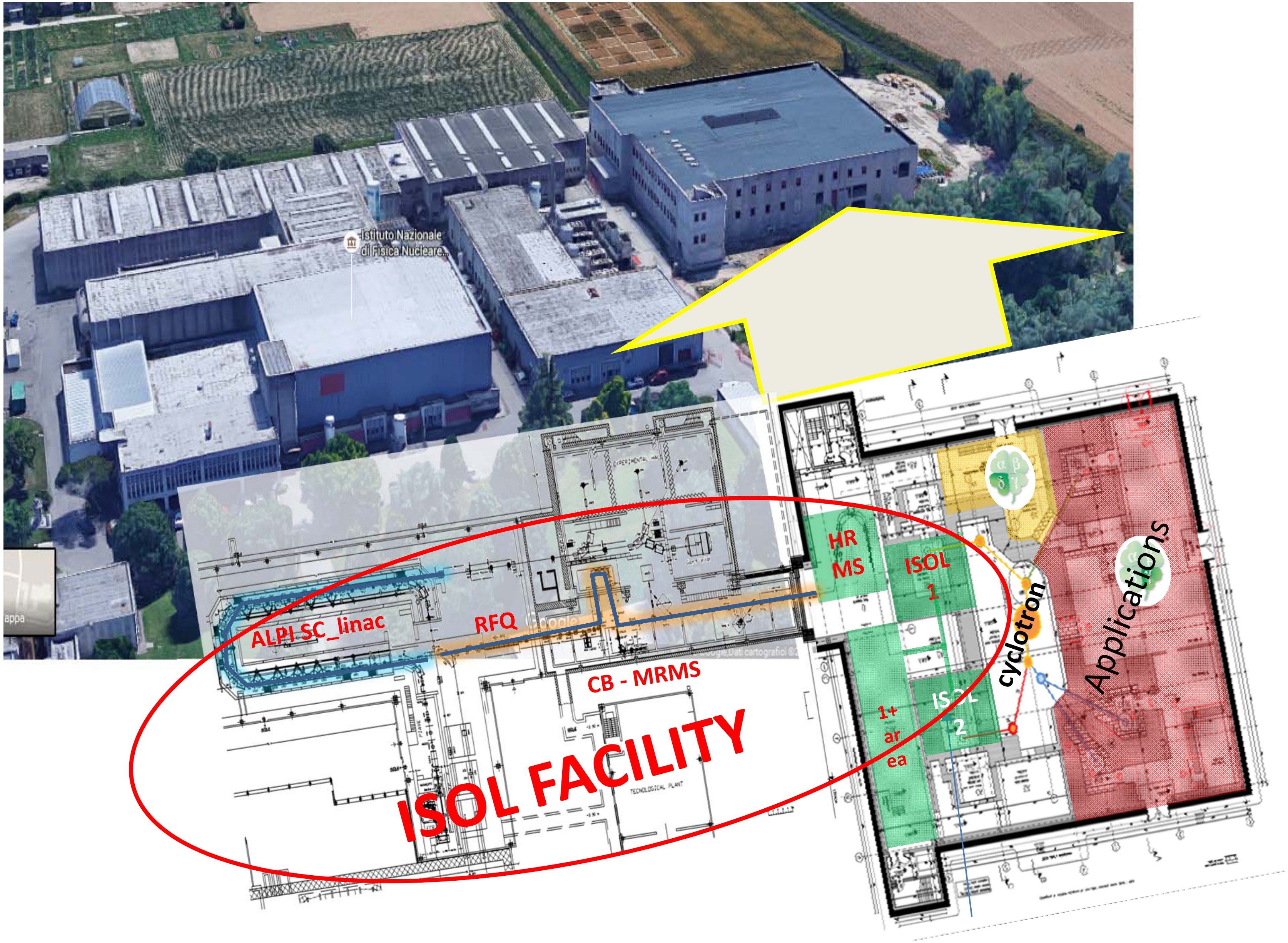
Status of the SPES project

Selective Production of Exotic Species

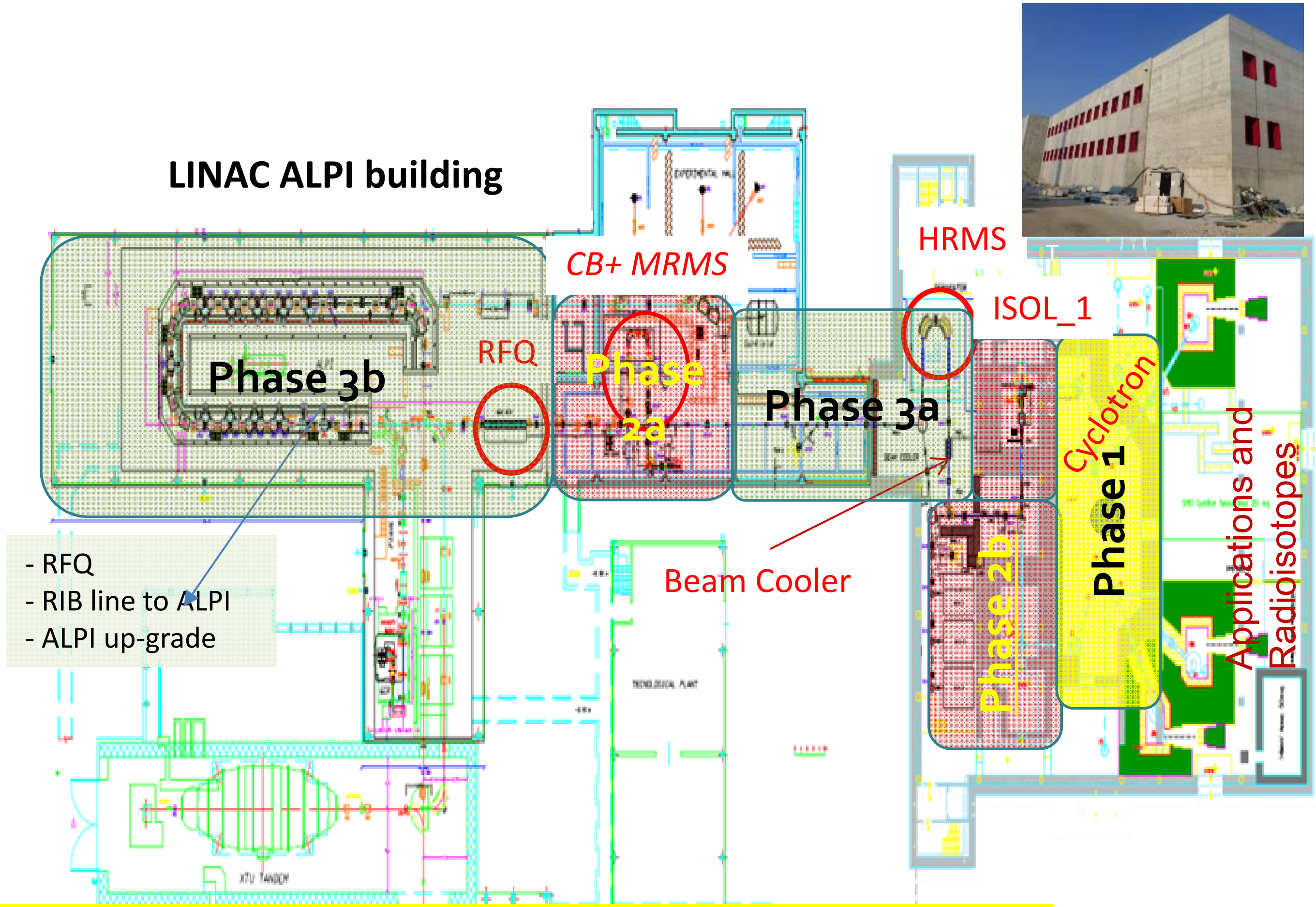
Gianfranco Prete LNL-INFN
On behalf of the SPES Collaboration

GDS Topical Meeting: GDS coupling to auxiliary detection systems
25-27 January 2017
INFN Laboratori Nazionali di Legnaro

SPES infrastructure - layout



SPES layout: ISOL facility installation phases



- **Phase 1. 2016** - Building + First operation with the cyclotron NOW!
- **Phase 2. 2017-18** - From C.B. to RFQ + SPES target, LRMS, 1+ Beam Lines
- **Phase 3. 2019 – 20 -** HRMS-BeamCooler + RFQ to ALPI

2019: phase2b
no-reaccelerated
radioactive beams

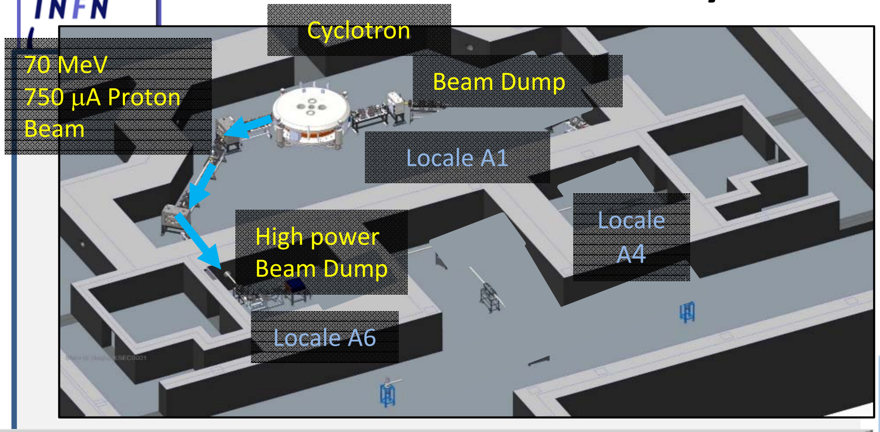
The SPES cyclotron

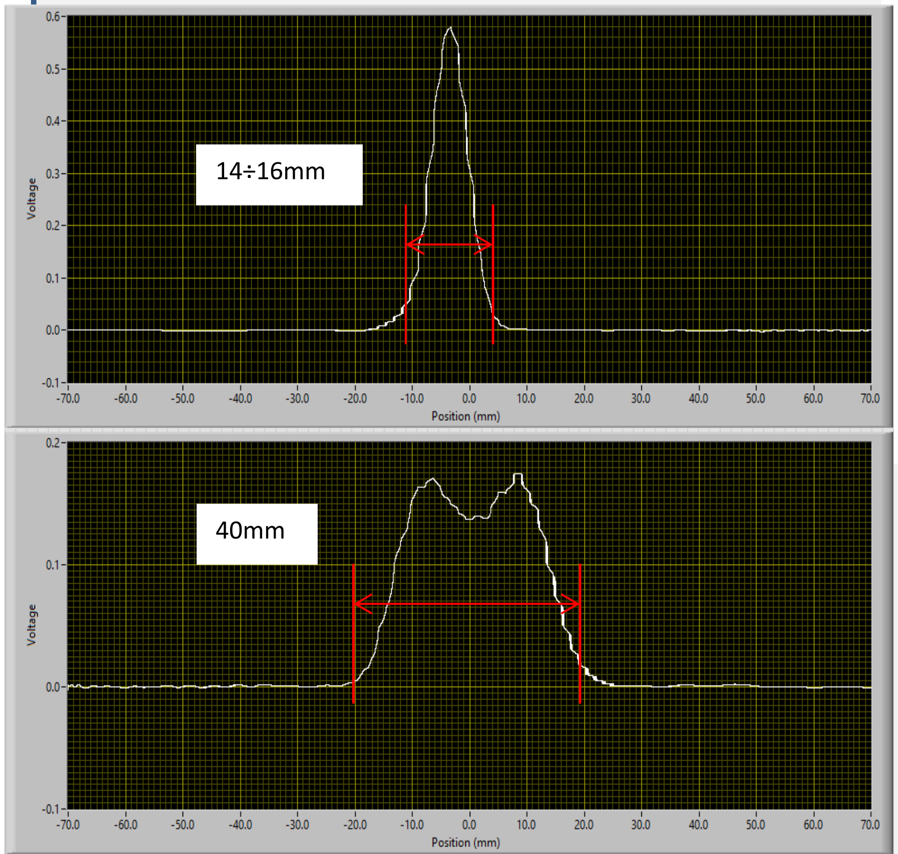
Built by BEST Cyclotron Systems

- Negative Hydrogen ion (H-)
- Simultaneous **double beam** extraction
- 35 to 70 MeV variable energy
- 700 μA combined beam current (to be upgraded to 1 mA)

-Factory Acceptance Tests (FAT) passed
-Cyclotron arrived at LNL in May 2015
-Dual beam operation demonstrated
-Cyclotron commissioning at final step
(endurance test to be performed)

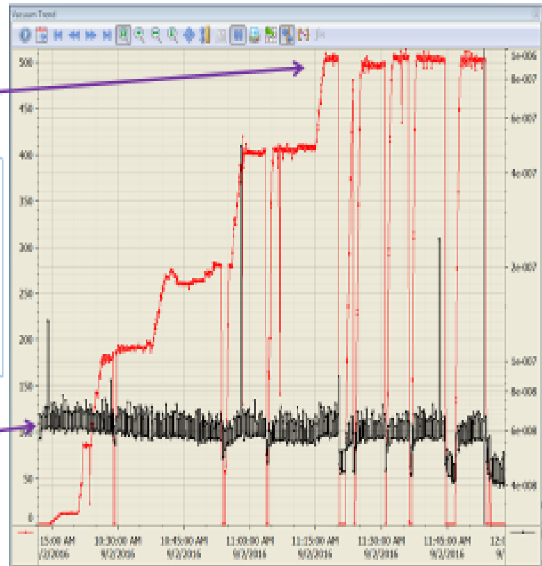
Cyclotron beam operation:



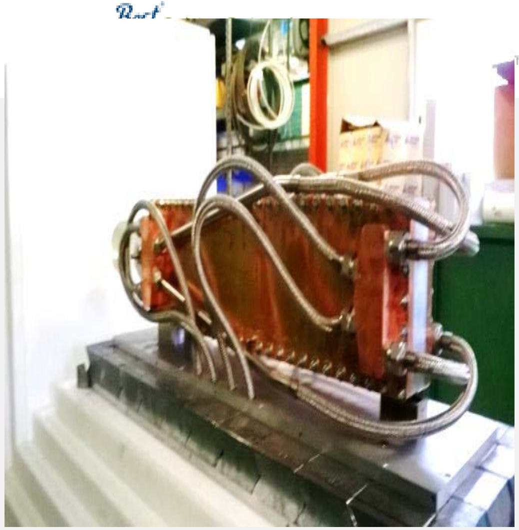


Beam profile with wobbler ON

Beam test on 50kW INFN target

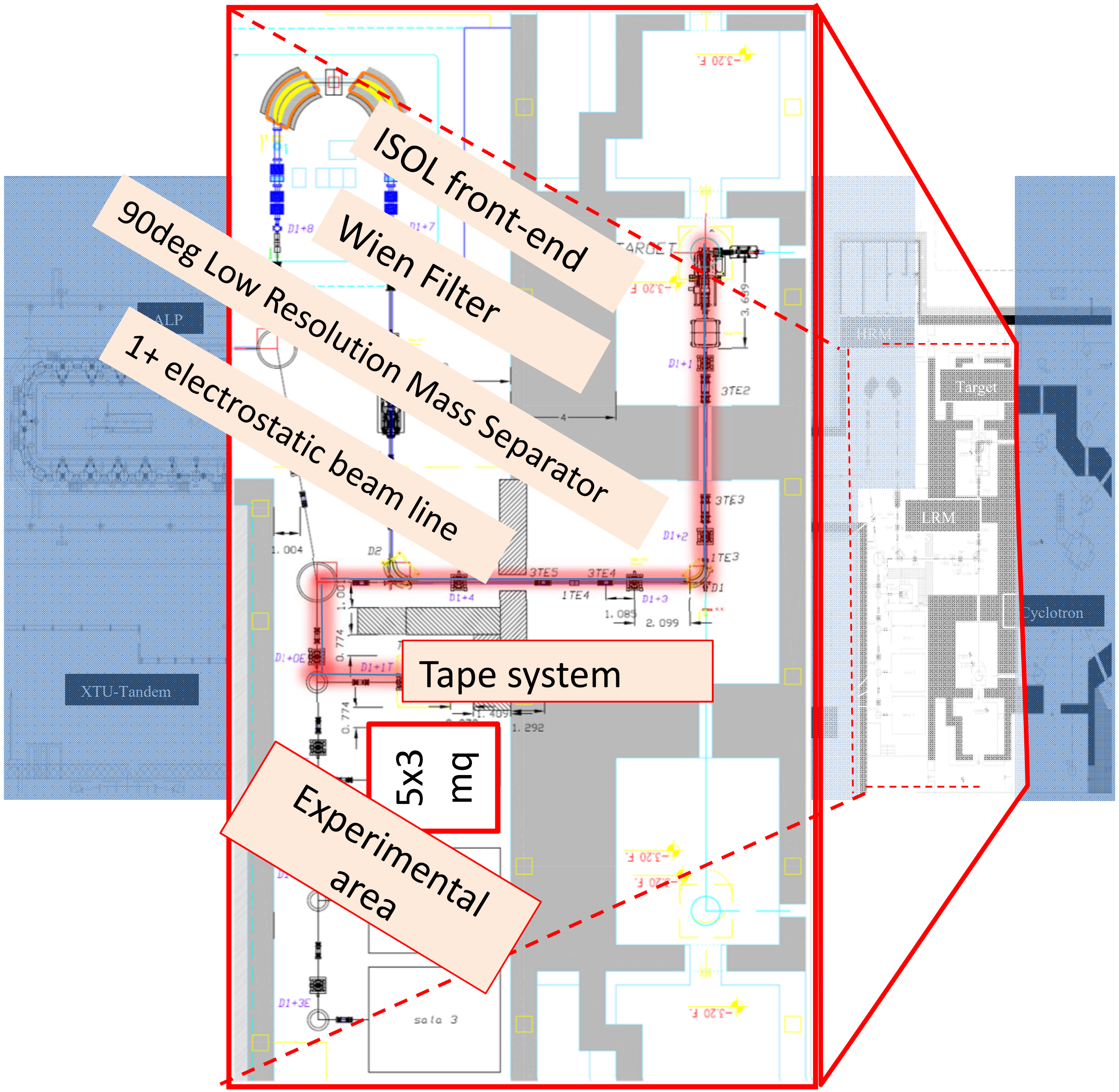


Beam dump start losing vacuum and went to the 10(-4) Torr range.
The beam was stopped.
Operation resumed, beam on target incrementally increase up to 200µA.
Vacuum recovers increasing the current



High power
Beam Dump
(50kW)

ISOL system and phase 2b

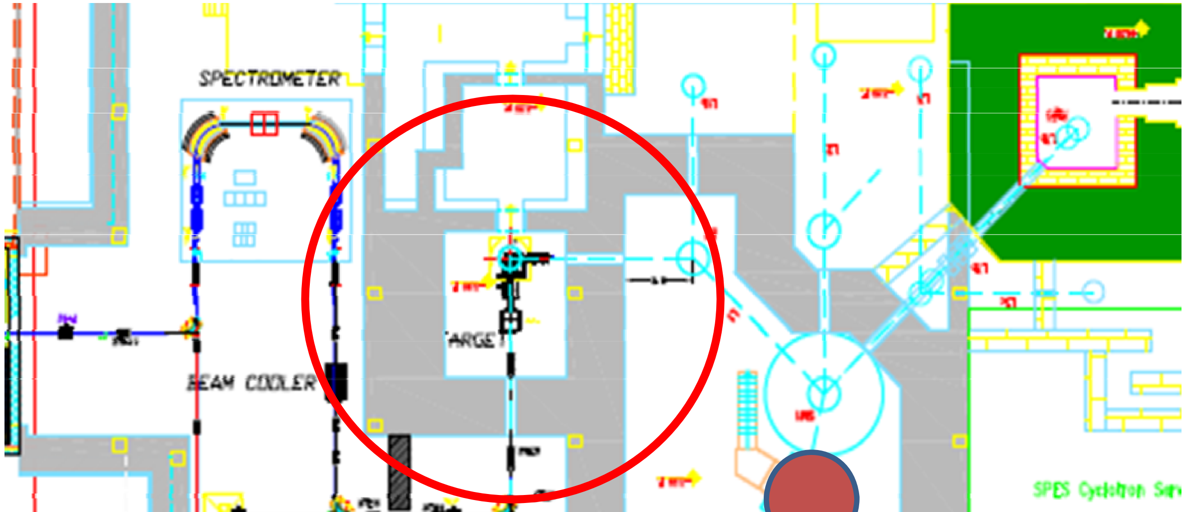


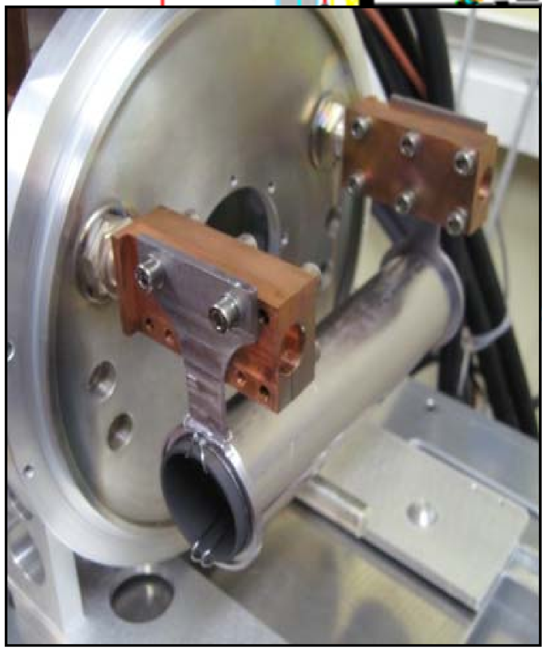
ISOL system with Direct target & H^+ Cyclotron

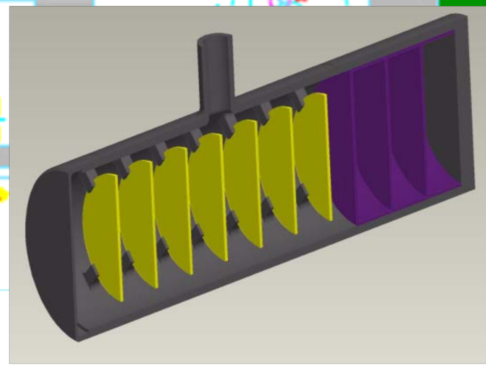
INFN-LNL-223 (2008)

NEW concept developed for the Direct Target: **Multi-foil UCx** designed to sustain 10kW beam power to reach **10^{13} f/s**

A proton beam of 40 MeV, 0.2mA will produce up to **10^{13} f/s** in the UCx target (~ 30 g).

