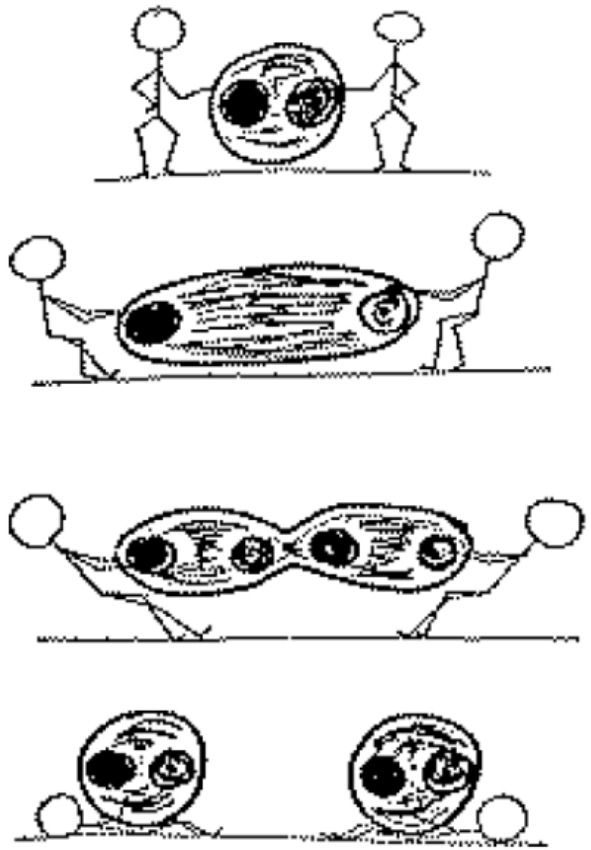
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Nuclear Physics at the Frascati National Laboratories

Silvia Pisano

Local coordinator of the
Nuclear Physics group



CSN3
Fisica
Nucleare

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Carlo

The National Scientific Committee 3

1. QUARKS AND HADRON DYNAMICS

KAONNIS, JLAB12, MAMBO, ULYSSES, EIC

2. PHASE TRANSITION IN HADRONIC MATTER

ALICE, NA60+

3. NUCLEAR STRUCTURE AND REACTION MECHANISMS

FORTE, GAMMA, CHIRONE, NUCL-EX, NUMEN, PRISMA_FIDES

4. NUCLEAR ASTROPHYSICS

ASFIN, ERNA, LUNA, n_TOF, PANDORA

5. FUNDAMENTAL INTERACTIONS

LEA, ALPHA, JEDI, VIP, FAMU

6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

Research lines follow those of NuPECC

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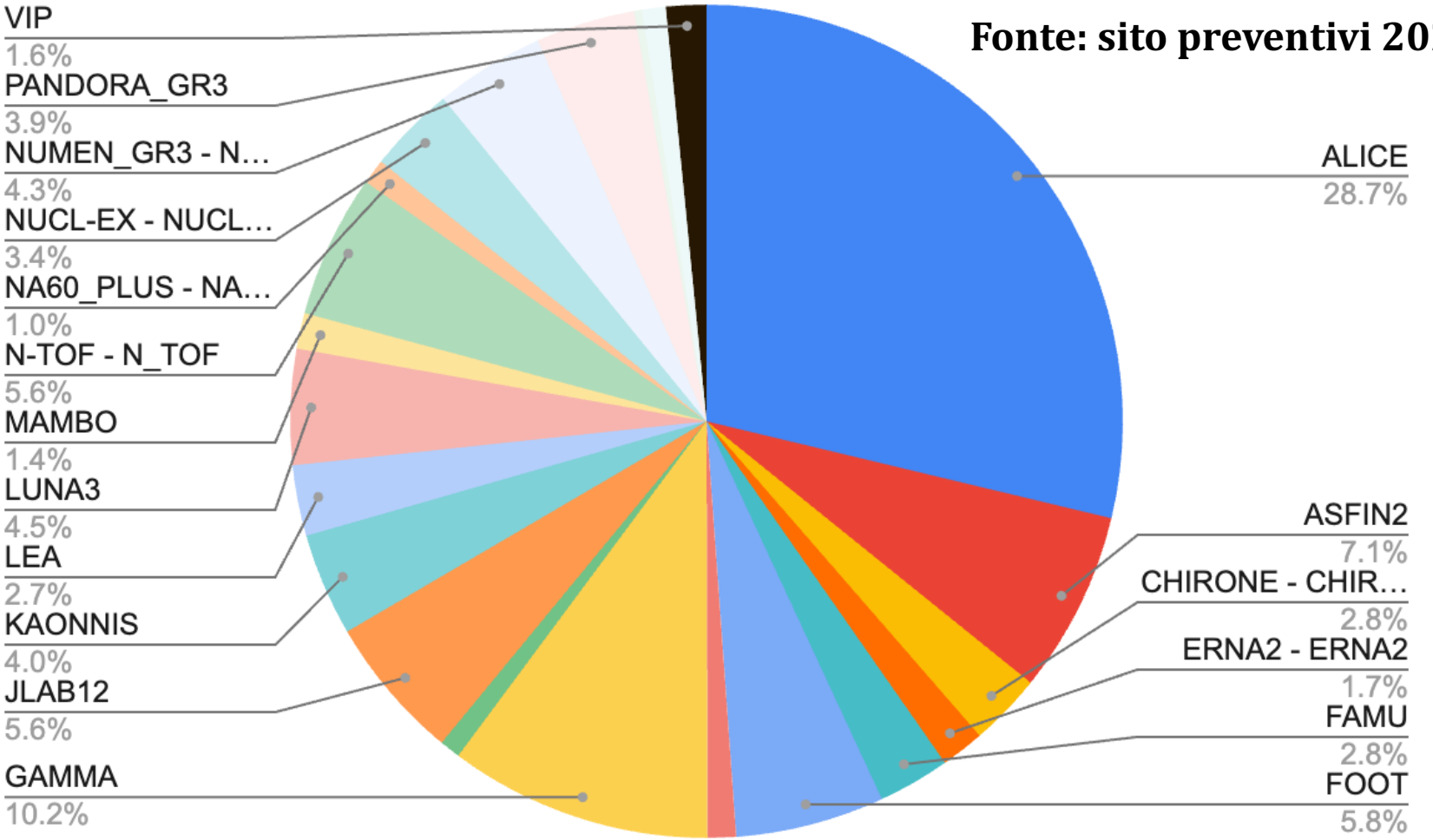
Commissione Scientifica Nazionale 3

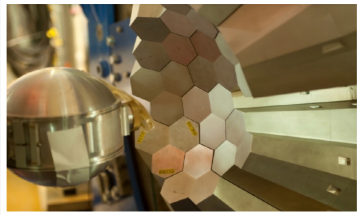
Fonte: sito preventivi 2025



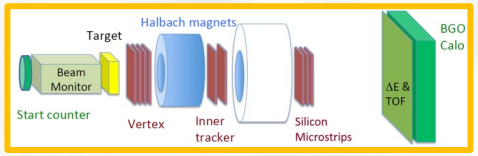
The CSN3 experiments

LUNA

GAMMA

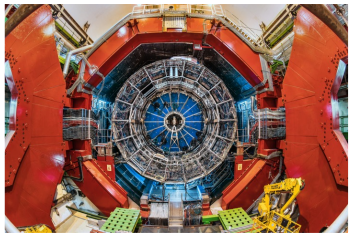


FOOT



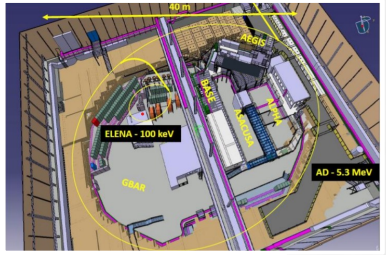
JLAB, MAMBO

ALICE

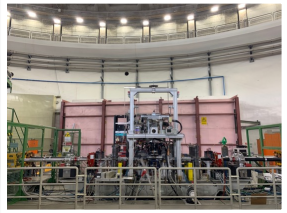


keV MeV GeV TeV

E_{beam}

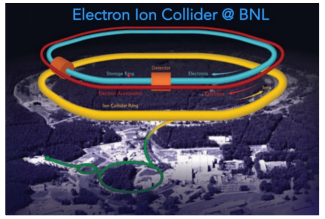


NUMEN, ASFIN2,NUCLEX, CHIRONE, FORTE…



SIDDHARTA

JEDI



EIC

CSN3 experiments use different type of beams (stable or radioactive), from low to very high energies

Experiments and people

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

ALICE	CERN	QGP	5.3 FTE	A. Fantoni
FOOT	CNAO/TIFPA /LNS/BTF	Framm. Nucleare	1.05 FTE	E. Spiriti
e-JLab12	JLAB	Fisica adronica	1.4 FTE	M. Mirazita
BGOOD	Bonn/Mainz	Fisica adronica	1.2 FTE	P. Levi Sandri
	LNF	Fisica nucleare	15 FTE	C. Curceanu
	LNGS	Fisica nucleare	6.5 FTE	C. Curceanu
nTOF	CERN	Astrofisica nucleare	3.2 FTE	G. Claps

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FOOT

ALICE@CERN

The LNF Group Joined ALICE in 2006

Study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus high energy collisions

LNF people significantly involved in detectors R&D and construction, data analysis, operations and management roles

ALICE	Afferenza (%)
Nicola Bianchi	60
Alessandra Fantoni (RL)	100
Valeria Muccifora	100
Silvia Pisano	100
Federico Ronchetti	LD@CERN
Marco Toppi	100
Oton Vazquez Doce	70
FTE totali	5.3

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Responsibilities at CERN

Management Board (AF: 11/2019-11/2022 & FR: 11/2022 - on going)

Collaboration Board (VM: 06/2017-today)

Run Coordinator (FR: 2015, 10/2019-2022)

Run Manager (SP: 04/2024, 10/2024)

EPN Technical Coordinator (FR: 01/2013 – on going)

Training Coordinator (SP: 01/2023 – on going)

EMCAL Deputy Project Leader (AF: 01/2013 – on going)

Editorial Board (OVD 12/2023– on going)

PWG Correl. & Flow Conveener (OVD 06/2024 – on going)

ALICE Activities at LNF

Physics Analysis on femtoscopy

ITS QC for checking offline the functionality of ITS during data taking

Shifts for data taking at CERN

Training people for shifts

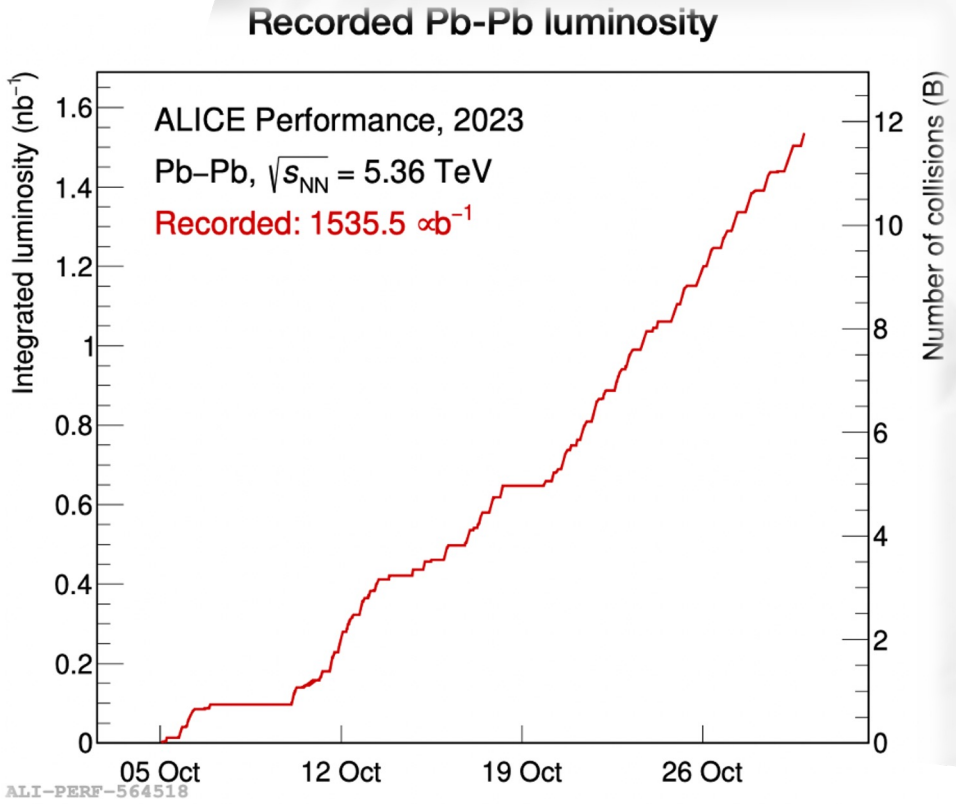
EPN coordination

ITS QC for checking offline the functionality of ITS during data taking

ALICE@CERN

ALICE standard **interaction rate**:

- 500 kHz (pp)
- Peaking at 47 kHz in 2023 (Pb-Pb)



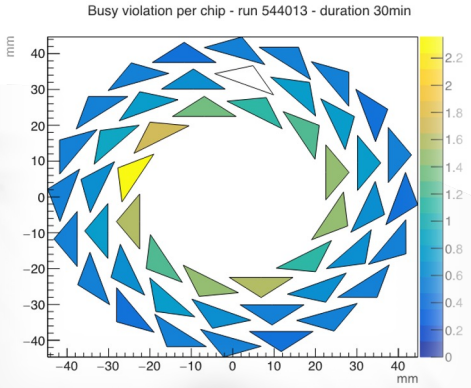
Successful 2023 Heavy-Ion run!

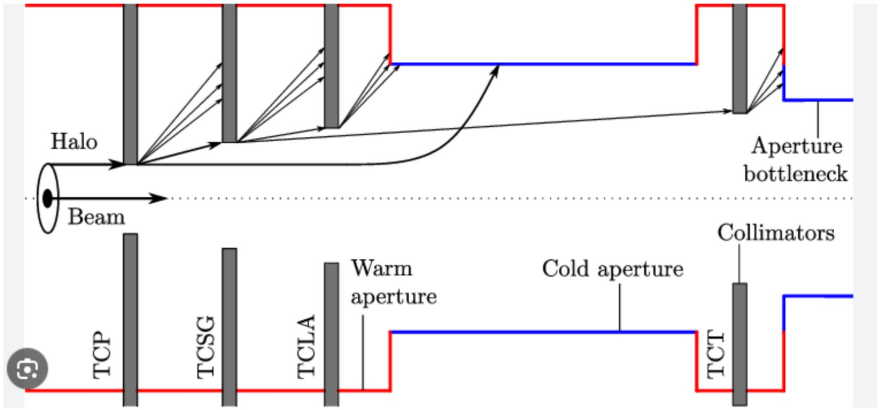
- Instantaneous luminosity: ~1031 (pp) – 1027 (Pb -Pb) cm^{-2} s^{-1}
- Nominal ITS framing rate: 202 kHz (pp) – 67 kHz (Pb -Pb)
- Successfully tested up to 4 MHz interaction rate in pp

