Status of the SPES project

Gianfranco Prete
SPES project leader

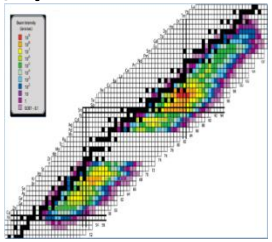
Third International SPES Workshop

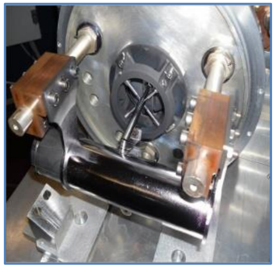
10-12 October 2016 *INFN Laboratori Nazionali di Legnaro*
Europe/Rome timezone

SPES Strategy

Second generation ISOL facility towar EURISOL

Neutron–rich ions by **p-induced Fission** on **UCx (10^{13} f/s)**



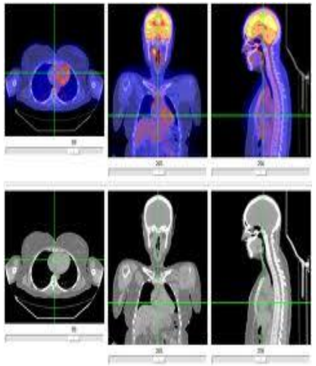


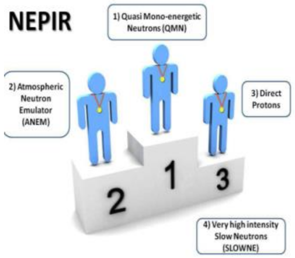
Cyclotron

ISOL RIBs+ Post-Acc.

Nuclear Medicine

Nuclear Applications





Research and Production of **Radio-Isotopes for Nuclear Medicine**

LARAMED

Accelerator based neutron source (**Proton and Neutron Facility for Applied Physics**)

Design study

Direct target & H$^+$ Cyclotron

INFN-LNL-223 (2008)

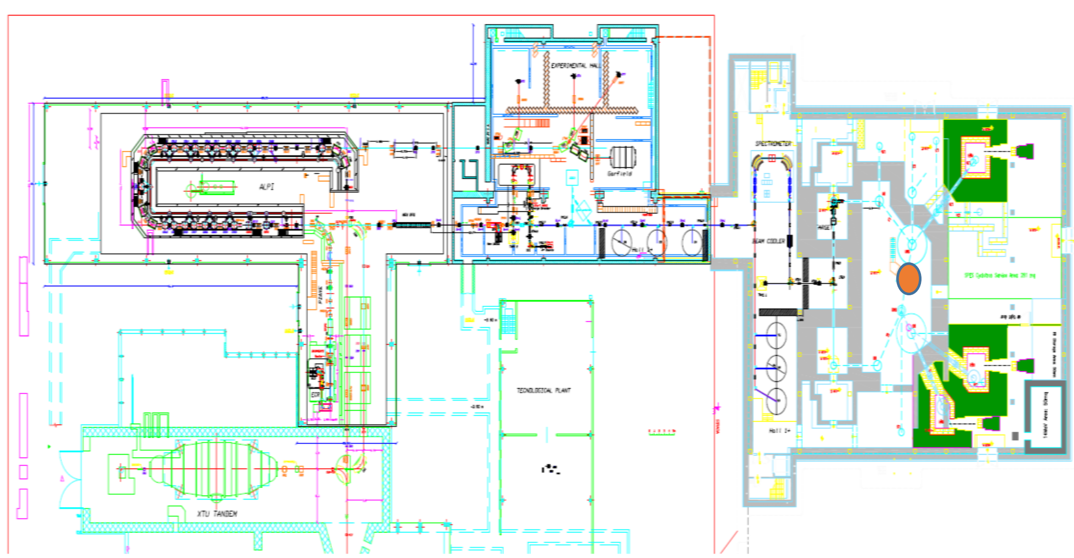
NEW concept developed for the Direct Target: **Multi-foil UCx** designed to sustain 10kW beam power to reach **10^{13} f/s**

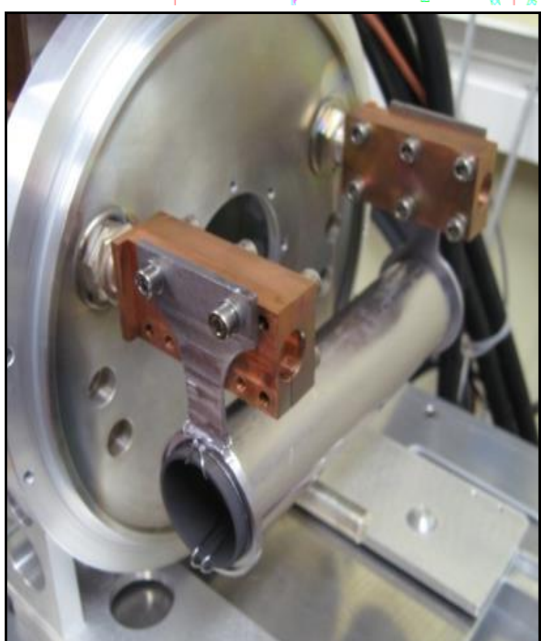
The ISOL front-end design follows the ISOLDE system.

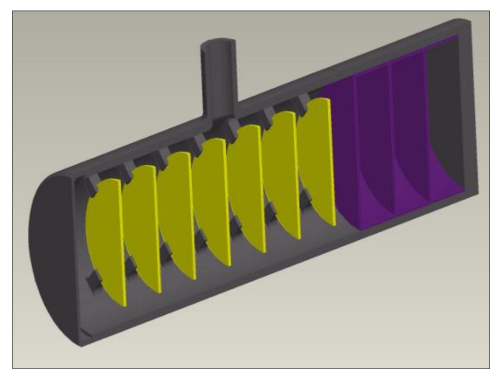
A proton beam of 40 MeV, 0.2mA will produce up to 10^{13} f/s in the UCx target (~ 30 g).

The cyclotron accelerates H+ and will produce 2 proton beams, feeding 2 targets at the same time.

