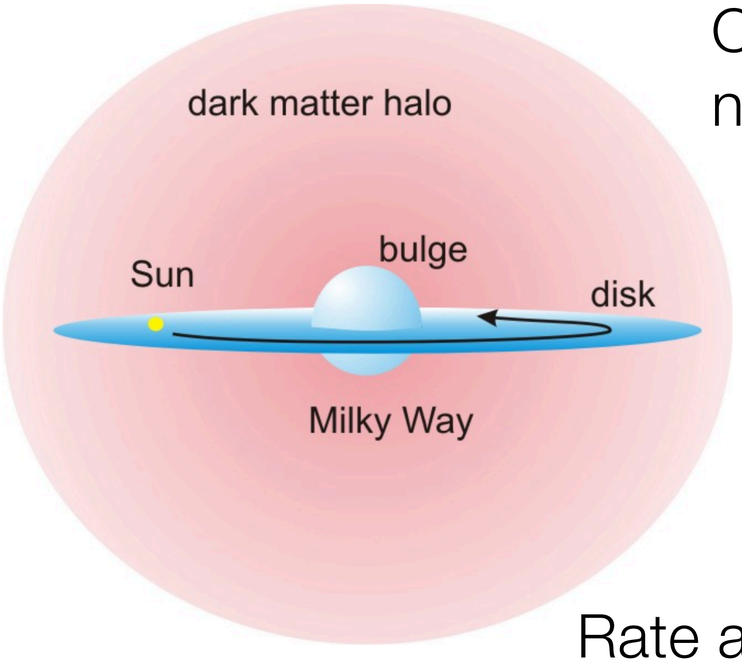
The CYGNO Experiment

F. D. Amaro, R. Antonietti, E. Baracchini, L. Benussi, S. Bianco, C. Capoccia, M. Caponero, G. Cavoto, A. Cortez, R. J. de Cruz Roque, I. A. Costa, E. Dané, E. Di Marco, G. D'Imperio, G. Dho, F. Di Giambattista, R. R. M. Gregorio, F. Iacoangeli, H. P. Lima Júnior, G. Maccarrone, R. D. P. Mano, G. Mazzitelli, A. G. Mc Lean, A. Messina, M. L. Migliorini, C.M.B. Monteiro, R. A. Nóbrega, A. Orlandi, I. F. Pains, E. Paoletti, L. Passamonti, F. Petrucci, S. Pelosi, S. Piacentini, D. Piccolo, D. Pierluigi, D. Pinci, A. Prajapati, F. Renga, C. Riggio, F. Rosatelli, A. Russo, J.M.F. dos Santos, G. Saviano, A. da Silva Lopes Júnior, N. Spooner, R. Tesauro, S. Tomassini, S. Torelli, D Tozzi and special guest A. Rodano

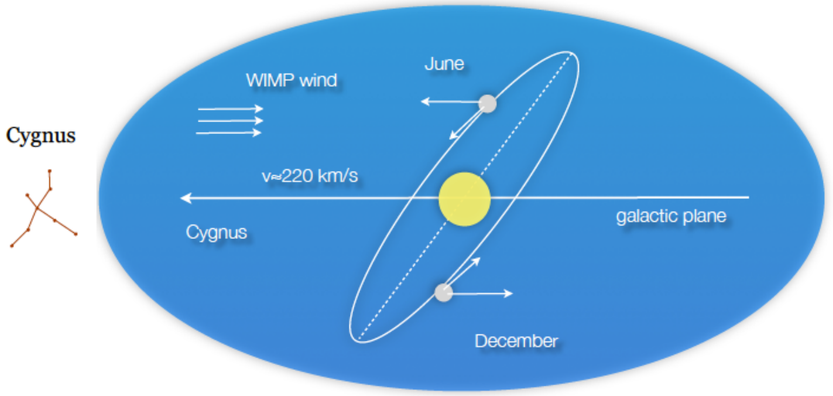
Dark Matter and WIMPs

- One of possible constituents of **Dark Matter** are the **Weakly Interacting Massive Particles**: neutral particles with a very low interaction probability with ordinary matter;



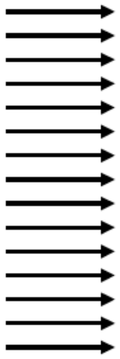
Our Milky Way, is surrounded by an approximately spherical not luminous halo of WIMPs.

