Update on the TREX-DM experiment at LSC

Ana Quintana García on behalf of the TREX-DM team

aquintana@unizar.es

PhD student at CAPA, Universidad de Zaragoza

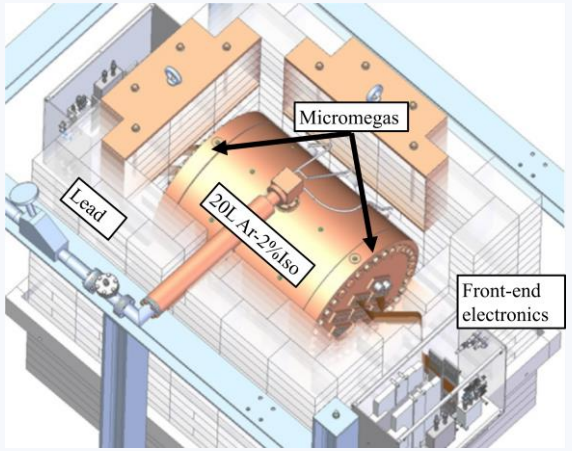
XVII CPAN Days, Valencia, 19-21/11/2025

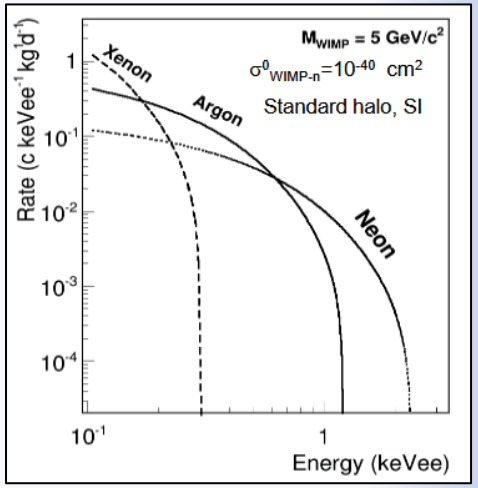
Universidad Zaragoza
1542

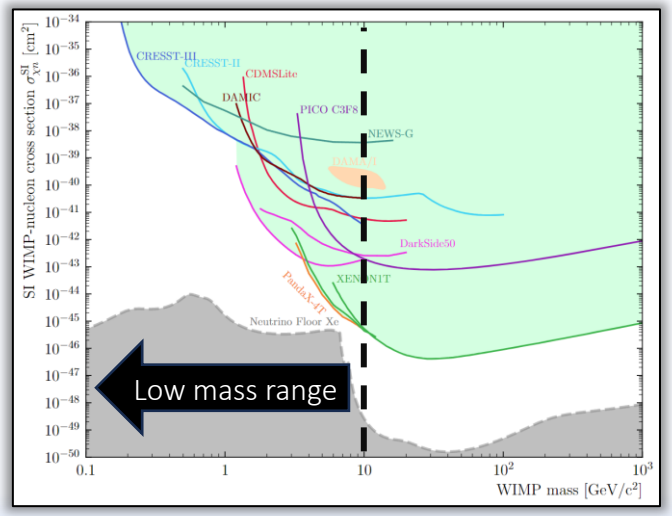
CAPA Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

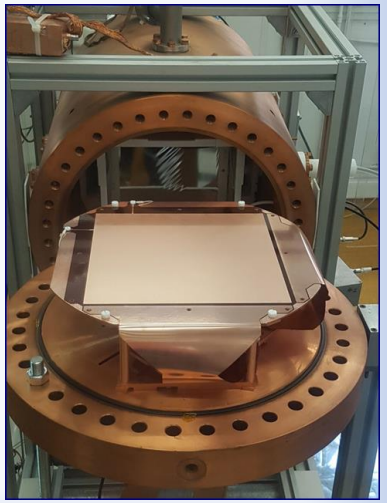
TREX-DM

- Detector to search for **low-mass WIMPs**.
- High Pressure Gas Time Projection Chamber (**HPTPC**):
  - active volume ~ 20 L.
- **Requirements** → TREX-DM prospects:
  - Light nuclei as target → Ar/Ne + Isobutane
  - Very low **energy threshold → < 100 eVee**
  - Ultra-low **background → < 10 dru (c/keV/kg/d)**
- Using novel Micro-MEsh GAseous Structure (**Micromegas**) readouts. 2 readouts, 1 cathode.
- Located at the **Canfranc Underground Laboratory**:
  - ~ 2400 m.w.e



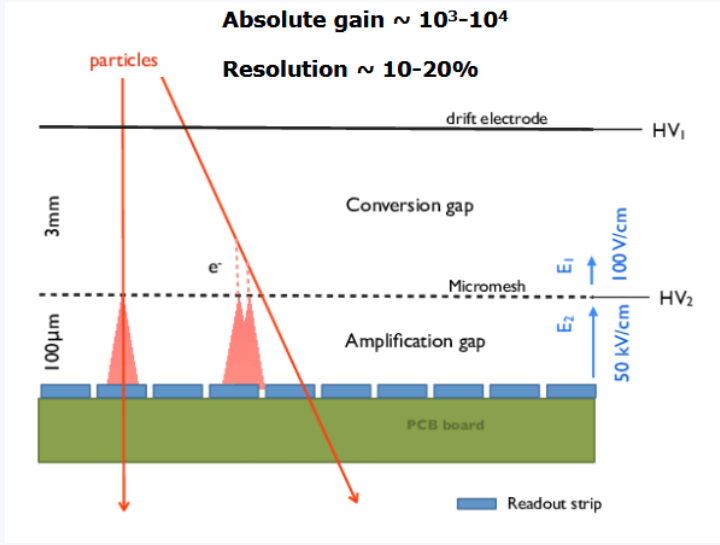


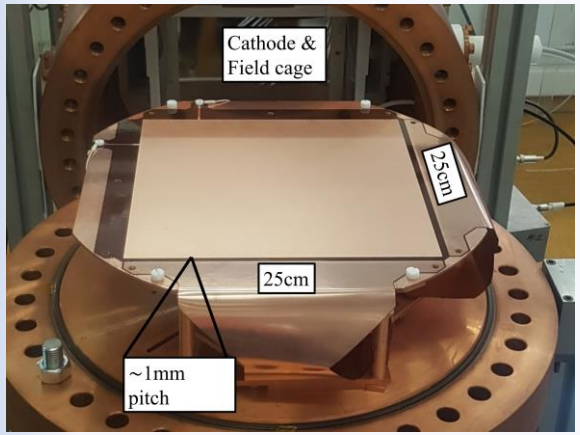


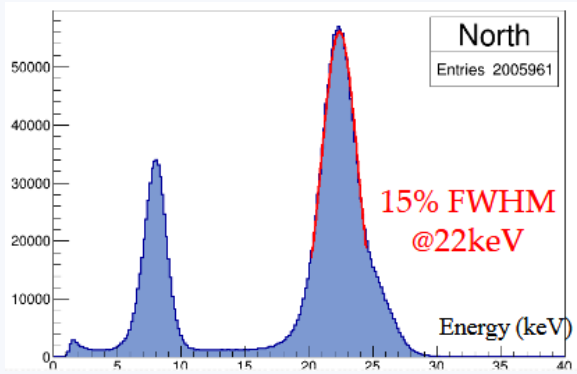


Microbulk Micromegas

- **Micromegas** are a consolidated technology for TPC readouts.
- Advantages of the **Microbulk-mM**:
  - **Topological information**: to discriminate background from expected DM signal.
  - **Low intrinsic radioactivity**: kapton and copper.
  - Good **energy resolution**: ~ 10-20%
  - Potential to reach low **energy threshold**.







- **Two Microbulk-mM readouts**: the largest surface (~ **25x25 cm²**) ever produced with this technology.
- **512 channels**: 256 X strips, 256 Y strips, ~ 1 mm pitch.
- **Flat cables** to extract the signals and **connectors** made of **radiopure** material (FaceToFace).

Experiment chronology

2018	2019	2022	2023	2024	2025
Installation at LSC.	Commissioning and data taking with Ar & Ne. High background (600 dru). 222Rn from gas filters.	New Micromegas installed. Threshold ~ 1 keV Background reduce to 80 dru (open loop)	Relocation and commissioning at LAB2500. Same Alpha background. GEM+MM test at Zaragoza.	GEM+MM installation in TREX-DM. Threshold ~ 20 eV Cathode replaced, still contaminated.	GEM commisioning efforts. Ar & Ne opperation. **Major intervention** - Wire cathode - New field cage - GEM replaced

Main challenges:

- Energy threshold
- Background level
- Gas sensitivity increase

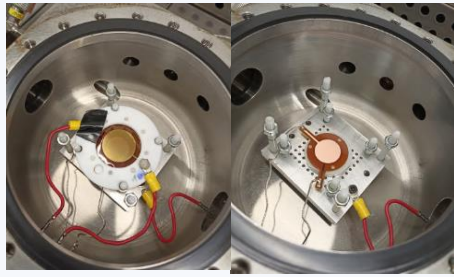
Castel Pablo JF et al., *Open Res Europe,* 2025
doi.org/10.12688/openreseurope.19258.2

