# SPES Project

# SPES status


Gianfranco Prete

Project leader


"SPES one-day Workshop"

Nuclear Astrophysics at SPES

Royal Palace of Caserta on November 12-13, 2015.

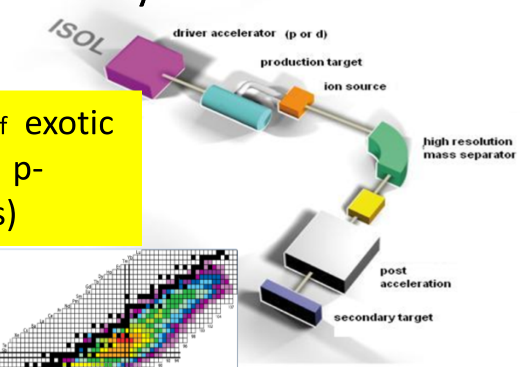
# SPES Strategy

BEST Cyclotron installation & commissioning:
- 70 MeV proton beam
- 750 μA

Funded

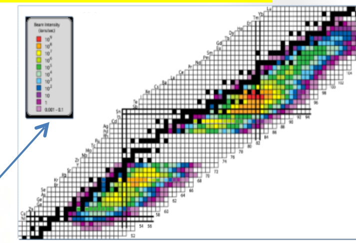
Second generation ISOL facility

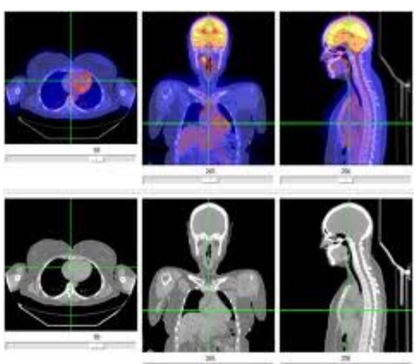
Toward EURISOL




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

Funded



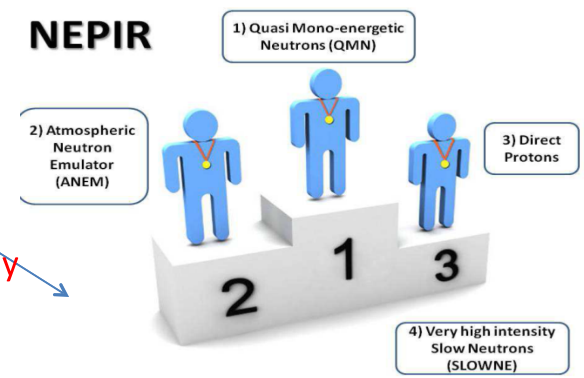
LARAMED

Partially funded 6.8 M€

Research and Production of Radio-Isotopes for Nuclear Medicine

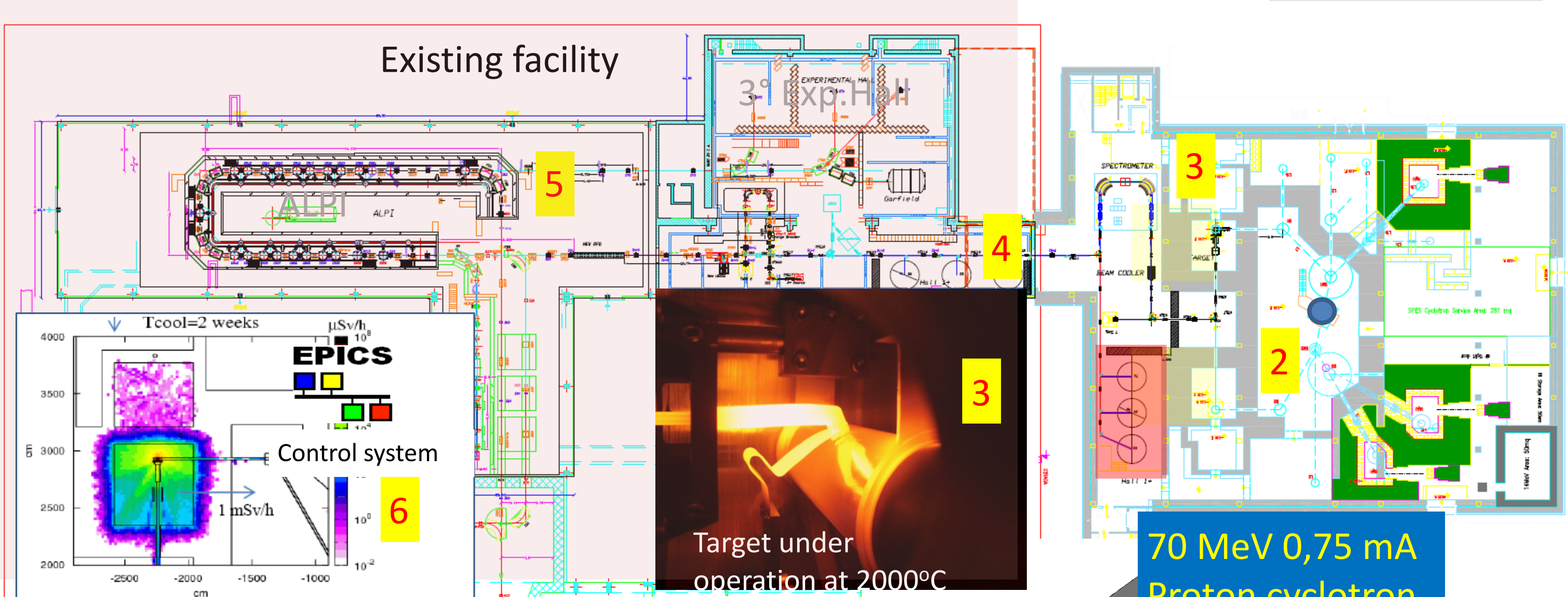
Design study

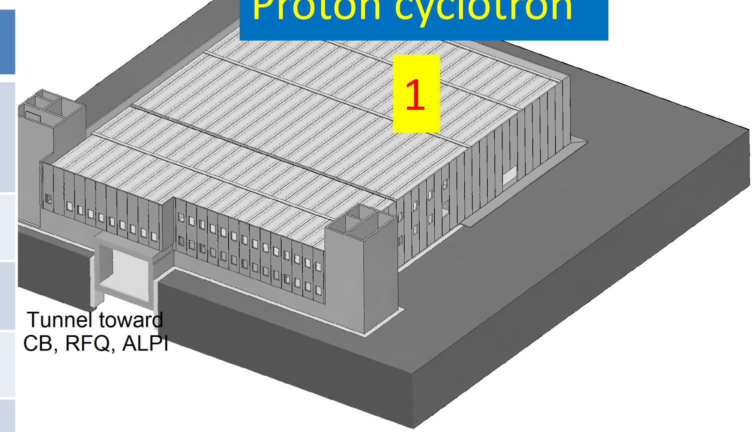
NEPIR




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

# SPES Facility Layout



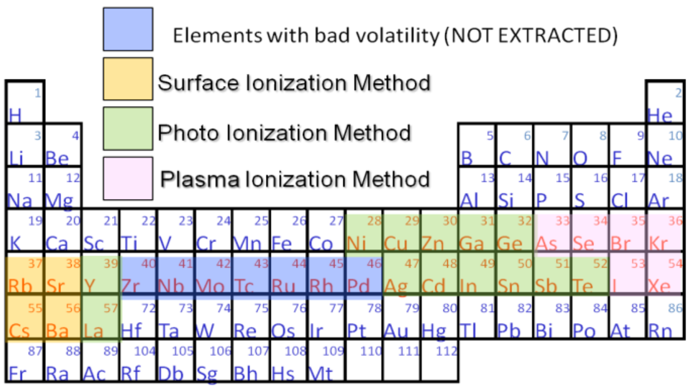

| | SPES sub-systems |
|---|---|
| 1 | Building and infrastructures with 2 ISOL bunkers for radioactive beam and application area for radioisotopes and neutrons |
| 2 | Cyclotron 70 MeV protons with 2 independent exits |
| 3 | ISOL UCx target designed for $10^{13}$ f/s |
| 4 | Beam transport with High Resolution Mass Separation |
| 5 | Reacceleration with RFQ and ALPI superconducting linac (10A MeV A=130) |
| 6 | Radioprotection, safety & controls |

# SPES: Target Ion Source System

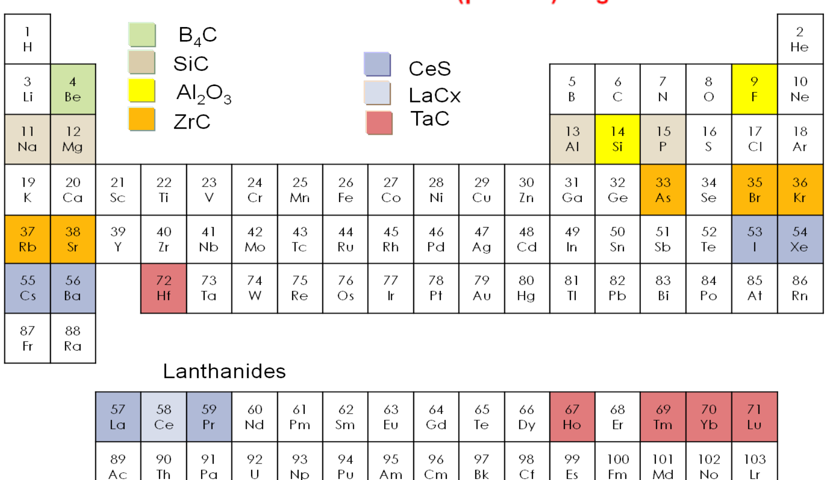
## Production Target

Characterized by:

- Material of the target (production yield)
- Release time (≈1s for Fast Targets)
- Element Vapour pressure


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



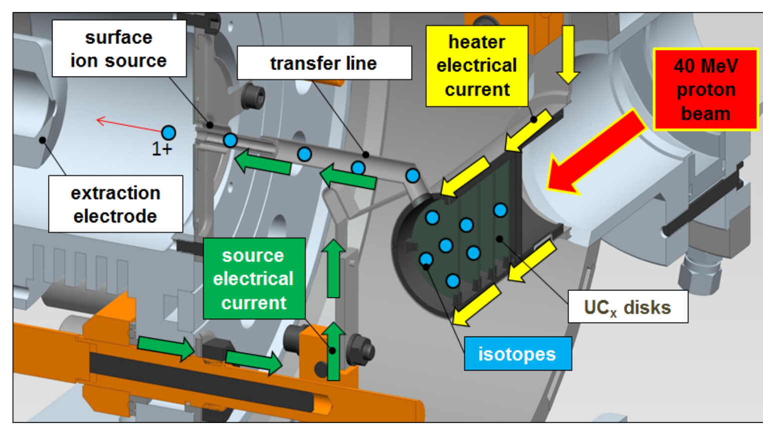

## Ion source

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

## Yield of a nuclear species

$$Y = \sigma \cdot \Phi_p \cdot N \cdot \varepsilon_d \cdot \varepsilon_e \cdot \varepsilon_i \cdot \varepsilon_t$$

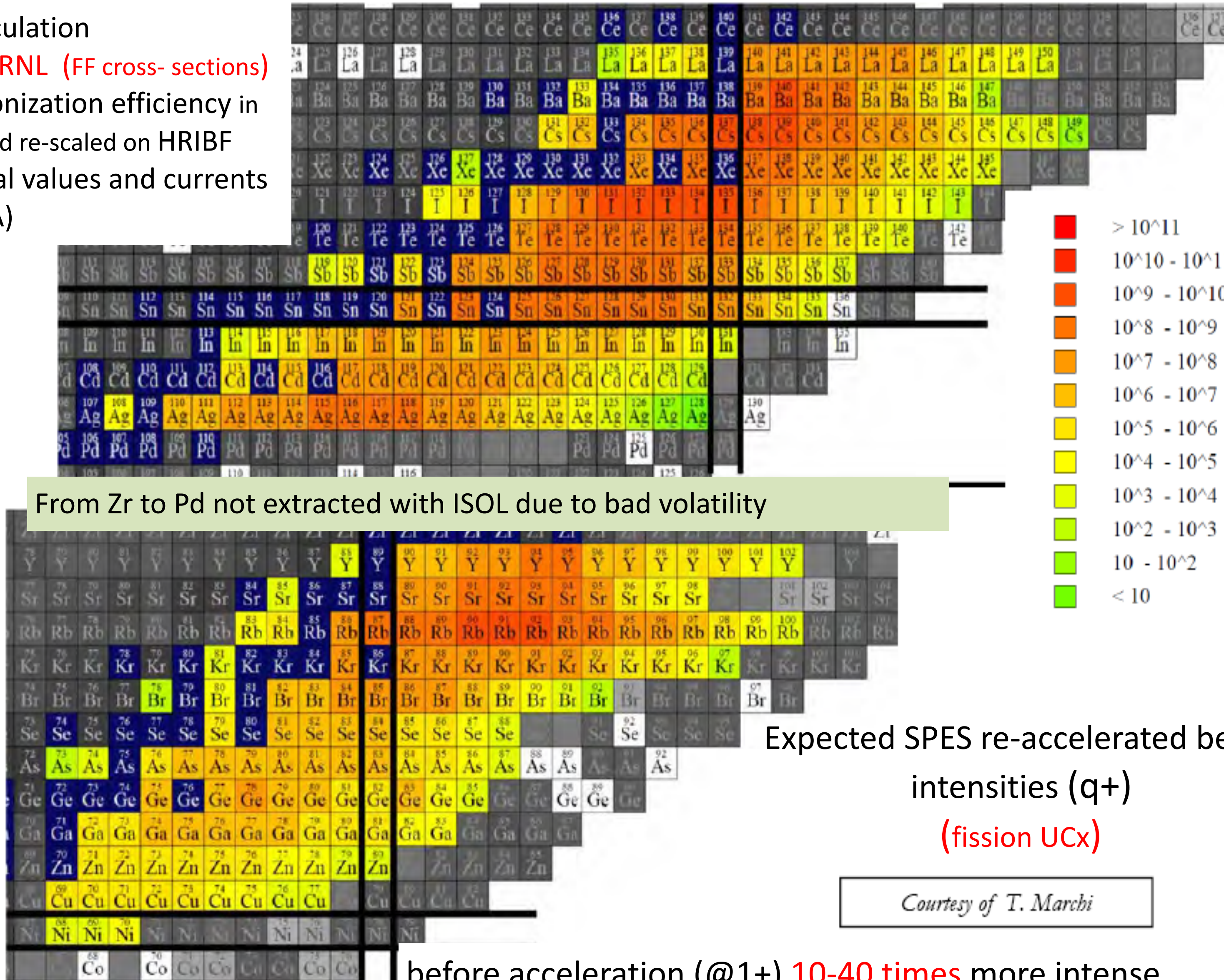
It depends on → half-life, cross-section, proton flux, diffusion and effusion time, ionization and transport efficiencies