Evaluated cost ~ **50 M€**

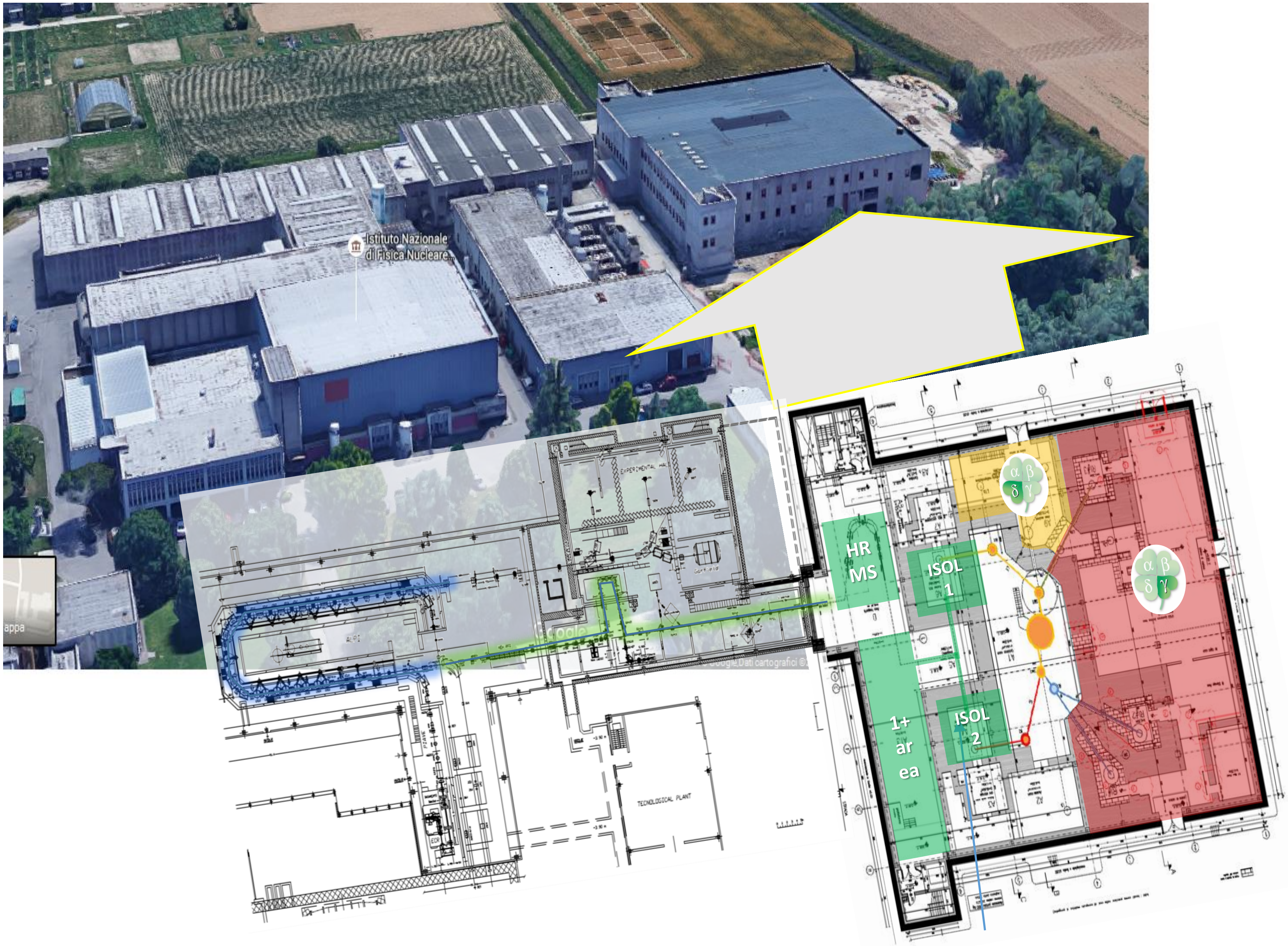


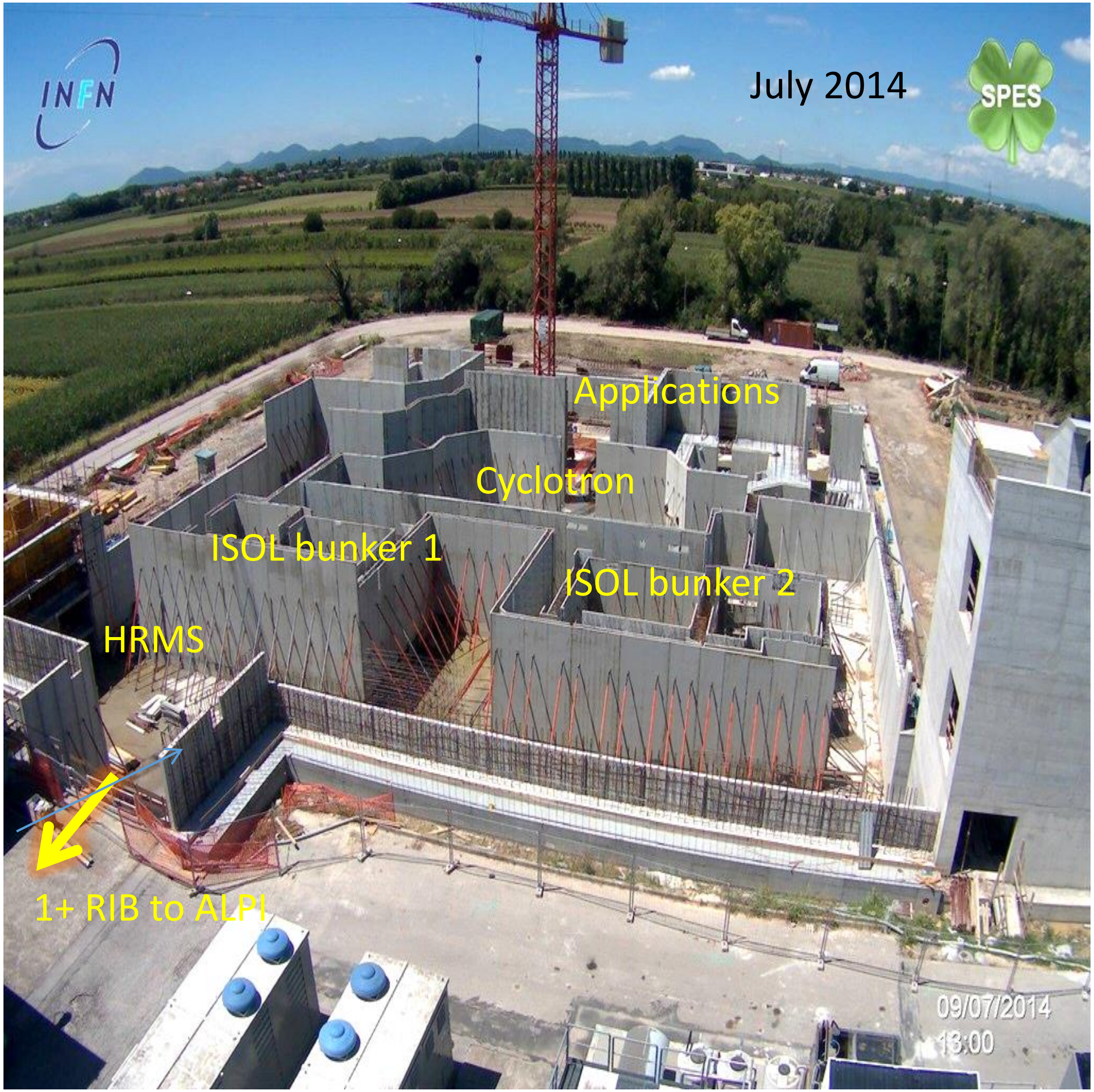




7 UCx disks + 3 graphite
1mm x 40 mm dia each

SPES infrastructure - layout





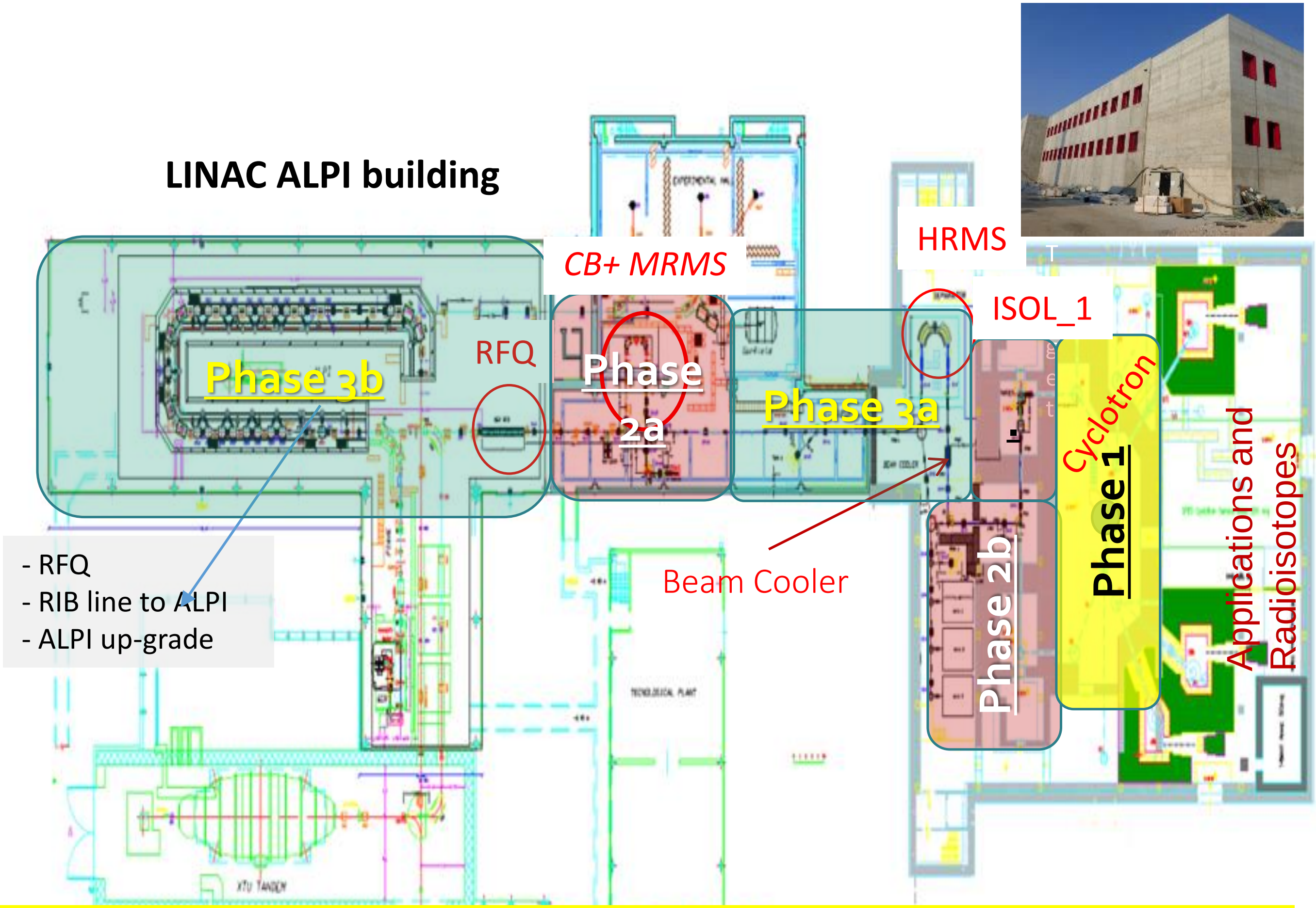
SPES building

50x60 m^2
-3 to +11 m height
24.000 m^3 of concrete
1.150 tons iron

3-4 m shielding wall thick

The SPES building 2016

SPES layout: ISOL facility installation phases



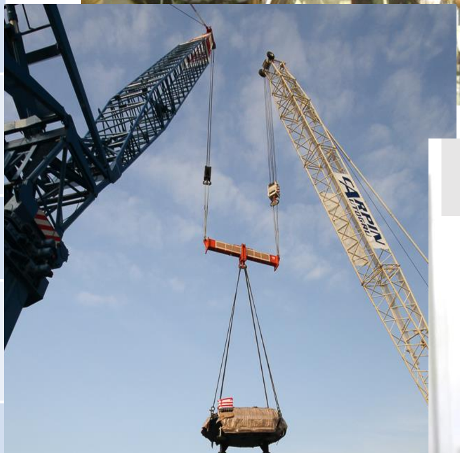
- **Phase 1. 2016** - Building + First operation with the cyclotron NOW!
- **Phase 2. 2017-18** - From C.B. to RFQ + SPES target, LRMS, 1+ Beam Lines
- **Phase 3. 2019 – 20 -** HRMS-BeamCooler + RFQ to ALPI

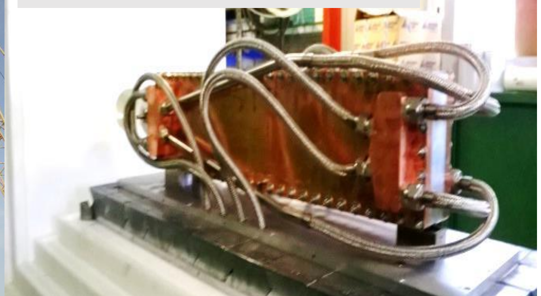
Breaking News:
May 30th 2016 → dual extraction 70 MeV beam – 3 μA
Sept 9th 2016 → acceleration 70 MeV beam – 500 μA
End Oct 2016 → expected to complete Site Acceptance Test

Cyclotron highlights

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

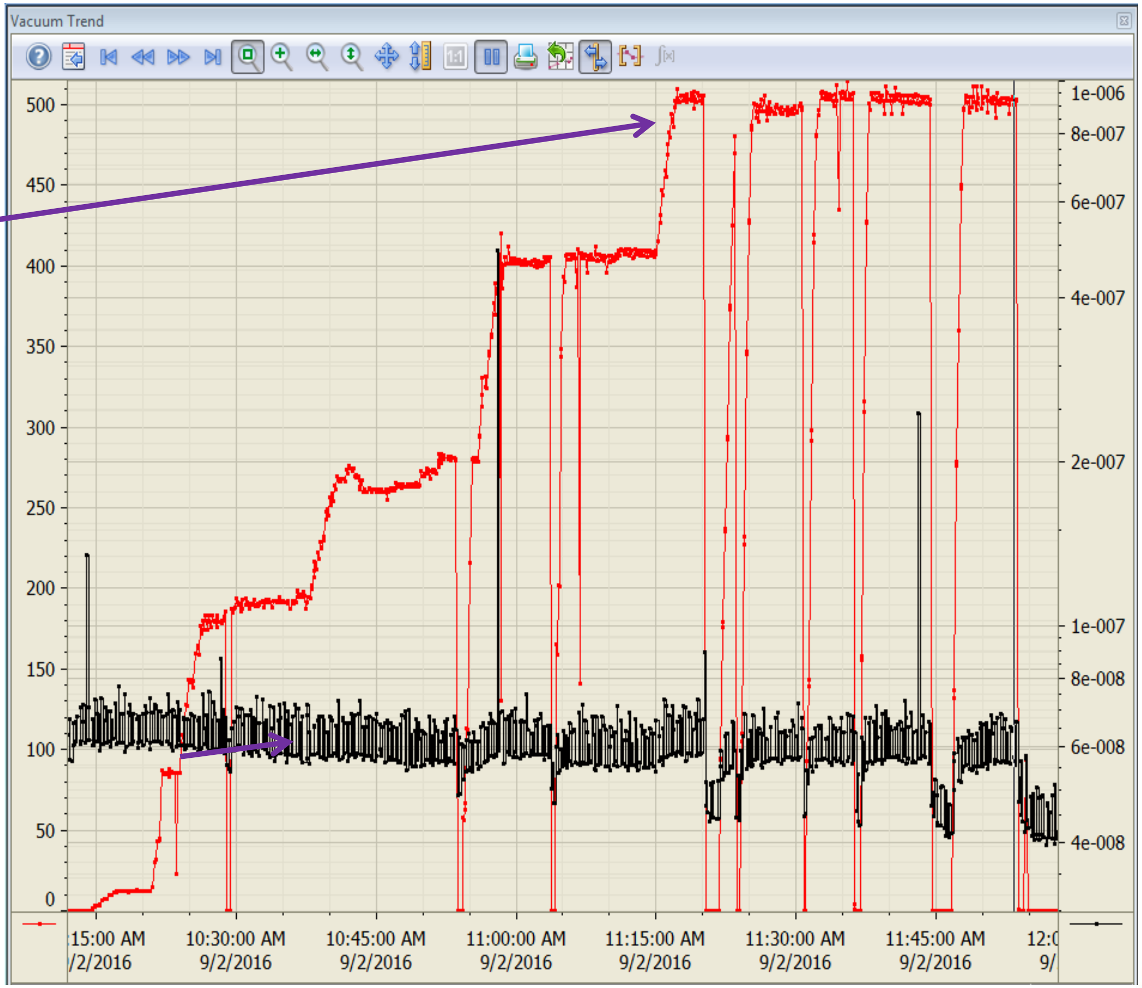

May 12, 2015

52kW beam dump

E.Boratto, F.Pasquato

Beam test on 50kW INFN target

500μA
70 MeV

$6x10^{-8}$ Torr

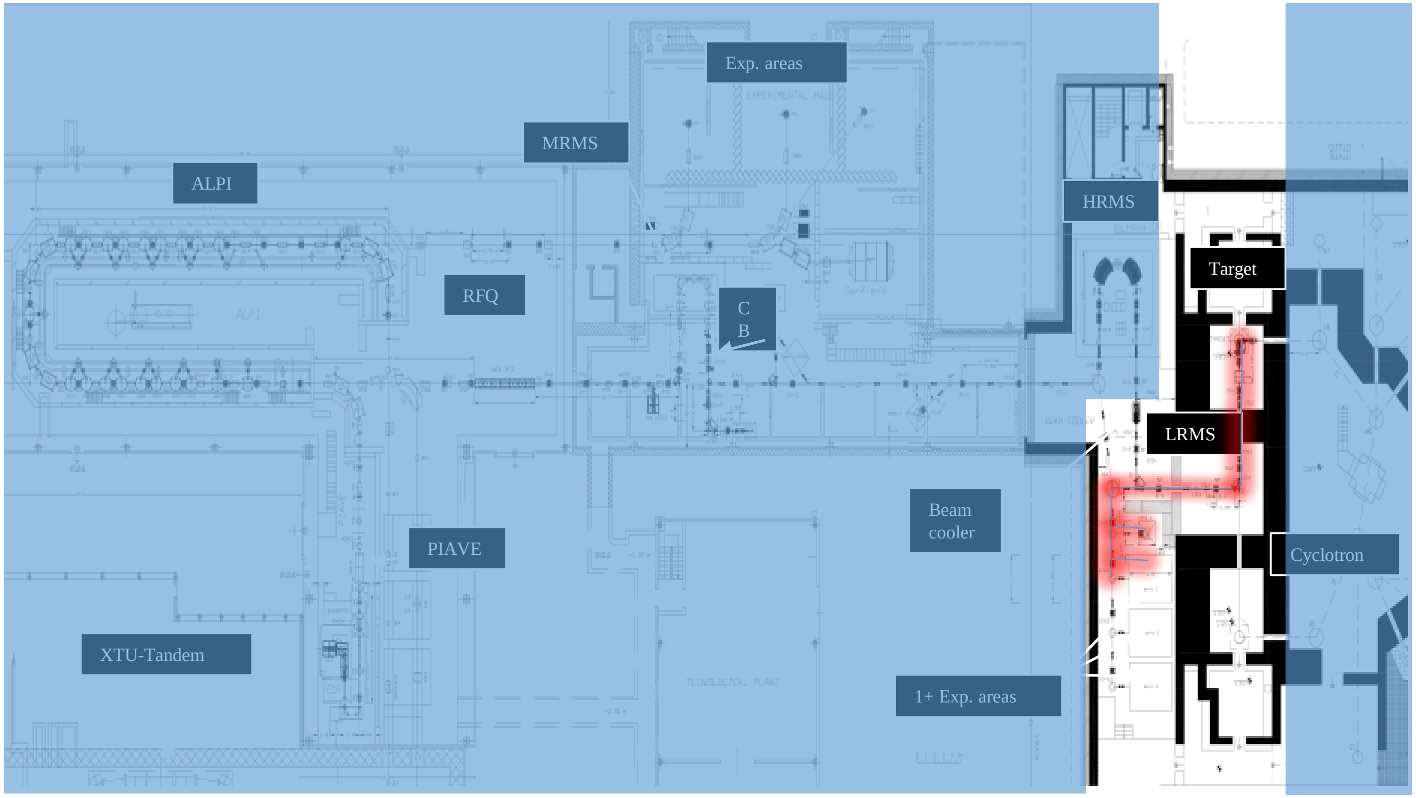


Best Cyclotron Systems, Inc.

