SPES Project

Selective Production of Exotic Species

SPES exotic beams for science

Gianfranco Prete LNL-INFN

On behalf of the SPES Collaboration

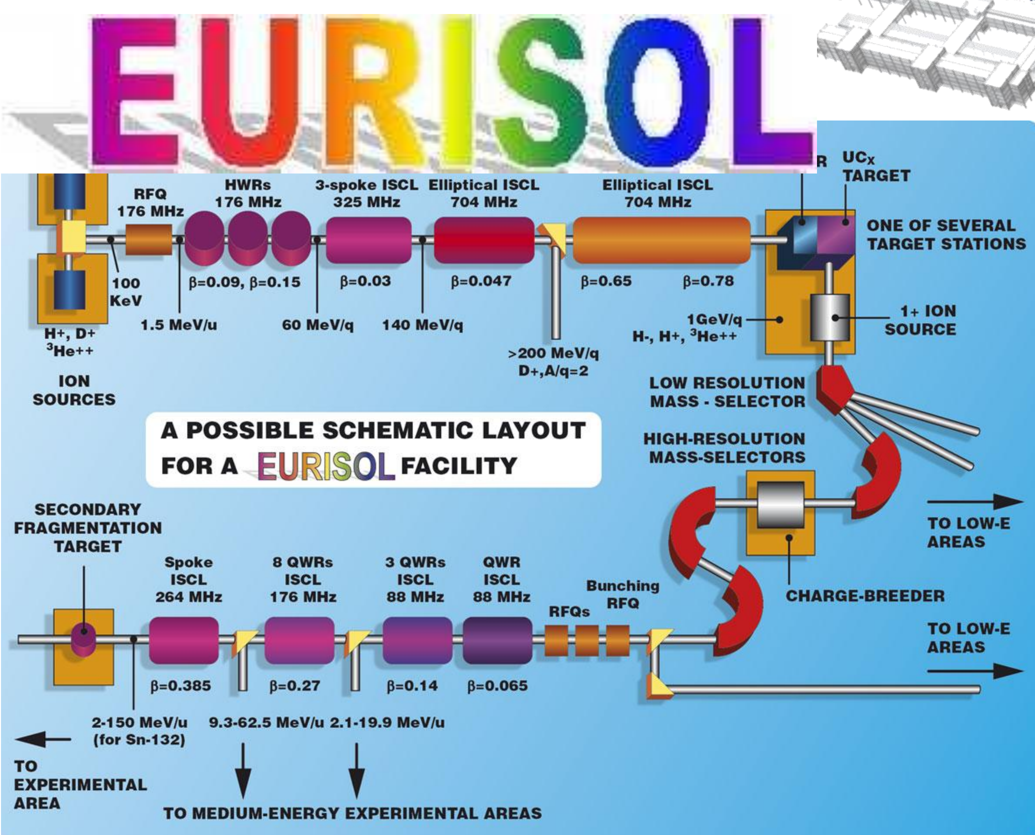
7th Italy - Japan Symposium on Nuclear Physics

Milan (Italy), November 20-23, 2012

Long Range Plan for Nuclear Physics in Europe

Nuclear Physics European Coordination Committee

European ISOL facility



European In Flight facility

SPES strategy

ISOL second generation facility

1. Develop a *Neutron Rich ISOL* facility delivering Radioactive Ion Beams at 10AMeV using the LNL linear accelerator ALPI as re-accelerator .

2. Make use of a *Direct ISOL Target* based on UCx and able to reach 10^{13} Fission/s to produce neutron rich exotic beams.

3. Apply the technology and the components of the ISOL facility to develop applications in neutron production and medicine.

Exotic nuclei

ISOL facility for Neutron rich nuclei by U fission 10^{13} f/s

high purity beam Reacceleration up to $\geq$10 MeV/u

Applications

Proton and neutron facility for applied physics

Radioisotope produduction & Medical applications

ISOL Roadmap in EUROPE

TODAY Generation 1

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

Effective Mass resolution 1/4000

SPIRAL – GANIL

ISOLDE CERN

INFN LNS - EXCYT

2014-2025 Generation 2

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

Effective Mass resolution 1/20000

GANIL spiral2 laboratoire commun CEA/DSM CNRS/IN2P3

HIE ISOLDE

SPES exotic beams for science

European ISOL facility EURISOL

FROM 2025

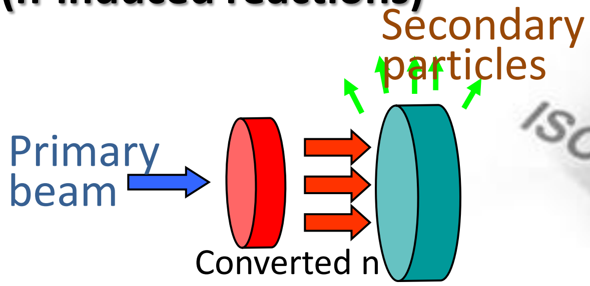
> 10^{15} fission/s
100 MeV/n (A=130)
Mass resolution 1/20000

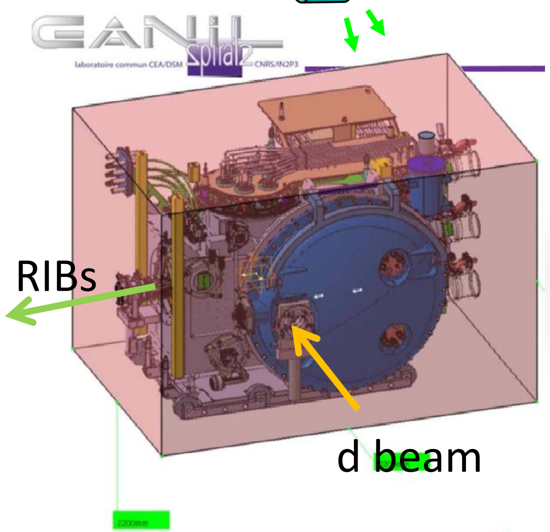
Radioactive Ion Beams: ISOL production methods

2 step

High Power target (n-induced reactions)

➡ Decoupling the power of the driver beam from the RIB production target





Height: 2.15 m
Length: 3.20 m
Width: 2.20 m
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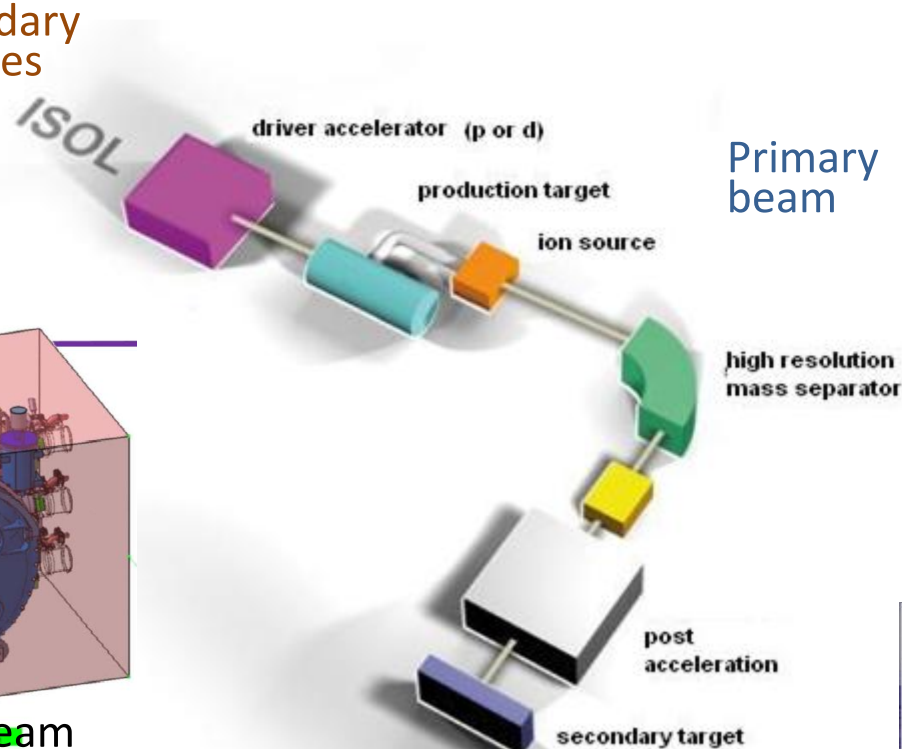
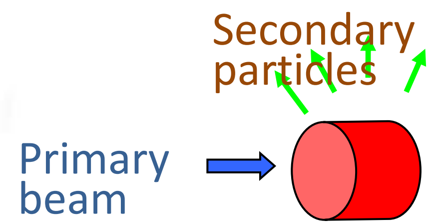
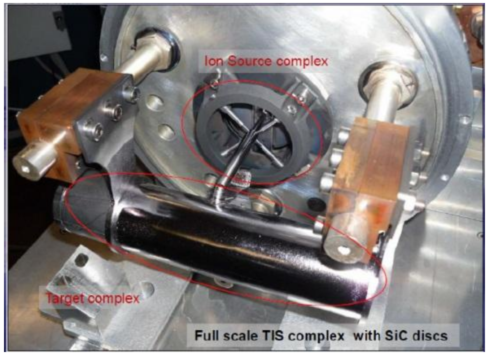


Direct target

Proton –induced reactions



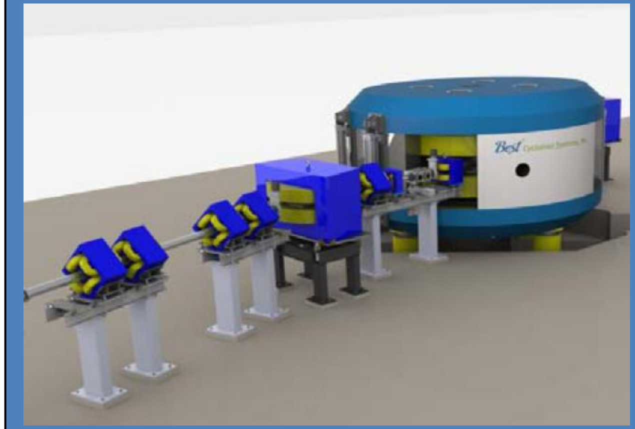
SPES direct target-ion source
50x50x50 cm3
25 kg
ISOLDE-type target

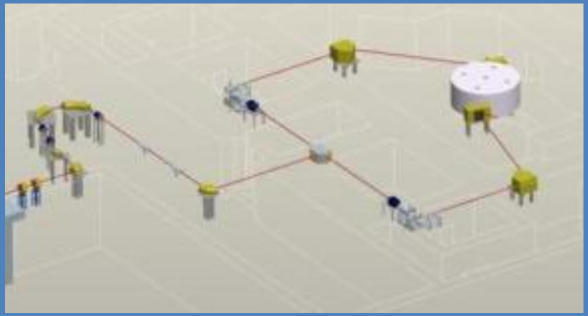


The SPES choice for ISOL

Driver:

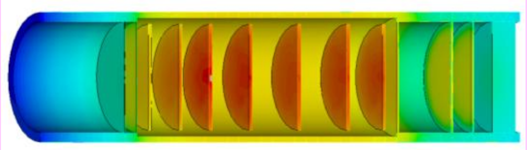
'Commercial' cyclotron

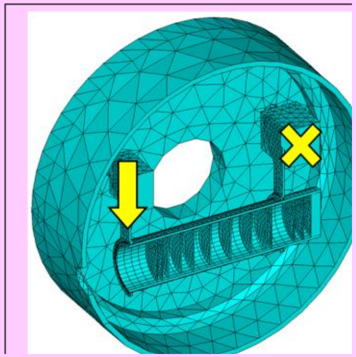




Production Target:

NEW CONCEPT
Multi-foil UCx direct target designed to reach 10^{13} f/s





Post Accelerator:

Normal conductive RFQ

(new development)

&

Alpi existing complex

Second generation ISOL facilities in Europe (UCx target)

Production and study of neutron-rich nuclei

	Primary beam	Power on target	UCx target (UCx grams)	Fission s-1	Reaccelerator	Nominal energy AMeV A=130
HIE ISOLDE upgrade	p 1-1.4 GeV - 2 μA	0.8 kW	Direct (150g)	**$4 \cdot 10^{12}$**	SC Linac	5-10
SPIRAL2	d 40 MeV 5mA	200 kW	Converter (4000g)	**10^{13}** 10^{14}	CIME Cyclotron	5
SPES	p 40 MeV 200 μA	8 kW	Direct (30g)	**10^{13}**	ALPI SC Linac	10

Synergy & complementarity

will offer to the Nuclear Physics community up-to date facilities to improve the knowledge of nuclei

SPES collaboration network

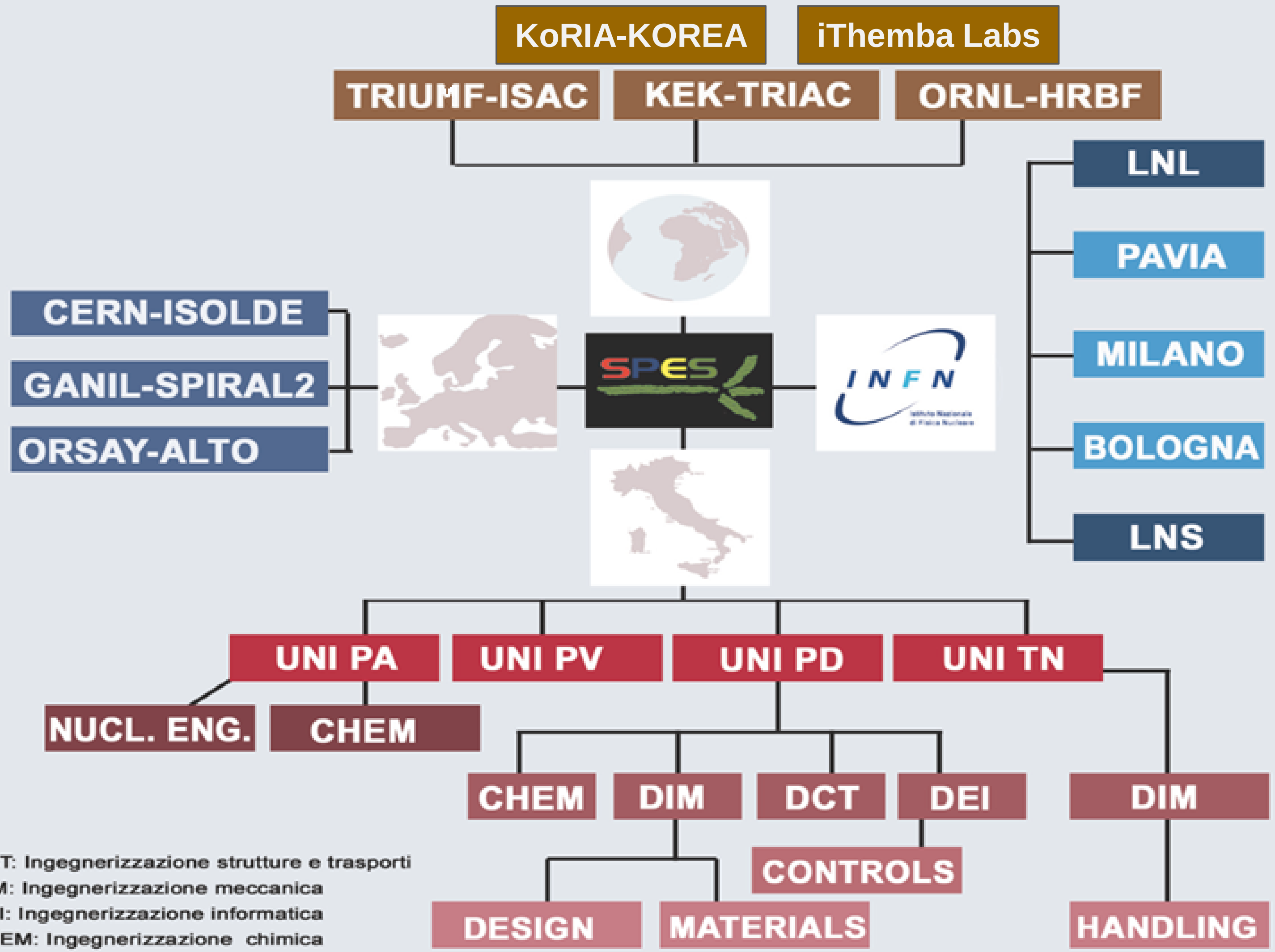
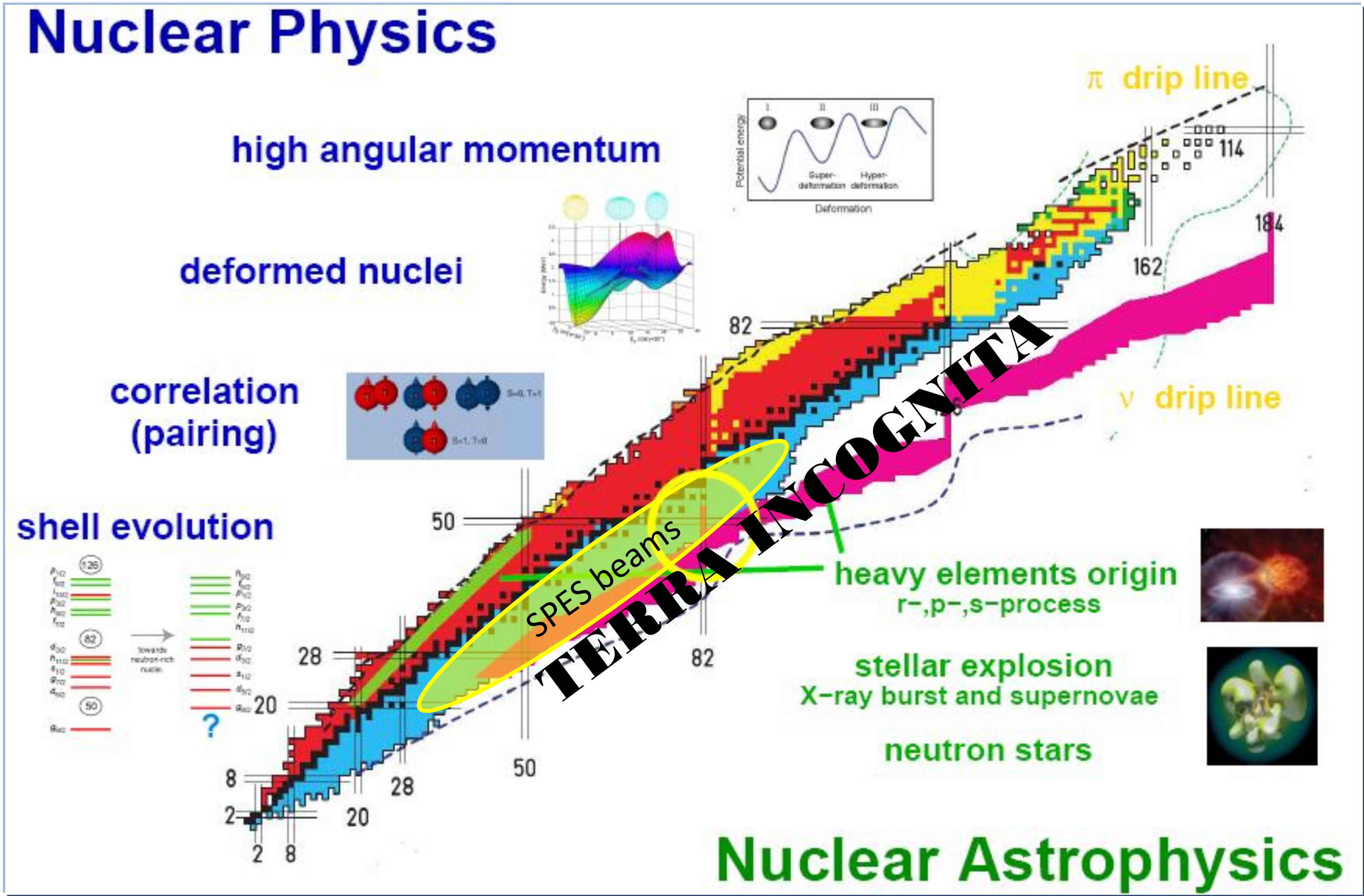


Fig. 3.25: Rete delle collaborazioni di SPES.

