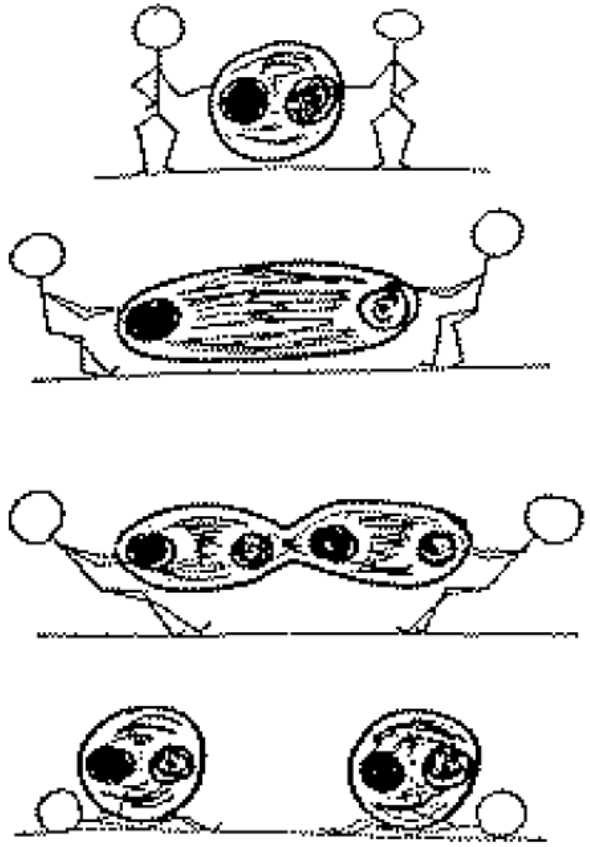
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Nuclear Physics at the Frascati National Laboratories

Silvia Pisano

Local coordinator of the
Nuclear Physics group

Consiglio di Laboratorio
Preventivi 2026
LNF, 14 Luglio 2025



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

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

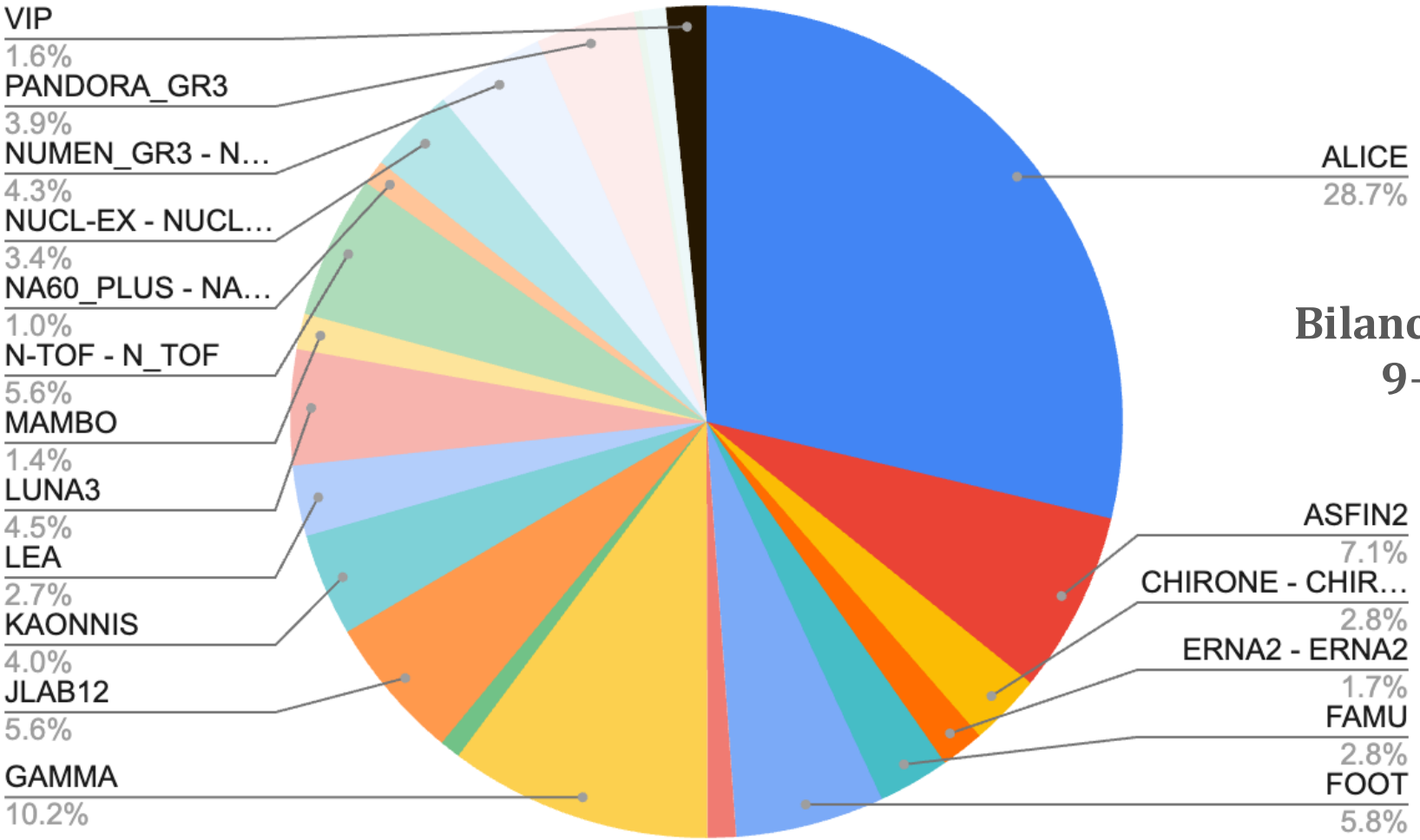
5. FUNDAMENTAL INTERACTIONS

LEA, ALPHA, JEDI, VIP, FAMU

6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

Commissione Scientifica Nazionale 3

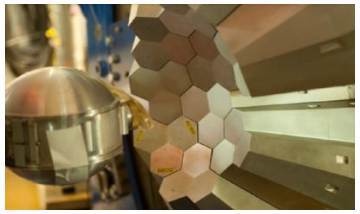


Bilancio annuale:
9÷10 M€

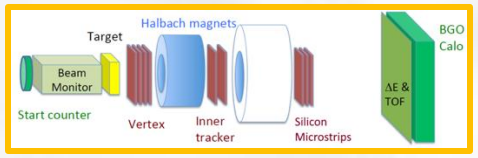
The CSN3 experiments

LUNA

GAMMA



FOOT

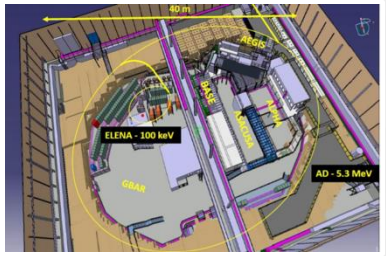


JLAB, MAMBO

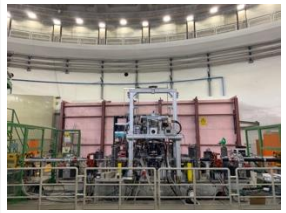
ALICE

keV MeV GeV TeV

E_{beam}

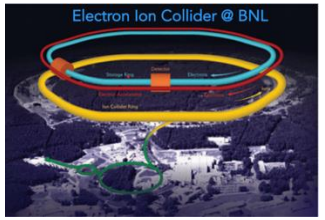


NUMEN, ASFIN2,NUCLEX, CHIRONE, FORTE…



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	5.4 FTE	A. Fantoni
FOOT	CNAO/TIFPA /LNS/BTF	Framm. Nucleare	1.4 FTE	E. Spiriti
e JLab12	JLAB	Fisica adronica	1.2 FTE	M. Mirazita
BGOOD	Bonn/Mainz	Fisica adronica	In chiusura	P. Levi Sandri
	LNF	Fisica nucleare	14.35 FTE	C. Curceanu
	LNGS	Fisica nucleare	8.2 FTE	C. Curceanu
nTOF	CERN	Astrofisica nucleare	2.0 FTE	G. Claps

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

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
Francesca Carnesecchi	100
Oton Vazquez Doce	80
FTE totali	5.4

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 Activities at LNF

Physics Analysis on light flavors and femtoscopy

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

Shifts for data taking at CERN

ALICE operations (run manager terms, training coordination, run coordination)

EPN coordination

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

Past and present responsibilities at CERN

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

Collaboration Board (VM: 06/2017 - ongoing)

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

Run Manager (SP: 10/2022, 05/2023, 10/2023, 04/2024, 10/2024)

EPN Technical Coordinator (FR: 01/2013 – ongoing)

Training Coordinator (SP: 2023-2024)

Deputy Run Coordinator (SP: 01/2025 - ongoing)

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

Editorial Board (OVD 12/2023– ongoing)

PWG Correl. & Flow Convener (OVD 06/2024 – ongoing)

ALICE Collaboration Board Chair (AF: 07/2025 - ongoing)

ALICE Activities at LNF

Physics Analysis on light flavors and femtoscopy

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

Shifts for data taking at CERN

ALICE operations (run manager terms, training coordination, run coordination)

EPN coordination

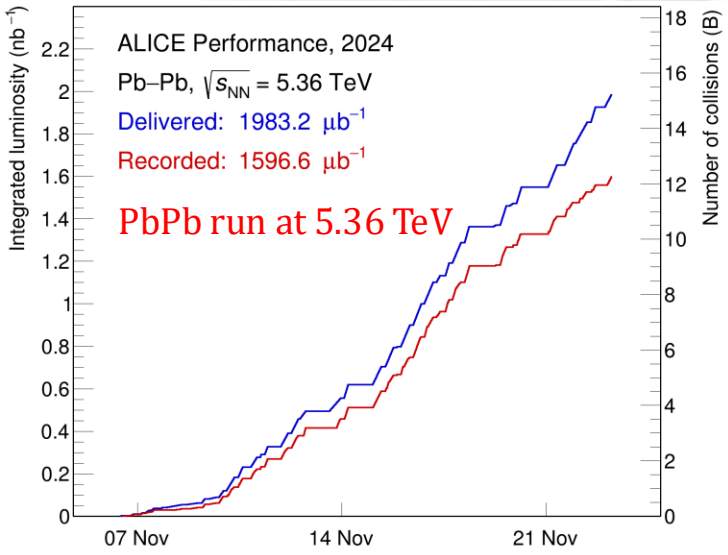
New RL: Oton Vasquez Doce

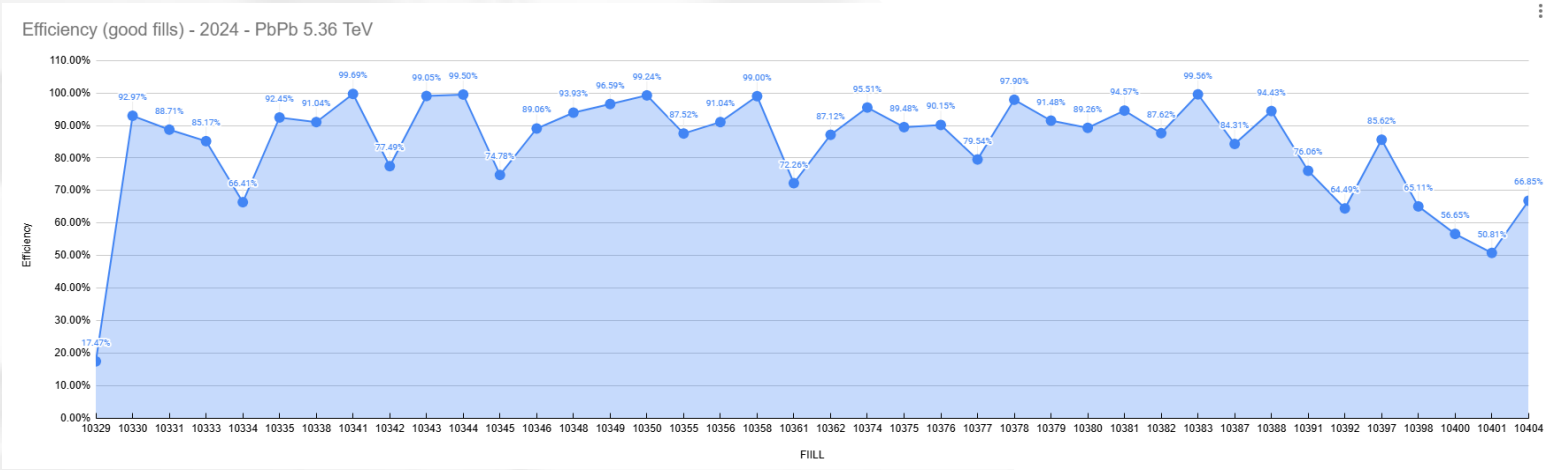
ALICE@CERN: 2024 data taking

Very successful 2024 PbPb data taking!

Total luminosity production for PbPb surpassed the optimistic projections

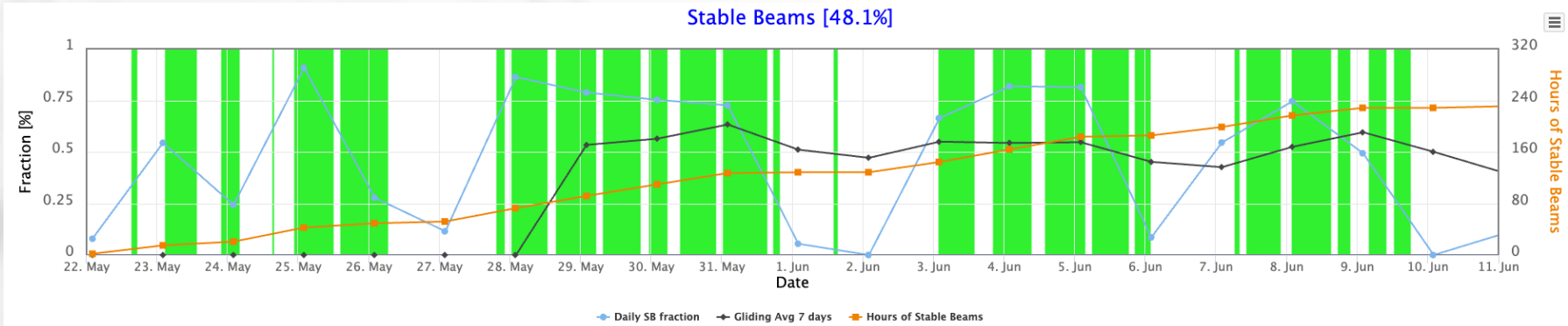
- Prediction 0.1-0.15 nb^{-1} per day
- **Achieved: 0.144 nb^{-1}** (~0.17 nb^{-1} w/o quenches)

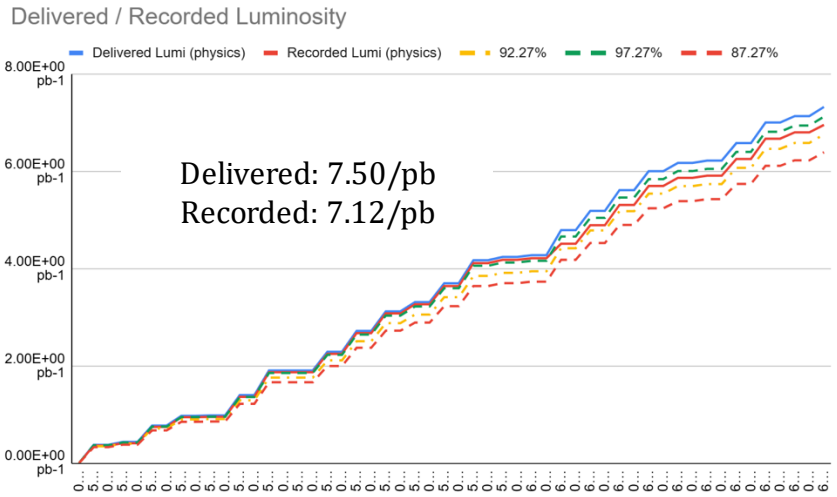


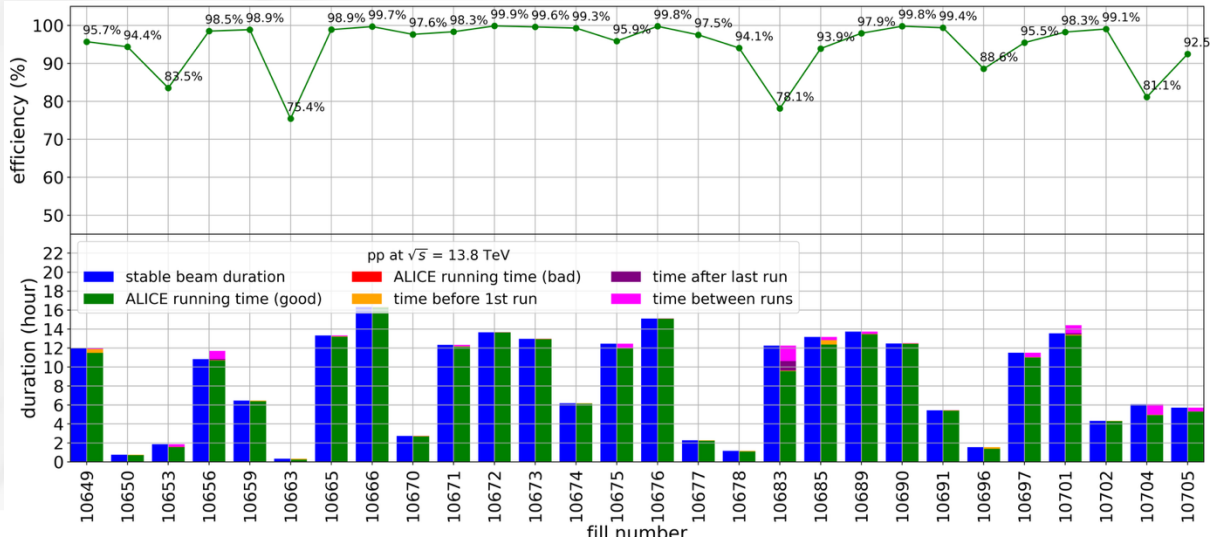


ALICE@CERN: 2025 data taking

Proton data taking started at the end of May
→ **efficiency at the level of the 2024 values, systematically higher than 95%**







ALICE@CERN: 2025 data taking

Light Ion runs

Very succesful Light Ion Period so far (machine availability > 90%)

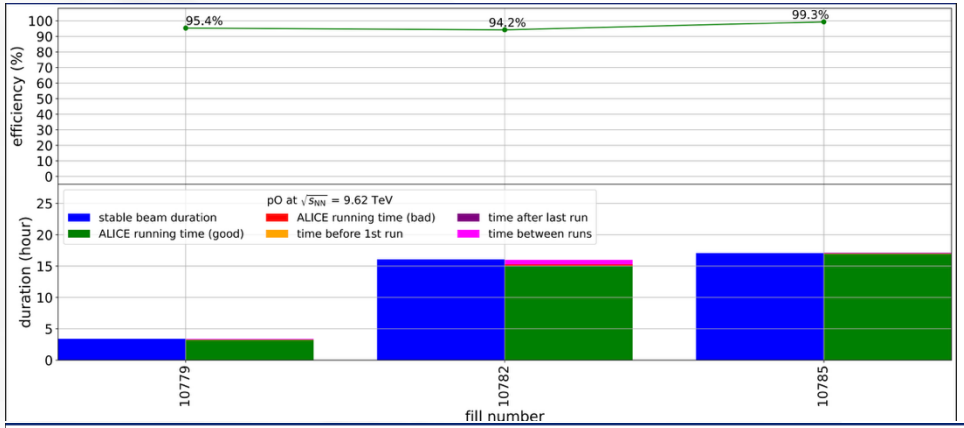
- pO, OO campaign finished
- Neon still ongoing → Delay by loss of cryogenics

