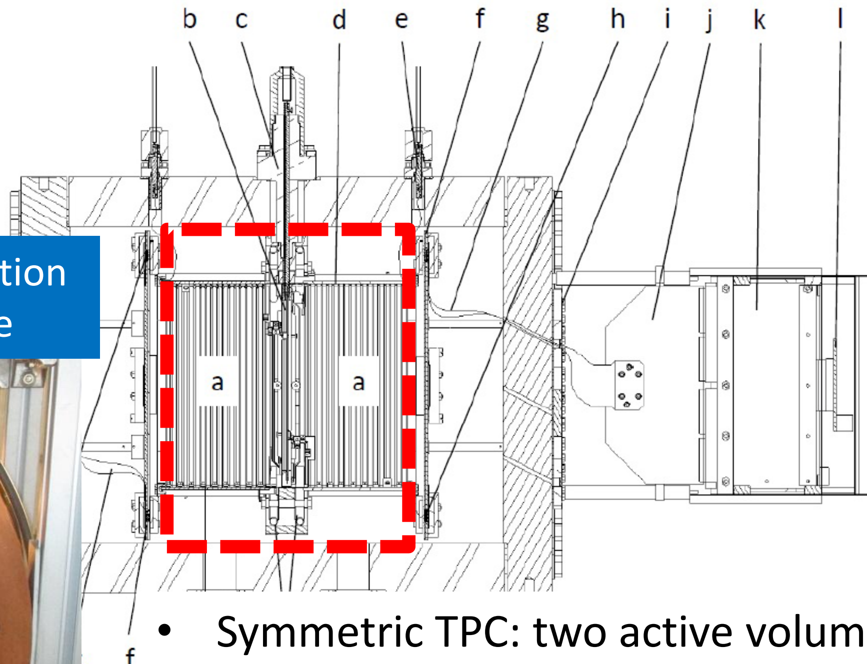
Timeline:

- **2012-15: Proof of concept, not fully radiopure.**
  - Design, construction & comissioning.
  - Systematic measurement of the radiopurity of all components.
  - Test bulk MM in argon- & neon-based mixtures at high pressure.
    - Study of the dependence of the energy threshold with pressure.
    - Validation of the simulation chain.
  - **Pending issue:** An automatic calibration system.

- **2015-16: Radiopure version for a physics run at LSC.**
  - Installation of radiopure components: Micromegas detectors, flat cables, ...
  - Modification of the setup for a 10 cm thick lead shielding.

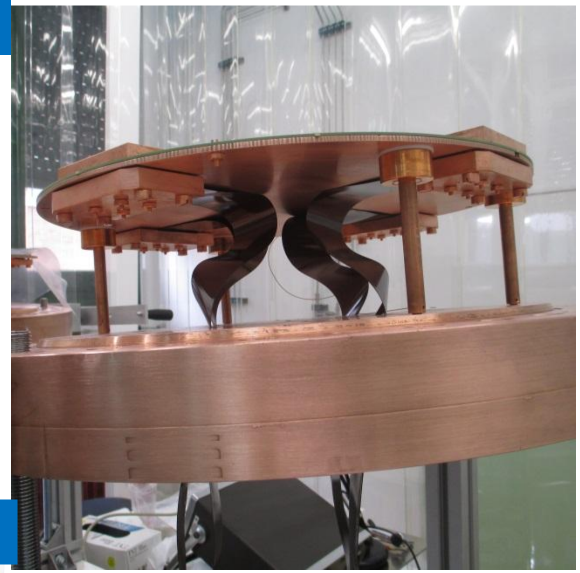
TREX-DM: a MM-TPC for low mass WIMPs

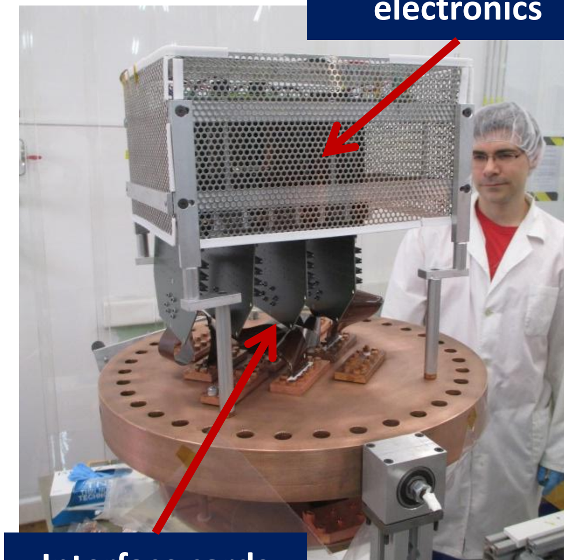


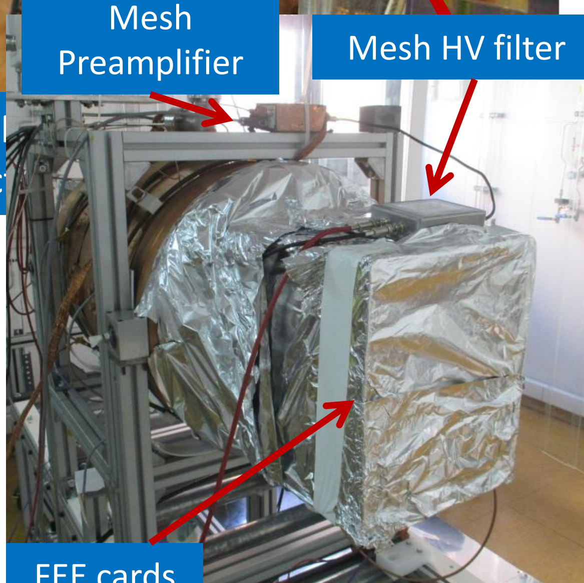


- Symmetric TPC: two active volumes: 19 cm x 20 cm x 20 cm.
- Central cathode of mylar, electrically isolated from inner walls by teflon.
- Field cage made of kapton & copper, covered by teflon walls. No soldering used.
- Calibration by ^{109}Cd, inside a Teflon tube.

TREX-DM: detector & electronics

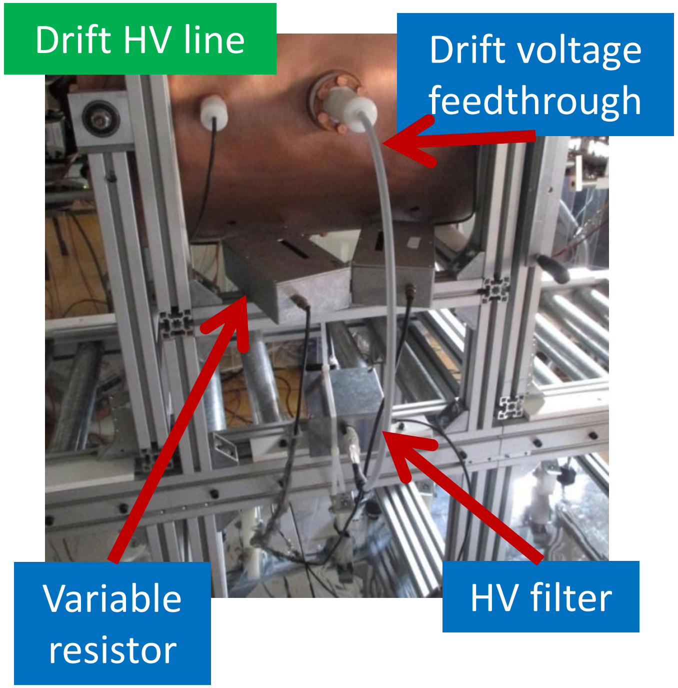


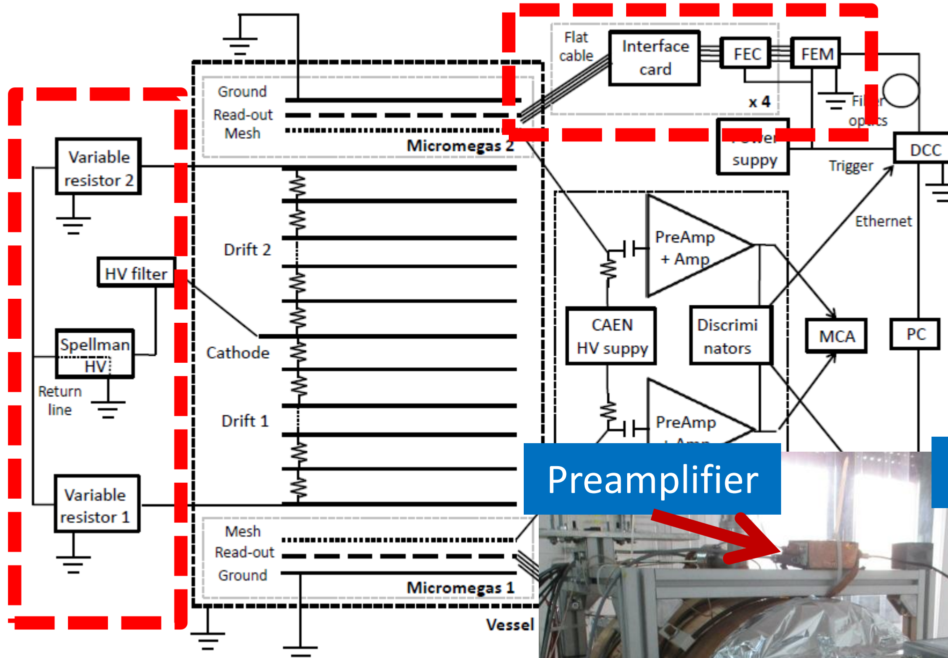


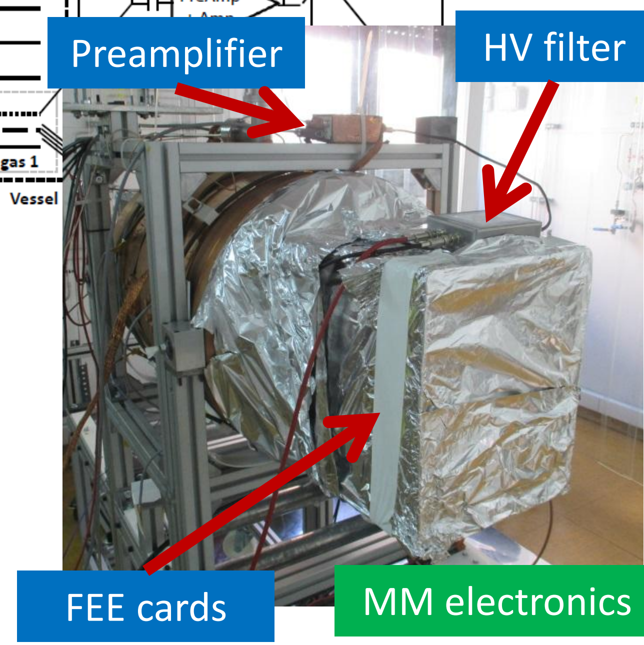


- 20 x 20 cm^2 bulk MM detectors. 432x432 strips, 0.6 mm pitch, 128 μm gap.
- Signals extracted by flat cables + feedthroughs.
- Sampling-ADC electronics record strip signals with external (mesh) trigger. Possible update to auto-trigger electronics → lower threholds expected.

