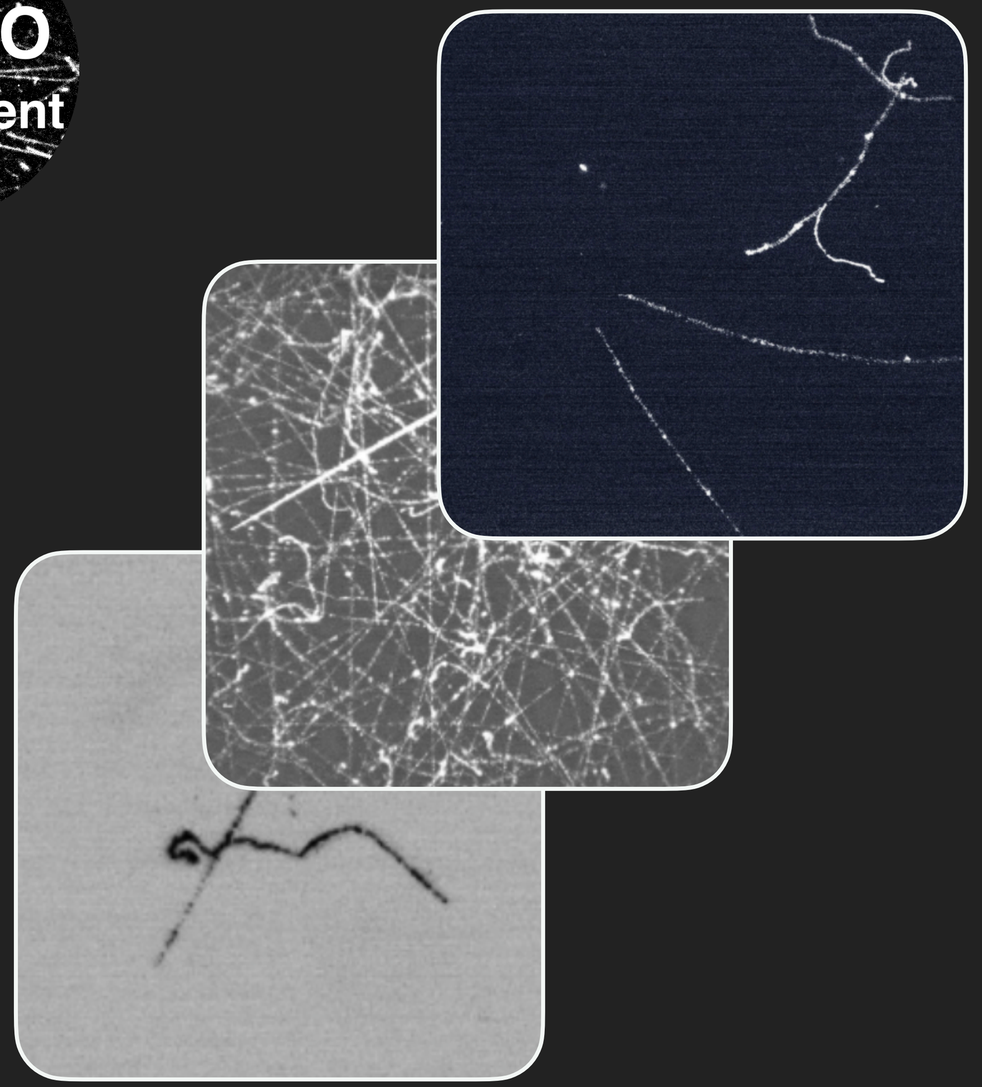
THE CYGNO EXPERIMENT

MELBA D'ASTOLFO

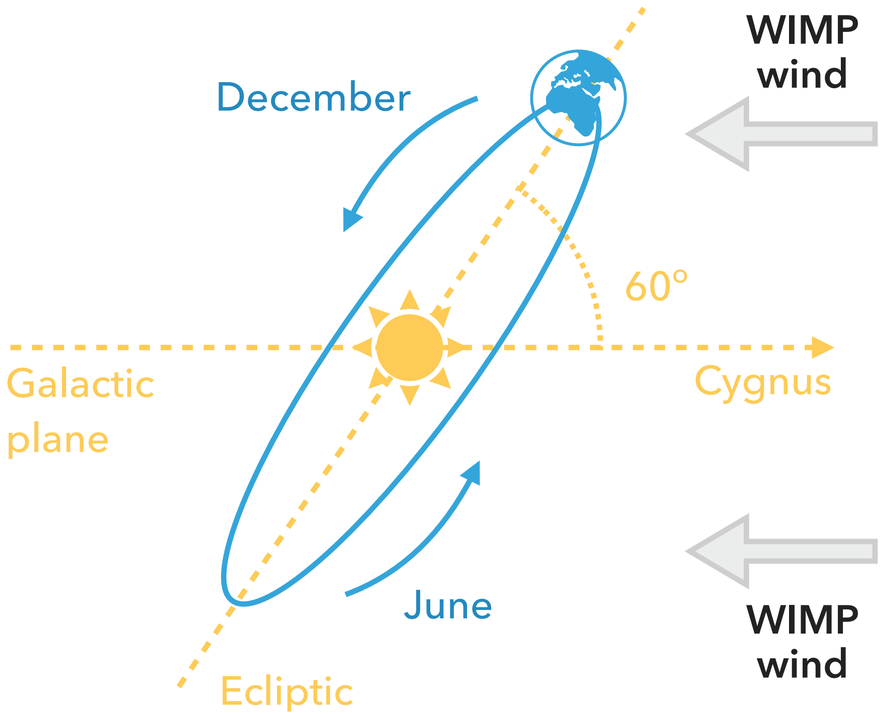
On behalf of the CYGNO collaboration

Gran Sasso Science Institute

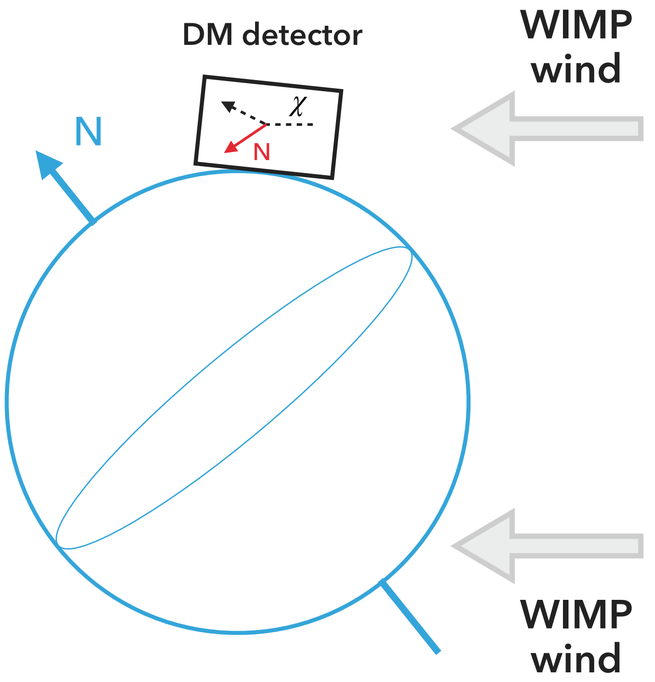
melba.dastolfo@gssi.it



Our galaxy

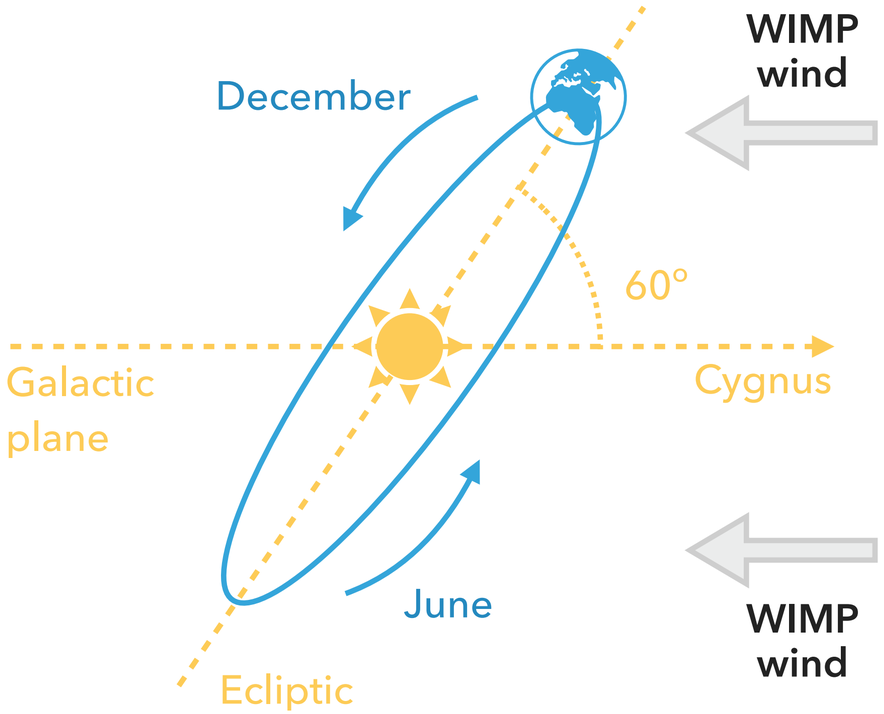


Solar System



Earth

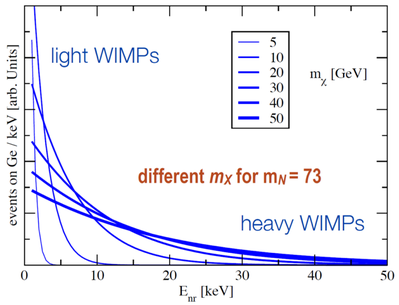
Our galaxy



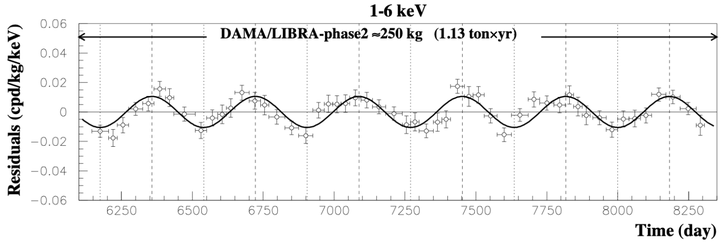
Solar System

Main physical observables

ENERGY DEPOSIT



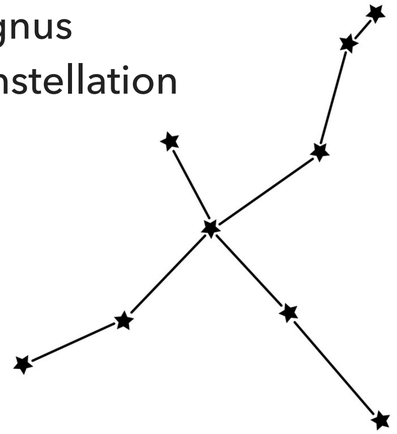
ANNUAL MODULATION

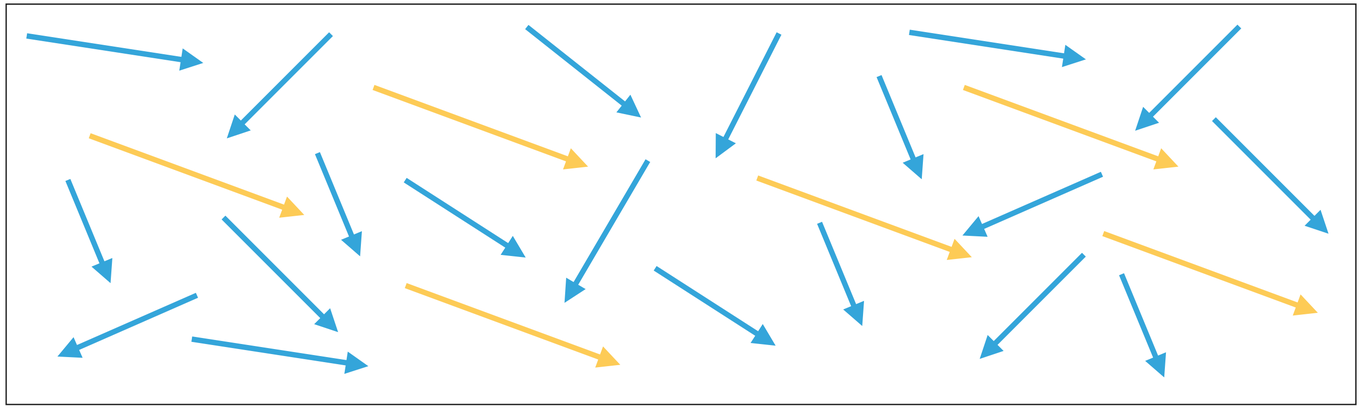


