CSN3

M.Taiuti

OVERVIEW OF THE NUCLEAR PHYSICS ACTIVITY WITHIN INFN

OUTLOOK

- The Community
- Current Activity
- Perspectives
- Final remarks

The INFN Organization

The 4 Research Lines

Line 1 – 120 FTE

Quarks and Hadron Dynamics

(Jlab, LNF, German-Labs)

Line 2 – 165 FTE

Phase Transitions in Nuclear Matter (160 in Alice)

CSN3

512 FTE

Line 4 – 73 FTE

Nuclear Astrophysics and Interdisciplinary Research

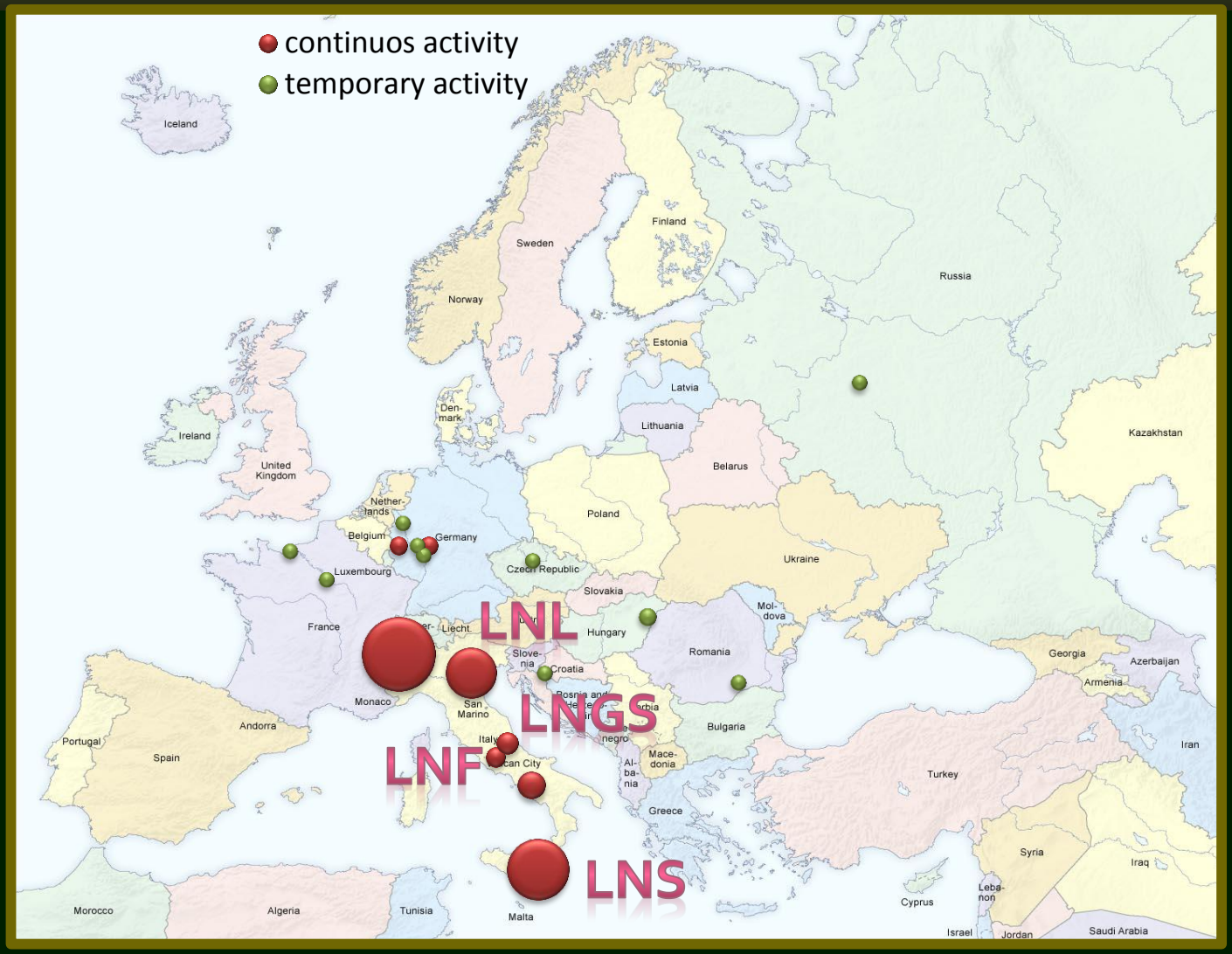
(LNGS, LNS)

Line 3 – 154 FTE

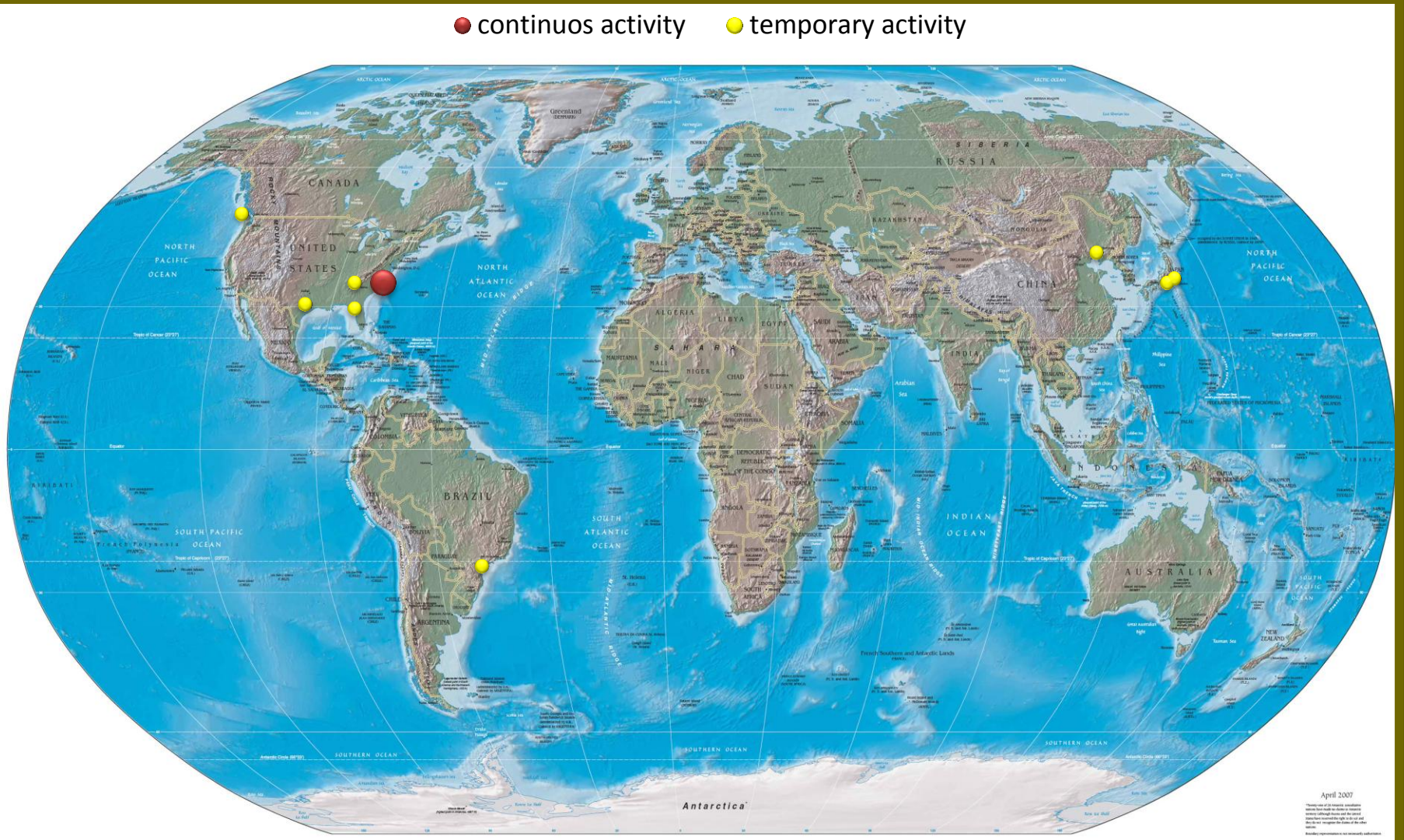
Nuclear Structure and Reaction Mechanisms

(LNL, LNS)

Facilities- european



Facilities– extra-european



L1 - Quarks and Hadron Dynamics

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

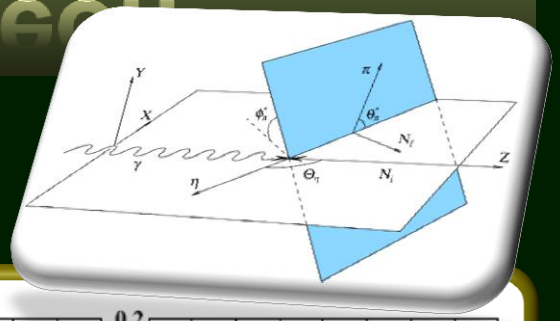
- Non perturbative QCD (baryons and mesons)
- NLO pQCD
- Hadronization phenomena in nucler matter
- Strangeness physics in nuclear matter
- N-N correlations
- Spin physics

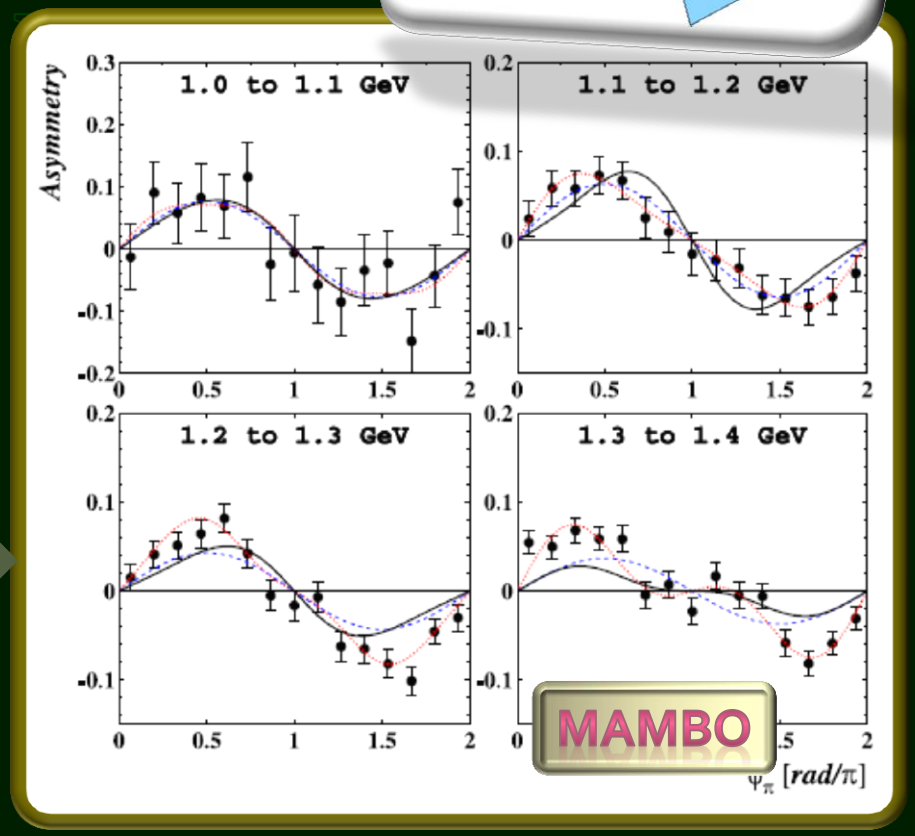
The Structure of the Nucleon

- Proton and neutron e.m. form factors
- Study of Baryonic Resonances

  W ~ 1.5 GeV – 3 GeV

First measurement of the circular beam asymmetry in the $\gamma p \rightarrow \pi^0 \eta p$ reaction



