Measuring Gamma Attenuation Of Polymeric and Metallic Materials

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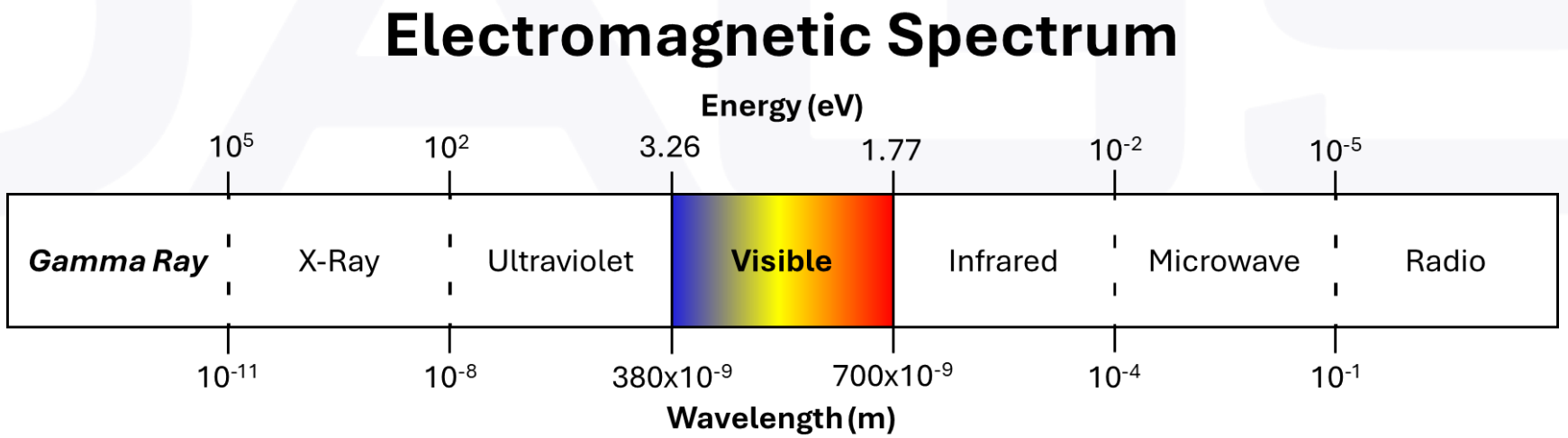
Background

Scope:

- Research and develop new light-weight and low-cost materials for shielding against gamma radiation for space applications

This presentation:

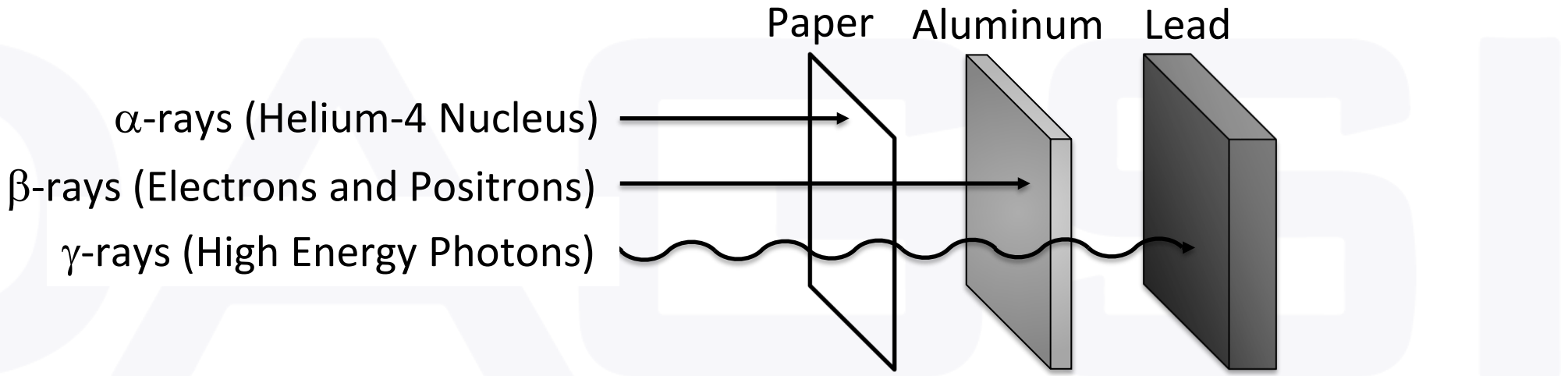
- Introduction to gamma radiation, software calculated attenuation properties, and measured attenuation of various materials using a Geiger-Müller counter



