Workshop

Digital LEAPS - Androids for remote access

Remote handling of radioactive targets at the SPES facility

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23rd May 2023

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- ISOL technique
- The SPES project
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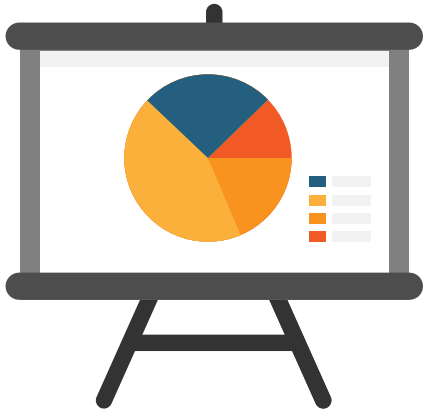
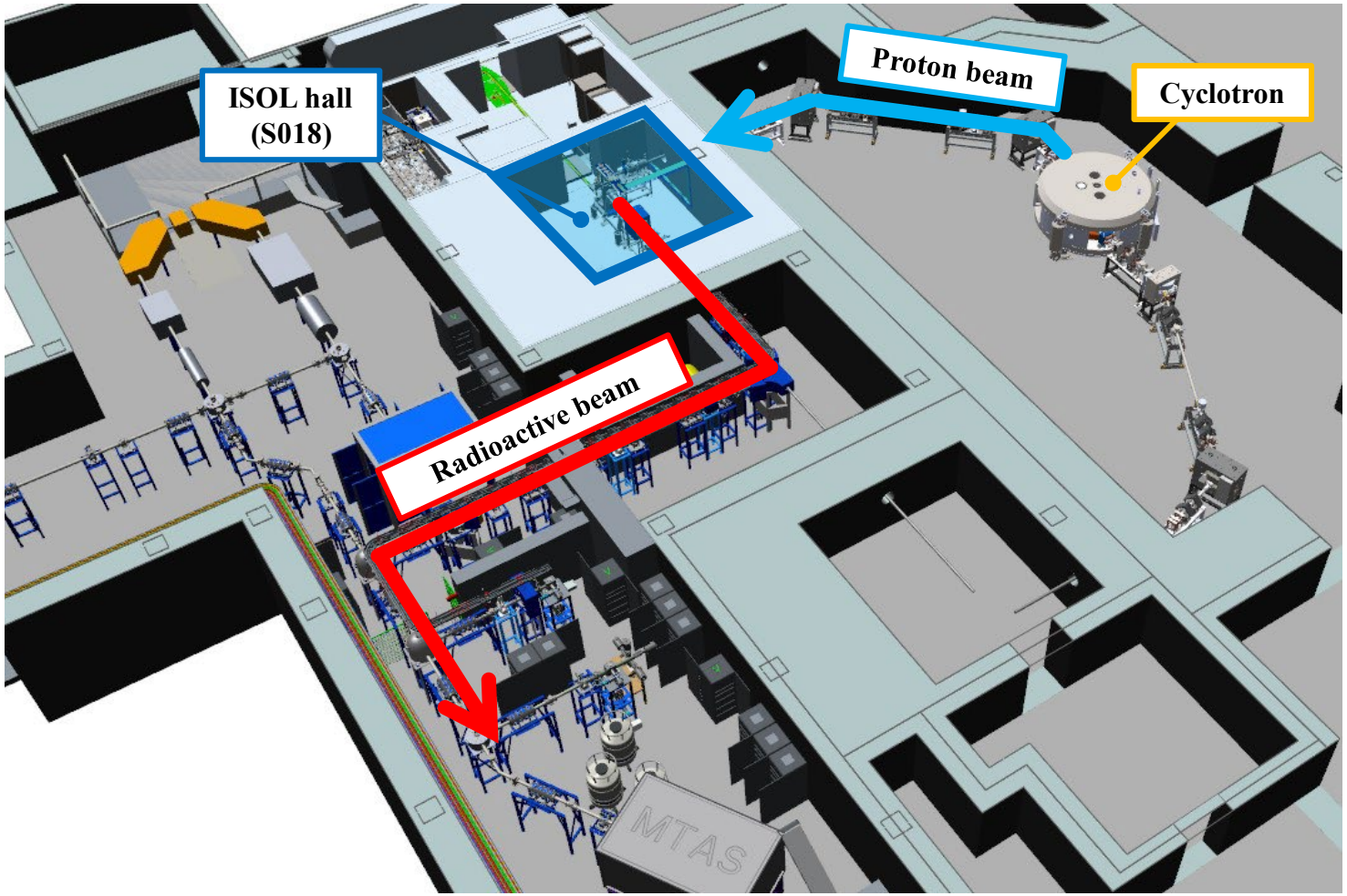
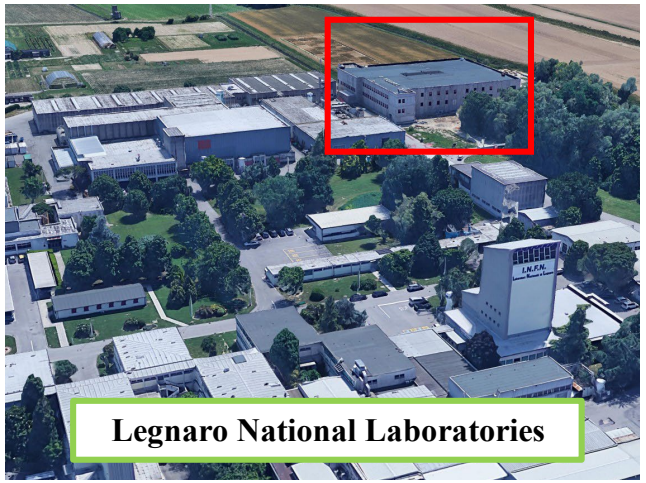


The SPES facility at INFN-LNL





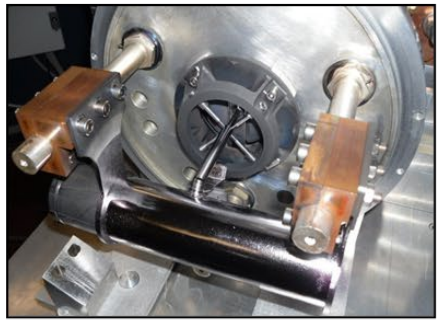
The Isotope Separation On-Line (ISOL) technique

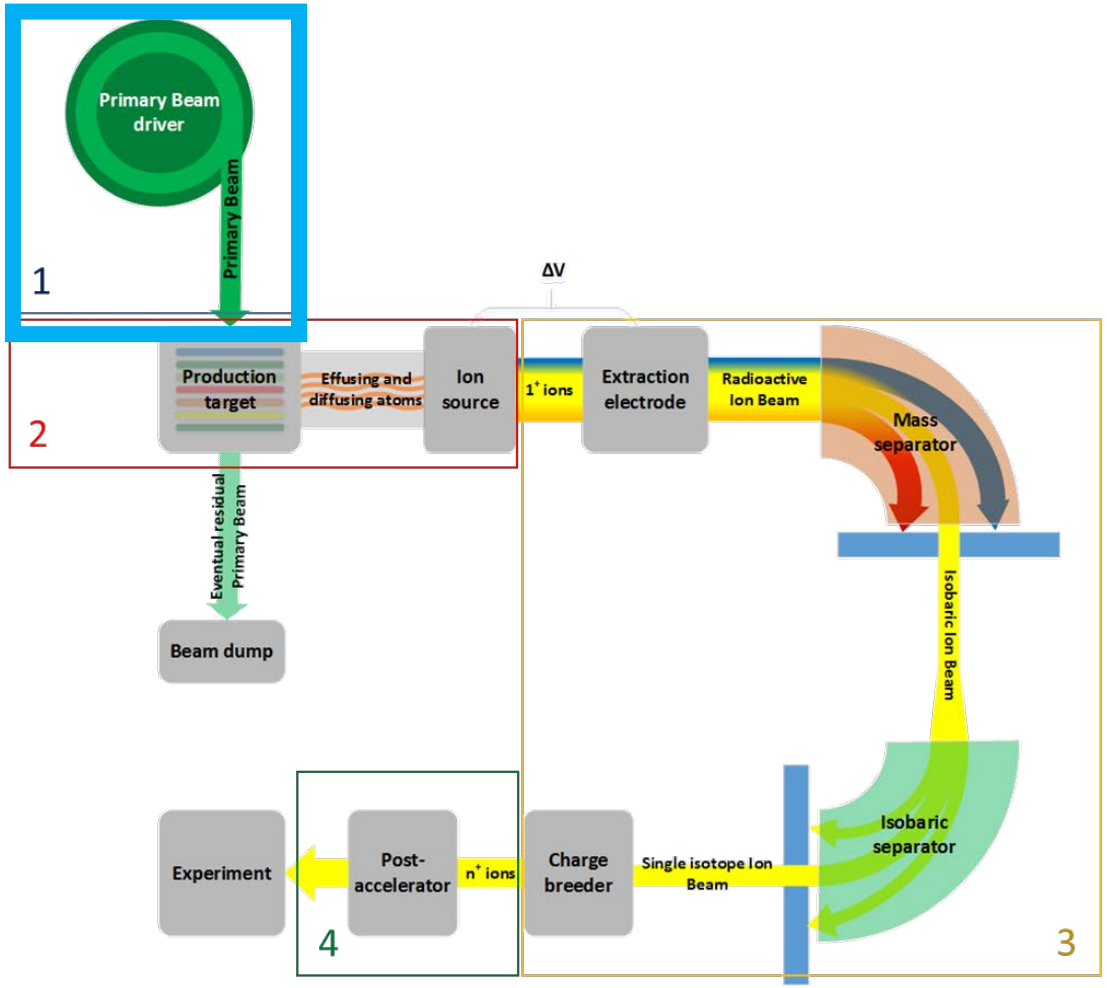
Process

1 - Driver

70 MeV commercial cyclotron

2 – Target-Ion Source unit





3- RIB manipulation

- Mass Separator (WF)
- Beam Cooler
- HRMS
- ECR Charge Breeder
- RFQ

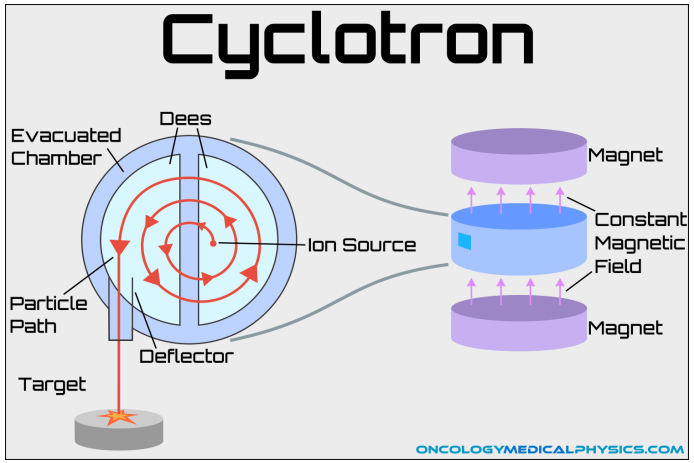
4 - Post Accelerator:

ALPI existing complex

The primary driver

The SPES Cyclotron

- Status: commissioned
- E = 70 MeV
- I = 750 μA



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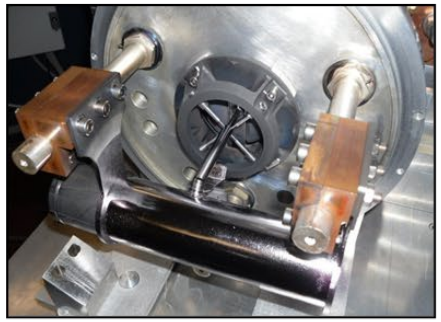
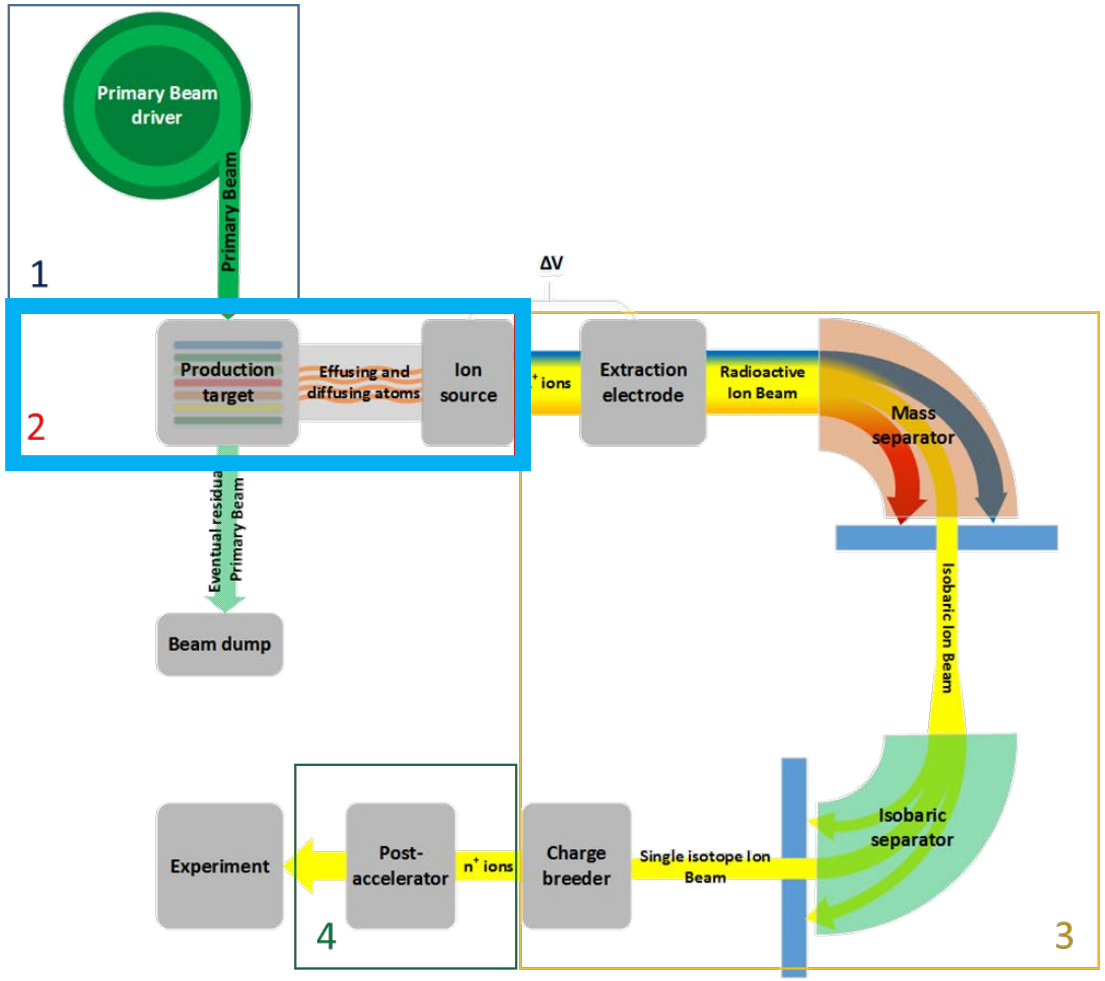




3- RIB manipulation

- Mass Separator (WF)
- Beam Cooler
- HRMS
- ECR Charge Breeder
- RFQ

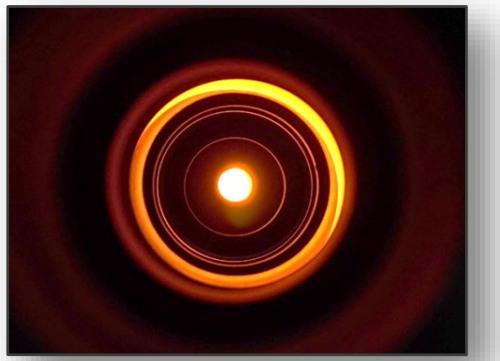
4 - Post Accelerator:

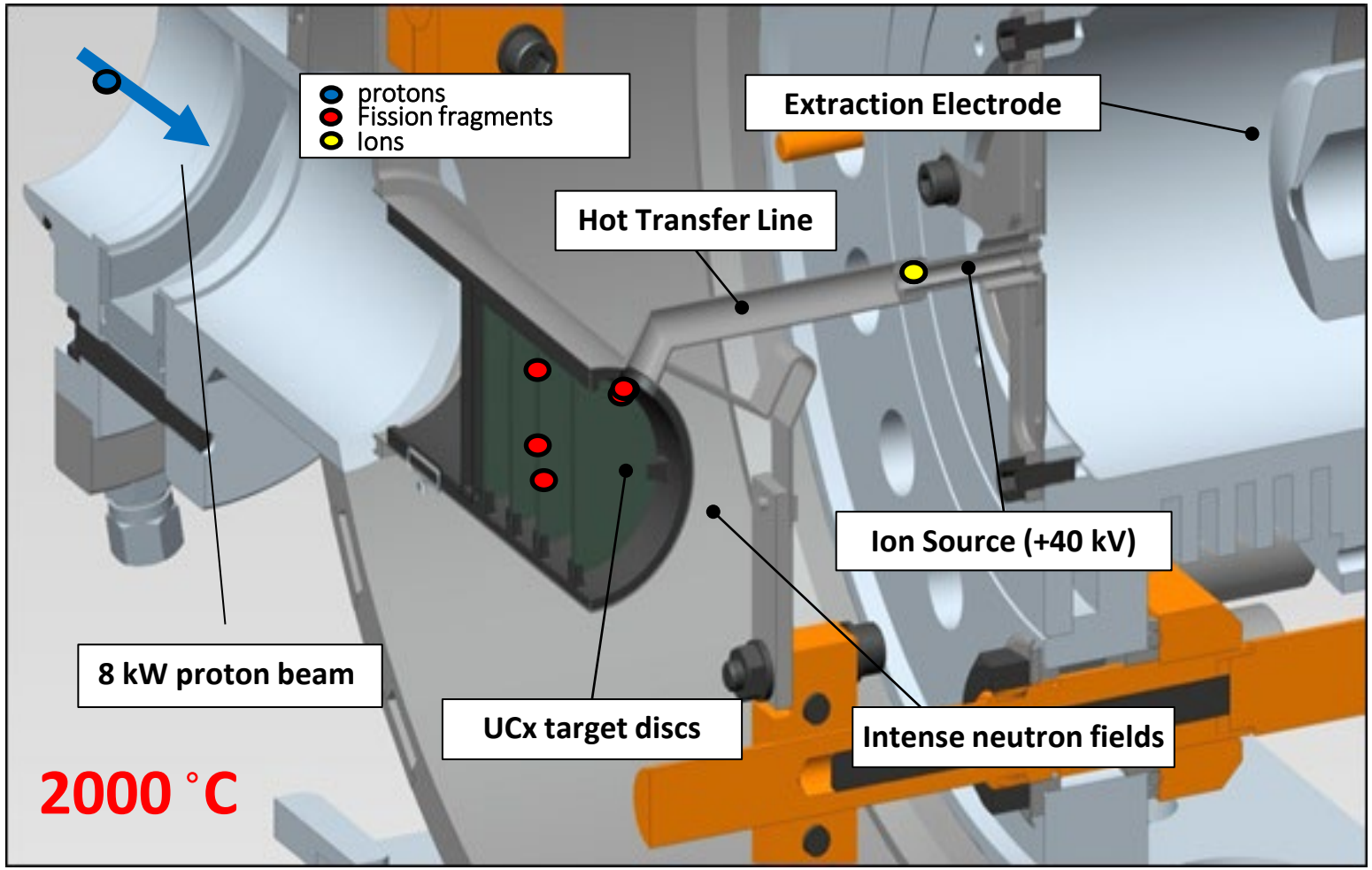
ALPI existing complex

Target and Ion Source

Process description

- 7 UCx disks
- Collision with 40 MeV 200 μA primary beam
- Fission reaction
- Heating up to 2300 °C
- Effusion/Diffusion process
- Ionization
- Isotopes extraction (E = 40 kV)





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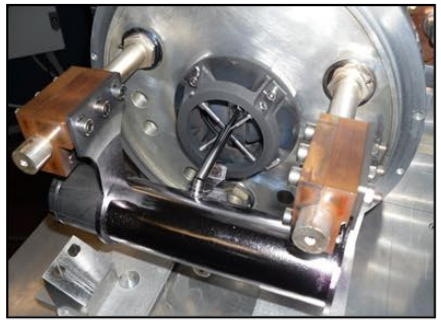

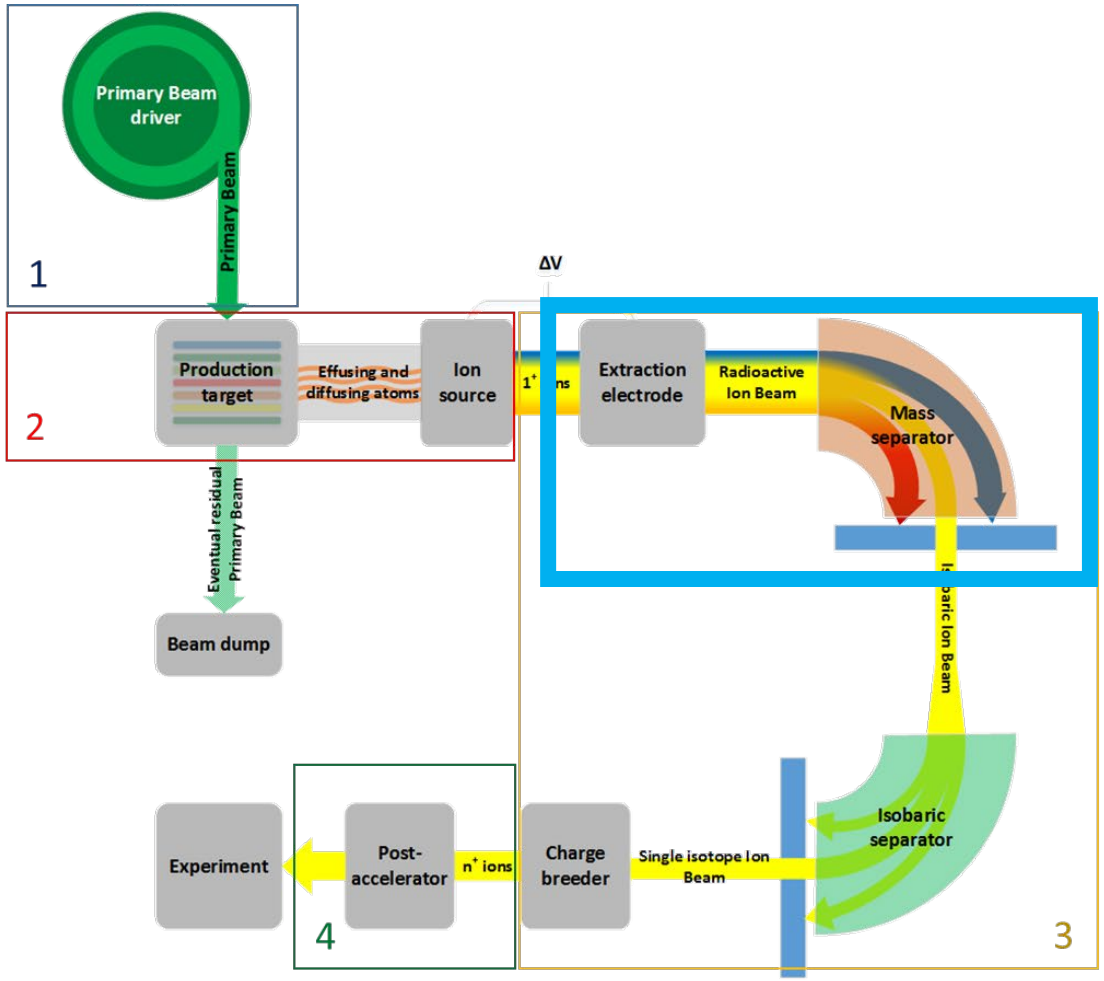

3- RIB manipulation

- Mass Separator (WF)
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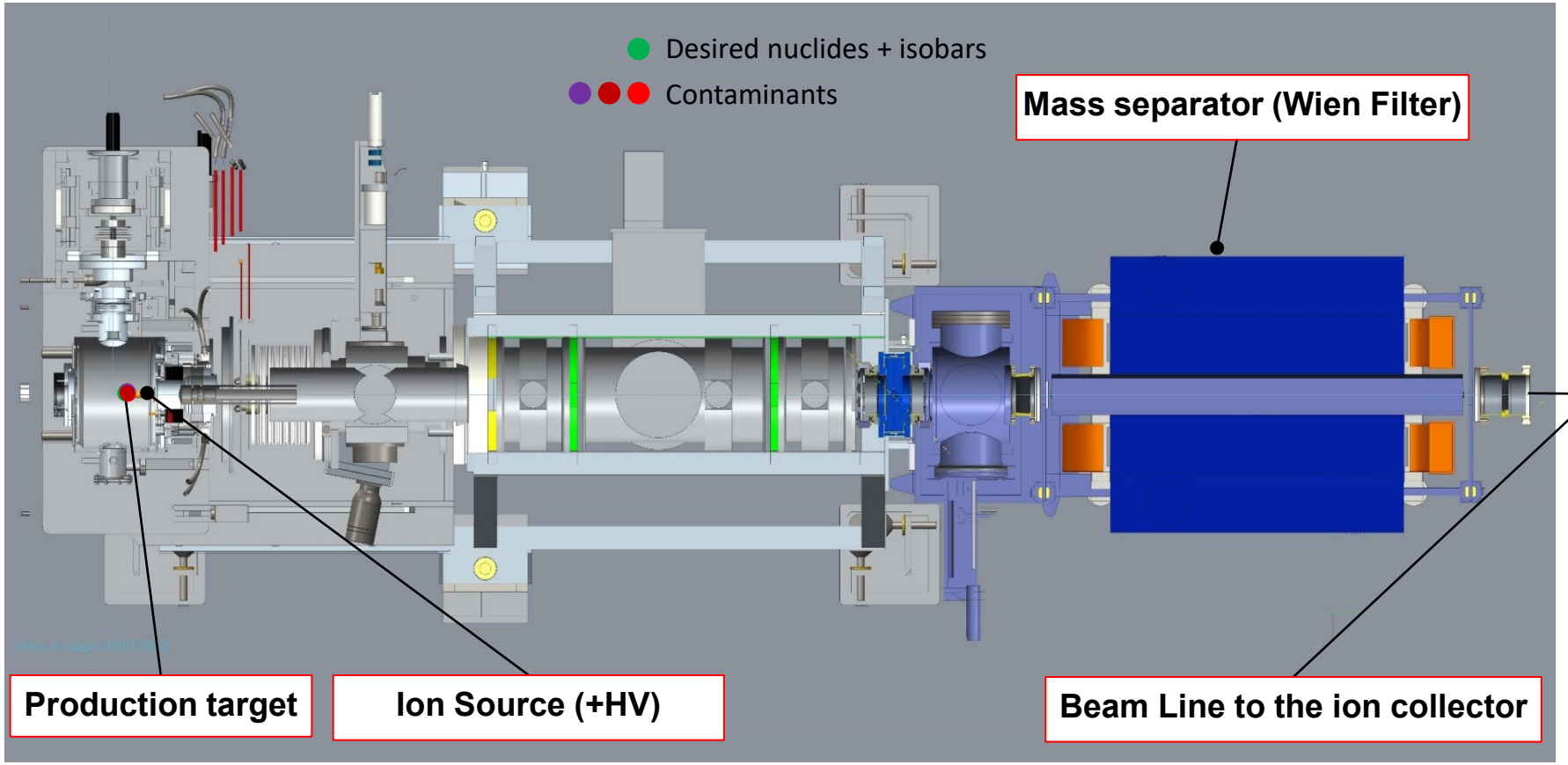
- RFQ

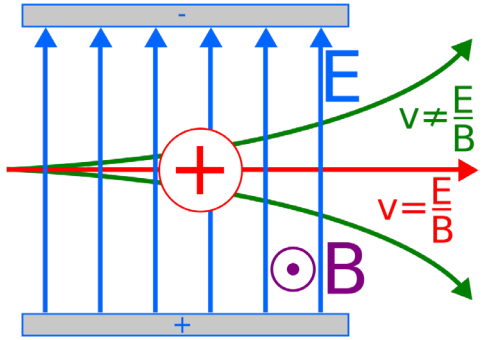
4 - Post Accelerator:

ALPI existing complex

Mass Separation

Wien-Filter



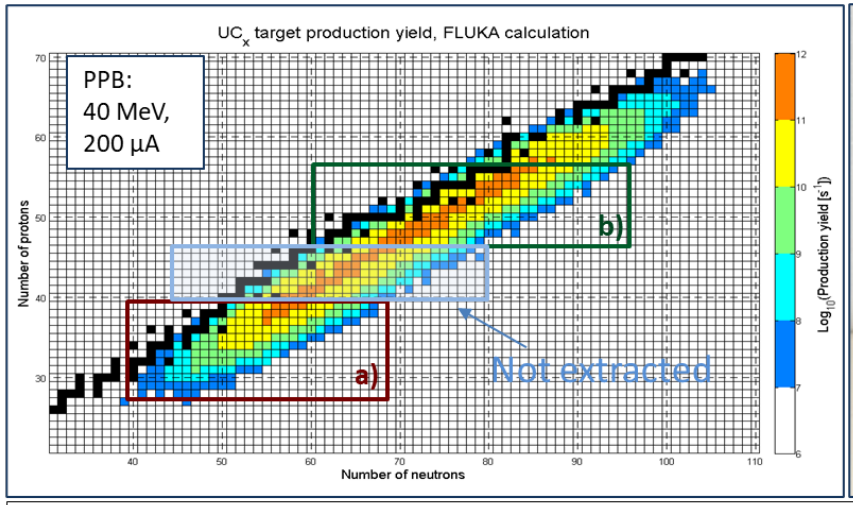


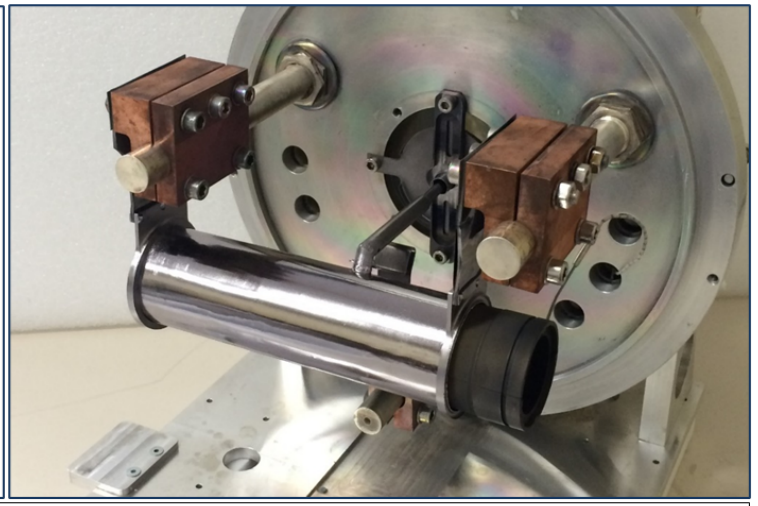
Target materials

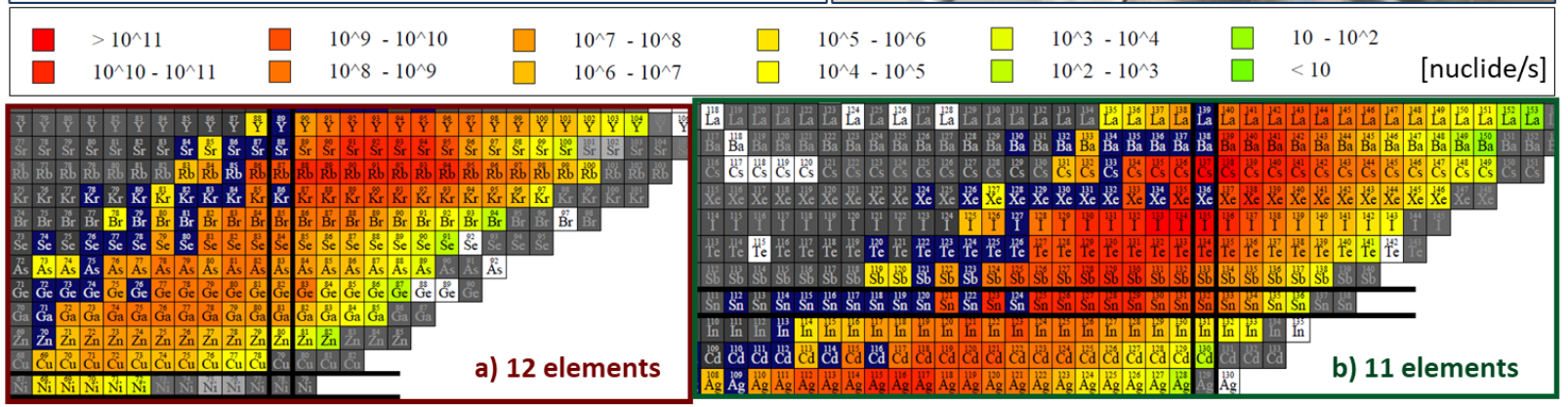
Isotope production

- Possibility to produce more than 500 isotopes …
- UCx target protype

	Standard (graphite)	Low density (MWCNTs)
Density (g/cm³)	4.25	2.59
Diameter (mm)	12.50	13.07
Thickness (g/cm²)	0.41	0.41
Calculated porosity (%)	58	75







