# Design of the 800 kW Target for the LANL Fast-Spectrum Materials Test Station (MTS)


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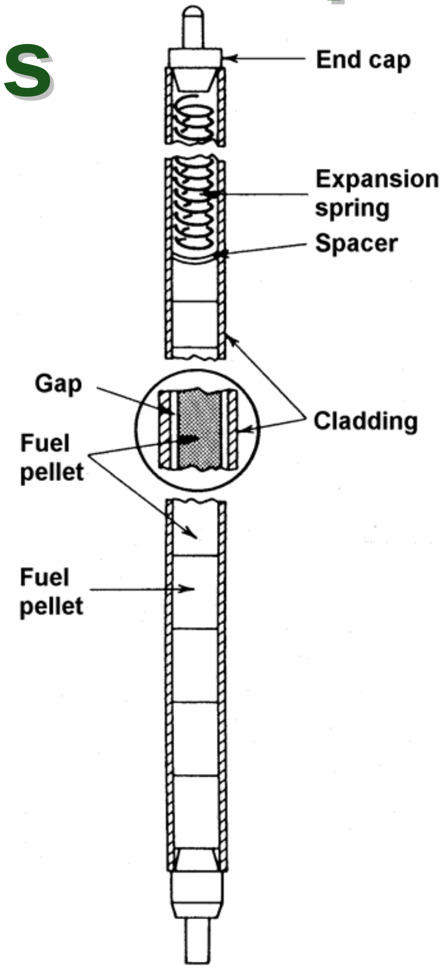
# DOE Advanced Fuel Cycle Initiative (AFCI) and Generation IV (GenIV) nuclear reactor programs both need a domestic fast-spectrum neutron irradiation capability.

- **AFCI is focused on closing of the fuel cycle to minimize waste and improve resource utilization.**
  - Irradiation tests on candidate transmutation fuels and materials need to prove (and certify) performance.
- **GenIV goal is "effective management of actinides through recycling of most components in the discharged (nuclear) fuel."**
  - Similar needs to AFCI.

DOE recognizes the close relationship between these two programs. (Joint working groups, etc.)

# A Fast Spectrum Irradiation Test Capability is Needed to Develop Transmuter Fuels

- Transmutation fuels containing the higher actinides are now being developed.
- First test pins made only in the last two years.
- Qualification is a long process (~10 years).
- Irradiation testing in a prototypic environment is essential.  Quick data turn around with a domestic facility is preferred.



# MTS performance specifications are driven by GenIV fuels and materials performance test needs

- Peak fast neutron flux (>0.1MeV) $\geq 1 \times 10^{15}$ n/cm$^2$/s
- $\geq$1 kW/cm$^3$ volumetric heating in at least 30 test fuel pellets
- Burn up rate of 3% per year in the peak flux region
- Displacement rate in iron of at least 10 dpa/y

*The MTS design meets or exceeds all of these requirements.*

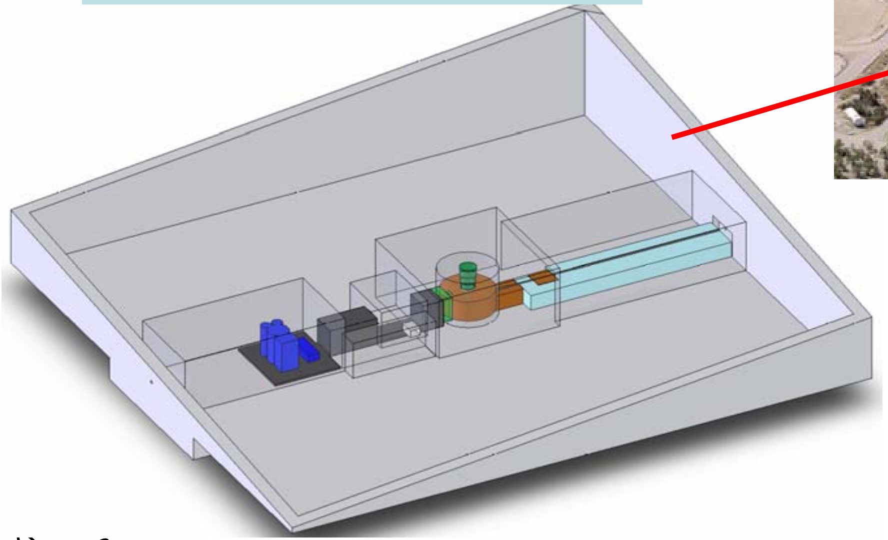
# MTS Target concept is based on proven technology from LANSCE, ISIS, HEARO, APT and others

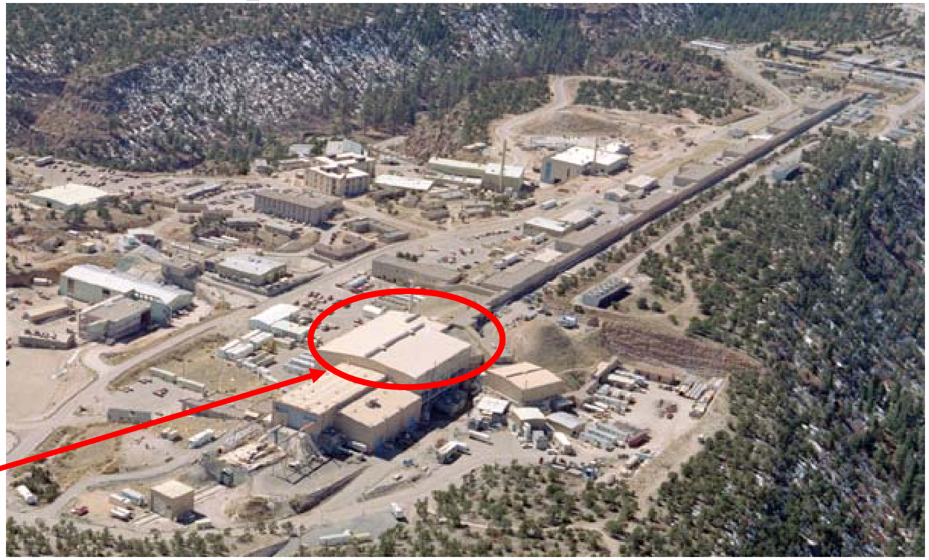
**Our Motto:** *"Plagiarism is the highest form of flattery."*

- High power proton beam on water-cooled (probably $D_2O$) tungsten target.
- High proton current density (55.5μA/cm$^2$) and close proximity to produce highest fast-neutron flux density on fuel and material samples.
- Expendable target assembly is flange-mounted to reusable shielded carriage, for rapid change-out and/or repair in dedicated hot cell.
- Tantalum-clad target avoids Tungsten/water chemistry.

