LIME: a gas TPC prototype for directional Dark Matter search for the CYGNO experiment

F. Di Giambattista[1,2,*] on behalf of the CYGNO Collaboration https://web.infn.it/cygnus/cygno/

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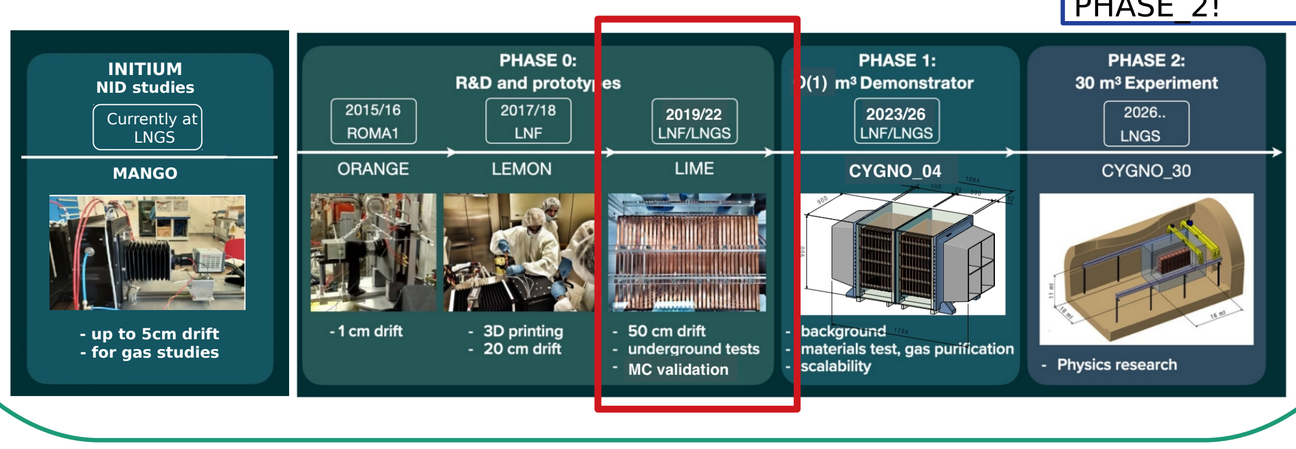
THE CYGNO EXPERIMENT

The **CYGNO** (CYGNus module with Optical readout) experiment [1] aims at the development of a large gaseous TPC with an optical readout to directly detect rare events such as Dark Matter and solar neutrinos through the identification of nuclear recoils (NR) and electron recoils (ER).

- He:CF_4 (60/40) gas mixture at atmospheric pressure and room temperature
- Triple-GEM charge amplification stage
- Secondary scintillation produced after charge amplification
- **Optical readout** for **3D** reconstruction of tracks
  - High granularity sCMOS cameras for x-y projection
  - Fast light sensor (PMT or SiPM) for z component
- **Direction + head-tail** sensitivity
- **NR/ER discrimination** capability from topological signature [2]

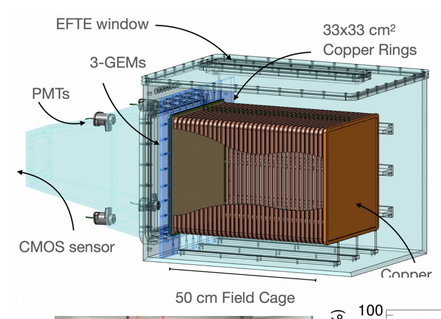
See G.Dho poster for details on PHASE_1 and PHASE_2!