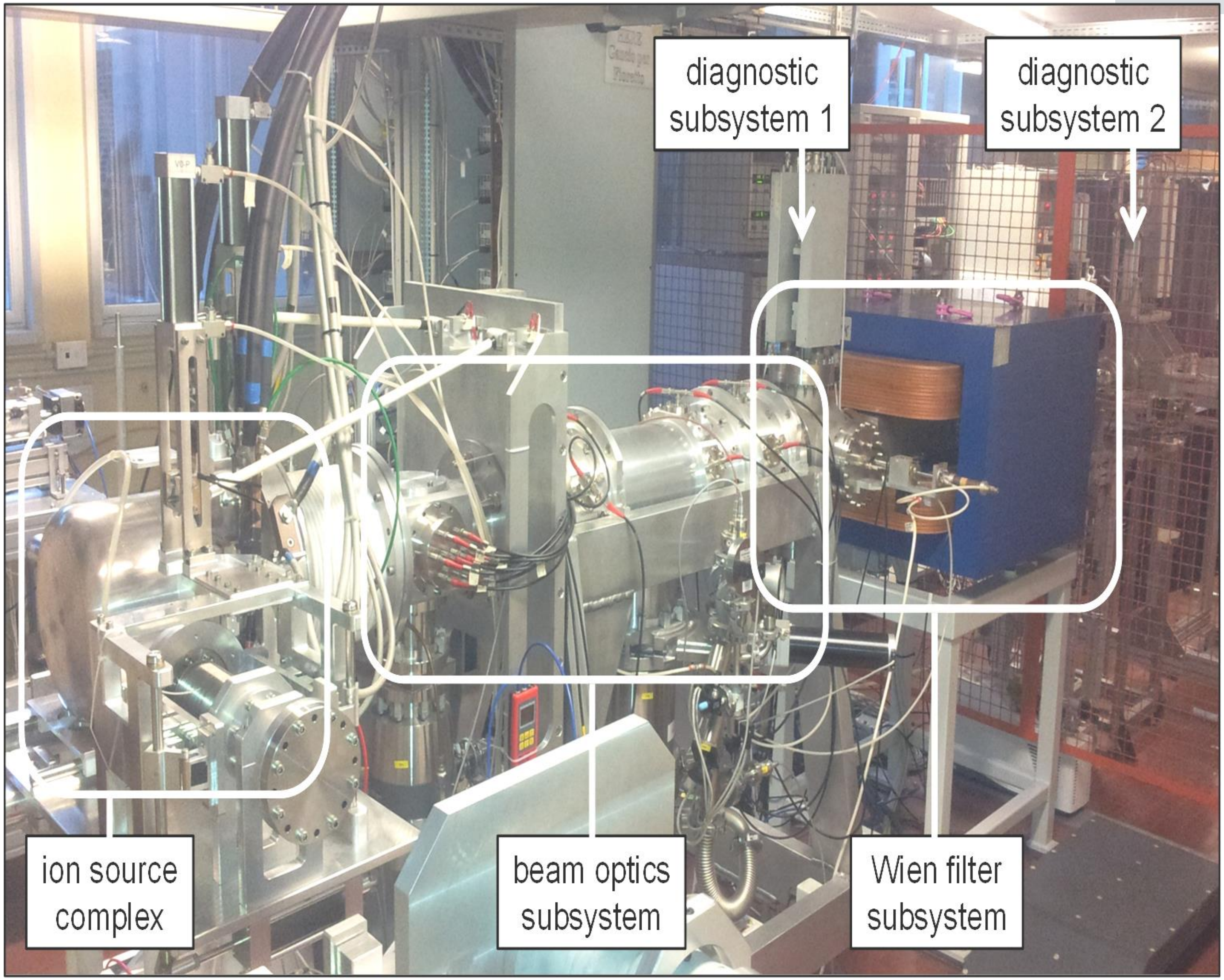
healthcare for everyone
TeamBest
Your True Partner

See A.Lombardi presentation

ISOL system and diagnostics



SPES_ISOL Front-End

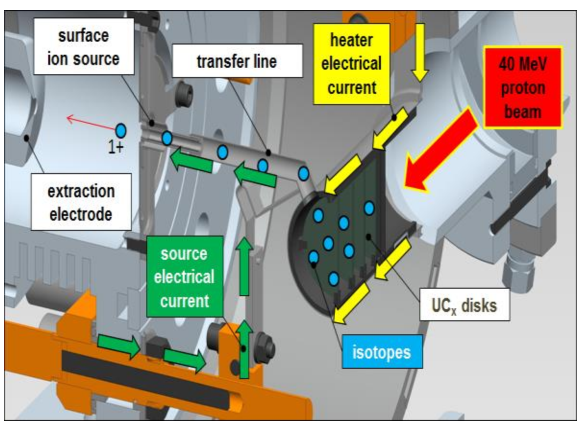


System under operation for ion sources commissioning.
Updated version under construction (radiation hardness improved). *See A.Andrighetto presentation*

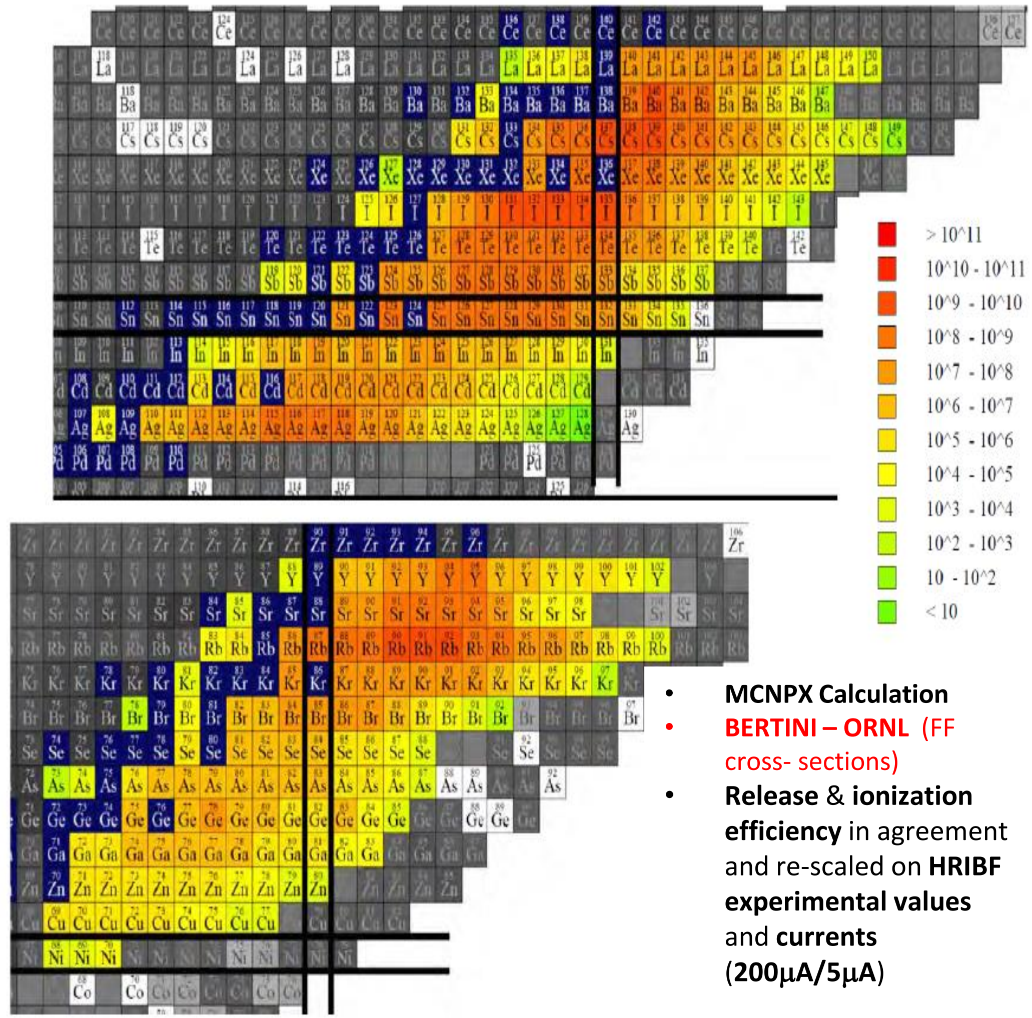
ISOL system: target material development

UCx target for neutron-rich ion production

Production Target



Expected intensity for reaccelerated beams (10^{13} f/s)

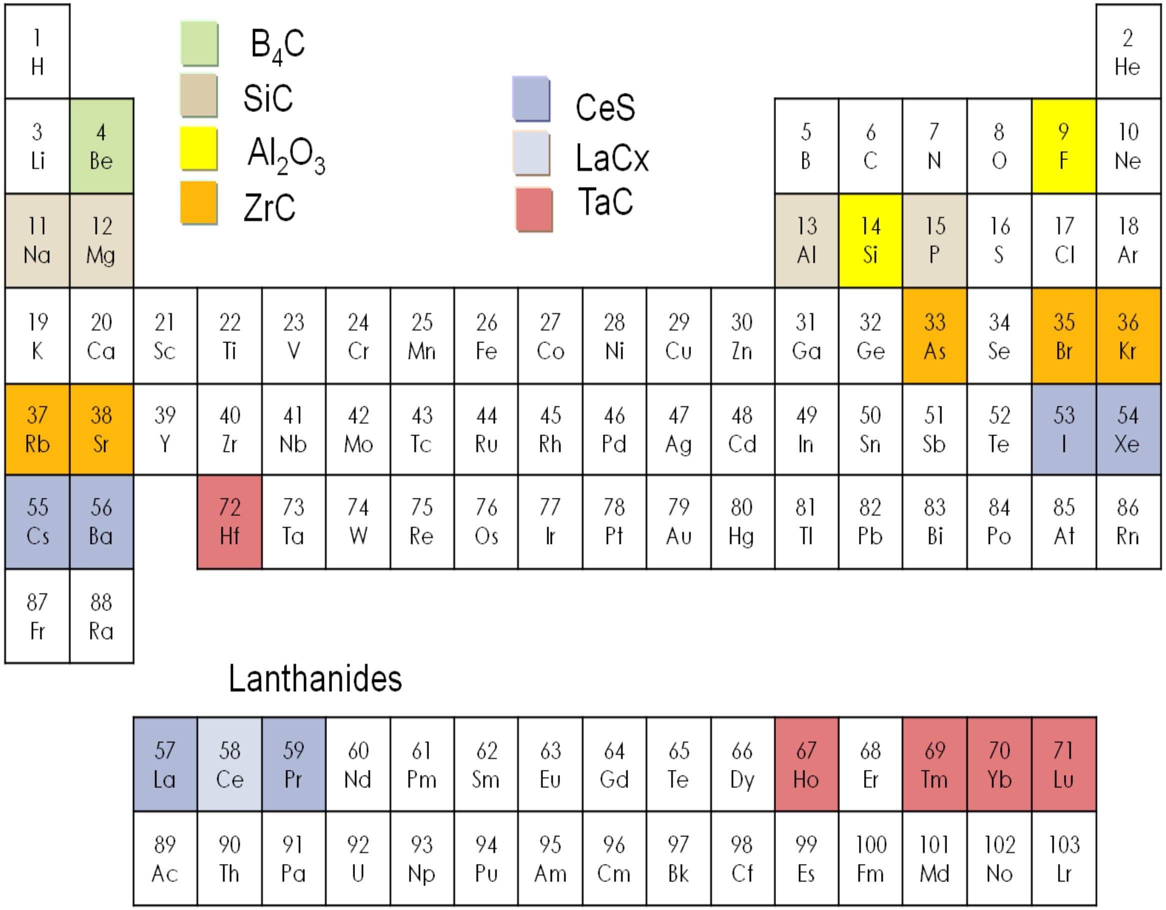


- **MCNPX Calculation**
- **BERTINI – ORNL** (FF cross- sections)
- **Release** & **ionization efficiency** in agreement and re-scaled on **HRIBF experimental values** and **currents** (**200μA/5μA**)

https://web.infn.it/spes/index.php/news/spes-beam-tables

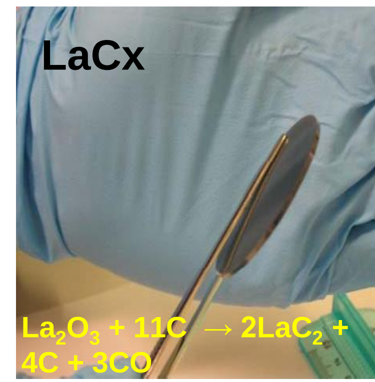
T. Marchi

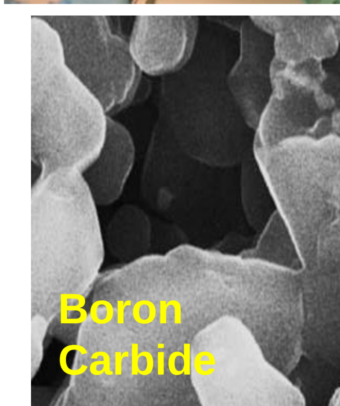
ISOL system: target material development



