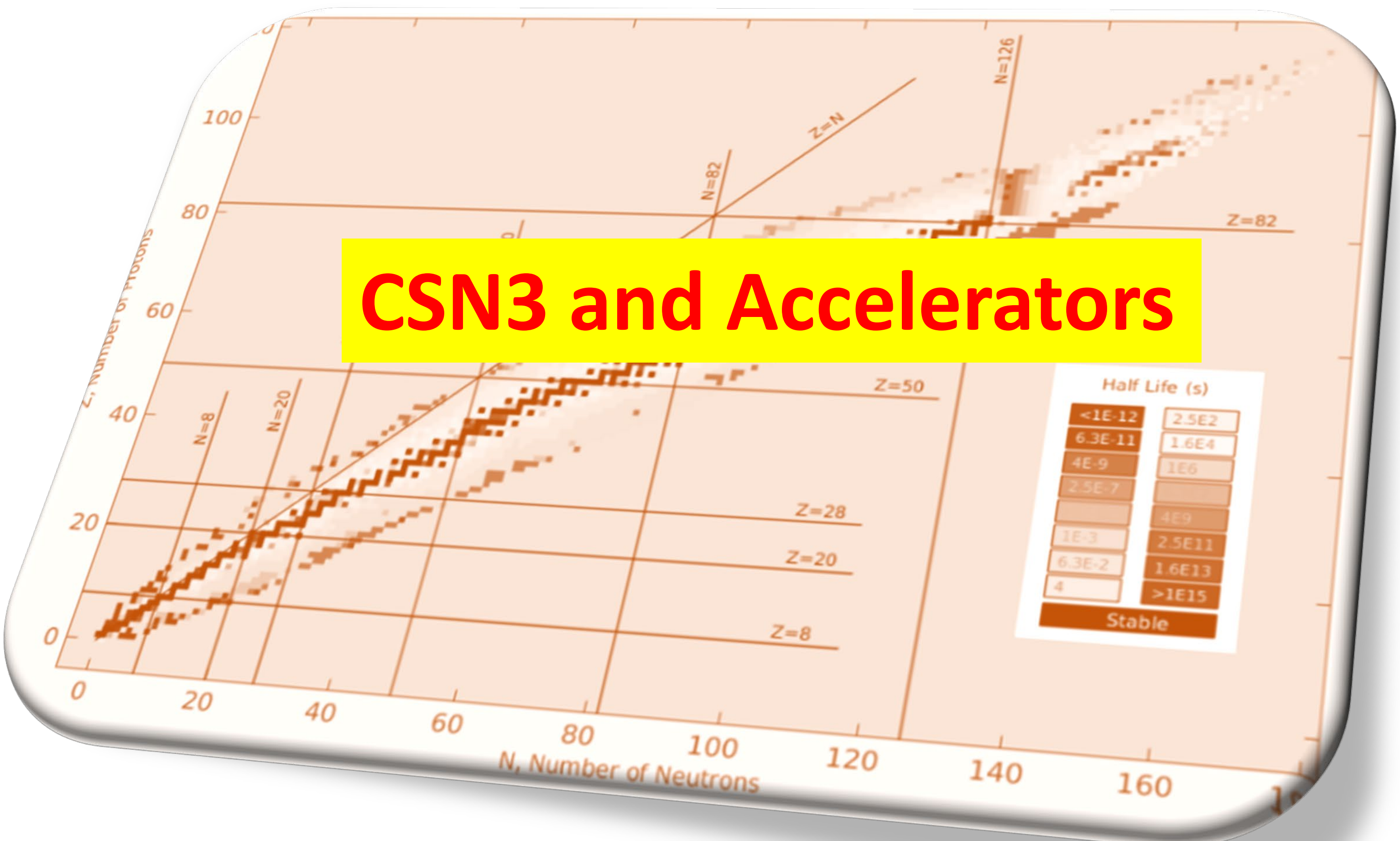
R. Nania
INFN acceleratori – 7 Aprile 2022

Thanks to
G. Bisogni, P. Camerini, M. La Cognata,
M. Osipenko, S. Piantelli, S. Palmerini ,
G. Boca, D. Mengoni, J. Valiente Dobon
+ Coordinators CSN3

CSN3 and Accelerators



INFN CSN3

CSN3 Fisica Nucleare

CSN3 Research Lines 2021 Following NUPECC indications

1 QUARKS AND HADRON DYNAMICS

KAONNIS (LNF) , JLAB12 (JLAB), MAMBO (Mainz-Bonn), ULYSSES (JPARC), EIC_NET (BNL)

2 PHASE TRANSITION IN HADRONIC MATTER

ALICE (CERN) , NA60_PLUS(CERN)

3 NUCLEAR STRUCTURE AND REACTION MECHANISM

FORTE, GAMMA, CHIRONE, NUCL-EX, NUMEN_GR3, PRISMA_FIDES (LNS, LNL, GANIL, ISOLDE, GSI, RIKEN,....)

4 NUCLEAR ASTROPHYSICS

ASFIN, ERNA, LUNA , n_TOF, PANDORA (LNS, LNL, LNGS, CIRCE , CERN...)

