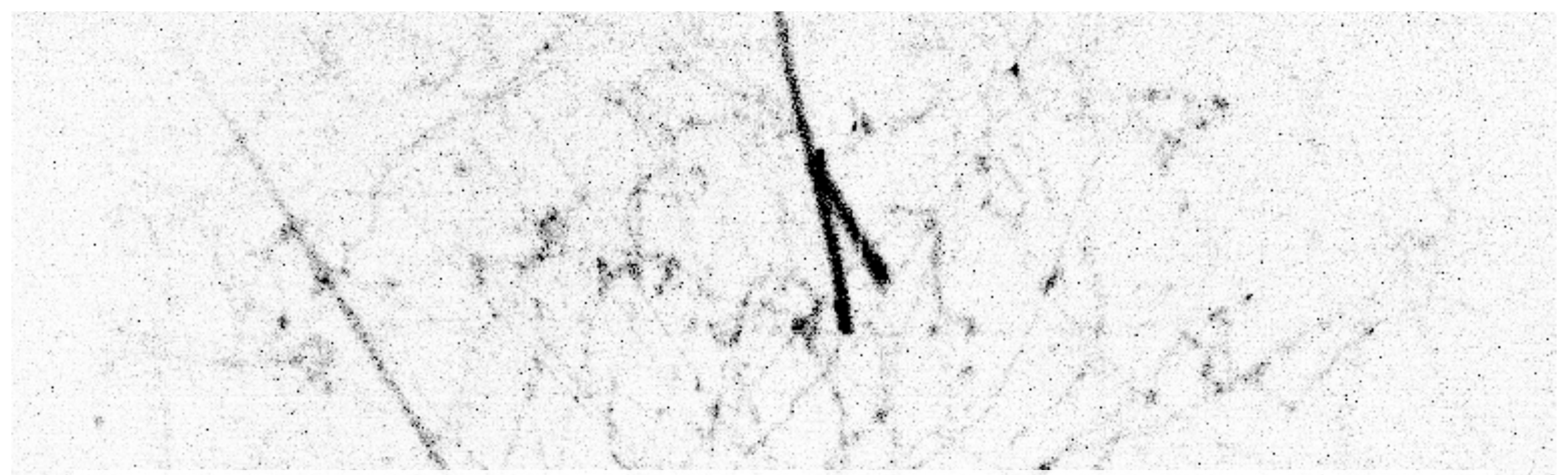


CYGNO Experiment

CYGNO status and plans
Feb 2025

INFN · Sapienza Università di Roma · GSSI · Roma Tre Università degli Studi · ENEA · The University Of Sheffield. · UFJF Universidade Federal de Juiz de Fora · UNICAMP · Universidade de Coimbra · CBPF · European Research Council Established by the European Commission

