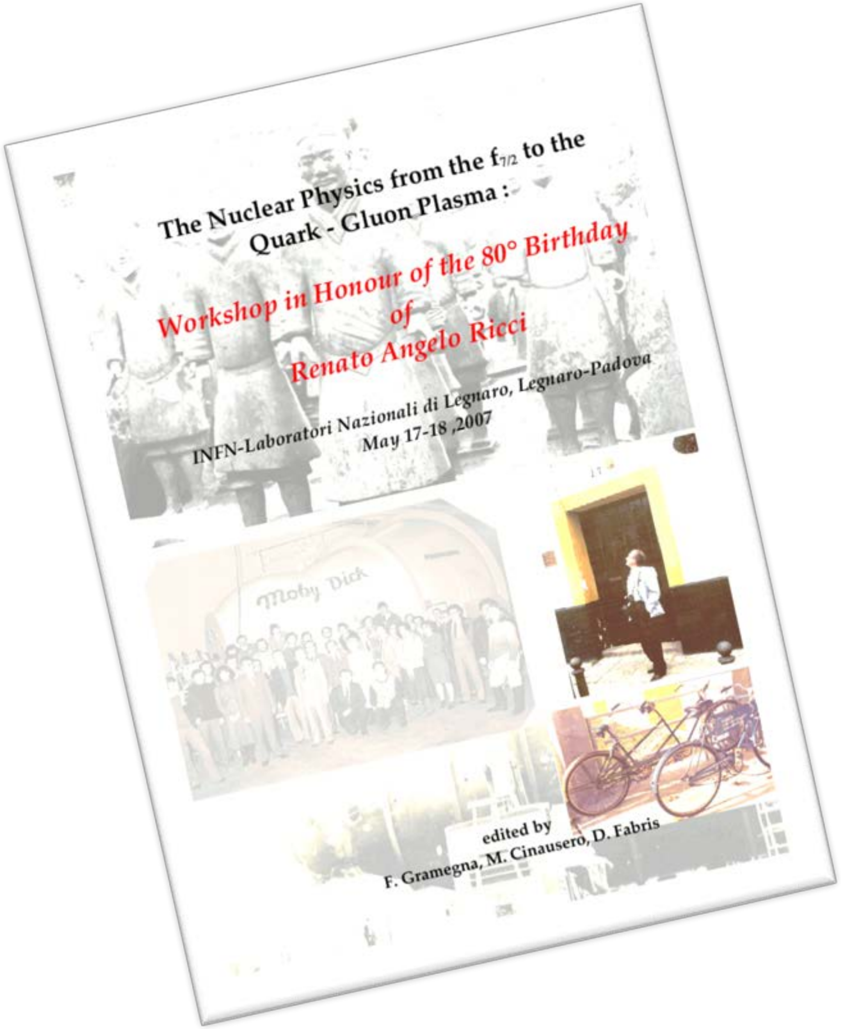
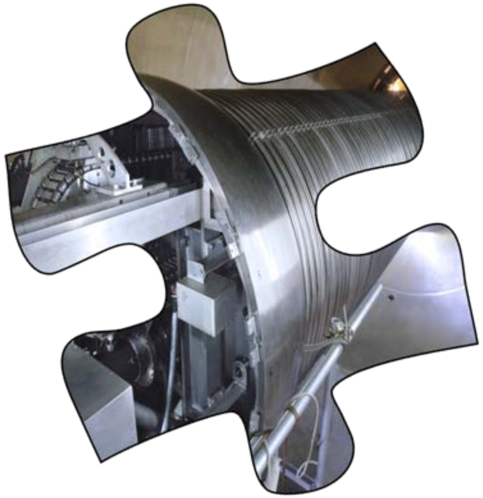
The SPES facility at LNL

T. Marchi, IKS-KU Leuven


The Nuclear Physics from the $f_{7/2}$ to the
Quark - Gluon Plasma :
Workshop in Honour of the 80° Birthday
of
Renato Angelo Ricci
INFN-Laboratori Nazionali di Legnaro, Legnaro-Padova
May 17-18 ,2007
edited by
F. Gramegna, M. Cinausero, D. Fabris



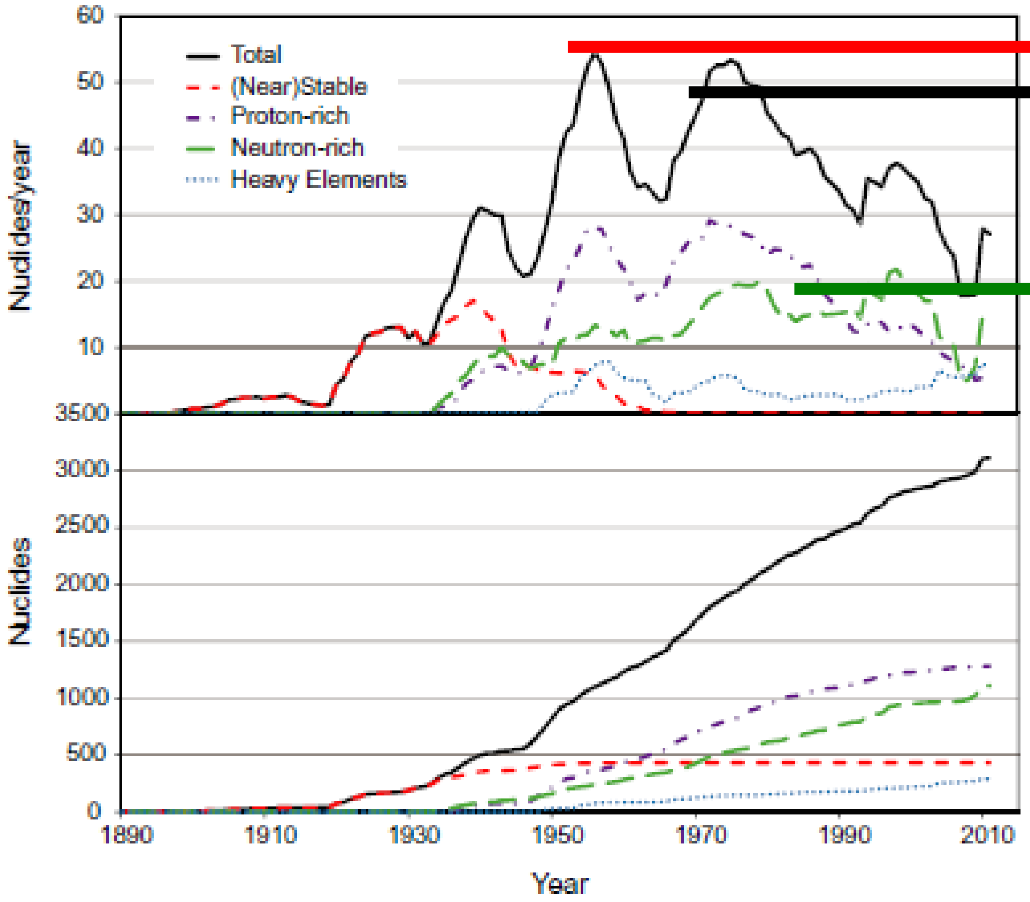
Contemporary alchemy

IOP Publishing Reports on Progress in Physics
Rep. Prog. Phys. 76 (2013) 056301 (14pp) doi:10.1088/0034-4885/76/5/05630

Current status and future potential of nuclide discoveries

M Thoennessen

Rep. Prog. Phys. 76 (2013) 056301

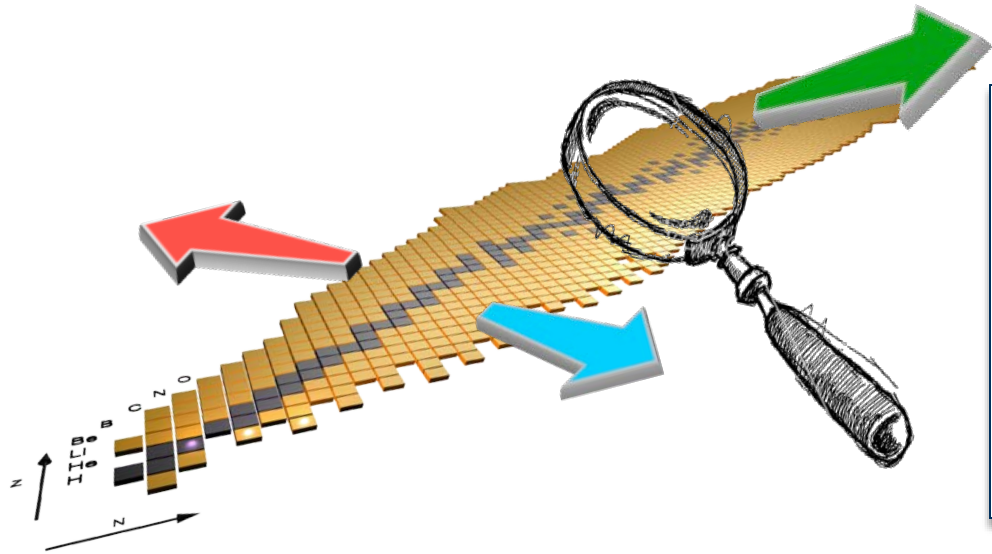


Fusion-Evaporation reactions with Heavy Ions. Increasing energy and intensities

High energy light beams: target fragmentation/fission. (ISOL)

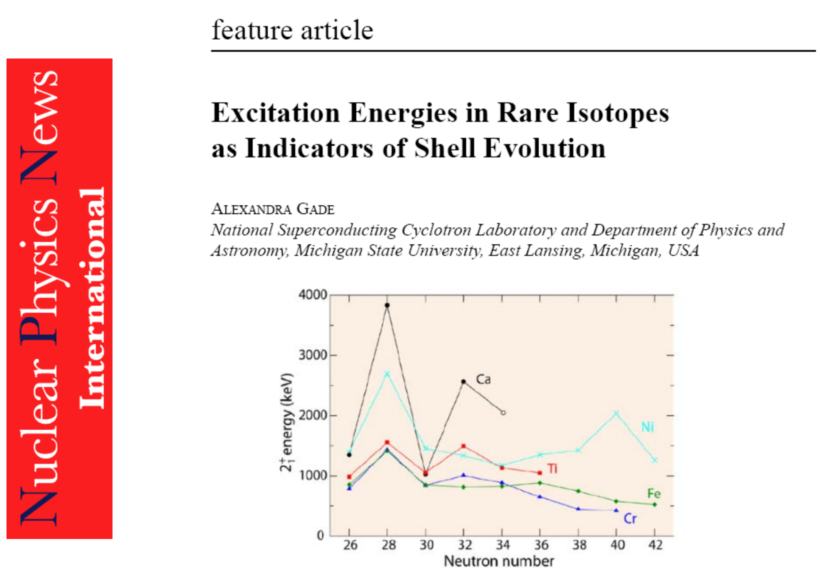
High energy heavy beams: projectile fragmentation/fission. (In-flight)

Beyond Isotopes discovery



Nuclear Physics will focus on Radioactive ion beams to:

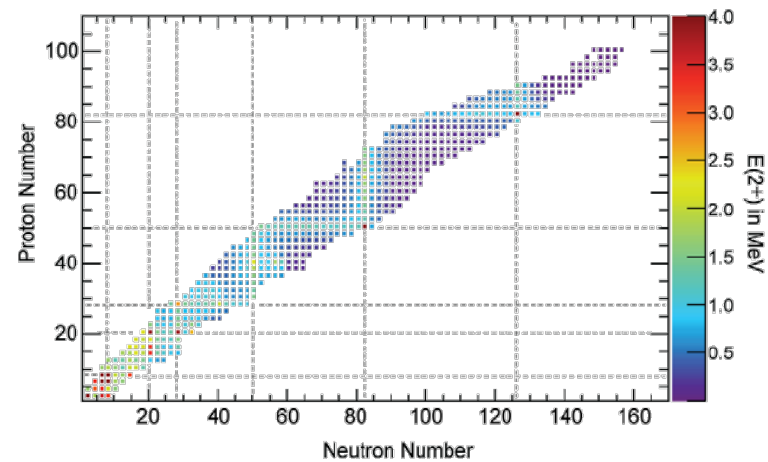
- **<u>Explore</u>** and locate the extremes of nuclear existence
- **<u>Discover</u>** exotic properties of nuclei (shapes, structure evolution)
- **<u>Explain</u>** the role of isospin in complex systems (nEOS, E_{sym})


