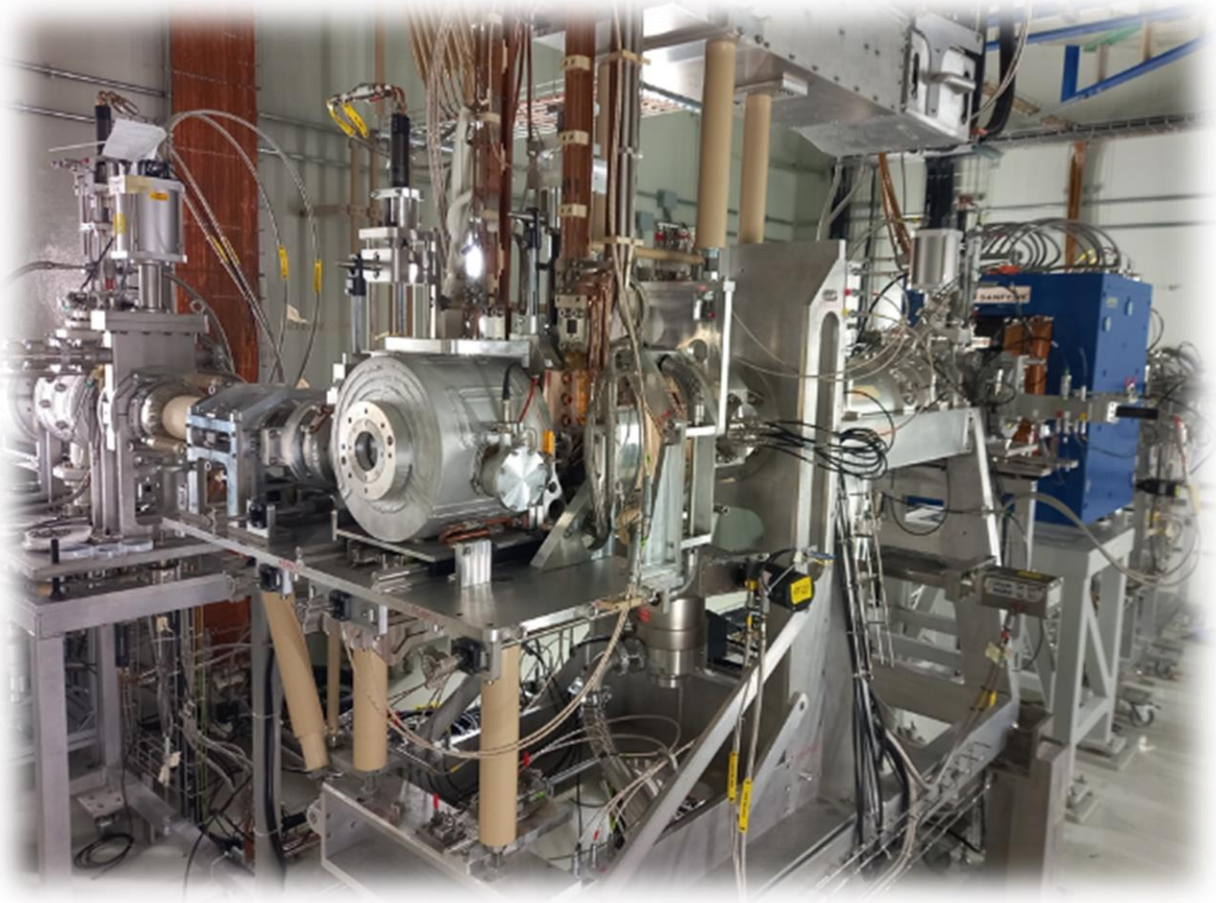
VIIth Topical Workshop on
Modern Aspects in Nuclear Structure

The Many Facets of Nuclear Structure

BORMIO 3-8 February 2025

SPES Low Energy RIB for nuclear physics and applications

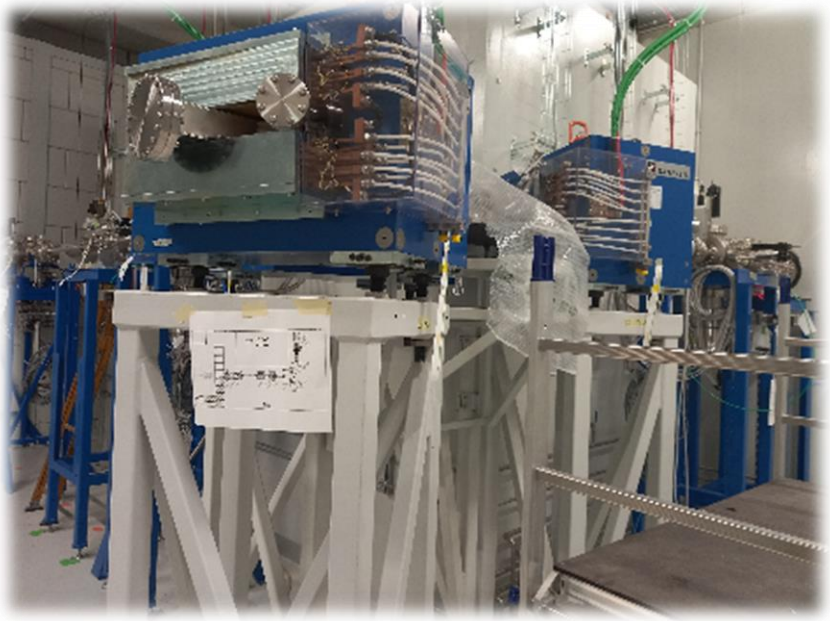


Alberto Andrighetto – INFN Laboratori di Legnaro

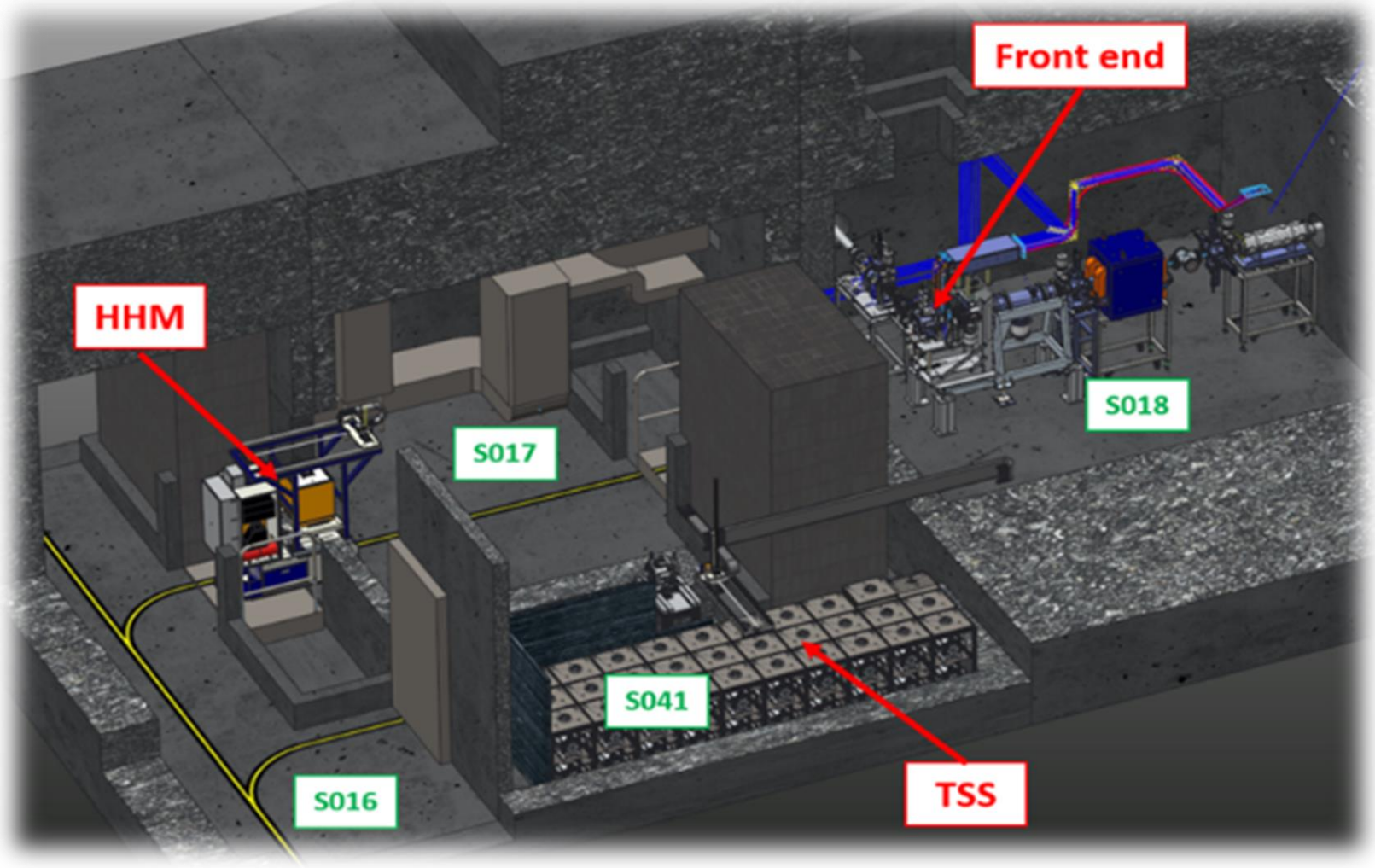
INFN LNL
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Talk overview

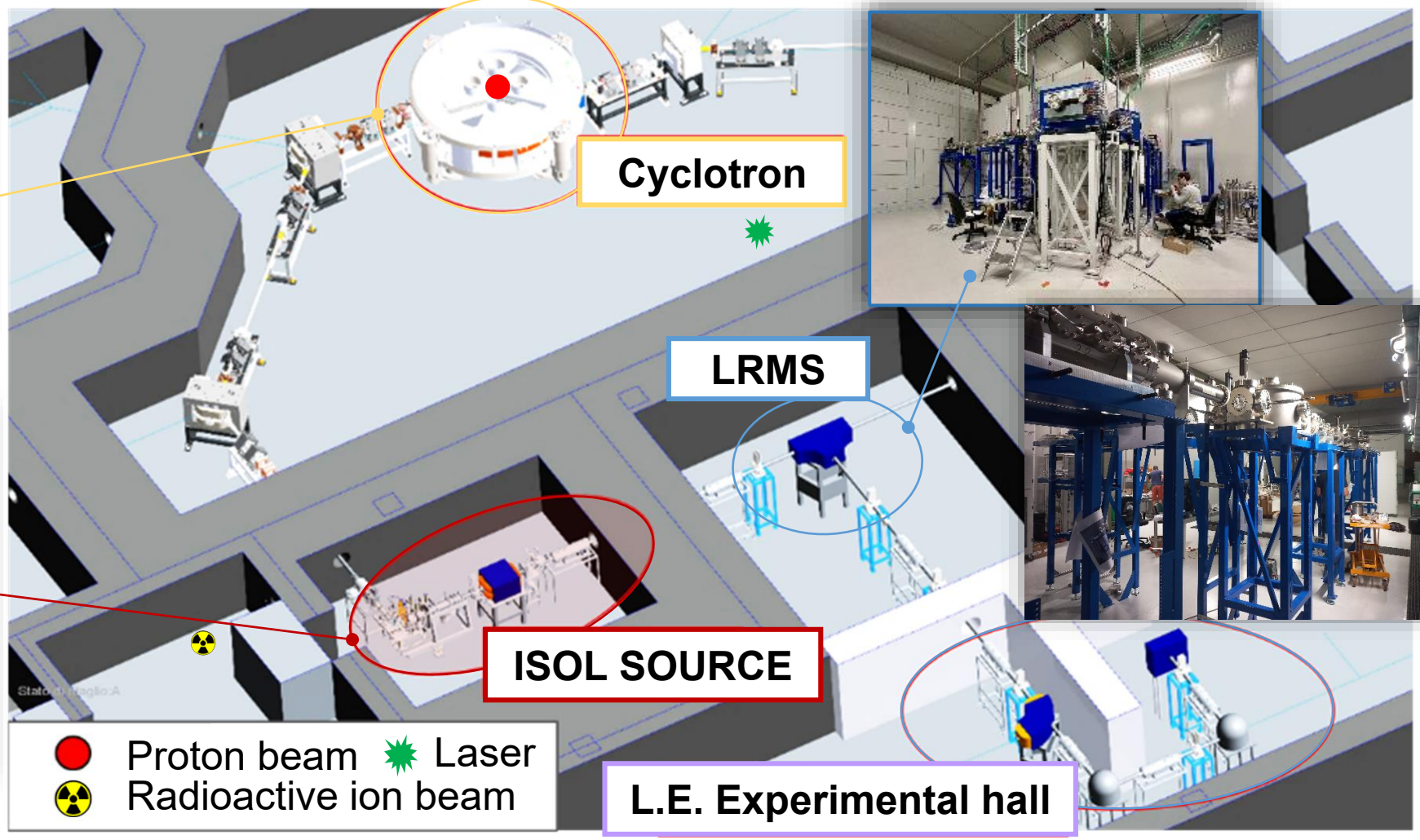
- The RIB production
- The Low Energy Beam Line
- The first radioactive beam
- Isolpharm: Radioisotopes for medicine