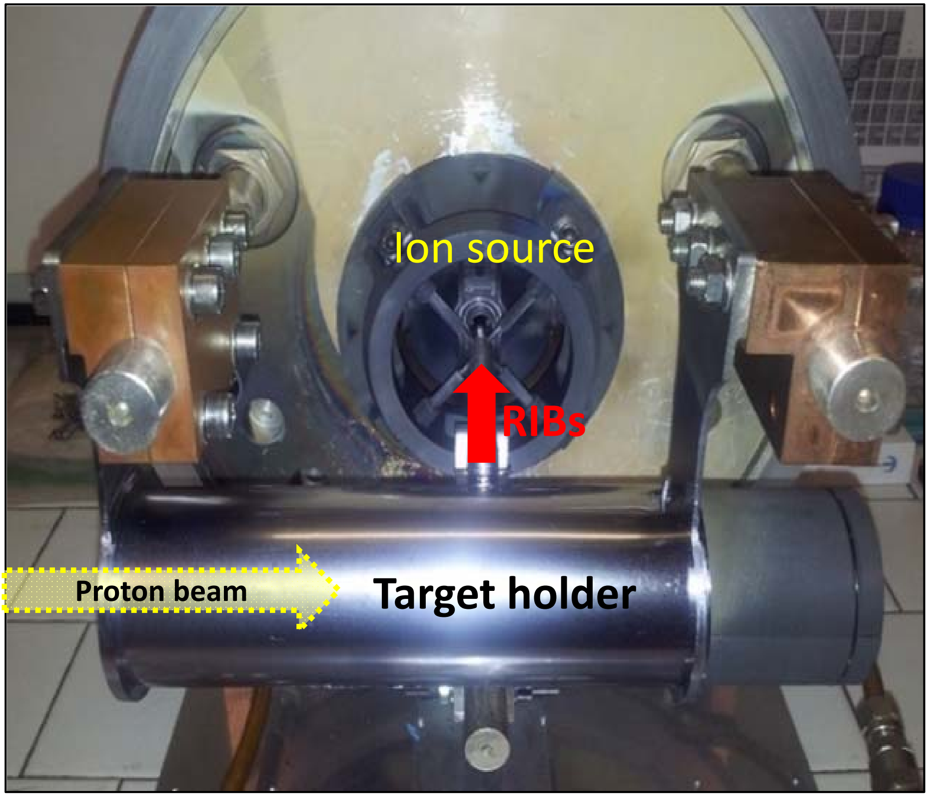




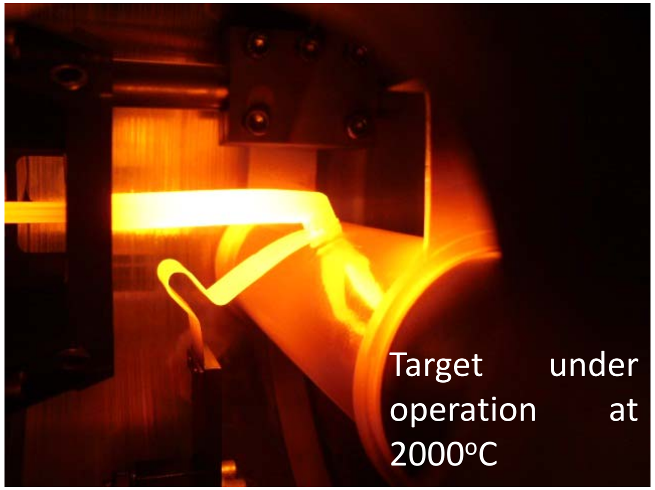


7 UCx disks + 3 graphite 1mm x 40 mm dia each

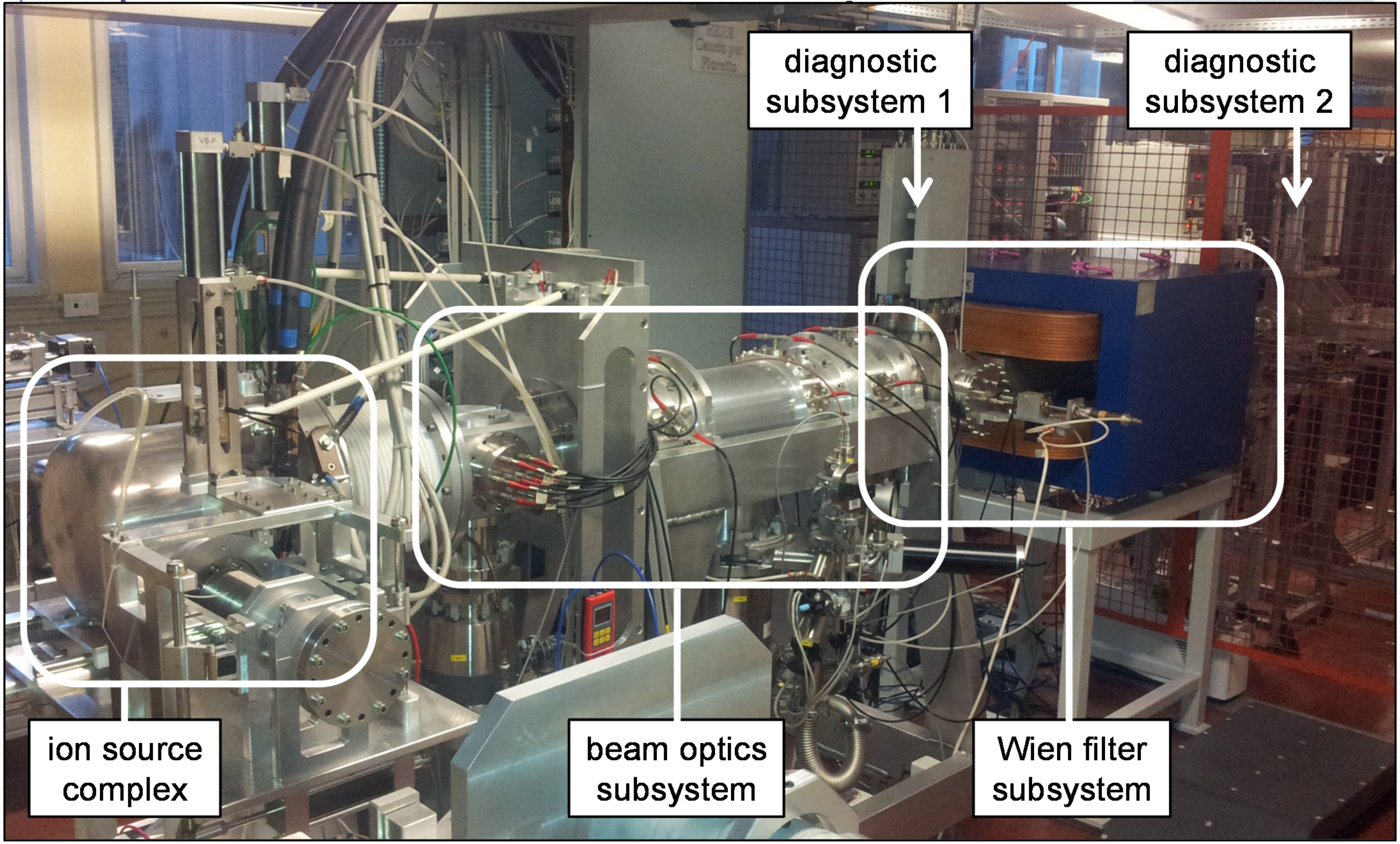
SPES Target ion source system



Multi disks Target



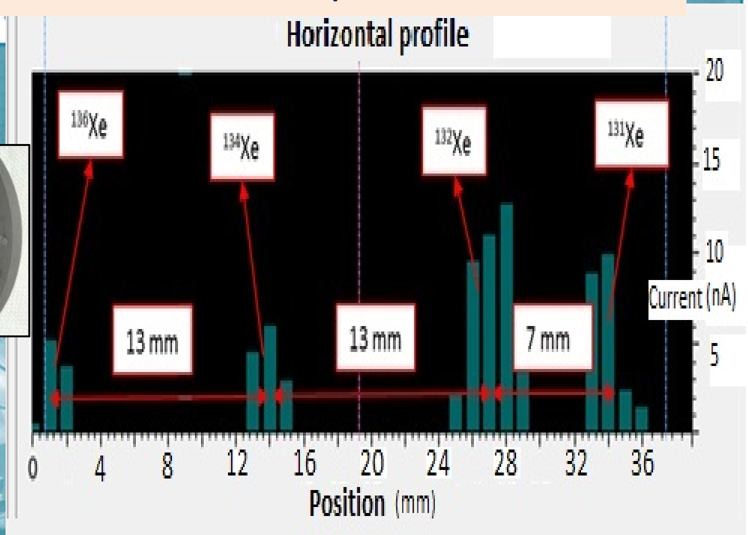
SPES ISOL system



System under operation for source commissioning.
Updated version (radiation hardness improved) under construction.

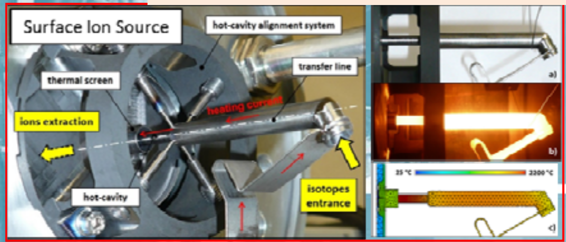
SPES ISOL system

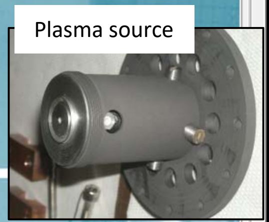
Wien filter upgrade (1/70→1/130)
Reduced radioactivity out of the bunker



Multi disk target

Source characterizzation and beam production





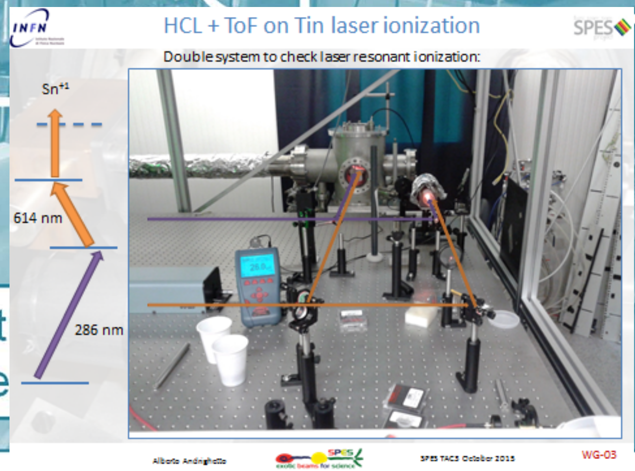
Target in-beam power test
SiC target tested with 4 kW proton beam.

- Stable temperatures
- Stable vacuum (3 10^{-5} mbar)

iThemba_LABS 2014.
(SiC target)

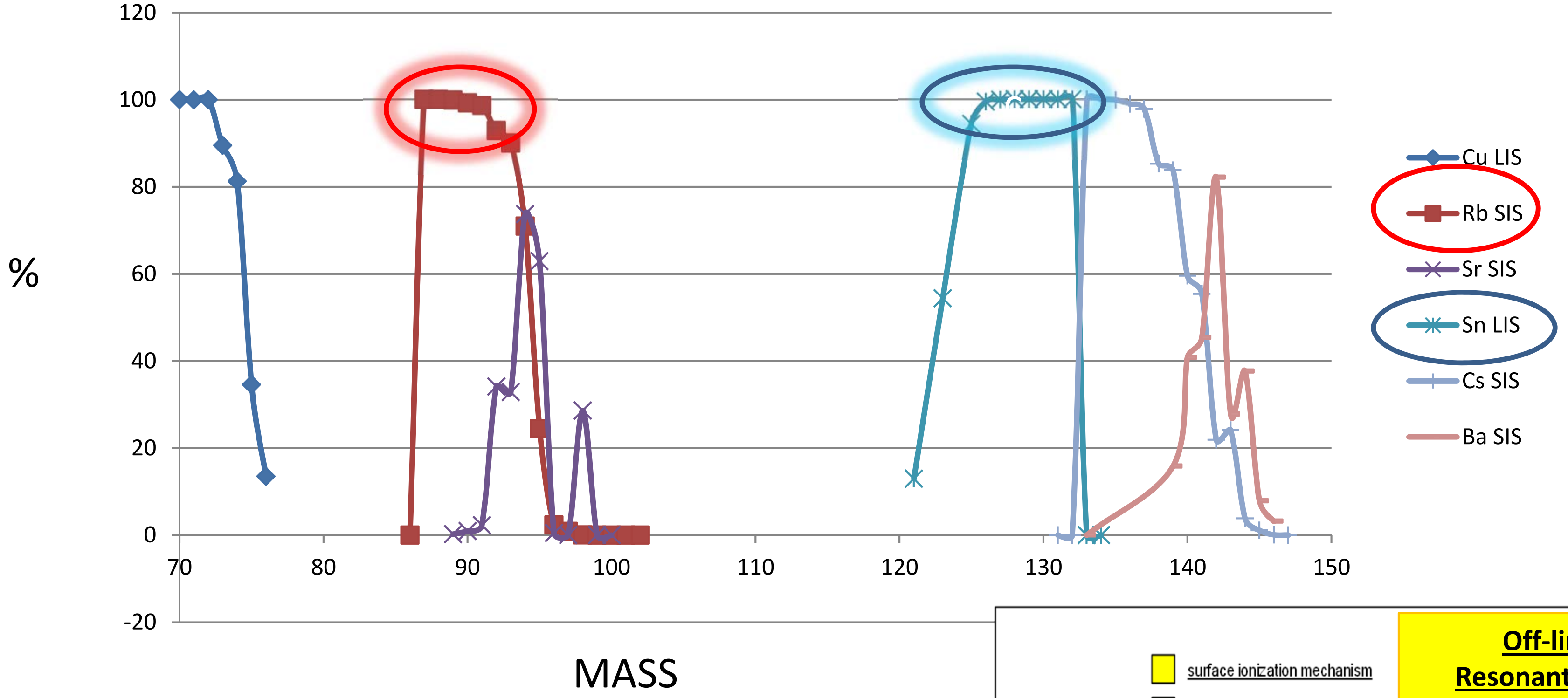
beam	ion. eff. (%)	hot-cavity temp. (°C)	hot-cavity material
Na	47,6	2200	Ta
K	55,4	2200	Ta
Ga	1,4	2200	Ta
Rb	54,5	2200	Ta
Sr	18,5	2200	Ta
In	3,2	2200	Ta
Cs	43,2	2200	Ta
Ba	58,8	2200	Ta
La	20,1	2200	Ta

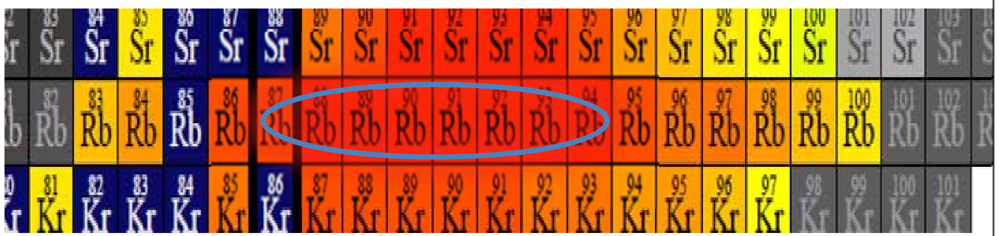
ion source complex

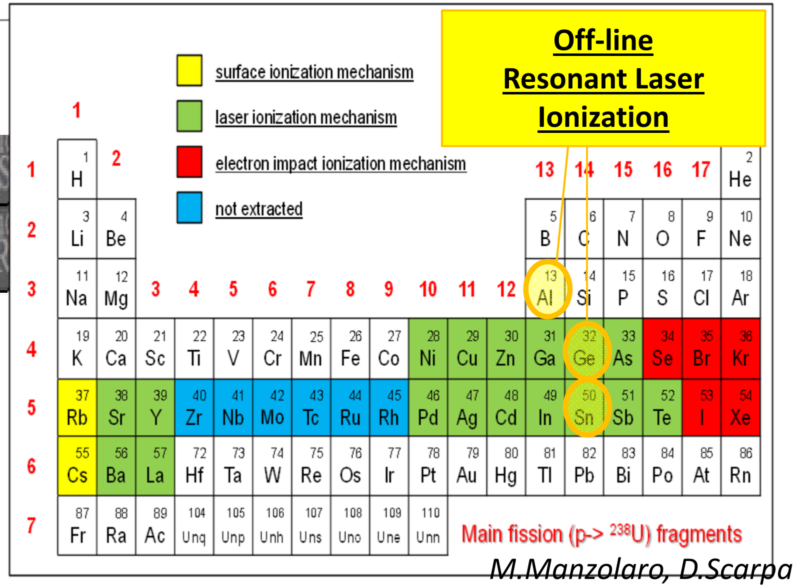


Ion source sectivity

Evaluated beam selectivity with mass selection 1/200







M.Manzolaro, D.Scarpa

Rb → Possible first n-rich beam

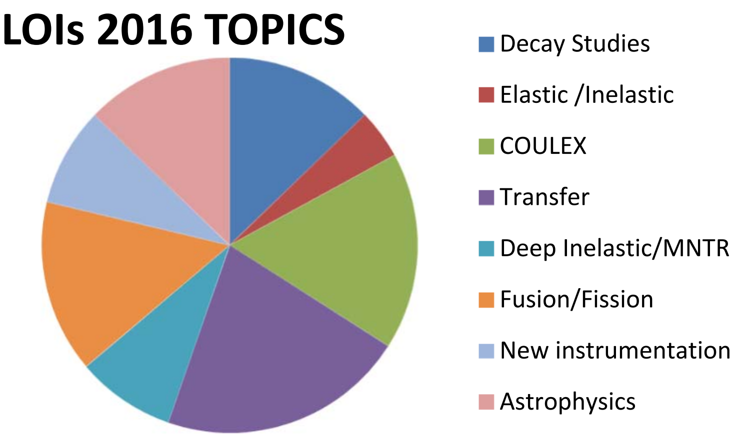
Good selectivity expected for 132Sn with LIS