# MTS will be located in the 3,000 $m^2$ LANSCE “Area A” experiment hall

**Existing assets include:**
**800-MeV proton linac**
**30-T crane**
**Secondary cooling loops**
**Back-up generator**
**Shield blocks**
**Utilities**

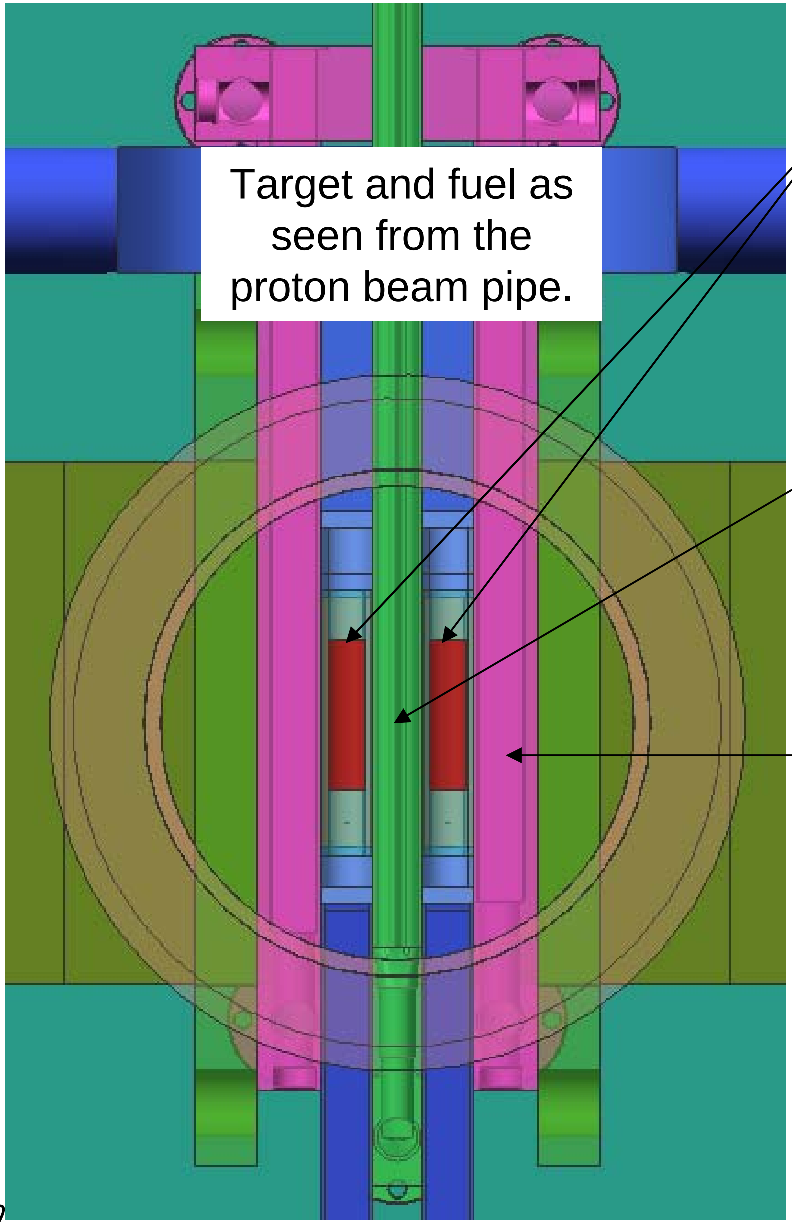




***MTS will provide the first fast neutron irradiation capability since the shutdown of the FFTF and EBR-II***

# MTS-1 plans for 1mA average

- With planned LANSCE-Refurbishment, actual linac capacity will be >1.2mA $H^+$ (16mA peak, 625usec macropulses at 120Hz.)
- However, 1/6 of the macropulses are dedicated to other established users.
- With additional RF system upgrades, MTS-2$^+$ current could eventually approach 2mA average. (Mostly by increasing macropulse duration and effective spot size.)



