HPTPC R&D in Spain for Dark Matter: The T-REX project

F.J. Iguaz

on behalf of Zaragoza group

Workshop on Neutrino Near Detectors based on gas TPCs

9th November 2016

Work partially supported by Juan de la Cierva program

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Acknowledgements

Work here presented made by many people:

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- Javier Gracia
- Diego González-Díaz (*-> now @ Univ. Santiago)
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- Paco Iguaz
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And also people from IRFU/SEDI,
CERN (Rui de Oliveira's workshop), LSC & GIFNA / UNIZAR.

erc
European Research Council
StG-2009: T-REX

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

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Outline

- The T-REX project & Micromegas-based TPCs.
- TREX-DM: description, results & upgrades for LSC.
- Conclusions.

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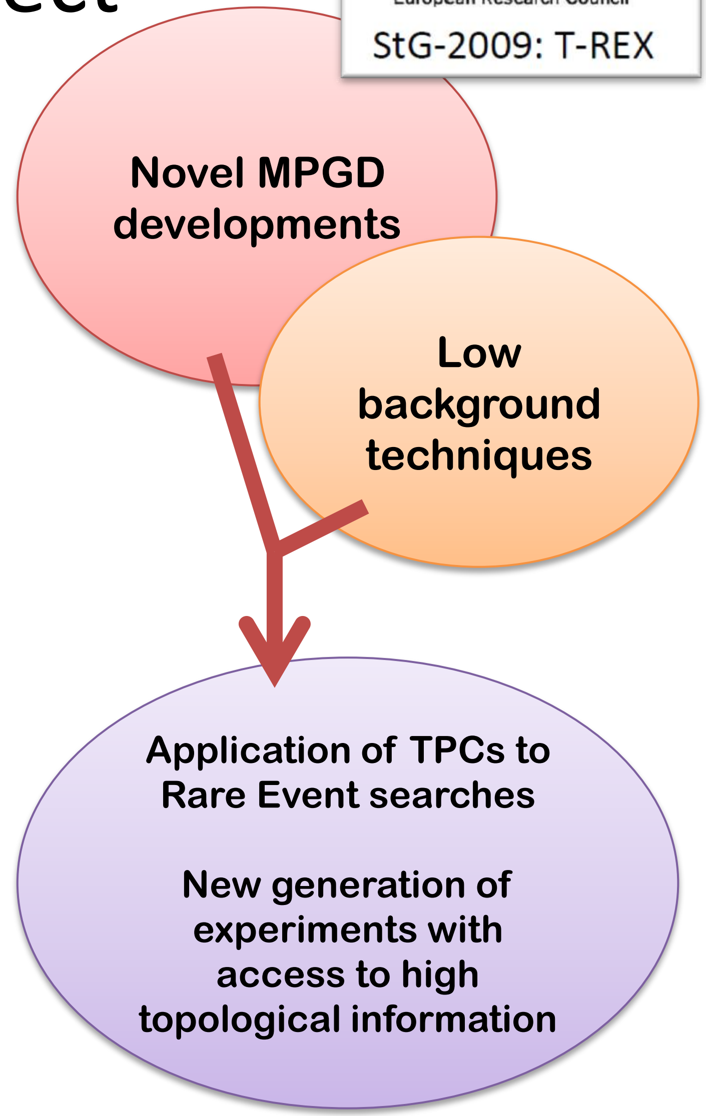
The T-REX project

European Research Council
StG-2009: T-REX

- ERC Starting-Grant by I.G. Irastorza:

  TPC for Rare Event search eXperiments
- TPCs offer high potential for rare event searches
  - Relative large choice of target gases.
  - Rich topological information in gas.
  - High granularity of readout plane.
- But…
  - Calorimetry?
  - Gas → low density → Scaling-up?
  - Complex detectors -> Radiopurity?



TREX claim:

TPCs equipped with MPGD (esp. Micromegas) may override traditional prejudices to gaseous TPCs: simplicity, robustness, scaling-up & radiopurity.

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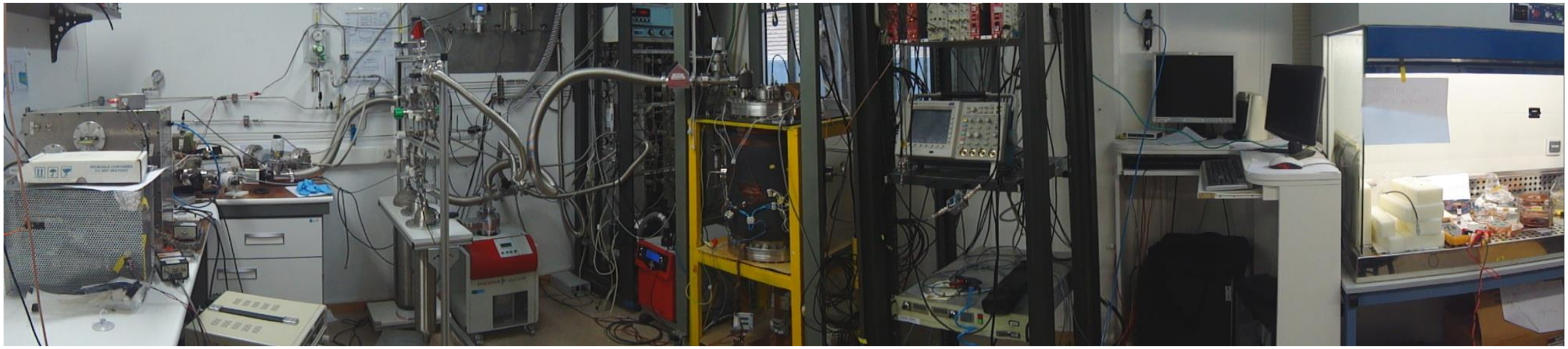
Infrastructure created: T-REX labs



About 100 m^2 lab space at UNIZAR…

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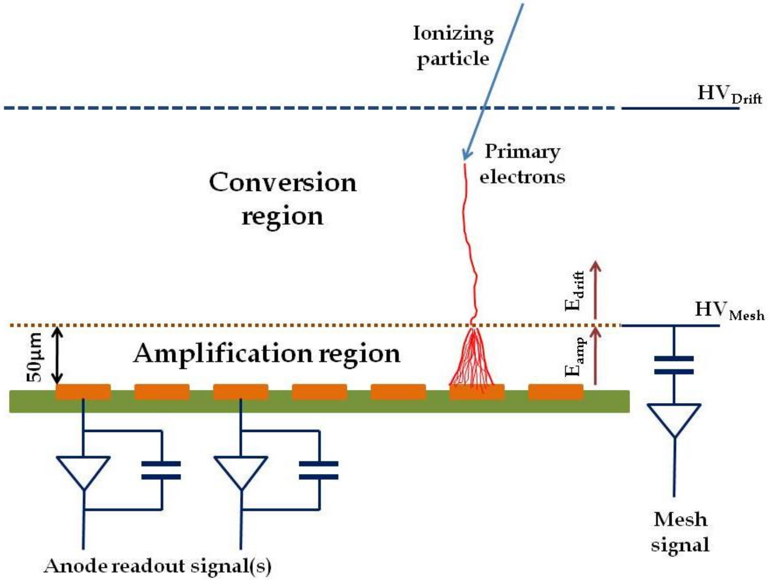
Micromegas-based TPCs

Micromegas readout plane

- Pixelised anode plane.
- Suspended metallic micromesh.



Micromegas working principle

- Primary e-s go through mesh holes.
- Trigger an e- avalanche in the gas, inducing signals both mesh and anode.

Three types of technologies:

- **Classical:** Mesh is mechanically fixed to the anode (CAST, ATLAS).
- **Bulk:** Mesh & anode in a sandwhich (COMPASS, T2K, CLAS-12, n_TOF, MIMAC…)
- **Microbulk:** Mesh & anode built in one piece by chemical processing (CAST & nTOF).

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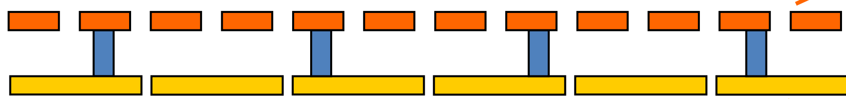
Micromegas-based TPCs

BULK
Robust
Very large areas available ($2\ m^2$)

Readout plane + mesh all in one



Woven Inox mesh 30 µm

Pyralux 128/256 µm

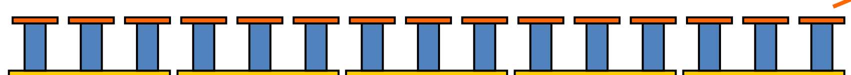
Readout pads

Well established technique

I. Giomataris et al., *Nucl. Instr. Meth. A***560** (2006) 405-408

MICROBULK
Better performance
Light weight
Radiopure

Readout plane + mesh all in one



Micromesh 5 µm copper

Kapton 50/25 µm

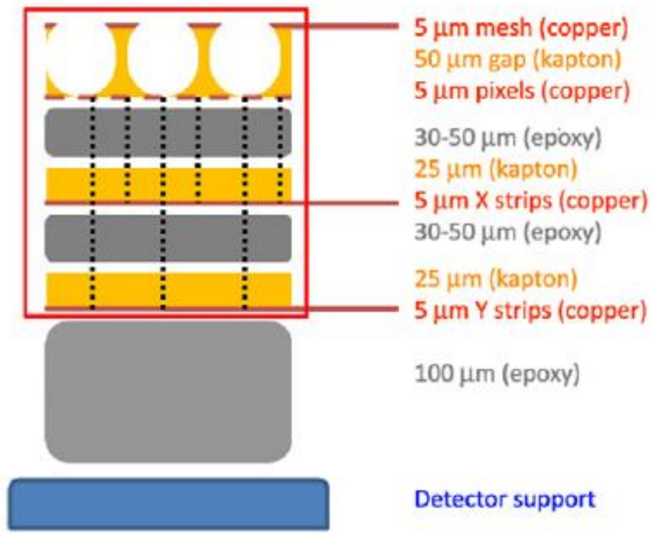
Readout pads

CERN+IRFU/Saclay development

S. Andriamonje et al., *JINST* **5** (2010) P02001
F.J. Iguaz et al., *JINST* **7** (2012) P04007
D. Attié et al., *JINST* **9** (2014) C04013

Micromegas results within T-REX project

It is intrisic radiopure if only made of kapton & copper…



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

Micromegas results within T-REX project

It is intrisic radiopure if only made of kapton & copper…

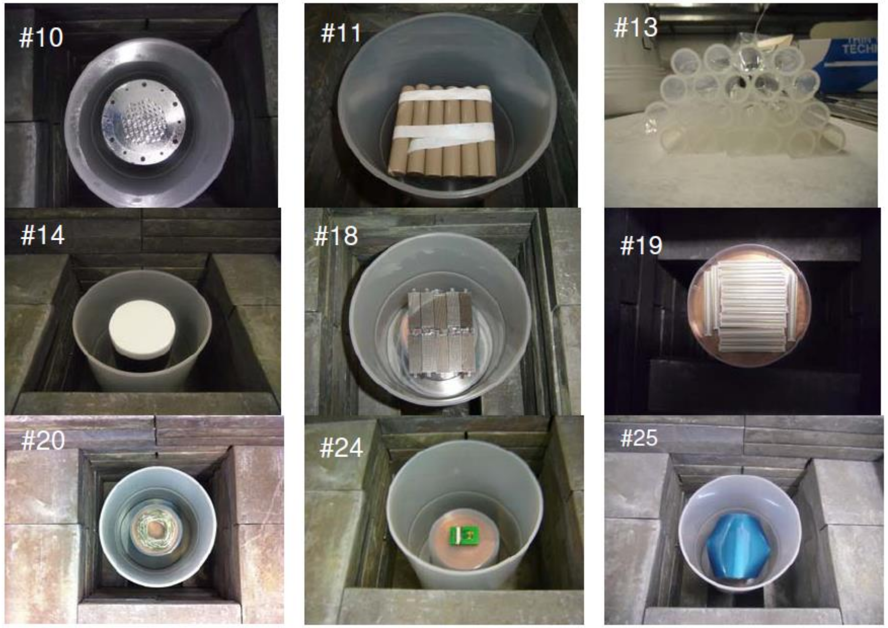
#	Material,Supplier	Method	Unit	^{214}Bi	^{208}Tl
16	Microbulk Micromegas, CAST/CERN	BiPo-3	μBq/cm^2	< 0.134	< 0.035
17	Cu-kapton-Cu foil, CERN	BiPo-3	μBq/cm^2	< 0.141	<0.012
18	Kapton-epoxy foil, CERN	BiPo-3	μBq/cm^2	< 0.033	<0.008
19	Vacrel foil, Saclay	BiPo-3	μBq/cm^2	< 0.032	<0.013
20	Kapton-diamond foil, CERN	BiPo-3	μBq/cm^2	< 0.055	<0.016

Much better than PMTs!
Recent data by BiPo-3 may improve these values!

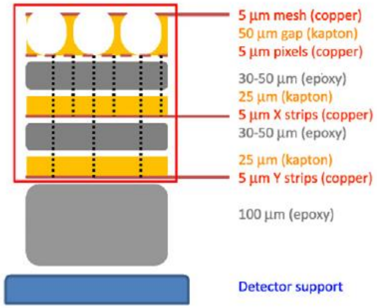
I.G. Irastorza et al., *JCAP* **1601** (2016) 033

Micromegas results within T-REX project

… and radiopurity control techniques can be applied.

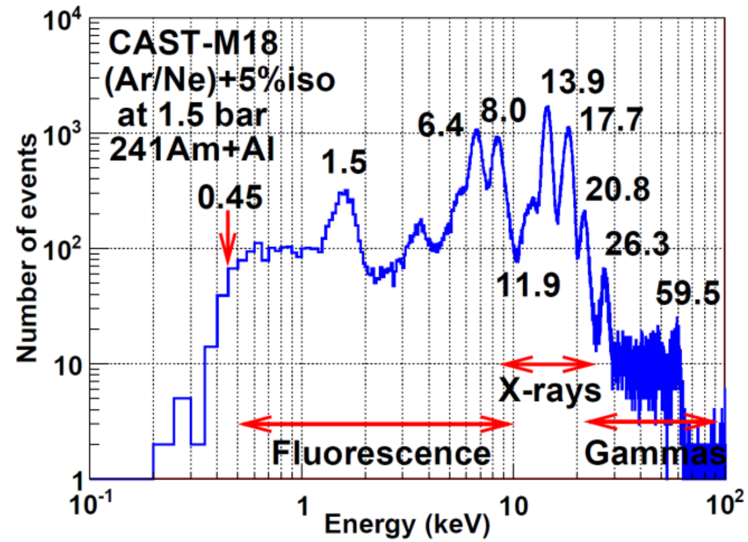


F. Aznar *et al., JINST* **8** (2013) C11012
F.J. Iguaz *et al., Eur. Phys. J.* C**76** (2016) 529

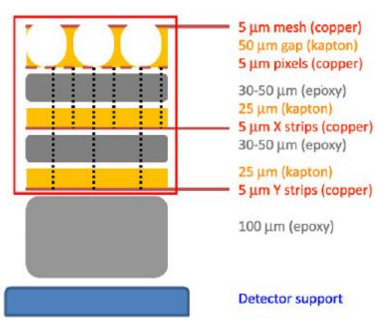


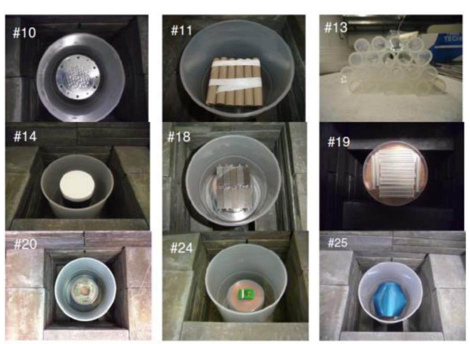
Micromegas results within T-REX project

A low energy threshold (< 450 eV) is feasible.



