MYRRHA phase 1 implementation

MINERVA

sck cen

Belgian Nuclear Research Centre

Medical Isotopes at ISOL@MYRRHA and SCK CEN

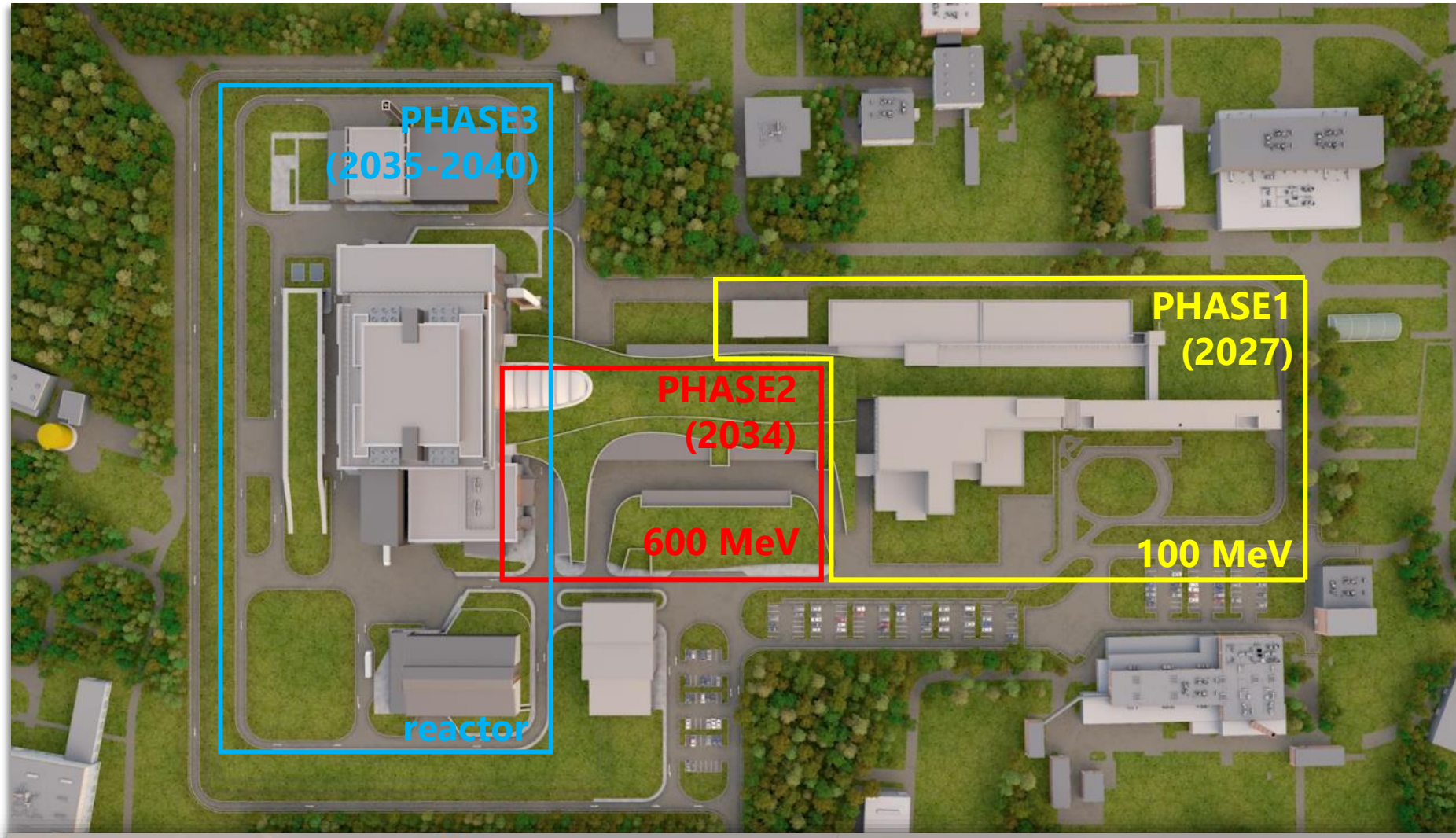
Lucia Popescu

SCK CEN

MYRRHA: Accelator Driven System

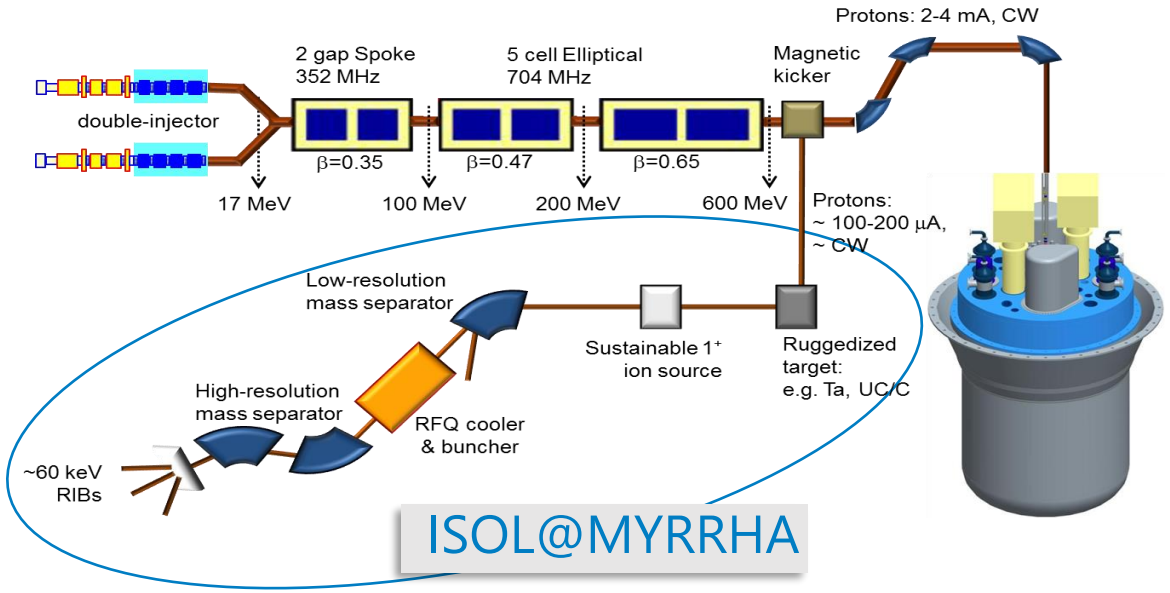
- 600 MeV p-linac; 2-4 mA DC
- PbBi spallation target
