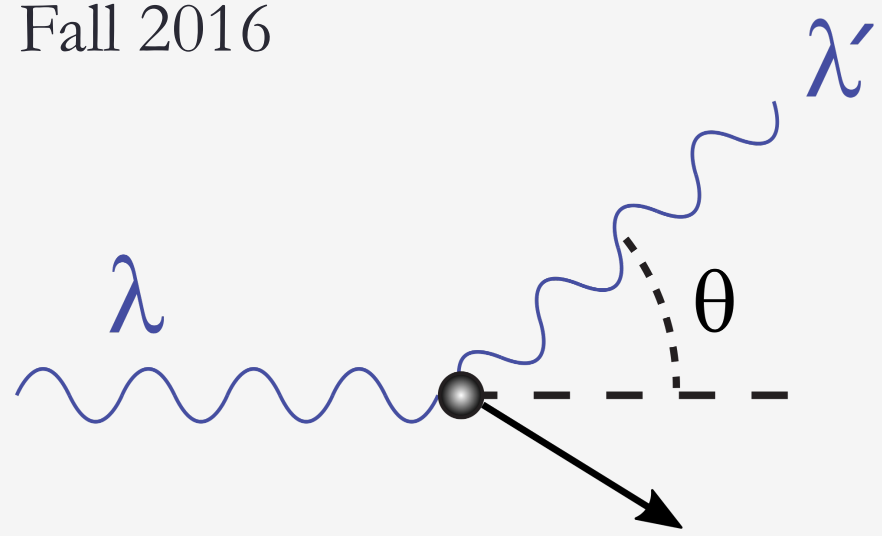
ASYMMETRIES, USING ACCUMULATORS*

*AND OTHER METHODS

Compton Polarimetry, Spring + Fall 2016



Larisa Thorne (CMU)
17 January 2017
DVCS Collaboration meeting

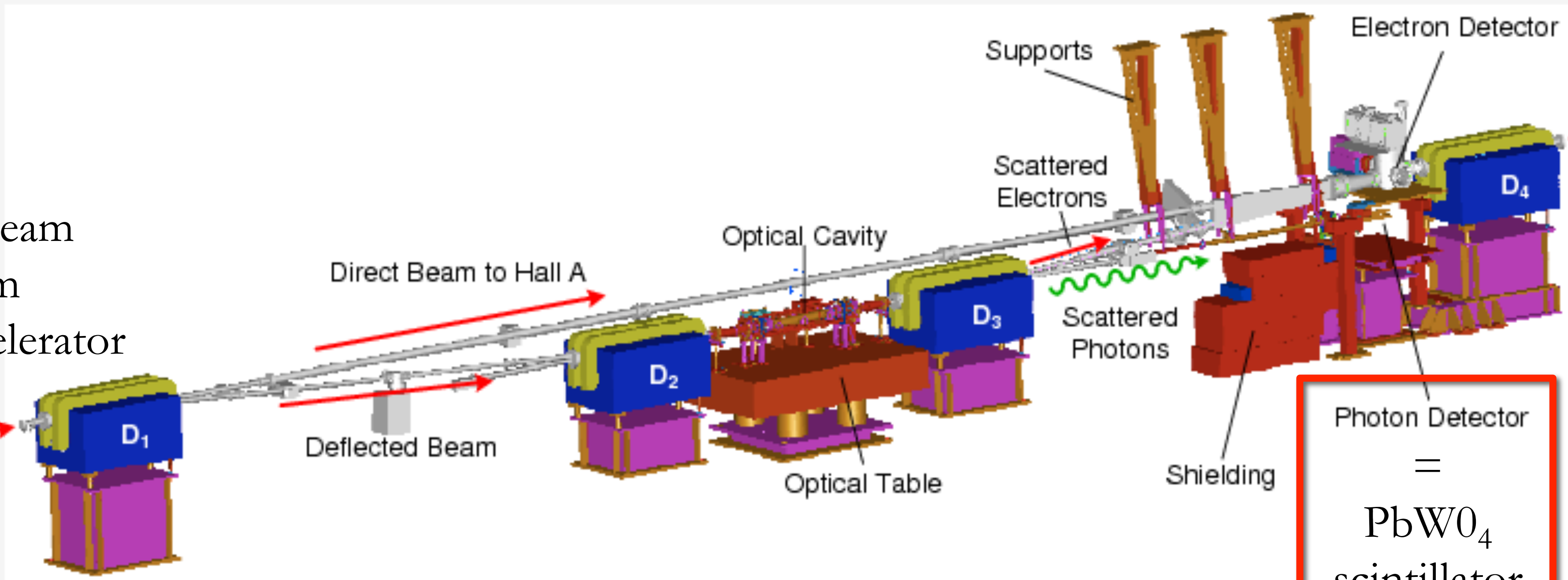
Outline

- Overview: Compton Scattering
  - Experimental setup
  - Fall 2016 upgrade
- Asymmetry via Accumulators
  - Cuts, corrections & scalings
  - Attempts to account for Acc0's behavior
- Asymmetry via Monte Carlo
- Results
  - Spring 2016
  - Fall 2016
- Conclusions

Overview: Compton Scattering

Hall A Compton chicane:

