Electroluminescence in He/CF_4 and hydrocarbons gas mixtures for directional dark matter searches with the CYGNO Optical Time Projection Chamber

F.D. Amaro, LIBPhys - University of Coimbra, Portugal
on behalf of the CYGNO collaboration:

F.D. Amaro, R. Antonietti, **E.Baracchini,** L. Benussi, S. Bianco, C. Capoccia, M. Caponero, D.S. Cardoso, G. Cavoto, I.A. Costa, G. D'Imperio, E.Dané, G. Dho, F. Di Giambattista, E. Di Marco, F. Iacoangeli, E. Kemp, H.P. Lima Júnior, G.S.P. Lopes, G. Maccarrone, R.D.P. Mano, R.R. Marcelo Gregorio, D.J.G. Marques, G. Mazzitelli, A.G. McLean, A. Messina, C.M.B. Monteiro, R.A. Nobrega, I.F. Pains, E. Paoletti, L. Passamonti, S. Pelosi, 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, N.J.C. Spooner, R. Tesauro, S. Tomassini, S. Torelli, J.M.F. dos Santos

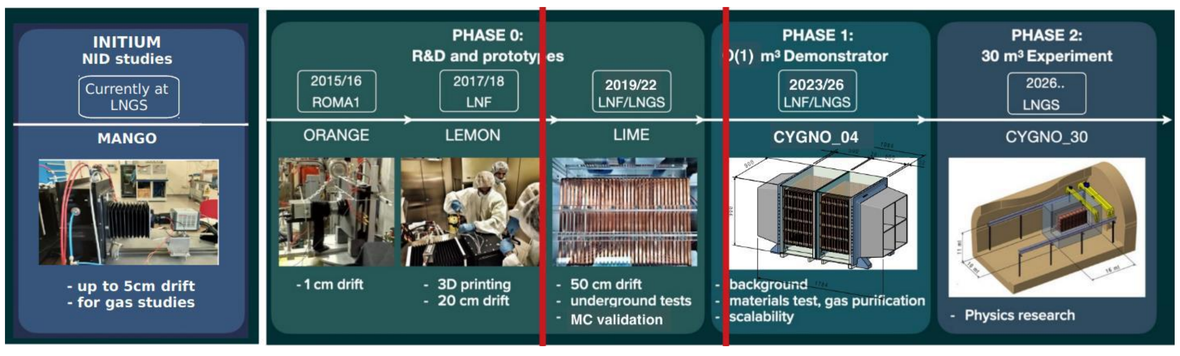
The CYGNO experiment: CYGNO (a CYGNus TPC with Optical readout) fits into the wider CYGNUS proto-collaboration, developing a ton scale Galactic Nuclear Recoil Observatory with directional sensitivity **for Dark Matter searches** below the Neutrino Floor and **Solar Neutrino Physics**.

CYGNO operates a **Time Projection Chamber** readout by a **Micro Pattern Gaseous Detector**, composed by a stack of three **Gas Electron Multipliers** (GEM), ensuring charge multiplication and electroluminescence (EL) production.

The visible component of the EL is collected by CMOS scientific cameras with sub-mm position resolution, enabling **particle identification** and **track reconstruction**, crucial to measure the nuclear recoils direction.

More insights on CYGNO @ MPGD2022 on the the talks by E. Barrachini and F. Petrucci

CYGNO TIMELINE

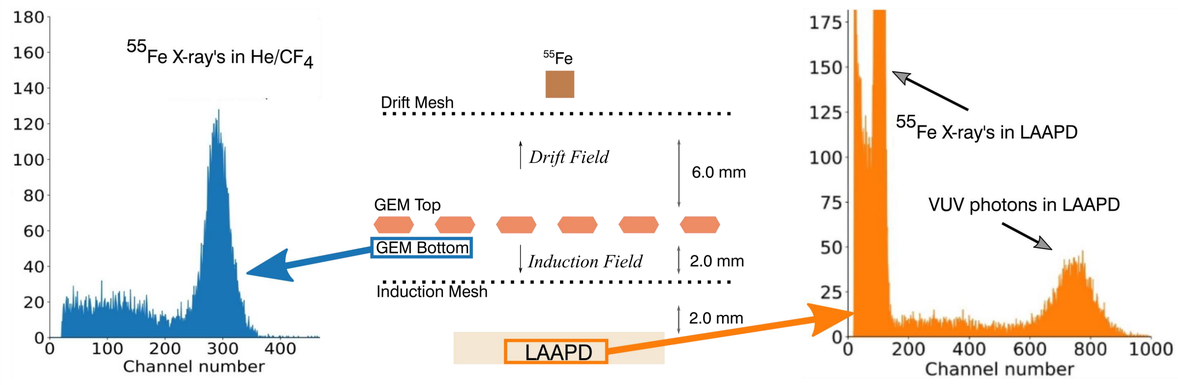


Motivation: The selected CYGNO TPC filling gas is a **He/CF_4** (60/40) mixture at atmospheric pressure, providing good particle identification in the keV range [1]. It allows to probe WIMP masses down to the sub-GeV range, for Spin Independent (SI) interactions. The presence of the He atoms allows for longer recoil tracks, improving the directionality, one of the key features of CYGNO. CF_4 allows matching the emission spectra of the gas mixture to the sCMOS camera sensitivity.

The inclusion of gases with high hydrogen content, such as **hydrocarbons**, will extend the CYGNO TPC **sensitivity to low mass WIMP's**, while **improving its tracking performance**.

