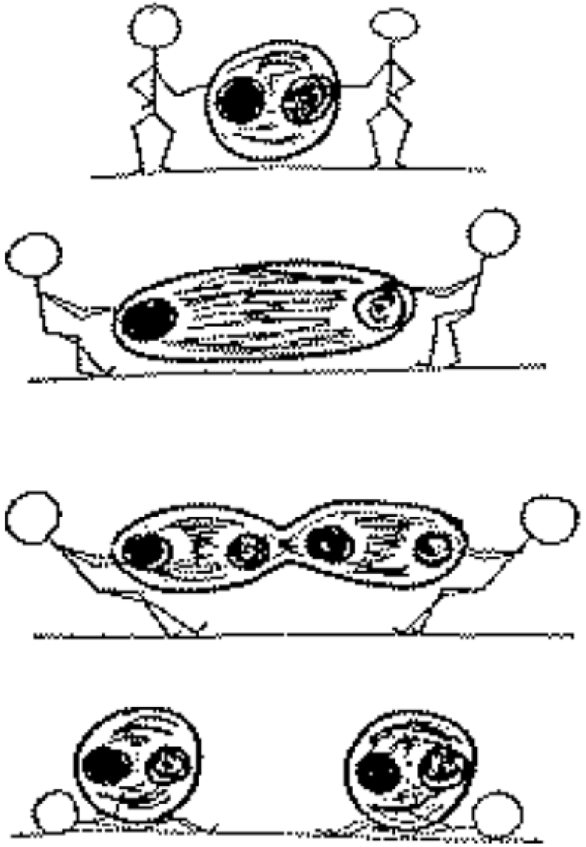
Nuclear Physics at the Frascati National Laboratories



Silvia Pisano

Local coordinator of the
Nuclear Physics group

CSN3 Fisica Nucleare

The National Scientific Committee 3

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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

CSN3 Fisica Nucleare

Istituto Nazionale di Fisica Nucleare
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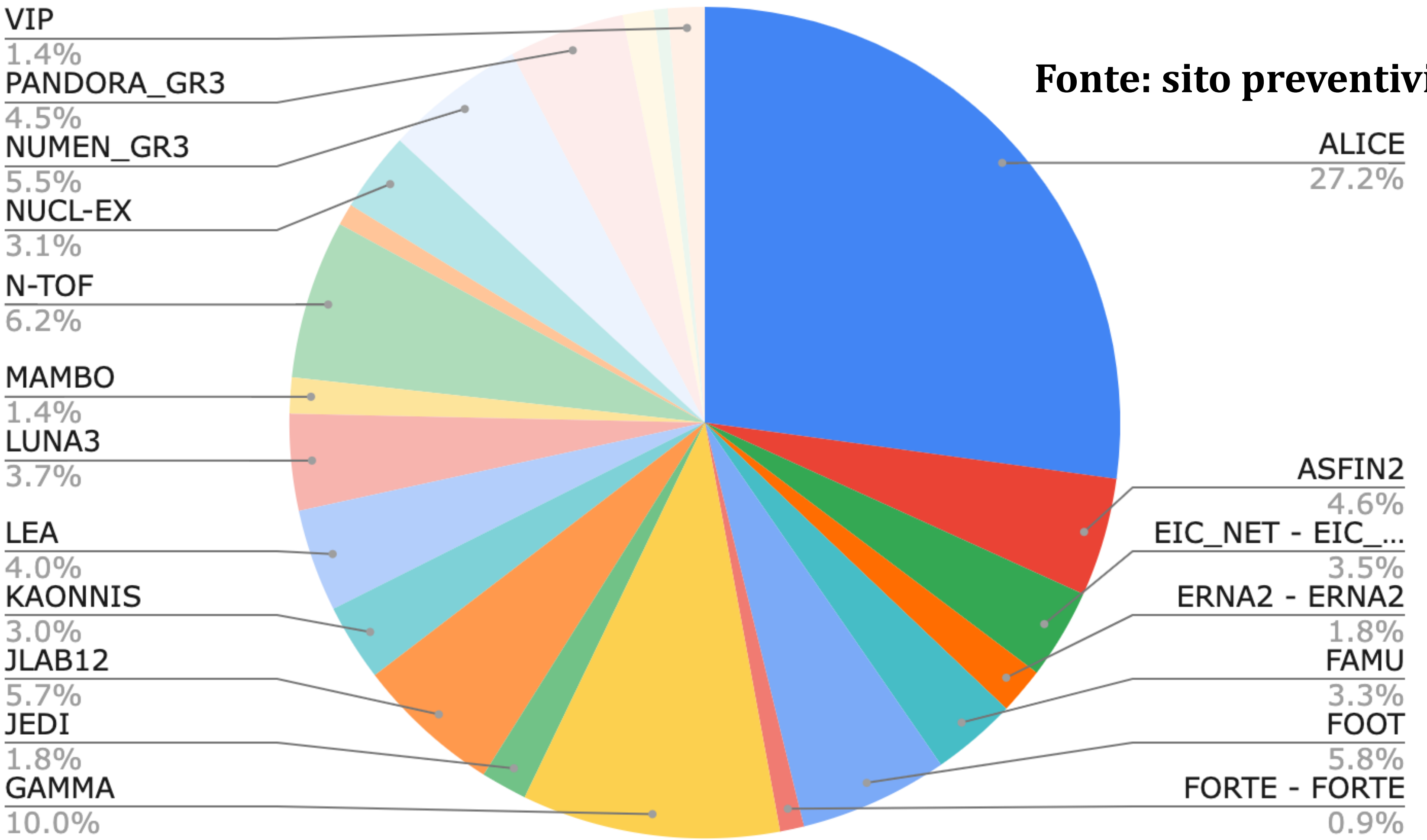
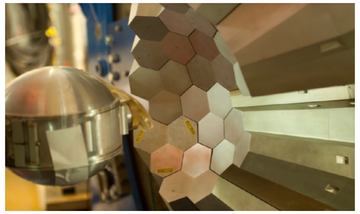
Fonte: sito preventivi 2024



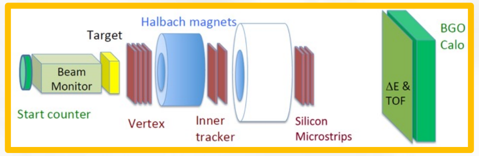
The CSN3 experiments

LUNA

GAMMA

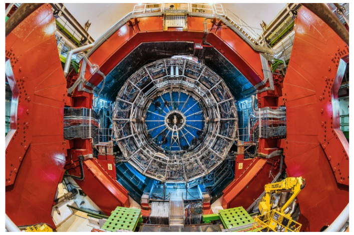


FOOT



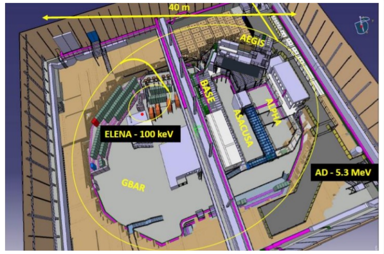
JLAB, MAMBO

ALICE

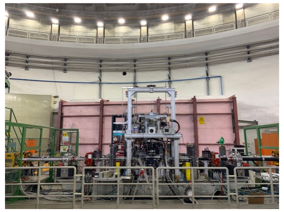


keV — MeV — GeV — TeV

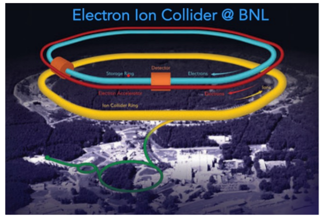
E_{beam}



NUMEN, ASFIN2,NUCLEX, CHIRONE, FORTE…



SIDDHARTA



EIC

JEDI

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	1.2 FTE	E. Spiriti
e-JLab12	JLAB	Fisica adronica	2.2 FTE	M. Mirazita
BGOOD	Bonn/Mainz	Fisica adronica	1.2 FTE	P. Levi Sandri
	LNF	Fisica nucleare	15.1 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

CSN3 Fisica Nucleare

ALICE@CERN

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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	From July, 1st LD@CERN
Eleuterio Spiriti	10
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: 10/2022, 5/2023, 10/2023 for the Heavy-Ion Run)

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

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

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

ALICE Activities at LNF

Physics Analysis on light flavor physics and 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

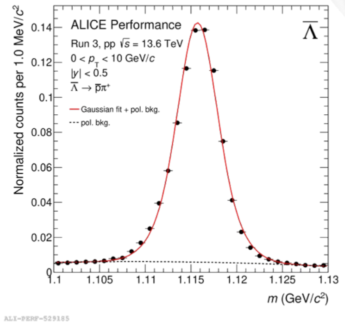
ALICE@CERN

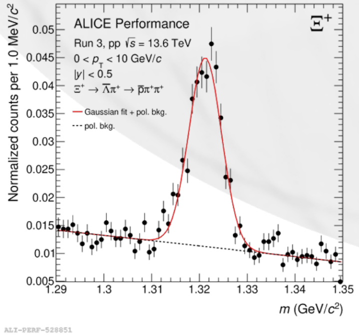
Run Coordination in 2022 for the LHC restart

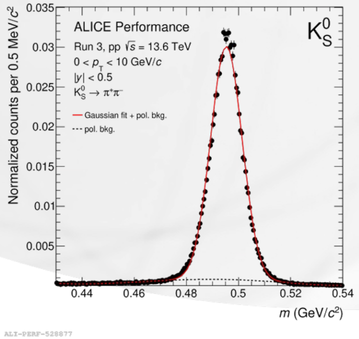
Study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus high energy collisions

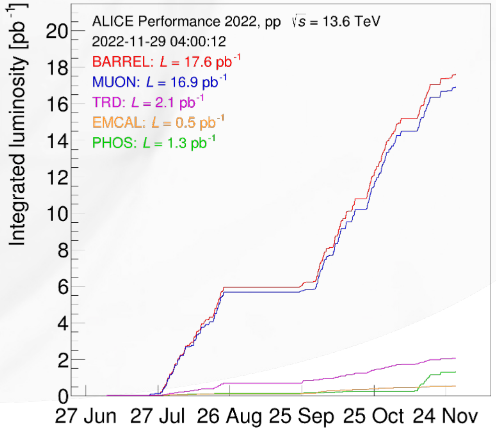
LNF people significantly involved in detectors R&D and construction, data analysis, operations and management roles

1. **Commissioning of the new continuous-readout detectors**
   - Focus on the new GEM TPC, and monolithic ITS (assembled at LNF 2016-19) and on the software and FW development for the ZDC
2. **Validation of the ALICE synchronous dataflow**
   - GPU-based online data reconstruction and calibration
3. **pp production data taking at 13.6 TeV**









pp integrated lumi

LHC luminosity: it includes the lumi delivered for commissioning during the ALICE HI rate scans and tests.

ALICE@CERN

Run Coordination in 2022 for the LHC restart

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CSN3 Fisica Nucleare

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

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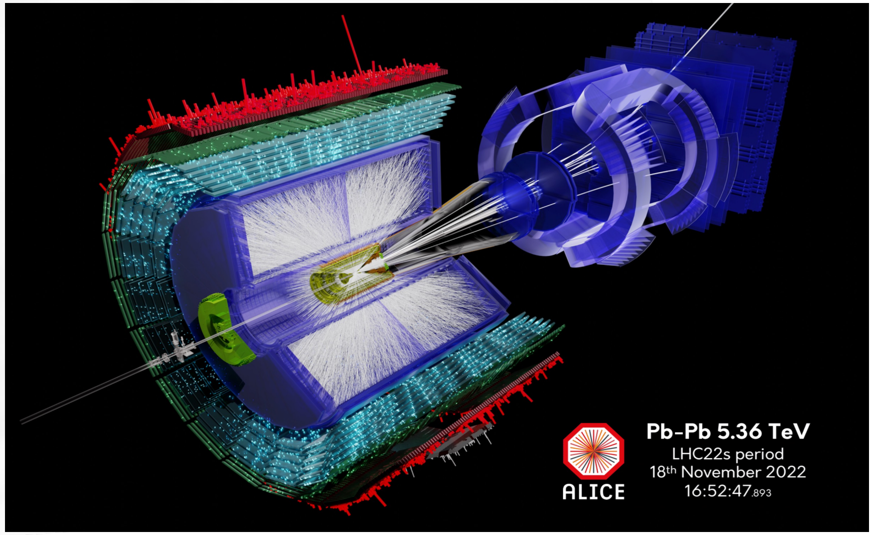
- HI run postponed to 2023 for LHC RF incident + energy crisis
- **PbPb pilot run at top energy (5.36 TeV)**
  - Used new slip-stacked filling from SPS to LHC (for 50 ns bunch spacing)
  - ZDC (HI luminometer) in full in production



ALICE@CERN

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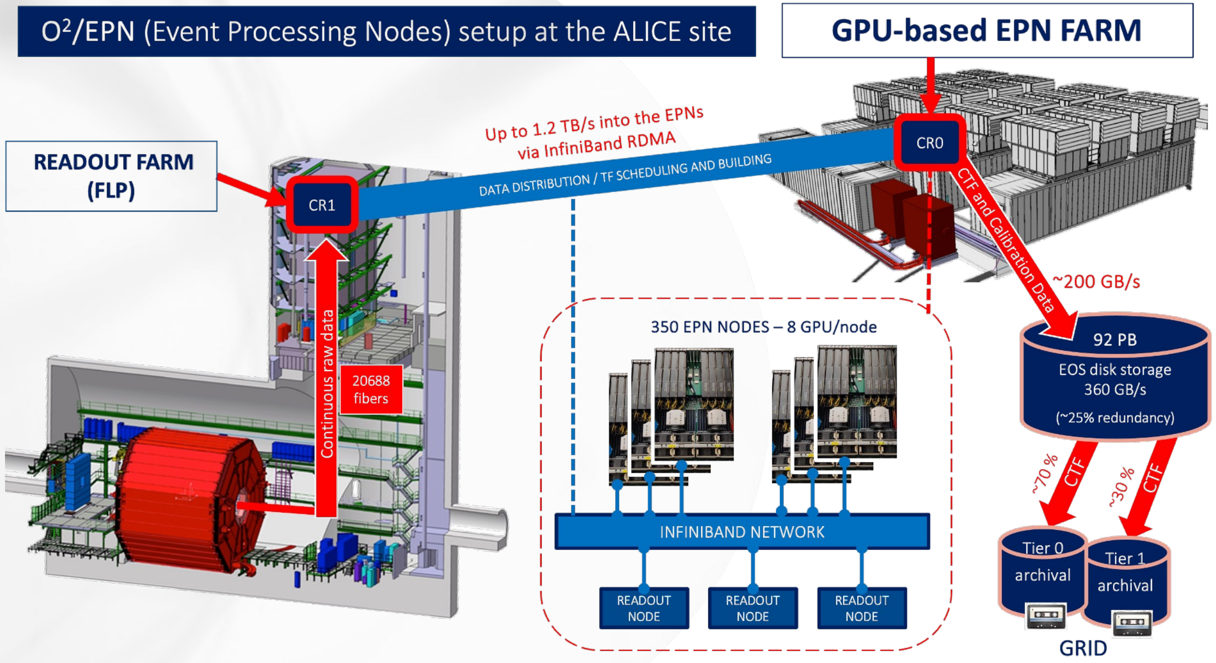

EPN technical coordination

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Istituto Nazionale di Fisica Nucleare
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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 @ 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

CSN3 Fisica Nucleare

ALICE@CERN

Istituto Nazionale di Fisica Nucleare
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Study of the $p-p-K^{+}$ and $p-p-K^{-}$ dynamics using the femtoscopy technique

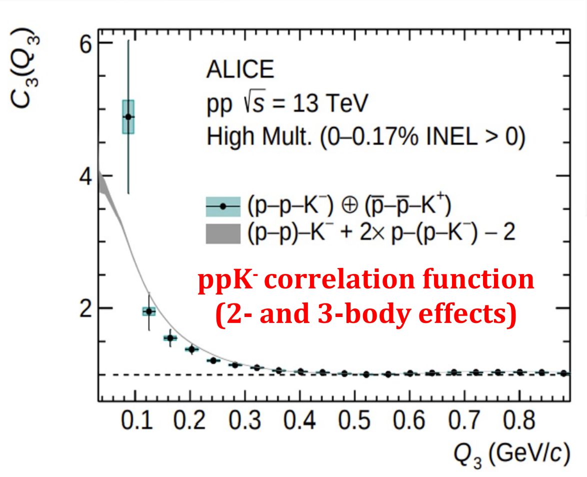
Study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus high energy collisions

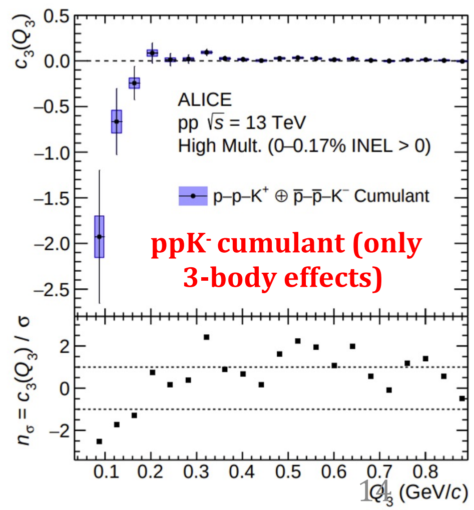
LNF people significantly involved in detectors R&D and construction, data analysis, operations and management roles

- first measurement of three-body correlation functions with Kaons
- the ppK^{+} and ppK^{-} cumulants are compatible with 0 within the uncertainties:
  - Confirmation of interpretation of ppK- nuclear state involving only 2-body forces
- **No effect beyond 2-body interaction**

Published in arXiv: [arXiv:2303.13448 [nucl-ex]]
Submitted to *European Physical Journal A - Hadrons and Nuclei*. Status: awaiting for initial review.

