INFN Istituto Nazionale di Fisica Nucleare

SPES Project

SPES exotic beams for science

SPES status

Gianfranco Prete
SPES Project leader

UCANS-V

The 5th International Meeting of
Union for Compact Accelerator-driven Neutron Sources
May 12-15, 2015
INFN-Laboratori Nazionali di Legnaro, Padova Italy

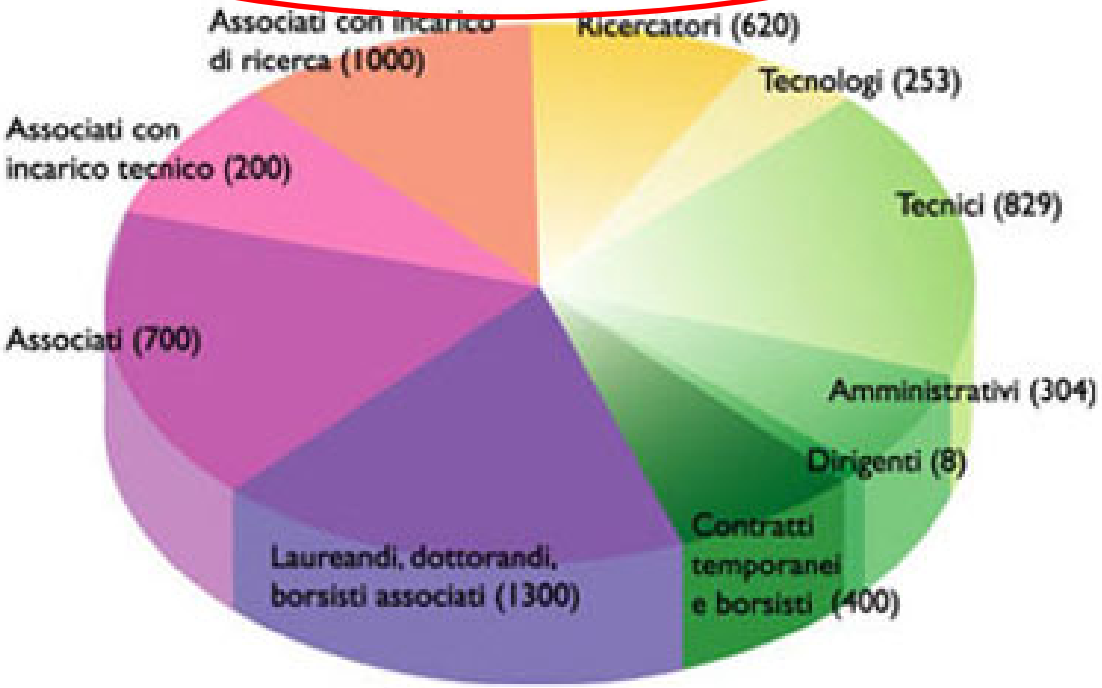
INFN

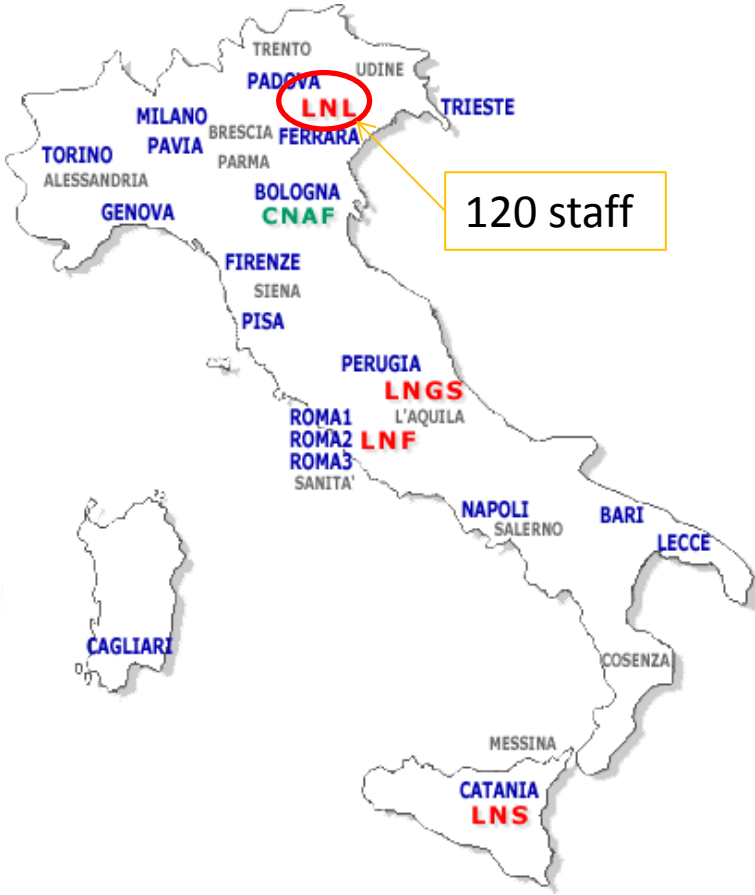
Istituto Nazionale di Fisica Nucleare

≈ 5600 persons involved

UNIVERSITÁ
1900 + 1300

INFN
2400

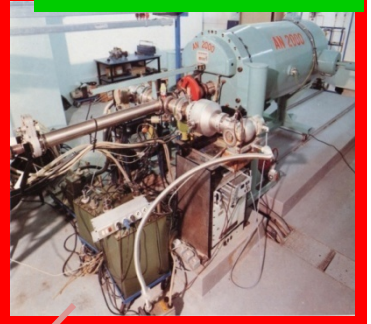




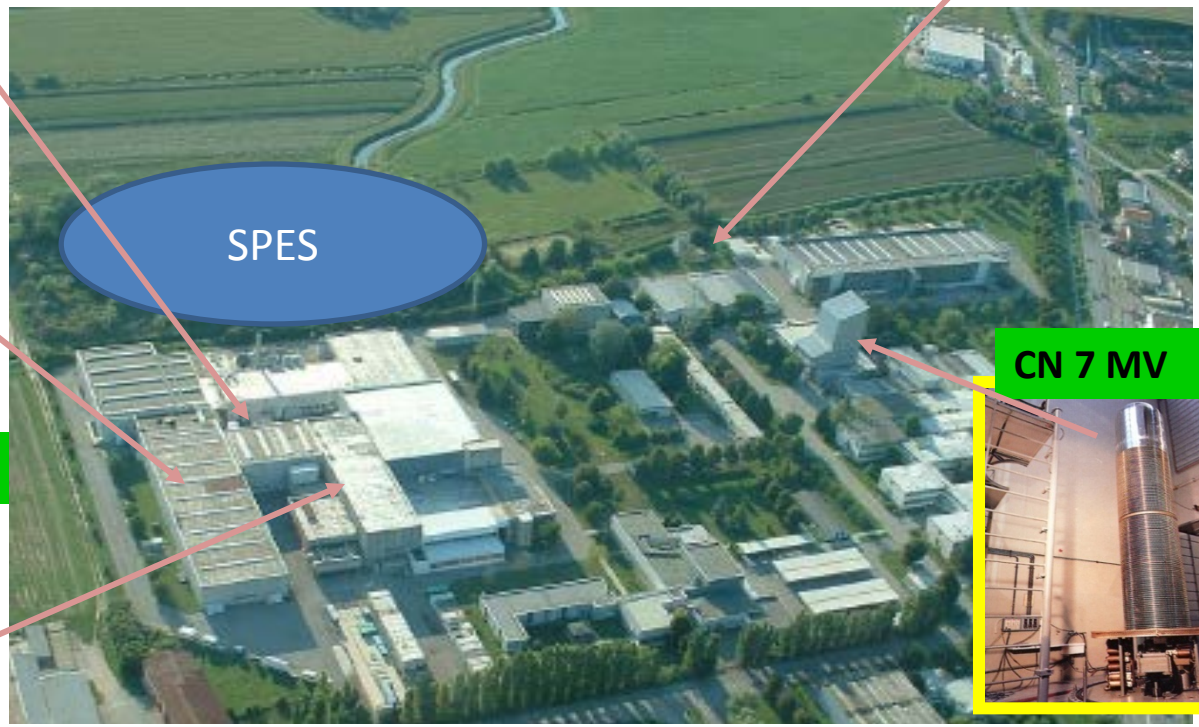
Laboratori Nazionali di Legnaro: site for SPES facility

PIAVE Heavy Ion Injector

AN2000 2 MV



ALPI Linac 48 MVeq



CN 7 MV

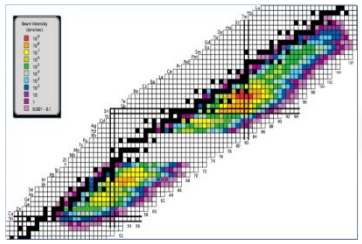
Tandem XTU 15 MV

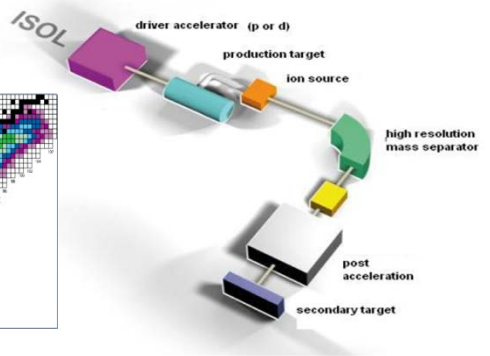
SPES Strategy

BEST Cyclotron installation & commissioning:

- 70 MeV proton beam
- 750 μA

Second generation ISOL facility
Toward EURISOL

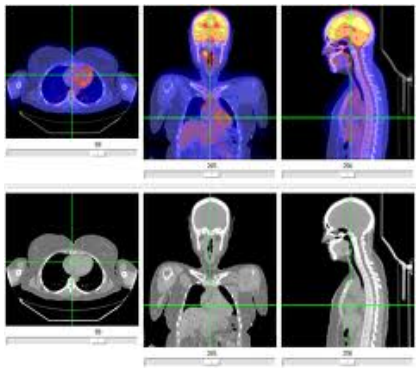




Funded

Funded

Production & re-acceleration of **exotic beams**. **Neutron–rich ions** from **p-induced Fission** on **UCx (10^{13} f/s)**



