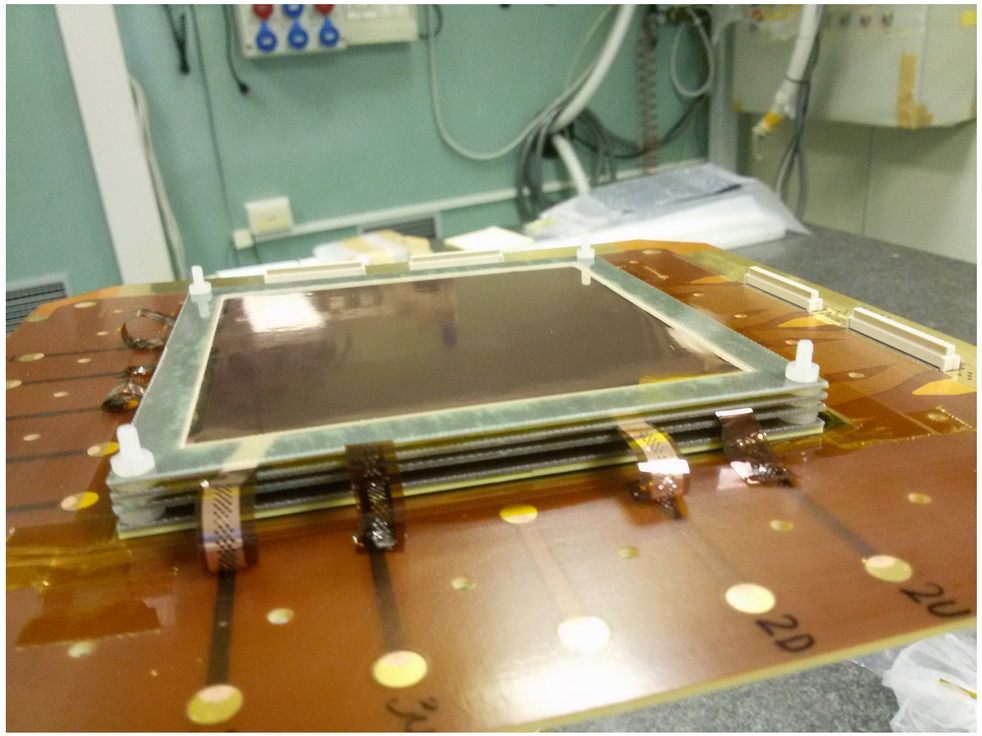
Status of the CYGNO project

2015-2016: The ORANGE age

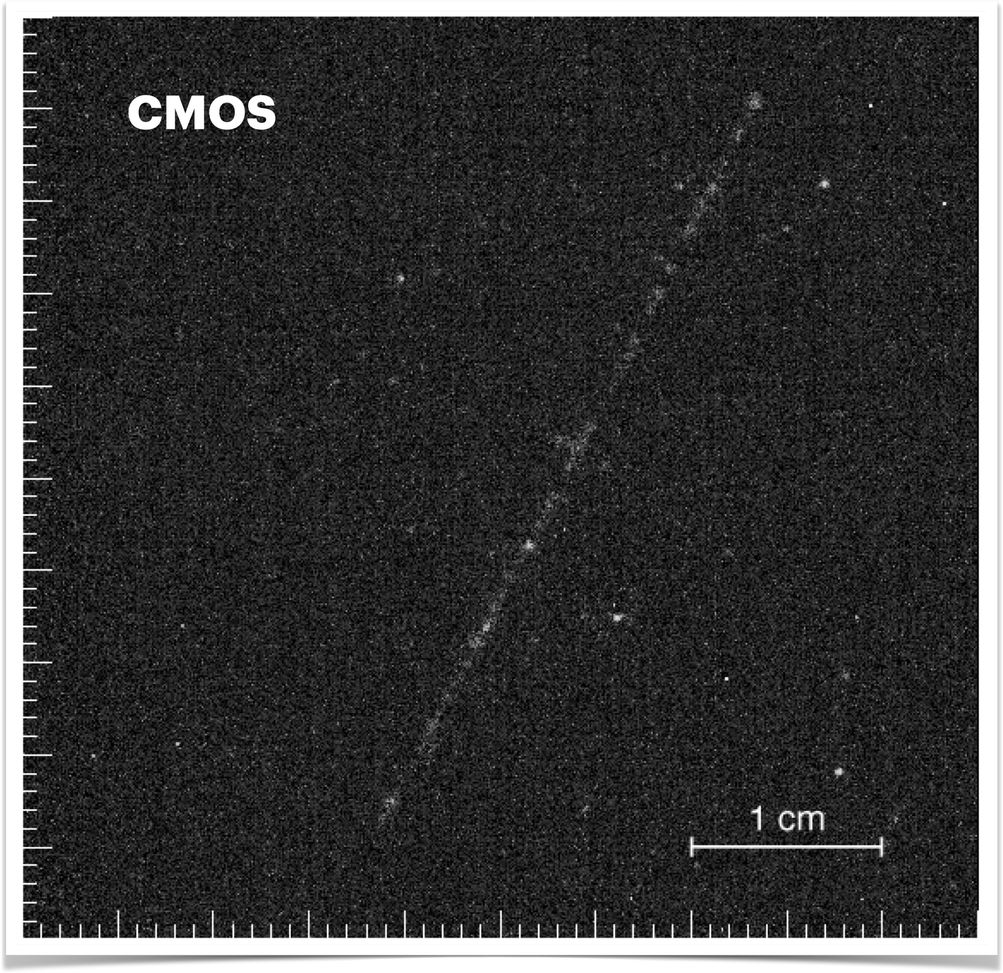


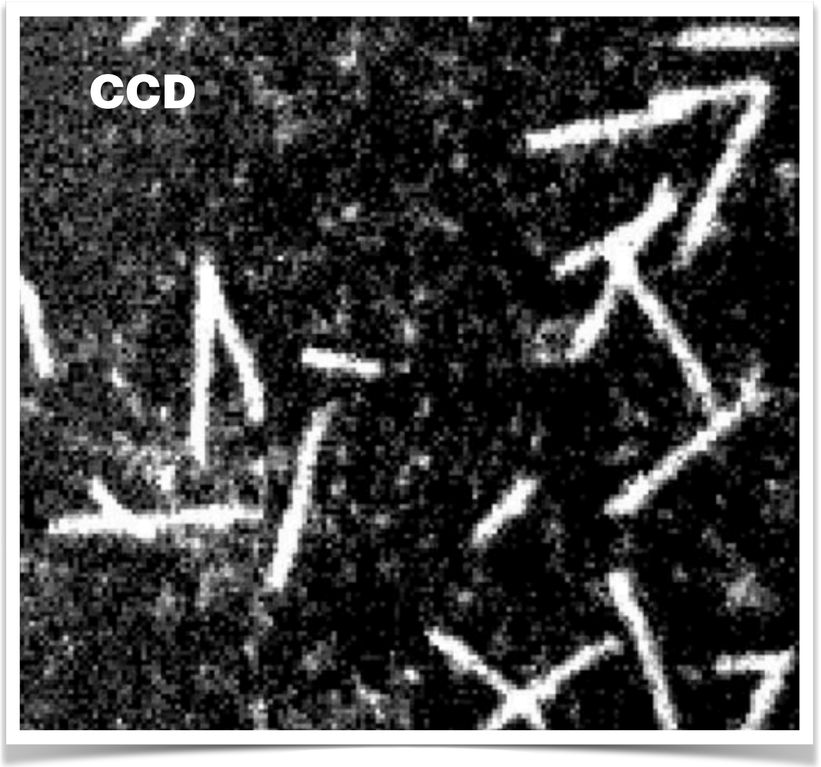
And a quite **rudimentary** set-up

This project, started by few people in **2015** with a **3 mm sensitive gap** detector (ORANGE the 1st)

2015-2016: The ORANGE age

The idea of using **sCMOS Active Pixel** Sensors, providing very **low noise** and **high granularity** and **sensitivity** allowed to obtain very clear **images** of m.i.p.

