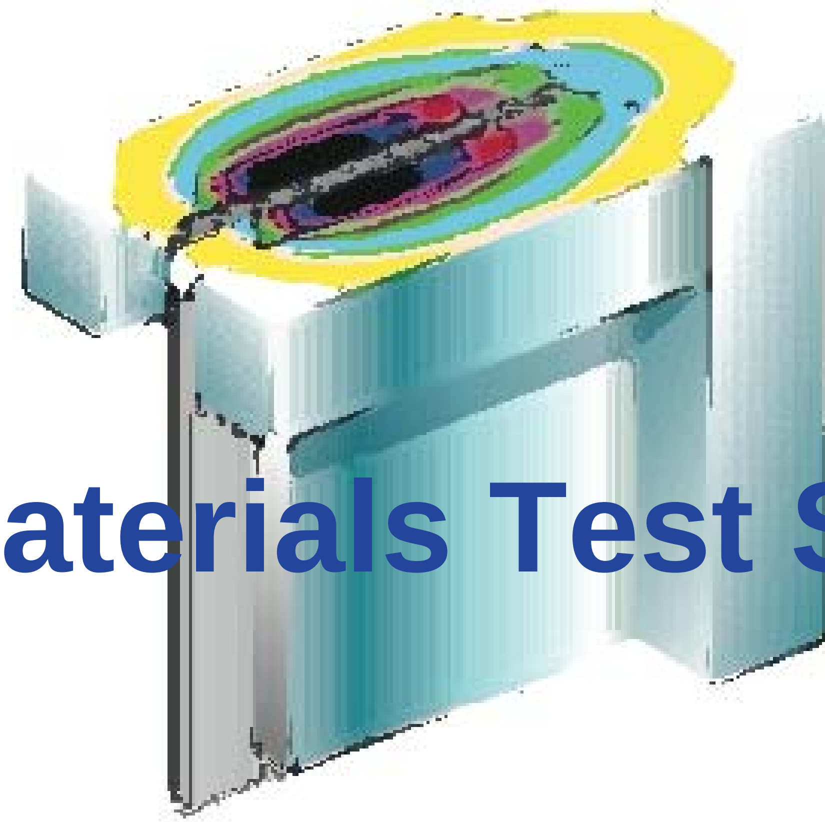

The Materials Test Station

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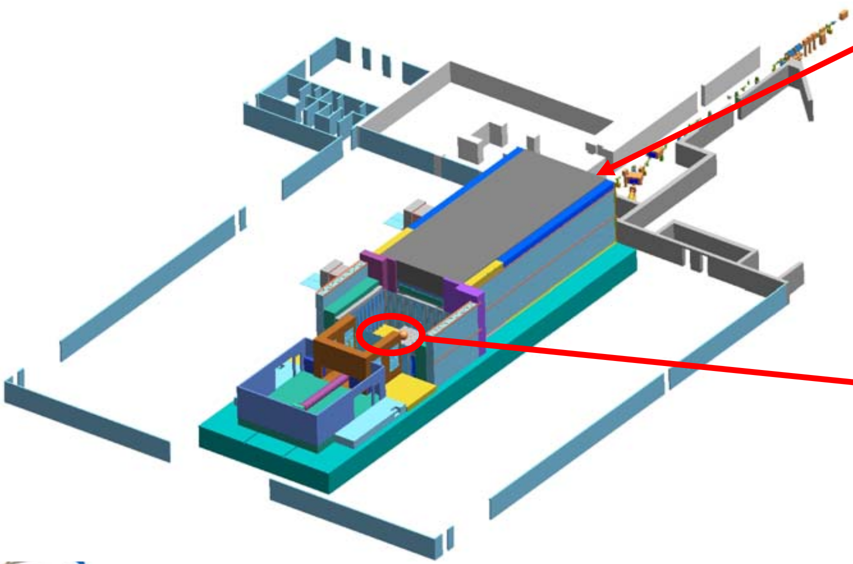
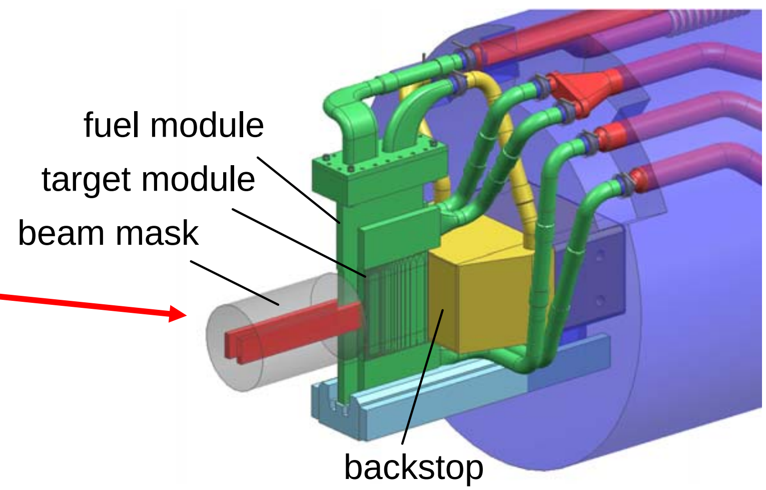
Presentation to:
AHIPA Workshop, Fermilab

October 19, 2009

The MTS will be a fast spectrum fuel and materials irradiation testing facility

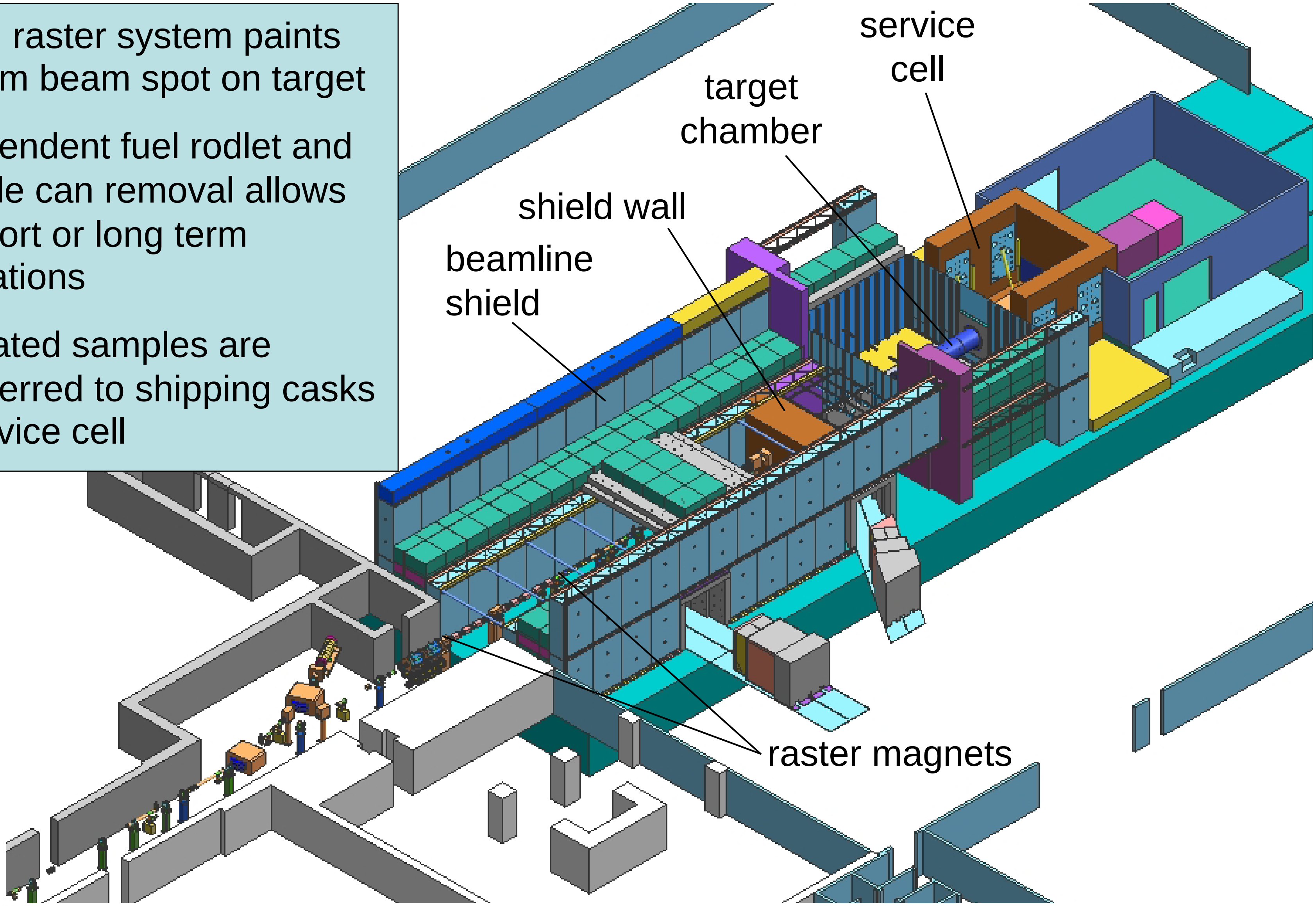
- MTS will be driven by a 1-MW proton beam delivered by the LANSCE accelerator
- Spallation reactions produce 10^{17} neutrons per second