Ionizing Radiation

Ionizing Radiation Includes: Alpha, Beta, Gamma, Neutron, and Ion

Materials used for shielding depend on the type and energy of the radiation:



Gamma radiation is highly penetrative and the most effective in terms of creating TID effects [1].

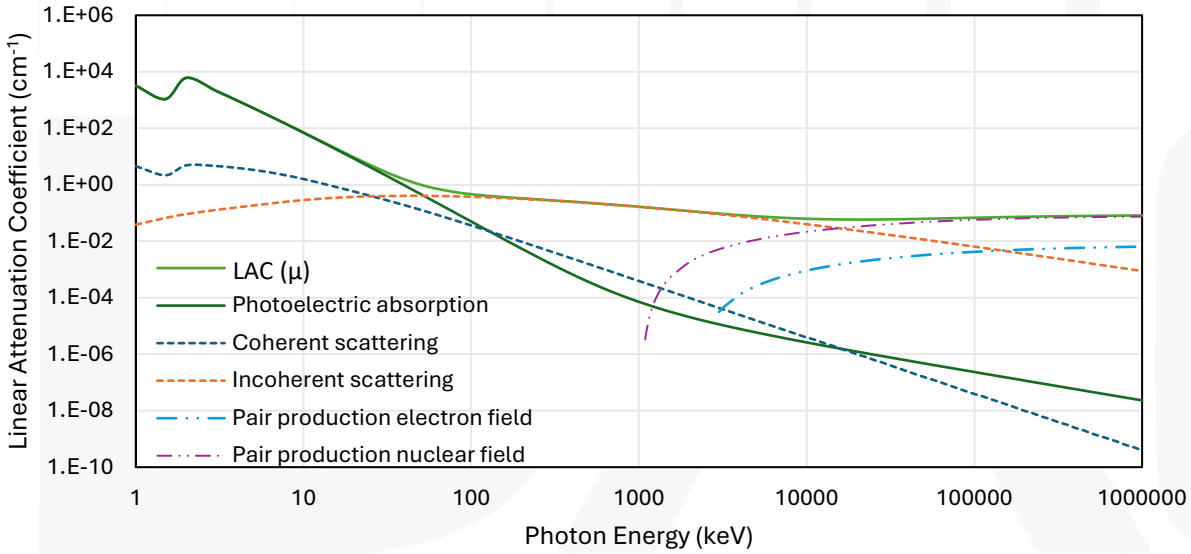
[1] Robert Baumann and Kirby Kruckmeyer. Radiation Handbook for Electronics, Texas Instruments, www.ti.com/applications/industrial/aerospace-defense/space/radiation-handbook-for-electronics.html