Nuclear Physics News International

feature article

Excitation Energies in Rare Isotopes as Indicators of Shell Evolution

ALEXANDRA GADE
National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA



[A. Gade, Nucl Phys News 23-4 (2013) 10]

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Beyond Isotopes discovery – challenges

Nuclear Structure

- Shell evolution
- G.s. & E.s. properties (masses, radii, deformation, …)
- Decay properties
- Collectivity
- Ab-initio models

Reaction Dynamics

- Characterize the mechanisms that drive nuclear reactions and describe reaction dynamics
- Study the interplay between structure and reactions (e.g. clusters)

Nuclear Astrophysics and Applications

- Provide Nuclear Data (cross sections, lifetimes …)

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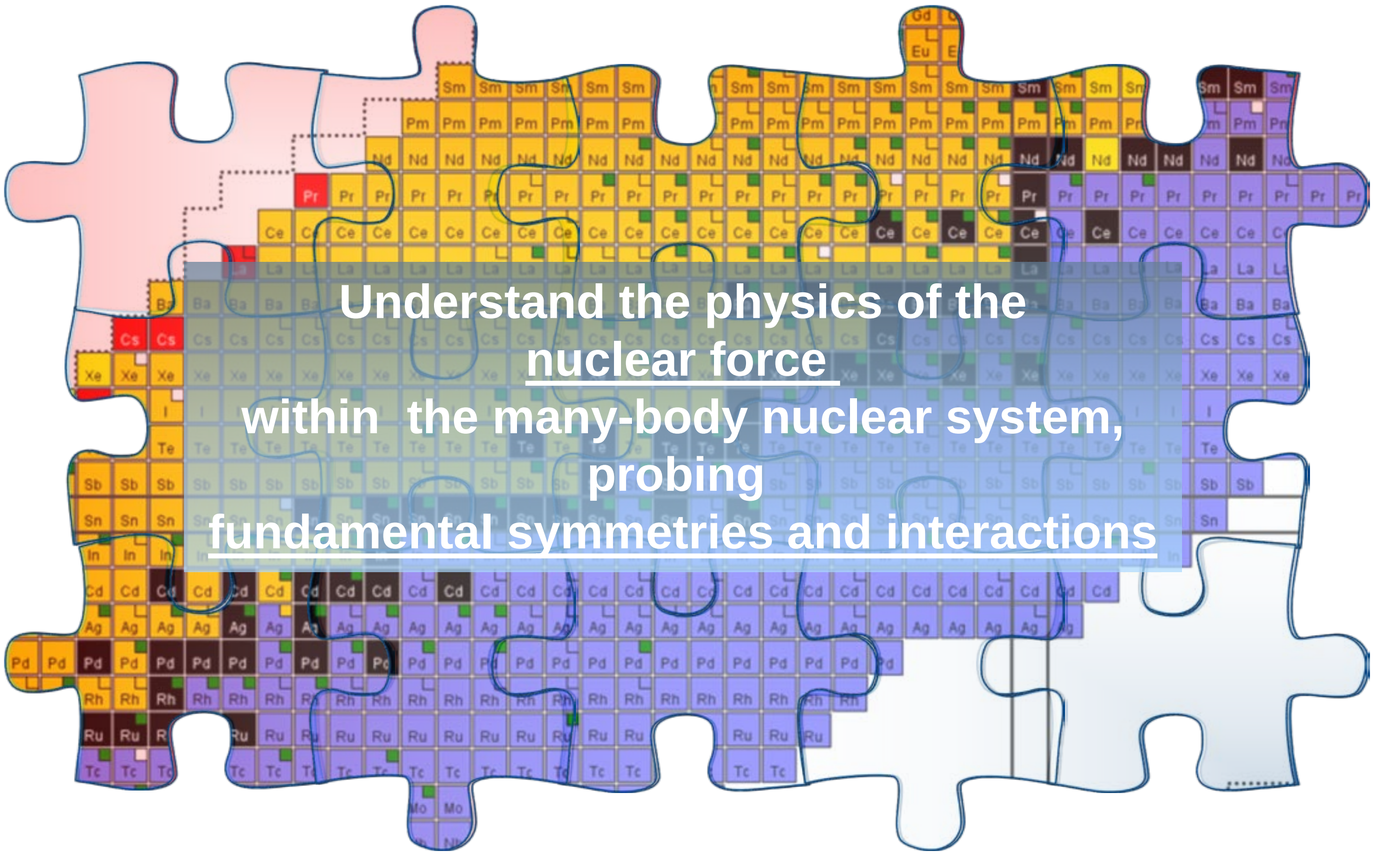
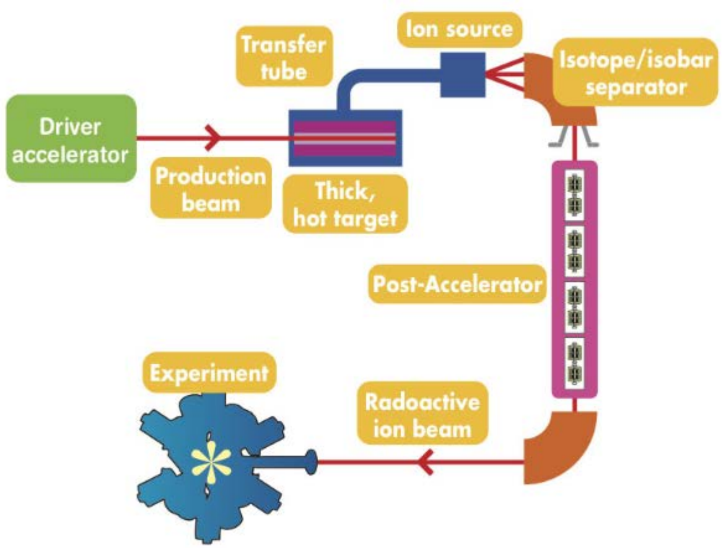
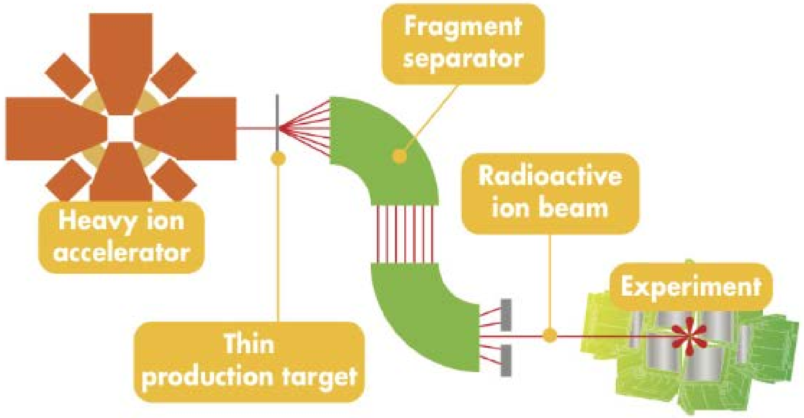
Beyond Isotopes discovery



Understand the physics of the <u>nuclear force</u> within the many-body nuclear system, probing <u>fundamental symmetries and interactions</u>

RIB production methods





ISOL

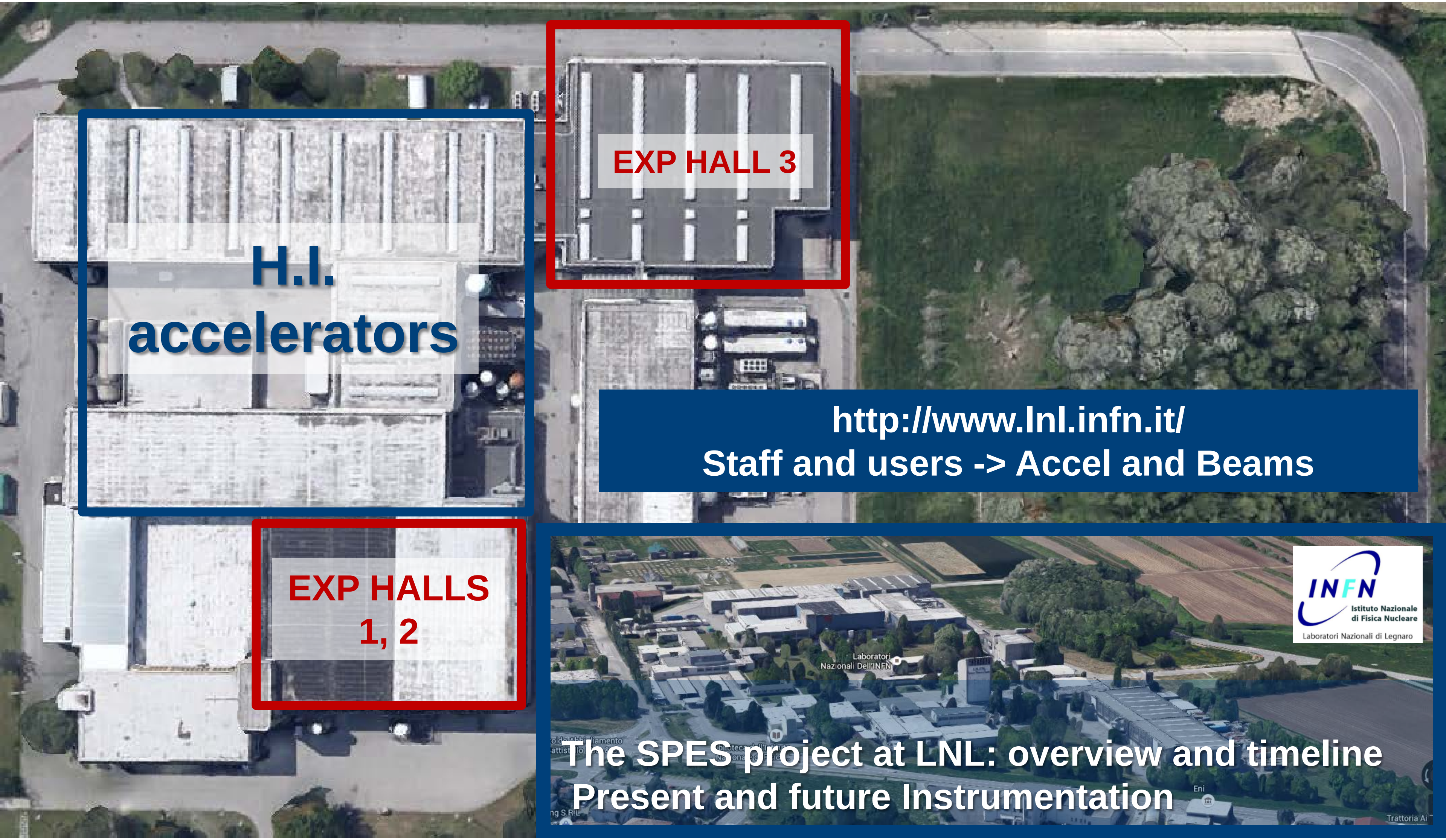
Small beam emittance
Small energy spread
Pure beams (HRS+lasers)
Slow
A lot of Chemistry involved
Needs post-acceleration

In-flight

Fast
No chemistry

Limited to high energy
Cocktail beam tagging

Operating facilities at LNL



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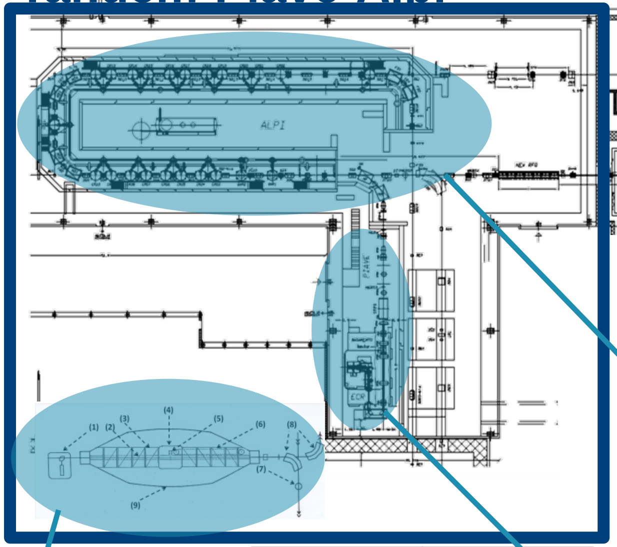
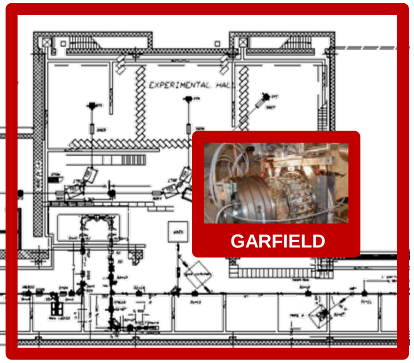
Slides mainly from F. Gramegna and G. Prete (LNL)

