Attività di Gruppo III

F. Noferini

Istituto Nazionale di Fisica Nucleare

Assemblea di sezione - Bologna, 11 luglio 2025

Esperimenti di G3 a B0

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

1) Quark and Hadron Dynamics (**EPIC**)
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**)

EPIC

Gruppo, FTE e ruoli rilevanti di Bologna in EPIC

gruppo impegnato nelle attività per il rivelatore dRICH dell'esperimento ePIC a EIC

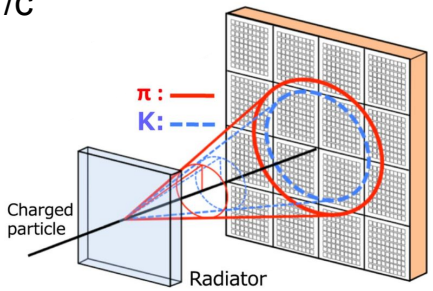
interessi verso la fisica SIDIS, adronizzazione, charm, saturazione e fisica diffrattiva

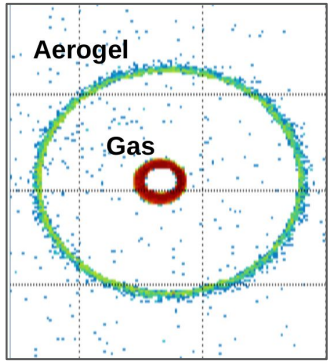
- **Responsabile Locale**
  - Roberto Preghenella
- **Consistenza Gruppo**
  - 16 pesone
  - 8.0 FTE
- **Ruoli Rilevanti nella Collaborazione Internazionale**
  - Responsabilità fotorivelatori SiPM e modulo PhotoDetector Unit rivelatore dRICH
    - Roberto Preghenella
  - Responsabilità scheda di readout RDO e DAQ rivelatore dRICH
    - Pietro Antonioli
  - Chair del "Elections and Nominating Committee" dello EIC User Group
    - Nicola Rubini
- **Responsabilità di Bologna per le costruzioni del rivelatore dRICH**
  - procurement di **6000 matrici SiPM** per un totale di ~ 380 k sensori SiPM
  - definizione e **supervisione dei test di qualità** sui sensori SiPM
  - construzione e test di **1500 moduli** Photodetector Units
  - produzione e test di **1500 schede** readout boards RDO

The dual-radiator (dRICH) detector for forward PID at the EIC

compact and cost-effective solution for **broad momentum coverage at forward rapidity up to 50 GeV/c at η = [1.5, 3.5]** with also electron-ID up to 15 GeV/c

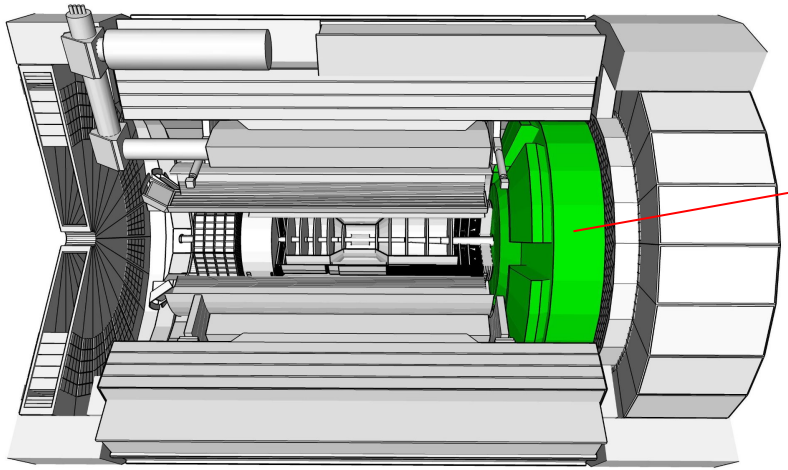
- **two radiators:** aerogel (n ~ 1.02) and C_2F_6 (n ~ 1.0008)
- **SiPM sensors:** 3x3 mm^2 pixel, ~ 3 m^2 of photodetectors



