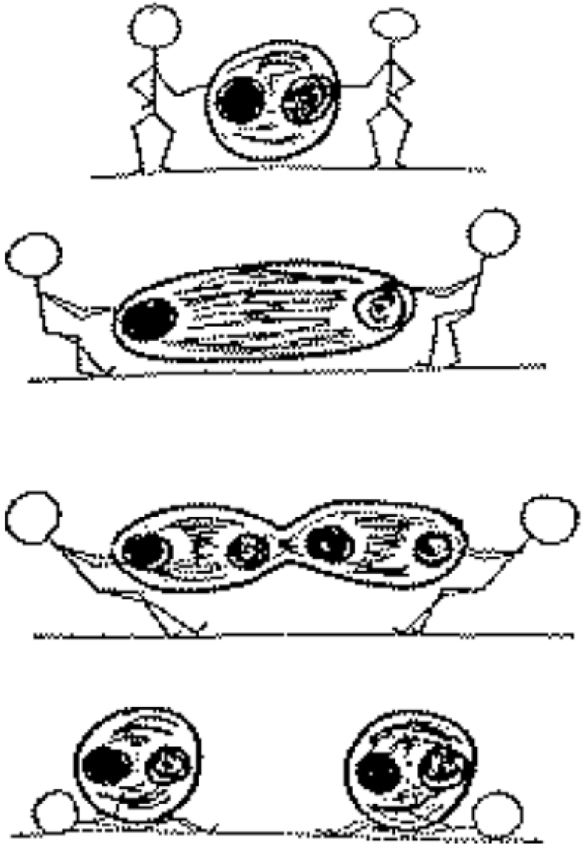
Nuclear Physics at the Frascati National Laboratories

Silvia Pisano

Local coordinator of the Nuclear Physics group

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati



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

Research lines follow those of NuPECC

CSN3
Fisica
Nucleare

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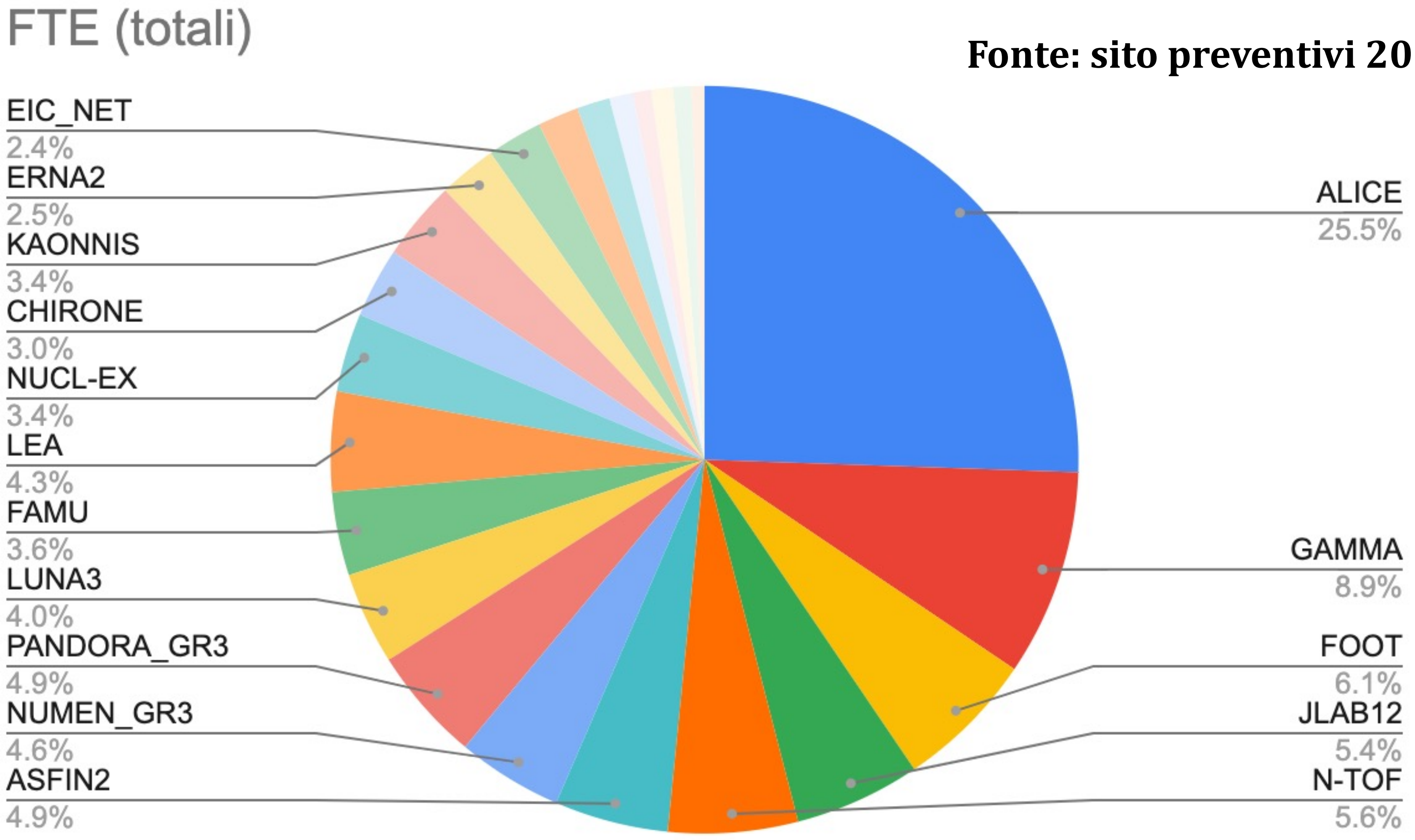
FOOT

Commissione Scientifica Nazionale 3

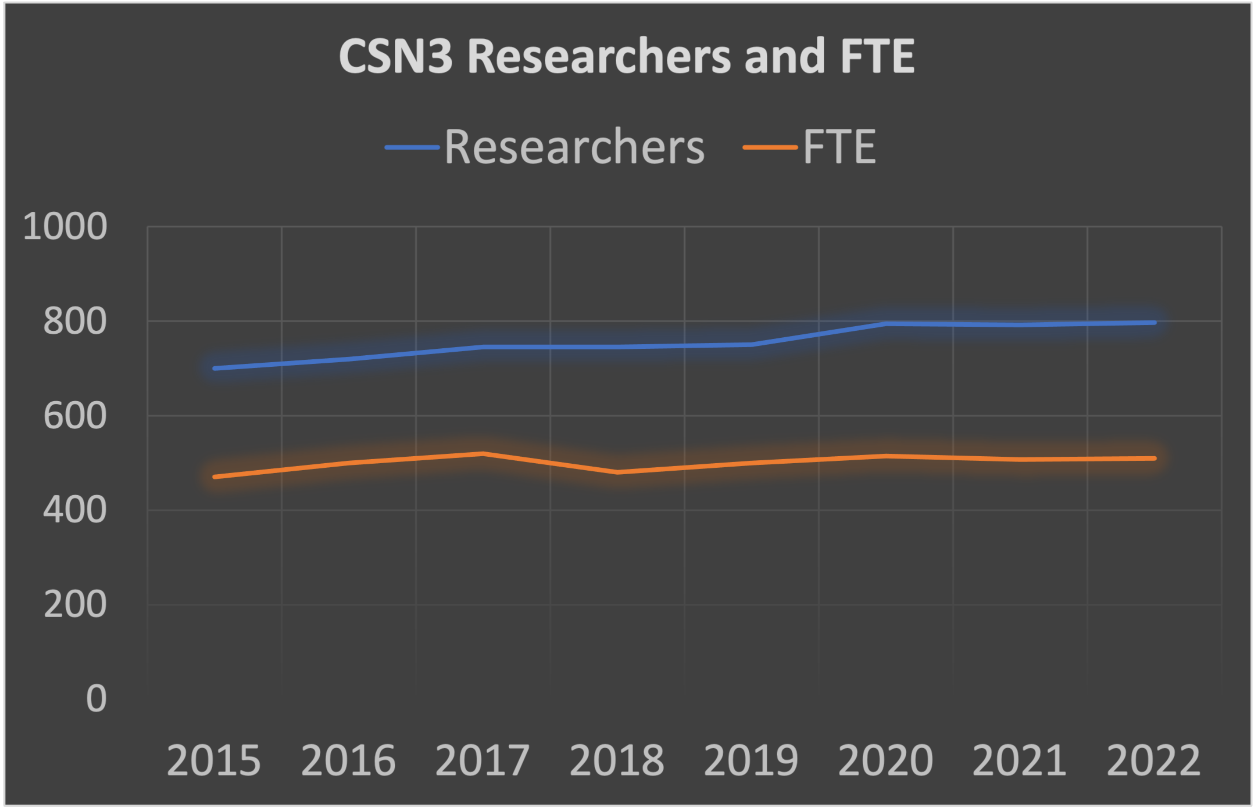
Fonte: sito preventivi 2023

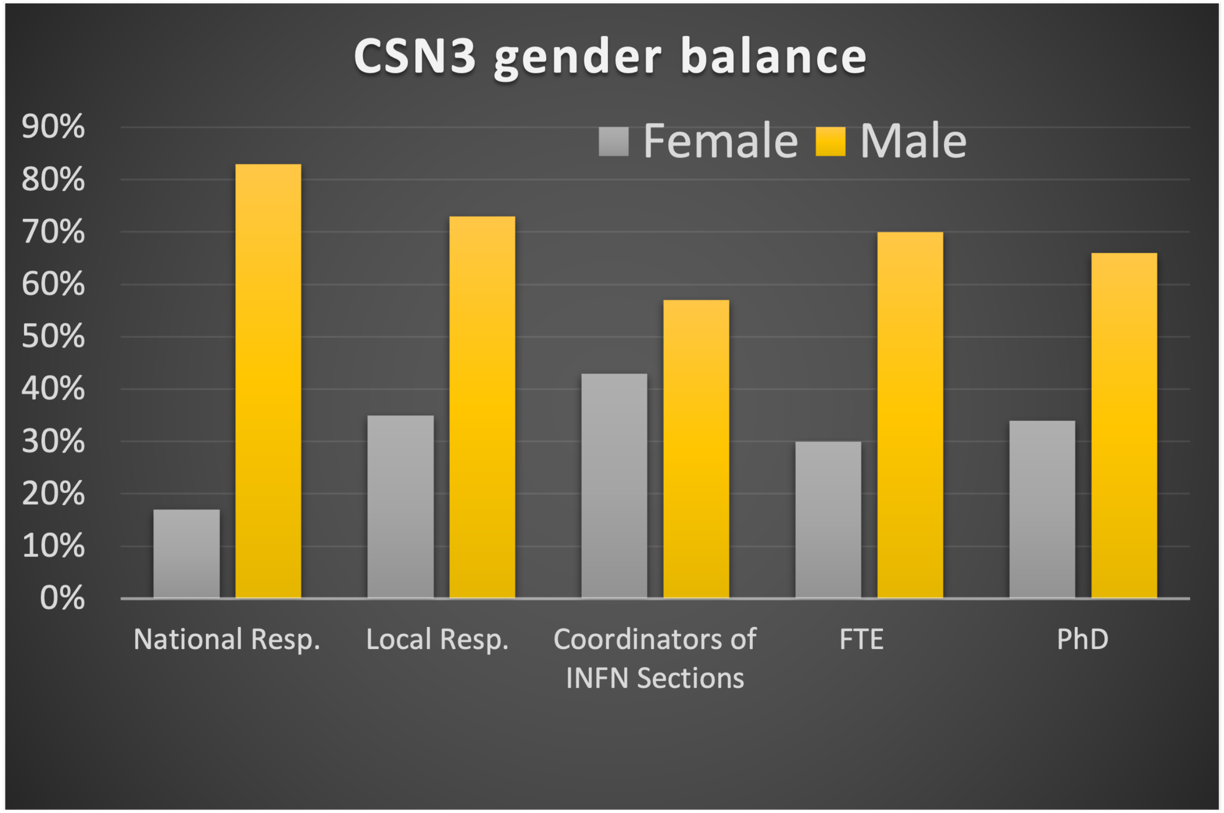


Commissione Scientifica Nazionale 3

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Talk at the ECFA roadmap





Commissione Scientifica Nazionale 3

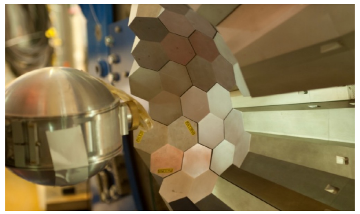
Ruolo	Numero	Uomini	Donne
Responsabili nazionali di esperimento	33	29 [88%]	4 [12%]
Responsabili locali di esperimento	118 (95 sedi)	88 [75%]	30 [25%]
Coordinatori	20	10 [50 %]	10 [50%]
Talks	322	209 [65%]	113 [35%]

The CSN3 experiments

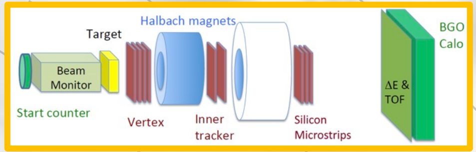
CSN3 experiments use different type of beams (stable or radioactive), from low to very high energies

LUNA

GAMMA

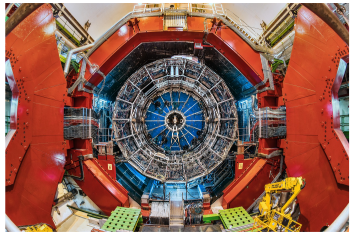


FOOT



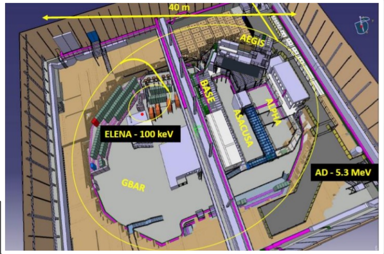
JLAB, MAMBO

ALICE



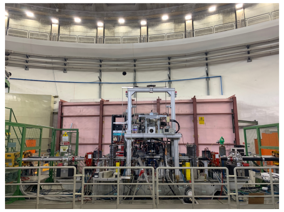
keV MeV GeV TeV

E_{beam}



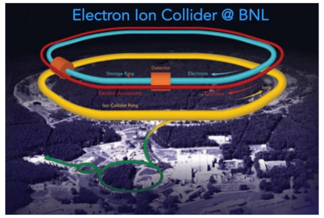
LEA

NUMEN, ASFIN2,NUCLEX, CHIRONE, FORTE…



SIDDHARTA

JEDI



EIC

Experiments and people

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

ALICE	CERN	QGP	7.9 FTE	A. Fantoni
FOOT	CNAO/TIFPA /LNS/BTF	Framm. Nucleare	2.1 FTE	E. Spiriti
JLab12	JLAB	Fisica adronica	2.1 FTE	M. Mirazita
BGOOD	Bonn/Mainz	Fisica adronica	1.2 FTE	P. Levi Sandri
	LNF	Fisica nucleare	14.5 FTE	C. Curceanu
	LNGS	Fisica nucleare	5.6 FTE	C. Curceanu
EIC_net	RHIC	Fisica adronica	0.1 FTE	M. Mirazita
nTOF	CERN	Astrofisica nucleare	3.0 FTE	F. Murtas

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FOOT

ALICE@CERN

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, management roles

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ALICE	Afferenza (%)
Nicola Bianchi	100
Emiliano Dane'	20
Alessandra Fantoni	100
Pavel Larionov	50
Valeria Muccifora	100
Silvia Pisano	100
Federico Ronchetti	100
Eleuterio Spiriti	10
Paula Fernanda Toledo Matuoka	50
Marco Toppi	100
Oton Vazquez Doce	70
FTE totali	8 (7)

ALICE@CERN

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

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Responsibilities at CERN

Management Board (AF, 11/2019-today)

Collaboration Board (VM, 06/2017-today)

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

Period Run Coordinator (AF, 2015)

Head of LS1 Consolidation ALICE Task Force (FR, 2013-2014)

Period Run Coordinator (FR, PDN, 2012)

EMCAL Deputy Project Leader (AF, 2013-today; NB, 2007-2012)

EMCAL/DCAL Euro-Asian Coordinator (AF, 2008-2012)

EMCAL System Run Coordinator (FR, 2011-2012)

EMCAL High Level Trigger Coordinator (FR, 2009)

ALICE Activities at LNF

ITS Upgrade production Local Technical Coordinator (FR, 2016-2019)

Physics Analysis Coordinator (SP, 2016-in carica)

EMCAL/DCAL production Local Technical Coordinator (AF, 2010-2011)

EMCAL production Local Technical Coordinator (FR, 2006-2009)

ITS Commissioning 2020 (shifts @CERN and remotely)

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

ALICE@CERN

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

2022

- ITS fully powered on and running stable at 202kHz in cosmic data taking and pilot collisions
- ITS online reconstruction and QC fully functional
- ITS ready for the rate ramp-up of RUN 3
- First collisions @450 GeV on mid May
- Stable beam @13.6 TeV on July 5°
- p-p data taking => manage preparation for Heavy Ion (software upgrade and commissioning) in parallel of pp operation
- Heavy Ion run from mid november to mid december 2022

2023

- ALICE data taking
- ITS QC offline and online checks
- discussions for analysis, papers, technical boards, management boards, collaboration boards

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ALICE

INFN
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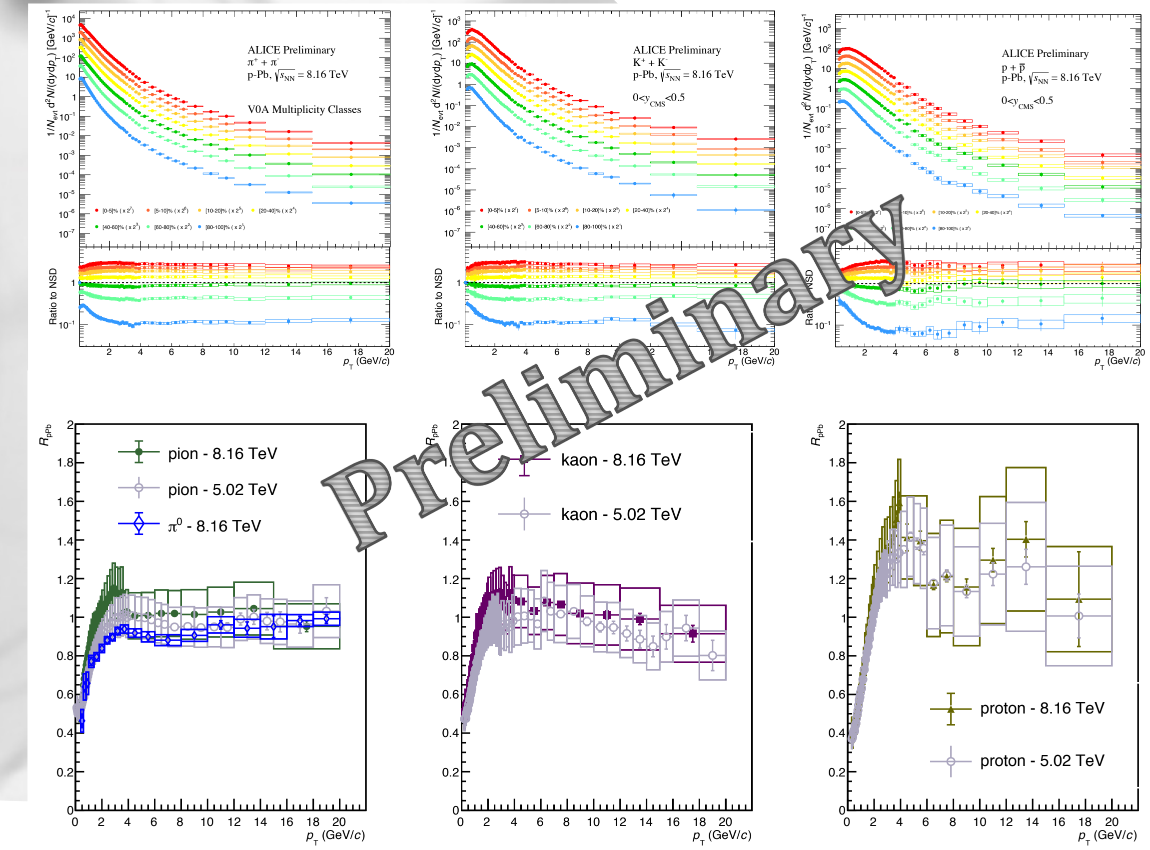
Data analysis activity

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, management roles

Light-flavour hadron production vs. multiplicity in pp and in p-Pb collisions with ALICE



ALICE@CERN

Fellini project by Otón Vázquez Doce

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, management roles

Femto-Strong: "**Antikaon-deuteron femtoscopic correlations with ALICE: A new era of hadron-hadron interaction measurements**" [Link to project pdf]

- Measurement of the K^--d correlation function in small collision systems with **Run2 (and Run3) ALICE data**
- **Joint-venture** with SIDDHARTA-2: Measurement of the antikaon-nucleon scattering parameters at threshold with SIDDHARTA-2, over threshold at low relative momentum with ALICE.

Fellini Fellow: Otón Vázquez Doce
Program delayed by 12 months due to pandemic
Duration of the fellowship: 28.5 months
1st June 2021 - 15th October 2023
Supervisors:
- ALICE: Alessandra Fantoni (main responsible + administrative duties)
- SIDDHARTA-2: Catalina Curceanu

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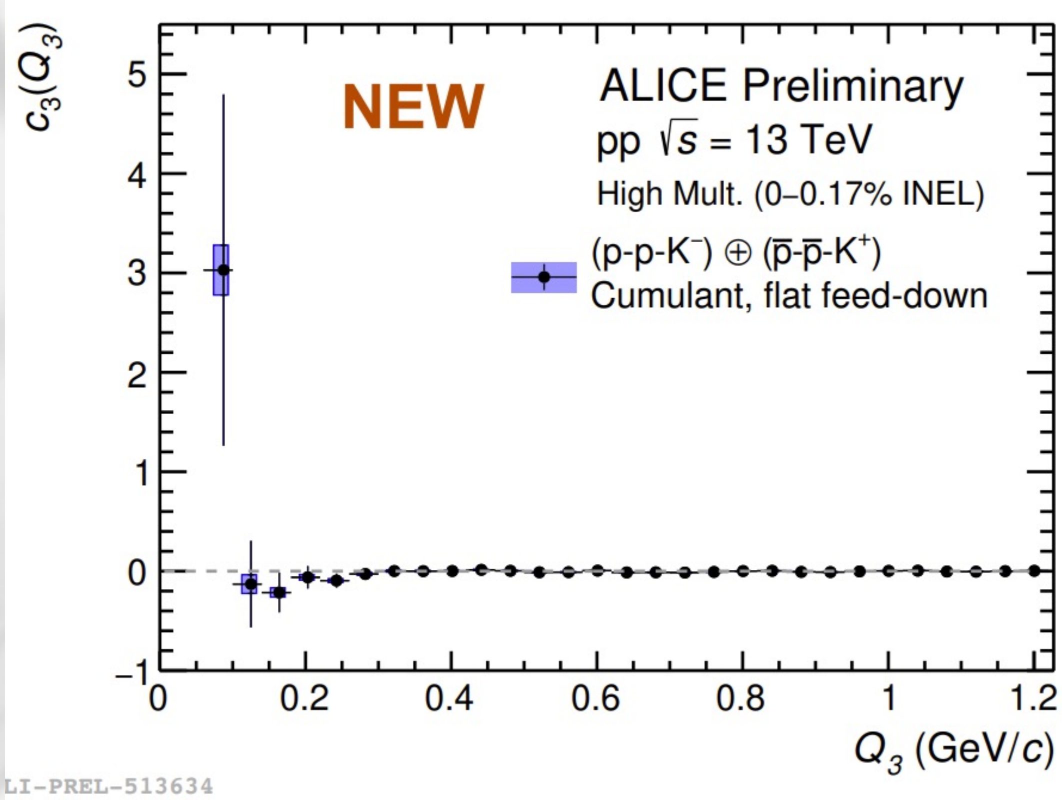
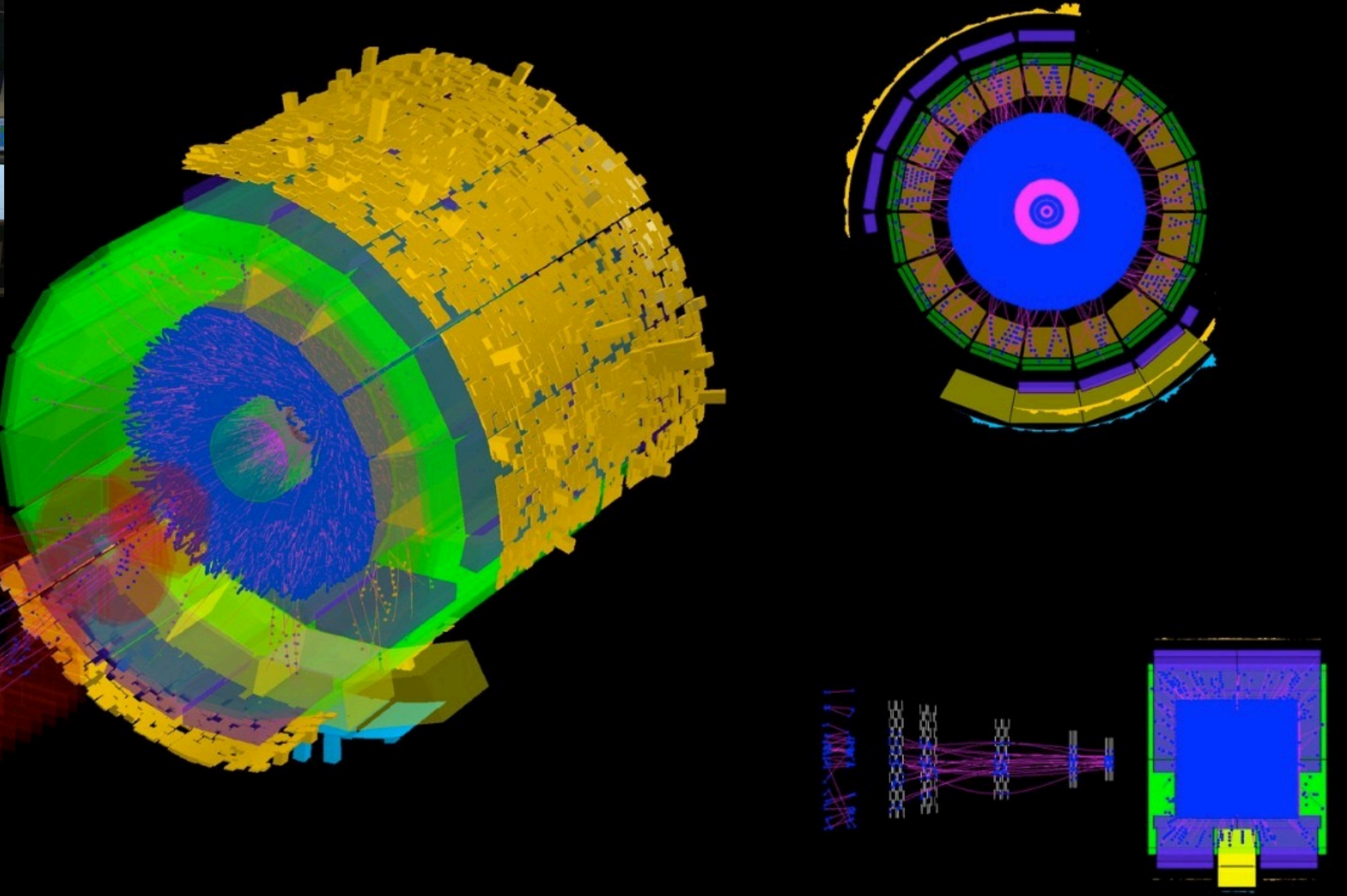
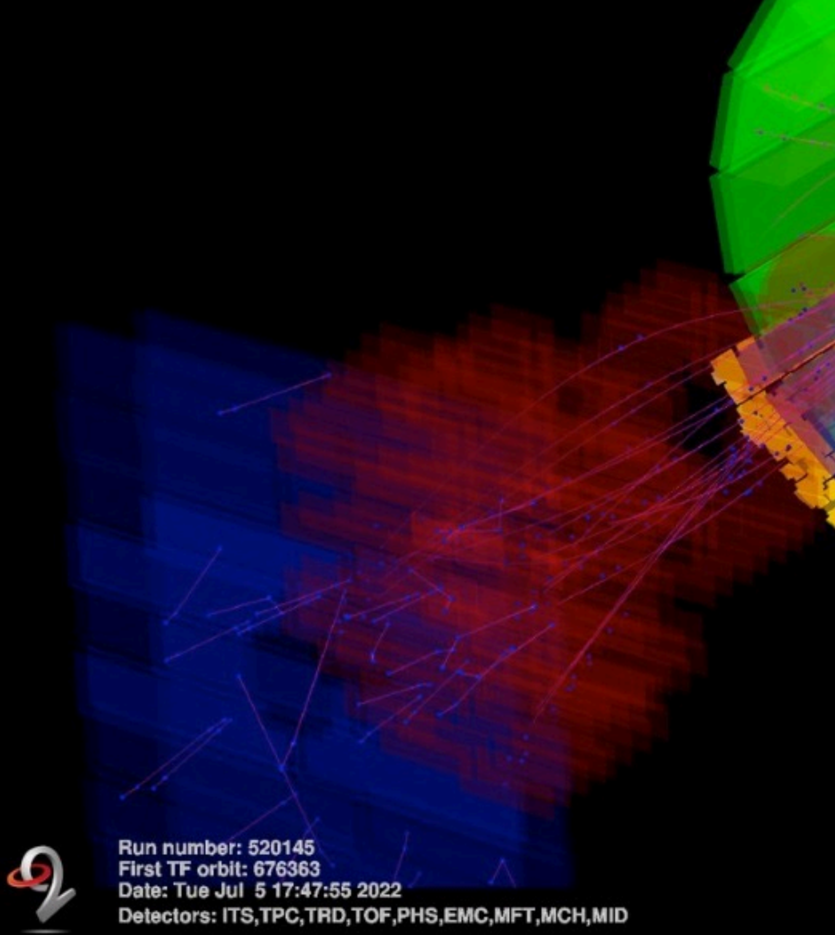
1. **Analysis finalized: AN https://alice-notes.web.cern.ch/node/1256** Paper proposal at Physics Forum 29-July-2022 accepted.
2. Analysis in advanced stage. Presentations at Femtoscopy PAG in June: *p-d: https://indico.cern.ch/event/1088099/; K+-d: https://indico.cern.ch/event/1088100/*