e- beam from accelerator



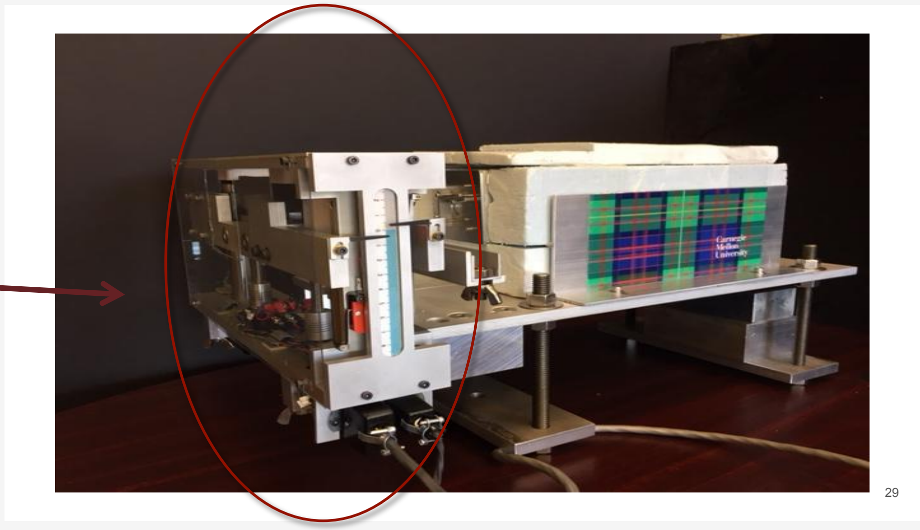
To target

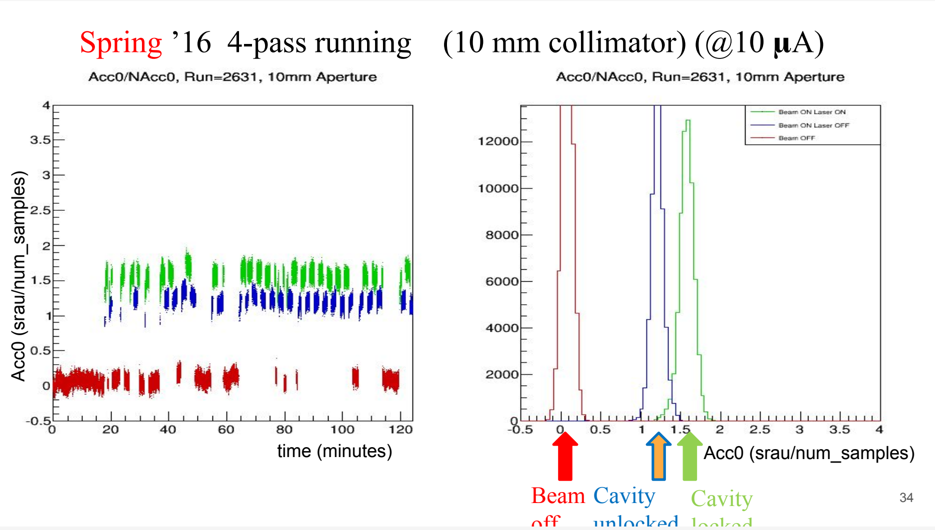
Photon Detector = $PbW0_4$ scintillator + PMT

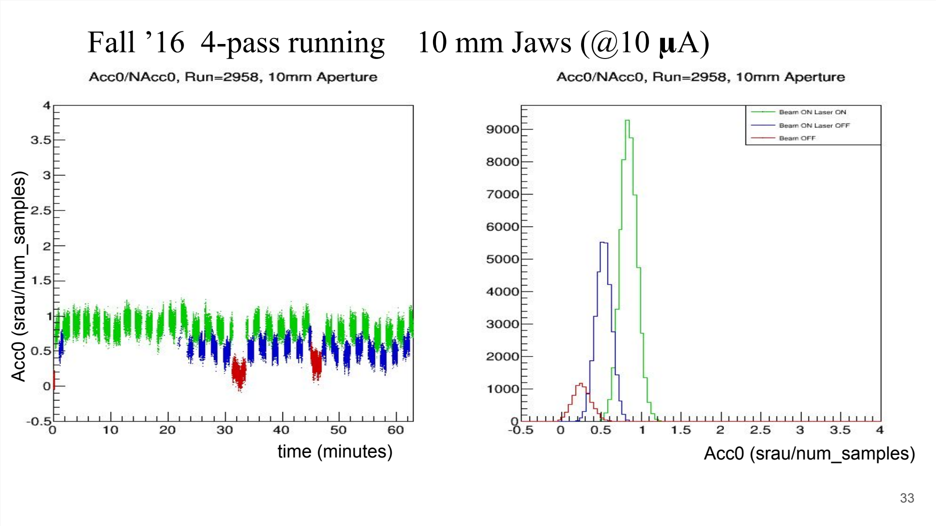
Source: http://inspirehep.net/record/1412123/files/Figures_ComptonChicaneToday1_3.png

Overview: Compton Scattering

- Fall 2016 upgrades
  - Problem: synchrotron radiation
  - Solution: remote-controlled Arduino collimator "JAWS"