5 FUNDAMENTAL INTERACTIONS

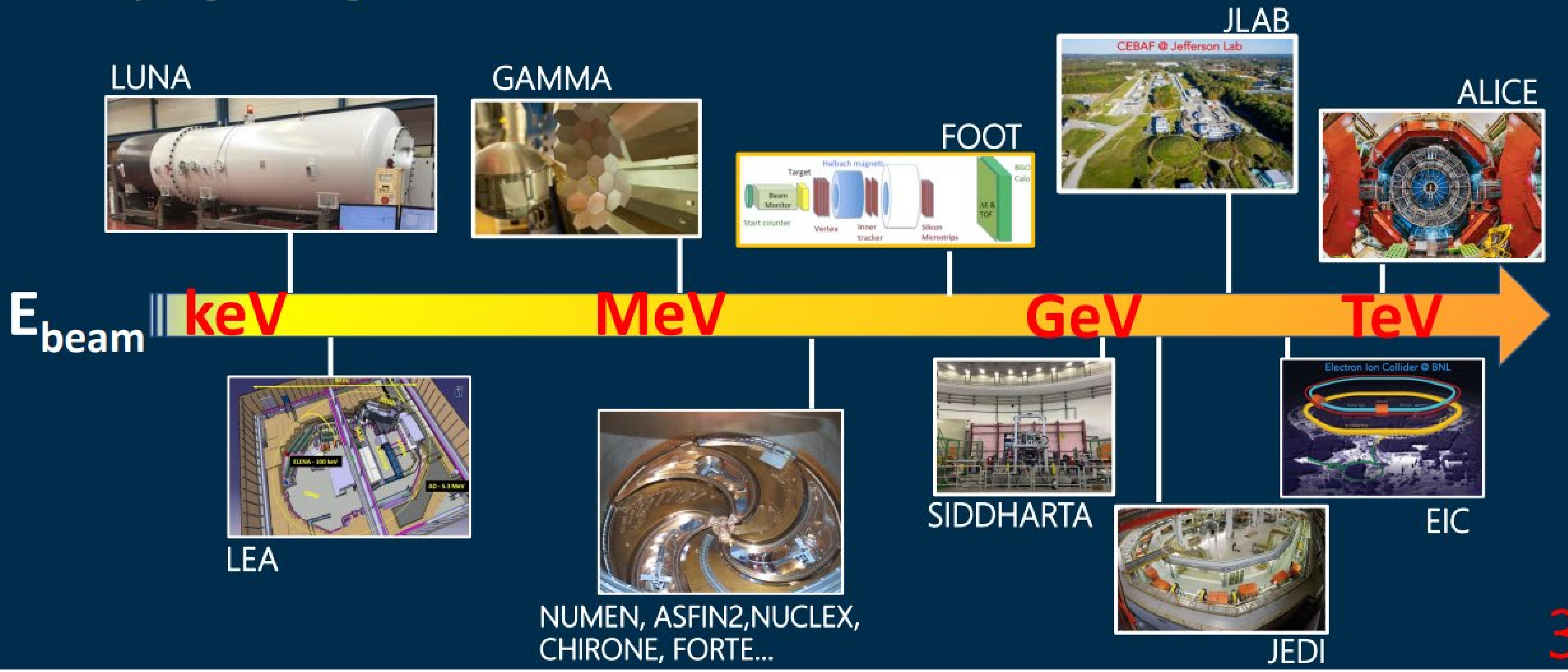
LEA (CERN), JEDI (Jülich),VIP (LNGS), FAMU (RAL)

6 APPLICATIONS AND SOCIETAL BENEFITS

TORIO (GE) ,
FOOT (GSI,CNAO,TIFPA, HIT)

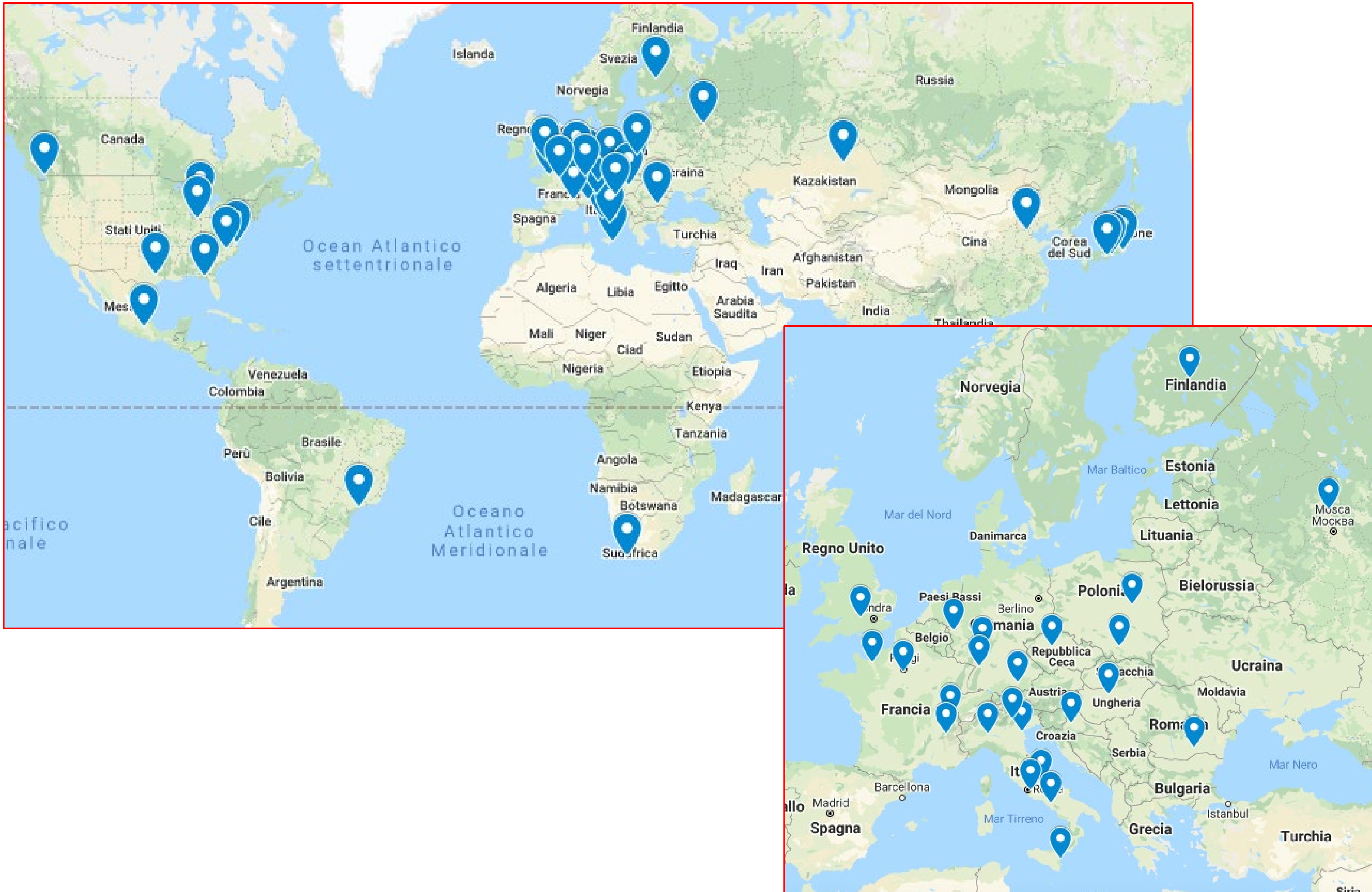
The CSN3 experiments

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



R. Arnaldi

National and International Laboratories for CSN3 experiments



Research Infrastructure Concept Development (INFRA-DEV)

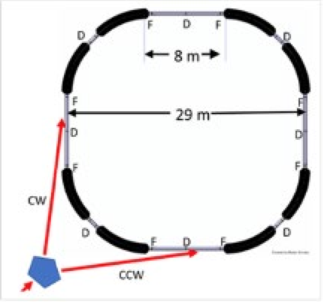
PRESTO @ Research Center Jülich

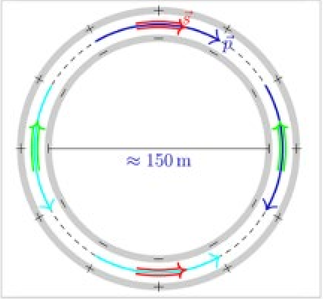
Pathfinder Facility for a New Class of Precision-Physics Storage Rings

