A hand-drawn technical sketch of a rectangular structure, possibly a component or a layout. The drawing is made with light pencil lines and includes several annotations: 'Kern' and 'Heli' at the top, 'ET' in a circle, 'Air hole' in the middle, and 'GEM' and 'flange' on the right side. The central rectangle has a smaller rectangle inside it, and there are various lines and scribbles around it.

The CYGNO-INITIUM TDR Status Report

G. Mazzitelli, I. Abritta Costa, E. Baracchini, R. Bedogni, F. Bellini, L. Benussi, S. Bianco, L. Bignell, M. Caponero, G. Cavoto, E. Di Marco, C. Eldridge, A. Ezeribe, R. Gargana, T. Gamble, R. Gregorio, G. Lane, D. Loomba, W. Lynch, G. Maccarrone, M. Marafini, A. Messina, A. Mills, K. Miuchi, F. Petrucci, D. Piccolo, D. Pinci, N. Phan, F. Renga, G. Saviano, N. Spooner, T. Thorpe, S. Tomassini, S. Vahsen.

Roma 2 maggio 2006

Le foto originali!



HOW WE DID IT

By
Victor Frankenstein



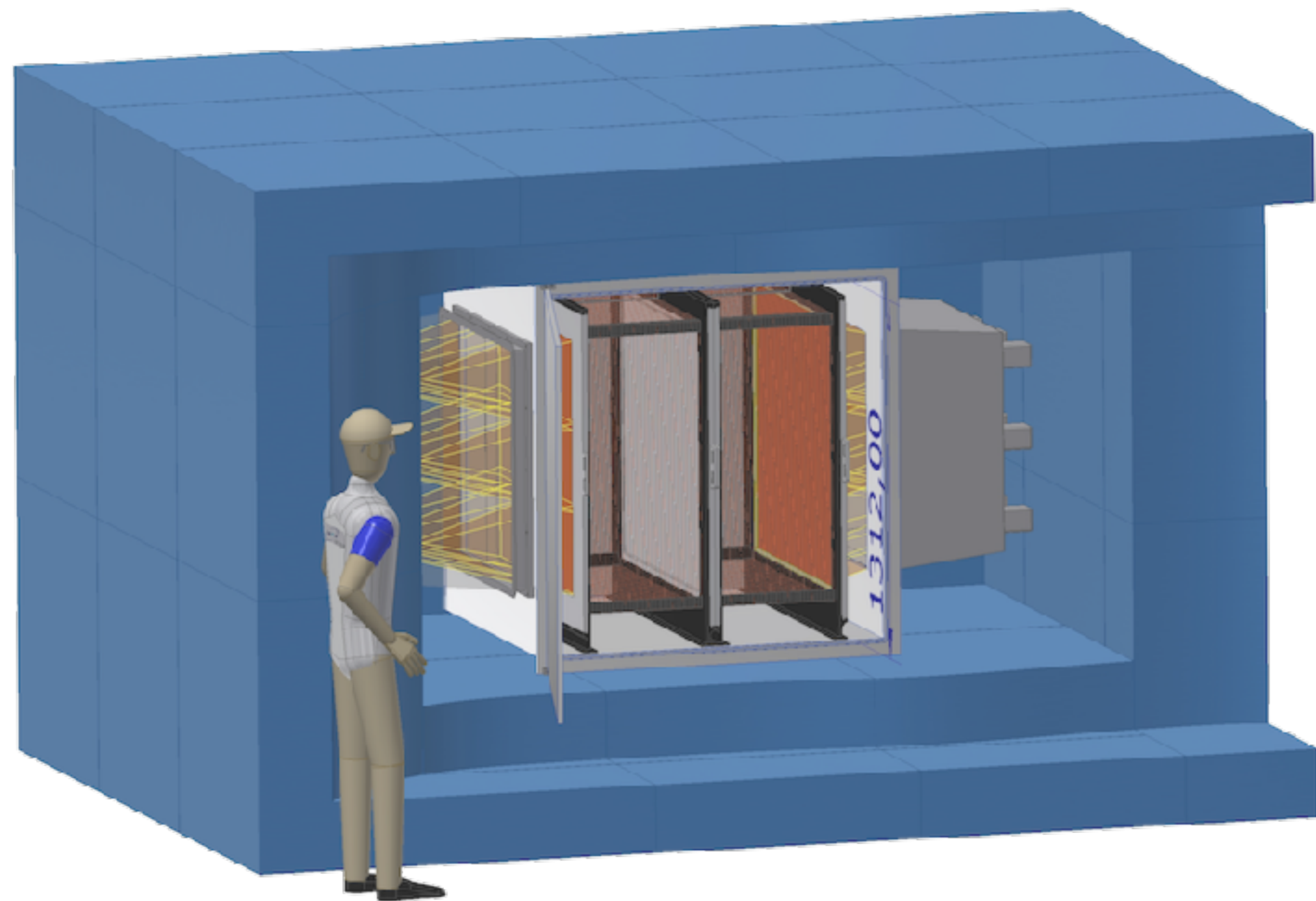
why not?

The CYGNO/INITIUM project

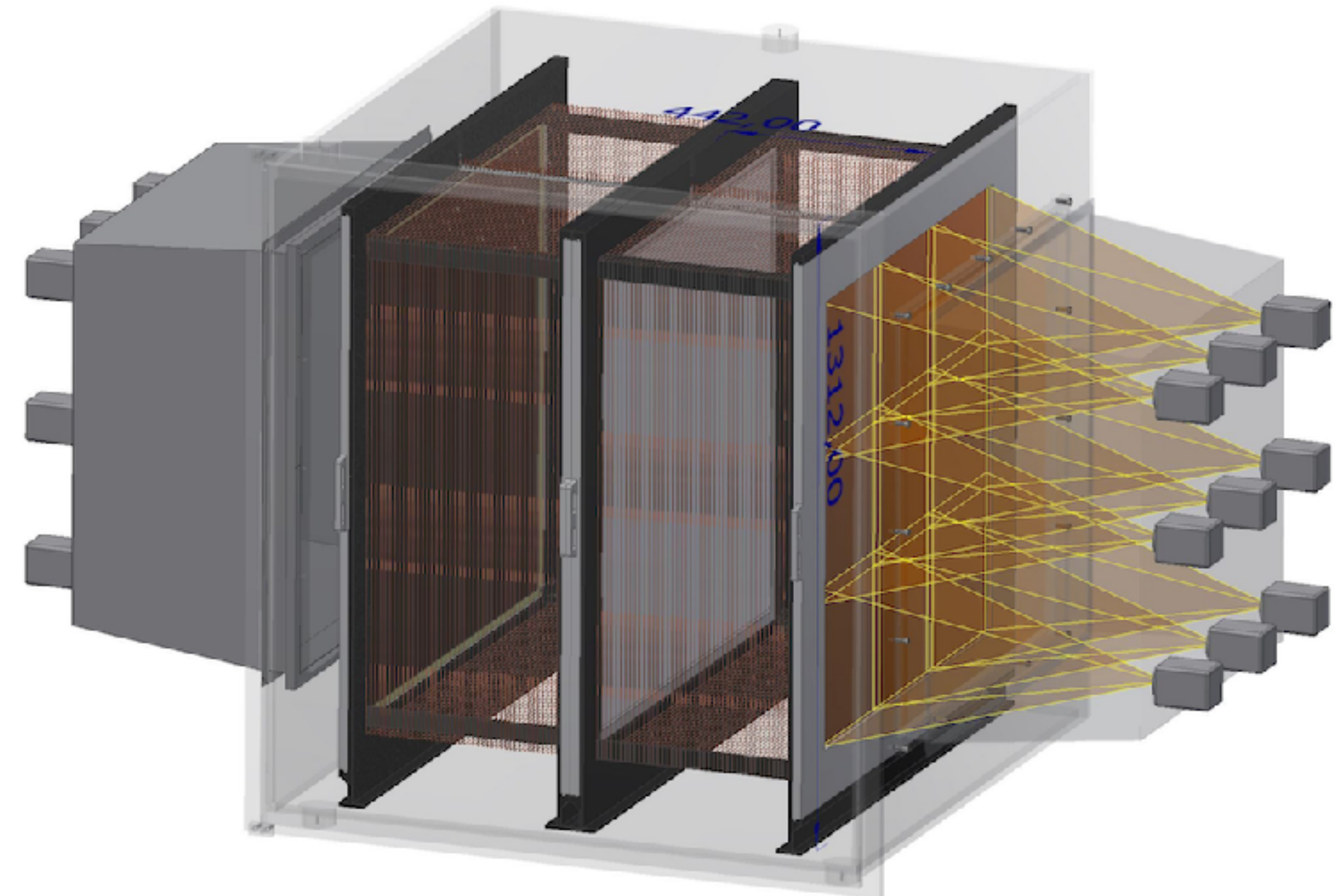
- The CYGNO/INITIUM project aims to **study and demonstrate the feasibility** of a large TPC detector based on high granularity and sensitivity of the **optically readout** and operated at **atmospheric pressure** in HeCF₄ gas mixture and test the possibility to improve the nuclear recoil threshold and directionality by means of **negative ions** gas mixture;
- The CYGNO/INITIUM is part of the R&Ds in the **CYGNUS international collaboration** to realize a distributed observatory for directional dark matter and solar neutrino study;
- The project has been divided in 4 phase:
 - **R&D** on high granularity and sensitivity of optically readout
 - **Phase-0**: R&D and **demonstrator TDR**, effort, cost estimation, CDR of CYGNO30
 - **Phase-1**: a **m³ demonstrator**, TDR, effort, cost estimation of CYGNO30
 - **Phase-2**: a **30-100 m³ detector** to be hosted at LNGS as brick of the distributed observatory



The CYGNO/INITIUM project



18 cameras monitoring
330*330 mm each
with **150 μm** resolution and
a sensitivity of **$\sim 1 \text{ ph} / 20 \text{ eV}$** released in gas



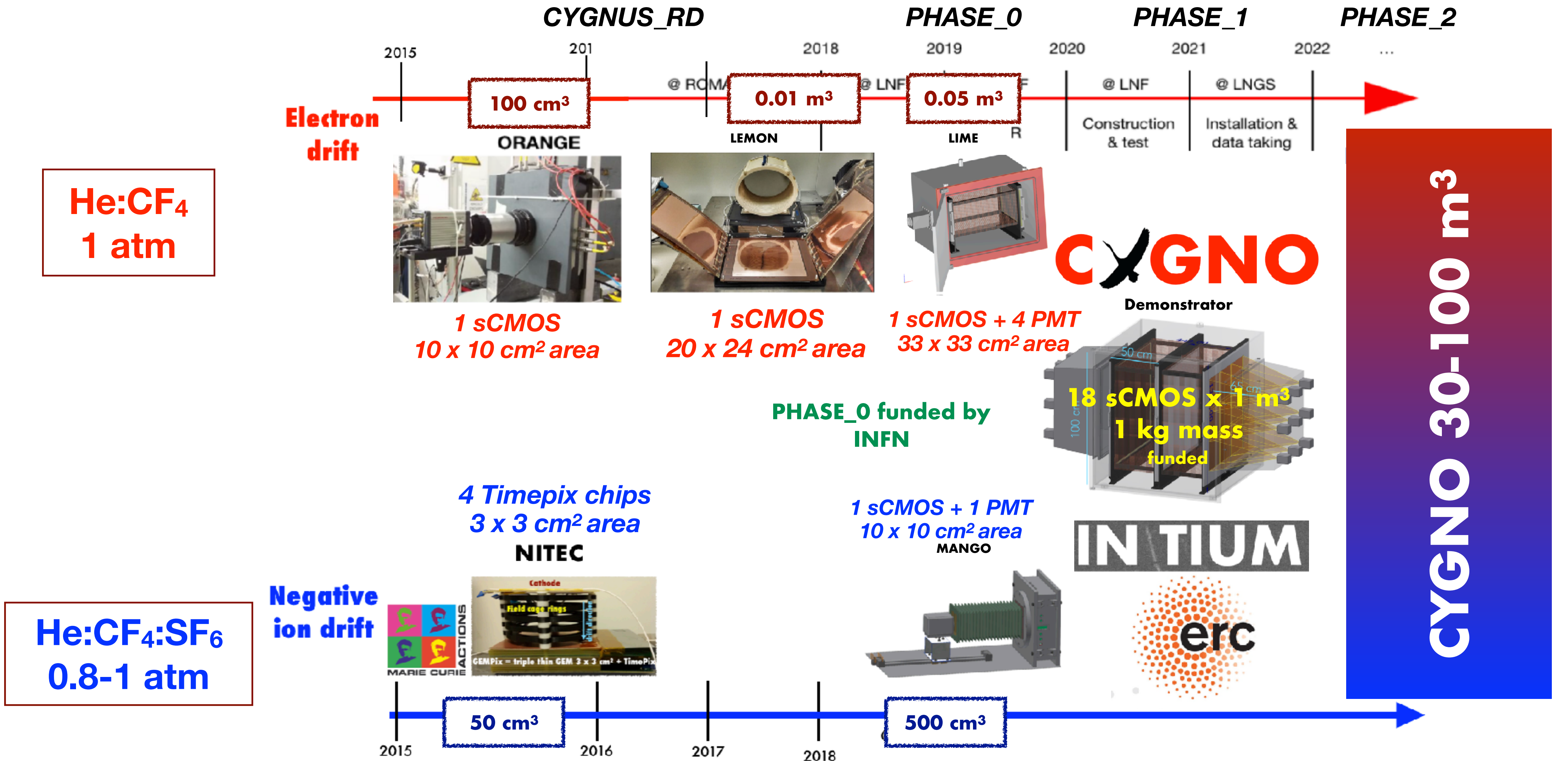
CYGNO is a demonstrator exploiting large gas TPC, GEM based charge amplification, high granularity and sensitivity of optically readout at atmospheric pressure in HeCF_4 based gas mixture