Paper Committee: *Raffaele Del Grande, Laura Šerkšnytė,* ***Oton Vazquez Doce***





ALICE@CERN

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

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

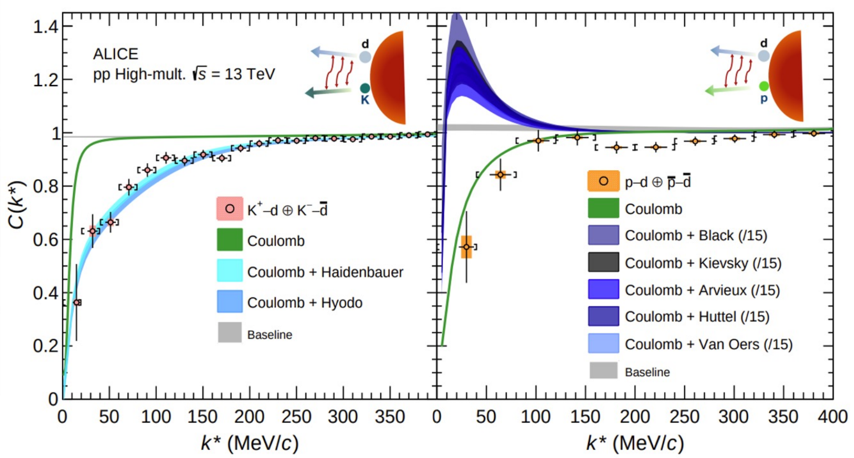
LNF people significantly involved in detectors R&D and construction, data analysis, operations and management roles

Two-body femtoscopy studies involving deuterons in pp collisions at the LHC allow to study the dynamics and the effects of the strong interaction in three-body systems:

- K+-d: calculations with point like particle via scattering lengths work with small radius (~1fm)
- p-d: detailed (and new) three-body calculations considering 2- and 3-body forces are necessary to explain the data.

Paper draft completed: to be uploaded to ArXiv and submitted to *Nature Physics.* Poster presentation at QM2023 by ***Oton Vazquez Doce.***

Paper Committee: *Bhawani Singh, Laura Fabbietti,* ***Oton Vazquez Doce****, Michael Jung, Harald Appelshaeuser*



 https://doi.org/10.48550/arXiv.2306.02478

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

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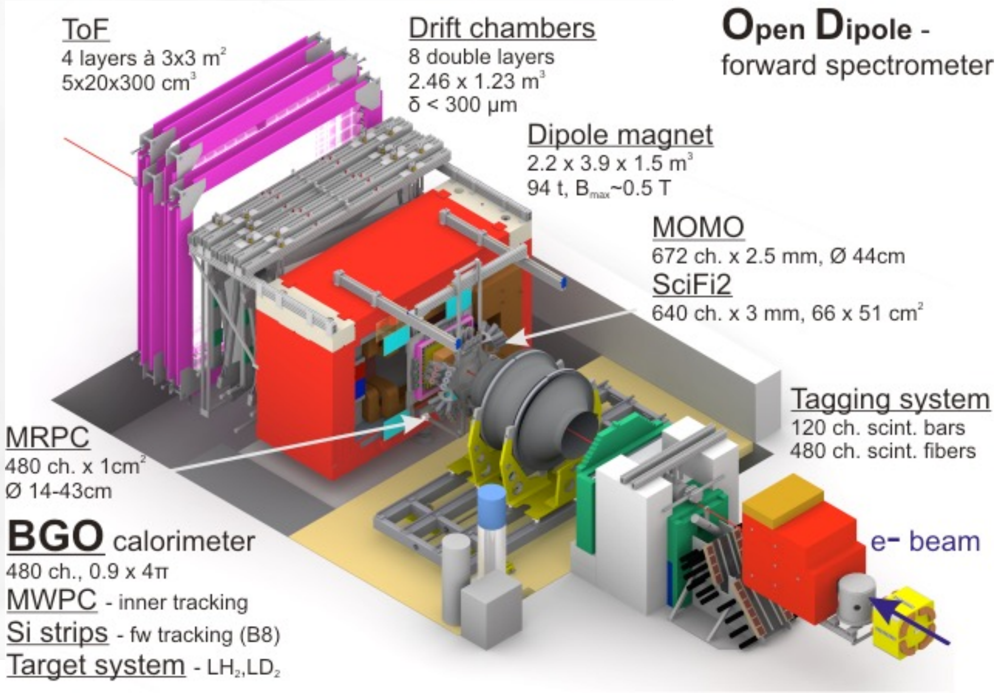
Nucleon excited states via meson photoproduction at MAMIc (A2@Mainz) and ELSA (BGOOD@Bonn)

- Transition form factor
- η' threshold anomaly



Quarks and hadron dynamics

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

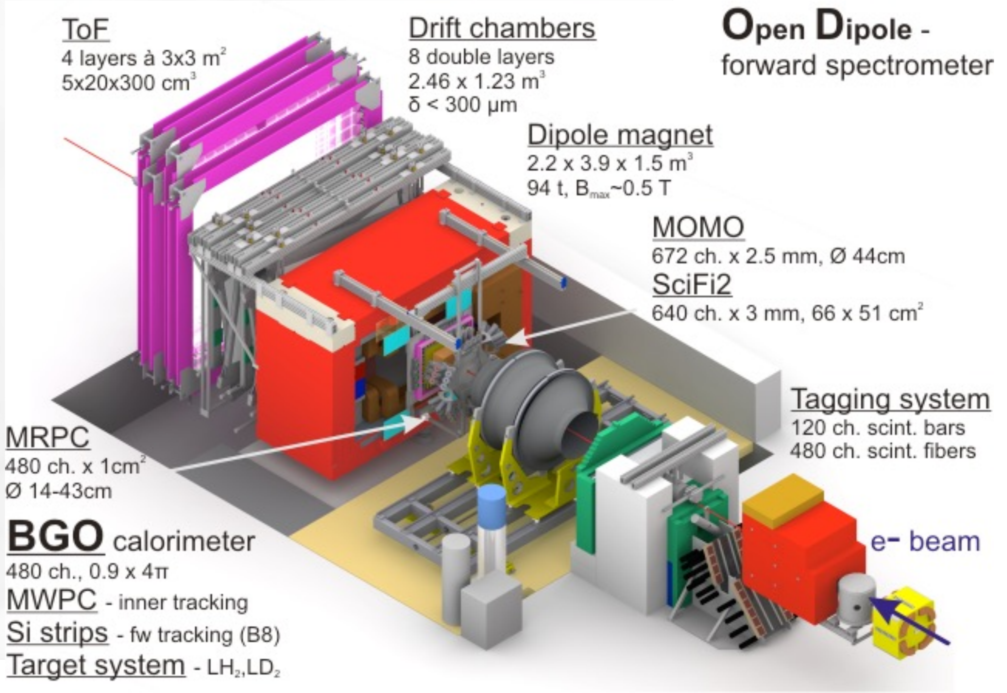
1. Tutti i rivelatori INFN (Calorimetro Barrel MWPC) sono funzionanti tranne MRPC: *final commissioning* in collaborazione con Bonn PI in standby per mancanza di personale

2. MonteCarlo in continuo sviluppo, generatore di eventi (LNF/Messina/Roma2).

- Co-spokesperson dell'esperimento BGOOD (LNF).
- Spokesperson della misura di fotoproduzione η' (LNF).
- Spokesperson fotoproduzione su neutrone (RM2)
- Rappresentante nazionale (LNF)

- 2020 nessuna presa dati
- 2021 una presa dati (3 settimane)
- 2022 due prese dati (6→4 settimane causa mancanza collaboratori russi)

- Transition form factor
- η' threshold anomaly



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International collaboration: Bonn PI, Bonn HISKP, Roma1, LNF, Messina (not INFN), Pavia, Roma2, Glasgow, PNPI Gatchina, 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 ~ 8 FTE

Quarks and hadron dynamics

BGOOD

INFN
Istituto Nazionale di Fisica Nucleare
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CSN3 Fisica Nucleare

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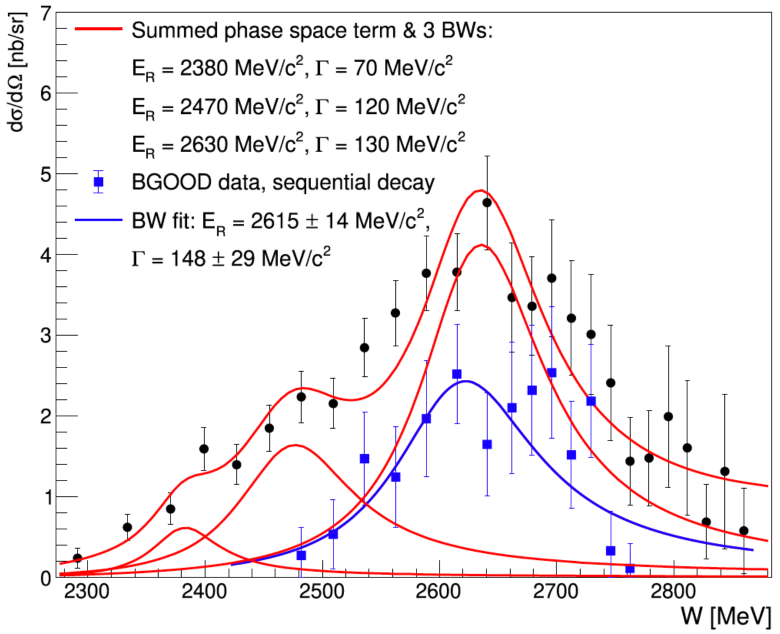
La possibilità di effettuare misure di fotoproduzione coerente apre una nuova linea di ricerca → estensione per altri due anni.

$\gamma+d \rightarrow d\,\pi^0\pi^0$ coerente



Physics Letters B 832 (2022) 137277

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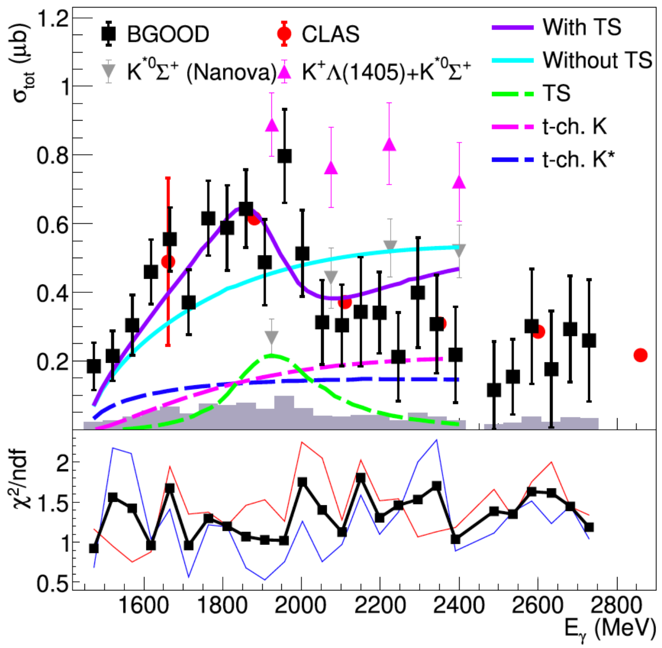
Misura della sez. d'urto e della line shape → *Evidenza per la singolarità di triangolo con contributo N*(2030)*

$K\!+\!\Lambda(1405) \rightarrow K\!+\!\pi^0\,\Sigma^0$



Physics Letters B 833 (2022) 137375

Quarks and hadron dynamics

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BGOOD

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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 2026 poi stop lungo per upgrade.
- 2023: richieste 1000 ore di beamtime per completare la raccolta dati su bersaglio di idrogeno e di deuterio.
- I colleghi russi sono ovviamente indisponibili (30% della collaborazione!) → run più brevi (3 → 2 settimane)
- Si apre una nuova linea di ricerca per la fotoproduzione coerente su deuterio → verrà richiesta un prolungamentoper altri due anni della sigla.

- Richieste economiche complessive: 23 k€

MI	ME	TRA	INV	C.APP	CON	Totale
0	13	0	0	0	10	23

- Nessuna richiesta ai servizi, salvo imprevisti

CSN3 Fisica Nucleare

Quarks and hadron dynamics

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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

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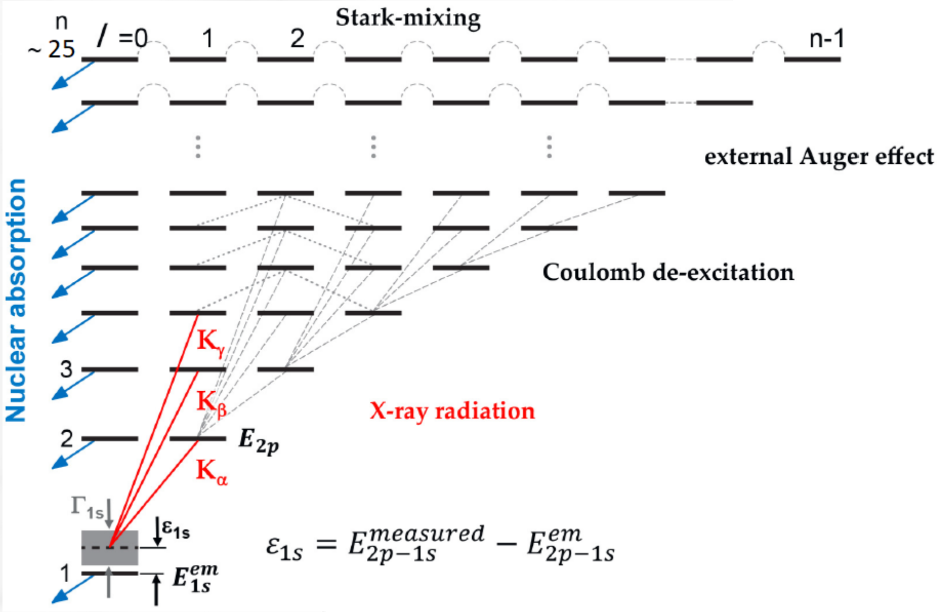
Precision measurement of the shift and of the width of the 1*s* level of kaonic deuterium and of other types of kaonic atom X-ray transitions → unique info about the QCD in non-perturbative regime in the strangeness sector not obtainable otherwise; impact in astrophysics (EOS neutron stars).



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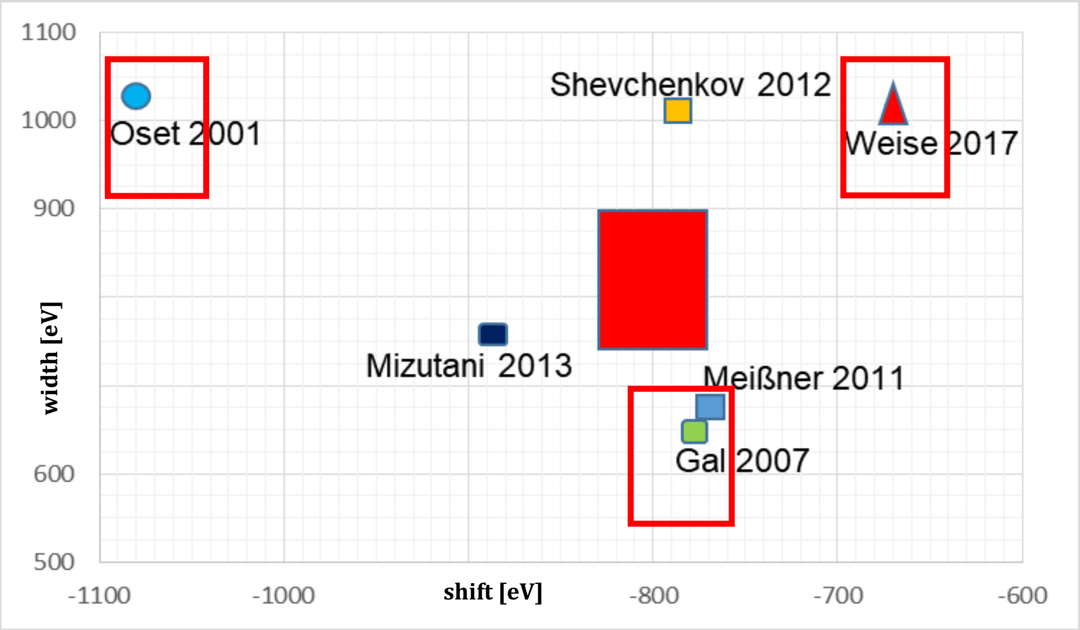

CSN3 Fisica Nucleare

Quarks and hadron dynamics

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

SIF 2022: Menzioni per le **Migliori Comunicazioni 2022** nella sezione 1: Fisica nucleare e subnucleare per Luca De Paolis: *Nuclear resonance effects in kaonic atoms*.

2 Master students with theses in SIDDHARTA:

Francesco Clozza and Francesco Artibani from La Sapienza University

1 Ph D student from Tokoku Japan, Toho Kairo, and 1 PdD student from Poli Milano, Lorenzo Giuseppe Toscano

1. **STRONG2020: WP8-JRA, WP16-NA, TA3-LNF**
2. **Bando regionale MITIQO**
3. **Croatian Science Foundation research project 8570**

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

27 Publications (2022-2023)

Journal of Physics G: Nuclear and Particle Physics Paper *A new kaonic helium measurement in gas by SIDDHARTINO at the DAΦNE collider*, D Sirghi et al 2022 J. Phys. G: Nucl. Part. Phys. 49 055106

Prog. MAECI: scambio scienziati Italy-Poland 2022-2023

KAONNIS	Afferenza (%)
Francesco Artibani	100
Massimiliano Bazzi	30
Damir Bosnar	50
Alexandru Mario Bragadireanu	50
Alberto Clozza	30
Francesco Clozza	100
Catalina Oana Curceanu	60
Luca De Paolis	50
Raffaele Del Grande	50
Carlo Guaraldo	
Mihail Antoniu Iliescu	40
Aleksander Khreptak	50
Paolo Levi Sandri	20
Marco Merafina	60
Catia Milardi	20
Fabrizio Napolitano	70
Szymon Niedwiecki	50
Alessandro Scordo	70
Francesco Sgaramella	100
Gruppo Palermo (3 persone)	50
Florin Catalin Sirghi	100
Magdalena Skurzok	50
Marlene Tüchler	100
K. Toho	100
Oton Vazquez Doce	30
Johann Zmeskal	30
K. Dulski	50
FTE totali	15.1

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.