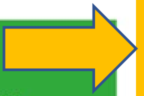
P. Lenisa

PRESTO

1 Precursor Experiment	2 Prototype Ring	3 All-electric Ring
dEDM proof-of-capability (orbit and polarization control; first dEDM measurement)	**pEDM proof-of-principle** (key technologies, first direct pEDM measurement)	**pEDM precision experiment** (sensitivity goal: 10^{-29} e cm)

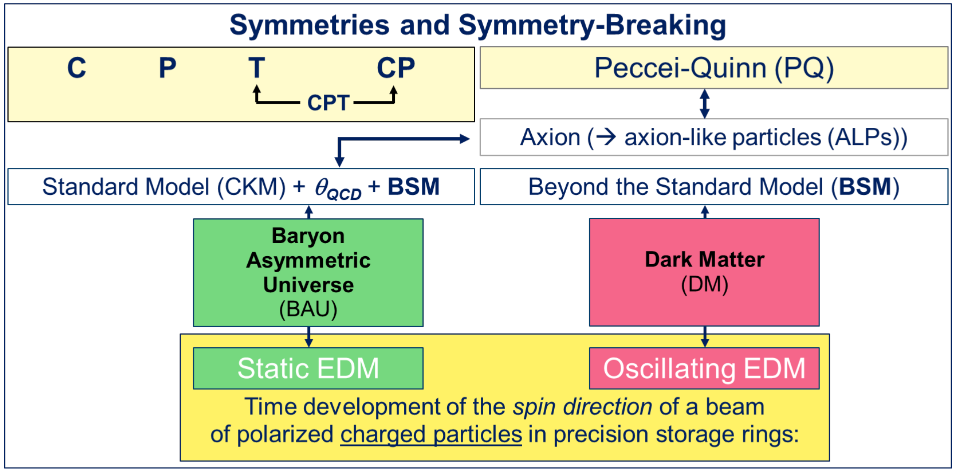






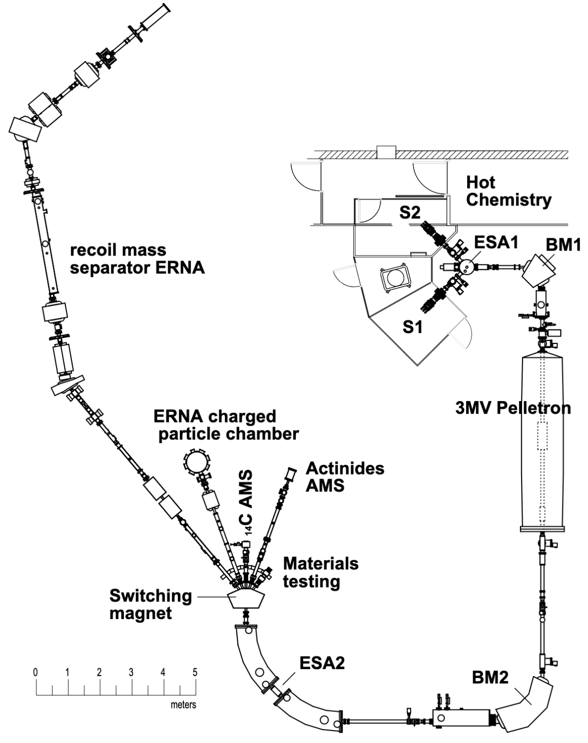
- large electric field (~10MV/m)
- proton momentum of 707 MeV/c
- storage ring of 500 m circumference.

Need an intermediate step to validate the principle of operation -> PRESTO



CIRCE Tandem Accelerator Laboratory

Dipartimento di Matematica e Fisica dell'Università della Campania



Accelerator Mass Spectrometry (AMS) for materials dating, extended to nuclear and application physics. Several activities connected to CSN3 (ERNA2, LUNA), CSN2 (KM3NeT), CSN5 (NEPTUNE), INFN-E

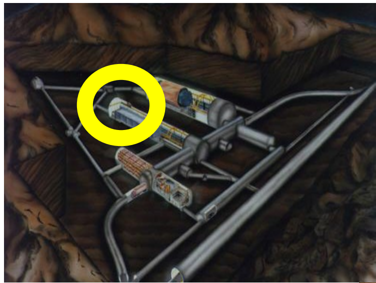
In CSN3 :

- Study of the reaction $^{7}Be(p,\gamma)^{8}B$ in reverse kinematic, important for nuclear astrophysics.
- Financed PRIN for the study of the lifetime of ionized ^{7}Be and related applications.

The ^{7}Be beam can be used also for study of materials, in particular those for space (in collaboration with Centro Italiano Ricerche Aerospaziali (CIRA))

- Electrostatic accelerator tandem (National Electrostatic Corp. 9SDH-2 Pelletron)
- Maximum voltage 3MV
- LE magnet ρ = 0.457 m, ME/Z2 = 15
- HE magnet ρ = 1.27 m, ME/Z2 = 176, M/ΔM = 725

From Hydrogen to Helium and Carbon burning or… from LUNA to LUNA MV facility at LNGS



In-line Cockcroft Walton

- In the energy range 0.3-3.5 MeV
- H^+ beam: 500-1000 eμA
- He^+ beam: 300-500 eμA
- C^+ beam: 100-150 eμA
- C^{++} beam: 100 eμA

Beam energy reproducibility : 10^{-4} * TV or 50 V
The accelerator hall will be shielded by 80 cm thick concrete walls: no perturbation of the LNGS natural neutron flux

$^{14}N(p,\gamma)^{15}O$: the bottleneck reaction of the CNO cycle in connection with the solar abundance problem. Also commissioning measurement for the LUNA MV facility

$^{12}C+^{12}C$: energy production and nucleosynthesis in Carbon burning. Global chemical evolution of the Universe

$^{13}C(\alpha,n)^{16}O$ and $^{22}Ne(\alpha,n)^{25}Mg$: neutron sources for the s-process (nucleosynthesis beyond Fe)

