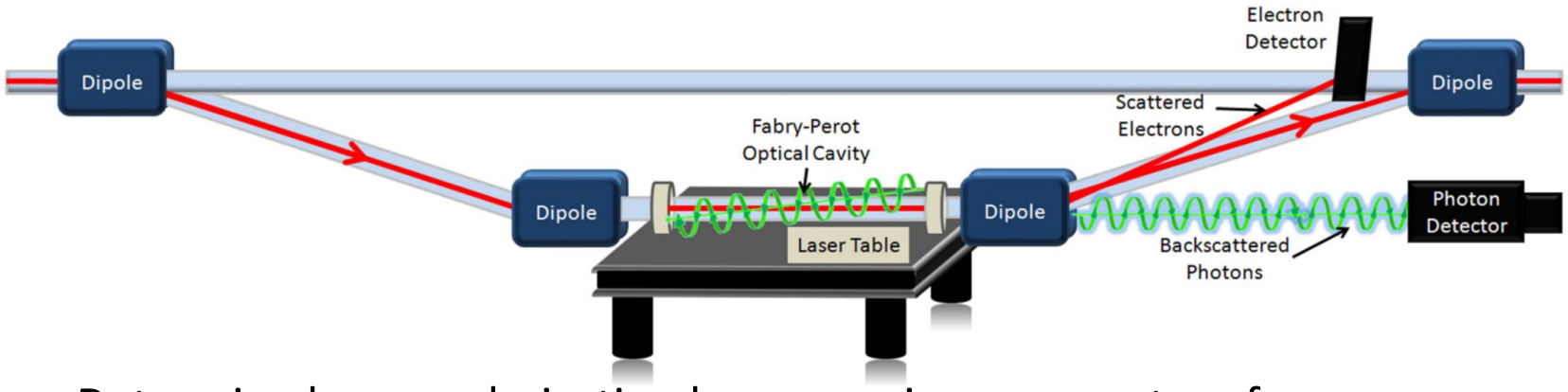
Compton Update for DVCS

Juan Carlos Cornejo

DVCS Collaboration Meeting

January 26, 2018

Overview of 6 GeV Era Hall A Compton Polarimeter

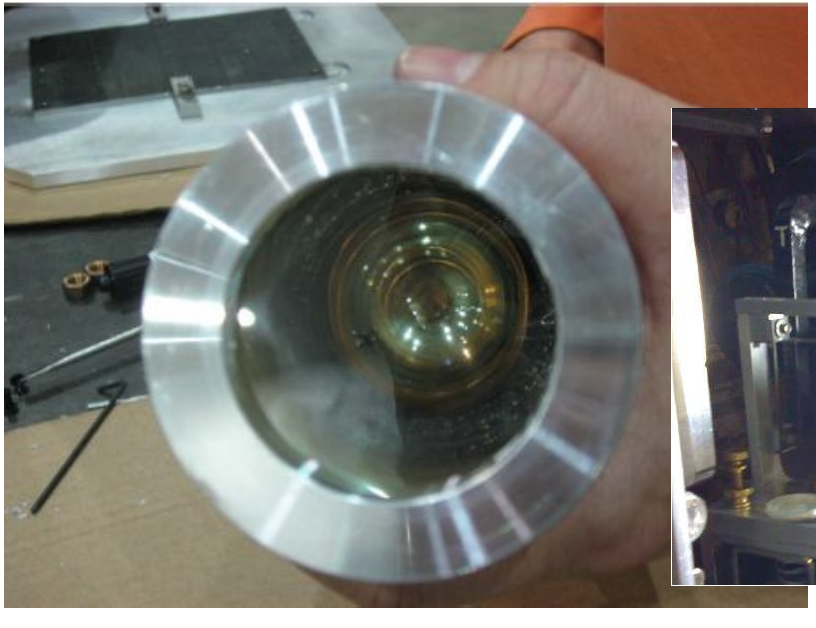


- Determine beam polarization by measuring asymmetry of $e + \gamma \rightarrow e + \gamma$
- Laser system: 1 W green drive laser coupled to a high gain Fabry-Perot cavity → several kW intracavity power.
- Photon Detectors: GSO ("low energy"), $PbWO_4$ ("high energy")
- Electron detector: silicon strip detector (evaluating other options for future)
- DAQ: integrating mode for γ-detector (restored by CMU/Gregg)
  - Under development: new counting mode DAQ for γ-detector + new electron detector DAQ (VETROC). Evaluating new integrating γ-detector DAQ options.

