Istituto Nazionale di Fisica Nucleare

Attività di Gruppo III

F. Noferini

Esperimenti di G3 a B0

Linee di ricerca di CSN3 (*esperimenti a Bologna*):

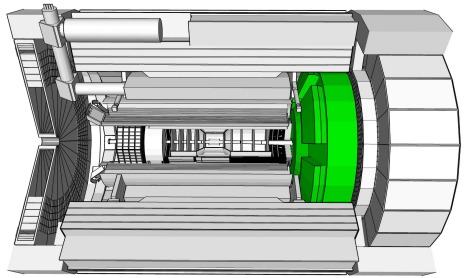
1) Quark and Hadron Dynamics (**EIC_NET → EPIC nel 2025**)
2) Phase Transitions of Nuclear and Hadronic Matter (**ALICE**)
3) Nuclear Structure and Reaction Dynamics
4) Nuclear Astrophysics and Interdisciplinary Researches(**n_TOF, PANDORA**)
5) Symmetries and Fundamental Interactions (**FAMU**)
6) Applications and societal benefits (**FOOT**)

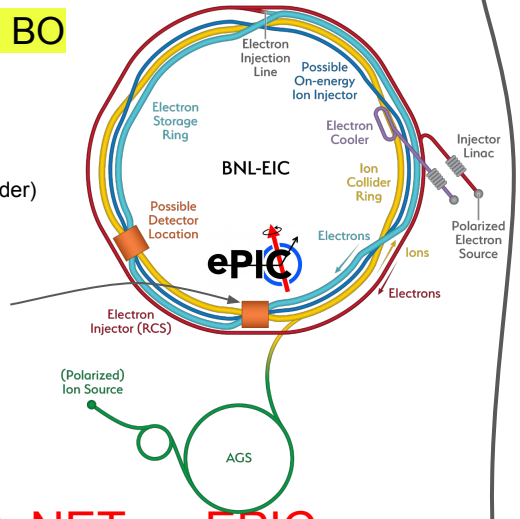
the experiment

ePIC

at the EIC
(Electron-Ion Collider)

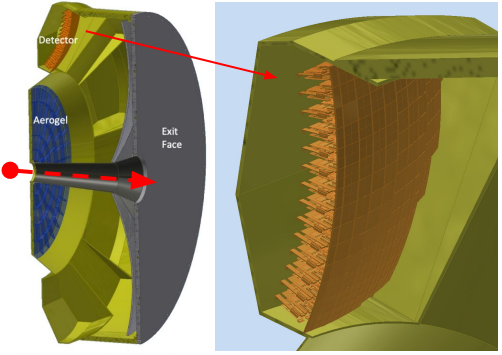
ePIC @ BO





big news: EIC_NET → EPIC

approvato dalla CSN3 passaggio
a sigla di esperimento dal 2025



the ePIC dual-radiator RICH detector

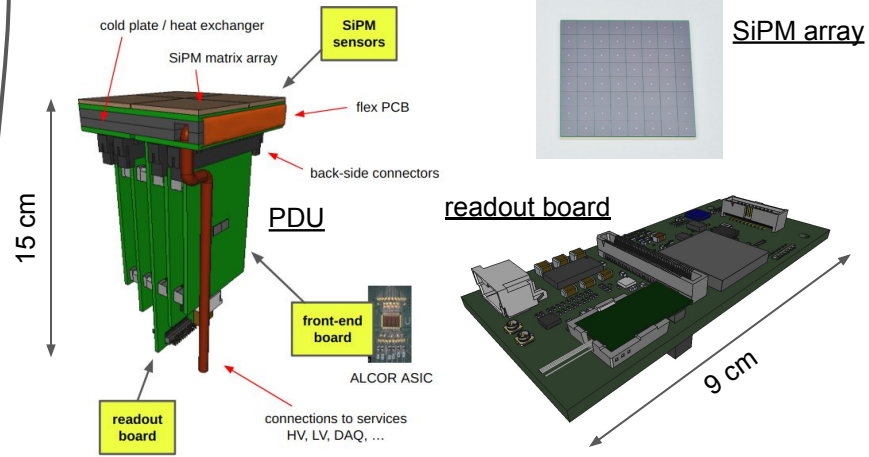
<u>congratulations RN</u>
(P.Antonioli) for the important step

<u>strong BO responsibilities</u>
for the design and construction
of the forward RICH detector

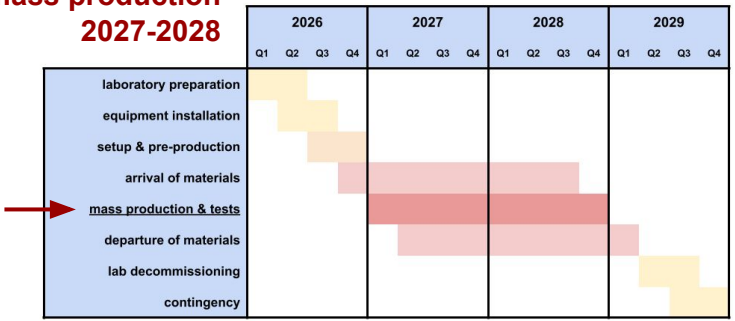
<u>growing BO team</u> (> 6 FTE)
Achari, Agrawal, Antonioli, Bellini,
Falchieri, Garbini, Giacalone, Khuntia,
Jacazio, Noferini, Paladino,
Preghenella, Rignanese, Rubini
(+ 1 PhD + 1 AdR in arrivo)

Bologna responsibilities for the dRICH construction

- construction and test of Photodetector Units (> 1000 PDUs)
- construction and test of Readout Boards (> 1000 RDOs)
- selection and procurement of SiPM sensors (> 300 k SiPM)
- supervision of SiPM QA tests



mass production 2027-2028



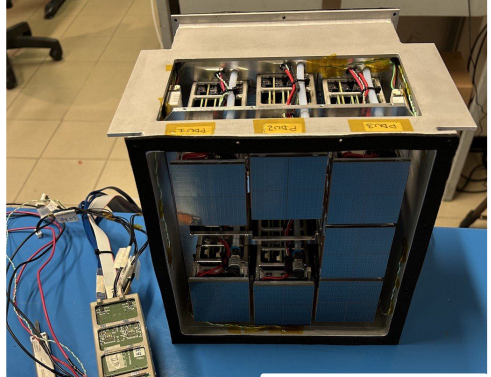
planning discussed with the Director, who supports the initiative (thanks)

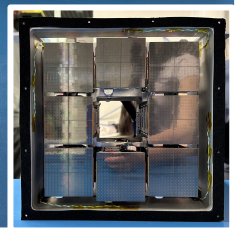
ePIC dRICH prototype on the CERN-PS T10 beam line

