New STIP PIE plan for tungsten and conceptual study for PIECE

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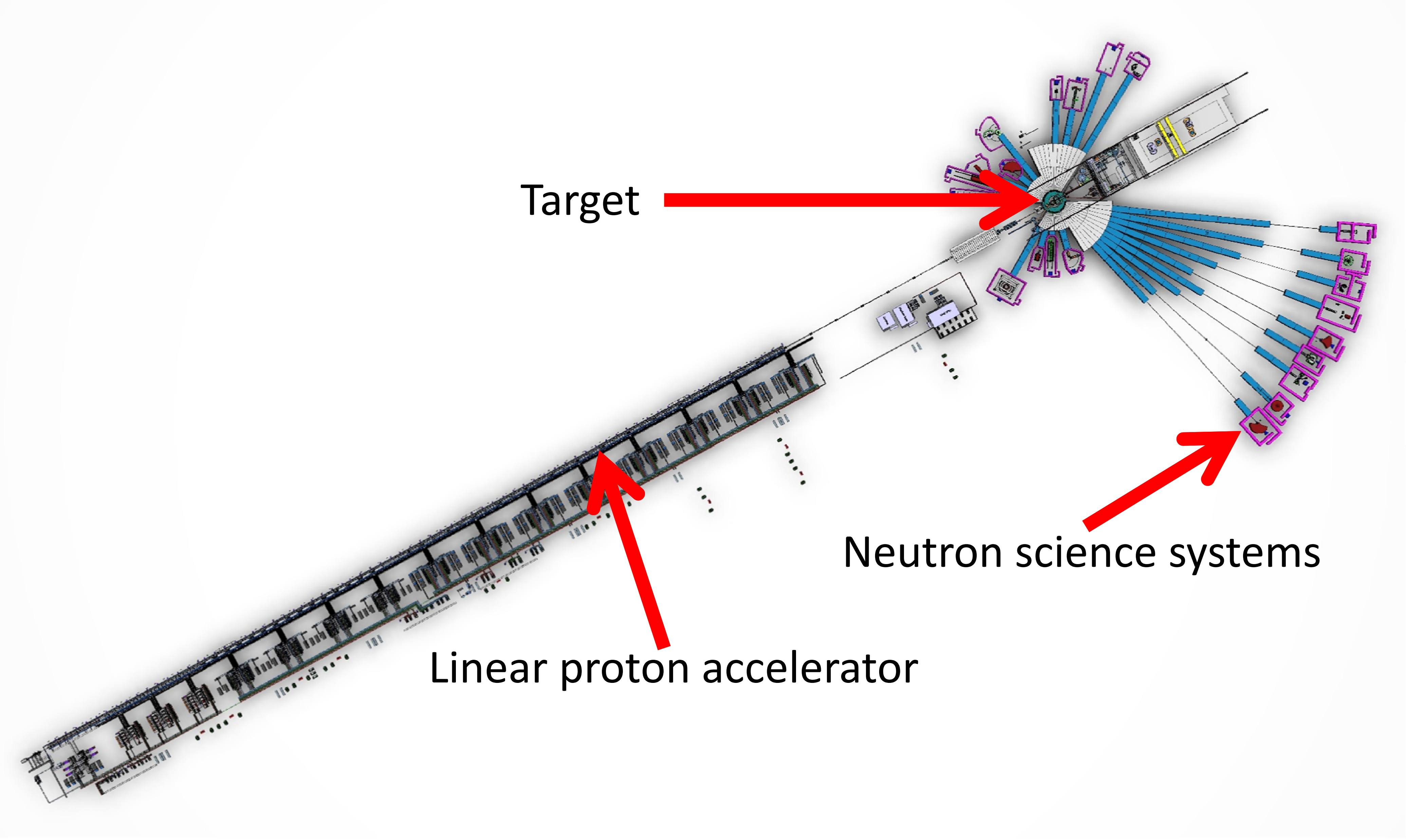
Target Division

The ESS Machine Layout



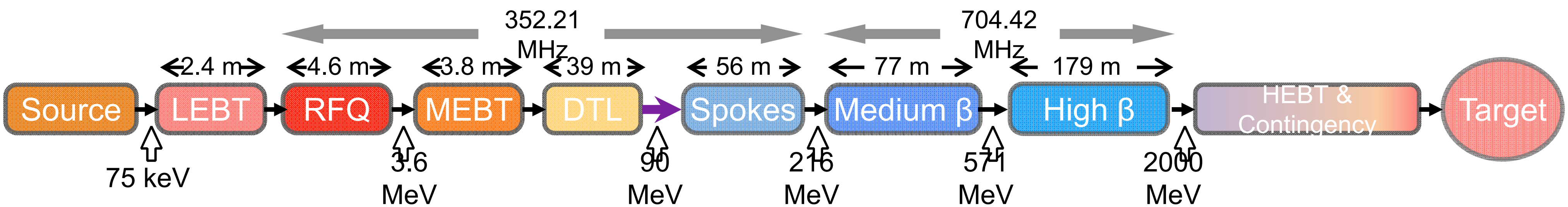
ACCSYS: A 5 MW SCRF linac

Design Drivers:

High Average Beam Power
5 MW
High Peak Beam Power
125 MW
High Availability
> 95%

Key parameters:

- -2.86 ms pulses
- -2 GeV
- -62.5 mA peak
- -14 Hz
- -Protons (H+)
- -Low losses
- -Minimize energy use
- -Flexible design for future upgrades

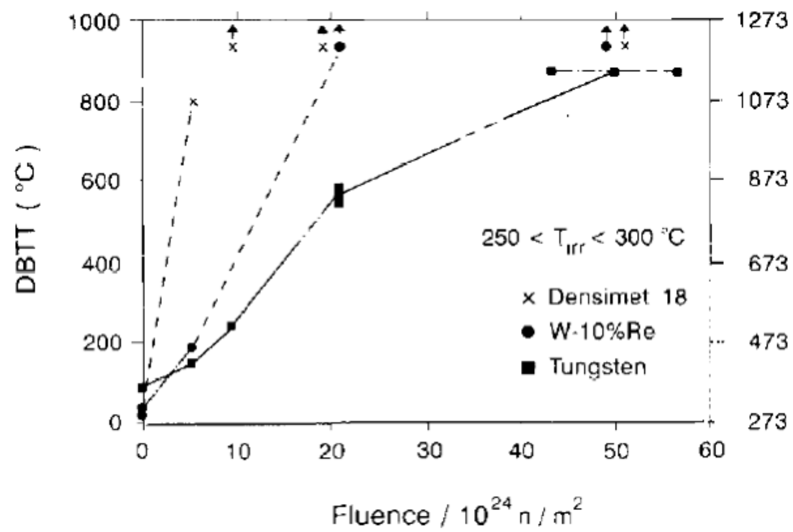


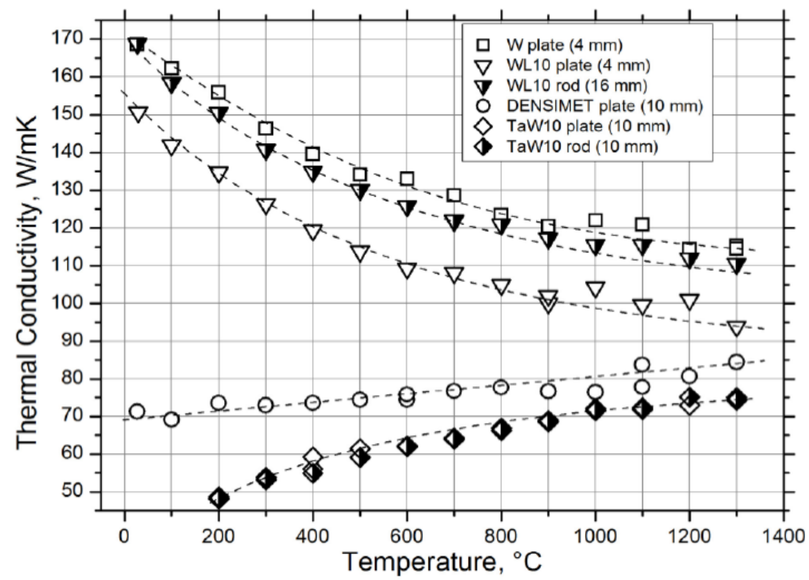
Spallation Material: Material Selection

- For better neutronic performance, the spallation volume must have high neuron production density.
  - Spallation material shall have high atomic number
  - Spallation material shall have high density
  - The material must be affordable, preferably with operational track records at other spallation sources.