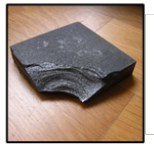
FLUKA& MCNPX calculations experimentally validated @ ORNL

Target materials

Isotope production

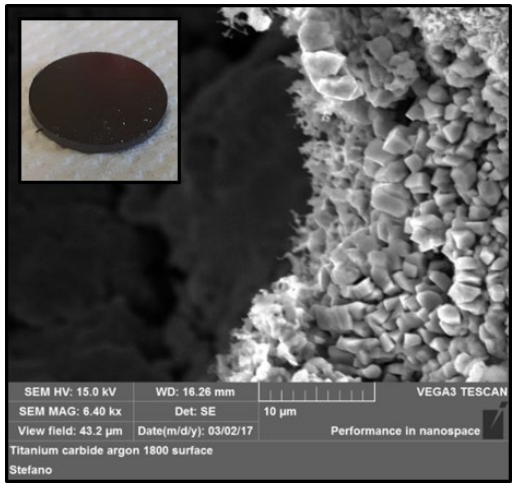
- Possibility to produce more than 500 isotopes …
- UCx target protype
- Other non fissile targets

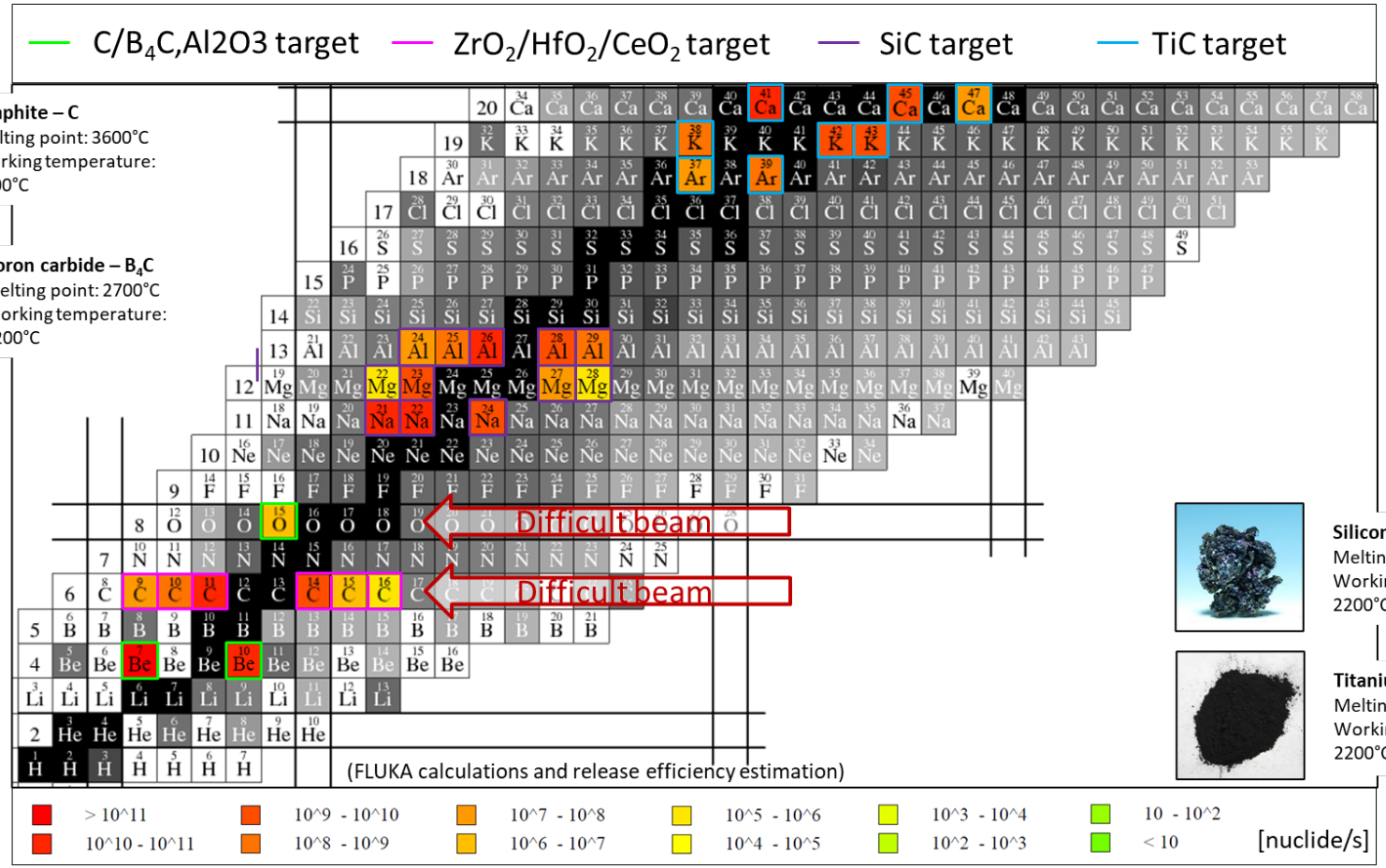
Graphite – C
Melting point: 3600°C
Working temperature: 2200°C



Boron carbide – B_4C
Melting point: 2700°C
Working temperature: 2200°C

Porous titanium carbide (TiC)

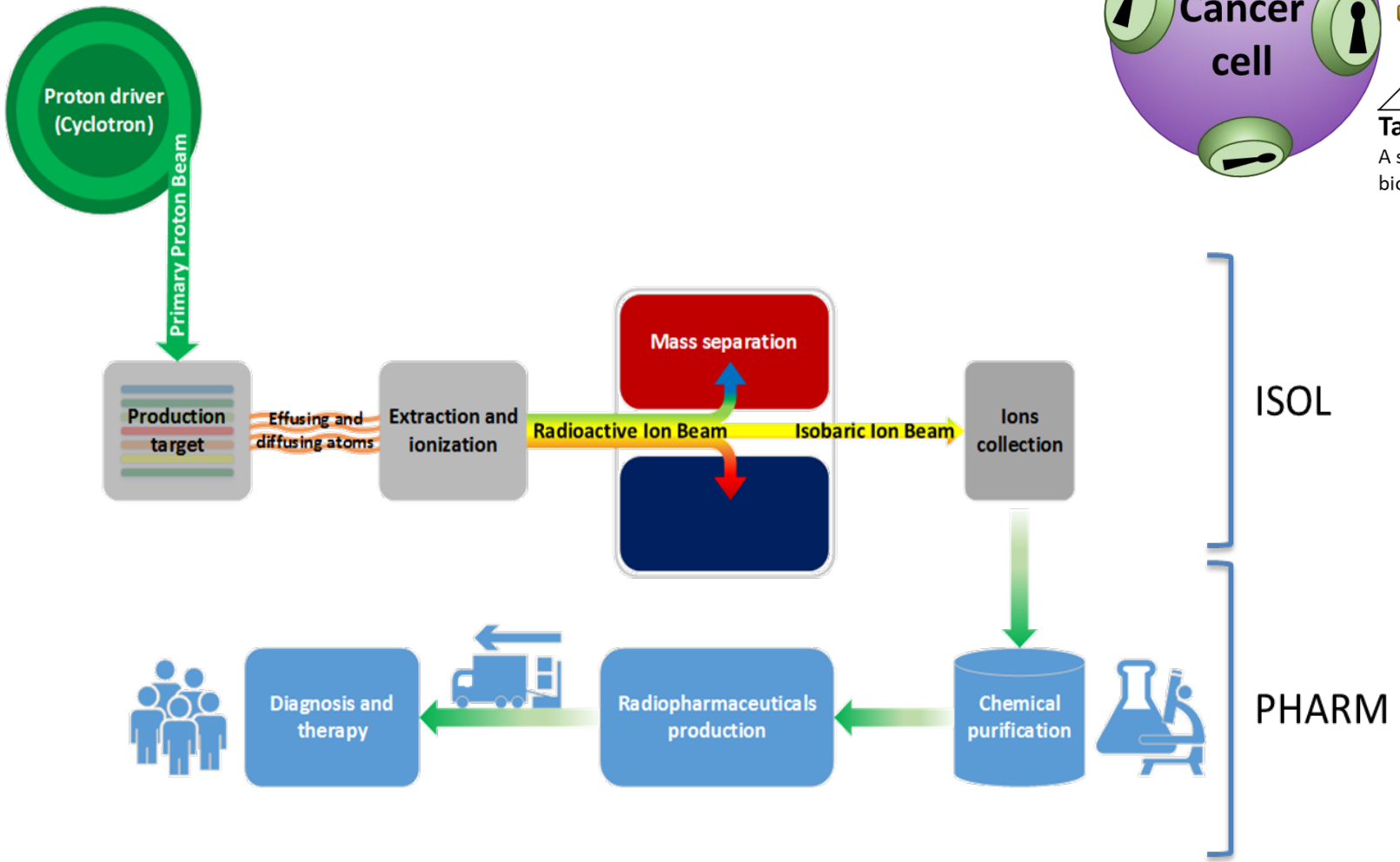


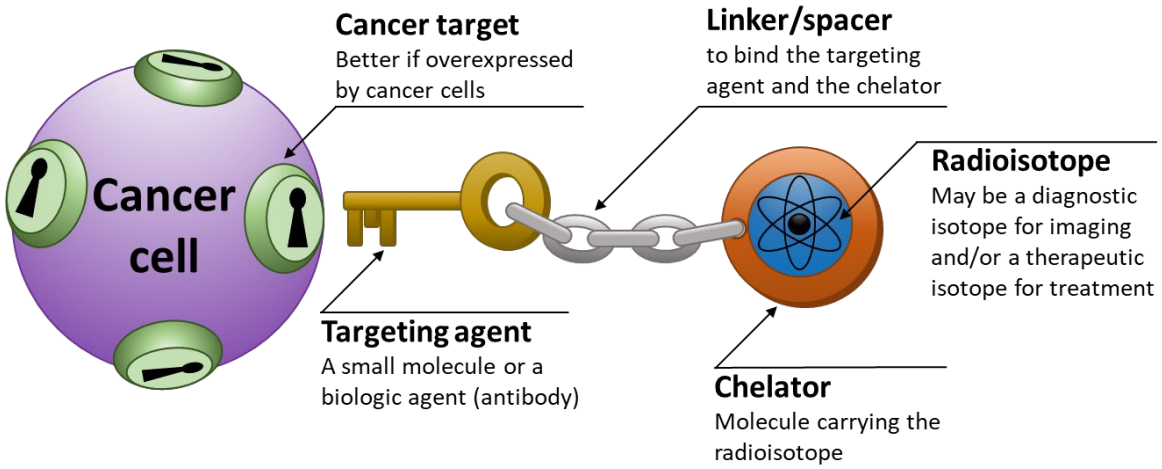


Silicon carbide – SiC
Melting point: 2700 °C
Working temperature: 2200°C

Titanium carbide – TiC
Melting point: 3100°C
Working temperature: 2200°C

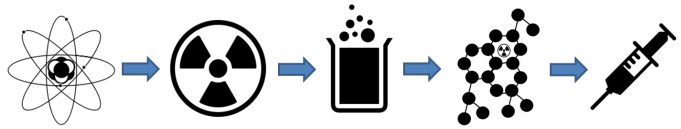
ISOLPHARM





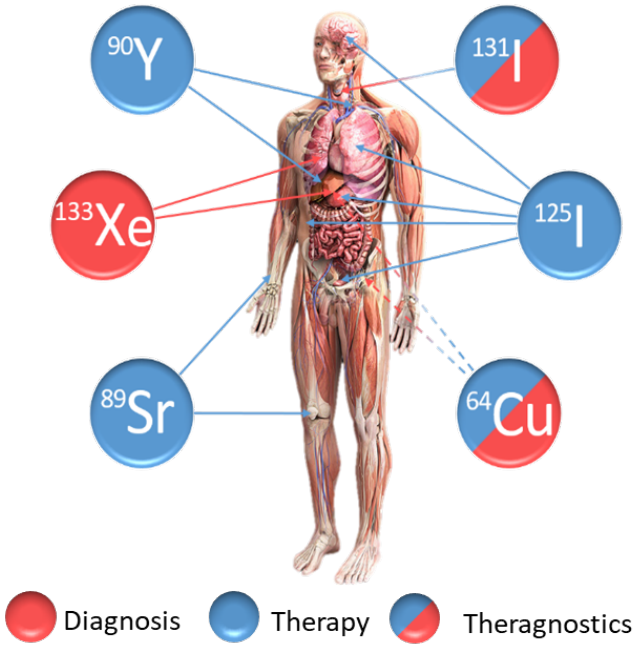
ISOLPHARM

SPES exotic beams for medicine



ISOLPHARM

Early feasibility studies were focused on state-of-art radionuclides:



F. Borgna *et al.*, *Appl. Radiat. Isot.*, 2017

ISOLPHARM true potential can be expressed if innovative/less available nuclides are considered

^{111}Ag
- $t_{½}$: 7.45 d
- 100% β- (360 keV av.)

^{64}Cu pair ^{67}Cu

^{64}Cu:
- $t_{½}$: 12.701 h
- 38,5% β- (191 keV av.)
- 61,5% β+ (PET)

^{67}Cu:
- $t_{½}$: 2.58 d
- 100% β- (162 keV av.)

^{43}Sc pair ^{47}Sc

^{43}Sc:
- $t_{½}$: 233 min
- 100% β+/ϵ (PET)

^{47}Sc:
- $t_{½}$: 3.4 d
- 100% β- (162 keV av.)