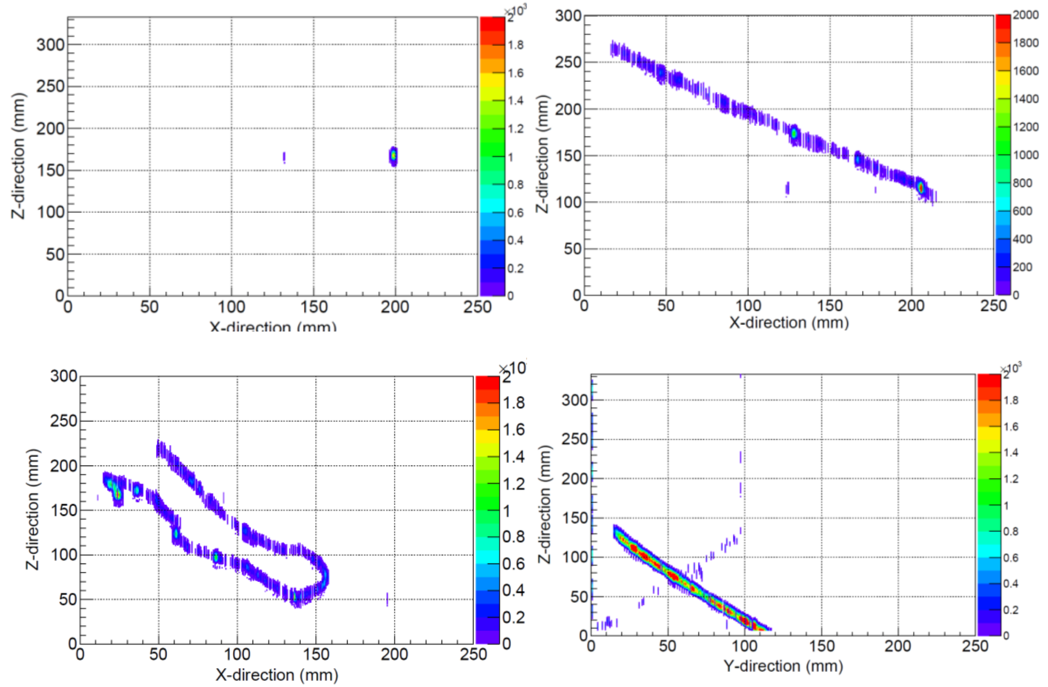
*S. Aune et al., JINST **9** (2014) P01001.*

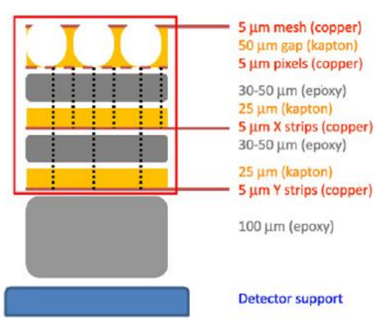


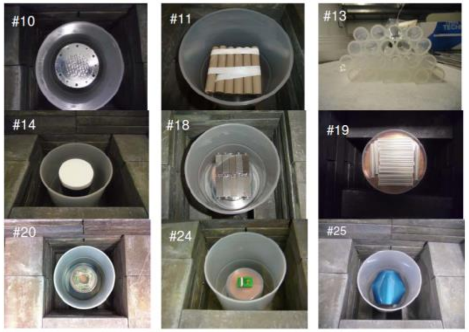


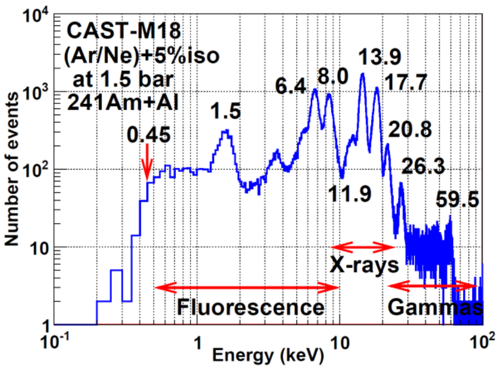
Micromegas results within T-REX project

A rich topological information is available…









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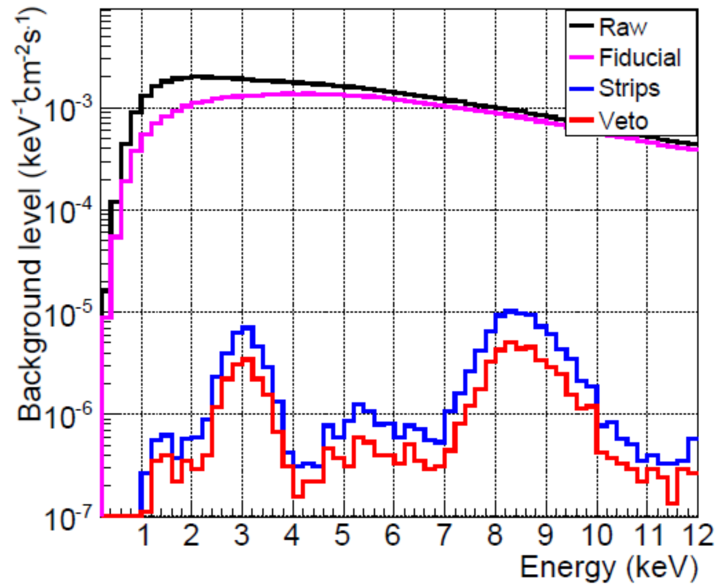
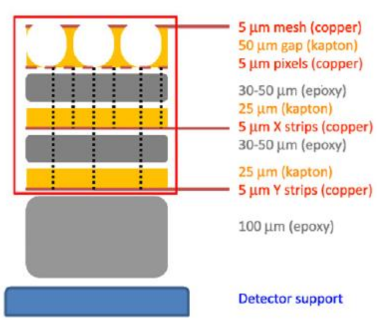
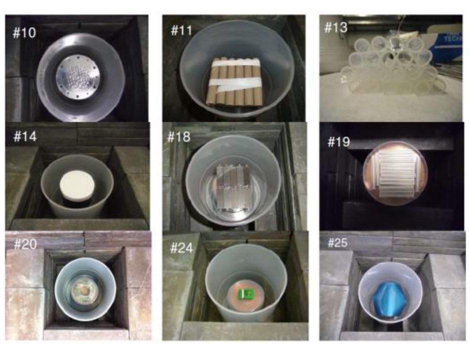
Micromegas results within T-REX project

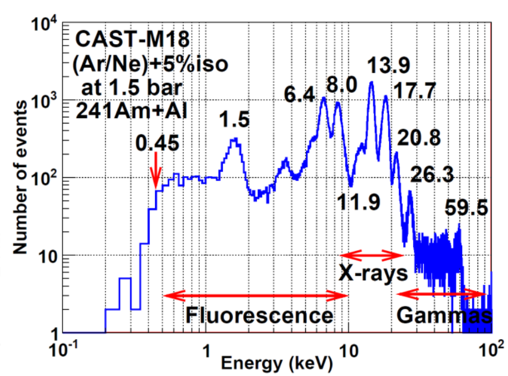
which has already been used in Axions Searches (CAST),



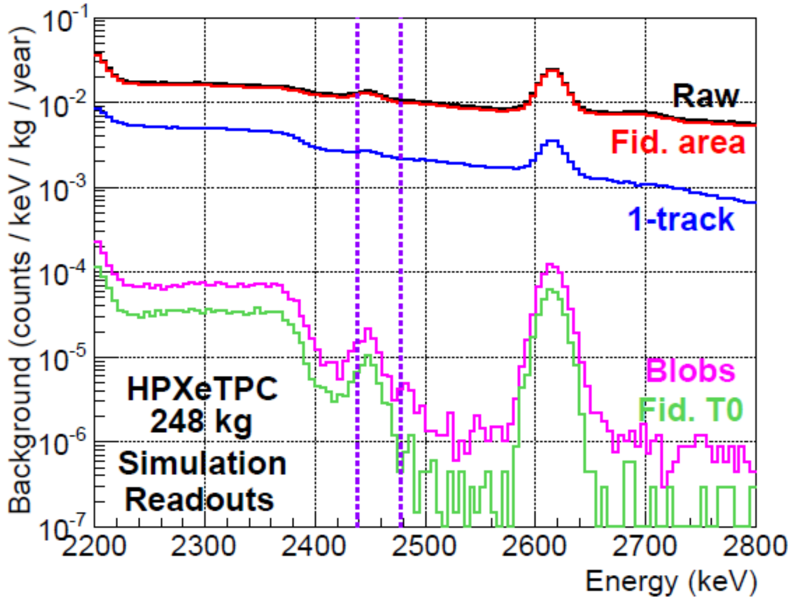
F. Aznar et al., *JCAP* **1512** (2015) 008







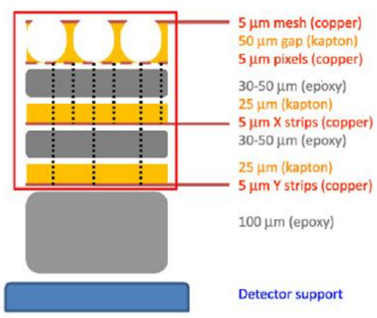
Micromegas results within T-REX project

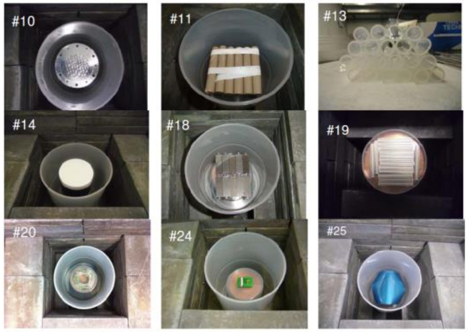


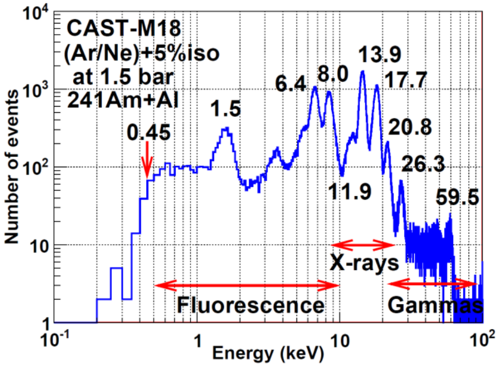
And may be used in future for Double-Beta Decay searches.

S. Cebrián *et al.*, *J. Phys. G***40** (2013) 125203.

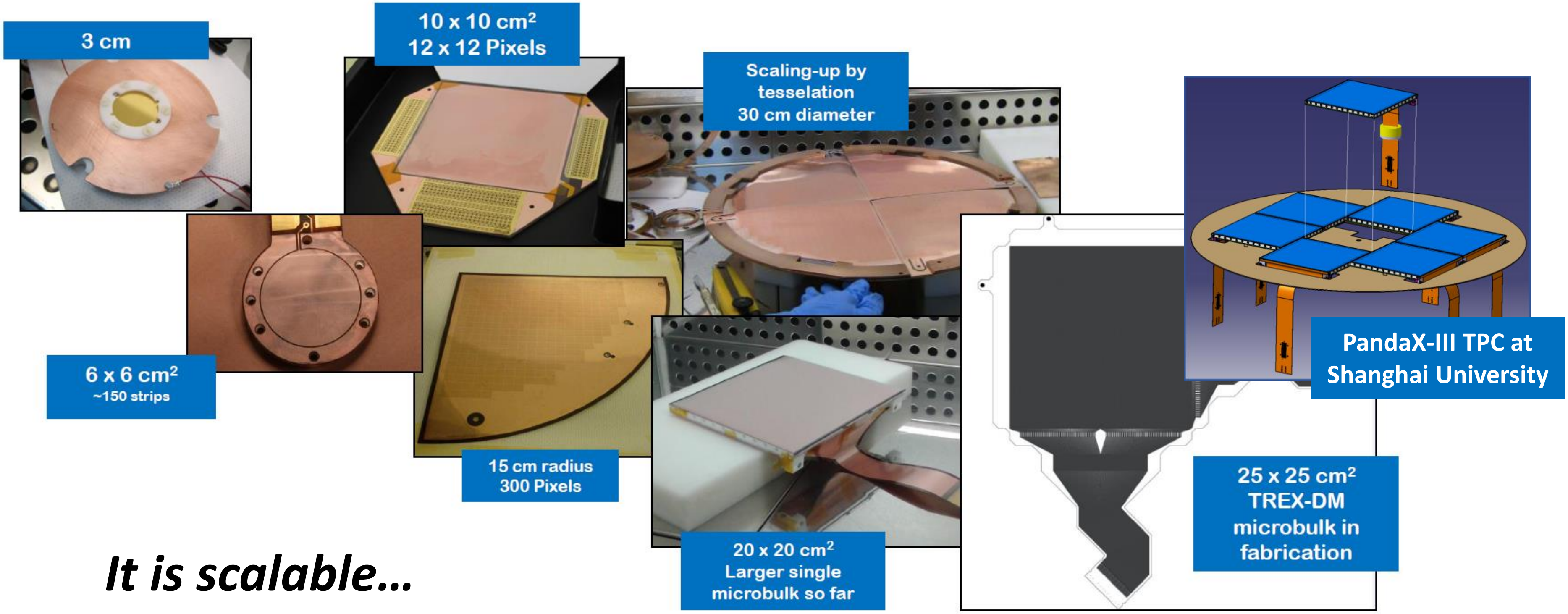
F.J. Iguaz *et al.*, *arXiv:1609.09735.*



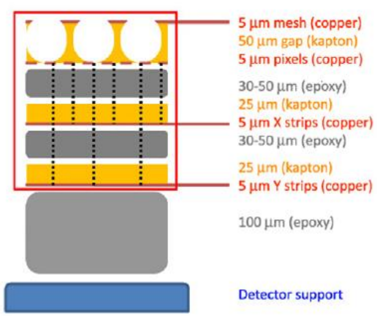


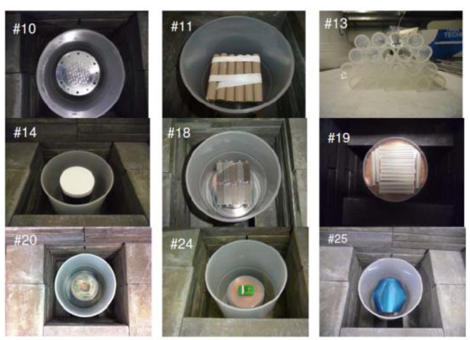


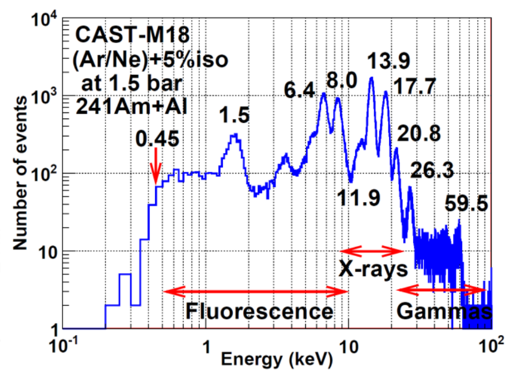
Micromegas results within T-REX project

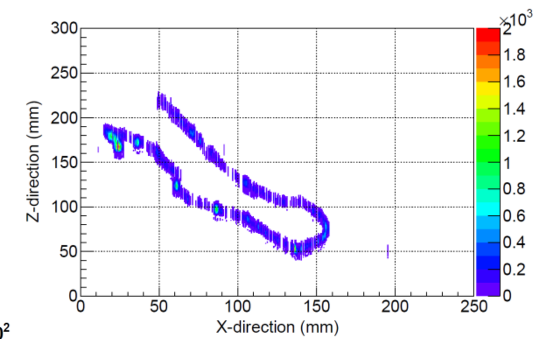


It is scalable…





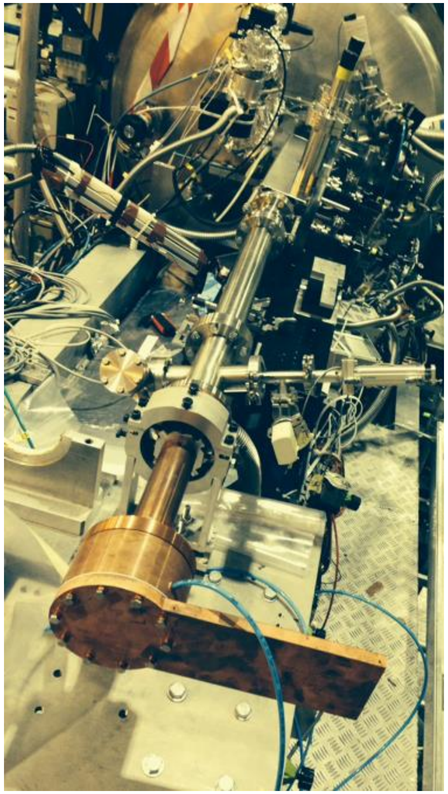




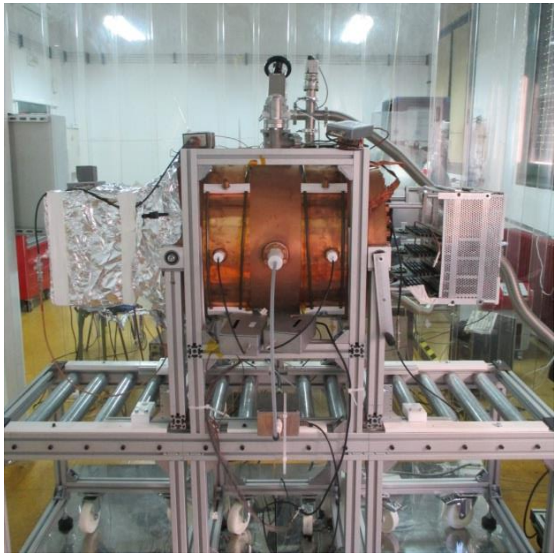
Micromegas results within T-REX

and it has been applied to:

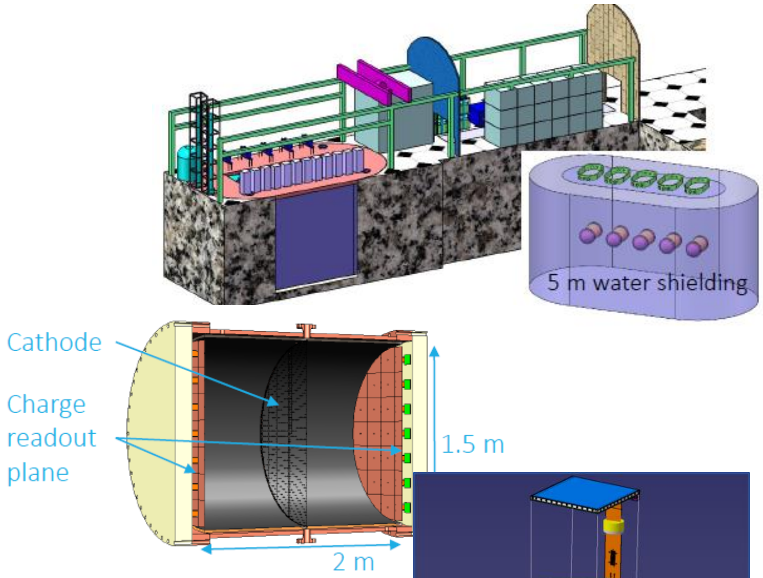
Axion search
CAST

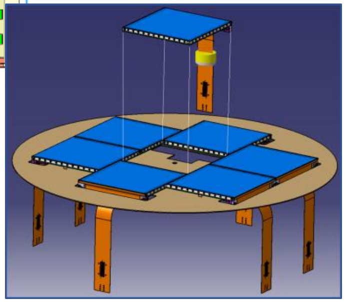


Dark Matter search
TREX-DM



Double beta decay search
PandaX-III





CDR of PandaX-III, arXiv:1610.08883

TREX-DM

A low-background Micromegas-based TPC for low-mass WIMP detection

F.J. Iguaz *et al., Eur. Phys. J.* C**76** (2016) 529

Proof of concept, not fully radiopure

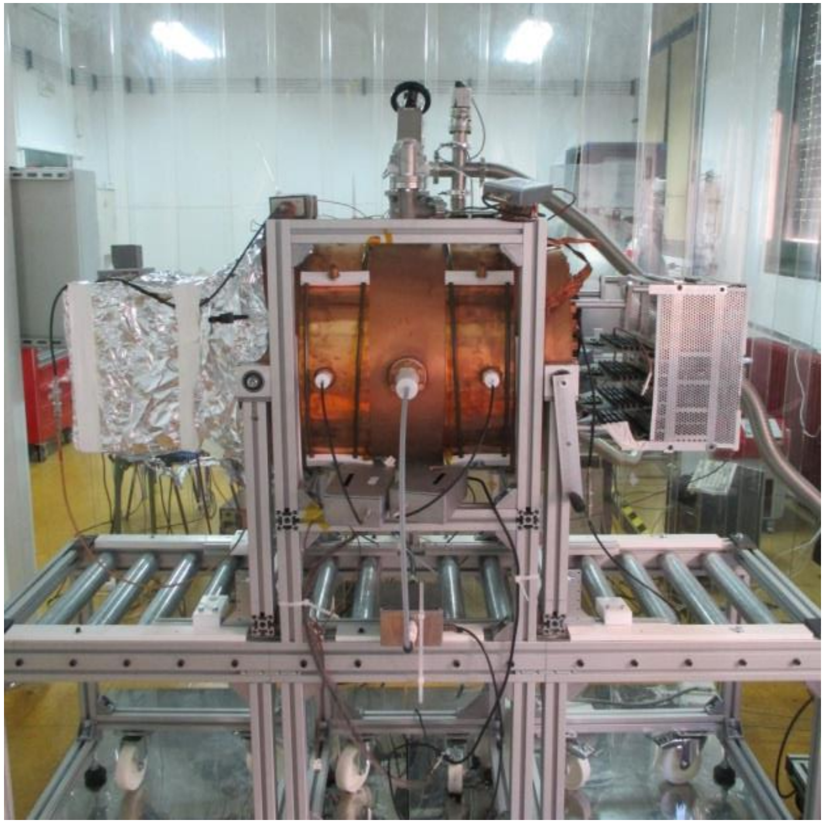
- Built & commissioned at TREX lab.
- Screening of all components.
- Bulk MM tested in Ar+2%iso at HP.