Spallation Material

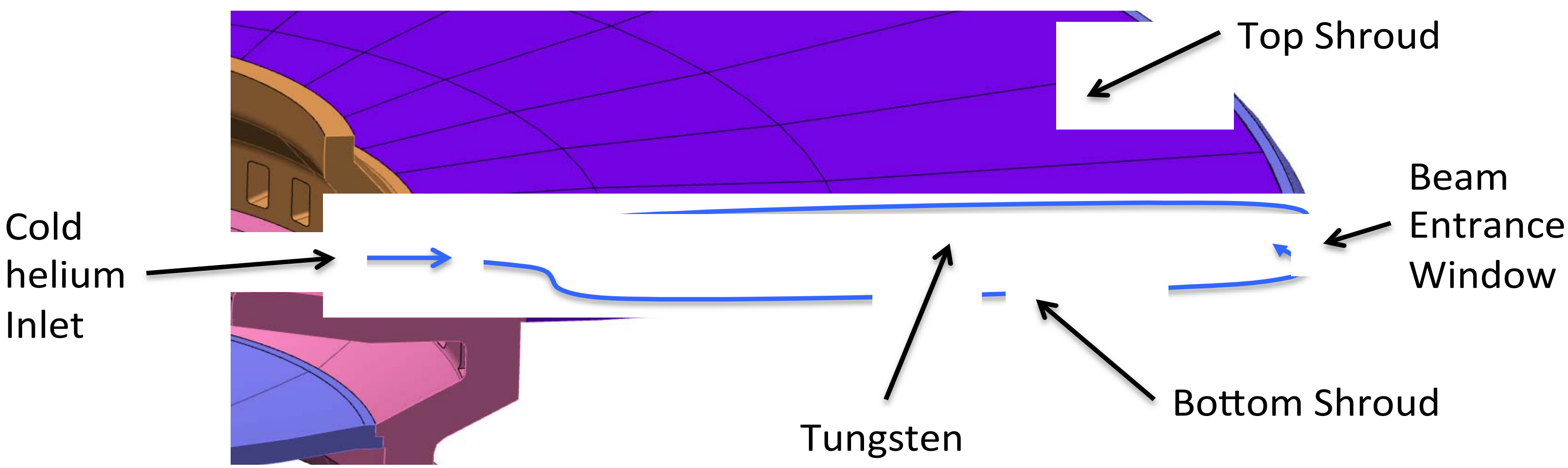
- Pure tungsten is chosen to be the spallation material at ESS:
  - Lower DBTT than W-10%Re for DPA > 0.3 [H. Ullmaier, F. Carsughi, NIM-B 101, 1995]
  - Higher thermal conductivity than other W-alloys [M. Rieth et al, Tech- Rep.-KIT]
  - Tantalum has a higher volumetric decay heat and lower neutron production density.





ESS Spallation Target

- Rotating tungsten target
  - Helium coolant at 1.0 MPa
  - Wheel diameter: 2.5 m
  - Tungsten slabs in 36 segments
  - Rotation speed: 23.3 rpm

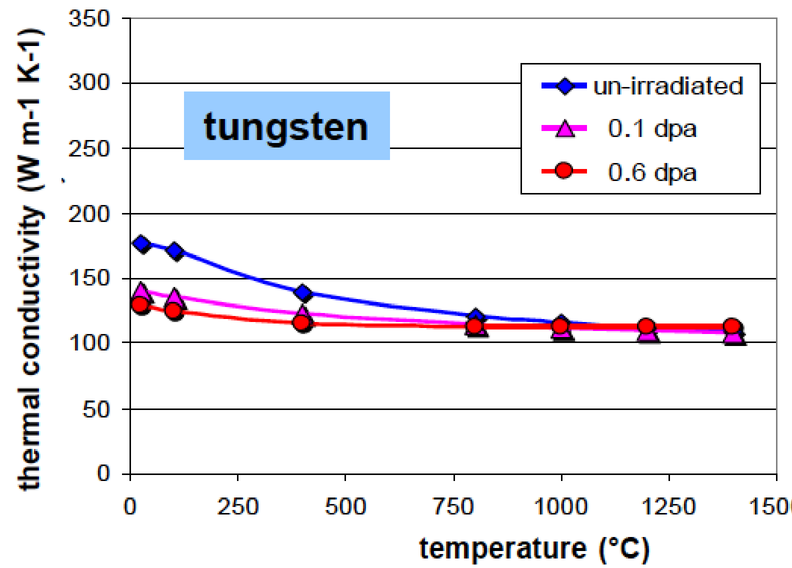


Issues on tungsten material at ESS

- Thermal fatigue caused by beam pulses and beam trips
- Tungsten oxidation and release of radioisotopes
- Radiation Damage:
  - Reduced or no ductility
  - Reduced thermal conductivity

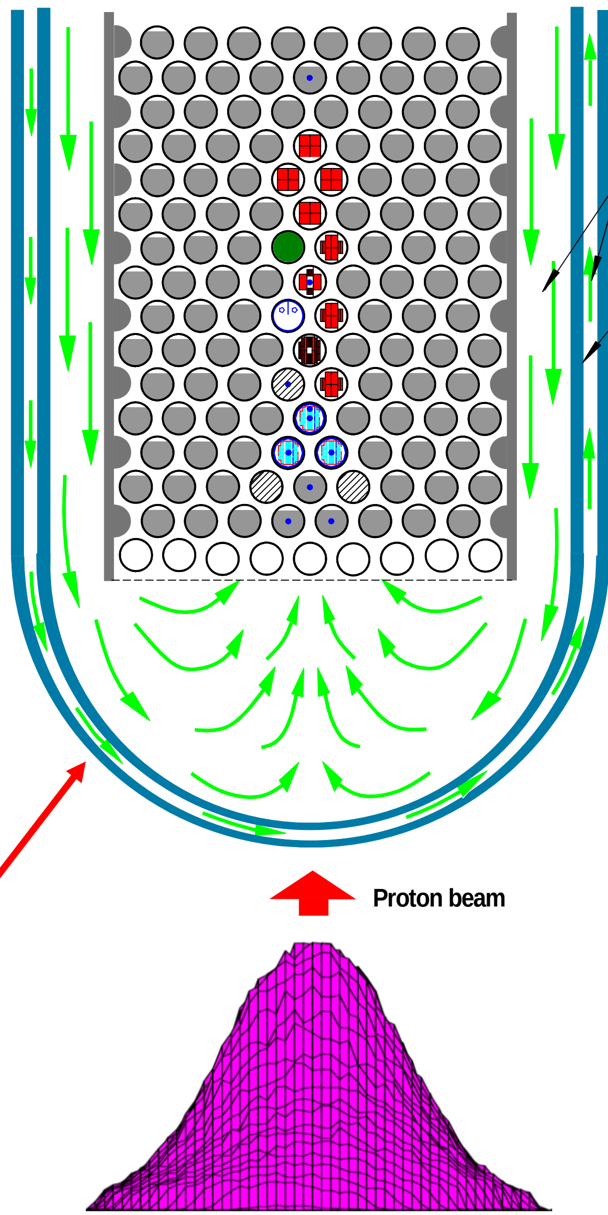
	Unirrad-iated	As irrad-iated	1050°C 1 h	1200°C 1 h
Tensile yield stress [MPa]	580	150	260	810
Total elongation [%]	10	*	*	4

Effect of irradiation on tensile strength at 500 C (T_{irrad}=700 C, ~2 dpa) [H. Ullmaier, F. Carsughi, NIM-B 101, 1995]