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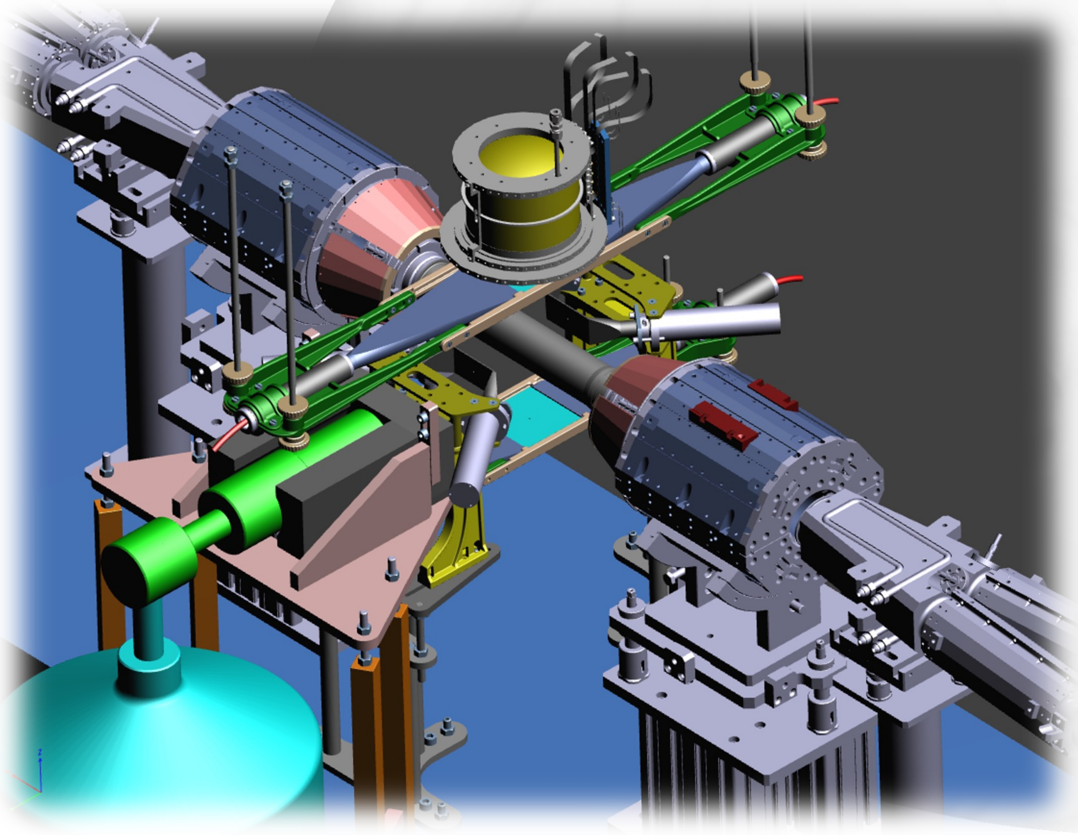
CSN3 Fisica Nucleare

Quarks and hadron dynamics

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

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati



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

KAONNIS activities:

- *2022*: full SIDDHARTA-2 setup in run at DAFNE (till *July 2022*) with KHe and Kd (test run); optimization of the setup: veto 3; target; cryogeny (*second half of 2022*)
- *April 2023*: SIDDHARTA-2 run with **kaonic neon** for debug and degrader optimization;
- *Since May 2023*: **Kaonic deuterium run ongoing**; **intermediate-mass kaonic atoms** with CdZnTe and HPGe setups

KAONNIS main outcomes 2022/3:

- Kaonic helium 4 L-lines yields measurements in gas → Nucl.Phys.A 1029 (2023) 122567
- Intermediate mass kaonic atoms – first meas. ever → Eur.Phys.J.A 59 (2023) 3, 56
- E31 J-PARC: Pole position of $\Lambda(1405)$ measured in $d(K^{-},n)\pi\Sigma$ reactions; Phys.Lett.B 837 (2023) 137637
- E62 J-PARC: KHe3, 4 with TES: Phys.Rev.Lett. 128 (2022) 11, 112503

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Quarks and hadron dynamics

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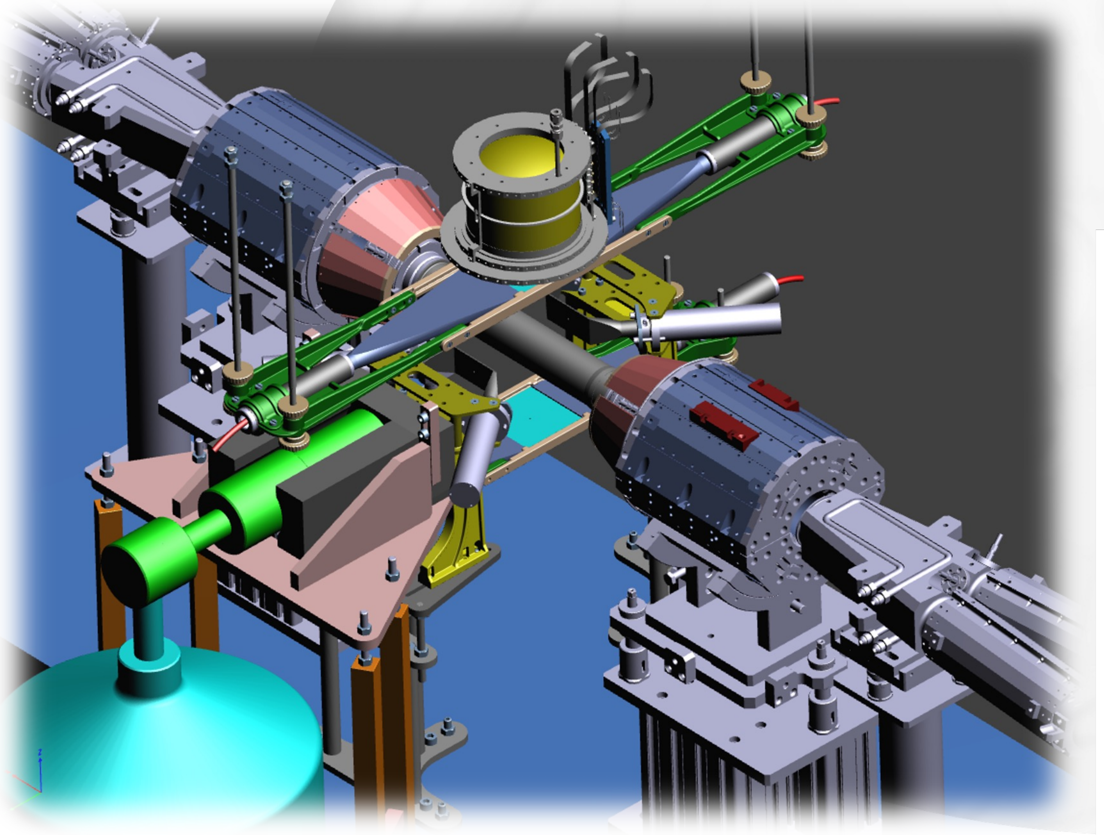
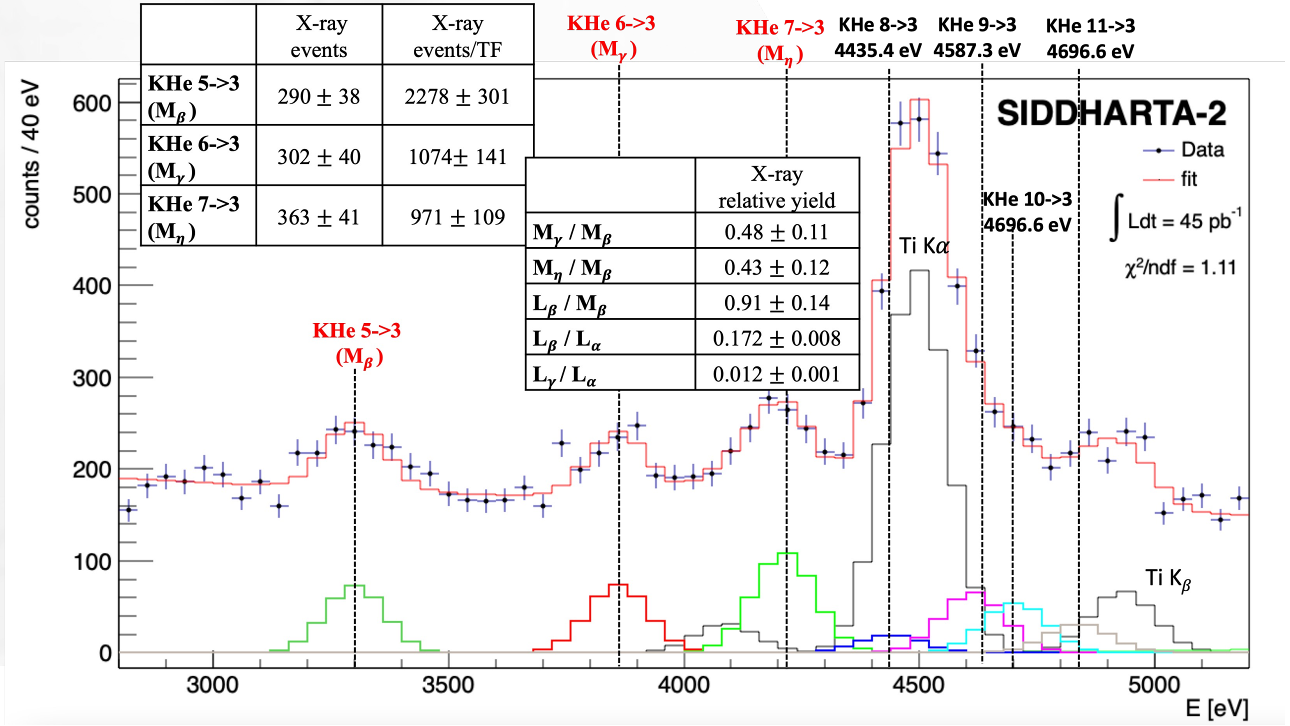
Laboratori Nazionali di Frascati



SIDDHARTA-2 Kaonic 4He (run 2022)
M-type transitions first ever measurement
analysis finalized - paper is being written

	X-ray events	X-ray events/TF
KHe 5->3 (M_β)	290 ± 38	2278 ± 301
KHe 6->3 (M_γ)	302 ± 40	1074± 141
KHe 7->3 (M_η)	363 ± 41	971 ± 109

	X-ray relative yield
M_γ / M_β	0.48 ± 0.11
M_η / M_β	0.43 ± 0.12
L_β / M_β	0.91 ± 0.14
L_β / L_α	0.172 ± 0.008
L_γ / L_α	0.012 ± 0.001



CSN3 Fisica Nucleare

Quarks and hadron dynamics

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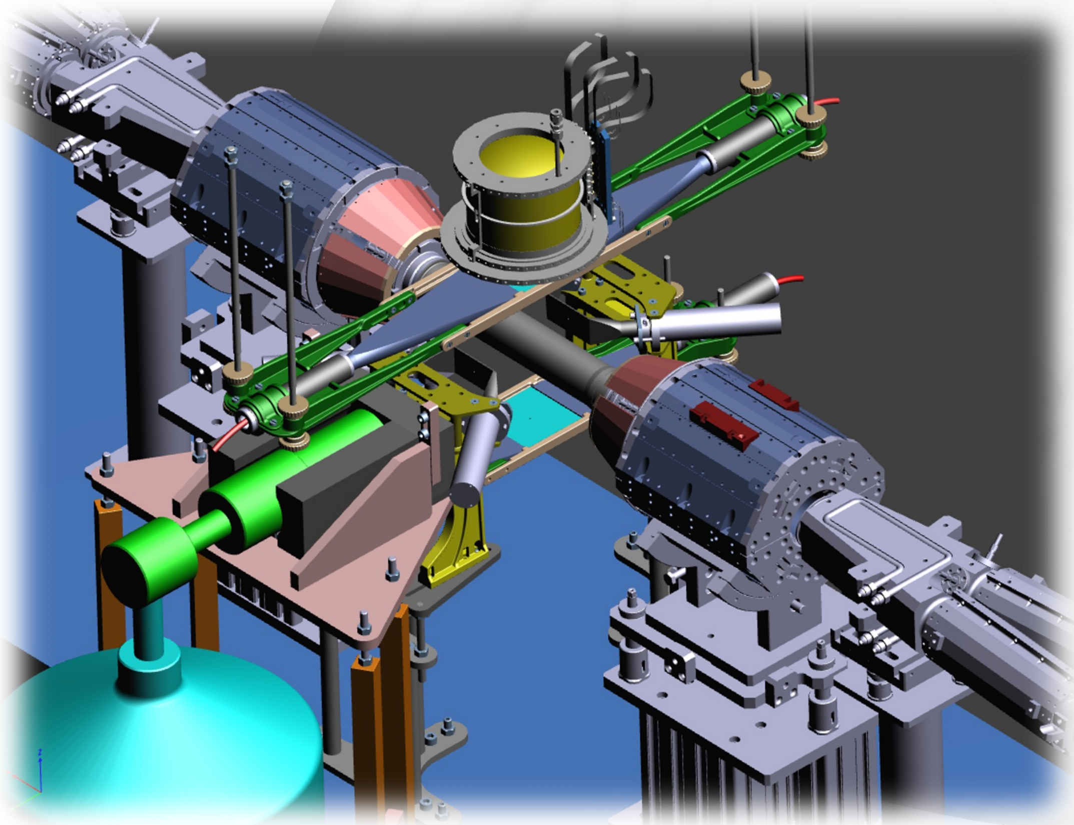
KAONNIS: low energy kaons interaction studies at Dafne and J-PARC



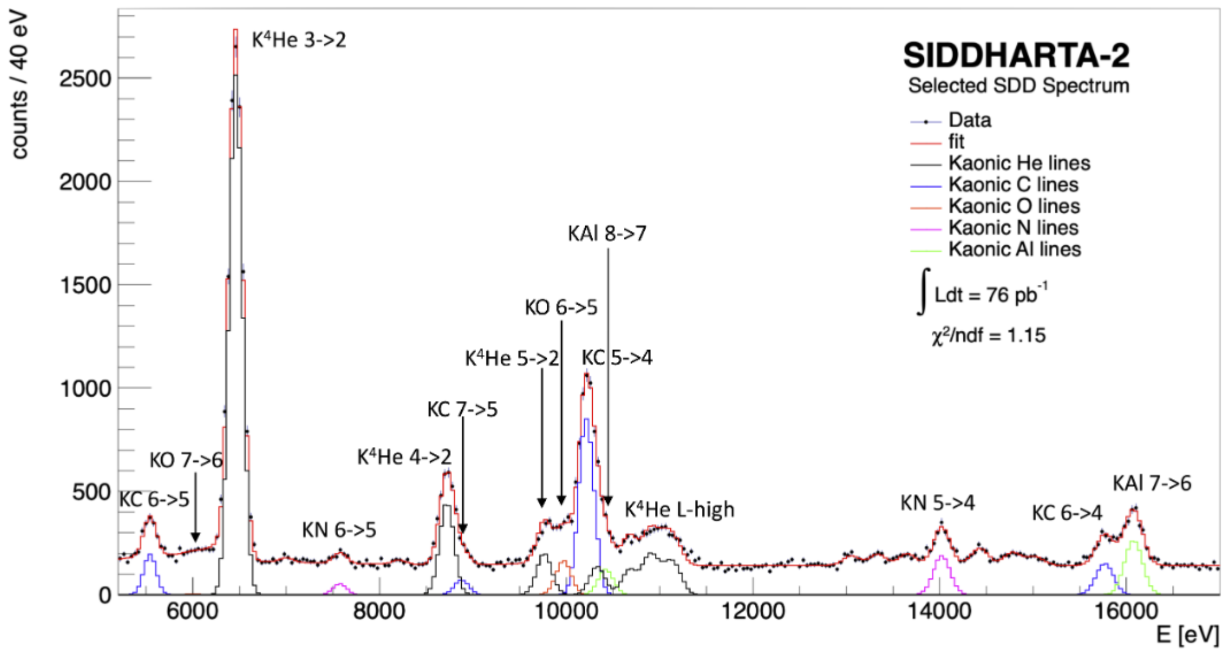
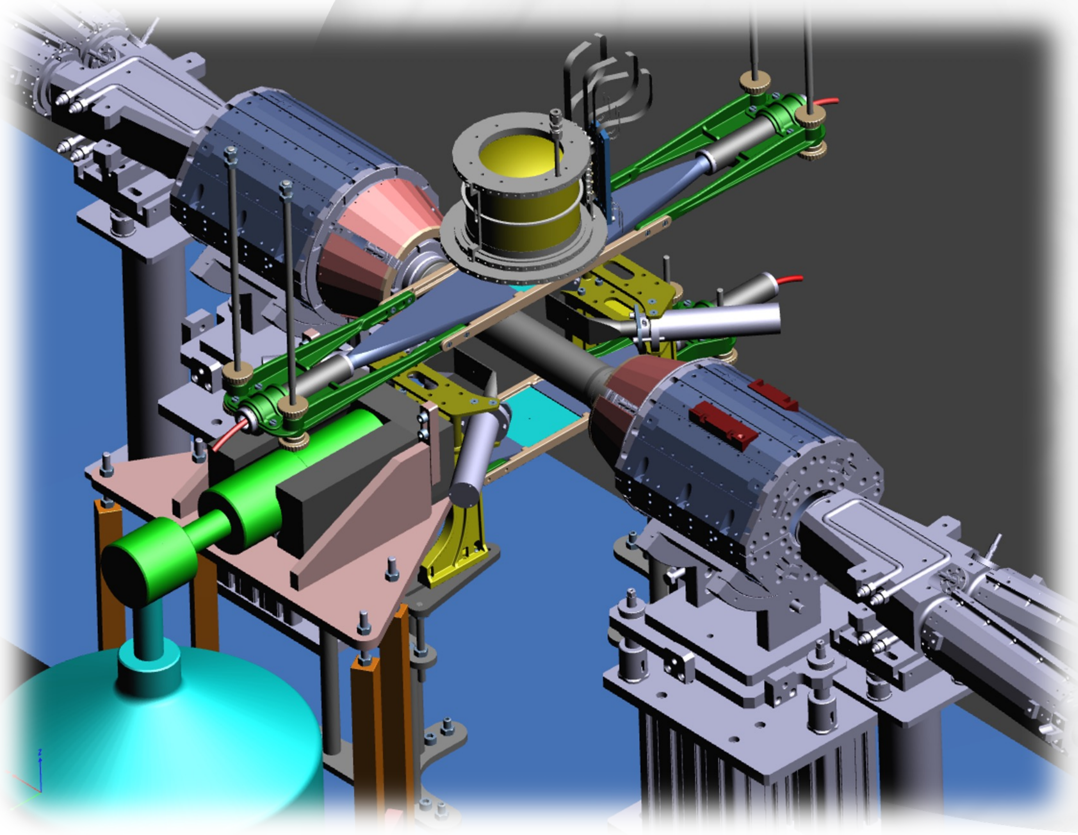


Figure 6. SDD energy spectrum and fit of SIDDHARTA-2 and SIDDHARTINO summed data after background suppression (see text). The kaonic helium signals are seen as well as the kaonic carbon (KC), oxygen (KO), nitrogen (KN) and aluminium (KAl) peaks.