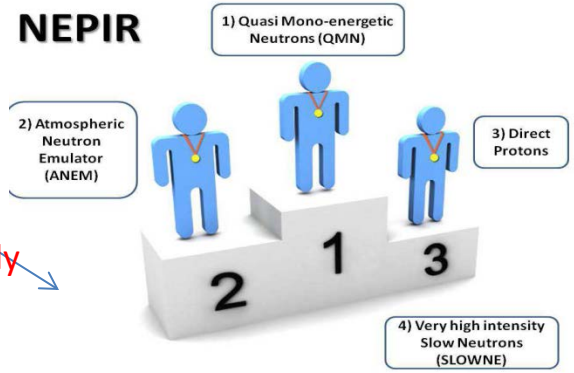
LARAMED

Partially funded 6.8 M€

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

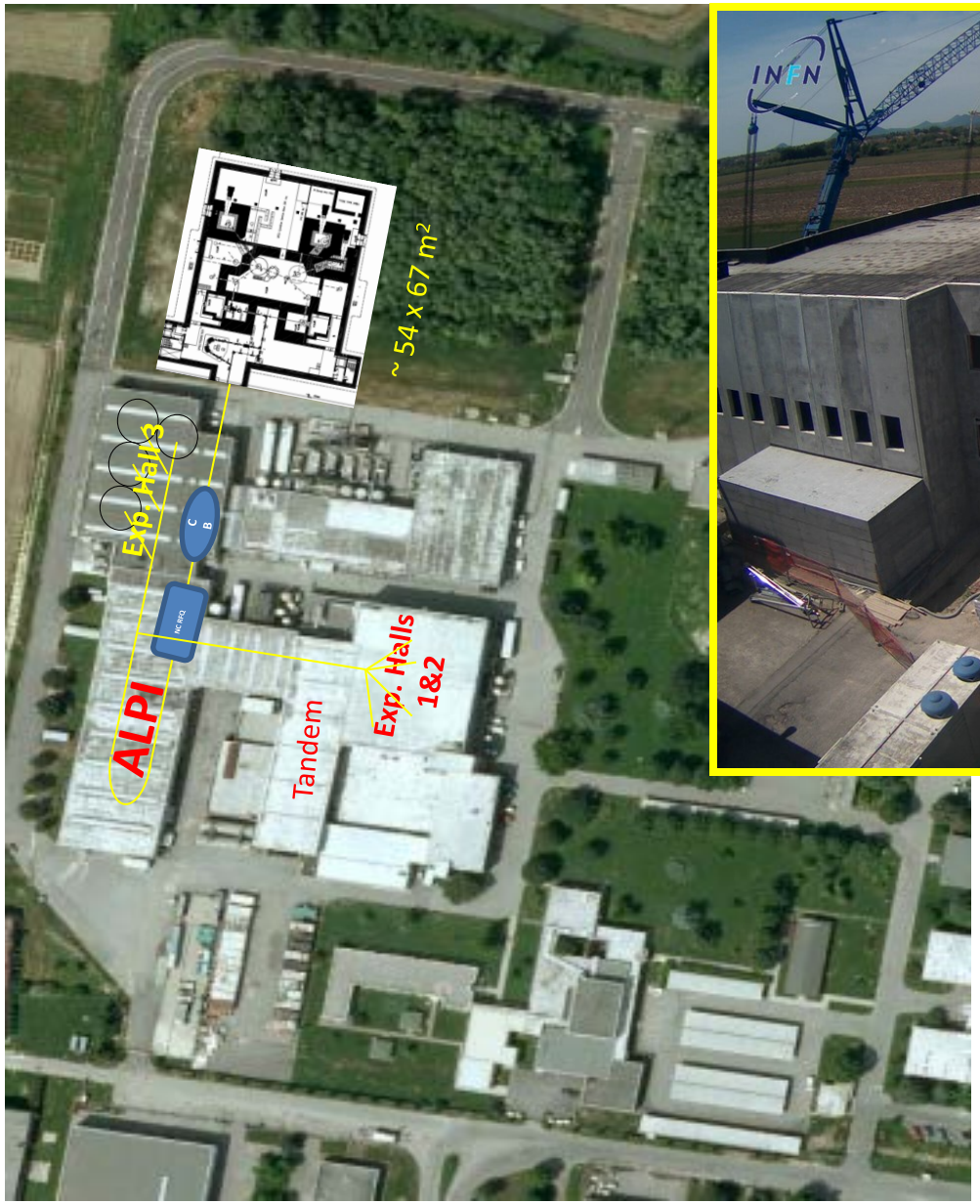
Design study

NEPIR



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

SPES Facility Layout



New infrastructure for:

- cyclotron
- RIB (Radioactive Ion Beam)
- application facility

SPES layout

Laboratori Nazionali di Legnaro

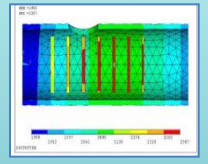
Proton and neutron irradiation areas (δ-phase)

CYCLOTRON α-phase

Radioisotopes for medical applications (γ-phase)

ISOL FACILITY β-phase

10kW UCx Direct Target: 10^{13} f/s

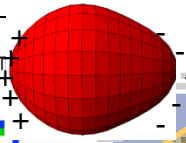


Radioactive Ion Beams are reaccelerated by the superconductive linac ALPI. A normal conductive RFQ placed before ALPI will match the input acceptance beam parameters.

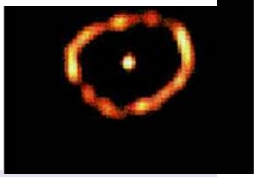
Physics Domain with RIB

Nuclear Physics and Astrophysics

Limit of existence:
new shapes, new collectivity



Origin of new elements, rare isotopes powering stellar explosions, neutron star crust



The Experimental techniques:

- **Coulomb Excitation**
- **Decay Spectroscopy**
- ***Transfer Reactions***
- ***Reaction Studies***

today
Second generation
EURISOL

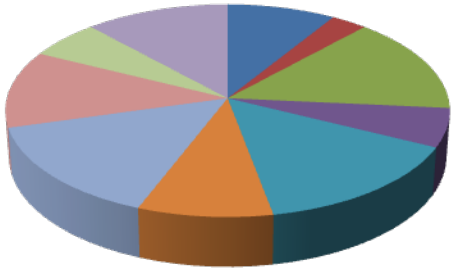
iCal export | More | Europe/Rome | English | Login

Second SPES International Workshop

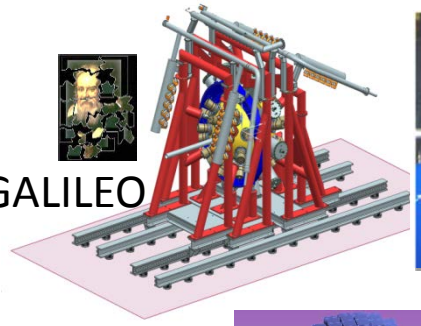
26-28 May 2014 *INFN Laboratori Nazionali di Legnaro*
Europe/Rome timezone

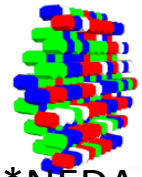
Presented 37 Letters of Intents

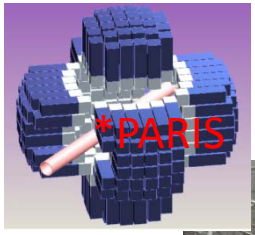
SPES LOIs Topics

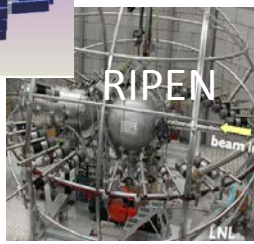


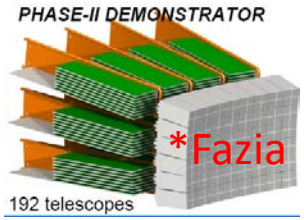
- GS properties
- moments
- Coulex
- DirReac with ActiveTarget
- DirReac with Si
- Mn transfer



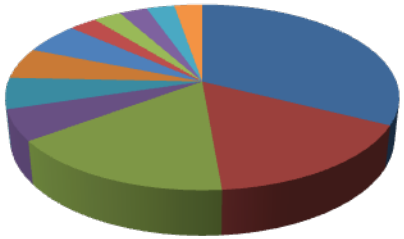




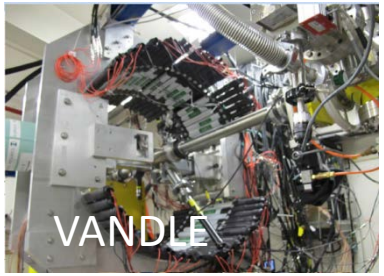


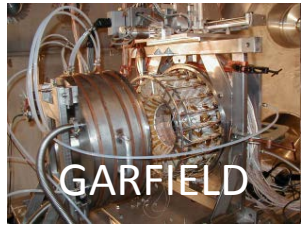


SPES LOIs Spokespersons



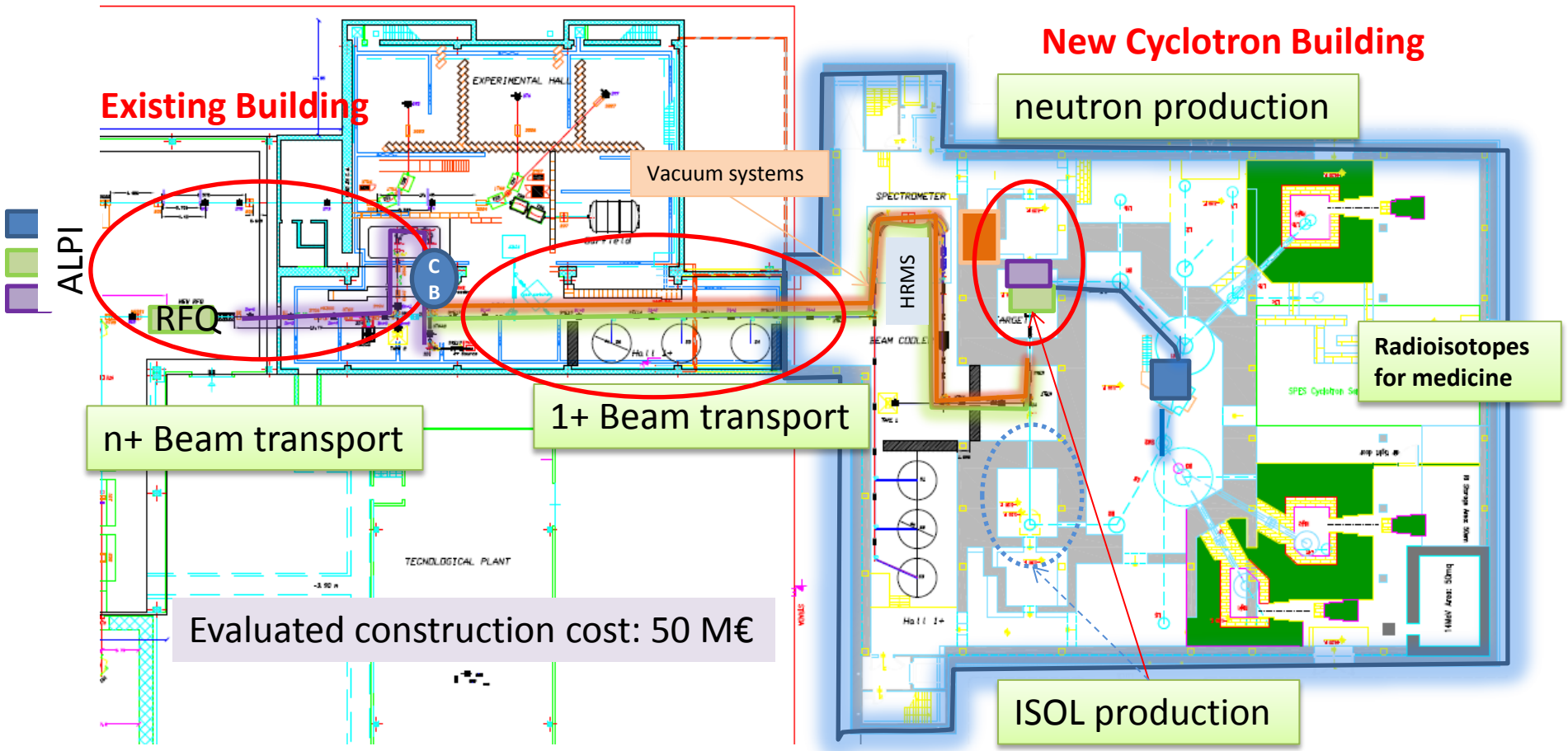
- Italy
- France
- Poland
- Russia
- USA
- Belgium
- Croatia
- Norway
- Bulgaria
- Spain
- Russia
- China





MAIN TENDERS

2010-2012	2013-2014	2015	2016	2017
ISOL target Cyclotron and Building	Laser source Charge Breeder and n+ beam transport	1+ beam line RFQ and safety	Vacuum systems and installation	High Resolution Mass Separator



SPES general planning

	2012	2013	2014	2015	2016	2017	2018	2019
Authorization to operate and safety	UCx 5microA							
ISOL Target-Ion Sources development								
ISOL Targets construction and installation								
ISOL on-line commissioning								
Building Construction	Executive project	raw building construction						
Cyclotron Construction & commissioning				Cyclotron at LNL				
RFQ development and Alpi up-grade								
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)								
Construction and Installation of RIBs transfer lines , CB and spectrometers								
Stepwise commissioning and first exotic beam (2018), HRMS in 2019								

Cyclotron Site Test at BEST Company (Ottawa)