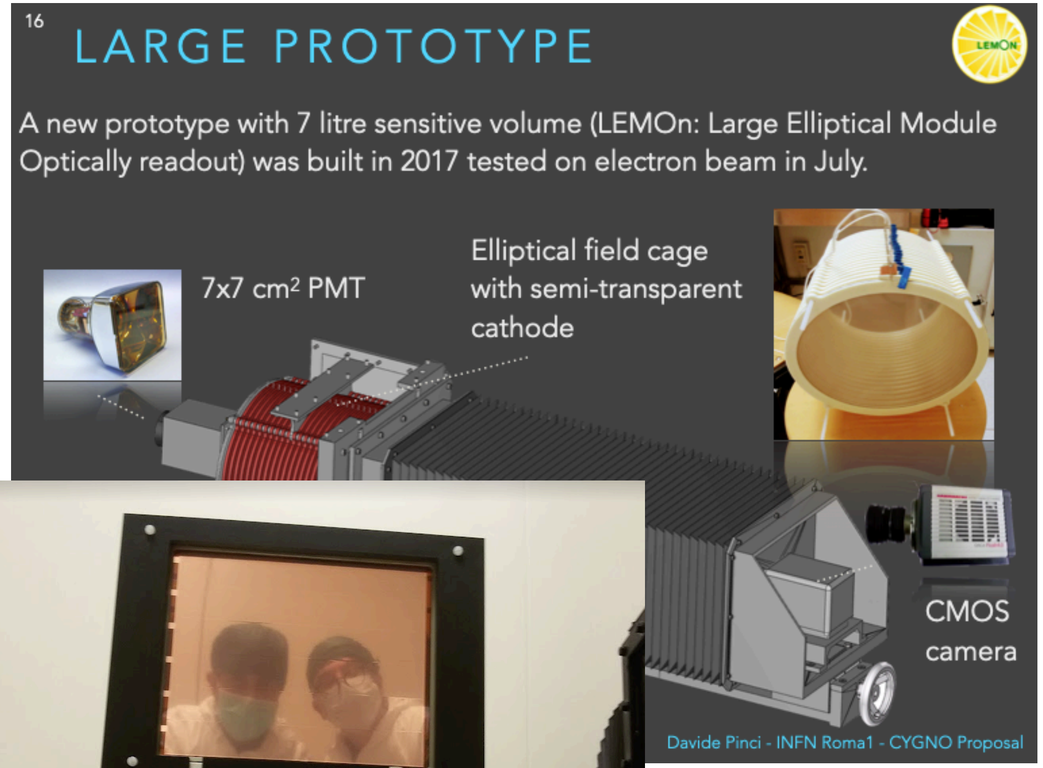


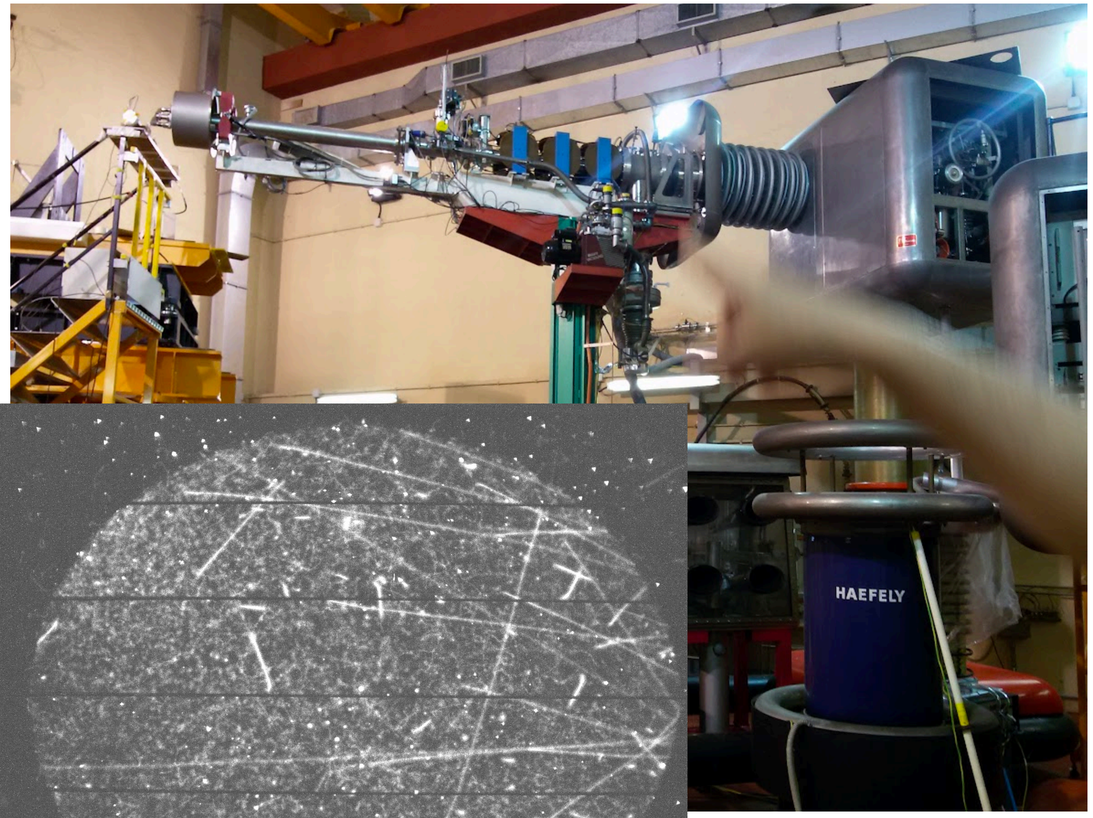


While the **high noise** level of **CCD** sensors used in **previous** attempts only allowed to image **highly ionising particles** (alpha)

2017-2018: The LEMON age

2017-2018: CYGNUS_RD in CSN5.





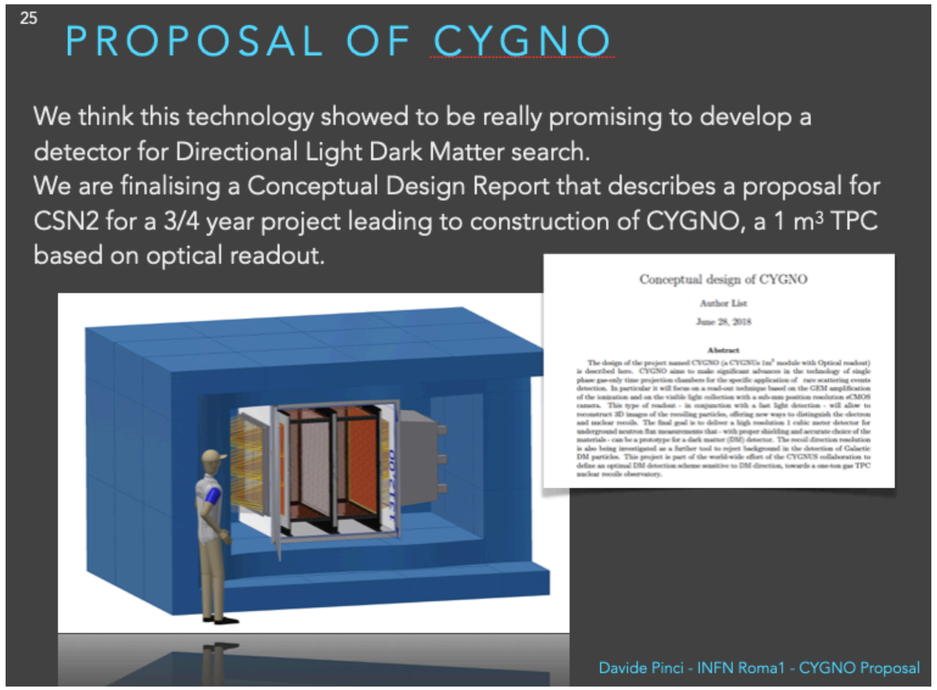
At the Frascati Neutron Gun

Large program of R&D, test beam and data analysis and papers!

2018: The CYGNO proposal

2018: **proposal** to INFN-CSN2 for the realisation of a **1 cubic meter TPC** based on optical readout

Approved for 1 year for the CDR drafting



The **CDR** presented in **2019** and was then the **basis** for the **future ideas** about the **cubic meter demonstrator**

2018: INITIUM!

In the meanwhile in October 2018 **INITIUM** was funded by the **ERC** to study **Negative Ion Drift** in a gaseous TPC with optical readout;

8

UPDATE: INITIUM!

Elisabetta Baracchini (GSSI) won an **ERC Consolidator Grant** with **INITIUM**

European Research Council

The proposal, presented at the beginning of 2018, is based on the experience gained in NITEC and CYGNUS_RD and aims at "the development and operation of the first **1 m³ Negative Ion TPC** (NITPC) with Gas Electron Multipliers (**GEMs**) amplification [in **He/CF_4/SF_6** mixture] and **optical readout** with CMOS-based cameras and PMTs"

IN TIUM

an Innovative Negative Ion TIme projection chamber for Underground Dark Matter searches

Elisabetta Baracchini

Gran Sasso Science Institute

ERC-COG-2018
Proposal number 818744
PE 2 - Fundamental Constituents of Matter

*Dark Matter-like signals (He recoils) in CYGNUS-RD 10 L TPC

9

UPDATE: INITIUM!

Project funded with **2 M€**: **1.1 at GSSI** (host) and **0.9 at INFN**.

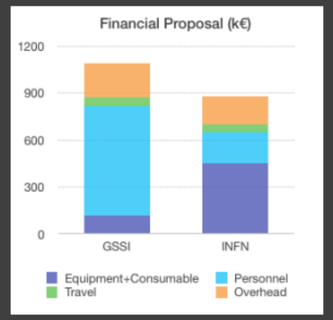
- **900 k€ for personnel**: 600 k€ for PhD or Post-Doc;
- **600 k€ for equipment and consumables**;

Although the different approaches (electron vs ion drift), INITIUM will largely be **synergic** with CYGNO-PHASE_1;

The two projects will have several **common items**:

- a low radioactivity vessel;
- GEM for the charge multiplication;
- optical sensors (CMOS and SiPM/PMT);
- services for gas, high-voltage, DAQ;

whose **costs can be covered by the ERC financing**.



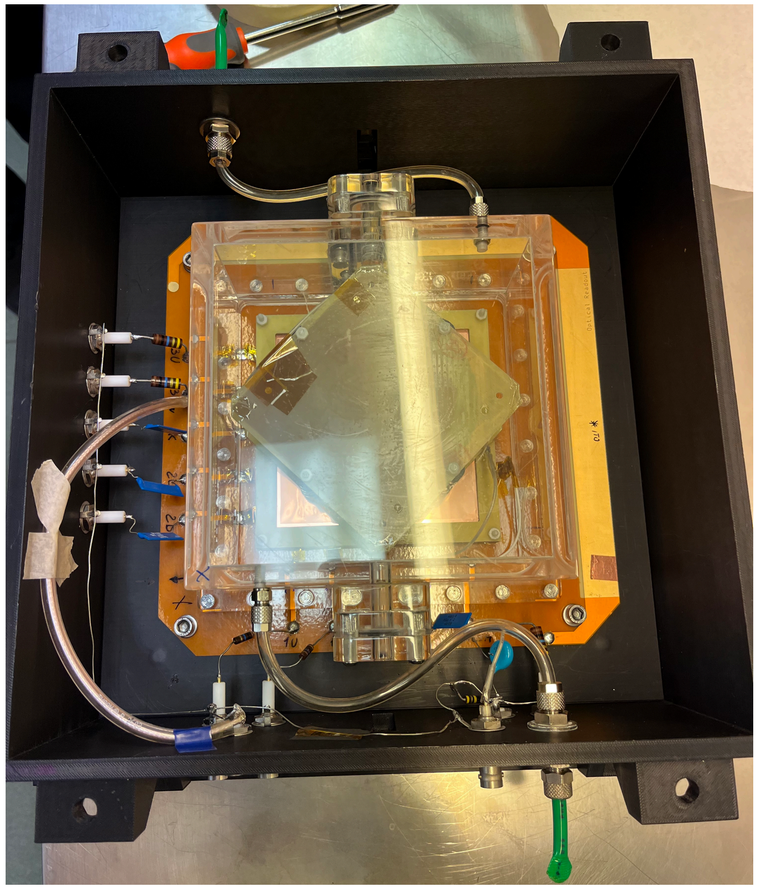
INITIUM will hire new people with a **net increasing of the number FTE involved**;

Since the beginning the idea was to **share** energies, ideas and tools between the two **synergic activities**

2019-2021: the LIME and MANGO era

We presented the **CYGNO CDR** to CSN2

In the meanwhile we assembled LIME and MANGO



Dipartimento di Fisica
Università di Genova

INFN Istituto Nazionale di Fisica Nucleare

Prof. Marco Pallavicini
Via Dodecaneso 33
16146 Genova Italy

dott. Davide Pinci
INFN Roma1

c.c.
CSN2
Referee CYGNO
dott. Sandra Zavatarelli
Prof. Maura Pavan

Caro Davide,

nel corso della riunione a Torino dal 16 al 20 settembre u.s. la Commissione II ha analizzato e valutato la proposta di estensione della sigla CYGNO da te richiesta.

La Commissione riconosce le potenzialità di CYGNO per la ricerca di materia oscura e apprende con soddisfazione che il progetto è finanziato in larga misura da un finaziamento ERC.

La sigla è quindi approvata nella modalità solita per questi casi, garantendo quindi solo il finanziamento per le voci di spesa ben motivate e non coperte dal progetto europeo. Ulteriori finanziamenti specifici sono possibili ma non garantiti e saranno discussi caso per caso, anche in relazione alla disponibilità di budget.