^{152}Tb pair ^{149}Tb pair ^{155}Tb

^{152}Tb:
- $t_{½}$: 17.5 h
- 100% β+/ϵ (PET)

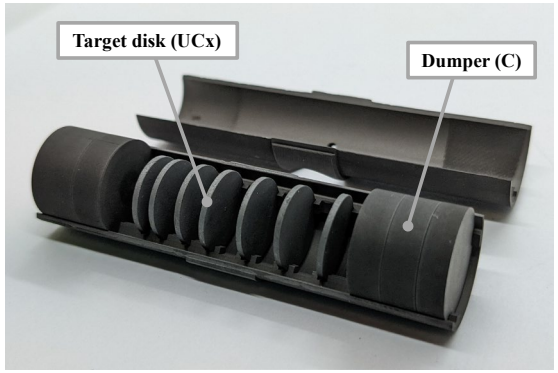
^{149}Tb:
- $t_{½}$: 4.12 h
- 16.7% α (3.97 MeV)

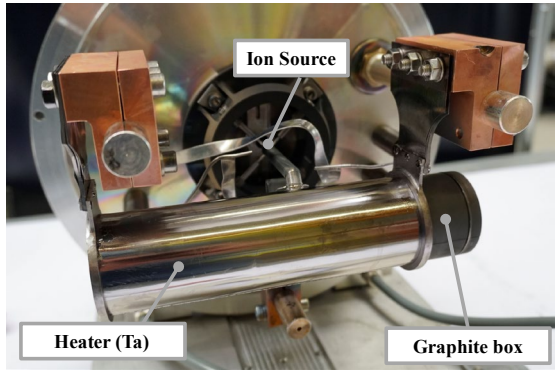
^{155}Tb:
- $t_{½}$: 5.32 d
- 100% β+/ϵ (SPECT)

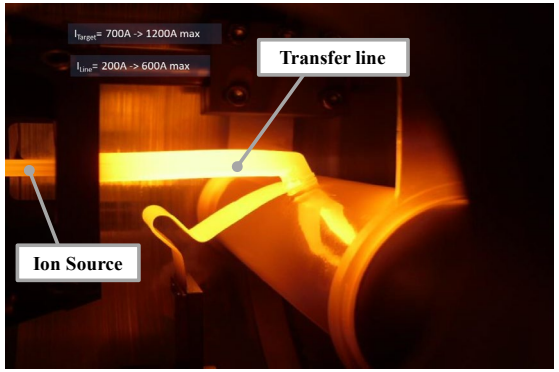
The Target Ion Source (TIS) unit

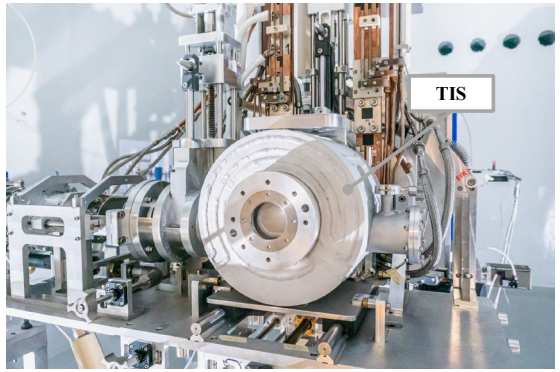
Preparation

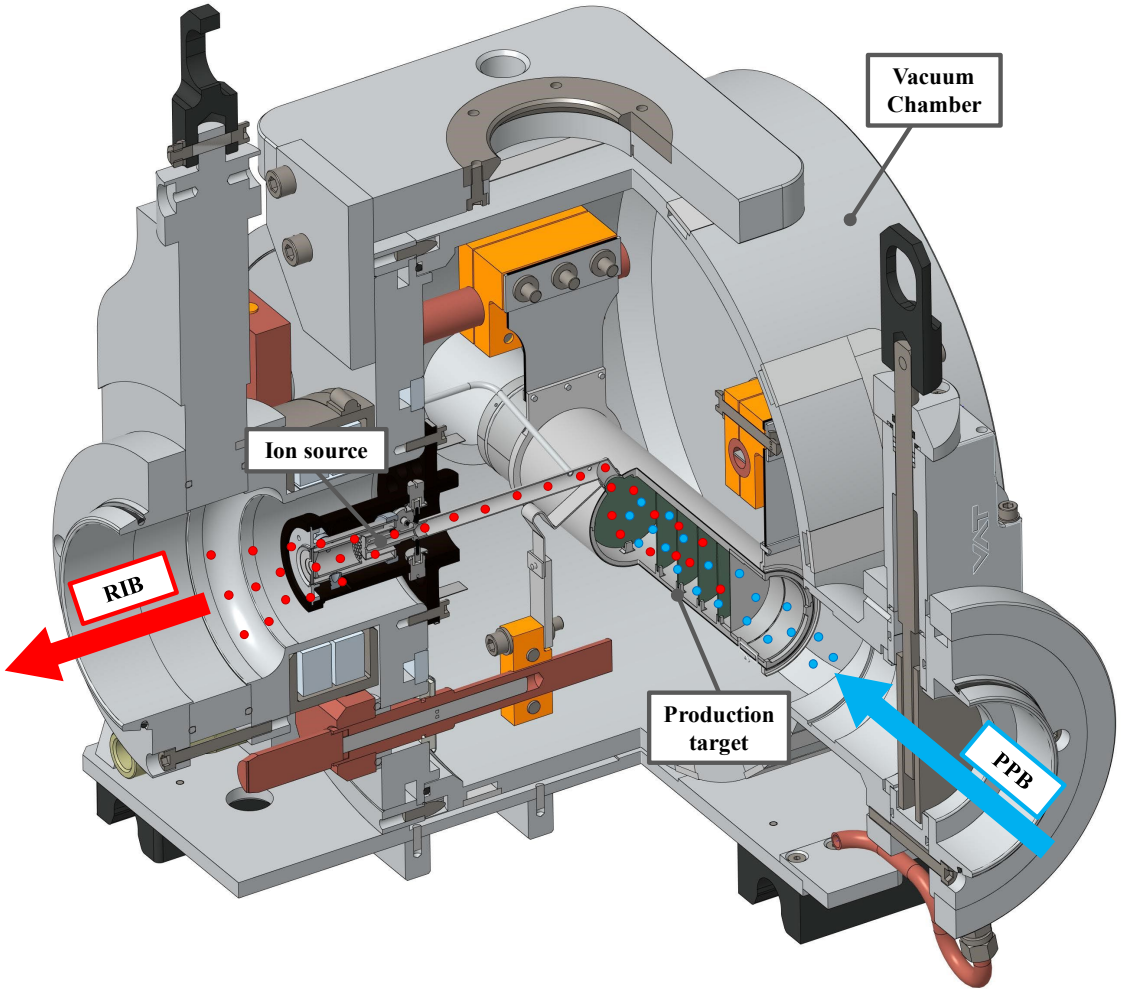
- Assembly, alignment, conditioning, tests, etc.







