Compton Polarimetry in Hall A

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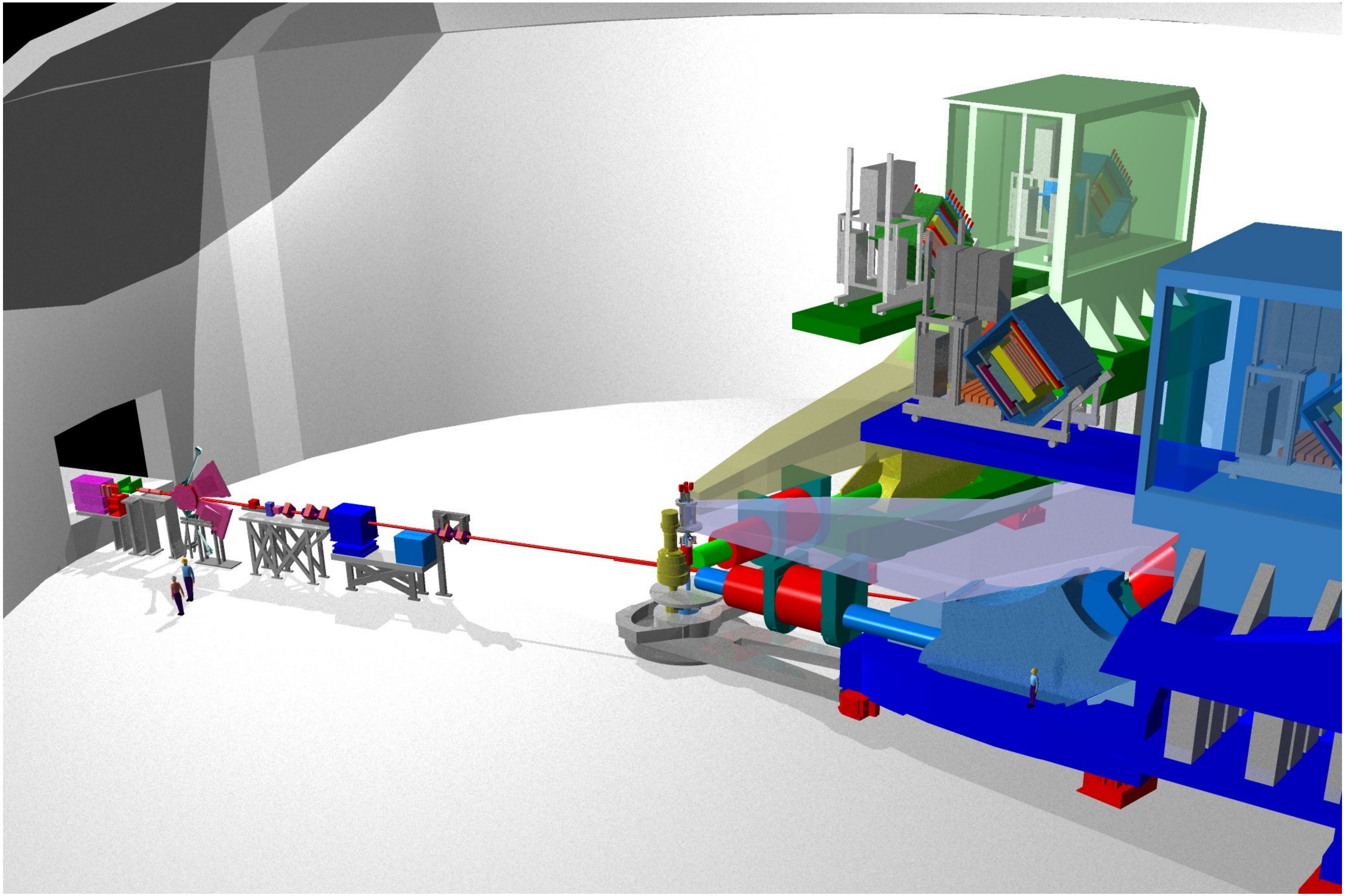
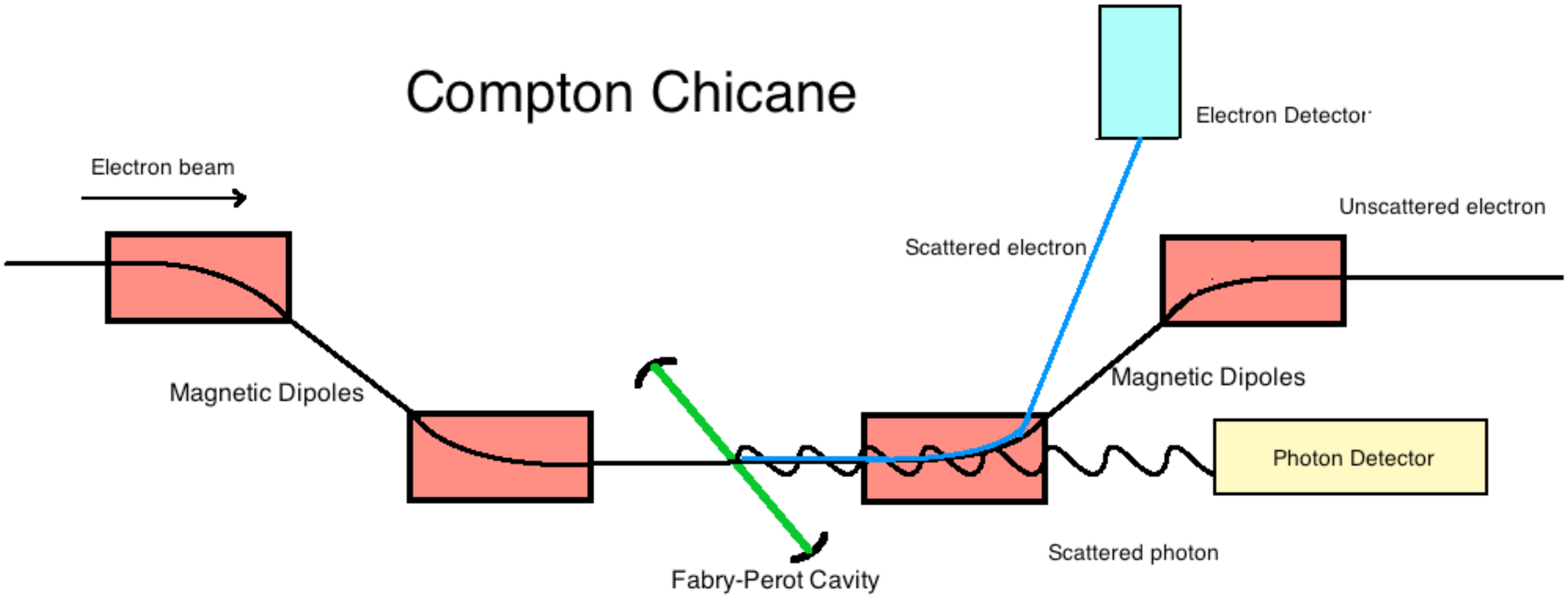
Hall A