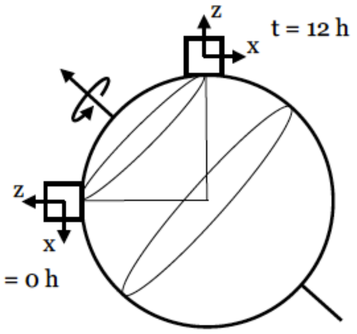
The Sun and the planets move through this halo at 220 km/s preceded by the CYGNUS



$$v(t)_{DM} = v_{sun} + v_{orb}\ cos\gamma\ cos(\omega(t - t_0))$$

Rate and direction modulation: **strong signature**

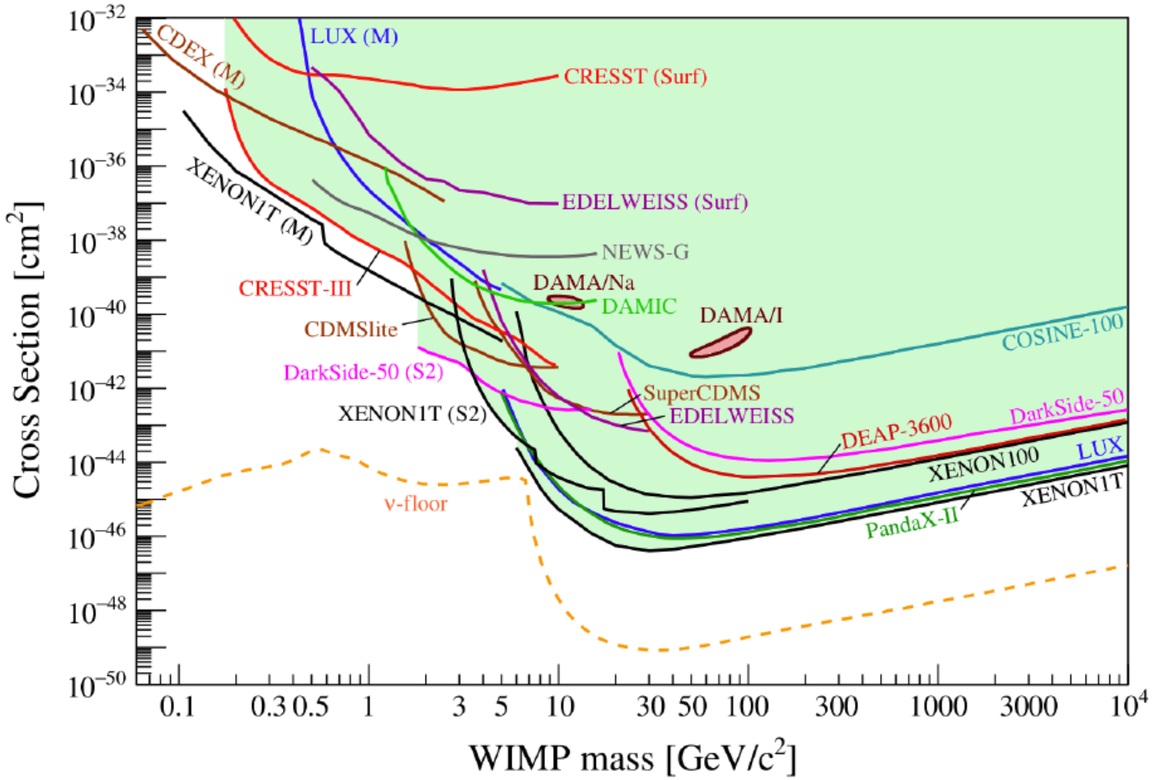




A **directional** detector will be crucial to **confirm** any future evidence of DM and to **determine** its **origin**

WIMP Masses

- Large regions of **high masses** spectrum already explored **without** any confirmed **evidence of WIMP**;



- Future focus on **masses below 10 GeV**;

Element	Max E transferred by a 1 GeV WIMP	Min WIMP mass with 1 keV threshold
H	2.00 keV	0.5 GeV
He	1.30 keV	0.9 GeV
C	0.57 keV	1.4 GeV
F	0.38 keV	1.7 GeV
Na	0.32 keV	1.8 GeV
Si	0.27 keV	2.0 GeV
Ar	0.20 keV	2.4 GeV
Xe	0.06 keV	4.2 GeV

- To explore the GeV mass range, **best candidates** are **He** and **H**

The CYGNO idea

The CYGNO collaboration is developing and optimising a new technique for the detailed study of Low Energy Rare Events;