Gamma Attenuation Properties

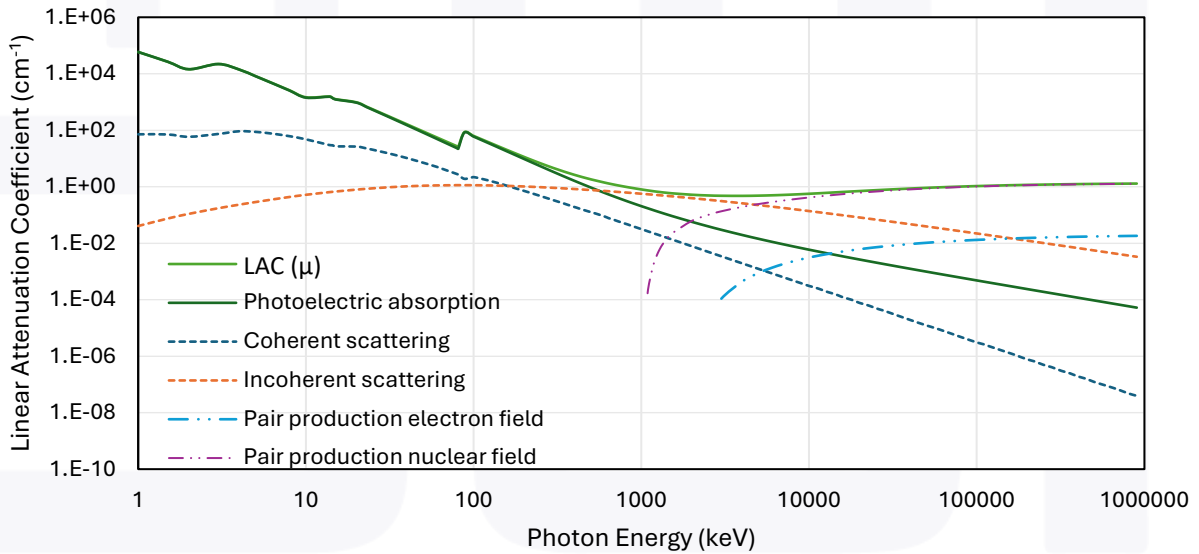
Linear Attenuation Coefficient (LAC): $\mu = \tau(Photoelectric) + \sigma(Compton) + \kappa(Pair)$

Depends on both photon energy and material

Al



Pb



Gamma Attenuation: $I = I_0 e^{-\mu t}$

Where: I_0 is initial intensity of radiation

I is intensity after passing through shield

t is thickness of shield

Half Value Layer (HVL): $\mathrm{HVL} = \frac{\ln 0.5}{-\mu} = \frac{0.6931}{\mu}$

HVL is the thickness needed to reduce the radiation intensity by a half

Figures: Produced using EpiXS

Attenuation Measurements

Materials:

- Al
- Pb
- PLA
- Nylon

Sources:

- Cs-137 (Gamma Source: 0.662 MeV)
- Co-60 (Gamma Source: 1.17 MeV and 1.33 MeV)

Equipment:

- Geiger-Müller Counter (ST365-B)
- PLA Beta Shield

Software (LAC and HVL):

