STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

A high power beam-dump for ISOL@MYRRHA phase 1

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Outline

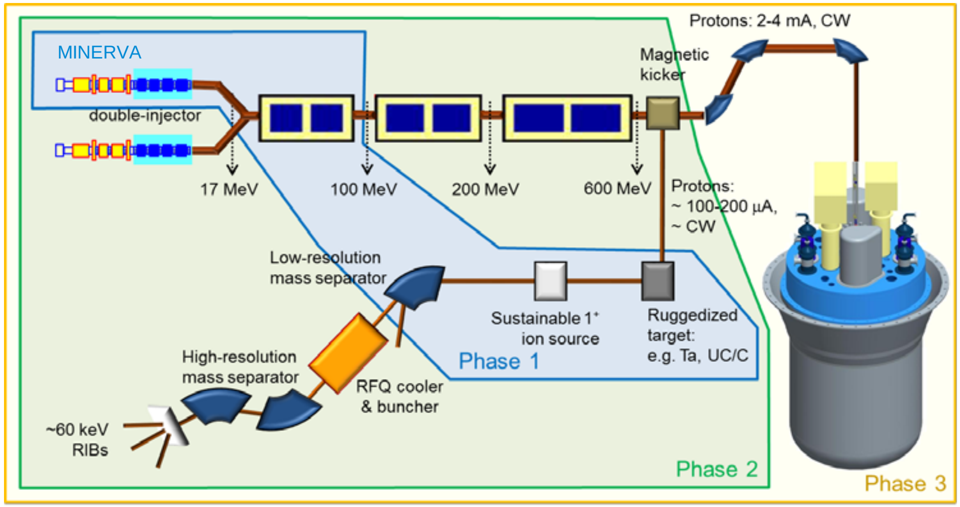
- ISOL@MYRRHA – the context
- Beam dump - requirements & material selection
- Investigated concepts – pros&cons
- Current reference beam dump – concept & analysis

The MYRRHA programme

- MYRRHA: - Accelerator Driven System (ADS) consisting of a proton accelerator coupled to a sub-critical reactor
  - Will provide high-intensity proton beams of 600 MeV and intensities up to 4 mA
- ISOL@MYRRHA: ISOL facility using a fraction of the MYRRHA proton beam to produce high intensity RIBs

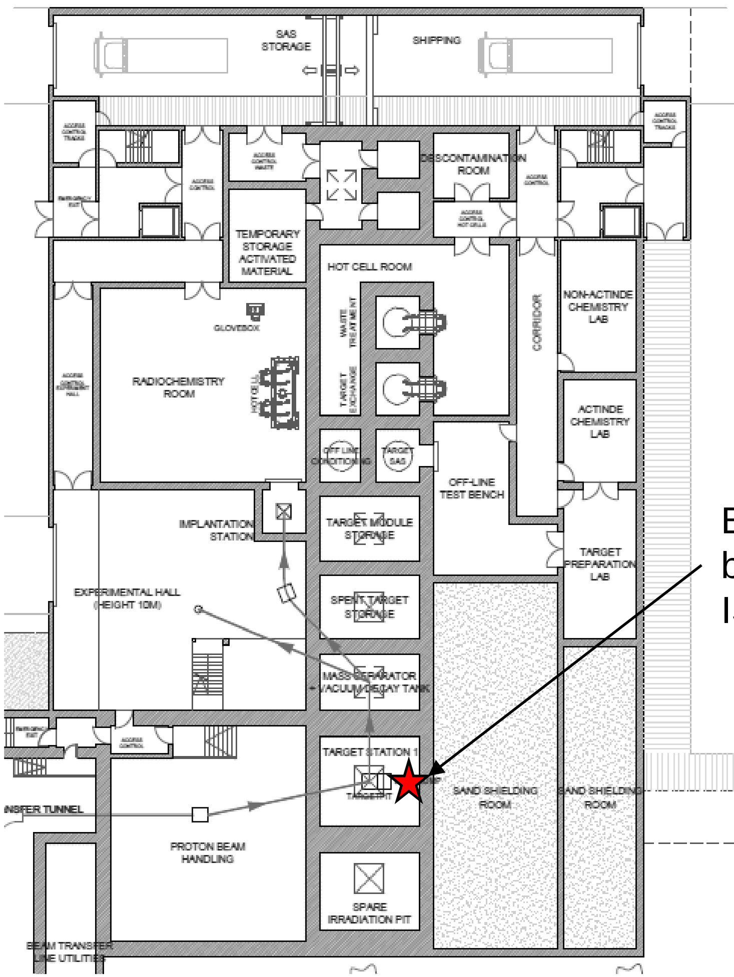
Phased implementation

- MYRRHA Phase 1
  - 2016 – 2024
  - 100-MeV LINAC
  - ISOL System
- MYRRHA Phase 2 & 3