Gaseous TPC

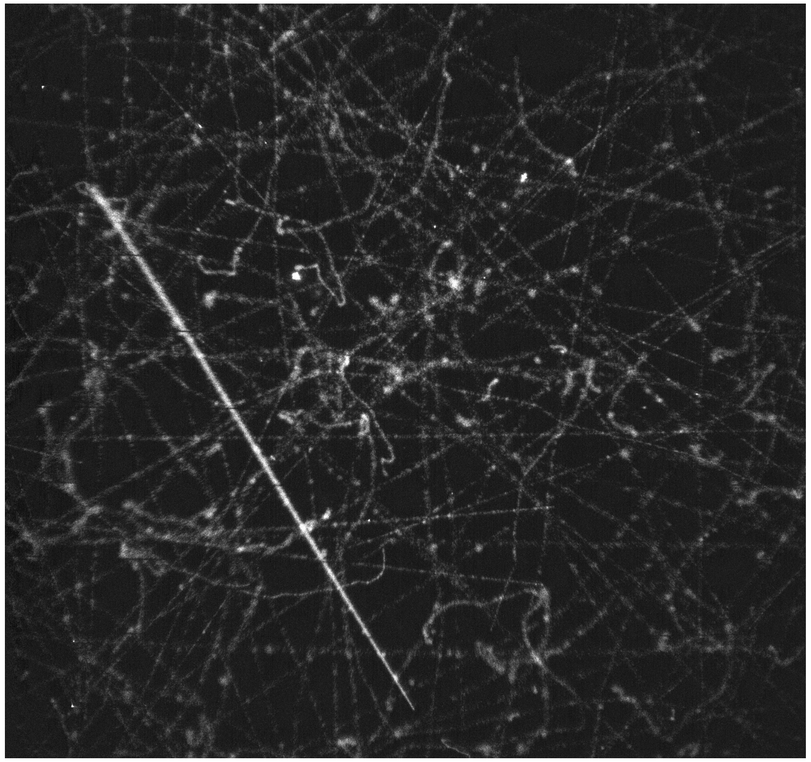
- Released energy, dE/dx profile, track position and direction, hundreds eV threshold;

Triple-GEM amplification

- Large surface easy instrumentation, high reliability;

Optical readout

- high granularities together with very low noise and high sensitivity;
- optical coupling allows to keep sensor out of the sensitive volume;