Cordiali saluti e buon lavoro,

Genova, 9 ottobre 2019

Prof. Marco Pallavicini
(Presidente della Commissione 2 INFN)

the project was **approved in** September **2019**

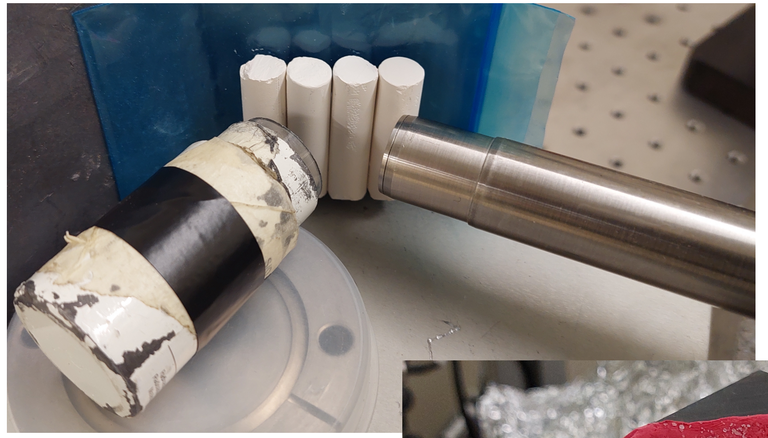
2019-2021: the LIME and MANGO era

2020: construction of **LIME**

2020: LIME commissioning in clean room

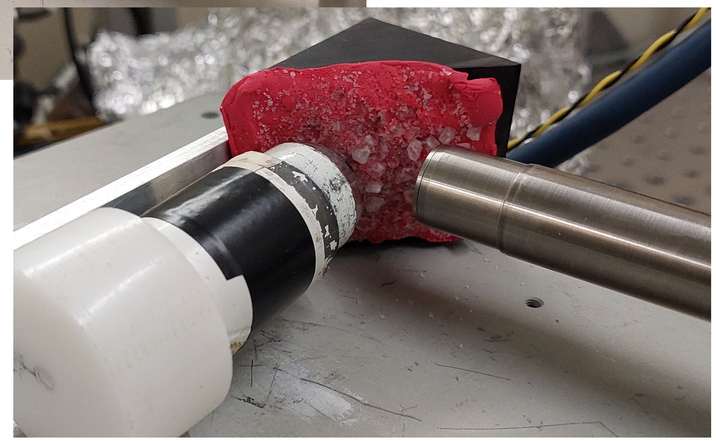
2019-2021: the LIME and MANGO era

2021: test of **LIME overground:**
setup still rudimentary



The Calcium target

The Clorine target

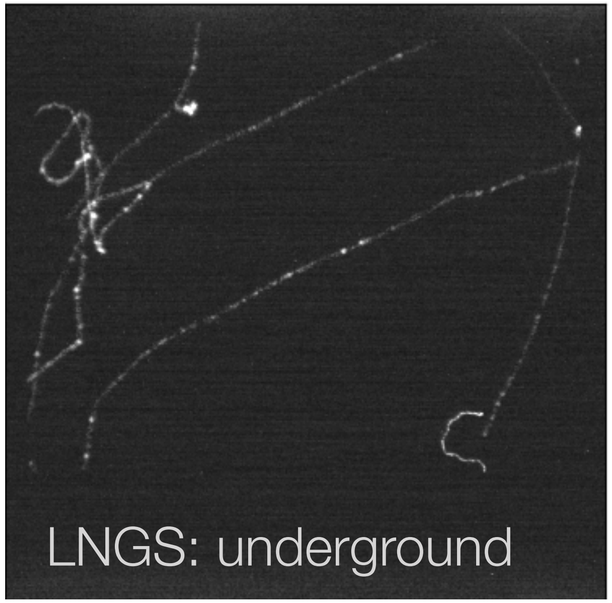


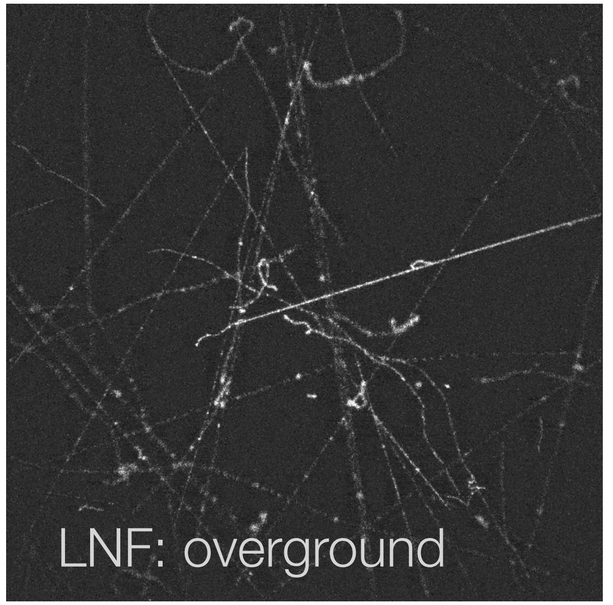
High precision **low energy** studies

2022: LIME underground

May **2022:** we installed **LIME underground**

Unshielded LIME





Probably more than 10^6 pictures have been acquired so far

Important upgrade on the Trigger and DAQ system, while gas system is still under test

2022: CYGNO-04

We presented the **TDR** for the 0.4 cubic meters demonstrator to INFN in July and to **LNGS in September 2022**

INFN Istituto Nazionale di Fisica Nucleare

DocID	Rev.	Validità
INFN-PM-QA-504	1.0.2	Rilasciato

Data 31/8/2022

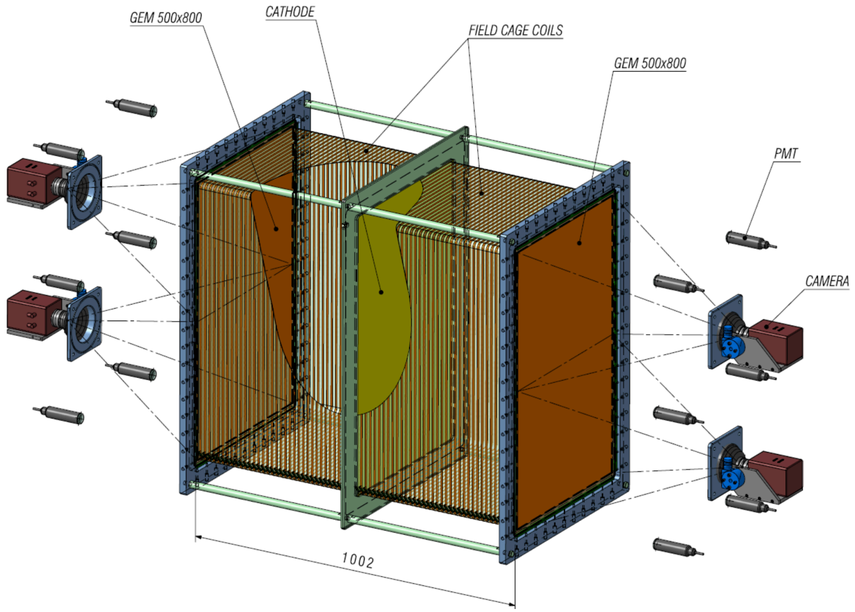
Piano Qualità – CSN2

Technical Design Report - TDR
CYGNO-04/INITIUM

This document identifies and describes the characteristics and technical requirements from the CYGNO-04/INITIUM Experiment related to the installation at Hall F of the Gran Sasso National Laboratories (LNGS)

Autore	Verificato da	Approvato da
E. Baracchini C. Capoccia L. Leonzi G. Mazzitelli D. Pinci F. Rosatelli S. Tomassini	G. Bucciarelli M. Tobia A. Goretti R. Adinolfi L. Cappelli	E. Privitali

Distribution list:
- Commissione Scientifica Nazionale 2 (CSN2)
- Direttore LNGS
- Servizi LNGS
- SCICOM LNGS



INFN Istituto Nazionale di Fisica Nucleare

Dr. Oliviero Cremonesi
Piazza della Scienza, 3
20126 Milano Italy

Milano, 28 Settembre 2022

Dr. Davide Pinci
INFN - Roma
c.c.
CSN2
Referee CYGNO
prof. Maura Pavan
dott. Giorgio Riccobene
dott. Sandra Zavatarelli

Caro Davide,
nel corso della riunione di bilancio della CSN2 tenutasi a Napoli dal 19 al 23 Settenbre 2022, la Commissione II ha analizzato e valutato il TDR e le richieste presentate dal gruppo INFN della sigla CYGNO.

La commissione giudica positivamente il TDR di Cygno-04 notando che, in quanto progetto finanziato ERC, ha un profilo di rischio più alto di quello normalmente accettato per un progetto di commissione 2. Richiede che il TDR venga aggiornato appena siano disponibili i risultati ottenuti dal run underground del prototipo LIME (performance, stabilità temporale, background model) e dai test previsti per il prossimo anno su catodo, field cage, ecc.

La commissione approva il piano finanziario proposto dalla collaborazione CYGNO che prevede, da parte della Commissione, un contributo massimo di 120 k€/anno (inclusivo di ogni voce di spesa). L'approvazione si riferisce per il momento ai due anni previsti per la costruzione: 2023 e 2024. Quando sarà disponibile il TDR aggiornato secondo le richieste sopra menzionate, la Commissione procederà alla discussione del piano di spesa previsto per gli anni 2025-2027 che servirebbe a sostenere i costi di operazione del dimostratore.

Distinti saluti,

Dr. Oliviero Cremonesi
(Presidente CSN2 dell'INFN - Fisica Astroparticellare)

The **project** is approved for the next **2 years**;

Experiment **running costs** for 25/27 to be discussed on the **basis of LIME results**: **performance**, **stability** and **background** model.

CYGNO-04 motivations

In order to **demonstrate** the **achievability** of the **CYGNO-30 experiment**, CYGNO-04 should**:**

- **evaluate the actual potentialities** of a large PHASE 2 detector to reach the expected performance;
- **study** and **minimize radioactivity** (material, gas, sensors) on a realistic experimental layout and scale;
- **develop** and test a **modular readout and DAQ**, able to and properly **reconstruct events** acquired by **different sensors;**

CYGNO-04: the cost plan (23-27)

Core costs: 912 k€
(233 k€ already **spent): 669k€**
90 k€ of **copper** from Opera**: 579k€**
fully covered by **INITIUM-ERC**

The **INFN-CSN2** funds will be needed to **run** the **experiment** and to carry on the **R&D** that can be exploited **to upgrade the PHASE 1 performance** and to evaluate possible solutions for **PHASE 2**

INFN - CSN2	2023	2024	2025	2026	2027
Gas Bottle	10	5	15	15	0
Gas Recovery	10	0	20	20	0
Consumables	10	20	20	10	20
R&D	50	50	30	20	0
Tot w/o Travels (k€)	80	75	85	65	20
Travels - Shift	30	20	20	30	0
Travels - Installation	10	30	30	0	30
Tot Travels (k€)	40	50	50	30	30
Tot (k€)	**120**	**125**	**135**	**95**	**50**