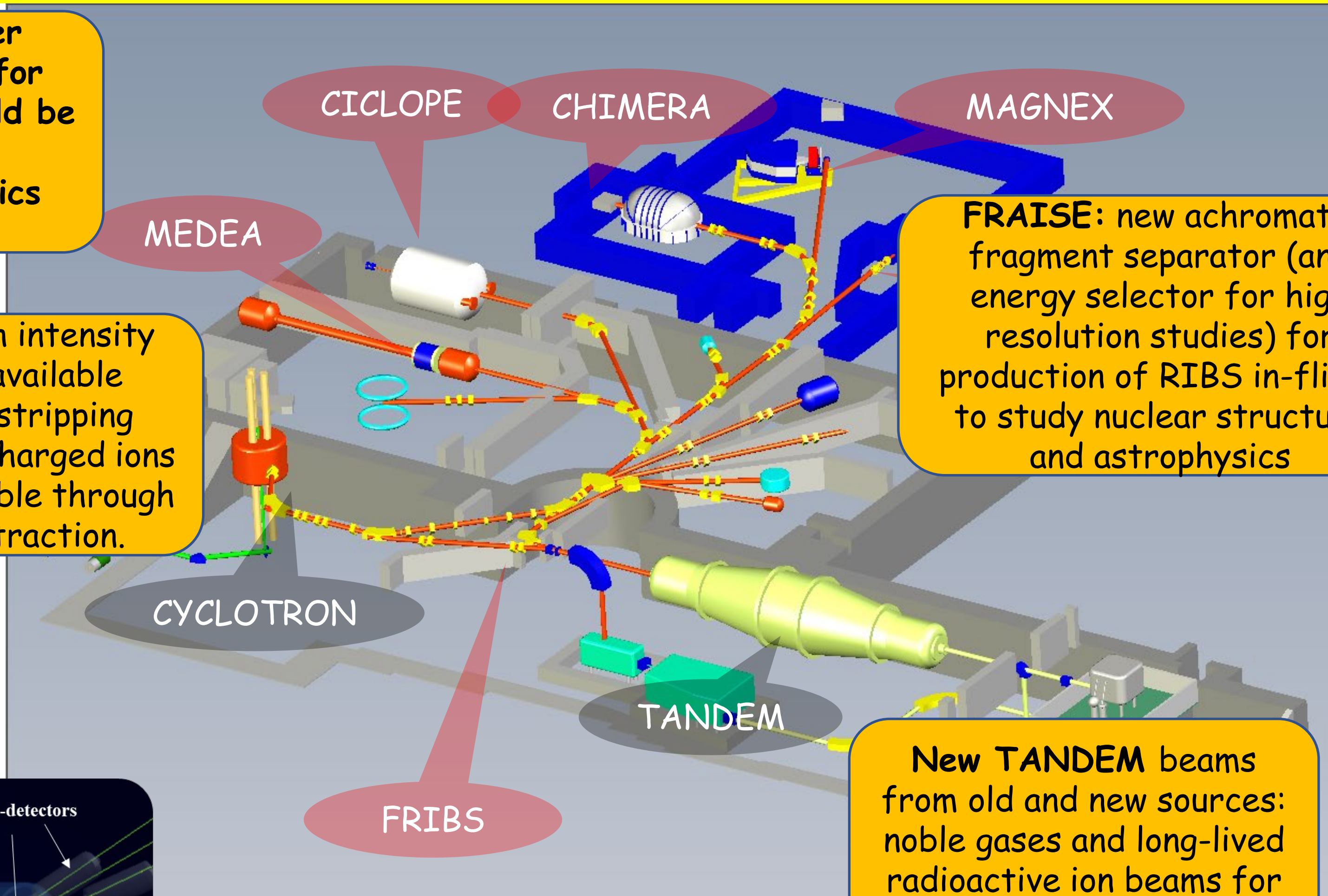
Later on…

$^{12}C(\alpha,\gamma)^{16}O$: key reaction of Helium burning: determines C/O ratio and stellar evolution
…..

Laboratori Nazionali del Sud : from past to future (2024)

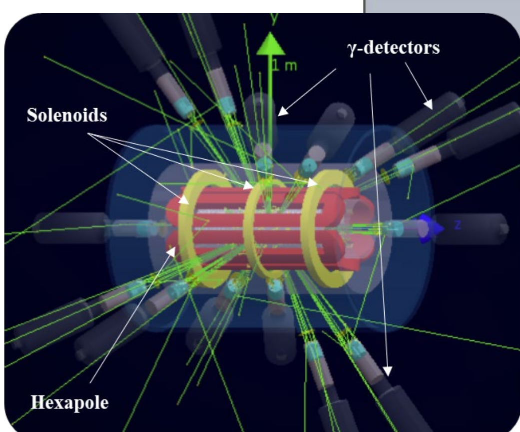
Hopefully a Laser facility financed for medical studies could be also used for fundamental physics studies

CYCLOTRON: High intensity light-ion beams available through the new stripping extraction. Highly charged ions will be always available through electrostatic extraction.



FRAISE: new achromatic fragment separator (and energy selector for high resolution studies) for production of RIBS in-flight to study nuclear structure and astrophysics

New TANDEM beams from old and new sources: noble gases and long-lived radioactive ion beams for nuclear astrophysics



Magnetic Trap 70 cm x 28 cm

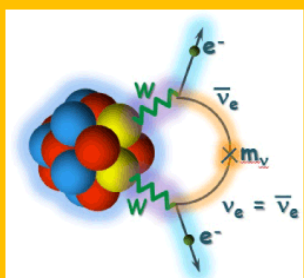
New – PANDORA

- In-plasmas β-decay measurements of astrophysical interest: isotopes can change their lifetime of several order of magnitude when ionized
- Opacity measurements

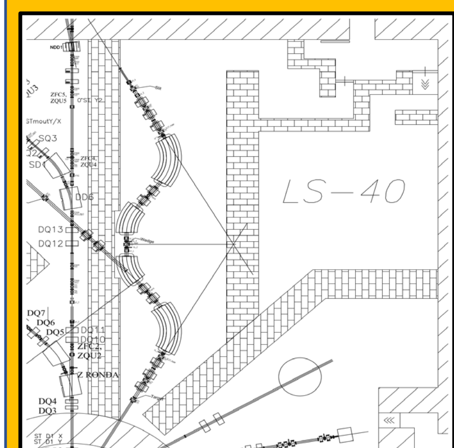
New beams at the CS and at the TANDEM accelerator

New beams at the CS and …

High-intensity stable beams: Example NUMEN-MAGNEX
Driving physical case is the investigation of neutrinoless double beta decay to get an insight on the physics beyond the standard model: from nuclear physics (nuclear matrix elements) to neutrino physics



$$1/T^{0\nu}_{1/2}(0^+ \to 0^+) = G_{01} \left|M^{\beta\beta 0\nu}\right|^2 \left|\frac{\langle m_\nu \rangle}{m_e}\right|^2$$



High-intensity RIBS with FRAISE

- Production in-flight → complementarity with SPES in terms of species and lifetimes
- <u>Broad range of physical cases:</u>

→ Study of nuclei under extreme conditions and far from the valley of stability
→ Nuclear astrophysics for explosive phenomena (supernovae, novae, etc)

… at TANDEM accelerator

<u>Stable beams of NOBLE GASES</u>
- Measurements of reactions for the Big Bang
- Implantation + low energy reactions with high intensity beams using a new source