More details in backup slides


ALICE Control Room
Federico Ronchetti
ALICE Run Coordinator
#LHCRun3




Run number: 520145
First TF orbit: 676363
Date: Tue Jul 5 17:47:55 2022
Detectors: ITS,TPC,TRD,TOF,PHS,EMC,MFT,MCH,MID

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FOOT

Quarks and hadron dynamics

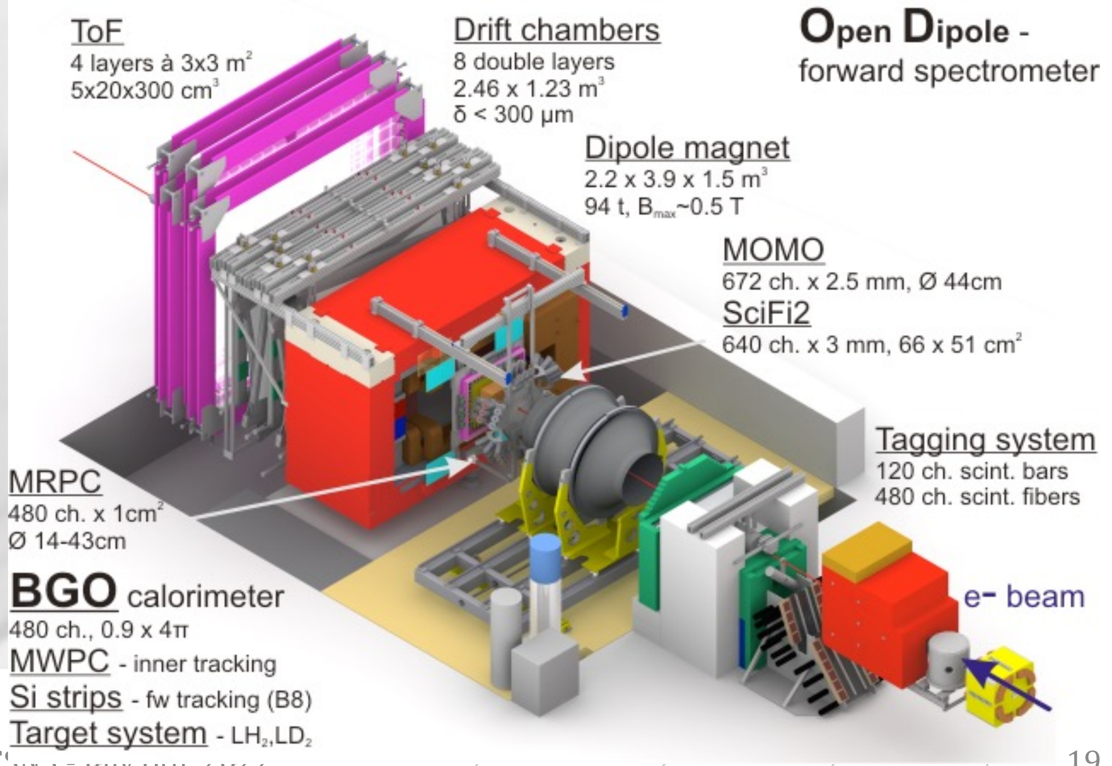
Study of the quark dynamics inside hadrons and nuclei, to understand the strong interaction, searching for effects beyond those predicted by QCD.

- 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?

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

- Transition form factor
- η' threshold anomaly

- BGO (+ Roma2)
- Barrel (+ ISS)
- MRPC (+ Roma2)



Quarks and hadron dynamics

CSN3 Fisica Nucleare

BGOOD

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

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- Transition form factor
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- BGO (+ Roma2)
- Barrel (+ ISS)
- MRPC (+ Roma2)

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

1. Tutti i rivelatori INFN (Calorimetro Barrel MWPC) sono funzionanti tranne MRPC: *final commissioning* in collaborazione con Bonn PI
2. MonteCarlo in continuo sviluppo, generatore di eventi (LNF/Messina/Roma2).
3. Co-spokesperson dell'esperimento BGOOD (LNF)
4. Spokesperson della misura di fotoproduzione η (LNF)
5. Spokesperson fotoprod. su neutrone (RM2)
6. Rappresentante nazionale (LNF)

2020 nessuna presa dati
2021 una presa dati (3 settimane)

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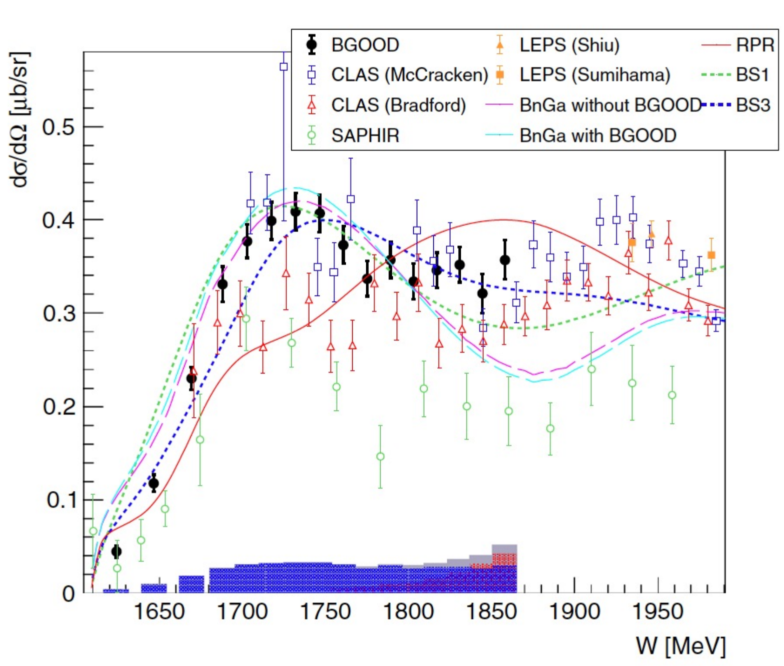
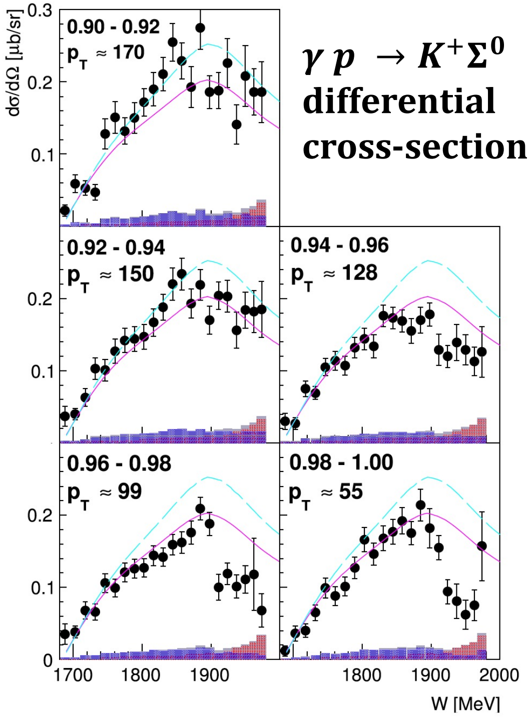
$\gamma\, p \;\to K^+\Lambda$ differential cross-section



Eur. Phys. J. A (2021) 57:80

$\gamma\, p \;\to K^+\Sigma^0$ differential cross-section



Physics Letters B 820 (2021) 136559

Quarks and hadron dynamics

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- ELSA ha ripreso il normale funzionamento per esperimenti di fisica adronica
- 2022: richieste 1500 ore di beamtime per completare la raccolta dati su bersaglio di idrogeno e di deuterio.
- I colleghi russi sono ovviamente indisponibili (30% della collaborazione!)➞ verranno diminuite le ore di fascio richieste ~ 1000
- Si apre una nuova linea di ricerca per la fotoproduzione coerente su deuterio (un lavoro già inviato a PLB)

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

- Nessuna richiesta ai servizi, salvo imprevisti

Quarks and hadron dynamics

Istituto Nazionale di Fisica Nucleare
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CSN3 Fisica Nucleare

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

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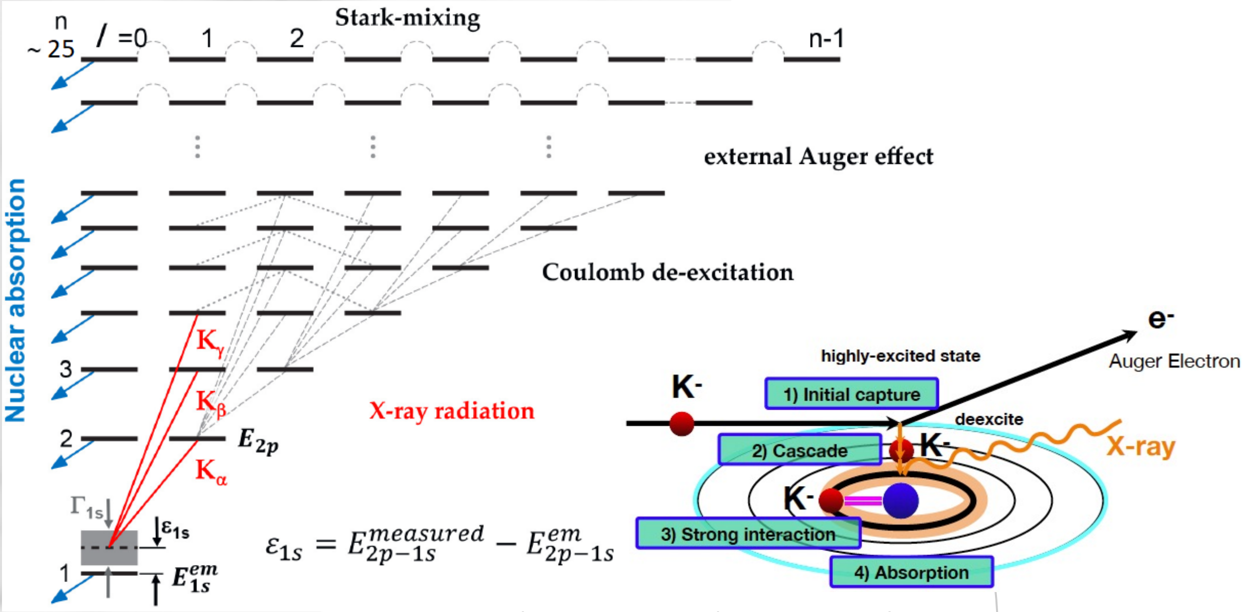
Precision measurement of the shift and of the width of the 1*s* level of kaonic deuterium and of other types of kaonic atom X-ray transitions → unique info about the QCD in non-perturbative regime in the strangeness sector not obtainable otherwise; impact in astrophysics (EOS neutron stars).



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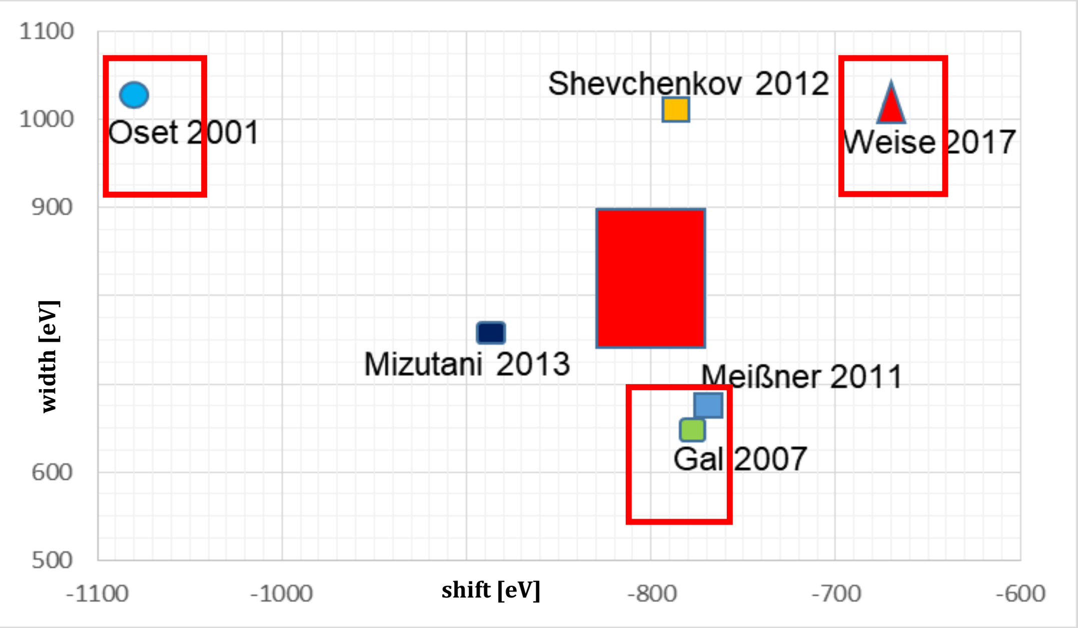

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Integrated initiative (SIDDHARTA + AMADEUS + Giappone + Future)

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

KAONNIS	Afferenza (%)
Massimiliano Bazzi	10
Damir Bosnar	50
Alexandru Mario Bragadireanu	100
Alberto Clozza	40
Catalina Oana Curceanu	55
Sultan Dabagov	10
Luca De Paolis	100
Raffaele Del Grande	50
Carlo Guaraldo	
Mihail Antoniu Iliescu	100
Aleksander Khreptak	50
Paolo Levi Sandri	20
Marco Merafina	60
Catia Milardi	10
Marco Miliucci	60
Fabrizio Napolitano	20
Szymon Niedwiecki	50
Alessandro Scordo	75
Francesco Sgaramella	100
Hexi Shi	50
Diana Laura Sirghi	50
Florin Catalin Sirghi	100
Magdalena Skurzok	50
Antonio Spallone	80
Marlene Tüchler	50
Oton Vazquez Doce	30
Johann Zmeskal	50
FTE totali	14.2

CSN3 Fisica Nucleare

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22 Publications (2021-2022)

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

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

Events (2020-2021)
Workshop: Investigating the Universe with exotic atomic and nuclear matter, online LNF-INFN, 28-30 September 2020.
STRANU Workshop ECT*: 24-28 May 2021

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

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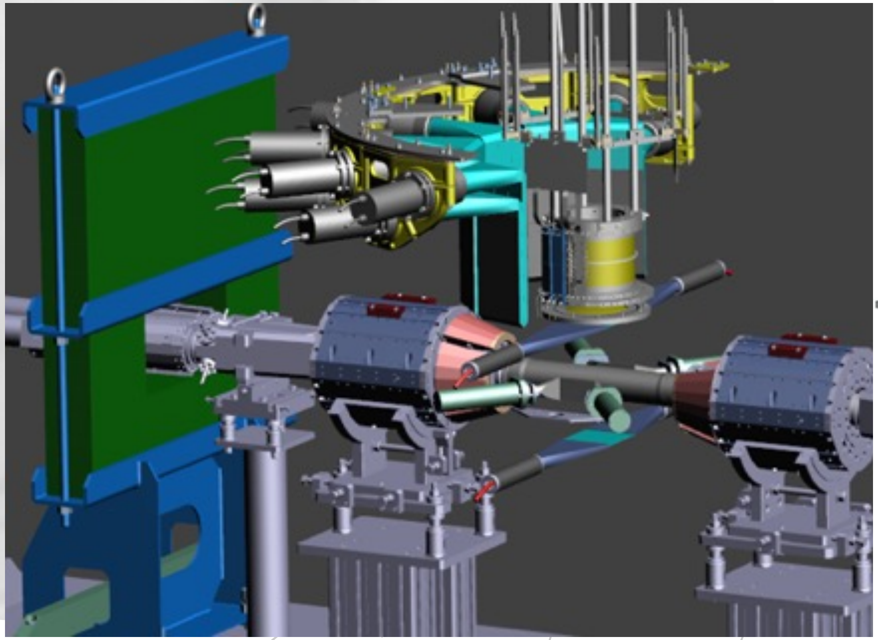
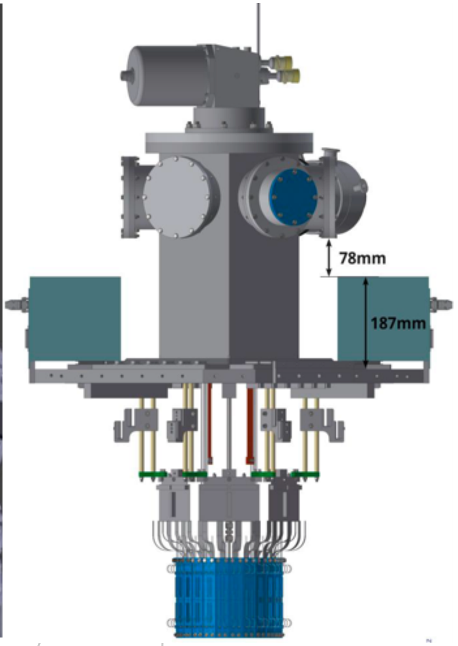
PHASE 1: during the commissioning of DAΦNE an optimization with the SIDDHARTINO setup for the K-4He measurement (with 8 SDD arrays) was performed. Optimization of S/B.





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PHASE 1 outcome: optimization of degrader & the most precise measurement of kaonic helium transitions to 2p level in gas: *"A new kaonic helium measurement in gas by SIDDHARTINO at the DAΦNE collider"*

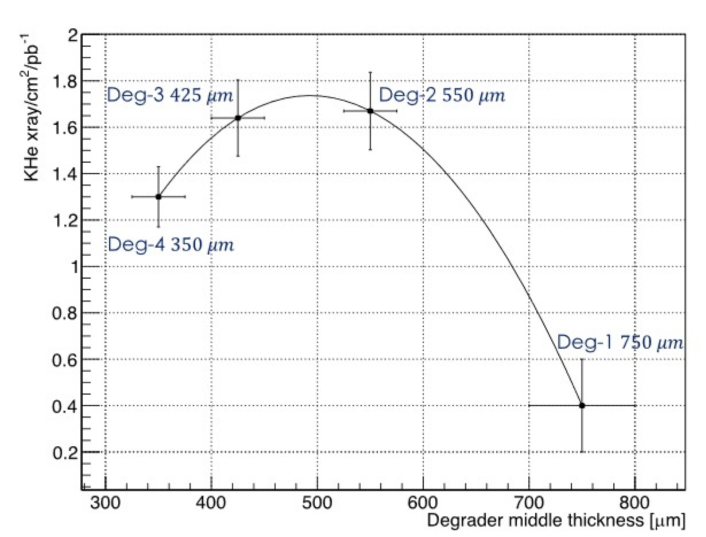

Figure 5. Degrader optimization curve: the horizontal axis is the central thickness and the vertical one the corresponding $K^4He(3d \rightarrow 2p)$ signal normalized by integrated luminosity and effective detection surface.

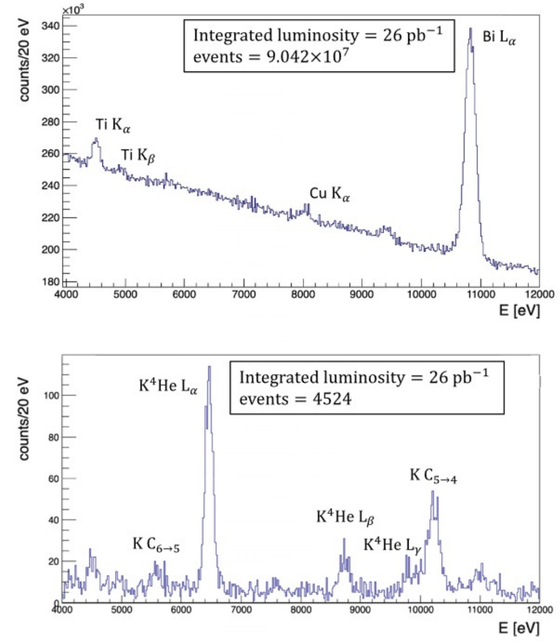

Figure 4. Spectra without (top) and with (bottom) KT selections, from which the $\simeq 10^5$ rejection factor can be obtained (bottom). See text for details.

Quarks and hadron dynamics

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

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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
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- how does the spin of the nucleon arise?
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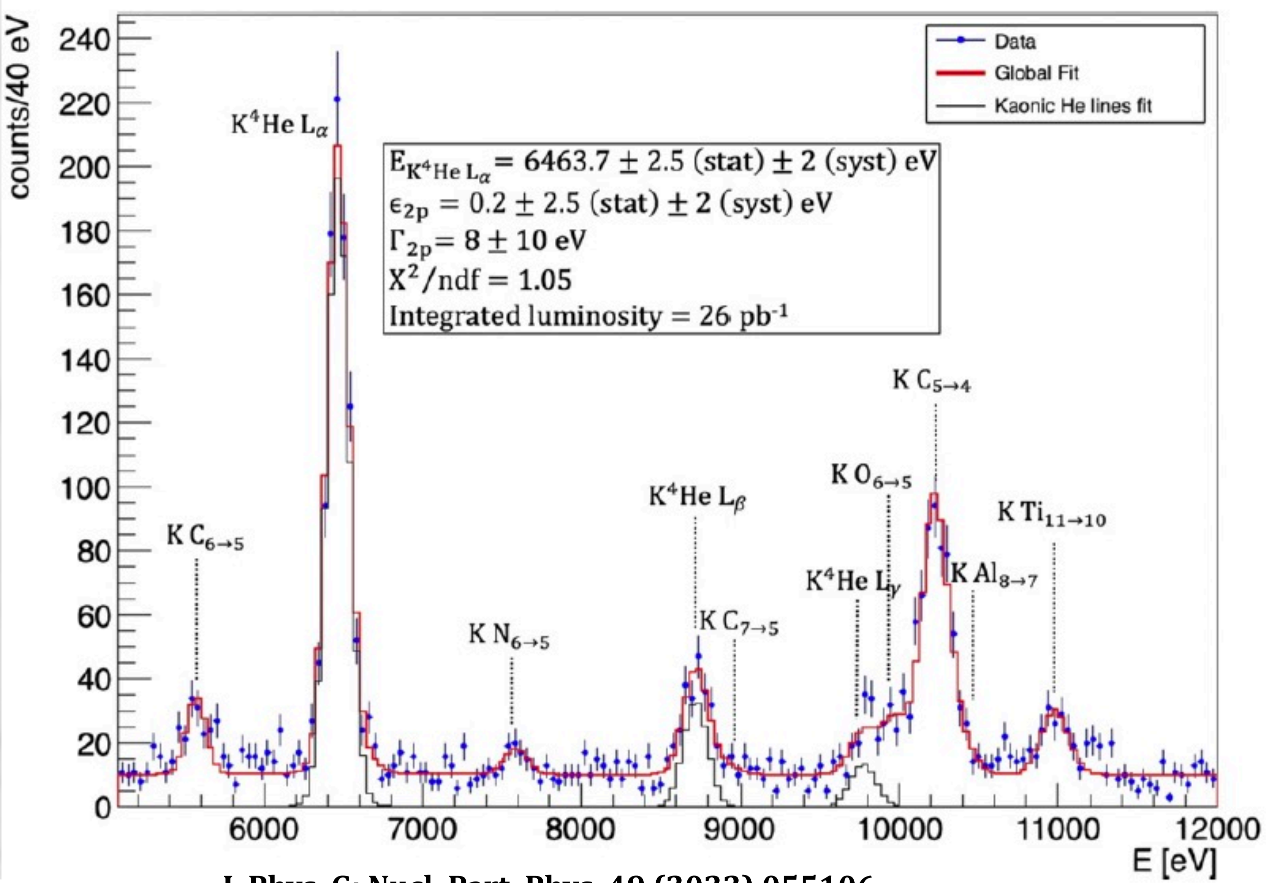