Bernabei et al., arXiv:1805.10486

Earth

Cygnus Constellation





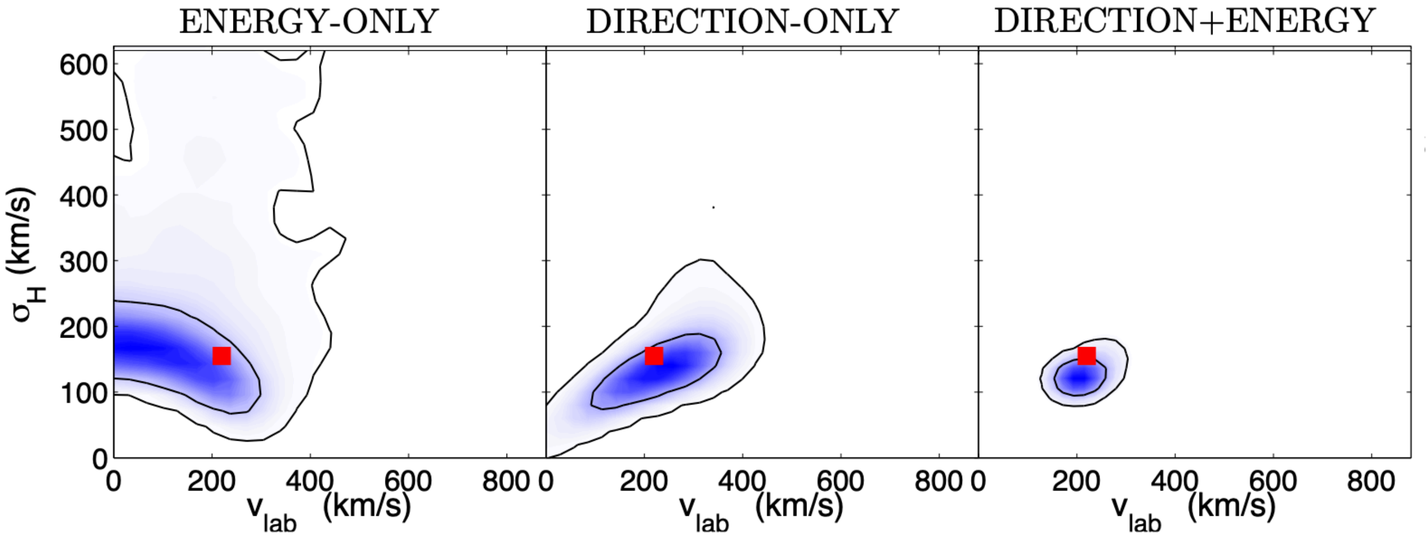
Signal

Background

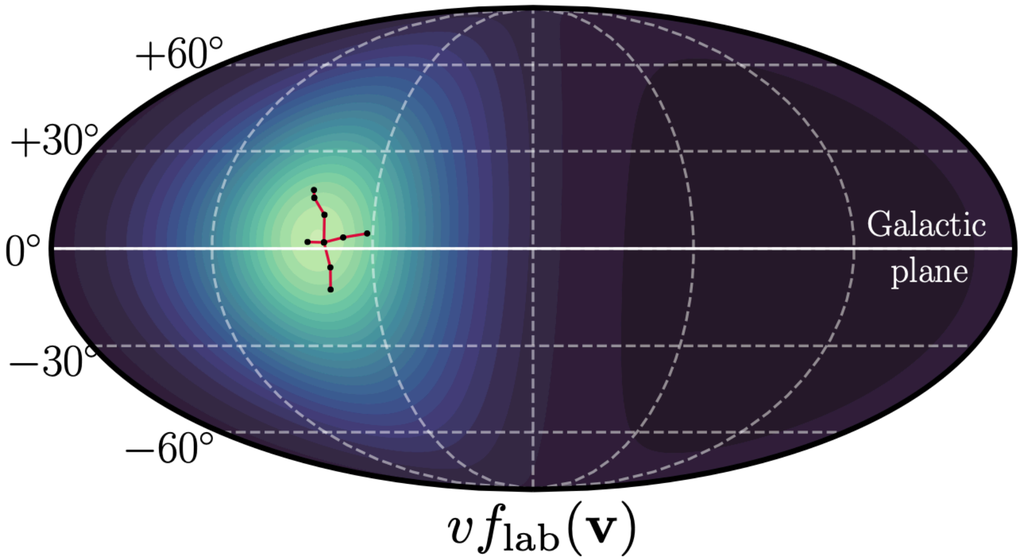
Directional detection aims to measure **both the energy and the direction** of the recoiling nuclei

ASSUMPTIONS

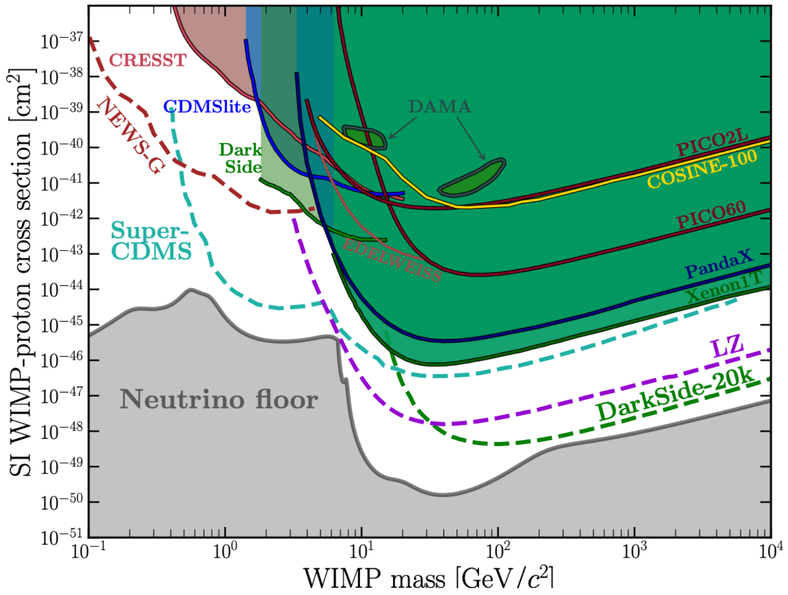
- $m_\chi = 50$ GeV
- MIMAC-like experiment



Physics Reports - Volume 627, 20 April 2016, Pages 1-49

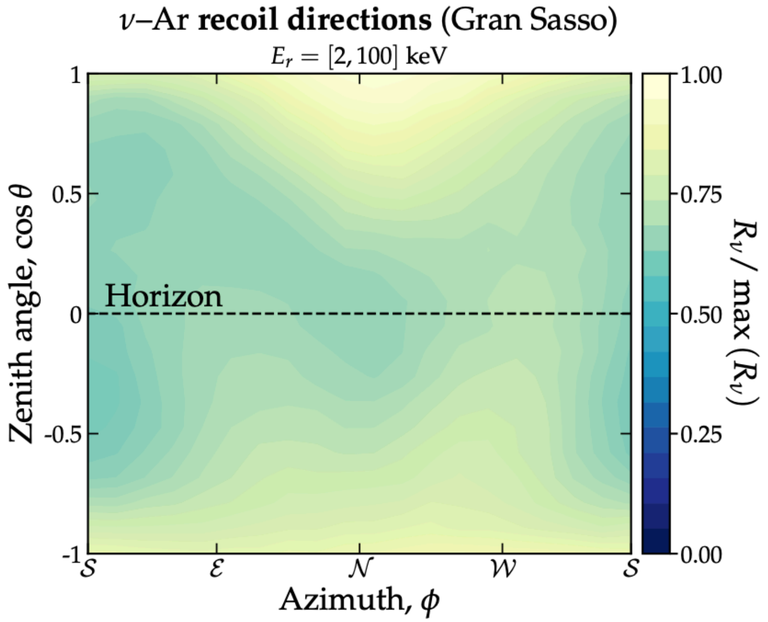


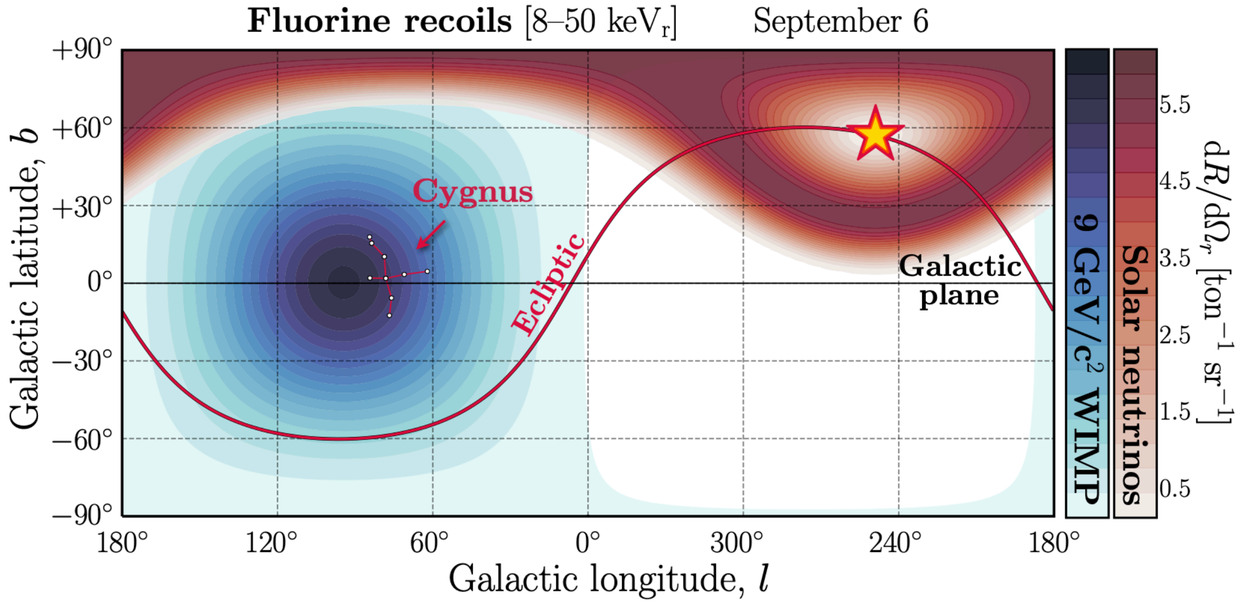
Provide a means of discovering dark matter