Ready for installation at LSC after:

- Installation of radiopure components.
- Design & built of a shielding.
- Upgrade to auto-trigger electronics.

Expectations (real/optimal) at LSC:

- Threshold of 0.4/0.1 keVee.
- Background of 1.0/0.1 c keV^{-1} kg^{-1} day^{-1}.



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TREX-DM

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Proof of concept, not fully radiopure

- Built & commissioned a
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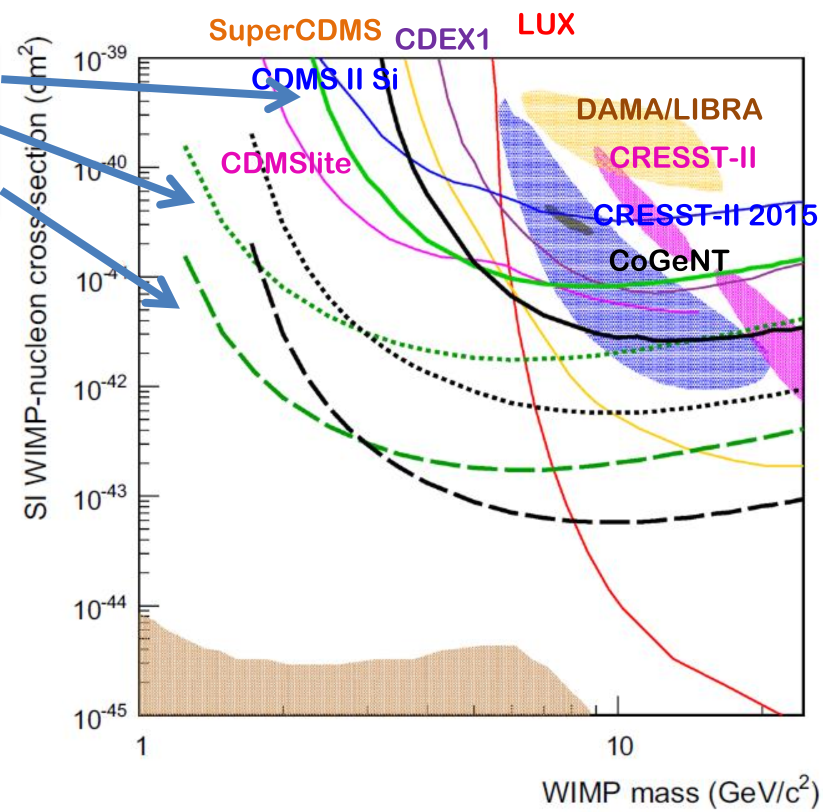
Th=0.4 B=10
Th=0.1 B=1
Th=0.1 B=0.1 exp x10



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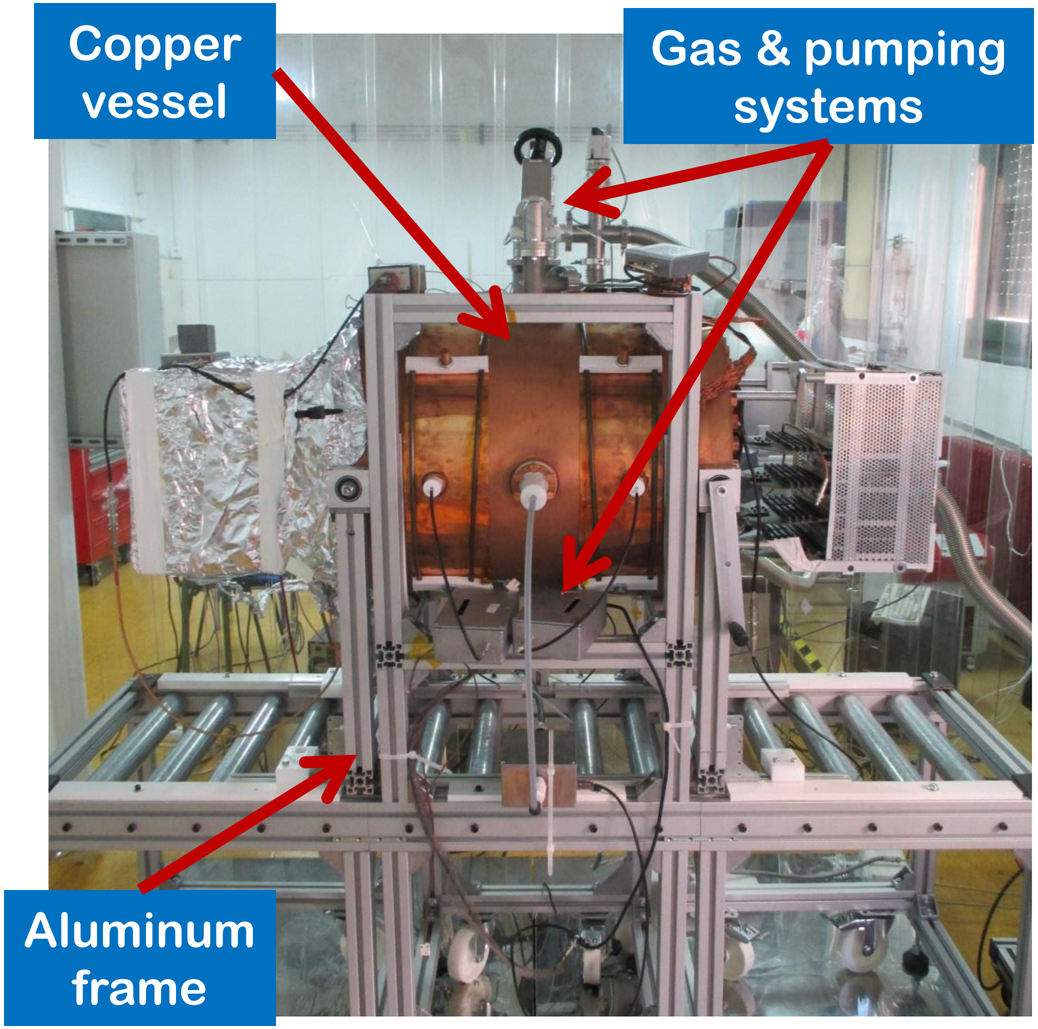
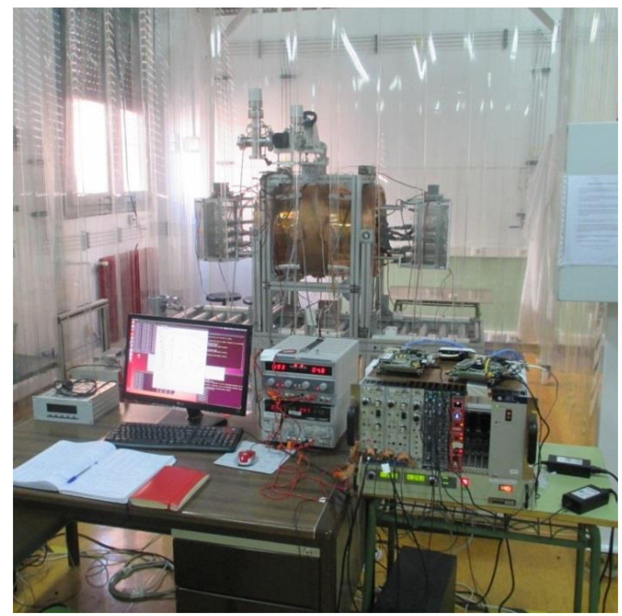
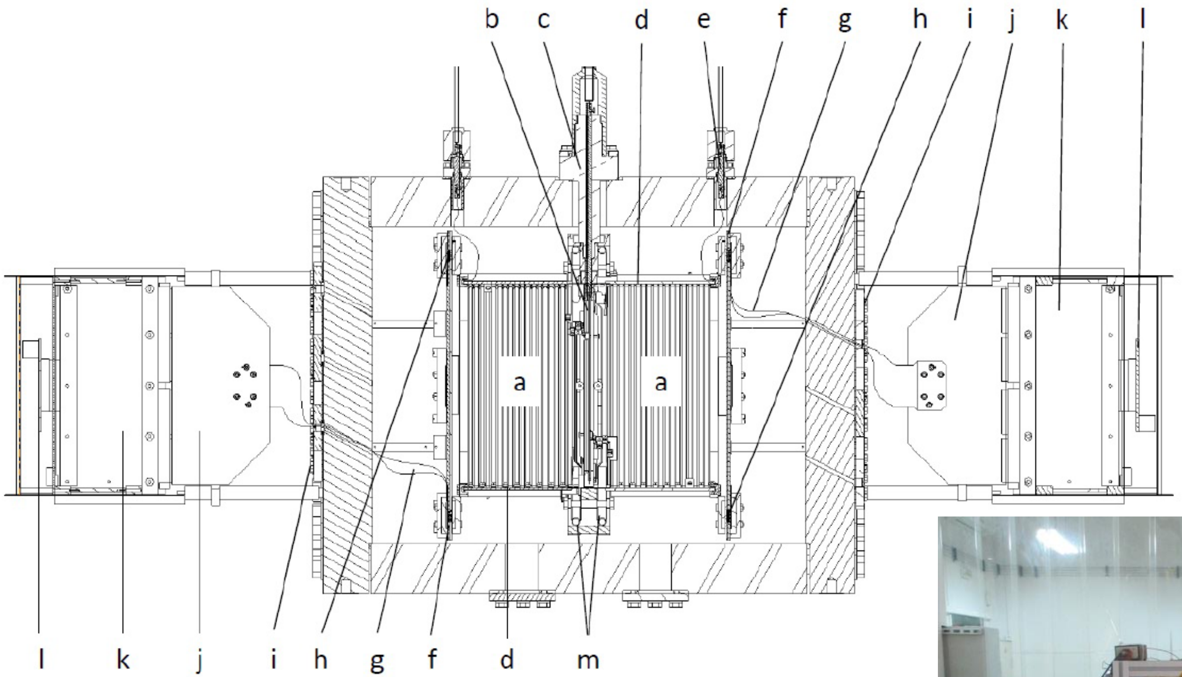
The TREX-DM detector outside

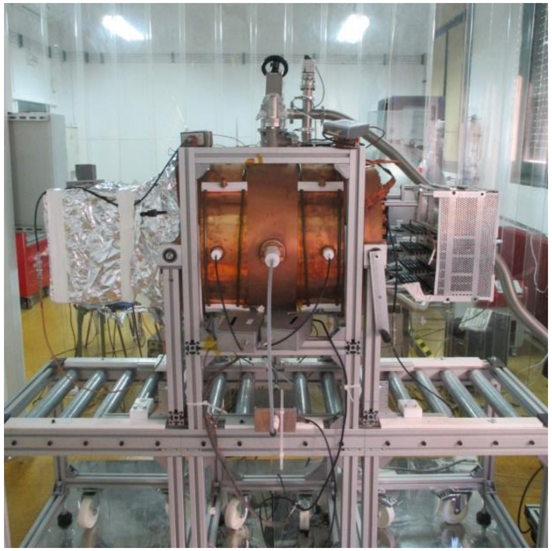


- Central sleeve & 2 flat end caps.
- Aluminum frame as support.
- Inside a clean flow tent.
- Equipped with a gas system, vacuum system & slow control.