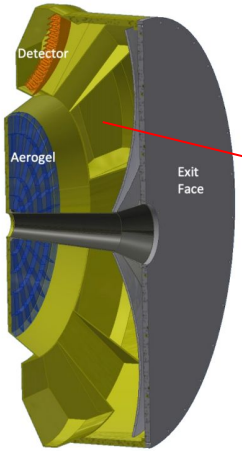


ePIC

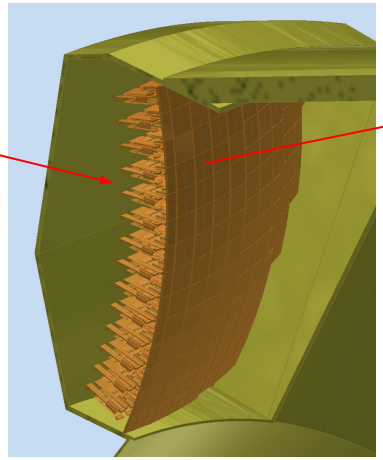
8.5 m



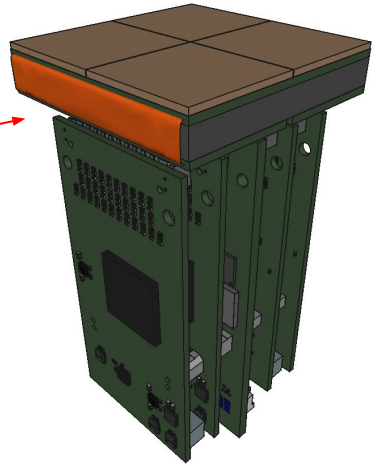
adroni → ← elettroni



rivelatore dRICH



photodetector box

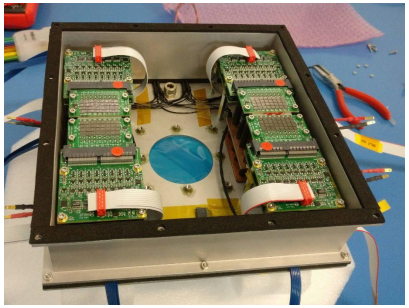


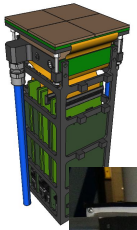
SiPM photodetector unit

from the first prototype

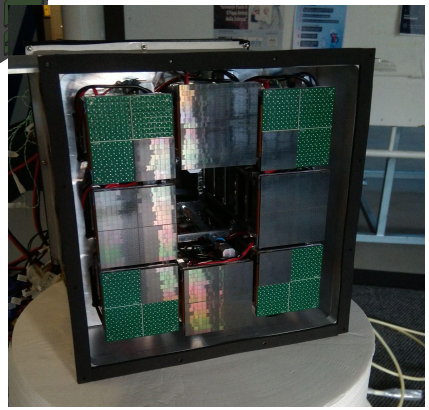
towards detector construction

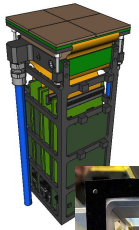
2022
electronics v1



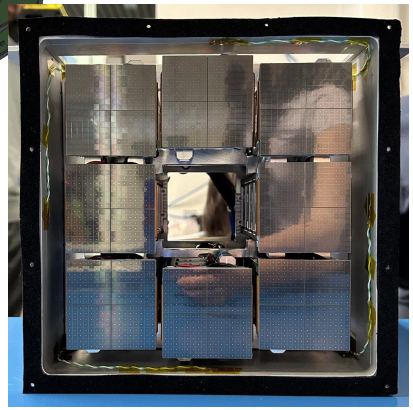


2023
electronics v2

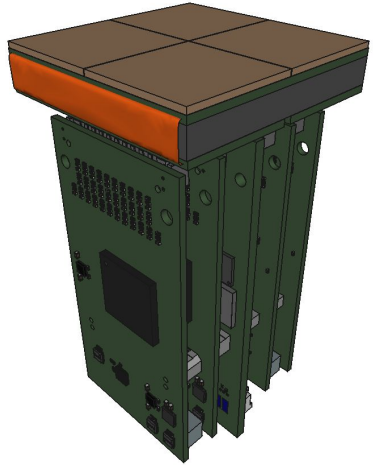


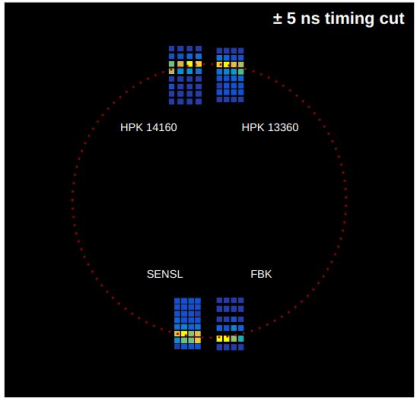


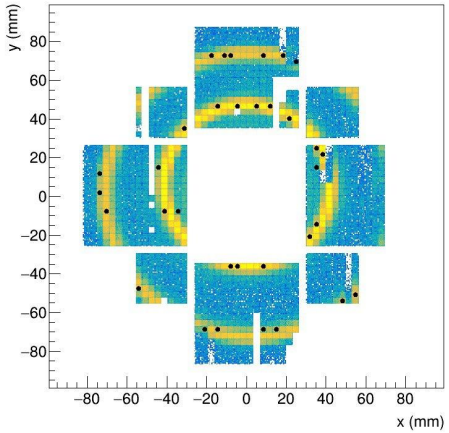
2024
electronics v2.1

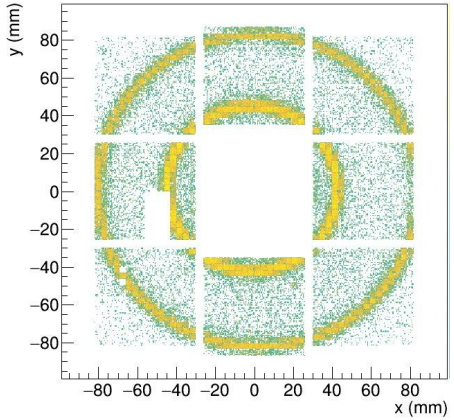


2025
electronics v3
final prototype



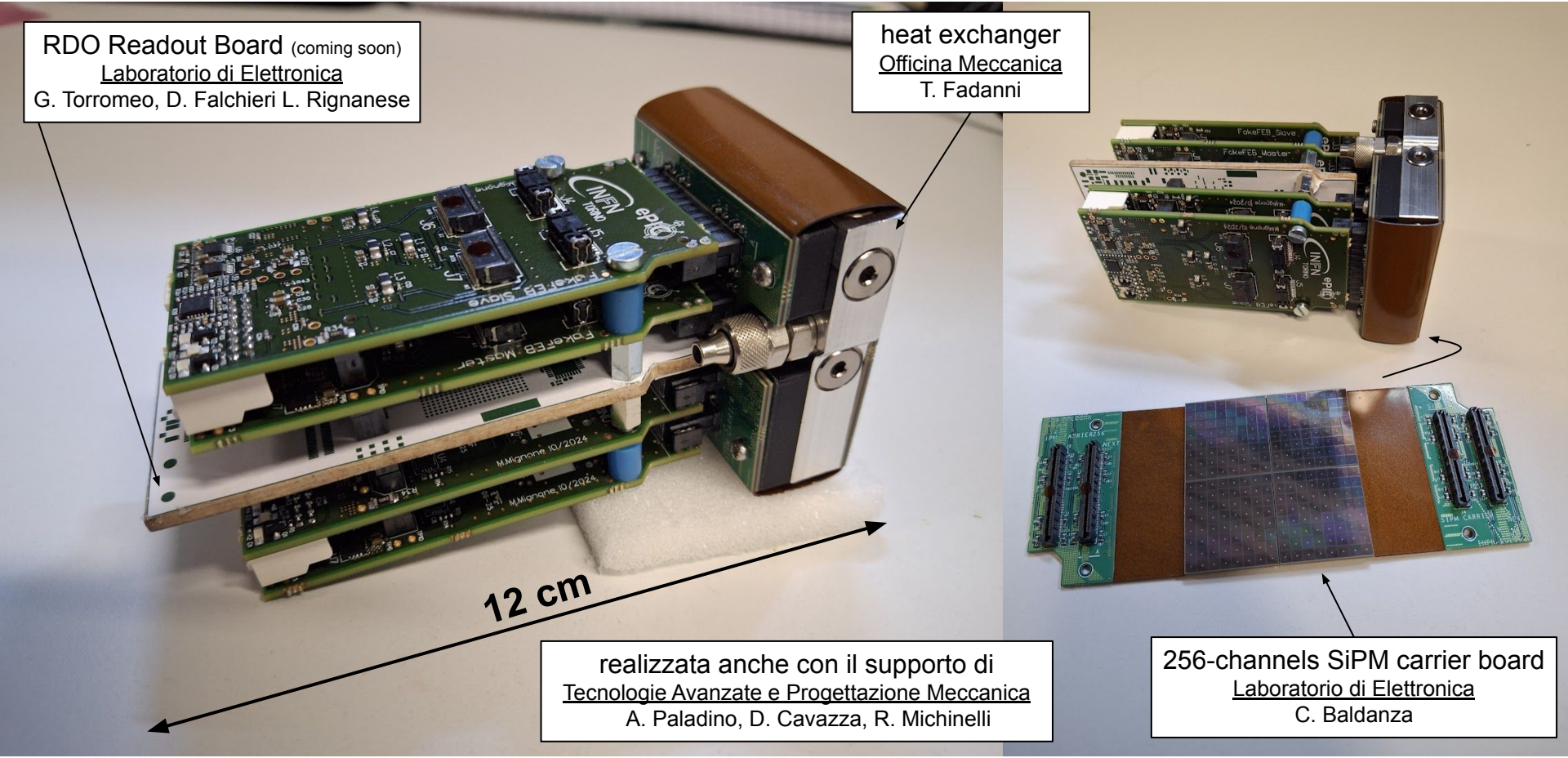






SiPM procurement
expected to start next year

La versione finale della PhotoDetector Unit del rivelatore dRICH prende forma nei nostri laboratori



e soprattutto grazie anche al supporto di TUTTI i servizi di base (personale, acquisti, missioni, …)

Richieste ai servizi

Servizio Tecnico Generale	1 MU
Servizio Tecnologie Avanzate	5 MU
Servizio Elettronica	11 MU
Servizio Officina Meccanica	4 MU
Servizio Progettazione Meccanica	2 MU
Servizio Calcolo e Reti	2 MU

ALICE

ALICE-TOF Bologna

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

Responsabile Locale: **A. Alici** □ **F. Bellini**

Staff: 13 (5 UniBO, 8 INFN)
1 INFN Fellow per stranieri
6 Assegni di Ricerca
4 PhD

‡ENEA, Staff
*Centro E. Fermi, PostDoc
†U. Piemonte Orientale, RTT
** Contratti ERC-CosmicAntiNuclei

CosmicAntiNuclei

erc
European Research Council
Established by the European Commission

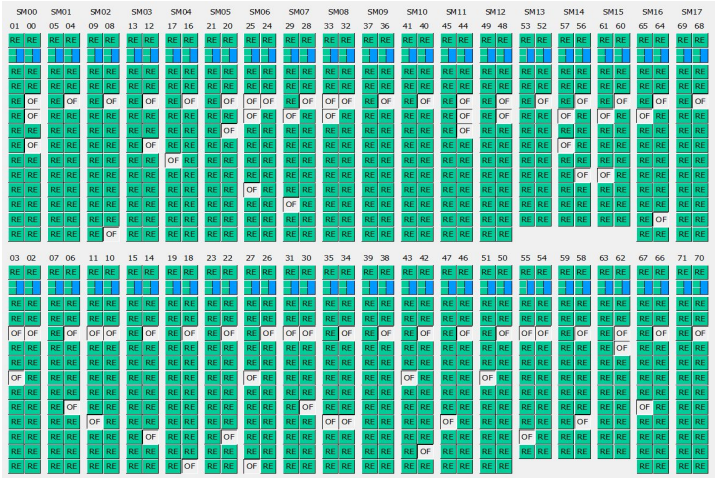
Ruoli di responsabilità in ALICE e ALICE3 (NEW):

Management Board: **P. Antonioli**
Outreach Coordinator: **D. Hatzifotiadou**
PWG-LF Strangeness Coordinator: **F. Ercolessi**
Junior Representative: **B. Sabiu**

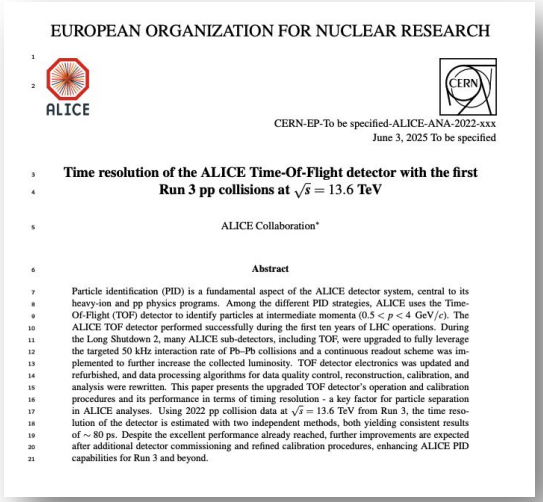
TOF Project Leader: **L. Cifarelli, P. Antonioli** □ **A.Alici**
TOF Team Leader: **A. Alici**
Technical Coordinator: **G. Scioli**
System Run Coordinator: **S. Strazzi**
ALICE3-TOF Coordinator: **M. Colocci**

Stato del rivelatore TOF

- **72/72** crates in readout
- **91.6%** canali TOF in readout (140118/152928)
- **95.3%** MRPC in acquisizione (1518/1593, le mancanti OFF a causa di connettori HV rotti)
- Ancora nessuna MRPC si è rotta dopo 17 anni di operazioni!