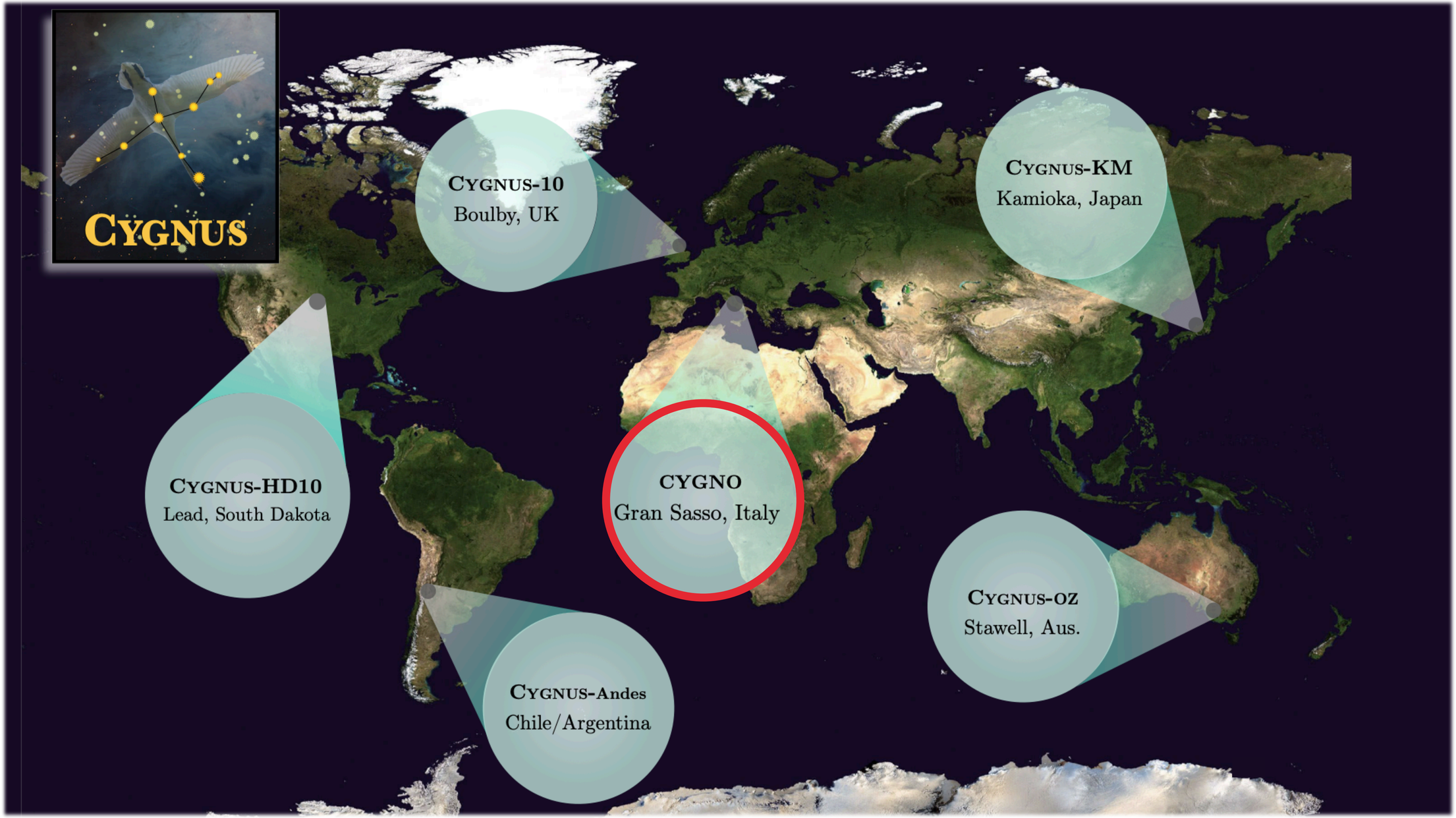


Extend searches for WIMPs below the neutrino floor

Capability to discriminate against neutrinos






CYGNUS
CYGNUS-10
Boulby, UK
CYGNUS-KM
Kamioka, Japan
CYGNUS-HD10
Lead, South Dakota
CYGNO
Gran Sasso, Italy
CYGNUS-OZ
Stawell, Aus.
CYGNUS-Andes
Chile/Argentina

Gaseous TPC

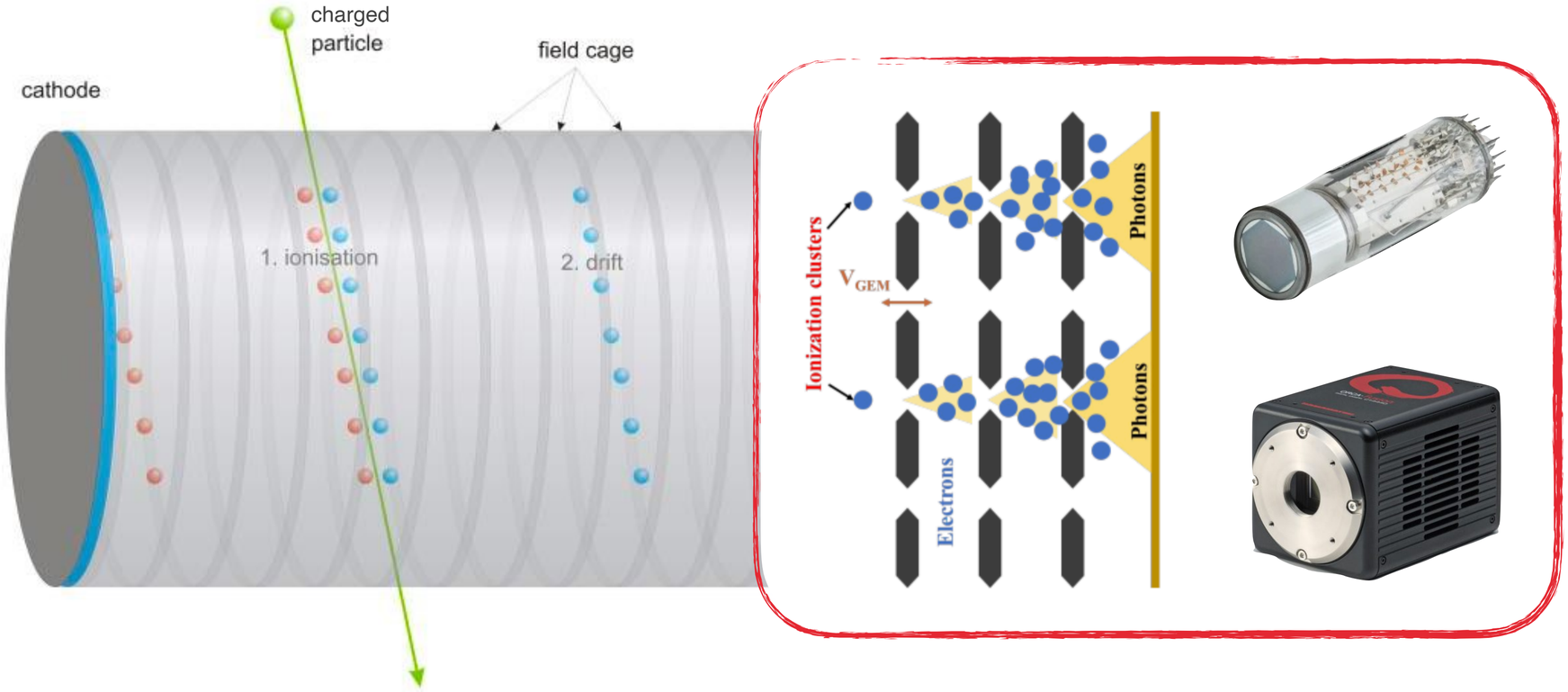
- He:CF_4 (60:40)
- Room temperature
- Atm pressure

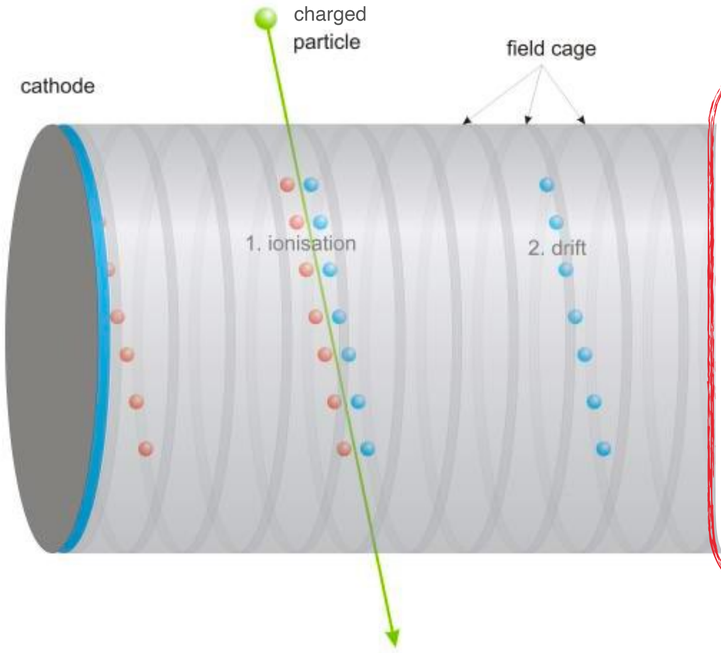
Triple GEM

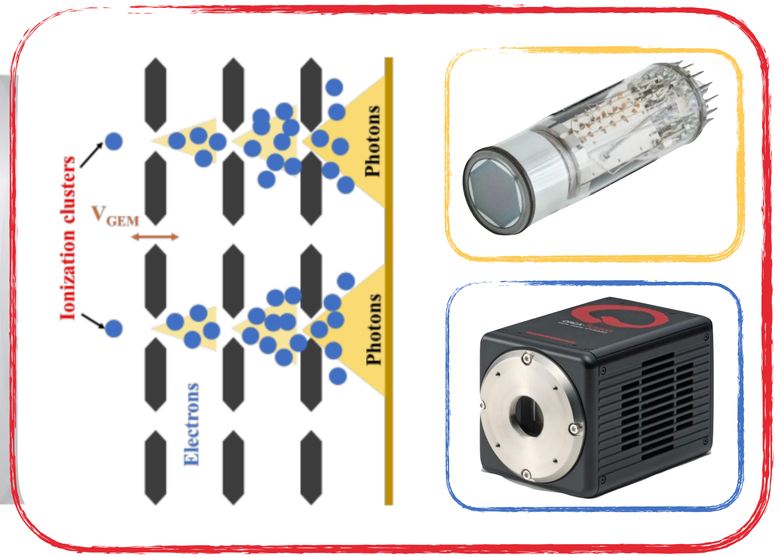
Charge multiplication

Camera + PMT

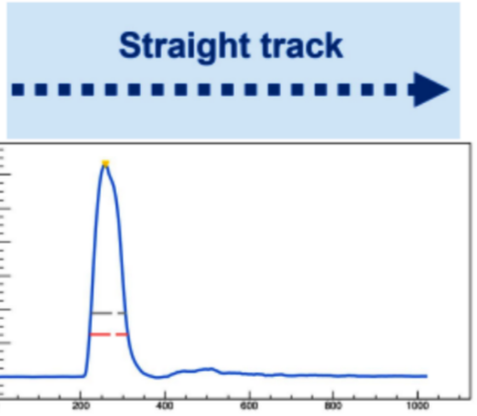
Light from gas scintillation during electron avalanche