Operating facilities at LNL

Tandem-Piave-Alpi





ALPI

SC- LINAC

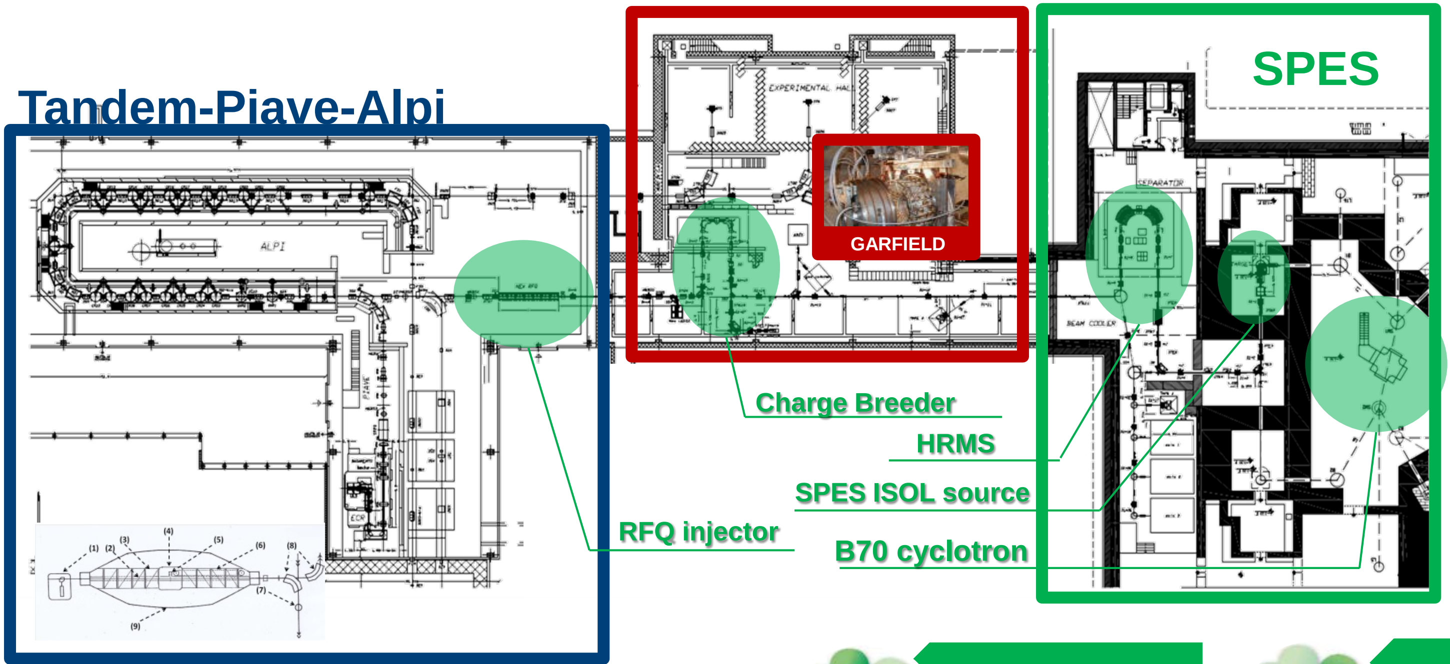
PIAVE

ECR Ion source + RFQ injector

TANDEM-XTU

14 MV - Tandem

The SPES project at LNL



Cyclotron

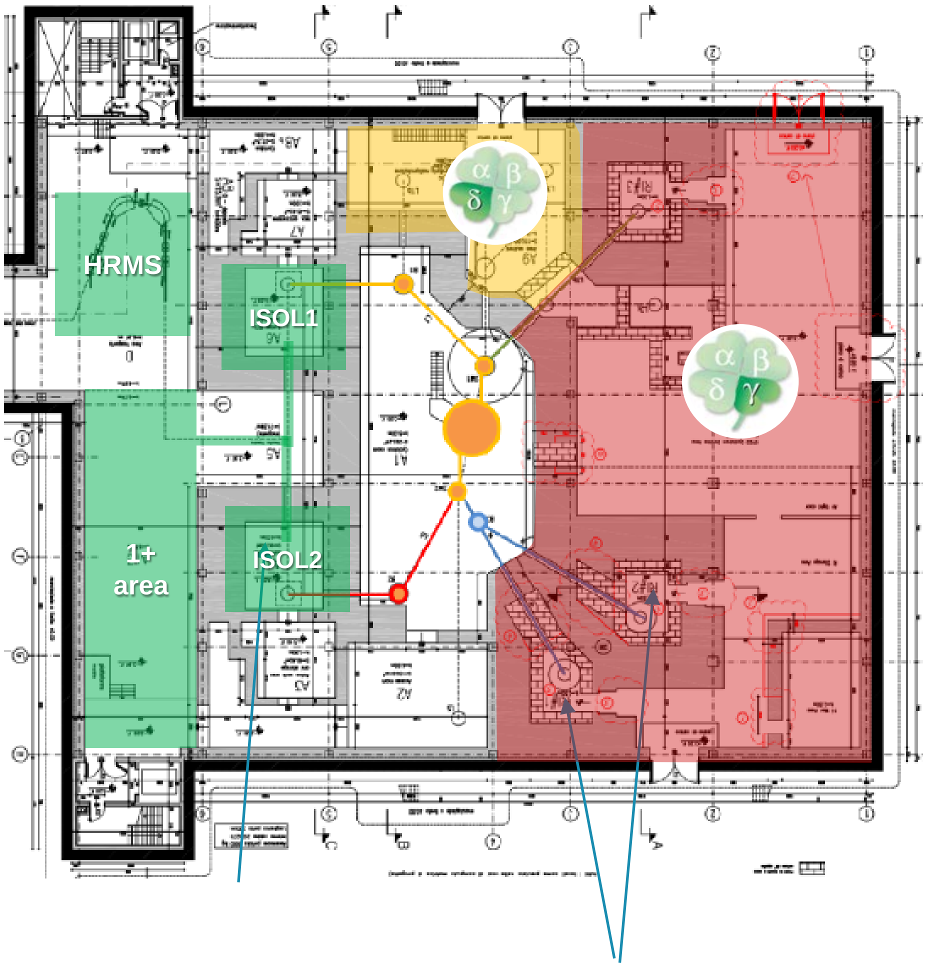
ISOL RIBs+ Post-Acc.

Nuclear Medicine

Nuclear Applications

SPES infrastructure - layout

SPES infrastructure - layout



The weight of science

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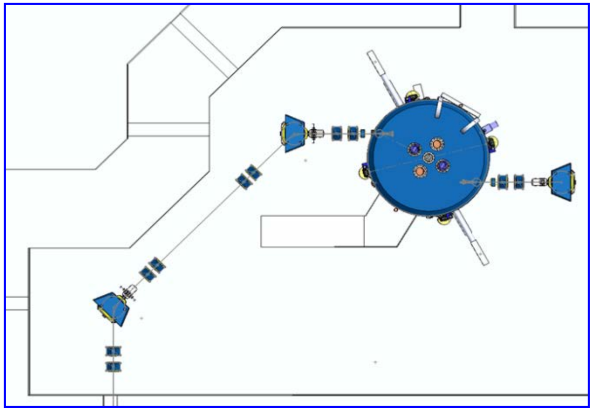
SPES core: α

Cyclotron installed at LNL

BEST B70
- H^-
- 35-70 MeV
- 0.750 mA
- 2 exits

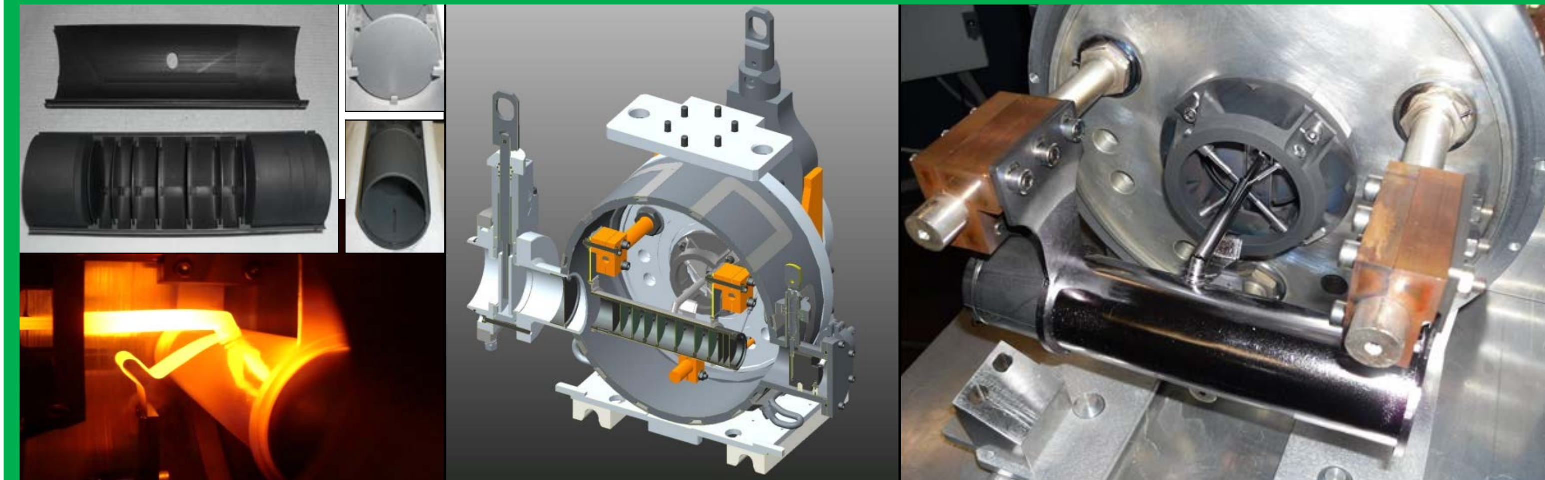
Main Parameters	
Accelerator Type	Cyclotron AVF 4 sectors
Particle	**Protons (H^- accelerated)**
Energy	**Variable within 30-70 MeV**
Max Current Accelerated	**750 µA** (52 kW max beam power)
Available Beams	**2 beams at the same energy** (upgrade to different energies)
Max Magnetic Field	1.6 Tesla
RF frequency	56 MHz, 4th harmonic mode
Ion Source	Multicusp H^- I=15 mA, Axial Injection
Dimensions	Φ=4.5 m, h=1.5 m
Weight	150 tons

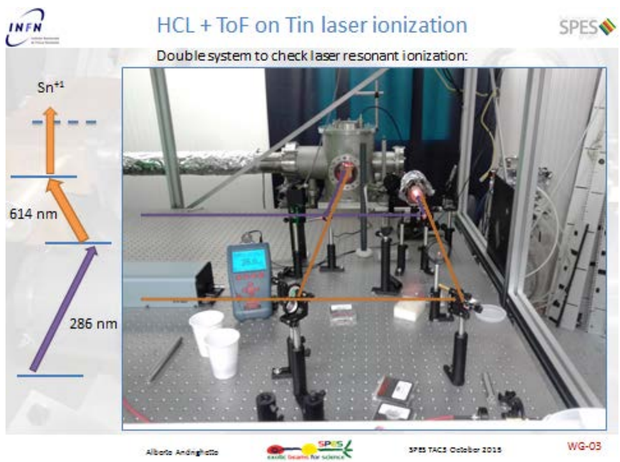


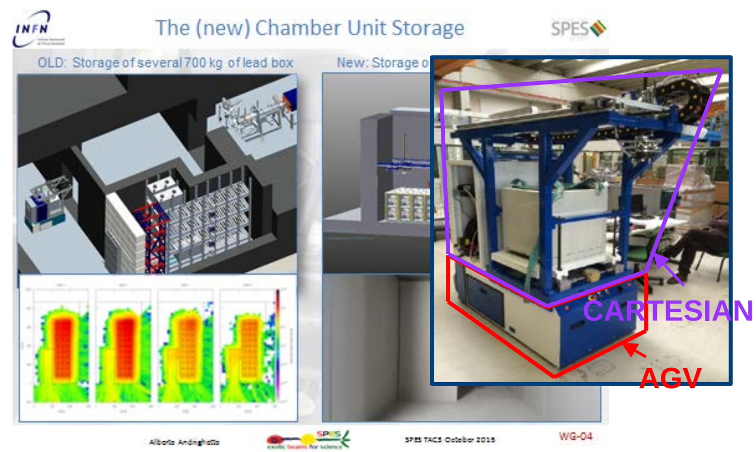
SAT and commissioning close to completion (2017)

SPES core: β

SPES ISOL Target:
UCx, SiC,...
10^{13} fiss./s
T ~ 2000°C
3 sources SIS, LIS, PIS
~ 8 kW power







Beam test at iThemba lab. (2014): 66MeV protons, 60 μA on full scale SiC prototype at 1600 °C (FEM sim. Validation)
Former beam tests: ORNL (2007, 2010-2011) SiC, Ucx; ISOLDE(2009) UCx, IPNO (2013) UCx.
Front End and Target System: advanced nuclearization phase.
Target handling systems, <u>Heat resistance tests</u>, Nuclear Safety.

