INFN NUCLEAR PHYSICS ACTIVITIES

AN OVERVIEW

Pasquale Di Nezza

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

The 4 Research Lines

Quarks and Hadron Dynamics
112 FTE

Phase Transitions in Nuclear Matter
142 FTE

CSN3
474 FTE

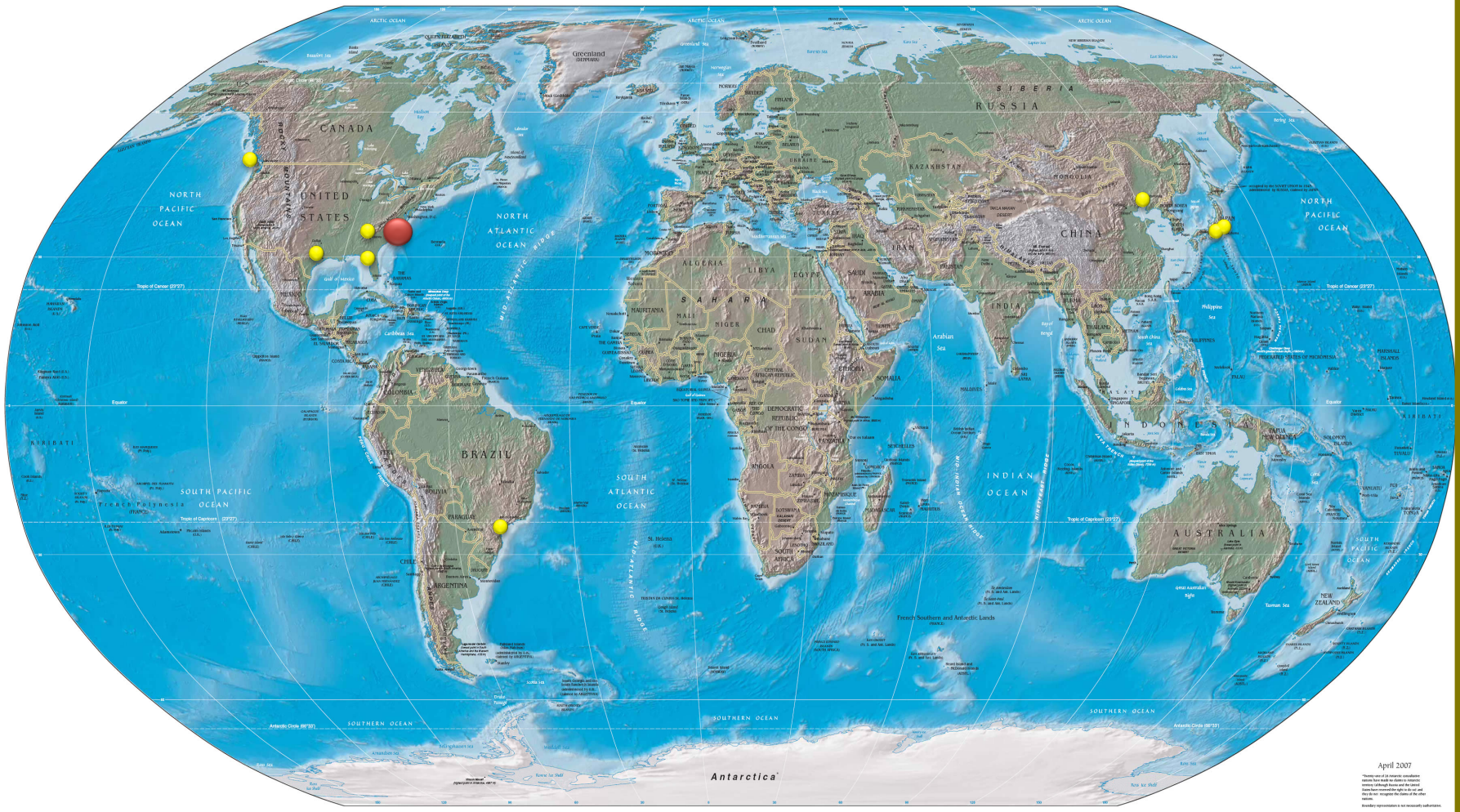
Nuclear Astrophysics and Interdisciplinary Research
86 FTE

Nuclear Structure and Reaction Mechanisms
134 FTE

European Facilities

Extra-European Facilities

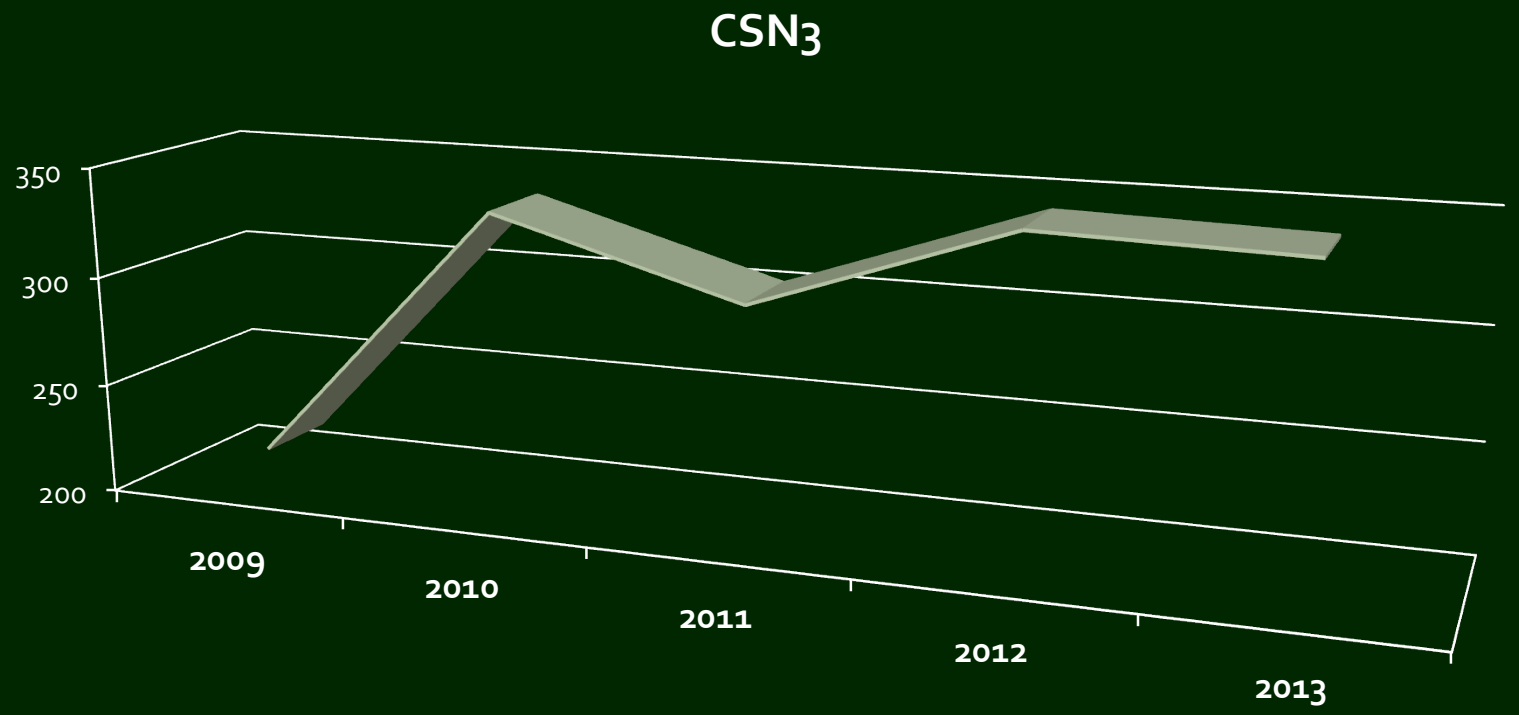
continuos activity temporary activity



Papers, Contr. to Conf., …

349	• Papers (ISI)
432	• Contribution to Conferences
18	• Doctoral Thesis
20	• Master Thesis

Paper Production



L1 - Quarks and Hadron Dynamics

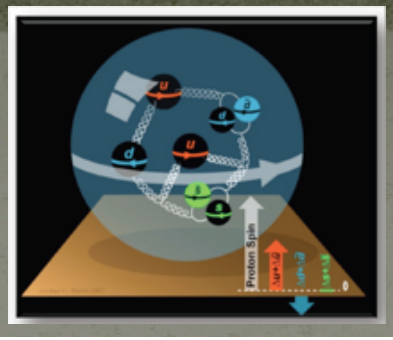
- Physics performed with Leptonic probes (Jlab, Bonn, Mainz) and Hadronic probes (DAϕNE@LNF)

- Non perturbative QCD (baryons and mesons)
- NLO pQCD
- Hadronization phenomena in nuclear matter
- Strangeness physics in nuclear matter
- N-N correlations
- Spin physics

JLAB12 collaboration @ JLab

- JLAB12, 65 scientists (~45 FTE, 14 INFN Units) is supporting the JLab broad experimental program in Hall-A and Hall-B
- INFN theoretical community, 30 scientists involved in JLAB12 physics is supporting the experimental effort
- JLAB12 activity supported by the EU FP6-7 (HPH) and linked to the hadron physics experiments in Europe: HERMES, COMPASS, PANDA
- INFN financial contribution (2009-14): €3.0M
- Significant INFN responsibilities: spokespersons of 12GeV experiments, chairmen and members of Collaboration Committees, Project-Leaders of major equipments

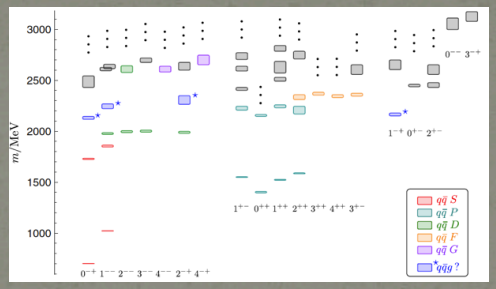
3-D mapping of the nucleon: understanding its spin



Nucleon Structure

- EM, EW, and Flavor-Separated Form Factors
- Structure functions
- Transverse Momentum Distributions (TMD)

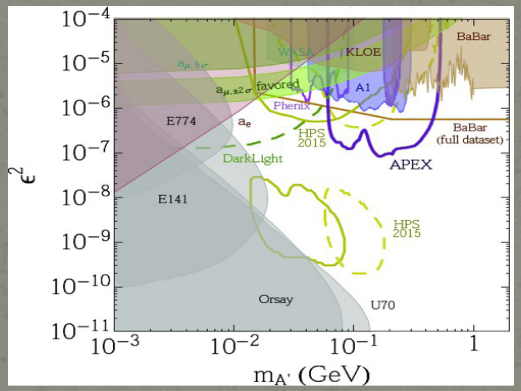
Understanding the origin of the hadrons mass



The Physics of Confinement

- Baryon spectroscopy
- Meson spectroscopy

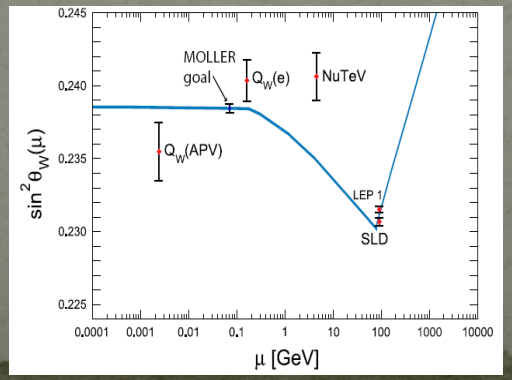
Physics beyond the Standard Model (I)



Light Dark Matter searches

- Dark forces (A')
- Beam dump experiments

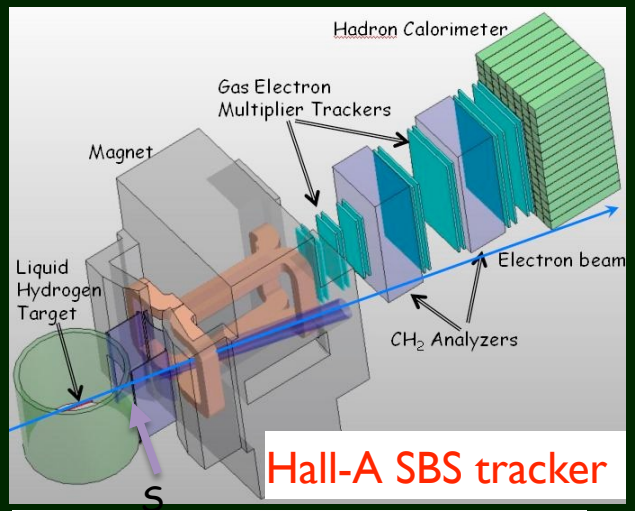
Physics beyond the Standard Model (II)



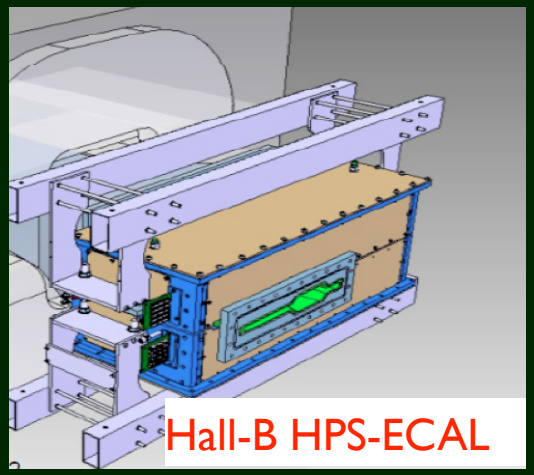
Standard Model tests

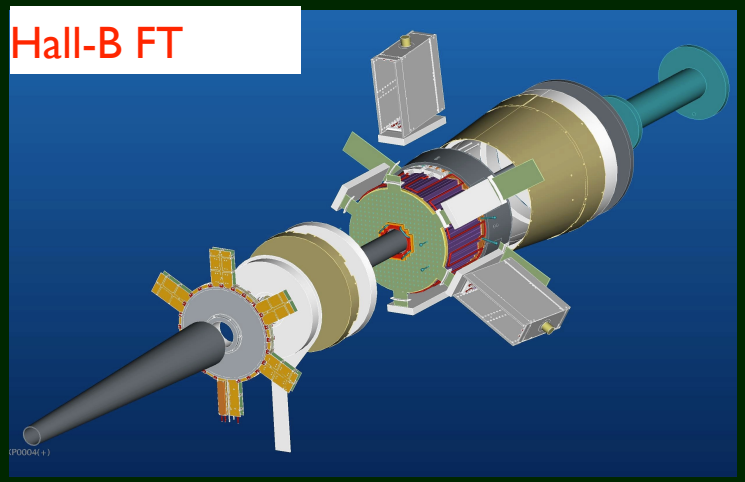
- Weak coupling measurements
- Weak charges determination
- Weinberg angle measurement

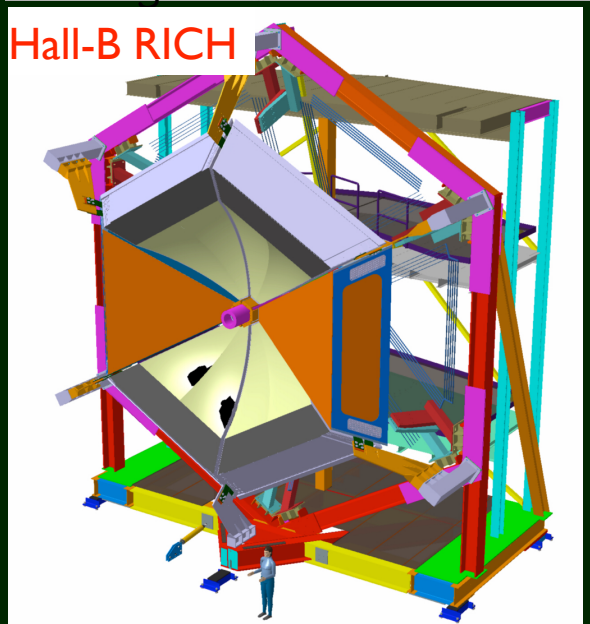
INFN contributions to 12 GeV program

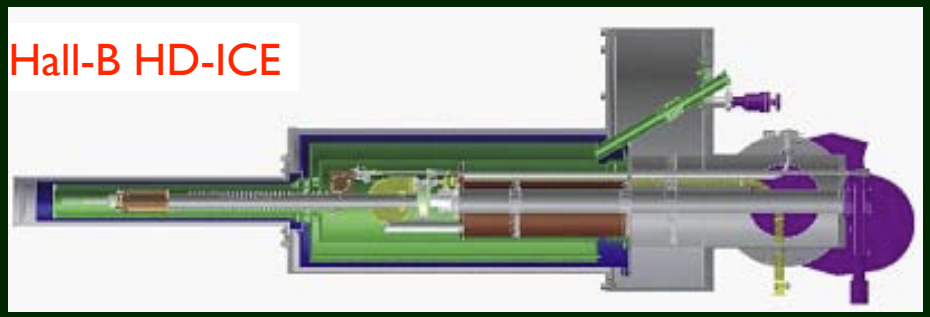


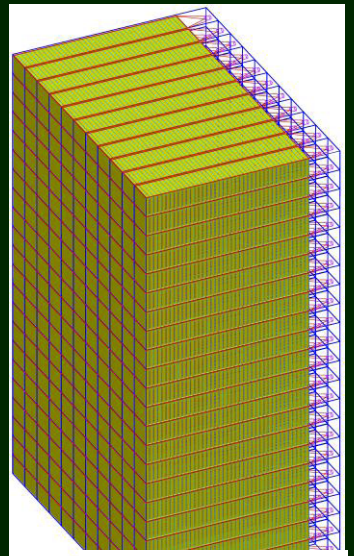
Hall-A SBS tracker


Hall-B HPS-ECAL


Hall-B FT


Hall-B RICH


Hall-B HD-ICE

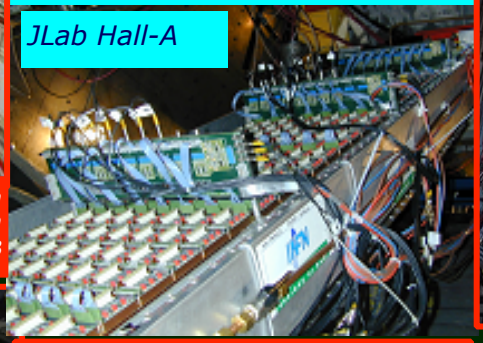

Hall-A HCAL

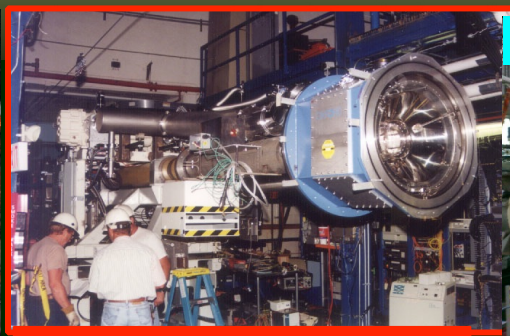
INFN contributions to (past) 6 GeV program