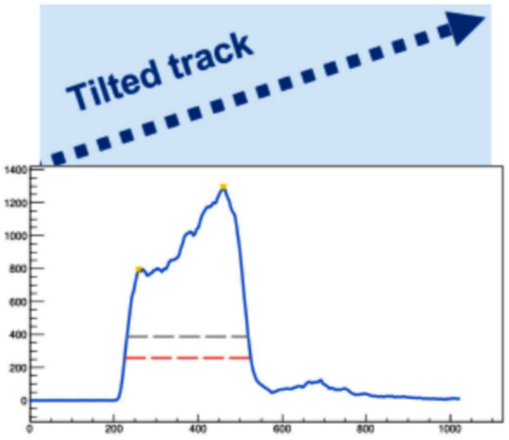




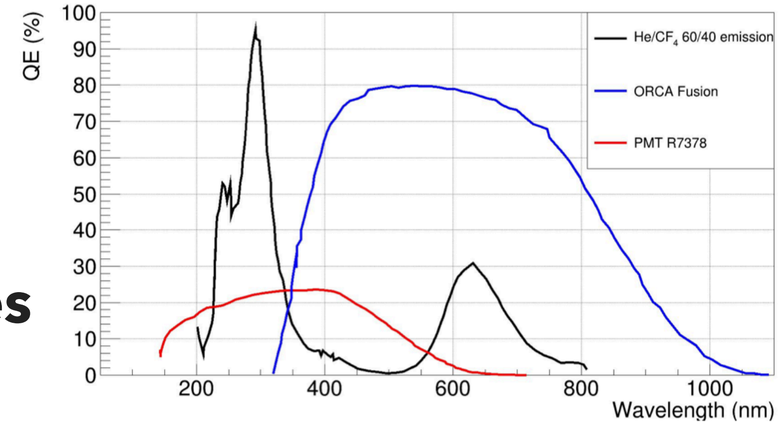


Integrated z + Energy

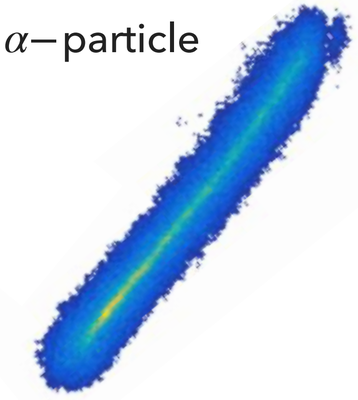




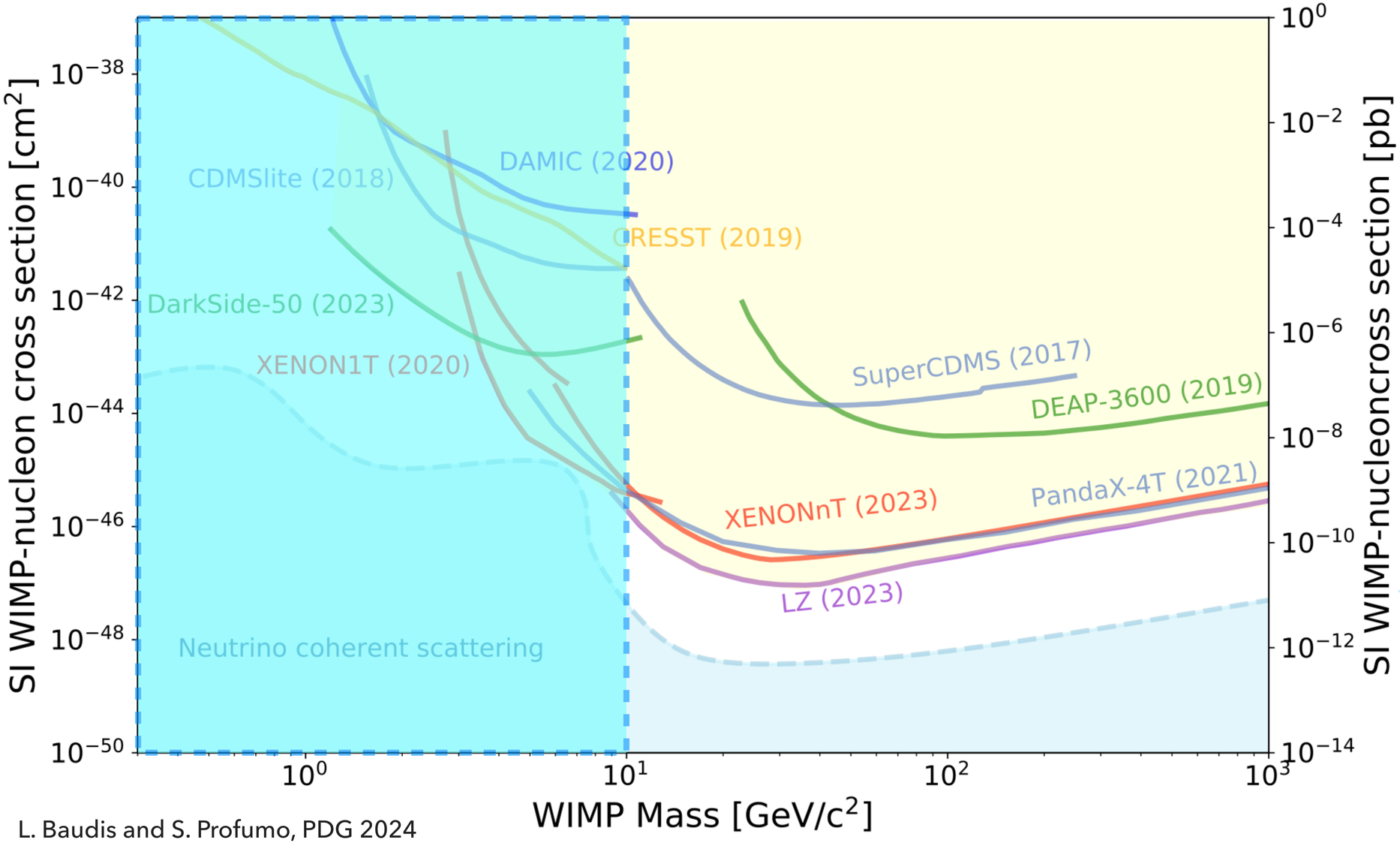
Energy + X & Y coordinates



$\alpha-$particle



CYGNO Dark Matter exploration region



L. Baudis and S. Profumo, PDG 2024

2
He

- ***Light*** target for low mass WIMPs
- Sensitive to ***SI*** couplings

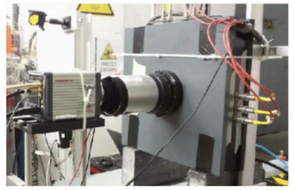
9
F

- ***Heavier*** target for intermediate masses
- Sensitive to ***SD*** couplings

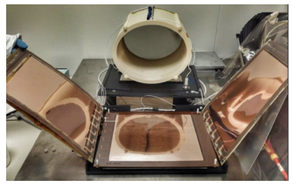
PHASE 0 - R&D and prototypes | PHASE 1 | PHASE 2

2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027

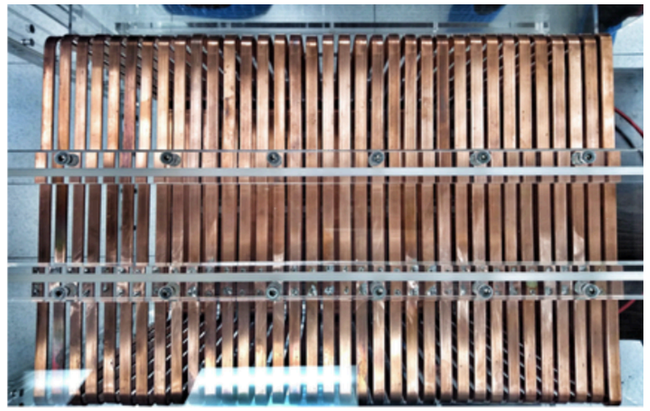
ORANGE | LEMON | LIME | CYGNO_04 | CYGNO_30



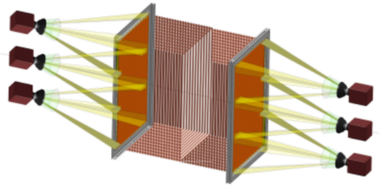
- 1 cm drift



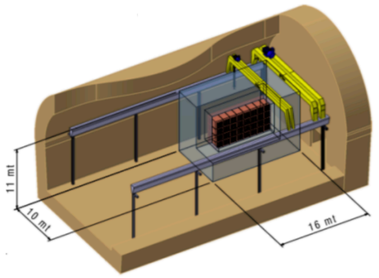
- 3D printing
- 20 cm drift



- 50 cm drift
- Underground tests
- MC validation



- Background
- Material tests
- Gas purification
- Scalability



- Physics research

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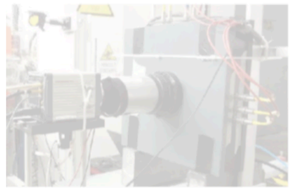
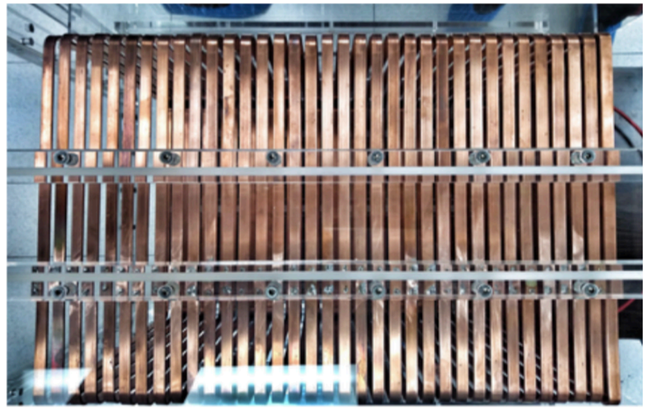


