



Founded from ERC in Horizon 2020 program (grant agreement 818744)



SAPIENZA
UNIVERSITÀ DI ROMA



Istituto Nazionale di Fisica Nucleare

CYGN0 : Directional Dark Matter with optical readout



E. Baracchini on behalf of

S. Piacentini for the CYGN0 collaboration

R. Antonietti, E. Baracchini, L. Benussi, S. Bianco, R. Campagnola, C. Capoccia, M. Caponero, L. G. Carvalho, G. Cavoto, I. A. Costa, A. Croce, M. D'Astolfo, G. D'Imperio, E. Danè, G. Dho, F. Di Giambattista, E. Di Marco, J. M. F. dos Santos, D. Fiorina, F. Iacoangeli, Z. u. Islam, E. Kemp, H. P. Lima Jr, G. Maccarrone, R. D. P. Mano, R. R. Marcelo Gregorio, D. J. G. Marques, G. Mazzitelli, A. G. McLean, P. Meloni, A. Messina, C. M. B. Monteiro, R. A. Nobrega, I. F. Pains, E. Paoletti, L. Passamonti, F. Petrucci, S. Piacentini, D. Piccolo, D. Pierluigi, D. Pinci, A. Prajapati, F. Renga, R. J. d. C. Roque, F. Rosatelli, A. Russo, G. Saviano, P. A. O. C. Silva, N. J. Spooner, R. Tesauo, S. Tomassini, S. Torelli, D. Tozzi

11th Astroparticle Physics Science Fair 2024/2025: Underground Physics

24 / 02 / 2025

Email: stefano.piacentini@gssi.it - Office: S2A (Mariani Building)

Dark Matter in the Milky Way

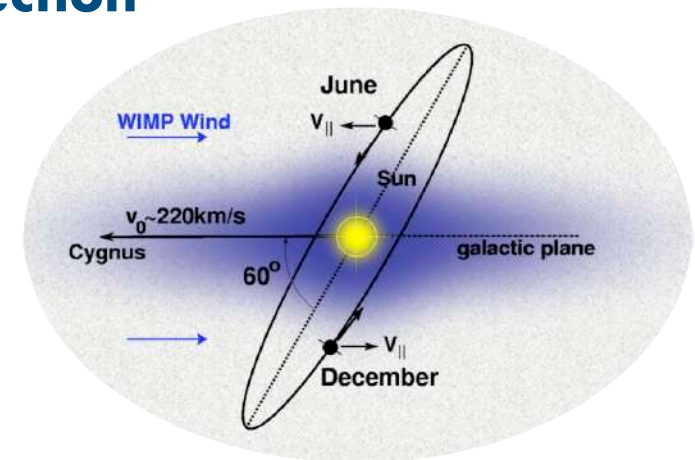
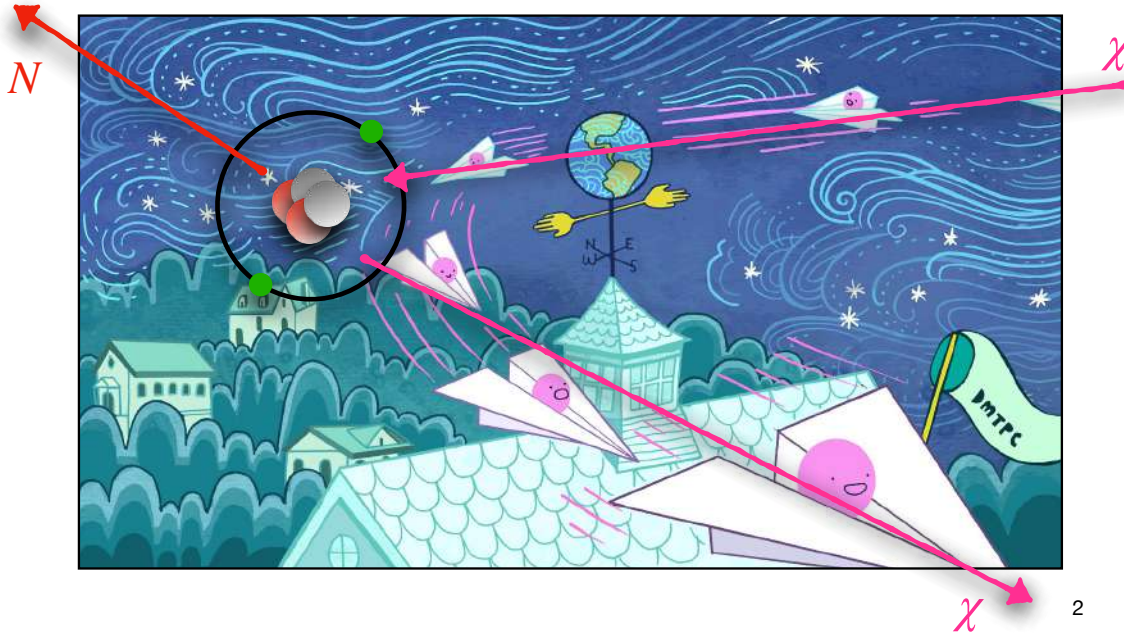
- **Dark Matter (DM)** forms a spherical **halo** permeating the Milky Way