ISOL in MYRRHA Phase 1

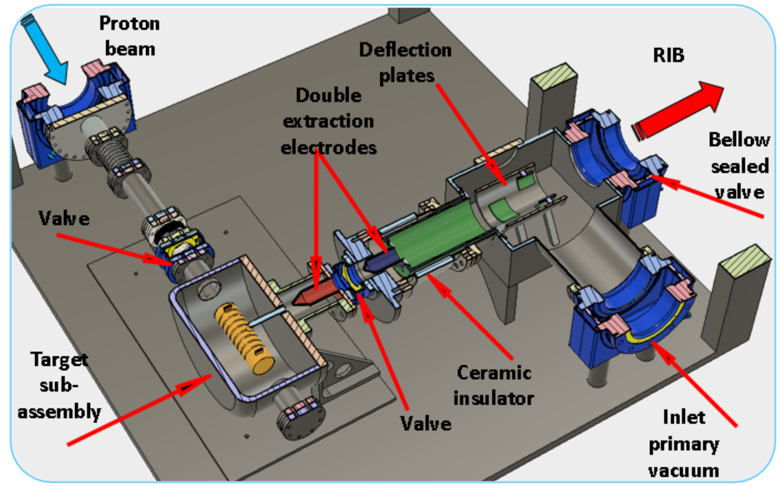
- Facility concept



Beam dump behind the ISOL target

P. Creemers, M. Dierckx, J. Engelen, M. Gomez, J. Habraken, K. Nikel, L. Popescu (SCK•CEN)

- Target Module concept



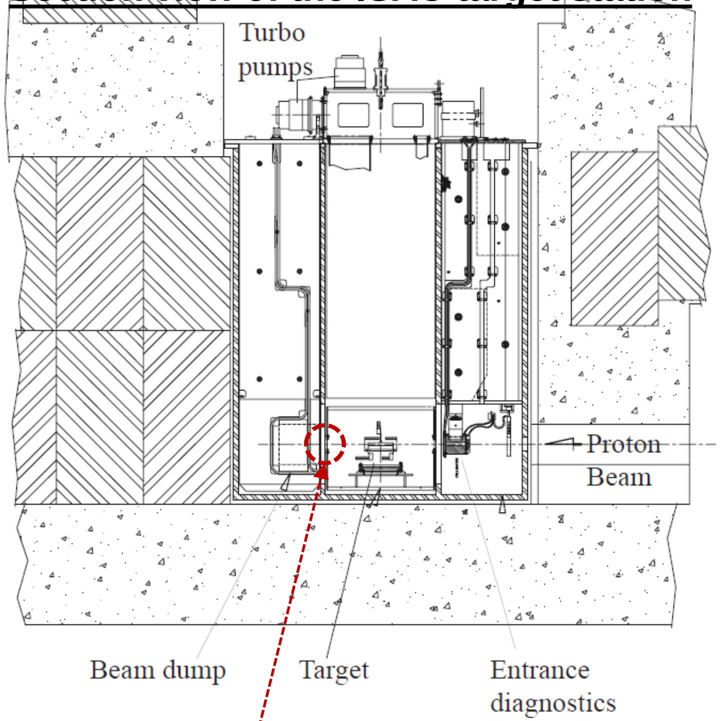
P. Creemers (SCK•CEN)

- 100 MeV , up to 500 µA
- ~30 MeV deposited in reference target
- ~70 MeV to be dissipated in a beam dump

ISOL facility beam dump – Context

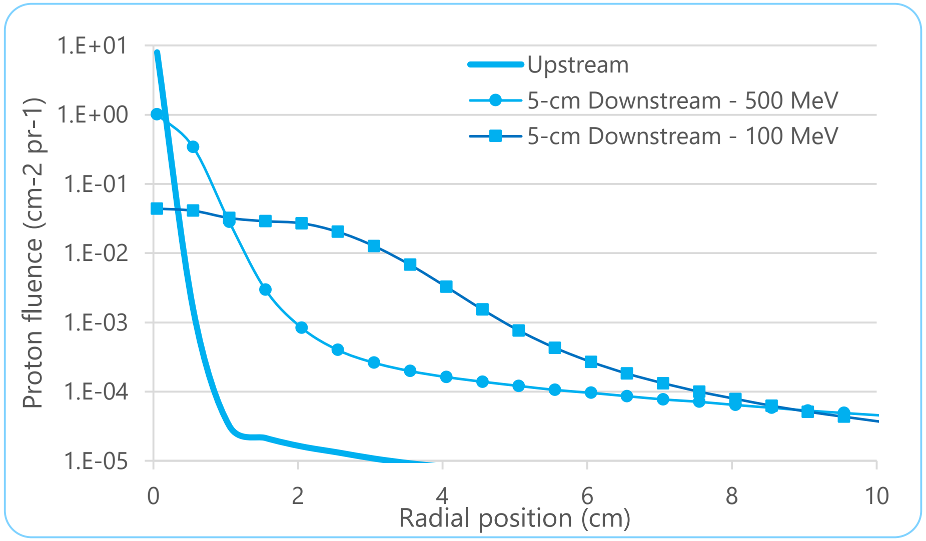
- ISOL beam dumps typically ≥ 60 cm downstream the target

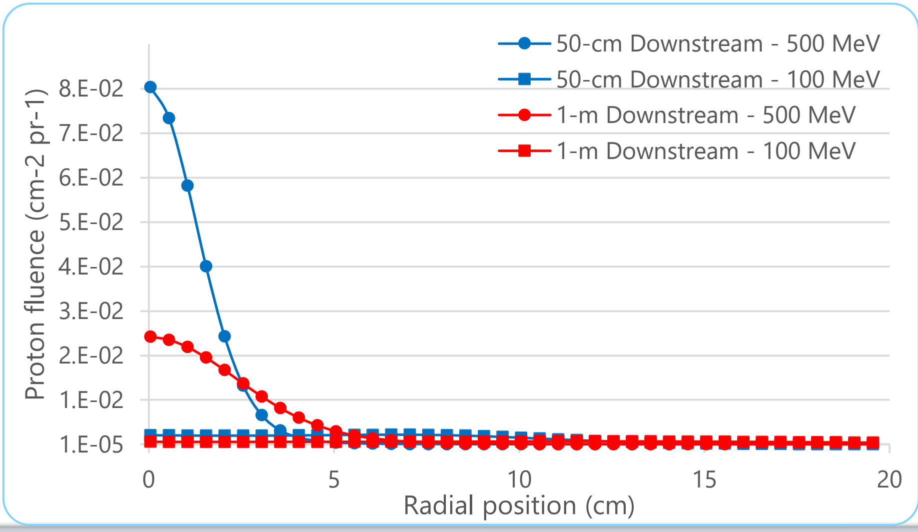
Section view of the ISAC target station



Residual beam window (e.g. Al)

