



CYGNO status and plans

Feb 2025



Collaboration Meeting 2024

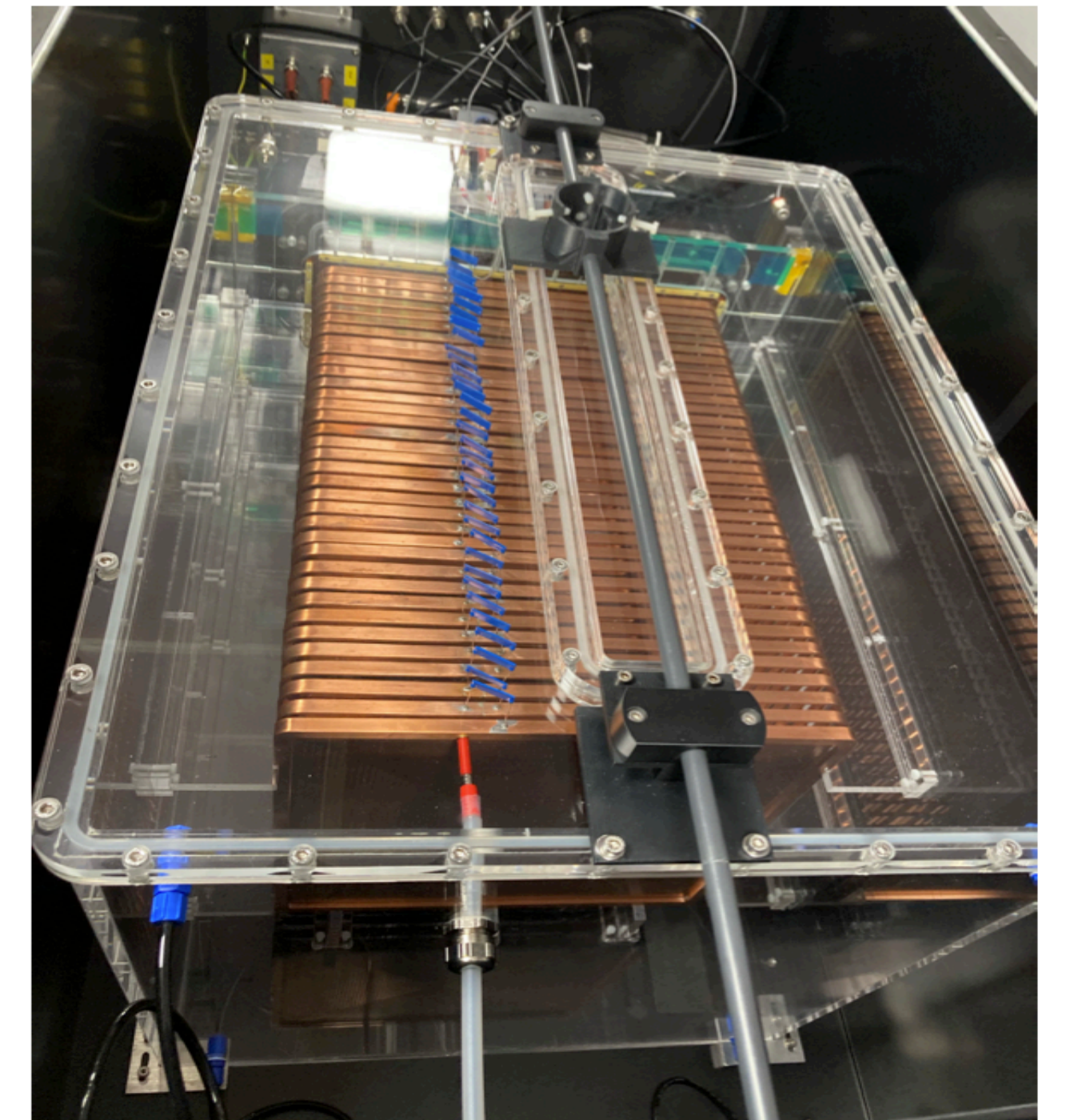
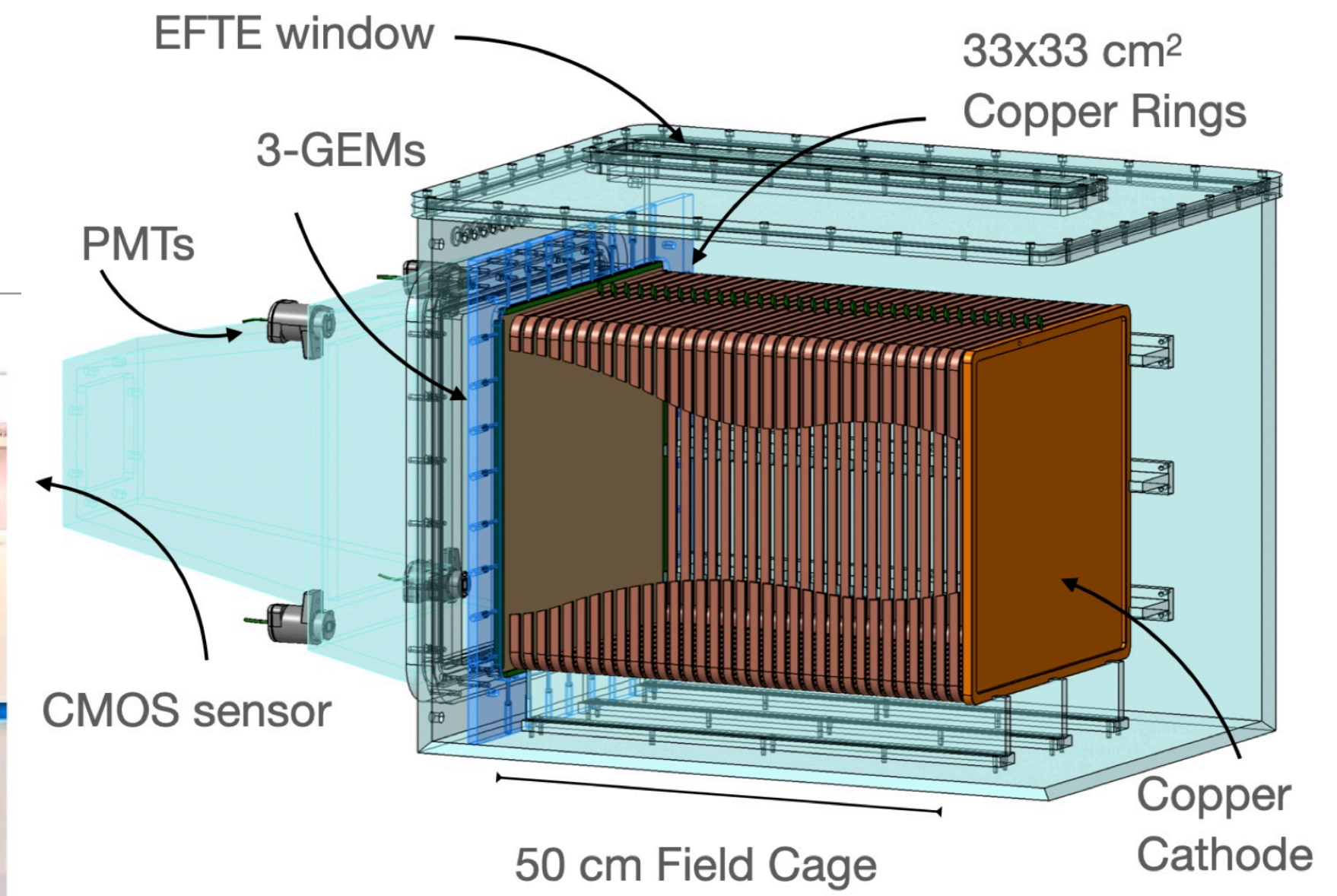
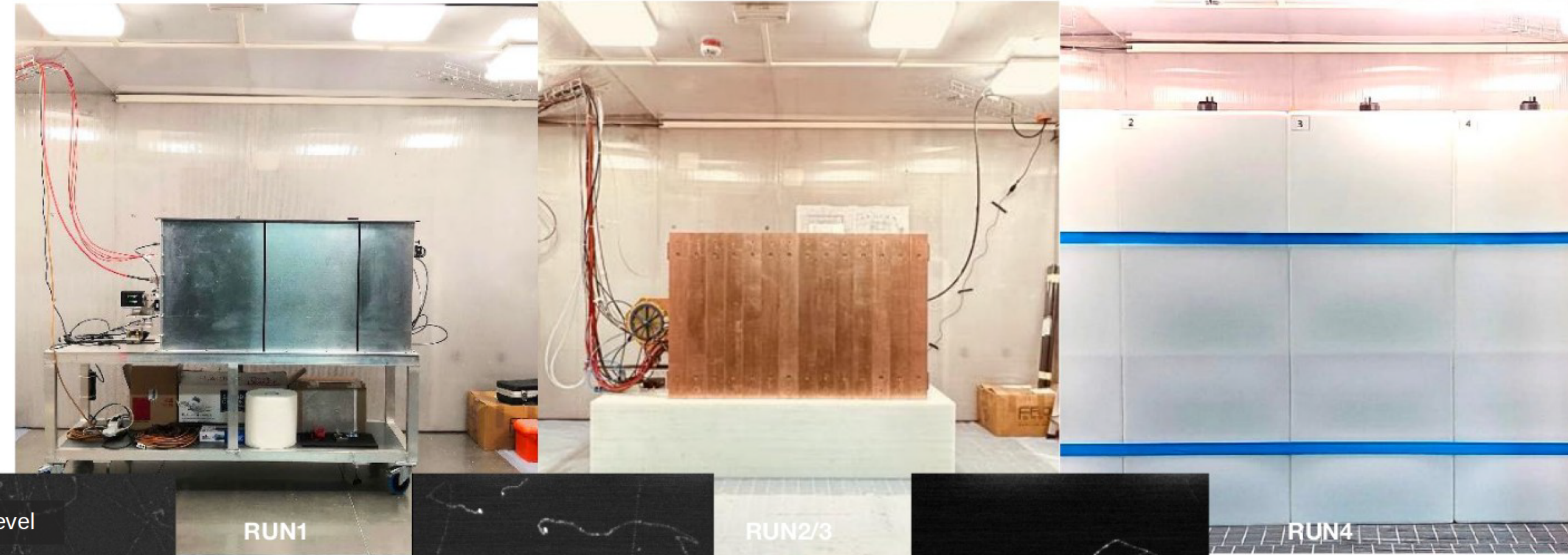


Three days of discussion about status and plans of the CYGNO collaboration:

- **LIME**: data acquisition, analysis and schedule;
- **CYGNO04**: drawing, component validation, handling procedures and simulation;
- **Project** management and financial status;

LIME

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, and **background simulation**;

LIME: RUNs 1-5



	Time slot	Number of pictures	Event rate	Number of events
RUN 1: No-shielding	3 Nov 2022 - 15 Dec 2022	$4 \cdot 10^5$	35 Hz	$4 \cdot 10^6$
RUN 2: 4 cm Cu shielding	15 Feb 2023 - 15 March 2023	$4.5 \cdot 10^5$	3.5 Hz	$5 \cdot 10^5$
RUN 3: 10 cm Cu shielding	5 May 2023 - 16 Nov 2023	$1.6 \cdot 10^6$	1.5 Hz	$7.3 \cdot 10^5$
RUN 4: 10 cm Cu + 40 cm water shielding	30 Nov 2023 - 31 March 2024	$2 \cdot 10^6$	1.0 Hz	$6 \cdot 10^5$
RUN 5: 10 cm Cu shielding (neutron flux measurements)	17 May 2024 - 1 Dec 2024	$12 \cdot 10^6$	1.5 Hz	$5.4 \cdot 10^6$

