TREX-DM
A search for low-mass WIMPS with mM

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Outline

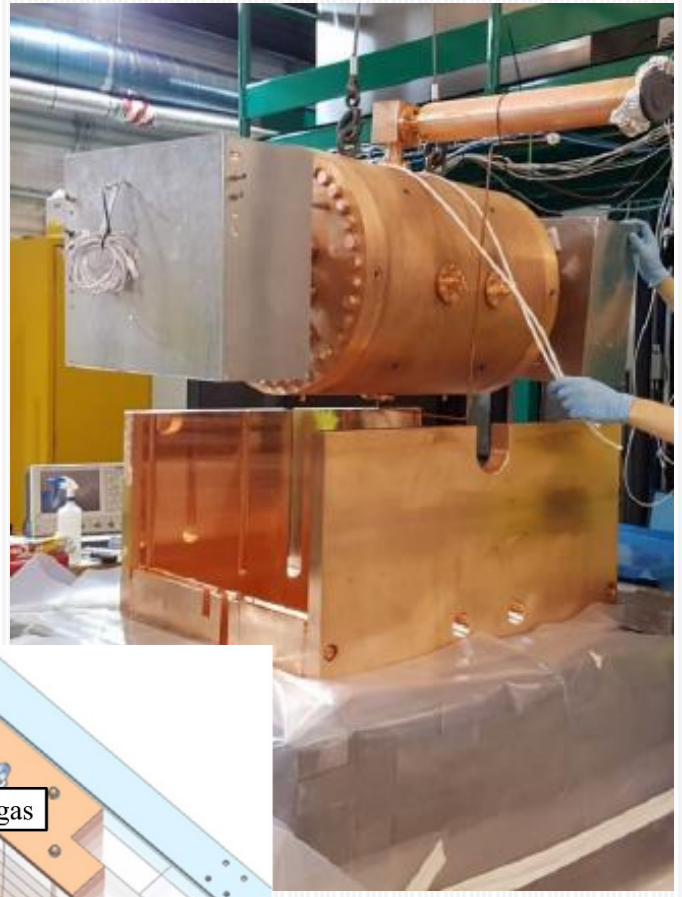
What, Why and How .. Is TREX-DM

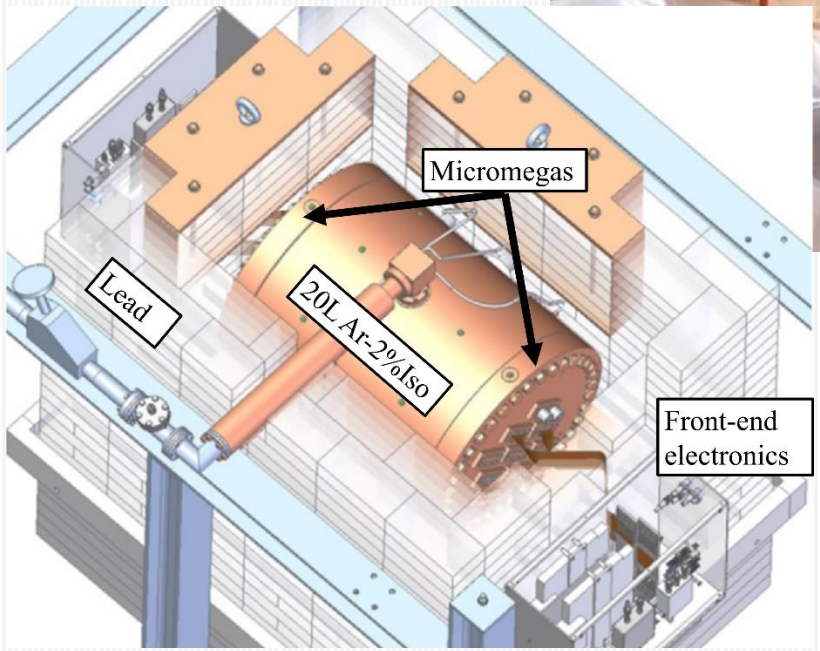
Past and current challenges

Prospects

TREX-DM

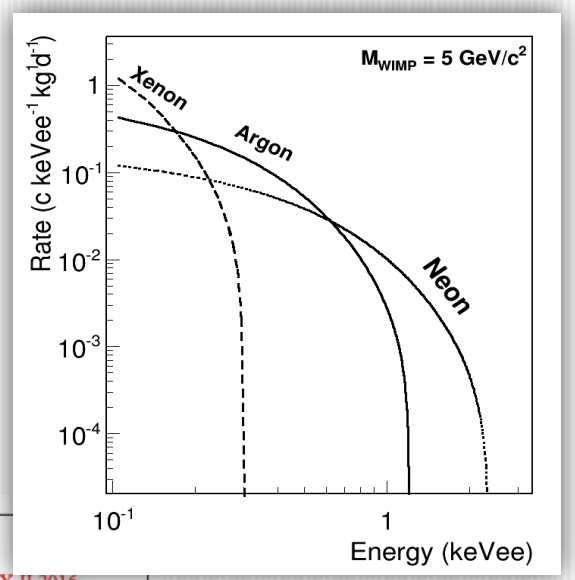
- Detector looking for low-mass WIMPs
- HP (up to 10 bar), symmetrical gas TPC
  - Active volume of 20L @ 10bar
    (~0.32 kg Ar or ~0.16 kg Ne)
- Shielding
  - 5cm copper + 20cm lead walls
  - Polyethylene ceiling + water
- Located at Laboratorio Subterráneo de Canfranc (LSC) (2400 m.w.e.)

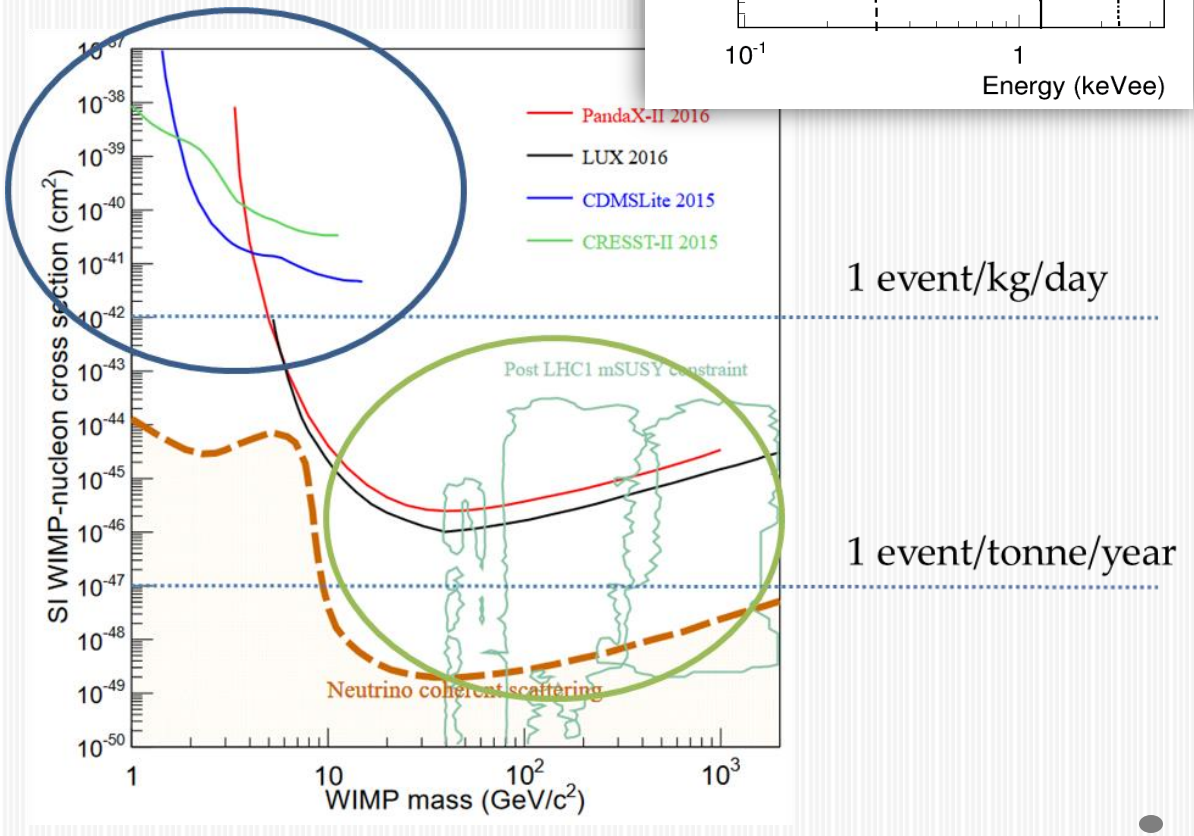




Purpose and motivation

- Community interest shifted to low masses (< 10 GeV/c^2)
- Requisites:
  - Light nuclei as target
  - Very low energy threshold (< 1 keVee)
  - Low background level



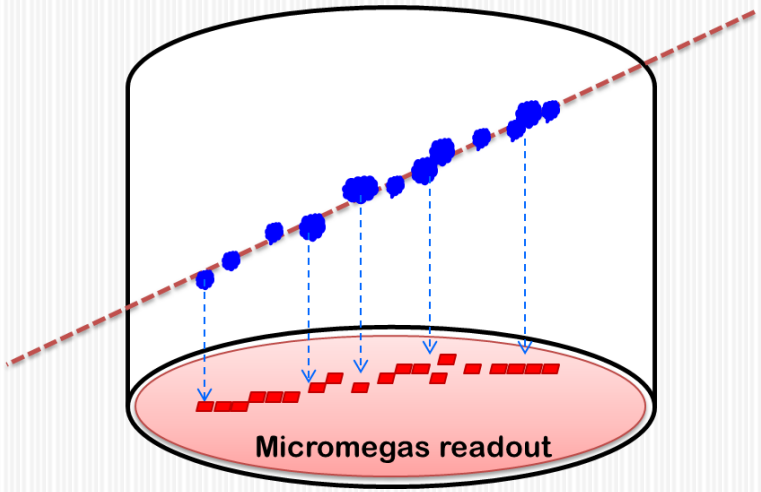


Why Gas TPC?

