



CYGN0

Directional Dark Matter with Optical Readout + Negative Ions (?)

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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



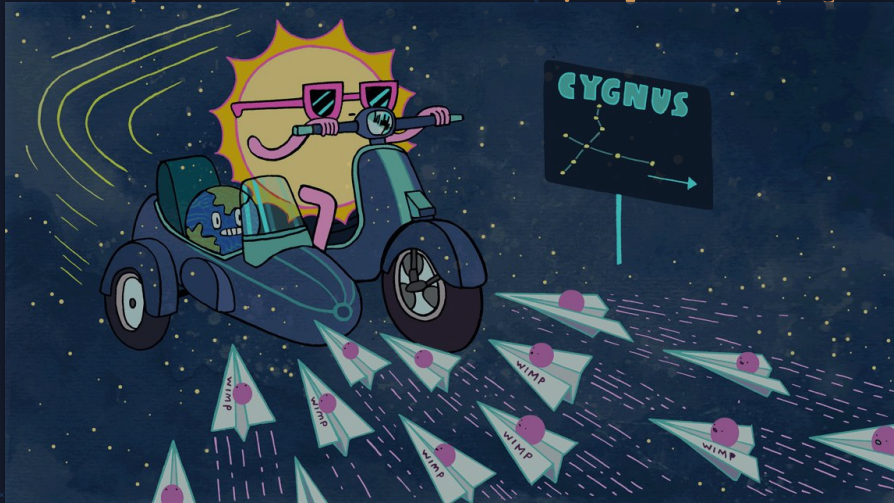
DM forms an halo within our galaxy.



Solar system rotates around galaxy towards Cygnus constellation

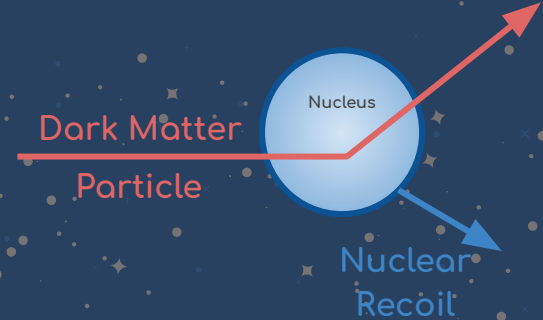


Earth susceptible to an apparent WIMP wind from Cygnus direction!



Direct detection

- ❖ $SM + \chi \rightarrow SM + \chi$
- ❖ SM particle's recoil



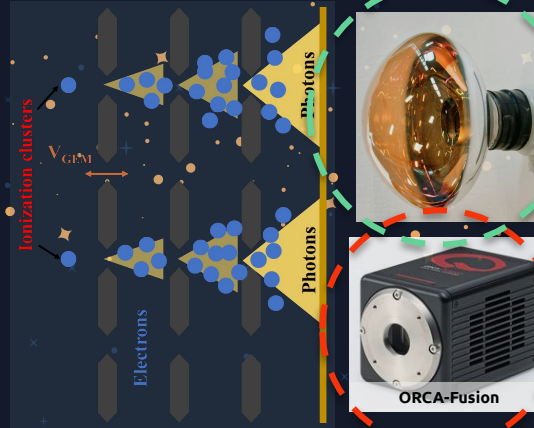
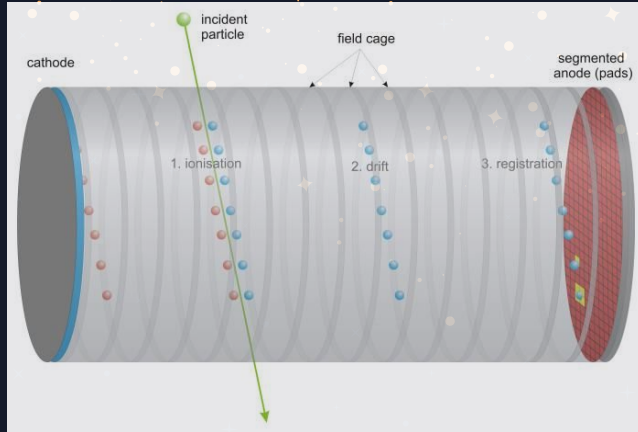
The CYGNO setup