Compton Photon Detector 6 GeV Era

Single GSO crystal manufactured by Hitachi Chemical

- 0.5% Ce-doped Gd_2SiO_5
- 6 cm diameter x 15 cm length
- X_o~ 1.4 cm



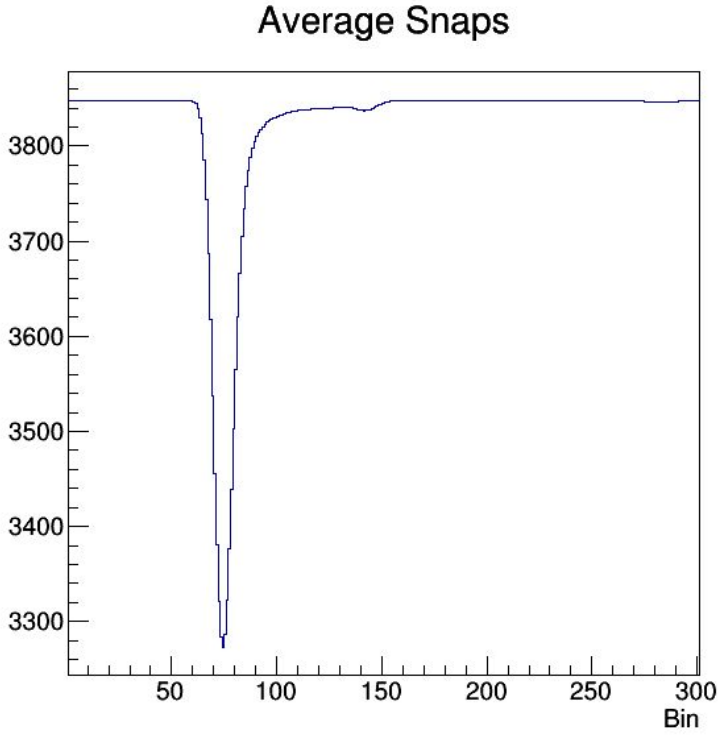
Flash ADC integrating DAQ:

- Customized Struck SIS3320 FADC @ 200 MHz
- No threshold (Accumulator 0) → Dead-timeless
- 1 Primary Data word for each helicity period (Ex: 1/30 second)

- Additional accumulators
  - Accumulator 4 (with threshold)→ "stretched-window"
- Auxiliary diagnostic data taken simultaneously.

A Bit About Accumulators

- The fADC samples at 200 MHz
  - 1 sample (bin) every 4 ns
- During one helicity flip
  - @ 30Hz ⟶ ~30 ms window
- So per helicity the fADC will have ~7 million samples
- We cannot possibly readout that many samples fast enough
- So instead we read out the integral
  - Struck fADC does this integral internally
  - Has several integrating methods
- We also write few “snapshots” (300 samples) for systematic studies



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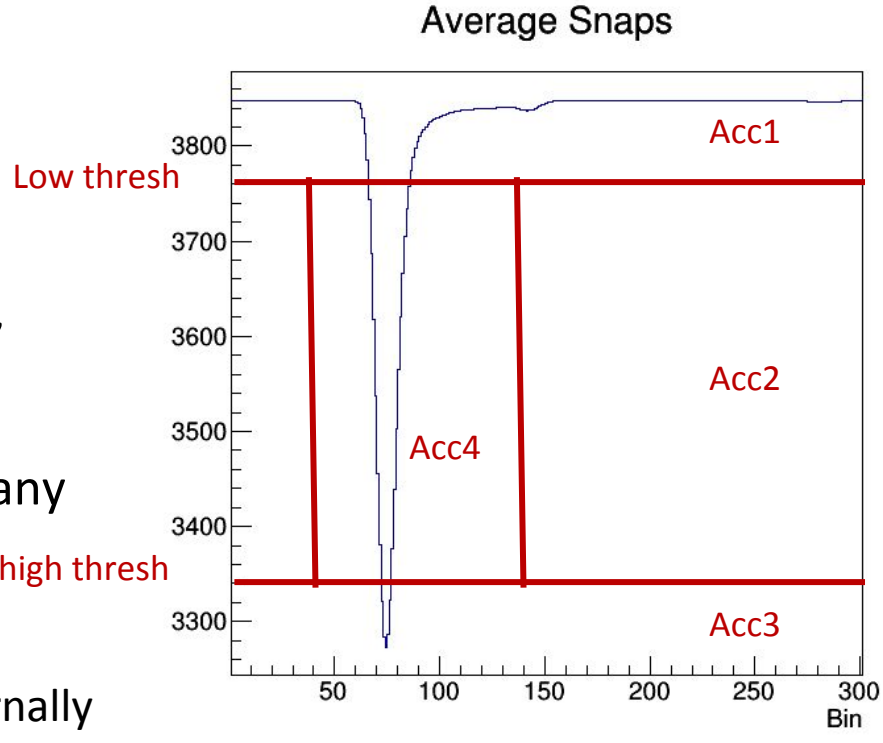


Acc0 has no threshold

Thresholds are to get rid of synchrotron and high energy backgrounds.