Large Angle Calorimeter *for electron beam*
JLab Hall-B

gas cherenkov
JLab Hall-A

RICH Detector
JLab Hall-A

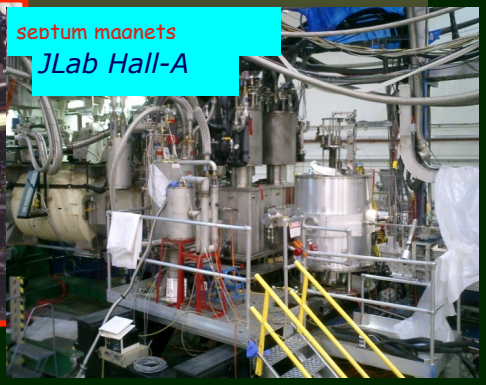




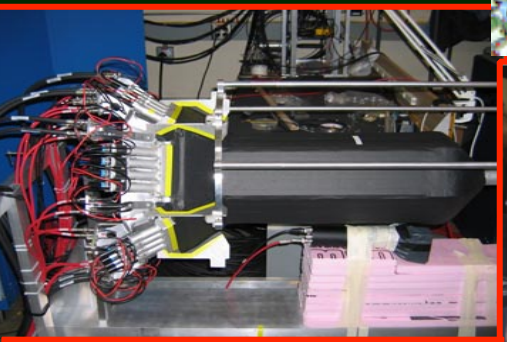
Polarized Target *for electron beam*
JLab Hall-B

Cerenkov Counter *for low-Q²*
JLab Hall-B

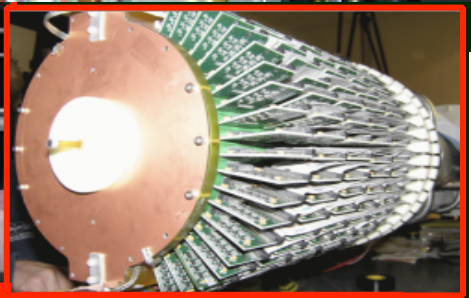
septum maanets
JLab Hall-A



waterfall
JLab Hall-A



Start Counter *for photon beam*
JLab Hall-B

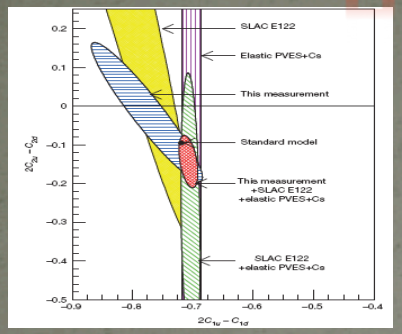


Upgrade of the Bonus Detector Electronics
JLab Hall-B

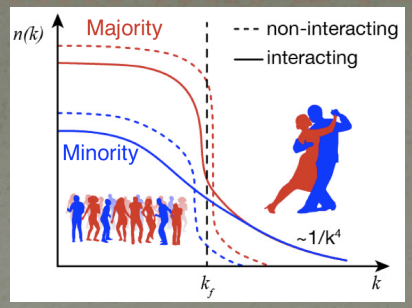
aerogel, cherenkov
JLab Hall-A

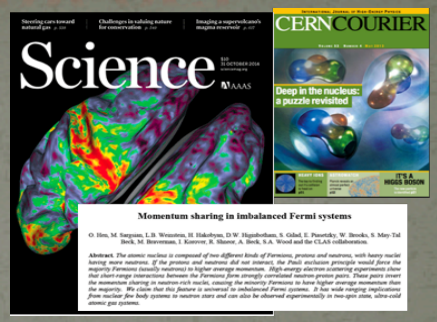
Tagger Electronics Upgrade
JLab Hall-B

Highlights from the 6 GeV era

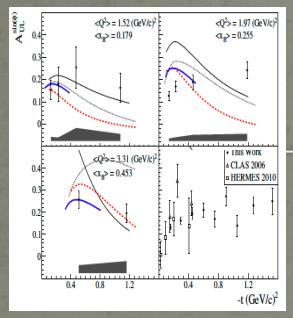


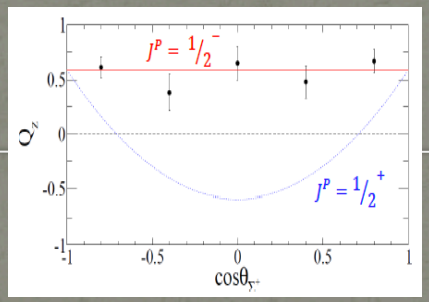
Measurement of the weak quark – electtron couplings
Nature 506 (2014) 67

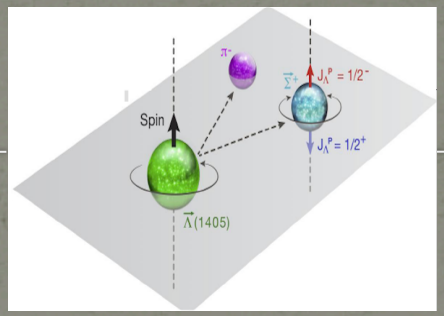


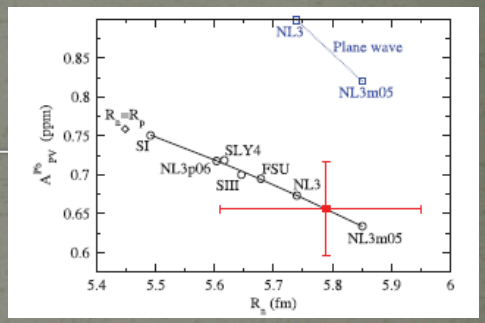


Short Range Correlation in nuclei
Science 31 October 2014: Vol. 346 614-617





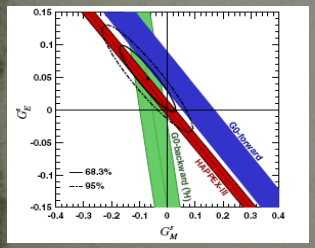


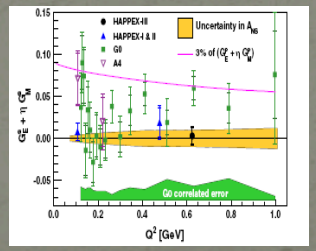


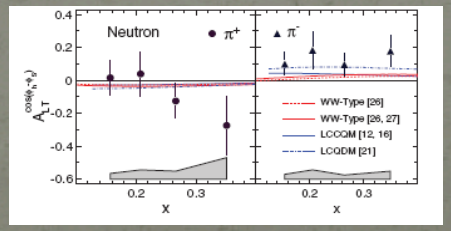
Long target spin asymmetries for DVCS
Phys Rev Lett 114, 032001 (2015)

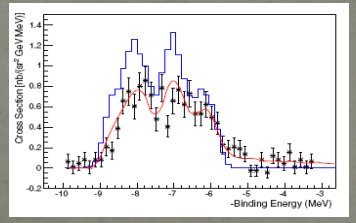
Measurement of the Spin and Parity of the Λ(1405)
Phys Rev Lett 112, 082004 (2014)

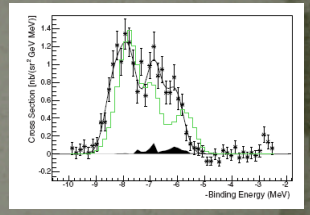
Neutron skin in Lead
Phys Rev Lett 108 112502 (2012)









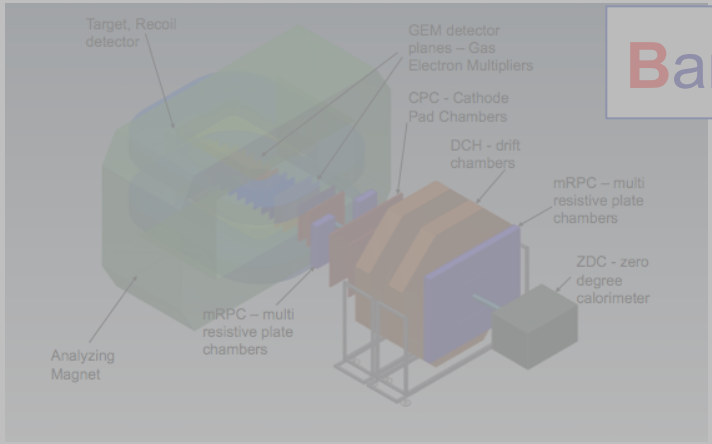


Strange vector form factors of the proton
Phys Rev Lett 108 102001 (2012)

Double-Spin Asymmetry in Charged Pion Production from DIS on Transversely Polarized 3He (quark spin-orbit correlations)
Phys Rev Lett 108 112502 (2012)

Spectroscopy of ${}^{9}_{\Lambda}Li$
Phys Rev C 91 034308(2015)

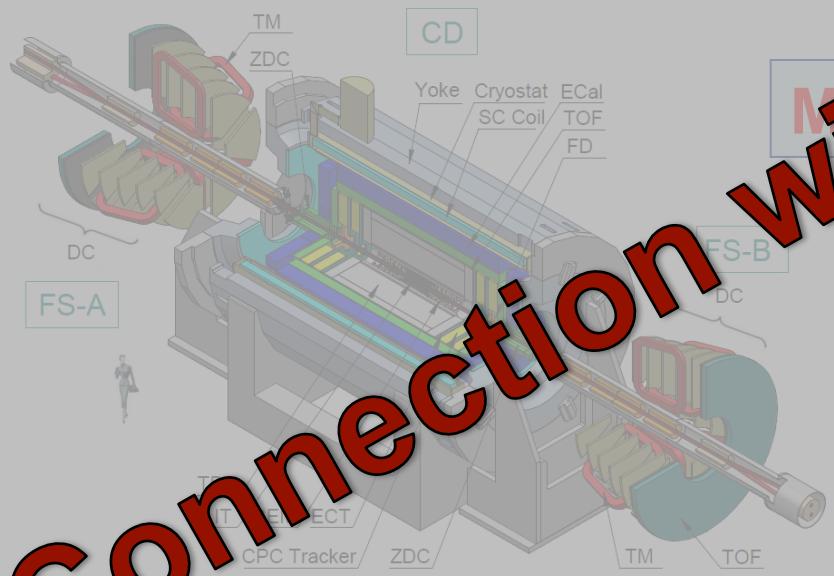
3 detectors



Baryonic **M**atter at **N**uclotron (**BM@N**)

the fixed target experiment at the Nuclotron

Stage I **2017**



Multi**P**urpose **D**etector (**MPD**)

at the Collider

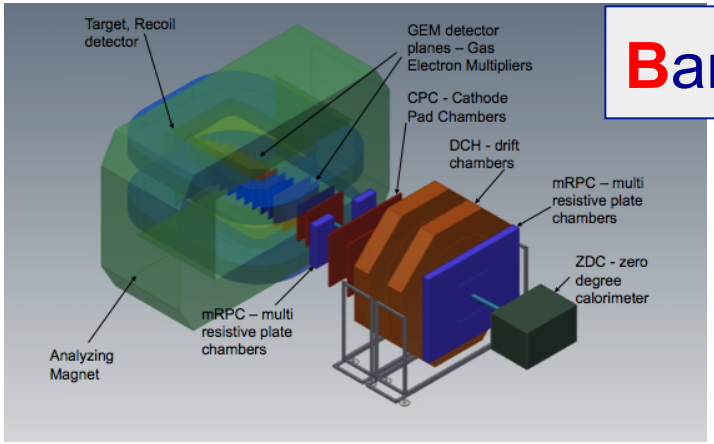
Stage I **2019**

Connection with NICA-JINR

SPD (Spin Physics Detector) *at the Collider*

project is under preparation

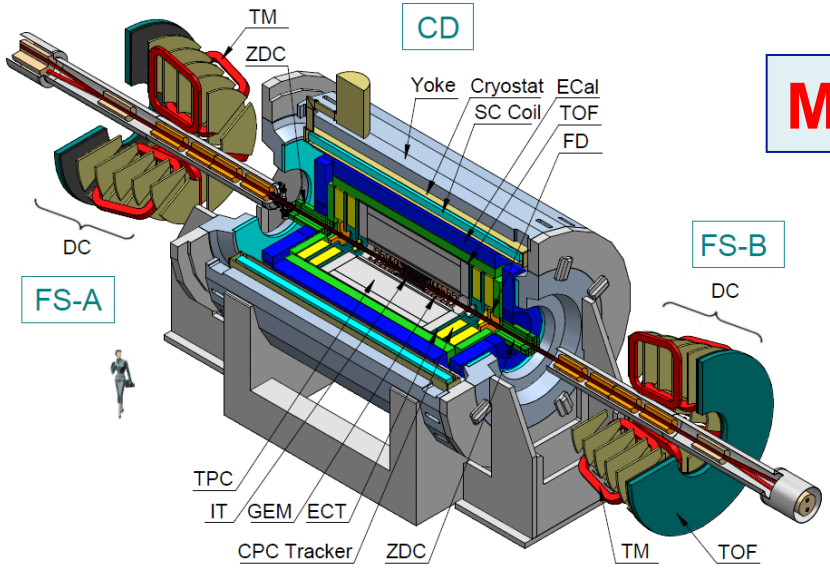
3 detectors



Baryonic **M**atter at **N**uclotron (**BM@N**)

the fixed target experiment at the Nuclotron

Stage I 2017



MultiPurpose Detector (MPD)

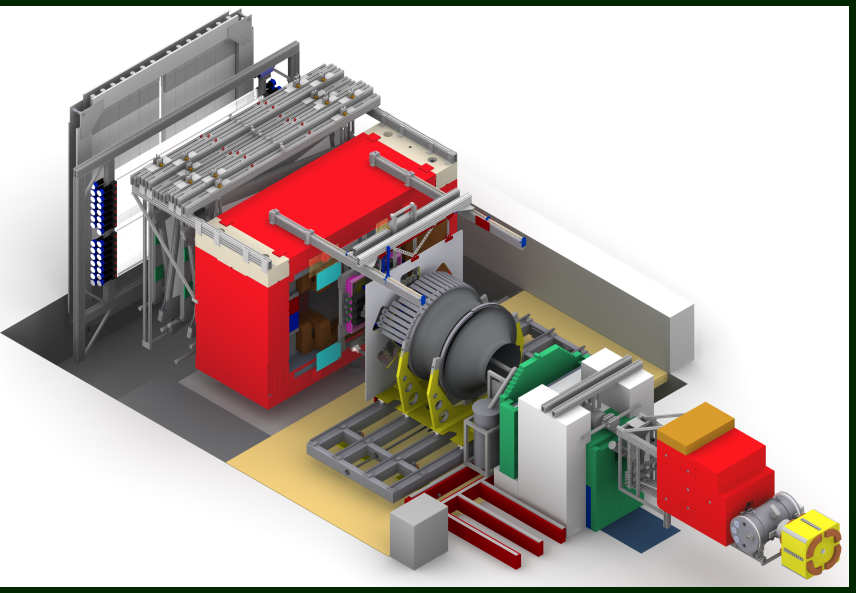
at the Collider

Stage I 2019

SPD (Spin Physics Detector) *at the Collider*

project is under preparation

BGO-OD EXPERIMENT @ ELSA



Energy tagged bremsstrahlung photon beam up to 3 GeV (linear polarisation up to 1.8 GeV). 5 Mev tagging resolution

BGO calorimeter in the central region and Open Dipole spectrometer in the forward direction

High momentum resolution, excellent neutral and charged particle ID

- Experimental program: meson photoproduction (η, η', ω, Φ, open strangness) off proton and off neutron (bound in D). η' mesic nuclei (C target)