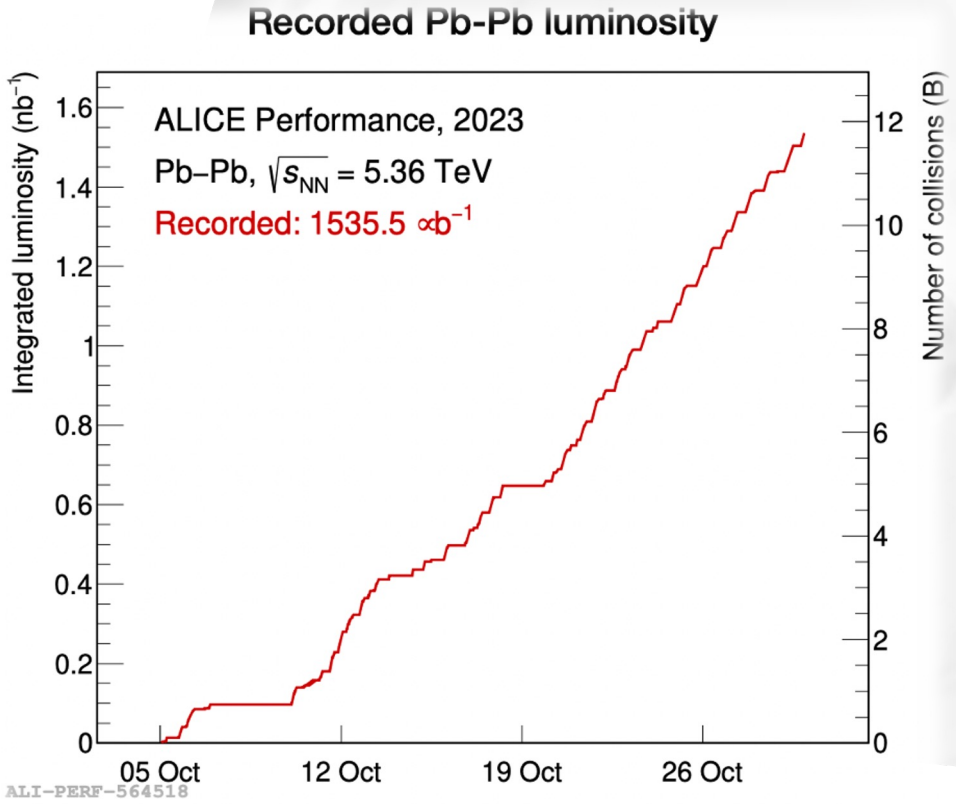
- 0.4% pixel excluded in the whole detector
- 94 chips dead/excluded, 970k dead pixels and 500k noisy pixels

ALICE@CERN

...but for a big drama at the beginning







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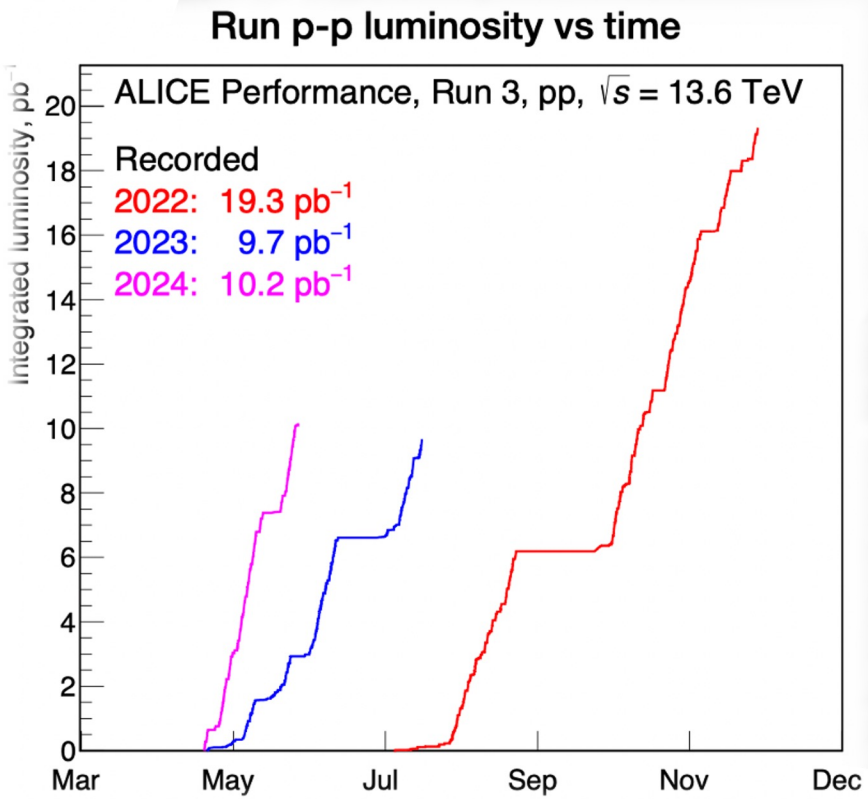


Excellent start of pp operations in 2024:

- data taking efficiency systematically exceeding 95%
- 10.2 pb^{-1} already collected

- Instantaneous luminosity: ~1031 (pp) – 1027 (Pb -Pb) cm^{-2} s^{-1}
- Nominal ITS framing rate: 202 kHz (pp) – 67 kHz (Pb -Pb)
- Successfully tested up to 4 MHz interaction rate in pp

- 0.4% pixel excluded in the whole detector
- 94 chips dead/excluded, 970k dead pixels and 500k noisy pixels

During fill 9860 (8h15m duration) the shift crews established the new record of data taking efficiency, scoring an impressive 99.77% with a single run of 8h14m duration!

ALICE@CERN

ITS Quality Control

Study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus high energy collisions

LNF people significantly involved in detectors R&D and construction, data analysis, operations and management roles

LNF provided 1/4 of the total Outer Barrel staves, building and assembling 29 staves between the end of 2018 and end of 2019

- Analysis of new runs 3x/week, coordinated via the JIRA ticket system
- Cluster analysis → bad run if :
  - 1 layer with >25% empty staves (cluster occupancy is 0 cluster/pixel/nChip);
  - the run has >10% empty lanes overall;
  - the average cluster size is out of limits by 3-7 pixels
  - detector occupancy has been studied → cluster size is independent of the Interaction Rate (IR); decrease of the cluster size at the end of the fill can be due to the beam-gas interactions

Tracks analysis → good run if:

1. no anomalies in angular track distribution
2. the Z vertex shape ranging between -1.5 and 1.5 cm;
3. the average nClusters per track ranging between 5 to 6.

Stable performance → in 2022 5.6% of physical runs globally labeled as bad

Stable performance since the very beginning of Run3, even in Heavy Ion runs

ALICE@CERN

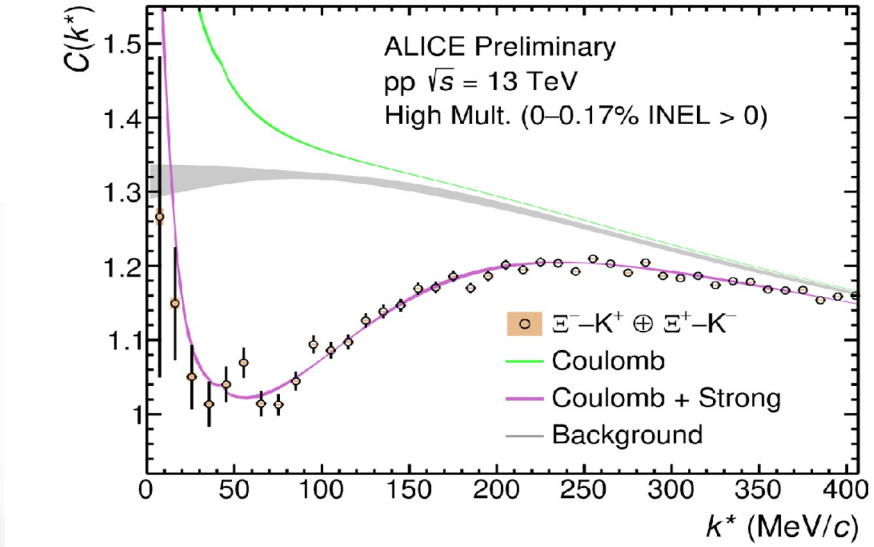
ΞK and Ξπ femtoscopy in pp collisions

ALICE preliminary results show the most precise data on ΞK and Ξπ at low momenta, to be added to the other meson-baryon systems K^-p, $K^-\Lambda$ already studied

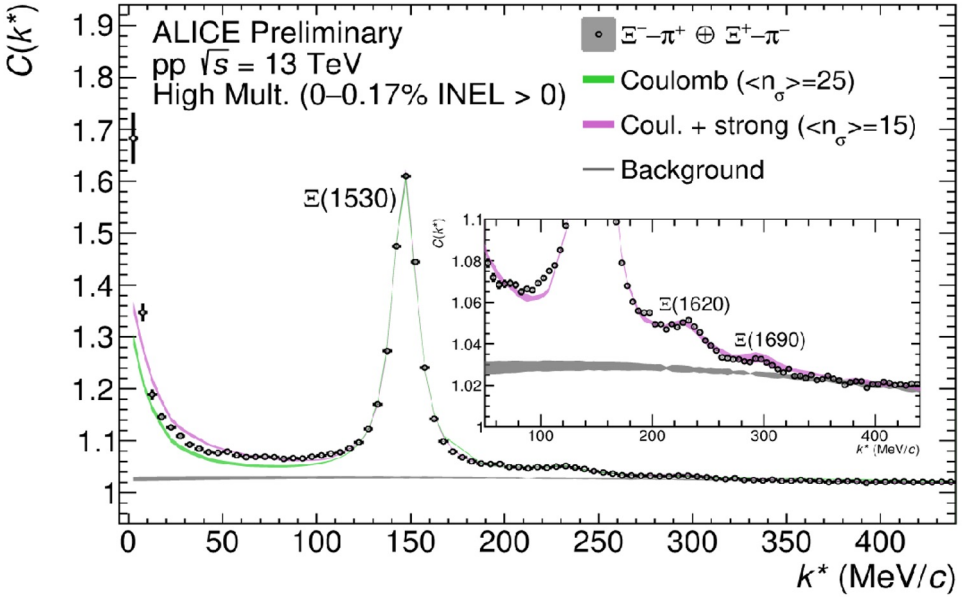
→ novel high-precision constraints on S=-1 and S=-2 meson-baryon interactions

- Valuable input for low-energy effective chiral lagrangians
- Complementary tool to study exotic states: in this case Ξ(1620), Ξ(1690)

Possibility to explore other relevant systems in these sectors with on-going Run 3! *Preliminary data presented at SQM2024*



ALI-PREL-574336



ALI-PREL-573869

ALICE@CERN

Exploring the strong interaction of three-body systems at the LHC

Published in arXiv:2308.16120 [nucl-ex]. *Under review by Physical Review X*

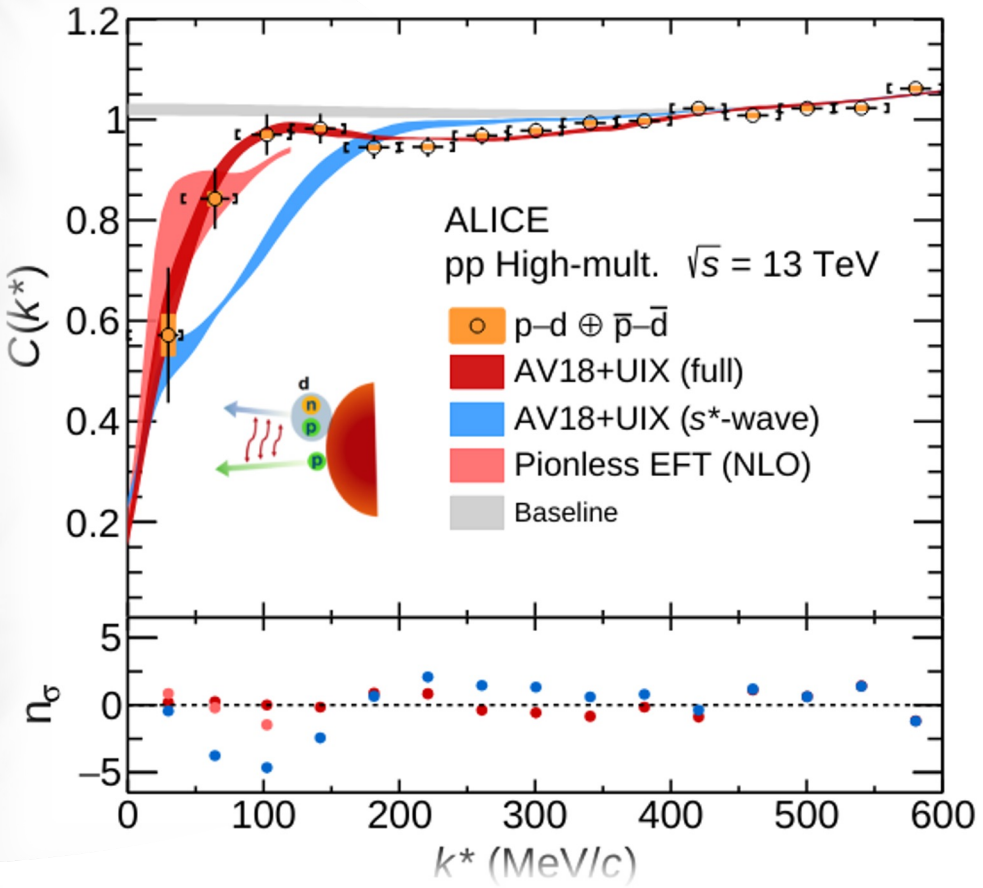
Physics message: *two-body femtoscopy studies involving deuterons in pp collisions at the LHC enable access to study the dynamics and the effects of the strong interaction in three-body systems.*

ALICE results show that for the p-d detailed full three-body calculations *considering the internal structure of the deuteron* are necessary to explain the data:

→ Calculations (red) from back-to-back paper published in *Phys.Rev.C 108 (2023) 6, 064002*, «*Role of three-body dynamics in nucleon-deuteron correlation functions*»

→ M. Viviani *et al.,* and include 2- and 3-body forces

→ *Expectation to be sensible to 3-body forces with ALICE Run-3 data!*



ALICE@CERN

2024 activities and requests

Study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus high energy collisions

LNF people significantly involved in detectors R&D and construction, data analysis, operations and management roles

- ALICE data taking
- Training Coordination & Run Managements
- ITS QC offline
- Discussions for analysis, papers, technical boards, management boards, collaboration boards
- Possible test on sensors at BTF for ALICE 3
- Possible test on sensors at BTF for ALICE 3

- Nessuna richiesta sostanziale ai servizi.
- Richieste economiche (oltre MOF) principalmente di missioni.
- Circa 40k€ per 2024 per missioni
    1. turni presa dati ALICE, supporto/oncall ITS2
    2. riunioni/discussioni fisica per ITS3
    3. riunioni MB, CB, TB

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6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

Quarks and hadron dynamics

Study of the quark dynamics inside hadrons and nuclei, to understand the strong interaction, searching for effects beyond those predicted by QCD.

- 3D imaging of the nucleon
- quark dynamics
- nuclear and hyper-nuclear dynamics
- nucleon excited states via meson photoproduction
- low energy kaons interaction
- how does the mass of the nucleon arise?
- how does the spin of the nucleon arise?
- what are the emergent properties of dense systems of gluons?