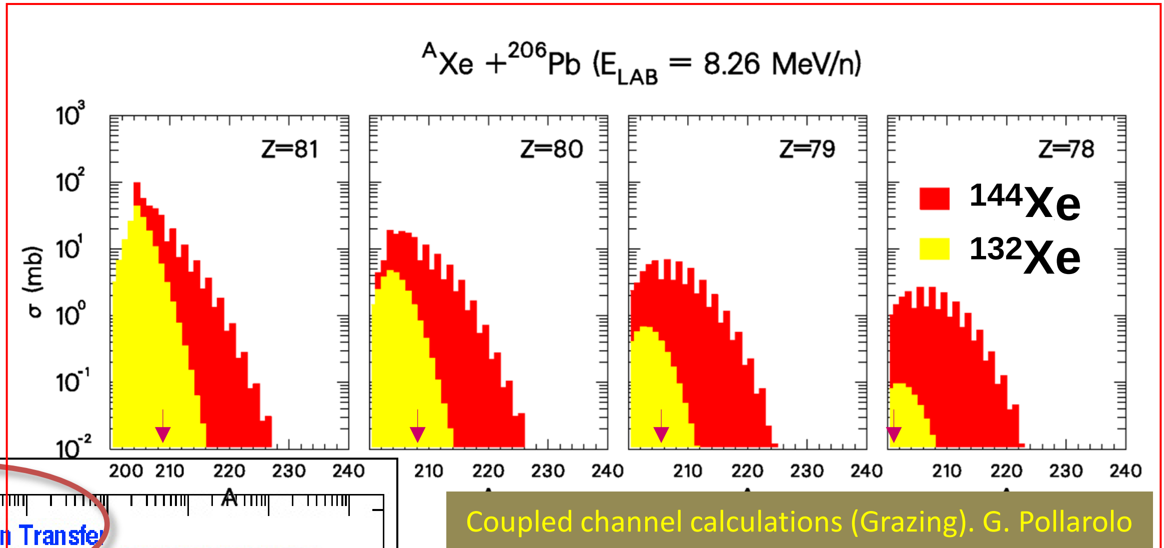
Radioactive beams at SPES

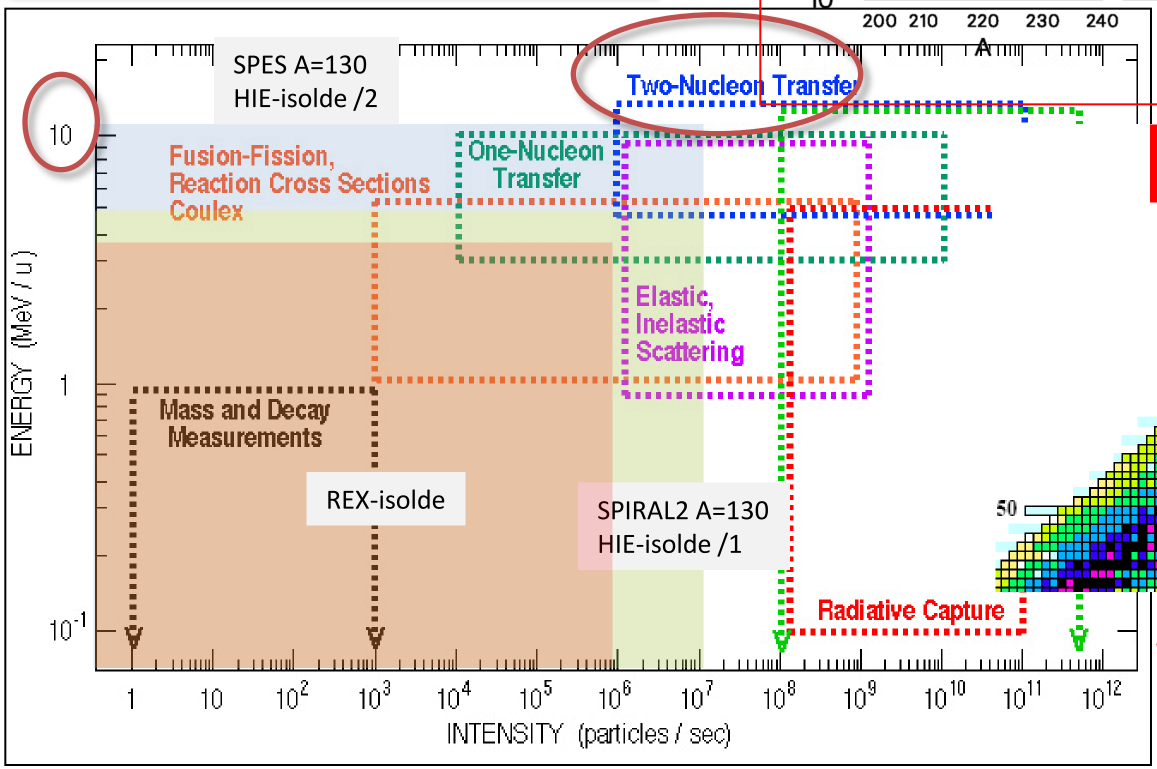


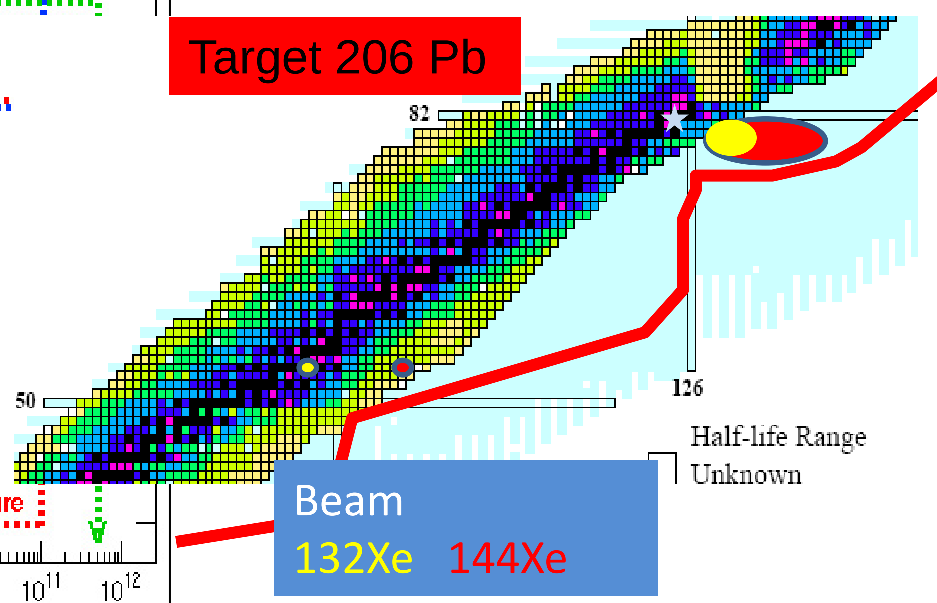
Why exotic beams at ALPI energy

At beam energy 8-10 AMeV **multi-nucleon transfer** reaction channels will open. Nuclei well far from stability will be populated.

SPES (10^{13}f/s), A=130, E=10 AMeV)



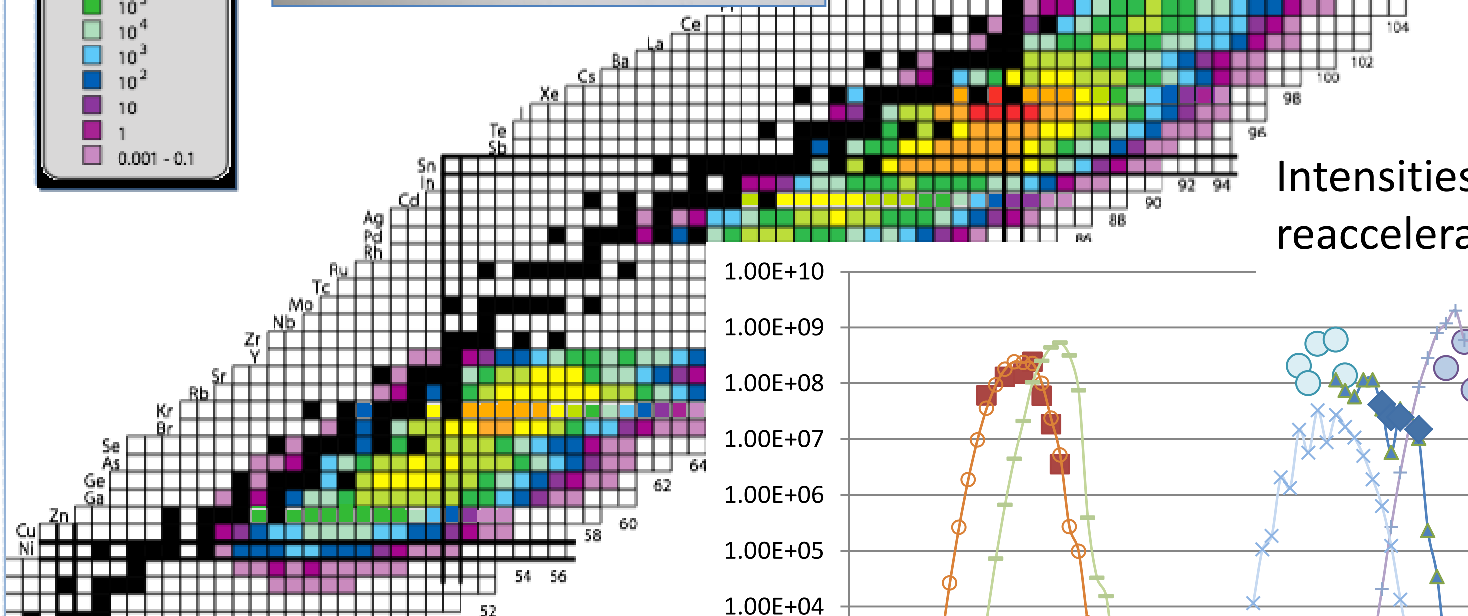




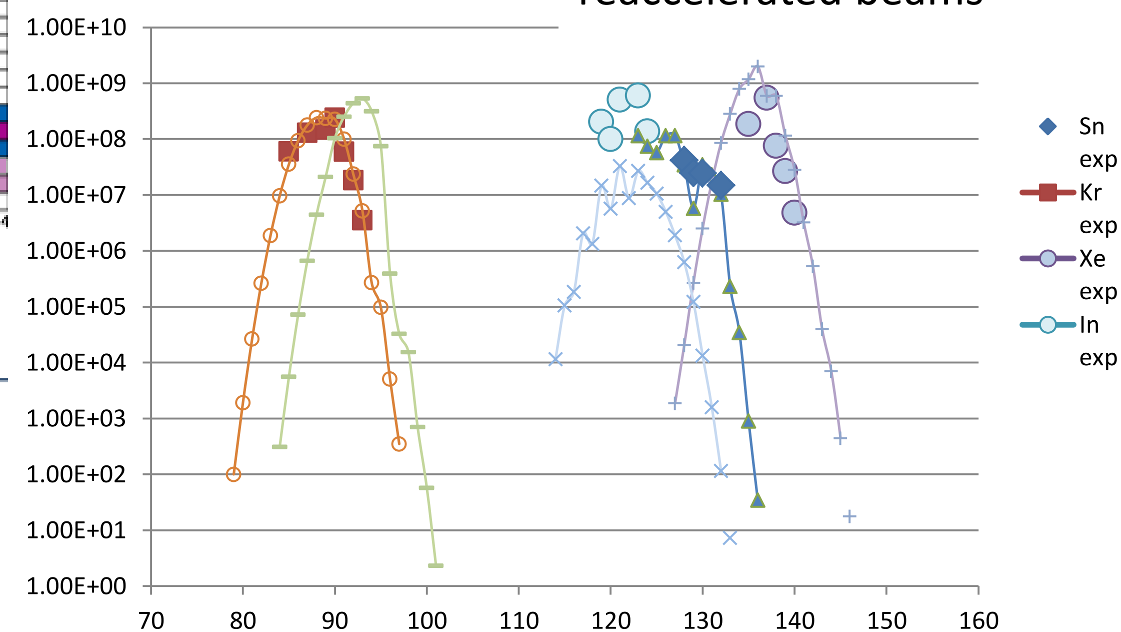
“Neutron-Rich” beams at SPES

UCx target, SPES design, irradiated at ORNL

Proton induced fission of U



Intensities expected for reaccelerated beams



In-beam tests performed at ORNL with 40MeV protons on UCx SPES target

Letters of Intent for SPES

SPES2010 Workshop
(LNL- November 15th-17th, 2010)

24 LoI's for reaccelerated exotic beams

Nuclear structure and reaction mechanism

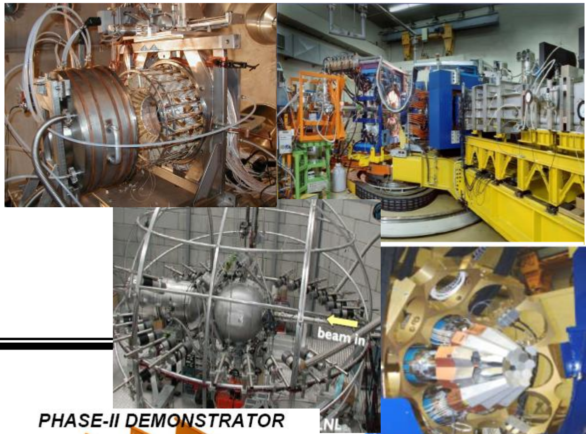
International collaborations:

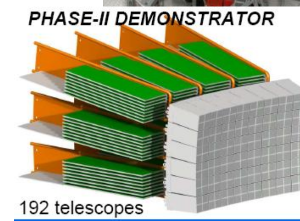
Italy
Bulgaria
Hungary
France
Poland
Spain
Great Britain
Turkey
USA
Slovakia
Romania
Croazia
Russia
India
Germany
Canada

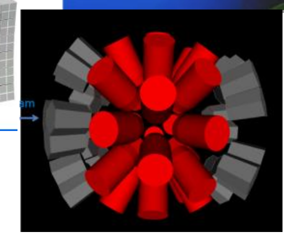
Instrumentation:

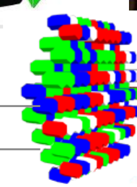
1 **GARFIELD** Low threshold 4π LCP-Fragment array - **F. Gramegna**
2 **PRISMA** Large acceptance spectrometer - **A.M. Stefanini**
3 **8PLP** 4π LCP-Fission Fragment array - **M. Cinausero**
4 **RIPEN** Neutron array - **M. Cinausero**
5 **GALILEO** γ-array - **C. Ur**
6 **TRACE** Compact LCP array - **D. Mengoni**
7* **AGATA** High performance γ-array - **E. Farnea**
8* **FAZIA** High performance LCP-Fragment array - **G. Casini**
9* **NEDA** New generation neutron array - **J.J. Valiente Dobon**
10* **PARIS** New generation high energy γ-ray array - **A. Maj**
11** **CHIMERA** Low threshold 4π LCP-Fragment array – **S.Pirrone**

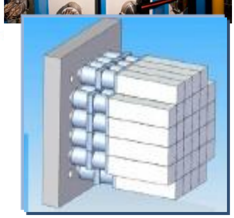
* SPES&SPIRAL2 collaboration LEA-Colliga
** part of Chimera installed at SPES

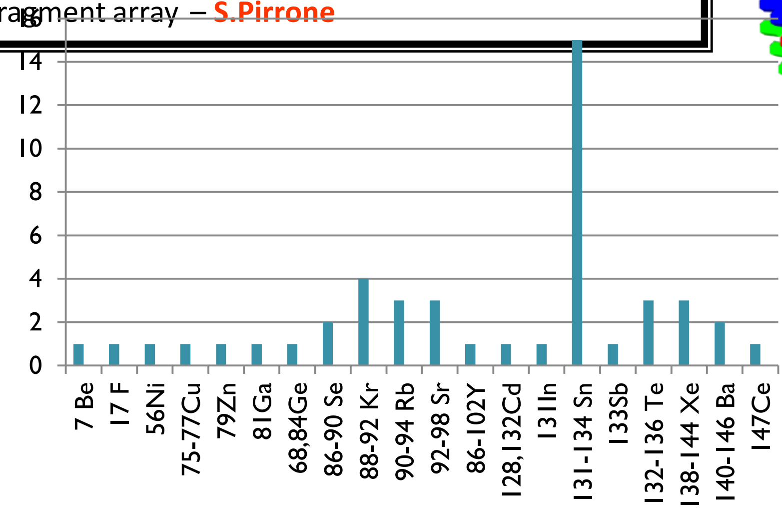




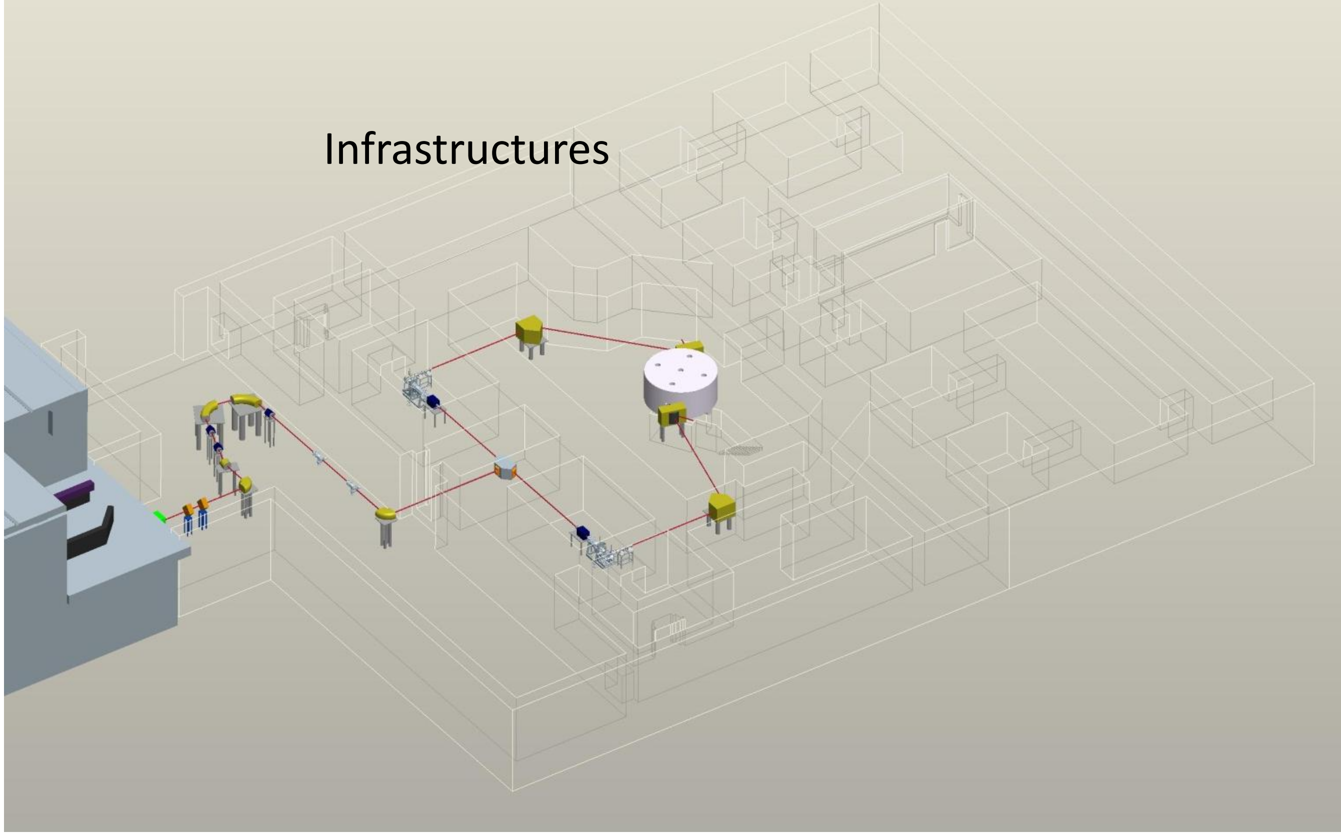








Definition of First Day Experiments:
- Scientific priorities
- Instrumentation development
- RIB production

