Mott Polarimeter Upgrade at Jefferson Lab

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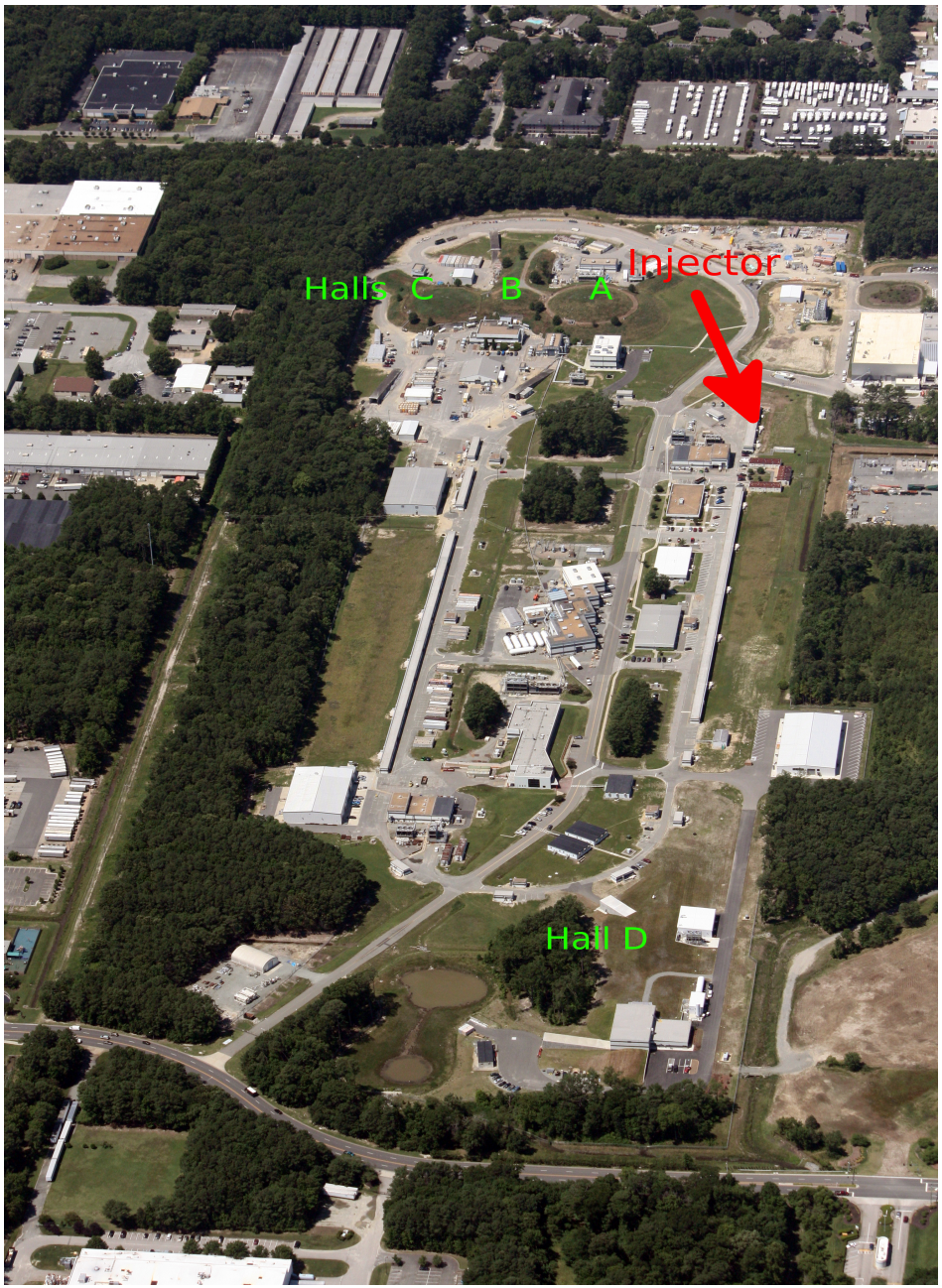
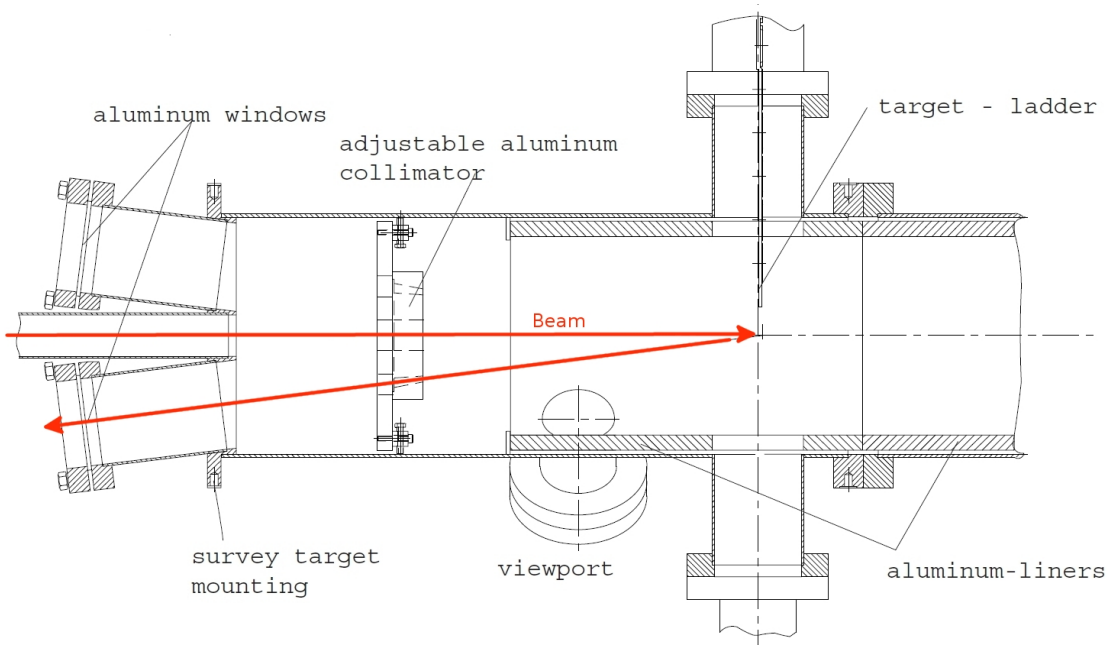
Jefferson Lab