The RIB production

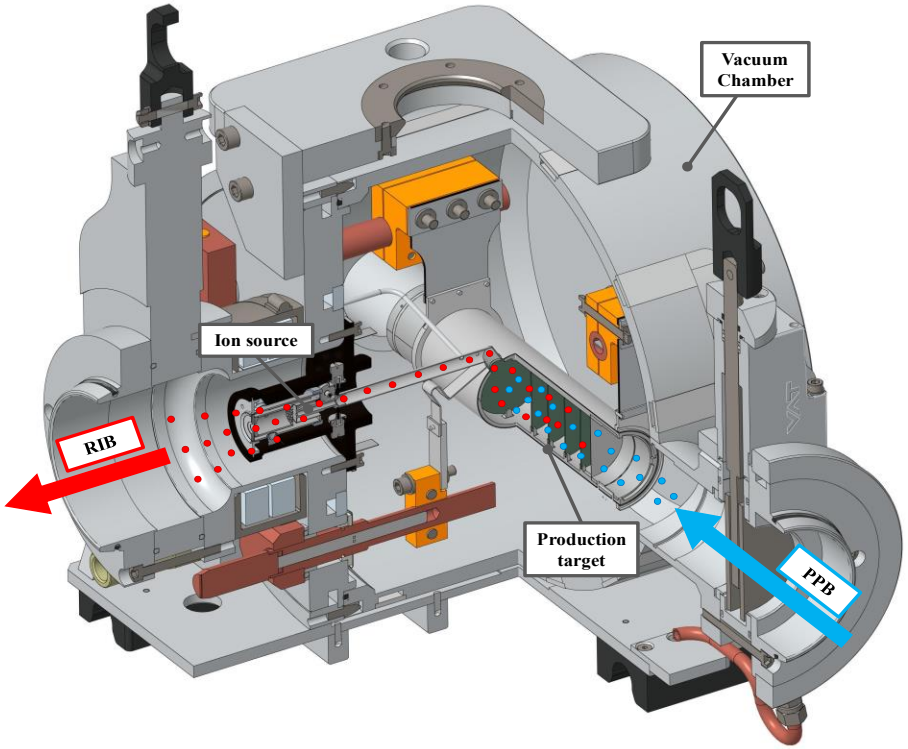


RIB production area

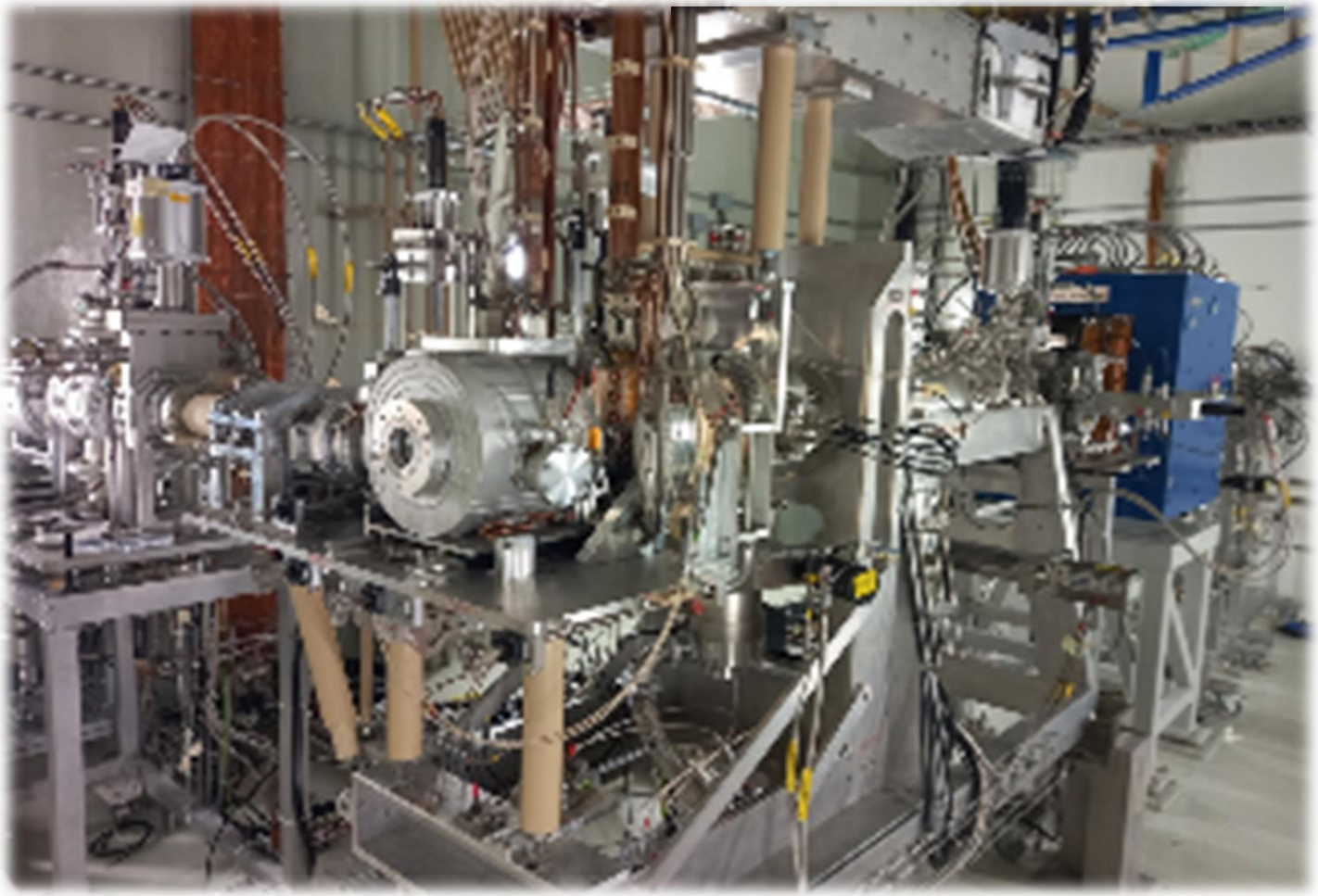


The Target Ion Source system

The SPES TIS unit:



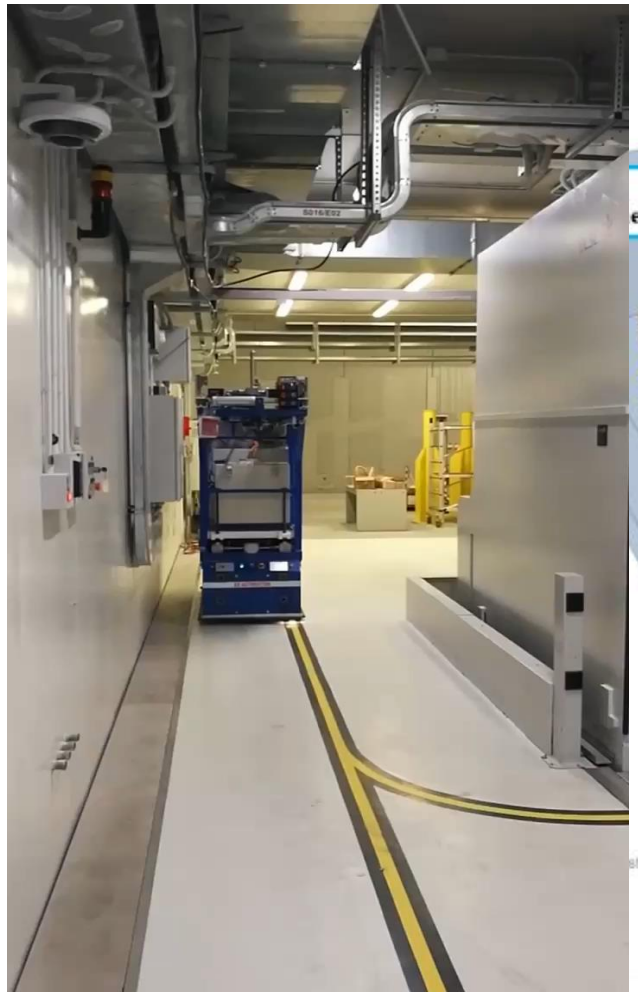
The SPES Front-End:

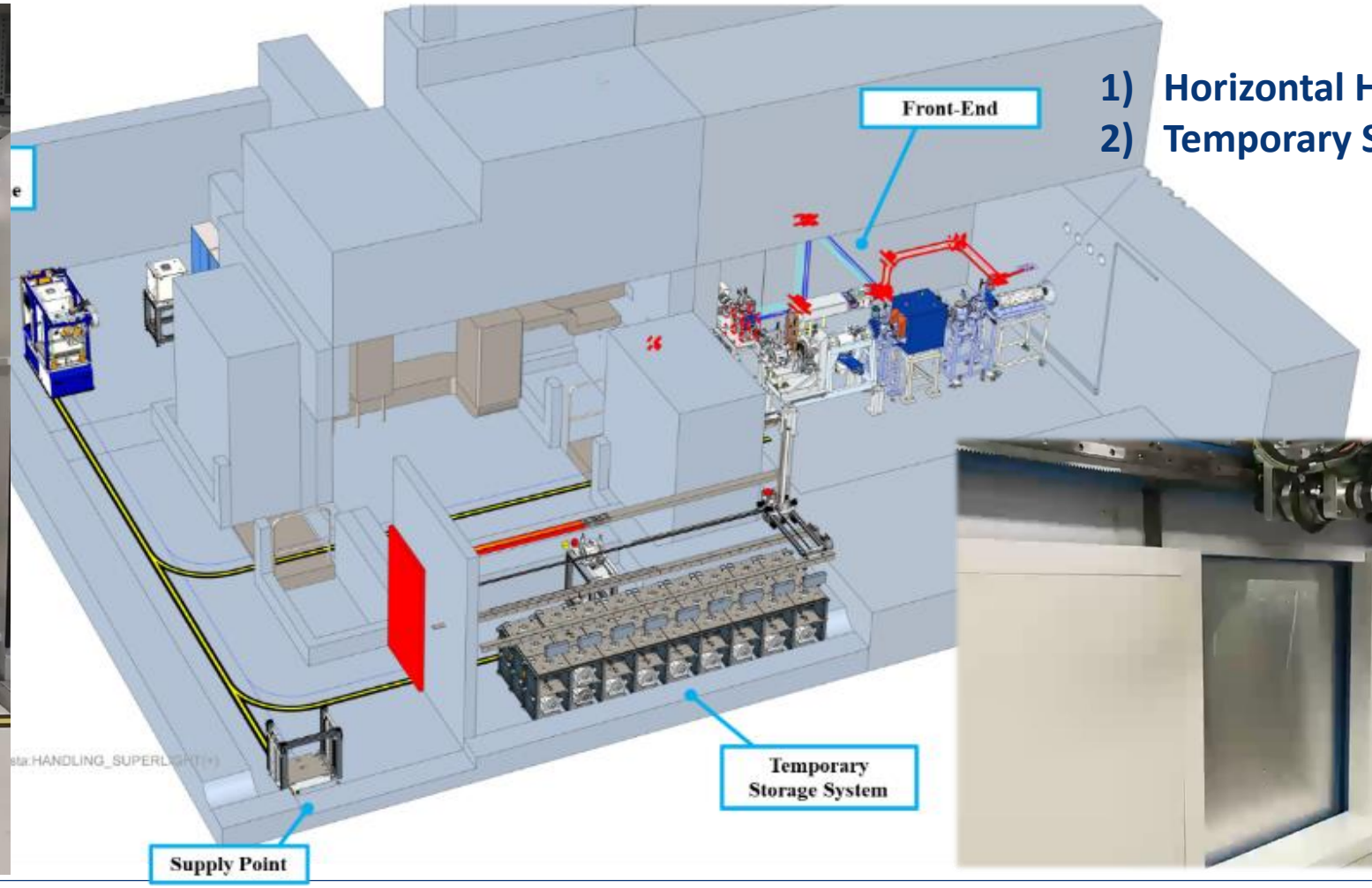


TIS Remote Handling

Remote Handling Framework:

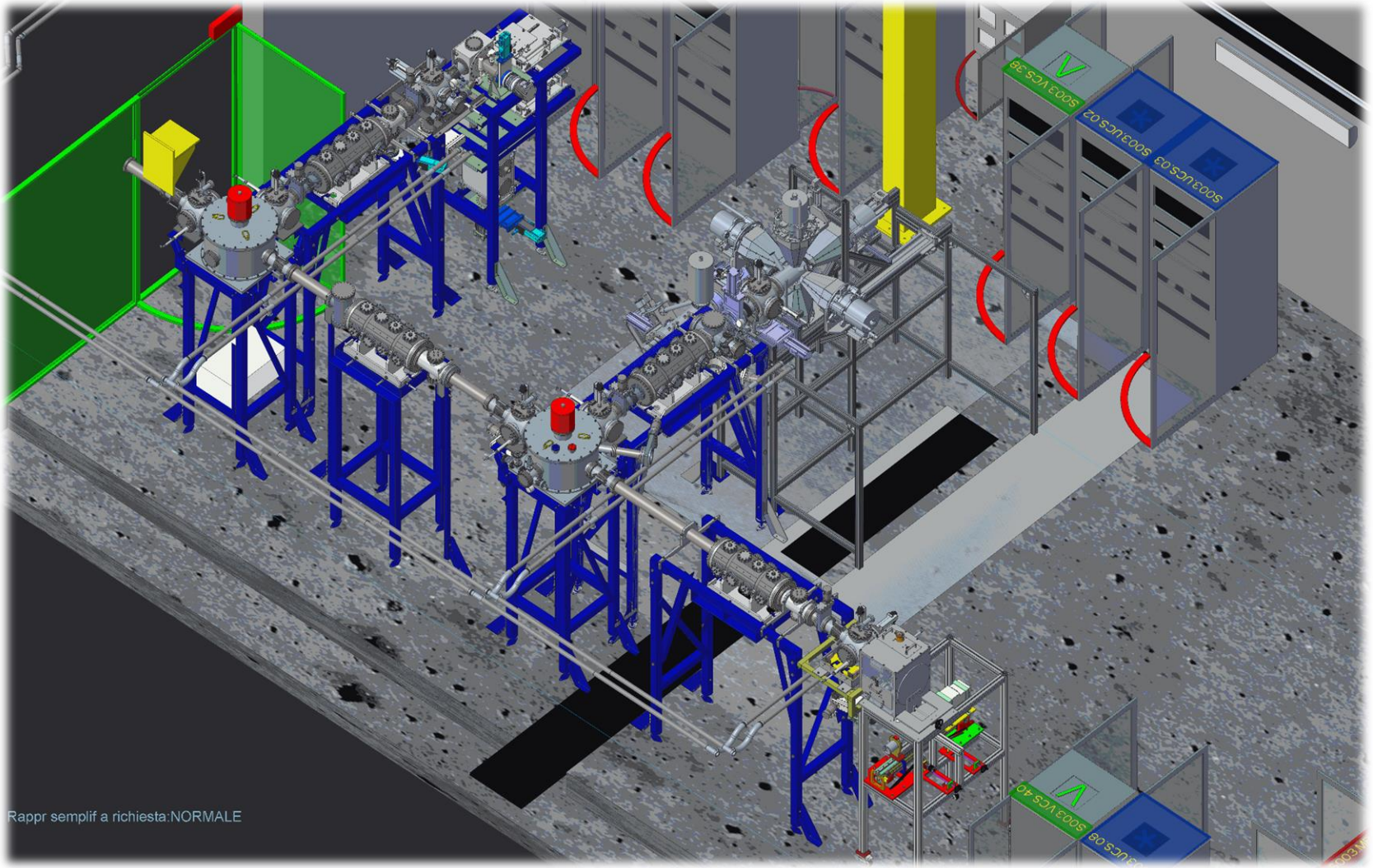
Design focused on TIS unit lifecycle -> Positioning in the FE, Irradiation, Storage -> Ready for Commissioning