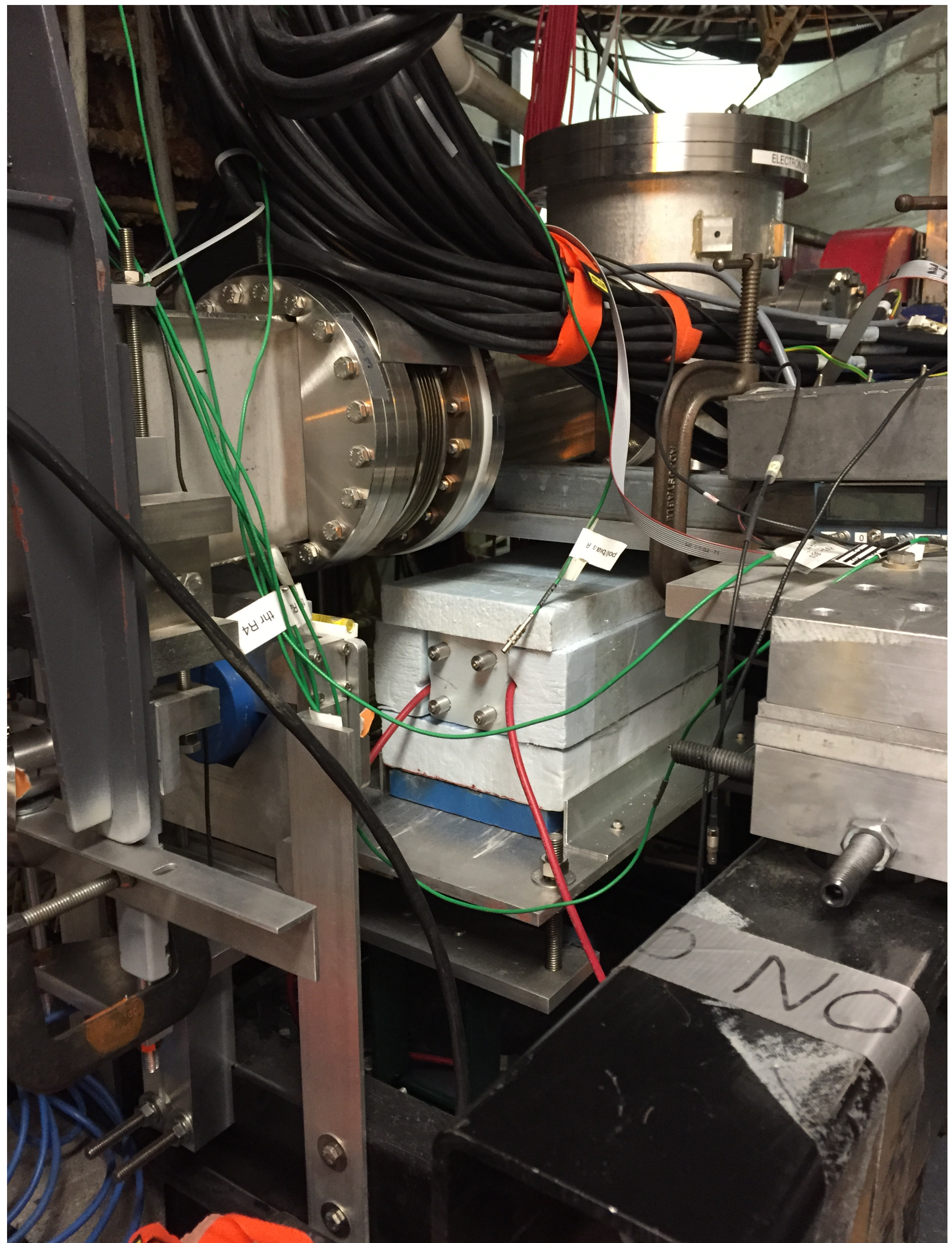
https://www.jlab.org/help/Ghelp/halla3d.html



- Polarized electrons scatter off polarized photons in a Fabry-Perot cavity
- Spin-dependent Compton scattering

Photon Detector

An array of 4, 3cm x 3cm x 20cm PbWO4 crystals



Monte Carlo

The polarimeter's response can be modeled using an accurate **Geant4** simulation, containing all relevant, physical beamline components :

- Photons corresponding to Compton-scattered photons are generated in the simulation, and sent through the PbWO4 crystal array.
- The energy deposited in the crystal is recorded.

Monte Carlo

The scattering cross section is:

$$\frac{d\sigma}{d\rho_{in}} = a\left(\frac{(\rho_{in}(1-a))^2}{1-\rho_{in}(1-a)} + \left(\frac{1-\rho_{in}(1+a)}{1-\rho_{in}(1-a)}\right)^2 + 1\right)$$

$$\rho_{in} = \frac{E_{in}}{E_{max}}$$

$$a = \frac{1}{1+\frac{4E_{ph}E_{beam}}{M_e^2}}$$

- E_{in} = Scattered photon energy
- M_e = Electron mass
- E_{ph} = Laser photon energy
- E_{max} = Energy of Compton edge
- E_{beam} = Electron beam energy

We define the spin-dependent cross sections as:

$$\left(\frac{d\sigma}{d\rho_{in}}\right)_{\pm} = \frac{d\sigma}{d\rho_{in}}(1 \pm A)$$

Where: $$A = \frac{a}{\frac{d\sigma}{d\rho_{in}}}(1-\rho_{in}(1+a))\left(1 - \frac{1}{(1-\rho_{in}(1-a))^2}\right)$$

Monte Carlo

Experimentally, we do not have access to E_{in} , and see only the signal of an event in the detector, defined both aligned and anti-aligned spin events as:

$$S_{\pm}(\rho_{dep}) = \int d\rho_{in} R(\rho_{in}, \rho_{dep}) \frac{d\sigma}{d\rho_{in}}_{\pm}$$

Define the signal dependent asymmetry as:

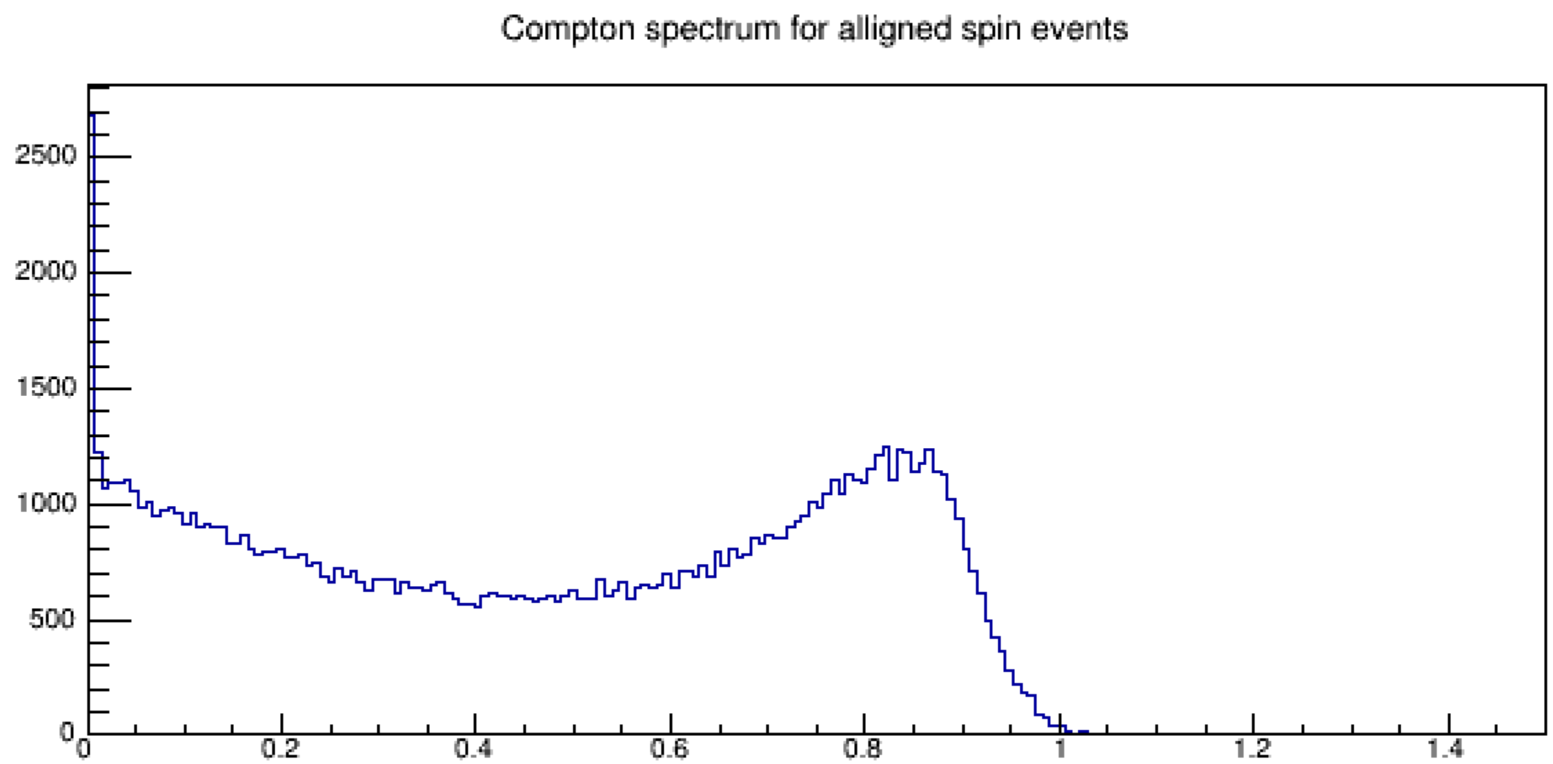
$$A(\rho_{dep}) = \frac{S_{+}(\rho_{dep}) - S_{-}(\rho_{dep})}{S_{+}(\rho_{dep}) + S_{-}(\rho_{dep})}$$

Compare to what we can measure experimentally:

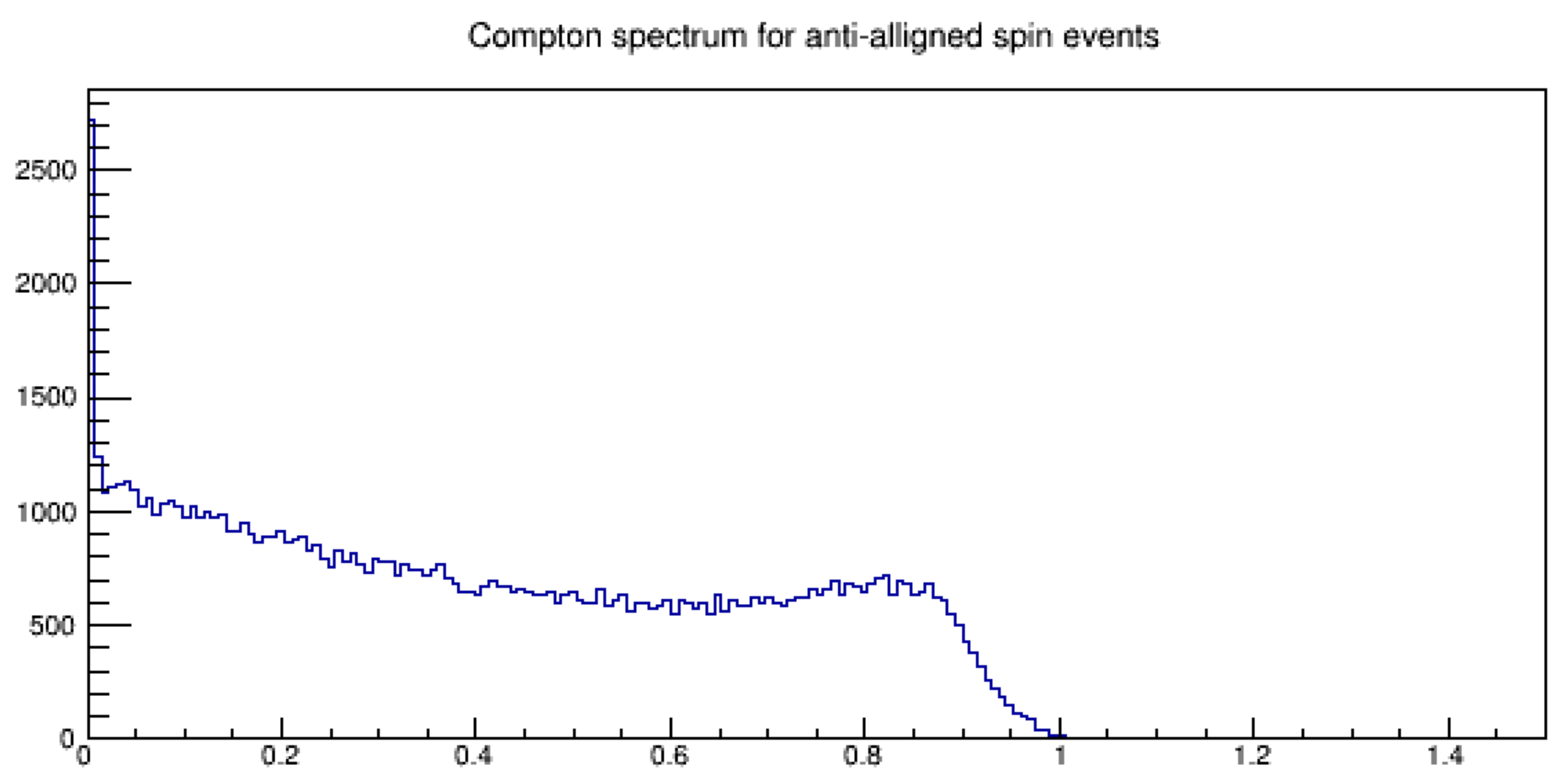
$$A_{Exp} \equiv \frac{S^{+} - S^{-}}{S^{+} + S^{-}} = P_e P_\gamma A$$