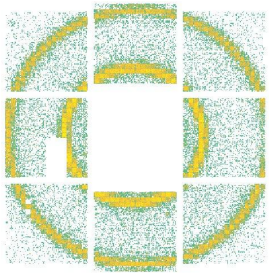
services

dRICH prototype

SiPM camera

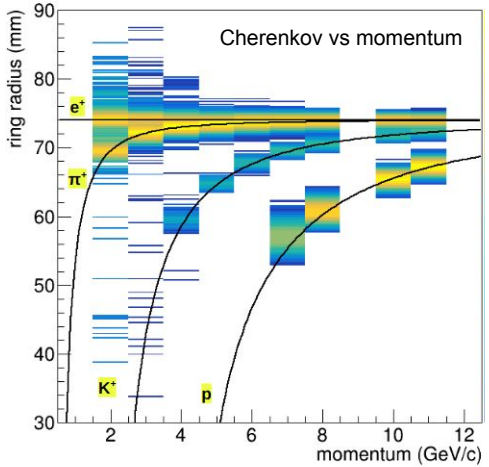




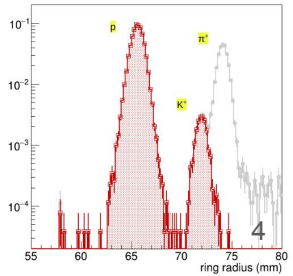


upgraded readout box

2K SiPM channels in a compact Cherenkov camera (20x20x20 cm) with TDC electronics

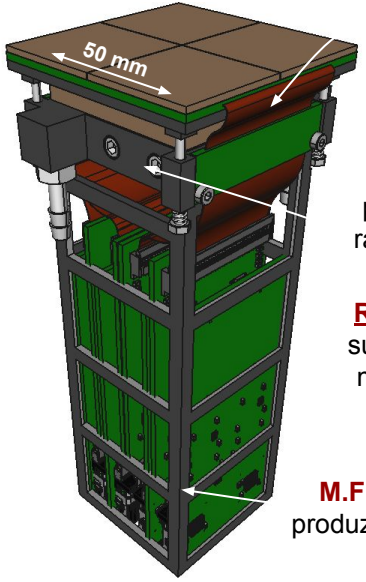


just concluded another very **successful beam tests** of the prototype
CERN-PS May-June 2024



advances since presentation at AdS in December

dRICH prototype photodetector
256-channel SiPM array with integrated cooling and electronics
BO leadership

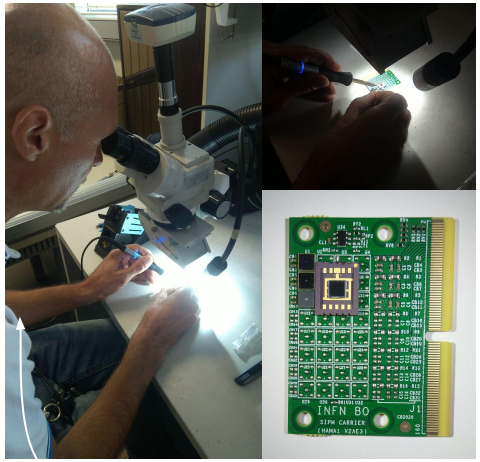


C.Baldanza (elettronica)
progettazione e sviluppo SiPM carrier flex 256 ch.

T.Fadanni (officina)
produzione piastra di raffreddamento liquido

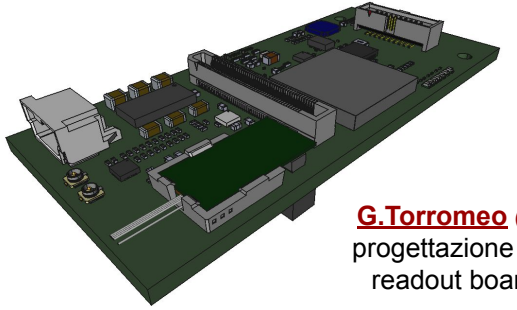
R.Michinelli (progettazione)
supporto alla progettazione meccanica del prototipo e disegno tecnico

M.Furini (officina)
produzione mini-crate



M.Zuffa (elettronica)
saldatura delicata sensori SiPM prototipi Hamamatsu

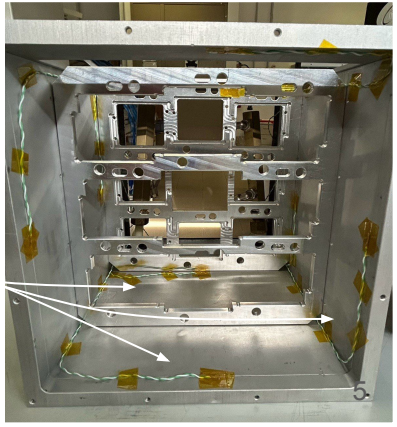
EIC setup, laboratorio silici



working on readout upgrade
FPGA with VTRX+ optical link
BO leadership

G.Torromeo (elettronica)
progettazione e sviluppo readout board (RDO)

A.Brusegan (elettronica)
sviluppo e realizzazione scheda custom per Arduino per lettura termocoppie (Alberto's K-probes)