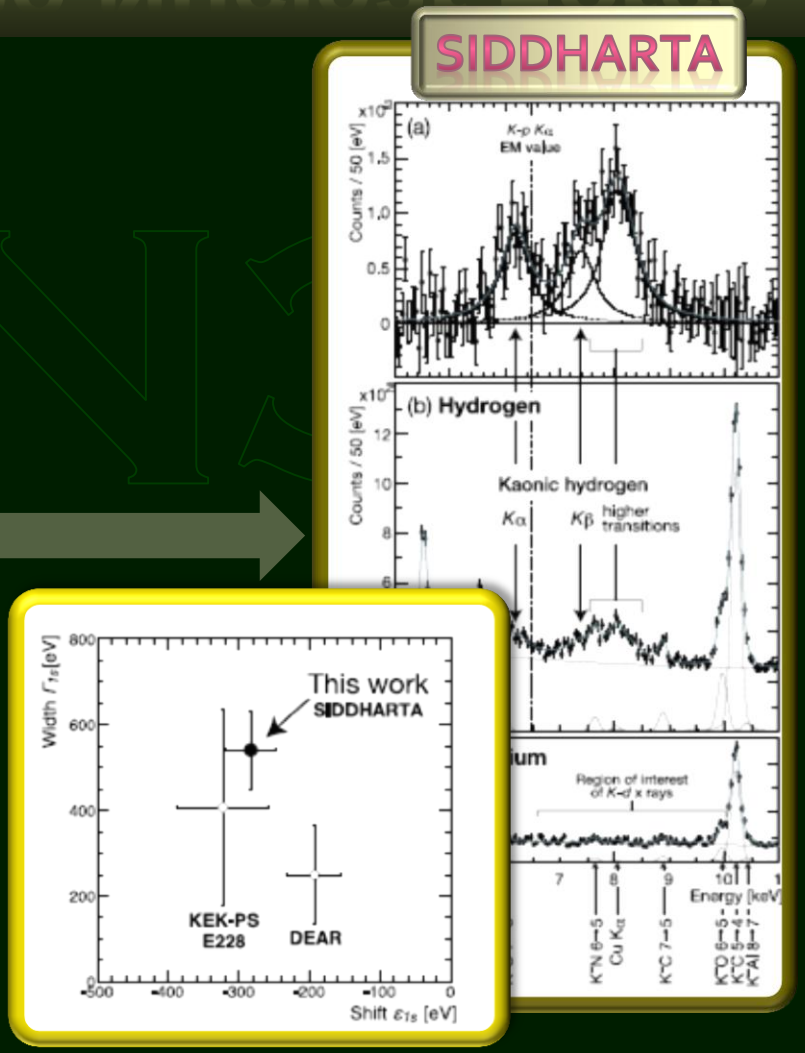


- Search for exotic mesons

Strangeness and the Nuclear Force

- @LNF
- Kaonic atoms

Measurement of the energy for the level 1s for the hydrogen kaonic atom

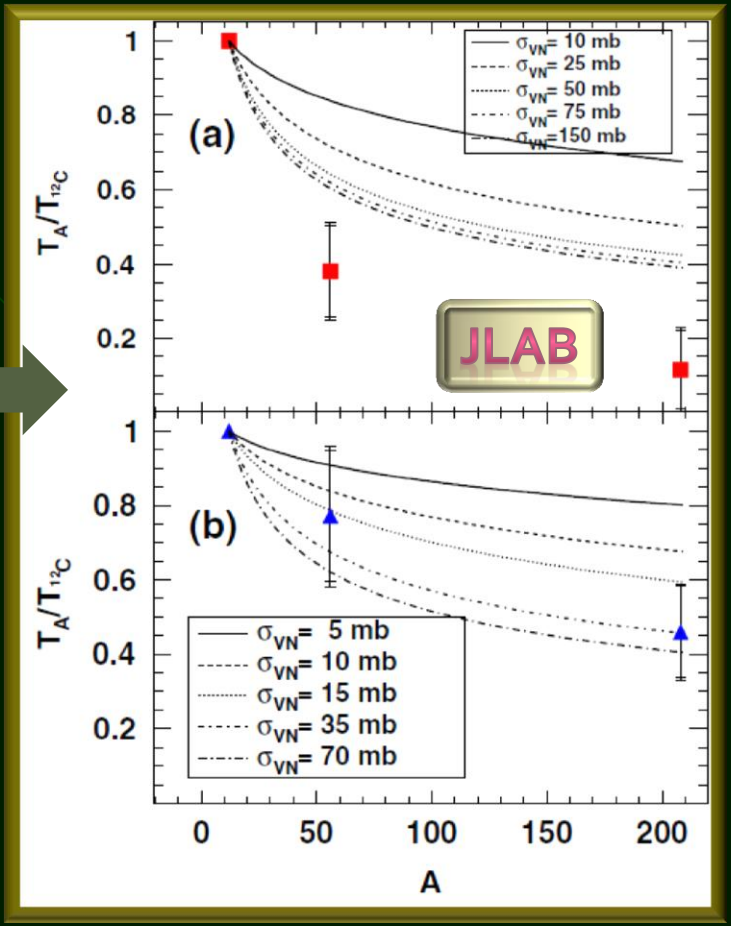


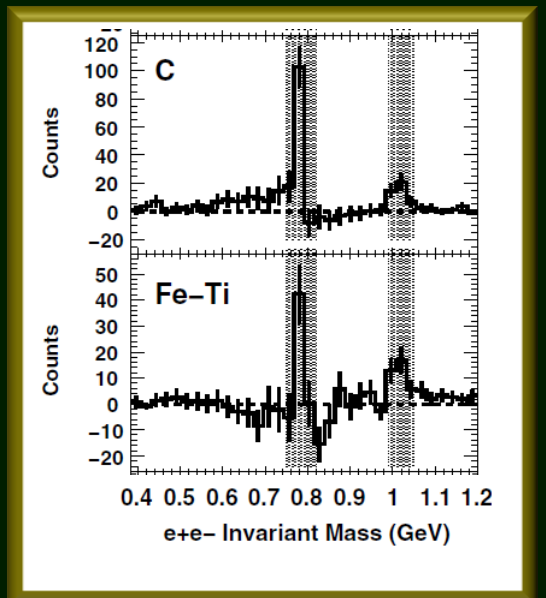
- Next measurement:
  - deuterium

Strangeness and the Nuclear Force

- Strangeness to probe hadronization phenomena in nuclear matter

Evidence of a larger interaction cross section in nuclei

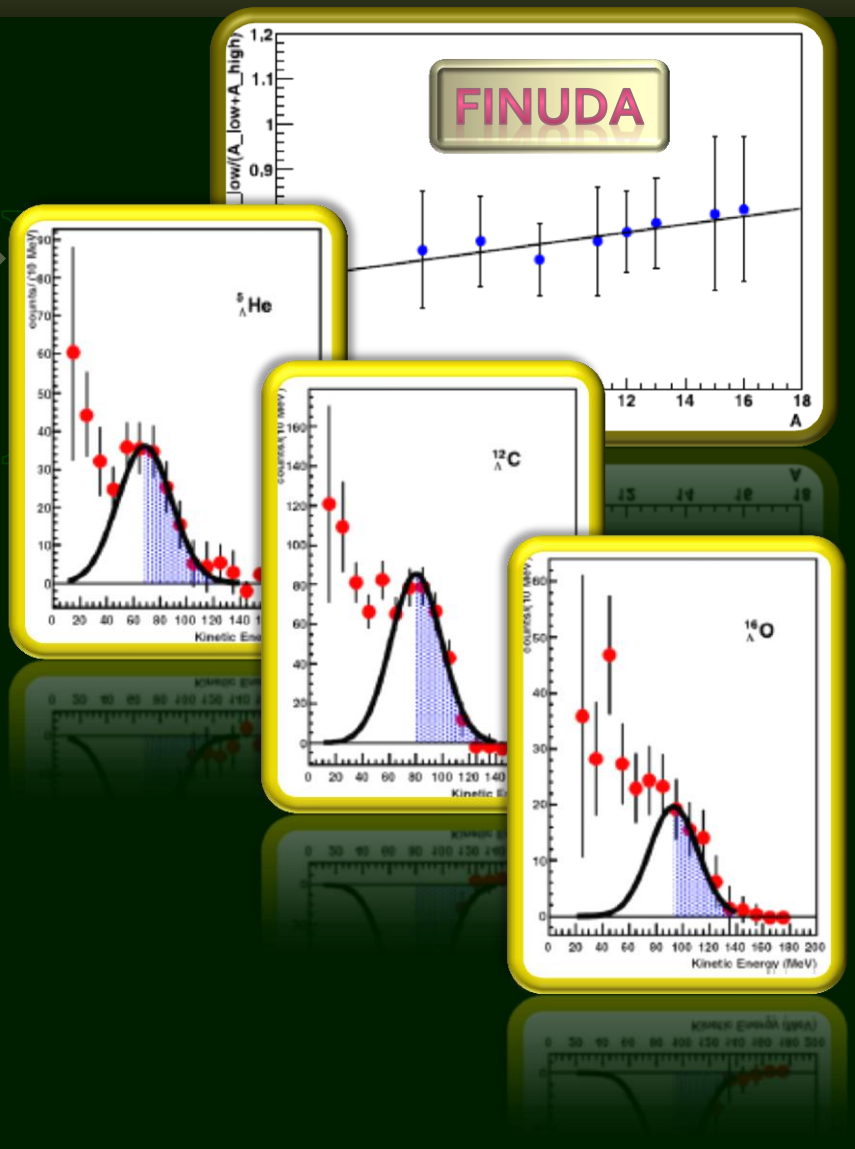




Strangeness and the Nuclear Force

- **@LNF**

  Evidence for the two-nucleon induced process in the hypernuclei decay with p-wave Λ