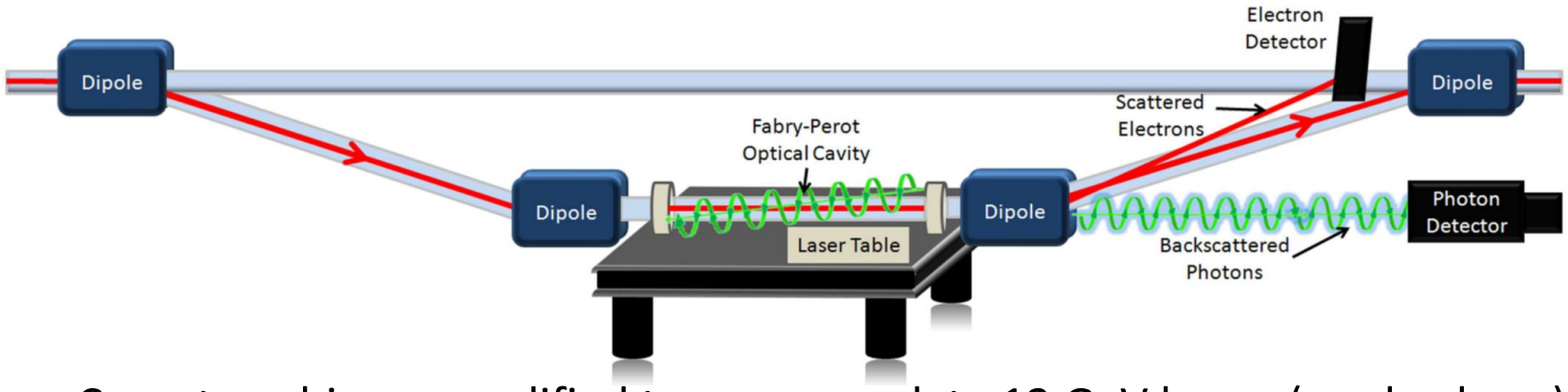
In the Past: Acc0 Prefered Method

- Working without threshold reduces systematics
- Do not need to worry about pedestal

$$A_{msr} = \frac{(S_p - P \cdot N_p) - (S_n - P \cdot N_n)}{(S_p - P \cdot N_p) + (S_n - P \cdot N_n)}$$

- Where ‘S’ is the integral of an accumulator for plus/minus helicities respectively.
- P is the pedestal, and N is the number of samples
- For Acc0 $N_p = N_n \longrightarrow$ pedestal cancels out
- For the other accumulators, we would need to precisely measure the pedestal because it does not drop out.
    - Additionally, we’d have to understand and monitor thresholds.