First measurement ever → *Eur.Phys.J.A 59 (2023) 3, 56*

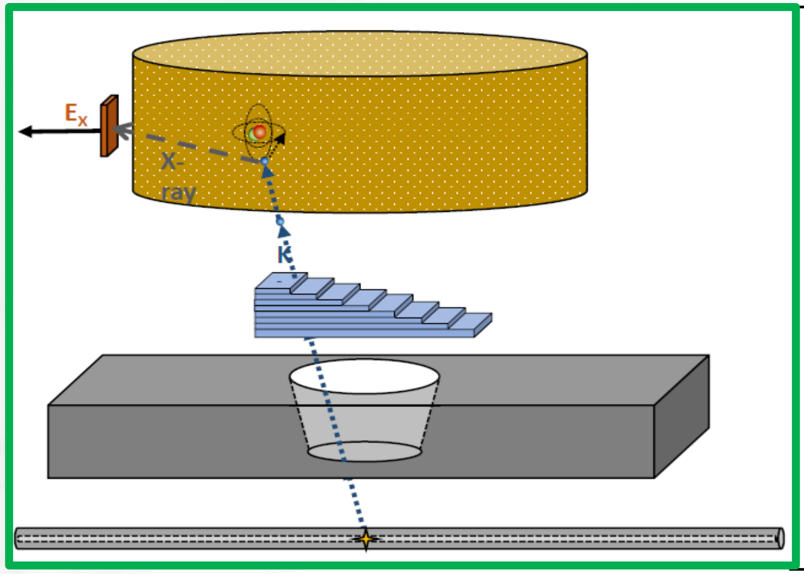
Quarks and hadron dynamics

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



SIDDHARTA-2 Kaonic Neon

Degrader optimization: sensitivity to 100 microns over all material budget (about 4 mm materials of various densities) → a very delicate and fundamental operation (knowledge of material budget at 2.5% level)



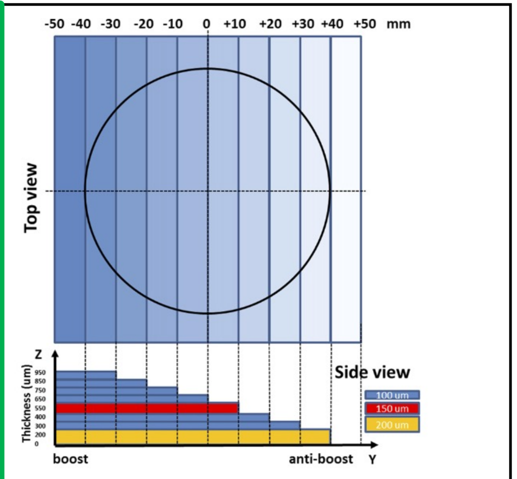


Figure 6. Nearest to optimal configuration of the Mylar degrader: the circle represents the size of the entrance window of the vacuum chamber; direction '*Y*' points to the outer side of the DAΦNE ring, corresponding to the anti-boost side for kaons. The degrader has eight steps to compensate for the boost effect, with thicknesses shown in the lower part of the figure.

CSN3 Fisica Nucleare

Quarks and hadron dynamics

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

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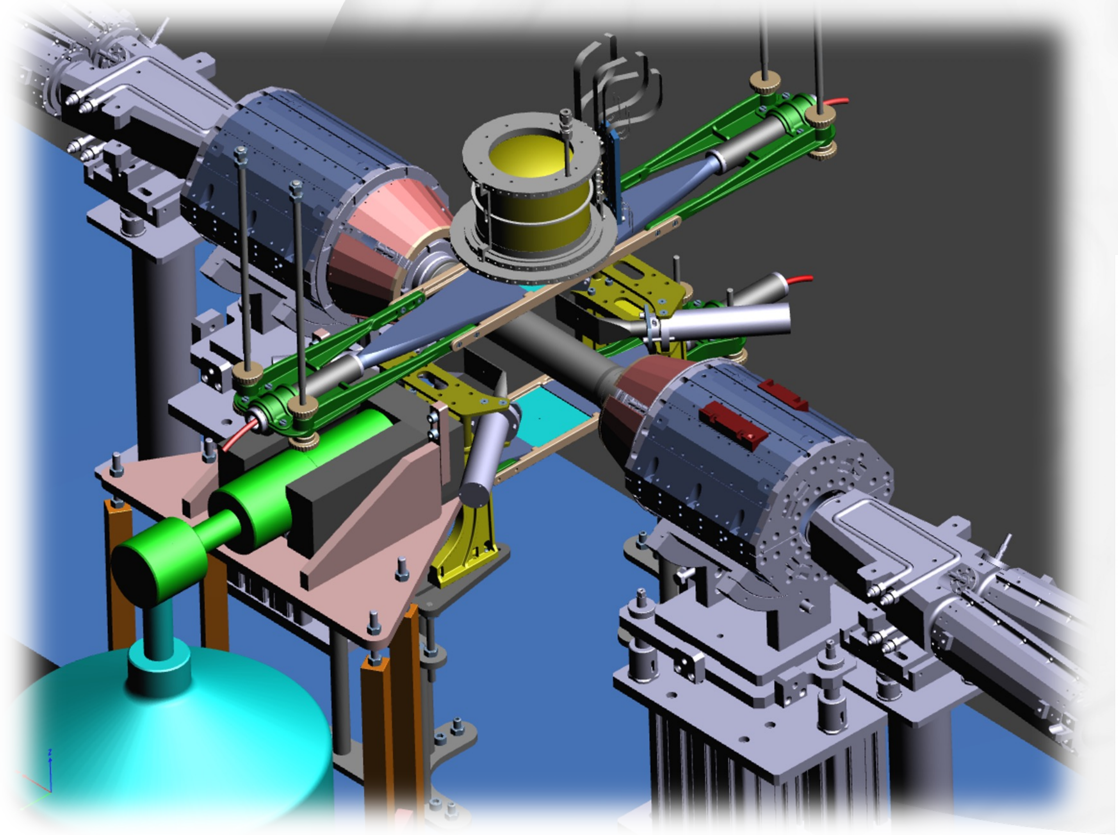
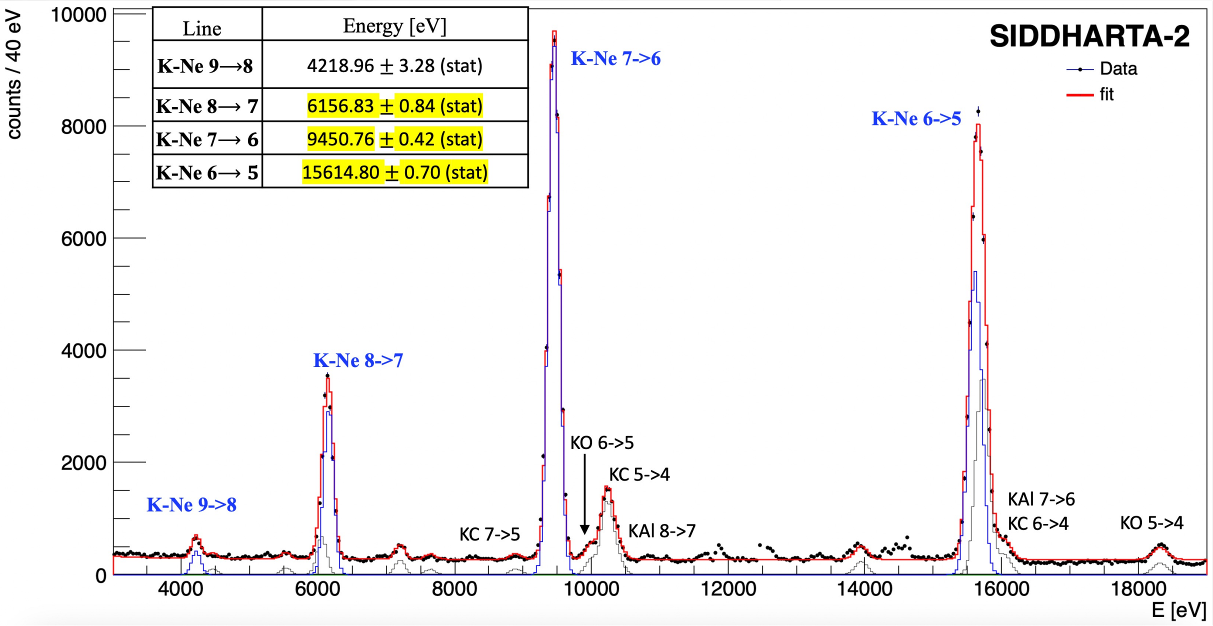


SIDDHARTA-2 Kaonic Neon

Degrader optimization: sensitivity to 100 microns over all material budget (about 4 mm materials of various densities) → a very delicate and fundamental operation (knowledge of material budget at 2.5% level)

All degraders; 275 SDDs; L = 124 pb^{-1}



Line	Energy [eV]
K-Ne 9⟶8	4218.96 ± 3.28 (stat)
K-Ne 8⟶ 7	6156.83 ± 0.84 (stat)
K-Ne 7⟶ 6	9450.76 ± 0.42 (stat)
K-Ne 6⟶ 5	15614.80 ± 0.70 (stat)

Quarks and hadron dynamics

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Progettazione: 6 m.u. Ottimizzazione supporteria/schermature/ setup SIDDHARTA-2 più nuovi setup misure con nuovi rivelatori SDD 1mm; test Ge, CdZnTe e VOXES
Officina meccanica: 4 m.u. per costruzioni supporterie, schermature, setup SDD 1mm, test setup Ge, CdZnTe VOXES
Tecnici: 2 x 0.5 FTE installazioni e costruzioni varie

MI	ME	TRA	INV	MAN	CON	Totale
0	25	0	50	15	60	150

Quarks and hadron dynamics

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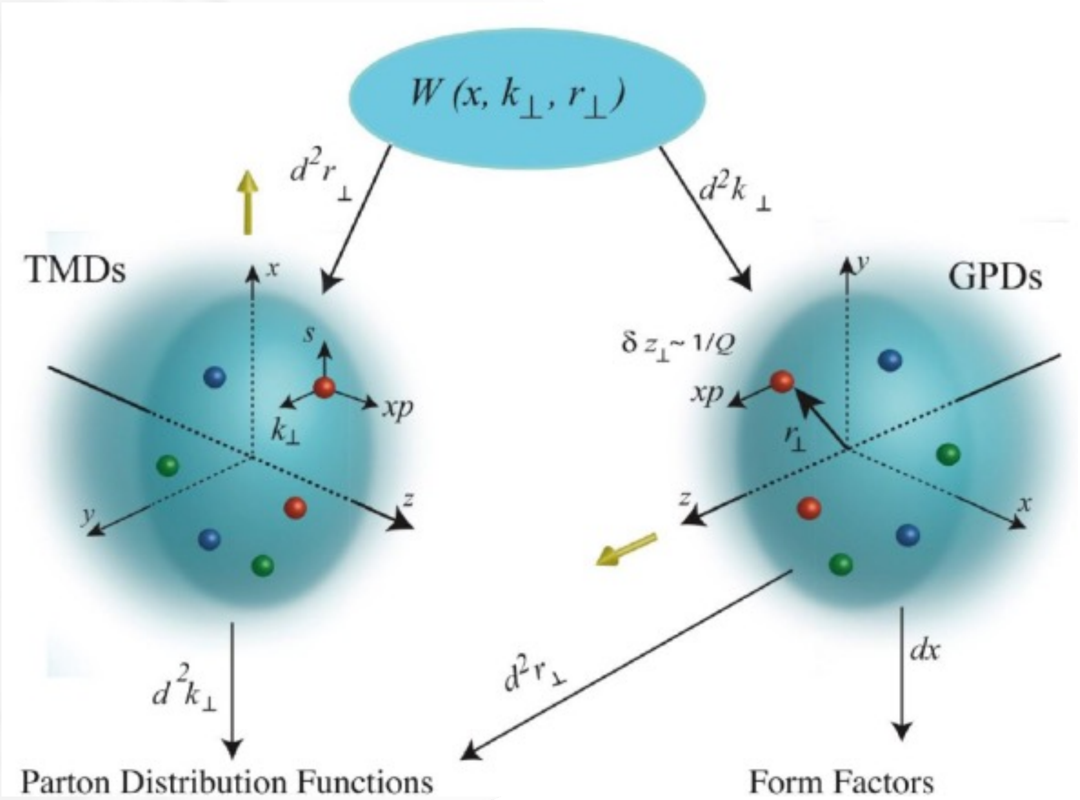

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Anagrafica: M. Mirazita (100%, resp), A. Gyurjinyan (AdR, 100% STRONG), P. Rossi (0%), S. Tomassini (20%)

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

- Continuazione della presa dati di CLAS12
- Avvio analisi con K nello stato finale e con la PID dal RICH
- Sviluppo nuovi strumenti software per la ricostruzione del RICH

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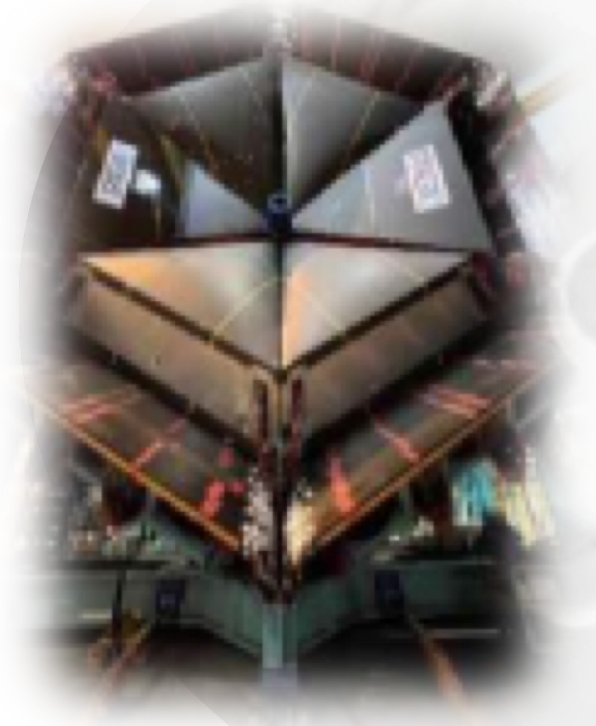
The CLAS12 experiment is taking data in Hall B since January 2018 with several experiments (Run Groups)

RG-A	**Unpol. LH2, 11 GeV**	**Nucleon structure (SIDIS,DVCS,DVMP), spectroscopy, J/y**	**50%**
RG-B	Unpol. LD2, 11 GeV	Nucleon structure (SIDIS,DVCS,DVMP), spectroscopy, J/y	50%
RG-K	Unpol LH2, lower energy	Spectroscopy, hybrid baryon and mesons	15%
RG-M	Nuclear targets, lower energy	Data for n experiments, short range correlations in nuclei	80%
RG-F	Gaseous target, RTPC for recoil, 11 GeV	Free neutron structure	100%

Quarks and hadron dynamics



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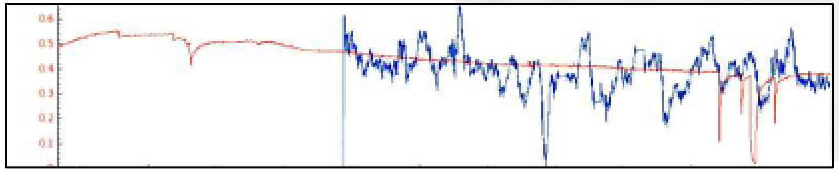
RG-K	Unpol LH2, lower energy	Spectroscopy, hybrid baryon and mesons	15%
RG-M	Nuclear targets, lower energy	Data for n experiments, short range correlations in nuclei	80%
RG-F	Gaseous target, RTPC for recoil, 11 GeV	Free neutron structure	100%

2022-23: First experiment with polarized targets

RG-C	Long. pol. NH3,ND3, 11 GeV, 2 RICH modules	Nucleon structure (SIDIS,DVCS,DVMP)	65%