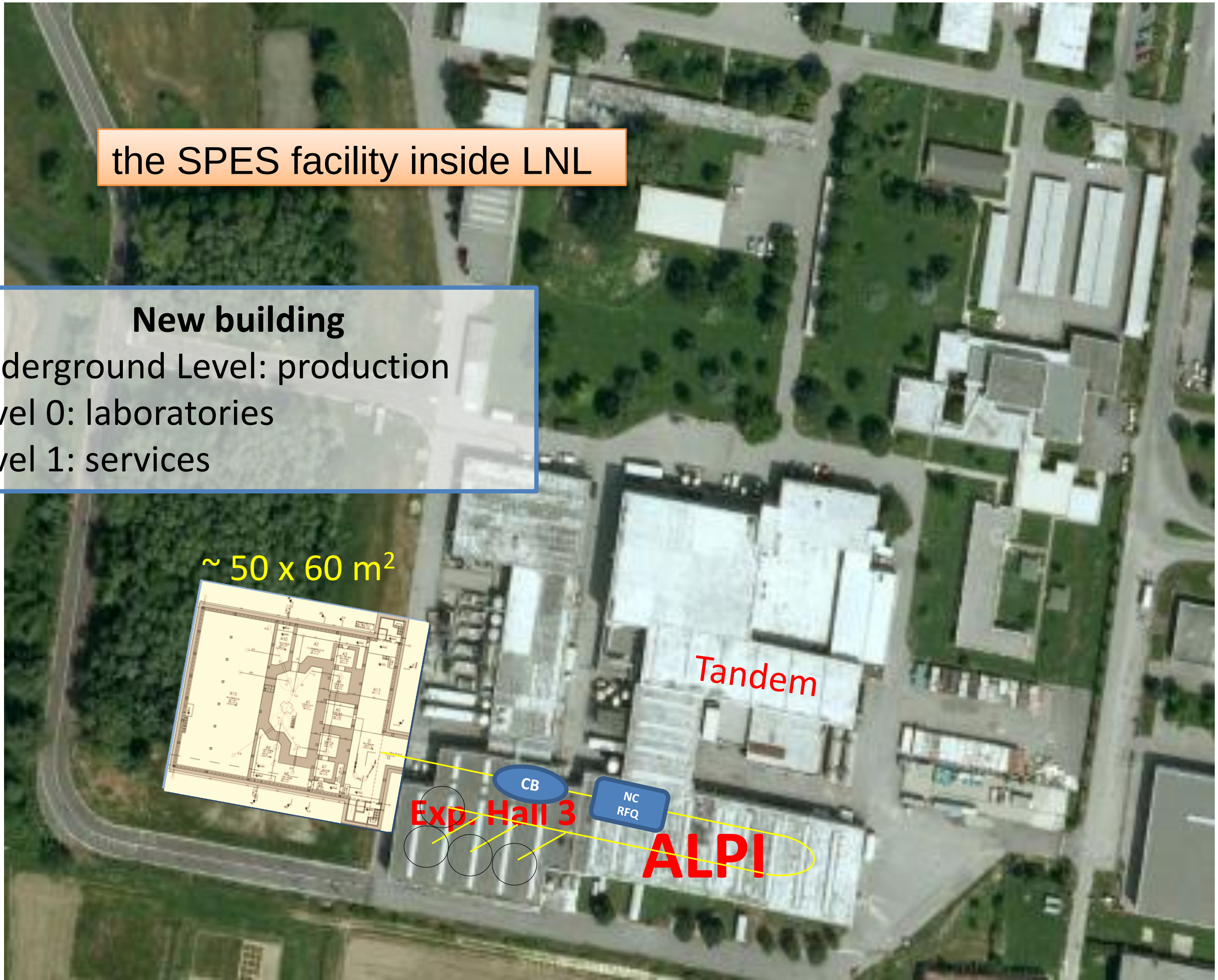


SPES Project

SPES FACILITY infrastructures

Bid for construction concluded in September 2012
ground breaking expected in January 2013

SPES Facility Layout



the SPES facility inside LNL

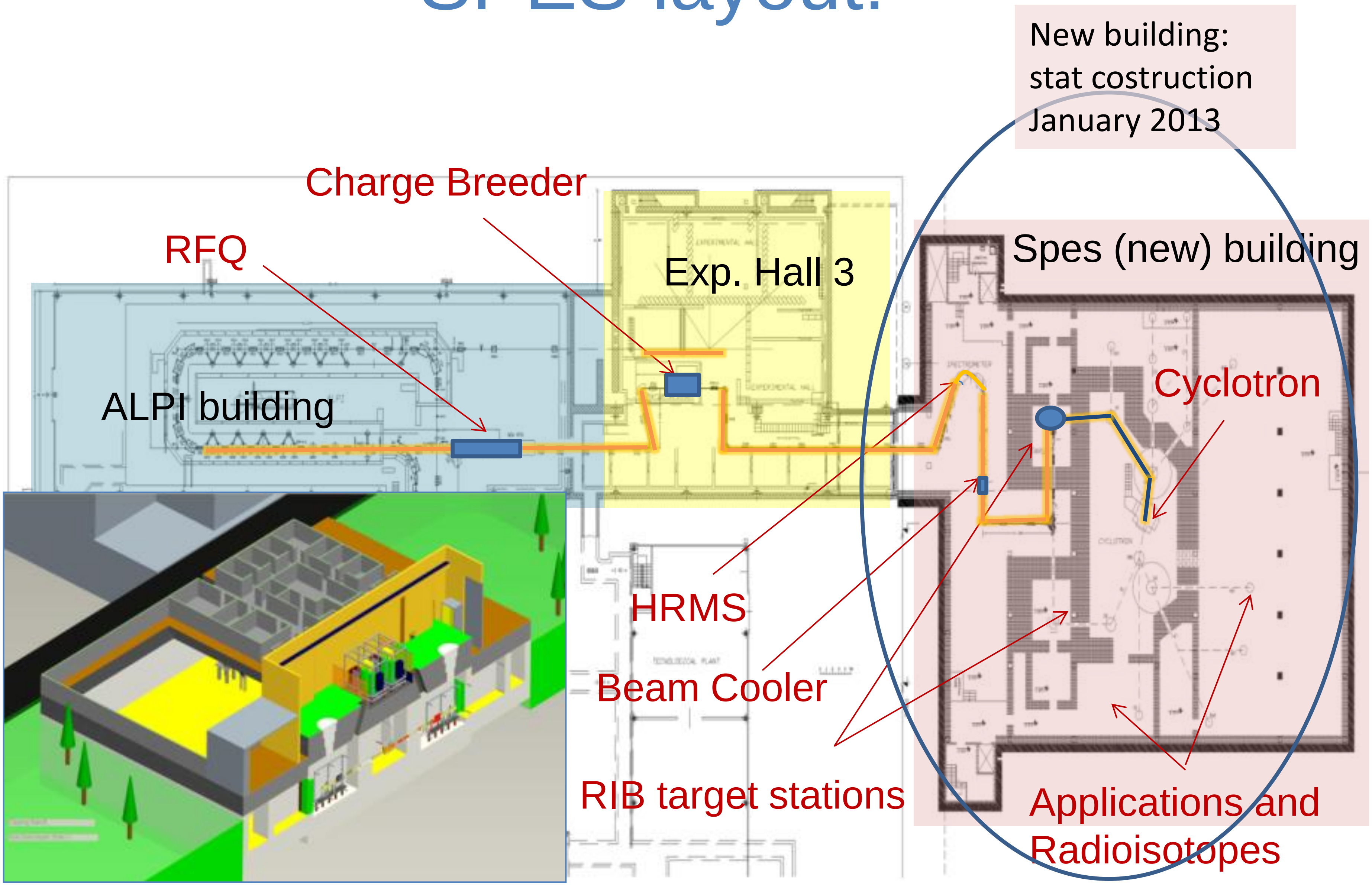
New building

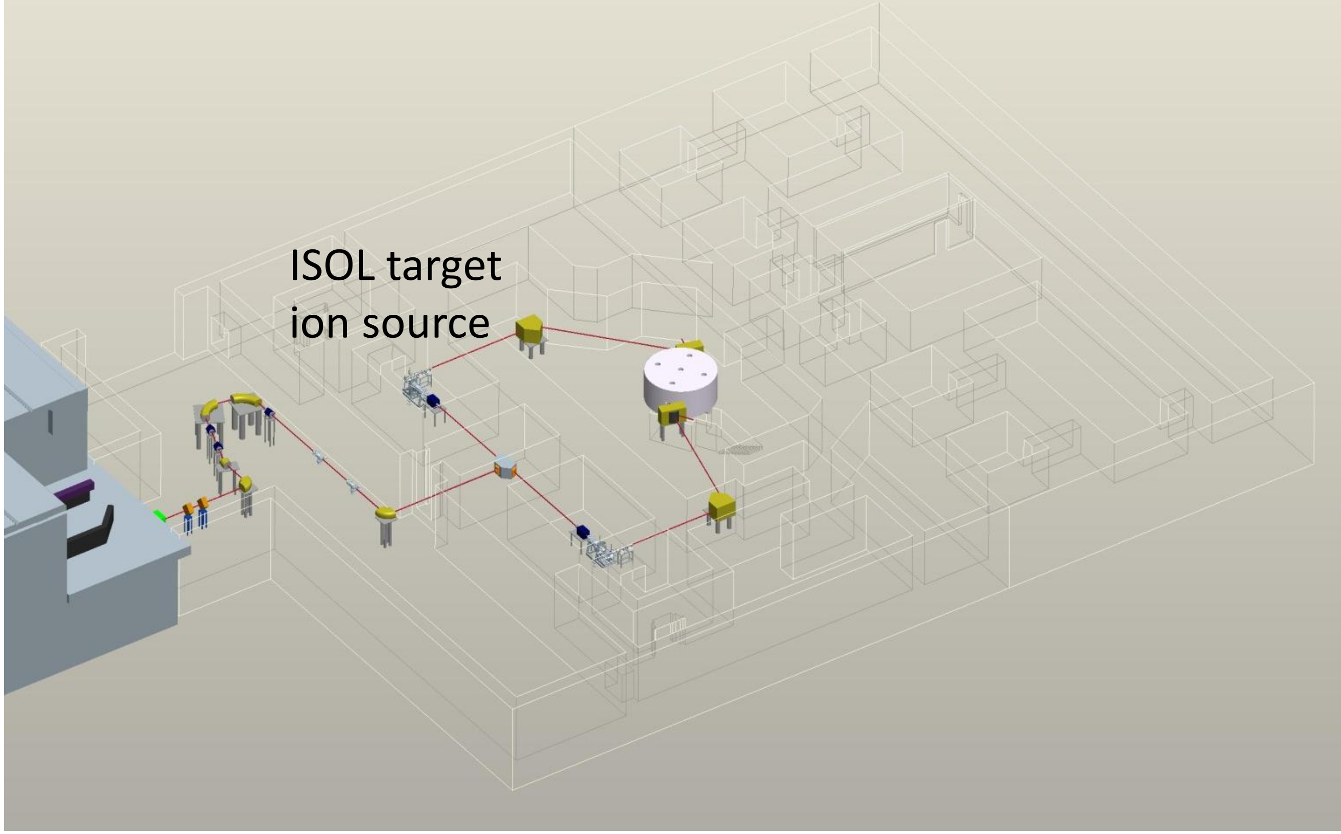
Underground Level: production

Level 0: laboratories

Level 1: services

SPES layout:


New building:
stat costruction
January 2013
Charge Breeder
RFQ
Exp. Hall 3
Spes (new) building
ALPI building
Cyclotron
HRMS
Beam Cooler
RIB target stations
Applications and
Radioisotopes



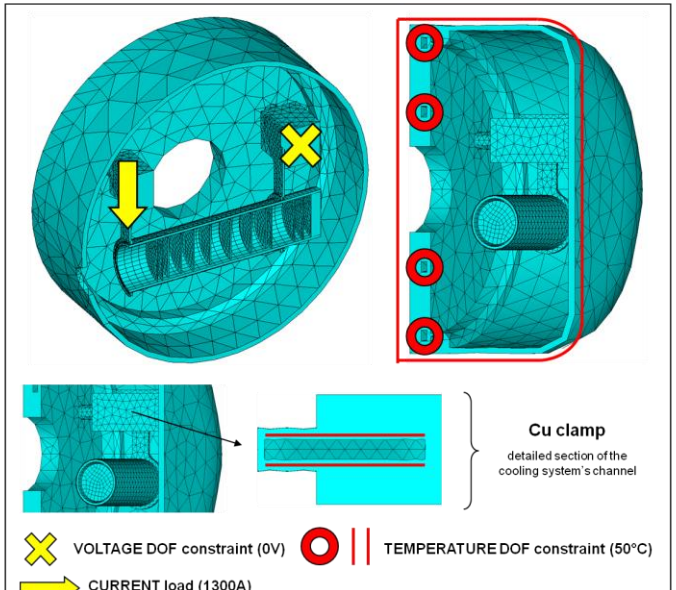
SPES Project

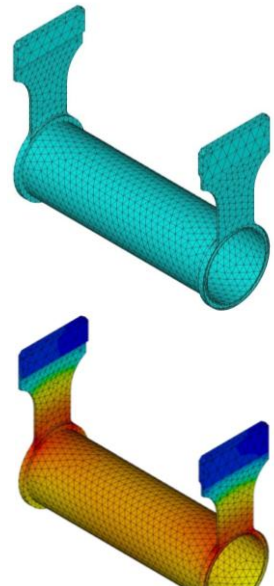
SPES ISOL TARGET-ION-SOURCE

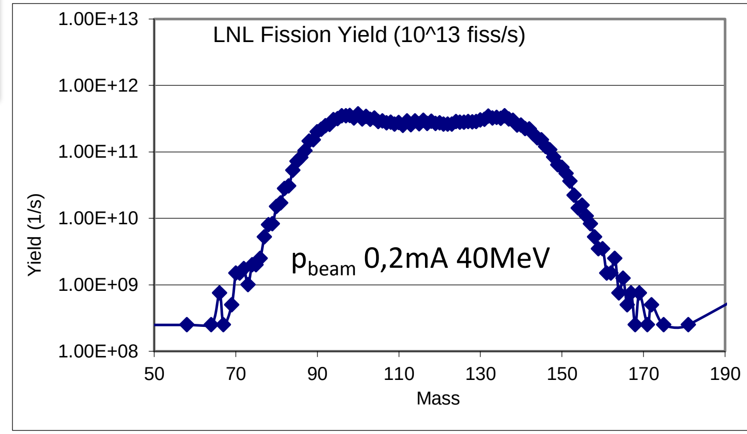
Target Ion Source Complex under characterization

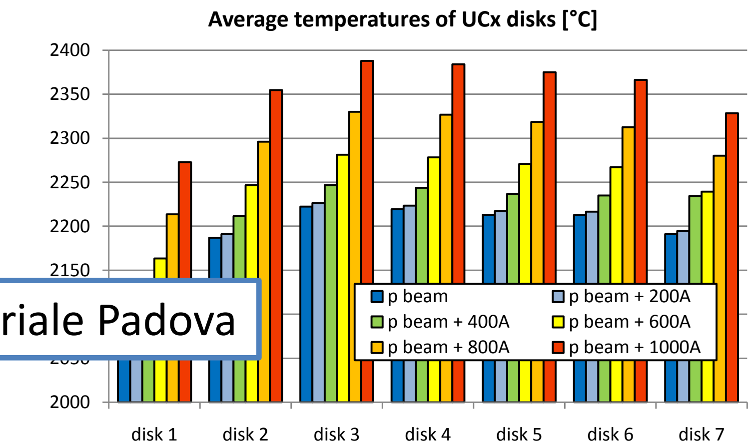
NEW DIRECT TARGET CONCEPT to operate with 10kW proton beam

The SPES choice: optimize the Direct Target design and material production to reach 10^{13} fissions/s