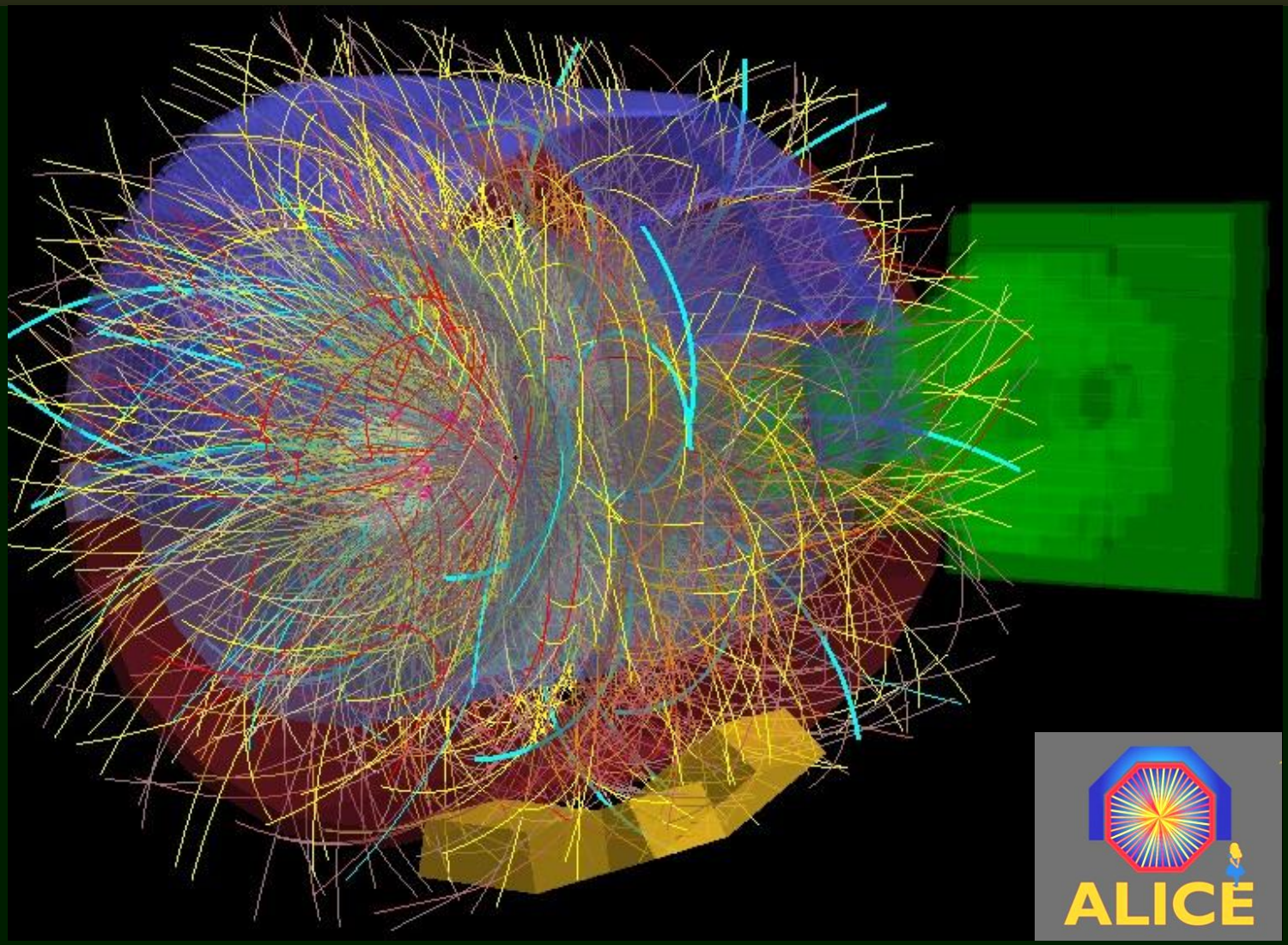
- The Hypernuclear Physics is planned @ JLAB12 and JPARC