T-REX: merge MPGD-read TPC + low background techniques

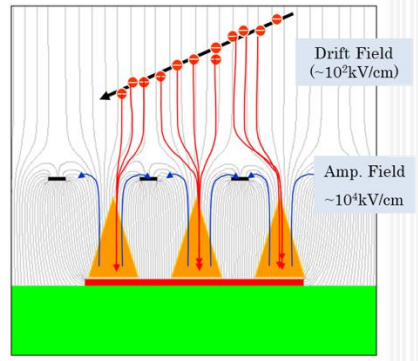
TPCs for Rare-Event searches

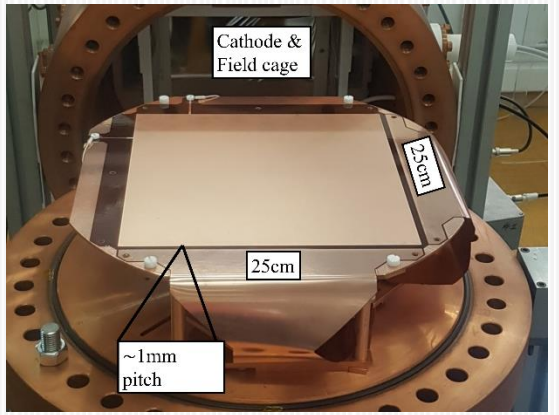
- Target selection flexibility
- Low energy threshold
- Highly segmented readouts available
- Access to rich topological information



Micromegas

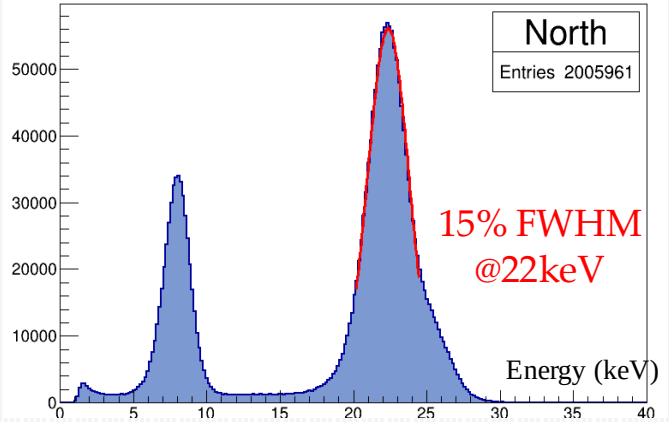
- Consolidated structures
- Microbulk flavour particularly interesting
  - Low intrinsic radioactivity
  - Good energy resolution
  - Low energy threshold
  - Topological information
  - Scaling-up

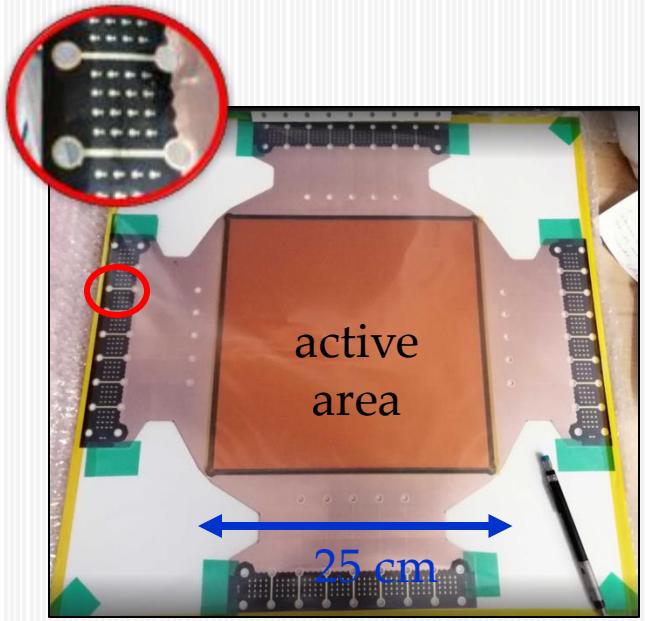


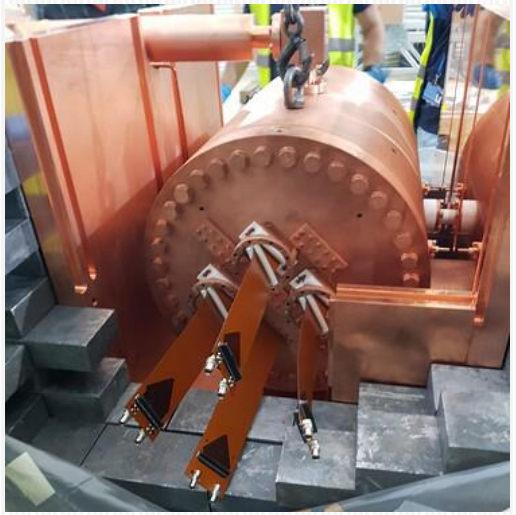


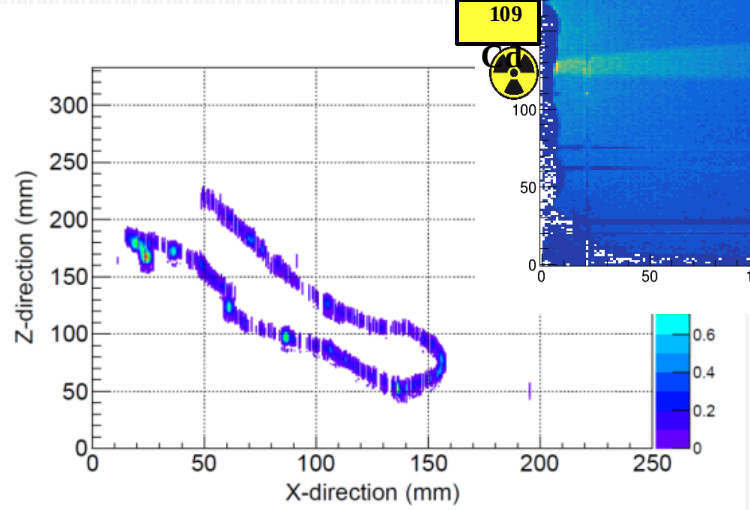
Equipping TREX-DM with microbulk mM

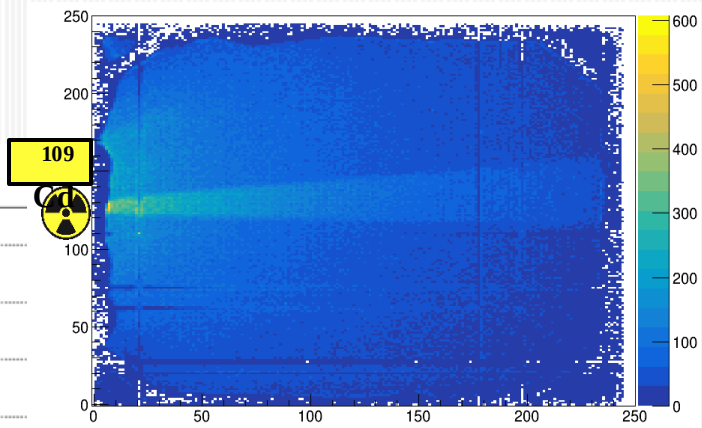
- Biggest microbulk surface built
- Radioactivity Control in process
- Energy resolution
- Segmentation 512 channels: 256 X strips, 256 Y strips