Time
Projection
Chamber

Triple GEM
Charge
amplification
& light production

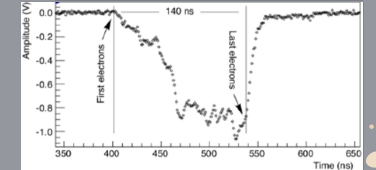
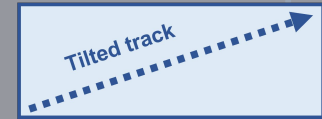
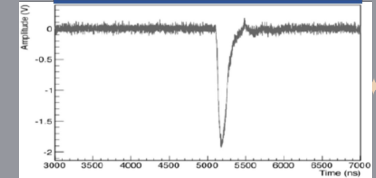
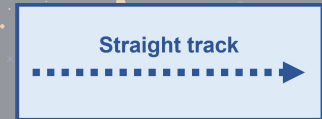
Camera & PMT

Optically read the **light produced by the de-excitation of the gas molecules** during electron multiplication.

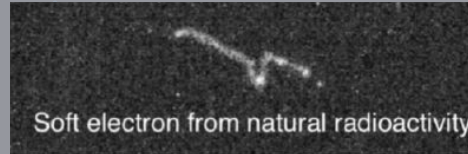
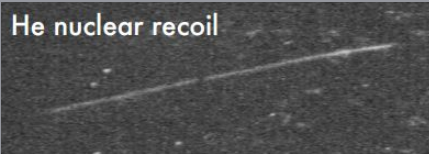


1. Measure integrated energy.
2. Charge carriers' times of arrival →

dZ coordinate (track's tilt)

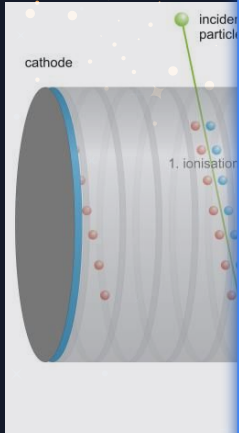


Using the camera's high granularity, we can measure the **energy** & **X & Y coordinates**



The CYGNO setup

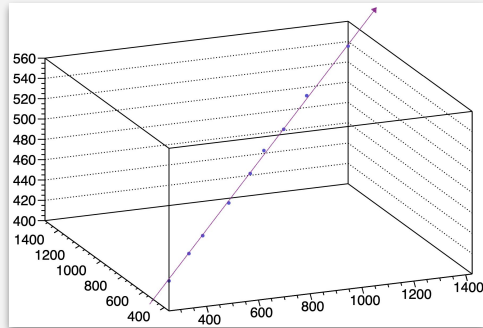
Time
Projection
Chamber



Triple GEM

Charge

$X + Y + dZ =$
3D reconstructed track



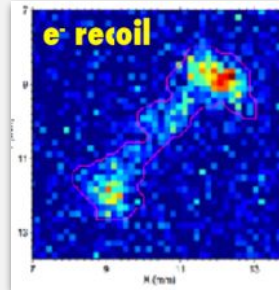
Camera & PMT

Optically read the **light produced by the**

Track's deposited energy
topology (dE/dx)

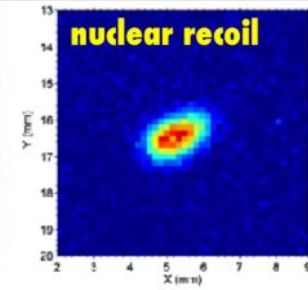
Head-tail asymmetry

↓
Directionality



Particle

↓
BG rejection



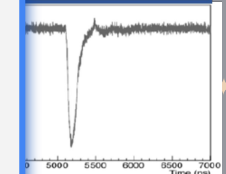
1. Measure integrated energy.

Charge carriers'

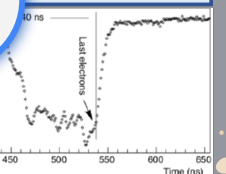
of arrival →

Time (ns)

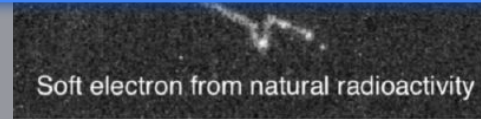
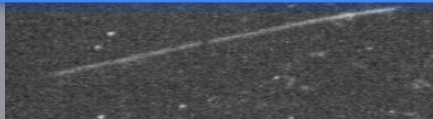
Light track