7 Be*
10 Be*
21 Na*
22 Na*
22 Mg*
23 Mg*
24 Al*
25 Al*
26 Al*
29 P*

SiC (Saint Gobain)

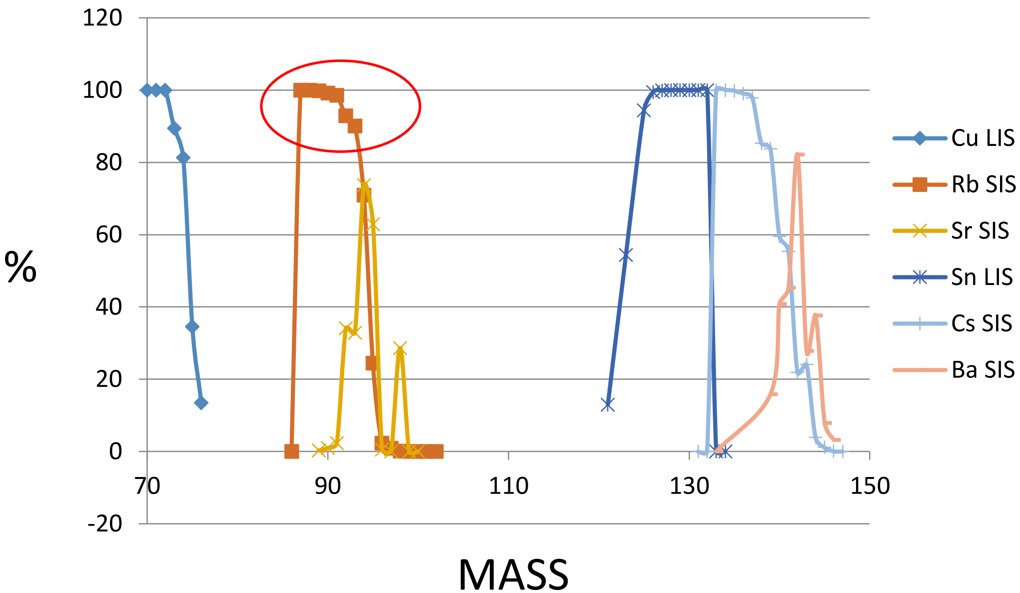




S.Corradetti

Ion source sectivity

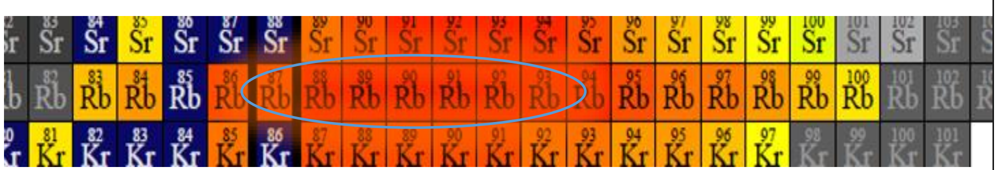
Evaluated beam selectivity with mass selection 1/200

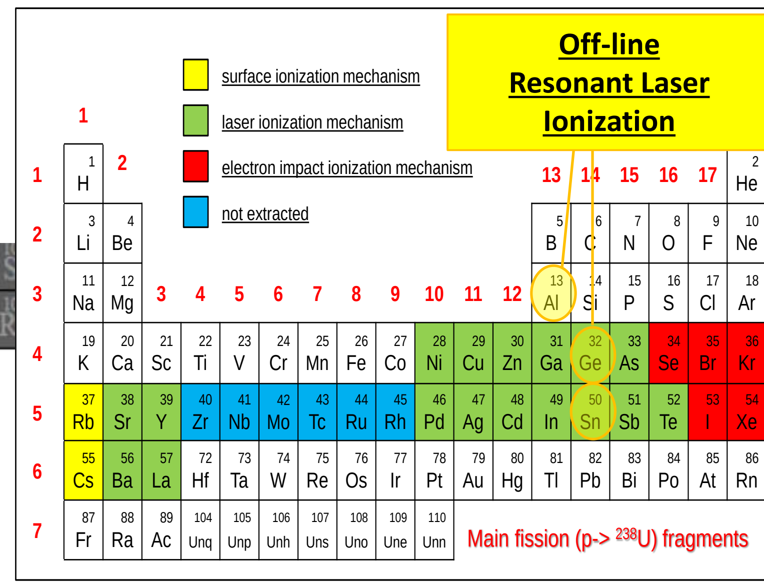


- Characterized by:
  - Ionization efficiency
  - Emittance
- The SELECTIVITY of the source depends on the ionization efficiency of each element.

Ion sources

Surface Ionization
Resonant Laser
Plasma ionization





Possible first n-rich beam: Rb

M.Manzolaro, D.Scarpa

Target Ion Source status

SPES target **in-beam power test** (SiC target)

Heater power compensated by proton beam.

- Up to **4 kW proton** beam in target.
- Stable temperatures
- Stable vacuum (3 10^{-5} mbar)
- **Validated FEM symulations**

(iThembaLABS, May 2014)

TIS unit endurance test:

Target system:
Tests at high temperature with Joule heating thermal load. **Heating power ≈ 12 kW**
≈ 415 testing hours at high temperature

Surface ionization source:
≈ 380 h (16 days) of operation at 2000-2200°C

Plasma source: optimized to avoid hot-spot and new alignment system.
≈ 160 working hours @ 2000°C

See A.Andrighetto presentation

Wien Filter optimization

Improved mass selection from 1/70 to more than 1/100
new design of electric and magnetic fields (A.Monetti PhD thesis)

INPUT

Emittance @ 25 keV = 5 π mm mrad (measured)

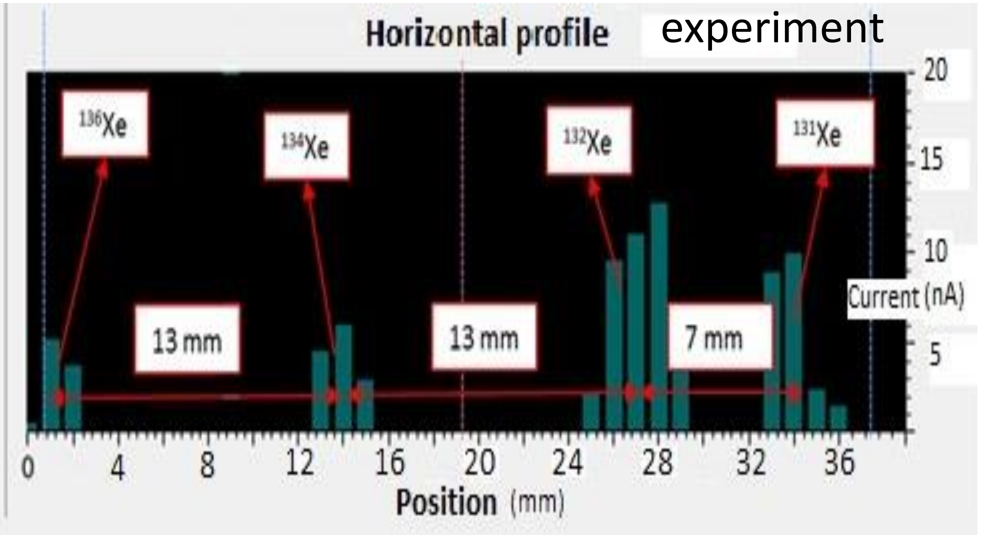
ΔE = 5 eV (assumed)

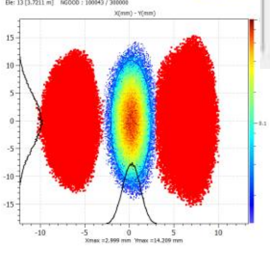
m = 150 amu

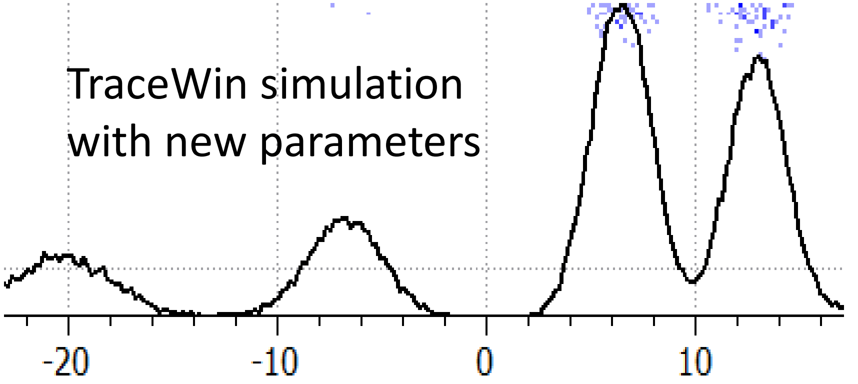
Energy = 42 keV
β = 0.8 T

Worst case

Plasma source, Xe @ 40 kV extraction







RESULTS

Beam size: 6 mm

M_{150} particle lost: 0.04%

“Unwanted” particles: 0.08% (M_{149})

Remote target handling

- Electro-Mechanical system based on AGV
- completed and under endurance test operation

R.Silingardi, A.Mozzi

See A.Andrighetto presentation

Phase 2: Low energy, low intensity beam monitors

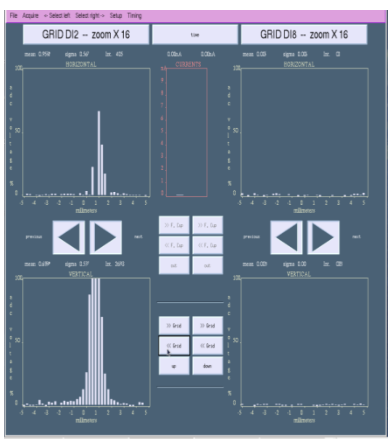
Diagnostic element	Number of units
Beam profile Monitor	58 (31+27)
Beam Current Monitor	50 (29+21)
Beam Emittance Meter	3
Tape Station	2
Energy, timing (Si, MCP)	

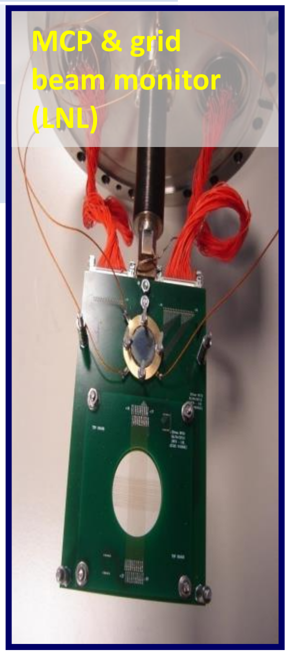
Linac

Report of the working group "Diagnostica SPES"

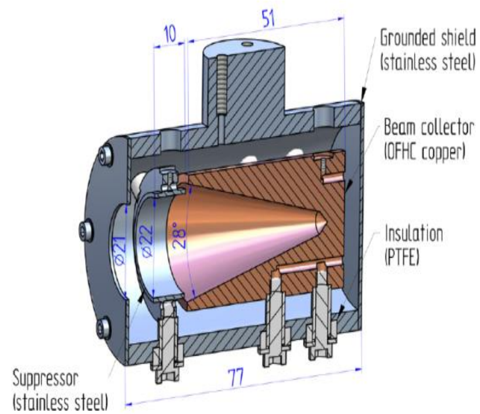
E. FIORETTO, R. CHERUBINI, M. POGGI
INFN - Laboratori Nazionali di Legnaro

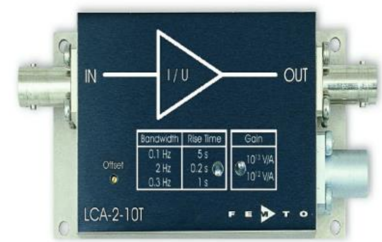
G. COLLAZUOL, D. FABRIS, D. MENGONI, G. MONTAGNOLI
University and INFN Padova





Horizontal and vertical profiles of a ^{40}Ca beam (charge state 9^+) at current of about 10 fA (10^4 pps).



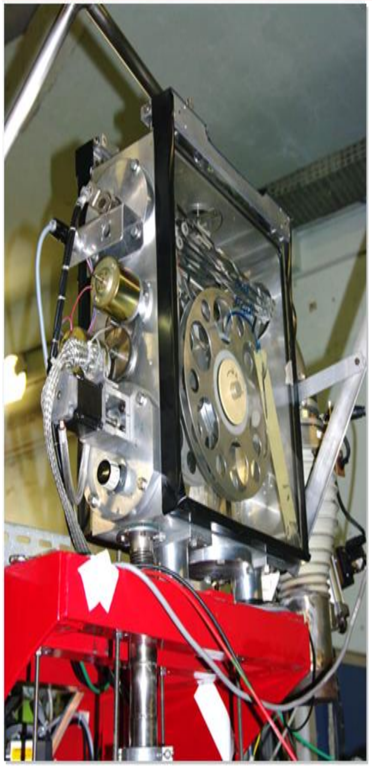


A FC prototype for measuring intensities of the order of the fA has been designed for the USR facility at GSI and tested at LNS.