- **0.45** MeV/mm at 1.39 GeV
- **0.59** MeV/mm at 485 MeV
- **2.0** MeV/mm at 70 MeV





P. Bricault et al, Proceedings of Particle Accelerator Conference, New York, 1999

ISOL at MYRRHA Phase 1 – Beam dump requirements

- Stop the proton beam at the ISOL facility
  - Nominal - Residual proton beam
    - 70-50 MeV & up to 500 μA
    - Significant beam scattering
  - Incidental - As transported proton beam
    - 100 MeV & up to 500 μA
    - Small beam spot σ ~ 2 mm

- Minimize radiation hazards
  - Activation of dump material
  - Contamination of dump material

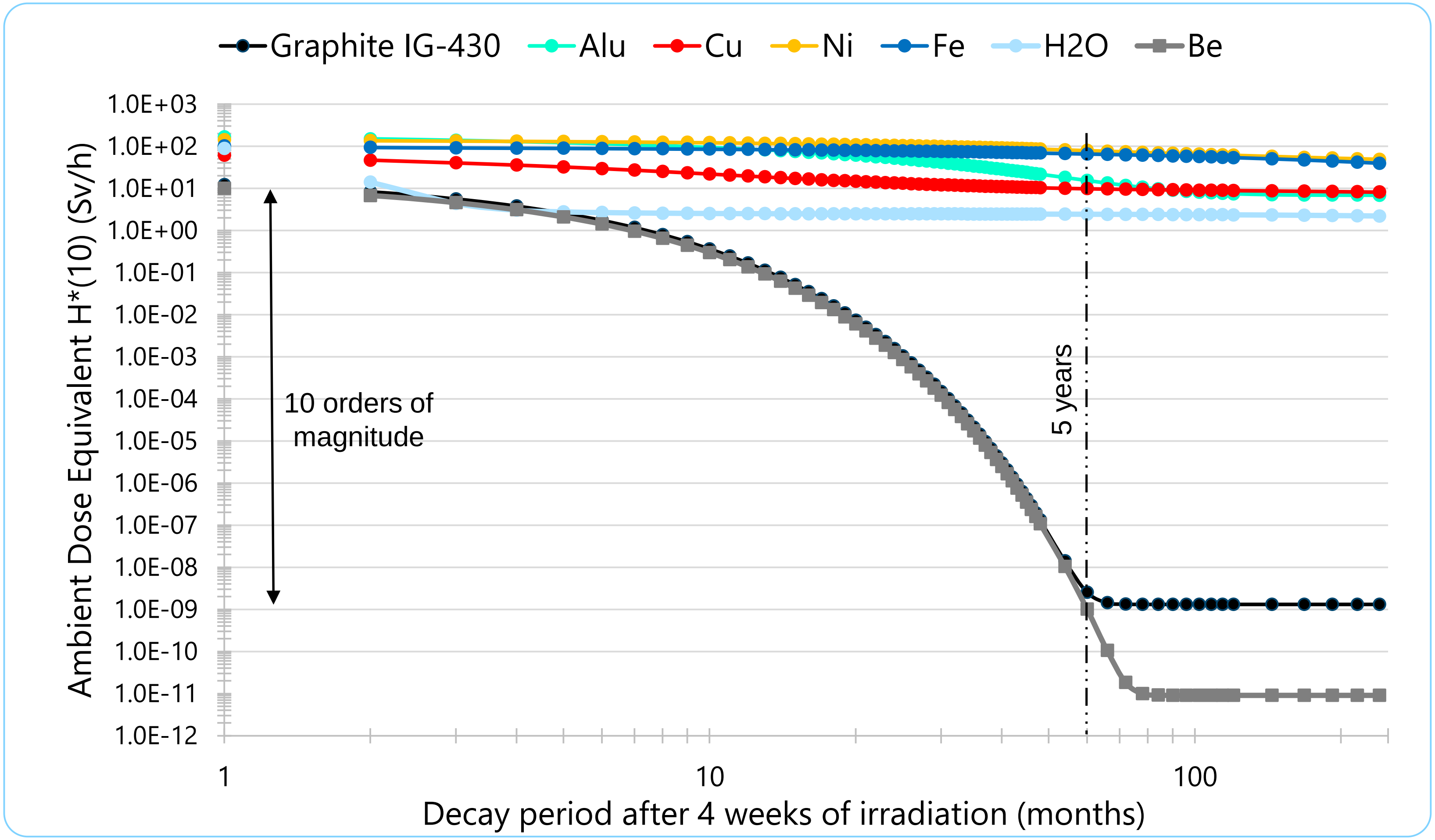
- Limit added complexity
  - To the target module
  - To the target station