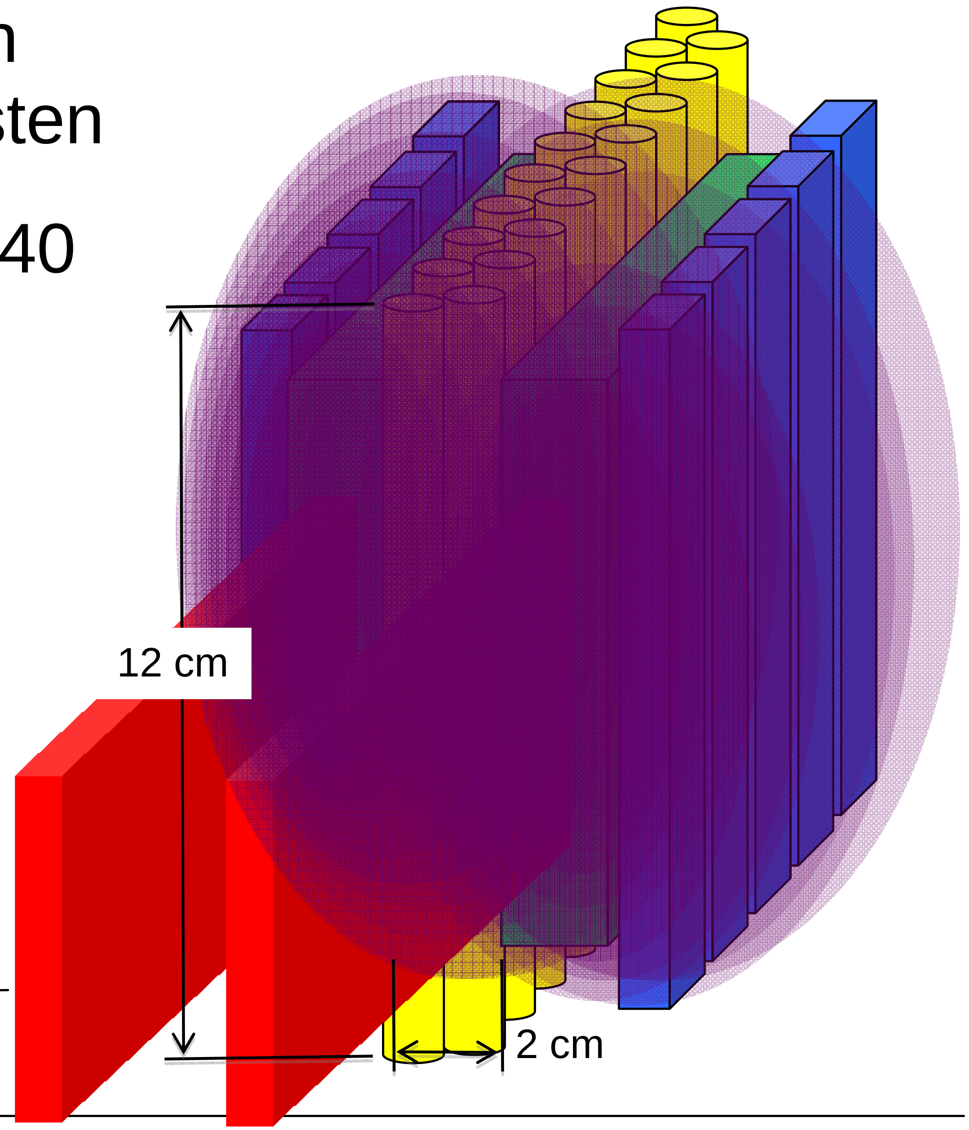
The MTS design includes all the services needed to maintain the target and change out samples

- Beam raster system paints uniform beam spot on target
- Independent fuel rodlet and sample can removal allows for short or long term irradiations
- Irradiated samples are transferred to shipping casks in service cell

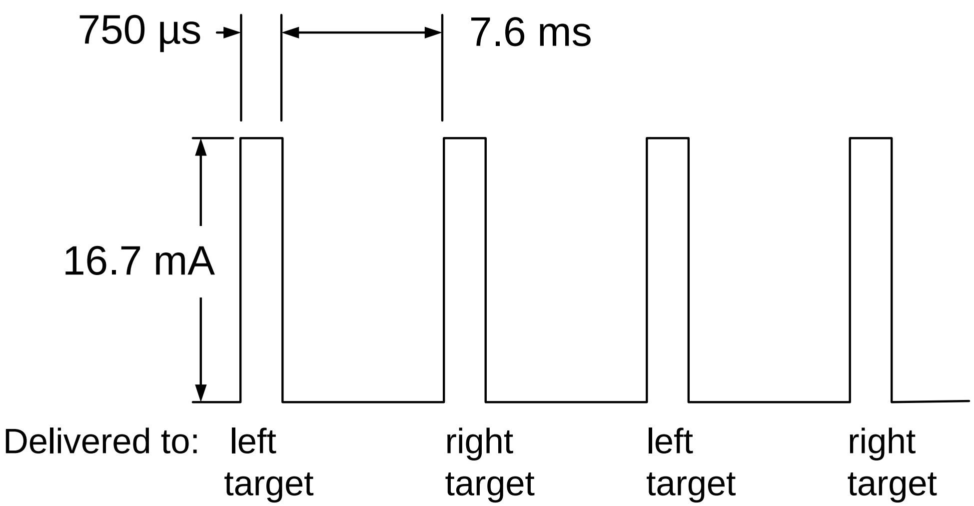


The MTS target consists of two spallation target sections separated by a “flux trap”