Instrumentation@SPES: Tape system

Collaboration ALTO-INFN-iThembaLabs

Tape station based on Orsay design

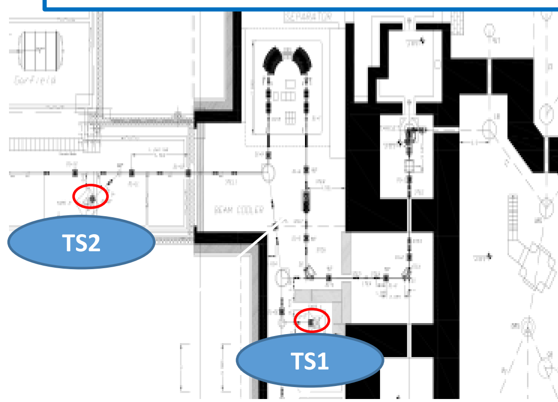


Beta decay station as a permanent and flexible setup
- Tape station + β detector
- Coupling to HPGe, LaBr3, neutron detectors etc…

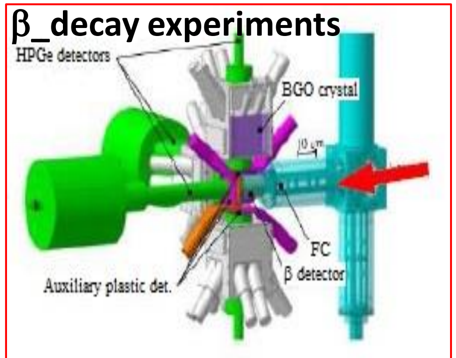
Diagnostics for SPES:
tape stations
to characterize RIBs

First station for target characterization

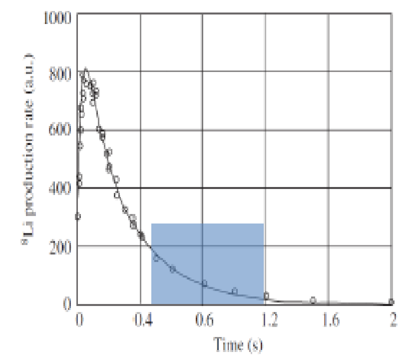
Second station for beam characterization after HRMS



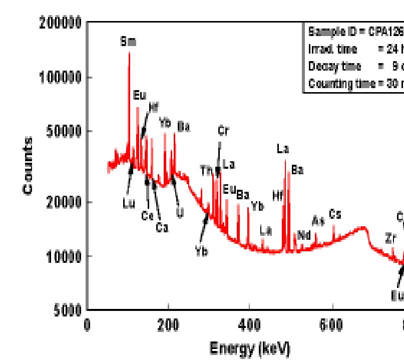
β_decay experiments



Beam characterization:
- Release Curve

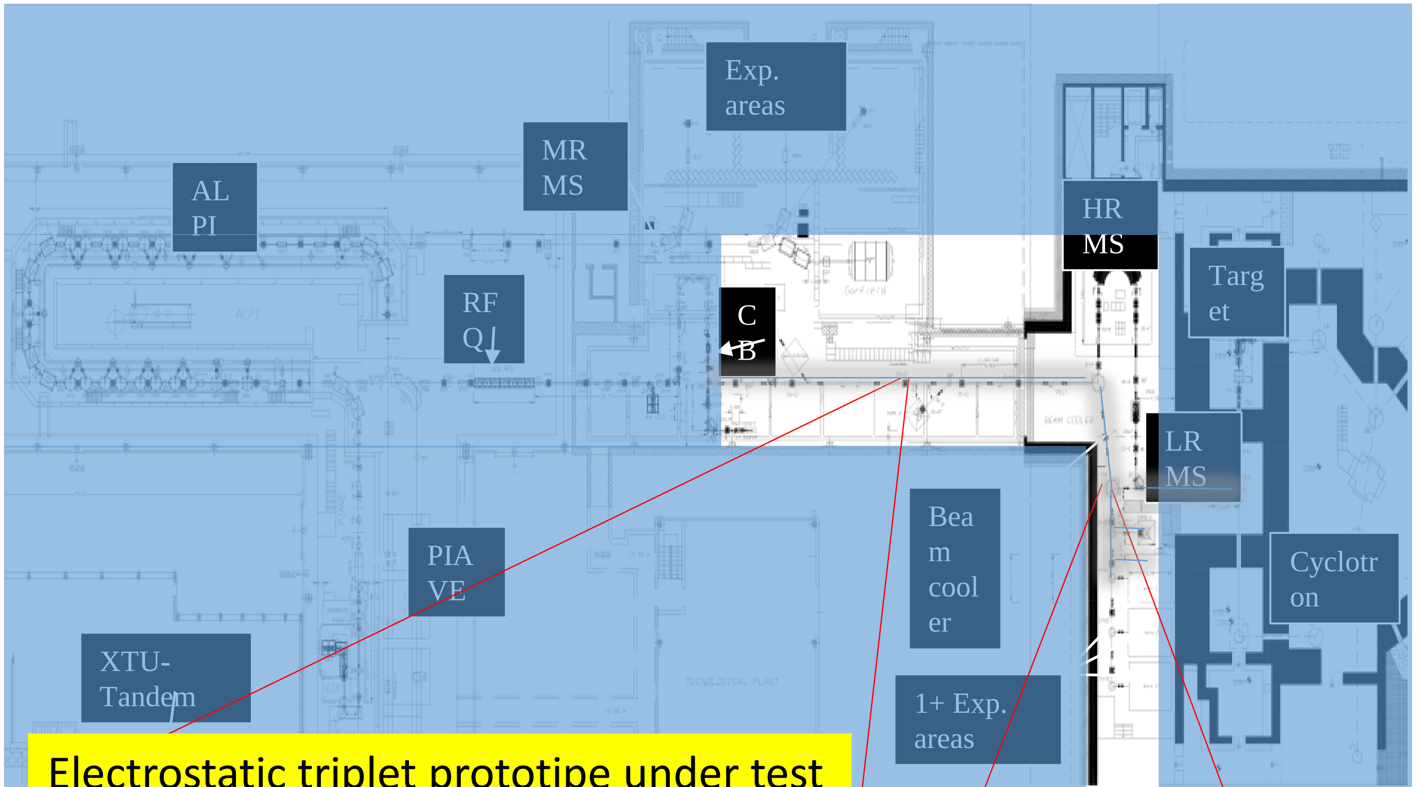


- Beam Composition and Isotopic Yields

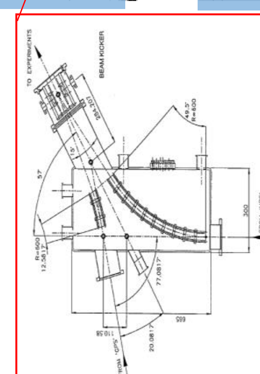


Phase 3: Beam transport and mass selection

1+ beam transport and selection



Electrostatic triplet prototipe under test

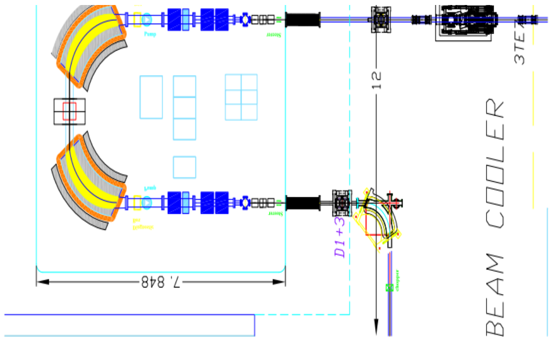


Electrostatic dipoles under development

Collaboration with Tony Mendez (ORNL-HRIBF)

Phase 3: High Resolution Mass Separation

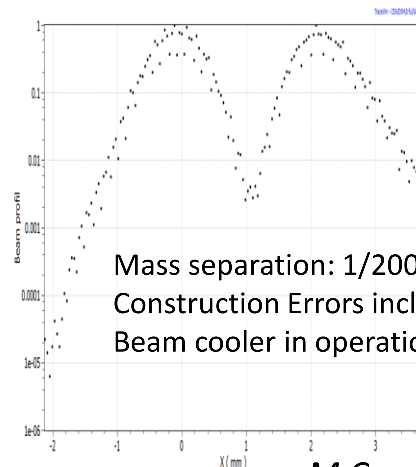
Collaboration: LNS, LNL, CENBG Bordeaux
Physics design: 1/40000



ΔE= ± 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%

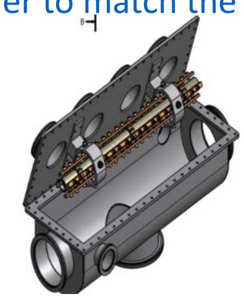
^{132}Sn beam in simulations

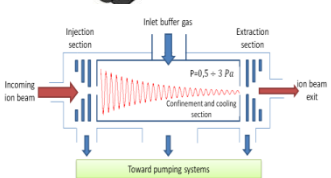


Mass separation: 1/20000
Construction Errors included
Beam cooler in operation

M.Comunian

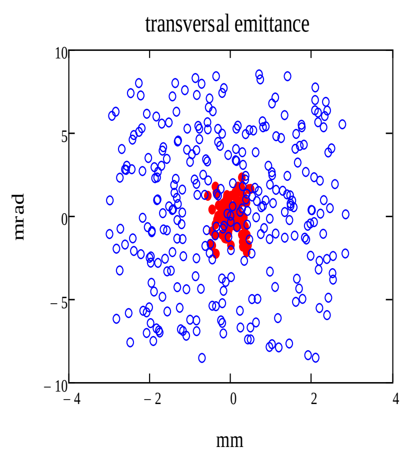
Beam Cooler to match the HRMS input requirements





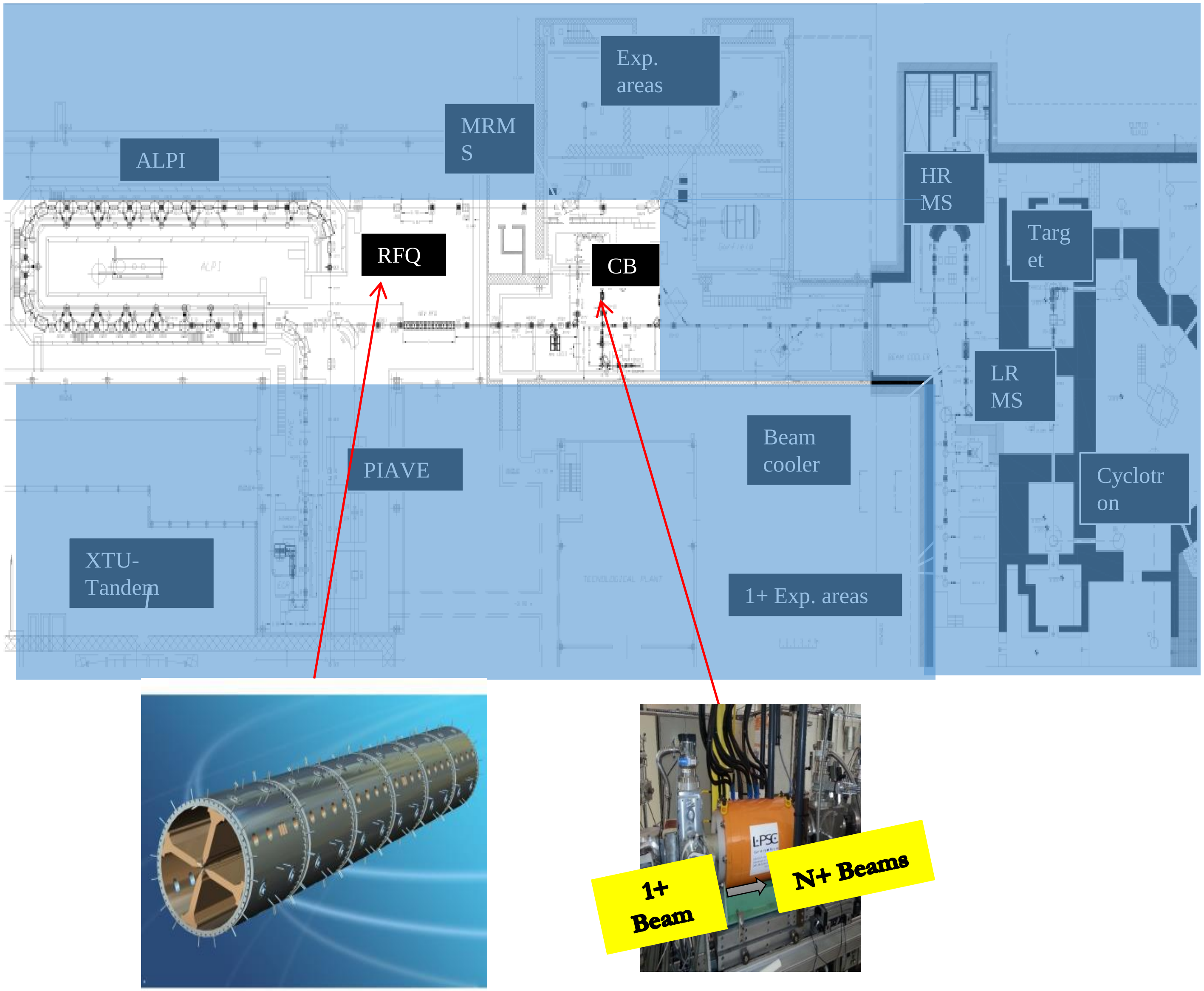
M.Maggiore

Collaboration with LPC_Caen for BC development (SPIRAL2)

