

**MYRRHA phase 1
implementation**
MINERVA

High-purity radionuclides at ISOL@MYRRHA

Lucia Popescu (SCK CEN)

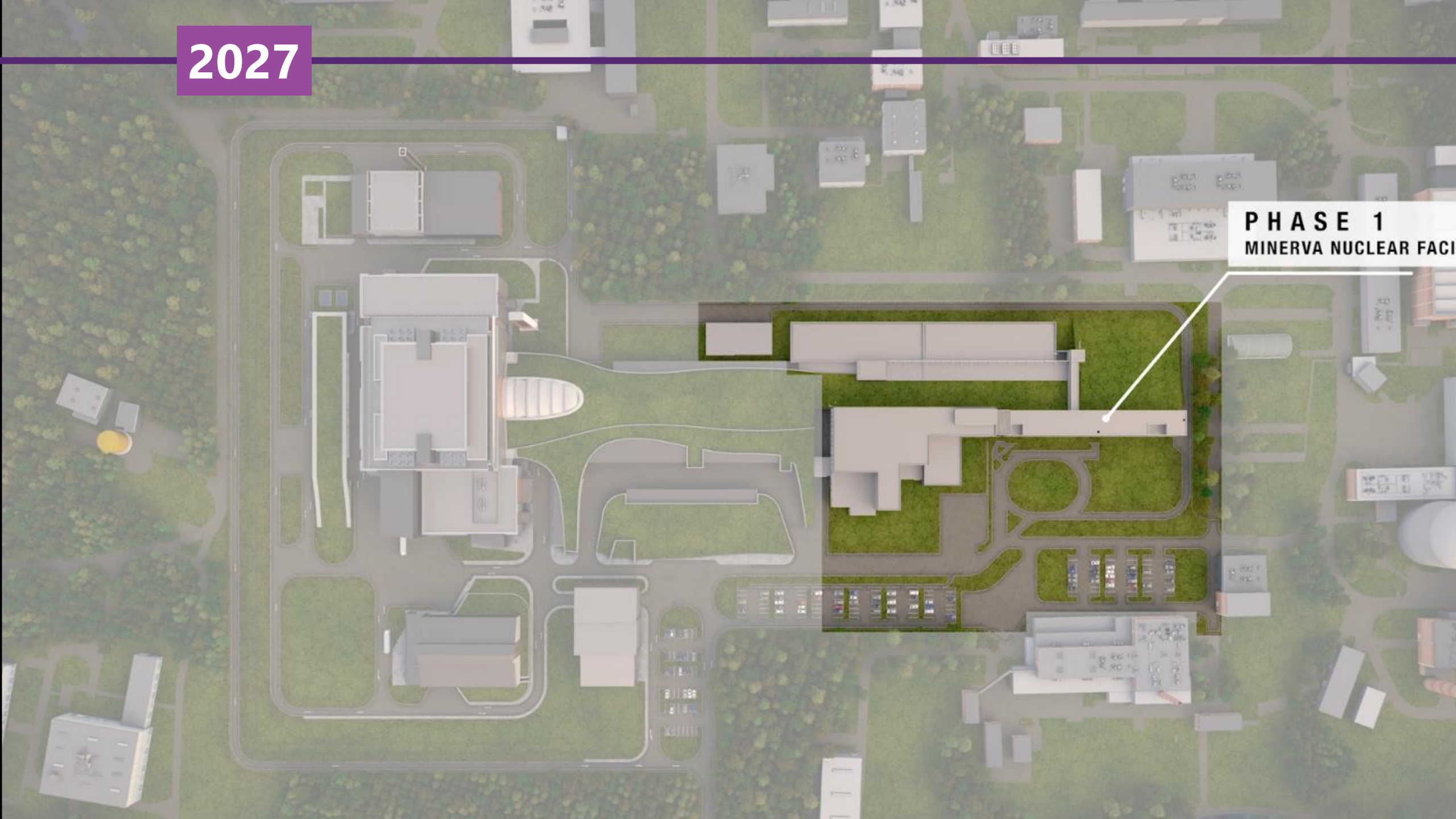
MYRRHA: Accelerator Driven System

- 600-MeV proton linac (2-4 μA , DC)
- Sub-critical reactor (fast n spectrum)
- Core coolant: molten PbBi = spallation target for generating n's