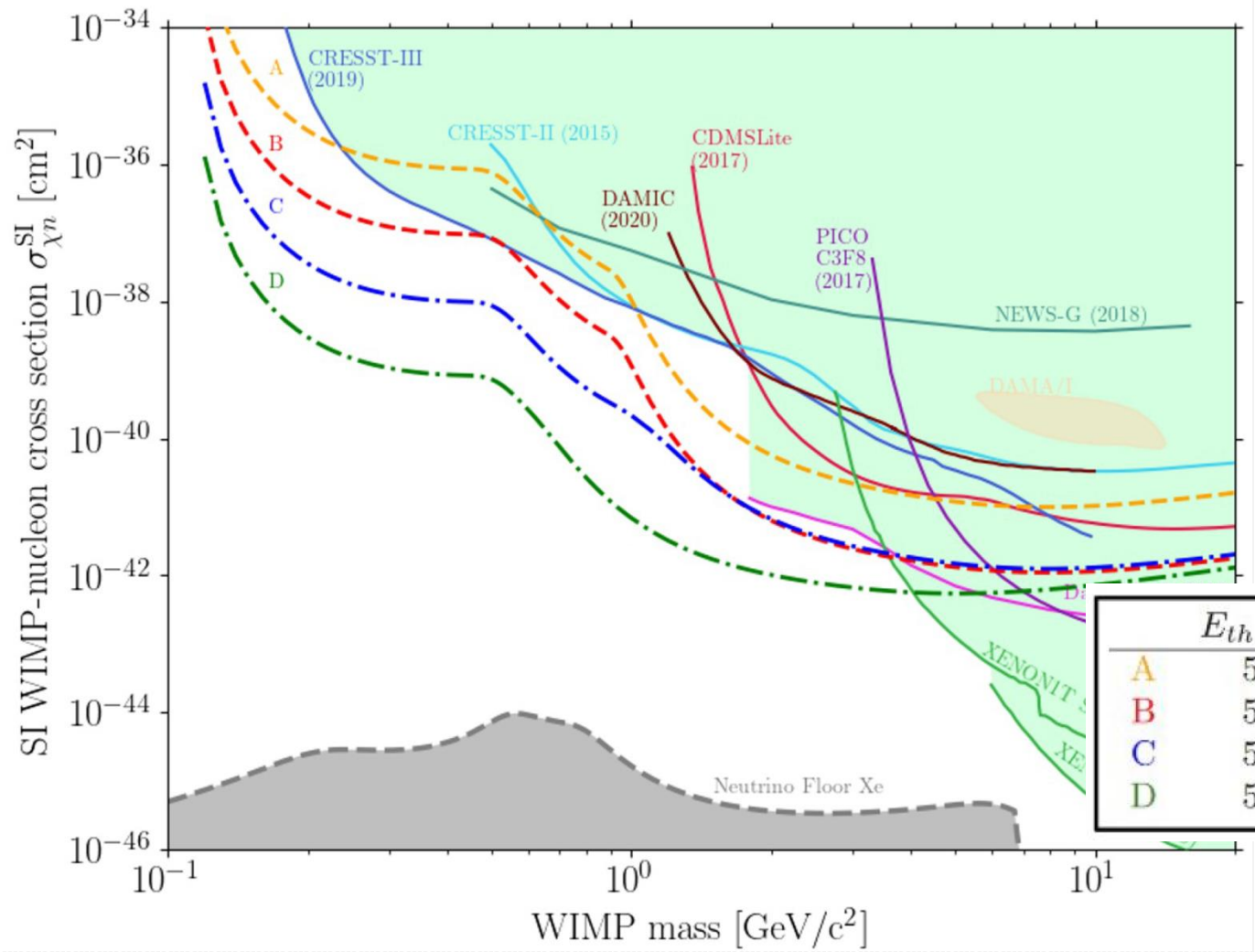






Building TREX-DM with the new mM

What can TREX-DM do?



Probe uncharted area

Offer a new technology

Change target

	E_{th} (eV_{ee})	B(dru)	Exp (kg y)	Gas
A	50	100	0.32	Ar-1%Iso
B	50	1	0.32	Ar-1%Iso
C	50	1	0.32	Ar-10%Iso
D	50	0.1	1.6	Ne-10%Iso

What has TREX-DM done so far?

2018:
Installation at LSC

2019-2021:
Data taking with Ar & Ne

Data-taking at 4 bar, sealed mode
Connectivity issues with mM
Background level 2 orders higher than expected
^{222}Rn Contamination, reduced to 1 order

June 2022:
New Micromegas

New mM
Face-to-face connectors
Change of internal components
Open-loop operation

Sep 2022-July 2023:
Relocation tasks

Site preparation (electrical, gas, crane, …)
Chamber transportation and installation
Lead shielding assembling
DAQ & SlowControl re-commissioning
Leak tests, High Voltage tests
…

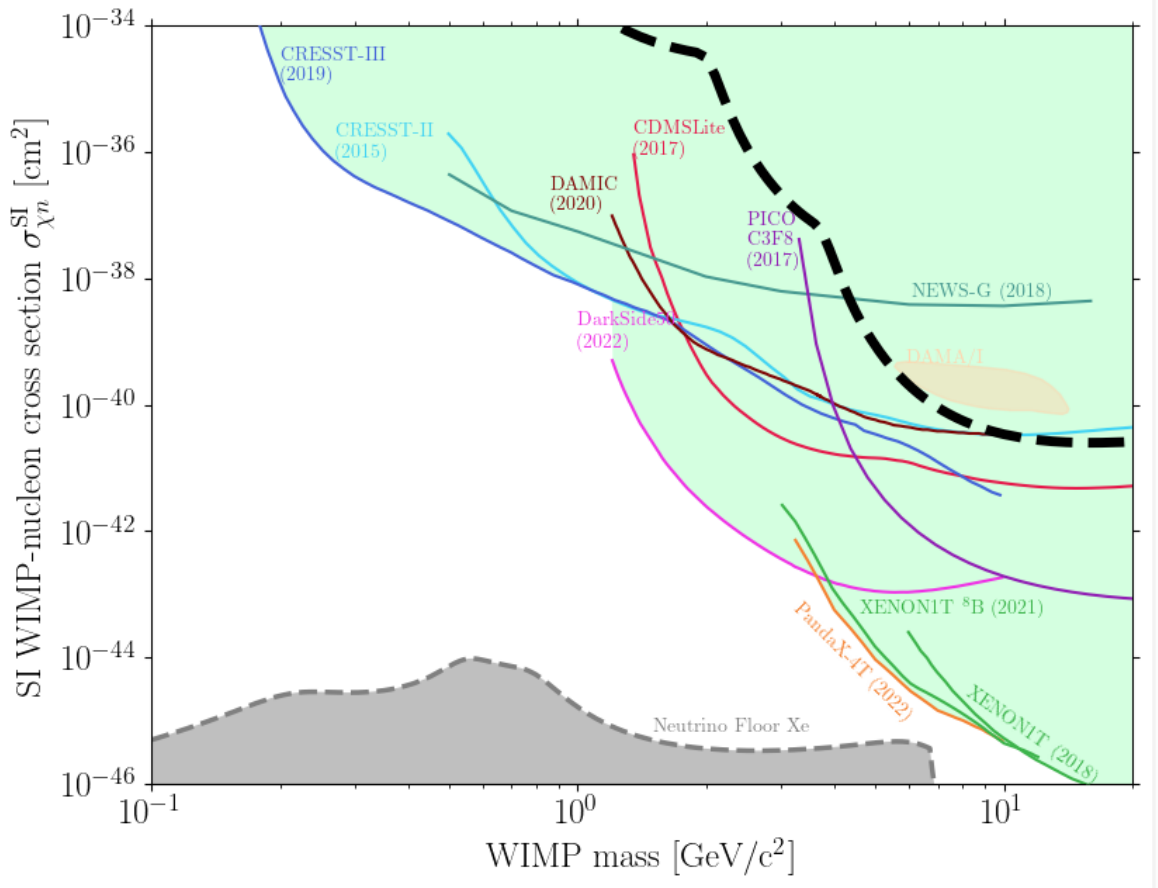
July 2023:
Commissioning @LAB2500

Some issues came up:
addressed April and July 2024

Aug 2023 – present:
Data-taking for comparison

So, currently…

	E_{th} (eV_{ee})	B(dru)	Gas
Z	1000	100	Ar-1%Iso



(dru = keV $^{-1}$ kg $^{-1}$ day $^{-1}$)

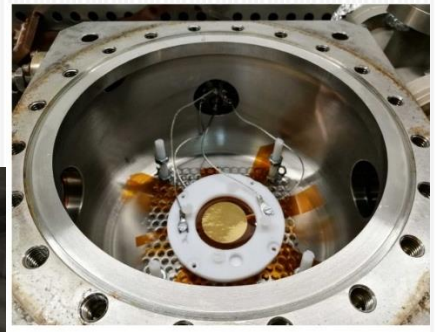
How can it be improved?