INITIUM-ERC is an R&D for testing possibility to improve nuclear recoil threshold and directionality by means of negative ions gas mixture in CYGNO demonstrator

A total of **$\sim 10^7$** channels
readout + time signals

sCMOS sensors look to be the most cost-effective high granularity and high sensitivity readout

Roadmap R&D and project Phase

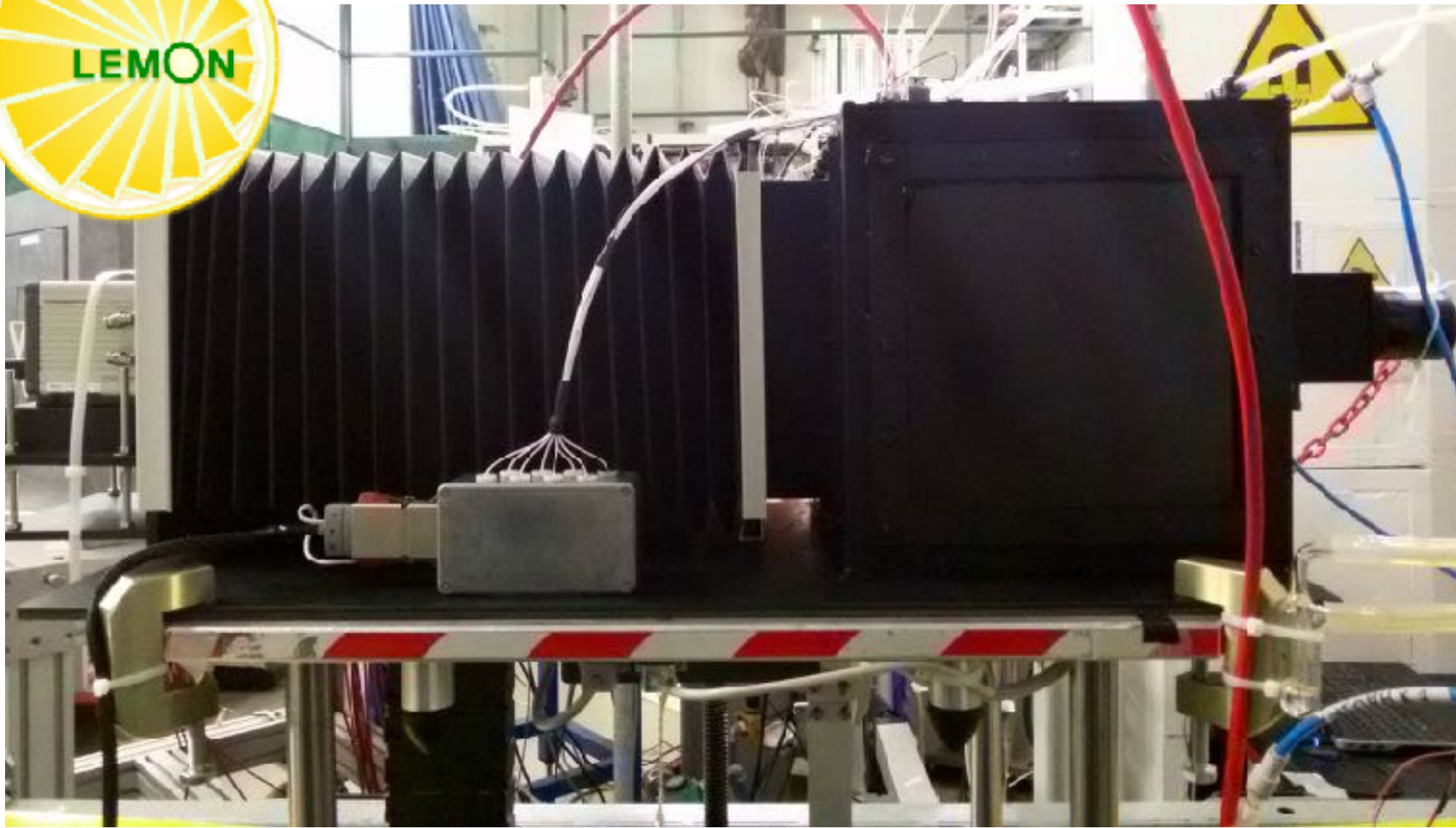


Phase-0 / Overview



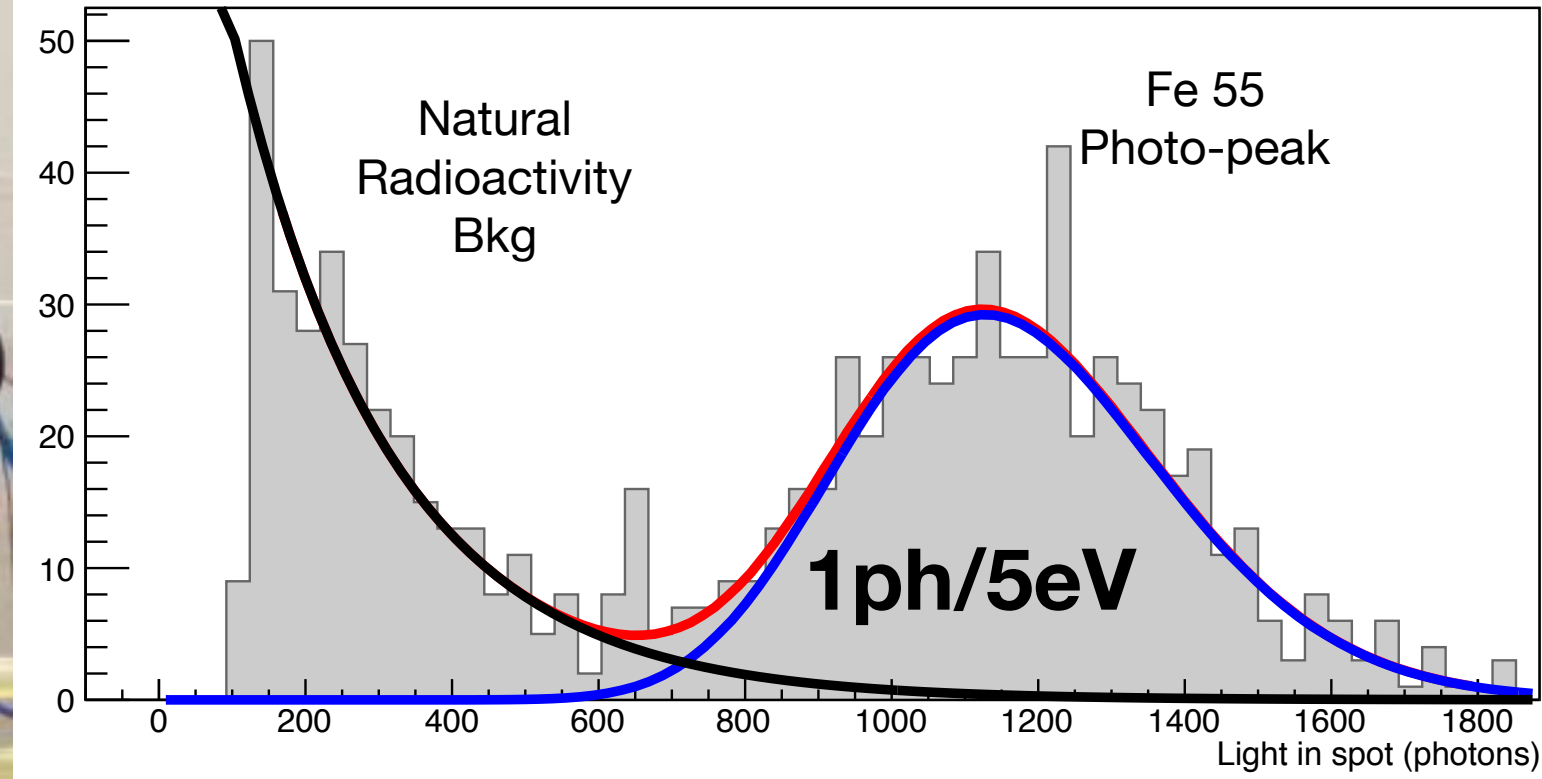
- LEMOn: long term stability, threshold and tracking performance
- MANGO: negative ion study
- LIME: scale to a real demonstrator CYGNO module
- CYGNO TDR