TREX-DM: detector & electronics



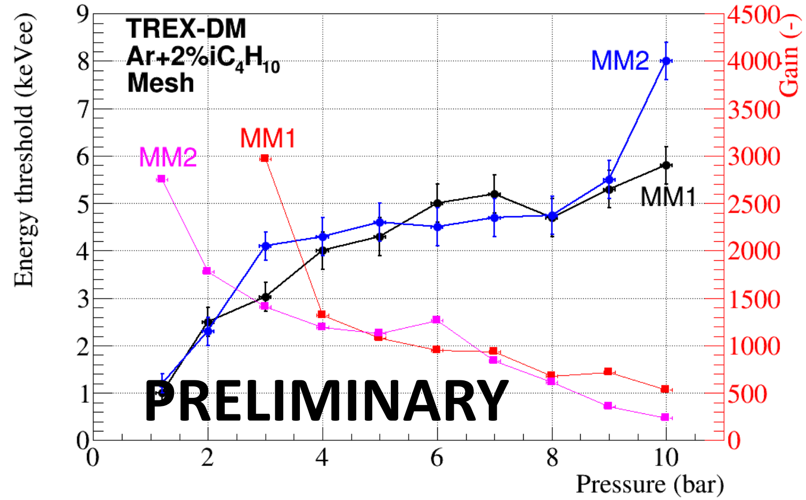




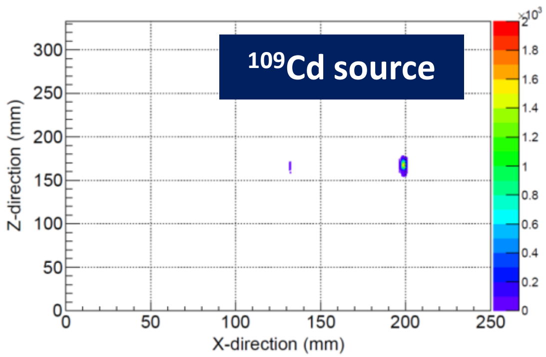
- Special care in grounding for a low energy threshold.
- All high voltage lines have a dedicated filter.
- Strips signals shielded by a ground layer.
- FE electronic cards inside a Faraday cage.

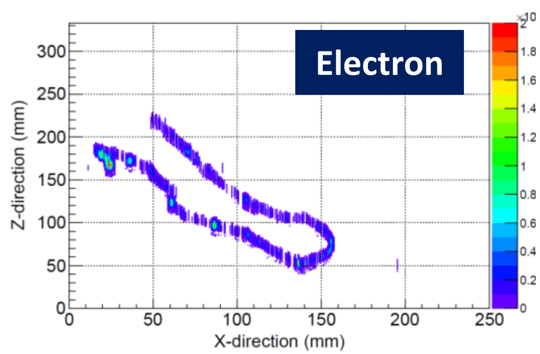
Some preliminary results…

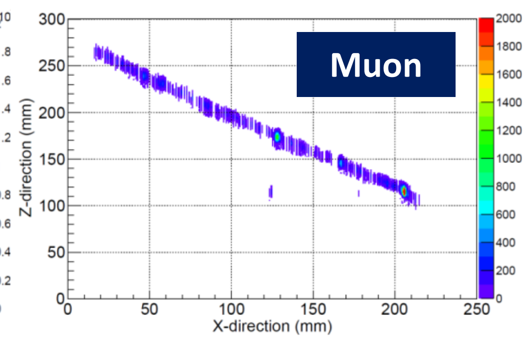
- Detectors characterized in Ar+2%iso up to 10 bar.
- Degradation of performance with pressure:
    - **Gain:** 3 x 10^3 (1.2 bar) -> 5 x 10^2 (10 bar).
    - **Threshold:** 1.0 keV -> 6.0 keV.
    - **Resolution:** 16% FWHM -> 27% FWHM.
- Results limited by noise (later removed) & a low quantity of quencher.
- New data-taking in Ar+5%iso on going. Better results already obtained.
- Near-term: neon-based mixtures.



J.G. Garza *et al., MPGD 2015*



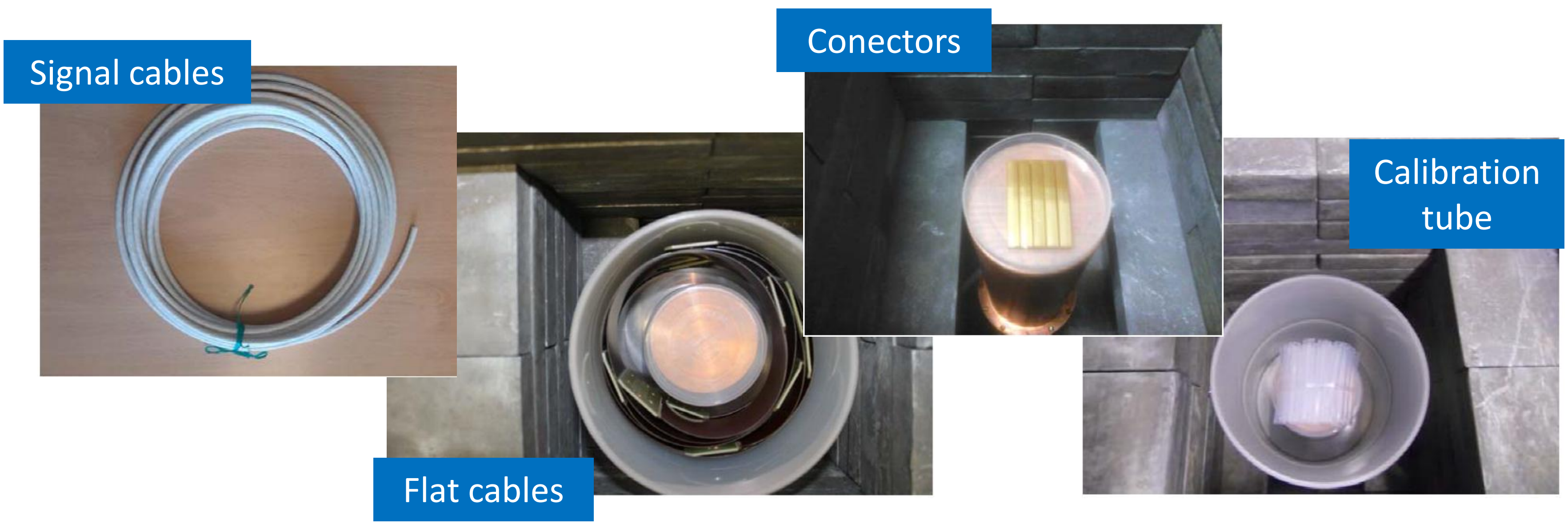




Universidad Zaragoza

Material screening program

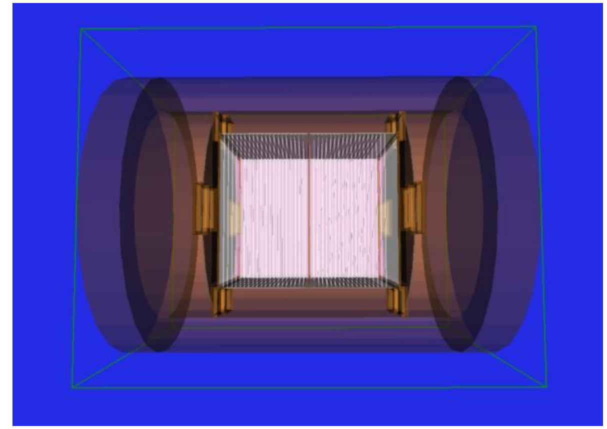
- The radioactivity measurement of all relevant components of the experiment: shielding, vessel, calibration system, field cage, electronics & detectors.
- Mainly based on a germanium gamma-ray spectrometry at LSC.
- Found radiopure versions of the micromegas detectors, flat cables and conectors. They will be installed in the final version for LSC.
- More details: F. Aznar *et al.*, *JINST* **8** (2013) C11012 & future article.