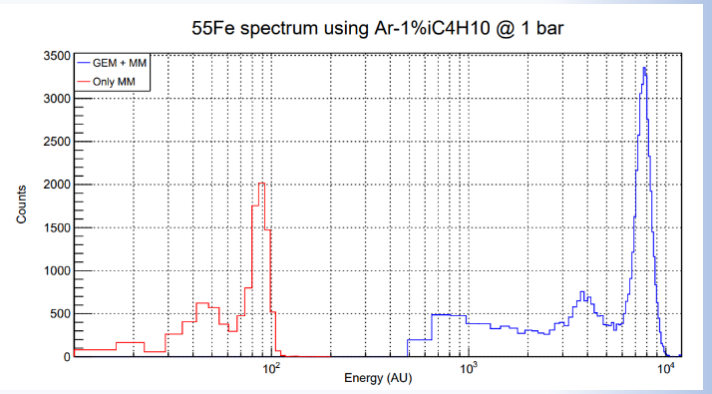
Energy threshold reduction

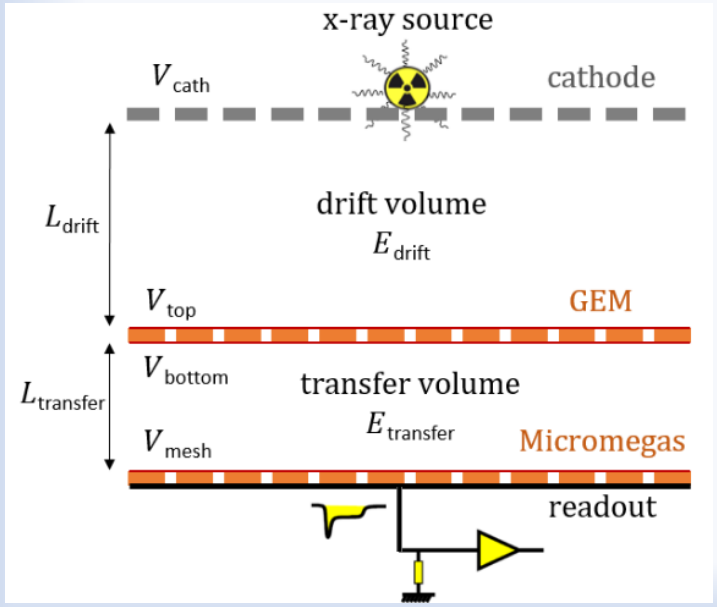
Preamplification stage: GEM + MM

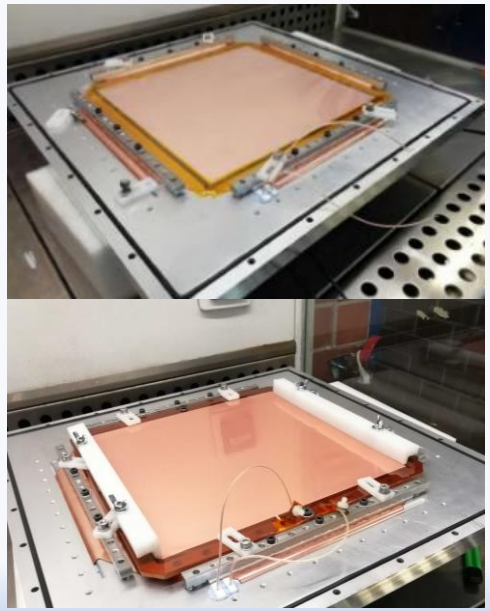
It allows higher gain → increase signal-to-noise ratio.

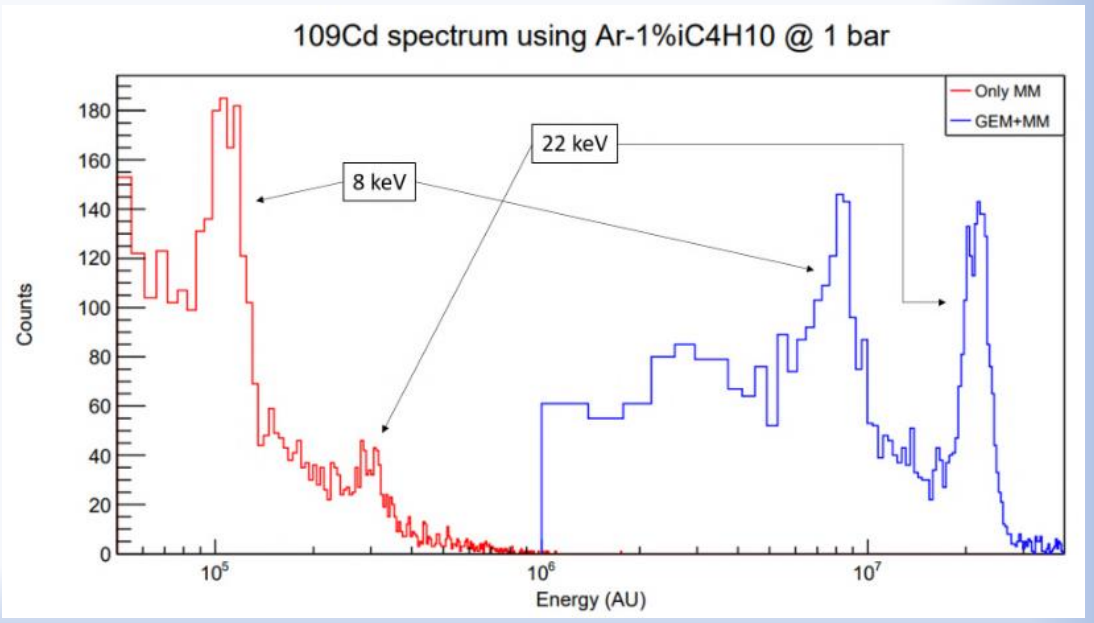
- Small microbulk mM @1-10 bar (×100 to ×10)
- 25×25 cm^2 microbulk mM @1bar (×100)









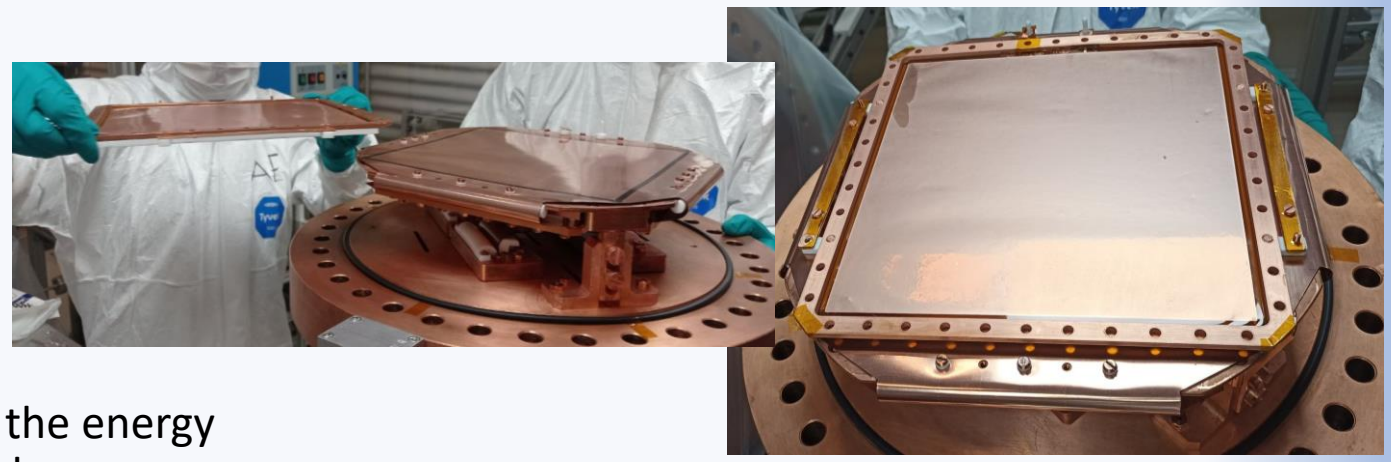


Pérez Ó. et al., 2025 arXiv 2510.05877

Energy threshold reduction

GEM + MM installed in TREX-DM:

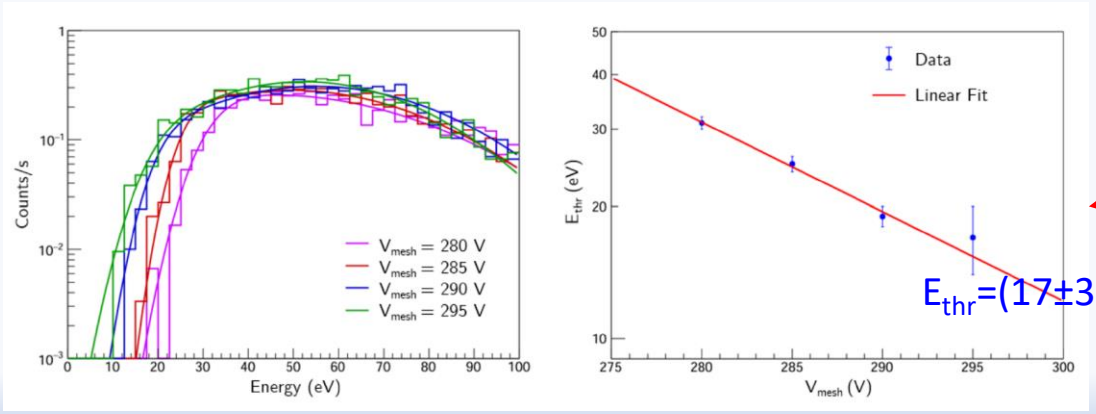
Demostrates x20 amplification during opperation in Ar+1%iso at 1bar.



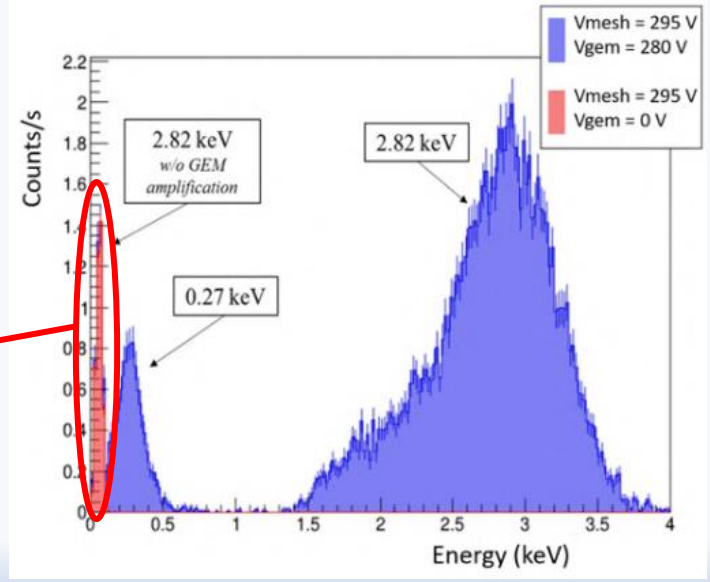
Low-energy calibrations:

Understanding of the detector's behavior and the energy reconstruction at those energies → need for a low-energy calibration with high statistics.