Phase0 - R&D



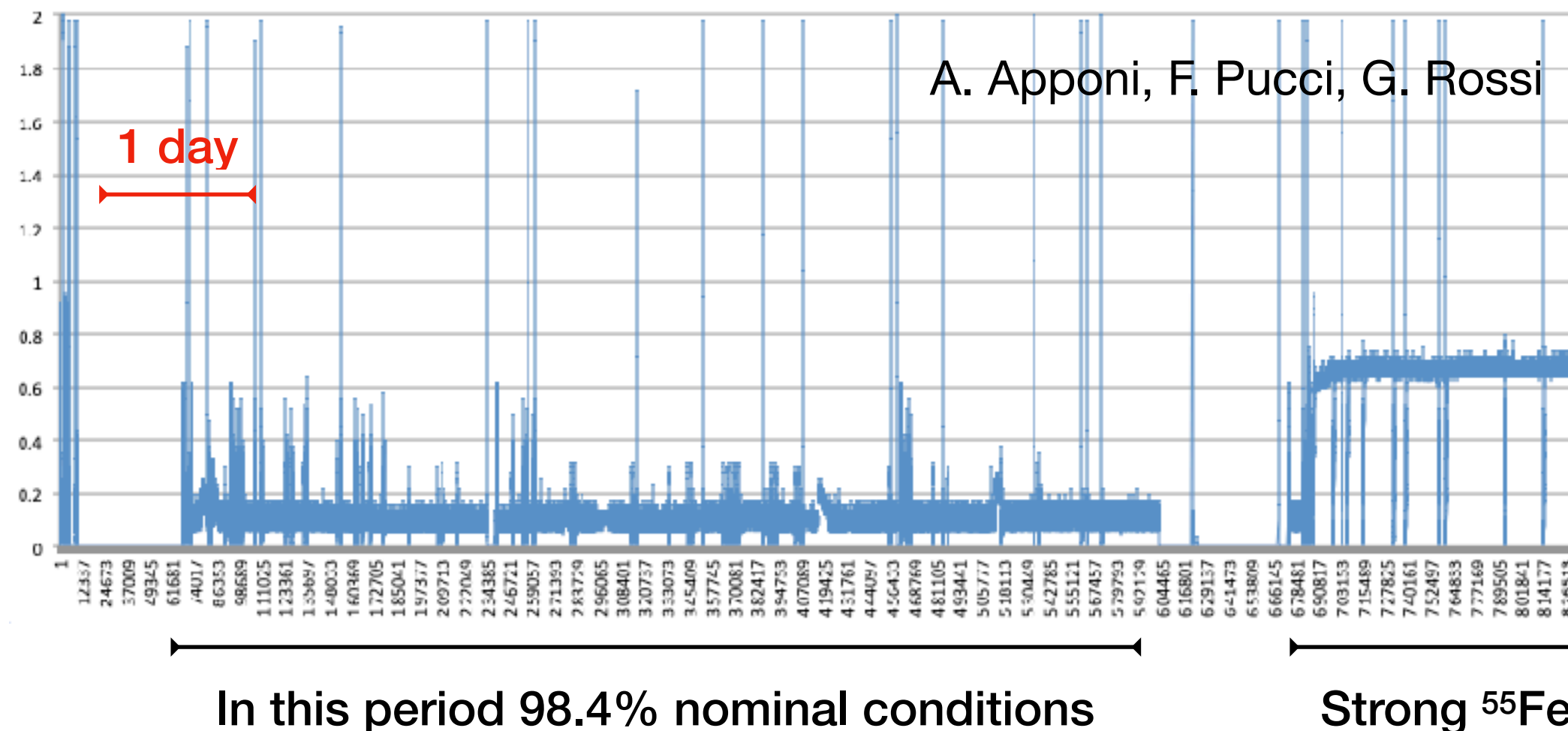
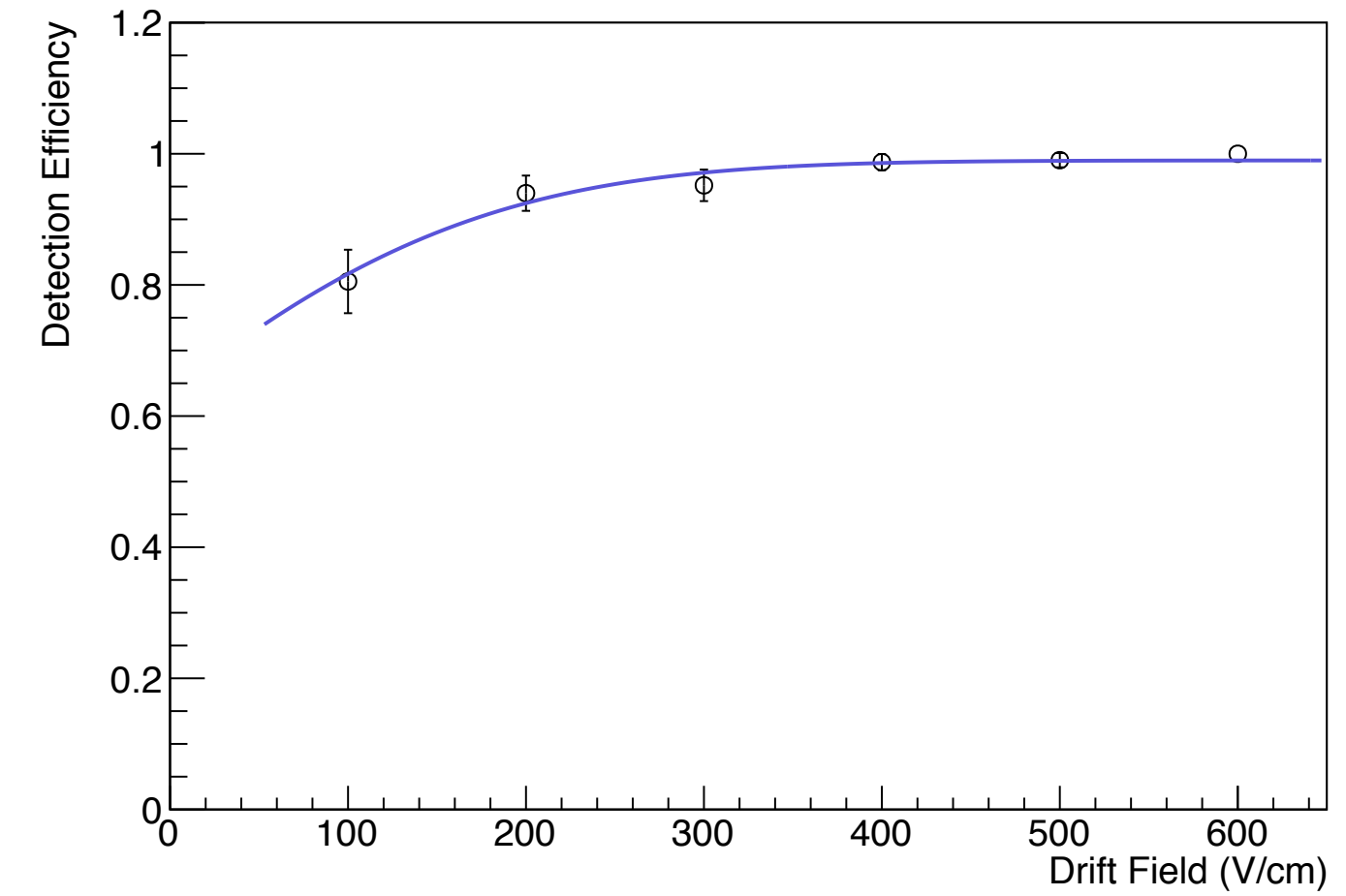
LEMON: Large Elliptical Module Optically readout

- 7 litre sensitive volume
- 25 cm drift
- 20*24 GEM
- 3D printed
- semi-transparent cathode



2 keV energy threshold (conservative) with 18% energy resolution @ 5.9 keV for events at 20 cm drift distance

JINST_024P_0519



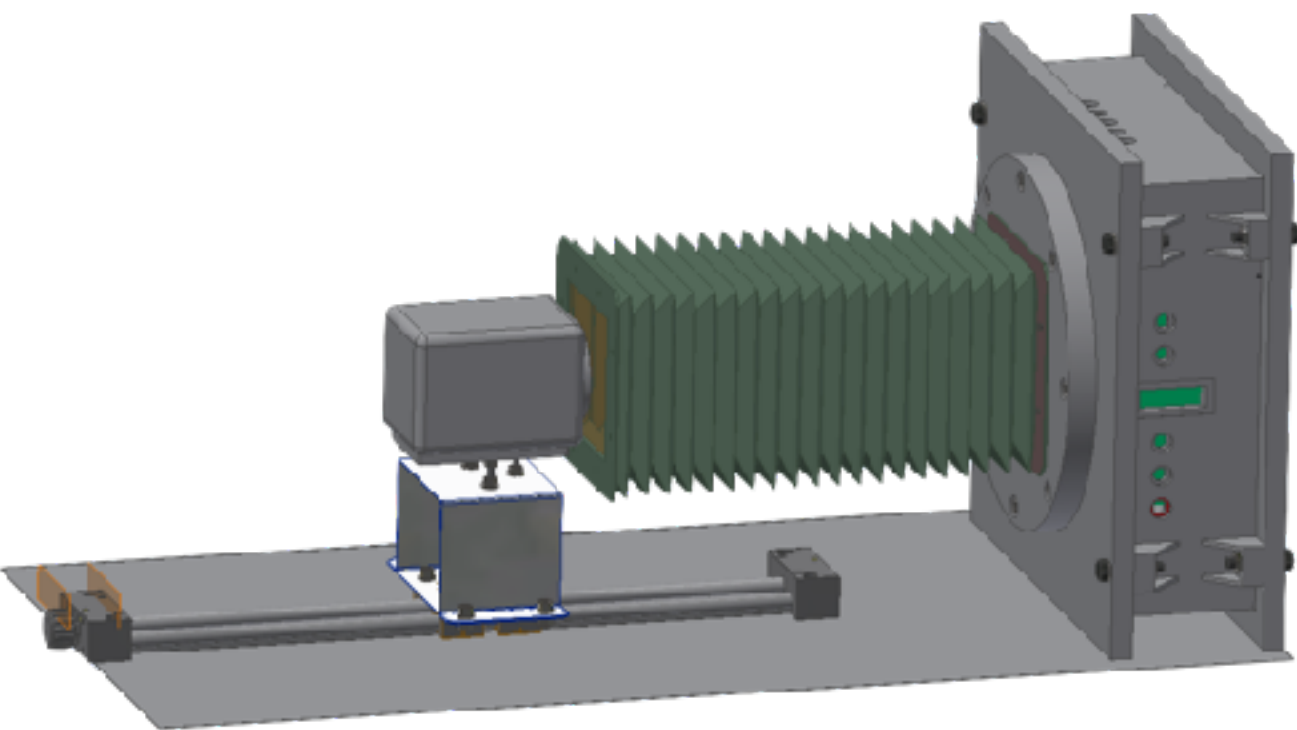
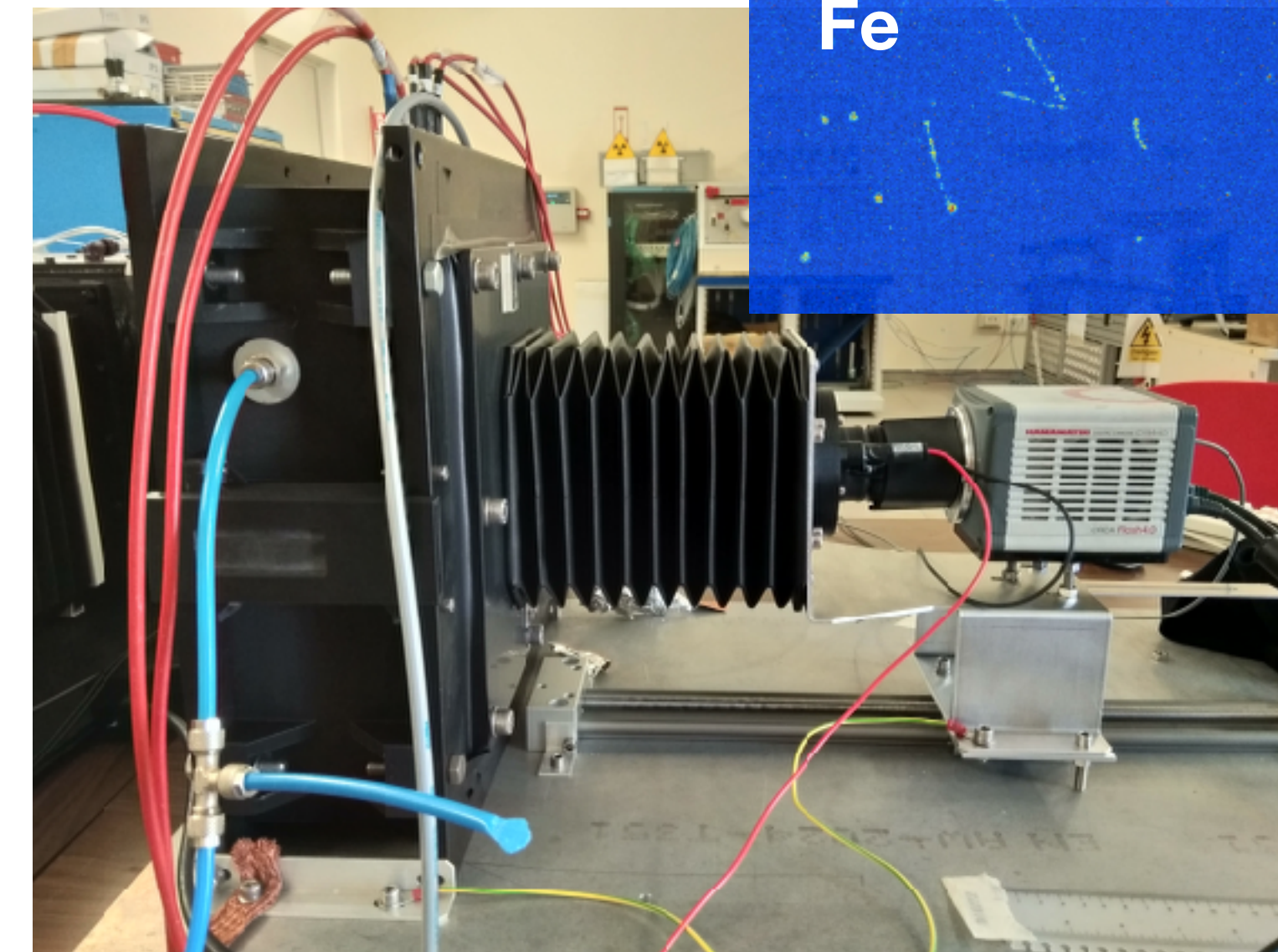
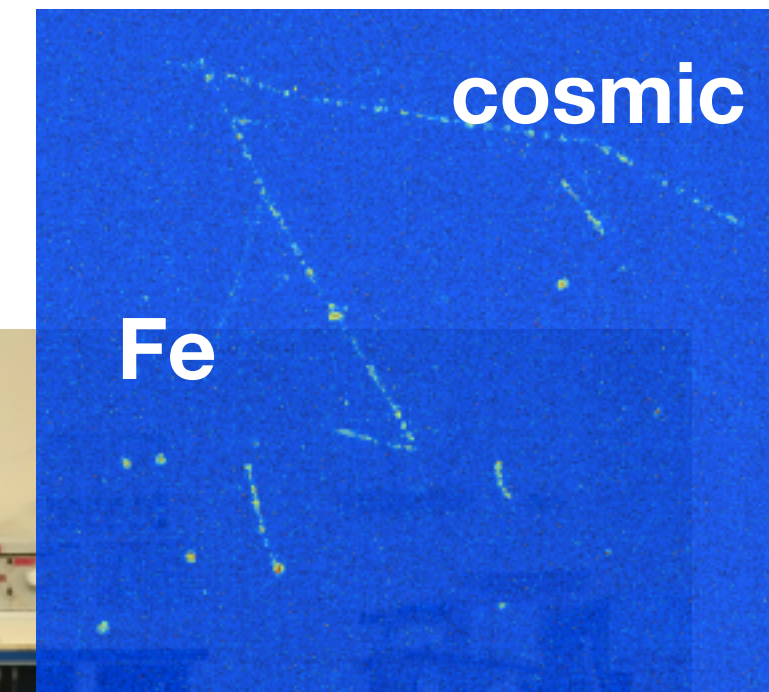
In this period 98.4% nominal conditions