- Solar system **travels through this halo**
- **Apparent DM wind** from the **Cygnus** direction

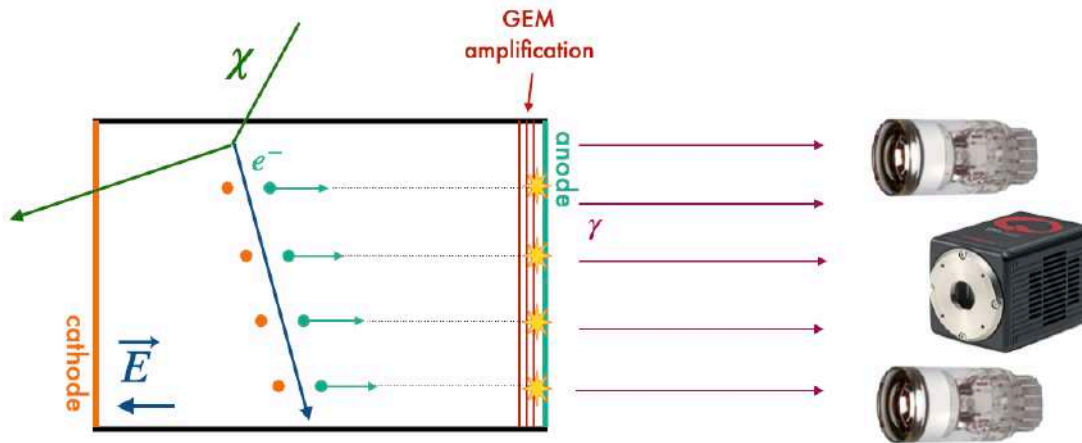
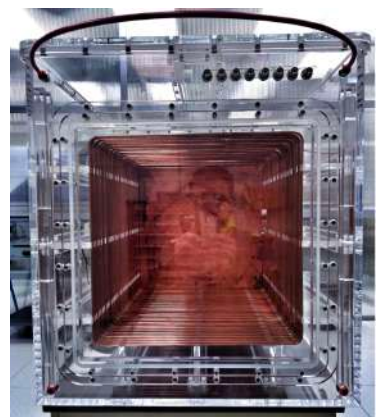
DM Direct Detection:

Recoiling nucleus

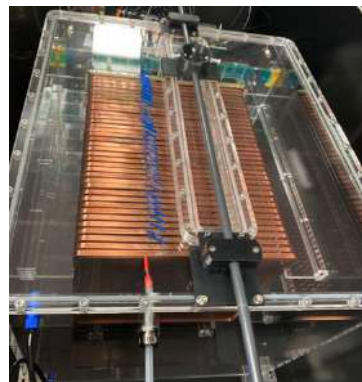
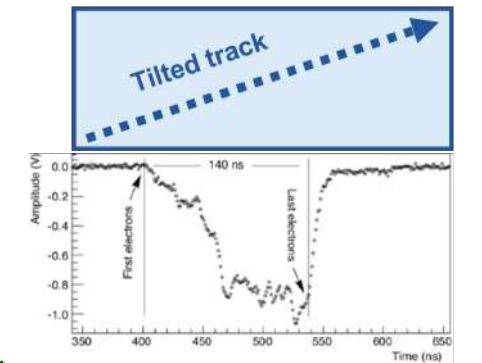
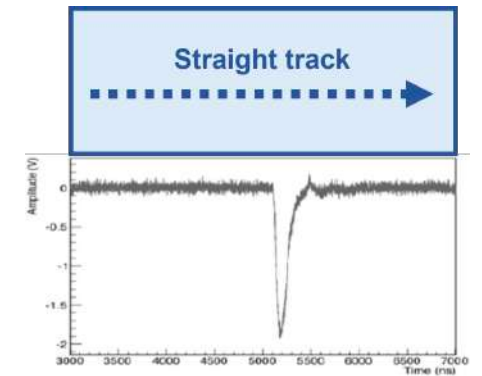


The **CXGNO** project

- **Aiming for** a large detector for high precision **3D tracking of rare low energy nuclear recoils** (keV) possibly induced by **dark matter** (DM) particles and solar neutrinos
- **Strategy: photograph nuclear recoils** in a (1 atm) He:CF₄ TPC with a GEM amplification stage
 - ➔ low energy events in 1 atm gas ➔ visible tracks ➔ optical readout



- Independent measurement of the **energy**
- **Temporal** evolution → **z evolution** → **3D reconstruction** (PMT + Camera)