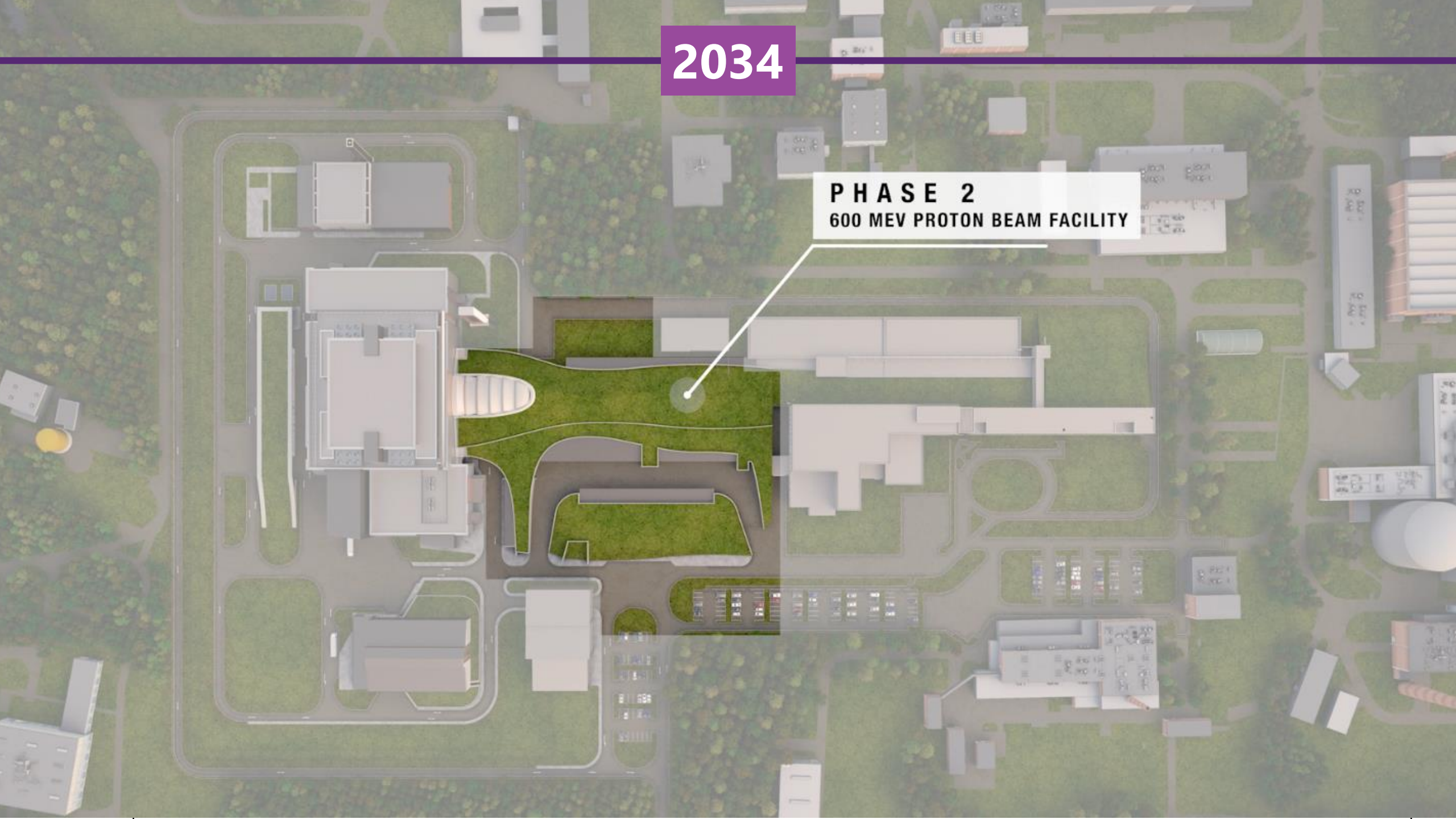
2027

PHASE 1
MINERVA NUCLEAR FACILITY



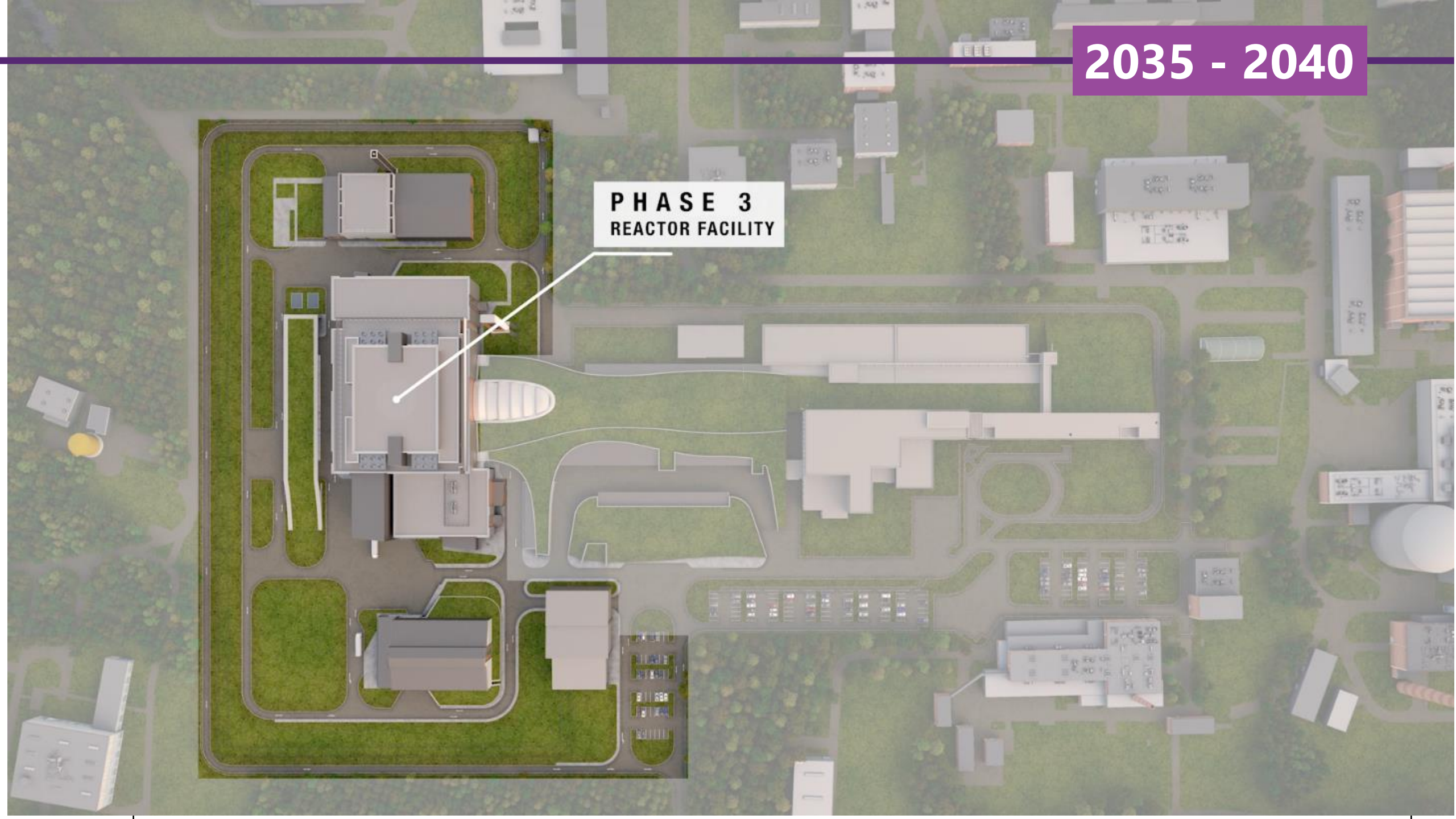
2034

PHASE 2
600 MEV PROTON BEAM FACILITY



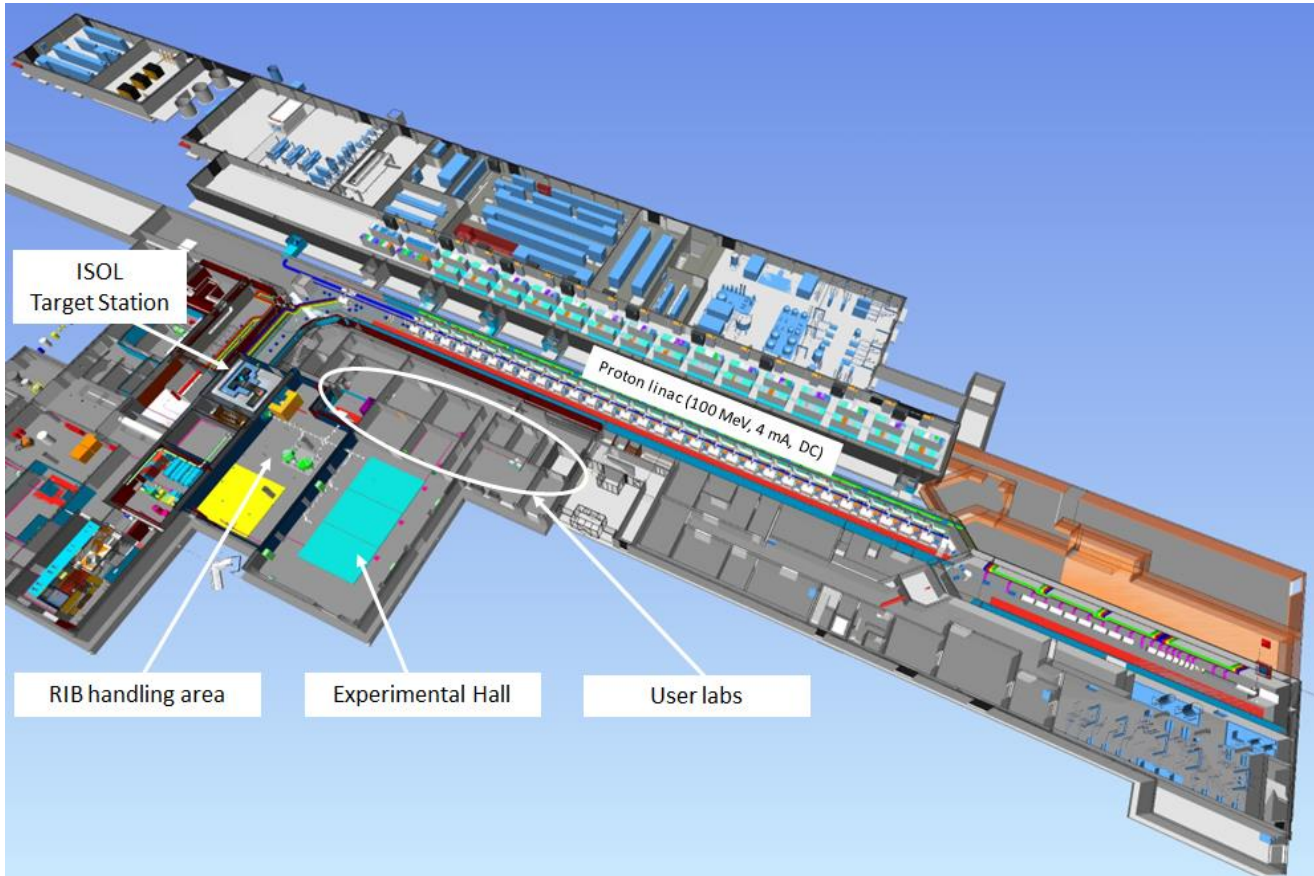
2035 - 2040

**PHASE 3
REACTOR FACILITY**

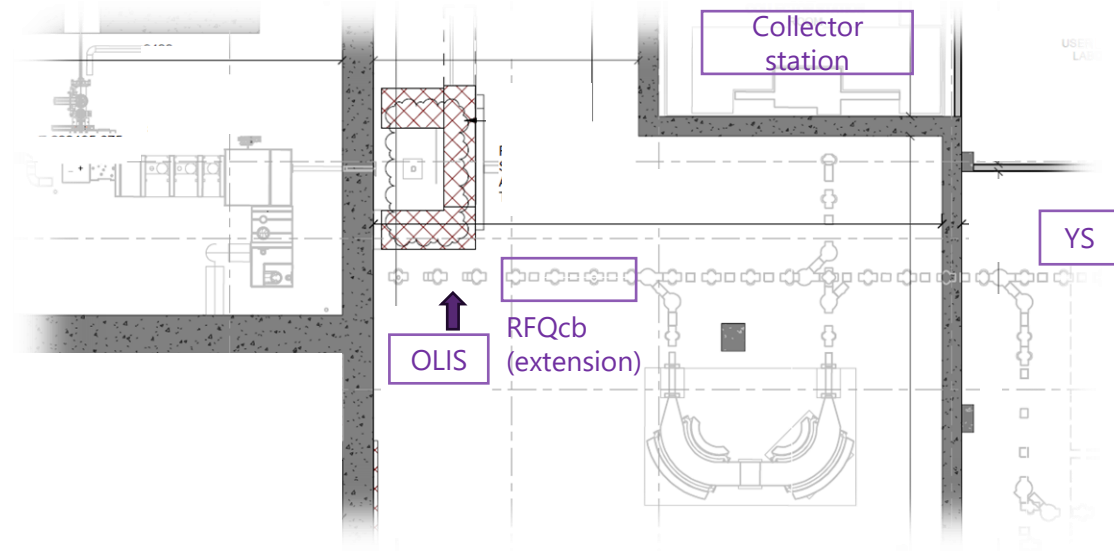


MYRRHA-phase1 (MINERVA) under construction -> ISOL@MYRRHA

- **ISOL Target Station** based on ARIEL/TRIUMF
 - Primary beam on target
 - 100 MeV, up to 500 μ A available
 - Up to 250 Hz pulse-repetition rate
 - Mass pre-separator ($M/\Delta M = 300$)