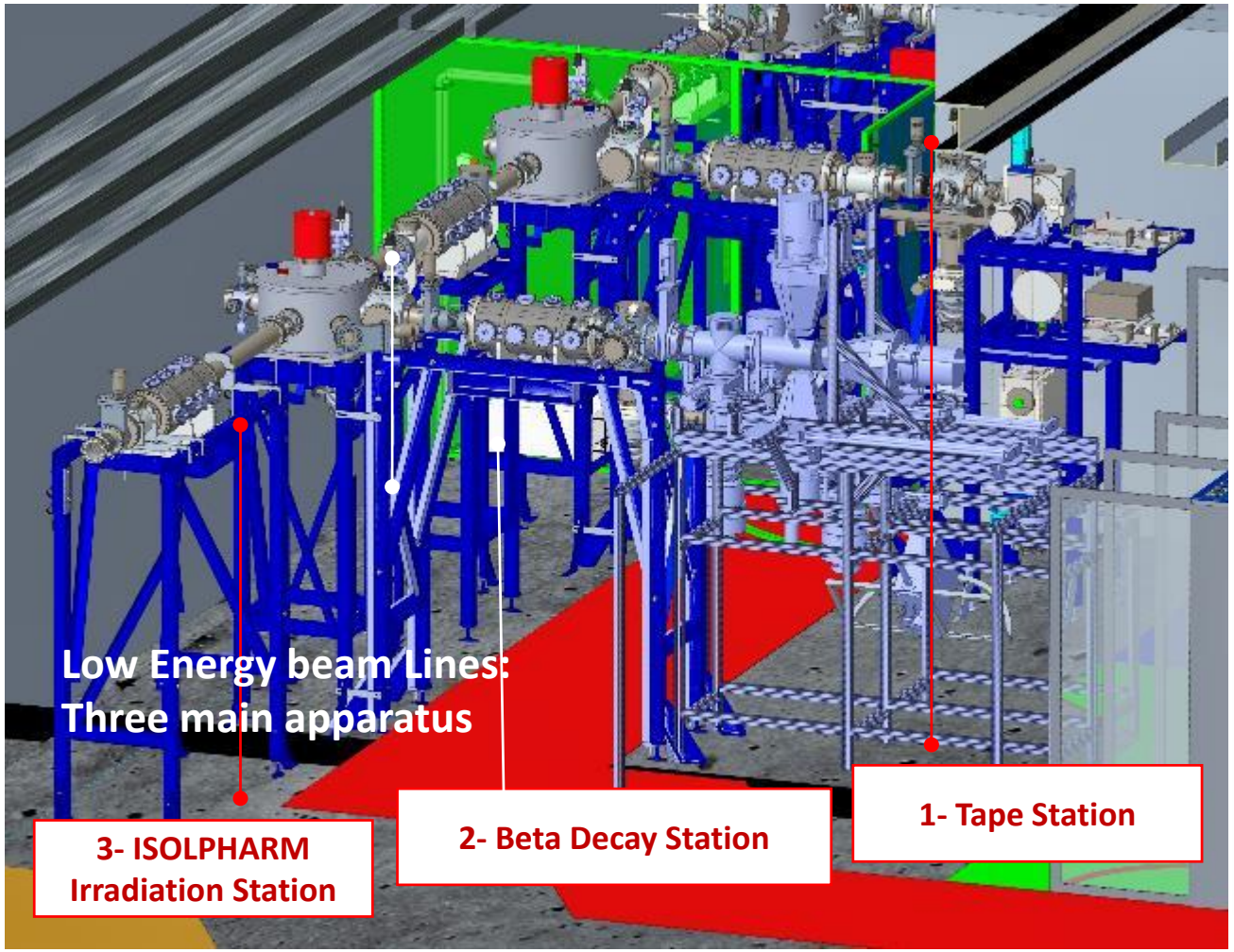


1) **Horizontal Handling Machine**
2) **Temporary Storage (54 unit)**

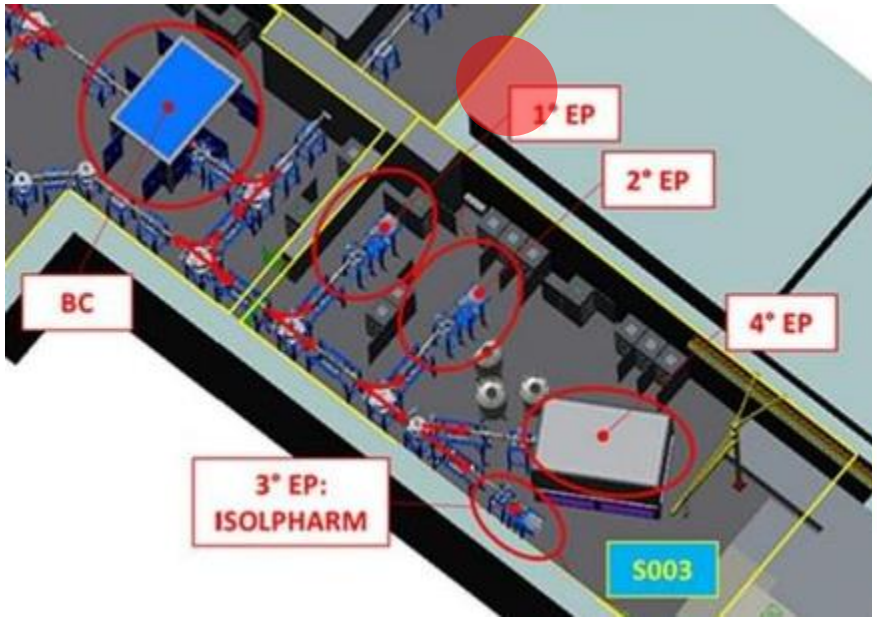
The Low Energy Beam Line

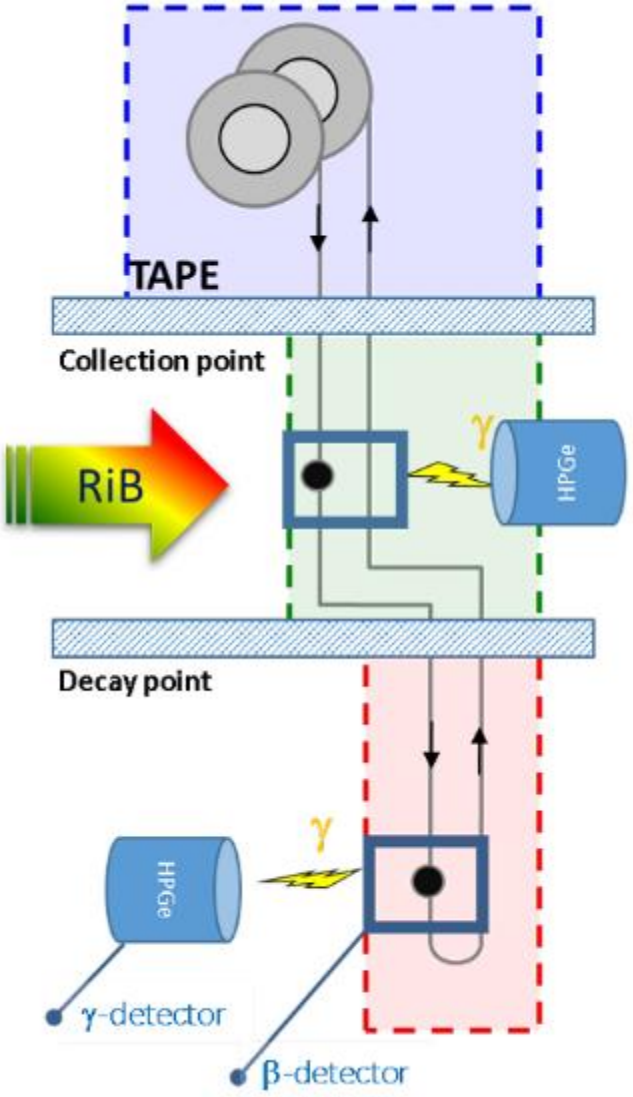


Low Energy Experimental area



1- SPES Tape Station (STS) for beam diagnostic

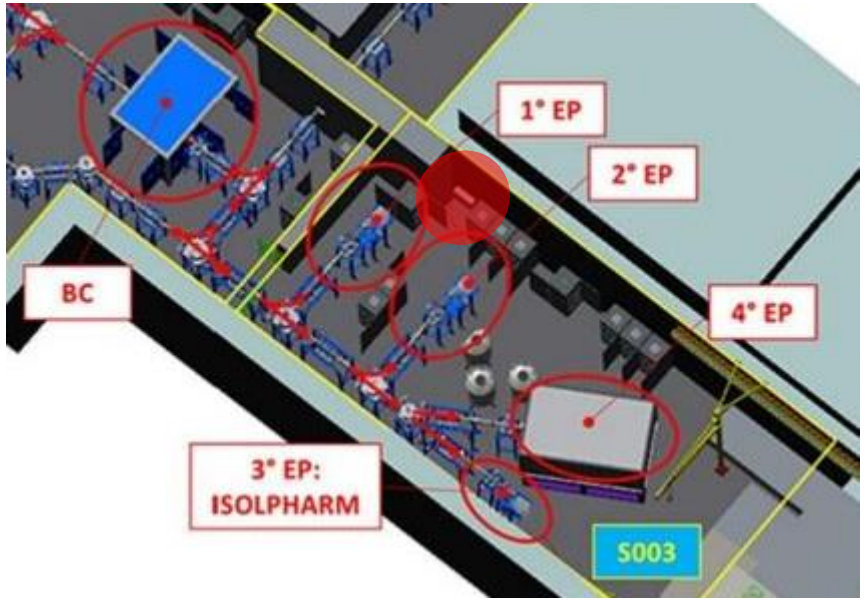


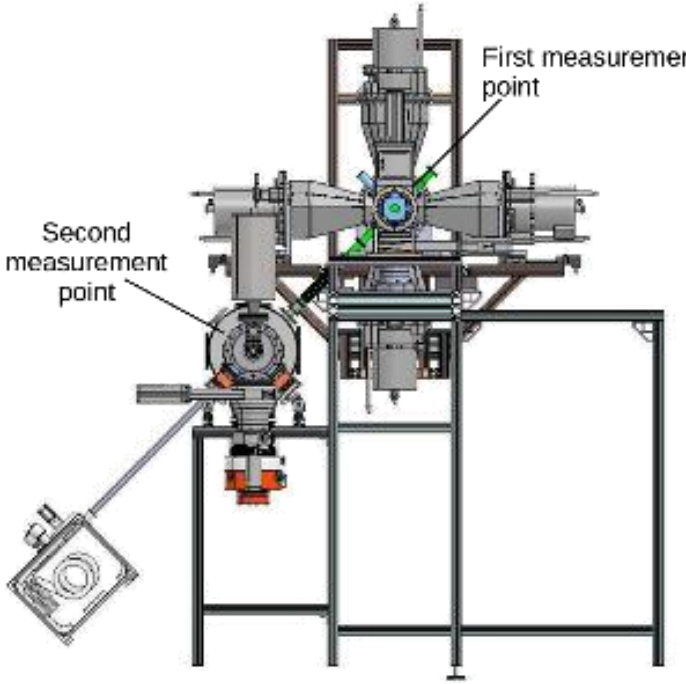


➔ **Monitoring RIB composition and intensity by γ-ray spectroscopy**

- 2 HPGe deterctor
- Coincidence with beta counters
- As a reference for SPES-MED experiment

2 - Beta decay station (INFN-Milano)



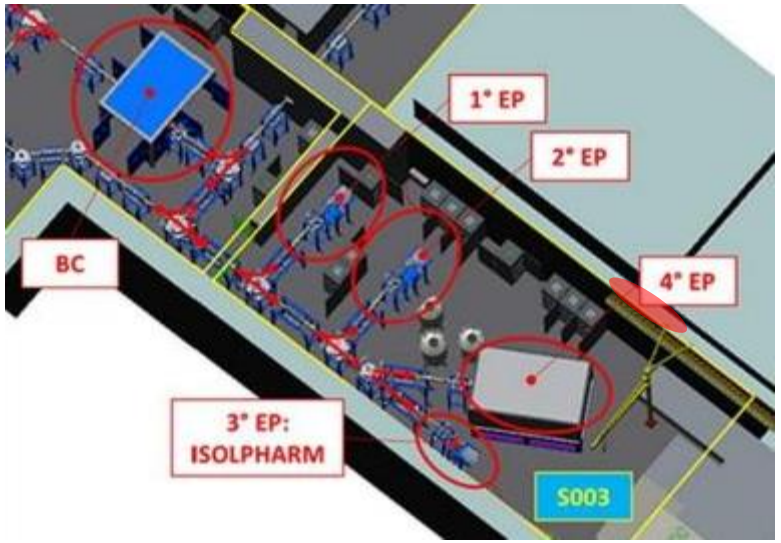


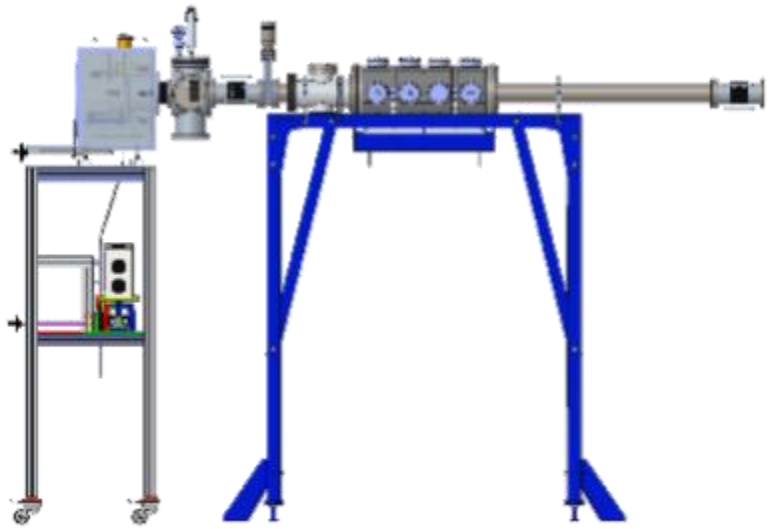
-> Study on the structure of excited states in atomic nuclei

- Gamma detection using 5 HPGe detector (Galileo like)
- Beta tagging by EJ212 plastic scintillator
- Second detection point for Conversion Electron Spectroscopy