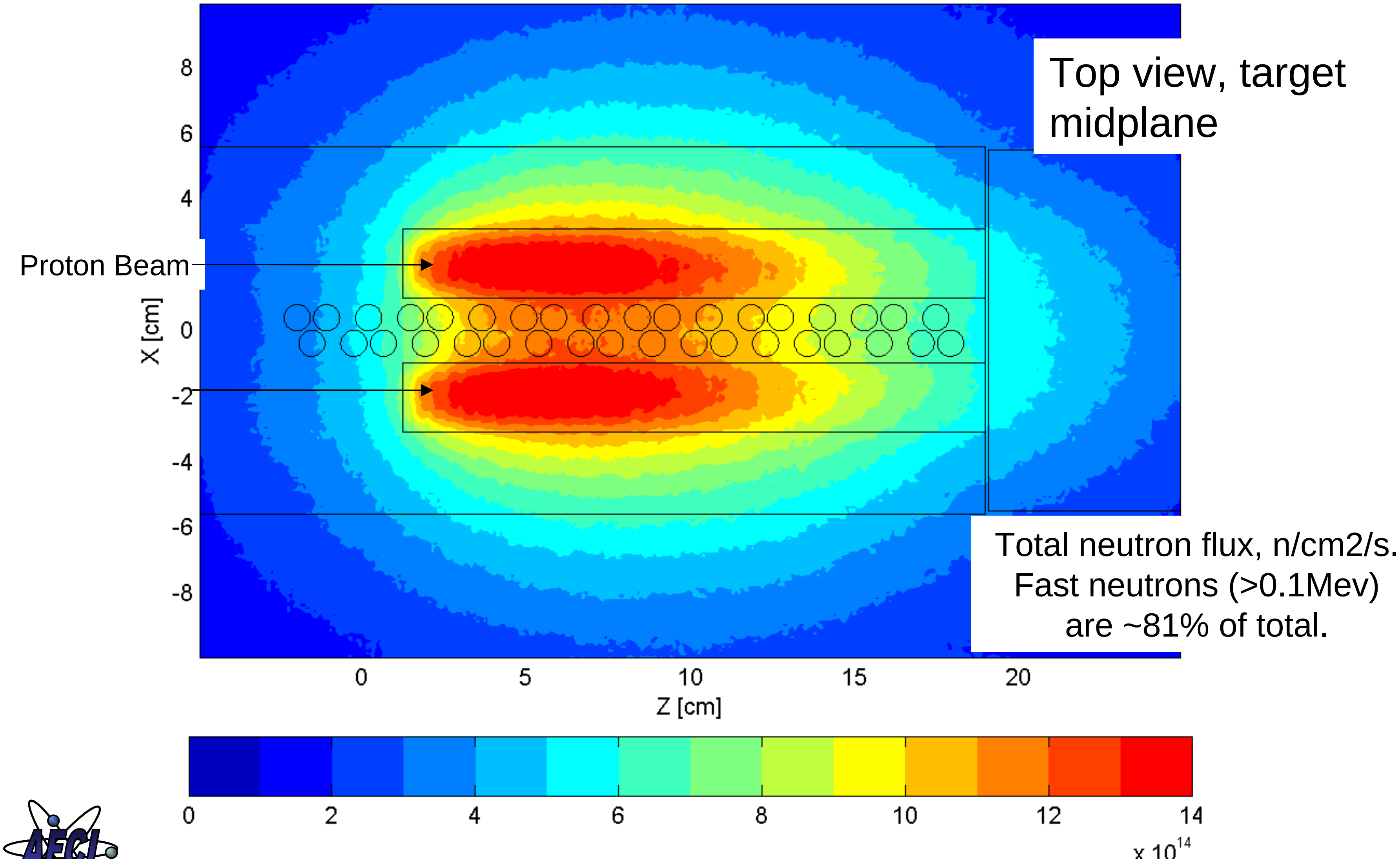

**Two rectangular proton beam "spots" (15mmX60mm) are produced by painting alternate macro-pulses onto the two target halves.**

**Water-cooled fuel rods are located in the uniform neutron flux region between the target halves.**

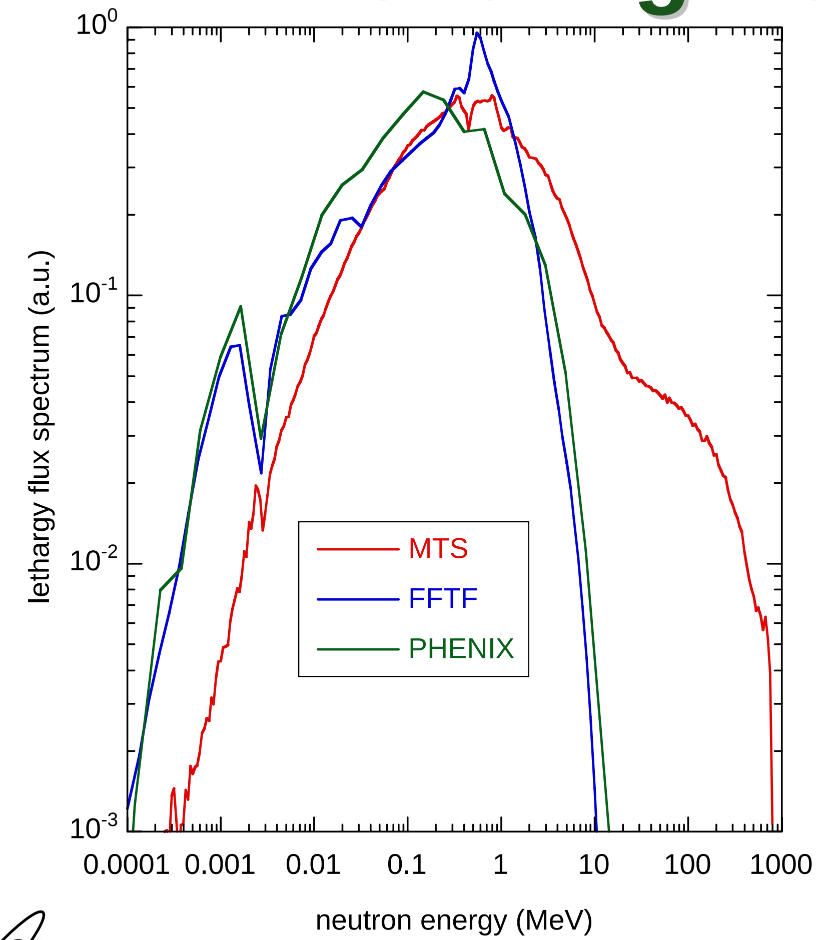
**Water-cooled material samples are placed on either side of the target.**