Special data takings

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

LIME PLANS



With the **end of RUN4** in March 2024, LIME data taking for **PHASE_0** is considered closed with **3 months delay** (including the delayed start due to civil works) in over **27 months of operations**;

The water shielding was then removed 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 on future experiments”**;

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

Description	Group	25-11-24	02-12-24	09-12-24	16-12-24	23-12-24	30-12-24	06-01-25	13-01-25	20-01-25	27-01-25	03-02-25	10-02-25	17-02-25	24-02-25	03-03-25	10-03-25	17-03-25	24-03-25
		1-12-24	08-12-24	15-12-24	22-12-24	29-12-24	5-1-25	12-01-25	19-01-25	26-1-25	02-02-25	09-02-25	16-2-25	23-02-25	02-03-25	9-3-25	16-03-25	23-03-25	30-3-25
End of RUN5	CYGNO Collab.																		
AmBe Source [low gain]	CYGNO Collab.																		
AmBe Source [high gain]	RM1																		
Pedestal studies	RM1																		
Gas Mixture Recovery	RM1																		
Scans in z, VGEM, VDRIFT	LNF, RM3																		
Test of new optical system	GSSI																		
Filters Tests	RM1																		
Radon Monitor	RM1																		
83Rb Source	GSSI																		
NID	GSSI																		

From **January 2025** we are taking **technical runs** intended as **pre-commissioning** of sub-parts of **CYGNO04: new camera + lens, gas filters, new calibration source**;

A **Negative Ion Drift** run is foreseen before the closure;

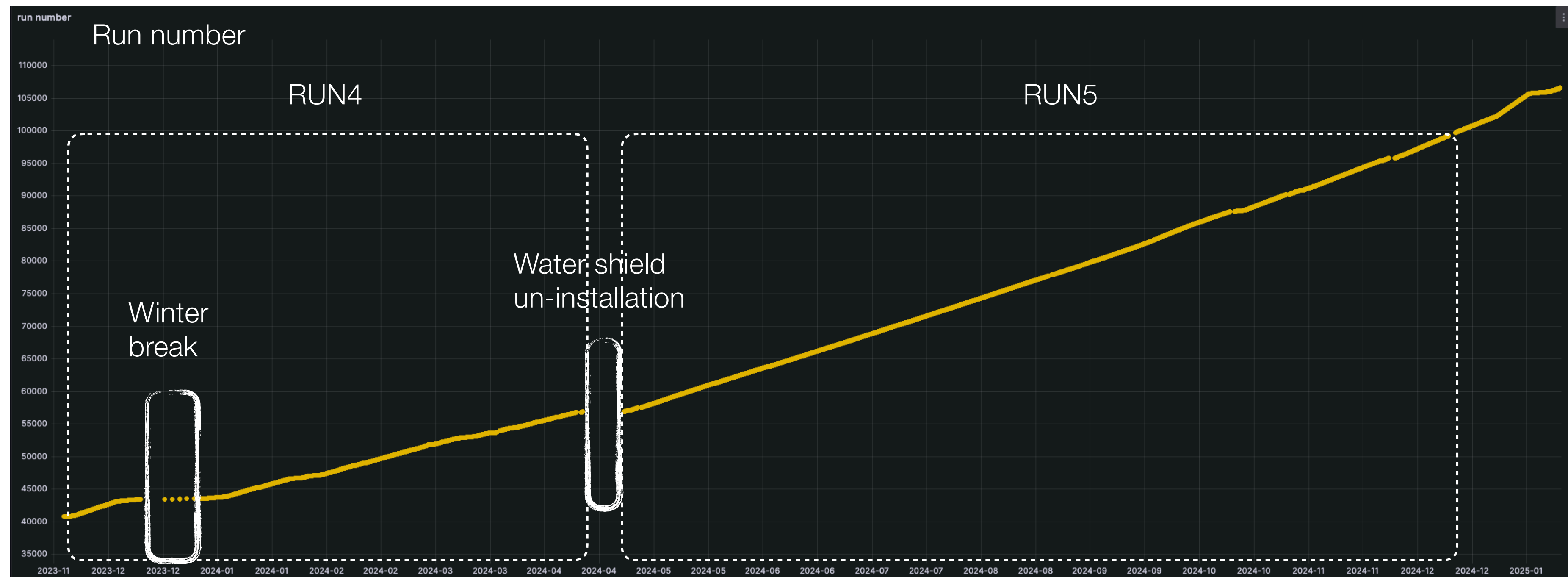
No shifts are required to the collaboration, only sub-groups are responsible for these data taking;

Ancillary systems: DAQ, Slow control



Data taking started in October 2023 never stopped;

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



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

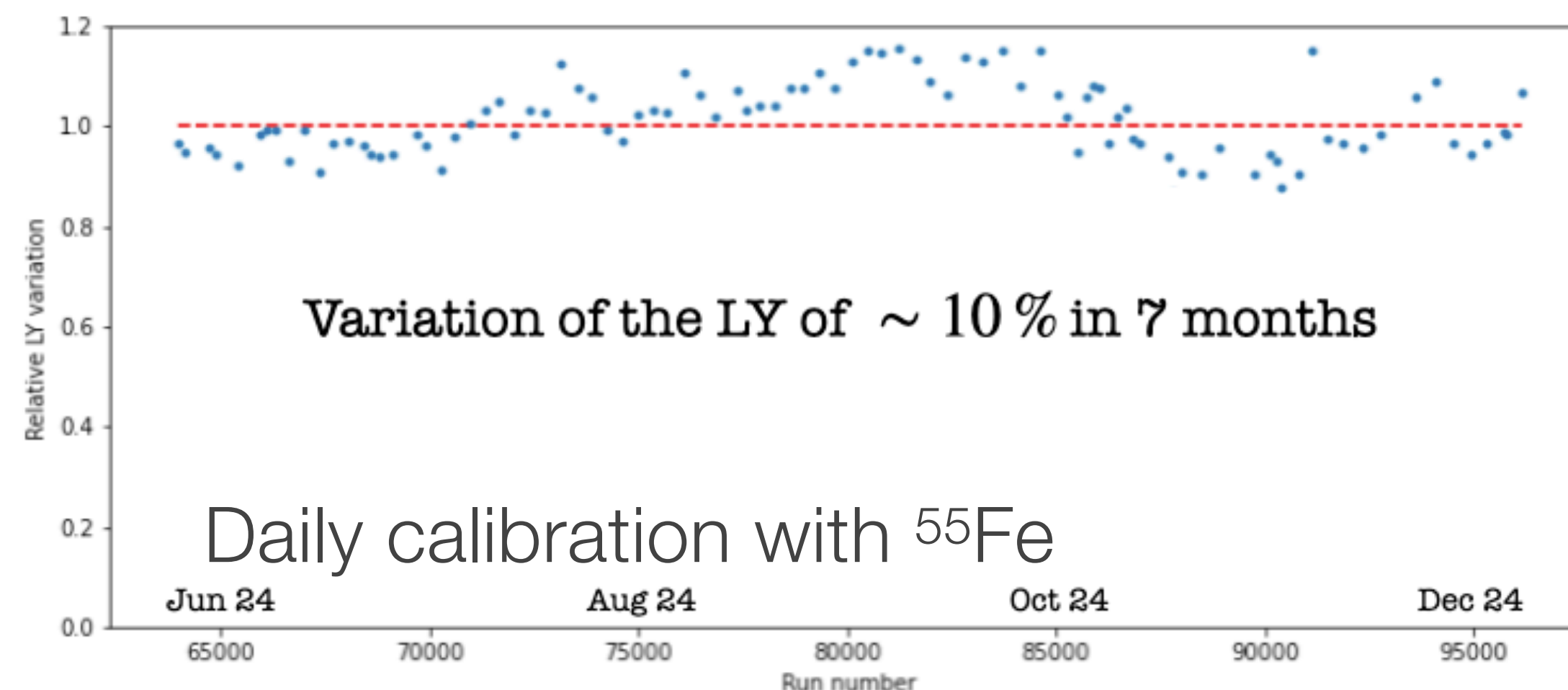
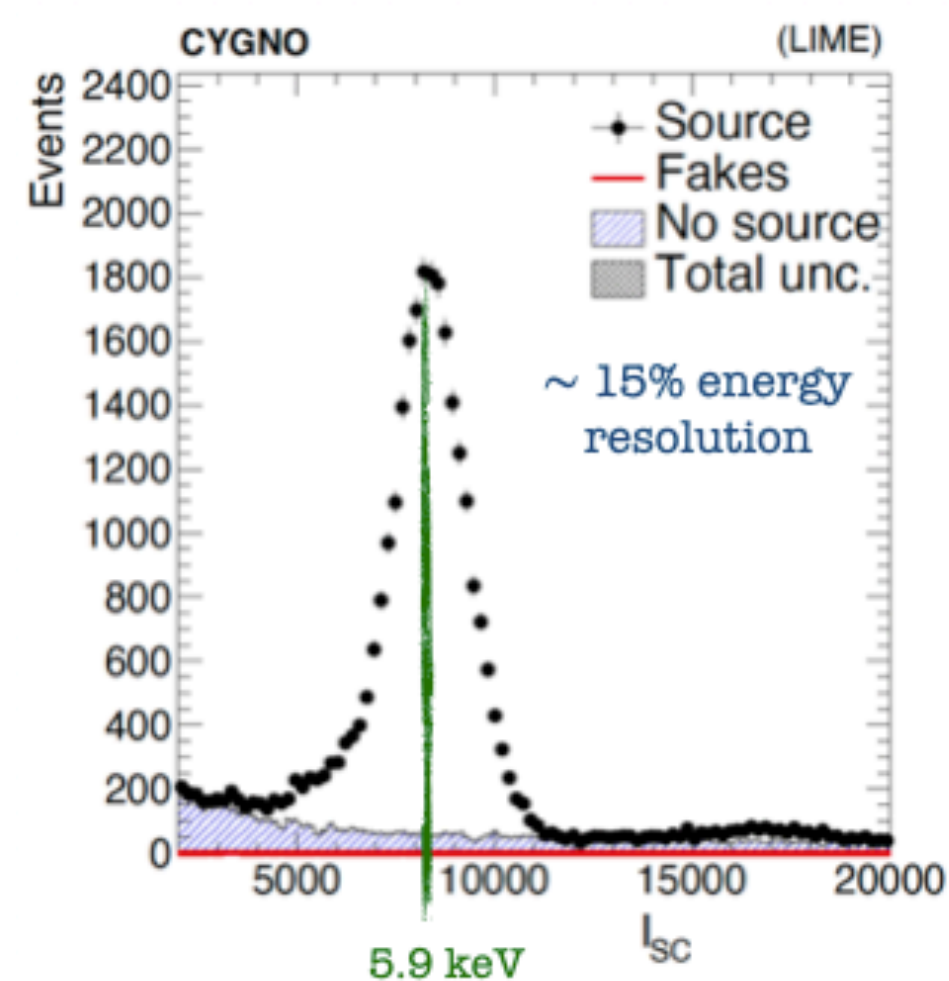
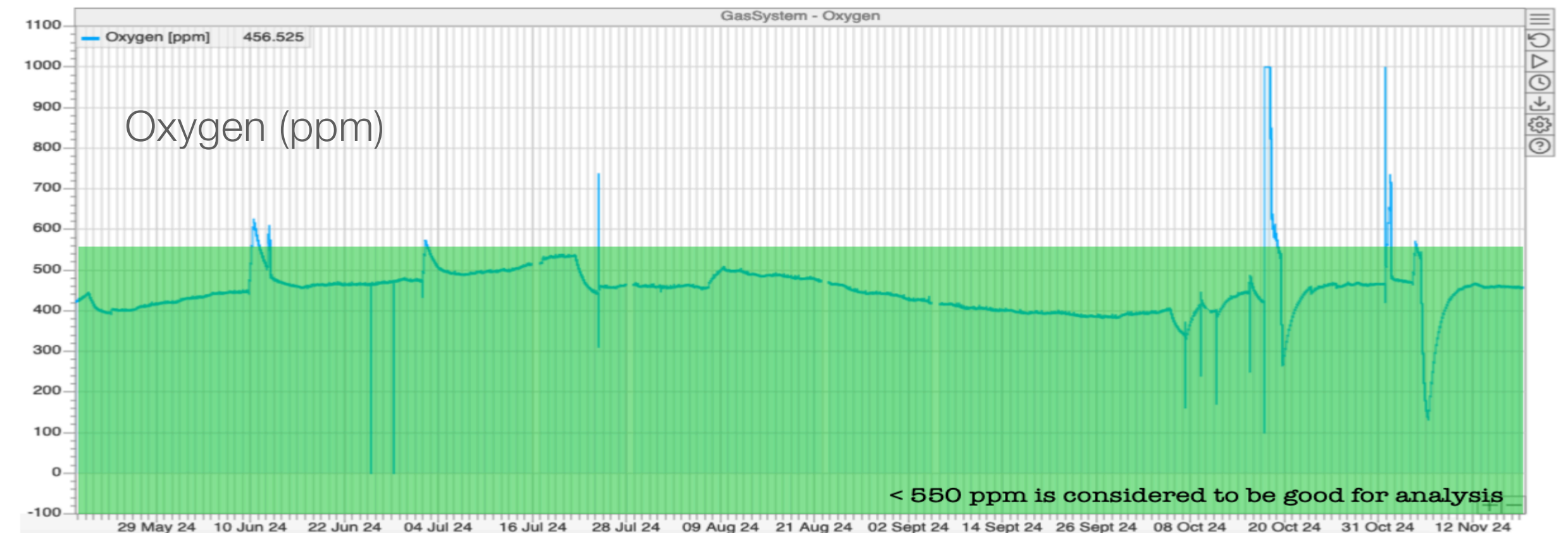
Reco-files are made available to the CYGNO users **few minutes after** the run was taken;