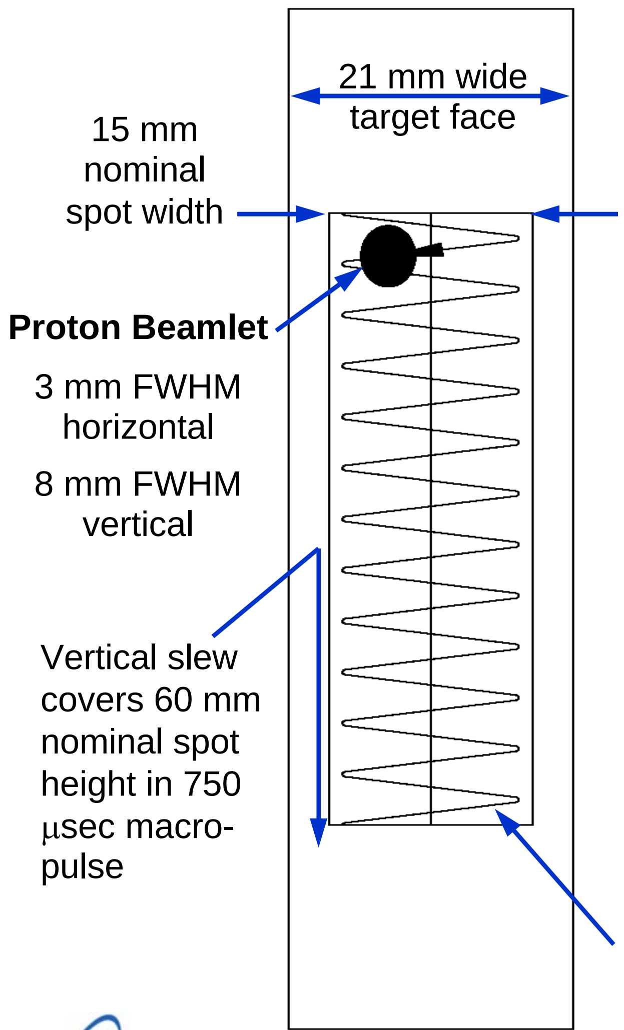
- Neutrons generated through spallation reactions in tungsten
- 2-cm-wide flux trap that fits 40 rodlets

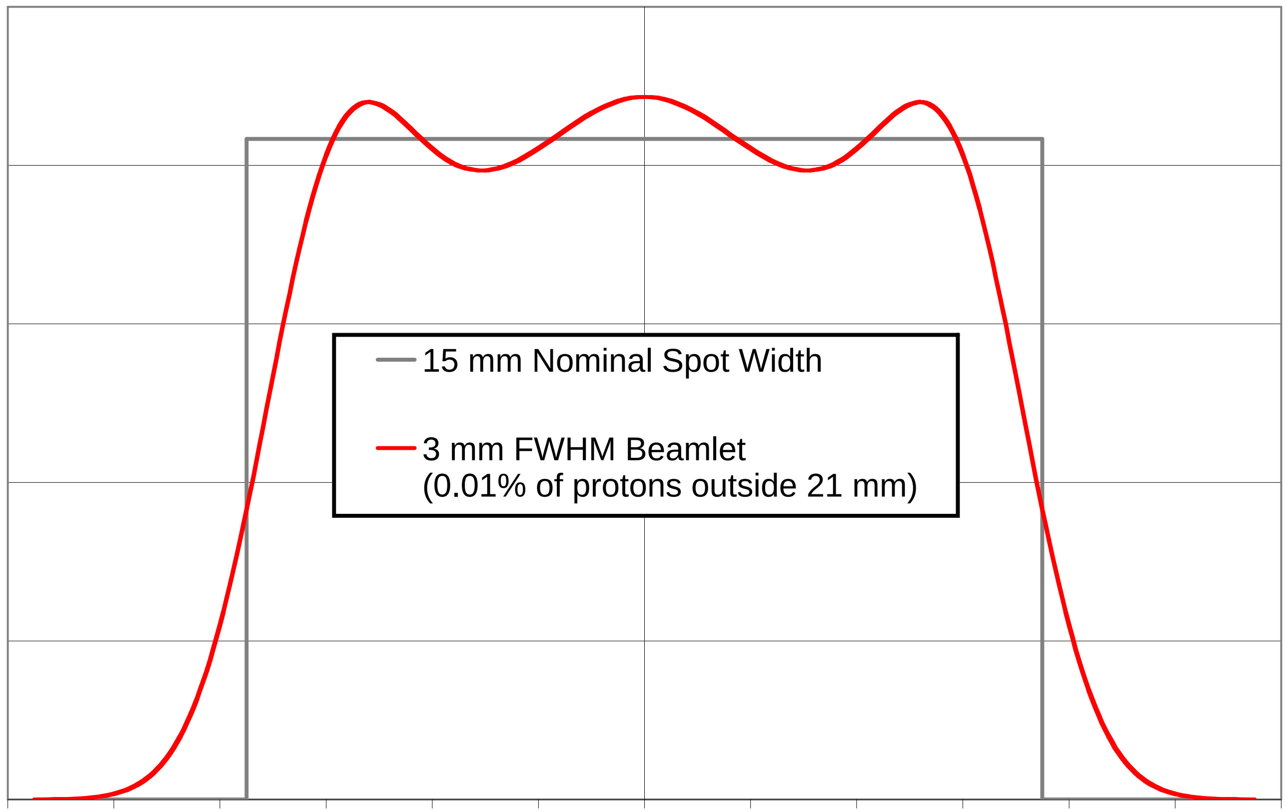


Beam pulse structure:



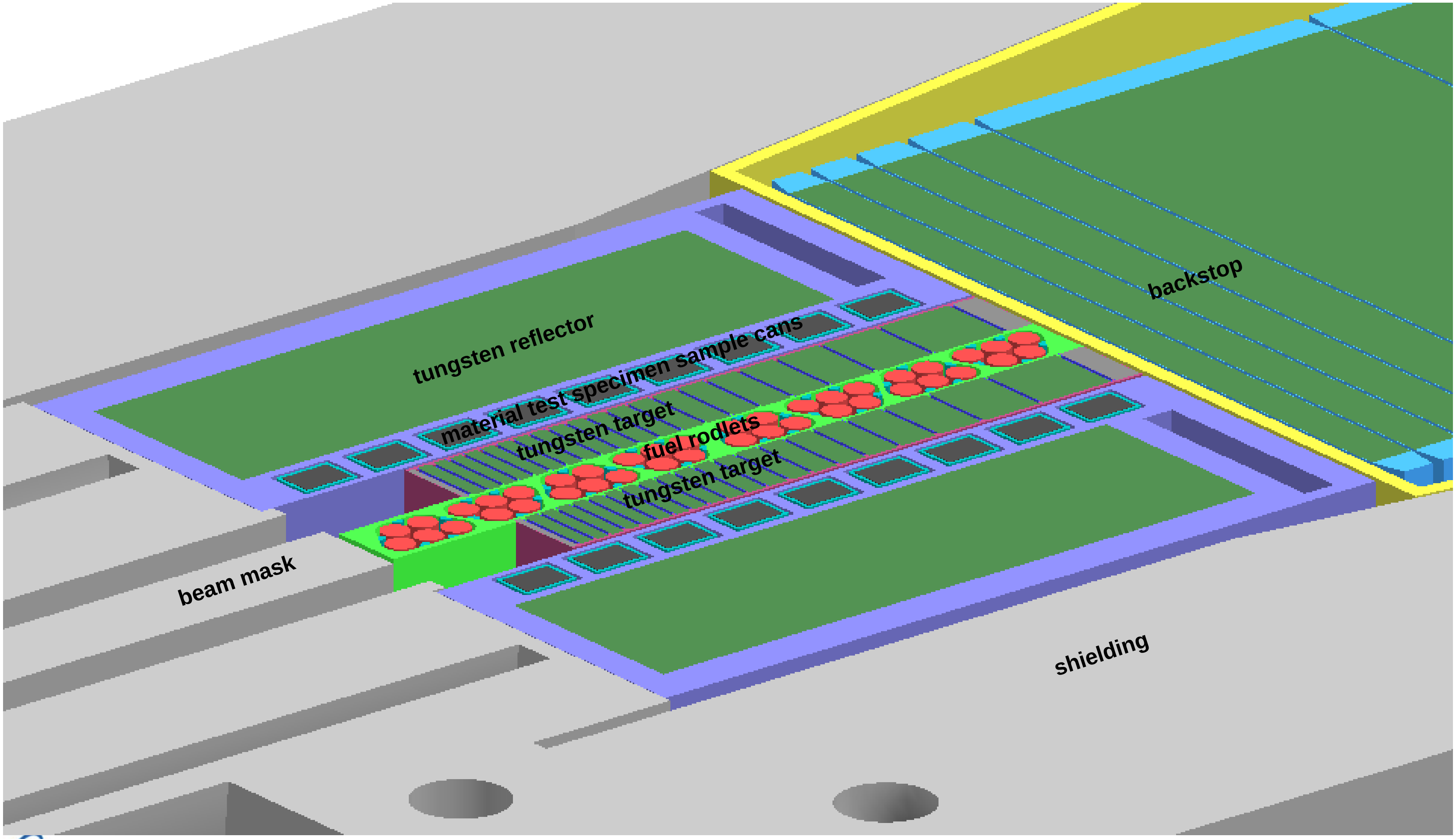
The rastered beam provides nearly uniform current density over a 60 mm x 15 mm beam spot