**Tungsten "mask" (not shown) prevents direct proton beam impingement on fuel or material samples.**

# Neutron Flux Intensity and Uniformity is Enhanced using a Split Target Geometry

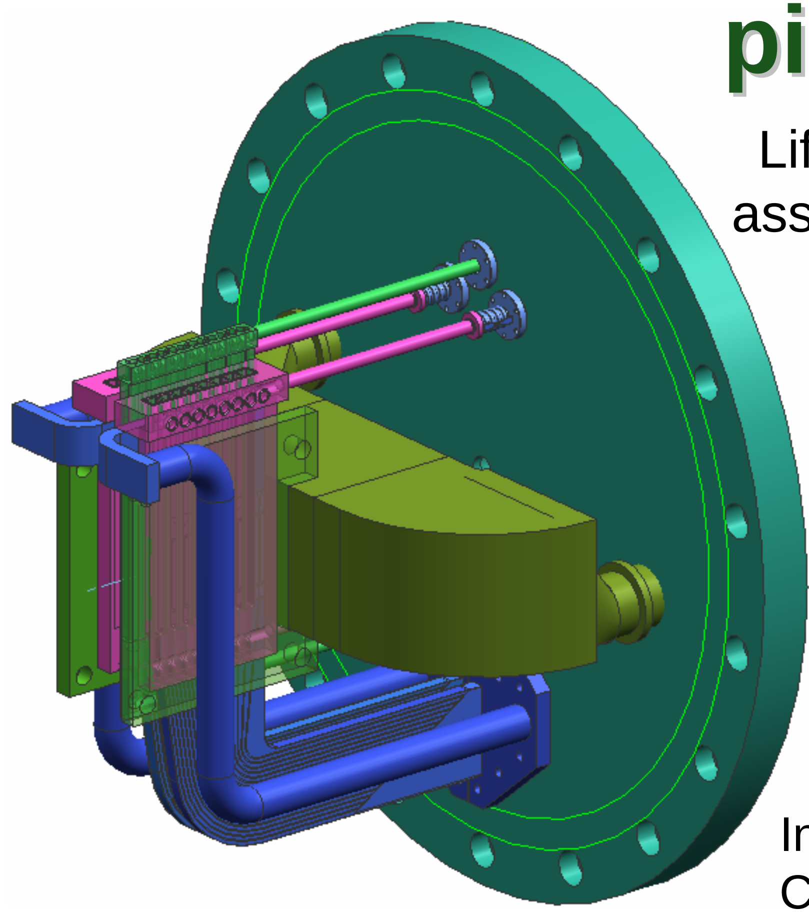


# MTS neutron spectrum is similar to that of a fast reactor with the addition of a high-energy tail

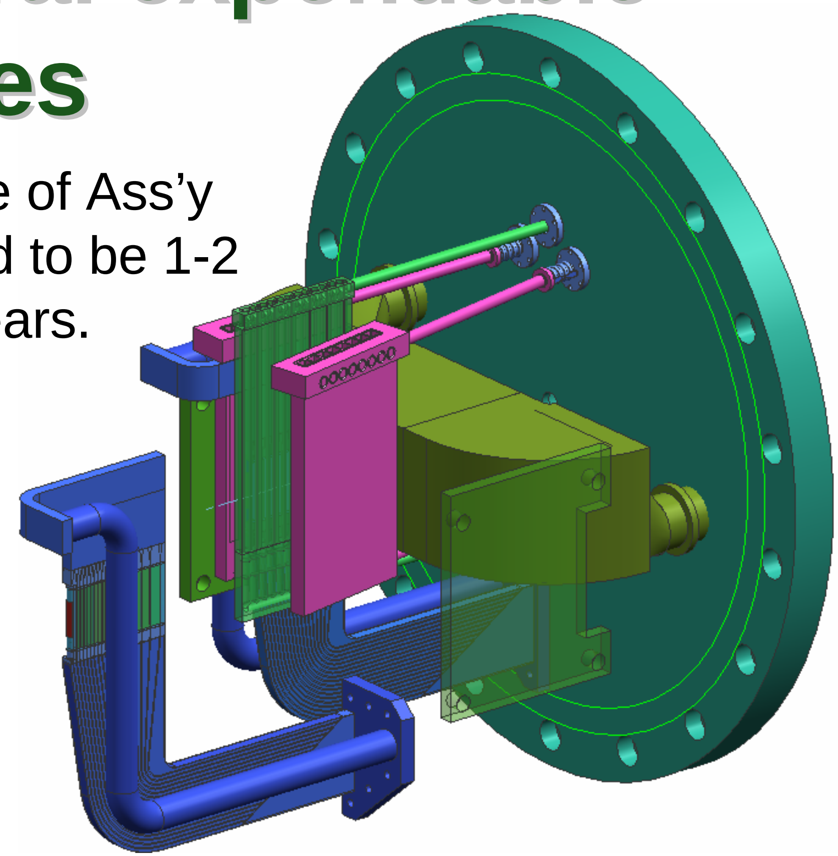



- Mimics fast spectrum
- Approximately 5% of the neutrons > 20 MeV.
- The high-energy neutrons produce:
  - Higher helium production in steels
  - Slightly different fission product yields (symmetric fission)

# MTS Target/Sample Assembly consists of several expendable pieces

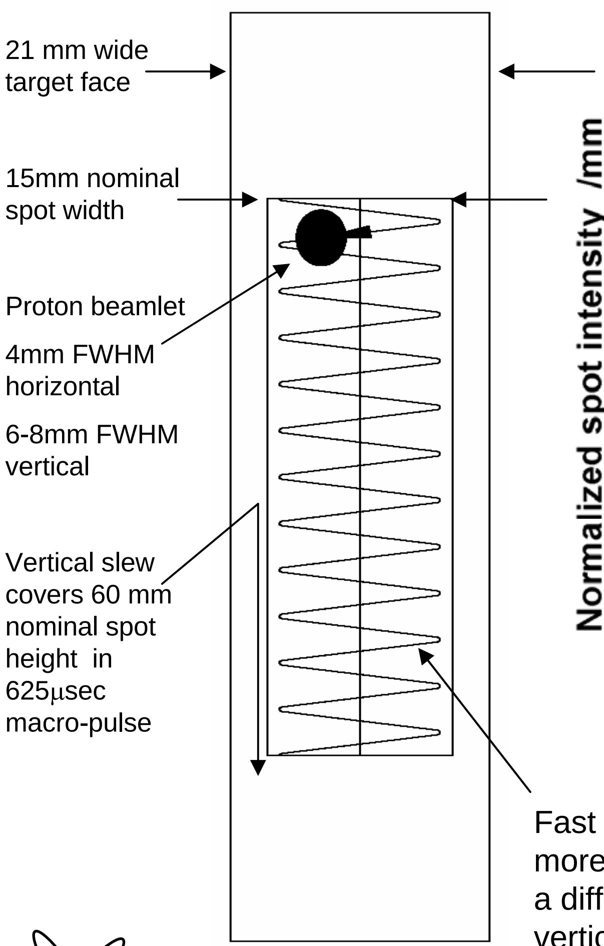


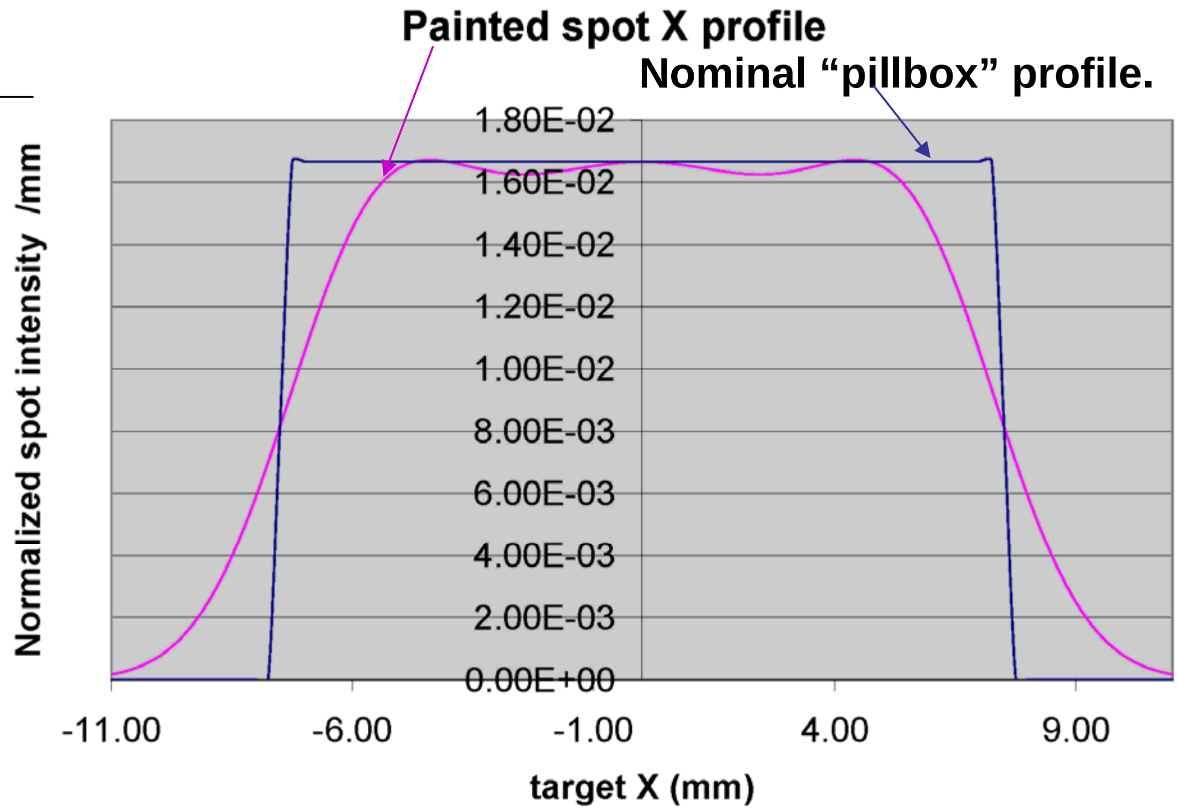
Lifetime of Ass'y assumed to be 1-2 years.