- XCOM, Phy-X/PSD, NGCal, EpiXS

Detects Alpha, Beta, and High Energy Photons

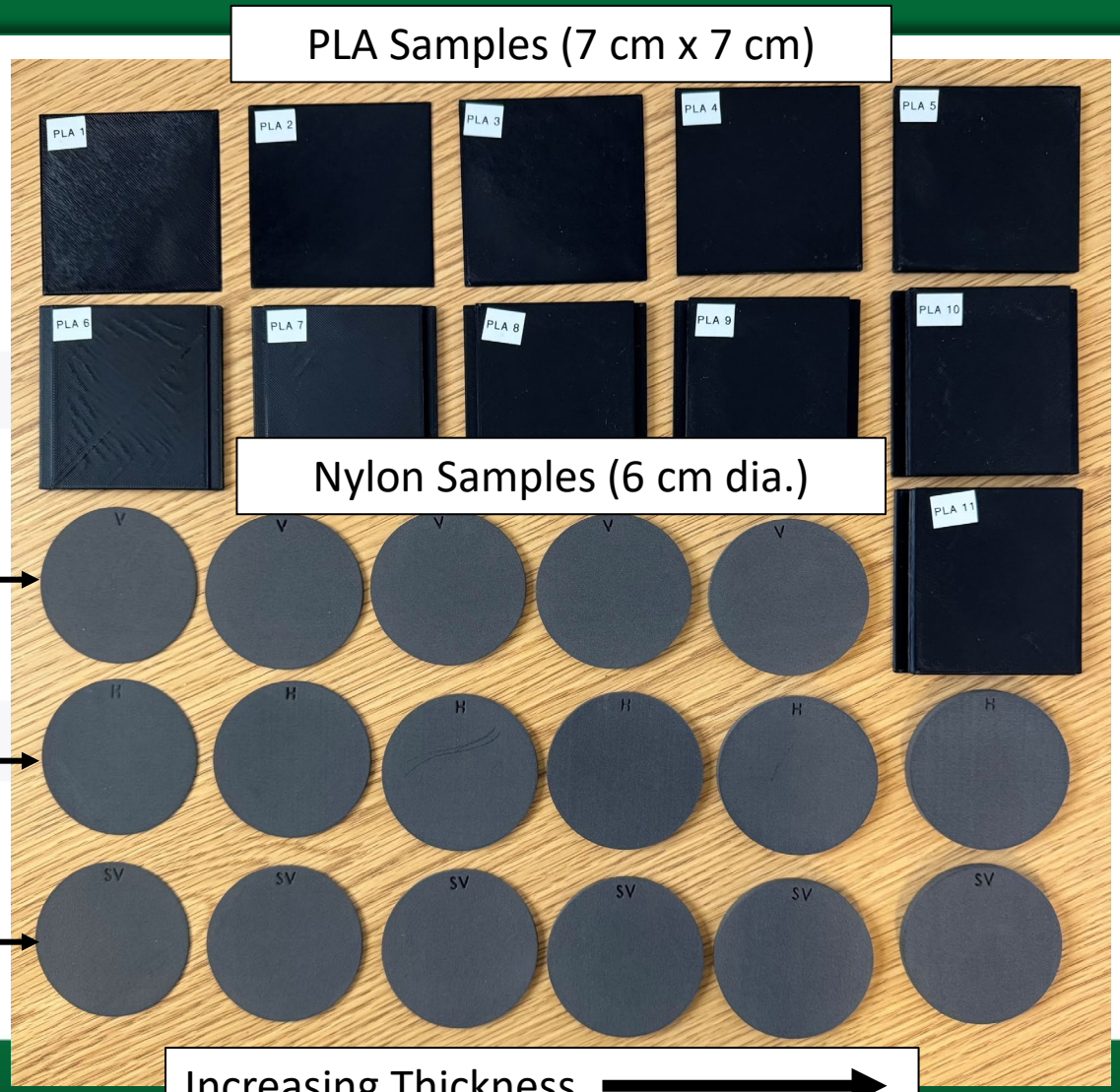
Figure: *Spectrum Techniques, LLC*, www.spectrumtechniques.com