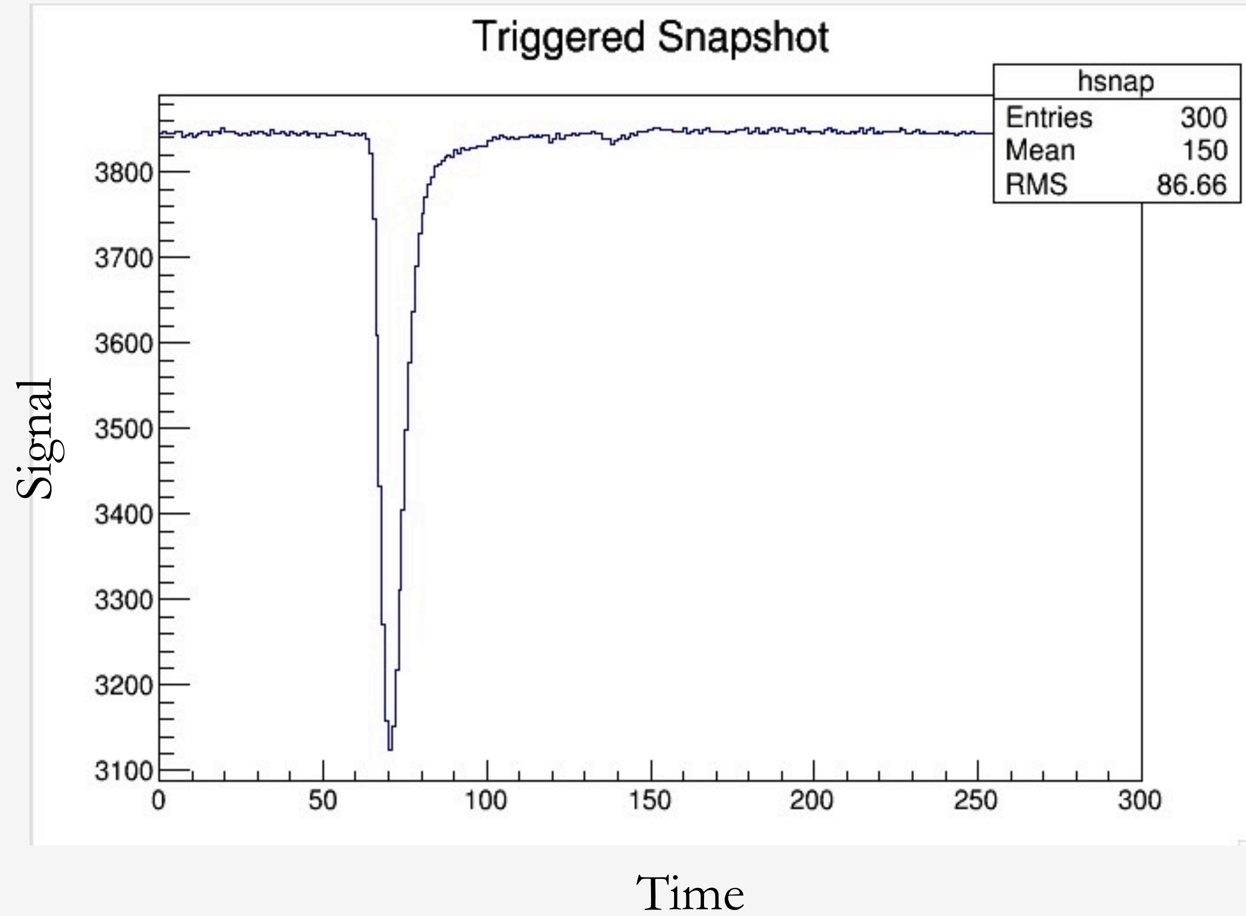


Source: Juan Carlos, High Precision Polarimetry slides (2016-11-21)

Asymmetry via Accumulators

Two accumulator types:

- Acc0
- Acc4

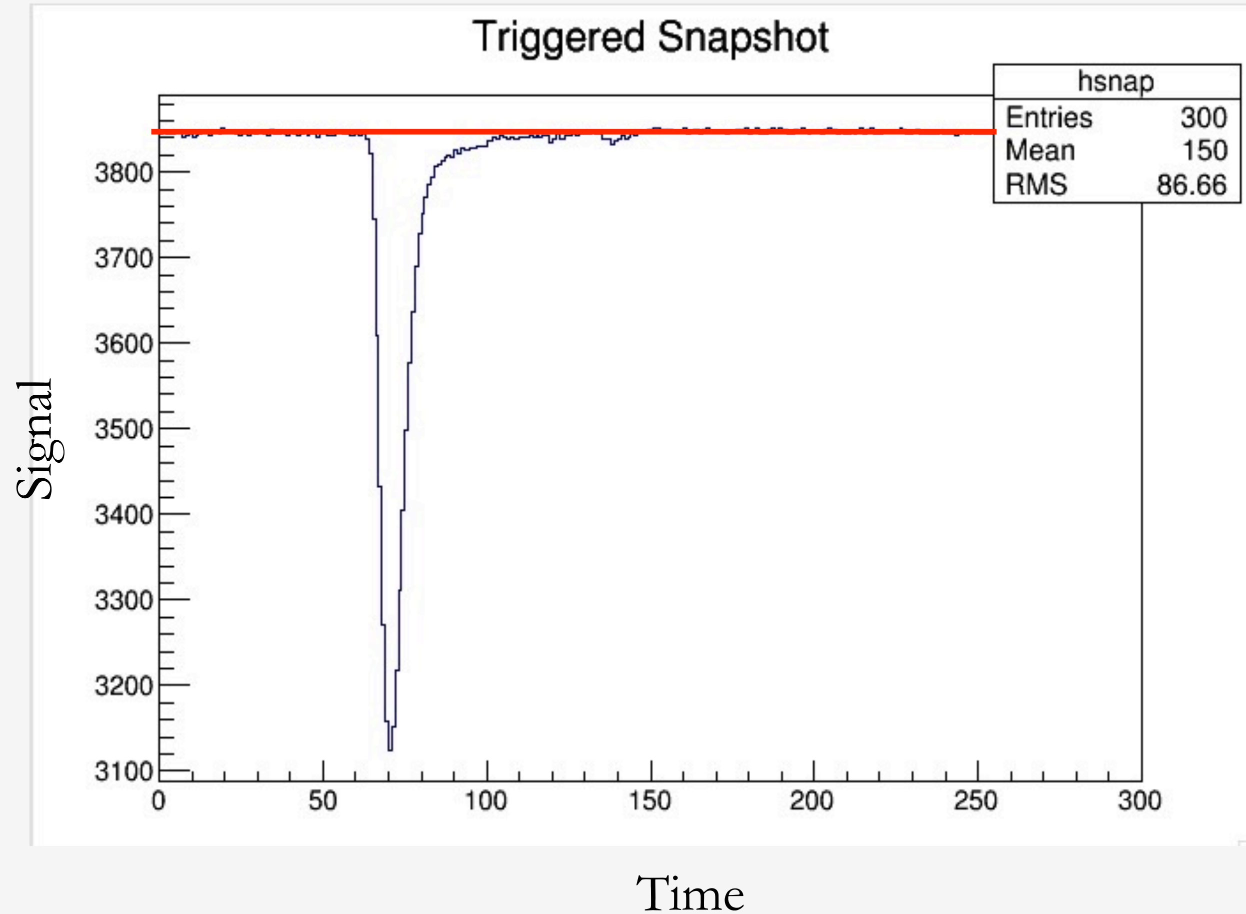


Source: Gregg Franklin (plotSnaps.C

Asymmetry via Accumulators

Two accumulator types:

- Acc0
  - No threshold
  - Sensitive to things that affect pedestal (synchrotron radiation, afterglow, etc)
- Acc4

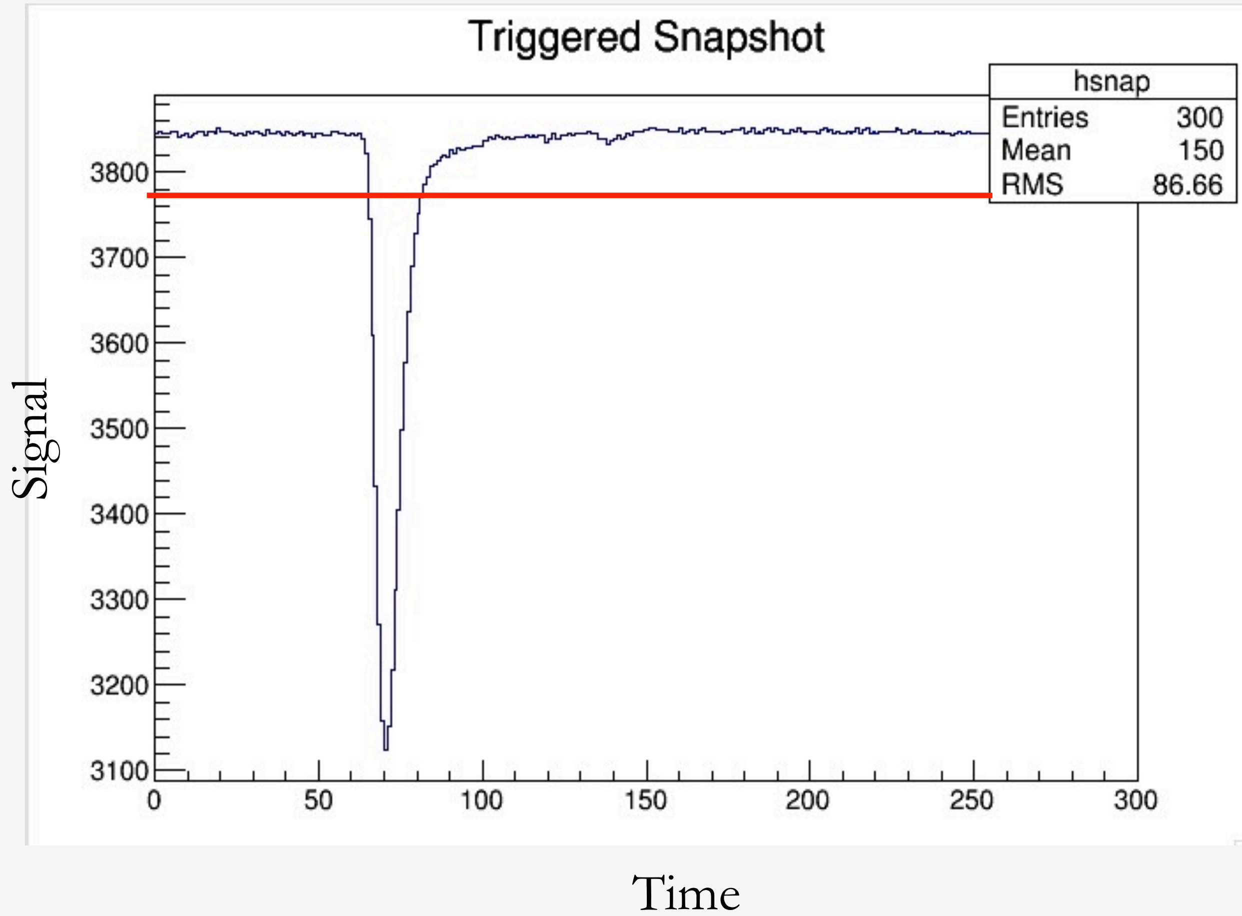


Source: Gregg Franklin (plotSnaps.C

Asymmetry via Accumulators

Two accumulator types:

- Acc0
  - No threshold
  - Sensitive to things that affect pedestal (synchrotron radiation, afterglow, etc)
- Acc4
  - Threshold value set by difference between observed pedestal and ped_value in .flags file



Source: Gregg Franklin (plotSnaps.C

Asymmetry via Accumulators

To calculate asymmetry using accumulators:

1. Sort accumulator values for unique states, by "quartet" event
   - Helicity, Accumulator, Beam, Laser
2. Fill histograms for a unique state (beam off/laser on) and (beam off/laser off)
   - h^{sum} : add both (+/-) helicity accumulator values
   - h^{diff} : add (+), subtract (-) helicity accumulator values
3. Fit with Gaussians to get at the mean, then calculate:

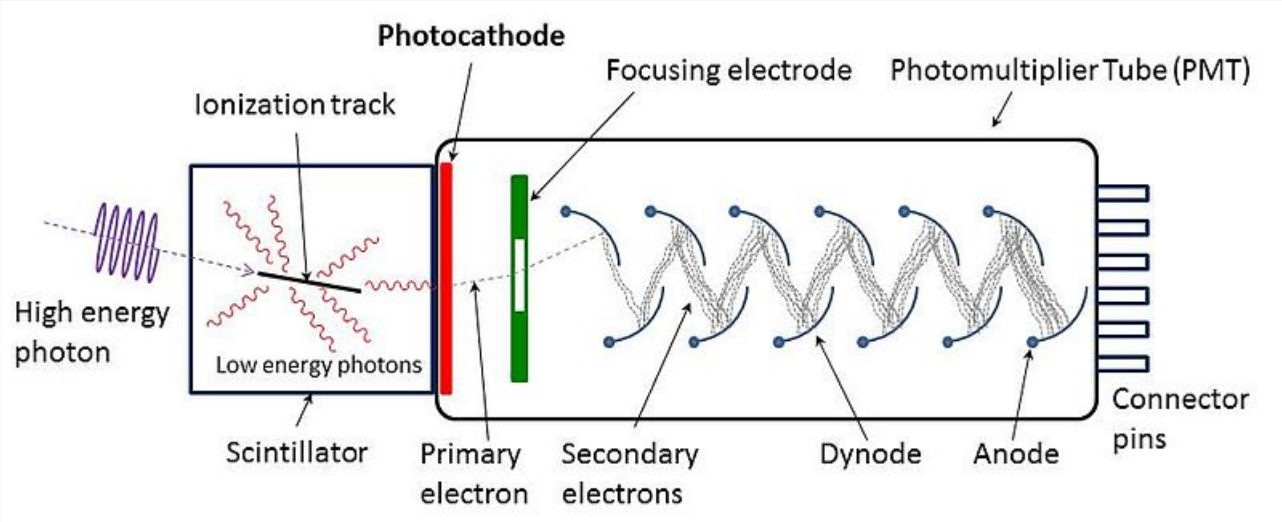
$$A_{exp} = \frac{\bar{h}_{on}^{diff} - \bar{h}_{off}^{diff}}{\bar{h}_{on}^{sum} + \bar{h}_{off}^{sum}}$$