TOF readout cards



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE

CERN

CERN-EP-To be specified-ALICE-ANA-2022-xxx
June 3, 2025 To be specified

Time resolution of the ALICE Time-Of-Flight detector with the first Run 3 pp collisions at $\sqrt{s} = 13.6$ TeV

ALICE Collaboration*

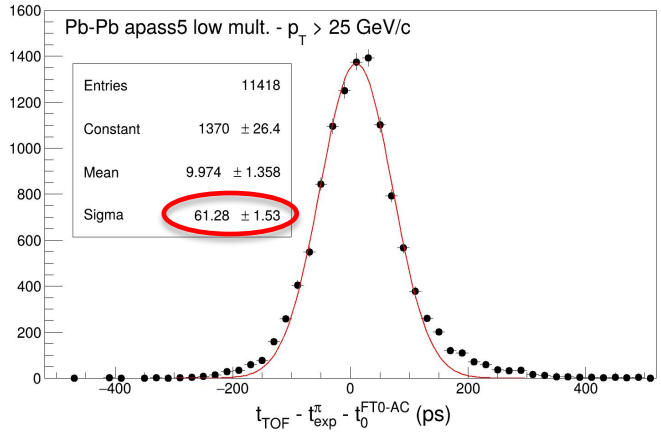
Abstract

Particle identification (PID) is a fundamental aspect of the ALICE detector system, central to its heavy-ion and pp physics programs. Among the different PID strategies, ALICE uses the Time-Of-Flight (TOF) detector to identify particles at intermediate momenta ($0.5 < p < 4$ GeV/c). The ALICE TOF detector performed successfully during the first ten years of LHC operations. During the Long Shutdown 2, many ALICE sub-detectors, including TOF, were upgraded to fully leverage the targeted 50 kHz interaction rate of Pb–Pb collisions and a continuous readout scheme was implemented to further increase the collected luminosity. TOF detector electronics was updated and refurbished, and data processing algorithms for data quality control, reconstruction, calibration, and analysis were rewritten. This paper presents the upgraded TOF detector's operation and calibration procedures and its performance in terms of timing resolution - a key factor for particle separation in ALICE analyses. Using 2022 pp collision data at $\sqrt{s} = 13.6$ TeV from Run 3, the time resolution of the detector is estimated with two independent methods, both yielding consistent results of ~ 80 ps. Despite the excellent performance already reached, further improvements are expected after additional detector commissioning and refined calibration procedures, enhancing ALICE PID capabilities for Run 3 and beyond.

Eccellenti performance in termini di risoluzione sul tempo di volo

□ Articolo in preparazione

In Pb-Pb al Run 3 raggiunte le stesse risoluzioni del Run 2 ~ 60 ps !!!



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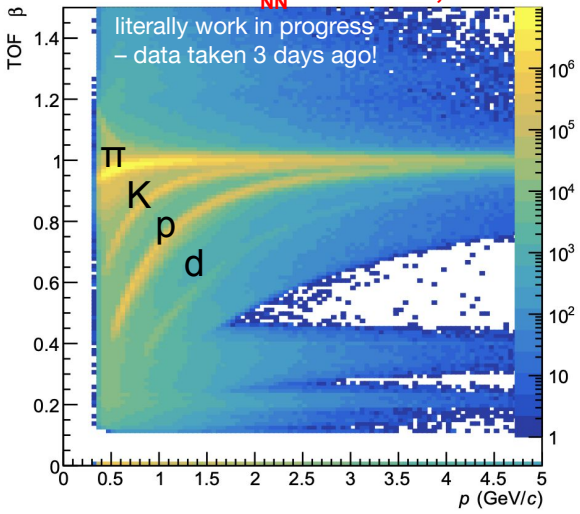
- Ancora nessuna MRPC si è rotta dopo 17 anni di operazioni!

TOF readout cards

NEW: O-O $\sqrt{s_{NN}}$ = 5.36 TeV, 2025



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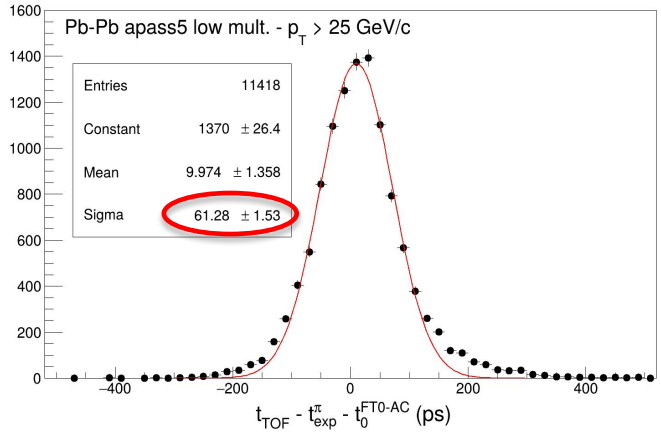
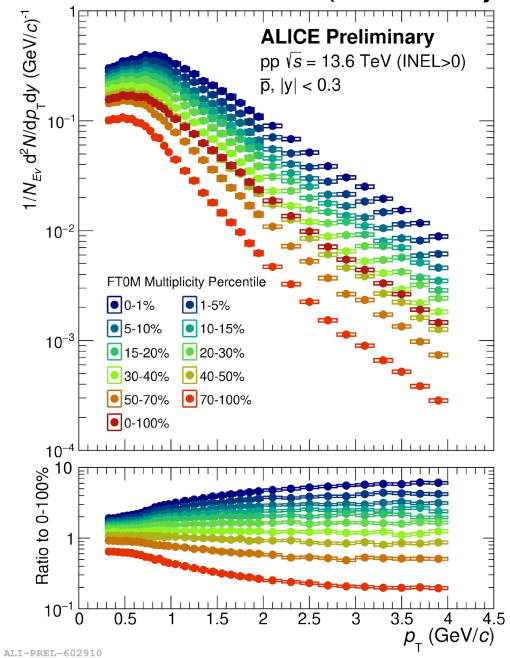


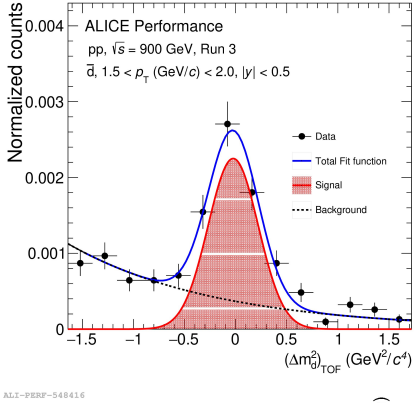
Fisica col TOF: selezione di risultati di Run 3

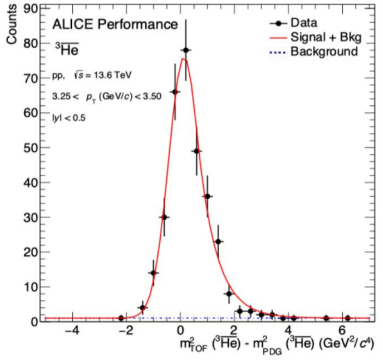
Misure multi-differenziali di abbondanze di **adroni identificati**

 studio della **composizione chimica** dello stato finale e sua evoluzione con molteplicità, studio dei meccanismi di **produzione e frammentazione** (in- e out-of-jets)

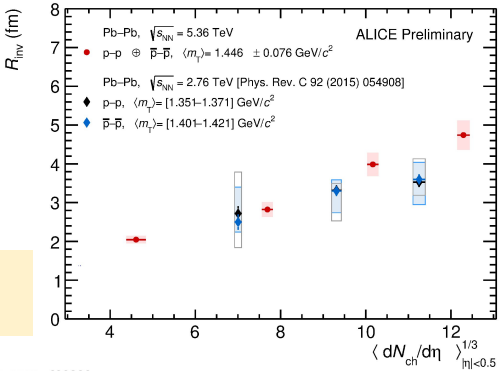


Nuclei e antinuclei leggeri studio dei **meccanismi di formazione**, input per astrofisica





Femtoscopia con protoni caratterizzazione delle dimensioni fisiche della **sorgente**, evoluzione idrodinamica



Risultati presentati a conf. internazionali Quark Matter 2023 e 2025, ICHEP 2024

ALICE3

Il Gruppo ALICE-BO è attivamente coinvolto nella progettazione del sistema di Time-of-Flight di ALICE 3 (M. Colocci coordinatore del WG TOF detectors).