In theory, we can replace spent target in Hot Cell without disturbing sample coolant circuits.

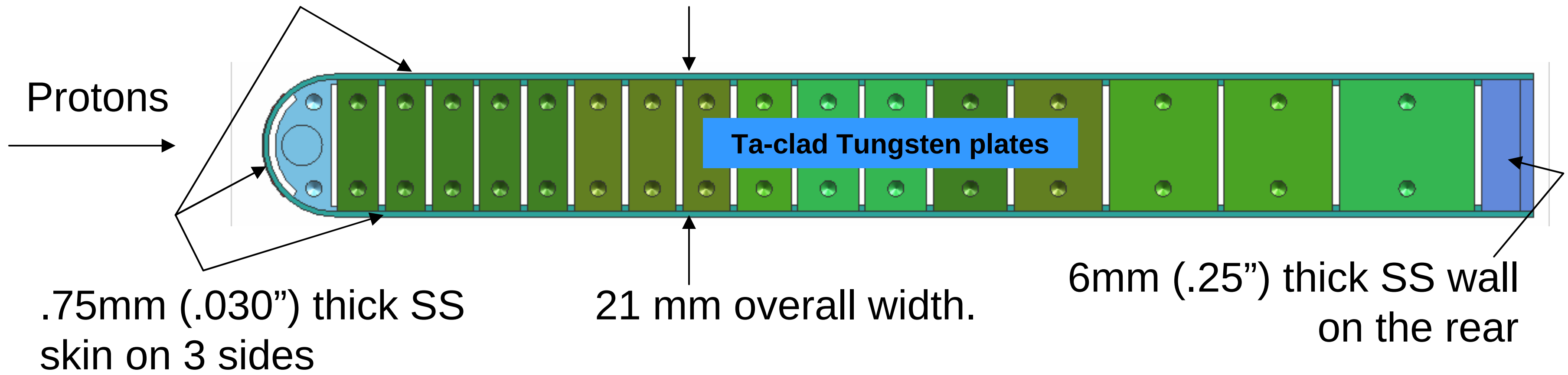
# Beam Raster concept




Fast raster is 20kHz sinusoid plus 7.7% 60kHz to make it more sawtooth shaped. Subsequent macropulses arrive at a different temporal phase, smearing the average spot vertically.

# Target plates & $D_2O$ are contained in thin-walled 316LN housing.



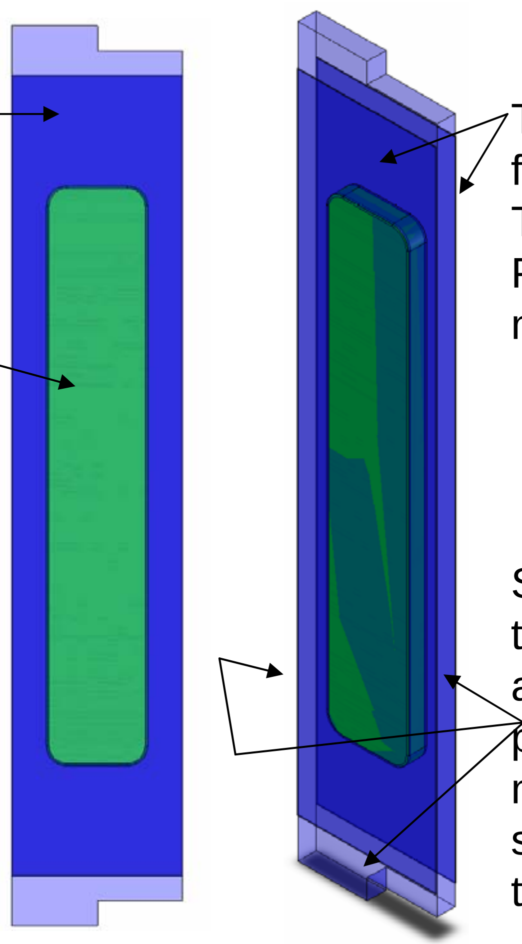

Sides are not bonded to the target plates. Target must be clamped between the fuel housing and material sample housing before applying internal coolant pressure.

# Tungsten target cores will be clad with tantalum as in ISIS, KENS

99.99% Ta "frame"

99.96% W core, 15mm X 90mm.

Total thickness ranges from 6-20mm*.