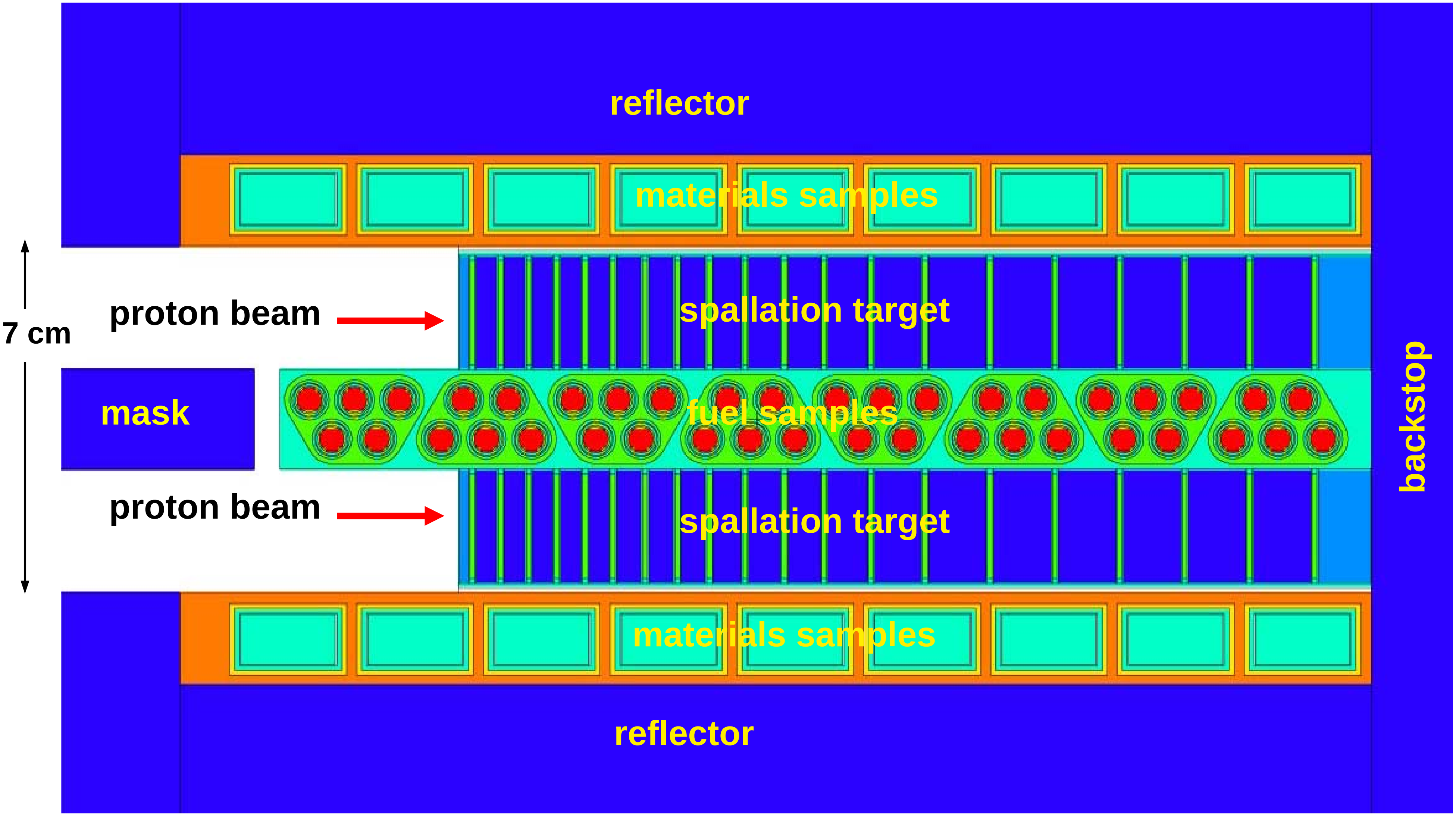


Fast raster is 20kHz sinusoid plus 8.8% 60kHz to make it more sawtooth shaped. Subsequent macropulses arrive at a different temporal phase, smearing the average spot vertically.

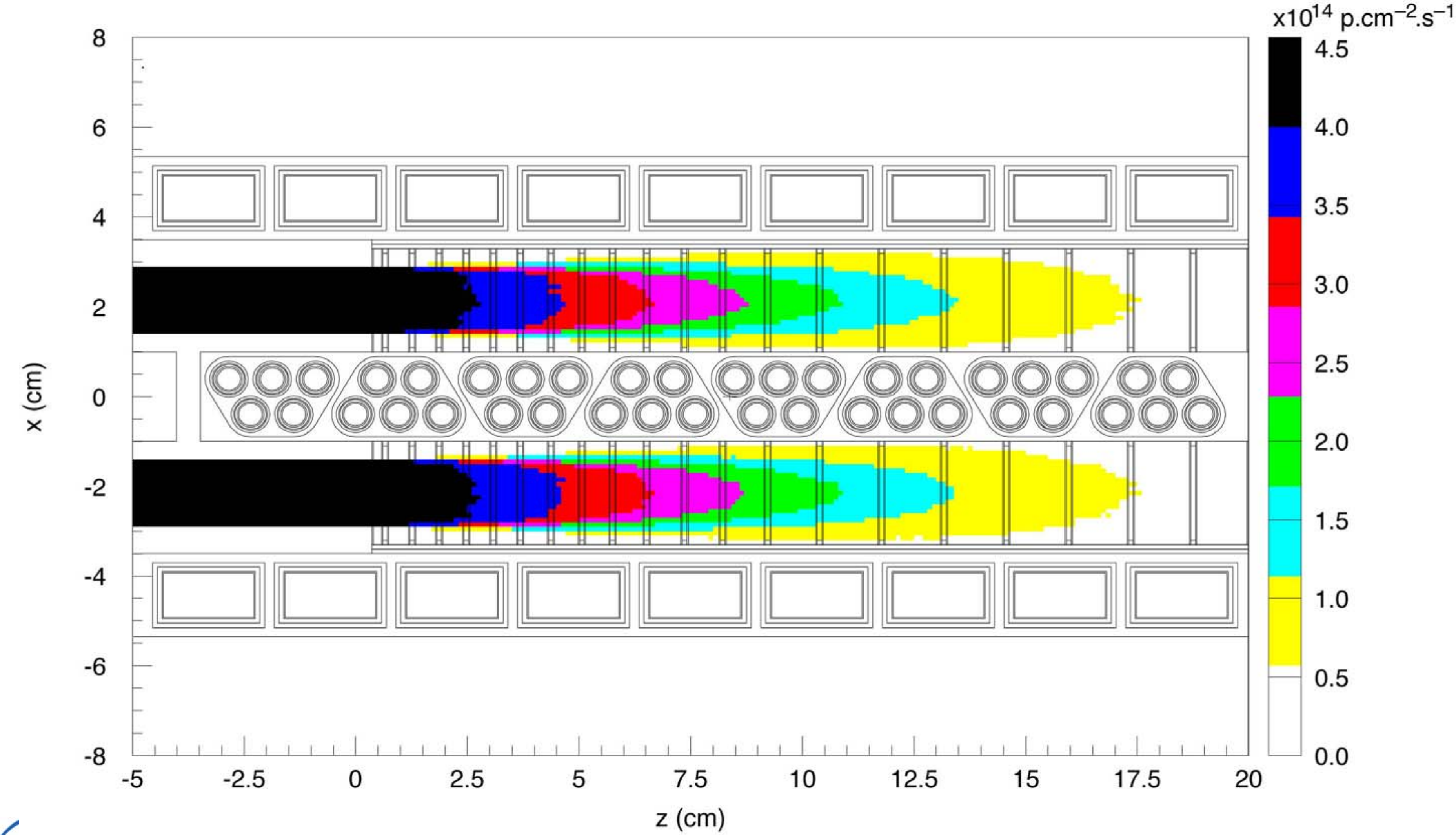
Horizontal cut through the target assembly at target mid-plane (magnified)