Strong ⁵⁵Fe

A. Apponi, F. Pucci, G. Rossi

1 day

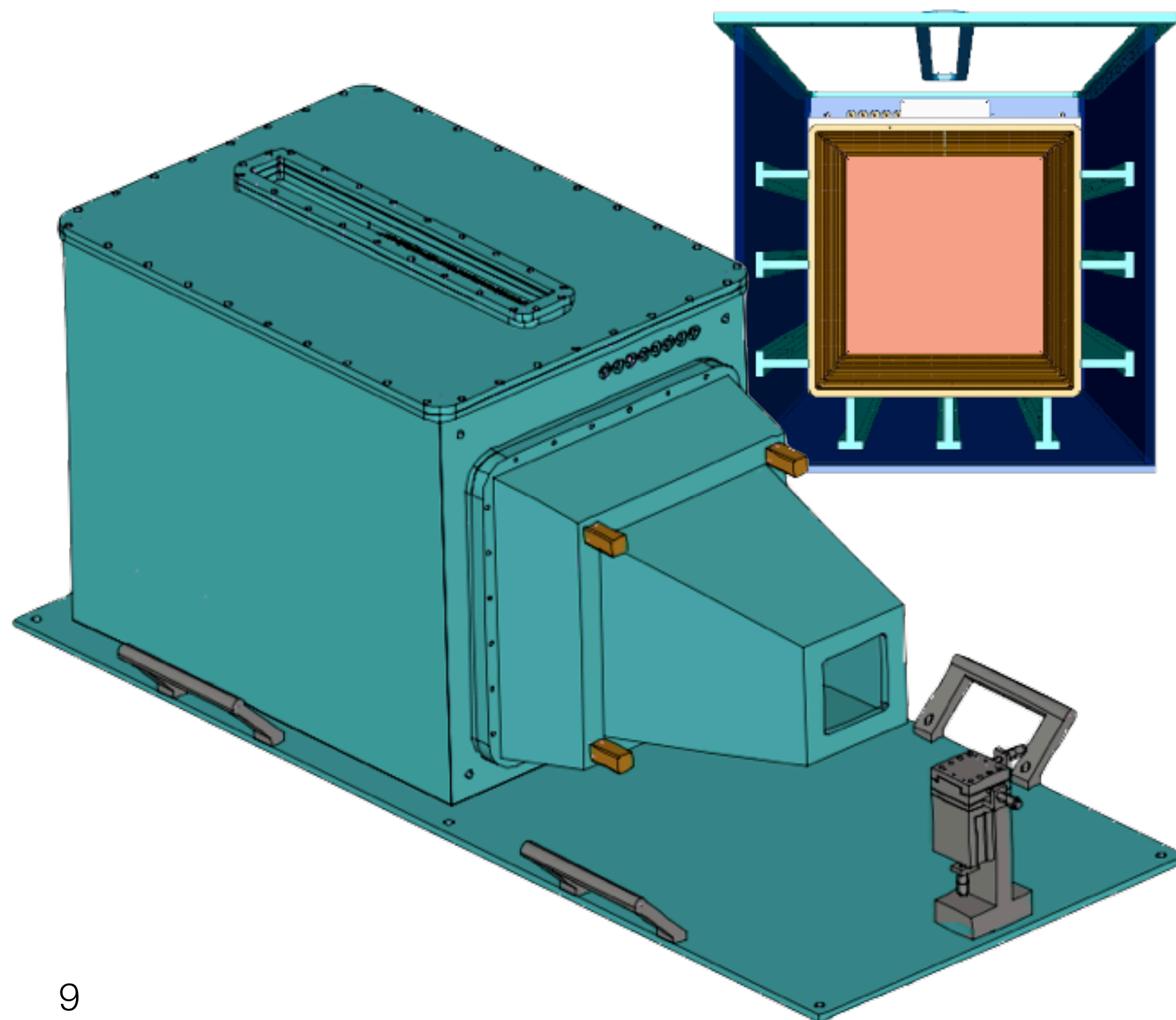
Phase0 - R&D



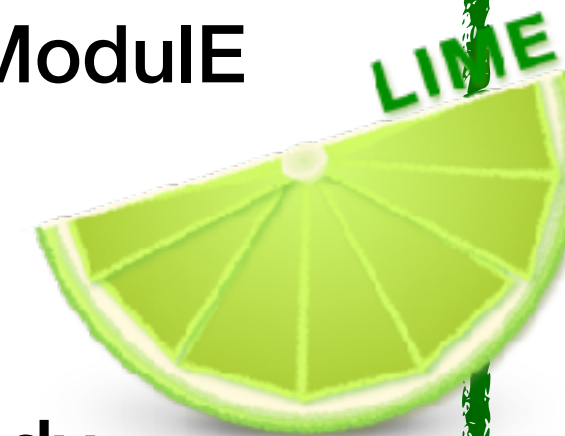
MANGO - Multipurpose Apparatus for Negative ion studies with GEM and Optical readout

- 5 cm drift gap
- THGEM test
- 4 GEM test
- Negative Ion test

C. Capoccia, A. Pelosi, F. Rosatelli, S. Tomassini



LIME: Long Imaging Module



- 50 cm long drift gap
- studying materials
- performing a detailed study, minimisation and simulation of radioactive background;
- gas re-circulation and purification.
- optimisation of PMT/SiPM readout and trigger.
- HV Test

50-liter prototype the delivery is foreseen for half of July!

Tests expected in fall 2019 @ BTF and the in 2020 at LNGS

10/7/2019 @ Palazzi

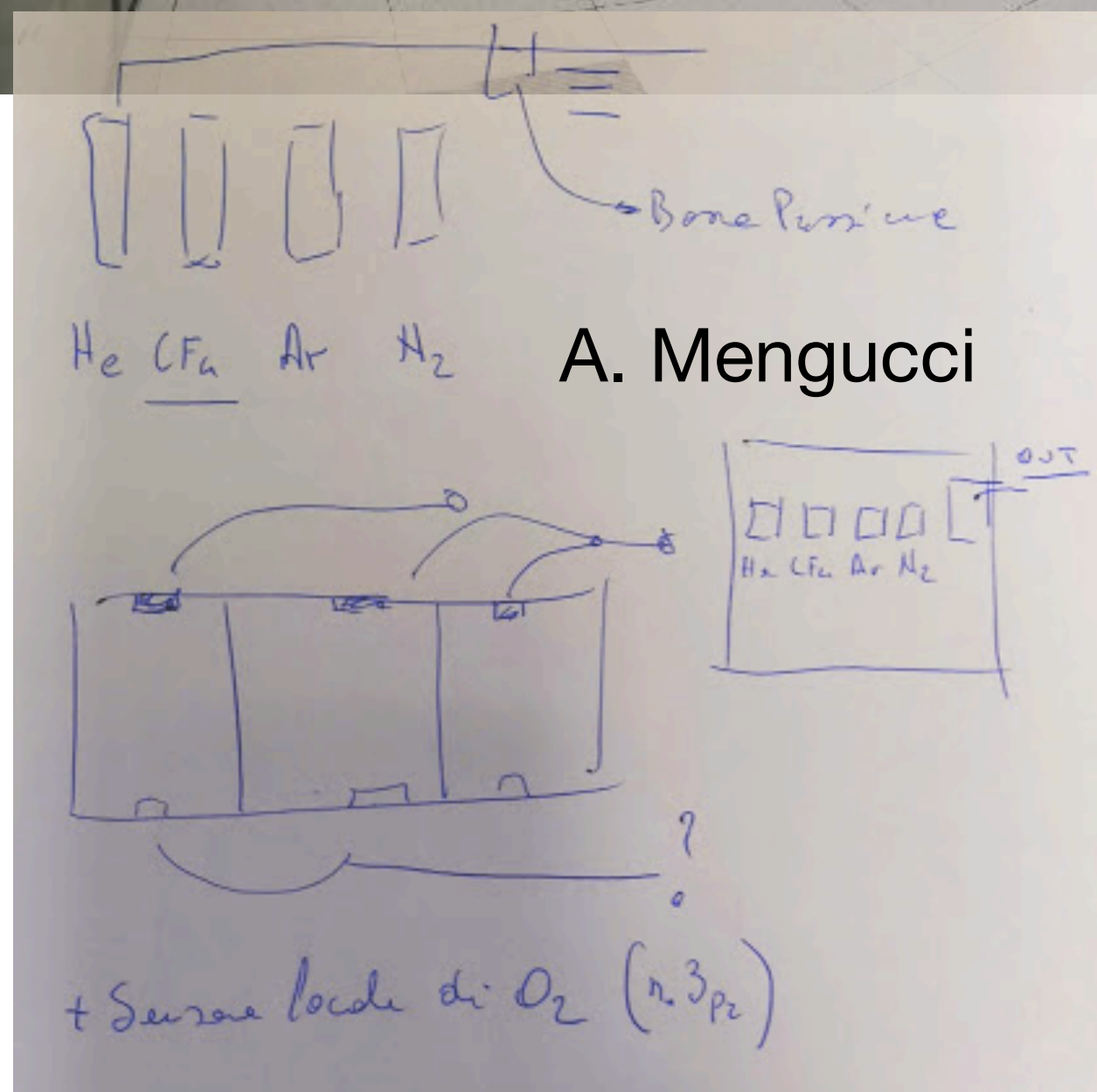
A. Orlandi, E. Paoletti, L. Passamonti, D. Pierluigi, A. Russo