Mott Polarimeter Location



- Located in the injector.
- Measures transverse polarization close to the source, before main accelerator.
- Used along with spin rotators to set the polarization in the halls.
- Can be used for independent energy measurements in halls (via spin precession).
- In use for over 15 years.
- New effort at understanding and improving is underway.

Polarimeter Overview



- Measures elastic scattering asymmetry, A_{exp}, in thin (d = 0.01-1.0 μm) Au foil.
- $P = \frac{A_{\mathrm{exp}}}{S_{\mathrm{eff}}(\theta,d)}$

Al collimator defines $\theta = 172.6^{\circ} \pm 0.45^{\circ}$ and $\delta\Omega = 0.21$ msr.

Typical Parameter Ranges	
I_{beam}	¡ 1.5 μA
Beam Energy	2 MeV - 10 MeV
Event Rate	¡5 kHz
Spin Flip Rate	30 Hz - 960

Mott Scattering Asymmetry

e^- – nucleus scattering:

$$\sigma(\theta) = I(\theta)\left[1 + S(\theta)\mathbf{P}\cdot\mathbf{n}\right]$$

with $\mathbf{n} = \frac{\mathbf{k}\times\mathbf{k}'}{|\mathbf{k}\times\mathbf{k}'|}$. If $\mathbf{P}$ is horizontal, measure an up-down asymmetry:

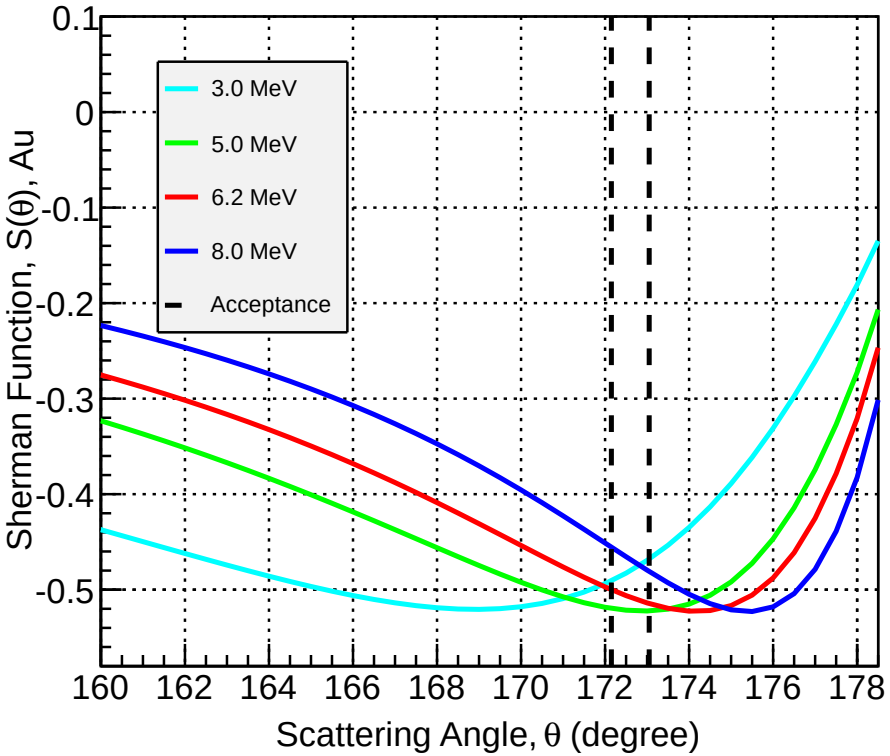
$$A_{UD} = \frac{\sigma_U - \sigma_D}{\sigma_U + \sigma_D} = S(\theta)P.$$

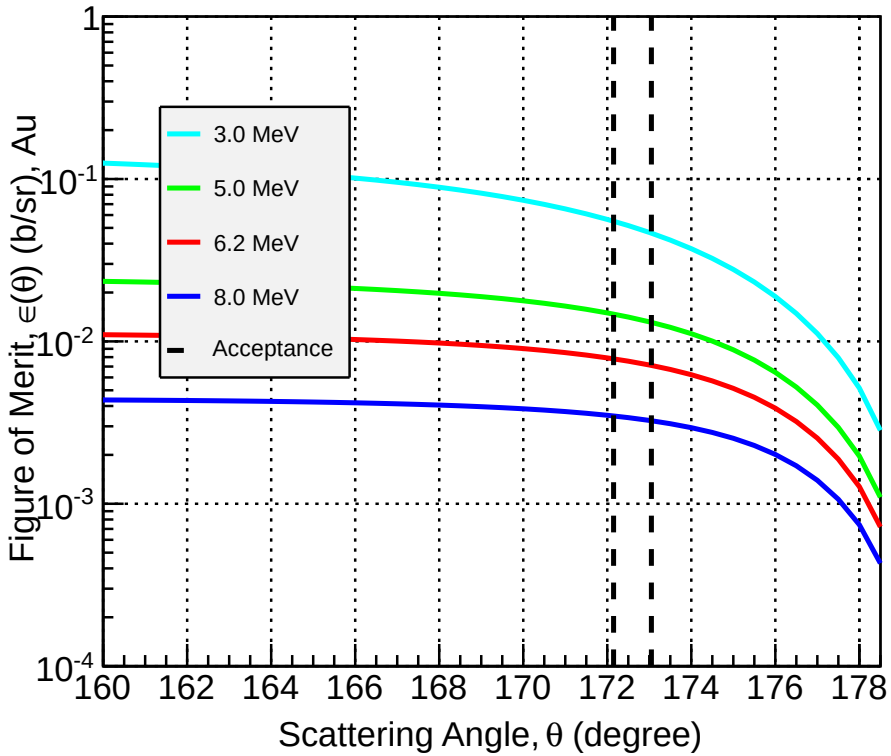
Use the cross-ratio method:

$$A_{UD} = \frac{1-r}{1+r} \qquad \text{with} \qquad r = \sqrt{\frac{N_U^{\uparrow} N_D^{\downarrow}}{N_U^{\downarrow} N_D^{\uparrow}}}.$$

Insensitive to false asymmetries at **all orders** from detector solid angle and efficiency, beam current, and target thickness.
To **first order** from polarization differences and scattering angle.

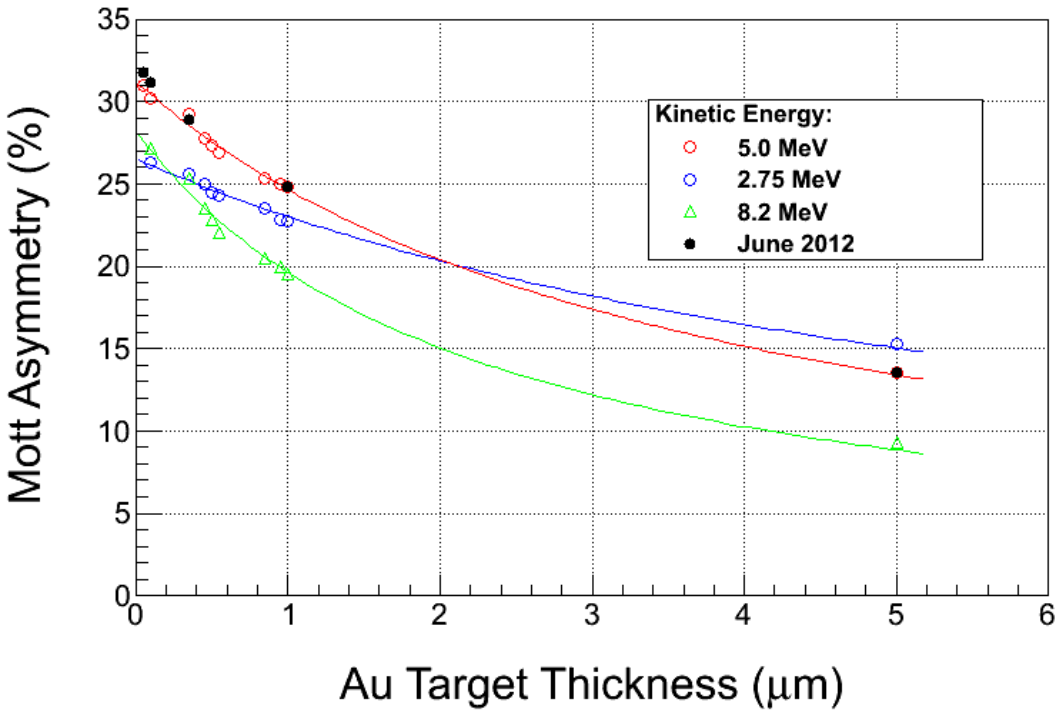
Polarimeter Optimization





- Designed to run at 5 MeV.
- Figure of Merit, $\epsilon(\theta) = I(\theta)S(\theta)^2$, is inversely related to δP.
- Can measure to $\delta A \approx 0.5\%$ stat. using typical setup (1μA on 1 μm Au) in 5 minutes.

