CYGNO/INITIUM - Annual Report

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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 CYGNO experiment [1)] is ending the R&D phase with the installation and first scientific run of LIME prototype at LNGS. The schedule for 2022 was achieved and first data were collected. Now the preparation of run 2 in ongoing, while the design of the final detector, CYGNO04, and the infrastructure to host it in 2024 at the Hall F of LNGS are under definition.

In the following a brief report of tasks under the responsibility of LNF in the CYGNO collaboration developed in 2022.

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

LNF group is in charge of all the design and installation and test of all the detectors of the CYGNO project. This has foreseen in 2022 the design of the GIN prototype, devoted to test mechanics and electronics for CYGNO04 detectors, and the installation of LIME detector, aimed to validate Montecarlo simulation and long term detector performances, in the TIR gallery at the LNGS.

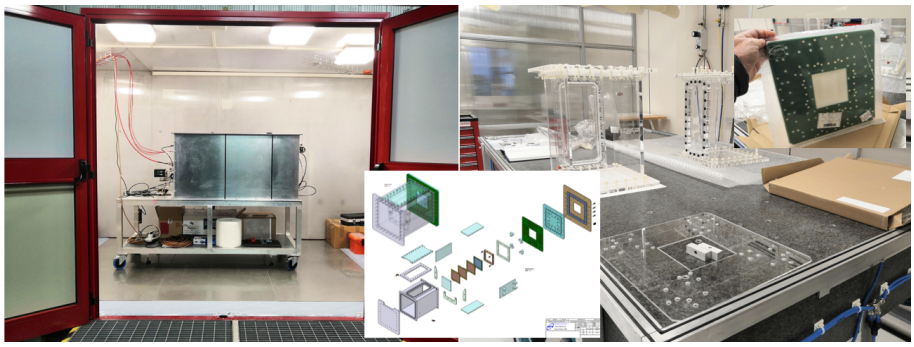

Figure 1: *left: LIME installed at the LNGS for run 1; right: GIN under assembly at the LNF;*

This imply also the setup of all the infrastructure facility needed: electronics and control room, gas systems, auxiliary sensors, cooling, purification filters, ecc. LIME setup and detector installation experience where presented at VCI 2022 [2)] conference.

Moreover, a strong effort has been put in the preliminary design of the of CYGNO04 detector, that required a TDR [3)] to be submitted to LNGS SCICOM and CSN2 committee for final

space allocation, economical sustainability evaluation and scientific validation. The TDR has been approved in September 2022 and the installation and commissioning of the CYGNO04 detector is foreseen in 2024 in the Hall F at the LNGS.

2 Setup and coordination of overground R&D faculties LNF/LNGS and of the underground sites at LNGS

Frascati host at building 48 a spare detector, mirror of LIME at LNGS, that, is operated to make all tests on trigger and DAQ, electronics, gas mixture, ecc, ecc. and where innovative detector components produced in the clean room of building 28 are tested. In the mean time the GIN prototype, has started to be assembled, and in 2023 will be devoted to validation of the filed cage made of flexible PCB. finally, the design and purchase of low radioactivity GEM for CYGNO04 was done and soon will be assembled and tested.

The Frascati group is also have in charge the support (design and technical implementation) to tests done in 2022 overground at LNGS, where the optical read out technique has been applied, in the framework of the INITIUM ERC, to gas mixture composed by SF6 to exploit negative ion behaviour with interesting and promising results.

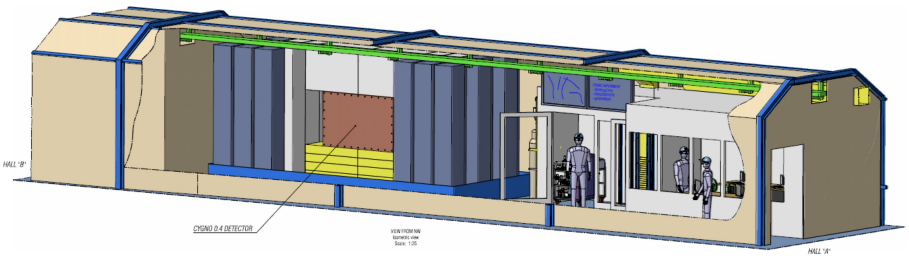

Figure 2: *preliminary design of CYGNO04 in Hall F at LNGS*

Finally the TDR required the design of the new service infrastructure in Hall F, today an empty small gallery with only concrete floor and to study safety and environmental interference for the CYGNO04 installation. Thus has required a Preliminary Risk and Environmental Evaluation (PRA/PEA) and a VINCA.

3 GEM tests, detector materials choice, tests and radioactivity measurements and validation

This activities has been devoted to define, test and acquires low radioactivity materials and the procedure to handle it for the construction of CYGNO04. The TDR and the schedule of 2023 foreseen to important milestone: test and validation of low reactivity GEM and Field Cage. Connected to this there are the choice of resistors, solder paste, PMMA etc, etc. In 2022 may study started and some materials, as GEM, has been designed and part f materials purchased to be soon tested.

4 Design and development of the computing infrastructure

The LNF are in charge to design and implement the experiment computing infrastructure and service.