Material selection - Radiation hazards

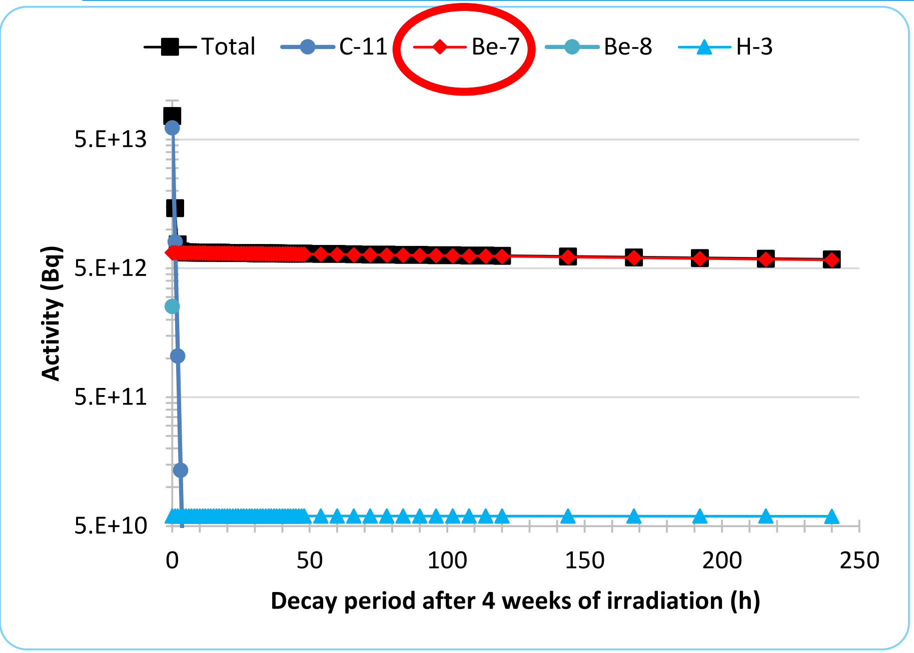
- Candidate materials pre-selection
  - Low-Z materials to reduce heat deposition density
  - Materials with typical usage in ISOL / industrial applications

- Radiation hazards post-irradiation: Activation
  - Focused beam directly on dump
  - Simulated 4 weeks of irradiation at 500 μA
  - Cubical beam dump edge scaled on stopping range in material
  - Compute Ambient Dose Rate H*(10) 50-cm of air away from the dump
  - Check production of gaseous species & isotopes responsible for the activity

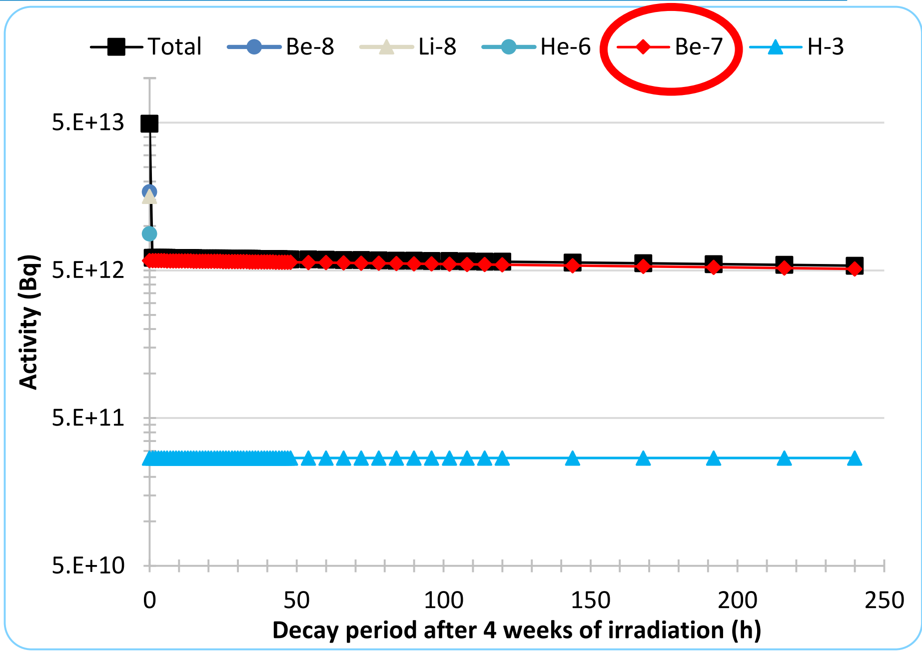
Ambient Dose Rate post-irradiation – H*(10)



Main Gaseous species & Radio-isotopes



Residual activities of main contributors in **graphite**

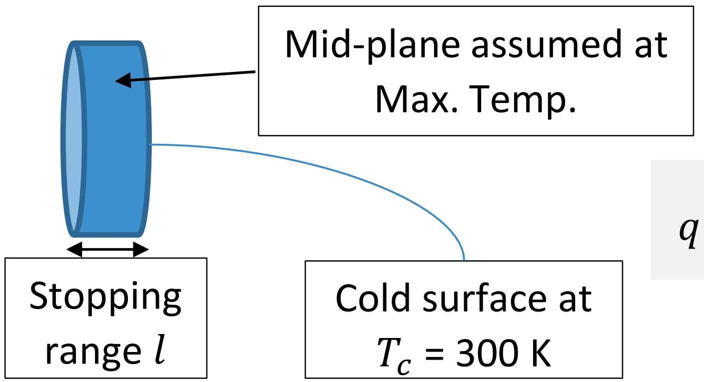


Residual activities of main contributors in **beryllium**

- Graphite & Beryllium activity are similar
- ^{7}Be (53.2 days) is the nuclide responsible for most of the activity and particle emission in both graphite and Be
- ^{3}H activity in Be is ~ 5 times higher than in graphite