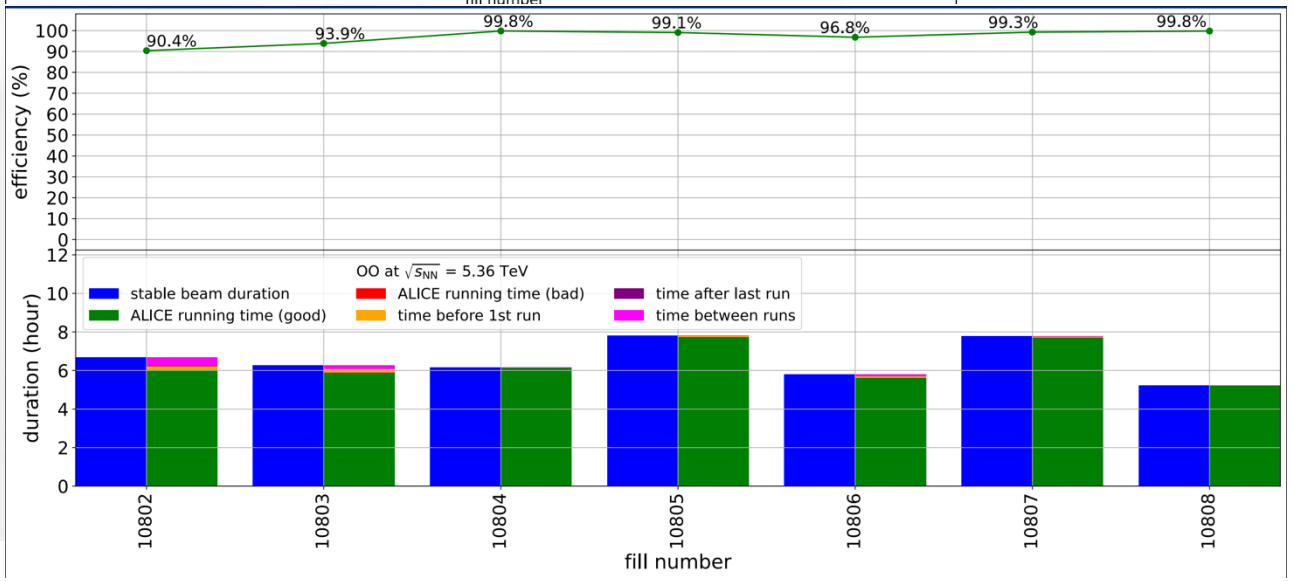
ALICE took data with a very high efficiency:

1. pO: 7.27 nb^{-1} recorded/7.85 nb^{-1} delivered (target: 5 nb^{-1})
2. OO: **recorded 5.01 nb^{-1} recorded**/5.15 nb^{-1} delivered **(target: 0.5 nb^{-1})**

Oxygen data taking – luminosity program:

1. Background test carried out during pO/OO commissioning
2. Short vdM during pO
3. vdM scan during OO





ALICE@CERN

ΞK and Ξπ femtoscopy in pp collisions

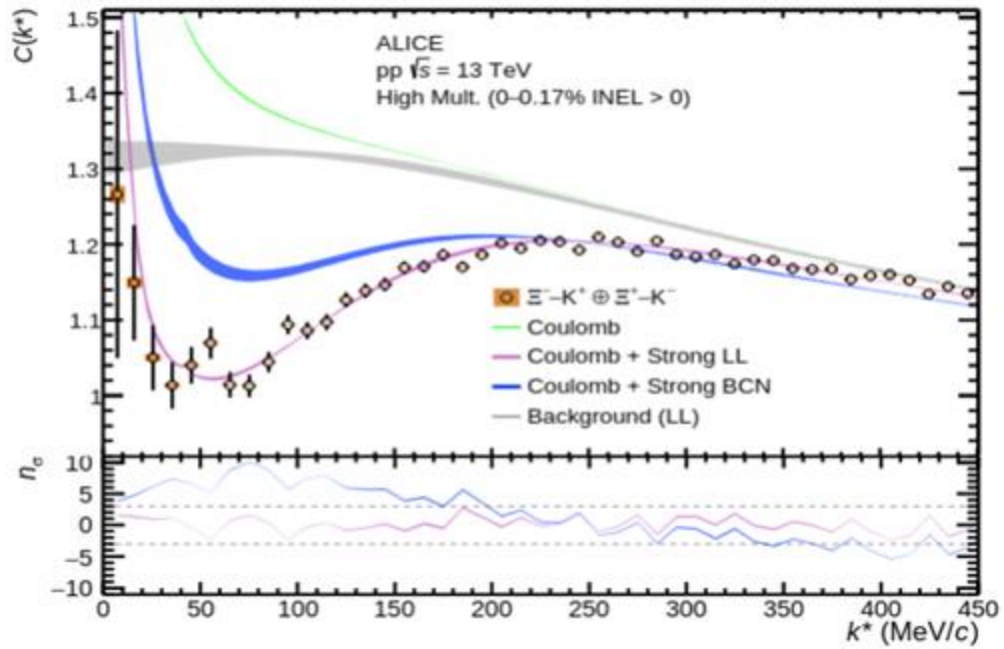
Article to be submitted to PLB (currently draft in Collaboration review)

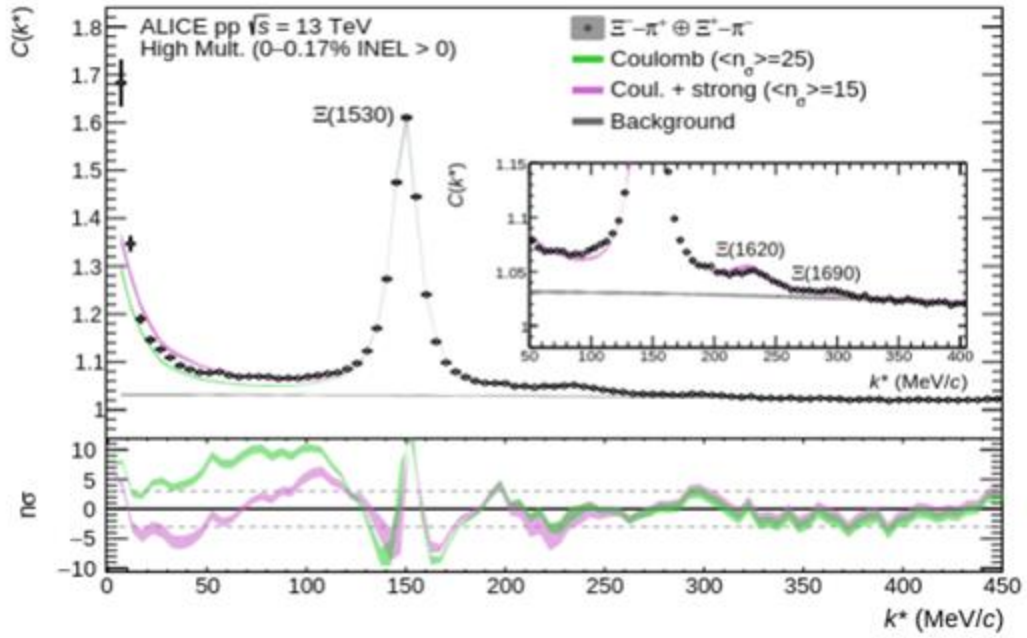
ALICE preliminary results show the most precise data on ΞK and Ξπ at low momenta, to be added to the other meson-baryon systems $K^-p, K^-\Lambda$ already studied → *novel high-precision constraints on S=-1 and S=-2 meson-baryon interactions*

- Machine learning techniques for Ξ reconstruction used for the first time in femtoscopy analysis
- Complementary tool to study exotic states: in this case Ξ(1620), Ξ(1690)

Measurement of scattering parameters (real and imaginary part of scattering length) for both systems

- First ever measurement
- ΞK: Current models, constrained to scarce scattering data do not describe ALICE data
- Ξπ: Complementary tool to study exotic states: in this case Ξ(1620), Ξ(1690)





ALICE@CERN

2026 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

- Nessuna richiesta sostanziale ai servizi.
- Richieste economiche (oltre MOF) principalmente di missioni.
- Circa 70k€ per il 2026 per missioni
    1. turni presa dati ALICE, supporto/oncall ITS2
    2. riunioni/discussioni fisica per TB, EB, PWG & ITS3
    3. presenza come CB chair al CERN
    4. *RC supportato dall'esperimento*

- ALICE data taking
- Run Coordination (Silvia)
- ITS QC offline (Alessandra, Oton, Valeria)
- Discussion with all Team Leaders and Management (Alessandra)
- Discussions within Editorial Board and PWG Correlations & Flow (Oton)
- Discussions for analysis, papers, collaboration boards (all)
- Possible test on sensors for ITS3 & ALICE3 (Alessandra, Valeria, Francesca)
- ALICE 3 simulations (Francesca)

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

Quarks and hadron dynamics

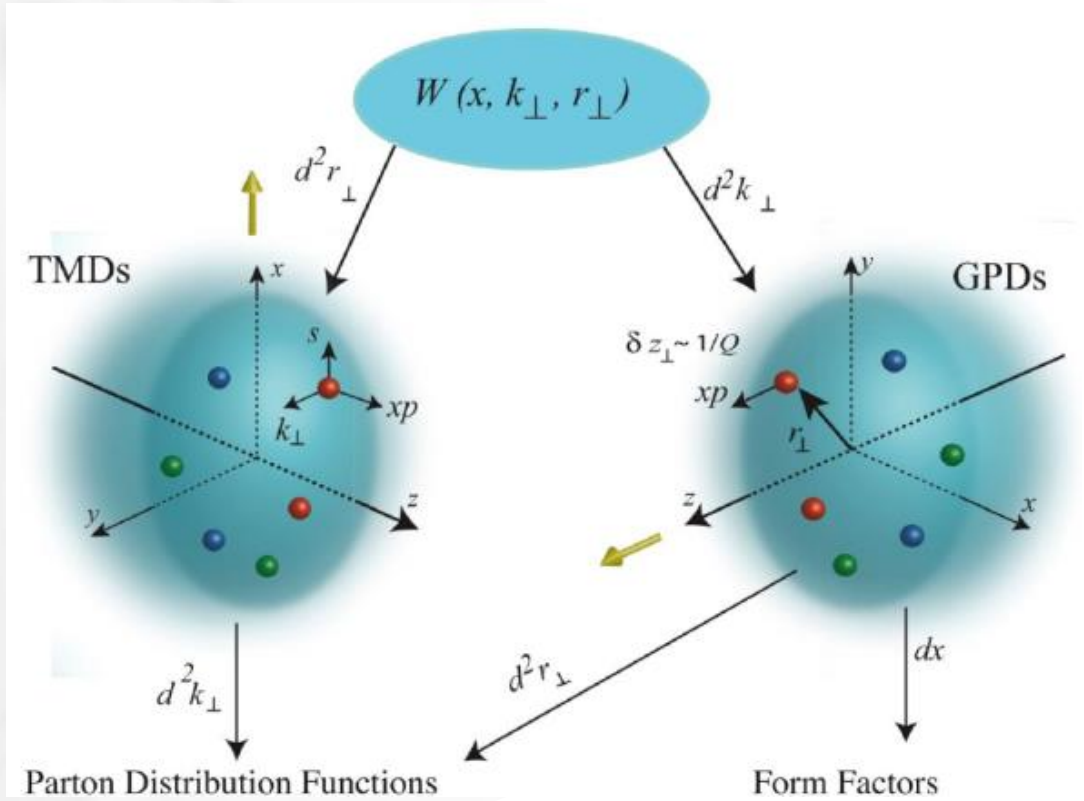
Study of the quark dynamics inside hadrons and nuclei, to understand the strong interaction, searching for effects beyond those predicted by QCD.

- 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?

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?



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?

Anagrafica: M. Mirazita (100%, resp), P. Rossi (0%), S. Tomassini (20%)

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

- analisi dati di CLAS12, in particolare per lo studio del Semi-Inclusive DIS con K nello stato finale
- completamento strumenti software del RICH
- 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, possibile contributo al recoil detector
Missioni al Jefferson Lab: lavoro sul recoil detector, sviluppo di software per il RICH
Dettaglio delle cifre da **discutere nella riunione nazionale di JLAB12**

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?

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

2025: ongoing

RG-L	**Gaseous low energy recoil detector**	**PDFs and DVCS on light nuclei, EMC, etc. Will end in September**

2026: no CLAS data taking

RG-O	**PRad-II**	**Charge radius of the proton**
RG-Q	X17 search	Search for the X17 resonance

Quarks and hadron dynamics

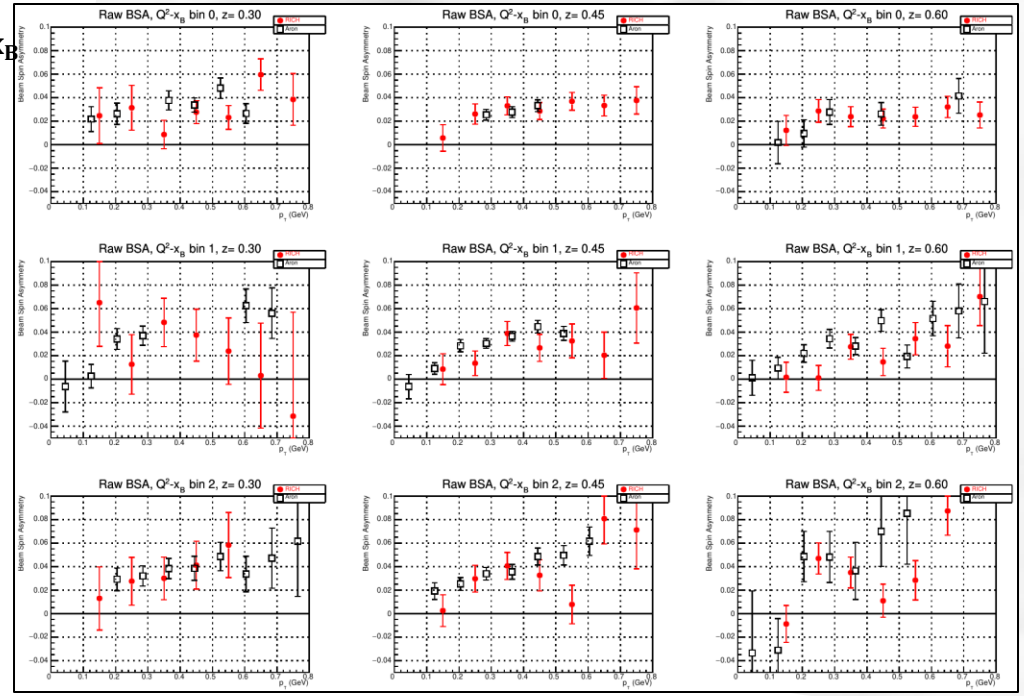
Measurement of the Beam Spin Asymmetry in ep→eK+X (submitted to PRL)

Long standing analysis with a fraction of available data processed in 2020

- Kaon ID with TOF in a limited phase space
- RICH used *"a posteriori"* to define the safe kinematic region, tune the Monte Carlo and for cross checks

FTOF (6sector) **RICH (1sector)**

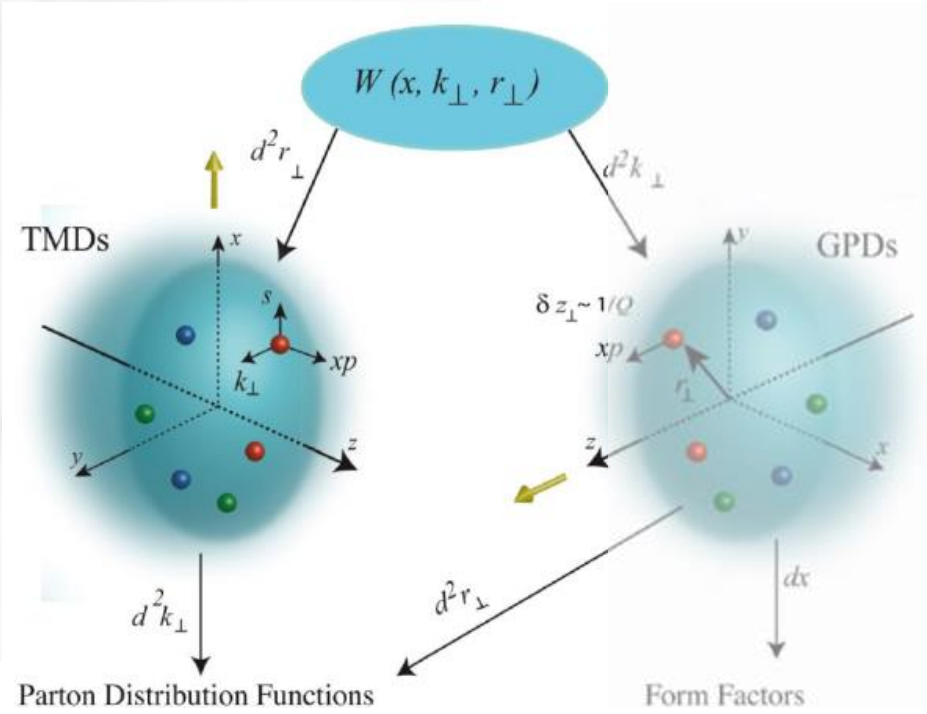
Q^2-x_B



z

Analysis with full statistics on proton and deuteron target with Kaon id from RICH is underway (S. Vallarino , INFN Ge)

Understanding the parton momentum distribution



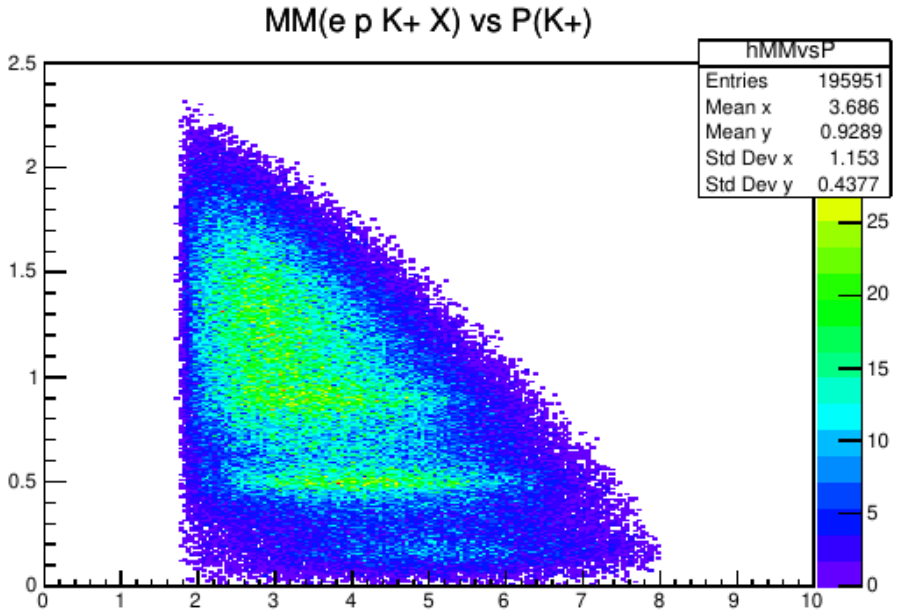
Quarks and hadron dynamics

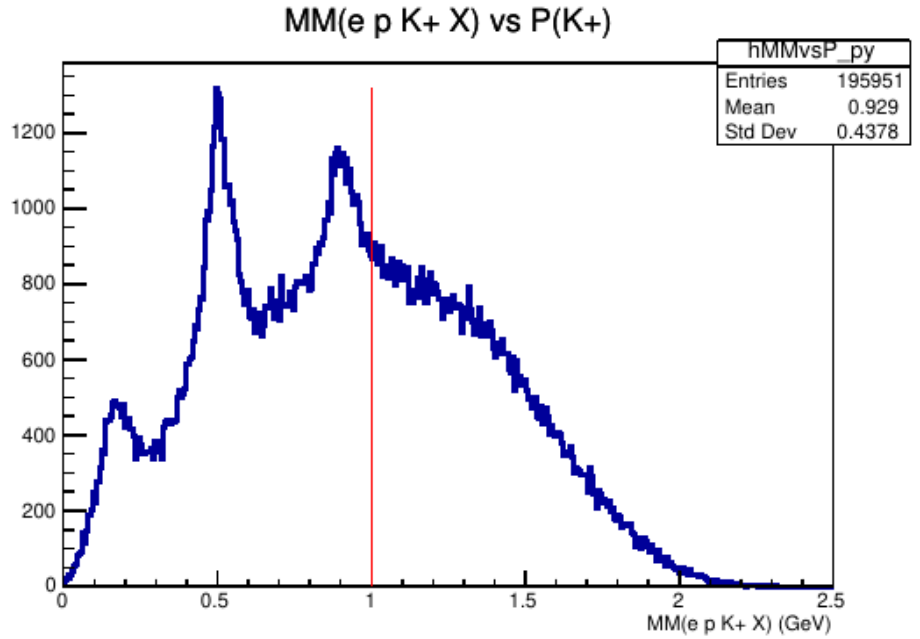
Measurement of the Beam Spin Asymmetry in back-to-back K+ proton electroproduction

Just started in collaboration with Duquesne University: N. Nicholson and G. Pecar currently visiting LNF