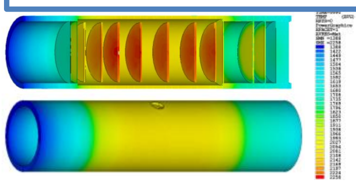


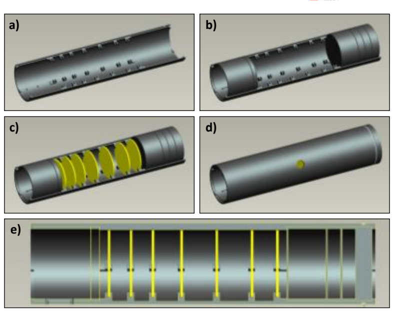


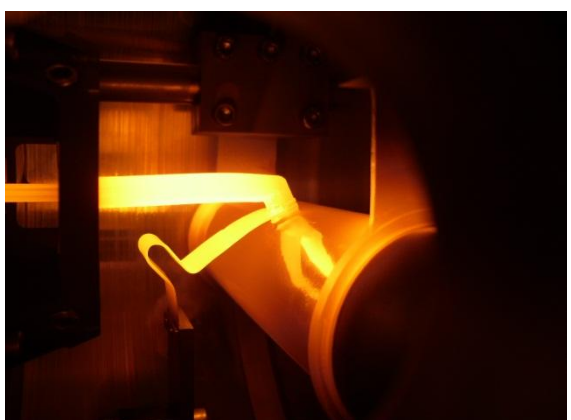


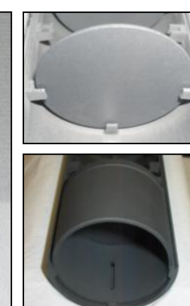


Collaboration with ENEA-Bologna and Ingegneria Industriale Padova



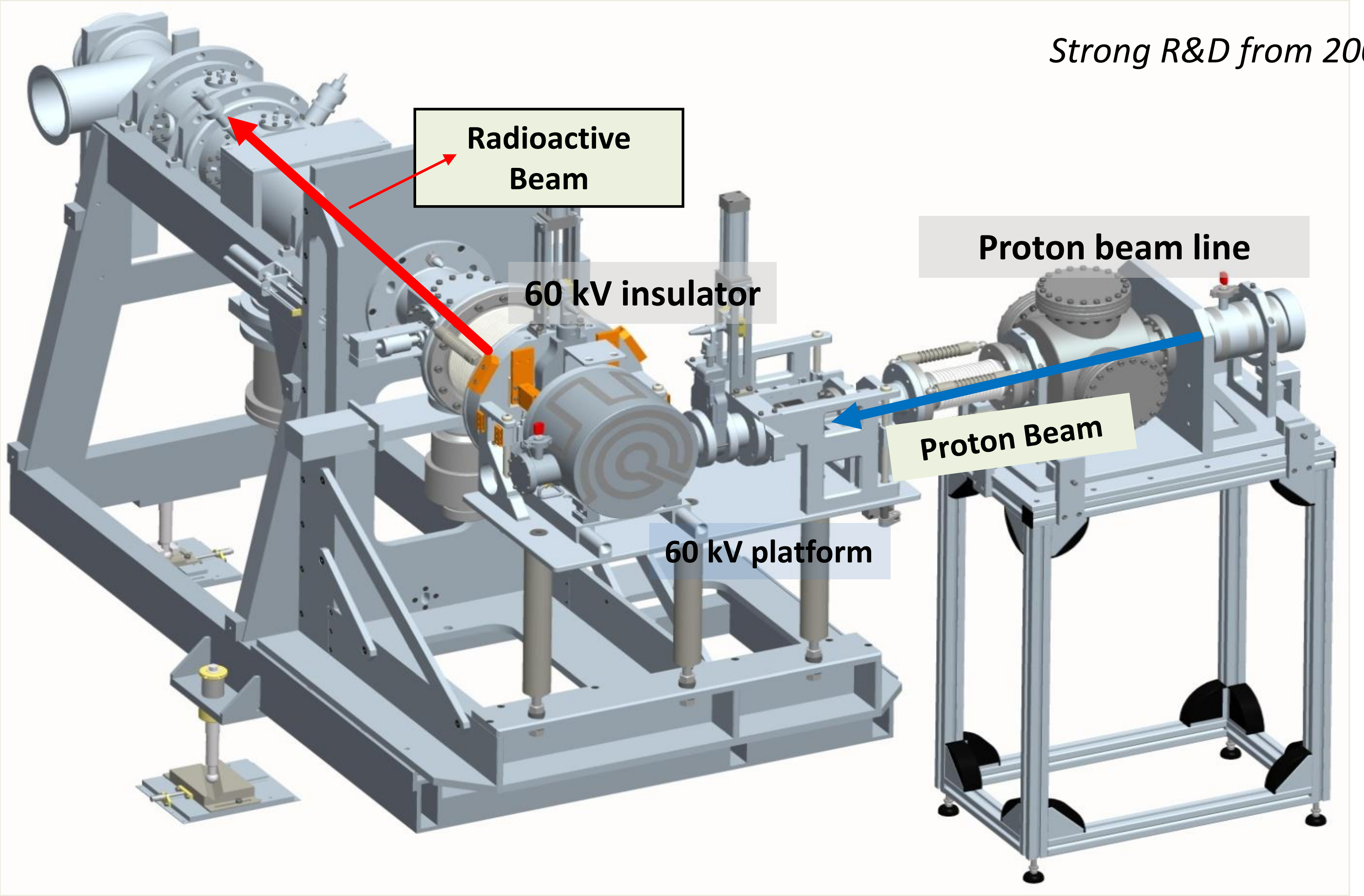






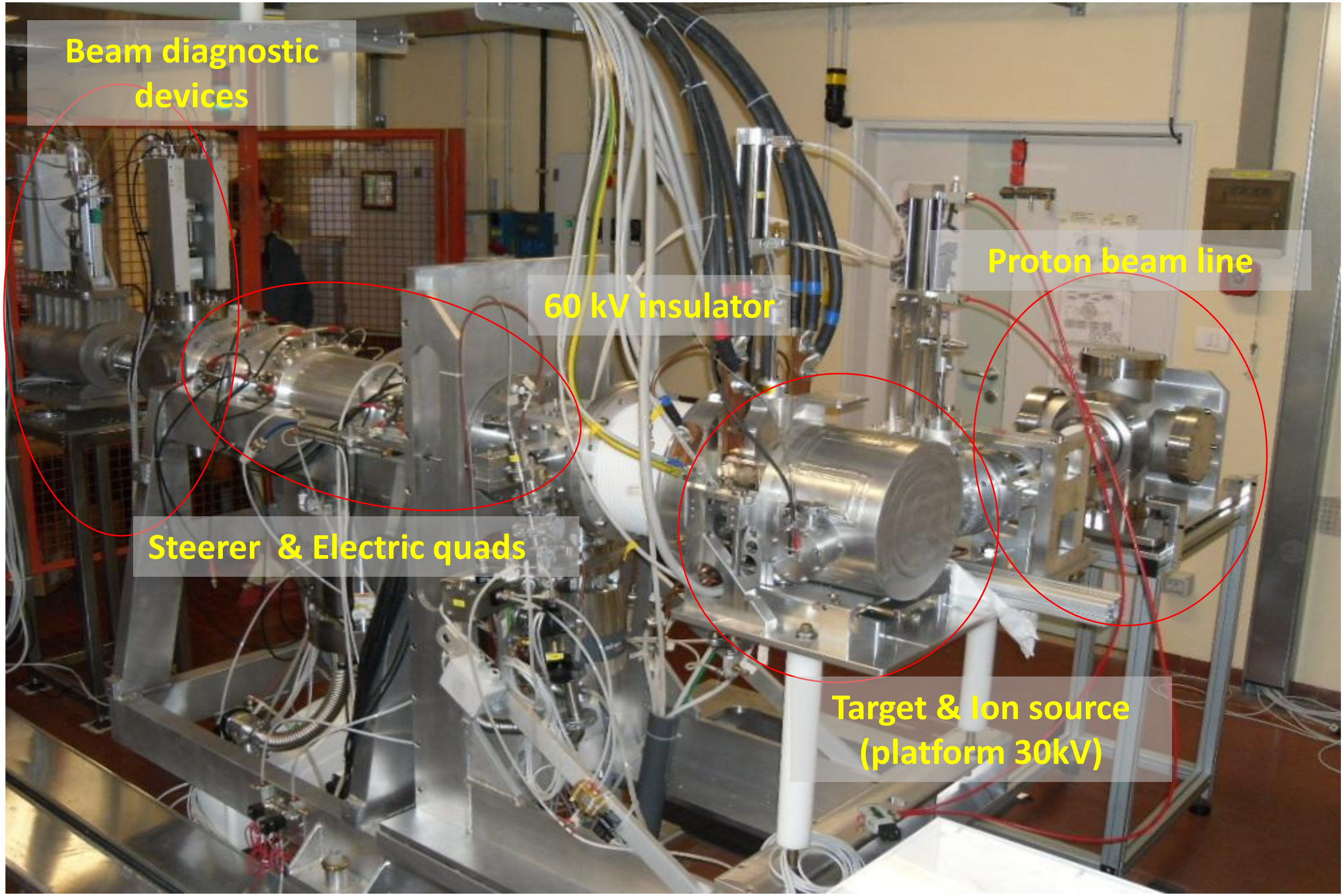
The SPES Front - End

Strong R&D from 2006



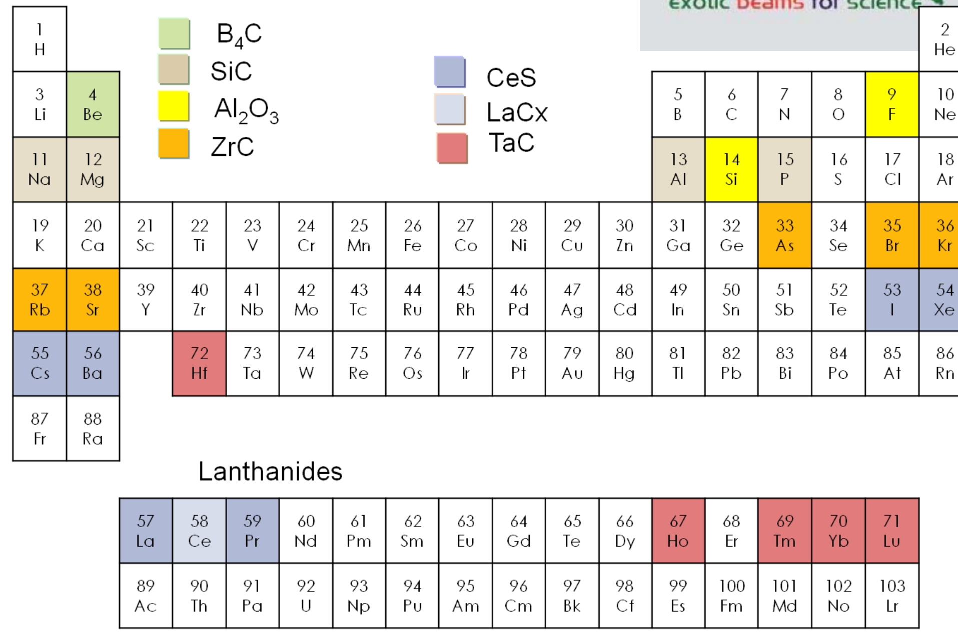
(SPES - ISOLDE collaboration)

The SPES Front-End is fully operative!

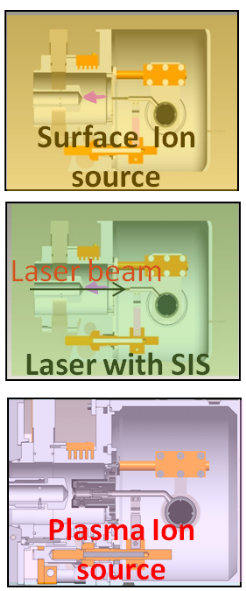


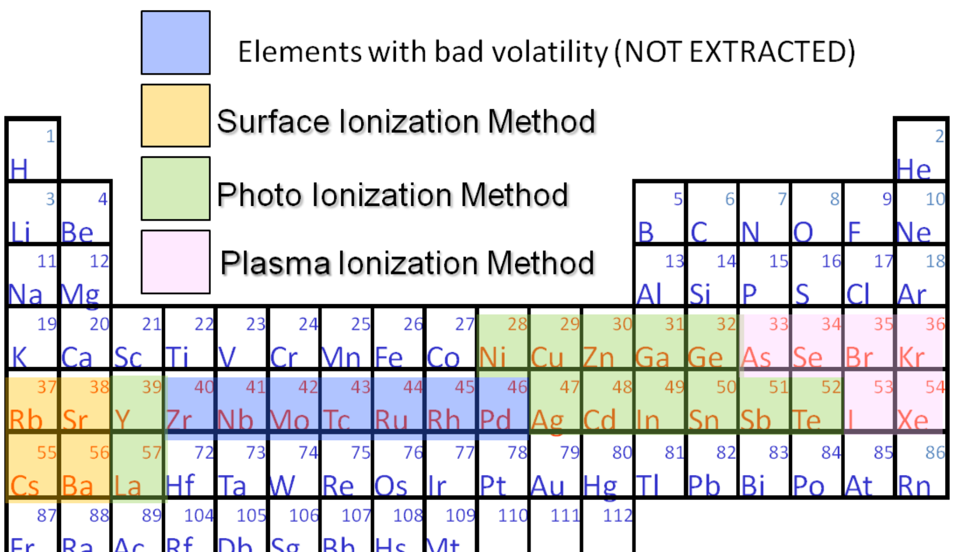
Target materials & ion source development

Targets developed for SPES ISOL facility allow to produce a variety of beams in the proton-rich and neutron-rich area



UCx



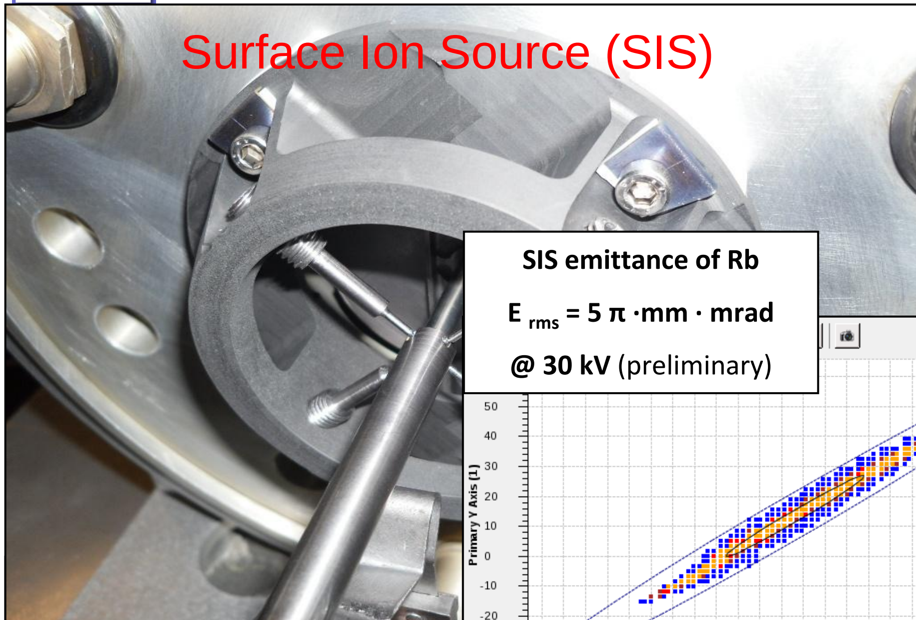


Main fission (p-> ^{238}U) fragments

The BAD VOLATILITY elements are produced and trapped in the target. These elements are highly required for nuclear medicine applications.

The SPES Ion Sources

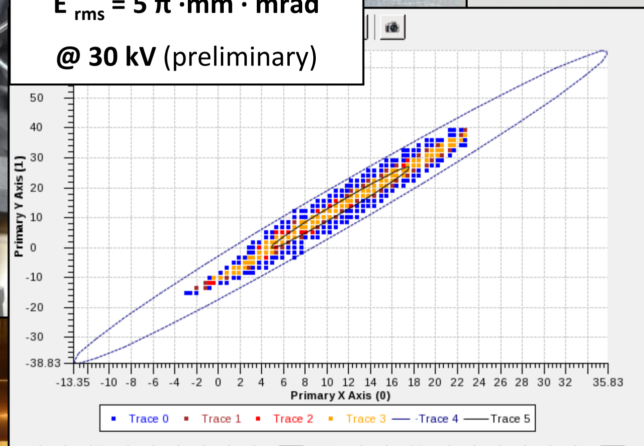
Surface Ion Source (SIS)

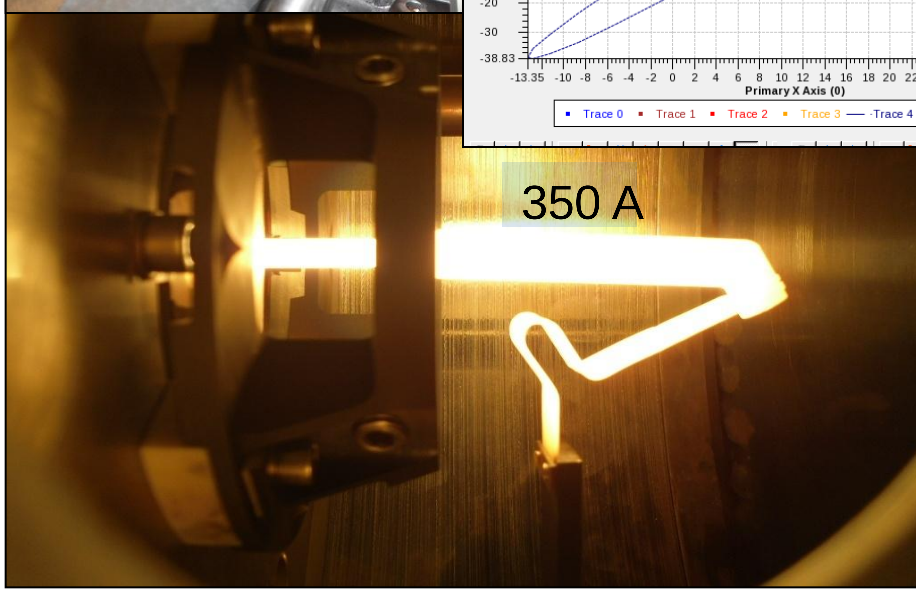


SIS emittance of Rb

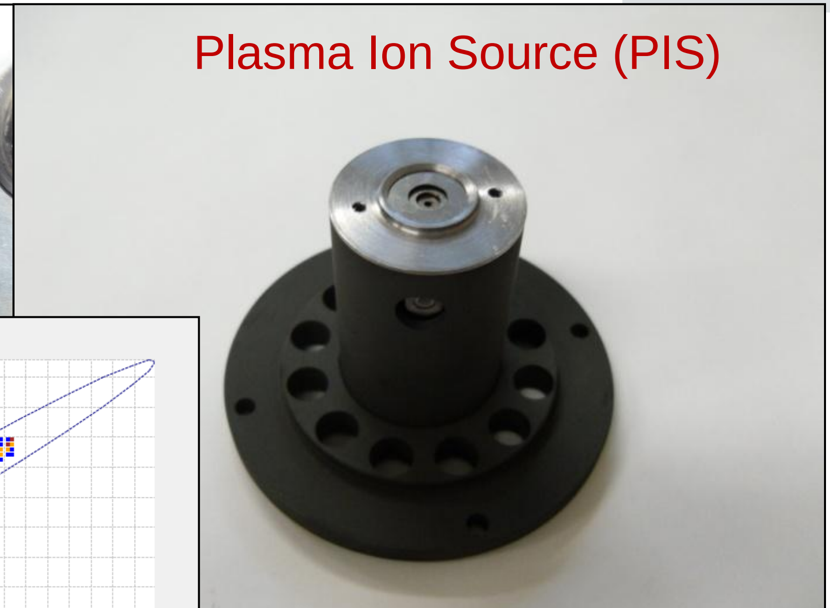
E_{rms} = 5 π ·mm · mrad

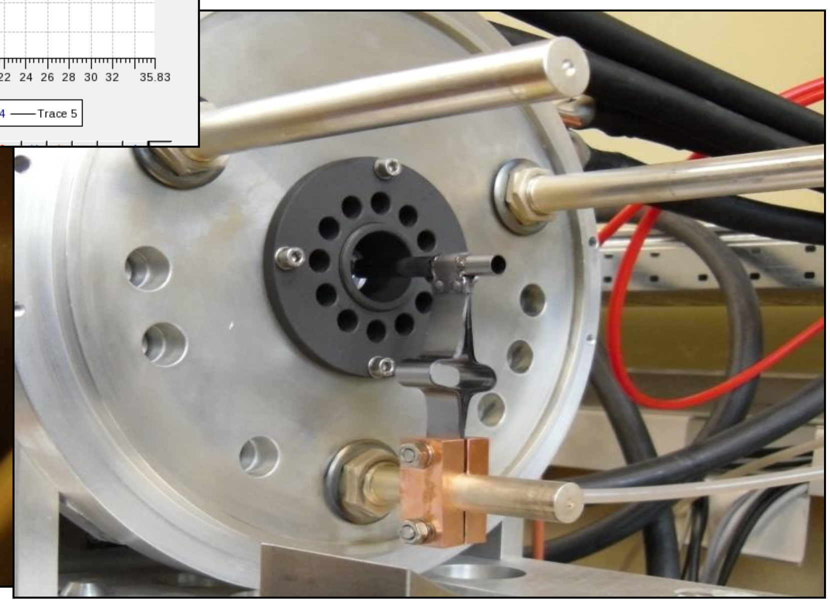
@ 30 kV (preliminary)