Heat removal

- Heat removal flux:
  - Conductive heat flux from bulk material to surface



$$q = \frac{k(T_{max} - T_c)}{0.5 * l}$$

	Max Temperature (K)	Thermal conductivity (W/mK)	Material conductive power (W/cm2)
Be	1100	100	315
C	1800	30	191

  - Radiative heat flux from material surface to sink

	Max Temperature (K)	Emissivity	Surface emissive power (W/cm2)	Max combined heat transfer power (W/cm2)
Be	1100	0.18	1.5	**~1.5**
C	1800	0.8	48	**~30**

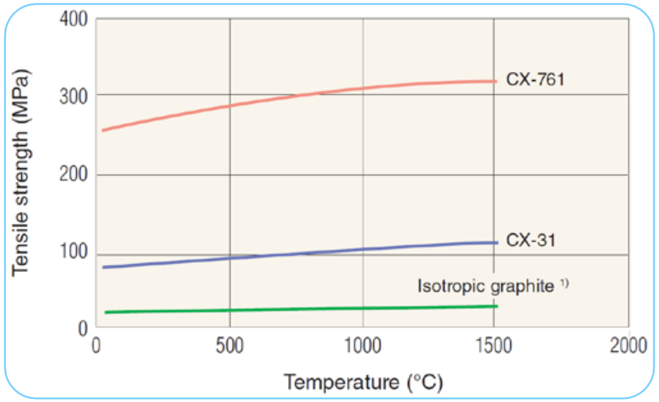
- Beam heat flux for a 4-cm diameter spot is ~ 4 kW/cm^2

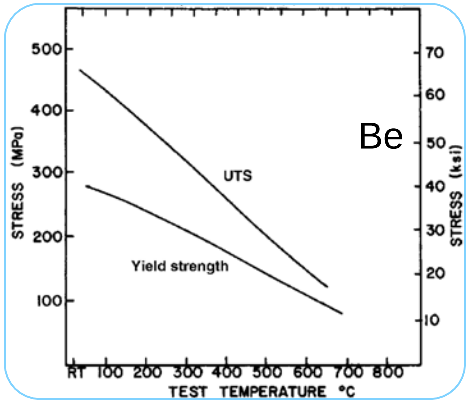
Thermal-shock mitigation

- Relevant parameters

	Max Temperature (K)	Specific heat (J/gK)	Coefficient of Thermal Expansion K^{-1}	Yield strength (MPa)
Be	1100	~3	$\sim 2\ 10^{-5}$	**20~100**
C (CX-761)	1800	~2	$\sim 8\ 10^{-6}$ (⊥) $<1\ 10^{-6}$ (//)	**~300**