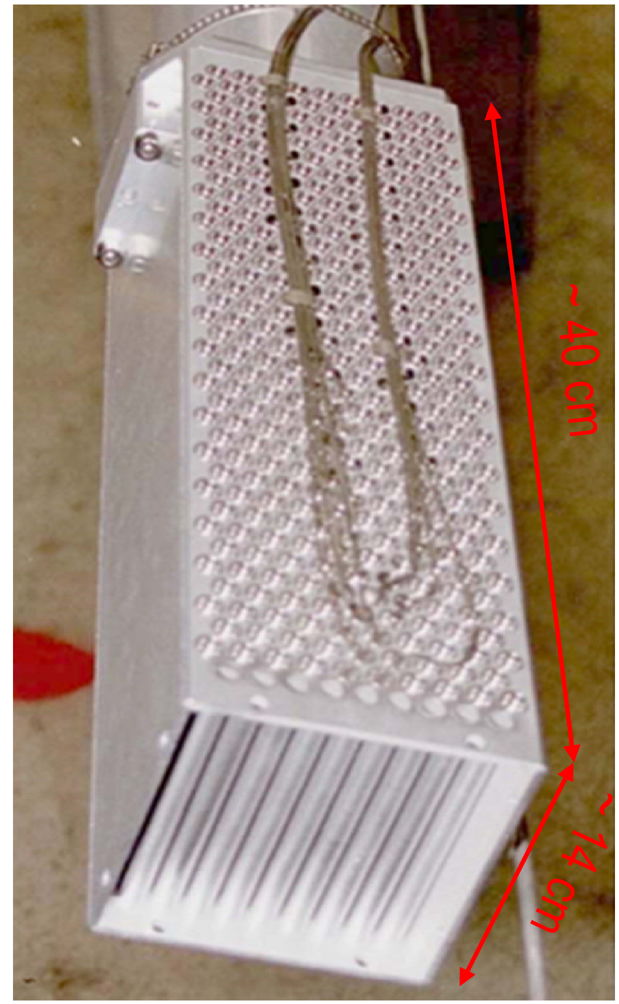


[J. Linke et al. First meeting of CRP on irradiated tungsten, Vienna, 26-28 Nov 2013]

SINQ Target (Y. Dai)

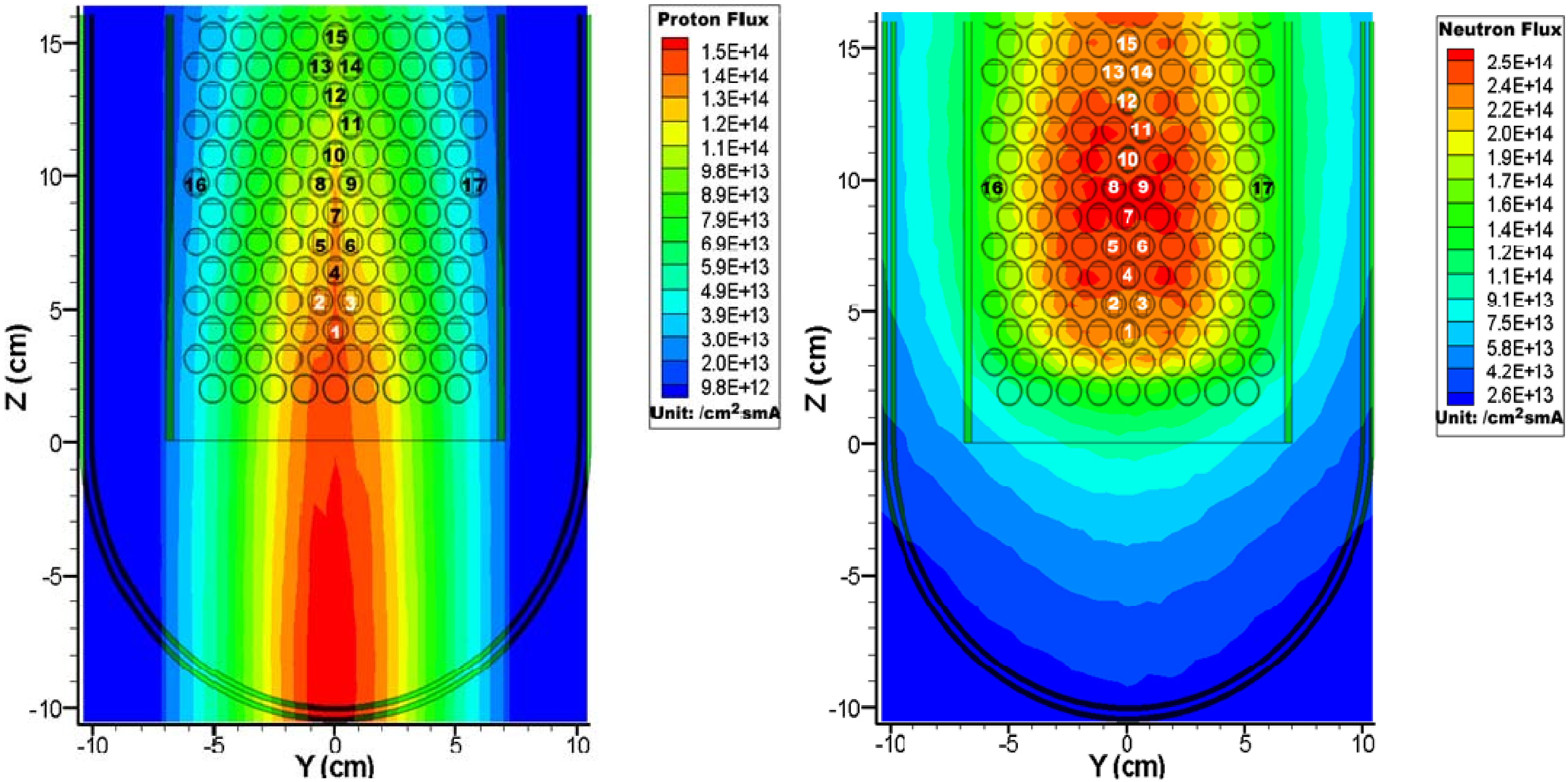


σ_x~3.5cm, σ_y~2cm



~360 Pb rods with SS / Zy-2 tubes

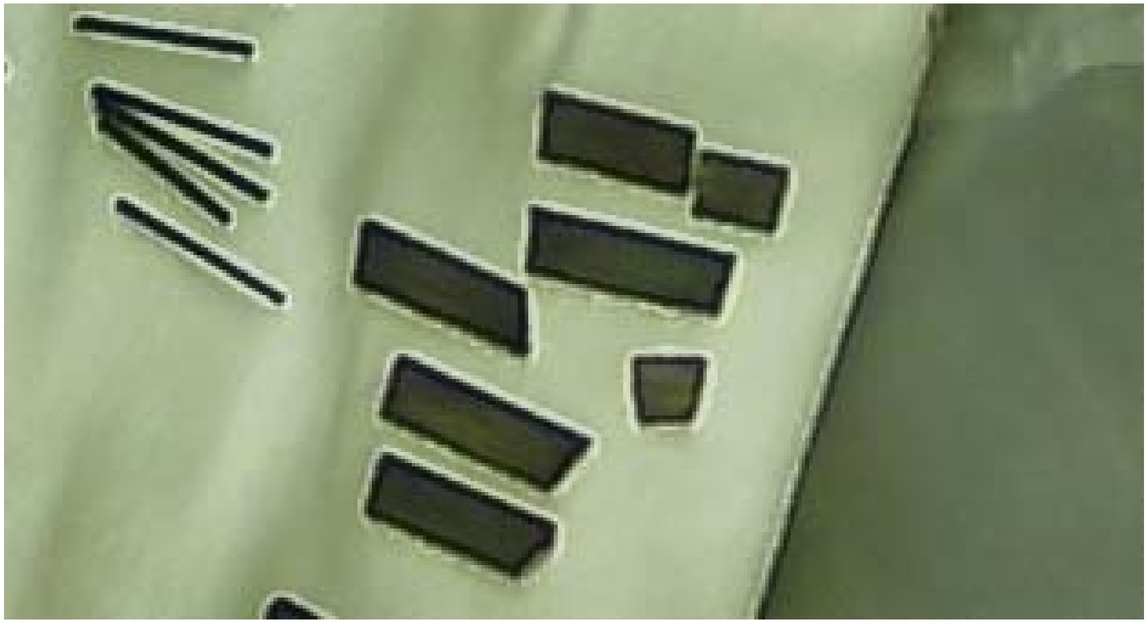
Proton and neutron flux distribution (Y. Dai)