Track

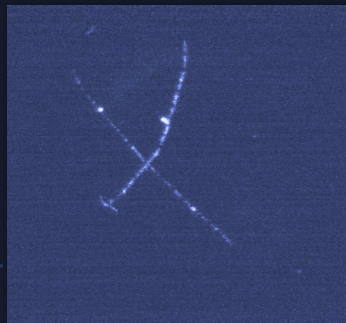
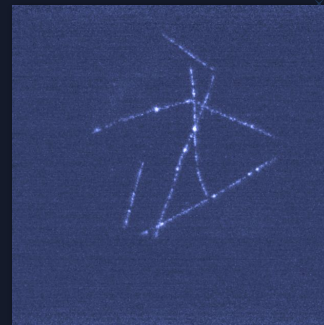
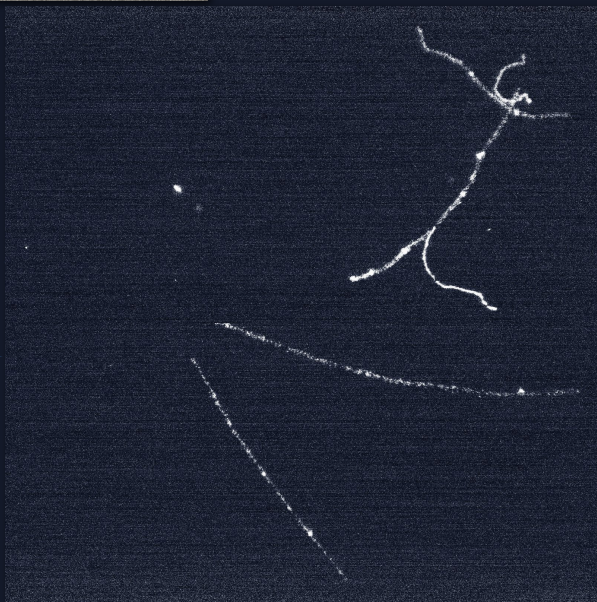
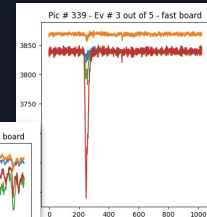
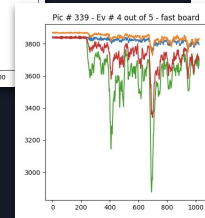
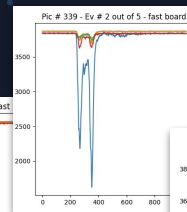
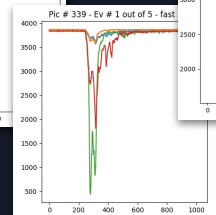
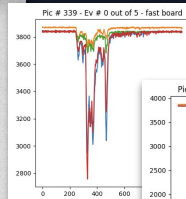
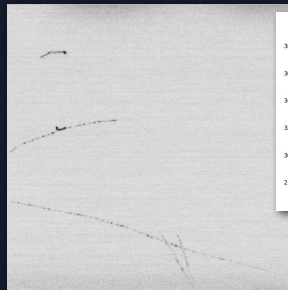
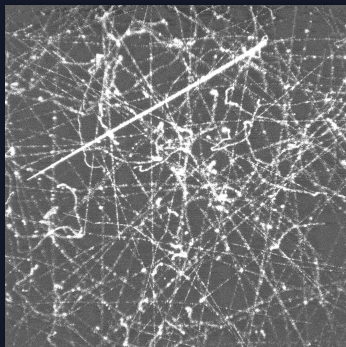


Using the camera's high
granularity, we can
measure the **energy** &
X & Y coordinates



