SVT Beam Accident Analysis

Tim Nelson - SLAC

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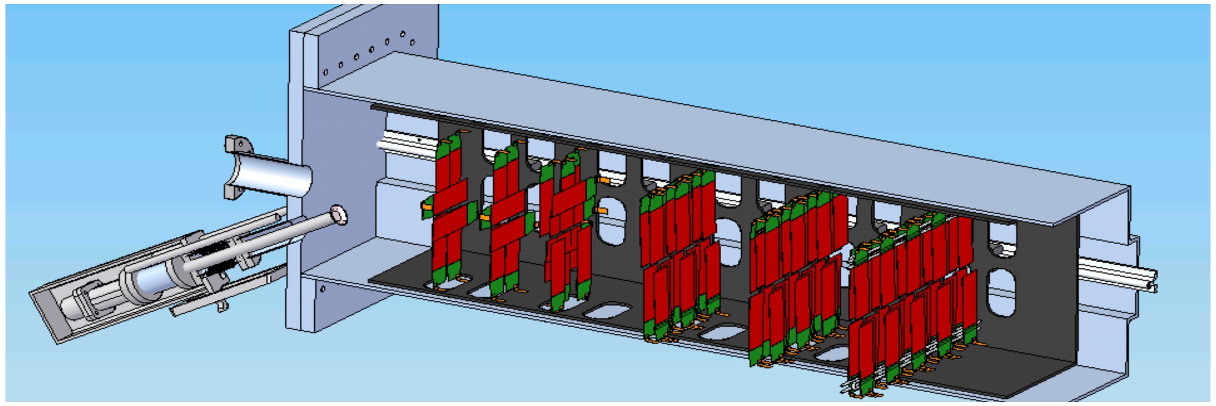
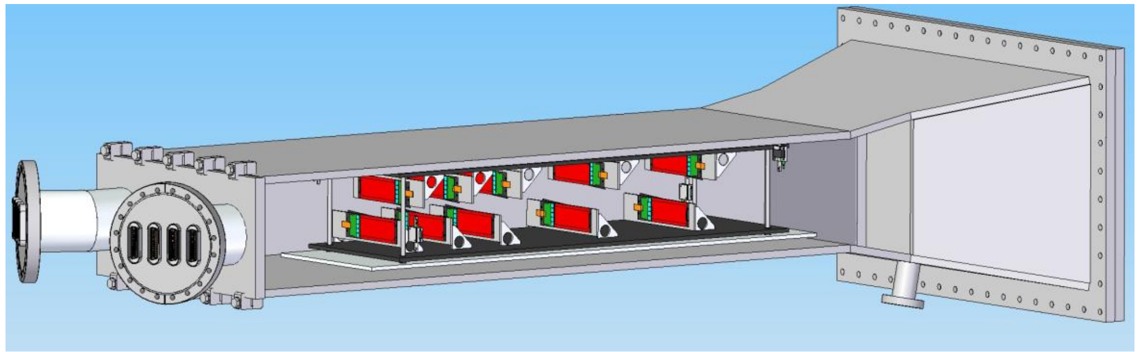
HPS Target History

2010 proposal



- The tracker measured x-y equally well. (We assumed a bigger magnet)
- The beam spot was circular and smaller (10 microns) to take advantage of this
- In proposal, it was said we would melt the target (>1000 °C) in 7 ms at 450 nA.