Ancillary systems: Gas and HV



Less than one **spark**-like every 3 days was recorded in 2024 (12 times lesser than previous best limit ...)

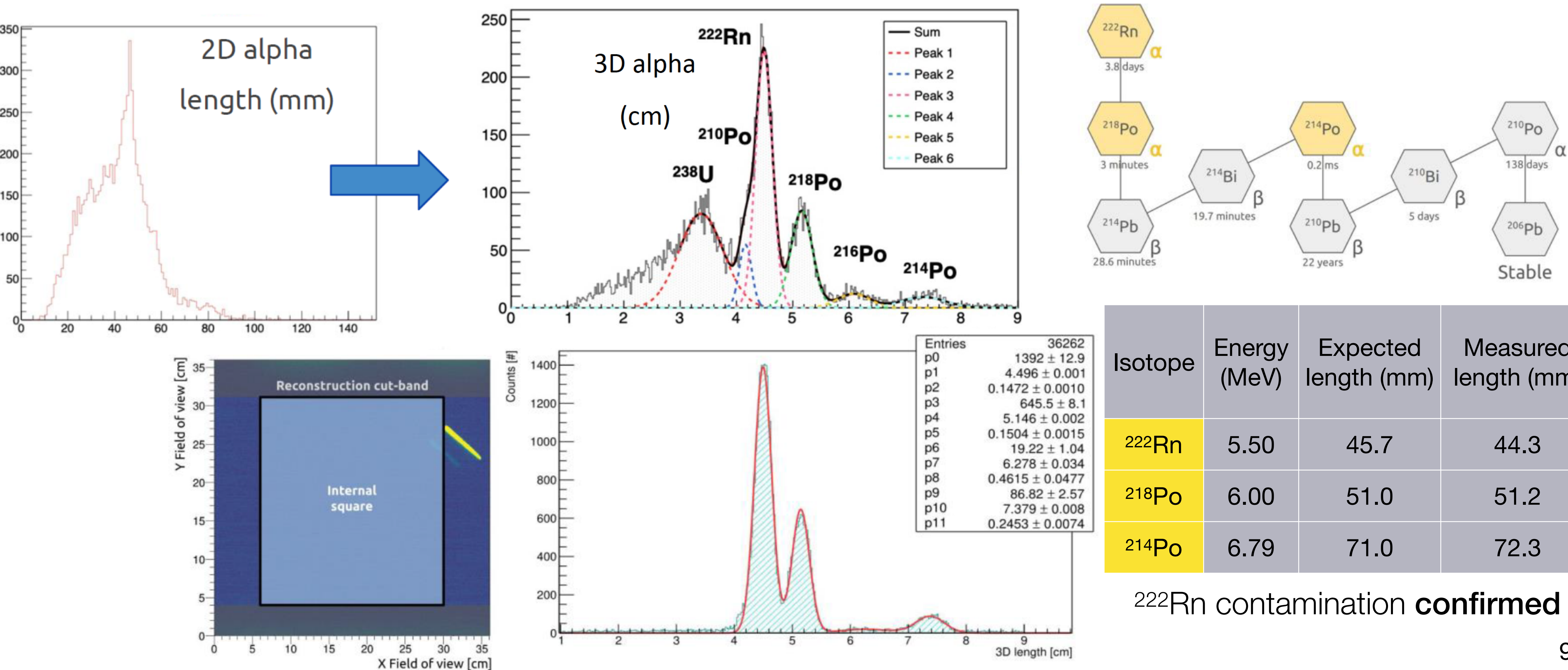
Gas **humidity**, **oxygen** and other **contaminants** were **under control** for the whole **2024**



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

3D and Radon

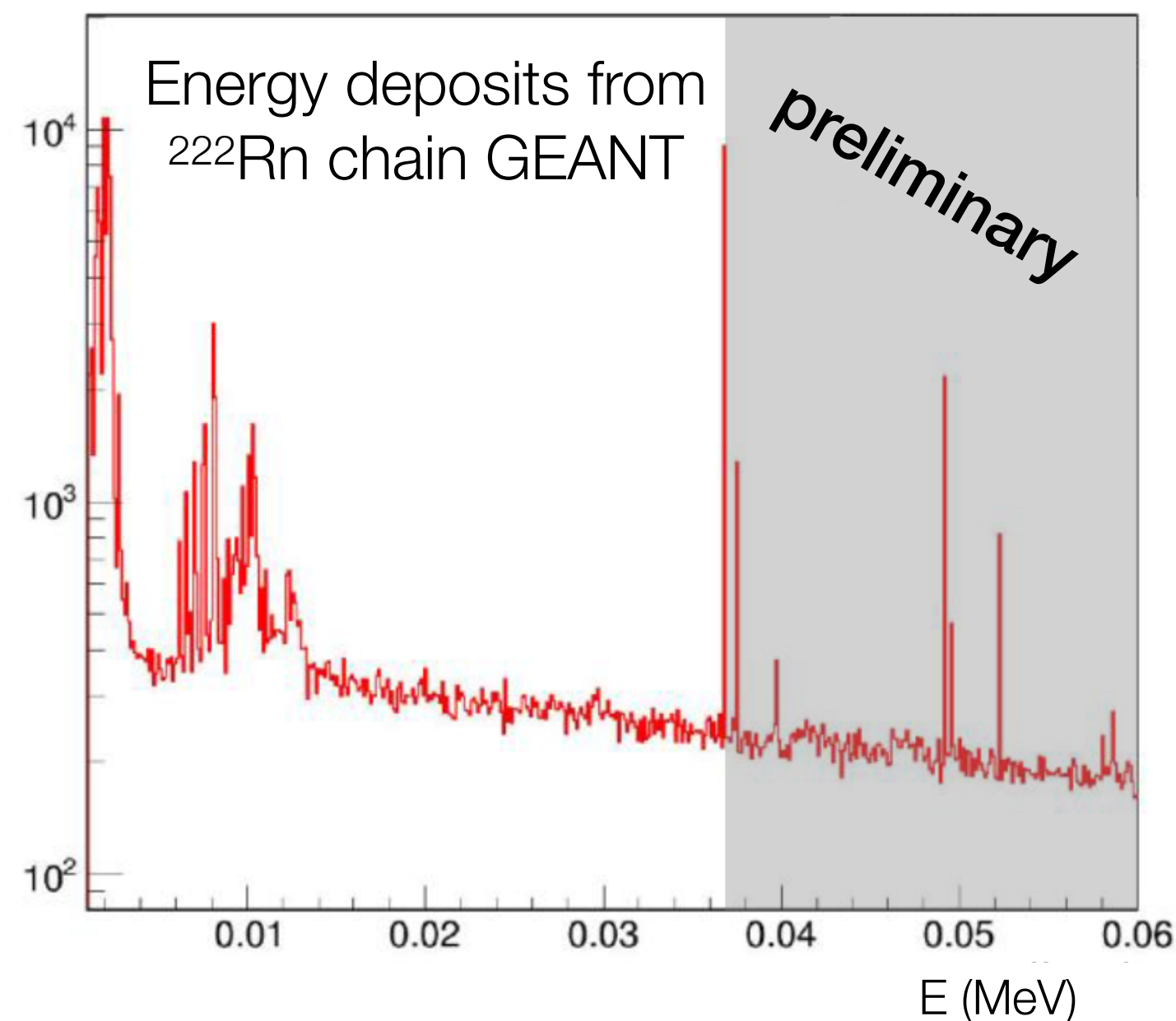
3D reconstruction allowed a precise measurement of the length of the alpha tracks with a consequent assessment of their energies



