CYGNO/INITIUM experiment

Dark Matter direct detection

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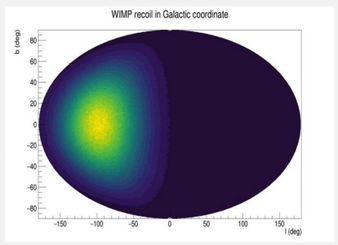
Part of this project has been funded by the European Union's Horizon 2020 research and innovation programme under the ERC Consolidator Grant Agreement No 818744

Physics

Dark Matter (DM)?

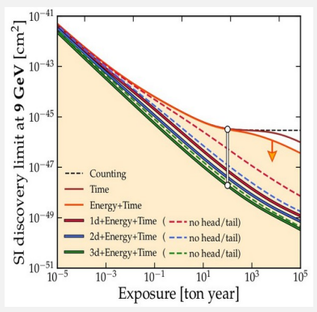
What we **know** so far?

- " A Mystery that effects gravity but does not emit light "
- " Electromagnetically inert and color neutral "
- " May only interact through gravity "
- " Stable (~160 Gyr) " (Stacy Y.Kim et al., Phys. review .lett 2018)
- " Non-baryonic"
- " Mass $\sim 10^{-21}$ eV – 10^{18} GeV (Julien Billard et al., 2022)



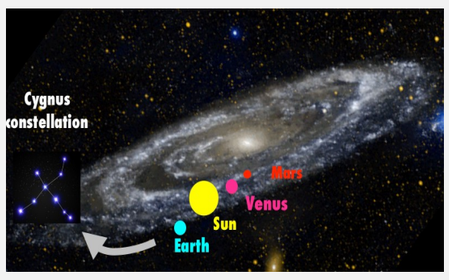
Strong anisotropical angular distribution imprinted in WIMP case

https://link.aps.org/doi/10.1103/PhysRevD.102.075036



Vahsen et al., Annual review,71 (1) (2021)

Where other experiments struggle to **find striking features to prove the existence of DM**, **directional discrimination** emerges as a unique and efficient strategy to ***positively identify*** **Dark Matter!**



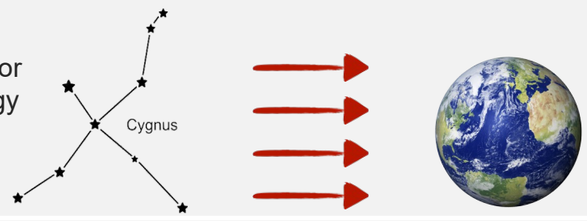
A TPC for directional DM searches

The CYGNO project aims for a large detector for high precision 3D tracking of low energy (0.5-100 keVee) nuclear recoils from rare interactions (such as WIMPs);

Assuming DM can be detected via scattering (WIMPS)

Directional information essential for direct detection

- Better statistical rejection of background
- Sidesteps the neutrino fog problem (especially for Solar neutrinos)
- Will allow 3D astronomy of DM
- **Requires: imaging of nuclear recoils (NRs)**

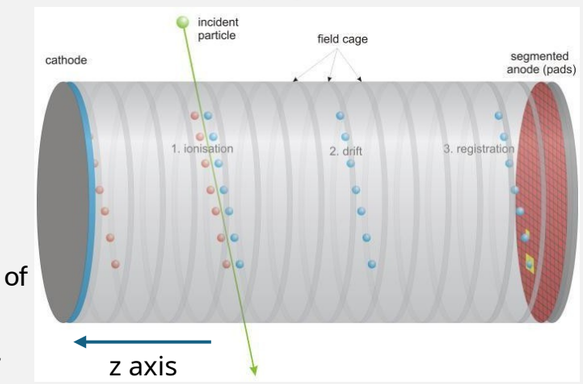


Detector

Core Aspects

- Imaging detector of low energy ERs and NRs (E_{th}~ 0.5 keV_{ee})
- Operated at atmospheric pressure and room temperature with mixture of He:CF_4 (60/40)
- Sensitivity to SI and SD for WIMP mass range of 0.7-50 GeV/c^2
- Triple Gas Electron Multiplier (GEM) stack for signal amplification
- 3D reconstruction with combined use of the camera and PMTs

TPC



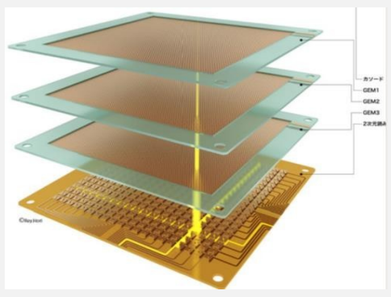
He:CF_4 gas 60/40: room temperature atmospheric pressure

F gives spin dependent sensitivity He for low DM mass sensitivity CF_4 scintillates in visible range

