Tritium Elastic Sieve Energy Loss

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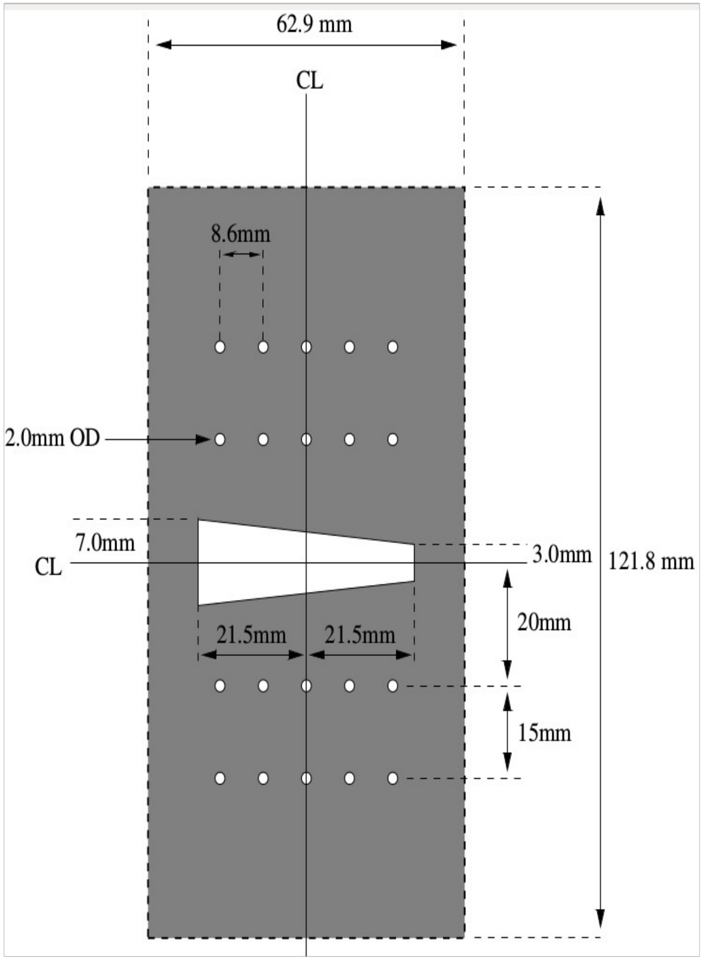
Introduction

- Experiment E12-14-009 requires a special sieve to be constructed to keep rates acceptable.
- Goal is to knock electrons incident on plate out of momentum acceptance.
- HRS momentum acceptance is -4.5% < δp/p < 4.5%.
  - E_{lhrs}=1070 MeV → E_{min}=1021.85 MeV
  - E_0=1100MeV → 7.1% energy loss.



Theory

- At energies above a few tens of MeV Bethe-Bloch collisional losses are minimal and Bremsstrahlung dominates.
- Bremsstrahlung loss depends of E_0 and electric field the electron experiences.
  - Cross section: E_0, impact parameter and Z.
- Screening of the nucleus by electrons:

$$\zeta = \frac{100 m_e c^2 h\nu}{E_0 E Z^{-1/3}}$$

  - If $m_e c^2 << E_0 << 137 m_e c^2 Z^{-1/3} \rightarrow \zeta >> 1 \rightarrow$ no screening.
  - If $E_0 >> 137 m_e c^2 Z^{-1/3} \rightarrow \zeta \sim 0 \rightarrow$ complete screening.
  - Al = 29.77 and W = 16.67 → complete screening.

Energy Loss Calculation

- Cross section for complete screening (Leo):

$$d\sigma = 4Z^2 r_e^2 \alpha \frac{d\nu}{\nu} \left\{ \left(1 + \epsilon^2 - \frac{2\epsilon}{3}\right) \left[ln\left(183Z^{-1/3}\right) - f\left(Z\right)\right] + \frac{\epsilon}{9} \right\}$$

- Radiative energy loss can be found by integrating the cross section times the photon energy over the allowable energy range of the emitted photons.

$$-\left(\frac{dE}{dx}\right)_{rad} = N \int_0^{\nu_0} h\nu \frac{d\sigma}{d\nu}\left(E_0, \nu\right) d\nu$$

Energy Loss Calculation Cont.