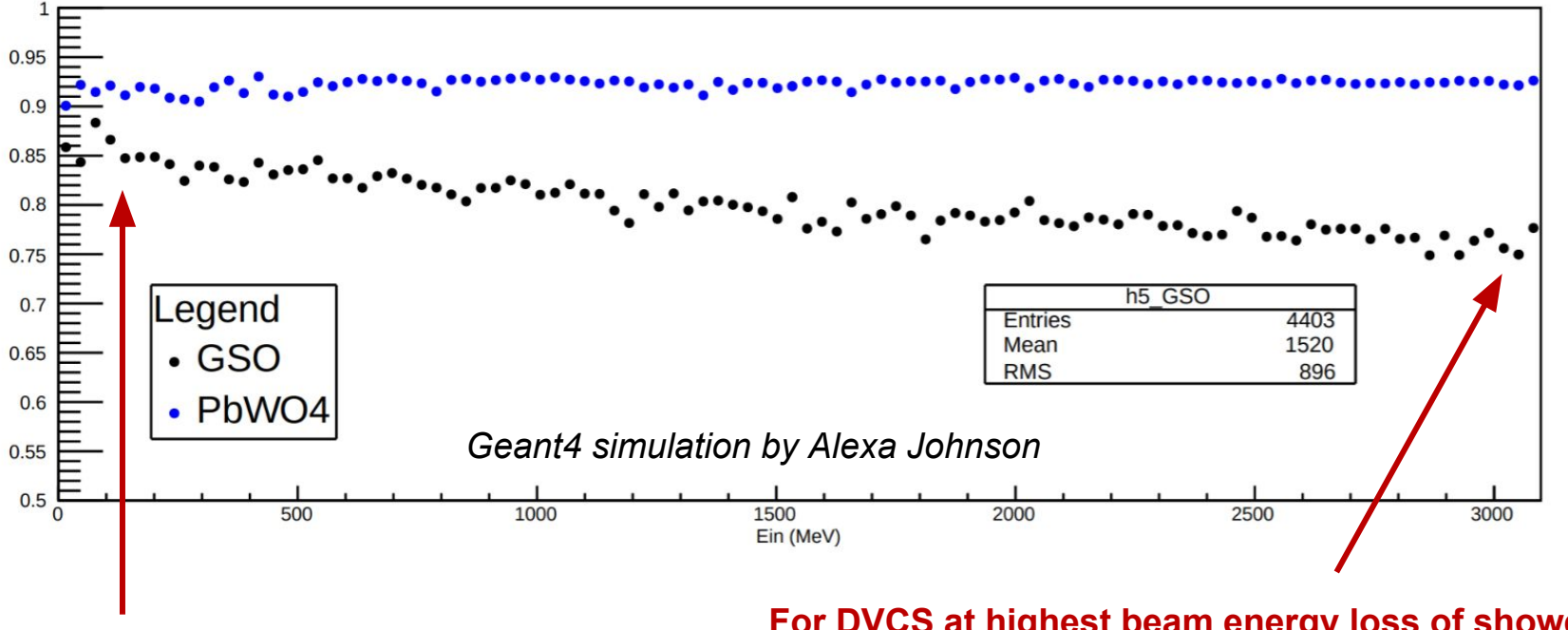
Compton Polarimeter During DVCS-III (12 GeV Era)



- Compton chicane modified to accommodate 12 GeV beam (see backups)
- Photon Detectors
  - **$PbWO_4$** was used to span full range of DVCS beam energies (up to 12 GeV)
- Electron detector:
  - Not used for production running
- DAQ:
  - integrating mode for γ-detector (restored by CMU/Gregg)

Why Did We Use PbWO4 Instead of GSO?

- GSO has large radiation length (~1.4 cm)
- PbWO4 much denser so radiation length is ~0.9 cm



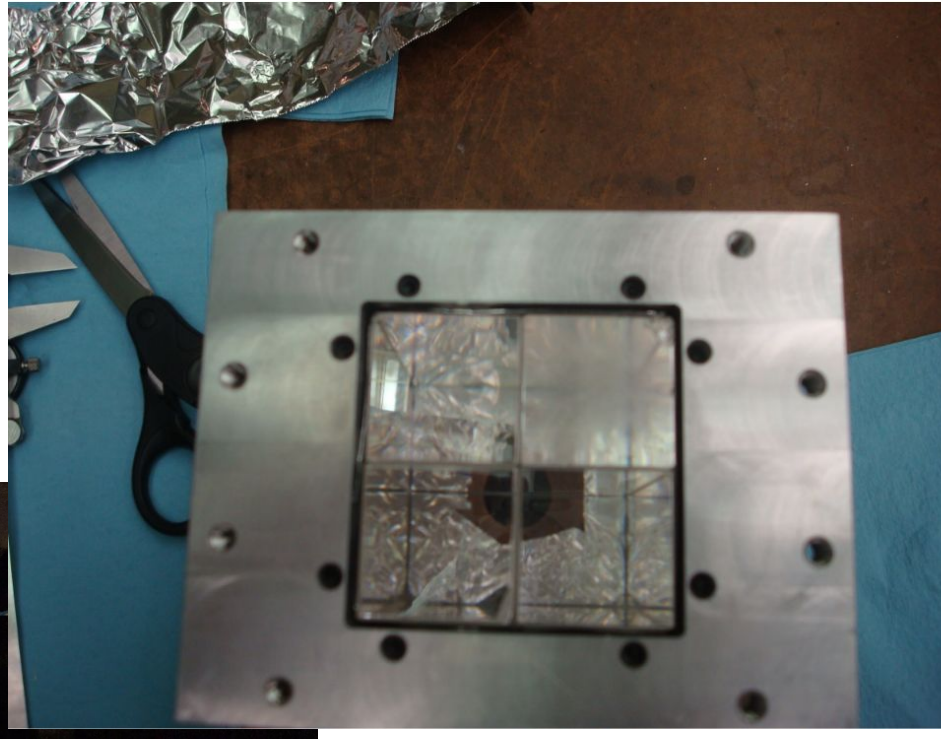
Last experiment (HAPPEx-III)

For DVCS at highest beam energy loss of shower would have been > 20% !!!