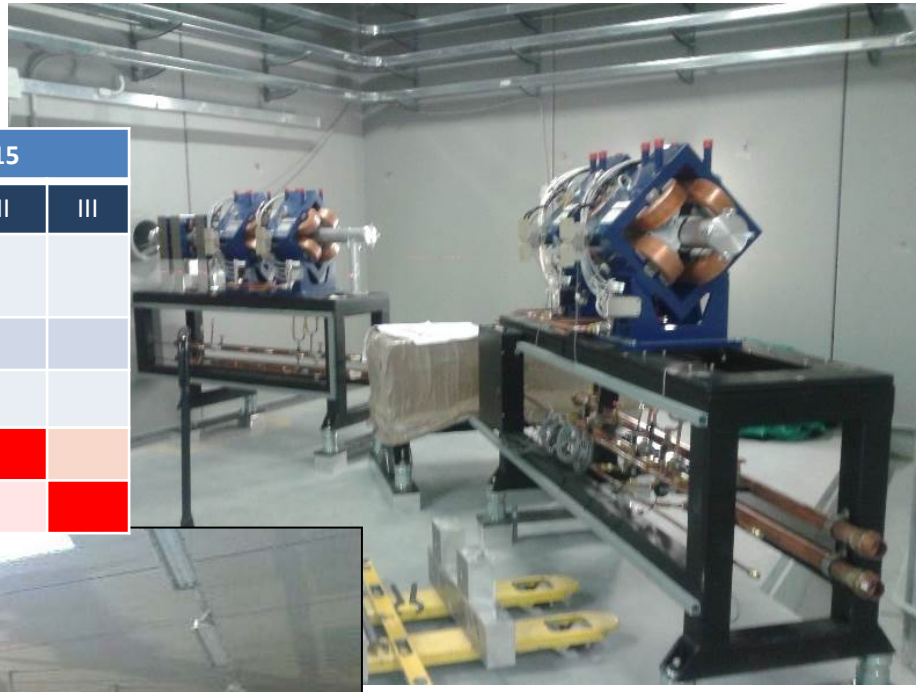
November 2014 Factory Acceptance Test

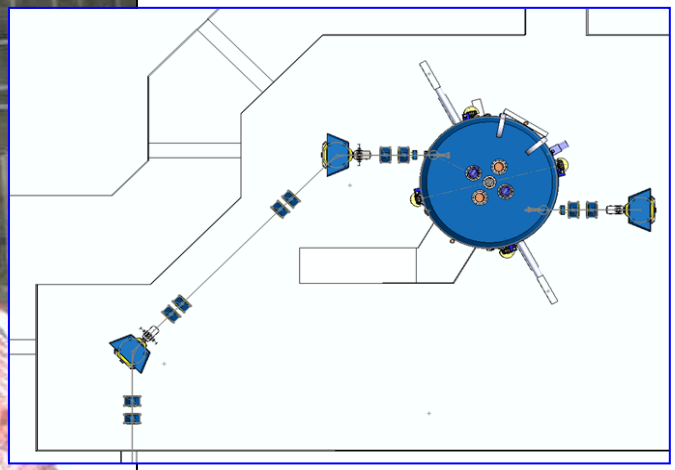
Main Parameters	
Accelerator Type	Cyclotron AVF 4 sectors
Particle	**Protons (H^- accelerated)**
Energy	**Variable within 30-70 MeV**
Max Current Accelerated	**750 µA** (52 kW max beam power)
Available Beams	**2 beams at the same energy** (upgrade to different energies)
Max Magnetic Field	1.6 Tesla
RF 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

Cyclotron assembled and operated with 700 µA at 1MeV

SPES: Cyclotron Schedule (2013-2015)

	2013		2014			2015		
	II	III	I	II	III	I	II	III
Final Assembly and Testing								
Factory Commissioning								
Disassembly and Shipping								
Installation at LNL								
Commissioning at LNL								





SPES CYCLOTRON
load work per year

Compact, high current, H- cyclotron:
70 MeV, 0.7 mA shared on 2 exits

2 proton beams are available at the same time

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.

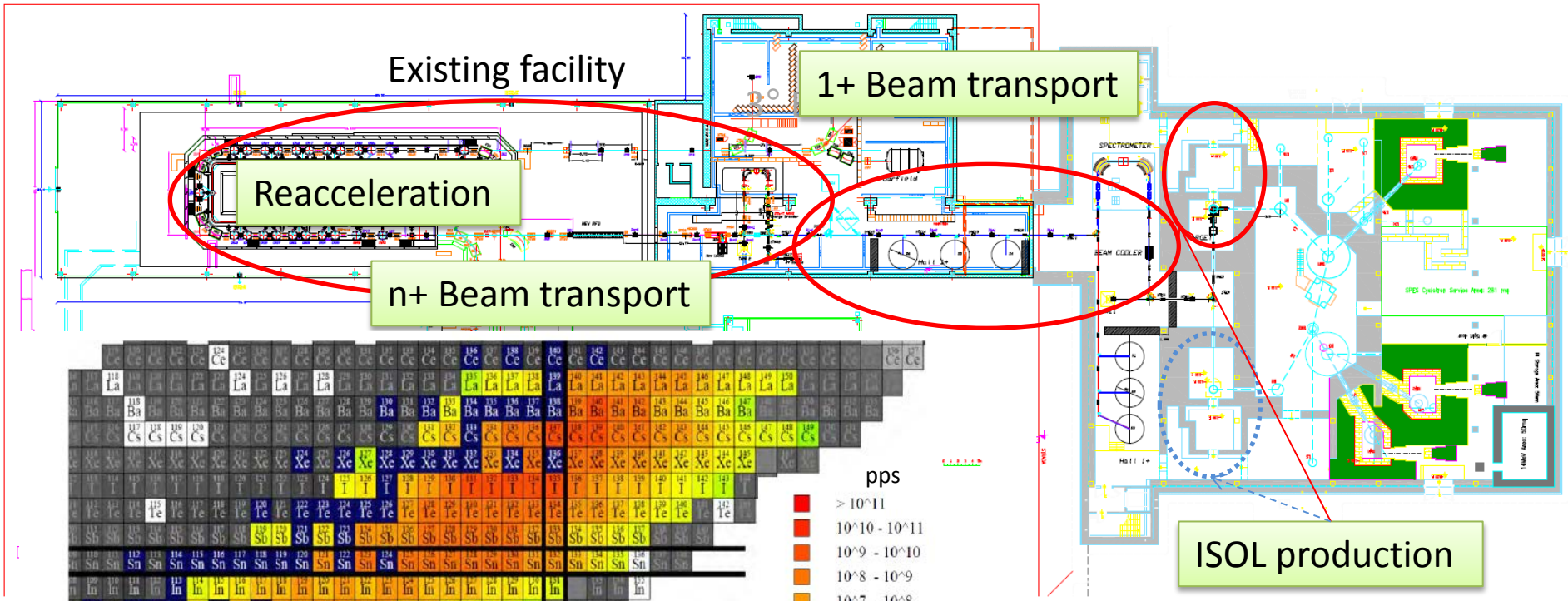
Expected Beam on target:
10600 hours per year

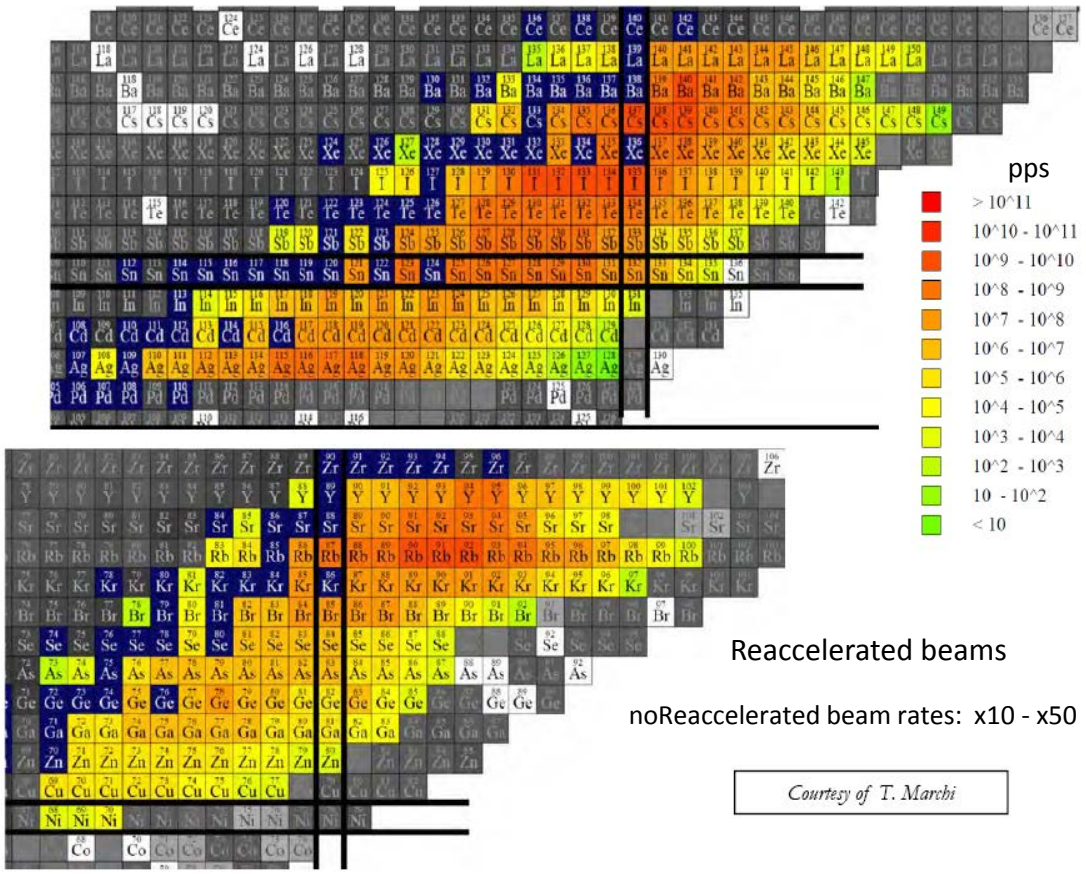
More than 5000 hours/year of proton beam available for applications

Beam sharing

	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

ISOL FACILITY

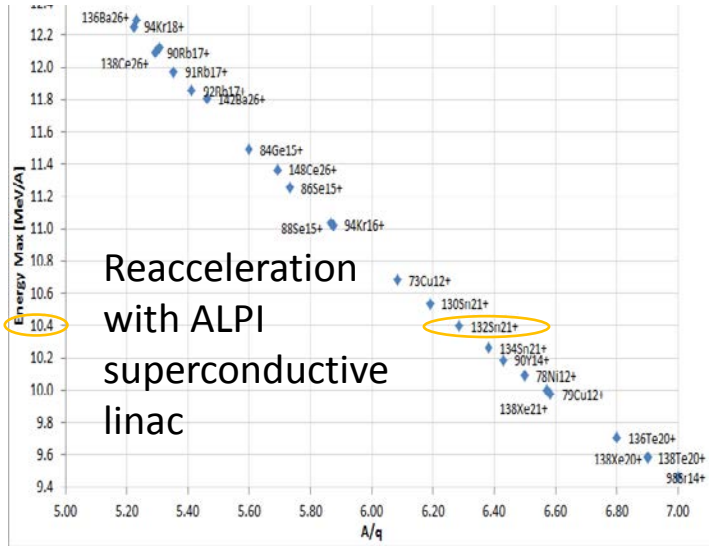




Reaccelerated beams

noReaccelerated beam rates: x10 - x50

Courtesy of T. Marchi



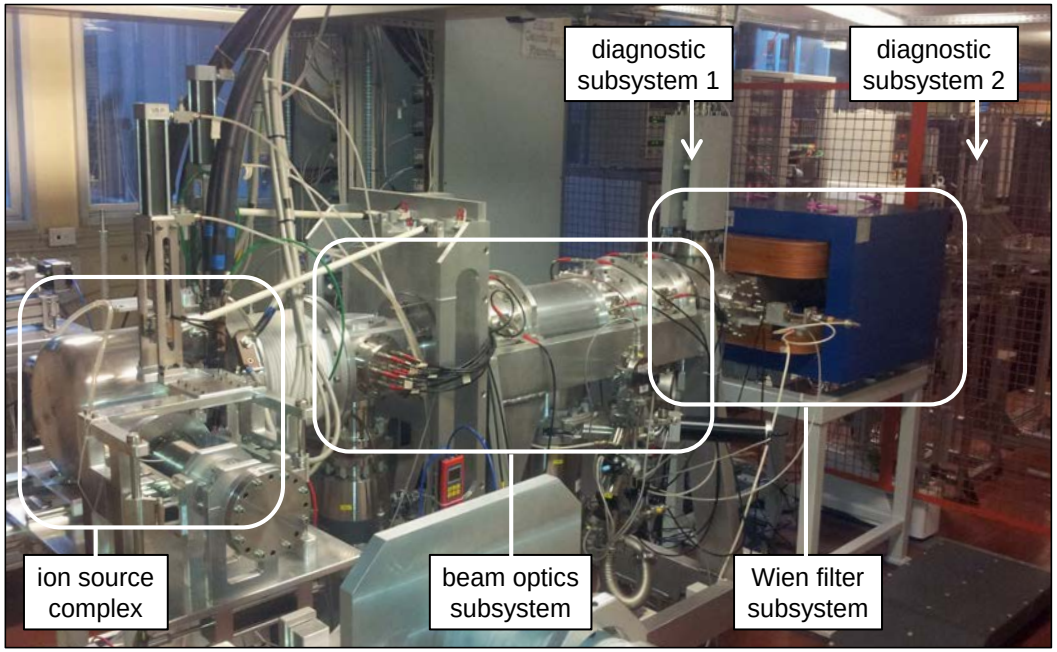
Reacceleration with ALPI superconductive linac

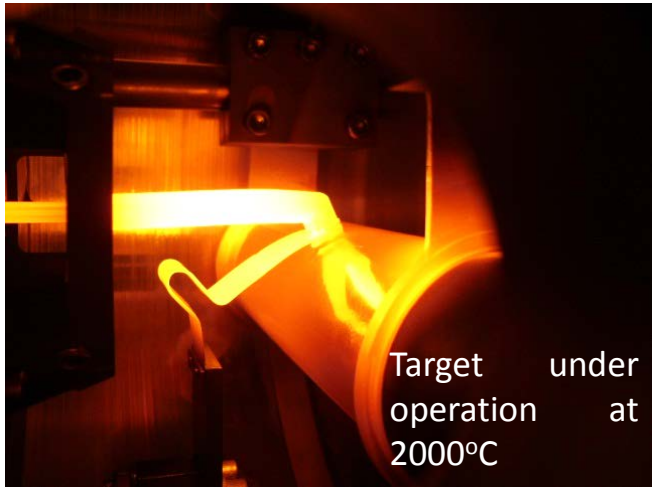
Technical highlights: the production target