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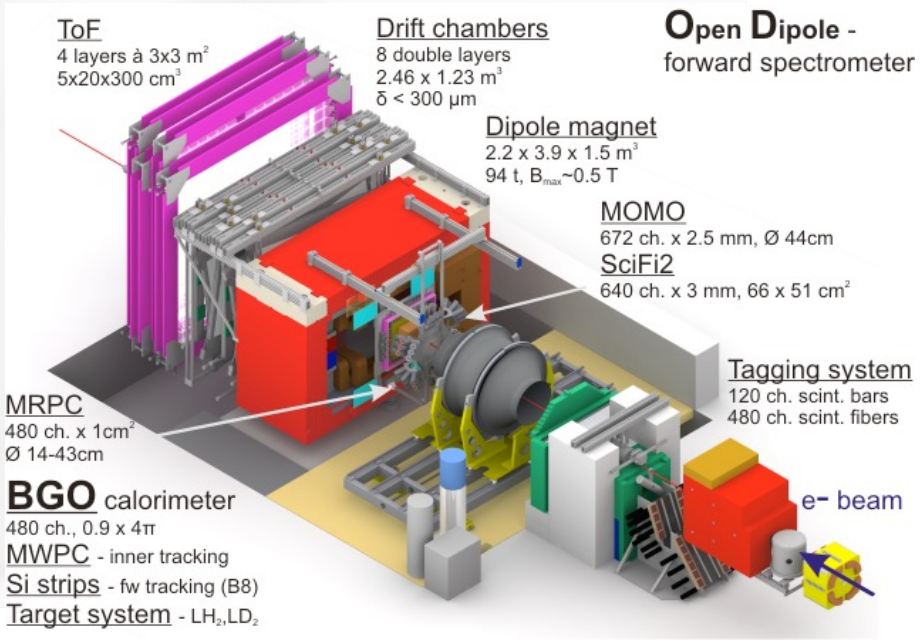
Nucleon excited states via meson photoproduction at MAMIc (A2@Mainz) and ELSA (BGOOD@Bonn)

- Transition form factor
- η' threshold anomaly
- Dibarion-exaquark searches



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International collaboration: Bonn PI, Bonn HISKP, Roma1, LNF, Messina (not INFN), Pavia, Roma2, Glasgow, PNPI Gatchina (presently suspended), INR Mosca, IHENP Kharkov, INR Kyiv, Lamar U. (Texas)

Responsabilities:

- Co-spokesperson of BGOOD (LNF)
- Spokesperson of the η photoproduction (LNF)
- RN (LNF)
- BGO (+ Roma2)
- Barrel (+ ISS)
- MRPC (+ Roma2)

2 researchers for 1.2 FTE

Total INFN ~ 7 FTE

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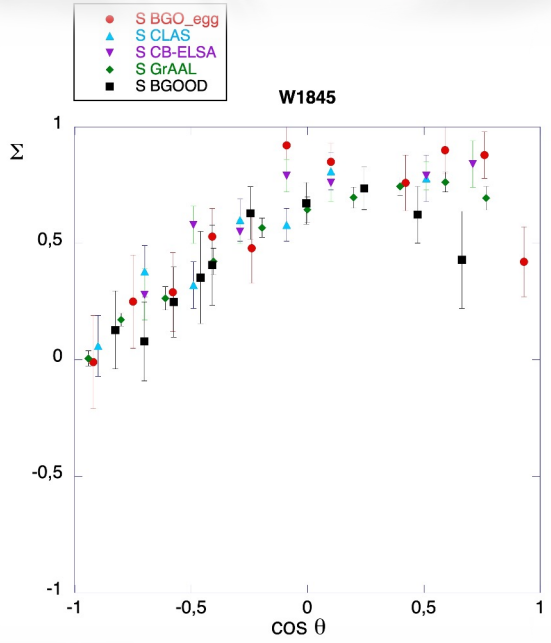
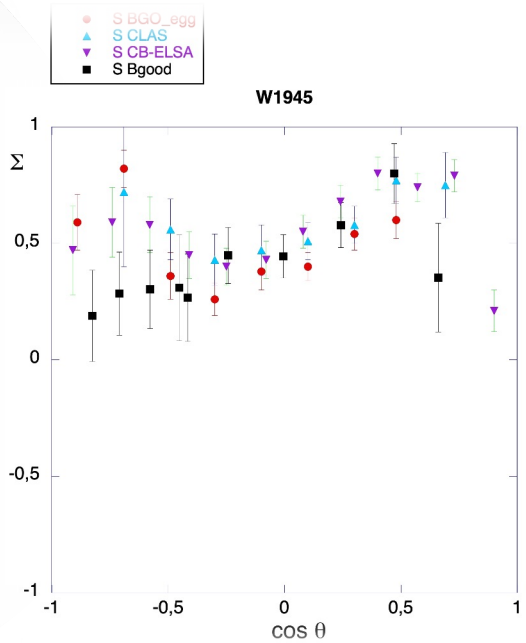


Estrazione delle sezioni d'urto di foto-produzione di η



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- ELSA ha ripreso il normale funzionamento per esperimenti di fisica adronica.
- Il programma a media scadenza prevede il funzionamento fino al 2025, seguito da un lungo stop per upgrade.
- Proseguimento dell'attività di analisi nei canali η e η'
- Ottobre 2025 fine delle prese dati → chiusura esperimento
- Richieste economiche complessive: 10 k€

- Nessuna richiesta ai servizi, salvo imprevisti

MI	ME	TRA	INV	C.APP	CON	Totale
0	10	0	0	0	0	10

Quarks and hadron dynamics

KAONNIS: low energy kaons interaction studies at Dafne and J-PARC

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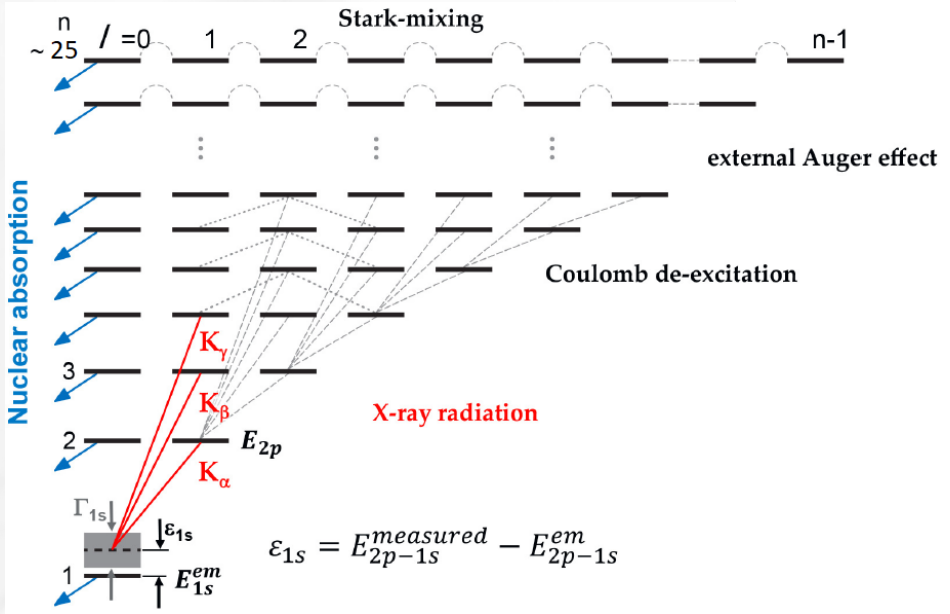
Precision measurement of the shift and of the width of the 1*s* level of kaonic deuterium and of other types of kaonic atom X-ray transitions → unique info about the QCD in non-perturbative regime in the strangeness sector not obtainable otherwise; impact in astrophysics (EOS neutron stars).



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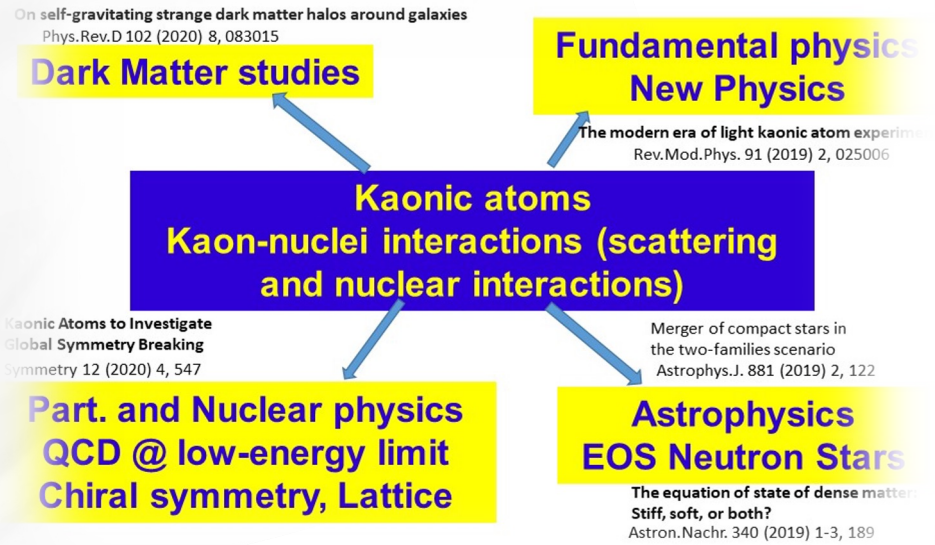

Quarks and hadron dynamics

KAONNIS: low energy kaons interaction studies at Dafne and J-PARC

Integrated initiative (SIDDHARTA + AMADEUS + Giappone + Future). **International collaboration**:

1. INFN; SMI-OAW (Austria)
2. IFIN-HH (Romania); Politecnico MI
3. TUM, Helmholtz I. (Germany)
4. RIKEN, Tokyo U. (Japan)
5. Jagellonian U. (Poland)
6. Zagreb U. (Croatia)
7. ELPH Tohoku University

25 Publications (2023-2024),
Organization of 5 workshops

1. M . Bragadireanu	0.5	16. A. Scordo	0.7
2. M. Bazzi	0.3	17. A. Buttacavoli	1
3. F. Sgaramella	1	18. F. Principato	1
4. A. Clozza	0.3	19. F. Sirghi	1
5. C. Curceanu	0.7	20. M. Skurzok	0.5
6. L. De Paolis	0.5	21. F. Napolitano	0.2
7. R. Del Grande	0.5	22. O. Vazquez D.	0.3
8. D. Bosnar	0.5	23. K. Toho	1
9. M. Iliescu	0.4	24. J. Zmeskal	0.3
10. P. Levi Sandri	0.2	25. K. Dulski	0.5
11. A. Khreptak	0.2	26. D. Sirghi	0.2
12. M. Merafina	0.6	27. C. Cantone	0.2
13. C. Milardi	0.2	28. A. Pietropaoli	0.1
14. F. Artibani	1	29. A. C. Pacheco	0.1
15. L. Abbene	1	**FTE totali**	**15**

Quarks and hadron dynamics

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Integrated initiative (SIDDHARTA + AMADEUS + Giappone + Future). **International collaboration**:

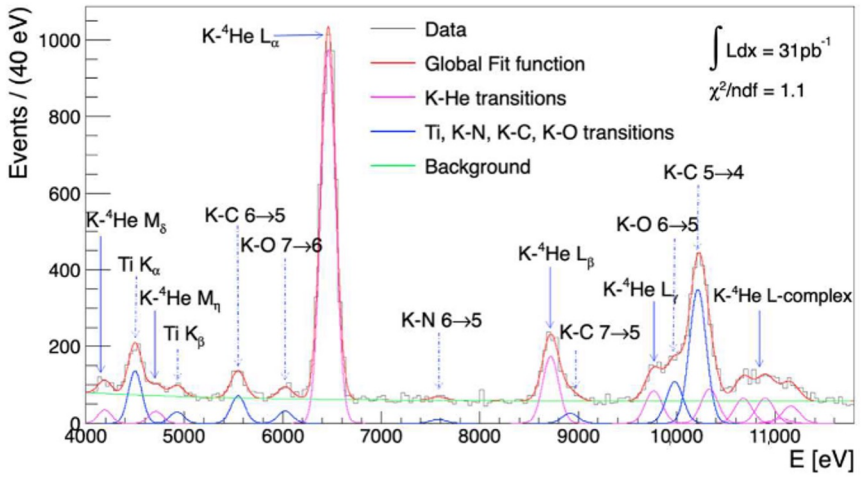


Figure 9. X-ray energy spectrum and fit to the data after the data selection. The lines of kaonic helium transitions are fitted with a Voigt function, and the other lines are fitted with a Gaussian. The L-complex is described by a convolution of the higher energy lines of the L-series transitions.

April 2023: SIDDHARTA-2 run with kaonic neon for debug and degrader optimization

From May 2023 to April 2024: Kaonic deuterium runs (Run1, Run2 and Run3) for 975 pb (815 with good background); kaonic atoms with CdZnTe and HPGe setups

From 10th May: run Kd at half density (yields puzzle) – up to now about 140 pb

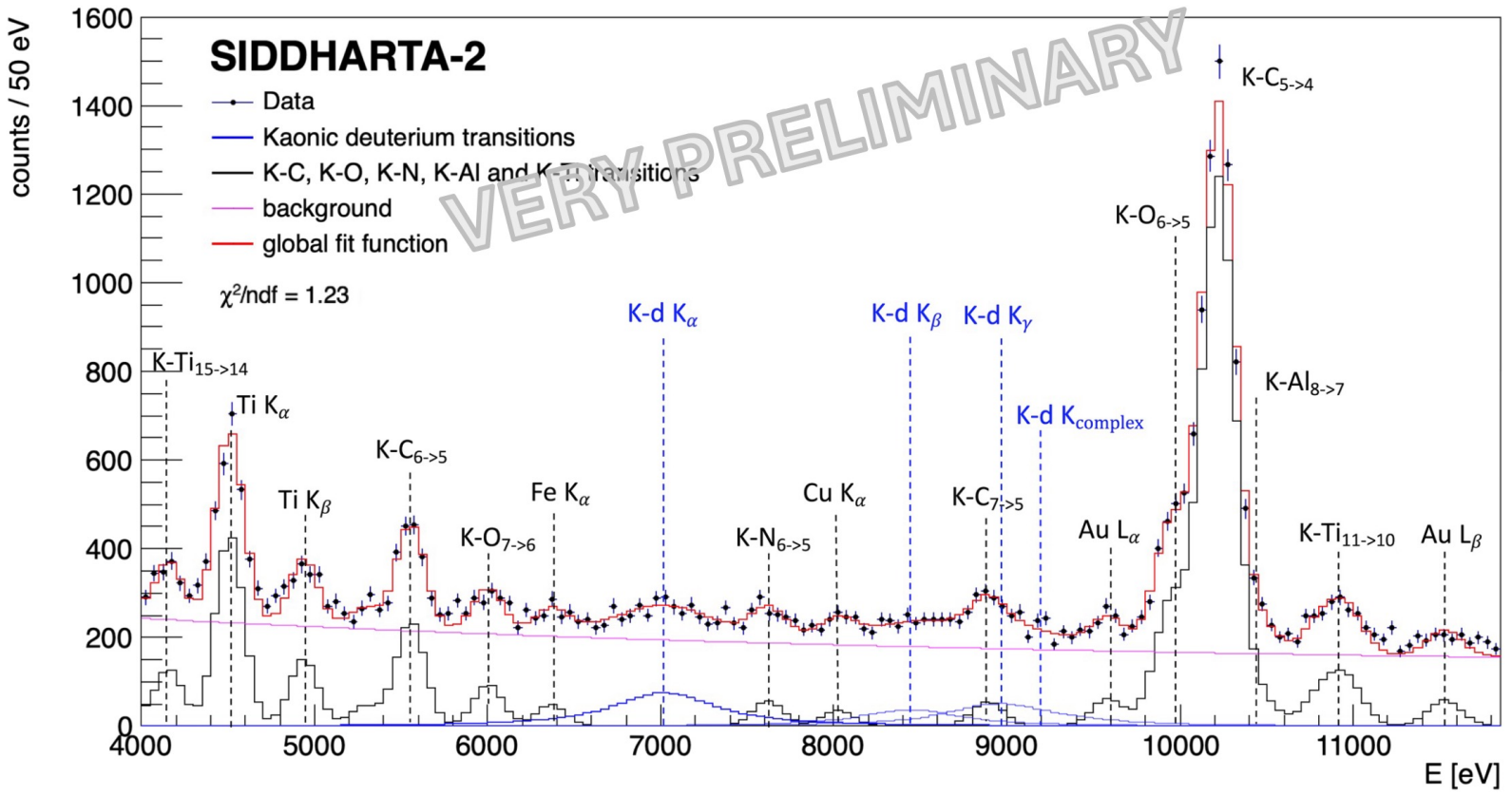
KAONNIS main outcomes 2023/4:

1. *First measurement of kaonic helium-4 M-series transitions, J. Phys. G, 51 055103, 2024*
2. Characterization of the SIDDHARTA-2 Setup via the Kaonic Helium Measurement, *Condensed Matter. 2024; 9(1):16*
3. Kaonic atoms at the DAFNE collider: a strangeness adventure, *Front.in Phys. 11 (2023) 1240250*
4. First simultaneous K−p→Σ0π0, Λπ0 cross section…at 98 MeV/c; *Phys.Rev.C 108 (2023) 5, 055201*

Quarks and hadron dynamics

$$\varepsilon_{1s} = -816 \pm 53\ (\text{stat}) \pm 2\ (\text{syst})\ \text{eV}$$
$$\Gamma_{1s} = 756 \pm 271\ (\text{stat})\ \text{eV}$$

