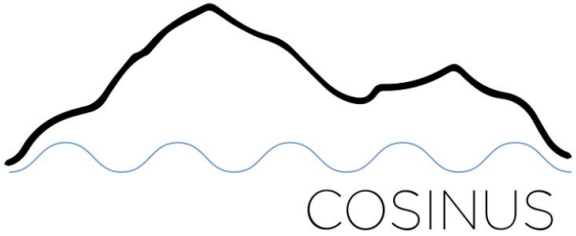

The COSINUS experiment: utilizing cryogenic NaI crystals for direct dark matter detection

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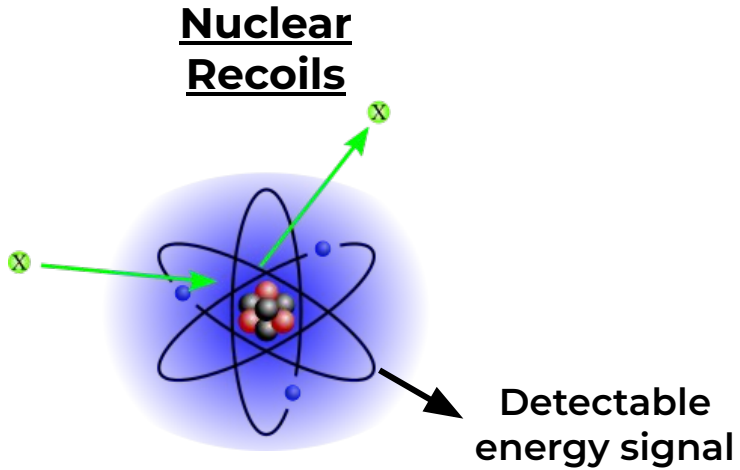
Direct dark matter detection