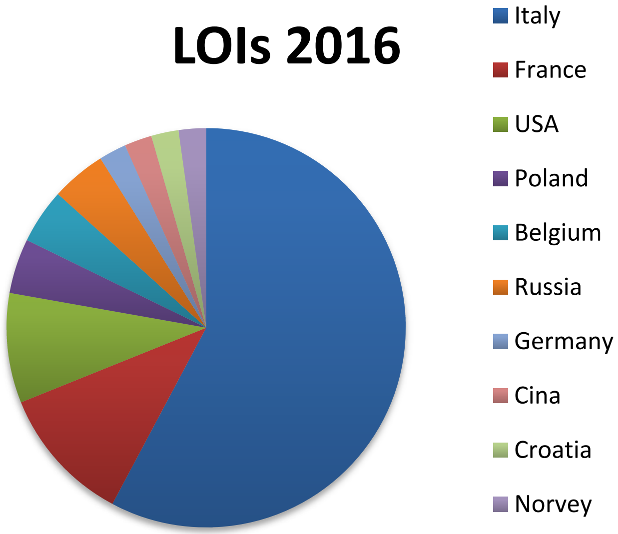
Third International SPES Workshop

10-12 October 2016 *INFN Laboratori Nazionali di Legnaro*

Europe/Rome timezone

Presented 47 Letters of Intents





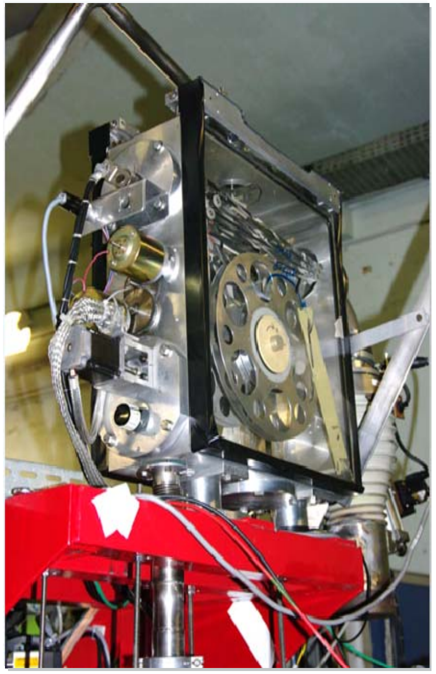
The SAC was pleased to note the good progress of the SPES project and the interesting physics program making use of the capabilities of SPES as described in the different. The large number of international co-authors and the interest from outside groups to bring state-of-the-art detection systems and instrumentation to SPES was highly appreciated and shows the importance of the SPES program for the international nuclear-physics community.

SPES_Scientific Advisory Committee: <u>Piet Van Duppen</u> (KU Leuven), Thomas Aumann (GSI), Gianluca Colò (Uni-Mi), Gilles De France (GANIL), Bogdan Fornal (INP Krakow), Tohru Motobayashi (Riken), Alessandro Olmi (INFN-FI), Andrea Vitturi (Uni PD)

Instrumentation@SPES: Tape system

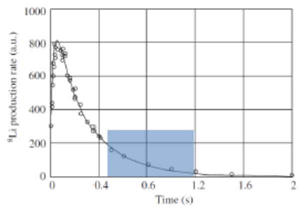
Tape station based on Orsay design (BEDO)

Collaboration ALTO-INFN-iThembaLabs

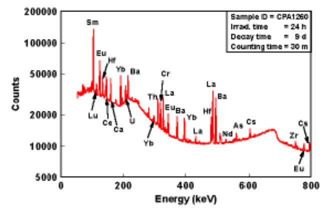


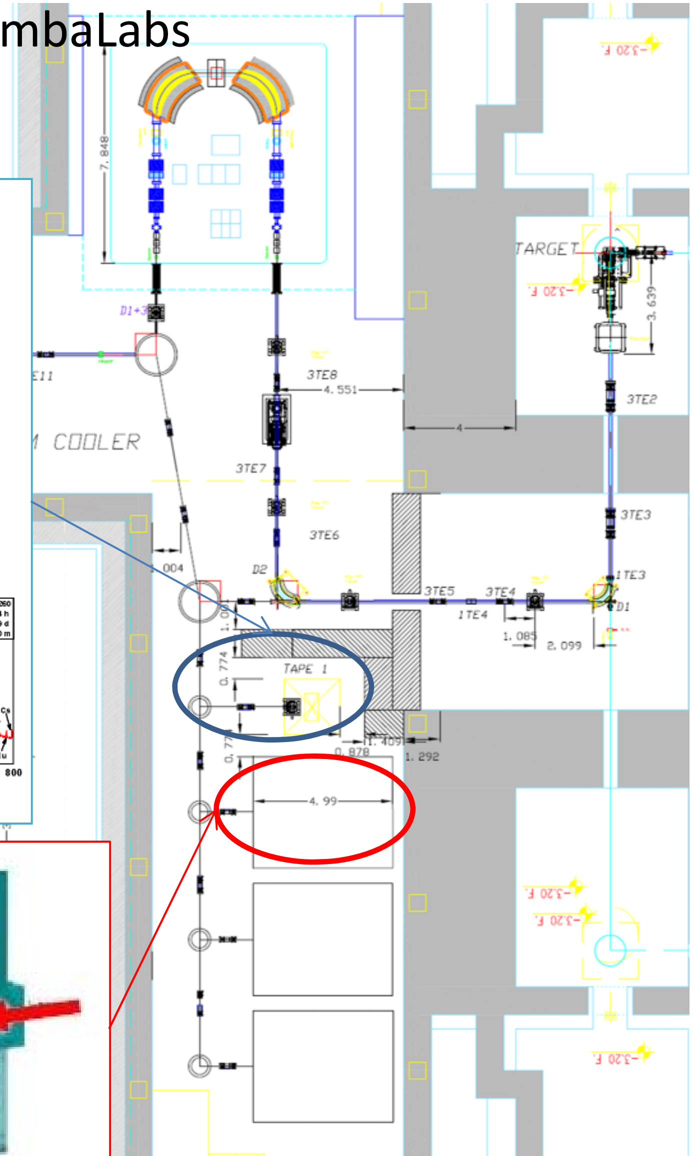
Diagnostics for SPES:
tape stations
to characterize RIBs

Beam characterization:
- **Release Curve**



- **Beam Composition and Isotopic Yields**

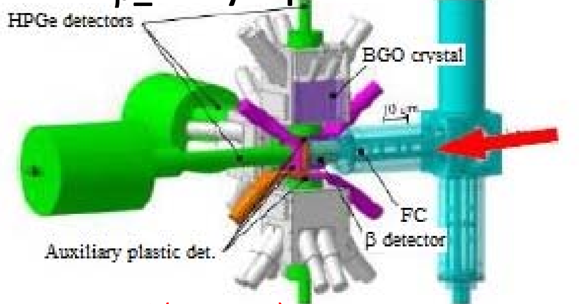




Beta decay station as a permanent and flexible setup

- Tape station + β detector
- Coupling to HPGe, LaBr3, neutron detectors etc…

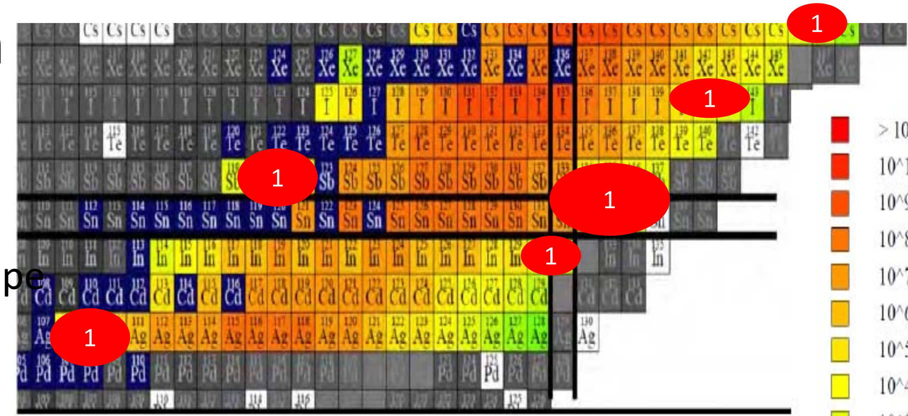
β_decay experiments

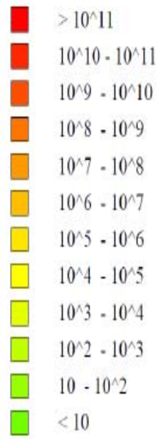


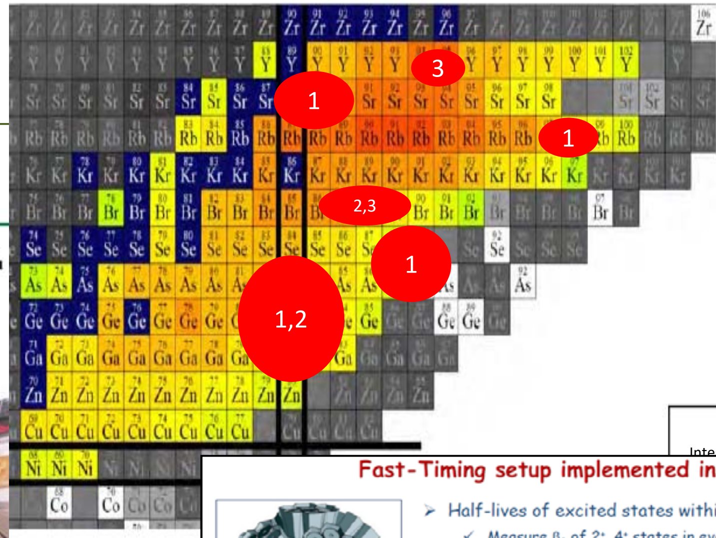
G. Benzoni (INFN Mi) contact person

SPES LoI's for beta decay station

1_Astrophysics: input for r and s process
2_Nuclear structure: Shell evolution and nuclear shape
3_Exotic decay : Pygmy resonance by β_decay







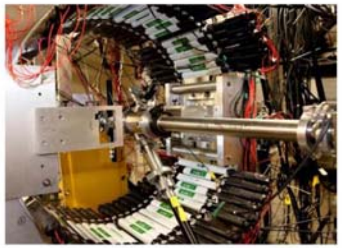
Courtesy of T. Marchi
Intesities for re-accelerated beams

Additional instrumentation and collaborations

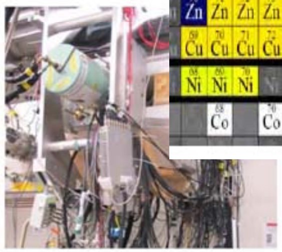
Decay spectroscopy techniques to study neutron-rich fission fragments at SPES

Krzysztof P. Rykaczewski, Robert Grzywacz, Carl J. Gross, Daniel W. Stracener, Yuan Liu
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6371, USA
in collaboration with
C. Mazzocchi, A. Korgul, M. Karny, K. Miernik, U. of Warsaw, Warsaw, Poland
W. Krolas, Institute of Nuclear Physics PAN, Krakow, Poland

MTAS = Modular Total Absorption Spectrometer



VANDLE = Versatile Array of Neutron Detectors for Low Energy



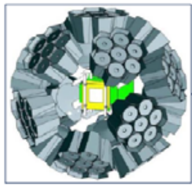
3Hen = Helium-3 Neutron Detectors
Hybrid-3Hen = 3Hen + Clover Ge