- This can be rewritten as:

$$-\left(\frac{dE}{dx}\right)_{rad} = NE_0\Phi_{rad}, \quad where \quad \Phi_{rad} = \frac{1}{E_0}\int h\nu\frac{d\sigma}{d\nu}\left(E_0,\nu\right)d\nu$$

- In the case of complete screening we have:

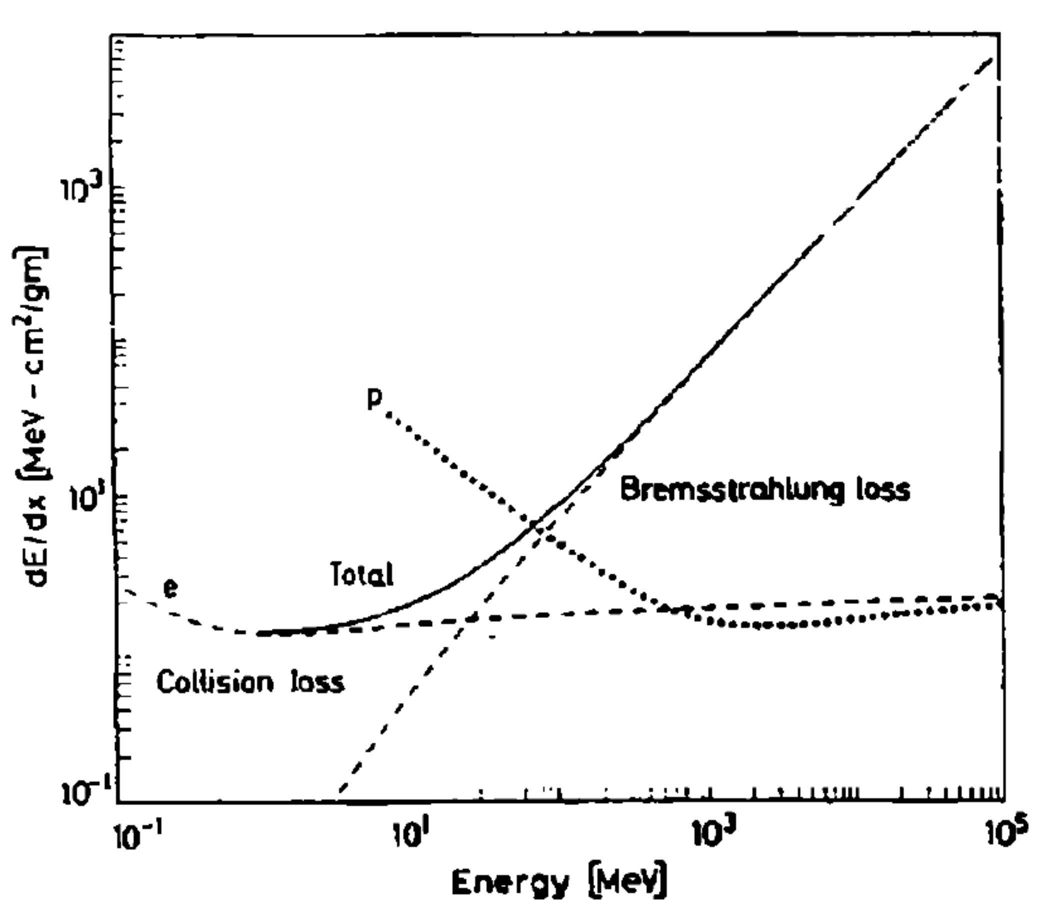
$$\Phi_{rad} = 4Z^2r_e^2\alpha\left[ln\left(183Z^{-1/3}\right) + \frac{1}{18} - f\left(Z\right)\right]$$