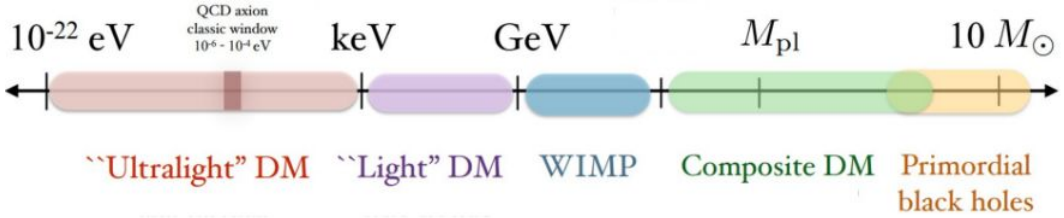
Dark matter

- No charge
- No self-interaction
- Cold
- Stable

WIMP

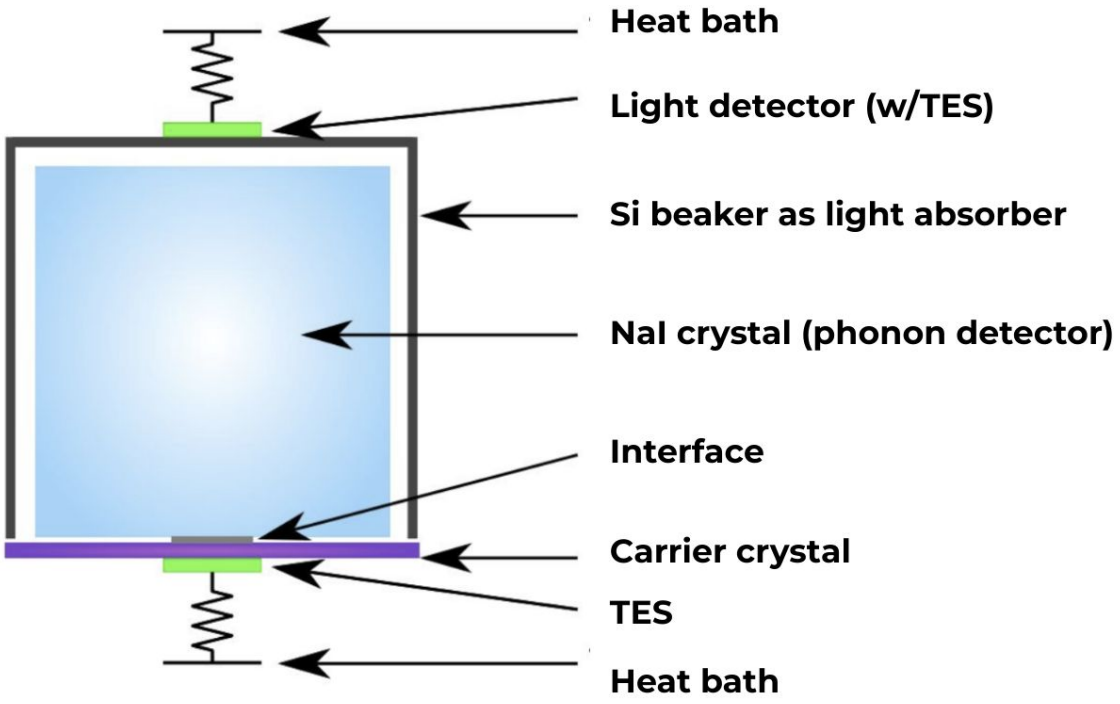
- All above and…
- O(GeV) mass

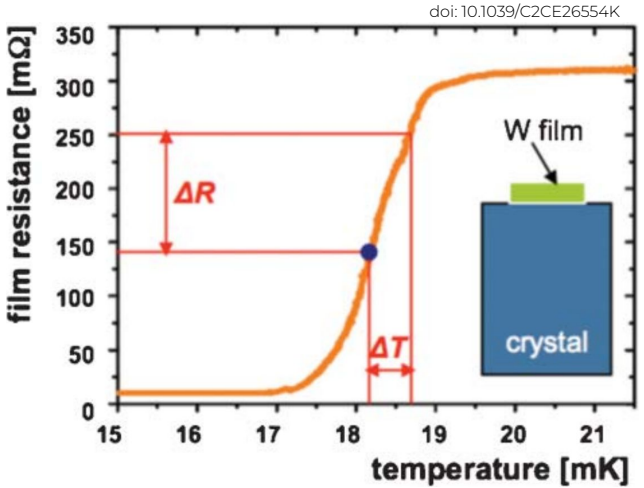




T. Lin (2019)

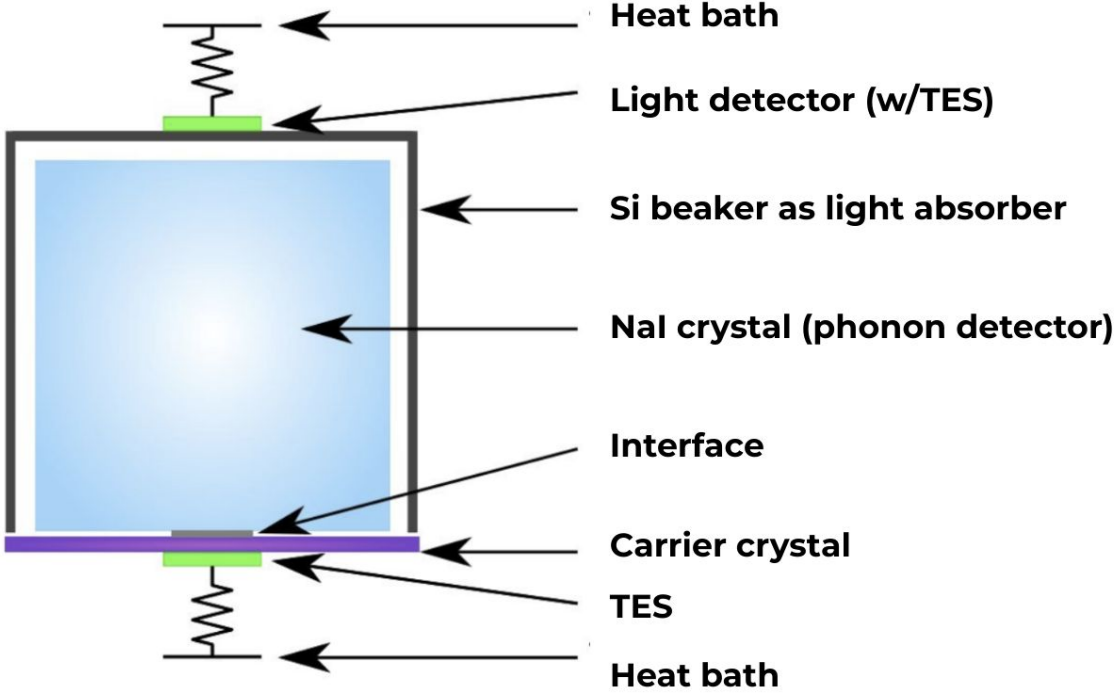
Cryogenic detectors



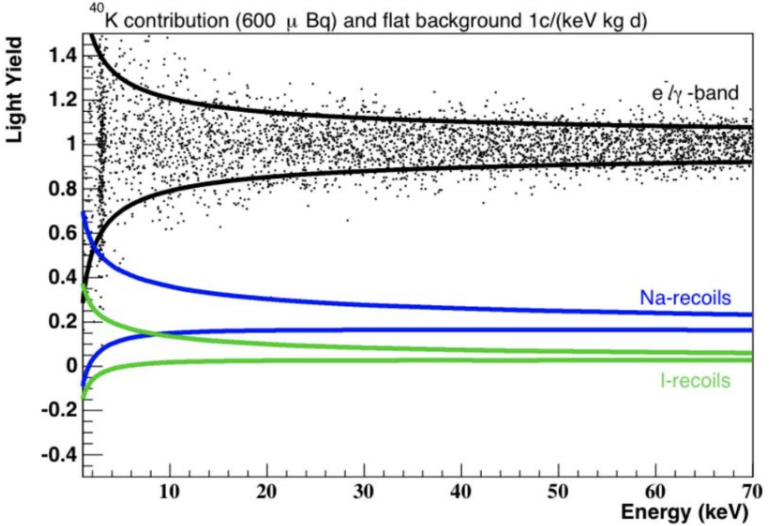


doi: 10.1140/epjc/s10052-022-10184-5

Cryogenic detectors



Particle discrimination (NaI)



$$Light\ yield = \frac{Energy\ in\ Light}{Total\ Energy}$$

doi: 10.1140/epjc/s10052-022-10184-5

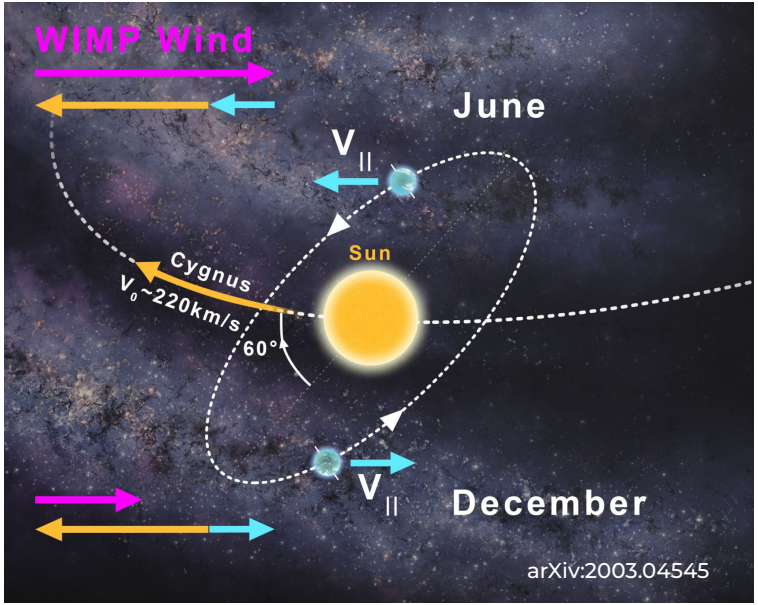
COSINUS

Cryogenic Observatory for Signals seen in Next Generation Underground Searches

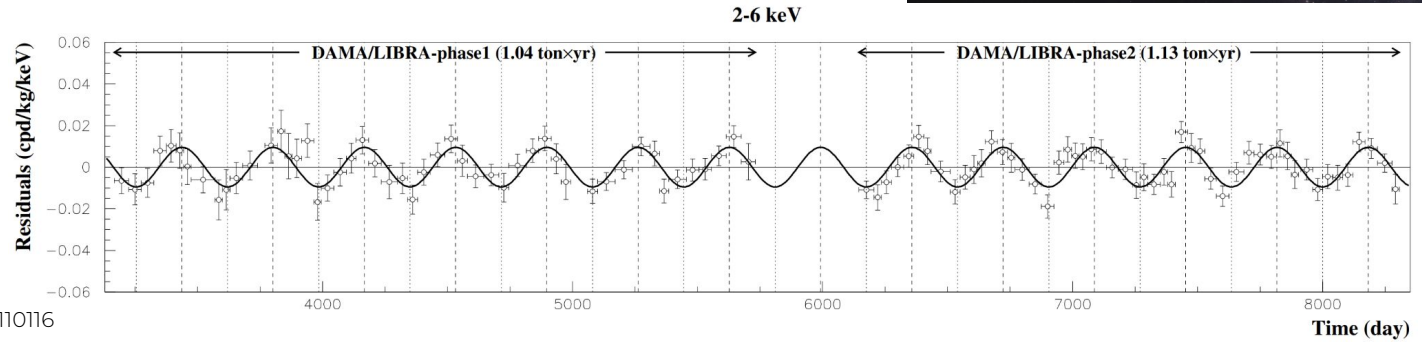
COSINUS

DM signal annual modulation

→ Movement of Earth respect to DM wind should lead to an annual modulation of the DM signal.