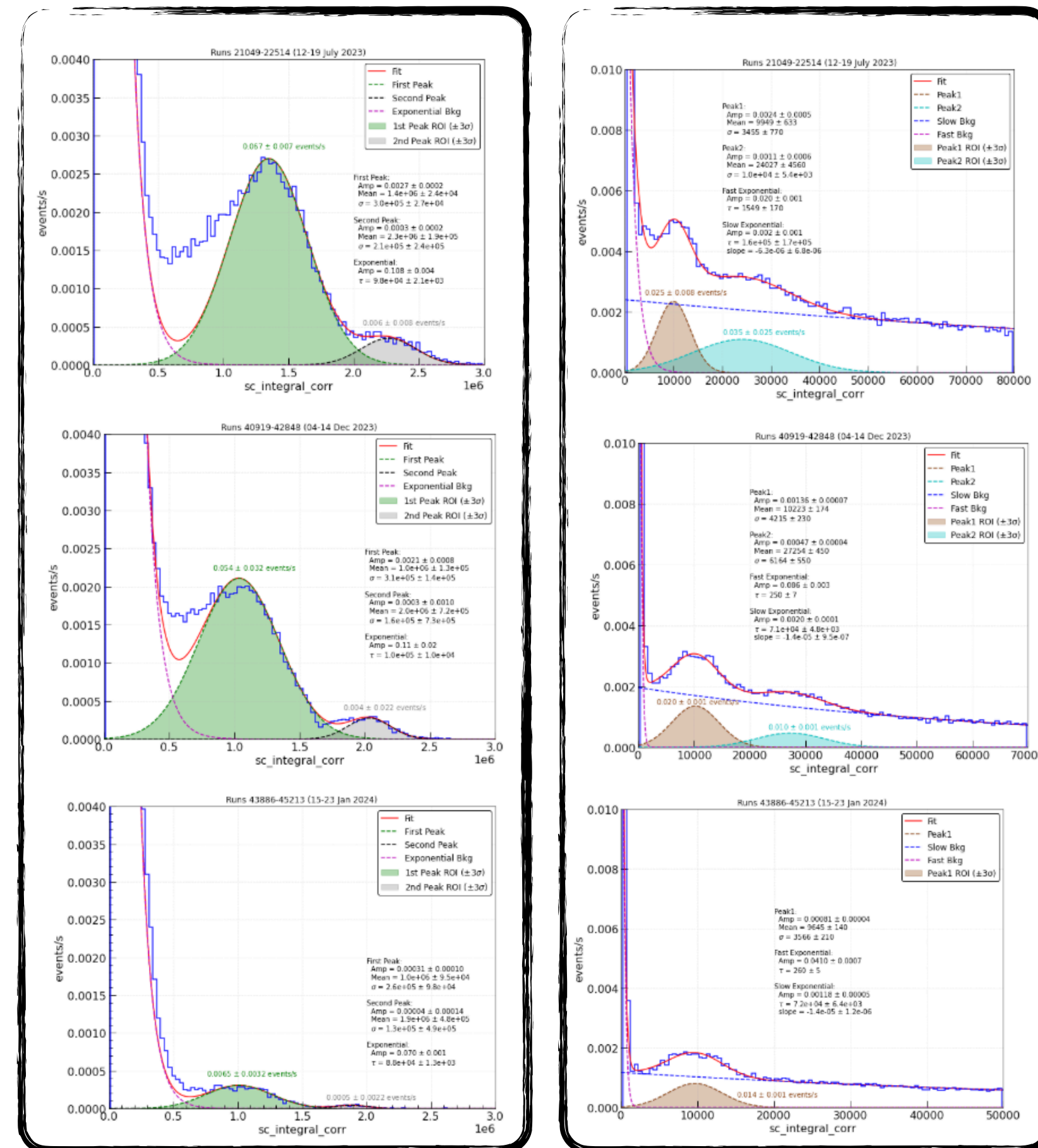
Radon and Energy Spectrum



From GEANT we expect low energy (**tens of keV**) deposits due to the **^{222}Rn decay chain**



Is there any correlation between the rate of the **alpha tracks** and the **low energy part** of the spectrum?



RUN3: July 2023
high contamination

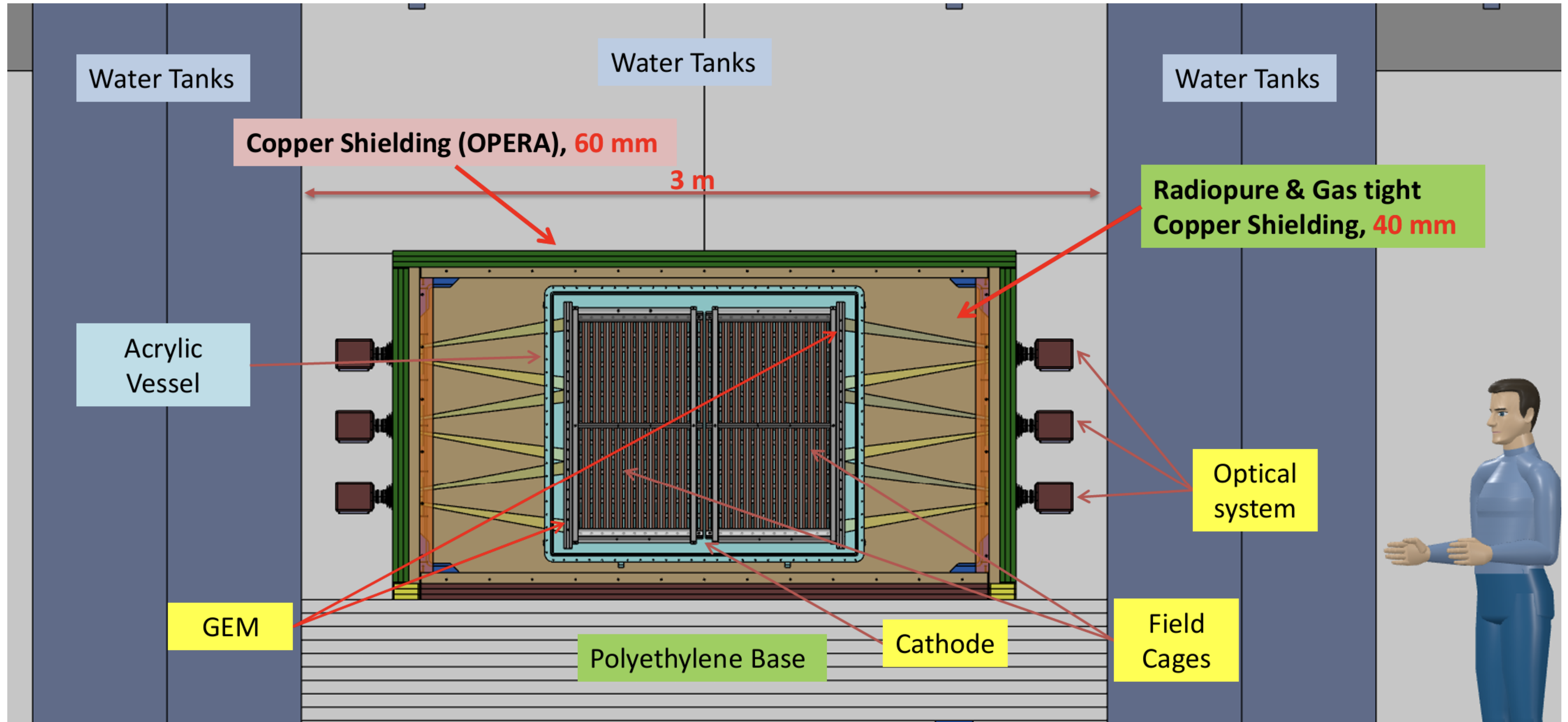
RUN4: Dec 2023
part-unfiltered

RUN4: Jan 2024
filtered

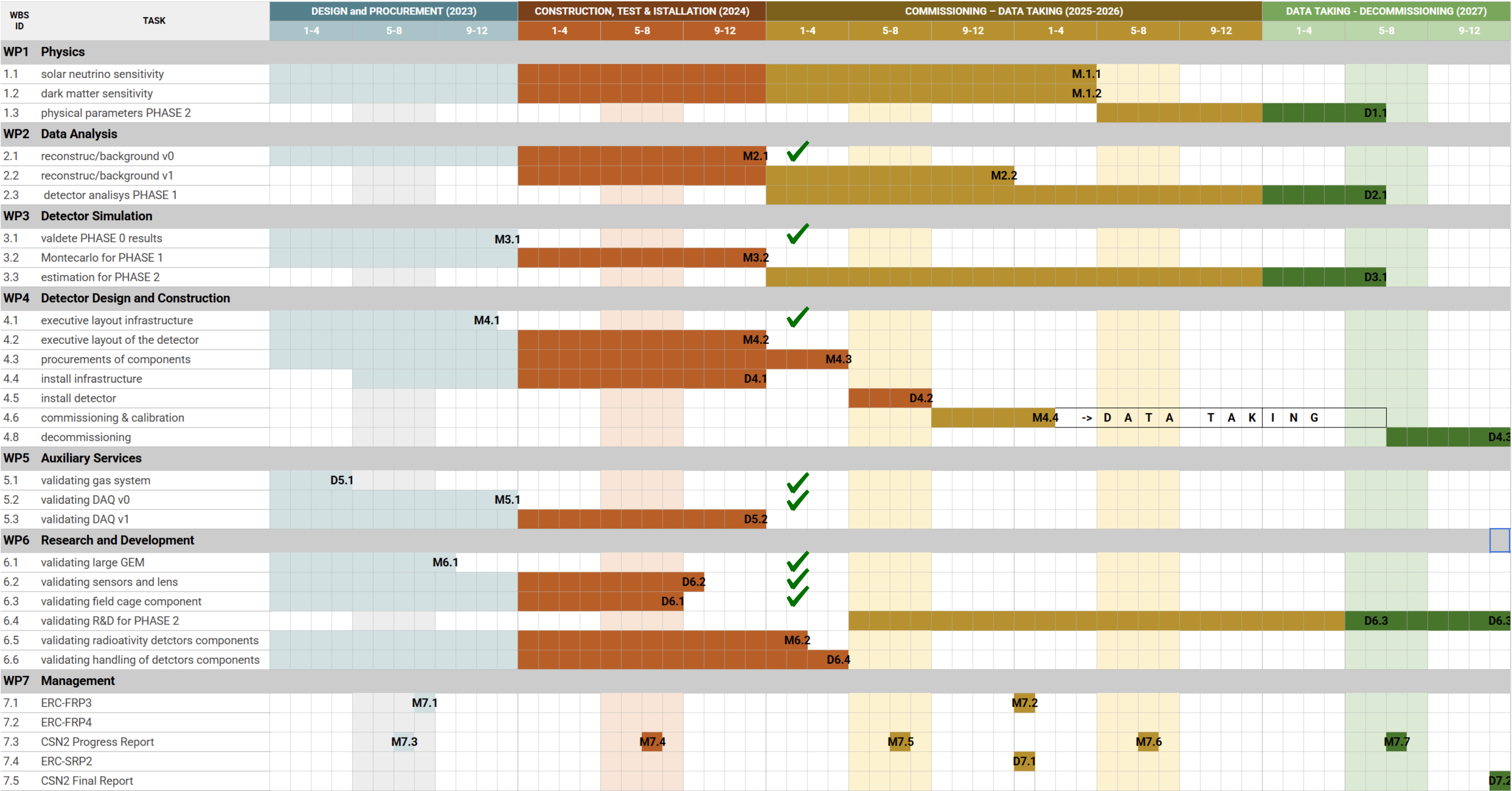
A **quantitative** study on the **correlation** between the two regions is **under study**;

Measurement campaign with a new **radon-meter** will start in 10 days;