2011 proposal

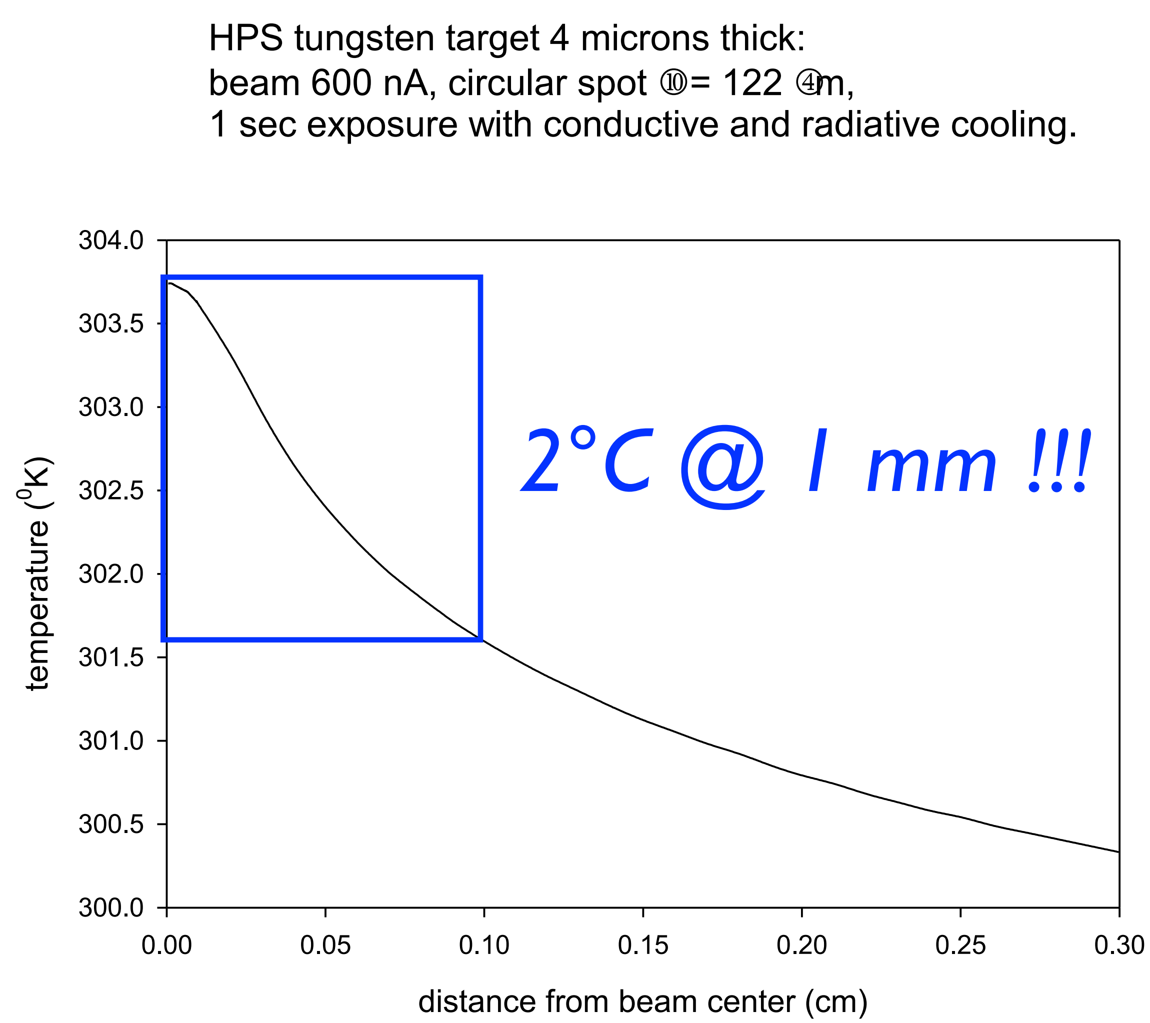


- To use PS magnet/chamber and existing sensors, tracker measures y better than x.
- Beam spot can be larger in x: designed at 20 μm x 250 μm to avoid destroying target.

These designs assumed heat loss only by radiation!!

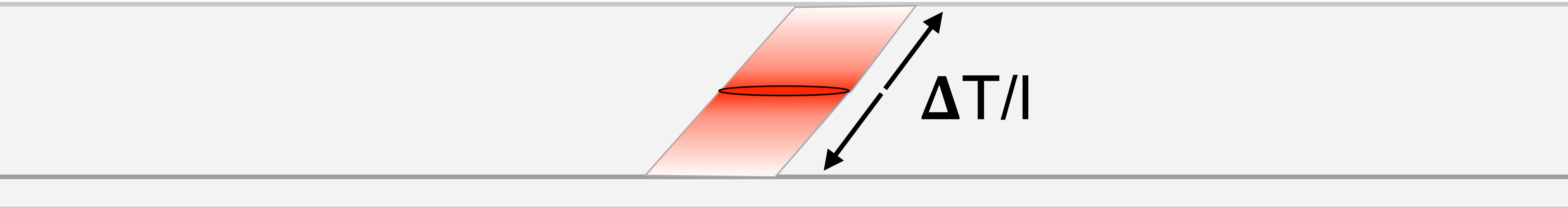
Conduction is Critical

- Temperature profile as calculated for tungsten at 600 nA by an iterative code:



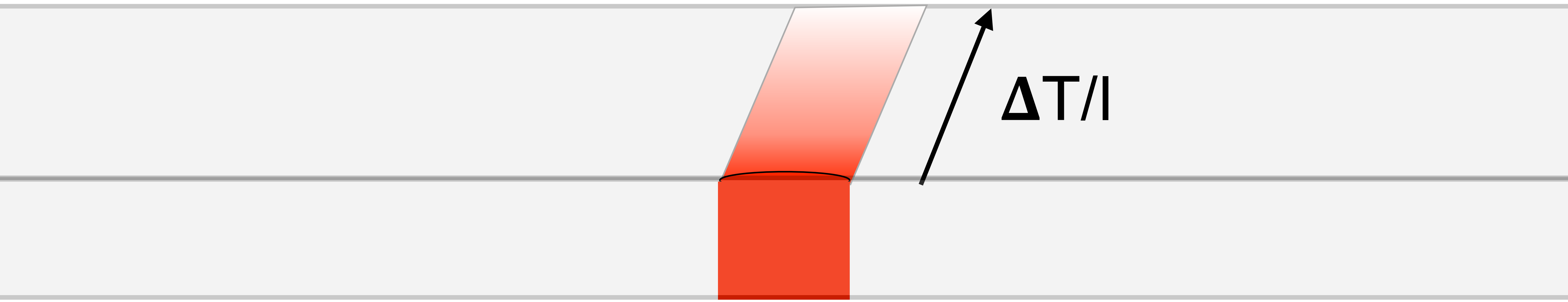
Clive Field @ Jan. 2014 Collaboration Meeting

Toy Calculation for Target



- 50 nA beam strikes target, 4 microns thick.
- Power is applied to a plane inside the target silicon 300 microns wide. (320 microns X 4 microns)
- Assume heat must flow through target perpendicular to that surface. In reality, it spreads radially outward, but gives an idea what the drops are.
  - Collisional energy loss in silicon for electrons $dE/dx = 1.6\ \text{MeV cm}^2 / \text{g}$
  - Power = $19.25\ (\text{g/cm}^3) \cdot .0004\ \text{cm} \cdot 1.6\ \text{MeV cm}^2/\text{g} \cdot 50\times10^{-9}\ \text{A} / 1.6\times10^{-19}\ \text{C} = 616\ \mu\text{W}$
  - $\Delta T/l = (6.2\times10^{-4}\ \text{W})/(173\ \text{W/m-°K})/(2 \cdot 0.0003\ \text{m} \cdot 0.000004\ \text{m}) = 1.5\ \text{°K / mm}$
- Temperature rise is very small, generally agrees with Clive's simulation.