Detector: commissioned (~90%)
Beam: commissioned
Data taking: starting

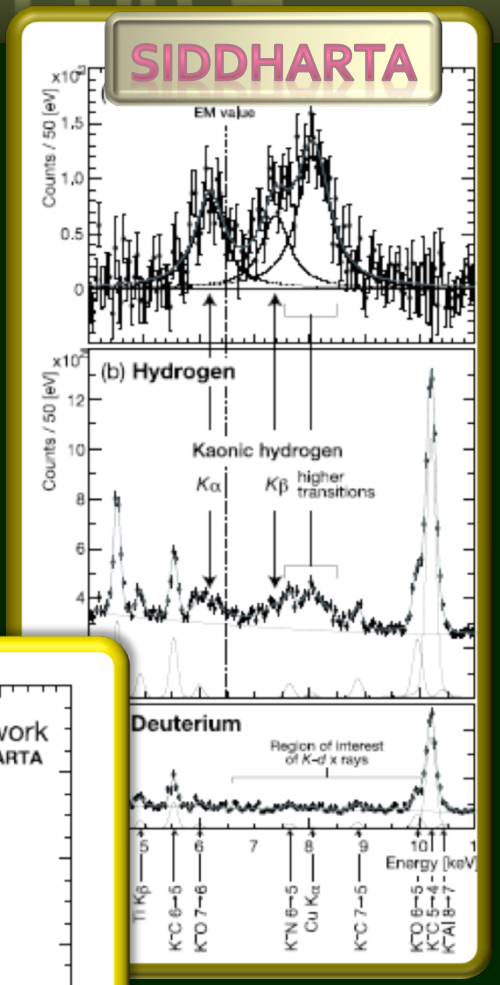
Collaboration: Bonn PI, Bonn HISKP, Gießen, ISS, LNF, Messina, Pavia, Roma2, Torino, Glasgow, Basel, PNPI Gatchina, INR Moscow, IHENP Kharkov, Iowa State U

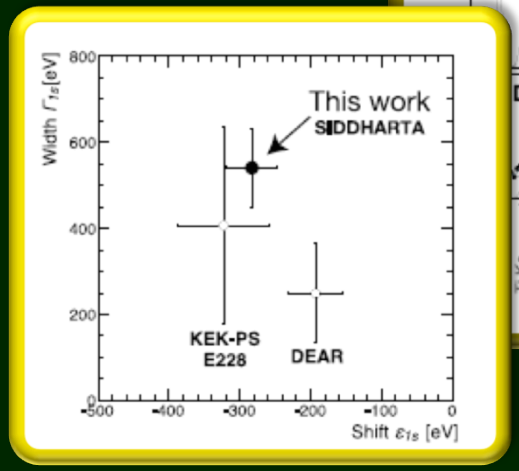
Strangeness and Nuclear Force

- **SIDDHARTA @DAΦNE (LNF-INFN)**
- Kaonic atoms: KH,KD, KHe3, KHe4

Measurement of the energy for the level 1s for the kaonic hydrogen (most precise ever)

- Unique facility. Next: LNF phase-II: SIDDHARTA2 and JPARC





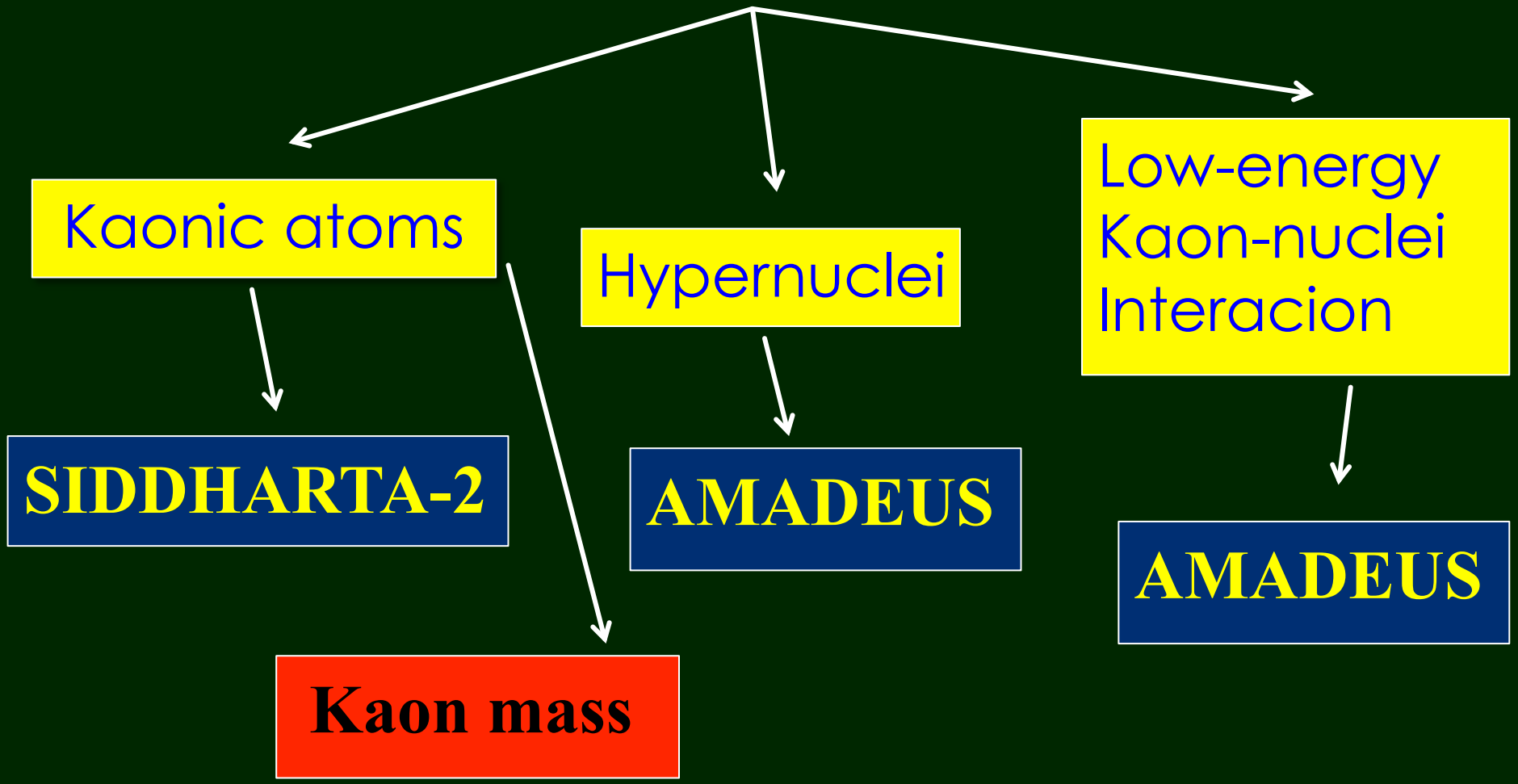
Experimental program of AMADEUS

The DAFNE collider the best possible beam of low energy kaons

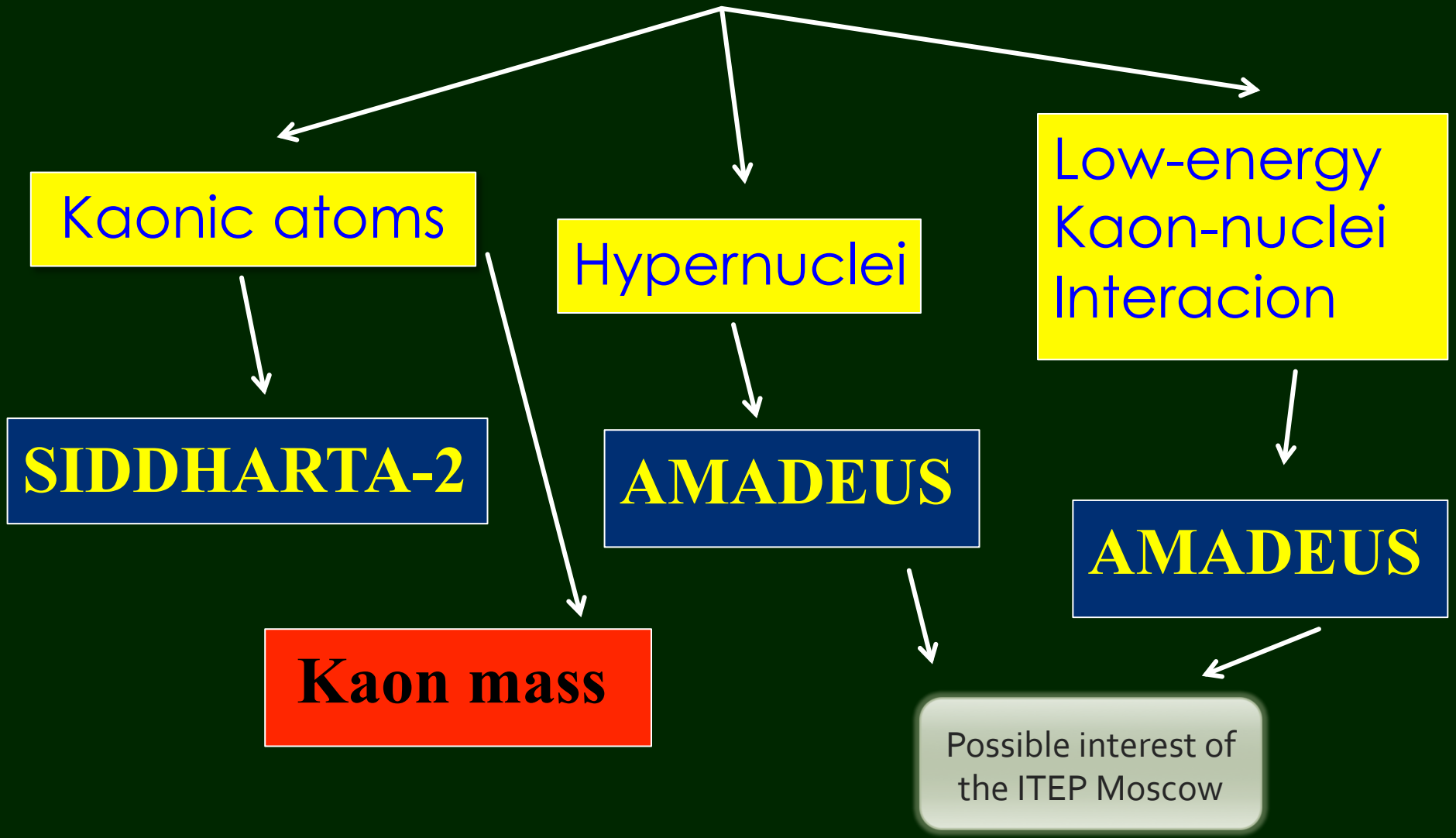
Unprecedented studies of the low-energy charged kaons interactions in nuclear matter: solid and gaseous targets (d, ^{3}He, ^{4}He) in order to obtain unique quality information about:

- Nature of the controversial **Λ(1405)**
- Possible existence of **kaonic nuclear clusters** (deeply bound kaonic nuclear states)
- Interaction of **K^-** with **one** and **two nucleons.**
- Low-energy charged kaon **cross sections** for momenta lower than 100 MeV/c (missing today)
- Many other processes of interest in the low-energy QCD in strangeness sector -> implications from particle and nuclear physics to astrophysics (dense baryonic matter in **neutron stars**)

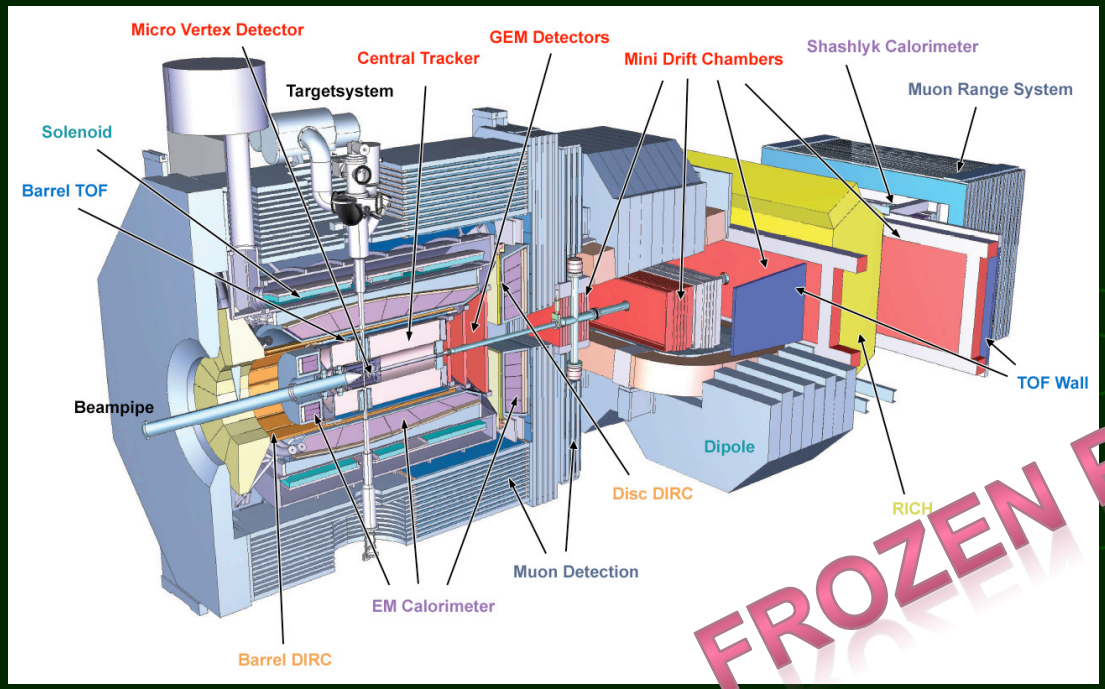
(Possible) Future @ Daphne - LNF



(Possible) Future @ Daphne - LNF



PANDA @GSI



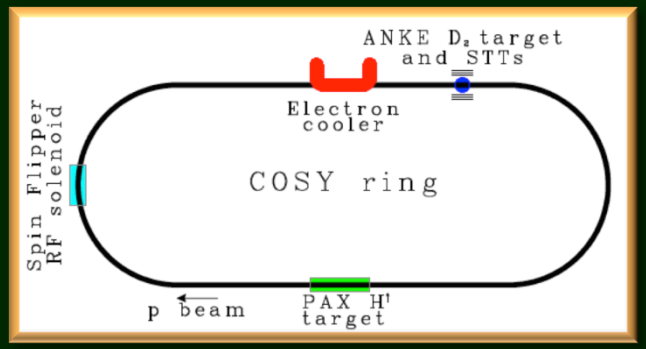
FROZEN PROJECT

...prolific collaboration INFN-JINR

- Magnets
- Instrumented iron
- Software packages (simulation, track reconstruction, online muon selection, calibration)

PAX @ COSY

Spin filtering for anti-proton (transverse) polarization



Possible extension to preparatory studies for EDM measurements


Physics Letters B 718 (2012) 64–69
Contents lists available at SciVerse ScienceDirect
Physics Letters B
www.elsevier.com/locate/physletb

Polarization of a stored beam by spin-filtering

W. Augustyniak [a], L. Barion [b], S. Barsov [c], U. Bechstedt [d,e], P. Benati [b], S. Bertelli [b], V. Carassiti [b], D. Chiladze [f], G. Ciullo [b], M. Contalbrigo [b], P.F. Dalpiaz [b], S. Dymov [g,h], R. Engels [d,e], W. Erwen [e,i], M. Fiorini [b], M. Gaisser [d,e], R. Gebel [d,e], P. Goslawski [j], K. Grigoriev [c,d,e], G. Guidoboni [b], A. Kacharava [d,e], A. Khoukaz [j], A. Kulikov [h], H. Kleines [i,e], G. Langenberg [d,e], A. Lehrach [d,e], P. Lenisa [b,*], N. Lomidze [f], B. Lorentz [d,e], G. Macharashvili [h,d,f], R. Maier [d,e], B. Marianski [a], S. Martin [d,e], D. Mchedlishvili [f], S. Merzliakov [h,d,e], I.N. Meshkov [h], H.O. Meyer [k], M. Mielke [j], M. Mikirtychiants [c,d,e], S. Mikirtychiants [c,d,e], A. Nass [d,e], M. Nekipelov [d,e], N. Nikolaev [d,e,l], M. Nioradze [f], D. Oellers [b,d,e], M. Papenbrock [j], L. Pappalardo [b], A. Pesce [b], A. Polyanskiy [d,e,m], D. Prasuhn [d,e], F. Rathmann [d,e], J. Sarkadi [d,e], A. Smirnov [h], H. Seyfarth [d,e], V. Shmakova [h,d], M. Statera [b], E. Steffens [g], H.J. Stein [d,e], H. Stockhorst [d,e], H. Straatman [n,e], H. Ströher [d,e], M. Tabidze [f], G. Tagliente [o], P. Thörngren-Engblom [b,p], S. Trusov [r,q], A. Trzcinski [a], Yu. Valdau [d,e,c], A. Vasiliev [c], K.M. von Würtemberg [s], Chr. Weidemann [b,d,e], P. Wüstner [i,e], P. Zupranski [a]