- K+ detected in the RICH

Understanding the parton fragmentation





Quarks and hadron dynamics

Transverse target experiment

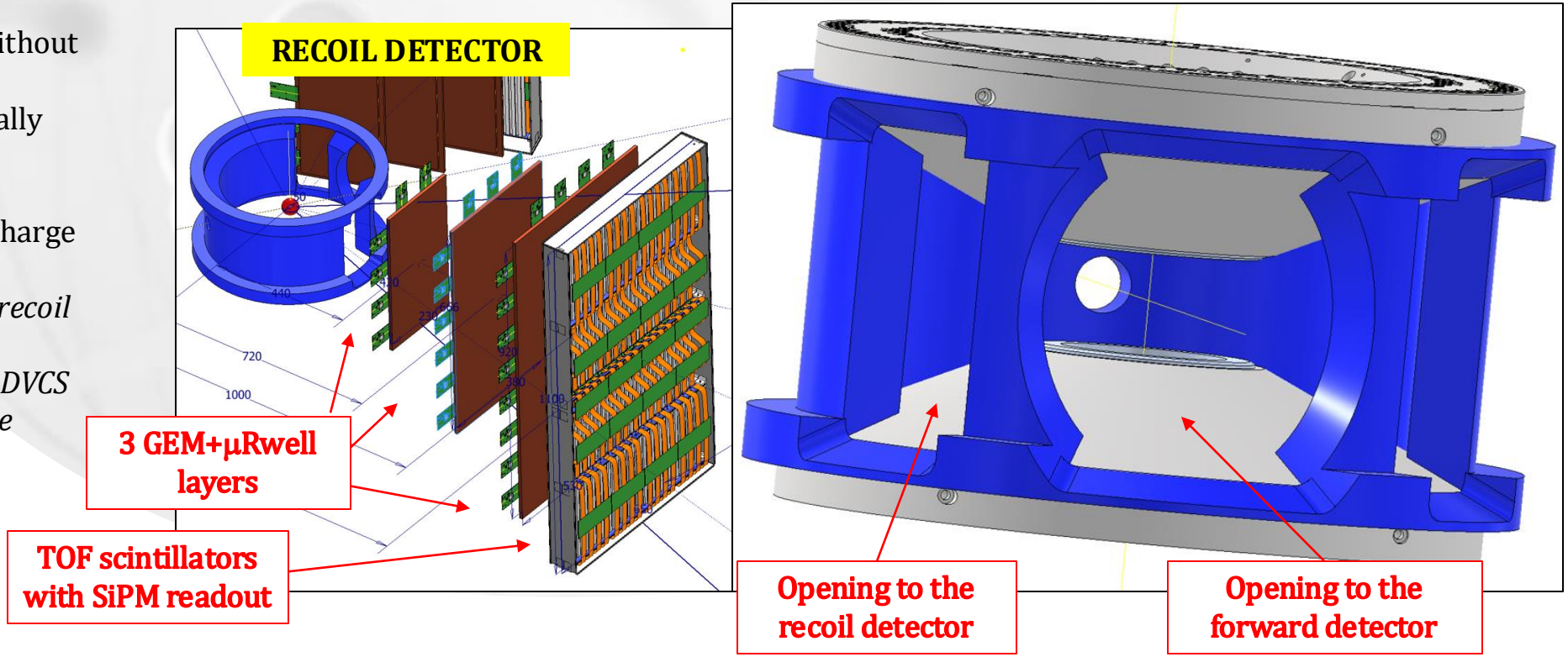
DVCS, Semi-Inclusive DIS with one and two hadrons in the final state with 11-GeV polarized electron beam and transversely polarized target: all approved with the highest rate

The proposal will be examined by JLab PAC in July

New design of CLAS12 without the central detector to accommodate a dynamically polarized NH3 target.

LNF (S. Tomassini) is in charge of:

- *the design of the new recoil detector to detect low energy protons in the DVCS*
- *the optimization of the cryostat of the target magnet*



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?

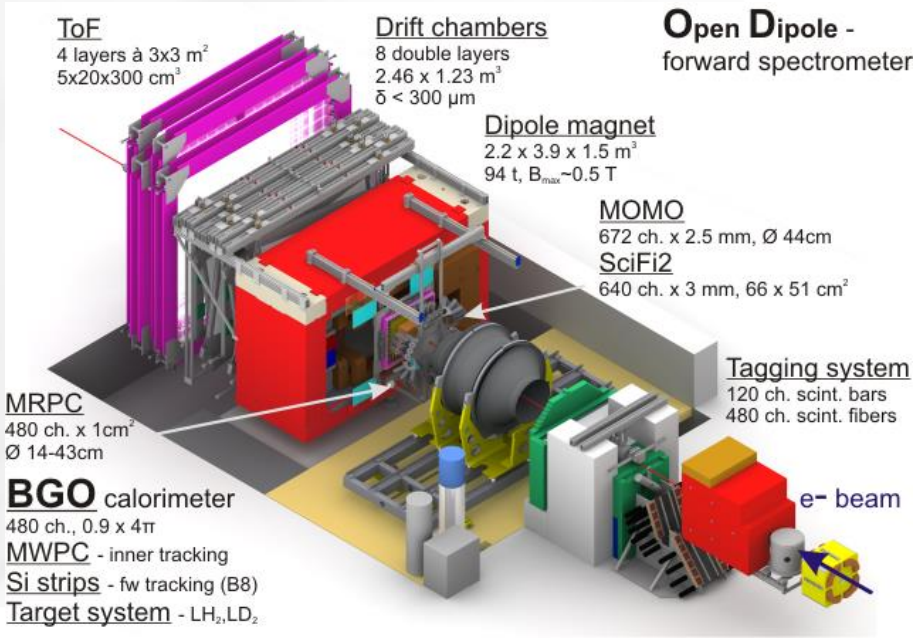
Quarks and hadron dynamics

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?

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

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



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?

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

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?

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)

Main results:

- Strangeness photo-production measurements at small angle and at small momentum transfer
- Measurements of cross-section of coherent photo-production on deuterium
- Beam-spin asymmetry of η and η' photo-production on hydrogen

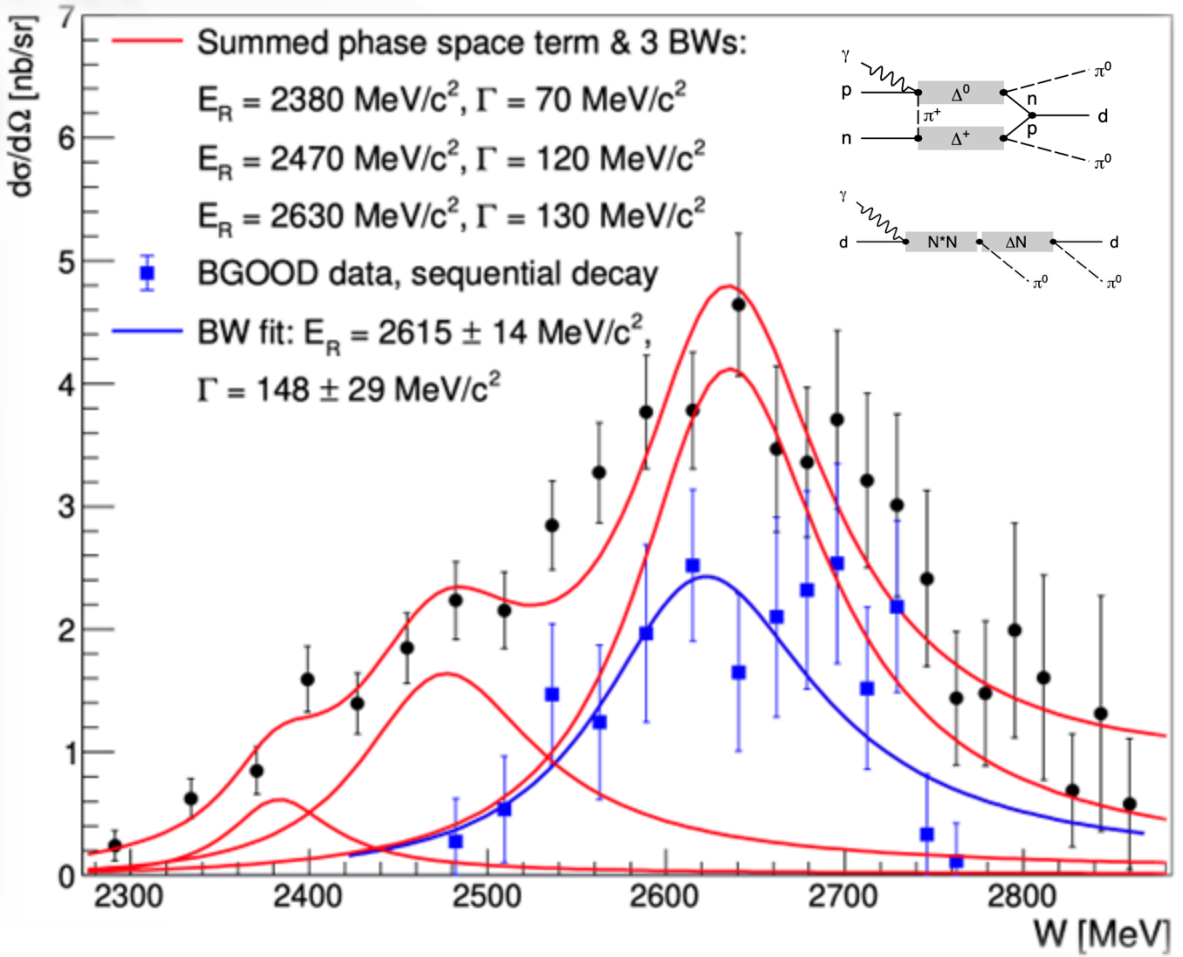
Some analyses are still in progress, but the main scientific goals have been obtained.

Quarks and hadron dynamics

$\gamma d \rightarrow d\pi^0\pi^0$: possible sequential decay through a dibaryonic state

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?



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?

BGO crystals:

- BDX@JLAB
- ~20 → Fireball

HV, ADC → at disposal of interested projects

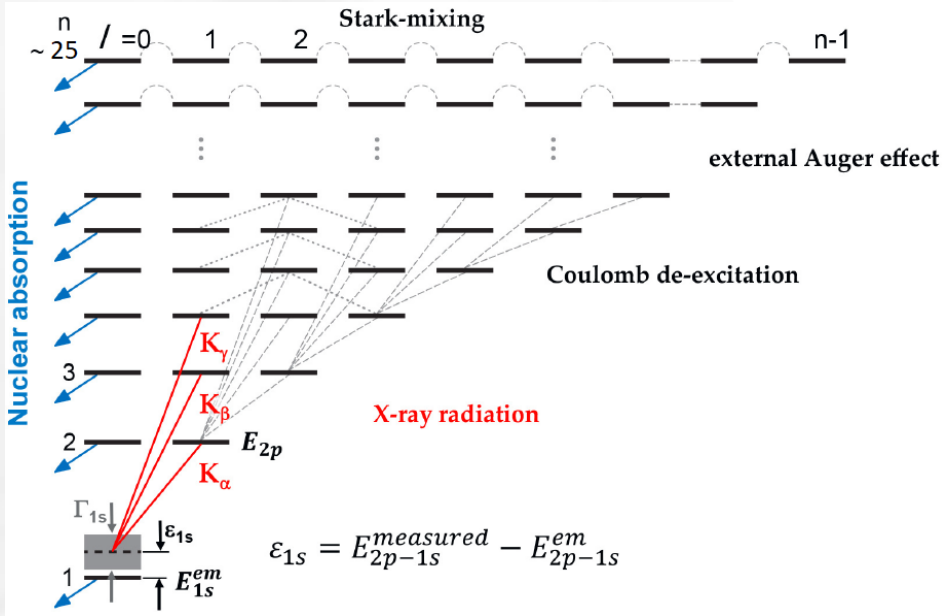
Quarks and hadron dynamics

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?

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).



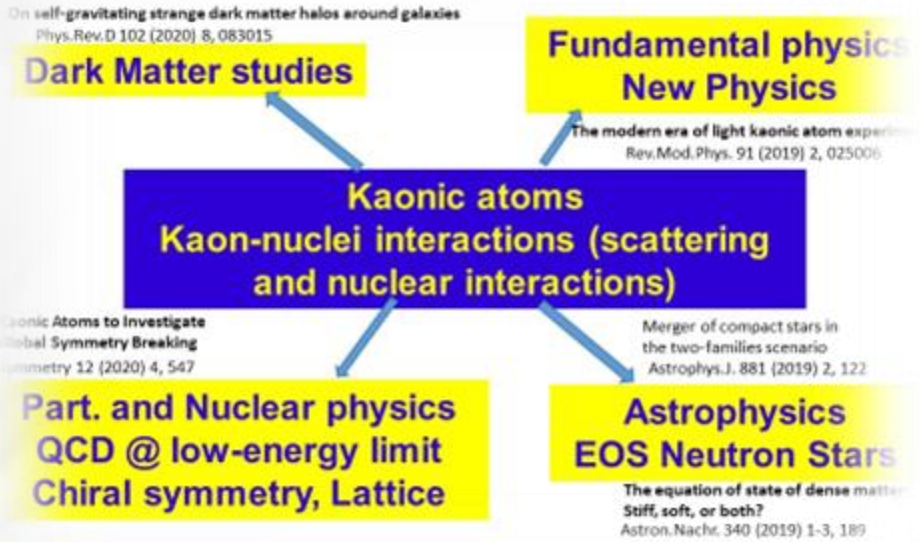
Quarks and hadron dynamics

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?

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) → strong phenomenological power



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

22 Publications, 4 in preparation (2024-2025), Organization of 5 workshops

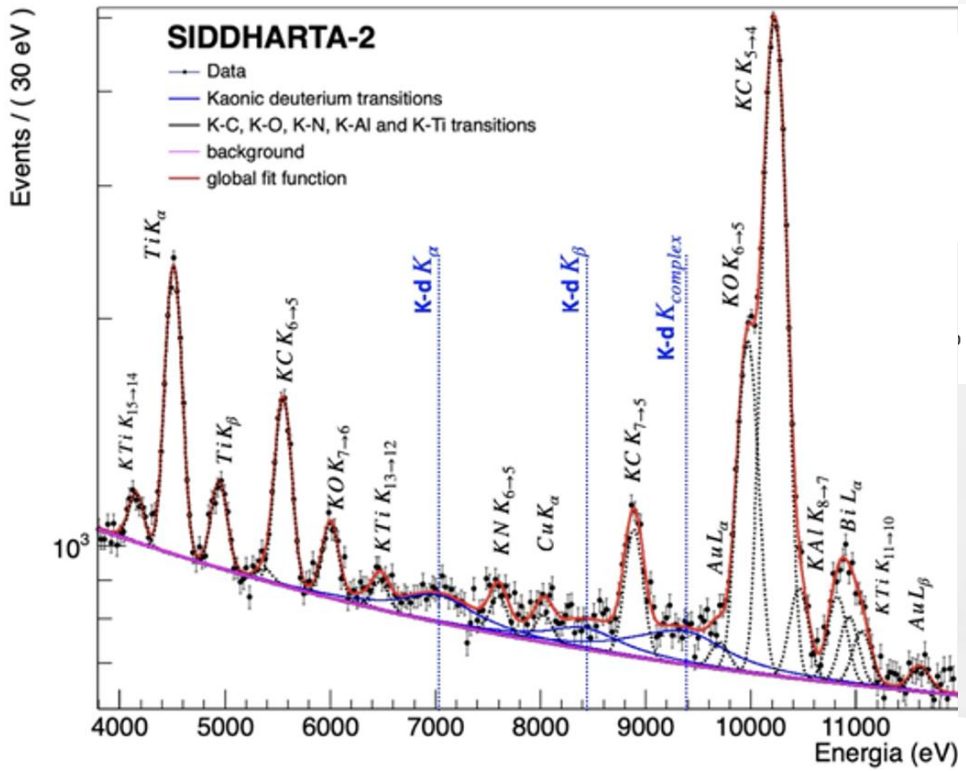
- STRONG2020: WP8-JRA, WP16-NA, TA3-LNF
- Croatian Science Foundation research project 8570

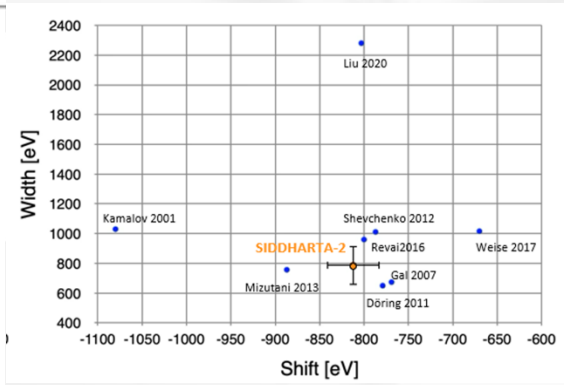
A. Pietropaolo	0.2	A. Scordo	0.7
M. Bazzi	0.3	A. Buttacavoli	1
F. Sgaramella	1	F. Principato	1
A. Clozza	0.2	F. Sirghi	0.5
C. Curceanu	0.6	M. Skurzok	0.5
L. De Paolis	0.5	C. Cantone	0.2
R. Del Grande	0.5	O. Vazquez Doce	0.2
D. Bosnar	0.5	K. Toho	1
M. Iliescu	0.3	L. Russo	0.35
P. Levi Sandri	1.0	R. Bedogni	0.2
A. Khreptak	0.5	D. Sirghi	0.2
M. Merafina	0.6	F. Artibani	1
C. Milardi	0.4	L. Abbene	1
		FTE totali	**14.35**

Quarks and hadron dynamics

$$\varepsilon_{1s} = E^{exp}_{2p\to 1s} - E^{QED}_{2p\to 1s} = 7021.9 - 7834.0 = -812.1 \pm 29.8\,(stat) \pm 2.1\,(syst)\ \text{eV}$$

$$\Gamma_{1s} = 787 \pm 126\,(stat) \pm 33\,(syst)\ \text{eV}$$





*"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)

Proposals for future experiments at DAFNE/J-PARC:

- EXKALIBUR - Front. in Phys. 11 (2023) 1240250 and EPJP-D-25-00691 in print
- Continue and reinforce collaboration in experiments at J-PARC
- Detectors: possible use at Fireball

Quarks and hadron dynamics

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

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

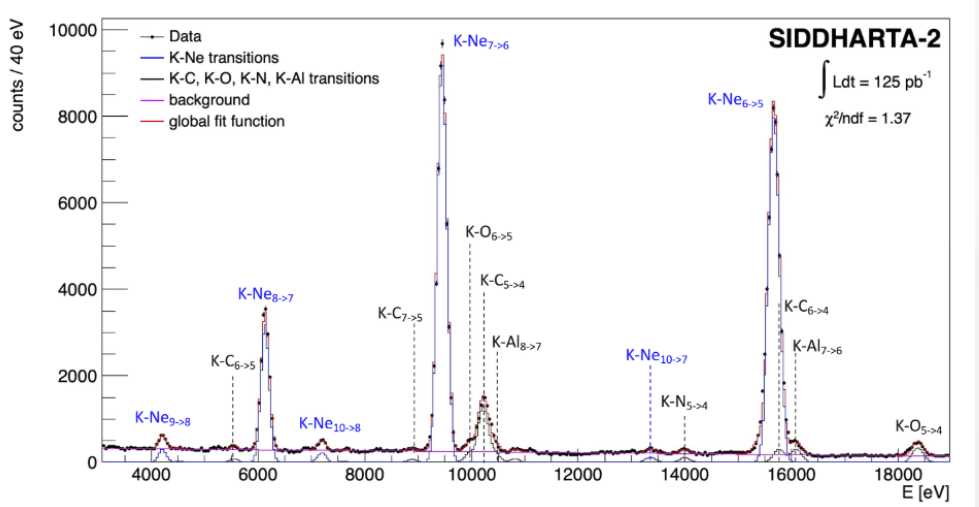


Figure 3: Kaonic Neon energy spectrum and relative fit after the events selection. The energy transitions are identified by the initial (n_i) and final (n_f) principal quantum numbers of the atomic levels. The several contributions of the fit function (red line) are highlighted: the kaonic neon (K-Ne) transitions in blue, the kaonic carbon (K-C), nitrogen (K-N), oxygen (K-O) and aluminium (K-Al) in black and the background in pink.