$R(\rho_{in}, \rho_{dep})$ is the crystal's resolution function

Monte Carlo

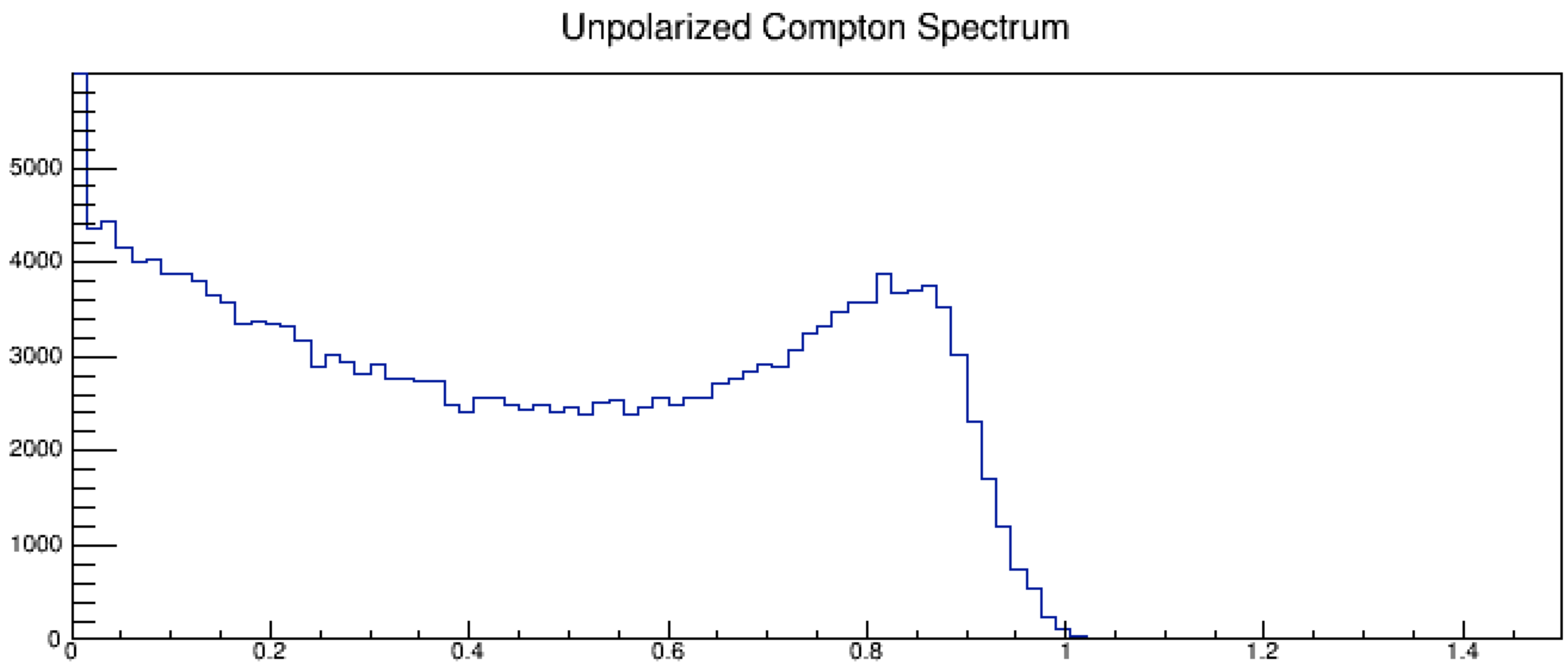


$S_+(\rho_{dep})$ vs. ρ_{dep}

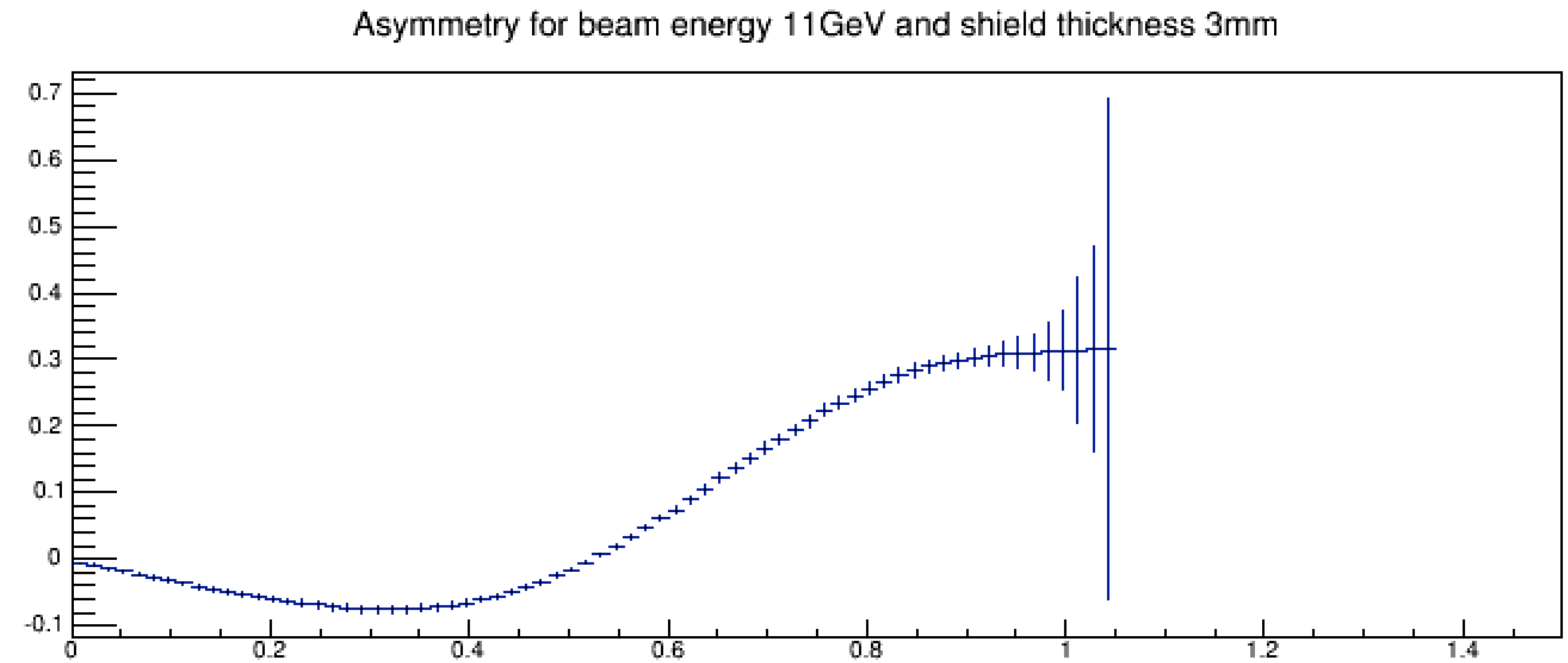


$S_-(\rho_{dep})$ vs. ρ_{dep}

Monte Carlo



$$S_+(\rho_{dep}) + S_-(\rho_{dep})$$



$$A(\rho_{dep}) = \frac{S_+(\rho_{dep}) - S_-(\rho_{dep})}{S_+(\rho_{dep}) + S_-(\rho_{dep})}$$

Measurements

Compton PMT signal leads to FADC, where three measurements are recorded:

My talk →

1. All individual PMT events
2. Integrate PMT signal with **no** threshold
3. Integrate PMT signal with **high** threshold