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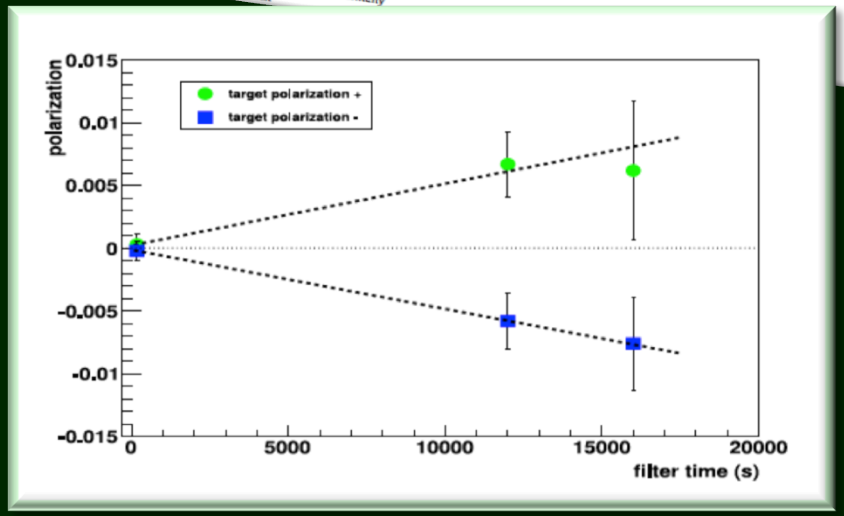
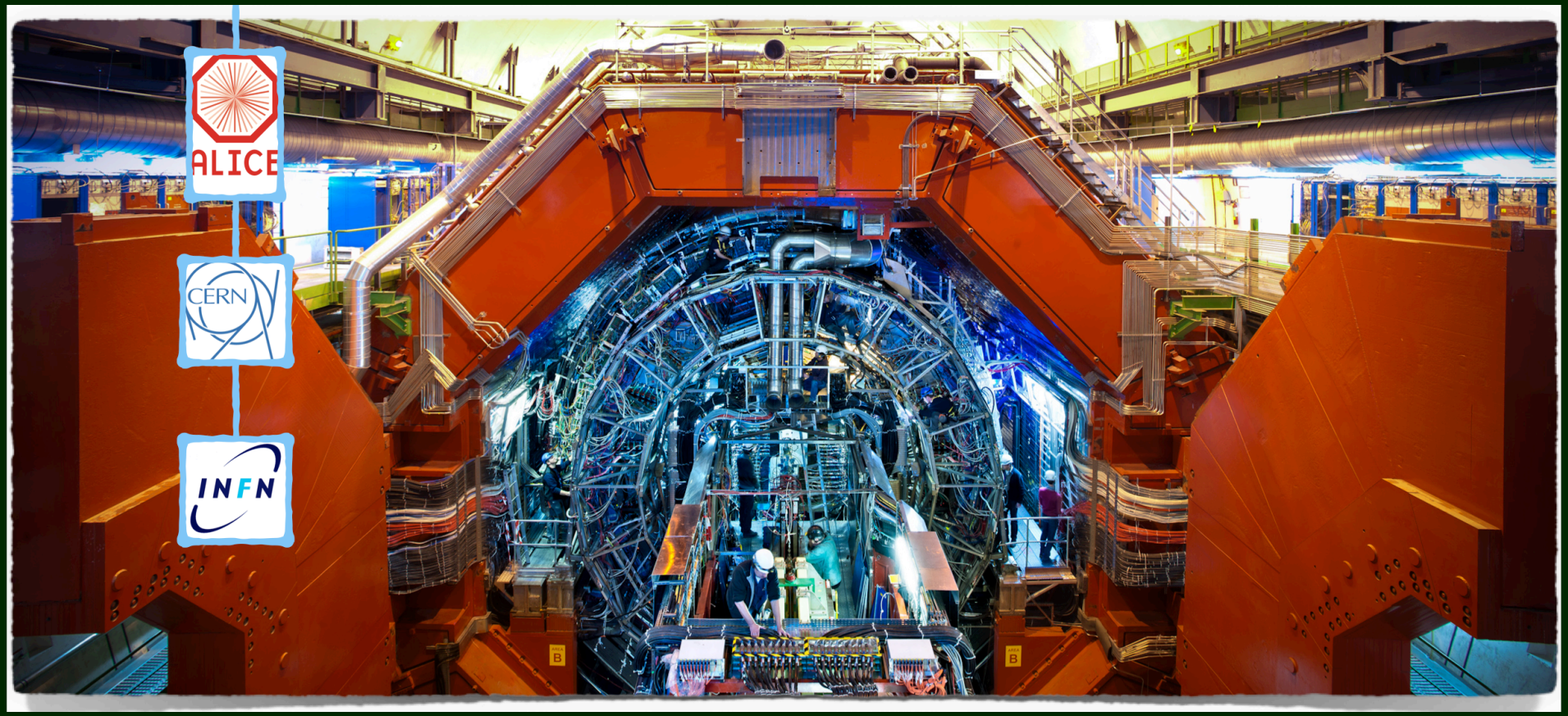
[k] Physics Department, Indiana University, Bloomington, IN 47405, USA
[l] L.D. Landau Institute for Theoretical Physics, 142432 Chernogolovka, Russia
[m] Institute for Theoretical and Experimental Physics, 117218 Moscow, Russia
[n] Zentralabteilung Technologie, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany
[o] INFN, Sezione di Bari, 70126 Bari, Italy
[p] Department of Physics, Royal Institute of Technology, SE-10691, Stockholm, Sweden
[q] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, 119991 Moscow, Russia
[r] Institut für Kern- und Hadronenphysik, Forschungszentrum Rossendorf, 01314 Dresden, Germany
[s] Department of Physics, Stockholm University, SE-10691, Stockholm, Sweden



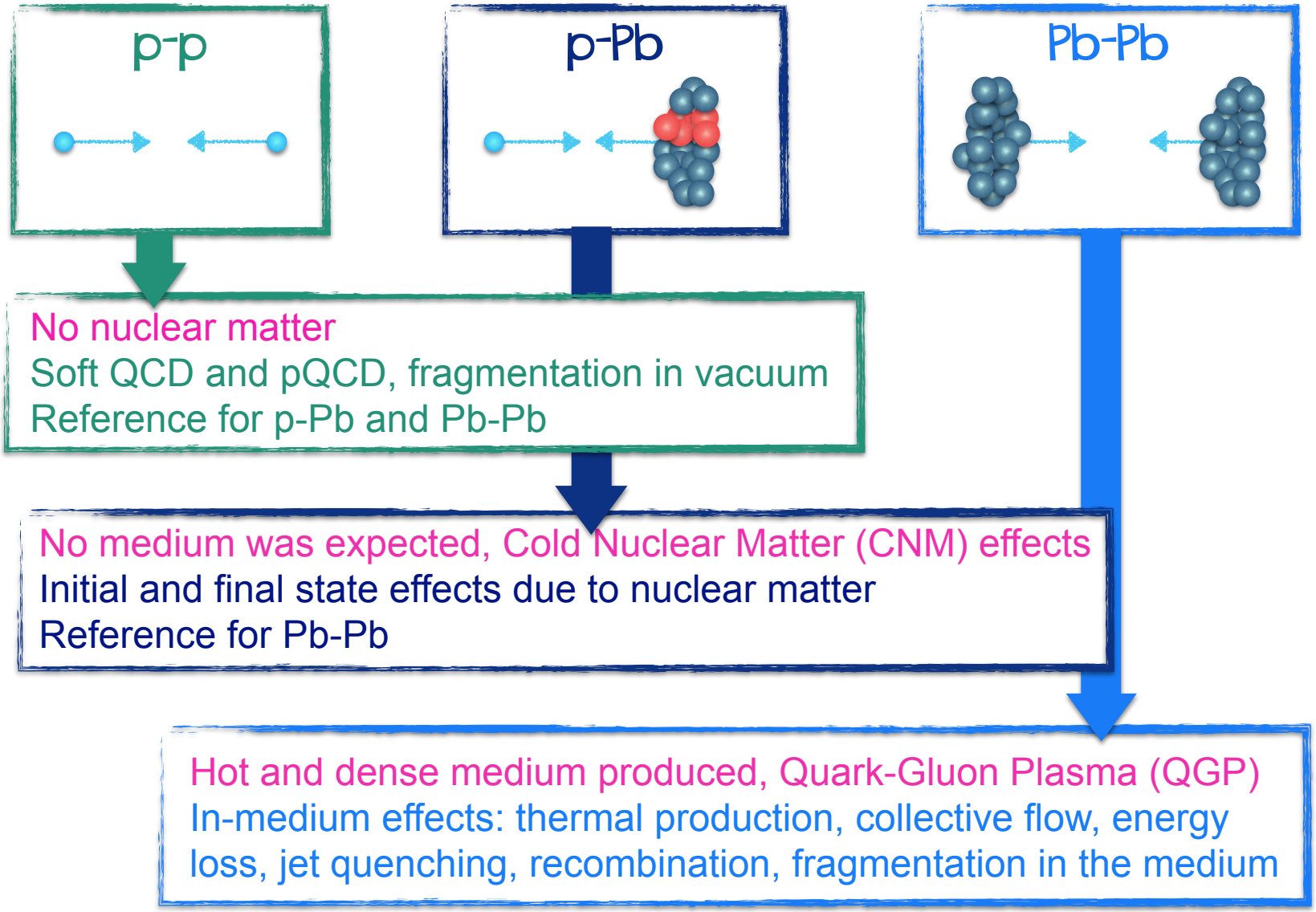
INFN-JINR collaboration for:

- Electron cooling
- Data analysis

L2 – Phase Transitions in NM



ALICE, not only QGP

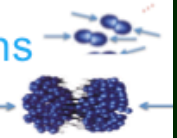


Medium Characterization

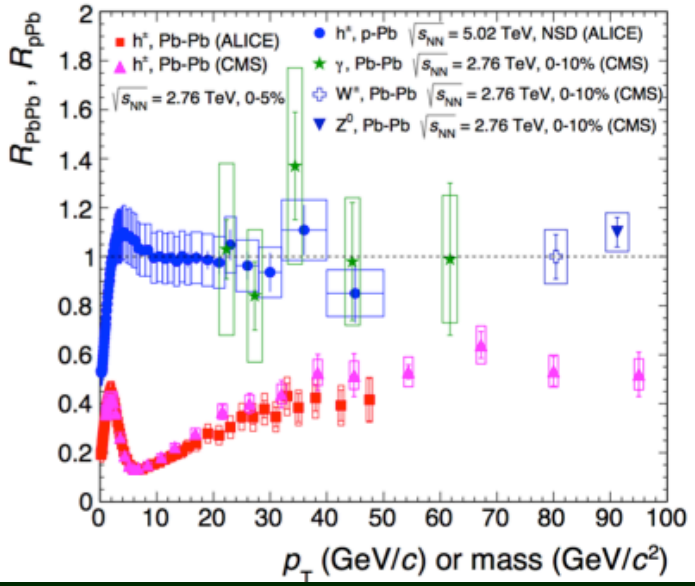
$$R_{AA}(p_T) = \frac{dN^{AA}/dp_T}{<N_{coll}> dN^{pp}/dp_T}$$

=1 ➧ binary scaling, no nuclear modifications

<1 ➧ suppression, nuclear modifications



- R_{pA} deviation from binary scaling due to COLD NUCLEAR MATTER EFFECTS
  - ➧ modifications in PDFs, gluon saturation
- R_{AA} deviation from binary scaling due to HOT NUCLEAR MATTER EFFECTS
  - ➧ partonic energy loss, suppression/(re)generation in the hot and dense medium

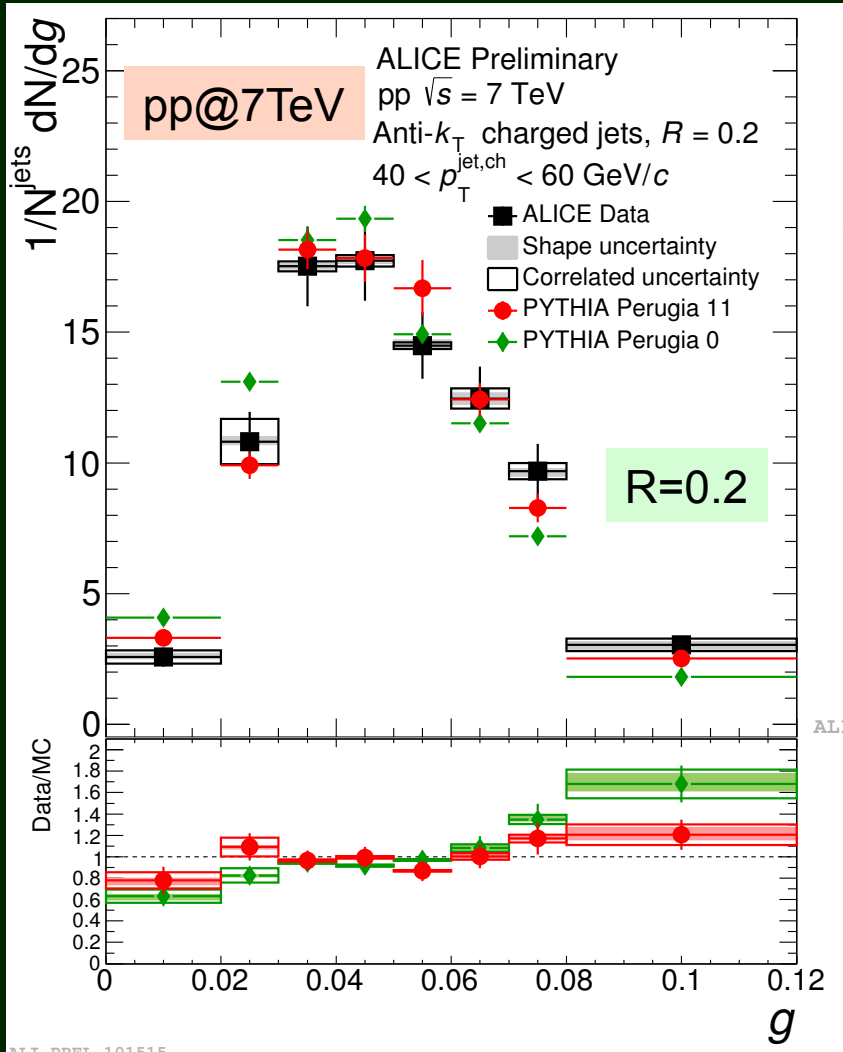


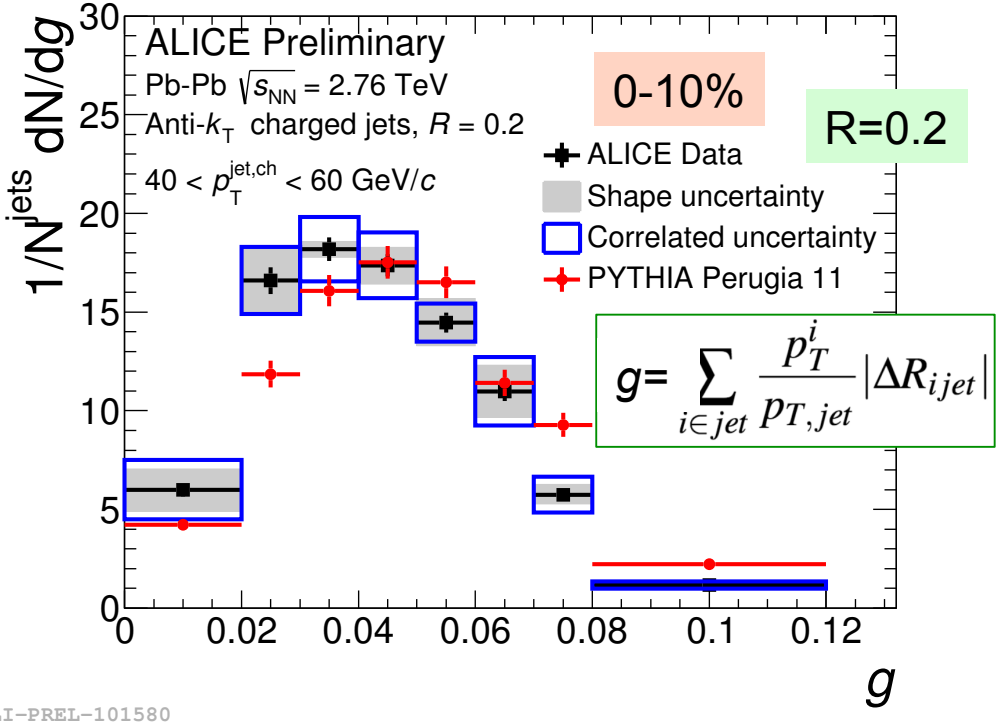
EM probes ➧ no modification since they do not interact with the medium formed in A-A collisions

p-A collisions ➧ used to disentangle hot nuclear effects since only COLD MATTER EFFECTS expected to occur

➧ If no suppression is observed in p-A collisions, then the suppression in A-A collisions is a HOT MATTER EFFECT due to the hot and dense medium

Selected result: Jet Shape

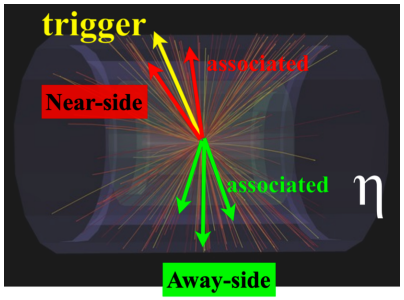


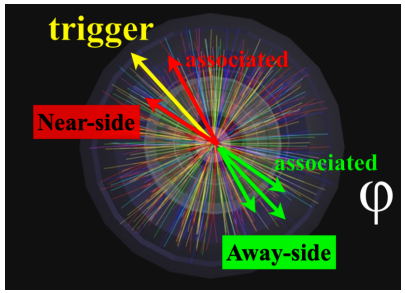


- New variables to characterize Jet-core shapes (constituents in R=0.2)
  - ✓ Radial moment (g), Dispersion in p_T, leading-sub leading p_T
- Consistent with PYTHIA in pp
- Core of Pb-Pb jets more collimated than pp jets