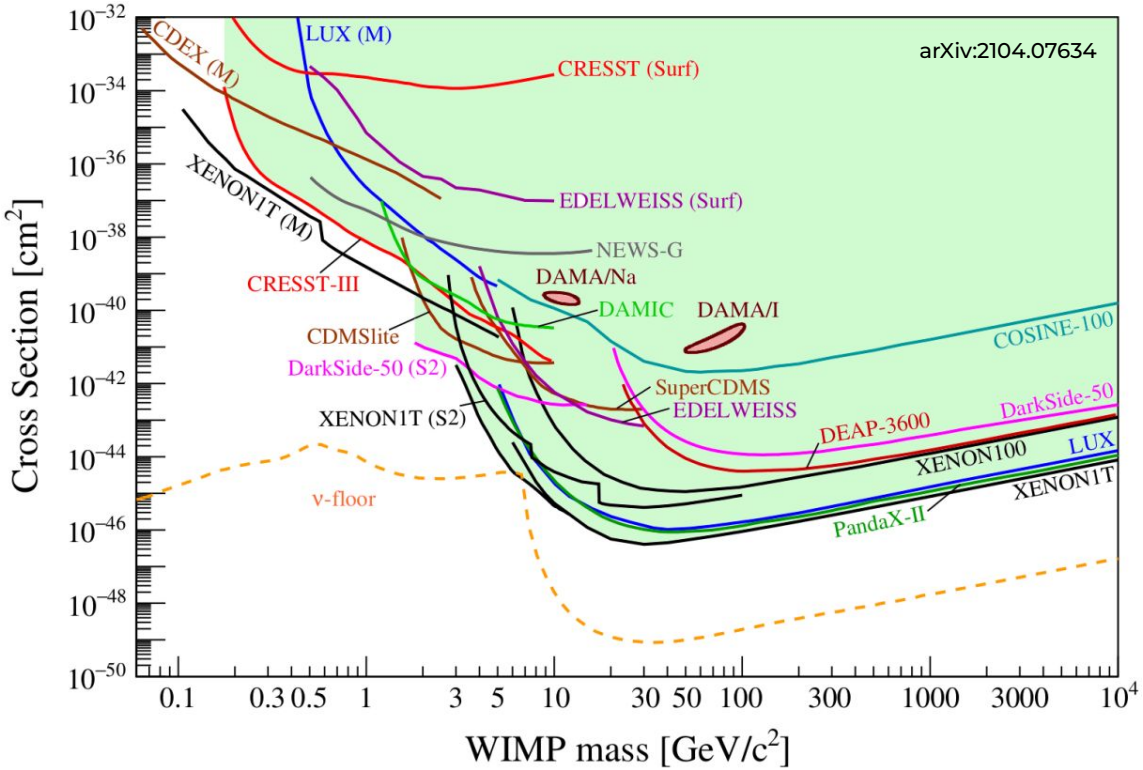
→ DAMA/LIBRA (here below) claims to have seen DM annual modulation with a **13.7σ** significance.



doi: 10.3390/universe4110116

The DAMA/LIBRA claim

→ This result has been excluded by several other experiments...



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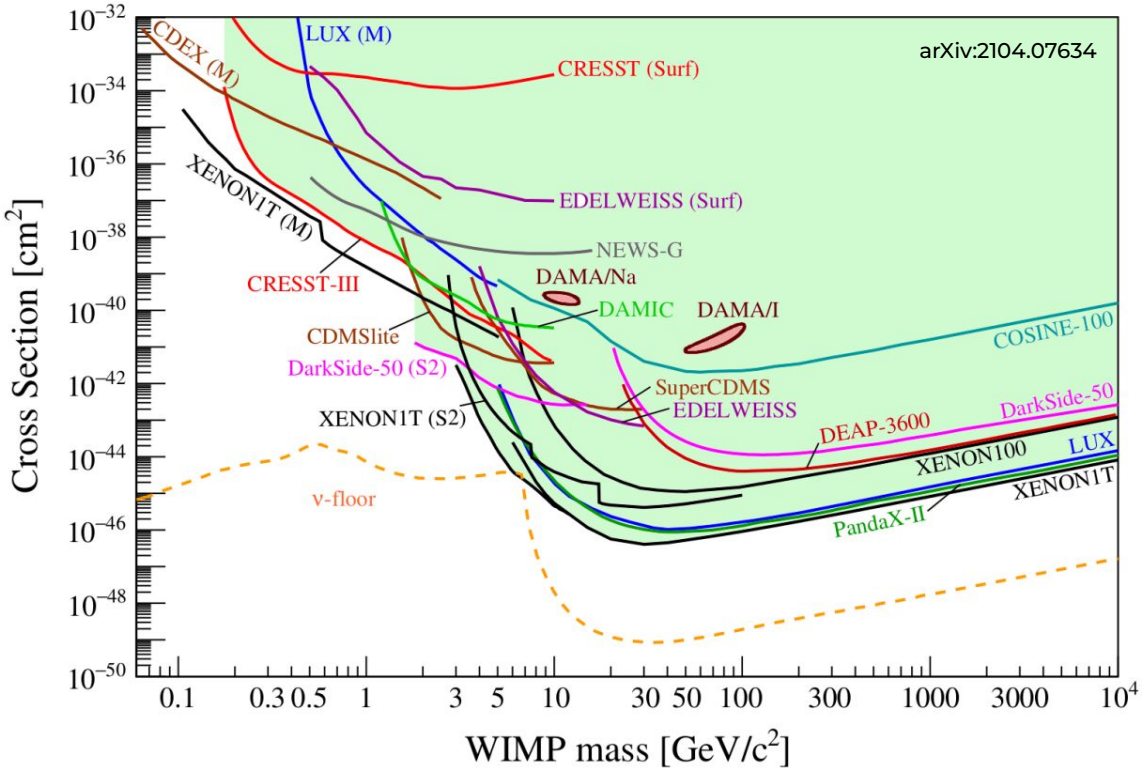


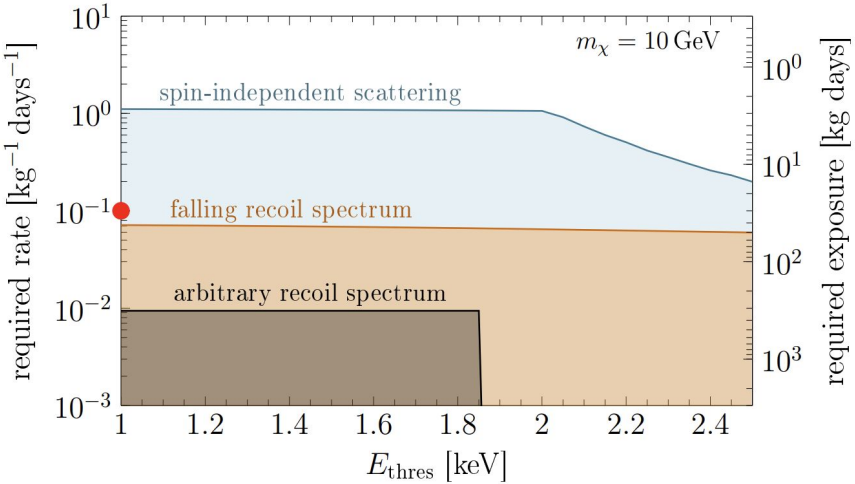
→ But no NaI-based experiment in a model independent way yet!

The COSINUS experiment

→ Same cryogenic technology used by CRESST, utilizing NaI crystals, to carry out a **model-independent verification** of the DAMA/LIBRA signal.

→ Same site as DAMA/LIBRA (LNGS)

→ Practically background freedom (active and passive shielding), particle discrimination and better energy resolution allow COSINUS to look not for annual modulation, but **total event rate**, eliminating the possibility of other annually-modulated background sources.



arXiv:1802.10175

The remoTES design

→ Quite a special challenge: NaI is hygroscopic, soft and has a low (~650 °C) melting point.