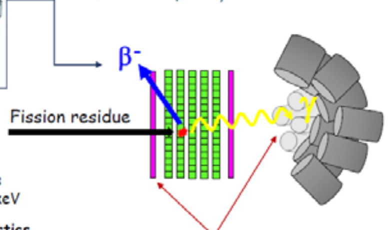
The physics of neutron-rich fission fragments
- nuclear structure evolution as N >> Z
- spectroscopy near and above the neutron separation energy
- rapid-neutron capture half-lives and beta-delayed neutron branchings
- societal impact in better data for modeling neutron-rich environments such as nuclear reactors
- more detailed understanding of the anti-neutrino spectra from reactors

U.S. DEPARTMENT OF ENERGY
OAK RIDGE NATIONAL LABORATORY

Fast-Timing setup implemented in spring 2013

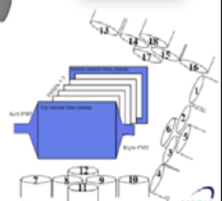
- Half-lives of excited states within the ps-ns range
  - ✓ Measure β_2 of 2⁺, 4⁺ states in even-even deformed nuclei
  - ✓ Inspect configuration mixing, seniority scheme in spherical nuclei
  - ✓ Search for β-delayed short-lived isomers





- 18 $LaBr_3(Ce)$
  - 1.5"x 2"
  - 5 mm lead shields
  - Eff 1.5% @ 660 keV
- 2 BC-418 fast plastics
  - 45x150 mm²
  - 2 mm thick
  - 3-5 mm from WAS3ABi
  - Eff ~ 50%

Fast-timing βγ correlations



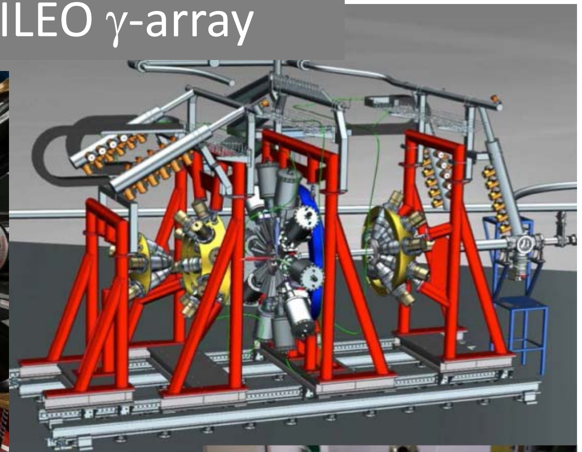
EUREKA collaboration

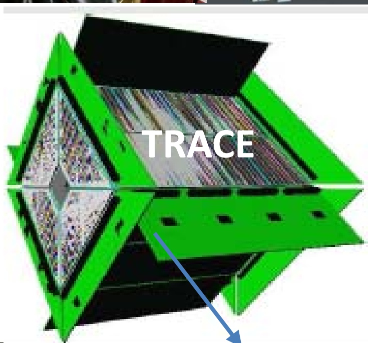
A.I. Morales, SPES one-day workshop, 20-21 April 2015, Milano

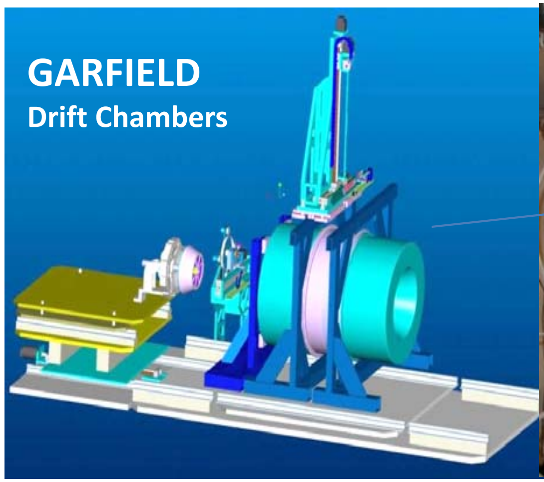
Instrumentation @ SPES

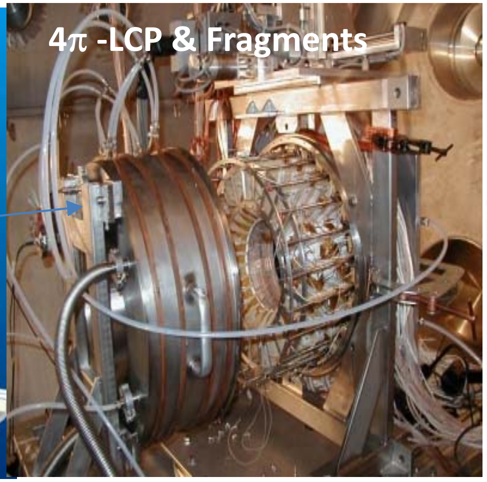
PRISMA large acceptance **magnetic spectrometer**
$\Omega \approx 80$ msr; $B\rho_{max} = 1.2$ Tm $\Delta A/A \sim 1/200$
Energy acceptance ~ ±20%

GALILEO γ-array





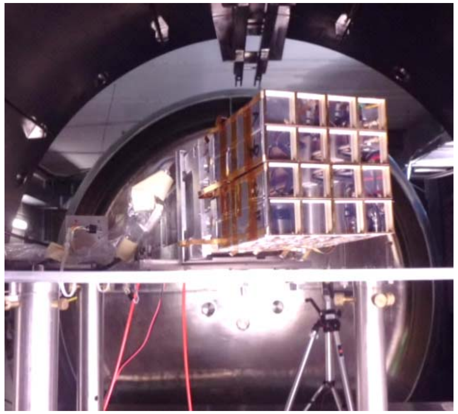


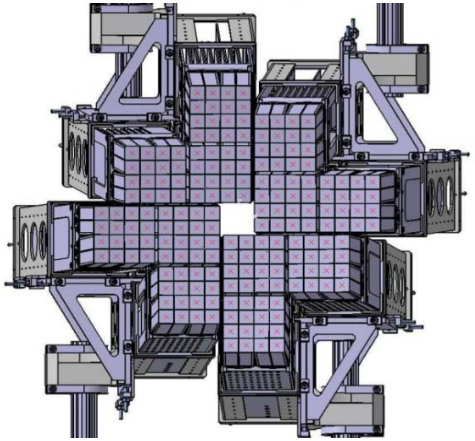


Instrumentation @ SPES

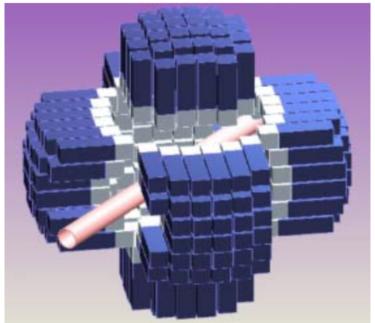
International Collaborations:
itinerant detectors

FAZIA: **LCP & fragments detection**

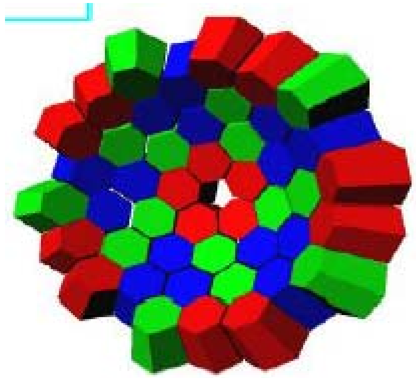




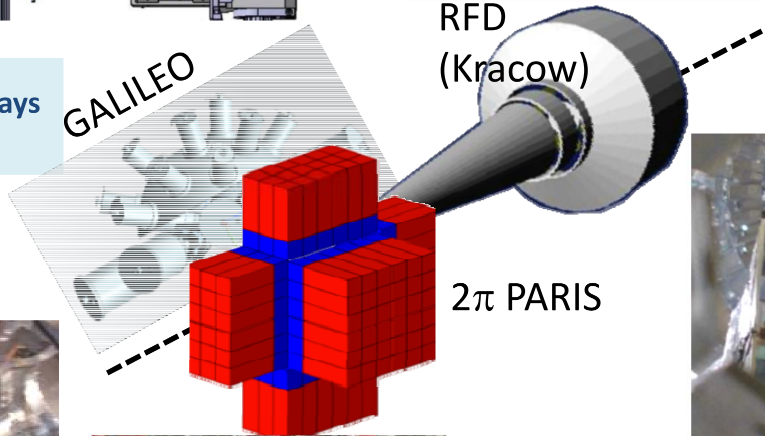
PARIS **(High Energy γ-ray Detector Array)**

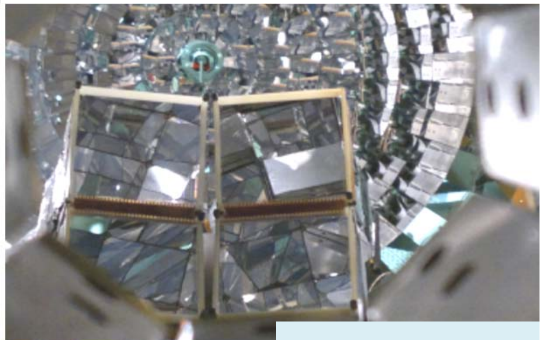


NEDA **(NEutron Detector Array)**



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





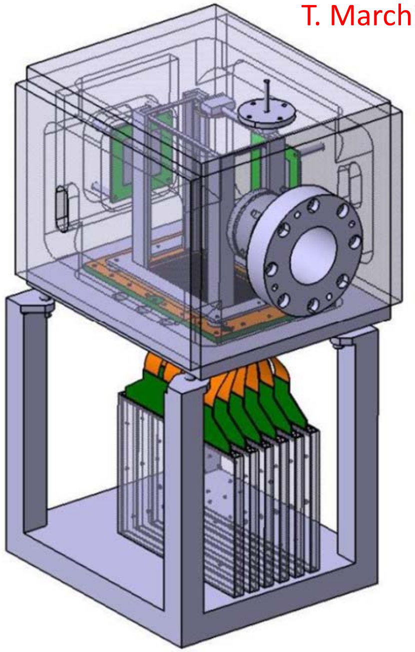
FARCOS

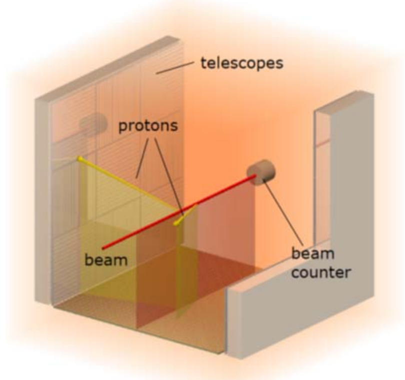
GALILEO
+nWall

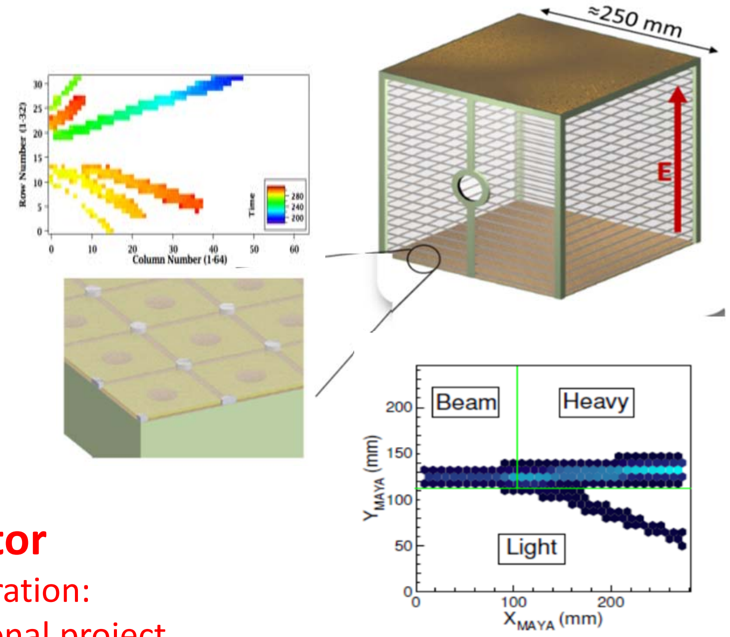
Instrumentation @ SPES

ATS @ SPES within the NUCL-EX collaboration
(LNL, Bologna, Fi, Pd, Mi, Na) + LNS_Stream

T. Marchi KU Leuven – contact person

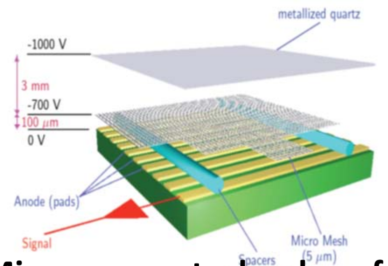




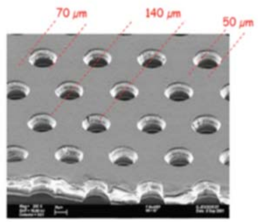


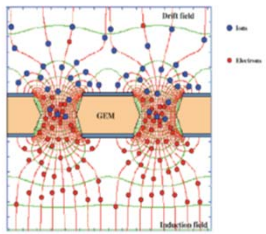
ACTAR : **Active Target Detector**

Starting activity with ACTAR collaboration:
ENSAR2 GDS network and PRIN national project (submitted)