- **RIB handling area**
 - Electrostatic optics - modular design (TRIUMF)
 - Additional mass separator
 - initially $M/\Delta M = 1500$
 - ultimately $M/\Delta M = 10\,000$
 - Yield station – compact design from CERN
 - Offline ion source – surface ionization



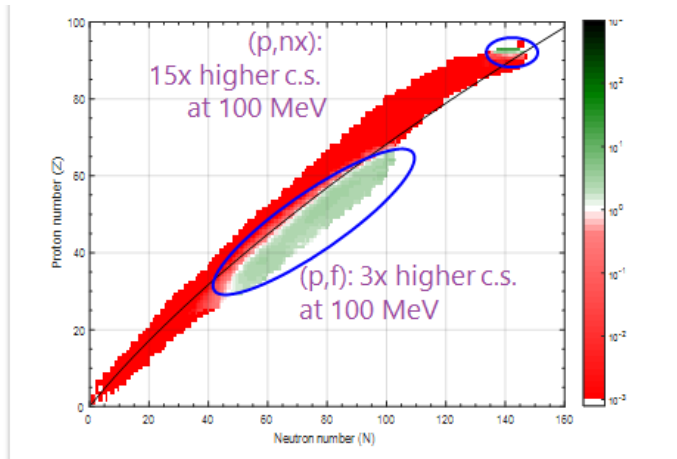
- **Experimental hall & User labs**

ISOL@MYRRHA RIBs

- Exploring the regions of the nuclear chart specific to “low” energy p-driver beams
- Main targets: UCx & ThCx
 - n-rich FF
 - (p,xn) products

Production in UCx target (Fluka results):