Analysis on 20% of the available data



*"The **most important experiment to be carried out in low energy K-meson physics today** is the **definitive determination of the energy level shifts in the K–p and K–d atoms**, because of their direct connection with the physics of $\bar{K}N$ interaction and their complete independence from all other kinds of measurements which bear on this interaction".*

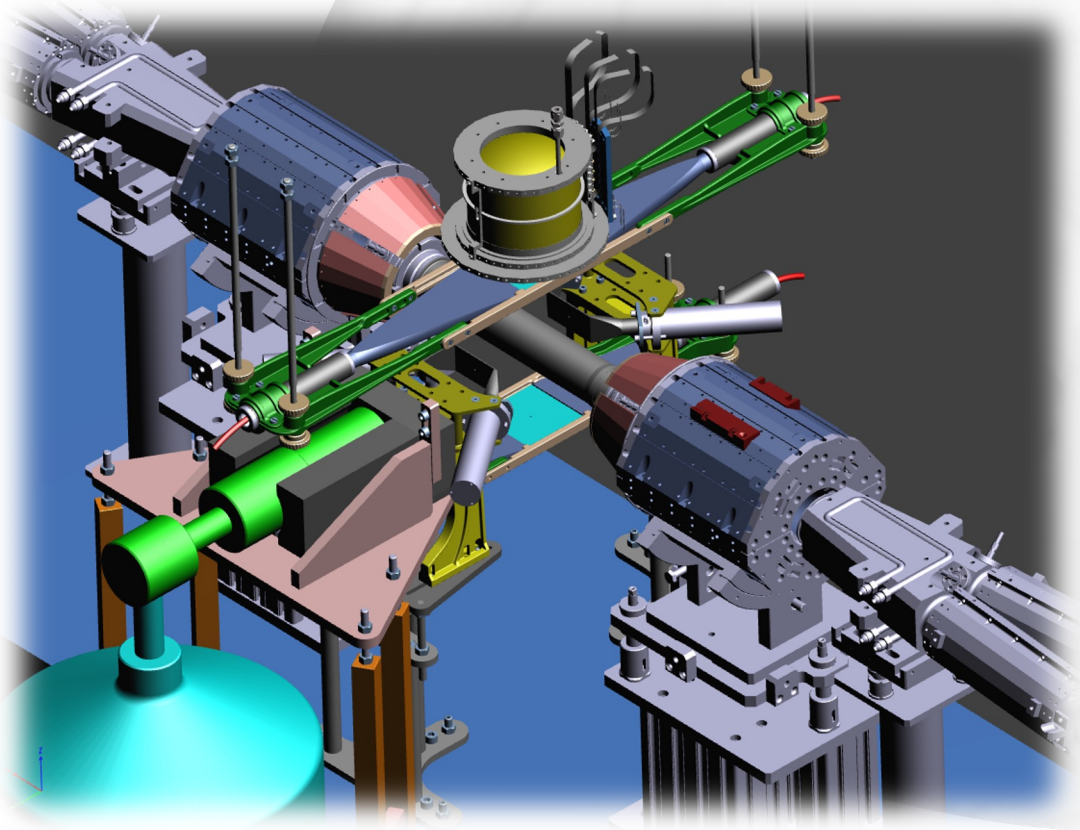
R.H. Dalitz (1982)

We did it!!!

Tanti ringraziamenti a: Divisioni Acceleratori e Ricerca, DAFNE, Direttore LNF, Gr. 3, INFN e tutto lo staff LNF!!!

Quarks and hadron dynamics

KAONNIS: low energy kaons interaction studies at Dafne and J-PARC



High and Intermediate-mass kaonic atoms with
HPGe and CZT detectors as test measurements in parallel with SIDDHARTA-2

KAONNIS activities:

- Finalize Kd analyses → extraction of the shift and the width of the transition: high-impact in understanding QCD in the strange sector; extraction of the Kd yields: impact in understanding the cascade processes
- Extract antiK-nucleon scattering lengths (with theoreticians)
- Publish Kaonic Neon → Kaon mass
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Fundamental physics at the strangeness frontier at DAΦNE. Outline of a proposal for future measurements, *C. Curceanu et al., Front.in Phys. 11 (2023) 1240250*

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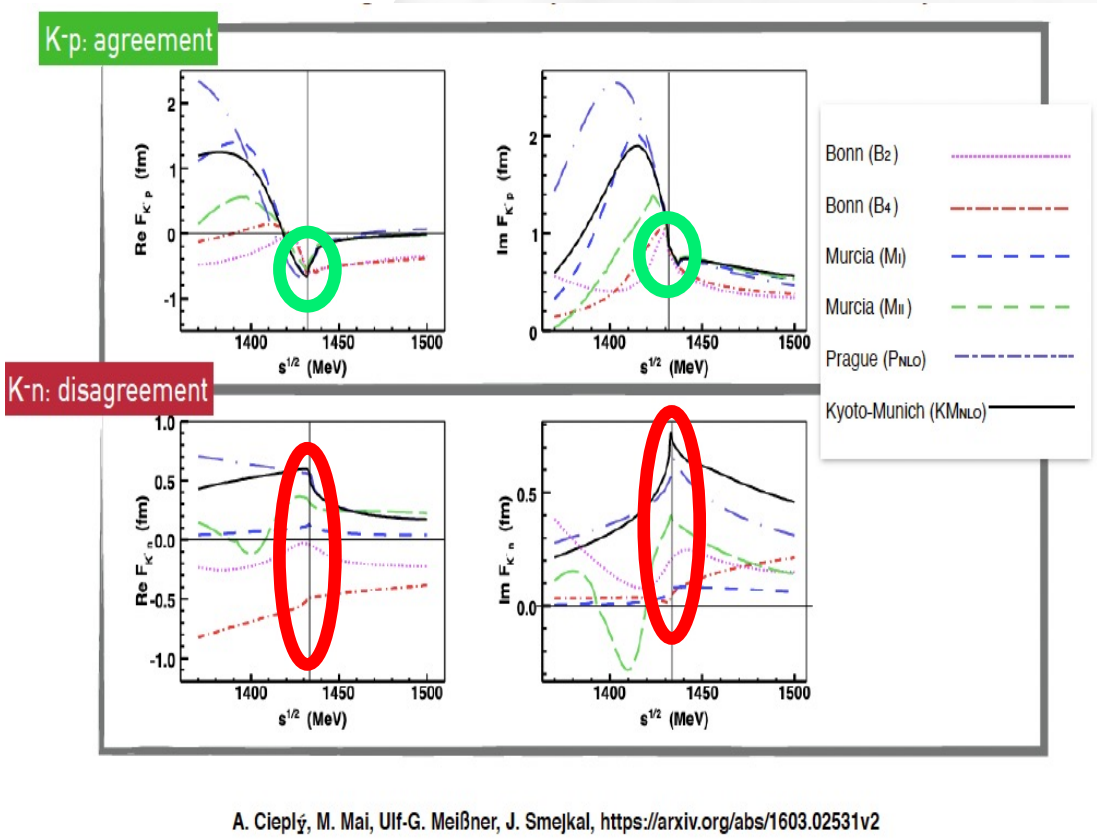

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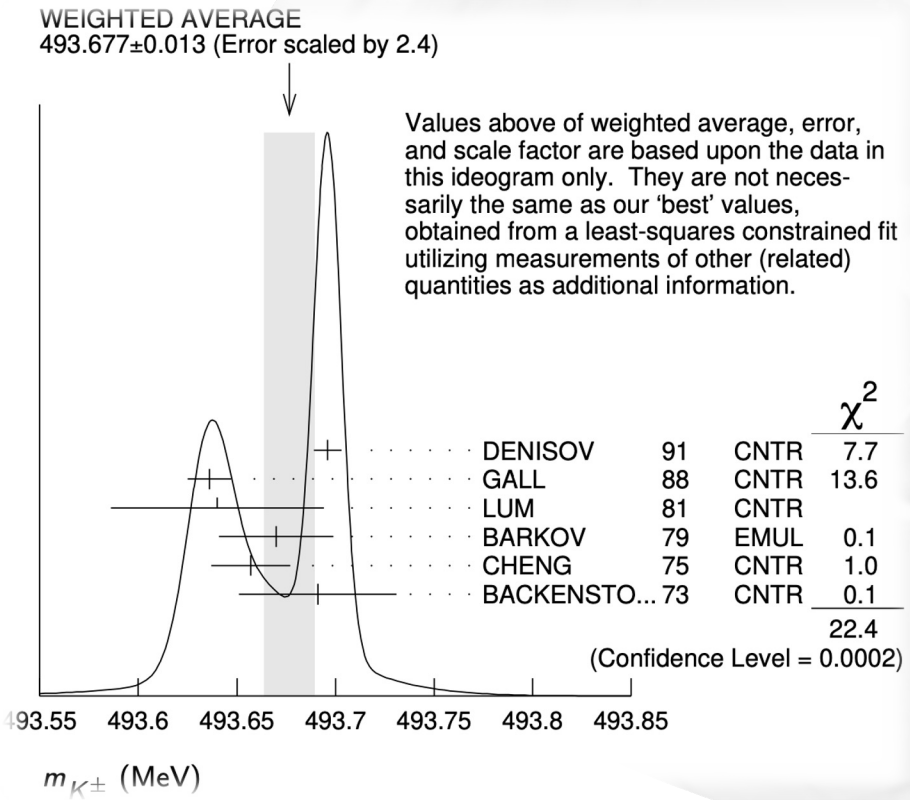

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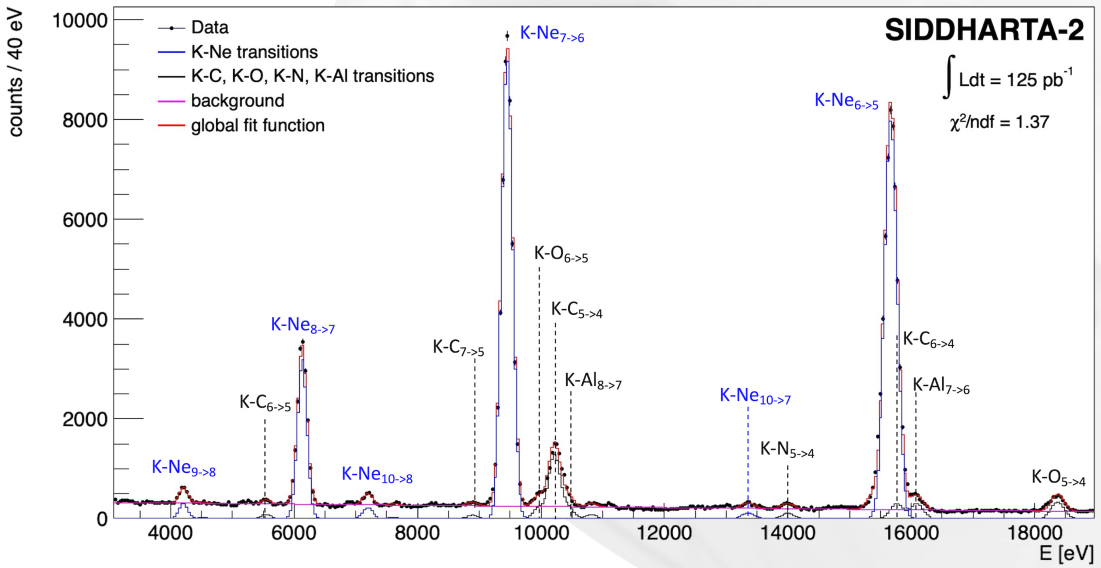

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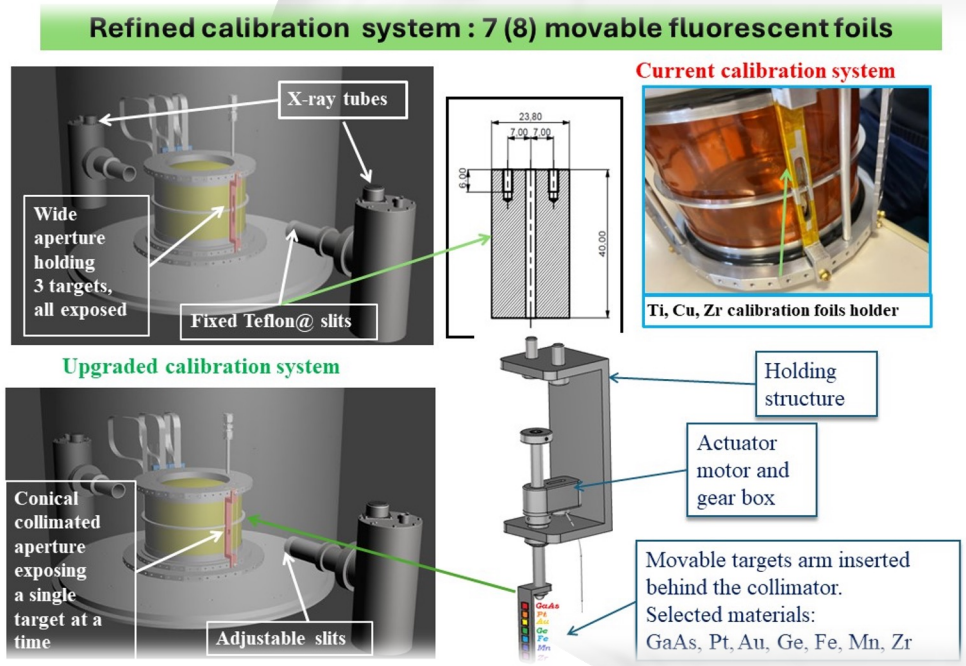

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Quarks and hadron dynamics

KAONNIS: low energy kaons interaction studies at Dafne and J-PARC

EXKALIBUR step 1: Kaonic neon for the charged kaon mass

- First measurement: kaonic neon high-n levels transition ***with precisions below 1 eV, to extract the charged kaon mass***.
- By using a gaseous target → to resolve the **ambiguity in the charged kaon mass determination**, providing a new precise value through the measurement of kaonic neon high-n transitions (and precision tests of QED in atomic systems with strangeness).
- Integration of an **advanced calibration system** for sub-eV precision measurements of X-rays transitions, to achieve a systematic error at the same level of the statistical one.
- **An integrated luminosity of about 200-300 pb-1 to achieve an overall precision on the charged kaon mass below 7 eV (ready from January 2025)**

KAONNIS activities:

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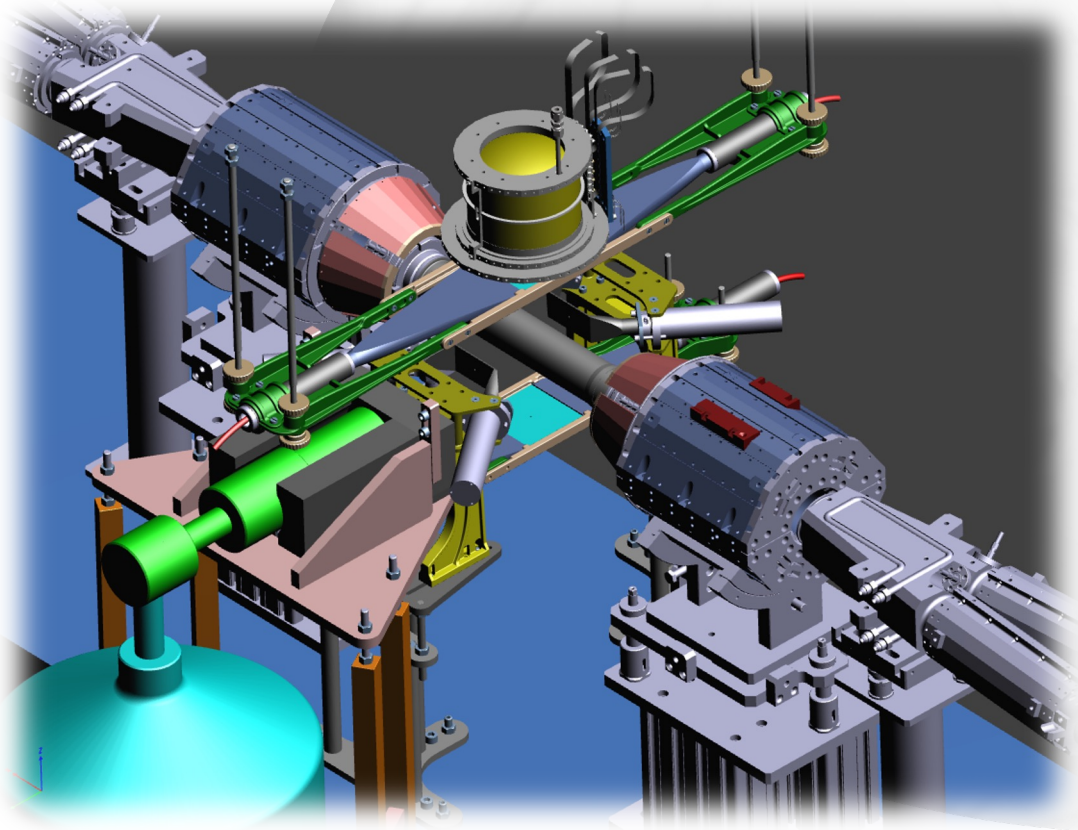