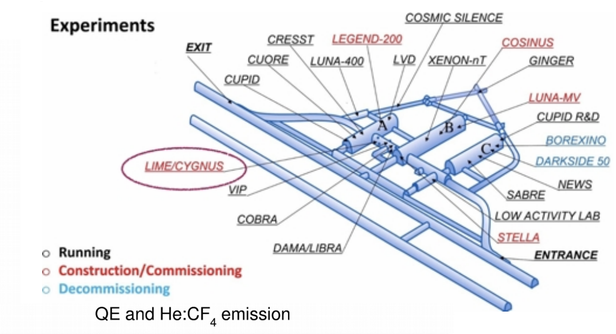


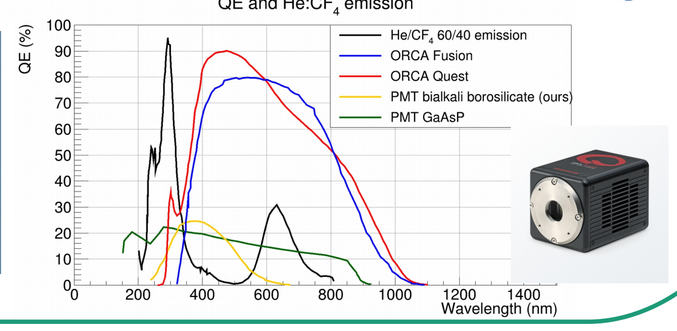
PHASE_0: THE LIME PROTOTYPE

LIME (Long Imaging ModulE) is the largest prototype built so far, it concludes the R&D phase

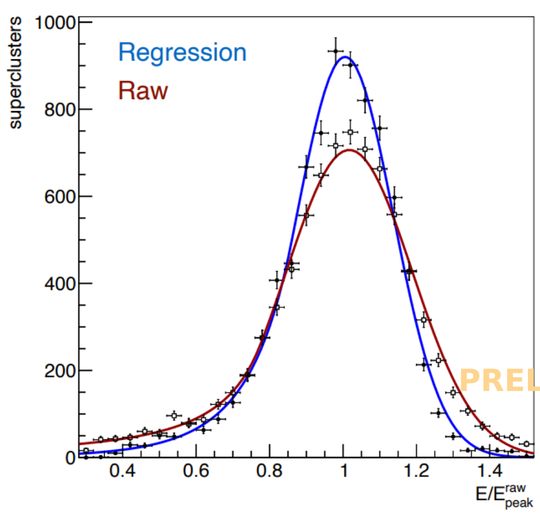
- 33×33 cm² readout area, 50 cm drift distance (50L volume)
- 4 PMTs at the corners
- 1 sCMOS camera (Hamamatsu ORCA Fusion)
  - 2304×2304 pixels, low noise (1 ph/pixel), high granularity 160×160 μm²

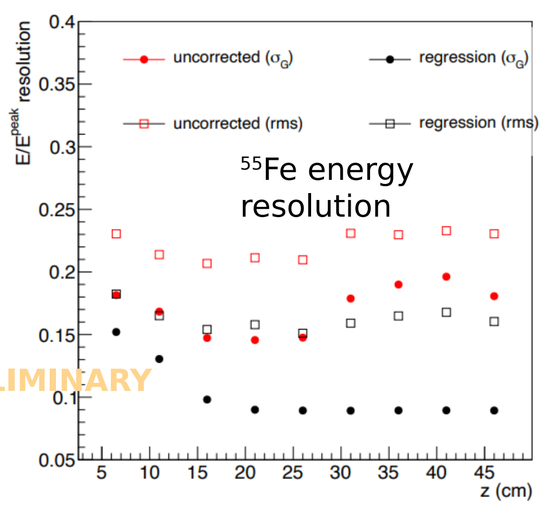


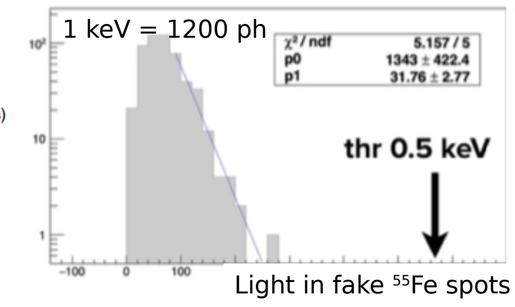


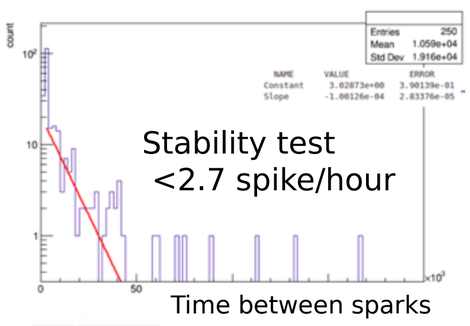


TESTS WITH LIME IN FRASCATI NATIONAL LABORATORIES (LNF-INFN)