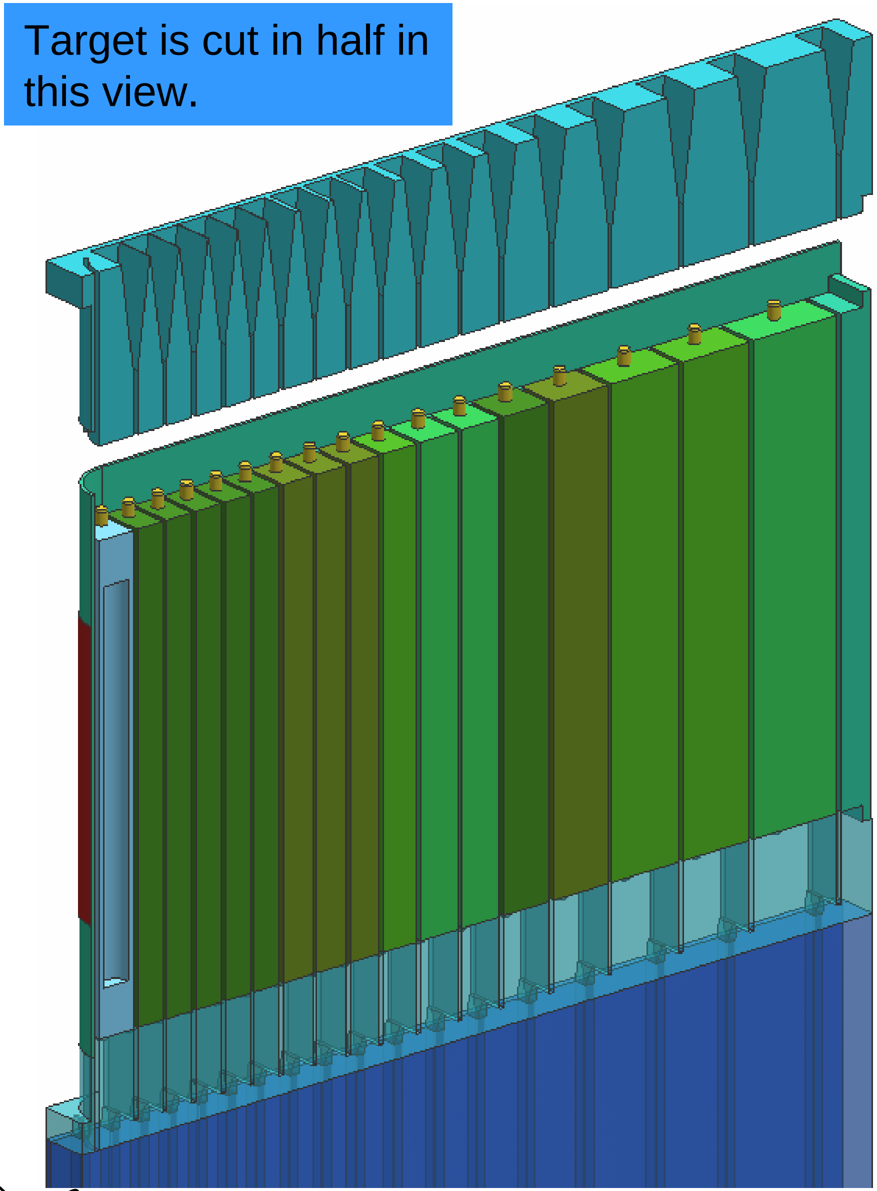


Tantalum foil on front and back. Thickness TBD*. Probably not re-machined after HIP.

Sides and ends to be finished after HIP, to produce true mounting surfaces for target housing.

Prototypes now being made, using HIP parameters recommended by HEARO for the KENS target.

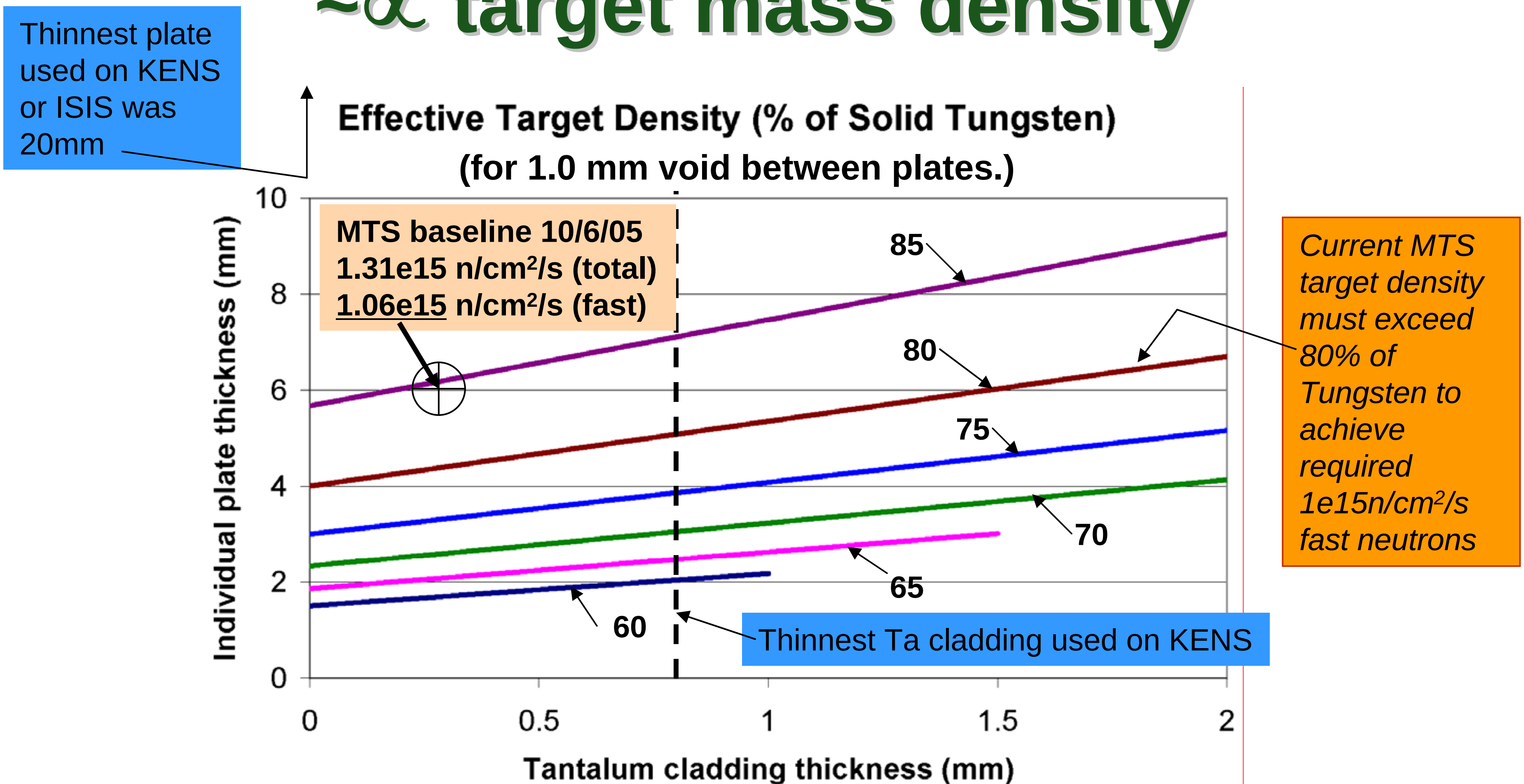
<u>MTS is attempting much thinner Ta cladding than KENS or ISIS.</u>