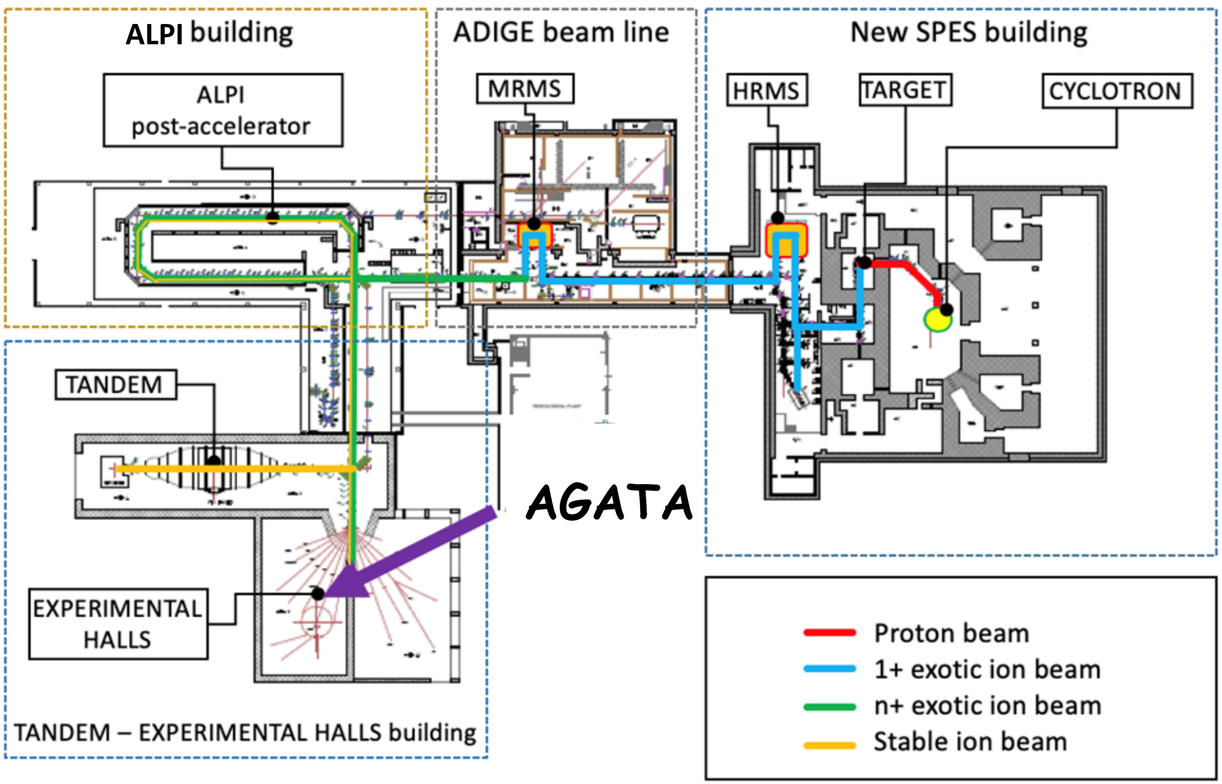
<u>Long-life radioactive beams</u>
- Average half lives > 10^5 years (low activity)
- **From MultiMessenger Astronomy to studies on the formation of the Solar System**

Examples:
^{10}Be (Half life: 1.51 My) already measured
^{26}Al (Half life: 0.72 My) under study
^{60}Fe (Half life: 2.62 My) under study

Why SPES at LNL ?

- Our knowledge of the nuclear interaction mainly comes from nuclei studied near the valley of stability
- The goal of SPES is to provide high-quality beams to overcome this gap of knowledge → scrutinize the nuclear interaction far from the stability line (neutron-rich side)
- A facility like SPES also provides a framework to applications, such as radioisotope production and neutron sources.
- SPES will represent a second generation radioactive ion beam → a step forward toward EURISOL

TDR 2008

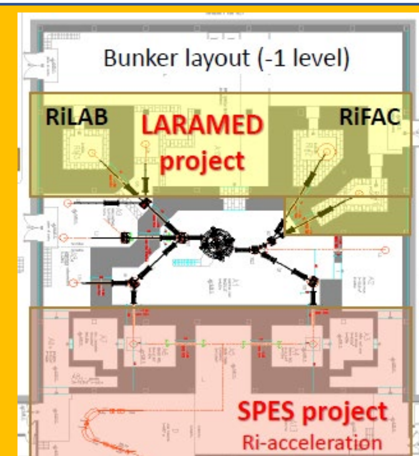


SPES at LNL

- new cyclotron: primary p beams E= 70 MeV, I = 200 μA
- p on target to produce radioactive ion beams (10^{13} fissions/s)
- **Broad range of physical cases**

LNL SPES Beams:
2023 – low energy RIBs
2024 – re-accelerated RIBs in ALPI

AGATA installation at LNL



LARAMED project
Laboratory of Radionuclides for Medicine.

A production facility (RIFAC)
operated by INFN and a private partner
Production of ^{82}Sr/ ^{82}Rb and ^{68}Ge/ ^{68}Ga

A research laboratory (RILAB)
jointly owned by INFN and CNR
Target preparation, target processing, radiochemistry, spectrometry, QC labs for:

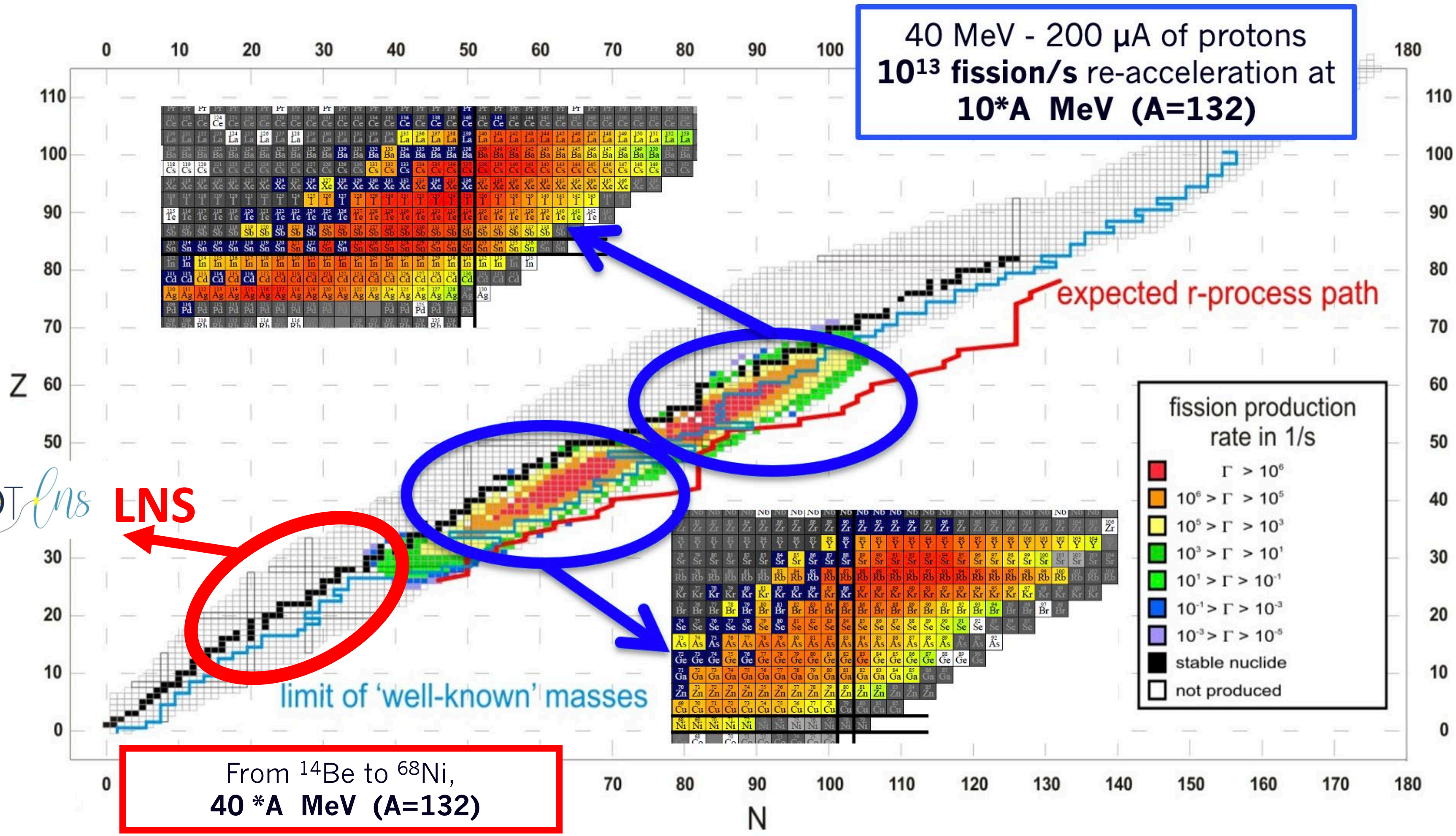
- Nuclear cross section measurements
- Low activity production
- High power target development