- Sub-critical reactor core

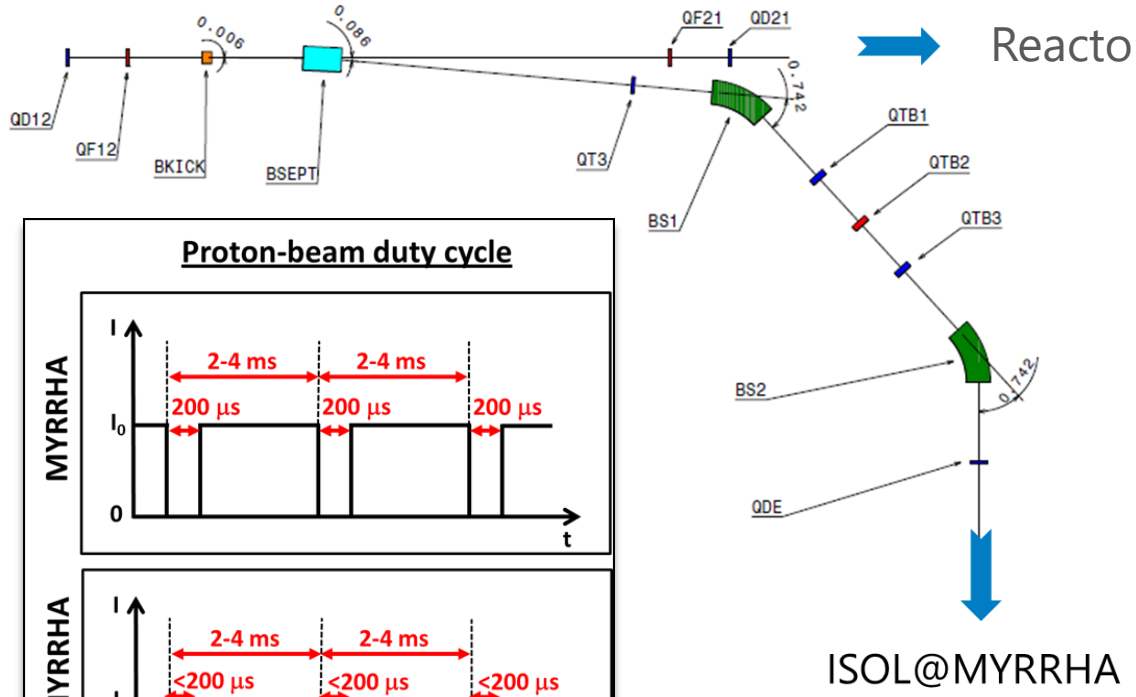
+ Target facilities



ISOL@MYRRHA: an ISOL facility at the MYRRHA accelerator

- **2007-2017** Concept and Scientific Cases developed within BriX
  The **B**elgian research **i**nitiative on e**X**otic nuclei for atomic, nuclear and astrophysics studies