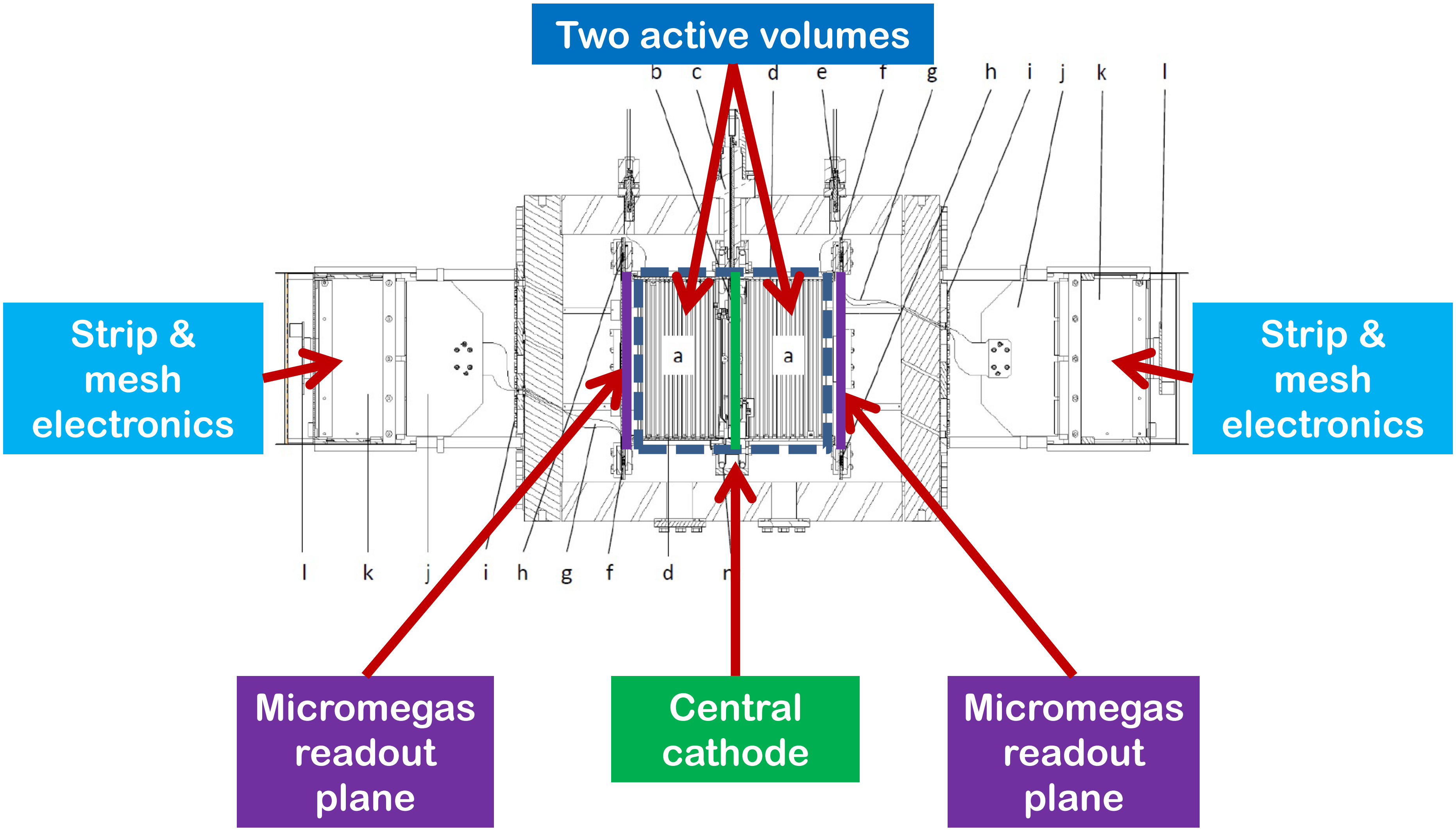


The TREX-DM detector inside

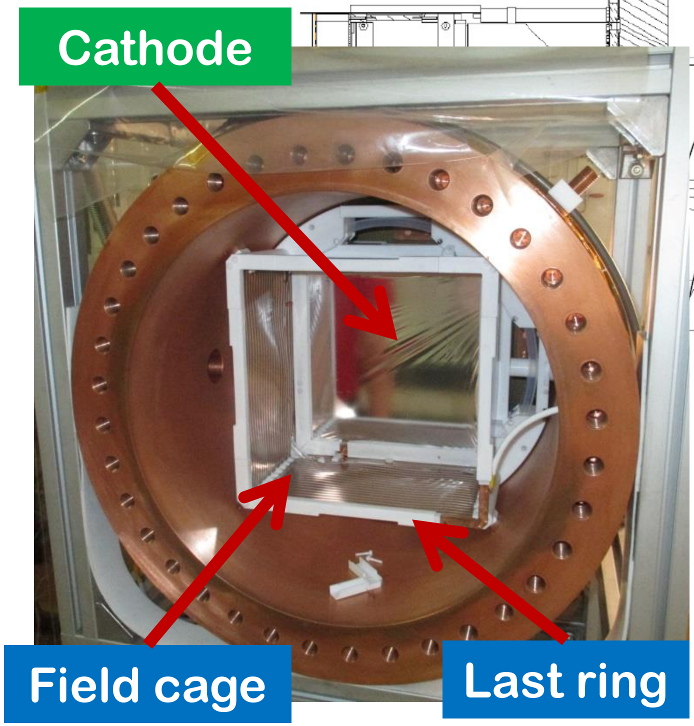


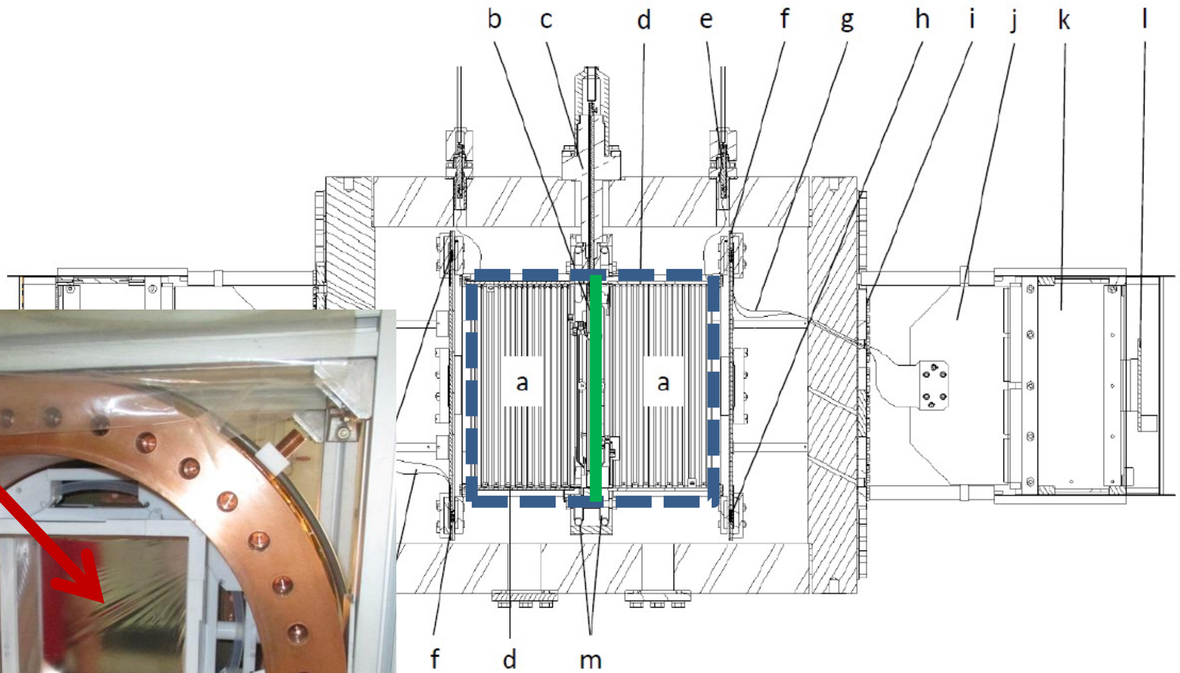


The TREX-DM detector inside



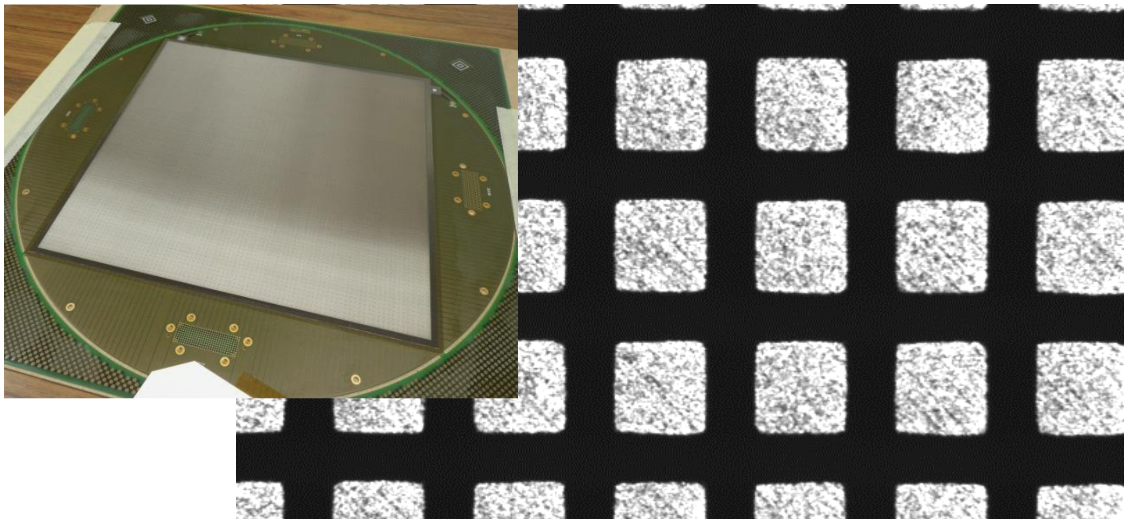
Drift cage



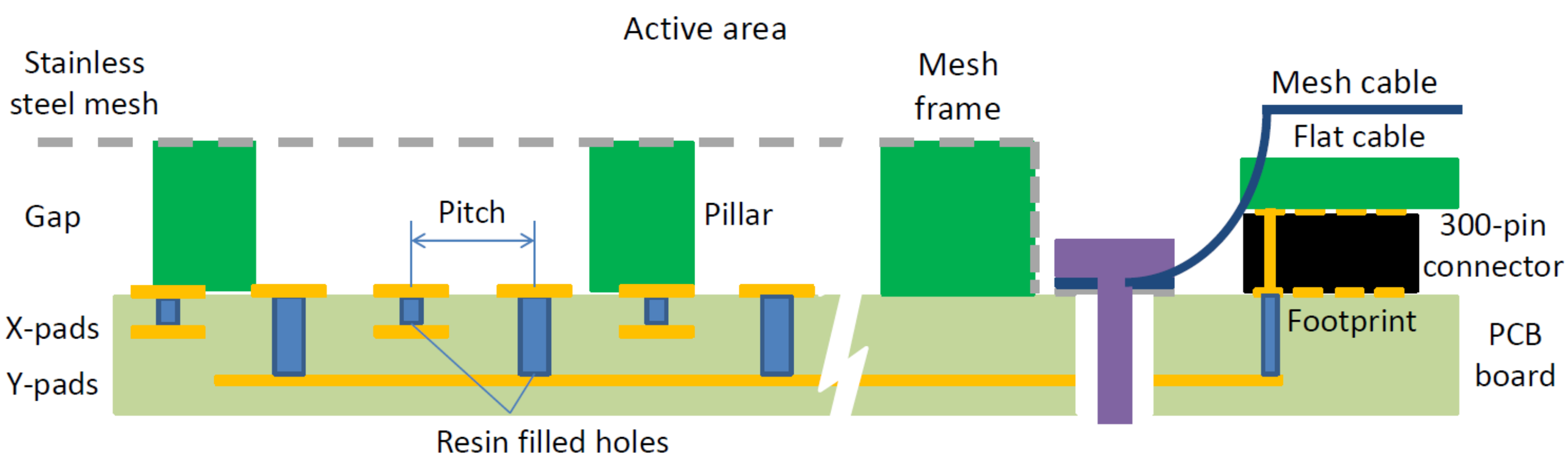


- Drift fields: 50 – 200 V/cm/bar.
- Central cathode of mylar.
- Field cage: copper-polyimide printed circuit + resistors.
- Each field cage ends at a copper ring.

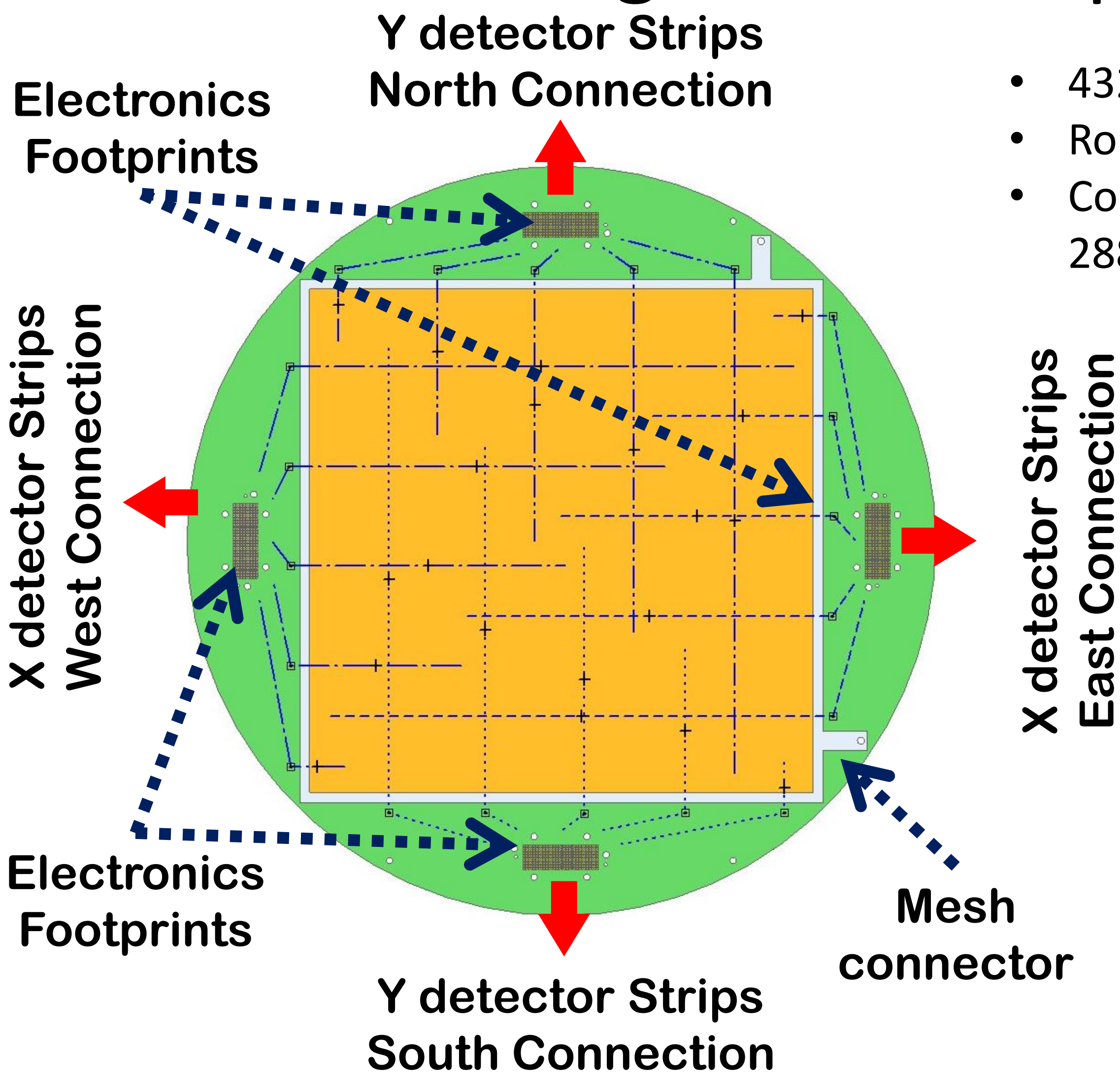
Micromegas readout planes



- Bulk @ IRFU/Saclay.
- PCB @ Somacis.
- Area: 25.2 x 25.2 cm^2.
- Squared pads 332 μm, pitch 583 μm.
- Interconnected to 432 strips/direction.

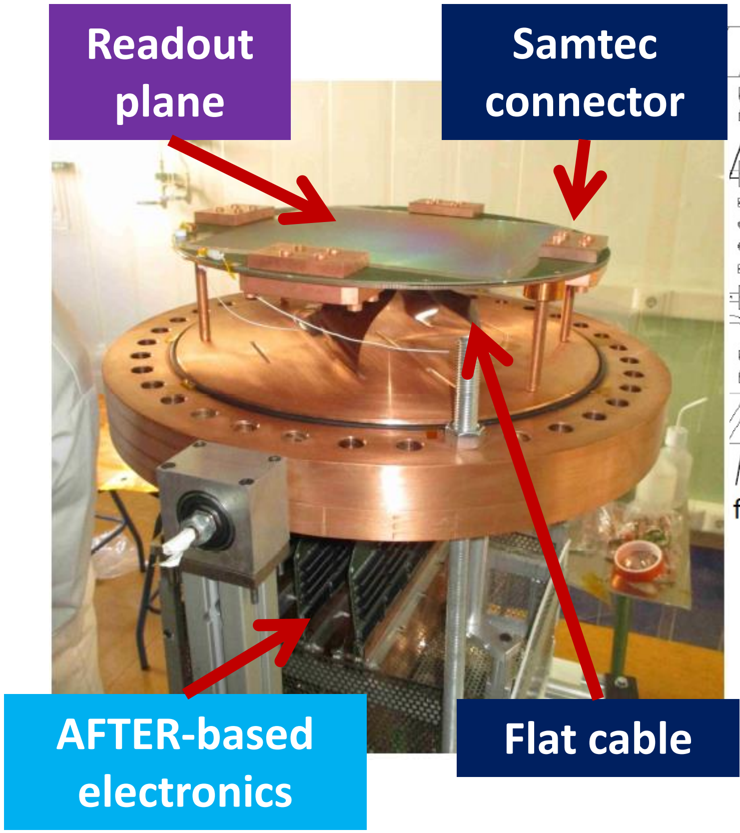


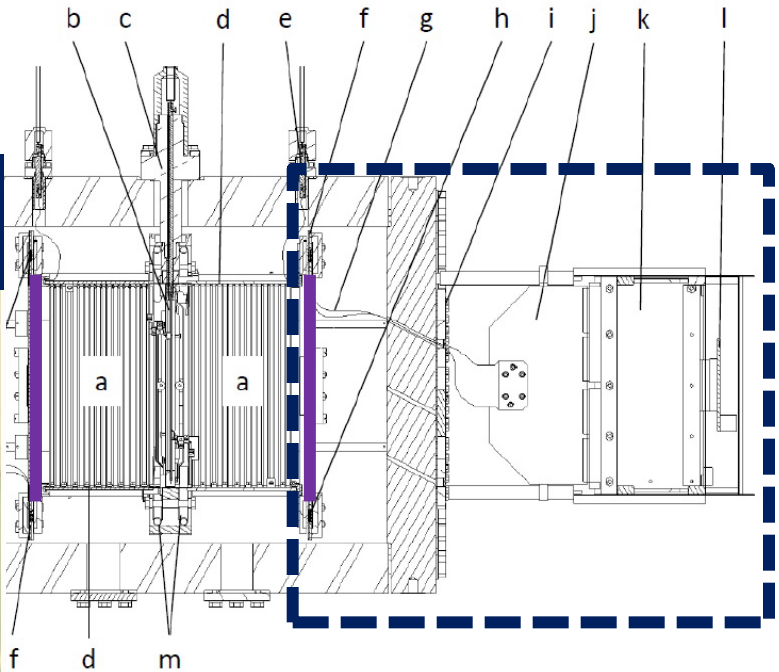
Micromegas readout planes



- 432 strips/direction.
- Routing to 4 footprints.
- Connector print of 300 pads: 288 or 144 used.

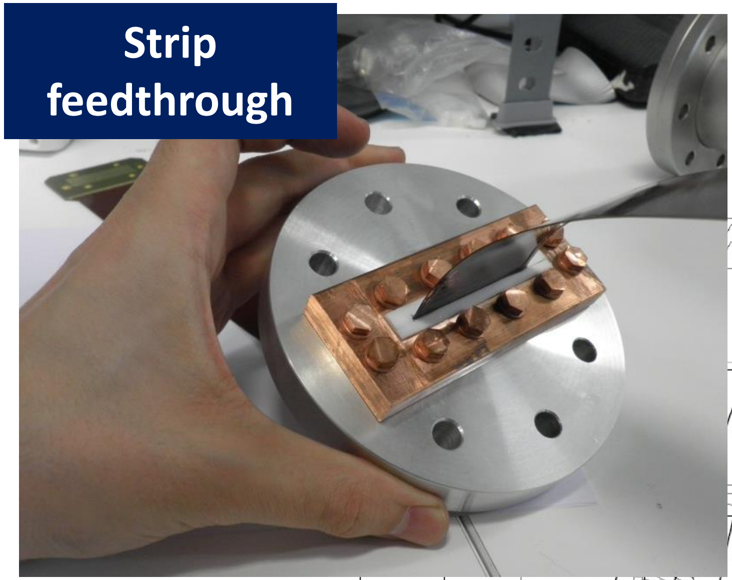
The signal extraction chain

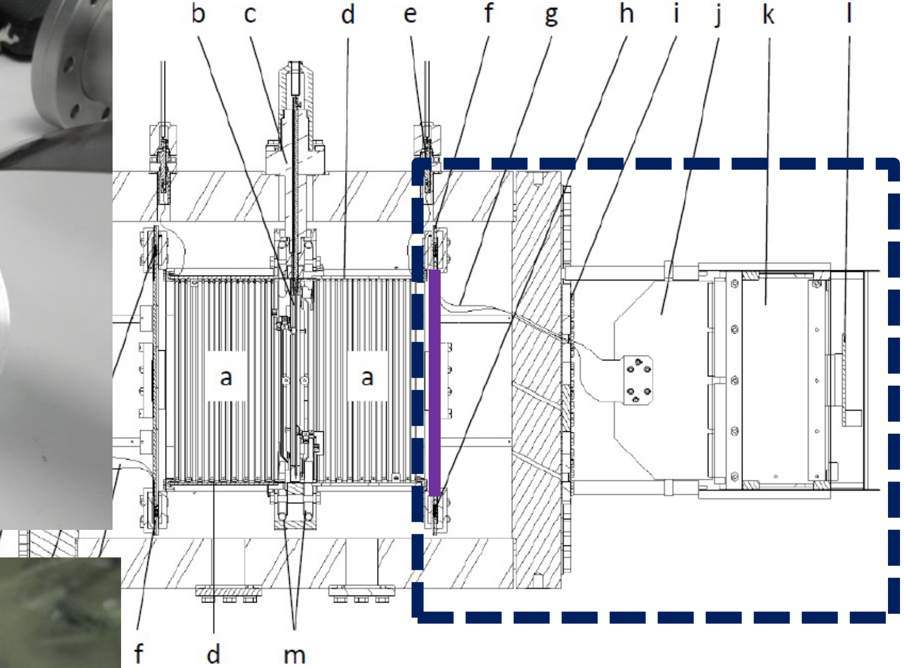


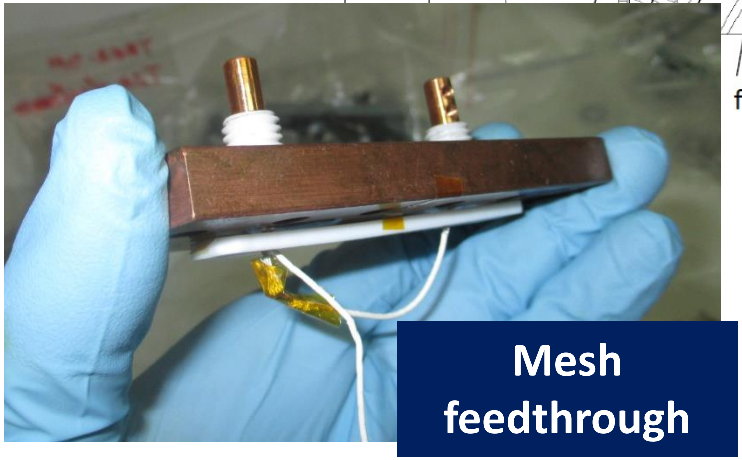


- 4 connector print by readout plane.
- Flat cable: connector -> interface card.
- Interface card -> Front-end Cards (FECs).
- Flat cable is glued to a feedthrough.
- Mesh signal is extracted by a feedthrough.