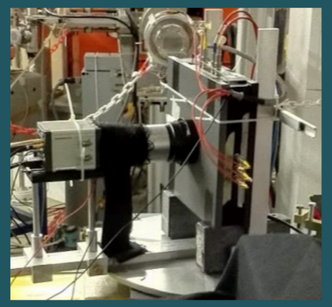
The CYGNO project

We are here

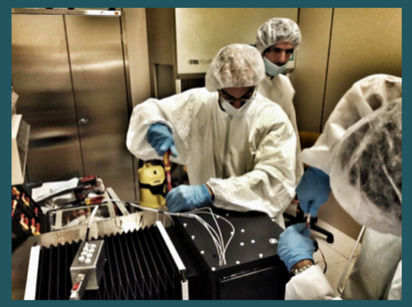
PHASE 0: R&D and prototypes

2015/16 ROMA1 → 2017/18 LNF → 2019/21 LNF/LNGS

ORANGE → LEMON → LIME



- 1 cm drift



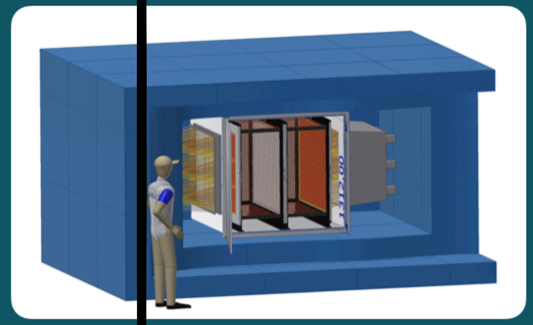
- 3D printing
- 20 cm drift

- 50 cm drift
- underground tests
- shielding

PHASE 1: 1 m³ Demonstrator

2022/25 LNF/LNGS

CYGNO_01

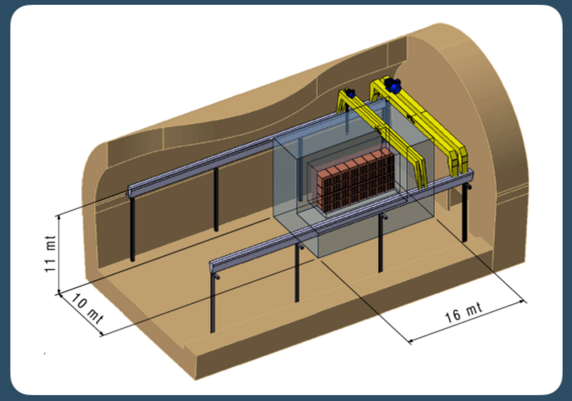


- background
- materials test, gas purification
- scalability

PHASE 2: 30 m³ Experiment

2026.. LNGS

CYGNO_30



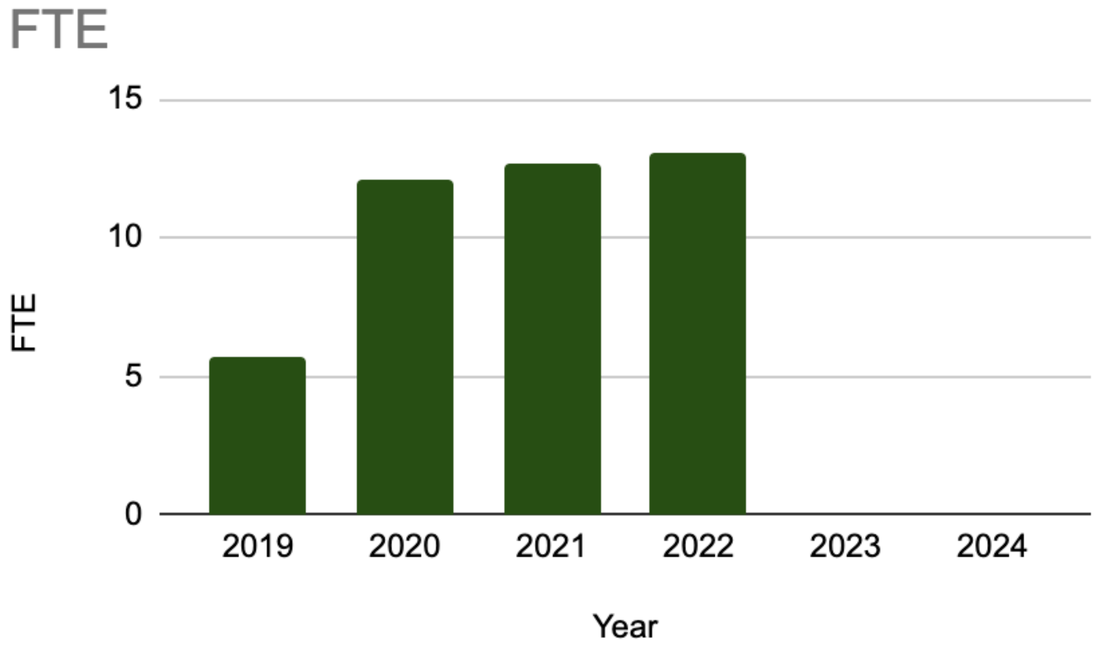
- Physics research

CYGNUS_RD - CSN5 — **NITEC**

CYGNO - CSN2 — **INITIUM**

Project FTE and International collaboration

This project, started by a few people in 2016, has now more than **50 collaborators**, from **8 Institutions in 4 Countries**



INFN FTE (CYGNO+INITIUM) since the project start

Institution	Total FTE
INFN - RM1	2.7
INFN - LNF	4.2
INFN - LNGS	5.4
INFN - RM3	0.4
University of Sheffield	0.45
Universidade de Coimbra	2.5
Universidade Federal de juiz de Fora	2
Centro Brasileiro de Pesquisas Físicas	0.6
Tot	**18.25**

FTE (CYGNO+INITIUM) distribution in the different groups in 2022.