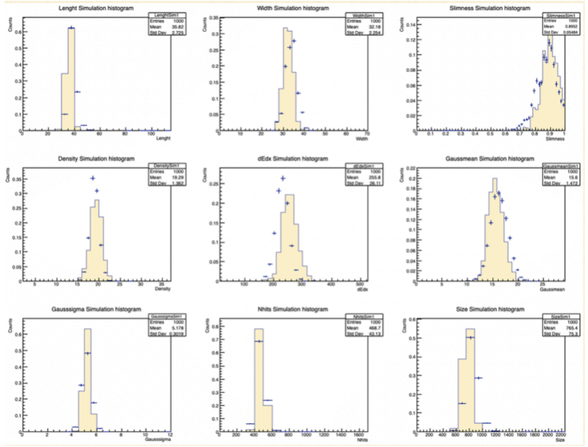
Running costs on INFN-CSN2

Ref.	WBS NUMBER 1	2	3	4	5	6	7	DESCRIPTION	UNIT	QUANTITY AT WBS LEVEL 1	2	3	4	5	6	7	TOTAL (kEuro)	Unit Cost	COMPONENT COST AT WBS LEVEL (kEuro) 7	6	5	4	3	2	1	CORE COST already covered	CORE COST to be covered	NOTES
GM	1							CYGNO/INITIUM Project	EACH	1														752.75	912.75		679.45	
GM	1	1						DETECTOR	EACH		1												268.20					
GM	1	1	1					TPC	EACH			1										33.20						
GM	1	1	1	1				GAS VOLUME	EACH				1								30.00								estimation based on PALAZZI quotation
ST	1	1	1	1	1			PMMA gas vessel	EACH					1						30.00								estimation based on PALAZZI quotation
ST	1	1	1	1	2			PMMA cameras cones	EACH					4				0.30		1.20								LNF workshop estimation based on LIME costs
ST	1	1	1	1	3			PMMA GEM frame holder	EACH					2				1.00		2.00								
DP	1	1	1	2				READOUT	EACH					4								190.00						quotation by CERN
LB	1	1	1	2	1			GEM foil	EACH						2			3.00	6.00									quotation by CERN
CC	1	1	1	2	2			GEM frame	EACH						2			0.20	0.40									quotation by CERN
LB	1	1	1	2	3			GEM holder	EACH						3			0.20	0.60									quotation by CERN
LB	1	1	1	2	4			GEM connectors	SET						2			0.20	0.40									estimation based on Hamamatsu quotation
DP	1	1	1	2	5			Cameras	EACH						1			32.00	32.00									estimation based on snheider quotatiom
DP	1	1	1	2	6			Optics	SET						1			2.20	2.20									
RO	1	1	1	2	7			Cameras holedrs mechanics	SET						1			3.00	3.00									estimation based on Hamamatsu quotation (partialy purchased)
DP	1	1	1	2	9			PMTs	EACH						3			0.80	2.40							4.8		
DP	1	1	1	2	10			Cable & connectors	SET						1			0.50	0.50									
	1	1	1	3				CATHODE	EACH				1									17.00						
	1	1	1	3	1			Feed through	SET					1				1.00		1.00								
CC	1	1	1	3	2			Cathode frame	SET					1				1.00		1.00								
	1	1	1	3	3			Cathode foil	SET					1				15.00		15.00								quotation based on experince of DRIFT collaborator
	1	1	1	4				FIELD CAGE	EACH				1									13.00						
CC	1	1	1	4	1			Cu rings	EACH					100				0.10		10.00								quotation by ELTOS
	1	1	1	4	2			Resistors	EACH					100				0.01		1.00								quotation by RS for standard restori
CC	1	1	1	4	3			PMMA box	EACH					1				2.00		2.00								
RO	1	1	1	5				CALIBRATION SYSTEM	EACH					1								15.00						
	1	1	1	5	1			Calibration source	EACH					1				5.00		5.00						5.00		device purchased
RO	1	1	1	5	2			Mechanics	EACH					1				5.00		5.00								cost based on LIME experince
RO	1	1	1	5	3			Stepper motors	SET					1				5.00		5.00								cost based on LIME experince
	1	1	2					SHIELDING	EACH		1												281.05					
CC	1	1	2	1				Cu bricks	SET			9500						0.019				180.50						estimation based on CSN Carl Schreiber GmbH quotation
CC	1	1	2	2				Water tanks	SET			48						1.300				62.40						estimation based on MULDING quotation
CC	1	1	2	3				Frame (consumable/carpentry)	SET			1						20.000				20.00						LNF workshop estimation based on LIME costs
CC	1	1	2	4				Politilene base	SET			3300						0.006				18.15						estimation based on ADVIPLAST quotation
	1	1	3					GAS SYSTEM	EACH		1												123.00					
	1	1	3	1				gas system	EACH				1					85.00				85.00				85.00		device purchased
	1	1	3	2				gas distribution	SET				1					5.00				5.00						
	1	1	3	3				gas system mechanics	SET				1					5.00				5.00						
	1	1	3	4				gas contingency (consumable)	SET				1					5.00				5.00						
	1	1	3	5				gas purification system	SET				1					10.00				10.00				10.00		device purchased
	1	1	3	6				CF4 analyzer	SET				1					13.00				13.00				13.00		device purchased
	1	1	4					HV SYSTEM	EACH		1												35.00			35.00		device purchased
	1	1	4	1				CAEN LV crate	SET			2						5.00				10.00						
	1	1	4	1				CAEN LV board	SET			2						5.00				10.00						
	1	1	4	1				ISEG HV PS	SET			3						5.00				15.00						
	1	1	5					DAQ & SLOW CONTROLS	EACH		1												45.50			45.50		device purchased
	1	1	5	1				server	SET			2						10.00				20.00						
	1	1	5	2				aux pc	SET			4						1.00				4.00						
	1	1	5	3				monitors	SET			5						0.30				1.50						
	1	1	5	3				aux readout board	SET			1						5.00				5.00						
	1	1	5	4				aux readout sensor	SET			1						5.00				5.00						
	1	1	5	5				triggger system	SET			1						5.00				5.00						
	1	1	5	6				cables & connectors	SET			1						5.00				5.00						
	1	2						COMPRESSED AIR SYSTEM	EACH		1													12.00					
	1	2	1					air distribution system	SET			1						5.00					5.00			5.00		device purchased
	1	2	2					air filter	SET			1						2.00					2.00			2.00		device purchased
	1	2	3					tubes & connectors	SET			1						5.00					5.00					
	1	3						ELECTRIC SERVICES	EACH		1													20.00					cost estimated by LNGS services
	1	3	1					power distribution system	SET			1						10.00					10.00					
	1	3	2					cables & connectors	SET			1						5.00					5.00					
	1	3	3					UPS	SET			1						5.00					5.00					
	1	4						NETWORK DISTRIBUTION	EACH		1													13.00			13.00		device purchased
	1	4	1					network distribution system	SET			1						5.00					5.00					
	1	4	1					switch	SET			1						1.00					1.00					
	1	4	2					router	SET			1						5.00					5.00					
	1	4	3					cables & connectors	SET			1						2.00					2.00					
	1	5	4					COOLING and CONDITIONING	EACH		1													29.00					
	1	5	1					Conditioning	SET			1						20.00					20.00					cost estimated by LNGS services
	1	5	2					Cameras chiller	SET			1						5.00					5.00			5.00		device purchased
	1	5	3					PMTs flow system	SET			1						2.00					2.00					
	1	5	4					Cables & connectors	SET			1						2.00					2.00					
	1	6						SAFETY (PRA-VIA)	EACH		1													41.00					
	1	6	1					PRA	SET			1						2.50					2.50			2.50		device purchased
	1	6	2					VIA+VINCA	SET			1						3.50					3.50			2.50		device purchased VICA to be done, cost estimated by NIER
	1	6	3					fire detection system	SET			1						10.00					10.00					cost estimated by LNGS services
	1	6	4					gas monitor system	SET			1						15.00					15.00					cost estimated by LNGS services
	1	6	5					fire safety design and adminstration	SET			1						10.00					10.00					cost estimated by LNGS services
	1	7						CIVIL WORK	EACH		1													40.00				
	1	7	1					controll room container	SET			1						25.00					25.00					cost estimated by LNGS services
								gas system box										10.00										cost estimated by LNGS services
	1	7	2					water tub	SET			1						15.00					15.00					cost estimated by LNGS services
	1	8						DESIGN AND DOCUMENTATION	EACH		1													5.00				
	1	8	1	1				software	SET			1						5.00					5.00			5.00		

https://docs.google.com/spreadsheets/d/1IdVnZN-t4iXgnNmQ8otjlN_2WeyrBTSeeFI_lVX8w14/

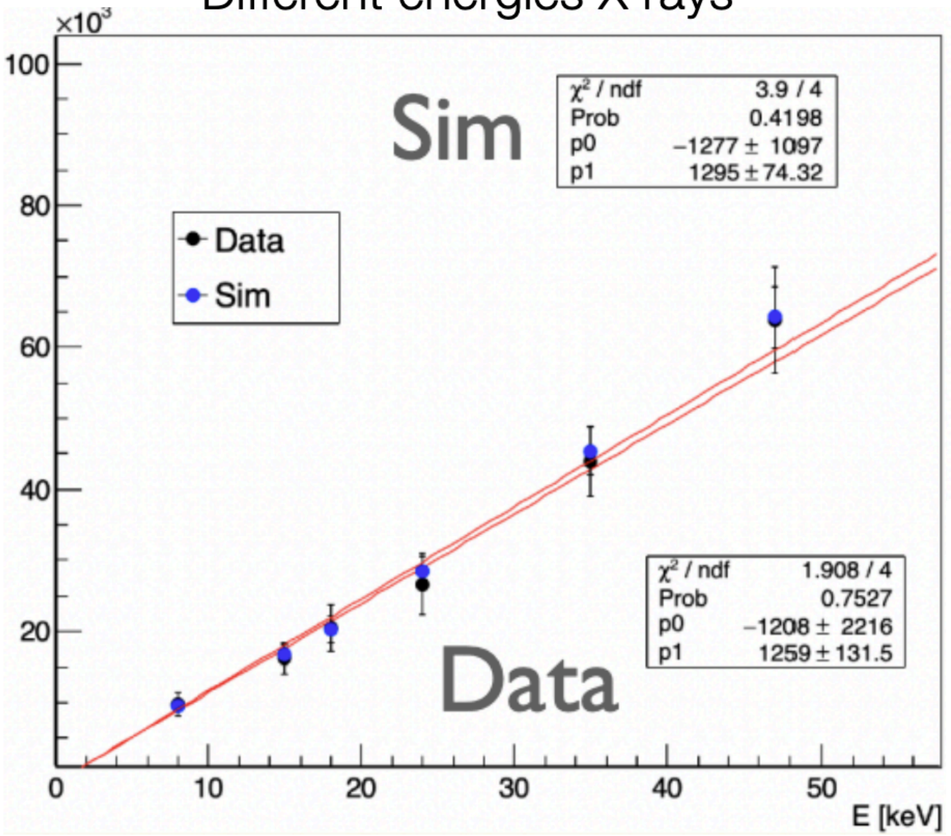
Optical Readout response simulation

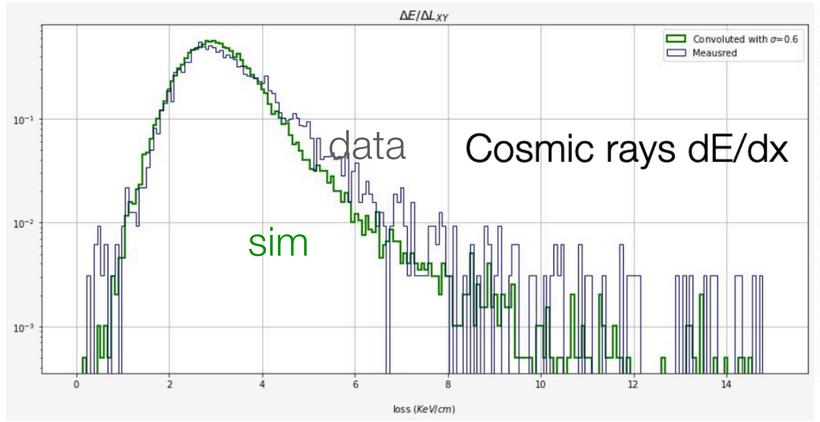
We developed a python code to completely **simulate** detector **response**: from the **energy release** to the optical signal formation in the **CMOS** sensor and **PMT**