J. Phys. G: Nucl. Part. Phys. 49 (2022) 055106

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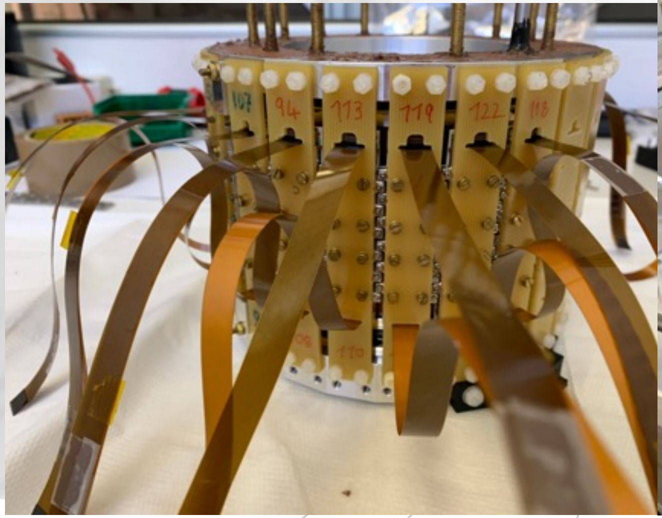
PHASE 2: Installation of SIDDHARTA-2

- SDD detectors
- Veto-2
- Front-end electronic
- Veto-1



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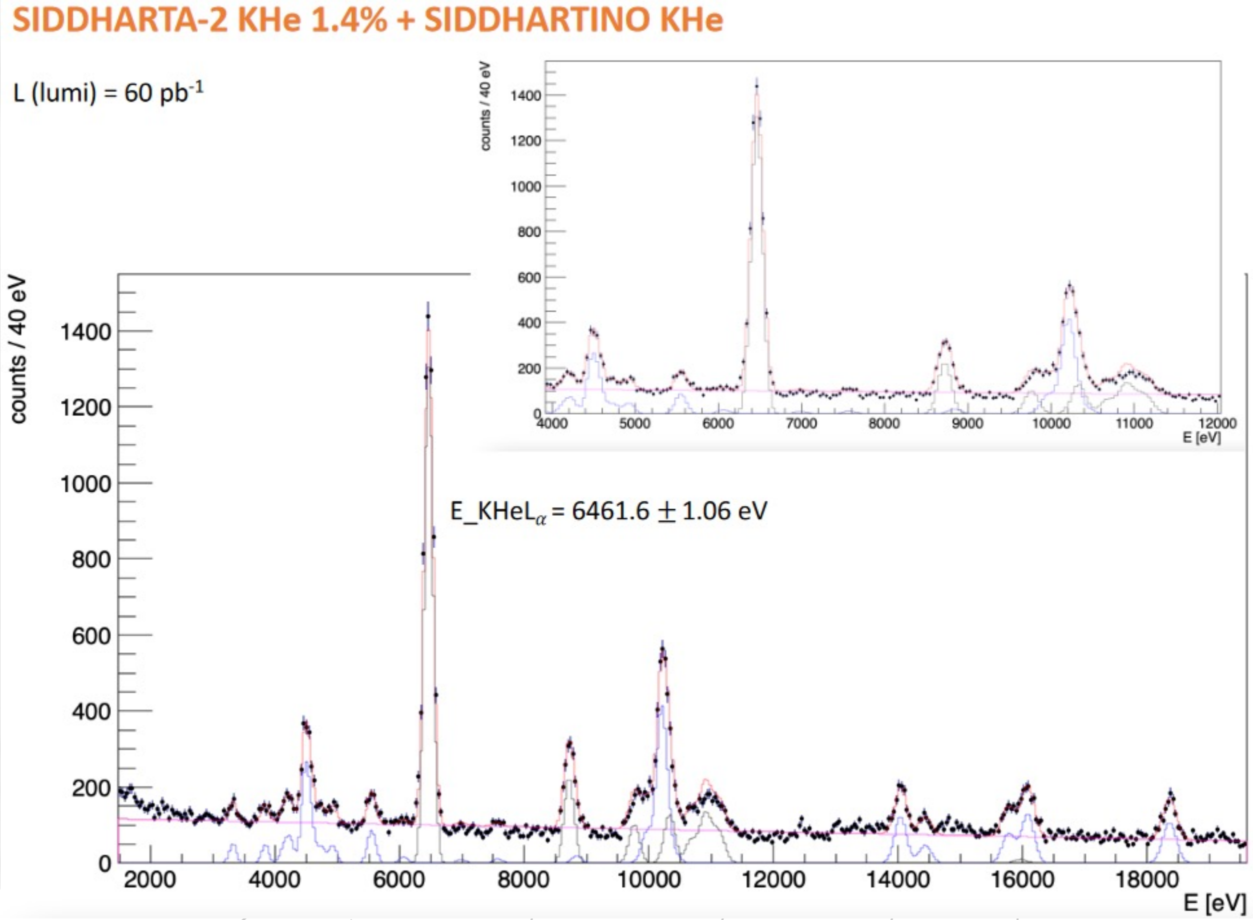

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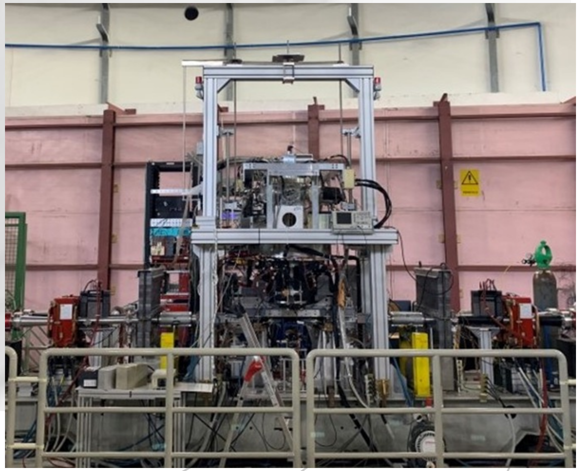
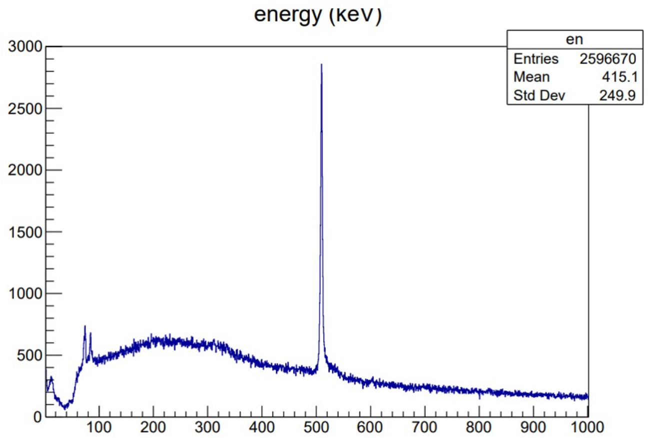
Phase 2 with SIDDHARTA-2 (48 SDDs KD): full setup installed on DAFNE within October 2021
Characterization of the SIDDHARTA-2 setup with kaonic helium (few days in December 2021, then from April to May 2022) – even more precise KHe measurement (+KAl) -> 2 publications in preparation
Run with kaonic deuterium started June 2022 – till 11th July 2022 (Phase 1 of Kd run)
In parallel with SIDDHARTA-2 Kd measurement: feasibility tests for future measurements with 1 mm SDD; Ge; CdZnTe and VOXES detectors: future dedicated measurements



First HPGe spectrum (we plan a technical paper)



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Quarks and hadron dynamics

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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Richieste ai servizi

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	40	15	70	150

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

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
Probability of PEP violation b2/2<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 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
Sergio Bartalucci	
Massimiliano Bazzi	35
Maurizio Benfatto	60
Alberto Clozza	10
Catalina Oana Curceanu	20
Carlo Guaraldo	
Antonino Marcianò	50
Johann Marton	
Marco Miliucci	40
Fabrizio Napolitano	80
Elisabetta Pace	55
Kristian Piscicchia	100
Diana Laura Sirghi	50
FTE totali	5.5

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1. VIP-2 version 1 with 6 SDDs (SIDDHARTA type) installed at LNGS end of 2015 – data taking (no shielding) till end of 2017 (**Eur. Phys. J. C (2018) 78: 319**)
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 (Cu and Pb) installed in November 2018 – **data taking ongoing** (with and without current) thanks to the slow-control remote system
4. Optimization of the shielding ongoing (MC, veto system); strategy of data taking optimization

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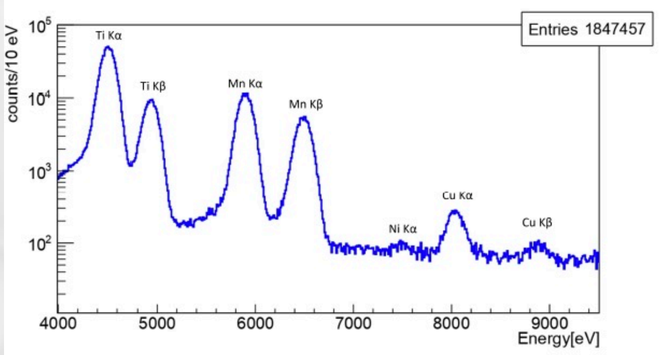

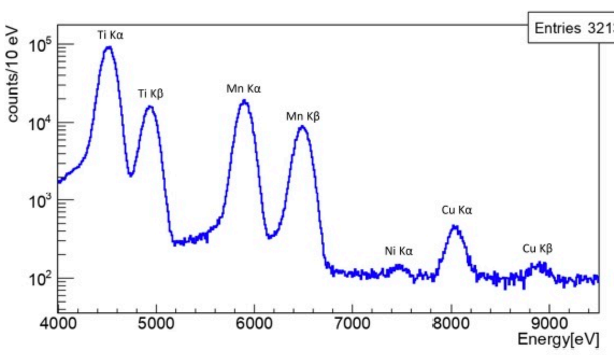

Spectra collected with the SDDs installed in the VIP-2 experiments, in partial shielding configuration (lateral walls).

Left: 40 days of data collected with 100 A DC circulating on target
Right: 61 days of data collected with 0 A circulating on target

Copper lines: from the target
Titanium and manganese lines: from the Fe-55 radioactive source, installed in the apparatus for detectors calibration.
Nickel line: from the detectors' ceramic support.

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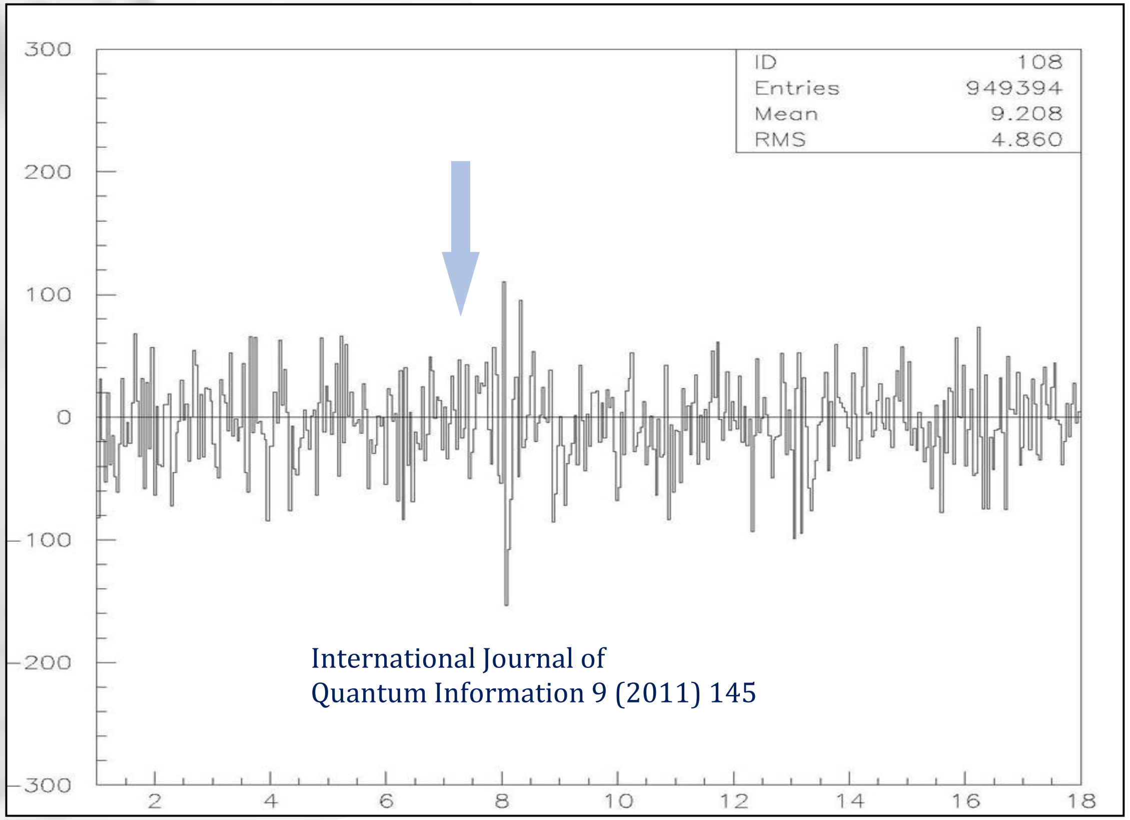
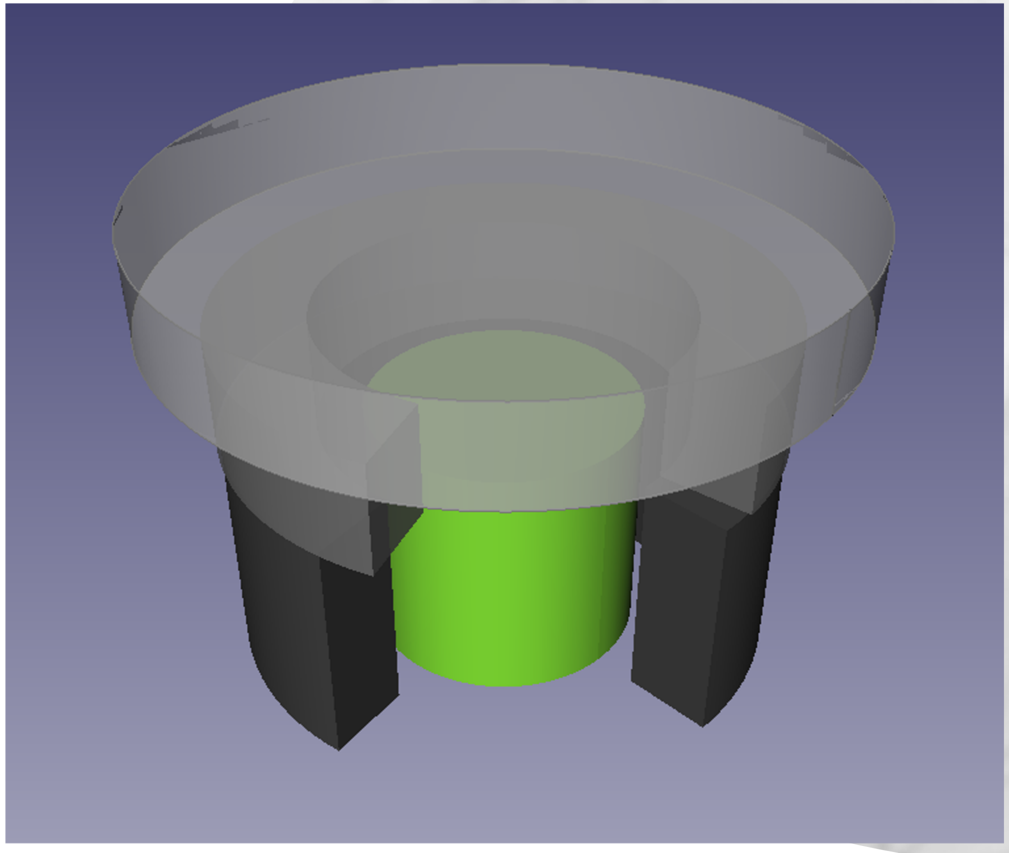


VIP Lead



High purity Ge detector measurement (M. Laubenstein):

- Ge detector surrounded by roman lead target + complex electrolytic Cu + Pb shielding
- 10B-polyethylene plates reduce the neutron flux towards the detector
- shield + cryostat enclosed in air tight steel housing flushed with nitrogen to avoid contact with external air (and thus radon)

θ-Poincaré Non Commutative Quantum Gravity model excluded for the first time above the Planck scale.

Publications:

1 - "Strongest atomic physics bounds on Non-Commutative Quantum Gravity Models", *submitted to Phys. Rev. Lett.*

2 - "Experimental test of Non-Commutative Quantum Gravity by VIP-2 Lead", *submitted to Phys. Rev. D*

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Plans and requests

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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
- nalysis of the data collected with BEGe detector
- Studies in Frascati laboratory of a possible setup to test anisotropy effects – quantum-gravity tests

CSN3 Fisica Nucleare

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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), <u>for which experimental measurements are absent in the energy range used in hadrontherapy</u> (100-300 MeV/nucleon).

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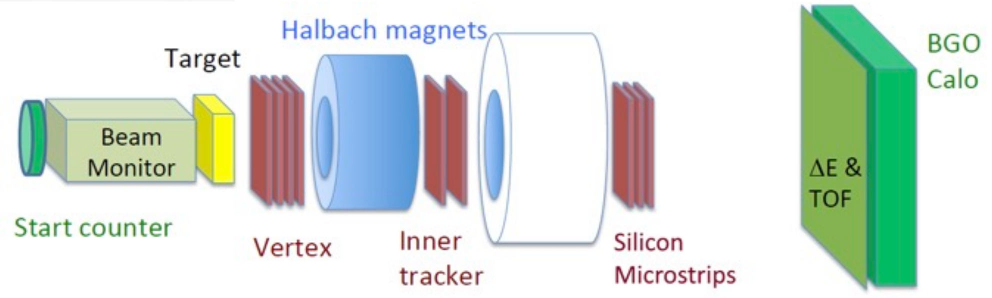

Fixed target experiment: the beams of interest, with an energy of hundreds of MeV, impinge on a material representative of the human tissue (mainly hydrogen, carbon and oxygen) and the produced fragments are detected and measured by a multi-purpose detector

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

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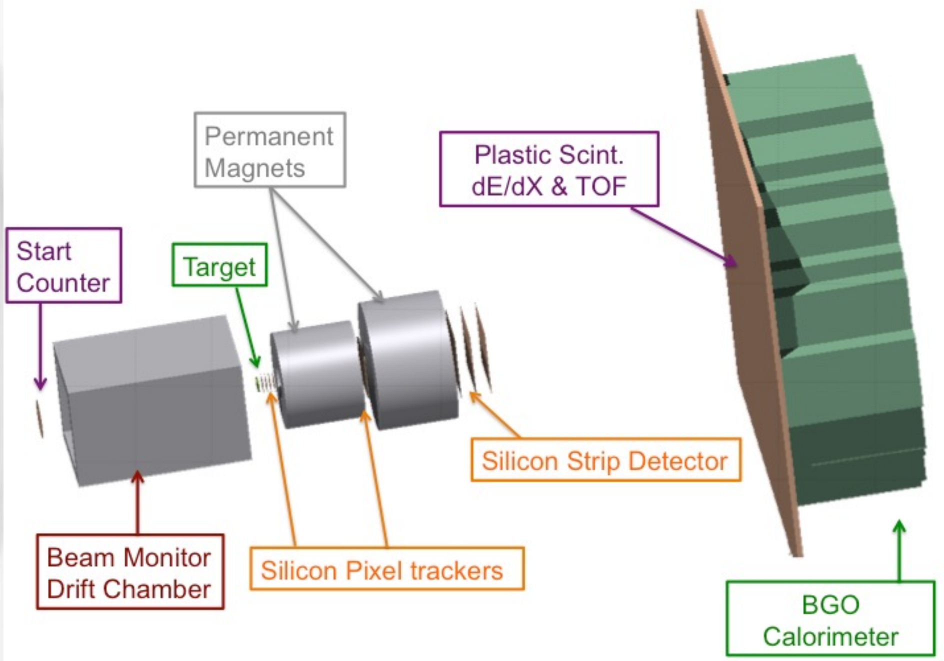

@LNF:
1. vertex tracker
2. inner tracker
3. mechanical support

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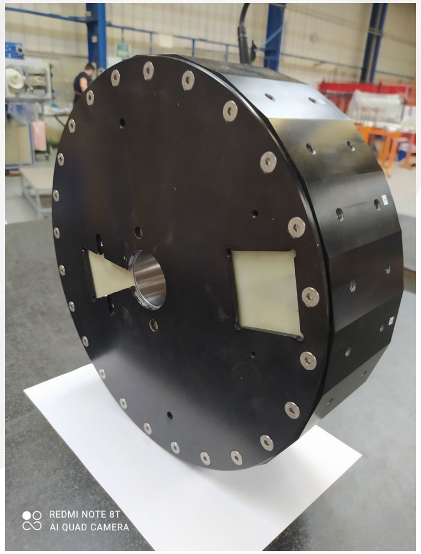
- Front faces not flat (**as it should be**), up to 5 mm of swellingUp to 4 kN repulsion internal forces
- Several magnet elements broke during assembly
- Magnet fragments between the two internal planes of magnet material
- Disassembly and reassembly option not workable (brittle elements)



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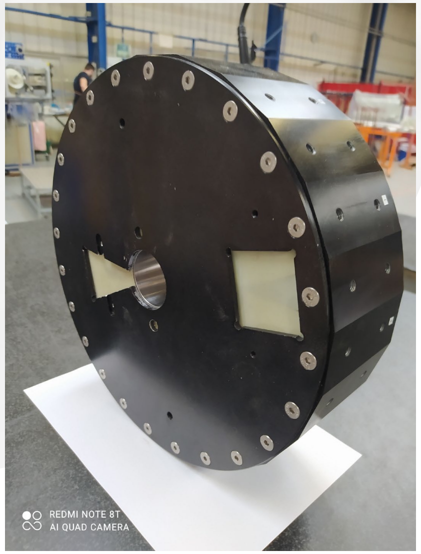
- The firm decided to restart the entire project from scratch, changing the magnetic material to NdFeB.
- No additional cost for us, just delays.
- They started from scratch both the magnetic and mechanical design.
- We have now weekly meetings with Sigma-Phi to follow the development. People involved: M. Villa (Bo), A. Moggi (Pi), S. Tomassini (LNF), L. Sabbatini (LNF) and E. Spiriti.



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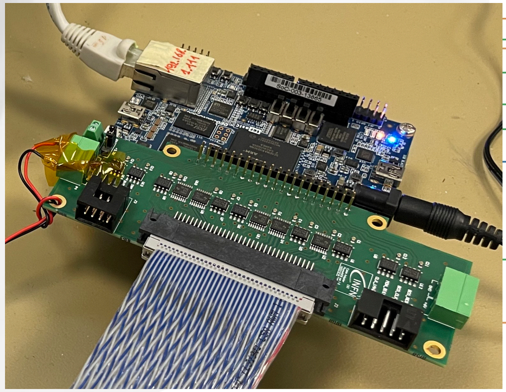
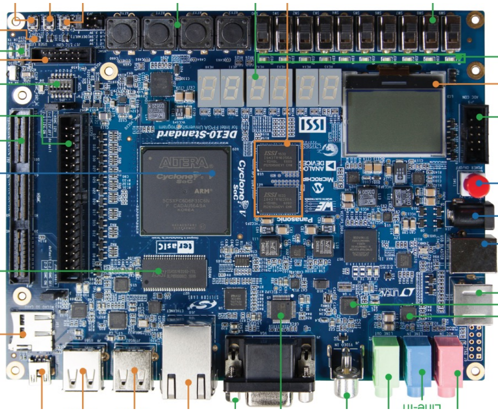
Replacing the 68 pin connector on the Cable_adapter_PlumeM28 with two of the 40 pin connector to the Ultimate_boards.
NEW: **Cable_adapter_Ultimate** board (2 needed to read the Vertex). Two **Cable_adapter_Ultimate** are read out by one Terasic DE0nano-SoC.
Same hardware and software (VTX and IT) interface to the general daq system!



IT Cable_adapter_board and DE0nano Terasic board



Terasic DE10 SoC - Vertex DAQ: FPGA firmware + Read Out

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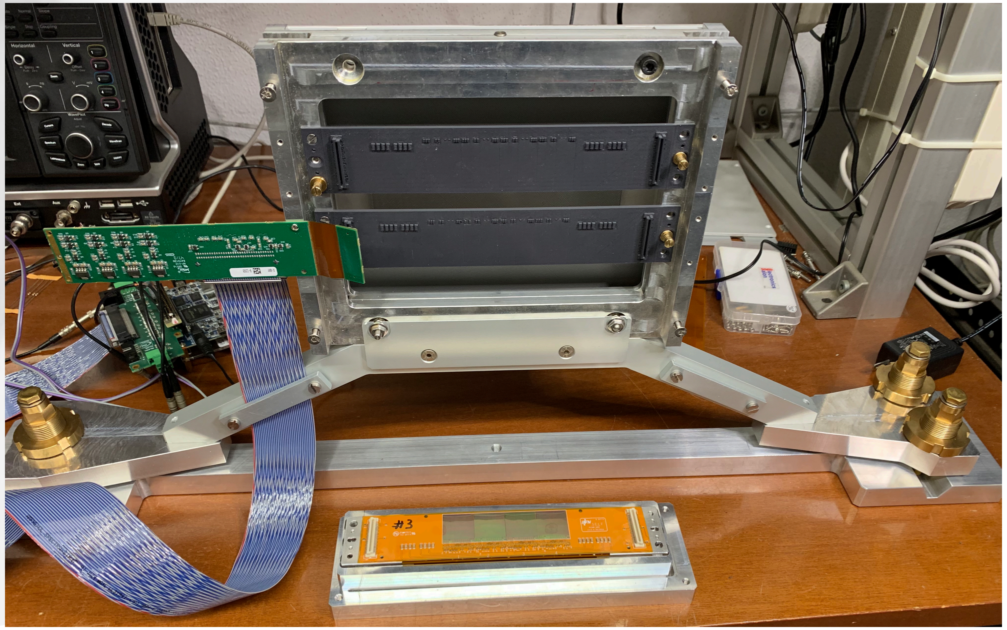
Inner Tracker mechanical compatibility checks under way



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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
Claudio Sanelli	
Adalberto Sciubba	
Eleuterio Spiriti	60
Sandro Tomassini	10

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), <u>for which experimental measurements are absent in the energy range used in hadrontherapy</u> (100-300 MeV/nucleon).

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.