Universidad Zaragoza

Background model in argon & neon

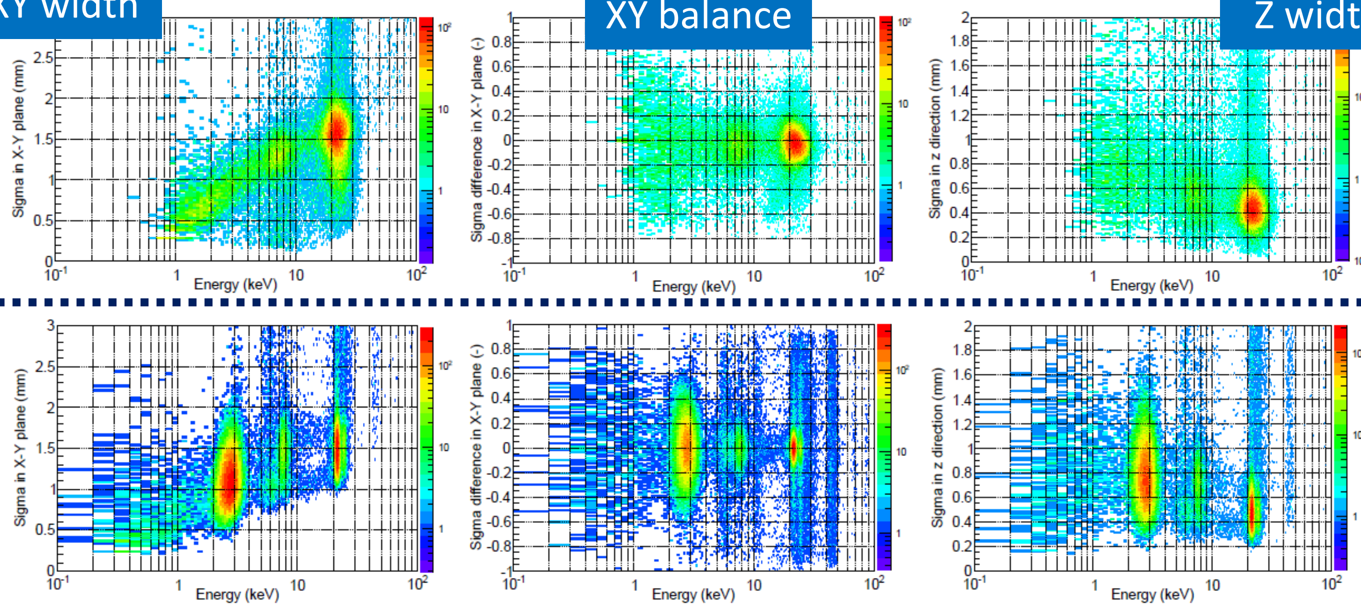
- Two gases studied: Ar & Ne + 2%iso @ 10 bar.
- Results are scaled by the measured activities.
- Geant4 + REST code + cluster analysis + discrimination.
- Final data in FEE-based format.
- Analysis based on cluster features.
- Simulation chain validated by real data.



XY width

XY balance

Z width



Real data

Simulation

^{109}Cd source
Ar+2%iso@2 bar

Universidad Zaragoza

Background model in argon & neon

Component	Material	Back. level ($keV^{-1}kg^{-1}day^{-1}$)		Reference	
		Argon	Neon		
Muons	-	0.019	0.026	LSC	G. Luzon, IDM 2008
Cosmogenics	^{39}Ar	**2.04**	-	DarkSide	J. Xu et al, Astr. Part 66 (2015) 53
Vessel	Copper	**< 0.33**	**< 0.37**	EXO-200	D.S. Leonard et al., NIMA 591 (2008) 490
Connectors	Fujipoly	**0.58**	**0.87**	This work	
Field cage	Teflon	1.0×10^{-3}	1.2×10^{-3}	EXO-200	D.S. Leonard…
Cathode	Copper	< 0.020	< 0.022	EXO-200	D.S. Leonard…
mM detectors	Cu-Ka	< 0.1	< 0.084	BiPo	Unpublished
TOTAL		**3.09**	**1.38**		

RoI: 2-7 keV. Statistical error < 10%. 80% signal efficiency.

- Results mainly determined by the measured activities.
- **Pending issues:** outer gamma flux, external shielding & neutrons not yet included.
- Main contributions: **^{39}Ar** (for argon based), **electrical connectors** and **vessel**.
- **^{39}Ar** contribution will be **2×10^2 keV^{-1} kg^{-1} day^{-1}** if argon comes from **surface** sources, i.e., not depleted.

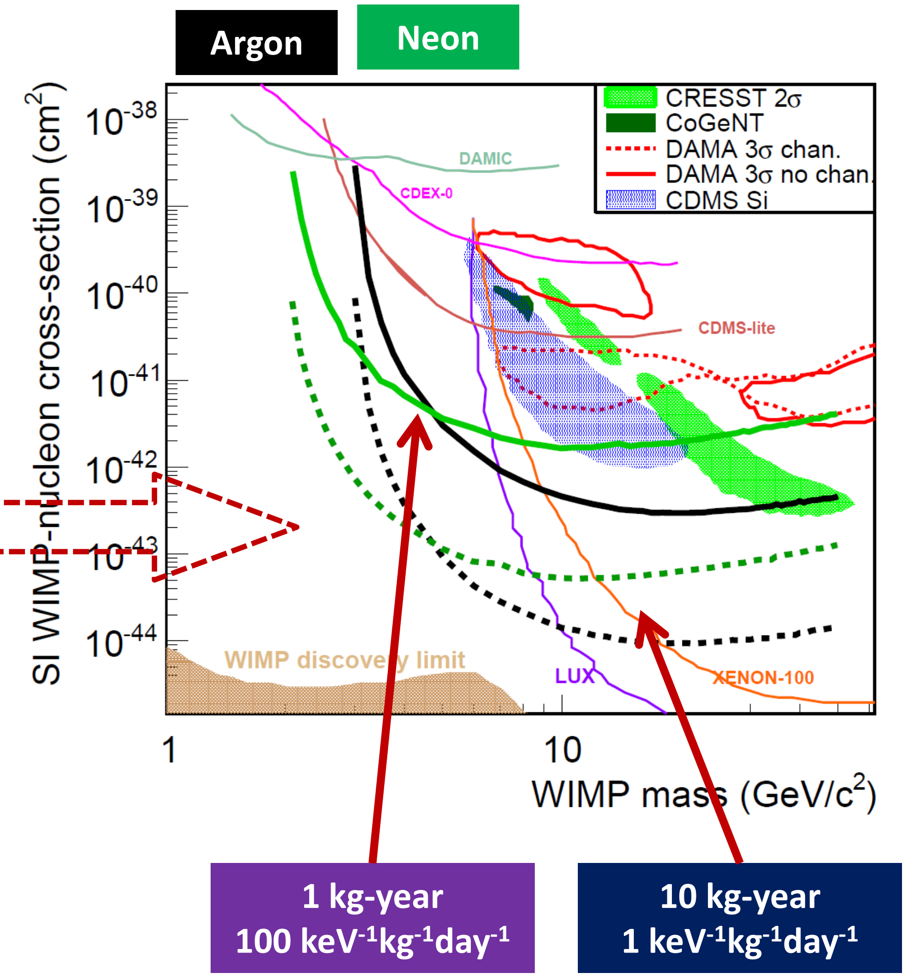
Prospects of TREX-DM experiment

Summary of background levels:

- **Argon @ 10 bar**: ***3.09 keV^{-1} kg^{-1} day^{-1}***.
- **Neon @ 10 bar: *1.38 keV^{-1} kg^{-1} day^{-1}***.

(mainly defined by the measured activities)

*Supossing a **0.4 keVee** energy threshold & that this background model is valid, it could be sensitive to the regions defined by WIMPs hints in a conservative scenario.*



Challenges for near-term future:

- **Low energy threshold** at high pressures.
- **Quenching factor** must be measured.

Conclusions

TREX-DM: a large Micromegas-based TPC for low WIMP masses.

- **Challenges:** low energy threshold for a large detector area at high pressure.

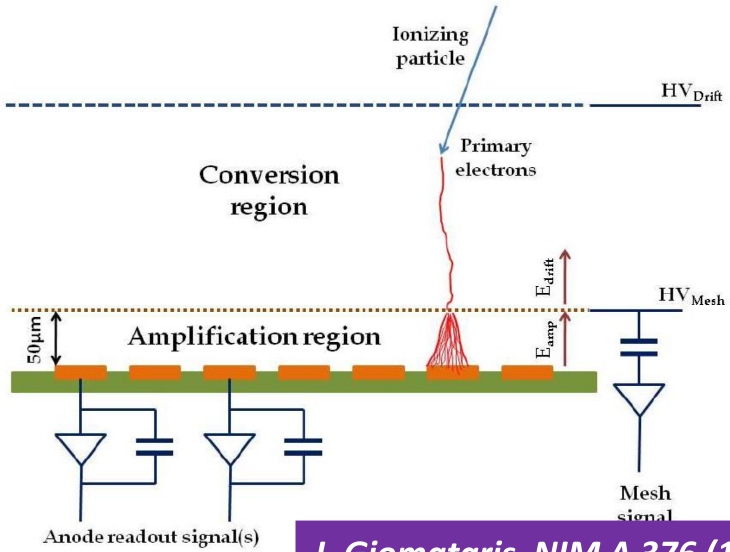
Comissioning

- **Actual status:** commissioning of a not fully radiopure setup.
  - Test bulk MM in argon- & neon-based mixtures at high pressure.
    - Study of energy threshold with electronics chain & pressure.
    - Validation of the simulation chain.
  - Pending issue: An automatic calibration system.
- **Future**: update to a fully radiopure setup, to be possibly installed at LSC during 2016.

Prospects:

- A first background model of TREX-DM in argon & neon-based gases has been created.
- Background levels around **1-3 count keV^{-1} kg^{-1} day^{-1}** for a **80%** signal efficiency.
- Supossing a **0.4 keVee** energy threshold, TREX-DM be sensitive to the regions defined by WIMPs hints in a conservative scenario.

