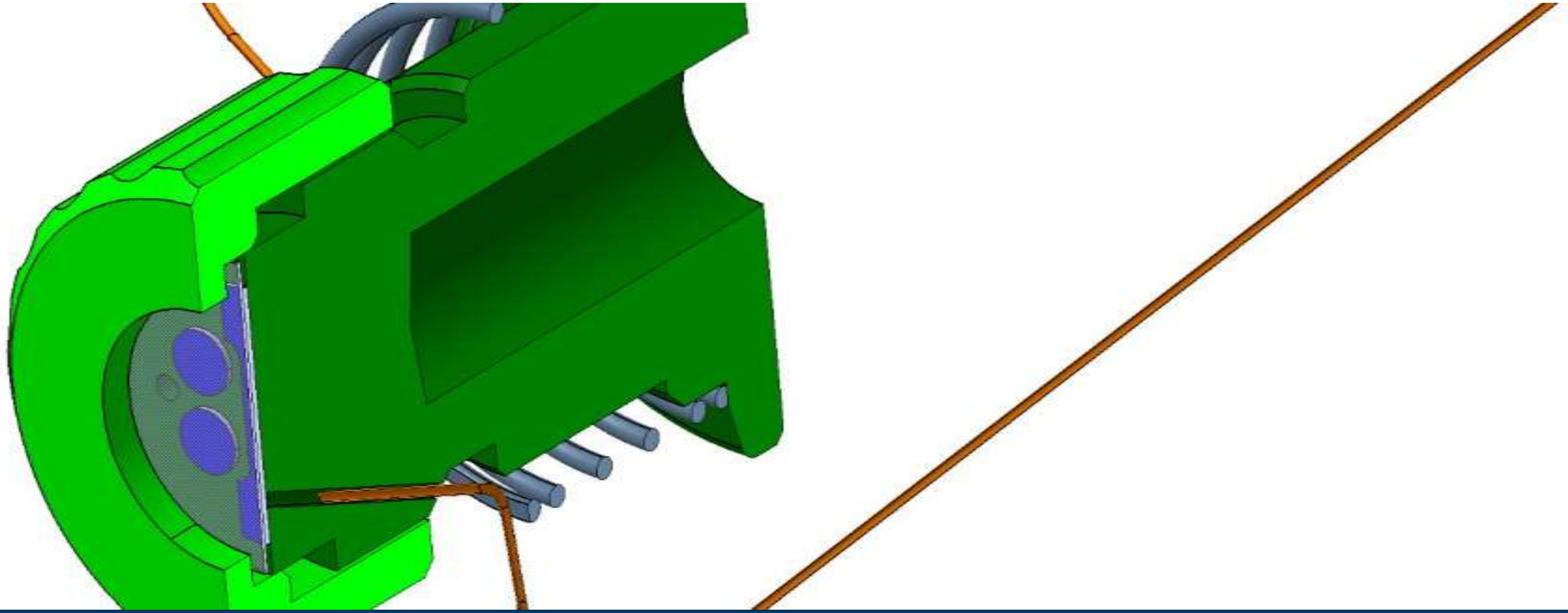
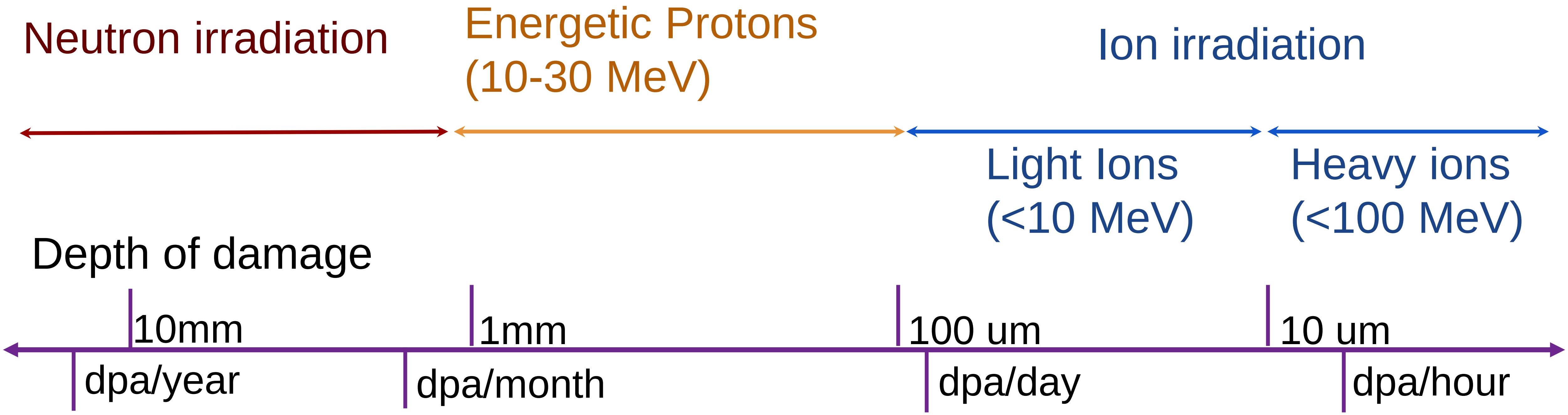