- **^{37}Ar** (2.82 keV, 0.27 keV)



E_{thr}=(17±3) eV



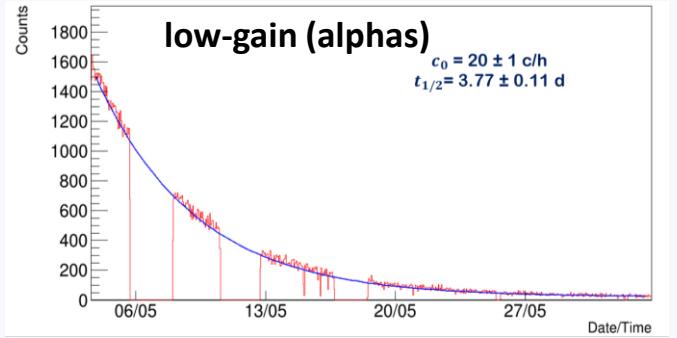
Background level

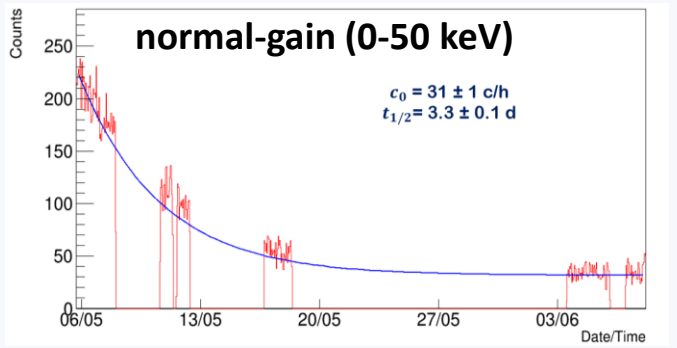
Background model simulation → ~10 dru

Rn issue:

- Filters in the gas system (H_2O and O_2)
- LE and HE runs in seal mode → Rn + constant component
- Before Rn decay (0-50 keV) → 600 dru
- After Rn decay (0-50 keV) → **100 dru**
- Open loop, surface contamination (^{210}Pb) → **< 80 dru**

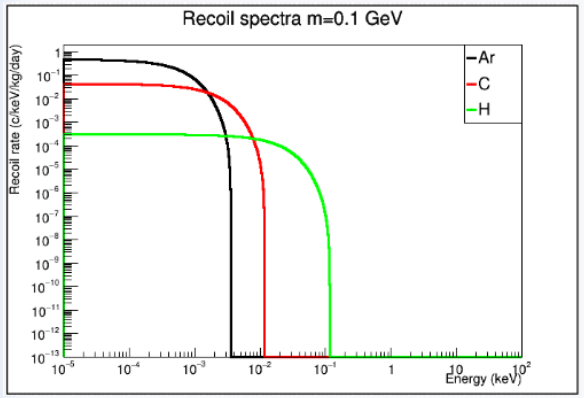
  Dominated by the contamination on the cathode surface?

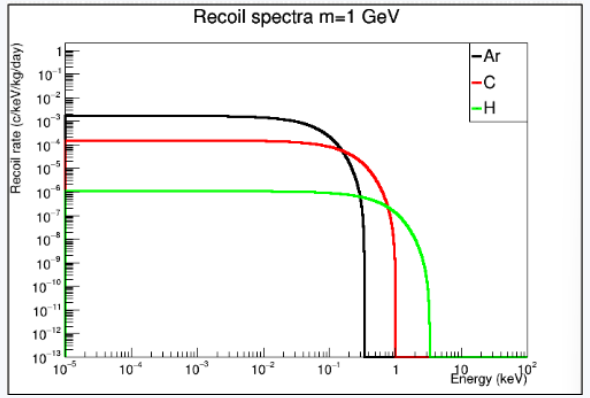


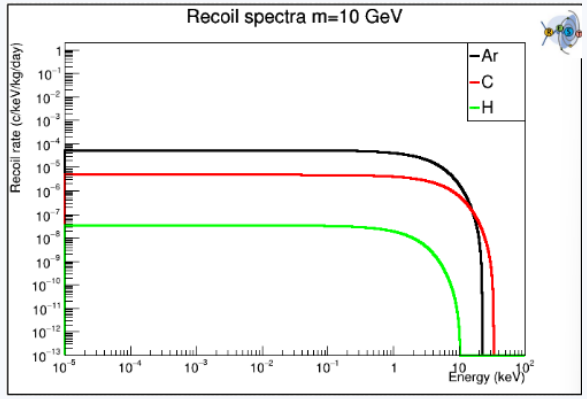


Gas composition

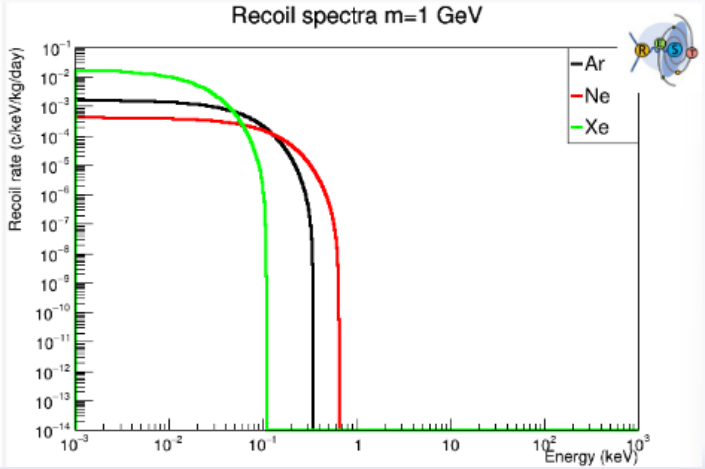
Incrementing presence of H (iC_4H_{10})



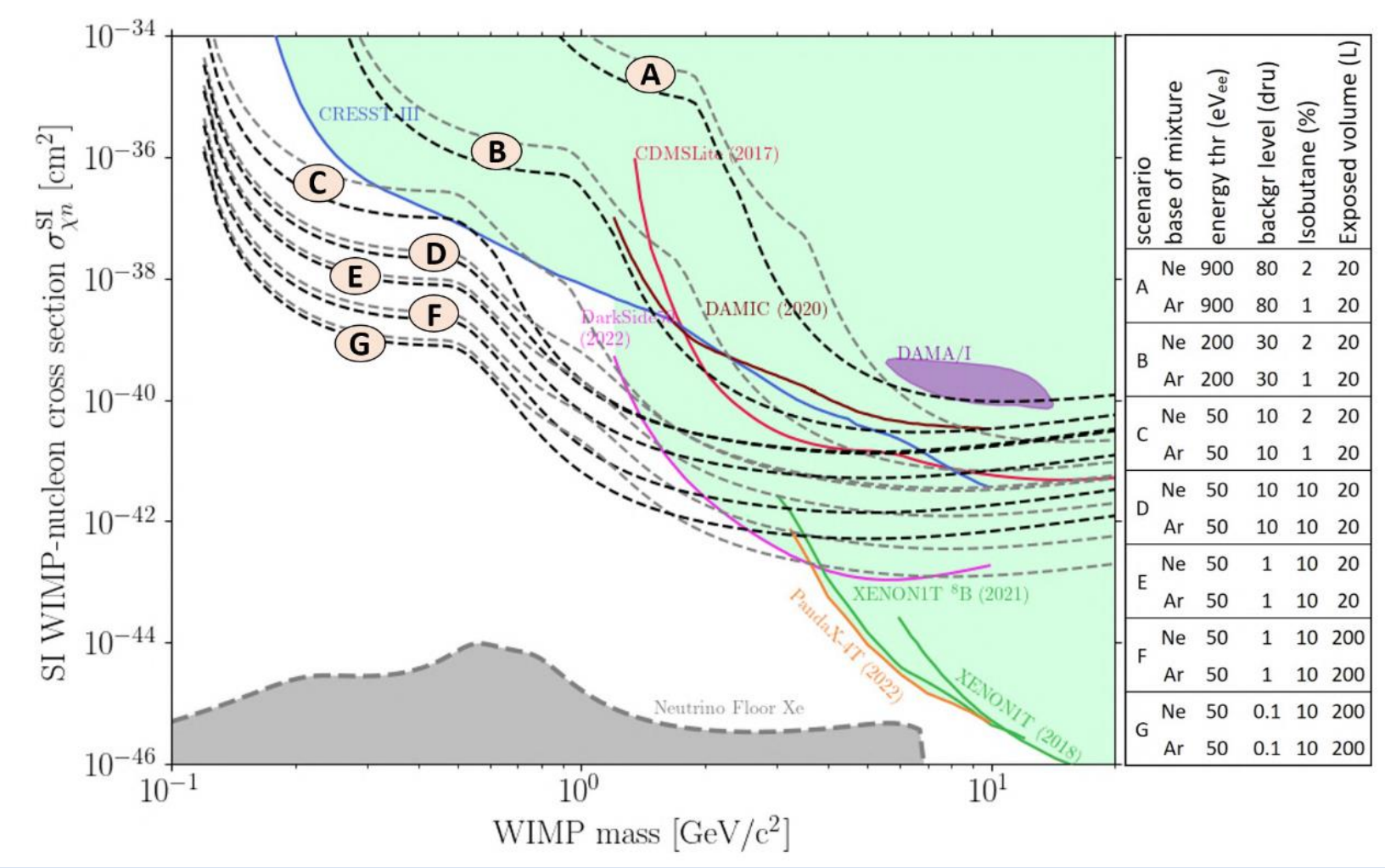




Target change (Ne, Ar depleted)



Sensitivity prospects



scenario	base of mixture	energy thr (eV_{ee})	backgr level (dru)	Isobutane (%)	Exposed volume (L)
A	Ne	900	80	2	20
	Ar	900	80	1	20
B	Ne	200	30	2	20
	Ar	200	30	1	20
C	Ne	50	10	2	20
	Ar	50	10	1	20
D	Ne	50	10	10	20
	Ar	50	10	10	20
E	Ne	50	1	10	20
	Ar	50	1	10	20
F	Ne	50	1	10	200
	Ar	50	1	10	200
G	Ne	50	0.1	10	200
	Ar	50	0.1	10	200

2022 conditions

Lowering Threshold and Background

Gas mixture

Long-term


THANKS!

Acknoledgements

The work presented in this talk is part of the work carried out by the TREX-DM team and funded by different agencies.