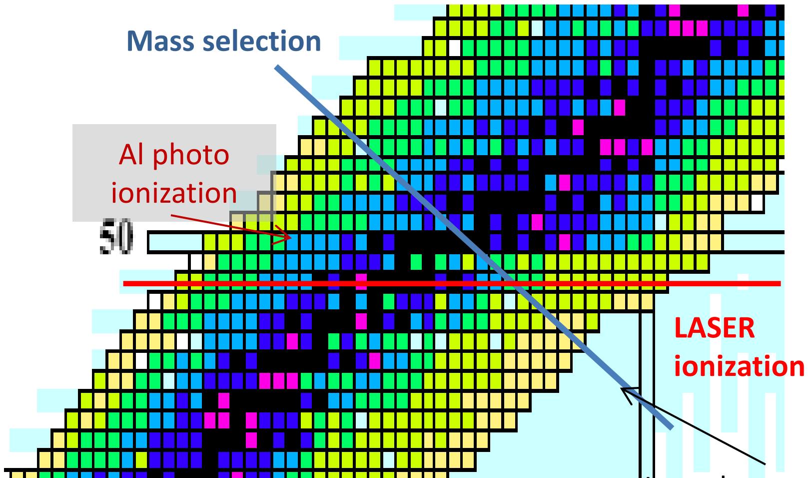


Plasma Ion Source (PIS)

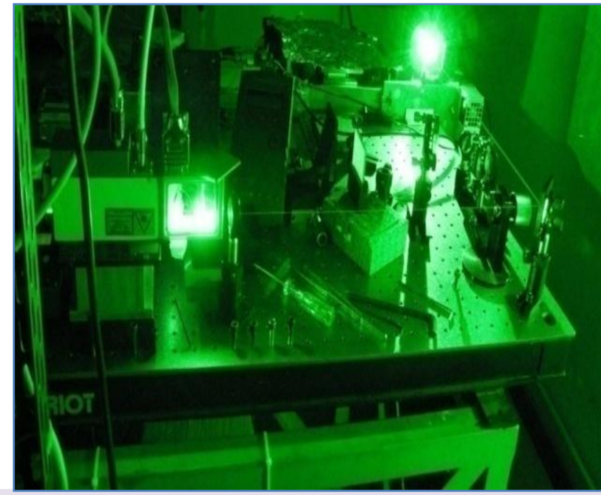




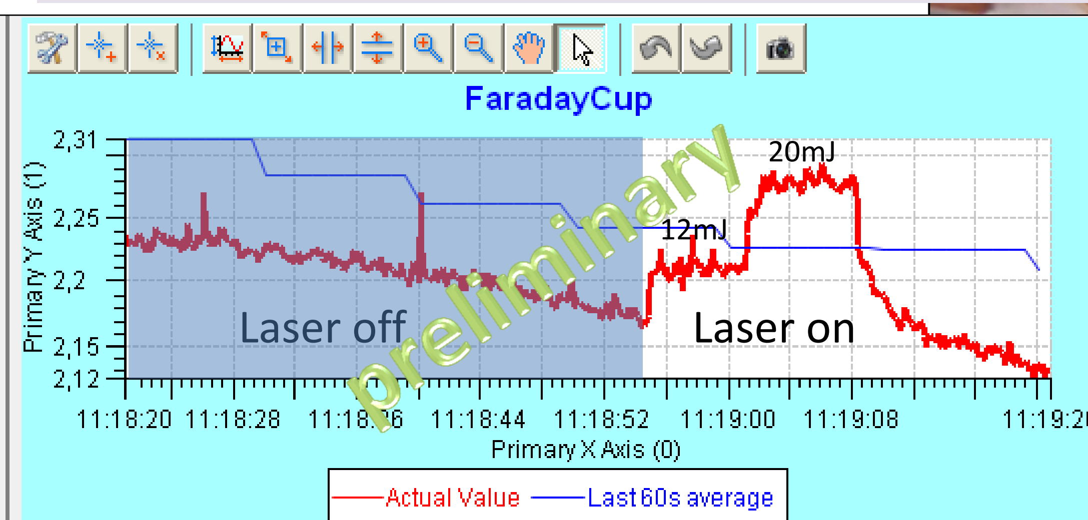
LASER source development

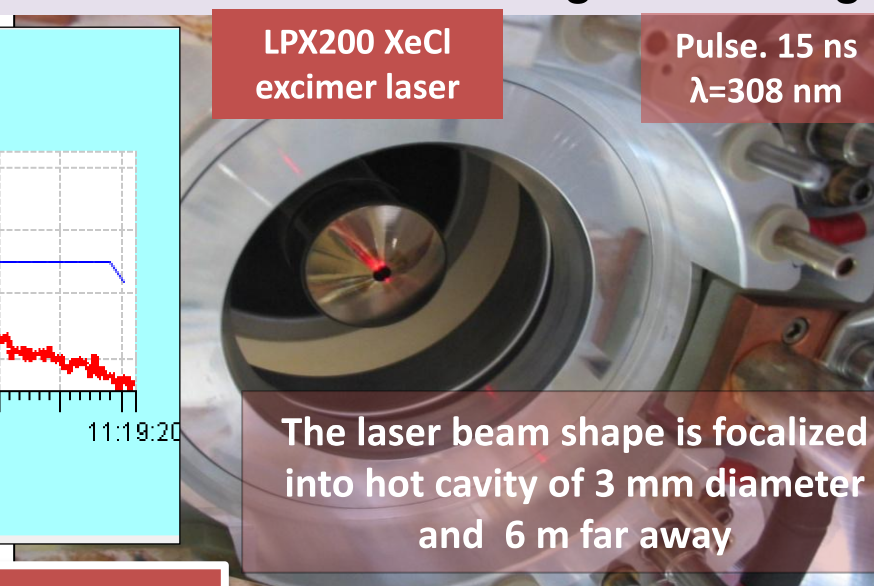


Pavia Laboratory
Study of selective laser ionization
Nd-YAG



Laser test at LNL with excimerAluminum ionization with a single wavelength



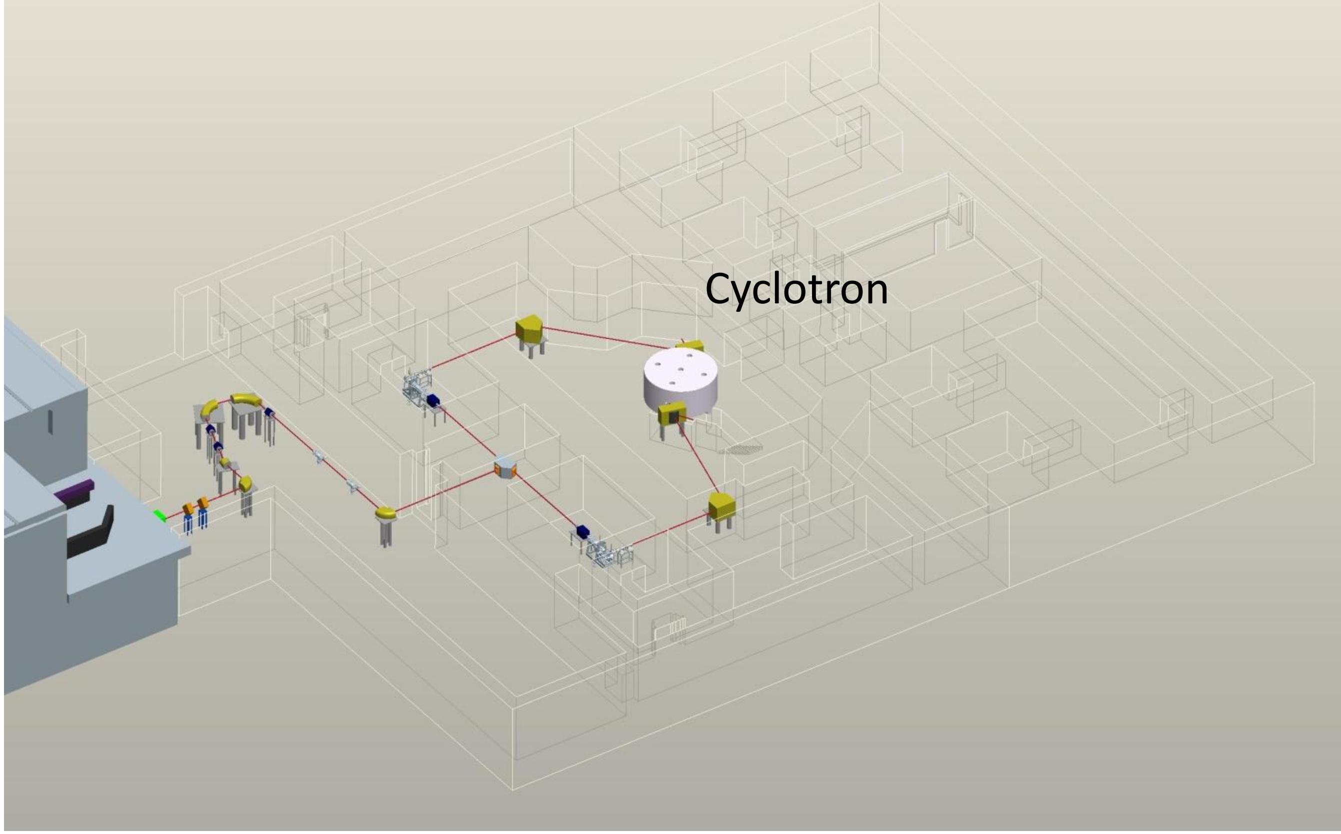


LPX200 XeCl excimer laser

Pulse. 15 ns
λ=308 nm

The laser beam shape is focalized into hot cavity of 3 mm diameter and 6 m far away

Collaboration with INFN-PAVIA



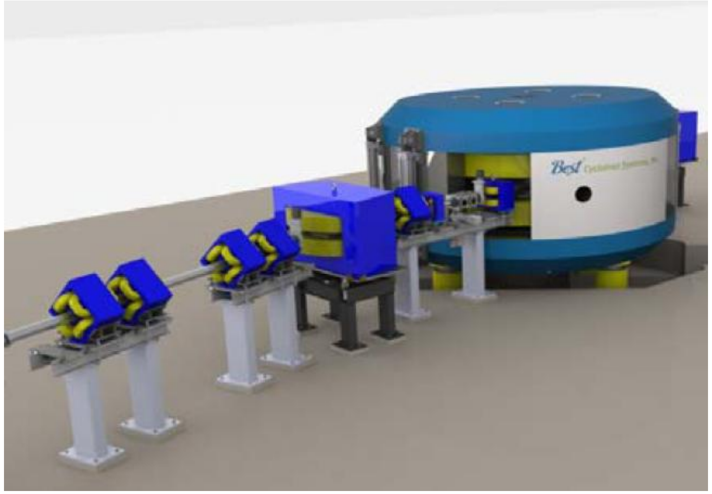
SPES Project

SPES CYCLOTRON

Cyclotron realization in progress

BEST Cyclotron parameters

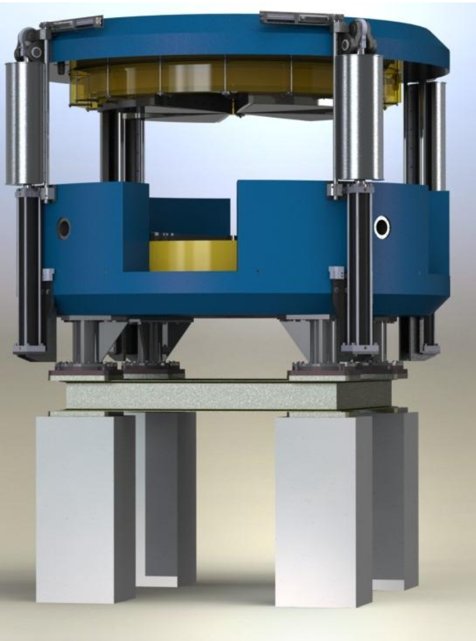
Total Costs:
cyclotron and 1 beam line 10 M€
Delivery 3-4 years (start 28 Oct '10)



Main Dimensions
Diameter = 4.5 m
Height= 1.7 m
Weight = 210 tons

BEST 70 MeV Cyclotron	
Accelerated Particle	H-
Extracted Particle	**Protons**
Energy	**35-70 MeV (variable)**
Current	**> 700 uA (variable)**
Extraction System	**By stripping → simultaneous dual beam extraction**
Injection System	Axial Injection → External Multicusp Ion Source 15-20mA DC
Main Magnet	B_{max} = 1,6 T Coil current = 127 kAt Power supply = 30 kW 4 sectors, deep valley
RF System	2 resonators Frequency= 58 MHz Harmonic mode=4 Dissipated Power=15 kW per cavity DEE voltage=60-80 kV
Operational Vacuum	2 e -7 mbar

BEST 70p Model & Magnet



70p Model.

70p Magnet in Japan (Dec 2011)

Best 70p Magnet

70p Magnet in Baltimore. (March 2012)

Machining done in Marmen, under completion in December 2012.

SPES CYCLOTRON
load work per year

Expected Beam on target: 10600 hours per year.

Over 5000 hours/year of proton beam available for RIB production and 5000 hours/year for applications.

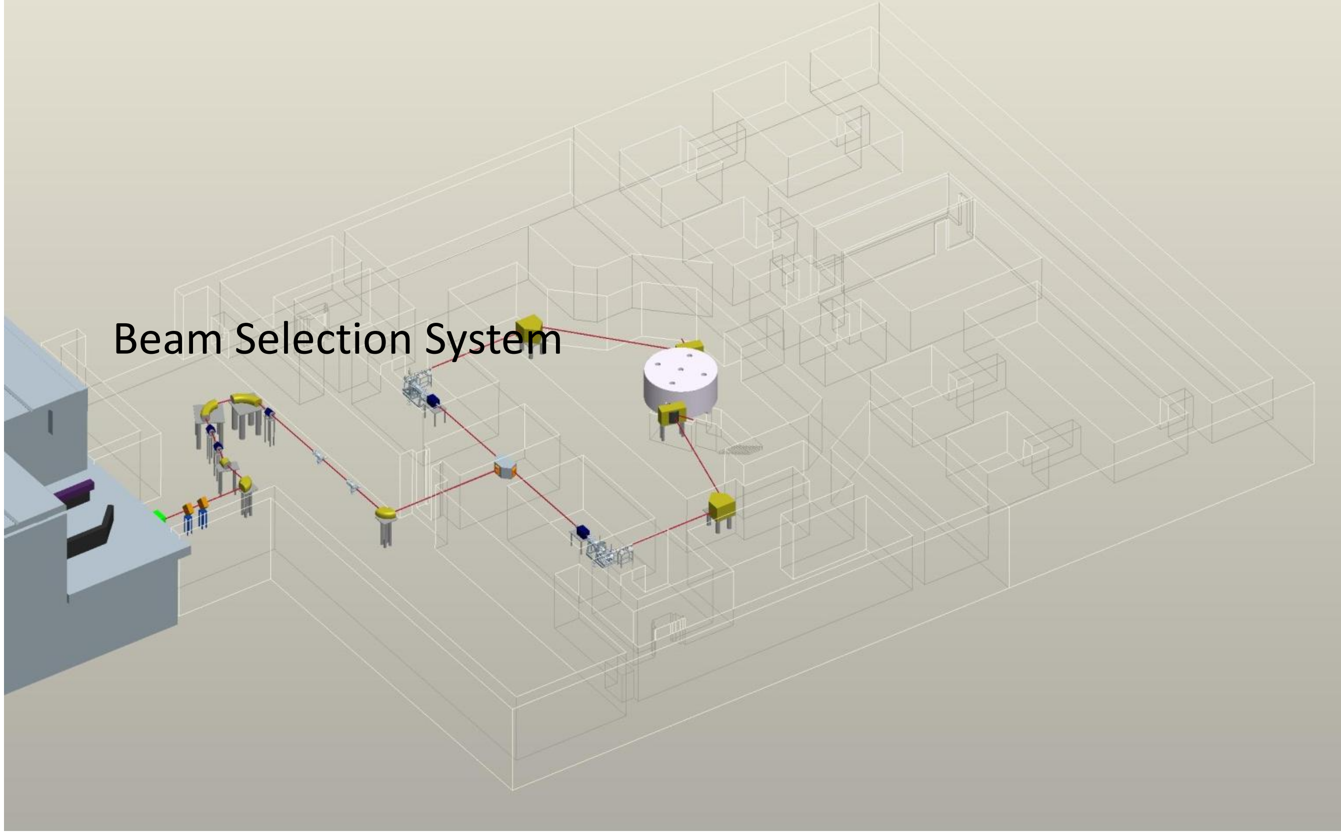
2 weeks per shift
Beam preparation 2 days
Beam on target 12 days

Beam on target →280 hours per shift

Each bunker will cool down for 14 days after target irradiation.