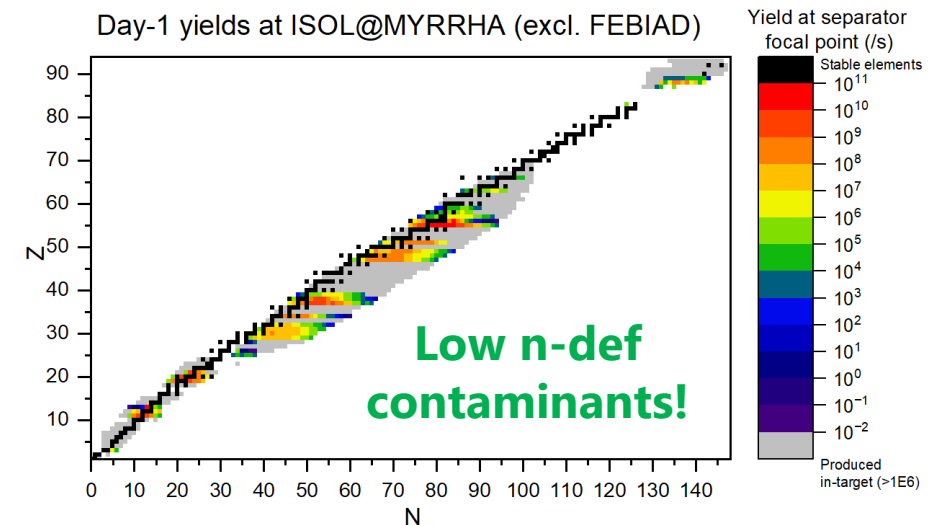
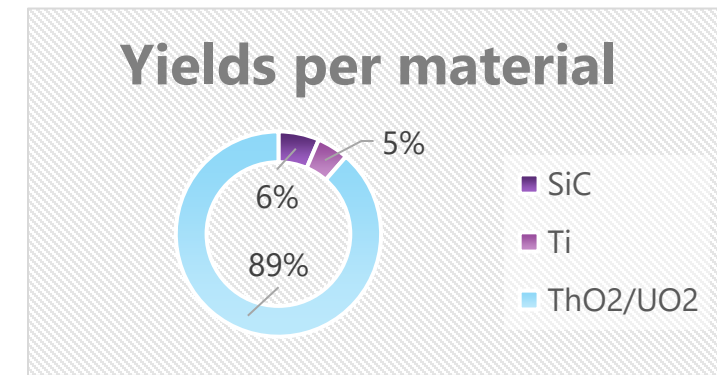
σ ratios
100MeV/1GeV



- Non-actinide targets
 - @100 MeV, spallation channel suppressed
=> limited sets of isotopes,
but with high purity

RIBs at start-up

- Day-1 (low power target):
 - Up to 15 μ A driver beam intensity
 - Non-pyrophoric target materials
 - Selected **surface** and **laser** ion sources





Complementarity with other ON-LINE facilities

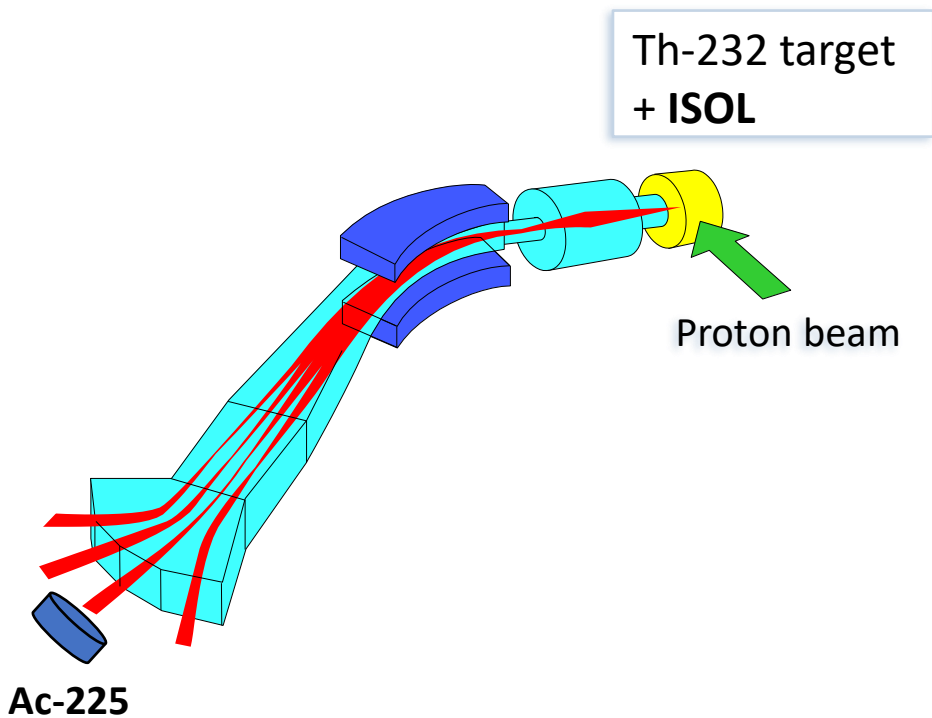
- Different spectrum of isotopes given different primary beam energies
- Finding the niche:
 - Programs requiring extended beam times
 - Fundamental interactions
 - Laser spectroscopy
 - SSP, medical isotopes
 - ...
 - Adapting operation approach to user needs

Medical applications – requirements:

- Reliable schedule
- Extended operation enabling pre-clinical studies
- Additional off-line separator next to the on-line facility
- Accurate characterization of the sample

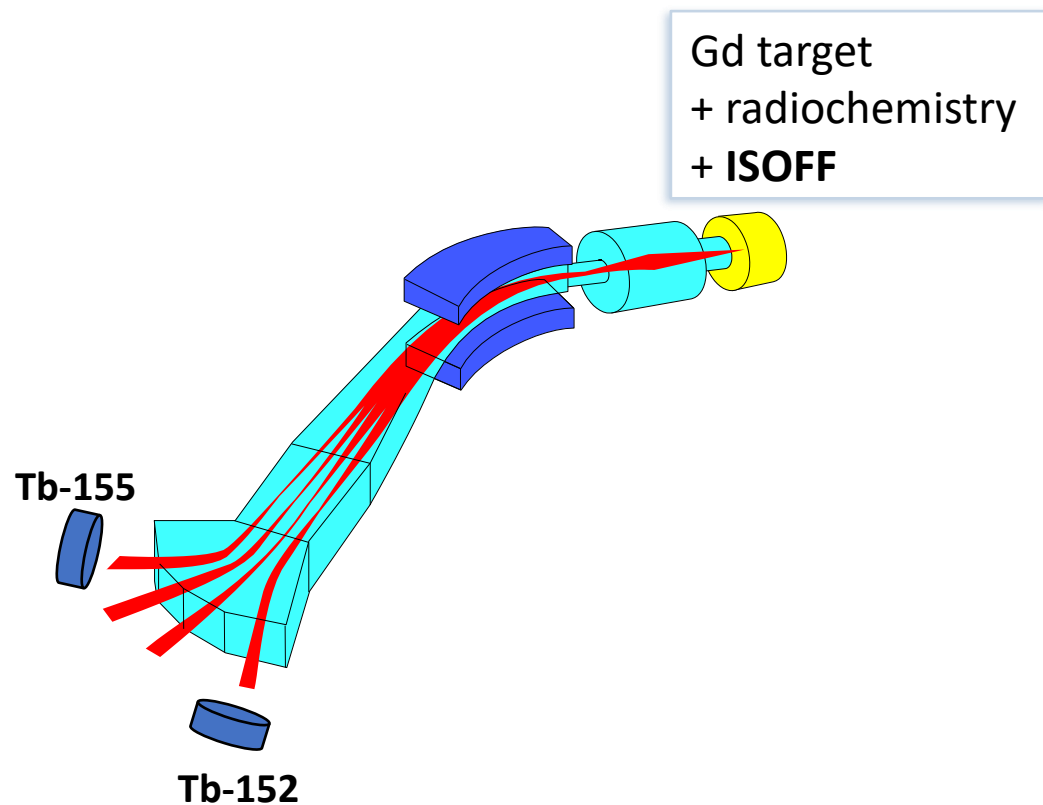
e.g. Production of Ac isotopes

- Proton-irradiation of ^{nat}Th targets + ISOL
- Production of samples with high isotopic purity



e.g. Production of Tb isotopes

- Proton-irradiation of Gd targets at MYRRHA
100-MeV p-beam
+ chemical purification
+ isotope separation off-line