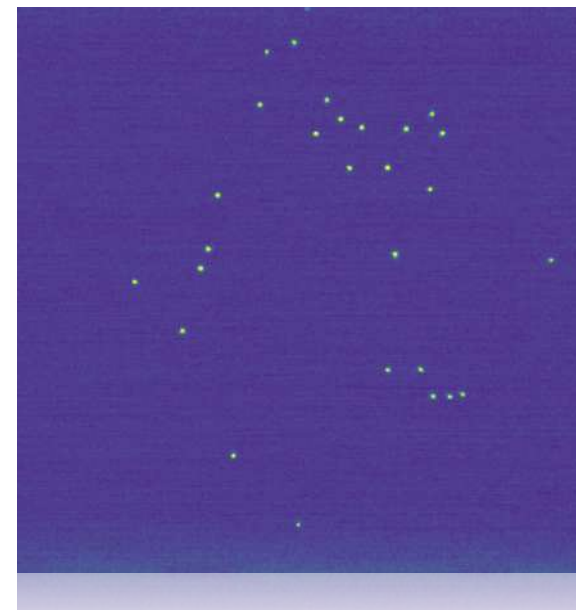
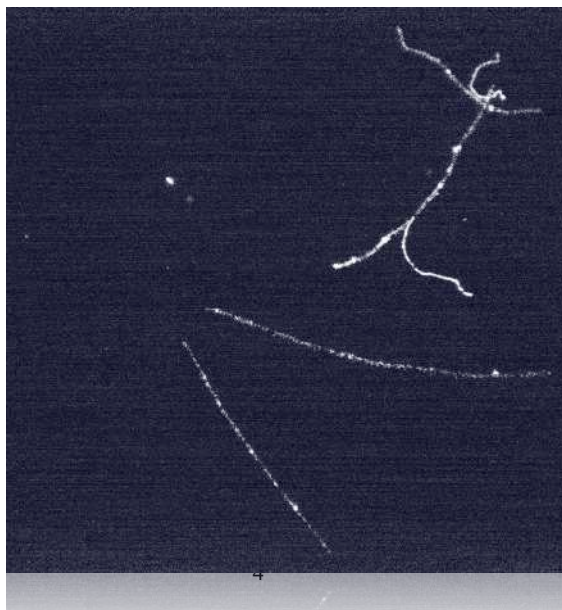
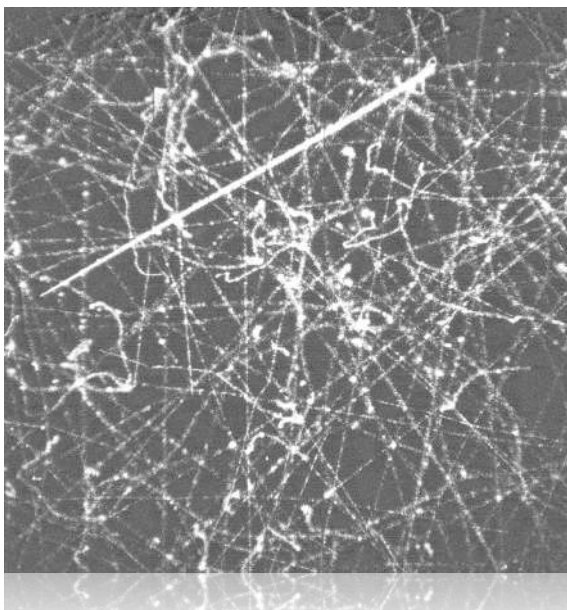
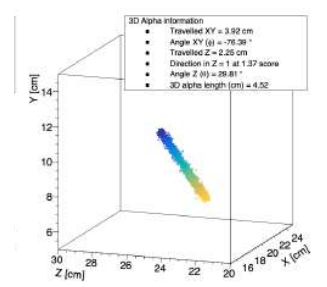
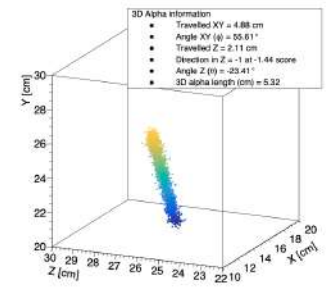
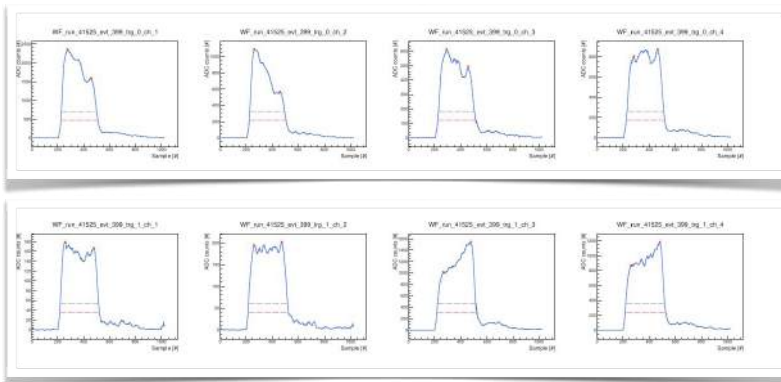
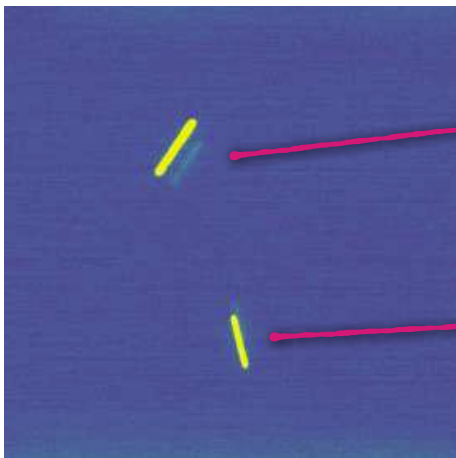
Camera **sensitivity** + **high granularity**