Selected result: 2-particle correlation

Distributions of relative angles $\Delta\varphi$ and $\Delta\eta$ between pairs of particles: "trigger" particle in a certain transverse momentum $p_{T,trig}$ interval and "associated" particles in a $p_{T,assoc}$ range



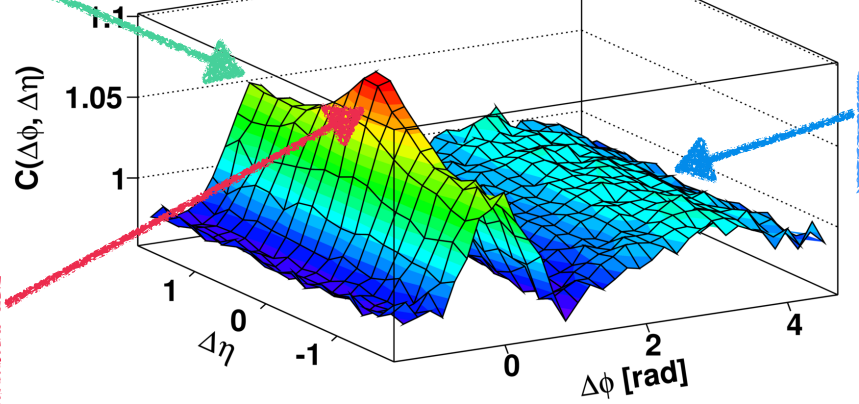


Long range ridge
($\Delta\varphi \sim 0$, elongated in η)

$3 < p_T^t < 4$ GeV/c

$2 < p_T^a < 2.5$ GeV/c

Pb-Pb 2.76 TeV
0-10%

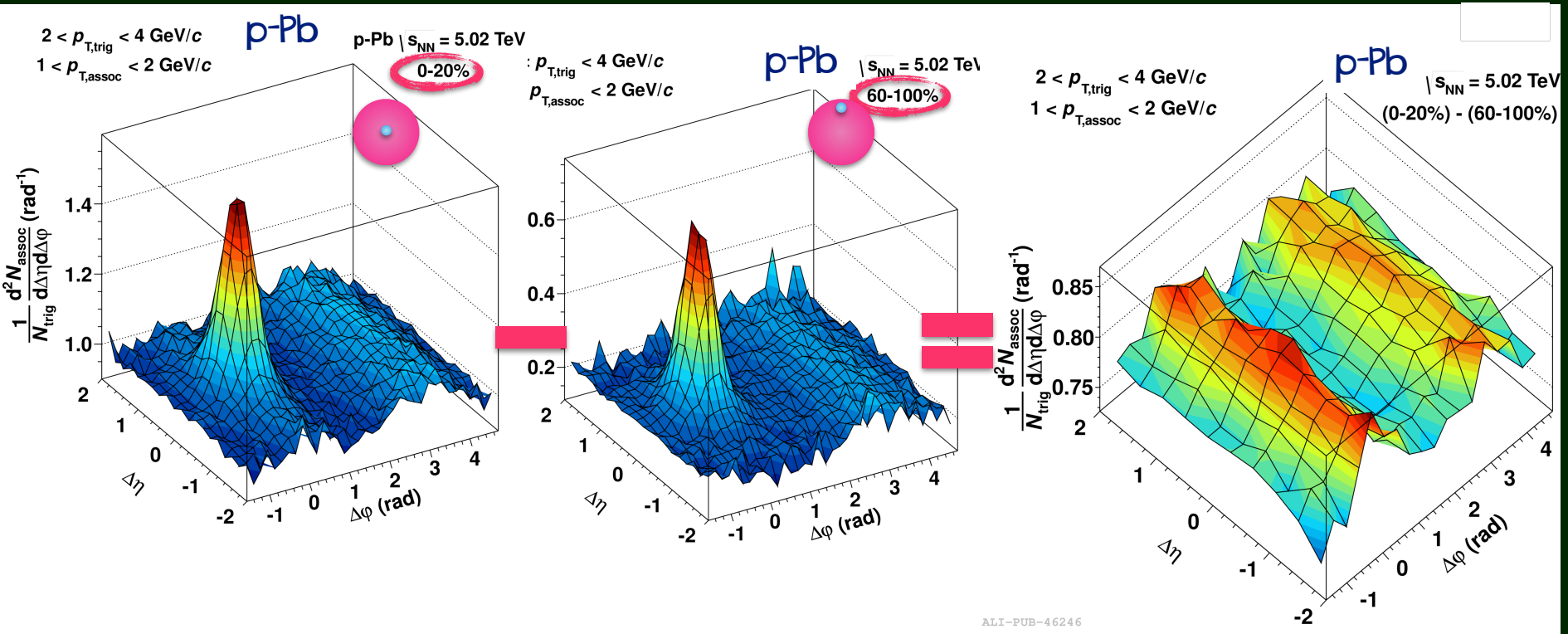


Away-side (recoil) jet
($\Delta\varphi \sim \pi$, elongated in $\Delta\eta$)

Near-side jet peak
($\Delta\varphi \sim 0$, $\Delta\eta \sim 0$)

- long range "ridges" are interpreted as evidence of collective behavior in the dense medium

Selected result: 2-particle correlation



- symmetric double ridge observed in p-Pb collisions where collective behaviors were not expected (no flowing medium is expected to be formed)!
- Proposed (and debated) explanations of the double ridge:
  - correlations established in initial high gluon dense state through partonic interactions
  - hydrodynamic flow

… and intriguing pp results

ALICE

ALICE @ QM2015

and more and more....

ALICE @ QM2015

27 talks and 50 posters in QM2015
ALICE's Adventure continues.

Correlations and Fluctuations
- Rashmi Raniwala: Longitudinal Asymmetry in Pb-Pb
- Ludmila Malinina: Femtoscopy in Pb-Pb
- Evgeny Kryshen: F-C correlations in p-Pb
- Panos Christakoglou: Balance function

Quarknoia
- Marco Leoncino: Psi(2S) in p-Pb
- Hugo Denis Antonio Pereira Da Costa: Charmonium in Pb-Pb
- Gines Martinez-Garcia: Low pT J/psi in Pb-Pb
- Indranil Das: Upsilon production in ALICE

Open Heavy Flavors and Strangeness
- Alessandro De Falco: ϕ in p-Pb and Pb-Pb
- Natasha Sharma: (anti-)(hyper-)nuclei and exotics
- Andrea Dubla: Heavy flavors in Pb-Pb
- Jeremy Wilkinson: Heavy flavors in p-Pb
- Fabio Filippo Colamaria: Heavy flavors in pp and correlations

QGP in small systems
- Antonio Ortiz Velasquez: Light flavors in p-Pb
- Livio Bianchi: Strangeness production in p-p

Jets and High pT Hadrons
- Leticia Cunqueiro Mendez: Jet structure in Pb-Pb
- Redmer Alexander Bertens: Charged jet anisotropy
- Astrid Morreale: High p_T photons and π^0 in Pb-Pb

Collective Dynamics
- Ramona Lea: (anti-)deuteron in Pb-Pb
- Anthony Robert Timmins: Event shape engineering
- You Zhou: Correlations of flow harmonics
- Naghmeh Mohammadi: Higher harmonics in Pb-Pb

Initial State Physics and Approach to Equilibrium
- Valentina Zaccolo: Multiplicity over wide rapidity in p-p

Electromagnetic probes
- Baldo Sahlmueller: Direct photons in Pb-Pb
- Patrick Simon Reichelt: Low mass dielectrons

Future Experimental Facilities, Upgrades, and Instrumentation
- Petra Riedler: ALICE ITS upgrade
- Chilo Garabatos Cuadrado: ALICE TPC upgrade

Including the new results @ 13 TeV

Italian Participation

ALICE has >1300 members (960 authors) from 156 institutes

The Italian participation has 180 members

Spokesperson	P. Giubellino (To)
Physics Coordinator	F. Antinori (Pd)
Management Board	R. Nania (Bo), E. Vercellin (To) , E. Scomparin (To), A. Zichichi (Bo), F. Ronchetti (LNF)
Tech. Board	G. De Cataldo (Ba), N. De Marco (To), M. Gagliardi (To), V. Manzari (Ba), P. Mereu (To), R. Nania (Bo), F. Prino (To), A. Rashevsky (Ts), G. Scioli (Bo), F. Ronchetti (LNF), C. Cicalo (Ca)
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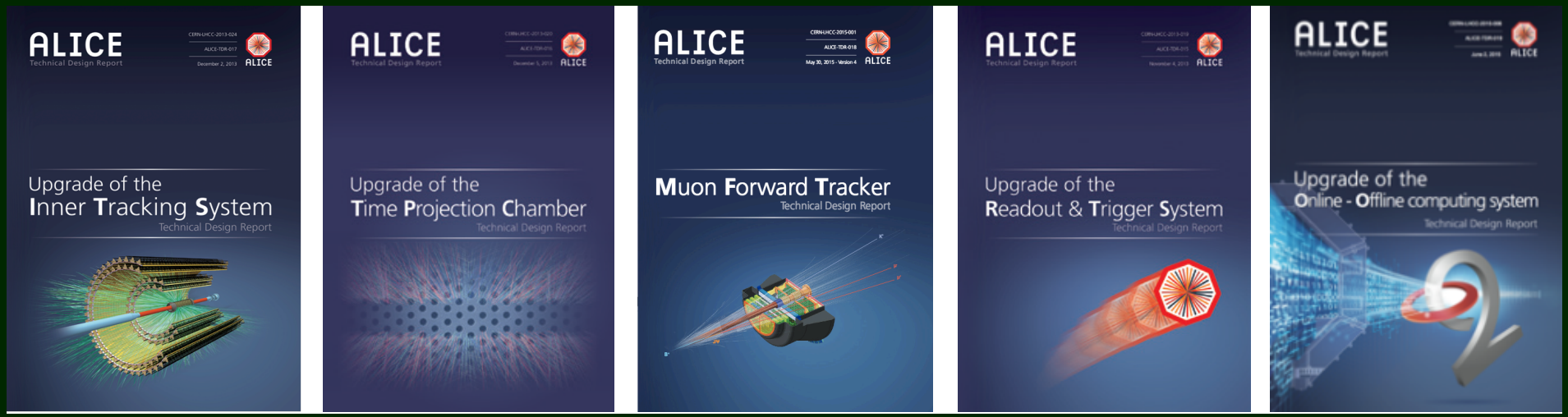
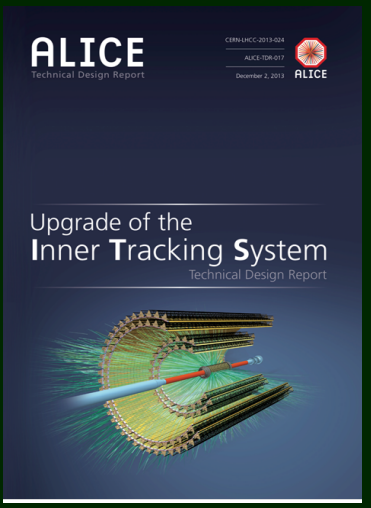
mitato di gestione Tier-1: D. Elia (Ba)

FN Grid EB: S. Bagnasco (To), A. Masoni (Ca)

ALICE Upgrade for Run 3



ALICE Upgrade for Run 3

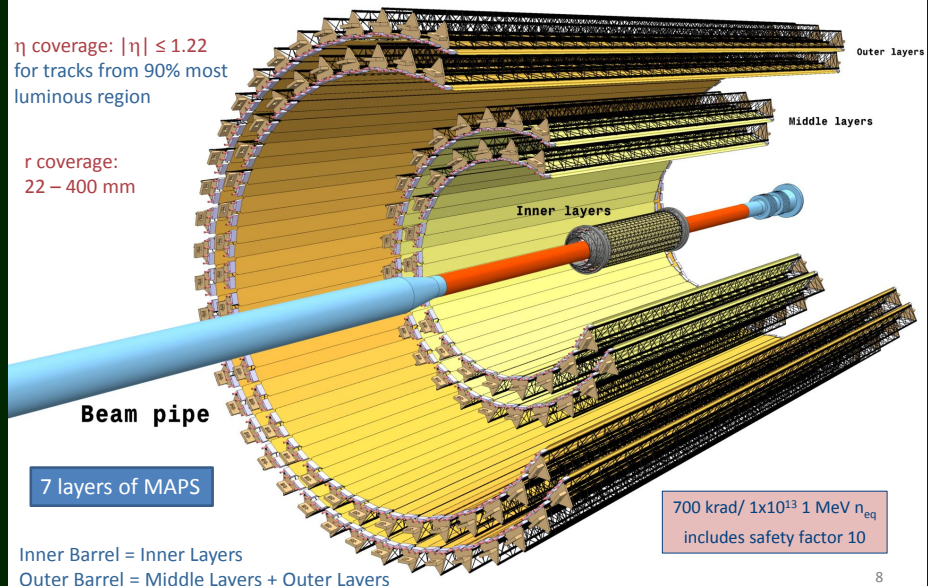


New ITS Layout

12.5 G-pixel camera (~10 m²)

η coverage: |η| ≤ 1.22 for tracks from 90% most luminous region

r coverage: 22 – 400 mm



7 layers of MAPS

700 krad/ 1x10¹³ 1 MeV n_{eq} includes safety factor 10

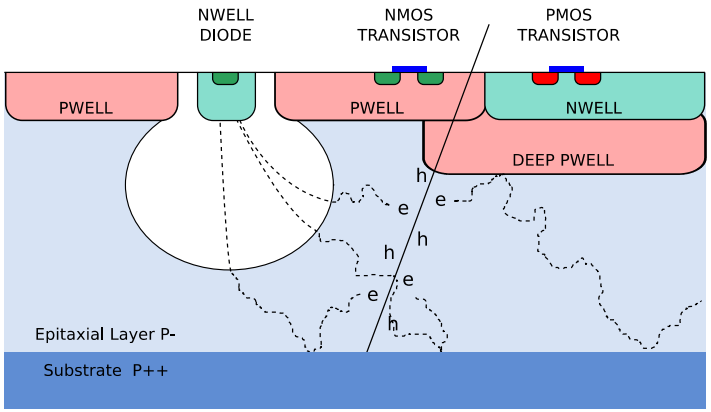
Inner Barrel = Inner Layers
Outer Barrel = Middle Layers + Outer Layers

8

PIXEL Chip

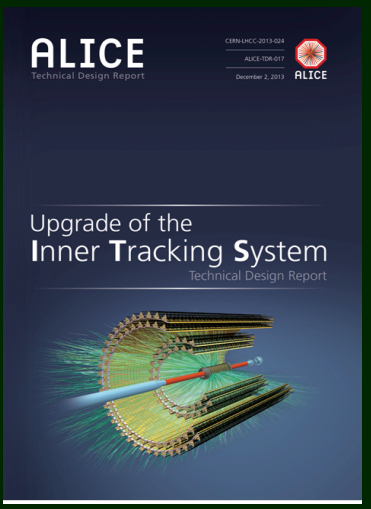
Monolithic PIXEL chip using Tower Jazz CMOS 0.18 µm

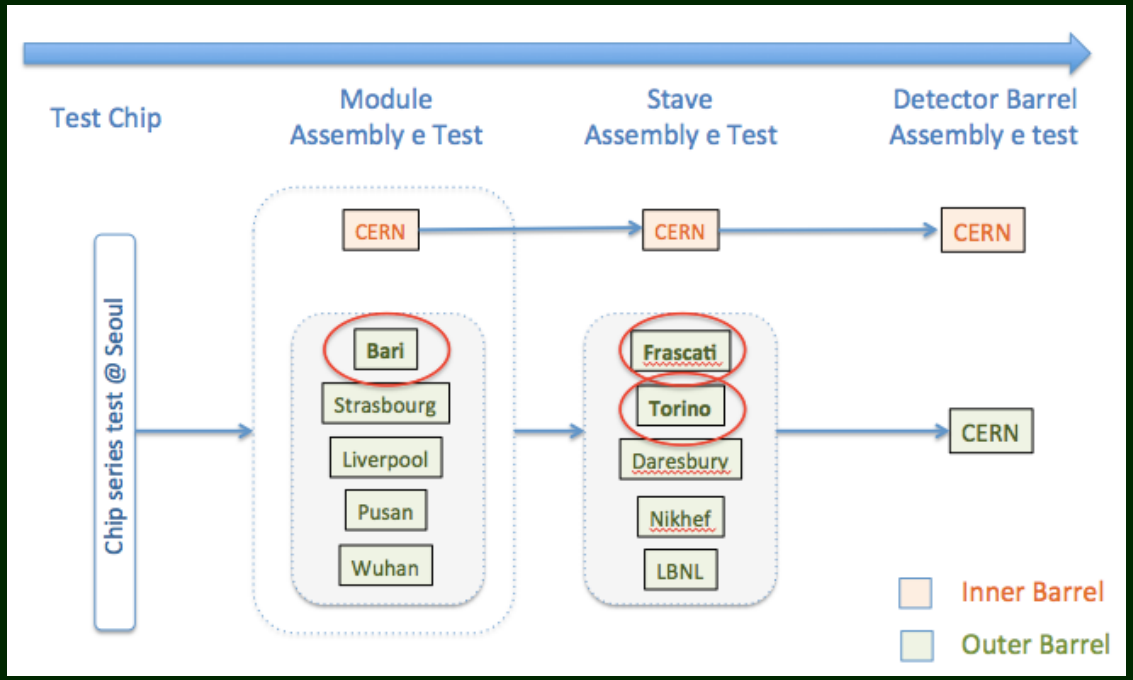
- Chip size: 15mm x 30mm
- Pixel pitch ~ 30 µm
- Spatial resolution ~ 5 µm
- Power density < 100 mW/cm²
- Architectures: MISTRAL, ALPIDE