In particular, we acknowledge the support from:

- The Spanish **Agencia Estatal de Investigación AEI** under grant PID2019-108122GB-C31 funded by MCIN/AEI/10.13039/501100011033
- The **European Union NextGenerationEU/PRTR** (Planes complementarios, Programa de Astrofísica y Física de Altas Energías), co-funded by Gobierno de Aragón

Relevant publications:

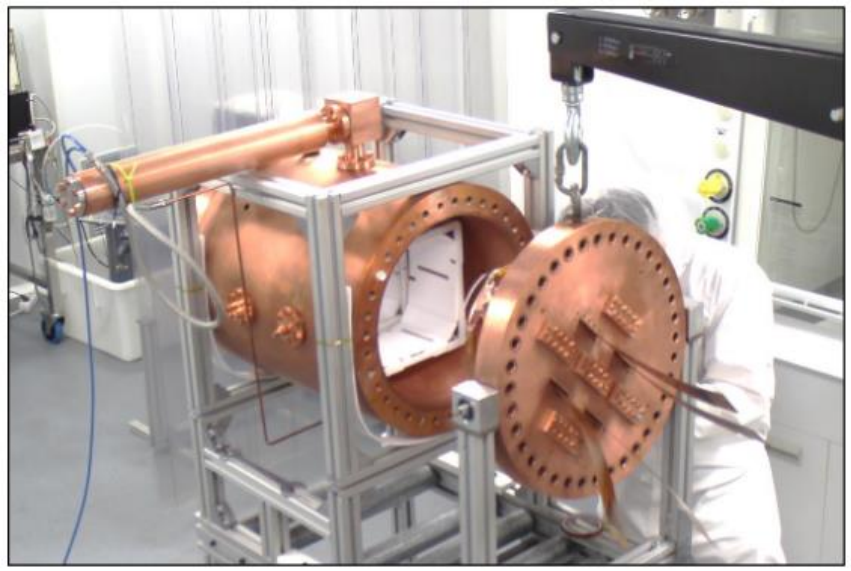
- *Gaseous time projection chambers for rare event detection: Results from the T-REX project. II. Dark matter*. JCAP 01 (2016) 034. Err: **JCAP 05(2016) E01**
- *TREX-DM: a low-background Micromegas-based TPC for low-mass WIMP detection*. Eur. Phys. J. C (2016) 76: 529.
- *Assessment of material radiopurity for Rare Event experiments using Micromegas*. JINST 8 (2013) C11012
- *Radiopurity of Micromegas readout planes*, Astrop. Phys. 34 (2011) 354-359
- *Background assessment for the TREX dark matter experiment*, Eur. Phys. J. C 79, 782 (2019)
- *Cosmogenic production of tritium in dark matter detectors*, Astrop. Phys. 97 (2018) 96-105
- *Development and performance of Microbulk Micromegas detectors*, 2010 JINST 5 P02001*Microbulk Micromegas in non-flammable mixtures of argon and neon at high pressure*, 2022 JINST 17 P07032
- *AlphaCAMM, a Micromegas-based camera for high-sensitivity screening of alpha surface contamination*, 2022 JINST 17 P08035
- *Micromegas with GEM preamplification for enhanced energy threshold in low-background gaseous time projection chambers.* Open Research Europe, vol. 5, no. 53, 2025. doi: 10.12688/openreseurope.19258.2.
- *Low-energy threshold demonstration for dark matter searches in TREX-DM with an ^{37}Ar source produced at CNA HiSPANoS*. arXiv:2510.05877 [physics.ins-det].

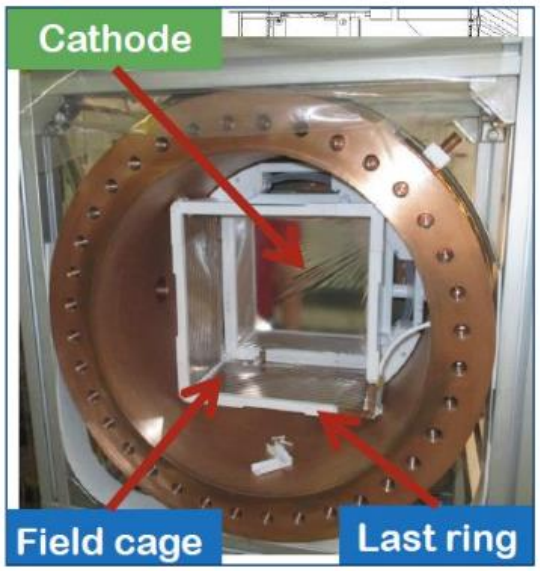
BACK-UP

Vessel & gas system

Vessel:

- Cylindrical vessel made of **copper** (cleaned with nitric acid and demineralised water, passivated with citric acid).
- Designed and certified to operate up to 10 bar.



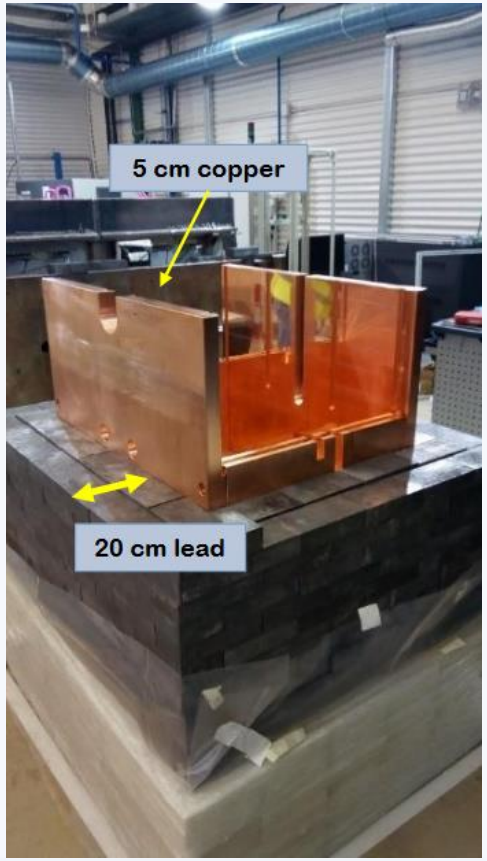


Gas system:

- Consisting of recirculation part + purification branch

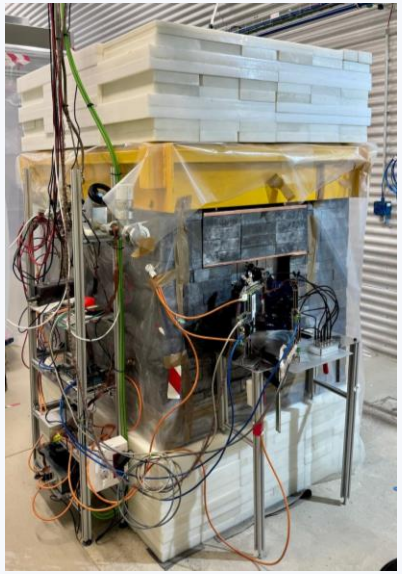
Shielding

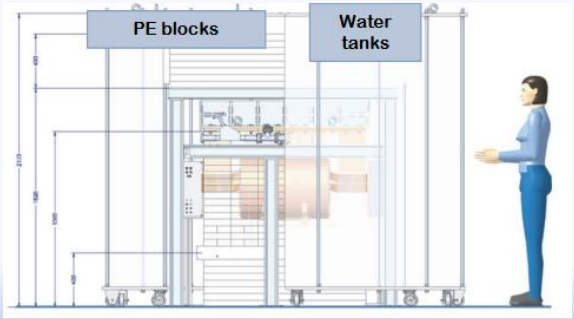
5 cm **copper** + 20 cm **lead**



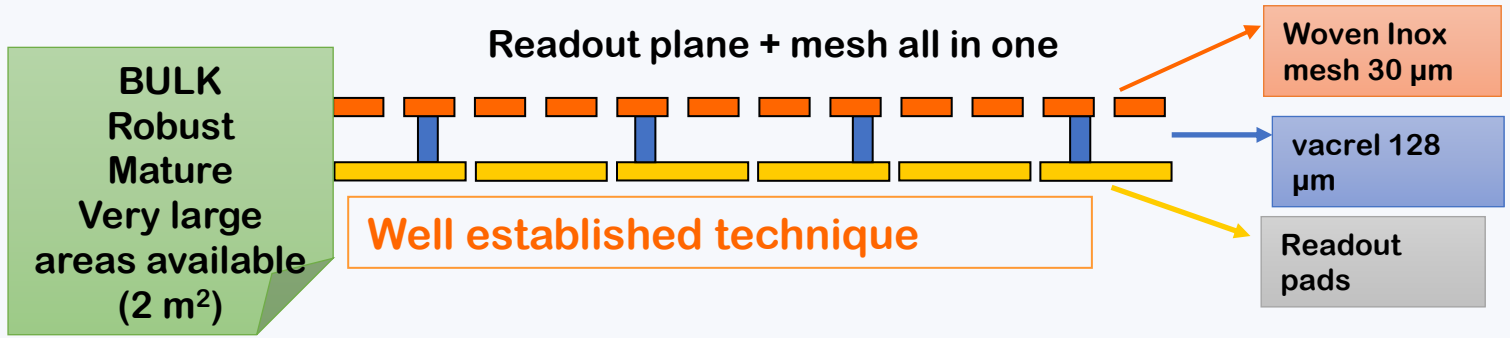
DAQ outside the shielding

Neutron shielding: PE ceiling + water tanks

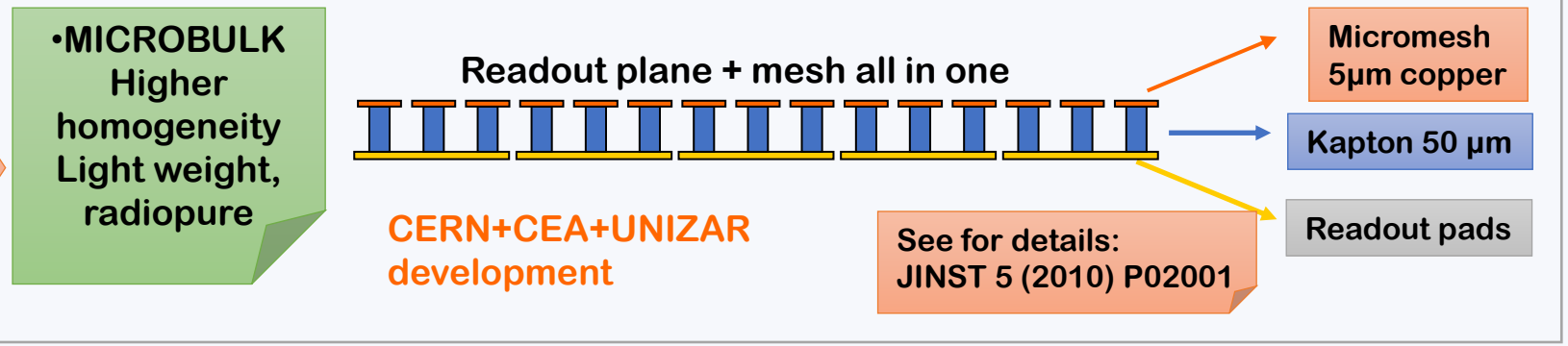




Micromegas readouts



T-REX R&D



Beyond microbulk?