Target polarization during RGC experiment: P(NH3)~70%, P(ND3)~50%

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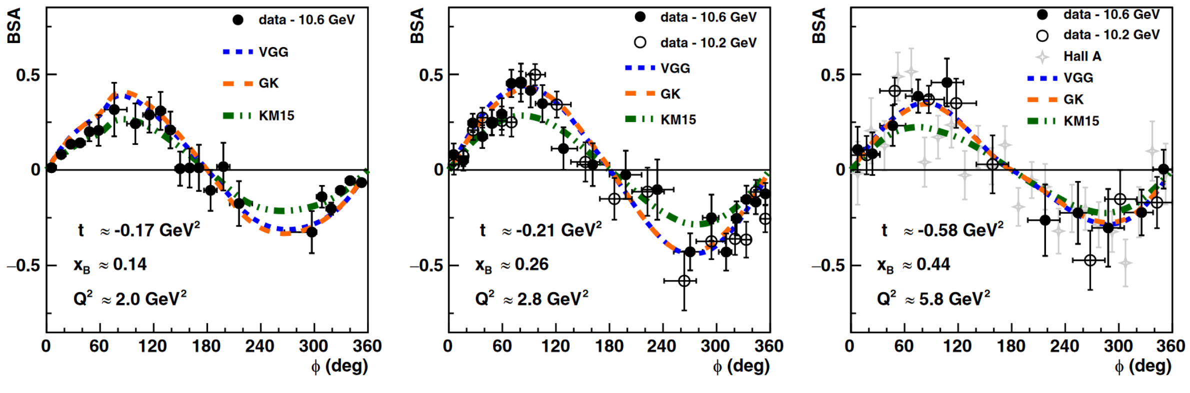
The first CLAS12 publications were based onabout 20% of the data taken in 2018 on unpolarized proton target and processed in summer 2020

1. Nucleon distribution functions in SIDIS
2. GPDs in exclusive reactions

Many more analysis in progress on proton and deuteron targets: DIS cross section, DVMP π0 and ρ0, J/ψ, DVCS, plus several analysis on old CLAS 6 GeV



Beam spin asymmetry ep → e p γ

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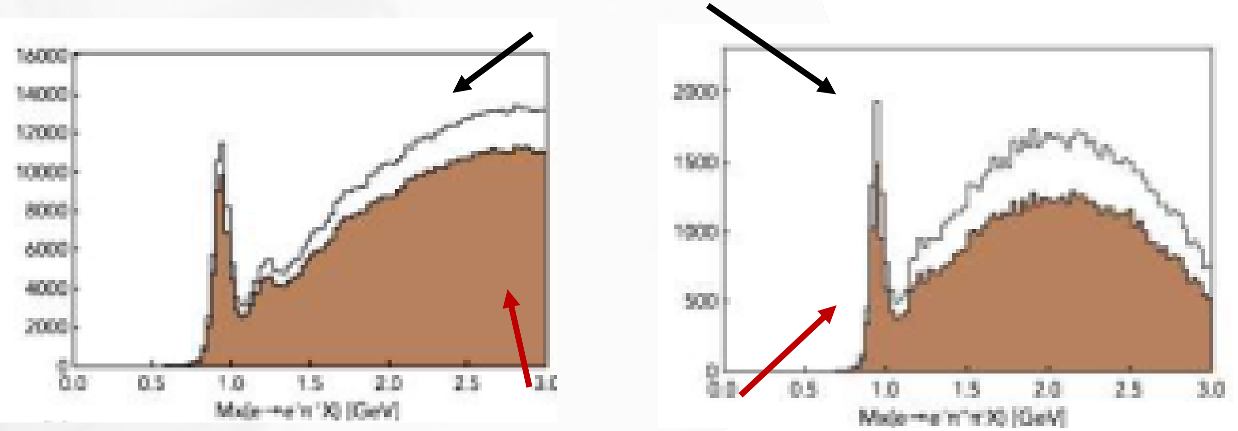
Implementation of **AI assisted algorithm** for

- track reconstruction
- denoising

From 10 to 35% increase in the reconstruction efficiency

AI-assisted



conventional

The complete (and last?) reprocessing of all the data taken so far has started this June and will continue for the next months. In parallel the Monte Carlo simulations will also start → *New publications*

Quarks and hadron dynamics

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Laboratori Nazionali di Frascati

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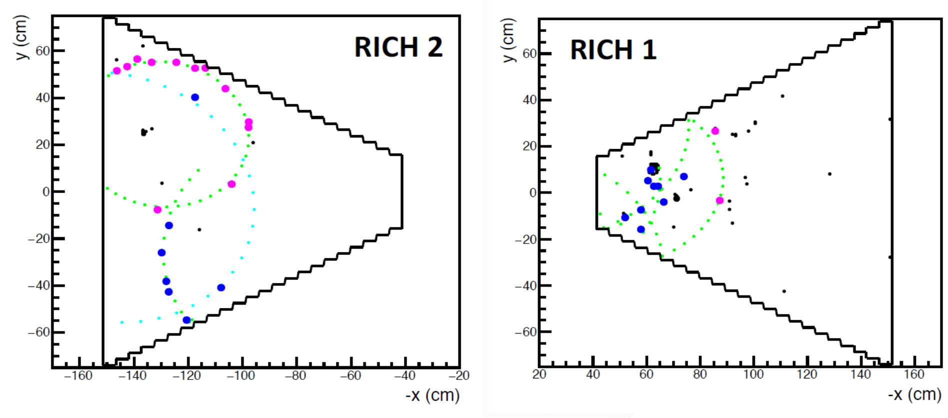
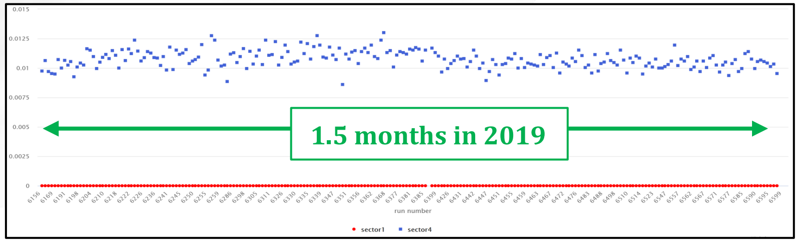
Complete revision of the RICH reconstruction software

- implementation of the second module
- optimization of the info output
- new and improved calibration and alignment tools





Number of K+ in the RICH per DIS electron

Quarks and hadron dynamics

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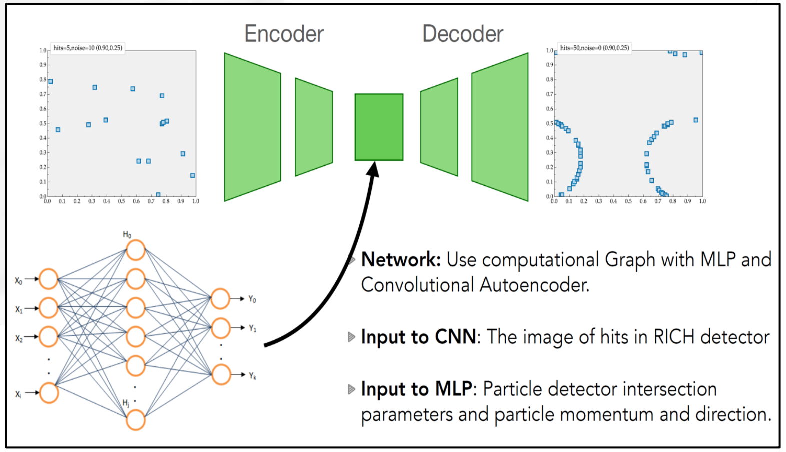
A workshop dedicated to the Kaon physics with CLAS12 has been organized in December 2022 at LNF

- *about 20 participants, half of them in person*
- *2 half-days dedicated to physics*
  1. single and double hadron final states with kaons
  2. Current vs Target fragmentation regions
  3. multidimensional fits to extract the relevant amplitudes
- *2 half-day dedicated to technical aspects*
  - application of ML techniques to improve the quality of the alignment of the RICH components
  - AI assisted particle ID in the RICH based on hit pattern recognition: similar approach used successfully to improve CLAS12 tracking efficiency



preliminary MC studies of the new AI assisted RICH ID

The National Scientific Committee

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Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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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 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

15 Publications (2021-2022)
Nature Physics 17 (2021) 1, 74-78
Eur.Phys.J.C 81 (2021) 8, 773
Physics of Life Reviews, Volume 42, (2022) 8-14

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
Carlo Guaraldo	
Antonino Marcianò	50
Johann Marton	
Fabrizio Napolitano	80
Elisabetta Pace	80
Kristian Piscicchia	100
Alessio Porcelli	100
Diana Laura Sirghi	30
FTE totali	6.5

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Physics cases explored by the VIP experiment family:

- 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 → collaboration with Lajos Diosi; Roger Penrose; Steve Adler

VIP-2 → new SDD detectors SDD:
- higher resolution: 190 eV (fwhm)
- faster (triggerable) → VETO system
- higher acceptance
- higher current → low background
- higher efficiency

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

CSN3 Fisica Nucleare

VIP-2 setup at LNGS and status

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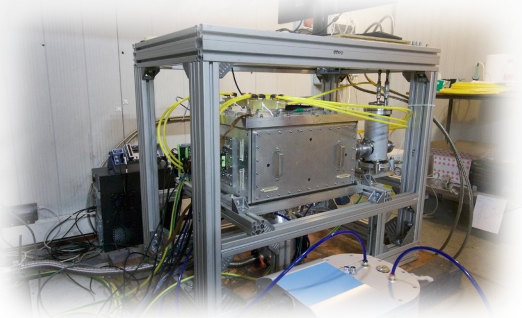
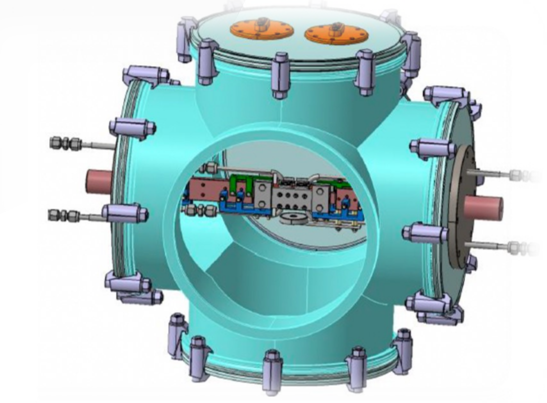
- VIP-2
  1. version 1 with 6 SDDs (SIDDHARTA type) installed at LNGS end of 2015 – data taking (no shielding) till 2017
  2. VIP-2 with upgraded SDDs (4 arrays of 2x4 SDD detectors) installed at LNGS in April 2018; tests and data taking without shielding till November 2018
  3. Shielding installed in November 2018 – data taking till May 2021
  4. VIP-2 Maintenance/renovation during shack renovation (Data taking Dec-2022-ongoing),
- Current modulation data analyzed (paper under finalization)
- **VIP-3: new SDDs 1mm thick produced** (FBK+PoliMi), setup under finalization, *Acta Phys.Polon.A 142 (2022) 3, 361-366*
- Optimization, design and realization of test VIP-GATOR setup (HPGe + copper target with current),
- VIP-Closed Systems (HPGe + Roman Lead & other targets) & BEGe





Lead

High purity Ge detector measurement

- Advanced phenomenological studies of anisotropy effects on the PEP Violation amplitude predicted in Quantum Gravity Models
- Ongoing design of a dedicated experiment

Ongoing activity: BEGe detector

- Improved setup
  1. Flash-ADC-Computer optical fibre interface
  2. wide band low noise amplifier
  3. extremely-low noise power supply for digitizer and amplifier

- New Pulse shape discrimination algorithm convolutional neural networks based,

- Data taking and data analyses ongoing

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VIP future plans

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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 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:

- Finalize and submit for publication the papers on data analyses whole statistics (at least 1 paper), study and optimization of the data taking strategy and continuation of Monte Carlo simulations and studies for optimization of the run
- VIP-3 Open Systems with Ag, Sn, Pd targets and 1mm SDD detectors (**preparation of the VIP-3 setup and run 2023-2025**)

VIP-Lead:

- Finalize and submit for publication new analysis on theoretical interpretation of the VIP-lead results (k-Poncaré parametrization of the probablity in terms of power expansion of the non-commutativity scale), refined data analyses for additional targets: V, Pt, Hf, Ta /existent) and study of the limit of PEP-violation on various materials, which has strong impact on quantum gravity inspired models
- Continuation collaboration with theoreticians
- Analysis of the data collected with BEGe detector
- Studies in Frascati laboratory of a possible setup to test anisotropy effects – quantum-gravity tests

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

The National Scientific Committee 3

CSN3 Fisica Nucleare

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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)

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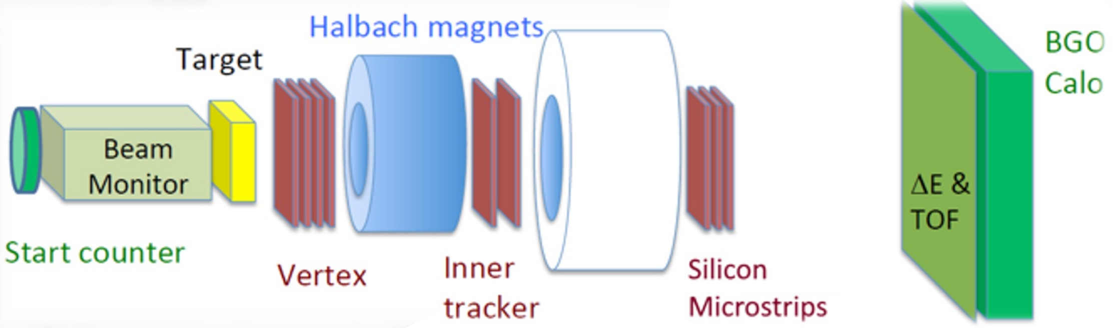
Fixed target experiment: the beams of interest, with an energy of hundreds of MeV, impinge on a material representative of the human tissue (mainly hydrogen, carbon and oxygen) and the produced fragments are detected and measured by a multi-purpose detector

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

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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

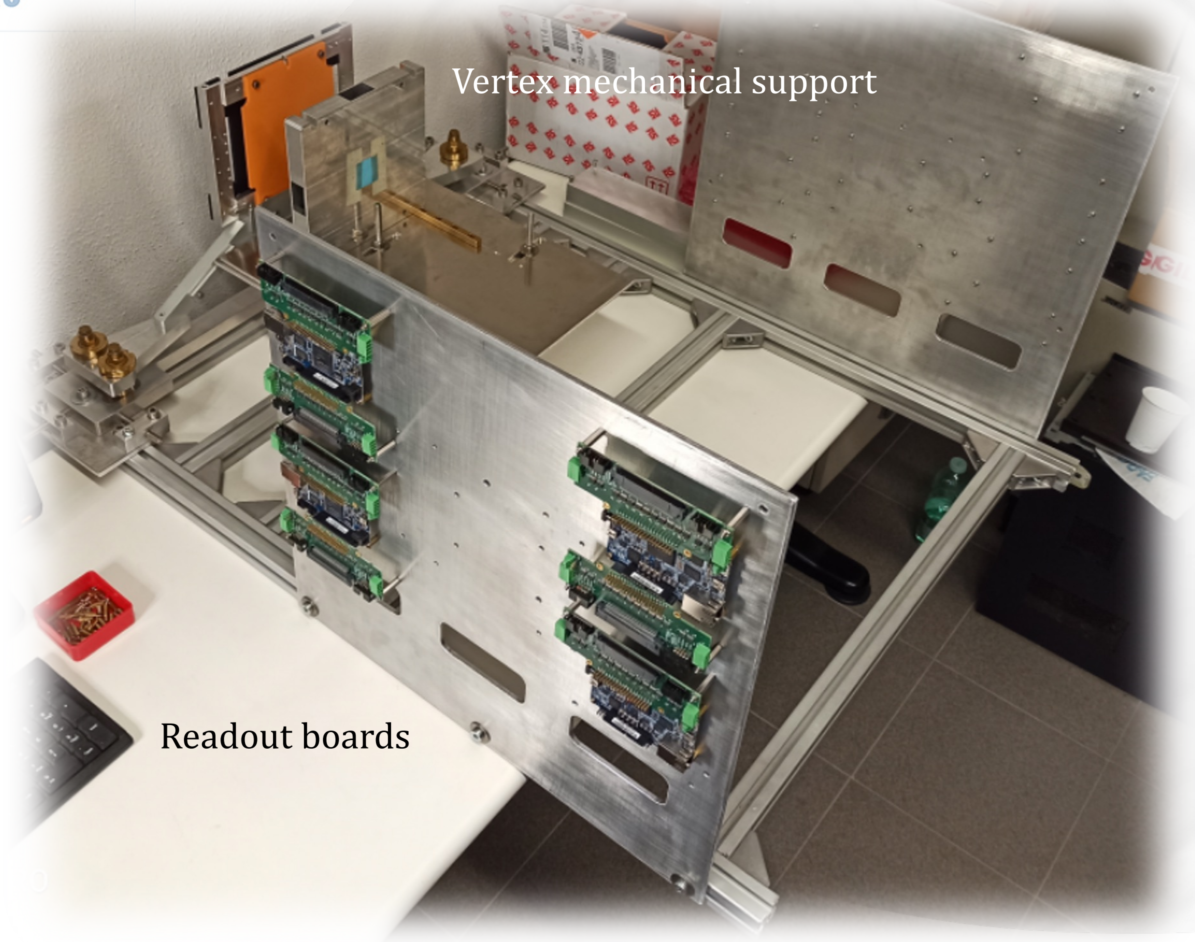
- Used at GSI and at CNAO (last november)
- New Vertex readout board under production

Inner Tracker

- Plume ladder assembly process definition concluded in Strasbourg
- All production tools available
- First module tested at LNF, wrong bonding discovered (bonding plan modified)
- 10 modules assembled
- 1 ladder (out of 5) assembled (problems in dead sensors!!!) → SHOWSTOPPER
- 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

Inner tracker mechanical support



Four final ladders in Frascati (tested in Strasbourg, under test at LNF)

- Fifth ladder (spare) to be assembled in Strasbourg
- Cabling under way: control, trigger, power, console cables system to be used for integration test at the BTF (LNF) end of September 2023.

Magnets expected to be delivered at LNF at the end of August

Overall arrangement
(partially final) foreseen for test beam

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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.