Deep p-well allows truly CMOS circuit inside pixel

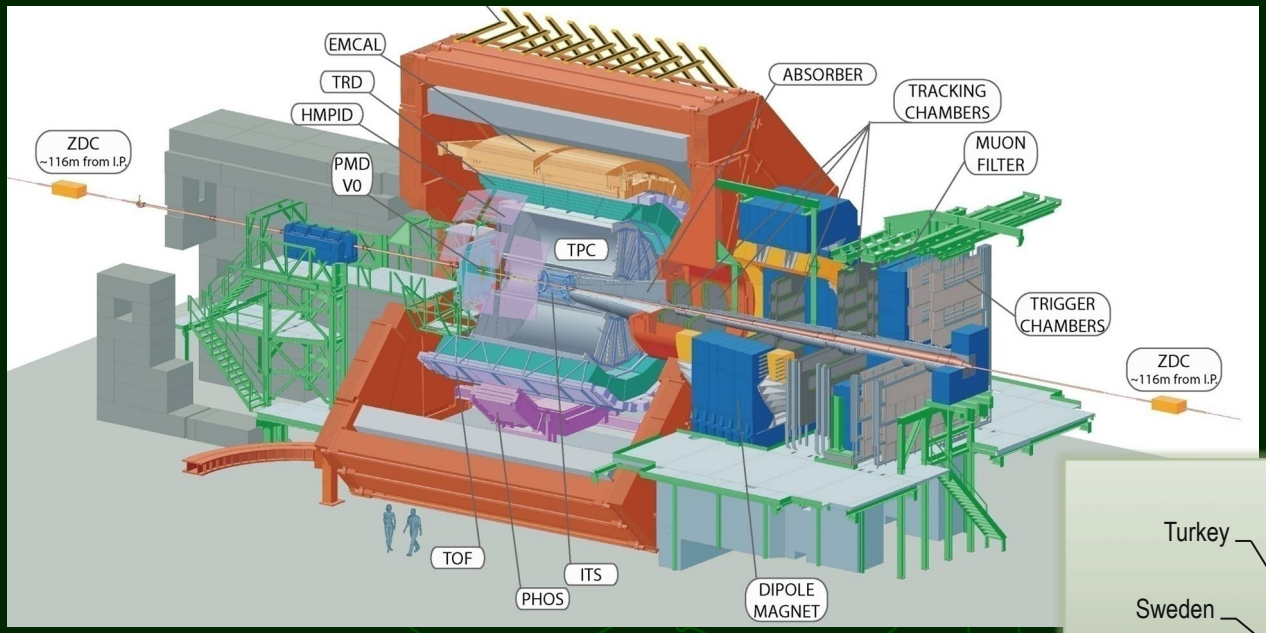
ALICE Upgrade for Run 3





INFN Units	Main responsabilities
Bari	• OB module production • Module ans Stave test system • Power Supply System
Cagliari	• Chip architecture (Priority encoder & R/O Interface) • Pixel Chip test system
Catania +Trieste	• Production and test for the OB-FPC
LNF +Roma	• OB Stave production • LNF Beam Test Facility
Padova	• OB Integration: End-wheels, Conical Structural Shell, Half-Layer e Half-barrel
Torino+ Alessandria	• PLL & DTU of the Pixel Chip • FPC Design • OB Stave production

RUSSIA IN ALICE



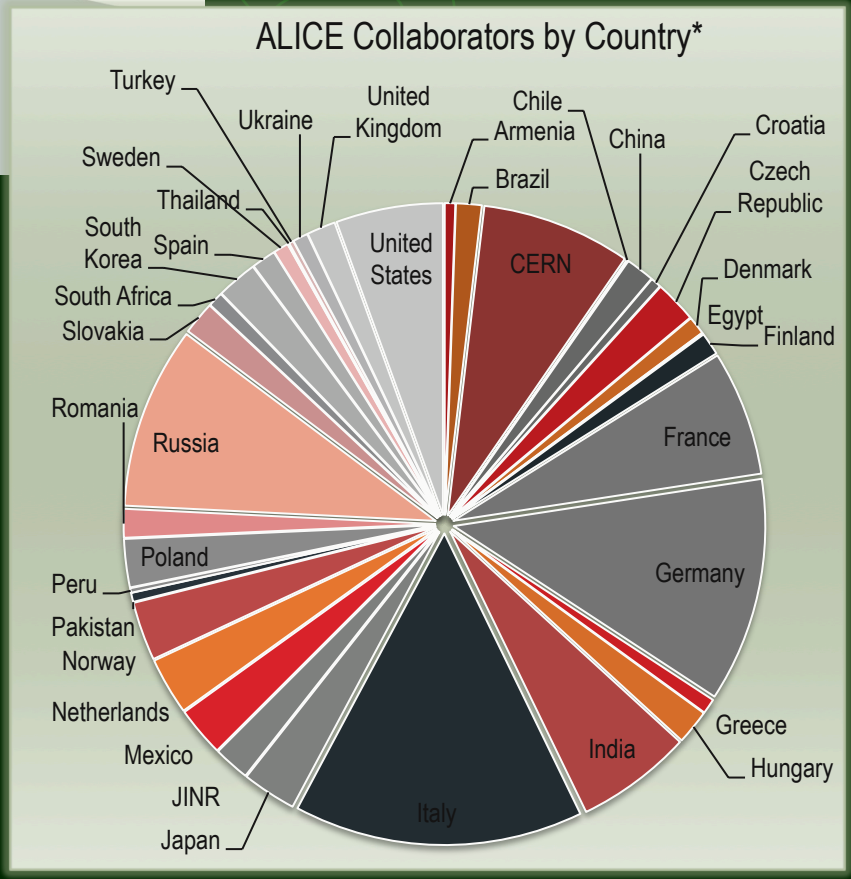
Inner Tracking System (ITS)

Inner Tracking System – Silicon Drift Detector (SDD)

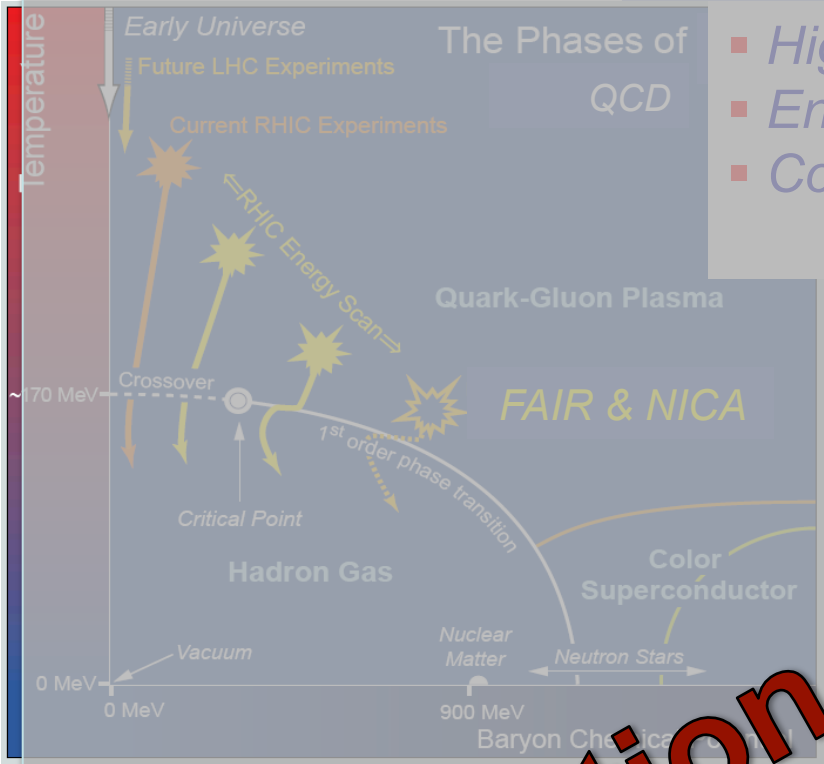
Inner Tracking System – Silicon Strip Detector (SSD)

Photon Spectrometer (PHOS)

Muons Tracking

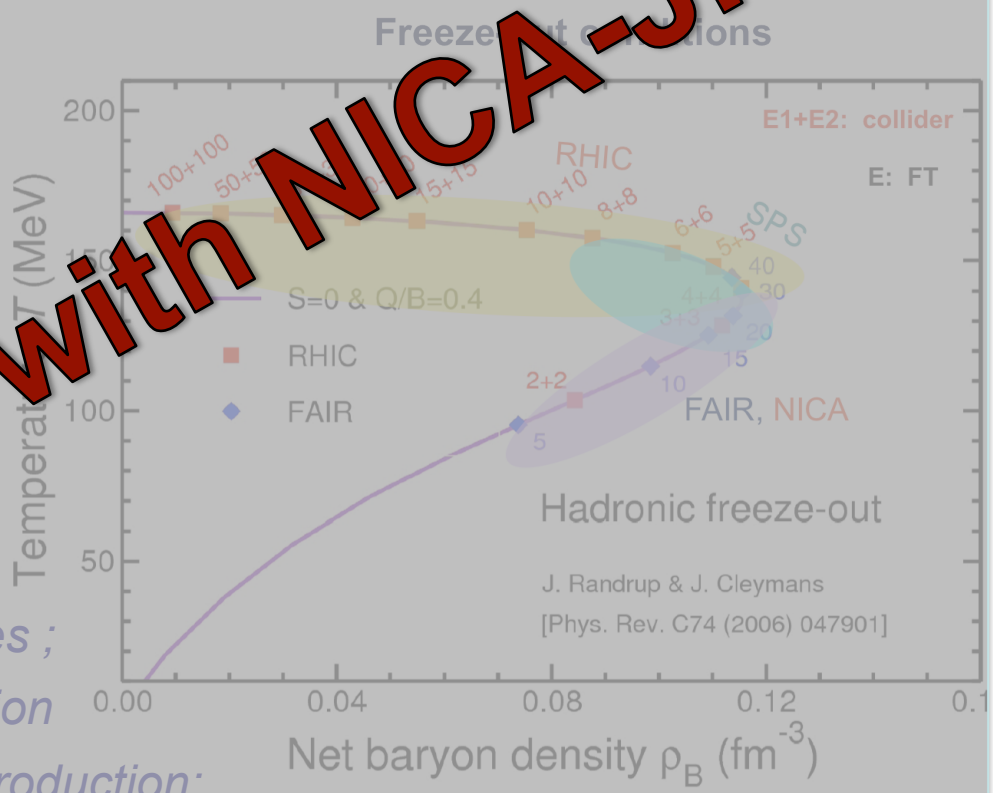


QCD matter at NICA



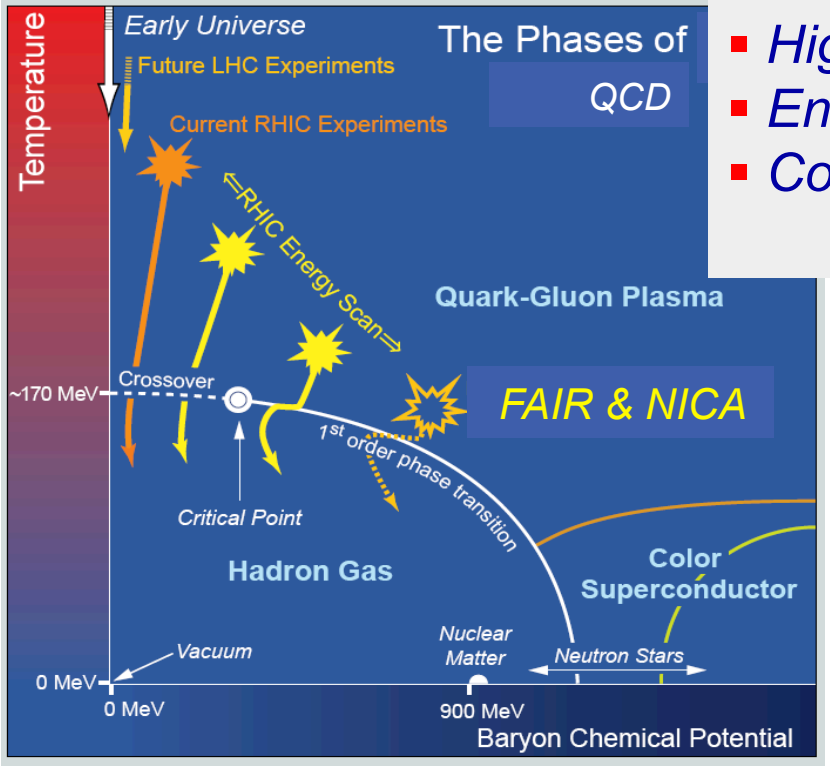
- *Highest net baryon density*
- *Energy range covers onset of deconfinement*
- *Complementary to the RHIC/BES, FAIR and CERN experimental programs*

Connection with NICA-JINR



- *Bulk properties, EOS - particle yields & spectra, ratios, femtoscopy, flow;*
- *In-Medium modification of H properties ;*
- *Deconfinement (chiral), phase transition at high ρ_B - enhanced strangeness production;*
- *QCD Critical Point - event-by-event fluctuations & correlations;*
- *Strangeness in nuclear matter - hypernuclei*

QCD matter at NICA



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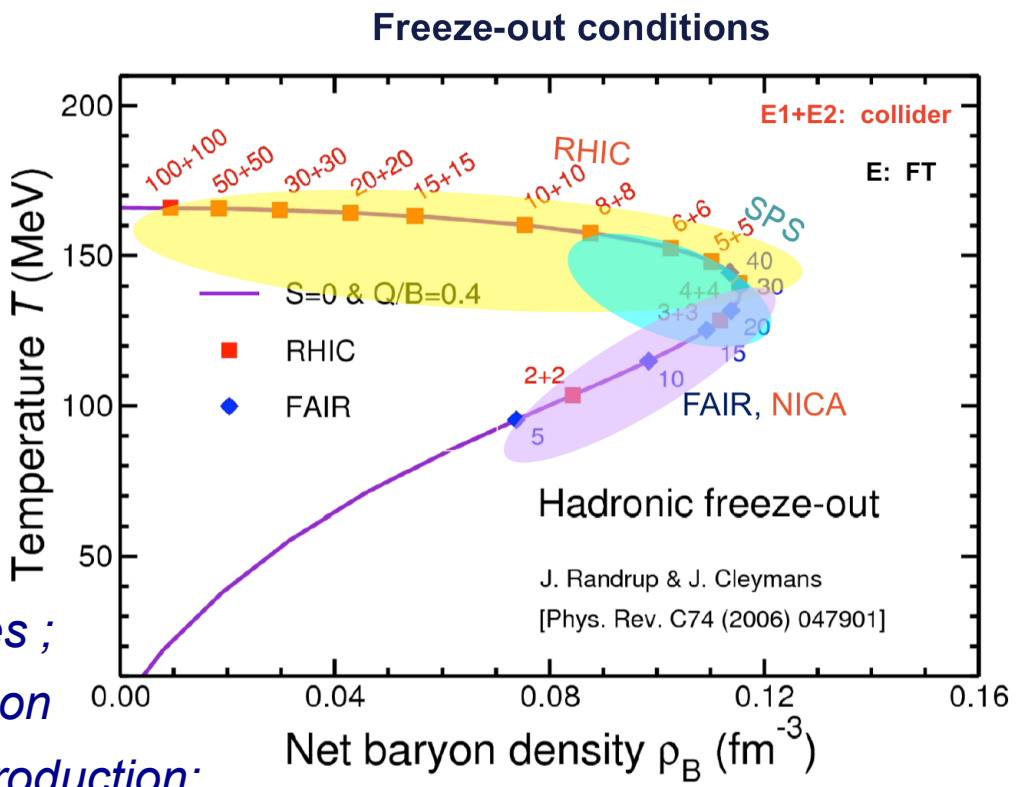

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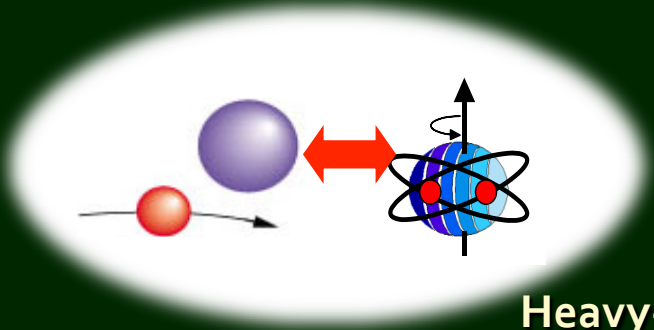
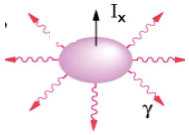
L3 - Nuclear Structure and Reaction Mechanisms



5-10 MeV/A — Heavy-ions — 50 MeV/A

Decays
(in beam)