# SPES PHYSICS: Expected beams

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

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



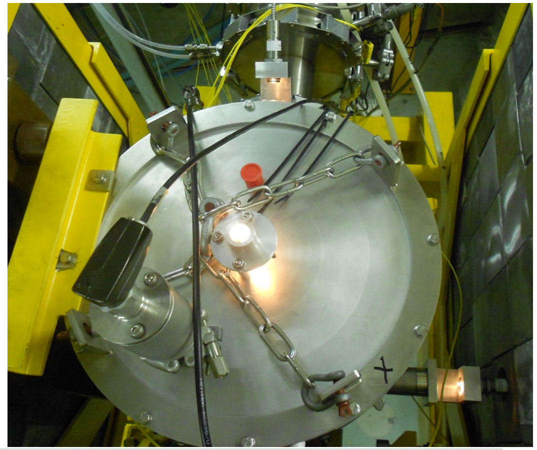

From Zr to Pd not extracted with ISOL due to bad volatility

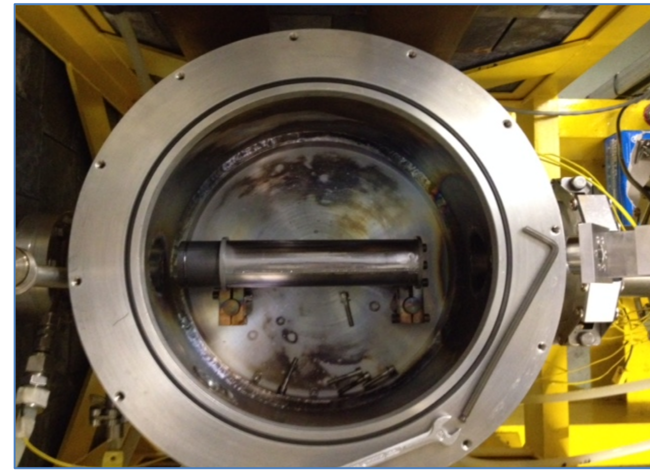
Expected SPES re-accelerated beam intensities (q+)
(fission UCx)

before acceleration (@1+) 10-40 times more intense

# SPES: Target Power test @ iThemba LABS

Proton beam 66MeV 60 μA



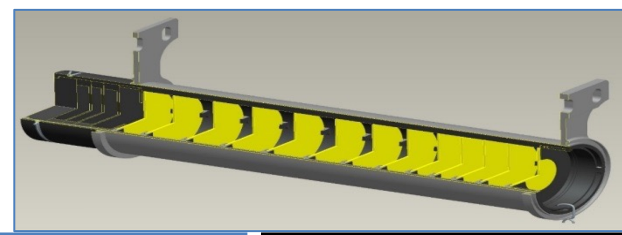


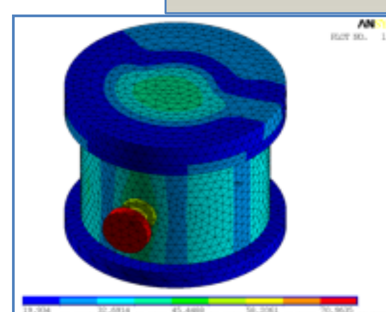
SPES target in-beam power test (SiC target) May 2014

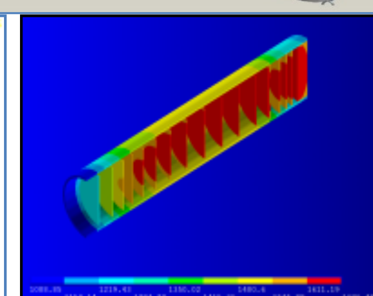
Heater power compensated by proton beam.

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

| Measure [°C] | Estimated by FEM model [°C] |
|---|---|
| 1° disk: 1365 ± 30°C | 1390 |
| Box: 1230 ± 25°C | 1267 |
| Dump on chamber: 728°C ± 10°C | 750 |







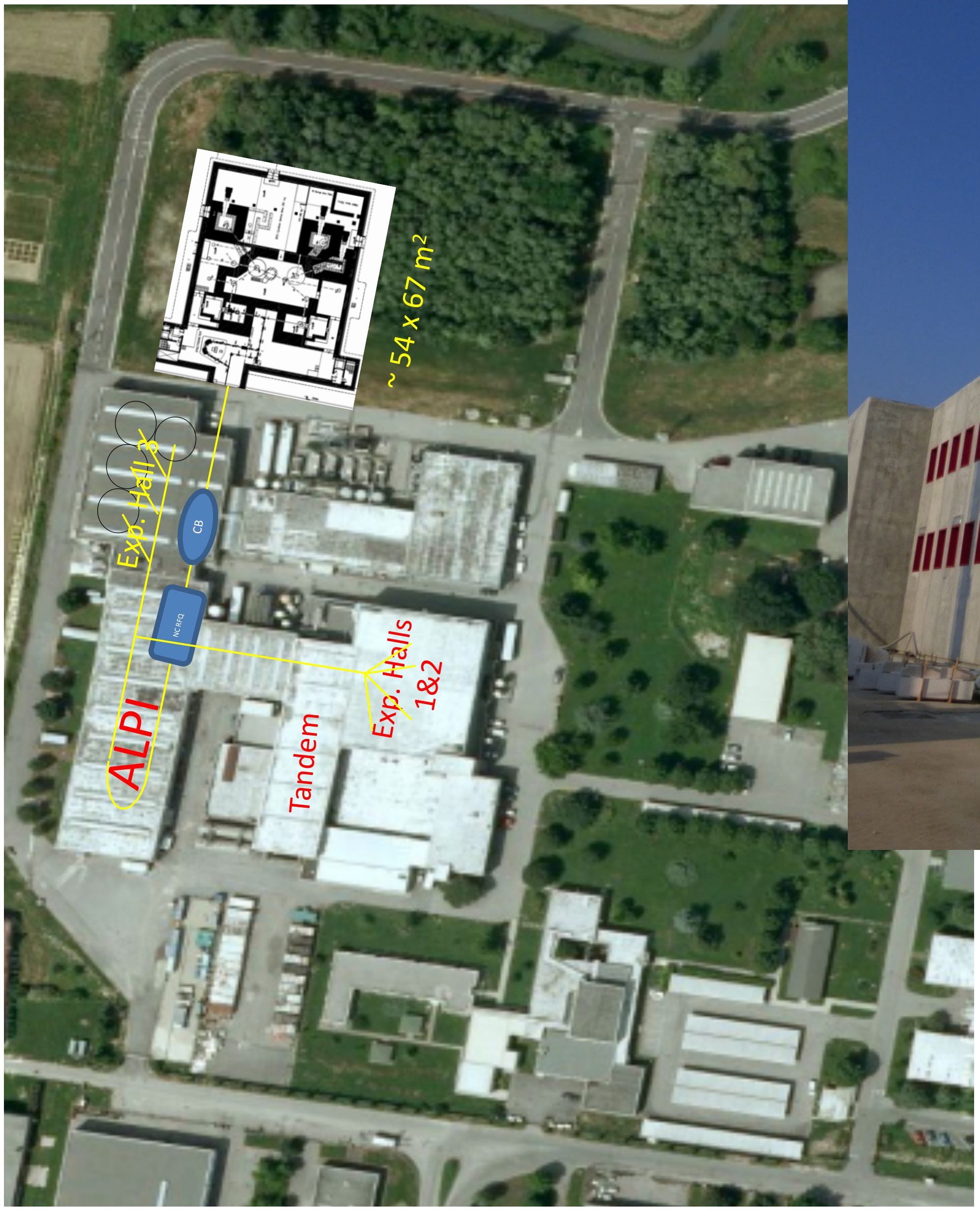
Thanks to Rob, Lowry and all the iThemba_Labs Cyclotron staff

# Main activities during 2015

- One-day workshop: Physics with non re-accelerated beams (April, 2015)
- One-day workshop: Nuclear Astrophysics at SPES (Nov, 2105)
- Special review for the Safety of the First Operation with the Cyclotron (July 2015)
- Special review for the RFQ (Sept 2015)
- Technical Advisory Committee review (TAC3) (Oct 2015)

| | SPES sub-systems | Main Activity 2015 |
|---|---|---|
| 1 | Building and infrastructures with 2 ISOL bunkers for radioactive beam and application area for radioisotopes and neutrons | Building almost completed.<br>Preliminary delivery Nov 2015.<br>Final building acceptance March 2016 |
| 2 | Cyclotron 70 MeV protons with 2 exits | Installed and under test |
| 3 | ISOL UCx target, ion-sources, remote handling | Endurance tests, Tin laser ionization, installed remote handling system, new temporary storage design |
| 4 | Beam transport with High Resolution Mass Separation | Completed design and launched tender for beam transport CB to RFQ |
| 5 | Reacceleration with RFQ and ALPI superconducting linac<br>(10A MeV A=130) | Charge Breeder developed<br>RFQ design completed: tender for electrodes<br>ALPI Cryogenic plant upgraded, |
| 6 | Radioprotection, safety & controls | Under construction access system for SAT.<br>Tender for safety system.<br>Development of control components. |

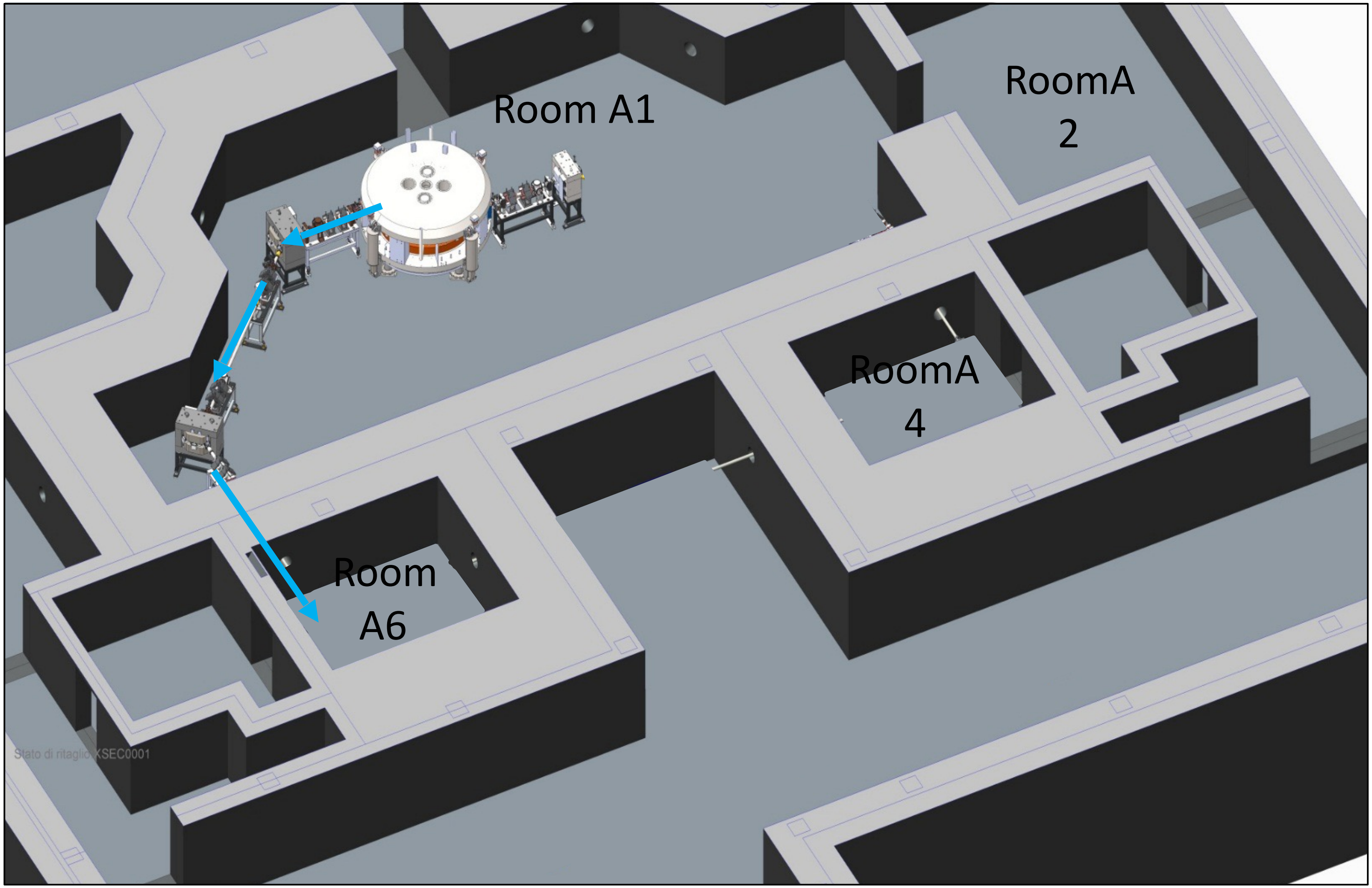
# SPES Facility Layout

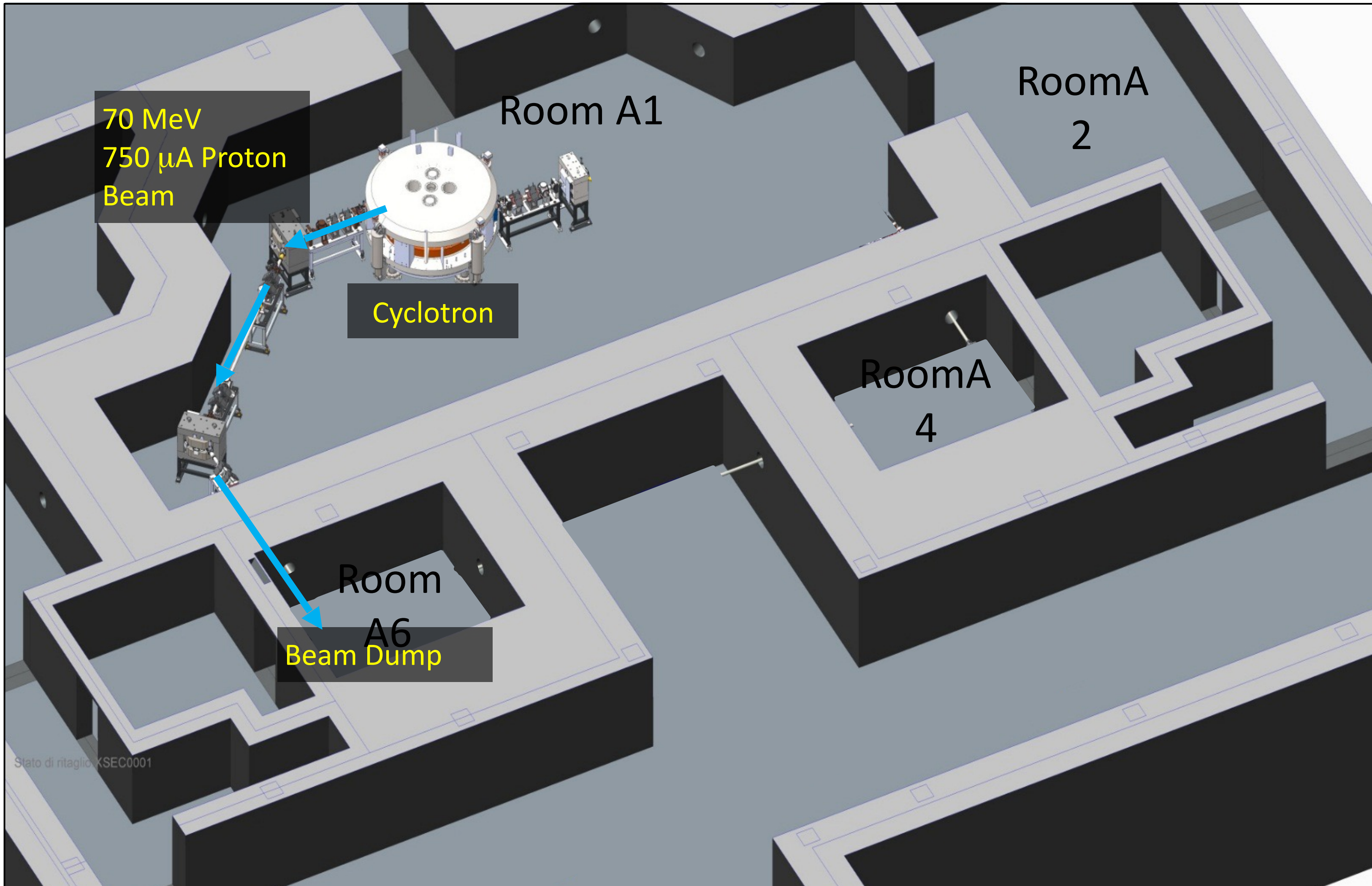



New infrastructure for:

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

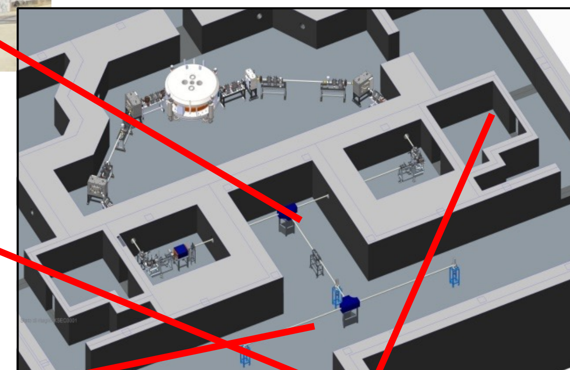
https://www.youtube.com/watch?v=gOcJFW4I6_Q

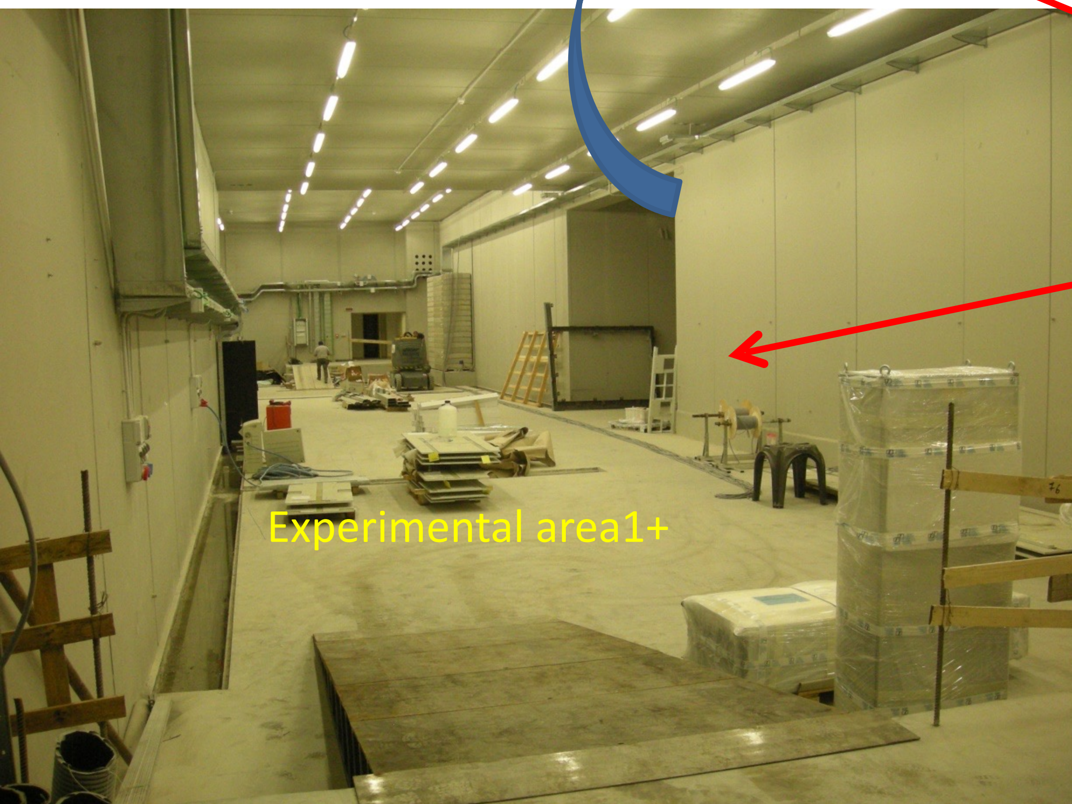

Room A1
RoomA
2
RoomA
4
Room
A6
Stato di ritaglio XSEC0001


70 MeV
750 μA Proton
Beam
Room A1
RoomA
2
Cyclotron
RoomA
4
Room
A6
Beam Dump
Stato di ritaglio XSEC0001

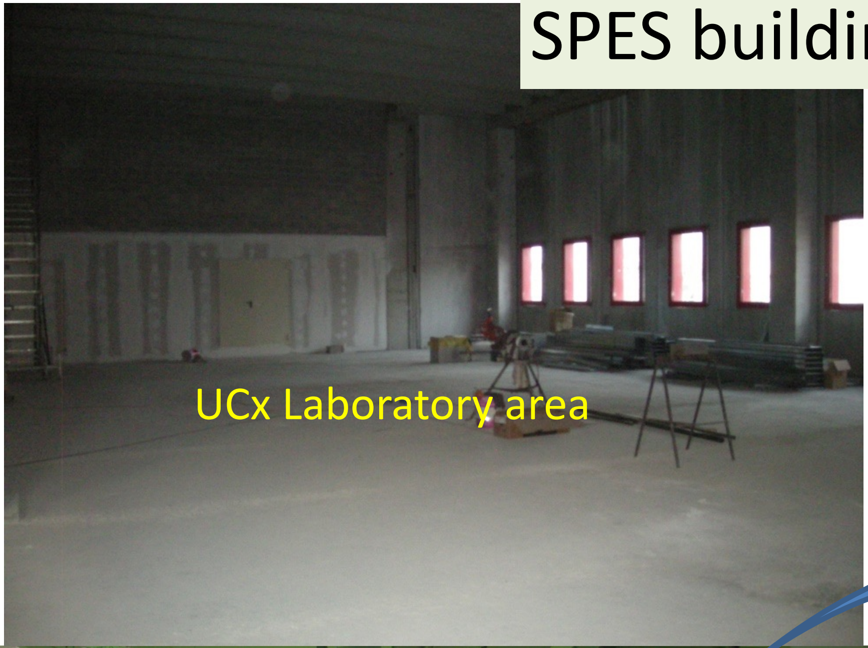
SPES
exotic beams for science



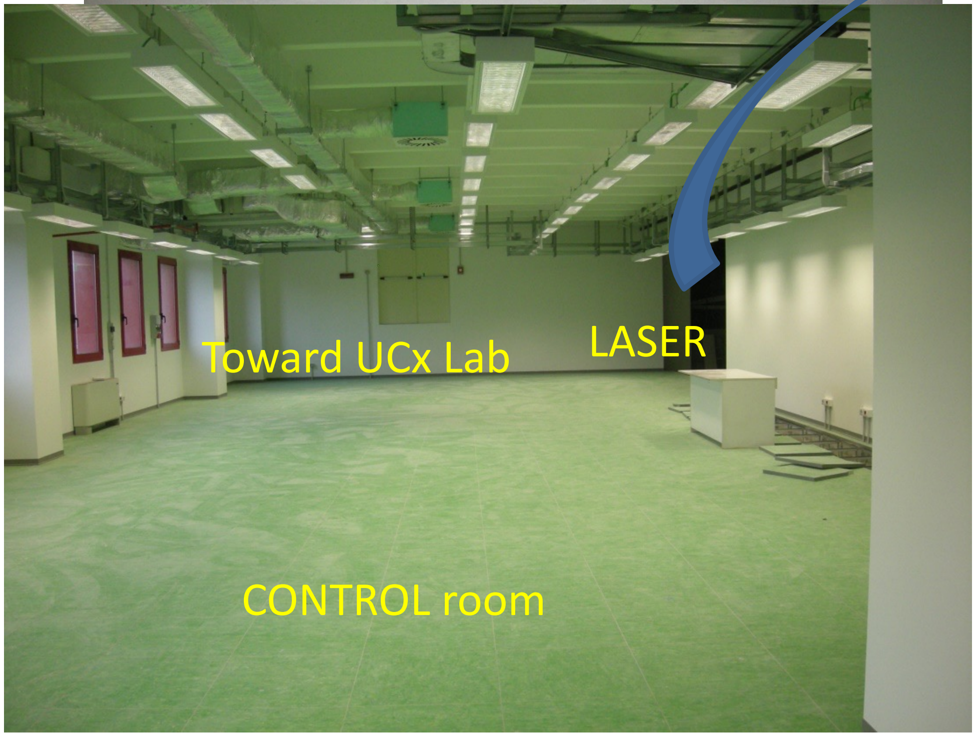




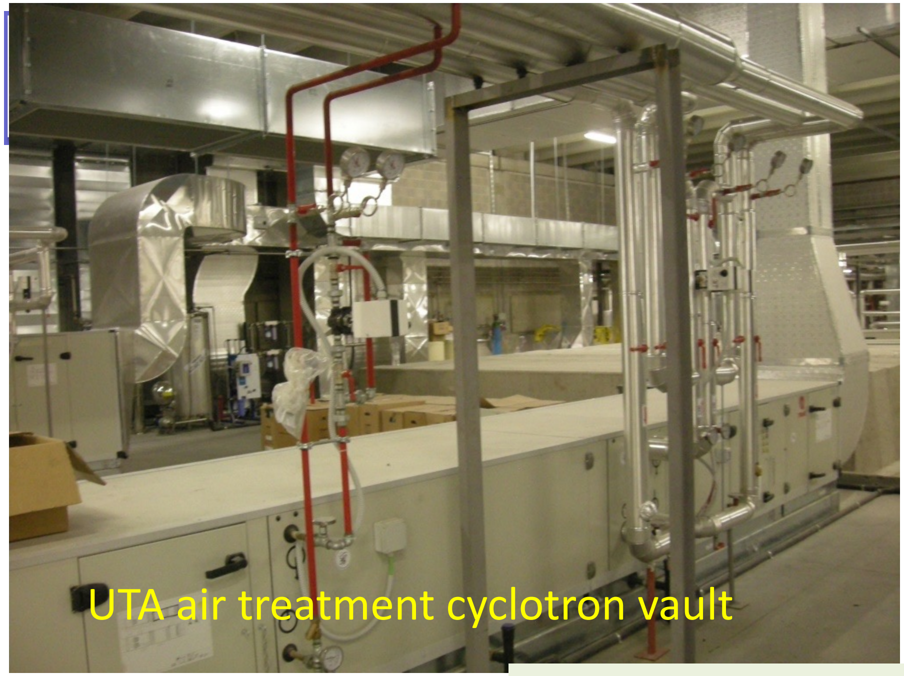

# SPES building: LEVEL +1

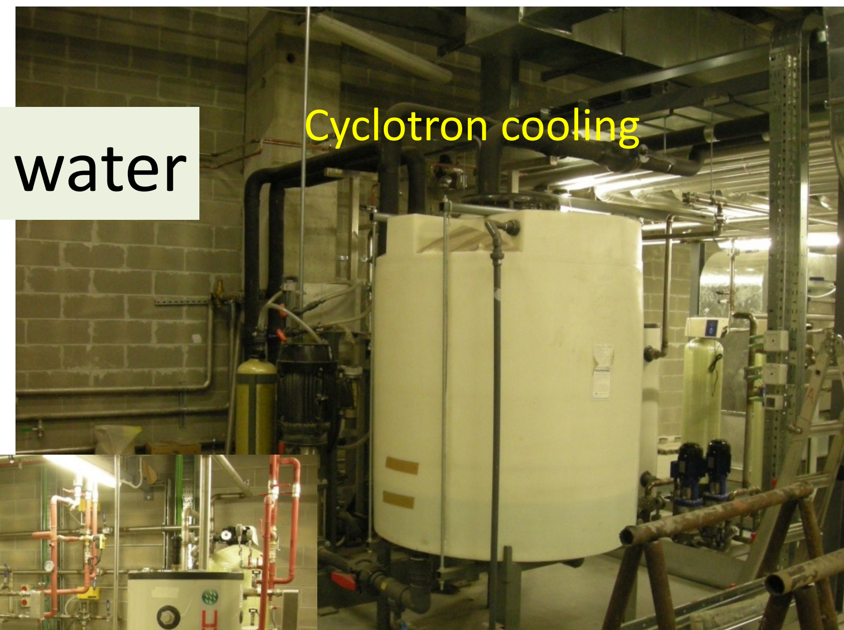






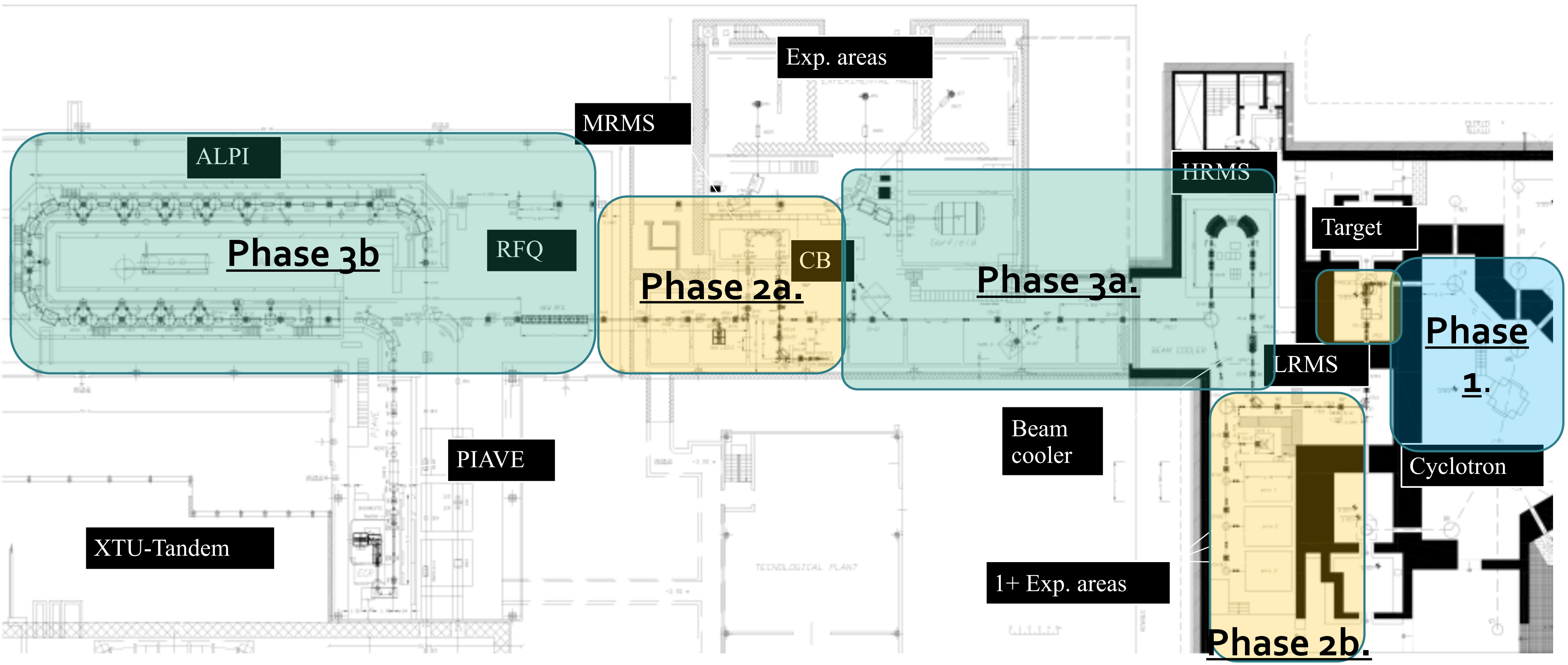

# PLANTS: air and water




Moduls for cooling water

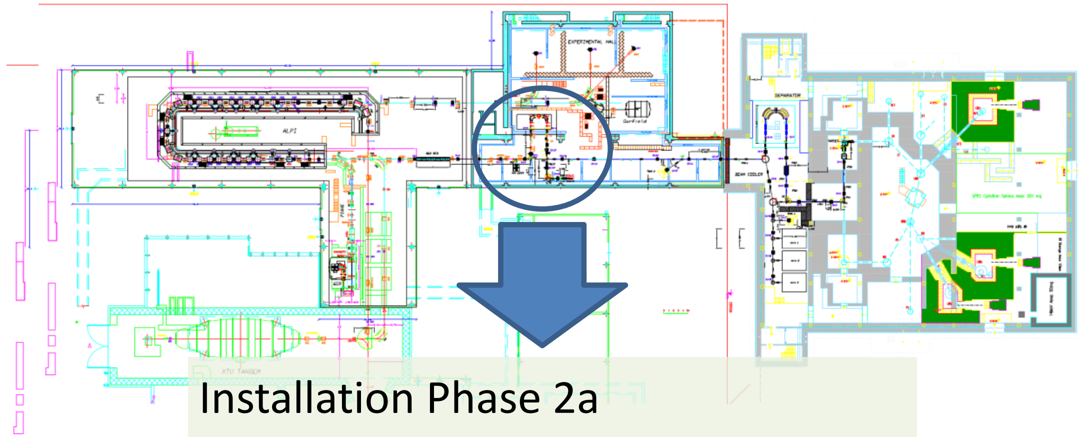
# SPES installation Phases




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

# Phase 1: cyclotron installation and SAT


| 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, $4^{th}$ harmonic mode |
| Ion Source | Multicusp $H^-$ I=15 mA, Axial Injection |
| Dimensions | Φ=4.5 m, h=1.5 m |
| Weight | 150 tons |