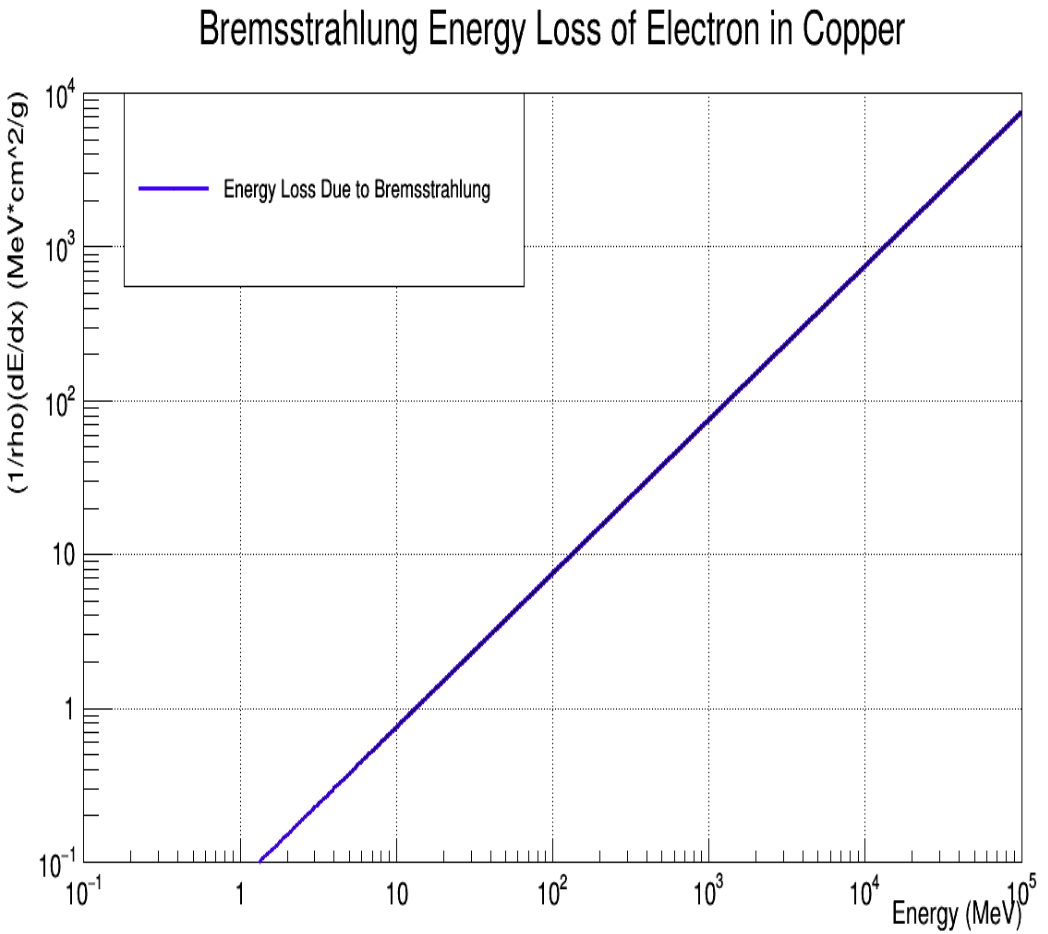
- Here f(Z) is a Coulomb correction with a=Z/137:

$$f\left(Z\right) = a^2\left[\left(1+a^2\right)^{-1} + 0.20206 - 0.0369a^2 + 0.0083a^4 - 0.002a^6\right]$$

Calculation Check

- Plot (1/ρ)(dE/dx) from Bremsstrahlung for Cu.
  - Good agreement (low energy has no screening).