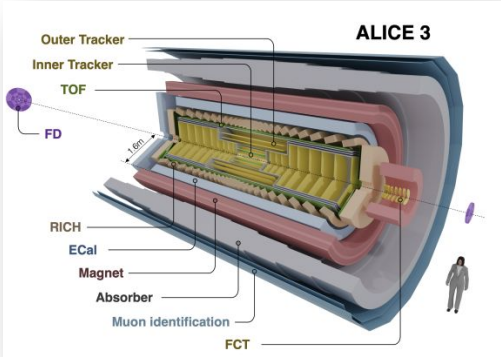
- ✔ Letter of Intent pubblicata il 4/11/2022 - arXiv:2211.02491
- ✔ Scoping Document pubblicato il 27/02/2025 - CERN-LHCC-2025-002
- ✔ Ambito di ALICE 3 supportato e considerato prioritario in diversi contributi comunitari alla European Strategy for Particle Physics 2026
- ✔ Emerso come prioritario dal CERN Heavy Ion Town Meeting di Febbraio 2025

- ✔ **Review di LHCC conclusa** al LHCC meeting di marzo
- ✔ Conclusioni del CERN Research Board sulla base dell'input di LHCC:
  - ❑ Focus su versione senza Ecal
  - ❑ Puntare a magnete da 2T e l'accettanza maggiore consentita dalle risorse
  - ❑ Puntare a un magnete superconduttore con soluzione(i) di fallback

→ **Definizione dello *scope* commisurato alle risorse entro fine 2025**

> • **ALICE 3** is a completely new dedicated high-energy nuclear physics experiment, based on innovative detector concepts, with particle identification and unprecedented pointing resolution over large acceptance in rapidity and transverse momentum. It offers unique opportunities to advance quark matter research in HL-LHC Run 5, in particular via measurements of electromagnetic radiation, heavy flavour, and particle correlations.

> "**ALICE 3 is a unique detector at the LHC** in terms of having a low material budget, a few-micron pointing resolution, a large acceptance in eta, and hadron, electron and muon identification."
> "The **LHCC recognises** that the different scoping options presented would enable a **compelling and unique heavy ion physics program** in Run 5."



Attività in corso:

- **Definizione formale delle collaborazioni di progetto in corso da parte degli istituti per i rivelatori più grandi, tra cui il TOF**
- **R&D e test beam per tutti i sottosistemi – per il TOF, test di irraggiamento dei CMOS-LGAD e caratterizzazione dei sensori SiPM nel lab di BO e al CERN**
- **Kickstart del gruppo di lavoro su Simulazione e performance**

Richieste

Servizio	Richiesta mesi uomo	Attività
Lab. Elettronica	13	- supporto per test e sviluppo firmware TRM2 di ALICE - supporto al design chip di readout per ALICE3-TOF
STG	0	
Officina meccanica	0.5	- supporto attività TOF e ALICE3
Progettazione meccanica	5	- progettazione di supporti meccanici e sistema di raffreddamento per ALICE3-TOF
CCL	0.5	- supporto a macchine di laboratorio e di esperimento
Tecnologie avanzate	6	- supporto attività TOF e ALICE3 in Lab. Silici e test beam
Totale	**25**	**GRAZIE!**

Il gruppo ringrazia

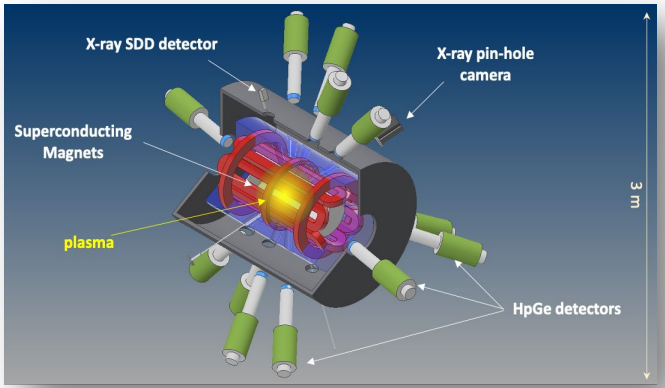
- Il servizio Lab. di elettronica, e in particolare *D. Falchieri e C. Baldanza*, per il supporto alla scheda picoTDC board e test e sviluppo firmware per TRM2 di ALICE-TOF
- L'officina meccanica per il supporto alle attività di test su fascio e di lab.
- Il servizio di progettazione meccanica, e in particolare *M. Guerzoni, C. Guandalini e G. Piazza*, per l'attività di progettazione meccanica per ALICE3-TOF
- Il Centro di Calcolo, e in particolare *A. Paolucci*, per il supporto alle macchine di lab e ALICE-TOF
- il servizio di tecnologie avanzate, e in particolare *D. Cavazza*, per il supporto alle attività di test su fascio e in lab a Bologna per ALICE3-TOF

PANDORA

The PANDORA experiment

measuring nuclear β-decay lifetimes in magnetized plasmas

- **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 m^2);

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:

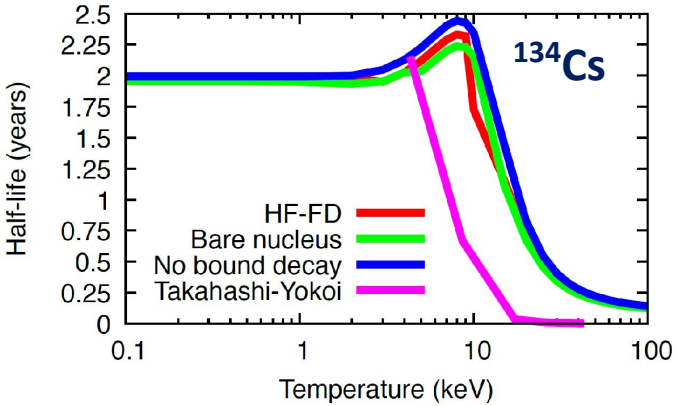
- Theory and Models («physics cases approver»)
- Inner Plasma Chamber (design, construction & control)
- Auxiliary e-gun (design, construction & control)

Services requests (2026):

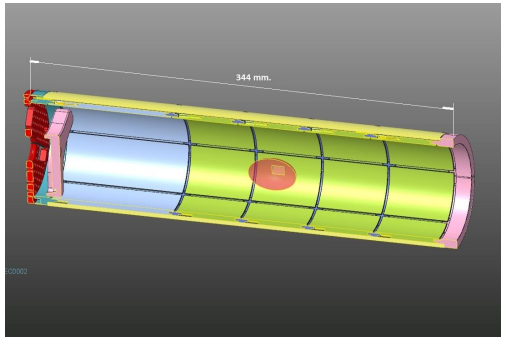
- Mechanical design: 2 months
- Mechanical workshop: 3 months
- Electronics workshop: 0.5 months

Bologna activities in PANDORA

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 Plasma Active Inner Chamber:

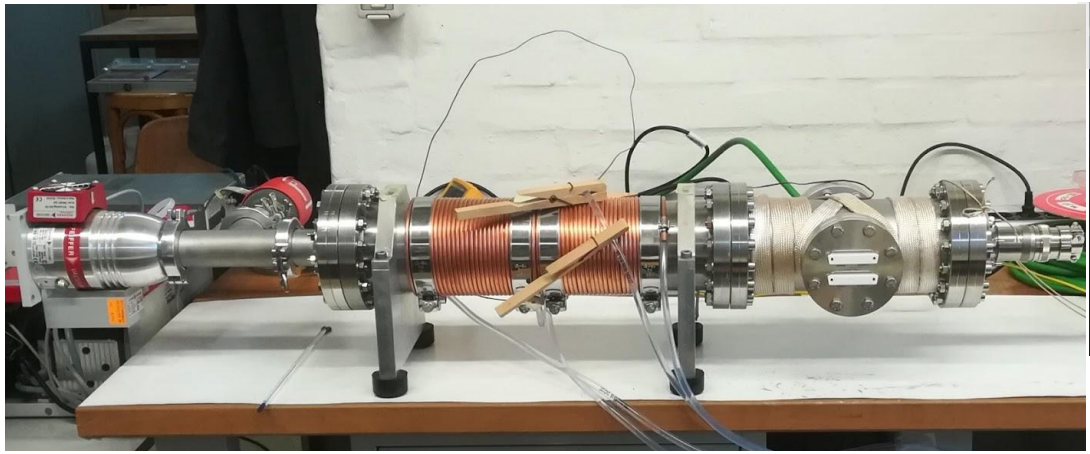


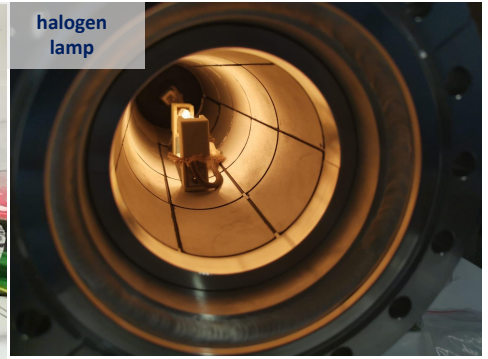
a reduced scale prototype (~1:3) of the Plasma Inner Chamber has been **designed and constructed in Bologna** (tech. work of R. Michinelli, M. Furini, C. Gessi, M. Guerzoni, A. Margotti) within the IONS experiment in GR5. The prototype **will be tested on the AISHa ion source @ LNS by end-2025**.

Several pre-tests of the inner chamber have been successfully performed in Bologna (2023÷2025), in order to verify degassing, mechanical tolerances, thermal conductivity and electrical insulation, by using a specially constructed dummy chamber, identical to that of AISHa **even in terms of water-cooling (2025)**.

The prototype of the Plasma Active Inner Chamber:
latest tests on a water-cooled dummy chamber in Bologna (2025)

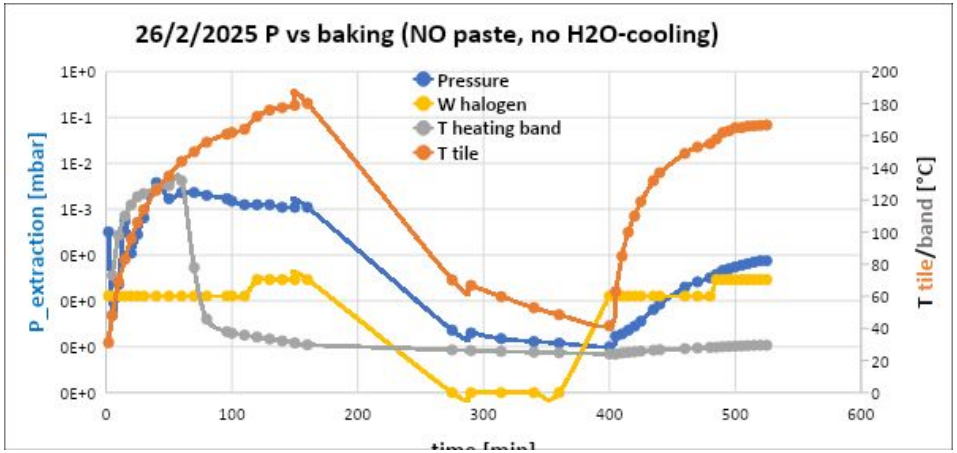
«Tails» and anodized rings





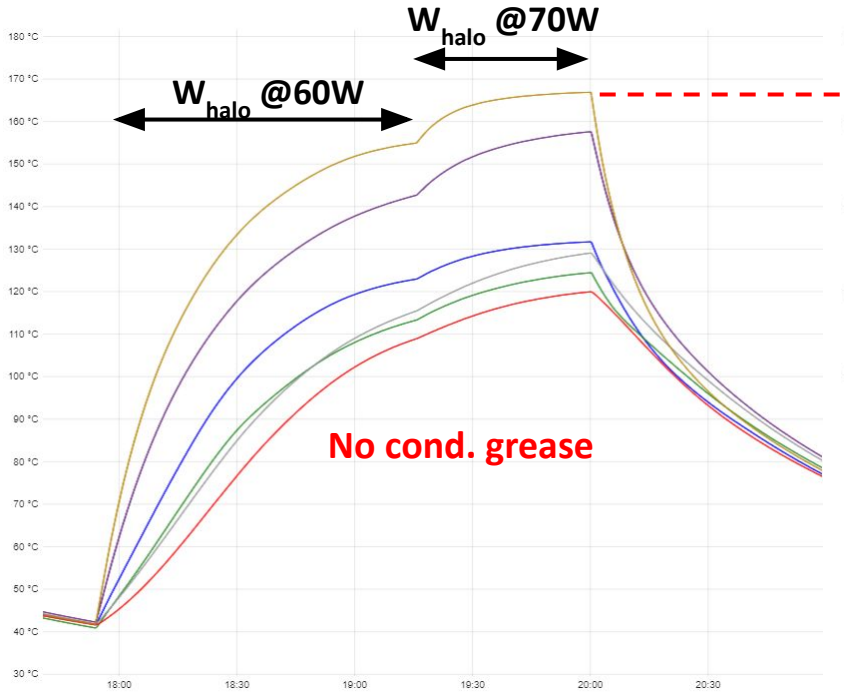
Test under vacuum @ 200°C:

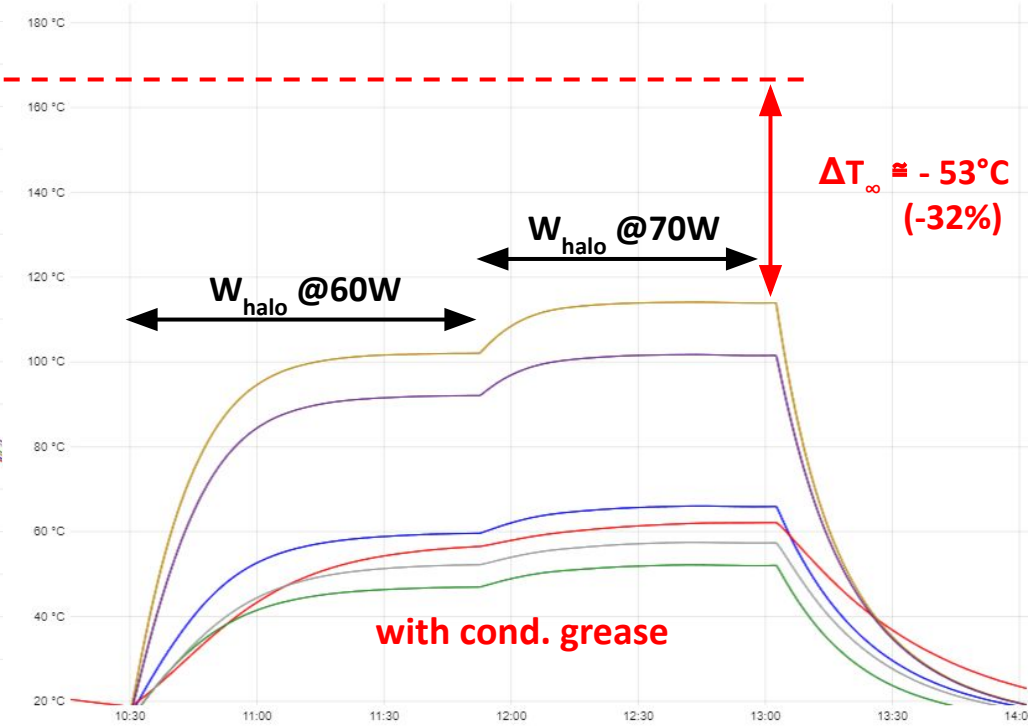
- **check degassing**
- **electrical insulation**
- **thermal conductivity with thermally conductive grease for high vacuum**