SPES DIRECT TARGET CONCEPT to operate with **8 kW** proton beam

- Direct Target carefully designed to reach **10^{13} fissions/s** with **8 kW** proton beam (thermo-mechanical considerations);
- **In beam test** performed at **iThemba labs (South Africa)** on May 2014;
- Prototype under operation.
- Fully developed **front-end** following ISOLDE design

UCx target completely developed



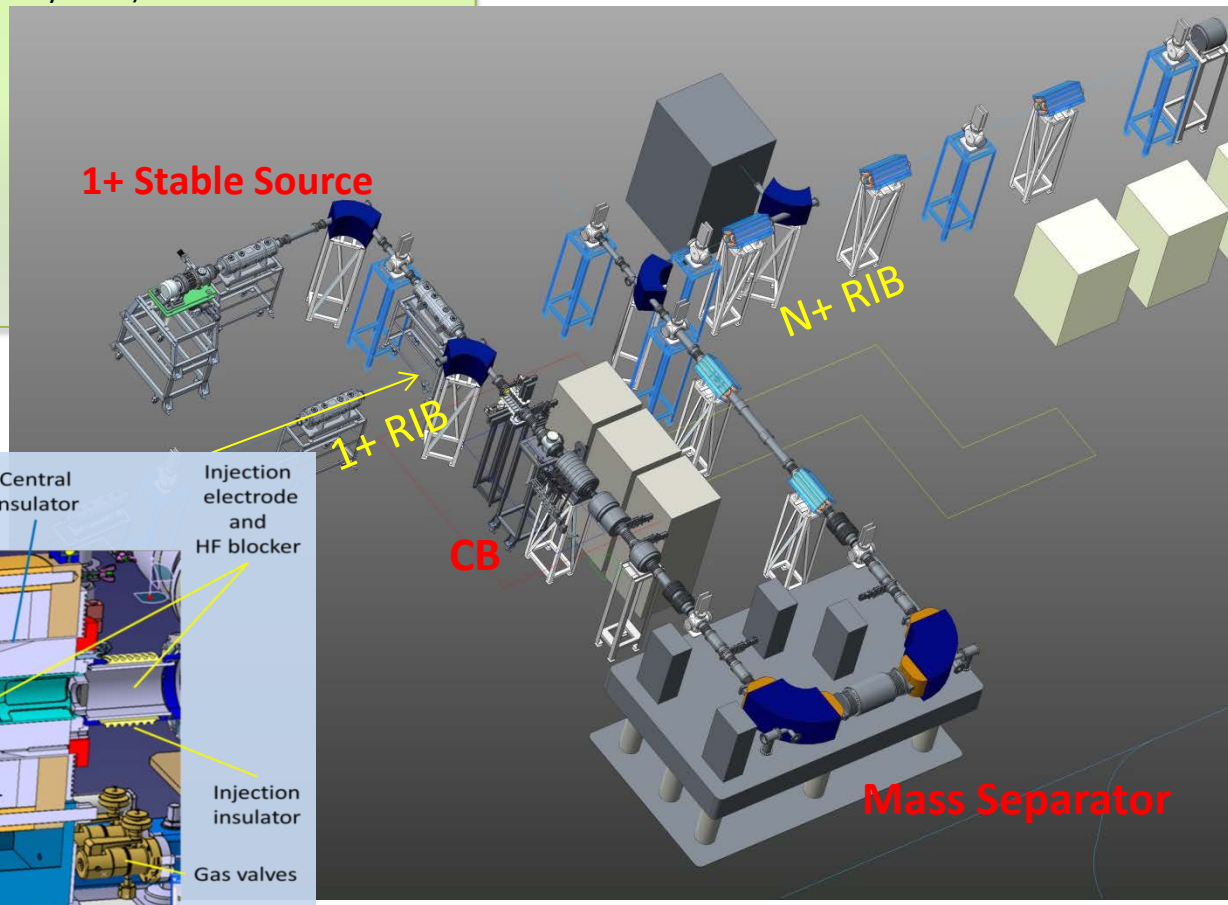


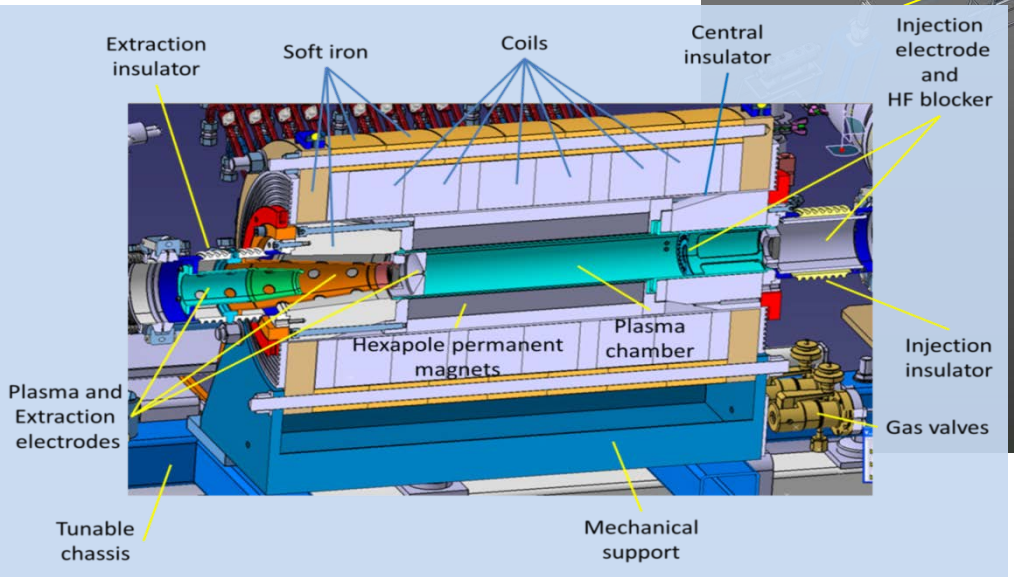
Exotic Beam reacceleration

Collaboration with LPSC (Grenoble) for the SPES Charge Breeder

The development of an Upgraded PHOENIX booster is Part of a MoU in the frame of the European Associated Laboratories (LEA-Colliga) with GANIL.
(In exchange: development of SPIRAL2 n-converter by INFN)
Project and construction by LPSC_Grenoble

- 2010 Preliminary measurements
- 2011 Conceptual design and schedule
- 2012 Design
- 2013 Agreement definition
- 2014 Construction
- 2015 Commissioning





Validation of the SPES-CB

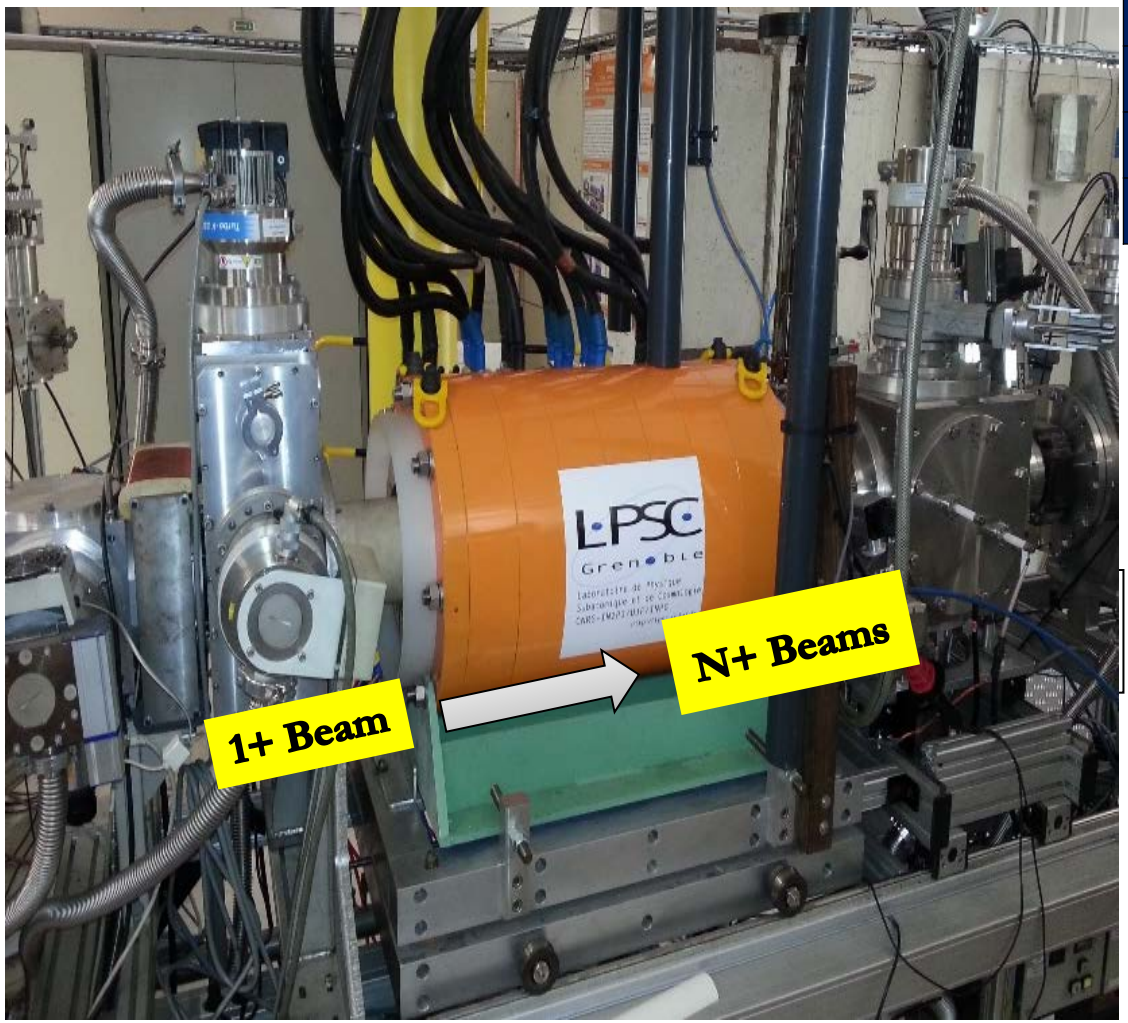
LPSC April 4th, 2015

Charge Breeder Beams:

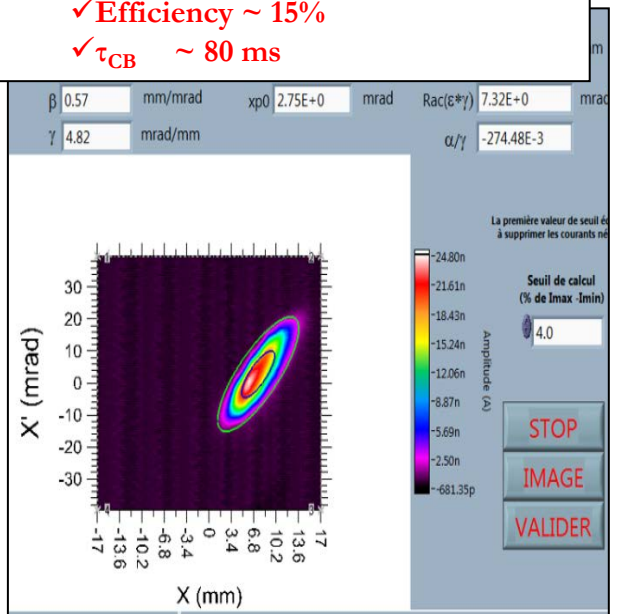
✓Global capture up to 90% !