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

Until July 2024: Kaonic deuterium runs (Run1, Run2 and Run3) about 100 pb^{-1}, kaonic atoms with CdZnTe and HPGe setups

KAONNIS main outcomes 2024/5:

1. *High precision spectroscopy of kaonic neon;* first meas. ever, *Phys.Lett.B 865 (2025) 139492*
2. Kaonic lead measurement with HPGe → kaon mass, *Nucl.Instrum.Meth.A 1069 (2024) 169966*
3. First Stability Characterization for a CZT Detection System in an e+e− Collider Environment, *Sensors 24 (2024) 23, 7562*
4. Measurement of the mesonic decay branch of the K^-NN quasibound state; *Phys.Rev.C 110 (2024) 1, 014002*

Quarks and hadron dynamics

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

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

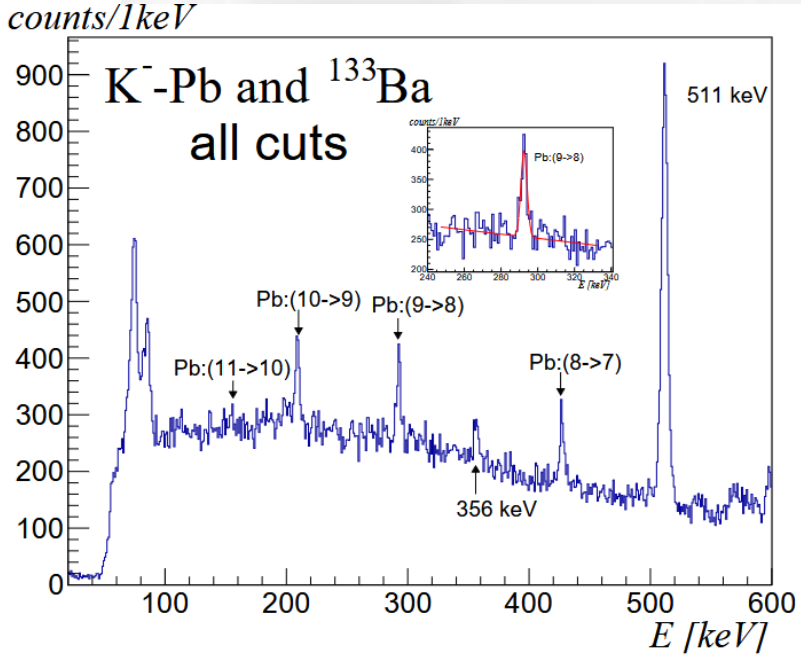


Figure 7: The spectrum seen by the HPGe detector after applying all cuts. The inset shows the peak at 292.47 ± 0.17 keV with a fit done by a Gaussian and a linear function for the background, the energy resolution is 3.97 ± 0.49 keV (FWHM).

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

Until July 2024: Kaonic deuterium runs (Run1, Run2 and Run3) about 100 pb^{-1}, kaonic atoms with CdZnTe and HPGe setups

KAONNIS main outcomes 2024/5:

1. *High precision spectroscopy of kaonic neon;* first meas. ever, *Phys.Lett.B 865 (2025) 139492*
2. Kaonic lead measurement with HPGe → kaon mass, *Nucl.Instrum.Meth.A 1069 (2024) 169966*
3. First Stability Characterization for a CZT Detection System in an e+e− Collider Environment, *Sensors 24 (2024) 23, 7562*
4. Measurement of the mesonic decay branch of the K⁻NN quasibound state; *Phys.Rev.C 110 (2024) 1, 014002*

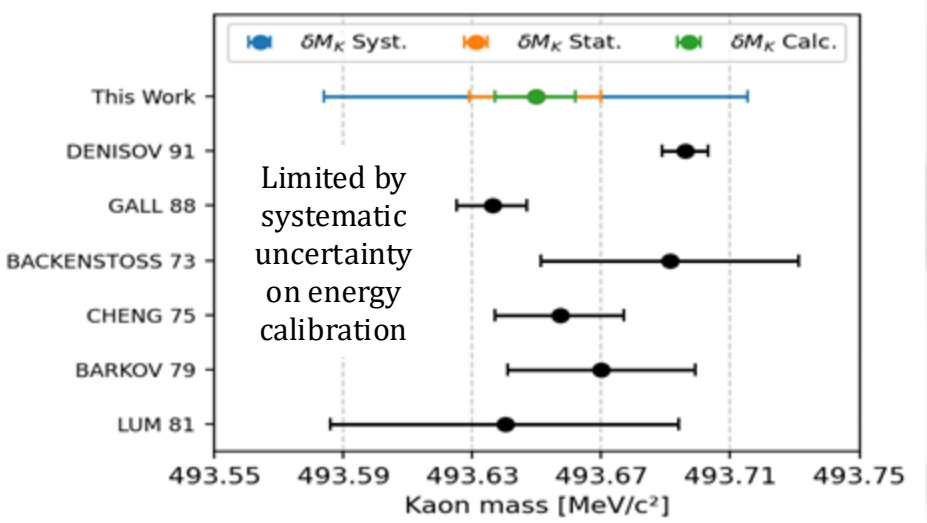
Quarks and hadron dynamics

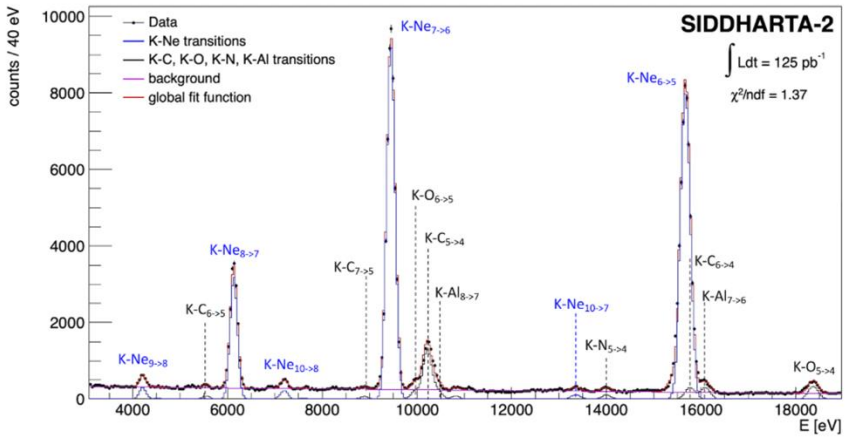
KAONNIS: 2025-2026 activities

- **Finalize K_d analyses**
  - → calibration and events selection of the entire data set
  - → evaluation of the 1s level energy shift and width and implications for the low energy QCD with strangeness
  - → Evaluation of the kaonic deuterium X-ray yields (high and low density runs)
  - → Combined Evaluation of the kaonic deuterium scattering length (in collaboration with theoreticians)
  - → **Combined analysis of kaonic hydrogen and deuterium to determine the isospin dependent antikaon-nucleon scattering lengths (in collaboration with theoreticians) and implication for theory**
- Kaonic Boron and Fluorine: finalize data analyses
- Data analyses for kaonic aluminum and fluorine with CZT setup completed
- Experimental activities: EXKALIBUR first measurements module and J-PARC (E57) → measurements on both gaseous and solid targets
  - enriched scientific program
  - realization and test of refined calibration system ongoing: test in DAFNE
  - 1 mm SDD detector system: production of 3 buses and tests (in cryo gas)
  - CZT detector optimizations (Enrich COST Action)
  - Ready to start as soon as possible: requested 300 pb^{-1}+ 200 pb^{-1}

Quarks and hadron dynamics

KAONNIS: 2025-2026 activities

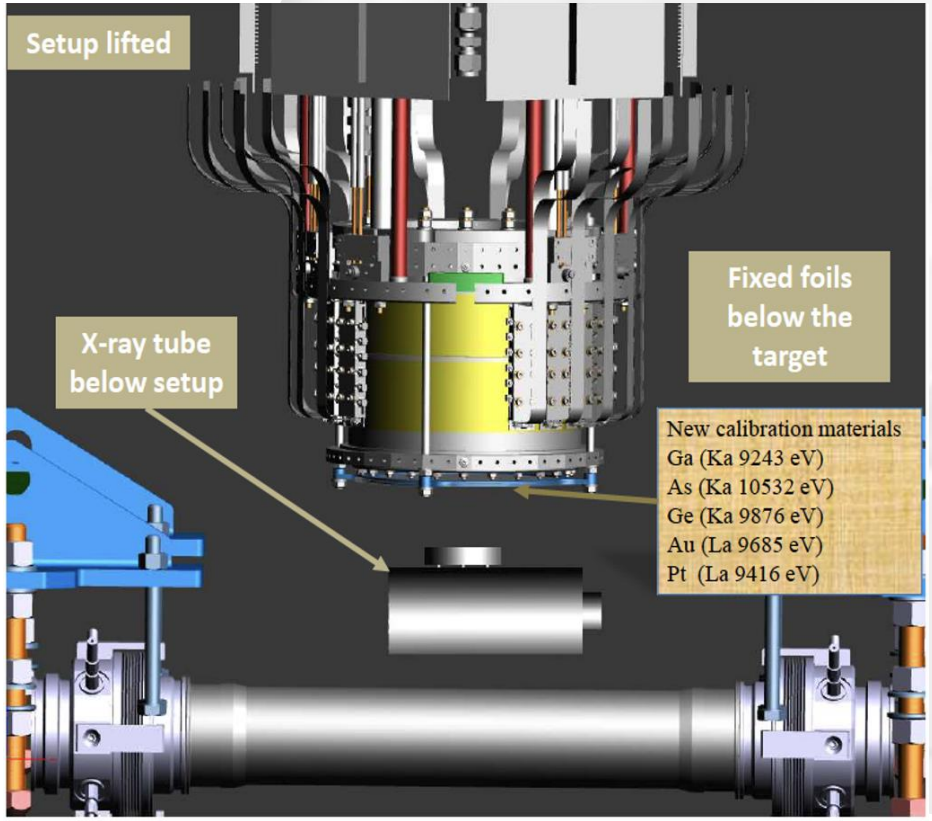




- Finalize K_d analyses
  - → calibration and events selection of the entire data set
  - → evaluation of the 1s level energy shift and width and implications for the low energy QCD with strangeness
  - → Evaluation of the kaonic deuterium X-ray yields (high and low density runs)
  - → Combined Evaluation of the kaonic deuterium scattering length (in collaboration with theoreticians)
  - → Combined analysis of kaonic hydrogen and deuterium to determine the isospin dependent antikaon-nucleon scattering lengths (in collaboration with theoreticians) and implication for theory
- Kaonic Boron and Fluorine: finalize data analyses
- Data analyses for kaonic aluminum and fluorine with CZT setup completed
- Experimental activities: EXKALIBUR first measurements module and J-PARC (E57)
  - enriched scientific program
  - **realization and test of refined calibration system ongoing: test in DAFNE**
  - 1 mm SDD detector system: production of 3 buses and tests (in cryo gas)
  - CZT detector optimizations (Enrich COST Action)
  - Ready to start as soon as possible: requested 300 pb^{-1}+ 200 pb^{-1}

Quarks and hadron dynamics

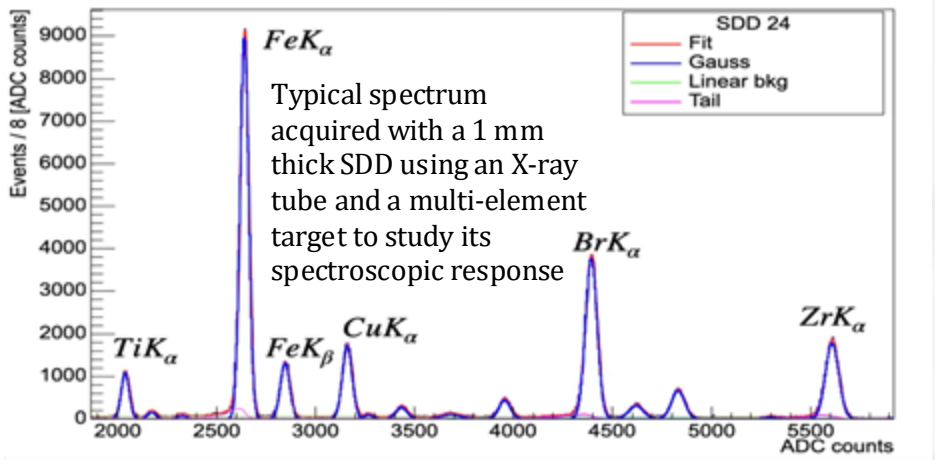
KAONNIS: 2025-2026 activities

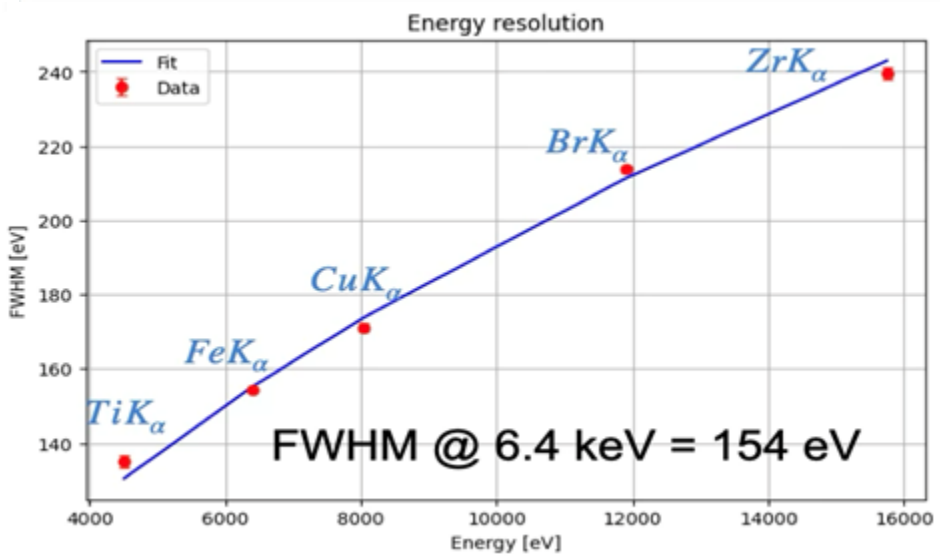


- Finalize K_d analyses
  - → calibration and events selection of the entire data set
  - → evaluation of the 1s level energy shift and width and implications for the low energy QCD with strangeness
  - → Evaluation of the kaonic deuterium X-ray yields (high and low density runs)
  - → Combined Evaluation of the kaonic deuterium scattering length (in collaboration with theoreticians)
  - → Combined analysis of kaonic hydrogen and deuterium to determine the isospin dependent antikaon-nucleon scattering lengths (in collaboration with theoreticians) and implication for theory
- Kaonic Boron and Fluorine: finalize data analyses
- Data analyses for kaonic aluminum and fluorine with CZT setup completed
- Experimental activities: EXKALIBUR first measurements module and J-PARC (E57)
  - enriched scientific program
  - **realization and test of refined calibration system ongoing: test in DAFNE**
  - 1 mm SDD detector system: production of 3 buses and tests (in cryo gas)
  - CZT detector optimizations (Enrich COST Action)
  - Ready to start as soon as possible: requested 300 pb^{-1}+ 200 pb^{-1}

Quarks and hadron dynamics

Optimisation of the detectors' energy response: excellent energy resolution and linearity



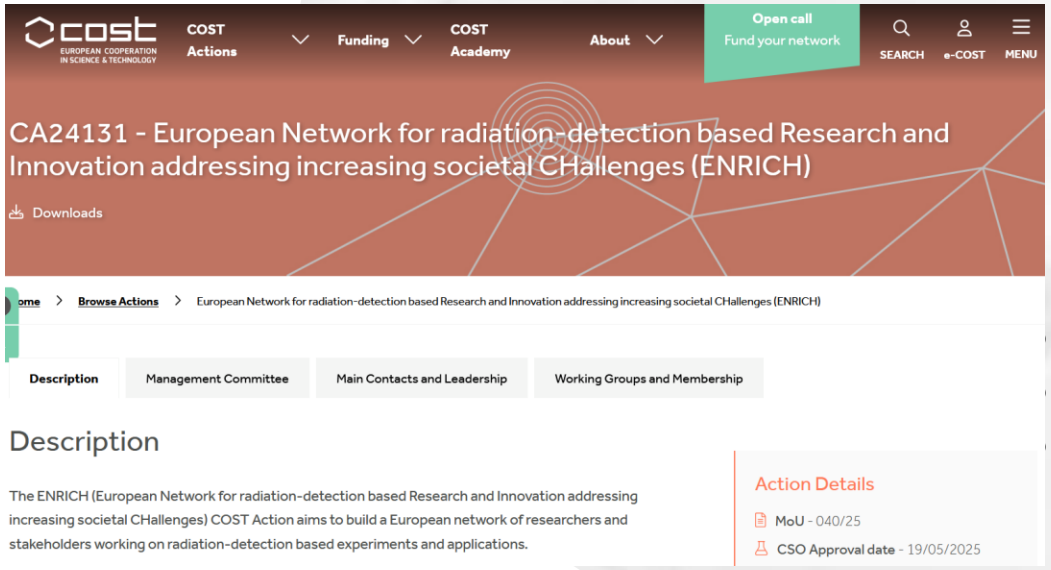


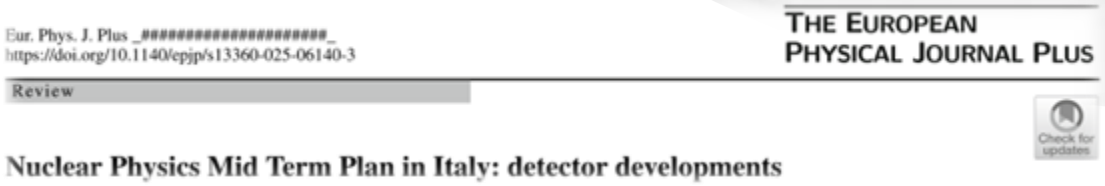
- Finalize K_d analyses
  - → calibration and events selection of the entire data set
  - → evaluation of the 1s level energy shift and width and implications for the low energy QCD with strangeness
  - → Evaluation of the kaonic deuterium X-ray yields (high and low density runs)
  - → Combined Evaluation of the kaonic deuterium scattering length (in collaboration with theoreticians)
  - → Combined analysis of kaonic hydrogen and deuterium to determine the isospin dependent antikaon-nucleon scattering lengths (in collaboration with theoreticians) and implication for theory
- Kaonic Boron and Fluorine: finalize data analyses
- Data analyses for kaonic aluminum and fluorine with CZT setup completed
- Experimental activities: EXKALIBUR first measurements module and J-PARC (E57)
  - enriched scientific program
  - realization and test of refined calibration system ongoing: test in DAFNE
  - **1 mm SDD detector system: production of 3 buses and tests (in cryo gas)**
  - CZT detector optimizations (Enrich COST Action)
  - Ready to start as soon as possible: requested 300 pb^{-1}+ 200 pb^{-1}

Quarks and hadron dynamics

KAONNIS: 2025-2026 activities

Based on KAONNIS detector leading developments: (A. Scordo)





- Finalize K_d analyses
  - → calibration and events selection of the entire data set
  - → evaluation of the 1s level energy shift and width and implications for the low energy QCD with strangeness
  - → Evaluation of the kaonic deuterium X-ray yields (high and low density runs)
  - → Combined Evaluation of the kaonic deuterium scattering length (in collaboration with theoreticians)
  - → Combined analysis of kaonic hydrogen and deuterium to determine the isospin dependent antikaon-nucleon scattering lengths (in collaboration with theoreticians) and implication for theory
- Kaonic Boron and Fluorine: finalize data analyses
- Data analyses for kaonic aluminum and fluorine with CZT setup completed
- Experimental activities: EXKALIBUR first measurements module and J-PARC (E57)
  - enriched scientific program
  - realization and test of refined calibration system ongoing: test in DAFNE
  - 1 mm SDD detector system: production of 3 buses and tests (in cryo gas)
  - **CZT detector optimizations (Enrich COST Action)**
  - Ready to start as soon as possible: requested 300 pb^{-1}+ 200 pb^{-1}

Quarks and hadron dynamics

KAONNIS: 2025-2026 activities

Richieste finanziarie 150k€

Consumo	70 k€
Inventariabile	40 k€
Manutenzione	15 k€
Missioni	25 k€

Richieste ai servizi

Progettazione: 3 m.u. → Progettazioni e ottimizzazione sistemi calibrazione e test rivelatori

Officina meccanica: 3 m.u. → costruzioni setup tests

Tecnici: 0.5 FTE → installazioni e costruzioni

- Finalize K_d analyses
  - → calibration and events selection of the entire data set
  - → evaluation of the 1s level energy shift and width and implications for the low energy QCD with strangeness
  - → Evaluation of the kaonic deuterium X-ray yields (high and low density runs)
  - → Combined Evaluation of the kaonic deuterium scattering length (in collaboration with theoreticians)
  - → Combined analysis of kaonic hydrogen and deuterium to determine the isospin dependent antikaon-nucleon scattering lengths (in collaboration with theoreticians) and implication for theory
- Kaonic Boron and Fluorine: finalize data analyses
- Data analyses for kaonic aluminum and fluorine with CZT setup completed
- Experimental activities: EXKALIBUR first measurements module and J-PARC (E57)
  - enriched scientific program
  - realization and test of refined calibration system ongoing: test in DAFNE
  - 1 mm SDD detector system: production of 3 buses and tests (in cryo gas)
  - CZT detector optimizations (Enrich COST Action)
  - Ready to start as soon as possible: requested 300 pb^{-1}+ 200 pb^{-1}

CSN3
Fisica
Nucleare

We dedicated our results to our dear colleagues and friends Prof Carlo Guaraldo and Dr. Johann Zmeskal

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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

FOOT experiment

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

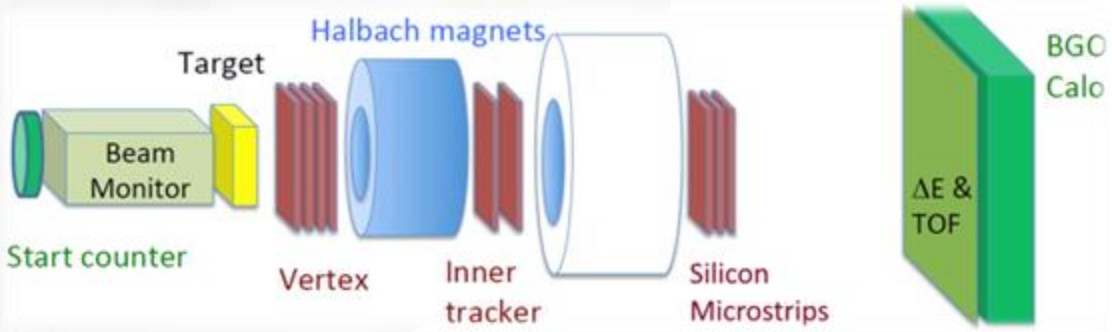
Nuclear fragments: important source of biological damage, both for cancer cells and for nearby healthy tissues.