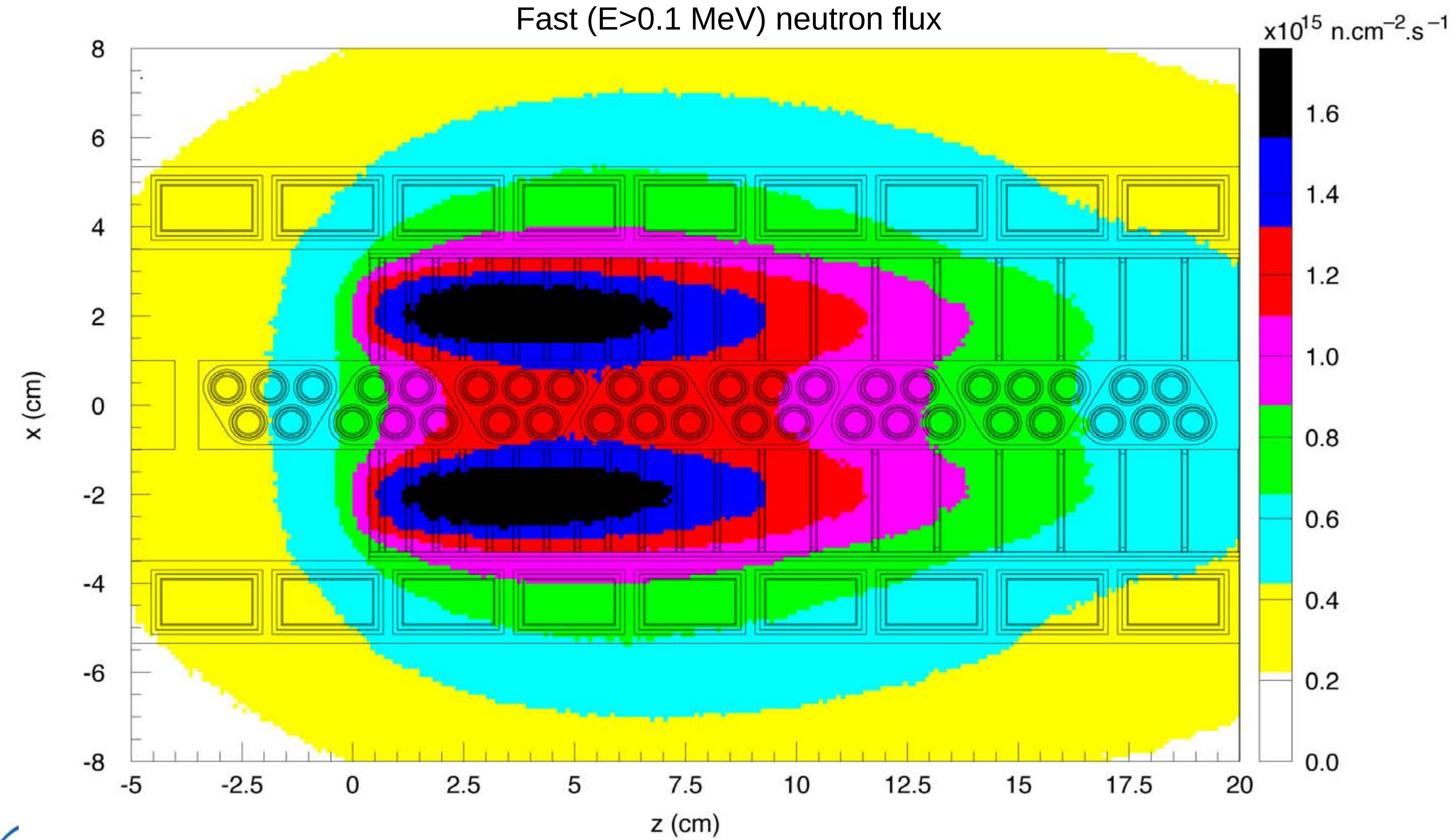
Horizontal cut through the MTS target assembly at beam centerline – MCNP(X) model



Spatial distribution of the proton flux shows low proton contamination in the irradiation regions