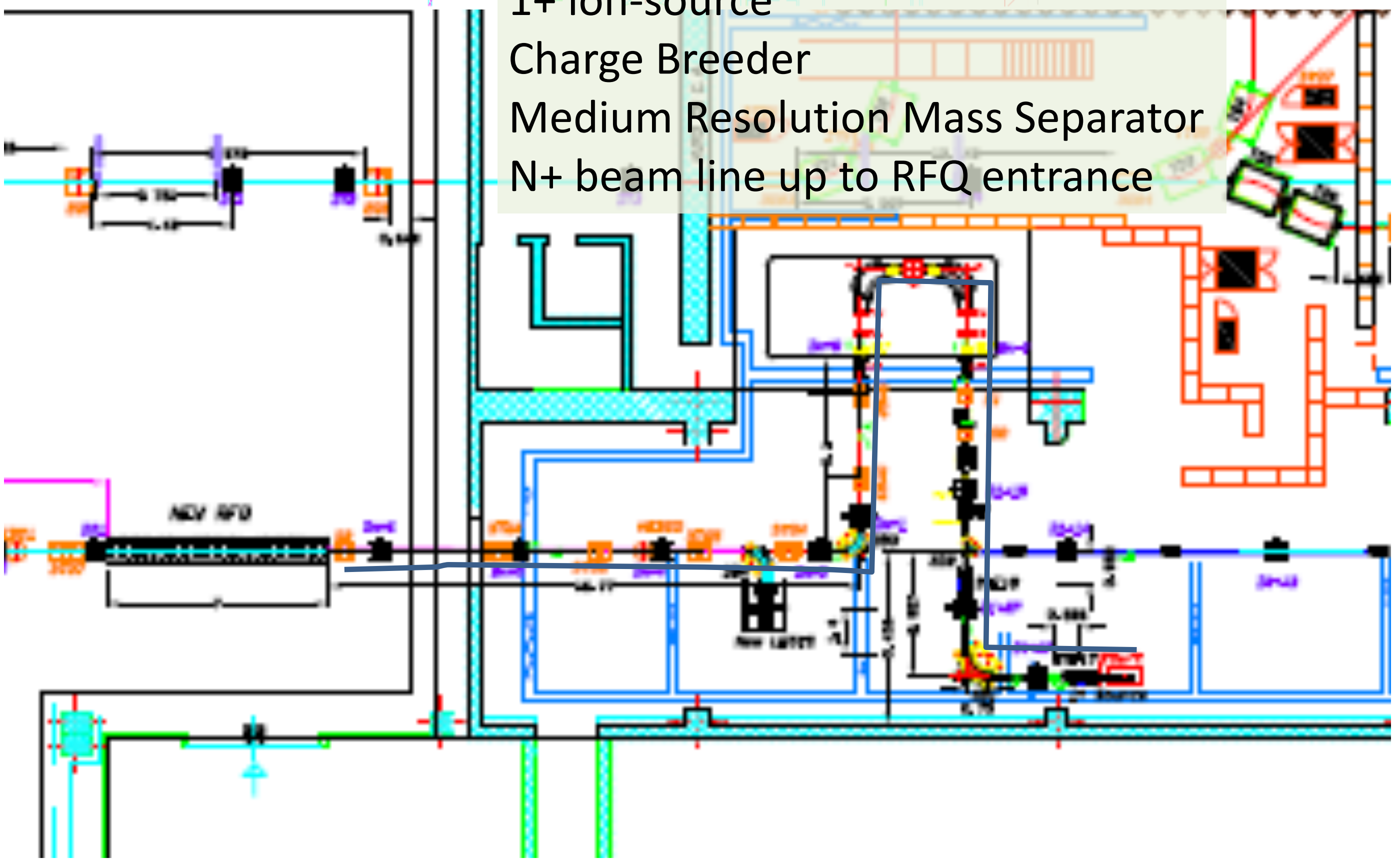
Installation Phase 2a

1+ ion-source

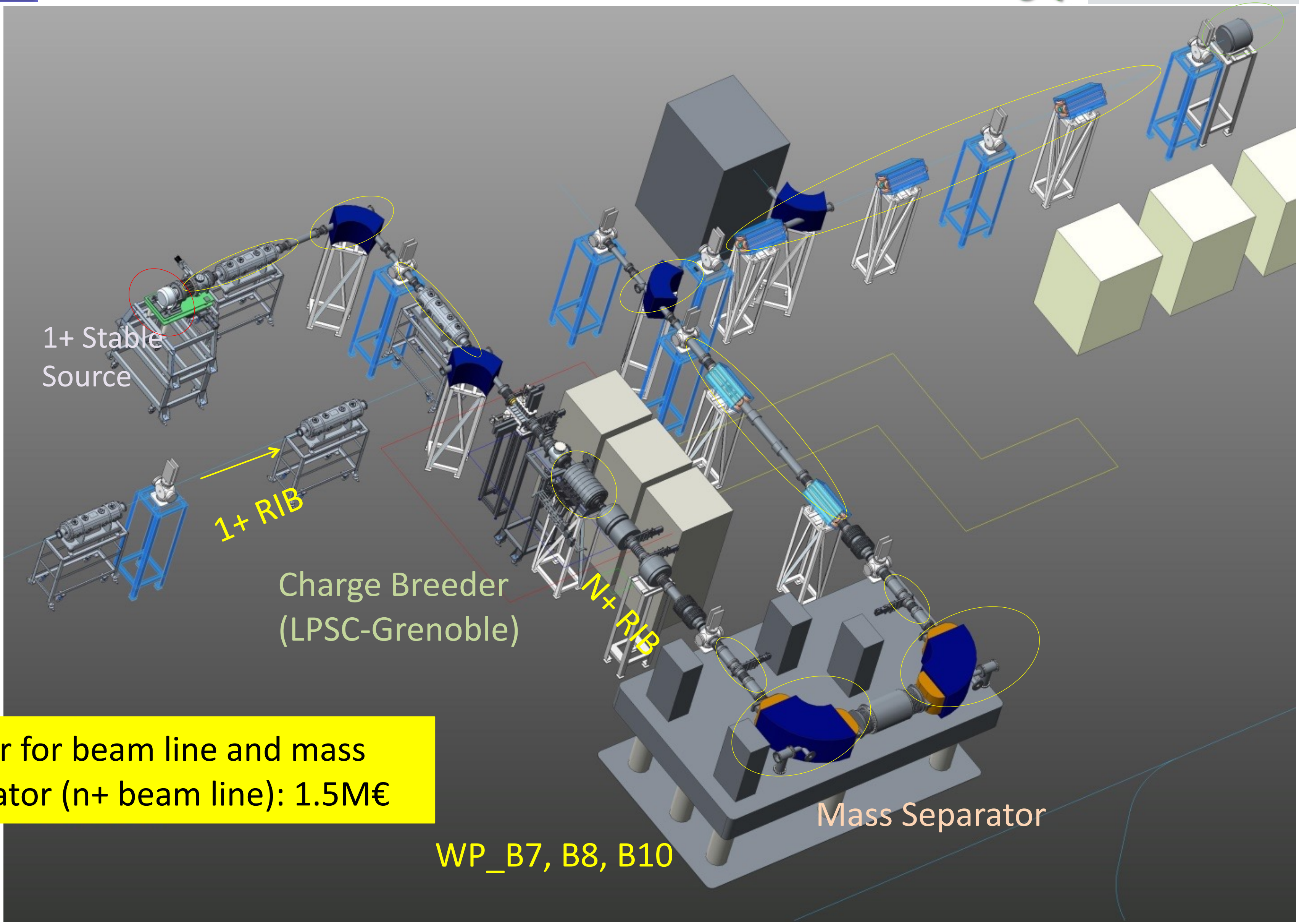
Charge Breeder

Medium Resolution Mass Separator

N+ beam line up to RFQ entrance



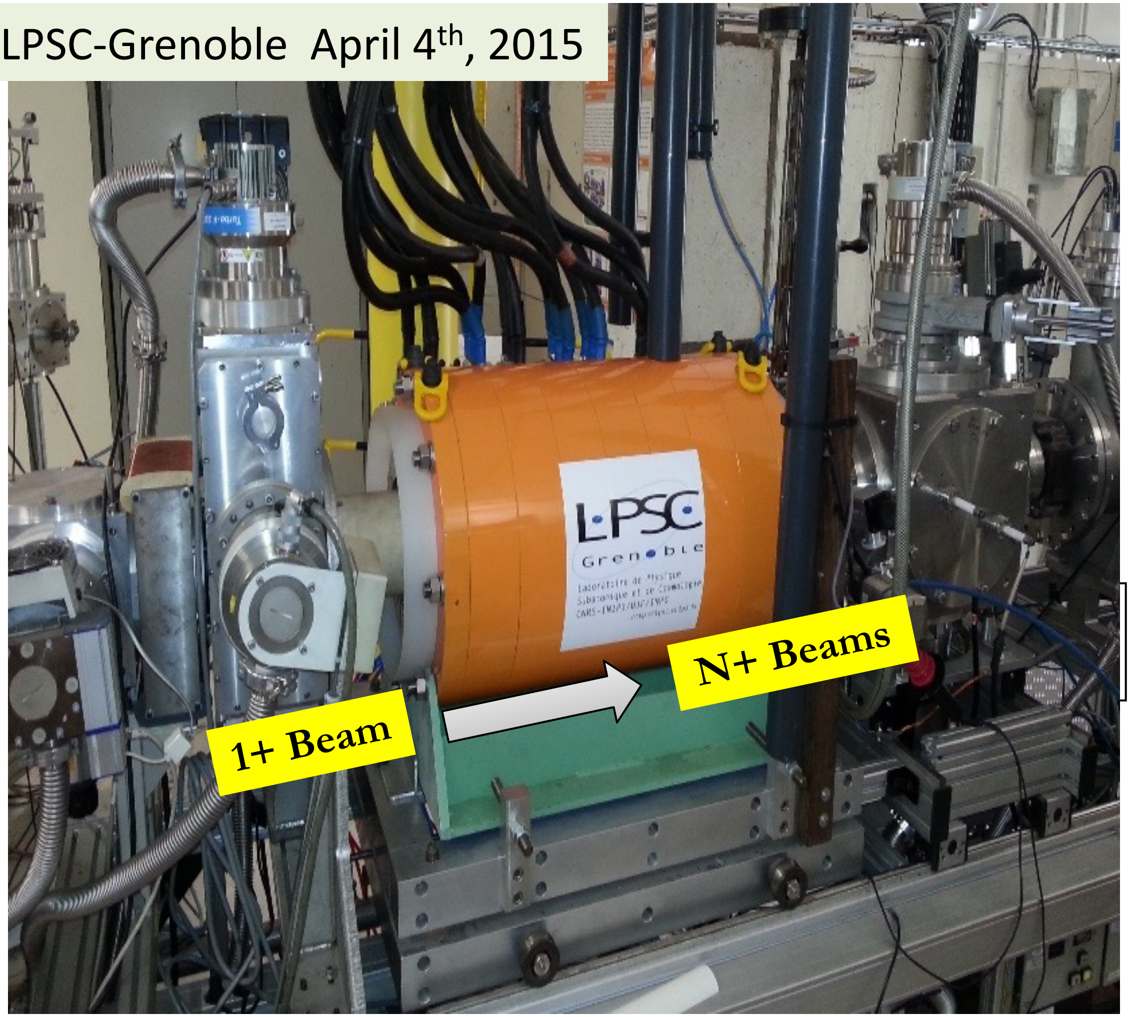
# Exotic Beam reacceleration: Charge breeder and MRMS up to RFQ




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

# Validation of the SPES-CB

LPSC-Grenoble April 4th, 2015



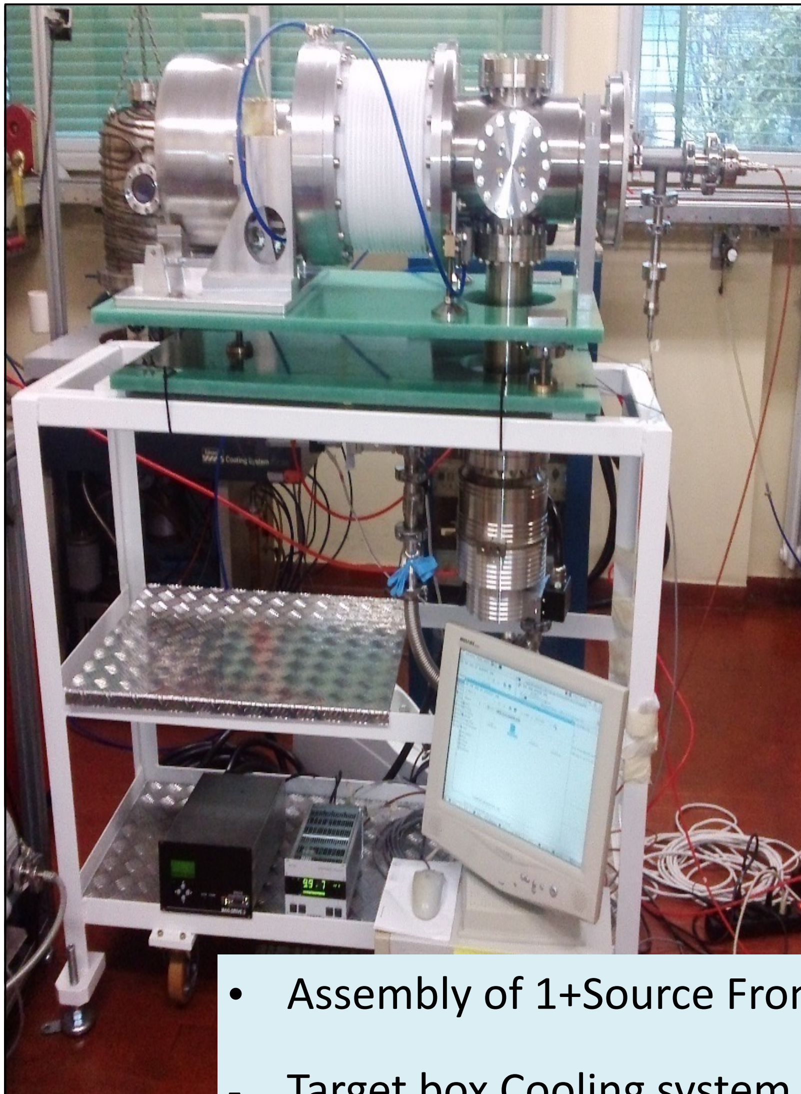

Development at LPSC (Grenoble) of an Upgraded PHOENIX booster as Part of a MoU in the frame of the European Associated Laboratories (LEA-Colliga)

