Mott Polarimeter Upgrade at Jefferson Lab

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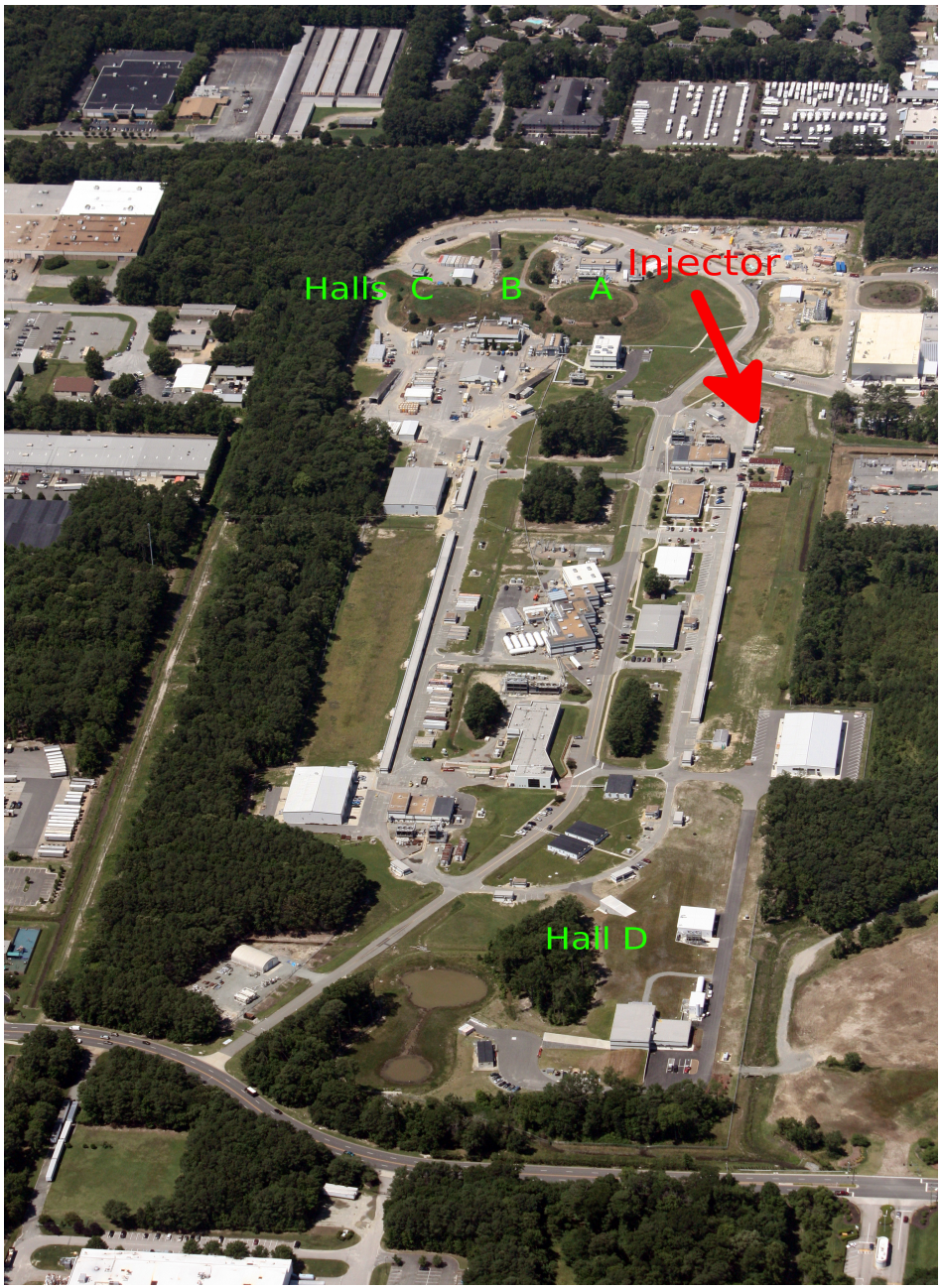
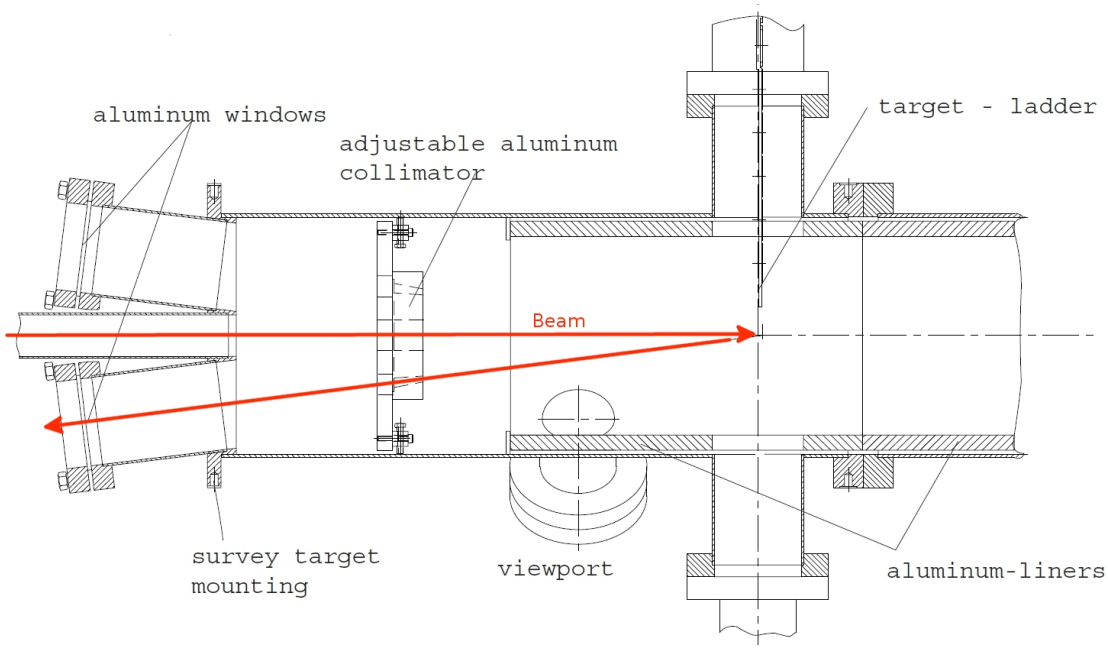
Jefferson Lab