Project WP and TASKS

Physics		Analysis		Simulation		Detector		Services		Management		R&D	
Elisabetta Baracchini		Emanuele Di Marco		Giulia d'Imperio		Giovanni Mazzitelli		Francesco Renga		Elisabetta Baracchini Giovanni Mazzitelli Davide Pinci		Davide Pinci	
Task	**Coordinator**	**Task**	**Coordinator**	**Task**	**Coordinator**	**Task**	**Coordinator**	**Task**	**Coordinator**	**Task**	**Coordinator**	**Task**	**Coordinator**
Dark Matter	G. Dho	Reconstruction Development	E. di Marco	Prototypes with GEANT	G. d'Imperio	Design	S. Tomassini	DAQ	A. Messina	INFN Responsible	D. Pinci	ECO-GAS studies	D. Piccolo
Solar Neutrinos	S. Torelli	Online-Offline software integration	G. Mazzitelli	Nuclear interactions with SRIM	F. di Giambattista	Integration	G. Mazzitelli	Trigger	H. Lima	Technical Coordination	G. Mazzitelli	Negative Ions	E. Baracchini
Super Nova DM	E. Baracchini	Data Analysis	E. di Marco	Gas properties with Garfield	D. Pinci	CMOS sensor	R. Nobrega	HV	F. Renga	Pubblications and Conferences	G. Maccarrone	Gas Mixtures	F. Amaro
Sensitivities and discovery potential	G. Dho	Software Maintenance	E. di Marco	Sensor performance	R. Nobrega	GEM	L. Benussi	Gas System and Slow Control	F. Renga	International Collaborations	E. Baracchini	Field Cage	G. Mazzitelli
Migdal	A. Messina	Infrastructures	G. Mazzitelli	Integration	F. Petrucci	Performance Studies	D. Pinci	Gas Purification	R. Gregorio	Safety and Environment	G. Mazzitelli	Gas Luminescence	D. Pinci
LNGS Neutron Flux	F. di Giambattista			Infrastructures	G. Mazzitelli	Light Sensors	F. Iacoangeli	Calibration	G. Cavoto	Call Applications	E. Baracchini	Alternative MPGD	E. Baracchini
								Storage and Networks	G. Mazzitelli				

Activities

Mon 20/12

14:00	**Welcome & Introduction**	*Prof. Elisabetta Baracchini*	
	Rectorate-Building-Auditorium, GSSI		14:00 - 14:10
	Status and Plans of the CYGNO		
	Rectorate-Building-Auditorium, GSSI		14:10 - 14:30
	it could work! (cit.)		
	Rectorate-Building-Auditorium, GSSI		14:30 - 14:50
	Discussion		
	Rectorate-Building-Auditorium, GSSI		14:50 - 15:00
15:00	**LIME: calibration with 55Fe source**	*Davide Pinci*	
	Rectorate-Building-Auditorium, GSSI		15:00 - 15:20
	Studies on LIME performance stabilities		
	Rectorate-Building-Auditorium, GSSI		15:20 - 15:40
	LIME clustering and energy response		
	Rectorate-Building-Auditorium, GSSI		15:40 - 16:00
16:00	**Electroluminescence and gas studies with MANGO**		
	Rectorate-Building-Auditorium, GSSI		16:00 - 16:20
	Further studies on He-CF4-isobutane mixtures for the CYGNO TPC and studies of the P/T detector response	*Mrs Rita J C Roque et al.*	
	INITIUM: an Innovative Negative Ion Time projection chamber for Underground Dark Matter searches	*Prof. Elisabetta Baracchini*	
17:00	**Sensor Dark Noise Studies**		
	Rectorate-Building-Auditorium, GSSI		17:00 - 17:20
	Coffe break		
	Rectorate-Building-Auditorium, GSSI		17:20 - 17:40
	Gas system status		
	Rectorate-Building-Auditorium, GSSI		17:40 - 18:00
18:00	**Molecular sieve-based gas recycling system with radon reduction for rare-event gaseous detectors**		
	Rectorate-Building-Auditorium, GSSI		18:00 - 18:20
	Status of the data acquisition and trigger system		
	Rectorate-Building-Auditorium, GSSI		18:20 - 18:40
	Discussion		
	Rectorate-Building-Auditorium, GSSI		18:40 - 19:00
19:00			

Tue 21/12

14:00	**Direct detection for CYGNO**	*Giovanni Grilli di Cortona*	
	Rectorate-Building-Auditorium, GSSI		14:00 - 14:20
	Detector simulation and saturation		
	Rectorate-Building-Auditorium, GSSI		14:20 - 14:40
	Directionality of low energy electron recoil		
	Rectorate-Building-Auditorium, GSSI		14:40 - 15:00
15:00	**Electron and Nuclear Recoil Discrimination Studies**		
	Rectorate-Building-Auditorium, GSSI		15:00 - 15:20
	Background simulations for CYGNO detector		
	Rectorate-Building-Auditorium, GSSI		15:20 - 15:40
	Background simulation in LIME		
	Rectorate-Building-Auditorium, GSSI		15:40 - 16:00
16:00	**Cygno PubComm Activity**	*Dr Giovanni Maccarrone*	
	Rectorate-Building-Auditorium, GSSI		16:00 - 16:20
	Discussion and Goodbyes		
	Rectorate-Building-Auditorium, GSSI		16:20 - 16:50
17:00	**Coffee break**		
	Rectorate-Building-Auditorium, GSSI		16:50 - 17:20