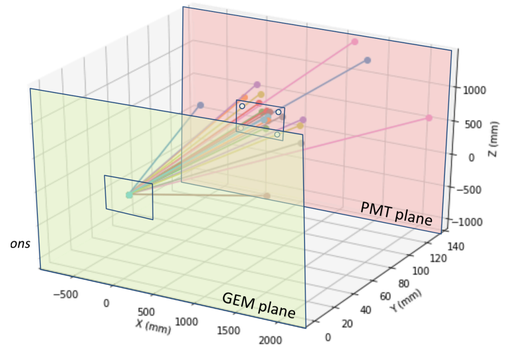
We cross check several observables

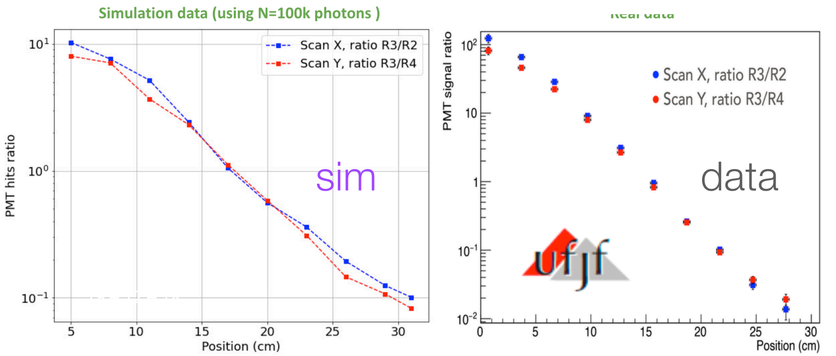
Different energies X rays



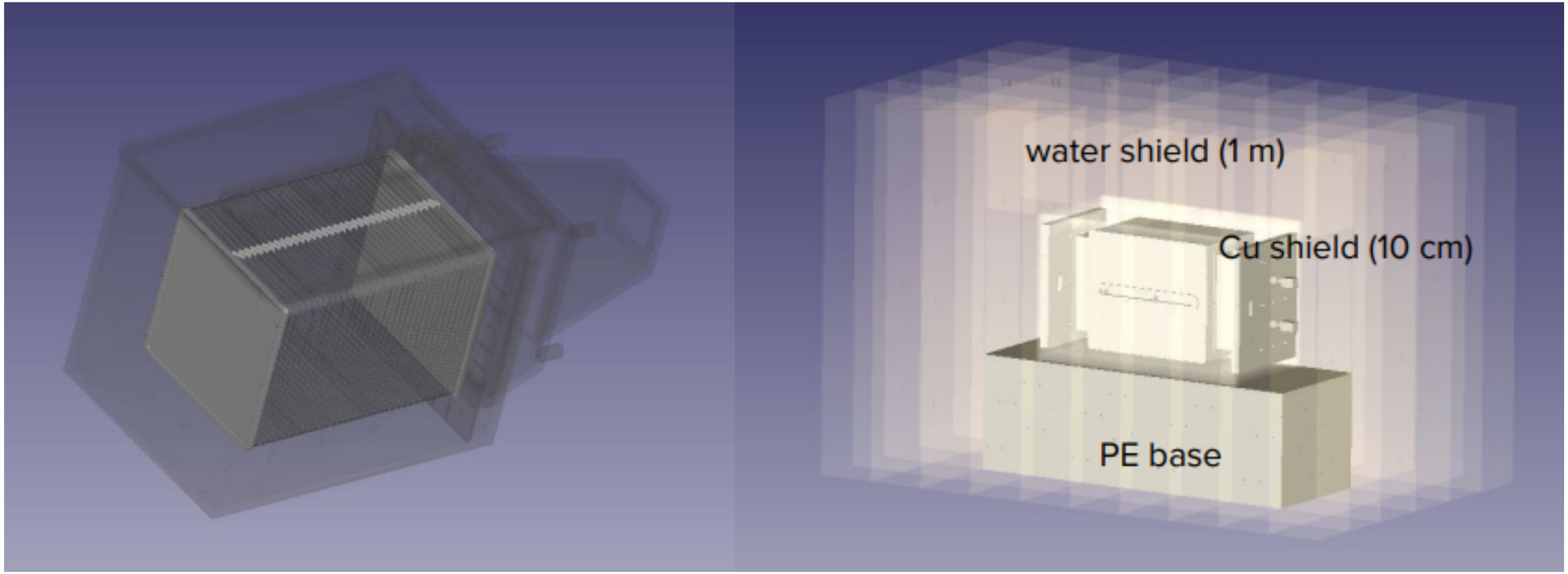


Work on PMTs still ongoing





LIME and CYGNO-04 simulation

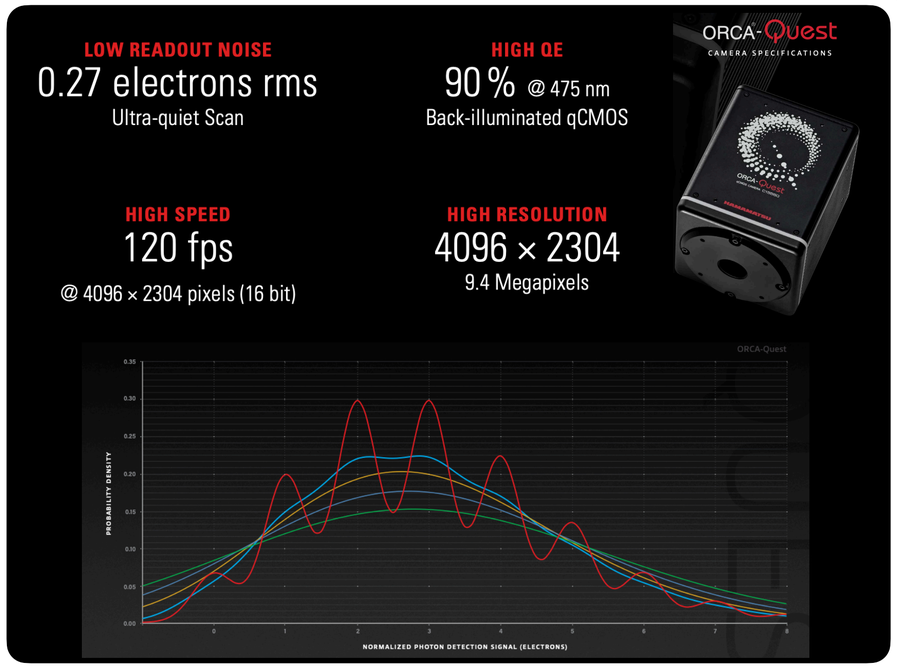


By using **GEANT4** the **internal** and **external** contributions to the radioactive background were evaluated in **different** detector **setup** and **shielding schemes**

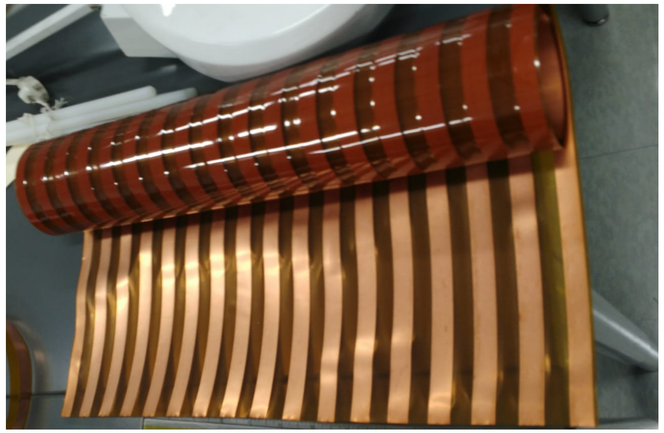
CYGNO-04: ongoing technical tests

Technical upgrades will be adopted in the realization of the PHASE 1 demonstrator.

In most cases they have **already been successfully employed** in **detectors** for the search of **rare events**.



2 Hamamatsu qCMOS camera (**8M pix**) per side to readout **80x50cm² GEM;**

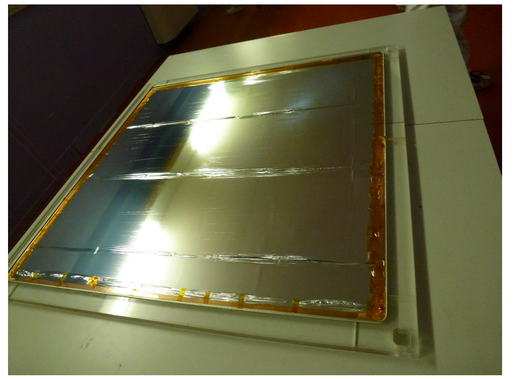


Copper on **kapton** printed strips for the **Field Cage** employed in **DRIFT III** detector;

Contacts with **ELTOS** to evaluate mechanical **requirements** for **support design**

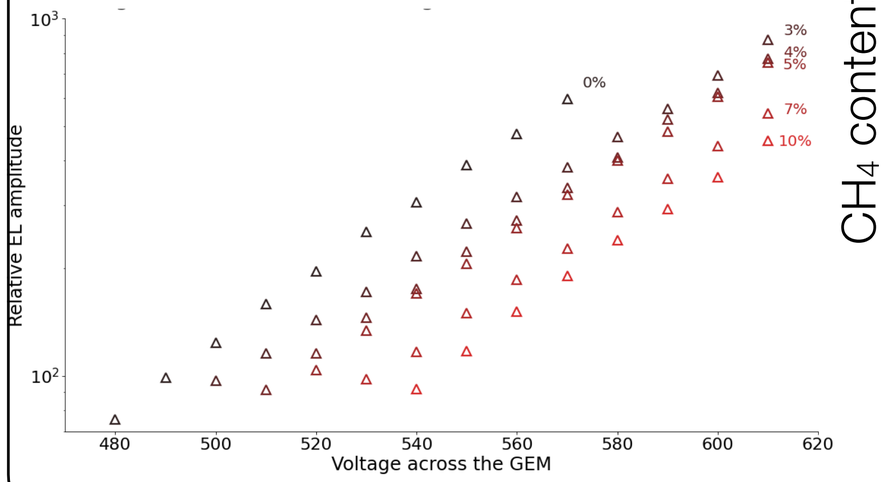
Central common **0.9 μm** thick **aluminum** cathode;

Employed and **provided** by the **DRIFT III** collaboration, already in our hands, to start **mechanical** and **electrical tests**

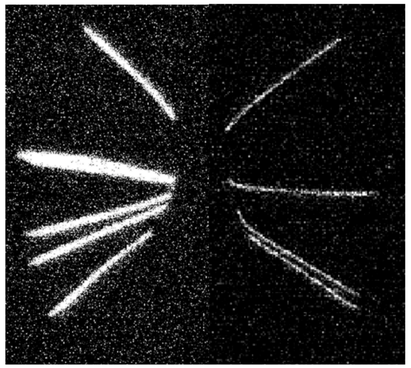


R&D for further improvements

Charge and light yield of different **hydrogen rich** mixtures are being studied that would further enhance the experiment sensitivity to low O(GeV) WIMP masses.