Mott Polarimeter Location



- Measures transverse polarization in the injector, just before before main accelerator.
- 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.
- $P = \frac{A_{\text{exp}}}{S_{\text{eff}}(\theta,d)}$

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

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

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:

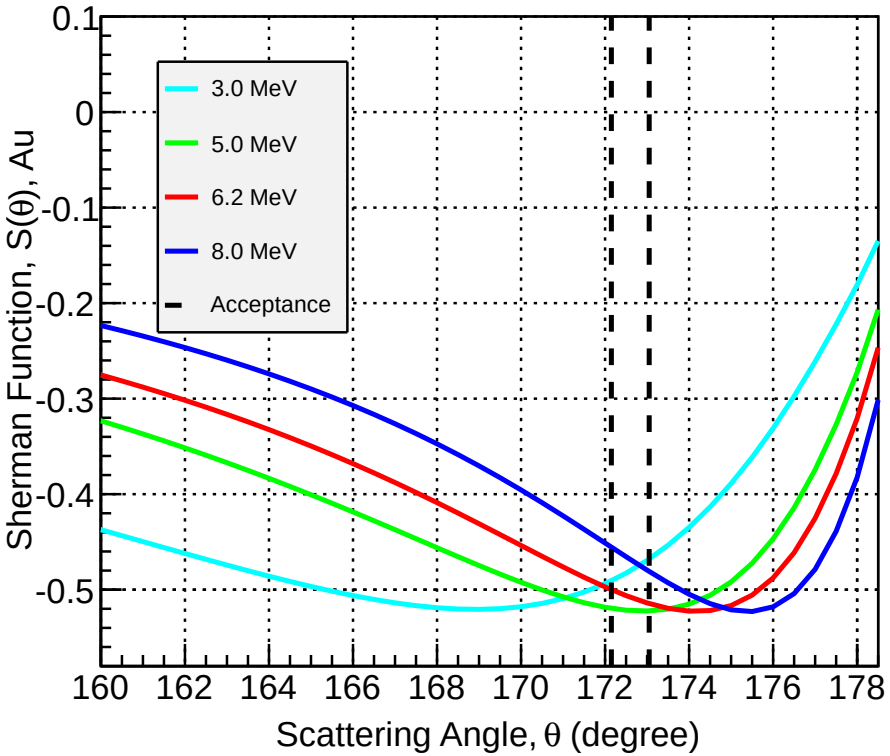
$$A_{UD} = \frac{\sigma_U - \sigma_D}{\sigma_U + \sigma_D} = S(\theta)P.$$