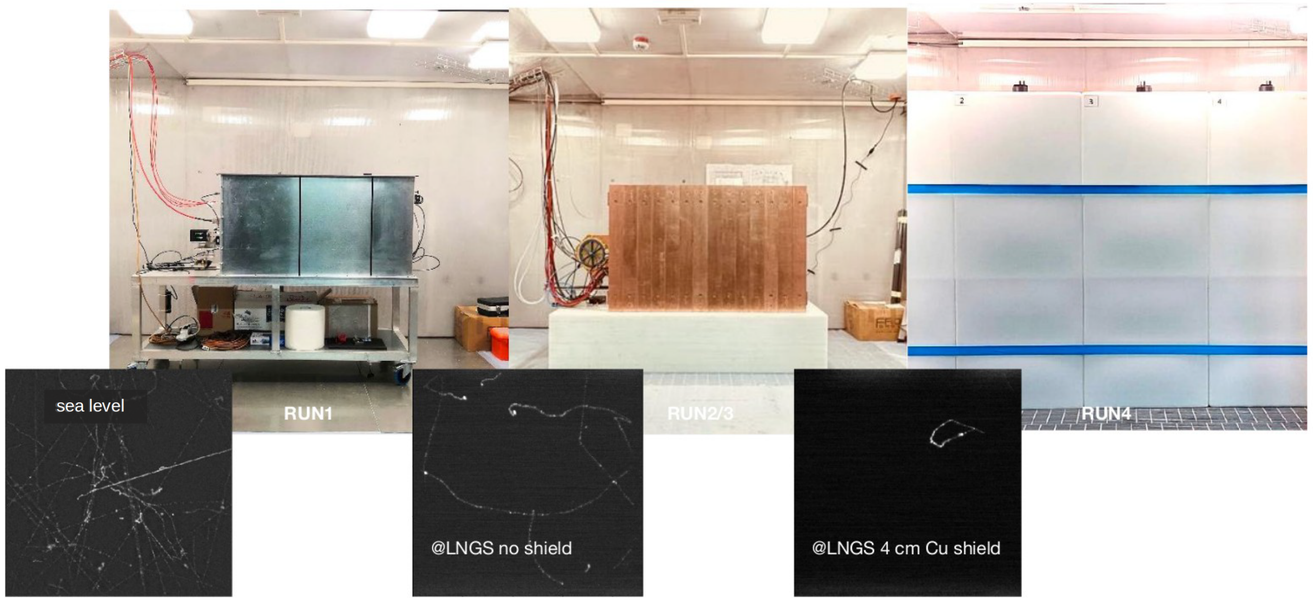
Collaboration Meeting 2024

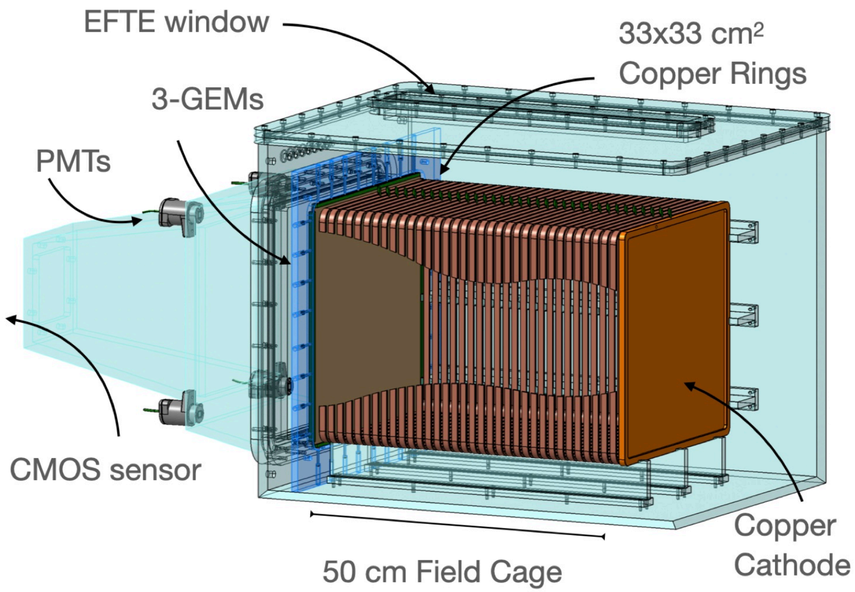
CYGNO Collaboration Meeting 2024

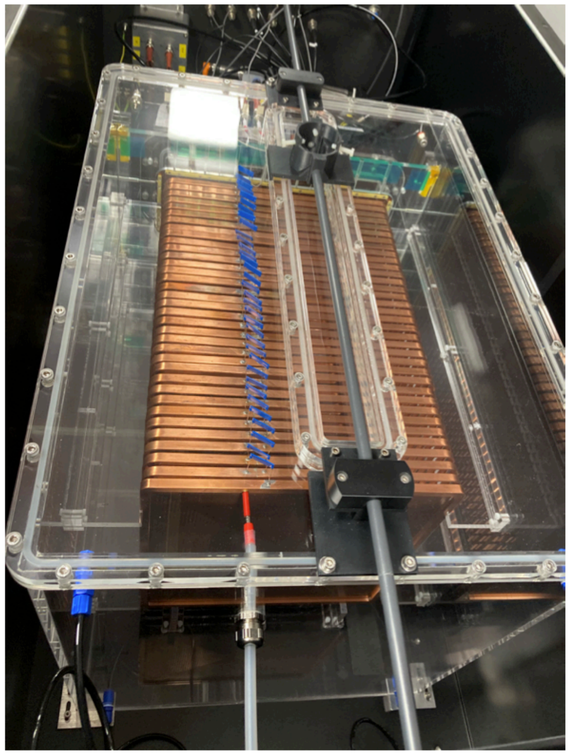
3 days of discussion about status and plans of:

- LIME DAQ and Analysis;
- CYGNO04 drawing and simulation;
- Material scrutiny;
- Project management and financial status;

LIME: RUNs 1-5







- testing and optimisation of **ancillary systems** (HV, Gas, Slow Control, DAQ, Reco, Monitoring);
- development and optimisations of data **analysis algorithms** and performance study;
- development and validation of **detector** and **background simulation**;

LIME: RUNs 1-5

Data taking campaigns

Program from last year's CM presentation:

- **RUN2:** 2023
  - 4 cm Cu shielding
  - 15th Feb 2023 → 9th March 2023
- **RUN3:**
  - 10 cm Cu shielding
  - 5th May 2023 → 16th November 2023
- **RUN4:**
  - 10 cm Cu + 40 cm water shielding
  - 30th November 2023 → 15th December 2023

LIME data taking in 2024

2024

- **RUN4:**
  - 10 cm Cu + 40 cm water shielding
  - 30th November 2023 → 15th December 2023
  - 15th Jan 2024 → 22nd April 2024
  - Optimization of parameters for low gain campaign of RUN5
- **RUN5:**
  - 10 cm Cu shielding, **low gain**
  - 17th May 2025 → **4th Dec 2024**
- **AmBe:**
  - 10 cm Cu shielding, **low gain**
  - 4th Dec 2025 → 17th/18th December 2024
- **Latest tests**
  - Gas purity filters;

Slide by S. Piacentini, LIME Run Coordinator

LIME: RUNs 1-5

	Time slot	Number of pictures	Event rate	Number of events
RUN 1: No-shielding	3 Nov 2023 - 15 Dec 2023	4 10^5	35 Hz	4 10^6
RUN 2: 4 cm Cu shielding	15 Feb 2023 - 15 March 2023	4.5 10^5	3.5 Hz	5 10^5
RUN 3: 10 cm Cu shielding	5 May 2023 - 16 Nov 2023	1.6 10^6	1.5 Hz	7.3 10^5
RUN 4: 10 cm Cu + 40 cm water shielding	30 Nov 2023 - 31 March 2024	2 10^6	1.0 Hz	6 10^5
RUN 5: 10 cm Cu shielding (neutron flux measurements)	17 May 2024 - 1 Dec 2024	12 10^6	1.5 Hz	5.4 10^6