By courtesy of Giovanna Benzoni

3 – ISOLPHARM Irradiation Station

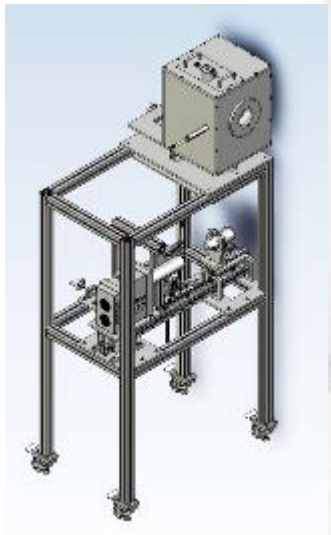




-> Station for Radionuclide Deposition &

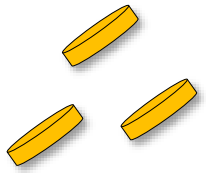
Quality Control

* Beam Collection on secondary target
* Isotopes Detection
* Pellet Handling

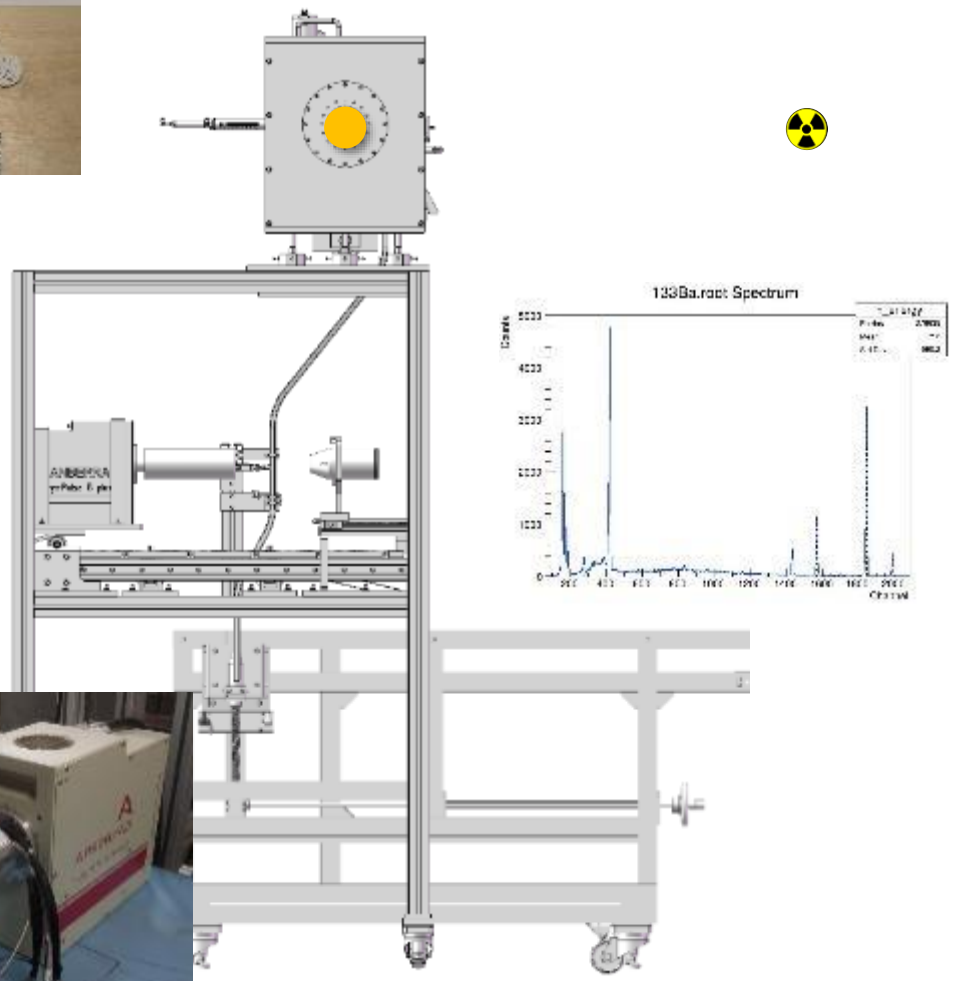


IRIS - Life cycle of the secondary target

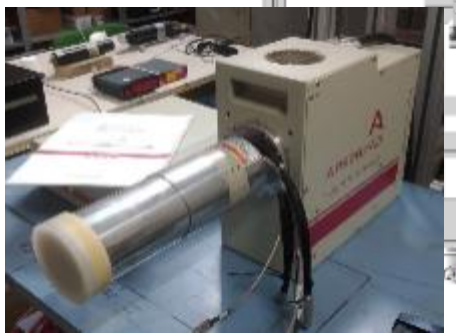
Target development



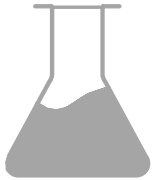
Irradiation and characterization



Transportation



Post-processing



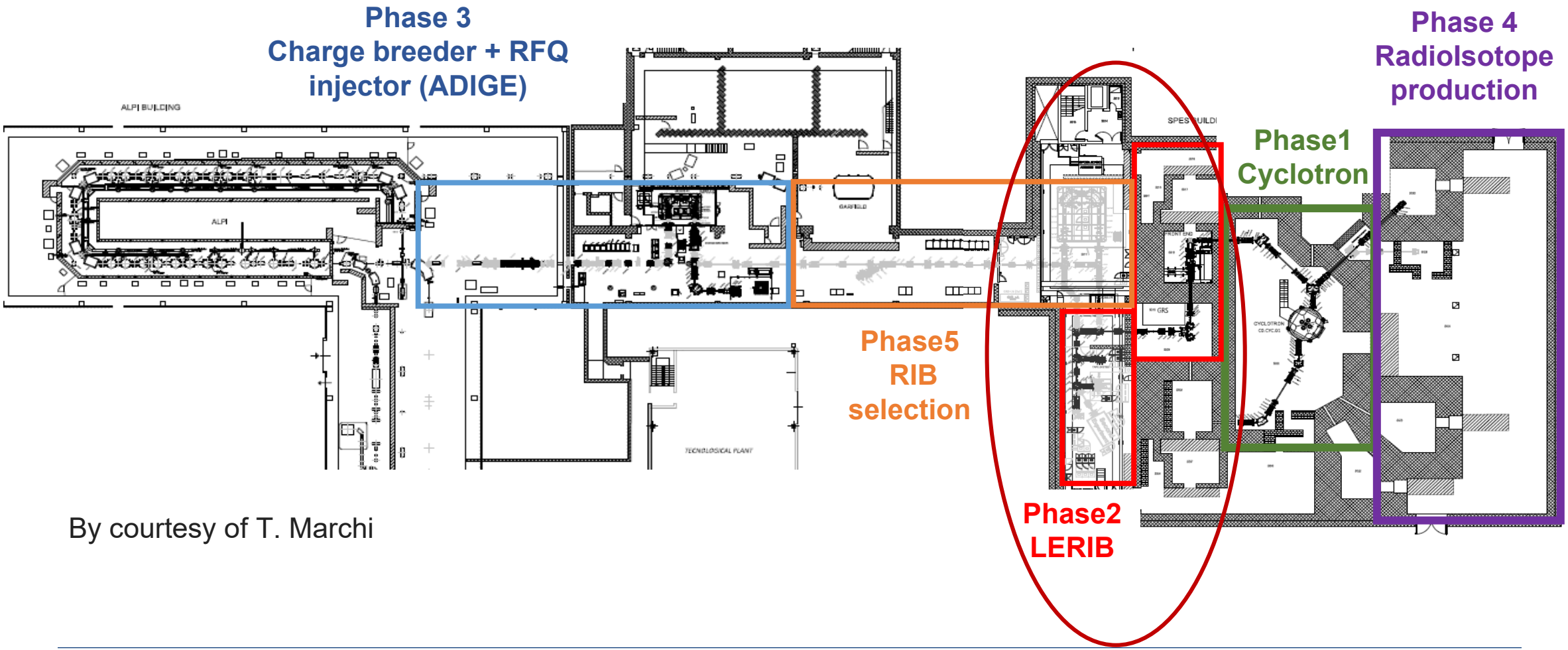
The first ISOL beam

(for Source Commissioning)

SPES Phase 2a - commissioning of the **ISOL machine** - Production of the first Radioactive Ion Beam at LNL

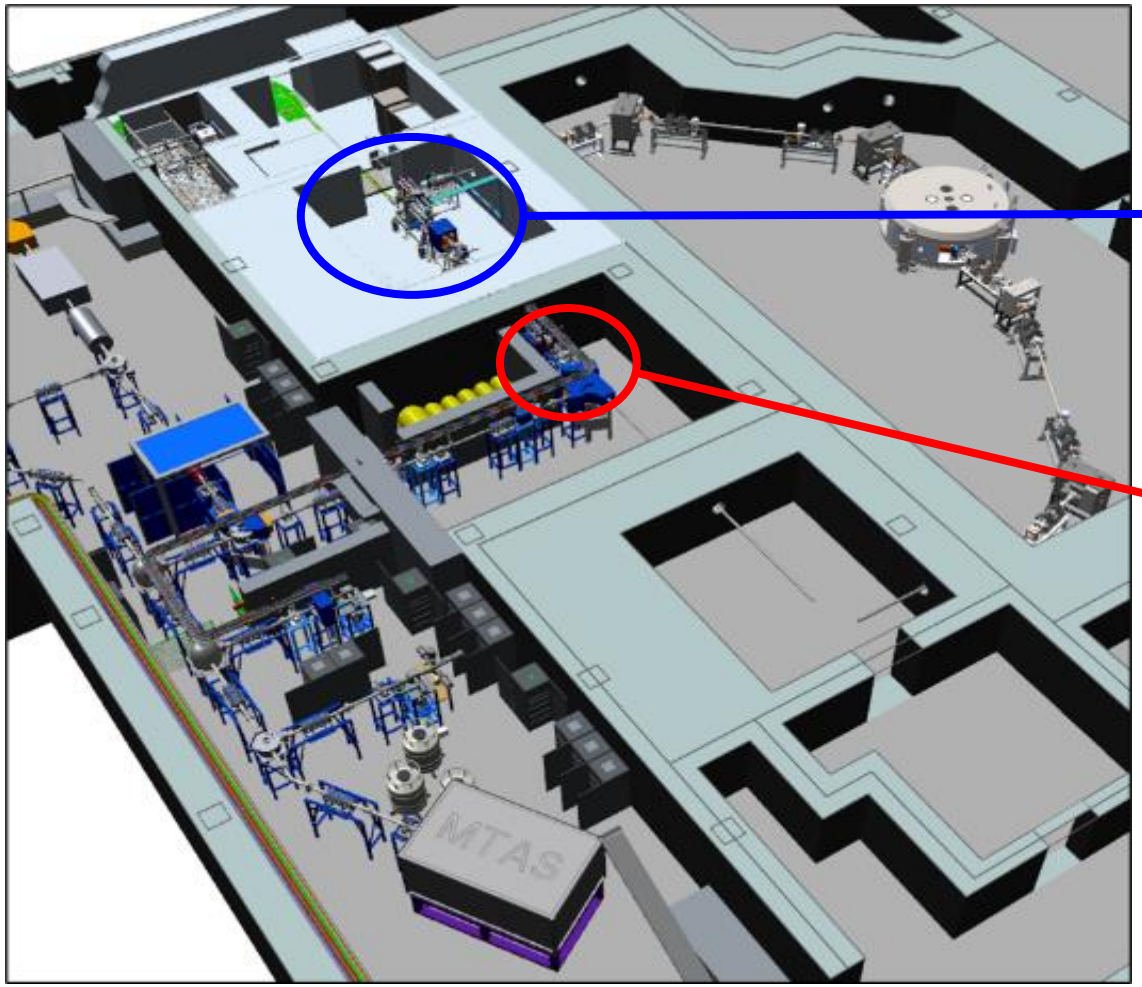
1st RIB @ LNL: 14/11/2024

The SPES commissioning phases



By courtesy of T. Marchi

Experimental Layout



-> Detection point installed just out of the ISOL Source bunker

Beam (pre-operation phase) **:**

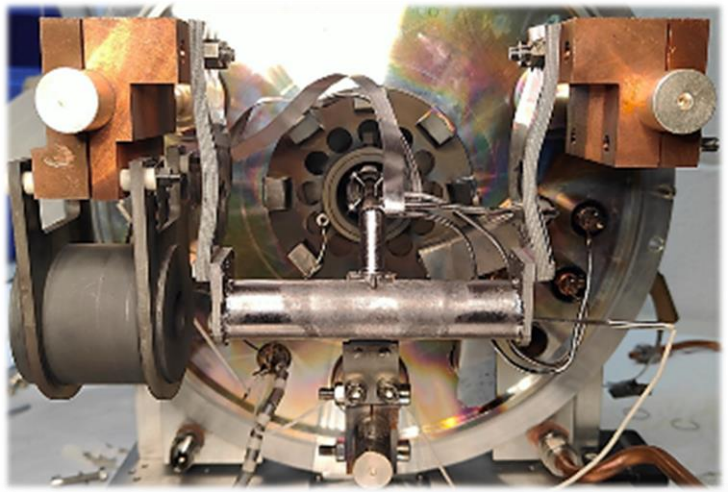
E_{proton}= 40 MeV

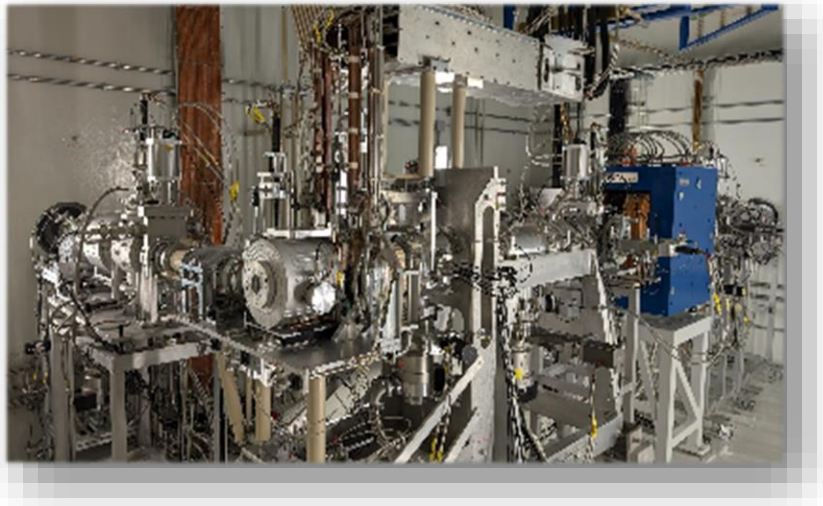
$I_{prorton}$= 100nA

Detectors:

- 2 LaBr Scintillator
- 2 HPGe
- 5 Beta counters EJ212

Experimental settings





proton beam

- 40 MeV
- 100 nA

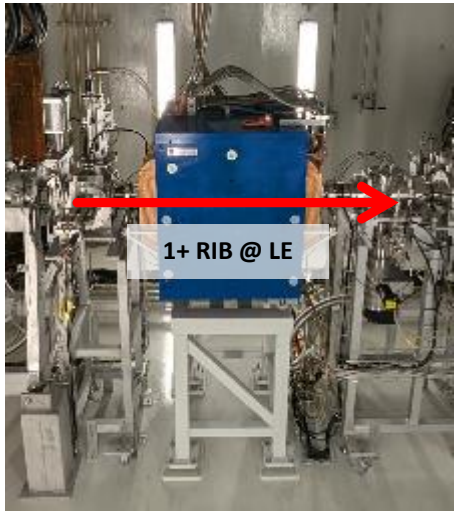
SPES SiC target (1600°C)

13 mm diameter

SPES FEBIAD Ion Source

(30 KeV 1+ Ion Beam)

Wien Filter set for mass 28 (a.m.u.)