→ 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)

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

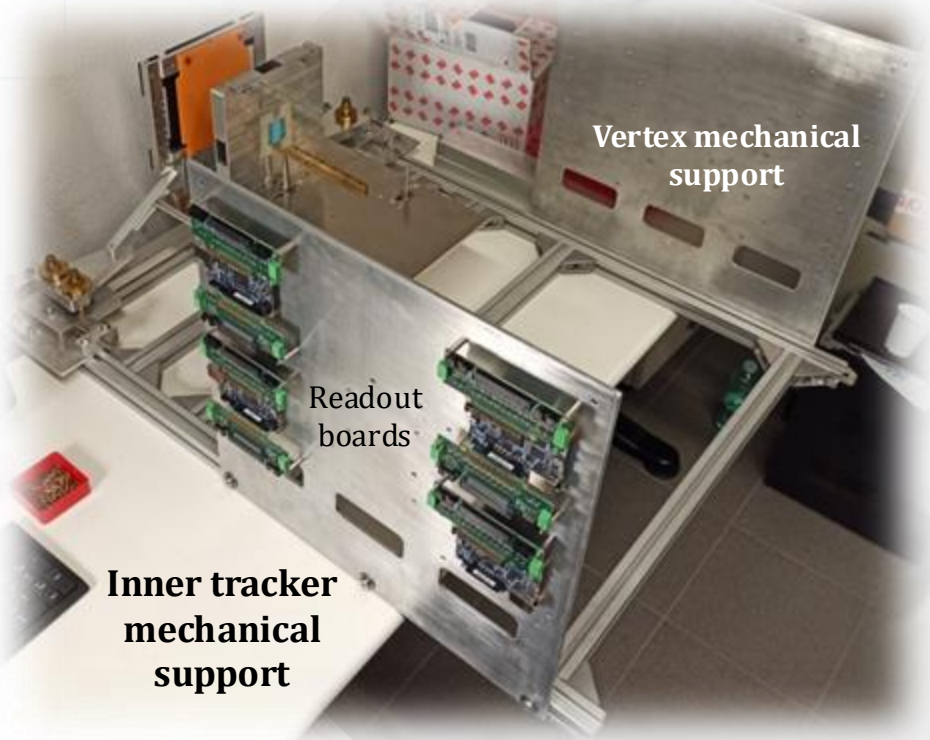
1. Start counter to monitor the primary particle rates
2. Beam monitor: low-density material to minimize multiple scattering, aiming at measuring the direction and the impinging point of the ion beam on the target
3. Vertex/Trackers/MSD: combined for tracking
4. ToF/Calorimeter for PID

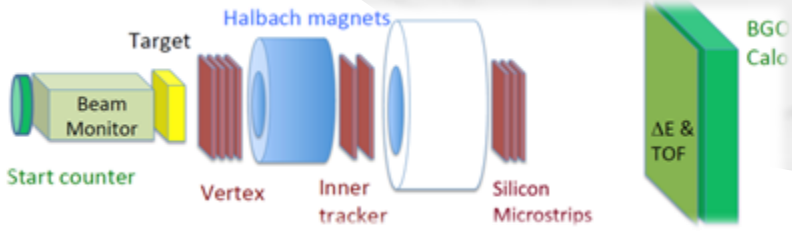


@LNF:

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

FOOT experiment





FOOT tracker mechanical setup:

- System brought at CNAO on 2023.
- A first data taking was performed in 2023, a second in 2024

Pixel vertex detector

- Mechanics for vertex positioning ready, control software in preparation

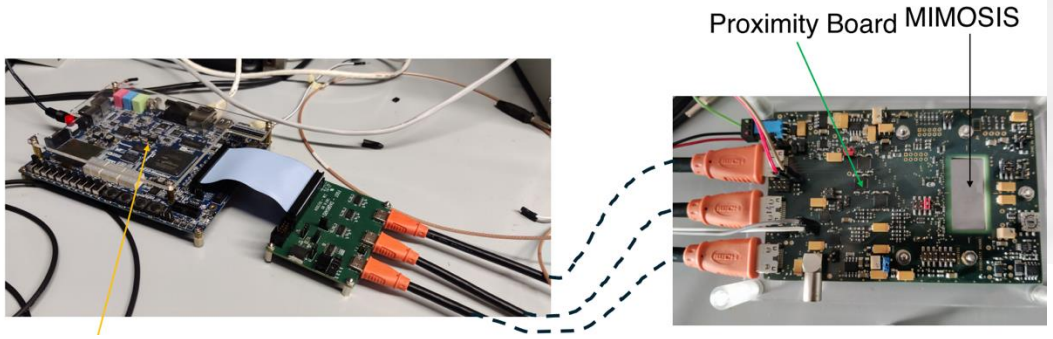
Inner Tracker and magnet system: ready and tested at CNAO

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»

Time resolution: 185 $\mu s \rightarrow 5\ \mu s$



Program for 2026: pixel vertex detector

- CNAO 2024 data: 2 VTX sensors changed; no more spares available
- A new version in preparation: former monolithic pixel sensor M28 (Mimosa28) substitued by MIMOSIS
- Firmware FPGA ready and tested for simulation

FOOT	Afferenza (%)
G. Raffone	50
E. Spiriti	70
S. Tomassini	20
FTE totali	1.4

Miss.	TRA	INV	MAN	CON	Totale
11	2			2	15

The National Scientific Committee

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

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

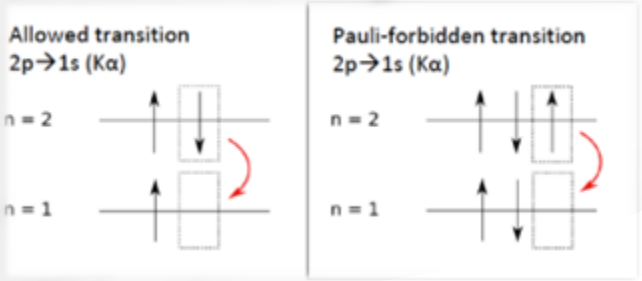
VIP already established a probability of PEP violation
$\beta^2/2 < 4x10^{29} \rightarrow$ previous limit $< 1.7x10^{26}$ (PLB 328, 1990, 438)
⇒ VIP-2 aims at an improvement of at least 2 orders of magnitude

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

13 Publications (2024-2025):

Phys. Rev. Lett. 132, 250203 (2024)
Eur. Phys. J. C (2024) 84: 214
Eur.Phys.J.C 84 (2024) 11, 1137

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



VIP	FTE
Andrea Addazi	0.5
Massimiliano Bazzi	0.5
Maurizio Benfatto	1
Alberto Clozza	0.6
Catalina Oana Curceanu	03
N. Bortolotti	1
Antonino Marcianò	0.5
Catia Milardi	0.2
Elisabetta Pace	0.6
Kristian Piscicchia	1
Alessio Porcelli	0.5
Diana Laura Sirghi	0.7
Alessandro Scordo	0.3
Simone Manti	?
F. Sirghi	0.5
FTE totali	8.2

15 researchers for **8.3 FTE**
Average participation of 55%

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 $\beta^2/2 < 4x10^{29}$ → 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

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, VIP-3-HYYBRID
- **Ar, Sn, Zn targets,** new SDDs 1mm thick produced (FBK+PoliMi), setup (2 SDDs 1 mm + 2 SDDs 0.45 mm) ready. VIP-3 setup under finalization, *Entropy 26 (2024) 9, 752*
- 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

VIP-3 status

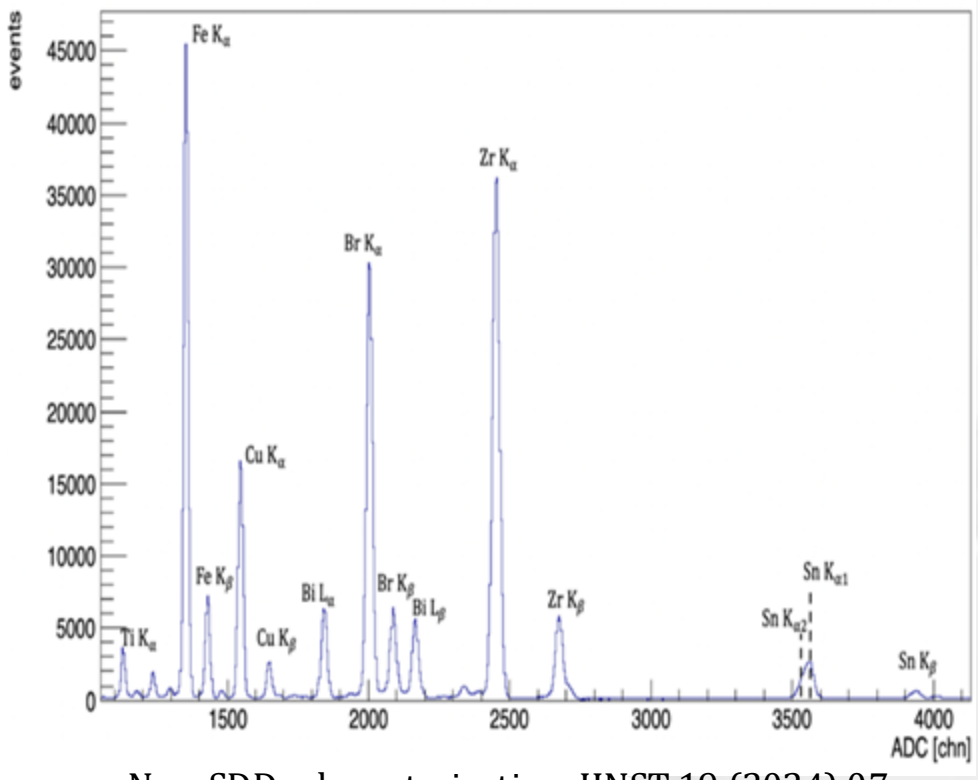
VIP-2 → new SDD detectors:
- higher resolution: 190 eV (fwhm)
- faster (triggerable) → VETO system
- higher acceptance and efficiency
- higher current → low background
- current modulation data analyzed (*Eur. Phys. J. C (2024) 84: 214*)

VIP-3, VIP-3-HYYBRID
- **Ar, Sn, Zn targets,** new SDDs 1mm thick produced (FBK+PoliMi), setup (2 SDDs 1 mm + 2 SDDs 0.45 mm) ready. VIP-3 setup under finalization, *Entropy 26 (2024) 9, 752*
- 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

VIP-3 status



- New SDDs characterization: JINST 19 (2024) 07, P07039
- New front end electronics under testing at LNF → installation at LNGS early 2026.

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, VIP-3-HYYBRID
- **Ar, Sn, Zn targets,** new SDDs 1mm thick produced (FBK+PoliMi), setup (2 SDDs 1 mm + 2 SDDs 0.45 mm) ready. VIP-3 setup under finalization, *Entropy 26 (2024) 9, 752*
- extend the search for PEP-violating transition to a higher energy

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

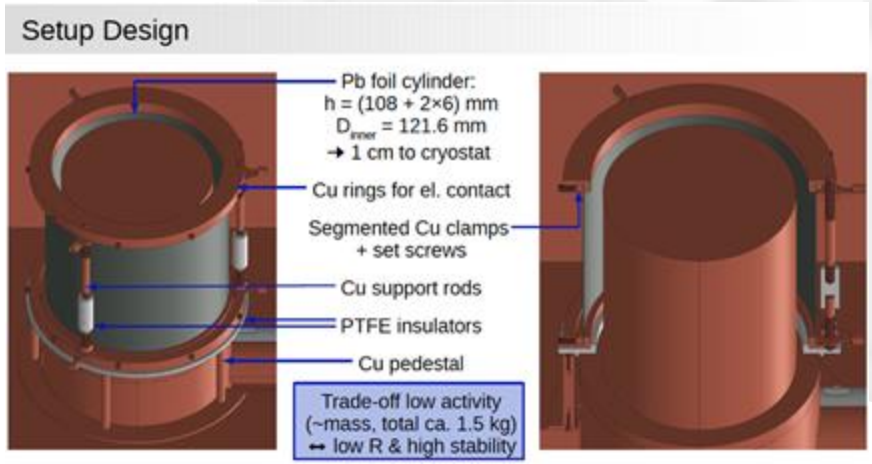
VIP-CLOSED SYSTEMS → Ge detectors
- high radio-purity HPGe & BEGe
- several targets

VIP-GATOR at LNGS

Goal: MG-test of $\beta^2/2$ for Z = 82 (lead) with 40 A circulating current - *Eur.Phys.J.C 84 (2024) 11, 1137*

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

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



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, VIP-3-HYYBRID
- **Ar, Sn, Zn targets,** new SDDs 1mm thick produced (FBK+PoliMi), setup (2 SDDs 1 mm + 2 SDDs 0.45 mm) ready. VIP-3 setup under finalization, *Entropy 26 (2024) 9, 752*
- 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

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
BEGe based setup realized and installed at LNGS, with isolation system to reduce the microphonic background - *Condens. Matter 2024, 9(2), 22*

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, VIP-3-HYYBRID
- **Ar, Sn, Zn targets,** new SDDs 1mm thick produced (FBK+PoliMi), setup (2 SDDs 1 mm + 2 SDDs 0.45 mm) ready. VIP-3 setup under finalization, *Entropy 26 (2024) 9, 752*
- 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

VIP future plans

Richieste ai servizi

Progettazione: 2 m.u per realizzazione setup dedicati (BEGe ed HPGe) per misure di *wave function collapse* e PEPV in QG, e anisotropia in QG models

Officina meccanica: 2 m.u. //

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

Miss.	TRA	INV	MAN	CON	Totale
30	0	80	10	60	180 k€

VIP-3, open systems:

- Prepare and submit for publication the papers with data analyses on last data taking periods (at least 1 paper)
- VIP-3 Hybrid data taking - assessment of VIP-3 performance in known (ideal) conditions; 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):

VIP-Lead and other materials, closed systems:

- Analysis of the data collected with improved BEGe based test setup. Optimization of a dedicated final setup → improve sensitivity on Non-commutative QG models up to the Planck scale
- Collaborations 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.

Dissemination activities: presentation of the VIP results in at least 3 events (Workshops/conferences) and in public events – such as Open Labs and talks/seminars at schools.