Asymmetry via Accumulators

- Cuts:
  - Laser cavity power (min/max)
  - BCM (cuts out beam trips)
  - Epics (identifies timeouts in data stream: "old" data)
- Scaling:
  - BCM values fluctuated during run, needed to normalize relative to nominal value
- Possible sources of corrections to check:
  - Run-by-run effects due to inserting HWP, changing Wien angle, etc (accelerator physics domain)
- Afterglow

Asymmetry via Accumulators

- Afterglow (induced phosphorescence)
  - "A study on the properties of lead tungstate crystals", by Zhu et al describes methods for measuring afterglow in scintillator, depending on its construction
  - Lifetime of effect: 15 – 127 ms after irradiation

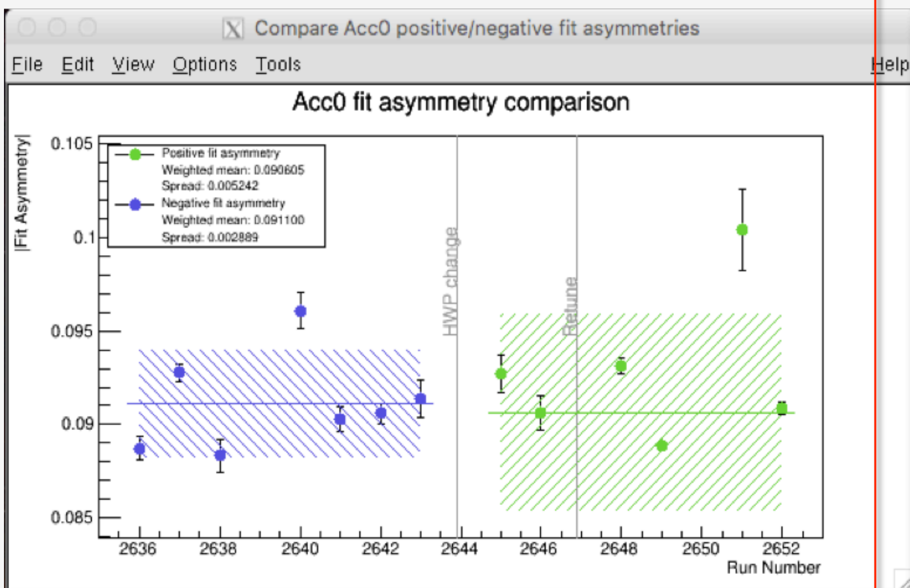


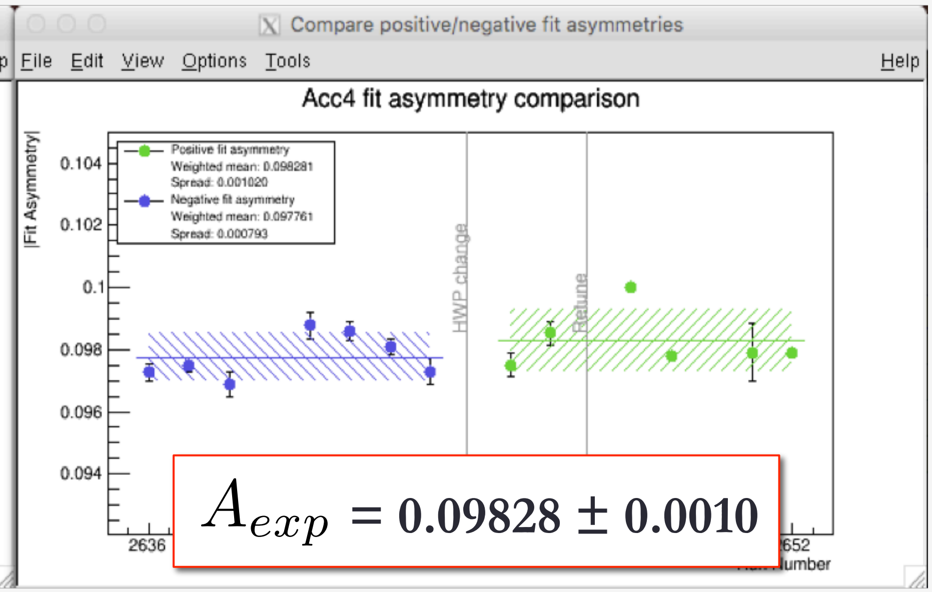
- Has "diluting" effect on Acc0 data: causes part of accumulator data near start of laser cycle to be pushed into next event
- Software testing hasn't found significant effects (yet?), even at high E

Source: https://en.wikipedia.org/wiki/Scintillation_counter#/media/File:PhotoMultiplierTubeAndScintillator.jpg)

Results (Accumulators, Spring 2016):