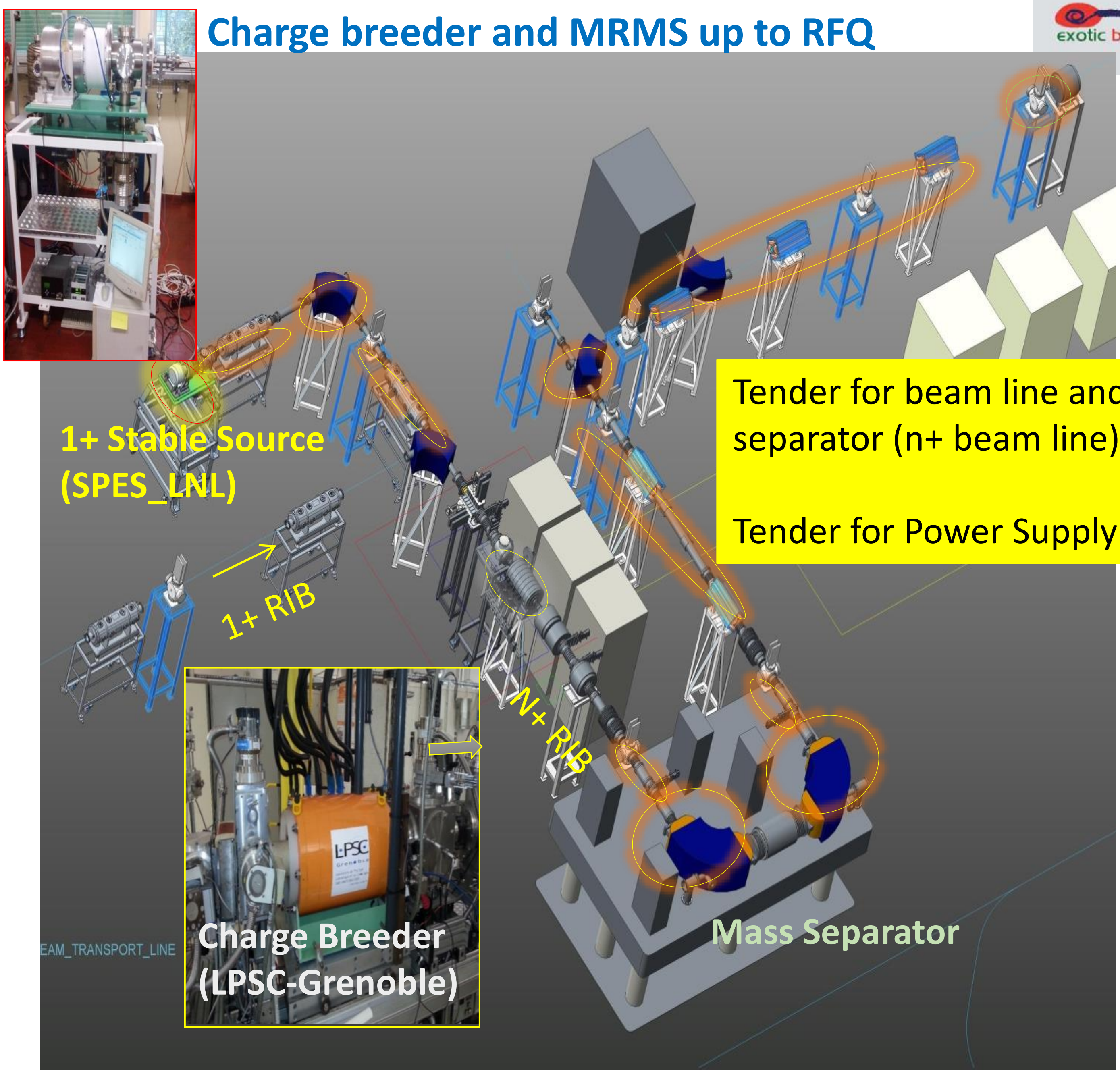


Input T emittance
Output T emittance

Beam transport and reacceleration



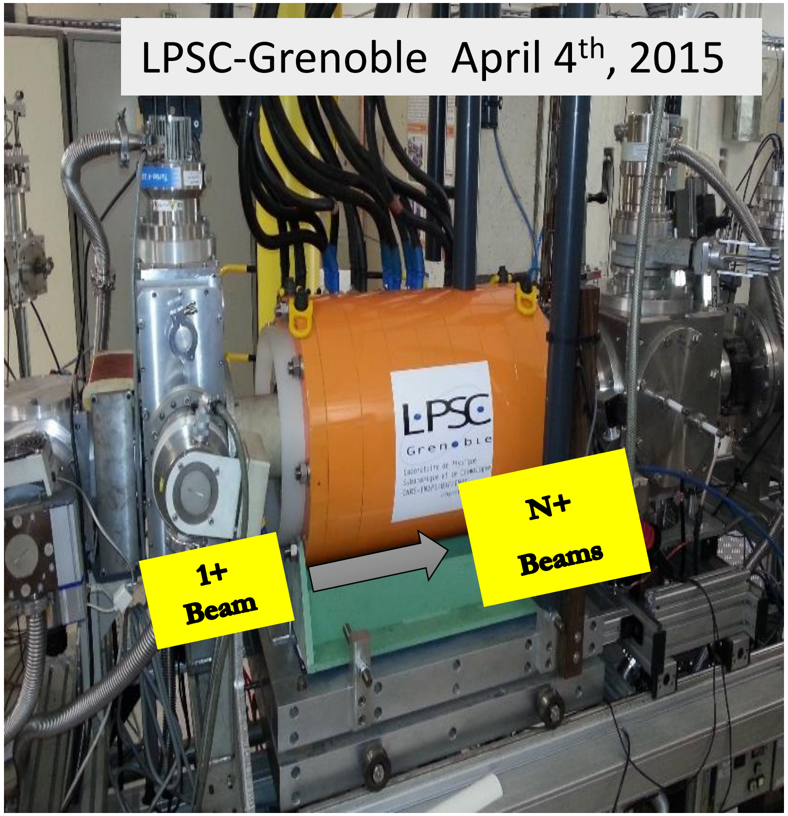
Phase 2: Exotic Beam reacceleration: Charge breeder and MRMS up to RFQ



Tender for beam line and mass separator (n+ beam line): 1.5M€

Tender for Power Supply: 0.7M€

Phase 2: Validation of the SPES-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*

A.Galatà

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

- 2015 Commissioning at LPSC
- 2015 Delivery to LNL
- 2016-17 Installation and test

M.Manzolaro

Assembly of 1+Source Front-End

SPES production, similar to ISOL source

Phase 3: the SPES-RFQ

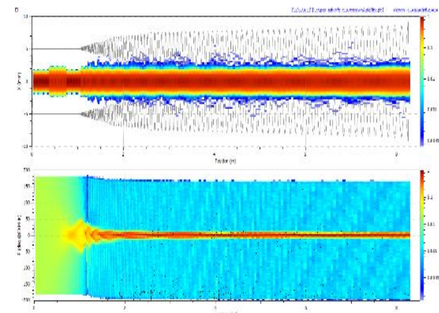
Synergies with IFMIF project

Design completed
Construction started (electrodes 1,3 M€)
Additional study to finalize RF

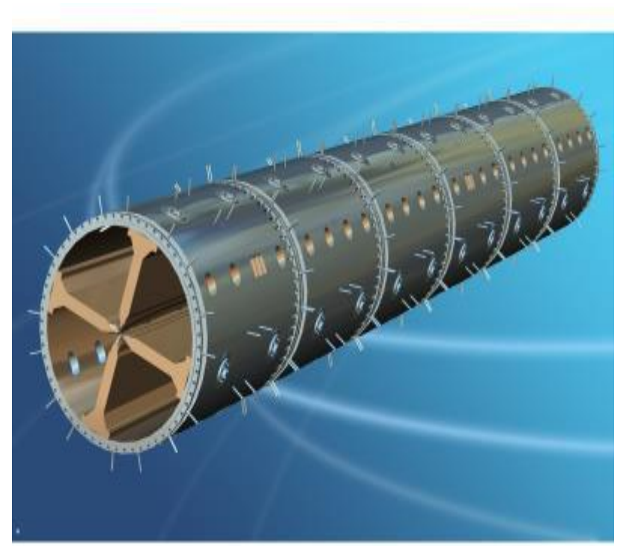
Production sequence & Scheduling
Appoved by TAC

- Schedule : Dec 2015 to Sept 2019
  - Electrodes call for tender : dec 2015
  - Electrode production : sept 2016
  - Completion of 24 electrodes : sept 2018
  - Tank call for tender : march 2016
  - Tanks Completion : dec 2018
  - Assembly and low power testing : june 2019
  - High power tests : sept 2019

High power RF
Coupler 200kW 100%
duty cycle

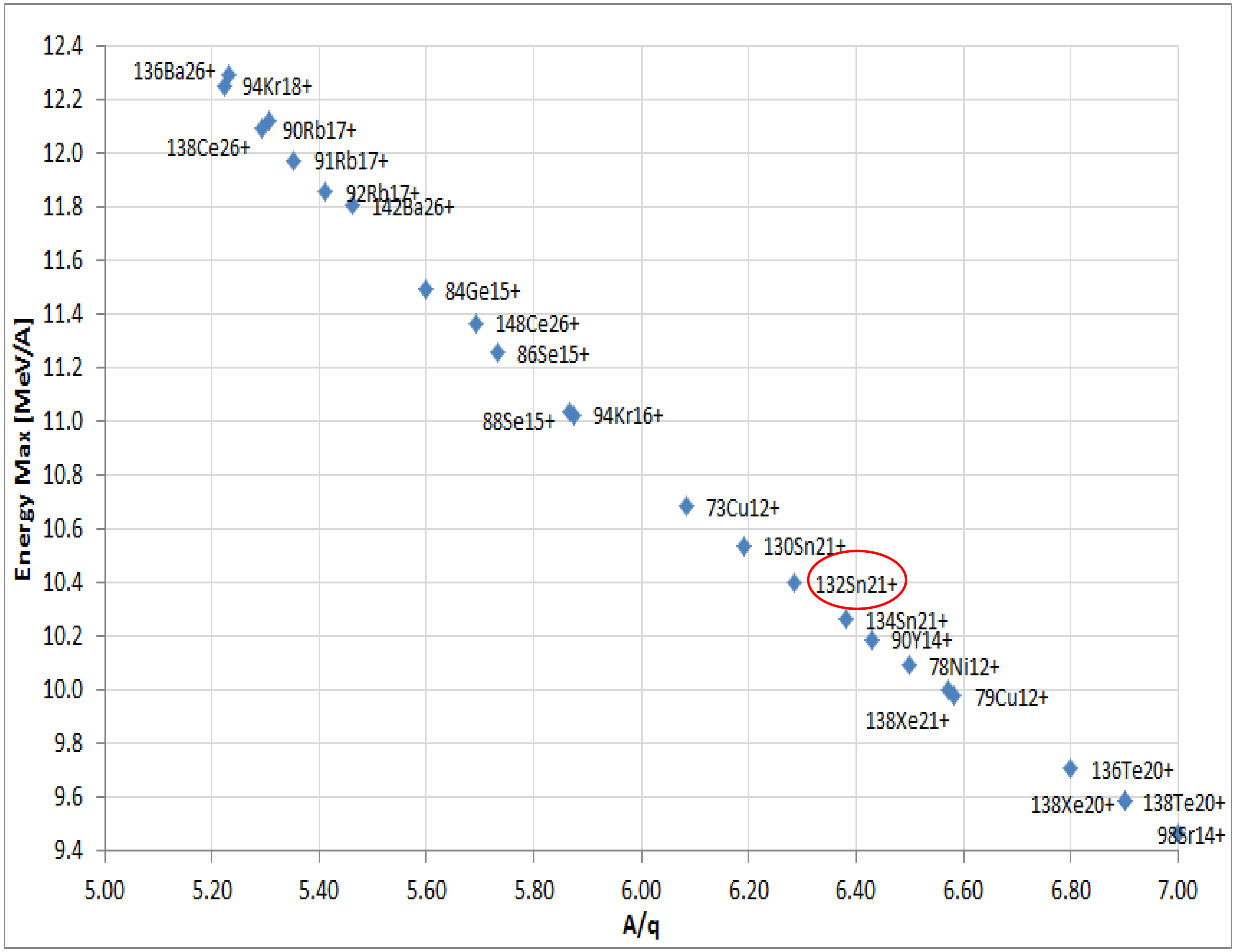


Physics design



A.Palmieri, A.Pisent

Energy from SPES Post-Accelerator as function of A/q



(M. Comunian)

Preliminary results from alpi performances with 2 cavities as margin, Low Beta=5 MV/m, Medium Beta=4.3 MV/m, High Beta=5.5 MV/m