Production of high specific activity ^{153}Sm

Today developments (multi-site)

sck cen



Irradiation of ^{152}Sm at BR2

Specific Activity: 7.03 GBq/mg



MEDICIS KU LEUVEN



Mass separation at CERN-MEDICIS



sck cen



Radiochemical purification of ^{153}Sm

Specific Activity: 1.5 TBq/mg

Envisaged in the future (single-site)

sck cen



Irradiation of ^{152}Sm at BR2



sck cen



Mass separation at ISOL@MYRRHA (off-line)



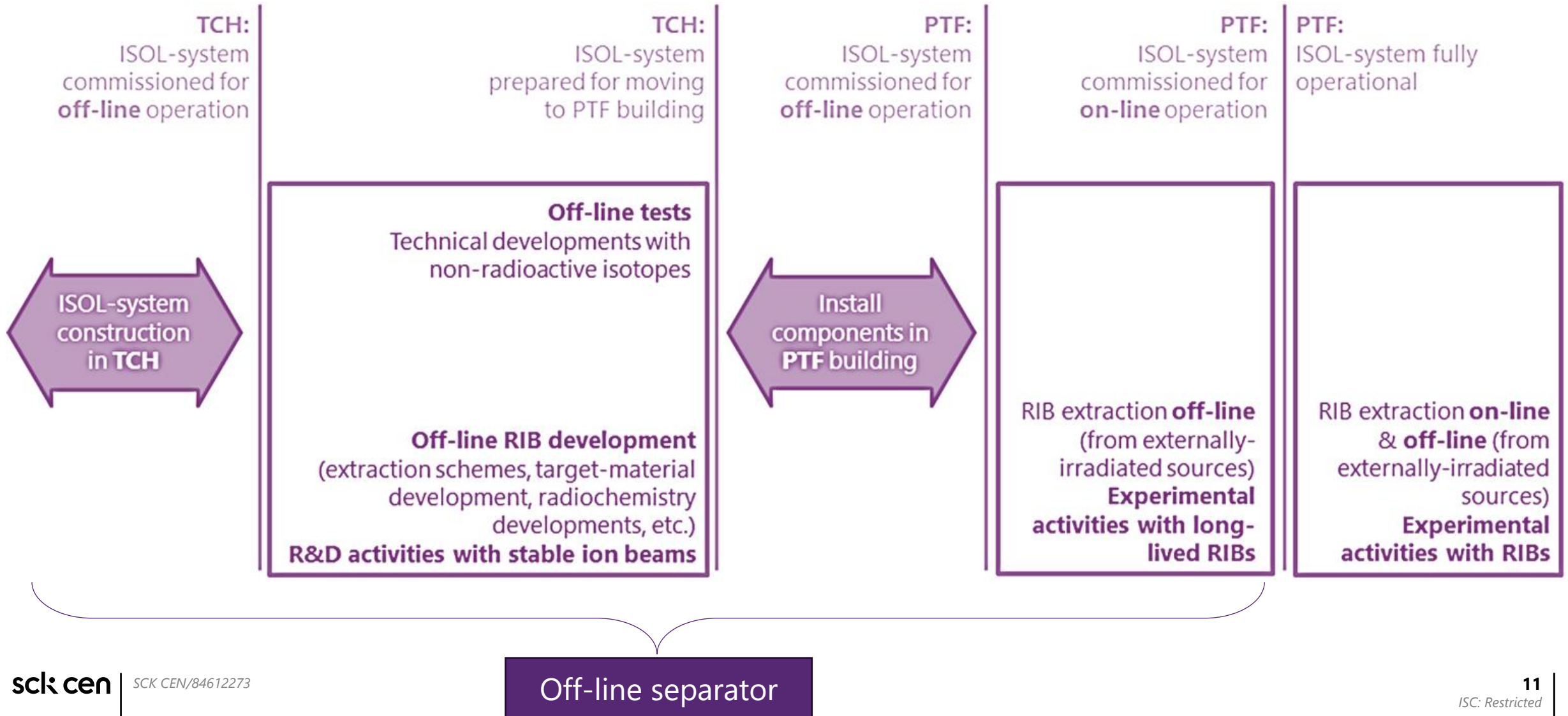
sck cen



Radiochemical purification (&, if interest from end-users, radiopharmaceutical development)