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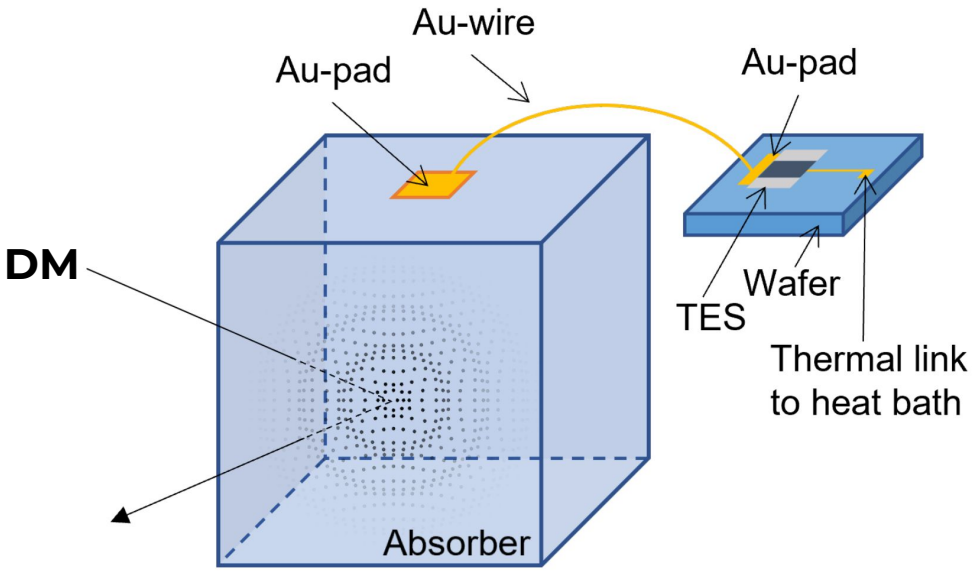
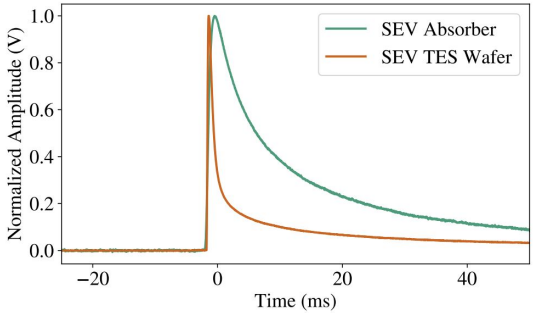


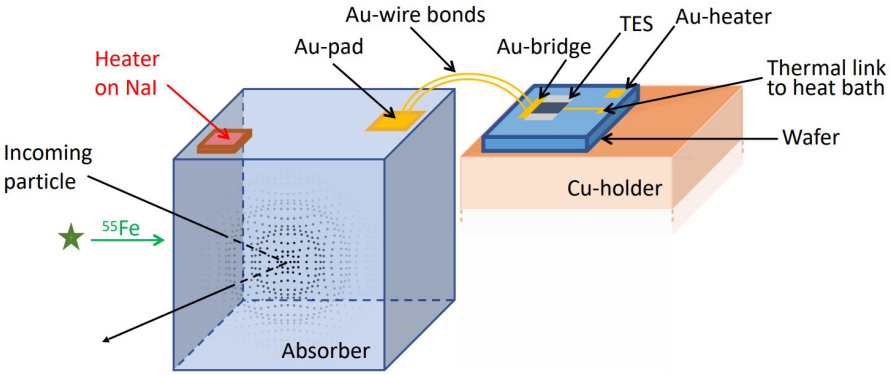
- Physical decoupling of TES from crystal
- Easy to reproduce
- It worked on Silicon and TeO_2

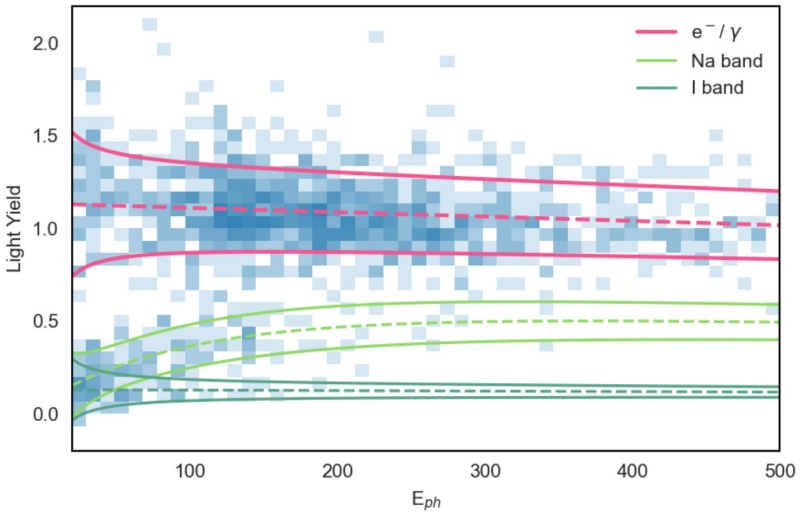


arXiv:2111.00349

Above ground proof of principle

- NaI (3.7g; 10x10x10mm^2), W-TES on Al_2O_3 wafer.
- Baseline resolution: 2 keV
- Energy threshold: 15 keV
- Test with neutron (AmBe) source showed **particle discrimination** (population below e/γ band)

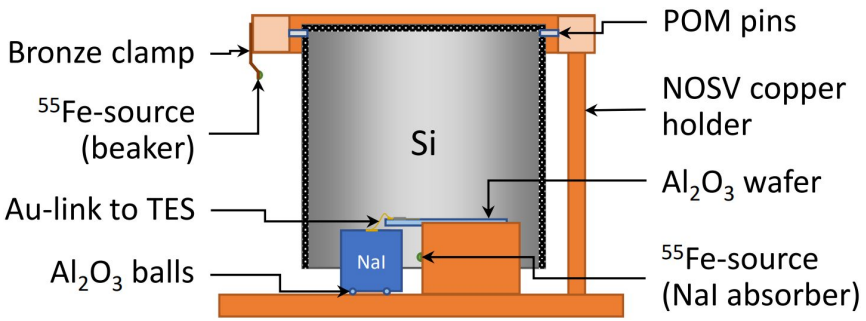


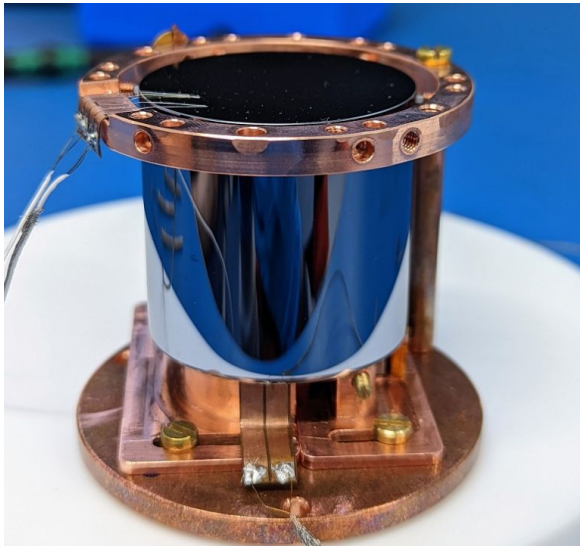


arXiv:2307.11066

First underground measurement

- NaI (3.67g; 10x10x10mm²), W-TES on Al_2O_3 wafer.
- Baseline resolution: 0.44(1) keV
- Energy threshold: 2.66(4) keV
- Light channel (Si with remoTES design) yields ~1keV$_{ee}$ energy resolution.