- **Single photon sensitivity**
- **High granularity (2304x2304 pixels)**

Amplification

Grants large gains with high granularity O(50) µm



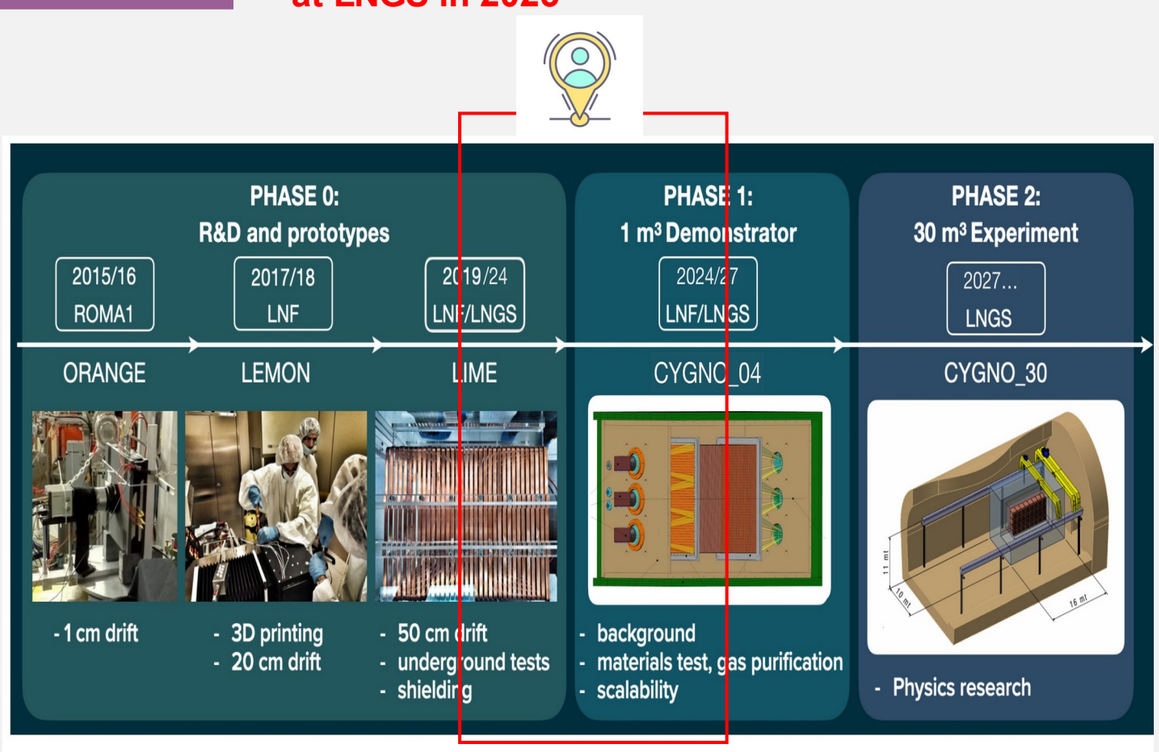
Gas Electron Multipliers (GEMs)

sCMOS Camera

PMT

CYGNO Path

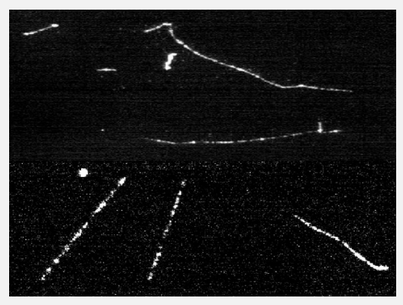
CYGNO_04: 0.4 m³ demonstrator to be operative at LNGS in 2025



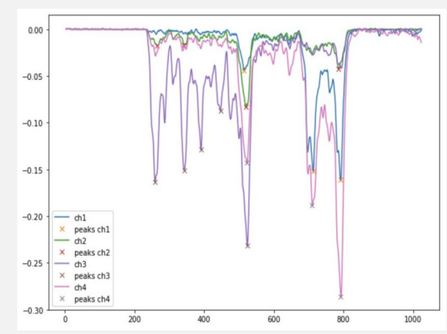
CYGNO_30: O(30 - 100 m³) for directional DM searches in GeV/c² mass region

Optical Readout

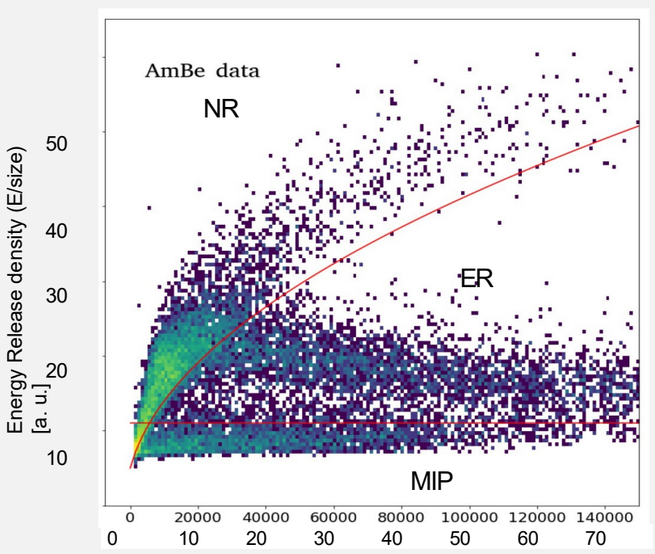
Nuclear Recoils: by means of the energy release density (E/size) it is possible to separate the NR from the ER and MIP tracks