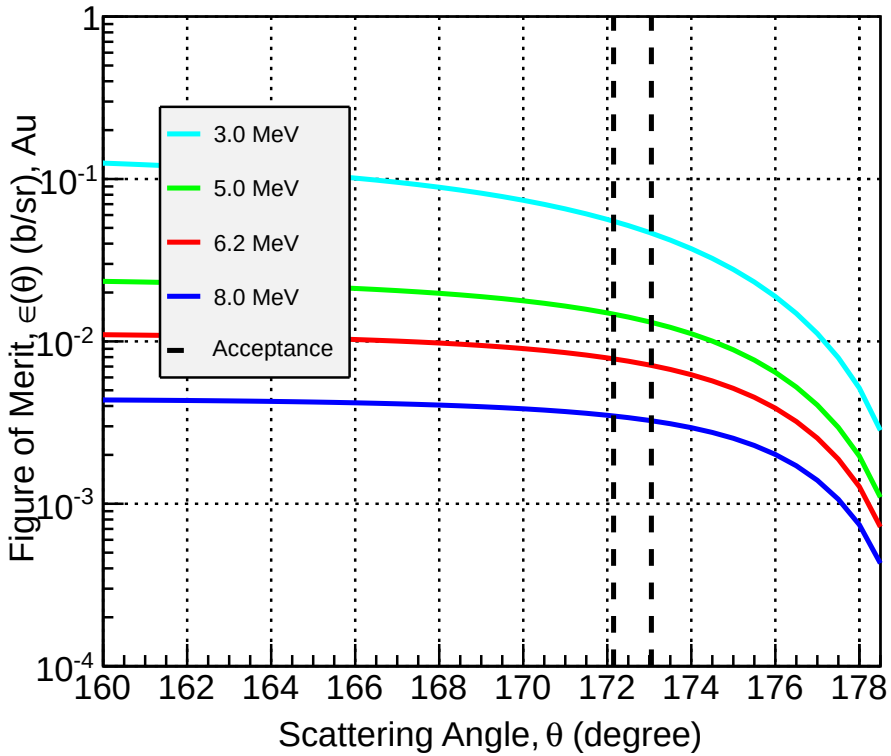
Use the cross-ratio method:

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

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.