Micro-megas technology for the amplification region : low cost 5€/cm





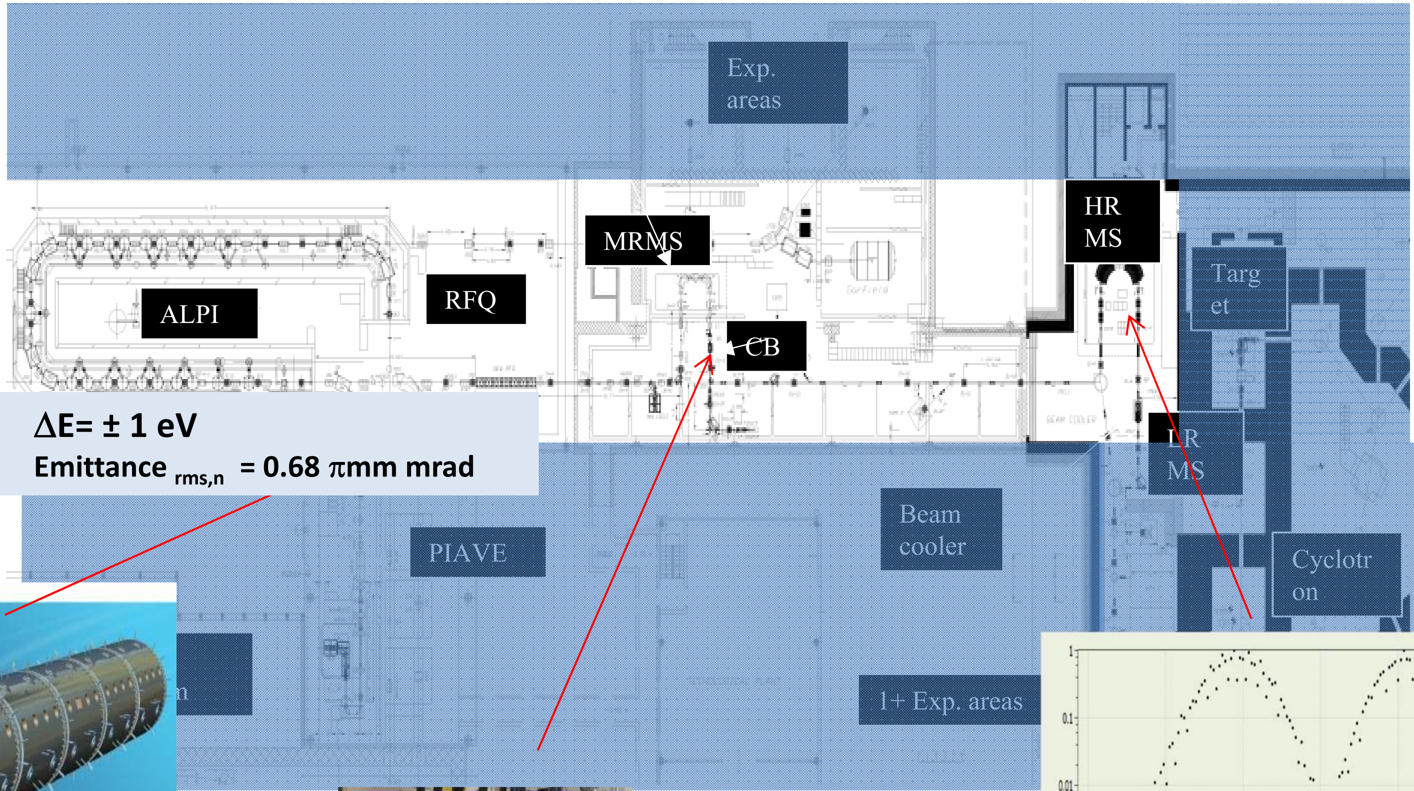
Gas Electron Multipliers: GEM

Courtesy of R. Raabe & G.F. Grinyer

The **ACTAR TPC** collaboration is actually composed by:
Centre d'Etudes Nucleaires de Bordeaux Gradignan (CENBG), France
Grand Accelerateur National d'Ions Lourds (GANIL), France
Institut de Physique Nucleaire d'Orsay (IPNO), France
Institut de Recherche sur les lois Fondamentales de l'Univers (IRFU), France
University of Leuven (KUL), Belgium
Universidade de Santiago de Compostela (USC), Santiago, Spain

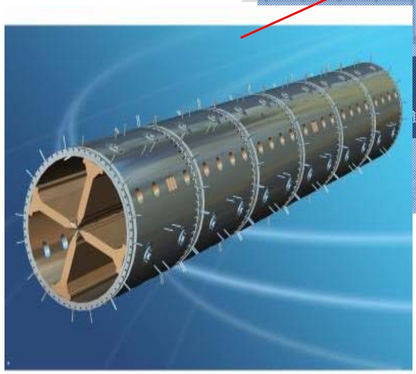
GDS – Network within ENSAR2 – INFN WP leader

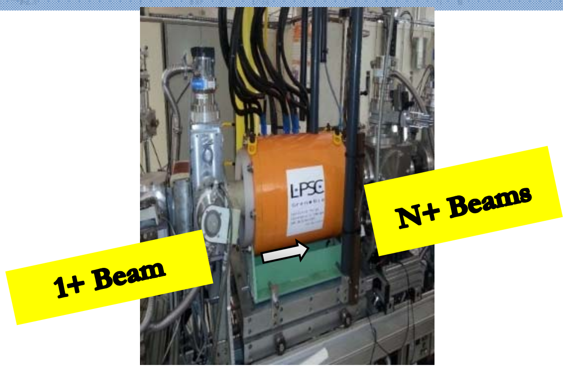
Beam transport and reacceleration

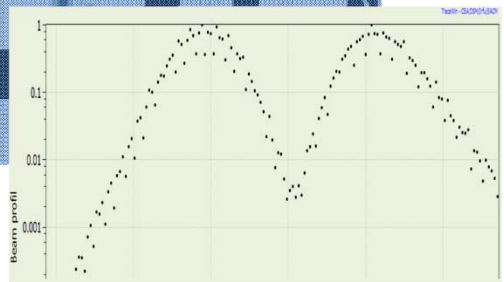


$\Delta E = \pm 1$ eV

Emittance $_{rms,n}$ = 0.68 πmm mrad







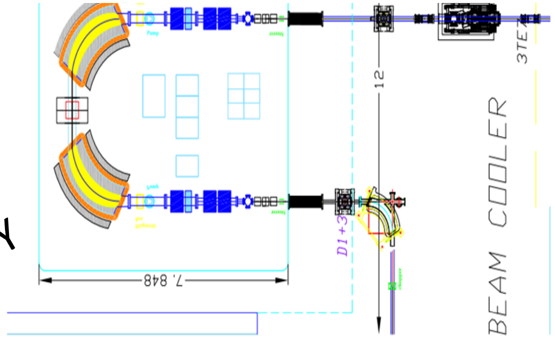
HRMS design:
Mass separation: 1/20000
Errors included
$\Delta E = \pm 1$ eV
Emittance $_{rms,n}$ = 0.68 πmm mrad

Phase 3: High Resolution Mass Separation

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

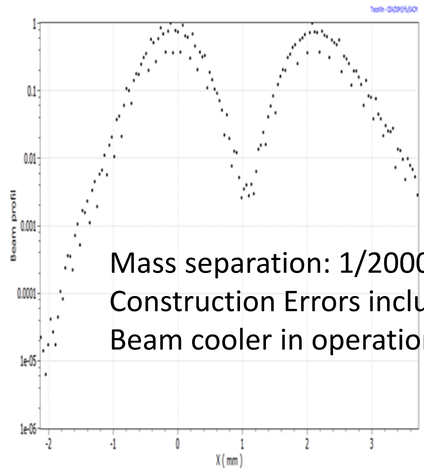
^{132}Sn beam in simulations

DESIGN STUDY



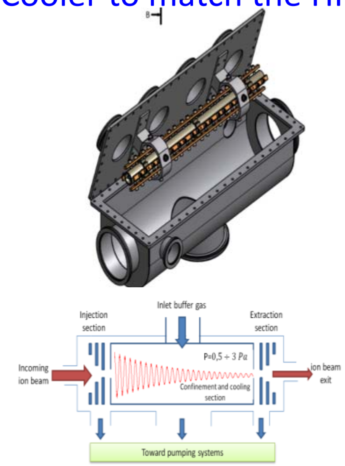
$\Delta E = \pm 1$ eV
Emittance $_{rms,n}$ = 0.68 πmm mrad

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%

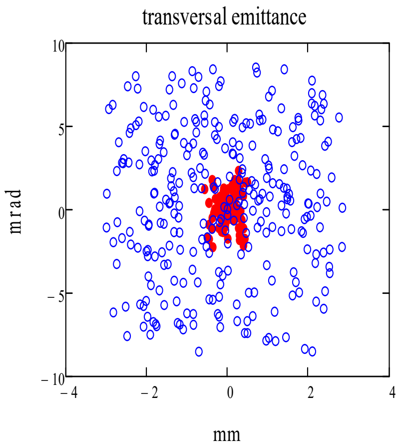


Mass separation: 1/20000
Construction Errors included
Beam cooler in operation

Beam Cooler to match the HRMS input requirements



Contacts with LPC_Caen for SHIRaC type Beam Cooler development (SPIRAL2)

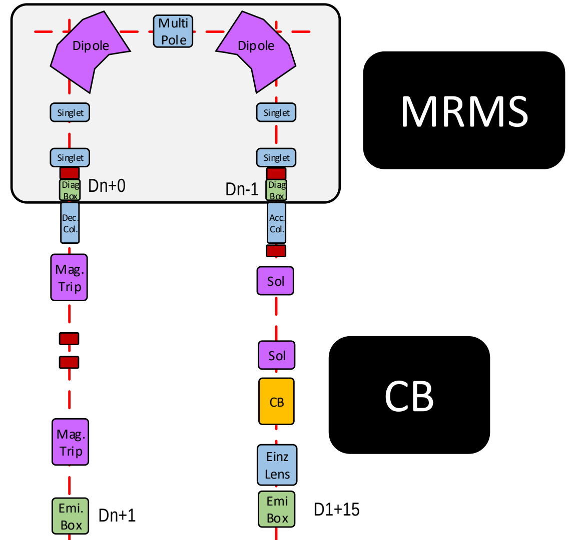


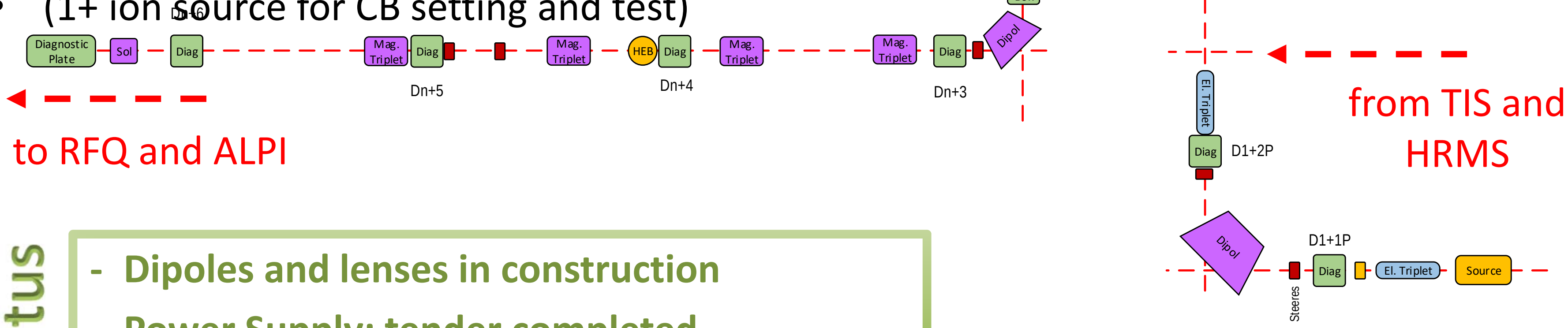
Input T emittance
Output T emittance

Phase 2A: Installation of Charge Breeder and n+ beam line

Purpose:
- boost the 1+ beam from TIS and HRMS
- clean & transfer n+ beam to RFQ pre-accelerator

Components:
- Charge Breeder: ECR type
- Medium Resolution Mass Separator (MRMS) on HV platform (1/1000 mass separation)
- Beam line components and diagnostics
- (1+ ion source for CB setting and test)





Status

- **Dipoles and lenses in construction**
- **Power Supply: tender completed**
- **Fully equipped HV Platform: tender launhed**