PIE Plan using STIP (SINQ Target Irradiation Program) tungsten specimens

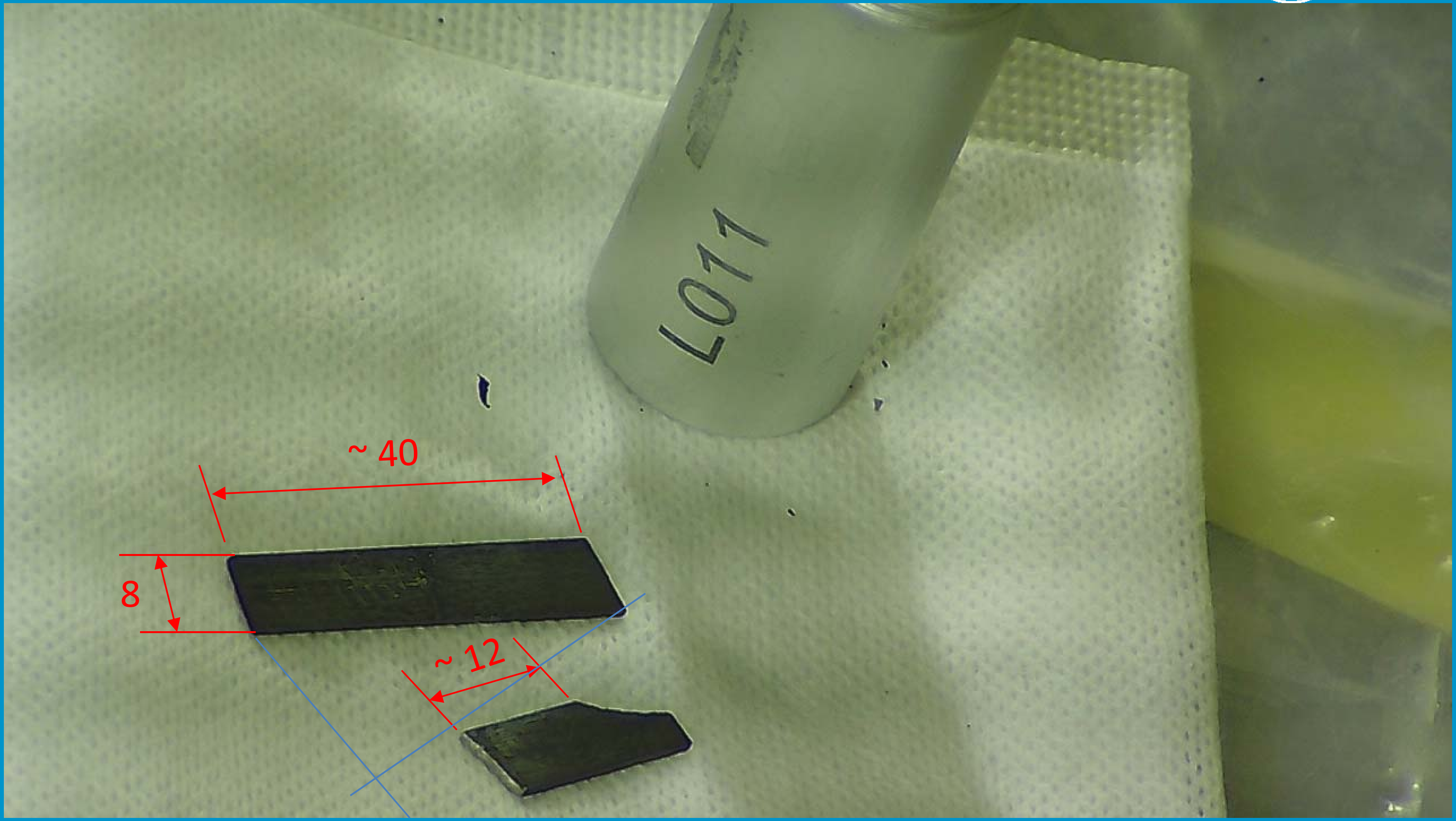
STIP	Irradiated Period	Total p^+ Charge	Tungsten Type	Dimension	Quantity	Irradiated Condition
STIP-V	2007-2008	9.83 Ah	Rolled W for CSNS	$60 \times 8 \times 1$ mm^3	2	5-28 dpa at 100-800 °C
STIP-VI	2011-2012	13.16 Ah	Rolled W from Goodfellow	$27 \times 5(6) \times 0.5$ mm^3	52	5-25 dpa at 100-600 °C
STIP-VII	2013-2014	-	Rolled W from a Chinese company	bend bar	10	5-35 dpa at 100-600 °C
		-		rod with HIP'ed cladding	9	5-35 dpa at 100-600 °C
		-		HIP'ed full rod	1	5-35 dpa at 100-600 °C
		-		canned full rod	1	5-35 dpa at 100-600 °C
		-	HIP'ed W from KIT	bend bar	5	5-35 dpa at 100-600 °C
STIP-VIII	2015-2018	-	To be defined by June 2014	TBD	TBD	TBD

7 Pieces of tungsten sheets in Rod 5 of STIP-5 (Y. Dai)



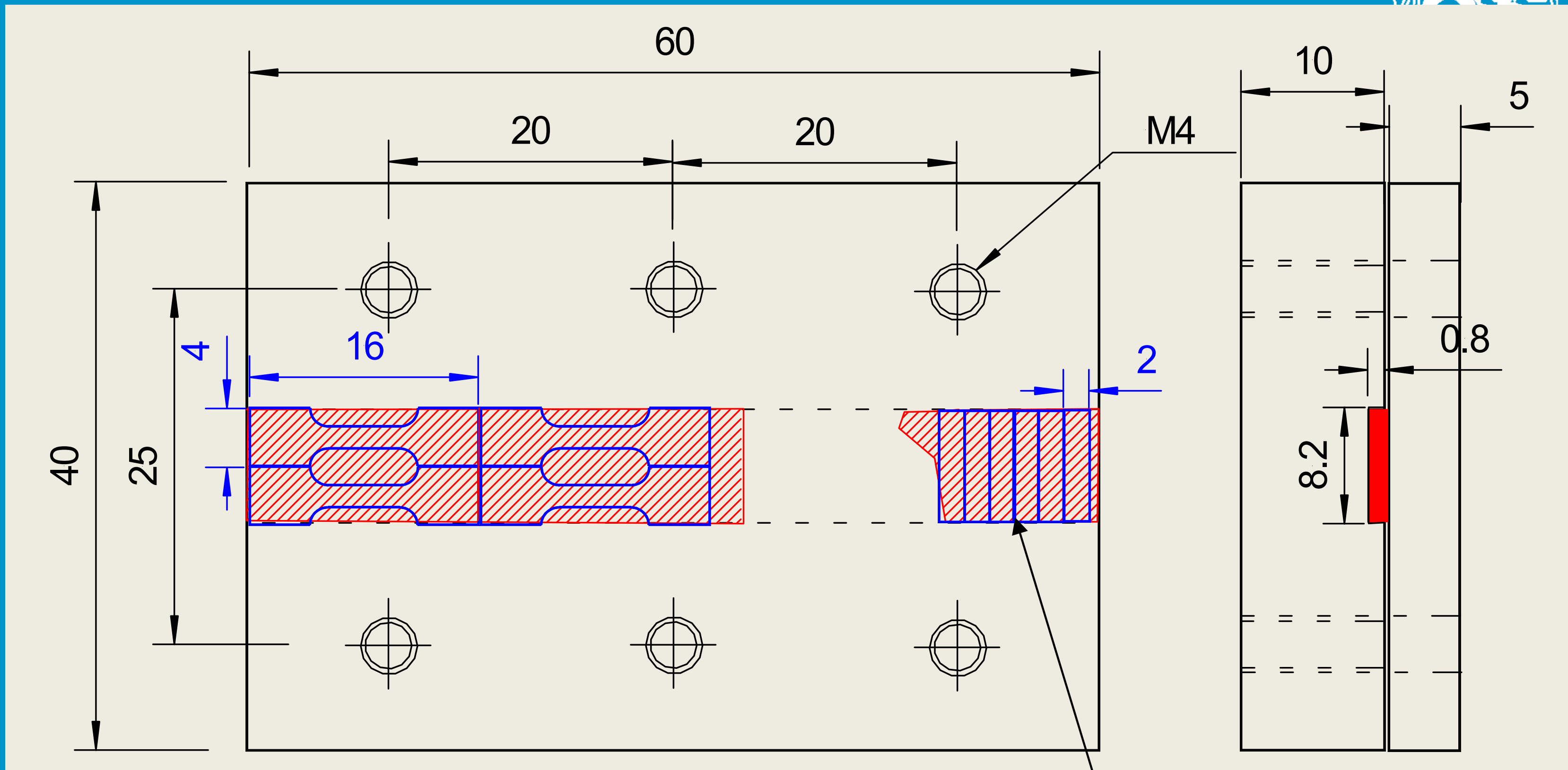
The 5 larger pieces are about 15-20 mm long.