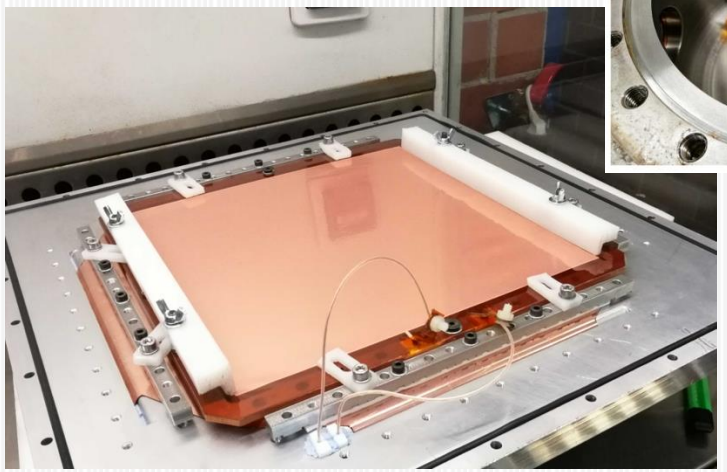
- Main Challenges to be addressed
  - Energy threshold
  - Background level
  - Gas composition
  - Operation stability

How can it be improved? (I)

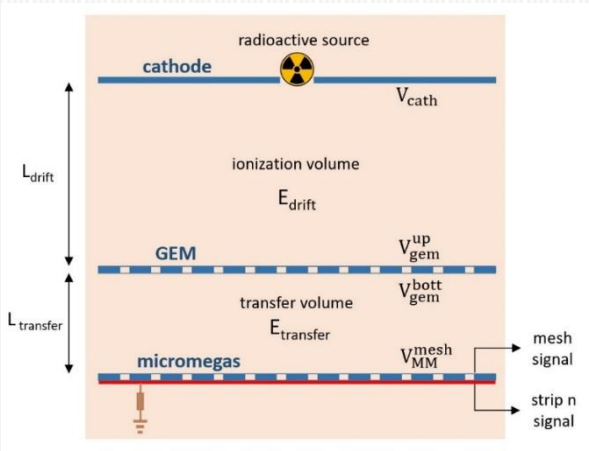
- Main Challenges to be addressed
  - **Energy threshold**
    - preamplification volume (with a GEM?)

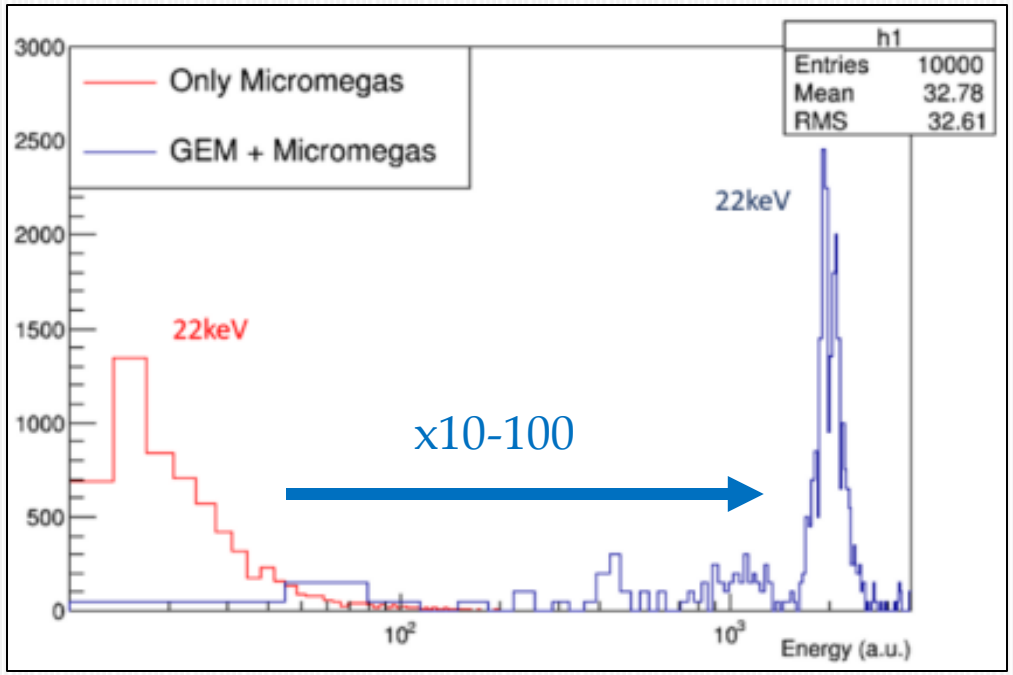
    factors would allow very low energy threshold (even single electron)
      - Big microbulk mM @1bar (x100)
      - Small microbulk mM @1-10bar (x100 to x10)





publication in preparation





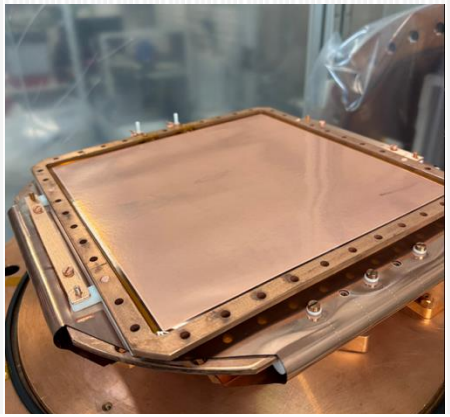
How can it be improved? (Ib)

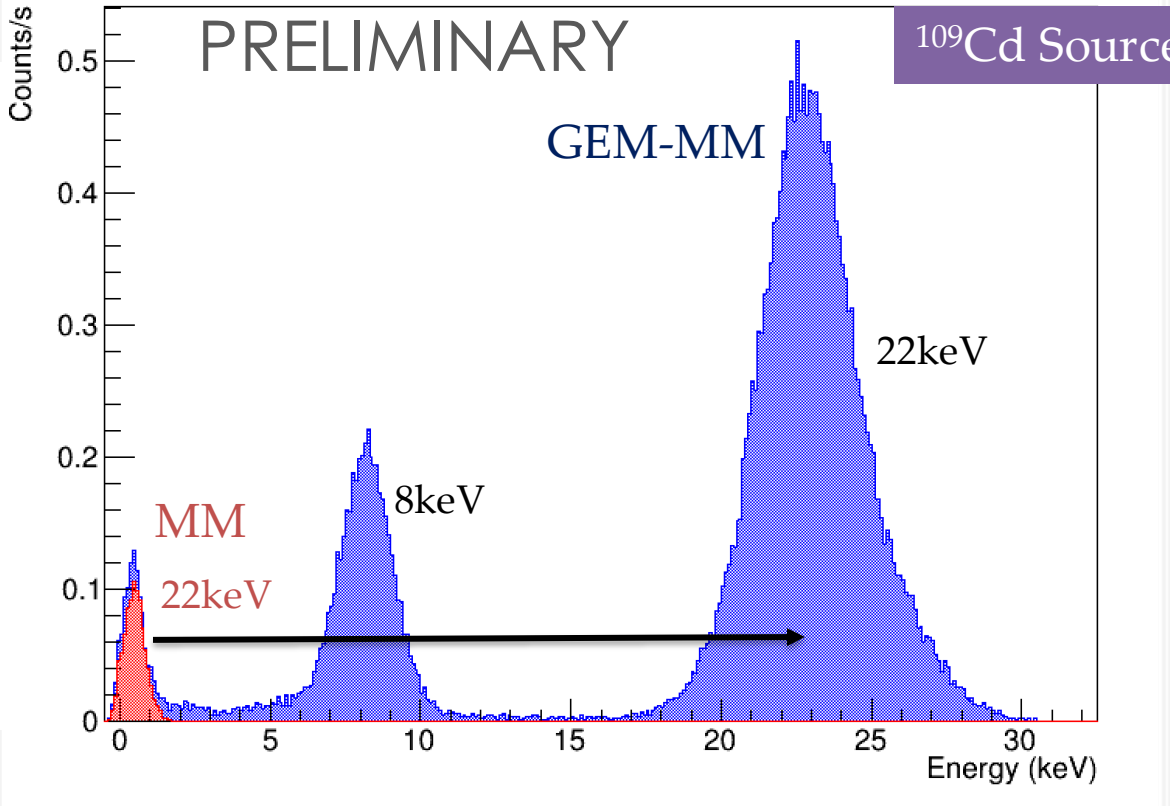
- Main Challenges to be addressed
  - **Energy threshold**
    - preamplification volume (with a GEM?)

    factors would allow very low energy threshold (even single electron)
      - Big microbulk mM @1bar (x100)
      - Small microbulk mM @1-10bar (x100 to x10)
  - In TREX-DM since July
    - Ar 1bar, moderate gains