Special data takings

AmBe for Nuclear Recoils	2-4 Aug 2023	2 10^5	0.04 Hz of NR	2.5 10^3 NR
^{241}Am for Electron Recoils	7-16 Nov 2023	7 10^5	50 Hz	10^6
AmBe for Nuclear Recoils	5-15 Dec 2024	5.7 10^5	0.04 Hz of NR	7.0 10^3 NR

LIME PLANS

With the **end of RUN4** in March 2024, LIME data taking for **PHASE_0 is considered closed**;

The whole schedule successfully concluded with **3 months delay** (including the delayed start due to civil works) in over **27 months of operations**;

The water shielding was then removed and in **May 2024** and **RUN5** has been taken for 6 months to measure the **flux of underground neutrons**, in the framework of **PRIN** “Zero Radioactivity”**.**

Good exercise to **tune and test simulation and analysis algorithms** for **NR**, propaedeutical to DM search…

In **December 2024** a 10 days long **AmBe campaign** was performed to have a good calibration on signal-like events;

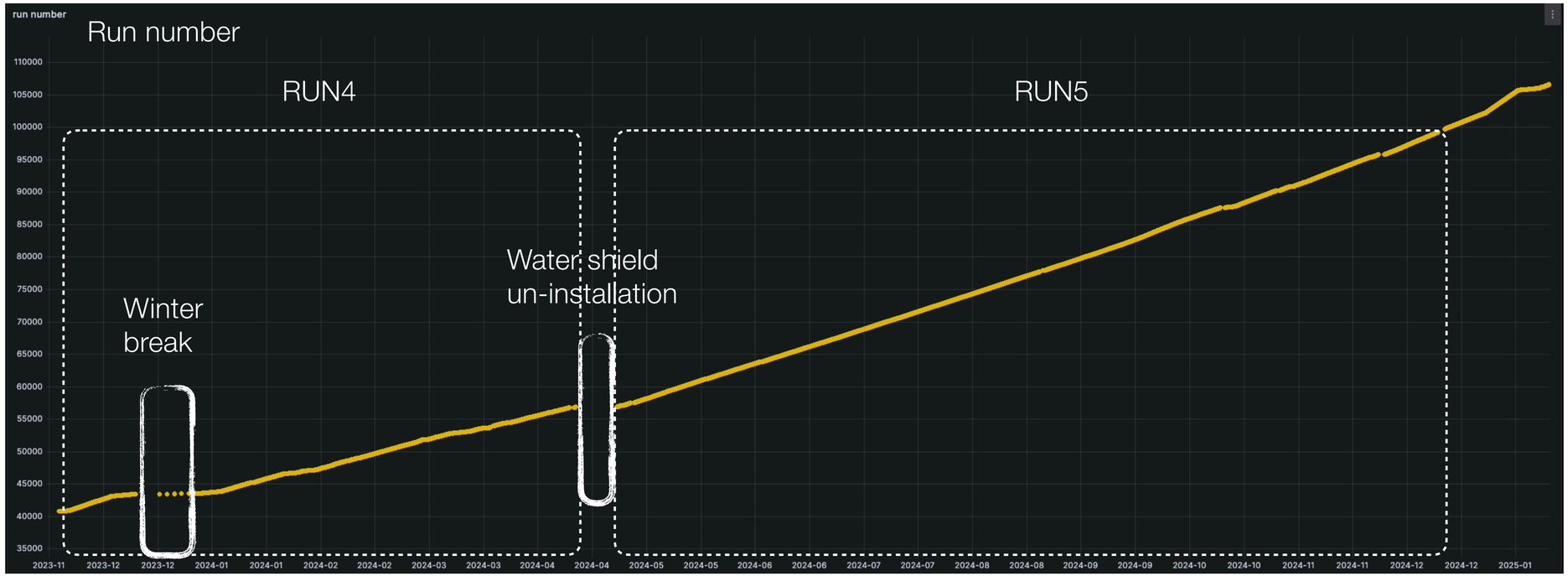
From **January 2025** we are taking some **“technical runs”** to study the effects of **gas filters,** a **new camera**, and **calibration** with ^{85}**Kr**

LIME DATA TAKING SUMMARY

Ancillary systems: DAQ and Slow control

Data taking started in October 2023 never stopped;

More than **7x10^4 runs** have been taken for a total of **28 x 10^6 pictures**;



All of them have been **promptly transferred** on the INFN-Cloud and **reconstructed**;

Reco-files are made available to the CYGNO users **few minutes after** the run was taken;