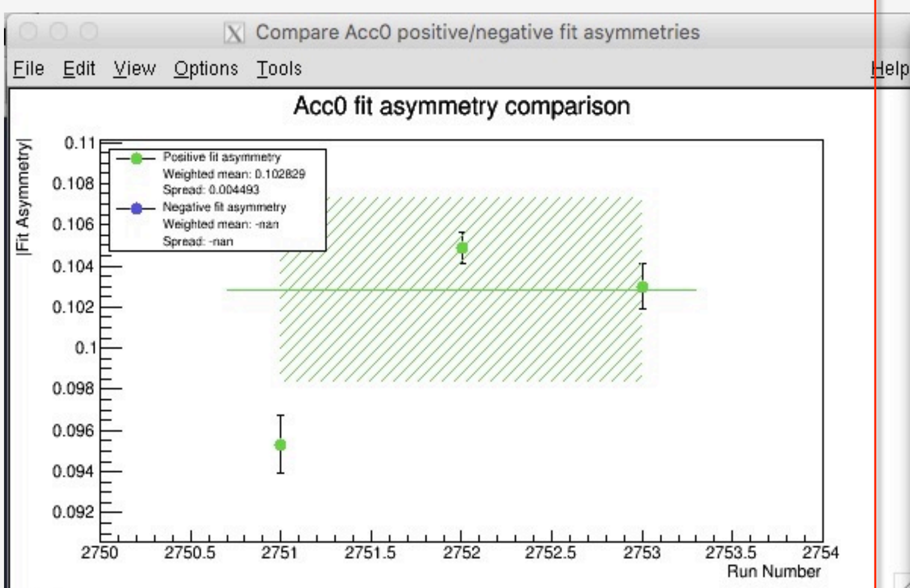
4-pass (8.8GeV)

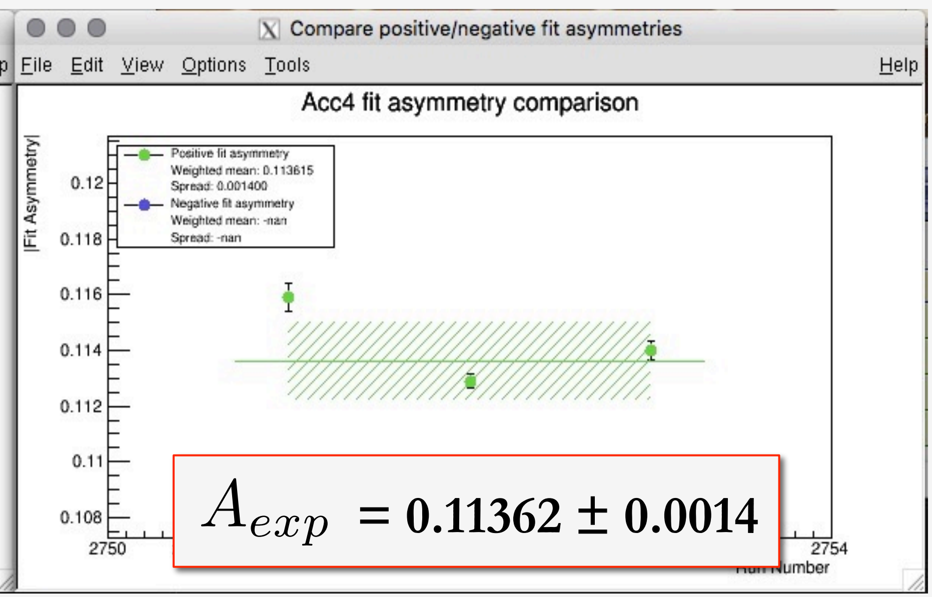




$$A_{exp} = 0.09828 \pm 0.0010$$

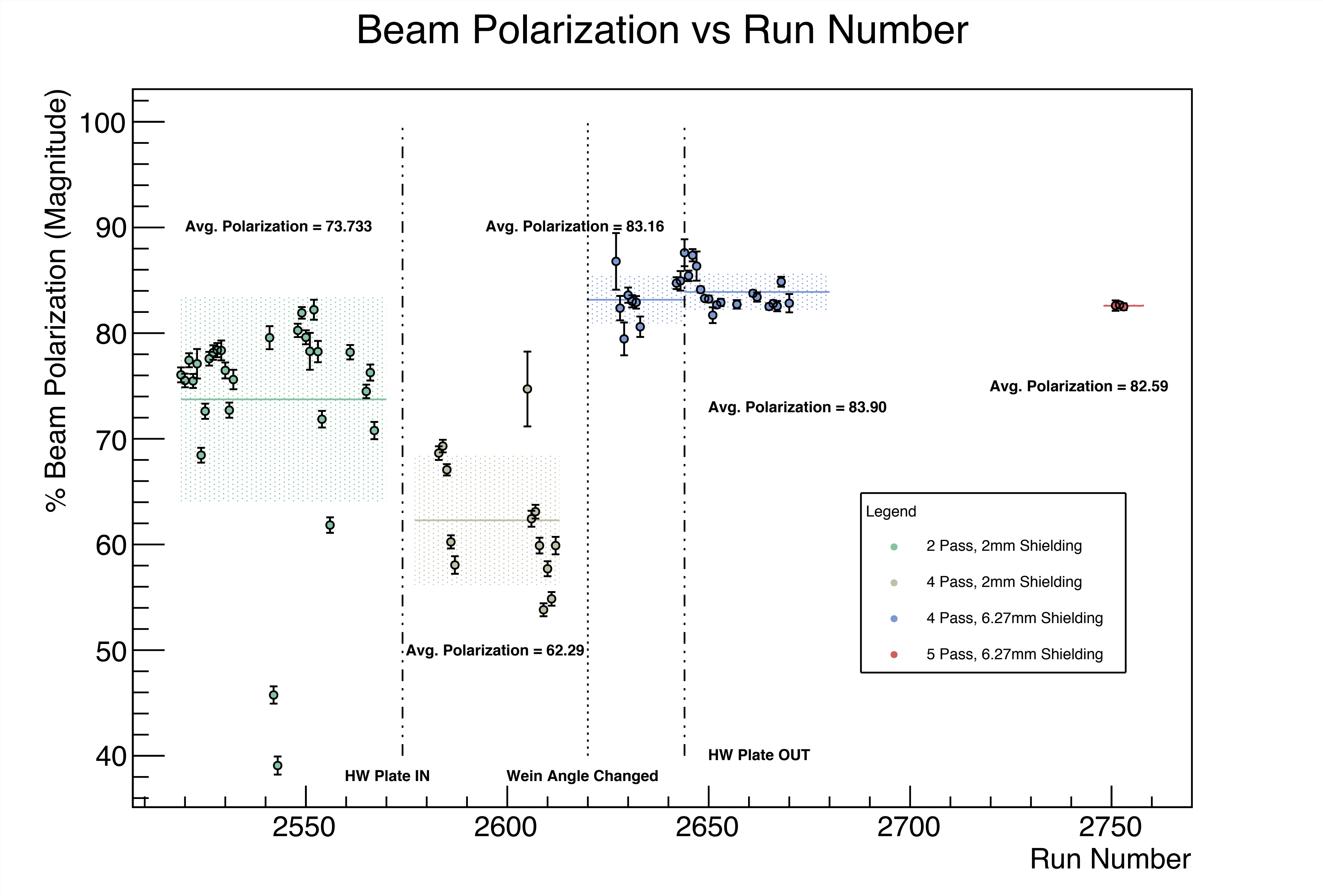
5-pass (11GeV)