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

Tests in 2025: water-cooled dummy chamber + thermally conductive grease

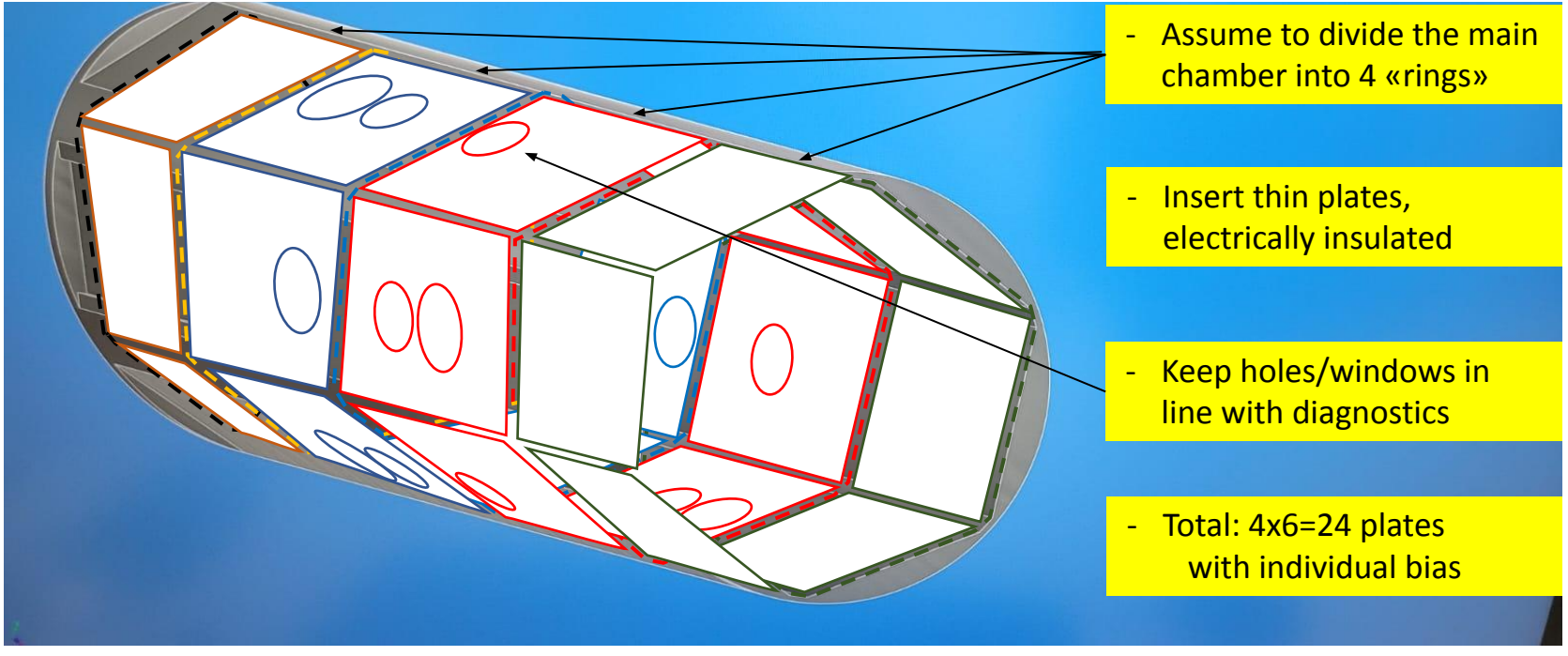




Chamber water cooling + thermally conductive grease (silver based) for high vacuum did a BIG improvement in heat transport and dissipation

Work in 2025-2026: design & constr. & commissioning of the final Plasma Active Inner Chamber for PANDORA apparatus

The design of the Main Plasma Chamber is ongoing (LNS + INFN-PD): design could change from a cylindrical geometry to an extrusion of an hexagonal section this geometry simplifies a lot the integration of detectors on the Active Inner Chamber. The final design will be possible only when the technical specifications (dimensions) of the magnetic trap will be known (expected in 2-3 months).

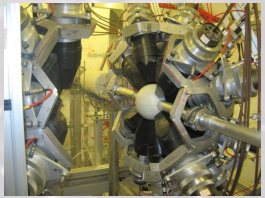


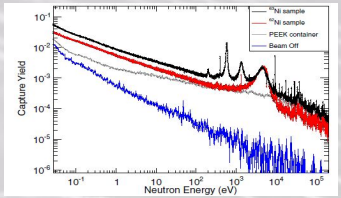
- Assume to divide the main chamber into 4 «rings»
- Insert thin plates, electrically insulated
- Keep holes/windows in line with diagnostics
- Total: 4x6=24 plates with individual bias

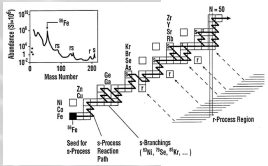
n_TOF

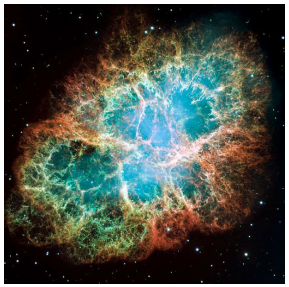
n_TOF

Neutron cross sections for science and technology







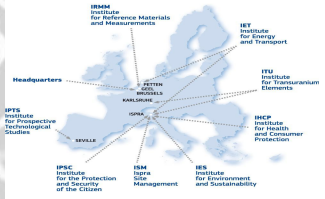


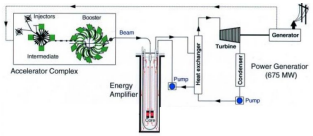
n_TOF

neutron Time Of Flight

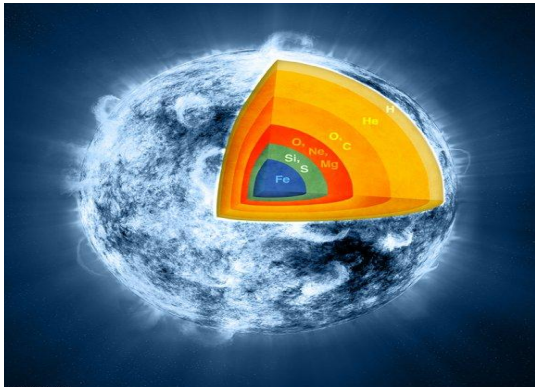
GELINA

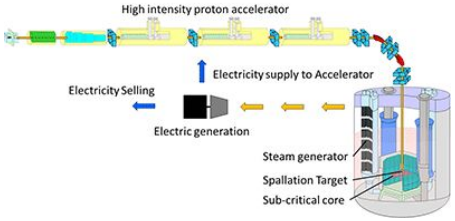
@ EC-JRC-GEEL

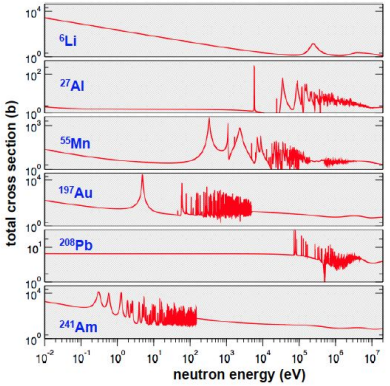




Research fields







Nuclear Astrophysics

- ✔ **N**ucleosynthesis of heavy elements
- ✔ **S**tellar evolution
- ✔ **B**ig bang nucleosynthesis

Nuclear technology and medical application:

- ✔ **F**ission reactors (Gen-IV, ADS)
- ✔ **F**usion
- ✔ **T**ransmutation of nuclear waste
- ✔ **N**eutron capture therapy (hadrontherapy)

Basic Nuclear Physics

- ✔ **N**uclear structure effects on fission
- ✔ **E**xcited states (spin parity of resonances)
- ✔ **S**ymmetries and fundamental interactions

n_TOF Collaboration

n_TOF - Italia

49 ricercatori, 11 tecnologi
26.5 FTE

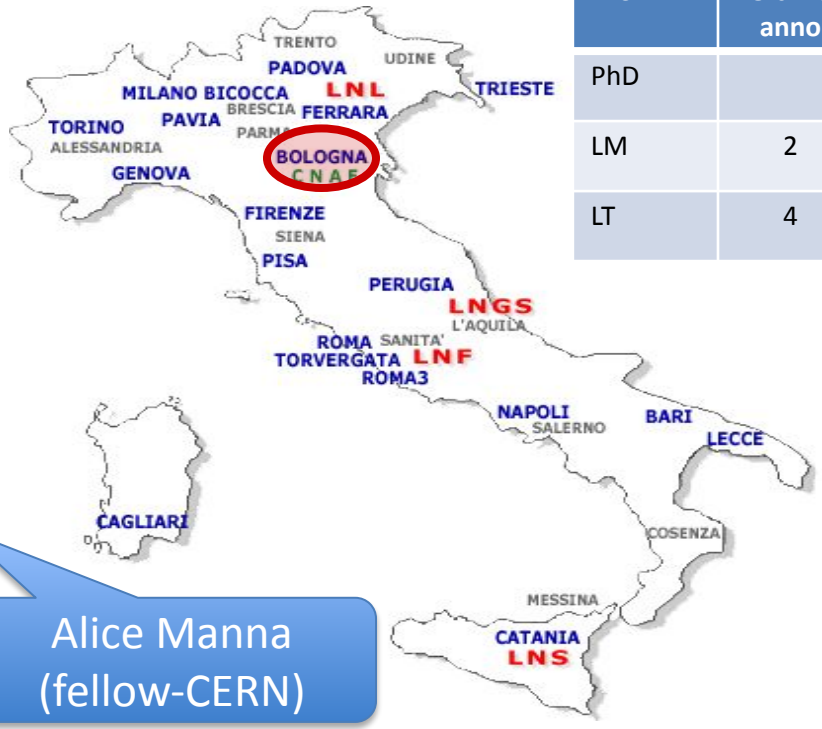
Collaborazione con
ENEA (Bologna, Frascati)
INAF (Teramo), **CNR** (Bari)