G. Mazzitelli for CYGNO/INITIUM Collaboration

Phase0 - LNF infrastructure

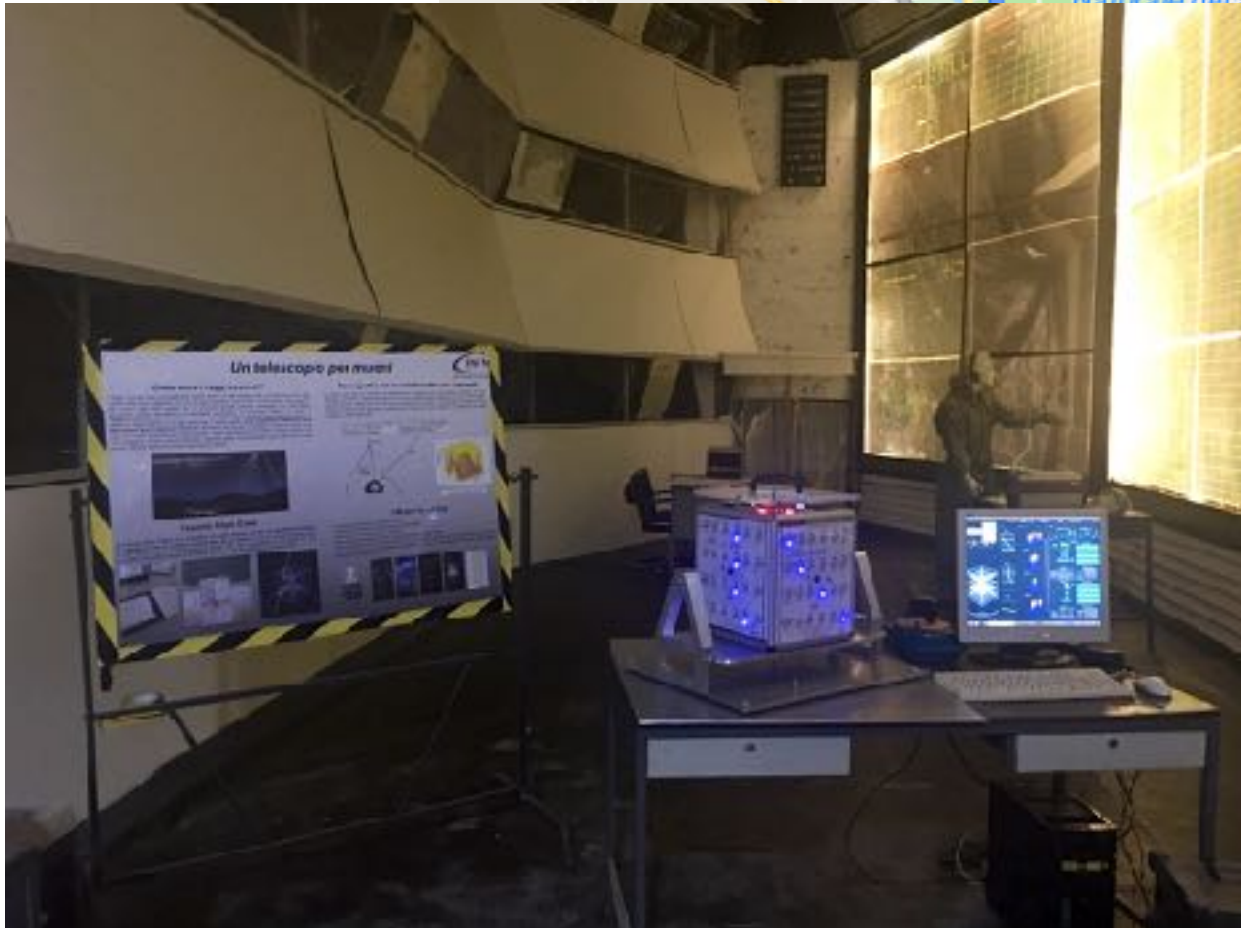
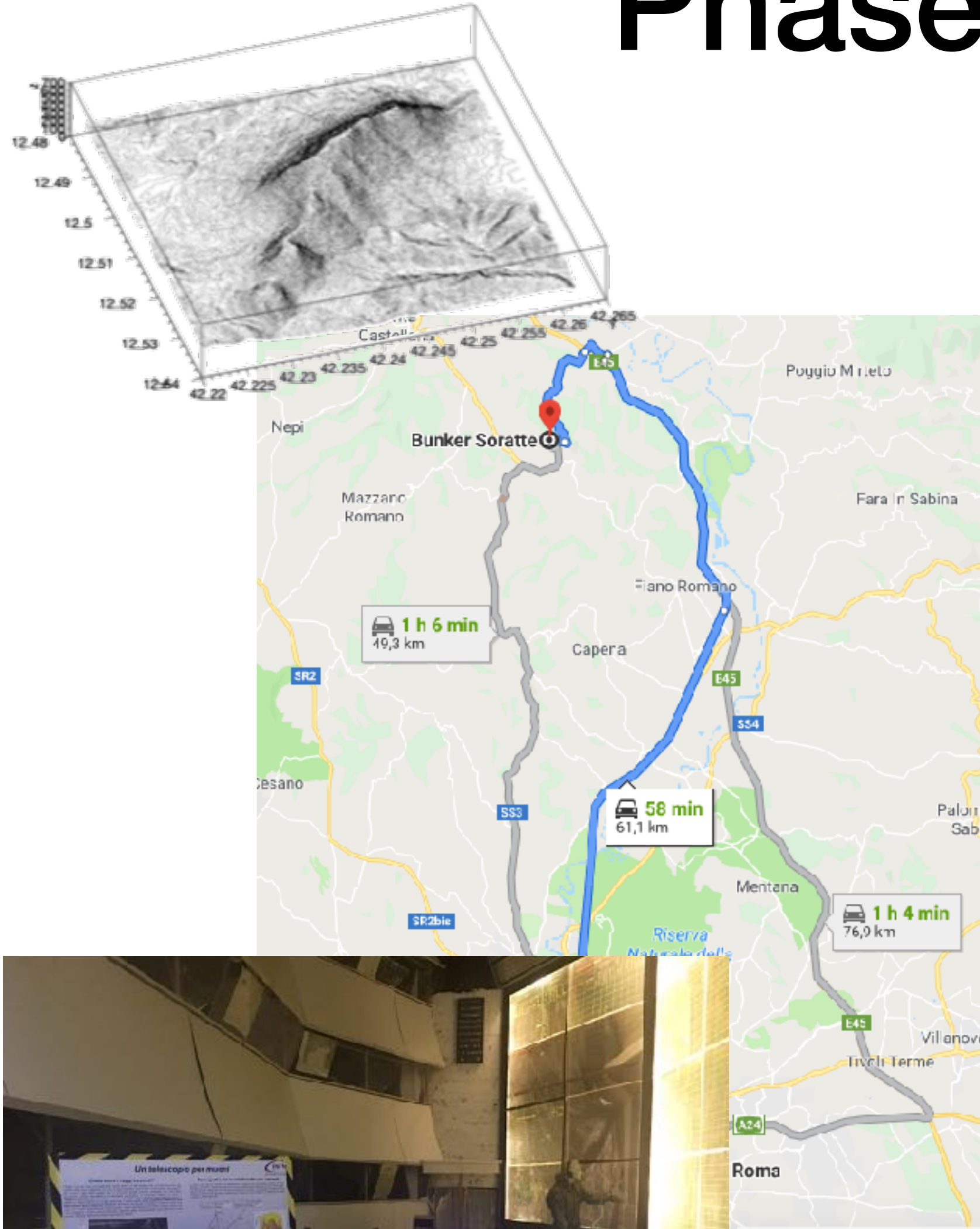


many thanks to MU2E group and in particular to E. Paoletti and F. Marino



clean room
1/1000

Phase1 - Monte Soratte site



- Under M. Soratte, a dismissed bunker partially used as a museum
- Some free galleries could be used as a site for tests under **reduced radioactivity conditions**:
- 200 - 400 m of rock (limestone) in vertical direction, few 10 m in horizontal direction
- cosmic ray measurements on going (LNGS + C. Gustavino), ~ 1/100 w.r.t. outside

- Identified as a possible site for the PTOLEMY experiment
- There is an interest by the CYGNO/INITIUM group for tests of prototypes
- What about building **a facility for tests under reduced environmental radiation** (cosmics + natural radioactivity)?
- Possible short-term plan:
 - site characterisation (cosmics, gamma, neutrons, radon,...) in collaboration with LNGS and **LNF**
 - evaluation of safety issues
 - evaluation of potential interest of other groups (**multidisciplinary** and **interdisciplinary**)
 - evaluation of possibile **public engagement** impact
- Initial costs could be borne by the PTOLEMY & CYGNO/INITIUM group, then?

Phase-0 / CYGNO TDR

Technical Design Report

Esperimento XXX

In questo documento sono descritte le linee guida principali che necessariamente devono essere presenti nella redazione di un Technical Design Report (TDR).

Questo documento è derivato dal template redatto e approvato dal Gruppo di Lavoro "Project Management" dell'Istituto Nazionale di Fisica Nucleare (INFN) ed è declinato tenendo conto delle peculiarità dei Laboratori Nazionali del Gran Sasso (LNGS).

Autore	Verificato da	Approvato da
--------	---------------	--------------

Summary

Lista degli autori.....	4
Executive Summary	4
1. Motivazioni scientifiche.....	4
2. Risultati dall'R&D	4
3. Organigramma Esperimento	4
4. Specifiche e parametri - Overview	4
5. Descrizione Tecnica	5
6. Validazione	6
7. Installazione e Commissioning	6
8. Aspetti HSE	6
9. Radioprotezione	7
10. Gestione del Progetto	7
Fasi del Progetto.....	7
Work Breakdown Structure	7
Cronoprogramma	8
Budget	8
Risks	9
Organizational Breakdown Structure	9

- The requirement to access the LNGS are:
 - preliminary approval of the **CSNII** (half of Sep.)
 - preliminary approval of the **LNGS SCICOM** (begin of Oct.)
 - delivering the final **TDR** document (begin of Dec.)
- Moreover,
 - The LNGS are under **Seveso** safety regulation until LVD and BOREXINO are not removed (end of 2020)
 - The LNGS will assign room for **new experiment** only after a meeting foreseen next year where the proposal will be discussed
- In the meantime, CYGNO have the financial support to be built by INITIUM-ERC that ensure the realizability

Phase-0 / TDR structure

The TDR template requested by LNGS have to describe:

1. Scientific Motivations
2. R&D results
3. Organization
4. Specifications and Parameters
5. Technical Description
6. Validation
7. Installation and Commissioning
8. HSE-Health and Safety at Work aspects
9. Radiation Protection
10. Project Management

- **Spokesperson:** E. Baracchini (GSSI), D. Pinci (RM1-INFN)
- **Technical Coordinator:** G. Mazzitelli (LNF-INFN)
- **Engineering Coordinator:** S. Tomassini (LNF-INFN)
- **Services Coordinator:** D. Pinci (RM1-INFN)
- **Read Out Coordinator:** L. Benussi (LNF-INFN)
- **Physics Coordinator:** E. Baracchini (GSSI-INFN)
- **Simulation Coordinator:** G. Cavoto (RM1-INFN)
- **DAQ & Analysis Coordinator:** A. Messina (RM1-INFN)