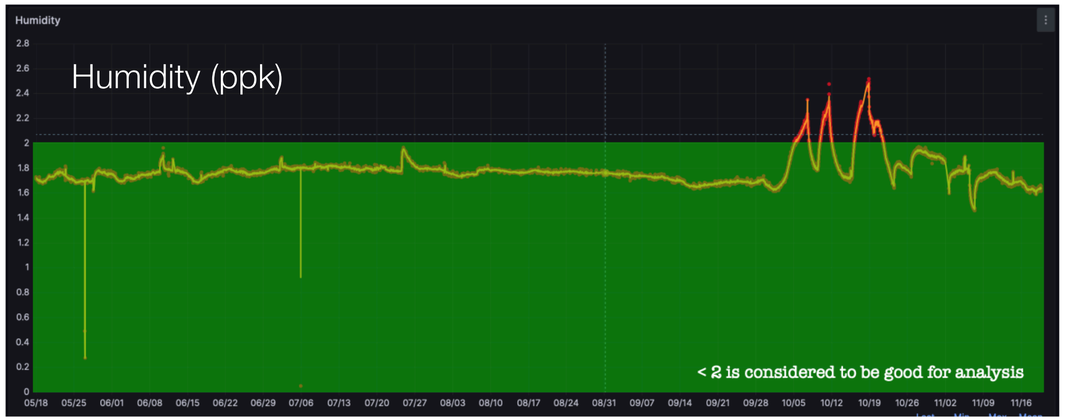
Slide by S. Piacentini, LIME Run Coordinator

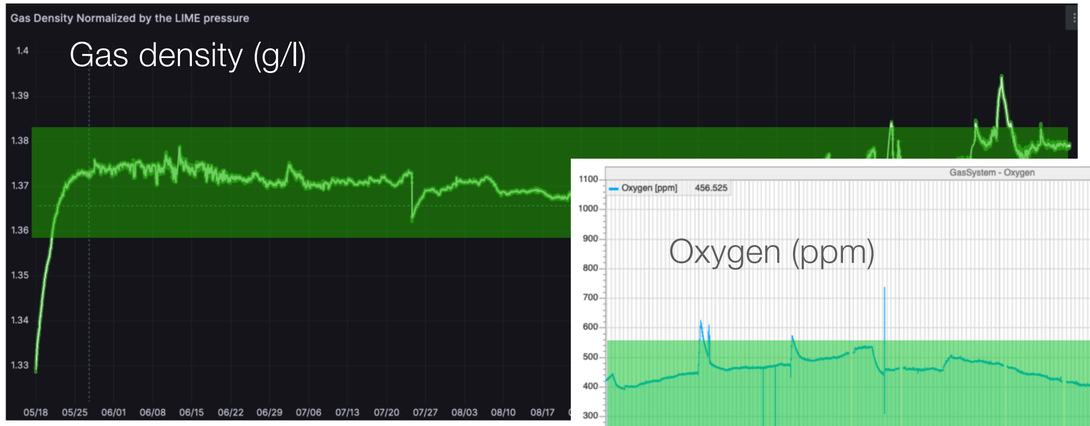
Ancillary systems: Gas and HV

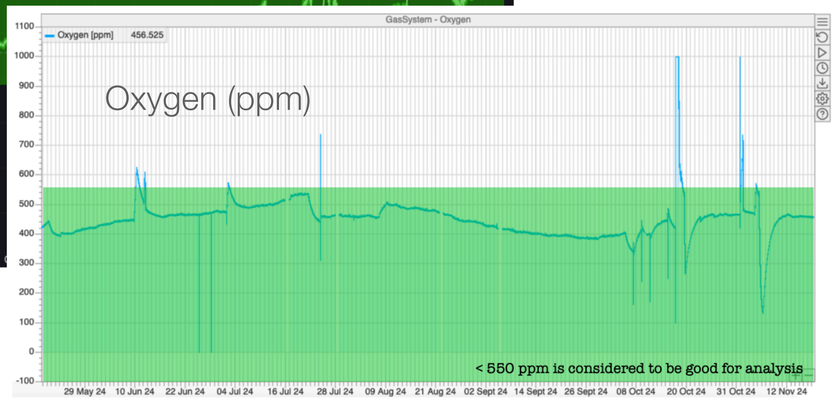
Less than one **HV** spike every 3 days was recorded in 2024 (12 times lesser than previous best limit …)

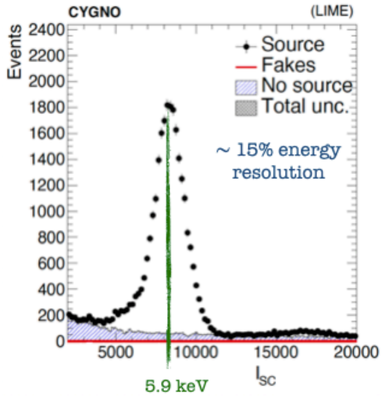
Several **grafana** pages allows to monitor the **detector operation**, its main parameters and **data quality;**

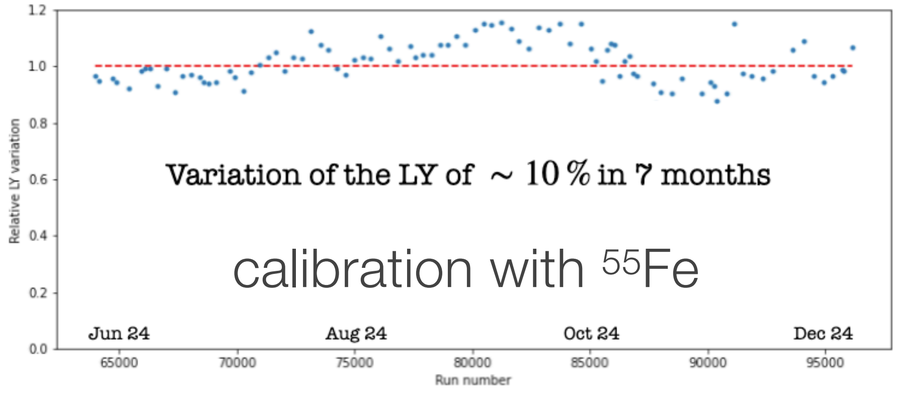
Gas **humidity, oxygen** and other **contaminants** were **under control** for the whole **2024**