2 Pieces of tungsten samples in Rod 3 of STIP-5 (Y. Dai)

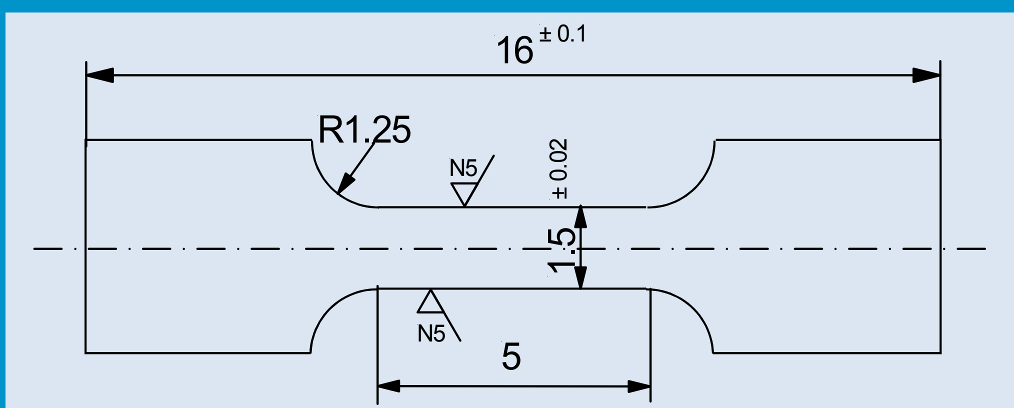


Samples from the 2 Pieces of tungsten sheets in Rod 3 of STIP-5 (Y. Dai)