Proton irradiation for pre-sampling of IFMIF-DONES experiments

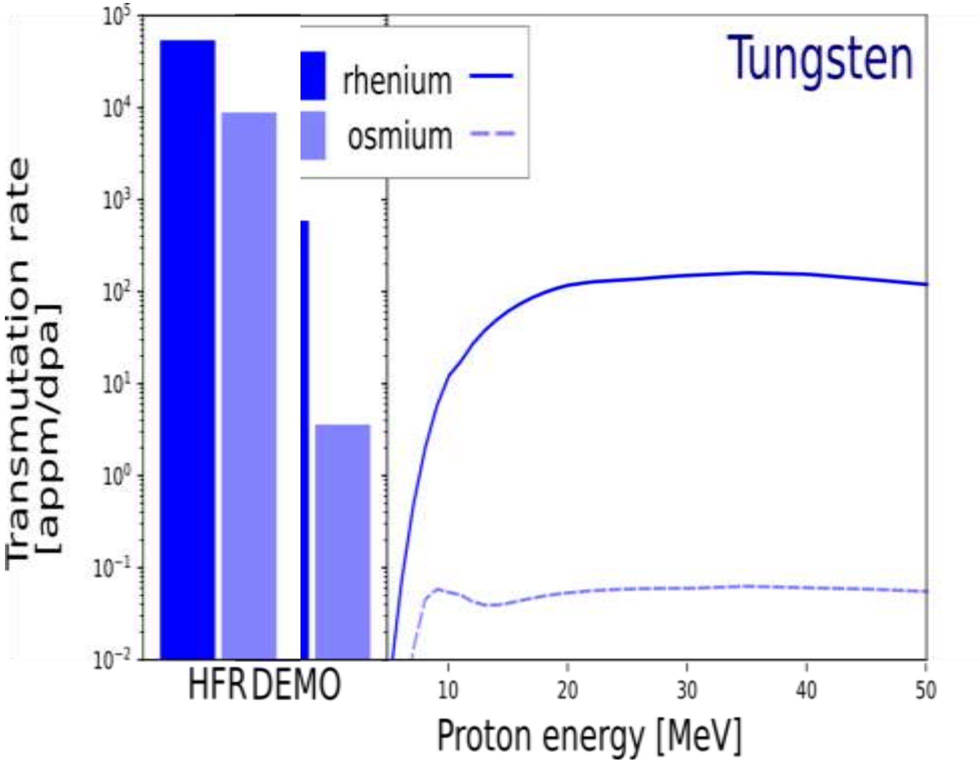
26.09.2022 I R.Rayaprolu, I. Spahn, D. Höschen, S. Möller, Ch. Linsmeier

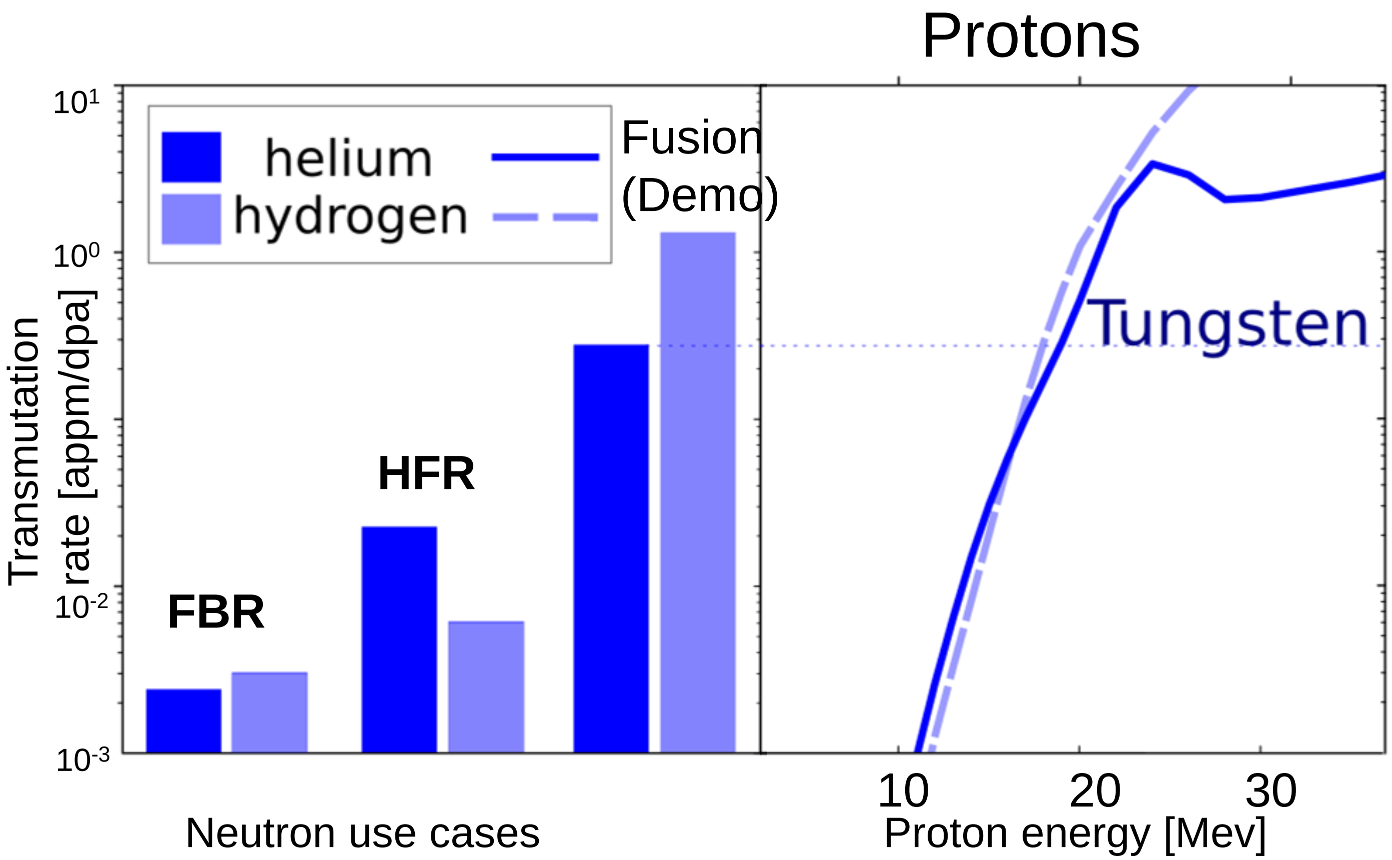
Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, 52425 Jülich,