- 1 cm drift

- 3D printing
- 20 cm drift



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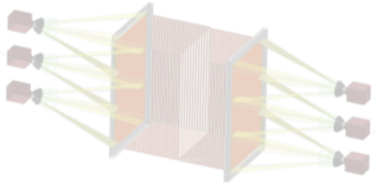
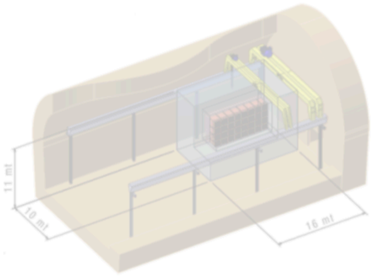
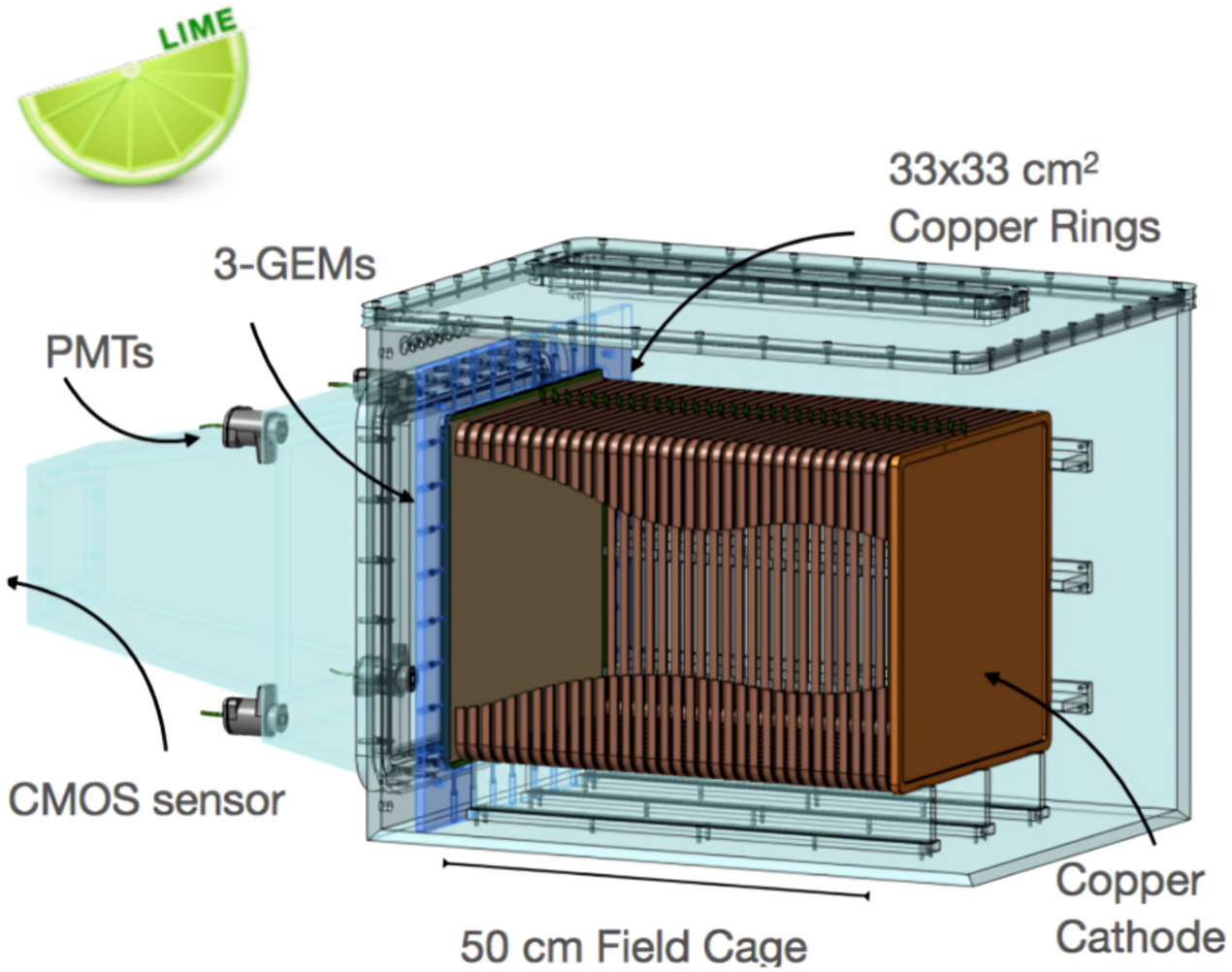


- Background
- Material tests
- Gas purification
- Scalability



- Physics research

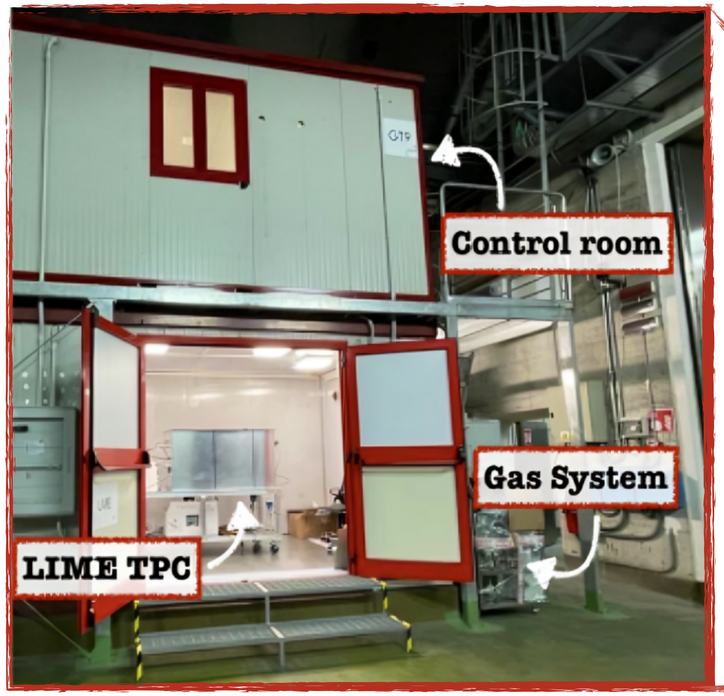


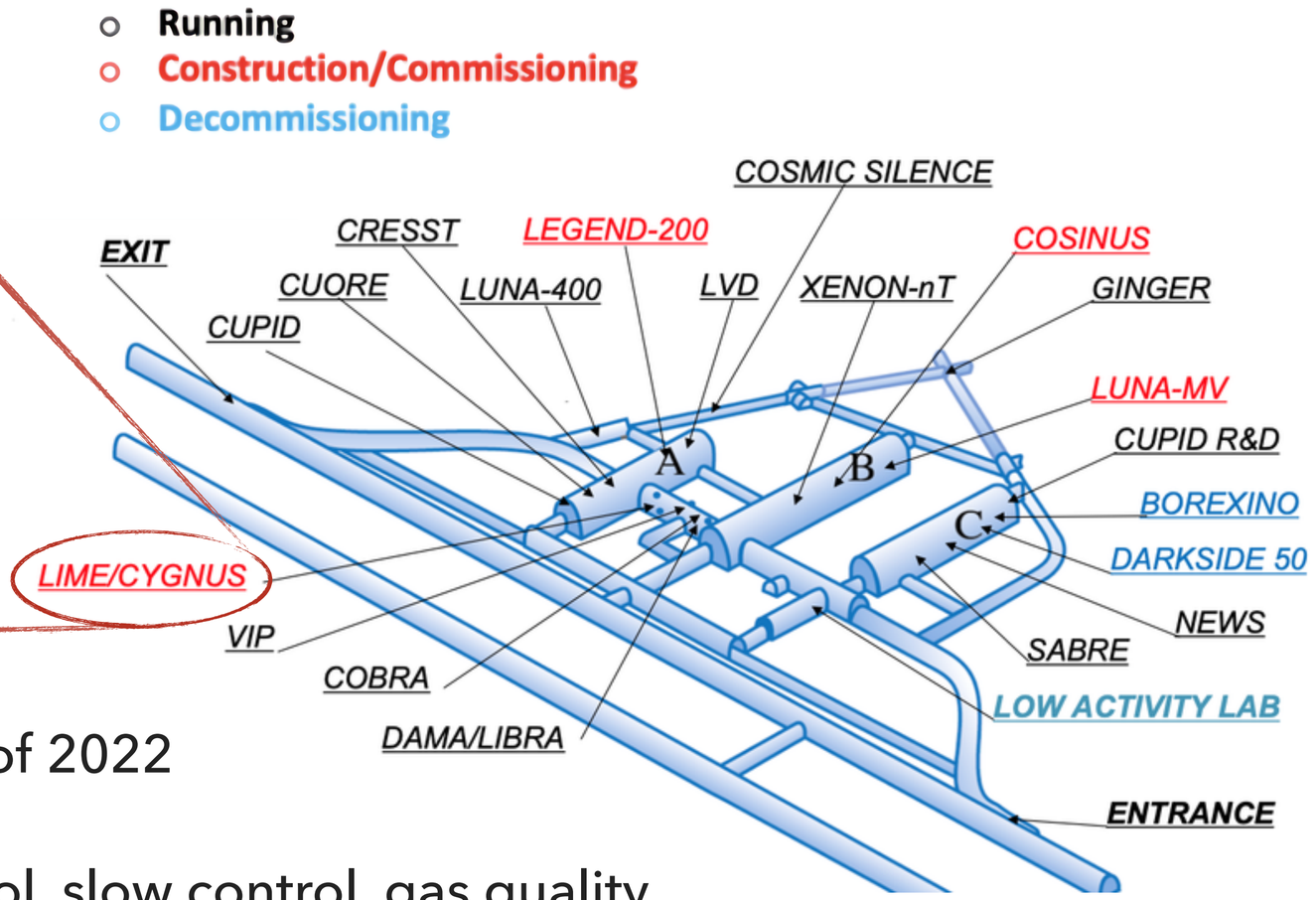
50 L active volume of $He:CF_4$ (60:40)

Atmospheric pressure and room temperature

Triple 33x33 cm^2 GEM stack for amplification

Optical readout → 4 PMTs + 1 sCMOS camera (ORCA fusion)





Placed underground at the beginning of 2022

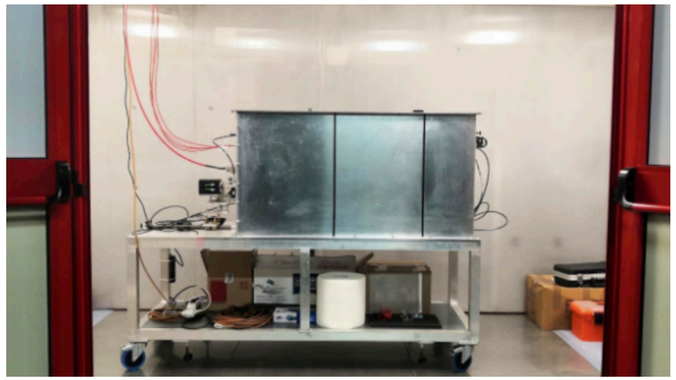
Several initial tests: DAQ, remote control, slow control, gas quality, detector operation optimization

Multiple radioactive source runs: ^{55}Fe, ^{133}Ba, ^{152}Eu, AmBe

Phase	Shielding	GEM V [V]	# Pictures	Live time [s]	Rate PMTs [Hz]	Fresh gas flux [L/h]
RUN 1	None	420	2,86E+05	1,76E+05	30	10
RUN 2	4 cm Cu	440	2,98E+05	1,91E+05	3.5	20
RUN 3	10 cm Cu	440	1,72E+05	1,91E+05	1.6	20
RUN 4	+ 40 cm H_2O	Under analysis				

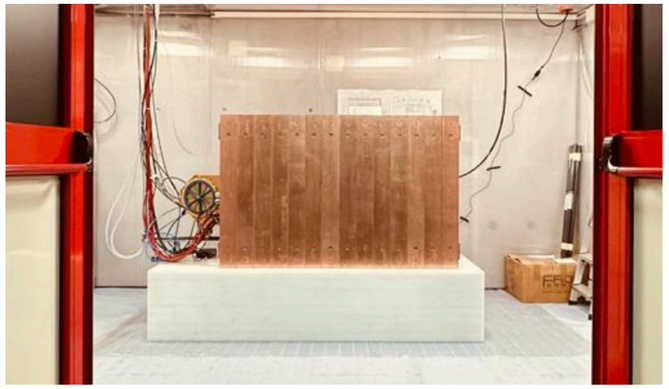
RUN 1

Background dominated by the external sources



RUN 2-3

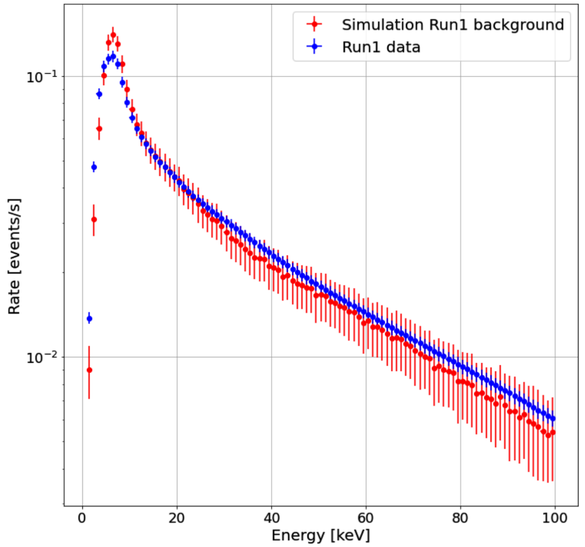
External background suppressed by a factor ~40-600