Samples and Printing

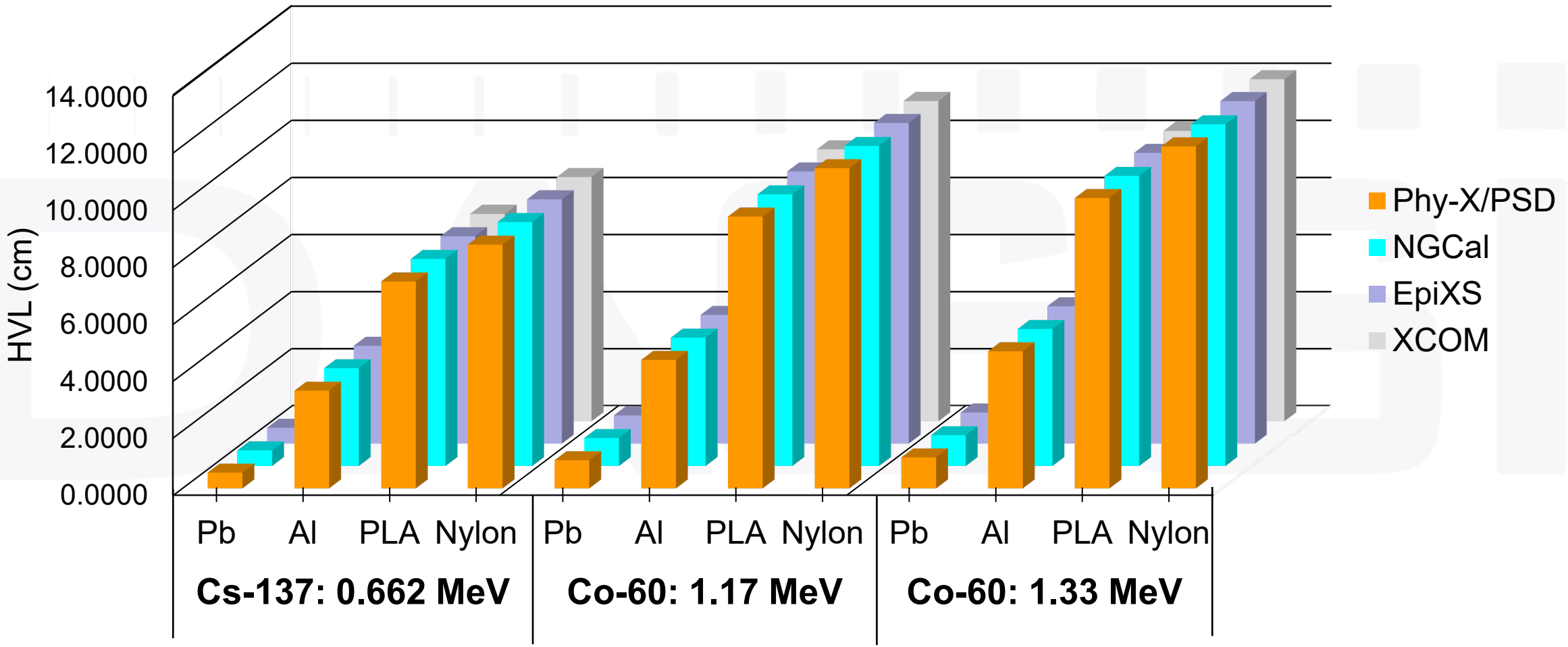
Al and Pb Plates:
- Absorber Set (Spectrum Techniques)

PLA:
- Prusa MK3S
- 1.75mm diameter filament (Overture)
- Infill: 90%

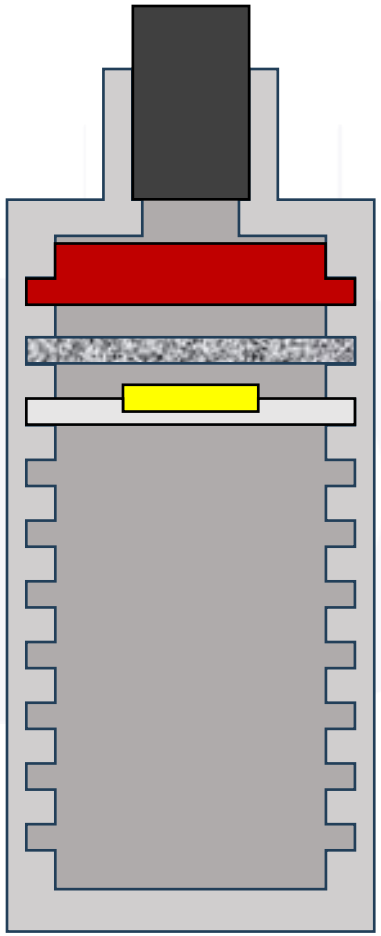
Nylon:
- Fuse 1 (Formlabs)
- Nylon 12 powder (Formlabs)
- 110µm layer thickness
- Varying print orientations