Introduction



Proton irradiation of tungsten

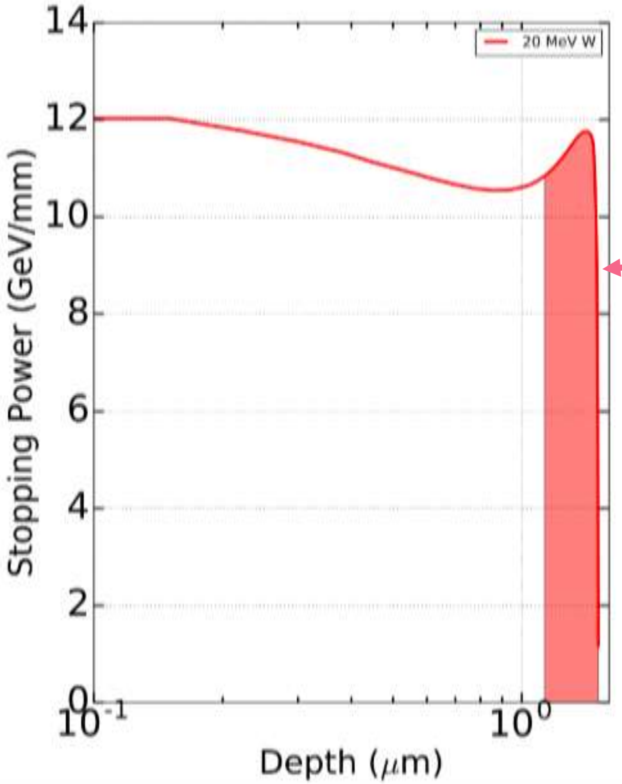




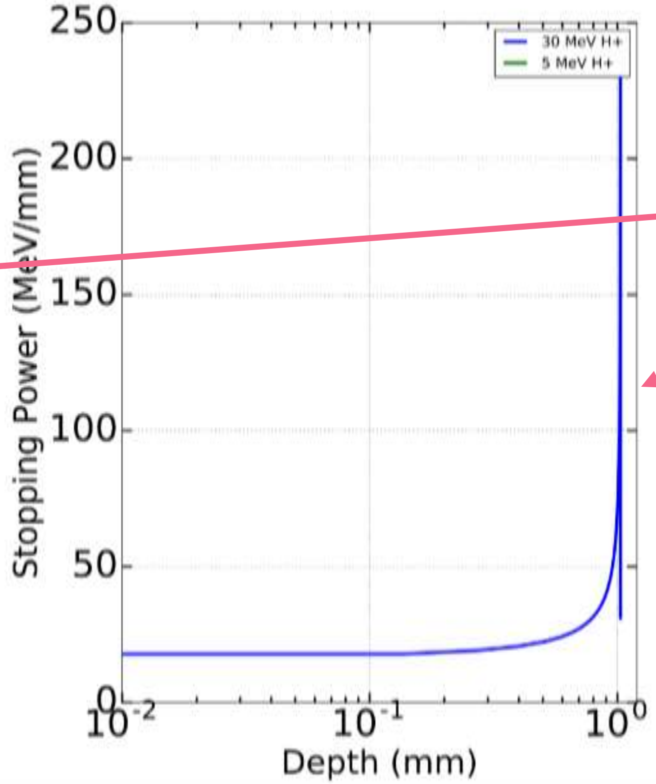
Collaborated work with M. Gilbert, UKAEA; S.Jepeal, MIT

Irradiation methodology

Traditional method



Self ion damage (W)



30 MeV proton damage

Bragg peak
(Intense damage)

Bragg peak damage	
High dose rates	10^{-3} dpa/s
Limited damage regime	~ 1 µm
Condensed damage and overlap of damage	
IMPLANTATION!	

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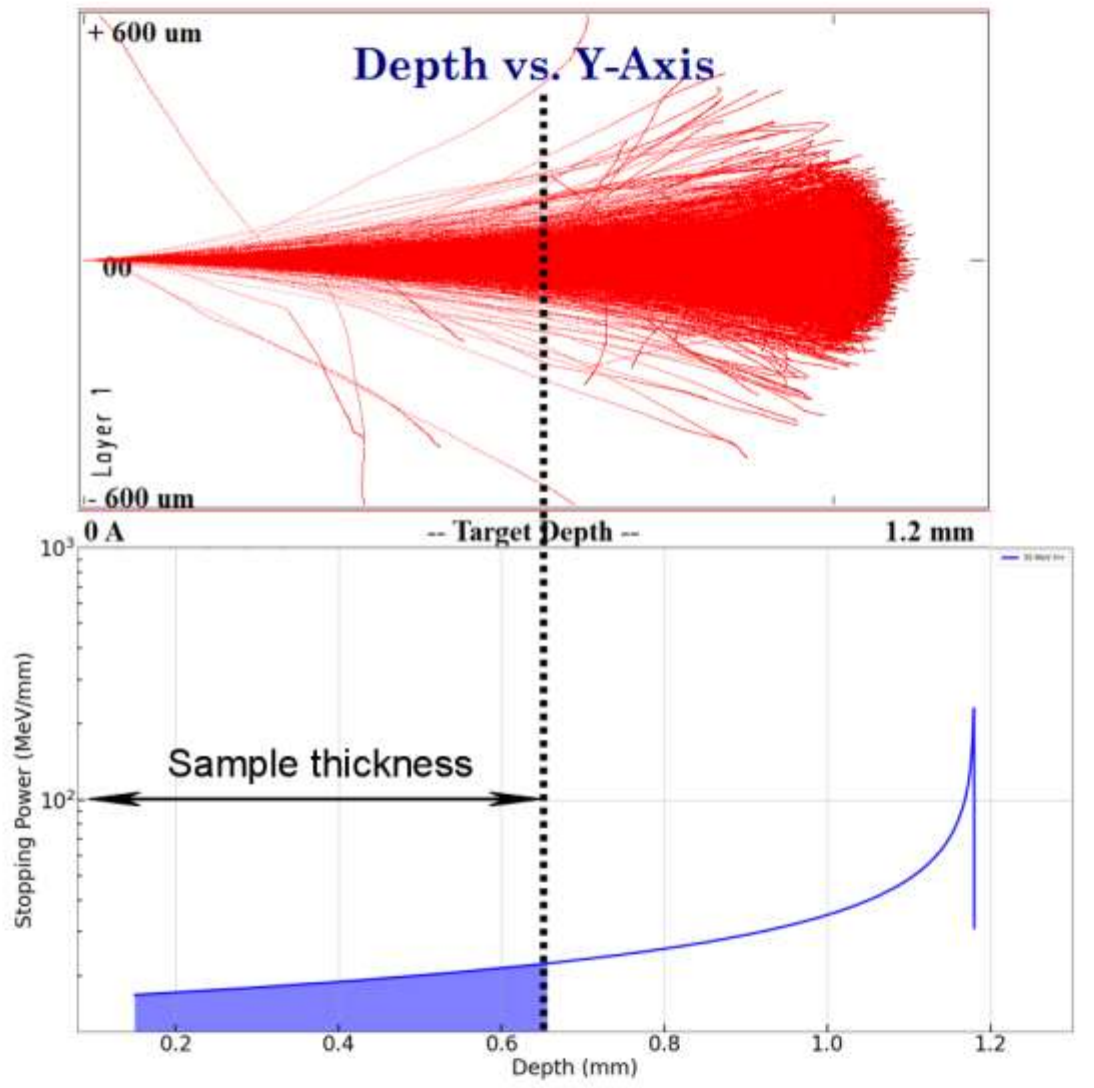
Irradiation methodology