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

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

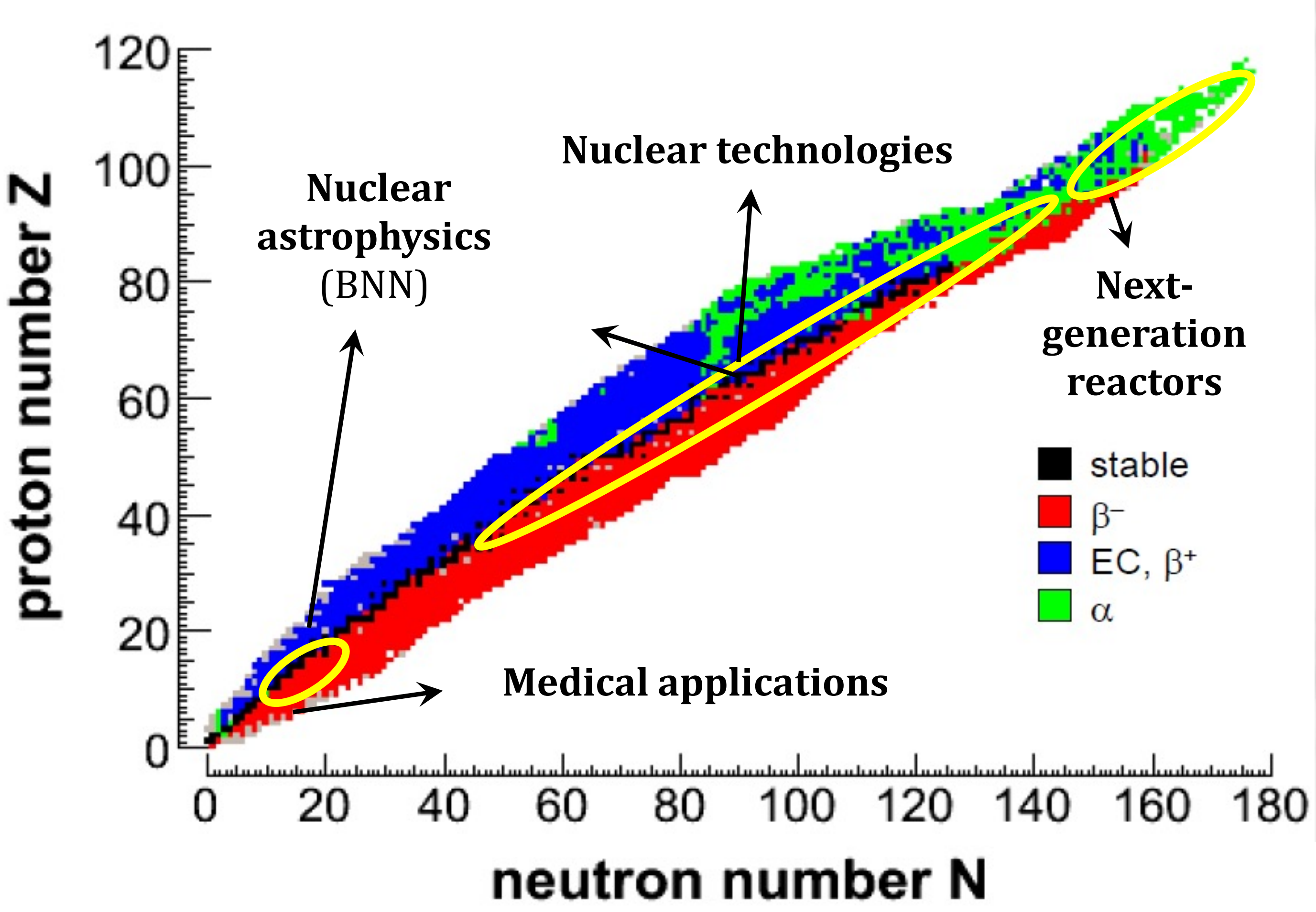
5. FUNDAMENTAL INTERACTIONS

LEA, ALPHA, JEDI, VIP, FAMU

6. APPLICATIONS AND SOCIETAL BENEFITS

FOOT

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



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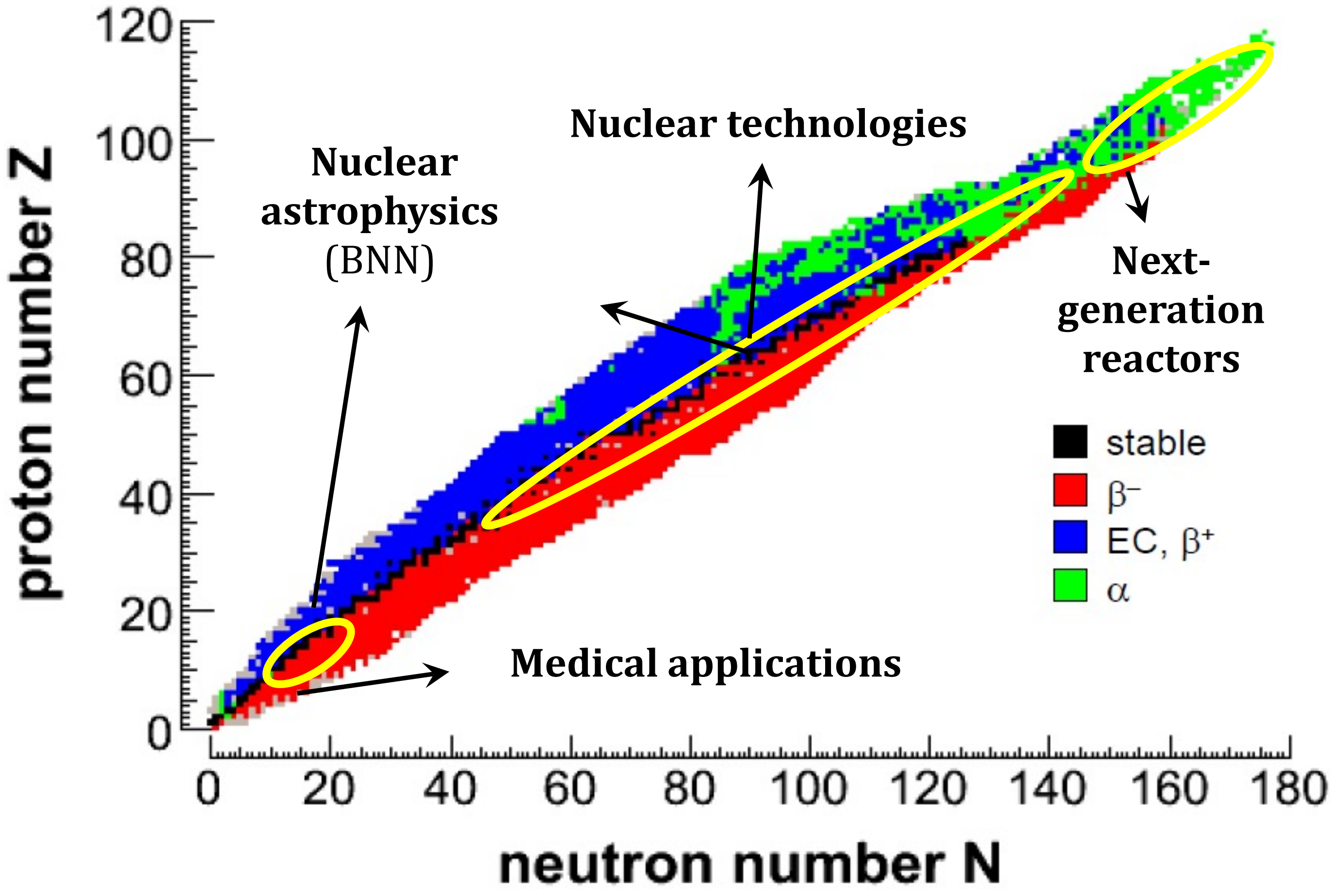
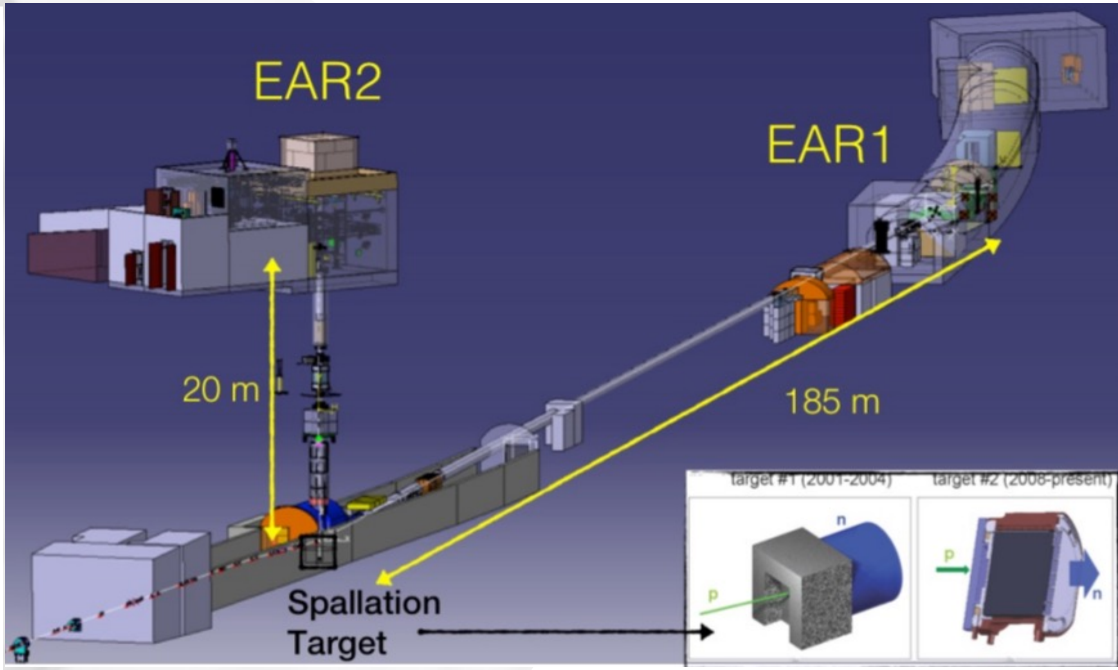
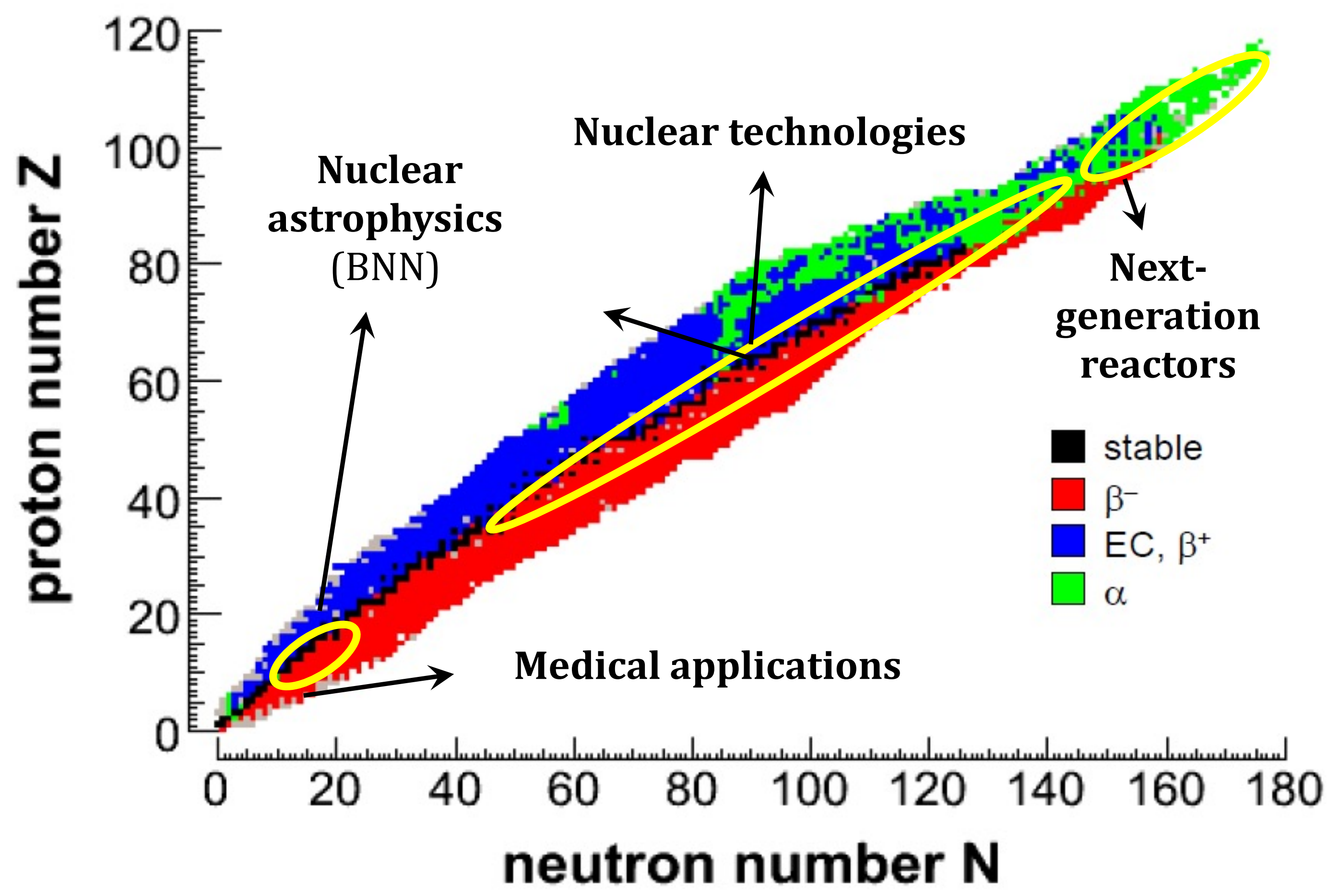
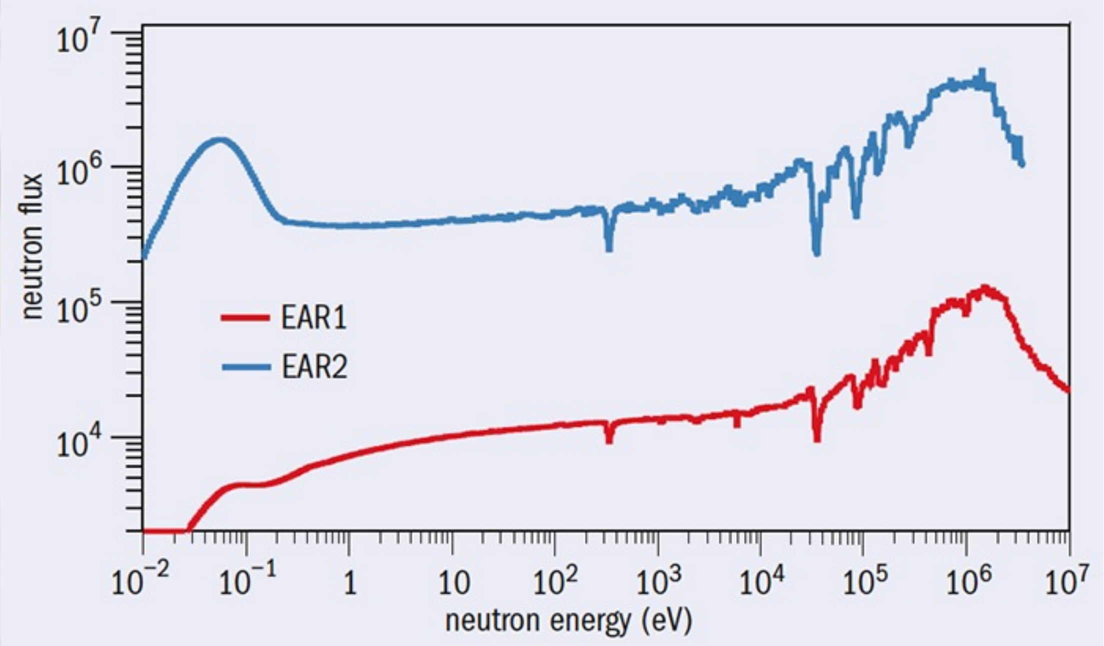




→ select neutrons with E_{kin} from few meV to GeV, via time of flight measurements

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





@LNF

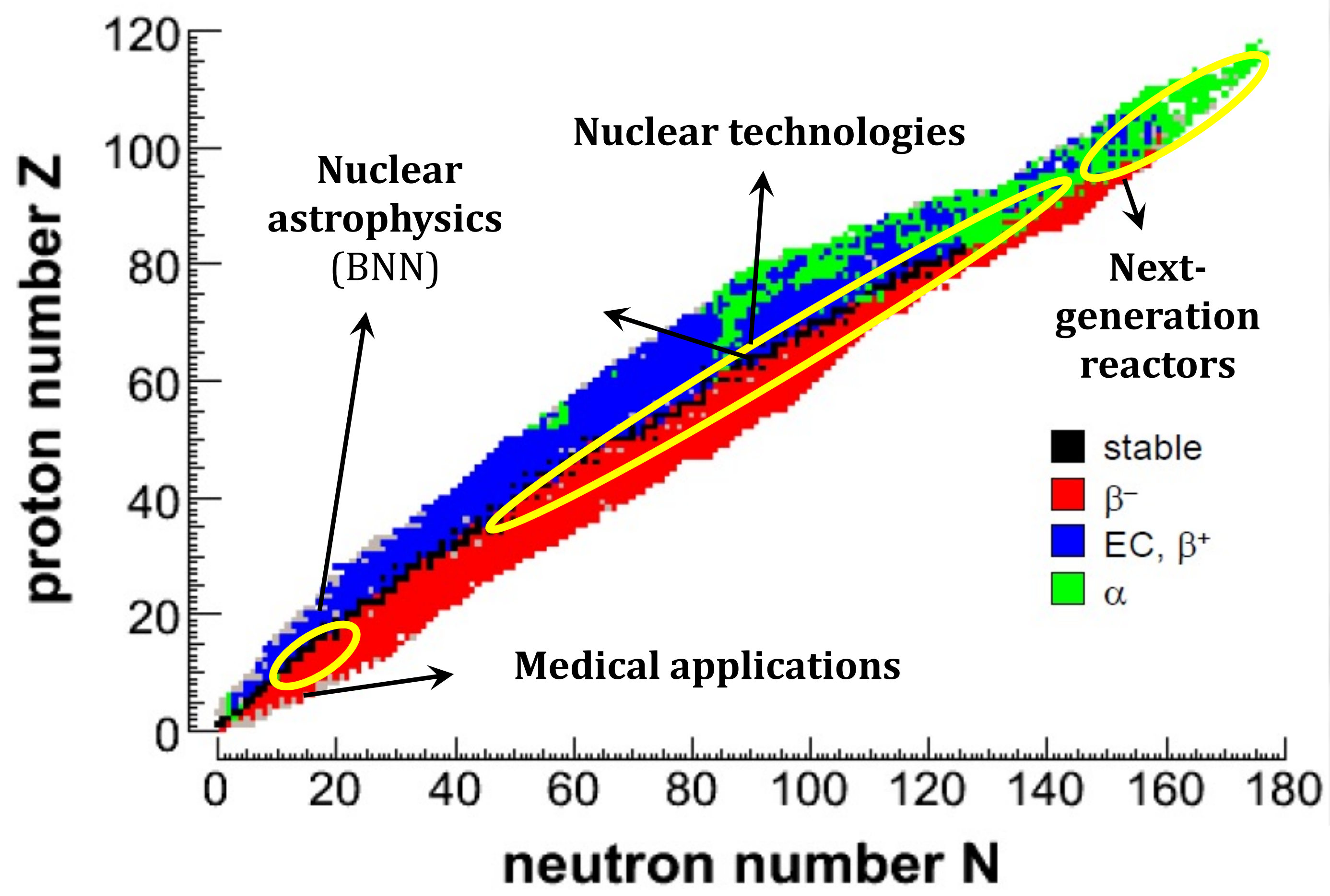
- Beam monitor (area beam dump)
- New neutron detectors based on GEM (Beam4Fusion)

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

CSN3 Fisica Nucleare

nTOF

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati



LNF contribute to nToF activities with GEM, Timepix and Timepix3 technology

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

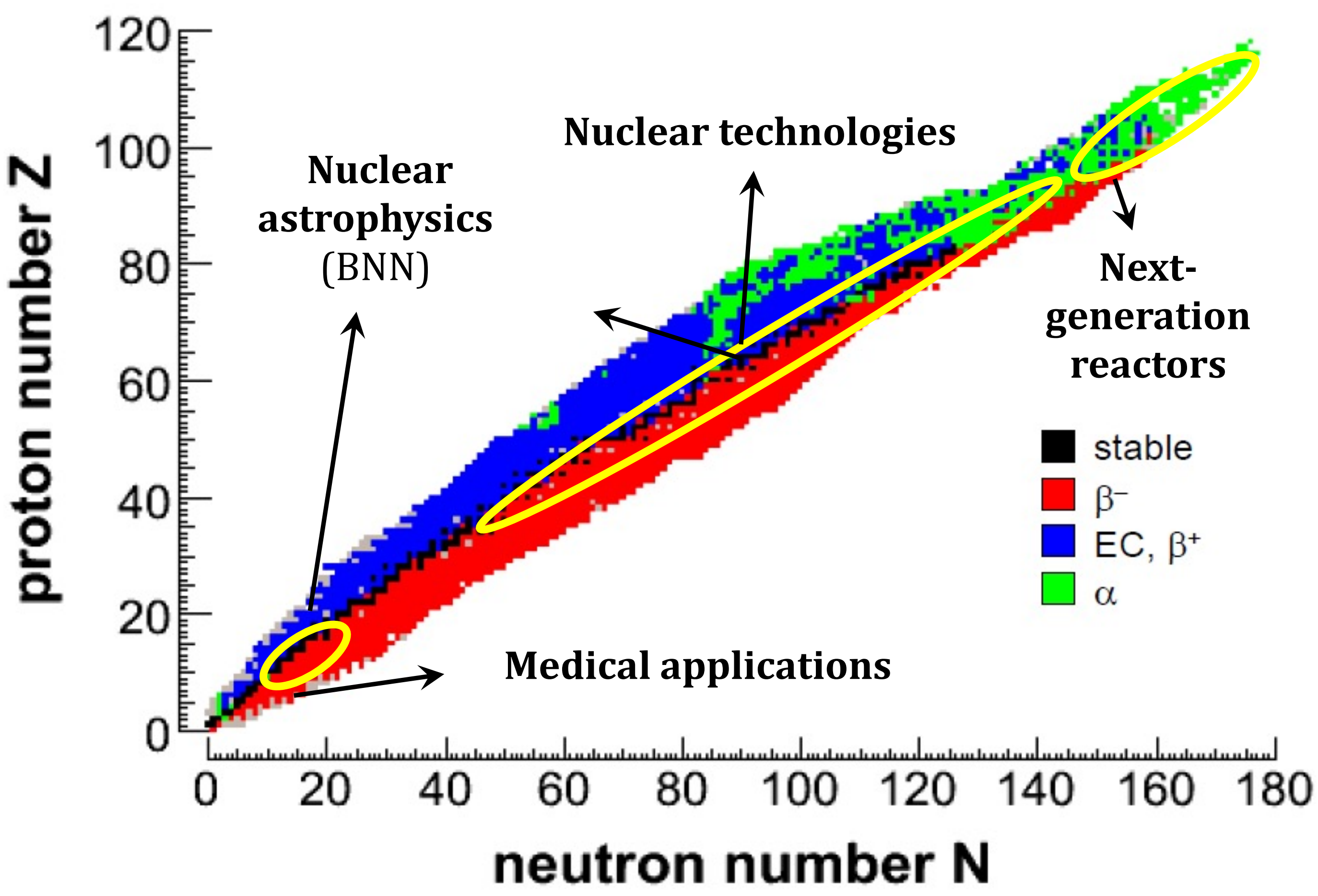
Test of new detectors for measurements of (n,cp) reactions in EAR1 and EAR2 at n_TOF

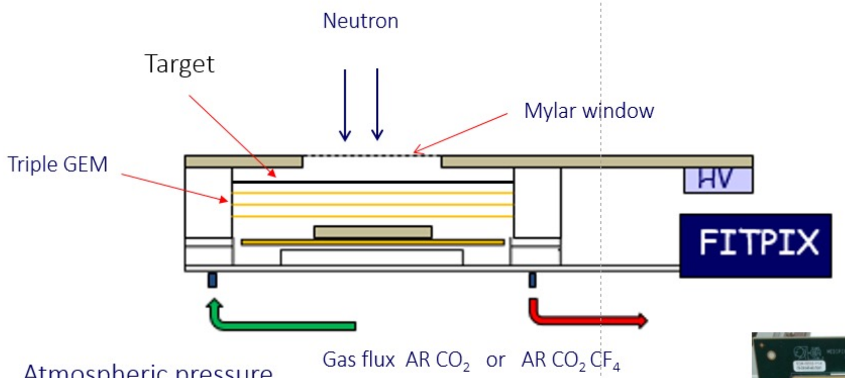
L. Cosentino[1], F. Murtas[2,3], S. Amaducci[1,3], M. Mastromarco[4], G. Lovecchio[1], P. Finocchiaro[1], N. Patronis[5], S. Goula[5], A. Mengoni[3], C. Massimi[6], A. Mazzone[4], N. Colonna[4]

1 INFN - Laboratori Nazionali del Sud, Catania, Italy
2 INFN - Laboratori Nazionali Frascati, Frascati, Italy
3 CERN
4 INFN - Sezione de Bari, Italy
5 University of Ioannina, Greece
6 Università and INFN, Bologna, Italy

Spokespersons: Luigi Cosentino (cosentino@lns.infn.it) and Fabrizio Murtas (fabrizio.murtas@lnf.infn.it)
Technical coordinator: Olivier Aberle (Olivier.Aberle@cern.ch)

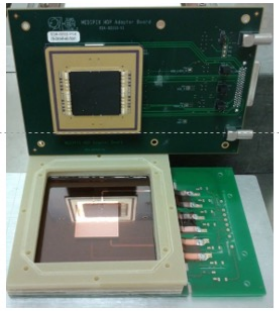
Misura di precisione di sezioni d'urto di indotte da neutroni





Atmospheric pressure
Active Area : 3x3 cm^2
Time resolution : 5 ns
Space resolution : 200 um
Particle id capability (dE/dX)

The target doesn't have to produce oxygen inside the gas



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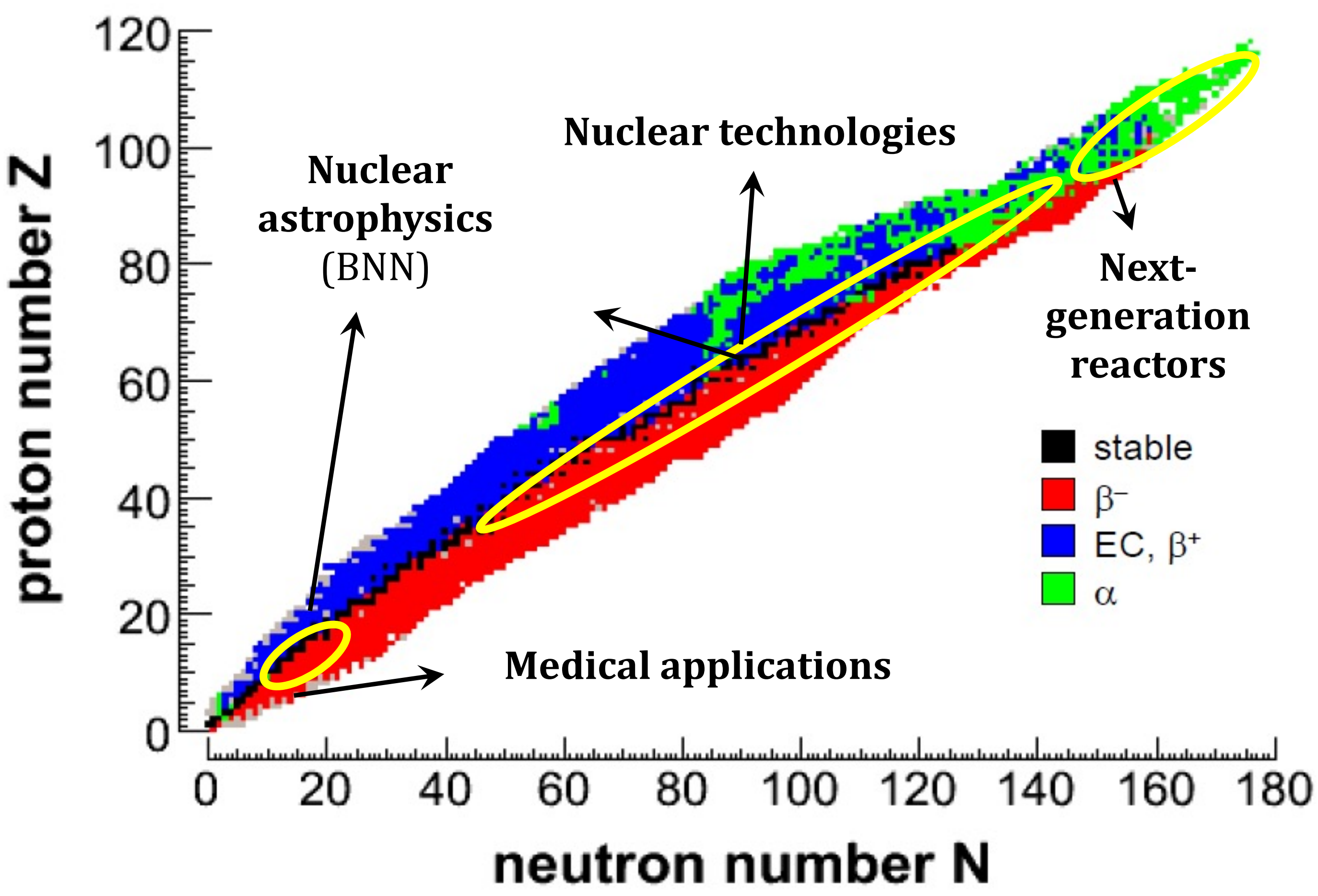


nTOF	Afferenza (%)
Gerardo Claps	30
Fabrizio Murtas	50
Antonino Pietropaolo	20
Nicholas Terranova	50
Antonella Tamburrino	50
Alessandro Feruglio	100
FTE totali	3

Financial requests :
10 k€ Gempix3 subjudice to the first results with GEMPIX for (n,cp) rections

Missions :
5k€ for installations and collaboration meetings and shifts

LNF Facility: clean room (we need as soon as possible!!)