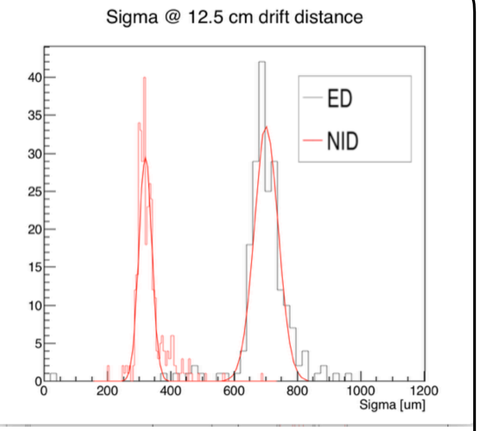


In studies with **SF_6** our group at GSSI showed for the first time the possibility of exploiting **negative ion drift** operation at **atmospheric pressure**



$He:CF_4$
60:40
1 kV/cm
(ED)

$He:CF_4:SF_6$
59:39.4:1.6
0.4 kV/cm
(NID)



significant **reduction** of the **diffusion** effect

First evidence of luminescence in a He/CF_4 gas mixture induced by non-ionizing electrons

E. Baracchini,[a,b] L. Benussi,[c] S. Bianco,[c] C. Capoccia,[c] M. Caponero,[c,d] G. Cavoto,[e,f] A. Cortez,[a,b] I. A. Costa,[e] E. Di Marco,[e] G. D'Imperio,[e] G. Dho,[a,b] F. Iacoangeli,[e] G. Maccarrone,[c] M. Marafini,[e,g] G. Mazzitelli,[c] A. Messina,[e,f] A. Orlandi,[c] E. Paoletti,[c] L. Passamonti,[c] F. Petrucci,[h,i] D. Piccolo,[c] D. Pierluigi,[c] D. Pinci,[e,1] F. Renga,[e] F. Rosatelli,[c] A. Russo,[c] G. Saviano[c,j] and S. Tomassini[c]

We demonstrated the possibility of **increasing** the **light yield** without increasing the GEM gain by **accelerating electrons** in a small gap after the charge amplification stage

Our group has started to study the possibility of employing **freon-free eco-friendly** gas mixtures. Light yield studies for **He/HFO** were performed

Tests of Eco-Friendly Gas Mixtures in GEM Based Detectors with Optical Readout

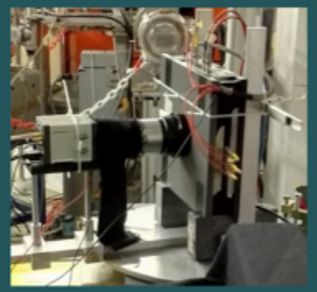
I. Abritta Costa, E. Baracchini, R. Bedogni, F. Bellini, L. Benussi, S. Bianco, M. Caponero, G. Cavoto, E. Di Marco, G D'Imperio, F. Iaconageli, G. Maccarone, M. Marafini, G. Mazzitelli, A. Messina, L. Passamonti, F. Petrucci, D. Piccolo, D. Pierluigi, D. Pinci, F. Renga, A. Russo, G. Saviano, S. Tomassini

The CYGNO project timeline

PHASE 0: R&D and prototypes

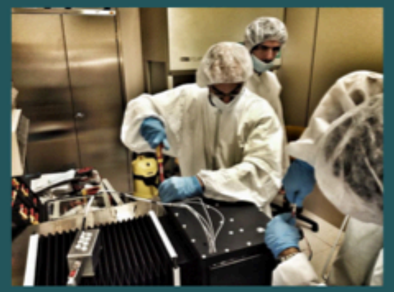
2015/16 ROMA1 → ORANGE

- 1 cm drift



2017/18 LNF → LEMON

- 3D printing
- 20 cm drift

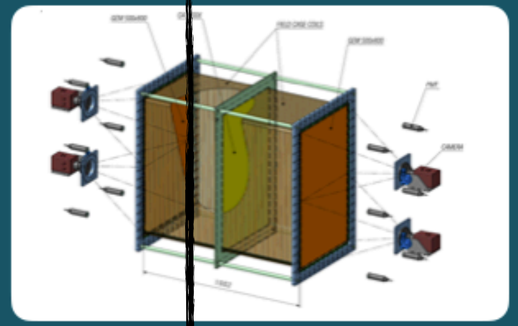


2019/22 LNF/LNGS → LIME

- 50 cm drift
- underground tests
- shielding

PHASE 1: 1 m³ Demonstrator

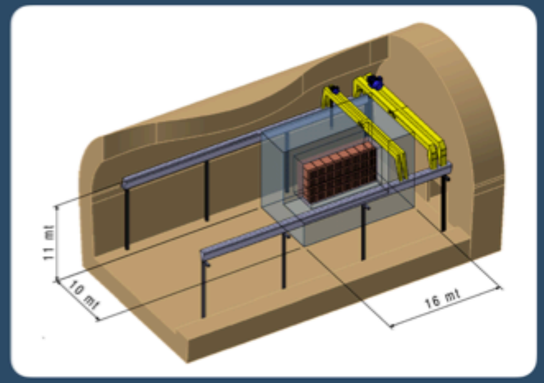
2022/27 LNF/LNGS → CYGNO_04



- background
- materials test, gas purification
- scalability

PHASE 2: 30 m³ Experiment

2027… LNGS → CYGNO_30



- Physics research

we are here

2023: what to do with LIME

- LIME **data taking** will go on in the whole **2023**;
- **“LIME Operation” WG** will help, with Run Coordinators, Shift Teams;
- **tools** for monitoring the **detector** and **data quality;**
- **Fix** issues with **gas system** and test **filtration** and **purification**;
- Upgrade **Trigger** and **DAQ** system to increase **efficiency** and **stability**;
- **Analysis** will be **focused** on LIME data;
- A **complete Data/MC comparison** is expected by the end of 2023;

Milestone	31 dic 2023	Validazione del Monte Carlo dei fondi di LIME underground

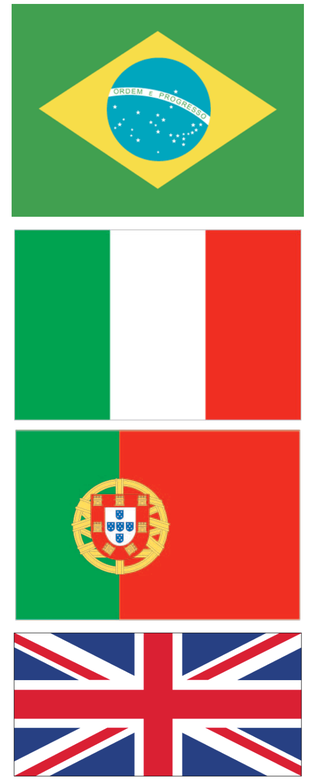
2023: what to do with CYGNO-04

- **infrastructure designs** are expected to be ready by the beginning of 2023 and then **detector design;**
- Based on the LIME experience, we expect to **validate** gas **system** by the **beginning** of **2023** and **DAQ** system by the **end** of **2023;**
- In 2023 **test on cathode and field cage** will be carried on, to freeze detector **construction procedures;**
- Work on the **material scrutiny** for **low radioactive** solution. A WG on this would help in coordinating the work.

Milestones

30 lug 2023	Realizzazione dei disegni esecutivi dell'infrastruttura nella hall-F per ospitare il dimostratore CYGNO-04
30 ott 2023	Realizzazione disegni operativi del dimostratore CYGNO-04

The CYGNO people



Currently there are more than **50 collaborators** in CYGNO/INITIUM;

9 Institutions in 4 Countries;

The CYGNO people

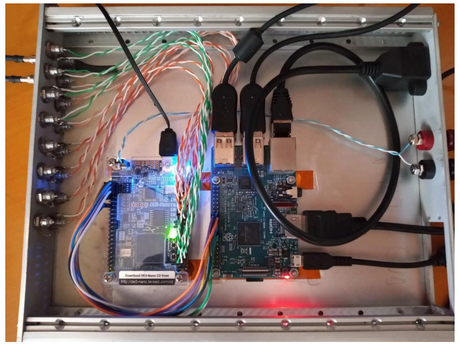
Institution	CYGNO	INITIUM	PRIN	Total FTE	PhD-Authors
INFN - RM1	2.7	0.3		3	8
INFN - LNF	2.3	0.5		2.8	9
INFN - LNGS	0.9	4.4	0.7	6	6
INFN - RM3	1.9			1.9	3
University of Sheffield (UK)	0.45			0.45	3
Universidade de Coimbra (PG)	2.5			2.5	5
Universidade Federal de juiz de Fora (BRA)	2			2	1
Centro Brasileiro de Pesquisas Físicas (BRA)	0.6			0.6	1
Universidade Estadual de Campinas (BRA)	0.5			0.5	2
Tot	13.35	5.2	0.7	19.25	36

Total of **19.25** FTE (**13.7 from INFN**) including also FTE from synergic activities in INITIUM and PRIN: T54J9J Zero radioactivity in future experiments (it ends in 22) and MZ884C - X ray polarimetry (it starts in 22);

2.4 FTE of LNF **technical team** not included;

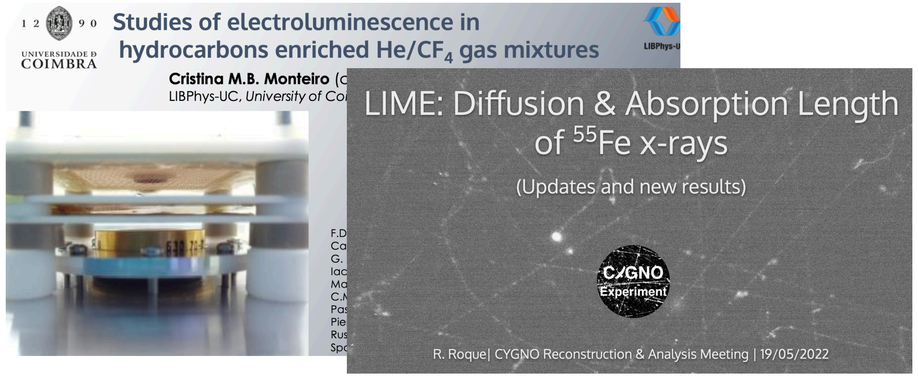
International Collaboration

UFJF and CBPF groups are mainly **electronic engineers** expert in signal processing and **data acquisition**



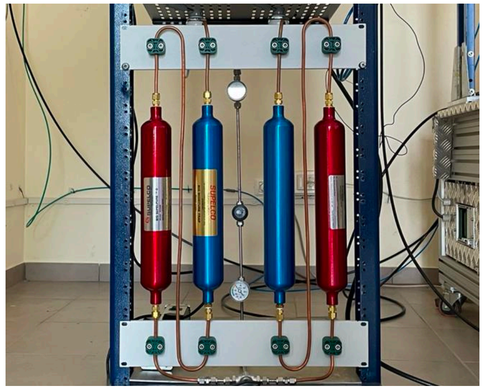
They are working on the hardware and firmware of the final **Trigger** and **DAQ** system, on the study of the noise and sensitivity of the different light sensors, on the **simulation** of the **sensors** and **photomultipliers**

Coimbra team has large experience in **MPGD** and **electroluminescence** in gases is performing all studies about **hydrocarbons** and helping in **LIME data analysis**



Sheffield team is expert in **radioactivity reduction**.