Eliminating decay-losses during transportation

Implementation of ISOL@MYRRHA scientific programme



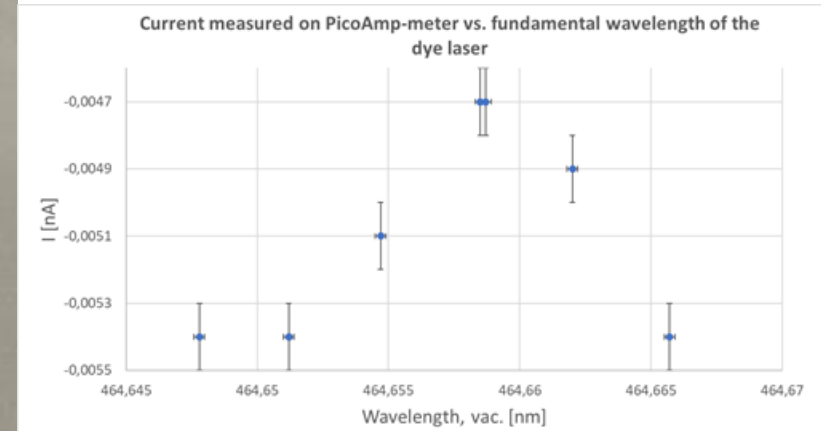
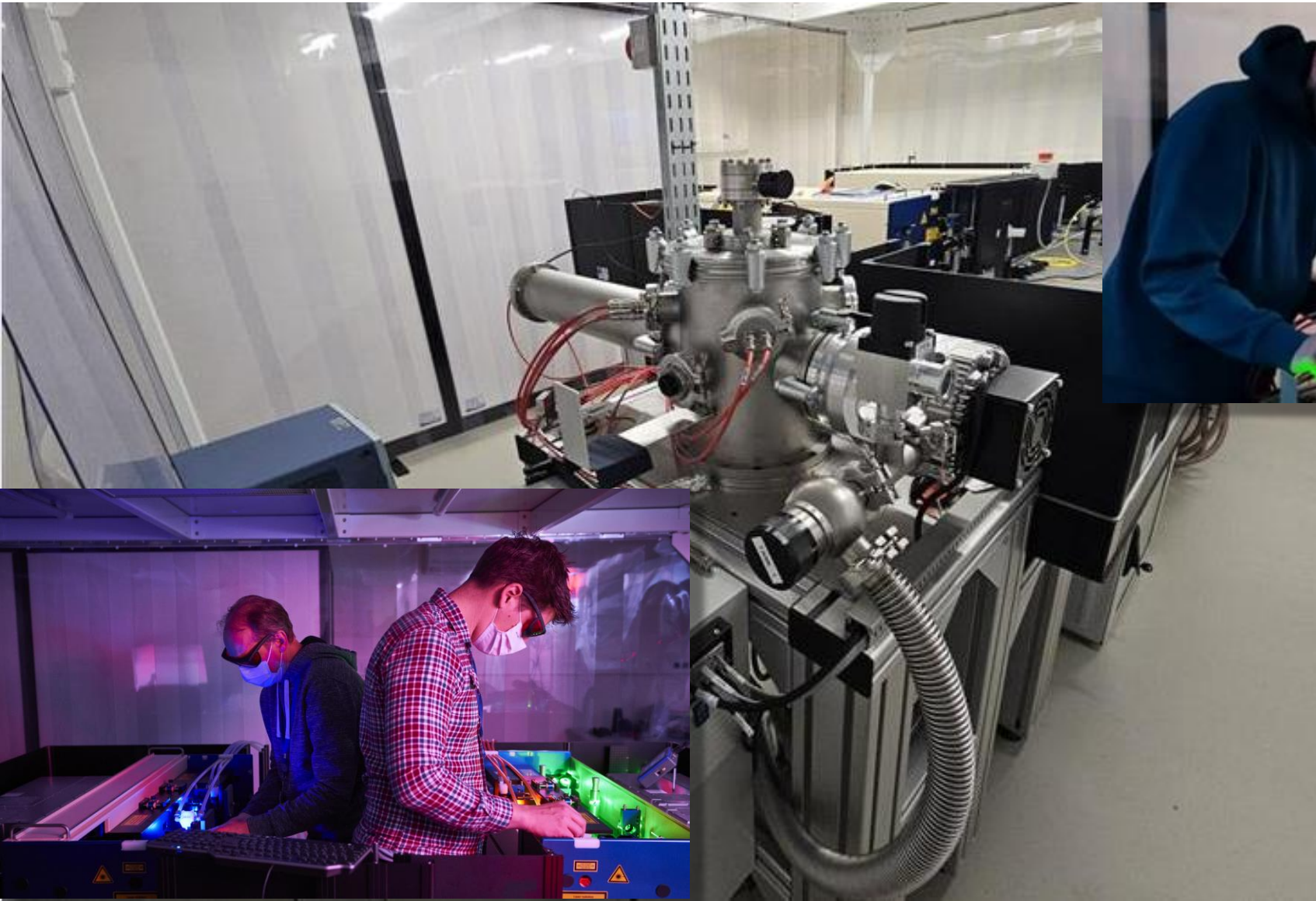
ISOL@MYRRHA off-line separator at SCK CEN



Under commissioning

Isotopes collector system






ISOL@MYRRHA laser laboratory at SCK CEN











Off-line developments @ ABU

Radionuclides production R&D

Ongoing PhD research

- High-intensity ISOL@MYRRHA ion source for long-term irradiation

- On-line optimization of I@M performance through an intelligent and automated control system

- Development of a Th-based target for the production and release of Ac-225 at I@M

- First generation targets for the I@M (SiC and Ti targets)

- Laser-ionized Radioactive Ion Beams at Day1 of I@M


Current research through Master thesis:

- Sahinidis Matthieu, *Modeling and optimization of an ion source heating system*, EPF – Engineering School (Montpellier, France)

- Alberto Gil Cordero, *Tuning of ThO₂ target materials properties towards highly porous structure to produce radioisotopes for medical applications*, Universidad Politécnica de Madrid (Spain)

- Serdar Yildiz, *Heat load and inventory simulation of the proton-beam Halo-Monitor at ISOL@MYRRHA under different scenarios*, Vrije Universiteit Brussel (Belgium)

- Flavia Guidubaldi, *Oxidation studies of un-irradiated and irradiated UCx targets for ISOL@MYRRHA*, Università di Bologna (Italy)

- New topics:
 - Synthesis and characterisation of highly porous zirconium carbide ceramics, collab. KU Leuven (Belgium)

 - Development of I@M yields database, collab. Universidad Politécnica de Madrid (Spain)
 - UOx target development, Universidad Politécnica de Madrid (Spain)

 - Carbon source assessment for ISOL ThCx target materials, Universidad Politécnica de Madrid (Spain)



Active Project-Collaborations



High-intensity ISOL ion source for long-term irradiations



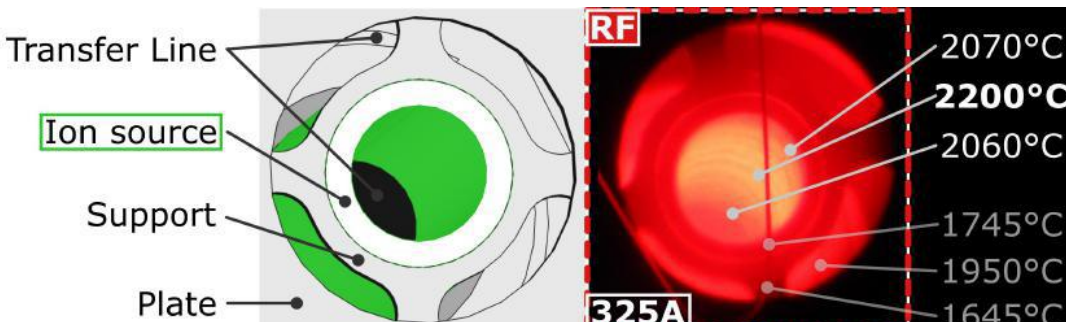
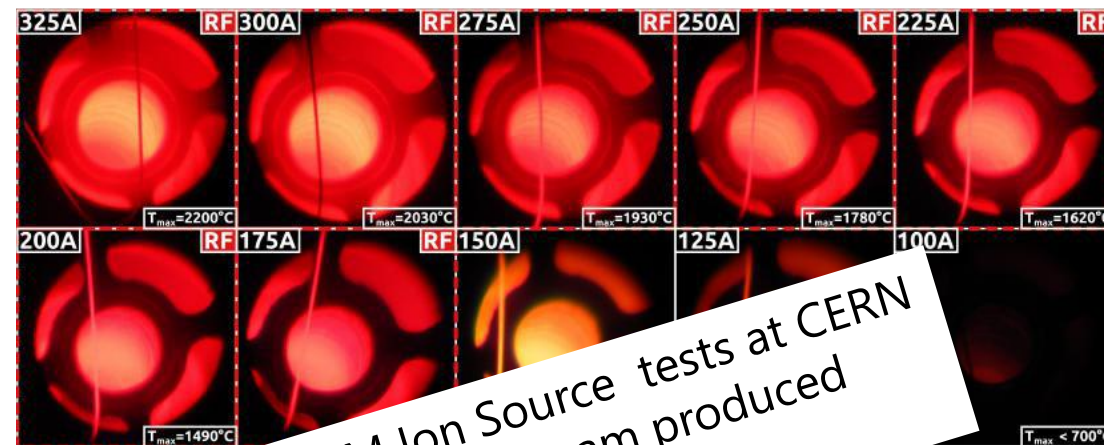
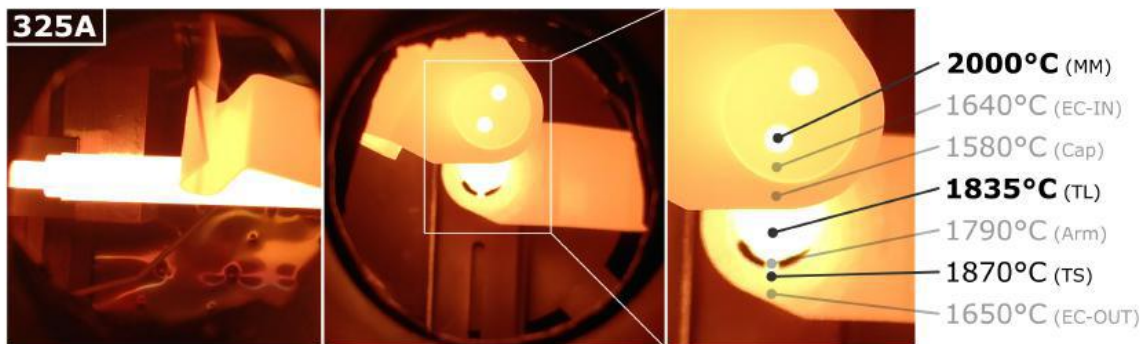
Final assembly preparation & testing made at CERN