Shell structure
Collettive modes-shape vs N/Z

Symmetries

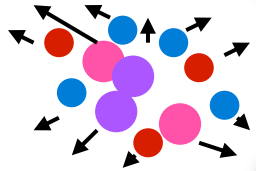
Reactions

peripheral

Nuclear structure

Termodynamics
Viscosity-high spin

Multi-framm



Equation of state

LNL

GAMMA- PRISMA- EXOTIC- NUCLEX

DREAMS - LNS_STREAM - EXOCHIM

LNS

LNL and LNS

~ 30% of the researchers working on nuclear physics is involved in experiments @ LNL or LNS

LNL (~250 people including ~120 INFN employees, ~700 users)

Strength points : **SPES** is the acronym for "Selective Production of Exotic Species", project devoted to basic research in nuclear physics and astrophysics as well as to interdisciplinary applications, ranging from the production of radionuclides of medical interest to the generation of neutrons for material studies, nuclear technologies and medicine

LNS (~ 200 people including ~120 INFN employees, ~500 users)

Superconducting Cyclotron: reaction mechanism at intermediate energies – EOS

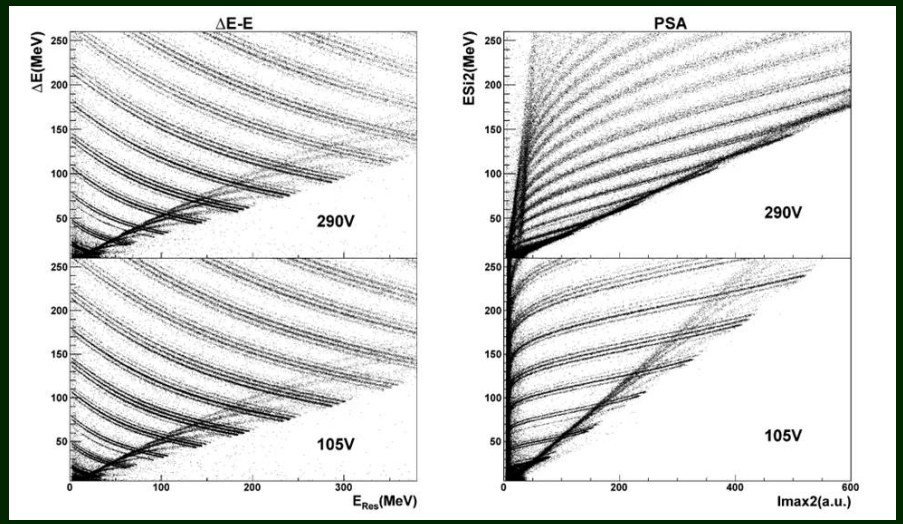
TANDEM: nuclear astrophysics - nuclear structure - reaction mechanism

KM3Net: deep-sea research infrastructure devoted to search for neutrinos from distant astrophysical sources

Development Activities @ LNL, LNS

- R&D for charged particle arrays to be used with radioactive beams (activity FAZIA – PP-SPIRAL2 in FP7)

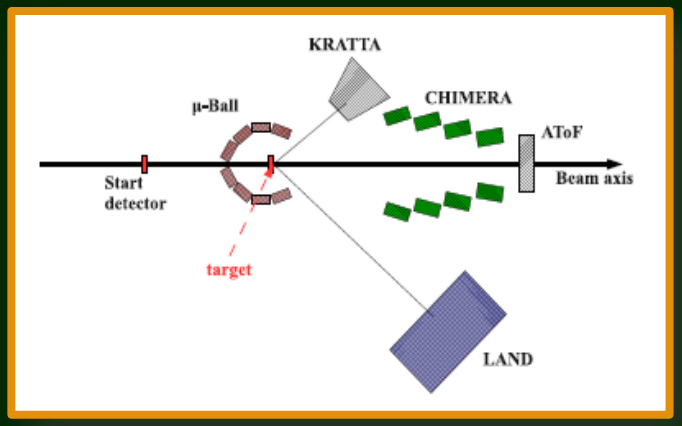
- Improvement in A and Z identification using DE-E and PSA on new FAZIA detectors

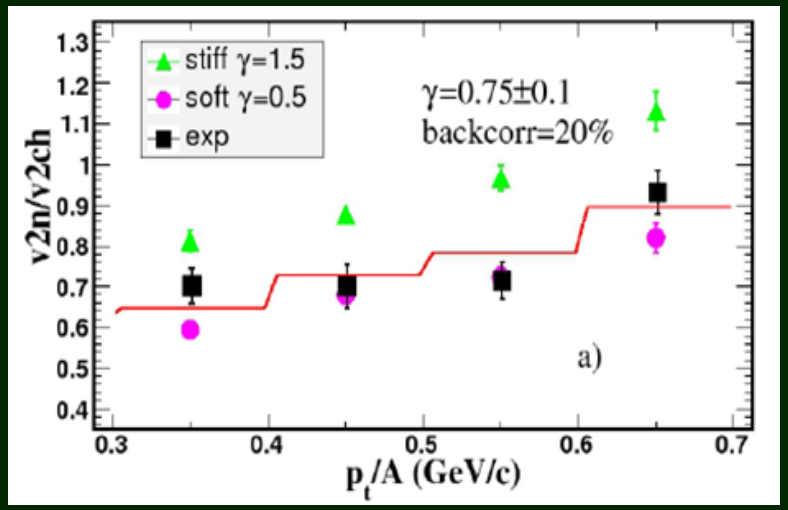


G. Pasquali et al. Eur. Phys J. A50 (2014) 86
G. Pastore et al. EPJ Web of Conf. 88 (2015)01013

EXOCHIM

- Study of EOS dependence on the Symmetry Energy term above saturation density ($\rho > \rho_o$)
- Collaboration CHIMERA-GSI-Krakow-MSU-IN2p3 (ASY – EOS experiment @ GSI)
- Study of the reactions Au+Au @ 400 AMeV, ^{76}Zr+^{76}Zr @ 400 AMeV, ^{96}Ru + ^{96}Ru @ 400 AMeV
- Measurement of elliptic-flow ratio of neutrons to proton -> observable sensitive to symmetry energy term of EOS at supra-saturation densities





γ = 0.75± 0.20 ; L=73±13

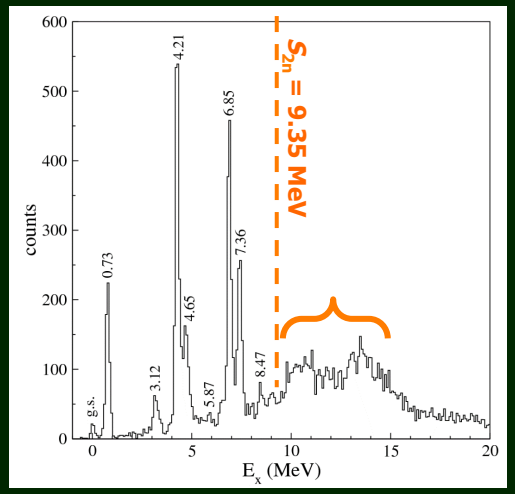
P. Russotto et al .– EPJ Web of Conference vol.88, (2015) 00022

DREAMS @ LNS

Discovery of the GPV using the reactions:

- $^{12}C(^{18}O,^{16}O)^{14}C$ @ 84 MeV
- $^{13}C(^{18}O,^{16}O)^{15}C$@ 84 MeV
- $^{12}C(^{18}O,^{16}O)^{14}C$ @ 270 MeV

$^{13}C(^{18}O,^{16}O)^{15}C$@ 84 MeV



F. Capuzzello et al. – Nature Comm. Vol.6, Art. Num. 6743 (2015)

MAGNEX

- ✓ Right energy
- ✓ Right width
- ✓ Right cross section
- ✓ *L* = 0 transfer

GPV population

Particle-hole symmetry confirmation

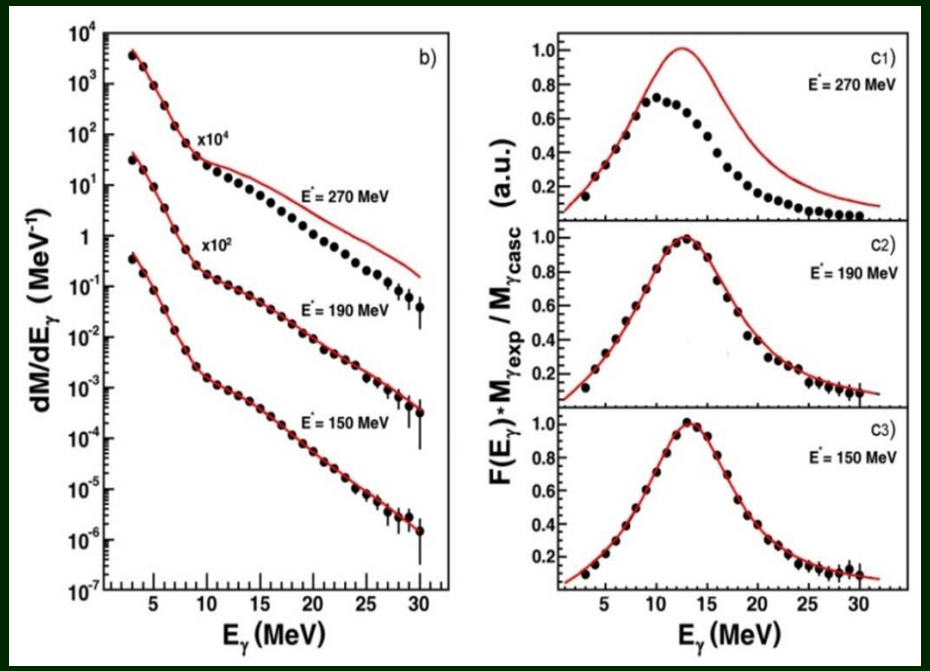
NUMEN @ LNS

- Towards the determination of the Nuclear Matrix Elements of Neutrinoless Double Beta Decays by Heavy-Ion Double Charge Exchange Reactions
- First pioneering experimental results obtained for the $^{40}Ca(^{18}O,^{18}Ne)^{40}Ar$ reaction at 270 MeV are very encouraging (double charge exchange cross section 11 mb/sr at $\Theta_{c.m.} = 0°$)

LNS-STREAM2 @ LNS

- Study of the evolution of the GDR properties vs. E* (150<E*< 270 MeV) in nuclei of mass A~120 - 130
- Evidence for a GDR quenching at E*=270 MeV
- Limiting excitation energy for the collective motion E*=230 MeV
- Evidence of a mass dependence of the limiting E* for the collective motion (possible link with phase transition in nuclear matter which shows similar trend)

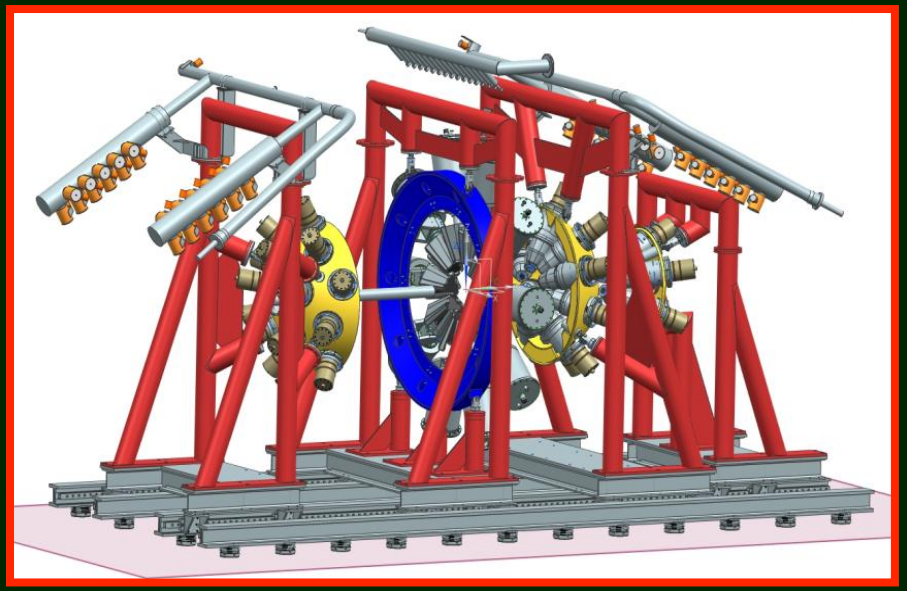
MEDEA

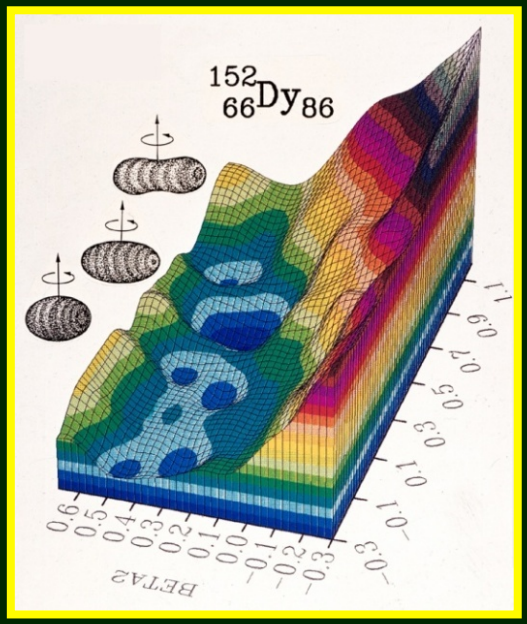


D. Santonocito et al. PRC90, (2014) 054603

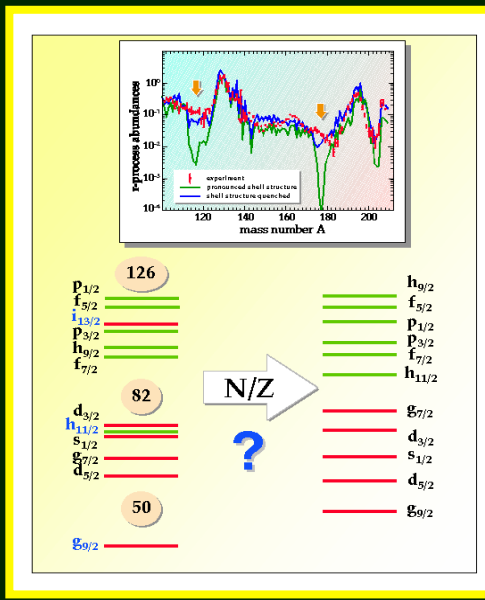
Nuclear Structure research @ LNL

GALILEO
γ-ray spettroscopy



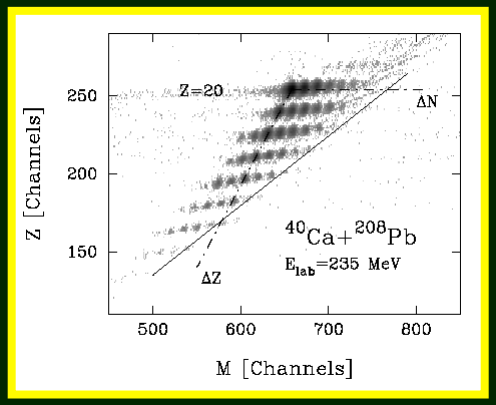


- High spin states
  - Collectivity and shell model
- Isospin symmetries
- Isospin mixing in N=Z nuclei
  - Spectroscopy at the dripline
- Shell stability and evolution in neutron rich nuclei
- Symmetries at the critical point
- Rotational damping



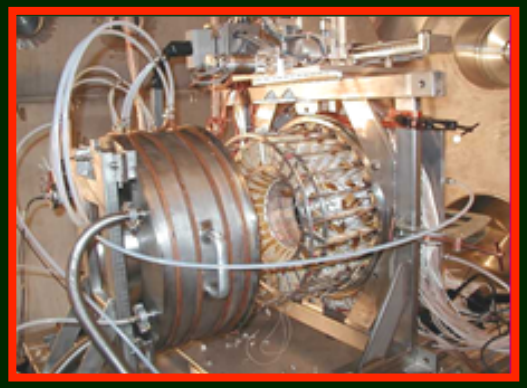
Reaction dynamics research @ LNS

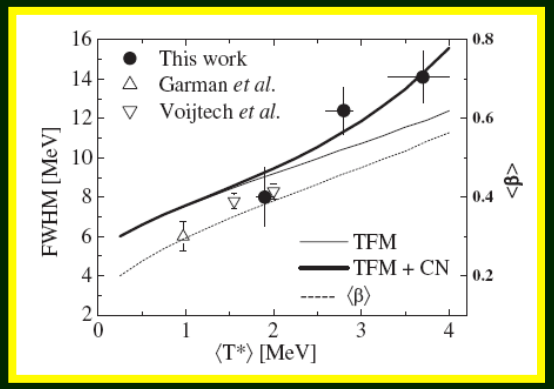
PRISMA and PISOLO



-Multinucleon transfer
- Nuclear superfluidity (pair transfer)
- Elastic and inelastic scattering
- Near and sub-barrier fusion