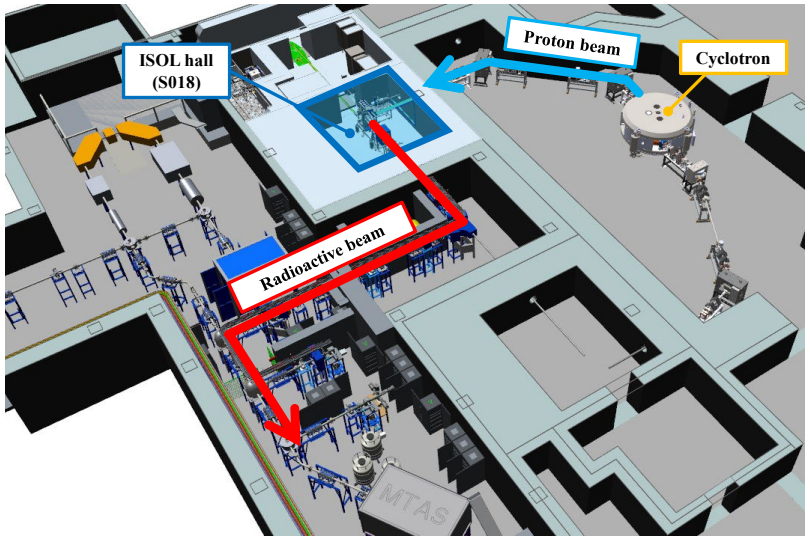


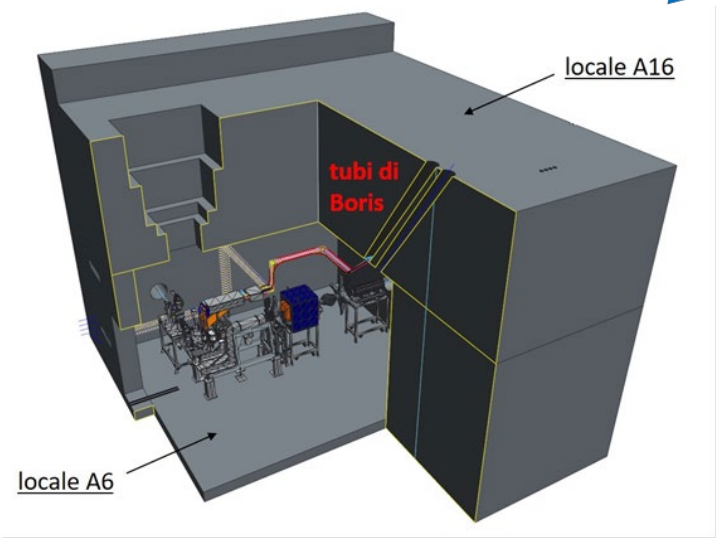


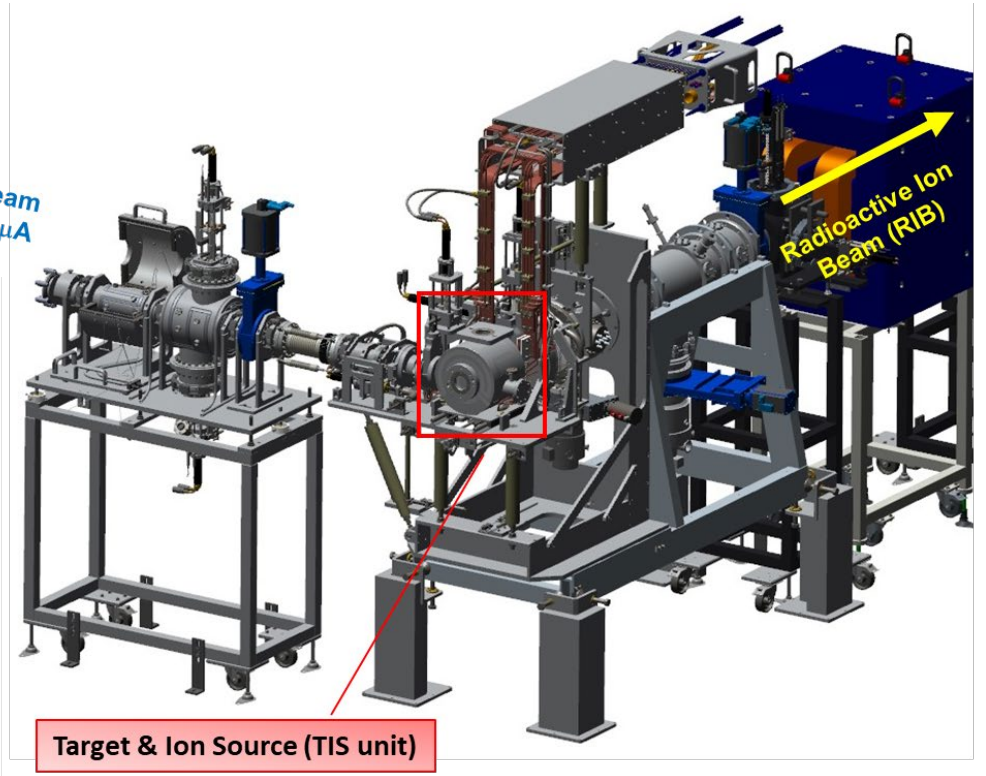
The Target Ion Source (TIS) unit

Periodic replacement

- Maintain process efficiency
- Study different materials



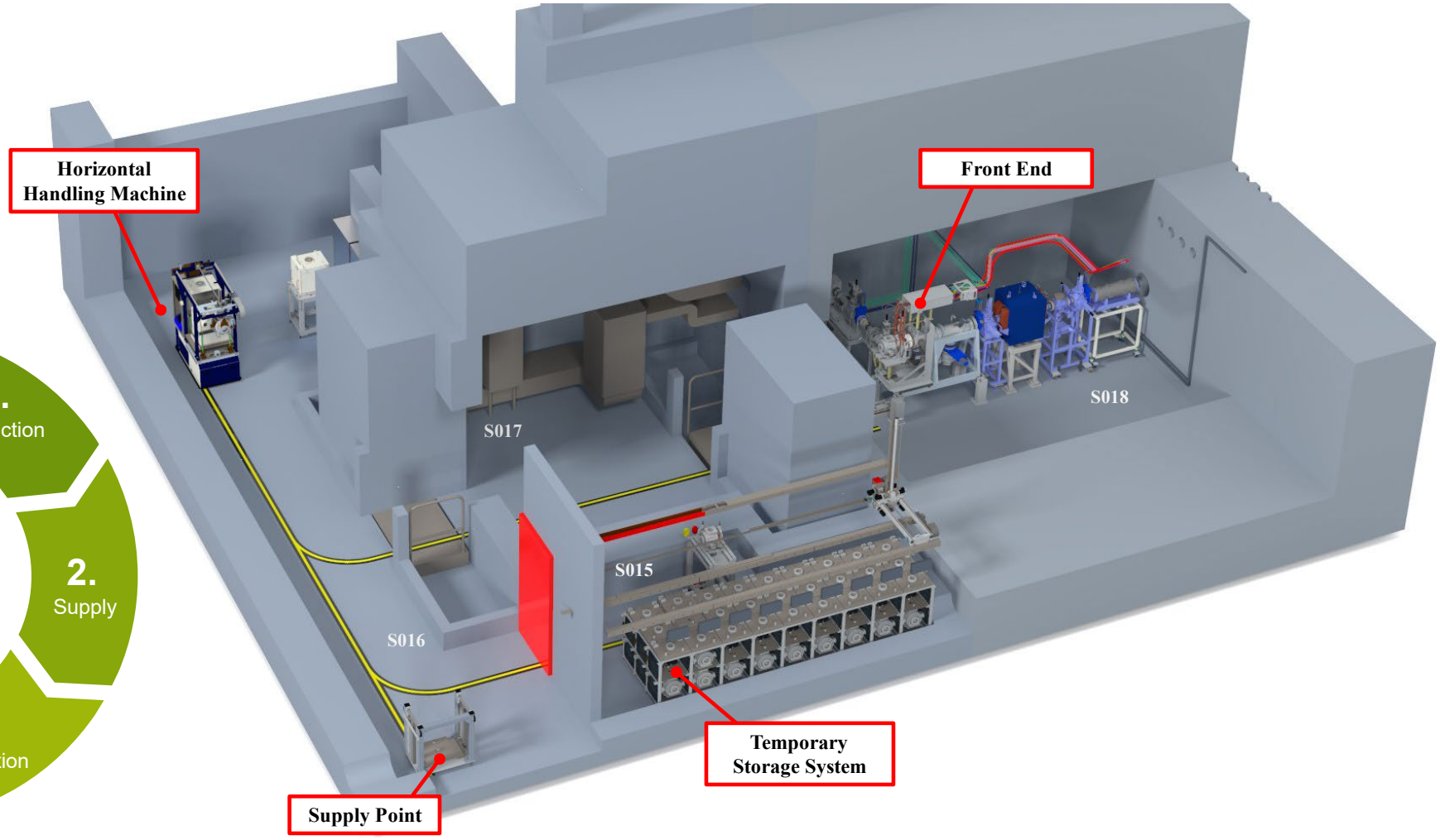




The SPES Remote Handling framework

The TIS unit life cycle

- Production
- Supply
- Installation
- Retrieval
- Storage
- Dismantling

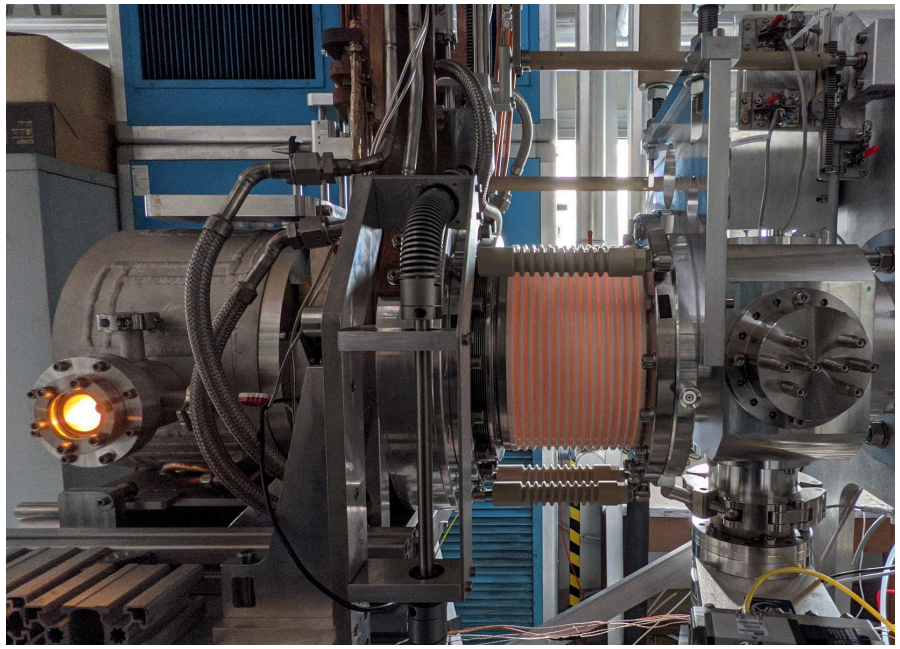


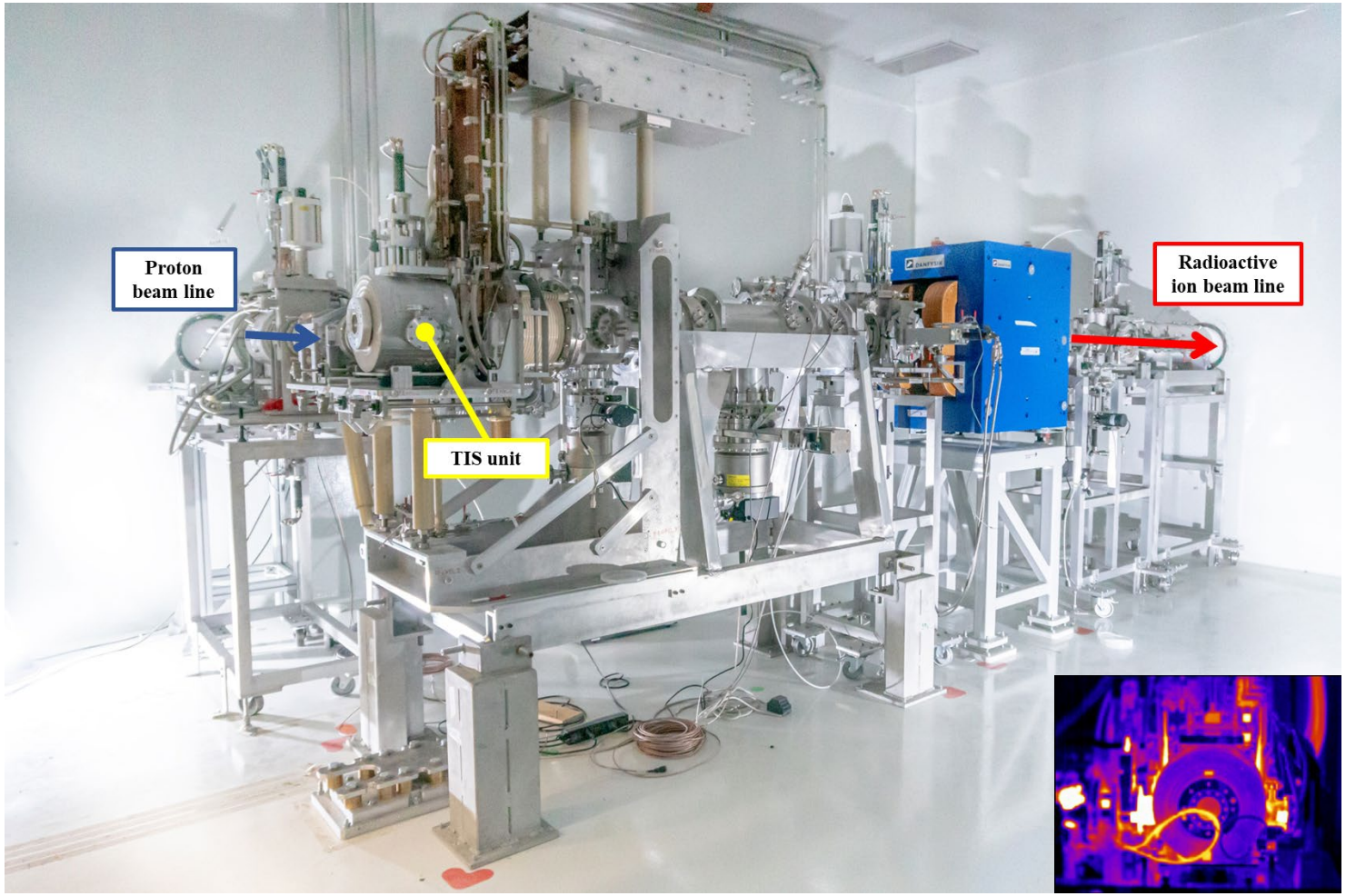
G. Lilli, et al., Remote handling systems for the Selective Production of Exotic Species (SPES) facility, Nucl. Eng. Technol. 55 (2023) 378–390. https://doi.org/10.1016/J.NET.2022.08.034.

The SPES on-line Front-End

Tasks:

- Couple new TIS to the Front-End for irradiation
- Uncouple irradiated TIS for removal

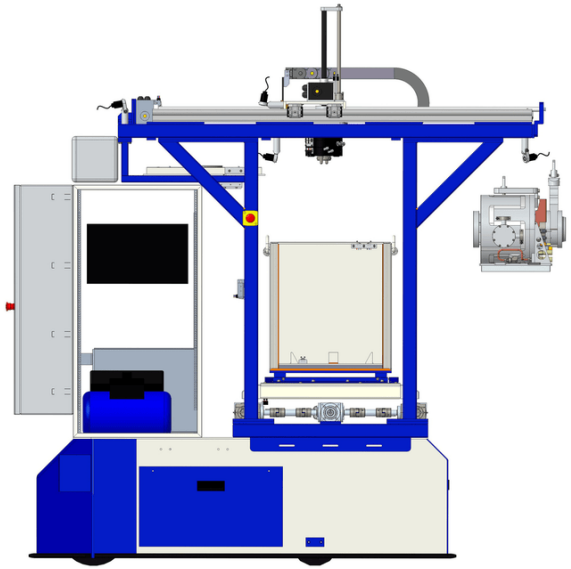


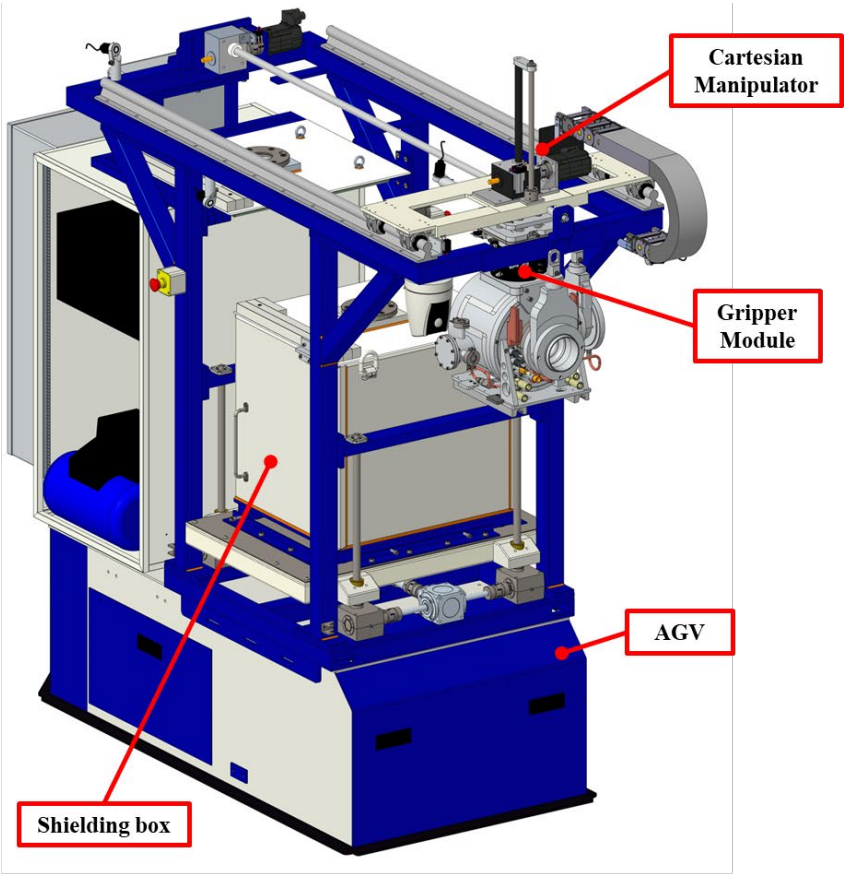


Horizontal Handling Machine (HHM)

Tasks:

- Install new TIS to the SPES Front-End for irradiation
- Retrieve irradiated TIS from the SPES Front-End
- Transport irradiated TIS to the Temporary Storage System (TSS)

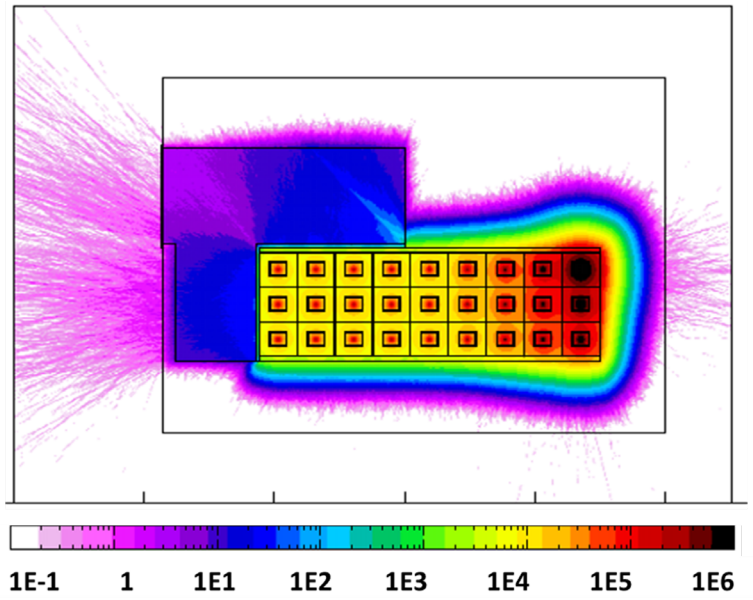


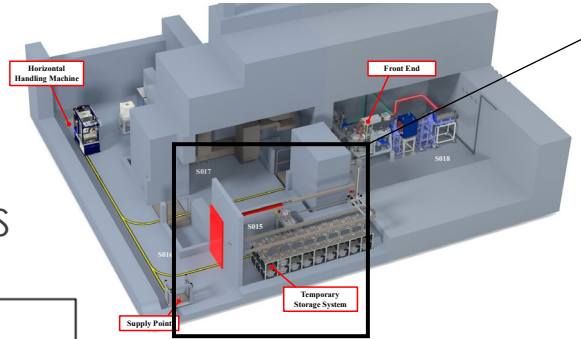


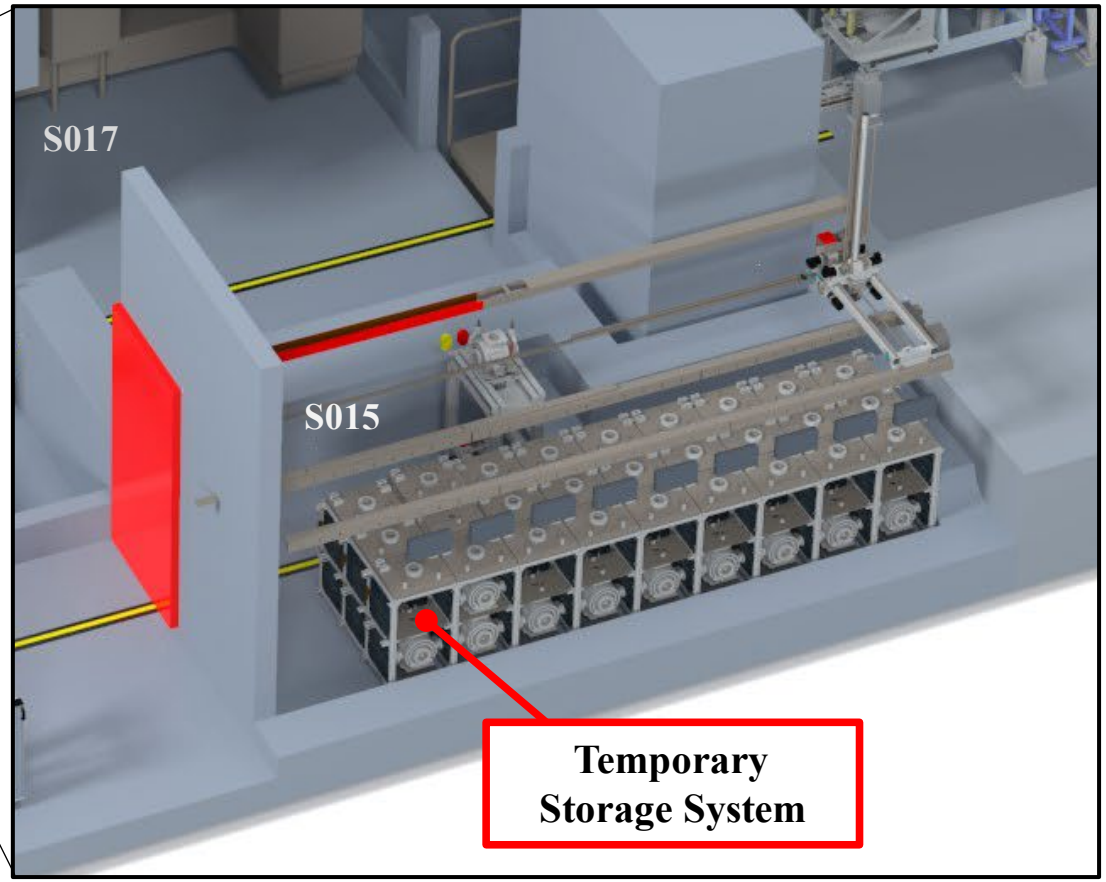
Temporary Storage System (TSS)

Tasks:

- Store irradiated TIS on the storage positions
- Retrieve exhausted TIS from the storage for dismantling
- Swap irradiated TIS within the TSS to free space