		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*



- Ar^{8+}:
  - ✓$\varepsilon_{norm,rms}$ ~ 0,03*π*mm*mrad (96%)
  - ✓Efficiency ~ 15%
  - ✓τ_{CB} ~ 80 ms



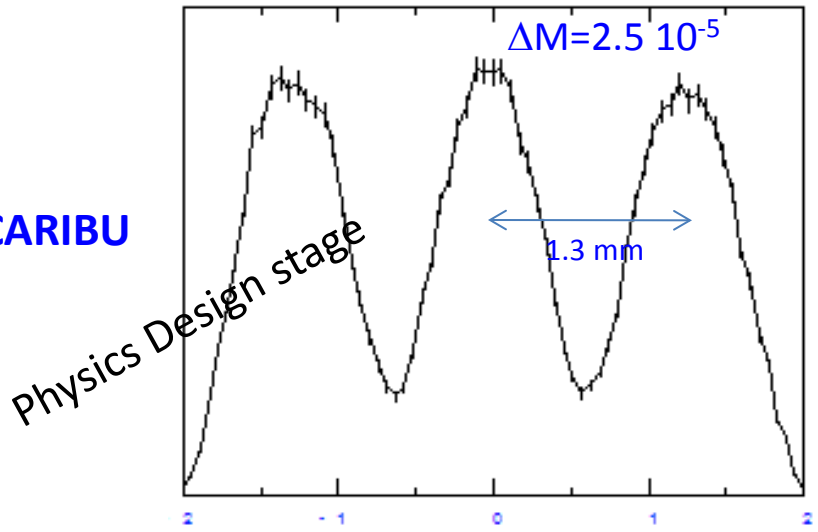
High Resolution Mass Separator & Beam Cooler

Approaching Mass resolution: 1/40000 !

L.Calabretta, M.Comunian, A.Russo, L.Bellan

Synergies with LNS
Collaboration SPES – CENBG Bordeaux

Scaled-up version of the separator designed for CARIBU
Mass resolution: 1/40000

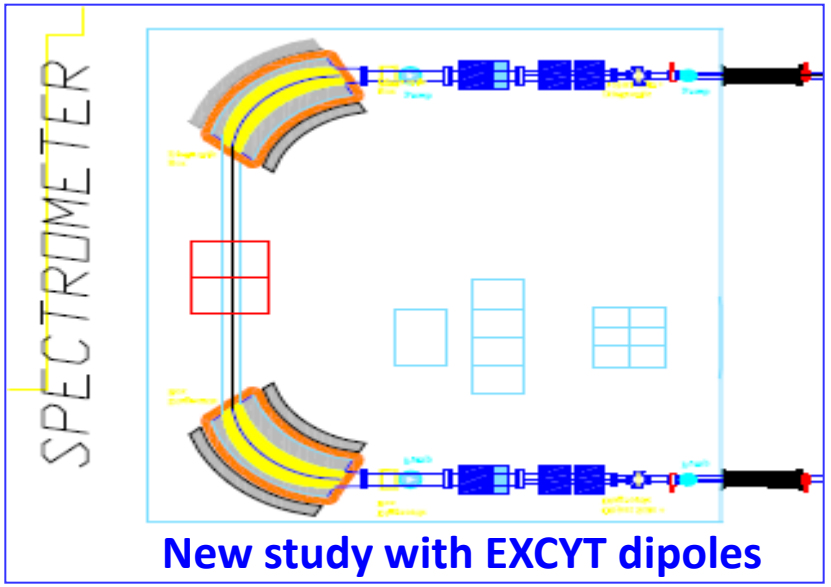


High Resolution Mass Separator

Beam Cooler to match the HRMS input requirements

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

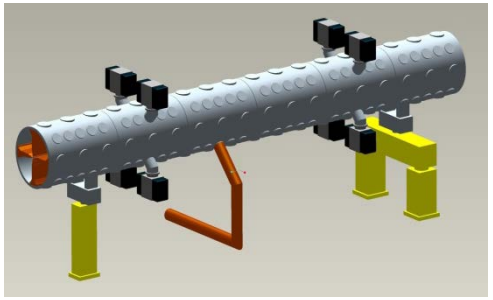
M.Maggiore



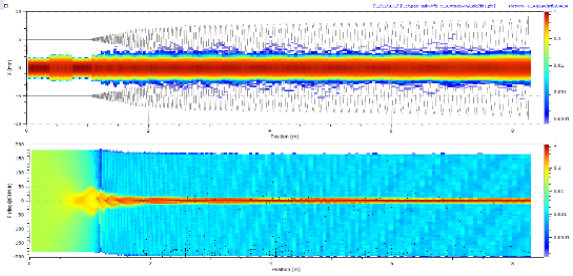
New study with EXCYT dipoles

Exotic Beam reacceleration: room temperature RFQ

Mechanical layout of the **RFQ**

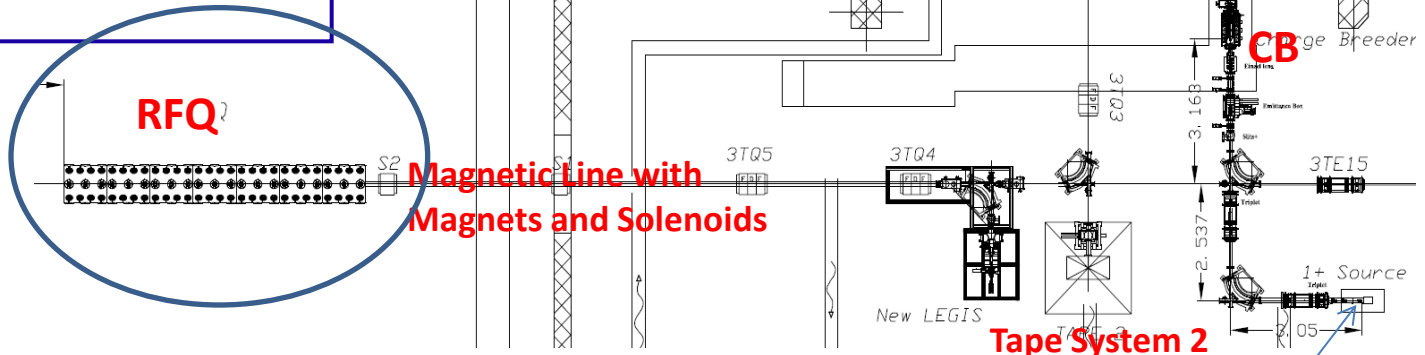


Physics design



High power RF Coupler 200kW
100% duty cycle

- Energy 5.7 → 727.3 [β=0.0395] KeV/A (A/q=7)
- Frequency 80 MHz
- Beam transmission >95%, low RMS longitudinal emittance at output: 0.15 ns*keV/u.
- Length 695 cm (**7 modules**) intervane voltage 63.8 – 85.8 kV
- RF power (four vanes) 100 kW.
- Mechanical design and realization, taking advantage of IFMIF experience (LNL, INFN_Pd, Bo, To).



E. Fagotti, A. Pisent

LARAMED Project

Funded with 6.8 Meuro

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

- Measurement of cross section through targets activation
- High power targets tests
- Radioisotopes/radiopharmaceuticals Production test facility (^{99m}Tc, ^{64}Cu, ^{67}Cu, ^{82}Sr, ...)

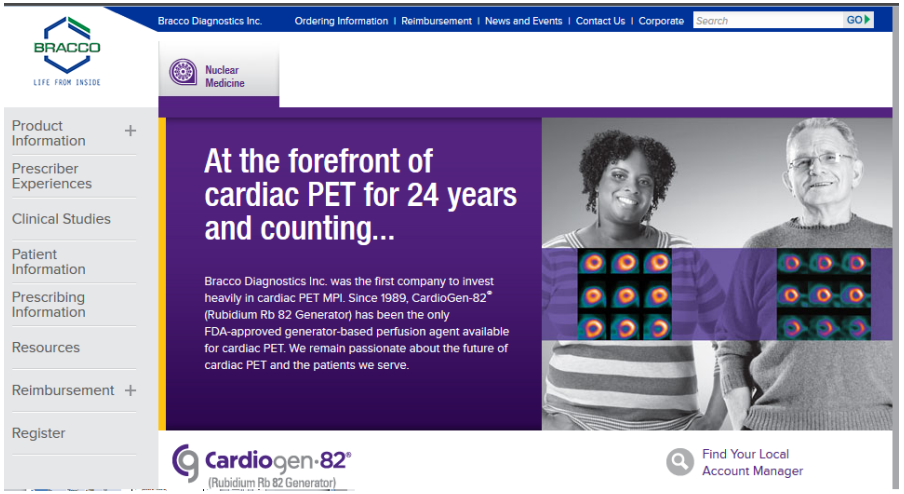
STATUS:

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

Production laboratory joint venture with external companies:

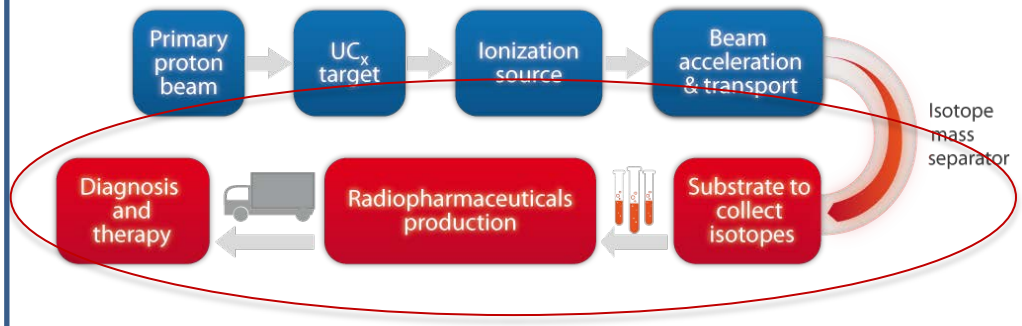
Selected isotopes of medical interest

Sr-82/Rb-82 generator



ISOLPHARMA*

- **Use of ISOL technique:** Direct isotope on-line separation



A suitable substrate is used to collect the radioisotope of interest. A Sodium Chloride substrate is suggested in order to obtain a biocompatible formulation.

HIGH Specific Activity and Purity

Radiopharmaceutical	Targeted organs	Half-life	Specific Activity (GBq/mg)		Radionuclide Purity
			SPES production	Neutron capture reaction	SPES production
^{89}Sr-$SrCl_2$	Bone	50.5 d	≥ 597	≥ 0,004	100%

After 2 days of irradiation:

→ 4.1E+15 atoms of ^{89}Sr collected

→ 18 mCi= 4 doses

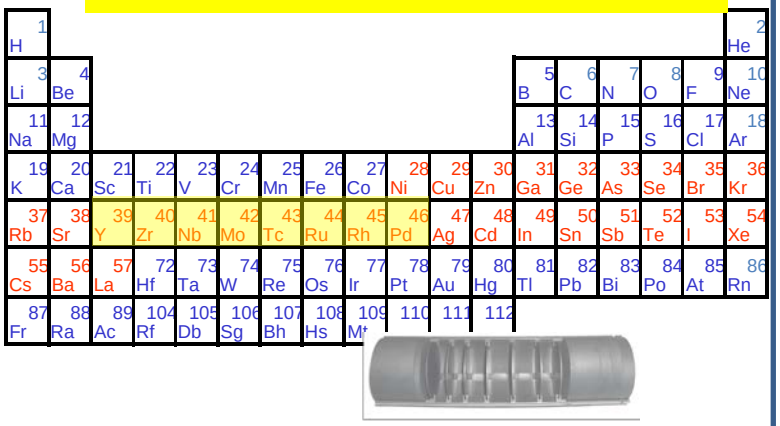
(patient dose: 4 mCi every 6 months).

About 100 patients may be treated every year. Allow the production of radiopharmaceutical on a regional scale.