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Quarks and hadron dynamics

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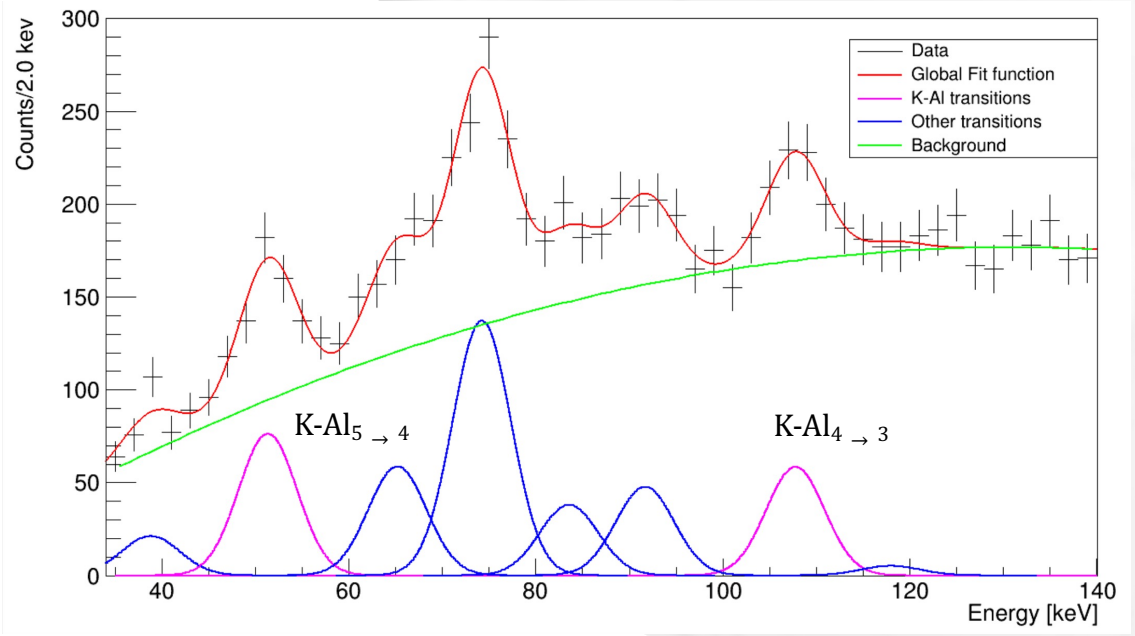

K-Al$_{4\to3}$: 107.8 ± 0.6 keV
K-Al$_{5\to4}$: 51.4 ± 0.4 keV

High and Intermediate-mass kaonic atoms with
HPGe and CZT detectors as test measurements in parallel with SIDDHARTA-2

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Quarks and hadron dynamics

KAONNIS: low energy kaons interaction studies at Dafne and J-PARC

EXKALIBUR step 2: Light Mass (low-Z) Kaonic Atoms:

- The second module of measurement are light mass (Li, Be, B) kaonic atoms, to study in detail the strong interaction between kaon and few nucleons (many body).
- Now precise measurements for these kaonic atoms of the shifts, widths and yields will result in a significative improvement on the knowledge of the interactions of kaons in matter, with a great impact on the low energy QCD and astrophysics (equation of state for neutron stars).

Maximal scientific outcome for:

1. Kaonic Neon → kaon mass
2. Light kaonic atoms (KLi; Be; B)
3. Intermediate mass kaonic atoms (CdZnTe and HPGe)

KAONNIS activities:

- Finalize Kd analyses → extraction of the shift and the width of the transition: high-impact in understanding QCD in the strange sector; extraction of the Kd yields: impact in understanding the cascade processes
- Extract antiK-nucleon scattering lengths (with theoreticians)
- Publish Kaonic Neon → Kaon mass (with a gaseous Ne target)
- Finalize CZT data analyses: KCu, KAl – publications on data taking in parallel to Deuterium run
- **EXKALIBUR initiative put forward at Sci Com for 2025: step 2**

Lithium-6		Lithium-7		Beryllium-9		Boron-10		Boron-11	
Transition	Energy (keV)	Transition	Energy (keV)	Transition	Energy (keV)	Transition	Energy (keV)	Transition	Energy (keV)
3 → 2	**15.085**	**3 → 2**	**15.261**	**3 → 2**	**27.560**	**4 → 3**	**15.156**	**4 → 3**	**15.225**
4 → 2	**20.365**	**4 → 2**	**20.603**	**4 → 3**	**9.646**	**5 → 3**	**22.171**	**5 → 3**	**22.273**
5 → 2	**22.809**	**5 → 2**	**23.075**	**5 → 3**	**14.111**	5 → 4	7.015	5 → 4	7.047
4 → 3	5.280	4 → 3	5.341	5 → 4	4.465	6 → 4	10.826	6 → 4	10.875
5 → 3	7.724	5 → 3	7.814	6 → 4	6.890	6 → 5	3.811	6 → 5	3.828
5 → 4	2.444	5 → 4	2.472	6 → 5	2.425				
6 → 4	3.771	6 → 4	3.815						

Quarks and hadron dynamics

KAONNIS: low energy kaons interaction studies at Dafne and J-PARC

Study of the quark dynamics inside hadrons and nuclei, to understand the strong interaction, searching for effects beyond those predicted by QCD.

- 3D imaging of the nucleon
- quark dynamics
- nuclear and hyper-nuclear dynamics
- nucleon excited states via meson photoproduction
- low energy kaons interaction
- how does the mass of the nucleon arise?
- how does the spin of the nucleon arise?
- what are the emergent properties of dense systems of gluons?

Progettazione: 4 m.u. per progettazione setup per misure massa kaone e soldi targets; setup CdZnTe per misurea tomi kaonici massa intermedia

Officina meccanica: 4 m.u. per costruzioni setup massa kaone; light targets; setup con rivelatori CdZnTe

Tecnici: 2 x 0.5 FTE installazioni e costruzioni varie

MI	ME	TRA	INV	MAN	CON	Totale
0	25	0	40	15	50	130

Quarks and hadron dynamics

- Purple: setup maintenance, upgrade and installation
- Green: test and characterization of the detectors in laboratory
- Orange: commissioning and test with beam at DAΦNE or BTF.
- Yellow: production of the new 1mm SDDs, solid target, front-end electronics and mechanical support frames.
- Blue: data taking.
- X: closure of the lab

ID		Preparation: June W1	W2	W3	W4	July W5	W6	W7	W8	August W9	W10	W11	W12	September W13	W14	W15	W16	October W17	W18	W19	W20	November W21	W22	W23	W24	December W21	W22	W23	W24	Run: 1 W1	W2	W3	W4	2 W5	W6	W7	W8	3 W9	W10	W11	W12	4 W13	W14	W15	W16	5 W17	W18	W19	W20	W21	6 W22
M	**General maintenance of the setup**										x	x																x	x																							
M.1-M.5	Maintenance of the setup										x	x																x	x																							
KNe	**Kaonic Neon measurement**										x	x																x	x																							
KNe.1-KNe.2	Realization of the calibration system and test in lab										x	x																x	x																							
KNe.3	Installation and test of SIDDHARTA-2 setup for KNe run in DAFNE										x	x																x	x																							
KNe.4	Commissioning and calibration of the experimental apparatus with beam										x	x																x	x																							
KNe.5	Data taking: kaonic neon (300 pb^{-1} integrated luminosity)										x	x																x	x																							
SDD	**Activities for 1mm SDDs modules**										x	x																x	x																							
SDD.1-SDD.2	Installation and test of two 1mm SDDs prototypes in lab and BTF										x	x																x	x																							
SDD.3-SDD.4	1mm SDDs arrays bonding and new front-end electronic production										x	x																x	x																							
SDD.5-SDD.7	Preparation and characterization in lab of one bus of 1 mm SDDs										x	x																x	x																							
SDD.8-SDD.9	Test and characterization of the second bus in lab										x	x																x	x																							
LM	**Light mass solid target measurements**										x	x																x	x																							
LM.1-LM.2	Solid target, vacuum flanges and power supply production										x	x																x	x																							
LM.3-LM.5	Installation of the solid target and one/two buses 1mm SDDs in DAFNE										x	x																x	x																							
LM.6	Commissioning with beam										x	x																x	x																							
LM.7	Kaonic atoms from solid target measurement (200 pb^{-1} Integrated luminosity)										x	x																x	x																							

Quarks and hadron dynamics

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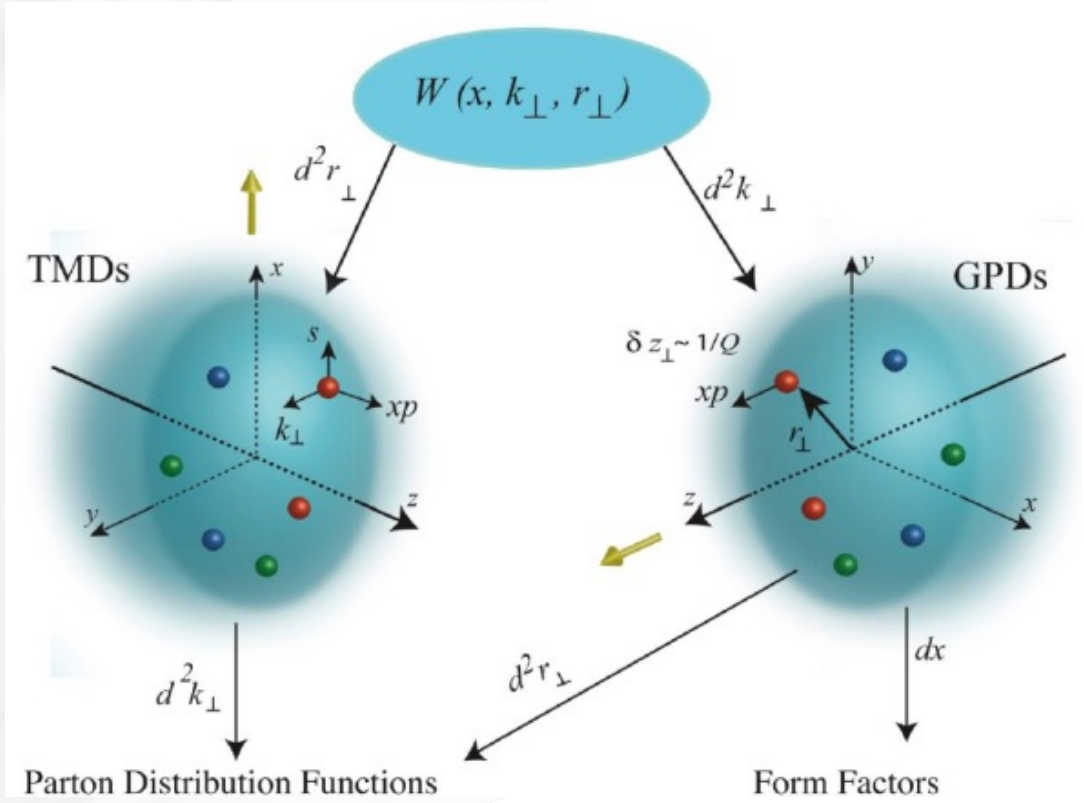

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Anagrafica: M. Mirazita (100%, resp), P. Rossi (0%), S. Tomassini (40%)

Attività di ricerca nella Sala B del Jefferson Lab con lo spettrometro CLAS

- manutenzione del RICH di CLAS12 (installazione completata a giugno 2022), sviluppo di software
- contributo alle analisi sperimentali della collaborazione su calibrazione dei rivelatori, verifica delle analisi, revisione degli articoli

Attività programmata per il prossimo anno

- Continuazione della presa dati di CLAS12
- Prosecuzione analisi SIDIS con K nello stato finale
- Possibile contributo a nuovi progetti:
  1. recoil detector per run con bersaglio polarizzato trasversalmente
  2. rivelatore di neutroni per misura del fattore di forma assiale del nucleone in sala C

Richieste economiche

Metabolismo per manutenzione RICH

Missioni al Jefferson Lab: turni presa dati, meeting di Collaborazione, sviluppo di software per il RICH

Dettaglio delle cifre da **discutere nella riunione nazionale di JLAB12**

Quarks and hadron dynamics

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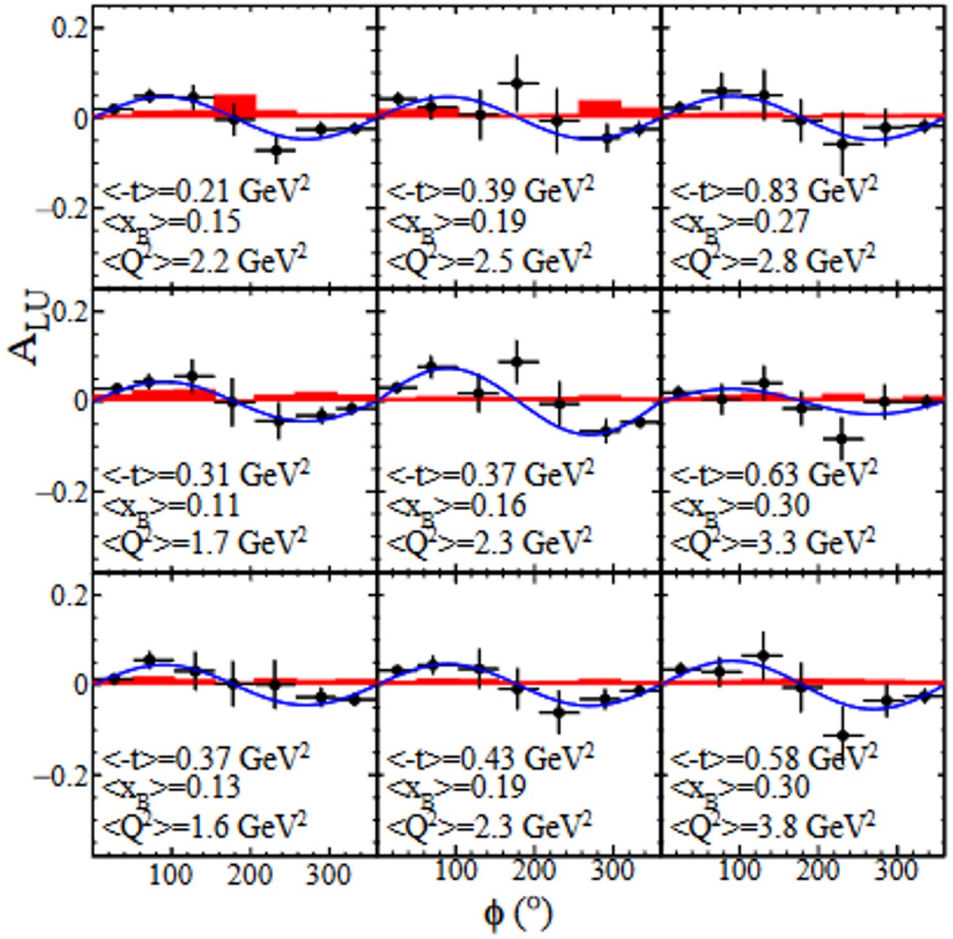
The CLAS12 experiment is taking data in Hall B since January 2018 with several experiments (Run Groups):