A Micromegas TPC for Dark Matter detection



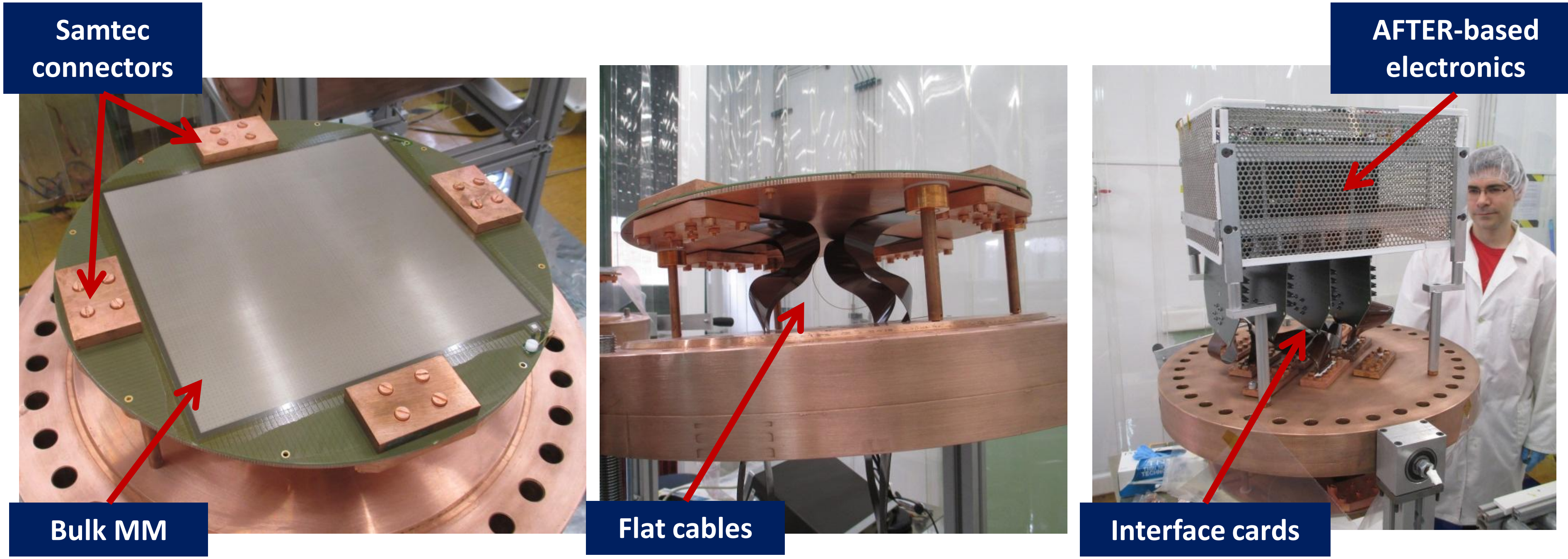
I. Giomataris, NIM A 376 (1996) 29

Radiation create electrons, which drift to the readout.

Electrons are amplified & the electron-ion movement induces signals in both ***mesh & strips****.*

- It is an amplification structure used as readout in a TPC.
- Invented in 1996. Many developments since then. Extensively used in particle phyiscs (ATLAS, T2K, nTOF, COMPASS, CLAS-12, MIMAC, CAST)…
- Many interesting feautres for Dark Matter searches.

The Micromegas detectors in detail



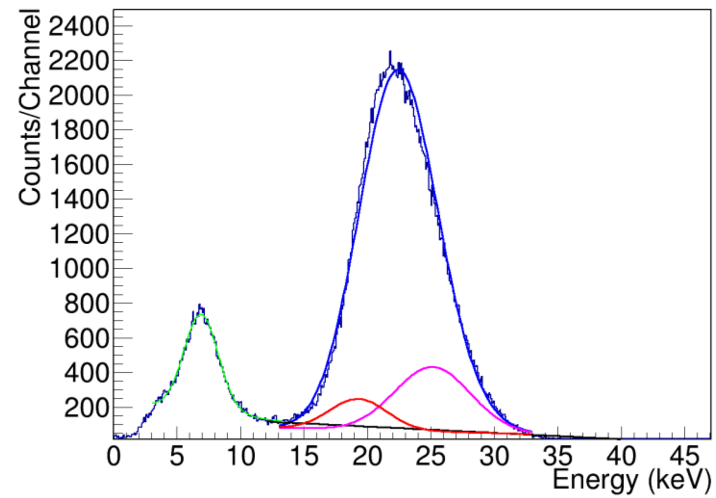
- 20 x 20 cm^2 bulk Micromegas: 432 X-strips & 432 Y-strips, 0.6 mm pitch, 128 μm gap.
- Signals extracted by 4 flat cables using 300-Samtec connectors. A small shielding included too: **1 cm copper + 1 cm lead**.
- An interface card links a flat cable to the FEC. Any short-cut may be eliminated by a jumper.
- **AFTER**-based electronics. Possible update to **AGET**, with **autotrigger capabilities**.

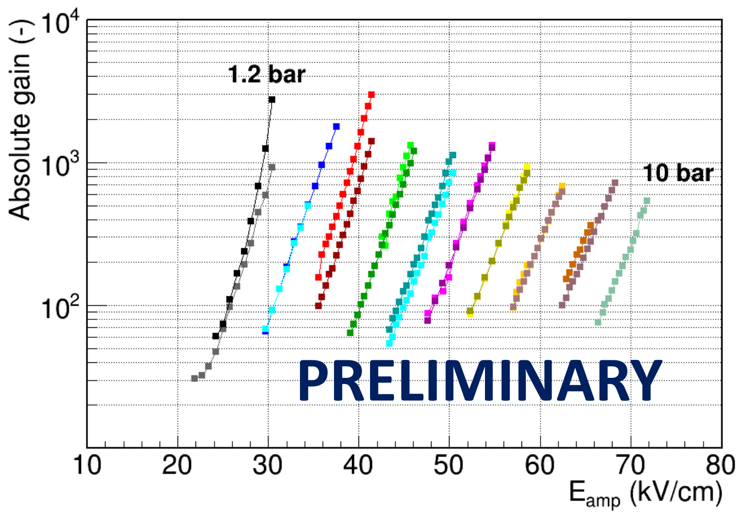
Many thanks to IRFU/SEDI-Micromegas workshop!!!

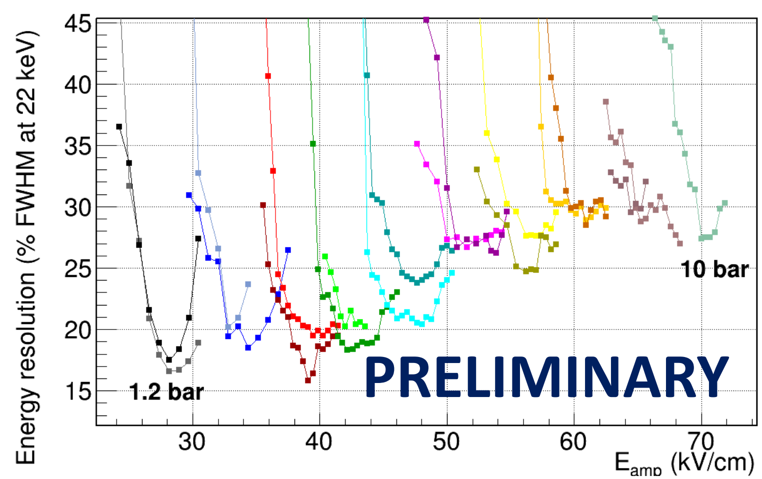
Some preliminary results

J.G. Garza *et al.*, *MPGD 2015*

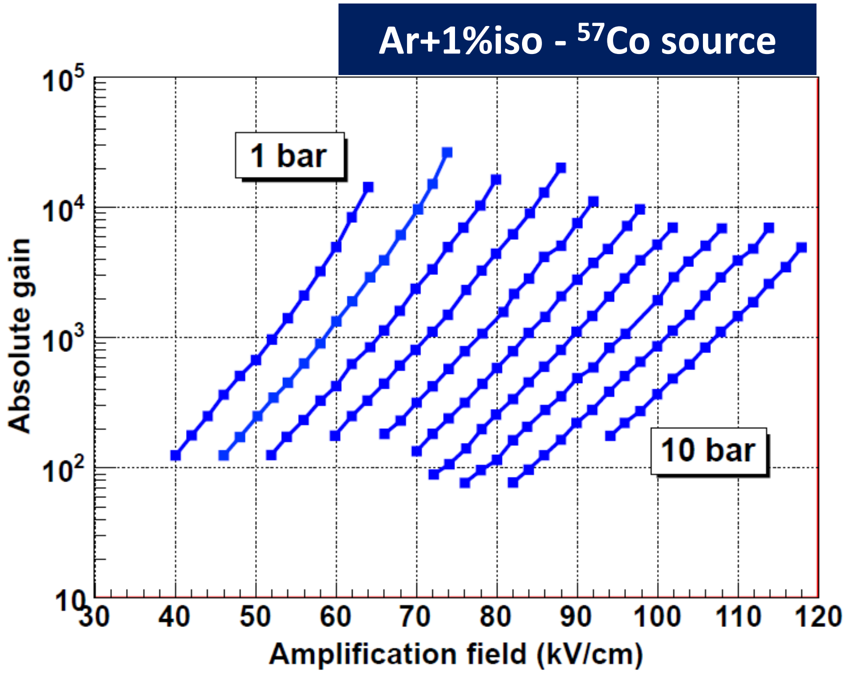
- Detectors characterized in Ar+2%iso up to 10 bar.
- Degradation of performance with pressure:
    - **Gain:** 3 x 10^3 (1.2 bar) -> 5 x 10^2 (10 bar).
    - **Threshold:** 1.0 keV -> 6.0 keV.
    - **Resolution:** 16% FWHM -> 24% FWHM.
- Results limited by noise (later removed)
  & a low quantity of quencher.