↓

- **Energy**
- **2D** coordinates

PMTs

Our data



erc **INTIUM: the Negative Ion Drift**

Advantages

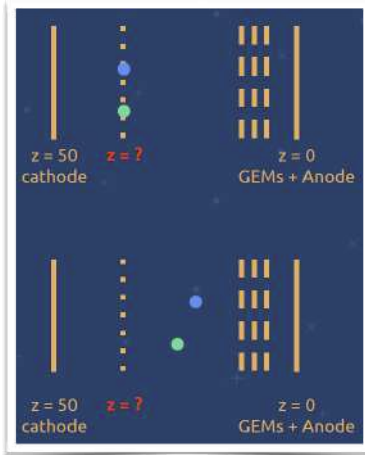
Reduced diffusion

Multiple charge carriers

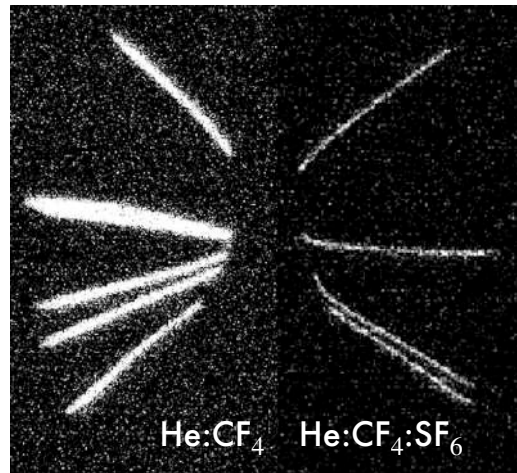
Better spacial resolution

Better directionality

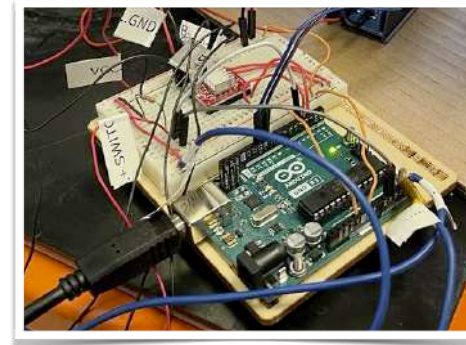
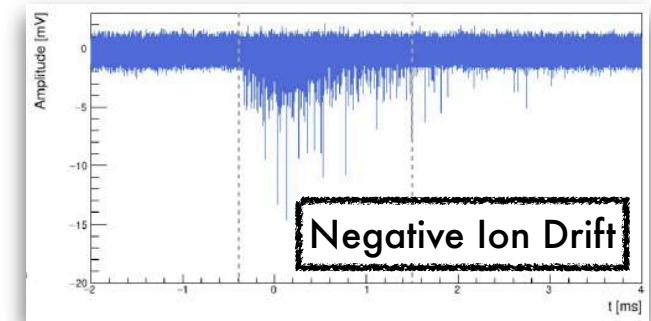
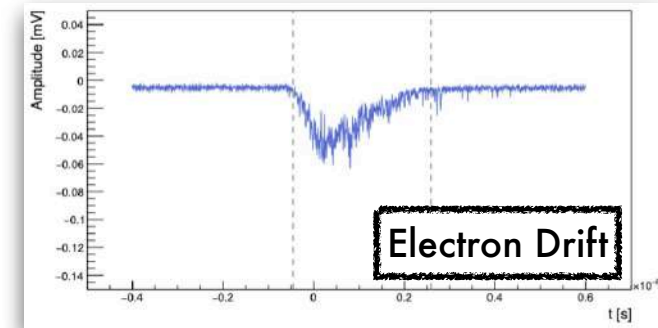
Better sensitivity to directional signals



Absolute Z

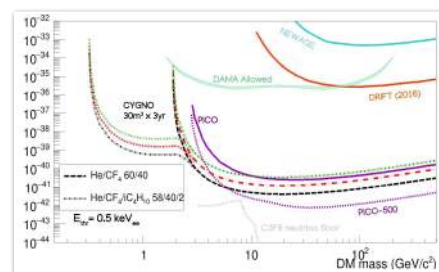
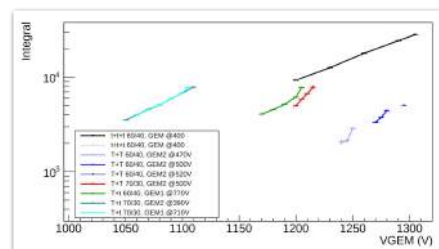


- ◎ Same light yield, smaller diffusion
- ◎ Slower signals: O(ns) → O(ms)