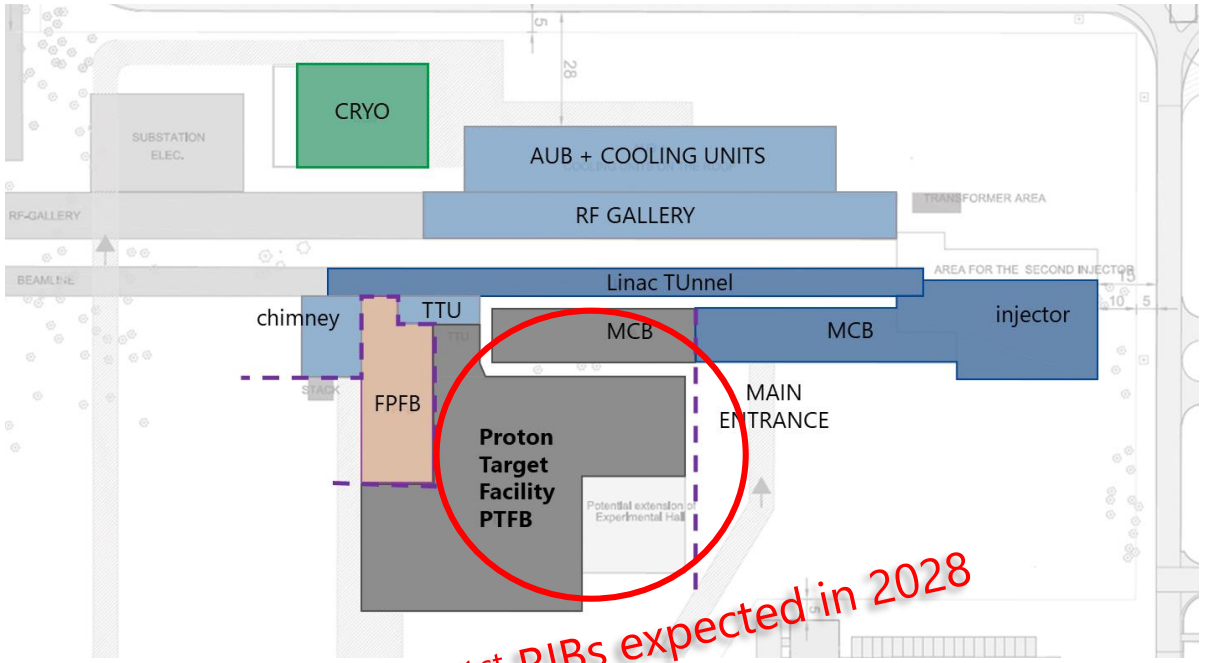


- 4 mA CW p-beam: parallel operation I@M & reactor
  - duty cycle (time structure: 250 Hz)
  - *extraction* from main linac beam
    → kicker/septum layout (safety through limiting stored energy in kicker PS)

ISOL@MYRRHA: an ISOL facility at the MYRRHA accelerator

- 2018 decision to include ISOL in MYRRHA phase 1 (MINERVA)
- Two target facilities:
  - Full Power Facility – FPF (100 MeV protons, 2-4 mA)
    - full-power beam dump + irradiation facility for fusion materials research
  - Proton Target Facility – PTF (100 MeV protons, up to 0.5 mA)
    - ISOL@MYRRHA

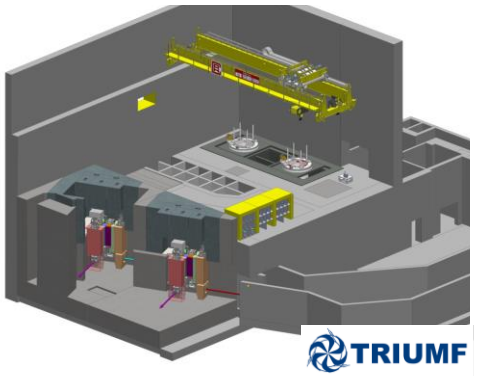
ISOL@MYRRHA
Implemented at the **Proton Target Facility**