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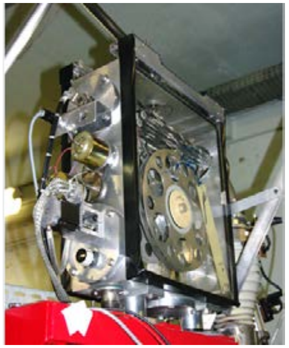
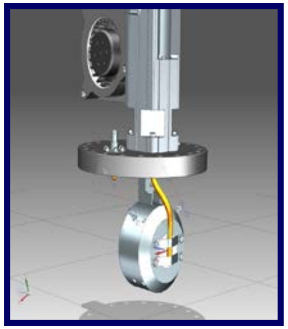
Low energy beams and beam diagnostic

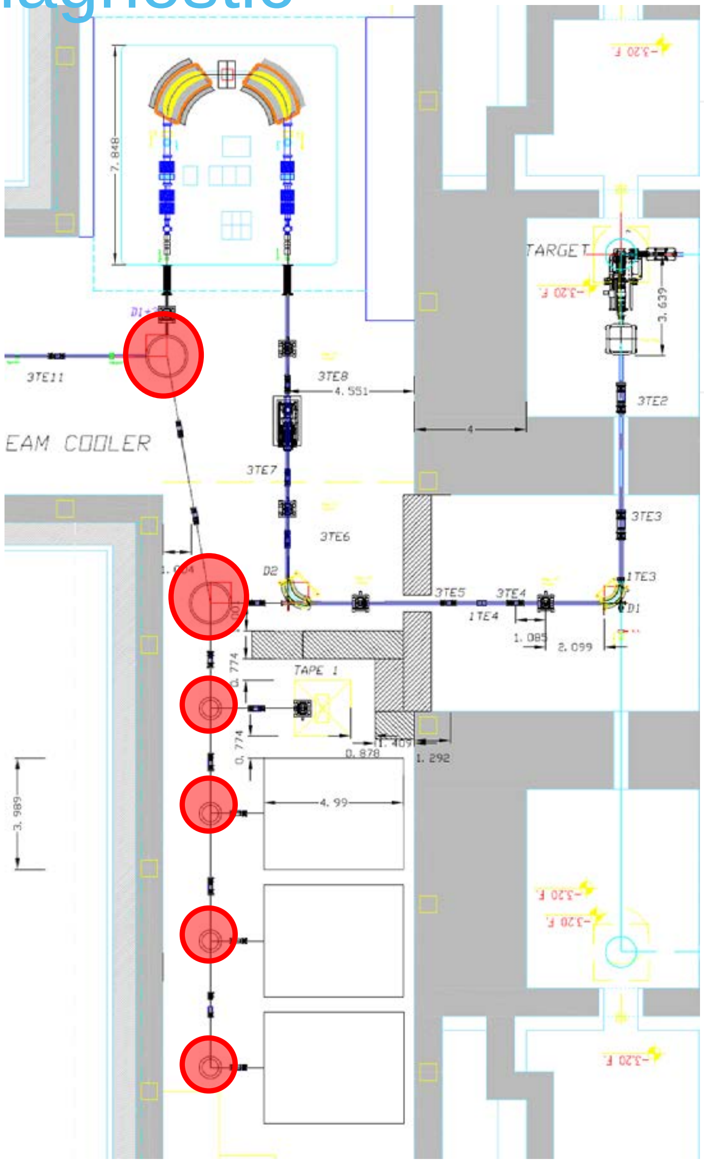
Tape station for beam characterization



Low intensity beam monitors

MCP & grid beam monitor





Electrostatic dipoles

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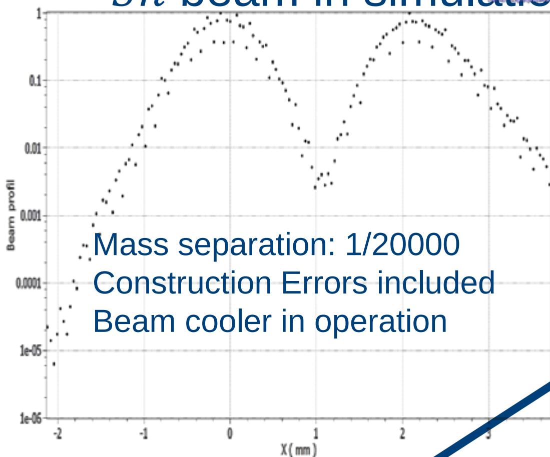
HRMS

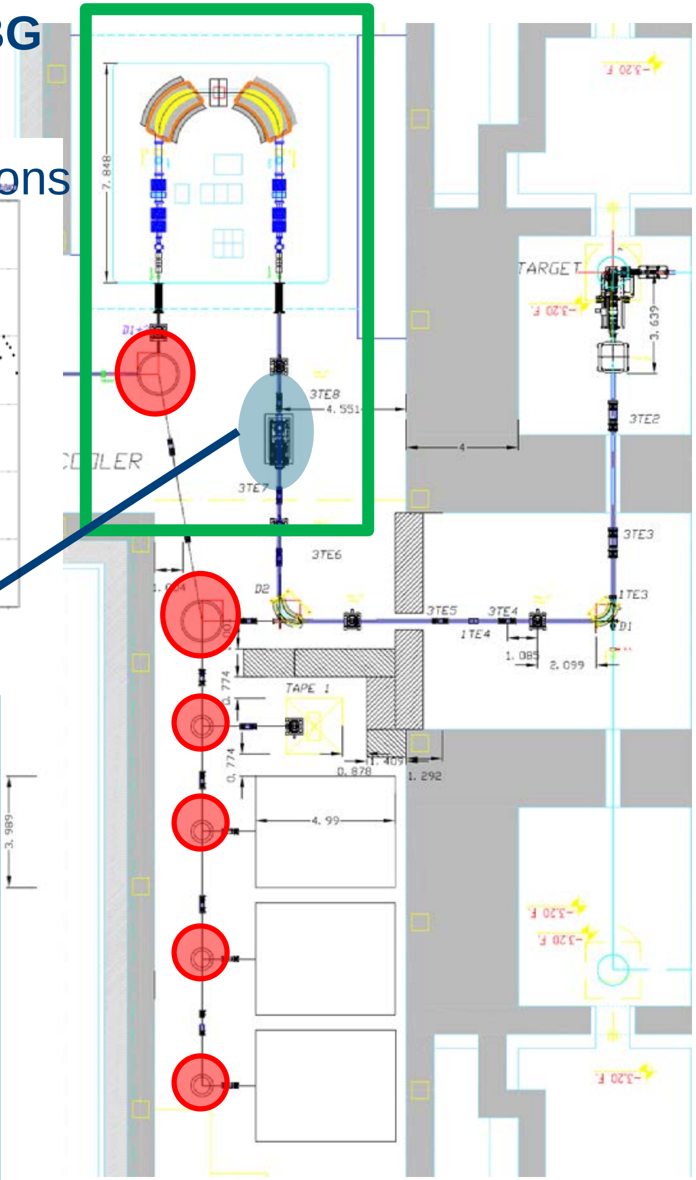
Collaboration: LNS, LNL, CENBG
Physics design: 1/40000

Type	Max range
Misalignment (x,y) (*no effect on R*)	0.5 mm
Tilt (xy,yz,xz)	0.1°
Field error	0.05%
All errors	0.25 mm, 0.05°, 0.025%