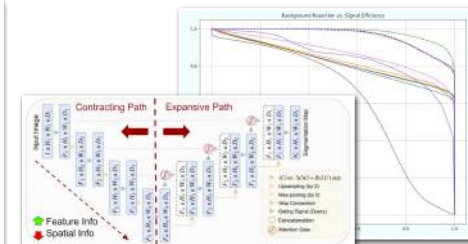


CYGNO generations at GSSI

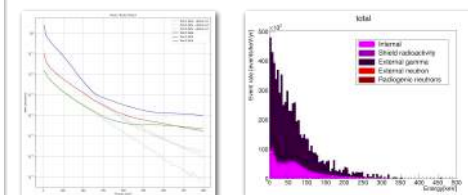
Prof. Elisabetta Baracchini



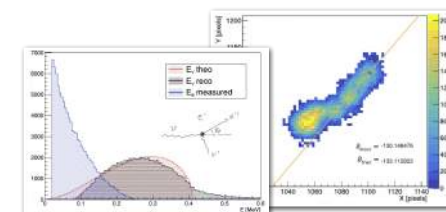
- Track reconstruction
- PID with ML



- Data-MC comparison
- Simulation



- Directionality
- Feasibility of neutrino searches with CYGNO-30



- BaBar
- MEG
- ERC: INITIUM (NID)
- DM, TPCs, MPGDs,
- ...

- CYGNO DM sensitivity
- Light yield enhancement
- Optics
- NID

GEN 0

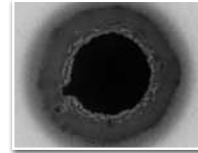
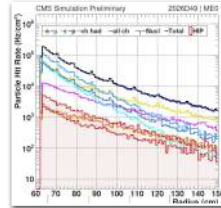
GEN 1

GEN 2

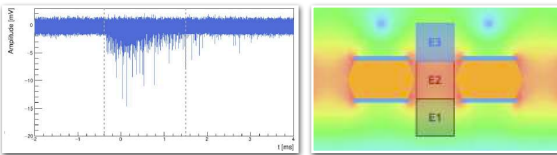
CXGNO generations at GSSI



- CMS
- GEMs
- Picosec (timing)
- Polarimetry

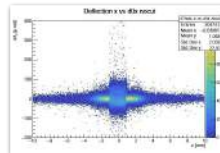


- LIME operations
- Analysis (PMT and camera)
- DAQ
- DarkSide
- Sensitivity projections and limit setting

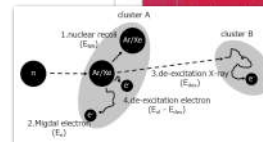
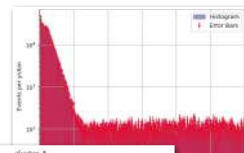


- Maxwell simulations
- DAQ / Detector operation
- PMT reconstruction / 3D
- NID (PMT)

- Crystal collimation
- SiPMs
- Migdal



- Neutron simulation
- Migdal
- Analysis



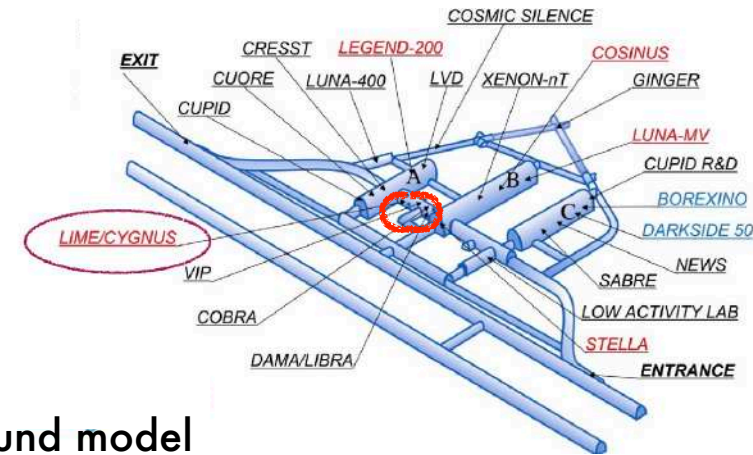
GEN 3

GEN 4

GEN 5

LIME

the first underground CYGNO



- LIME underground since 2022
 - ➔ Validation of our MC and background model
 - ➔ Latest tests ongoing in sight of CYGNO-04
 - ➔ Analysis of 2-years long data taking

