CYGNO/INITIUM - Annual Report

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CYGNO collaboration: INFN (LNF, RM1, RM3),
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Università di Roma Tre, GSSI, Centro Fermi
University of Sheffield (GB), University of Coimbra (PT)
and University of UFJF and CBPF (BR)

The project funded in 2019 by the CSN2, the ERC grant (ERC-INITIUM-818744) and by the PRIN project *Zero Radioactivity in Future Experiments* in collaboration with GSSI and LNGS, foresees the construction of a detector to be located at LNGS to demonstrate the feasibility of large gas TPC for Directional Dark Matter search and Solar Neutrino Astronomy. This demonstrator exploits the high energy sensitivity to nuclear and electron recoil of "light" gas mixture (He/CF^4) and the high sensitivity and granularity of innovative sCMOS sensors.

All the design, construction and test of the CYGNO detector and its prototypes are on charge of the LNF staff and require large clean room and test with radioactive sources. Because of this, the LNF building 28 was renovated restoring all area as ISO-7 clean room and equipping it with new gas distribution system for He, CF^4, Ar and Nitrogen. Moreover in the LNF building 48, tables and the remotely controlled irradiation facility has been modify to host and test of large volume (see figure 1).

Figure 1: *Facility upgrade LNF building 48 and 28*

The main activities on duty of the 2020 of the LNF were:

- write and collaborate to drafting of the various published articles.
- design, construction and test of prototypes at LNF

- design, construction and test of the main detector for the underground site at LNGS.
- organization and setup of overground and underground laboratories at LNGS, technical support to the overground LNGS R&D on INITIUM project.
- design and coordination of the underground sites at LNGS
- cloud computing infrastructure for CYGNO experiment

The second year of the CYGNO project, due also to COVID19 pandemic constraint, was characterized by a massive publication of the results previously obtained. The publications concern various aspect of the data collected mainly in 2019 on the LEMOn, Large Elliptical Module Optically read out, prototype: test beam results on tracking performance of optical read out [1)], nuclear recoil detector capability [2)], clustering algorithm optimization [3)], long term performance of the TPC optically readout [4)], Moreover include first results on the R&D on how to increase light signal, lowering the electrical gain (see next), through the light amplification via luminescence effect [5)]. Finally five conference record see the contribution of LNF work [6, 7, 8, 9, 10)]

In 2020 the LIME prototype, Long Imaging ModulE 1/18 of the final detector, was put in operation. The objective of LIME were to test 50 cm drift (nominal CYGNO value) and large GEM (330×330 mm^2) performance, stability and efficiency; verify the feasibility with low radioactive materials (acrylics and Cu); optimize light yield and gas mixture. Two LIME prototype were operated, the first one made of a standard Cu ring Filed Cage (FC), the second one with very low quantity of materials and radioactivity made of plastic resistive foils (see figure 2). LIME is foreseen to be installed at the underground laboratory of Gran Sasso in late spring 2021 (see next).

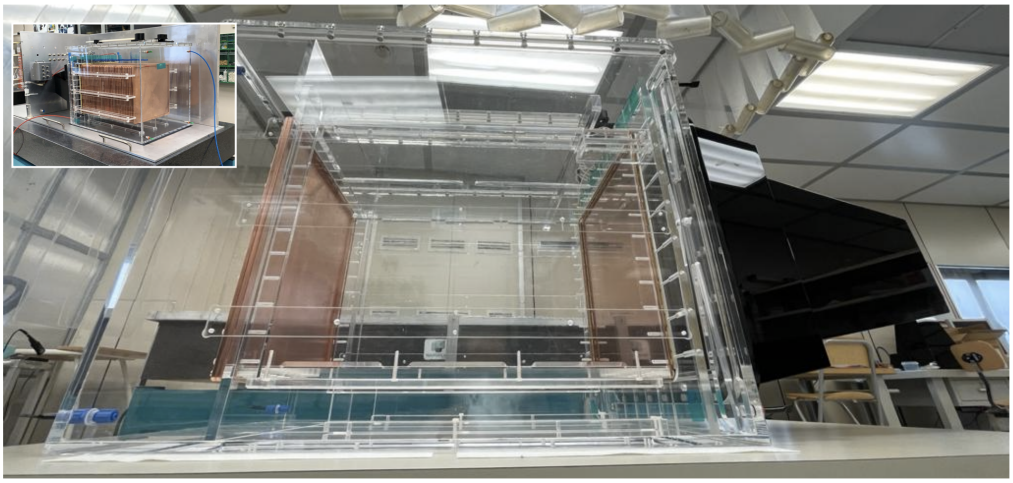

Figure 2: *LIME prototype equipped with the Field Cage made of resistive foil. In the inset the LIME prototype equipped with standard Cu ring.*

The two detectors equipped with the different FC were tested in spring 2020 and in last part of the 2020. Measurements are still on going to better understand field quality, optical distortion and aging of the materials especially for plastic resistive foils prototype. The FC equipped with the

Cu ring was extensively tested with Fe, Ce and AmBe sources. Deep data analysis is still ongoing showing a good stability and performance, although a saturation effect has been evidenced and quantified (see figure 3). This saturation effect as been also studied with LEMOn prototype, where the possibility to use the GEM charge application at lower voltage has been studied compensating the lost of light emitted by the introduction of a drift where luminescence light is produced. The result are promising and the optimization of the setup is ongoing.