Detector calibration with **^{55}Fe** is now a **completely automated** procedure and showed a **stability with 7% RMS** over 6 months

Slide by S. Piacentini, LIME Run Coordinator

CYGNO04

TDR CYGNO financial plan and CSN2 proposal

The TDR submitted in **2022** included:

- infrastructure installation by Oct 2024;
- detector installation by Dec 2024;
- start of data taking Sept 2025;

Since the spring **2024** an important delay started to accumulate leading to 5-6 months delay

- infrastructure installation by the end of Feb 2025;
- detector installation by summer 2025;
- data taking to start at the beginning of 2026;

La commissione apprezza il lavoro di analisi compiuto dalla collaborazione su LIME ma invita la collaborazione a finalizzare la realizzazione di CYGNO-04 non oltre i primi mesi del 2026, recuperando, ove possibile i ritardi. La CSN2 raccomanda alla collaborazione un adeguato periodo di presa dati prima del *decommissioning* previsto nel 2027. La commissione inoltre puntualizza che la maggior parte delle spese di costruzione costruzione e caratterizzazione di CYGNO-04 devono essere sostenute su fondi ERC e si impegna a dare supporto all'esperimento secondo il piano finanziario esposto nel CDR a fronte del raggiungimento delle *milestone* di progetto, che saranno puntualmente verificate dai Referee.

Financial profile for ERC and INFN from the **2022 TDR**

Year	INITIUM/ERC	CYGNO/INFN
2019	20	54
2020	201	44
2021	71	96
2022	40	96
2023	374	120
2024	302	125
2025	60	135
2026	0	95
2027	0	50
Tot 23-27	736	525
Tot	**1068**	**815**

CYGNO04 drawings

Between December and January, it became clear that the delay in producing the executive drawings for CYGNO04 was unrecoverable by relying solely on the forces available to LNF's design service

We therefore asked the LNGS design service for support: merging and sharing their resources with LNF’s one is the only possible solution to finalise the work done so far in a reasonable time interval;

In order to reach this aim, the proposal issued by the LNGS+LNF Design Services is that they should work together, having as only one direct link to CYGNO Collaboration the Technical Coordinator (Davide Fiorina since September after Giovanni Mazzitelli resigned in April);

A Task Force has then started to work also including, along with the TC a designer from both the Labs (Alessandro Lalli - LNGS and Antonio Croce - LNF) with supervision of the two heads of the Services (Donato Orlandi - LNGS and Cesidio Capoccia - LNF, head of the service) and Davide Pinci as CYGNO spokesperson to support TC activities;

CYGNO current financial plan

The new situation had very negligible effects on the financial plans:

- A total of **490 k€** are expected to being funded by INFN for the quinquennium 2023-2027 (**515 k€** foreseen in the **TDR)**

- In particular **305 k€** foreseen by INFN in 25-27;

- A total of **1099 k€** are expected to being funded by ERC for the quinquennium 2023-2027 (**1068 k€** foreseen in the **TDR)**

Financial plan for INFN from the 2024 Progress Report

INFN - CSN2	2025	2026	2027
Gas Bottles	16	20	10
Gas Recovery	15	20	10
Consumables	25	10	20
Optics and DAQ	50	0	0
Tot w/o Travels (k€)	106	50	40
Travels - Shift	14	20	10
Travels - Installation	25	10	30
Tot Travels (k€)	39	30	40
Tot (k€)	**145**	**80**	**80**

Year	INITIUM/ERC	CYGNO/INFN
2019	20	54
2020	201	44
2021	71	96
2022	40	96
2023	164	93.5
2024	528	91.5
2025	75	145
2026	0	80
2027	0	80
Tot 23-27	767	490
Tot	**1099**	**780**

CYGNO04 Economic sustainability

Currently, from the ERC fundings, to cover the core costs of CYGNO04, there are a total of **304 k€** available at **INFN** and **GSSI**

Part of the equipment needed for CYGNO04 was already bought and is currently being used and validated on LIME:

- high voltage system;
- gas system;
- DAQ and trigger;

According to the latest quotations received, the **other costs** expected for the **construction** of CYGNO04 is of **304 k€**, therefore an expense that can **be fully covered with ERC funds**