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

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Key points
Time resolution
- MIMOSIS 5 µs
- Ultimate (M28) 185.6 µs

MIMOSIS – global shutter
Ultimate (M28) – rolling shutter
MIMOSIS active area:
Active area: 30.935×13.520 mm2
Pixel pitch: 26.88 x 30.24 µm2
two sensors per plane:
Active area: about 30×30 mm2
(similar to FIRST vertex arrangement)

Add one station before target.

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Attività FOOT-LNF 2023

1. Caratterizzazione dei magneti (Laboratorio misure magnetiche)
2. Assemblaggio del sistema meccanico complessivo (SEA + SPAS)
3. Test alla BTF del sistema di tracciamento elettronico.
4. Trasporto al CNAO e test
5. Turno di presa dati al GSI

Necessario individuare uno spazio ai LNF per l'assemblaggio di cui sopra.

FOOT	Afferenza (%)
Guido Raffone	50
Eleuterio Spiriti	60
Sandro Tomassini	10

MI	ME	TRA	INV	C.APP	CON	Totale
0	15	2	0	4	3	24

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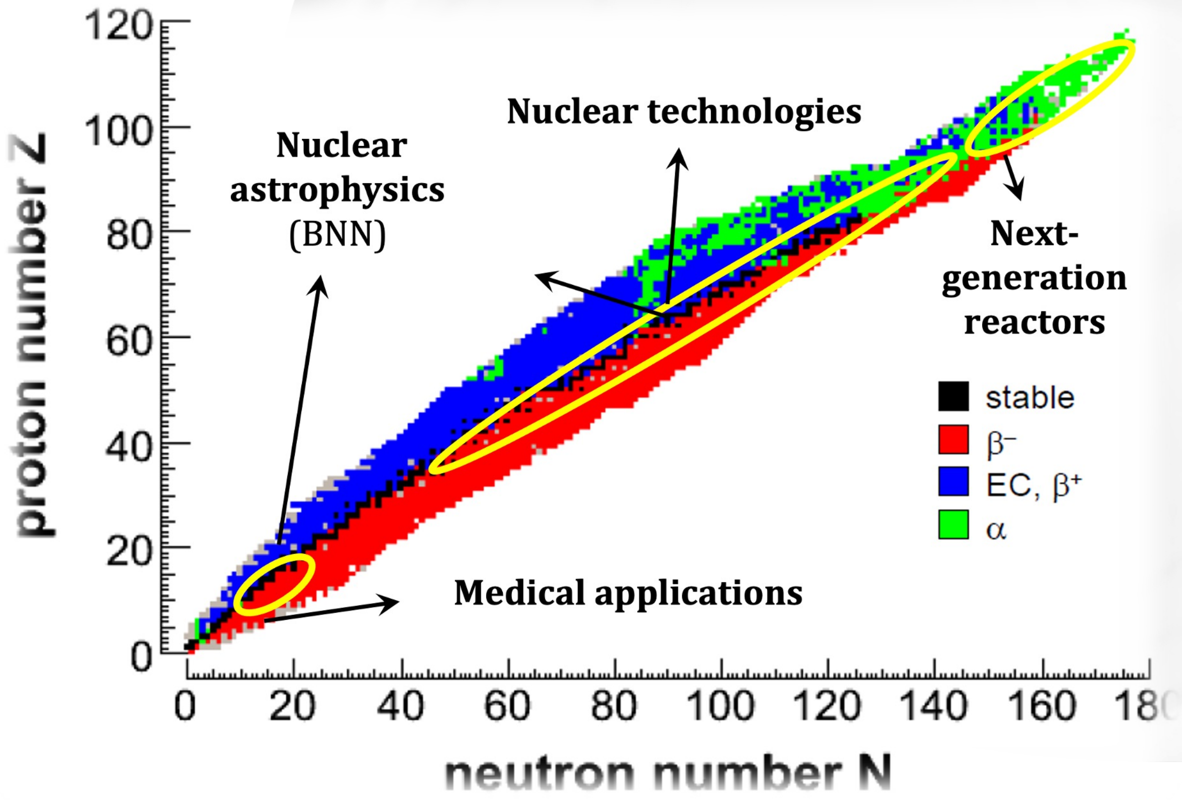
FOOT

nTOF

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



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nTOF

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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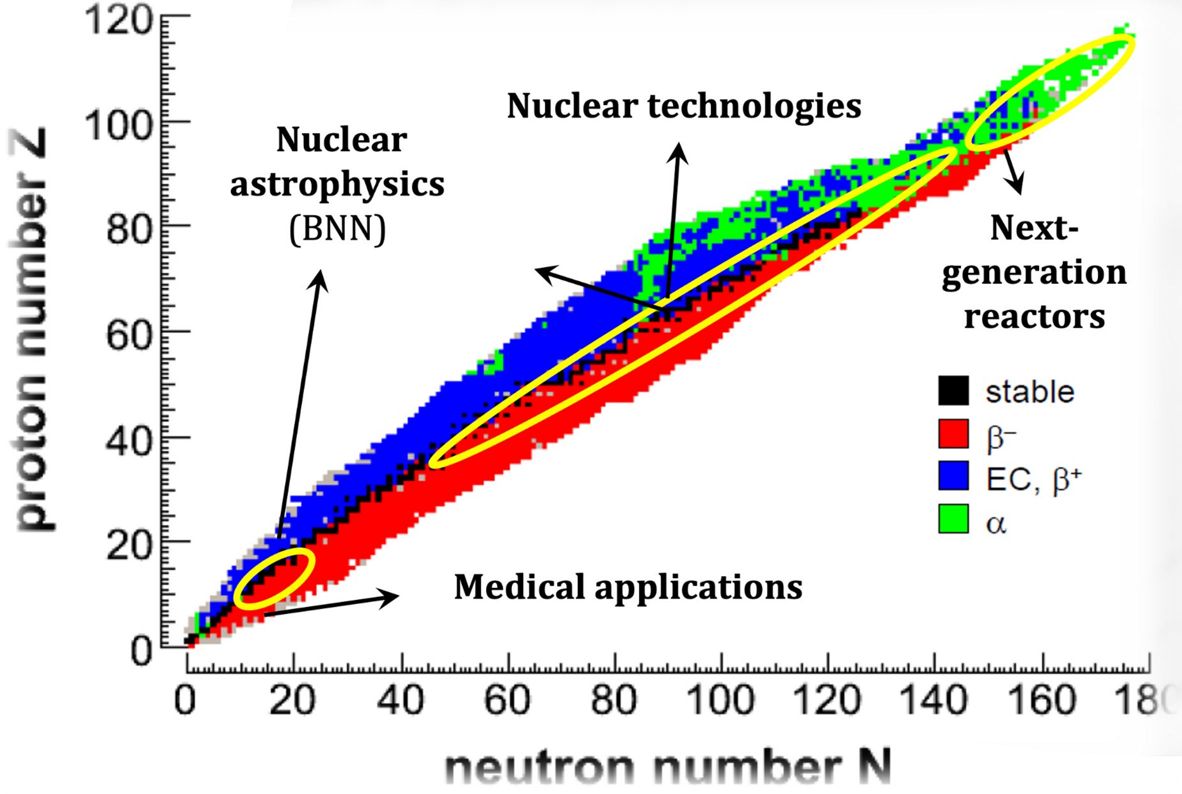
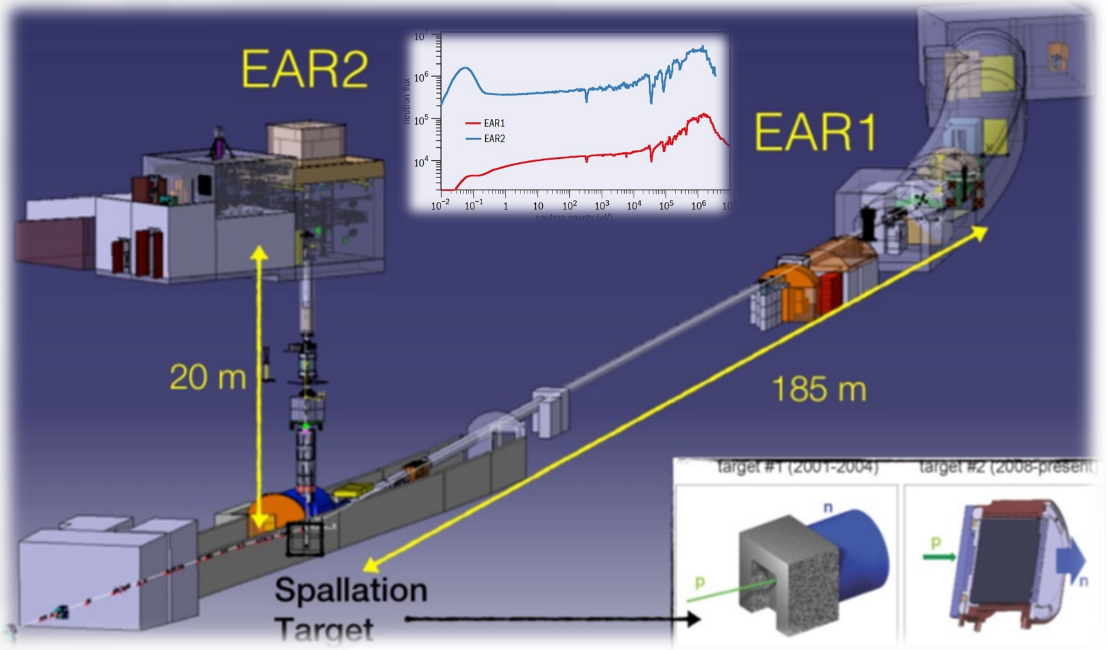


→ select neutrons with E_{kin} from few meV to GeV, via time of flight measurements



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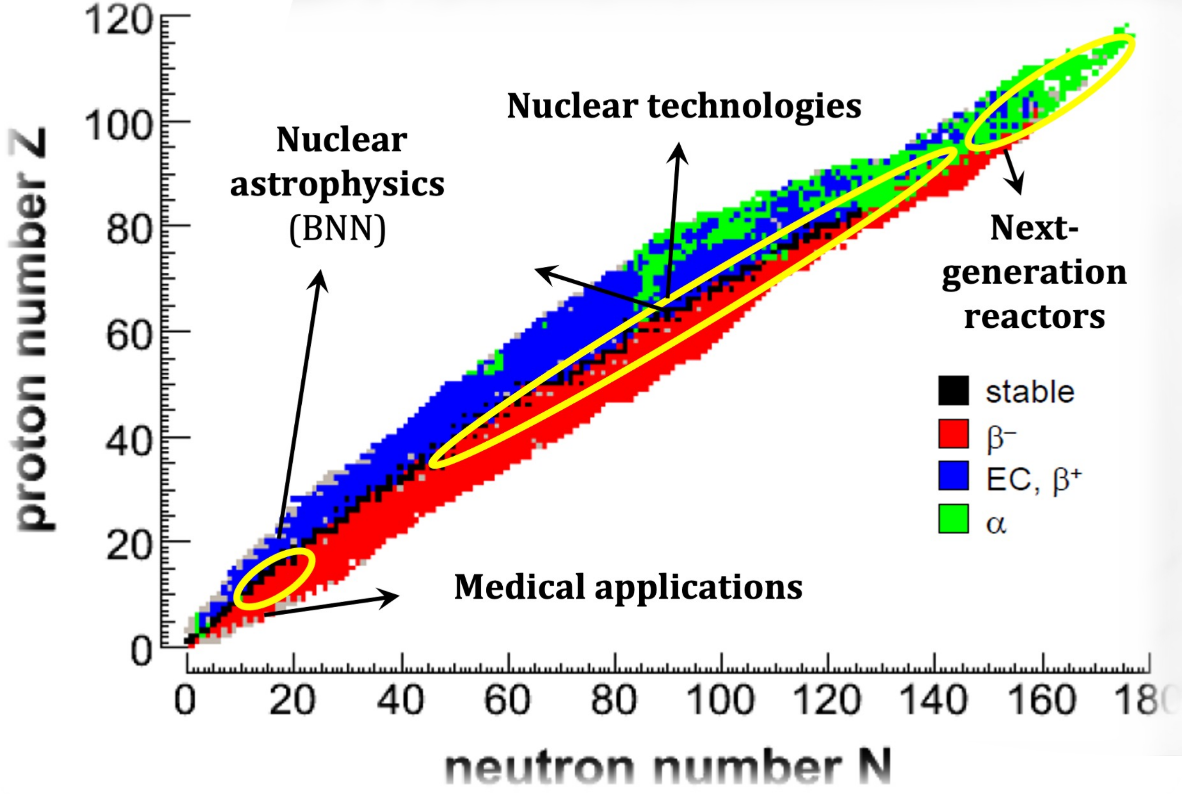
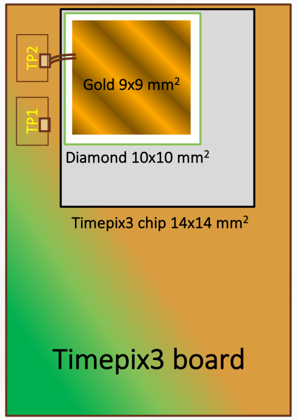
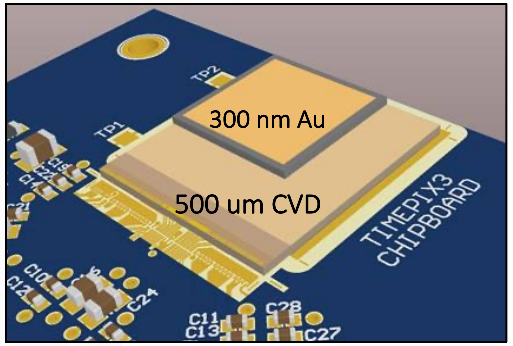
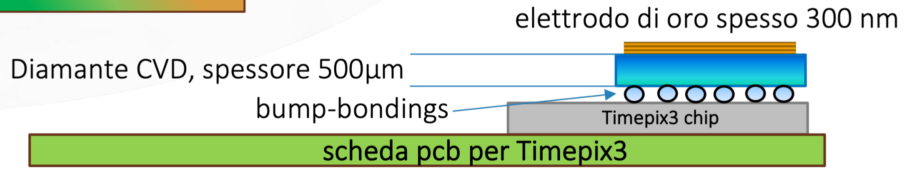


Caratterizzazione di un nuovo rivelatore al diamante basato su chip Timepix3 (il "*diamondpix*") per misure di neutroni veloci su plasmi a confinamento magnetico per la fusione nucleare → *studio della capacità di discriminare i segnali neutronici tramite l'analisi morfologica delle tracce e la misura in carica*. L'intervallo di energia sotto esame va da 1 a 20 MeV, ovvero il range energetico di interesse nel campo della fusione







nTOF

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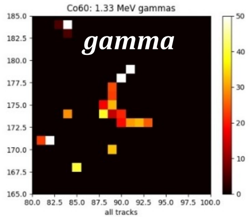
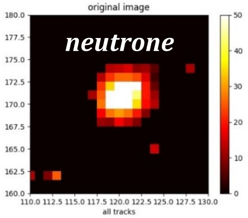
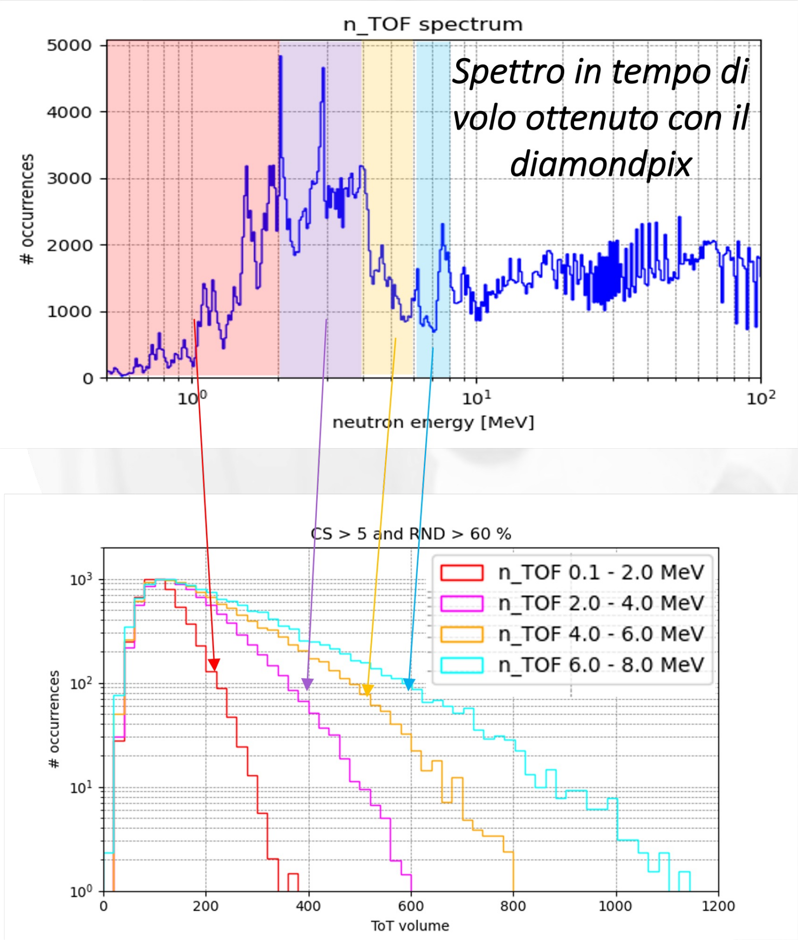
Laboratori Nazionali di Frascati

A differenza del Timepix1, il Timepix3 può acquisire simultaneamente in:

- Counting (medipix mode)
- Carica (Time over Threshold mode)
- Tempo (Time of Arrival mode)