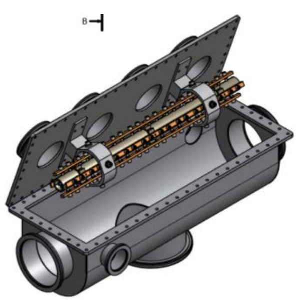
^{132}Sn beam in simulations

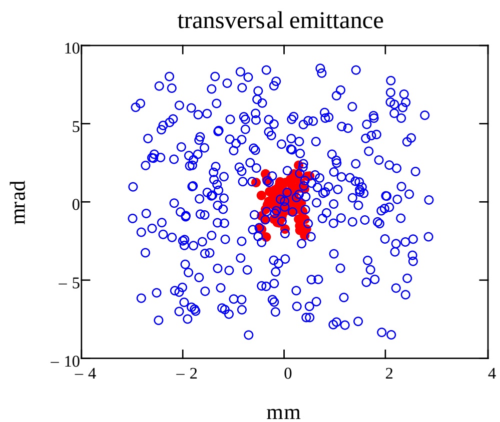


Mass separation: 1/20000
Construction Errors included
Beam cooler in operation



COOLBEAM experiment financed by INFN-CSN5, 2012→2015 -Collaboration: LNL-LNS-Mi





Input T emittance
Output T emittance

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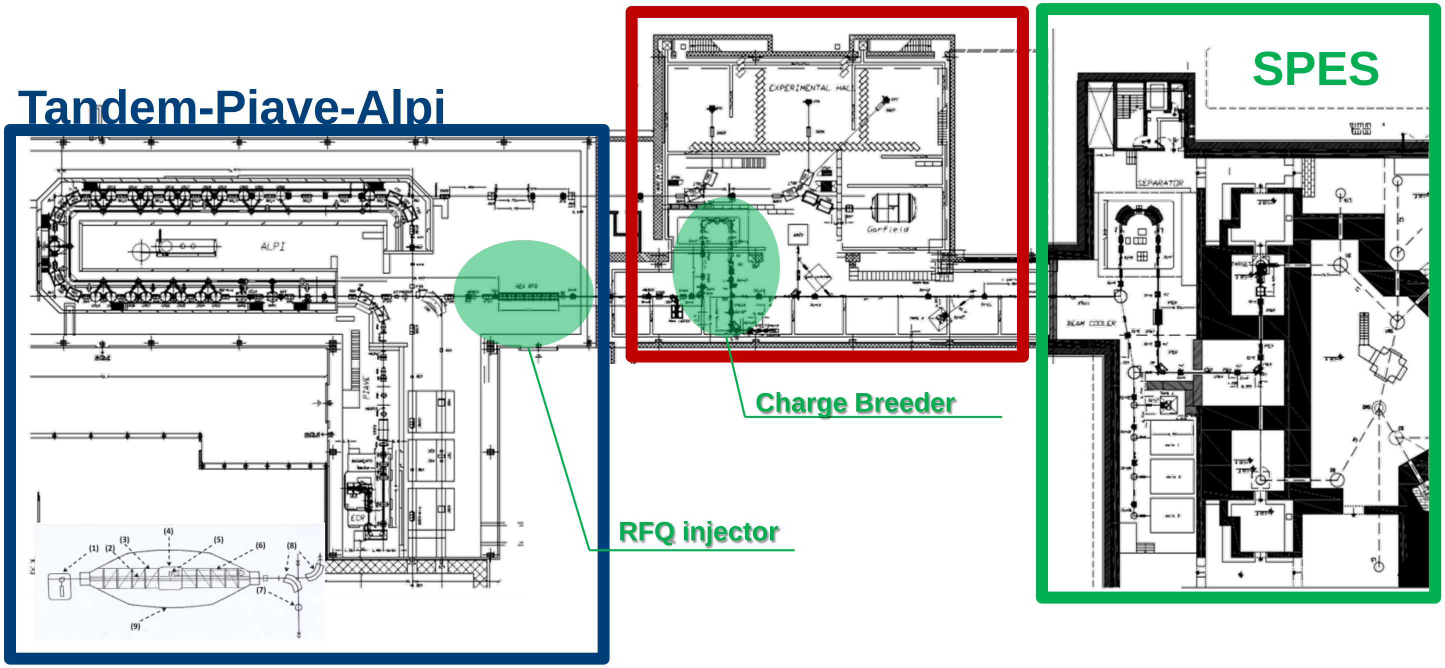
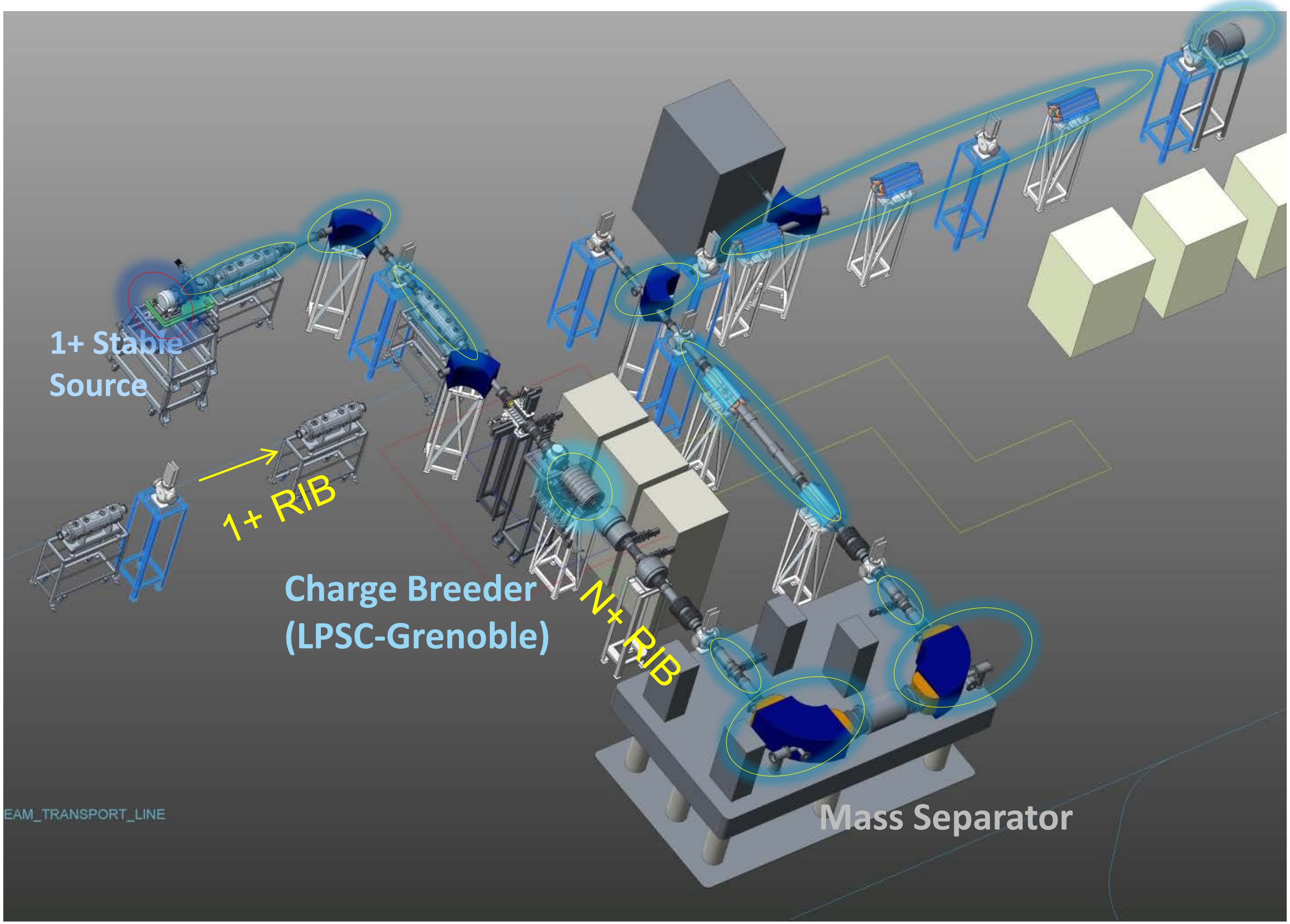
Reacceleration



Towards ALPI: Charge breeder + MRMS + RFQ



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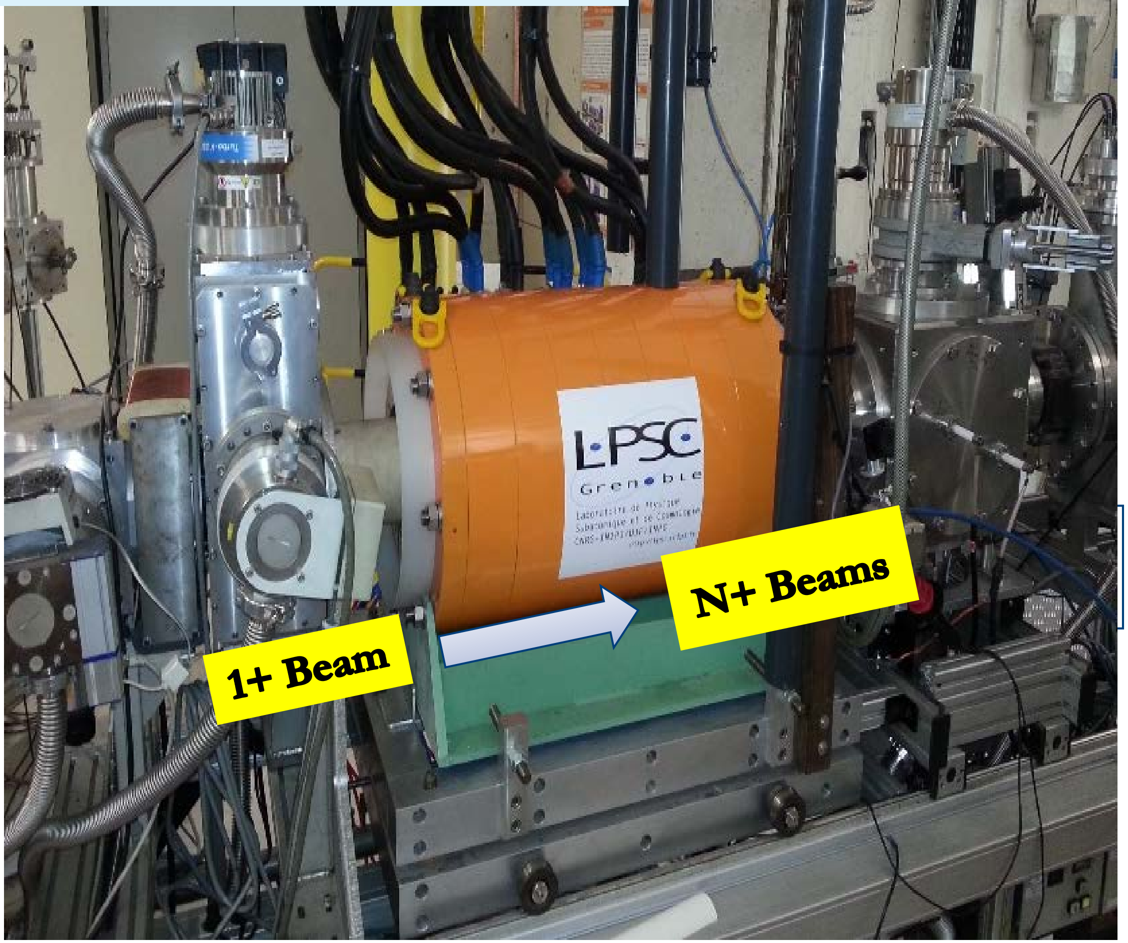
Towards ALPI: Charge breeder + MRMS + RFQ

LPSC-Grenoble April 4th, 2015



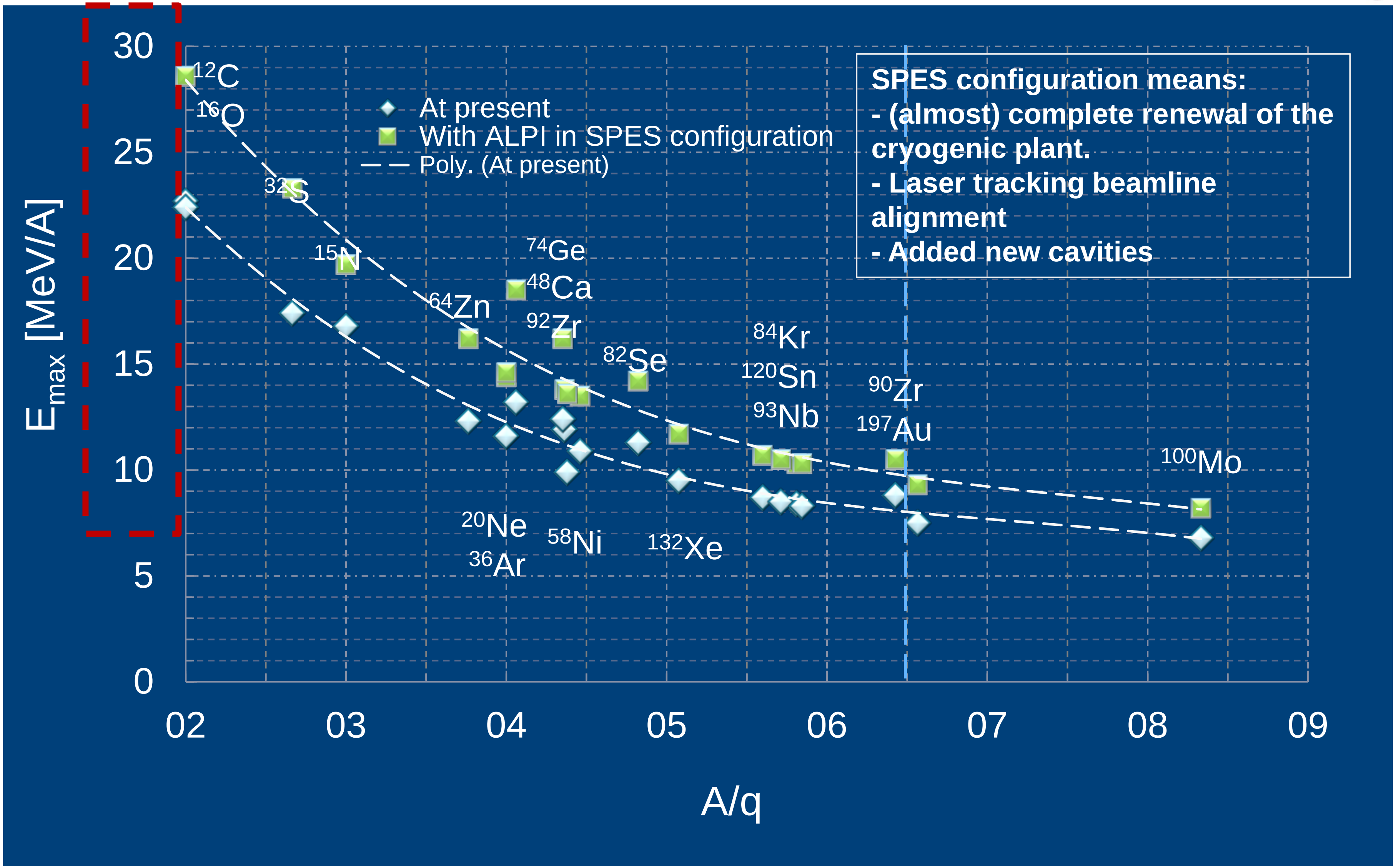
Development at LPSC (Grenoble) of an Upgraded PHOENIX booster as Part of a MoU in the frame of the European Associated Laboratories (LEA-Colliga)

- 2010 Preliminary measurements
- 2011 Conceptual design
- 2012 Design
- 2013 Agreement definition
- 2014 Construction
- 2015 Commissioning at LPSC
- 2015 Delivery to LNL
- 2016 Installation and test