The **total value** of **CYGNO04** is of about **920 k€.**

		Unit cost	Needed Quantity	Total Cost	We Have	To Buy	Still To Spend	Still To Spend
GAS VOLUME	Cone and GEM holders	5	1	5	0	1	5	35
	Vessel	30	1	30	0	1	30	
READOUT	4-GEM Set	10	2	20	2	0	0	14
	Orca Quest	26	6	156	6	0	0	
	Camera mechanics	1	6	6	0	6	6	
	Lenses	2	6	12	2	4	8	
	PMT+Socket	1	16	16	16	0	0	
CATHODE	Frame+foil+feedthrough	17	1	17	0	1	17	17
FIELD CAGE	Field Cage	13	1	13	0	1	13	13
CALIBRATION SYSTEM	Kripton-Rubidium	6	1	6	0	1	6	8
	55-Fe system	2	1	2	0	1	2	
SHIELDING	4 ton Copper Elsasser	156	1	156	1	0	28	193
	copper precision machinering	10	1	10	0	1	10	
	Opera copper refurbishing	30	1	30	0	1	30	
	High Voltage feed through	10	1	10	0	1	10	
	Optical windows	10	1	10	0	1	10	
	water tanks	65	1	65	0	1	65	
	frame	20	1	20	0	1	20	
	polietilene	20	1	20	0	1	20	
GAS SYSTEM	gas system	85	1	85	1	0	0	0
	filters	1	8	8	8	0	0	
HV SYSTEM	GEM-HV	5	1	5	1	0	0	0
	PMT-HV	3	2	6	2	0	0	
	Cathode HV	5	1	5	1	0	0	
DAQ & SLOW CONTROLS	modules	45.5	1	45.5	1	0	0	0
COMPRESSED AIR SYSTEM	filters and pipes	5	1	5	0	1	5	5
ELECTRIC SERVICES	power distribution system	10	1	10	1	0	0	0
	cables & connectors	5	1	5	1	0	0	
	UPS	5	1	5	1	0	0	
NETWORK DISTRIBUTION	network distribution system	13	1	13	1	0	0	0
COOLING and CONDITIONING	Conditioning	20	1	20	1	0	0	4
	Cameras chiller	5	1	5	1	0	0	
	PMTs flow system	2	1	2	0	1	2	
	Cables & connectors	2	1	2	0	1	2	
SAFETY (PRA-VIA)	pra+vinca	6	1	6	1	0	0	0
	fire detection	10	1	10	1	0	0	
	gas monitor	15	1	15	1	0	0	
	safety design	10	1	10	1	0	0	
CIVIL WORK	total	40	1	40	1	0	0	0
DESIGN AND DOCUMENTATION	software	5	1	5	0	1	5	15
	final audit	10	1	10	0	1	10	
			Gran Total	921.5			304	304

Component Validation

Copper analysis with ICPMS

- They used the described procedure to clean it and measured the U and Th content

	Etching 2	Etching 3
	[pg * g^{-1}]	[pg * g^{-1}]
Th	9 ± 3	7 ± 2
U	5 ± 2	2 ± 1

- These were the Matthias results

```
radionuclide concentrations:

Th-232:
Ra-228:          < 0.38 mBq/kg          <==>    < 9.3 E-11 g/g
Th-228:          < 0.20 mBq/kg          <==>    < 4.9 E-11 g/g

U-238:
Ra-226           < 0.44 mBq/kg          <==>    < 3.5 E-11 g/g
Th-234           < 17 mBq/kg            <==>    < 9.3 E-10 g/g
Pa-234m          < 11 mBq/kg            <==>    < 6.5 E-10 g/g

U-235:           < 0.37 mBq/kg          <==>    < 6.5 E-10 g/g

K-40:            < 3.2 mBq/kg           <==>    < 1.0 E-7 g/g

Cs-137:          < 0.14 mBq/kg

Co-60:           < 0.12 mBq/kg

Co-58:           (0.8 +- 0.1) mBq/kg

Mn-54:           (0.12 +- 0.05) mBq/kg
```

^{58}Co has an half life of 70 days
^{54}Mn has an half life of 1 year

	October
Layer_0 (1-20 keV) [evts/yr]	14655 ± 347
Layer_1 (1-20 keV) [evts/yr]	4518 ± 176
Layer_2 (1-20 keV) [evts/yr]	10588 ± 2671
TOTAL	**29761 ± 2700**

Significant **improvement** thanks to ICP-MS measurement of Schrieber's copper

Huge statistics required to see first effects of Bi210 in OPERA's copper
→ **more storage space needed**

In light of the updated results, the most viable option is still
4 cm clean copper + 6 cm OPERA

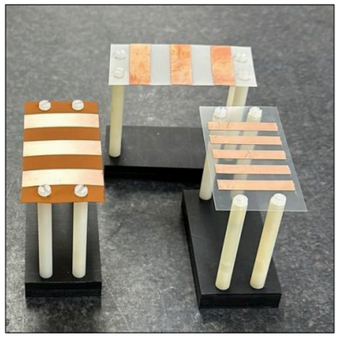
Upper limits on U and Th obtained with Germanium detector, 10 times larger than actual values