Local Responsible: to be define

Site Manager: to be define

GLIMOS: to be define

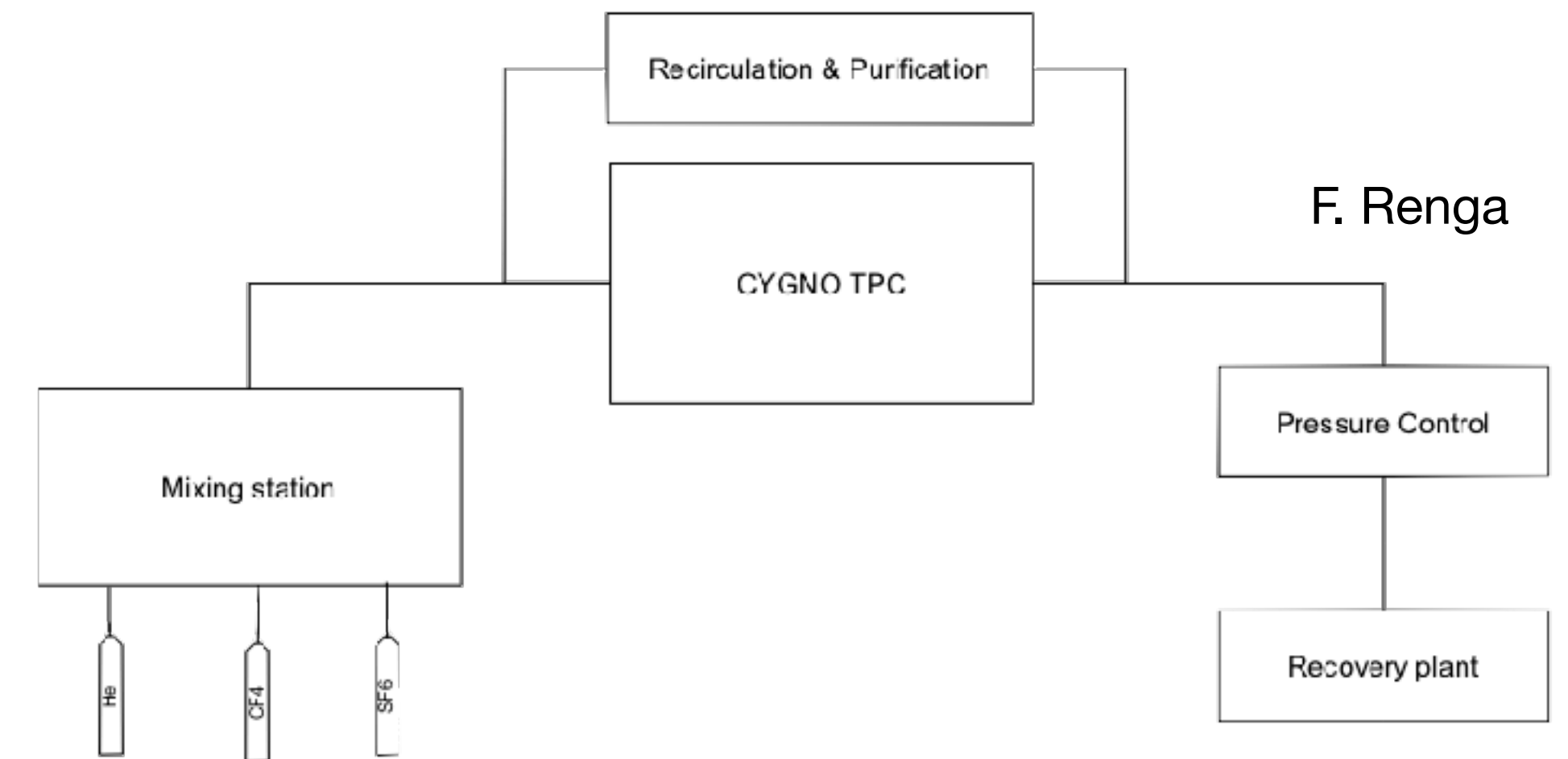
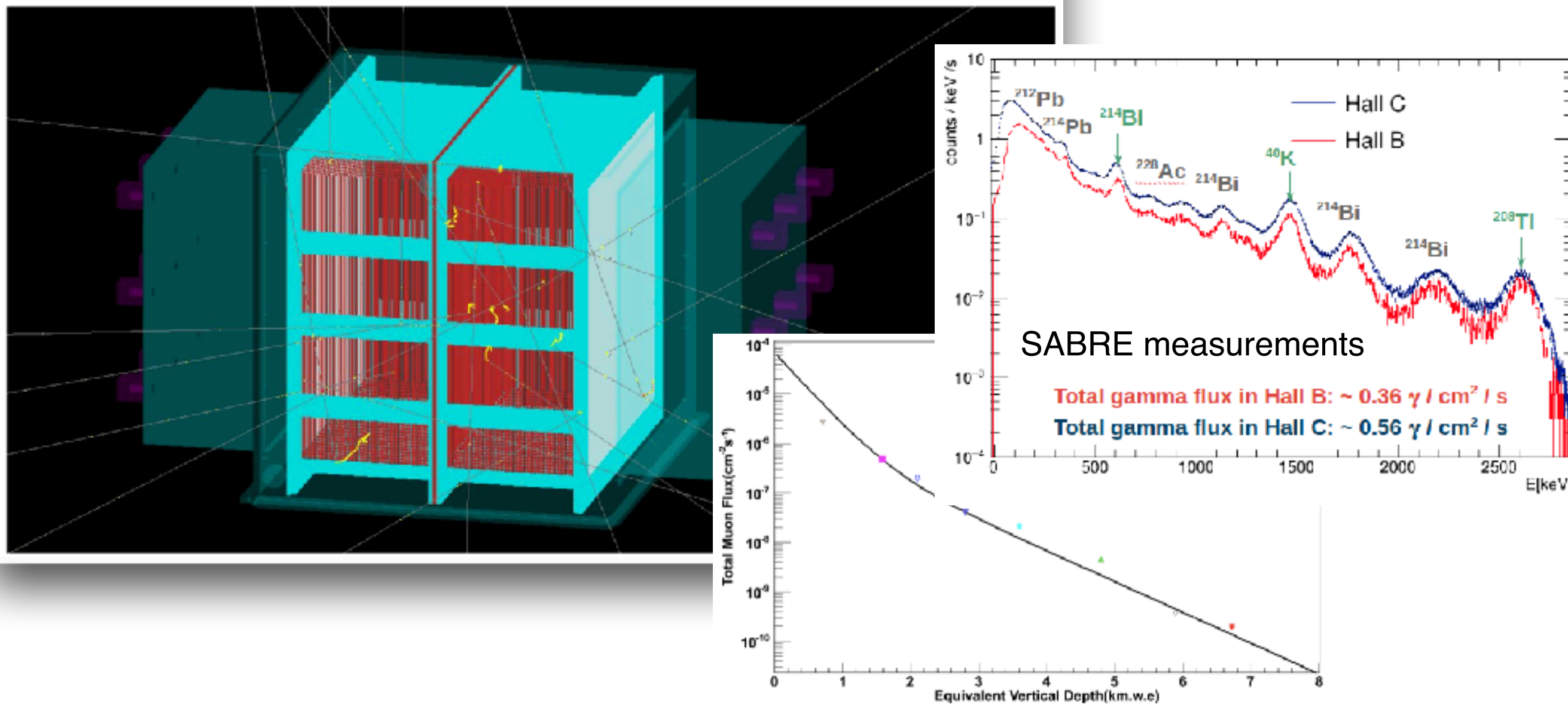
RAE: to be define

done or easy to complete; need attention; to be done

critical issues

- **internal background:**
gas radioactivity and materials: materials choice and gas purification
- **external background:**
gamma, neutrons, and comics: shielding (water+Cu+Pb?+...)

Example: ^{14}C decays in the gas



CYGNO gas system (He, CF_4 , SF_6) block diagram executive design and construction under evaluation

G. Cavoto, F. Bellini, A. Messina, G. D'Imperio

material budget radioactivity

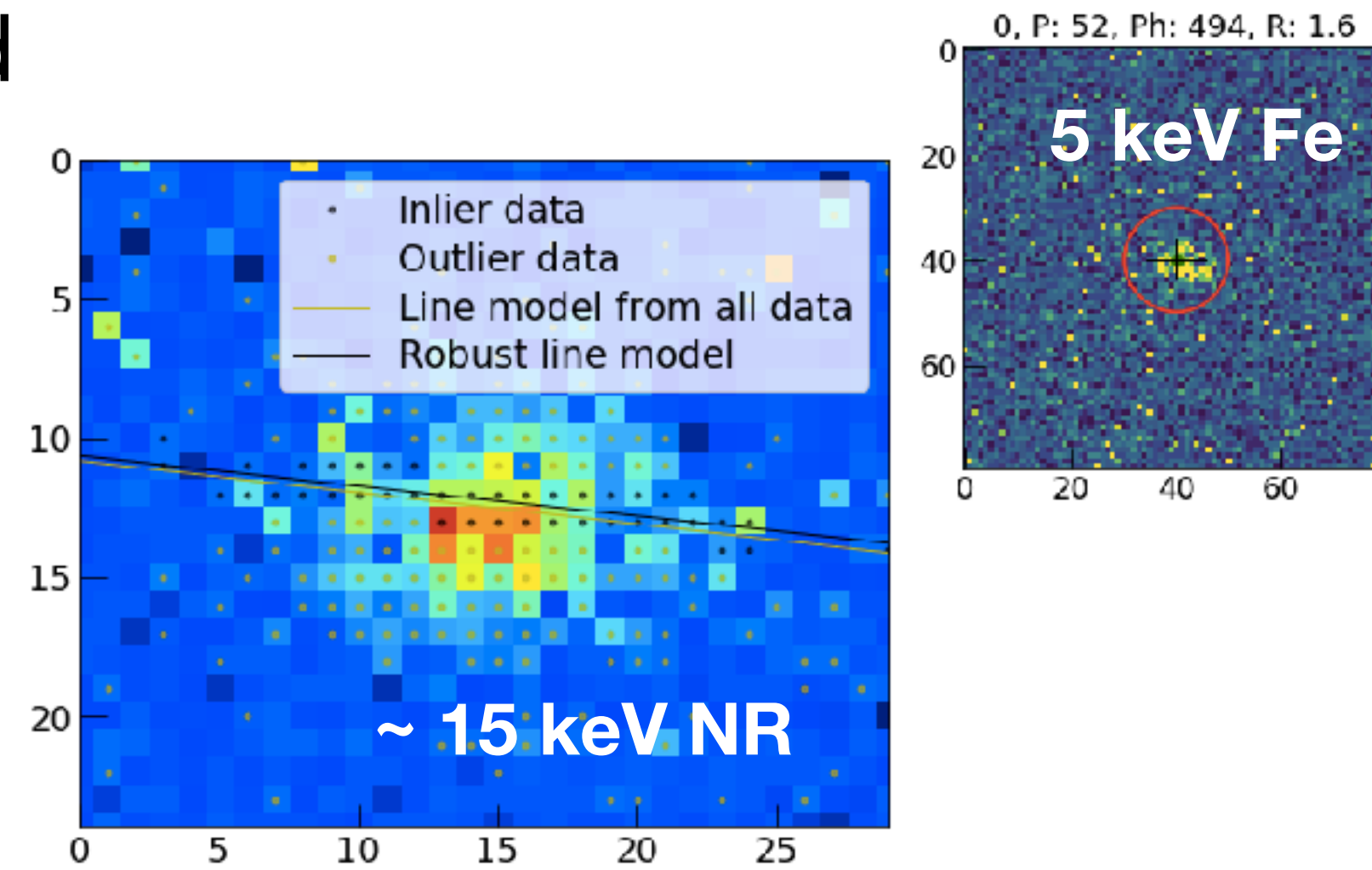
DAQ/Data analysis

The effective energy threshold is determinate by the ability to identify candidate over background