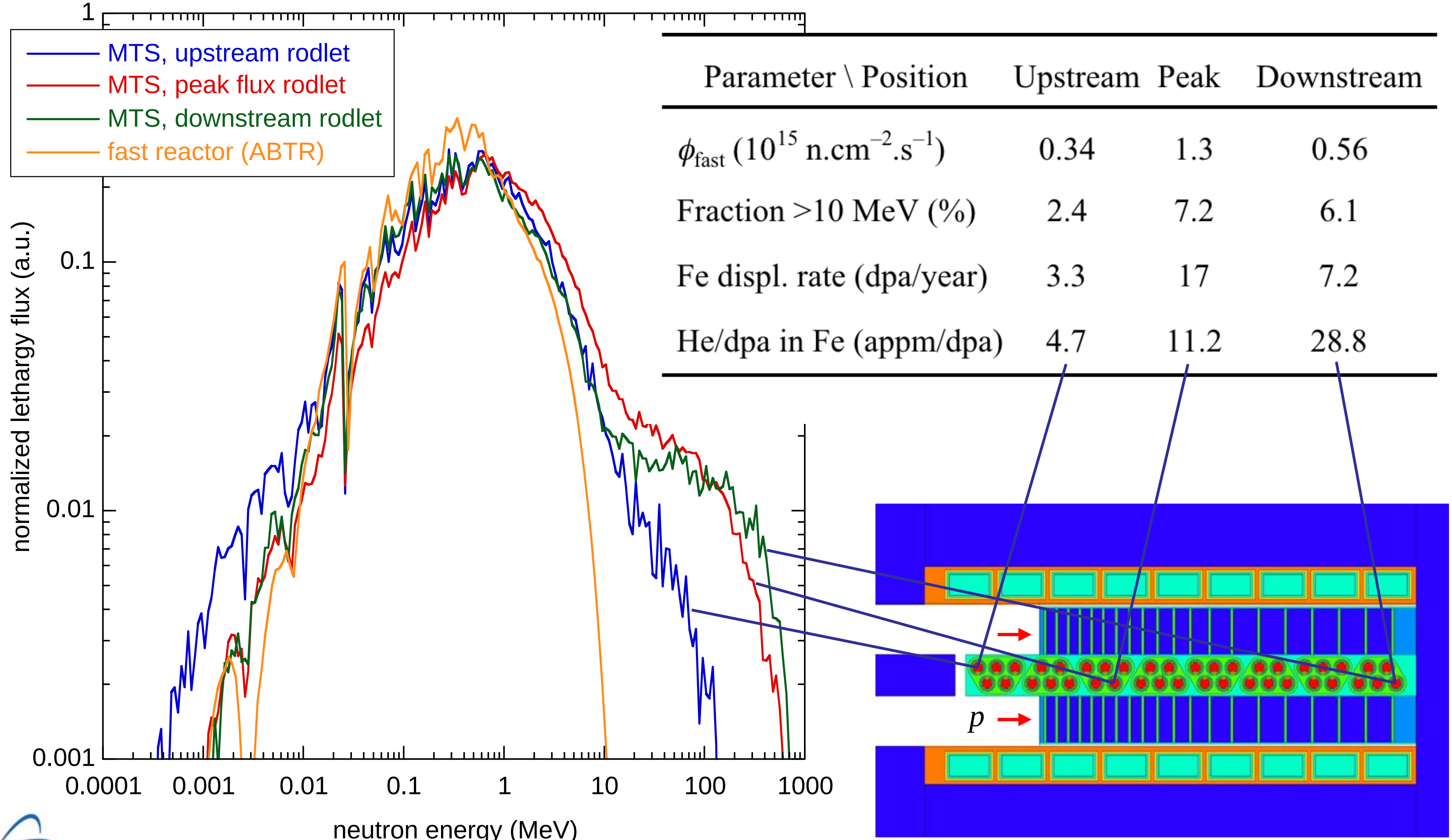


Spatial distribution of the fast neutron flux shows uniformity over the dimensions of a fuel pellet



The neutron spectrum in MTS is similar to that of a fast reactor, with the addition of a high-energy tail

Parameter \ Position	Upstream	Peak	Downstream
ϕ_{fast} (10^{15} n.cm^{-2}.s^{-1})	0.34	1.3	0.56
Fraction >10 MeV (%)	2.4	7.2	6.1
Fe displ. rate (dpa/year)	3.3	17	7.2
He/dpa in Fe (appm/dpa)	4.7	11.2	28.8



MTS flux level is one-third to half of the world’s most intense research fast reactors

Facility	Peak Fast Flux (10^{15} n/cm^2/s)	Peak Annual Fast Fluence* (10^{22} n/cm^2/y)	Peak Annual Displacement Rate* (dpa/y)
MTS (USA)	1.3	2.1	17
BOR-60 (Russia)	2.8	4.6	24
JOYO (Japan)	4.0	6.9	36

**Accounts for facility availability.*

Many MTS characteristics are substantially similar to a fast reactor

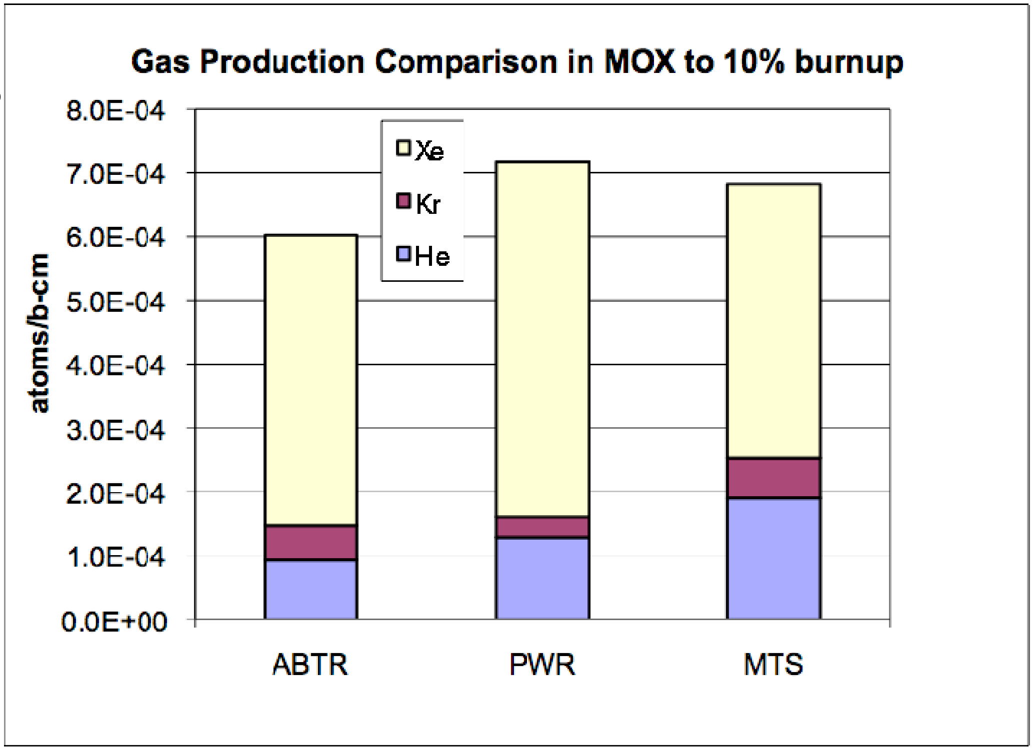
- Same fission rate for fissile isotopes
  - For many fuel compositions the burnup evolution (actinide and fission product concentrations) is nearly the same
- Uniform fission rate throughout the fuel pellet or slug
- Clad irradiation temperature up to 550° C
- Same radial temperature profile for a given linear heat generation rate and pellet/slug radius
- Same burnup-to-dpa ratio

Principal differences between MTS and a fast reactor

- High-energy tail of neutron spectrum
- Pulsed nature of the neutron flux
- Beam trips

High-energy tail of neutron spectrum produces differences from fast reactor irradiations

- Higher helium production in steels
  - Known to embrittle austenitic steels operating above 0.5 T_m
  - Effect on ferritic/martensitic steels not yet well understood
  - 0.5 T_m is 550° C for SS316, 610° C for T91
- Higher helium production in oxide fuels from O(n, α) reactions
  - He production 2x greater than ABTR, but total gas production is only 10% greater
- Higher Np production in fertile fuel from ^{238}U(n,2n) reaction