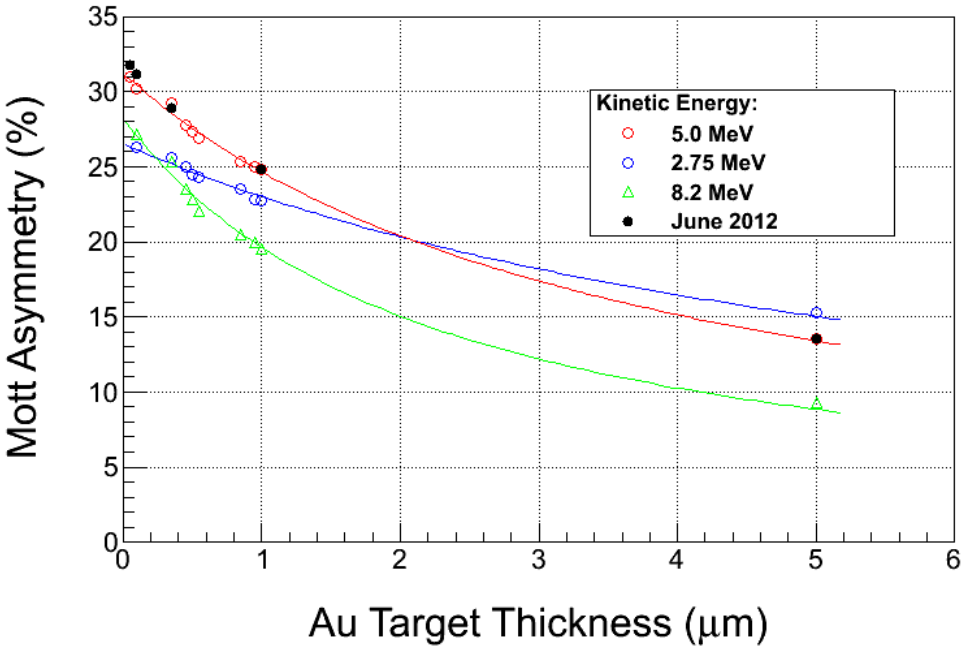
Polarimeter Optimization





- Designed to run at 5 MeV.
- Figure of Merit, $\epsilon(\theta) = I(\theta)S(\theta)^2$, is inversely related to $\delta A/A(t)$.
- 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

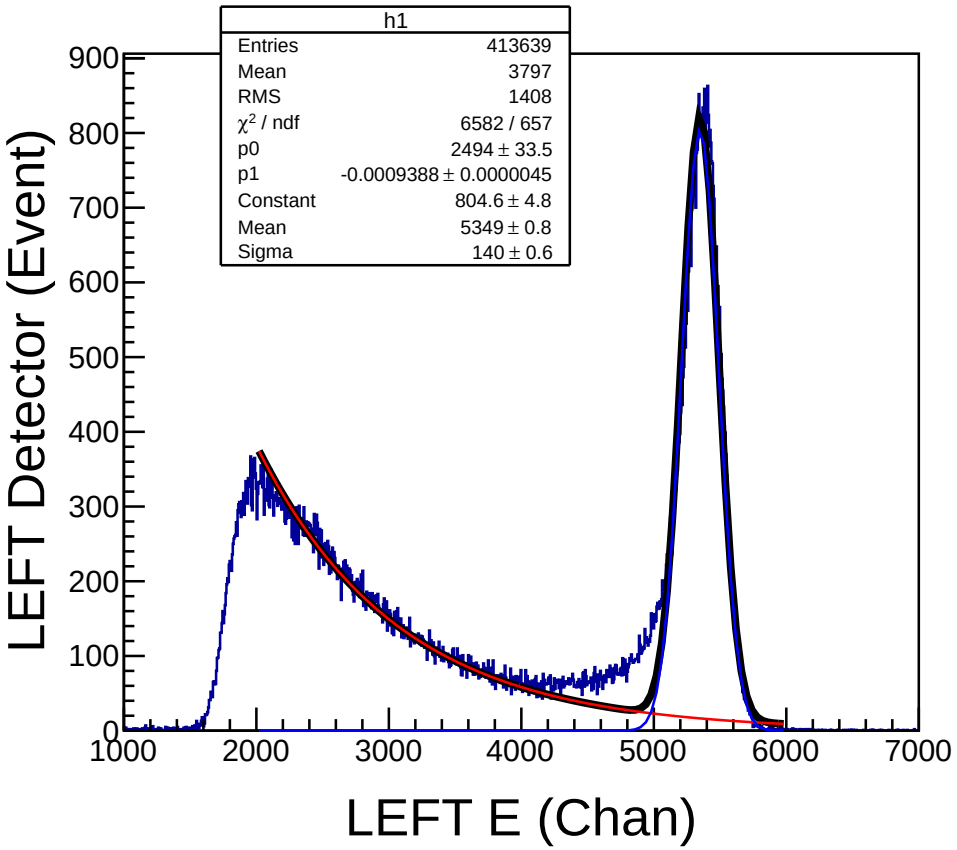


Error bars smaller than points
Curves are fits

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

- Paper in 2000 quoted 1.1% uncertanty for $S(\theta)$.
- Uncertainty in $S_{eff}(\theta, d)$ dominant systematic error.
- GEANT4 Simulation with theory support will improve this.