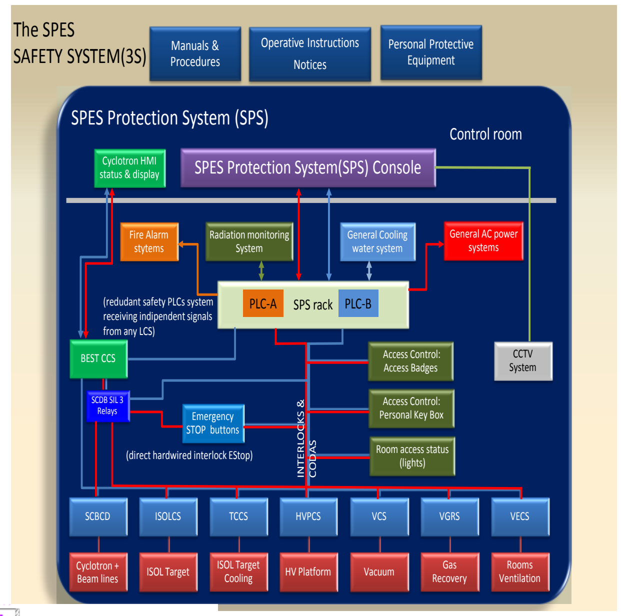
SPES safety system

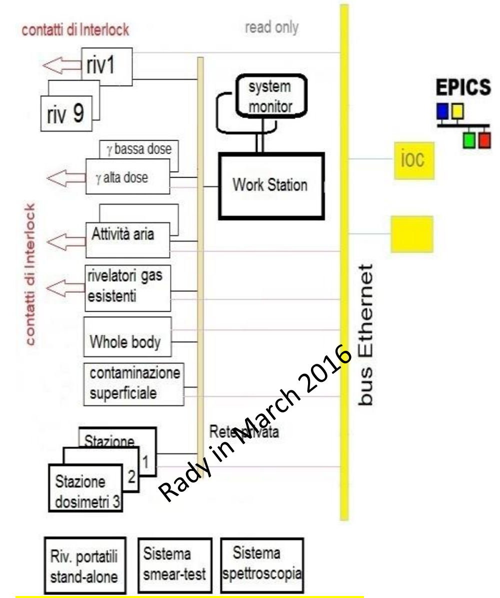
A SIL3 safety system is under development (assigned to PILZ)

A simplified system is in operation for cyclotron test

Cyclotron and beam lines

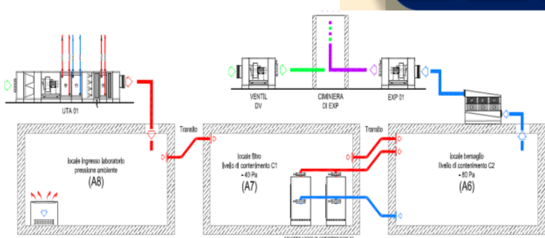
ISOL target



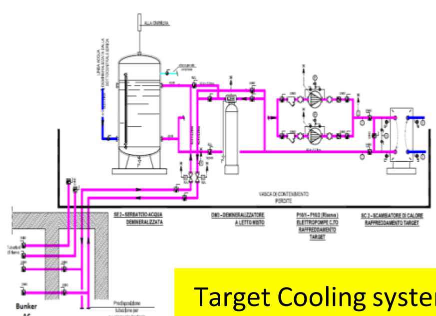


Radiologic survey system

Access Control System



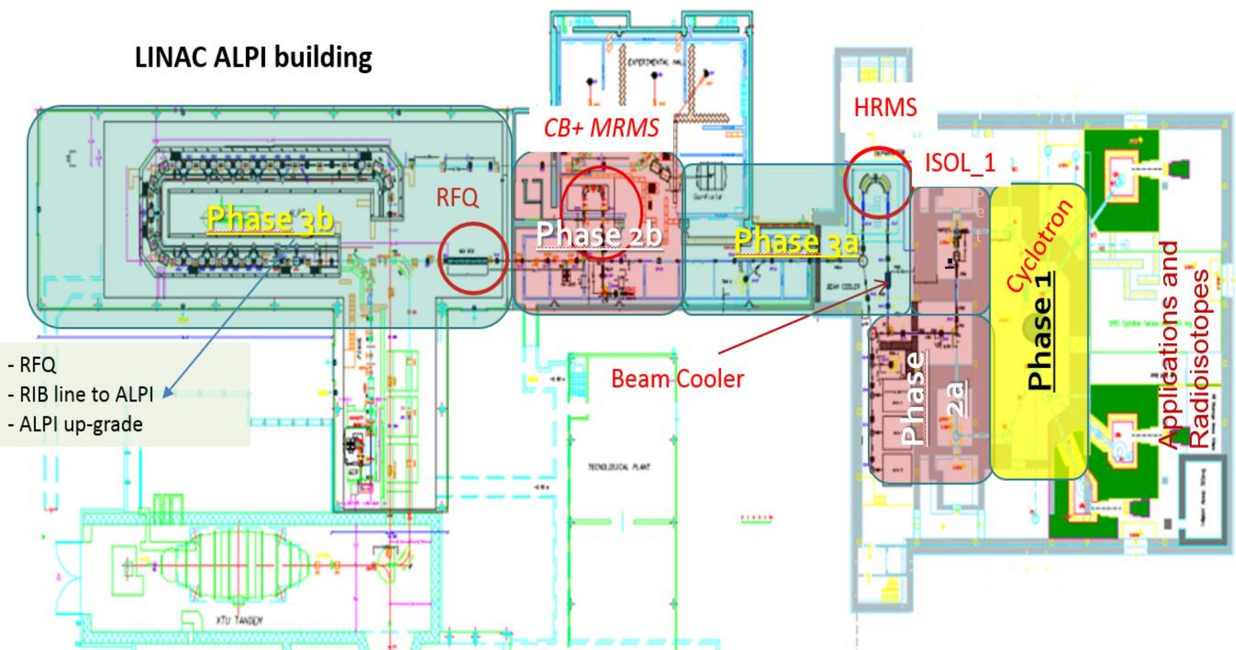
ventilation



Target Cooling system

SPES installation timing

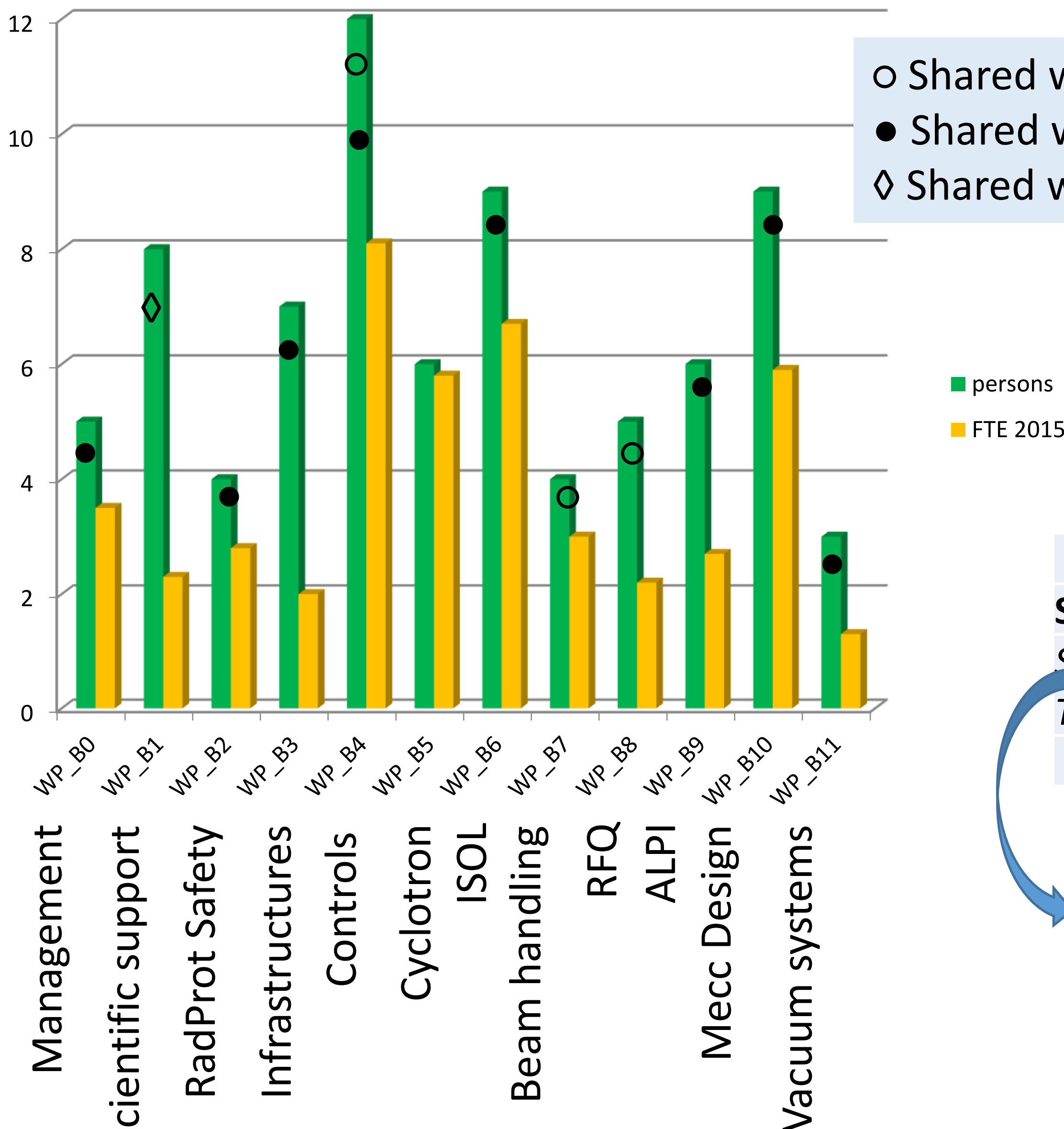
2017				2018				2019				2020				2021			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	FASE 2A: INSTALLATION					FASE 2A: HW COMM	FASE 2A: BEAM COMM												
								FASE 3A: INSTALLATION					FASE 3A: HW COMM		FASE 3A: BEAM COMM				
			FASE 2B: INSTALLATION					FASE 2B: HW COMM	FASE 2B: BEAM COMM										
										FASE 3B: INSTALLATION					FASE 3B: HW COMM	FASE 3B: BEAM COMM			



- INSTALLATIONS
- HW COMMISSIONING
- STABLE BEAM COMMISSIONING
- RIB COMMISSIONING
- Critical installation periods

Phase 1 completed

SPES personnel (46,2 FTE/ 78 persons)



○ Shared with IFMIF
● Shared with LNL operation
◊ Shared with INFN research

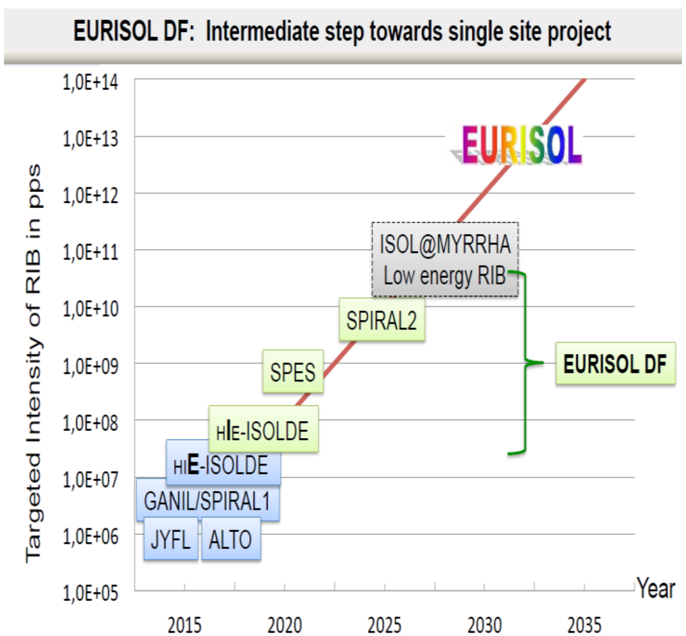
	persons	FTE
SPES total	**78**	**46**
STAFF	*40*	*15*
TD, fellowship	*38*	*31*