progresso e successo del progetto
grazie al supporto dei servizi della Sezione

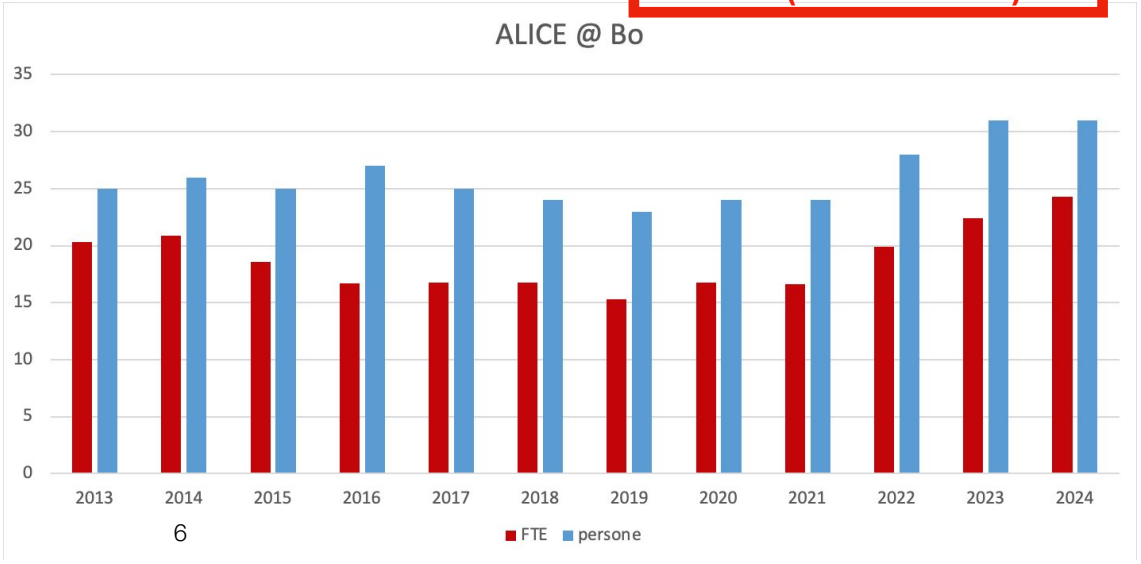
Composizione gruppo ALICE

N. Agrawal**, A. Alici, P. Antonioli, S. Arcelli, F. Bellini, F. Carnesecchi*, L. Cifarelli, F. Cindolo, G. Clai, M. Colocci, F. Ercolessi, D. Falchieri, M. Giacalone, D. Hatzifotiadou, N. Jacazio**, A. Kunthia, G. Malfattore**, A. Margotti, R. Nania, F. Noferini, O. Pinazza, R. Preghenella, G. Romanenko**, N. Rubini, B. Sabiu, E. Scapparone, G. Scioli, S. Strazzi, S. Tomassini, P. Veronesi, A. Zichichi.

Staff: 17 (5 UniBO, 11 INFN, 1 ENEA)
1 RTDb, 1 RTDa, 1 INFN Fellow per stranieri, 4 Borse PostDoc
5 PhD

* CERN Applied Fellow
** contratti ERC CosmicAntiNuclei

FTE 2024 (esclusi tecnici) 24.3



Responsabilità del gruppo in ALICE

ALICE

Management Board: **P. Antonioli**
Outreach Coordinator: **D. Hatzifotiadou**
DPG Coordinator: **F. Noferini**
PWG Light Flavour Convener: **N. Jacazio**
PWG-LF Strangeness Coordinator: **F. Ercolessi**
PWG-MM Rivet and Generators Coordinator: **M. Giacalone**
Service Work Board Junior Representative: **N. Rubini**

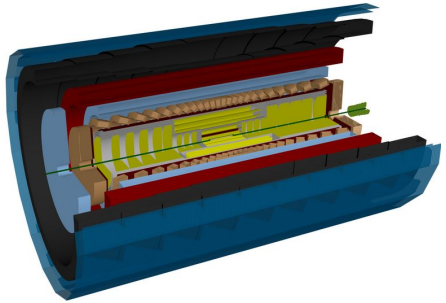
TOF

Project Leader: **A. Zichichi**
Team Leader: **A. Alici**
Technical Coordinator: **G. Scioli**
System Run Coordinator: **S. Strazzi**

ALICE3 Working Groups

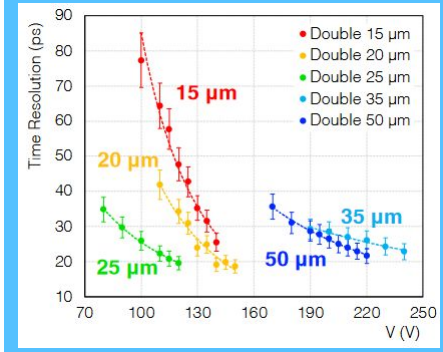
Time-of-Flight Coordinator: **M. Colocci**

ALICE3 @ Bologna



Il Gruppo ALICE-BO è attivamente coinvolto nella progettazione del sistema di Time-of-Flight di ALICE 3 (**M. Colocci** coordinatore del WG Time-of-Flight detectors). Letter of Intent pubblicata il 4/11/2022 (https://doi.org/10.48550/arXiv.2211.02491), Scoping Document in preparazione (sottomissione entro Settembre).

Attività principale: sviluppo, caratterizzazione e test di nuovi sensori al silicio con elevate risoluzioni temporali (ALICE 3 target < 20 ps): LGAD, SiPM e fully-depleted CMOS.

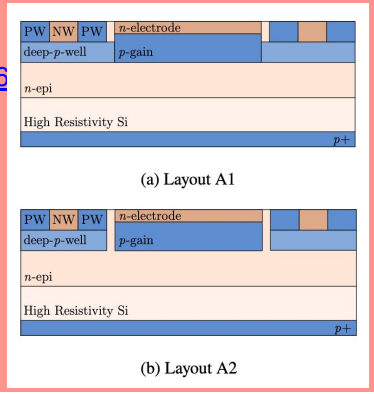


Intense beam-test campaigns at CERN-PS **demonstrated the possibility of achieving a time resolution of 20 ps with thin LGAD design**

- 25 and 35 µm thickness tested already in https://doi.org/10.1140/epjp/s13360-022-03619-1 (Jan 23)
- **15 µm thickness tested for the first time in July and Oct 2023**

the **first prototype of a monolithic sensor with internal gain based on a commercial 110 nm CMOS process** (Monolithic CMOS Avalanche Detector PIXelated - MadPix) has been tested with beam of charged particles at CERN-T10 East Hall

https://doi.org/10.48550/arXiv.2406.19906

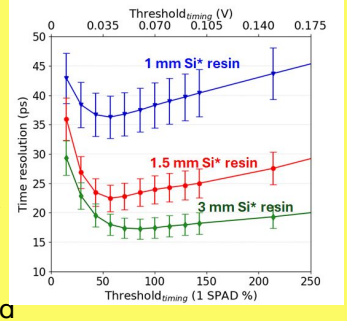


ALICE3 @ Bologna

Il Gruppo ALICE-BO è attivamente coinvolto nella progettazione del sistema di Time-of-Flight di ALICE 3 (**M. Colocci** coordinatore del WG Time-of-Flight detectors). Letter of Intent pubblicata il 4/11/2022 (https://doi.org/10.48550/arXiv.2211.02491), Scoping Document in preparazione (sottomissione entro Settembre).

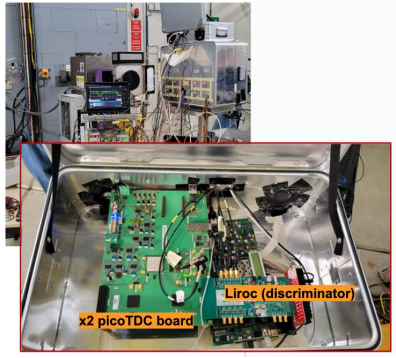
Attività principale: sviluppo, caratterizzazione e test di nuovi sensori al silicio con elevate risoluzioni temporali (ALICE 3 target < 20 ps): LGAD, SiPM e fully-depleted CMOS.