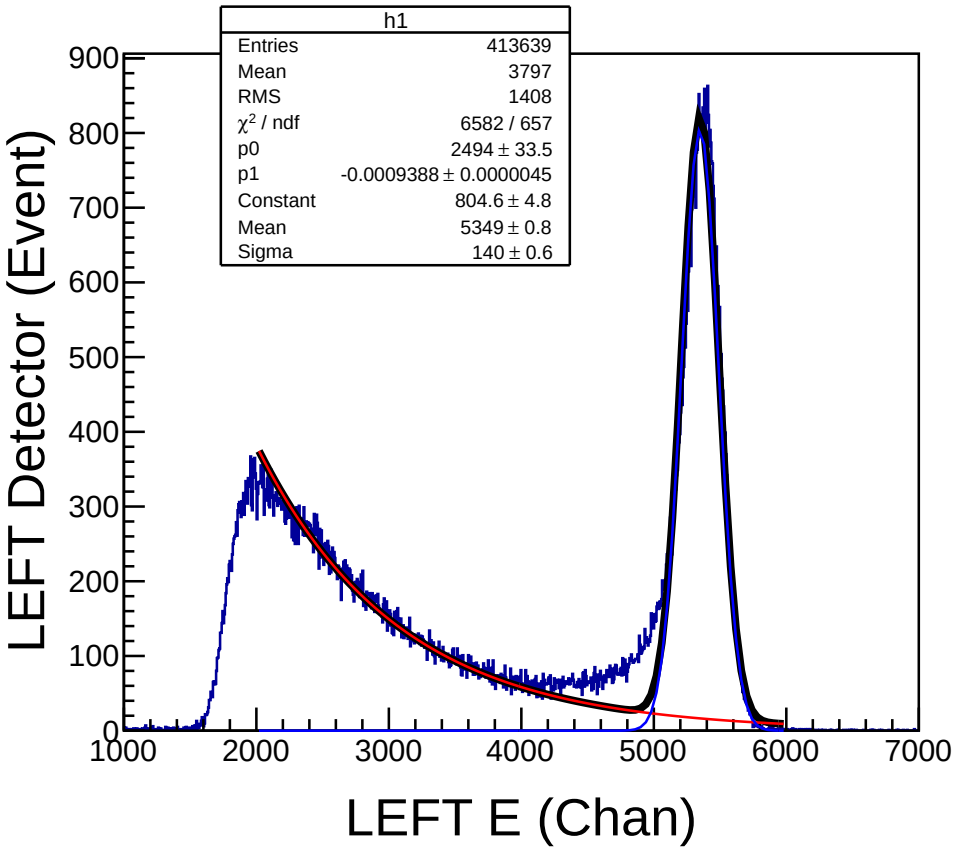
Multiple Scattering and Effective Sherman Function



$$A(\theta, d) = PS_{eff}(\theta, d) = \frac{PS(\theta)}{1 + \alpha(\theta)d}$$

- Study in 2000 yeilded 1.1 % total uncertainty dominated by $S_{eff}(\theta, d)$.
- Recent measurements don't agree to this level.
- Upgrade to improve and characterize polarimeter is underway.