- PANDA: contribution to the Central Tracker TDR

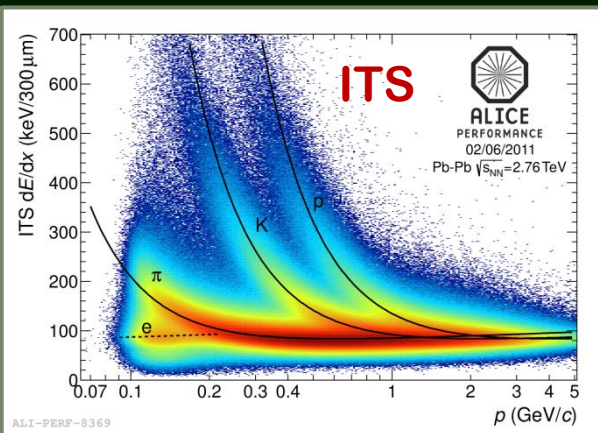
L2 – Phase Transitions in NM

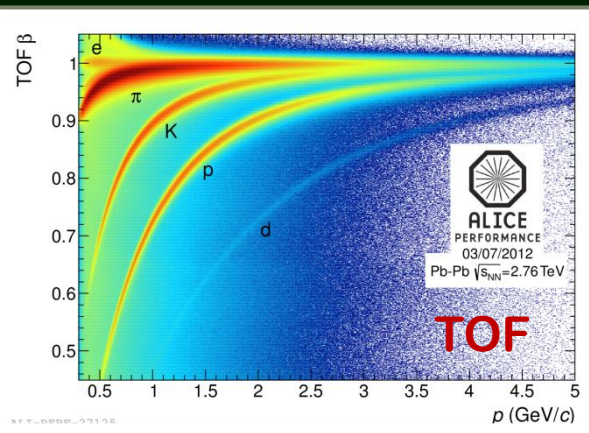
CSN3

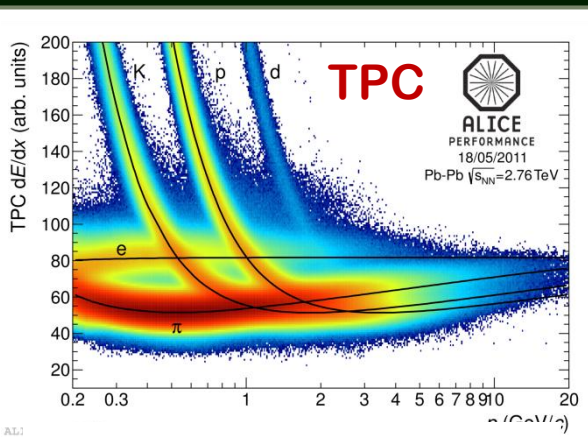
L2 – Phase Transitions in NM

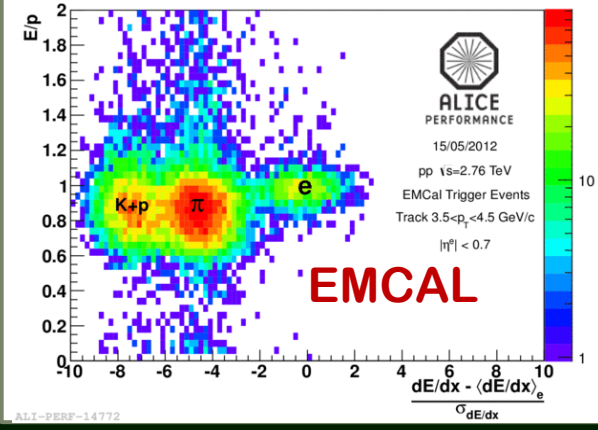


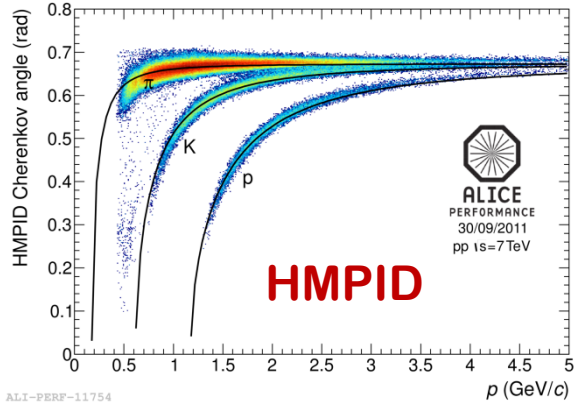
ALICE Performances

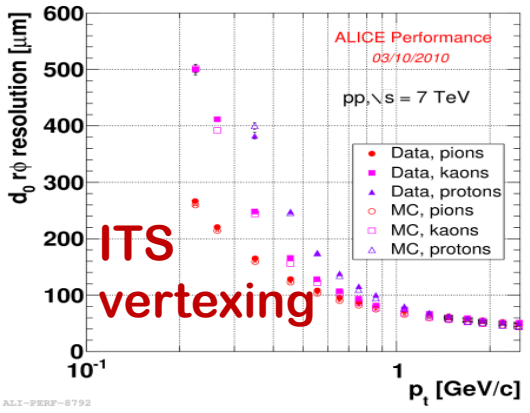






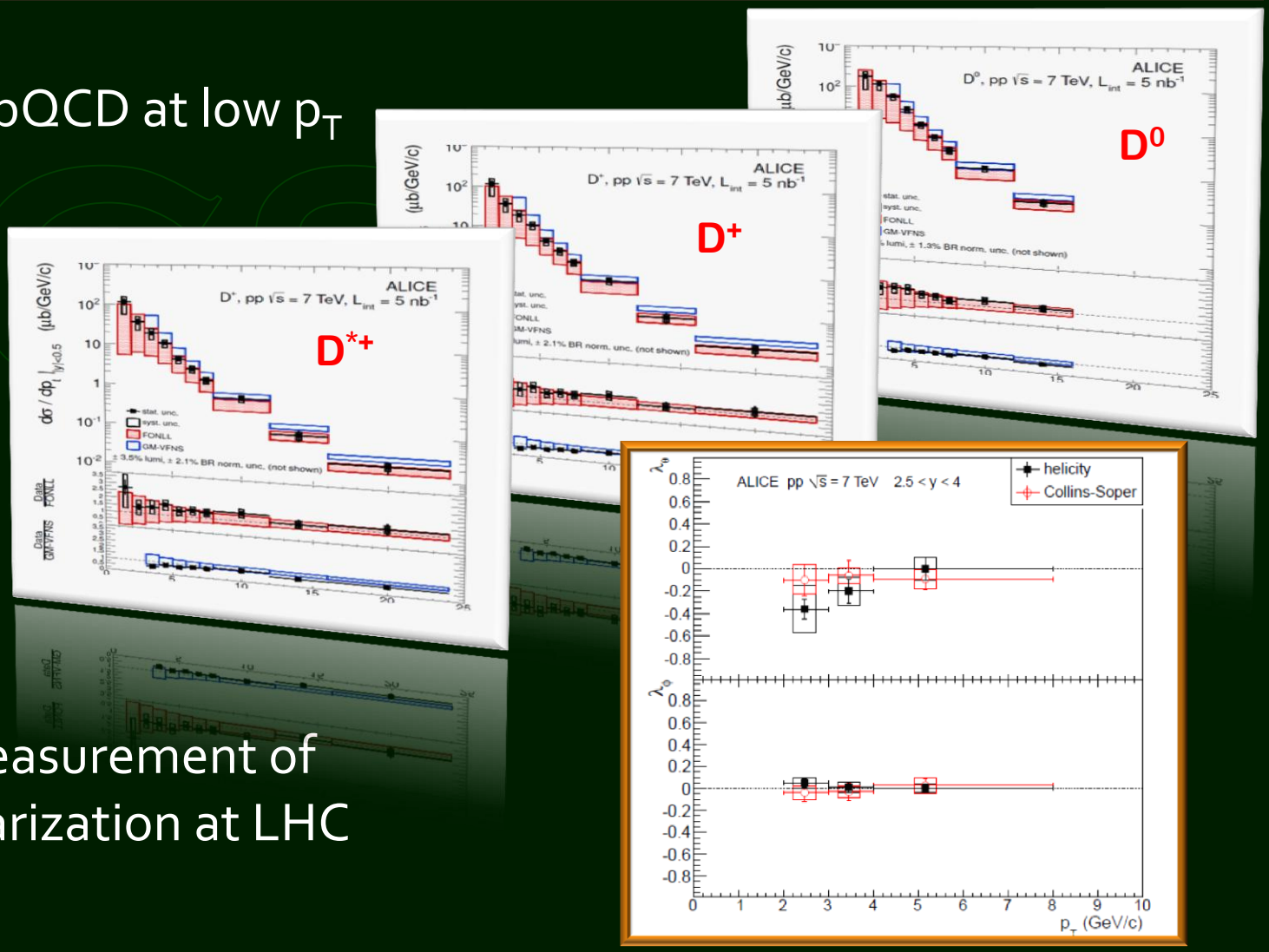






ALICE - p-p Run

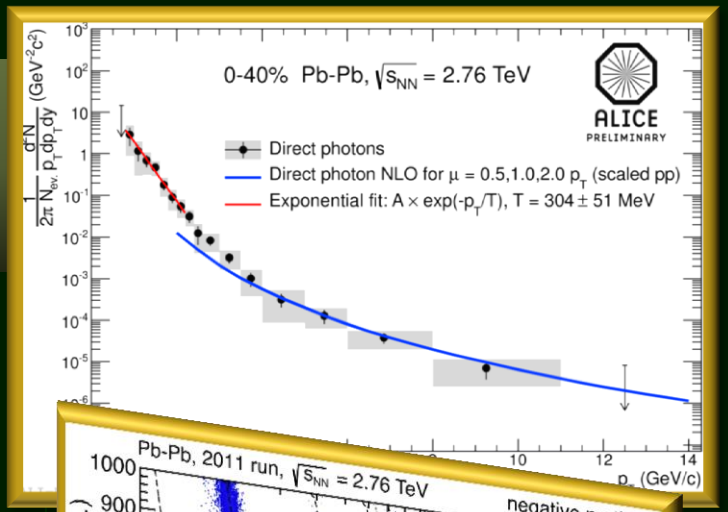
- Test of pQCD at low p_T

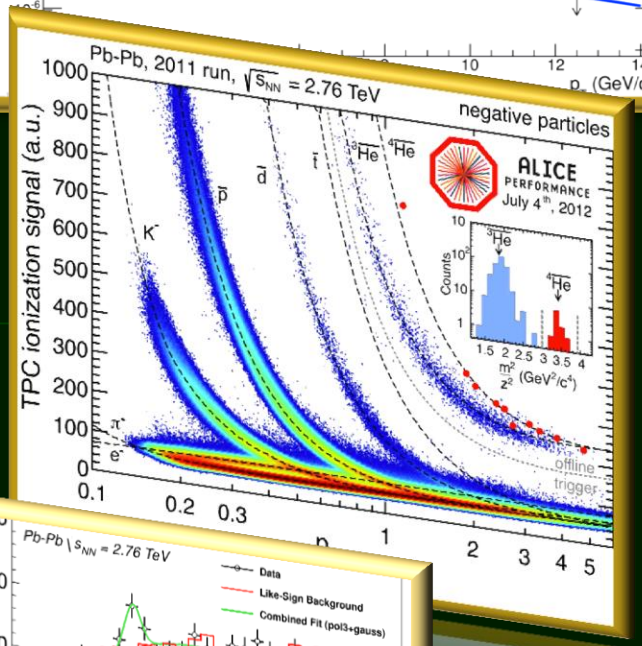


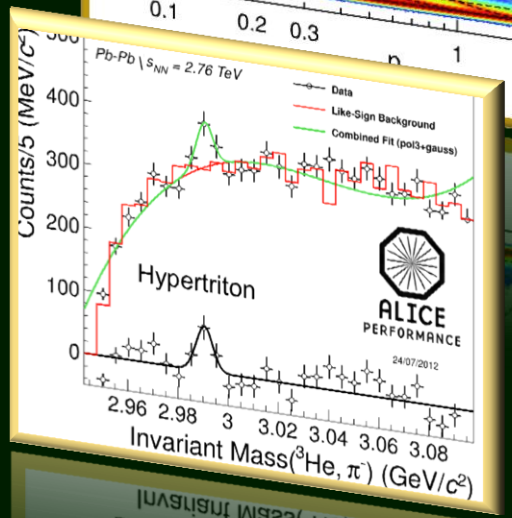
- First measurement of J/ψ polarization at LHC

ALICE Results

- Measured Temperature of the QGP fireball from photon spectrum
  - T ≈ +30% (≈ 300 MeV); highest T in Universe…
- Hadronization of the partonic system produces also large objects like nuclei and hyper-nuclei



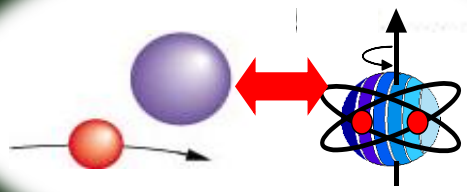




ALICE Results - Summary

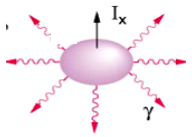
- Recent results from lead-lead collisions
  - Global observables ⇔ the QGP fireball @ LHC
  - Bulk particle prod. ⇔ particle formation from the QGP
  - Jet quenching ⇔ opacity of the QGP
  - Heavy flavour prod. ⇔ transport properties of the QGP
  - Charmonium prod. ⇔ deconfinement in the QGP

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

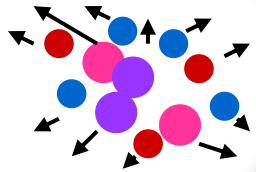
Reactions

peripheral

Nuclear structure

Termodynamics
Viscosity-high spin

Multi-framm



Equation of state

LNL

GAMMA- PRISMA- EXOTIC- NUCLEX

DREAMS - LNS_STREAM - EXOCHIM

LNS

Overview

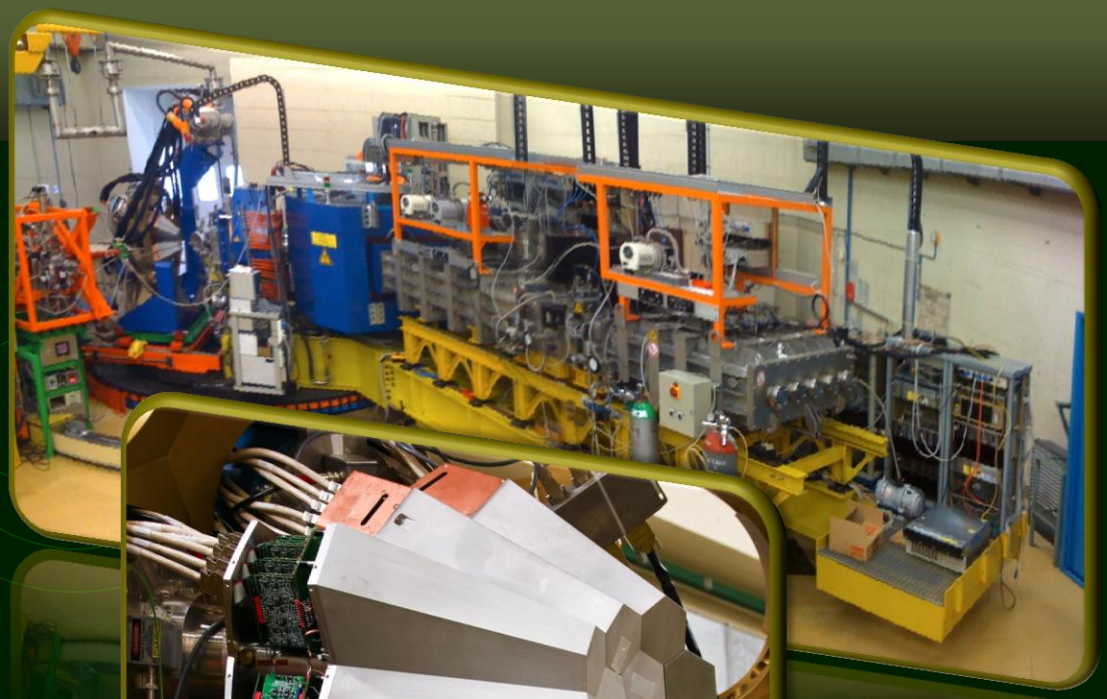
- LNL
  - 142 researchers
  - 101.8 FTE
- LNS
  - 212 researchers
  - 151.1 FTE

- 30% of the CSN3 researchers have experiments @ LNL and LNS
- Availability of RIB "cocktail beams"