Microfabricated Micromegas

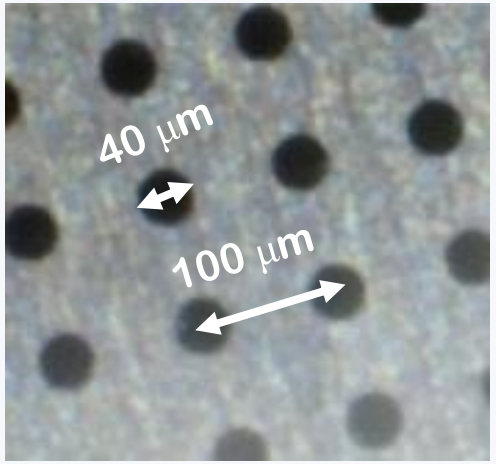
Started development with CNM

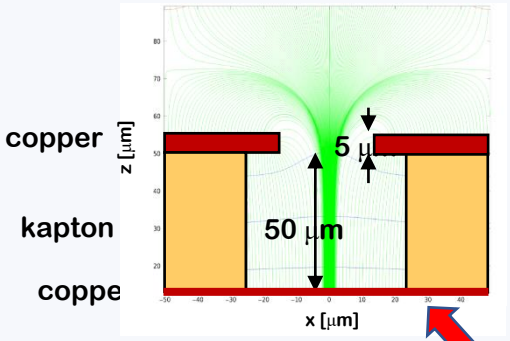
Micromegas structures with Si-wafer microfabrication techniques…
Higher Flexibility & precision in geometrical parameters
Better tailored to application…

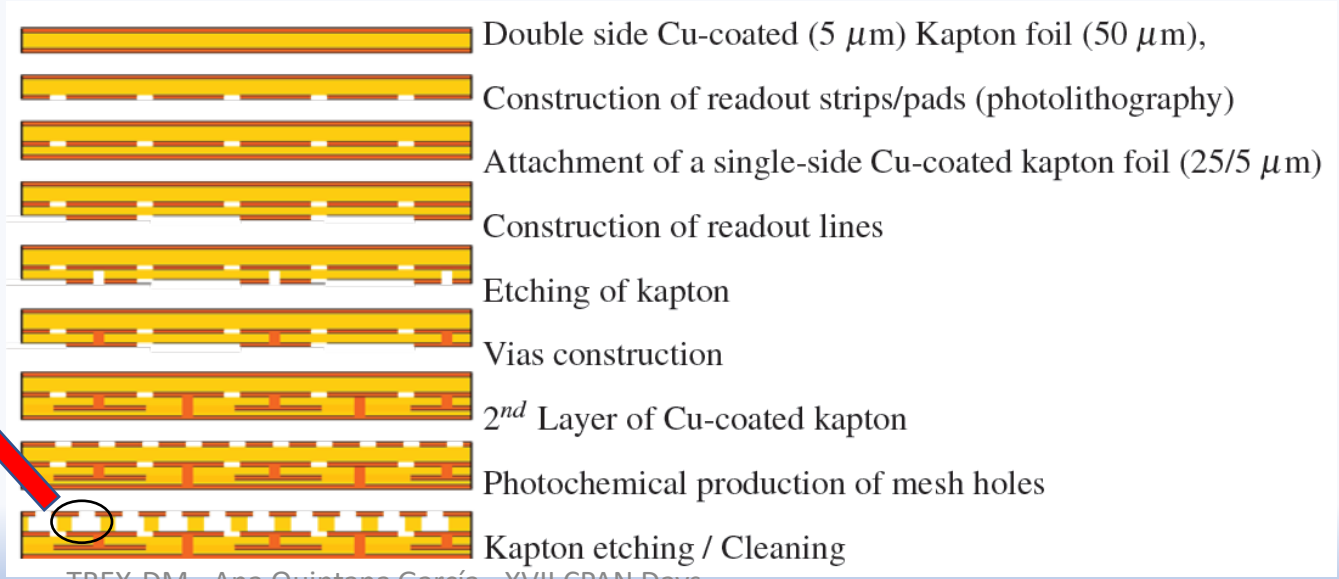
Microbulk Micromegas

- Made out of copper & polyimide (kapton)
  - potentially very radiopure
- High gap homogeneity
  - good energy resolution
  - Stability/homegeneity in response

Manufactured at Rui de Oliveira's workshop at CERN





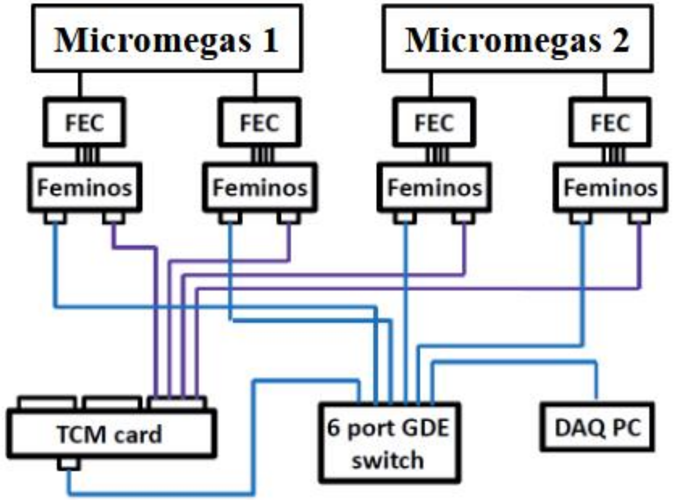


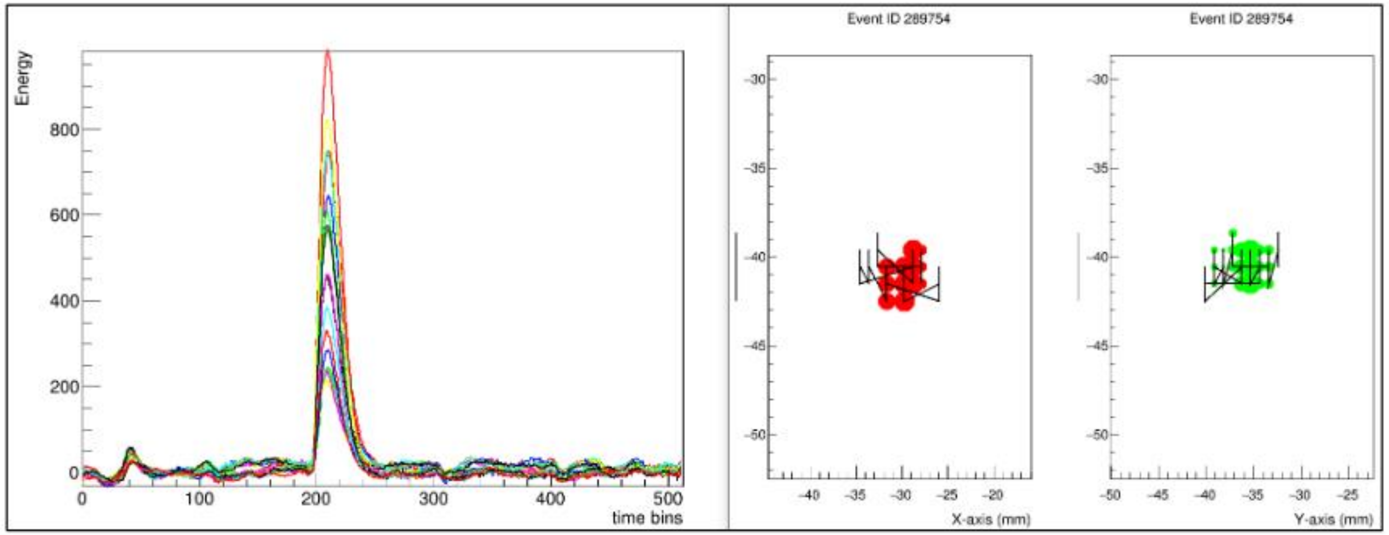
See for details:
JINST 5 (2010) P02001

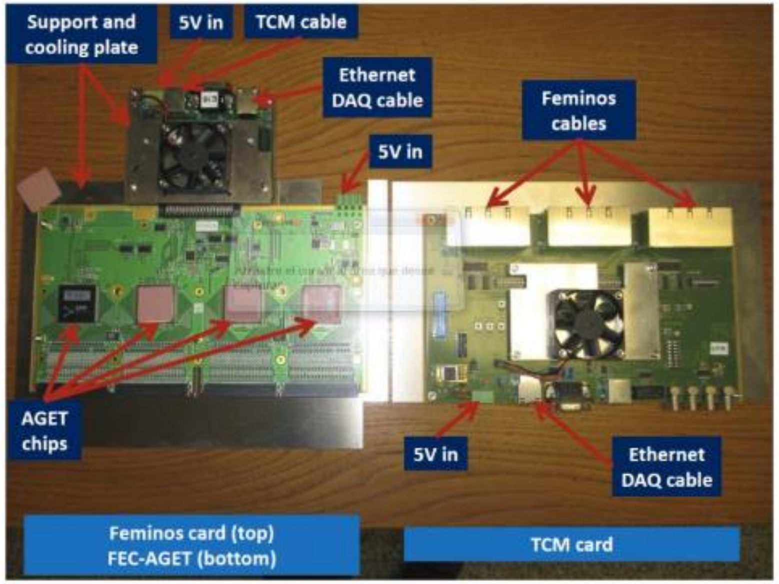
Credit:
H. Mirallas

Readout electronics

- **AGET-based system**: **self-trigger**, allowing to trigger the acquisition from the strips signals
- Two **Front End Cards (FEC), with 4 AGET chips** each, read out the 2 x 256 channels of each micromegas detector. Each FEC is connected to one **Feminos** card (FPGA)
- Employing more than one FEC-Feminos requires the use of a synchronization board **(Trigger Clock Module, TCM**). The TCM distributes a common 100 MHz reference clock and the trigger to all the FECs