    Vmesh: 270V, Vgem:270V
    - factor~20

GEM-MM
in TREX-DM



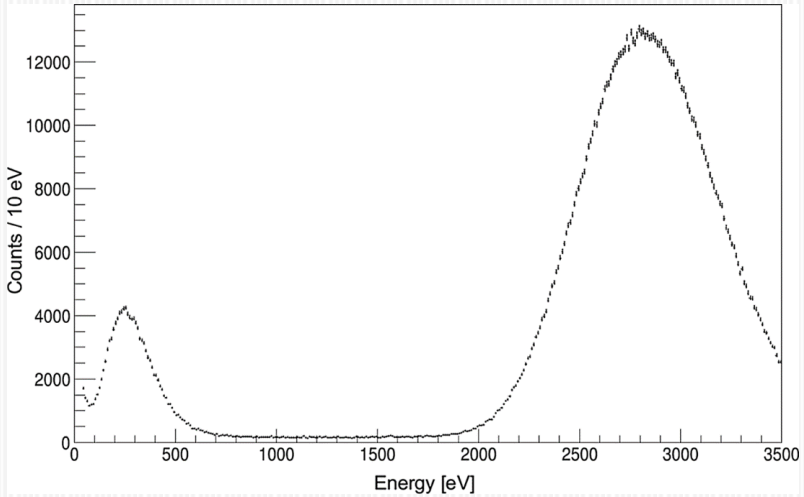


How can it be improved? (Ic)

- Main Challenges to be addressed
  - **Energy threshold**
    - Low-energy calibrations
      - ^{37}Ar (2.82 keV, 0.27 keV)
        - Used in XENON1T and NEWS-G
        - Gas, volumetric distribution
      - Tests at CEA, Saclay with an Am-Be source
      - ^{40}Ca (n, a) ^{37}Ar

Using an Am-Be source

In a small setup @CEA, Saclay



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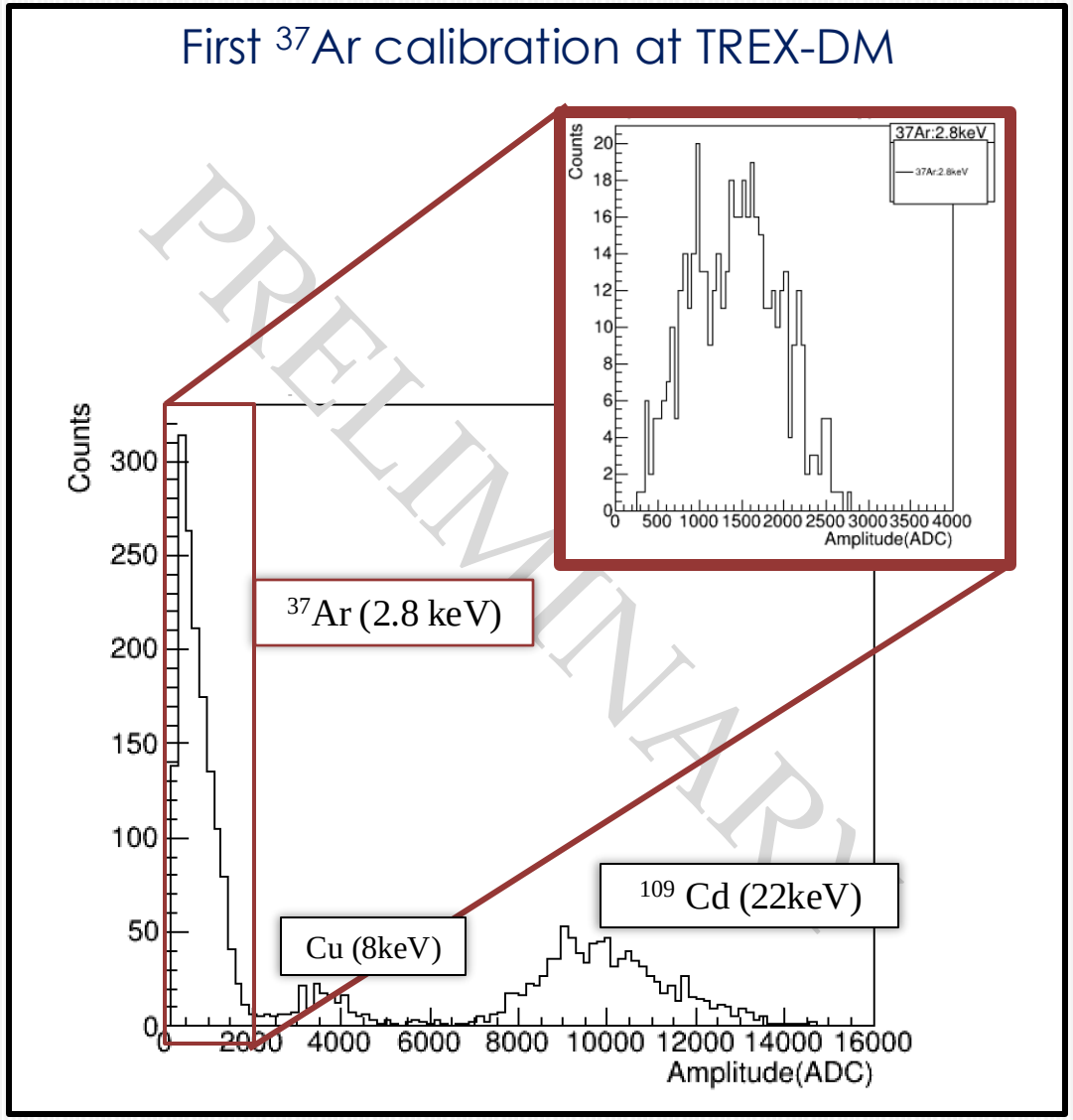
  - **Energy threshold**
    - Low-energy calibrations
      - ^{37}Ar (2.82 keV, 0.27 keV)
        - Used in XENON1T and NEWS-G
        - Gas, volumetric distribution
      - Irradiation with n beam at CNA, Sevilla
      - ^{40}Ca (n, a) ^{37}Ar

40Ca

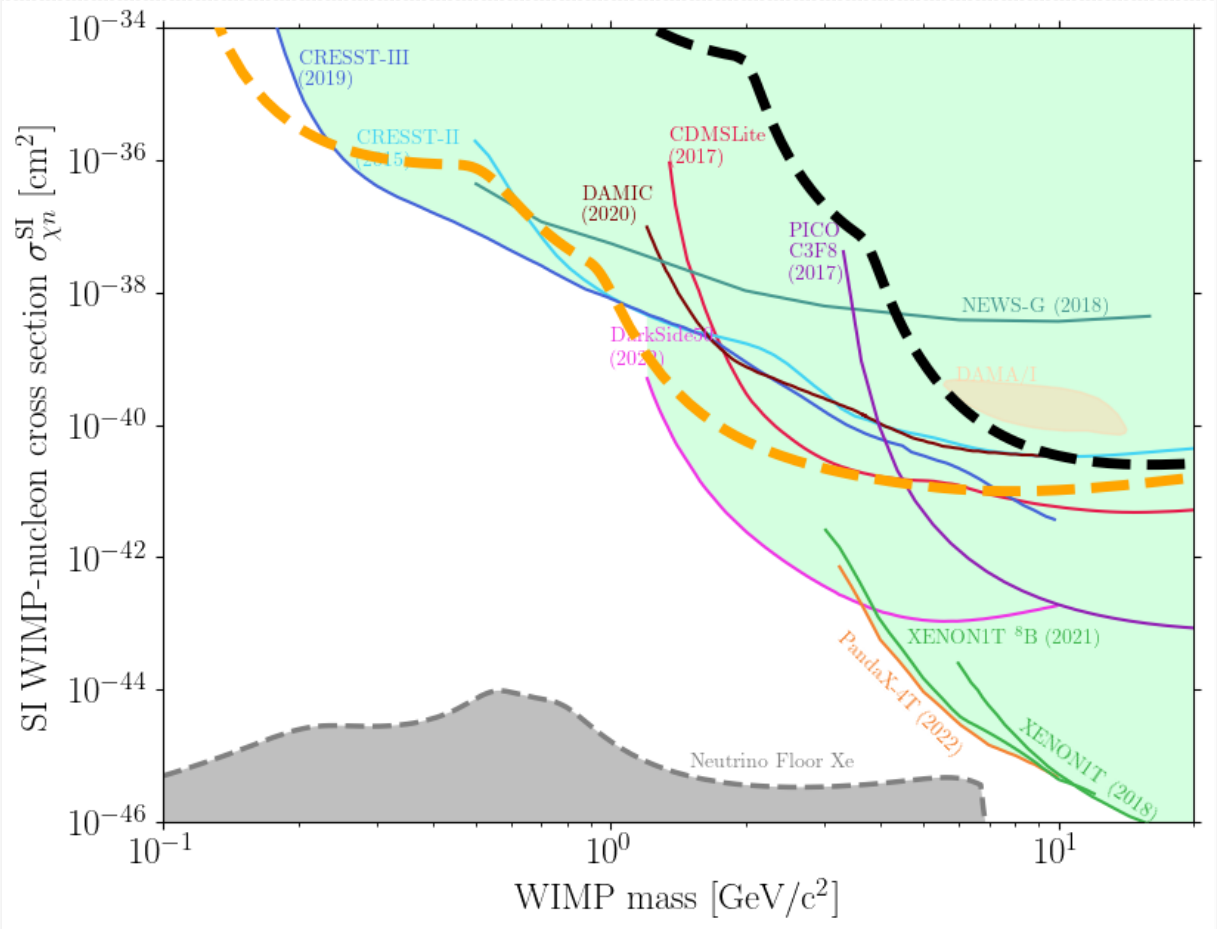
6 h
~ 1 kBq



How can it be improved? (Ic)