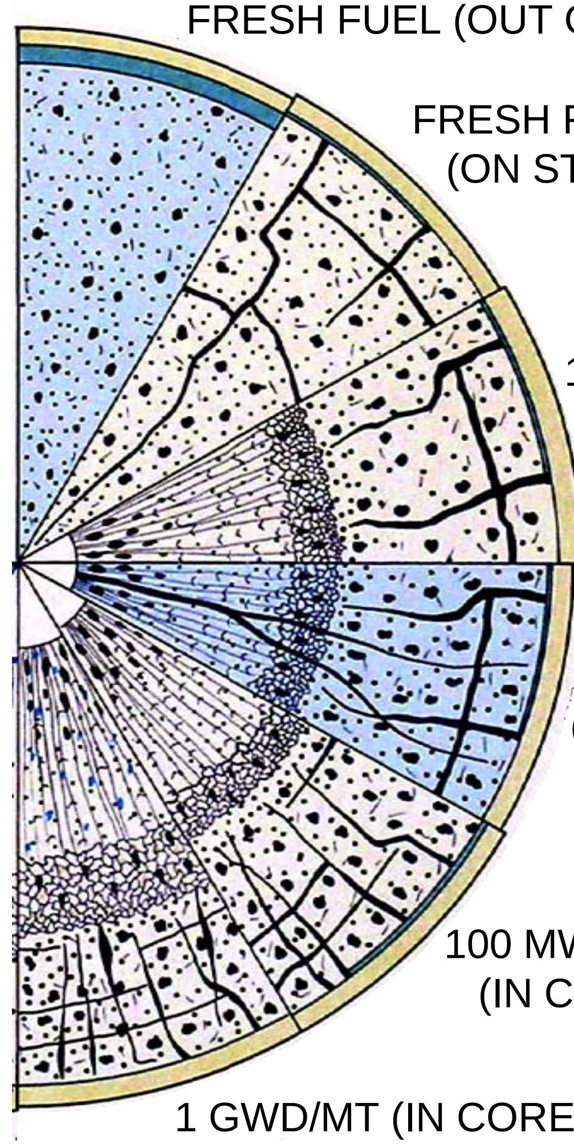


Pulsed neutron flux issues

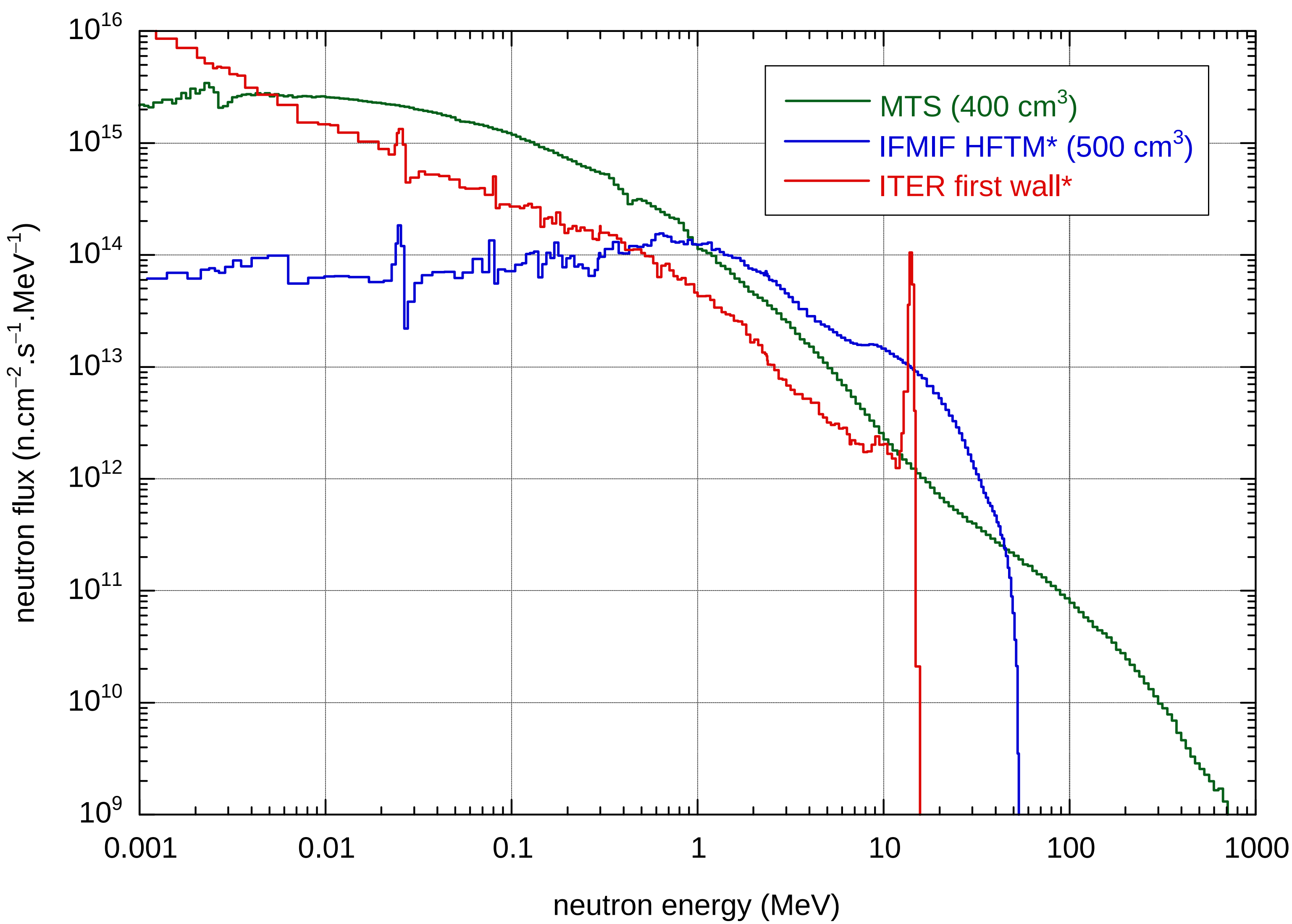
- Temporal peak of the neutron flux is inversely proportional to the beam duty factor (7.5%)
- Beam pulse repetition rate is 100 Hz
  - For oxide fuel, thermal cycling is not significant because thermal time constant (~100 ms) is much longer than the time between pulses (~10 ms)
  - Metal fuels may exhibit thermal cycling in MTS
- Studies show that 100 Hz is nearly equivalent to steady-state with respect to bubble nucleation in steels

Accelerator beam trips are a potential issue for oxide fuel irradiation in MTS

- Normal reactor conditions:
  - On startup, thermal stresses crack oxide pellets
  - Cracks in the columnar grain region heal during reactor operation
  - When reactor is shut down, pellets re-crack
- The LANSCE accelerator will trip several times each day, during which the fuel temp drops to ~300° C
  - Cracks in the columnar grain region likely will not have time to fully heal between thermal cycles