11 Sezioni INFN

n_TOF @ BO

Membri	Ruolo	FTE
Castelluccio D.M.	Ricercatore ENEA	0.5
Console Camprini P.	Ricercatore ENEA	0.3
Massimi C.	Prof. Ass.	0.5
Mengoni A.	Associato senior	0.8
Pieretti N.	PhD	1
Sahoo R.N.	Assegnista	1
Zarrella R.	Assegnista	0.5
Totale		**4.6**

TESI	Ultimo anno	Dal 2012
PhD		2
LM	2	12
LT	4	23



Alice Manna (fellow-CERN)

RUOLI

- A. Mengoni **Spokesperson** della **collaborazione internazionale**
- C. Massimi membro dell'**Editorial Board**

n_TOF (CSN3) sinergia con RIPTIDE (CSN5)

n_TOF @ BO – 2024/2025

Proposal presentati a guida BO

Scientific Committee Paper

Report number	CERN-INTC-2024-006 ; INTC-P-689
Title	**Study of n+^{63,65}Cu reactions and their relevance for nuclear technologies and Astrophysics**
Project Manager/ Technical Coordinator	Massimi, Cristian

Scientific Committee Paper

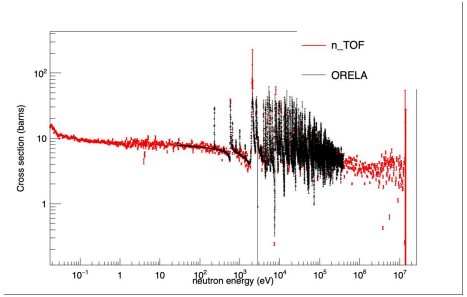
Report number	CERN-INTC-2025-009 ; INTC-P-732
Title	**Search for a resonance in ^{25}Mg(n,γ) cross section to constrain the ^{22}Ne(α,n)^{25}Mg neutron source reaction rate**
Project Manager/Technical Coordinator	Massimi, Cristian

Scientific Committee Paper

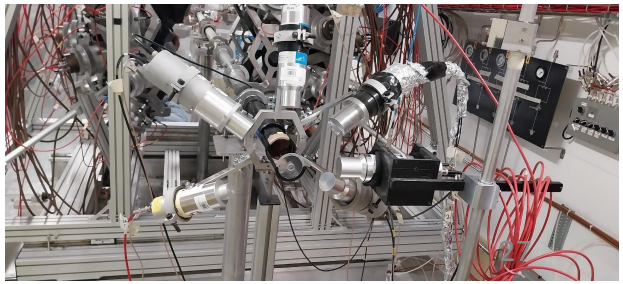
Report number	CERN-INTC-2025-031 ; INTC-P-743
Title	**Production of ^{10}Be and ^{26}Al radionuclides via neutron reactions in SiO_2 rocks: implications for burial dating related to the Cradle of Humankind--UNESCO World Heritage Site**
Project Manager/Technical Coordinator	Rabaglia, Sara; Massimi, Cristian

HIGHLIGHTS 2024-2025

primo esperimento di trasmissione a n_TOF (modifica della beamline) per la misura della sezione d'urto totale su rame



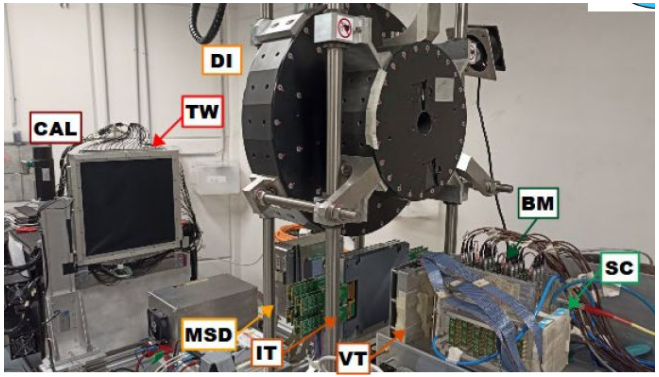
primo esperimento di cattura radiativa con rivelatori $LaBr_3$ e $LaCr_3$ su ^{25}Mg



FOOT

FOOT: General Information

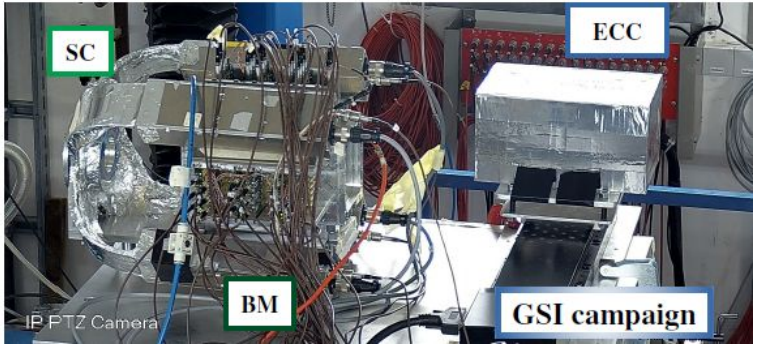
MAGNETIC SPECTROMETER



2 SETUPS

DETECTORS COMPLETED

EMULSIONS



- **FTE FOOT in BOLOGNA:**
  - 2026: 4.85

- **DATA TAKING in 2025:**
  - CNAO: 6 sept 2025
  - CNAO: November 2025

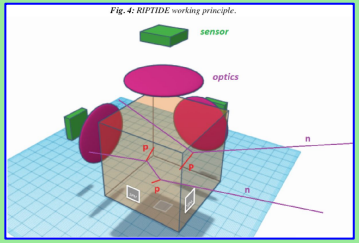
Service Requests (FOOT/RIPTIDE):

- ELE: 2
- STG: 1
- STA: 2
- OFF: 2
- PR. MEC: 1

- **THESIS FOOT/RIPTIDE BOLOGNA (july24-july25):**
  - Bachelord: 9
  - Master: 4

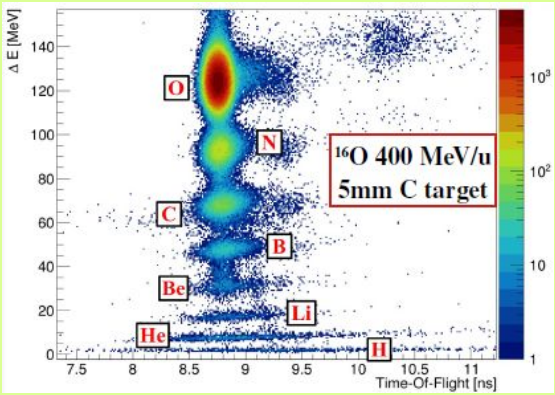
SPIN OFF ACTIVITY:

- RIPTIDE: neutron detector (Gr 5 talk)