Compton Photon Detector for “High Energy” Experiments

Need denser material to contain shower of ~3 GeV photon → $PbWO_4$ (2x2 stack)

- 6x6 cm x 20 cm length (total)
- On loan from Yerevan/Hall C
- Suitable for > 6 GeV beam
- Light output changes ~2%/℃
  - Wrapped in styrofoam

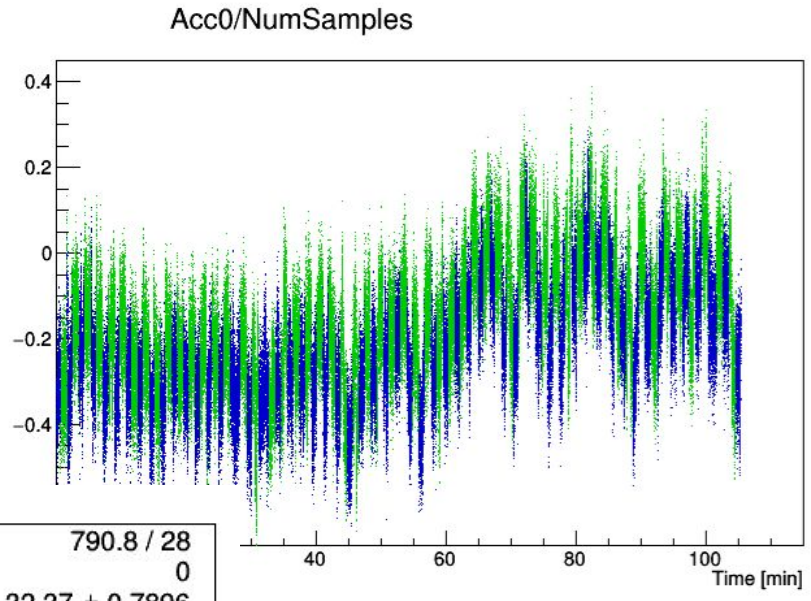


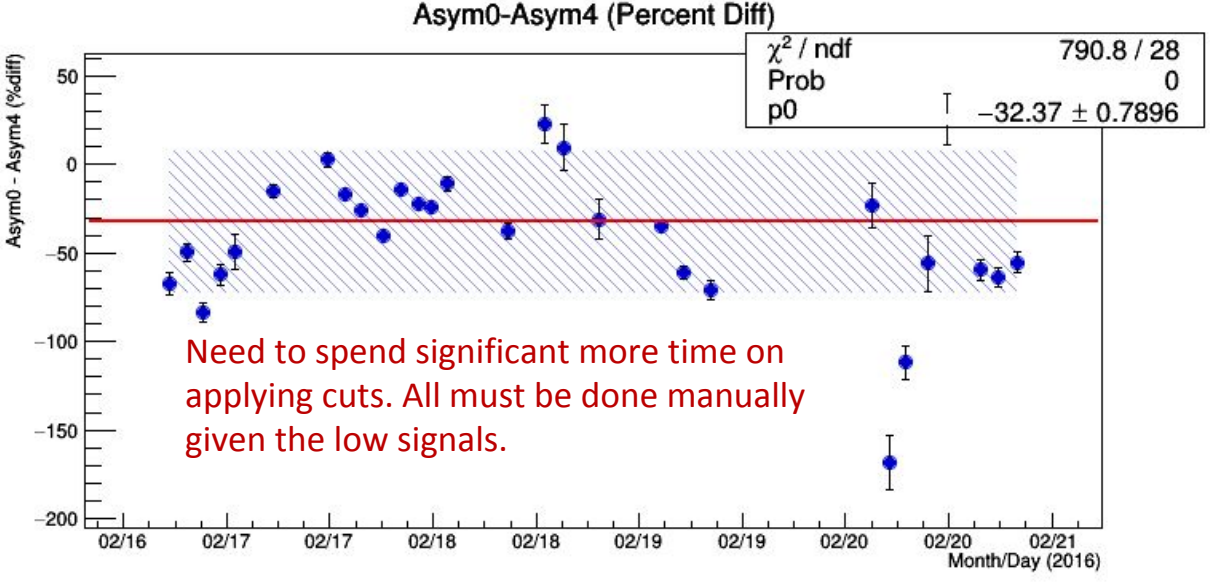
Summary of Spring 2016 Production Running