Br g peak amage	
High dos	10^{-3} dpa/s
Limited dama	~ 1 µm
Condensed d age a overlap of damage	

Linear non-peak damage	
Low uniform damage dose	10^{-7} dpa/s
Macroscopic damage	> 300 µm
Scattered damage	
Bulk property measurement	
Electronic loss – Heating	2 MW/m^2

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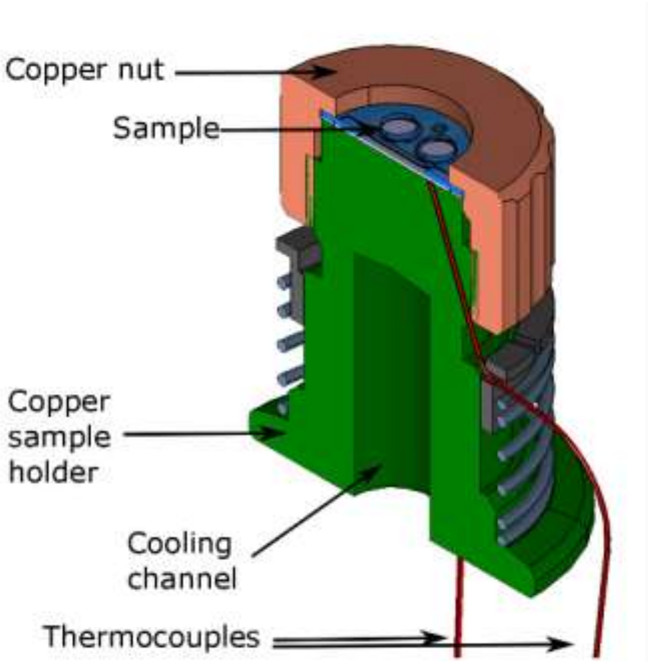
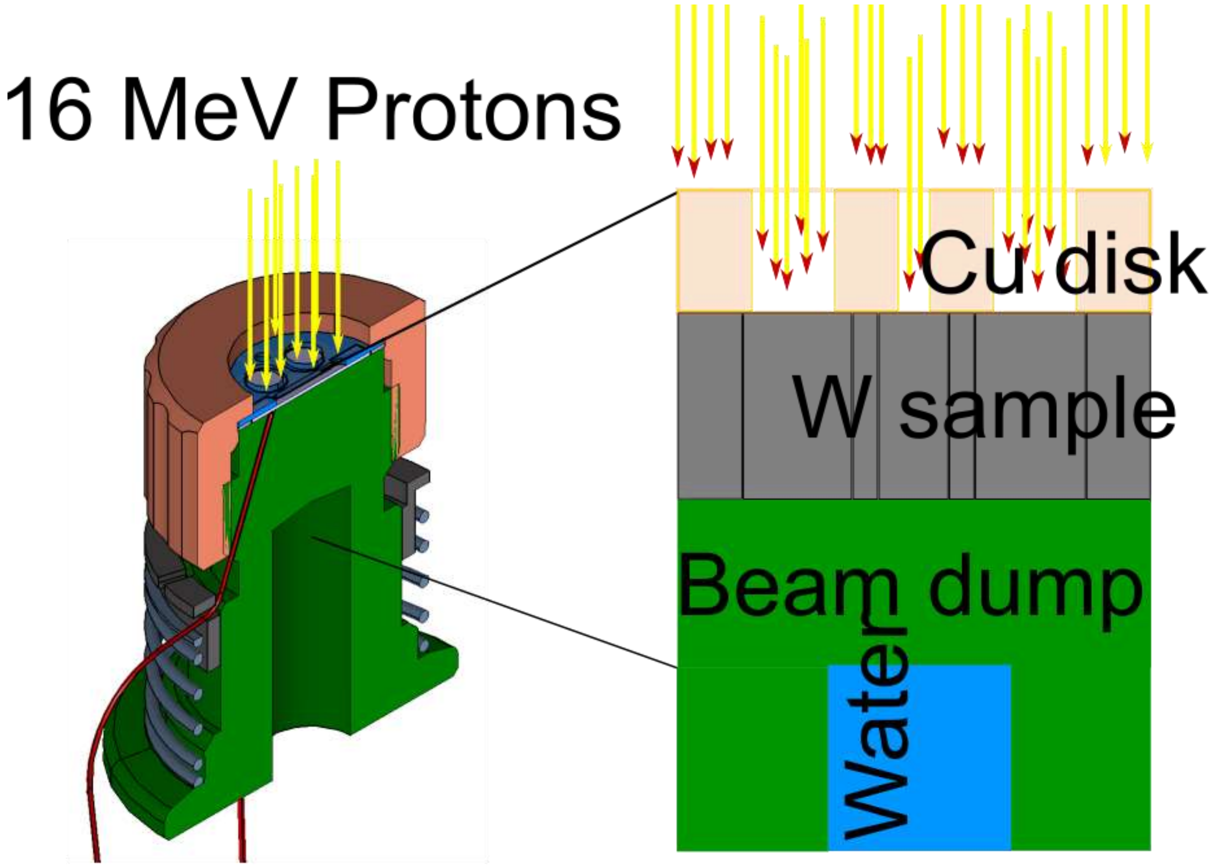
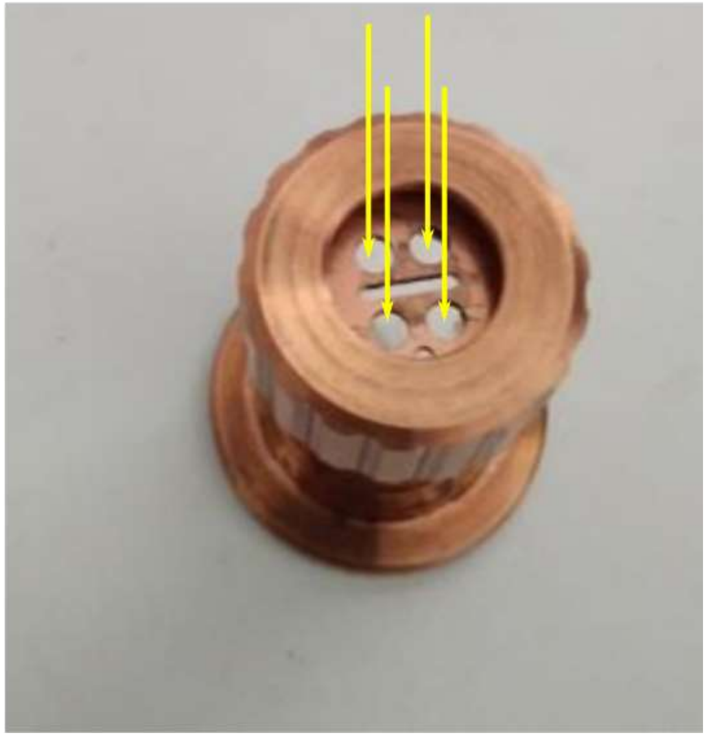
Sample design