Detector Spectrum

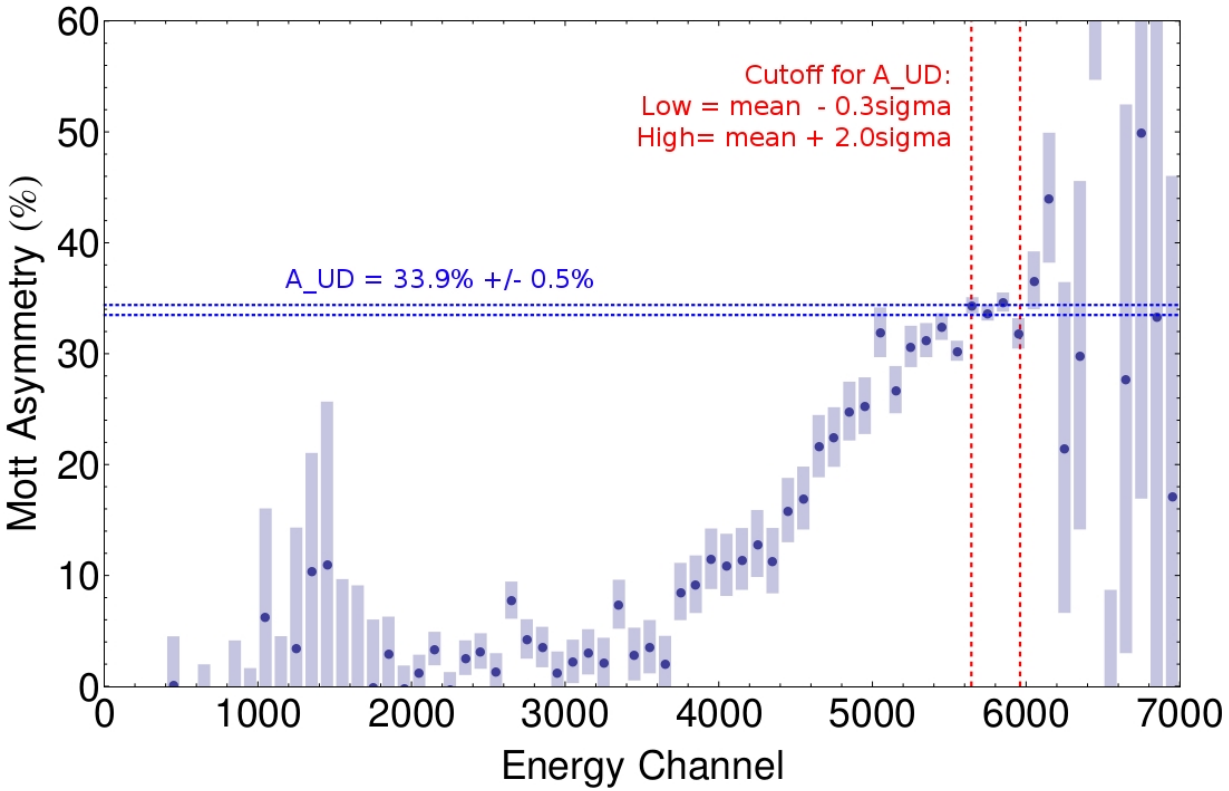


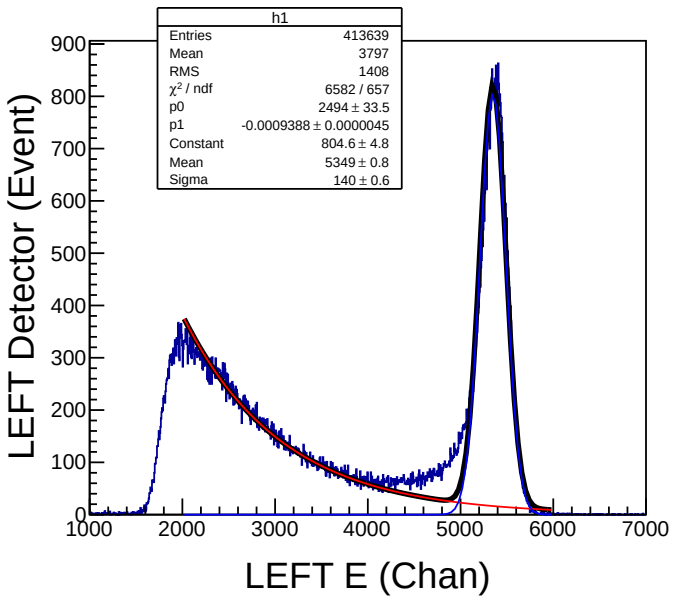
Three main components:

- Background (Descriminator threshold at 2000)
- Low Energy Shoulder (4000 - 5000)
- Elastic Peak

Data taken with 1.25 μA on 1 μm Au. Asymmetry calculated with events in range: $[E_{\text{mean}} - 0.3\sigma, E_{\text{mean}} + 2\sigma] = [5391, 5629]$