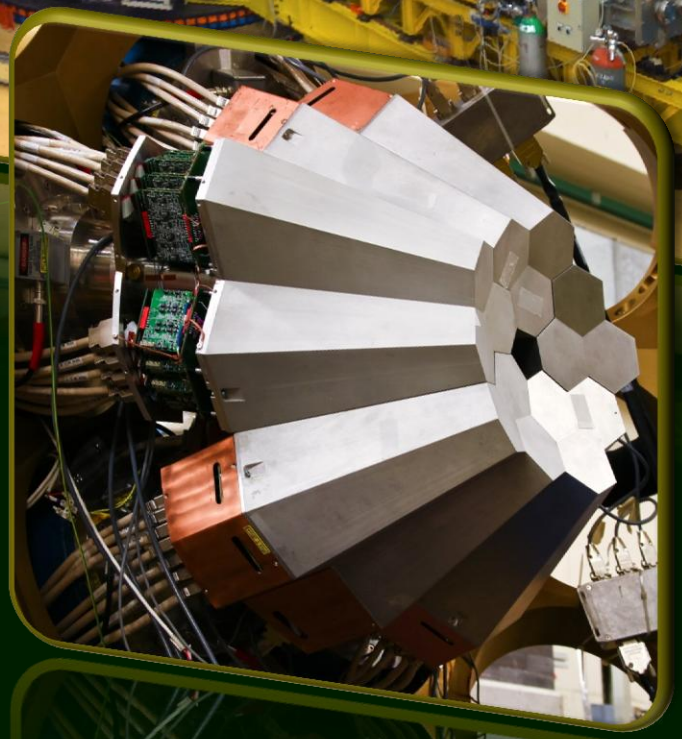
  EXOTIC @ LNL, FRIBS @ LNS

@ LNL

- PRISMA



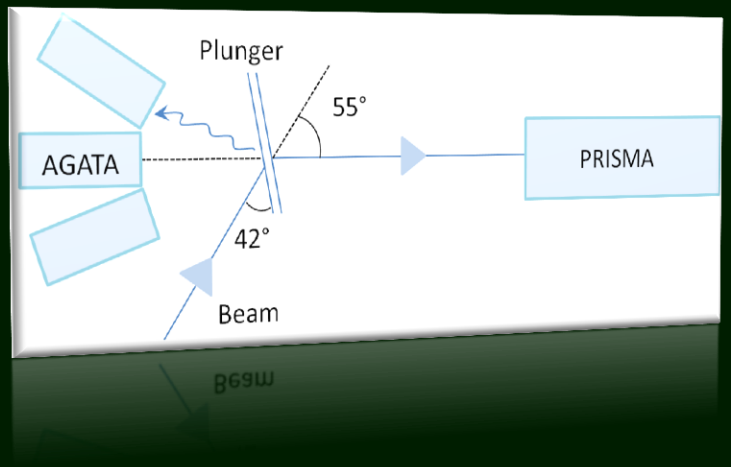
- AGATA
  - Presently @GSI

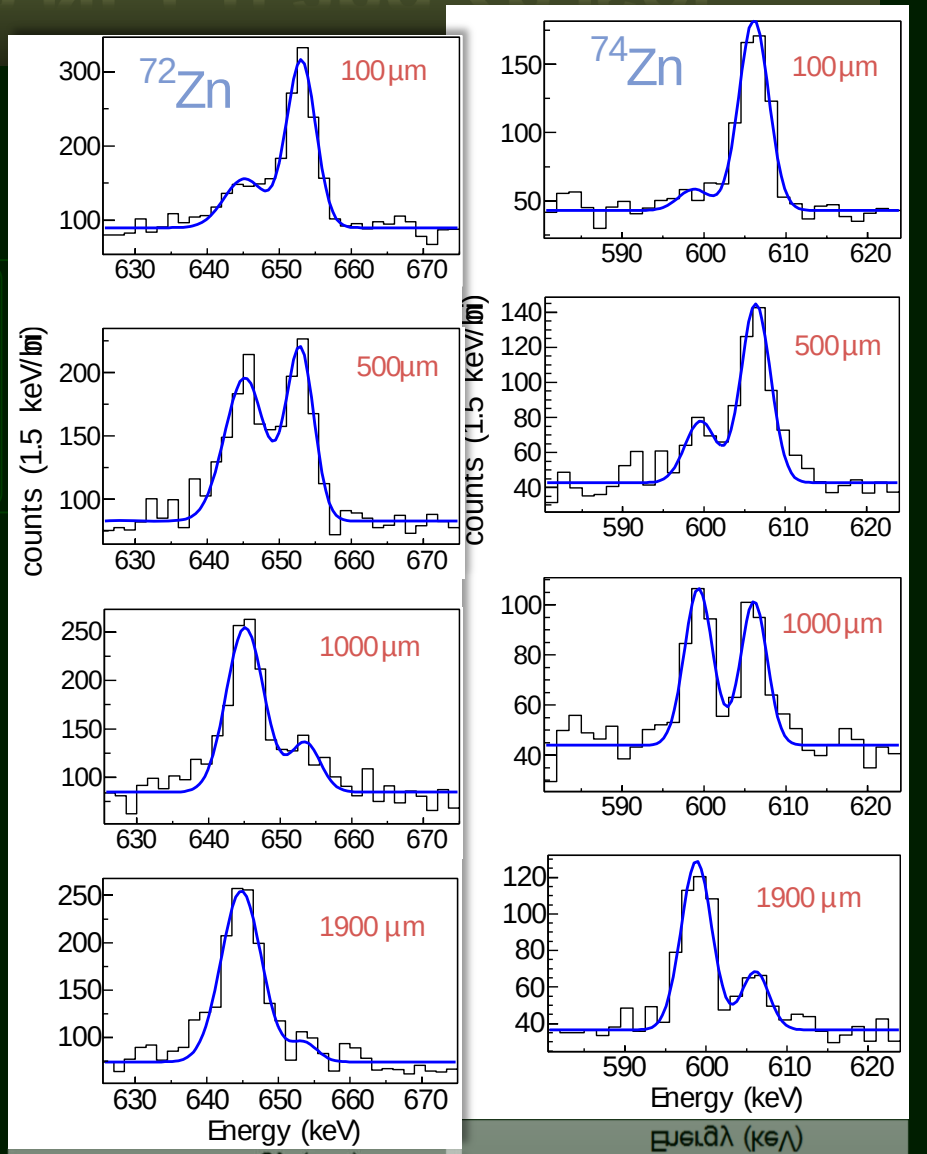


- Previously Euroball now Eurika @ RIKEN

Lifetime Meas. in n-rich Ni, Cu and Zn Isot.

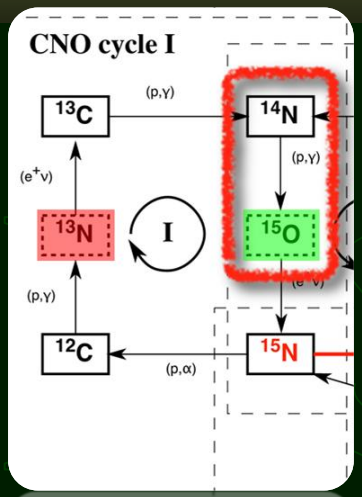
- AGATA+PRISMA+ differential plunger
- ^{76}Ge(577MeV) + ^{238}U, Nb degrader



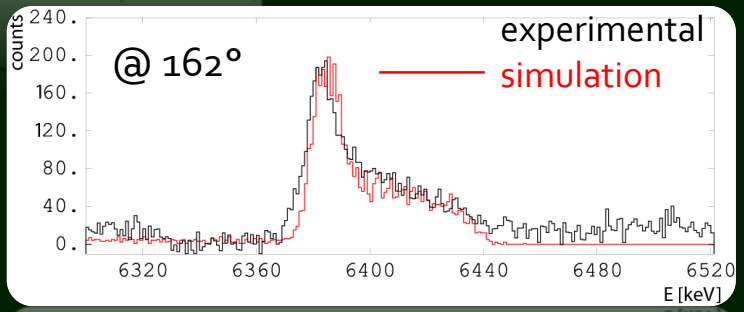


Lifetime Measurement with AGATA

- Stellar burning rates and $^{14}N(p,\gamma)^{15}O$ reaction
- The sub-threshold resonance corresponding to the first excited 3/2+ state in ^{15}O (6.79 MeV) is predicted to play a dominant role when extrapolating the cross-section to the Gamow peak region
- @fs nuclear level lifetime

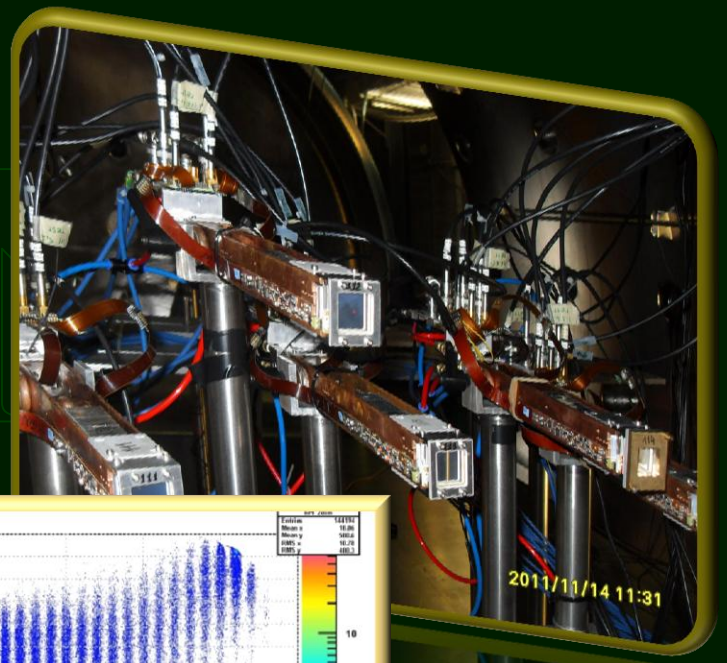


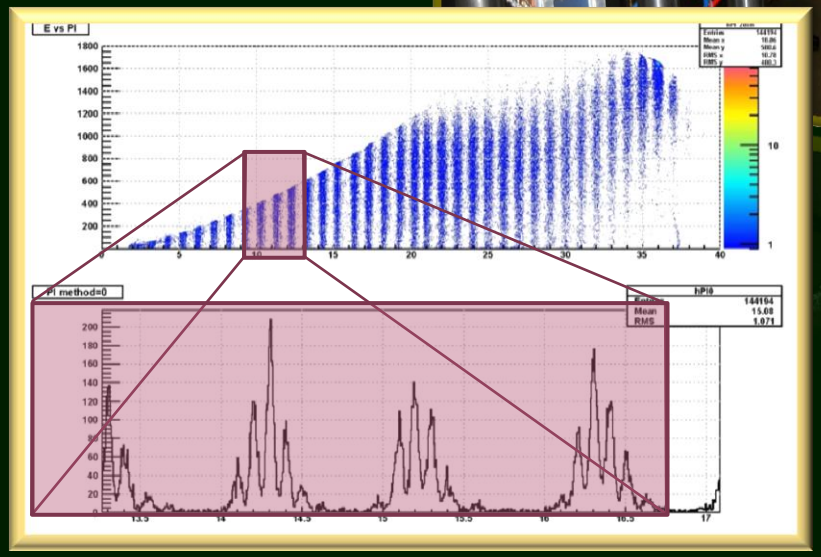
$^{14}N(^{2}H,n)^{15}O$ reaction @ 32 MeV (XTU LNL Tandem)



Development Activities @LNL,LNS

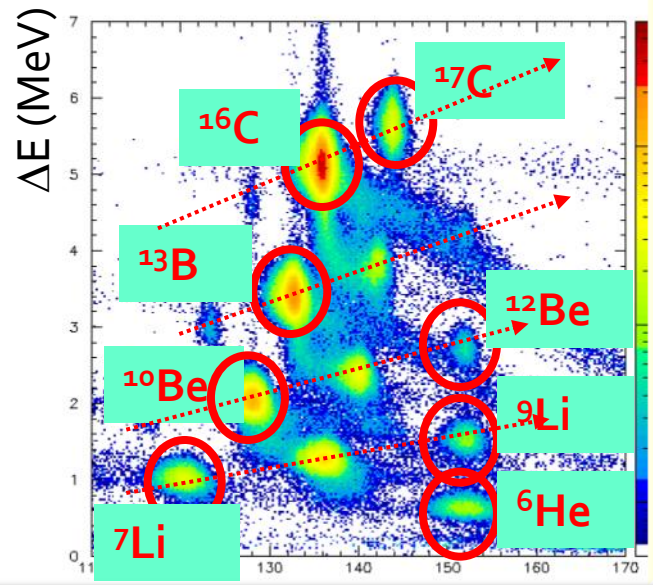
- R&D for charged particle arrays to be used with radioactive beams (activity FAZIA – PP-SPIRAL2 in FP7)