EUROPEAN
SPALLATION
SOURCE

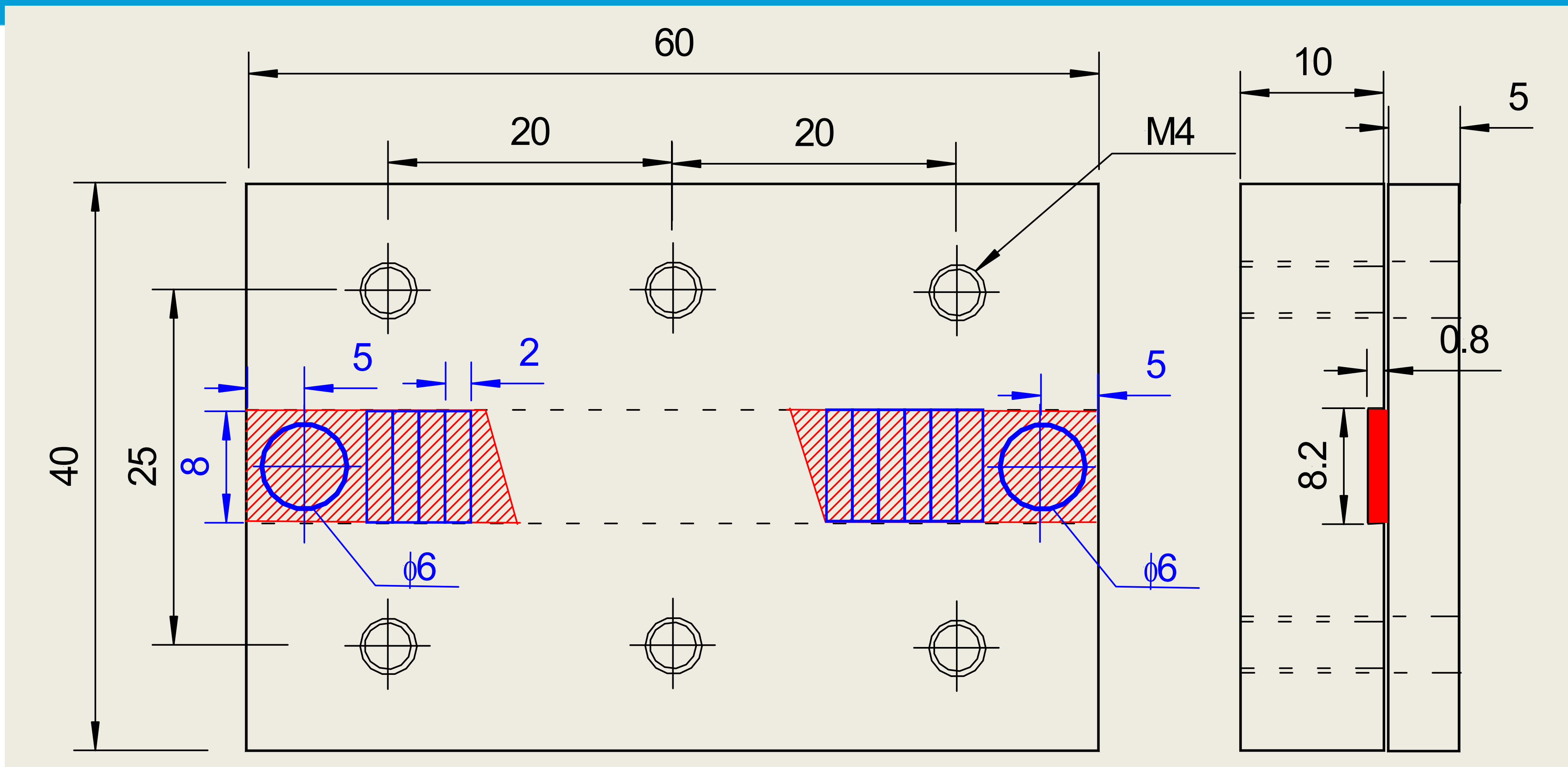


~ 6x small bend samples
Size: 8x2x1 mm



Tensile samples

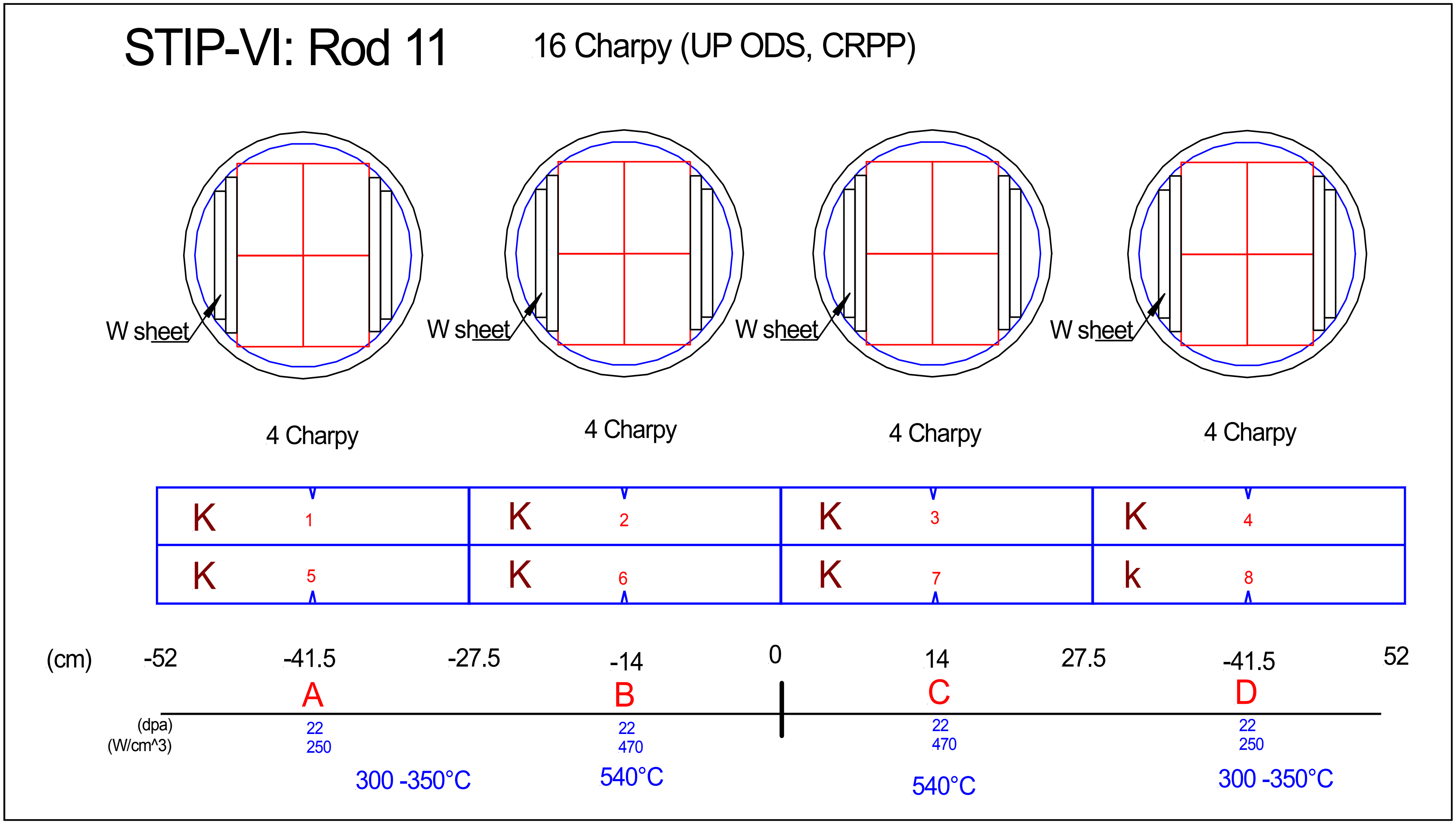
Sample from the 7 Pieces of tungsten samples in Rod 5 of STIP-5 (Y. Dai)



For the 5 larger pieces, one 6mm diameter disc and 4-6x bend samples of 8x2 mm will be cut from each piece.

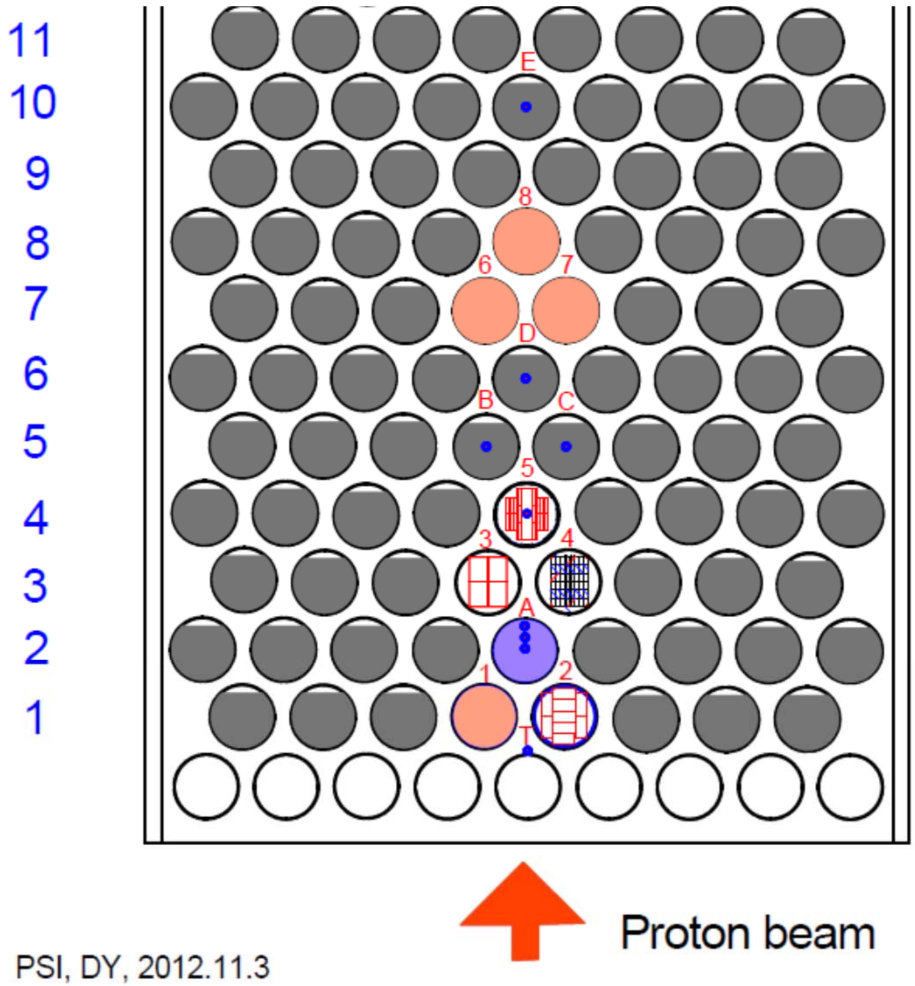
Irradiate W samples in STIP-VI (Y. Dai)

Irradiation: 2011-2012, PIE: 2016 -



Irradiate W samples in STIP-VII (Y. Dai)