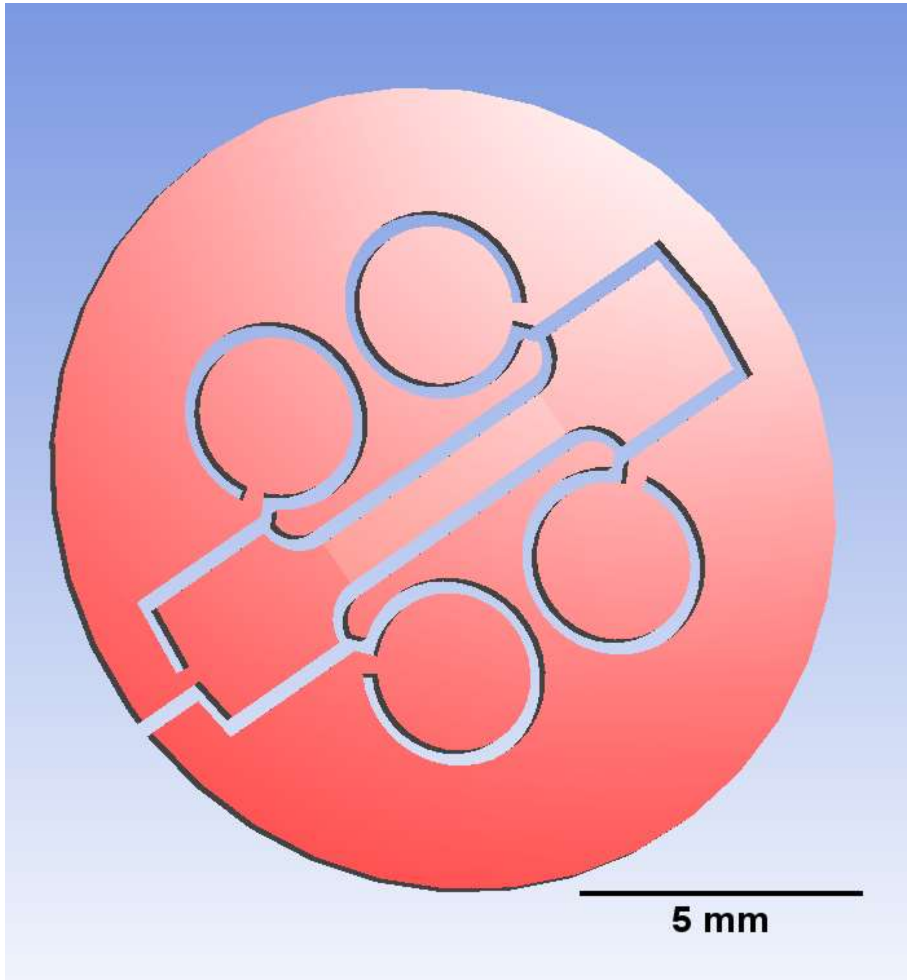
Sample design

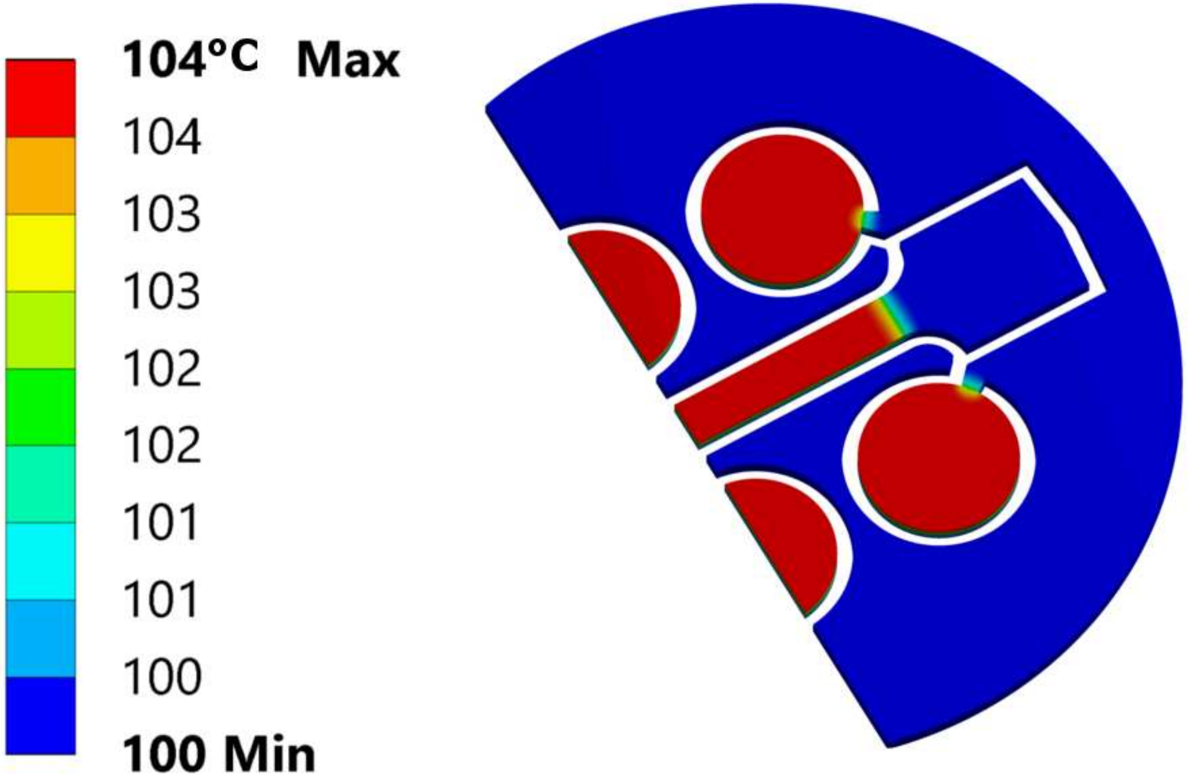




Sample temperature

Low temperature & full contact





Pilot irradiations

Type 1

16 MeV protons

On

300 µm W sample

@

4.7 x 10^{-7} dpa/s

=

0.006 dpa (6 mdpa)