The signal extraction chain







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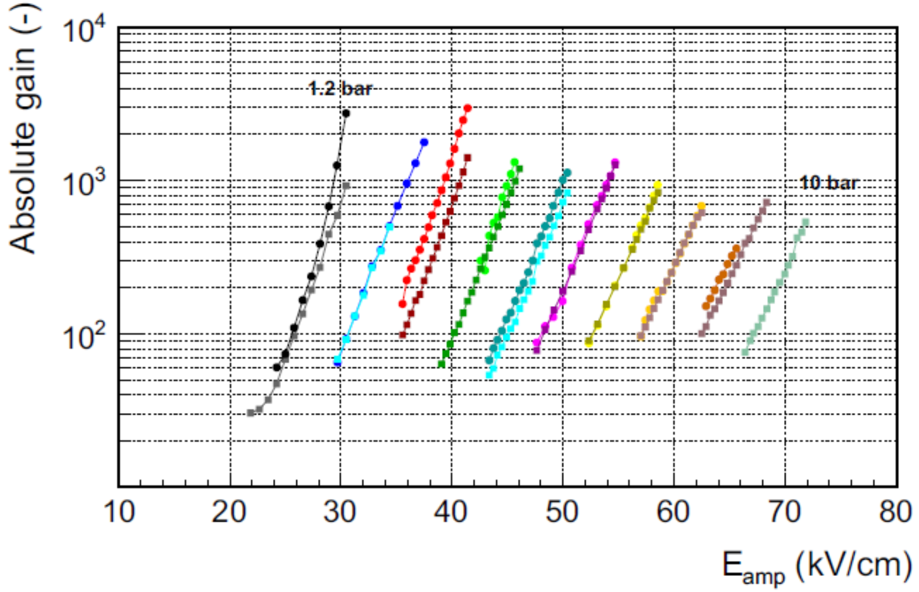
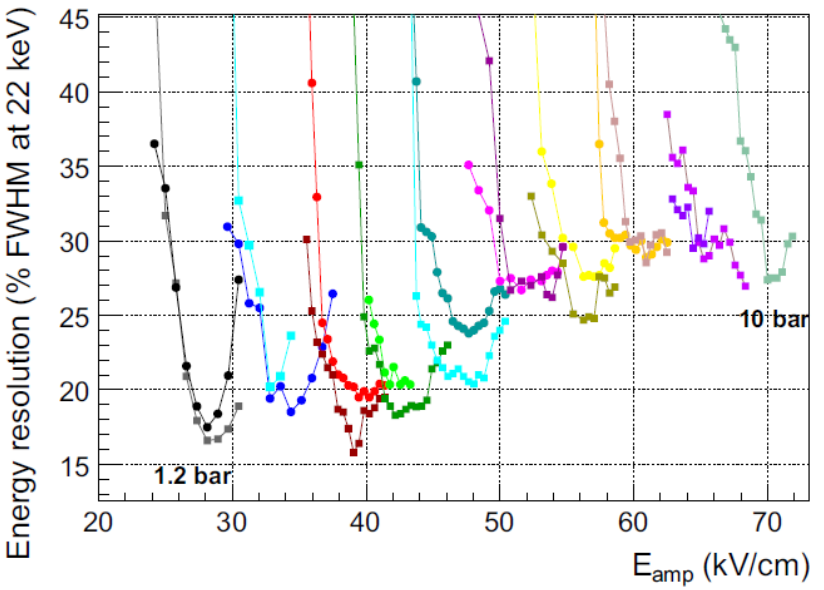
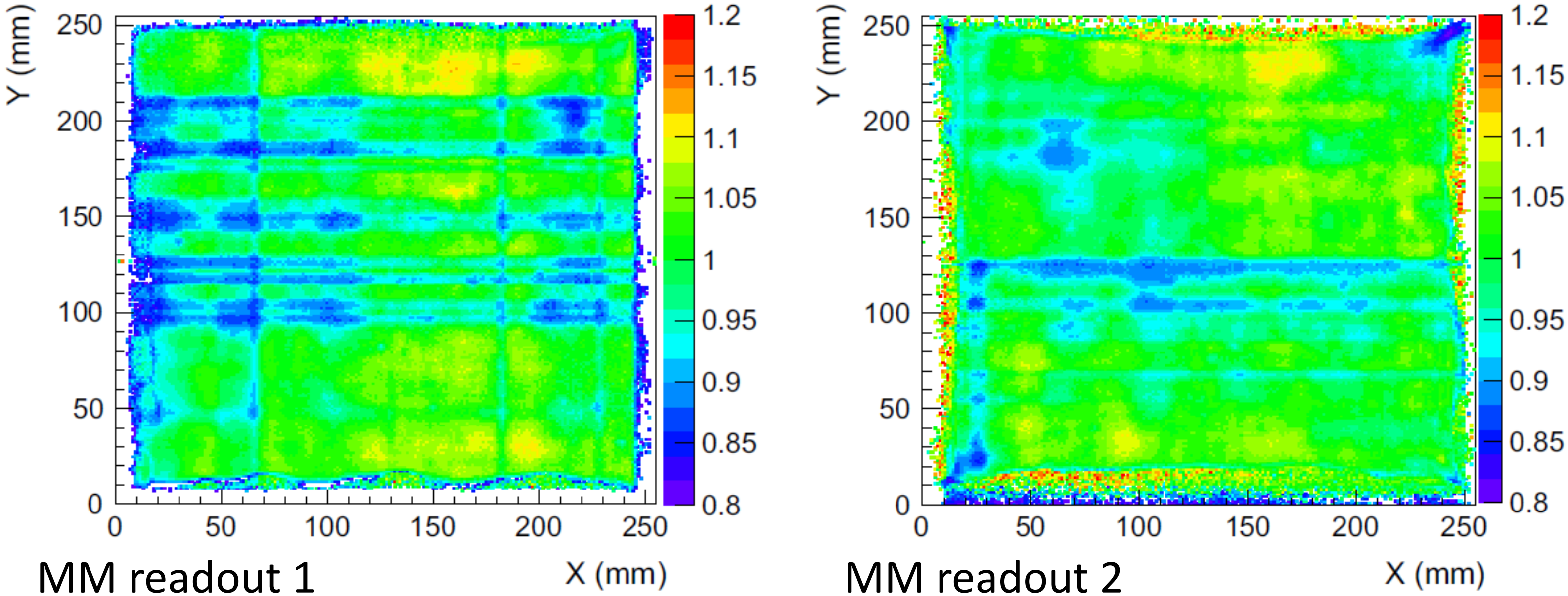
Results of the commissioning





- Characterization in Ar+2%iso @1-10 bar, using a ^{109}Cd source (22.1 keV x-rays).
  - Gain: 3 x 10^3 (1.2 bar) -> 5 x 10^2 (10 bar).
  - Resolution: 16% FWHM -> 27% FWHM.
- Gain uniformity of readout planes: 10%.
- Energy threshold: **0.60 keVee** for a gain of 10^3, limited by mesh trigger.
- Data used to validate the simulation of the detector signal response.

Results of the commissioning



- Characterization in Ar+2%iso @1-10 bar, using a ^{109}Cd source (22.1 keV x-rays).
  - Gain: 3 x 10^3 (1.2 bar) -> 5 x 10^2 (10 bar).
  - Resolution: 16% FWHM -> 27% FWHM.
- Gain uniformity of readout planes: 10%.
- Energy threshold: **0.60 keVee** for a gain of 10^3, limited by mesh trigger.
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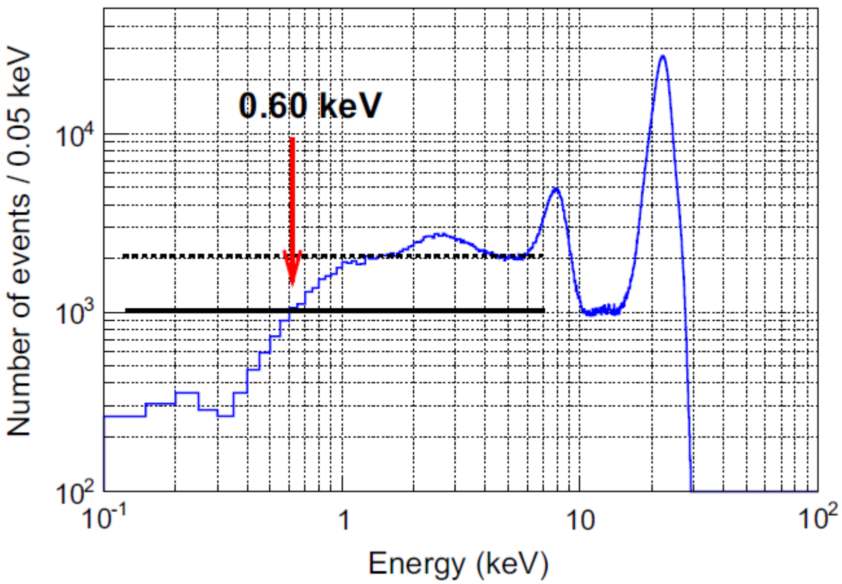
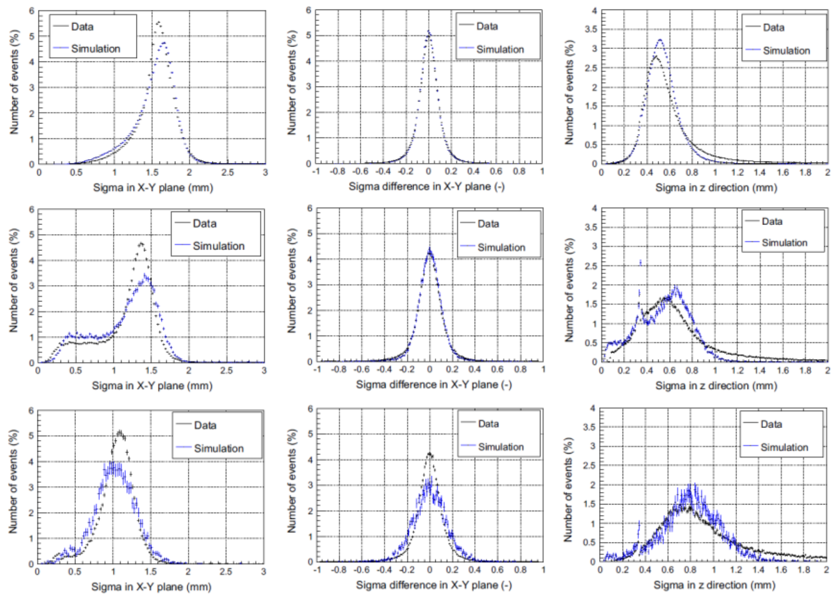
Results of the commissioning





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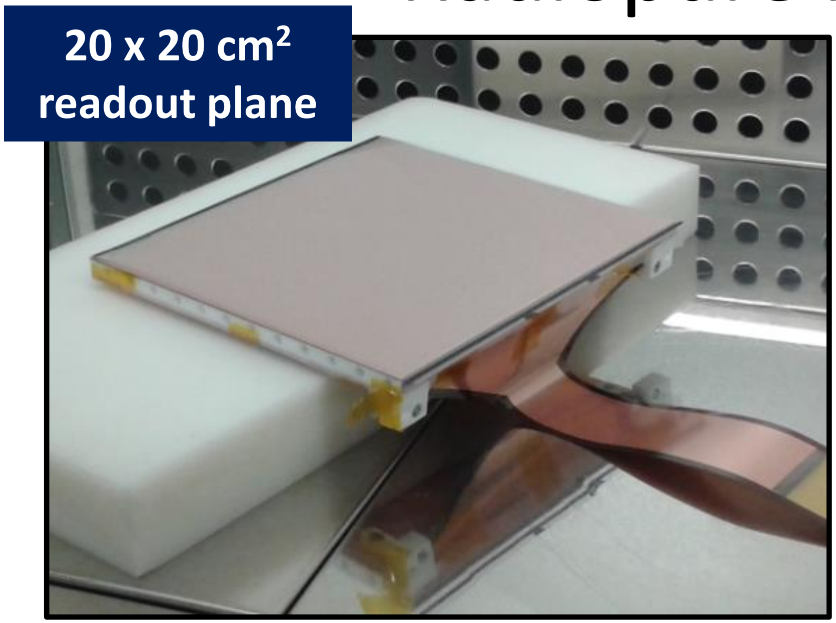
- Data used to validate the simulation of the detector signal response.

Upgrades for LSC setup

- The shielding & external support.
- The gas system.
- The calibration system.
- The readout planes.
- The electronics.
- The gas.

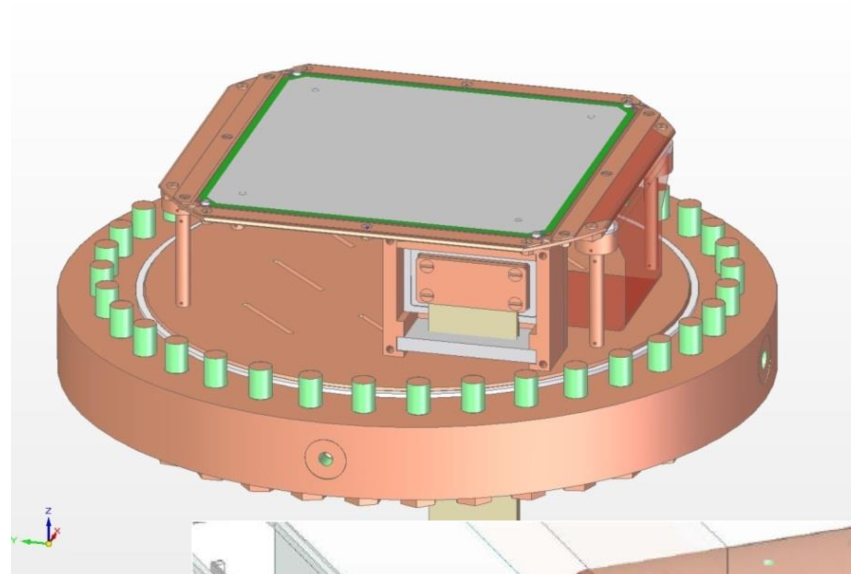
LSC
Laboratorio Subterráneo de Canfranc

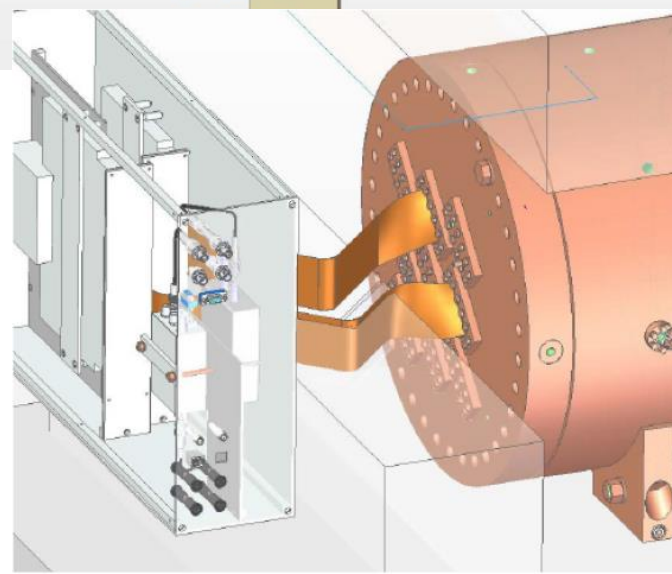
Radiopure readout planes



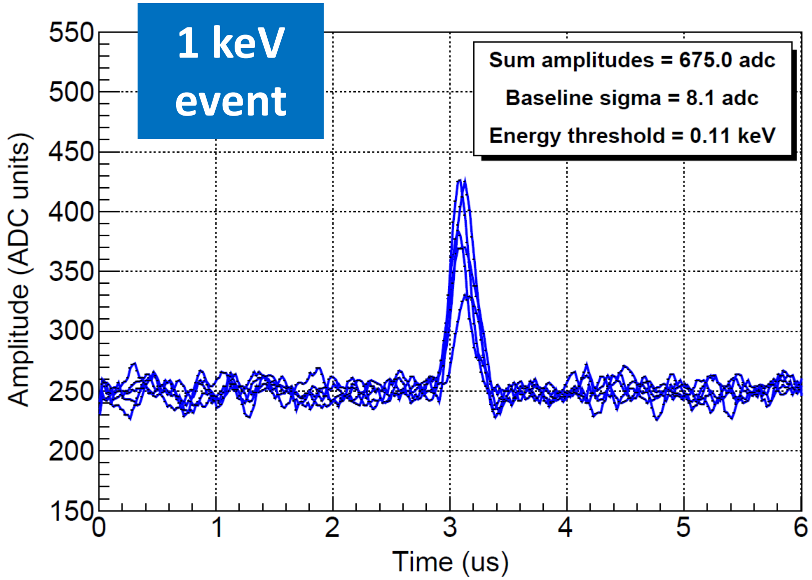
PandaX-III collaboration, arXiv:1610.08883

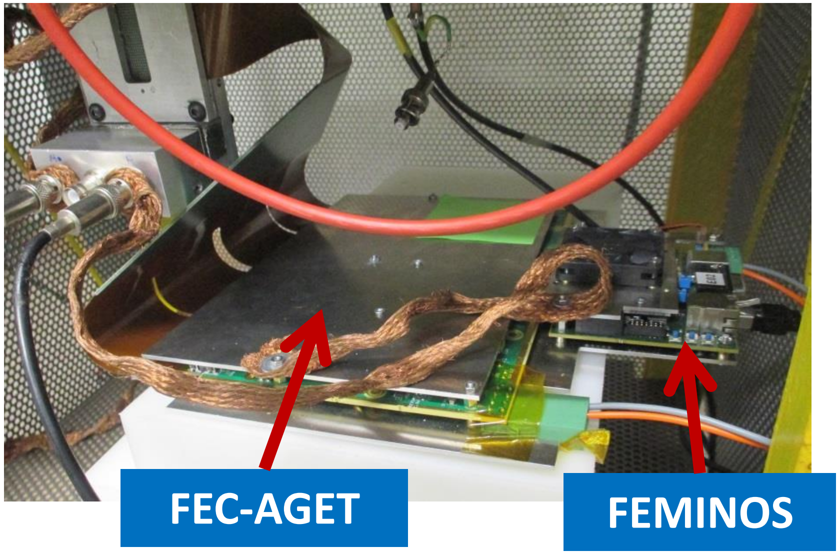
- Area = 25 x 25 cm^2, pitch = 1 mm.
- Microbulk technology @ CERN.
- Radiopure materials: copper & polyimide.
- Readout glued on a radiopure copper support.
- Signals extracted via a flexible part.
- Flat cables are long enough to cross the lead.