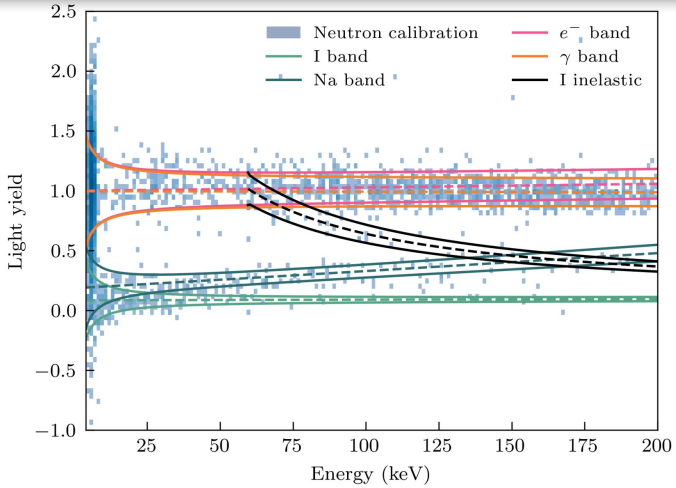


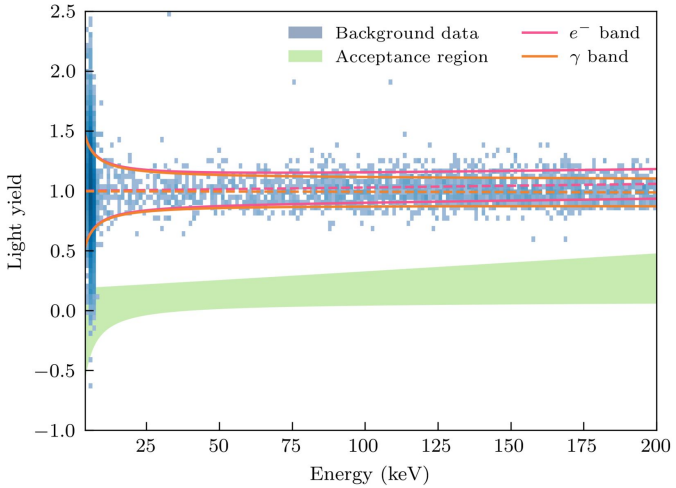


arXiv:2307.11139

First underground measurement

- Unbinned likelihood-fit tool that models all signals present in data.
- Neutron AmBe source + particle discrimination allows to estimate quenching factor for Na (~0.2@10keV) and I (~0.08@10keV) on the fly.
- 11.6 gram-day exposure data for DM search (only background - no source)

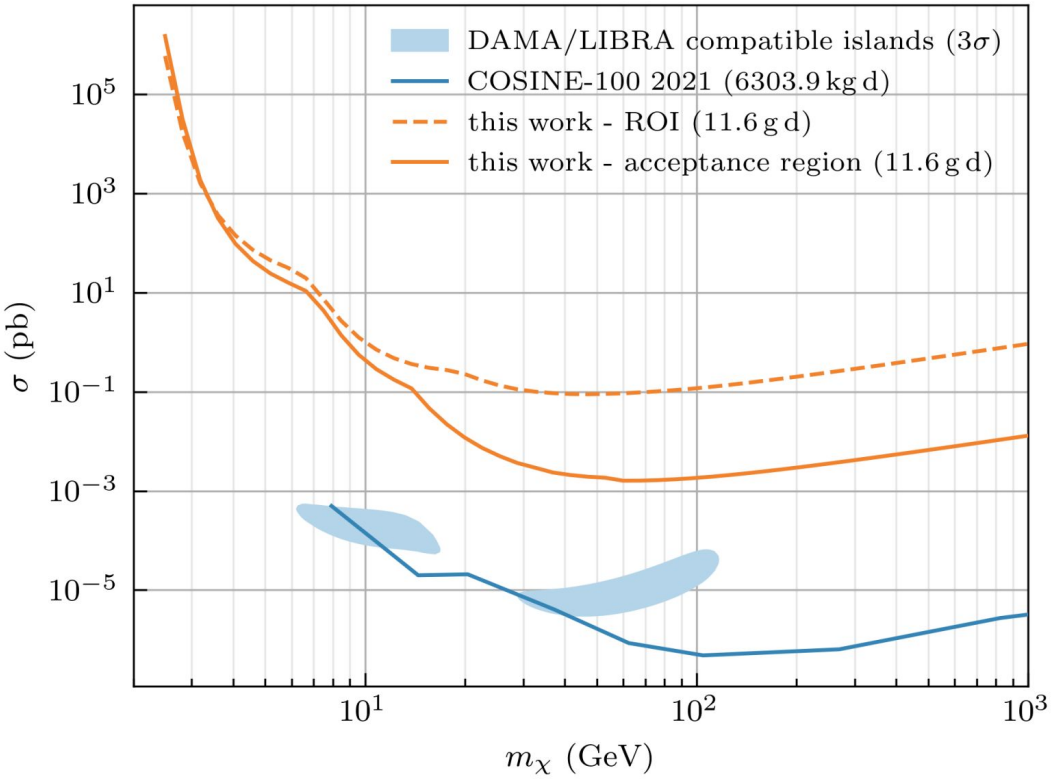




arXiv:2307.11139

First underground measurement

- DM exclusion limits (90% CL) using Yellin's optimum interval method.
- Dashed vs continuous line shows limit enhancement due to event-by-event particle discrimination
- A 11.6 gram-days prototype@LNGS stands ~2 orders above COSINE-100's 6303.9 **kg**-days run