A lot of activities are ongoing that will (partially) be discussed in this Collaboration Meeting

LIME

- Underground LIME tests will represent the last step of the PHASE_0;
- The idea is to take data (with periodic calibration runs) with different and increasing shield schemes: no shields, 6 cm Cu, 10 cm Cu, 10 cm Cu + 40 cm H_2O;
- This program will allow to characterise the real radioactive background present in the site and then to validate the GEANT4 simulation;
- Moreover, without the H_2O, we can also study the neutron flux in the site as a part of the PRIN “Zero radioactivity in future experiments”;
- Installation and data taking with complete (copper+water) shield will be performed in 2023;

LIME: Activities for 2022

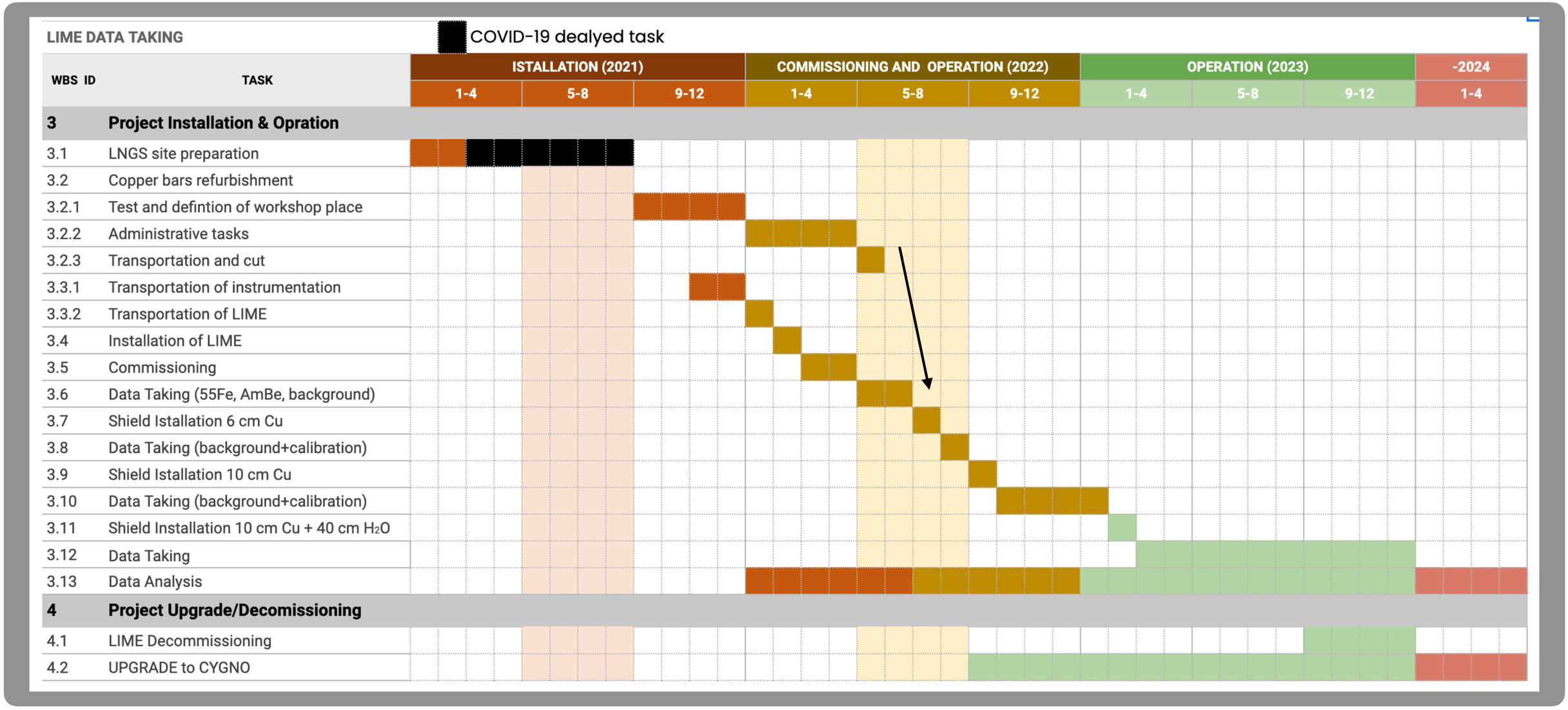
- **LIME** is now expected to start installation underground at the beginning of 2022;
- Installation of detectors and ancillary systems should finish by the end of Feb. 2022;
- Then, commissioning and data taking program is expected to start:
  - **Unshielded**:
    - detector characterisation with ^{55}Fe (we are buying a 7 MBq source) and AmBe;
    - bkg study (10^8 event/months), with periodic calibration with ^{55}Fe;