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

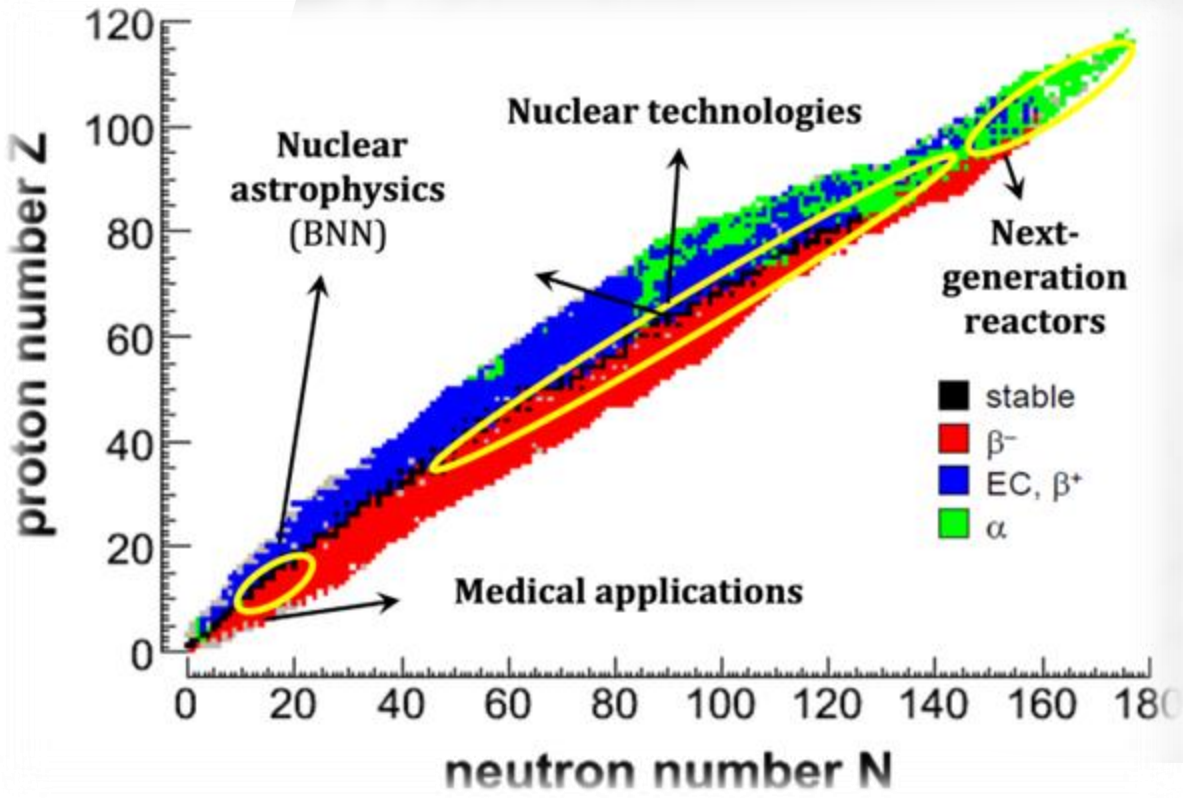
LEA, ALPHA, JEDI, VIP, FAMU

6. APPLICATIONS AND SOCIETAL BENEFITS

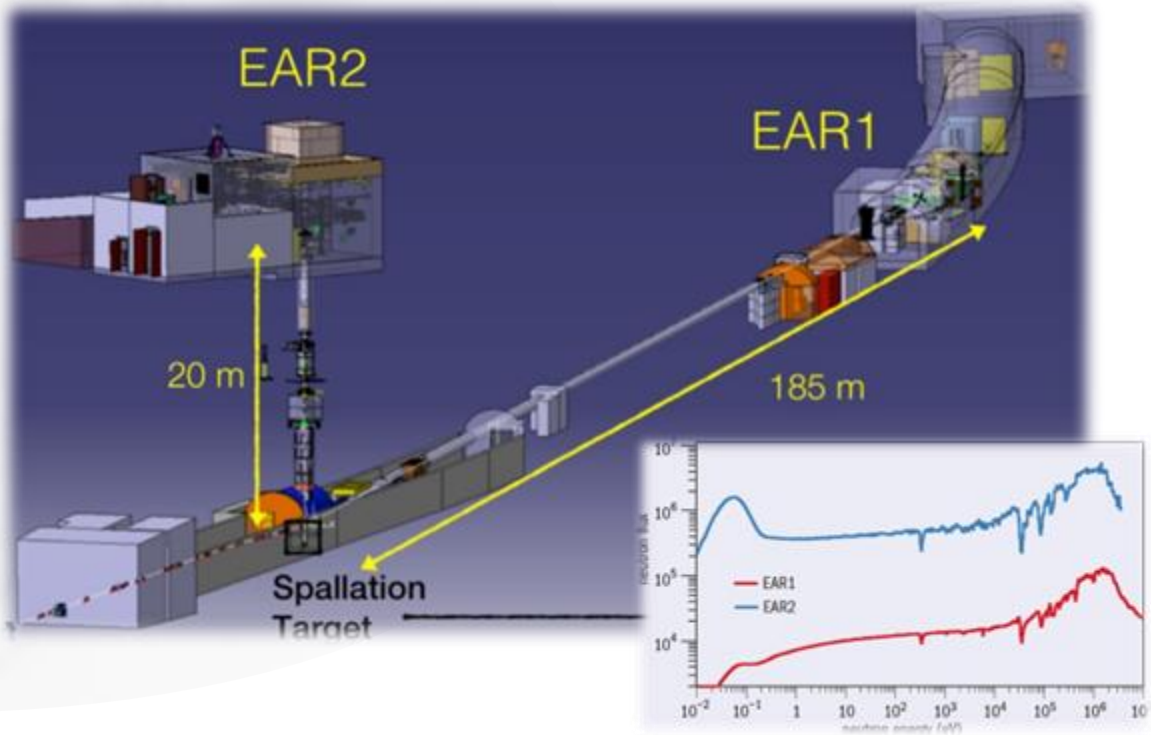
FOOT

nTOF

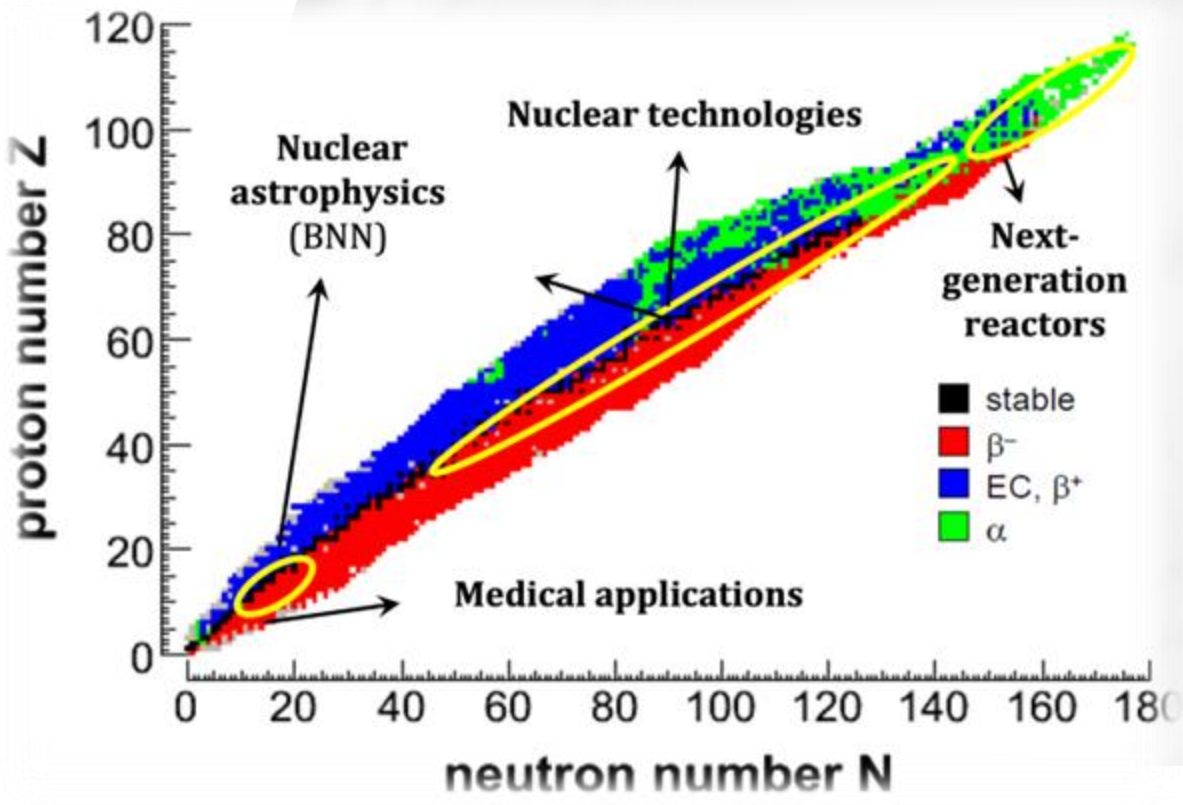
Misura di precisione di sezioni d'urto di reazioni indotte da neutroni



→ select neutrons with E_{kin} from few meV to GeV, via time of flight measurements



nTOF

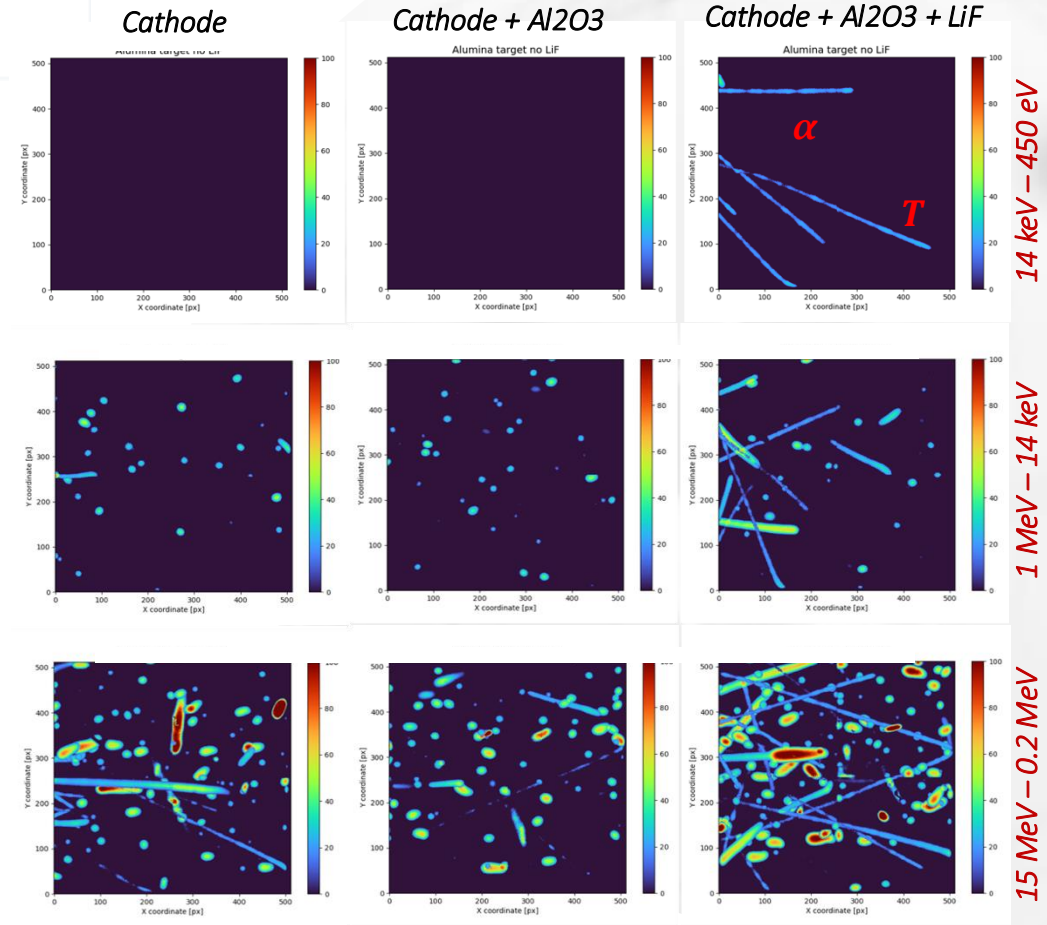


1. **Realizzazione di un rivelatore GEMpix in configurazione side-on per la misura di prodotti carichi da reazioni (n, cp)** → si rivela utile per la misura e l'identificazione di prodotti carichi di bassa energia (0.1 – 2 MeV), e come tale risulta complementare alle funzionalità espressa in accoppiamento col silicio

2. Per la misura di prodotti carichi a più alta energia (> 2 MeV), è stato messo a punto un **quad Timepix3 al silicio da 500 µm** che è stato testato in EAR2 (novembre 2024) ed EAR1 (marzo 2025) → nel caso del LiF, l'analisi di traccia ha mostrato una chiara discriminazione di alfa e tritoni per energie superiori a 3 MeV.

3. **Misura della concentrazione di ^{10}B su campioni biologici di interesse per la BCNT** → è stato messo a punto un quad Timepix3 da 100 µm di spessore e senza pcb in modo da ridurre il background e discriminare ulteriormente le tracce da alfa e ioni litio del boro. Si è ottenuta un imaging del campione con concentrazioni di 50 ppm di Boro, valore vicino a quelle tipiche previste per la pratica clinica.

nTOF



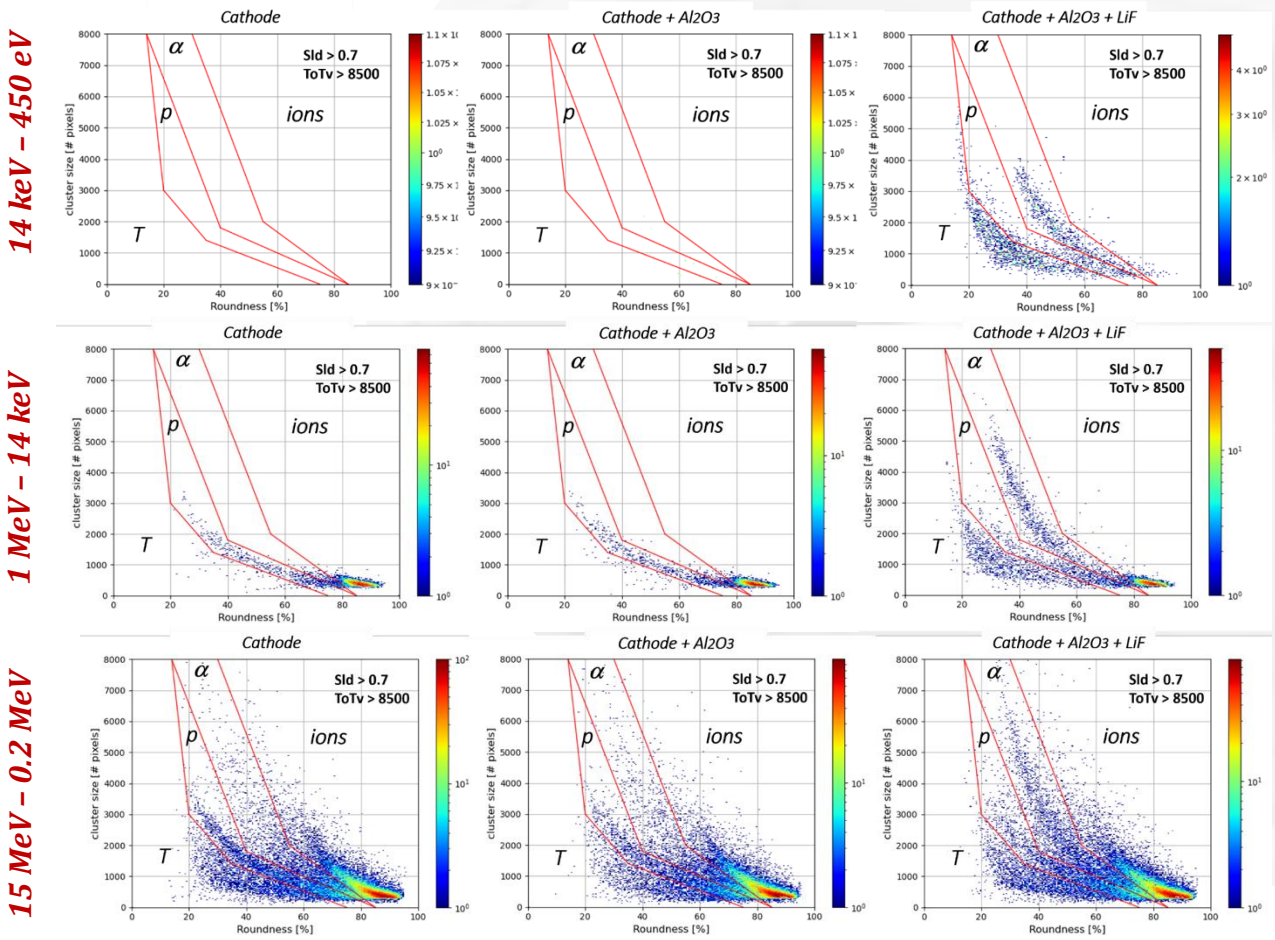
All'aumentare dell'energia si distinguono tracce che derivano dall'interazione dei neutroni con i materiali costituenti il rivelatore stesso (vetronite e fogli GEM)

1. **Realizzazione di un rivelatore GEMpix in configurazione side-on per la misura di prodotti carichi da reazioni (n, cp)** → si rivela utile per la misura e l'identificazione di prodotti carichi di bassa energia (0.1 – 2 MeV), e come tale risulta complementare alle funzionalità espressa in accoppiamento col silicio

2. Per la misura di prodotti carichi a più alta energia (> 2 MeV), è stato messo a punto un **quad Timepix3 al silicio da 500 µm** che è stato testato in EAR2 (novembre 2024) ed EAR1 (marzo 2025) → nel caso del LiF, l'analisi di traccia ha mostrato una chiara discriminazione di alfa e tritoni per energie superiori a 3 MeV.

3. **Misura della concentrazione di ^{10}B su campioni biologici di interesse per la BCNT** → è stato messo a punto un quad Timepix3 da 100 µm di spessore e senza pcb in modo da ridurre il background e discriminare ulteriormente le tracce da alfa e ioni litio del boro. Si è ottenuta un imaging del campione con concentrazioni di 50 ppm di Boro, valore vicino a quelle tipiche previste per la pratica clinica.

nTOF



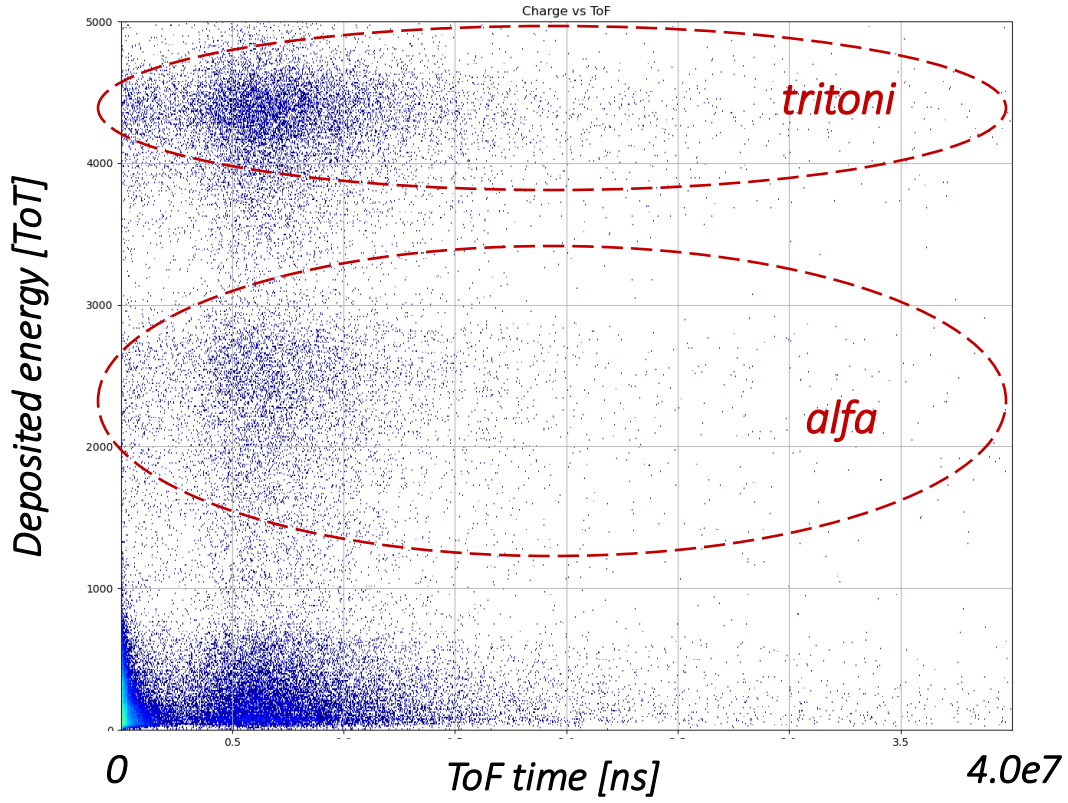
1. **Realizzazione di un rivelatore GEMpix in configurazione side-on per la misura di prodotti carichi da reazioni (n, cp)** → si rivela utile per la misura e l'identificazione di prodotti carichi di bassa energia (0.1 – 2 MeV), e come tale risulta complementare alle funzionalità espressa in accoppiamento col silicio

2. Per la misura di prodotti carichi a più alta energia (> 2 MeV), è stato messo a punto un **quad Timepix3 al silicio da 500 µm** che è stato testato in EAR2 (novembre 2024) ed EAR1 (marzo 2025) → nel caso del LiF, l'analisi di traccia ha mostrato una chiara discriminazione di alfa e tritoni per energie superiori a 3 MeV.

3. **Misura della concentrazione di ^{10}B su campioni biologici di interesse per la BCNT** → è stato messo a punto un quad Timepix3 da 100 µm di spessore e senza pcb in modo da ridurre il background e discriminare ulteriormente le tracce da alfa e ioni litio del boro. Si è ottenuta un imaging del campione con concentrazioni di 50 ppm di Boro, valore vicino a quelle tipiche previste per la pratica clinica.

nTOF

con LiF target

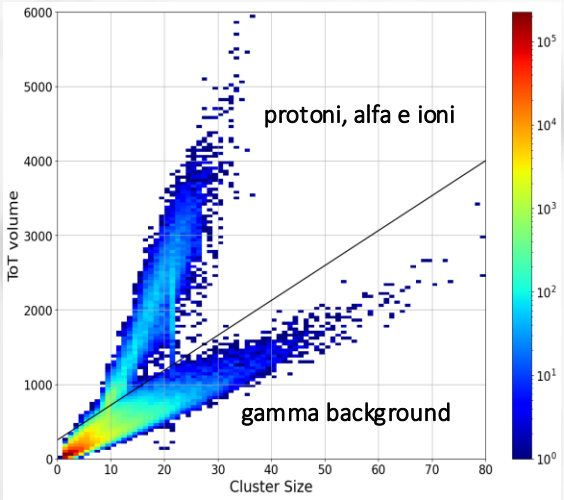


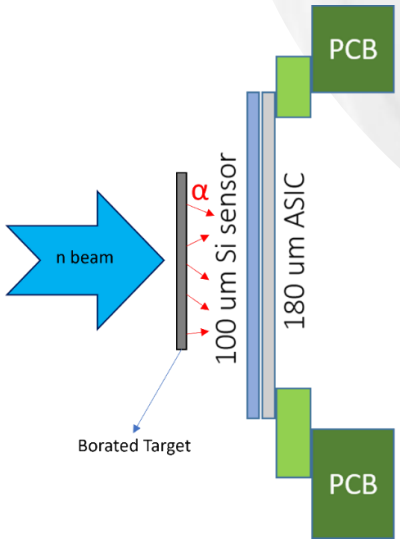
1. **Realizzazione di un rivelatore GEMpix in configurazione side-on per la misura di prodotti carichi da reazioni (n, cp)** → si rivela utile per la misura e l'identificazione di prodotti carichi di bassa energia (0.1 – 2 MeV), e come tale risulta complementare alle funzionalità espressa in accoppiamento col silicio

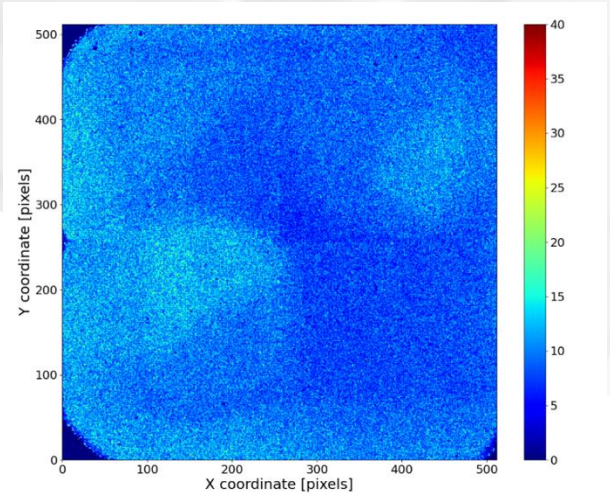
2. Per la misura di prodotti carichi a più alta energia (> 2 MeV), è stato messo a punto un **quad Timepix3 al silicio da 500 µm** che è stato testato in EAR2 (novembre 2024) ed EAR1 (marzo 2025) → nel caso del LiF, l'analisi di traccia ha mostrato una chiara discriminazione di alfa e tritoni per energie superiori a 3 MeV.