HVL Calculated Based on Composition, Density, and Photon Energy



Gamma Attenuation Measurements



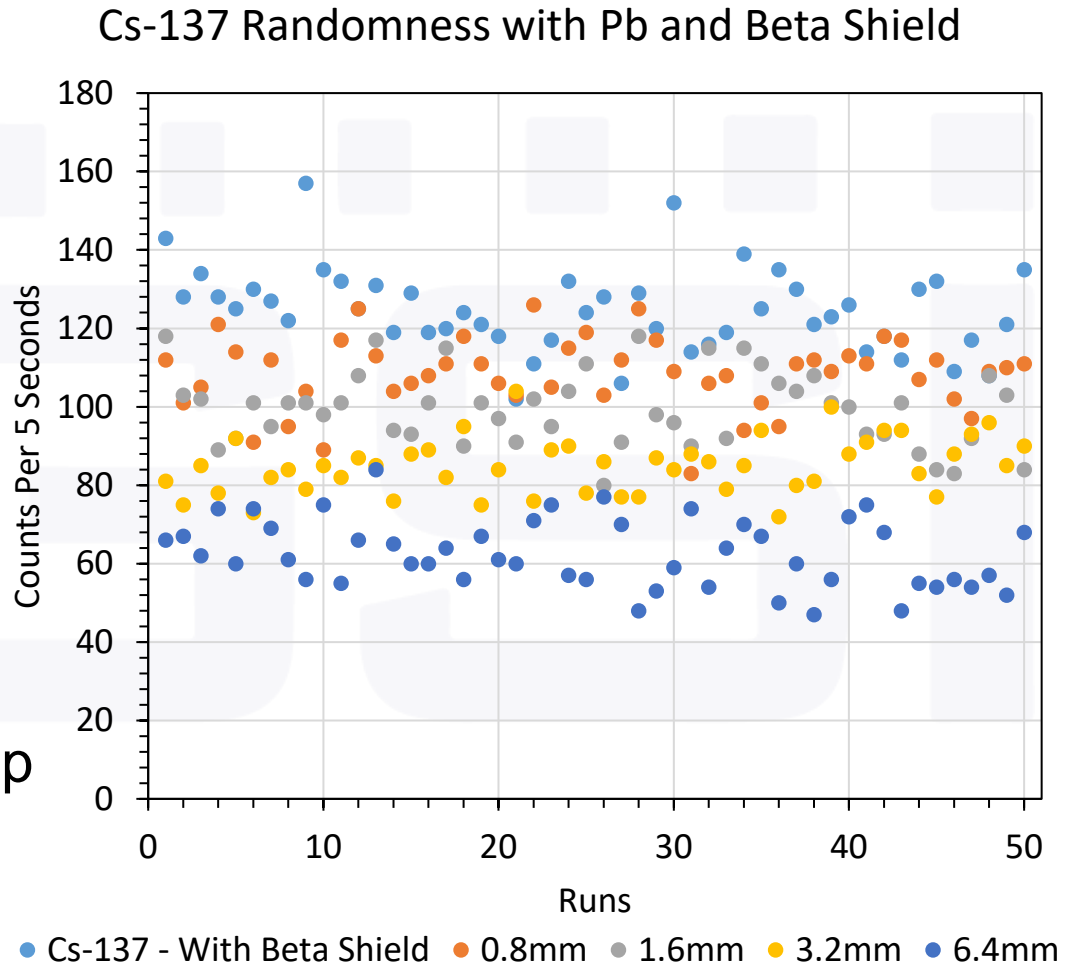