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The COSINUS experiment site

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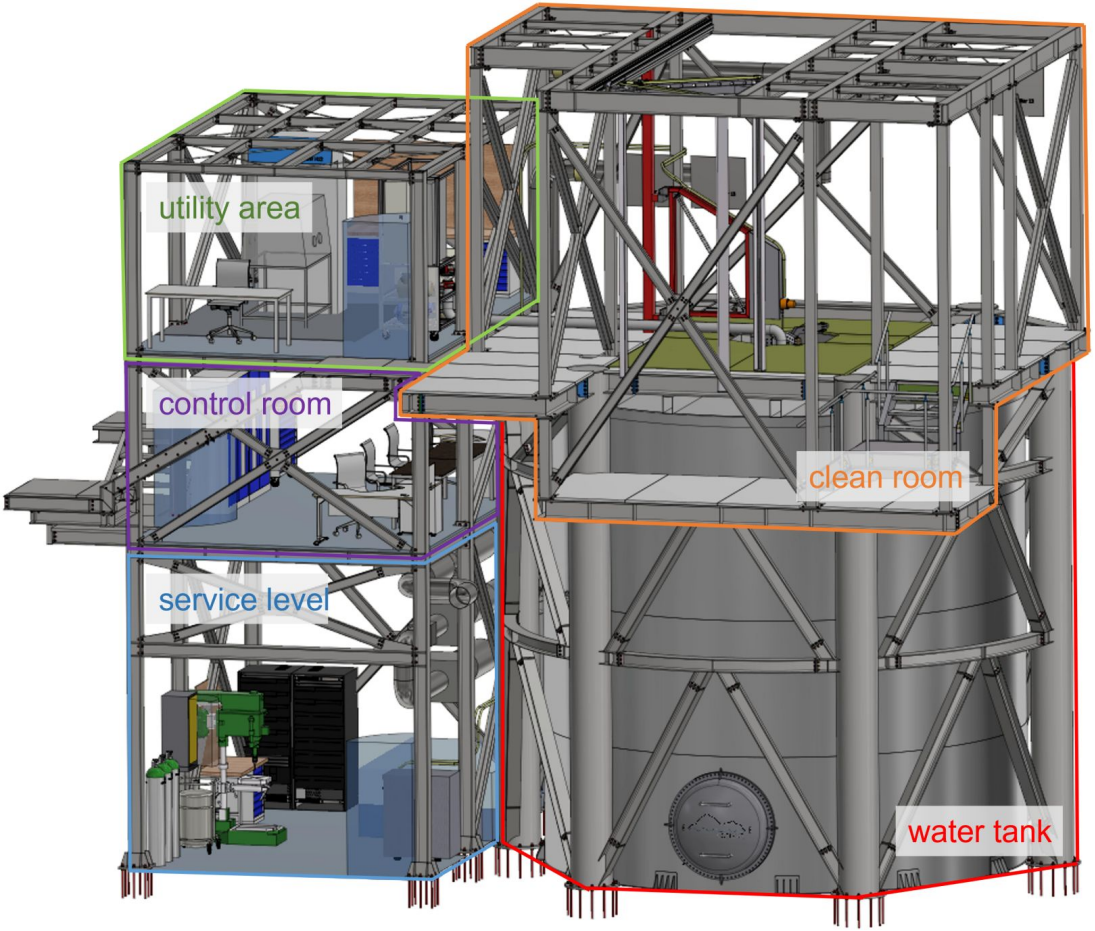
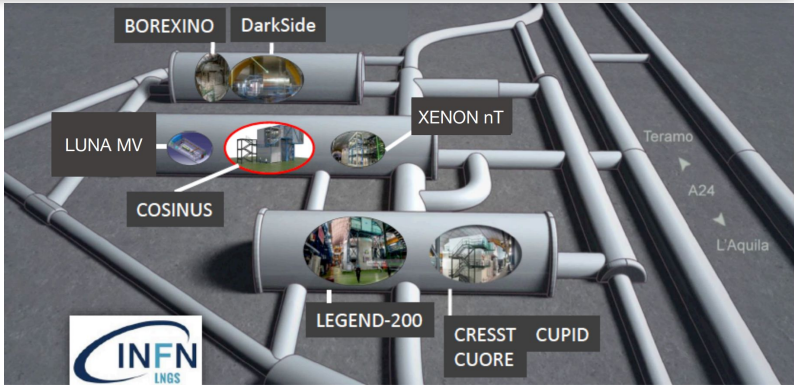


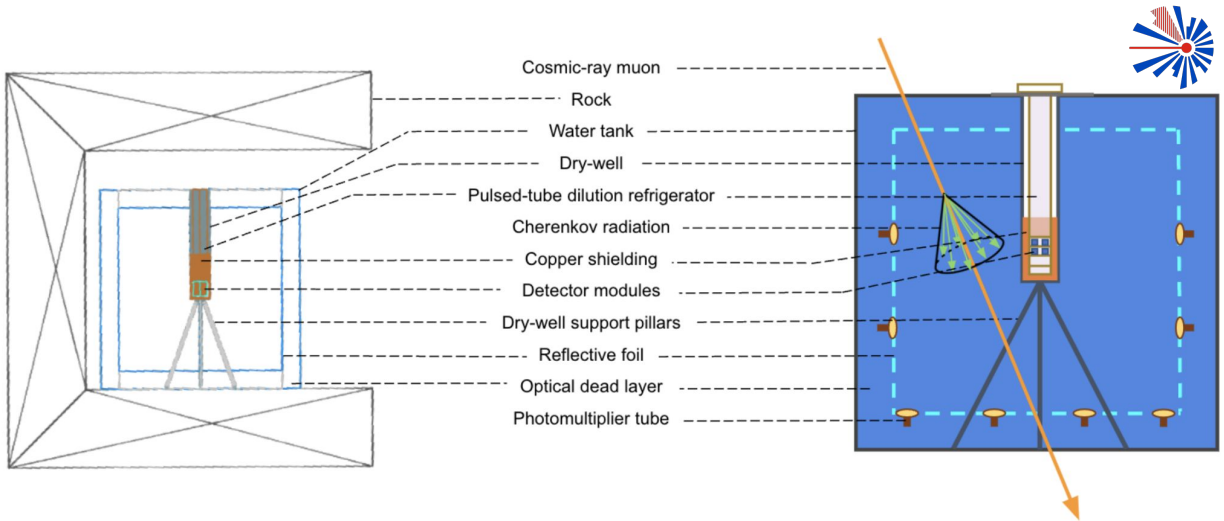


- Clear division in multiple working areas
- Instrumented water tank for muon veto, surrounding cryostat.
- Cleanroom facility above cryostat/water tank for easy access and sample manipulation

Active muon veto system

- Instrumentation of water tank as active muon veto system (Cherenkov effect) with 30 PMTs surrounding the tank. Effective vetoing of muon-induced neutrons that mimic DM candidate signal.

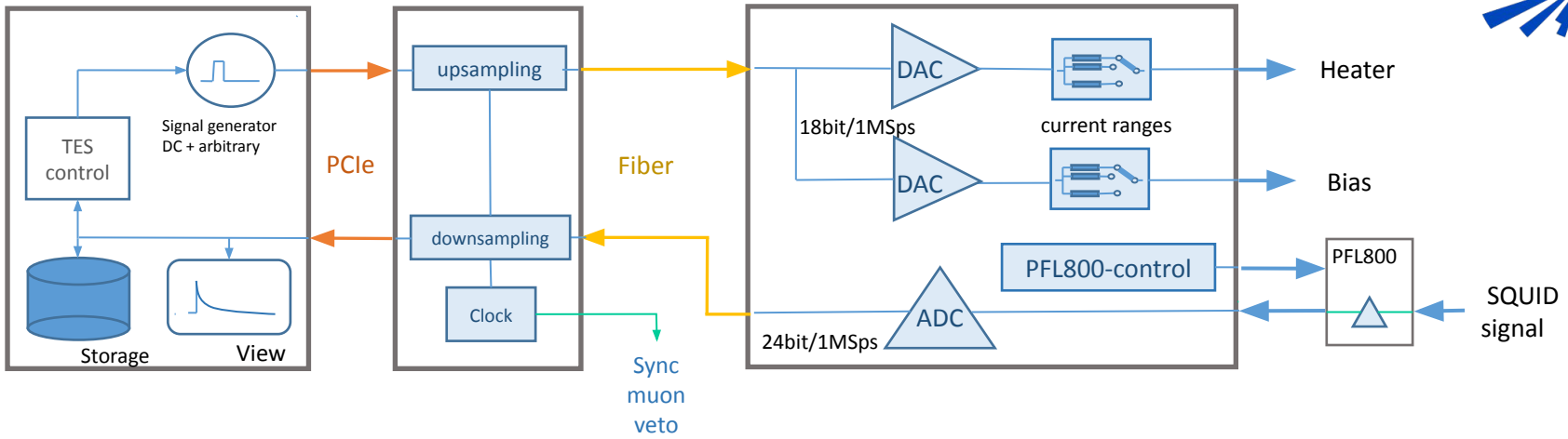
- Veto efficiency of **99.6%** and **45.4%** for muon (water interaction) and shower events (outside-tank interaction) leading to a muon-induced background rate of **0.11(2)** cts/kg/year