- 2 hour low temp ~100°C
- 4 hour of high temp ~950°C

Type 2

16 MeV protons

On

300 µm W sample

@

4.7 x 10^{-8} dpa/s

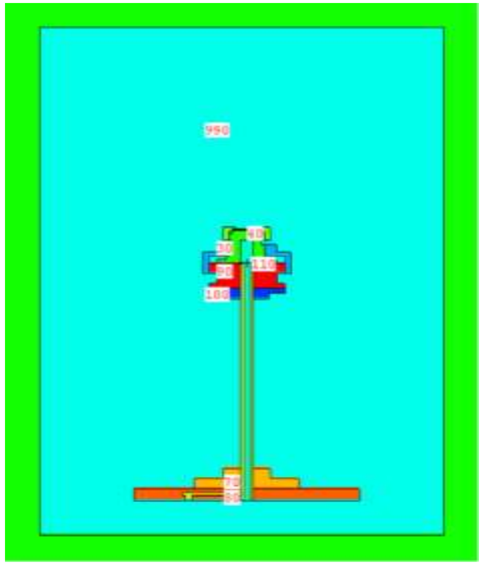
=

0.007 dpa (7 mdpa)

No heat loads

Post irradiation: Gamma spectroscopy

W irradiated to 6 mdpa dose at 4.3 x 10^{-7} dpa/s



MCNP6 with FISPACT-II estimates, TENDL2015 crosssection

Activity Comparison

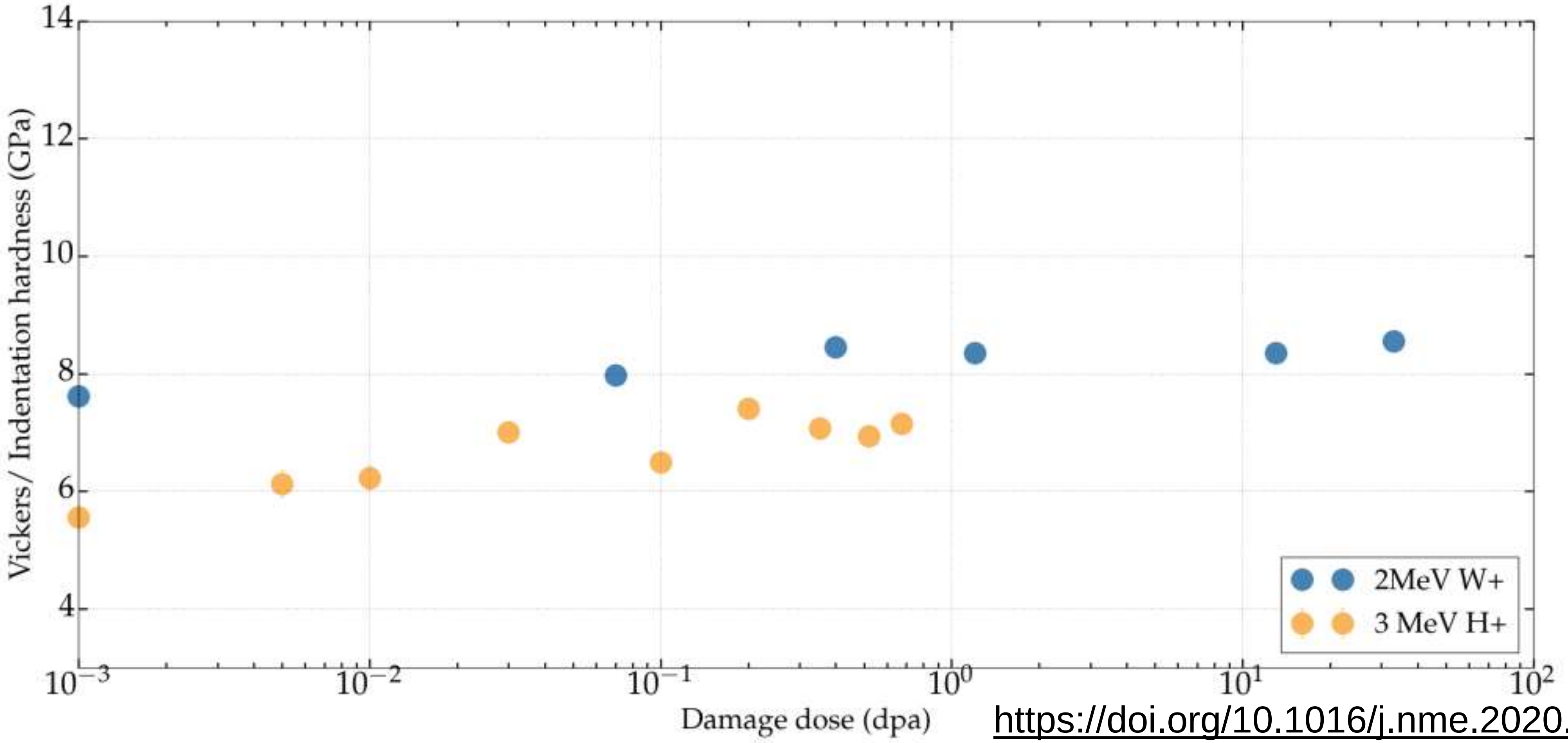
Nuclide	Simulated (Bq)	Measured (Bq)
^{184}Re	1.42 x 10^{6}	8 ± 0.2 x 10^{5}
^{184m}Re	1.96 x 10^{5}	8.8 ± 0.3 x 10^{4}
^{183}Re	1 x 10^{7}	9.2 ± 0.3 x 10^{5}

Dose Comparison

	Simulated (mSv/hr)	Measured (mSv/hr)
Contact dose	14.7	4.3
Lead shielding (3.5 cm)	0.2	0.11
Tensile sample	0.38	0.16

Using TENDL2017/2019 cross-sections, the ^{183}Re discrepency can be explained.