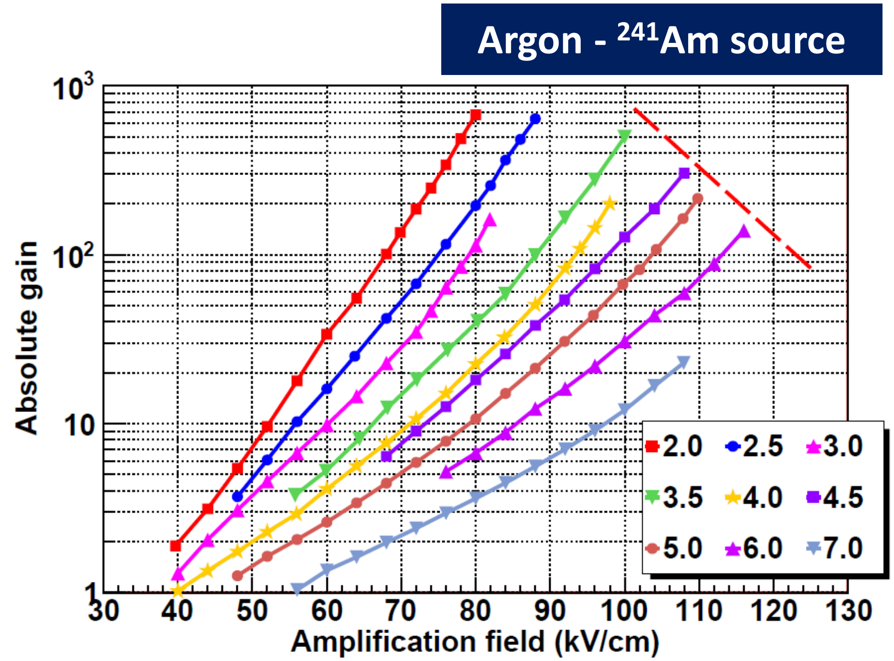






Micromegas detectors at high pressure



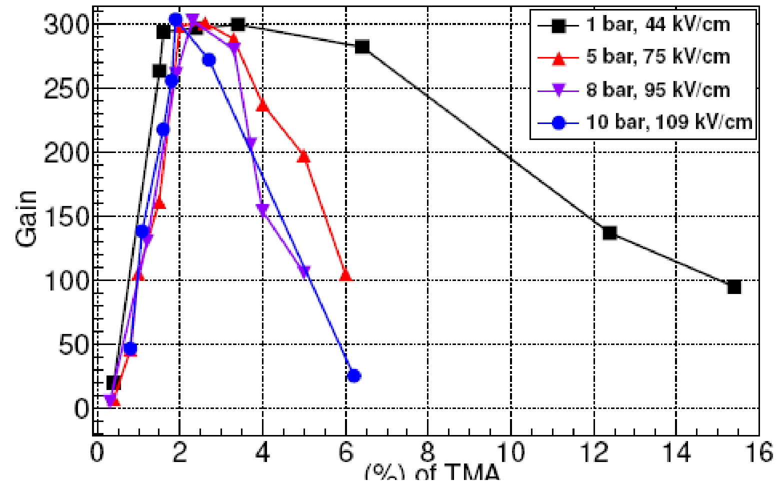


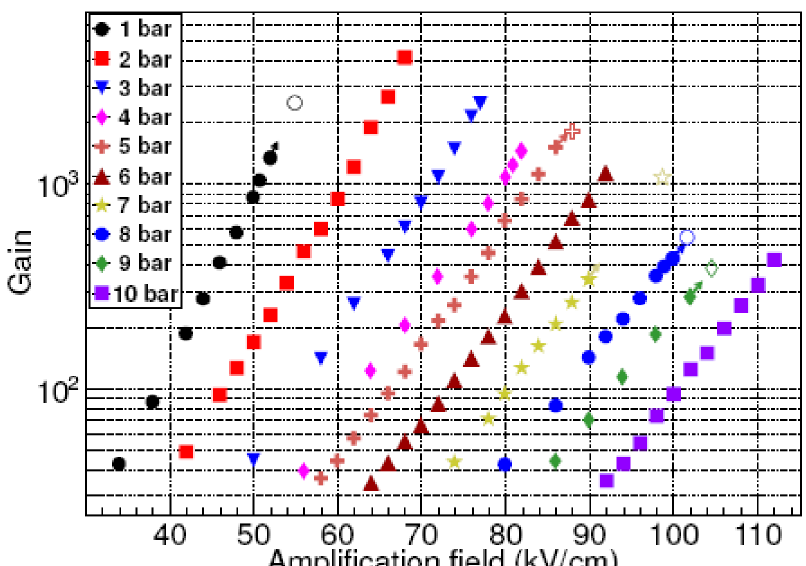
- Microbulk micromegas. 50 μm gap.
- Argon-based mixtures.

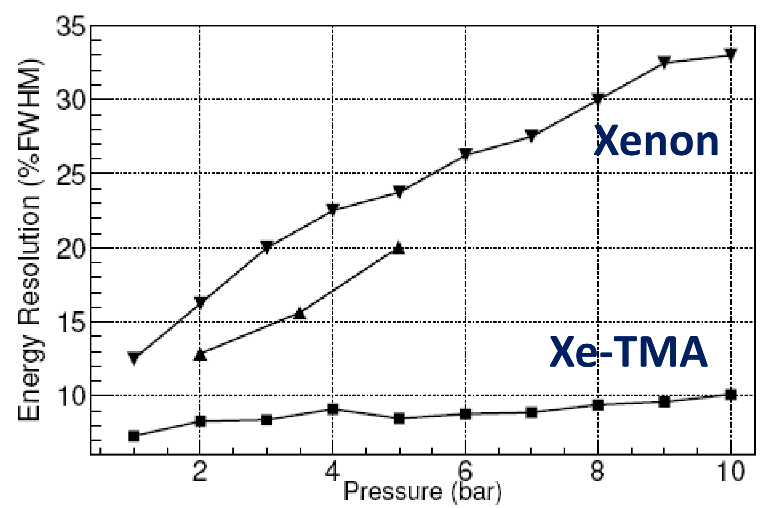
F.J. Iguaz et al., RD51 meeting, Fribourg May 2010

Micromegas detectors at high pressure

- Microbulk micromegas. 50 µm gap.
- Xenon-TMA mixtures.
- ^{109}Cd source (22.1 keV x-rays).
- Best performance for 1.5-2.5% TMA.
- Max, gain: $2\text{x}10^3$ ($5 \text{ x } 10^2$) at 1 (10) bar.
- Energy resolution: 7.3 (9.6) % FWHM at 22.1 keV for 1 (10) bar.



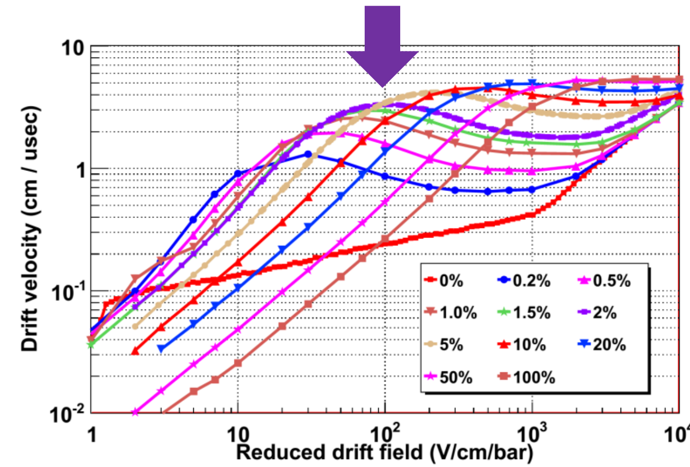


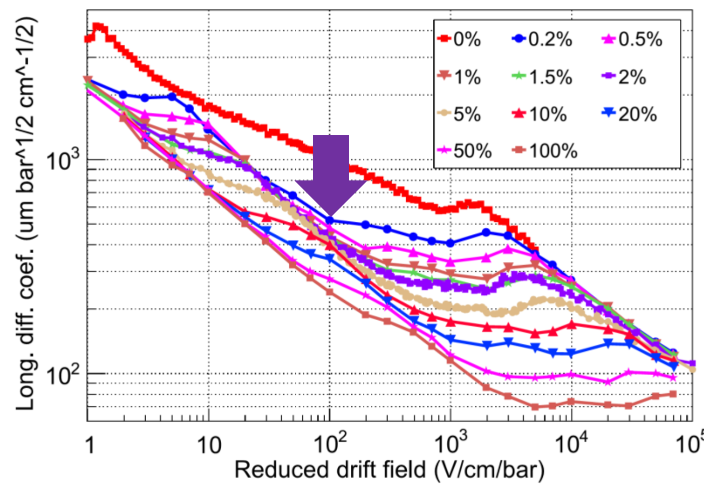


S. Cebrian et al., JINST 8 (2013) P01012

Simulation chain: gas & electronics

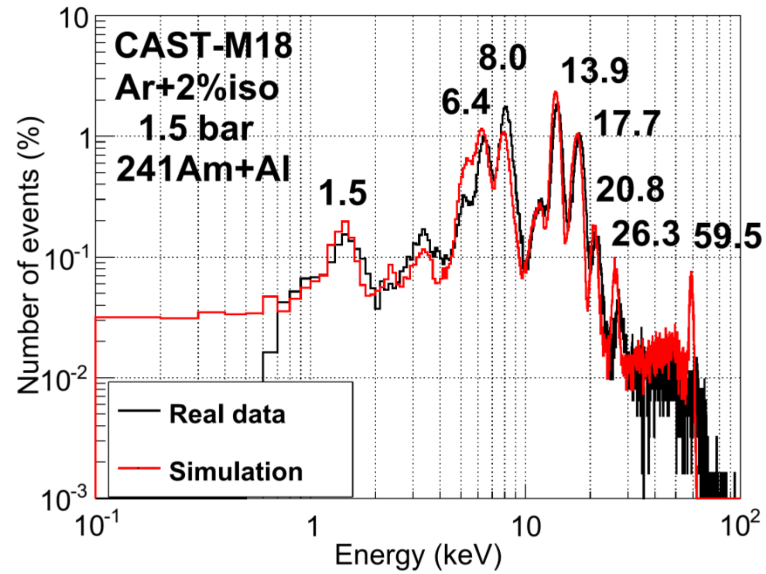
- Gas properties
  - $Ar+2\%iC_4H_{10}$ at 10 bar
  - Edrift = 100 V/cm/bar
  - Vdrift = 3.33 cm/μs
  - Transversal diffusion = 221 $\mu m/cm^{0.5}$
  - Longitudinal diffusion = 134 $\mu m/cm^{0.5}$
- Pixelization
  - Length = 0.5 mm
  - Sampling = 10 ns
  - Shaping time = 100 ns
  - Gain = 240 pF