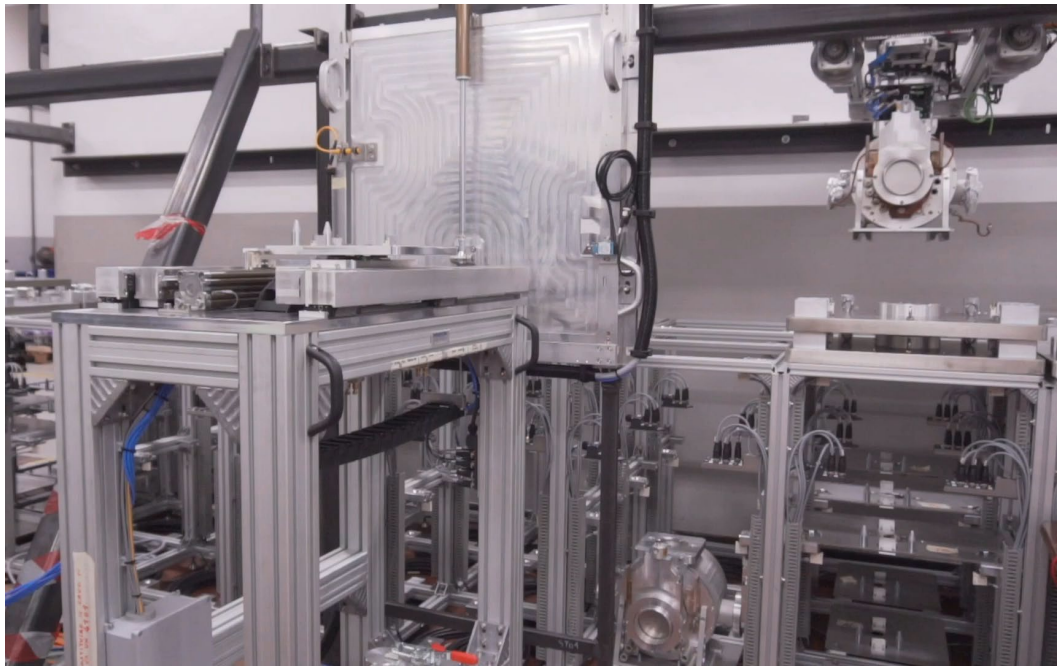


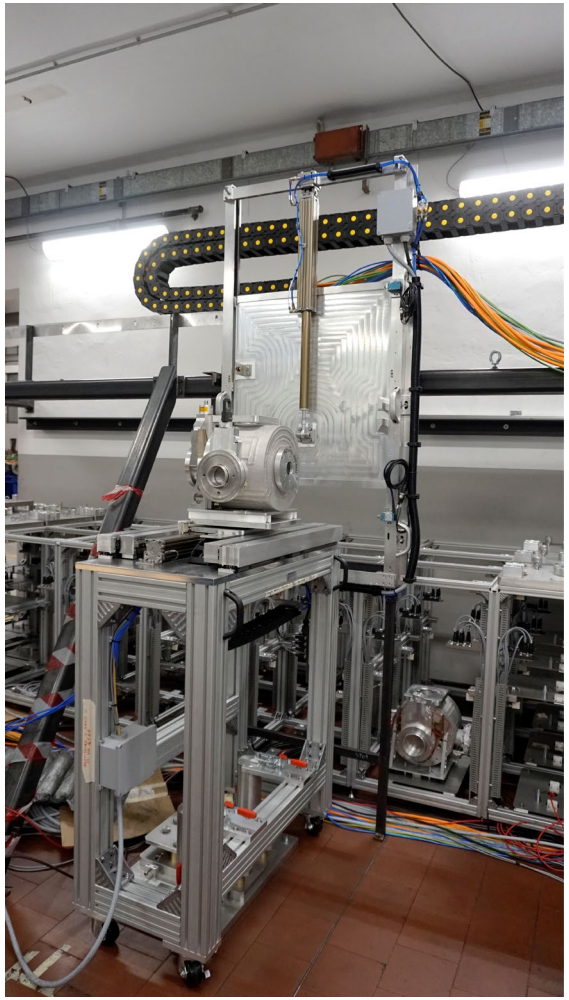


Temporary Storage System (TSS)

Description:

- Fully automatic storage
- Available storage positions: 54
- Foreseen decay period: 2-5 years





Temporary Storage System (TSS)

Description:

- Mechanical installation completed (January 2023)
- Compound works ongoing
- Cabling and system commissioning foreseen in Q4 2023

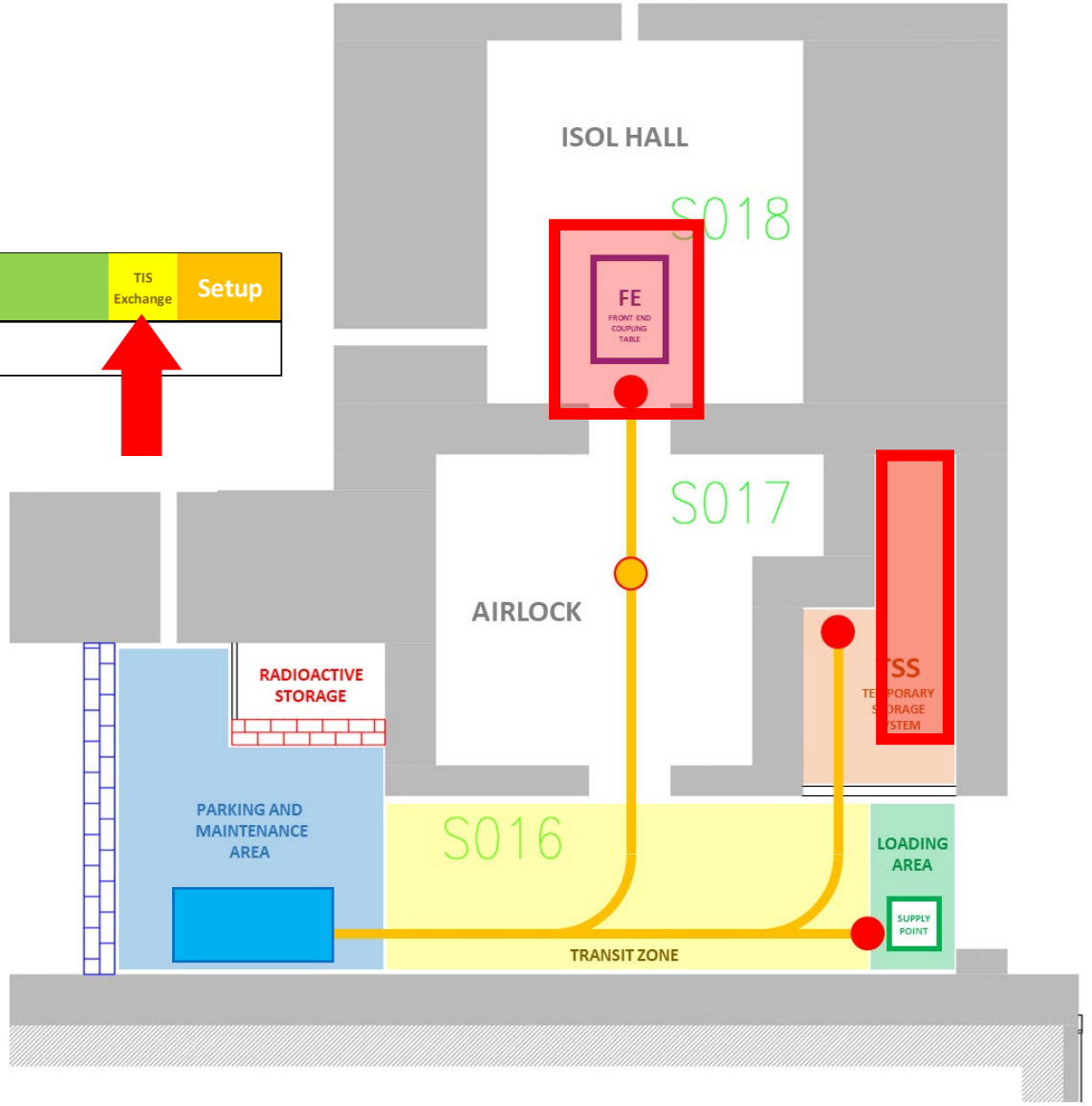
The TIS unit replacement

SPES Run schedule

Physics (Beam)	Cooling + Venting	TIS Exchange	Setup
15 days	15 days		

TIS Exchange Procedure

- Uncouple irradiated TIS from SPES Front End
- Retrieve TIS from SPES Front End and store it in a shielded sarcophagus during the transport
- Deposit TIS on the TSS Exchange Point
- Move irradiated TIS on a storage position in the TSS
- Install new TIS on the SPES Front End
- Couple new TIS on the SPES Front End



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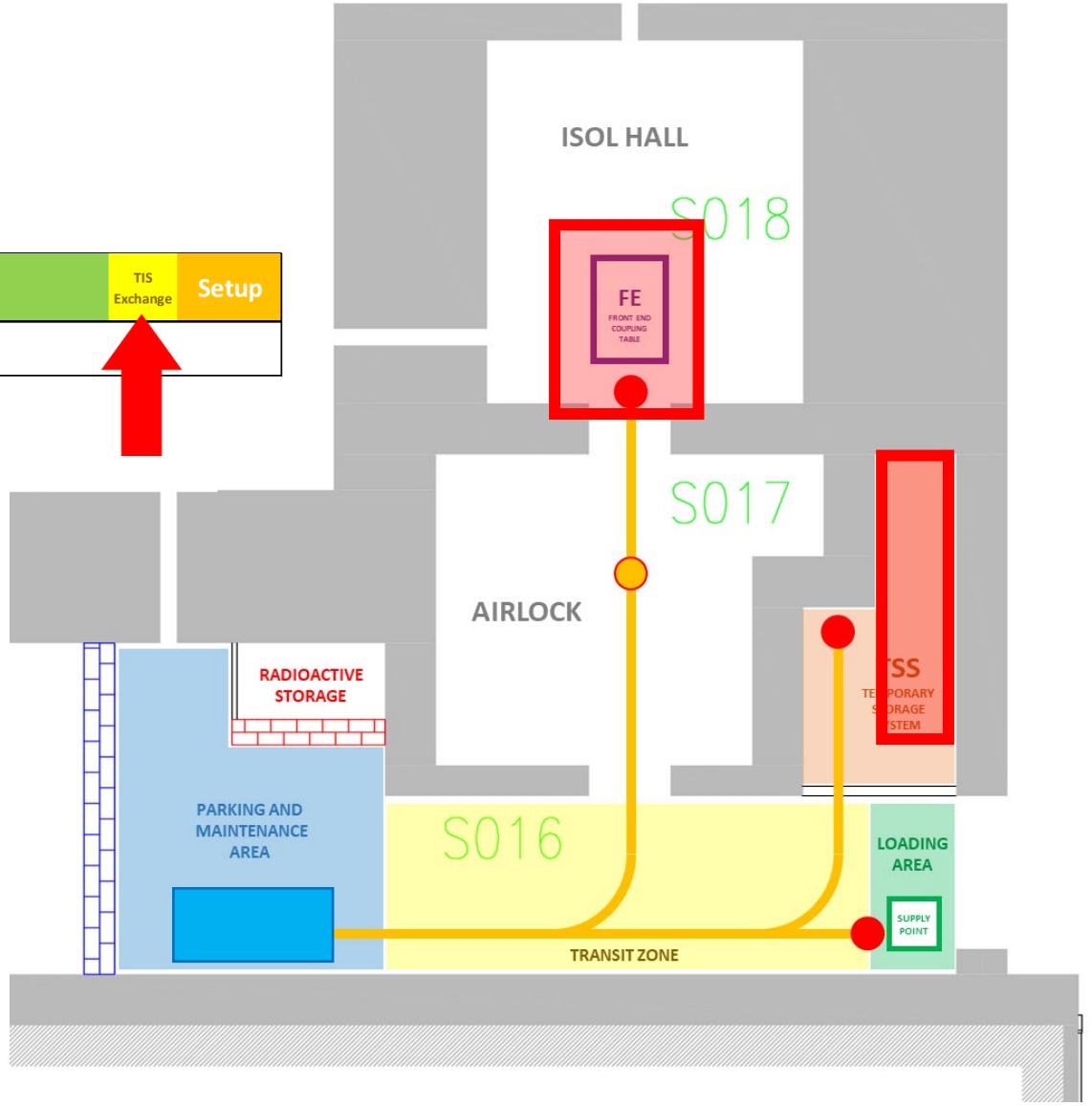
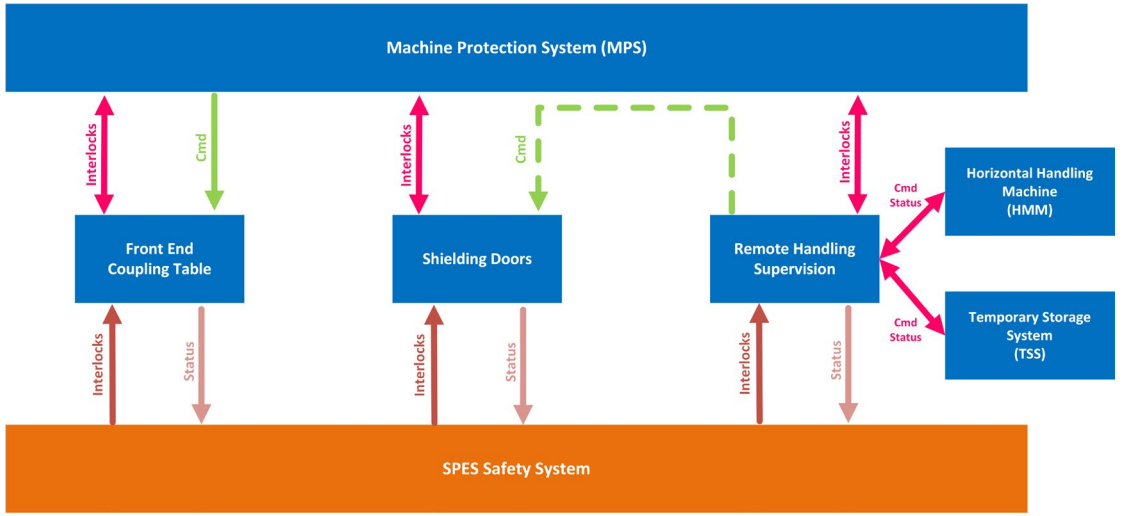
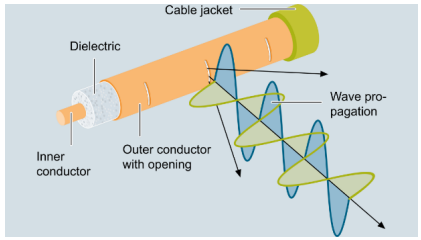


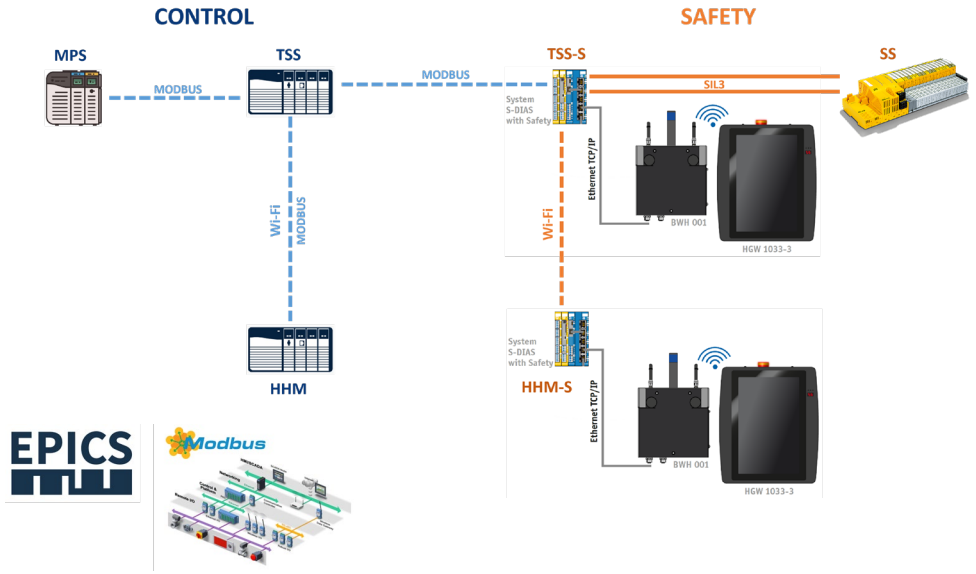
Control and Supervision

Infrastructure:

- Distributed Control Architecture
- Safety Architecture
- Communication
- Supervision



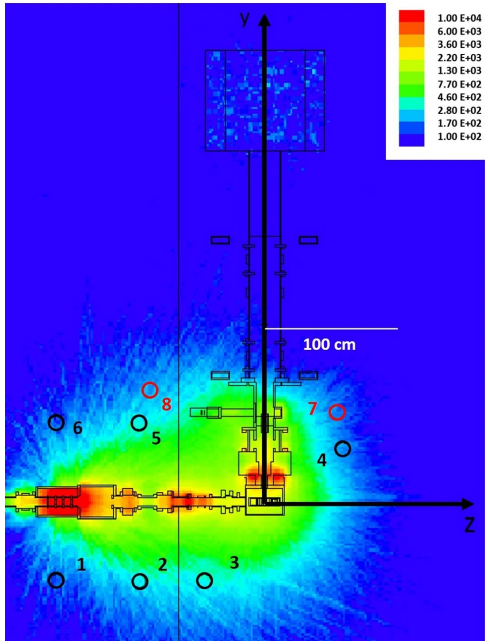


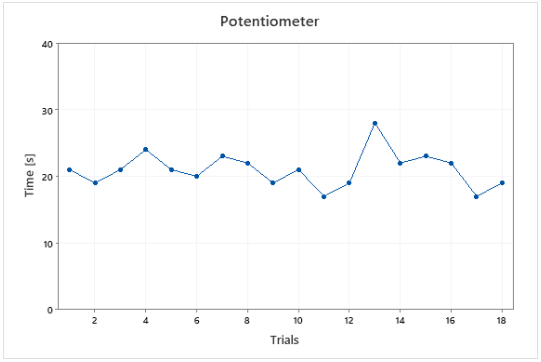


Safety and Maintenance

Optimization:

- Training of specialized operators, Procedures, PPEs (ALARA principle: As Low As Reasonably Achievable)
- Experimental test campaign:
  - Time and working position Estimation
  - Work and Dose Planning (WDP)
- Optimization process:
  - Identification of proper tools
  - Design for assembly review

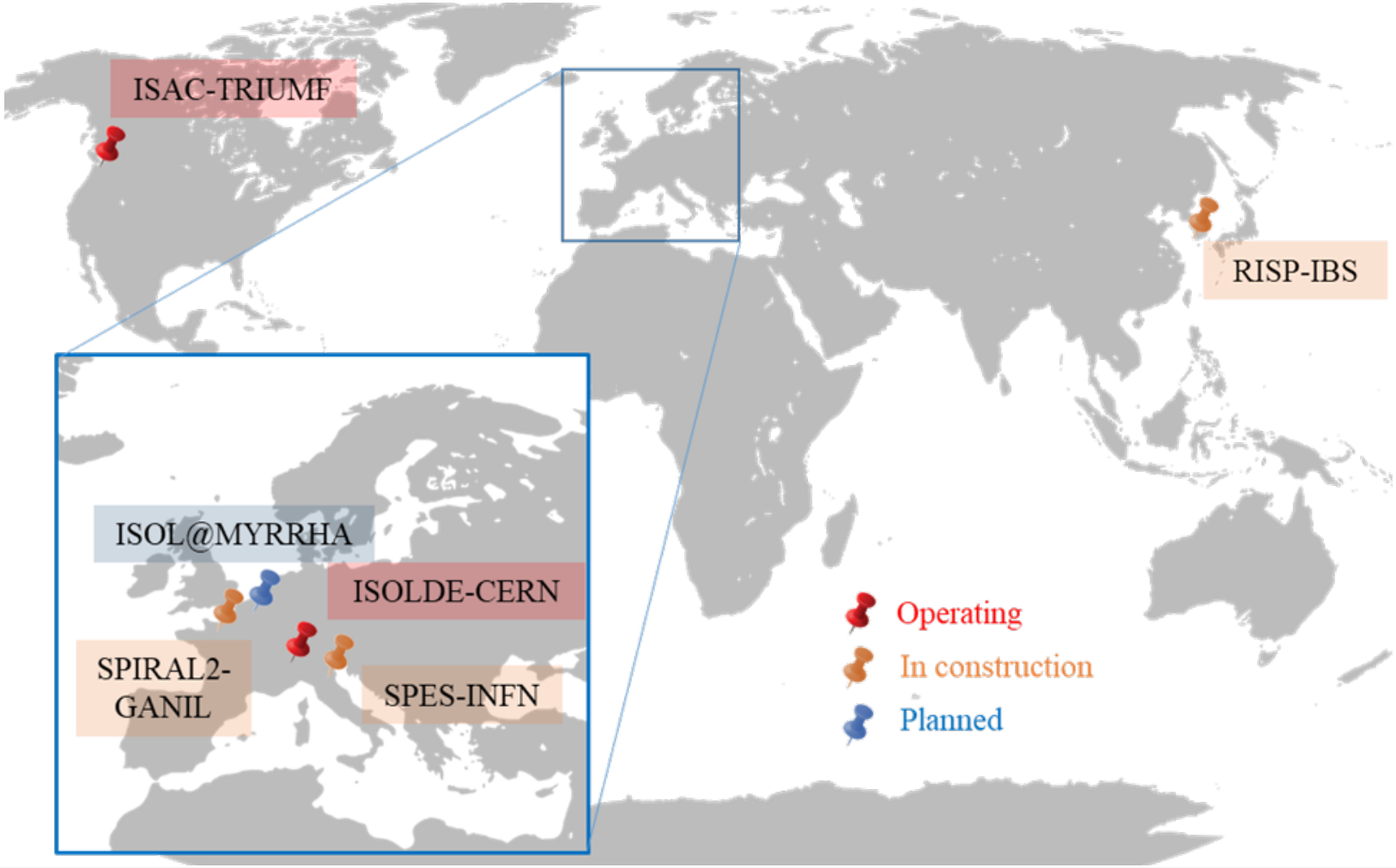




ISOL Facilities in the world

Main RIB facilities:

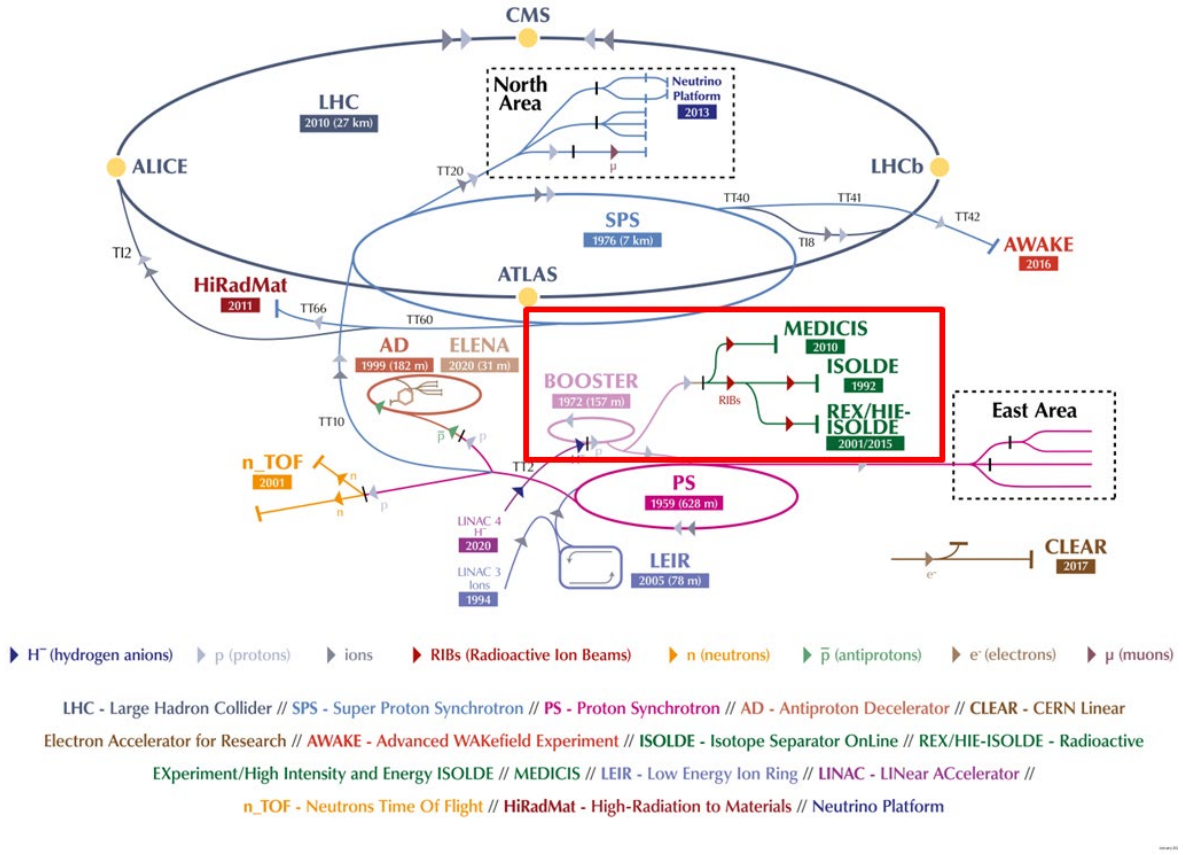
- ISOLDE (CERN)
- ISAC (TRIUMF)
- SPES now under construction: (LNL)
- Other ISOL facilities:
  - SPIRAL2-GANIL
  - ISOL@MYRRHA
  - HRINBF-US (low power, closed)

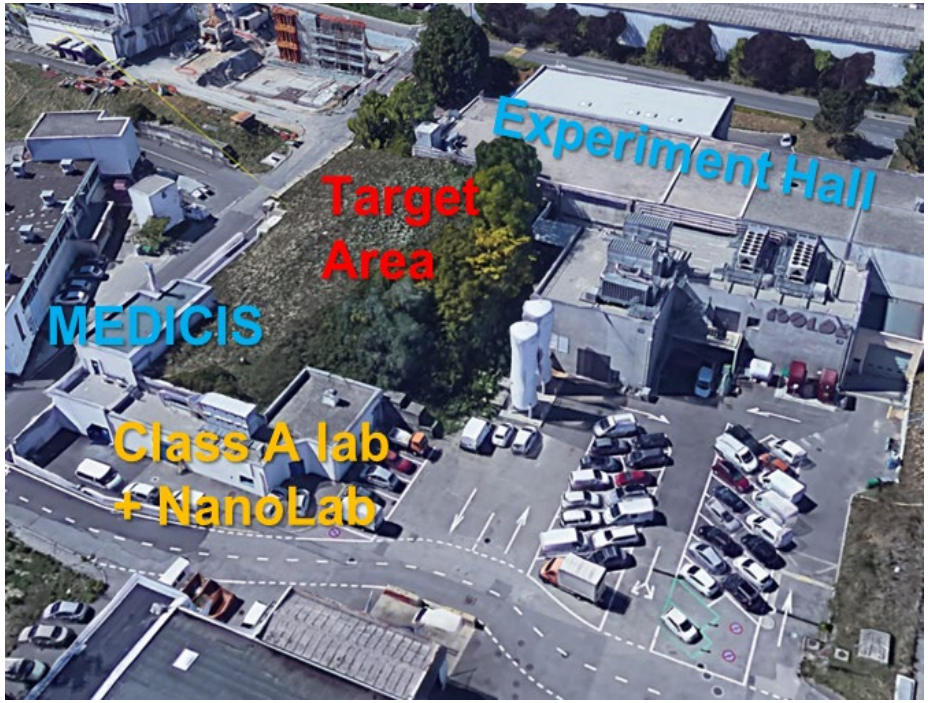


ISOLDE (Isotope Separator On-Line Device)

European Organization for Nuclear Research (CERN)

Geneva, CH



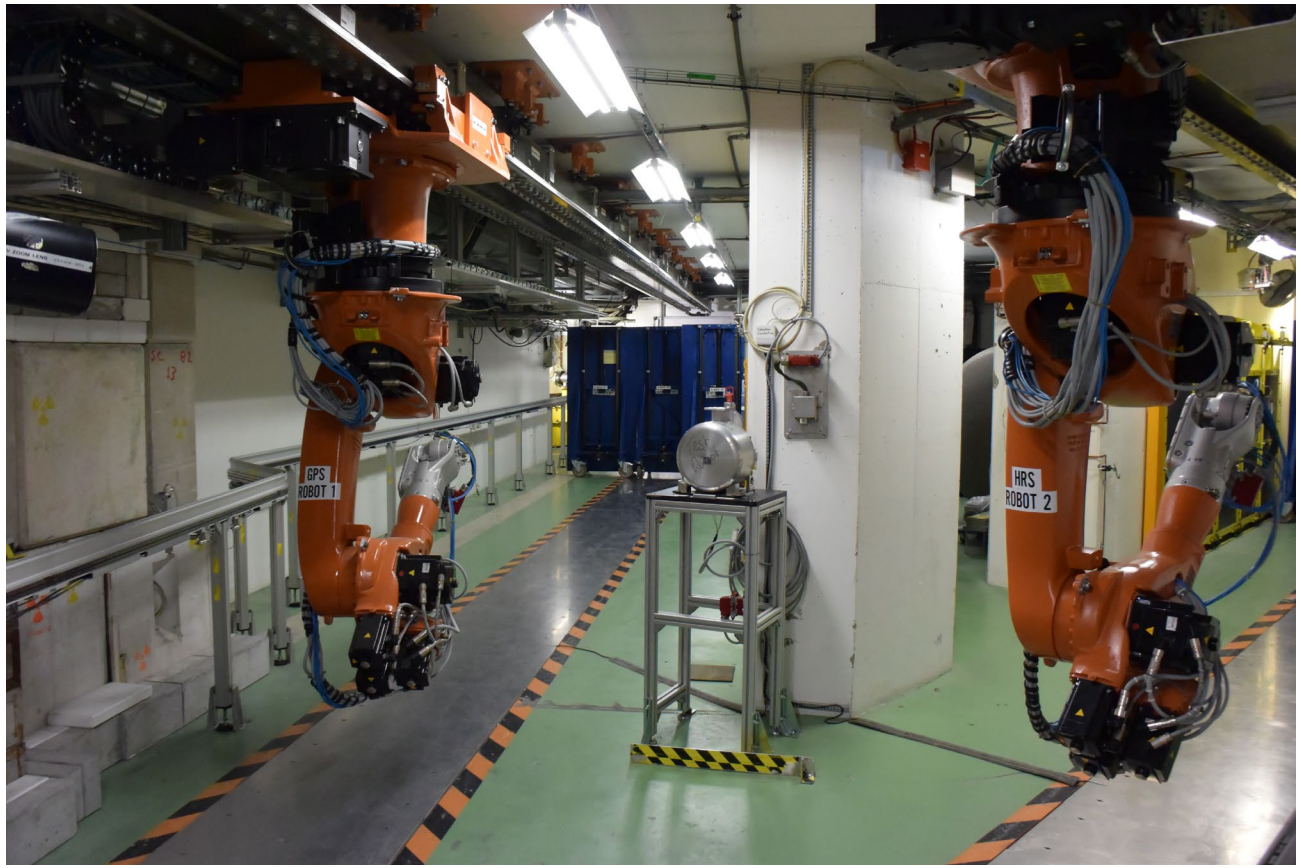


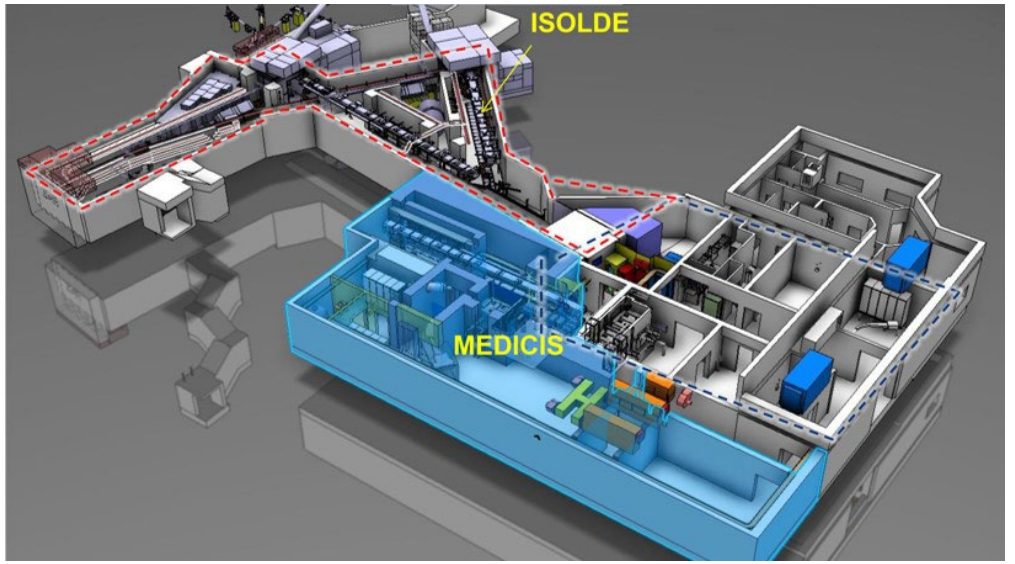
ISOLDE (Isotope Separator On-Line Device)