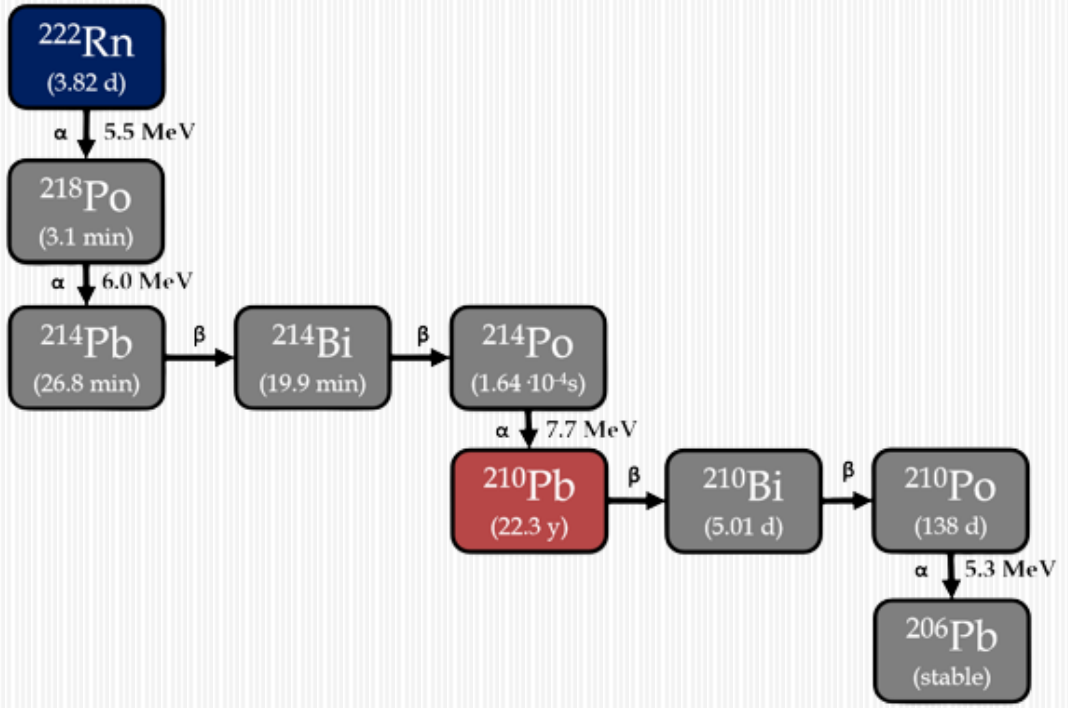
- Main Challenges to be addressed
  - **Energy threshold**

	E_{th} (eV_{ee})	B(dru)	Gas
Z	1000	100	Ar-1%Iso
A	50	100	Ar-1%Iso



How can it be improved? (II)

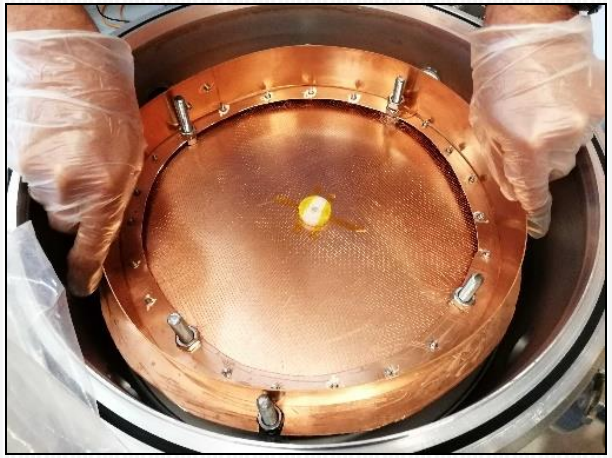
- Main Challenges to be addressed
  - Energy threshold
  - **Background level**
    - Initially dominated by ^{222}Rn, attributed to the purifiers
    - Switched from sealed mode to open loop:
      - 600dru to 100dru (dru = $keV^{-1}\,kg^{-1}\,day^{-1}$)
    - June 2022-now:
      - ^{222}Rn progeny contamination on mylar cathode surface
      - Changing to a cleaner cathode estimate: 1-10dru

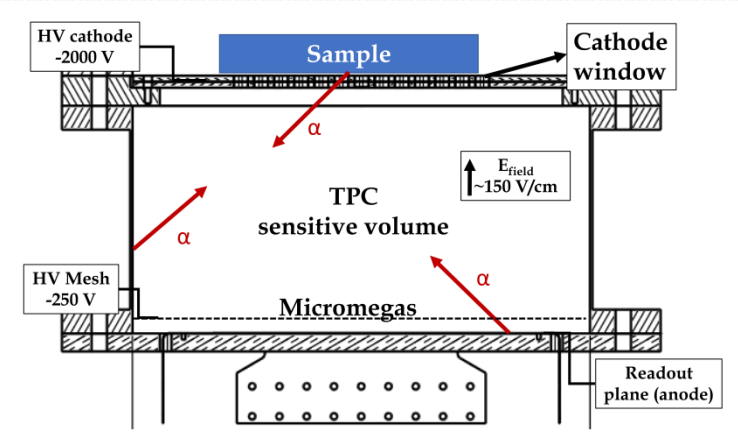


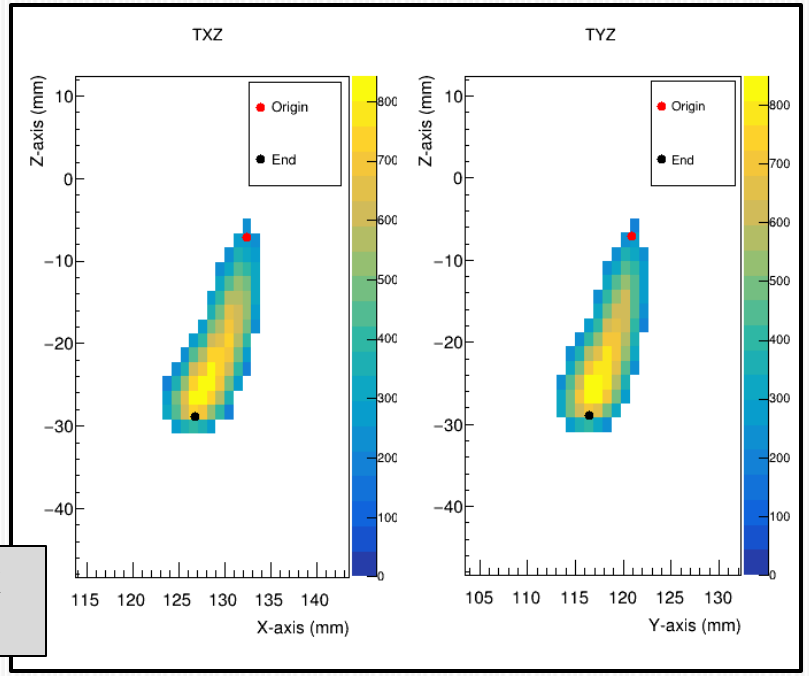
How can it be improved?(IIb)

- Main Challenges to be addressed
  - Energy threshold
  - **Background level**
    - AlphaCAMM:

      screening α surface contamination (^{210}Pb)
      - Goal sensitivity: 100nBq/cm^2
      - Excellent track reconstruction identifies tracks coming from sample