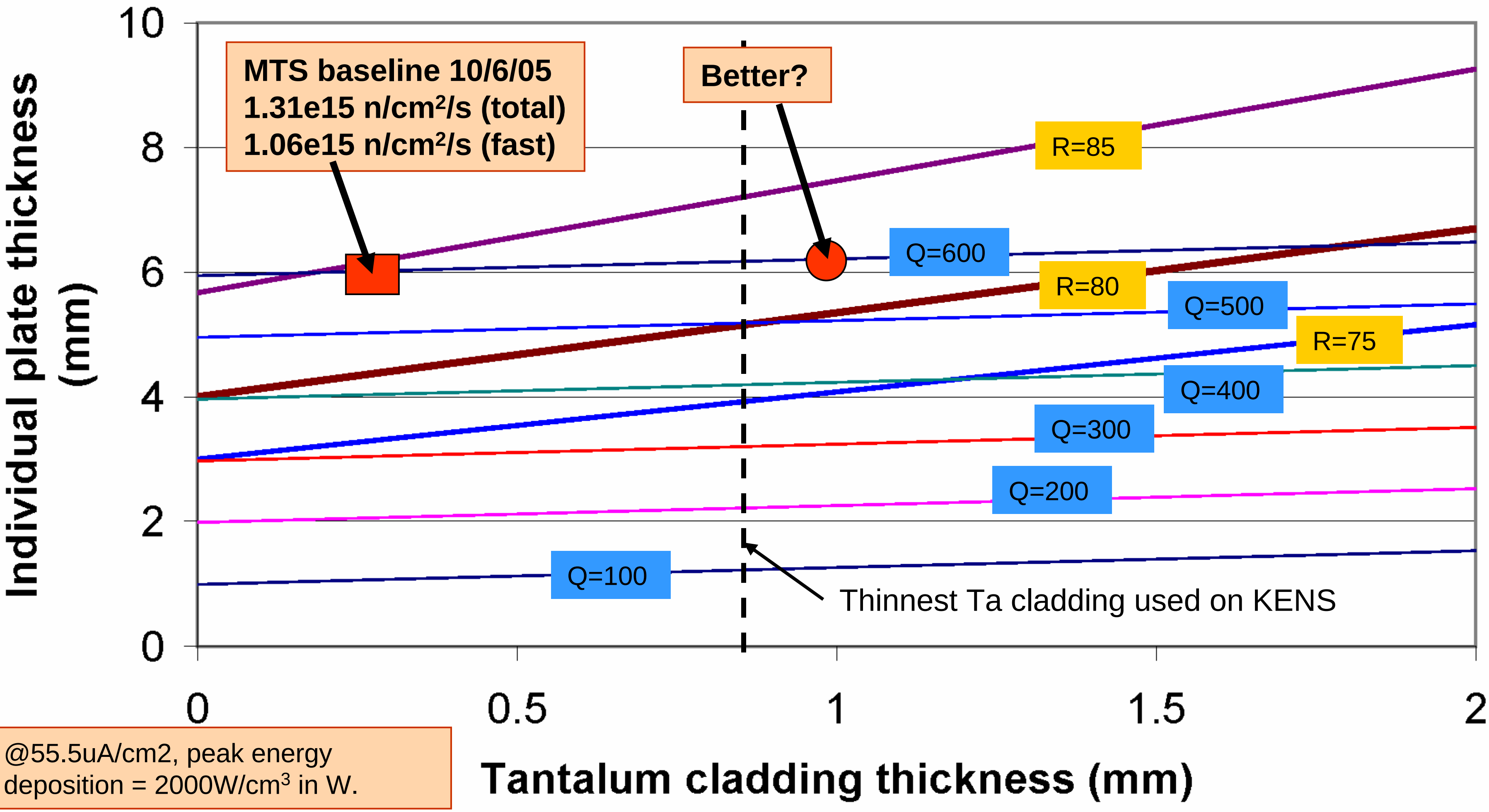

# 1mm wide passages carry $D_2O$ at 10m/s between W/Ta plates

Plate thicknesses are progressive, according to energy-deposition rates, to maximize W volume-fraction and stay below assumed max. convection flux value.*

# Peak neutron flux density ~∝ target mass density



# Target Density, "R" (% of Solid Tungsten)
# Convective Flux, "Q" ($W/cm^2$)




@55.5uA/cm2, peak energy deposition = 2000W/$cm^3$ in W.

# High convective heat flux ($\sim 600 W/cm^2$) is key to meeting 1e15 $n/cm^2/s$ (fast) requirement.

Single-phase $D_2O$:

10 m/s bulk velocity in 1mm gap $\Rightarrow$ hc $\approx$ 4.3 $W/cm^2$-C.

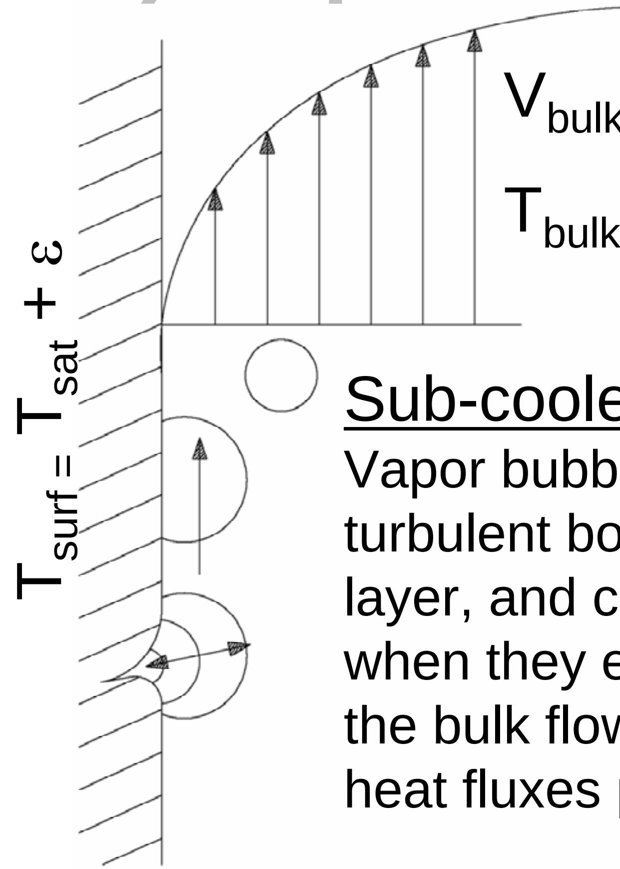
@600W/cm2, $T_{surf} \approx$ 140C* above bulk coolant temp.

If Tbulk = 40C, Tsurf=180C*.

Static pressure > 1MPa (150psi) to suppress boiling.