Risposta in carica per differenti intervalli di energia

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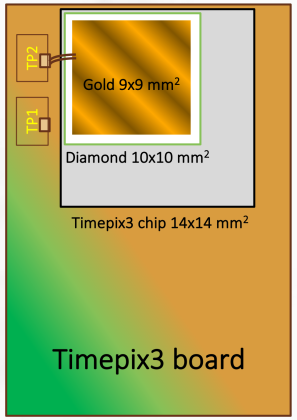
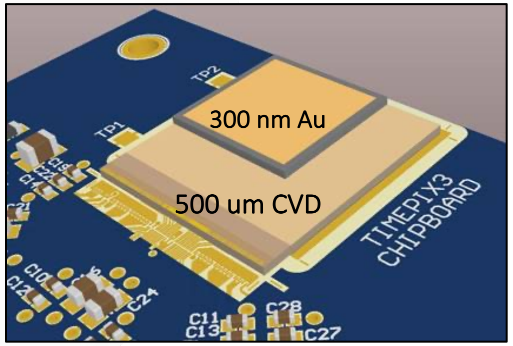
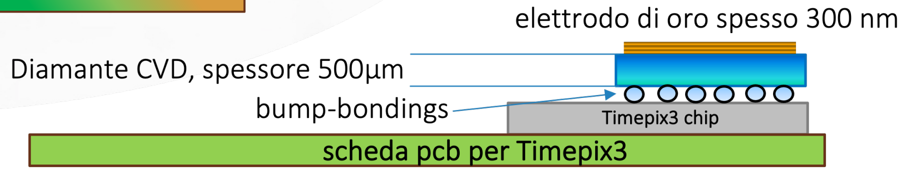
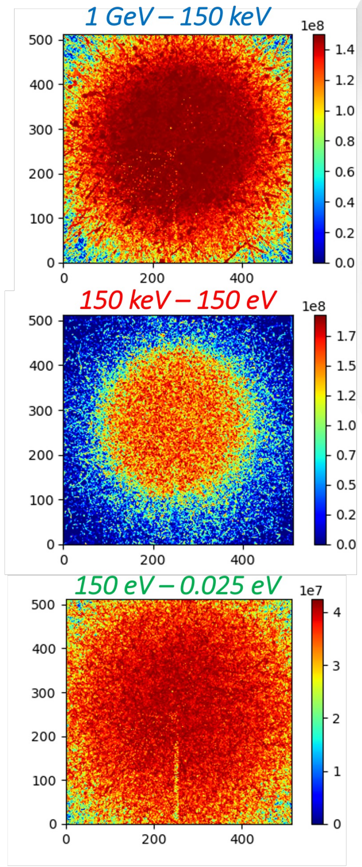


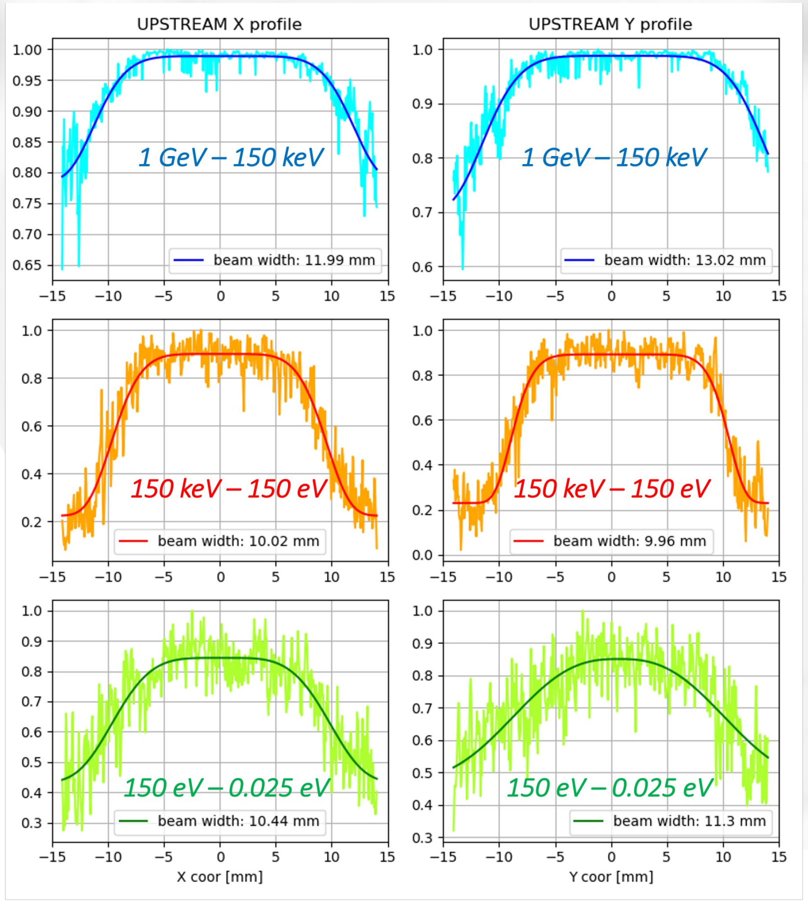




nTOF

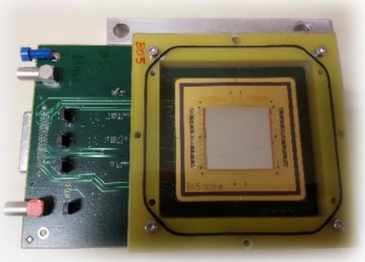
Misure di fascio nell'area EAR1 di n_TOF con i quad Timepix1 al silicio

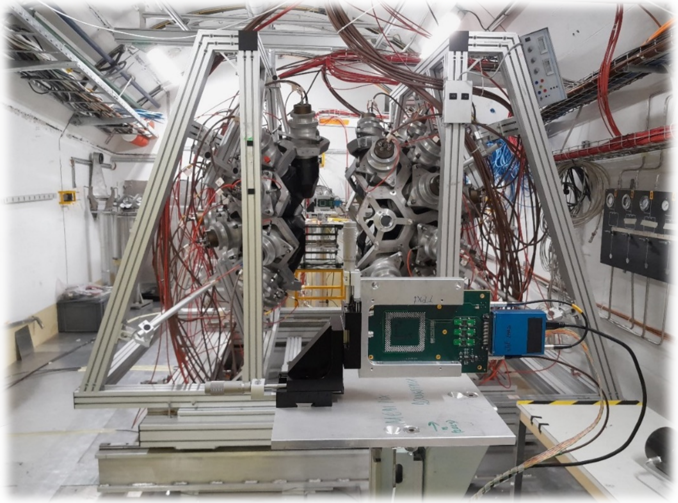




Messa a punto di quad-timepix1 al silicio per misure del fascio di neutroni su n_TOF per diversi intervalli di energia

1. realizzazione di rivelatori Timepix dotati di convertitori per neutroni termici basati su B4C e LiF → monitor di fascio e imaging con neutroni termici
2. Caratterizzazione di un nuovo quad Timepix3 che consentirà di effettuare misure simultanee di carica e tempo.





nTOF

Il rivelatore GEMpix per la misura di prodotti carichi da reazioni (n, cp) in EAR1 e EAR2

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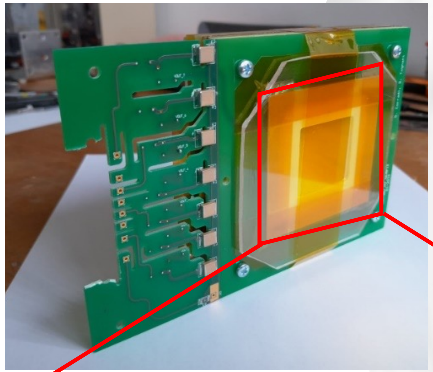
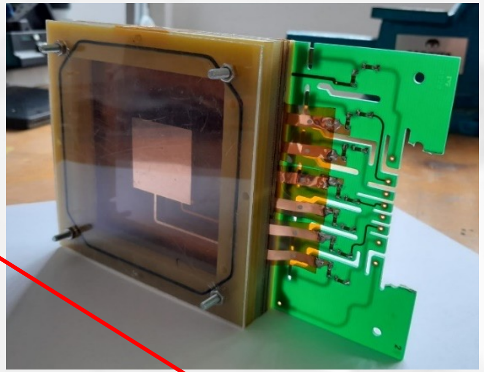
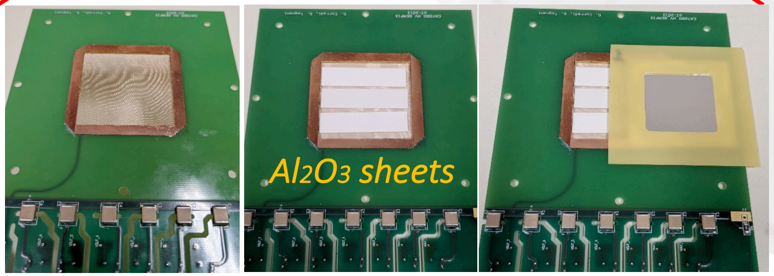
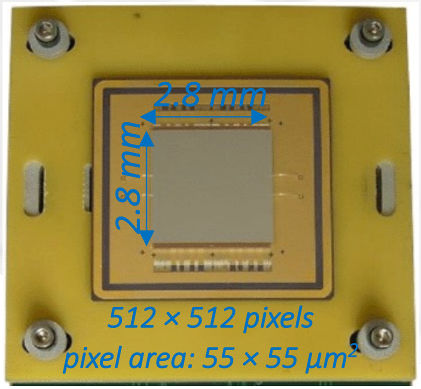
Il rivelatore GEMpix è costituito da una camera tripla-GEM letta da un quad Timepix1 privo di semiconduttore.







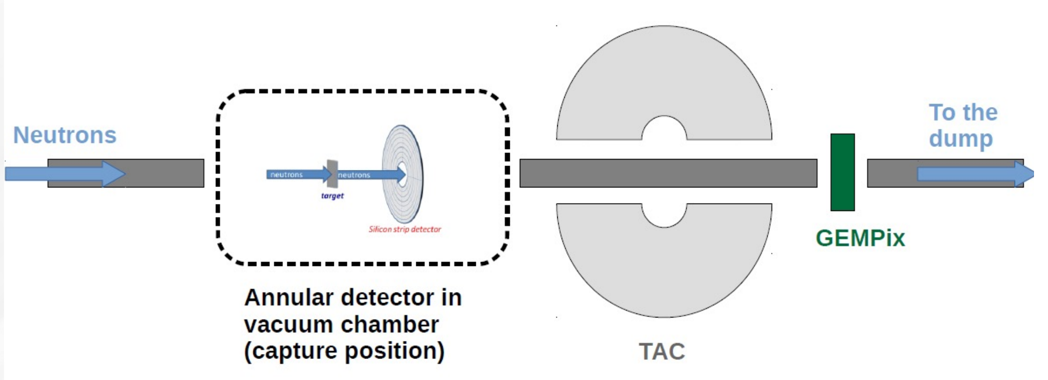


Layout del nuovo rivelatore GEMpix in costruzione presso i LNF. La finestra di ingresso ospita le targhette bersaglio.

Realizzazione di un rivelatore GEMpix per la misura di prodotti carichi da reazioni (n, cp):

1. finestra con bersaglio di allumina (Al2O3) per testare la risposta ai prodotti carichi che provengono da reazioni con l'ossigeno
2. In fase di valutazione anche un bersaglio di carbonio

Proposal INTC-P-629 → uso combinato del GEMpix e di un rivelatore anulare a stato solido realizzato presso gli LNS.



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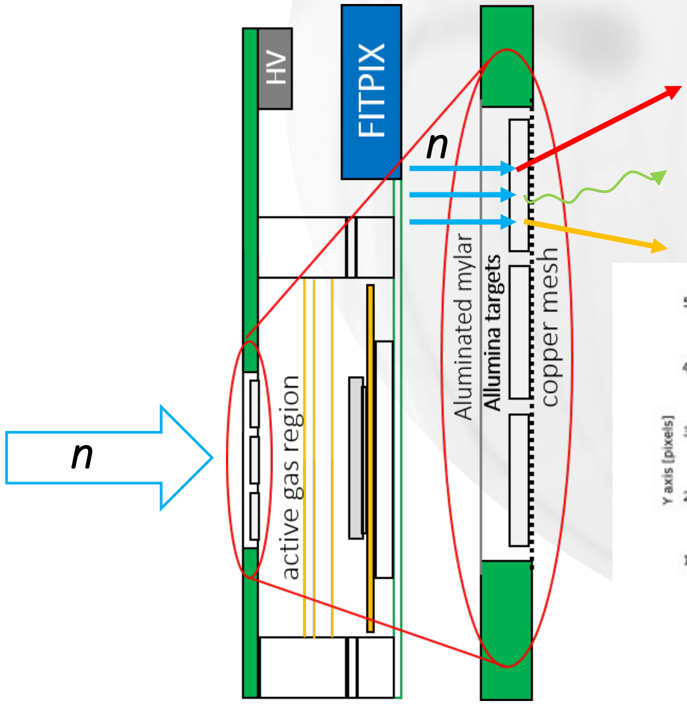
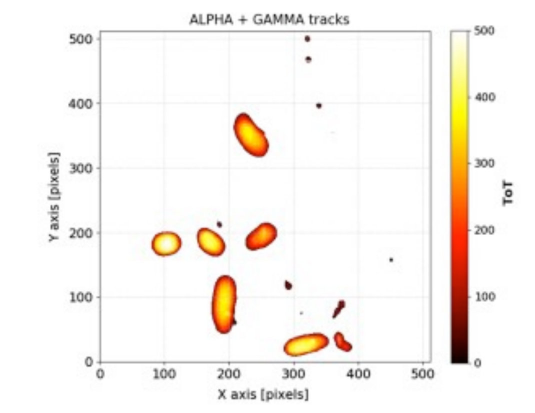
Il rivelatore GEMpix per la misura di prodotti carichi da reazioni (n, cp) in EAR1 e EAR2



Le particelle cariche interagiscono nel gas e vengono rivelate sotto forma di tracce.



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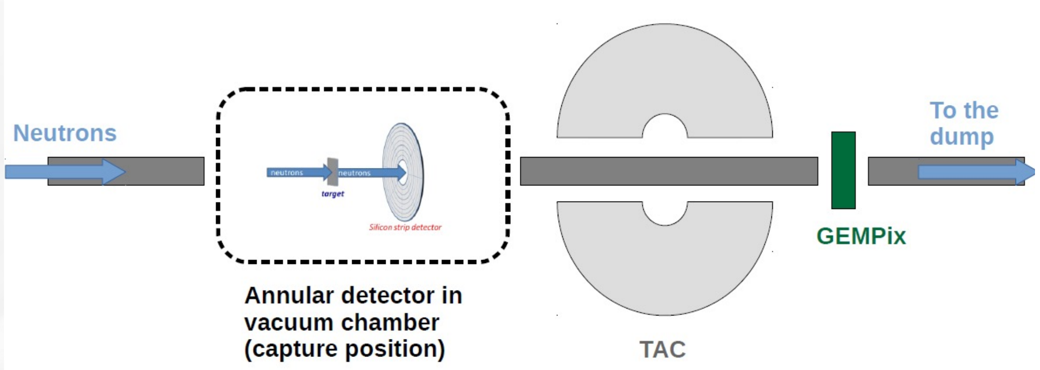
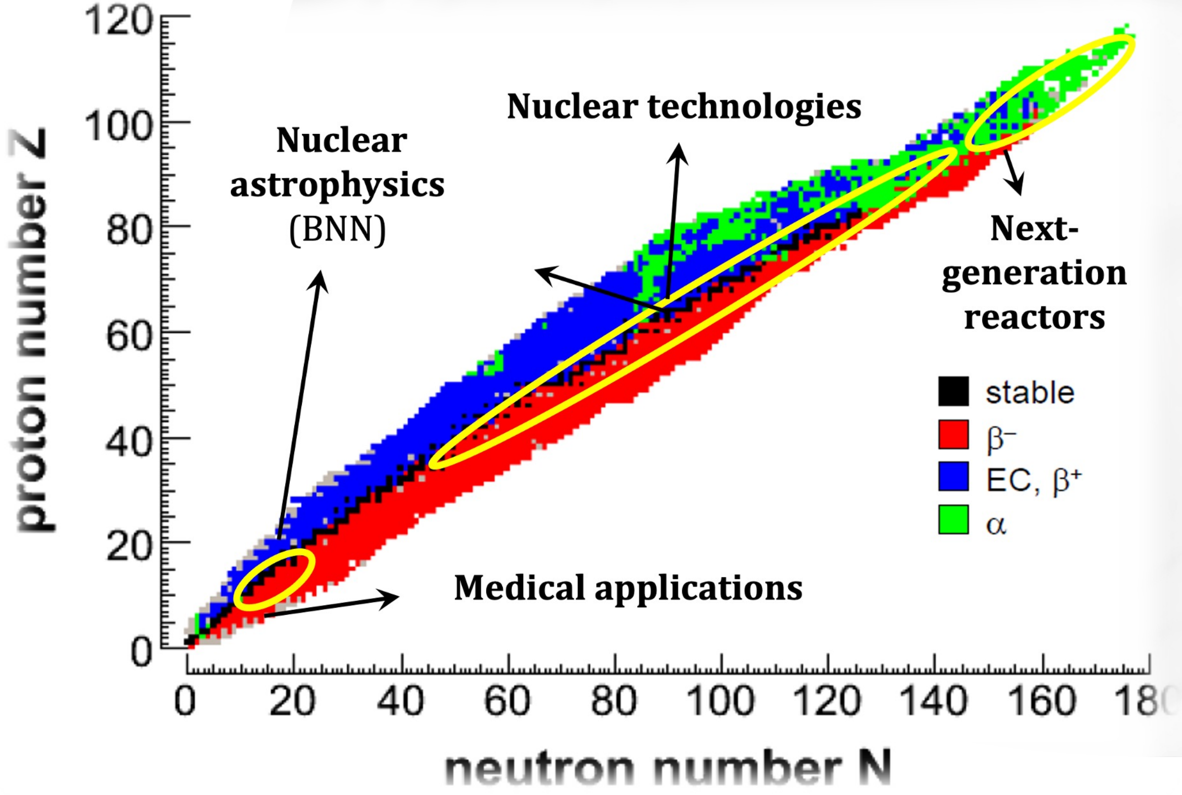


nTOF

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



Nome	Contratto	Qualifica	Ente appartenenza	%
Gerardo Claps	Associazione scientifica con incarico di ricerca	Ricercatore Confermato	ENEA Frascati	50
Nicholas Terranova	Associazione scientifica	Ricercatore Confermato	ENEA Frascati	50
Antonino Pietropaolo	Associazione scientifica	Ricercatore Confermato	ENEA Frascati	20
Antonella Tamburrino	Associazione scientifica	Dottoranda	Sapienza Università di Roma	100
Silvia Tosi	Associazione scientifica	Dottoranda	Università degli Studi Roma Tre	100