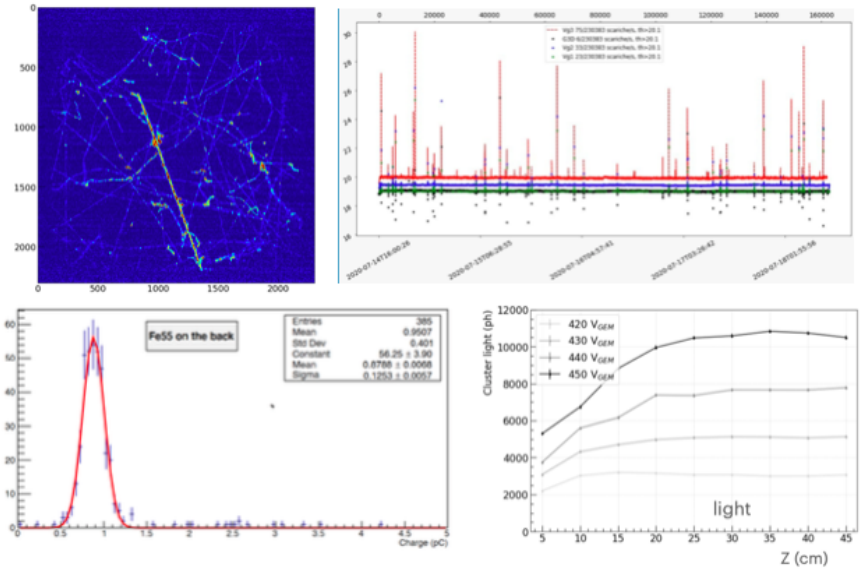

Figure 3: *left up - 100ms exposure image collected with the plastic resistive foils prototype; right up - long term stability of the GEM currents in LIME; left bottom - LIME energy resolution with Fe source; right bottom - saturation evidence in light collected in LIME as function of GEM Voltage and distance from the charge amplification stage.*

A huge activity of planning and design has been done at the LNGS in order to equip an overground laboratory where the negative ion test for INITIUM ERC are on going and to prepare the underground site to host LIME in late spring 2021. The site, located in the TIR tunnel at LNGS, is in the same container of the VIP experiment and to host bought the activities requires some civil and services renovation of all the area. Moreover, the introduction of large water shielding for LIME (see figure 4) and of a gas system (filling, purificating, recirculating and recovering the exhaust gas) required a careful risk assessment and the implementation of solutions for the safety of workers and the environment. For this a preliminary risk and environmental evaluation has been done with help of an external company and all the documentation - drawings, operations, safety issues, ecc - has been collected in the LIME Technical Report.

Finally, LNF are involved in data taking and analysis of the prototypes data as well as in the design and implementation of the computing infrastructure on the INFN Cloud. Indeed, the new INFN Cloud offer the possibility to optimize the usage computing resources for experiments of CYGNO scale characterized by a small amount of data respect to big physics experiments and vary varying in time usage of computing resources. So, In collaboration with CNAF has been