The ISOLPHARM project
Production of a wide set of high purity radioisotopes for medical use, either for diagnosis or for therapy.

LNL-LNS complementarity

SPES

LNL



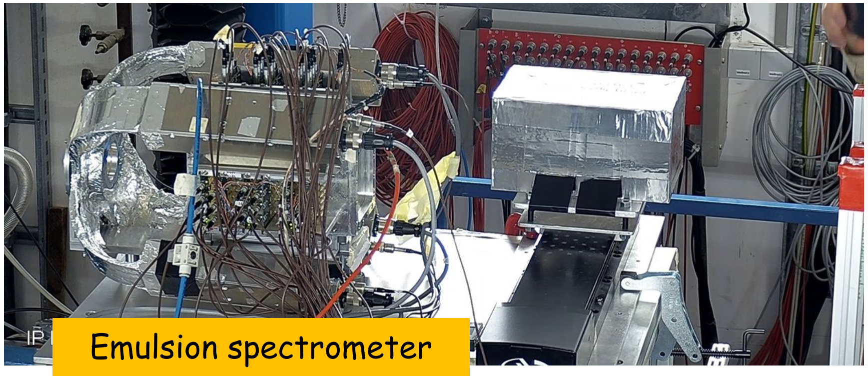
FOOT (FragmentatiOn Of Target)

Aims to study the fragmentation cross section of relevance for particle therapy with protons (target fragmentation), particle therapy with carbon beams (projectile fragmentation), and for radioprotection in space

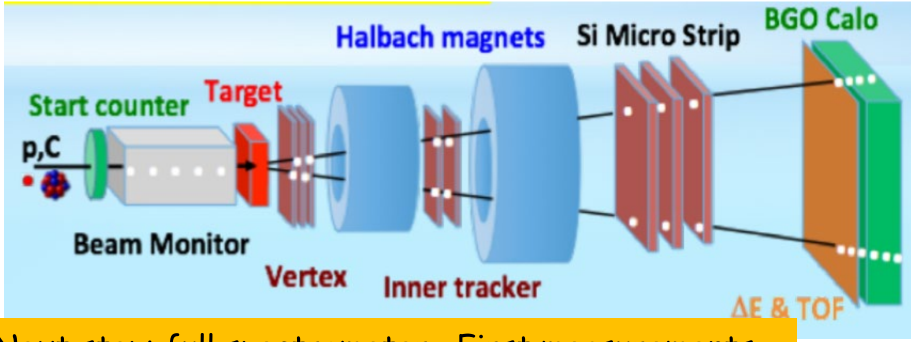
Member also of APPA GSI and part of the
International Biophysics Collaboration
Biophysics, Atomic, Plasma Physics and Applications. From the investigation of atoms and macroscopic effects in materials or tissues all the way to engineering and medical applications

Operates at CNAO,TIFPA Trento , GSI, Heidelberg ….

Hope to enlarge in future CSN3 involvment in such type of measurements, also in connection with INFN4LS.



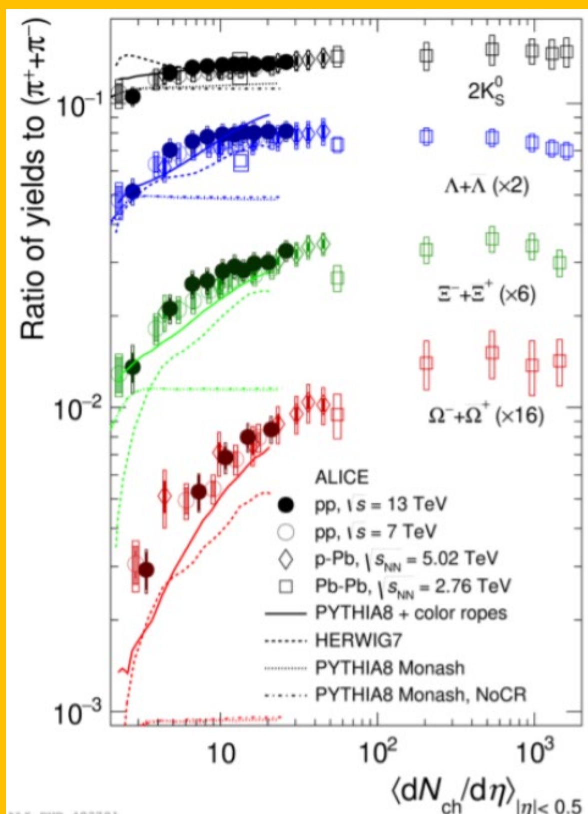
Emulsion spectrometer

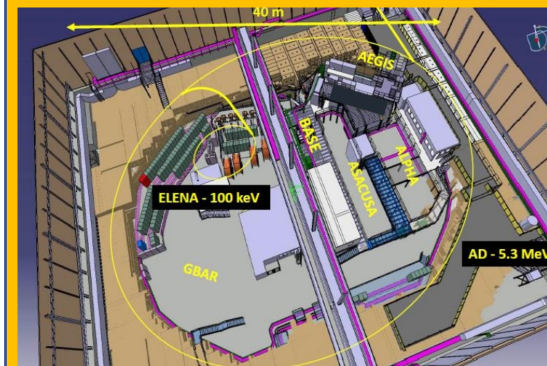


Next step: full spectrometer . First measurements with partial set-up at GSI and CNAO