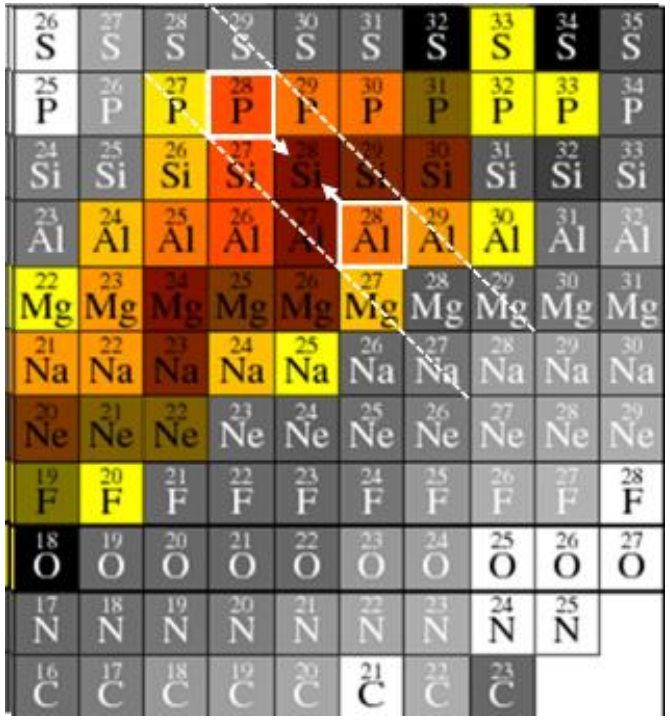
RIB characterization by beta-gamma spectroscopy

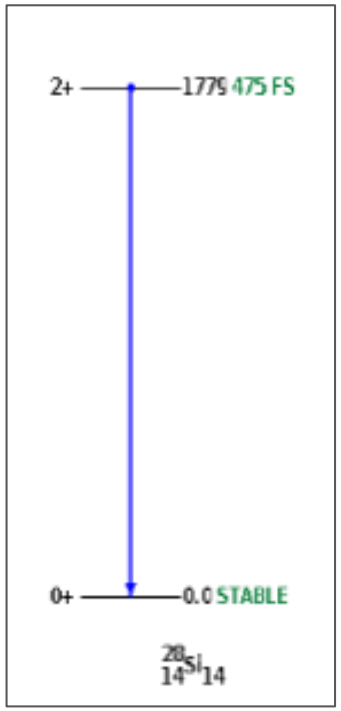
mass 28 composition:

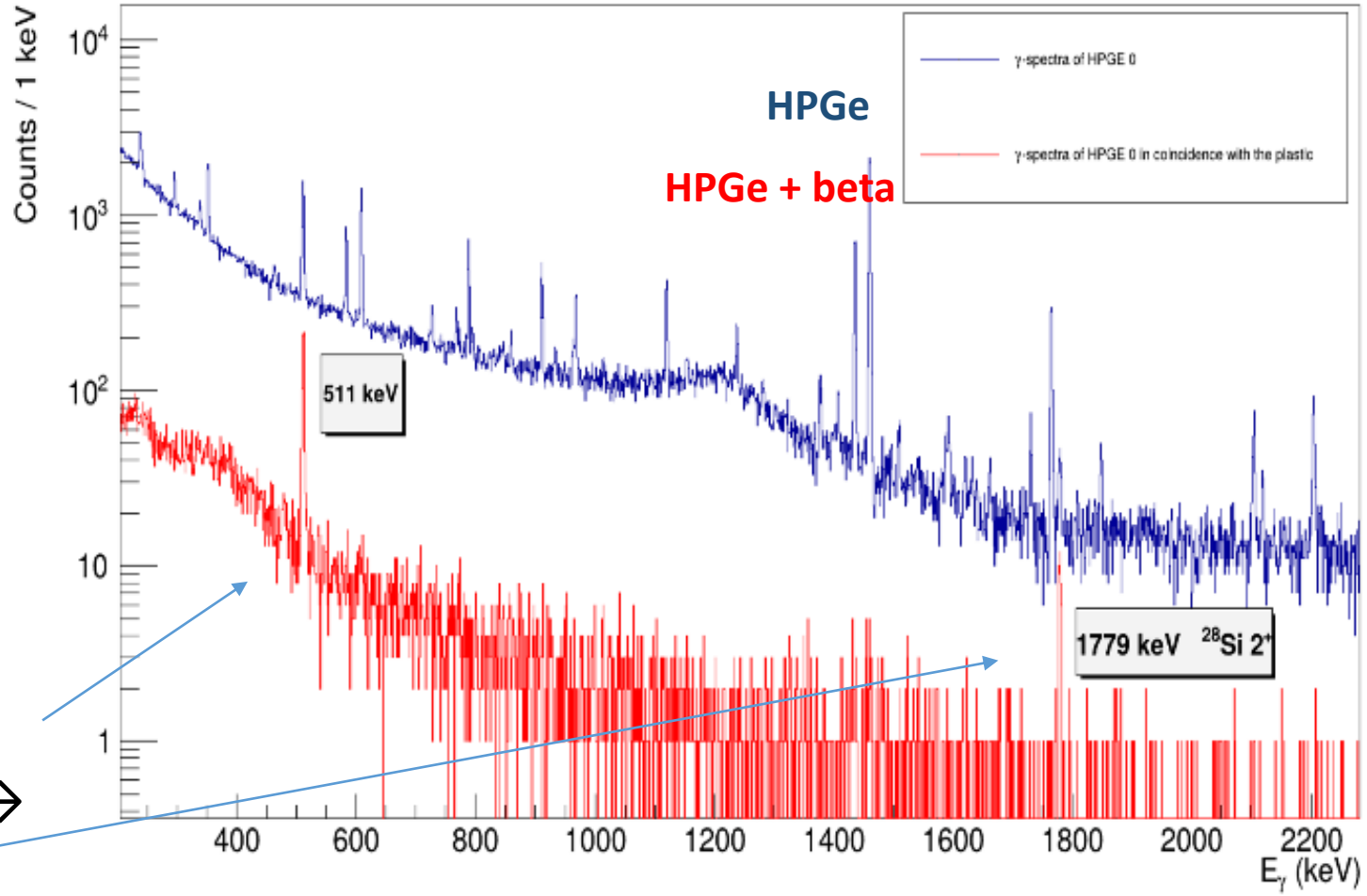
$^{28}P^{1+}$, $^{28}Al^{1+}$ (radioactive)

CO^{1+}, N_2^{1+} (stable)

Gamma in-beam spectrum







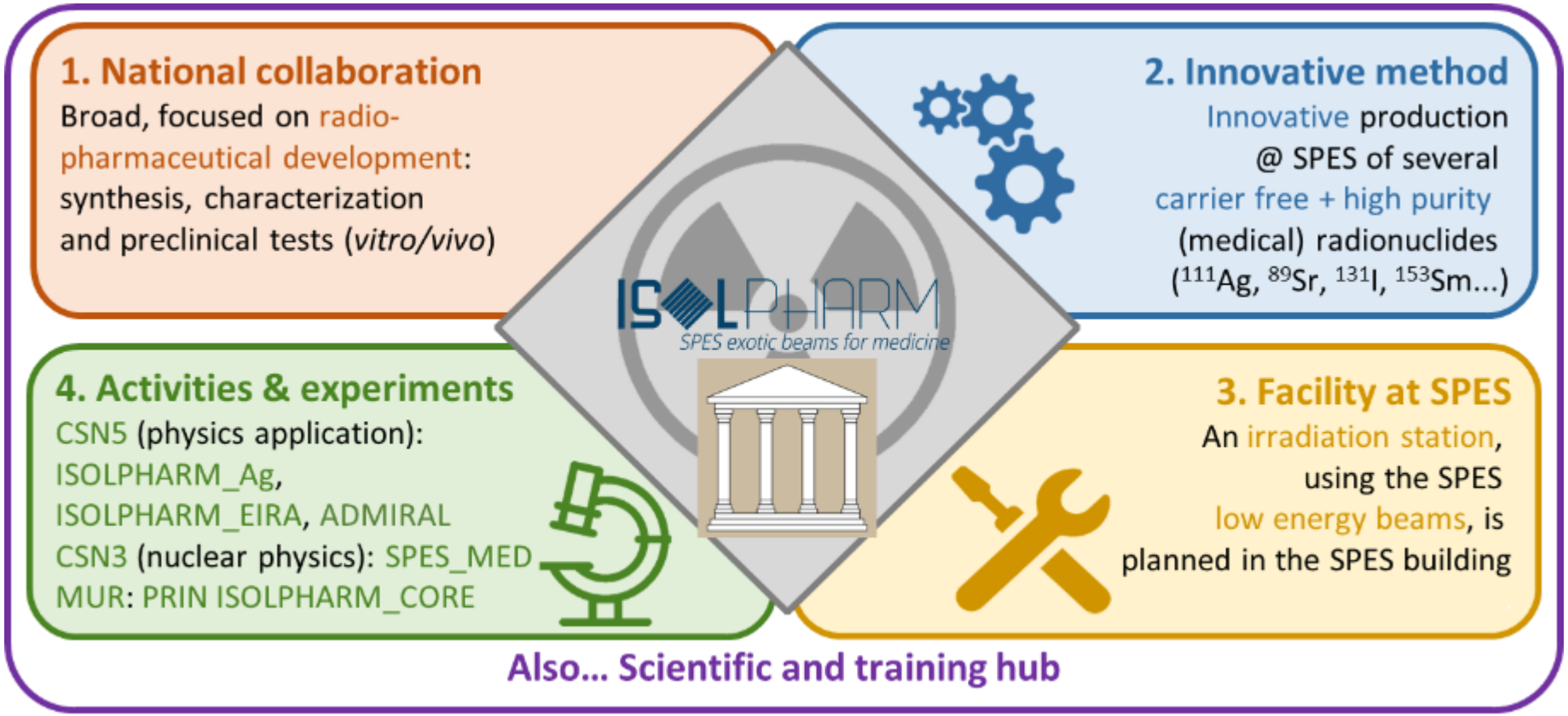
1) annihilation peak at 511 keV → P-28

2) de-excitation of Si-28 from 2^+ to 0^+ → P-28 or Al-28

By Courtesy of A. Gottardo, A. Goasduff

ISOLPHARM

SPES exotic beams for medicine



The ISOLPHARM method

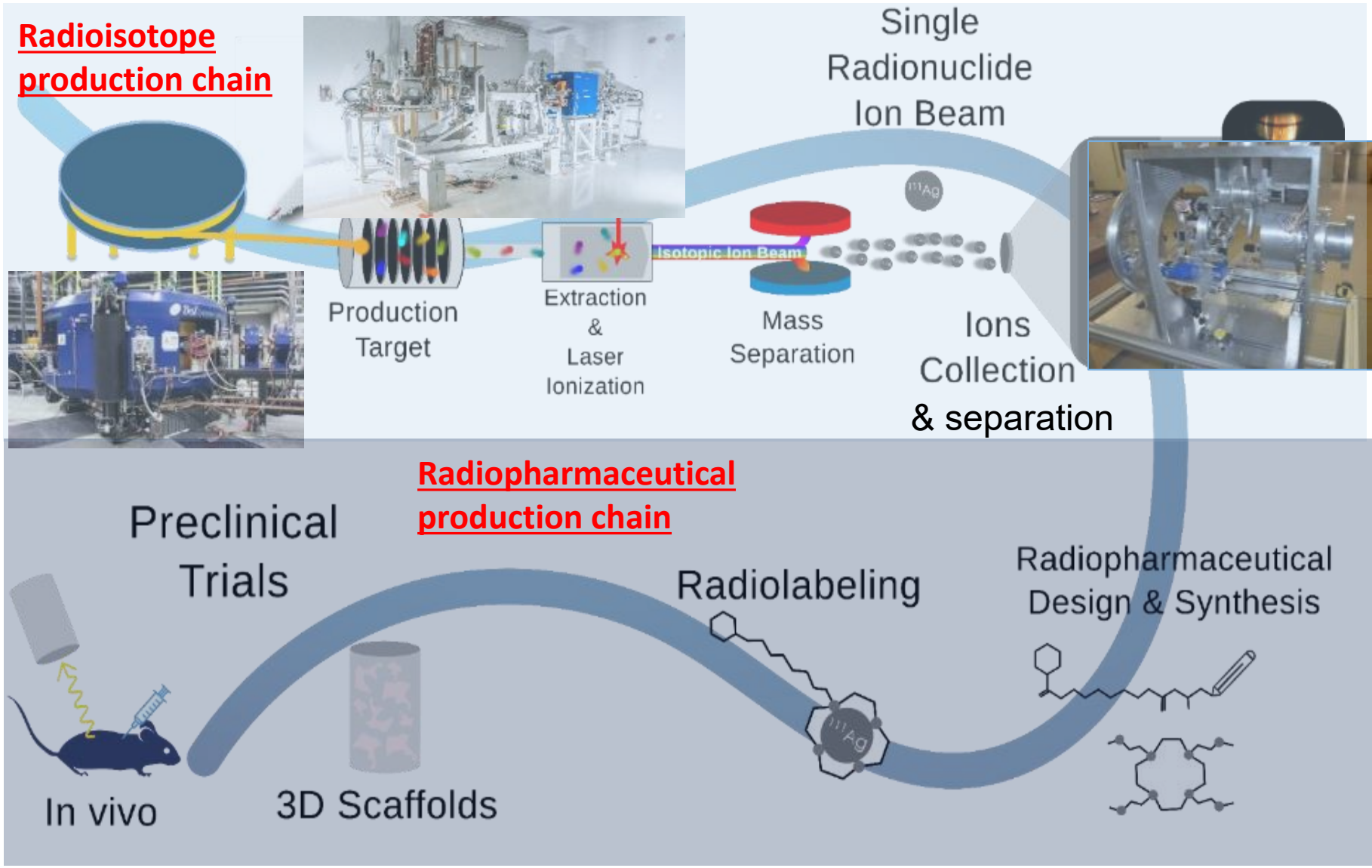
By the ISOL technique is possible to select and trap a _SINGLE RADIO-ISOTOPE- >