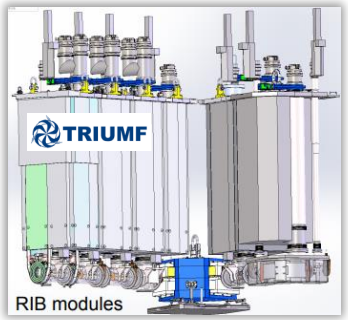


ISOL@MYRRHA installation in PTF

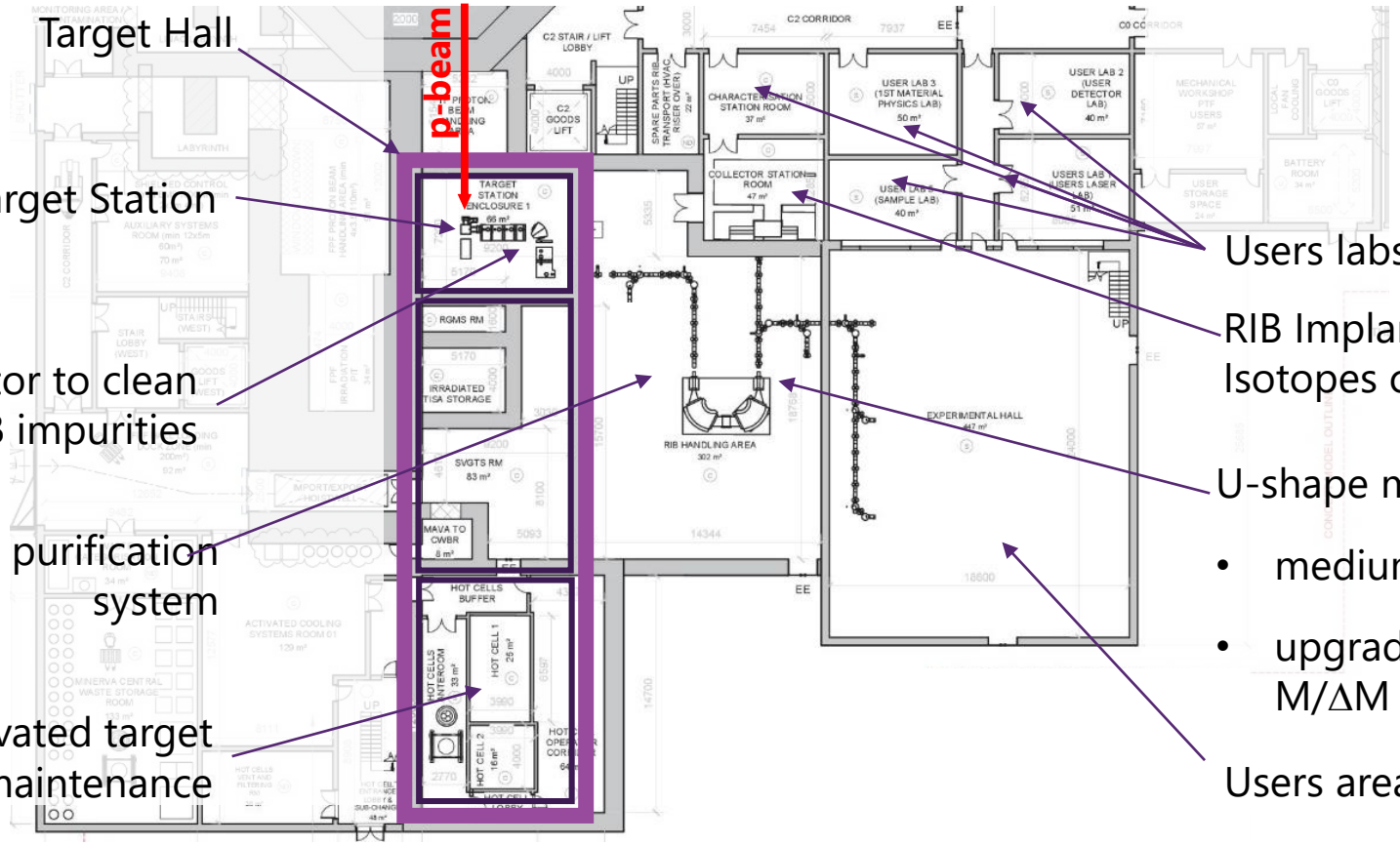
- TRIUMF-ARIEL concept at the basis of the facility design