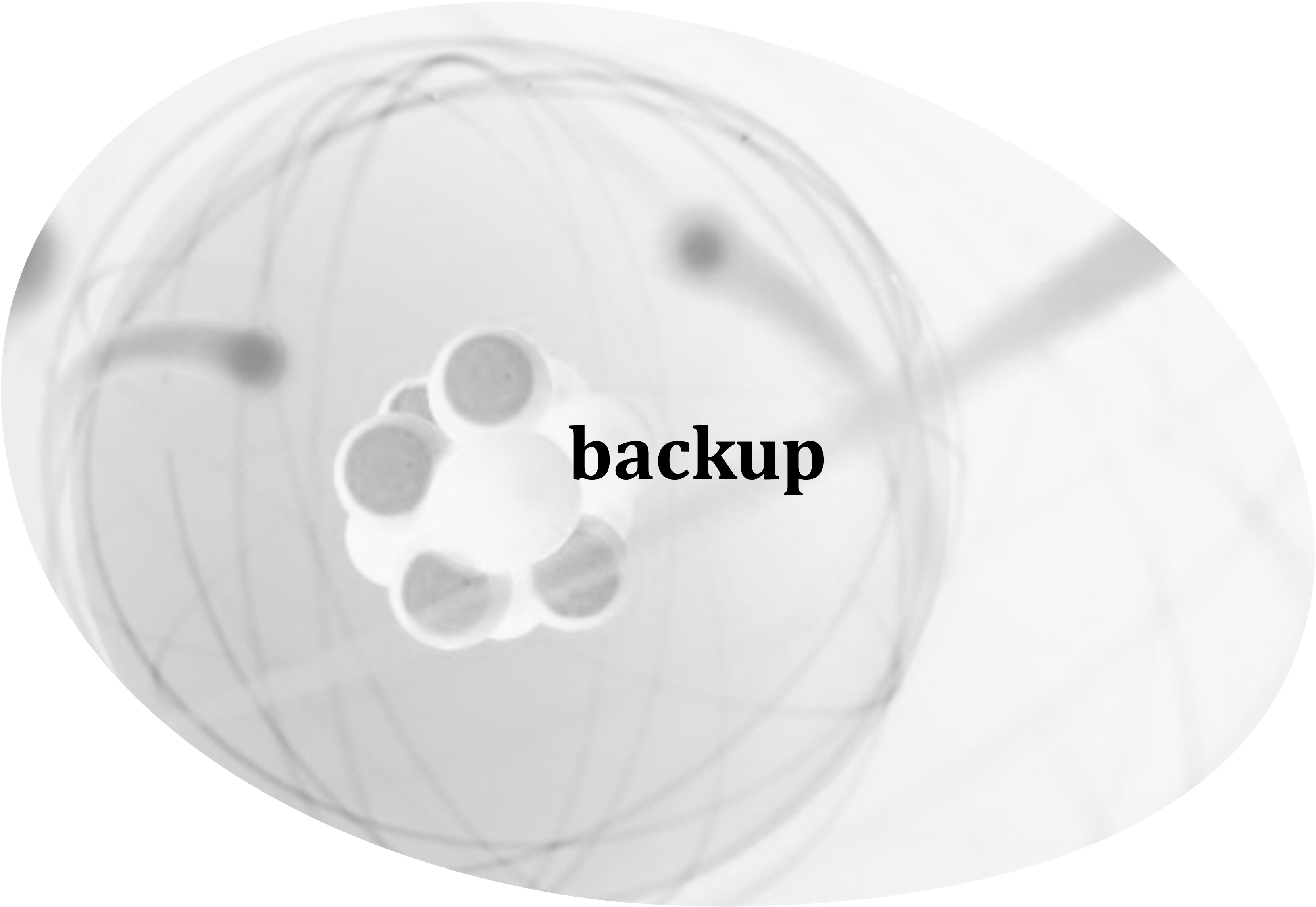
CSN3 Fisica Nucleare

Conclusioni

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

- Il coinvolgimento nelle sigle della CSN3 continua in modo stabile, così come le RN
- Incremento di personale a TI@LNF
- Mid-Term Plan for nuclear physics workshop series
- *New projects are being designed in the field on nuclear physics to be proposed at LNF...see next talk*

Working group (Chair)	Topic
Future possibilities for nuclear physics at DAFNE	Nuclear physics at DAFNE Femtoscopy at SIDDHARTA and ALICE
Charged particle detectors (G. Pasquali, F. Galtarossa, L. Servoli)	Pulse shape discrimination, silicon carbide detectors, active targets Segmented silicon detectors, heavy ion detection and spectrometers Diamond detectors, emulsions and other techniques
Neutron detectors (C. Massimi, A. Gottardo)	Organic scintillators for neutron detection Detectors for neutron beams and applications Innovative neutron detectors
Detectors for medical applications (R. Catalano, P. Cardarelli, M. Lunardon)	Treatment monitoring and optimisation Dosimetry, quality assurance and radiotherapy X-ray and gamma imaging
Targets development for nuclear physics (M. Cavallaro, S. Corradetti)	Innovative targets for nuclear physics experiments Innovative targets for new production facilities
Detectors for gamma/X-radiation (A. Scordo, W. Raniero)	X-ray detectors Gamma detectors
New facilities at LNF, LNL and LNS (A. Di Pietro, A. Gottardo)	New facilities at Laboratori Nazionali di Legnaro New facilities at Laboratori Nazionali del Sud New facilities for laser-based activities at LNF and LNS



backup

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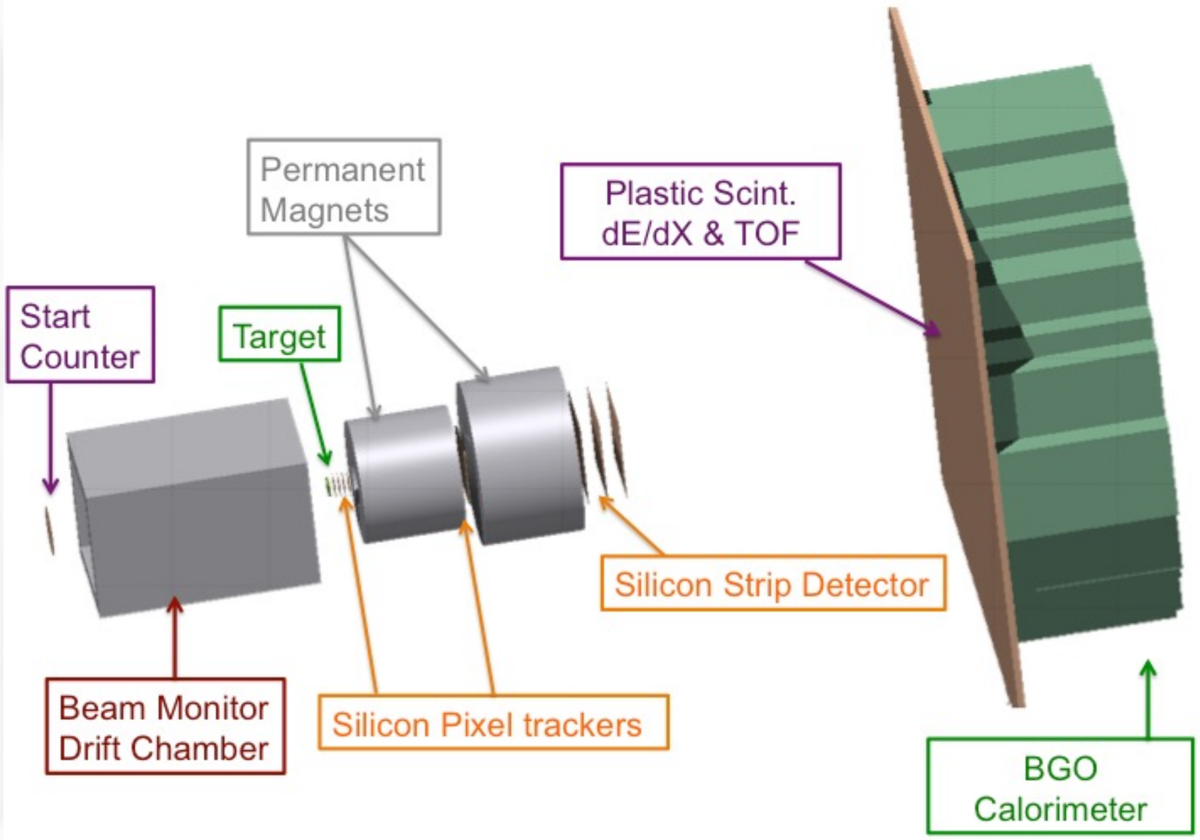

VIP-2 setup at LNGS and status

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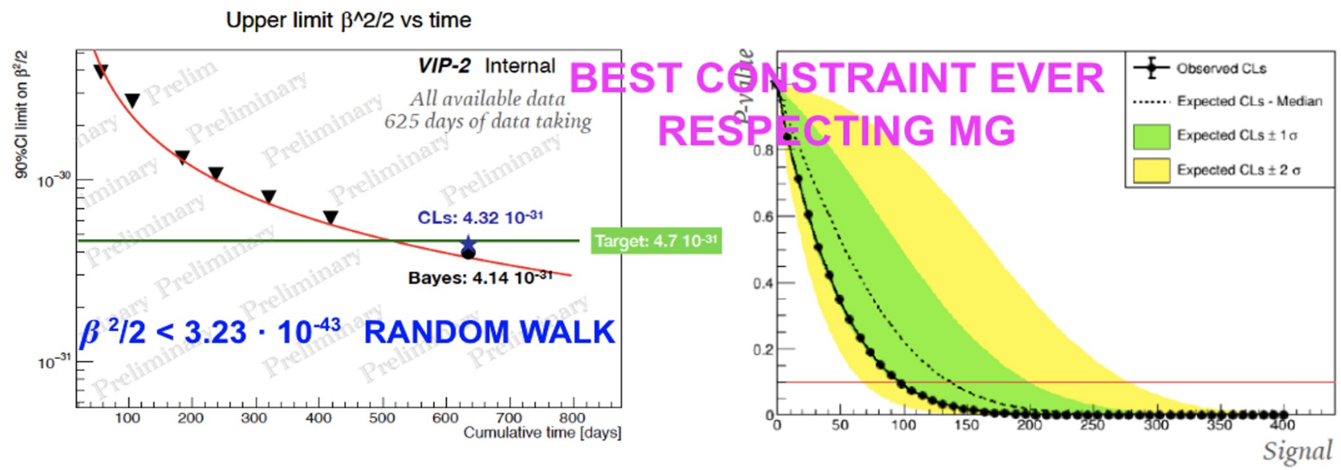


Analysis validated by means of frequentist CLs exclusion method, exploiting Neyman construction for a robust evaluation of the CLs.

Symmetry 2023, *15*(2), 480, *Phys.Scripta* 97 (2022) 8, 084001, *Symmetry* 14 (2022) 5, 893, *Nuovo Cim.C* 45 (2022) 5, 103, App. Rad. and Isotopes, 197 (2023), 110822

CSN3 Fisica Nucleare

EPN technical coordiation

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

- The ALICE Event Processing Nodes farm performs both synchronous and asynchronous (acting as a GRID node) data reconstruction.
- The IT infrastructure operates on a dual transformer feed able to sustain up to 2.1 MW of IT load and uses a mixed air-water cooling system.

- In 2022 the farm run **280 AMD Rome dual-socket 32-cores CPU NUMA nodes** each equipped with 8 AMD 32GB MI50 GPUs
- Due to the observed higher number and size of TPC clusters to be processed, **in 2023 the farm is being expanded with 70 more nodes running AMD 32-GB MI100 GPUs,**
  for a total of 2800 GPUs.
- **2023: work is ongoing to install the new nodes and commission the ALICE reconstruction SW for the heterogeneous HW in view of the PbPb run at 50 kHz (October).**

n_TOF

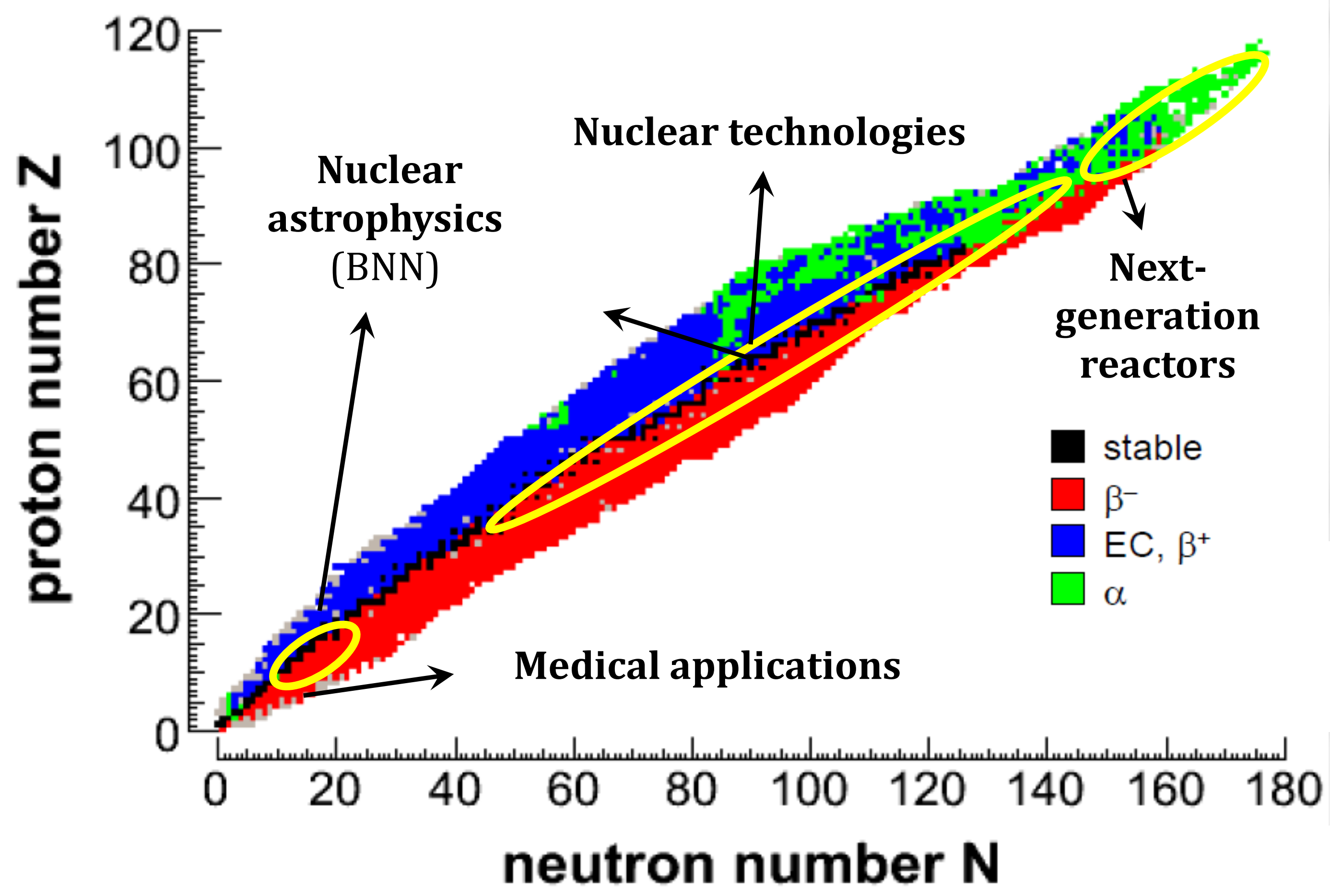
The measurements are performed by using the n_TOF facility at CERN. In this facility, the neutron beams, produced by spallation of 20 GeV/c protons from the CERN PS on Pb, uses two different path of flight: a shorter one of 19 m (very high beam intensity) and a longer one of 185 m (very high energy resolution).

The neutron beams present some unique performances:

1. a broad energy spectrum, ranging over 12 order of magnitude, from meV to GeV;
2. an extremely high flux (10^{13} neutrons.cm^{-2}.bunch^{-1} at the producing Pb block and 10^{6} neutrons.cm^{-2}.bunch^{-1} on the measuring sample)
3. an excellent energy resolution (DeltaE/E=10^{-4})
4. a low duty cycle (0.3 Hz).

Due to these characteristics, these beams allow the study of some reactions until yet unexplored.
In particular, high flux and low duty cycle allow to obtain very precise values of neutron cross sections for both stable and radioactive samples (even if available in few amount of mass).

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



LNF has developed GEM detectors for thermal neutrons, based on the conversion on Boron coated cathode ($^{10}B(n,\alpha)\,^{7}Li$) → good candidate for He^3 detector replacement:

1. Imaging capability
2. good time resolution (5 ns),
3. high gamma rejection ($>10^5$)
4. high-rate capability O(10 MHz/cm^2)
5. good spatial resolution O(mm)

MBGEM : a stack of Borated GEM detector for high efficiency thermal neutron detection

A.Muraro[5,6,10], G.Claps[1,4], G.Croci[5,6,10], C.C. Lai[8,3], R.De Oliveira[2], S.Altieri[7], S.Cancelli[5,6], G.Gorini[5,6,10], R.Hall-Wilton[8,6], C.Höglund[8,9], E.Perelli Cippo[5], L.Robinson[8], P.Svensson[8], and F.Murtas[1,2]