- Temperature dependence of material strength

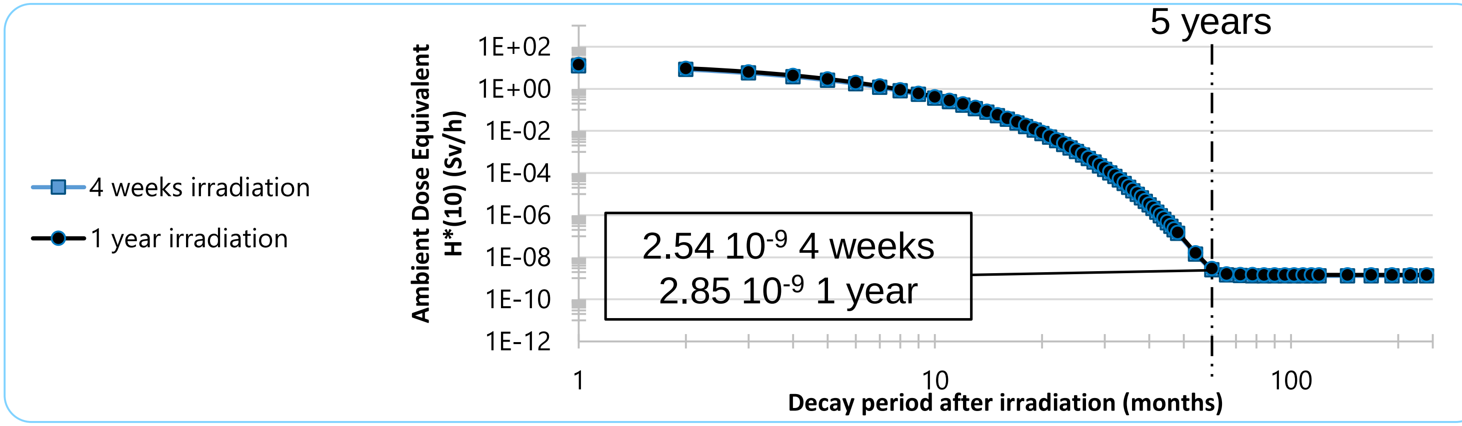




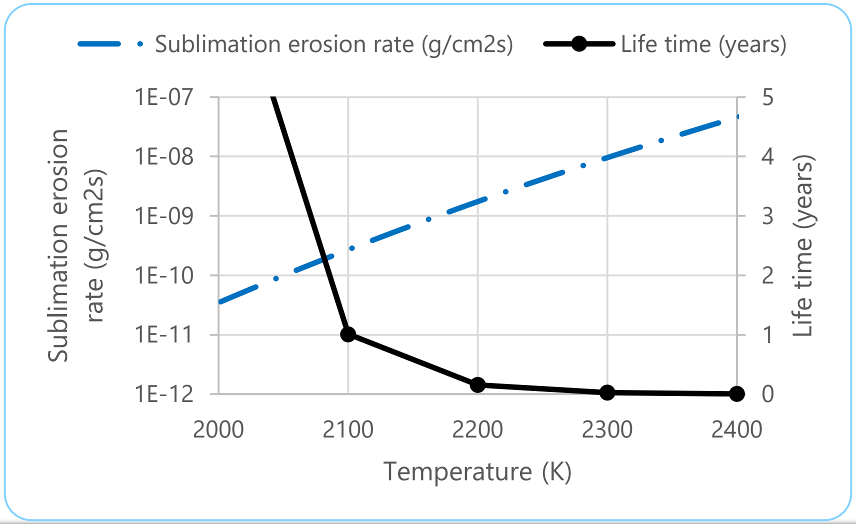
- Material of choice : Carbon (e.g. CX-761)

Selected Material - Disposal

- Effect of irradiation history



- Effect of evaporation

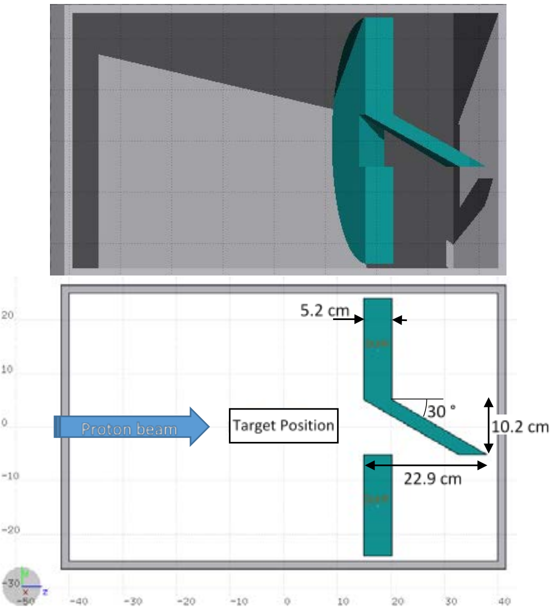


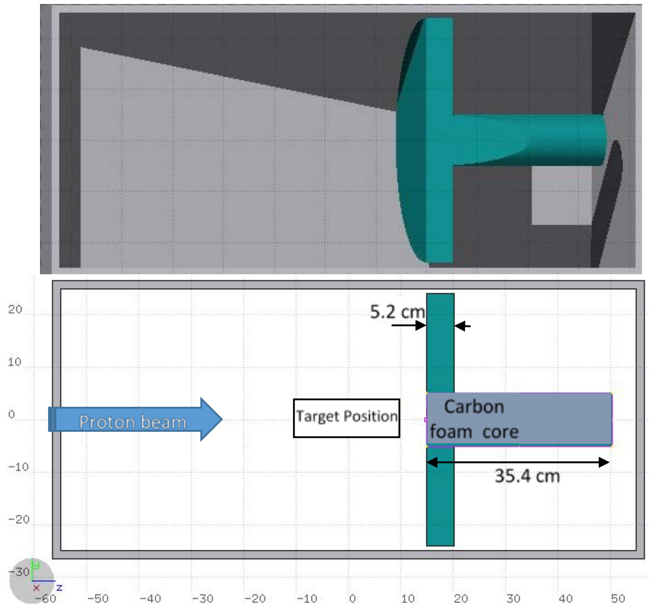
Evaporation rate (atoms/cm2s)	Be	C
1100 K	1 E14	7.5 E-4

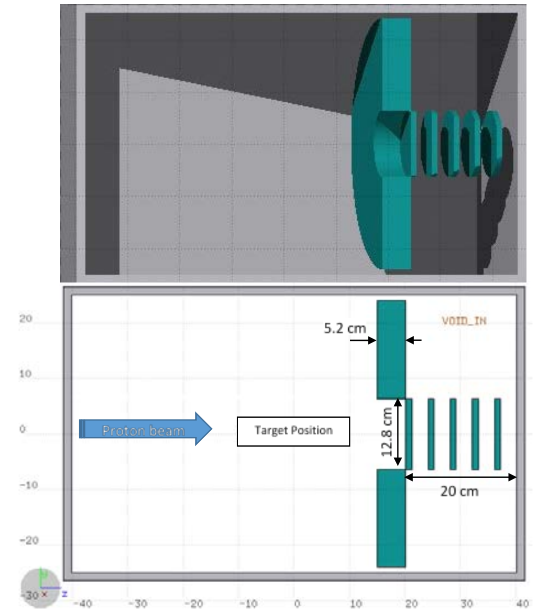
Graphite activity lower than estimated as ^{7}Be will have partially vaporized at operating temperatures