To be published very soon (EPJ-C)

Data acquisition system

√daq3



- One integrated system for current sources and digitizers, also integrated to VCCS
- Optical link (2 fiber cables only) to the server
- Continuous data taking only (24bits, 1MHz)
- SQUID amplifiers controlled in the same system

The COSINUS experiment site: status report

✔ Construction site concluded around mid-2023

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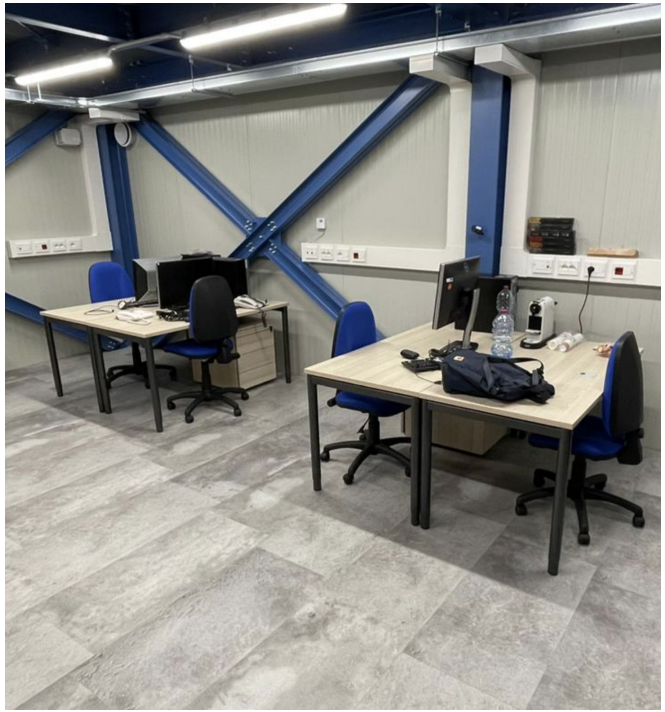

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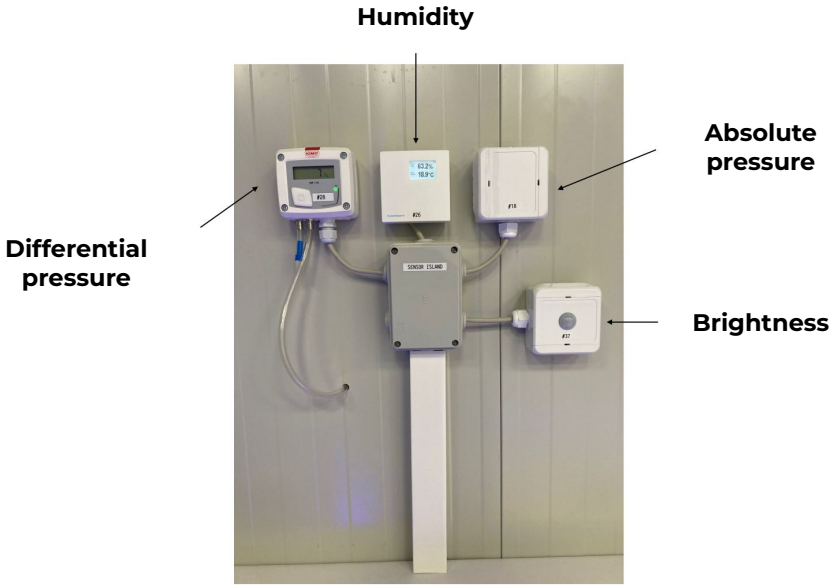

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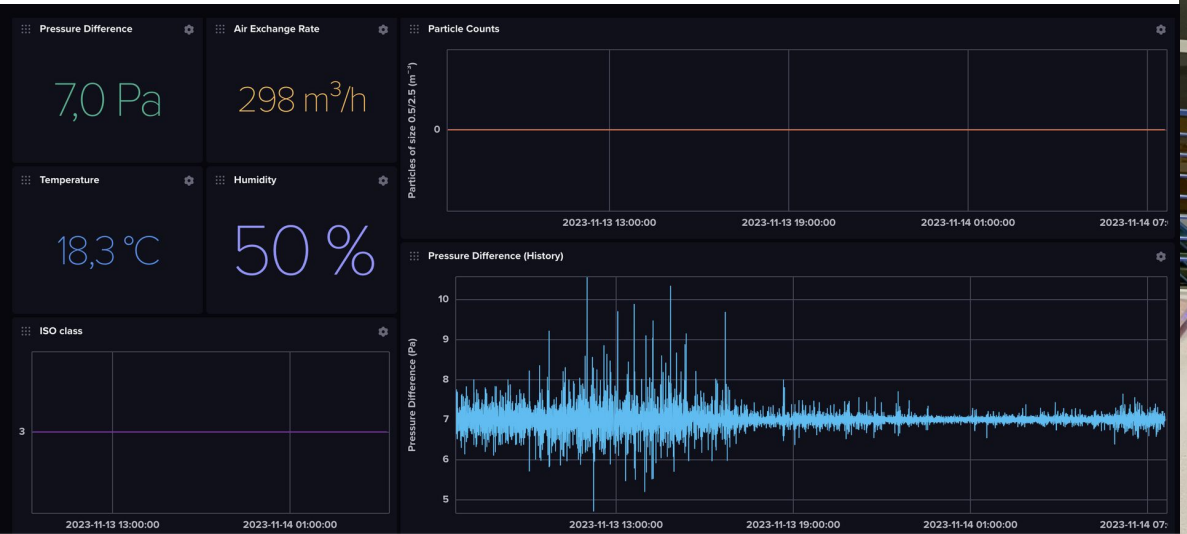

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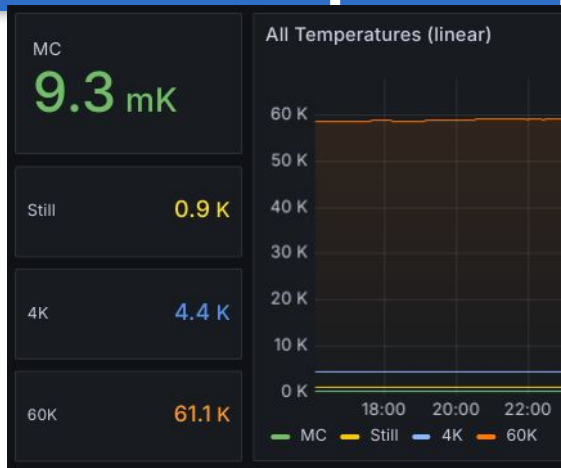