- **Different Silicon PhotoMultiplier (SiPM) sensors have been tested** with charged particles to characterize the Cherenkov light produced in the sensor protection layer.
- **Time resolution reach values below 20 ps** and the measurements provide significant insight into the capabilities of SiPMs in direct detection of charged particles and their potential for several applications
  as demonstrated in https://link.springer.com/article/10.1140/epjp/s13360-023-04397-0
- **Efficiency close to 100% at 6 phe**



- **New front-end and data readout operational since April 2024** for all sensor types (LGAD, CMOS, SiPM)
- **Liroc board (based on Weroc front-end ASIC for SiPMs) developed at INFN-BO**

picoTDC board (based on CERN picoTDC) developed at INFN-BO for the next upgrade of ALICE-TOF



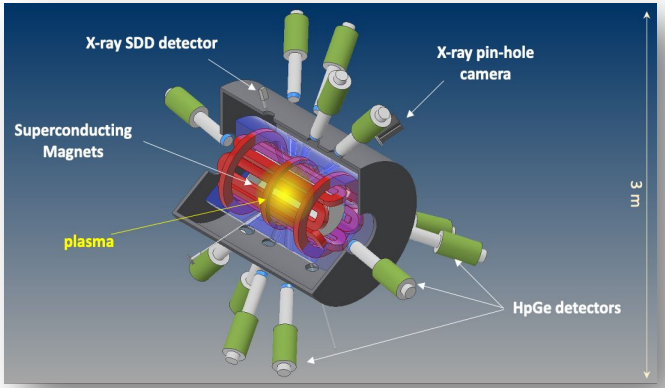
Ringraziamnenti speciali a:
D. Cavazza per supporto allestimento struttura di test, setup al T10, sistema di presa dati
D. Falchieri e **C. Baldanza** per scheda picoTDC board
C. Verri per scheda LIROC

The PANDORA experiment

measuring nuclear β-decay lifetimes in magnetized plasmas

Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry

- Make β-decay measurements in plasmas of astrophysical interest: **many isotopes can change their lifetime of several order of magnitude when ionized!!**
- a new "ECR Ion Trap" @ LNS **is under construction**:



STATUS:

- the superconducting magnetic trap has 1 year delay;
- the experimental area has been assigned (~ 7x10 m2);

The Collaboration: LNS, LNL, PG, TIFPA, Bologna

Bologna activities

Personnel (4 researchers, 1.4 FTE): M. Cuffiani (0.2 FTE), L. Malferrari (0.5 FTE), A. Mengoni (0.2 FTE), F. Odorici (0.5 FTE) local resp.

Official Responsibilities in PANDORA:

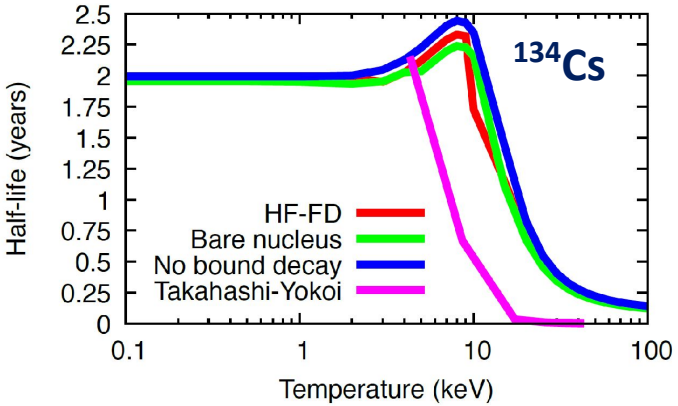
- Theory and Models («physics cases approver»)
- Inner Plasma Chamber (design, construction & control)
- Auxiliary e-gun (design, construction & control)

Services requests (2025):

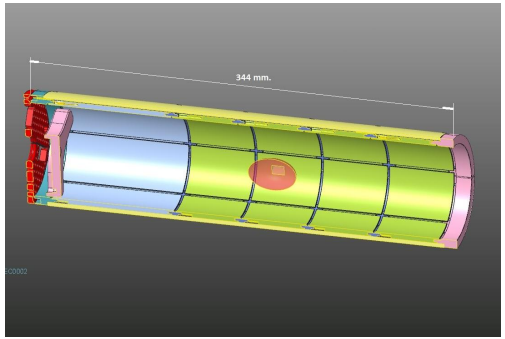
- Mechanical design: 2 months
- Mechanical workshop: 2 months

Bologna activities in PANDORA (in past 12 months)

1) THEORETICAL MODELS - Estimation of lifetime variation as a function of kT: development of the computational codes necessary for modeling the nuclear structure for the description of the decay rates in the stellar environment (see example for ^{134}Cs). The code for calculating the half-lives for beta decay of excited nuclei was used to produce the results presented in various journal publications and contributions to int. conferences.



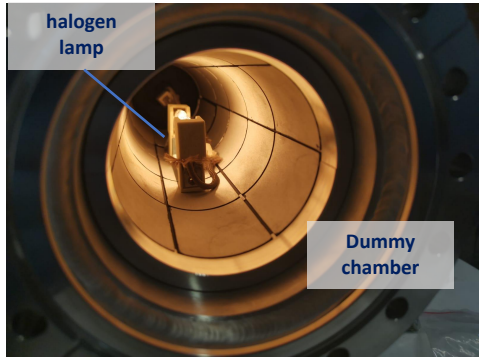
2) APPARATUS CONSTRUCTION – The Inner Plasma Chamber:



a reduced scale prototype (~1:3) of the Inner Plasma Chamber has been **designed and constructed in Bologna** (tech. work of R. Michinelli, M. Furini, C. Gessi, M. Guerzoni, A. Margotti) within the IONS experiment in GR5. The prototype **will be tested on the AISHa ion source @ LNS**. **Some pre-tests of the inner chamber** have been successfully performed in Bologna (end-2023/begin-2024), in order to verify degassing, mechanical tolerances, thermal expansion and electrical insulation, by using a specially constructed dummy chamber identical to that of AISHa. **The physical tests on AISHa is foreseen by end-2024/begin-2025.**

The prototype of the Inner Plasma Chamber: tests on a dummy chamber @ Bologna

«Tails» and anodized rings



Test under vacuum @ 200°C:

- check degassing
- thermal expansion
- electrical insulation

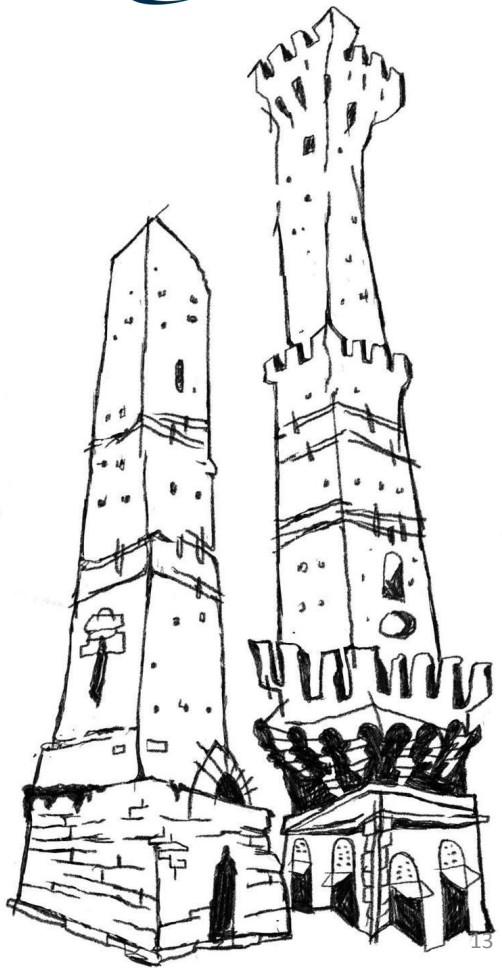
Pressure (mbar):

- 1x10E-4 in 90'
- 7.4x10E-6 after 17h
- After baking with alogena @ 77W
  - 8.6x10E-4 @ **Tmax tail 212°C**

Baking	Tmax	Pressure (mbar)
30 W	115°C	2.5x10E-6
38 W	127°C	1.0x10E-6
42 W	135°C	8.6x10E-7
51-61 W	145-155°C	7.4x10E-7
51-61 W	145-155°C	4.6x10E-7 after 3h pumping

INFN-Bologna: Team

Cristian Massimi (UNIBO/INFN-Bo)
Alice Manna (UNIBO/INFN-Bo/Research Fellow @CERN)
Rudra Narayan-Sahoo (post-doc INFN-Bo)
Nicholas Pieretti (UNIBO, master student)
Alberto Mengoni (RL, ENEA Team/n_TOF spokesperson)
Donato Castelluccio (ENEA team)
Patrizio Console-Camprini (ENEA Team)
Alberto Ventura (retiree)
Gianni Vannini (retiree)



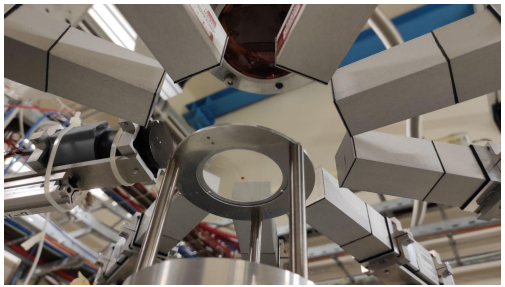
Neutron capture measurements

(n,γ) reactions are taking place in stars as well as in nuclear reactors and in other nuclear technology devices. Their cross sections are of paramount importance for understanding the origin of the chemical elements present in the Universe (and in our solar system).

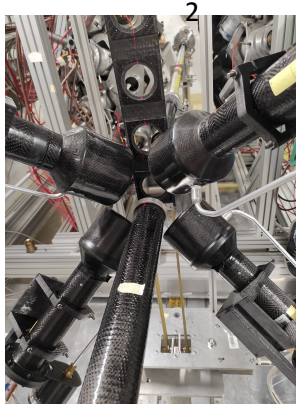
	field of interest	note	CERN experiment
^{28,29,30}Si(n,γ)	– classification of pre-solar grains – nucleosynthesis in massive stars	^{30}Si in 2023 ^{28,29}Si in 2024	INTC-P-577
^{94,95,96}Mo(n,γ)	– nucleosynthesis in massive stars – used for nuclear fuel & other technologies	stable samples	INTC-I-261
^{166,167}Er(n,γ)	– burnable absorbers in nuclear fuel	^{nat}Er in 2023	INTC-P-656
^{40}Ar(n,γ)	– large-scale particle physics detectors – nucleosynthesis in massive stars	gas target, test	INTC-I-256
^{64}Ni(n,γ)	– AGB and massive stars nucleosynthesis – anomalies in pre-solar grains	rare isotope	INTC-P-208-ADD

Planned for next year(s)

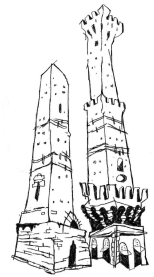
^{63,65}Cu(n,γ)	– nuclear technologies	RAMEN project	INTC-P-689
^{92,97,98,100}Mo(n,γ)	– nucleosynthesis in massive stars – used for nuclear fuel & other technologies	completing all stable isotopes	INTC-569-ADD