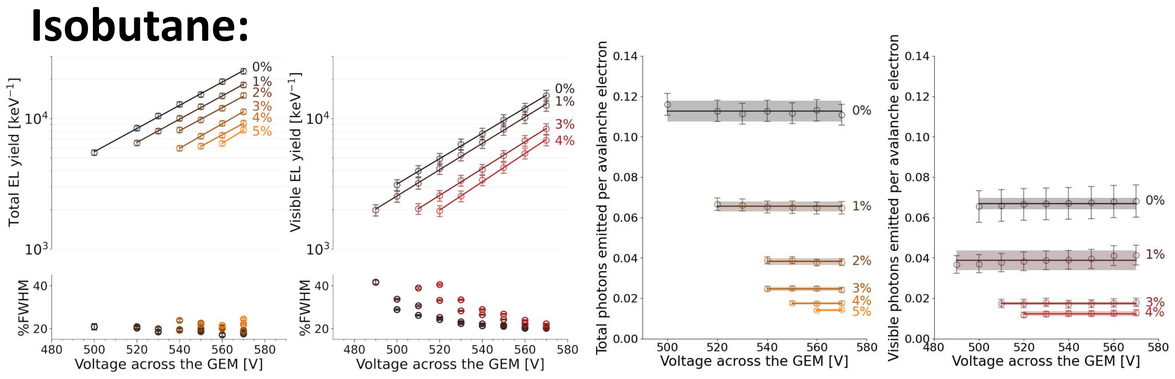
Experimental Setup and Methods:

- A Large Area Avalanche Photodiode (LAAPD) collects the EL produced in the avalanches of a **Gas Electron Multiplier (GEM)**, allowing the avalanche photon output determination [2].
- CH_4 and isobutane were added to the CYGNO gas mixture, He/CF_4 (60/40). Flow rate was 4 l/h.
- Signals from the charge collected at the GEM bottom electrode and from the EL collected in the LAAPD were independently



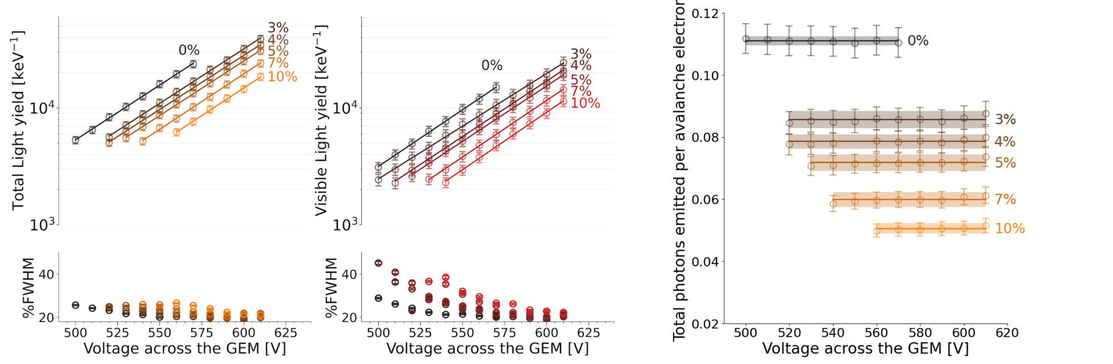
- Each electrode in the detector was independently biased
- The apparatus was irradiated with low energy X-rays (^{55}Fe)

Isobutane:



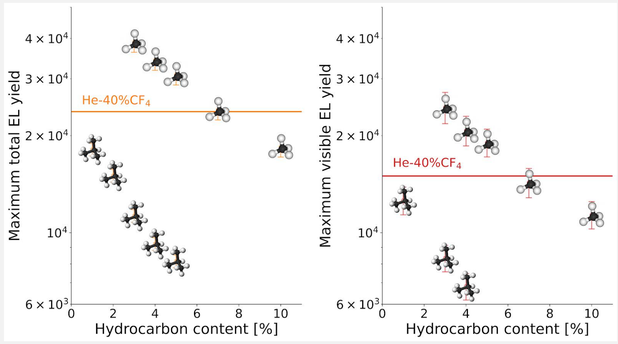
Isobutane concentrations up to 5 % were evaluated. As expected, a decrease in the EL yield was observed, for the visible and UV range.
The number of photons emitted per avalanche electron is constant, and independent of the electric field in the GEM holes.

Methane:



Methane concentrations between 3 and 10% were evaluated. A decrease in the EL yield was observed, both in the visible and UV range, for the same voltages across the GEM holes. Yet the inclusion of methane in the CYGNO TPC gas mixture allowed achieveing higher GEM voltages, resulting in higher absolute EL yield.

Conclusions:



Both isobutane and methane quench some of the the visible and UV photons emitted by He/CF_4. For the concentrations studied in this work (up to 10%) the absorption is partial and does not compromise the operation of the CYGNO TPC.

Methane is a better dopant for the He/CF_4 since it increases the maximum allowed voltage across the GEM foil, providing higher absolute EL yield. In fact, methane concentrations up to 7% allow to increase the EL emitted by the CYGNO TPC.

[1] E. Baracchini, et al., *Stability and detection performance of a GEM-based Optical Readout TPC with He/CF_4 gas mixtures*, *JINST* **15** (2020) P10001.
[2] C.M.B. Monteiro, et al., *Secondary scintillation yield from GEM and THGEM gaseous electron multipliers for direct dark matter search*, PLB 714 (1) (2012) 18-23.

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