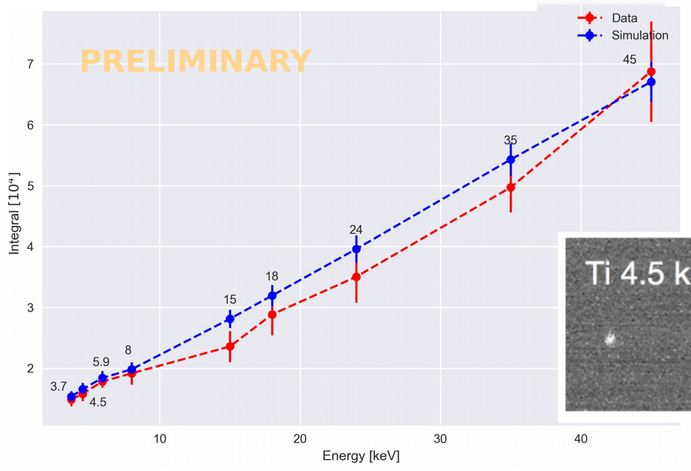


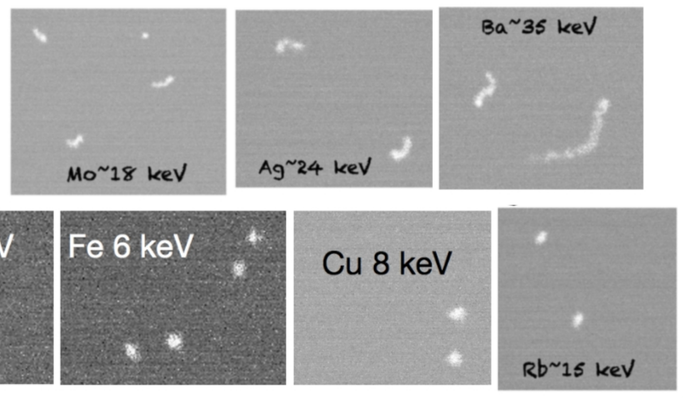




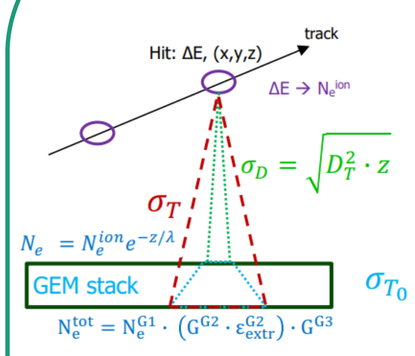
- Multi-source of X-rays for energy scan
- Good linearity
- MC/data agreement better than 10% in energy response

- Light yield studied using 55Fe (5.9keV X-ray)
- Reconstruction with a intensity-based DBSCAN clustering algorithm [3]
- MVA regression is used to infer the true energy, with x-y position and cluster shape variables as inputs (under development); improves significantly the energy resolution

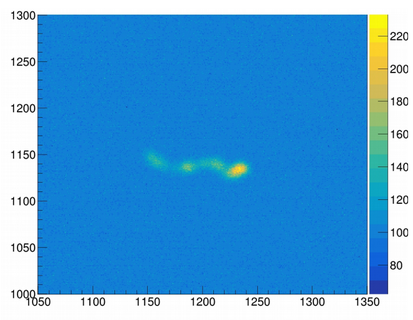




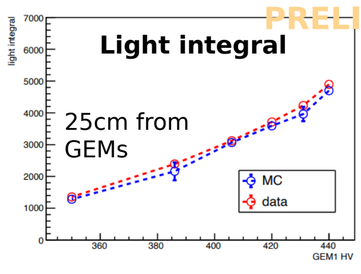
MC CMOS IMAGE SIMULATION

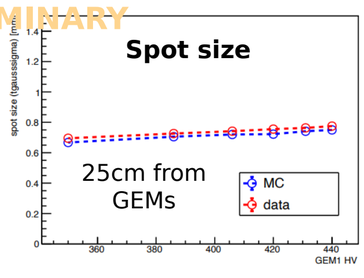


- GEANT4 for ER, SRIM for NR
- Gas properties simulated with Garfield, $D_T^2 \approx 130^2$ μm²/cm, $\sigma_0 \approx 300$ μm, confirmed by data [4]
- Ionization, e⁻ diffusion in drift region, partial re-absorption, multiplication in GEMs, diffusion in GEM stack, production of photons, gain saturation effects, collection of light on the sensor (solid angle efficiency), sensor noise