Credit:
O.Pérez

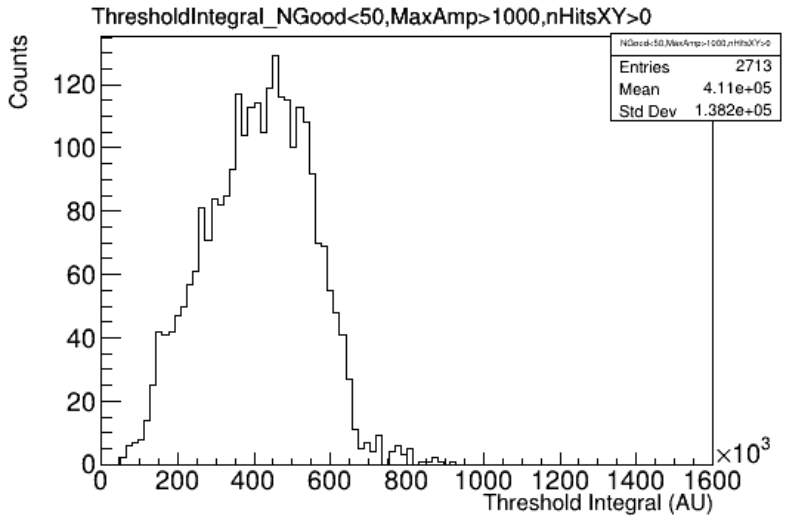
Background status: Rn issue

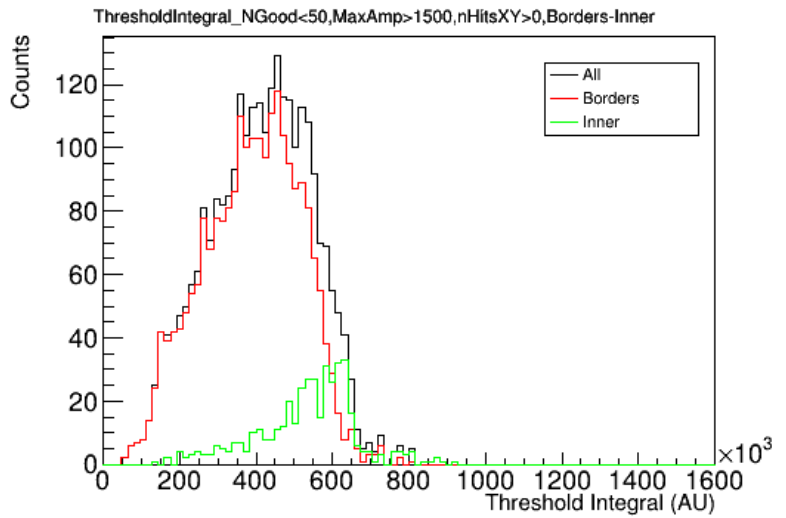
- **Internally emanated Radon is the main source of background (removing it takes us from ~600 dru down to ~100 dru in the 0-50 keV range)**
  - **A lot of effort put into removing it from the system:**
    - **Trying with several commercial filters**
    - **Testing 5Å molecular sieves (we found out they do trap Rn, but emanate more than Agilent filters, best commercial filters we have)**
    - **Testing a custom-made O2+H2O filter developed by the University of Birmingham with low-emanation materials (ongoing collaboration with NEWS-G)**
    - **Testing activated carbon filters**
    - **Open-loop operation bypassing the filters and the recirculation pump**

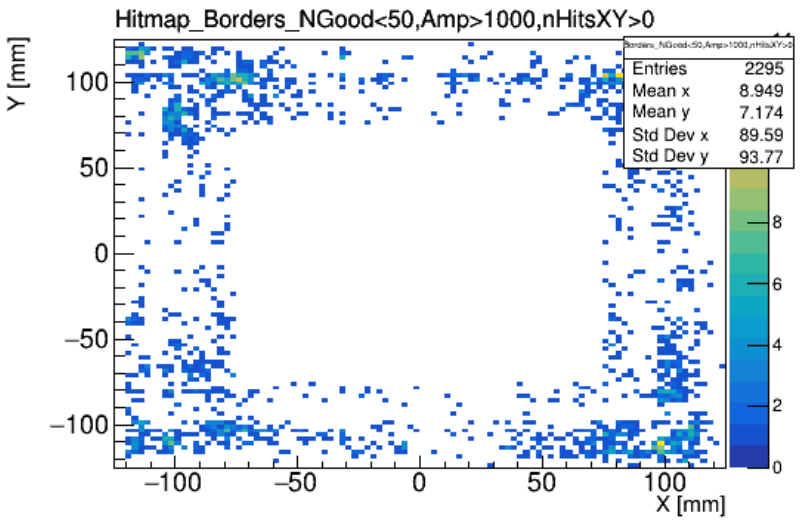
- **Rn progeny surface contamination may well be responsible for the rest of background not accounted for in our background model**
  - **A program to identify alpha surface contaminations + its mitigation is ongoing**

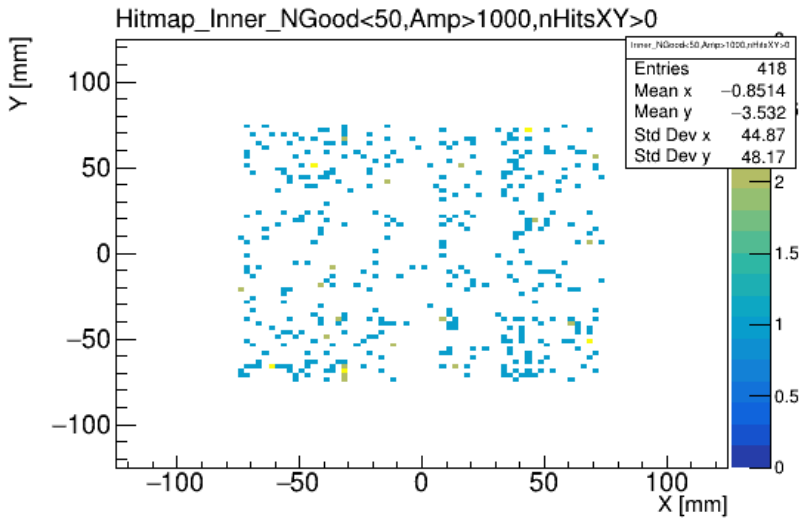
Credit:
O.Pérez

Open loop: no longer a Rn spectrum, only surface contamination





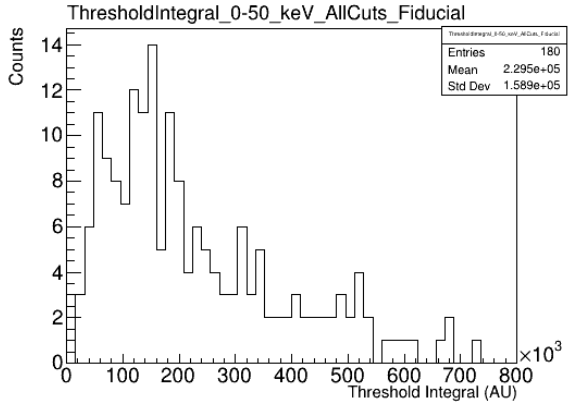


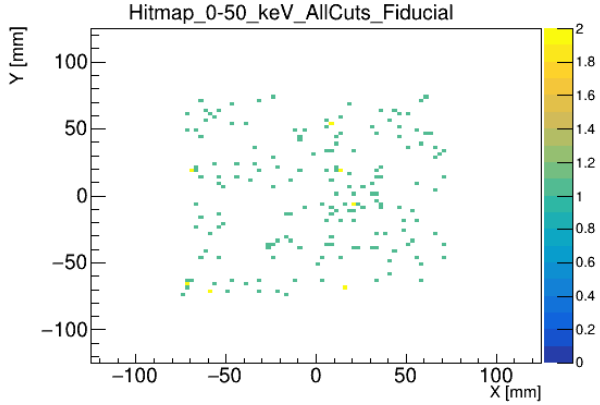


Credit:
O.Pérez

Background level comparison: seal mode in June 2021 vs. open loop

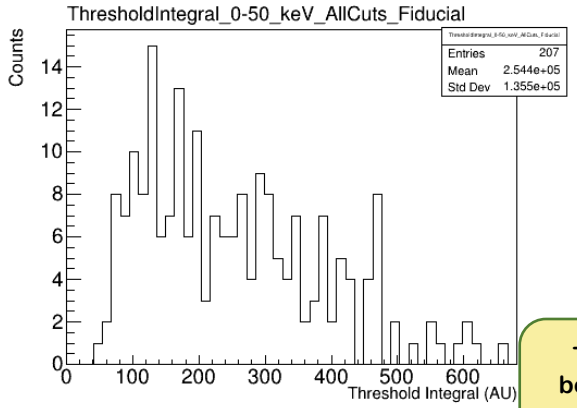
Sealed mode: after Rn decay

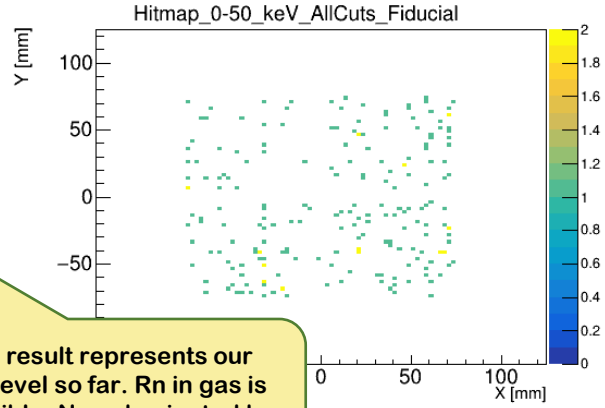




0-50 keV: 120 dru

Open loop





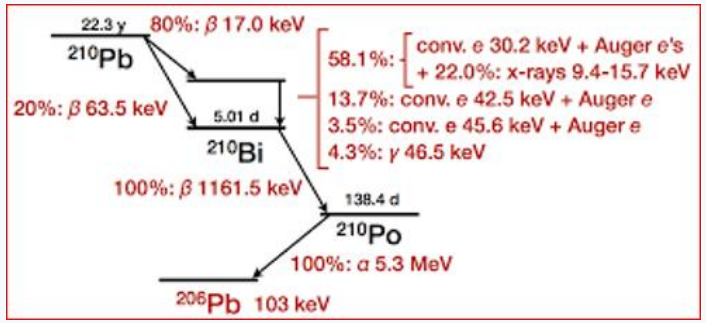
0-50 keV: <80 dru

This result represents our best level so far. Rn in gas is nebligible. Now dominated by Pb210 in surfaces