Auto-trigger front-end electronics (AGET)

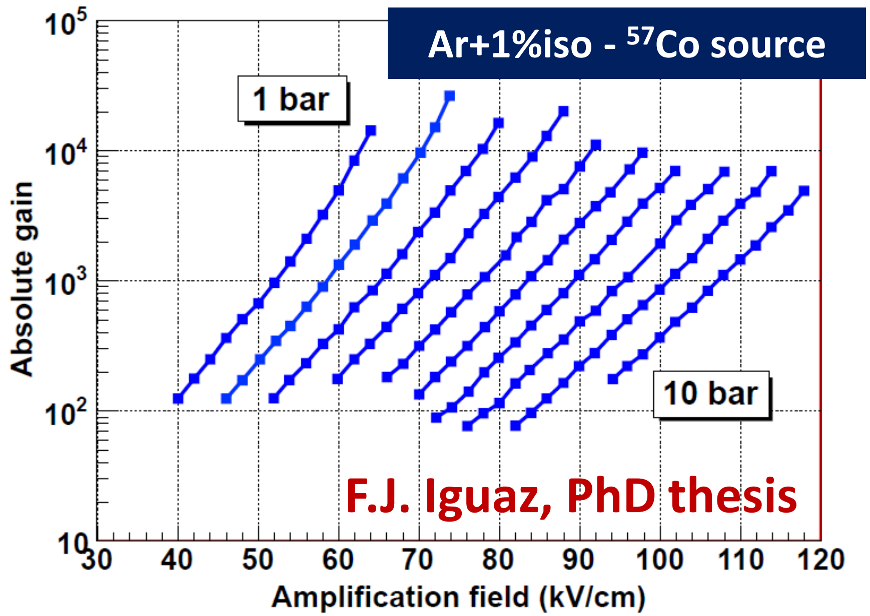




- Auto-trigger capabilities for strips. Mesh signal won't be needed!
- Capacitance: strips ~0.2 nF, mesh ~6 nF.
- A factor ~10 lower energy threshold (0.1 keV) expected.
- Layout: front-end (FEC-AGET), FEM (FEMINOS) & trigger module (TCM).

More details at Denis Calvet's talk (*Electronics based on the T2K TPC design*)!

The gas



- The gas used at LSC must be non-flammable.
- We plan to characterize microbulk Micromegas readout planes in
  - Ar+1%iso at 1-10 bar.
  - Ne+2%iso at 1-10 bar.
- Unpublished results show that Ar+1%iso is good enough to work at High Pressure.

Conclusions

TREX-DM: a low-background Micromegas-based TPC for DM searches.

- Challenge: low energy threshold for a large area at High Pressure.
- Prospects: threshold ~0.4 keVee, background ~1.0 counts keV^{-1} kg^{-1} day^{-1}.
- Commissioning stage at T-REX lab: bulk MM in Ar+2%iso at HP.
- Going to LSC: fully radiopure setup, microbulk MM, auto-trigger electronics, shielding installation.
- Microbulk MM readouts to be tested in Ar+1%iso & Ne+2%iso at HP.

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Conclusions

TREX-DM: a low-background Micromegas-based TPC for DM searches.

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Thanks for your attention!

Back-up slides

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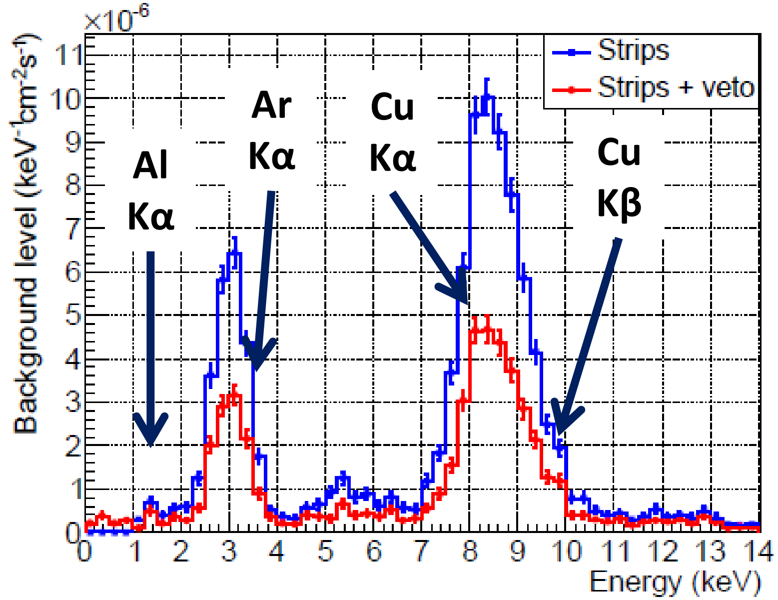
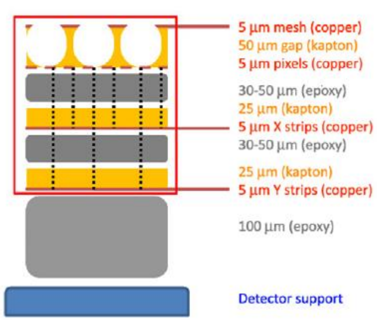
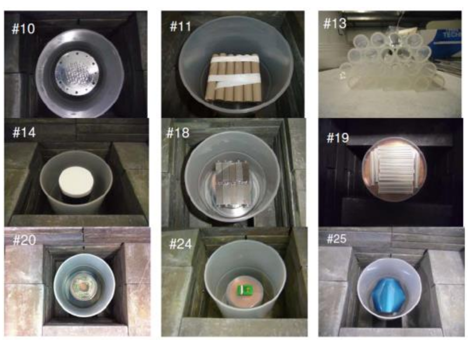
Micromegas-based TPCs

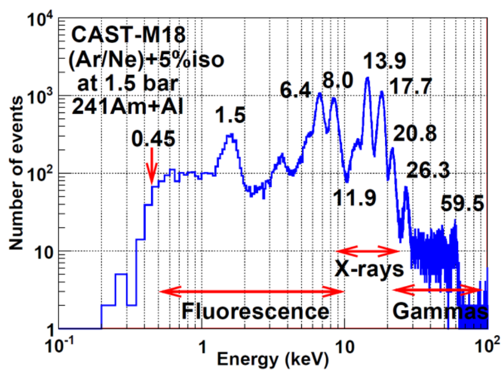


which has already been used in Axions Searches (CAST).

I.G. Irastorza et al., *JCAP* **1601** (2016) 033







Radiopurity of microbulk Micromegas

A key feature for applications in Rear Event Searches.

- First measurement made in 2011 by a Ge detector, already better than PMTs.
- The limits obtained for ^{214}Bi & ^{208}Tl isotopes by BiPo-3 experiment in 2016 are *a factor 100 better* than those set by Ge.
- Two new samples (x10 larger area) have been measured in BiPo-3. Preliminary limits are a factor 3 better!

Sample	^{232}Th	^{235}U	^{238}U
Micromegas without mesh	4.6 ± 1.6	<6.2	<40.3
Microbulk-Micromegas	<9.3	<13.9	26.3 ± 13.9
Kapton–copper foil	<4.6[a]	<3.1[a]	<10.8
Copper–kapton–copper foil	<4.6[a]	<3.1[a]	<10.8
Hamamatsu R8520-06 PMT [30]	27.9 ± 9.3	–	<37.2

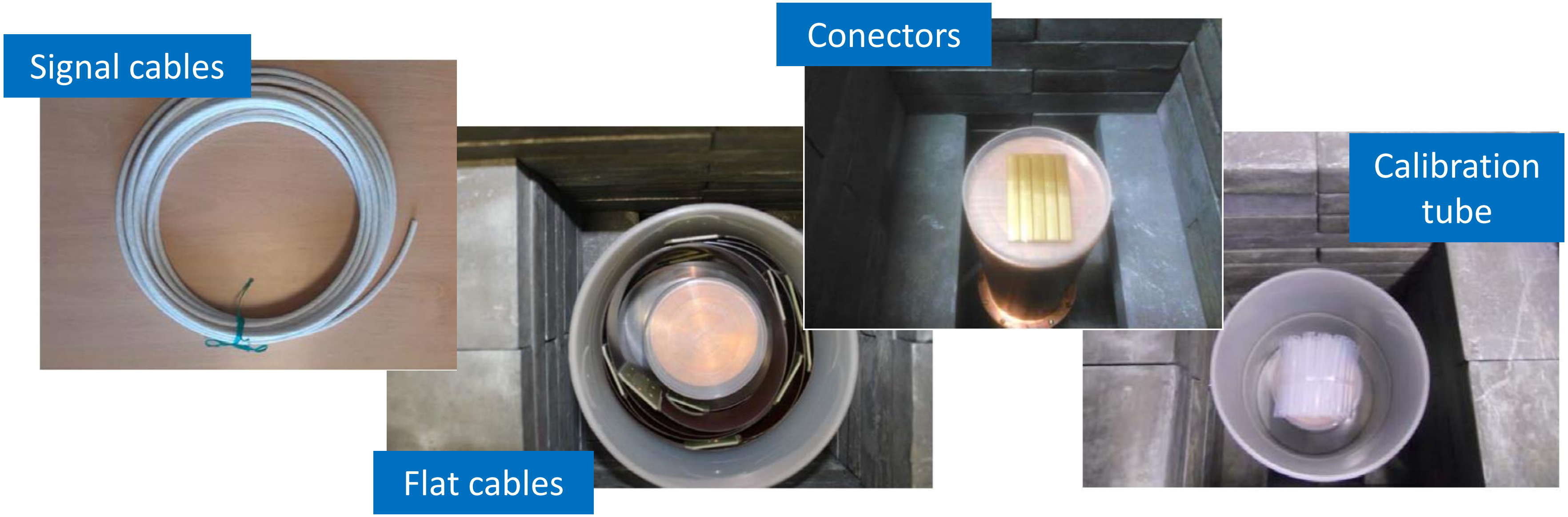
S. Cebrián et al., *Astropart. Phys.* **34** (2011) 354-359

#	Material,Supplier	Method	Unit	^{214}Bi	^{208}Tl
16	Microbulk Micromegas, CAST/CERN	BiPo-3	μBq/cm^2	< 0.134	< 0.035
17	Cu-kapton-Cu foil, CERN	BiPo-3	μBq/cm^2	< 0.141	<0.012
18	Kapton-epoxy foil, CERN	BiPo-3	μBq/cm^2	< 0.033	<0.008
19	Vacrel foil, Saclay	BiPo-3	μBq/cm^2	< 0.032	<0.013
20	Kapton-diamond foil, CERN	BiPo-3	μBq/cm^2	< 0.055	<0.016

I.G. Irastorza et al., *JCAP* **01** (2016) 033.

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 & JCAP01(2016)033.



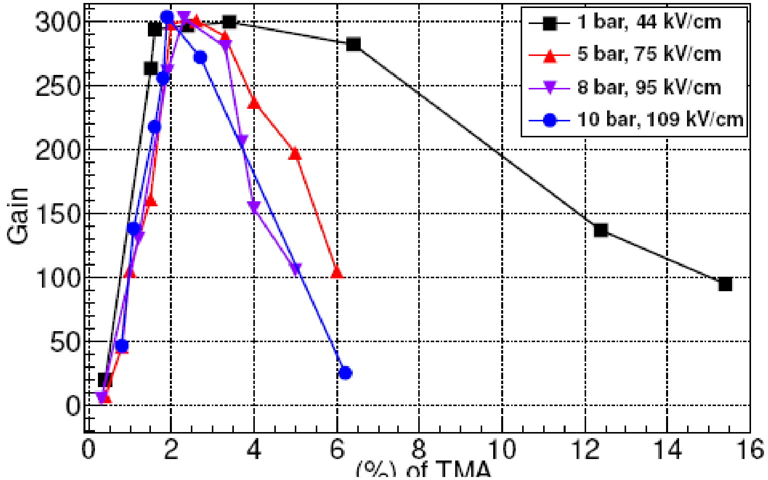
Material screening program

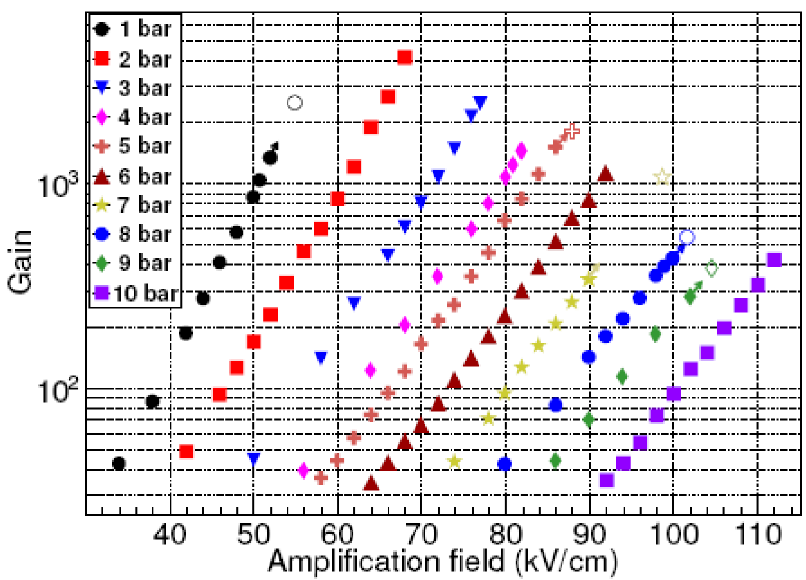
#	Material,Supplier	Technique	Unit	^{238}U	^{226}Ra	^{232}Th	^{228}Th	^{235}U	^{40}K	^{60}Co
1	Pb, Mifer	GDMS	mBq/kg	<1.2		< 0.41			0.31	
2	Pb, Mifer	GDMS	mBq/kg	0.33		0.10			1.2	
3	Cu, Sanmetal	GDMS	mBq/kg	<0.062		<0.020				
4	Cu, hot rolled, Luvata	GDMS	mBq/kg	<0.012		<0.0041			0.061	
5	Cu, cold rolled, Luvata	GDMS	mBq/kg	<0.012		<0.0041			0.091	
6	Cu, Luvata	Ge	mBq/kg		<7.4	<0.8	<4.3		<18	<0.8
7	Kapton-Cu, LabCircuits	Ge	μBq/cm^2	<160	<14	<12	<8	<2	<40	<2
8	Teflon, Sanmetal	Ge	mBq/kg	<157	<4.1	<6.6	<4.8	<4.8	<19	<1.2
9	Teflon tube, RS	Ge	mBq/kg	<943	<21	<37	<31	<19	510±170	<7.6
10	Stycast, Henkel	Ge	mBq/kg	(3.7±1.4)10^3	52±10	44±12	38±9		(0.32±0.11)10^3	<5.5
11	Epoxy Hysol, Henkel	Ge	mBq/kg	<273	<16	<20	<16		<83	<4.2
12	SMD resistor, Farnell	Ge	mBq/pc	2.3±1.0	0.16±0.03	0.30±0.06	0.30±0.05	<0.05	0.19±0.08	<0.02
13	SM5D resistor, Finechem	Ge	mBq/pc	0.4±0.2	0.022±0.007	<0.023	<0.016	0.012±0.005	0.17±0.07	<0.005
14	CF40 flange, Pfeiffer	Ge	mBq/kg		14.3±2.8	9.7±2.3	16.2±3.9	3.2±1.1	<17	11.3±2.7
15	Connectors, Samtec	Ge	mBq/pc	<77	9.2±1.1	19.6±3.6	18.5±2.2	1.5±0.4	12.2±4.1	<0.6
16	Connectors, Panasonic	Ge	mBq/pc	<42	6.0±0.9	9.5±1.7	9.4±1.4	<0.95	4.1±1.5	<0.2
17	Connectors, Fujipoly	Ge	mBq/pc	<25	4.45±0.65	1.15±0.35	0.80±0.19		7.3±2.6	<0.1
18	Flat cable, Somacis	Ge	mBq/pc	<370	101±13	165±29	164±23		80±25	<5
19	Flat cable (rigid), Somacis	Ge	mBq/pc	<1.5 10^3	123±17	225±40	198±29		112±40	<5.8
20	Flat cable (flexible), Somacis	Ge	mBq/pc	<102	<3.8	<4.0	<1.4	<1.8	<15	<0.7
21	Flat cable, Somacis	Ge	mBq/pc	<45	<1.7	<1.8	<0.61	<0.77	<6.6	<0.3
22	Flat cable, Somacis	Ge	mBq/pc	<14	0.44±0.12	<0.33	<0.19	<0.19	1.8±0.7	<0.09
23	RG58 cable, Pro-Power	Ge	mBq/kg	(2.2±0.9)10^3	(0.9±0.1)10^3	40±12	29±8	<212	108±43	<9.2
24	Teflon cable, Druflon	Ge	mBq/kg	<104	<2.2	<3.7	< 1.7	<1.4	21.6±7.4	<0.7
25	Teflon cable, Axon	Ge	mBq/kg	<650	<24	<15	<9.9	<7.9	163±55	<4.3
26	Kapton tape, Tesa	Ge	mBq/kg	<1.7 10^3	<34	<40	<22	<14	(0.46±0.15)10^3	<10
27	FR4 PCB, Somacis	Ge	Bq/kg	31±11	15.3±2.1	25.5±4.4	22.5±3.5		15.5±4.7	<0.16
28	PTFE circuit, LabCircuits	Ge	Bq/kg	<36	4.7±0.6	5.0±1.1	6.2±0.9	<0.50	4.5±1.5	<0.16
29	Cuflon, Crane Polyflon	Ge	mBq/kg	<103	<3.7	<3.6	<1.4	<1.8	<13	<0.6
30	Classical Micromegas, CAST	Ge	μBq/cm^2	<40		4.6±1.6		<6.2	<46	<3.1
31	Microbulk Micromegas,CAST	Ge	μBq/cm^2	26±14		<9.3		<14	57±25	<3.1
32	Kapton-Cu foil, CERN	Ge	μBq/cm^2	<11		<4.6		<3.1	<7.7	<1.6
33	Cu-kapton-Cu foil, CERN	Ge	μBq/cm^2	<11		<4.6		<3.1	<7.7	<1.6
34	Vacrel, Saclay	Ge	μBq/cm^2	<19	<0.61	<0.63	<0.72	<0.19	4.6±1.9	<0.10