Beam sharing skeme

	Proton beam	N.rs of SHIFTS	Beam on target: Total 10600 hours
ISOL 1	300μA 40MeV	10	2800
Irradiation 1	500 μA 70MeV	9	2500
Irradiation 2	500 μA 70MeV	10	2800
ISOL 2	300 μA 40MeV	9	2500
Maintanance		7	7x14x24= 2350
Cyclotron Operation		19	19x12x24= 5462 esperiment 19X2x24= 912 beam preparation



SPES Project

SPES BEAM SELECTION SYSTEM

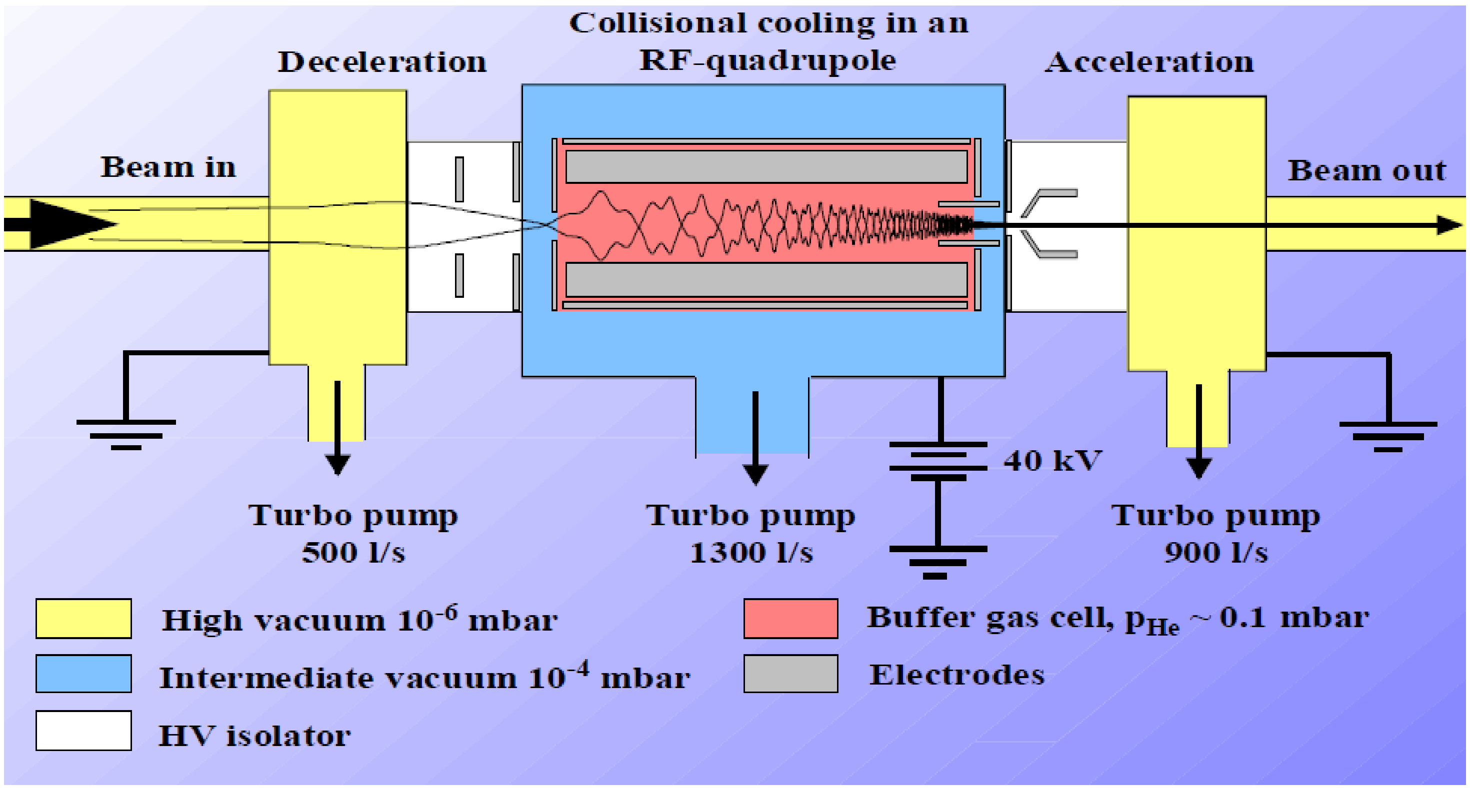
R&D Design studies in progress

RFQ Beam Cooler

Feasibility study in progress within
the INFN experiment

REGATA

R_iduttore di E_mittanza a GA_s TA_mpone



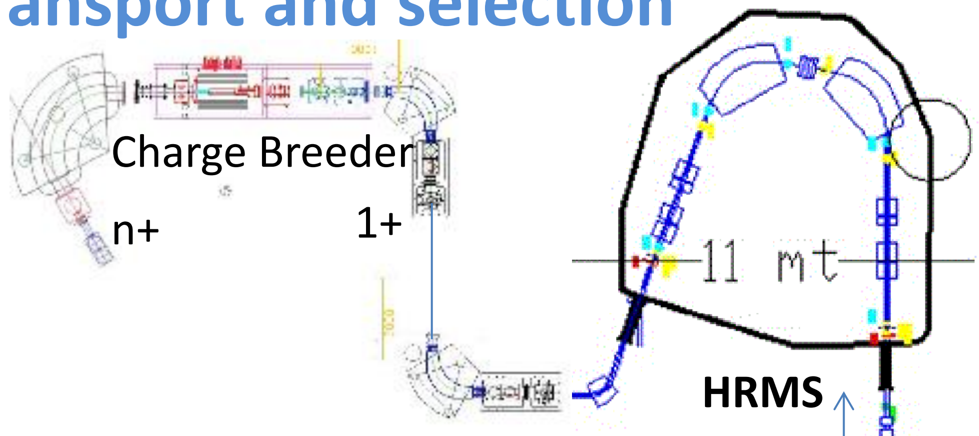
To reduce transversal emittance and energy spread

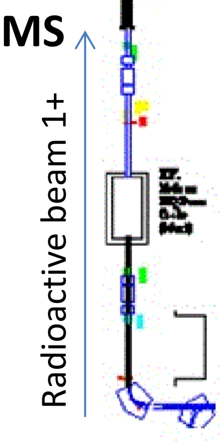
→ to improve resolving power of Mass separator

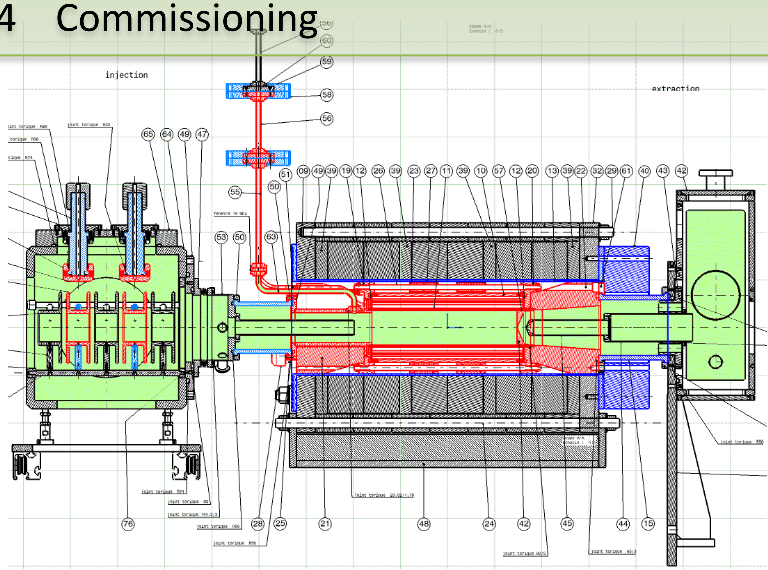
Radioactive Beam transport and selection

Development of an upgraded POHENIX booster
Part of MoU GANIL_SPIRAL2 – INFN_SPES

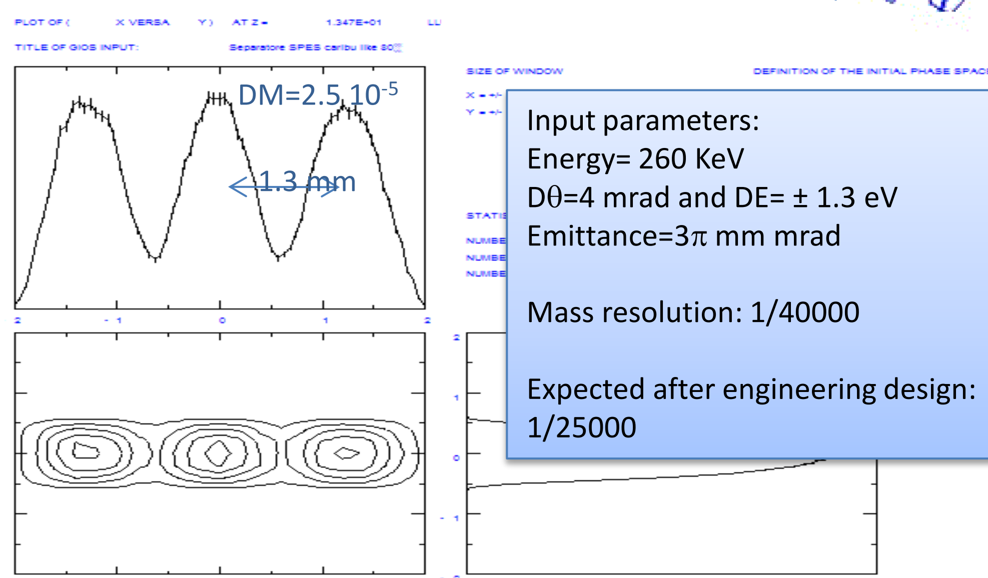
2010 Preliminary measurements
2011 Conceptual design and schedule definition
2012 Design
2013 Construction
2014 Commissioning







Physics design High Resolution Mass Spectrometer
3º order effects analysis
LNS-LNL

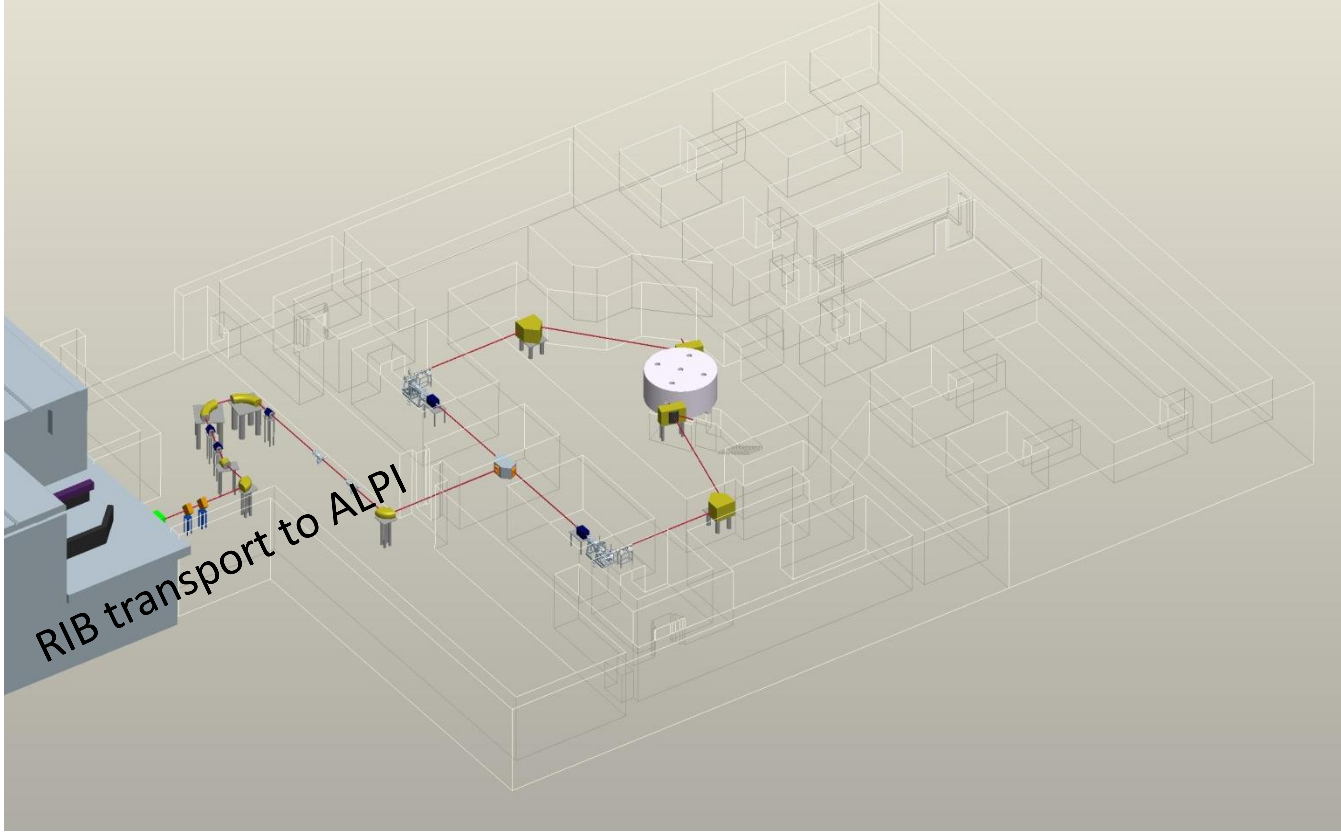


Input parameters:
Energy= 260 KeV
Dθ=4 mrad and DE= ± 1.3 eV
Emittance=3π mm mrad

Mass resolution: 1/40000

Expected after engineering design: 1/25000

INFN-GANIL MoU:
INFN: neutron converter for SPIRAL2
LPCS: Charge Breeder for SPES



SPES Project

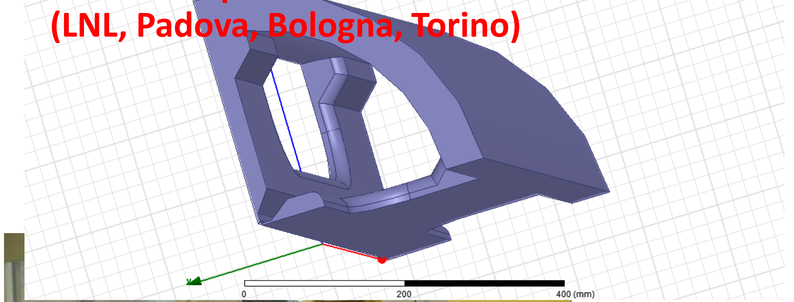
SPES POST ACCELERATION SYSTEM

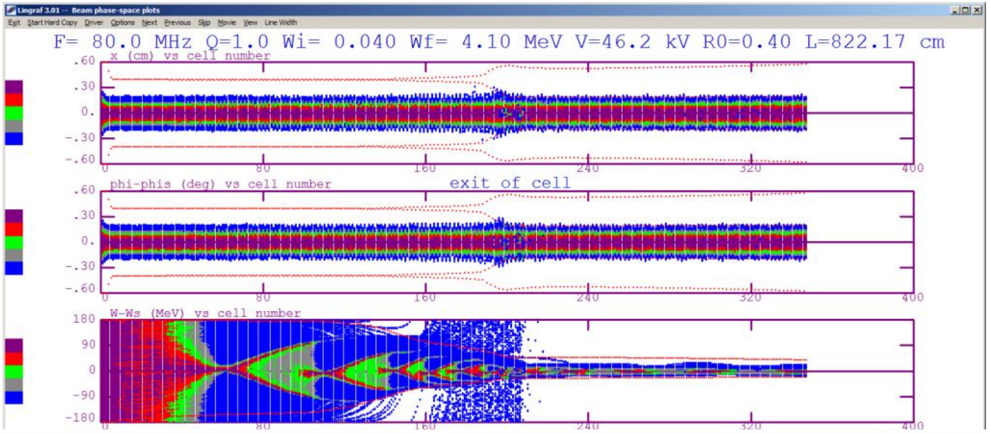
LINAC Upgrade in progress

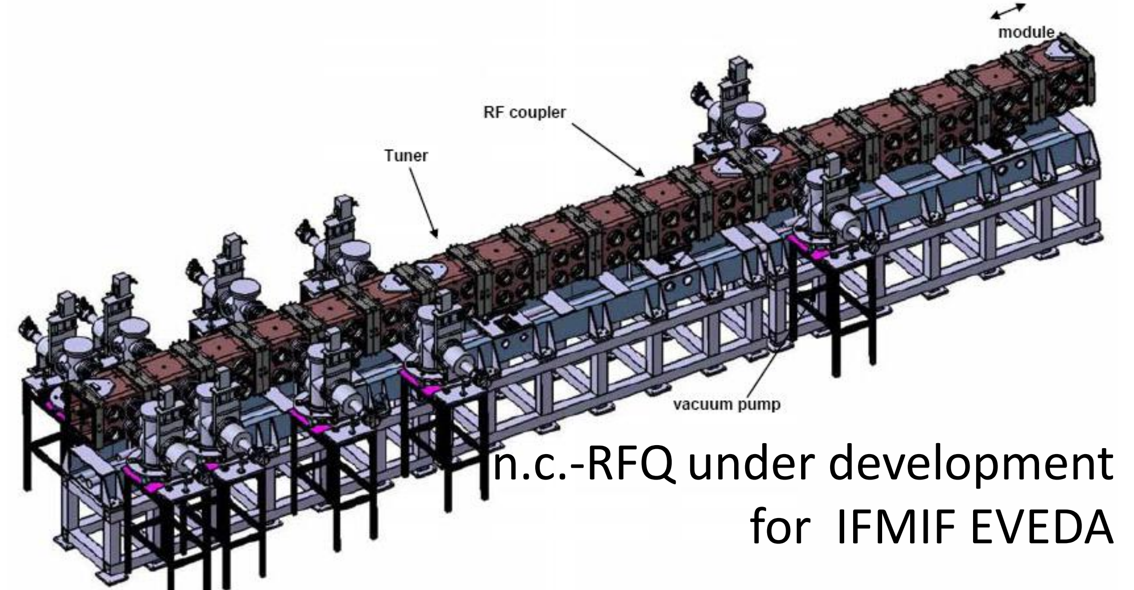
Pre-acceleration by normal conductive RFQ

- Energy 5.7 –> 700 KeV/A (A/q=7)
- Beam transmission >95%
- Length 650 cm intervane voltage = 46kV
- RF power Ladder 100 kW Q=9000
- DB Electronics amplifier 100kW CW 80 Mhz as SPIRAL2 RFQ can be used
- Mechanical design and realization takes advantage of IFMIF experience and follows same collaboration (LNL, Padova, Bologna, Torino)

New pre-accelerator to fit ALPI acceptance: development of a 80MHz normal conductive RFQ following the IFMIF-EVEDA technology.