* Patent pending

- **Use of exausted ISOL targets:** extraction of trapped elements

Isotopes trapped into the ISOL target



Mo-Tc 99m generator

↓

Useful as strategic production

↓

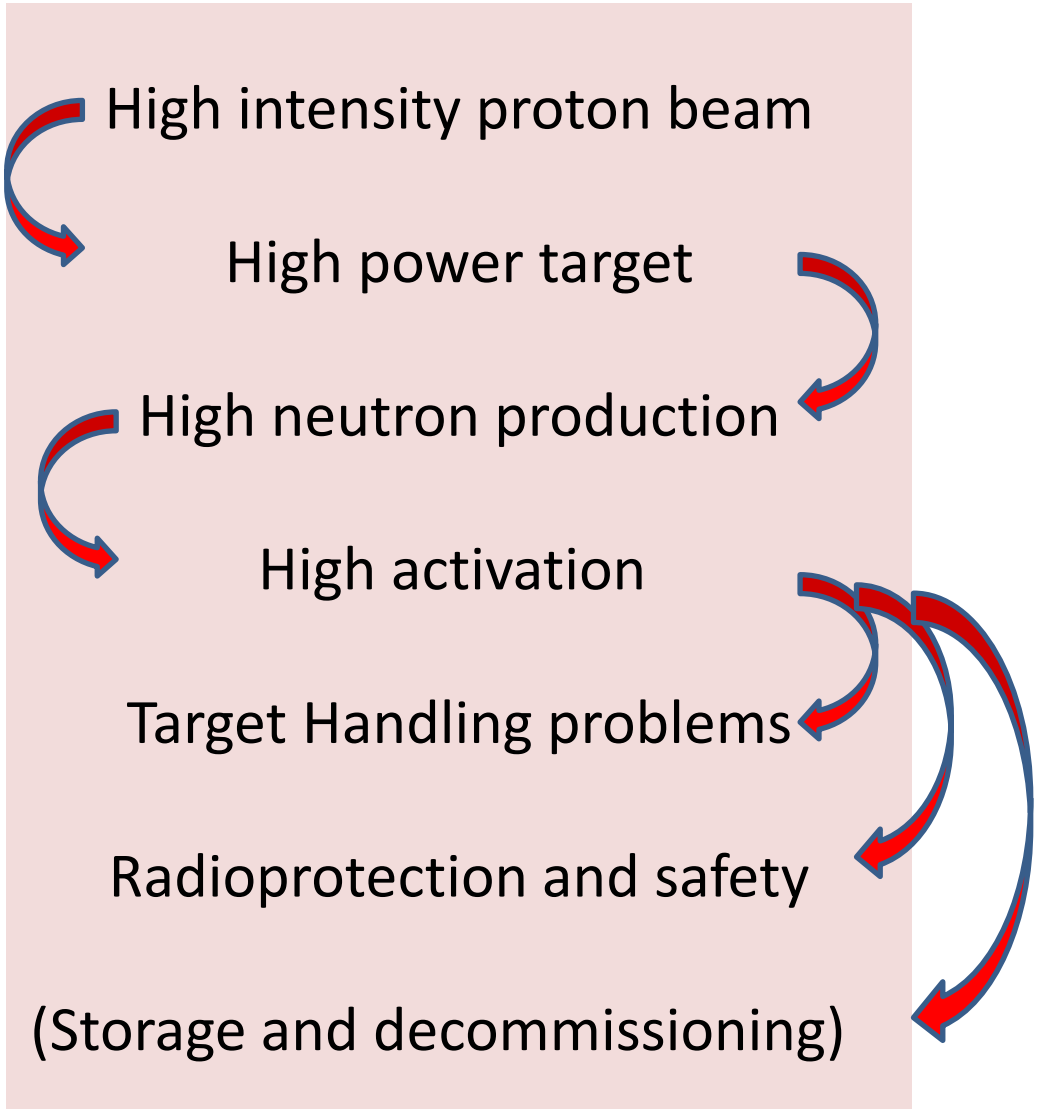
(Today not commercially competitive)

UCx Target conditioned following standard chemical procedures

↓

Regional production of Mo-99 1150 GBq_3day (needs of Veneto)

The chain of HIGH INTENSITY

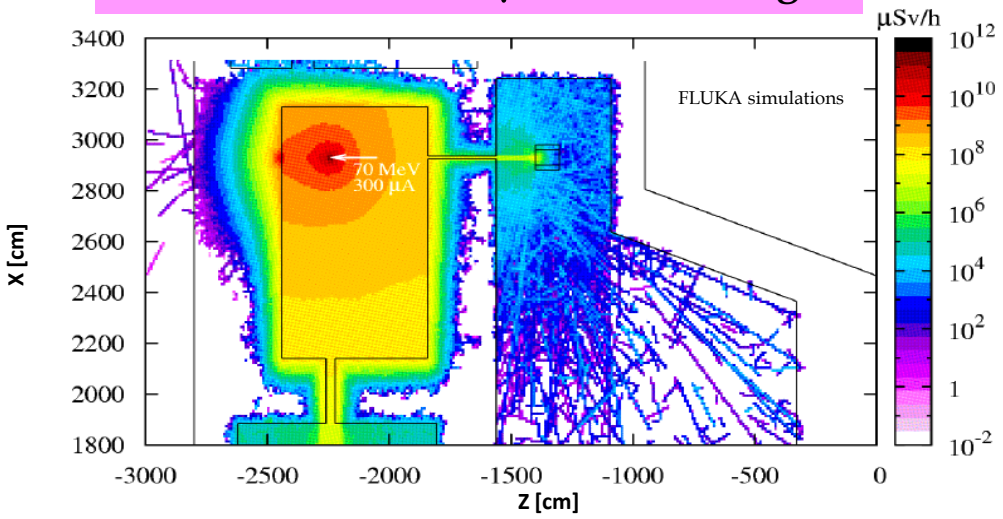


Neutron production at SPES

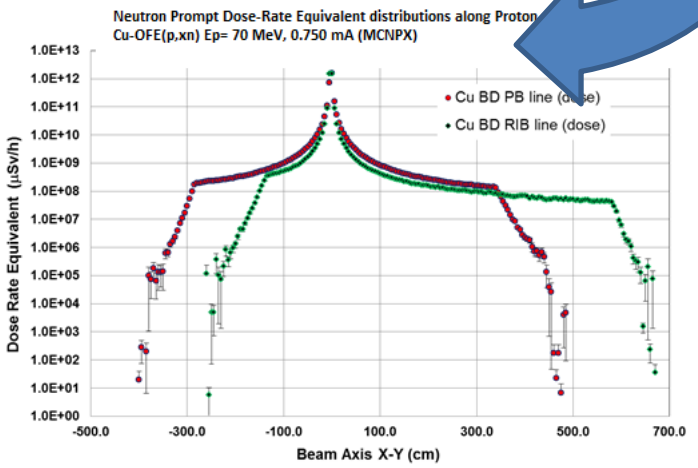
Integral neutron production at SPES Cyclotron
Proton beam= 70 MeV, 500 μA
Target = W 5mm

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

Protons 70MeV 300 μA on UCx target



Protons 70MeV 750 μA on Cu target



Neutron spectra for different targets

Continuum and Quasi Mono Energetic spectra

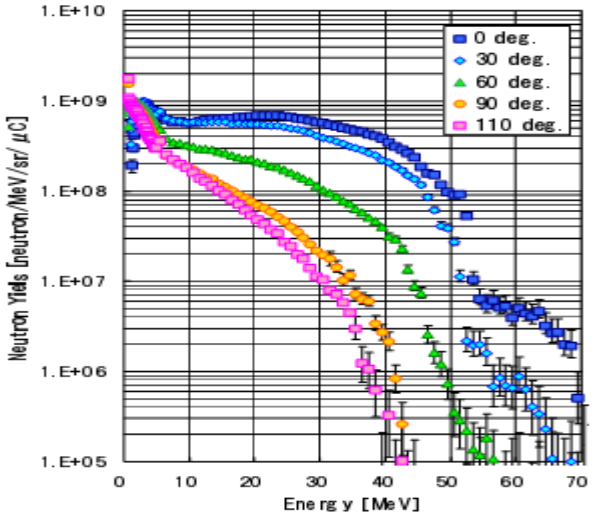


Figure 4: Thick target yield for C(p,xn) at 70 MeV

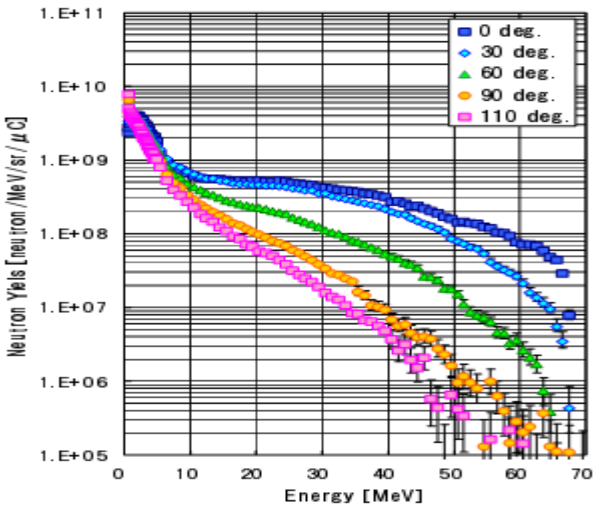


Figure 8: thick target yield for Al(p,xn) at 70 MeV

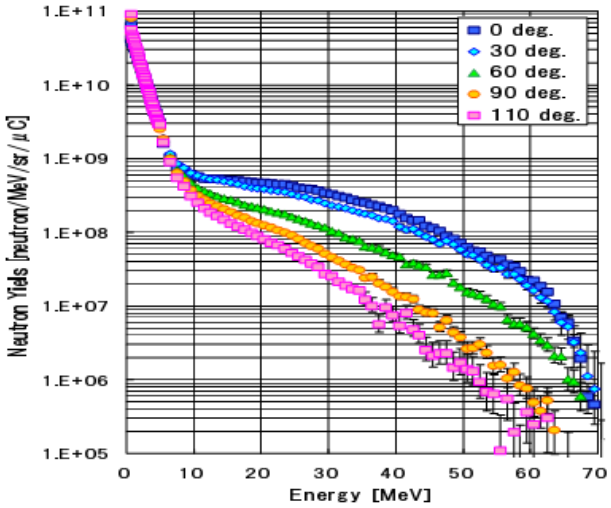
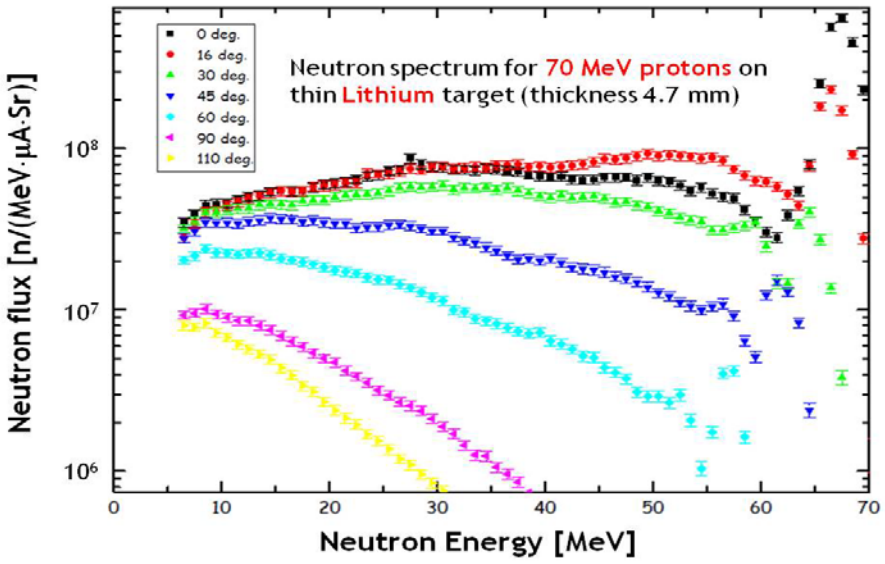
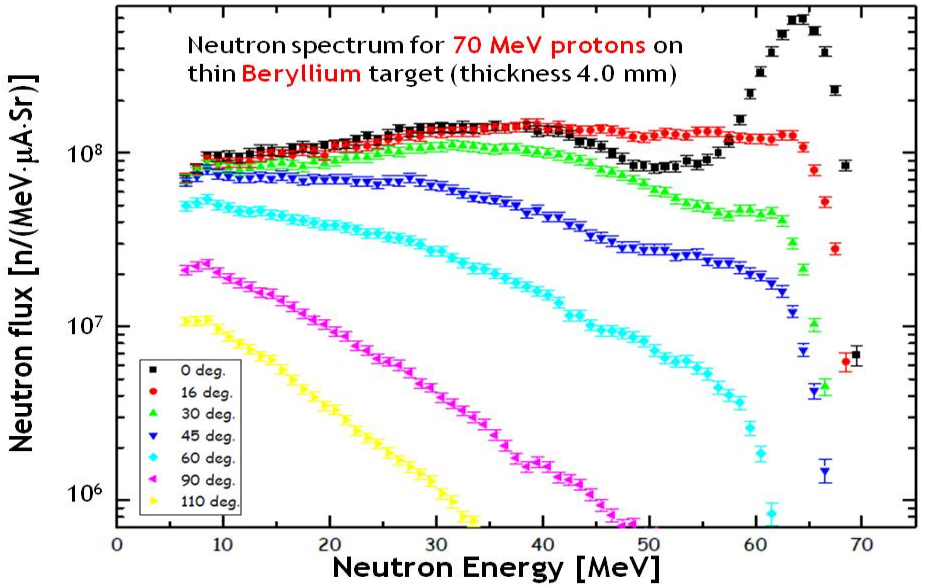
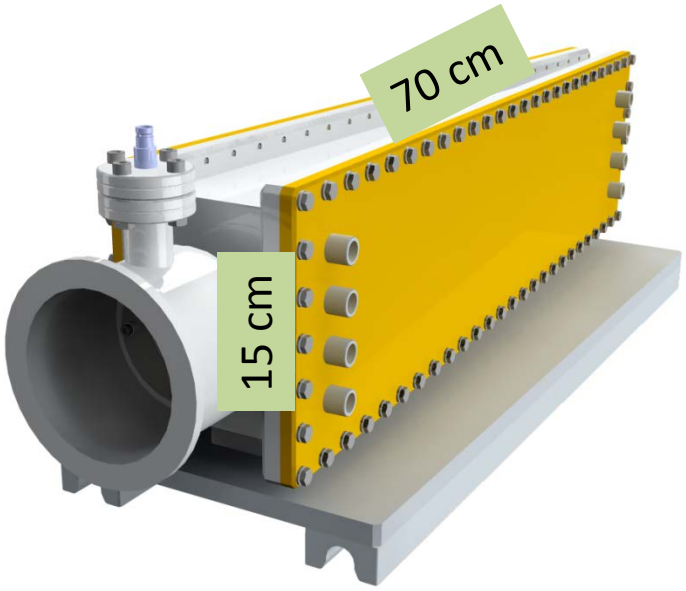