Conclusioni

- Il coinvolgimento nelle sigle della CSN3 continua in modo stabile, così come le RN
- Incremento di personale a TI@LNF
- Carico sui servizi in riduzione rispetto agli anni passati

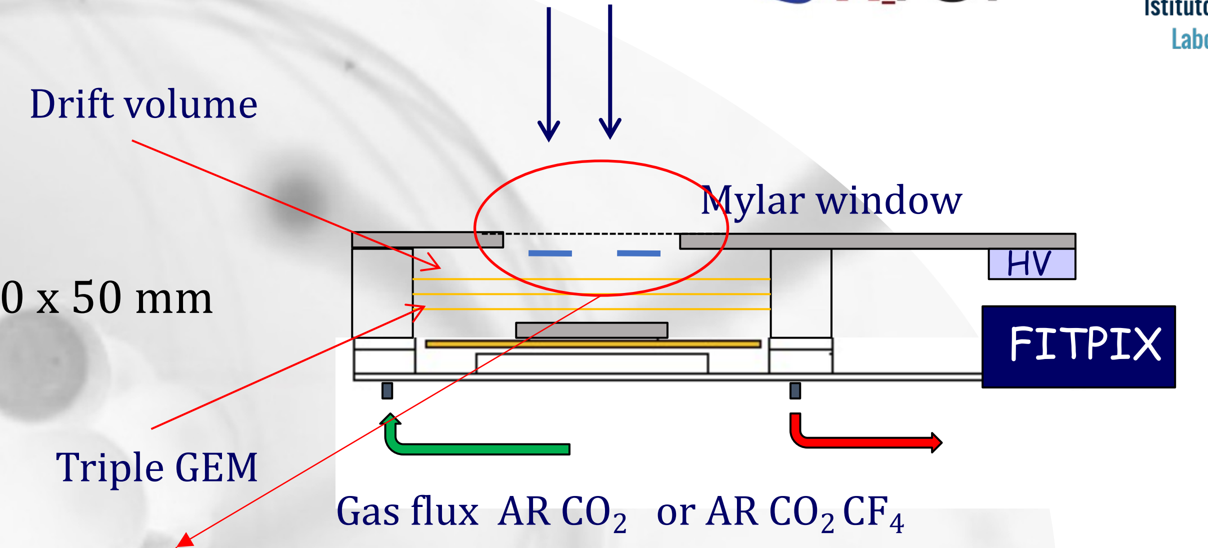
CSN3 Fisica Nucleare

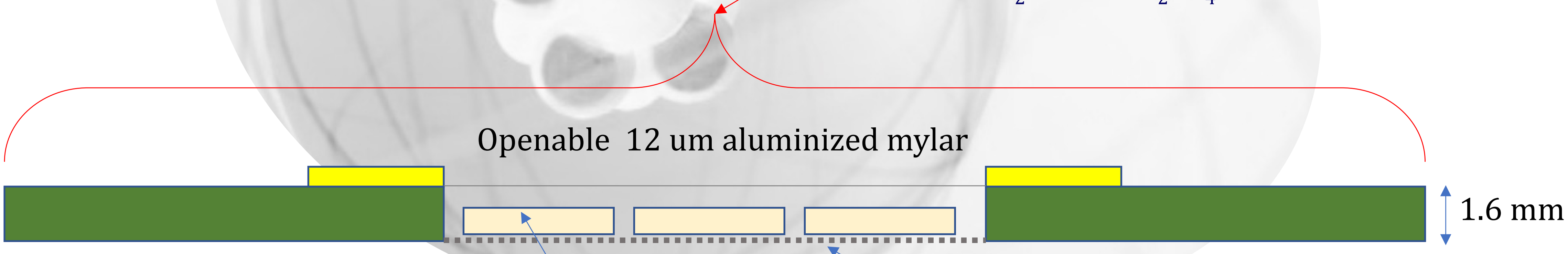
Mid-term plans for nuclear physics in Italy

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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

The alumina strips have dimension : 0.4 x 10 x 50 mm





The mesh and the aluminized mylar are at the same potential

ALICE@CERN

Data analysis activity

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, management roles

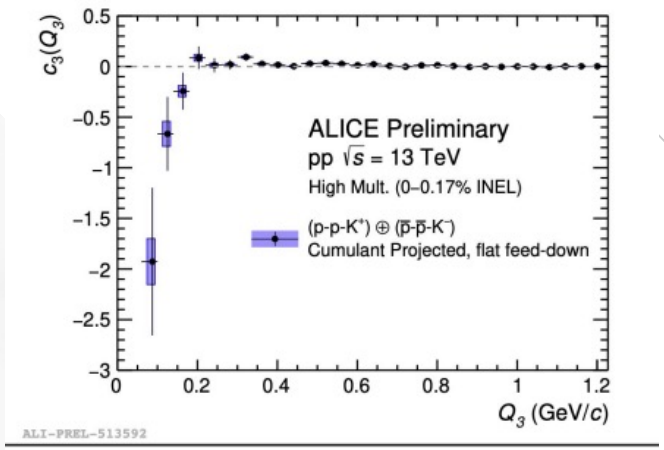
Analysis finalized: AN https://alice-notes.web.cern.ch/node/1256

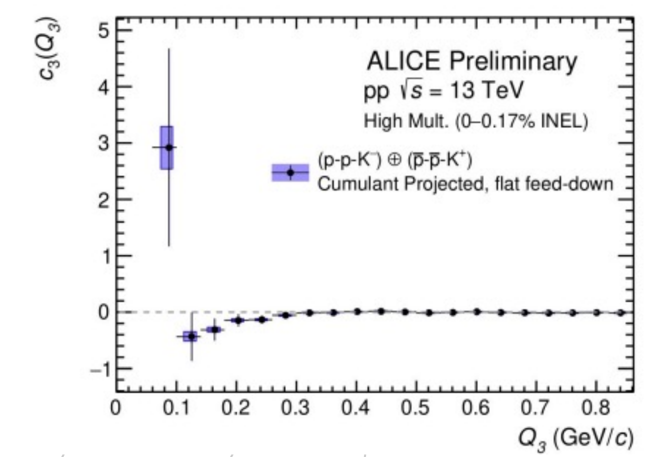
Paper proposal at Physics Forum 29-July-2022 Accepted.

Target Journal: European Physics Journal A

Physics messages: *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 signature of ppK- bound state in the correlation function*

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





ALICE@CERN

ALICE

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

CSN3
Fisica
Nucleare

Data analysis activity

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

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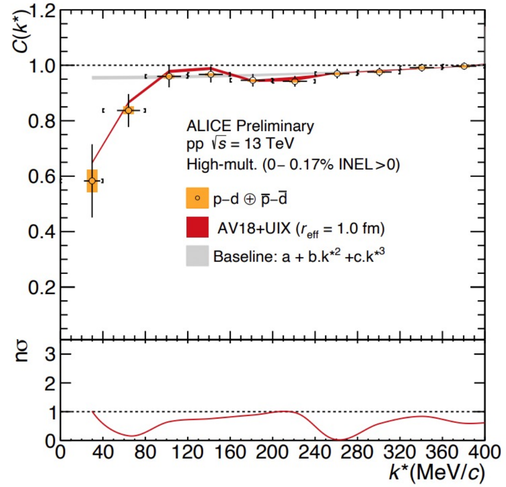
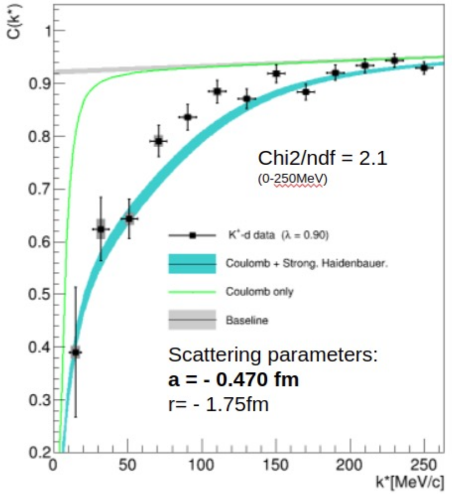
Analysis in advanced stage.
Presentations at Femtoscopy PAG in June:
p-d: https://indico.cern.ch/event/1088099/
K+-d: https://indico.cern.ch/event/1088100/

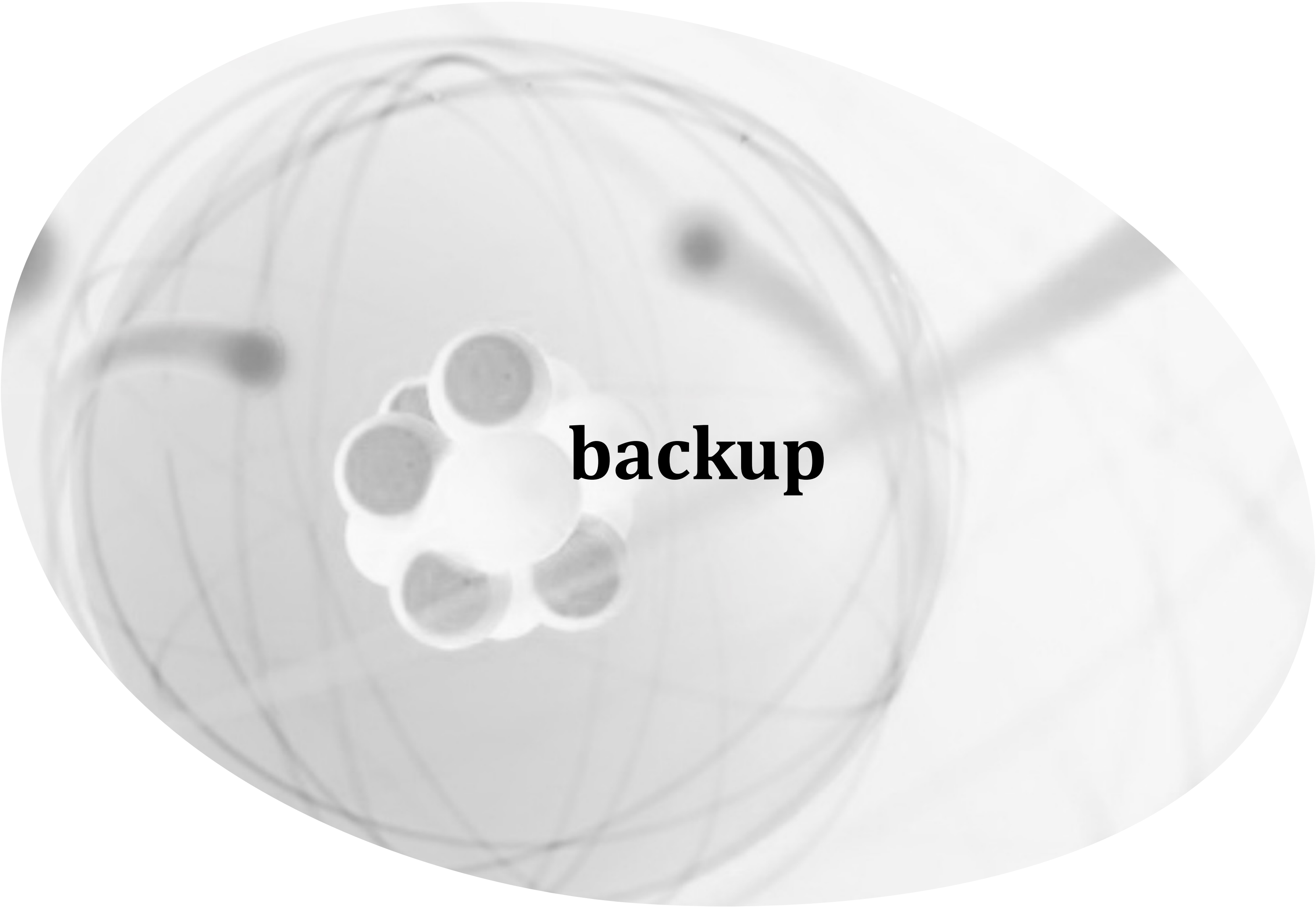
Planned paper proposal Physics Forum July 2022

Physics Message:
The interpretation of femtoscopy data with deuterons in small systems requires the assumption of a pre-formed deuteron. For p-d: assuming deuteron point like particle in calculations via scattering lengths does not work Projection of three-particle wave function to p-d provide excellent agreement with data requires a preformed deuteron. For K+-d: calculations with deuteron point like particle in calculations via scattering lengths work with small radius (~1fm)

Paper Committee: Oton Vazquez Doce, Bhawani Singh, Laura Fabbietti







backup

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
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- nuclear and hyper-nuclear dynamics
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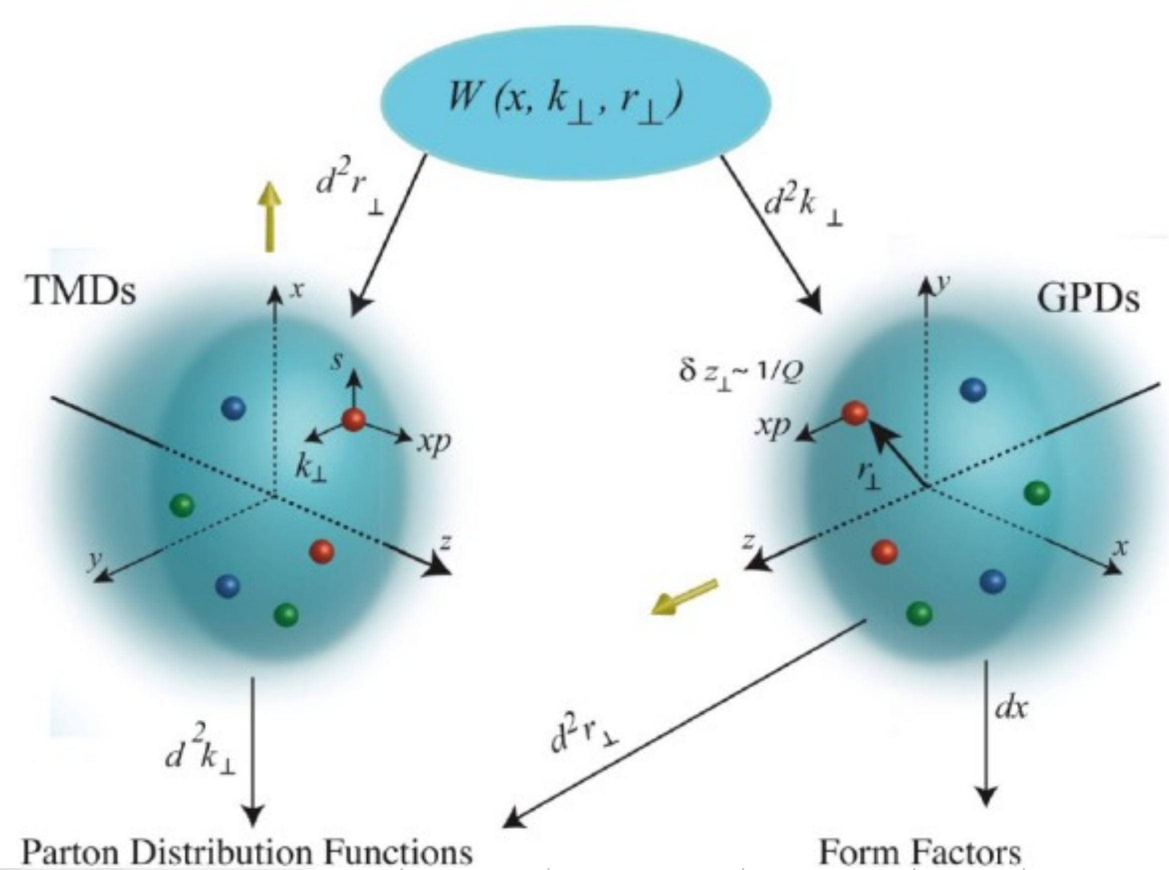

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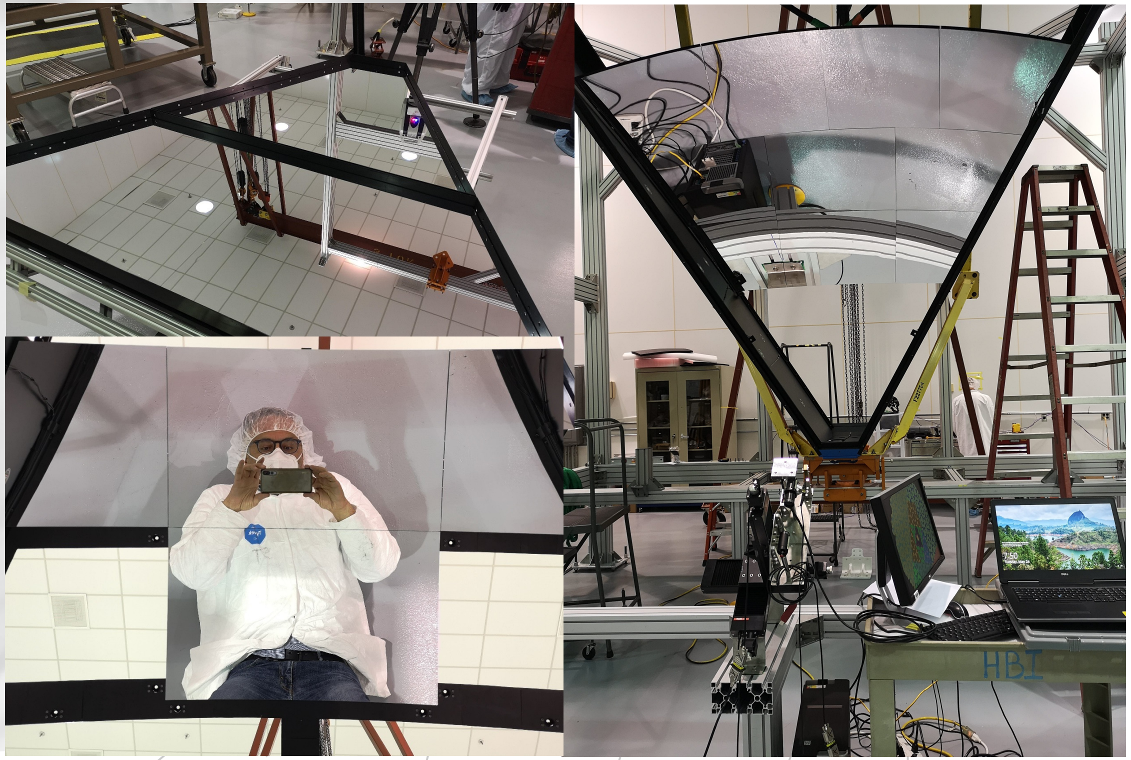
Mirrors under test, installation and alignment

- Ten spherical mirrors
- 7 flat mirrors under installation



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EIC_net

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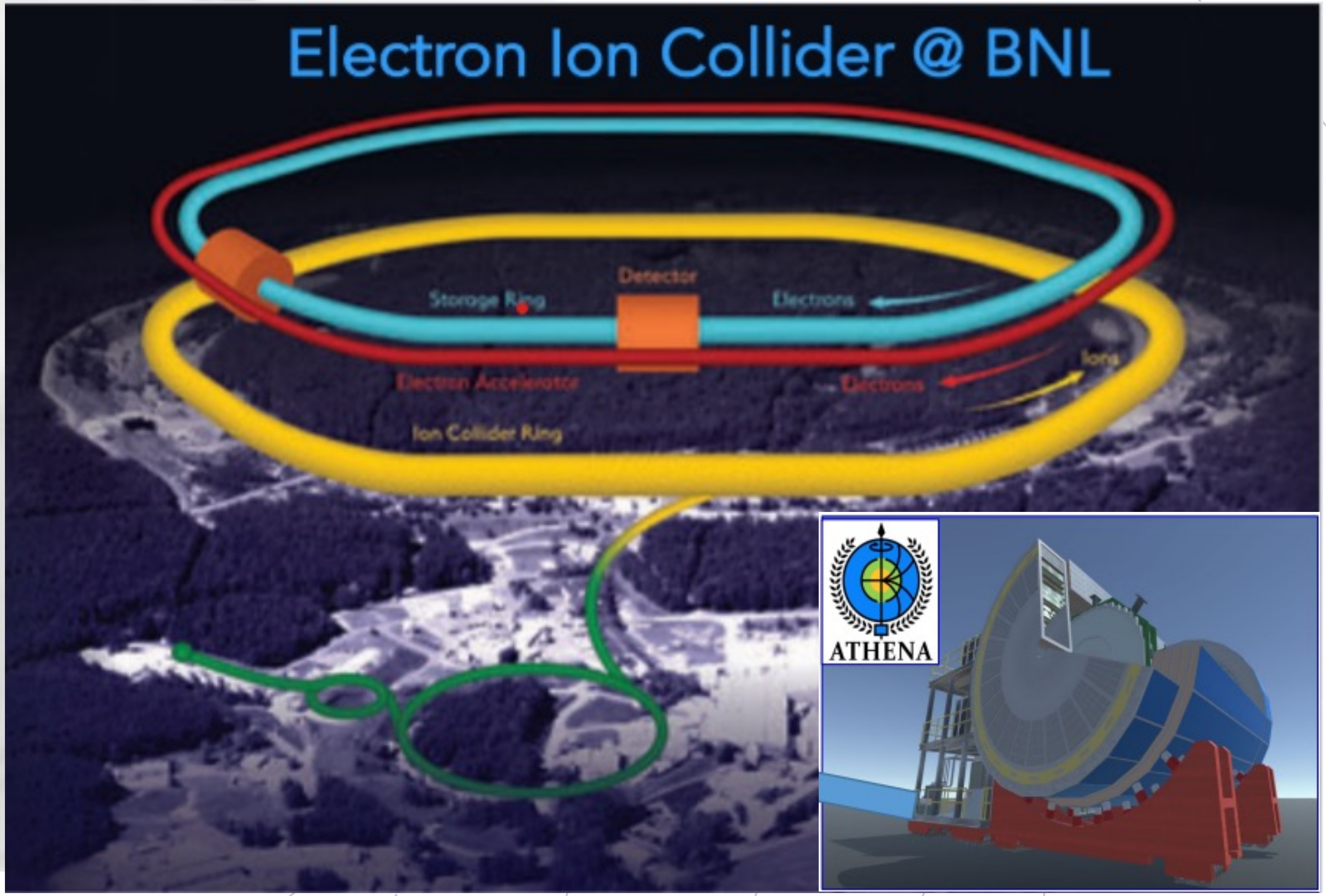

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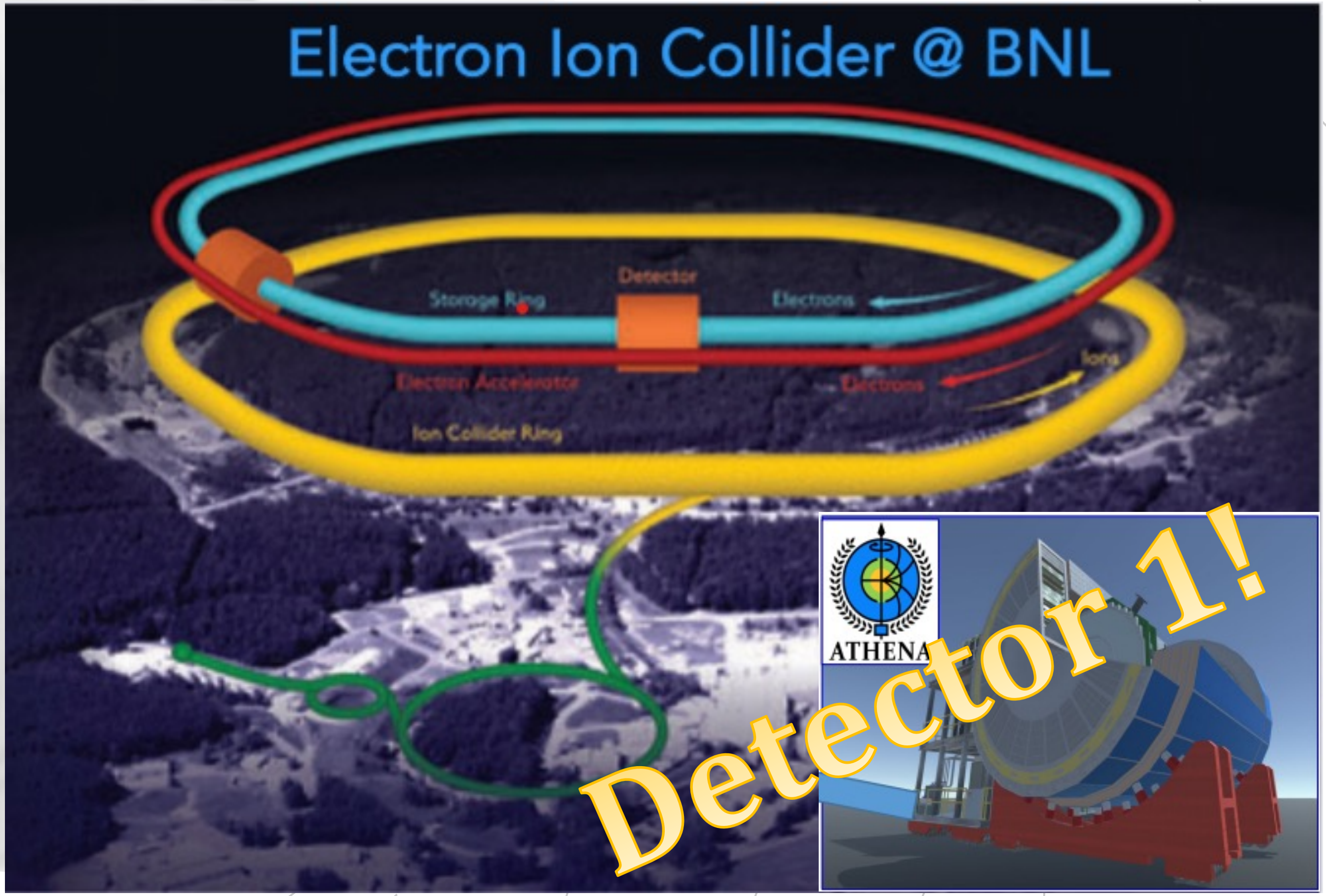