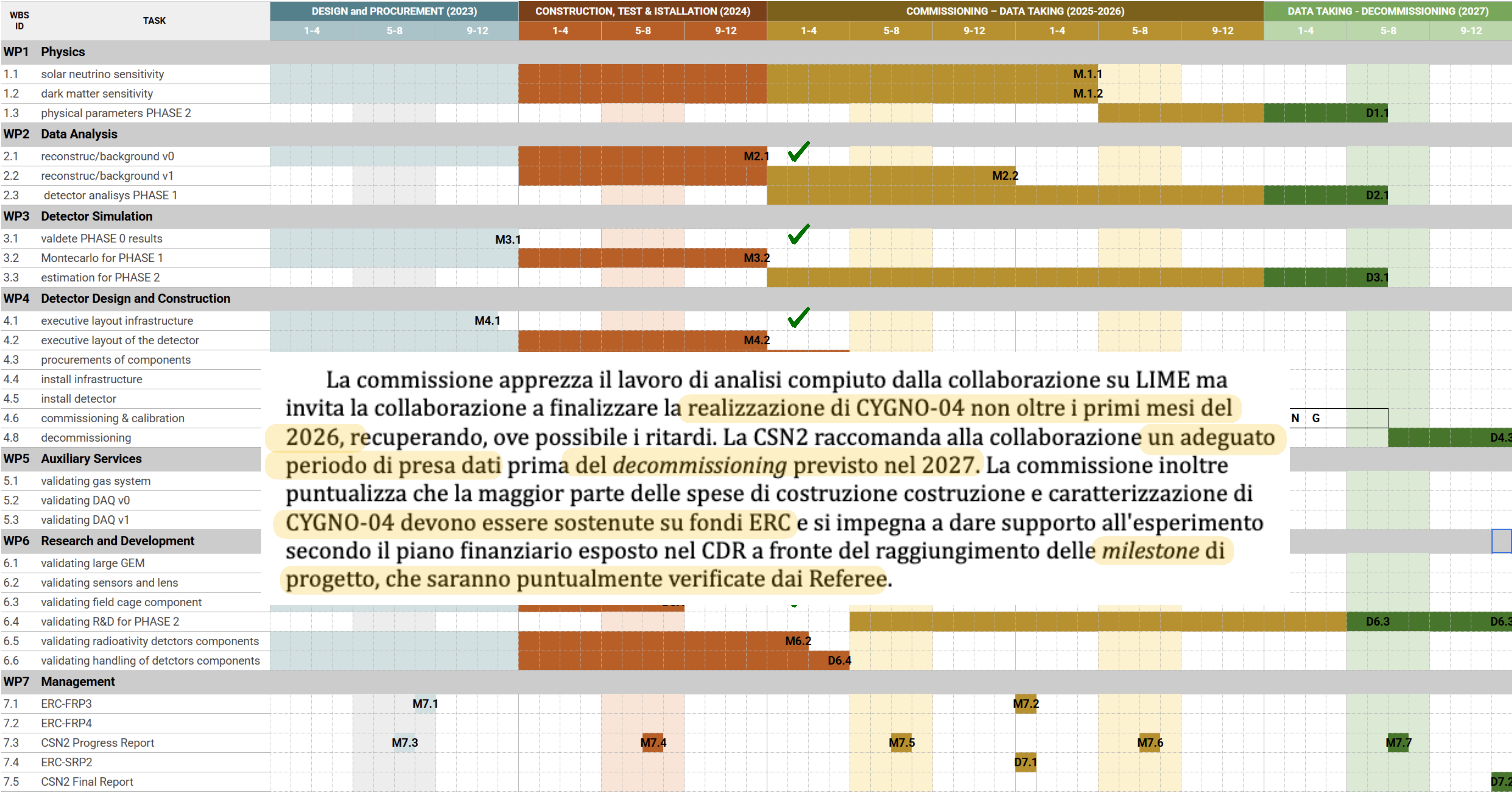
CYGNO04



CYGNO04 GANTT Progress Report 2024



CYGNO04 GANTT Progress Report 2024



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.

N G

In November 2024 **Davide Fiorina** (GSSI) was appointed as **Technical Coordinator** for CYGNO, 6 months after Giovanni Mazzitelli resignation;

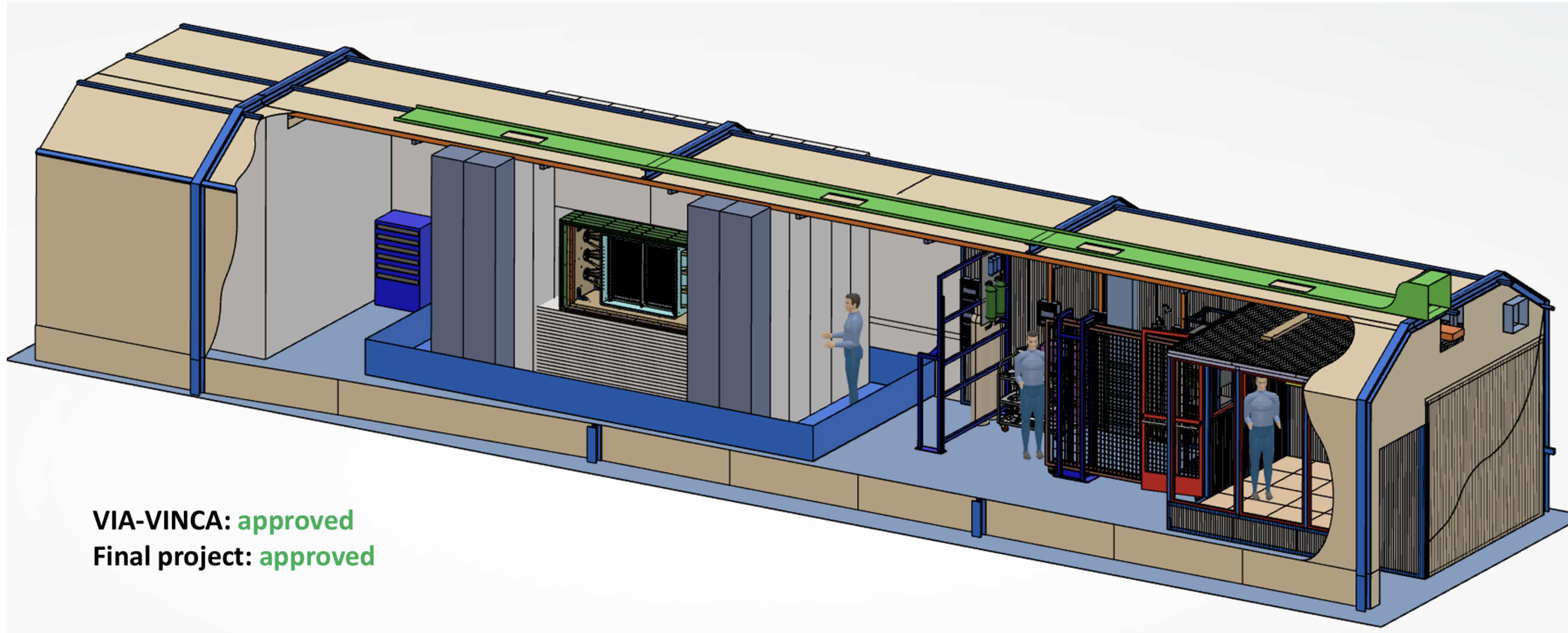
In January 2025, with more stable management structure, we realised that the **executive designs** for **CYGNO04** could not be completed **without further delays** by relying **solely on the forces** available to **LNF's Design Service**

We therefore asked the **LNGS Design Service** for support: merging and sharing their resources with LNF's one can be the **opportunity 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 Services is the creation of a **task force** including:

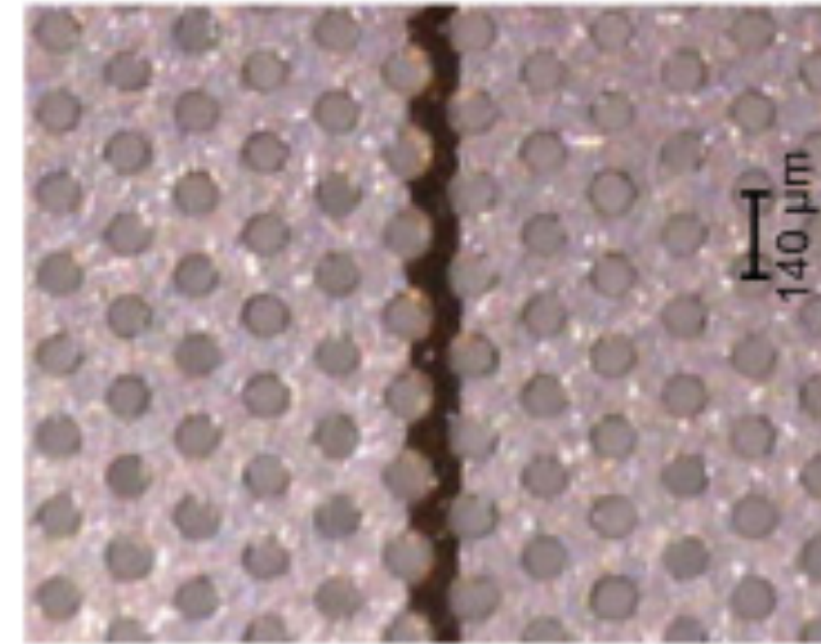
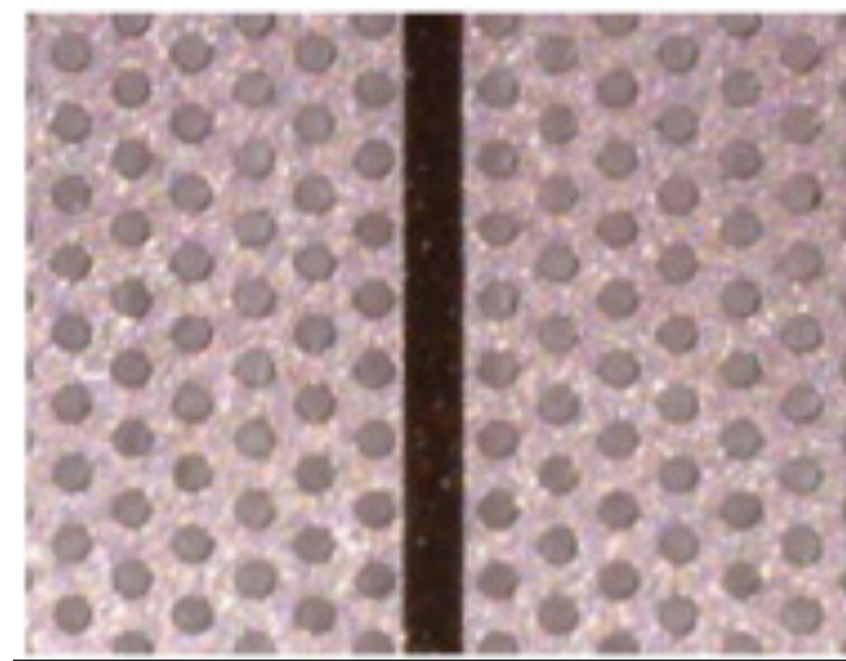
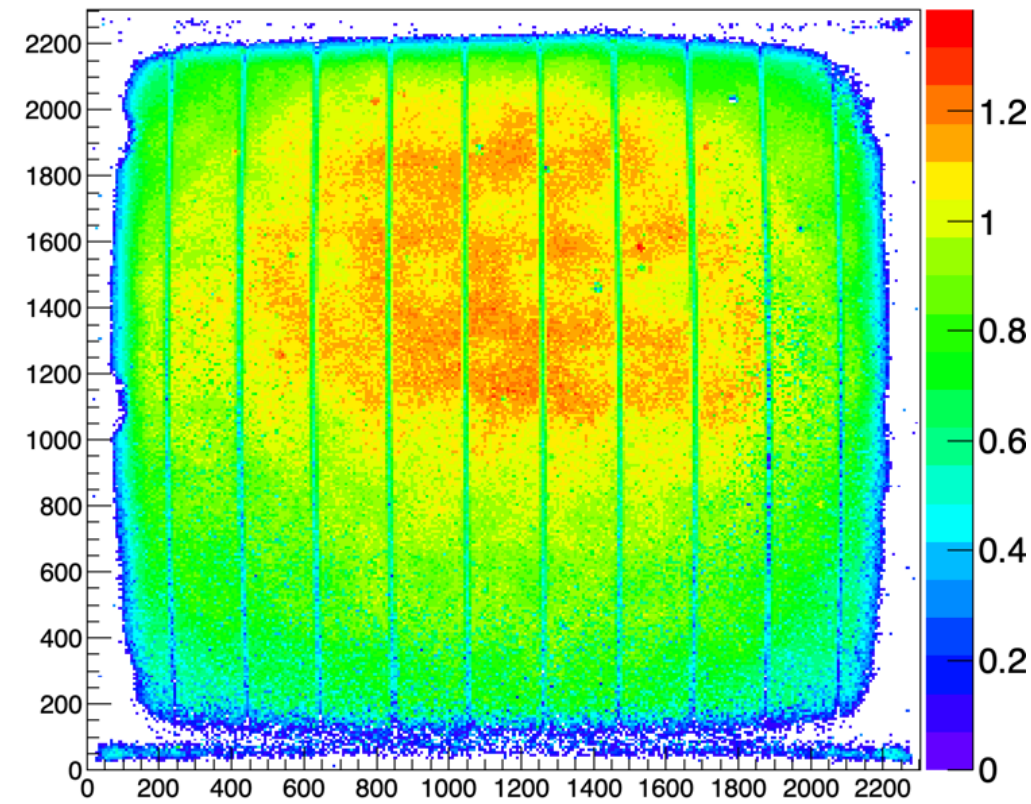
- **a designer** with the supervision of the **heads of the Services** from **both** the labs;
- having as **direct link to CYGNO** Collaboration the **Technical Coordinator** supported by Davide Pinci as CYGNO spokesperson;
- We are now on the correct path to deliver the detector in the **first trimester of 2026**