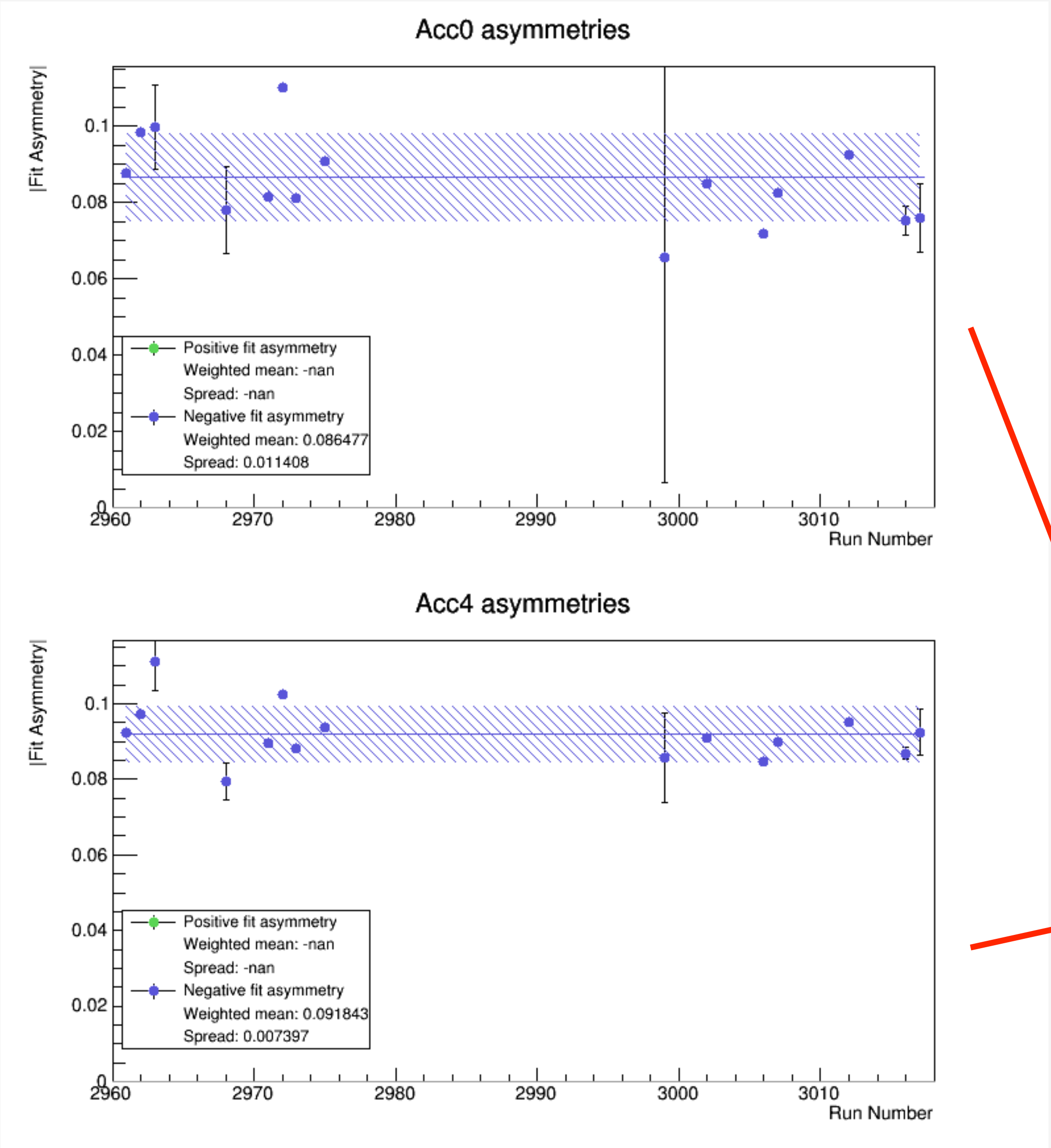
$$A_{exp} = 0.11362 \pm 0.0014$$

Results (Monte Carlo, Spring 2016):



Source: Alexa Johnson

Results (Accumulators, Fall 2016):



Conditions:

- Energy at 4-pass
- Half wave plate in
- Synch shield #5
- Collimator 2cm diameter
- Collimator 6mm aperture

A_{exp}= **0.086477 ± 0.011408**

A_{exp}= **0.091843 ± 0.007397**

Source: Larisa Thorne (https://logbooks.jlab.org/entry/3437287)

Results (Accumulators, Spring 2016):

Can use Compton Scattering asymmetries to calculate electron beam polarization:

$$P_{exp} = \frac{A_{exp}}{P_{theo} \times A_{theo}} \longrightarrow \begin{cases} \sim 85.0\% \text{ at } 8.8\text{GeV} \\ \sim 86.4\% \text{ at } 11\text{GeV} \end{cases}$$