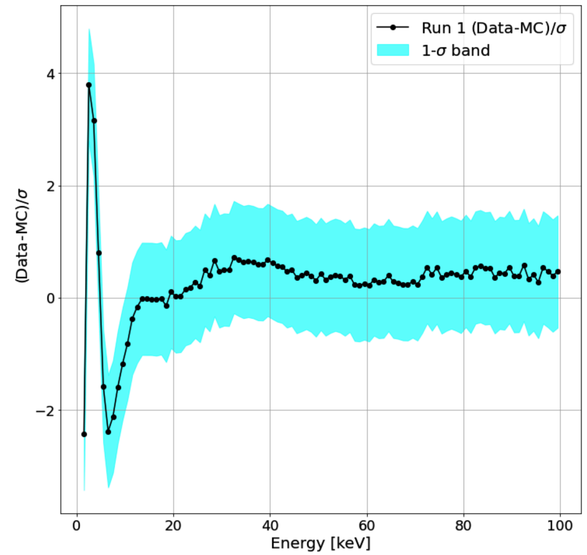


RUN 4

Residual external neutron background suppression

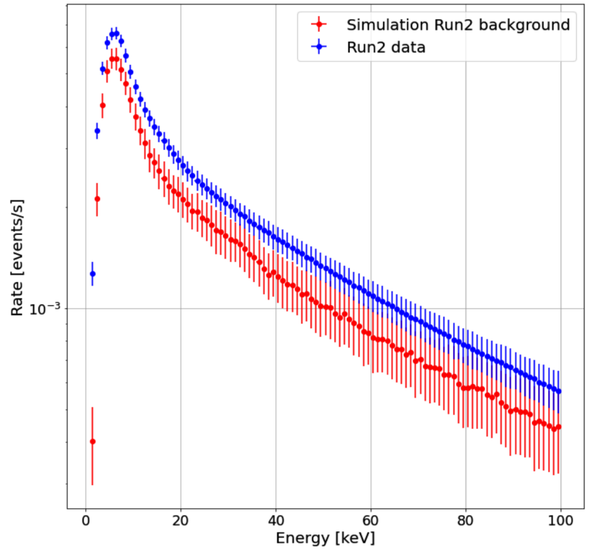
RUN 1

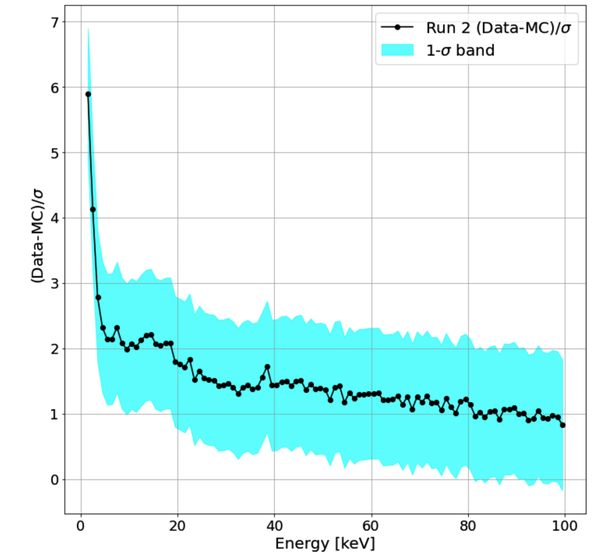




Agreement → capability of simulating external background

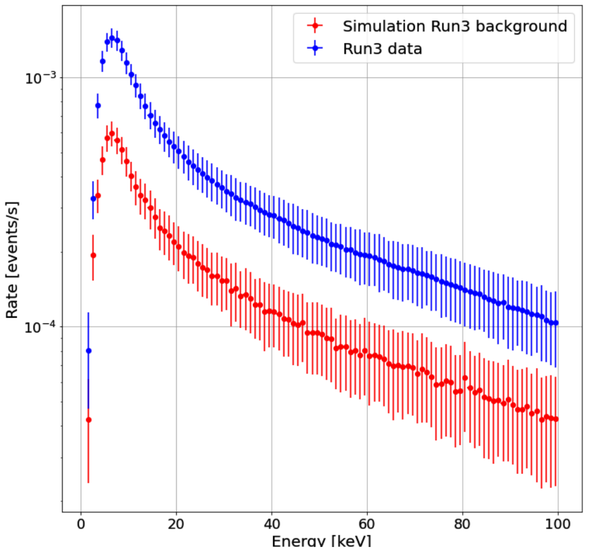
RUN 2

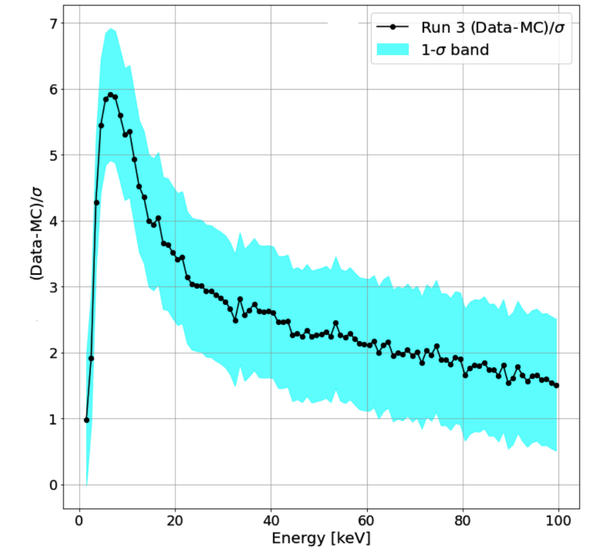




Difference ±22% → internal component missing

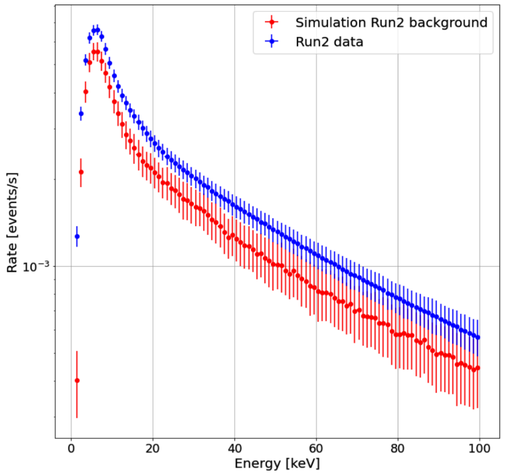
RUN 3





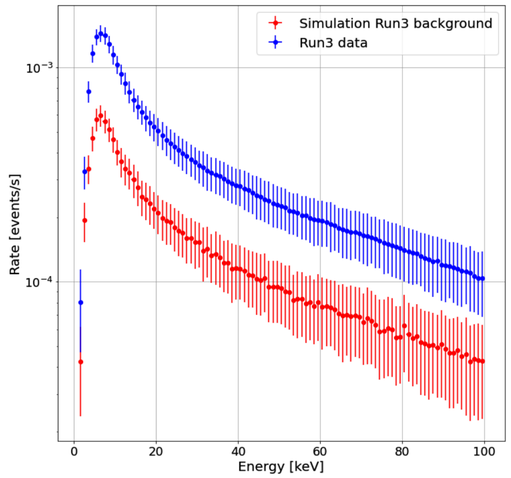
Difference ±60% → internal component missing

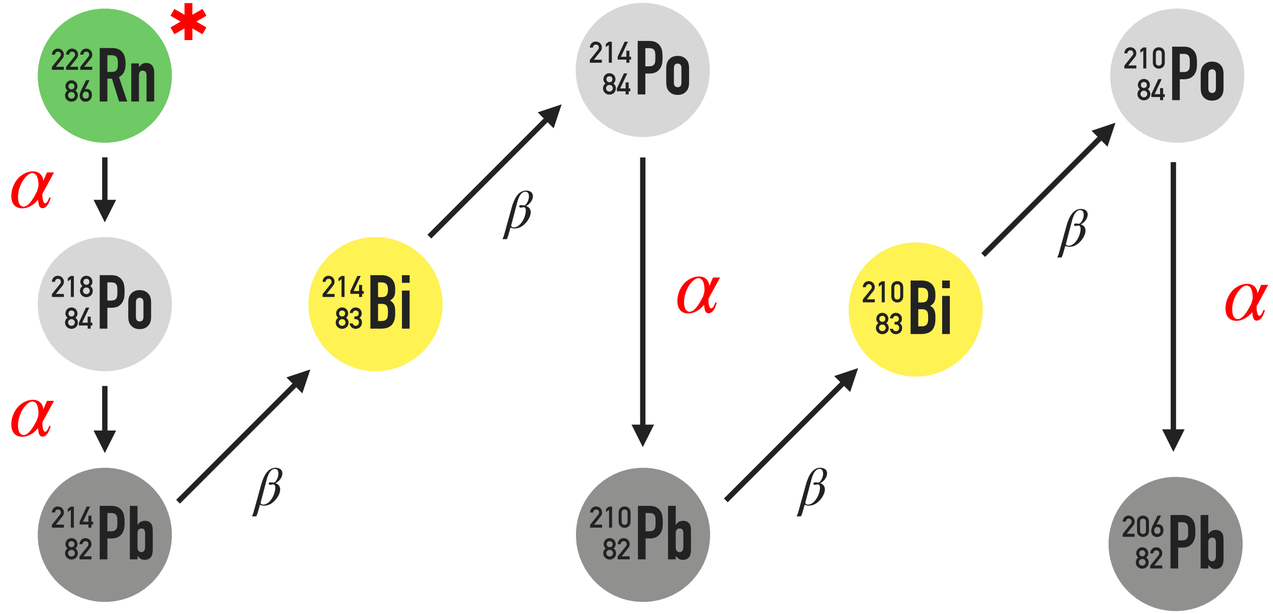
RUN2



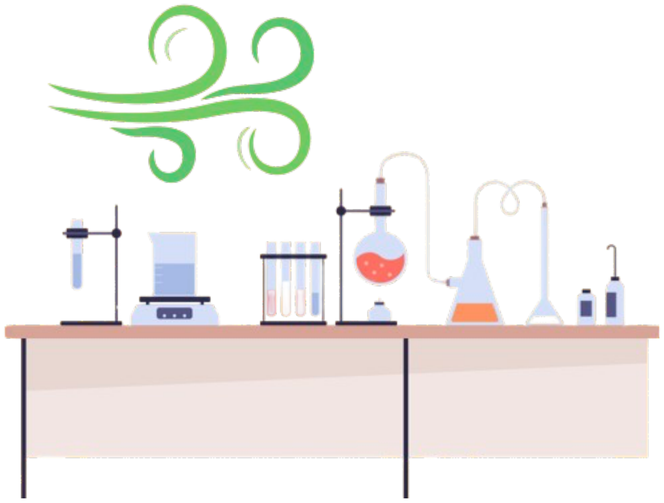
A deeper analysis suggests ***Radon contamination*** could explain the discrepancy

RUN3



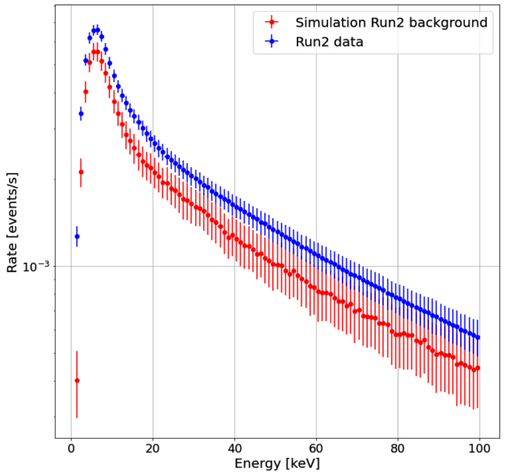


* RADON EMANATION



* UNDERGROUND LAB AIR

RUN 2



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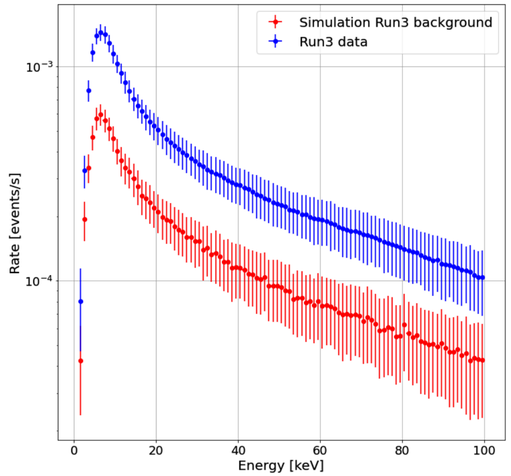
RUN 3



Low radioactivity ***Radon filter*** installed at the end of ***Run 4***!