Hall-F Infrastructure



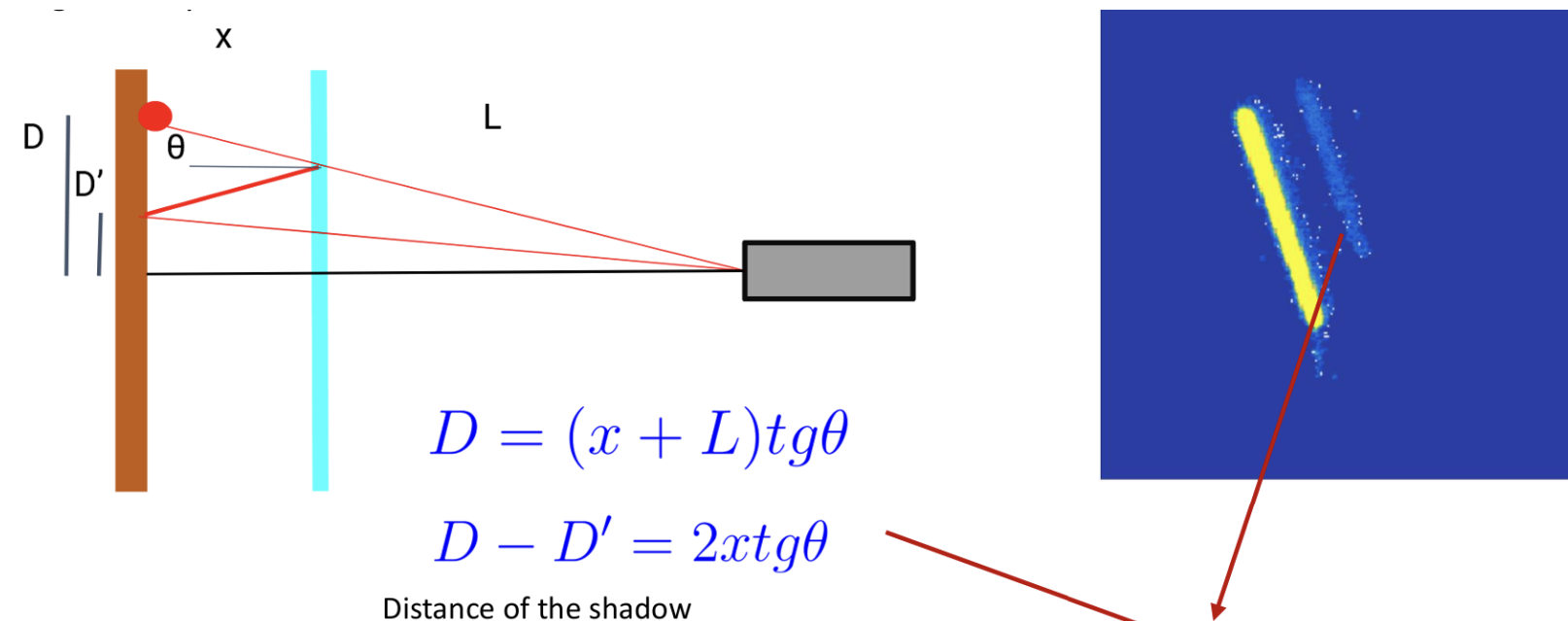
- Civil works **started** this week and **delivery** expected **end of February**;
- In accordance with the CYGNO04 timeline;

Component Validation - GEM

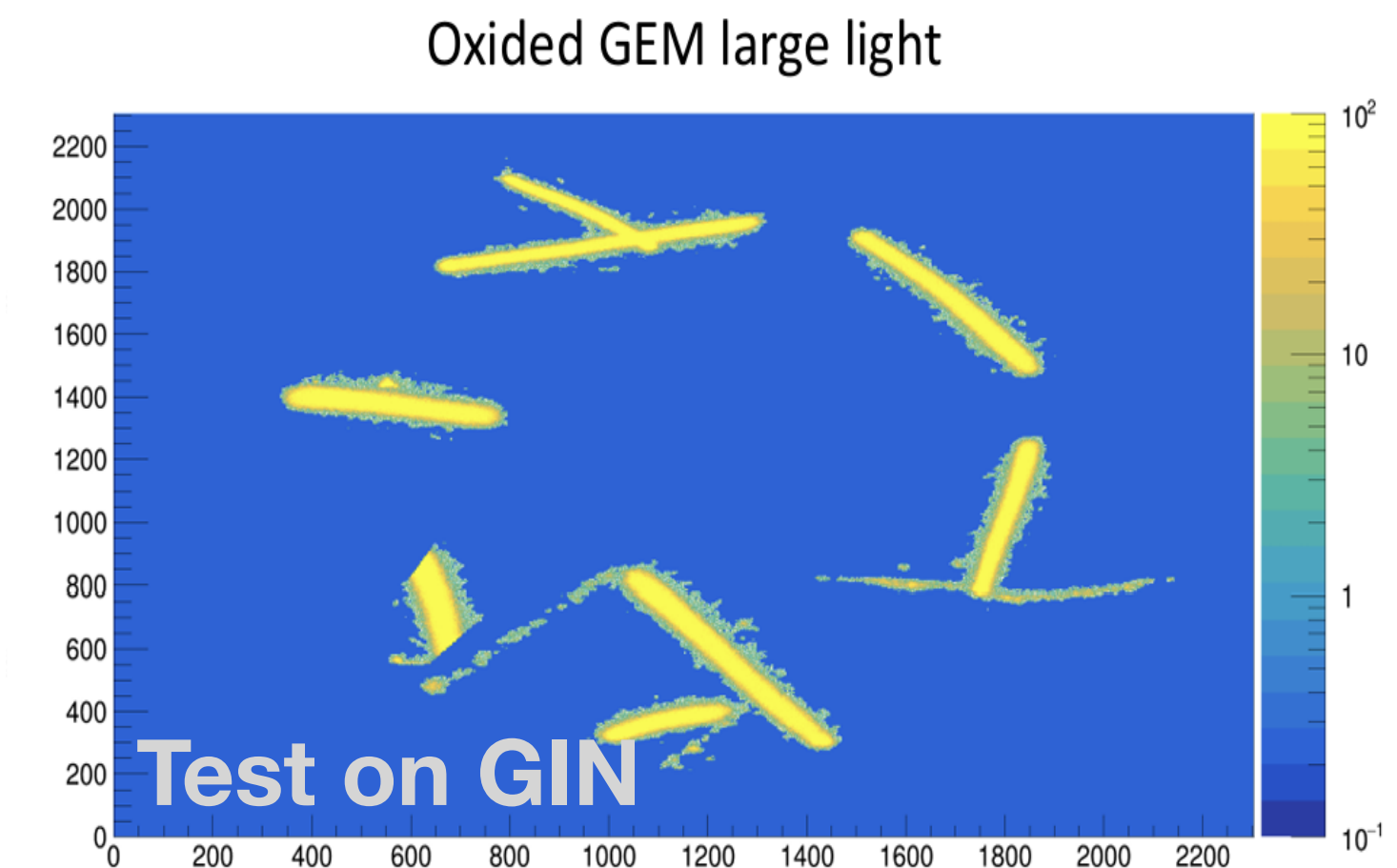
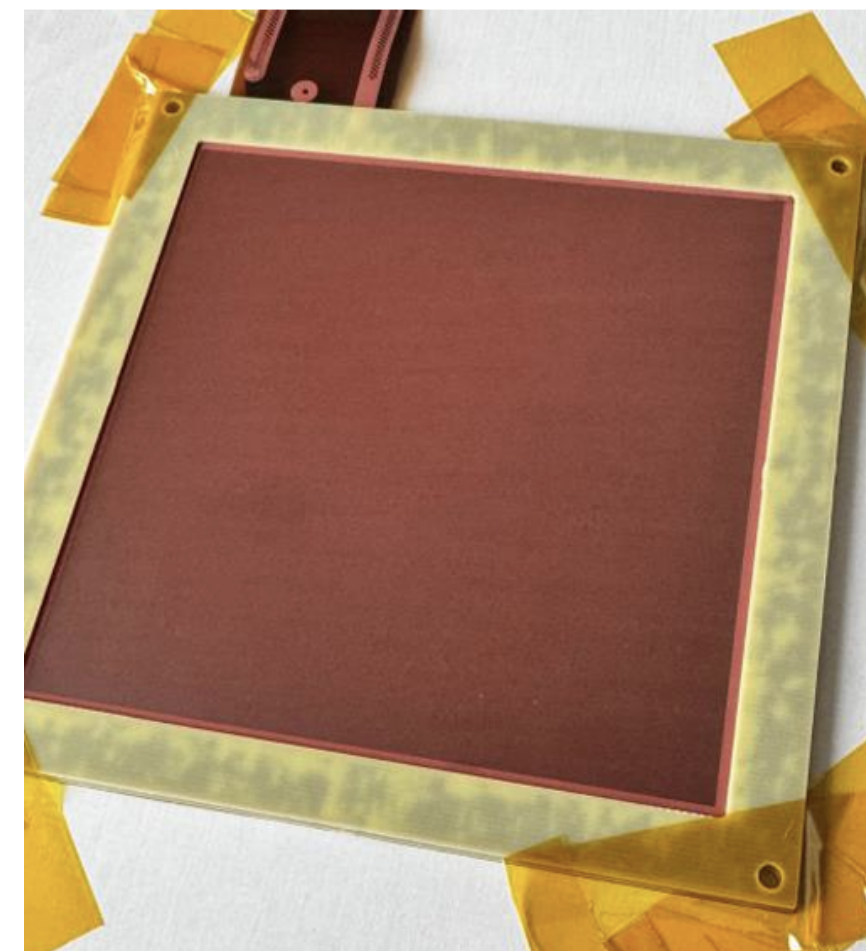


Random **segmentation** should reduce the dead area while keeping the operational stability (tested by CMS-GEM)

Oxidised GEM avoiding reflection of large light emission on the PMMA window as observed in LIME