Results (Accumulators, Fall 2016):

Using analyzing power calculated by Abel Sun:

$$P_{exp} = \frac{A_{exp}}{P_{theo} \times A_{theo}} \longrightarrow$$ ~83.1% at 8.8GeV

Compare polarizations:

	Spring 2016 4-pass	Spring 2016 5-pass	Fall 2016 4-pass
Compton: Acc4	~85.0%	~86.4%	~83.1%
Compton: Monte Carlo	~83.5%	~82.6%	-
Møller:	~87.7%	~87.3%	~87.36%

Møller Spring 2016 4-pass source: https://logbooks.jlab.org/entry/3386402 (March 1)

Møller Spring 2016 5-pass source: https://logbooks.jlab.org/entry/3393948 (March 31)

Møller Fall 2016 4-pass source: https://logbooks.jlab.org/entry/3434629 (Oct 31)

Conclusions:

- Acc4 and MC polarizations steady, but lower than Moller
- Applied various techniques in attempt to more closely match Compton and Moller
  - Accumulator: improved data clean up/selection, add synch shields
  - MC: add smearing, optimize resolution
  - Close but still not same
- Characterize non-linearity of PMT
- Isolate effects causing lower asymmetry in Acc0
  - Afterglow in crystal with long decay time
  - PMT dark current
  - Amplifier-zero shift, fADC pedestal shift

  } Bench tests show no evidence
  - Helicity bit pickup: managed via manual signal delay (~small)
  - Laser lock pickup: could affect background subtraction
  - More analysis/testing at CMU needed

Acknowledgements

- Thanks to:
  - Hall A Compton team (Dave Gaskell)
  - CMU (Gregg Franklin, Alexa Johnson, Juan Carlos Cornejo, Brian Quinn, Abel Sun)

Backup slides

Histogram Pedestals

- Care about pedestals when constructing sum/diff histograms:

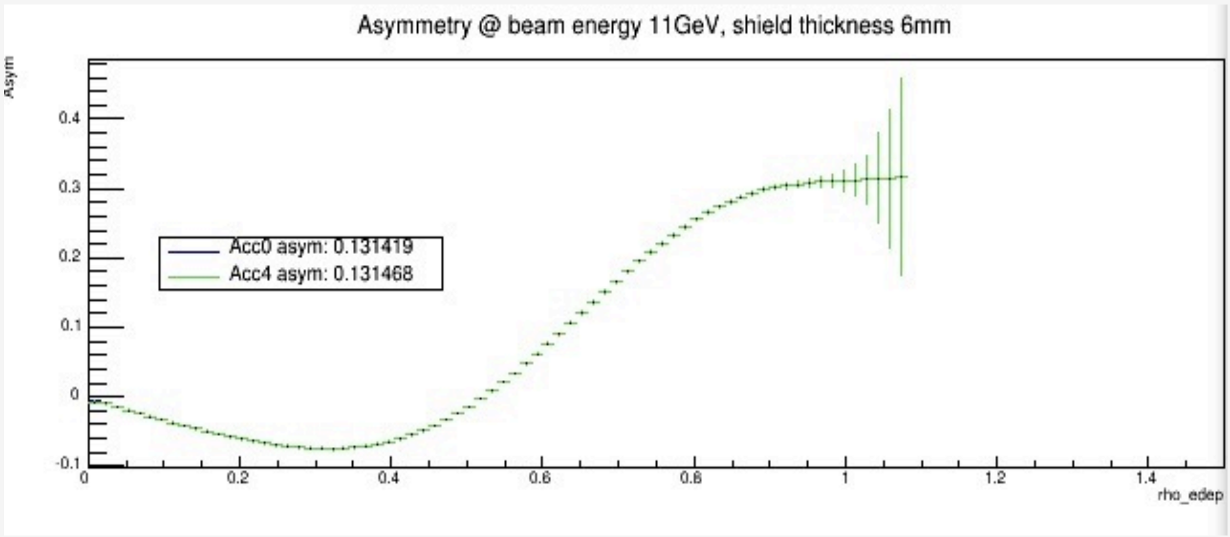
```
acc0Sum = PosHelAcc[0] + NegHelAcc[0] + beamOffZero0;
acc0Diff = PosHelAcc[0] - NegHelAcc[0];

Double_t pedestal = beamOffZero0 / (PosHelNSamples0 + NegHelNSamples0);
Double_t posContrib = PosHelAcc[4] + pedestal * PosHelNSamples4;
Double_t negContrib = NegHelAcc[4] + pedestal * NegHelNSamples4;
acc4Sum = posContrib + negContrib;
acc4Diff = posContrib - negContrib;
```

Source: Larisa Thorne (buildQuartets.C)

Asymmetry via Accumulators

- Use Monte Carlo to simulation of "ideal" asymmetry , A_{theo}
- A_{theo} == "analyzing power"
- Uses GEANT4 to simulate high energy photons impinging on Compton photodetector ($PbWO_4$ scintillator + PMT)
- Energy, geometry, accumulator cutoff dependent



Source: Larisa Thorne http://albert.phys.cmu.edu:8080/Thorne/170

Afterglow

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 376 (1996) 319–334

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

A study on the properties of lead tungstate crystals

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Abstract

This report summarizes the results of a study on the properties of five large and five small size lead tungstate ($PbWO_4$) crystals. Data are presented on the longitudinal optical transmittance and light attenuation length, light yield and response uniformity, emission spectra and decay time. The radiation resistance of large crystals and possible curing with optical bleaching are discussed. The result of an in depth materials study, including trace impurities analysis, are also presented. The general conclusion from this investigation is that further research and development is needed to develop fast, radiation-hard $PbWO_4$ crystals for the CMS experiment at the CERN LHC.

Systematic uncertainties

- Constraints on systematic uncertainties, thus far:

Noise source:	Effect: [%]
Thermal stability	< 0.2%
PMT non-linearity	~ 0.1%