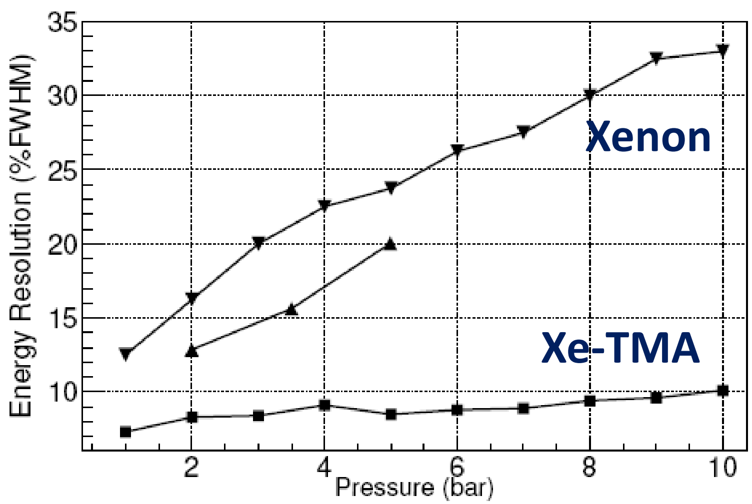
F.J. Iguaz et al.,
EPJC ***76*** *(2016) 529*

Micromegas TPCs in Xe-TMA at HP

- Microbulk micromegas. 50 µm gap.
- Xenon-TMA mixtures.
- ^{109}Cd source (22.1 keV x-rays).
- Best performance for 1.% TMA.
- Max, gain: $2x10^3$ (5×10^2) 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
***Erratum: JINST* 10 (2015) E07001**

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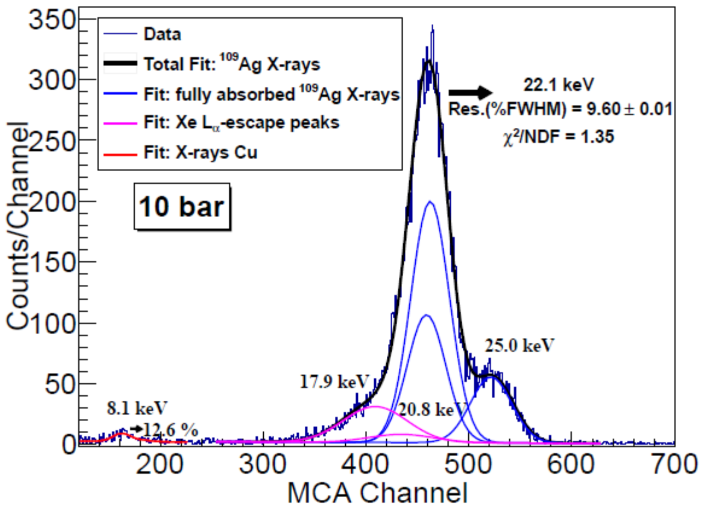
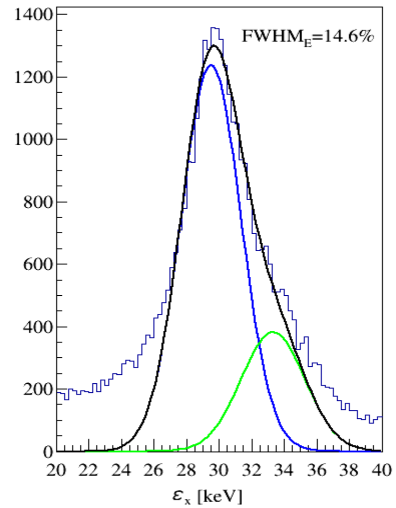
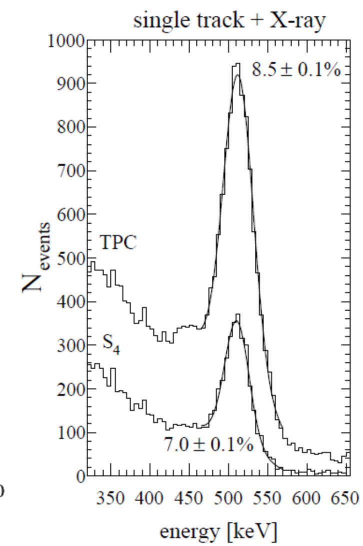
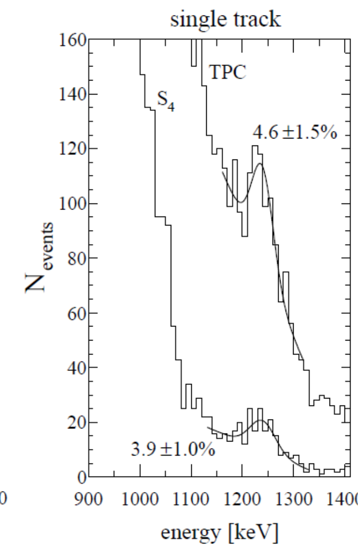
Energy resolution – realistic (ext. tracks)





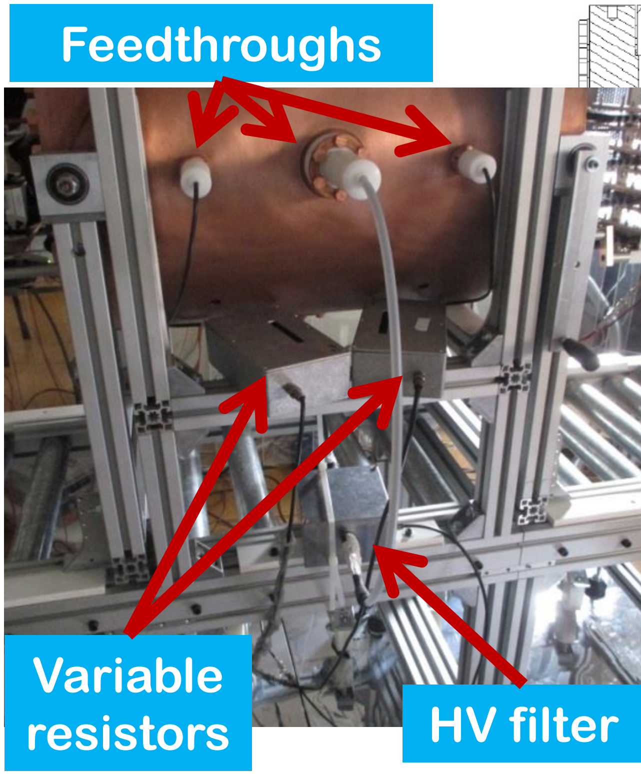


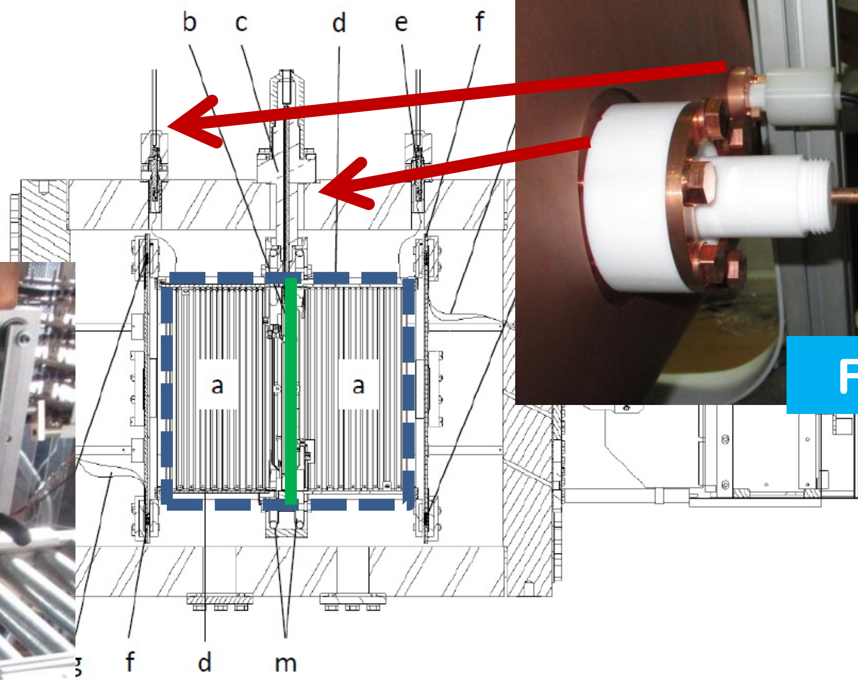


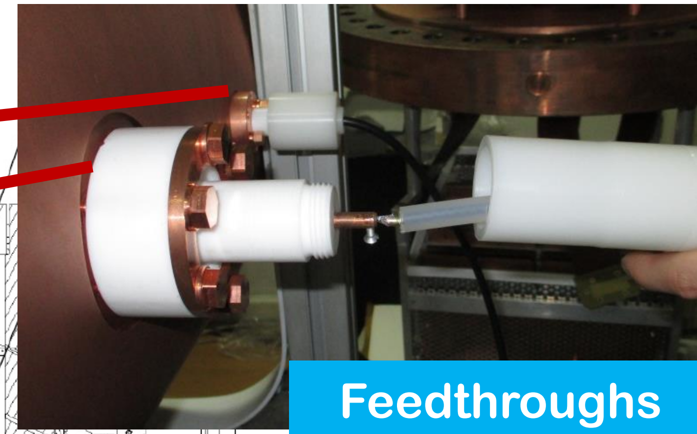
Setup:	**Small**	**Large**	**Large**	**Large**
Energy:	**X-ray (22 keV)**	**X-ray (30 keV)**	**γ (511 keV)**	**γ (1275 keV)**
ΔE (FWHM):	**~10%**	**~15%**	**~7%**	**~4%**
ΔE_{FWHM}@ Qββ	**~1%**	**1.5%**	**3%**	**3%**

*** Always 10 bar, Xe+TMA (~1%)**

Drift cage & mechanical support







- Feedthroughs for cathode & last rings.
- Variable resistor for an uniform drift field.

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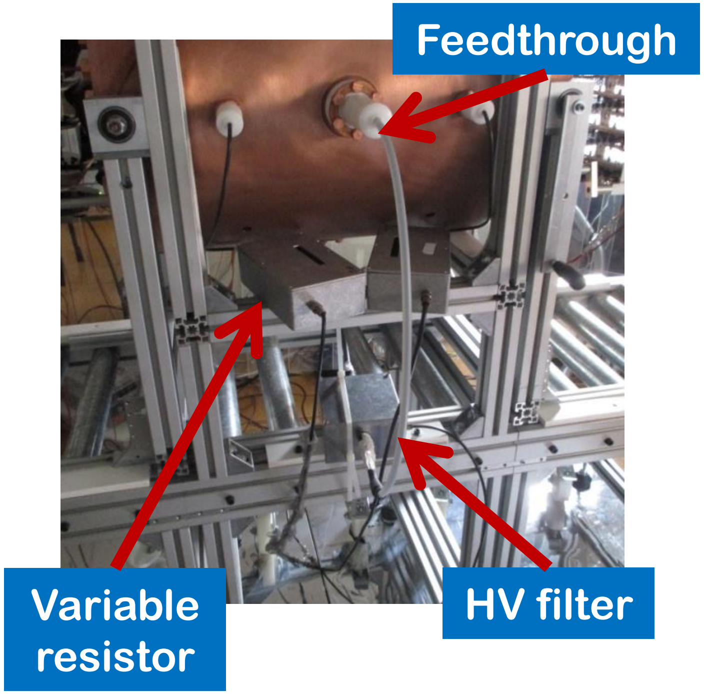
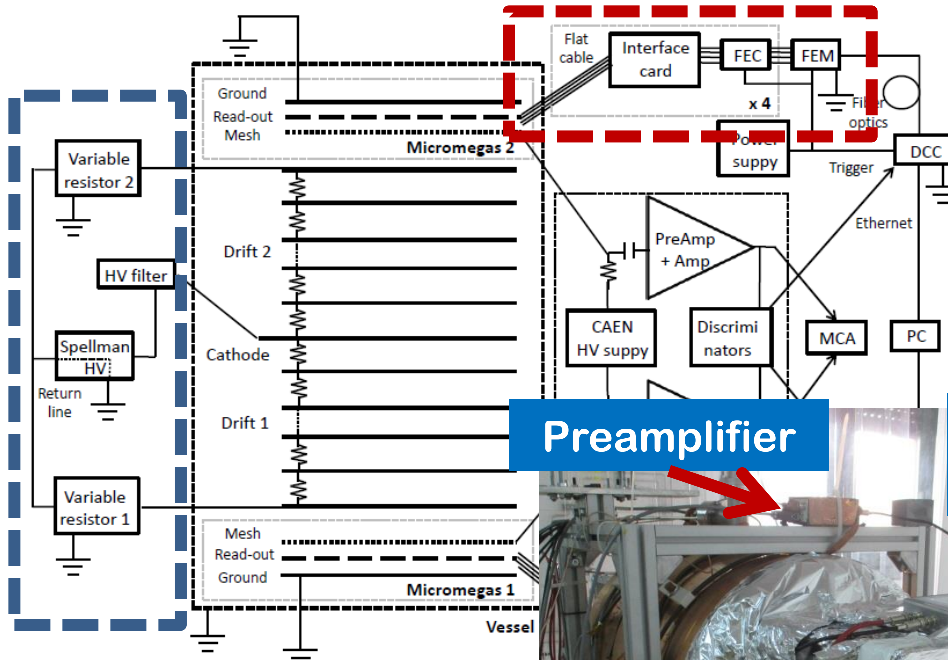
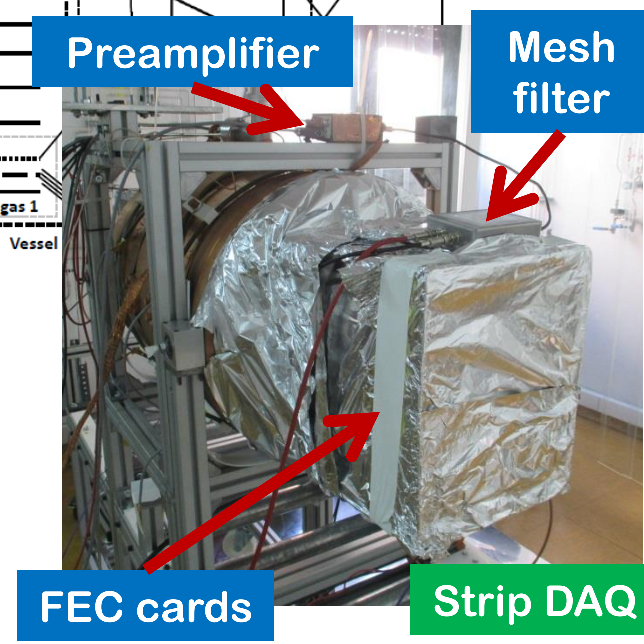
Grounding & filtering noise

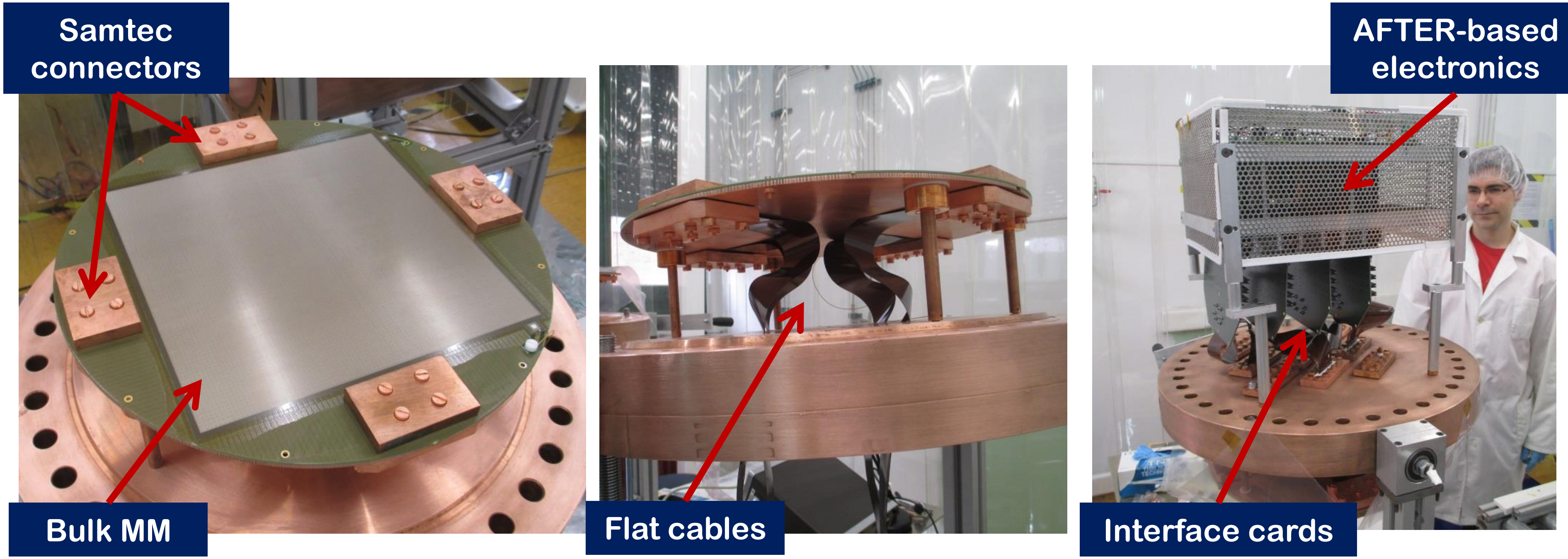






- All high voltage lines have a dedicated filter.
- Strips signals shielded by a ground layer.
- AFTER-based cards inside a Faraday cage.