They are performing all studies about effectiveness of Radon traps for the **gas purification** and provided us designs about the system purification section



Unicamp team has already worked in astroparticle experiments. Students and PhD will work on LIME data analysis. Already involved in **simulation** and **digitization**

The CYGNO Working groups

Tasks are subdivided in **7 WP**, working in parallel, with regular WP meetings and one **General Coordination** Meeting **every 2 weeks**;

The **parallel development** of the Working Groups **activities** is becoming **crucial** given the large amount of **tasks** to be **decided** and **realised**.

Physics WP1		Analysis WP2		Simulation WP3		Detector WP4		Services WP5		R&D WP6		Management WP7	
Elisabetta Baracchini		Emanuele Di Marco		Giulia d'Imperio		Giovanni Mazzitelli		Andrea Messina		Davide Pinci		Elisabetta Baracchini Giovanni Mazzitelli 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	ECO-GAS studies	D. Piccolo	INFN Responsible	D. Pinci
Solar Neutrinos	S. Torelli	Online-Offline software integration	G. Mazzitelli	Nuclear interactions with SRIM	F. di Giambattista	Integration	G. Mazzitelli	Trigger	H. Lima	Negative Ions	E. Baracchini	Technical Coordination	G. Mazzitelli
Super Nova DM	E. Baracchini	Data Analysis	E. di Marco	Gas properties with Garfield	D. Pinci	CMOS sensor	R. Nobrega	HV	F. Renga	Gas Mixtures	F. Amaro	Pubblications and Conferences	F. Petrucci
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	Field Cage	G. Mazzitelli	International Collaborations	E. Baracchini
Migdal	A. Messina	Infrastructures	G. Mazzitelli	Integration	F. Petrucci	Performance Studies	D. Pinci	Gas Purification	R. Gregorio	Gas Luminescence	D. Pinci	Safety and Environment	G. Mazzitelli
LNGS Neutron Flux	F. di Giambattista			Infrastructures	G. Mazzitelli	Light Sensors	F. Iacoangeli	Calibration	G. Cavoto	Alternative MPGD	E. Baracchini	Call Applications	E. Baracchini
								Storage and Networks	G. Mazzitelli				

CYGNO progeny

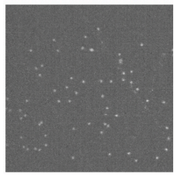
FINEM: Full Imaging of Nuclear recoils for Experimental Migdal measurement

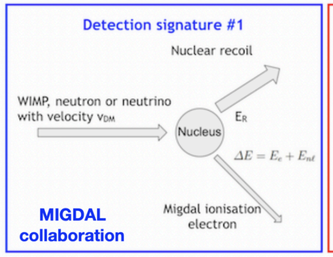
This project has been funded by the Italian Ministry of Education, University and Research through the project FARE: Framework per l'Attrazione e il Rafforzamento delle Eccellenze in Italia "FINEM: Full Imaging of Nuclear recoils for Experimental Migdal measurement" (Prot. R208LP3A4C)

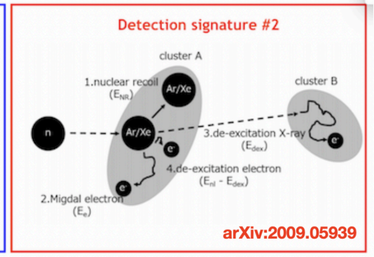
PLEASE NOTE: signature #1 is ALWAYS present (no X-ray needed) but might be difficult to distinguish ER + NR from same vertex

PLEASE NOTE: signature #2 is required for high density mixtures/low granularity readout BUT need an atom that makes X-ray

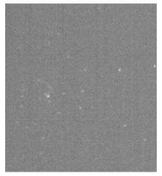
5.9 keV from ^{55}Fe in LIME
He/CF_4 (60/40)

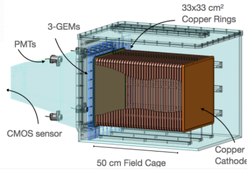






5.9 keV from ^{55}Fe in LIME
Ar/CF_4 (80/20)





FINEM GOAL: measure Migdal effect in He, CF_4 and Ar!

Exploiting signature #1 with He:CF_4

Exploiting signature #2 with Ar:CF_4

with a LIME-like detector

ray-CMOS: a wide field of view X-ray polarimeter

Elisabetta Baracchini[1,2*], Enrico Costa[3], Giorgio Dho[1,2], Flaminia di Giambattista[1,2], Alessandro Di Marco[3], Emanuele Di Marco[4], David Marques[1,2], Giovanni Mazzitelli[5], Fabio Muleri[3], Atul Prajapati[1,2], Paolo Soffitta[3], Samuele Torelli[1]

[1] Gran Sasso Science Institute, 67100 L'Aquila, Italy
[2] Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Gran Sasso, 67100 Assergi, Italy
[3] Istituto di Astrofisica e Planetologia Spaziali di Roma, Via Fosso del Cavaliere 100, I-00133 Roma, Italy
[4] Istituto Nazionale di Fisica Nucleare, Sezione di Roma1, 00185, Rome, Italy
[5] Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, 00044, Frascati, Italy

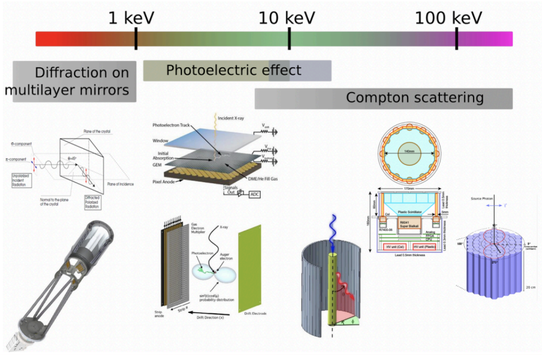
*N.B project started on 29 May 2022

This project has been funded by the Italian Ministry of Education, University and Research through the project PRIN: Progetti di Ricerca di Rilevante Interesse Nazionale "HypeX: High Yield Polarimetry Experiment in X-rays " (Prot. 2020MZB84C)

*Cosmic ray + low energy electron in LIME detector

Polarimetry basics

Experimental techniques vs energy range



Physics cases vs energy range

Scientific goals	Sources	< 1 keV	1-10	> 10 keV
Acceleration phenomena	PWN	yes (but absorp.)	yes	yes
	SNR	no	yes	yes
	jet (μQSO)	yes (but absorp.)	yes	yes
	jet (Blazars)	yes	yes	yes
Emission in strong magnetic fields	WD	difficult	yes	yes (difficult)
	AMS	no	yes	yes
	X-ray pulsator	difficult (absorp.)	yes (no cyclotron ?)	yes
	Magnetar	yes (better)	yes	no
Scattering in a-spherical geometries	Corona in XRB & AGNs	yes (but absorp.)	yes	difficult
	X-ray reflection nebulae	no	yes (long exposure)	yes
Fundamental Physics	QED (magnetar)	yes(better)	yes	no
	GR(BH)	no	yes	no
	QG (Blazars)	difficult	yes	yes
	Axions (Blazars, Clusters)	yes ?	yes	difficult

Galaxies 2018, 6(2), 54

Based on the **CYGNO** technology (optical readout of gas detector with Active Pixel Sensor) two **proposals** were **funded** for the study of the **Migdal** effect and the X-ray **polarimetry** in space;

In both cases we expect to have some synergic activity with teams foreseeing

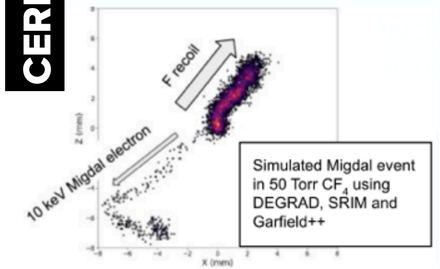
Optical Readout TPC projects

CYGNO Experiment

CERN 2020

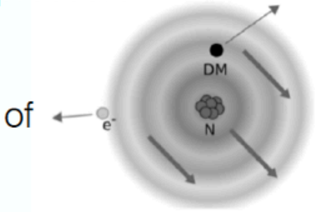
MIGDAL
Migdal In Galactic Dark mAtter expLoration

Low-pressure TPC with optical+electronic readout



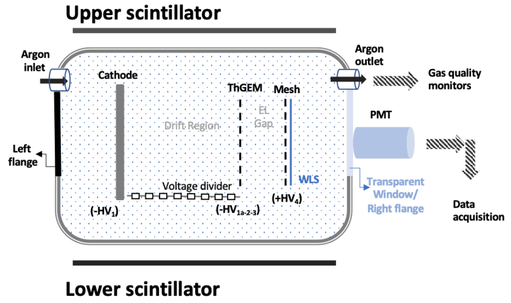
Migdal effect search in low-pressure CF_4 for DM searches in

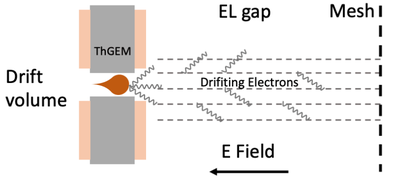
CMOS + electronic readout of **transparent strip anode**



P. Majewski, RD51 Mini-Week 2020, https://indico.cern.ch/event/872501/contributions/3730586/attachments/1985262/3307758/RD51_mini_week_Pawel_Majewski_ver2.pdf

A gaseous argon time projection chamber with electroluminescence enhanced optical readout



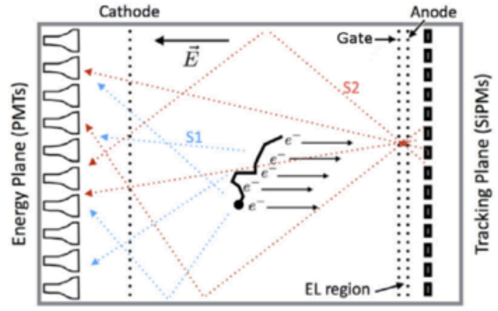


GENEVA UNIVERSITY 2022

arXiv:2212.02385v1 [physics.ins-det] 5 Dec 2022

next

High Pressure Xe gas TPC with electroluminescent amplification



Neutrinoless double beta decay searches in ^{136}Xe

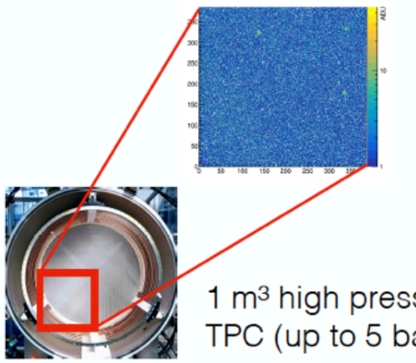
PMTs for energy measurement & t_0 from S1, **SiPM-based tracking** plane recording electroluminescence

https://next.ific.uv.es/next/experiment/detector.html
L. Arazi, Status of the NEXT project, https://doi.org/10.1016/j.nima.2019.04.080

CANFRANC 2019

High Pressure TPC

Towards a neutrino-nucleus cross section experiments



Stitched optical readout (4 CCD cameras) + **electronic signals** from meshes used for amplification

1 m^3 high pressure TPC (up to 5 bar)

DUNE COLLABORATION 2021

A. Deisting, HPTPC, https://arxiv.org/pdf/2102.06643.pdf

PubComm composition:

- At last Collaboration Meeting: **G. Maccarrone**, F. Amaro, E. Di Marco, F. Petrucci
- During this year:
  - A. Messina replaces E. Di Marco (March 2022)
  - F. Petrucci replaces G. Maccarrone as chair (October 2022)
- Currently: **F. Petrucci**, F. Amaro, A. Messina, G. Dho (warming up, active in January) (G. Maccarrone still helping until end of 2022)

Thanks to Giovanni for the work done in these years!!