FC and GEM foils are now on queue for the ICPMS tests

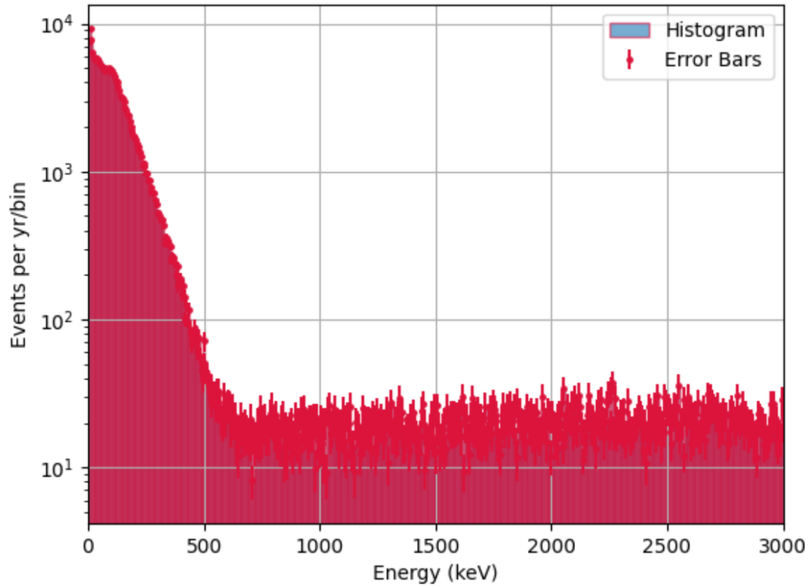
Component Validation

Field Cage Foils

- Three different field cage foils:
  - **PET+Cu with glue**: a polyethylene foil with Cu strips glued by spreading the adhesive over the entire foil
  - **PET+Cu with no glue**: a polyethylene foil with Cu strips glued by applying the adhesive only between the strips and the foil
  - **Kapton+Cu:** a kapton foil with Cu strips
- The foils were measured at LNGS



Sample Name	in measure	measured	analysed
FC-kapton+Cu	no	yes	yes
FC-PET+Cu	no	yes	yes
FC-PET+Cu no glue	no	yes	yes
nylon6	no	yes	on-going
GEM foil	no	yes	on-going
nylon screws	no	yes	on-going
steel screws	no	yes	on-going
SMD resistors	no	yes	on-going
CMOS camera	no	yes	yes
PMMA	yes	no	no



In the low energy range (0-20 keV):

- **(1.56 ± 0.01) 10^5** evt/year;
- **(1.20 ± 0.08) 10^3** NR evt/year;

Plans for 2025

LIME data taking is going on very smoothly. Activities will now focus on:

- Data analysis and validation of MC simulation (M2.1 - 31/12)
- Full GEANT4 simulation of CYGNO-04 (M3.2 - 31/12);
- Tenders for CYGNO-04 realisation (M4.3 - 31/08);
- Installation of the infrastructure (D4.1 - 30/10) and then of the detector (D4.2- 31/12);
- Validation of last components and ancillaries: field cage (D6.1 - 28/02), new optics (D6.2 - 30/09) and DAQ V1 (D5.2 - 31/12)

Papers in last year

Secondary scintillation yield from GEM electron avalanches in He-CF_4 and He-CF_4/butane for CYGNO – Directional Dark Matter Search with an optical TPC

Published by PLB

F.D. Amaro,[a] E. Bar... ...si,[d] S. Bianco,[d] C. Capoccia,[d] M. Caponero,[d,e] D.S. ... ...voto,[g,h] A. Corte... [b,c] L.A. Costa [i] F. Dané [d] G. Dho,[b,c] F. Di ... ...Di Marco,[h] G. D'Imp... P. Lima Júnior,[c] C. ... ...accarrone,[d] R.D.P. Ma... ...arcelo Grego... ...ues,[b,c] G. Mazzitelli,[d] A.G. M... C.M.B. M... ...orega,[i] I.F. Pains,[i] E. Paoletti,[d] ...si,[h] F. ...acentini,[g,h] D. Piccolo,[d] D. Pierluig... ...i,[b,c] F. ...d.C. Roque,[a,2] F. Rosatelli,[d] A. Russo, Sa... ...,[g,n] N.J.C. Spooner,[k] R. Tesauro,[d] S. Toma...

[a] *LIBPhys, Department of Physics, University of Coimbra, 3004-516 Coimbra; Portugal*

[b] *Gran Sasso Science Institute*

Prepared for submission to JINST

Charge Amplification in Low Pressure CF_4/SF_6:He Mixtures with a Multi-Mesh ThGEM for Directional Dark Matter Searches

Published on JINST

...racchini,[4,5] L. Benussi,[6] ...ardoso,[10] G. Cavo... ...ie,[11] E. ...a,[4,5] E. Di Ma... ...czeribe,[12] J.M. ...orton,[6] F... H.P. Lima Júnior,[10] ...D.P. Mano,[1] R.R. Marcelo ...n,[12,*] P. Meloni,[2,3] A. Messina,[7,8] C. M. B. Monteiro,[1] R.A. N... ...Paoletti,[6] L. Passamonti,[6] S. Pelosi,[7] F. Petrucci,[2,3] S. Pia... ...ierluigi,[6] D. Pinci,[7] A. Prajapati,[4,5] F. Renga,[7] R. C. P... ...usso,[6] G. Saviano,[6,16] A. Scarff,[12] N.J.C. Spooner.[12] ...ni,[6] S. Torelli,[4,5] and D. Tozzi[7,8]