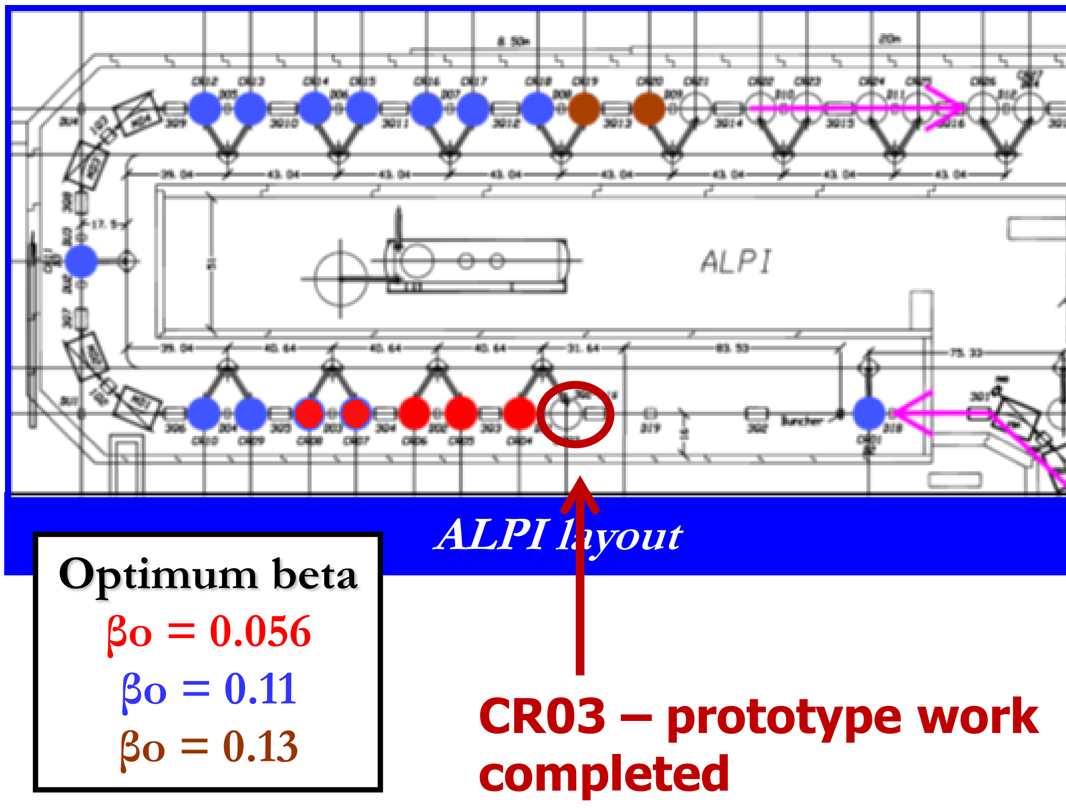


n.c.-RFQ under development for IFMIF EVEDA

ALPI Low-Beta Cavity Upgrade

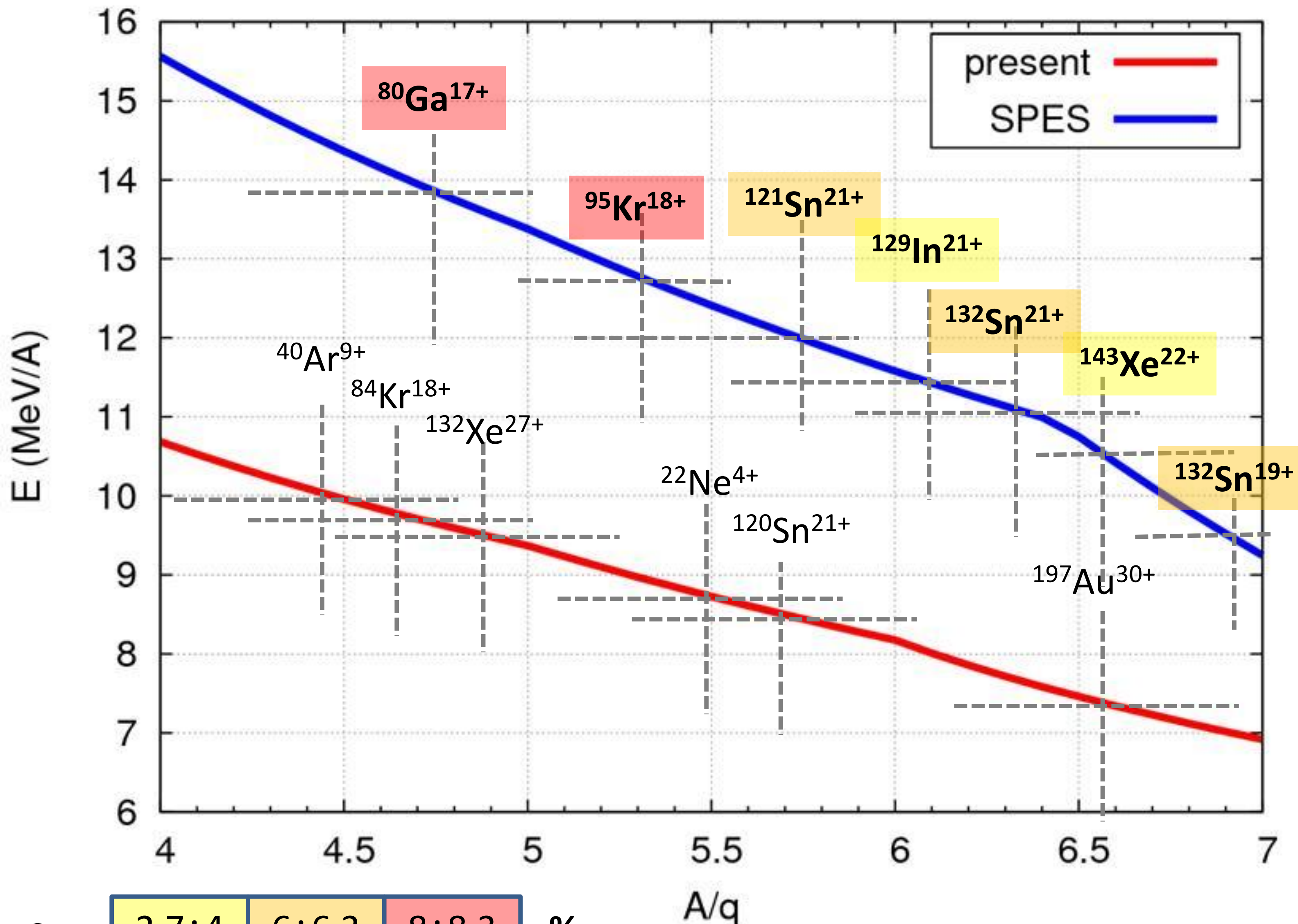
Motivation: to achieve at least **10 MeV/A up to A/q=7**
most beam species, up to the heaviest, with a more efficient linac
better beam dynamics → higher beam transmission

- **Starting situation: 20 QWRs in 5 cryostats**
  E_a~ 3 MV/m (limited by rf system) - total accelerating voltage ~ 11 MV
- ***After upgrade: 24 QWRs (one more cryostat with 4 cavities)***
  E_a = 5 MV/m (upgraded rf system) - total accelerating voltage ~ 21 MV

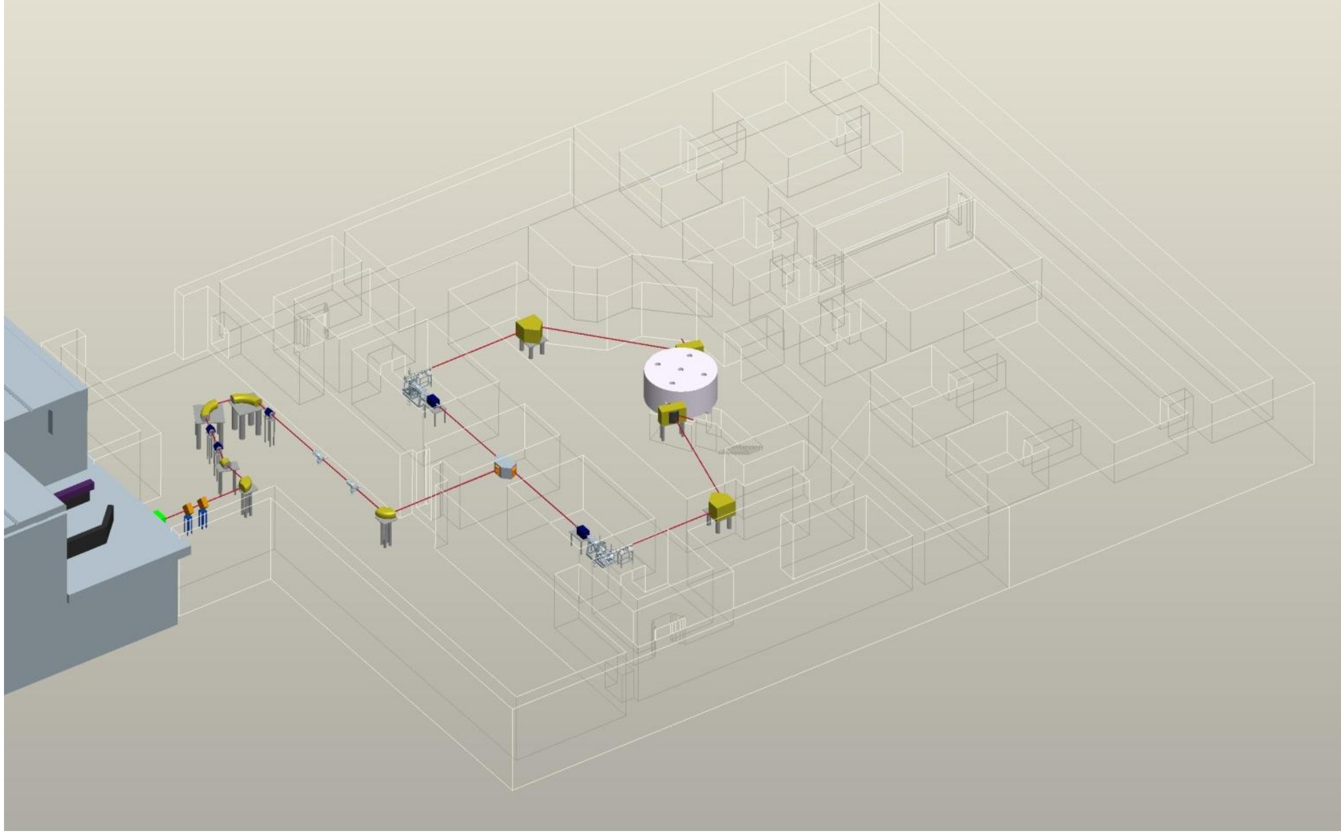


A. Facco, P. Modanese

SPES Final Performance (Phoenix charge- bred beams)



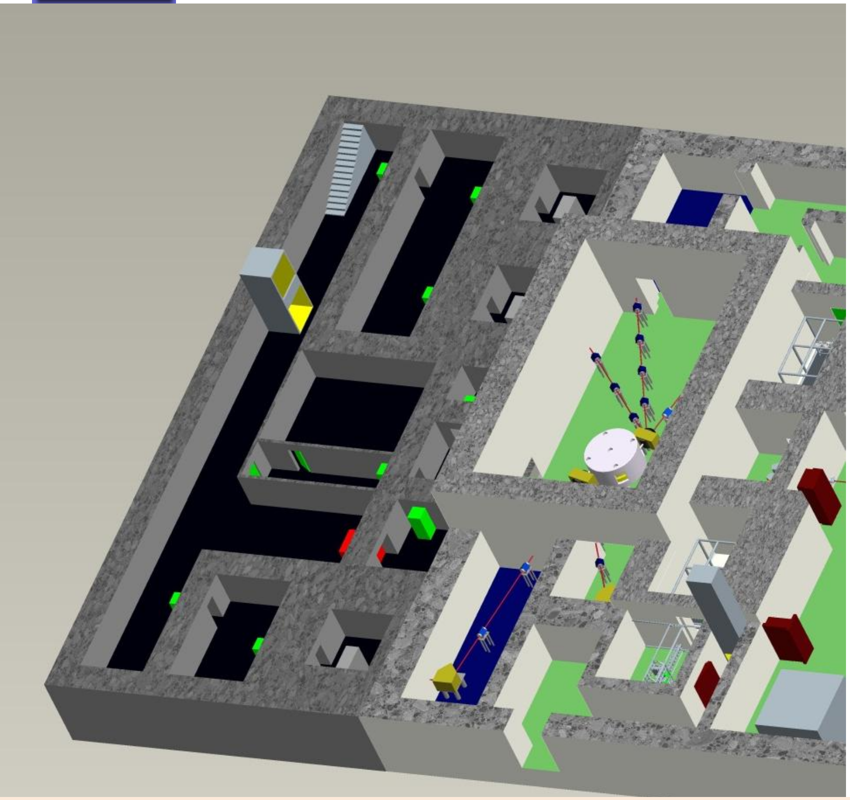
ε =	2,7÷4	6÷6,3	8÷8,3	%



SPES Project

APPLICATIONS

Radio-isotopes for medicine



LARAMED Facility:
Production of radionuclides of interest for medicine using the SPES cyclotron

Radionuclide	Target nucleus	Nuclear Reaction	Cross section (mbarns)	Needed energy (MeV)
^{64}Cu	Ni	^{64}Ni(p,n)	≈ 675	15
^{68}Ge	Ga	^{69}Ga(p,2n)	≈ 550	30
^{82}Sr	RbCl	^{nat}Rb(p,4n)	≈ 98	70
^{67}Cu	ZnO	^{68}Zn(p,2p)	≈ 10	70
^{44}Sc	Ca	^{44}Ca(p,n)	≈ 700	12
^{47}Sc	Ti	^{48}Ti(p,2p)	≈ 20	70

Collaborations

INFN – ARRONAX:

New target technology for the production of radionuclides

Development of new radiopharmaceuticals of copper-67/64

Investigation of the biological effect of alpha radiation

INFN – BEST Theratronics:

Study for Production of Mo-99/Tc-99m at clinical levels:

Direct Production of Tc-99m by p+^{100}Mo

Production via UCx Target (p-induced fission)

Neutrons beams with cyclotron

Integral neutron production at SPES Cyclotron

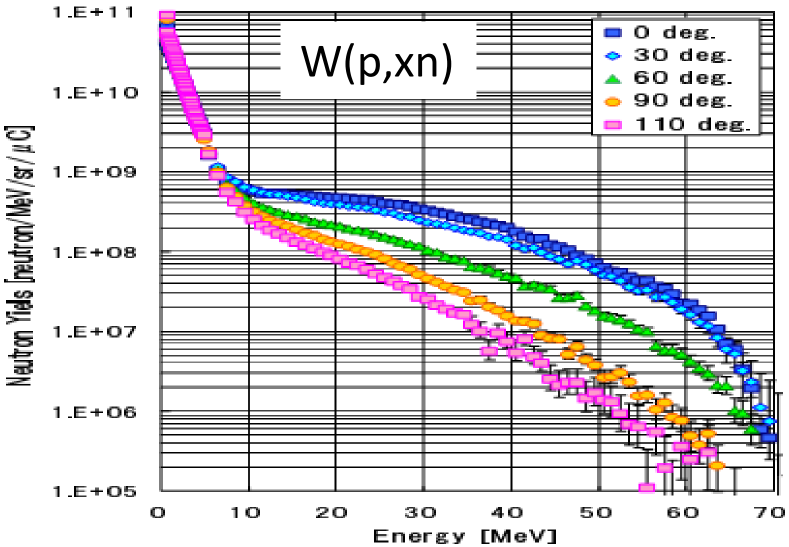
Proton beam= 70 MeV, 500 μA Target = W 5mm

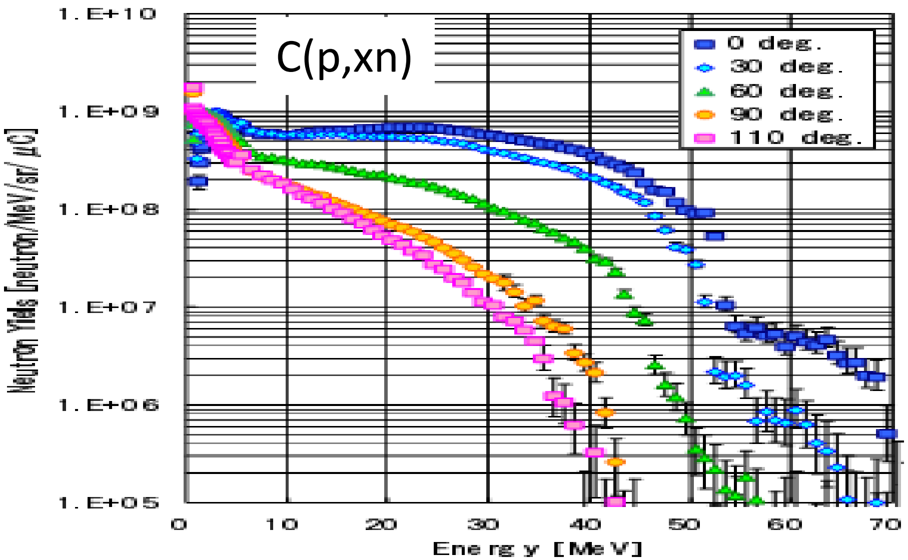
Energy region (MeV)	Sn (n/s) ~ $6\cdot10^{14}$ s^{-1}	Φ_n @ 2.5 m ($n\ cm^{-2}\ s^{-1}$)	Φ_n @ 1 cm ($n\ cm^{-2}\ s^{-1}$)
1 < E < 10	~ $5\cdot10^{14}$ s^{-1}	5×10^8	3×10^{13}
10 < E < 50	~ $1\cdot10^{14}$ s^{-1}	1×10^8	$6x10^{12}$

Union for Compact Accelerator-based Neutron Sources

UCANS

Next meetng: Hokkaido 24 September 2013

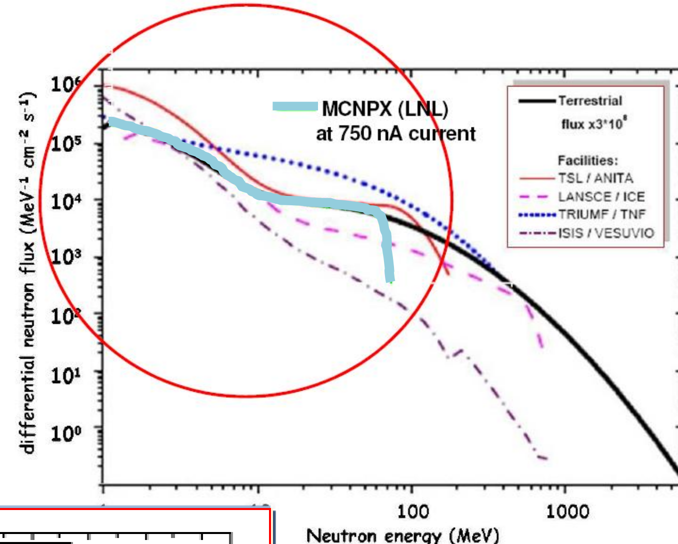


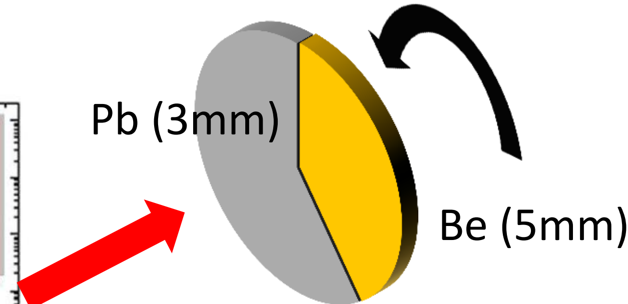


Neutrons beams with cyclotron

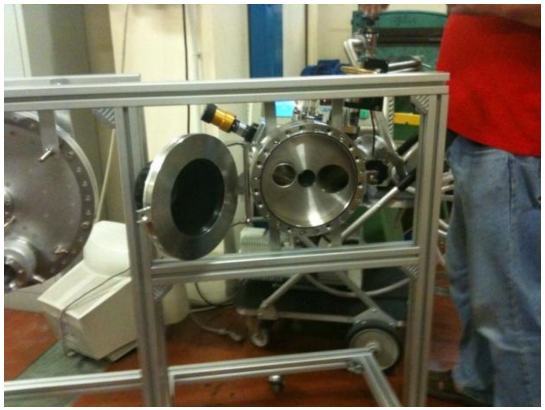
SEE facility (Single Event Effect)