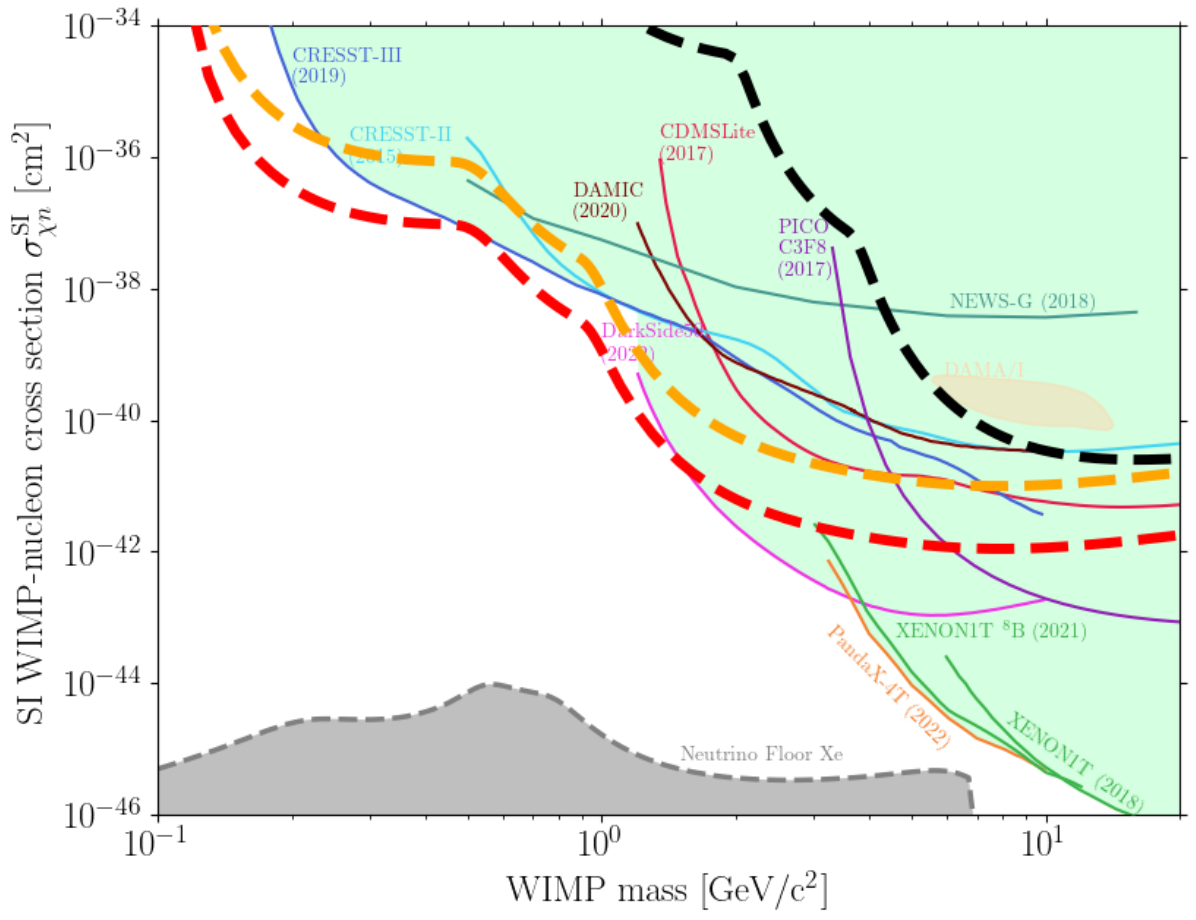
a particle track reconstruction

How can it be improved?(IIc)

- Main Challenges to be addressed
  - Energy threshold
  - **Background level**

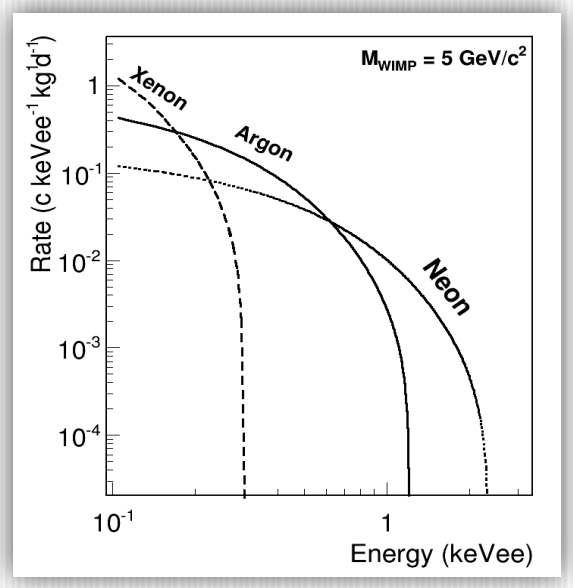
	E_{th} (eV_{ee})	B(dru)	Gas
Z	1000	100	Ar-1%Iso
A	50	100	Ar-1%Iso
B	50	1	Ar-1%Iso

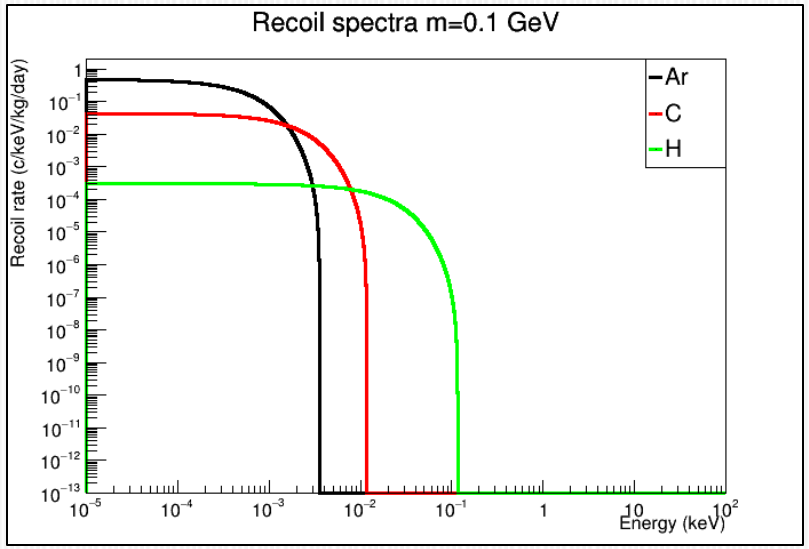
Exposure 0.32 kg y

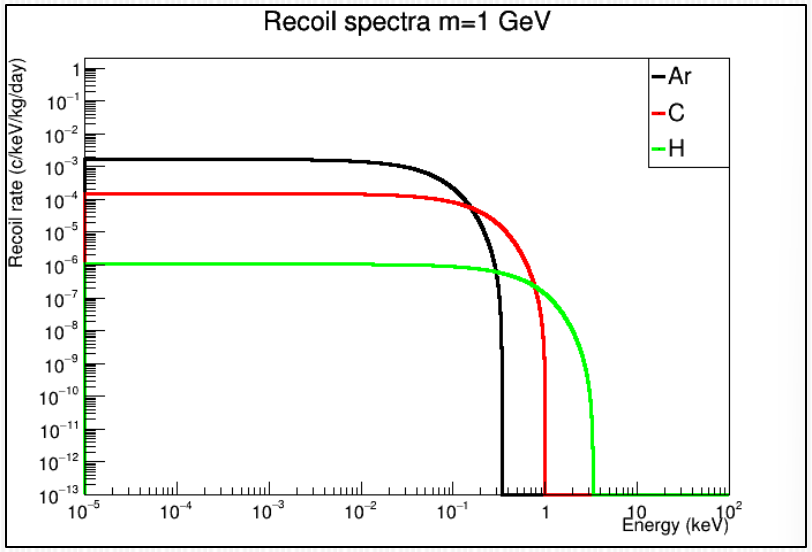


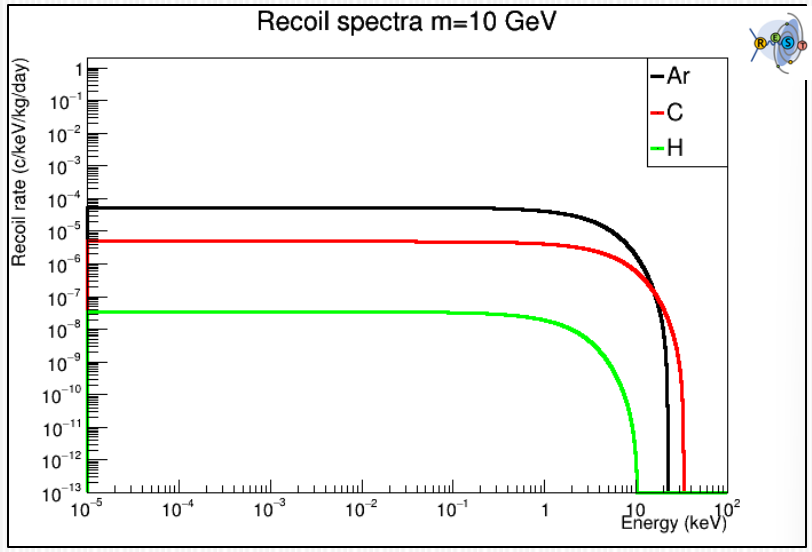
How can it be improved? (III)

- Main Challenges to be addressed
  - Energy threshold
  - Background level
  - **Gas composition improvement**
    - Target change (Ne, Ar depleted +iC4H10)
    - Increasing presence of H