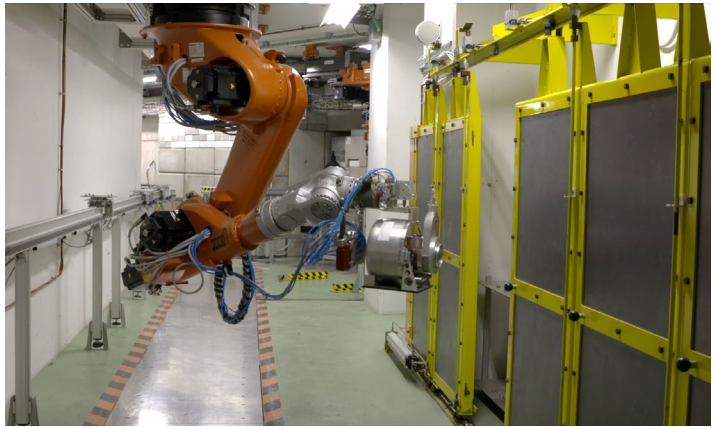
R. Catherall, et al., The ISOLDE facility, J. Phys. G Nucl. Part. Phys. 44 (2017). https://doi.org/10.1088/1361-6471/aa7eba

European Organization for Nuclear Research (CERN)

Geneva, CH





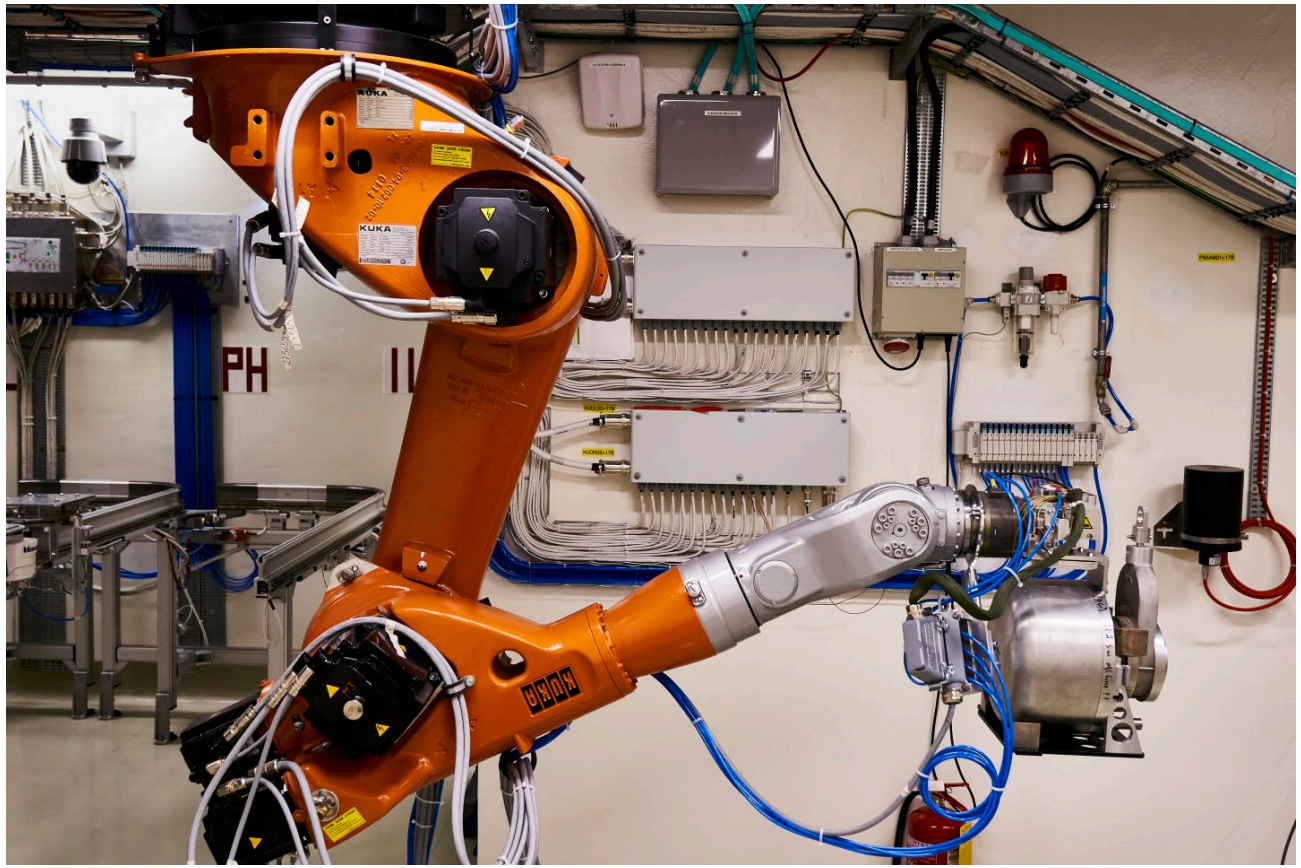


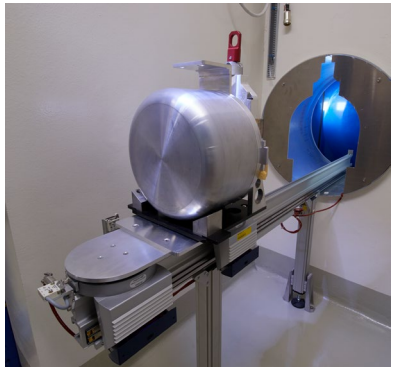
MEDICIS (Medical Isotopes Collected from ISOLDE)

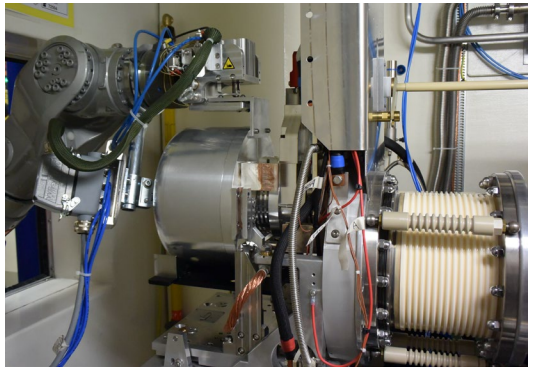
C. Duchemin, et al., CERN-MEDICIS: A Review Since Commissioning in 2017, Front. Med. 8 (2021). https://doi.org/10.3389/fmed.2021.693682

European Organization for Nuclear Research (CERN)

Geneva, CH





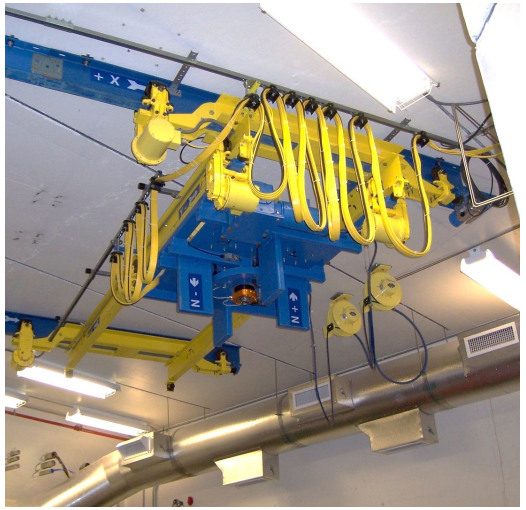


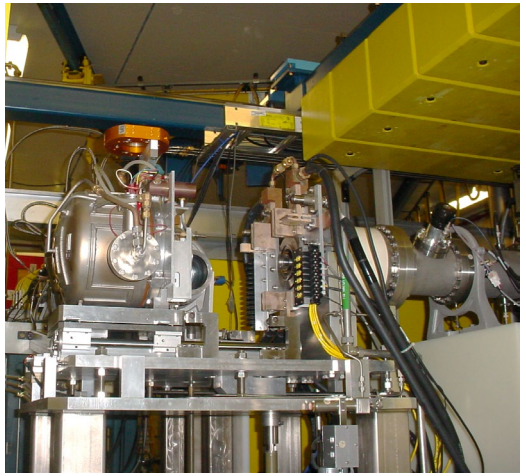
HRIBF (Holifield Radioactive Ion Beam Facility)

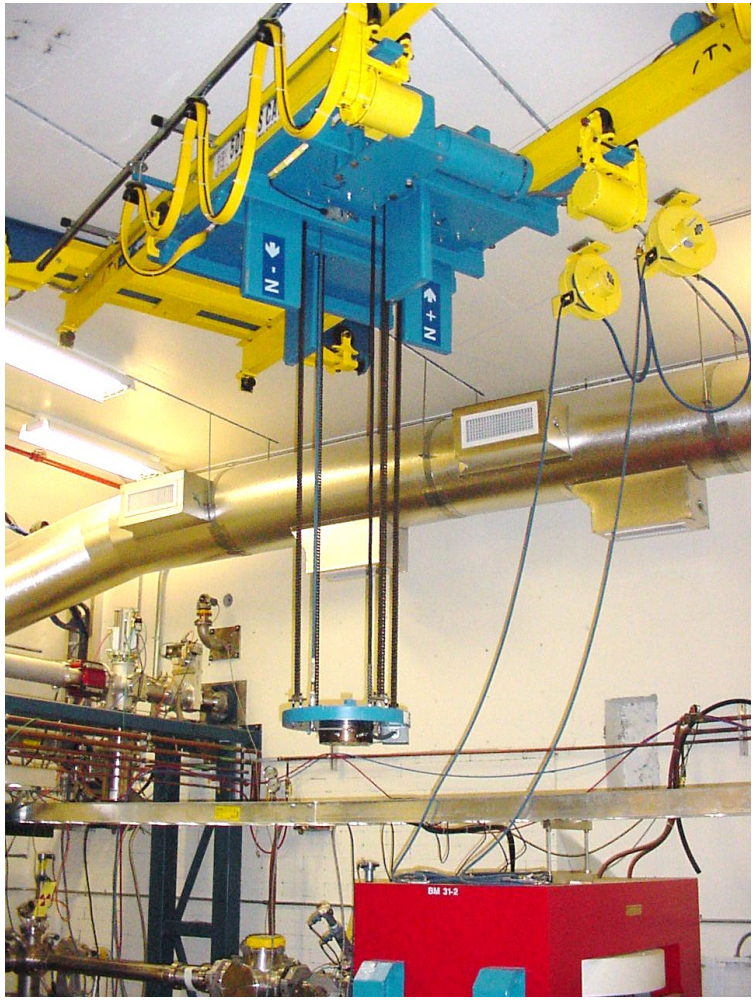
Courtesy of Dan W Stracener, ORNL

Oak Ridge National Laboratory (ORNL)

Tennesse, USA





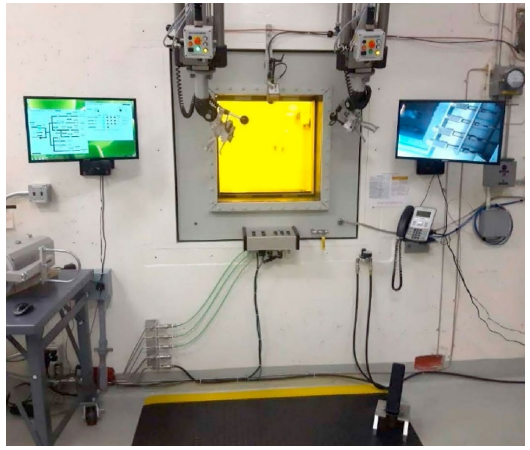


ISAC (Isotope Separator and Accelerator)

G. Minor, et al., Remote handling systems for the ISAC and ARIEL high-power fission and spallation ISOL target facilities at TRIUMF, Nucl. Eng. Technol. 53 (2021) 1378–1389. https://doi.org/10.1016/j.net.2020.09.024.

TRIUMF Canada's particle accelerator centre

Vancouver, CA



Summary

Topics:

- SPES as a new ISOL facility
- The Remote handling framework
- Comparison with other facilities

Main achievements

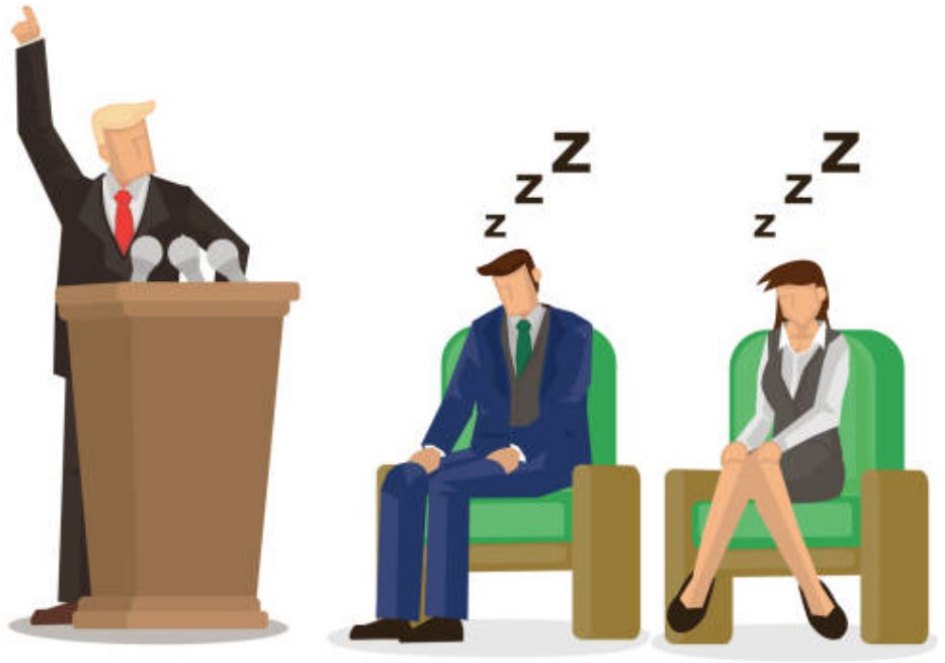
- Front-End installed, aligned, pre-commissioning done.
- Cabling and installations ongoing
- Remote handling systems commissioned off-line
- Integration ongoing

Future perspectives

Mid-term plan

- High-voltage commissioning
- Water cooling, Pneumatics, Vacuum, Heating commissioning
- Remote handling framework commissioning
- **First stable beam**
- **First RIB**


Any Questions?



Thank you!

Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI LEGNARO