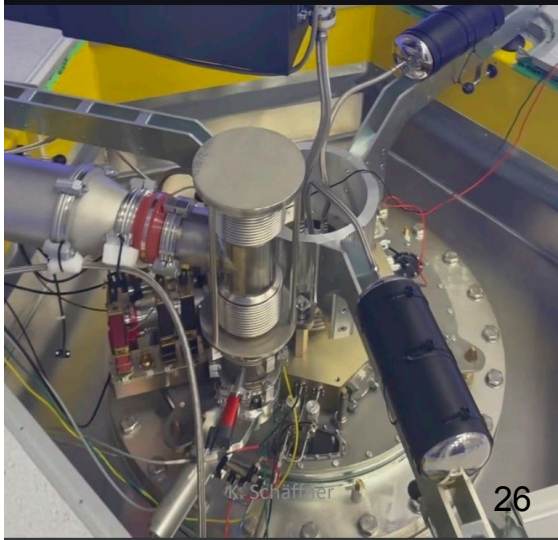

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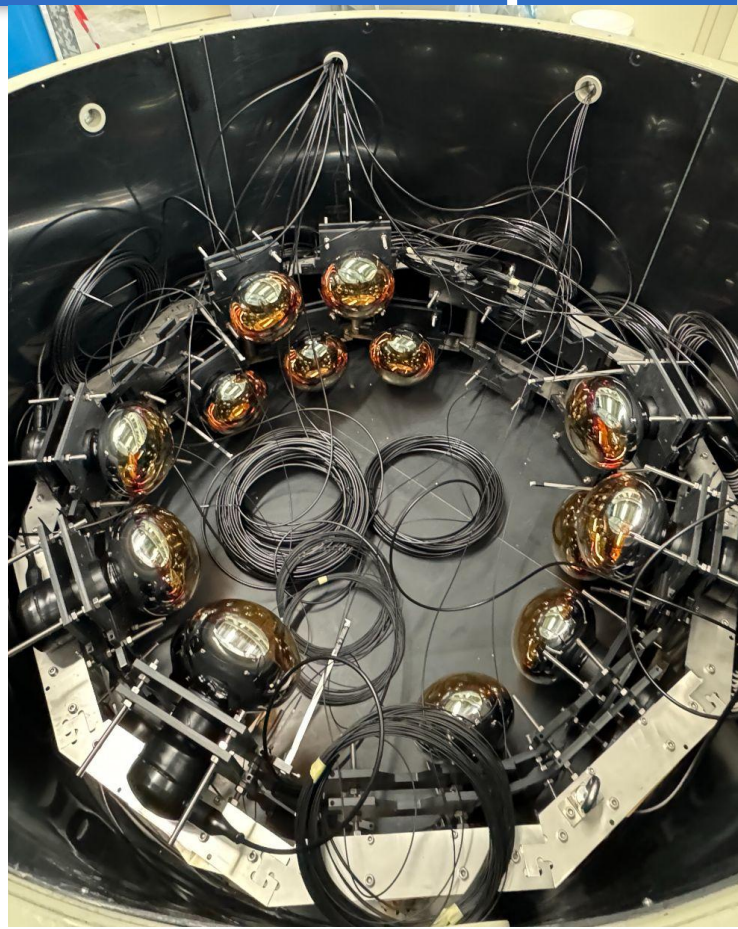
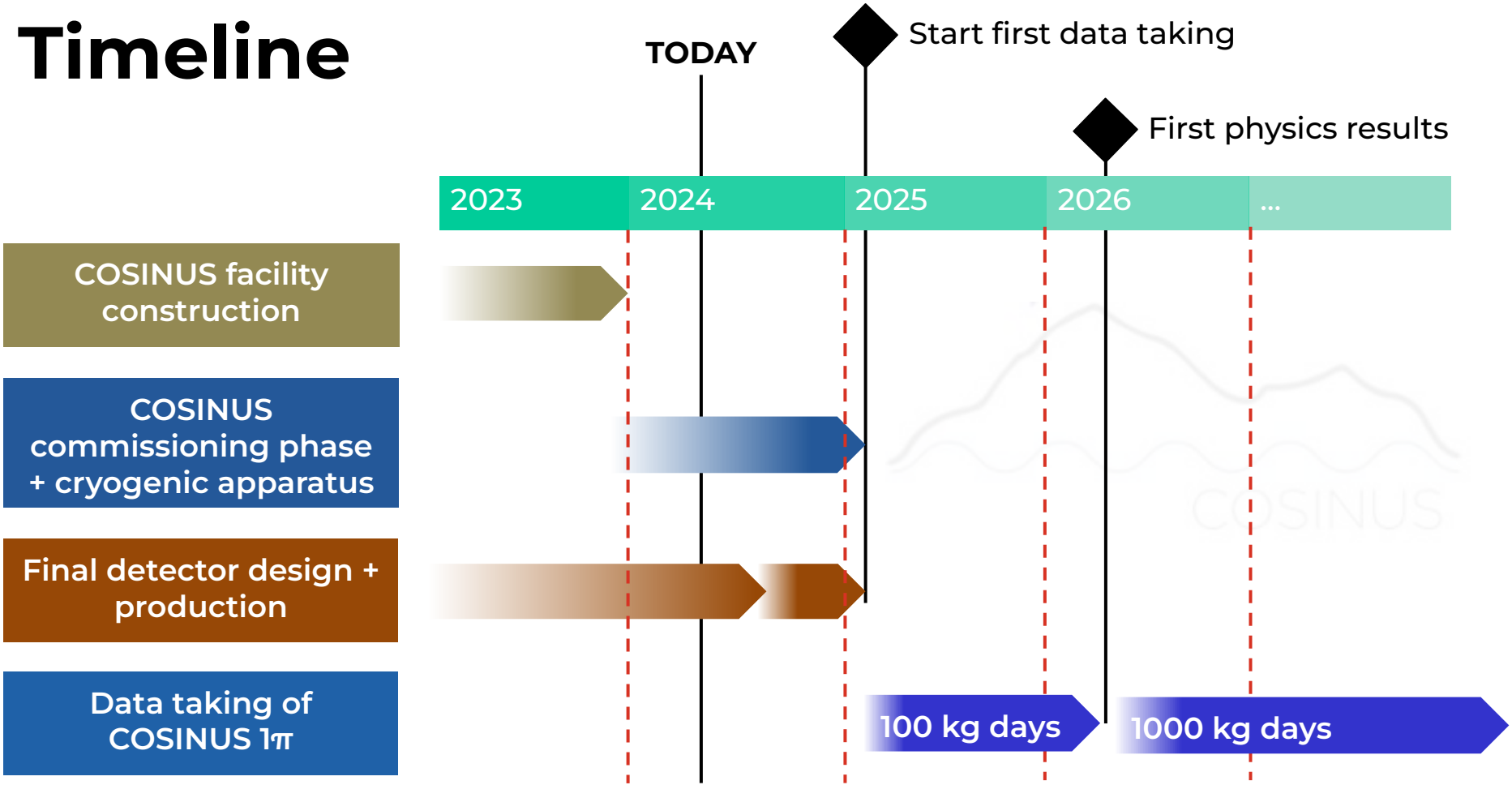
➔ Muon veto system PMTs testing on the move!

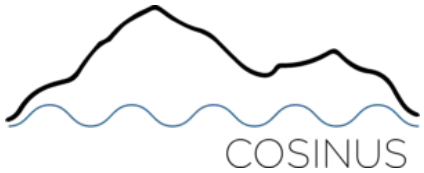


Timeline


TODAY
Start first data taking
First physics results
2023
2024
2025
2026
...
COSINUS facility construction
COSINUS commissioning phase + cryogenic apparatus
Final detector design + production
Data taking of COSINUS 1π
100 kg days
1000 kg days
COSINUS

Thank you for listening!
Any questions?

TU WIEN
TECHNISCHE UNIVERSITÄT WIEN



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