Figure 14: Thick target yield for W(p,xn) at 70 MeV

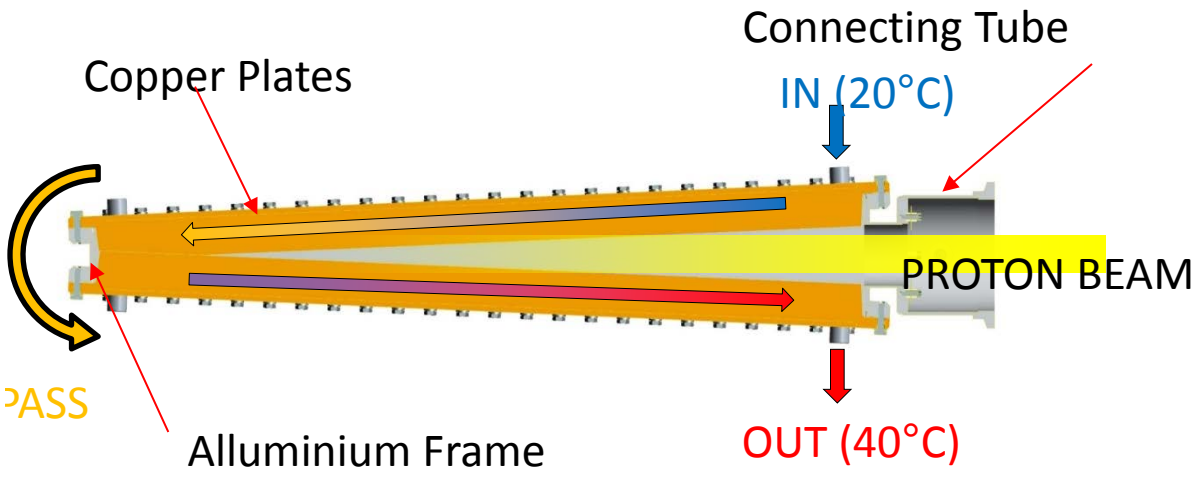


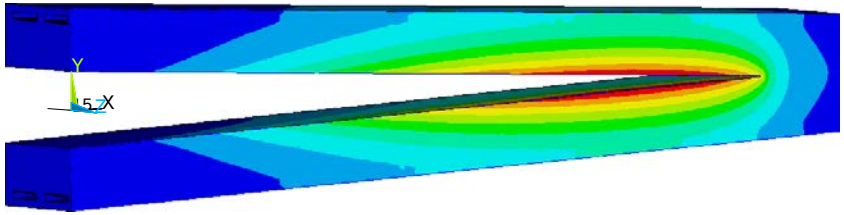


High Power Beam Dump

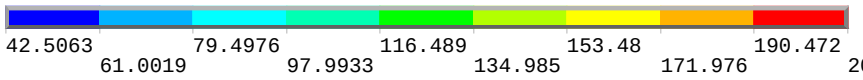


50 = kW proton beam (≈ 100 W/cm³ at 150°C)





52500 W



Cooling system:

Flow	*0,16 l/s*
Velocity	*1,25 m/s*
ΔT	*20 °C*

Input thermal power:

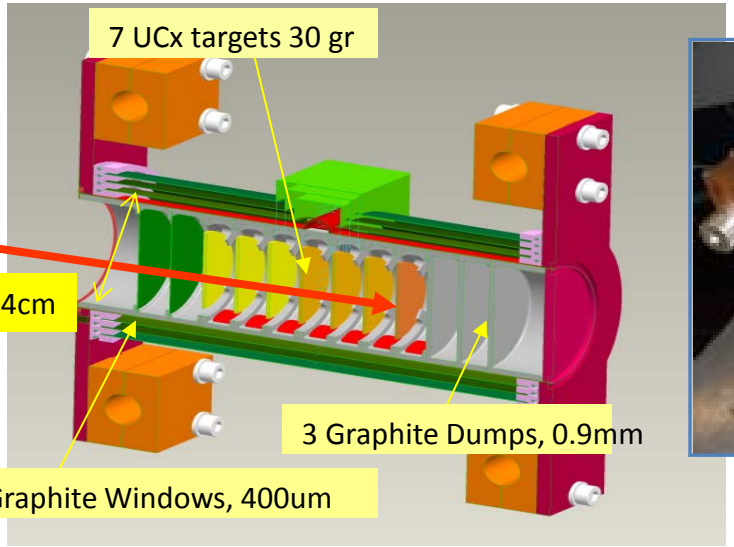
Energy	70 MeV
Current	750 μA
Power	52500 W

High power target at SPES

Cooling by irradiation

ISOL target
operation temp: 2000°C
10 kW (1kW/cm³)
Multi disks, thick target

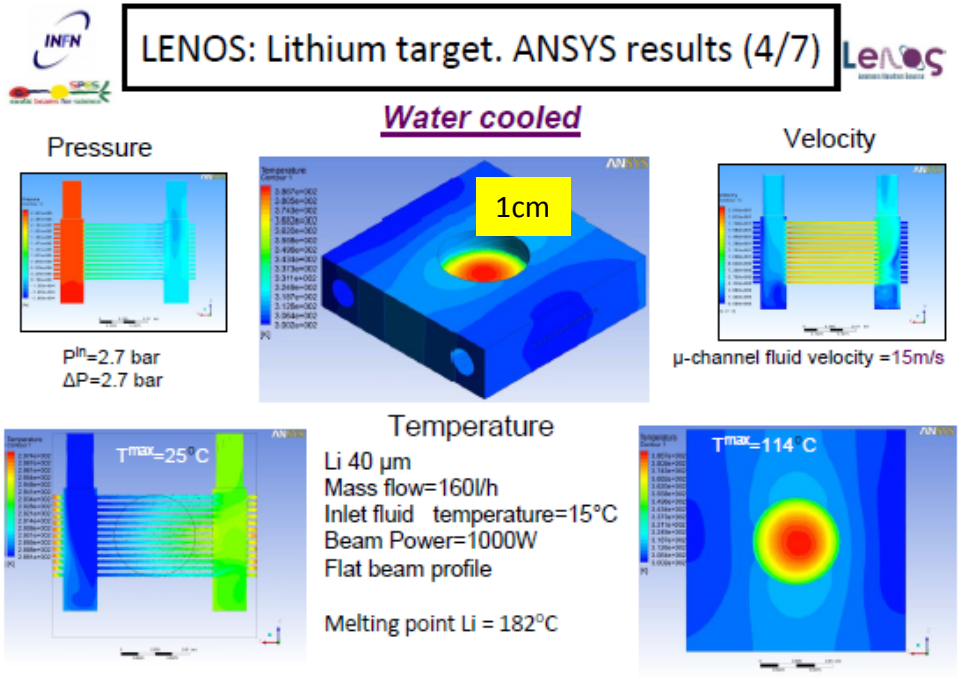
40 MeV
200μA
Protons uniformly



See Andrighetto talk

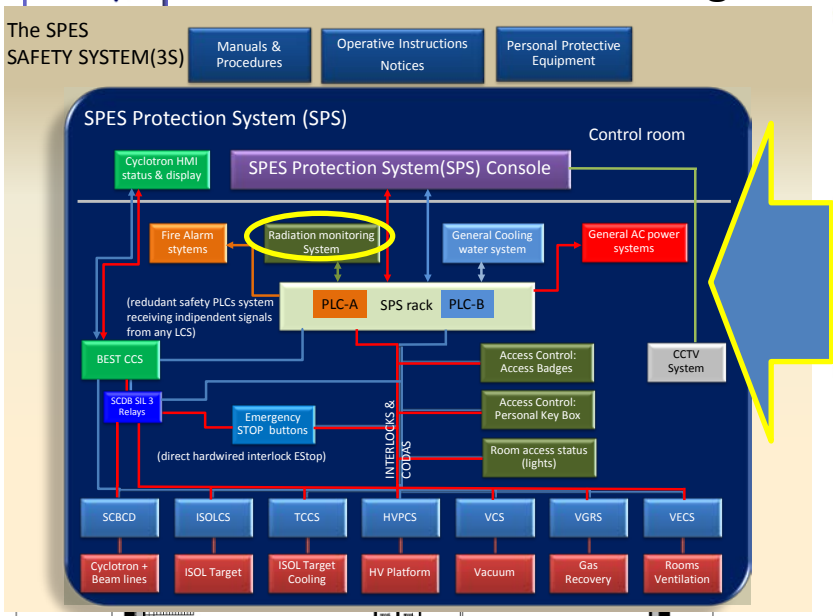
Cooling by micro channels

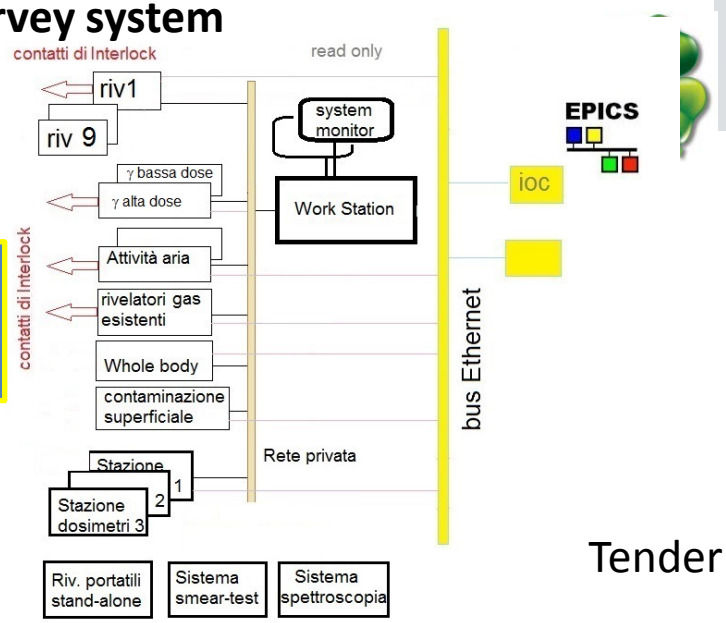
LENOS target
operation temp: 150°C
3 kW (3kW/cm², 300 kW cm³)
Single element, 100μmthin target