Detector Spectrum



Three main components:

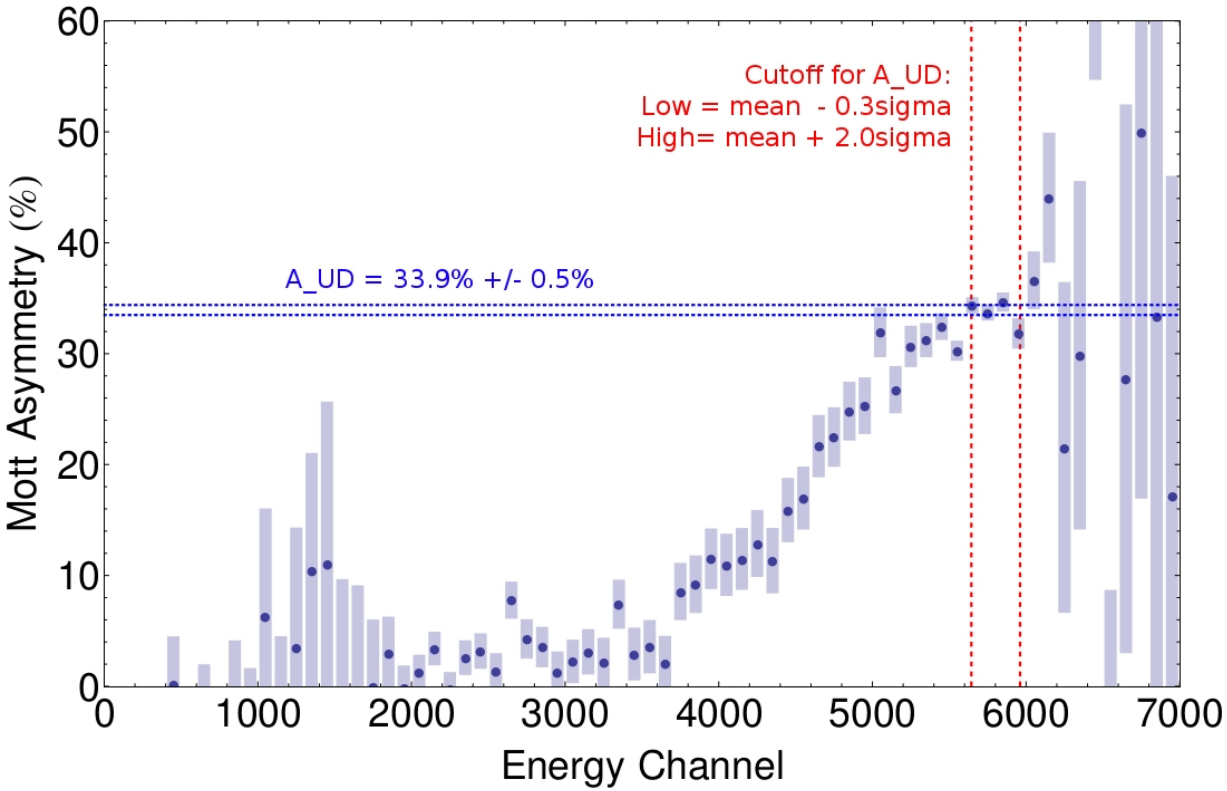
1. Background
2. Low Energy Shoulder (4000 - 5000)
3. Elastic Peak

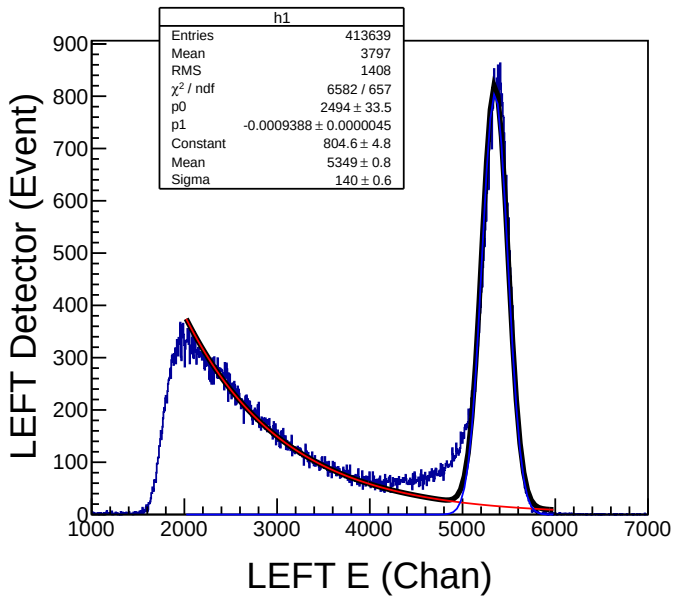
Data taken with 1.25 μA on 1 μm Au.