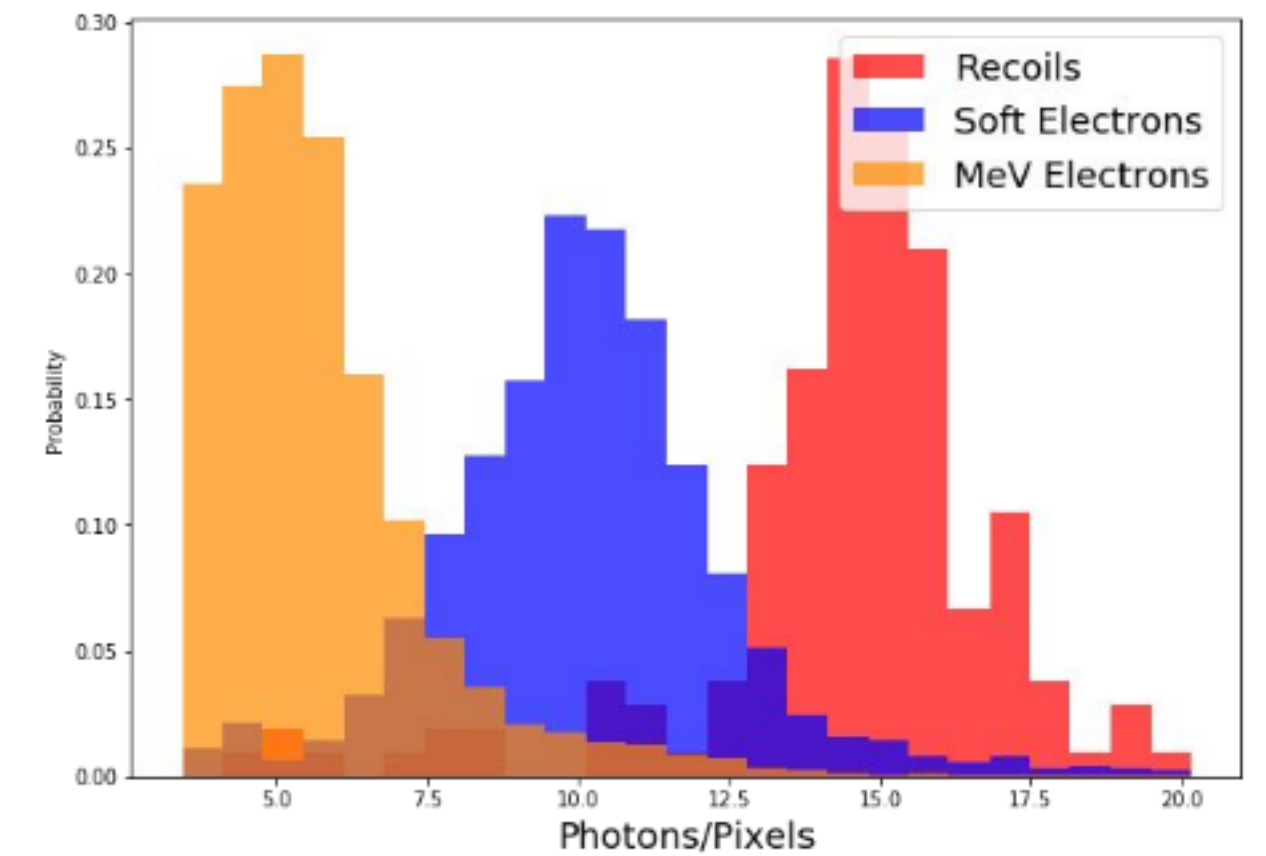
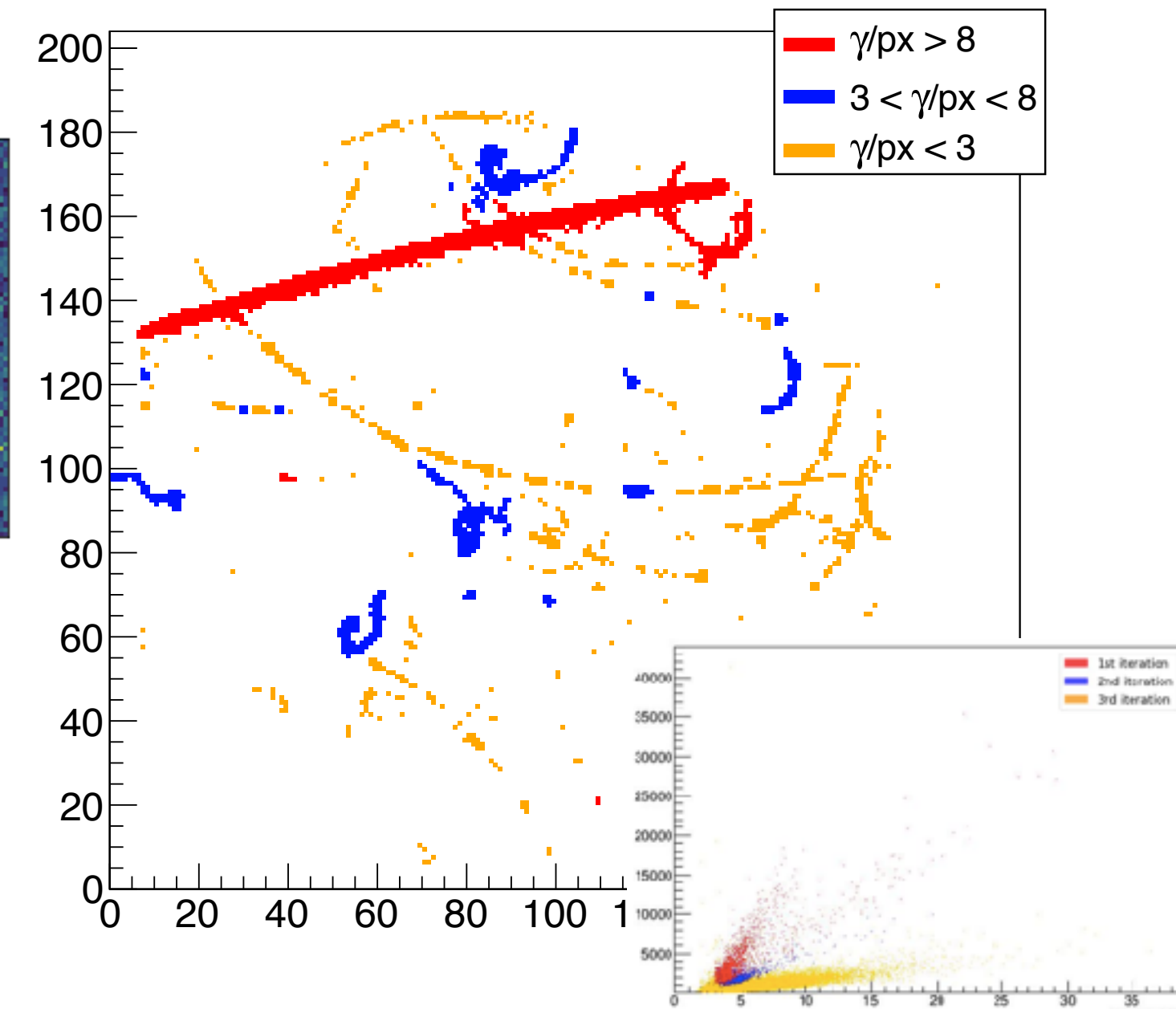
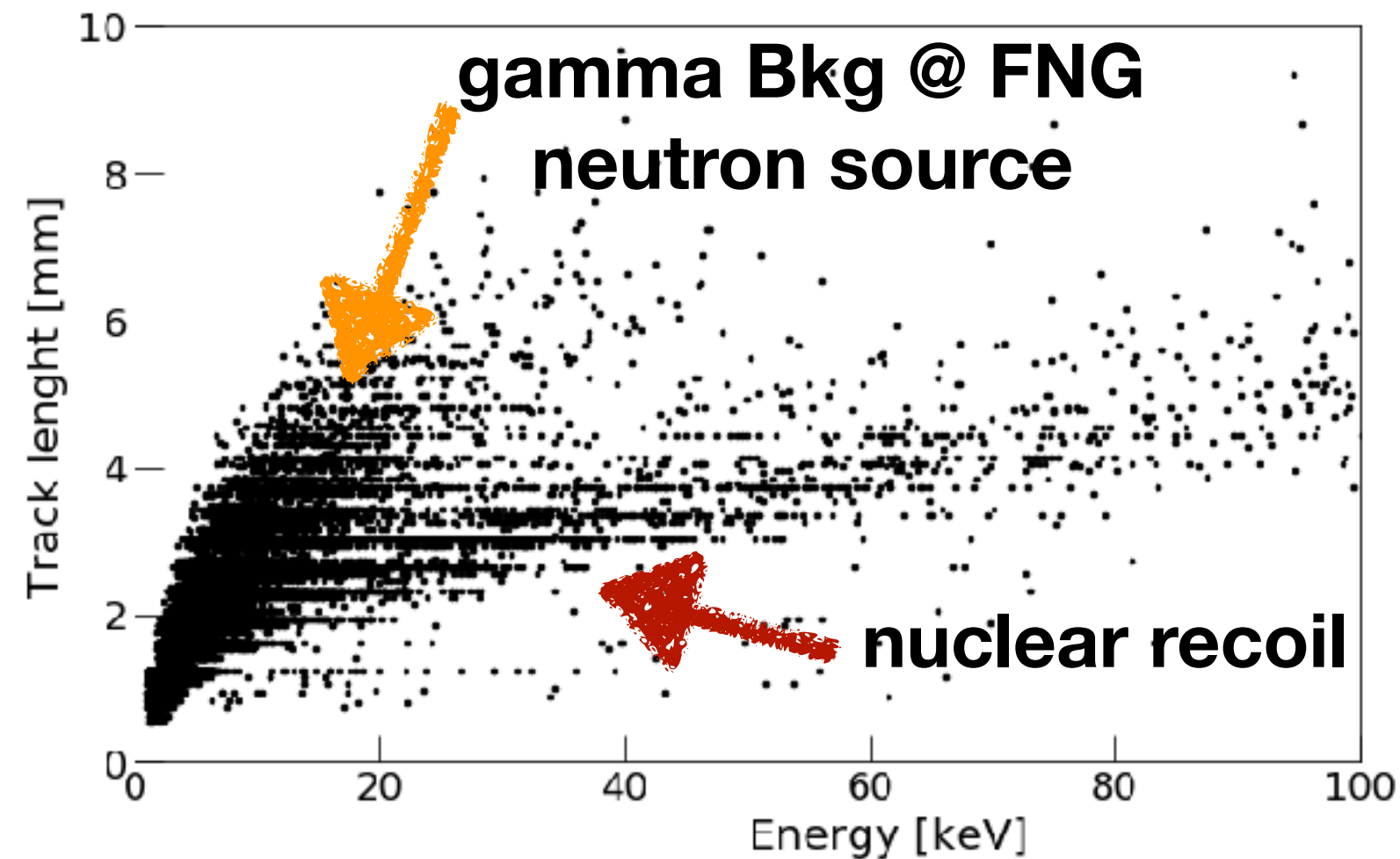
- Particle Identification (PID)
- directionality & head tail
- topology (sparsity, curly, etc)

Moreover, a throughput of \sim GB/s (strongly dependent on underground background condition) is foreseen and a first level real time analysis is need in order downsample data

- front end farm, GPU/FPGI
- machine learning tools



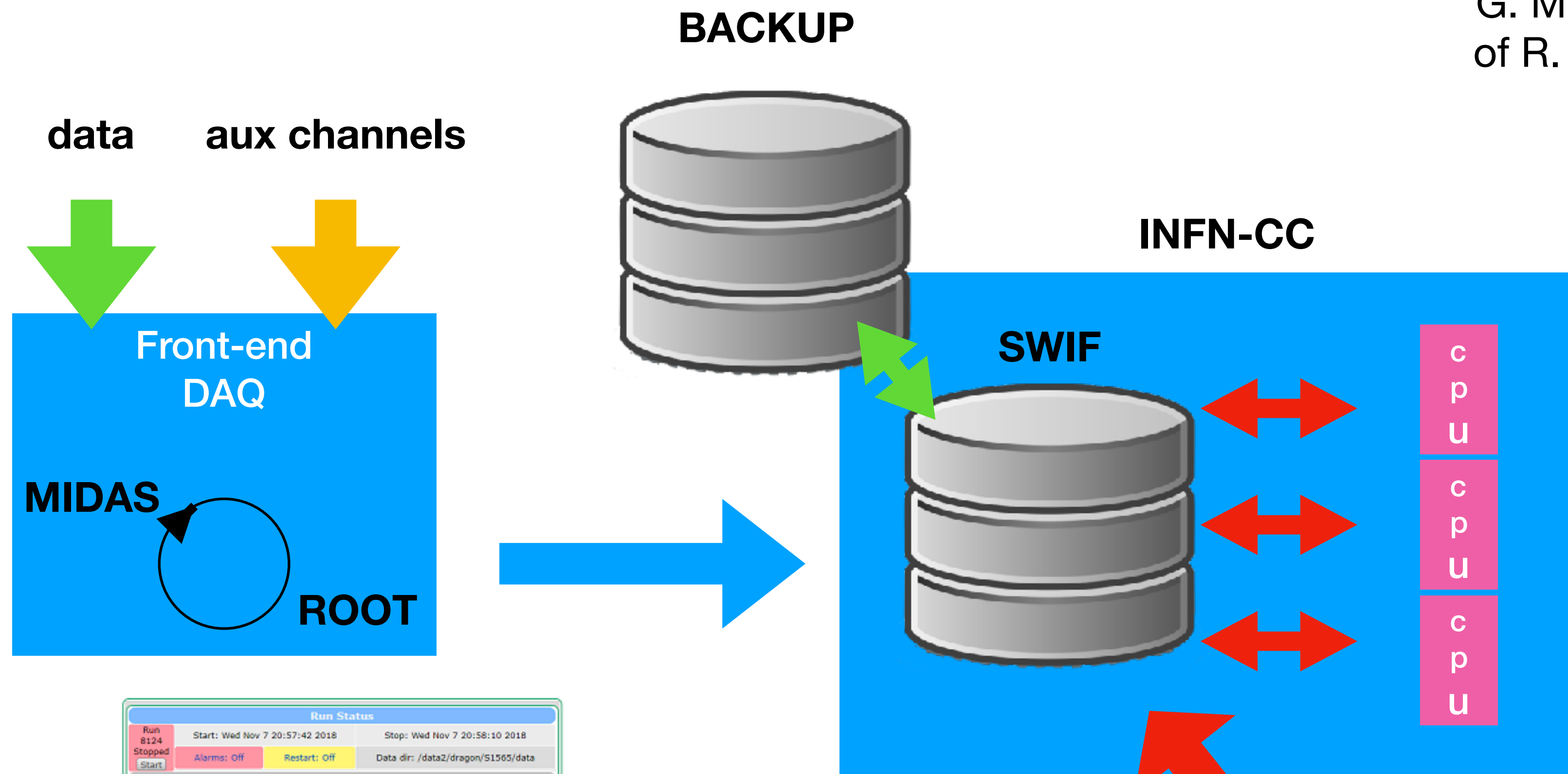
clustering_run831_Nsig_1_Mcut_350_Pcut_0_scale_4_close_2_nccs.txt