ISOL Beam dump at MYRRHA Phase 1 — Investigated concepts

- Initial concepts – Beam dump fully enclosed in primary vacuum







Slanted core

- Increased interaction volume
- Requires thin long and weak core

Carbon foam core

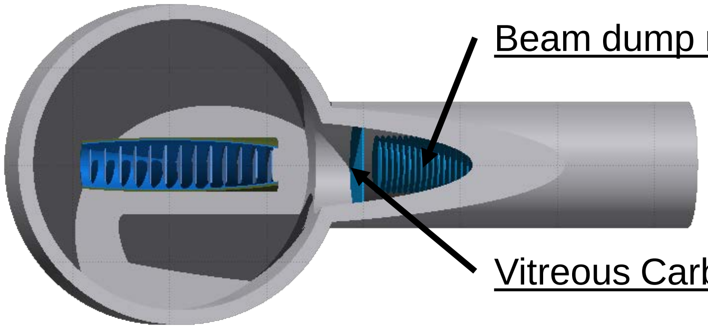
- Reduced stopping power
- Low equivalent thermal conductivity

Multi-disc core

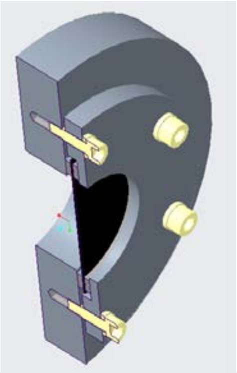
- Increased radiation surface

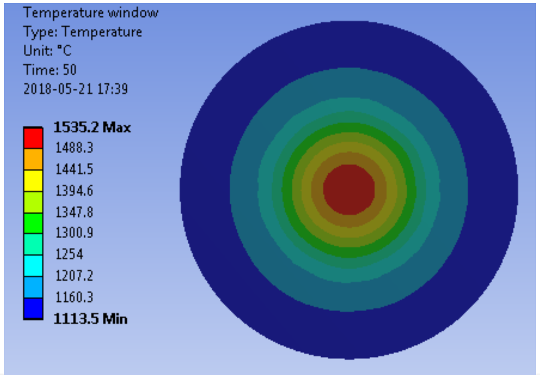
Radiation hazards - Contamination

- Motivation : Enable simpler post-irradiation processing of the dump material by avoiding its contamination with reaction products released from the target.
- Solution : Window very-close downstream the target



- Analysis :