CARRIER FREE RADIOISOTOPES

+ high specific activity
+ radionuclidic purity

ISOLPHARM is a Irradiation Station at spes

ISOL PHARM



ISOLPHARM: 11 Years of activity

INFN experiments

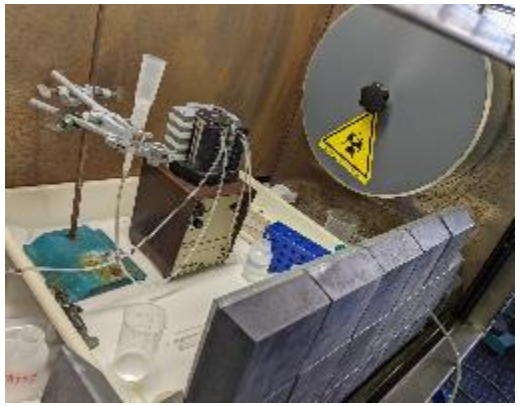
PRIN

2014 - 2017

Interdisciplinary Study Group on production of medical radioisotopes at SPES

2018 - 2019

Simulations and feasibility evaluation of Ag as radiopharmaceutical precursor

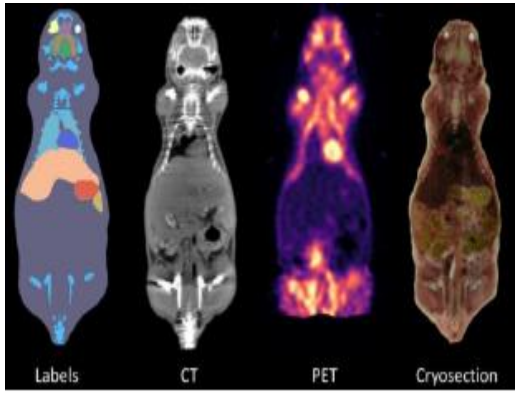


2020 - 2022

First production of ^{111}Ag in reactor and beginning of *in-vitro* and *in-vivo* testing

2023 - 2025

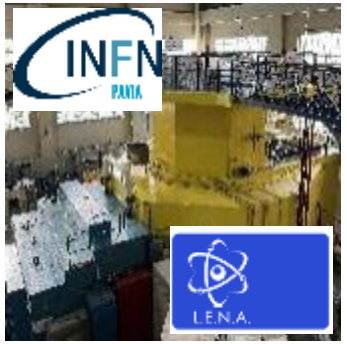
Providing new tools for preclinical trials on 3D scaffolds



2024 - 2025

Follows the technological aspect for the radionuclide production

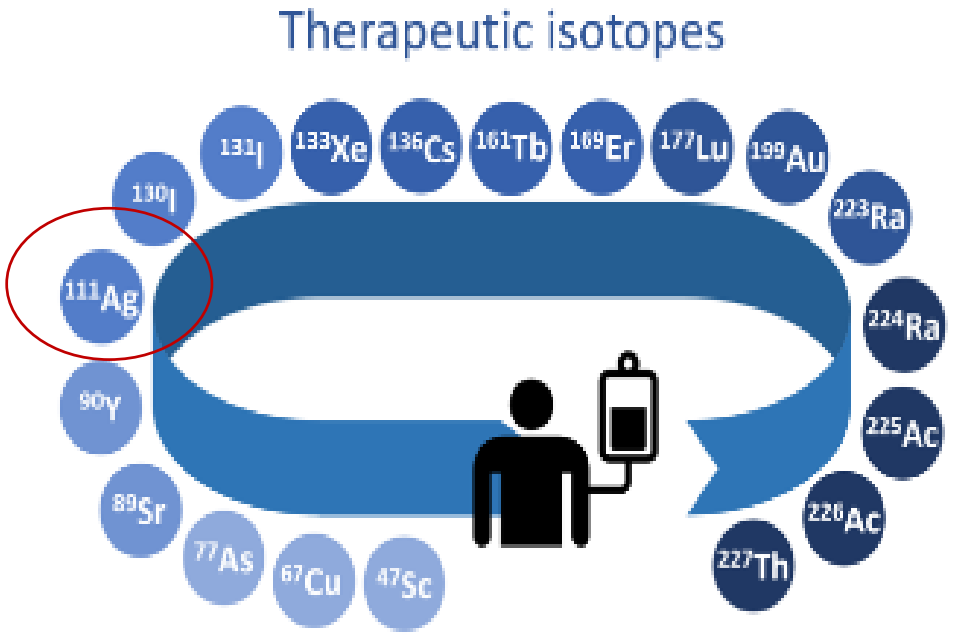
Collaboration infrastructures

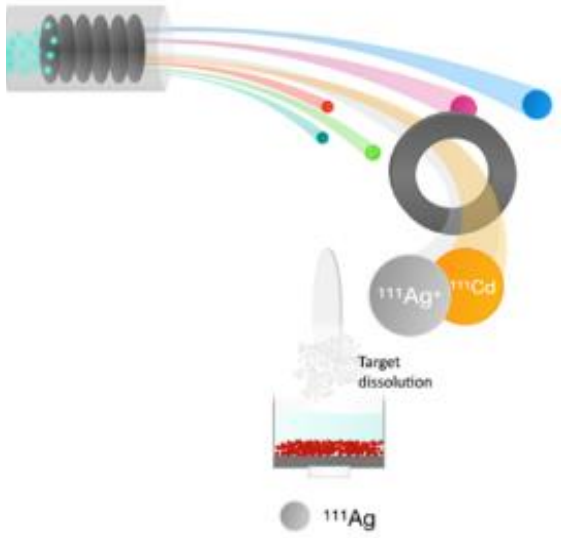


Radionuclides of interest: Main RIB available at SPES

	Isotope	Half-life	In-target production [nuclide/s]	Time to collect 1 MBq [h]	Activity for 1 day collection at EOB [MBq]	Activity for 1 day collection 1 day after EOB [MBq]	Application Ready in the market
Silicon carbide (SiC) target	^{24}Na	15.0 h	7.8e7	0.12	126	42	
	^{28}Mg	20.9 h	8.8e6	n/a	0.27	0.12	
	^{7}Be	53.2 d	9.5e10	0.13	183	181	
Titanium carbide (TiC) target	^{43}K	22.3 h	9.8e7	0.09	181	86	
	^{51}Cr	27.7 d	3.9e7	6.9	0.348	0.345	
	^{47}Sc	3.35 d	1.1e11	0.05	473	385	
Uranium carbide (UCx) target	**^{111}Ag**	**7.45 d**	**4.9e8**	**0.11**	**1635**	**1490**	NEW
	^{131}I	8.03 d	4.6e10	0.05	2078	1906	
	^{153}Sm	46.3 h	6.7e8	0.06	944	659	
	^{89}Sr	50.57 d	1.6e9	0.28	302	298	

Radiopharmaceutical radiolabeled with ^{111}Ag





→No radiopharmaceuticals radiolabeled with 111Silver in the market.

→ Silver-111 can be produced @ SPES with high purity & with high production rate

→ No Isobaric contamination in the secondary target (also with LASER off)!

→ ^{111}Ag exhibits possible 'theranostic' properties similar to ^{177}Lu which was recently approved by FDA.

→ ^{111}Ag has dosimetric behavior equal to ^{186}Re, which was recently studied in Phase II trials

^{111}Ag properties

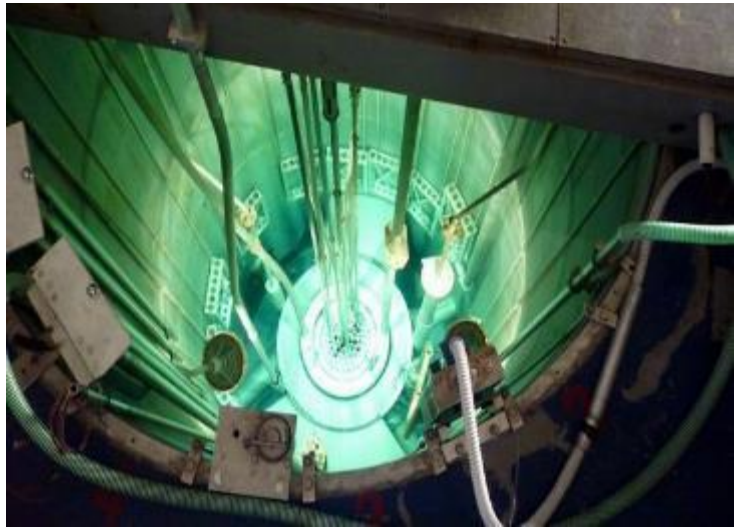
- **β^- emitter** (average energy **360 keV**)
- Good half-life (**7.45 days**)
- Average tissue penetration (**1.8 mm**)
- Medium energy *γ* rays -> SPECT candidate

111 Isobaric chain	Half-Life $T_{½}$	Decay	Target Yield
Cadmium-111	Stable		Low yield production
Silver-111	7.45 days	β^-	Good yield production
Palladium-111	23.4 min	β^-	Bad release, short $T_{1/2}$
Rhodium-111	11 sec.	β^-	No release, very short $T_{1/2}$

In vivo experiment with ^{111}Ag (april '24)

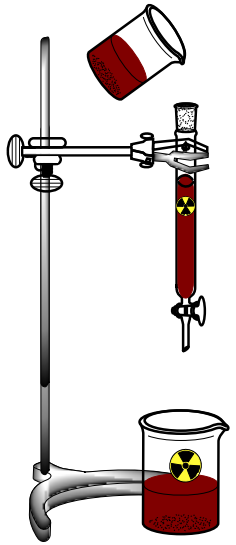
Routine production of Ag-111 at the LENA facilities, purification and quality control

1) 150 mg of ^{110}Pd
irradiated in the TRIGA reactor

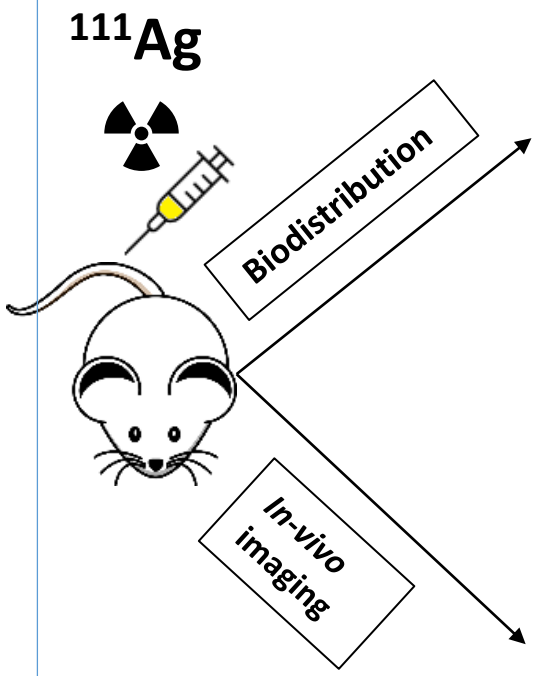


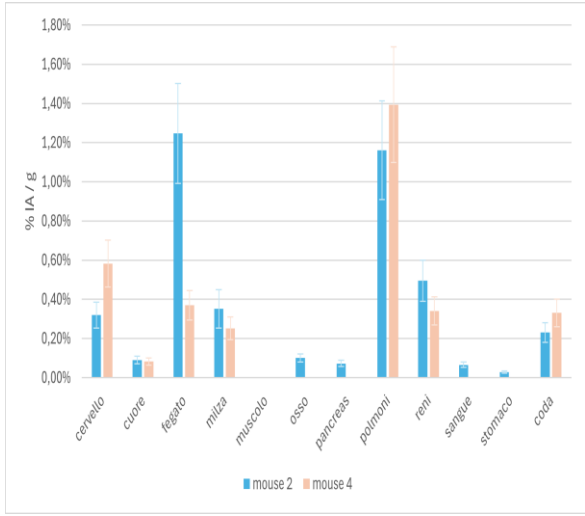
2) ^{110}Pd vs. ^{111}Ag
Separation at L.E.N.A.