Validation of the simulation chain

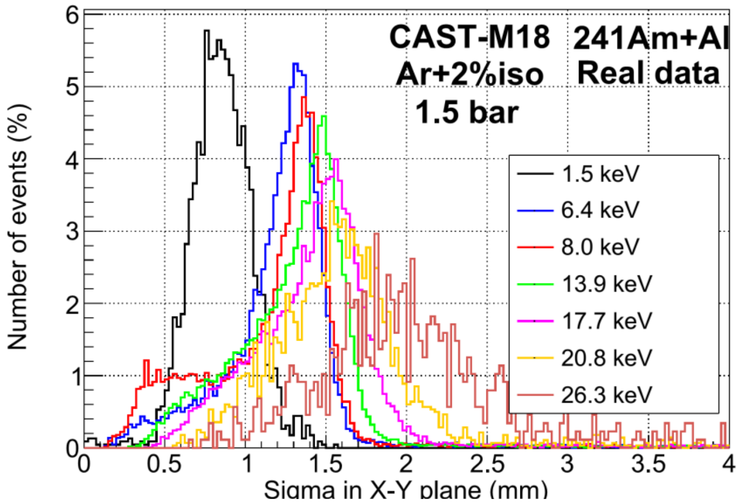
- As a validation of the complete chain, an ^{241}Am calibration of M18 has been used.
- Gas: Ar+2%iC_4H_{10} at 1.5 bar.
- **Pros:** many lines, energy dependece study.
- **Cons:** geometry of ^{241}Am not fully defined.
- Simulated the CAST-MM geometry implemented by A. Tomás & A. Rodríguez.
- Energy spectra quite similar. Big differences at high energy gammas (saturation?) and small ones at fluorescence lines.

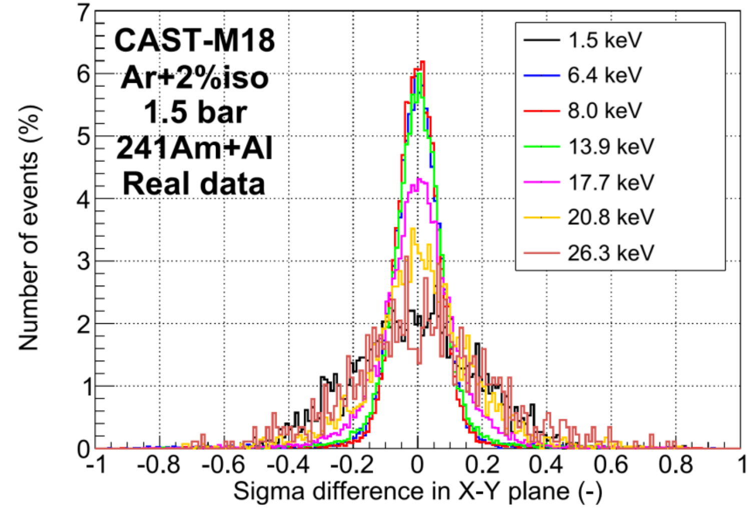


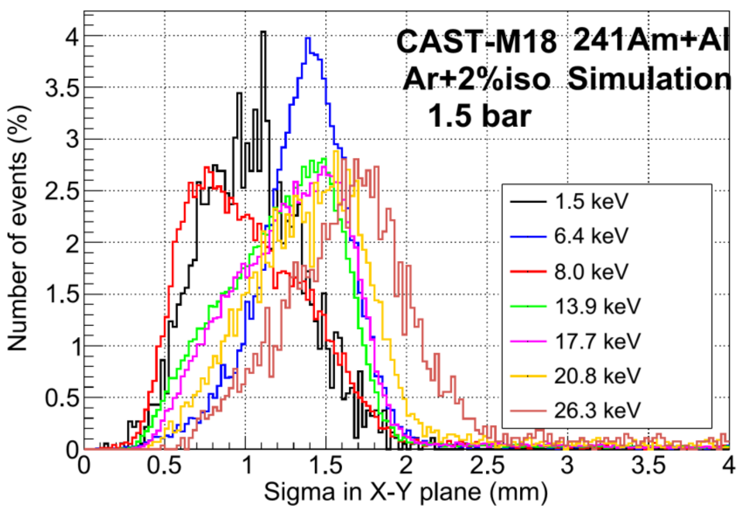
Conclusions

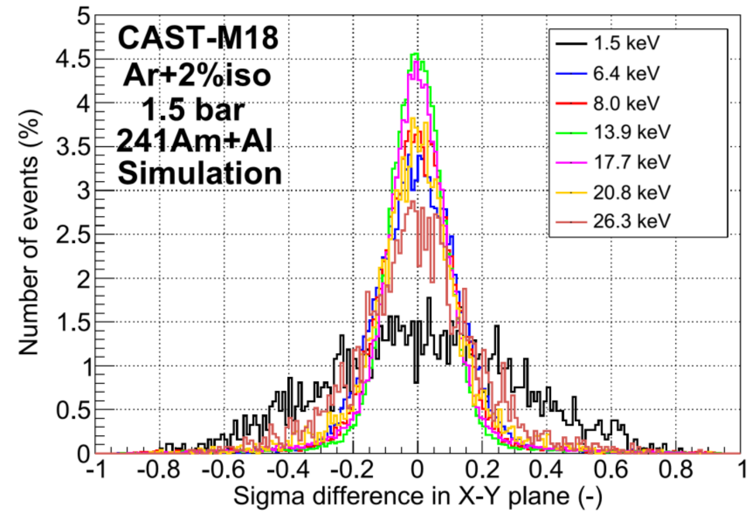
- Cluster width's distributions are quite similar, except for the 8 keV line (too much copper at the bottom?). Main differences at low widths.
- Less charge fluctuations between planes for real data at energies < 15 keV. At higher energies, the simulated fluctuations are little.

Validation of the simulation chain





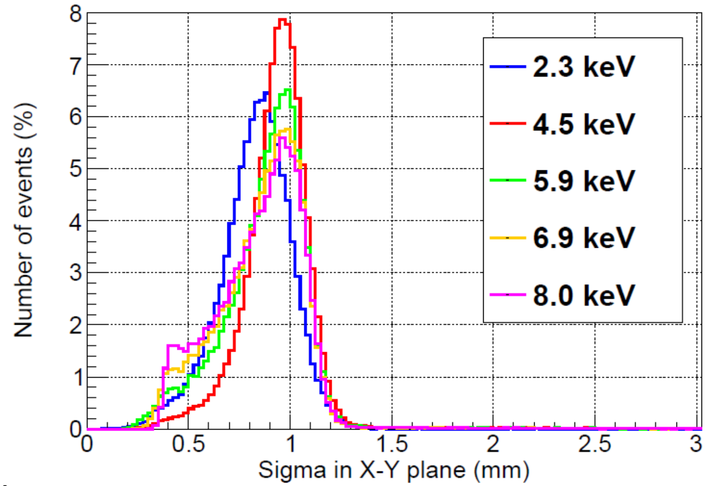


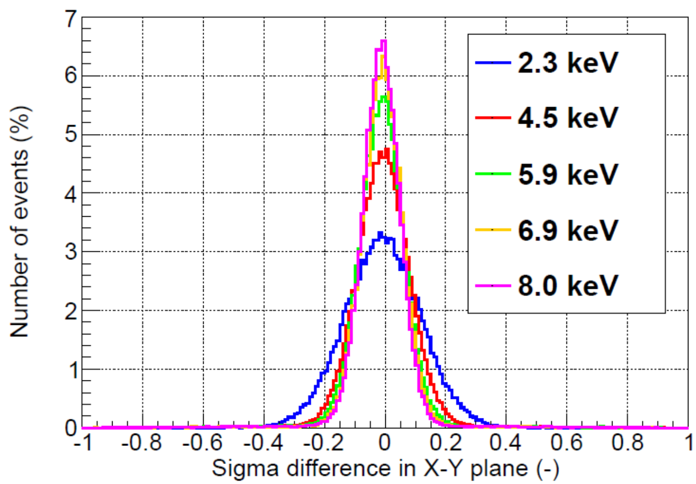


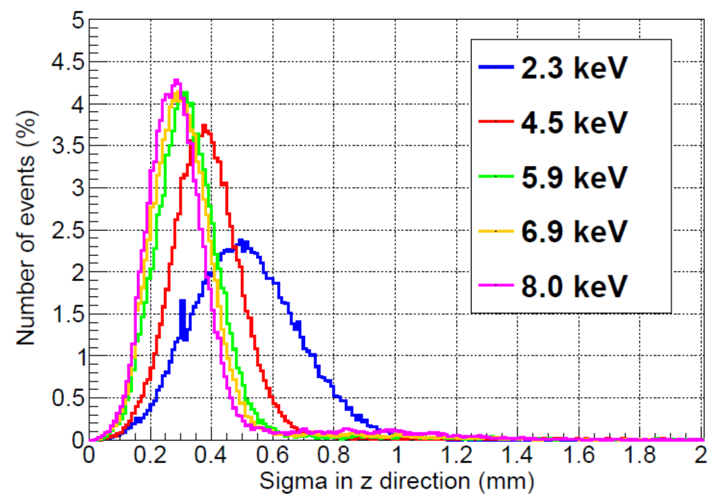
J.G. Garza et al., JINST 8 (2013) C12042
F.J. Iguaz et al., PoS(TIPP2014)295