Asymmetry calculated with events in range:

$[E_{\text{mean}} - 0.3\sigma, E_{\text{mean}} + 2\sigma] = [5391, 5629]$

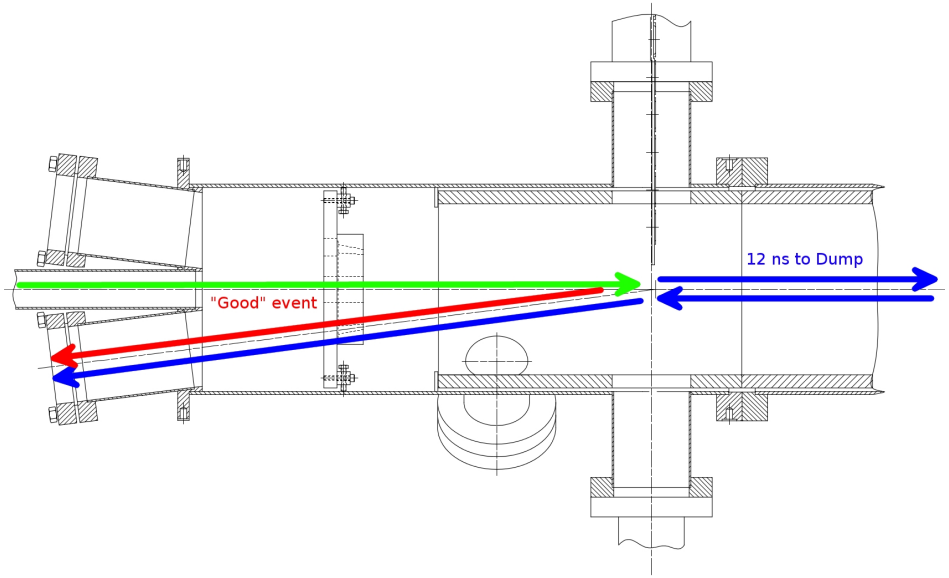
Asymmetry Vs. Energy

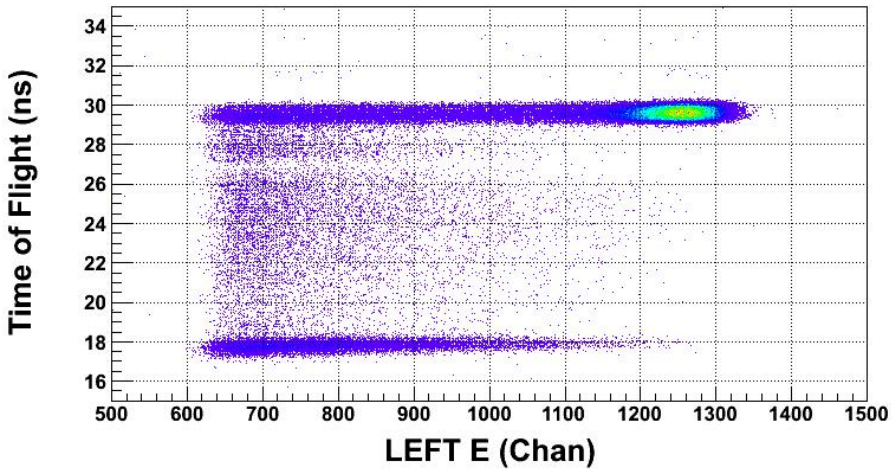




- Shoulder contains good events.
- Simulation points to elastic e^- with radiative losses in detectors.

Beam Dump Background





- Dump is 1" Al plate.
- Can use TDC to discriminate at low rep rate.
- $\approx$ 50% of events NOT from target on 1 μm
- 2% of events in asymmetry on 1μm Au.
- Need to determine dilution factor and asymmetry for this background.

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
   - Higher current running
   - New target ladder and inventory
3. Precision tests:
   - Determination of background dilutions and asymmetries
   - Improved extrapolation for $S_{eff}(\theta, d)$