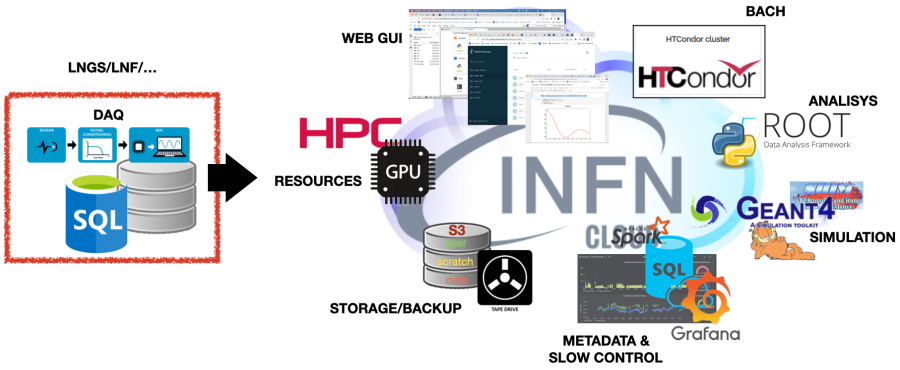

Figure 3: *The CYGNO computing model based on the INFN Cloud*

Because of the scarcity of personnel resources and the revolution in act in the INFN concerning the computing models and the meteorology to offer computing resources to experiments, CYGNO decided to implement all the service over the INFN cloud [6]. This also bring CYGNO to be the first use case of medium-small experiment exploiting and to be included in the Dynamic On Demand Analysis Service (DODAS) INFN project. Al the project is based on a set of services deployed on custom docker containers, ready to be generic (applicable to other use cases) and scalable (to optimize resources) in case of necessity. While analysis services based on Jupiter, integrated with the access to the experiment S3 storage and queues htcondor for simulation and reconstruction where previously develop, in 2022, the first run require to design the services needed for the Middle Ware (see next) and to handle data and metadata over automatic process (sql, grafana, backups) today available to monitor and ensure data preservation.

5 design and develop of Middle Ware for the "quasi online" analysis

Last but not least, LNF people in collaboration with ROMA3 are working on the software need for raw data retrieve (cygno library) and to monitor the data quality, slow control parameters, data validation, preservation, ecc. ecc. In 2022 many preliminary tests have been done and the beta realise of the Middle Ware [7] is running and continuously monitoring the data quality. Now we are working on redundant services implementation and optimization of the software.

and more...

The Frascati group also hosted in 2022 a student for 8 mouth, a DOE fellow, one fellow CSN2-INFN and three students of the La Sapienza Phys Lab II course.

Group organization, codes developed, computing infrastructure details, documentation, cads ecc are available at the link:

`https://github.com/CYGNUS-RD/WIKI-documentation/wiki/Integration`

Acknowledgements

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6 List of Conference Talks by LNF Authors in Year 2022

1. G. Mazzitelli - 50 litres TPC with sCMOS-based Optical Read Out for the CYGNO project, VCI 2022/21–25 Feb 2022 Vienna University of Technology

2. G. Mazzitelli - Applications of Machine Learning methods to Dark Matter search AI@INFN, 2–3 May 2022

List of Publications signed by LNF Authors in Year 2022

1. F. D. Amaro, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, 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]].

2. G. Mazzitelli, F. A. Domingues, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, D. S. Cardoso, G. Cavoto and A. Cortez, *et al.* "50 litres TPC with sCMOS-based optical readout for the CYGNO project," Nucl. Instrum. Meth. A **1045** (2023), 167584 doi:10.1016/j.nima.2022.167584

3. G. Mazzitelli et al, Technical Design Report - TDR CYGNO-04/INITIUM (2022) Technical note - INFN-23-06-LNF doi:10.15161/oar.it/76967

4. F. D. Amaro, R. Antonietti, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, D. S. Cardoso, G. Cavoto and I. A. Costa, *et al.* "The CYGNO experiment," PoS **ICHEP2022**, 1036 doi:10.22323/1.414.1036

5. F. D. Amaro, R. Antonietti, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, D. S. Cardoso, G. Cavoto and I. A. Costa, *et al.* "LIME: a gaseous TPC with optical readout," PoS **ICHEP2022**, 334 doi:10.22323/1.414.0334

6. F. D. Amaro, M. Antonacci, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, D. S. Cardoso, G. Cavoto and D. Ciangottini, *et al.* "Exploiting INFN-Cloud to implement a Cloud solution to support the CYGNO computing model," PoS **ISGC2022** (2022), 021 doi:10.22323/1.415.0021

7. F. D. Amaro, M. Antonacci, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, D. S. Cardoso, G. Cavoto and D. Ciangottini, *et al.* "INFN-Cloud solution for CYGNO computational model," **NSS/MIC 2022** and 2022 IEEE NSS-MIC-RTSD

8. C. A. J. O'Hare, D. Loomba, K. Altenmuller, H. Alvarez-Pol, F. D. Amaro, H. M. Araujo, D. Aristizabal Sierra, J. Asaadi, D. Attie and S. Aune, *et al.* "Recoil imaging for dark matter, neutrinos, and physics beyond the Standard Model," [arXiv:2203.05914 [physics.ins-det]].

9. Cygno *et al.* [CYGNO], "The Cygno experiment for Dark Matter direct detection," PoS **PANIC2021** (2022), 065 doi:10.22323/1.380.0065

10. F. D. Amaro *et al.* [CYGNO], "Performances of a 3D optical readout TPC for the CYGNO experiment," PoS **EPS-HEP2021** (2022), 799 doi:10.22323/1.398.0799

11. F. D. Amaro, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, D. S. Cardoso, G. Cavoto, A. Cortez and I. A. Costa, *et al.* "The Cygno Experiment," PoS **EPS-HEP2021** (2022), 159 doi:10.22323/1.398.0159