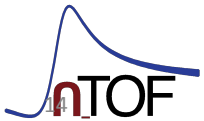


n_TOF experimental area 2

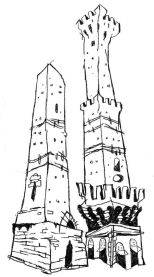


n_TOF experimental area 1

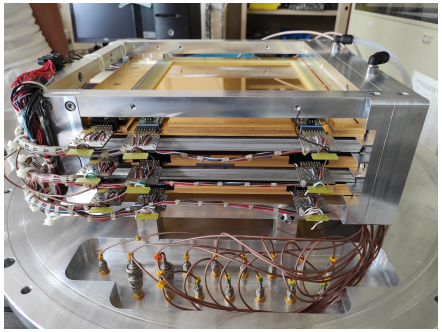




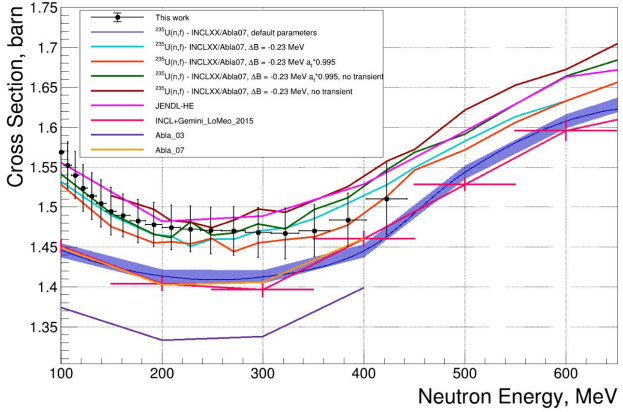
Neutron-induced fission measurements

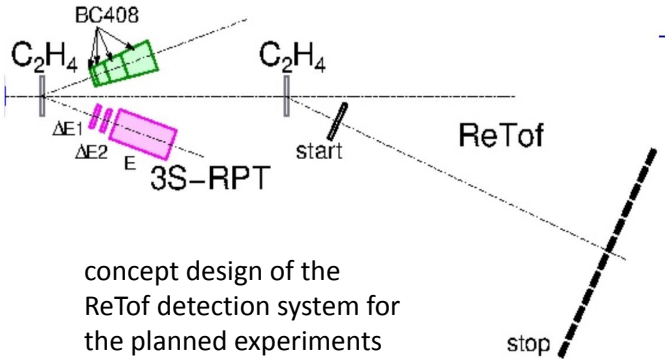


In spite of the advancements of the nuclear models and the abundance of experimental data, the current theoretical representations of the fission process largely rely on phenomenological approaches The ^{235}U(n,f) reaction cross section was measured relative to neutron-proton elastic scattering for the first time in the energy region from 10 MeV to 440 MeV at n_TOF, extending the upper limit of the only previous measurement in the literature by more than 200 MeV.



PPAC detectors





concept design of the ReToF detection system for the planned experiments

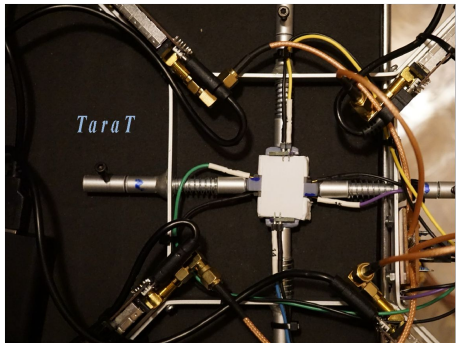
Planned for next year(s)

^{235}U(n,f)	– nuclear reactions at high energies – nuclear technologies	extending the energy limit up to 1 GeV (PPAC + ReToF)	INTC-P-507
^{239}Pu(n,f)			INTC-P-705

Detectors (management, development)

The **n_TOF Bologna team** has the responsibility of managing and developing several detectors for the n_TOF Collaboration. Amongst these:

PPAC (paralle plate avalanches counter)
TaraT (active target for n,p elastic scattering)
RiPTIDE (recoil proton track imaging detector)(*)
Chacterization of a neutron detector for a (possible) FOOT upgrade



Tara T

RiPTIDE concept

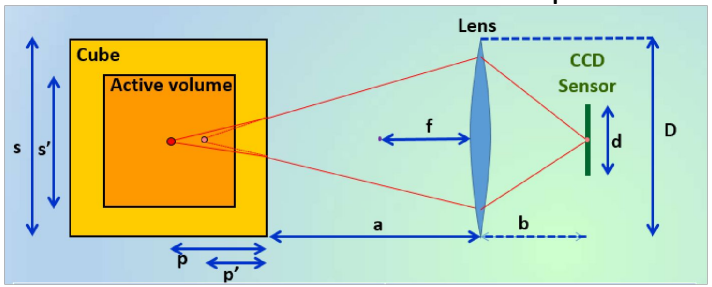
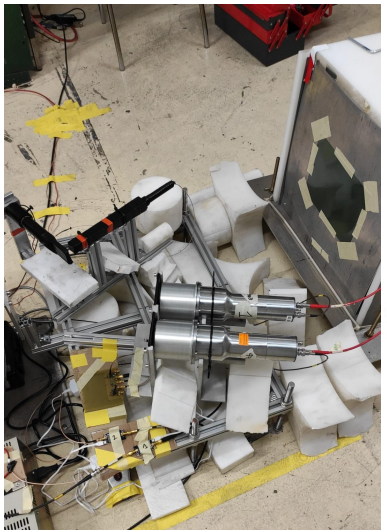


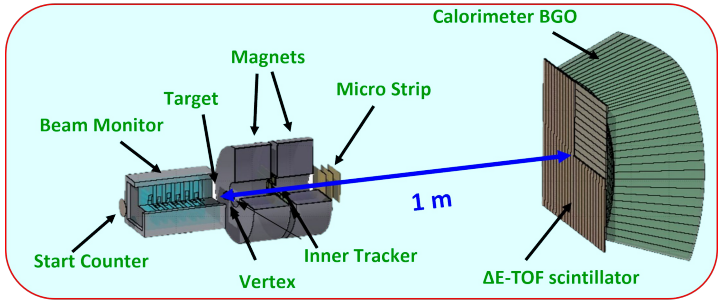
Figure 1. Sketch of a simple setup for the simulation of photon transport.

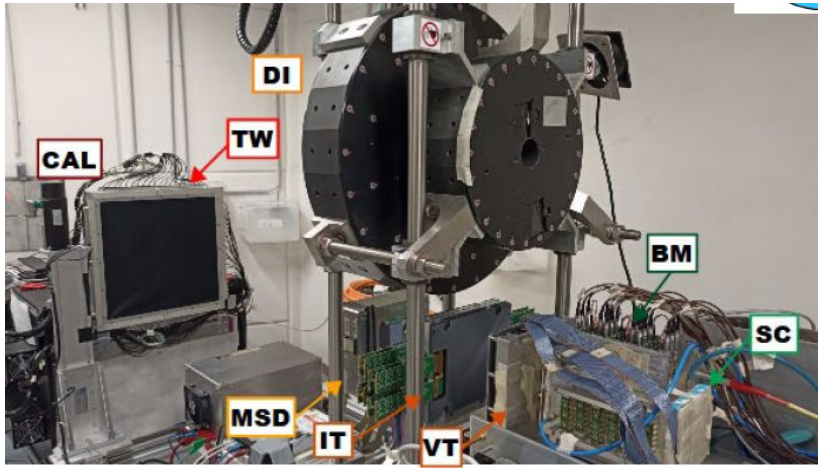


n@NEL4Foot (test)

(*) detector under development in the framework of INFN-Gruppo 5 activities. Synergic activity with n_TOF.