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

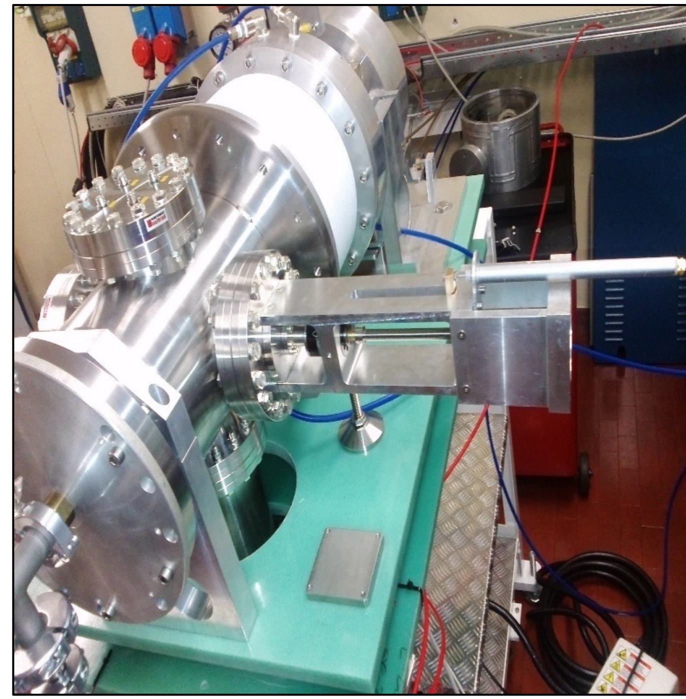
| | | EFFICIENCY* [%] | | |
|---|---|---|---|---|
| ION | Q | SPES req | Best LPSC | SPES-CB |
| Cs | 26 | ≥ 5 | 8,6 | 11,7 |
| Xe | 20 | ≥ 10 | 10,9 | 11,2 |
| Rb | 19 | ≥ 5 | 6,5 | 7,8 |
| Ar | 8 | ≥ 10 | 16,2 | 15,2 |

**results obtained for the same 1+ injected current*

# 1+ Source for Charge Breeder



Ready for installation



- Assembly of 1+Source Front-End

- Target box Cooling system tested - no leackage
- Vacuum of full system testes - final vacuum = 1.2E-6 mbar

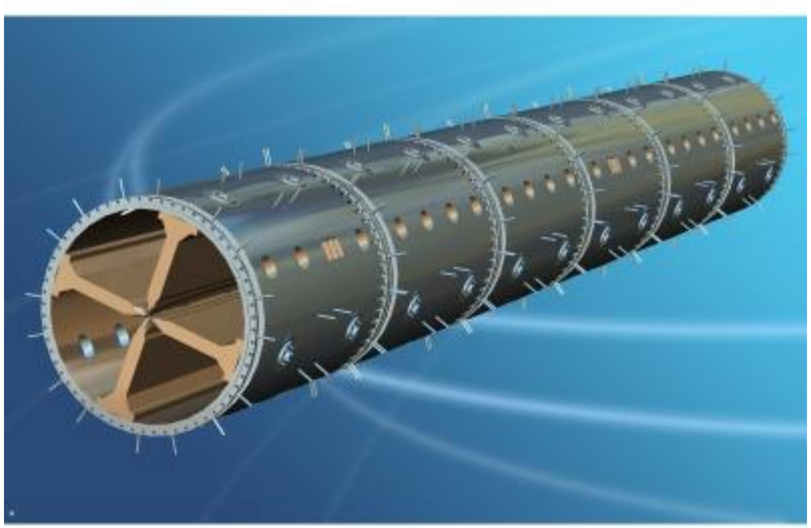
M.Manzolaro

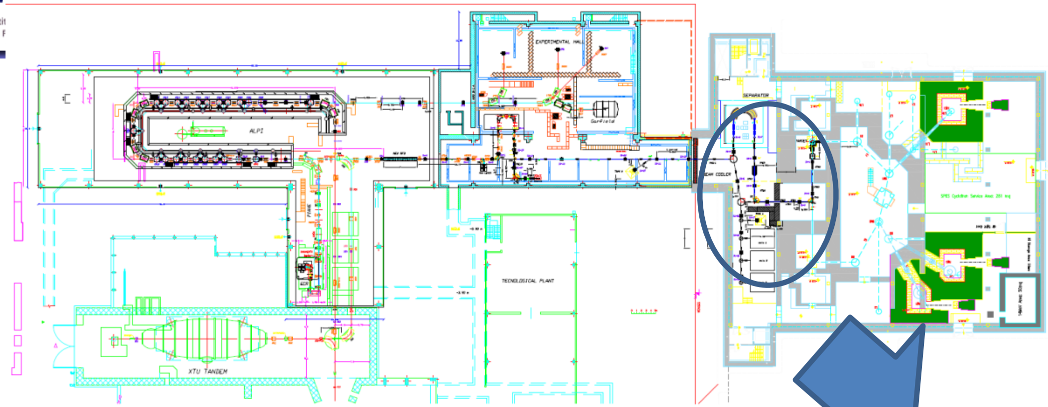
# SPES-RFQ

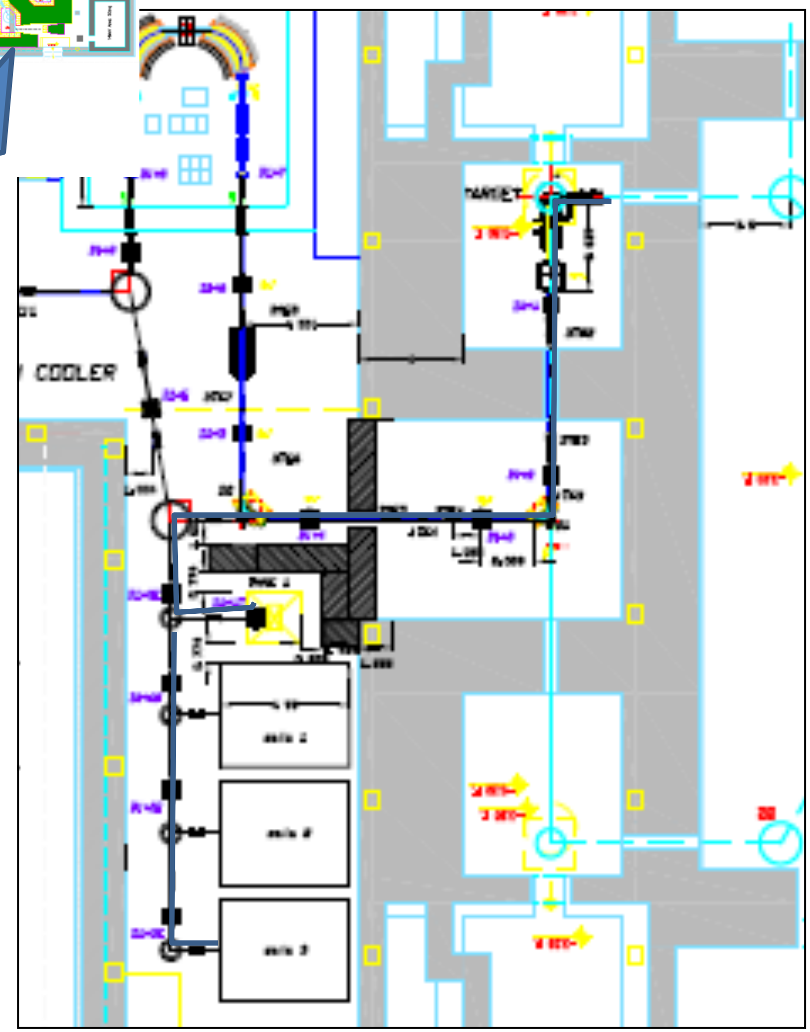
Design almost completed .
Additional study to finalize RF and Tank.
Construction started (electrodes).

| Parameter (units) | Design Value |
|---|---|
| Operational mode | CW |
| Frequency (MHz) | 80.00 |
| Injection Energy (keV/u) | 5.7 (β=0.0035) |
| Output Energy (keV/u) | 727 (β=0.0395) |
| Accelerated beam current (μA) | 100 |
| Charge states of accelerated ions (Q/A) | 7 – 3 |
| Inter-vane voltage V (kV, A/q=7) | 63.8 – 85.84 |
| Vane length L (m) | 6.95 |
| Average radius $R_0$ (mm) | 5.33 – 6.788 |
| Synchronous phase (deg.) | -90 – -20 |
| Focusing strength B | 4.7 – 4 |
| Peak field (Kilpatrick units) | 1.74 |
| Transmission (%) | 95 |
| Output Long. RMS emittance (mmmrad) / (keVns/u)/(keVdeg/u) | 0.055 / 0.15 / 4.35 |

- Andrea Pisent (WP coordinator, LNL)
- Antonio Palmieri (deputy coordinator, LNL)
- Luigi Ferrari (Mechanics design)
- Michele Comunian, Luca Bellan (Beam dynamics, LNL)
- Carlo Roncolato (Vacuum system and brazing, LNL)
- Next future
  - Enrico Fagotti (Acc. Physics and cooling system, LNL)
  - Damiano Bortolato and Francesco Grespan, Mauro Giacchini (RF system, controls)
- Synergies with Torino and Padova INFN sections for the mechanics development (P. Mereu and A. Pepato respectively), common aspects with ESS DTL and IFMIF RFQ design

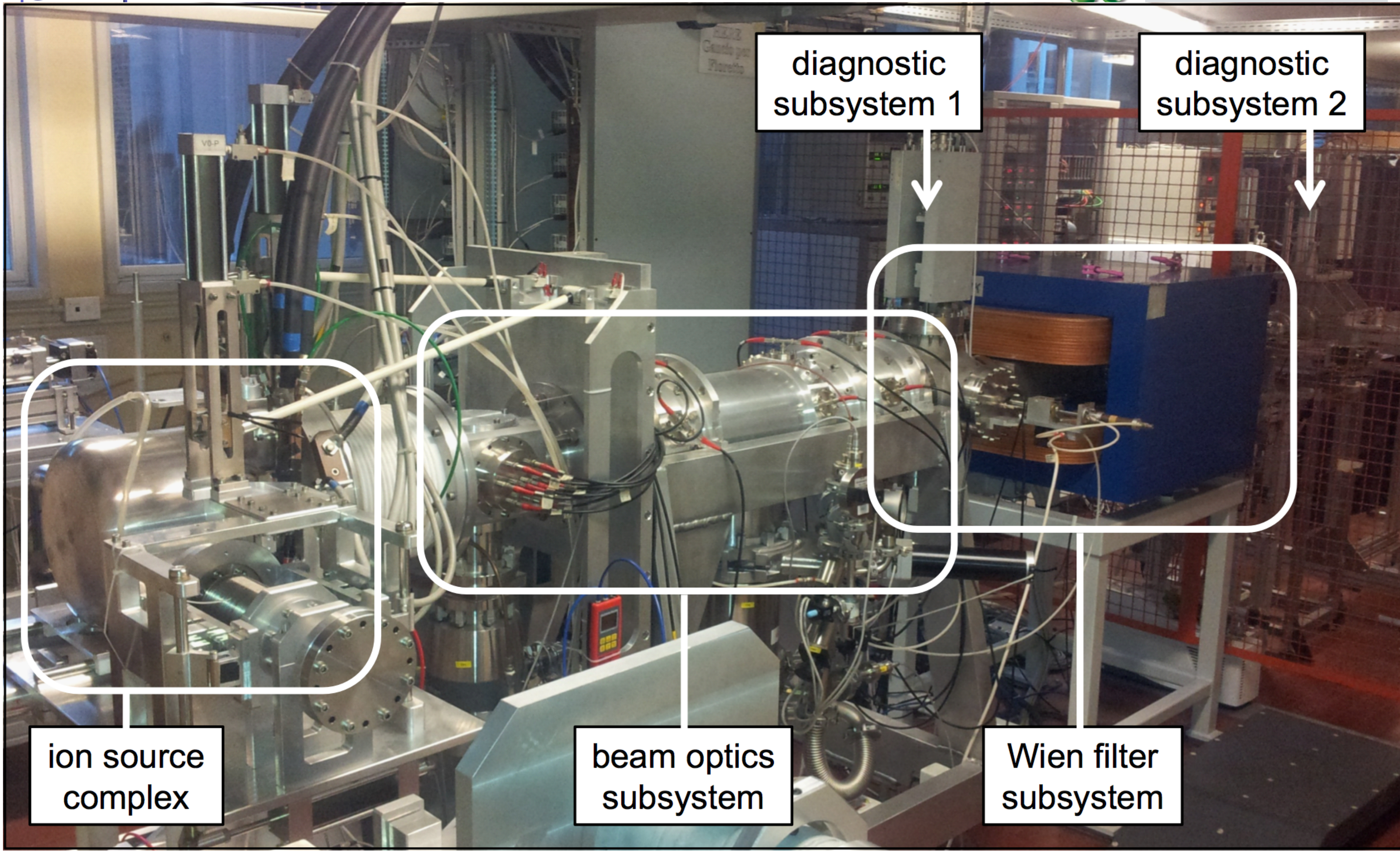







Installation Phase 2b
ISOL system
Wien Filter, Low Resolution Mass Separator
Tape Station1 ,
possibly 1+ beam lines for experiments

# SPES ISOL system

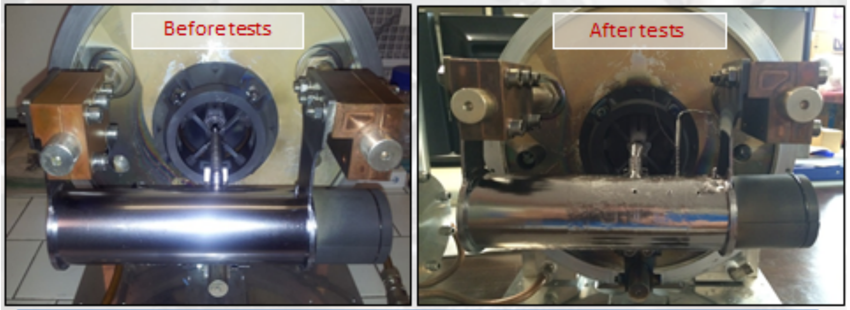



System under operation for source commissioning.
Updated version (radiation hardness improved) under construction.