@ LNS

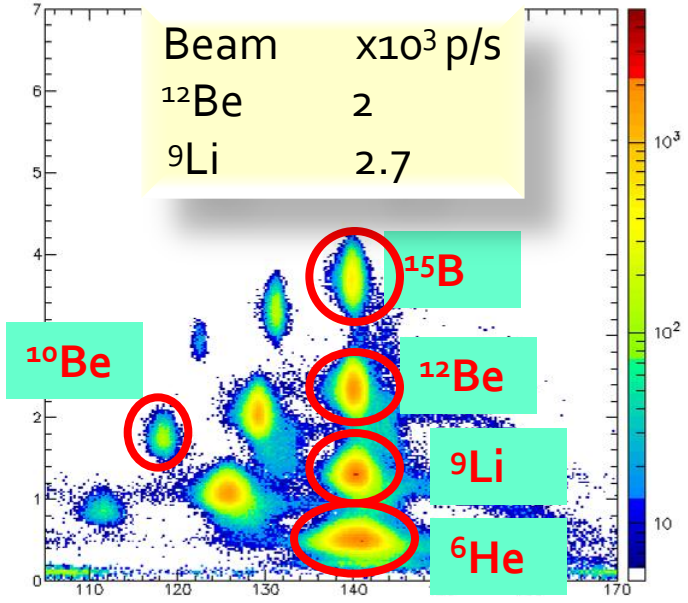
- CHIMERA
- MAGNEX
  + EDEN
- MEDEA



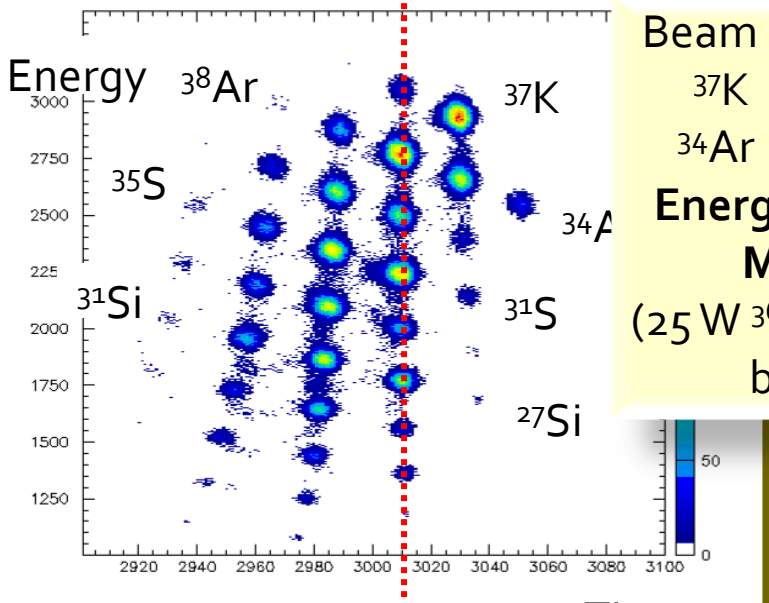
^{18}O 55 MeV/A
100 W primary beam (6.3x10^{11} p/s)

Beam	x10^3 p/s
^{16}C	60
^{13}B	40

E~50 MeV/A
ΔP/P <1%

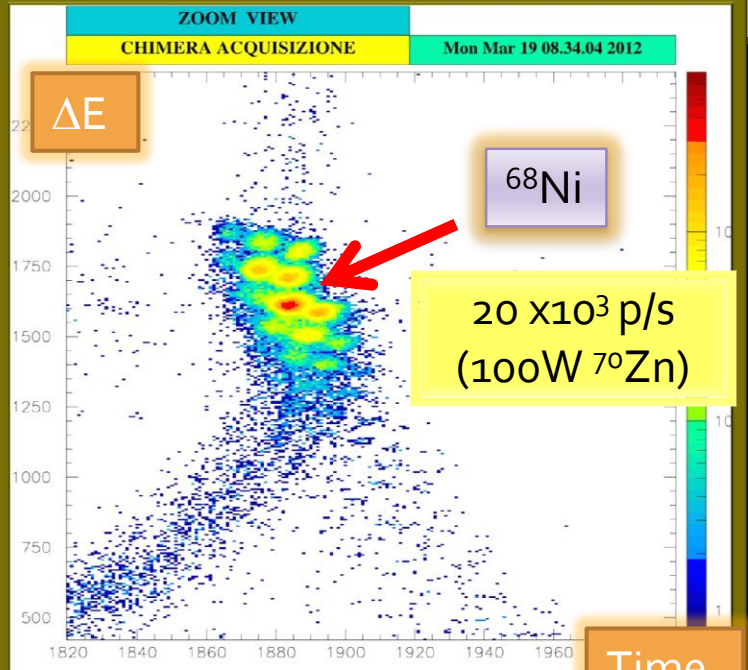


Beam	x10^3 p/s
^{12}Be	2
^{9}Li	2.7



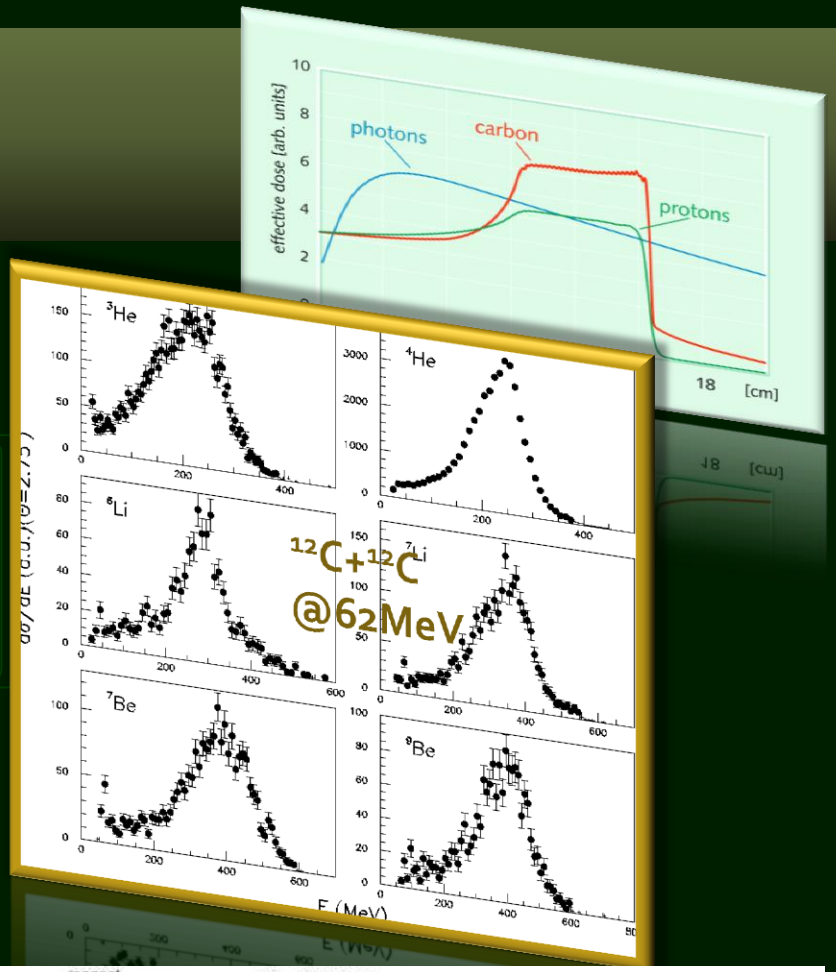
Beam	x10^3 p/s
^{37}K	14
^{34}Ar	1.8

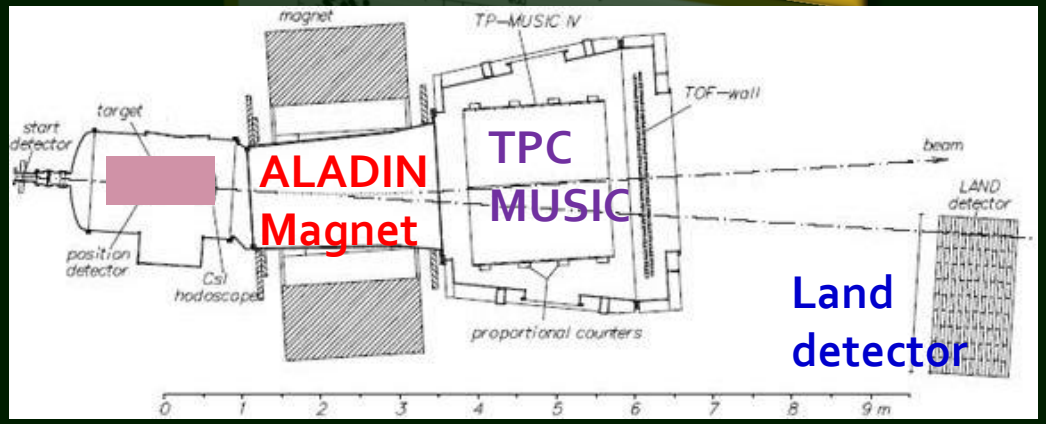
Energy ~ 20-25 MeV/A
(25 W ^{36}Ar primary beam)



FRAG @LNS

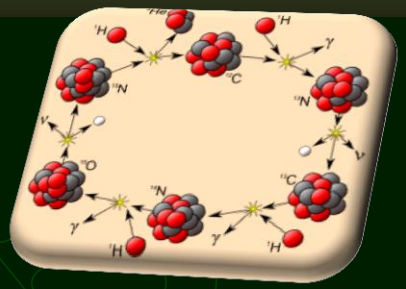
- Fragmentation of Ions
- Extensive study of nuclear reactions of interest for medical and space applications
- Relevant for Space and Hadron-Therapy
- Experimental activity extended at GSI at higher energy (FIRST)

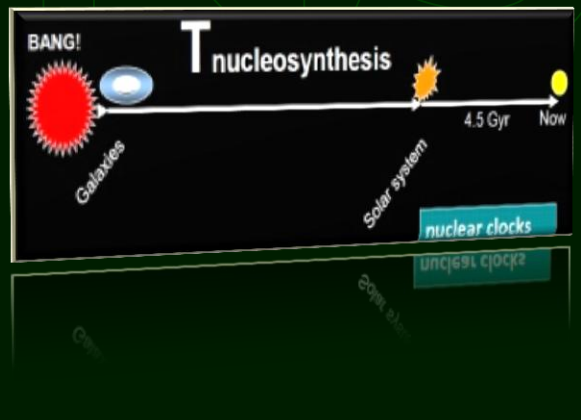


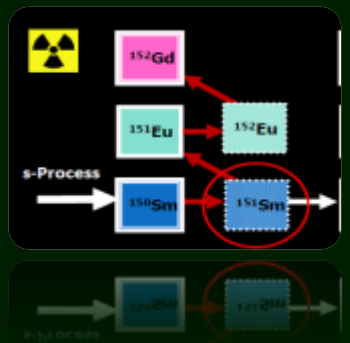


L4 - Nuclear Astrophysics and Interdisciplinary Research

- 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 nuclei 5keV – 5 MeV region of cosmological interest
  - ASACUSA @CERN
- Pauli principle violation in atomic transitions
  - VIP @LNGS
- Gravity effects on antimatter
  - AEGIS @CERN