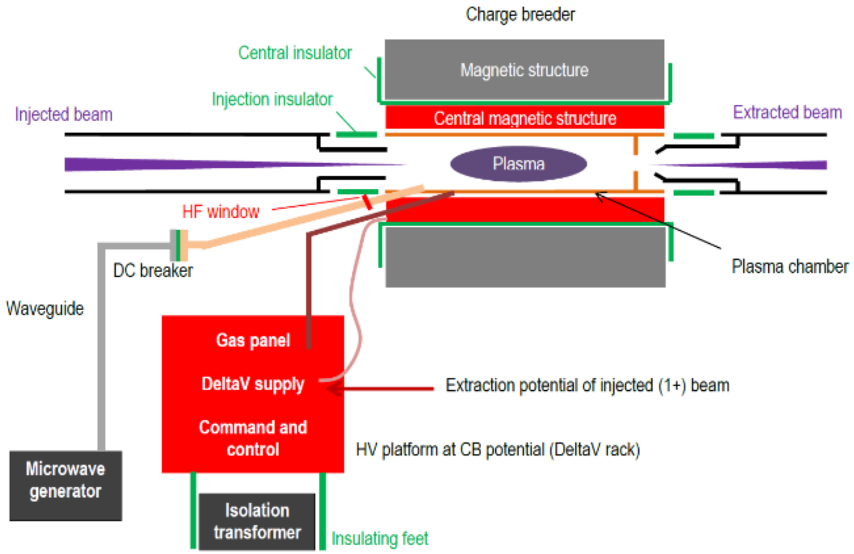
ECR-type Charge Breeder

ION	Q	EFFICIENCY* [%] 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*

R&D to reduce the ECR contaminats

Action	Expected result
New Aluminum plasma chamber	Better performances ad reduction of contaminants
Surface treatments	Reduction of surfaces de-gassing
Coating of plasma chamber with refractary	Reduction of contaminants
Use of hot liner	Improved "recycling" reducing the sticking time. Better performance and reduction of contaminants
MRMS	Beam selection and separation from contaminants

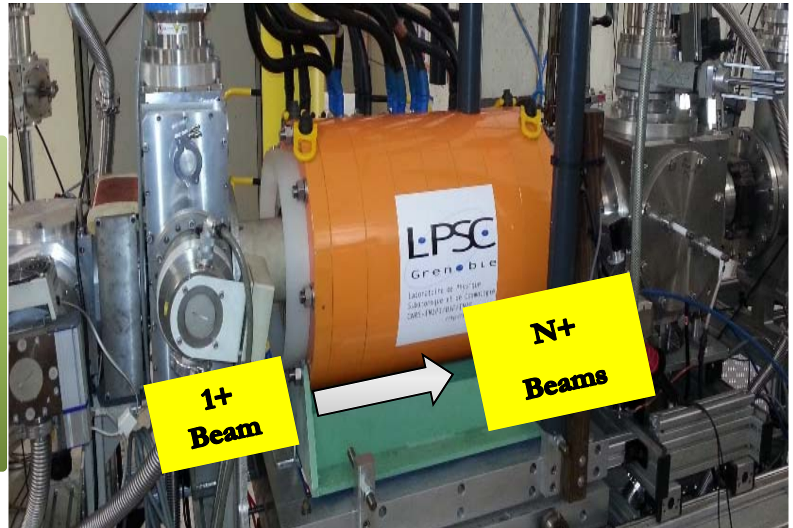


Phase 2A: Installation of Charge Breeder and n+ beam line

Assembly of 1+Source Front-End

SPES production, similar to ISOL source

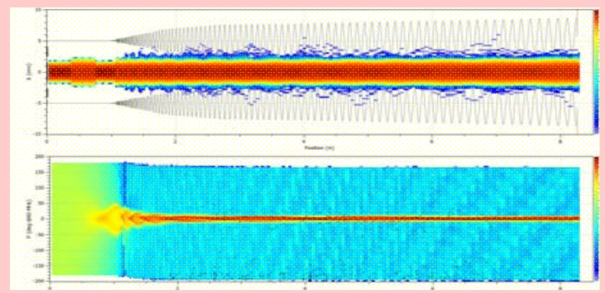
- Hall prepared
- Assembly and connection of 1+ source and CB in 2017

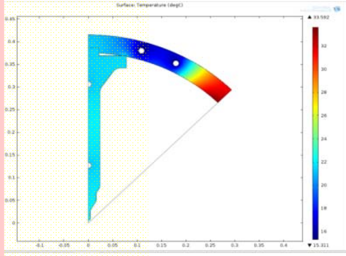


Charge breeder developed at LPSC (Grenoble)

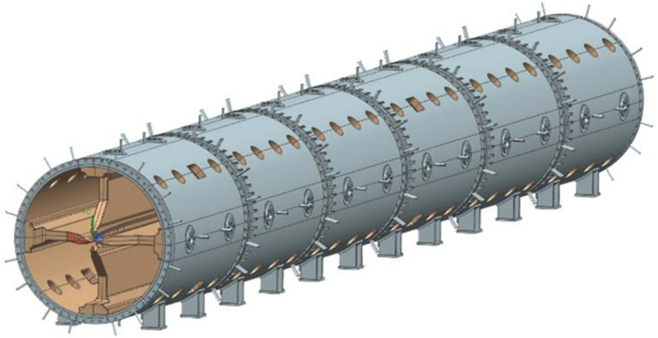
Exotic Beam RFQ Injector for ALPI (7 m, 6 modules)

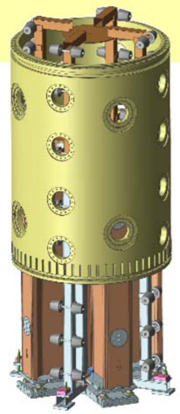
- **Energy 5.7 –> 727.3 keV/A** [β=0.0395] (A/q=7)
- **Beam transmission** >93% for **A/q=3÷7**
- **RF power** (four vanes) **100 kW** (f=80 MHz) **for up to 1 mA beam (**…future higher I stable beams**)**
- **Mechanical design** and realization, similar to the Spiral2 one, takes advantage of IFMIF technological experience





Beam dynamics, EM design, Mechanical design and Thermal Analysis COMPLETED



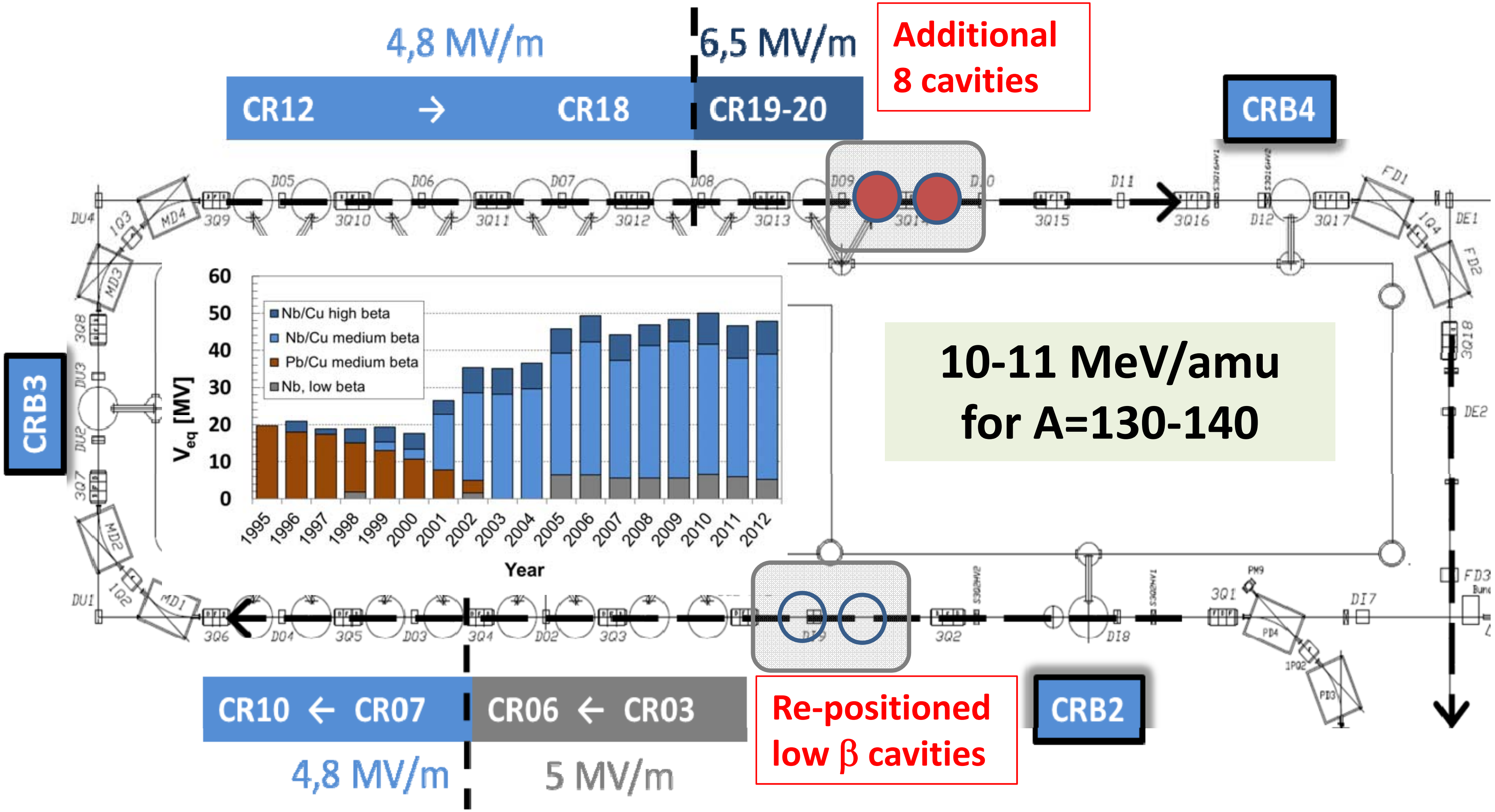


Status

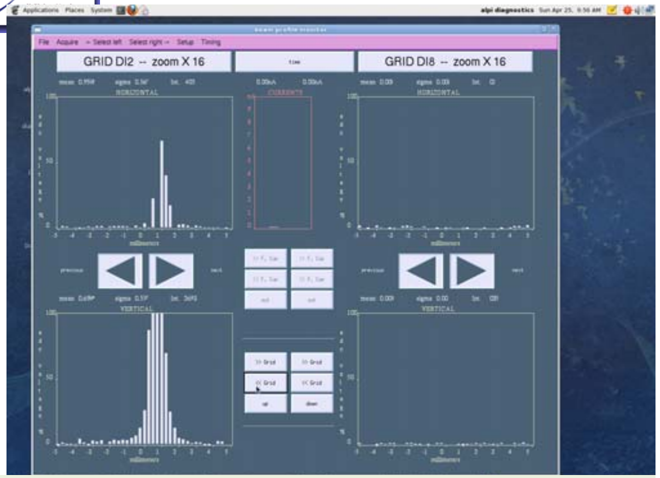
- **Materials ordered**
- **Construction of vanes: tender completed (July 2016)**
- **Prototype in preparation**

200 kW **RF amplifier** (175 MHz→ 80 MHz tuning required); 200 kW **Power Coupler** developed