Soft electron from natural radioactivity

Some cool pictures

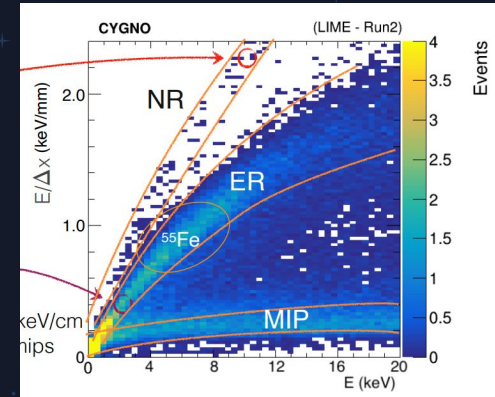
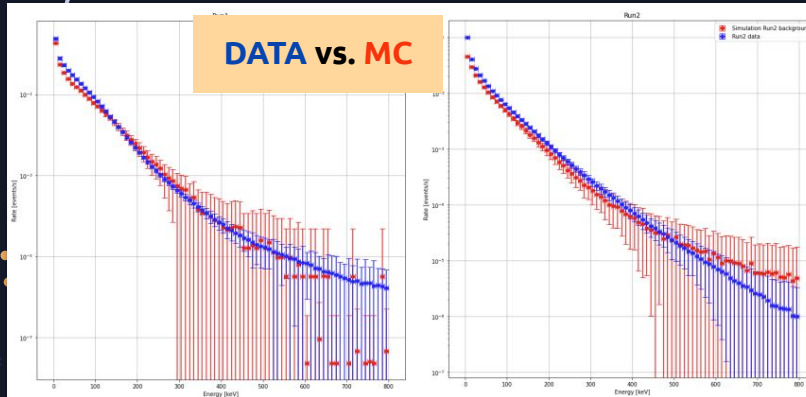
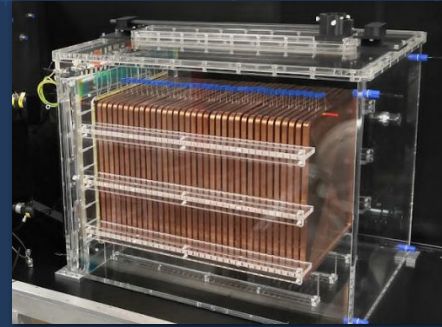
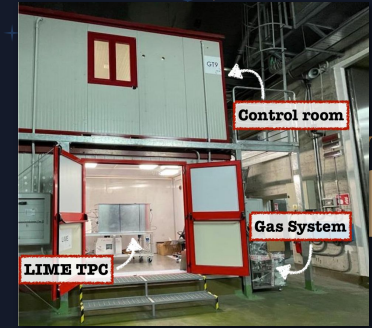


Check out our stand for real-time pictures

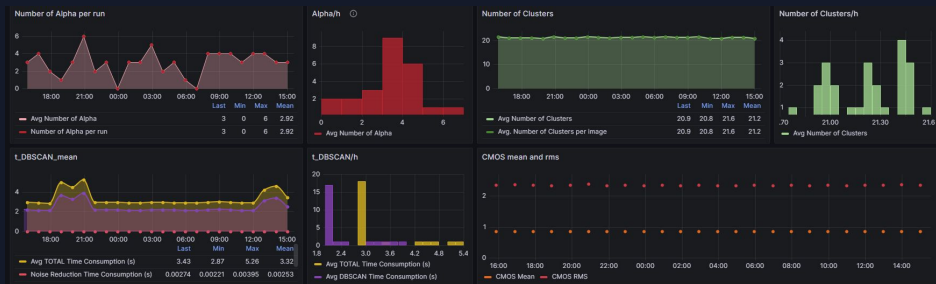
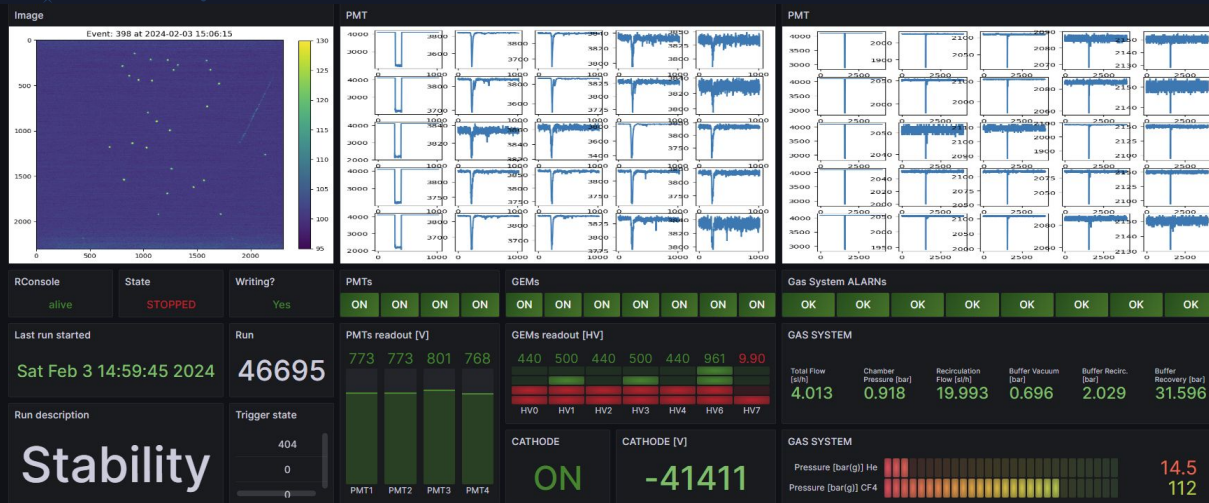


Current stage of CYGNO

- ★ **LIME** has been placed **underground** at LNGS in the beginning of 2022.
- ★ Several initial tests: DAQ, remote control, slow control, gas quality, detector operation optimization
- ★ Study of **shielding**
 - No shielding, 4cm copper, 10cm copper
 - 10cm copper+40cm water
- ★ Validation of **simulated BG model**.
- ★ ^{55}Fe , Ba, **Am[Be]** runs, background radioactivity, ...