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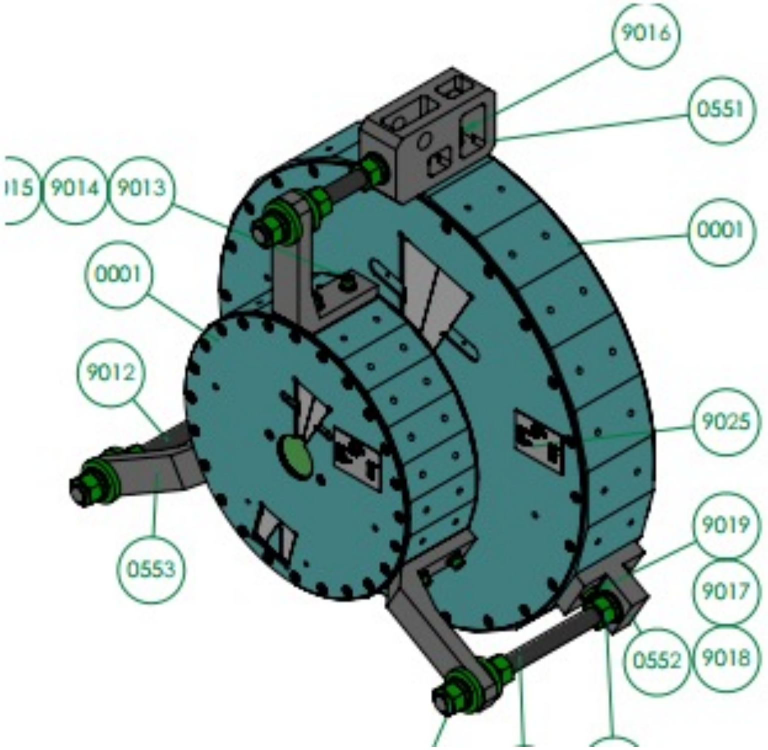
JLAB12	Afferenza (%)
Marco Mirazita	90
Sandro Tomassini	20
Patrizia Rossi	0
FTE totali	1.1

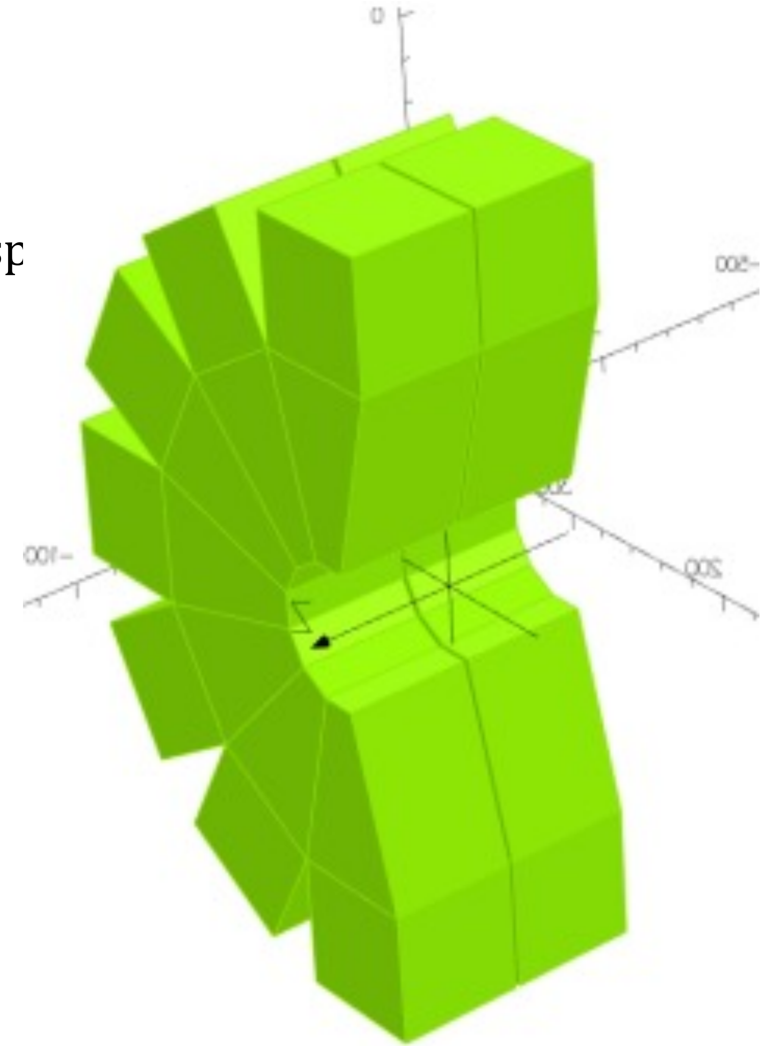
EIC_net (c/o dotazioni)	Afferenza (%)
Marco Mirazita	10
Patrizia Rossi	0
FTE totali	0.1

MI	ME	TRA	INV	C.APP	CON	Totale
0	60	0	0	0	0	60

FOOT magnet drama

The long story short: 3 firms invited to the bid; one resp
Phi. Decided for **NbSm** magnetic elements





M1: 96 elements on 2 disks, 2 rings
B max: 1.4 T → strong magnetic forces

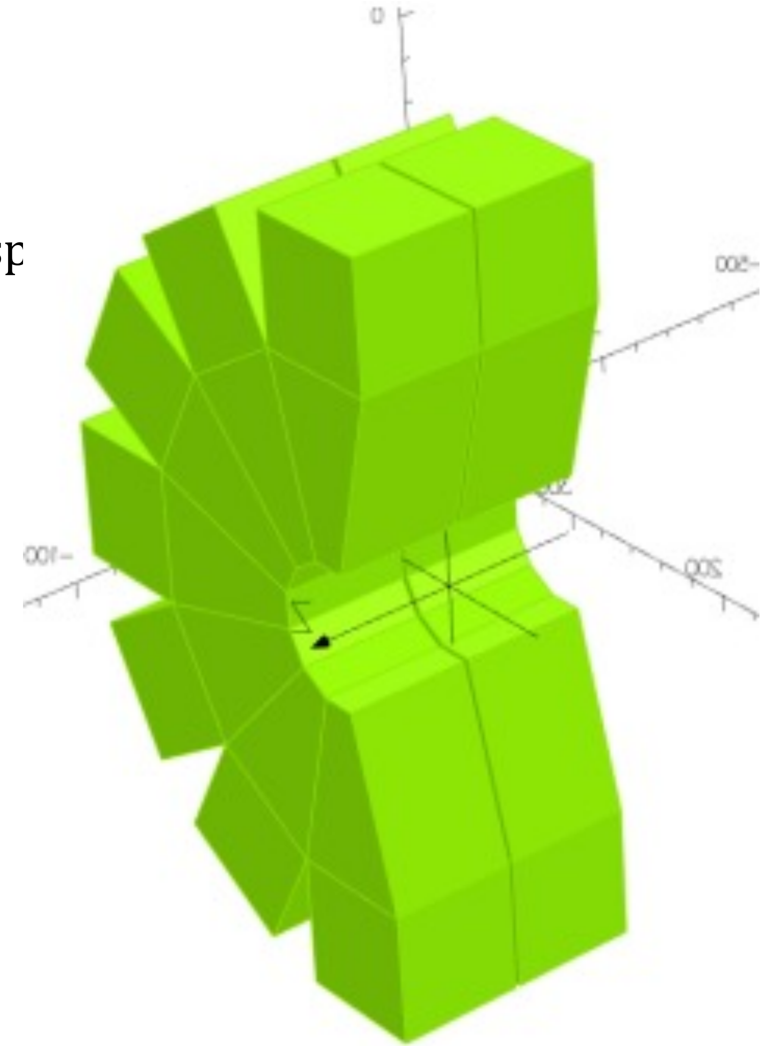
FOOT magnet drama

The long story short: 3 firms invited to the bid; one resp
Phi. Decided for **NbSm** magnetic elements

During assembly many magnetic elements broke. Front flanges do not look safe!

The firm made also M2 with the same problems. Even more magnetic elements broke. No picture given.
The firm decided to restart the design from scratch using Neodymium-Iron-Boron magnetic elements (harder) and avoiding
The longitudinal segmentation of magnets.

We decided to follow the process more closely and demanded weekly updates.
Asked Lucia Sabbatini (LNF magnet expert) to follow the development (Thanks, Lucia!)



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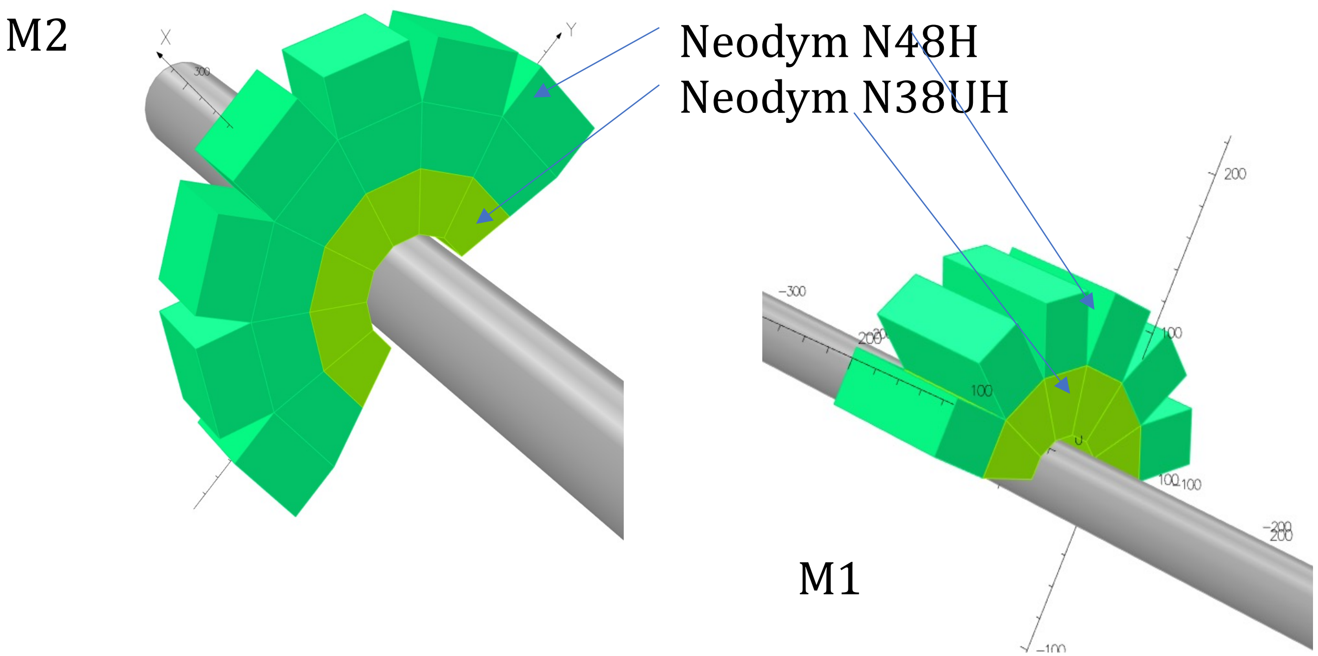
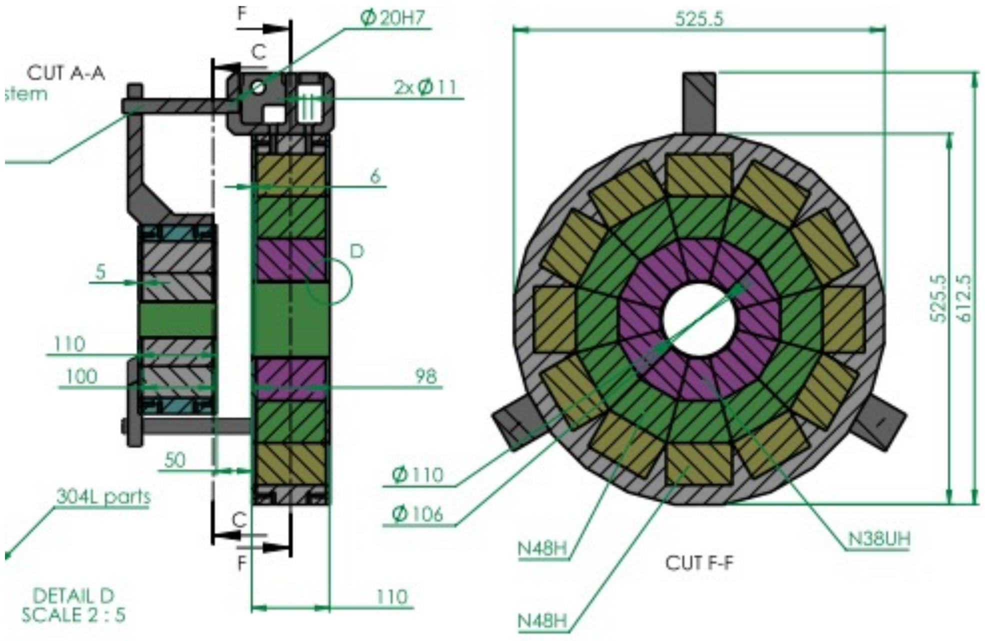




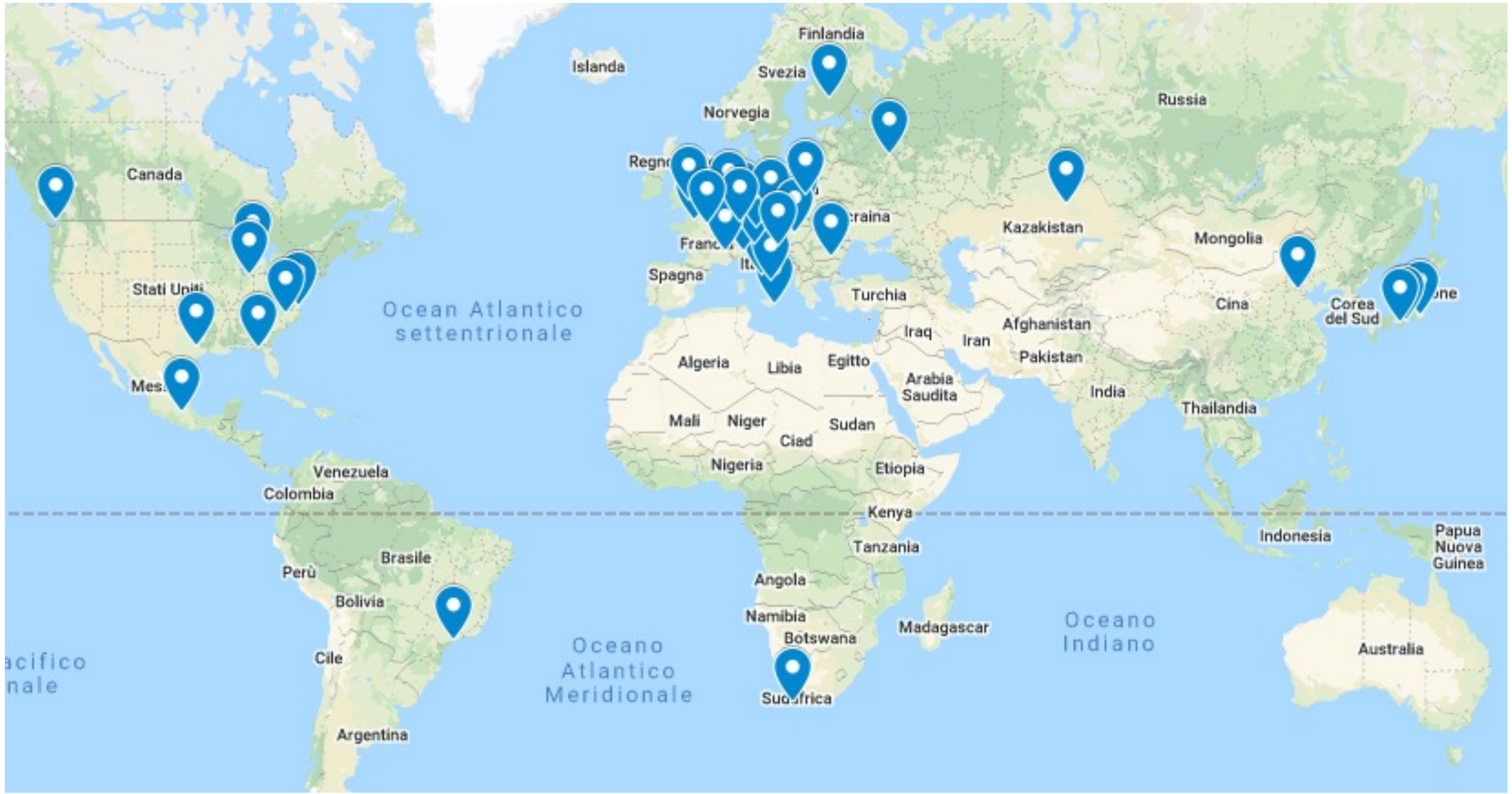
Waiting the quotation from a german firm; magnets will be placed in cages.

CSN3
Fisica
Nucleare

Nuclear Physics in Italy

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

CSN3 experiments use facilities all around the world and in particular INFN laboratories



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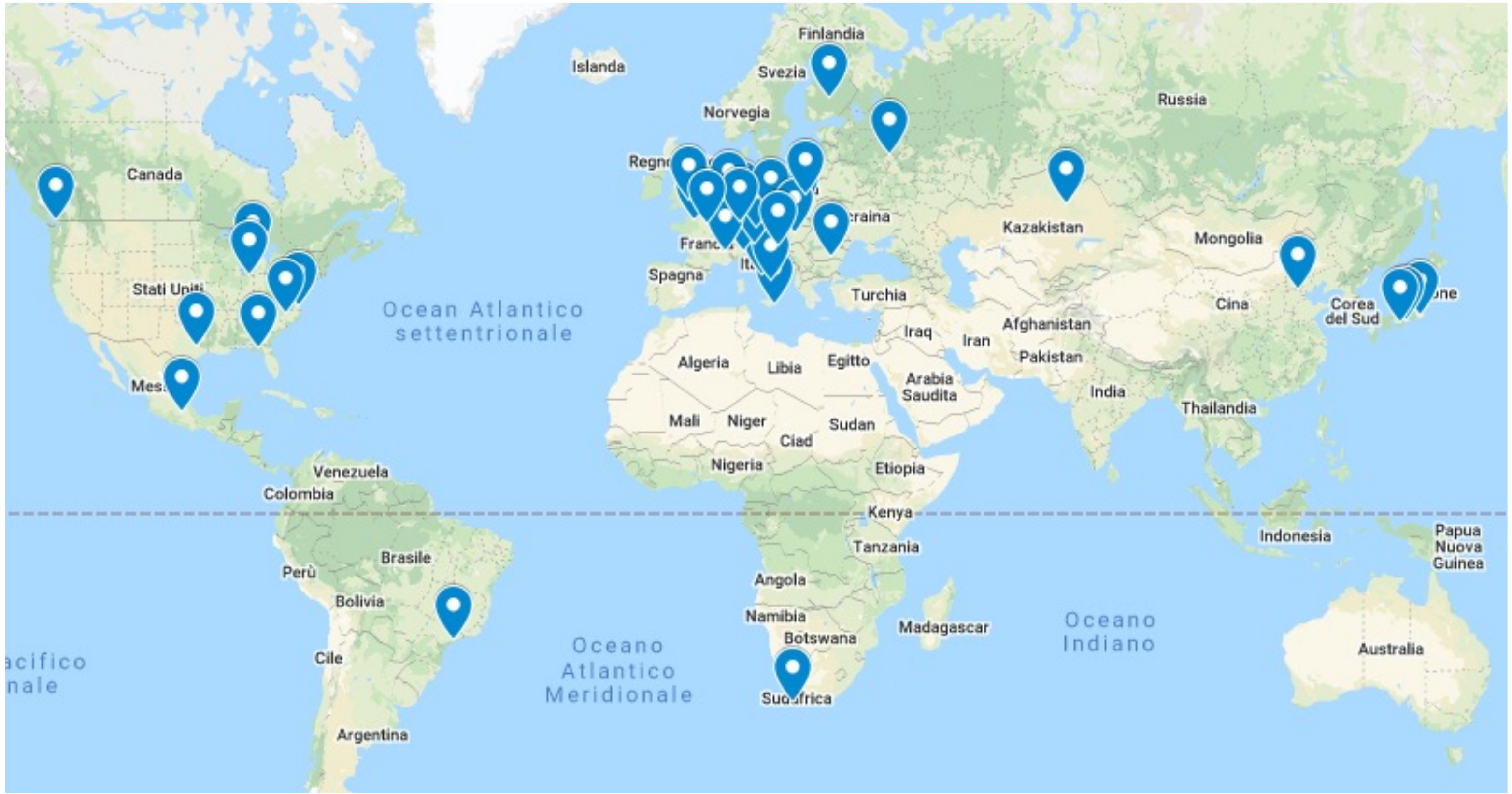
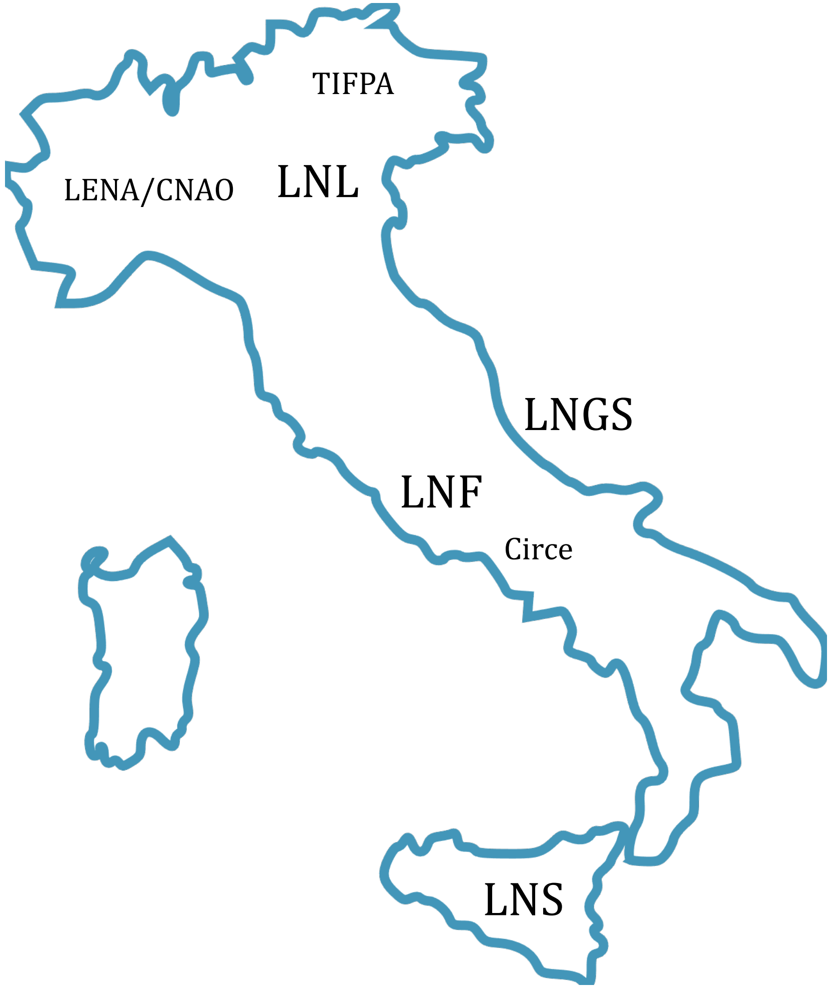




ALICE@CERN

Femto-Strong: "**Antikaon-deuteron femtoscopic correlations with ALICE: A new era of hadron-hadron interaction measurements**" [Link to project pdf]

- Measurement of the K^--d correlation function in small collision systems with **Run2 (and Run3) ALICE data**
- **Joint-venture** with SIDDHARTA-2: Measurement of the antikaon-nucleon scattering parameters at threshold with SIDDHARTA-2, over threshold at low relative momentum with ALICE.