3. **Misura della concentrazione di ^{10}B su campioni biologici di interesse per la BCNT** → è stato messo a punto un quad Timepix3 da 100 µm di spessore e senza pcb in modo da ridurre il background e discriminare ulteriormente le tracce da alfa e ioni litio del boro. Si è ottenuta un imaging del campione con concentrazioni di 50 ppm di Boro, valore vicino a quelle tipiche previste per la pratica clinica.

nTOF







1. **Realizzazione di un rivelatore GEMpix in configurazione side-on per la misura di prodotti carichi da reazioni (n, cp)** → si rivela utile per la misura e l'identificazione di prodotti carichi di bassa energia (0.1 – 2 MeV), e come tale risulta complementare alle funzionalità espressa in accoppiamento col silicio

2. Per la misura di prodotti carichi a più alta energia (> 2 MeV), è stato messo a punto un **quad Timepix3 al silicio da 500 µm** che è stato testato in EAR2 (novembre 2024) ed EAR1 (marzo 2025) → nel caso del LiF, l'analisi di traccia ha mostrato una chiara discriminazione di alfa e tritoni per energie superiori a 3 MeV.

3. **Misura della concentrazione di ^{10}B su campioni biologici di interesse per la BCNT** → è stato messo a punto un quad Timepix3 da 100 µm di spessore e senza pcb in modo da ridurre il background e discriminare ulteriormente le tracce da alfa e ioni litio del boro. Si è ottenuta un'immagine del campione con concentrazioni di 50 ppm di Boro, valore vicino a quelle tipiche previste per la pratica clinica.

nTOF

Attività previste per il 2026:

Realizzazione di una nuova camera GEMpix con lettura Timepix4 che, come il Timepix3, fornisce una misura simultanea di carica e tempo ma, rispetto a quest'ultimo, offre ulteriori vantaggi:

- un'area di singolo chip di 28.2×24.6 mm^2 (con una matrice di 512×448 pixels, sempre da 55×55 μm^2)
- acquisizioni con flussi più elevati (da 80 a 500 MHits/s)
- un'energia minima rivelabile 2 volte più bassa
- una risoluzione temporale di 200 ps (rispetto a 1.6 ns del Timepix3).

Realizzazione di una camera da vuoto per Timepix3 per la misura di prodotti carichi di più alta energia.

Nome	Contratto	Qualifica	Ente appartenenza	%
Gerardo Claps	Associazione scientifica con incarico di ricerca	Ricercatore Confermato	ENEA Frascati	50
Antonella Tamburrino	Associazione scientifica	Assegno di Ricerca	Centro Ricerche Enrico Fermi	80
Nicholas Terranova	Associazione scientifica	Ricercatore Confermato	ENEA Frascati	50
Antonino Pietropaolo	Associazione scientifica	Ricercatore Confermato	ENEA Frascati	20

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

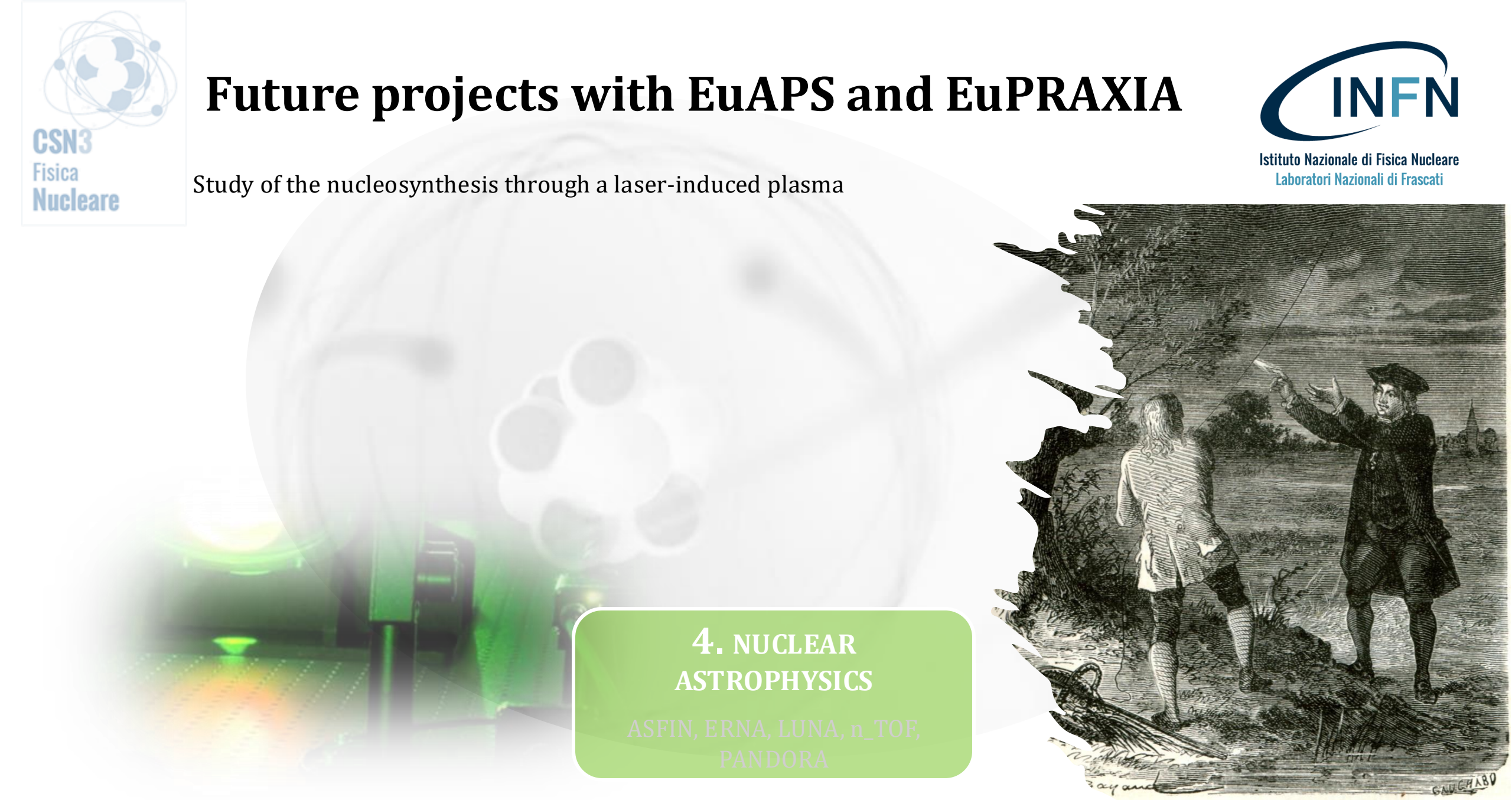
LEA, ALPHA, JEDI, VIP, FAMU

6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

Future projects with EuAPS and EuPRAXIA

Study of the nucleosynthesis through a laser-induced plasma

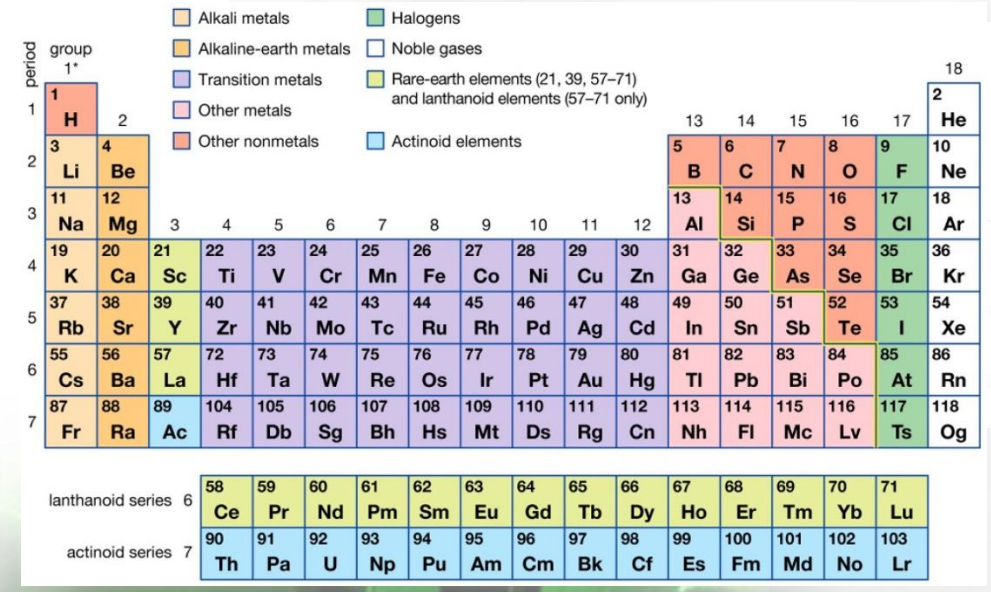


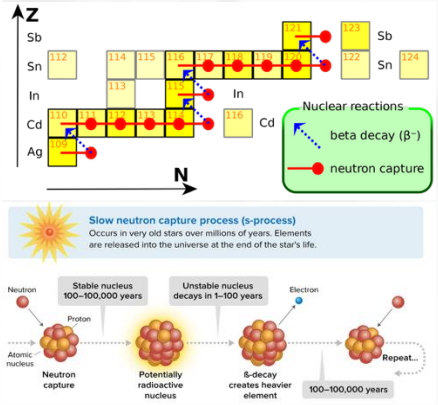
4. NUCLEAR ASTROPHYSICS

ASFIN, ERNA, LUNA, n_TOF, PANDORA

Future projects with EuAPS and EuPRAXIA

Study of the nucleosynthesis through a laser-induced plasma





4. NUCLEAR ASTROPHYSICS

ASFIN, ERNA, LUNA, n_TOF, PANDORA

Future projects with EuAPS and EuPRAXIA

Eur. Phys. J. Plus _####################_
https://doi.org/10.1140/epjp/s13360-025-06421-x

THE EUROPEAN PHYSICAL JOURNAL PLUS

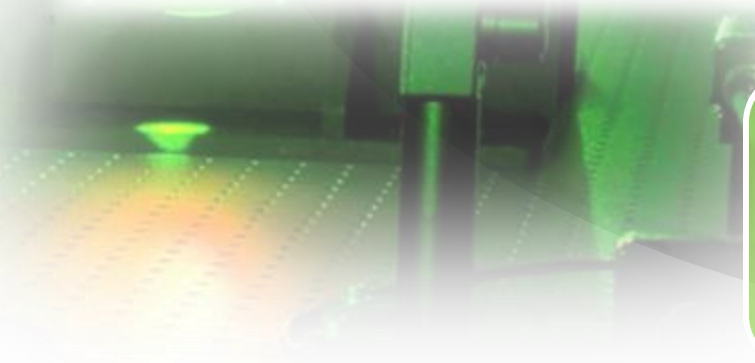
Review

Nuclear physics midterm plan in Italy: physics at INFN National Laboratories in Frascati

Simone Amaducci[2], Luigi Cosentino[2], Catalina Curceanu[1], Giovanni Luca Guardo[2], Mihai Iliescu[1], Dario Lattuada[2,3], David Mascali[2], Bharat Mishra[2], Rosario Nania[6], Eugenia Naselli[2], Silvia Pisano[1,4,a], Angelo Pidatella[2], Rosario Gianluca Pizzone[2,7], Domenico Santonocito[2], Alessandro Scordo[1], Francesco Sgaramella[1], Diana Sirghi[1,4,5], Florin Sirghi[1,5], Otón Vázquez Doce[1]

[1] Laboratori Nazionali di Frascati, Istituto Nazionale di Fisica Nucleare, Via Enrico Fermi, 54 (già 40), 00044 Frascati, Italy
[2] Laboratori Nazionali del Sud, Istituto Nazionale di Fisica Nucleare, Via S. Sofia 62, 95123 Catania, Italy
[3] Dipartimento di Ingegneria e Architettura, Università degli Studi di Enna KORE, Viale delle Olimpiadi, 94100 Enna, Italy
[4] Museo Storico della Fisica e Centro Studi e Ricerche "E. Fermi", Via Panisperna 89/A, 00184 Roma, Italy
[5] Institutul National Pentru Fizica si Inginerie Nucleara Horia Hulubei, IFIN-HH, Str. Atomistilor No. 407, P.O. Box MG-6, 077125 Magurele, Romania
[6] Bologna Section, Istituto Nazionale di Fisica Nucleare, Viale C. Berti Pichat 6/2, 40127 Bologna, Italy
[7] Dipartimento di Fisica e Astronomia "Ettore Majorana", Università degli Studi di Catania, via S. Sofia 64, 95123 Catania, Italy

Received: 14 February 2025 / Accepted: 10 May 2025



4. NUCLEAR ASTROPHYSICS

ASFIN, ERNA, LUNA, n_TOF, PANDORA

Future projects with EuAPS and EuPRAXIA

Workshop on December 4-6, 2024, **94 participants**!

Paper in preparation

Conclusioni

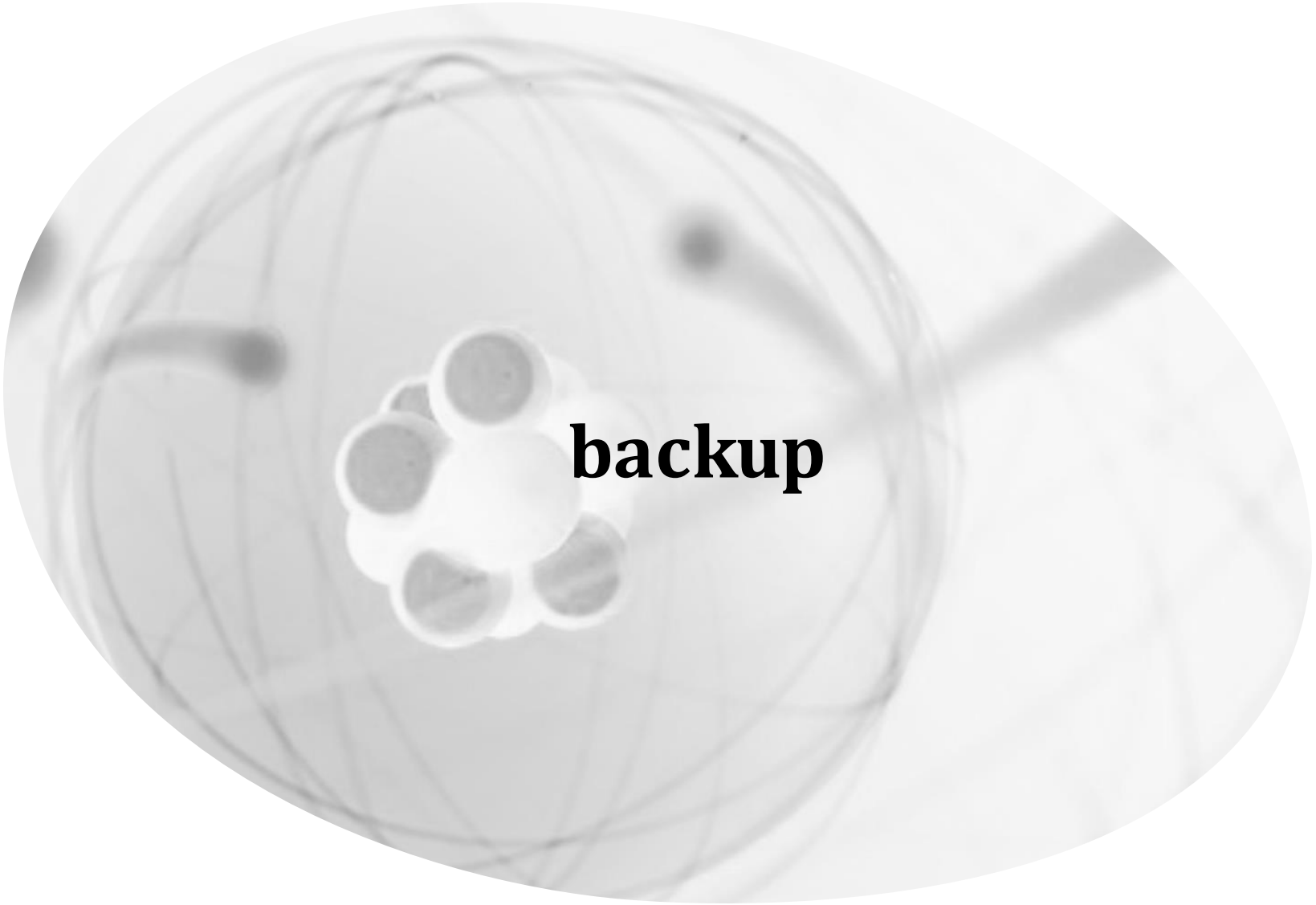
1. KAONNIS: the physics reach and the detector developments carried out withing the SIDDHARTA experiments can translate in a extended physics program encoded in the EXKALIBUR project to be continued at DAΦNE and/or JPARC

2. JLab12 is considering the possibility to take a leading role in the design and preparation of a new recoil detector

3. ALICE: strong involvement in the management and data taking. In definition the role in the ALICE3 R&D.

4. Continue the development of the TimePix-based detectors in the nTOF@LNF group (*thanks, Fabrizio!*) → it can be exploited in nuclear astrophysics experiments, in the fusion R&D and in the new physics program that is being defined for FLAME and EuPRAXIA