# ISOL system

## TIS unit endurance test:

Tests at high temperature with Joule heating thermal load (1300A target heater, 350A line):
**heating power ≈ 12 kW** > primary proton beam thermal load (≈10 kW)




- ≈ 415 testing hours at high temperature -> ≈ 220 hours at maximum power (12kW)
- 79 heating cycles sustained -> **9 with current ramps of 1 s from 0 A to 1300A (!)**
  **to 350A (!)**

**TIS UNIT STILL OPERATIVE !!**



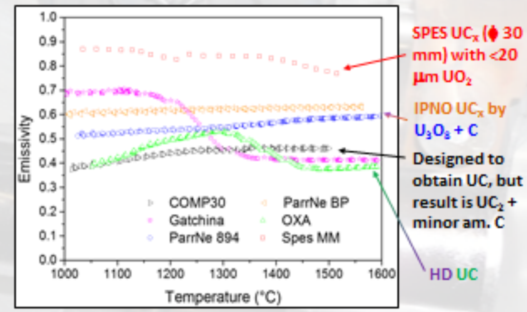
## Target materials production and tests 2/5

### Emissivity measurements on different uranium carbides

Direct emissivity measurements on heated $UC_x$ discs using a dual frequency pyrometer

Old UNIPD $UC_x$ lab

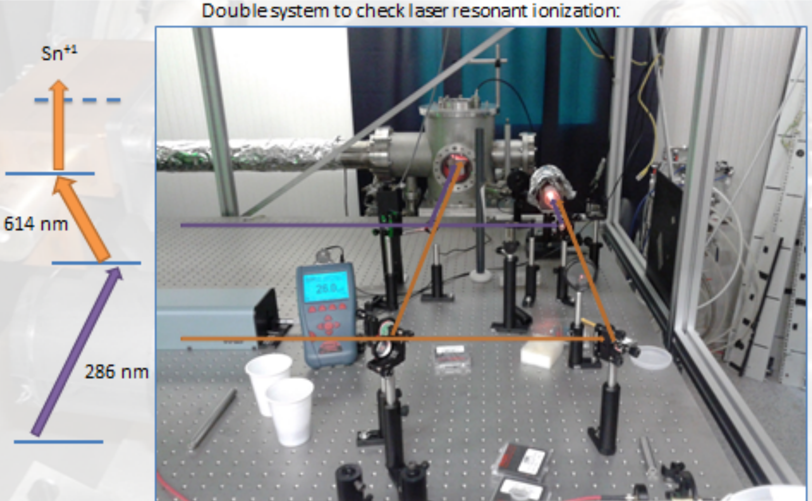
Uranium carbide samples of different composition and synthesis routes produced in different laboratories participating to ActiLab






## HCL + ToF on Tin laser ionization

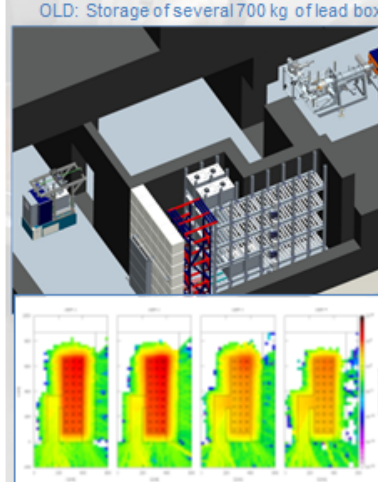
Double system to check laser resonant ionization:






## The (new) Chamber Unit Storage

OLD: Storage of several 700 kg of lead box

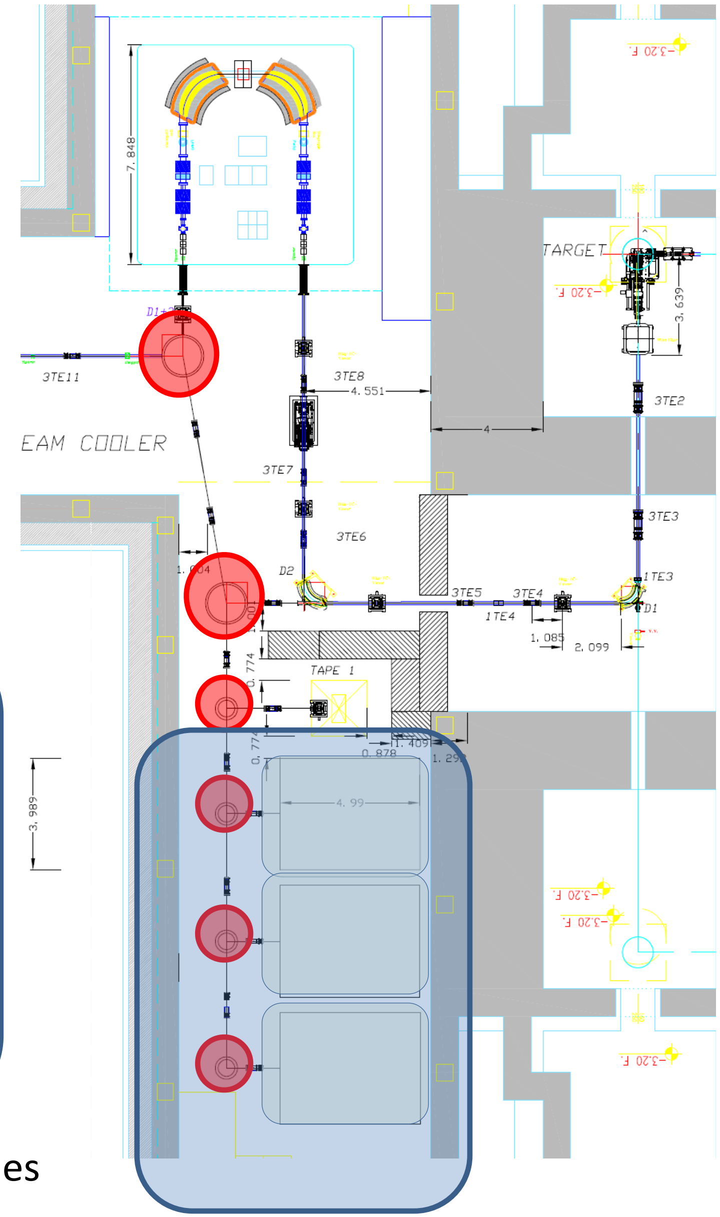


# Experimental area for non re-accelerated RIBs

According to the Scientific Advisory Committee advise, an area for non re-accelerated RIBs experiments was defined. Preliminary design was performed to evaluate general layout and cost.

Working group:
F.Gramegna, (coordination)
M.Cinausero (physics)
A.Mendez (ORNL, electrostatic design)
A.Monetti (engineering and beam transport)
L.Bellan (beam transport)

- Three experimental areas available (20m$^2$ each)
- Evaluated additional cost for installation (1M€)
- Proposal for construction to be submitted to INFN management

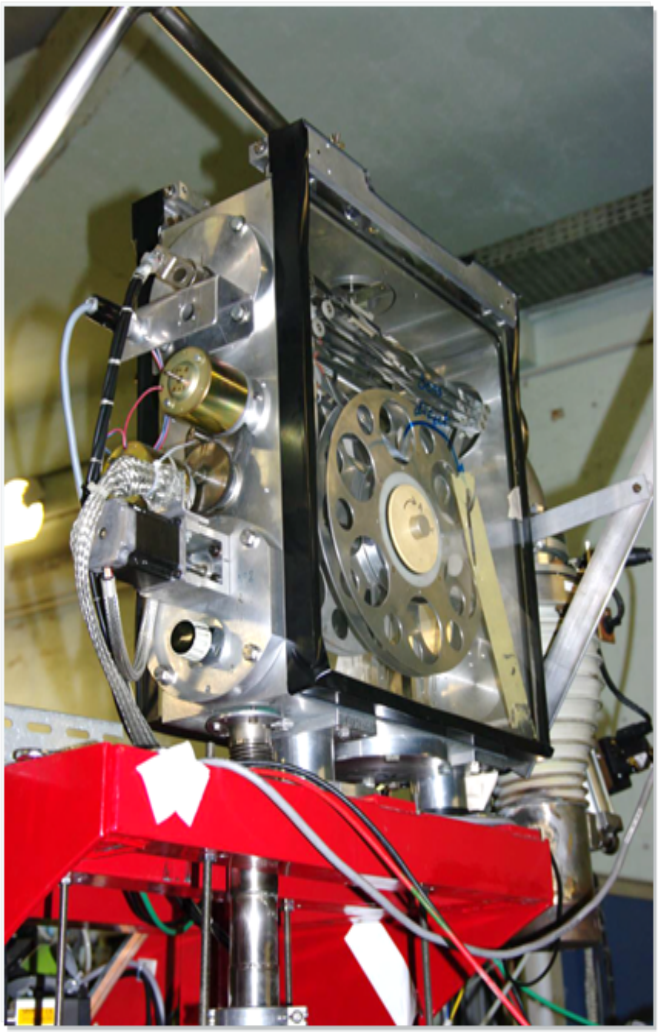



Electrostatic dipoles

# Diagnostics for radioactive beams

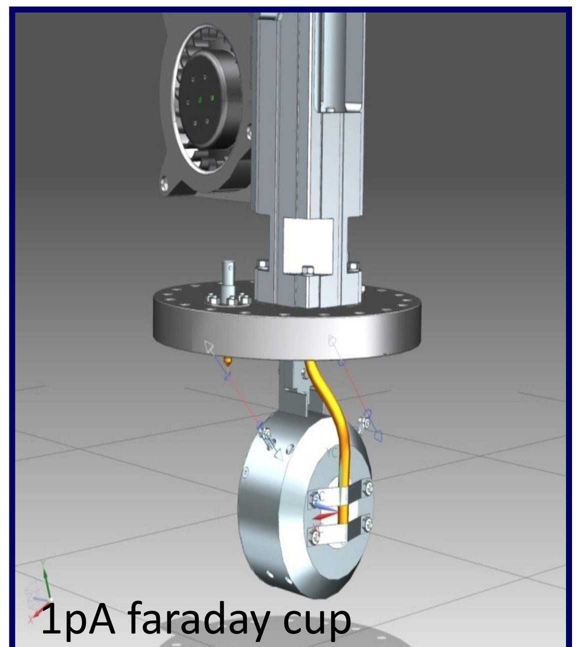
Study group (mainly physics researchers) to define instrumentation to be implemented for SPES (report at end 2015)

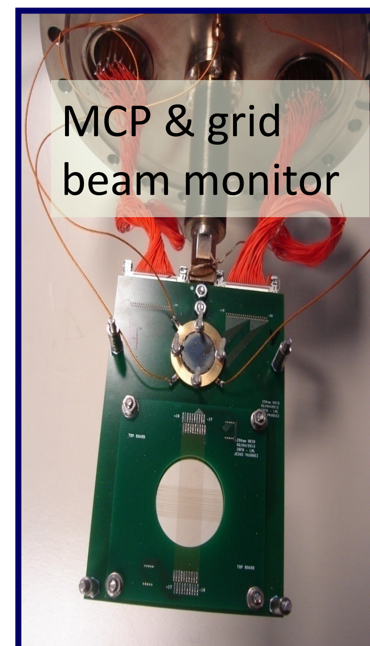
E.Fioretto (coordinator)
D.Fabris, G.Montagnoli, D.Mengoni, G.Collazuol, M.Poggi, R.Cherubini and collaboration with LNS



Tape station based on Orsay design

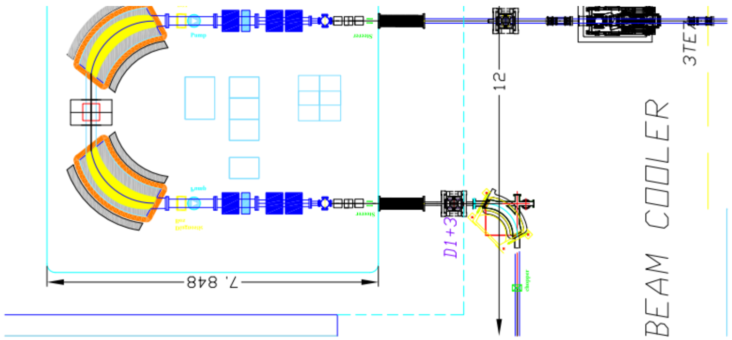
Low intensity beam monitors



# High Resolution Mass Separation

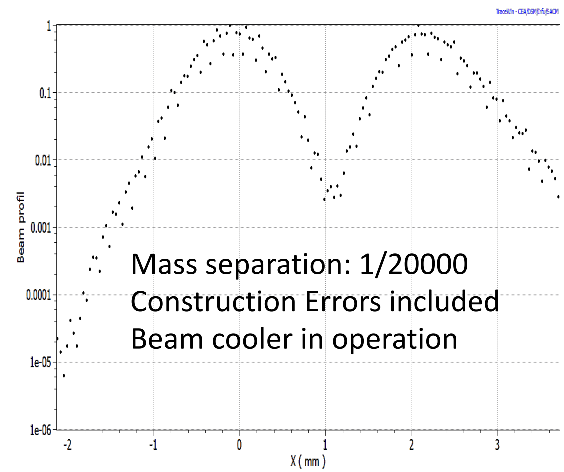
Collaboration: LNS, LNL, CENBG Bordeaux
Physics design: 1/40000



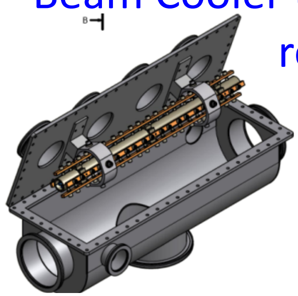

$\Delta E = \pm 1$ eV
Emittance rms = 0.68 $\pi$mm mrad

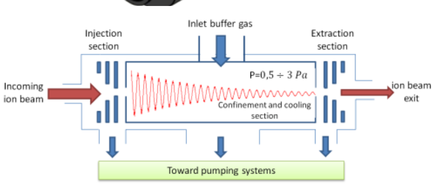
| Type | Max range |
|---|---|
| Misalignment (x,y) (no effect on R) | 0.5 mm |
| Tilt (xy,yz,xz) | 0.1° |
| Field error | 0.05% |
| All errors | 0.25 mm, 0.05°, 0.025% |