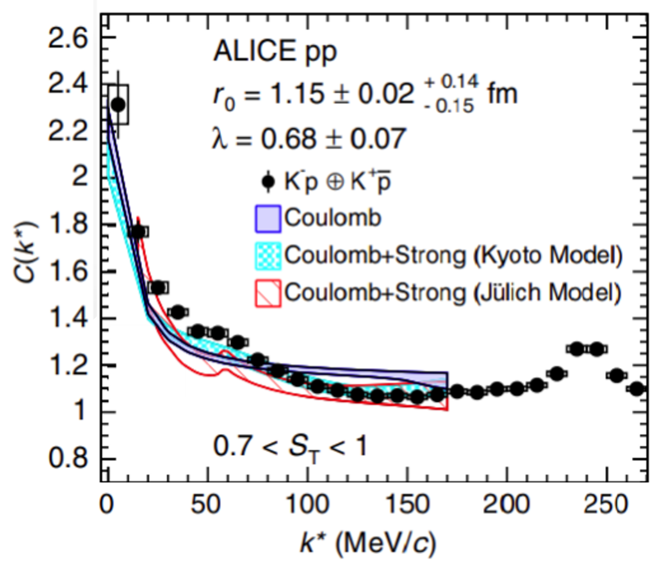
Fellini Fellow: Otón Vázquez Doce
Program delayed by 12 months due to pandemic
Duration of the fellowship: 28.5 months
1st June 2021 - 15th October 2023

Supervisors:
- ALICE: Alessandra Fantoni (main responsible + administrative duties)
- SIDDHARTA-2: Catalina Curceanu

Fellini Fellowship for Innovation at INFN
H2020 MSCA COFUND
G.A. 754496

⇒ Two-particle correlation studies open new precision era in the hadron-hadron interaction studies ALICE Coll. *Nature* **588**, 232 (2020)

⇒ Improved study following ALICE publication of K^--p femtoscopy in pp collisions ALICE Coll. Phys. Rev. Lett. 124 (2020) 092301
- Comparison with models anchored at threshold to SIDDHARTA data



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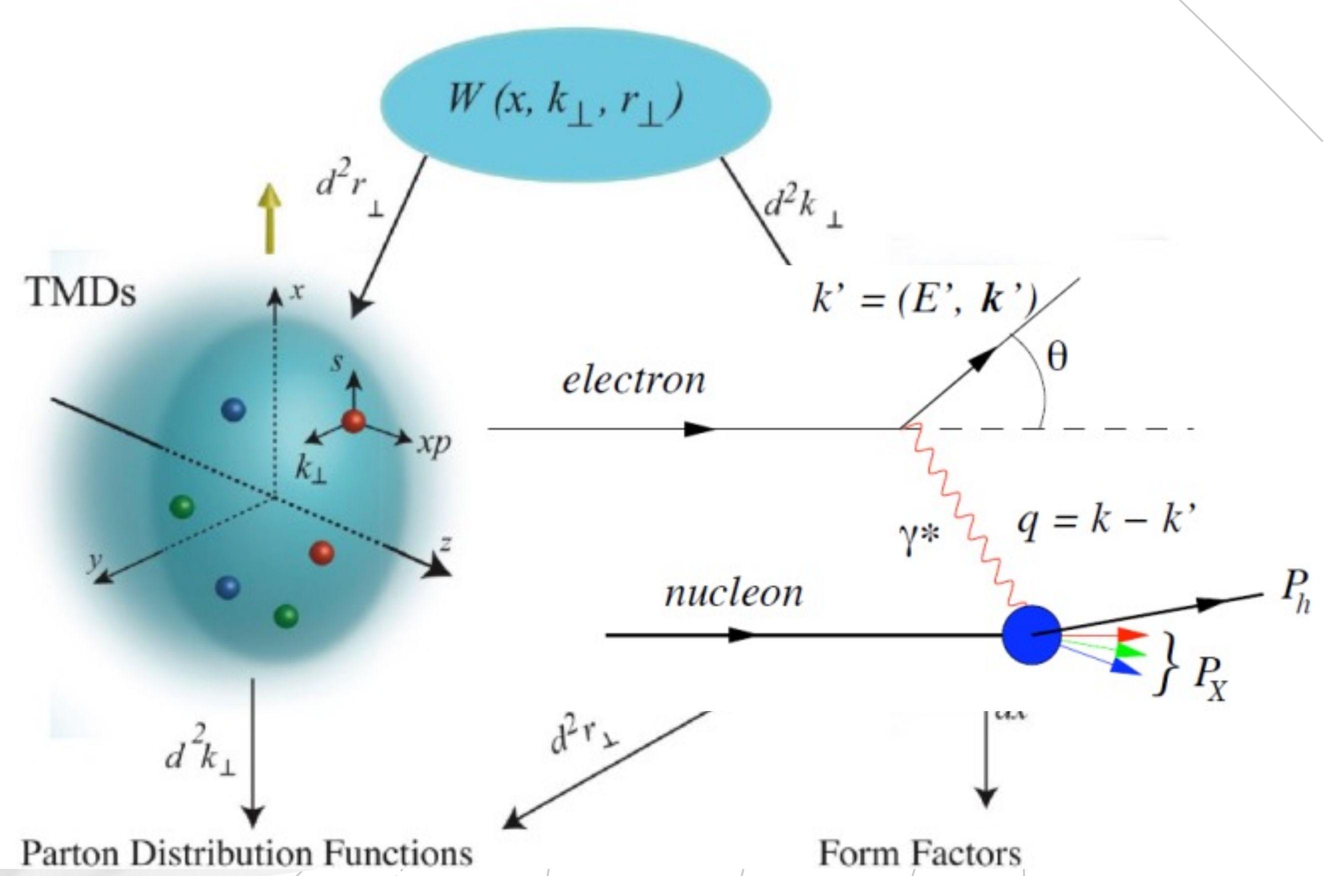

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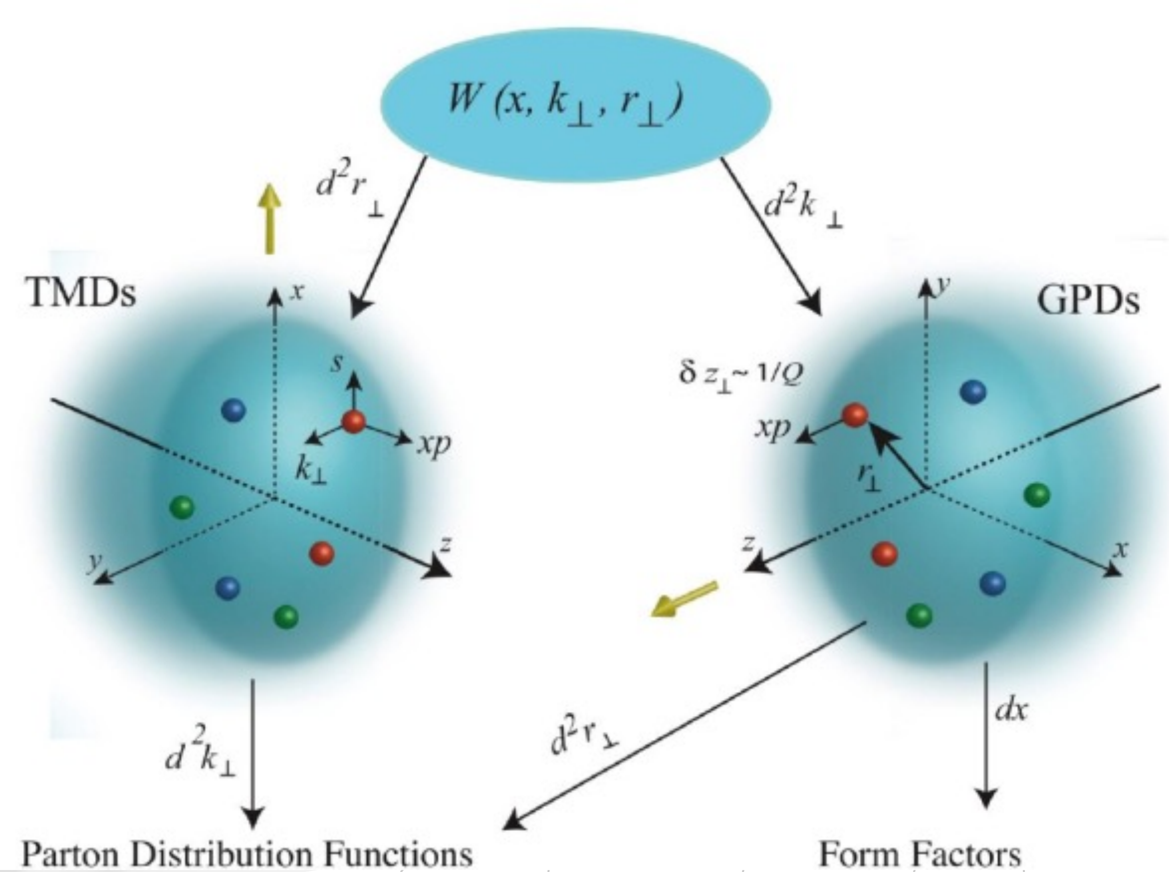

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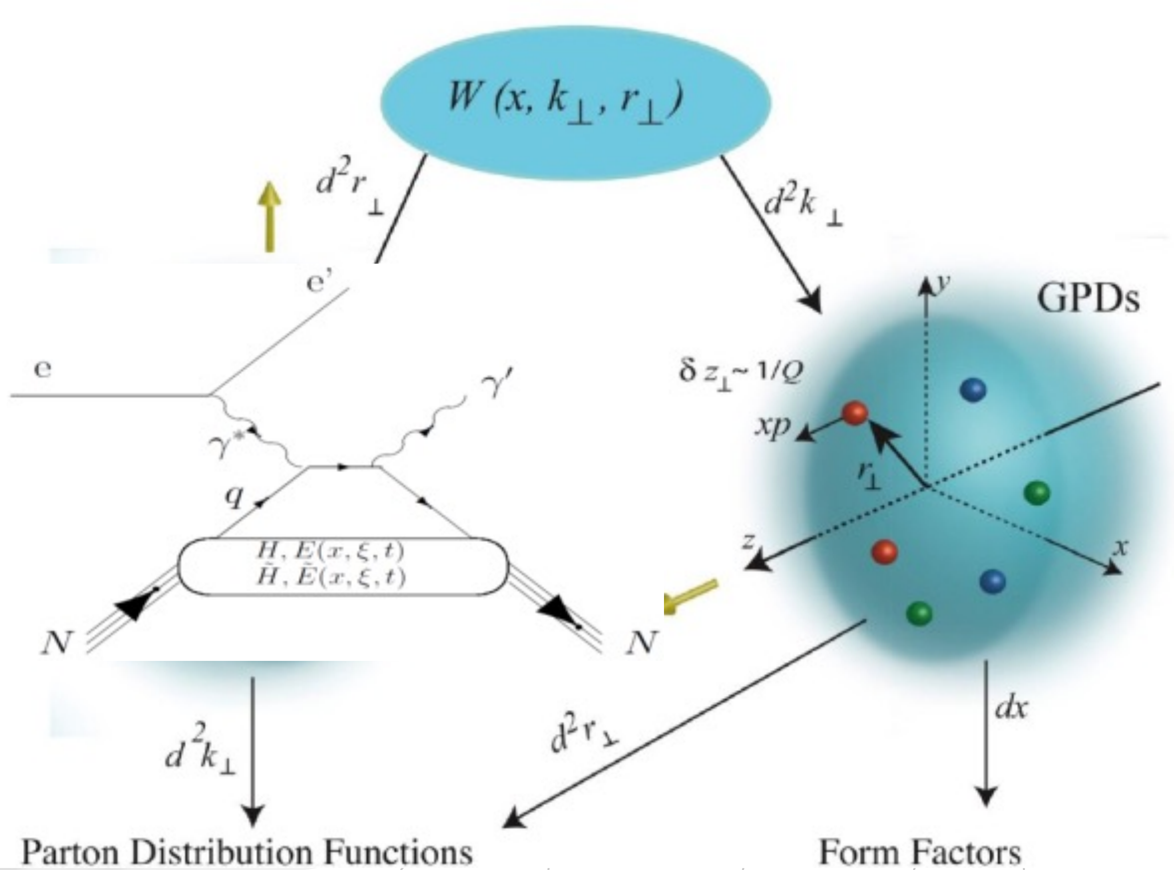

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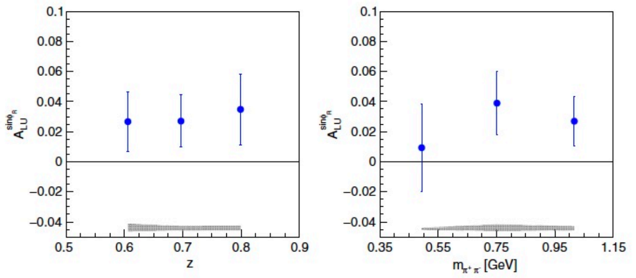
PHYSICAL REVIEW LETTERS **126**, 062002 (2021)

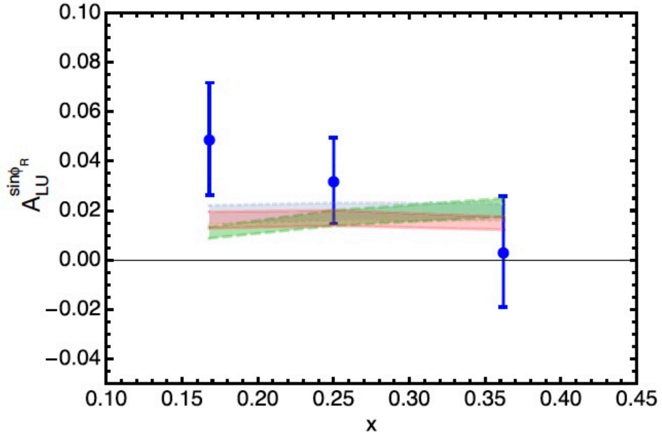
Beam Spin Asymmetry in Semi-Inclusive Electroproduction of Hadron Pairs

M. Mirazita,[19] H. Avakian,[42] A. Courtoy,[15] S. Pisano,[5] S. Adhikari,[13] M. J. Amaryan,[35] Giovanni Angelini,[16] H. Atac,[41]

First measurement of the di-hadron beam-spin asymmetry of charged pion pairs

x-dependence will allow the analysis of the higher-twist nucleon structure through the extraction of $e(x)$





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PHYSICAL REVIEW LETTERS 126, 152501 (2021)

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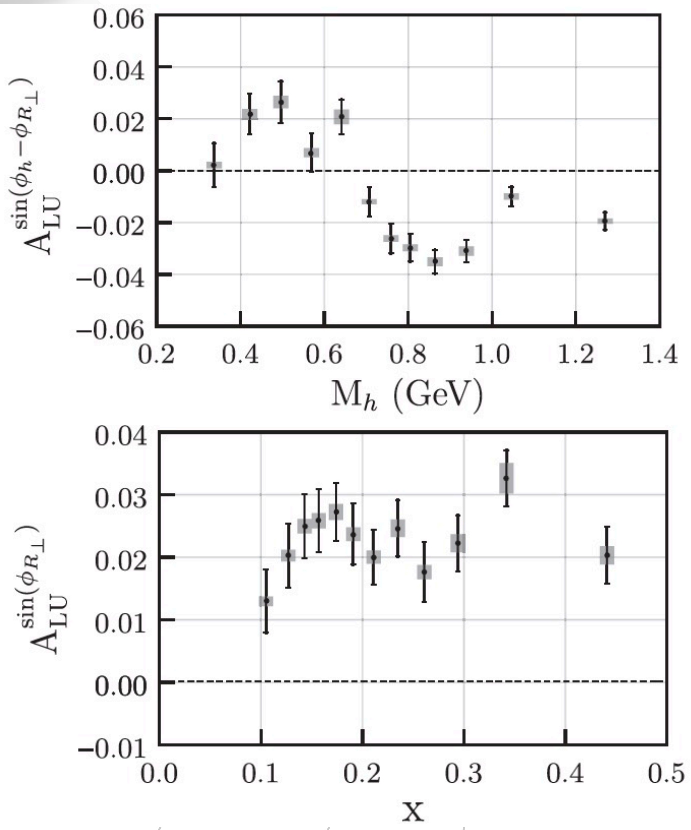

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- how does the spin of the nucleon arise?
- what are the emergent properties of dense systems of gluons?

1. Extend PID capabilities of CLAS12 to kaons in the 3÷8 GeV/c momentum range
2. Hybrid solution: proximity gap plus mirror focusing
3. First module installed in January 2018 → smoothly operated since then.
4. No major hardware problem have been reported.

System specifications

- Time resolution
  - Better than 1 ns to distinguish direct from reflected photons
- Cherenkov angle resolution (spe)
  - Direct photons: 4.5 mrad
  - Reflected photons: 5 mrad
- Particle identification
  - π/K rejection better than 500 for p 3÷8 GeV/c
  - p/K rejection better than 100 for p 3÷8 GeV/c

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: CLAS12 RICH
- quark dynamics
- nuclear and hyper-nuclear dynamics
- nucleon excited states via meson photoproduction
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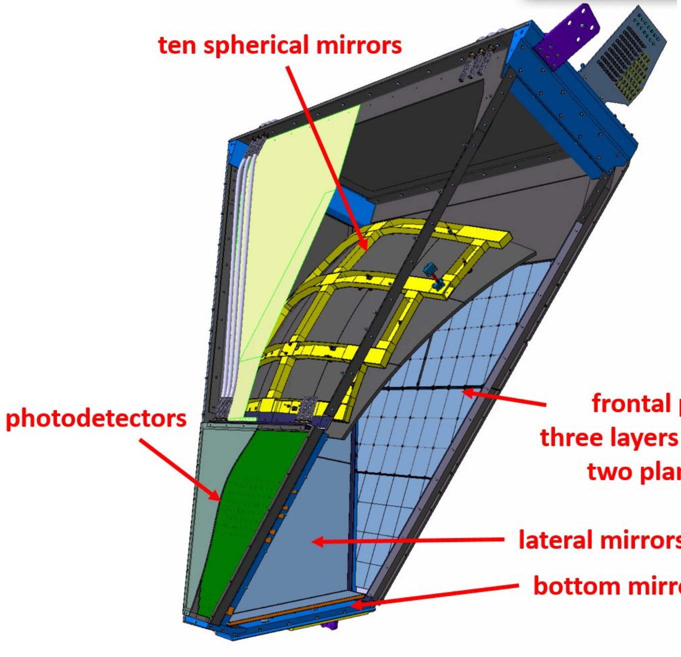

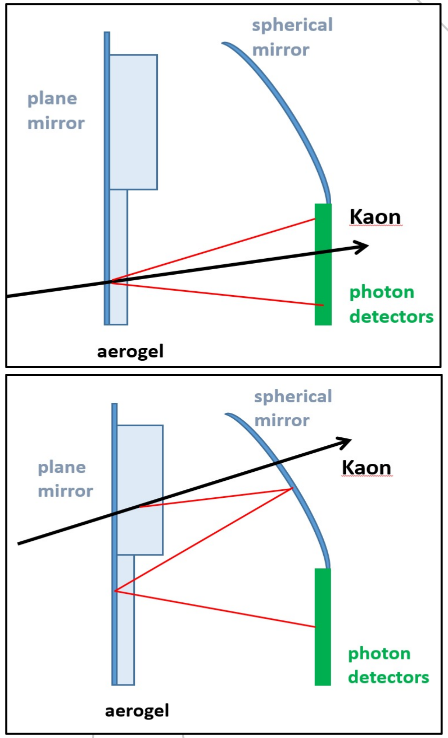

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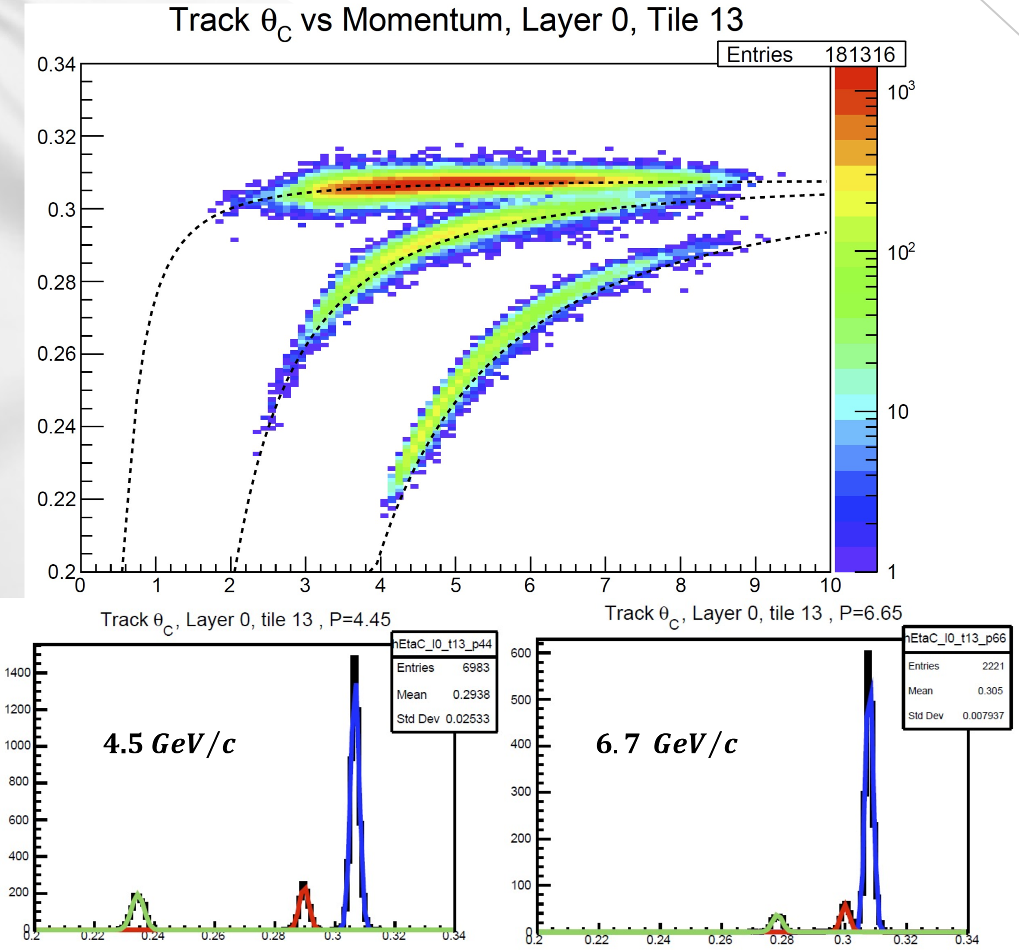

π/K well separated up to $7\ GeV/c$

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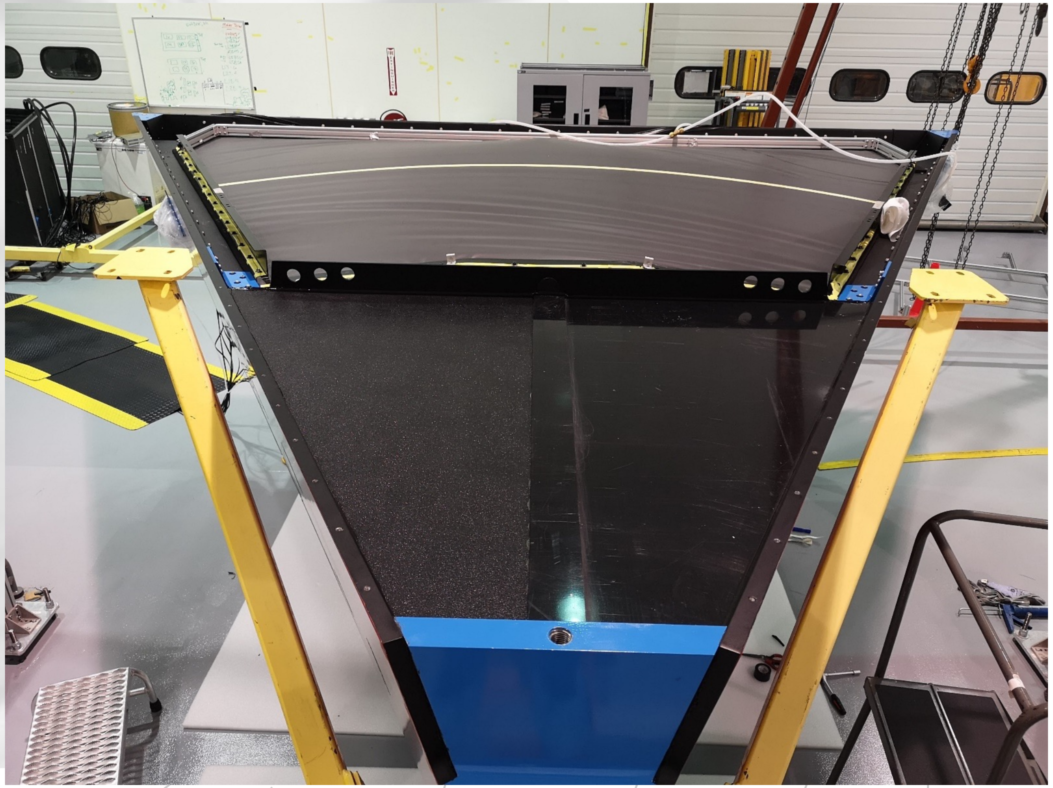
Second module under assembling, installation planned for June 2 for the start of the data taking with polarized target



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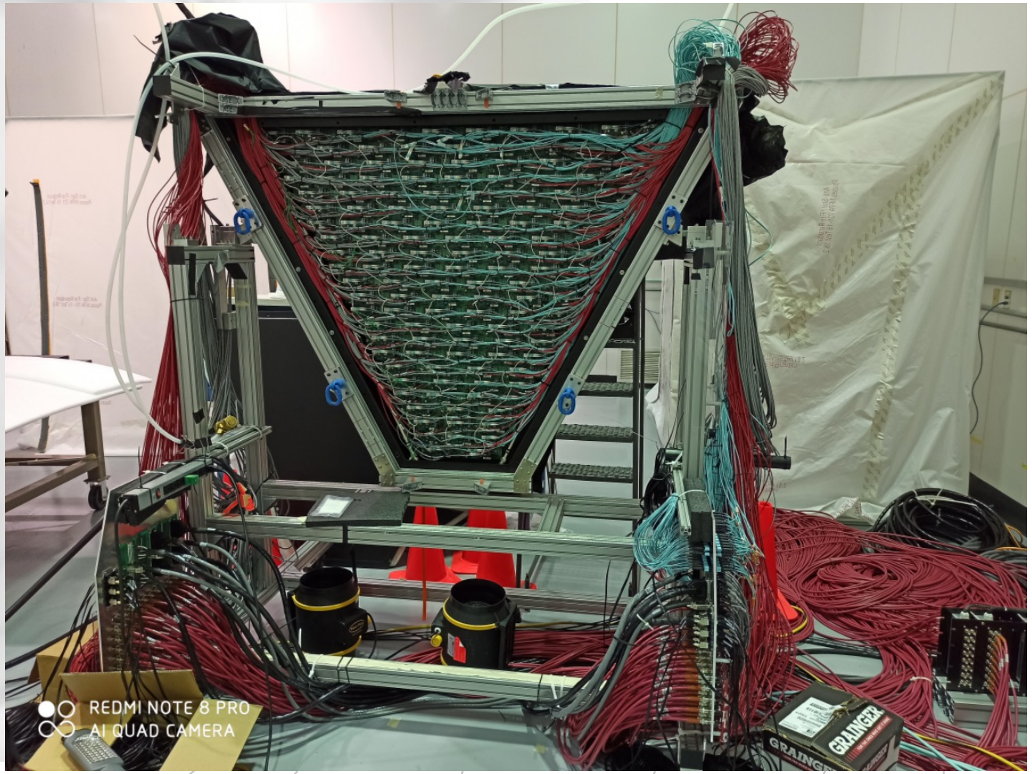
Electronic panel with 391 Multi-Anode PMTs, 138 Front-End units and 25024 readout channels assembled and operating