Accelerated atmospheric neutron spectra



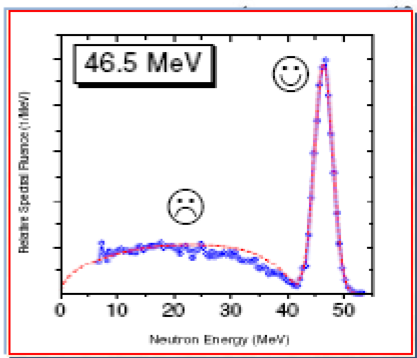


Multi-material Rotating target



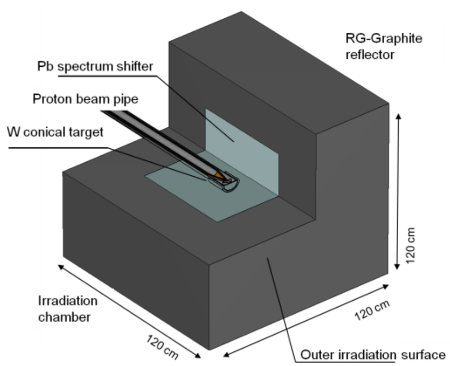
Quasi monoenergetic neutron beams

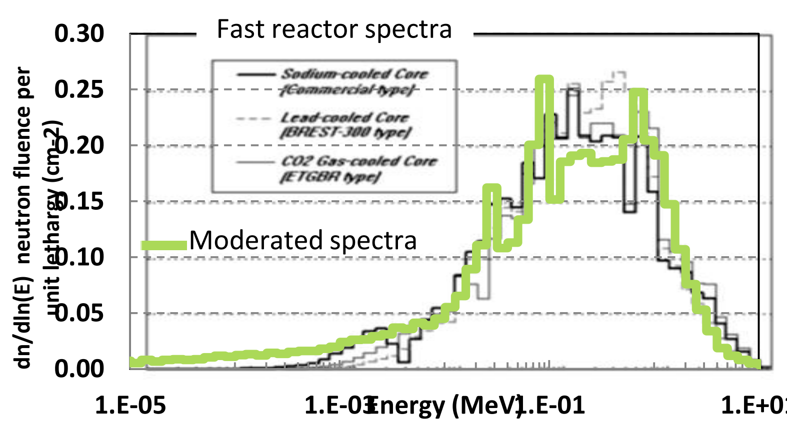
7Li(p,n) and 9Be(p,n) reactions on thin targets



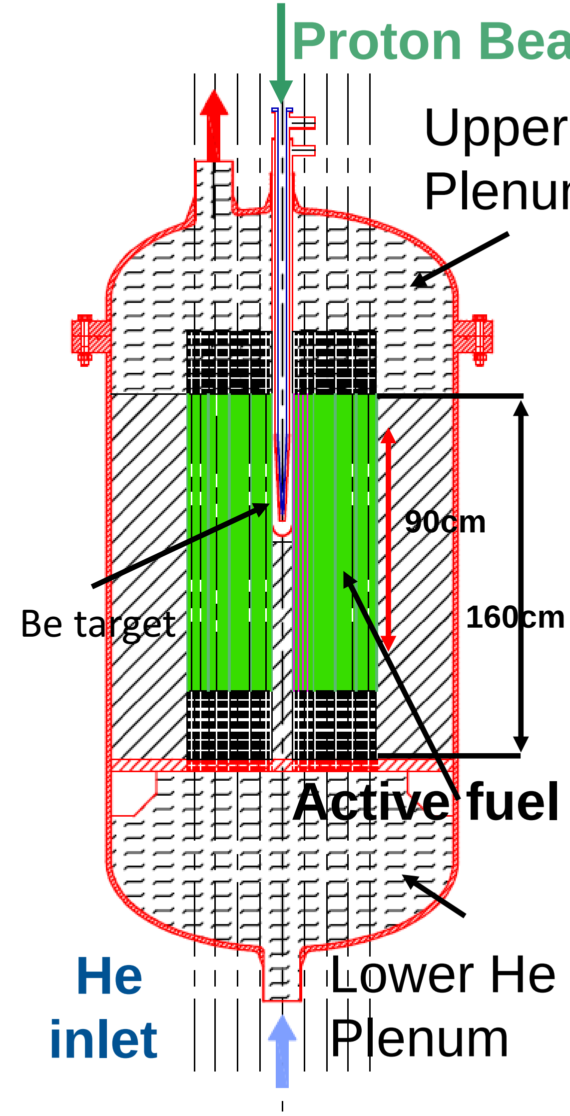
50MeV 10uA p on 4 mm ^{7}Li target

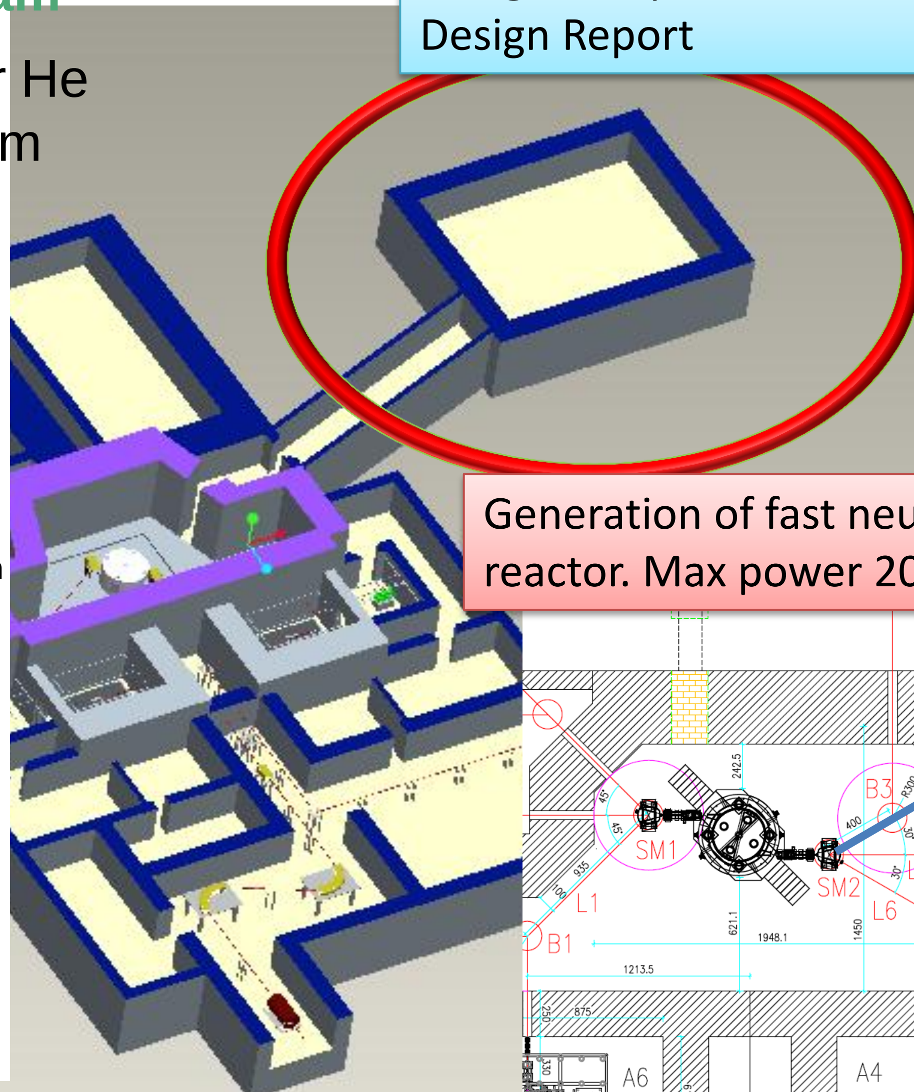
Moderated neutron beams





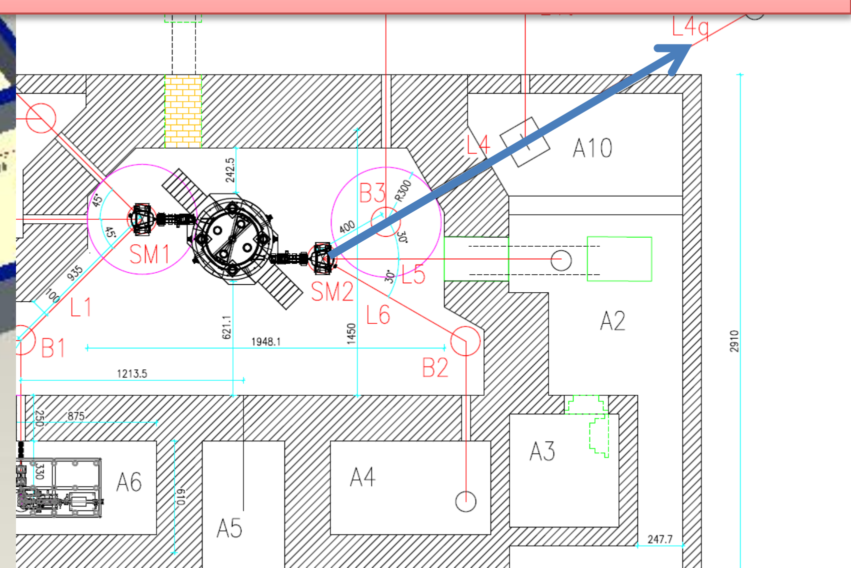
Fast neutrons generator

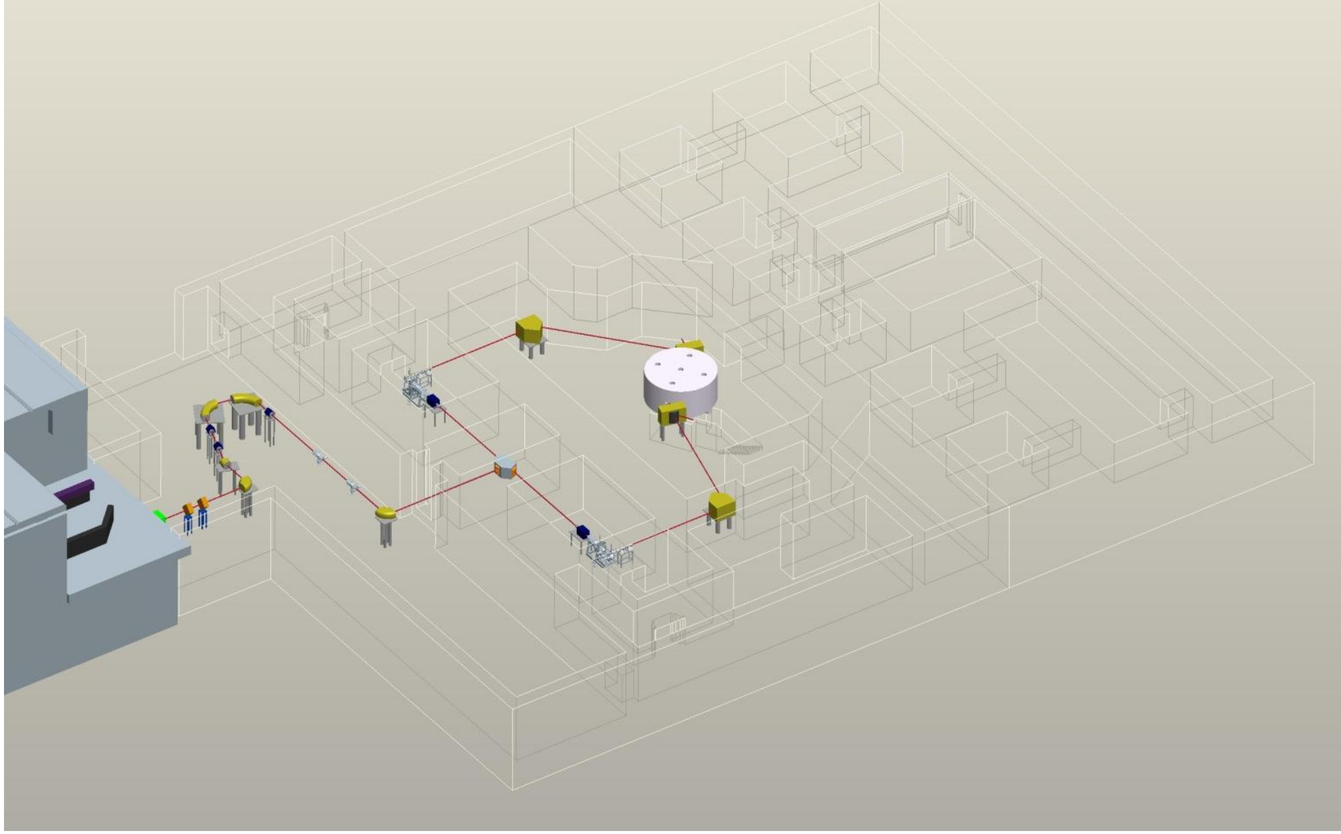




Design study : definition of a Technical Design Report

Generation of fast neutrons by a sub-critic reactor. Max power 200kW

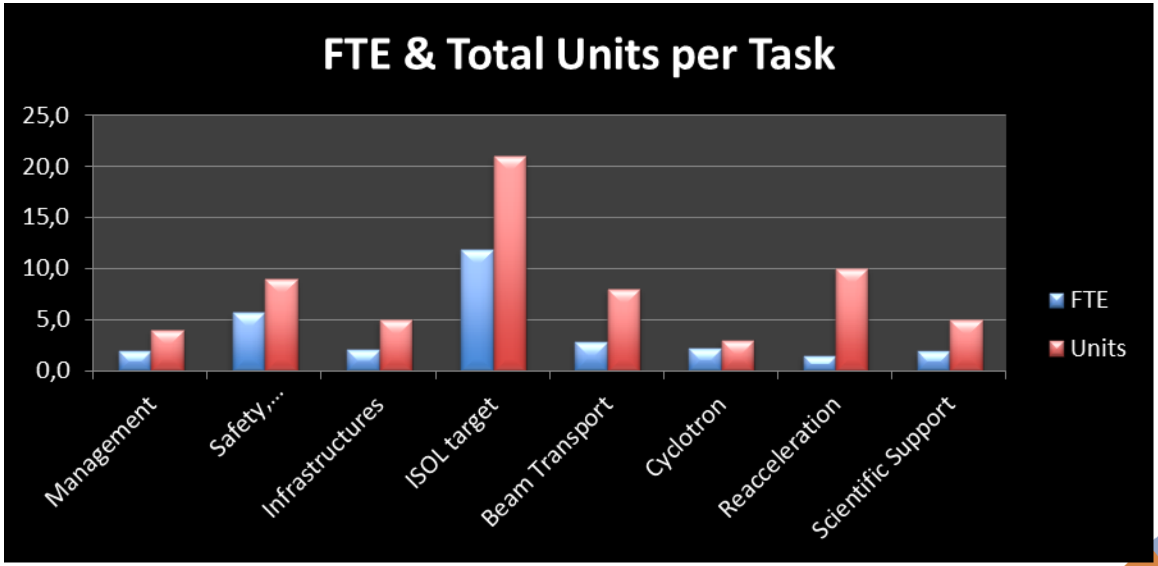


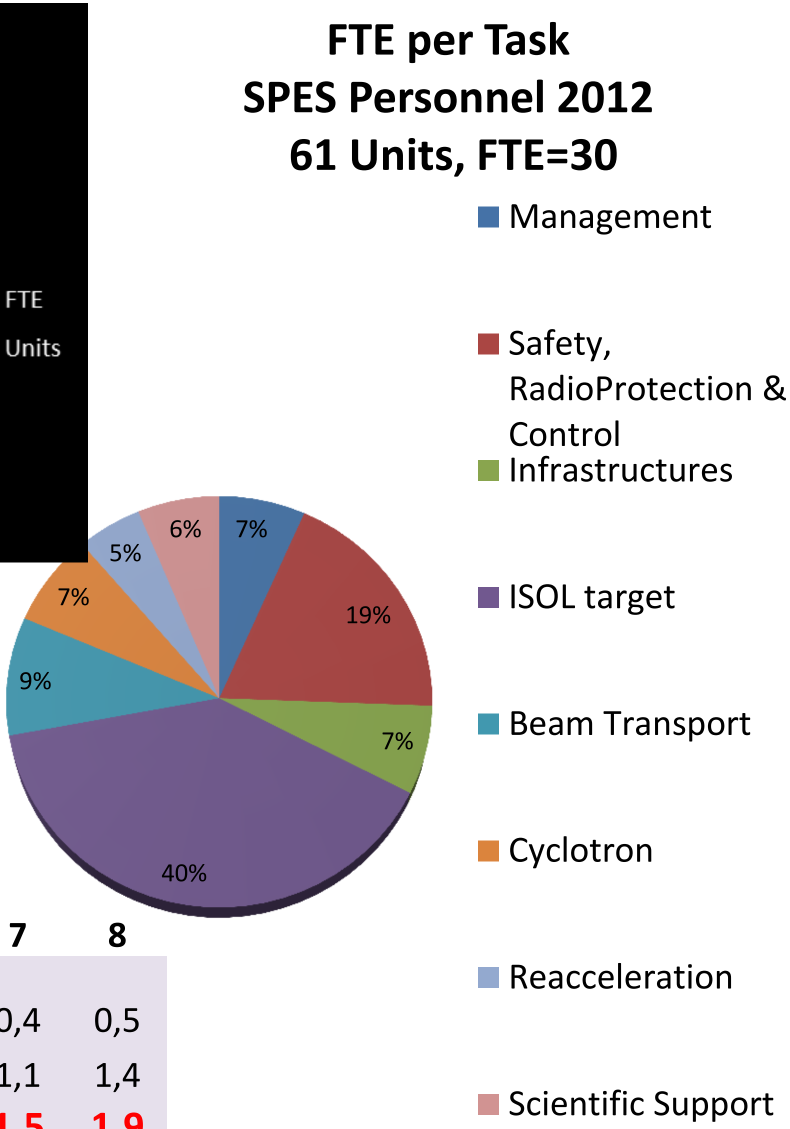


SPES Project

PERSONNEL AND STATUS

SPES – Personnel 2012





	units	FTE	task0	1	2	3	4	5	7	8
Temporary	19	**15,9**	0,2	3	0,3	8,8	1,4	1,3	0,4	0,5
Staff	42	**14,2**	1,8	2,7	1,8	3,1	1,4	0,9	1,1	1,4
total	**61**	**30,1**	**2,0**	**5,7**	**2,1**	**11,9**	**2,8**	**2,2**	**1,5**	**1,9**

INFN Fellowship for young foreign PhD

published on INFN jobs opportunity

INFN
Istituto Nazionale
di Fisica Nucleare

POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS IN THE FOLLOWING RESEARCH AREAS

EXPERIMENTAL PHYSICS (N. 20)

Next call: December 2012…..

Please contact me for further information's

E-mail: spes-segreteria@lnl.infn.it

SPES Schedule November 2012

	2012	2013	2014	2015	2016	2017
Authorization to operate and safety		UCx auth	orization			
ISOL Targets construction and installation						
Building Construction	building project					
Cyclotron Construction & commissioning	in	schedule				
Alpi up-grade & pre-acceleration						
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)						
Construction and Installation of RIBs transfer lines and spectrometer						
Complete commissioning and first exotic beam						

Current status

- Letters of Intent: under discussion to select first-day-experiments
- ISOL Target and Ion Source: under test with FEBIAD and Laser
- Layout for pre-acceleration: defined, RFQ physical design performed
- Safety report and radiation protection: authorized cyclotron operation at full power and preliminary test (low power) on UCx target
- Contract for cyclotron: signed November ‘10, final design accepted in June ’11, iron machined, under construction
- Building construction: international bid completed
- Expected ground breaking Feb.2013

SPES ISOL facility at LNL