

## **CYGNO/INITIUM - Annual Report**

I. Abritta Costa (TD), L. Benussi, S. Bianco, A. Biondi (Laureando), C. Capoccia (Tecn.), M. Caponero (Ass.), G. Dho (Ass. Ric), G. Maccarrone, G. Mazzitelli (Resp.), E. Paoletti (Tecn.), L. Passamonti (Tecn.), D. Piccolo, D. Pierluigi (Tecn.), F. Rosatelli (Tecn.), A. Russo (Tecn.), G. Saviano (Ass.), R. Tesauero (Tecn) , S. Tomassini, D. Tozzi (PhD).

CYGNO collaboration: INFN (LNF, RM1, RM3),  
La Sapienza Dip di Fisica and Dip di Ing. Chimica,  
Università di Roma Tre, GSSI, Centro Fermi  
University of Sheffield (GB), University of Coimbra (PT)  
and University of UFJF and CBPF (BR)

The activity of the LNF CYGNO <sup>1)</sup> in 2024 was mainly devoted to finalize the detector CYGNO-04 detector hosting infrastructure, validating the electromechanical and radiosensitive properties of the materials for the detector construction, to coordinate and improve the data analysis of LIME/GIN and MANGO prototypes, to design, develop and and put in operation the computing model on the INFN DataCloud infrastructure.

In the following, a brief report of tasks under the responsibility of LNF in the CYGNO collaboration developed in 2024 is presented.

### **1 Design, construction and test of R&D prototypes and CYGNO04 detector**

The LNF group is in charge of the design, installation and test of all the prototypes/detectors <sup>2)</sup> of the CYGNO project. During 2024 this has included operation with the GIN prototype, devoted to test electro-mechanics components for CYGNO-04 detectors and to validate the procurement chain for materials to be purchased. Components were validated mechanically by construction and fragility tests, from the point of view of the reactance by long run (7 months) of operation in a bath of the CYGNO gas mixture and electrically by operative tests with radioactive sources and natural radioactivity studying the response of the GIN prototype. The positively passed materials were controlled from the radioactivity point of view to be ready to use in the final detector. In this context, the Master's thesis of La Sapienza student Alex Biondi was carried out <sup>3)</sup>.

Meanwhile, the design service has developed the main solutions for the realization of CYGNO-04 and followed the recommendations from the internal review conducted in July for the acquisition of the most expensive raw materials, pending final solutions.

Additionally, the Frascati group is responsible for the MANGO prototype, which was modified to perform polarimetry measurements at the polarized photon facility at INAF-IAPS as part of the PRIN HypeX project. This involved both the design and the detector services which created and installed all the components. While the full analysis of the data is still ongoing, at the February LNF seminar <sup>4)</sup> a first positive measurement of polarized photons was shown.

Finally, the detector construction service is supporting data collection at LNGS for the LIME prototype by managing the gas system, electronics, and computing infrastructure.

In the context of the R&D of gaseous detector for rare events searches, since late 2023 G.Dho was selected as project coordinator in the Work Package 9 Project D for the DRD1 collaboration.

## 2 Data Analysis

Since October 2023 the LNF are in charge of data analysis coordination of the CYGNO experiment. The organization of the principal and long term goals of the collaboration have been thought upon and divided among the man-power available in the different CYGNO groups. Tasks span from the analysis of the underground data of the LIME prototype, to machine learning techniques applied to signal-background discrimination, from studies on the stability of the detector to the development of the fitting procedure of the data to estimate dark matter and neutrino limits/measurements and to the study of the directional capabilities of the detection technique. Meetings are organized every other Thursday.

Together with the analysis coordination, the LNF are in charge of the maintenance and development of the main reconstruction algorithm used to analyze the raw data of the experiment. Continuous checks on performance, bug fixes, improvements, introduction of new and more complete features of data reconstruction have been undertaken with the goal of restructuring and improving the algorithm to match the large data output of the CYGNO-04 future detector.

## 3 Design and development of the CYGNO computing model

The LNF are responsible to design and implement the experiment computing model and infrastructure.

The computing model (CM) for CYGNO <sup>5)</sup>, which is the benchmark and beta-tester for all small/medium experiments in the astroparticle physics community supported by the PNRR Spoke2, has been defined. The software architecture has been designed and is hosted on the INFN cloud infrastructure. The INFN cloud is providing the Virtual Machines (VM) where services, by means of a set of docker containers, are developed and under operation. The CM design foresees a set of services for data streaming, data management, data visualization, data analysis and simulation.