X-ray cluster's topology

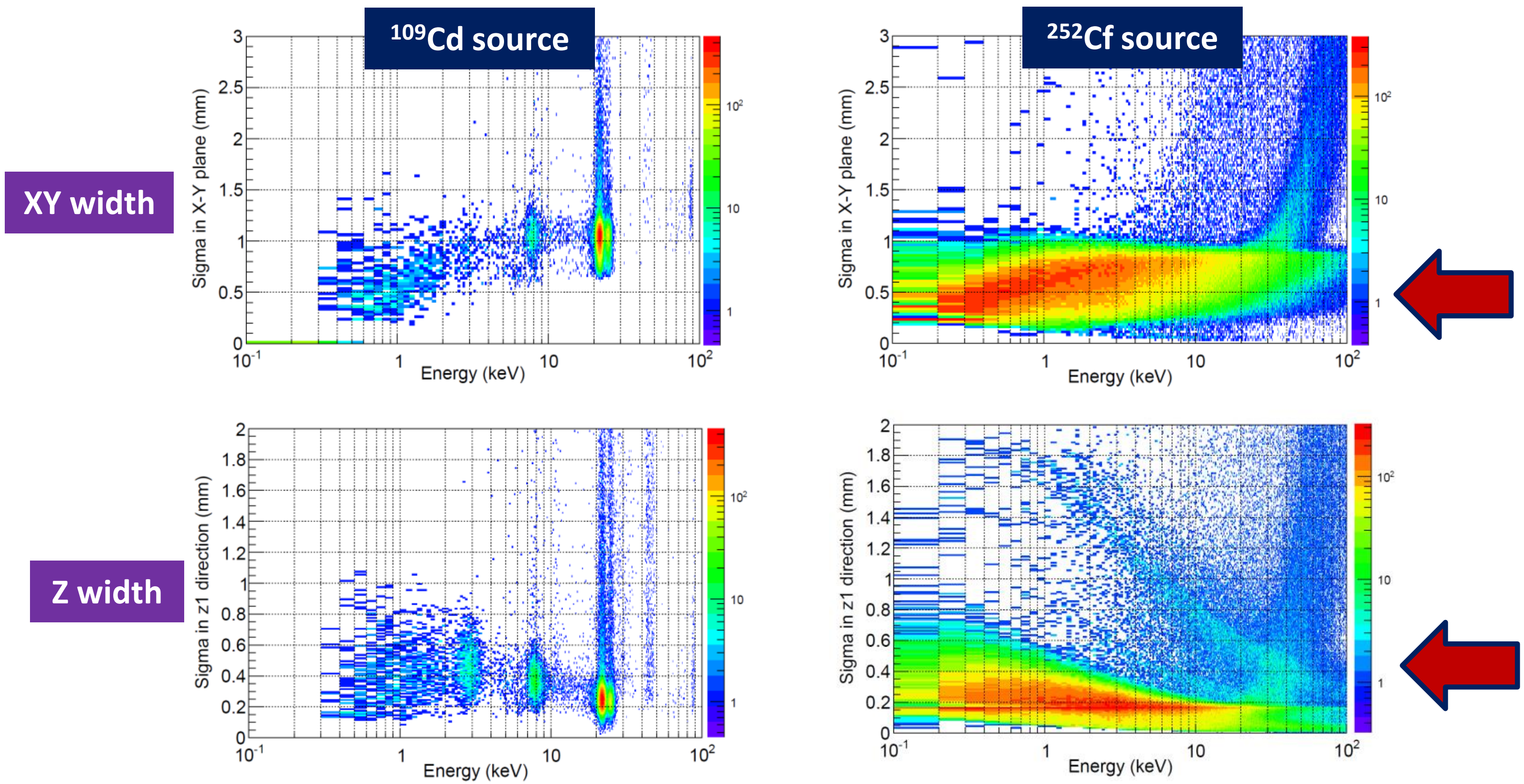
- CAST Microbulk micromegas. 50 µm gap.
- Electron beam at CAST Detector Laboratory.
- Fluorescence lines from 2.3 (gold) to 8.0 keV (copper) used to calculate the signal efficiency.
- Clusters are wider at low energies because most of the x-rays are absorbed in the first mms just after the window and suffer more diffusion.
- Cluster differences increase at low energies as more charge fluctuations between the XY planes.







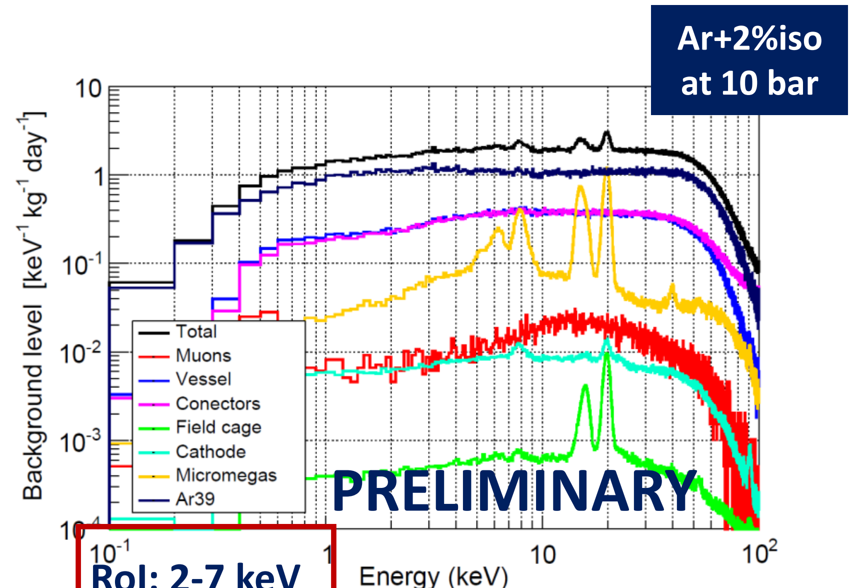
Electron/neutron discrimination



- A neutron source (^{252}Cf) has been simulated to verify if further background reduction could be reached by a neutron/electron discrimination.
- Neutrons show narrower cluster widths than x-rays but there is no clear separation between the two distributions.

Electron/neutron discrimination

Component	Material	Back. level ($keV^{-1}kg^{-1}day^{-1}$) ^{109}Cd analysis	^{252}Cf analysis
Muons	-	0.019	0.011
Cosmogenics	**^{39}Ar**	**< 2.04**	**< 1.14**
Vessel	Copper	**< 0.33**	**< 0.19**
Connectors	Fujipoly	**0.58**	**0.33**
Field cage	Teflon	1.0×10^{-3}	5.7×10^{-4}
Cathode	Copper	< 0.020	< 0.008
mM detectors	Cu-Ka	< 0.1	< 0.115
TOTAL		**3.09**	**1.79**

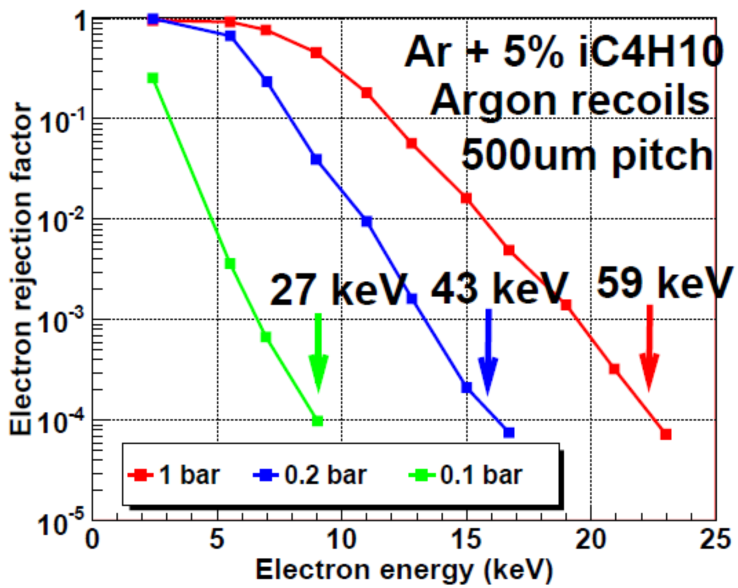


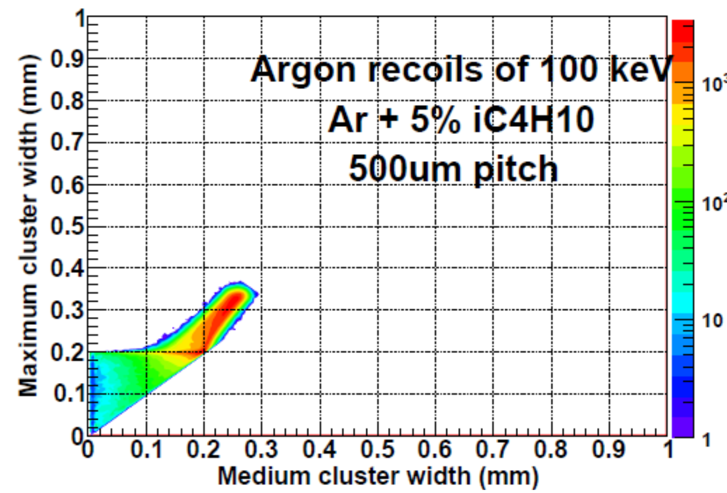
RoI: 2-7 keV Statistical error < 10%

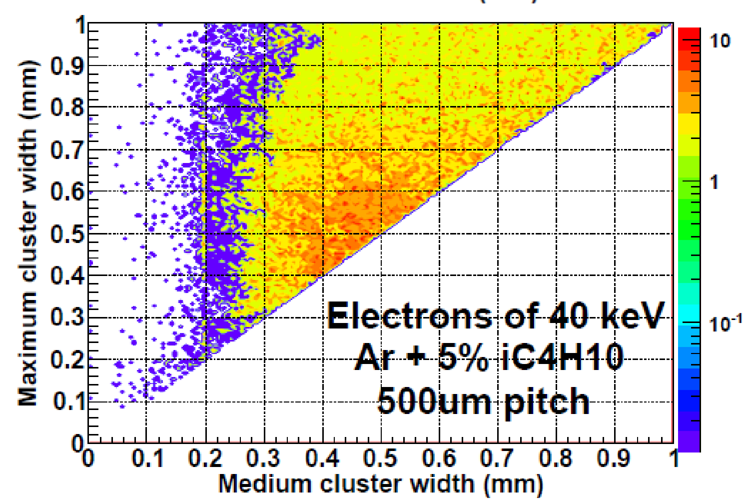
- Preliminary background reduction: **~44% (3.09 -> 1.79).**
- Effective for all components, except for Micromegas detectors (narrower clusters).