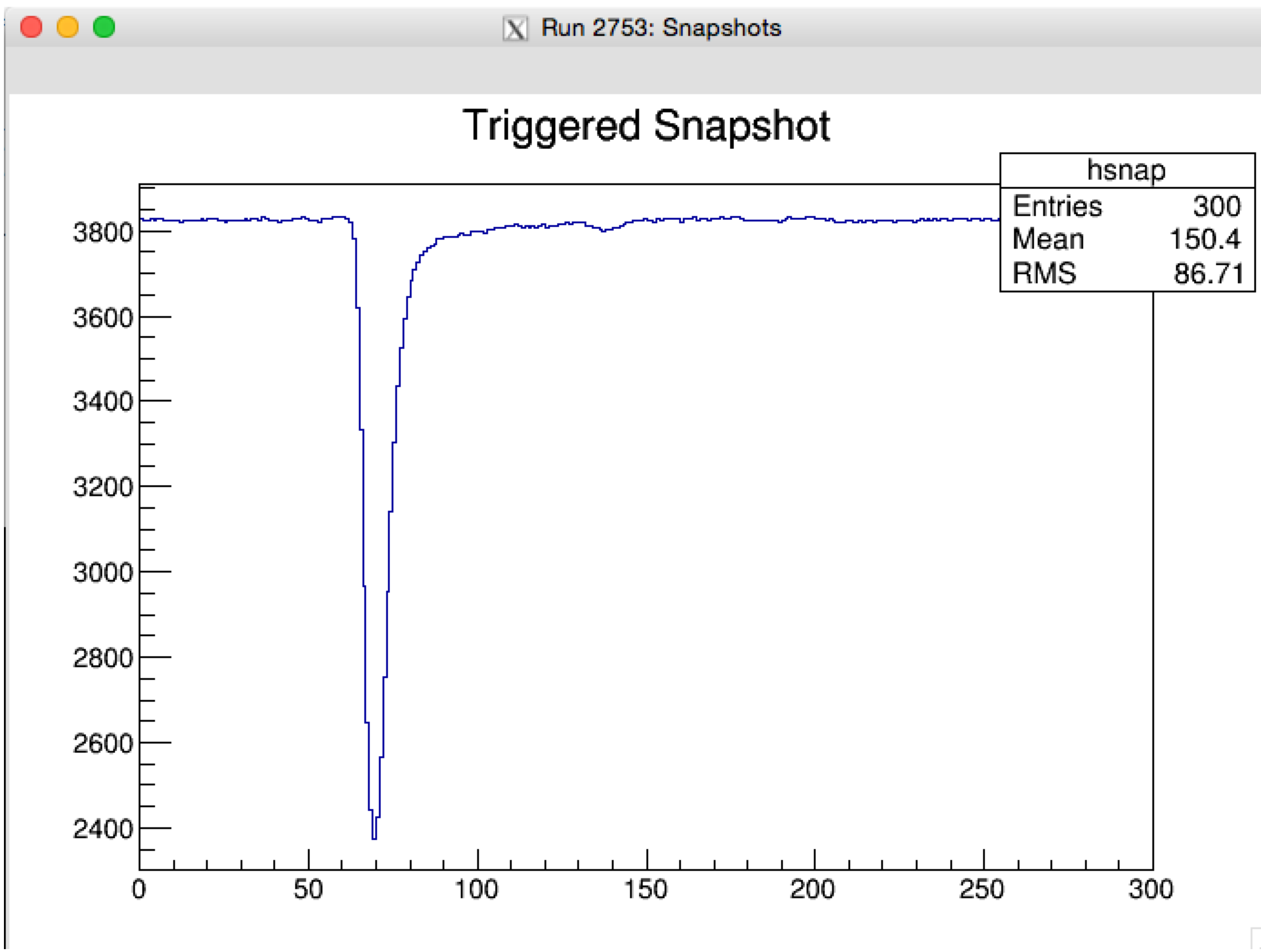
} Larisa's talk

***Each method can be used to determine the electron beam polarization percentage.

Raw Data

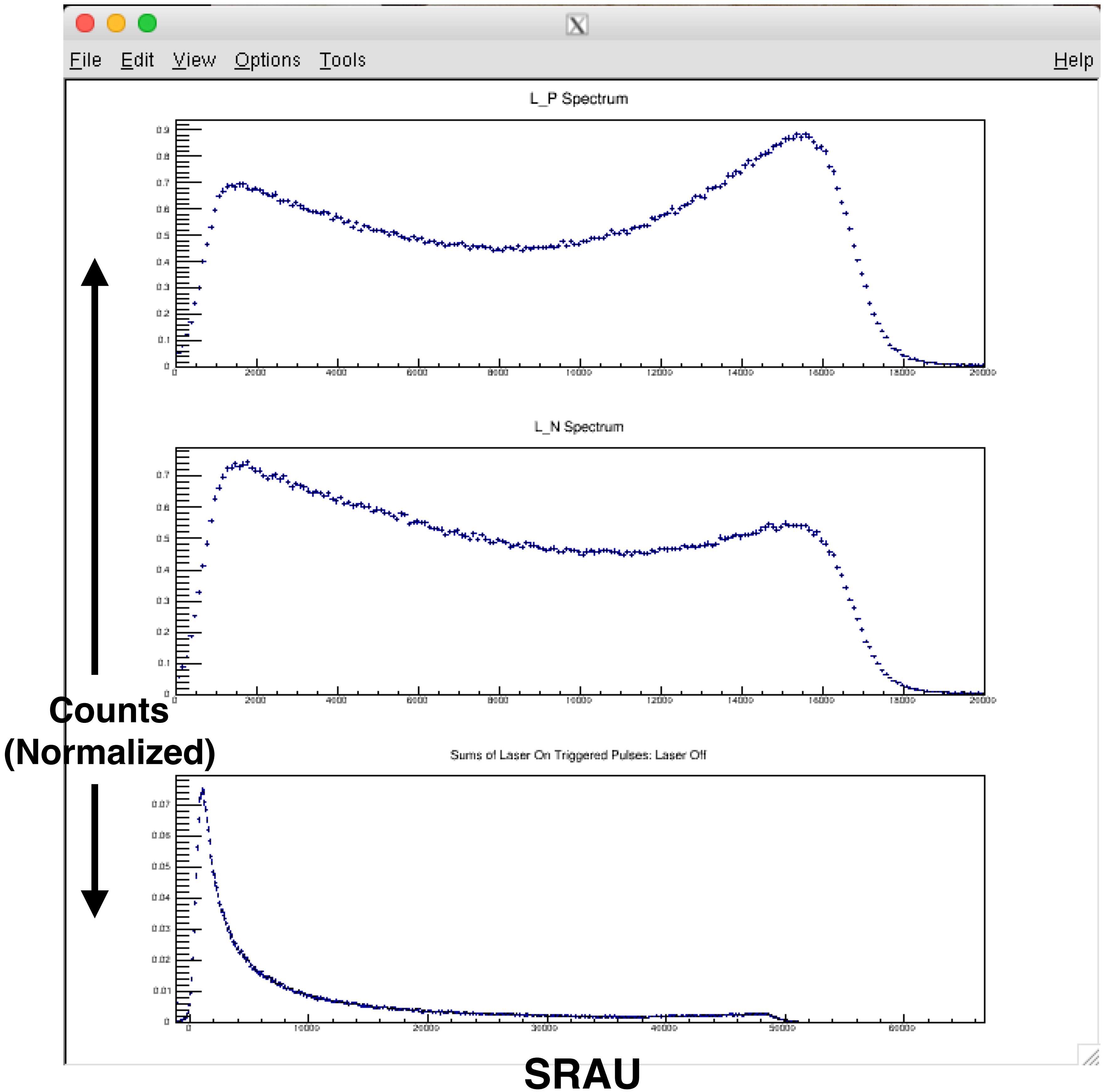
PMT signal is integrated for each event in the run. (~200,000)