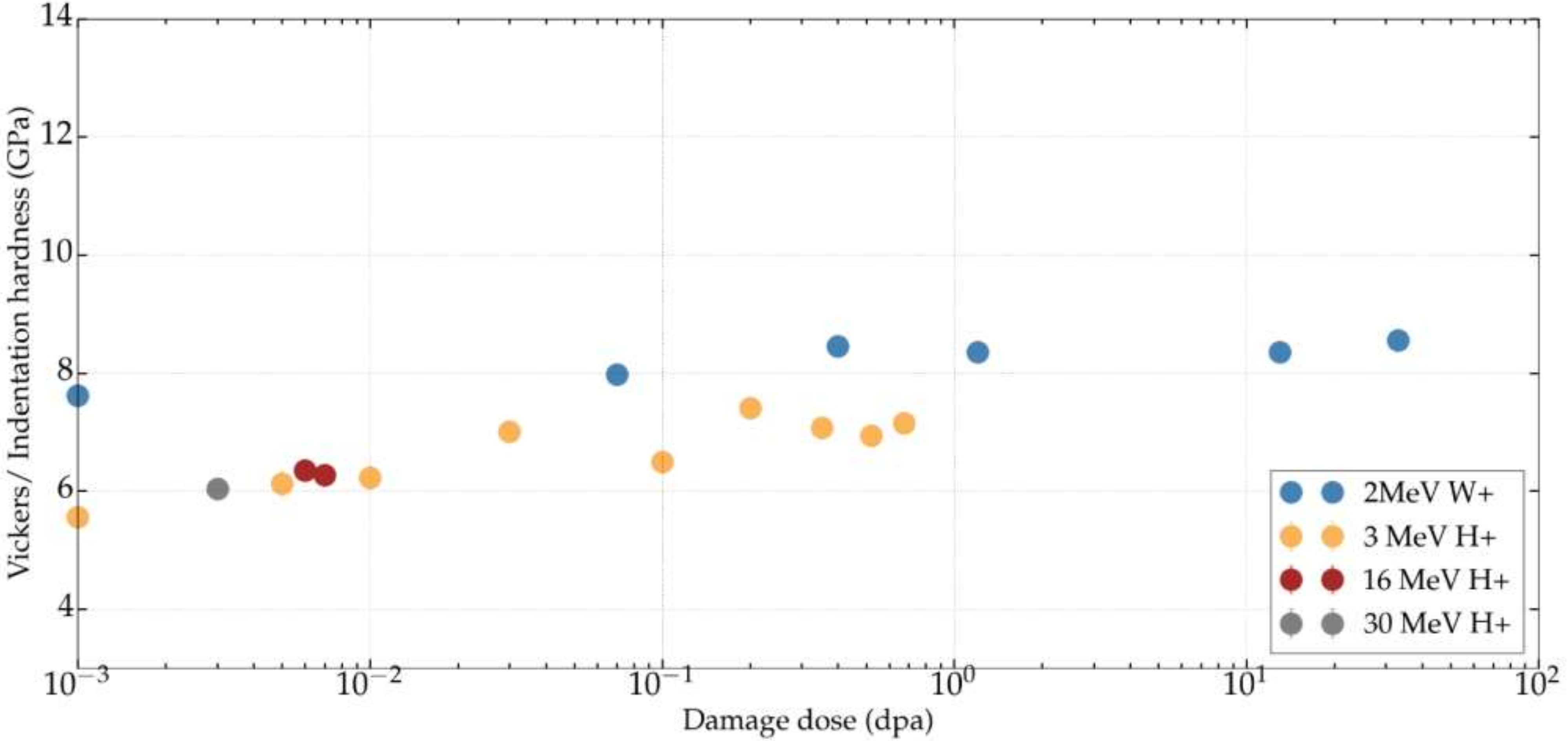
Post irradiation: Hardness



https://doi.org/10.1016/j.nme.2020.100776

[1]D. Armstrong et Al. JNM 432, 2013 [2] X. Hu et al. JNM 480, 2016 [3] Y. Katoh at Al. Fusion engg & design, 2017

Post irradiation: Hardness



[1]D. Armstrong et Al. JNM 432, 2013 [2] X. Hu et al. JNM 480, 2016 [3] Y. Katoh at Al. Fusion engg & design, 2017

Future plans – next steps

30 MeV cyclotron – higher doses of irradiation damage

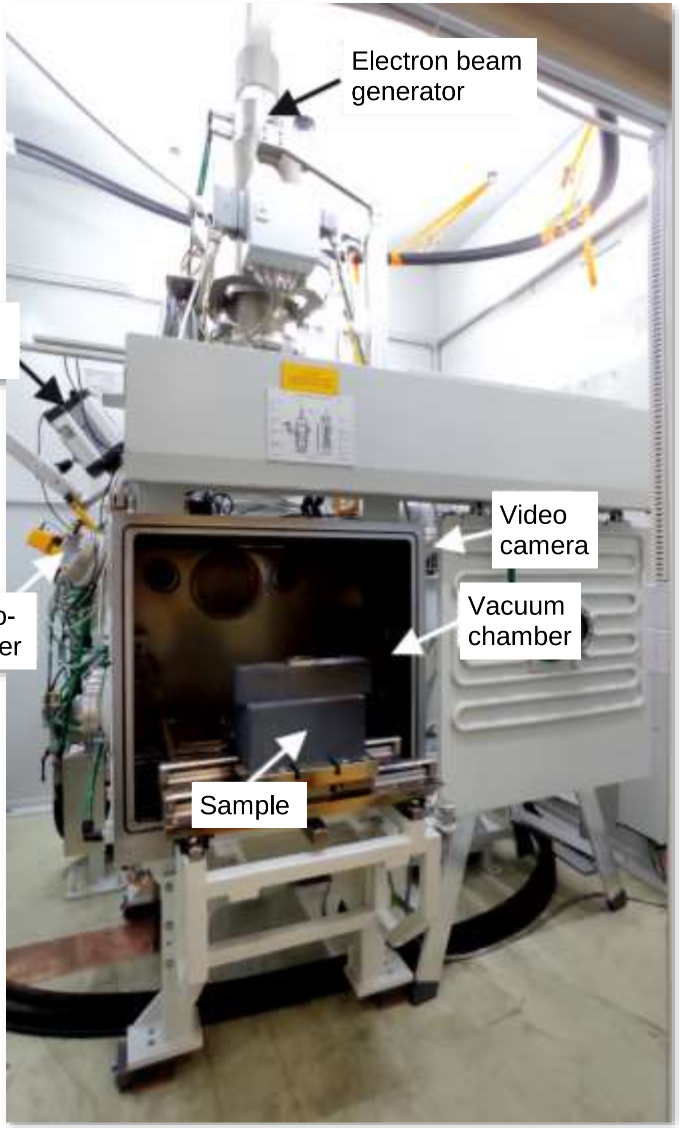
TEM analysis – microstructure investigations
formation of voids, precipitates