ARIEL target hall infrastructures





ISOL@MYRRHA in Proton Target Facility



Target Hall

Target Station

90° pre-separator to clean most RIB impurities

RIB-handling and purification system

Hot Cells for activated target handling and maintenance

Users labs

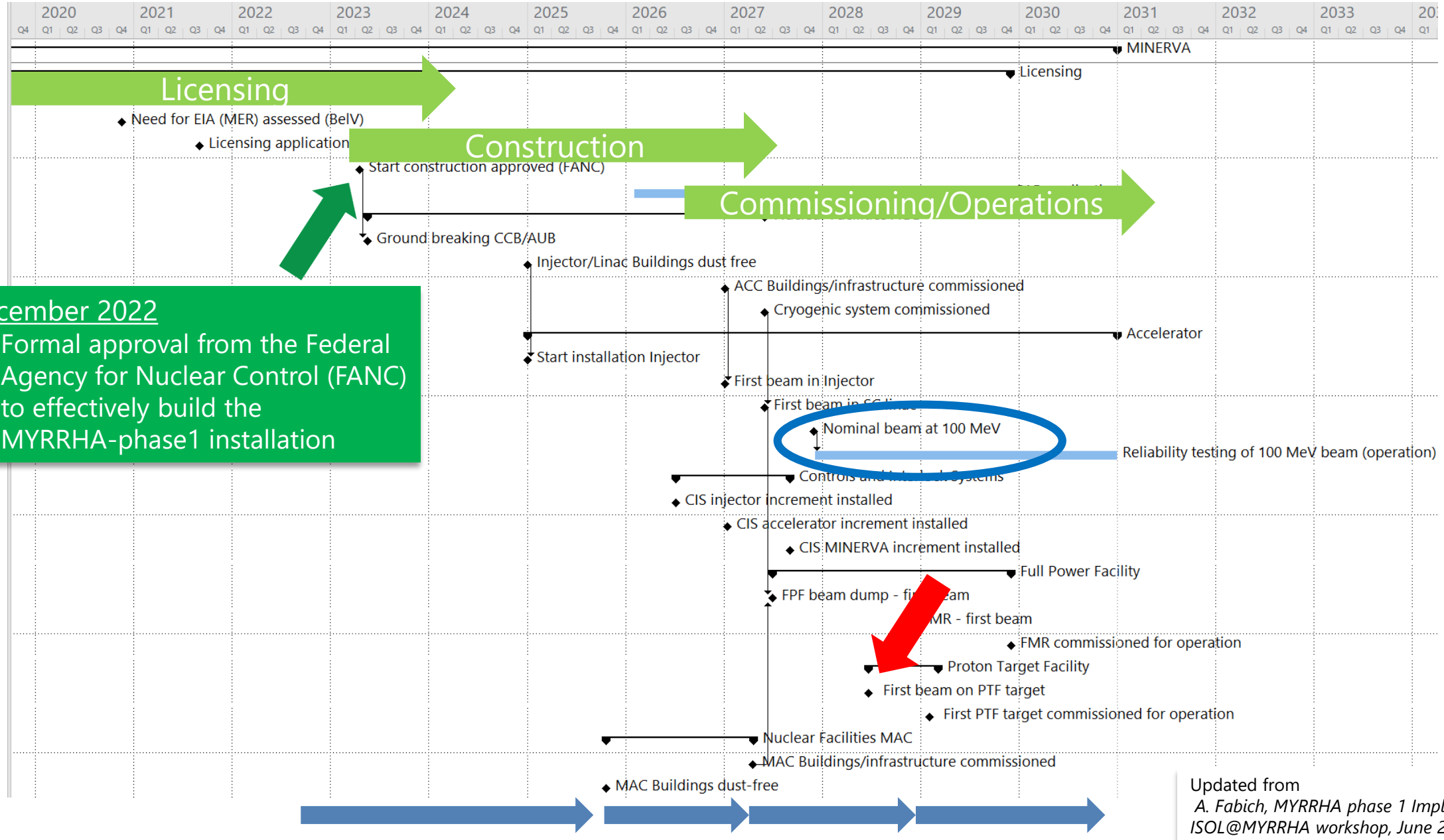
RIB Implantation (SSP) & Isotopes collector station

U-shape mass separator (ARIEL-concept)

- medium-resolution (M/ΔM~1 500)
- upgrade towards M/ΔM ~10 000 – 20 000

Users area (Experimental Hall - extendable)

Planning (ref June 2022)



December 2022

✓ Formal approval from the Federal Agency for Nuclear Control (FANC) to effectively build the MYRRHA-phase1 installation

ISOL System: Design & construction | Installation | Commissioning | RIBs to users

Updated from
A. Fabich, MYRRHA phase 1 Implementation, ISOL@MYRRHA workshop, June 2022

ISOL@MYRRHA Applications

Fundamental research

Connected to NuPECC community
- MYRRHA - member of NuPECC since 2019

Medical Applications

Connected to important consortia
- Tb-IRMA-V consortium
- PRISMAP consortium
- …

Solid-state physics and Biology

Community approached

Fundamental interactions
- Value of V_ud CKM-matrix element
- Possible presence of RH, S or T weak currents; weak magnetism; gA
- Search for T/CP violation
- Search for Atomic Parity violation
- …

Nuclear structure
- High-resolution experiments
  e.g. Octupole moments in light isotopes
- Radioactive molecules (as means to answering key questions)
  e.g. Q moments not accessible in the atom/ion
- …

Production of innovative medical isotopes
- Alpha- emitters
  - Ac-225
  - Tb-149
  - …
- Beta and gamma-emitters
- Theranostic pairs
  - E.g. Tb-149,152,155