Prepared for submission to JINST

Enhancing the light yield of He:CF_4 based gaseous detector

Published on EPJC

Fernando Domingues Amaro[1], Rita Antonietti[2,3], Elisab... ...tta Baracchini[4,5], Luigi Benussi[6], Stefano Bianco[6], Rob... Campagnola[6], Cesidio Capoccia[6], Michele Capo... ...lo Santos Cardoso[8], Luan Gomes Mattosinhos ... Gianluca Cavoto[10,11], Igor Abritta Cost... Emiliano Dané[6], Giorgio Dho[4,6,a], F... ...cista[4,5], Emanuele Di Marco[11], Melba D... ...Imperio[11], Davide Fiorina[4,5], Frances... ...or ul Islam[4,5], Herman Pessoa Lima ... ...emp[12], Giovanni Maccarrone[6], Rui ... ..., Robert Renz M... Gregorio[13], D... ...arques[4,5], Giovanni Ma... Alasdair C... ...ndrea Messina[10,11], Pietro Cris... ...Monteiro[1], Rafael Antunes N... ...miliano Paoletti[6], Luciano Passar... ...Stefano Piacentini[4,5], Davide Piccol... ...avide Pinci[11], Atul Prajapati[4,5], Francesco ...na da Cruz Roque[1], Filippo Rosatelli[6], Alessand... ...quim Marques Ferreira dos Santos[1], Giovanna Saviano[6,14], Pedro Alberto Oliveira Costa Silva[1], Neil John Curwen Spooner[13], Roberto Tesauro[6], Sandro Tomassini[6], Samuele Torelli[4,5]

...ins-det] 4 Nov 2024

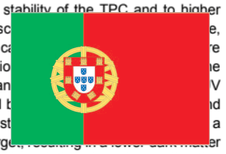
He-CF4-CH4 ternary mixtures as target gas... ...e CYGNO directional dark matter ex...

Under internal review

R. J. da C. Roque, R. D. P. Mano, C. M. B Monteiro (... ...GNO authorlist)

Abstract

The CYGNO collaboration ... ...solution optical Time Projection Chamber for directional dark matt... ...neutrino spectroscopy, to be deployed at LNGS. He-40% CF_4 is h... ...gas, at atmospheric pressure, and a triple-GEM cascade is being us... ...of the ionization signal, being the scintillation produced in the GEM ... ...d out by sCMOS cameras. High sensitivity to interactions in the few k... ...on event tracking and particle identification are enabled with this solution. ...y the addition of 3 to 10 percent of methane to He-40%CF_4 and demonstrate ...ane inclusion contributes to both the electrical stability of the TPC and to higher sc... ...on output from the GEM avalanches. In spite of the sc... the addition of methane increases the maximum voltage that ca... the onset of discharges, eventually resulting in higher scintillatio... visible component of the gas scintillation shows that isobutan... photons emitted by He-CF_4. The maximum voltage that could b... to be independent from the methane concentration in the st... hydrogen-based gas provides CYGNO with an even lighter targe... detection threshold, in longer track lengths of light nuclear recoils and, thus, in a clearer direction discrimination.



Modeling the detector response of the CYGNO optical readout TPC

Under internal review

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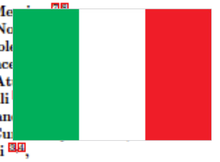
An analytical model of the response of the optically readout GEM based TPC for the CYGNO experiment

Under internal review



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PULP FICTION
Rita Roque
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Fernando Jerace
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THANKS!

CYGNO: GANTT (22-27)

CYGNO/INITIUM

PROJECT TITLE	CYGNO/INITIUM	**COMPANY NAME**	INFN
PROJECT MANAGER	Giovanni Mazzitelli	**UPDATE DATE**	30/6/22

WBS ID	TASK	APPROVAL (2022)			DESIGN and PROCUREMENT (2023)			CONSTRUCTION, TEST & ISTALLATION (2024)			COMMISSIONING – DATA TAKING (2025-2026)						DECOMMISSIONING (2027)		
		1-4	5-8	9-12	1-4	5-8	9-12	1-4	5-8	9-12	1-4	5-8	9-12	1-4	5-8	9-12	1-4	5-8	9-12
WP1	**Physics**																		
1.1	solar neutrino sensitivity													M.1.1					
1.2	dark matter sensitivity													M.1.2					
1.3	physical parameters PHASE 2																	D1.1	
WP2	**Data Analysis**																		
2.1	reconstruc/background v0									M2.1									
2.2	reconstruc/background v1												M2.2						
2.3	detector analisys PHASE 1																	D2.1	
WP3	**Detector Simulation**																		
3.1	valdete PHASE 0 results						M3.1												
3.2	Montecarlo for PHASE 1									M3.2									
3.3	estimation for PHASE 2																	D3.1	
WP4	**Detector Design and Construction**																		
4.1	executive layout infrastructure				M4.1														
4.2	executive layout of the detector						M4.2												
4.3	procurements of components								M4.3										
4.4	install infrastructure									D4.1									
4.5	install detector									D4.2									
4.6	commissioning & calibration													M4.4	-> D A T A T A K I N G				
4.8	decommissioning																	D4.3	
WP5	**Auxiliary Services**																		
5.1	validating gas system				D5.1														
5.2	validating DAQ v0						M5.1												
5.3	validating DAQ v1									D5.2									
WP6	**Research and Development**																		
6.1	validating large GEM						M6.1												
6.2	validating sensors and lens									D6.2									
6.3	validating field cage component							D6.1											
6.4	validating R&D for PHASE 2																	D6.3	
WP7	**Management**																		
7.1	ERC-FRP3						M7.1						M7.2						
7.2	ERC-FRP4																		
7.3	CSN2 Progress Report					M7.3			M7.4			M7.5				M7.6			M7.7
7.4	ERC-SRP2												D7.1						
7.5	CSN2 Final Report																		D7.2