Analysis still ongoing

PHASE 0 - R&D and prototypes | PHASE 1 | PHASE 2

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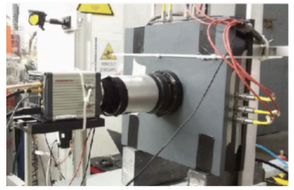
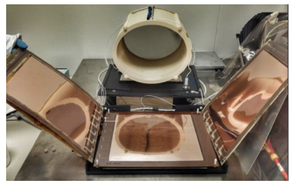
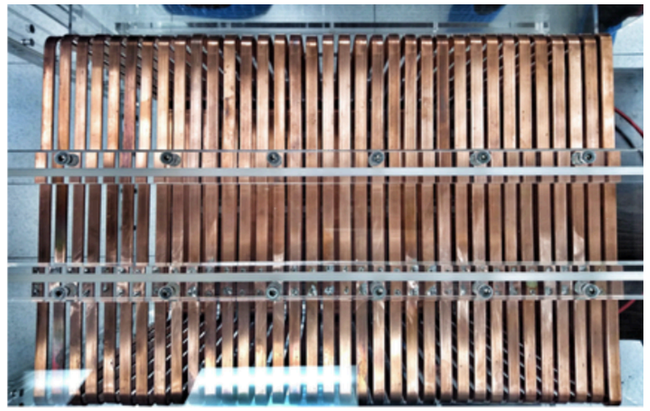
ORANGE | LEMON | LIME | CYGNO_04 | CYGNO_30



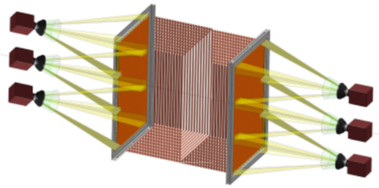
- 1 cm drift



- 3D printing
- 20 cm drift



- 50 cm drift
- Underground tests
- MC validation



- Background
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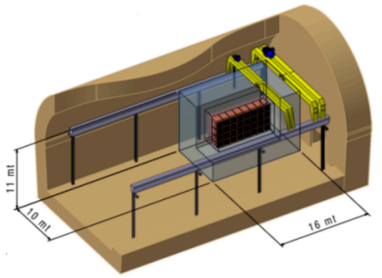

- Physics research

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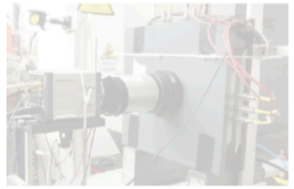
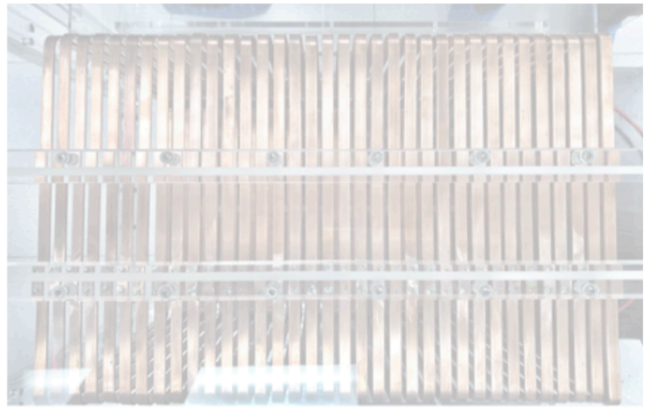
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027

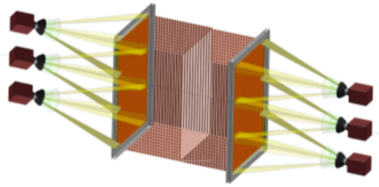
ORANGE | LEMON | LIME | CYGNO_04 | CYGNO_30



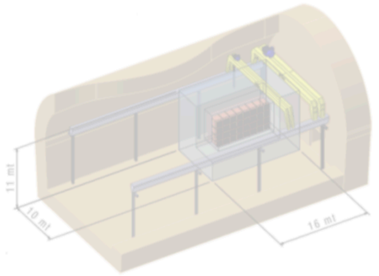
- 1 cm drift
- 3D printing
- 20 cm drift



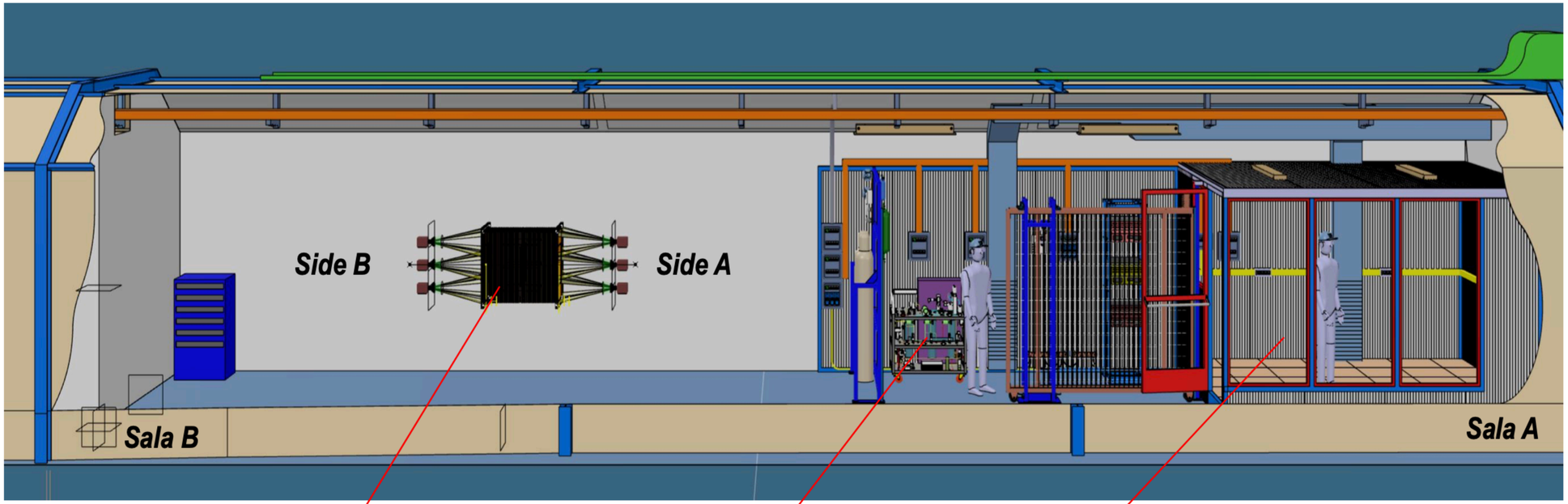
- 50 cm drift
- Underground tests
- MC validation