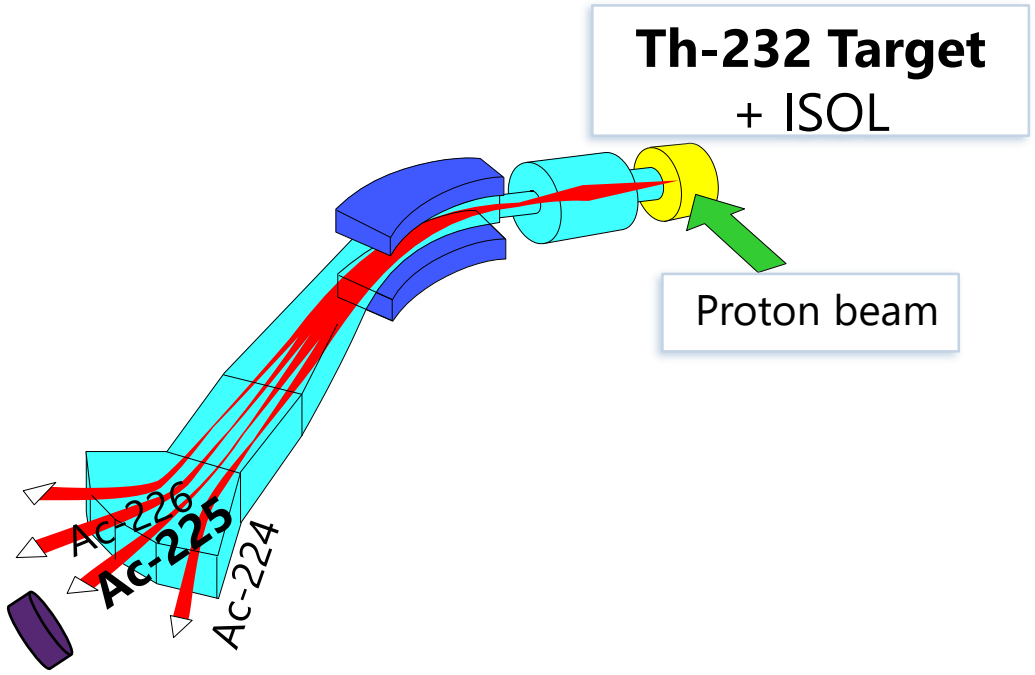
…

Studied for innovative materials development
- β-NMR
- PAC
- Emission channeling,
- Diffusion studies
- Positron beams from β^+ emitters

…

Examples of applications which can be implemented at ISOL@MYRRHA

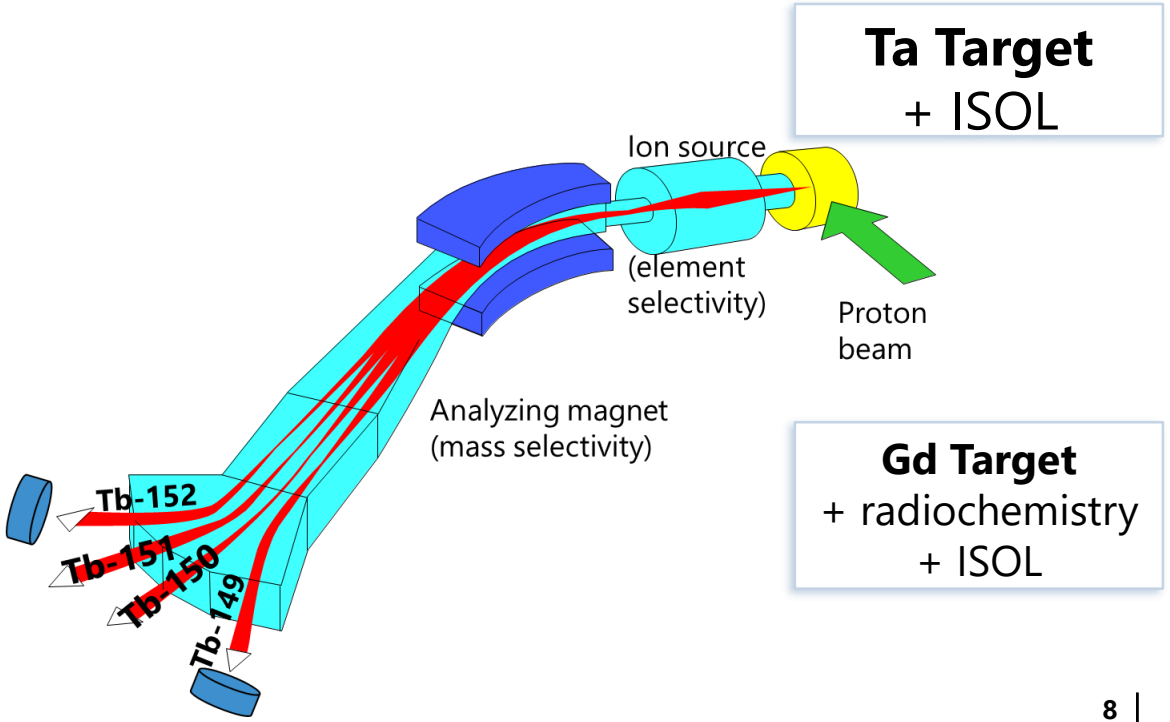
e.g. Production of Ac isotopes



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

e.g. Production of Tb isotopes

- Proton-irradiation of Ta targets + ISOL (at high p-energies)
- Alternative for 100-MeV protons: Gd Target + radiochemistry + ISOL (off-line) ^{152,155}Tb



Production of high specific activity Sm-153

Medical Isotopes

Today developments (multi-site)

Irradiation of ^{152}Sm at BR2

Specific Activity: 7.03 GBq/mg

Mass separation at CERN-MEDICIS

Radiochemical purification of ^{153}Sm

Specific Activity: 1.5 TBq/mg

Envisaged in the future (single-site)

Eliminating decay-losses during transportation

Irradiation of ^{152}Sm at BR2

Mass separation at ISOL@MYRRHA (off-line)

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

Key infrastructure & Expertise

BR2 & MYRRHA

Irradiation facility

Radiobiology

Radiochemistry

Dosimetry

NURA programme: a structure dedicated to radiopharmaceutical research and GMP production of therapeutic radionuclides; Nuclear Medical Applications (**NMA**) institute created in **2023**.