Electron/neutron discrimination

- First studies: A. Tomas in CYGNUS 2007.
- The cluster width is the key parameter and is more efficient at low pressures.
- It sharply increases from electrons but remains constant for neutrons.





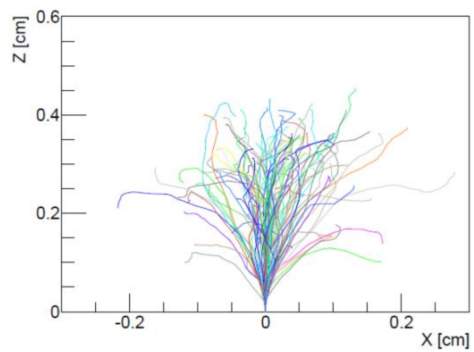


F.J. Iguaz, Phys. Proc. 37 (2012) **1079**

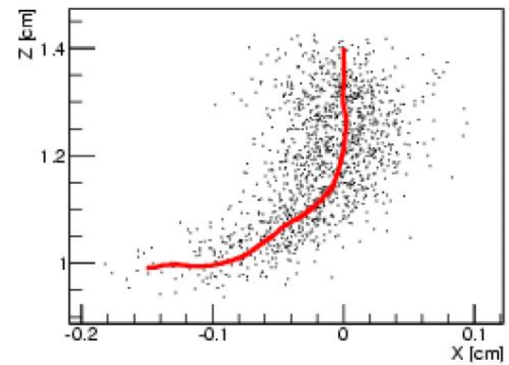
MIMAC directionality in CF_4

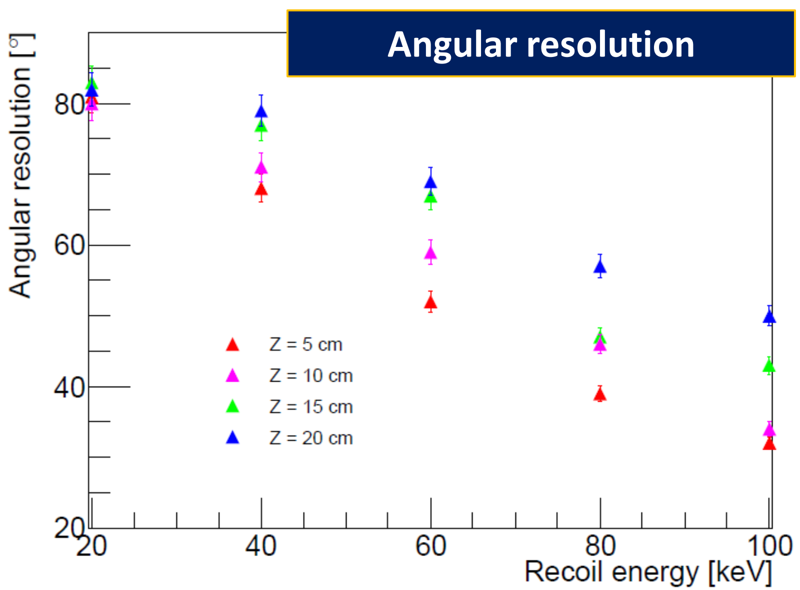
J. Billard, F. Mayet, D. Santos, JCAP 04 (2012) 006

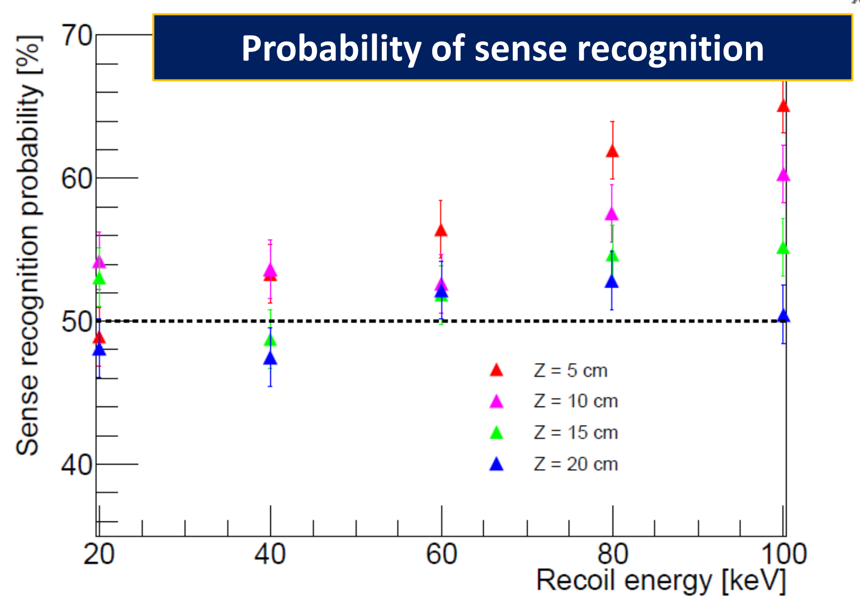
- The angular resolution & sense recognition depends on the energy and the drift distance.
- The sense recognition for recoil energies below 100 keV is unrealistic.
- Focus on axial directional detectors.



Fluorine recoil track







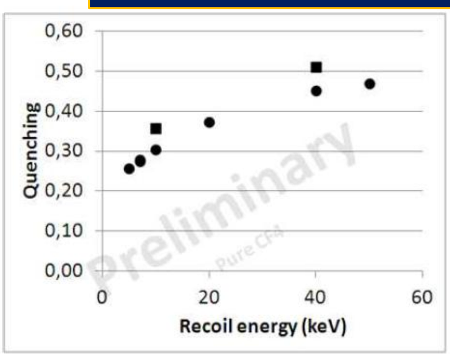
Universidad Zaragoza 1542

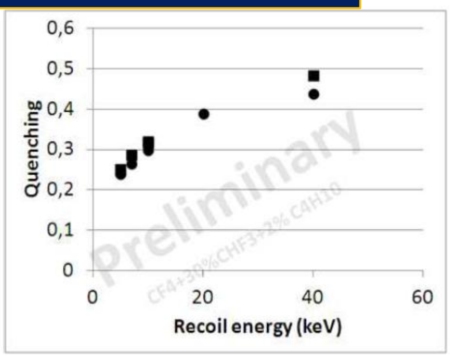
Measurement of quenching factor by MIMAC experiment

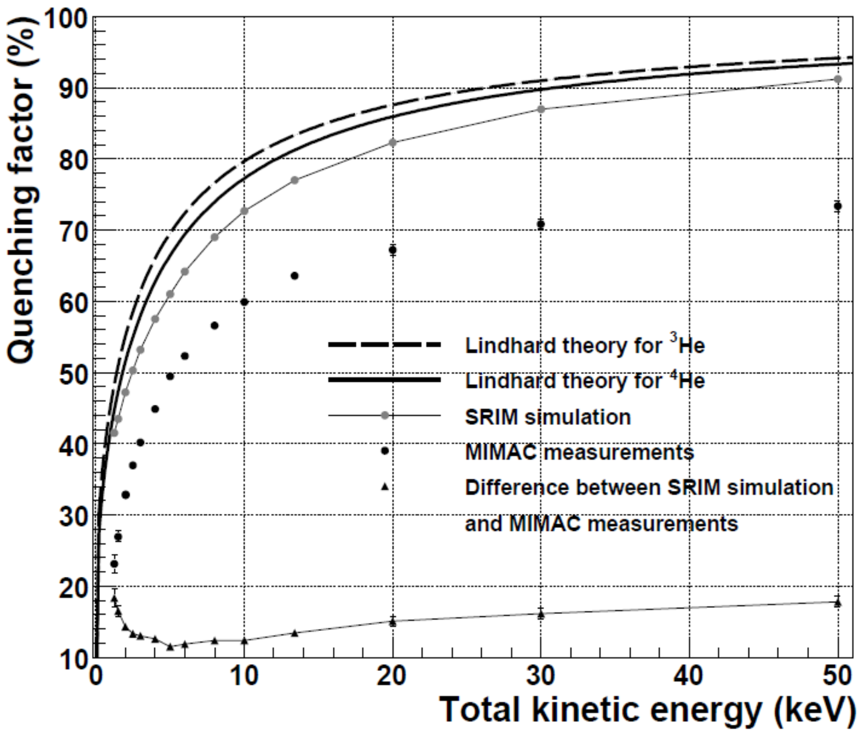
D. Santos et al., arXiv:0810.1137
O. Guillaudin et al., arXiv:1110.2042

- A complete R&D program to measure the quenching factor of energy recoils in different gas mixtures.
- Measured in ^3He & ^4He.
- Actual efforts focused on CF4.

Quenching factor in CF_4 & CF_4-CF_3







Quenching factor in Helium 3 & 4