- Background
- Material tests
- Gas purification
- Scalability



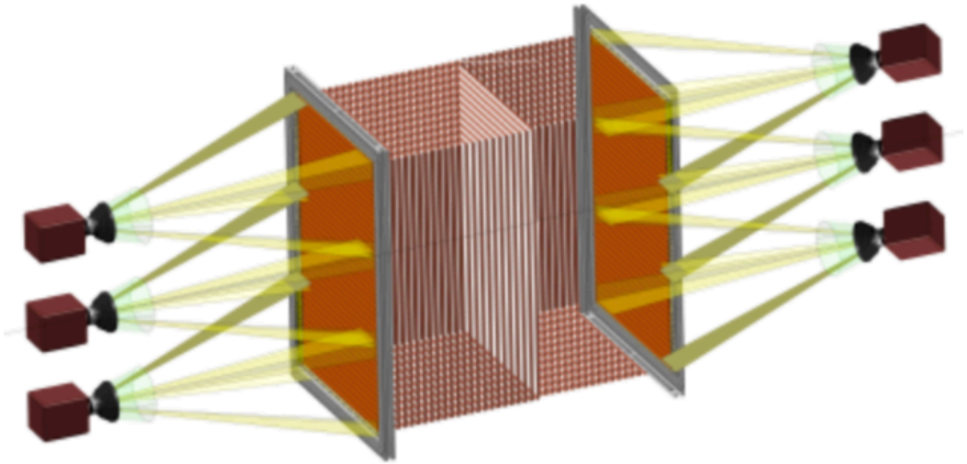
- Physics research



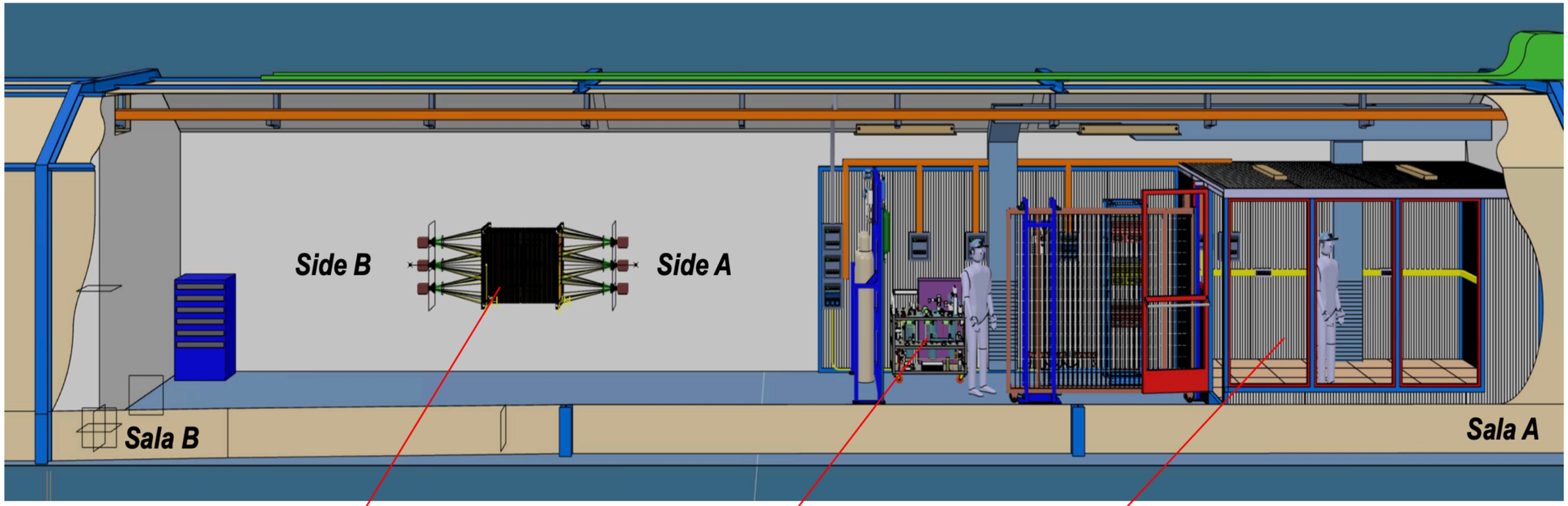
CYGNO_04

SERVICE AREA

CONTROL ROOM



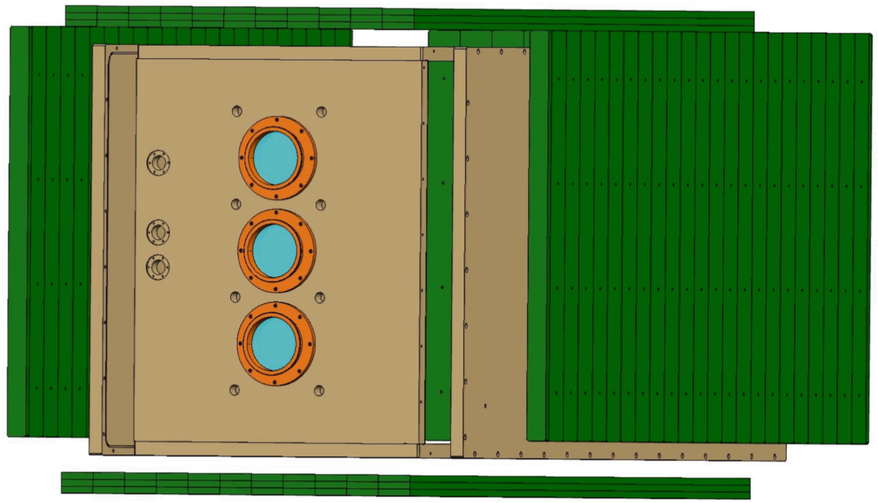
- Back-to-back 0.4 m³ TPC, with central cathode
- Triple 50 um GEMs amplification per side
- 3 sCMOS ORCA Quest per side + PMTs (# TBD)



CYGNO_04

SERVICE AREA

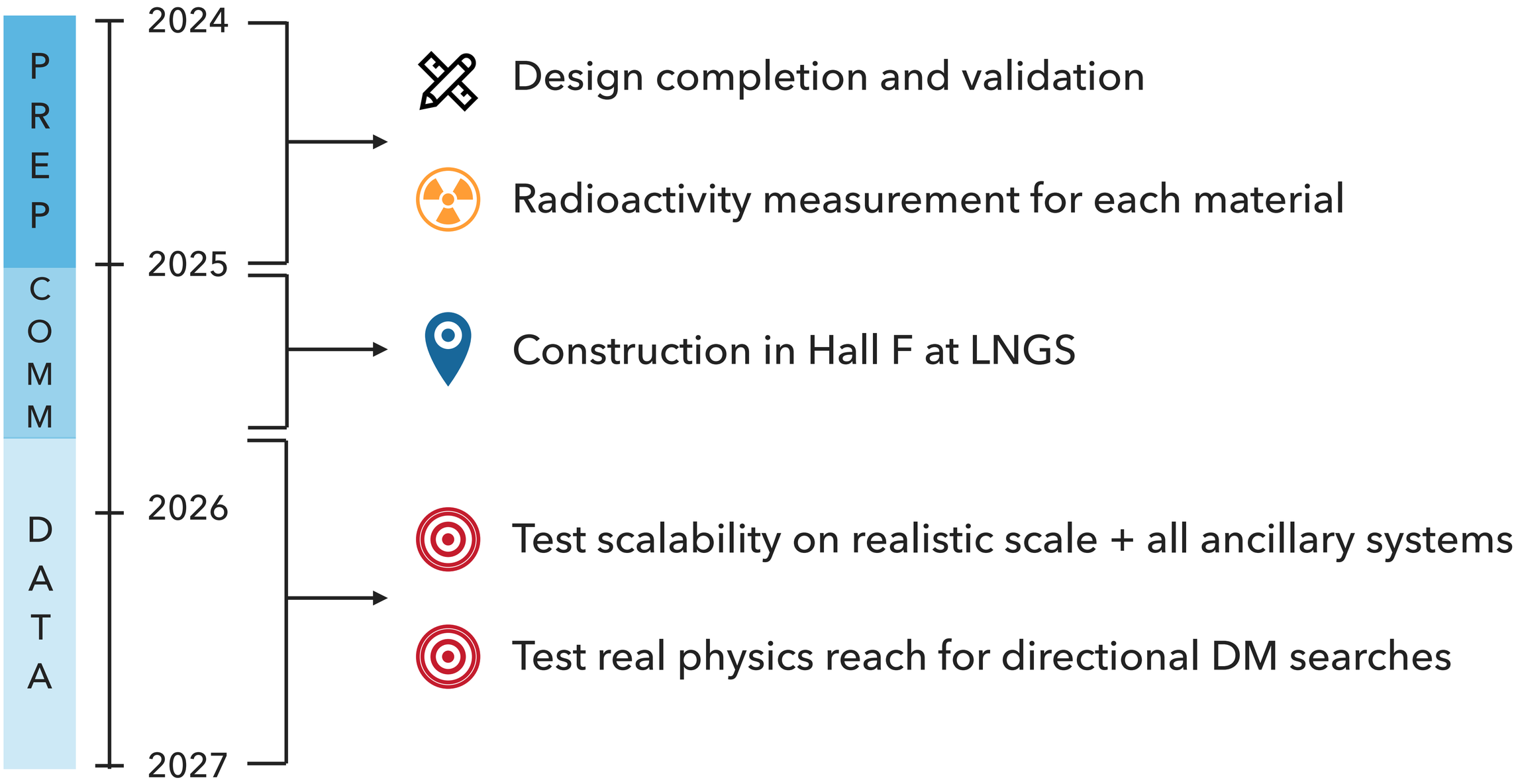
CONTROL ROOM



29 Cu

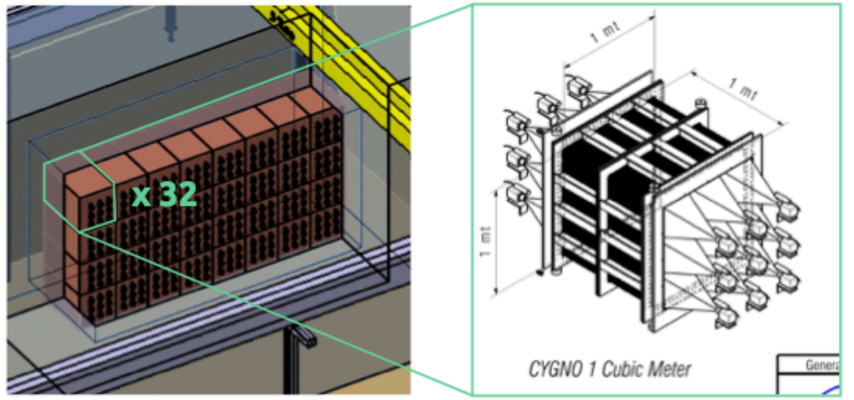
H_2O

Projected shielding composed of
10 cm Cu + 100 cm H_2O


PREP
COMM
DATA
2024
2025
2026
2027
Design completion and validation
Radioactivity measurement for each material
Construction in Hall F at LNGS
Test scalability on realistic scale + all ancillary systems
Test real physics reach for directional DM searches

CYGNO-30 - Prospects

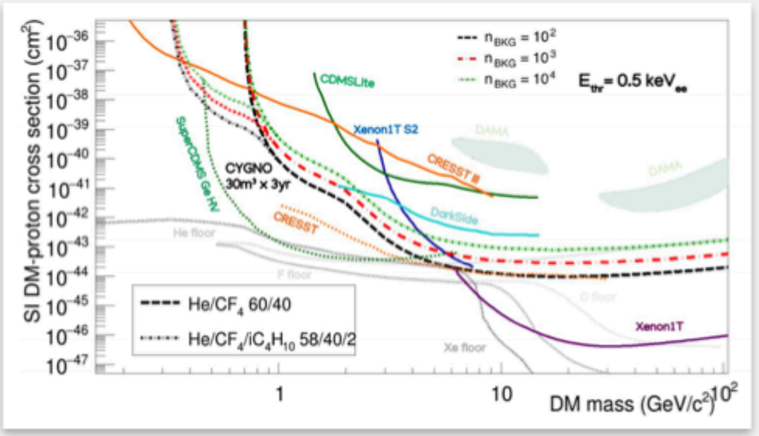
- ➔ **Low mass (0.5 - 10 GeV) directional DM searches**
- ➔ > 2027
- ➔ **30 - 100 m3** detector
- ➔ **0.5 - 1 keV_{ee}** energy threshold
- ➔ **30°** angular resolution

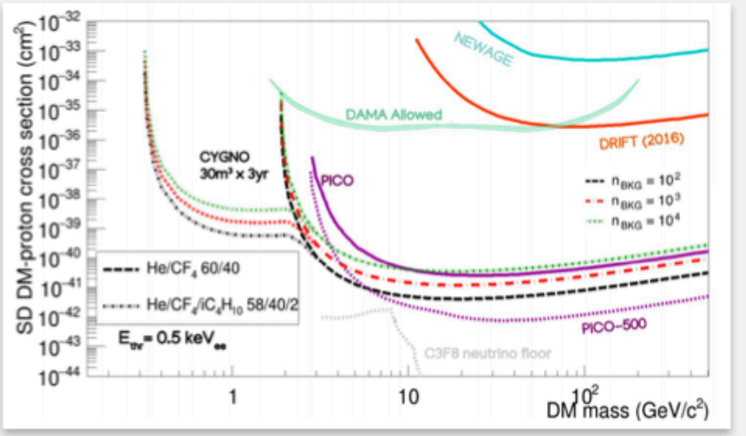


Expected **SI** and **SD** (90% CL)
interaction cross-section exclusion

Quenching factor simulated with **SRIM** → Direct measurement incoming!

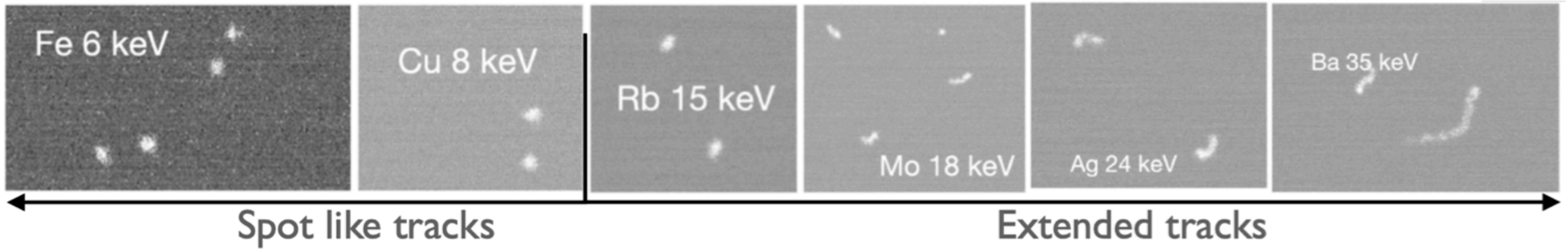
He / (eventually H) allows us to explore very low DM masses!





Energy response

Study of linearity and energy resolution (15-20%) performed with different X-ray sources



arXiv:2305.06168 **[hep-ex]**