Conferences:

2017-2020: 5 poster + 13 talks (probably something missing in the DB)

2021: 4 posters + 20 Talks

2022: 8 posters + 20 Talks

2023: 1 accepted talk (warning: this time last year already 5 submitted contributions …)

Very good numbers for our small collaboration. **Congratulations!**

(but can we sustain this pace?)

Papers:

2020: 5 papers 2021: 1 paper (No new paper started!)

2022: 1 paper (the CYGNO Experiment paper, started in 2020)

In 2022 we started several papers:

1. “Noise assessment in dark conditions of scientific CMOS sensors for the CYGNO Experiment”, c.a. R. Nobrega – waiting second draft
2. “Electroluminescence from GEM avalanches in He-CF4 and He-CF4-isobutane for CYGNO – Directional Dark Matter search with an optical TPC”, c.a. C. Monteiro – readers/reviewers: G. Maccarrone, G. Dho, waiting second draft
3. “Directional DBSCAN to detect cosmic-ray tracks for the CYGNO experiment”, c.a. I. Pains – first round ongoing

Other papers (with more relaxed timescales):

4. Topic: “LIME: overground performance” - C.a.: G. Cavoto - a first draft is expected soon
5. “Modeling the detector response of the CYGNO optical readout TPC” (proposed title) – c.a. F. Petrucci - first draft expected soon
6. Topic: “Negative Ion Drift” – c.a. E. Baracchini – first draft expected soon
7. Topic: “Electro-luminescence: latest results with ITO” – c.a. G. Dho - first draft expected soon
8. Topic: “CMOS-Performance: study of light yield of different CMOS” – c.a. UFJF colleagues - first draft expected soon
9. Topic: “Underground background simulation for CYGNO-04” – c.a. G. D’Imperio - first draft beginning 2023

Additional remarks and To Do list:

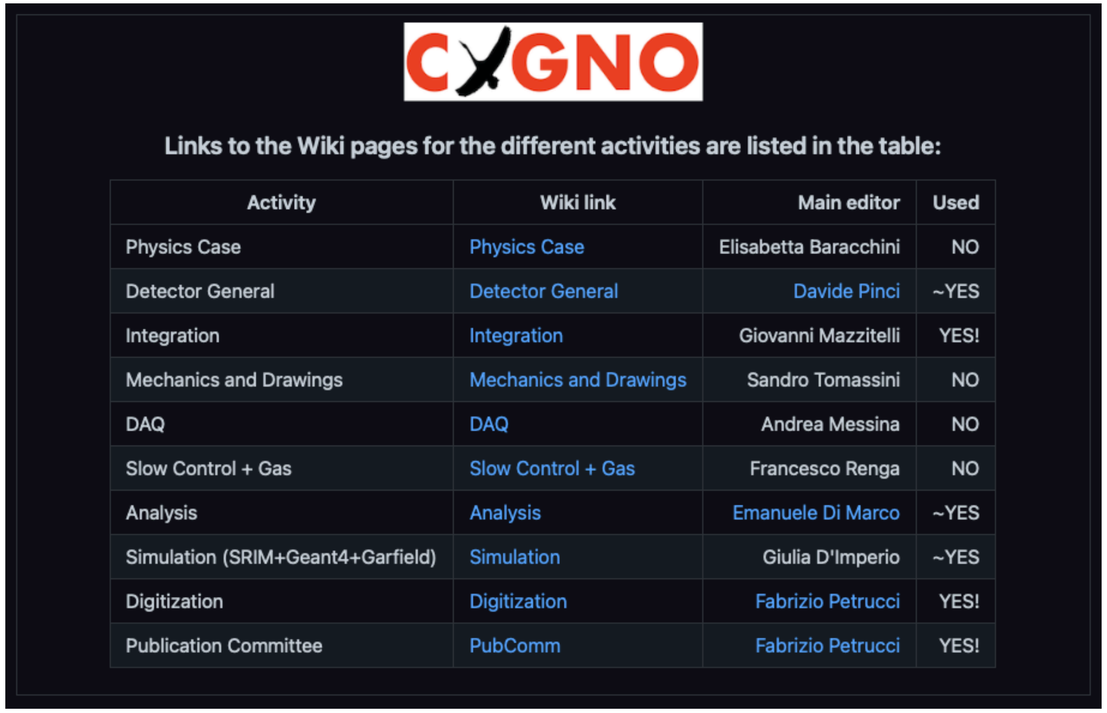
- Save paper materials somewhere to be accessible from collaboration members;
- Create an “approved” plots/pictures repository to be accessible from collaboration members;
- Create a repository of master and PhD theses;
- Our webpage https://web.infn.it/cygnus/cygno/ is obsolete! A major update cannot wait any longer. A separate discussion must start

Our WIKI page

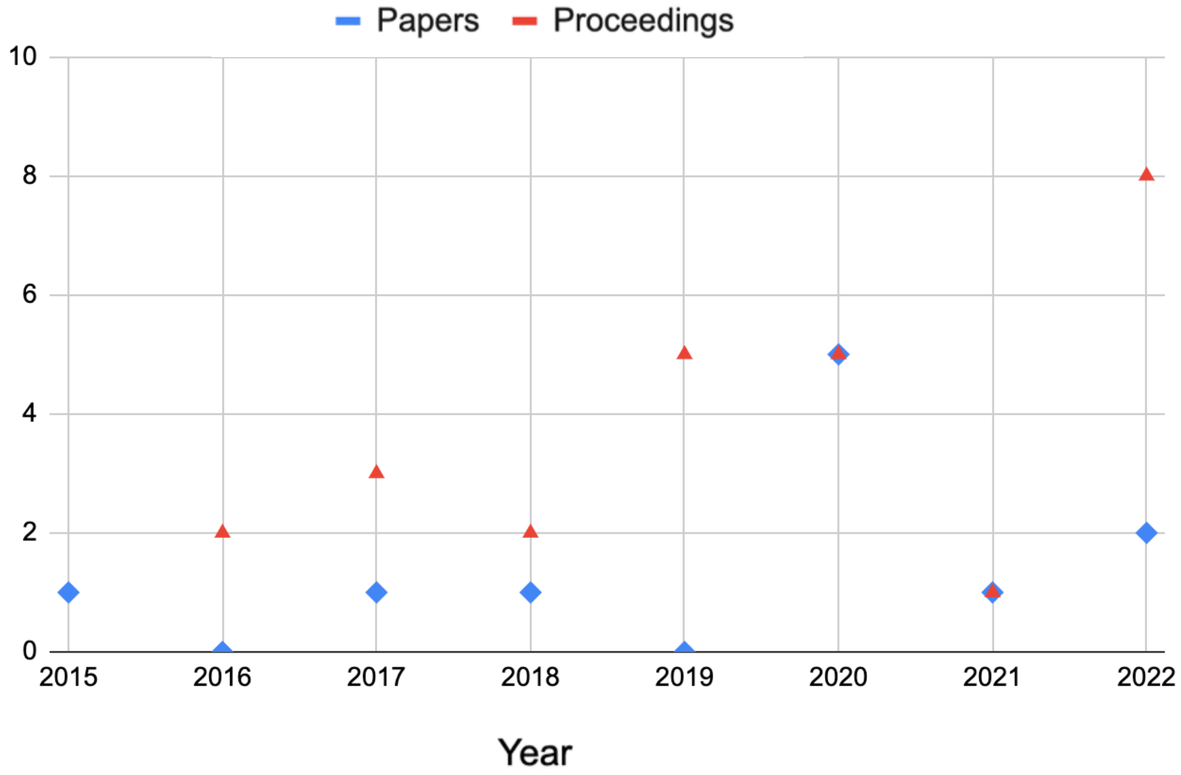
https://github.com/CYGNUS-RD/WIKI-documentation/wiki

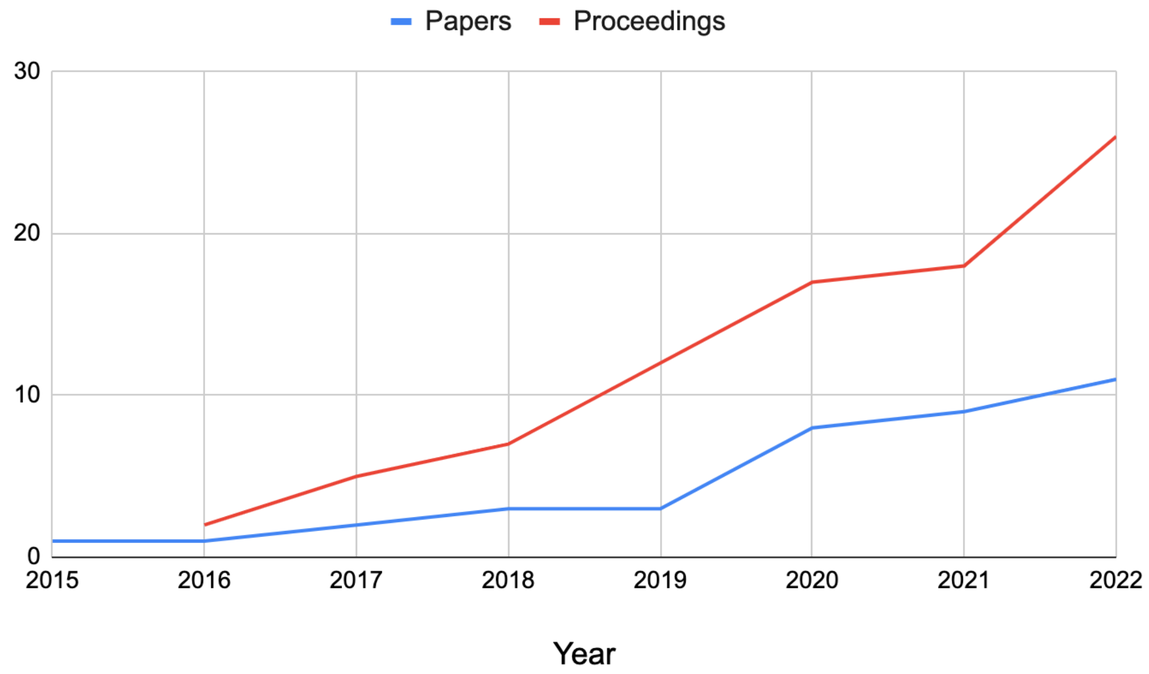
is in a “dual” state with some page used and others never implemented.

The “experiment” is positive, more pages have be used



The CYGNO publication timeline





11 papers and 26 proceedings;

20 citations (112 with self-citations);

Combined readout of a triple-GEM detector

23 citations

Identification of low energy nuclear recoils in a gas TPC with optical readout

14 citations


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