RG-K	**Unpol LH2, lower beam energy**	**Spectroscopy, hybrid baryon and mesons**
RG-D	liq. D2 and nuclear targets	Color transparency, nuclear TMDs
RG-E	liq. D2 and nuclear targets	Quark propagation and hadron formation in nuclei, nuclear PDFs

2025: CLAS12 will run for about 20 weeks

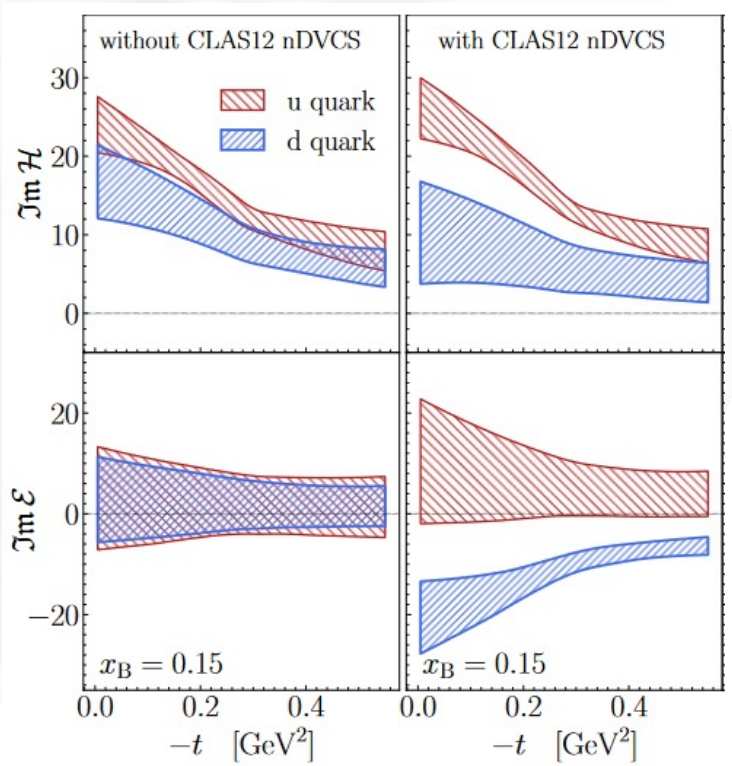
RG-L	**Gaseous low energy recoil detector**	**PDFs and DVCS on light nuclei, EMC, etc.**
RG-O RG-Q	PRad-II X17 search	Non CLAS experiments

Quarks and hadron dynamics

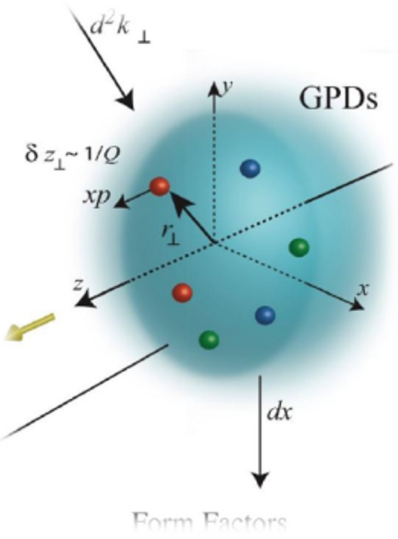


First Measurement of Deeply Virtual Compton Scattering on the Neutron, *arXiv:2406.15539, submitted to Phys. Rev. Lett.*

Hermes+CLAS+CLAS12 on p +CLAS12 on n

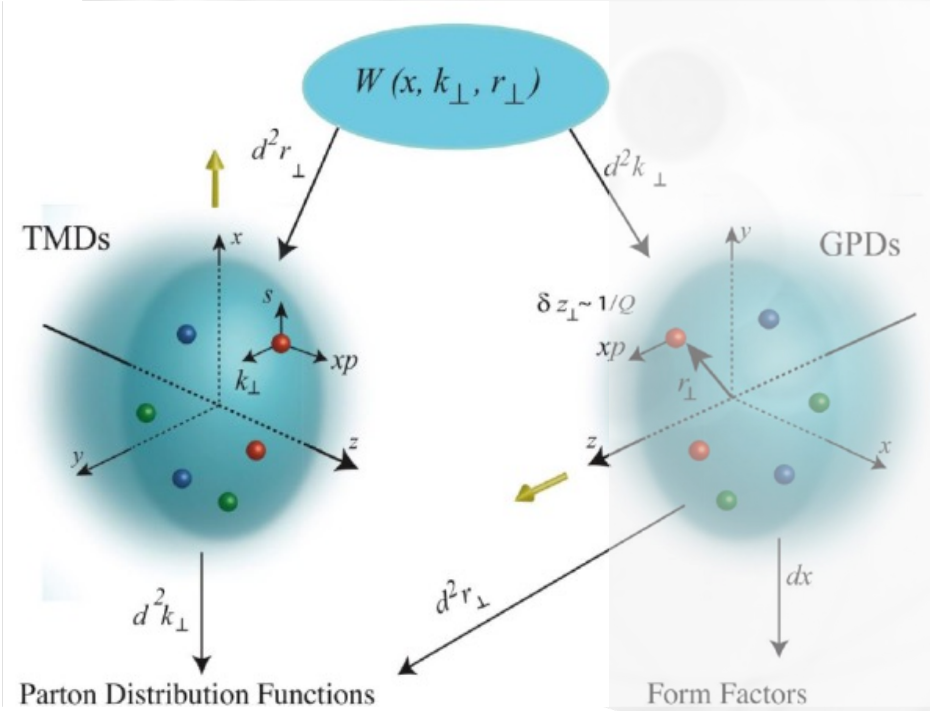


The CLAS12 data allowed the first successful attempt to the flavor separation of the GPD H and E

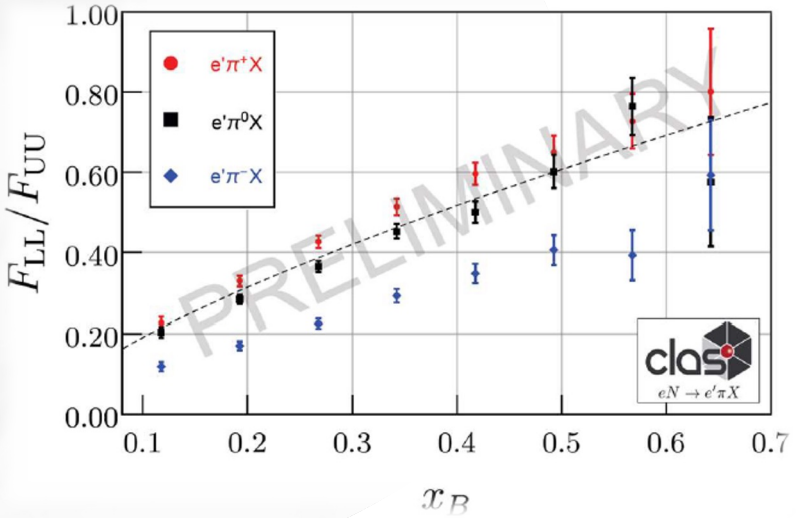


Quarks and hadron dynamics

First results with longitudinally polarized target with RG-C data collected in 2023



Double beam and target spin asymmetry in Semi-Inclusive DIS with pions, *H. Avakyan, Transversity workshop 2024*



Preliminary analysis on SIDIS single-spin asymmetries for kaons using the RICH detector

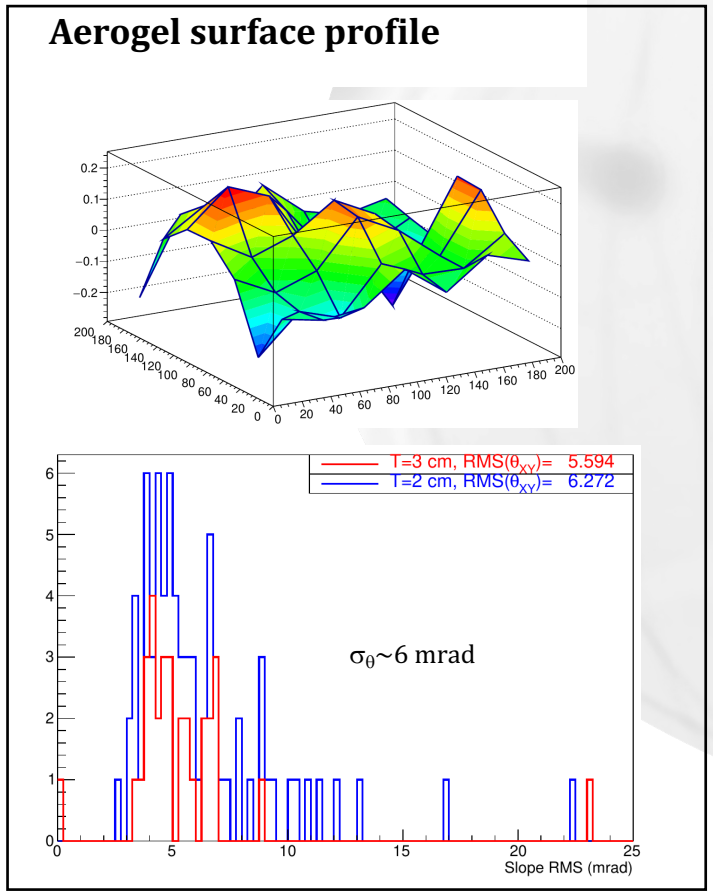
Quarks and hadron dynamics

The RICH is now fully integrated in the CLAS12 simulation package

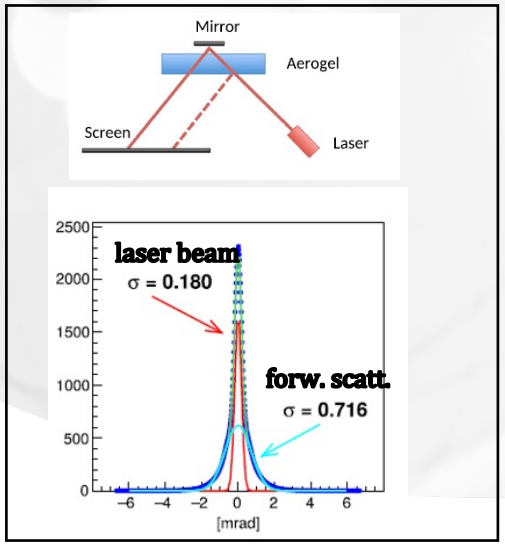
A fine tuning of the optical processes in GEANT4 has been performed based on the characterization measurements done on the various components:

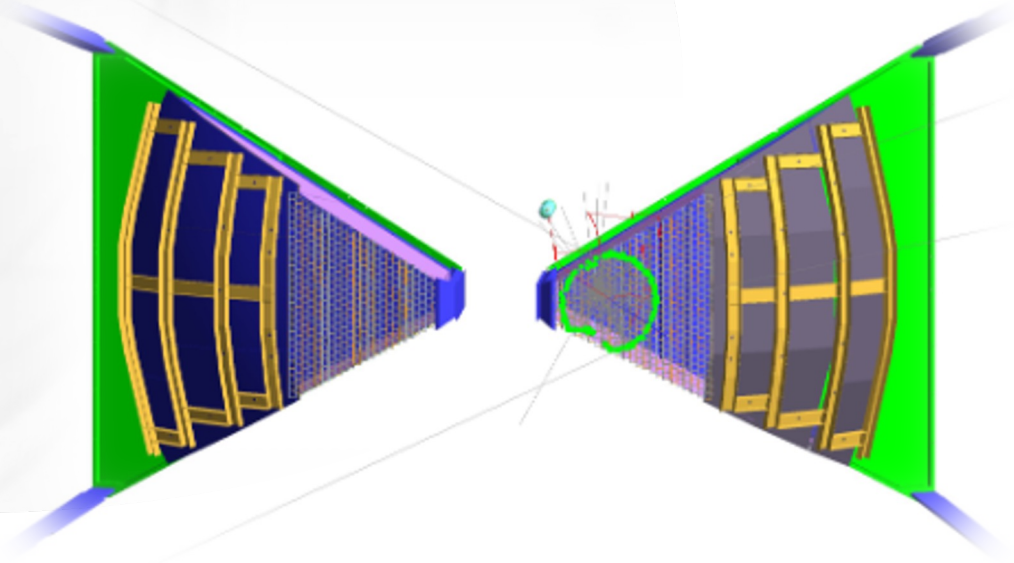
- mirrors: reflectivity, surface accuracy, roughness
- aerogel radiator: transparency, Rayleigh scattering, forward scattering, surface effects

Aerogel surface profile



Aerogel forward scattering





Quarks and hadron dynamics

RG-H: nucleon structure with transversely polarized targets

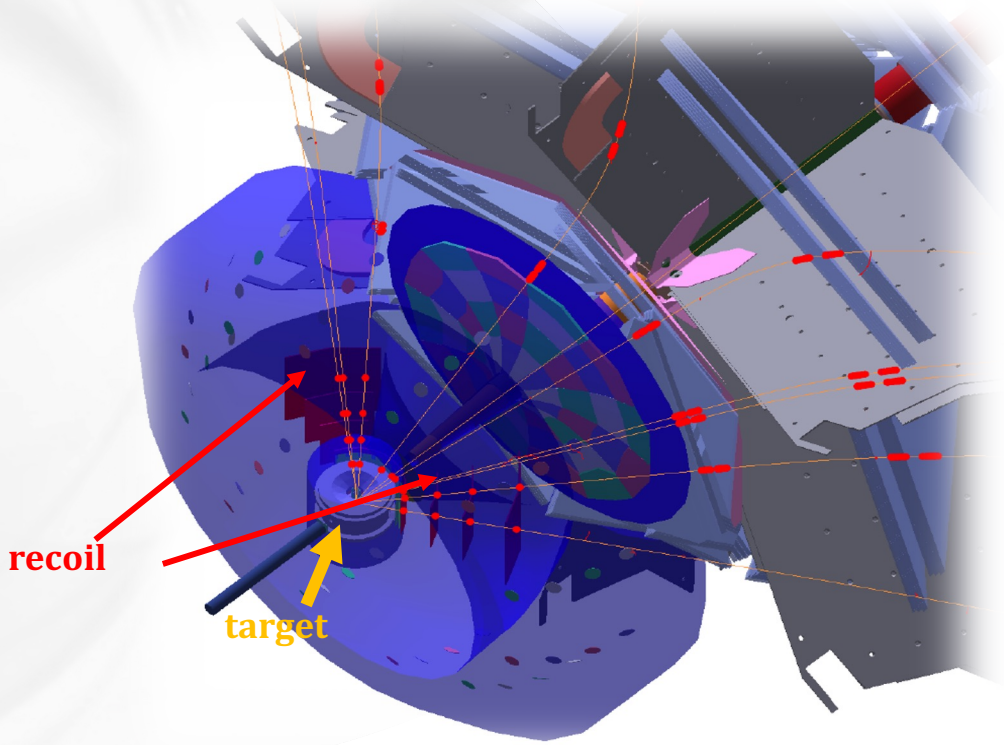
- NH3/ND3 targets with massive 5T magnet installed in place of the central detector
- recoil detector for DVCS experiments; tentative design:
  1. 3 layers of mRWell (100 mm resolution)
  2. 1 layer for time-of-flight (100 ps resolution)

The new set up will be presented to the PAC in July → time schedule ≥ 2028

Measurement of the nucleon weak axial form factor

- equipment now running in Hall A will be moved in Hall C
- SBS spectrometer (INFN contribution) to suppress backgrounds
- neutron detector under study:
  1. 2x8 m2 active area at 15m from the target
  2. 100 ps time resolution

A Letter Of Intent will be presented at the PAC in July: time schedule > 2028



Quarks and hadron dynamics

RG-H: nucleon structure with transversely polarized targets

- NH3/ND3 targets with massive 5T magnet installed in place of the central detector
- recoil detector for DVCS experiments; tentative design:
  1. 3 layers of mRWell (100 mm resolution)
  2. 1 layer for time-of-flight (100 ps resolution)