**BUT**, flow imbalances will be present, with obvious consequences.

*1-D analysis




$V_{bulk}$ = 10 m/s

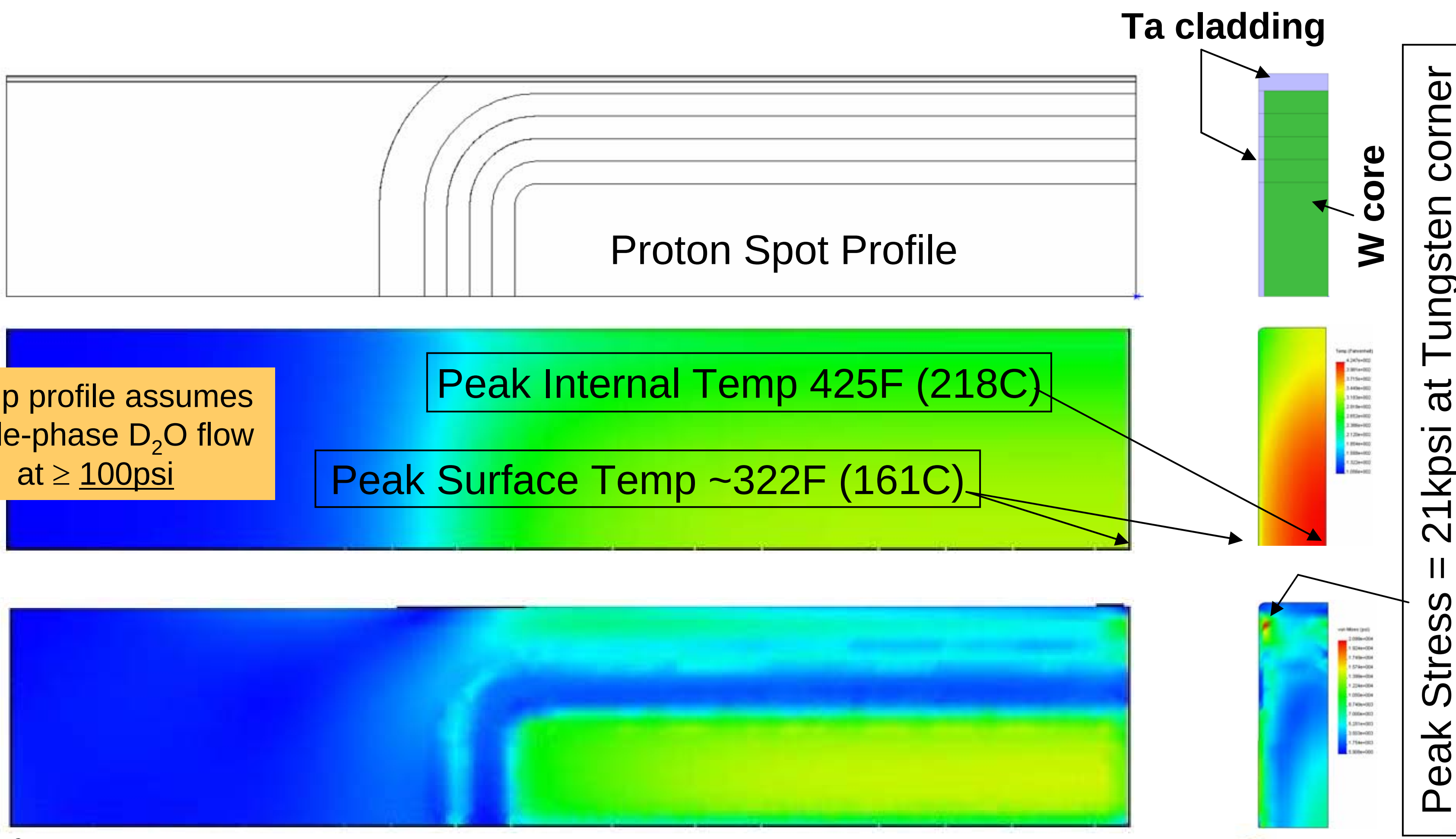
$T_{bulk} << T_{sat}$

Sub-cooled boiling:

Vapor bubbles arise in turbulent boundary layer, and condense when they encounter the bulk flow. HIGH heat fluxes possible.

# 3-D Thermal/structural FEA of 6mm tungsten target plates

Temp profile assumes single-phase $D_2O$ flow at ≥ 100psi

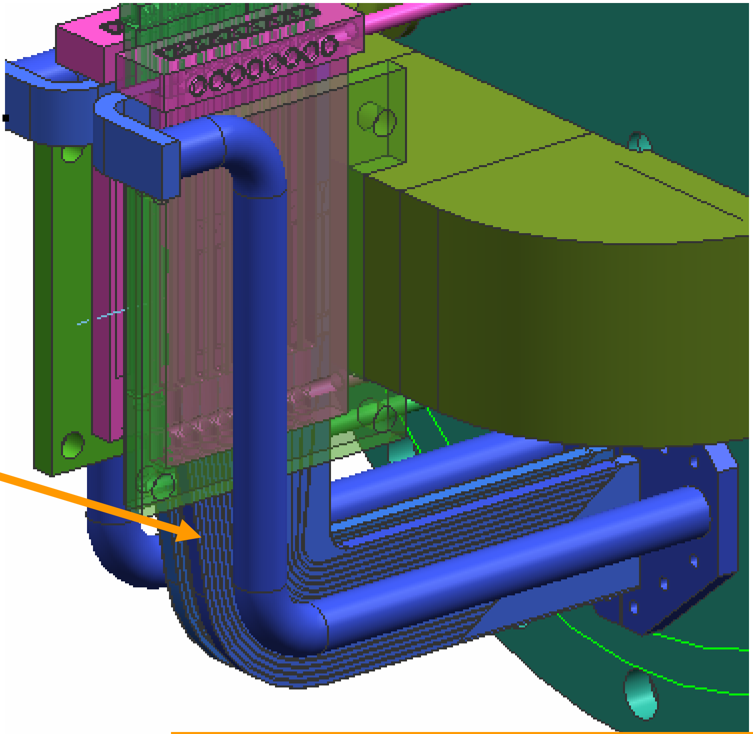


# MUST insure sufficient flow to EACH parallel coolant passage.

•~18 passages in each target "half".

•~65kPa (10psi) drop through the target itself.

• Mechanical flow restriction on the INLET side of <u>each</u> target channel causes 600-700 kPa (90-100psi) drop. Then, if boiling causes local flow restriction in any particular channel, the mechanical restriction dominates, no thermal run-away.



Elongated narrow channels shown. Orifices or labyrinth also being considered.

# Funding Status

- $7M FY2005 Funding provided by congressional earmark. Defacto CD-0 received.
  - NA-54 and pre-conceptual design reviews complete
  - MIE funding determination received
  - MTS determined to be within existing EIS, PHA in progress
- $7M FY2006 Funding in Senate Mark.
- MTS needs approval of LANSCE Refurbishment Project to move beyond conceptual design (CD-1).

# Summary

- AFCI is focused on closing of the fuel cycle to minimize waste and improve resource utilization.
- GenIV is focused on "effective management of actinides through recycling of most components in the discharged (nuclear) fuel."
- Fast Neutron fuel and materials irradiations are essential for both AFCI and GenIV Programs.
- MTS will provide a new domestic fast neutron irradiation capability.
- MTS project team is making good progress. Will be ready for CD-1 in February, 2006.
- A positive decision on LANSCE-Refurbishment is needed in order to move forward on MTS.