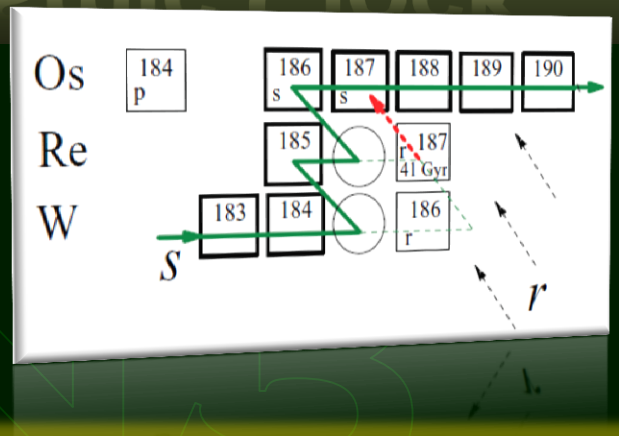


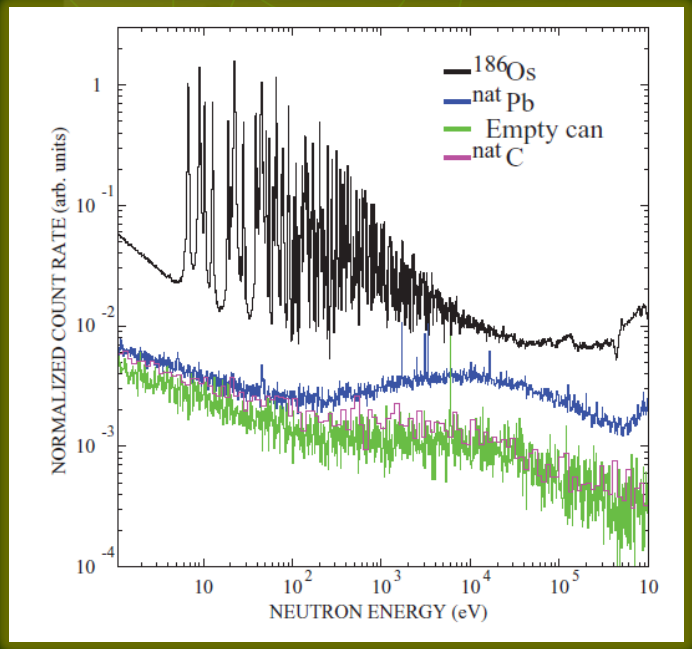


n_TOF@CERN a Cosmic Clock

- 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).

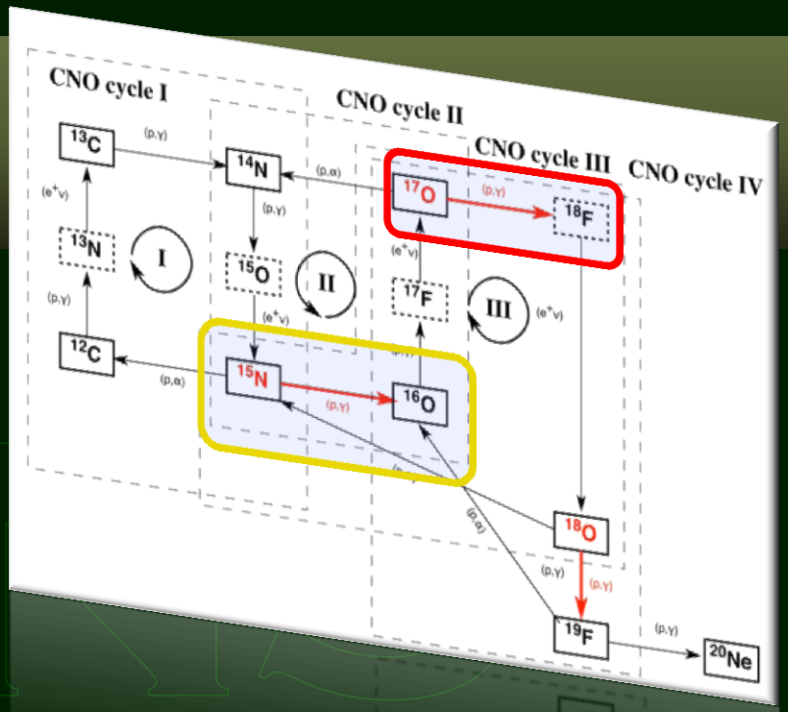


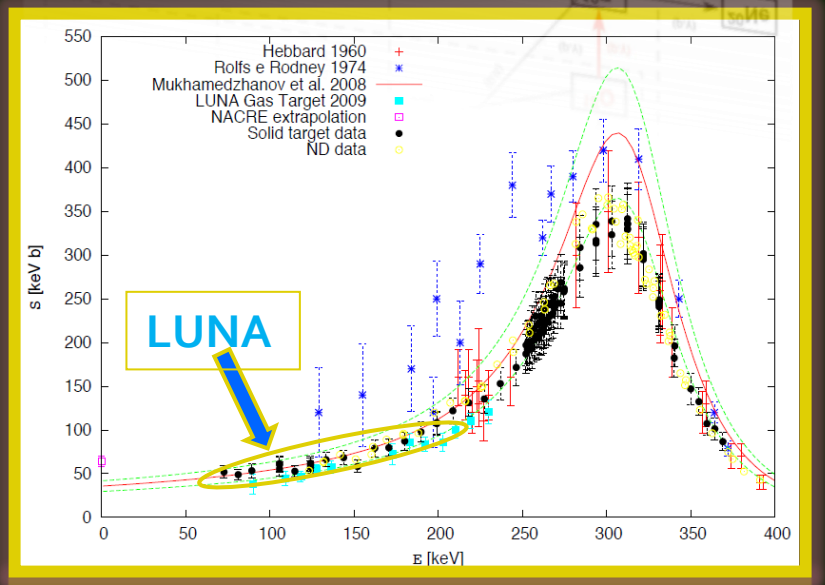


LUNA @LNGS

- $^{15}N(p,\gamma)^{16}O$ 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

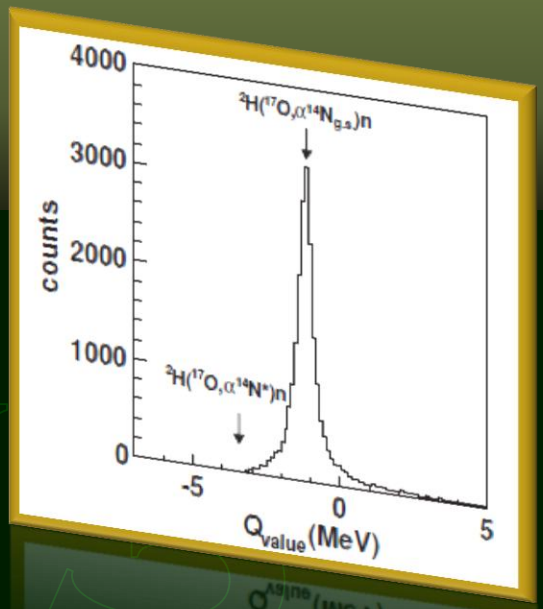
- Next measurement: $^{17}O(p,\gamma)^{17}F$

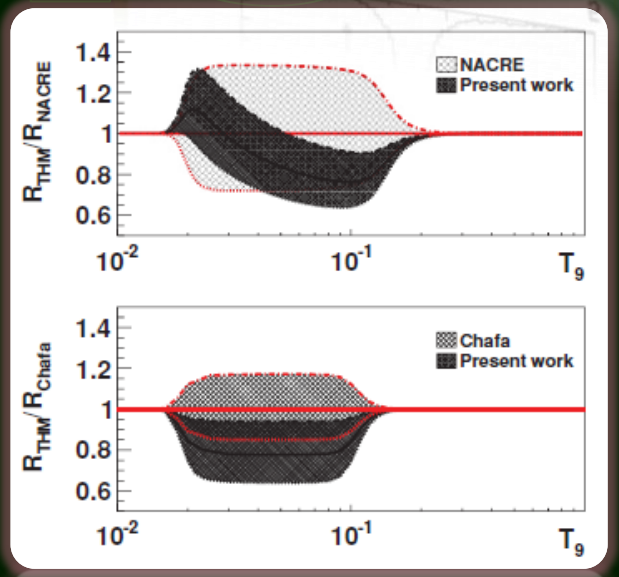




ASFIN@LNS

- $^{17}O(p,\alpha)^{14}N$ via the Trojan-Horse-Method
- ^{17}O is processed in the CNO cycle and play a key role in the novae nucleosynthesis and γ-ray astronomy
- Evaluation of the 65 keV resonance strength and its impact in the reaction rate





What is next?

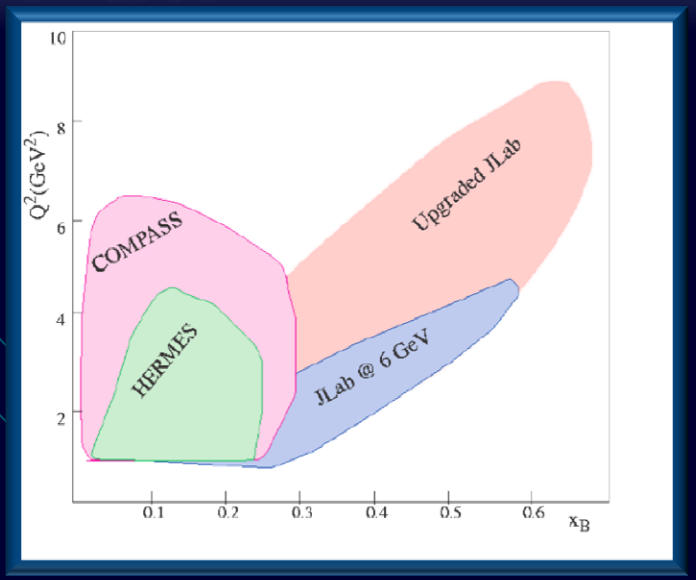
CSN3

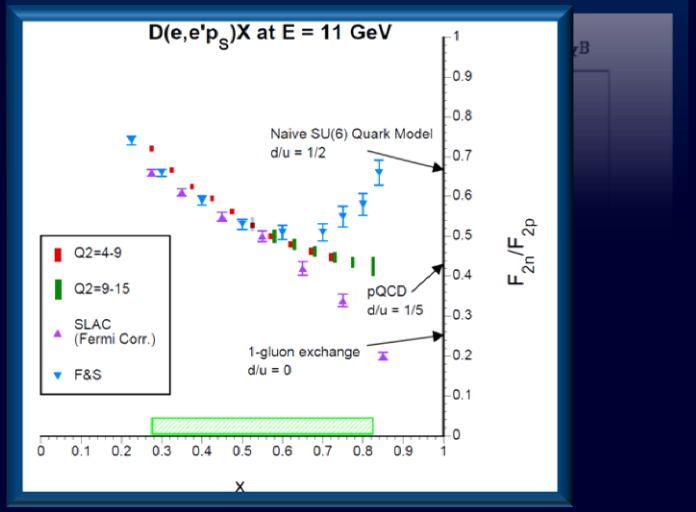
Upgrade to JLAB@12 GeV

- Forward tagger calorimeter
- Neutron detector
- R&D for the Rich detector
- Contribution to the new tracker with GEM detector