The CYGNO computing model is now complete with all components for data management, simulation, and the reconstruction and analysis of collected data. The services developed with the LIME data collection are now available for production, pending the arrival of the CYGNO-04 detector.

## 4 List of Conference Talks by LNF Authors in Year 2024

1. G. Dho - The CYGNO Experiment, at 1<sup>st</sup> DRD1 collaboration meeting, CERN, Switzerland, 29 January - 2 February 2024
2. G. Dho - The CYGNO Experiment, at IRN Terascale, INFN-LNF, Italy, 15-17 April 2024
3. G. Dho - Optimisation of gas composition and amplification stage for the CYGNO/INITIUM experiment, at IDM 24, L'Aquila, Italy, 8 - 12 July 2024 (poster)
4. G. Dho - Impact of a strong electric field below the GEM on light yield and saturation in a He:CF<sub>4</sub> based Time Projection Chamber, at MPGD2024 (Micro Pattern Gas Detector), Hefei, China, 14 - 18 October 2024 (poster)

## 5 List of Publications signed by LNF Authors in Year 2024

1. Amaro, F.D., et al., *Enhancing the light yield of He:CF<sub>4</sub> based gaseous detector*, Eur. Phys. J. C 84, 1122 (2024). <https://doi.org/10.1140/epjc/s10052-024-13471-5>
2. Amaro et al., *Secondary scintillation yield from GEM electron avalanches in He-CF<sub>4</sub> and He-CF<sub>4</sub>-isobutane for CYGNO — Directional Dark Matter search with an optical TPC*, Phys. Lett. B, 855, 138759, May 2024, DOI: 10.1016/j.physletb.2024.138759
3. Amaro et al., *Charge amplification in low pressure CF<sub>4</sub>:SF<sub>6</sub>:He mixtures with a multi-mesh ThGEM for directional dark matter searches*, JINST, 19 06, May 2024, DOI: 10.1088/1748-0221/19/06/P06021
4. Fiorina et al., *HypeX: high yield polarimetry experiment in x-rays*, Proceedings Volume 13103, X-Ray, Optical, and Infrared Detectors for Astronomy XI; 1310318, August 2024, DOI: <https://doi.org/10.1117/12.3021559>
5. Amaro et al., *Study of long term stability of a 50 liters TPC, based on TRIPLE-GEM with optical readout, for the CYGNO experiment*, NIM A, 1065 169473, May 2024, DOI: 10.1016/j.nima.2024.169473
6. Amaro et al., *The CYGNO experiment, a directional detector with optical readout for Dark Matter search*, Nuovo Cim., IFAE23, 126, Apr 2024, DOI: 10.1393/ncc/i2024-24126-8
7. A. Messina et al., *The CYGNO project for directional Dark Matter searches*, PoS, TAUP23, 020, Jan 2024, DOI: 10.22323/1.441.0020

## Bibliography

1. F. D. Amaro, E. Baracchini, L. Benussi, S. Bianco, C. Capocchia, M. Caponero, D. S. Cardoso, G. Cavoto, A. Cortez and I. A. Costa, *et al.* “The CYGNO Experiment,” Instruments **6** (2022) no.1, 6 doi:10.3390/instruments6010006 [arXiv:2202.05480 [physics.ins-det]].  
X-ray polarization from astrophysical sources. Current status and future prospects with HypeX project, at General Seminar of INFN, Frascati, Italy, 18 February 2025 (seminar) <https://agenda.infn.it/event/45029/>
2. G. Mazzitelli et al, Technical Design Report - TDR CYGNO-04/INITIUM (2022) Technical note - INFN-23-06-LNF doi:10.15161/oar.it/76967
3. A. Biondi, Components Validation Method for Dark Matter gaseous detectors for the CYGNO Experiment, Master Thesis at University of Rome La Sapienza <https://prodotti.dsi.infn.it/#/product/thesis/67ee5c93ee92a428e0ac4c6d>
4. G. Dho, X-ray polarization from astrophysical sources. Current status and future prospects with HypeX project, at General Seminar of INFN, Frascati, Italy, 18 February 2025, <https://agenda.infn.it/event/45029/>
5. <https://github.com/CYGNUS-RD/middleware>