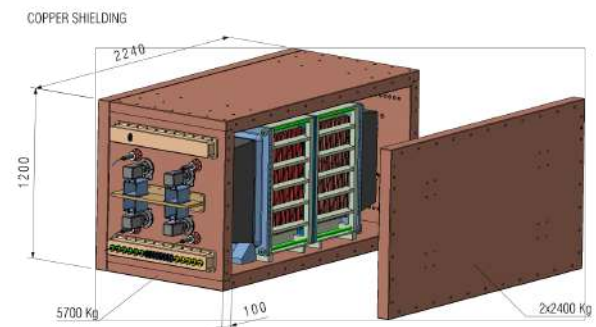
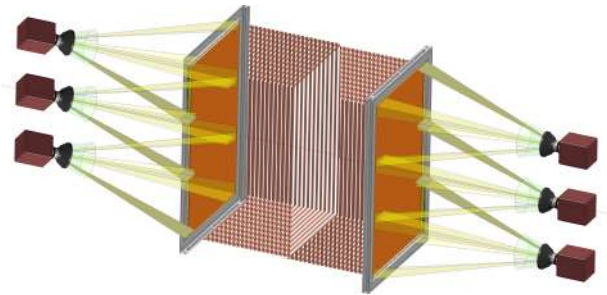
	Shielding	Number of bkg pictures	Event rate	Period
Run1	none	4×10^5	35 Hz	Oct 2022
Run2	4 cm Cu	4.5×10^5	3.5 Hz	Jan-Mar 2023
Run3	10 cm Cu	2.7×10^6	1.3 Hz	May-Nov 2023
Run4	10 cm Cu + 40 cm H ₂ O	2.8×10^6	0.9 Hz	Dec 2023-Apr 2024



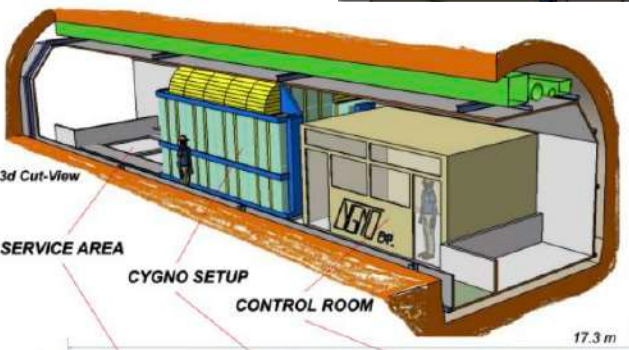
CYGNO-04

Building an experiment demonstrator: broke ground last week

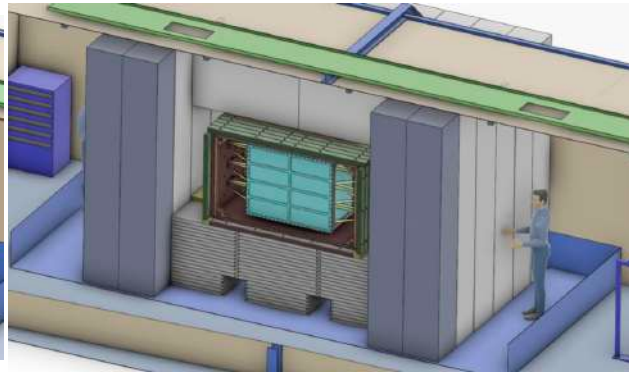
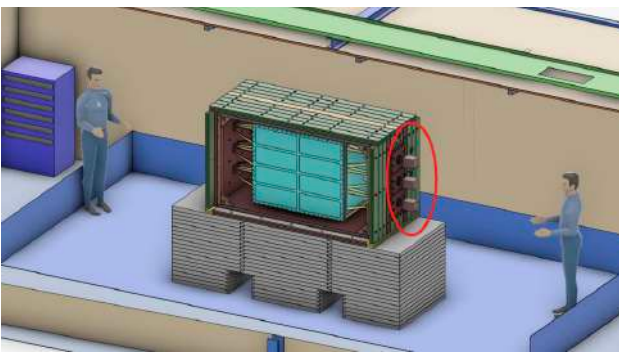
- Commissioning of CYGNO-04
 - ➔ Finalization of the executive design
 - ➔ Data taking foreseen to start in 2026
 - ➔ Prove the scalability to a larger detector



Hall F, or else how to build a cygnus in a bottle....