		EFFICIENCY* [%]		
ION	Q	SPES req	Best LPSC	SPES-CB
Cs	26	≥ 5	8,6	11,7
Xe	20	≥ 10	10,9	11,2
Rb	19	≥ 5	6,5	7,8
Ar	8	≥ 10	16,2	15,2

*results obtained for the same 1+ injected current

Reacceleration using ALPI



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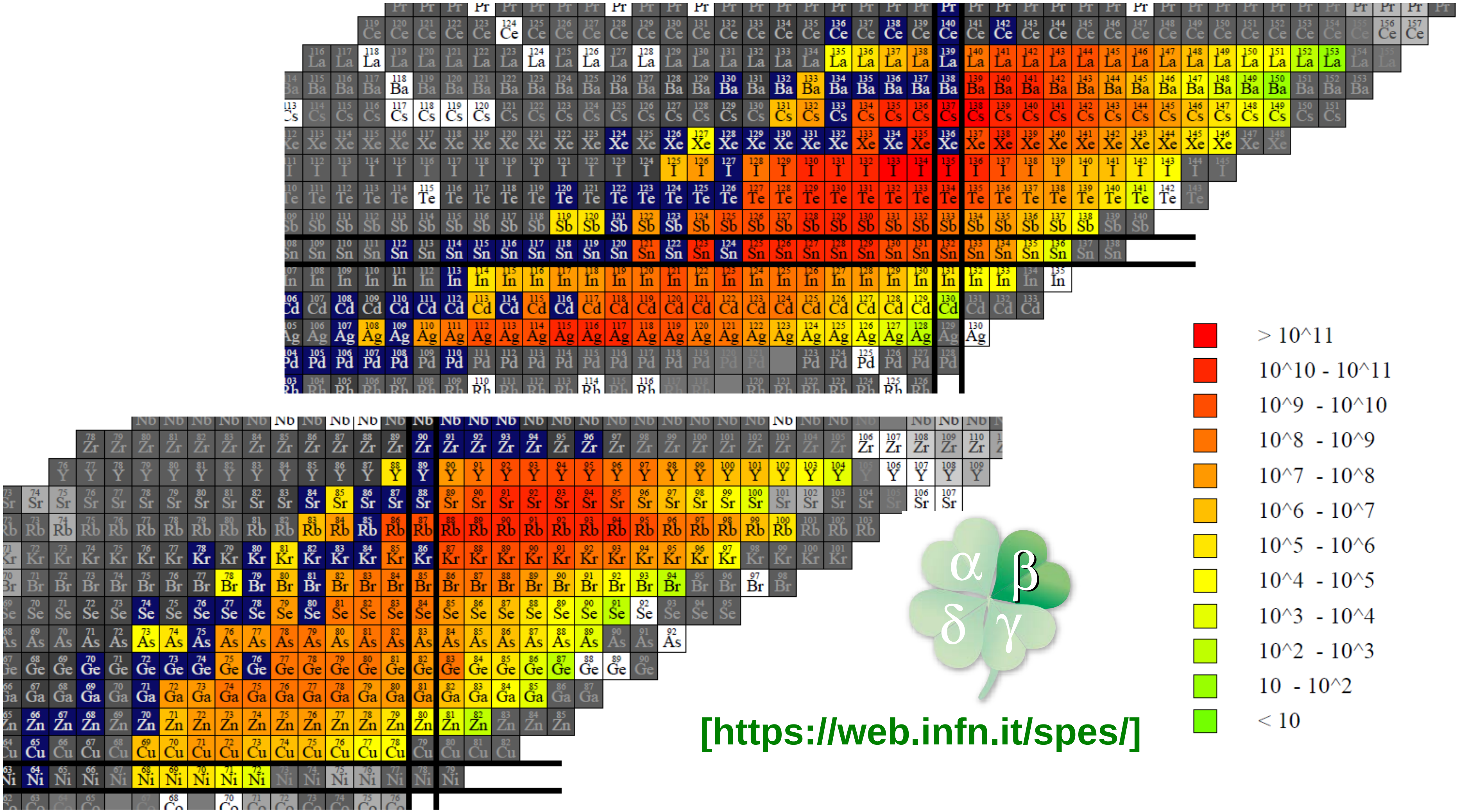
SPES BEAMS (ReA)



[https://web.infn.it/spes/]

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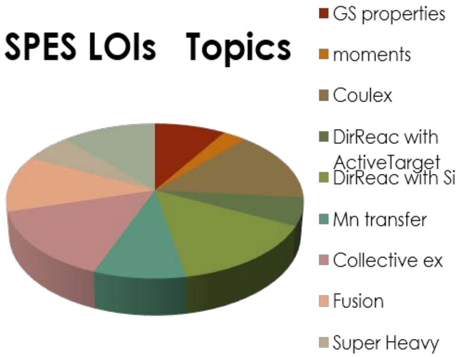
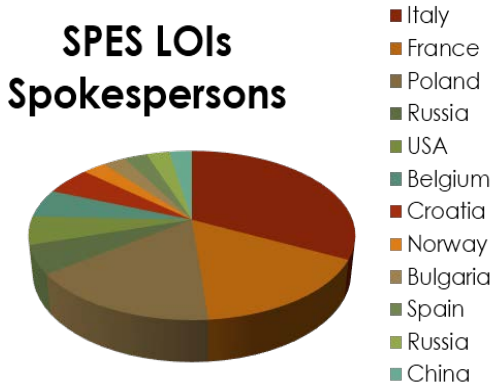
Physics at SPES

Third International SPES Workshop

10-12 October 2016 *INFN Laboratori Nazionali di Legnaro*
Europe/Rome timezone





The **SAC was impressed** with the **number of LOI's** and the **broad scientific spectrum** proposed to be studied with the SPES Radioactive Ion Beams (RIB). The SAC **appreciates the progress of the SPES project**

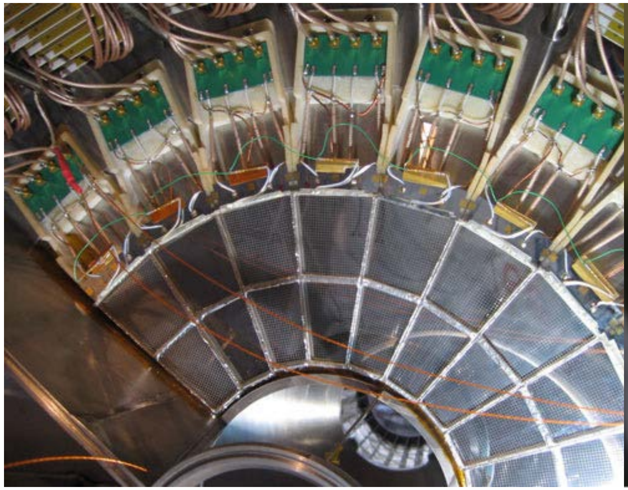
One Day Workshops

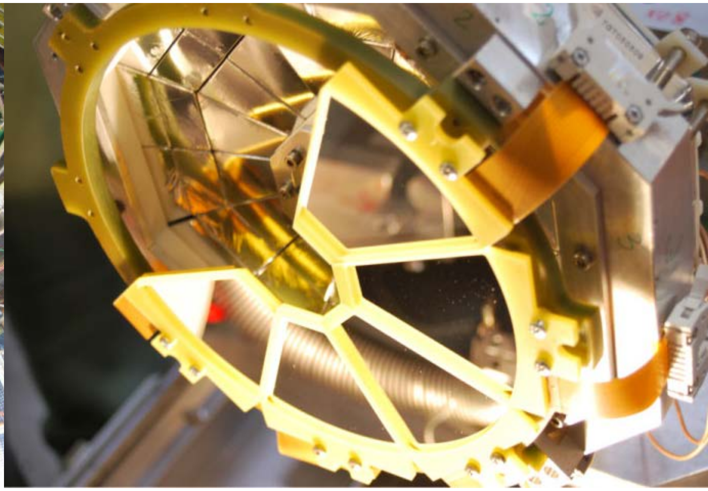
Napoli (2012): Transfer Reactions
Firenze (2012): Coulomb Excitation
Catania (2013): Isospin in Reaction Mechanisms with RIBs
Milano (2013): Collective Excitations of Exotic Nuclei
Legnaro (2014): Fusion-evaporation Reactions with RIBs
Milano (2015): Physics at SPES with non re-accelerated beams
Caserta (2015): Nuclear Astrophysics at SPES

Detector’s portfolio: resident setups I

PRISMA
Large acceptance
magnetic spectrometer
$\Omega \approx 80$ msr;
$B\rho_{max} = 1.2$ Tm
$\Delta A/A \sim 1/200$
Energy acceptance ~ ±20%

GARFIELD
Charged particle array
1-192 MSGC - CsI(Tl) telescopes
(30°-150°)
2-Rco IC-Si-CsI (5°-18°)



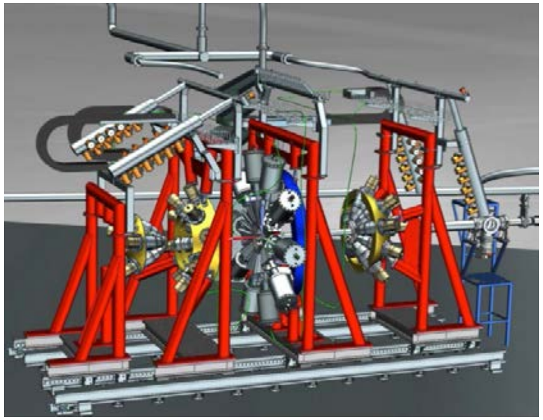


Detector's portfolio: resident setups II

GALILEO

Phase 1:
25 HPGe + 25 BGO + ancillaries
240 ch digital electronics (AGATA)

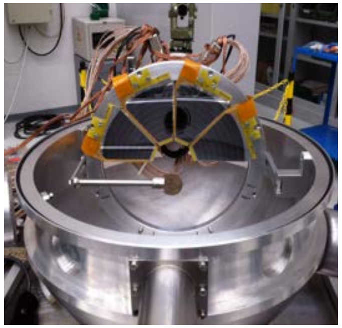
Phase 2:
30 HPGe + 30 BGO + 10 TC



- Light charged particle detectors
  EUCLIDES, SPIDER, TRACE
- Neutron detector
  N–Wall
- Lifetime measurements
  Plunger from Cologne
- Recoil detectors
  RFD
- Fast timing High–energy gamma–rays detector
  LaBr3 detectors

Study of weak reaction channels stable beams

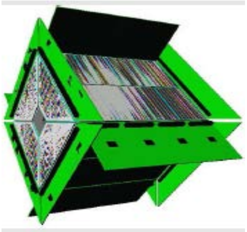
- High efficiency
- High resolving power

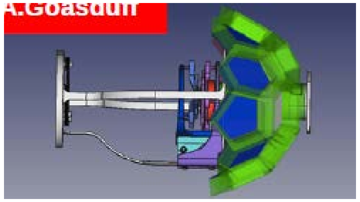


Commissioned dets

Commissioning phase

To be commissioned





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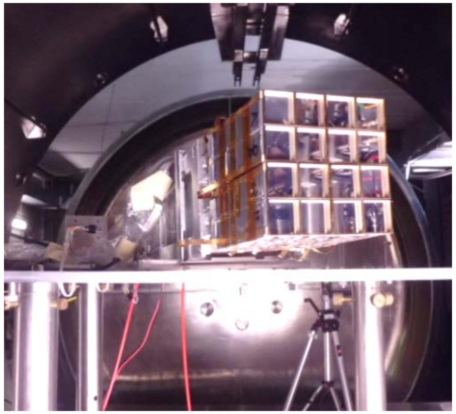
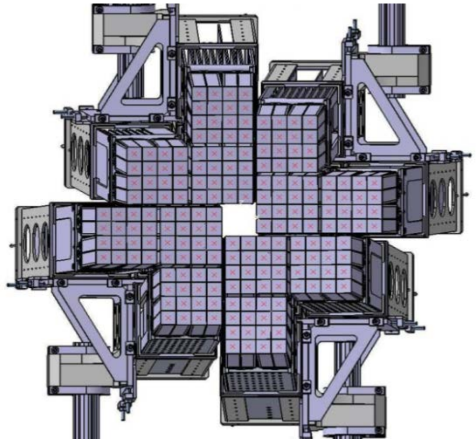
Courtesy of D. Mengoni