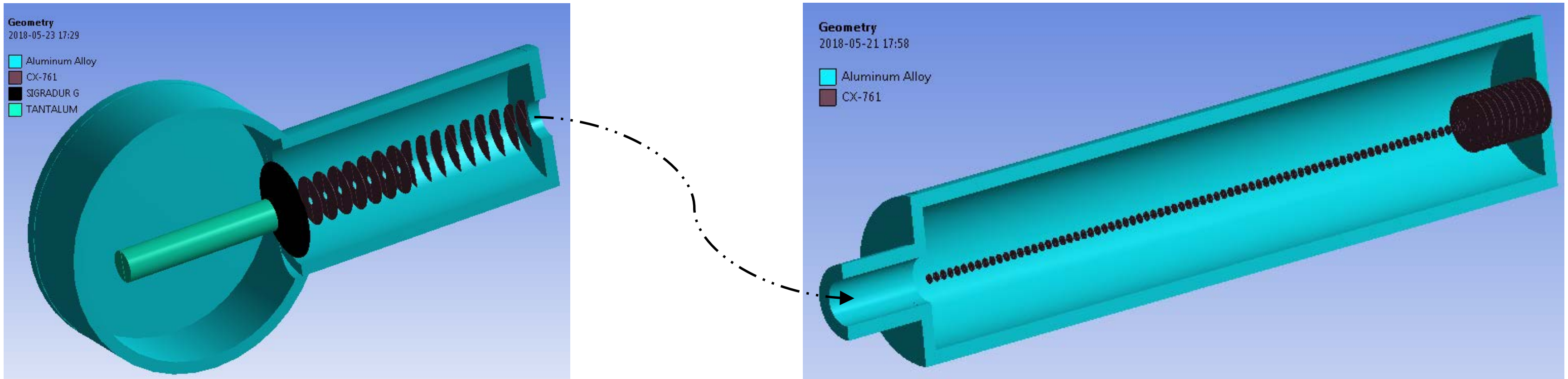


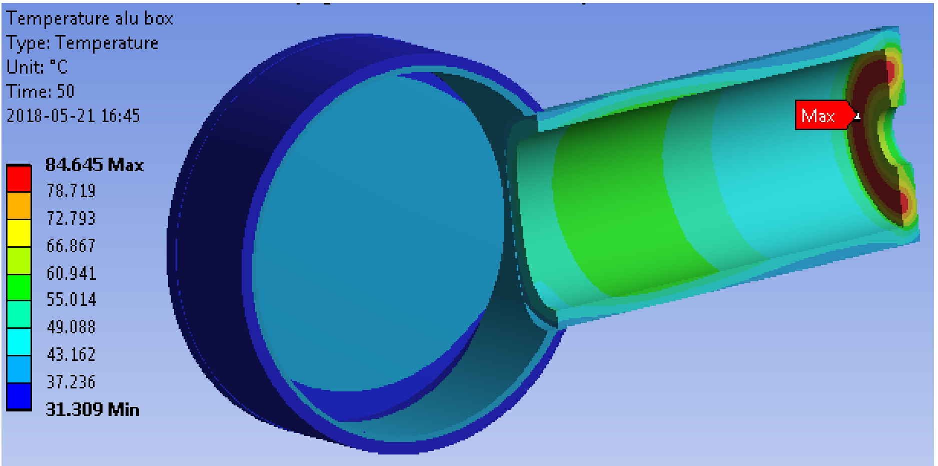


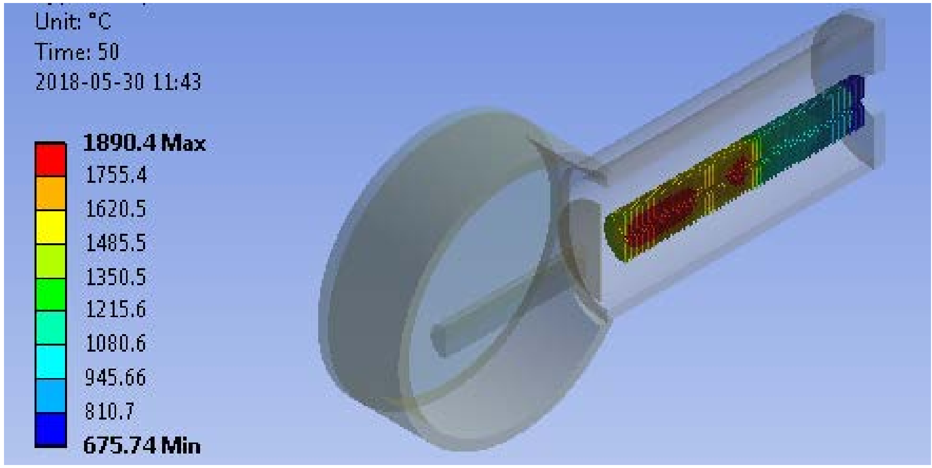
Rotating beam through target

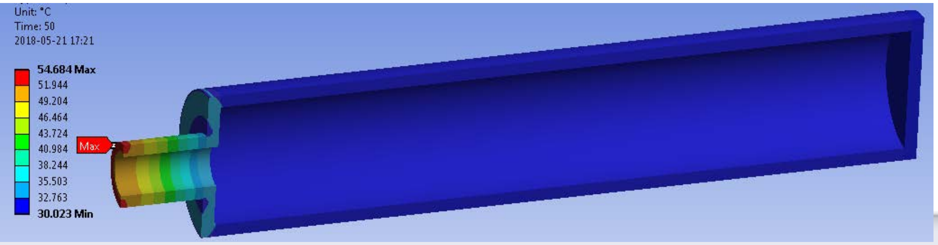
Max Temp. << 3000 °C (limit in inert gas or vacuum)

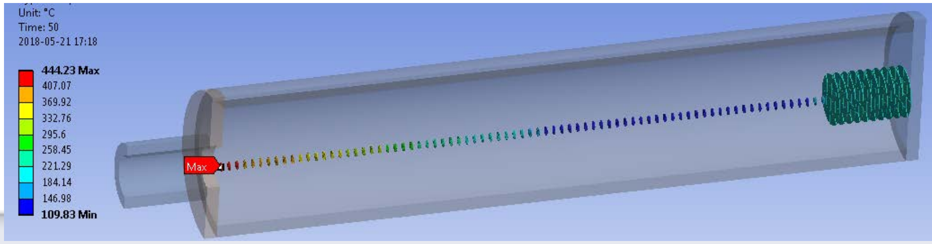
Current reference beam dump concept





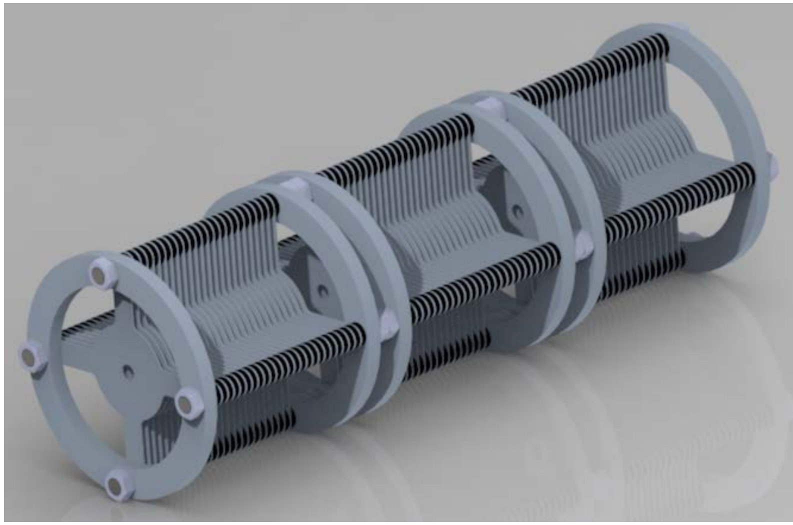


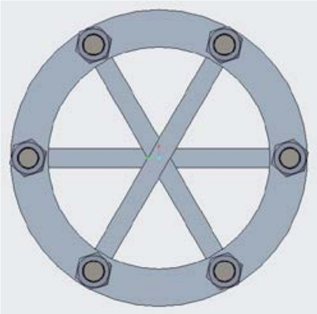


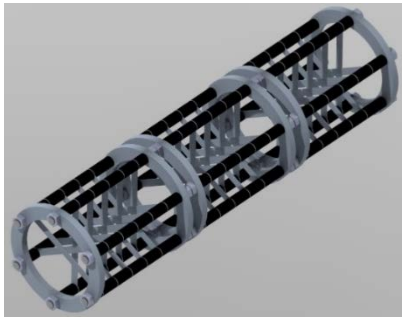


Summary

- First implementation phase – Under design
- 100 MeV, up to 500 μA
- 2 dissimilar requirements
- Carbon composite beam dump
- 2 modules radiatively cooled







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Thank you