The MTS neutron spectrum has potential application for fusion materials research

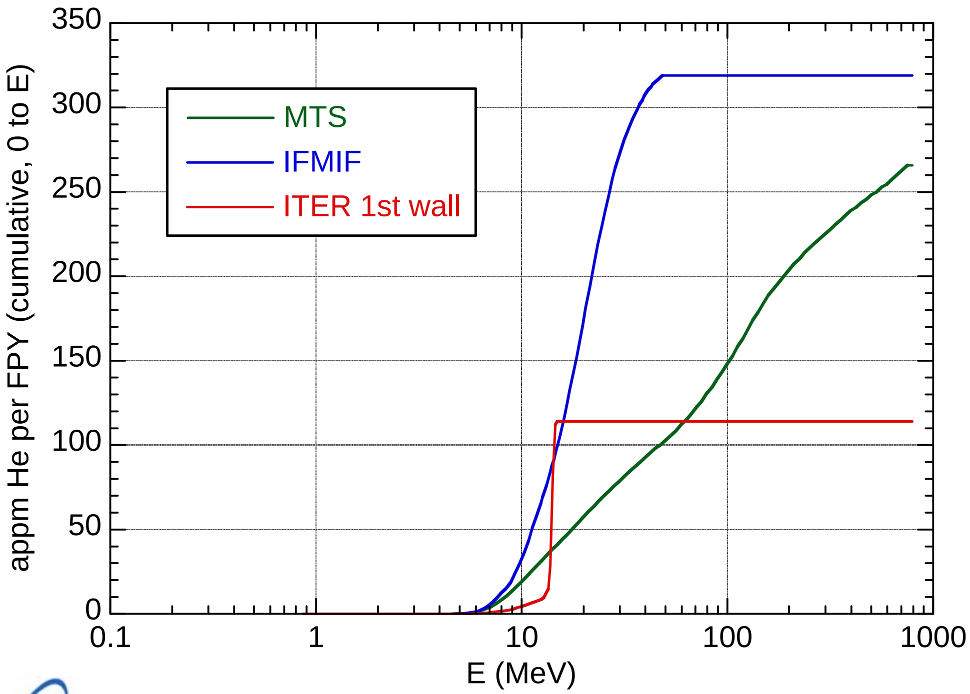


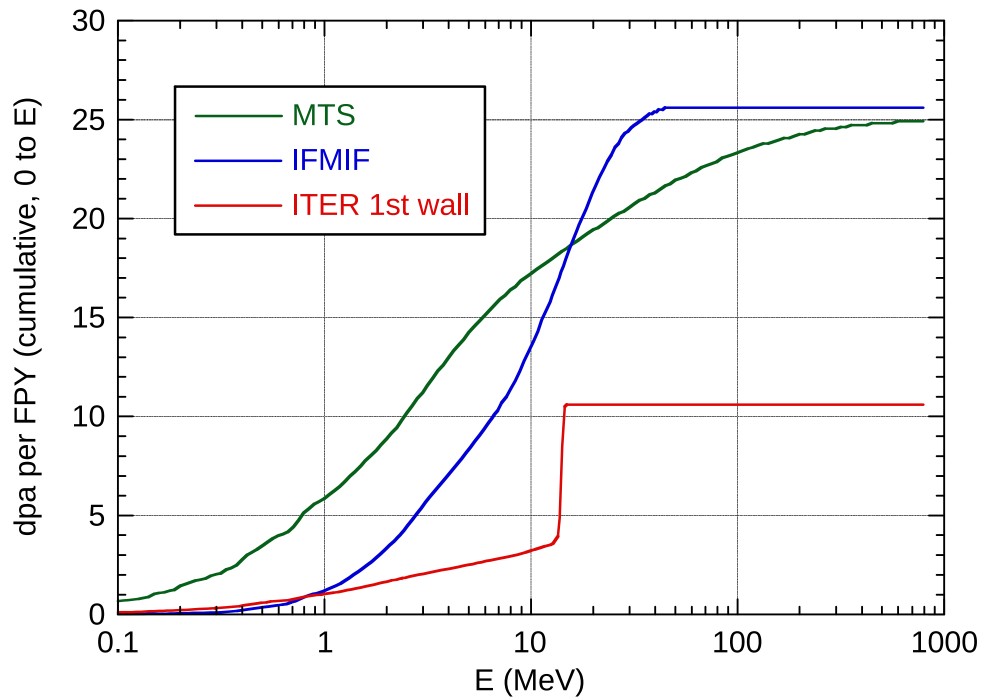
* *Data from U. Fischer et al., Fusion Engineering and Design 63-64 (2002) 493-500.*

The damage rates for the MTS approach those observed in IFMIF and are 3 times ITER

	appm He/FPY*	dpa/FPY*	He/dpa
ITER 1st wall	114	10.6	10.8
IFMIF HFTM (500 cc)	319	25.6	12.5
MTS (400 cc, fuel module)	266	24.9	10.7
IFMIF Li back wall	619	65.8	9.4
MTS (peak, fuel module)	393	33.9	11.6

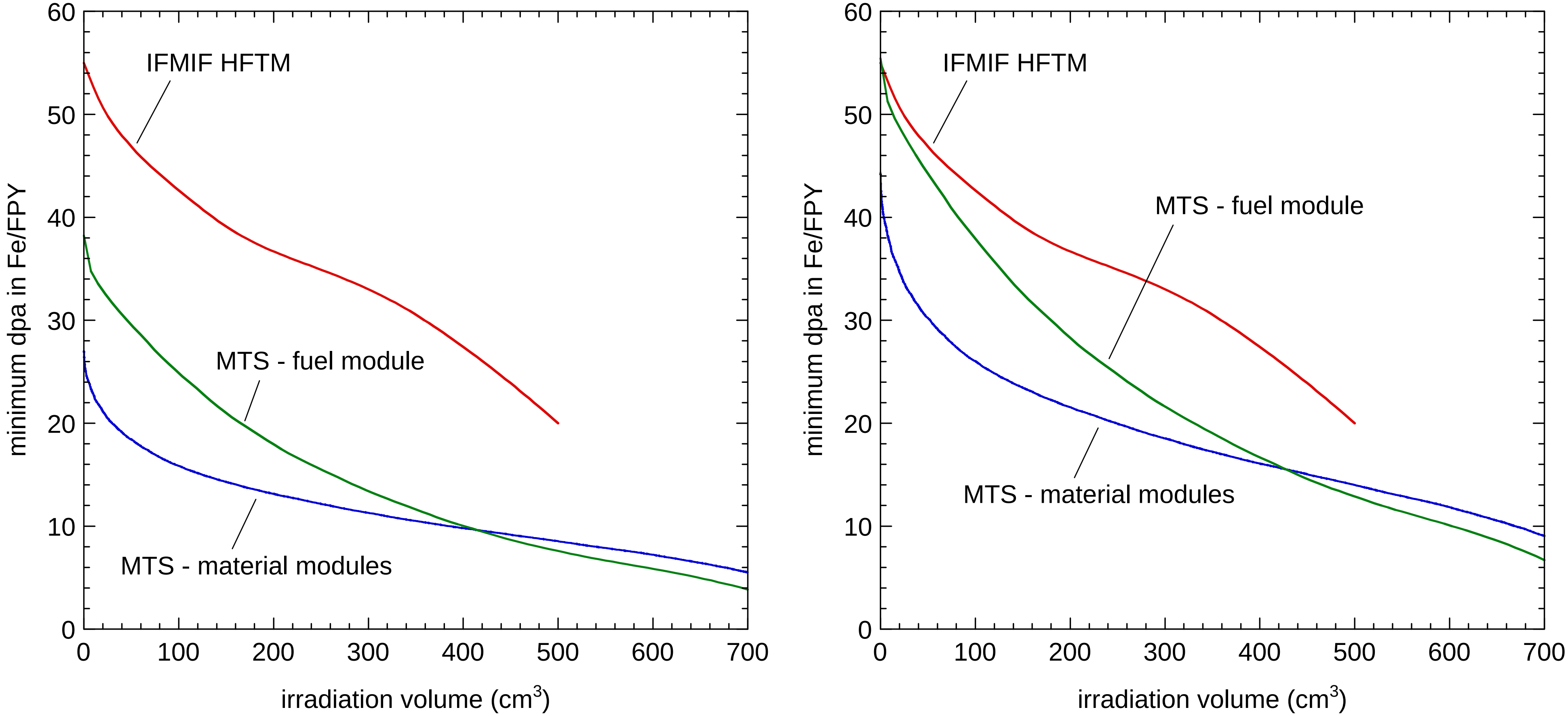
***FPY = full power year; MTS expected operation is 4400 hrs per year.**
Values for MTS assume 1 MW of beam power.





At 1.8 MW, MTS provides nearly the same dose and irradiation volume as IFMIF

MTS beam power = 1 MW **MTS beam power = 1.8 MW**



MTS project status

- In November 2007, DOE-NE approved CD-0 for a “Fast Neutron Test Capability.” MTS was one of three alternatives identified to meet the need
- In FY10 , MTS project expects to submit its CD-1 package for approval DOE-NE
- Pending receipt of adequate funding and timely DOE approvals of Critical Decisions, MTS can start operating in 2015
- Current cost range for MTS is $60M to $80M
- Project cost will be “baselined” during Conceptual Design

Summary

- MTS is not fully prototypic of a fast reactor and is therefore not appropriate for providing final engineering data needed to qualify fast reactor fuel
- Irradiation data obtained in MTS can advance our understanding of fuels and materials performance in a fast neutron spectrum
- MTS irradiation data, coupled with data obtained from other irradiation facilities, can be used to validate simulation models
- In addition to its primary mission of fission materials testing, MTS is well suited for irradiating fusion materials