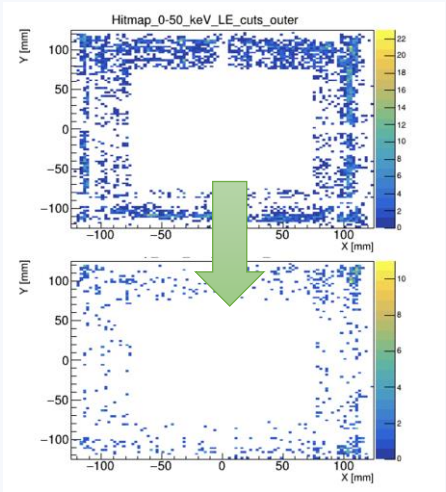
Credit:
O.Pérez

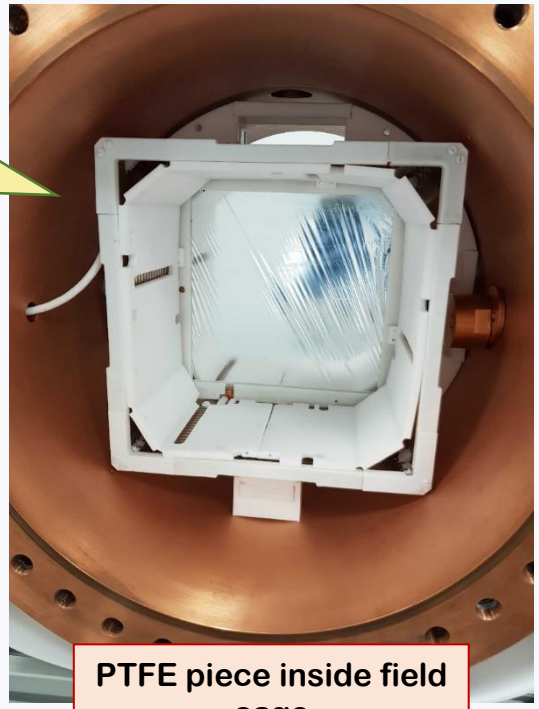
Surface alphas (Rn progeny)

- **Rn progeny (Pb210) attached to surfaces (from past exposure) produces alpha events, but also LE events (in similar proportion)**



Reminder: machining of the Teflon walls led to reduction of both HE and LE background counts in the outer region

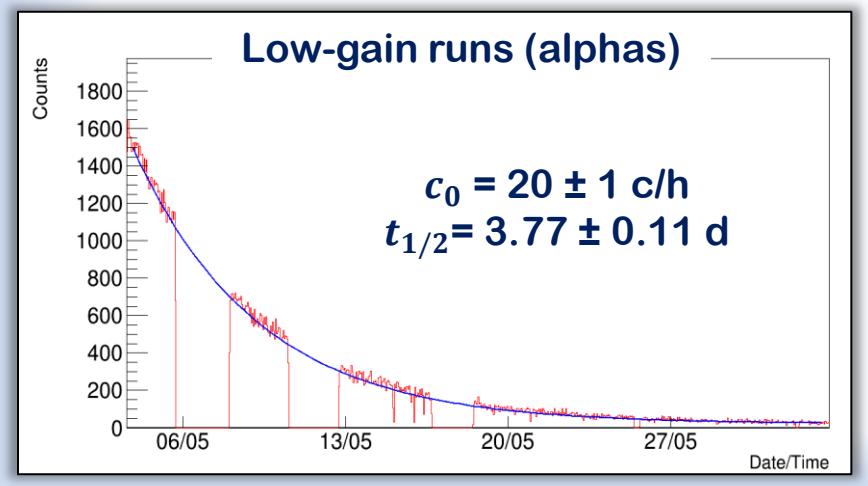


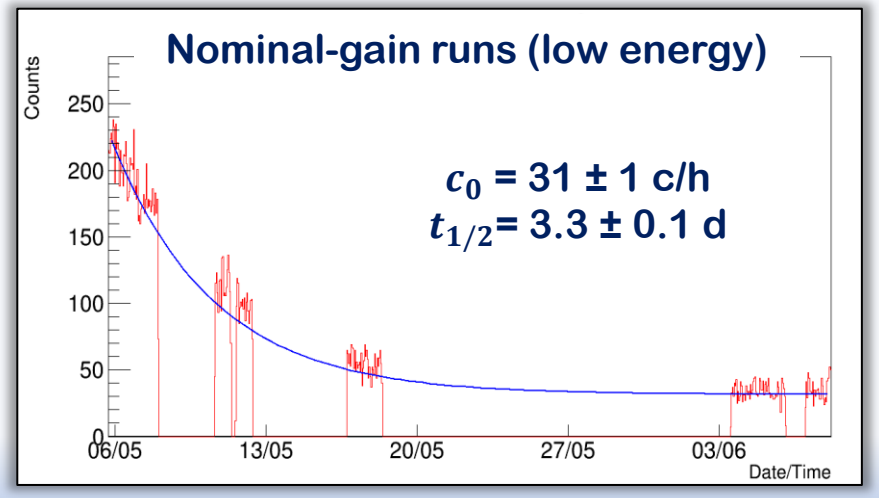


PTFE piece inside field cage

Background reduction overview

<2022	2022	2023	2024	2025
▪ High LE background: 600 dru ▪ Dominated by 222Rn from the gas filters	▪ Reduced LE background to 100 dru (open loop) ▪ New Micromegas installed	▪ Relocation to Lab2500 ▪ Same alpha background levels	▪ Replace cathode to Copper-Kapton ▪ Cathode still contaminated	▪ Major intervention to replace field cage ▪ New wired cathode installed



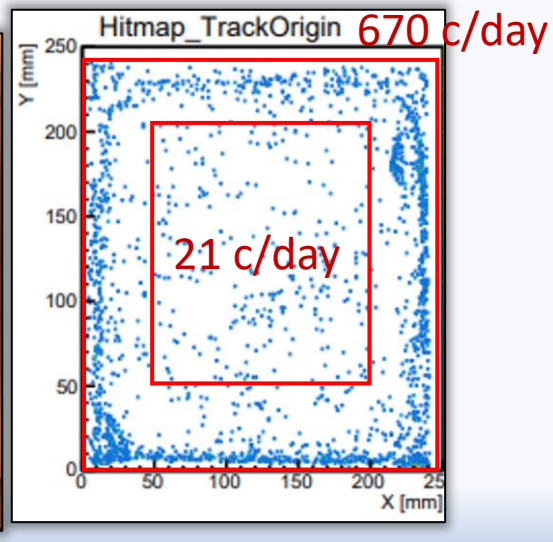


Background reduction overview

<2022	2022	2023	2024	2025
▪ High LE background: 600 dru ▪ Dominated by 222Rn from the gas filters	▪ Reduced LE background to 100 dru (open loop) ▪ New Micromegas installed	▪ Relocation to Lab2500 ▪ Same alpha background levels	▪ Replace cathode to Copper-Kapton ▪ Cathode still contaminated	▪ Major intervention to replace field cage ▪ New wired cathode installed

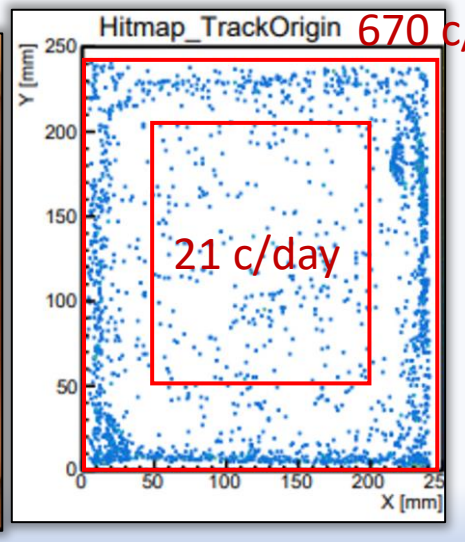
Background reduction overview

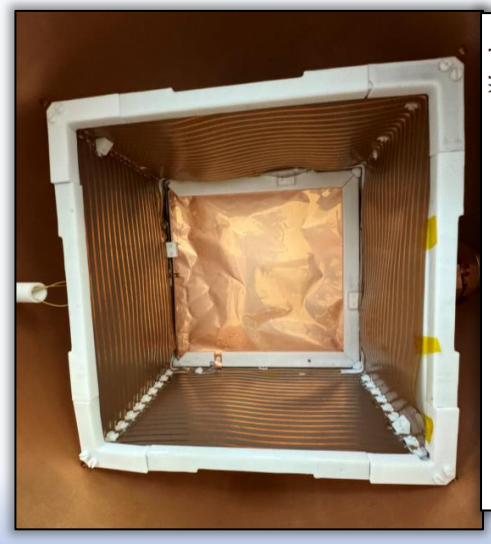
<2022	2022	2023	2024	2025
▪ High LE background: 600 dru ▪ Dominated by 222Rn from the gas filters	▪ Reduced LE background to 100 dru (open loop) ▪ New Micromegas installed	▪ Relocation to Lab2500 ▪ Same alpha background levels	▪ Replace cathode to Copper-Kapton ▪ Cathode still contaminated	▪ Major intervention to replace field cage ▪ New wired cathode installed

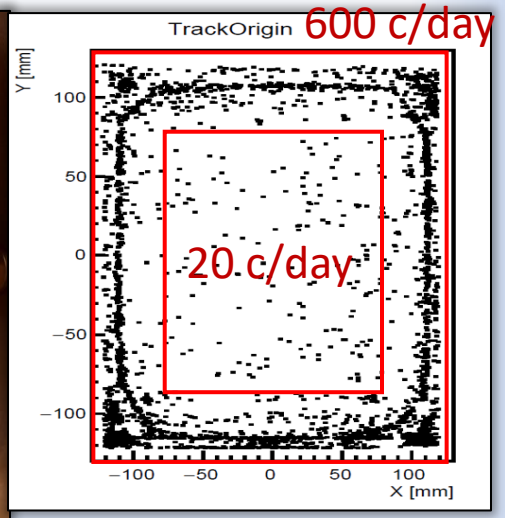


Background reduction overview

<2022	2022	2023	2024	2025
▪ High LE background: 600 dru ▪ Dominated by 222Rn from the gas filters	▪ Reduced LE background to 100 dru (open loop) ▪ New Micromegas installed	▪ Relocation to Lab2500 ▪ Same alpha background levels	▪ Replace cathode to Copper-Kapton ▪ Cathode still contaminated	▪ Major intervention to replace field cage ▪ New wired cathode installed