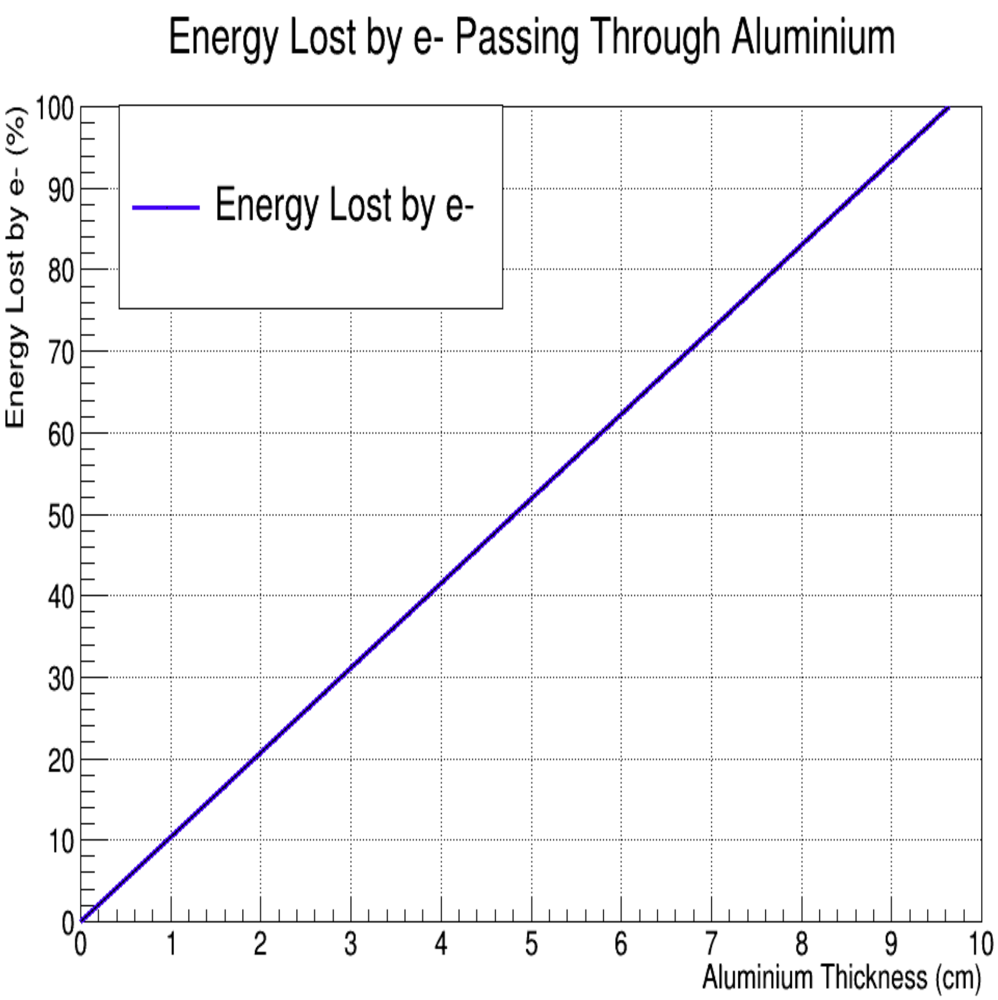


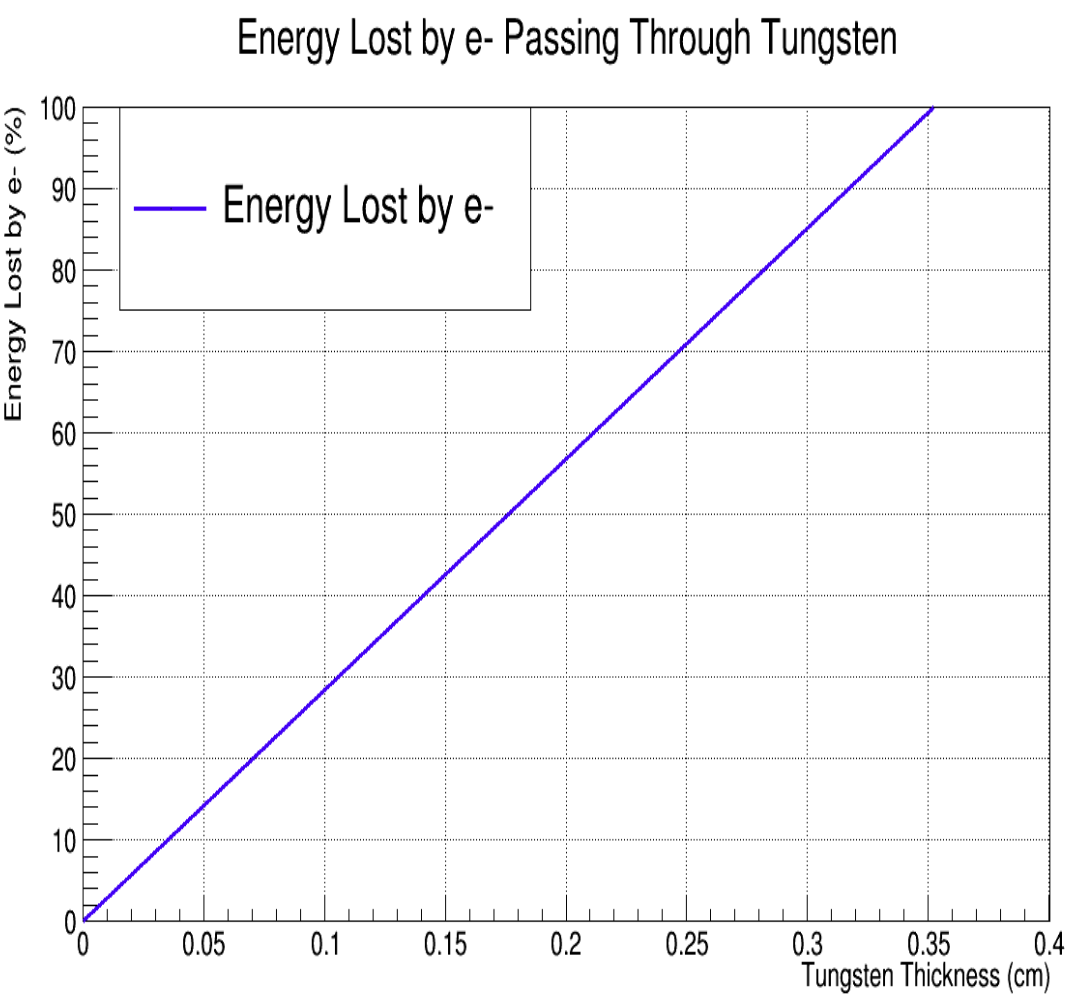
Results

- Proposed materials for sieve plate are Al and W.
- Φ_{rad} depends only on material.
- Must also multiply dE/dx by material thickness (length*density).

Parameter	**Al**	**W**
Atomic Number Z	13	74
Atomic Mass A, [amu]	26.98	183.84
Density ρ**,** $[g/cm^3]$	2.70	19.25
Number Density N**,** $[\frac{atoms}{cm^3}]$	$6.026 * 10^{22}$	$6.306 * 10^{22}$
Calculated X_0 $[g/cm^2]$	26.01	6.78
PDG X_0 $[g/cm^2]$	24.01	6.76
Calculated Radiation Length [cm]	9.633	0.3522
PDG Radiation Length [cm]	8.897	0.3504