FOOT: general information





Detector is COMPLETED:

- 2023 ultimate Magnet, tracker and calorimeter

- **FTE FOOT in BOLOGNA:**
  - 2023: 4.75
  - 2024: 4.75

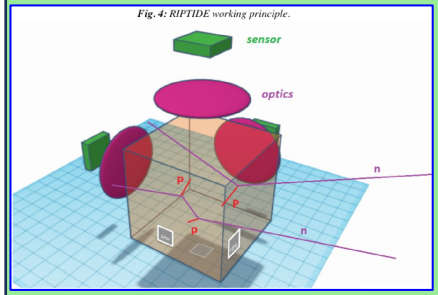
Service Requests (MU):

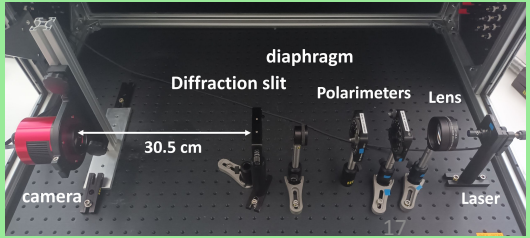
- ELEC: 1
- CCL: 1
- OFF: 1

- **DATA TAKING in 2024-25:**
  - CNAO (autumn 2024)
  - GSI (spring-summer 2025)

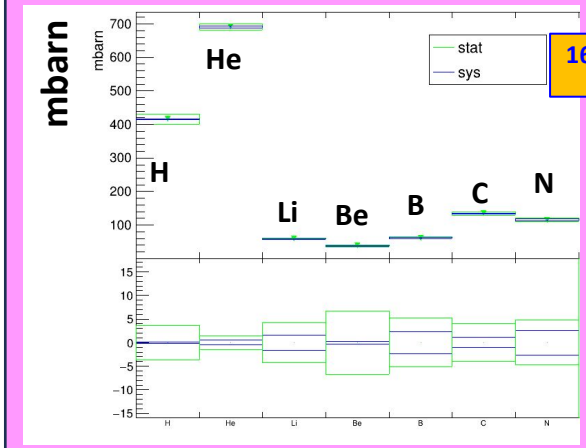
- **THESIS in FOOT/RIPTIDE BOLOGNA:**
  - 2023: 17
  - 2024: 13 (till December 2024)

- **SPIN OFF ACTIVITY:**
  - RIPTIDE: neutron detector (see Gr 5 talk)





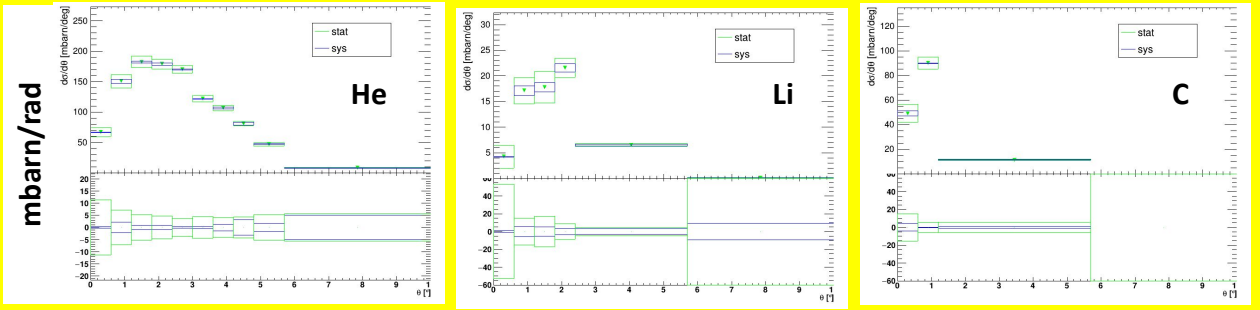
Elemental Integral σ(Z)



latest results

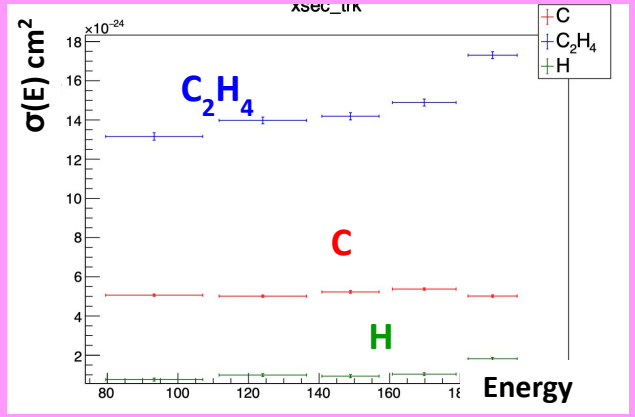
^{16}O (400 MeV/u) + C

Elemental differential dσ/dθ

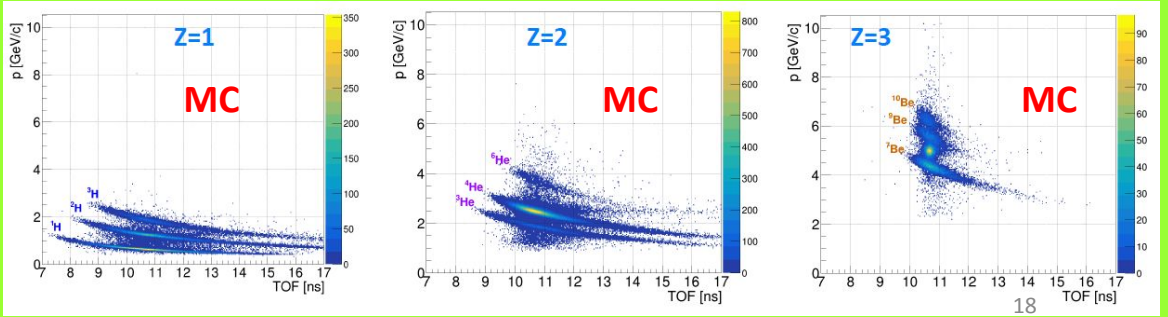


Total production σ

^{16}O (200 MeV/u) + C

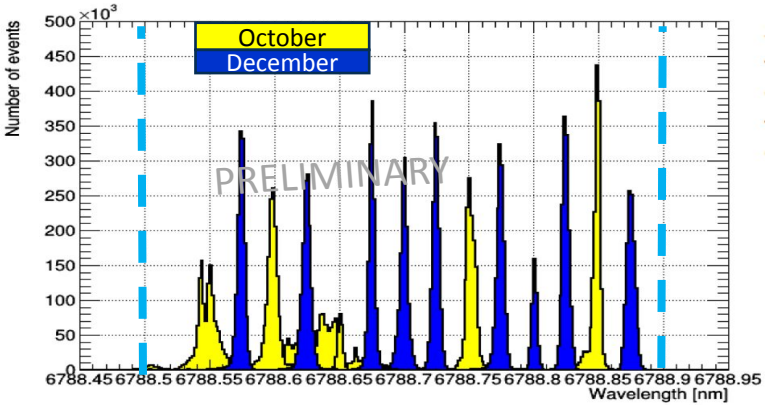


Next future with tracker and ToF □ isotopic identification

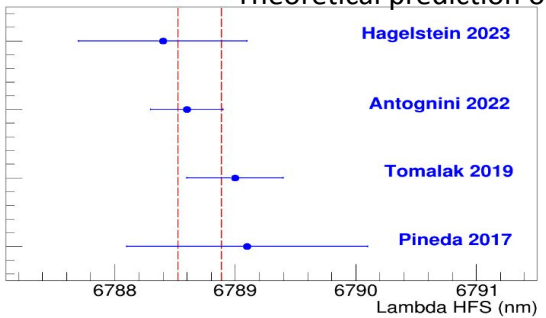


FAMU: a spectroscopic experiment for the measurement of the Hyperfine Splitting of muonic hydrogen in the ground level