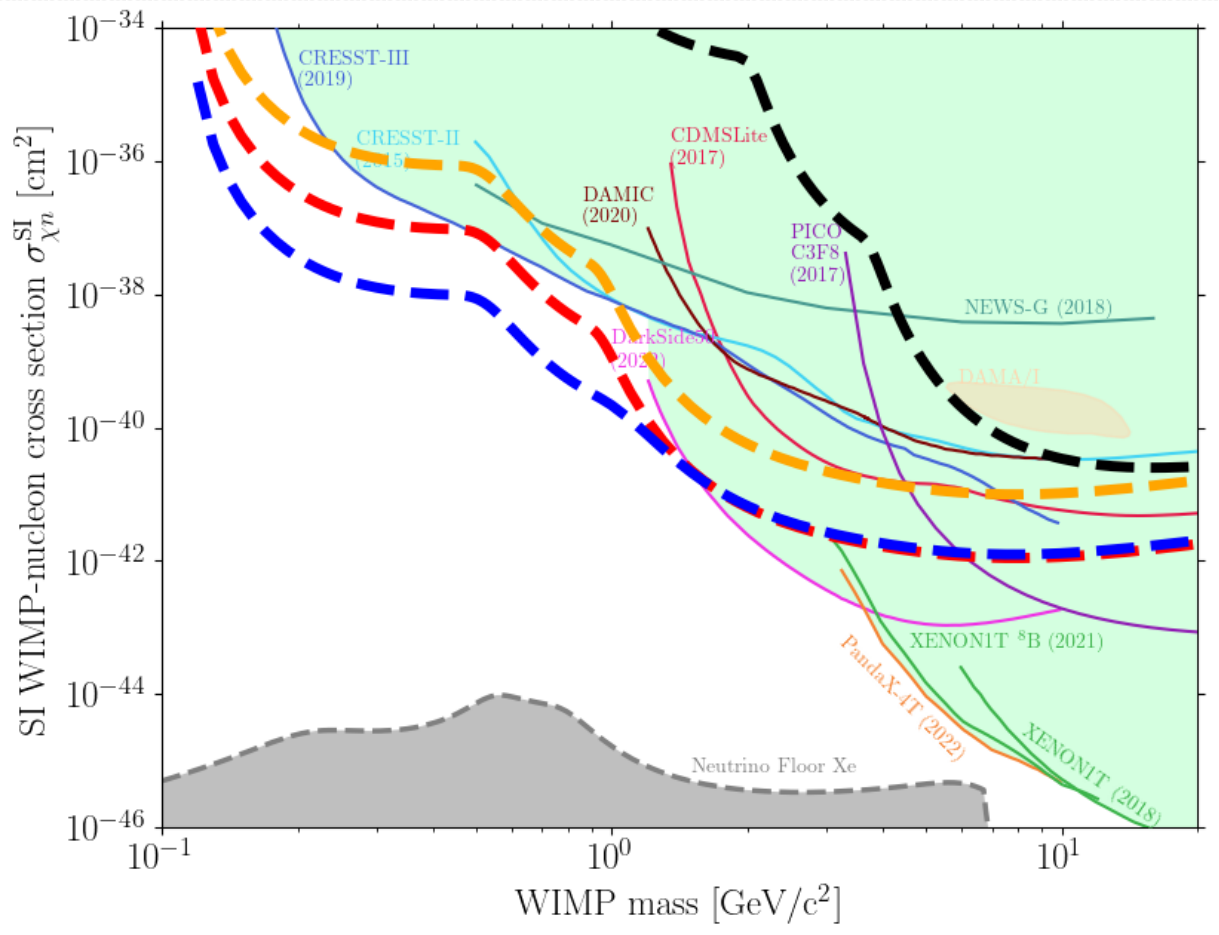


How can it be improved? (IIIb)

- Main Challenges to be addressed
  - Energy threshold
  - Background level
  - **Gas composition improvement**
    - Target change (Ne, Ar depleted)
    - Increasing presence of H

	E_{th} (eV_{ee})	B(dru)	Gas
Z	1000	100	Ar-1%Iso
A	50	100	Ar-1%Iso
B	50	1	Ar-1%Iso
C	50	1	Ar-10%Iso

Exposure 0.32 kg y



How can it be improved? (IV)

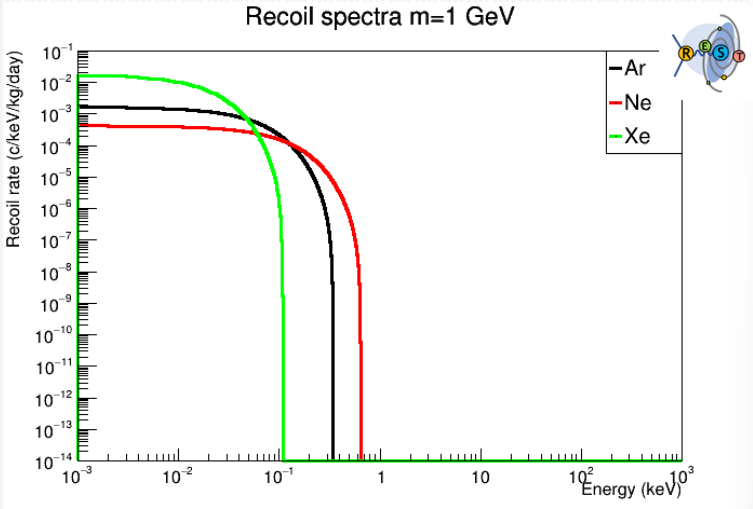
- Main Challenges to be addressed
  - Background level
  - Energy threshold
  - Gas composition improvement
  - **Operation stability**
    - Gas quality
    - Noise
    - Voltage operations
    - Leak currents at detector connections

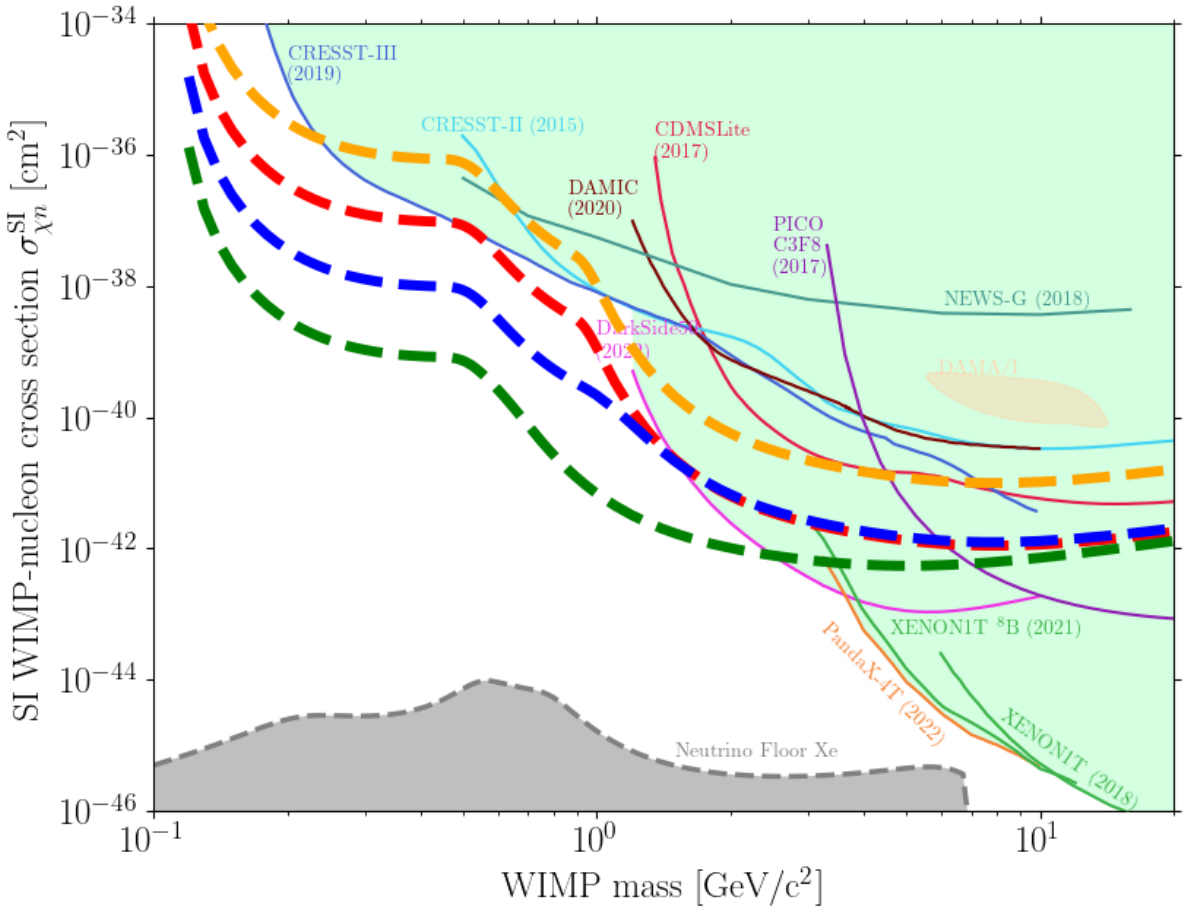
TREX-DM prospects

Exposure 0.32 kg y

	E_{th} (eV_{ee})	B(dru)	Gas
Z	1000	100	Ar-1%Iso
A	50	100	Ar-1%Iso
B	50	1	Ar-1%Iso
C	50	1	Ar-10%Iso
D	50	0.1	Ne-10%Iso

Exposure 1.6 kg y





Conclusions

- TREX-DM offers a technology that can be very sensitive to low-mass WIMPs
- Continuous R&D gives birth to ‘spin-off’ projects of great interest
- Despite the delay due to the relocation, TREX-DM continues data taking / near term roadmap towards competitive background level & threshold

TREX-DM

- 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**
- *Readout technologies for directional WIMP Dark Matter detection*. **Phys. Rept. 662 (2016) 1-46**
- *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**