    } **2 Months**
  - **6 cm Cu shield**:
    - bkg study (10^6 event/months), with periodic calibration with ^{55}Fe;

    } **1 Month**
  - **10 cm Cu shield**:
    - bkg study (10^5 event/months), with periodic calibration with ^{55}Fe;
    - In this configuration we plan to study the lab neutron flux. About 100 NR are expected in the range 20-100 keV in 4 months.

    } **4 Months**

LIME: Activities for 2022



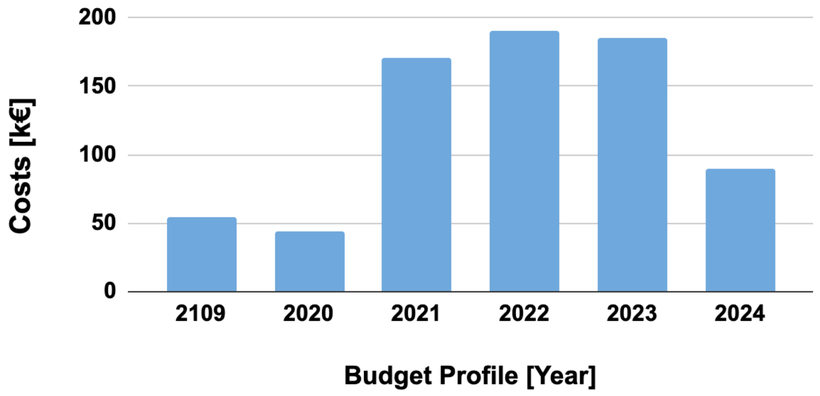
Final demonstrator

- A discussion with LNGS management and director has already started. We have sent a first version of required documents (CDR, application for a site) and we are waiting for following steps;
- Different designs of **final demonstrator** with a sensitive volume of the order of 1 cubic meter were prepared;
- They will be finalised in a **TDR** as soon as the space available at LNGS will be decided to be **submitted in September 2022**;
- In the meanwhile we are working on:
  - **economic** evaluation of the **detector** and **ancillaries** costs;
  - **internal radioactivity** study and reduction;
  - **Trigger** and **DAQ** based on **custom** and flexible **boards**;
  - **Data** storage and handling;