Systematic, comparative study

- I@M Ion Source
- SPES Ion Source
- CERN Ion Source

Tested under the same conditions at ISOLDE OffLine2

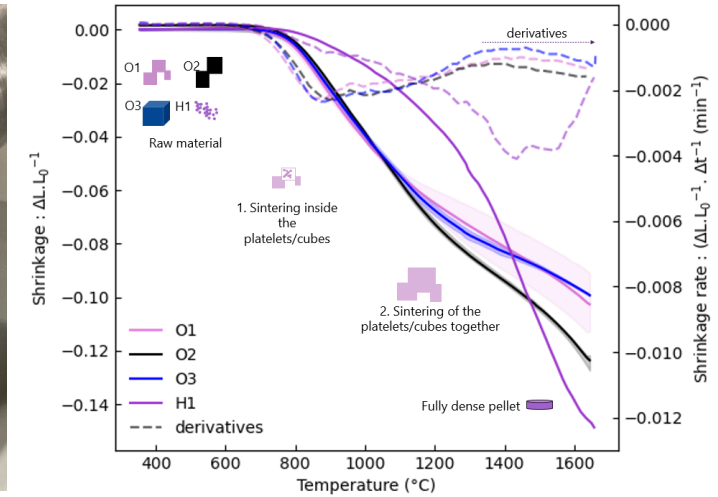
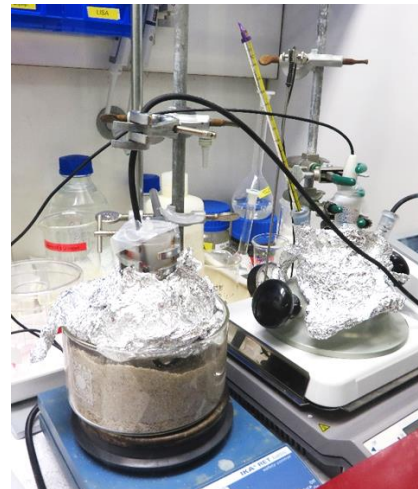
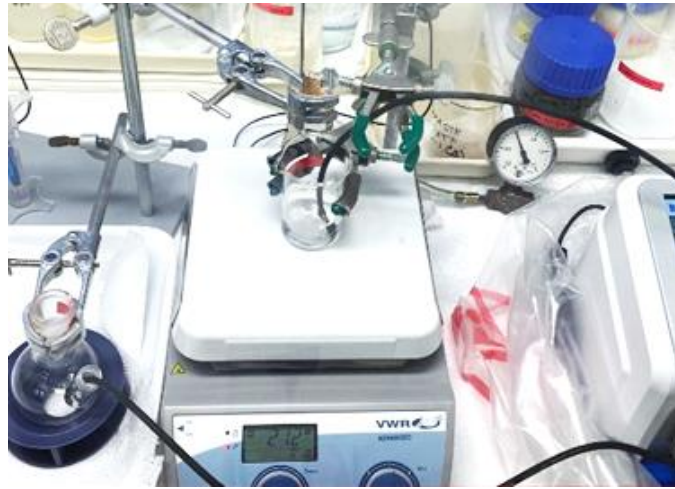


I@M Ion Source tests at CERN

- First Sm beam produced
- Robust design

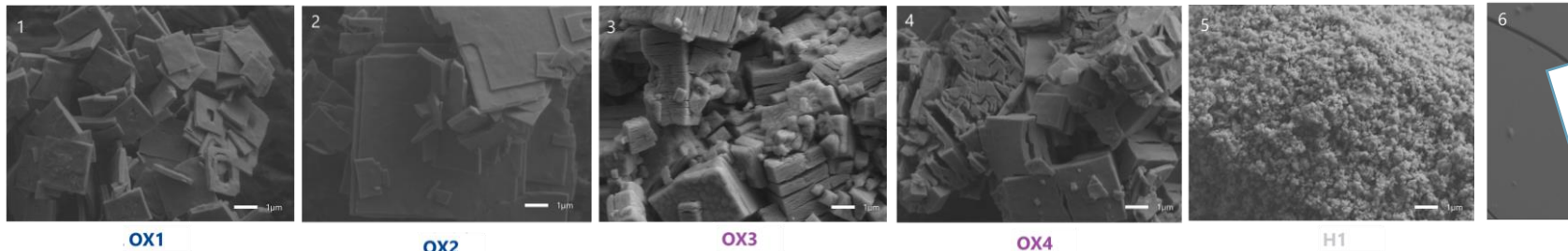
Development of a Th-based target for the production and release of ^{225}Ac

Synthesis, characterization and sintering tests of ThO_2 in the Fuel Material Group Laboratories at SCK CEN