Other facilities coming up

HAF

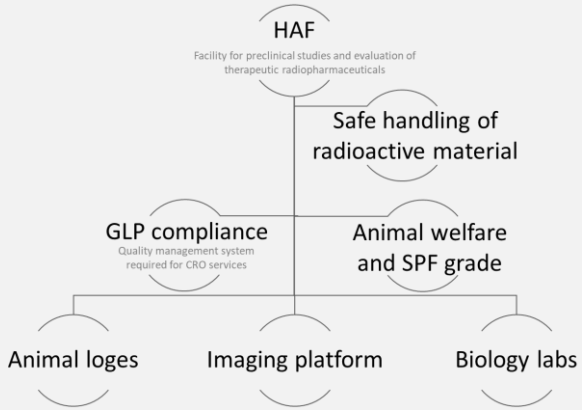
CRF

Pantera

Partnership with IBA

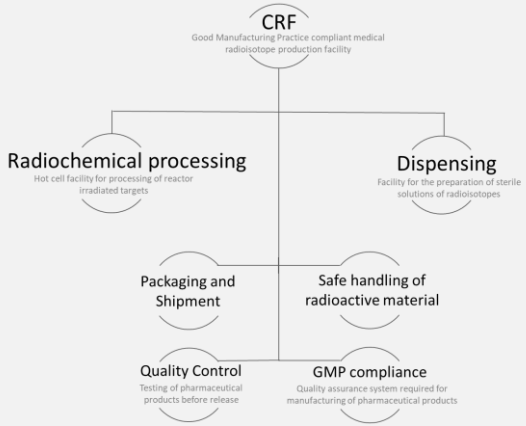
Hot Animal Facility
(2023)

Animal facility for pre-clinical evaluation of radiopharmaceuticals



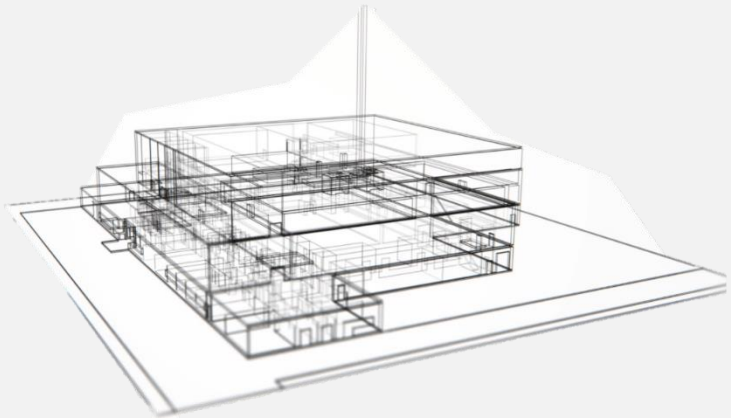
Centralized Radiochemistry Facility
(2026)

GMP radioisotope facility



Pantera
(2028)

Actinium production facility



Which therapeutic radio-isotopes includes our current portfolio?

^{177}Lu	^{161}Tb	^{225}Ac	^{153}Sm	^{188}Re
Lutetium-177	Terbium-161	Actinium-225	Samarium-153	Rhenium-188

+ R&D isotopes (see e.g. PRISMAP – Thierry Stora)

Recent Partnerships – from SCK CEN News

https://www.sckcen.be/en/news

PanTera and TerraPower Isotopes join forces to accelerate access to actinium-225

26 June '23

Strategic collaboration signed to support the development of radiopharmaceuticals in the fight against cancer

The Netherlands and Belgium stand shoulder to shoulder against cancer

14 June '23

Teamwork accelerates development of promising cancer treatment with Terbium-161

The United States and Belgium partner to accelerate the fight against cancer

26 May '23

SpectronRx will open its first European facility on SCK CEN's premises

IRE and SCK CEN Partnership on lutetium-177 production: a ray of hope for prostate cancer treatment

13 February '20

Radioisotope Production at SNS (RIPS) Workshop

September 27-28

Oak Ridge National Laboratory

Workshop Objectives:

1) **Define some unique, desirable radioisotopes that can be produced using high-energy protons incident upon various spallation targets.**
2) **Determine how we can effectively isolate/separate the desired radionuclide(s).**
   a) On-line mass separation?
   b) Bulk post-irradiation chemical and mass separation?
3) **Identify the most challenging technological implementations and roadblocks.**
   a) What are the target technology limitations?
   b) What is the target technical readiness?
   c) What target materials would be interesting in terms of production with either protons or neutrons and post-irradiation handling?
4) **Consider the regulatory aspects/challenges of adding isotope production to a facility (SNS) regulated by the Accelerator order.**

Isotopes @ 1 GeV: see MEDICIS

Separation method: Well formulated goal needed:

- R&D isotopes?
- Commercial?