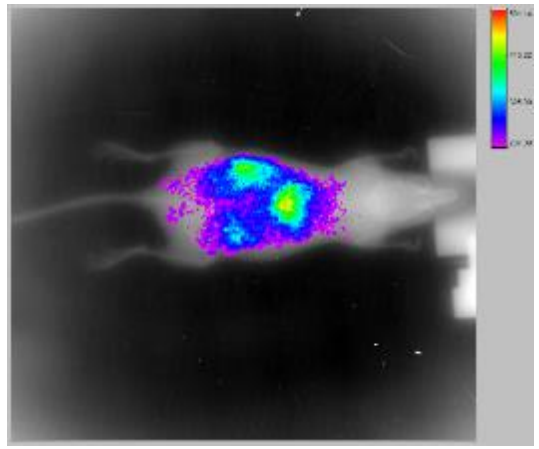
^{111}Ag ^{109}Pd contained
inside cold **^{110}Pd** target



3) **88 MBq** of **^{111}Ag**
ship to CAPIR Lab







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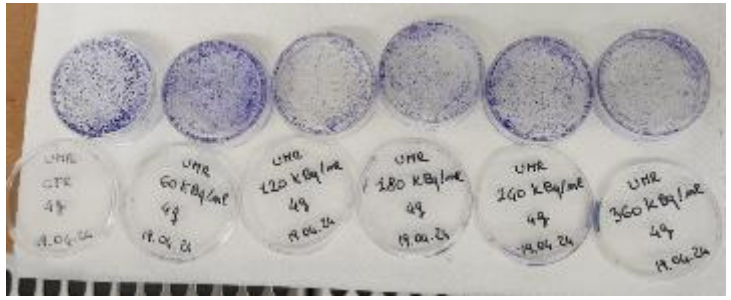
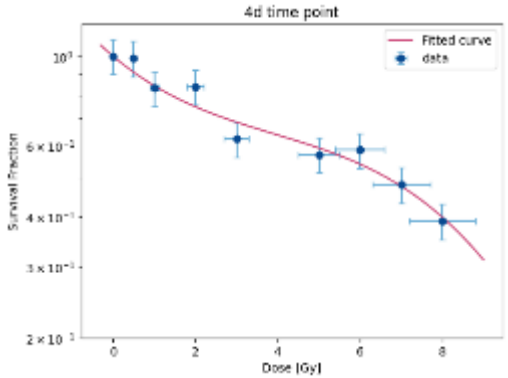
Other experiments with ^{111}Ag performed in 2024

1. ***In vitro* test - Cell survival**
   @ UniPv (**WP4**)

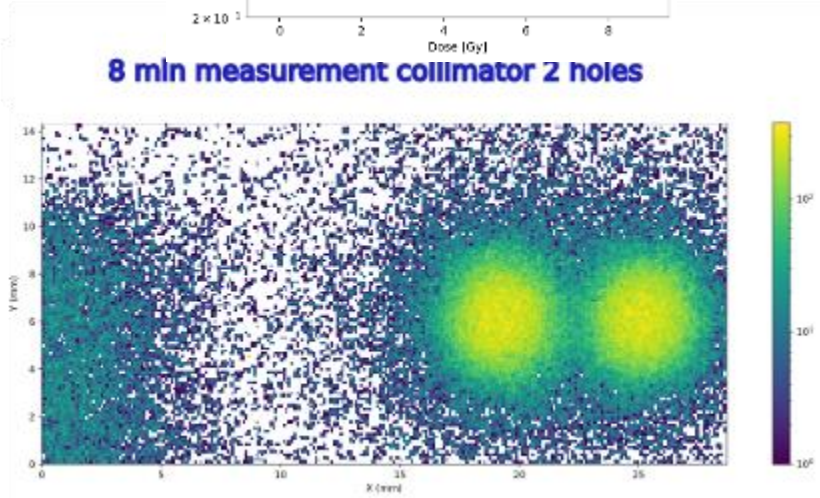
   20 MBq





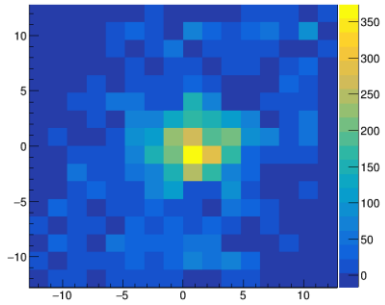
2. **Beta Ag detector test**
   @ L.E.N.A. (**WP2**)

   3 MBq



1. **Gamma Ag detector test**
   @ L.E.N.A. (WP3)

   1,6 MBq



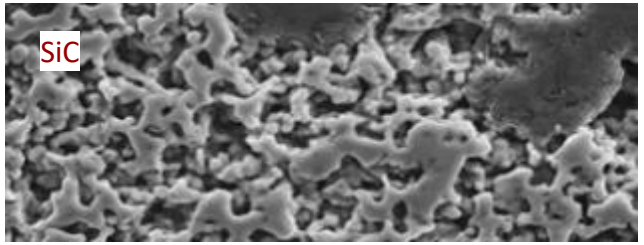
Conclusions

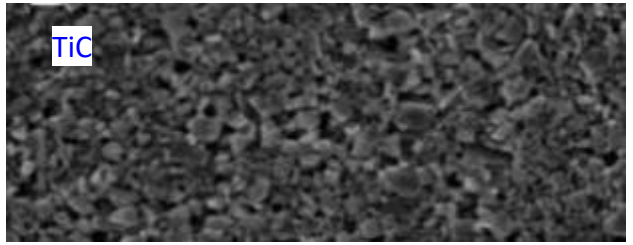
Low Energy RIBS at SPES: Future scenario

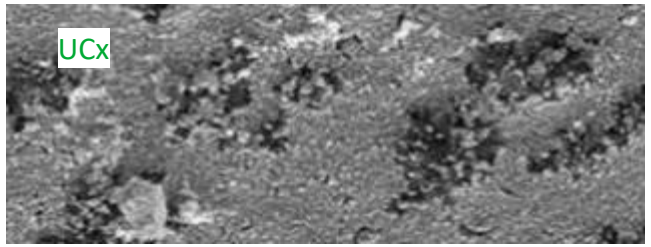
2025: ^{24}**Na** from SiC target (commissioning LIS)

2026: ^{7}**Be** from SiC target (low activity expected)

2027-28: ^{51}**Cr** (low activity expected), ^{43}**K** from TiC target + ^{111}**Ag +....** from UC_x







Yield measurement the radionuclides-radiotracers & study for possible applications in:

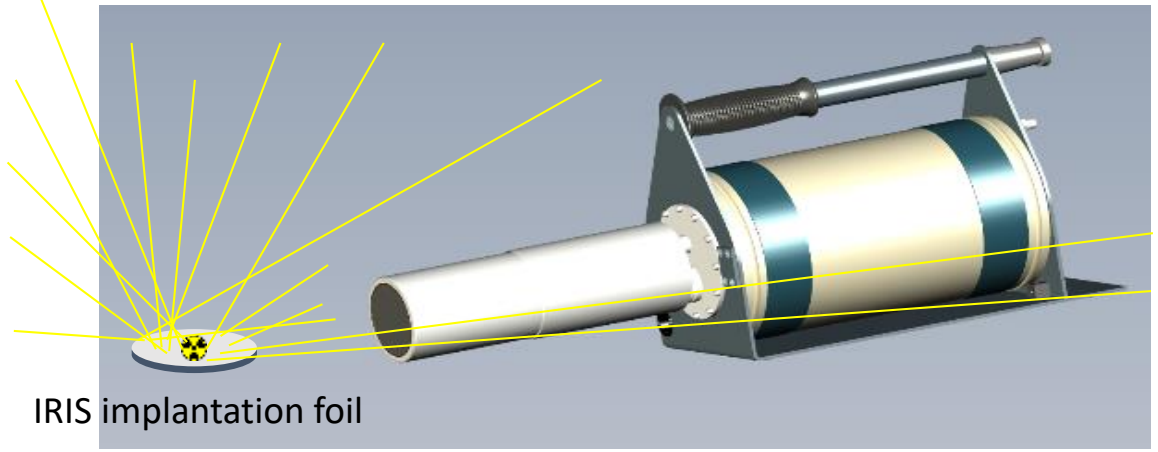
- medicine -> ISOLPHARM
- environment
- industry.

Activities with SPES radioisotopes at LNL

- In the Low Energy Experimental Room, it will be possible to start experiments with RIB for **Nuclear physics** and **Medical applications**

*** SPES_MED experiment**:

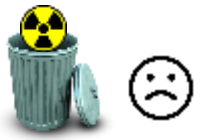
Nuclear Yield measurements of RIB produced by a Carbide target (just started at CSN3)



IRIS implantation foil

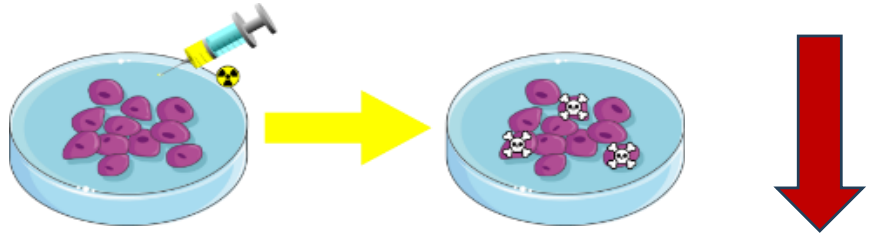
After measurements, either:

- dispose of the radionuclide
- reuse it for applications ?



*** ISOLPHARM – ADMIRAL experiment:**

Radiobiology, Detector Technology and Nuclear Medicine study whit ^{111}Ag produced by TRIGA reactor



Opportunity to start test of Radiobiology with new radiotracers coming from SiC & TiC target

Radiobiology is a field of sciences that involves **study of the effects of ionizing radiation on living things**, in particular health effects of radiation.

Collaboration network

Trento Institute for Fundamental Physics and Applications

UNIVERSITÀ DEGLI STUDI DI PADOVA

UNIVERSITÀ DEGLI STUDI DI BRESCIA

UNIVERSITÀ DI PAVIA

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

UNIVERSITÀ DI TRENTO

UNIVERSITÀ DI SIENA 1240

UNIVERSITÀ degli STUDI di CATANIA

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Dipartimento di Fisica e Astronomia Galileo Galilei

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

THANKS FOR YOUR ATTENTION!

The presented activities are the result of the work of the whole SPES-ISOL & ISOLPHARM teams