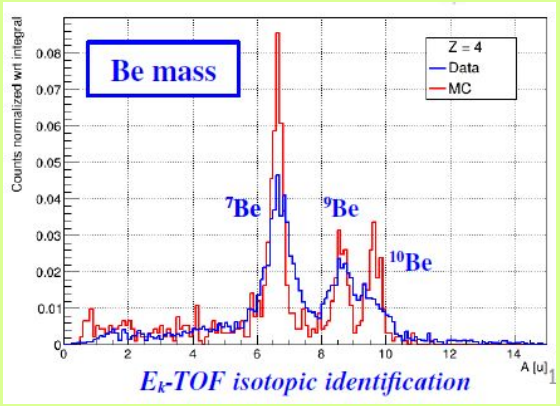


Fragment Identification

Charge

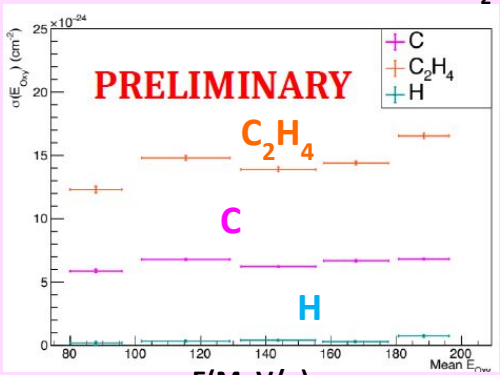


Mass



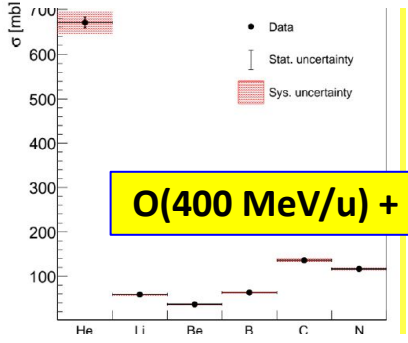
latest results

Integral cross sections O(200 MeV/u) + C,C_2H_4,H



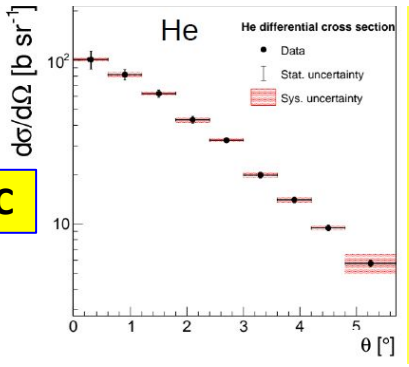
Cross Sections O(400 MeV/u) + C, C_2H_4

Integral

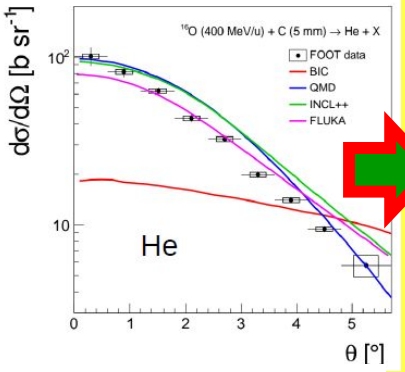


O(400 MeV/u) + C

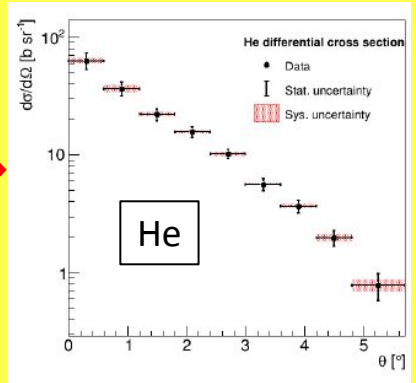
Differential



Model Comparison



BY SUBTRACTION O(400 MeV/u) + H



Also

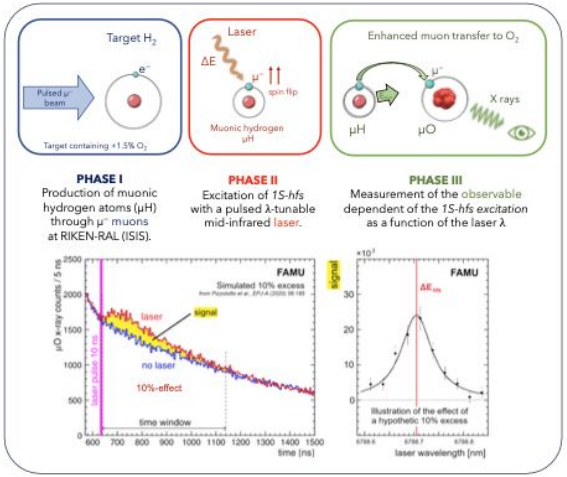
- He
- Li
- Be
- B
- C
- N

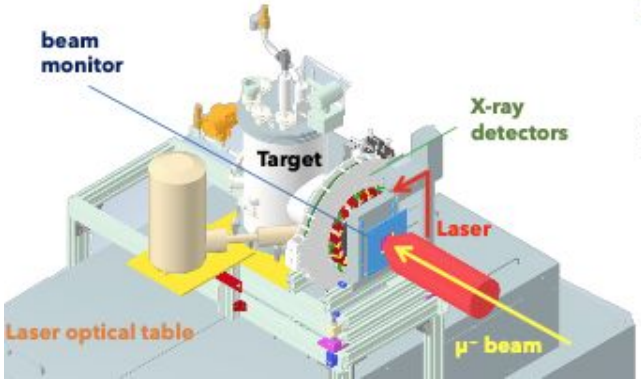
FAMU

FAMU

Misura spettroscopica **della transizione dello splitting iperfino** (HFS) dello stato 1S di **idrogeno muonico**

⇒ Informazione sulla struttura del protone (Raggio di Zemach) e dell'interazione muone-nucleone





The search for signal is performed comparing X-Ray spectra in presence and in absence of laser injection.
Comparison takes into account account muon flux, target temperature and pressure, etc…
Data taking per la misura dello splitting iperfino cominciata nel 2023.

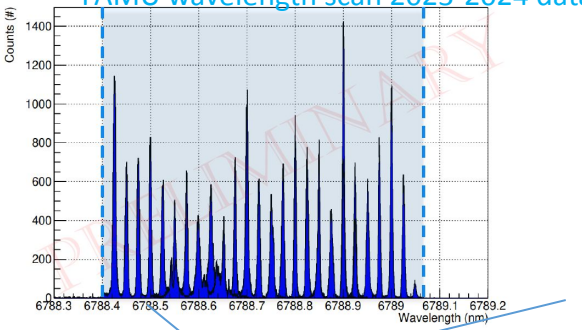
FAMU Highlights

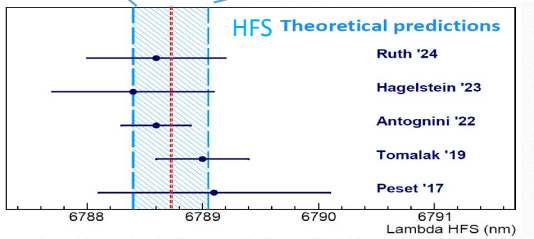
40 days of beamtime in 2023-24
-> analisi preliminare mostra miglioramento qualità dei dati del 2024 rispetto al 2023 (ex. aumentata energia laser)

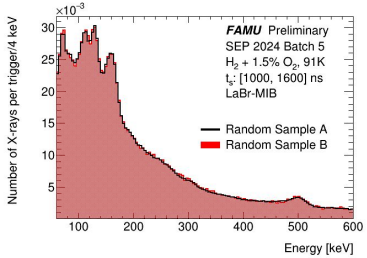
2025: previsti due beamtime (sett+nov) ~22 giorni

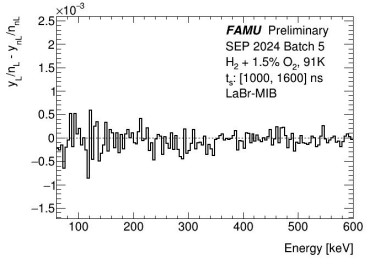
Indagate 26 wavelengths in step di 25 pm

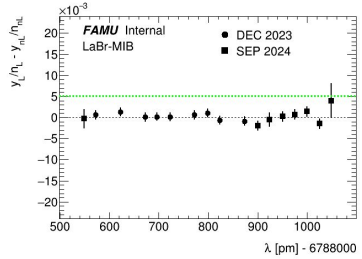
FAMU wavelength scan 2023-2024 data











$$\lambda = \lambda_{HFS}$$

$$y_{HFS} = \frac{y + S \times \varepsilon_{HFS}}{n} - \frac{y}{n} = \frac{S}{n} \times \varepsilon_{HFS}$$

Signal expected in case of an Oxygen X-rays excess of 3%.

In preparazione: 1 paper su performance ed 1 paper su laser.

FTE: 0.65 (FTE Baldazzi va a zero per raggiunti limiti di età)

Richieste:
Servizi: STG: 1 M.U., SE: 0.5 M.U.

RIASSUNTO RICHIESTE

Tabella riassuntiva richieste ai servizi Gr-III

ESPERIMENTO	LAB. ELETTRONICA(MU)	STG(MU)	OFFICINA(MU)	PROGETTAZIONE(MU)	CCL(MU)	TECNOLOGIE AVANZATE (MU)	TOT
ALICE	13	0	0.5	5	0.5	6	25
EPIC	11	1	4	2	2	5	25
FAMU	0.5	1	0	0	0	0	1.5
FOOT/RIPTIDE	2	1	2	1	0	2	8
PANDORA_GR3	0.5	0	3	2	0	0	5.5
n_TOF	→RIPTIDE						0

MESE UOMO	27	3	9.5	10	2.5	13	65