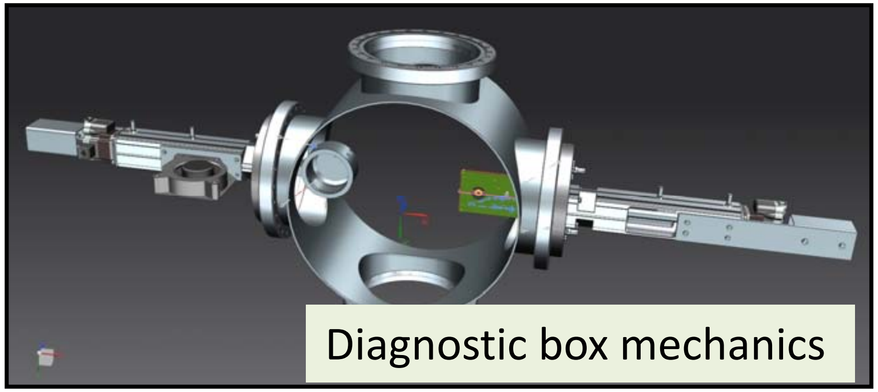
Matching into ALPI SC linac



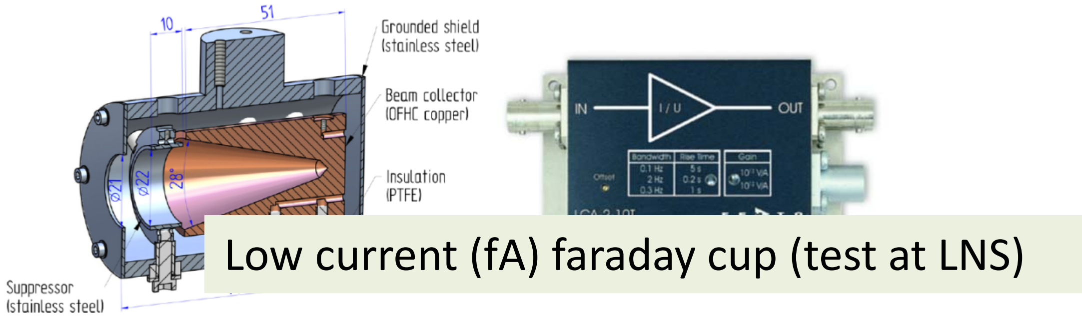
SPES DIAGNOSTICS



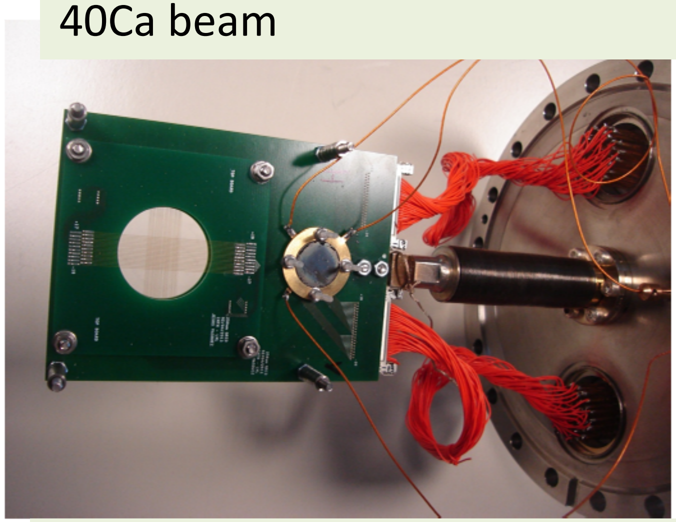
MCP_Low current test: 10 fA, 40Ca beam



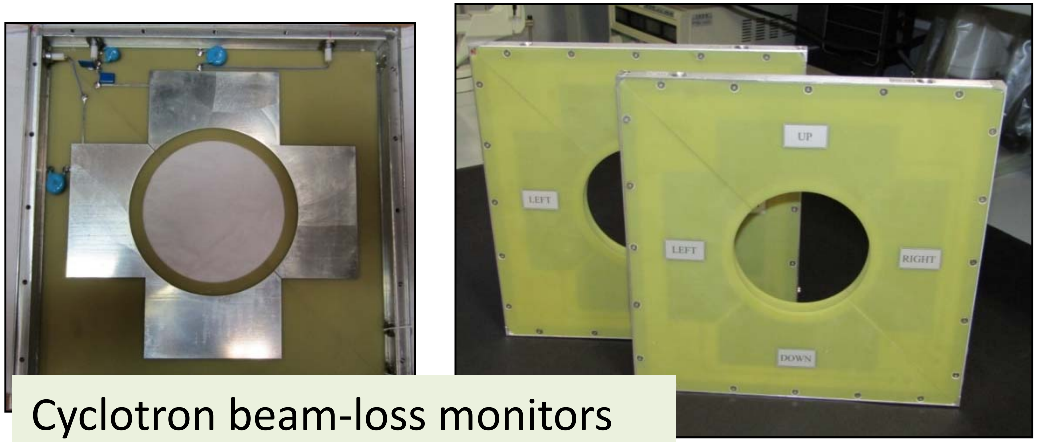
Diagnostic box mechanics



Low current (fA) faraday cup (test at LNS)



Wires – MCP high dinamic range SPES Beam Profile Monitor

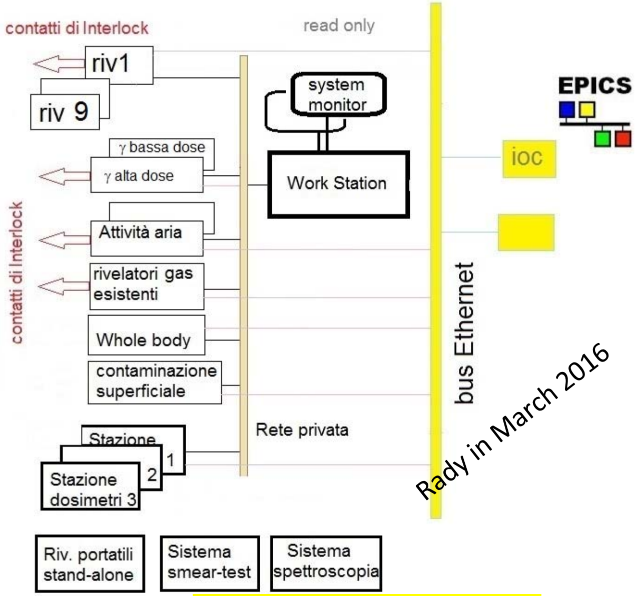


Cyclotron beam-loss monitors

SPES safety system

A SIL3 safety system is under development by PILZ

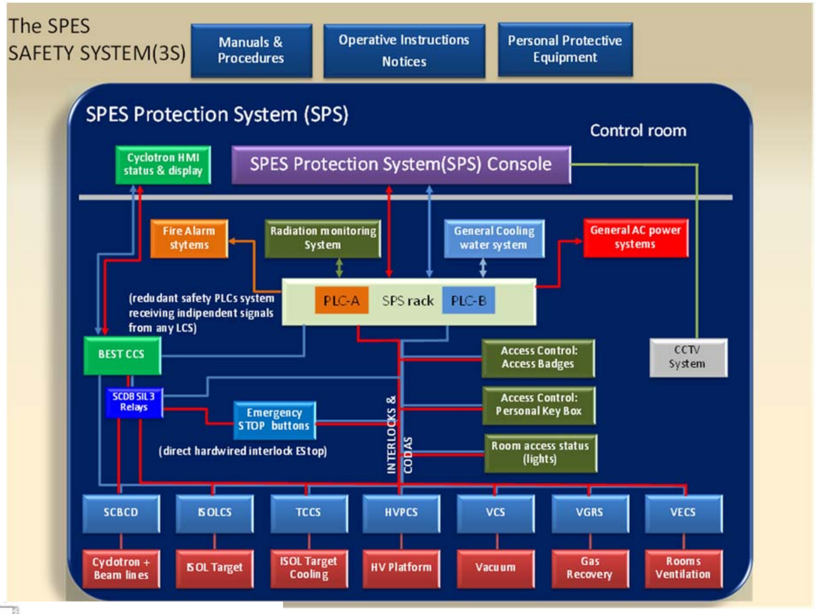
A simplified system is under use for cyclotron test

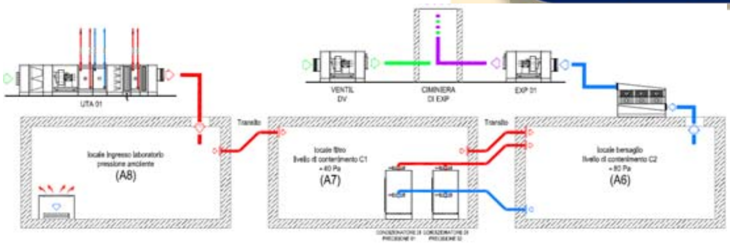


Radiologic survey system

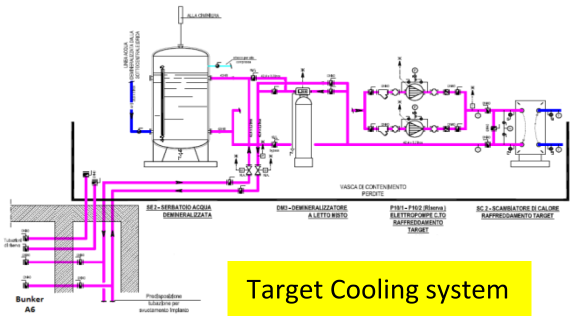
Cyclotron and beam lines

ISOL target

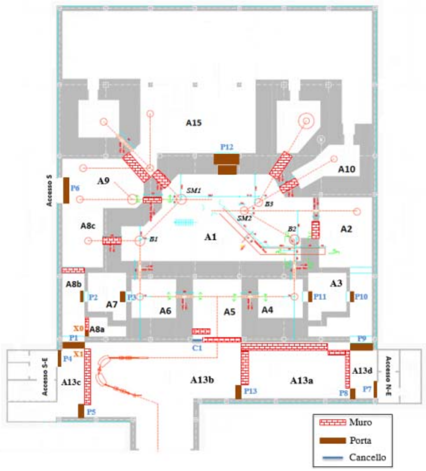




ventilation



Target Cooling system



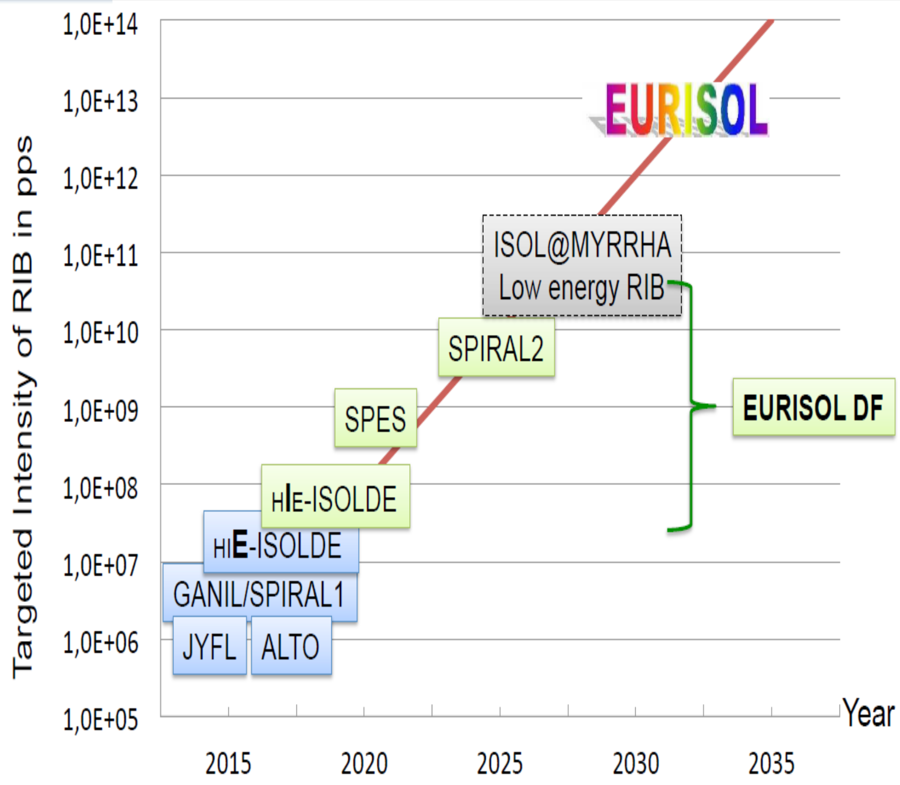
Access Control System

WP_B4, WP_B2

EURISOL Distributed Facility (DF) Initiative

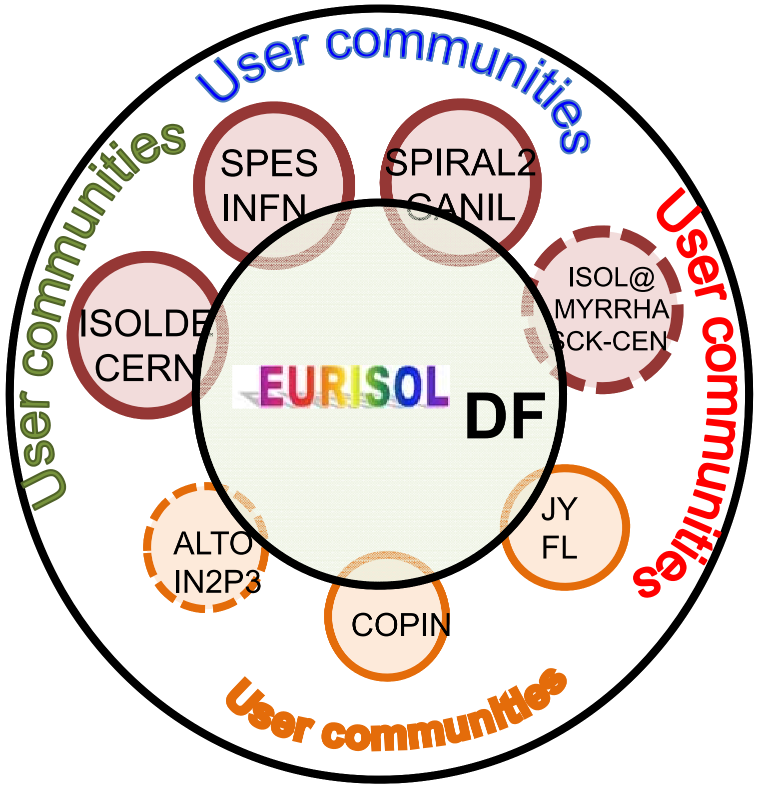
Project to be submitted for the 2018 update of the ESFRI roadmap

EURISOL DF: Intermediate step towards single site project



Complementarities: Instrumentation eg. AGATA, FAZIA, GASPARD, PARIS
Challenges: High-power targets & sources, purification of RIB

EURISOL DF



- A **distribute laboratory** for radioactive beams:
- **More exotic beams** available
- **Coordination of competences** to face EURISOL technologic challenges
- **Joint effort** to manage the activity at European level

CONCLUSIONS

- **SPES is in the construction phase**
- **Infrastructures and Cyclotron are completed**
- **In the next two years the ISOL system and the Charge Breeder will be installed**
- **In 2019 radioactive beams with no-reacceleration will be available**
- **Reacceleration will be completed in 2021 using ALPI to reach 10-11 MeV/n**
- **SPES is partner of EURISOL_DF**
  - **An European distributed facility for radioactive beams** will offer a wide alternatives of exotic beams to the international nuclear physics community