ALICE @ CERN LHC : pp pPb PbPb

Big Bang →QGP → QCD → FCC





AD: 5.3 MeV
Pulsed beam: 3×10^7 every ~ 100 s

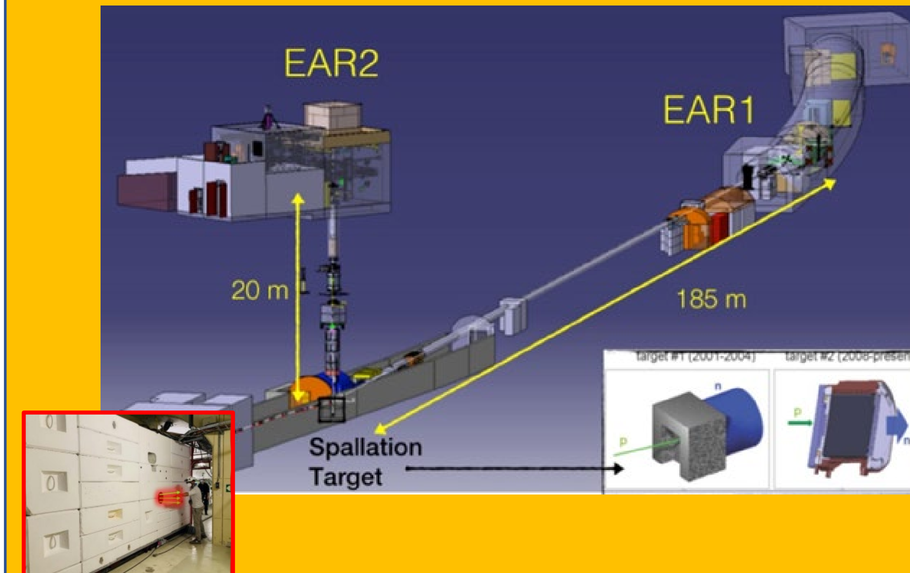
ELENA: 5.3 MeV → 100 keV

Antiproton Decelerator (AD) & ELENA @ CERN

- Spectroscopy of antihydrogen
- Test free fall/equivalence principle with antiH
- Antiprotonic helium spectroscopy
- Nuclear physics

ISOLDE @ CERN

ISOLDE offers the largest range of isotopes worldwide: more than 700 isotope beams, from 70 chemical elements

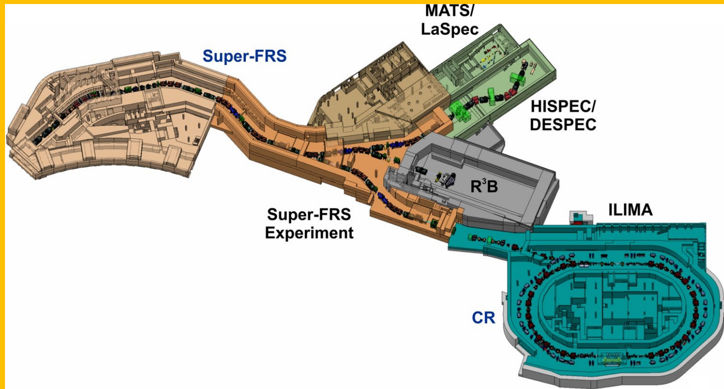


N_TOF @ CERN

Third beam line now available with a new neutron target

Nuclear Astrophysics: Nucleosynthesis A>60, Stellar evolution, Big bang nucleosynthesis
Nuclear technology and medical application: Fission reactors, Fusion, Transmutation of nuclear waste, Neutron capture therapy
Basic Nuclear Physics Nuclear interaction, Nuclear structure effects on fission, Excited states

CSN3 @ GSI/FAIR

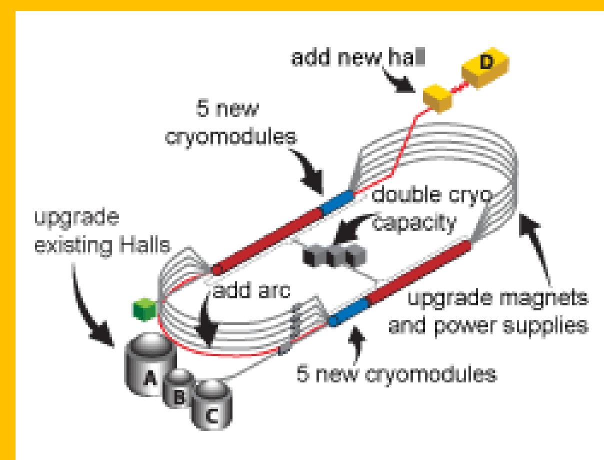


INFN groups join experiment at **NUSTAR** and **APPA**: no direct involvement in the machine, but…

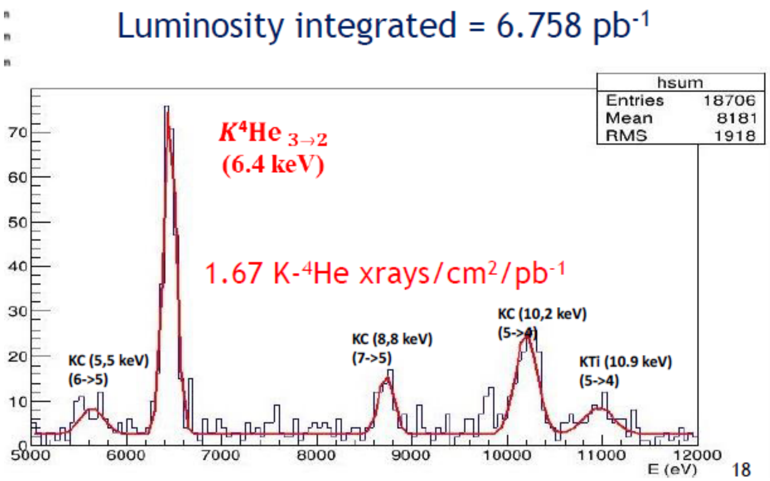
Cooperation Agreement with INFN for the cold Testing of more than 80 SIS100 Quadrupole in the test facility of NAFASSY in Salerno, Italy

CSN3 at JLAB (Class12, PREX …)

CEBAF superconduting electron accelerator , 12 GeV



- 3D imaging of the nucleon
- quark dynamics
- nuclear and hyper nuclear dynamics
- light dark matter search



SIDDHARTA/KAONNIS @ DAPHNE LNF

Unique facility to study kaonic atoms, kaonic deuterium, and strong interaction via low energy kaon nuclei scattering

Complementary approaches to study antikaon-deuteron interactions :

@SIDDHARTA spettroscopy of antikaonic atoms
@ALICE via femtoscopy

Next Possible Steps

- **Study Kd in 2022-2023**
- **Proposal for 2023-2025**

  First :

  Solid target for light kaonic atoms: e.g. Li. Be, B, C) with 1mm SDDs, Cd(Zn) Te.