LIME currently in data taking...



Checkout our stand for real-time monitoring

The Negative Ions Arc...

Advantages:

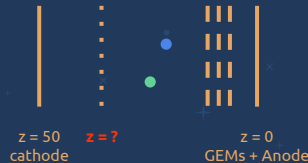
Reduced diffusion

Multiple charge carriers

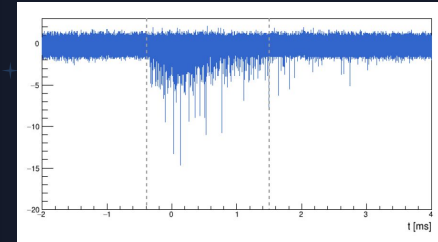
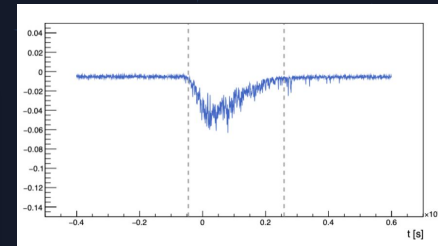
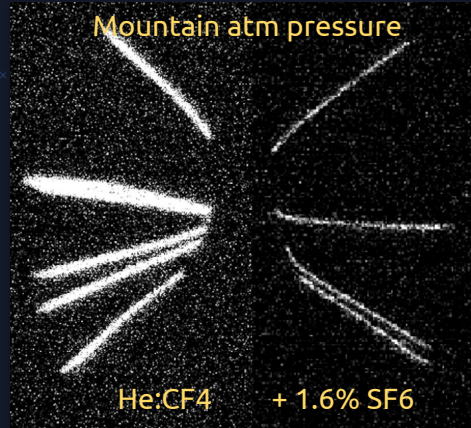
Better spatial resolution!

Better directionality

Better ER vs NR discrimination

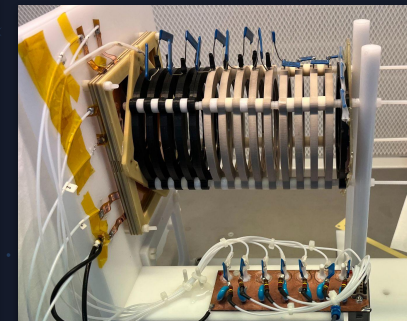
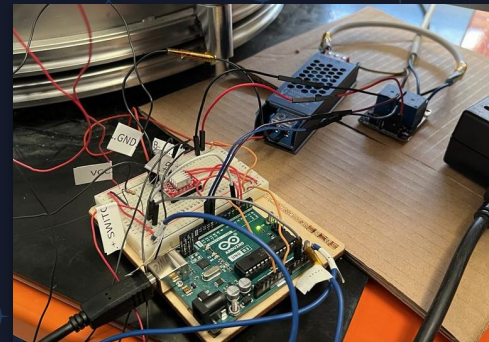


Absolute Z from Δt between minority charge carriers



- ★ Same light, less diffusion ✓
- ★ Signal length: O(ns) \Rightarrow O(ms) ✓

Nature, here we go!

The CYGNO family tree



E. Baracchini

- ★ BaBar
- ★ MEG
- ★ ERC ⇒
- ★ Negative Ions
- ★ DM, TPCs, MPGDs ...

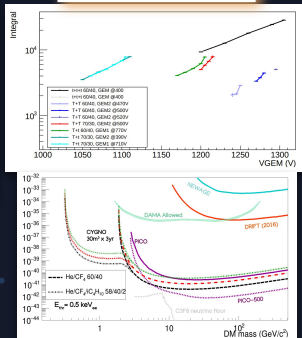
Root



Giorgio

- ★ CYGNO DM sensitivity
- ★ Light yield enhancement
- ★ Optics
- ★ Negative Ions (camera)