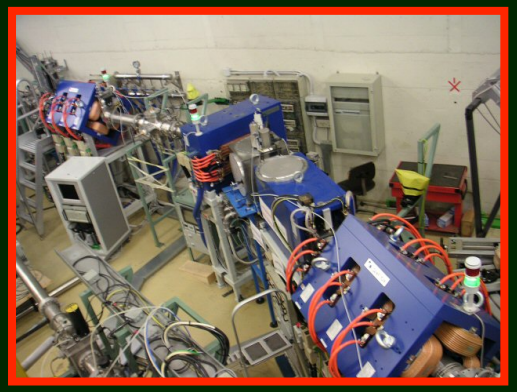
GARFIELD

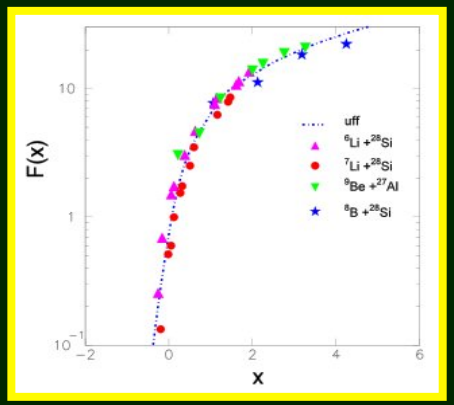




- Multifragmentation at low excitation energies
- Nuclear level density
-Collective modes
- Cluster structure

EXOTIC





-Reactions with secondary beams
- Quasi-elastic scattering
- Break-up processes

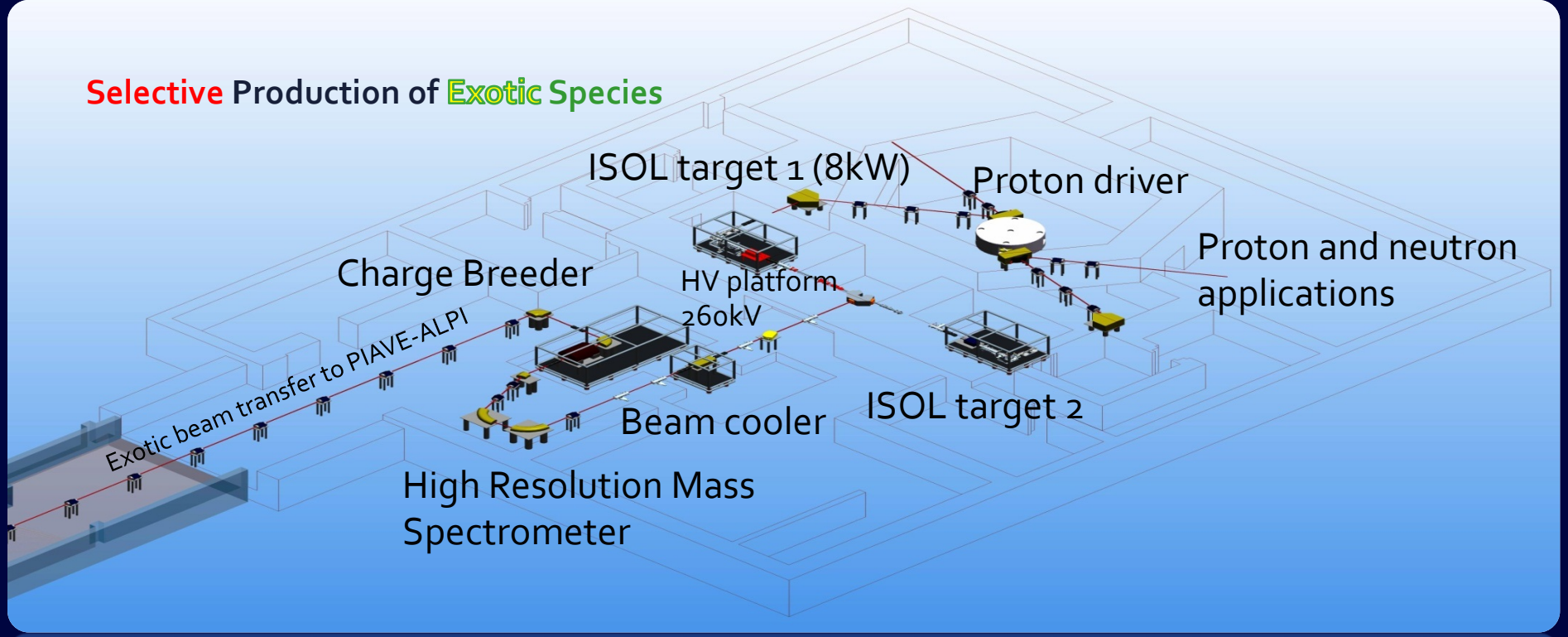
SPES ISOL facility @LNL

A second generation ISOL facility for neutron-rich ion beams and an interdisciplinary research center

SPES exotic beams for science

Proton induced fission on UCx
10^{13} fission/s - 8 kW on direct target

Selective Production of **Exotic** Species



ISOL Roadmap in EUROPE

TODAY

SPIRAL – GANIL

10^{12} fission/s ,
2 MeV/n (A=130)

ISOLDE CERN

INFN

LNS - EXCYT

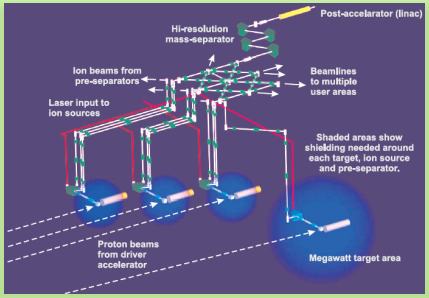
2014-2025

GANIL spiral2 laboratoire commun CEA/DSM CNRS/IN2P3

10^{13-14} fission/s
10 MeV/n (A=130)

HIE-ISOLDE

SPES exotic beams for science



EURISOL

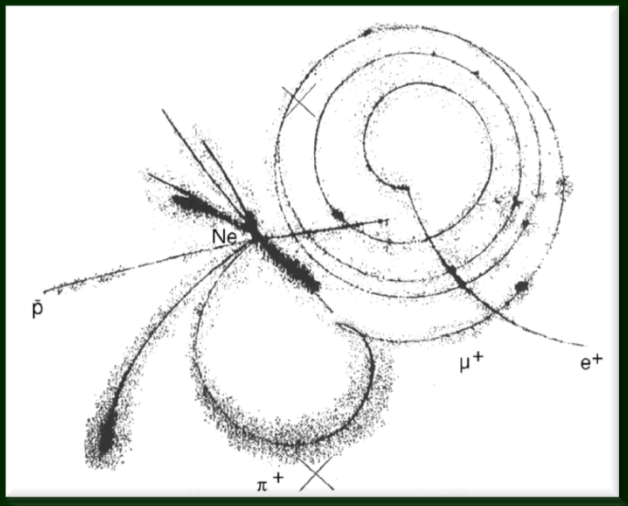
FROM 2025

> 10^{15} fission/s
100 MeV/n (A=130)

3x 100 kW direct target
1x 5 MW 2-step target

INFN at JINR → PAINUC

Low energy (< Δ(1232)) charged pions as a probe of the nuclear matter not describable by QCD



Self-shunted streamer chamber spectrometer with CCD

- Studies of light nuclei at the hadronic gas transition energy
- Measurements of the π-μ-e decay for the determination of the upper limit of the ν_μ and anti-ν_μ mass

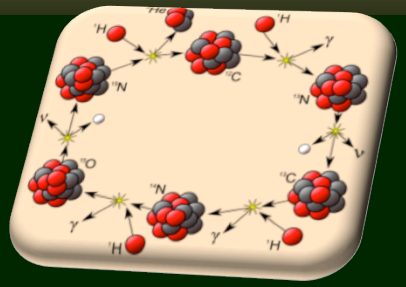
2005 starting of data taking / burning of the exp

2008 restart of activities

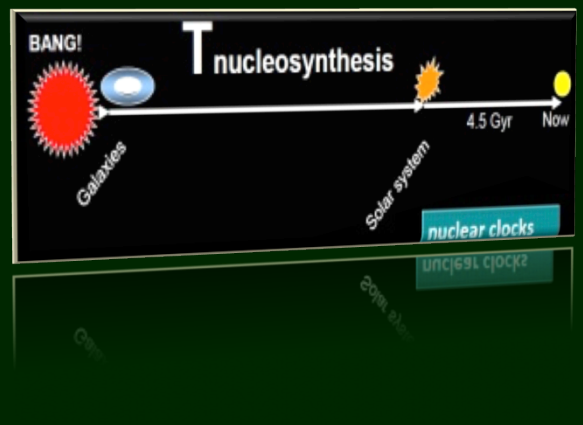
2011 data taking during nights and weekend with hadro-therapy activity

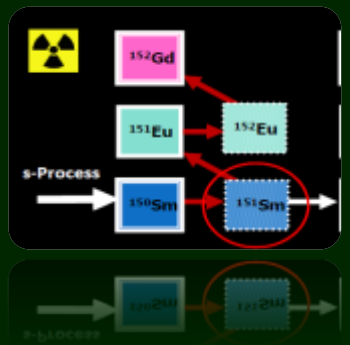
Experimental activity terminated
Still some data analysis ongoing

L4 - Nuclear Astrophysics and Interdisciplinary Research



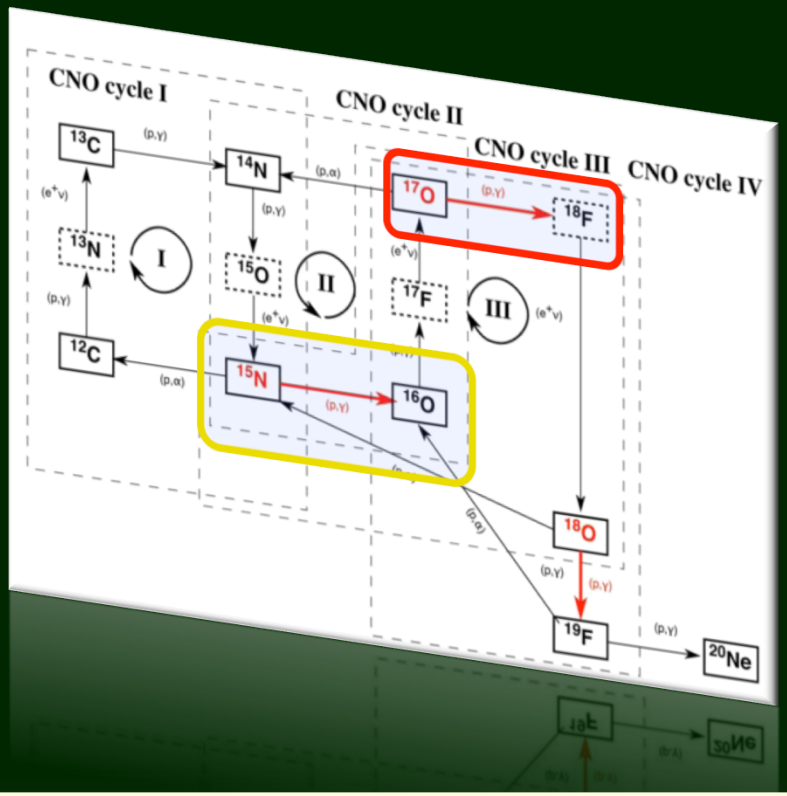
- Reactions @ stellar energy
  - Nucleosynstesis
  - LUNA@LNGS, ASFIN@LNS and ERNA
- n-capture for astrophysics and reactor applications
  - N_TOF @CERN
- Annihilation of anti-protons in nuclei in the 5keV – 5 MeV region of cosmological interest
  - ASACUSA @CERN
- Pauli principle violation in atomic transitions
  - VIP @LNGS
- Gravity effects on antimatter
  - AEGIS @CERN





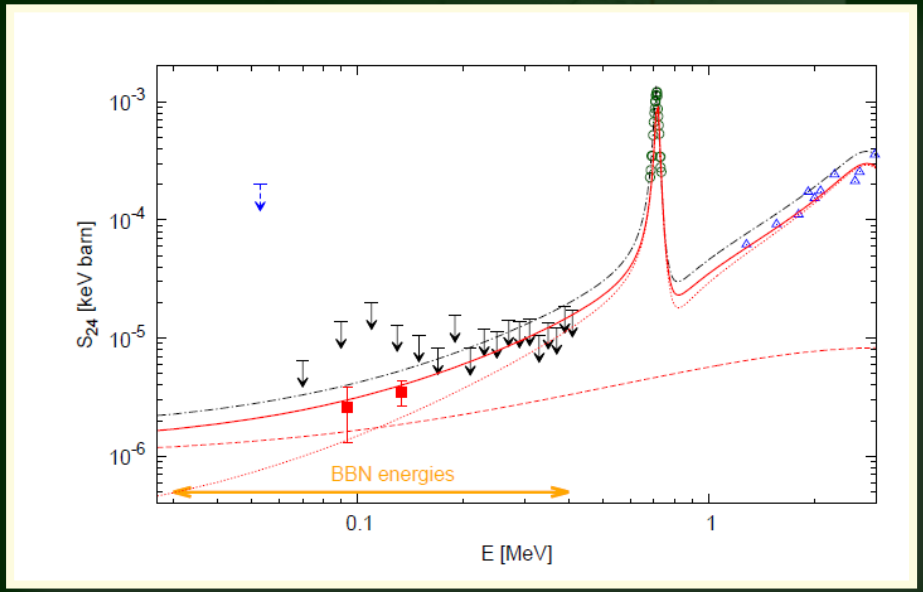
LUNA and LUNA3 @LNGS

$^{15}N(p,\gamma)^{16}O$ and $^{15}N(p,\alpha)^{12}C$: "bridge" reactions between CNO I e II. Consequences for O and next CNO cycles. Important in the novae explosion and in "Asymptotic Giant Branch" stars



The new LUNA data on the $^{2}H(\alpha,\gamma)^{6}Li$ reaction at Big Bang energies confirm validity of standard BBN theory for ^{6}Li abundance prediction

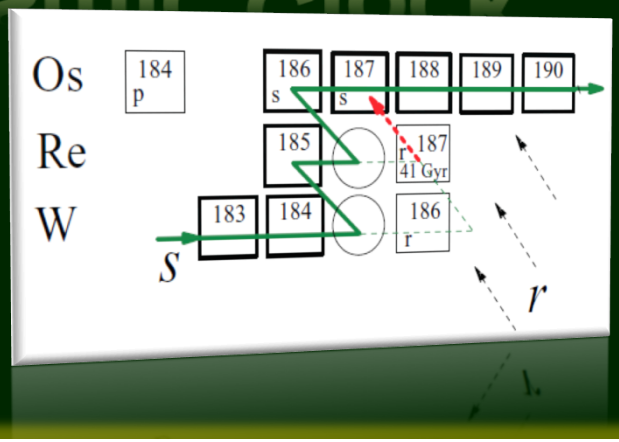
To explain the excess of ^{6}Li found in metal poor stars non-standard physics solutions are requested!

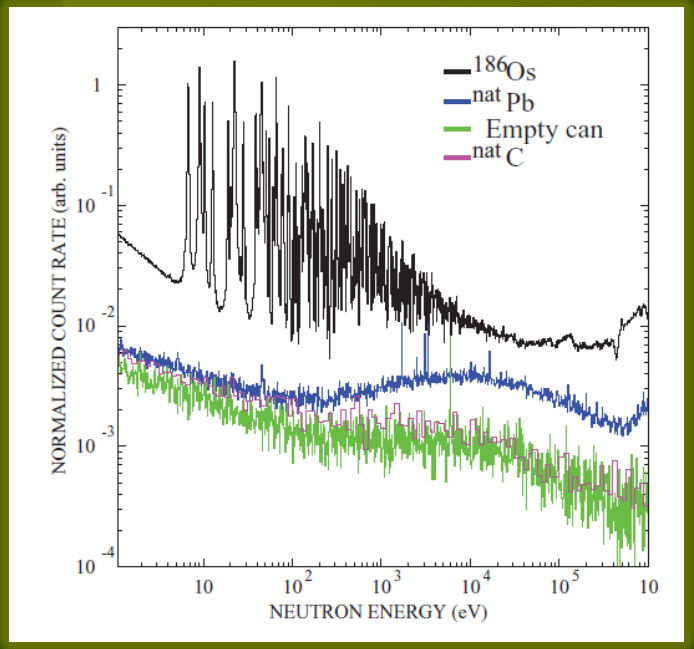


n_TOF@CERN a Cosmic Clock

- The precise determination of the neutron capture cross sections of ^{186}Os and ^{187}Os is important to define the s-process abundance of ^{187}Os at the formation of the solar system.

- This quantity can be used to evaluate the radiogenic component of the abundance of ^{187}Os due to the decay of the unstable ^{187}Re ($t_{1/2}$ = 41.2 Gyr) and from this to infer the time duration of the nucleosynthesis in our galaxy (Re/Os cosmochronometer).





WHERE INFN GOES: physics prospects much depends on the next 5 years …

- **LHC14** (high energy: ATLAS, CMS; flavor: LHCb; quark-hadron phase transition: ALICE)
- **JLAB – 12 GeV** physics program
- **Nuclear Astroparticle physics**: SPES, LUNA –MV etc.
- **Flavor**: NA62; upgraded MEG, Mu-e; BELLEII; EDMs; g-2
- **DM** 1-ton exps. → $10^{-10} – 10^{-11}$ pb
- **Neutrinoless double β** → ν mass degenerate region; enter IH region
- **Gravitational waves** → (EGO consortium) discovery
- **CMB**: final PLANCK; B-modes of the polariz.+ black-body spectrum : EU exps. QUBIC, LSPE, QIJOTE + many others on ground and balloons in US, Japan

Conclusions

The INFN Nuclear Physics activities:

- Quarks and Hadron Dynamics
- Phase Transitions in Nuclear Matter
- Nuclear Astrophysics and Interdisciplinary Research
- Nuclear Structure and Reaction Mechanisms

are all very productive, at the frontier of the physics knowledge and on the path for new physics

Prolific International Collaborations

A lot of efforts (+enthusiasm) for driving Future Projects to the success