Irradiation: 2013-2014, PIE: 2016 -

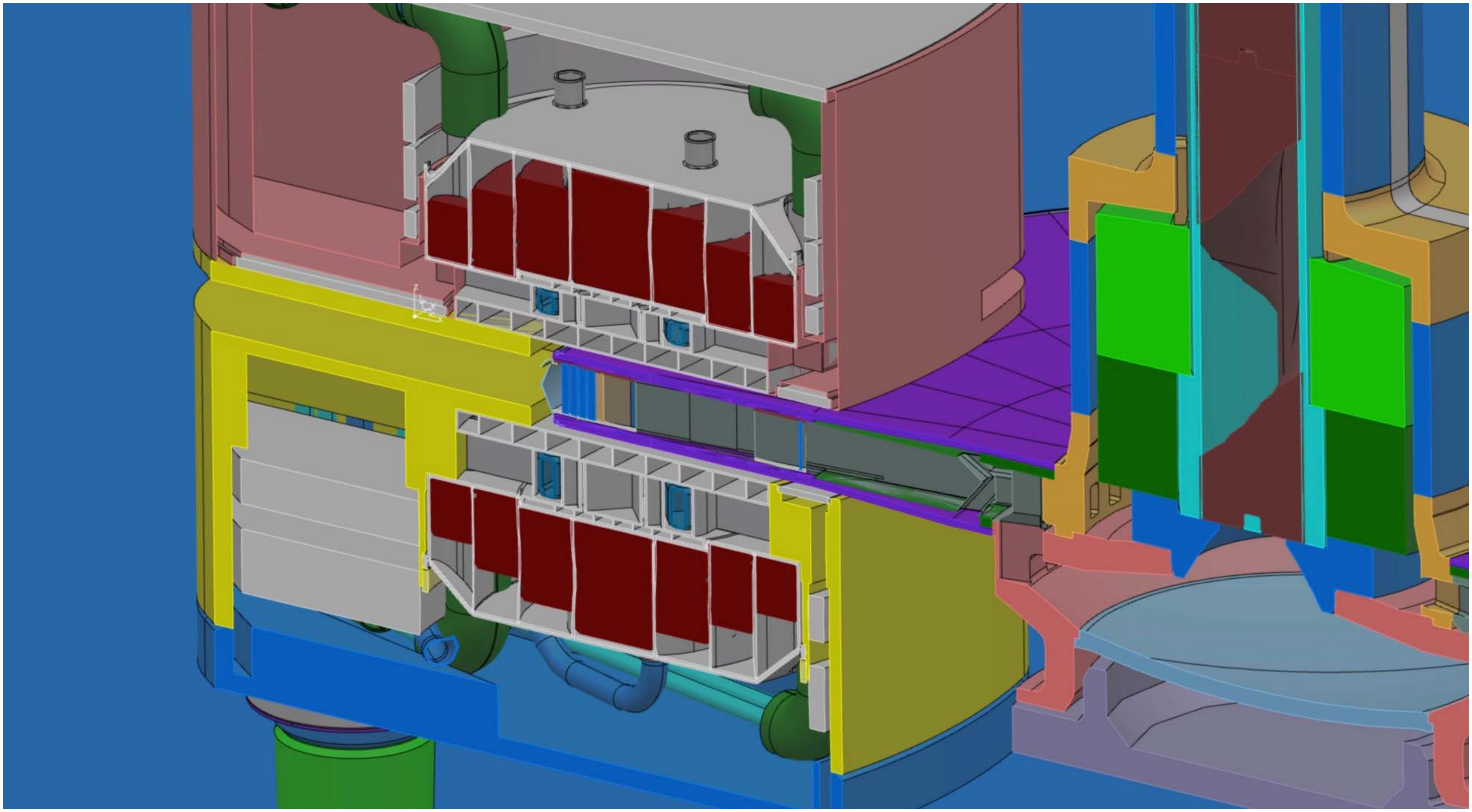


Rod	Samples
T	Tube with 1x TC
A	Zircaloy rod with 3x TC
B-E	Target rods with 1x TC each
1	W - with Ta, Zy, SS, HIP'ed
2	Bend bar, UCSB
3	Steels, Charpy
4	Steels, tensile (LT)
5	Steels, tensile (ST) and TEM
6	W, full rod, canned + He
7	W, full rod, canned + Pb filler
8	W+Ta HIP'ed
9	W, Steel, Bend Bars
10	Steels, Charpy
11	Steels, Charpy
12	Steels, bend bar
13	Steels, tensile (LT)
14	UCSB
15	UCSB
16	Steels, tensile (LT)

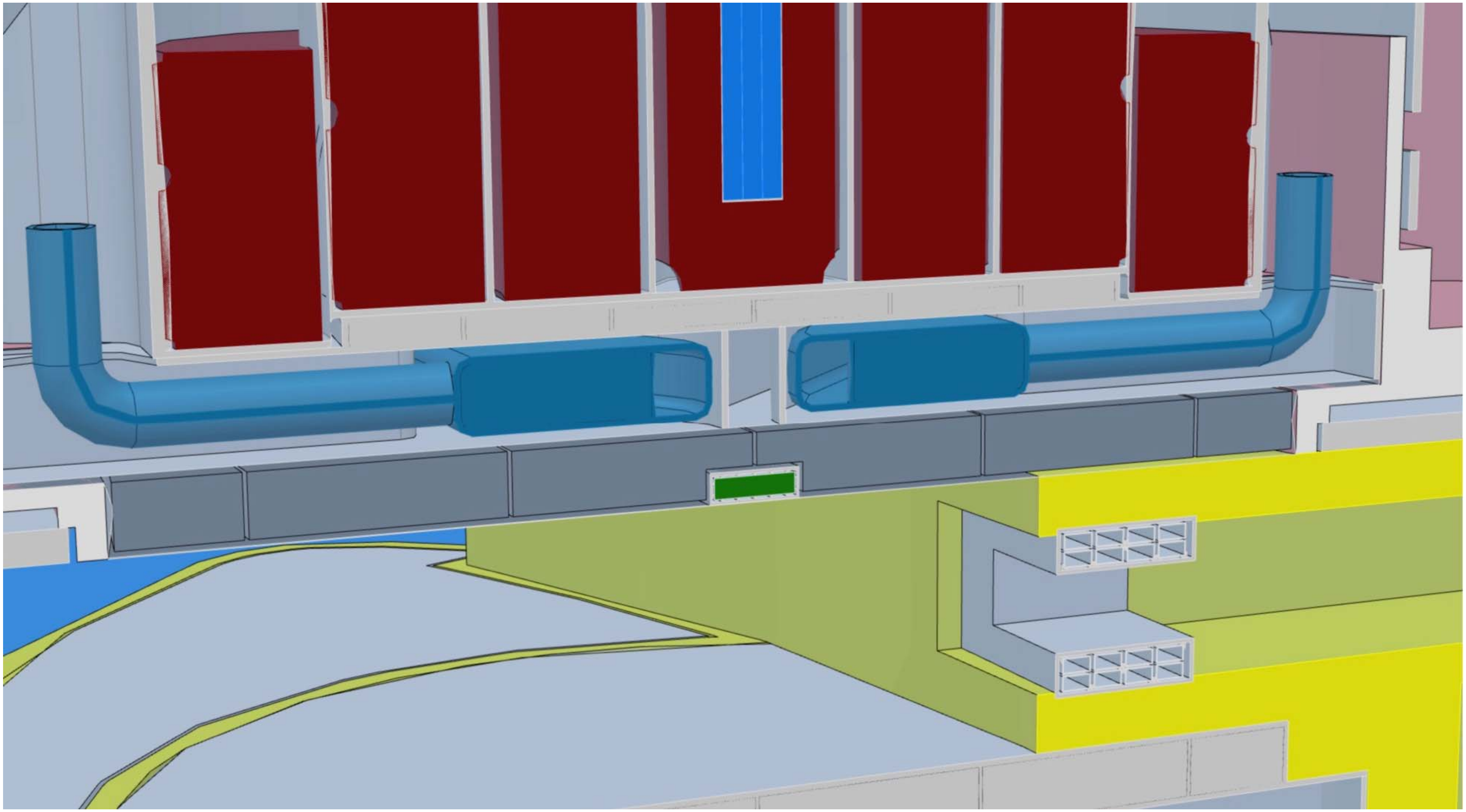
Summary: STIP tungsten specimens

- A series of STIP tungsten specimens PIEs are planned.
- The PIEs will be supplemented by small-scale cold and hot materials tests.
  - Fatigue tests
  - Oxidation tests in inert gas
  - Thermal cycling tests
  - Coating evaluation
  - Tungsten release factor