Raw ADC units (RAU)



Time (1 bin = 5 ns)

Making Histograms



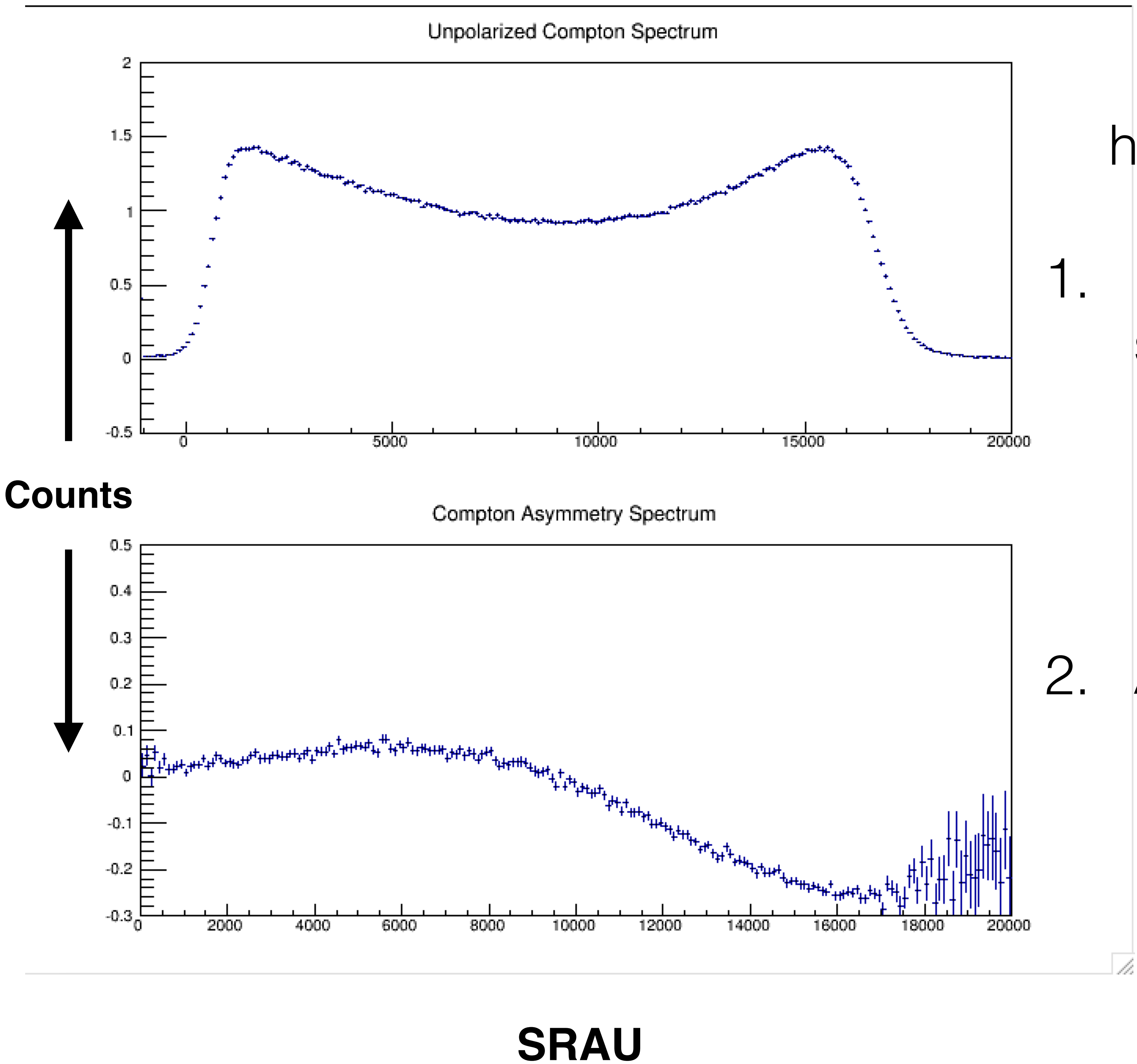
The integrated signal values then fill one of three histograms:

1. Laser **on**, beam helicity **positive** **L_P**

2. Laser **on**, beam helicity **negative** **L_N**

3. Laser **off**

More Histograms…



From the previous 3 histograms, create 2 more:

1. Unpolarized Compton spectrum

   L_P + **L_N** - 2***Off**

2. Asymmetry Spectrum

   (**L_P** - **L_N**)/
   (**L_P** + **L_N** - 2***Off**)