  Later :

  Heavier kaonic atoms (K Si, KPb…): with HPGe

  Radiative kaon capture Λ (1405)

  Possibility of the measurement of other types of hadronic exotic atoms

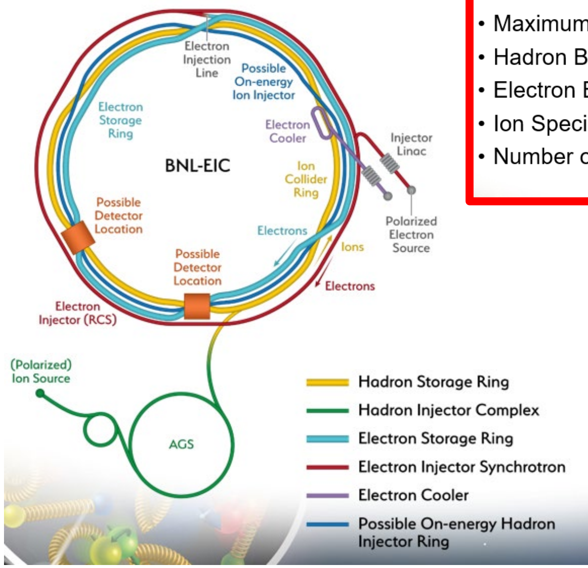
However…..

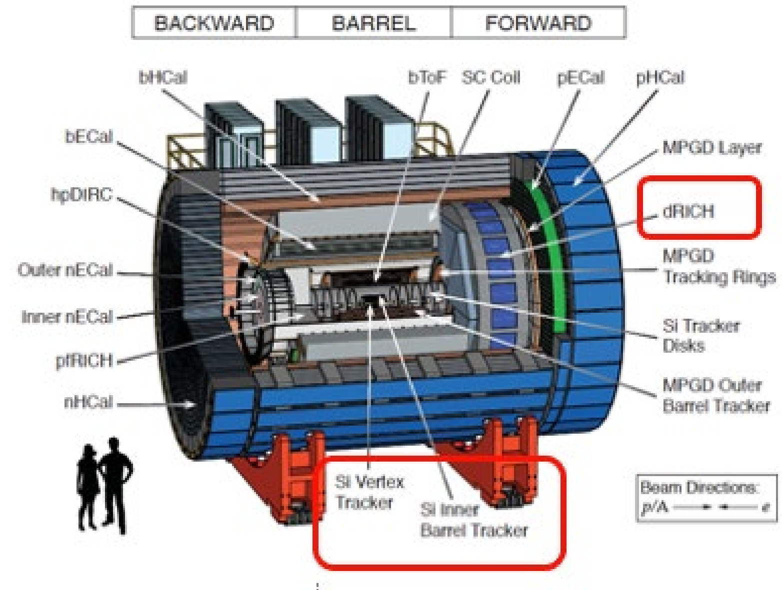
DAPHNE requires important maintenance
DAPHNE power consumption is an issue
DAPHNE manpower is an issue
… but DAPHNE is also THE INFN experience in collider accelerators : could it be useful for next generation colliders ?

INFN CSN3

Electron Ion Collider at BNL

• Center of Mass Energies	20 GeV – 141 GeV
• Maximum Luminosity	10^{34} $cm^{-2}s^{-1}$
• Hadron Beam Polarization	80%
• Electron Beam Polarization	80%
• Ion Species Range	p to Uranium
• Number of interaction regions	up to two





INFN groups joined the ATHENA proposal with main interests in dRICH and silicon tracker.

INFN

- CSN3 foresees <u>till 2030</u> FTE 15 →50 and about 7 M€
- Strong involvement of CSN4
- INFN management is positive toward contribution to the machine.

It is a mid-term project that could well exploit and strengthen INFN expertise in theory, experiment and machine. Also in preparation of FCC

INFN can be very incisive in this project

Main Time schedule:
1/12/2021 experiment proposals
8/3/2022 report of Detector Proposal Advisory Panel → merge ATHENA and ECCE
2023 Detector Approval
2030 Operation start…

Considerations

- CSN3 experiments operating with accelerators all around the world (CERN, JLAB, TRIUMF, GANIL, GSI-FAIR, LNL, LNS, LNF, LNGS, CIRCE, CNAO, TIFPA…)
- Important accelerator parameters span from beam energies (from keV to TeV) , to beam intensities, to species of accelerated particles (from stable to RI beams)
- Nuclear cross section measurements and CSN3 are strongly connected with the activities of INFN-accelerator, INFN-Energy, INFN-4LS, CSN5, CSN4. And we hope to increase transversal connections with CSN1 and CSN2 as what concern researchers' interests.
- Future of CSN3 experiments tightly related to the future of a wide range of different accelerators, both at laboratories in Italy and outside.
- For successful experimentation in Italian laboratories, we rely on the strong support of the INFN management to strengthen the man-power for accelerator operations of present machines and for future developments, pointing especially to young resources.

2022 series of workshops

Nuclear Physics Mid Term Plan

Physics, Theory, Machine

https://web.infn.it/nucphys-plan-italy/

INFN

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INFN is promoting a discussion forum on the future of nuclear physics research in Italy with particular emphasis on INFN laboratories that are preparing important upgrades for the accelerators complexes.

Specific working groups are discussing ideas and topics to be developed in the mid term future with the goal of defining experiments at the upgraded facilities or promoting ad-hoc developments for new setups.

Worldwide researchers interested in joining the working groups are welcome to register and participate to the ongoing discussions as active members of the community.

The working groups will report their activities in three final events, dedicated to each Laboratory:

Session 1 – LNS (4-5 April 2022)

Session 2 – LNL (11-12 April 2022)

Session 3 – LNGS/LNF (date to be announced)

UPDATE: Attendees registration is now open! You can find the form in each INDICO page.

REGISTER

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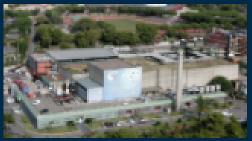
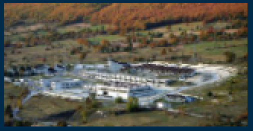
Nuclear Physics
Mid Term Plan in **Italy**

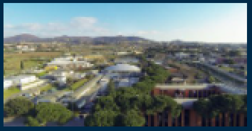
Laboratori Nazionali di Legnaro



Laboratori Nazionali del Sud



Laboratori Nazionali del Gran Sasso



Laboratori Nazionali di Frascati