First frequency scan of the wavelengths of interest: ✓



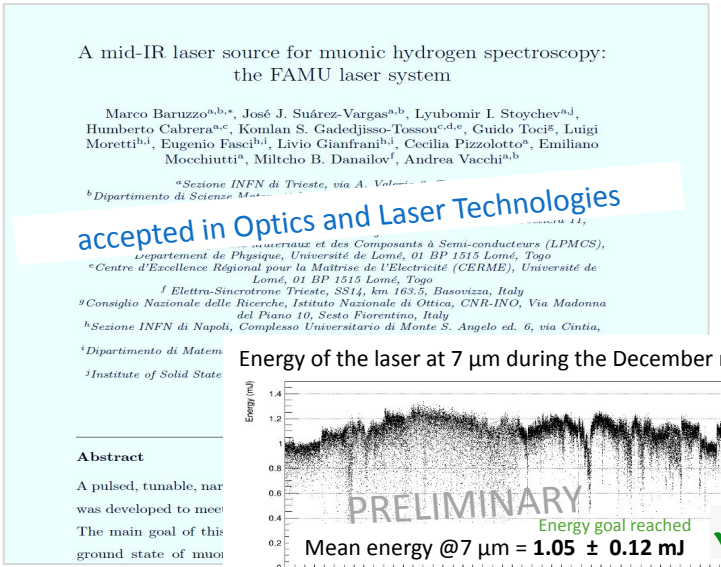
Theoretical prediction of the HFS



- The first experiment to perform HFS a frequency scan
- 14 frequencies investigated in 2023
- Analysis of the results is currently ongoing
- Further measurements planned in the second half of 2024

The FAMU laser is a unique system due to its characteristics

The laser system is fully described in a new paper:


A mid-IR laser source for muonic hydrogen spectroscopy: the FAMU laser system

Marco Baruzzo[a,b,*], José J. Suárez-Vargas[a,b], Lyubomir I. Stoychev[a,j], Humberto Cabrera[a,c], Komlan S. Gadedjisso-Tossou[c,d,e], Guido Tocì[g], Luigi Moretti[b,i], Eugenio Fasci[b,i], Livio Gianfrani[b,i], Cecilia Pizzolotto[a], Emiliano Mocchiutti[a], Miltcho B. Danailov[f], Andrea Vacchi[a,b]

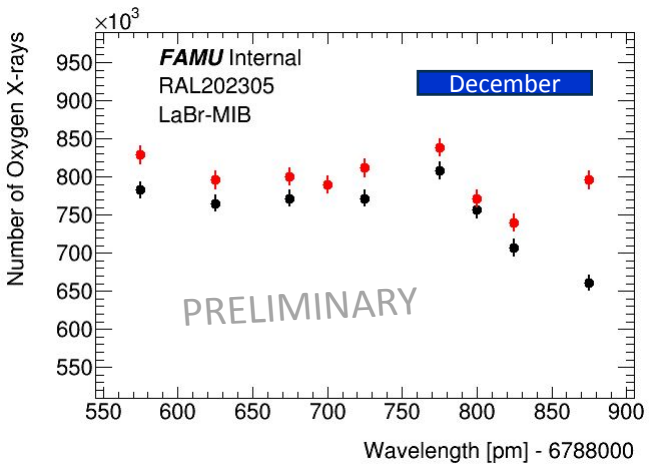
accepted in Optics and Laser Technologies

Abstract

A pulsed, tunable, nar
was developed to mee
The main goal of this
ground state of muo

Energy of the laser at 7 µm during the December run

Data-Analysis in progress



- Entire statistics of X-rays from Oxygen for each laser wavelength in December 2024.
- Data from all the 34 detectors installed around the target (6 LaBr + 28 MIB) are calibrated and added up.
- **Red points are normalized to the number of muon triggers. Normalization on the number of atomic targets and incoming muons is ongoing.**

- **Next step: define the experimental procedure to identify events with and without laser pulses.**

Bologna detectors upgrade

- **10 Hamamatsu PMTs have been ordered to complete the upgraded crown of LaBr detectors.**

- The crown with 8 working detectors (out of 17) has been successfully tested in May 2024 at RAL.
- New PiggyBack boards will be produced in Autumn with the help of Bologna electronic lab.
- The installation is planned for the first 2025 data-taking period (February).

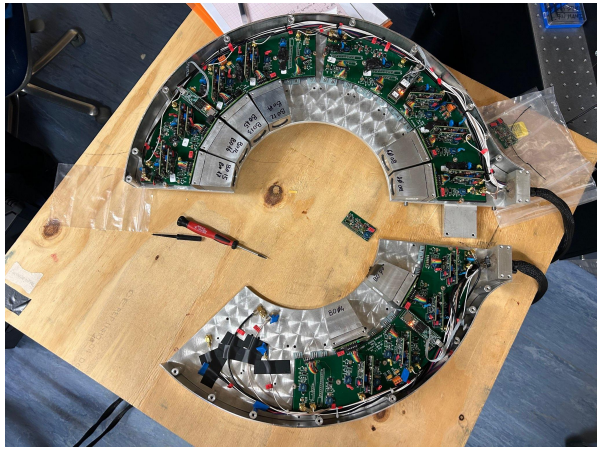


Tabella riassuntiva richieste ai servizi Gr-III

ESPERIMENTO	LAB. ELETTRONICA(MU)	STG(MU)	OFFICINA(MU)	PROGETTAZIONE(MU)	CCL(MU)	TECNOLOGIE AVANZATE (MU)	TOT
ALICE	16.5	0	0.5	4.5	0.5	6	28
EIC_NET	10	0	3	2	2	3	20
FAMU	1	2	0	0	0	0	3
FOOT	1	0.5	1	0	1	0	3.5
PANDORA_GR3	0	0	2	2	0	0	4
n_TOF	0	0	0	0	0	0	0

MESE UOMO	28.5	2.5	6.5	8.5	3.5	9	58.5

In rosso richieste ancora in discussione con il direttore