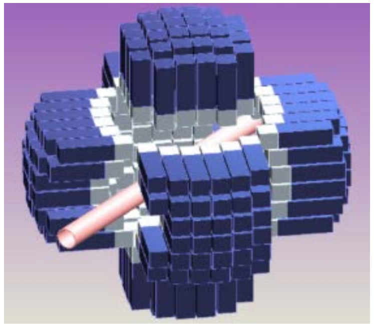
Detector’s portfolio: “traveling” setups

FAZIA: **LCP & fragments detection**

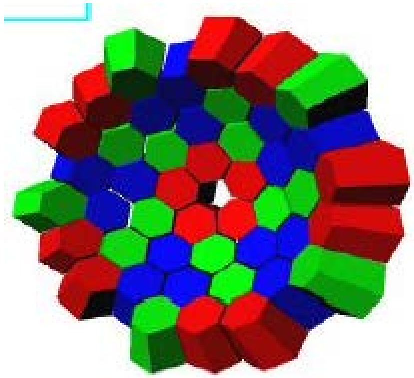




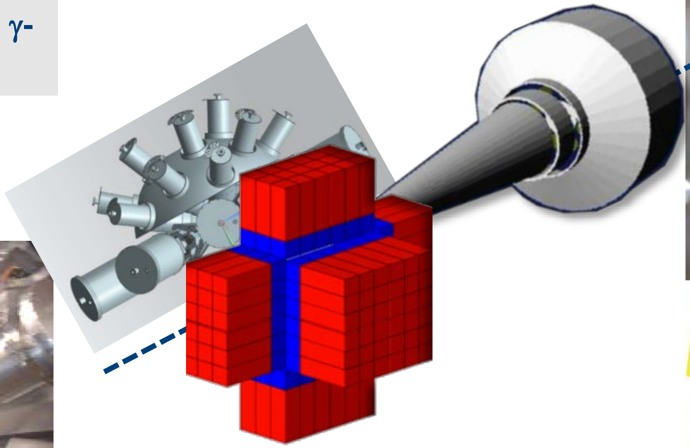
PARIS **(High Energy γ-ray Detector Array)**

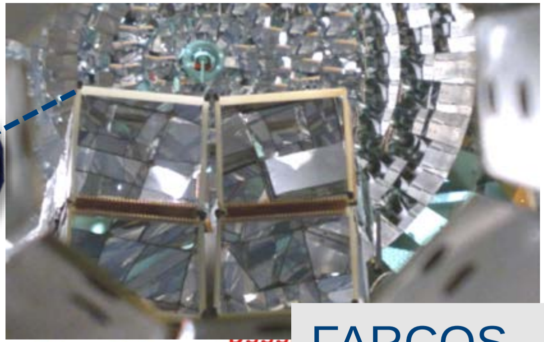


NEDA **(NEutron Detector Array)**

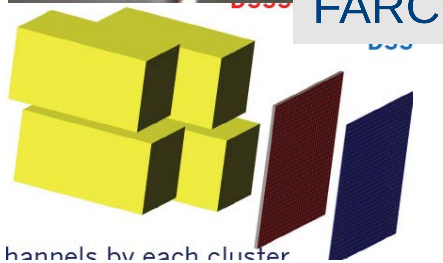


AGATA : **innovative γ-rays tracking array**)

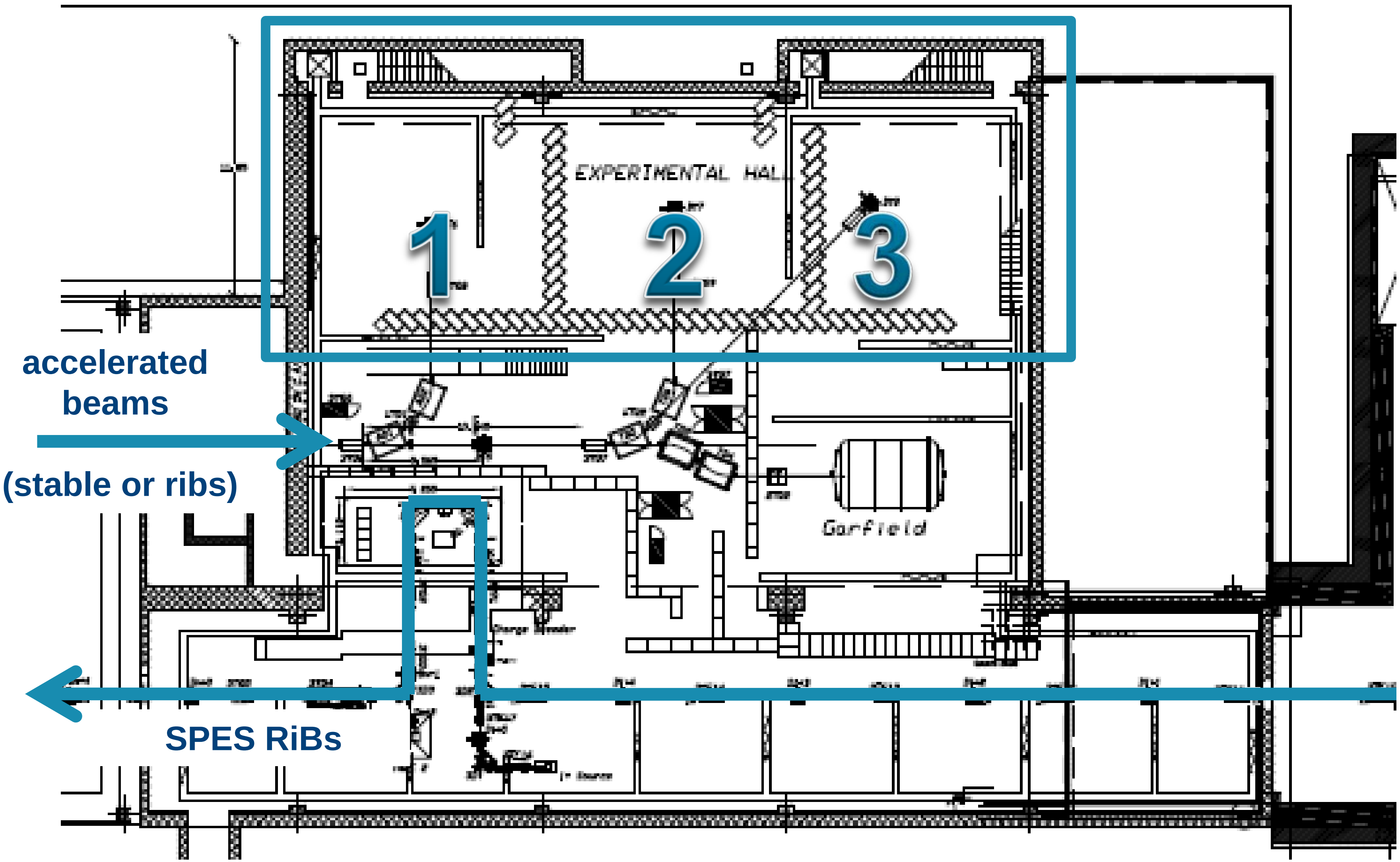




FARCOS



Free room for your favorite detector



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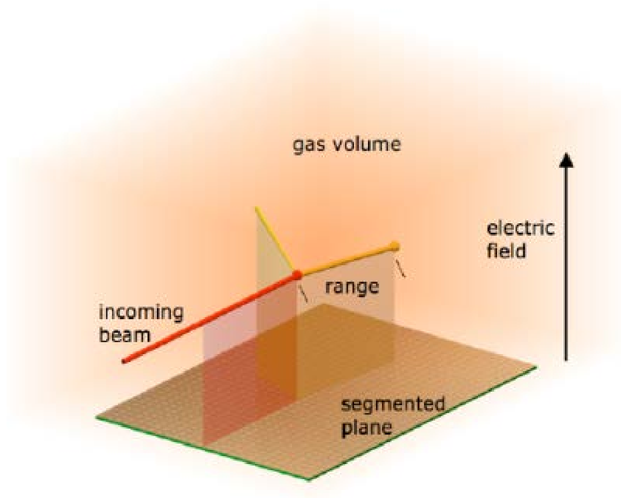
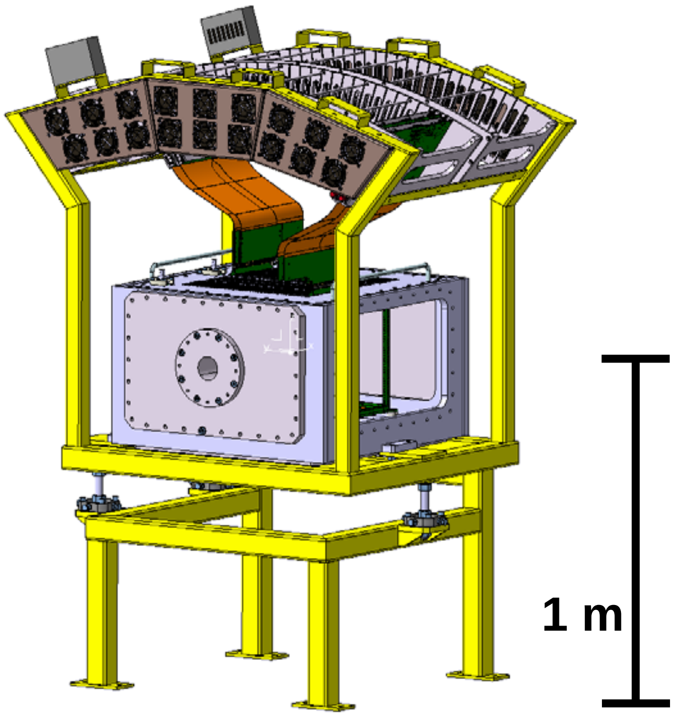
Active Target For SPES

In synergy with:
1. **ACTAR TPC**
2. **SpecMAT**

European Research Council
Established by the European Commission





Work of P. Gangnant

Two letters of intent for SPES endorsed by the SAC:
B. Fernandez Dominguez et al, Direct Reactions with exotic nuclei in the r-process using an active target
R. Raabe, T. Marchi et al, Shell Structure in the vicinity of ^{132}Sn with an active target

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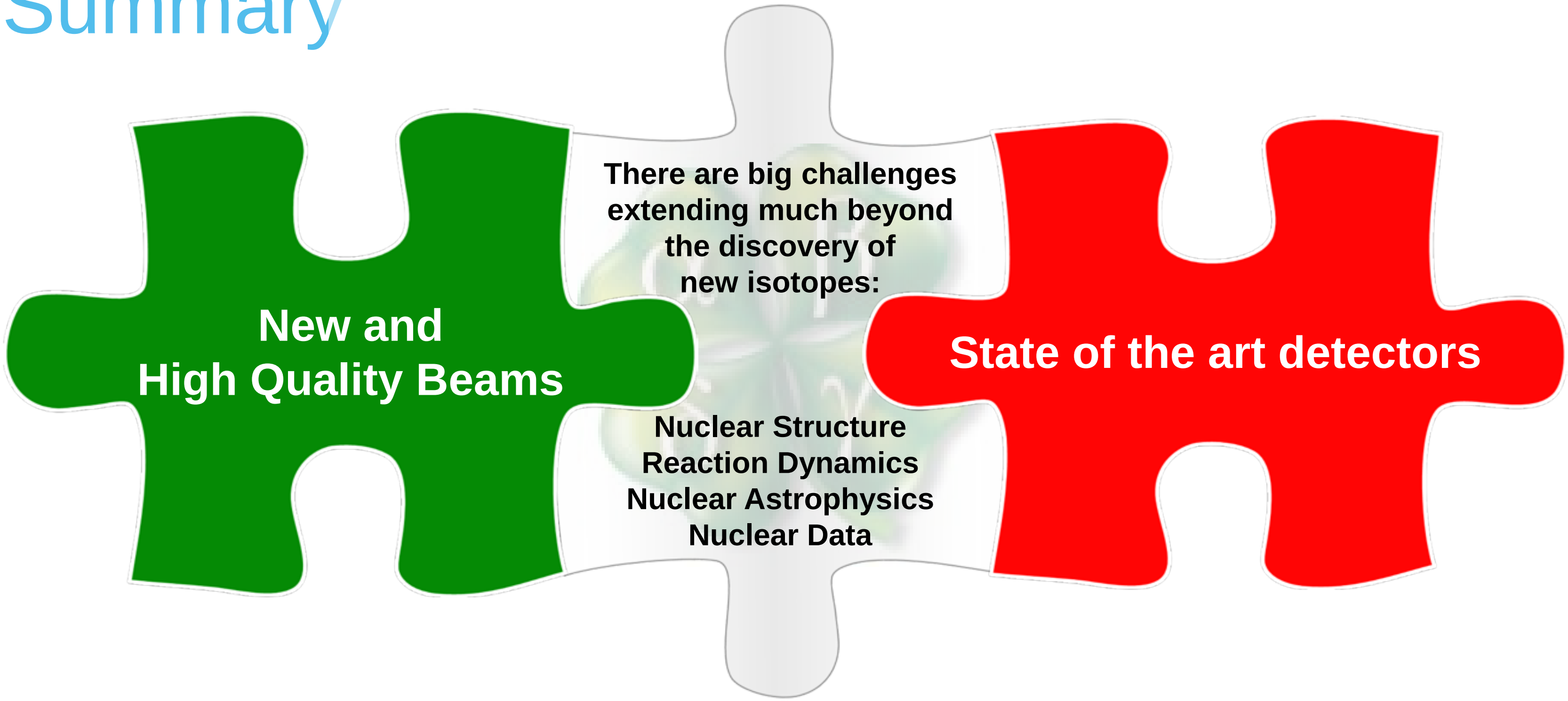
Summary