The new set up will be presented to the PAC in July → time schedule ≥ 2028

Measurement of the nucleon weak axial form factor

- equipment now running in Hall A will be moved in Hall C
- SBS spectrometer (INFN contribution) to suppress backgrounds
- neutron detector under study:
  1. 2x8 m2 active area at 15m from the target
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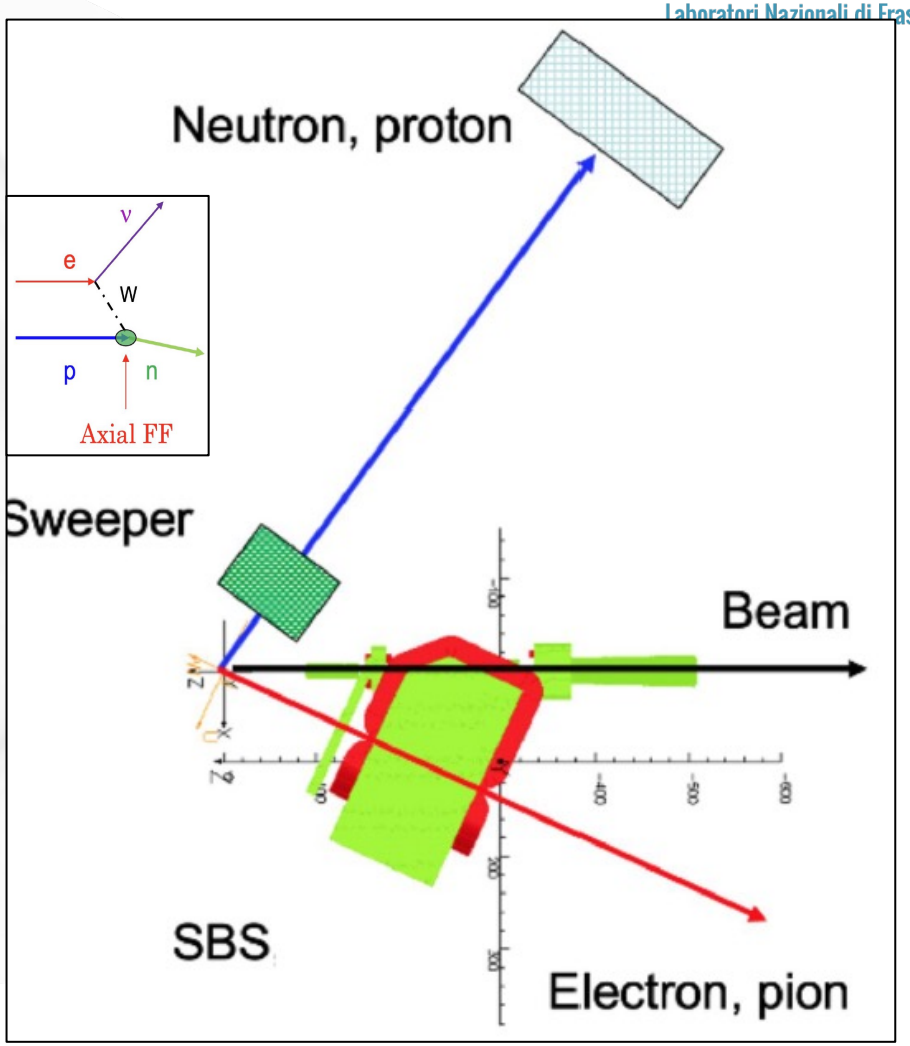

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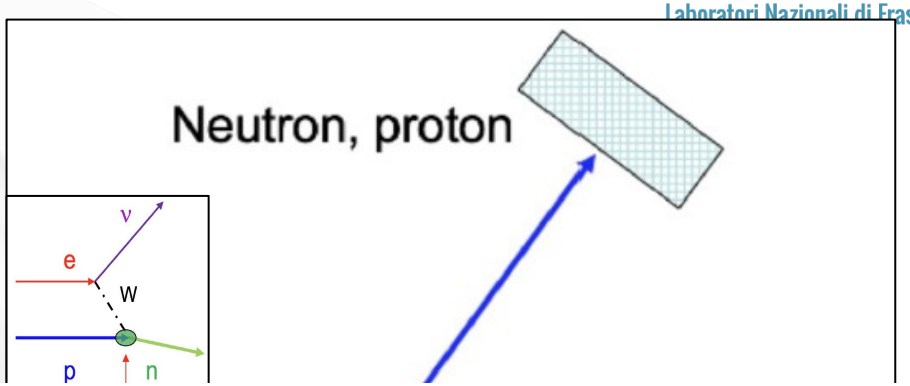
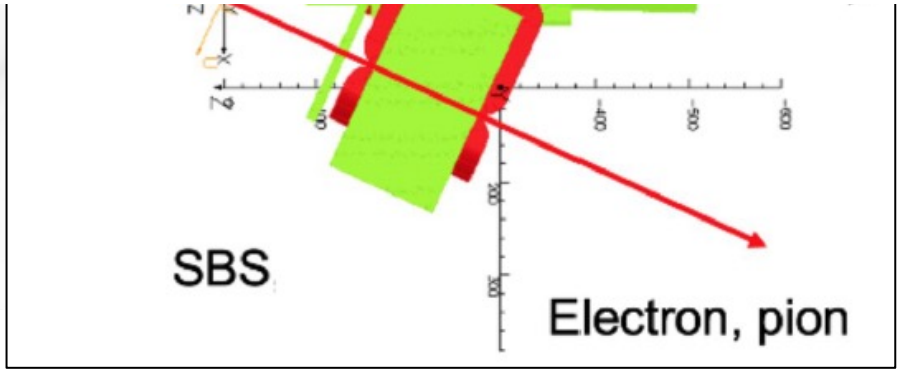


The possible involvement of LNF in the two projects is under discussion

- waiting for JLab PAC response
- LNF contribution to the new detector design
- no financial requests for the moment



The National Scientific Committee

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ALICE, NA60+

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LEA, ALPHA, JEDI, VIP, FAMU

6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

VIP-2 setup at LNGS and status

VIP = Violation Pauli Exclusion Principle (PEP)
Perform experimental test of PEP for e- at LNGS to reduce X-ray background

International collaboration: LNF, LNGS, Ts Univ. and INFN; SMI-OAW (Austria); IFIN-HH (Romania); Neuchatel U. (Switzerland); Uni & INFN BO; Fudan Univ. (China), Chengdu Univ. (China); IAS Princeton; Wigner Institute

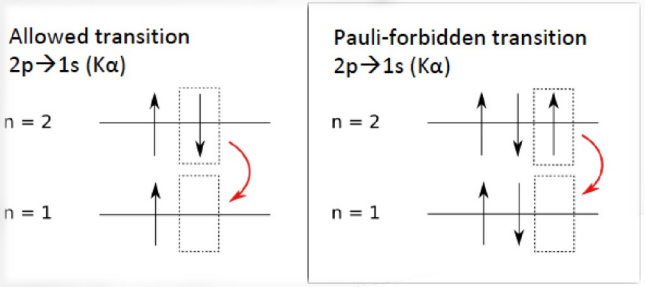
VIP already established a probability of PEP violation
$\beta^2/2 < 4x10^{29} \rightarrow$ previous limit $< 1.7x10^{26}$ (PLB 328, 1990, 438)
⇒ VIP-2 aims at an improvement of at least 2 orders of magnitude

VIP-3: PEPV scan over intermediate Z materials
VIP-GATOR collaboration: PEPV scan for high Z materials
VIP-CLOSED SYSTEM: experimental test of Quantum Gravity models
Other tests of Quantum Mechanics (collapse models) and quantum applications

20 publications (2023-2024):

Phys. Rev. Lett. 132, 250203 (2024)
Eur. Phys. J. C (2024) 84: 214
Phys. Rev. D 107, 026002 (2023)

External projects:
EU FET – TEQ
Centro Ricerche Enrico Fermi
Foundational Questions Institute FQXi
John Templeton Foundation



VIP	Afferenza (%)
Andrea Addazi	50
Massimiliano Bazzi	30
Maurizio Benfatto	50
Alberto Clozza	50
Catalina Oana Curceanu	30
N. Bortolotti	100
Antonino Marcianò	50
K. Dulsky	50
Fabrizio Napolitano	70
Elisabetta Pace	50
Kristian Piscicchia	100
Alessio Porcelli	100
Diana Laura Sirghi	70
Alessandro Scordo	30
Simone Manti	100
F. Nola	20
FTE totali	6.5

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VIP upgrade (CCD detectors replaced by SDD): VIP-2 in data taking at LNGS
Other tests of Quantum Mechanics (collapse models) and quantum applications → collaboration with Roger Penrose, Steve Adler

VIP-2 → new SDD detectors:
- higher resolution: 190 eV (fwhm)
- faster (triggerable) → VETO system
- higher acceptance and efficiency
- higher current → low background
- current modulation data analyzed (*Eur. Phys. J. C (2024) 84: 214*)

VIP-3
- **Ar, Sn, Zn targets,** new SDDs 1mm thick produced (FBK+PoliMi), setup
- New vacuum chamber, cooling system and current circulation system
- SDD: from 32 to 64 detectors 1-mm thick to access higher E and extend the search for PEP-violating transition to a higher energy

VIP-GATOR
- **Pb target** surrounding the HPGe detectors

VIP-CLOSED SYSTEMS → Ge detectors
- high radio-purity HPGe & BEGe
- several targets

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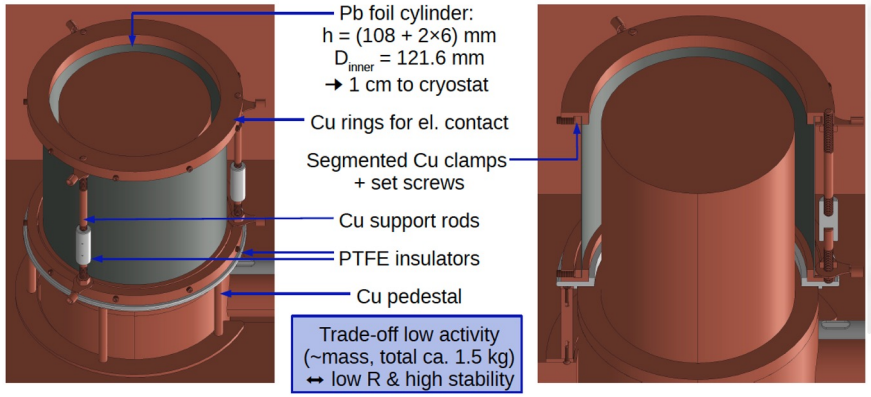
VIP-GATOR at LNGS

Goal: MG-test of $\beta^2/2$ for Z = 82 (lead) with 40 A circulating current. Paper under finalization, reporting the upper limit

$$\beta^2/2 < 4.8 \cdot 10^{-29}$$

more than 1 order of magnitude improvement w.r. to *Found.Phys.* 42 (2012)

Setup Design



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- several targets

VIP-Closed Systems

- High purity Ge detector surrounded by Roman lead & Ta targets.
- Advanced phenomenological studies of anisotropy effects on the PEP *and collapse models*
- Violation amplitude predicted in Quantum Gravity Models and ongoing R&D of a dedicated experiment

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VIP-CLOSED SYSTEMS → Ge detectors
- high radio-purity HPGe & BEGe
- several **targets (Pb, Ta)**

VIP future plans

Richieste ai servizi

Progettazione: 2 m.u. Per VIP-3 finalizzazione realizzazione setup (flanges, mechanical supports, …), realizzazione sistema di attenuazione BEGe, HPGe per misure anisotropia in QG models, VIP-Gator,

Officina meccanica: 2 m.u. Per VIP-3 finalizzazione realizzazione setup (flanges, mechanical supports, …), realizzazione sistema di attenuazione BEGe, HPGe per misure anisotropia in QG models, VIP-Gator,

Tecnici: 0.5 FTE installazioni e test dell'apparato VIP-3 ai fini dell'installazione ai LNGS, costruzioni varie per gli altri setup (BEGe, HPGe, VIP-Gator).

Miss.	TRA	INV	MAN	CON	Totale
25	0	20	10	40	95

VIP-3, open systems:

- Prepare and submit for publication the papers with data analyses on last data taking periods (at least 1 paper)
- Continuation of Monte Carlo simulations and studies for optimization of the future run
- **VIP-3 Open Systems with Ag, Sn, Zr targets** and 1mm SDD detectors (finalization of the VIP-3 setup, installation and run 2025-2028):
- Upgrade of the VIP-GATOR setup (higher circulating current, target cooling system), data taking period with **high Z ultra-radio-pure materials**.

VIP, closed systems:

- Finalize and submit for publication new analyses **exploiting different Z targets** (e.g. Ta) and study of the limit of PEP-violation on various materials, which has strong impact on quantum gravity models
- Continuation collaboration with theoreticians (Addazi, Marcianò, Illuminati …) and new collaboration for the interpretation of the VIP (closed systems) data in the framework of CPT deformation models (Prof. N. Mavromatos)
- R&D in Frascati laboratory of a future setup to test anisotropy effects in Quantum Gravity.

The National Scientific Committee 3

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6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

FOOT experiment

«Improve the tumor treatments in hadrontherapy by studying the behavior of the particle beams usually employed»

Nuclear fragments: important source of biological damage, both for cancer cells and for nearby healthy tissues.

→ it is of fundamental importance to have a deep knowledge of this process in order to make the most effective and safe medical treatment.

High-precision measurements of the nuclear fragmentation cross-section of medium-light ions (Carbon, Nitrogen, Oxygen)

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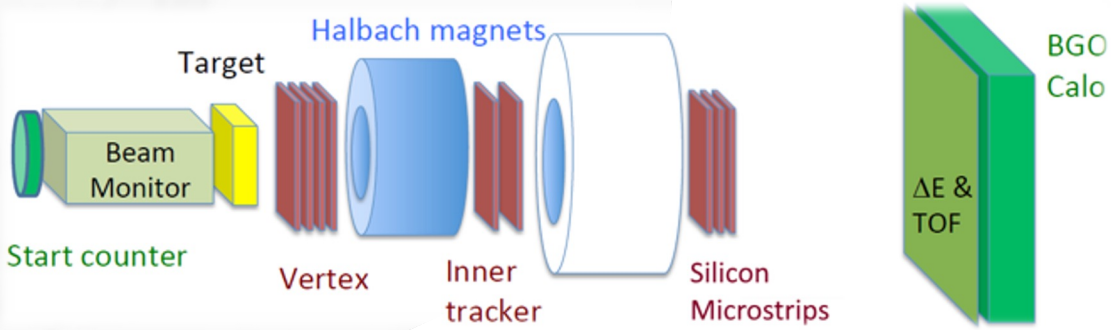
Fixed target experiment: the beams of interest, with an energy of hundreds of MeV, impinge on a material representative of the human tissue (mainly hydrogen, carbon and oxygen) and the produced fragments are detected and measured by a multi-purpose detector