Will change for installation

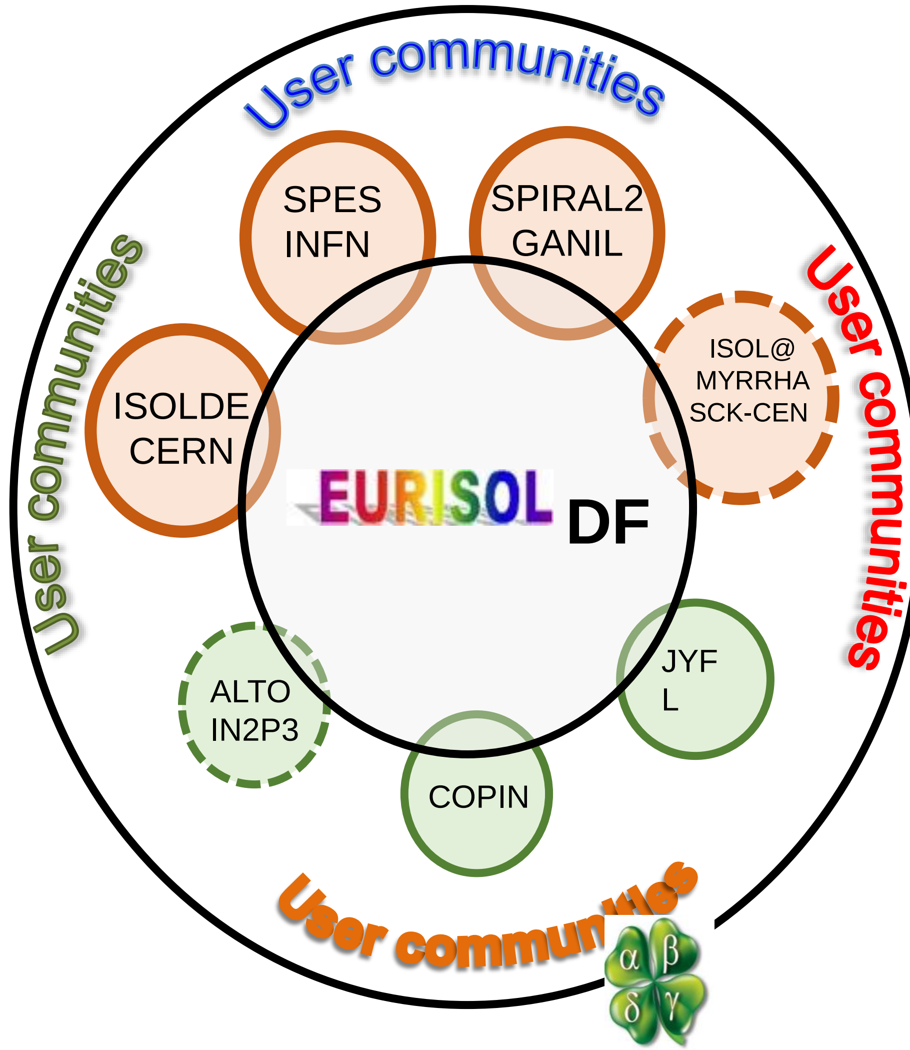
EURISOL Distributed Facility (DF) Initiative

- 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

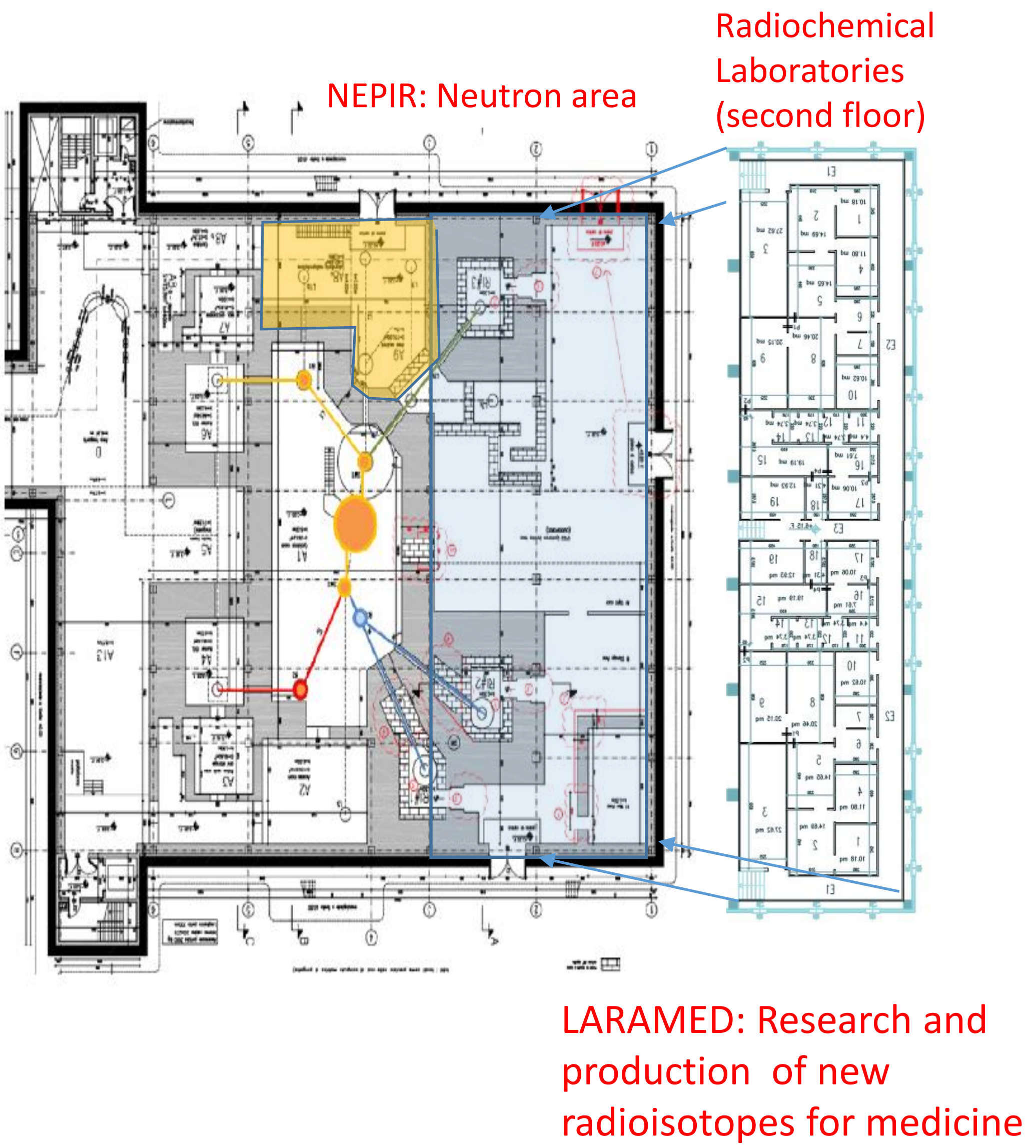
Project to be submitted for the 2018 update of the ESFRI roadmap



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



SPES LAYOUT: Applications areas



SPES γ: Radioisotope Production & research

LARAMED

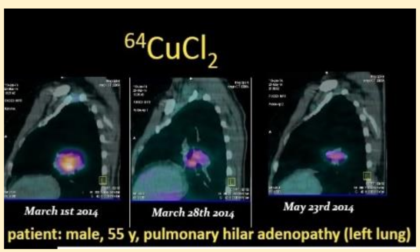
Funded with 6.8 Meuro

Production of radionuclides for medicine using the SPES cyclotron (production&research)

Joint Research lab of INFN, CNR, Universities and external companies:

- Cross Section measurements through target activation
- High power targets tests
- Radio-isotope/radio-pharmaceutical Production test facility

(^{99m}Tc, ^{64}Cu, ^{67}Cu, ^{82}Sr, ...)



Production laboratory in Joint Venture with external companies:

Selected isotopes of medical interest

Sr-82/Rb-82 generator

T1/2: 25.6 d EC 100% **/ 1.3 min** photons 511keV, 776keV

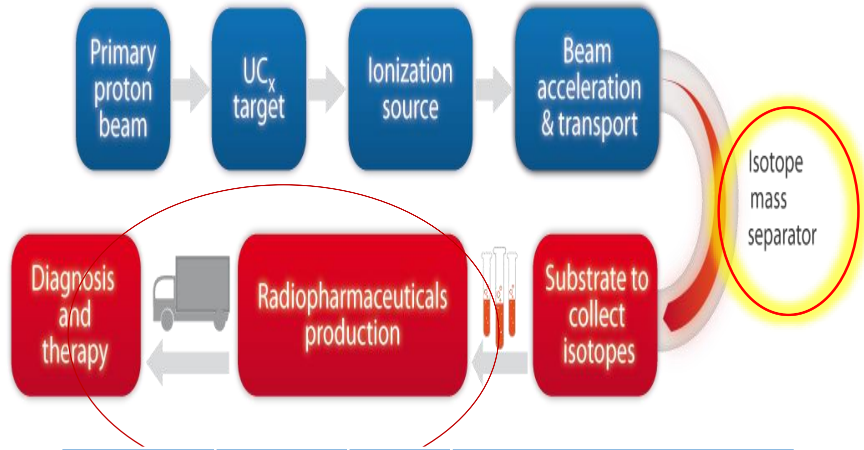
STATUS:

- Building and infrastructures under development
- Design of radiochemistry labs
- Design of beam line and target management
- Contract with company for radioisotopes production to be finalized

ISOLPHARMA*

* INFN Patent

Use of ISOL technique for Direct isotope on-line separation : very high specific activity (10^{4-5} than standard)



Radiopharmaceutical	Targeted organs	Half-life	Specific Activity (GBq/mg)	
			SPES production	Neutron capture reaction
$^{89}Sr\text{-}SrCl_2$	Bone	50.5 d	≥ 597	≥ 0,004

After 2 days of irradiation: 4.1E+15 atoms of ^{89}Sr = 18 mCi (patient dose: 4 mCi every 6 months).

ARRONAX (Nantes) – SPES collaboration: Isotopes and high-Power target developments

A.Duatti

Collaboration with Pd_University (Pharmacy) for preliminary test

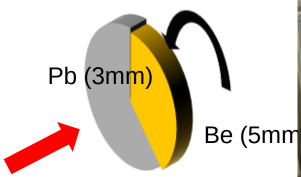
A.Andrighetto

SPES γ: NEPIR: Neutron production at SPES

Design study

Integral neutron production at SPES Cyclotron Proton beam= 70 MeV, 500 μA Target = W 5mm			
Energy region (MeV)	**Sn (n/s)** **$\sim 6 \cdot 10^{14}$ s^{-1}**	**Φ_n @ 2.5 m ($n\ cm^{-2}\ s^{-1}$)**	**Φ_n @ 1 cm ($n\ cm^{-2}\ s^{-1}$)**
1 < E < 10	$\sim 5 \cdot 10^{14}$ s^{-1}	5×10^{8}	3×10^{13}
10 < E < 50	$\sim 1 \cdot 10^{14}$ s^{-1}	1×10^{8}	$6x10^{12}$

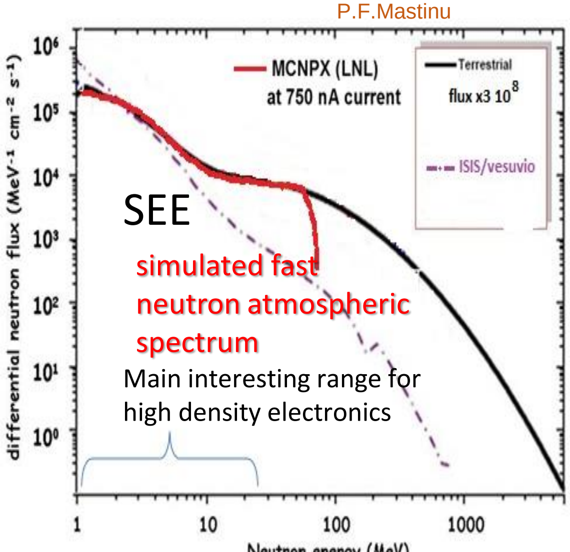
Continuum and Quasi Mono Energetic fast neutron spectra

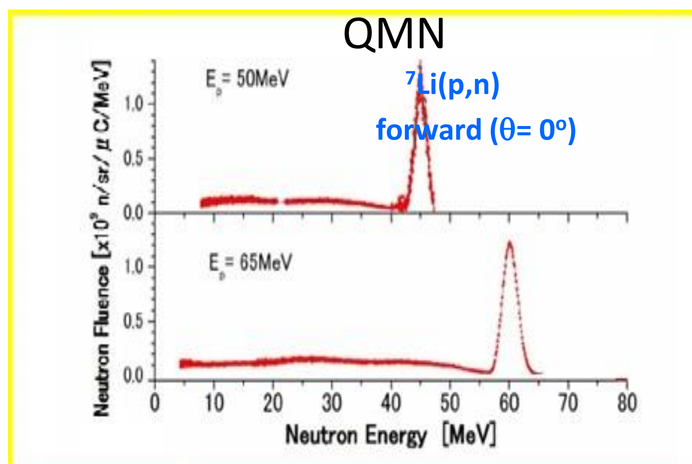


70 MeV protons

Target, P.F.Mastinu

- Cross section data for basic science and astrophisics
- Oncology studies
- Calibration of radiation instrumentation
- Radiation protection studies (shielding-benchmarks)
- Radiation hardness studies (Single Event Effect)





SPES in summary

Items in construction

- Building and infrastructures*
- Cyclotron*
- ISOL system and sources
- Charge Breeder (starting 2014)
- Linac ALPI up-grade
- Beam transport
- Control system*

- Authorization to cyclotron operation (completed)

Items under final Design

- RFQ
- MRMS (n+ separator)

- LARAMED

- Safety system*
- Authorization extension to UCx full power and applications

Items at Preliminary Design

- HRMS
- Beam cooler

- NEPIR neutron facility

Second SPES workshop 2014

* Items on critical path in 2014

SPES in summary

Items in construction

- Building and infrastructures
- Cyclotron
- ISOL system and sources (90%)
- Charge Breeder
- Linac ALPI up-grade
- Beam transport
- Control system*
- RFQ
- MRMS (n+ separator)
- LARAMED
- Authorization to cyclotron operation

Items under final Design

- RFQ
- MRMS (n+ separator)
- LARAMED
- HRMS (starting soon)
- Safety system
- Authorization extension to UCx full power and applications *

Items at Preliminary Design

- HRMS
- Beam cooler
- NEPIR neutron facility

Third SPES workshop 2016

* Items on critical path in 2016

(in RED= completed)

Thank you for your attention