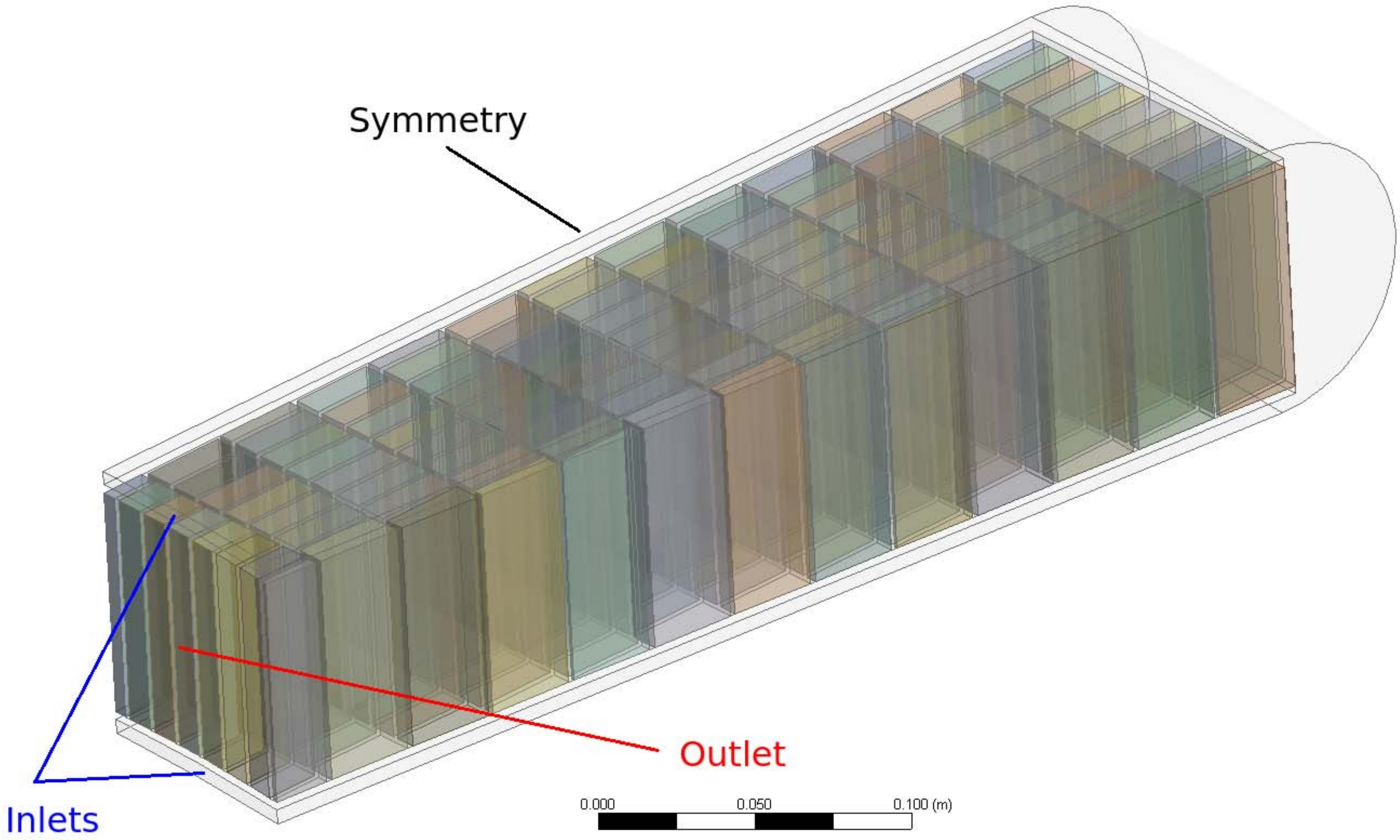
Irradiation Module Feasibility Study



Irradiation Module Feasibility Study



Irradiation Module Feasibility Study

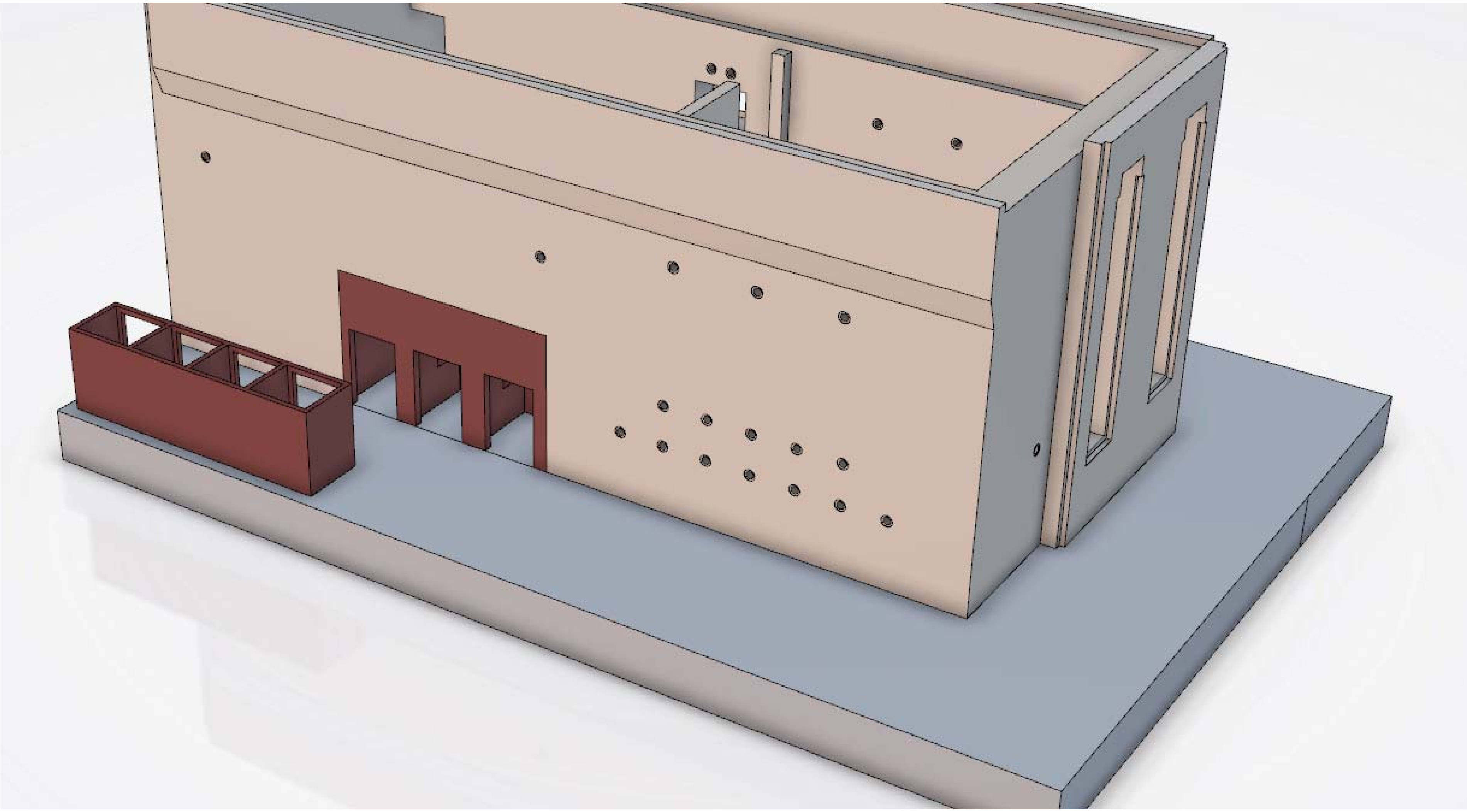


Irradiation Module Feasibility Study

- Four locations are identified for implementing irradiation modules for materials research
- The passive modules in the beryllium reflector and in the spallation target are within the allocated budget.

Location	Dominant particles	Estimated dose rate	Estimated He appm/dpa
Thermal moderator	Fast neutrons	7-14 dpa/GW-d	10 - 20
Target upstream	Fast neutrons with halo protons	2-8 dpa/GW-d	10 - 100
Beryllium reflector	Thermal neutrons	1.0E22 n/cm^2/GW-d	< 10
Spallation target	Protons and fast neutrons	1.0 dpa/GW-d	> 10

Feasibility of PIE Cells at ESS



Summary

EUROPEAN SPALLATION SOURCE

- A series of PIEs are planned on STIP tungsten specimens.
- Conceptual design of irradiation modules are under way.
  - A low budget modules will be realized during the construction phase.
- Conceptual design of PIE cells are under way.
  - Space allocation with appropriate preparation for the floor loading will be done during the construction phase.
- The feasibility/justification of chip irradiation facility is under investigation.