Background reduction overview

<2022

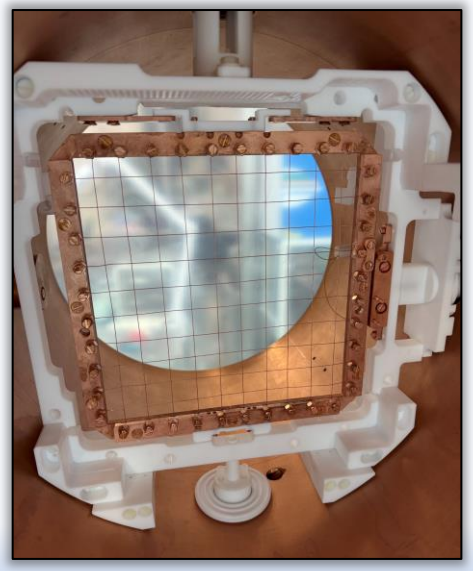
- High LE background: 600 dru
- Dominated by 222Rn from the gas filters

2022

- Reduced LE background to 100 dru (open loop)
- New Micromegas installed

2023

- Relocation to Lab2500
- Same alpha background levels



2024

- Replace cathode to Copper-Kapton
- Cathode still contaminated

2025

- Major intervention to replace field cage
- New wired cathode installed

Background reduction overview

- High LE background: 600 dru
- Dominated by 222Rn from the gas filters

- Reduced LE background to 100 dru (open loop)
- New Micromegas installed

- Relocation to Lab2500
- Same alpha background levels

- Replace cathode to Copper-Kapton
- Cathode still contaminated

- Major intervention to replace field cage
- New wired cathode installed

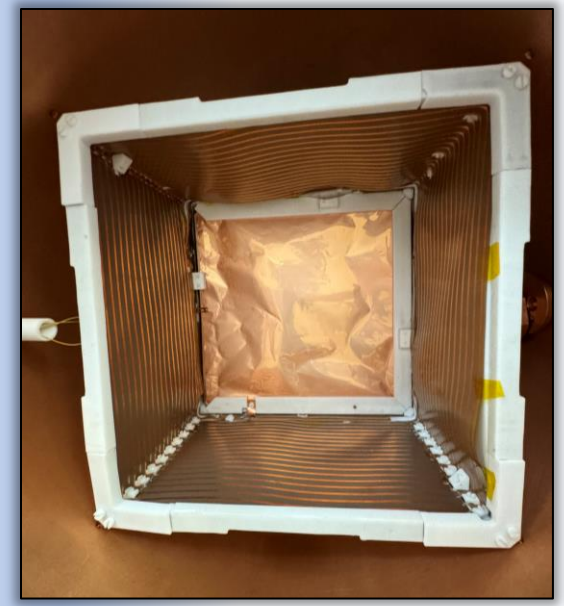
New since last SC presentation

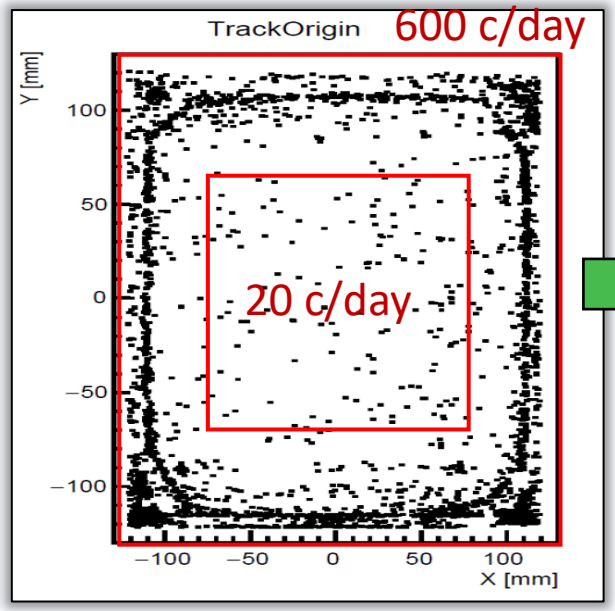
High energy background after intervention

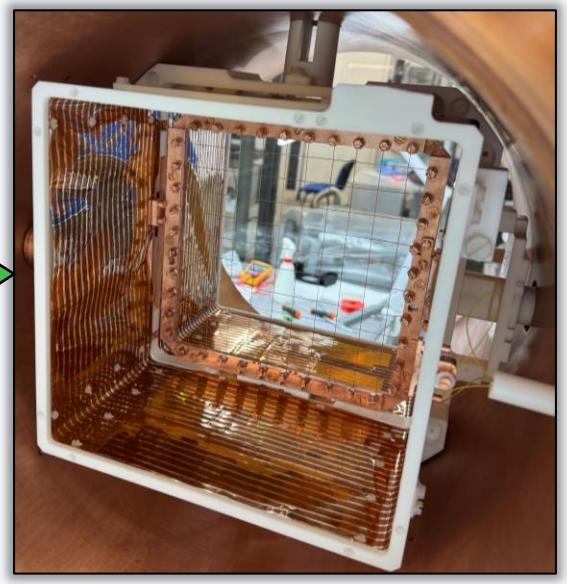
- Less overall alphas
  - Less teflon in the new field cage

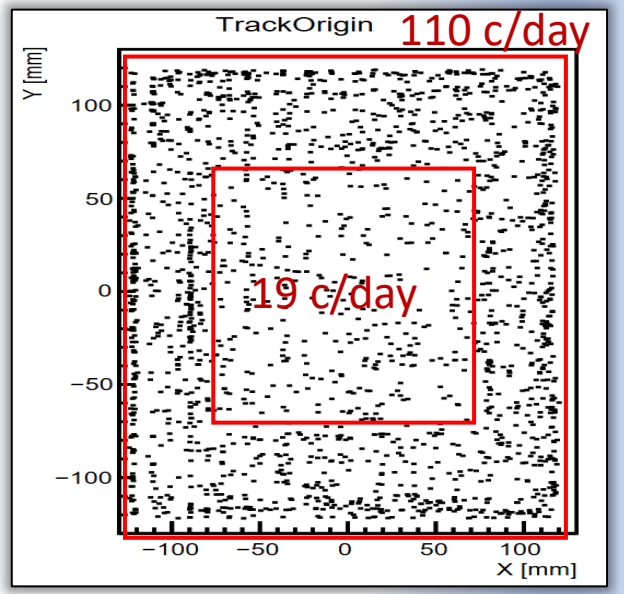
- Same fiducial area rate

PRELIMINARY



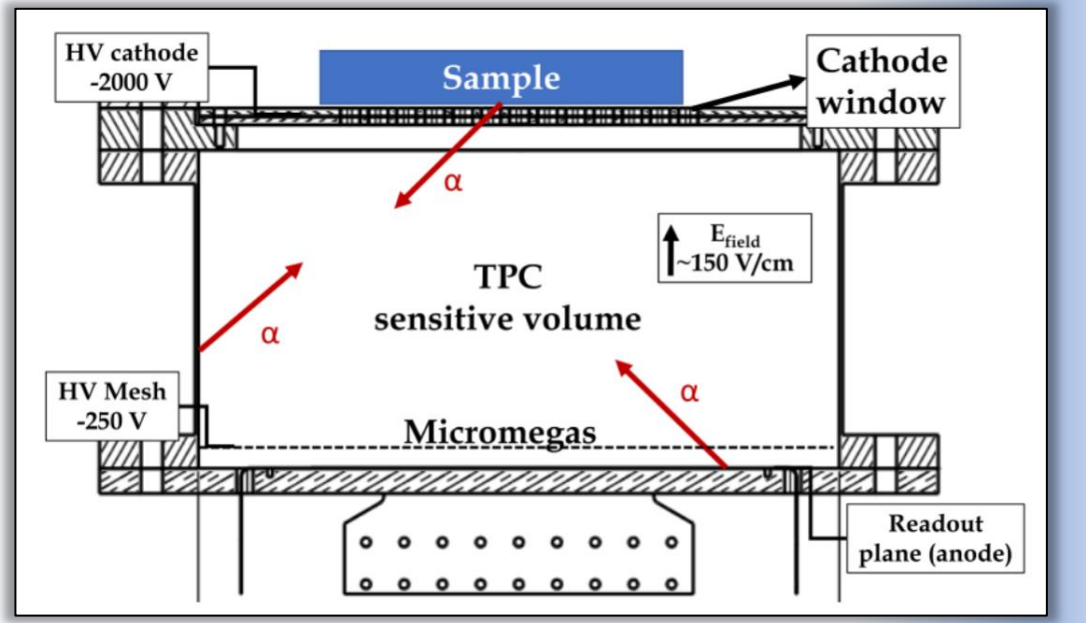


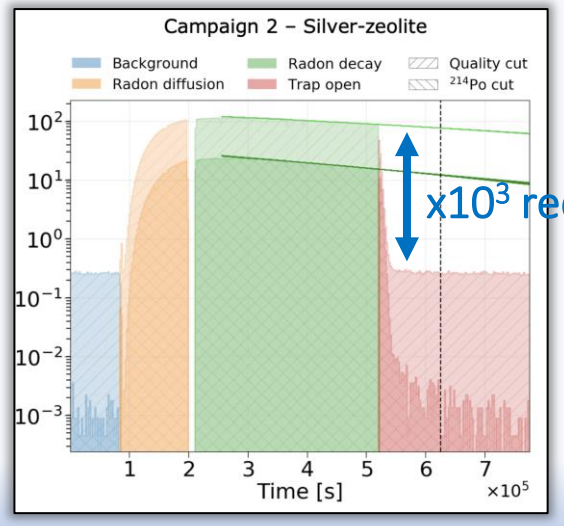




High energy background: AlphaCAMM

- Tests with wired cathode do not support the superficial contamination hypothesis
- Measurements with thoron emanator source
- First tests with silver-zeolite filters
  - x10 reduction after flushing with ^{222}Rn source
  - Improving the setup





arXiv:2505.07979

Future plans

End of 2025

- Commissioning and assessment of the intervention improvements
- Operation with Ne+2%iso
- Gas system upgrades for the use of flammable gases

First half of 2026

- Completion of neutron shielding
- Physics run with Ne+2% isobutane or more if possible
- Implementation of silver-zeolites filters

Second half of 2026

- Extended data-taking at higher pressure