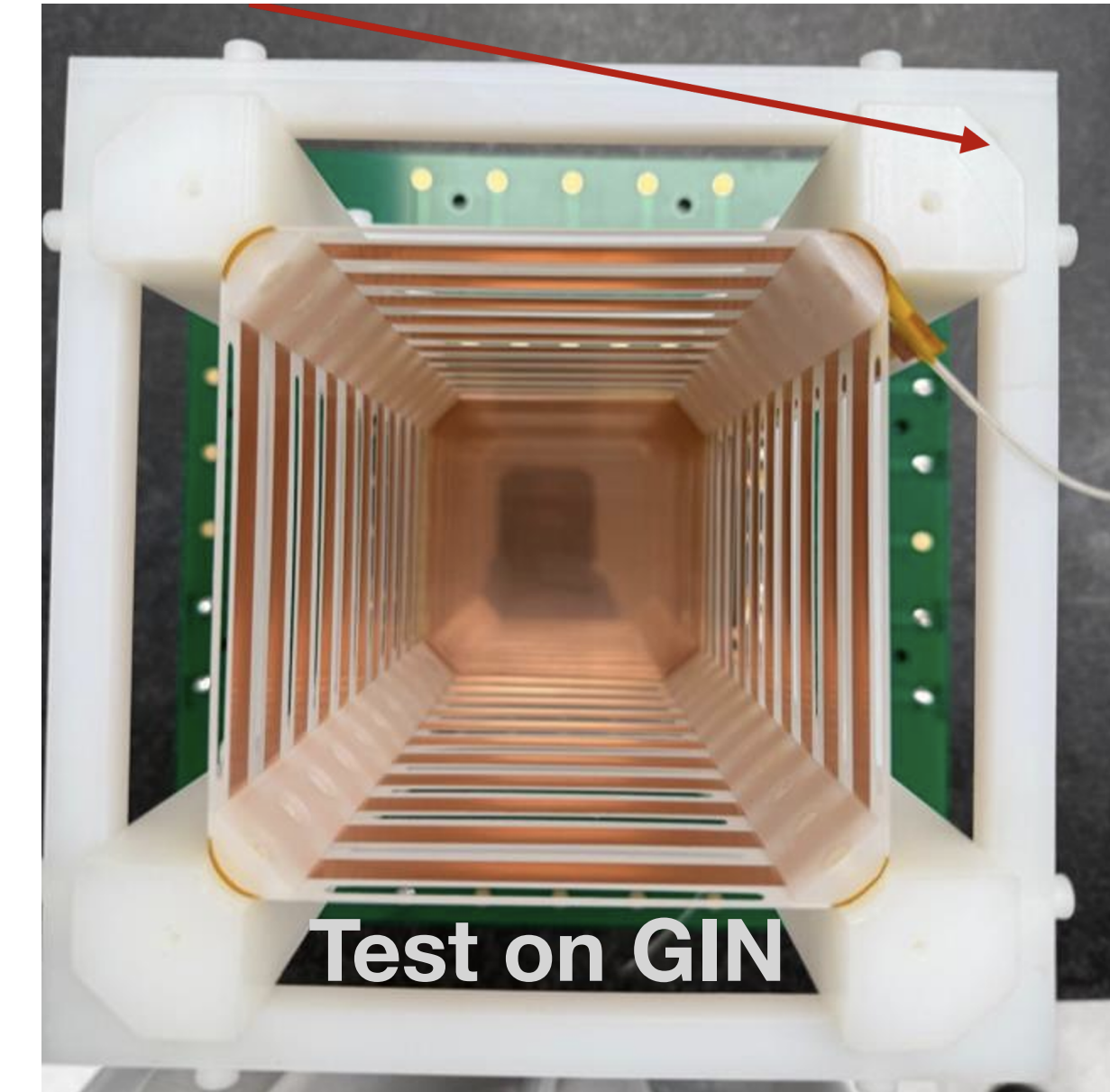
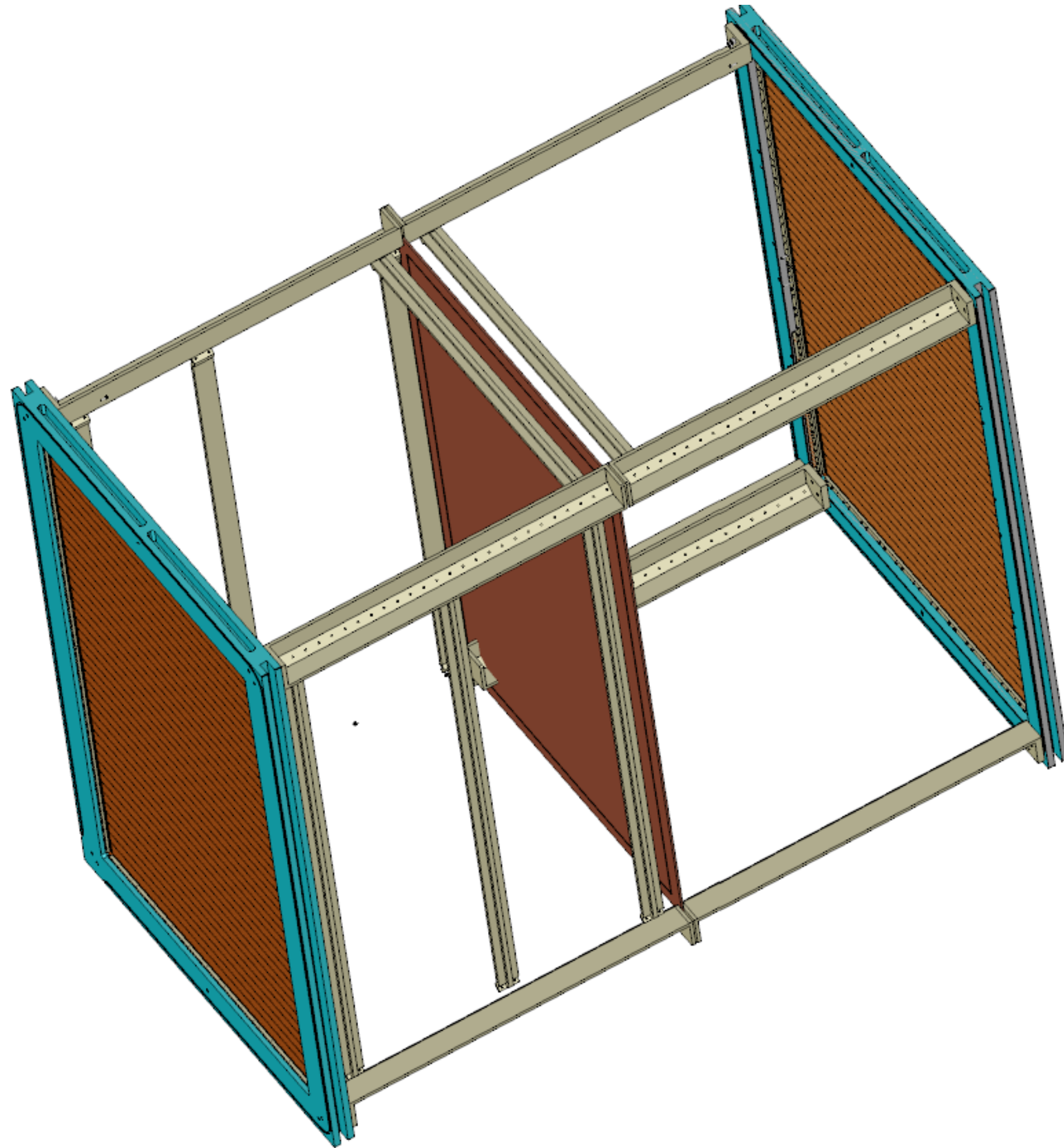
Theory and measurement agree



Done!

Studies and developments **funded** by CSN2 in past years

Component Validation - Field Cage



Field Cage Structure in Nylon66

- Field rings made by copper strips on Kapton (PET as backup)
- Resistors soldered on one side

The cathode will be a Kapton foil copper clad on both sides

- Backup solution, full copper plate

Done!

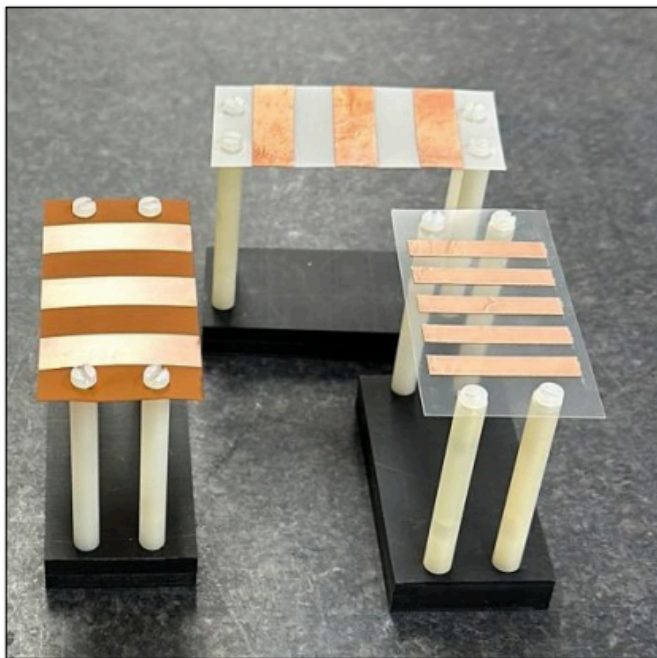
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Component Validation - Field Cage



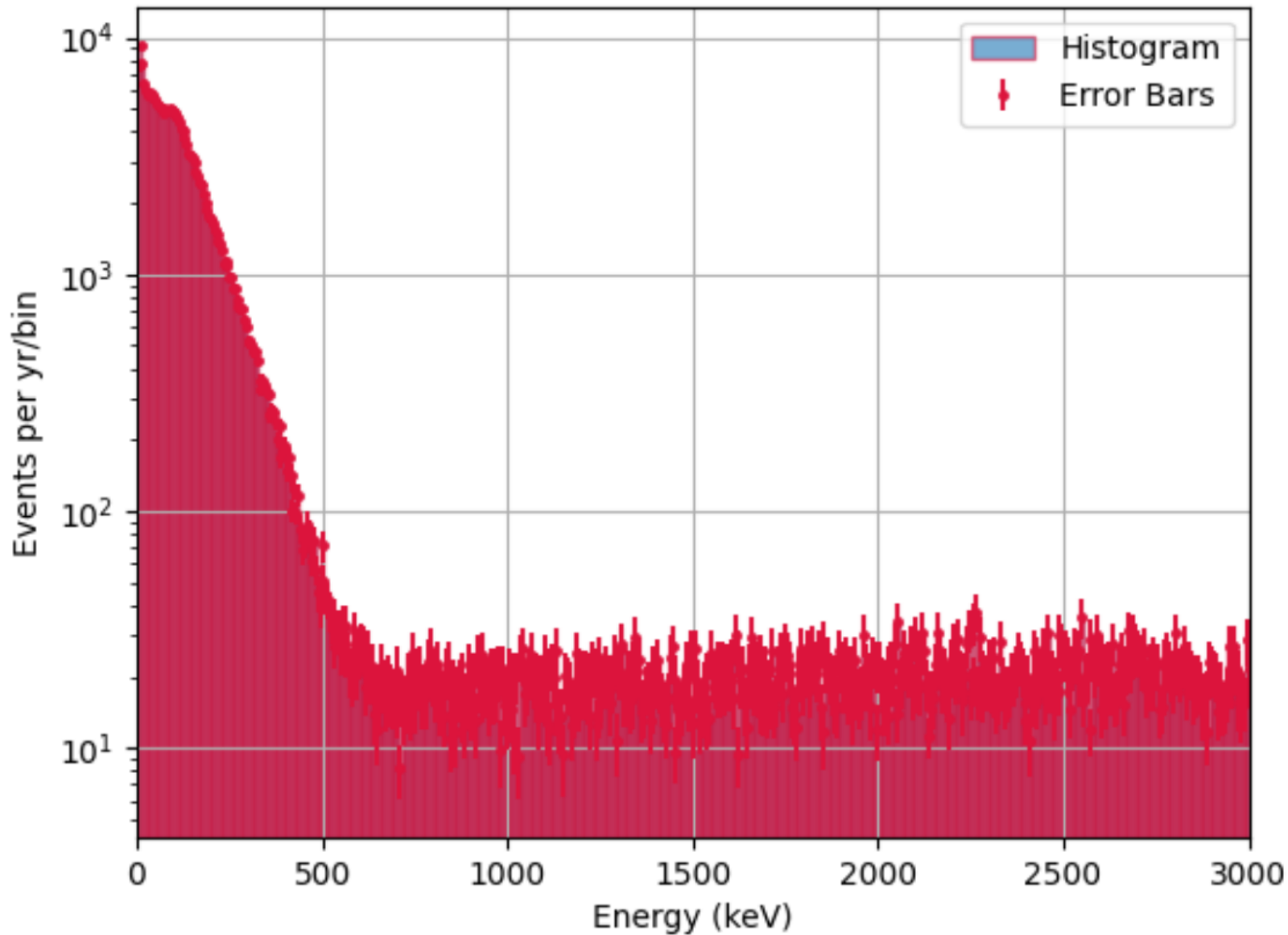
Field Cage Foils

- 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



Donatella Tozzi - Cygno CM 2024

2



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 (1-20 keV):

- $(1.56 \pm 0.01) \cdot 10^5$ evt/year;
- $(1.20 \pm 0.08) \cdot 10^3$ NR evt/year;

Done!