Conversion to ThC_x to be done in collaboration with CERN in their laboratories

ThO₂ mixed with pore formers to enhance porosity

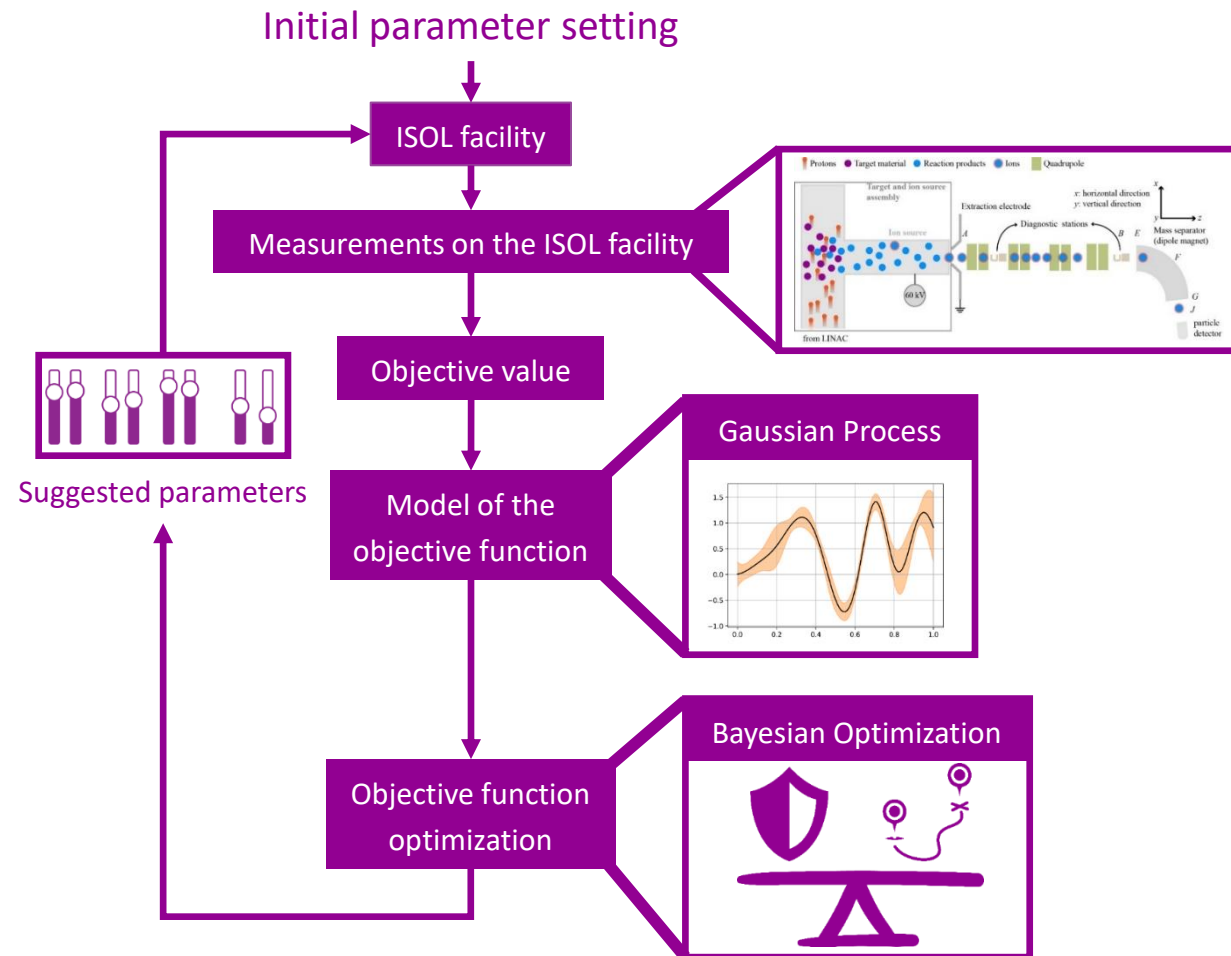


This year (October): Student traveling to CERN to test ThO₂ produced with poreformers at 2000 °C

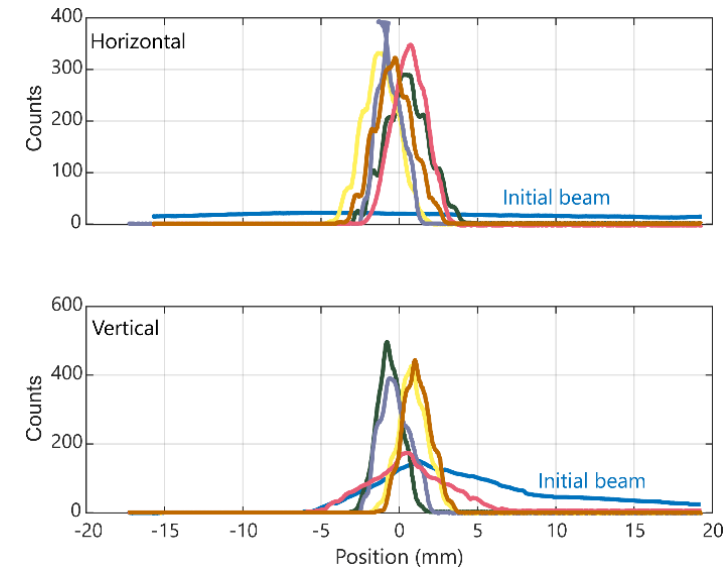
Followed by release studies/prototype target testing at MEDICIS or ISOLDE



On-line optimization of ISOL@MYRRHA performance through an intelligent and automated control system








First verification tests done in collaboration with CERN at the OFFLINE 2 setup











Radionuclides production R&D

Ongoing PhD research

- High-intensity ISOL@MYRRHA ion source for long-term irradiation

- On-line optimization of I@M performance through an intelligent and automated control system

- Development of a Th-based target for the production and release of Ac-225 at I@M

- First generation targets for the I@M (SiC and Ti targets)

- Laser-ionized Radioactive Ion Beams at Day1 of I@M


Current research through Master thesis:

- Sahinidis Matthieu, *Modeling and optimization of an ion source heating system*, EPF – Engineering School (Montpellier, France)

- Alberto Gil Cordero, *Tuning of ThO₂ target materials properties towards highly porous structure to produce radioisotopes for medical applications*, Universidad Politécnica de Madrid (Spain)

- Serdar Yildiz, *Heat load and inventory simulation of the proton-beam Halo-Monitor at ISOL@MYRRHA under different scenarios*, Vrije Universiteit Brussel (Belgium)

- Flavia Guidubaldi, *Oxidation studies of un-irradiated and irradiated UCx targets for ISOL@MYRRHA*, Università di Bologna (Italy)

- New topics:
 - Synthesis and characterisation of highly porous zirconium carbide ceramics, collab. KU Leuven (Belgium)

 - Development of I@M yields database, collab. Universidad Politécnica de Madrid (Spain)
 - UOx target development, Universidad Politécnica de Madrid (Spain)

 - Carbon source assessment for ISOL ThCx target materials, Universidad Politécnica de Madrid (Spain)



Active Project-Collaborations



Copyright © SCK CEN

All property rights and copyright are reserved.

This presentation contains data, information and formats for dedicated use only and may not be communicated, copied, reproduced, distributed or cited without the explicit written permission of SCK CEN.

If this explicit written permission has been obtained, please reference the author, followed by 'by courtesy of SCK CEN'.

Any infringement to this rule is illegal and entitles to claim damages from the infringer, without prejudice to any other right in case of granting a patent or registration in the field of intellectual property.

SCK CEN

Belgian Nuclear Research Centre
Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire

Foundation of Public Utility
Stichting van Openbaar Nut
Fondation d'Utilité Publique

Registered Office:

Avenue Herrmann-Debrouxlaan 40 - 1160 BRUSSELS - Belgium

Research Centres:

Boeretang 200 - 2400 MOL - Belgium
Chemin du Cyclotron 6 - 1348 Ottignies-Louvain-la-Neuve - Belgium

Thermal- and isotope-release test stands (for target-ion-source developments)