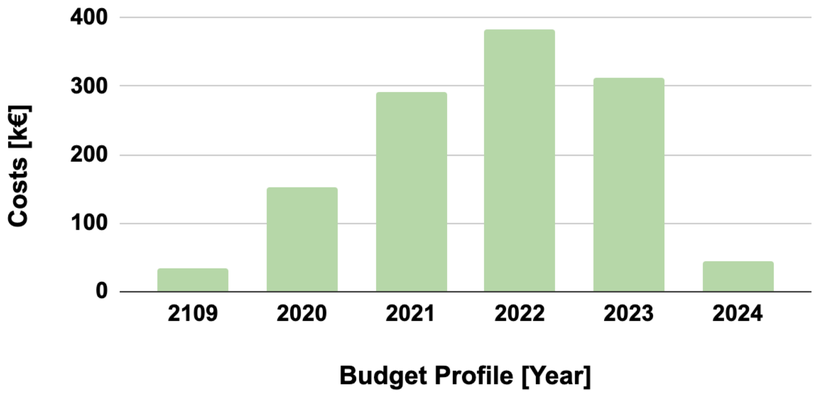
Budget Profile

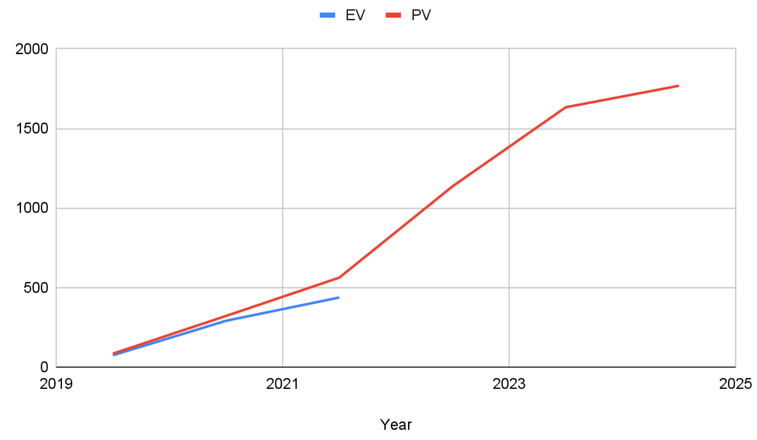
WBS ID	TASK	APPROVAL (2019)			LIME REALISATION (2020)			LIME INSTALLATION and COMMISSIONING (2021)			DESIGN and PROCUREMENT (2022)			CONSTRUCTION (2023)			INSTALLATION and OPERATION			Gran Total		
		CYGNO	INITIUM	Tot19	CYGNO	INITIUM	Tot20	CYGNO	INITIUM	Tot21	CYGNO	INITIUM	Tot22	CYGNO	INITIUM	Tot23	CYGNO	INITIUM	Tot24	CYGNO	INITIUM	Total
1.3.1	Safety & Healt	5		5			0			0	5		5	5		5			0	15	0	15
2.2.1	Vessel			0			0		20	20			0			0			0	0	20	20
2.2.2	GEM			0			0			0		20	20			0			0	0	20	20
2.2.3	FC & Cathode			0			0		12	12		0	0			0			0	0	12	12
2.2.4	Lens			0		5	5			0		36	36			0			0	0	41	41
2.2.5	Camera			0		16	16			0			0		160	160			0	0	176	176
2.2.6	PMT/SiPM	5.5		5.5			0			0		21	21			0			0	5.5	21	26.5
2.2.7	Shielding			0			0		150	150		200	200		77	77			0	0	427	427
2.2.8	CRT			0			0			0			0			0		20	20	0	20	20
2.2.9	DAQ & Storage			0			0			0		50	50		50	50		5	5	0	105	105
2.2.10	Calibration			0			0			0		12	12			0			0	0	12	12
2.2.11	High Voltage System		16	16		16	16		70	70			0			0			0	0	102	102
2.2.12	Gas System	7		7		60	60	30		30			0			0			0	37	60	97
2.2.13	Axiliary Services (Sensors)			0	6		6	8	20	28	0	25	25		5	5			0	14	50	64
2.2.14	Gas Bottles	5.5		5.5	4	5	9	30		30	20		20	20		20	20		20	99.5	5	104.5
2.2.15	Consumables	5		5	6		6	25		25	20		20	20		20	20		20	96	0	96
2.6.1	R&D LIME/MANGO	16.5	5	21.5			0	10		10			0			0			0	26.5	5	31.5
2.7.1	R&D GEM			0			0	5		5	5		5			0			0	10	0	10
2.8.1	R&D Camera			0	4	4	8			0	80		80	80		80			0	164	4	168
2.9.1	R&D Lens			0		10	10	5		5			0			0			0	5	10	15
2.10.1	R&D DAQ		3	3	5	26	31	18		18			0			0			0	23	29	52
3.2.1	Transportation			0	3		3	3		3	10		10	10		10			0	26	0	26
	Total (detector)	**44.5**	**24**	**68.5**	**28**	**142**	**170**	**134**	**272**	**406**	**140**	**364**	**504**	**135**	**292**	**427**	**40**	**25**	**65**	**521.5**	**1119**	**1614.5**
	Travels	9.5	10	19.5	16	10	26	37	20	57	50	20	70	50	20	70	50	20	70	175.5	80	255.5
	Total	**54**	**34**	**88**	**44**	**152**	**196**	**171**	**292**	**463**	**190**	**384**	**574**	**185**	**312**	**497**	**90**	**45**	**135**	**697**	**1199**	**1870**

CYGNO Budget Profile



INITIUM Budget Profile





R&D, Travels, Radioactivity Studies

Demonstrator Core Costs

About 500 k€ spent

Conclusion

We worked quite hard so far, and next years will be crucial for the project.

We have built and characterised a very good prototype, we (almost) setup an underground site, it’s time to exploit the work done and enter the “real experiment phase” (cit. INFN-referees);

Even without forgetting all the work needed for the final demonstrator, we should focus on LIME activities: installation, commissioning, data taking, analyses and publications.

Milestones (agreed with INFN-referees) can be used as lighthouses to keep the course:

- radioactive background characterisation with unshielded LIME underground at LNGS;
- submission of a paper on overground LIME performance at LNF;
- validation of underground MC and data-MC comparison;

Let’s have an interesting navigation with a safe landing.


PULP FICTION
Rita Roque
Cristina Bernardes Monteiro
Fernando Jerace
Daniel Mateo
THANKS!