Geiger-Müller Tube

***Beta Shield**

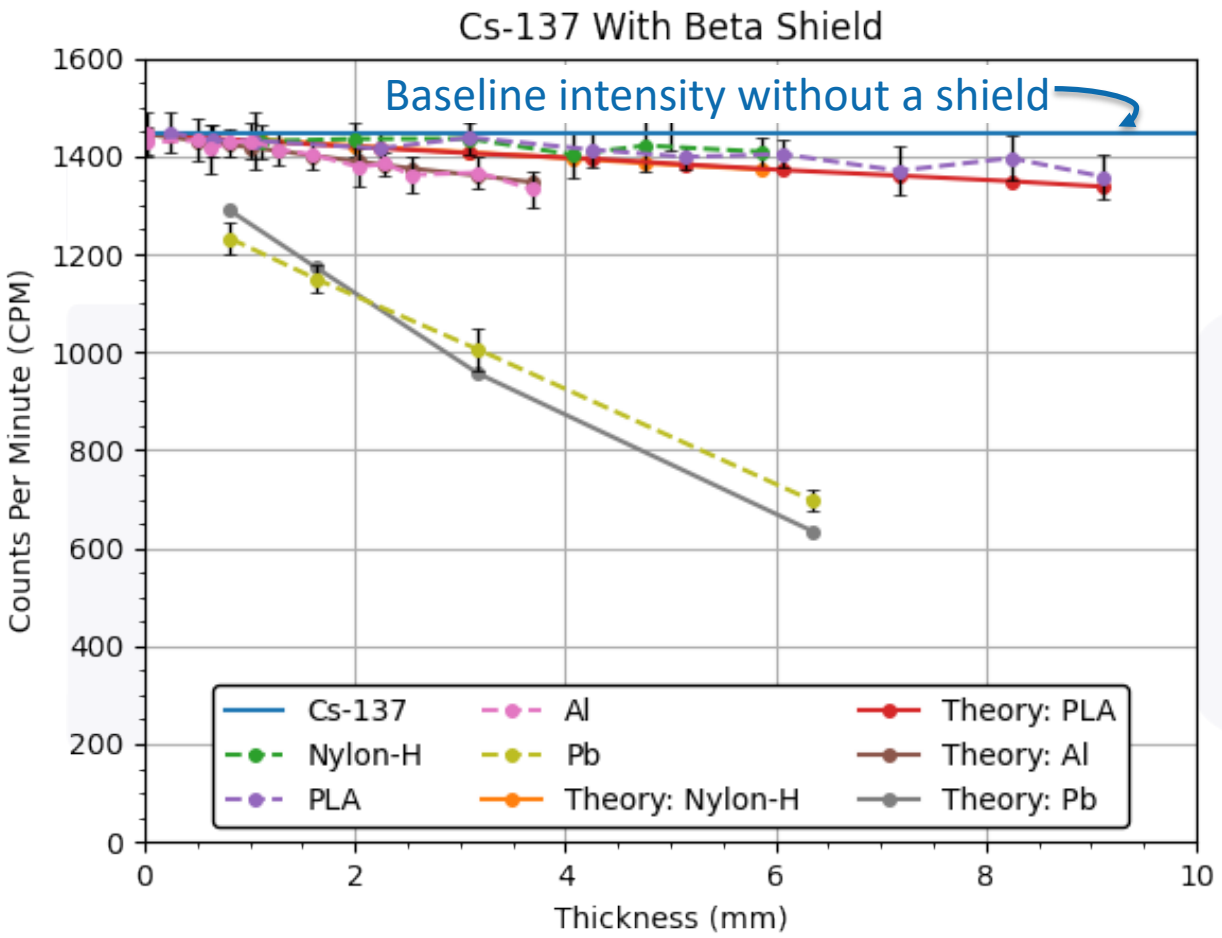
Shielding Material Of Varying Thicknesses