See Mastinu talk

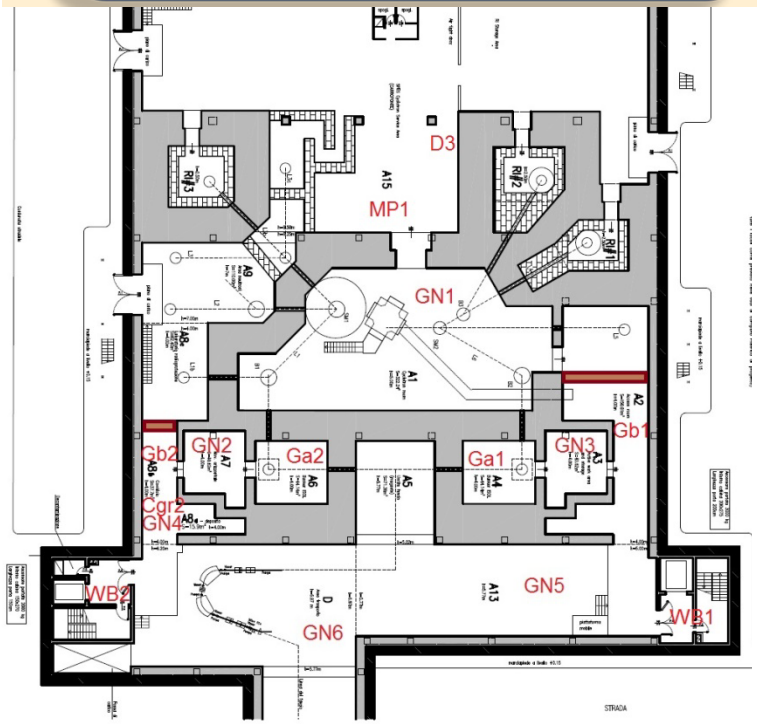
Radiologic survey system

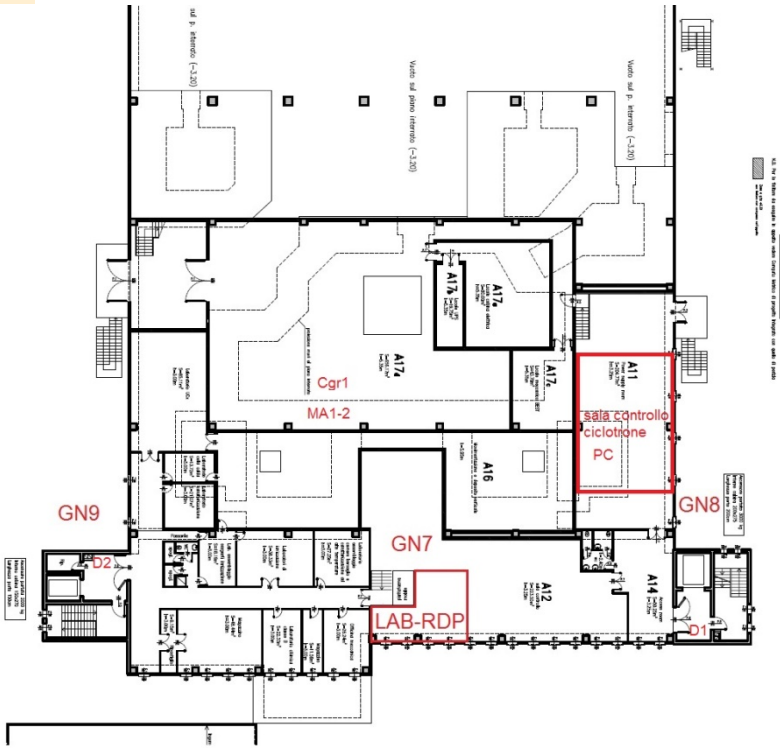




exotic beams for science

Tender for 1.2 Meuro



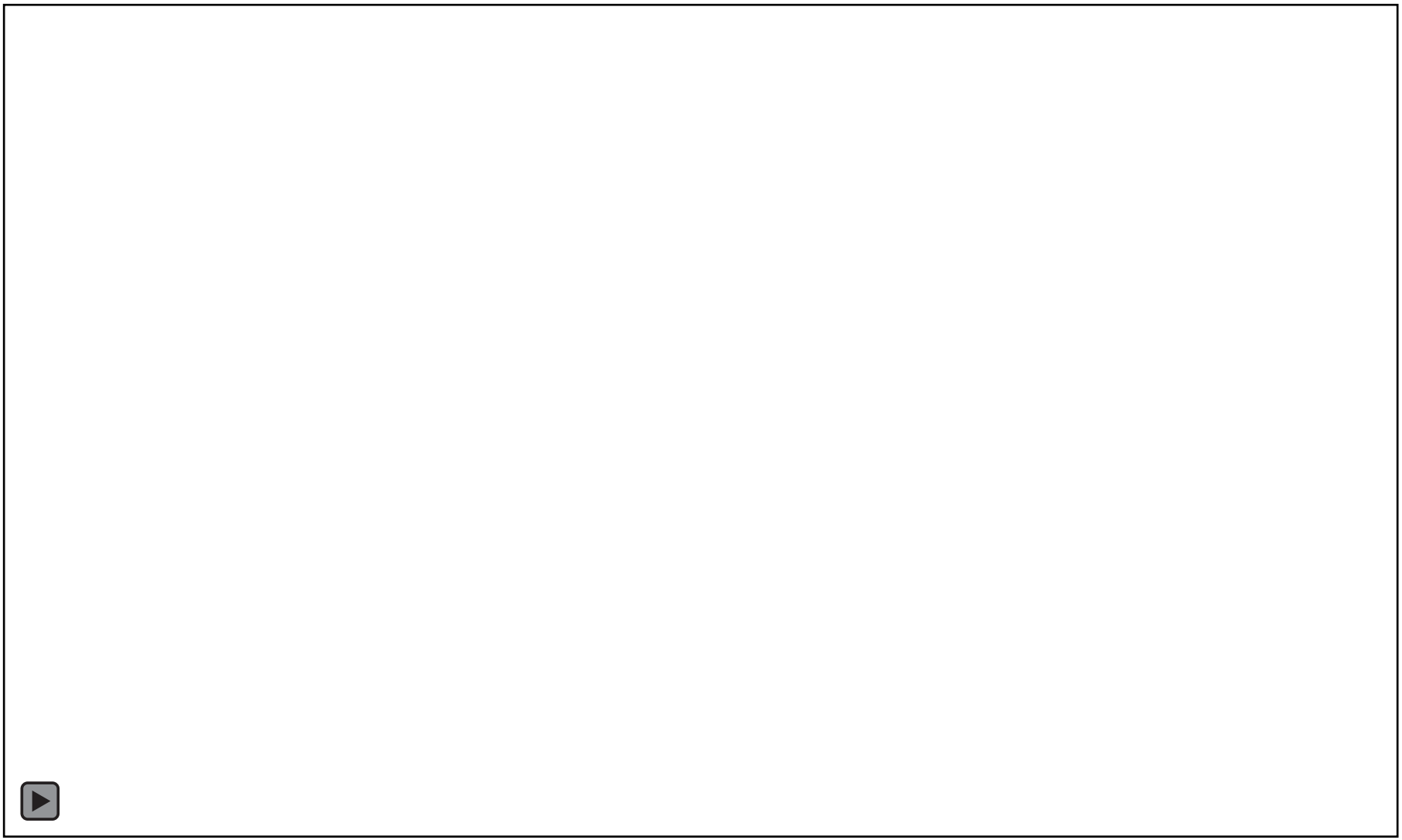


CONCLUSIONS

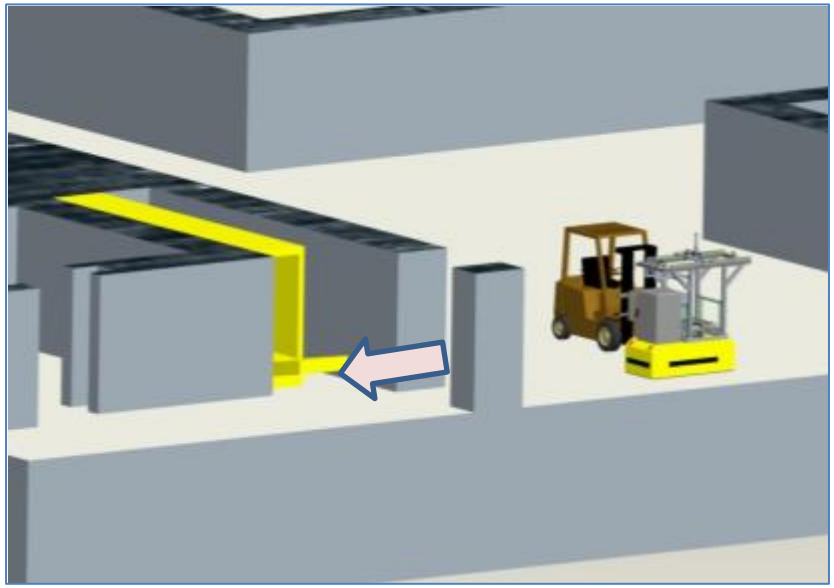
- The SPES project is financed by INFN up to the completion
- The cyclotron just arrived and it is under installation
- The proton beam is expected to be extracted in September 2015 for the Site Acceptance Test
- ISOL:
  - The ISOL sistem will be installed in 2016
  - First radioactive beam in 2018 (no reacceleration)
- Applications:
  - First beams available for medicine and neutrons in 2016
- Adressed several common aspects: target, radioprotection and safety

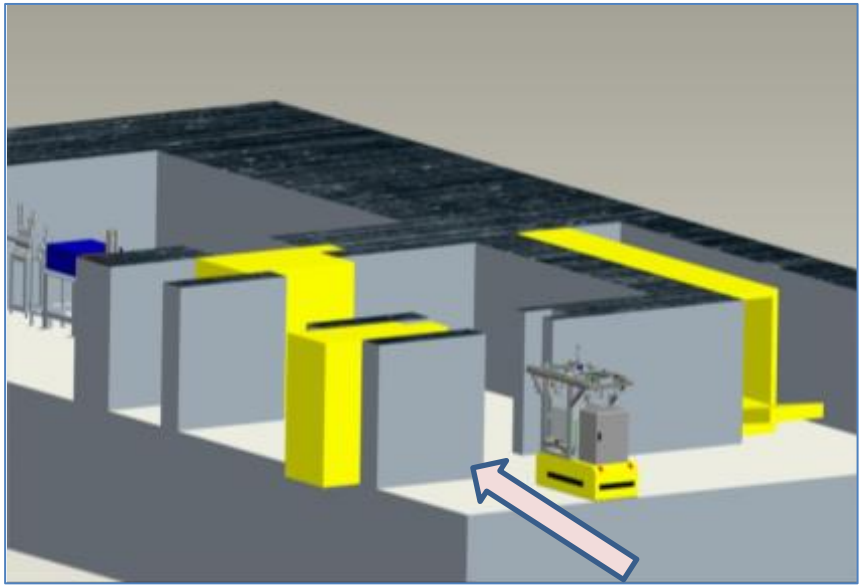
SPES Horizontal Handling system

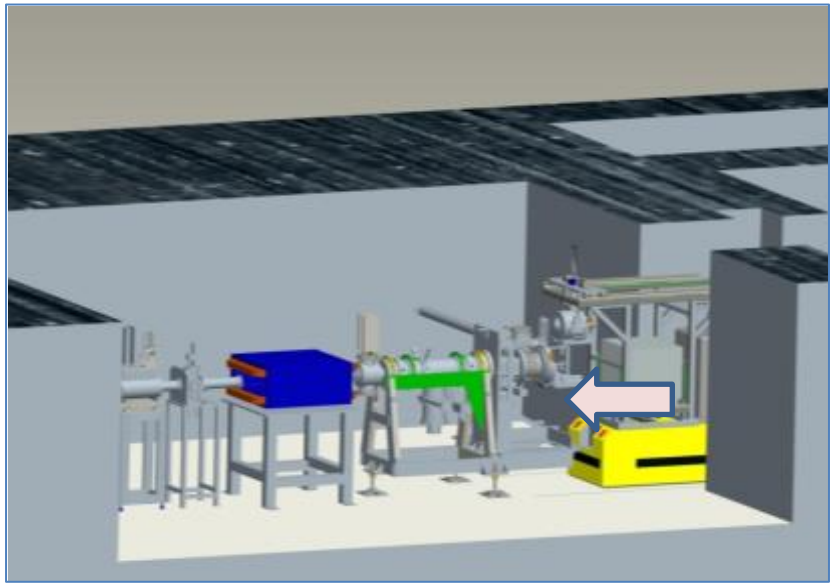
All system has been developed according the safety & radioprotection rules

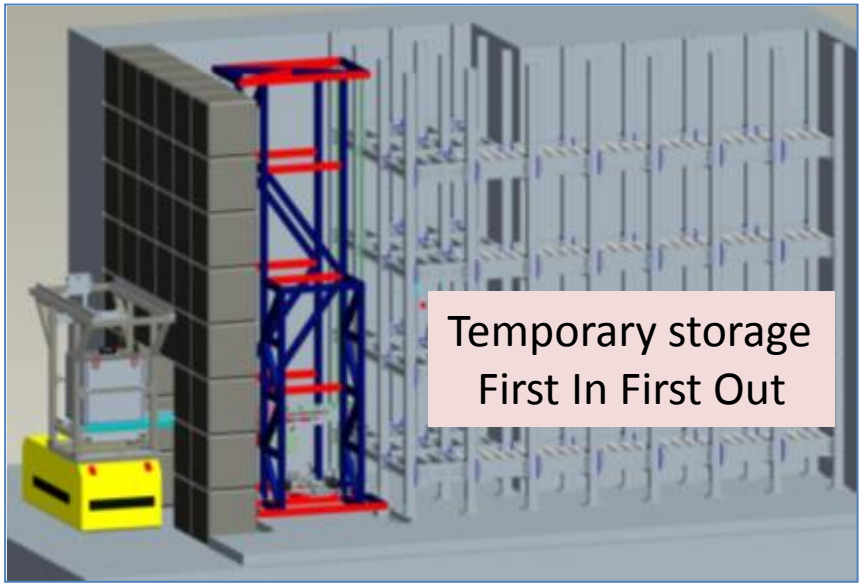


SPES Horizontal Handling system









Horizontal device (AGV based)

Devices under construction at the LNL mechanical workshop

WG-04

Target chamber rack-storage system

The storage system is able to accommodate up to 44 boxes, with the possibility of expelling the box with lower radioactivity (FIFO logic)
The system automatically picks up the Pb box from the AGV and placed in the rack.