$^{132}Sn$ beam in simulations

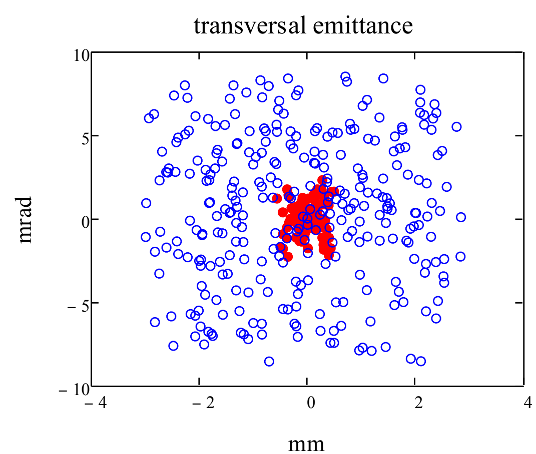



Beam Cooler to match the HRMS input requirements






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




Input T emittance
Output T emittance

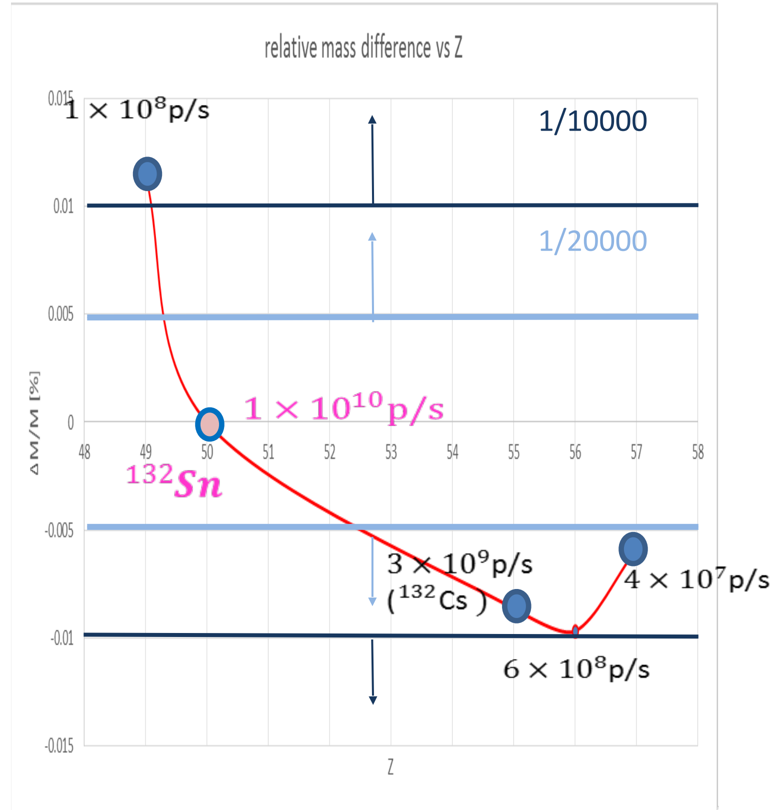
# Why 1/20000? An example

Ref case: $^{132}Sn$ produced by LIS

Zoom of the nuclide chart

| Z\A | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 42 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 43 | 0.00E+00 | 0.00E+00 | 0.00E+00 | | | | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 44 | 0.00E+00 | 0.00E+00 | 0.00E+00 | | | | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 45 | 0.00E+00 | 0.00E+00 | 0.00E+00 | | | | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 46 | 0.00E+00 | 0.00E+00 | 0.00E+00 | | | | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 47 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 48 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 49 | 3.60E+09 | 2.52E+09 | 4.20E+09 | 3.85E+09 | 4.19E+09 | 2.98E+09 | 2.52E+09 | 1.72E+09 | 1.26E+09 | 3.03E+08 | 1.73E+08 | 9.94E+07 | 2.31E+07 | 1.93E+06 | 1.96E+05 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 50 | 9.96E+09 | 1.84E+10 | 1.29E+10 | 2.10E+10 | 1.57E+10 | 2.36E+10 | 1.85E+10 | 2.42E+10 | 2.03E+10 | 2.43E+10 | 1.63E+10 | 1.30E+10 | 2.60E+09 | 2.52E+09 | 1.25E+09 | 2.09E+08 | 2.79E+07 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 51 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 52 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 53 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 54 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 55 | 0.00E+00 | 3.15E+06 | 1.95E+07 | 2.23E+07 | 1.24E+08 | 1.88E+08 | 5.05E+08 | 7.47E+08 | 1.40E+09 | 2.06E+09 | 3.75E+09 | 3.15E+09 | 7.56E+09 | 8.11E+09 | 1.29E+10 | 1.31E+10 | 1.87E+10 | 1.16E+10 | 1.44E+10 | 1.10E+10 | 1.33E+10 | 7.76E+09 | 1.13E+10 |
| 56 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.50E+06 | 1.51E+06 | 1.66E+07 | 6.34E+07 | 1.01E+08 | 2.93E+08 | 3.98E+08 | 5.74E+08 | 1.05E+09 | 2.01E+09 | 2.14E+09 | 4.07E+09 | 4.33E+09 | 6.79E+09 | 4.82E+09 | 6.24E+09 | 4.48E+09 | 6.78E+09 | 3.08E+09 |
| 57 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.77E+06 | 1.13E+07 | 3.62E+07 | 4.22E+07 | 1.33E+08 | 2.09E+08 | 4.46E+08 | 5.68E+08 | 1.03E+09 | 1.40E+09 | 2.23E+09 | 1.66E+09 | 2.41E+09 | 1.96E+09 | 2.32E+09 |
| 58 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 59 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 60 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 61 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

- HRMS selected species
- 1/200 selected species
- WF selected species
- Nominal beam



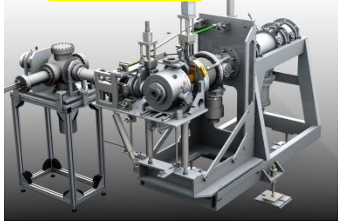

If mass separation is 1/10000, we can separate just one isobar from the nominal beam. Instead, a separation in mass of over 1/20000 ensures a “clean selection”, in particular versus $^{132}Cs$.

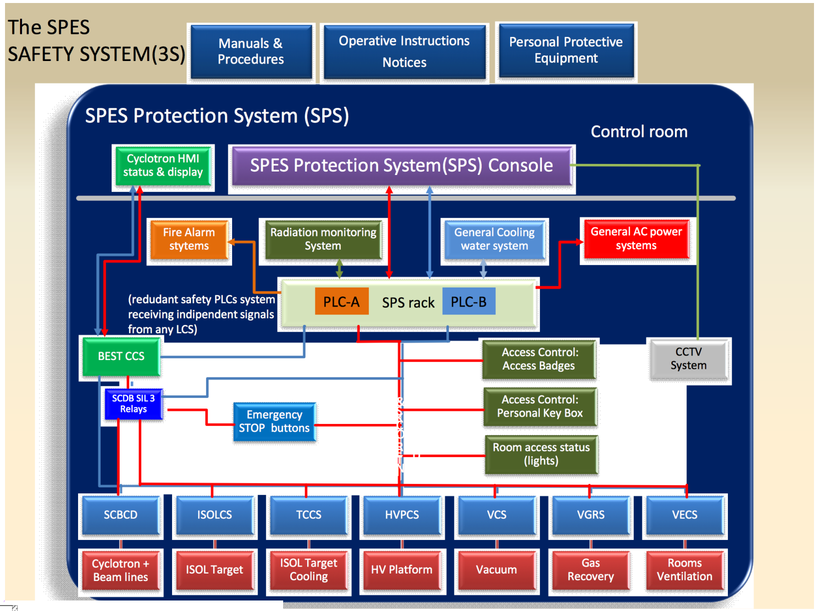
# SPES safety system

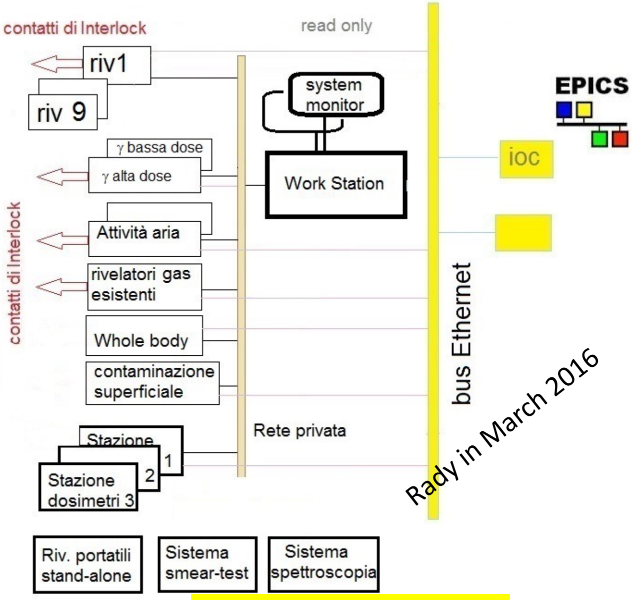
A SIL3 safety system is under development (tender launched)
Simplified system will be ready for cyclotron test

Cyclotron and beam lines

ISOL target

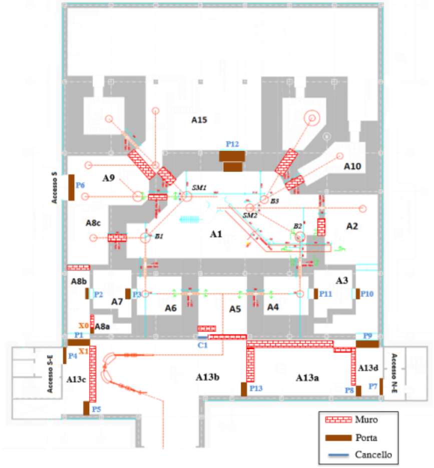




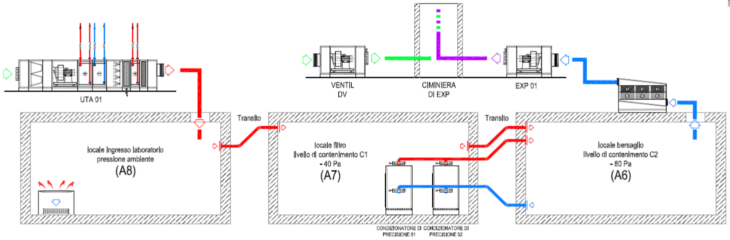




Rady in March 2016

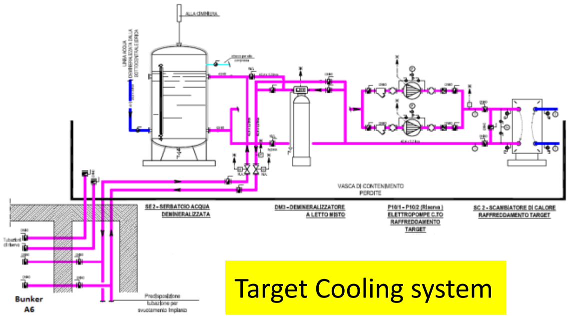
Radiologic survey system




Access Control System

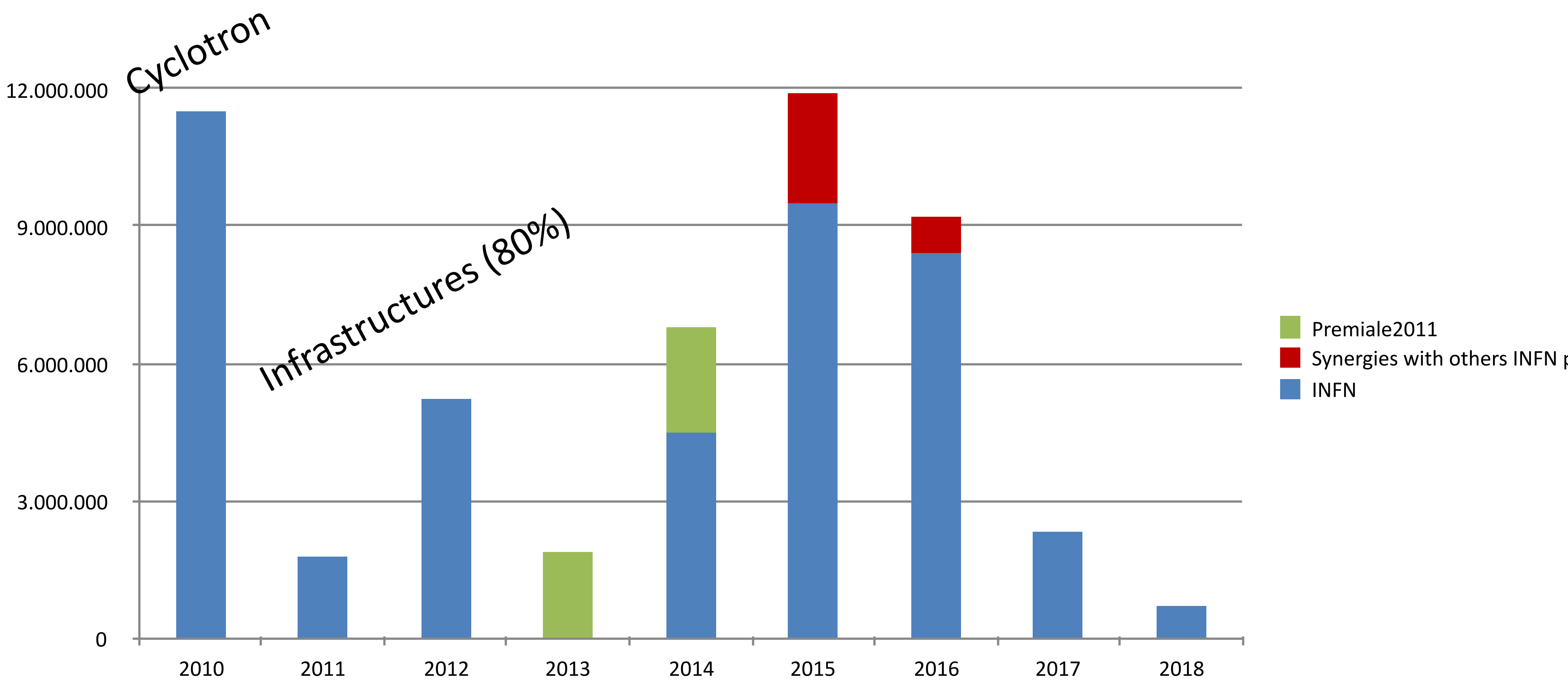



ventilation




Target Cooling system

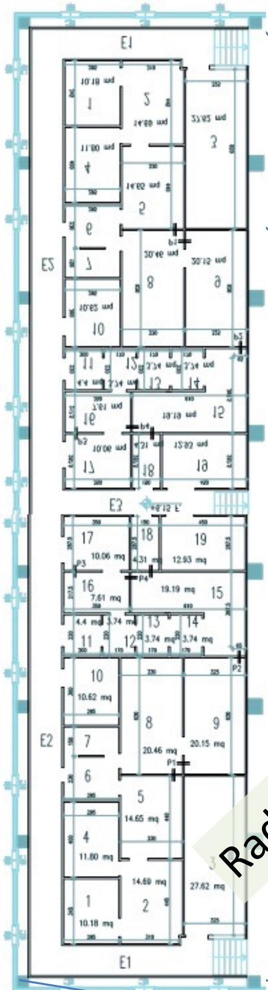
# Economic planning for SPES construction 2010-2018



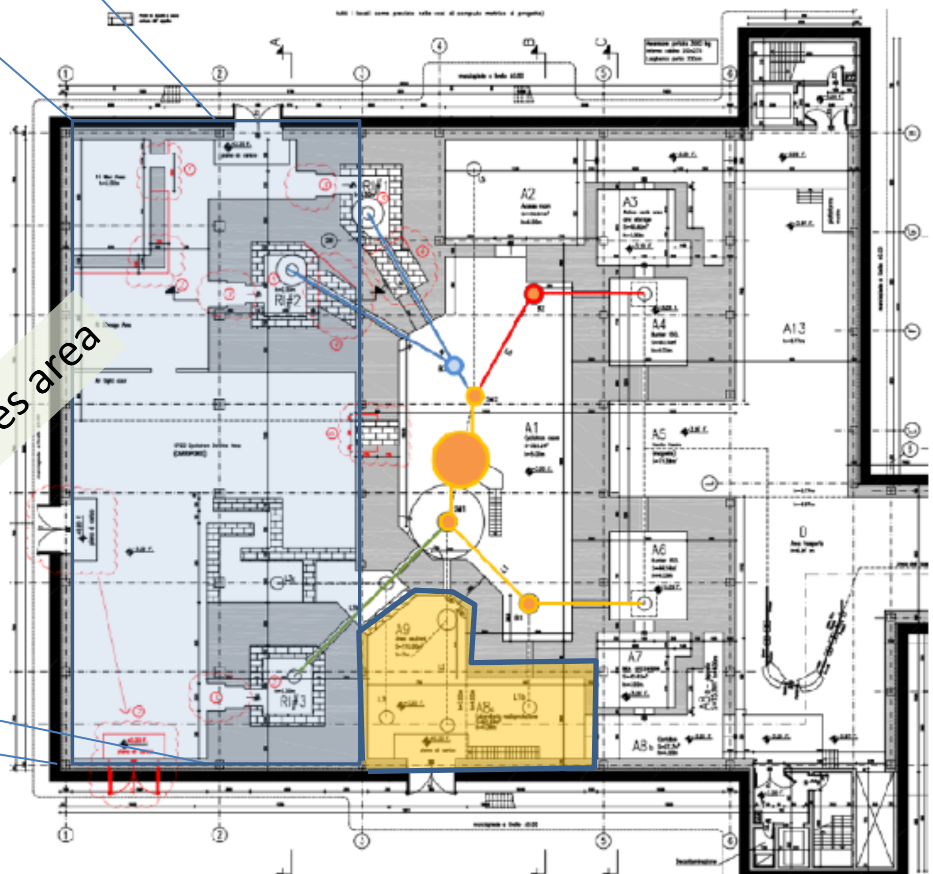

Approved project funding for ompletion: Nov 2014

| Total SPES construction 2010-2018 (51.200 kEuro) | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Estimate (2013) | 11,500 | 1,800 | 5,200 | 1,900 | 6,700 | 12,900 | 8,200 | 2,300 | 700 | 51,200 |
| Invested (June 2015) | 11,500 | 1,800 | 5,200 | 1,900 | 2,900 | 8.400 (+1.500) | | | | |