CONCLUSION:
It seems possible to arrange a "Cygnus Demonstrator" Setup with a water-shielding thickness close to 1 mt (0.9mt). Keep in consideration that due to the narrow hallway (1.2mt) we have to work like a: "Make a ship in a bottle"



Very exciting times ahead!

What **you** can do in **CYGN0!**

Phys.Lett.B 855 (2024) 138759

Eur.Phys.J.C 83 (2023) 10, 946

Instruments 6 (2022) 1, 6

Measur.Sci.Tech. 32 (2021) 2, 025902

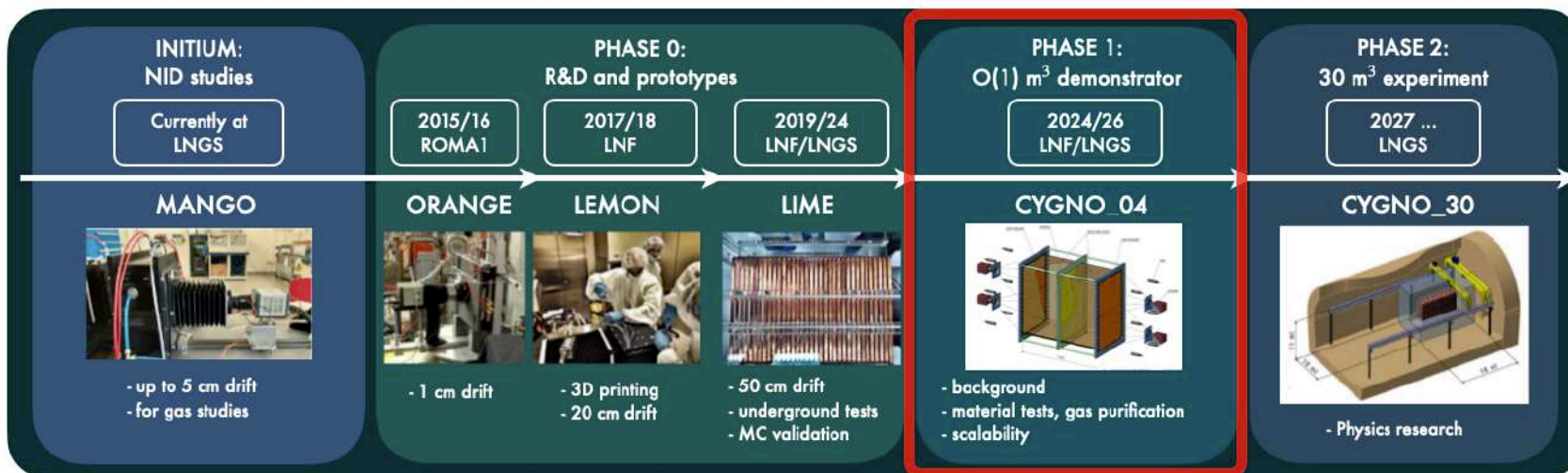
NIM A 999 (2021) 165209

JINST 15 (2020) 12, T12003

JINST 15 (2020) P10001

JINST 15 (2020) P08018

2019 JINST 14 P07011



- LIME sensitivity to DM and CYGNO limit setting tool
- Improve 3D reconstruction
- Directionality
- ER vs. NR discrimination
- Background model
- Detector response model
- Simulation
- Data vs. MC comparison
- Commissioning of CYGNO-04
- DAQ of CYGNO-04
- Neutrinos
- X-Ray polarimetry (see poster)
-