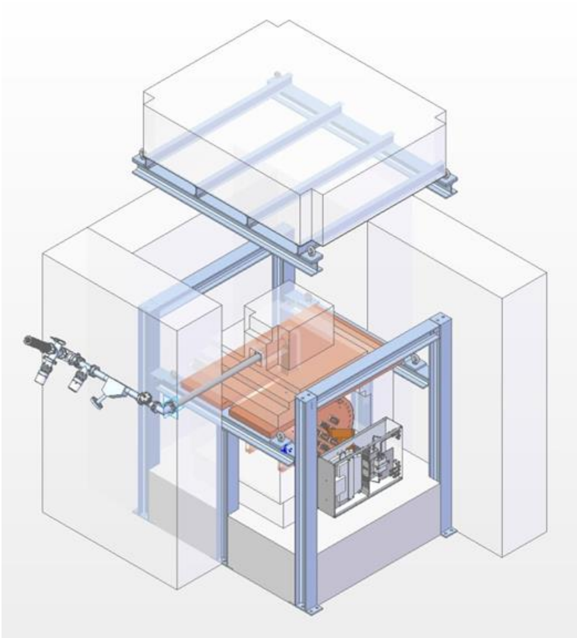
The Micromegas readouts in detail

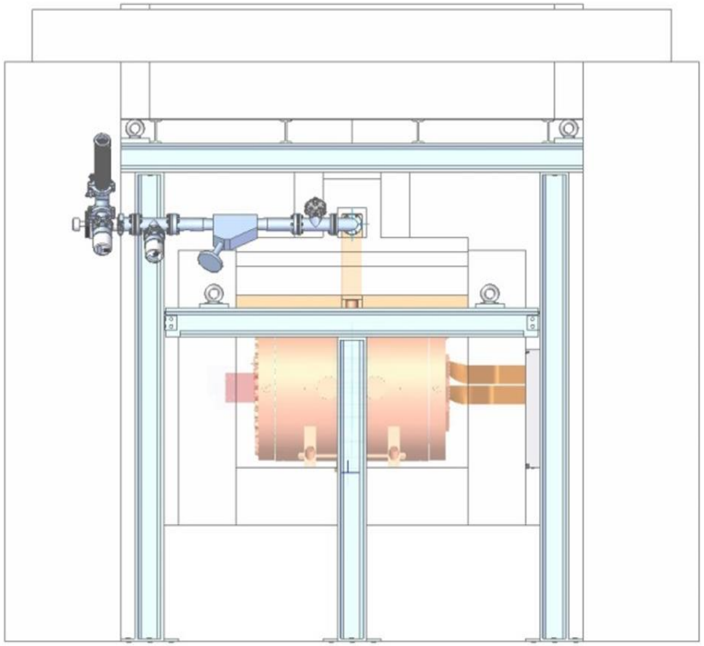


- 25 x 25 cm^2 bulk Micromegas, 0.6 mm pitch, 128 μm gap.
- Extraction: 4 flat cables + 300-pin Samtec connectors.
- A small shielding included too: 1 cm copper + 1 cm lead.
- The interface card links a flat cable to a FEC. Short-cuts can be removed by jumpers.

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

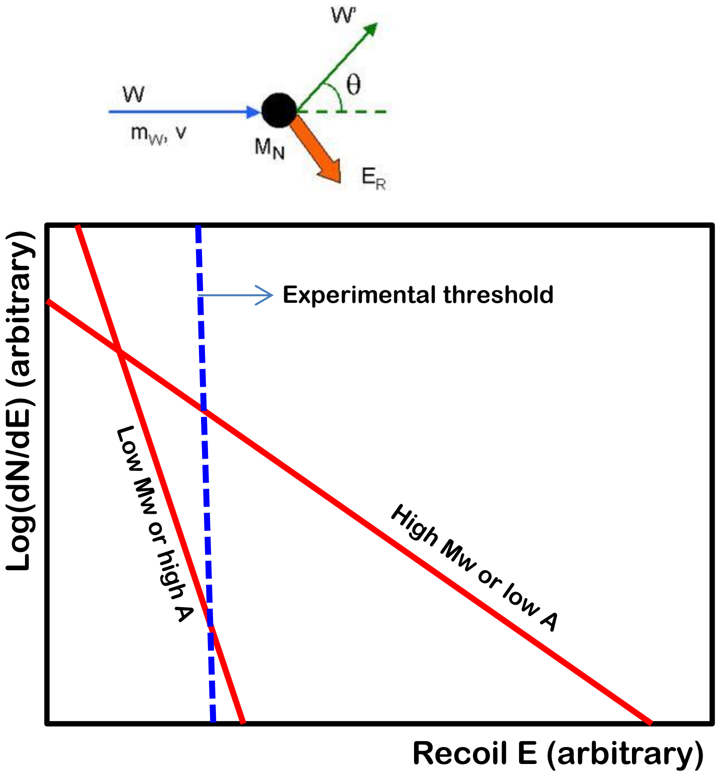
Support structure & shielding

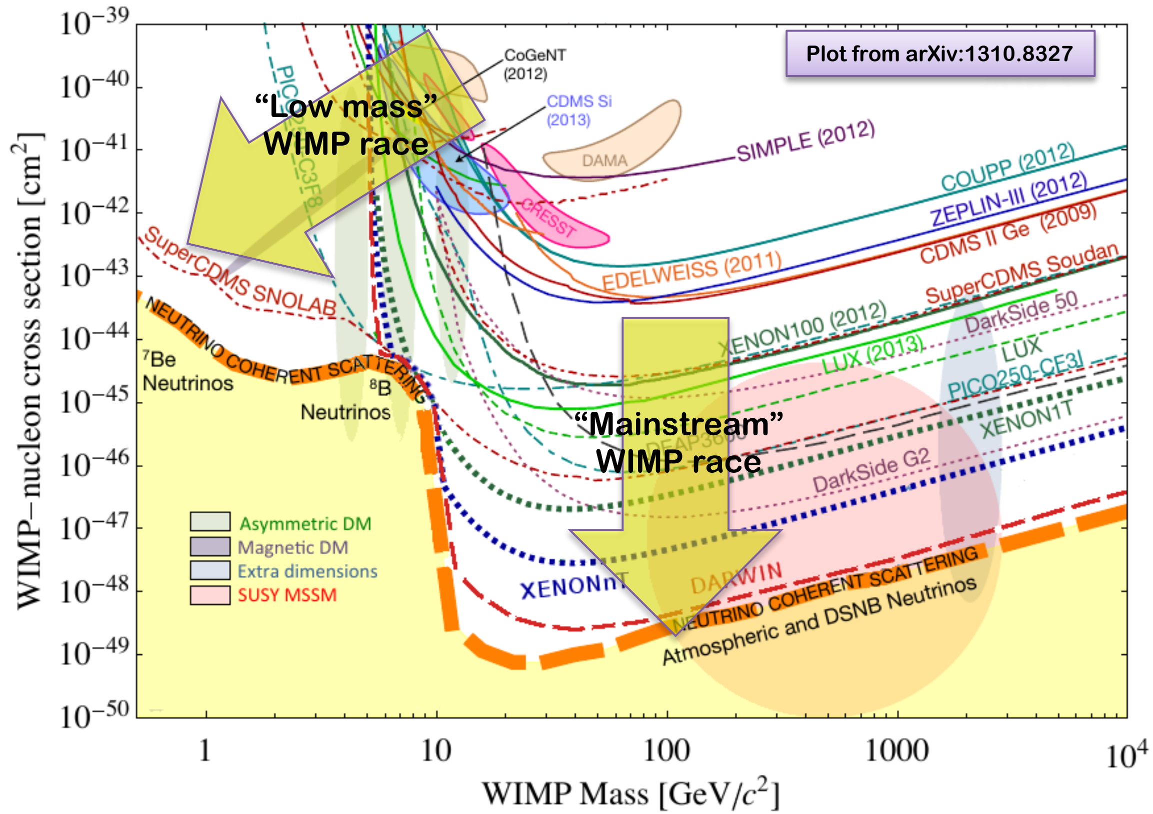




- **Gammas & electronics**: 20 cm lead shielding + steel structure.
- **Neutrons**: 40 cm of polyethylene or borated water.
- **Radon**: Rn-free air (or N_2) flush + polycarbonate box / plastic bag.
- Replacement of gas & vacuum components by copper-based ones.
- One lateral bore to extract signals, gas & vacuum systems.

Low mass WIMPs





- Mainstream experiments not adequate for the low WIMP mass region
- Need new specific WIMP experiments:
  - Low A target material.
  - Low intrinsic energy threshold.

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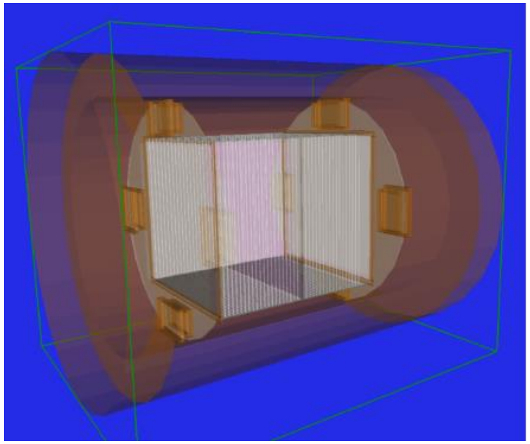
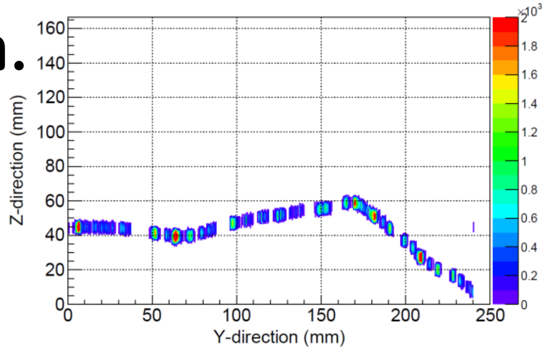
Simulation of the detector response



Geant4 ⟵
- **Physics processes.**

REST ⟵
- **Primary electrons.**
- **Diffusion effects.**
- **Charge amplification.**
- **X-Y readout.**
- **DAQ response.**



The resulting data has the same format as the DAQ data.

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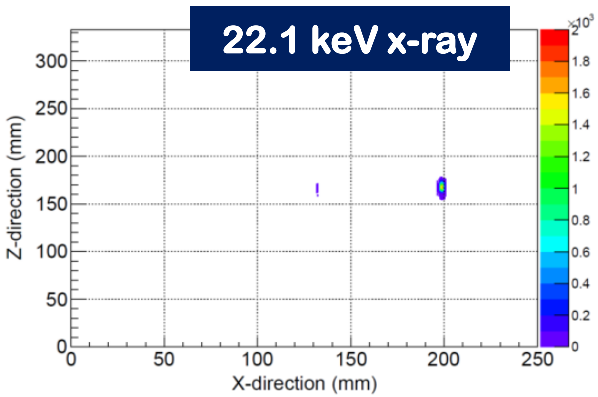
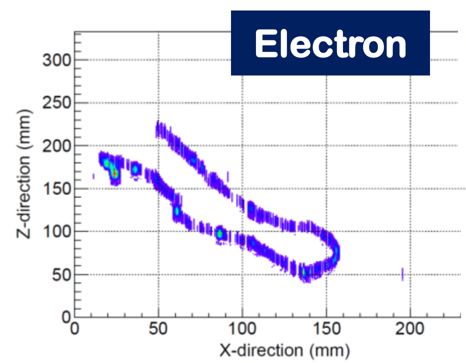
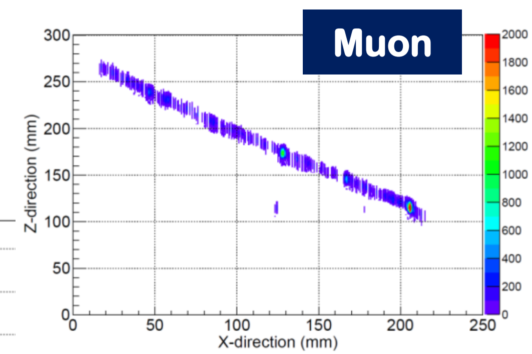
Expected signal & analysis

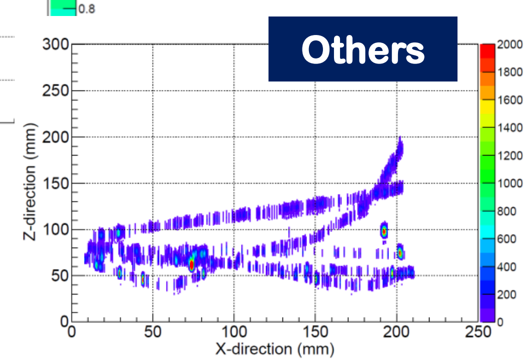
- Expected signal by DM: few microns track -> point-like event.
- Analysis to discriminate point-like events from complex topologies.
- Observables: event widths (XY & Z).
- Likelihood functions based on 3 & 22 keV lines of ^{109}Cd source.



Expected signal



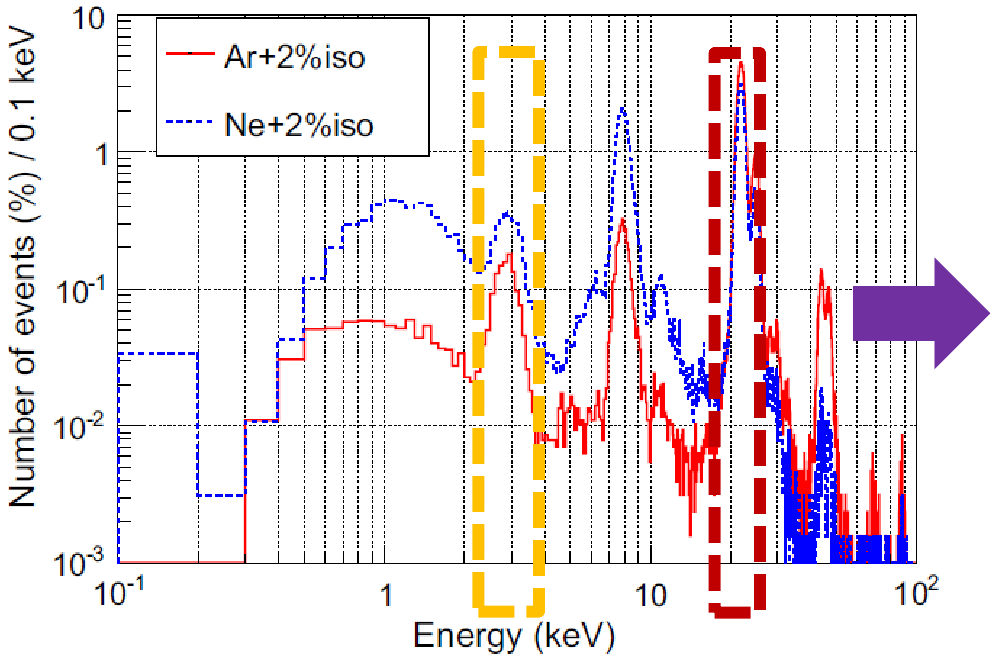




Backgrounds

Expected signal & analysis

- Expected signal by DM: few microns track -> point-like event.
- Analysis to discriminate point-like events from complex topologies.
- Observables: event widths (XY & Z).
- Likelihood functions based on 3 & 22 keV lines of ^{109}Cd source.



$$\mathscr{F}^j = -\log \mathscr{L}^j = -\sum_{i=1}^{3} \log\left(\frac{P_i^j}{1-P_i^j}\right)$$

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Status of background model

Table 5 Activities and estimated background levels (in keV^{-1} kg^{-1} day^{-1}) in the RoI (2-7 keV) of the different components of the TREX-DM experiment for an argon- and neon-isobutane mixture at 10 bar, using the analysis described in the text. The numbers with # at reference refer to Table 1. Upper limits of activities are given at 95 % C.L. In the specific case of connectors, the ^{238}U limit has been used for the upper part of the chain, while the ^{226}Ra value has been used for the lower part. The statistical error of these values is 5 %, while the systematic error includes a 30 % uncertainty associated to the measurement of the component's activity, a 60 % due to the simulation of the detector response and a 25 % for the fiducial efficiency of the analysis. For each component, the isotopes that gives the main contribution to background level have been specified for discussion purposes

Component	Refs.	Radioactive isotopes						Background level		Main contr.
		Unit	^{232}Th	^{238}U	^{40}K	^{60}Co	Others	Argon	Neon	
Muon flux	[77]	s^{-1} m^{-2}					5×10^{-3}	0.019	0.029	–
Vessel	#4	µBq/kg	<4	<12	<61			<0.079	<0.093	^{238}U
Connectors	#17	mBq /pc	1.2	<25	7.3	<0.1	^{226}Ra: 4.5	0.61	0.90	^{232}Th, ^{238}U
Field cage	[78]	µBq/kg	<1.2	<9.7	<10.0			<0.00096	<0.0012	^{238}U
Cathode	#4	µBq/kg	<4	<12	<61			<0.0042	<0.0046	^{232}Th, ^{238}U
Readouts	[32, 64]	nBq/cm^2	<120	<110	6×10^4	<3000		3.35	3.34	^{40}K, ^{60}Co
Target	[79]	mBq/kg					^{39}Ar: 0.73	0.084	–	–
Total background level								4.15	4.43	

F. J. Iguaz et al, EPJC 76 (2016) 529

Table 5: Estimated background level in keV^{-1} kg^{-1} day^{-1} in absence of shielding generated by different external components, a possible shielding against it and final level. Background levels have a statistical error less than 5% and its error is mainly dominated by the measurement error of the component's activity.

Component	Reference	Level (No shielding)	Shielding	Final level
External gamma flux	[95]	1.1×10^3	20 cm lead	3.2×10^{-2}
AGET-based electronics	Table 3, #27	4.3×10^2	20 cm lead	1.2×10^{-3}
LSC rock neutrons	[99]	4.9×10^{-1}	40 cm polyethylene	10^{-5}?
Lead shielding (No ^{210}Pb)	Table 3, #2	8.2×10^{-2}	-	-

TREX-DM LoI to LSC SC (April 2016)