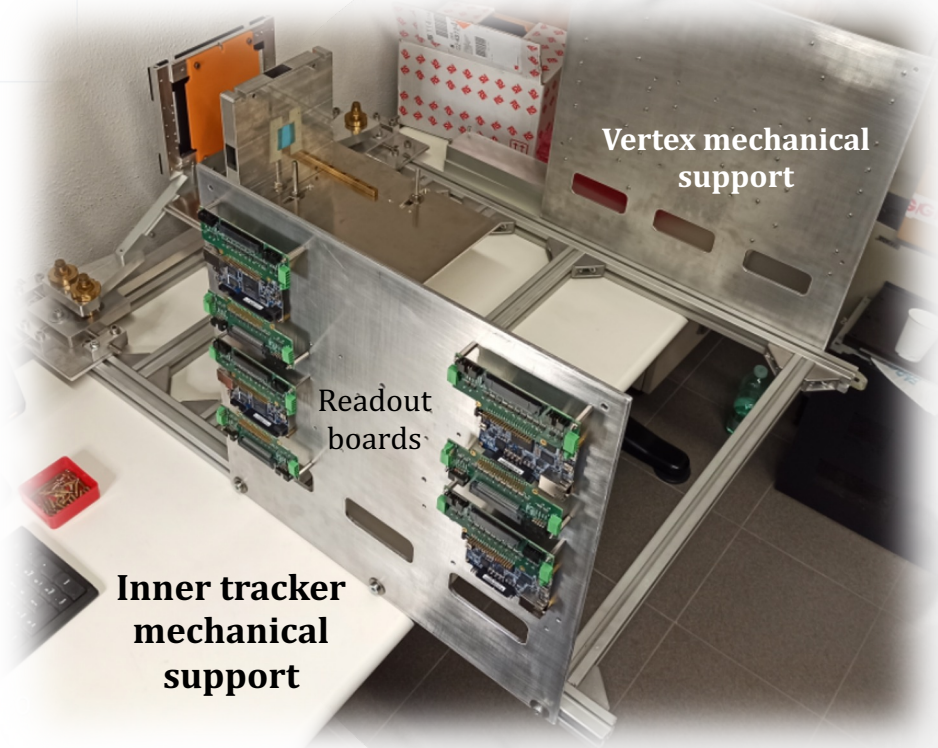
1. Start counter to monitor the primary particle rates
2. Beam monitor: low-density material to minimize multiple scattering, aiming at measuring the direction and the impinging point of the ion beam on the target
3. Vertex/Trackers/MSD: combined for tracking
4. ToF/Calorimeter for PID

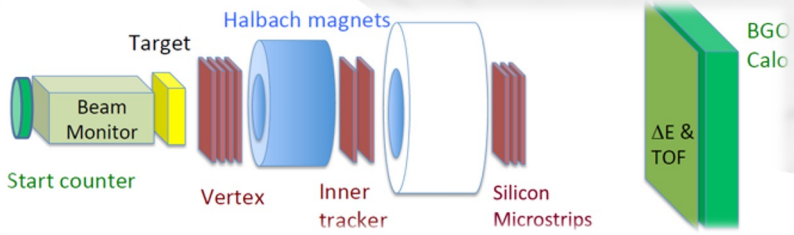


@LNF:

1. vertex tracker
2. inner tracker
3. mechanical support

FOOT experiment





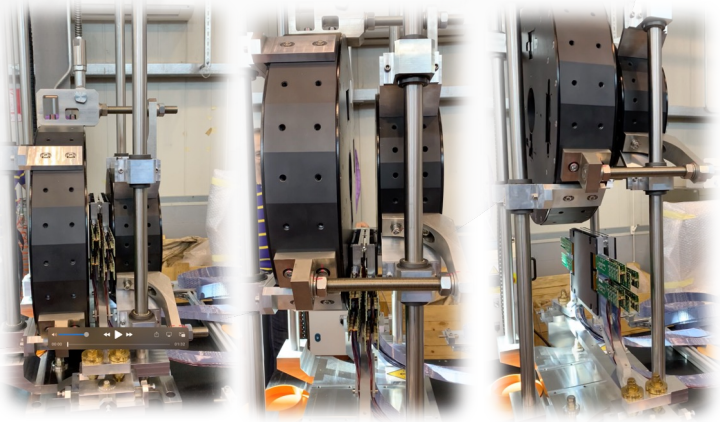
FOOT tracker mechanical setup:

- Final mechanical ready
- Electronic system support table ordered
- Inner Tracker readout electronics (Terasic boards) mechanical support under design.

Pixel vertex detector

- Mechanics for vertex positioning ready, control software in preparation

Inner Tracker and magnet system: ready and tested at CNAO



FOOT experiment

PRIN 2022 (Approved): «High performance DMAPS (Depleted Monolithic Active Pixel Sensor) for hadrontherapy», PI: E. Spiriti (LNF); RU UNIBO: S. Valentinetti

«We propose this project with the aim of significantly improving the capabilities of the pixel tracker, particularly in terms of the amount of data that can be collected for the same amount of time and spatial resolution, which for obvious statistical reasons allows for greater accuracy of the measurements to be made»

Goal: improve the detection characteristics of the FOOT experiment's replacing the vertex detector by using the MIMOSIS sensor, recently developed for the CBM experiment by the In2p3 research group in Strasbourg.

FOOT tracker mechanical setup:

- Final mechanical design available
- Electronic system support table ordered
- Inner Tracker readout electronics (Terasic boards) mechanical support under design.

Pixel vertex detector

- Chip functionality tested and demonstrated in May at Strasbourg
- First test beam in July at DESY
- Firmware FPGA ready and tested for simulation

MIMOSIS-1 chip – full scale prototype of one CMOS sensor
✓Matrix dimension: 1024 columns. X 504 rows
✓Pixel dimension: 26.88 μm (height) x 30.24 μm (width)
✓Fabricated with Tower Semiconductor, 180 nm technology

FOOT experiment

- August/September 2023: Magnets/IT mechanics arrived at LNF
- Summer 2023 – Inner tracker ladders tested in lab
- September 2023 – Full Inner tracker tested at the BTF (LNF)
- October 2023 – Full Inner Tracker (with old Vertex version) operational at CNAO
- Magnet system operational at CNAO
- December 2023 – Full pixel tracking system back at LNF
- October 2023 – HP-DMAPS (PRIN2022) started
- December 2023 – HP-DMAPS DAQ board design under way at LNF
- December 2023 – HP-DMAPS slow control software started in Bologna
- Spring 2024 – HP-DMAPS proximity board design foreseen at LNF
- December 11° 2023 – «*MIMOSIS-2.1 has been approved for submission*»
- January 2024 – MIMOSIS1 test boards available (at LNF and Bo)
- Beginning 2024 – refurbishment of Vertex

Attività FOOT-LNF 2024

1. Test alla BTF a fine novembre
2. In via di definizione all'interno della collaborazione

FOOT	Afferenza (%)
Guido Raffone	50
Eleuterio Spiriti	45
Sandro Tomassini	10

The National Scientific Committee 3

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→ see talk by G. Claps

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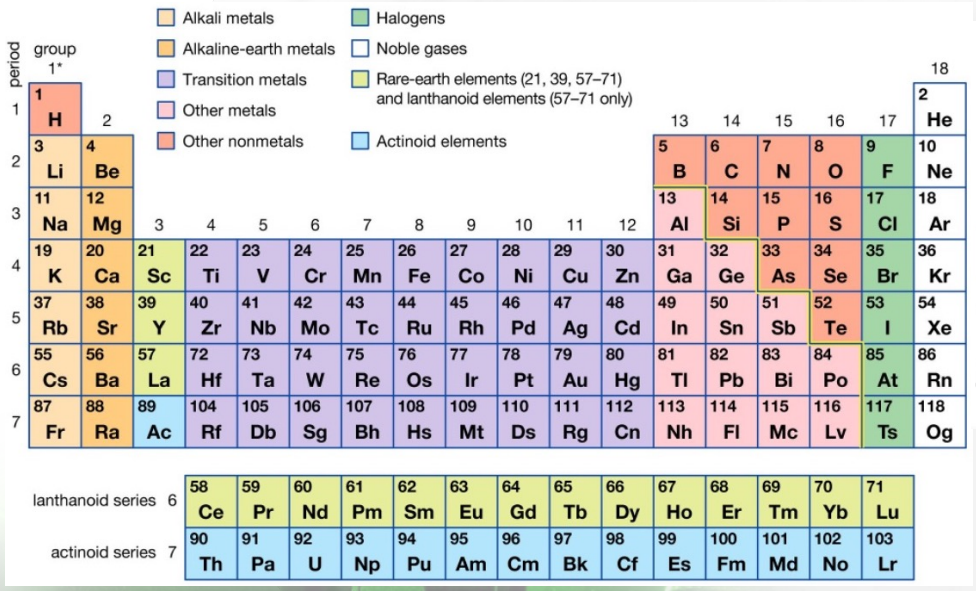
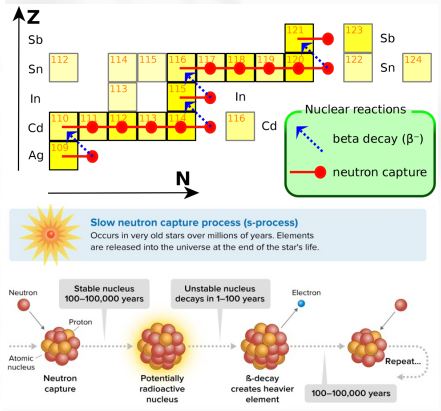
6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

Future projects with EuAPS and EuPRAXIA

Study of the nucleosynthesis through a laser-induced plasma





4. NUCLEAR ASTROPHYSICS

ASFIN, ERNA, LUNA, n_TOF, PANDORA

Conclusioni

Assestamento delle attività nell'ambito della CSN3

1. Possibili test alla BTF per ALICE e FOOT

2. In via di valutazione la partecipazione alla costruzione di un nuovo rivelatore per JLab12

3. Nuove iniziative in via di definizione per lo studio di processi di rilievo per l'astrofisica nucleare in plasma prodotto da laser a FLAME → *prima campagna di misure possibile nella primavera del 2025*

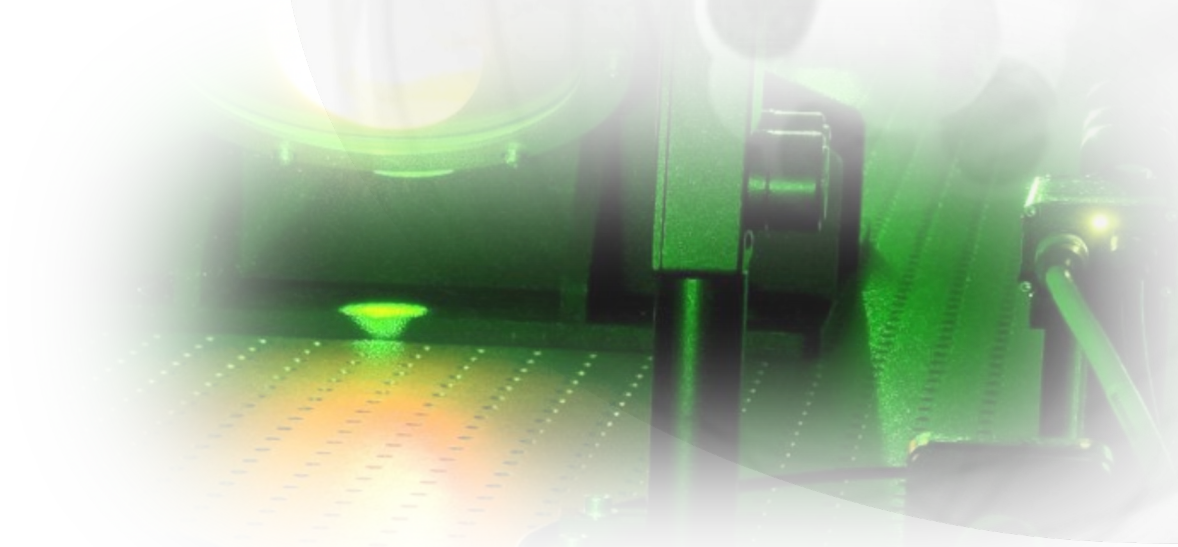
4. Sviluppo di rivelatori basati sul TimePix (gruppo nTOF@LNF) → analisi di un possibile utilizzo di essi per la misura di processi di fusione e per l'analisi dei processi di decadimento β nel plasma

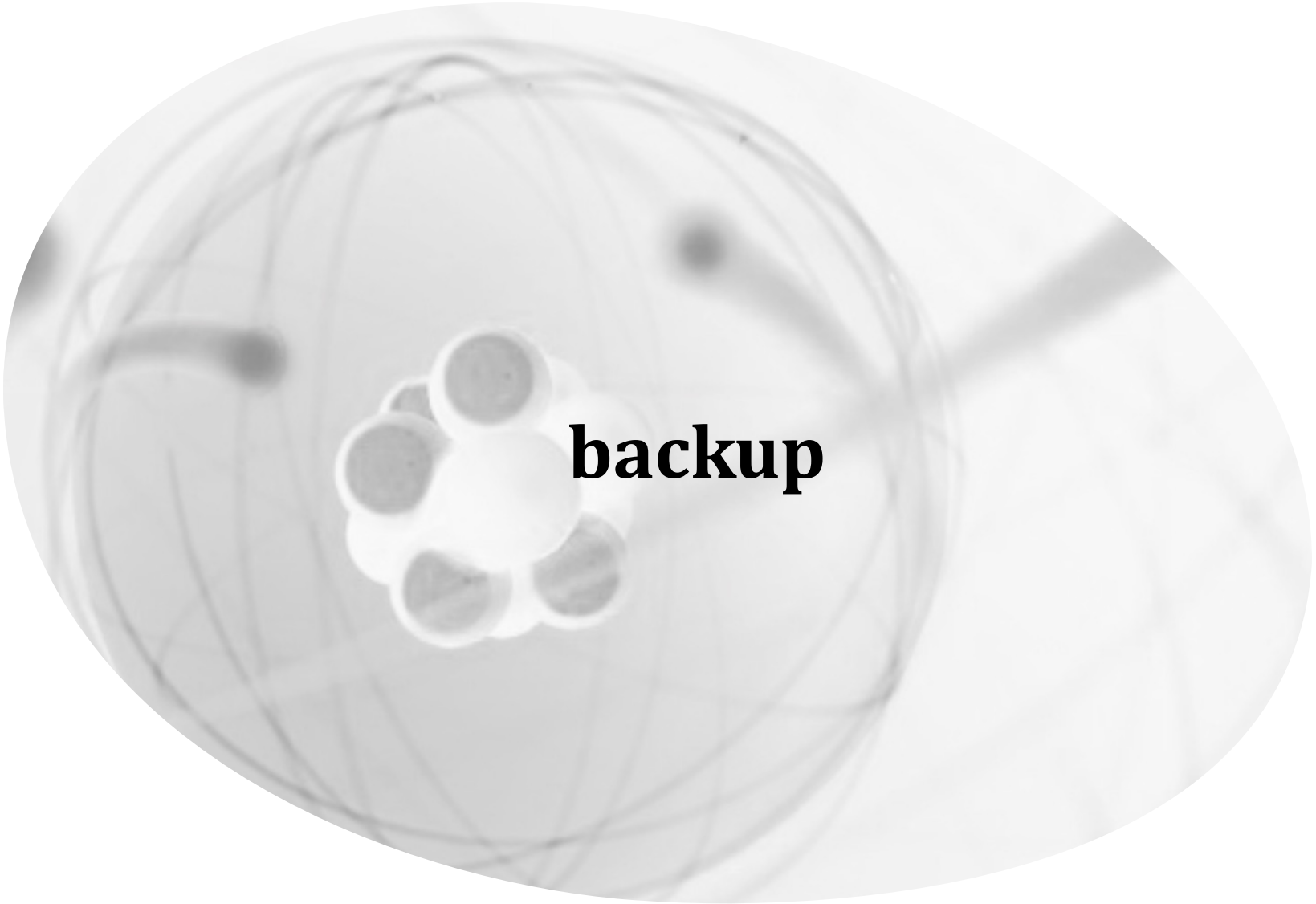
Future projects with EuAPS and EuPRAXIA

Workshop on December 4-6, 2024 on

«Fundamental research and applications with EuPRAXIA facility at LNF»

https://agenda.infn.it/event/42474/overview





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High-precision measurements of the nuclear fragmentation cross-section of medium-light ions (Carbon, Nitrogen, Oxygen)

FOOT tracker mechanical setup:
- Final mechanical design available
- Electronic system support table ordered
- Inner Tracker readout electronics (Terasic boards) mechanical support under design.

Pixel vertex detector
- Used at GSI and at CNAO (last november)
- New Vertex readout board under production

Inner Tracker and magnet system
- Plume ladder assembly process definition concluded in Strasbourg
- All production tools available
- 10 modules assembled
- All needed hardware/software pieces available
- Intermediate PC readout software (event building) written and tested at CNAO (for 2 channels out of 8 – extension to 8 not a problem)

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