Toy Calculation for Silicon

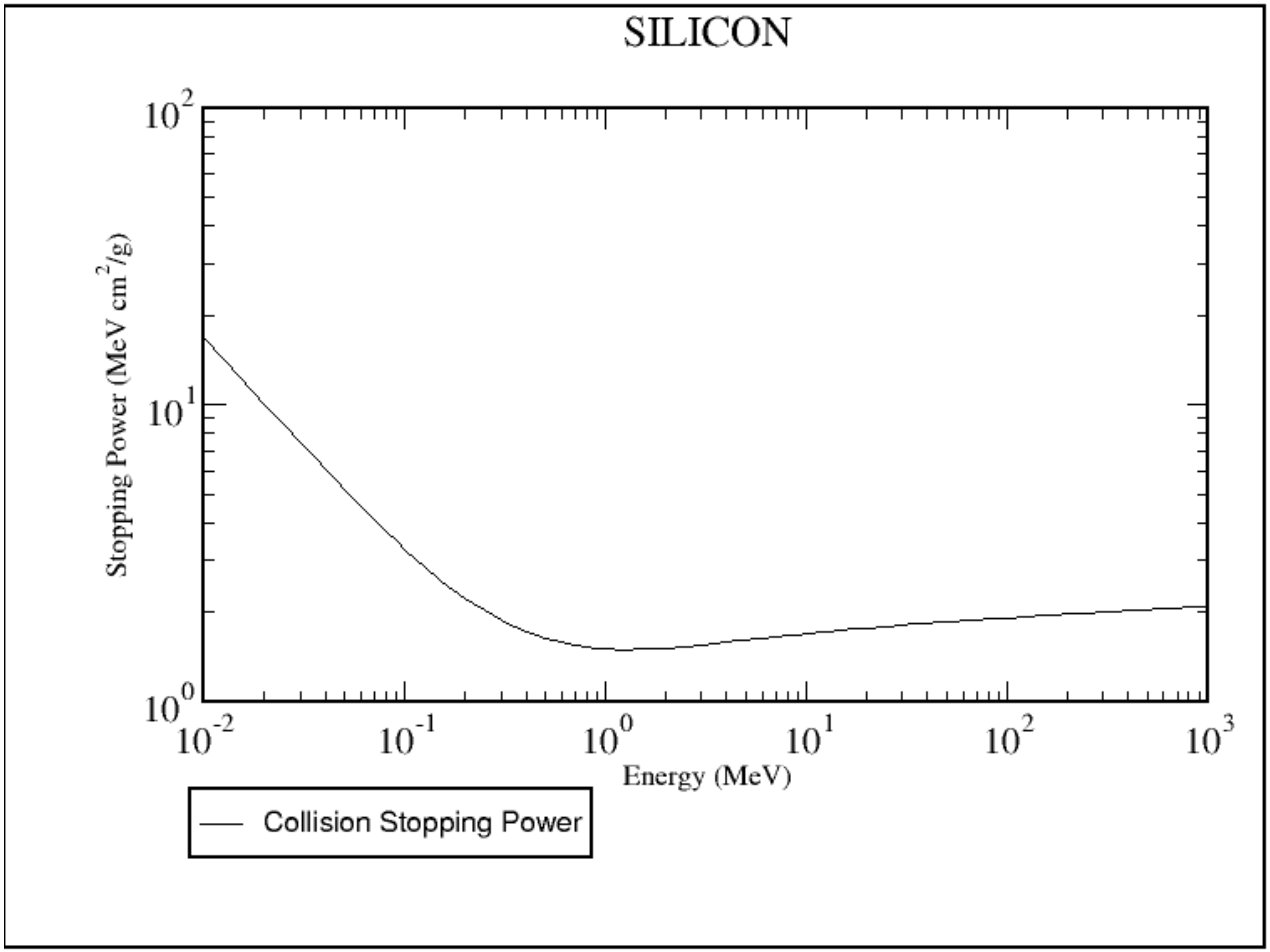


- 5 nA beam grazes silicon edge, 320 microns thick. Since this is ~3X thicker than our target, should raise FSD counter rates by ~30%.
- Power is applied to a surface along the edge of the silicon 300 microns wide. (320 microns X 300 microns)
- Assume heat must flow through silicon perpendicular to that surface. In reality, it spreads radially outward, but gives an idea what the drops are.
  - Collisional energy loss in silicon for electrons dE/dx = 2.1 MeV cm^2 / g
  - Power = 2.33 (g/cm^3) · .032 cm · 2.1 MeV cm^2/g · 5×10^{-9} A / 1.6×10^{-19} C = 784 μW
  - $\Delta T/l$ = (7.8×10^{-4} W)/(149 W/m-°K)/(0.0003 m · 0.00032 m) = 0.054 °K / mm
- Temperature rise is negligible.

Conclusion

- No danger of acute mechanical damage from beam strike. (Also no danger of melting the target with any beam that could be generated in Hall B).
- *Significant* beam dwelling continuously on silicon will lead to extreme radiation damage with unpredictable results, so it is best avoided.
- *Full* beam dwelling on silicon can also contribute to thermal runaway, so again… best avoided.
- FSD is still important, but there is little hazard of a beam accident destroying an entire sensor.

Silicon Stopping Power



Tungsten Stopping Power