With a lesson to learn from the past about:

- ✓ People
- ✓ Competences
- ✓ Cohesion
- ✓ Enthusiasm
- ✓ Engagement

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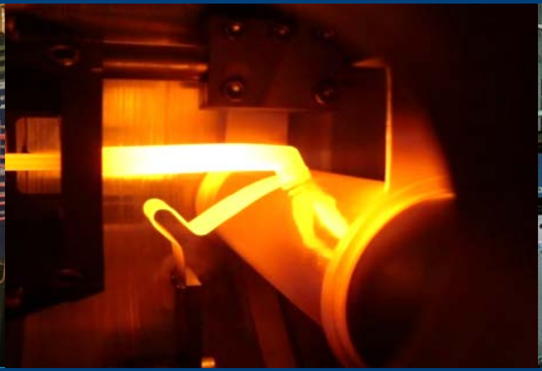
“E’ bene che i fisici ritornino a investigare serenamente le proprietà nucleari, con puro spirito scientifico: dalla più completa conoscenza delle cose non mancheranno di scaturire le più fruttuose applicazioni”.

A. Rostagni (1950)

Enjoying it,
a lot!



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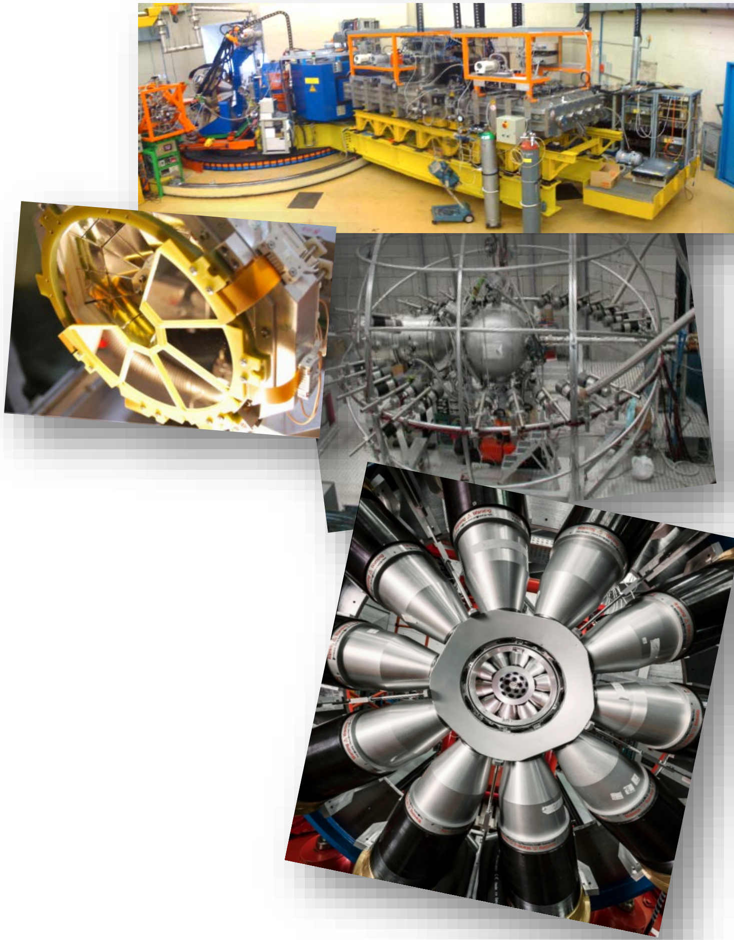
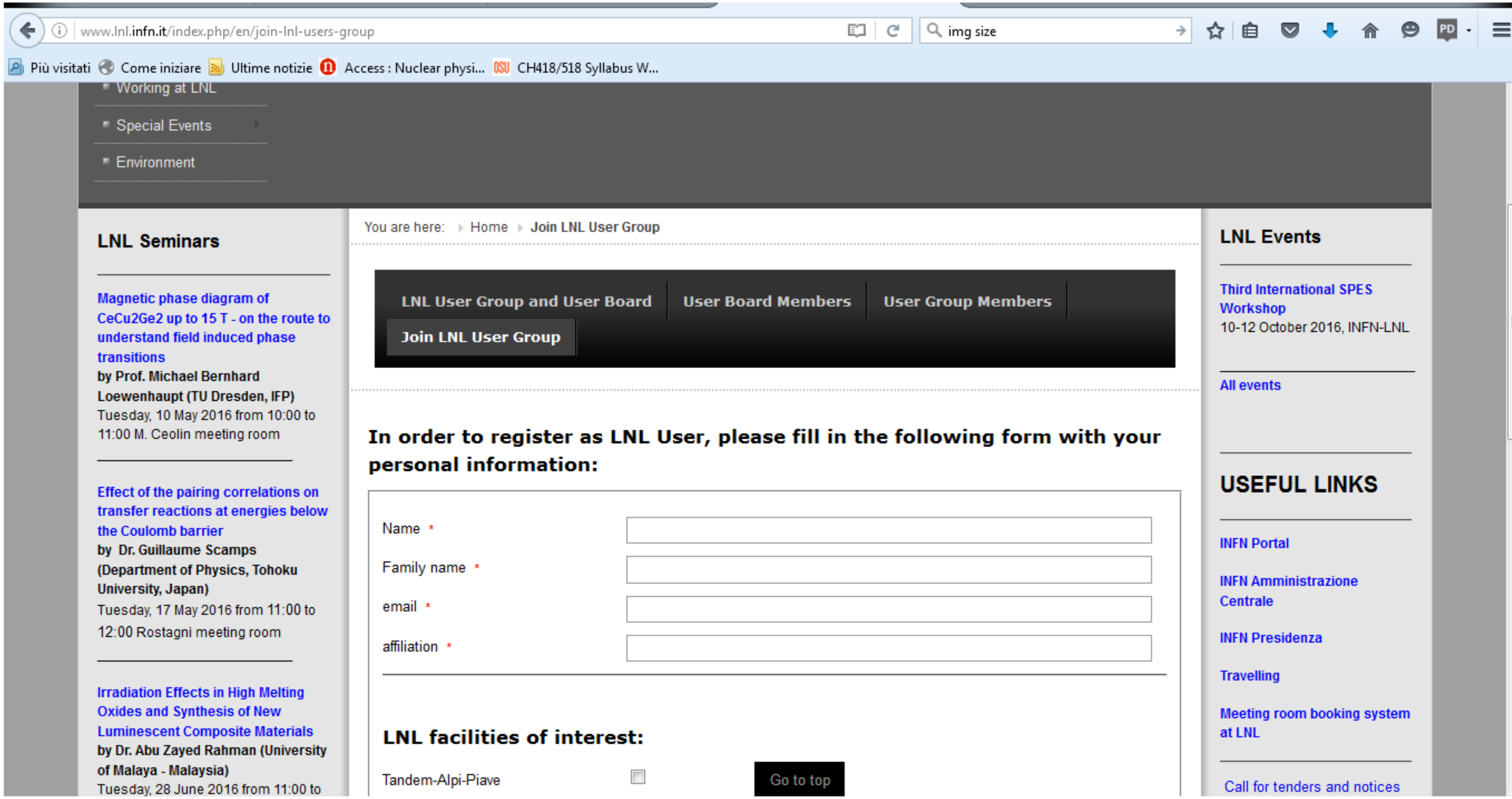
Summary



[https://agenda.infn.it/conferenceDisplay.py?confId=10539]

Join LNL User Group



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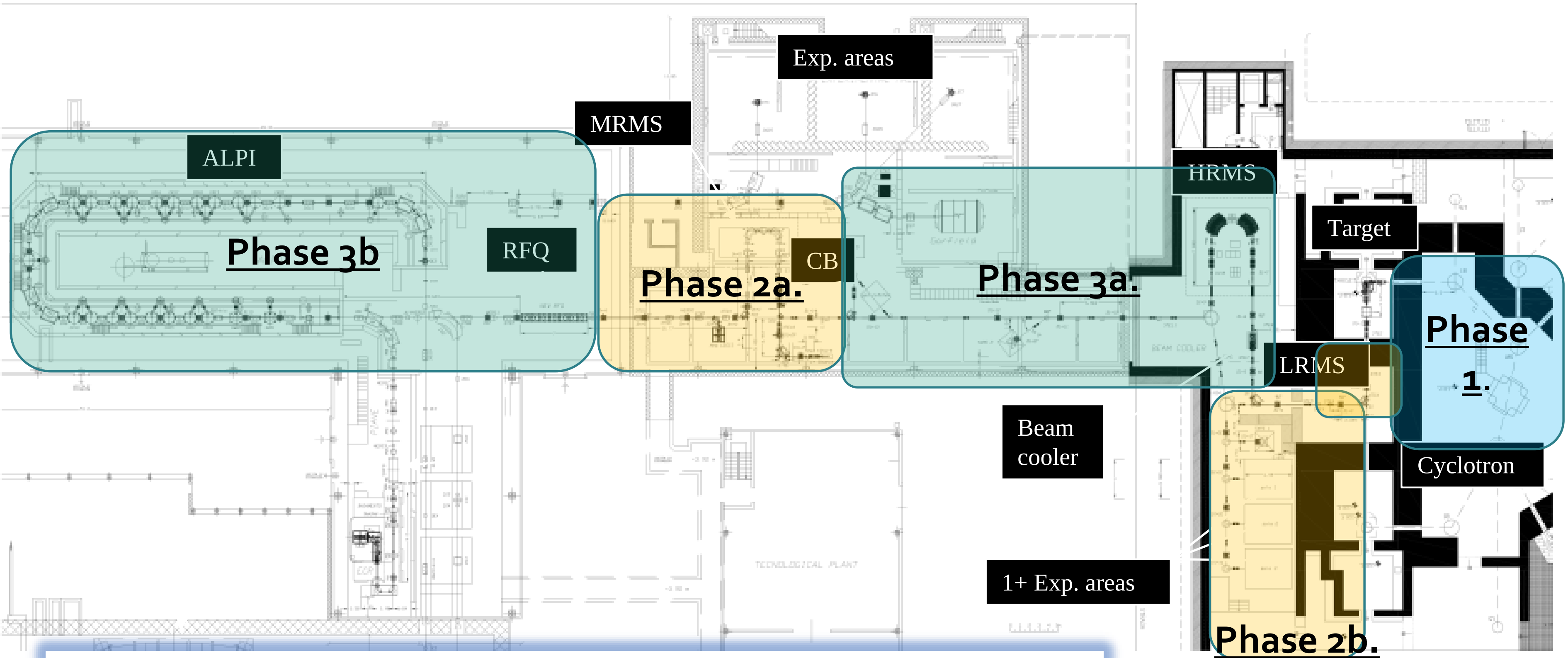
SPES Project Phases and Timeline



- Phase 1. 2016- Cyclotron operation
- Phase 2a. 2017- RNB ALPI Injector
- Phase 2b. 2018- SPES target, LRMS, experimental 1+ Beam Lines
- Phase 3a. 2019- HRMS and beam line to CB
- Phase 3b. 2019- RFQ and ALPI