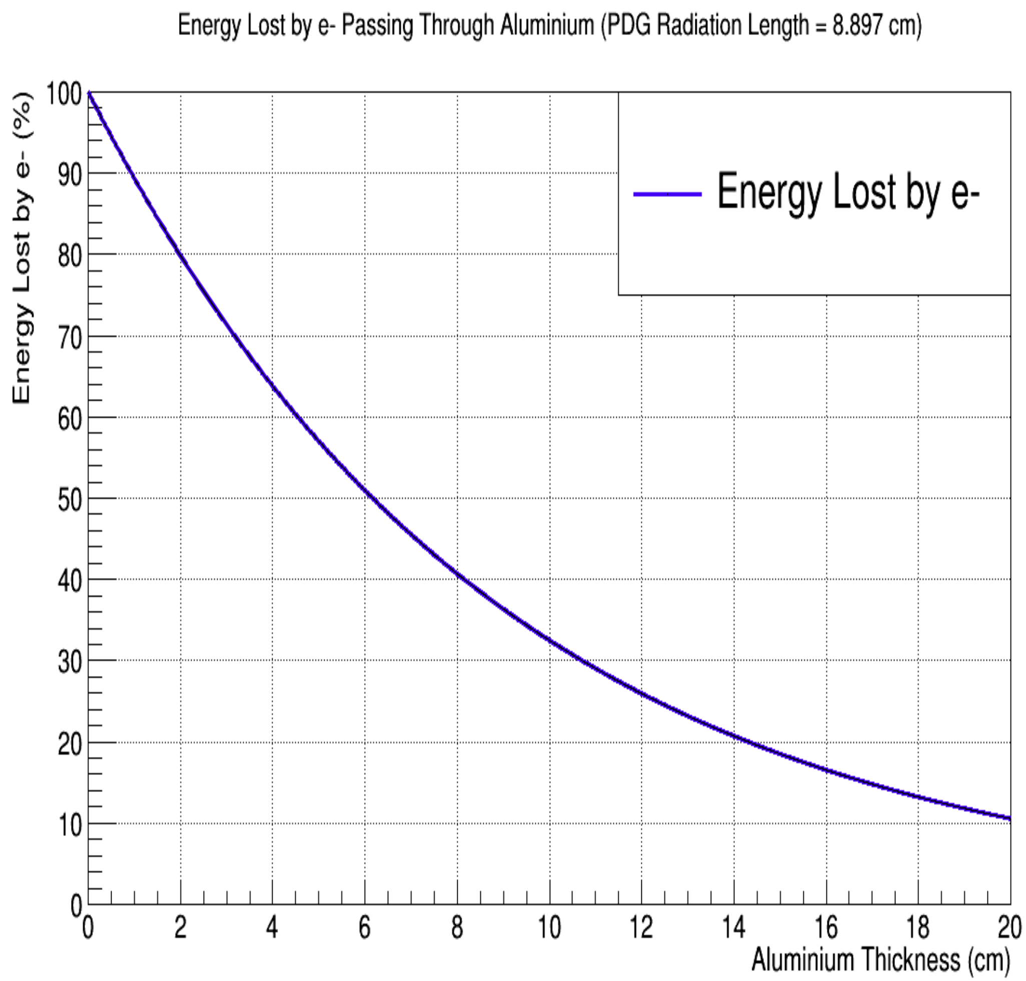
Energy Loss of Al and W dE/dx

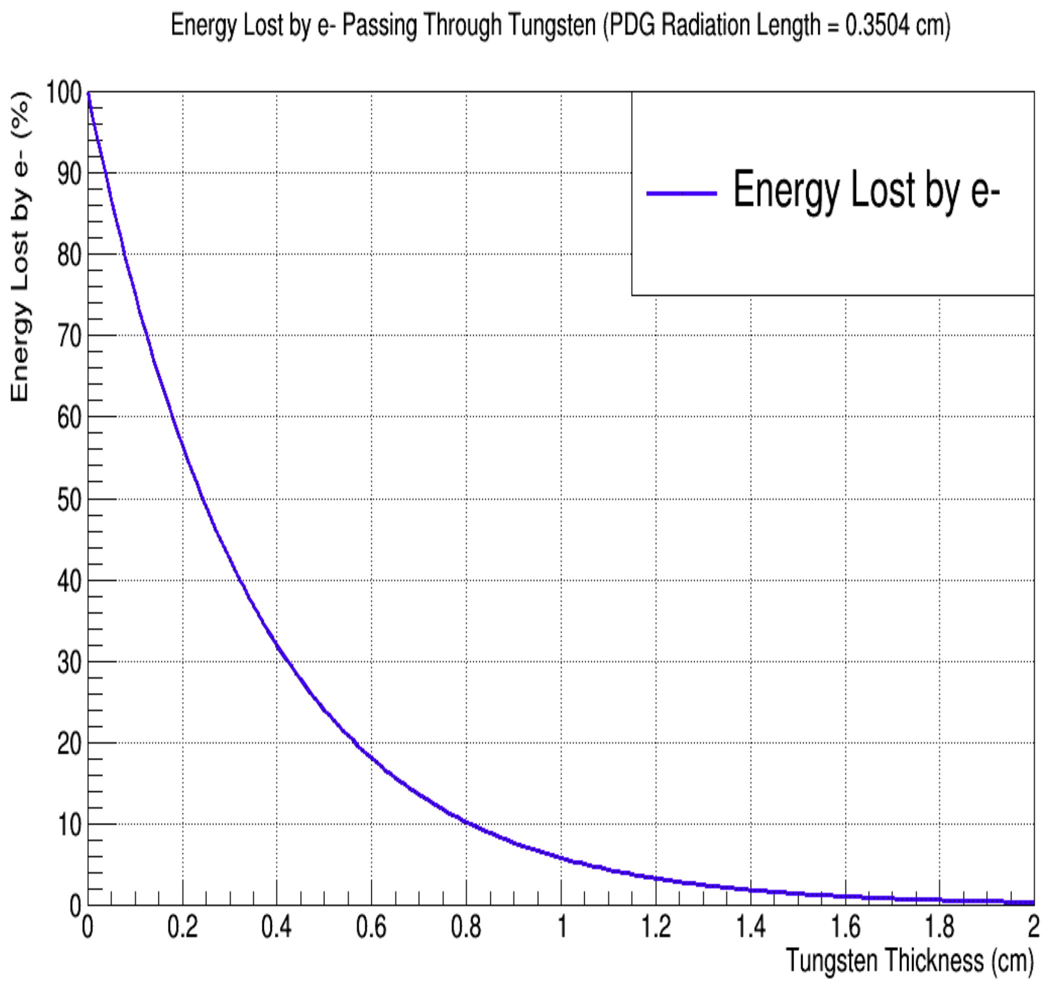




Energy Loss Radiation Length Al and W

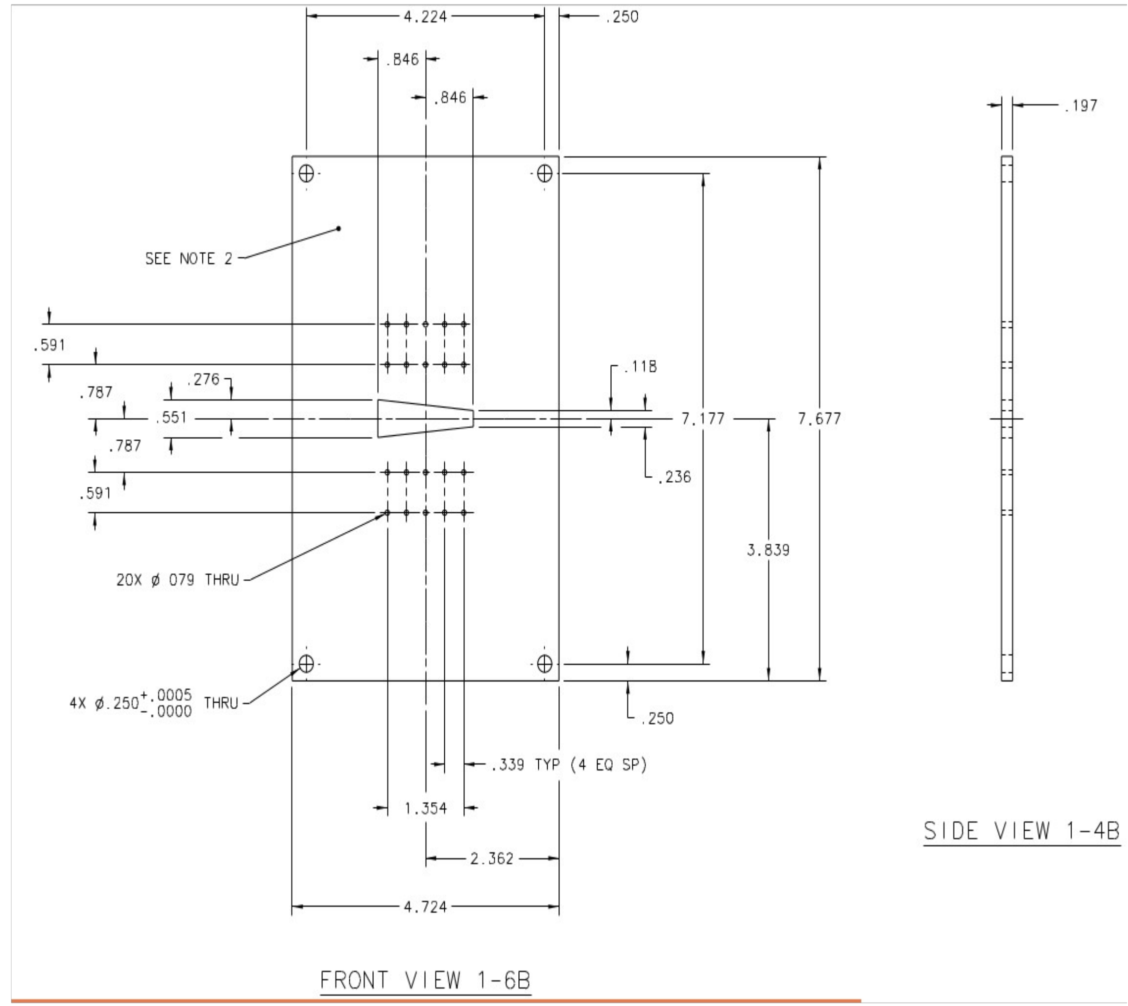
- Collisional losses dominate as energy is lost.
- 1 radiation length leave 1/e energy.





Conclusion/Future Work

- As expected tungsten depletes the electrons of energy faster than aluminum.
- Current proposal calls for a 0.5 cm thick tungsten plate which seems reasonable.
- Need to determine standard stock thicknesses to minimize machining costs.
- Need to determine plate size for current holder.



References

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