Upgrade to JLab@12 GeV

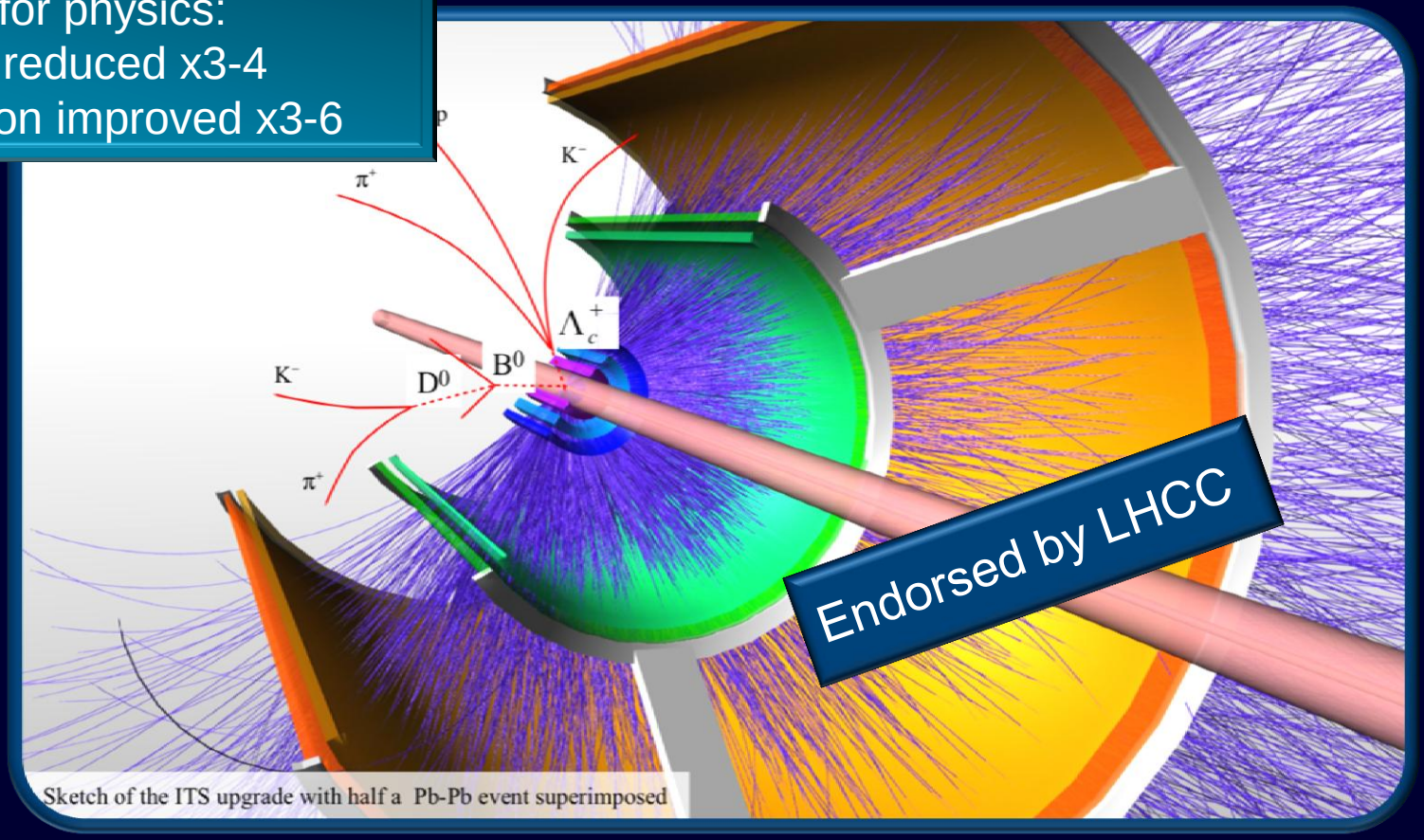
- JLab@12GeV will provide a wide kinematical coverage to study:
  - 3-D properties of the proton internal structure (GPDs)
  - pQCD prediction @ $x \to 1$
  - Form factors …





ALICE – ITS Upgrade CDR

Key aspects for physics:
1. Material reduced x3-4
2. Resolution improved x3-6



Sketch of the ITS upgrade with half a Pb-Pb event superimposed

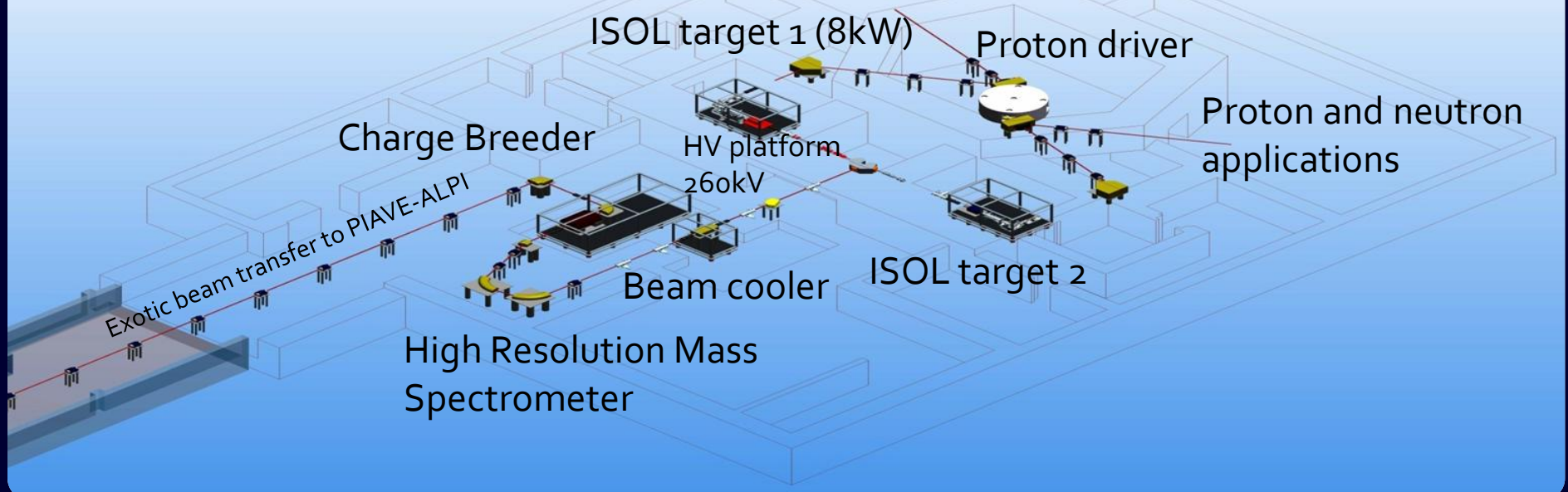
SPES ISOL facility @LNL

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

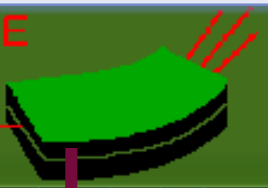


ISOL Roadmap in EUROPE

TODAY

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

ISOLDE
CERN



SPIRAL – GANIL

INFN

LNS - EXCYT

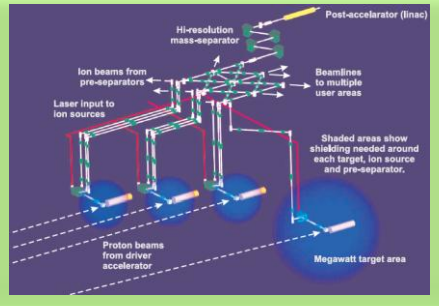
2014-2025

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

GANIL spiral2
laboratoire commun CEA/DSM CNRS/IN2P3

HIE-ISOLDE

SPES
exotic beams for science



EURISOL

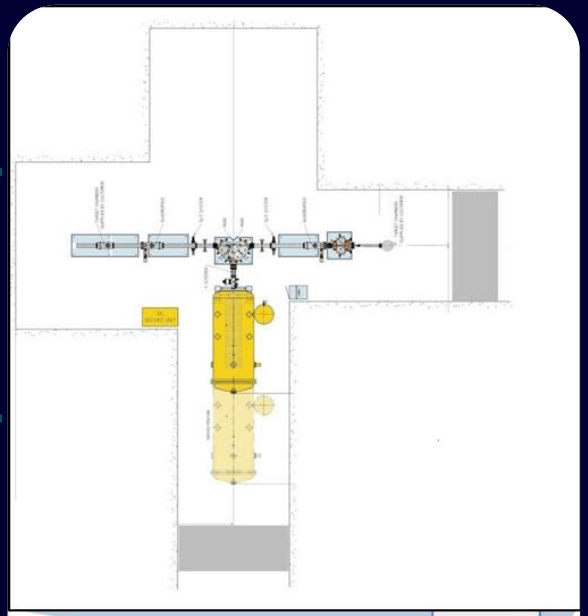
FROM 2025

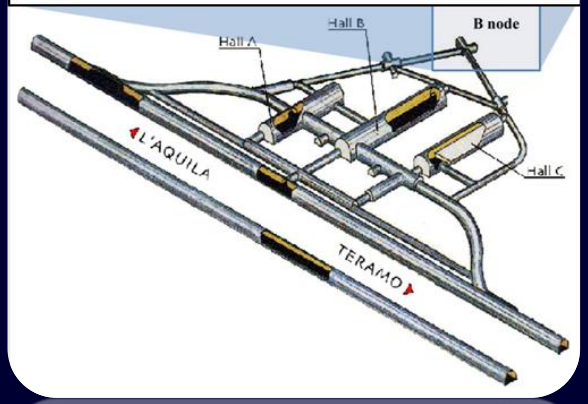
> 10^{15} fission/s
100 MeV/n (A=130)

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

LUNA-MV @ LNGS

- A 3.5 MV accelerator to measure key reactions of the Helium burning and neutron sources for the s-process:
  - $^{12}C(\alpha,\gamma)^{16}O$
  - $^{13}C(\alpha,n)^{16}O$
  - $^{22}Ne(\alpha,n)^{25}Mg$
  - (α,γ) reactions on $^{14,15}N$ and ^{18}O
- Relevant at higher temperatures (larger energies) than reactions belonging to the hydrogen-burning studied so far at LUNA





Major future development

- Line 1
  - JLAB upgrade
  - PANDA (?)
- Line 2
  - ALICE upgrade
- Line 3
  - related instrumentation (AGATA, FAZIA) for SPES@LNL
  - FRIB,EXCYT@LNS + upgrading of existing instrumentation (CHIMERA, MAGNEX, FARCOS)
- Line 4
  - related instrumentation (TbD) for LUNA-MV@LNGS

Conclusions

- ALICE has collected data with Pb-Pb and is ready for next p-Pb data taking.
- The experimental campaign with the AGATA demonstrator has been completed at LNL. The realization of ¼ of solid angle is in progress. Nuclei at extremes and more degrees of freedom will be investigated.
- Esperiments engaged in upgrades (such as JLAB and CHIMERA at LNS) are progressing.
- Several relevant results are obtained with the analysis under way. They are important to guide the future programs.
- Improvements to the national infrastructures are in progress.