Shear punch testing/ tensile testing – destructive testing
possibilty of dust formation, HML-2 should be okay

JUDITH 3

JUDITH 3 – machine parameters

max. beam power:	60 kW
acceleration voltage:	≤ 150 kV
irradiation area:	15 x 15 cm^2
power density:	≤ 2 GWm^{-2}
pulse length:	5 µs – cont.
beam diameter:	~1 mm FWHM



JUDITH 3 – cooling circuit

(to be installed in 2023)

temperature:	RT – 120 °C
pressure:	≤ 4 MPa
flow rate:	≤ 80-100 l/min

in-situ high purity control

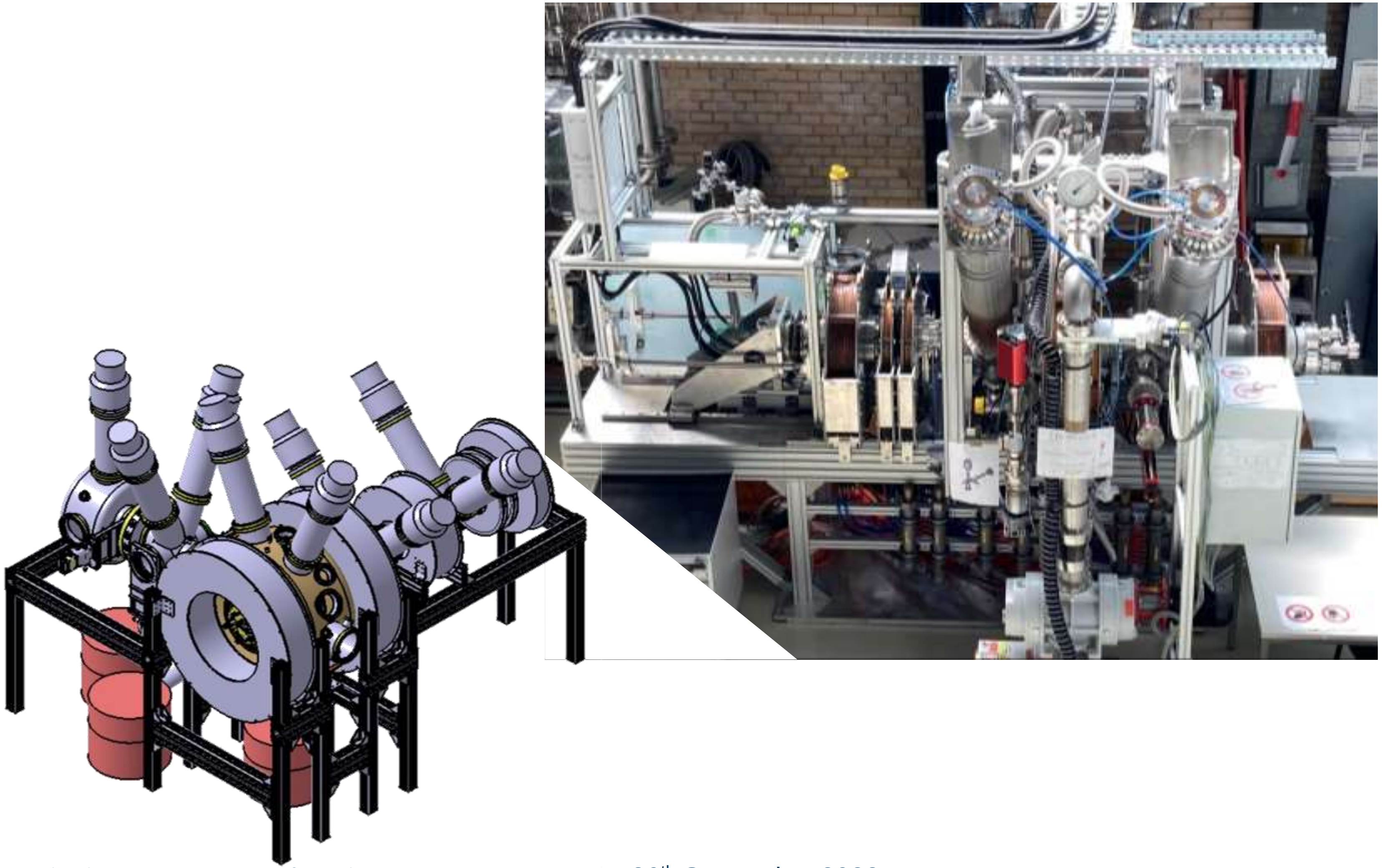
conductivity:	< 0.3 µS/cm
oxygen content:	< 0.04 mg/l

Provisional set-up in controlled area

To be installed in new hot-cell until 2025

JULE-PSI

Linear plasma device (under construction for implementation in a hot cell)



Planned diagnostics:

- Langmuir probe
- **I**nfra**r**ed (IR) camera
- **O**ptical **E**mission **S**pectroscopy (OES)
- **Q**uartz **M**icro **B**alance (QMB)
- **Q**uadrupole **M**ass **S**pectroscopy (QMS)

- **L**aser **I**nduced **B**reakdown **S**p. (LIBS)
- **L**aser **I**nduced **D**esorption-QMS (LIDS)

Thank you