# SPES Applications




Radiochemical Laboratories (second floor)




Neutron area

# SPES γ: Radio-isotopes for medicine

## «LARAMED» project

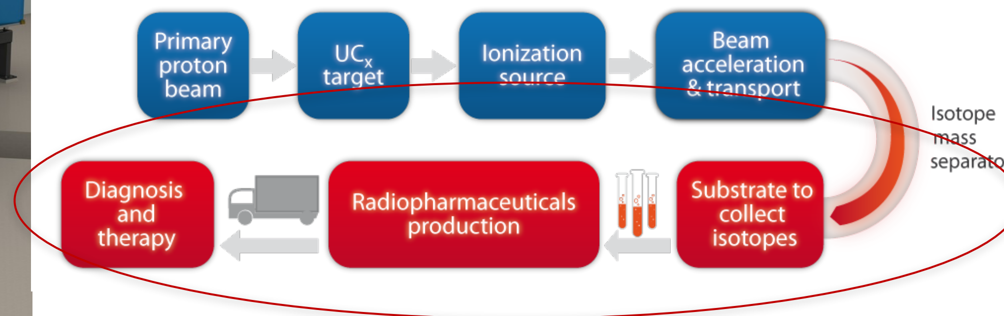
**Production of radionuclides for medicine using the SPES cyclotron (production&research)**


## ISOLPHARMA*

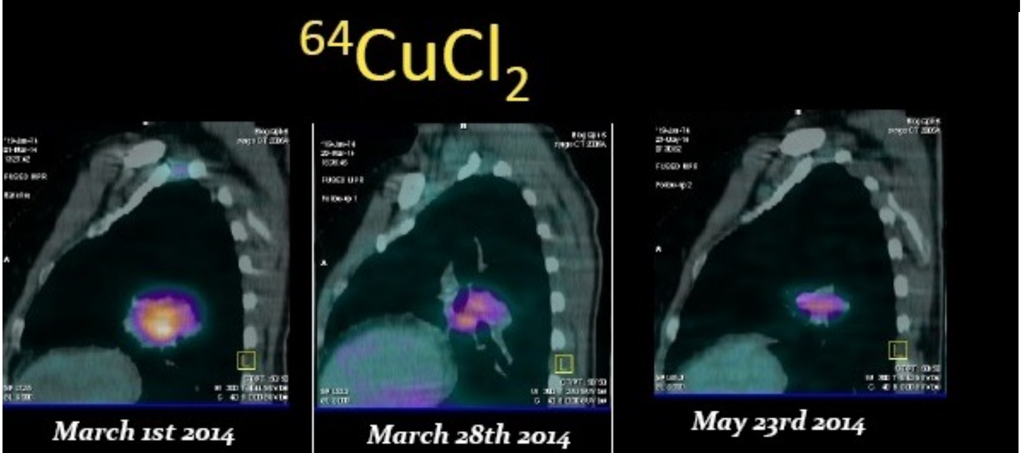
* INFN Patent pending

Use of ISOL technique for Direct isotope on-line separation : very high specific activity

(4-5 order of magnitude than standard)




Effect of cancer treatment with $^{64}Cu$ produced with proton beam at cyclotrons. Better result expected with $^{67}Cu$.




patient: male, 55 y, pulmonary hilar adenopathy (left lung)

| Radiopharm aceutical | Targeted organs | Half-life | Specific Activity (GBq/mg) | |
|---|---|---|---|---|
| | | | SPES production | Neutron capture reaction |
| $^{89}Sr$-$SrCl_2$ | Bone | 50.5 d | ≥ 597 | ≥ 0,004 |
| $^{90}Y$-$YCl_3$ | Liver and endocrine system | 64.1 h | ≥ 9480 | ≥ 0,8 |
| $^{125}I$-NaI | Prostat, brain, lung, pancreas, liver | 59.4 d | ≥ 552 | ≥ 6 |
| $^{131}I$-NaI | Thyroid | 8.02 d | ≥ 3911 | ≥ 0,7 |
| $^{75}Se$-$H_2SeO_3$ | Liver | 119.6 d | ≥ 323 | ≥ 3,7 |

# 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, ...)

See G.Fiorentini presentation

**STATUS:**

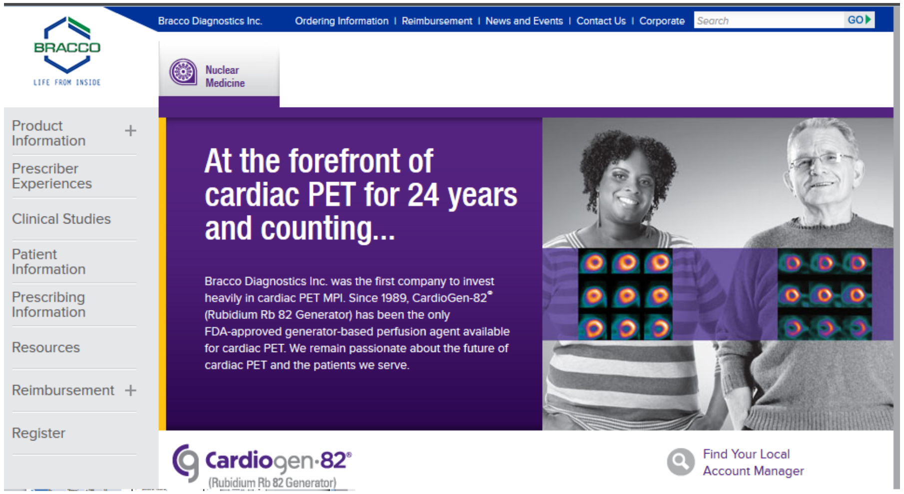
- Building and infrastructures under development
- Design of radiochemistry labs
- Design of beam line and target management
- Contract with company for radioisotopes production to be finalized

**Production laboratory in joint venture with external companies:**

Selected isotopes of medical interest

Sr-82/Rb-82 generator

$T_{1/2}$: 25.6 d EC 100% / 1.3 min photons 511keV, 776keV



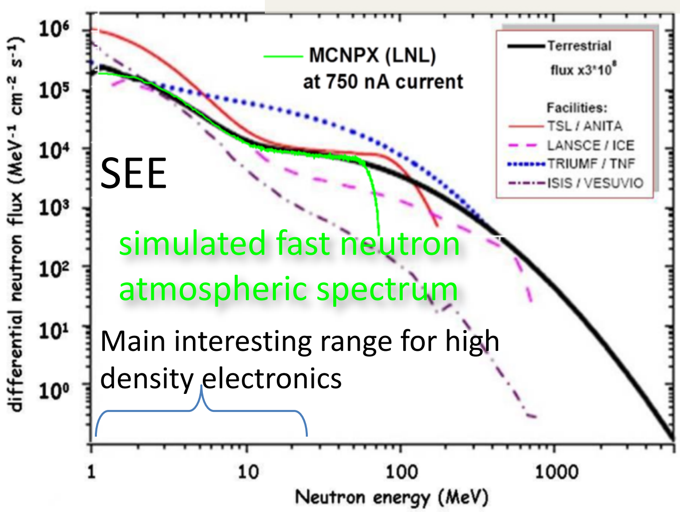
# NEPIR: Neutron production at SPES

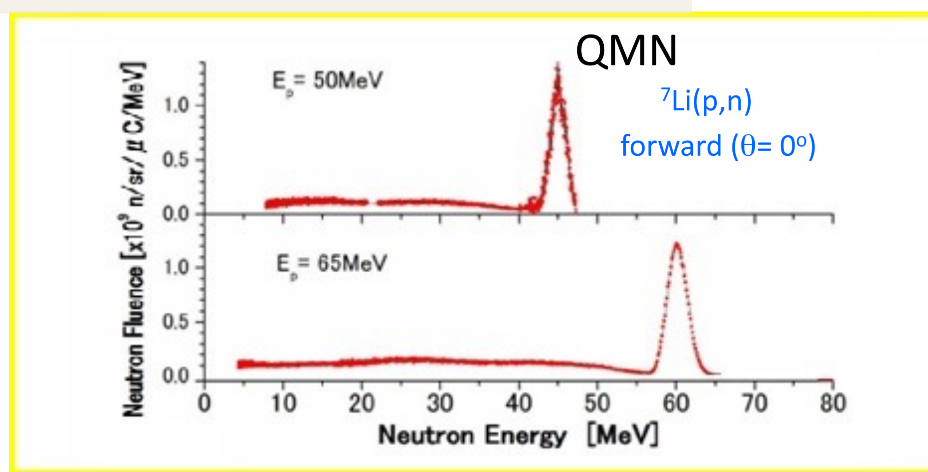
Design study

| Integral neutron production at SPES Cyclotron<br>Proton beam= 70 MeV, 500 μA Target = W 5mm | | | |
|---|---|---|---|
| Energy region (MeV) | Sn (n/s)<br>**$\sim 6\cdot10^{14}$ s$^{-1}$** | $\Phi_n$ @ 2.5 m<br>(n cm$^{-2}$ s$^{-1}$) | $\Phi_n$ @ 1 cm<br>(n cm$^{-2}$ s$^{-1}$) |
| 1 < E < 10 | $\sim 5\cdot10^{14}$ s$^{-1}$ | $5\times10^{8}$ | $3\times10^{13}$ |
| 10 < E < 50 | $\sim 1\cdot10^{14}$ s$^{-1}$ | $1\times10^{8}$ | $6\times10^{12}$ |

Continuum and Quasi Mono Energetic fast neutron spectra

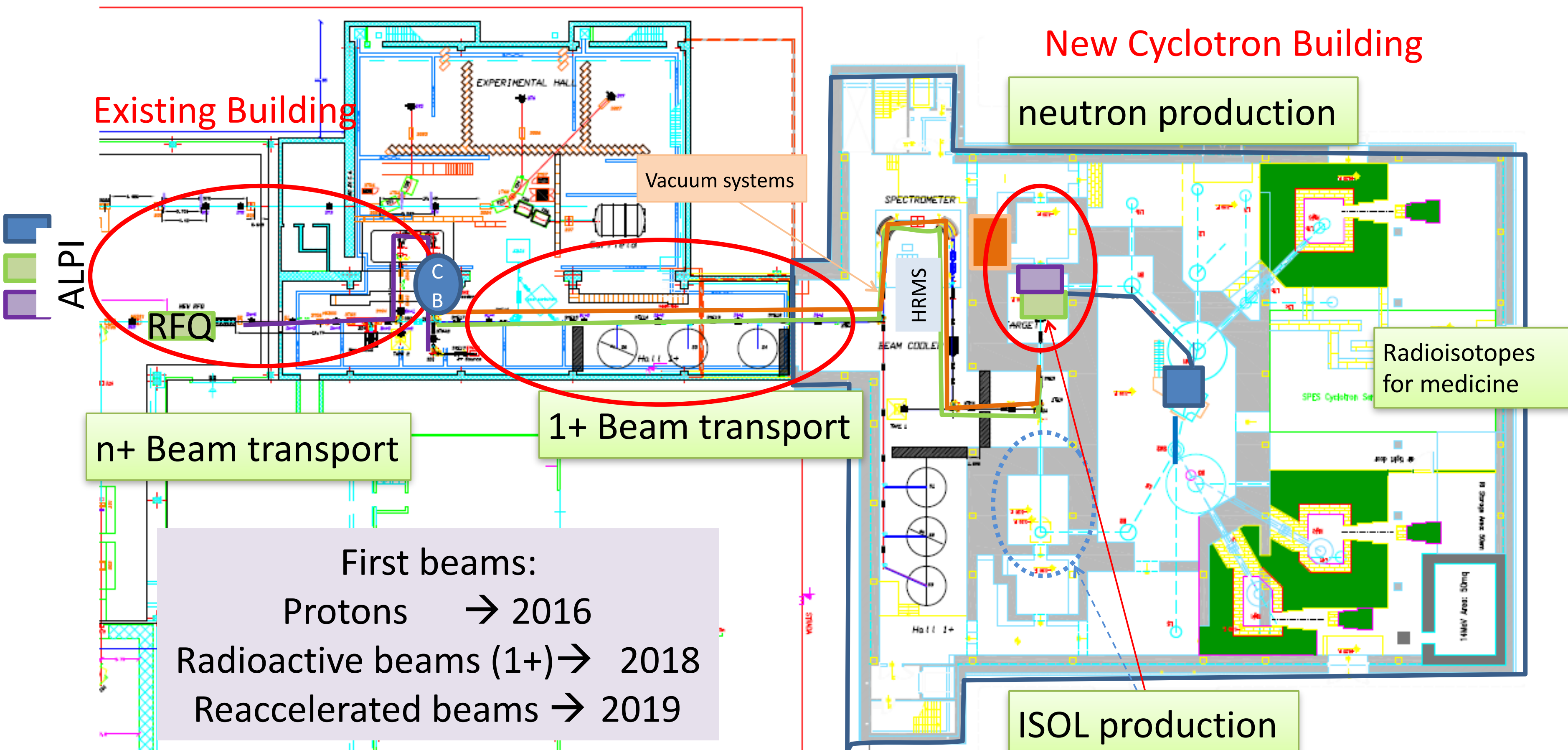
- Cross section data for basic science and astrophisics
- Oncology studies
- Calibration of radiation instrumentation
- Radiation protection studies (shielding-benchmarks)
- Radiation hardness studies (Single Event Effect)



# Construction phase: MAIN TENDERS

| 2010-2012 | 2013-2014 | 2015 | 2016 | 2017 |
| --- | --- | --- | --- | --- |
| ISOL target<br>Cyclotron and Building | Laser source<br>Vacuum systems<br>Charge Breeder<br>n+ beam transport | Safety, RFQ,<br>HVPlatform, UCx Lab design,<br>Plant upgrade | UCx Lab, 1+ line,<br>Vacuum systems,<br>ISOL installation,<br>Hot cell, RFQ | High Resolution Mass Separator |



# CONCLUSIONS

- The SPES project is financed by INFN up to the completion
- The cyclotron 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:
  - A program for study and production of radioisotopes for medical use is started
  - First beams available for medicine and neutrons in 2016
  - A neutron facility for fast neutrons is under design