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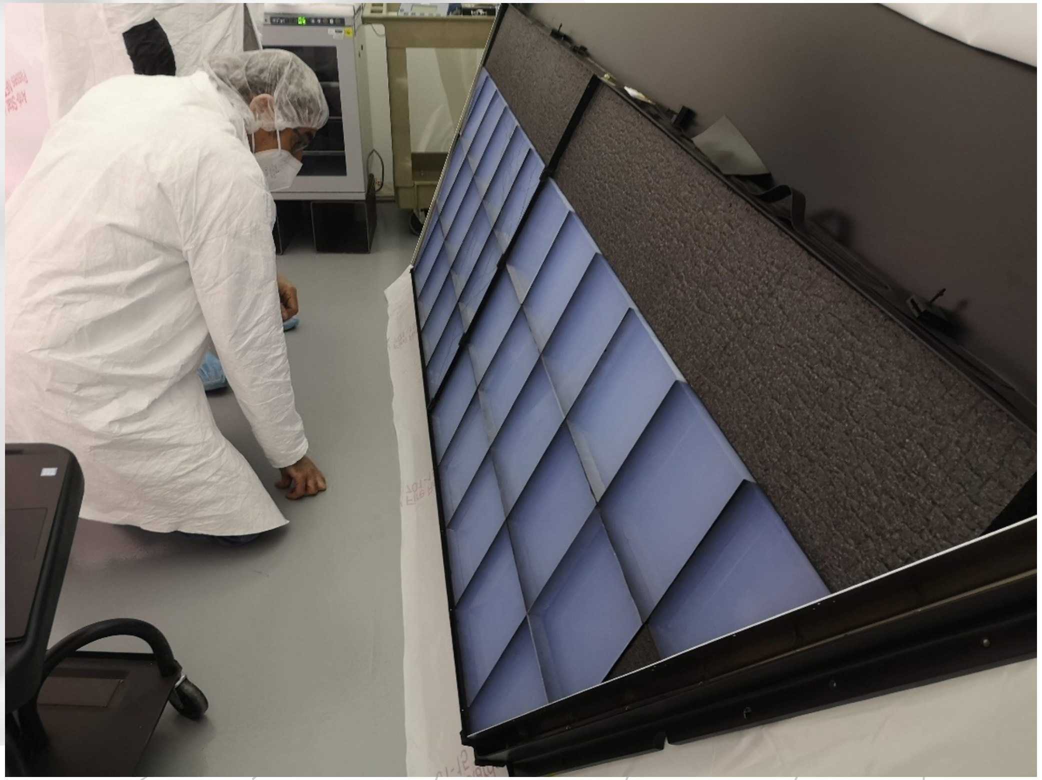
Aerogel radiator assembled:
- large angle particles: 64 tiles 20x20 cm squared, 3+3 cm thickness
- forward particles: 38 tiles 20x20 cm squared, 2 cm thickness



n_TOF

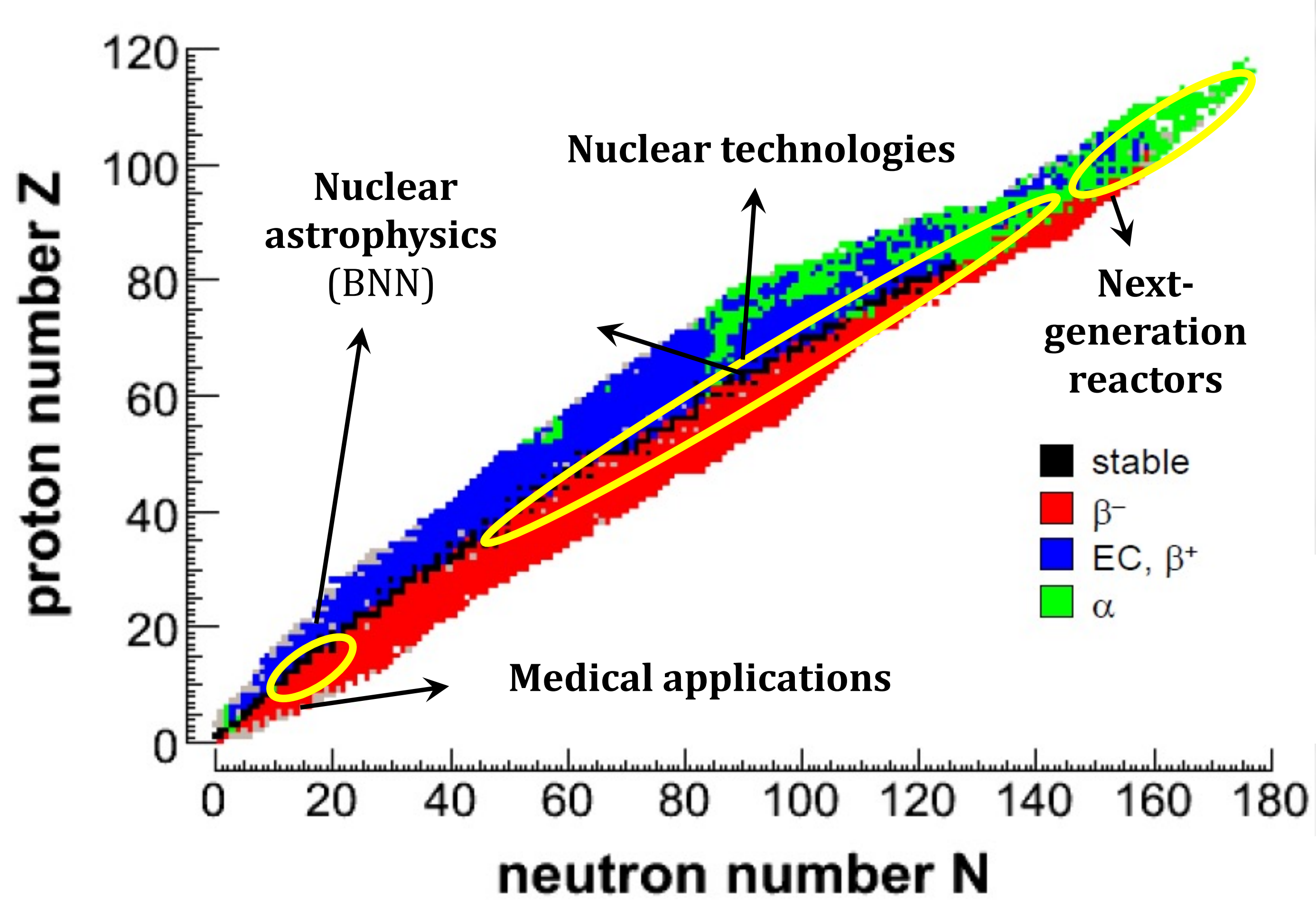
The measurements are performed by using the n_TOF facility at CERN. In this facility, the neutron beams, produced by spallation of 20 GeV/c protons from the CERN PS on Pb, uses two different path of flight: a shorter one of 19 m (very high beam intensity) and a longer one of 185 m (very high energy resolution).

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]

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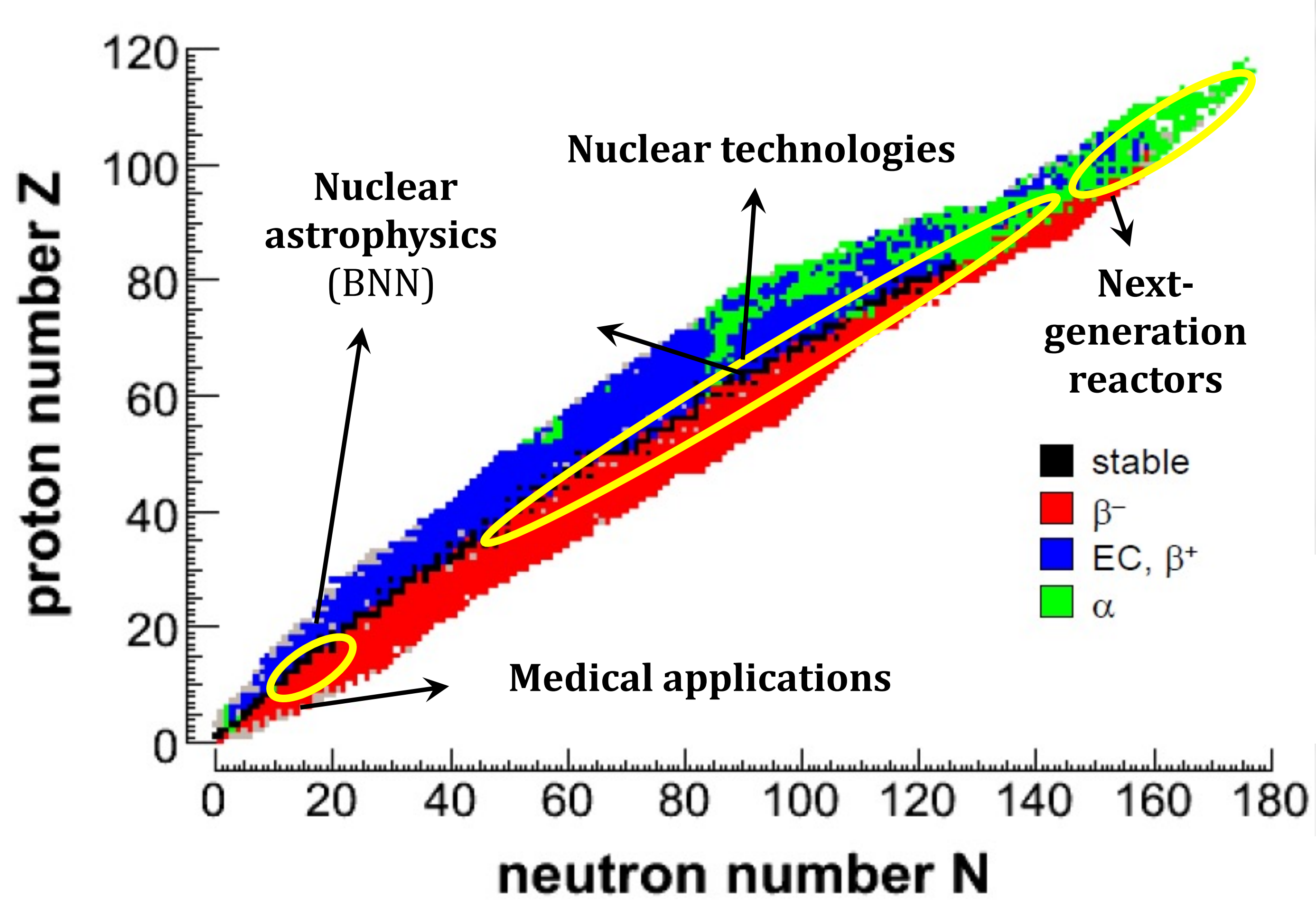

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ALICE@CERN

ALICE

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

Data analysis activity

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, management roles

Light-flavour hadron production vs. multiplicity in pp and in p-Pb collisions with ALICE

- Low-p_{T} hadrons containing light flavours (u, d, s) constitute the bulk of the particle production at LHC (99%)
- They allow one to study the whole system, analyzing its thermodynamic properties and exploring the emergence of collective phenomena
- **Are phenomena typical of QGP such as collectivity, chemical abundances, strangeness enhancement present in small systems?**

1. Spectra extraction extended up to 20 GeV thanks to the inclusion of the HMPID and TPCr analysis
2. Measurement of the nuclear modification factor R_{pPb}

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Femto-Strong: "**Antikaon-deuteron femtoscopic correlations with ALICE: A new era of hadron-hadron interaction measurements**" Link to project pdf

- Measurement of the K^--d correlation function in small collision systems with **Run2 (and Run3) ALICE data**
- **Joint-venture** with SIDDHARTA-2: Measurement of the antikaon-nucleon scattering parameters at threshold with SIDDHARTA-2, over threshold at low relative momentum with ALICE.

Fellini Fellow: Otón Vázquez Doce
Program delayed by 12 months due to pandemic
Duration of the fellowship: 28.5 months
1st June 2021 - 15th October 2023
Supervisors:

- ALICE: Alessandra Fantoni (main responsible + administrative duties)
- SIDDHARTA-2: Catalina Curceanu

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Access experimentally for the first time the strong interaction between antikaons and deuterons, **by measuring two complementary observables obtained using different experimental methods and facilities at different energy regimes**: i) the correlation function as a function of the relative momentum of K--d pairs produced at relativistic proton-proton (pp) collisions at TeV energies at the LHC; ii) the shift and width induced by the strong interaction in the X-ray lines of the kaonic-deuterium atom at the Daphne e+e- collider.

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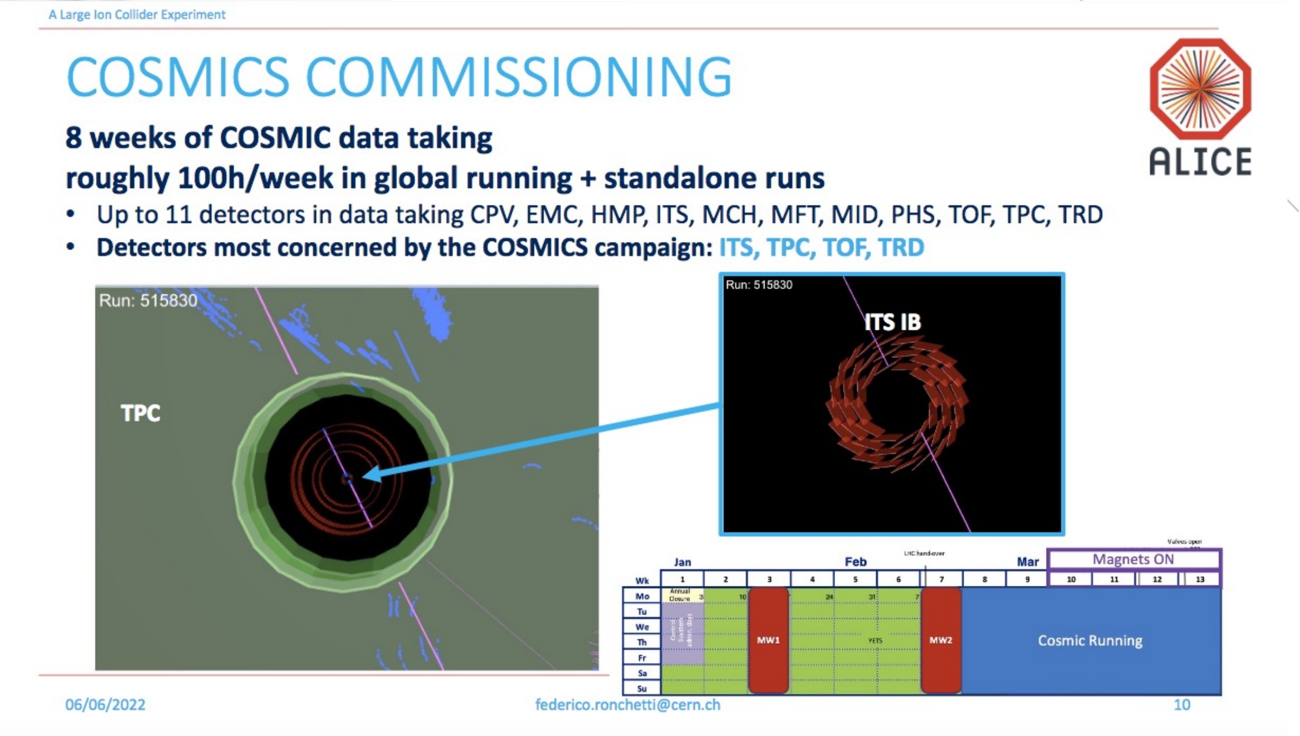
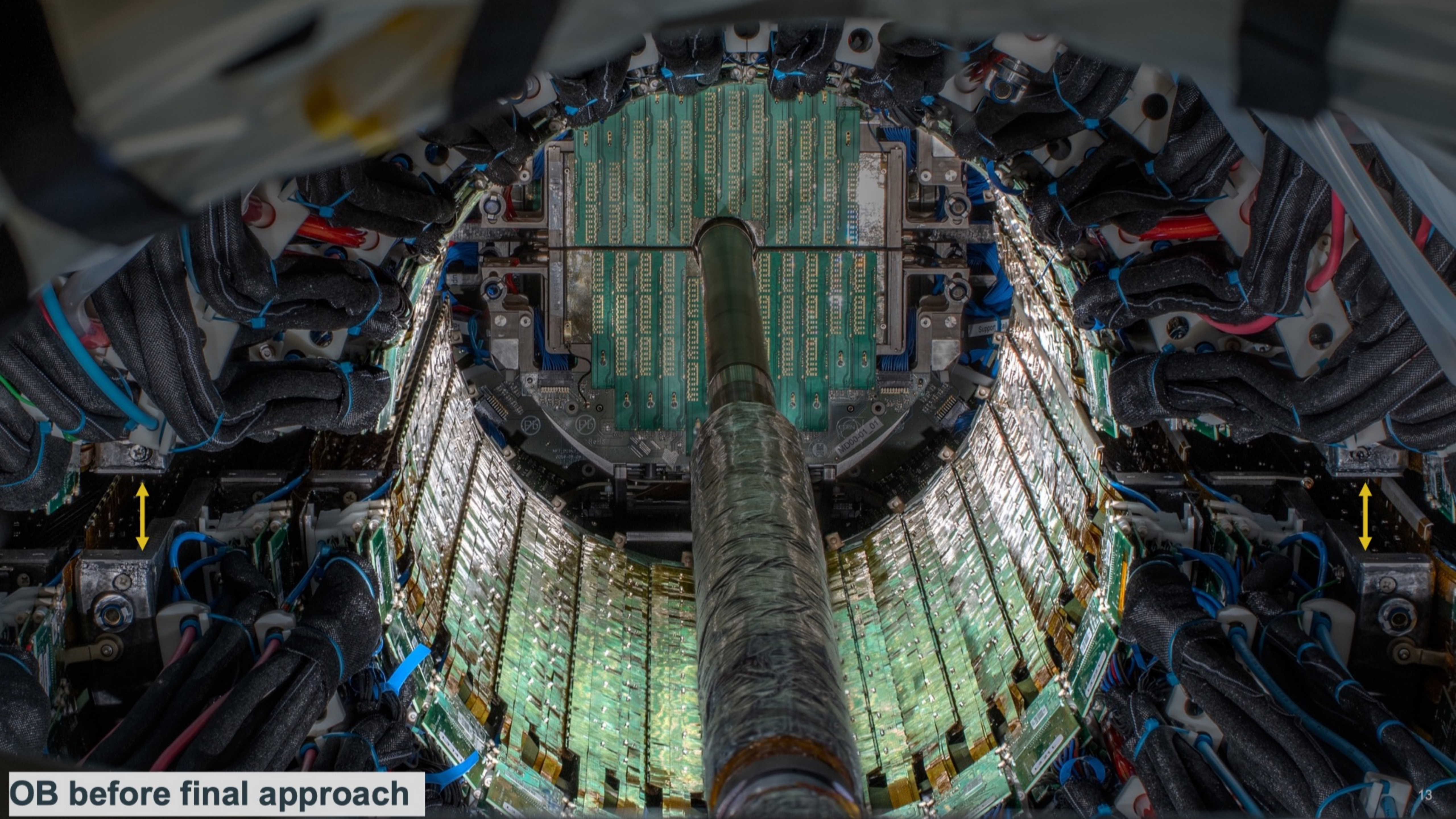


Nessuna richiesta ai servizi. Richieste economiche principalmente di missioni.

MI	ME	TRA	INV	C.APP	CON	Totale
0	60	0	0	0	0	60



OB before final approach

VIP Lead

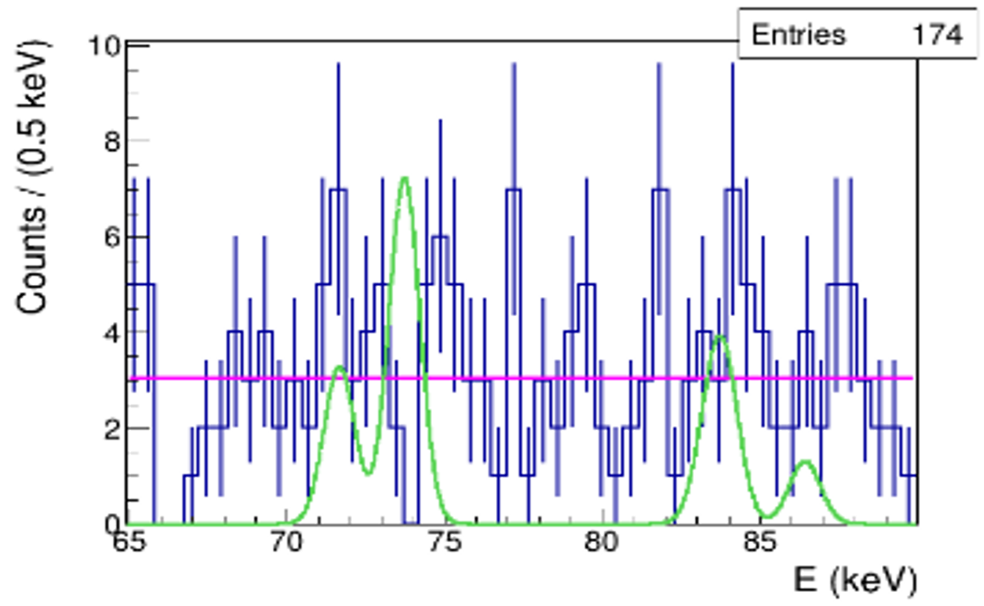


FIG. 1. The measured X-ray spectrum, in the region of the K_α and K_β standard and violating transitions in Pb, is shown in blue; the magenta line represents the fit of the background distribution. The green line corresponds to the shape of the expected signal distribution (with arbitrary normalization) for the A_3 analysis and the M_3 parametrization.

High purity Ge detector measurement (M. Laubenstein):

- Ge detector surrounded by roman lead target + complex electrolytic Cu + Pb shielding
- 10B-polyethylene plates reduce the neutron flux towards the detector
- shield + cryostat enclosed in air tight steel housing flushed with nitrogen to avoid contact with external air (and thus radon)

θ-Poincarè Non Commutative Quantum Gravity model excluded for the first time above the Planck scale.

Publications:

1 - "Strongest atomic physics bounds on Non-Commutative Quantum Gravity Models", submitted to Phys. Rev. Lett.

2 - "Experimental test of Non-Commutative Quantum Gravity by VIP-2 Lead", submitted to Phys. Rev. D

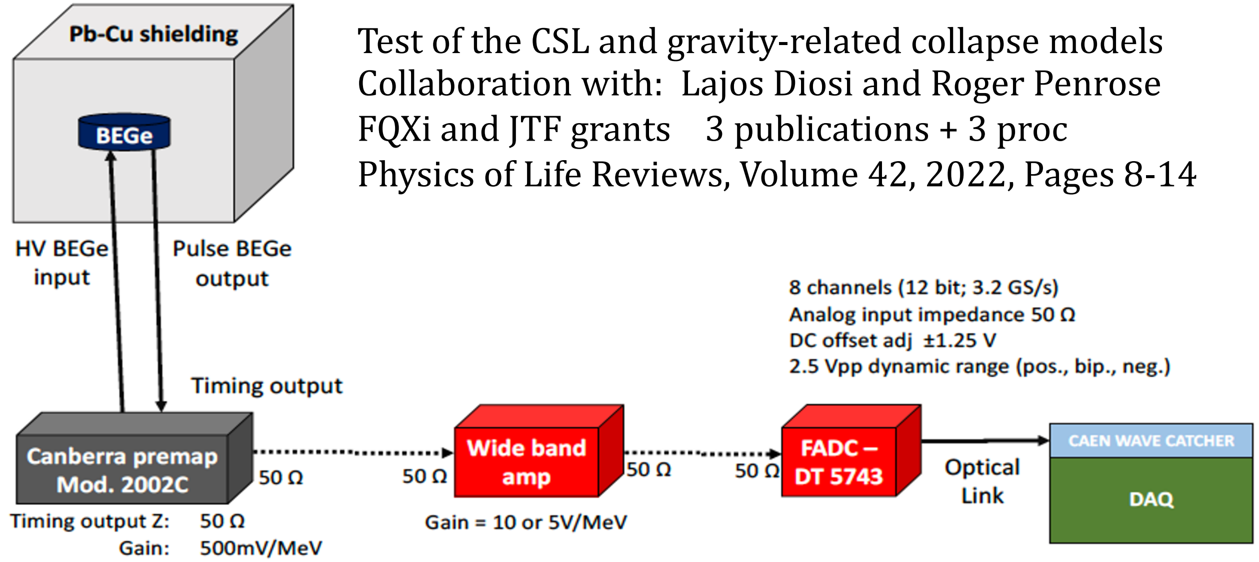
VIP-2 setup at LNGS and status

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
Probability of PEP violation b2/2<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 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

Ongoing activity
BEGe detector data taking 2021: data calibration, energy resolution & lower energy threshold studies completed. Dedicated pulse shape discrimination algorithm realized. New data taking 2022 ongoing: improved setup

- Flash-ADC-Computer USB optical fibre interface
- high insulation low noise amplifier introduced -> expected gain 10 in tension.

Test of the CSL and gravity-related collapse models
Collaboration with: Lajos Diosi and Roger Penrose
FQXi and JTF grants 3 publications + 3 proc
Physics of Life Reviews, Volume 42, 2022, Pages 8-14



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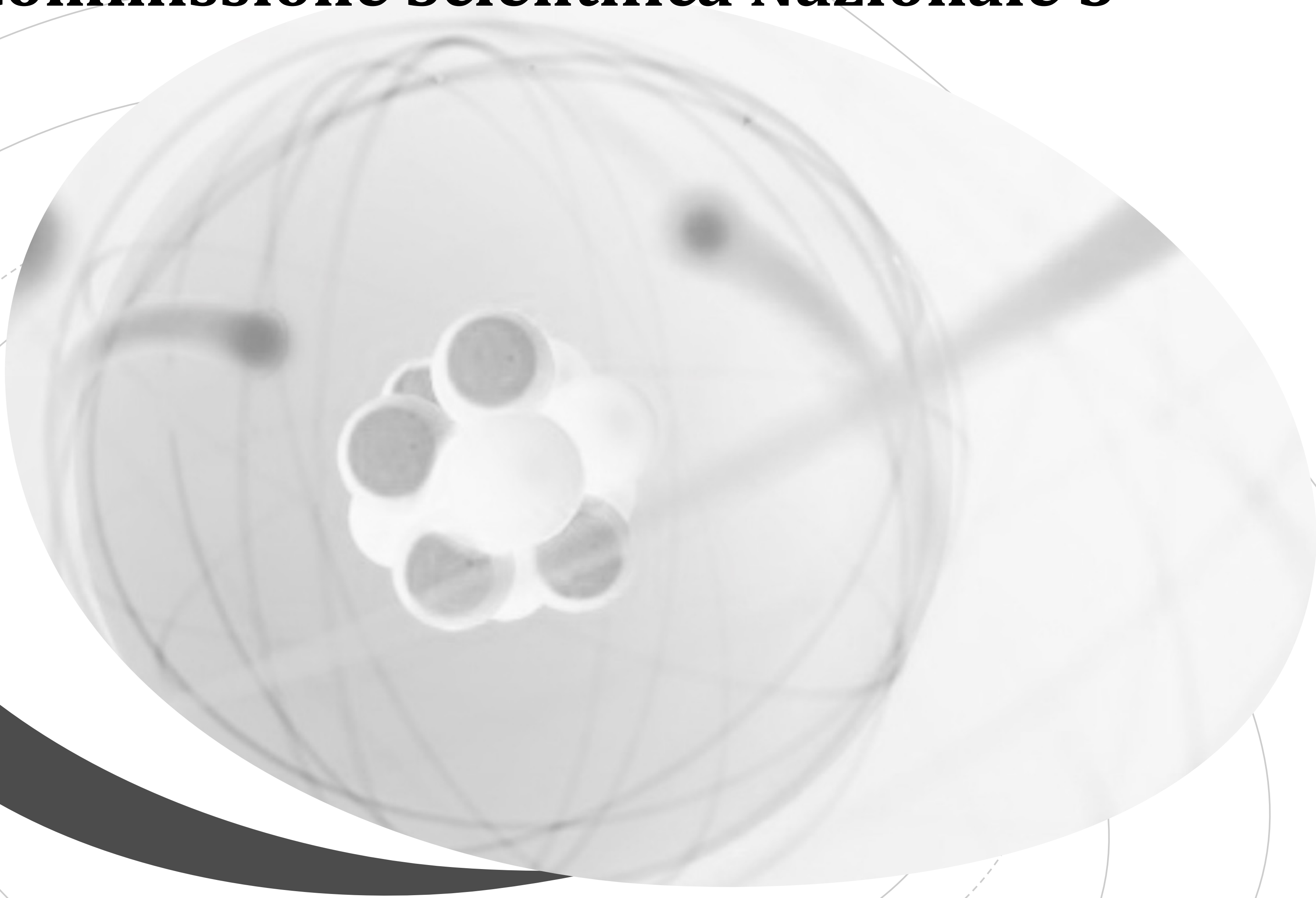

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