1st Gen



Atul



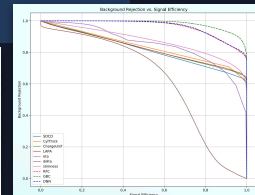
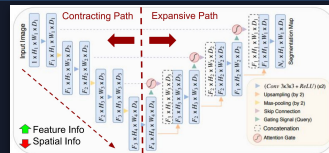
Flaminia



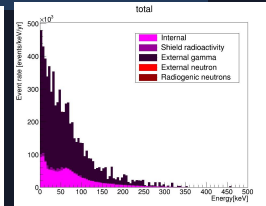
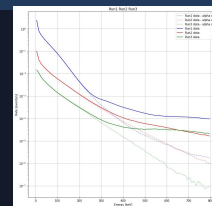
Samuele

2nd Gen

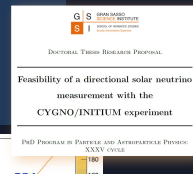
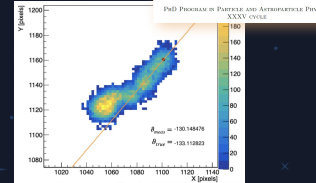
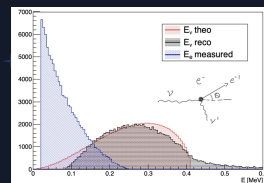
- ★ Track reconstruction
- ★ PID with ML



- ★ Data-MC comparison
- ★ Background & Shielding simulation



- ★ Directionality
- ★ Neutrino feasibility in CYGNO_30



The CYGNO family tree



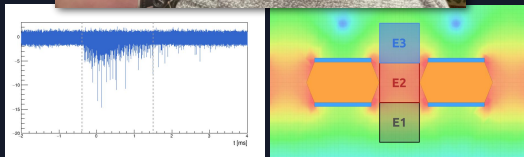
E. Baracchini

- ★ BaBar
- ★ MEG
- ★ ERC ⇒
- ★ Negative Ions
- ★ DM, TPCs, MPGDs ...

Root



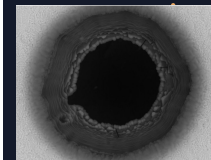
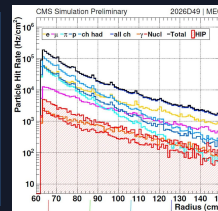
David



- ★ Maxwell simulations
- ★ DAQ/ Detector operation
- ★ PMT reconstruction / 3D
- ★ Negative Ion Drift (PMT)

3rd Gen

- ★ CMS
- ★ GEMs
- ★ Picosec (Timing)
- ★ Polarimetry



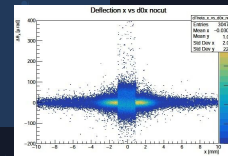
Zahoor

Davide

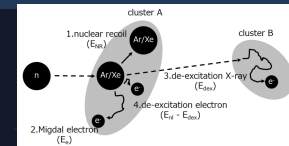
Melba

David (again)