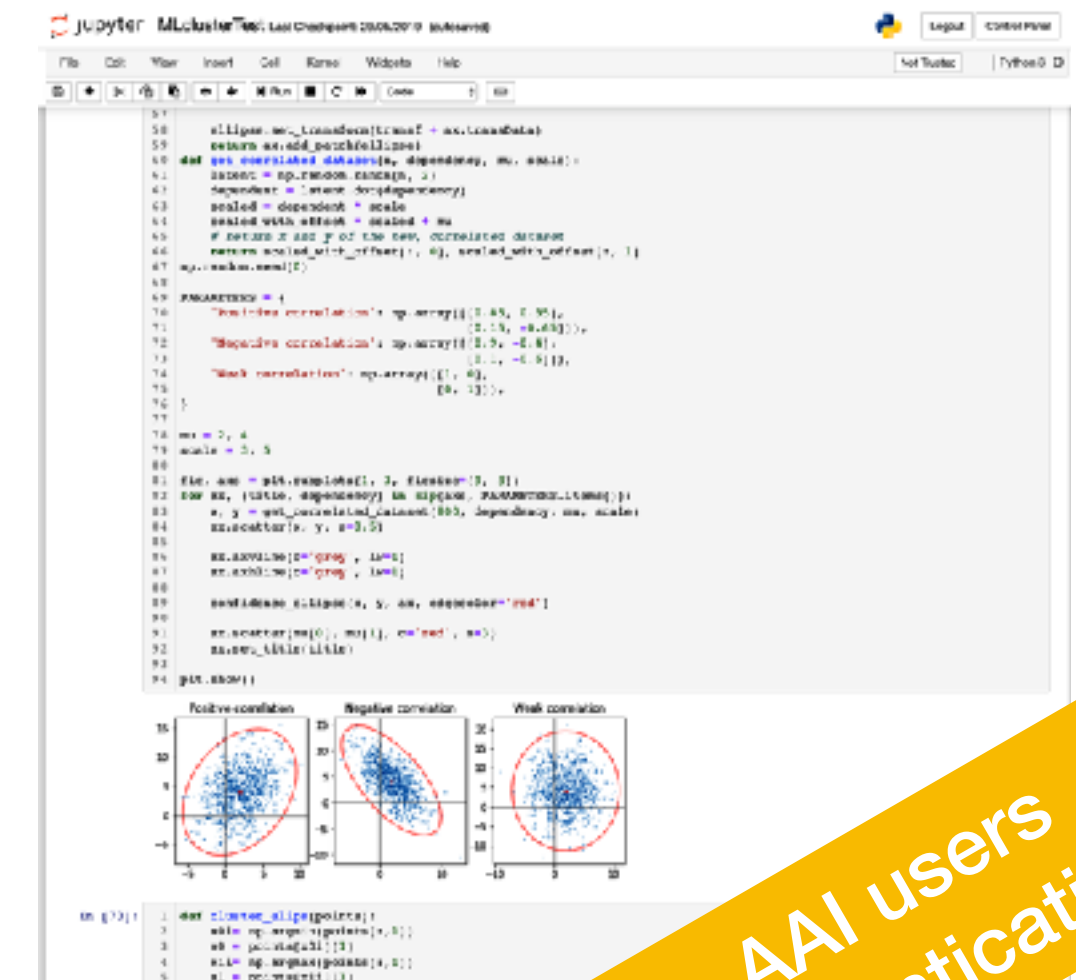
i2DBSCAN classification

Phase0/1 - INFN-CC @ LNGS-LNF

G. Mazzitelli thanks to the support of R. Gargana, D. Maselli, S. Stalio



Jupyter notebook: Python3, PyROOT, ROOT



AAI users authentication

Run Status				
Run 8124	Start: Wed Nov 7 20:57:42 2018	Stop: Wed Nov 7 20:58:10 2018		
Stopped	Alarms: Off	Restart: Off	Data dir: /data2/dragon/51565/data	
1552340687 14:44:47.821 2019/03/11 [thresh,INFO] Program thresh on host smaug stopped				
Equipment				
Equipment +	Status	Events	Events[/s]	Data[MB/s]
HeadVME	Idle	0	0.0	0.000
HeadScaler	Idle	2.754M	1.0	0.000
TailVME	Idle	0	0.0	0.000
TailScaler	Idle	0	0.0	0.000
Epics	Frontend stopped	0	0.0	0.000
Wiener	OK	0	0.0	0.000
Logging Channels				
Channel	Events	MB written	Compr.	Disk Level
#0: run8119.mid	0	0.000	0.0%	77.8%
Lazy Label	Progress	File Name	# Files	Total
g-drive	0%	run6895.mid	34	0.0%
Clients				
fe_head [lxdragon01.triumf.ca]	mhttpd [smaug.triumf.ca]	mserver [smaug.triumf.ca]		
Logger [smaug.triumf.ca]	fewiener [smaug.triumf.ca]	fevScaler [smaug.triumf.ca]		
fe_tail [lxdragon02.triumf.ca]				

MIDAS run control and slow control

User HTTP queries



Phase0 - dependency

- construction work <— clean room / control room <— **design**
- electrical systems <— **gas system**, cameras, HV...
- Heating, Ventilation and Air Conditioning (HVAC)
- water, compressed air & pressurised equipment <— camera cooling, DAQ cooling
- lifting and transport systems <— **design** & installation
- supervision and control <— cameras, oxygen monitor, etc
- IT <— DAQ (in cave), back end (computing center LNGS)
- radiation protection <— calibration
- mechanics <— design <— **shielding**
- electronics <— **DAQ**



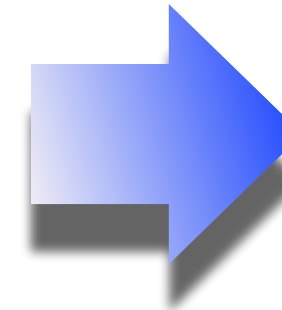
TDR - HSE-Health and Safety at Work aspects

- PRA HRA, etc <— specification and certification <— gas system
- PRA HRA, etc <— design <— scheldieg
- ...

Phase1 Effort 2020

anagrafica 2020

anagrafica 2019



Vai alla sezione: LNF LNGS RM1

SEZIONE	NOME COGNOME	TIPO	CONTRATTO	QUALIFICA	RICERCATORI	TECNOLOGI	TOT. PERS.	FTE	FTE / PERS.		
LNF	Bedogni Roberto				x			15			
	Benussi Luigi				x			10			
	Bianco Stefano				x			20			
	Maccarrone Giovanni				x			30			
	Mazzitelli Giovanni				x			60	+ 40 INITIUM		
	Piccolo Davide				x			20			
	Tomassini Sandro					x		10	+ 10 INITIUM		
LNF					1.55 fte	6 pers.	0.1 fte	1 pers.	7	1.7	0.236
LNGS	Baracchini Elisabetta				x			20	+ 80 INITIUM		
LNGS					0.2 fte	1 pers.	0 fte	pers.	1	0.2	0.200
RM1	Cavoto Gianluca				x			20	+ 10 INITIUM		
	D'Imperio Giulia				x			50			
	Di Marco Emanuele				x			10	+ 10 INITIUM		
	Marafini Michela				x			20			
	Messina Andrea				x			30			
	Pinci Davide				x			40	+ 10 INITIUM		
	Renga Francesco				x			30	+ 10 INITIUM		
RM1					2 fte	7 pers.	0 fte	pers.	7	2.0	0.286
TOTALE					3.75 FTE	14 PERS.	0.1 FTE	1 PERS.	15	3.85	0.257

1.7 INITIUM

activity partially founded by European Research Council (ERC) grant agreement No 818744

	Appartenenza	Qualifica	FTE CYGNO	FTE INITIUM
Baracchini E.	GSSI-LNGS	Professore	0.20	0.80
Dho G.	GSSI-LNGS	PhD		1.00
PhD 1	GSSI-LNGS	PhD		1.00
PhD 2	GSSI-LNGS	PhD		1.00
Postdoc	GSSI-LNGS	Postdoc		1.00
Bedogni R.	LNF	Ricercatore	0.05	
Benussi L.	LNF	Ricercatore	0.10	
Bianco S.	LNF	Primo Ricercatore	0.20	
Caponero M.	LNF	Primo Ricercatore	0.20	
Maccarone G.	LNF	Primo Ricercatore	0.40	
Mazzitelli G.	LNF	Primo Ricercatore	0.60	0.40
Piccolo D.	LNF	Primo Ricercatore	0.20	
Saviano G.	LNF	Ricercatore	0.20	
Tomassini S.	LNF	Tecnologo	0.10	0.10
Cavoto G.	Roma1	Ricercatore	0.20	0.10
D'Imperio G.	Roma1	Assegnista	0.50	
Di Marco E.	Roma1	Ricercatore	0.10	0.10
Marafini M.	Roma1	Ricercatore	0.20	
Messina A.	Roma1	Ricercatore	0.30	
Pinci D.	Roma1	Ricercatore	0.40	0.10
Renga F.	Roma1	Ricercatore	0.30	0.10
Iacoangeli F.	Roma1	Tecnologo	0.20	
Petrucci F.	Roma3	Ricercatore	0.20	
Totale			4.65	5.70

Phase0 → Phase1 main activities

ORCA-Fusion CAMERA SPECS

LOW NOISE AND EXCEPTIONAL
READOUT NOISE UNIFORMITY

HIGH RESOLUTION
2304 x 2304
5.3 Megapixels

HIGH SPEED
100 fps
At 2304 x 2048 ROI

DYNAMIC RANGE
21 400:1

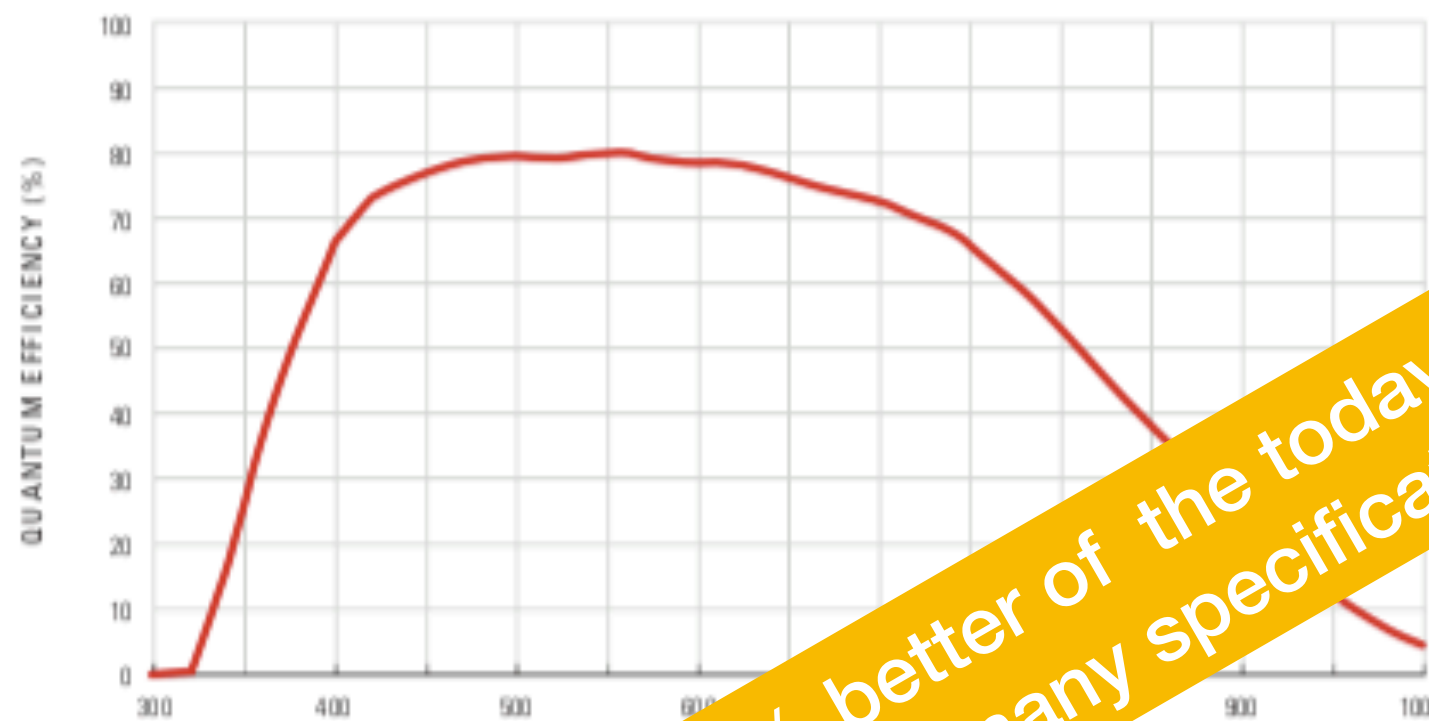
PIXEL SIZE
6.5 μm x 6.5 μm

READOUT NOISE
0.7 electrons rms
Ultra-quiet Scan

PRNU
0.06 % rms
@ 7500 electrons

DSNU
0.3 electrons rms

PEAK QE
80%



~ 30% better of the today camera
on many specification

- sCOMS sensor (low cost and low radioactivity)
- time resolved sensors
- optical lens
- DAQ
- shielding
- negative ion
- echo friendly gas
- low radioactivity materials (GEM, etc)
- ...

Phase1 Budget

Request @ CSNII ~ 300 k€/3years (related to R&D Phase2 and cost not fundable by INITIUM-ERC)

- DAQ study and development
- material test
- GEM test
- structural monitoring
- Preliminary Risk Evaluation
- gas eco-friendly

Budget INITUM (overhead subtracted)

- 500 k€ for detector contraction (5 years)
- 200 k€ for personnel at LNF (2 years * 2 persons)
- 600 k€ for personel at GSSI (PHD, ecc)



any help and suggestions are welcome ...