35keV ER @25cm

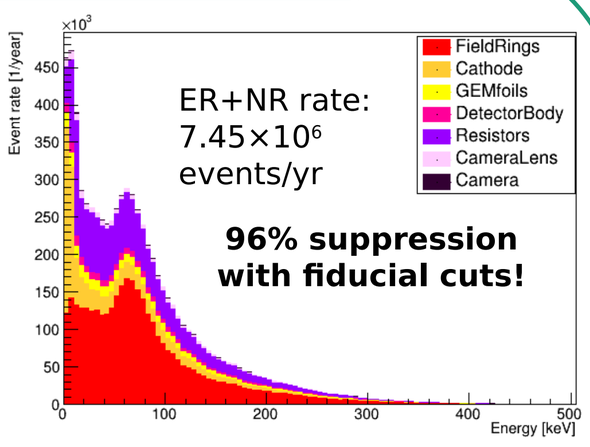


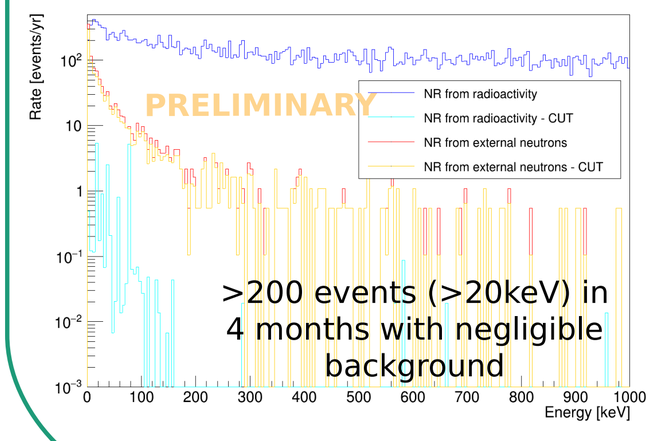


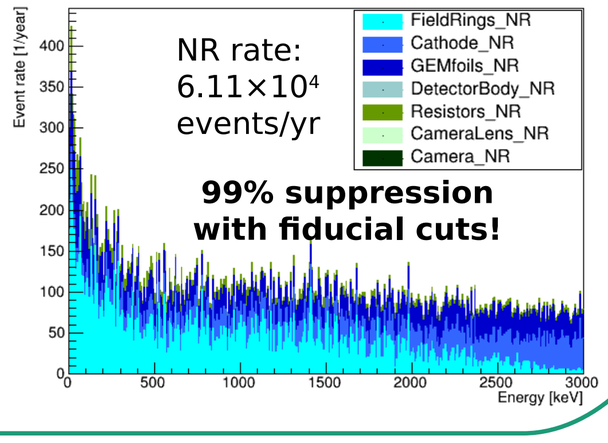
- MC/data comparison is ongoing using 55Fe data (5.9keV ER)
- Undergoing comparison on track shape variables

LIME BACKGROUND MC SIMULATION

- γ and neutron background at LNGS simulated with GEANT4
- Progressive shielding configurations for different data taking
  - Background characterization + MC validation towards CYGNO_04
- **Neutron flux measurement** (spectral and directional) with full Cu shielding







REFERENCES

[1] CYGNO Collaboration, Instruments 6(1), 6 (2022)
[2] E. Baracchini *et al.*, Meas. Sci. Technol. 32 025902 (2021)
[3] E. Baracchini *et al.*, JINST 15 no.12, T12003 (2020)
[4] V.C. Antochi *et al.*, Nucl.Instrum.Meth.A 999 (2021) 165209

ACKNOWLEDGMENTS

The CYGNO/INITIUM project is funded by INFN CSN2, the ERC grant (ERC-INITIUM-818744) and by the PRIN project "Zero Radioactivity in Future Experiments" (Prot. 2017T54J9J)