Optimization of a target with a microchannel cooling structure using particle transport simulations

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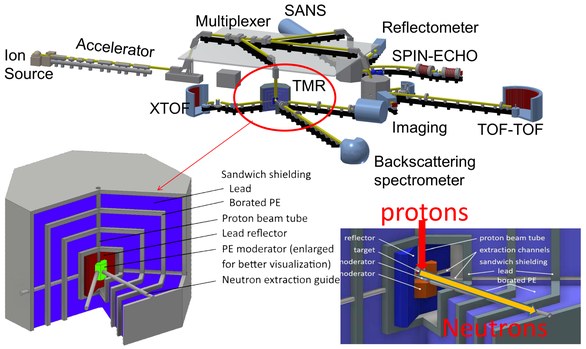
Motivation

- neutron scattering is a powerful tool for the investigations of material and soft matter
- HBS aims developing a compact accelerator-driven neutron source to deliver high brilliant neutron beams to a variety of neutron scattering instruments.



Within HBS project, a target with a sophisticated internally microchannel cooling was developed,

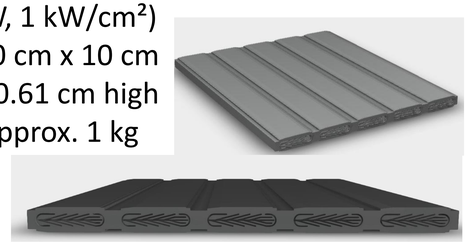
- Blistering problem due to high proton current (1 kW/cm^2)
- mechanical stress due to temperature gradient.

Method

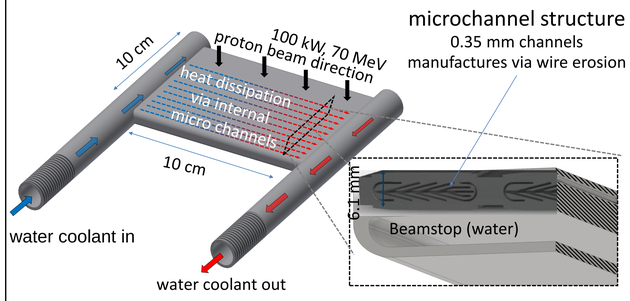
- Monte Carlo code FLUKA 2020

Target design

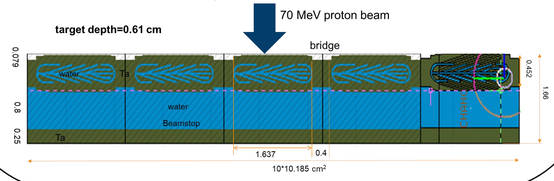
- high power density Tantalum target (100 kW, 1 kW/cm^2)
- Area: 10 cm x 10 cm
- Depth: 0.61 cm high
- Mass: approx. 1 kg



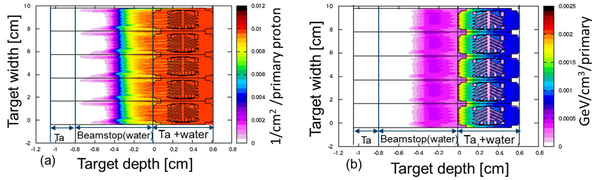
- Entire Target including water Beamstop and supply connection



- A sketch of a complete target including water Beamstop

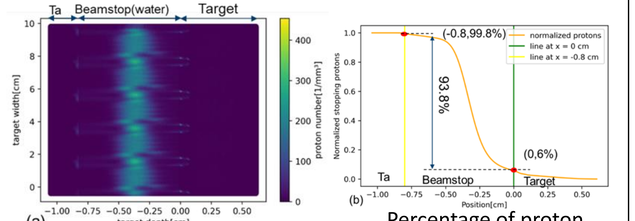


Target properties



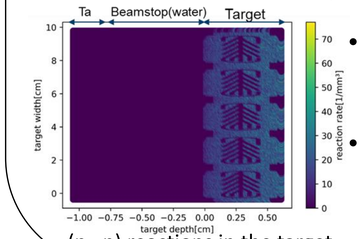
Proton flux | Energy deposition

- Proton flux is homogenous
- energy distribution is homogenous
- Bragg peaks appear in the Beamstop



Stopping proton distribution | Percentage of proton distribution along target depth

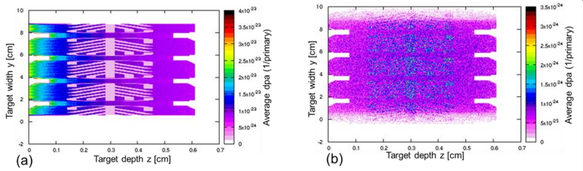
- Only 6% of protons accumulates in the tantalum target
- 93.8% of protons stops in the Beamstop



(p , n) reactions in the target

- Most (p , n) reactions happens at the beginning of the target
- Almost neutrons are produced by the metal target

Lifetime estimation



(a) DPA induced by protons | (b) DPA induced by neutrons

- the maximum values of the proton-induced DPA mainly concentrates on at the end of target
- the peaks of neutrons-induced damage appear at the beginning of the target

Table 1 Estimation of the minimum target lifetime

	Annual does [dpa/fpy]		Minimum target lifetime[years]
	Reference values	Calculated values	
Protons-induced	11 [1,2]	1.985±0.007	5.54
Neutrons-induced	0.14 [3]	0.162±0.017	0.86

1 T.S. Byun, S.A. Maloy, J. Nucl. Mater 377(1), 72 (2008).
2 J. Chen, H. Ullmaier,etc, J. Nucl. Mater 298(3), 248 (2001).
3 J. Chen, G. Bauer,etc, J. Nucl. Mater 318, 56 (2003).

Conclusions

- This design can significantly reduce the risk of blistering problem.
- has a homogeneous energy deposition without heat spots except slightly fluctuation between the end segments.
- the minimum service lifetime of the target is estimated to 1 year.

Outlook

- Further ANSYS simulations are needed to check the mechanical properties.
- Target prototype manufacturing and examination of critical heat flux under high electric beam

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