- ★ Crystal collimation
- ★ SiPMs
- ★ Migdal



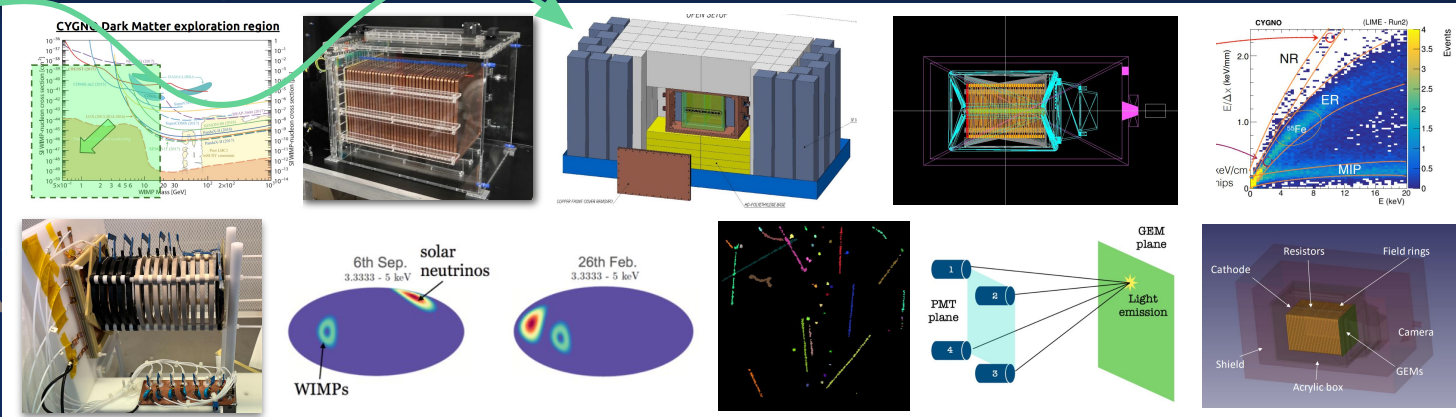
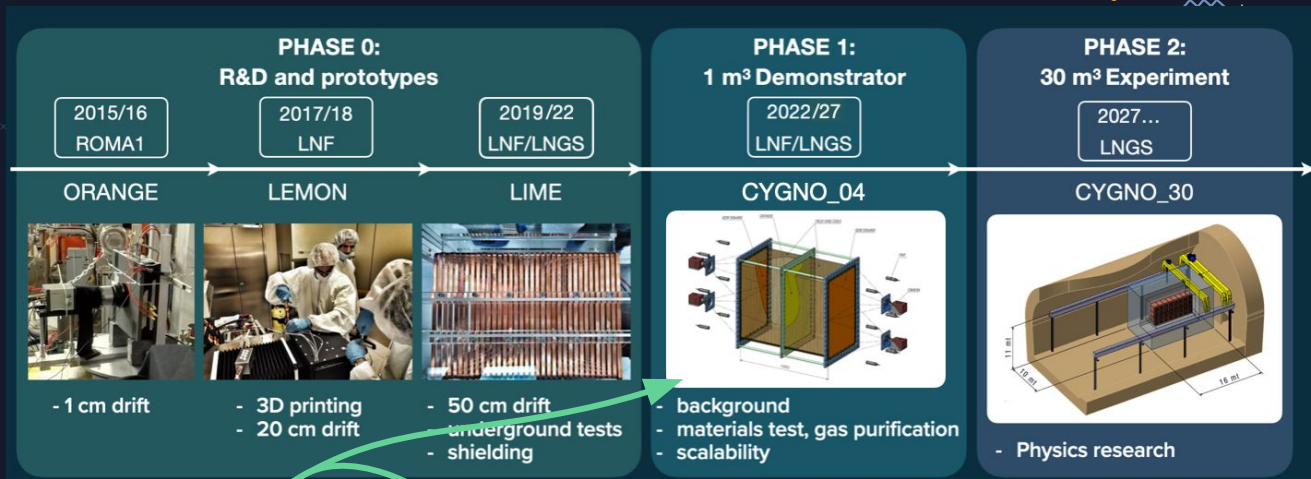
- ★ MIGDAL
- ★ TBD ...



4th Gen

The CYGNO roadmap \Rightarrow *What can you do?*

- ★ DM Sensitivity
- ★ 3D reconstruction
- ★ Directionality
- ★ ER vs. NR
- ★ Shielding
- ★ Background
- ★ Data vs. MC
- ★ Negative Ion Drift
- ★ Design and Commissioning of CYGNO_04
- ★ Fundamental physics
- ★ Axions
- ★ Neutrinos



The CYGNO roadmap: What can you do?

MIGDAL MEASUREMENT WITH CYGNO APPROACH

FARE
RICERCA IN ITALIA

Melba D'Astolfo, XXXVIII cycle

PHYSICS CASE

Migdal Effect - the nucleus after a scattering with a neutral projectile moves relative to the electron cloud. Individual electron might be ejected leading to ionisation. [A. Migdal ionisation atom on yandex.ru reaksyiah. arXiv:1403.1145 (1937); ZHEIT, V. 1142-1145 (1937);

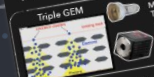


He nuclear recoil

CYGNO APPROACH
The CYGNO (CYGNO) module with Optical readout experiment aims for a large detector for high precision 3D tracking of rare low energy nuclear recoils (keV) as for example WIMPs.



CYGNO is a gaseous TPC filled with a gas mixture of He/CF4 (60-40) at 1 atm and room temperature



See others Cygno's posters for details

MANGO



The MANGO Multipurpose Apparatus for low energy ionisation is the smallest detector that performs the Migdal measurement due to its reduced size.