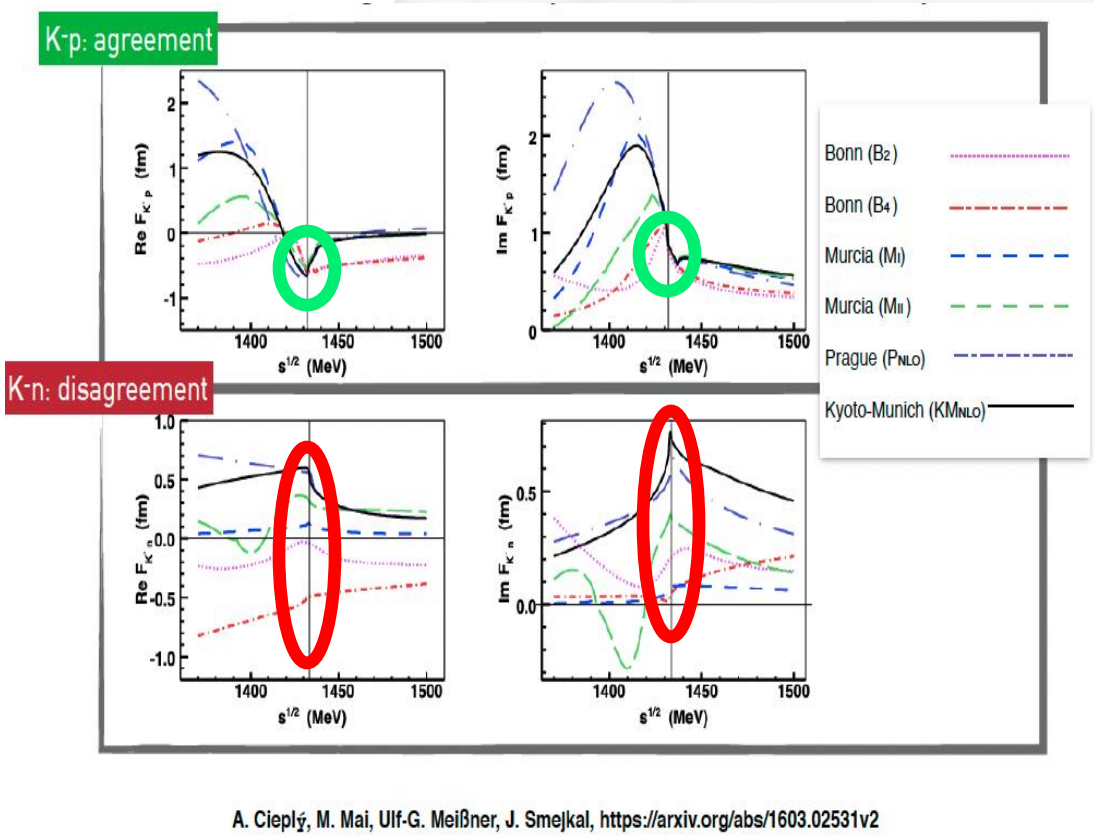
5. Nuclear astrophysics with innovative sources: new physics program in definition with the laser facilities at LNF → *first measurement campaign in the early 2026*



backup

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

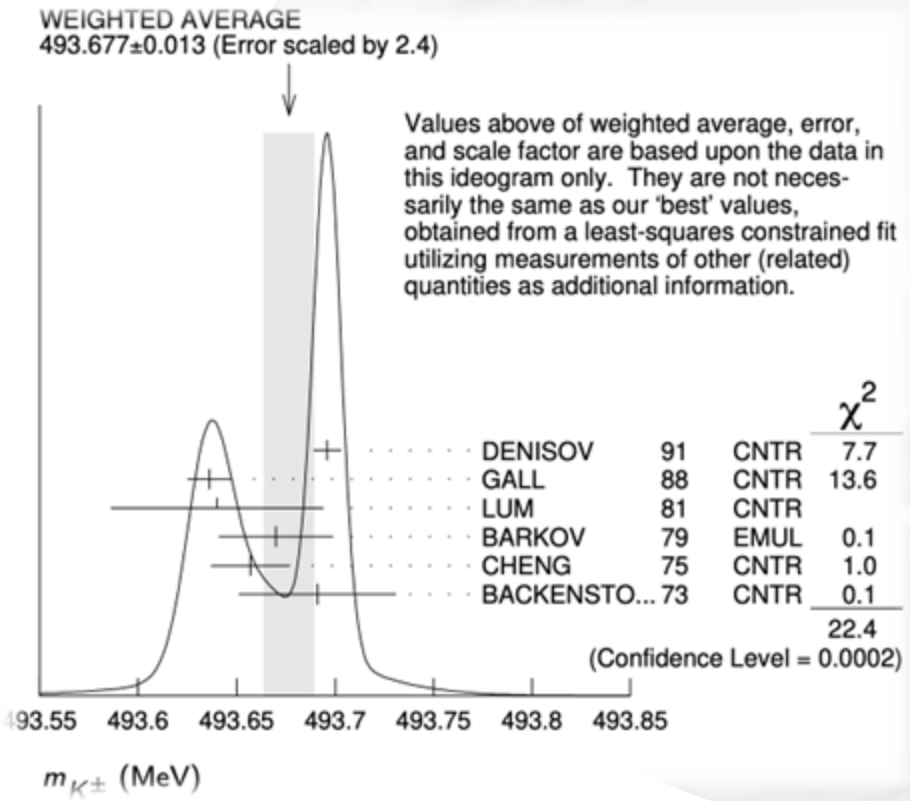
KAONNIS activities:

- 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
- Finalize CZT data analyses: KCu, KaI – publications
- EXKALIBUR initiative put forward at Sci Com for 2025

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*

Quarks and hadron dynamics

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



KAONNIS activities:

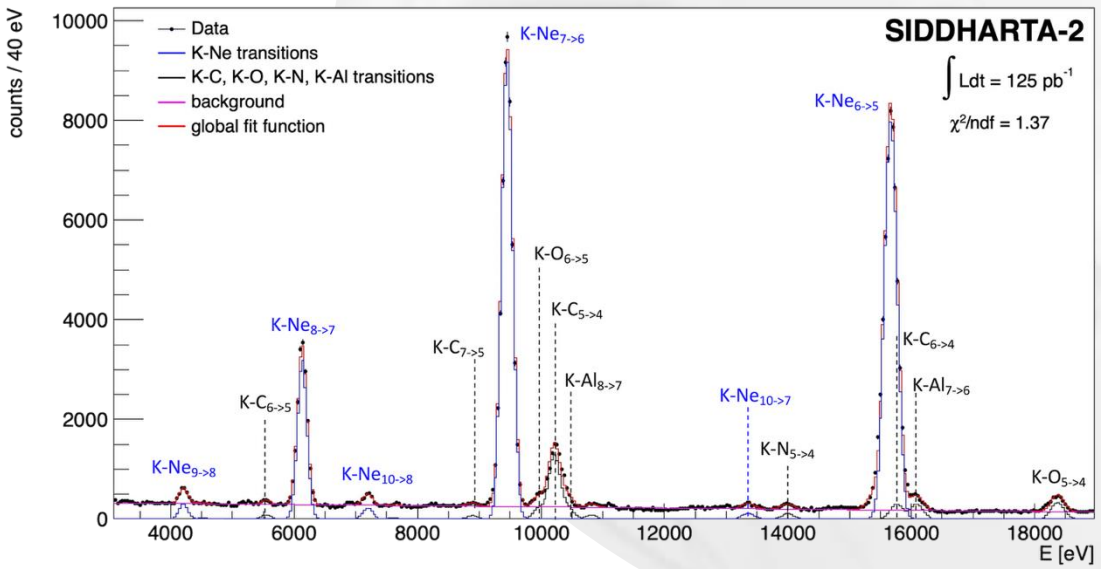
- Finalize Kd analyses → extraction of the shift and the width of the transition: high-impact in understanding QCD in the strange sector; extraction of the Kd yields: impact in understanding the cascade processes
- Extract antiK-nucleon scattering lengths (with theoreticians)
- **Publish Kaonic Neon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

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*

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

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

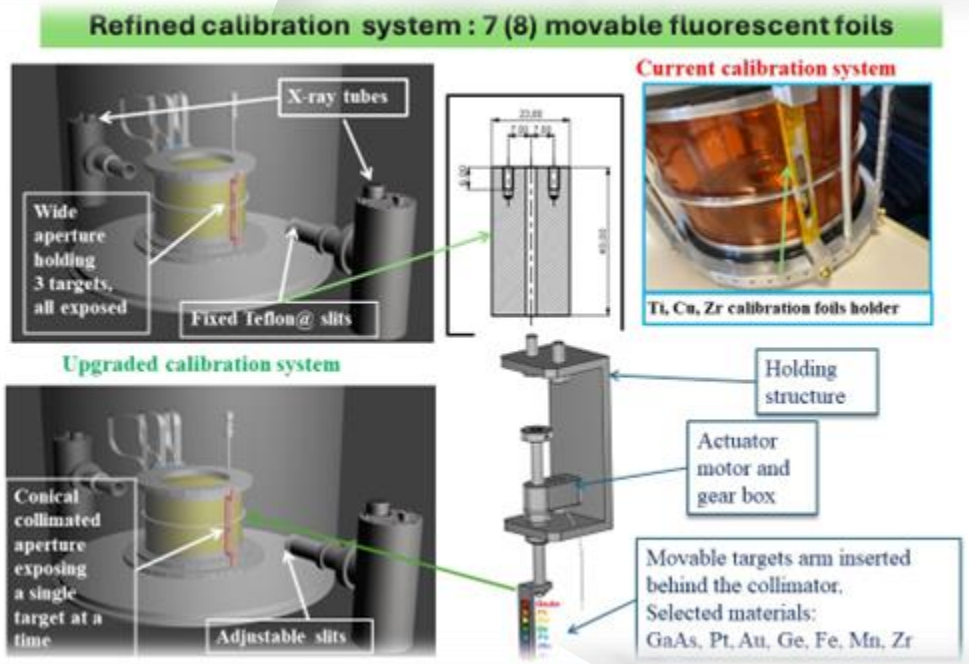
KAONNIS activities:

- 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 (with a gaseous Ne target)**
- Finalize CZT data analyses: KCu, KAl – publications
- EXKALIBUR initiative put forward at Sci Com for 2025

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*

Quarks and hadron dynamics

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



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, KaI – publications
- EXKALIBUR initiative put forward at Sci Com for 2025

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*

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

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:

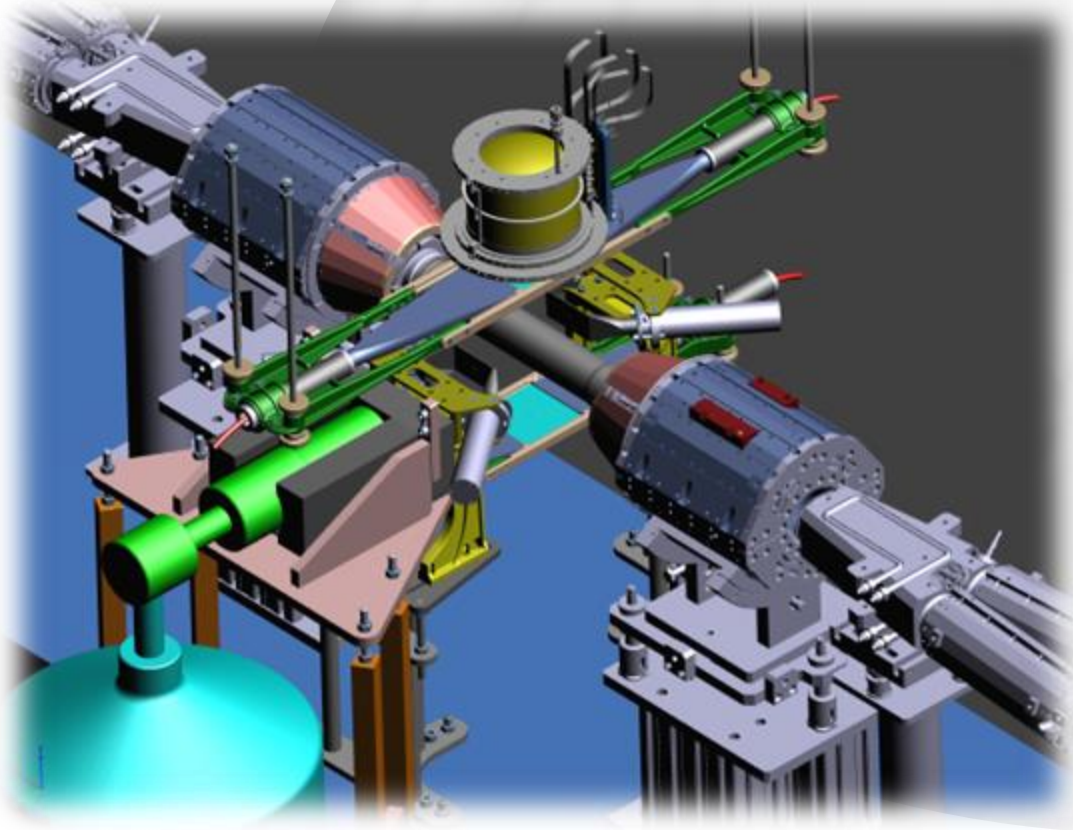
- Finalize Kd analyses → extraction of the shift and the width of the transition: high-impact in understanding QCD in the strange sector; extraction of the Kd yields: impact in understanding the cascade processes
- Extract antiK-nucleon scattering lengths (with theoreticians)
- **Publish Kaonic Neon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

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*

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

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

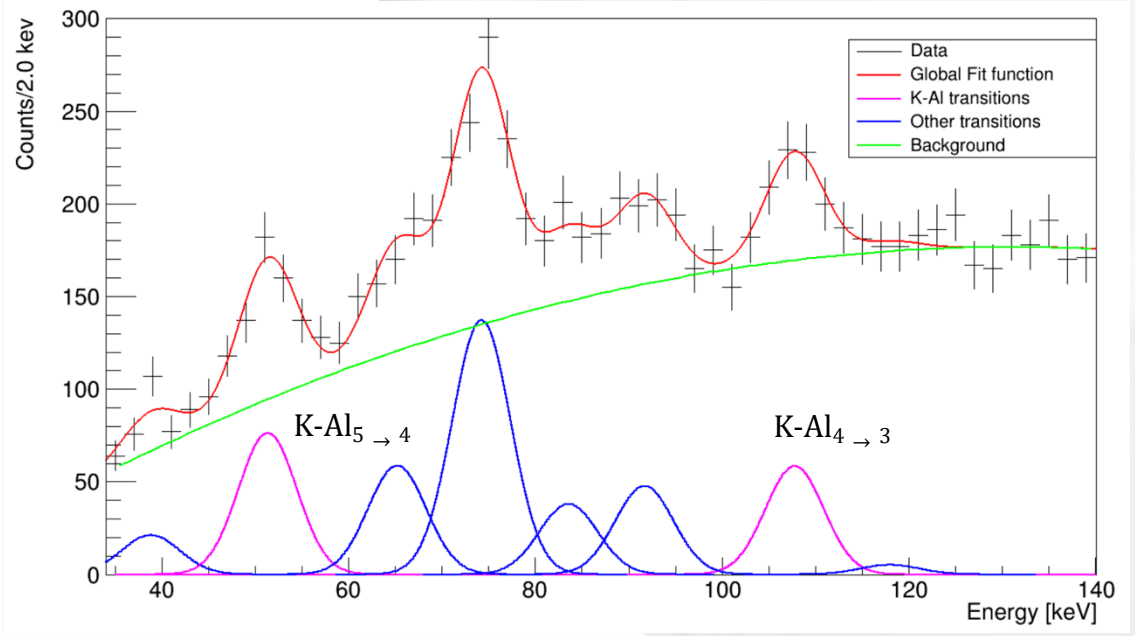
KAONNIS activities:

- 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 (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

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*

Quarks and hadron dynamics

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



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

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

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*

Quarks and hadron dynamics

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

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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

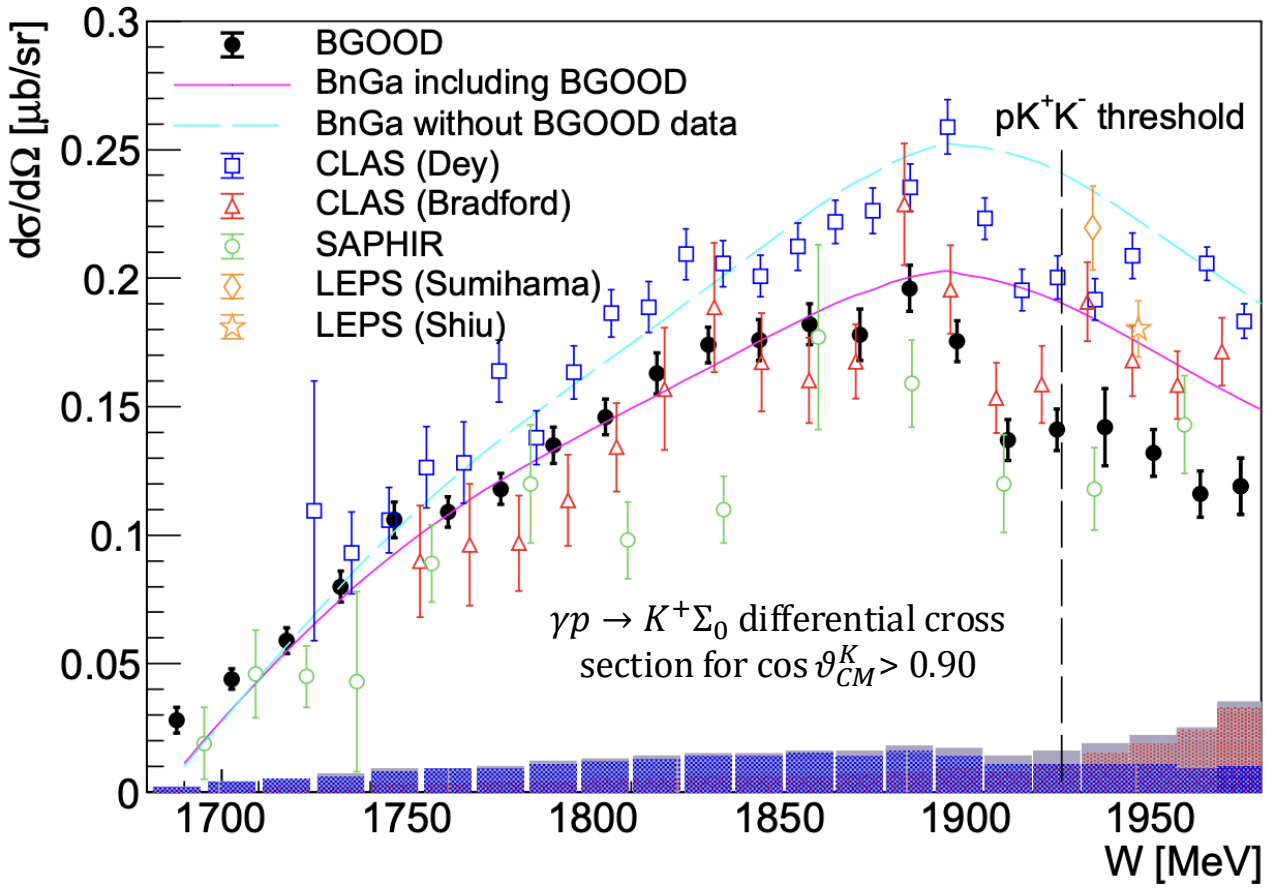
- Purple: setup maintenance, upgrade and installation
- Green: test and characterization of the detectors in laboratory
- Orange: commissioning and test with beam at DAΦNE or BTF.
- Yellow: production of the new 1mm SDDs, solid target, front-end electronics and mechanical support frames.
- Blue: data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

ID		Preparation: Month	June				July				August			September				October				November				December				Run:	1				2				3				4				5				6		
		Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
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

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

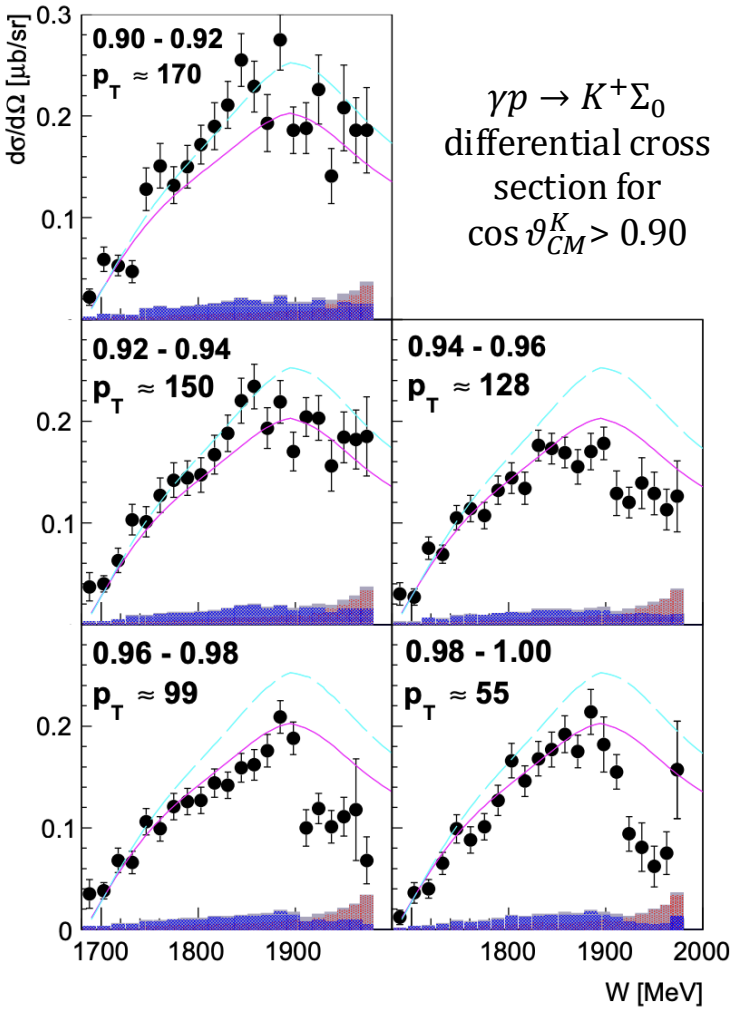
- 3D imaging of the nucleon
- quark dynamics
- nuclear and hyper-nuclear dynamics
- nucleon excited states via meson photoproduction
- low energy kaons interaction
- how does the mass of the nucleon arise?
- how does the spin of the nucleon arise?
- what are the emergent properties of dense systems of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



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?



$\gamma p \rightarrow K^+\Sigma_0$ differential cross section for $\cos\vartheta^K_{CM} > 0.90$

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

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)

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)

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)