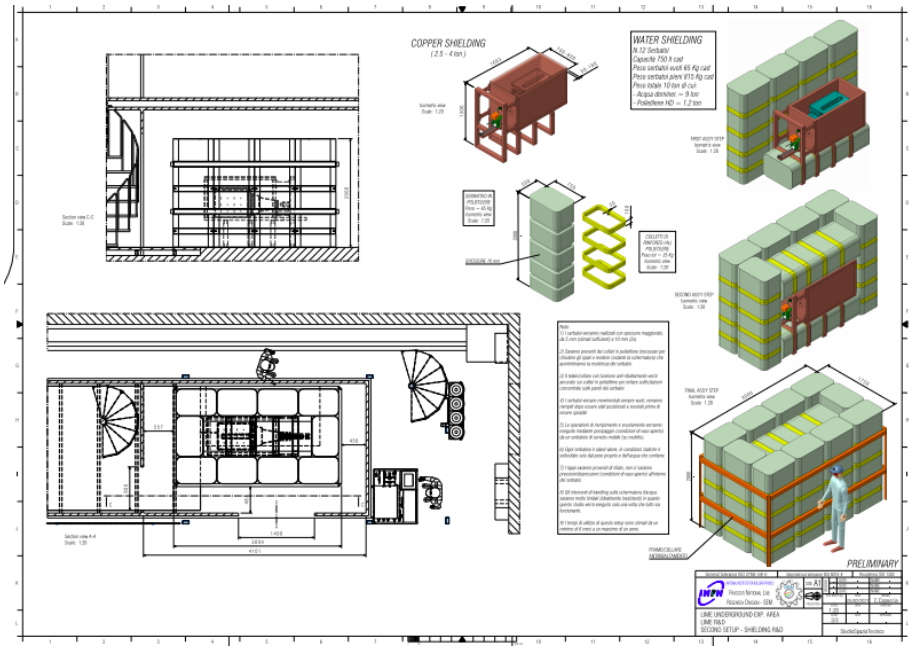

Figure 4: .

design container dedicated to the analysis and simulation of CYGNO data, hosting most of the common software use in HEP community that make it very general.

Acknowledgements

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List of Publications signed by LNF Authors in Year 2020

1. V. C. Antochi, G. Cavoto, I. A. Costa, E. Di Marco, G. D'Imperio, F. Iacoangeli, M. Marafini, A. Messina, D. Pinci and F. Renga, *et al.* "Performance of an Optically Read-Out Time Projection Chamber with ultra-relativistic electrons," [arXiv:2005.12272 [physics.ins-det], accepted for publication in Nucl. Instr. Methods A].

2. E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, G. Cavoto, A. Cortez, I. A. Costa, E. Di Marco and G. D'Imperio, *et al.* "Identification of low energy nuclear recoils in a gas time projection chamber with optical readout," Measur. Sci. Tech. **32** (2021) no.2, 025902 doi:10.1088/1361-6501/abbd12 [arXiv:2007.12508 [physics.ins-det]].

3. E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, G. Cavoto, A. Cortez,

I. A. Costa, E. Di Marco and G. D'Imperio, *et al.* "A density-based clustering algorithm for the CYGNO data analysis," JINST **15** (2020) no.12, T12003 doi:10.1088/1748-0221/15/12/T12003 [arXiv:2007.01763 [physics.ins-det]].

4. E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, G. Cavoto, A. Cortez, I. A. Costa, E. Di Marco and G. D'Imperio, *et al.* "Stability and detection performance of a GEM-based Optical Readout TPC with He/CF_4 gas mixtures," JINST **15** (2020) no.10, P10001 doi:10.1088/1748-0221/15/10/P10001 [arXiv:2007.00608 [physics.ins-det]].

5. E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, G. Cavoto, A. Cortez, I. A. Costa, E. Di Marco and G. D'Imperio, *et al.* "First evidence of luminescence in a He/CF_4 gas mixture induced by non-ionizing electrons," JINST **15** (2020) no.08, P08018 doi:10.1088/1748-0221/15/08/P08018 [arXiv:2004.10493 [physics.ins-det]].

6. I. Abritta Costa, E. Baracchini, F. Bellini, L. Benussi, S. Bianco, M. Caponero, G. Cavoto, E. Di Marco, G. Maccarrone and M. Marafini, *et al.* "Performance of Prototype of Optically Readout TPC with a ^{55}Fe source," J. Phys. Conf. Ser. **1498** (2020), 012017 doi:10.1088/1742-6596/1498/1/012017

7. G. Cavoto, I. Abritta, E. Baracchini, M. Angelone, F. Bellini, L. Benussi, S. Bianco, E. Di Marco, S. Fiore and S. Loreti, *et al.* "Micro pattern gas detector optical readout for directional dark matter searches," Nucl. Instrum. Meth. A **958** (2020), 162400 doi:10.1016/j.nima.2019.162400

8. E. Baracchini, R. Bedogni, F. Bellini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, G. Cavoto, I. A. Costa and E. Di Marco, *et al.* "Directional Dark Matter Searches with the CYGNO Project," J. Phys. Conf. Ser. **1468** (2020) no.1, 012039 doi:10.1088/1742-6596/1468/1/012039

9. D. Pinci, I. A. Costa, E. Baracchini, R. Bedogni, F. Bellini, L. Benussi, S. Bianco, M. Caponero, G. Cavoto and E. Di Marco, *et al.* "CYGNO: Light Dark Matter search with an optically readout TPC," Nuovo Cim. C **43** (2020) no.2-3, 91 doi:10.1393/ncc/i2020-20091-6

10. E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, G. Cavoto, A. Cortez, I. A. Costa, E. Di Marco and G. D'Imperio, *et al.* JINST **15** (2020) no.07, C07036 doi:10.1088/1748-0221/15/07/C07036 [arXiv:2007.12627 [physics.ins-det]].