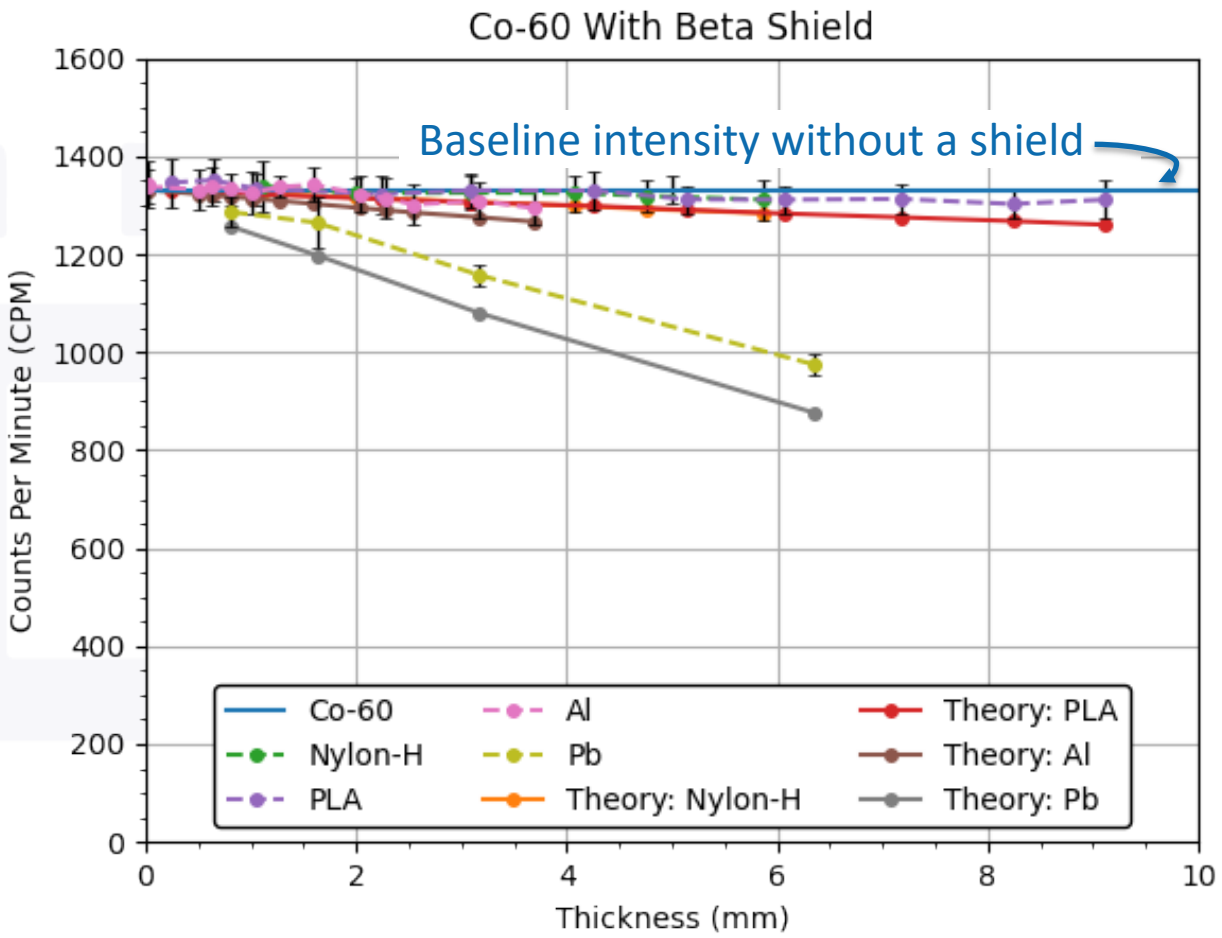
Radiation Source (Cs-137 or Co-60)

*A **beta shield** was used to stop the beta radiation emitted from the gamma sources from reaching the detector



Gamma Attenuation Measurements





***Pb sample had an aluminum backing plate which caused some deviation**

Conclusions

- Materials' experimental intensities matched closely to the theoretical intensities. Experimental intensities were slightly higher due to secondary radiation.
- Most to least effective at attenuating gamma radiation: *Pb, Al, PLA, Nylon*

Cs-137 (0.662 MeV)				
Material	**LAC, μ (cm^{-1})**		**HVL (cm)**	
	Software (Avg.)	**Experiment**	**Software (Avg.)**	**Experiment**
Lead	1.26	1.04	0.55	0.67
Aluminum	0.20	0.20	3.44	3.44
PLA	0.10	0.07	7.275	10.47
Nylon	0.08	0.07	8.5672	10.64

Future Work

- Calculate the attenuation properties of composites materials using available software
- Create and measure the properties of the best predicted shielding materials
- Examine the photon energy spectrum to account for secondary radiation