Component Validation - Copper Shield

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		

⁵⁸Co has an half life of 70 days
⁵⁴Mn 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**

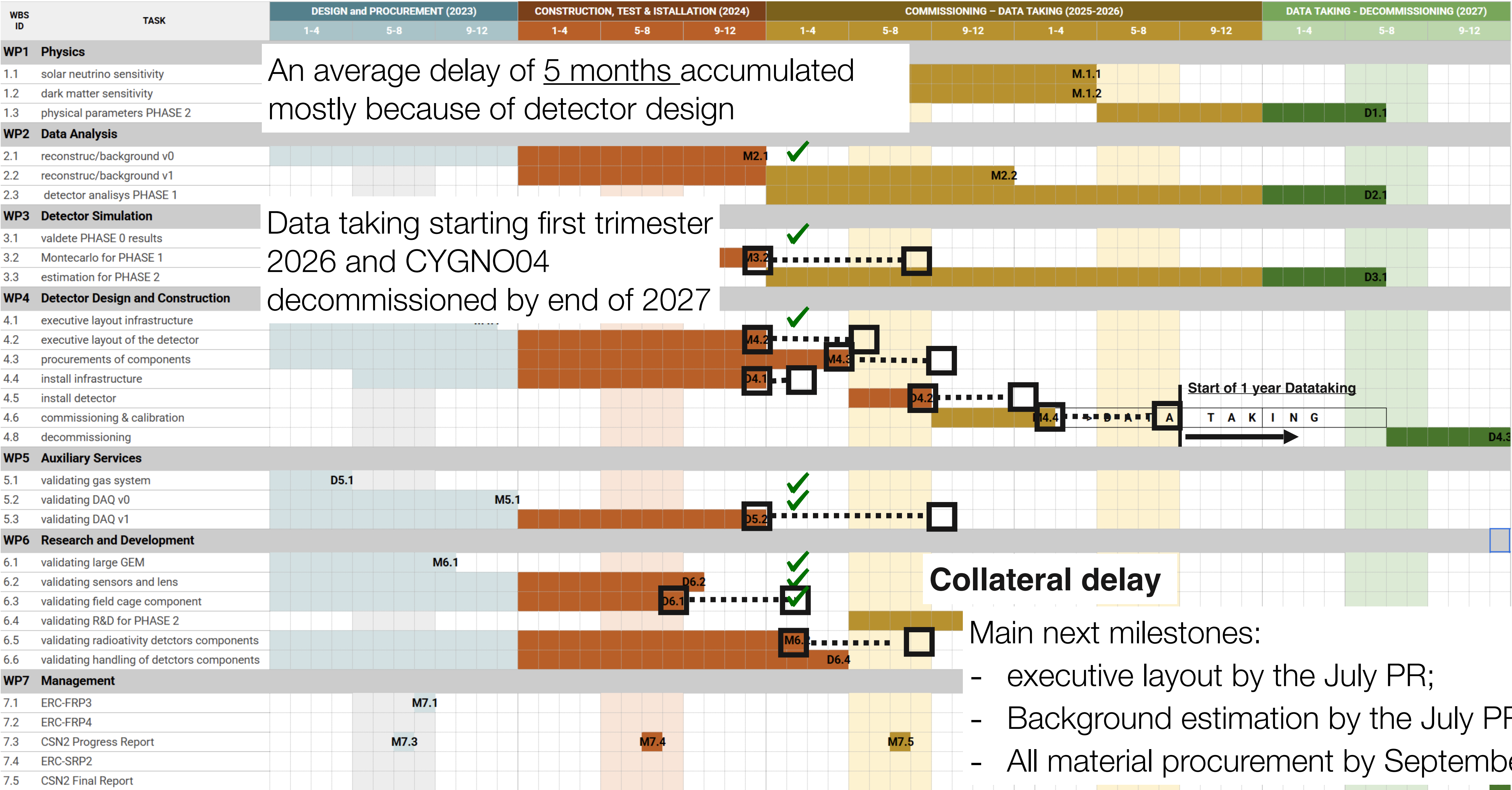
In light of the updated results, the most viable option is still **4 cm clean copper + 6 cm OPERA**

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

Field Cage and **GEM** foils are now on queue for the ICPMS measurements

PROJECT MANAGEMENT AND FINANCIAL STATUS

CYGNO04 GANTT Up to date



TDR CYGNO financial plan and CSN2 proposal



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

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**)

Financial profile for ERC and INFN
from the up to date

Year	INITIUM/ERC	CYGNO/INFN
2019	20	54
2020	201	44
2021	71	96
2022	40	96
2023	164	93.5
2024	359	91.5
2025	276	145
2026	0	80
2027	0	80
Tot 23-27	799	490
Tot	1131	780

- In particular **305 k€** foreseen by INFN in 25-27;
- A total of **1131 k€** are expected to being funded by ERC for the quinquennium 2023-2027 (**1068 k€** foreseen in the **TDR**)

CYGNO04 Economic sustainability



Currently, from the ERC fundings, to cover the core costs of CYGNO04, there are a total of **300 k€** available at **INFN** and **GSSI**

Part of the equipment is being used and validated on LIME:

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

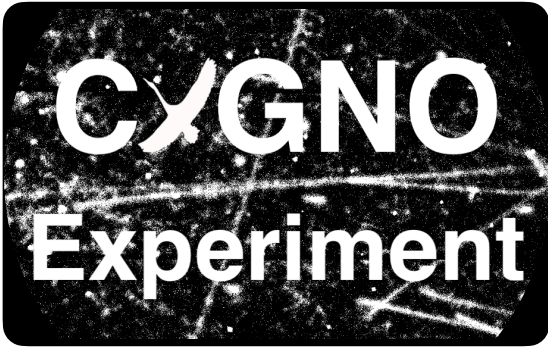
According to the latest quotations received, the **other costs** expected for the **construction** of CYGNO04 is of **276 k€**, therefore an expense that can **be fully covered with ERC funds**.

Deadline for finalizing purchases: **August 2025**

The **total value** of **CYGNO04** is of about **940 k€**.

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	Krypton-Rubidium	6	1	6	0	1	6	8
	55-Fe system	2	1	2	0	1	2	
SHIELDING	4 ton Copper Elsasser	176	1	176	1	0	0	165
	copper precision machining	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	
GAS SYSTEM	polietilene	20	1	20	0	1	20	0
	gas system	85	1	85	1	0	0	
HV SYSTEM	filters	1	8	8	8	0	0	0
	GEM-HV	5	1	5	1	0	0	
	PMT-HV	3	2	6	2	0	0	
DAQ & SLOW CONTROLS	Cathode HV	5	1	5	1	0	0	0
	modules	45.5	1	45.5	1	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		941.5				276	276	

Papers in last year



1 Secondary scintillation yield from GEM electron
2 avalanches in He-CF4 and He-CF4+isobutane for
3 CYGNO – Directional Dark Matter Search with an
4 optical TPC

5 F.D. Amaro,^a E. Baracchini,^{d,e} S. Bianco,^d C. Capocchia,^d M.
6 Caponero,^{d,e} D.S. Cardoso,¹⁰ G. Cavoto,^{g,h} A. Cortez,^{b,c} L.A. Costa,¹ E. Dané,^d G.
7 Dho,^{b,c} F. Di Giambattista,^{d,e} E. Di Marco,^h G. D'Imperio,¹¹ P. Lima
8 Júnior,^e C. Maccarrone,^d R.D.P. Mano,¹ G. Mazzitelli,^d A.G. McIlroy,¹² C.M.B.
9 Montenegro,¹ I.F. Pains,¹ E. Paoletti,⁶ L. Passamonti,⁶ S. Pelosi,⁷ F.
10 Piacentini,^{g,h} D. Piccolo,^d D. Pierluigi,^f F. Renga,⁷ R.J.d.C. Roque,^{a,2} F. Rosatelli,^d A. Russo,¹³
11 S. Tesauro,^d N.J.C. Spooner,^k R. Tesaro,^d S. Tomassini,⁶ S. Torelli,^{4,5} and D. Tozzi,^{7,8}
12
13
14 ^aLIBPhys, Department of Physics, University of Coimbra,
15 3004-516 Coimbra; Portugal
16 ^bGran Sasso Science Institute

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1 PREPARED FOR SUBMISSION TO JINST

2 Charge Amplification in Low Pressure CF4/SF6:He
3 Mixtures with a Multi-Mesh ThGEM for Directional Dark
4 Matter Searches



5 Baracchini,^{4,5} L. Benussi,⁶ S. Bianco,^d C. Capocchia,^d M.
6 Caponero,^{d,e} D.S. Cardoso,¹⁰ G. Cavoto,^{g,h} A. Cortez,^{b,c} L.A. Costa,¹ E. Dané,^d G.
7 Dho,^{b,c} F. Di Giambattista,^{d,e} E. Di Marco,^h G. D'Imperio,¹¹ P. Lima
8 Júnior,^e C. Maccarrone,^d R.D.P. Mano,¹ G. Mazzitelli,^d A.G. McIlroy,¹² C.M.B.
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12
13
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Modeling the detector response of the CYGNO optical
readout TPC

F.D. Amaro,^a R. Antonietti,^{b,c} E. Baracchini,^{d,e} S. Bianco,^d C. Capocchia,^d M. Caponero,^{f,i} D.S. Cardoso,¹⁰ G. Cavoto,^{g,h} A. Cortez,^{b,c} L.A. Costa,¹ E. Dané,^d G. Dho,^{d,e} F. Di Giambattista,^{d,e} E. Di Marco,^h G. D'Imperio,¹¹ P. Lima Júnior,^e C. Maccarrone,^d R.D.P. Mano,¹ G. Mazzitelli,^d A.G. McIlroy,¹² C.M.B. Montenegro,¹ I.F. Pains,¹ E. Paoletti,⁶ L. Passamonti,⁶ S. Pelosi,⁷ F. Petrucci,^{b,c} S. Piacentini,^{g,h} D. Piccolo,^d D. Pierluigi,^f F. Renga,⁷ R.J.d.C. Roque,^{a,2} F. Rosatelli,^d A. Russo,¹³ S. Tesauro,^d N.J.C. Spooner,^k R. Tesaro,^d S. Tomassini,⁶ S. Torelli,^{4,5} and D. Tozzi,^{7,8}
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Under internal review



Enhancing the light yield of He:CF4 based gaseous
detector

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

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He-CF4-CH4 ternary mixtures as target gas for the CYGNO
directional dark matter experiment

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Abstract

The CYGNO collaboration is developing a high-resolution optical Time Projection Chamber for directional dark matter search and neutrino spectroscopy, to be deployed at LNGS. He-40% CF4 is being used as target gas, at atmospheric pressure, and a triple-GEM cascade is being used for readout. The addition of methane to the gas mixture, being the scintillation produced in the GEM cascade, is being studied. High sensitivity to interactions in the few keV range is required for event tracking and particle identification are enabled with this solution. The addition of 3 to 10 percent of methane to He-40%CF4 and demonstrate methane inclusion contributes to both the electrical stability of the TPC and to higher scintillation output from the GEM avalanches. In spite of the scintillation being quenched by the addition of methane increases the maximum voltage that can be applied before the onset of discharges, eventually resulting in higher scintillation yield. The visible component of the gas scintillation shows that isobutane emits more photons emitted by He-CF4. The maximum voltage that could be applied to be independent from the methane concentration in the scintillation gas. A hydrogen-based gas provides CYGNO with an even lighter target, reducing the dark matter detection threshold, in longer track lengths of light nuclear recoils and, thus, in a clearer direction discrimination.

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