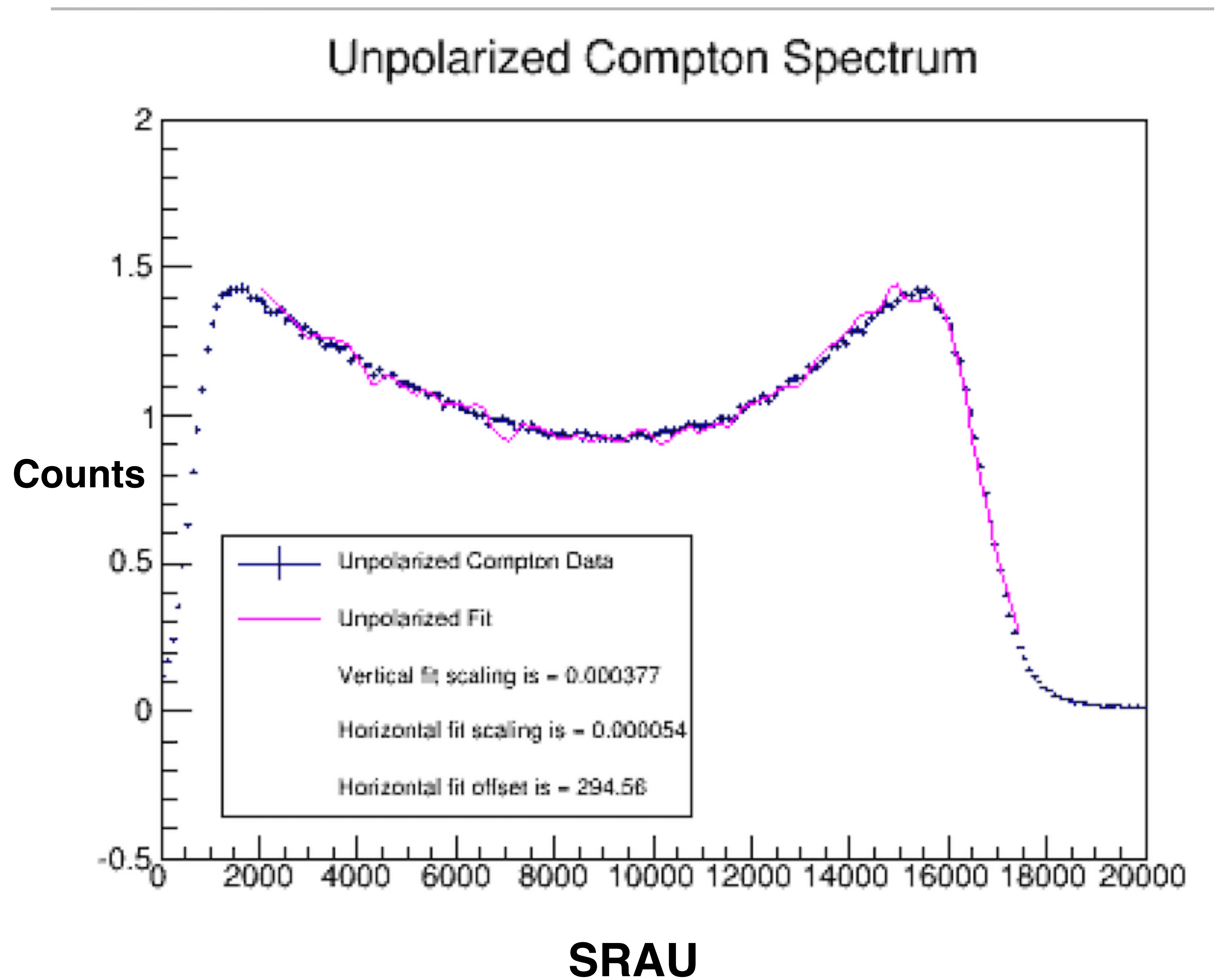
Fitting Data…

Fit the unpolarized Compton spectrum data to the Monte Carlo with 3 parameters:

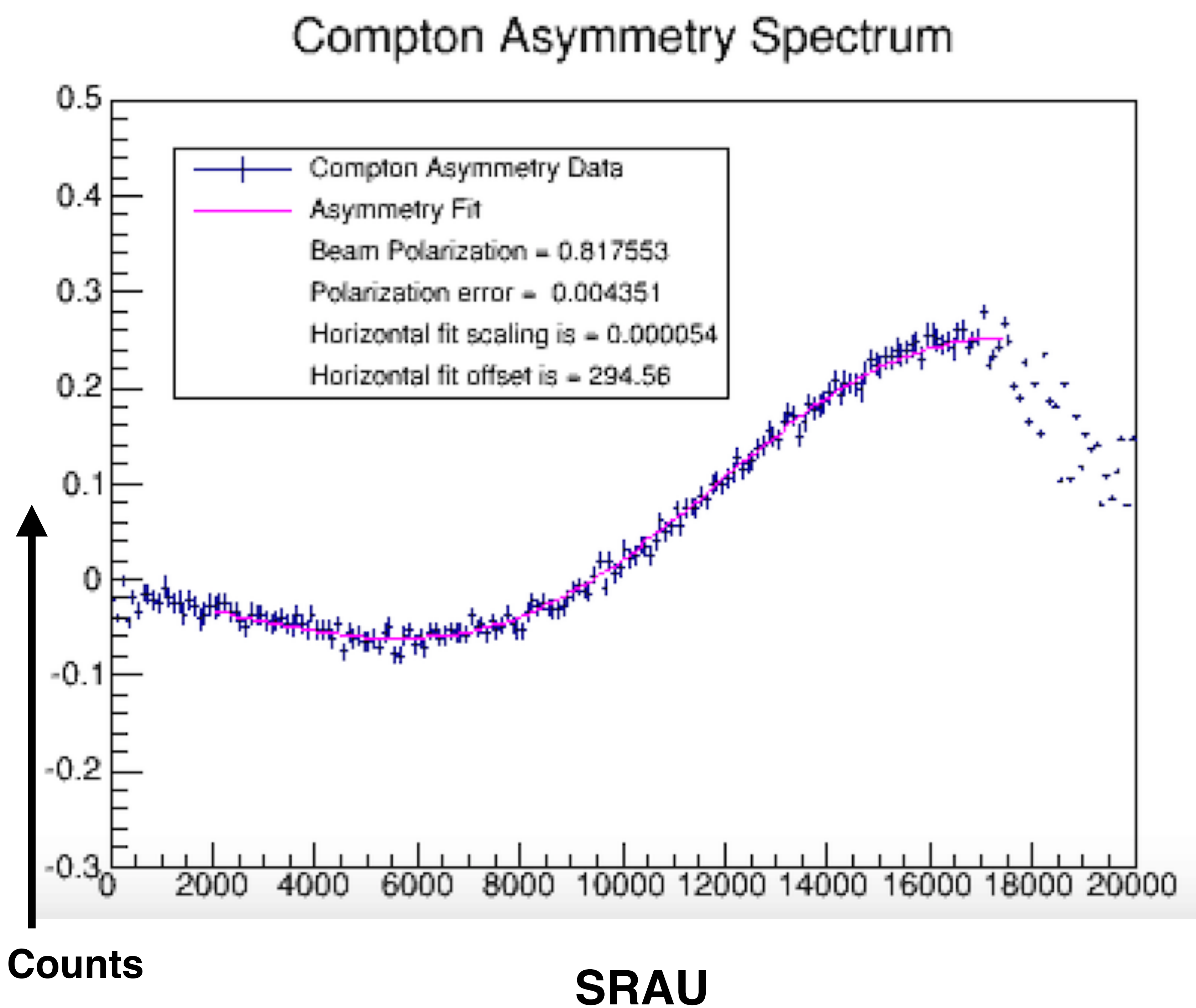
1. Vertical scaling

2. Horizontal scaling (proportional to the PMT gain)

3. Horizontal offset



Extracting Beam Polarization



Fit asymmetry spectrum to Monte Carlo, again using 3 parameters, but fixing 2:

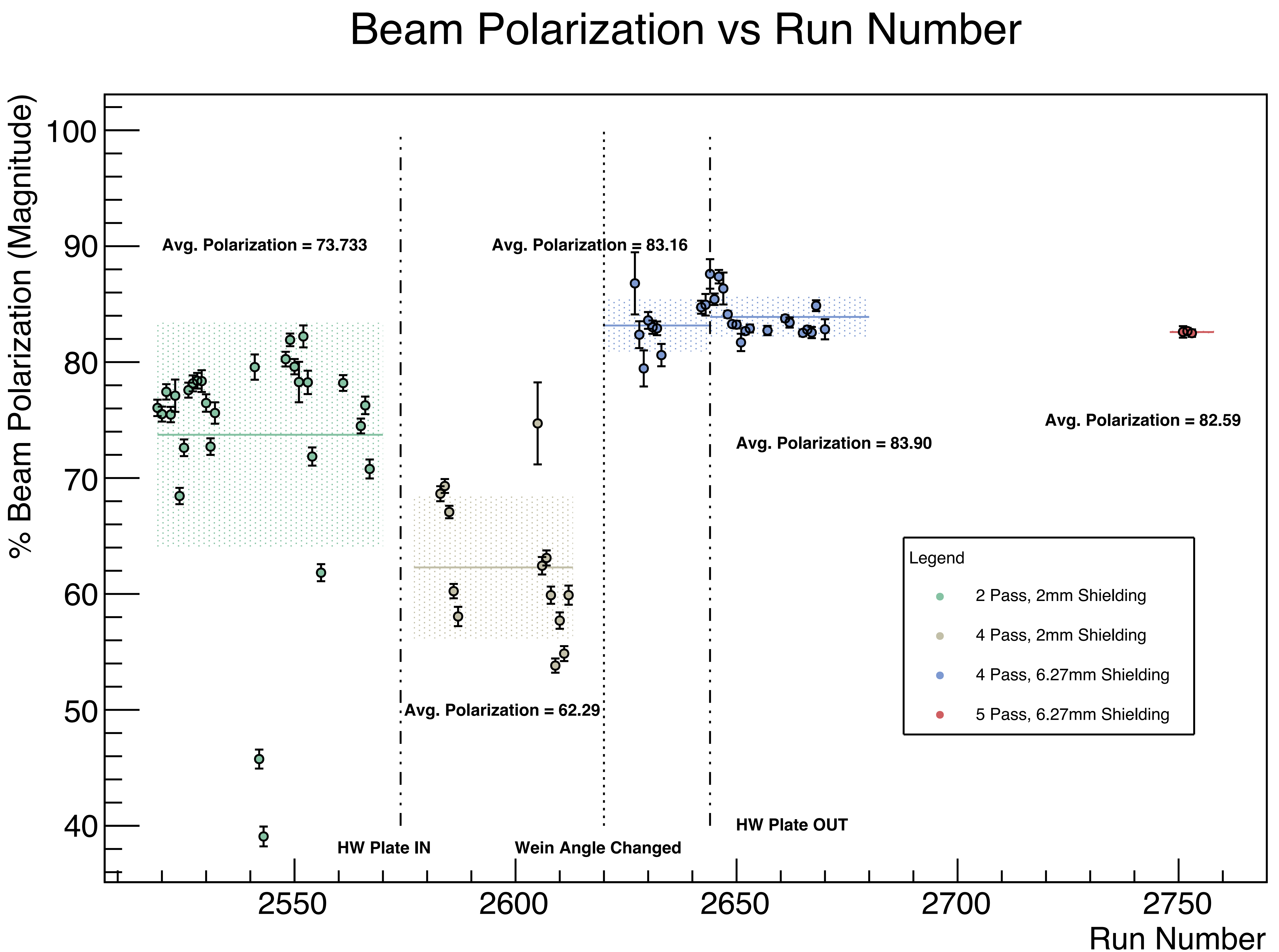
Fixed (from unpolarized fit):

1. Horizontal Scaling
2. Horizontal offset

Free:

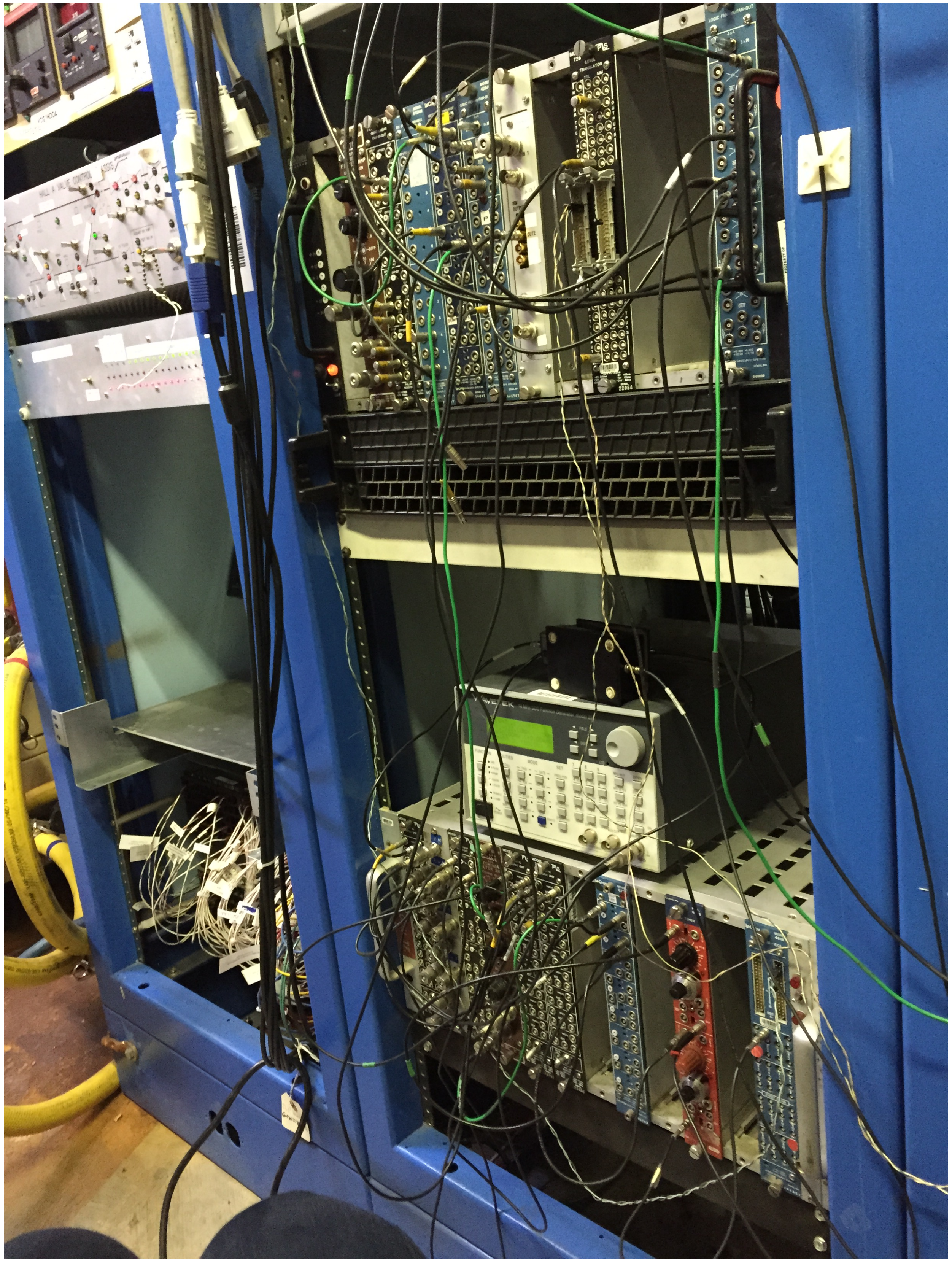
3. Vertical Scaling

Parameter 3 is just the **Beam Polarization**



Beam Polarization vs Run Number
% Beam Polarization (Magnitude)
Run Number
Avg. Polarization = 73.733
Avg. Polarization = 83.16
Avg. Polarization = 62.29
Avg. Polarization = 83.90
Avg. Polarization = 82.59
HW Plate IN
Wein Angle Changed
HW Plate OUT
Legend
2 Pass, 2mm Shielding
4 Pass, 2mm Shielding
4 Pass, 6.27mm Shielding
5 Pass, 6.27mm Shielding

Thank you!



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