Various challenges

- Target (facility) technology
- Radiochemistry
- Licensing
- Collaborations/partnerships

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SCK CEN
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Implementation of ISOL@MYRRHA scientific programme

TCH: ISOL-system commissioned for **off-line** operation

ISOL-system construction in **TCH**

TCH: ISOL-system prepared for moving to PTF building

Off-line tests
Technical developments with non-radioactive isotopes

Off-line RIB development
(extraction schemes, target-material development, radiochemistry developments, etc.)
R&D activities with stable ion beams

Install components in **PTF** building

PTF: ISOL-system commissioned for **off-line** operation

PTF: ISOL-system commissioned for **on-line** operation

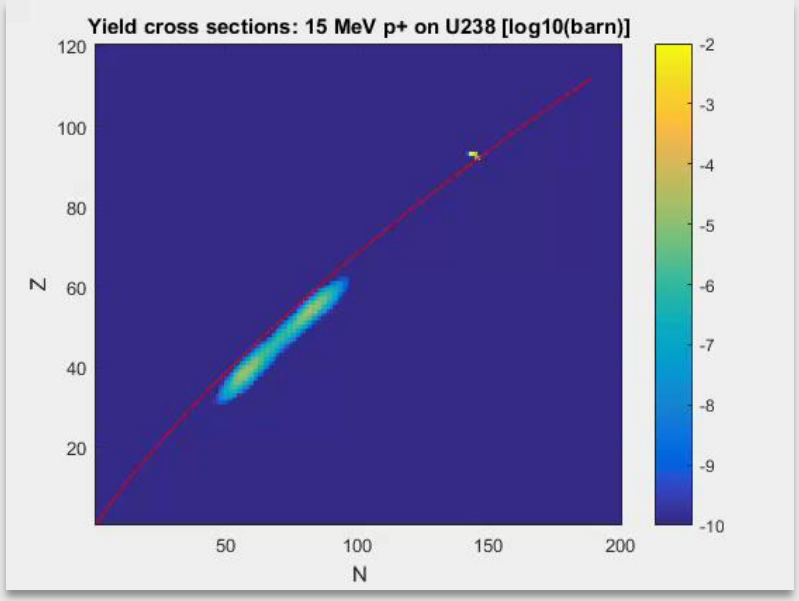
RIB extraction **off-line** (from externally-irradiated sources)
Experimental activities with long-lived RIBs

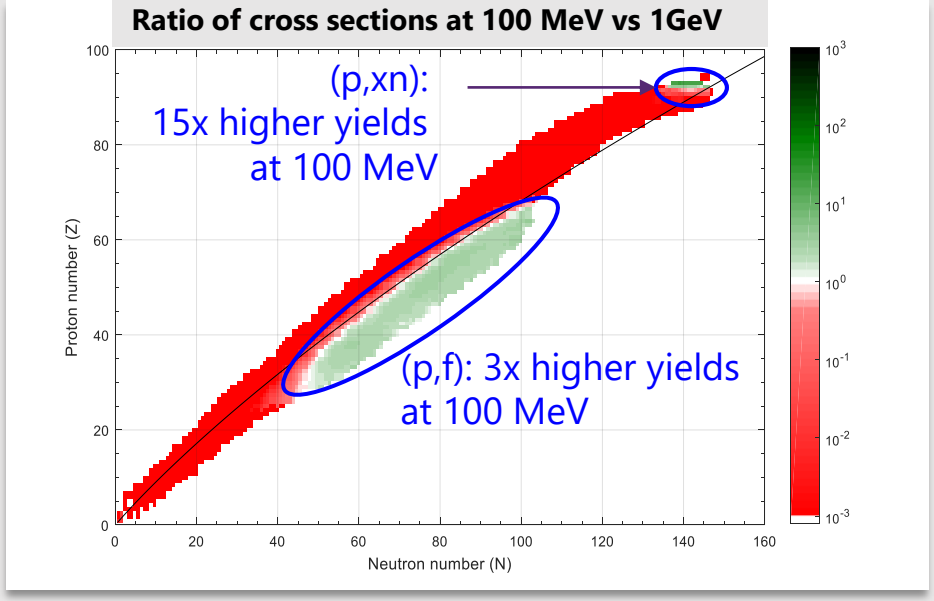
PTF: ISOL-system fully operational

RIB extraction **on-line** & **off-line** (from externally-irradiated sources)
Experimental activities with RIBs

RIBs at ISOL@MYRRHA

- ISOL@MYRRHA yields assessment - exercise is ongoing
  - E.g. FLUKA simulations for isotopes production by a p-beam of various energies on a **UCx** ISOL target)





- Using various primary-beam energies one populates different regions of the nuclear chart, which ensures a level of complementarity with respect to current operational ISOL facilities
- ISOL@MYRRHA will focus on neutron-rich fission fragments and neutron-deficient nuclei in the vicinity of the target nucleus (especially for light-nuclei produced by using non-actinide target material)