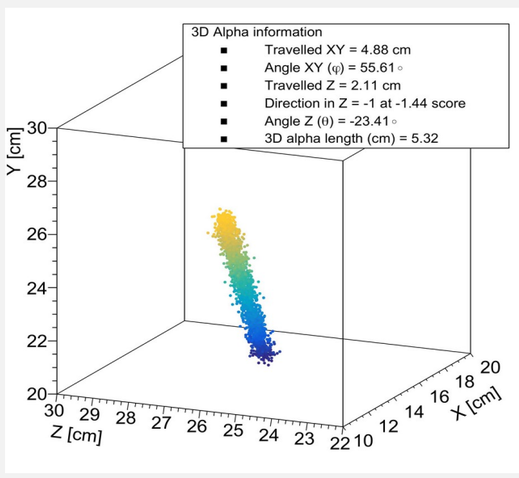


X and y coordinates of released Energy



PMT provides z coordinate of Energy



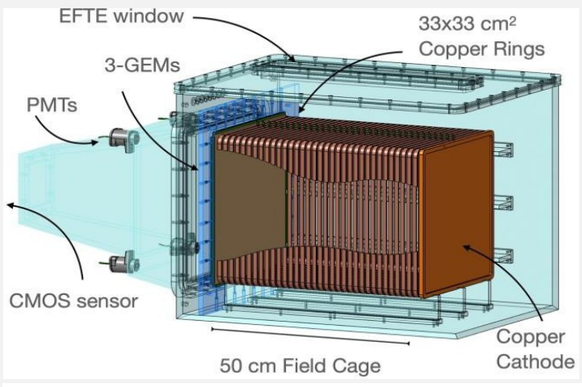


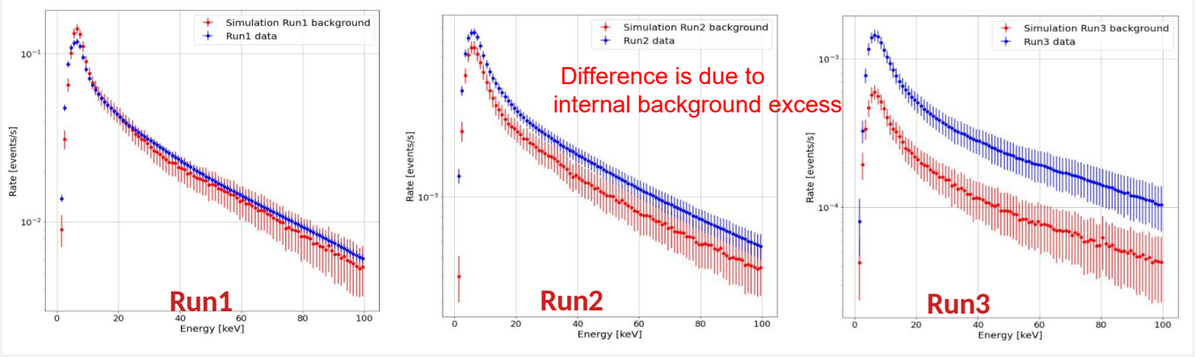
The combination of information allows a 3D reconstruction

Present/ LIME

Long **I**maging **M**odul**E** To validate MC chain and test the detector in a realistic environment for rare event searches

Large readout area imaged by 4 PMTs and 1 sCMOS camera





Phase	Shielding	GEM V(V)	Pictures (Num)	Live time (s)	Rate PMTs(Hz)
Run 1	none	420	285665	175627	30
Run 2	4 cm Copper	440	297992	191382	3.5
Run 3	10 cm Copper	440	171579	191471	1.6
Run 4	+40 cm H2O	Great external neutron suppression => Under analysis			

Future/ CYGNO_04

To prove the scalability of the technology to large volumes using more sensors per side (better than LIME)

To employ as low radioactive materials for gas detectors as possible

CYGNO_04

- **Structure**: TPC in back-to-back configuration, 50 cm drift per side and 0,4 m³ total volume
- **Amplification**: Triple standard GEM stack of 50x 80 cm² per side
- **Readout**: Optical with 3 sCMOS (Hamamatsu ORCA Quest) and 6 PMTs per side

Box clean Cu 2260x900x1100

Box Cu refurbished Opera

CAMERAs pass through

O-Ring cu for tightness