R. Antonielli, E. Baracchini, L. Benussi, S. Bianco, F. Borra, C. Caporaso, M. Caporaso, D. Fiorina, R. M. Gregorio, F. Licciardi, E. Kemp, H. P. Line Junior, G. S. P. Lopes, A. Lopez Giambattista, E. Di Marco, G. D'Inferno, J. M. F. dos Santos, D. Fiorina, R. M. Gregorio, F. Licciardi, E. Kemp, H. P. Line Junior, G. S. P. Lopes, A. Lopez Mascamanna, R. D. P. Mano, D. J. G. Marques, G. Mazzitelli, A. G. McLean, P. Maltoni, A. Marzola, C. M. B. Monteiro, R. A. Nobrega, I. F. Paine, E. Paolotti, F. Petrucci, S. Piacentini, D. Piccolo, D. Pierluigi, D. Pini, A. Prati, P. Ranca, E. C. Roque, F. Rossetti, A. Russo, G. Saviano, N. J. C. Spooner, R. T. Tommasini, S. Turchetta

erc IN TIUM

FRASCATI NEUTRON GENERATOR

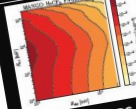
FNG is a linear electrostatic accelerator that can produce 14 MeV neutrons and 2.4 MeV neutrons
 $D + T \rightarrow n + \alpha$ (yield up to 10^{17} n/s)
 $D + D \rightarrow n + p$ (yield up to 10^{17} n/s)

SETUP



We are planning a background characterization campaign at the end of February of the FNG room. The outcome of these measurements will allow to select the optimal spot for the actual data taking.

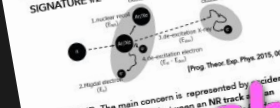
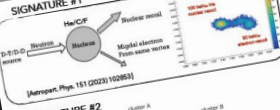
PREDICTIONS



NEXT STEPS

- Detector simulation
- Characterize the background
- Design of the shielding
- Operational test of the detector

HOW CAN WE MEASURE IT?



BACKGROUND: The main concern is represented by accidental coincidences between an NR track and a background event. In addition, background sources are the ER tracks and the ER tracks from the ER detector.

CYGNO COLLABORATION

ray-CMOS: a wide field of view X-ray polarimeter

Elisabetta Baracchini¹, Enrico Costa², Giorgio D'Onofri³, Flaminia Di Giambattista⁴, Alessandro Di Marco⁵, Emanuele Di Marco⁶, David Marques⁷, Giovanni Mazzitelli⁸, Fabio Muker⁹, Aida Poppe¹⁰, Paolo Sestini¹¹, Paolo Sestini¹², Samuele Torelli¹³

Measurements effects to take into account
 Photoelectric effect
 Compton effect
 Rayleigh scattering

Current detector approaches for X-ray polarimetry with photoelectric effect
 Incident X-ray polarisation
 Incident X-ray parallel to readout plane
 Incident X-ray parallel to readout plane

ray CMOS physics large field of view optical TPC
 1. Large area CMOS camera
 2. CMOS camera
 3. CMOS camera
 4. CMOS camera
 5. CMOS camera
 6. CMOS camera
 7. CMOS camera
 8. CMOS camera
 9. CMOS camera
 10. CMOS camera
 11. CMOS camera
 12. CMOS camera
 13. CMOS camera

LIME: a 50 E volume detector based on Xray-CMOS experimental approach developed for directional Dark Matter searches

50 E active volume
 1. CMOS + 4 PMT
 2. 50 x 50 cm² readout
 3. 50 cm DR length

Now @ underground LNGS
 1. 100 x 100 cm² readout
 2. 100 x 100 cm² readout
 3. 100 x 100 cm² readout

Energy threshold $E_{th} = 5.5$ keV

Stability
 1. 1 keV + 1200 photons
 2. 1 keV + 1200 photons
 3. 1 keV + 1200 photons

Energy response linearity
 1. 1 keV + 1200 photons
 2. 1 keV + 1200 photons
 3. 1 keV + 1200 photons

On a slightly smaller 230 cm drift detector absolute Z position from fit to diffusion with 1% uncertainty

Low energy electrons directionality on LIME simulated scmos images

Energy range simulated 10-50 keV

From S. Turchetta PhD thesis work
 Signal event simulation
 Angular resolution
 Energy resolution

Particles range in HeCF4
 1. 10-50 keV
 2. 10-50 keV
 3. 10-50 keV

Polarimetry physics cases

CURRENT polarimetry technique and sensitivity energy range to different physics cases

ACKNOWLEDGMENTS
 The CHONDROVITUM project is funded by INFN, the ERC Consolidator Grant (project #101017440) and the Italian Ministry of Education, University and Research through the project INFN-PRIN (project #101017440) and the Italian Ministry of Education, University and Research through the project INFN-PRIN (project #101017440).

Come check our posters!