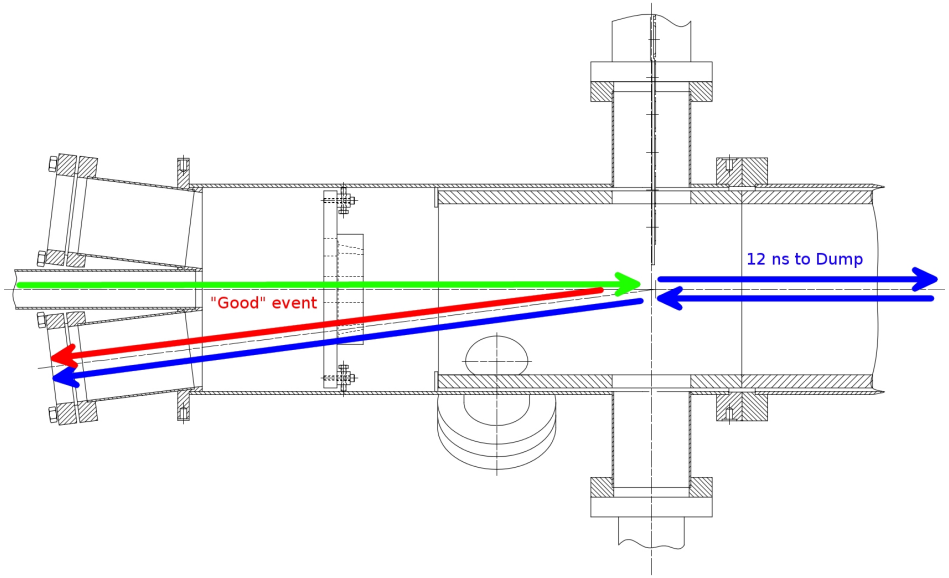
Asymmetry Vs. Energy

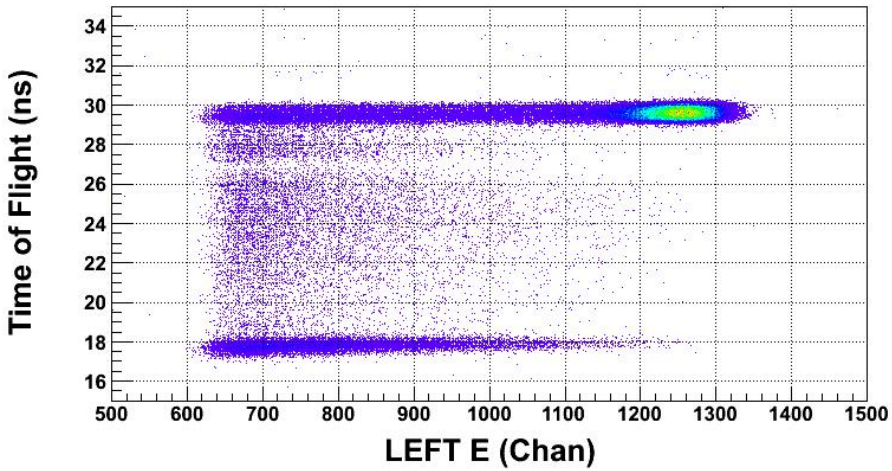




- Shoulder carries carries almost full strength of the physics asymmetry.
- Possible that these are good events loosing energy between the target and detector. Excluded from the asymmetry calculation.

Beam Dump Background





Dump is 1" Al plate.

- Large rate from dump ($\approx 50\%$ for 1 μm)
- Can use TDC to discriminate at low rep rate.
- 2% of events counted for asymmetry from dump on 1μm Au.

Work being done to determine dilution factor and asymmetry for this background.
Could account for discrepancy between Mott and hall polarimeters.

Future Work

1. GEANT4 Simulation:
   - Describe "shoulder" events
   - Identify and reduce backgrounds
   - Provide numerical support for $S_{eff}(\theta, d)$
2. Hardware update:
   - Be dump plate to reduce backgrounds
   - New target ladder and inventory
3. Precision tests:
   - Determination of background dilutions and asymmetries.
   - Improve systematics of measurement extrapolation to $d = 0$.