- Saw **significant** synchrotron radiation
  - Trouble centering beam on Photon Detector → used larger aperture collimator
  - Unexpected discrepancy between "accumulators"
  - Lots of system trouble (laser, DAQ, etc…)
- Pass 2 Data (E_{beam} = 4.4 GeV) Feb 16-23
  - 28 "good runs" (~2 hours each). 7 runs possibly recoverable
  - Accumulator data has not been fully analyzed
- Pass 4 Data (E_{beam} = 8.8 GeV) March 1 - March 7
  - 43 runs → still building "good" set
  - Scaler readout in DAQ went bad, so this set of data requires lots of manual parsing through data to select good cuts.
- Pass 5 Data (E_{beam} ~ 12 GeV) March 8
  - **3 runs** (1 suspect, but very likely recoverable)
- Laser died after these three runs. No more data for spring.

Spring 2016 Pass 2 Overview

- Low energy means low signal to noise
  - Must be very careful when subtracting background
- Large Acc0 - Acc4 discrepancy
  - Possibly helicity pickup or other effect

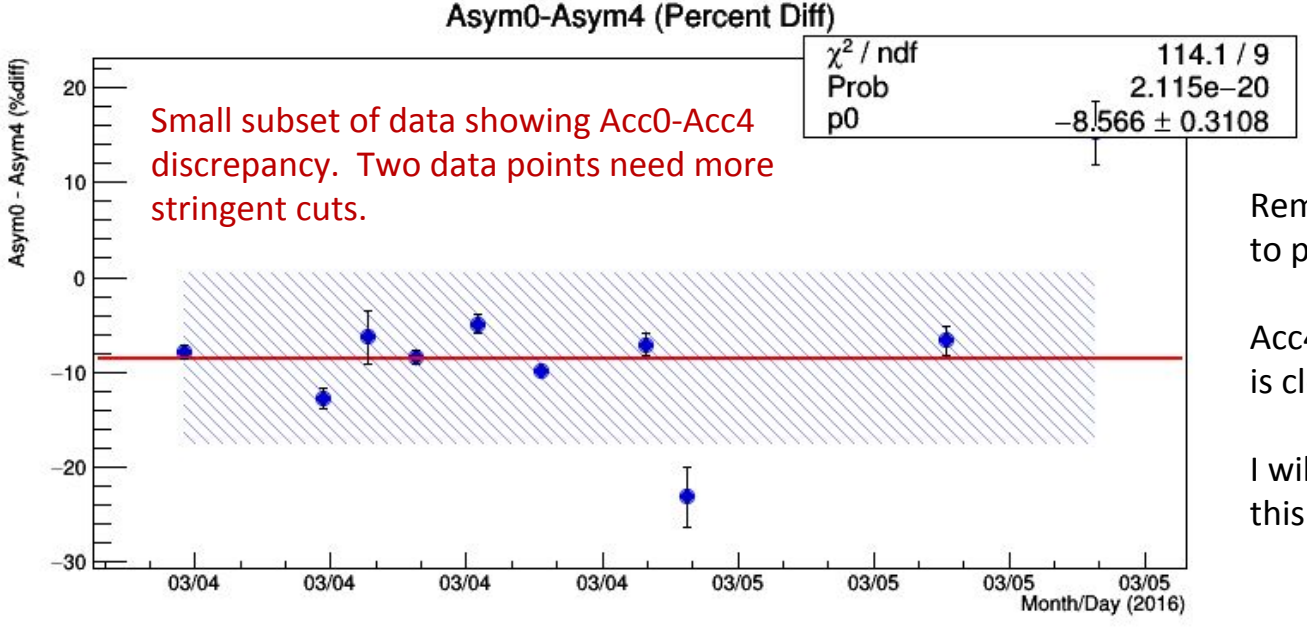




Need to spend significant more time on applying cuts. All must be done manually given the low signals.

Spring 2016 Pass 4 Overview

- Still needs to be parsed through same level as Fall data
  - Acc0-Acc4 not as large as Pass 2
- Lots of bench and dedicated analysis has been performed on this data to identify discrepancy → nothing so far has explained it.



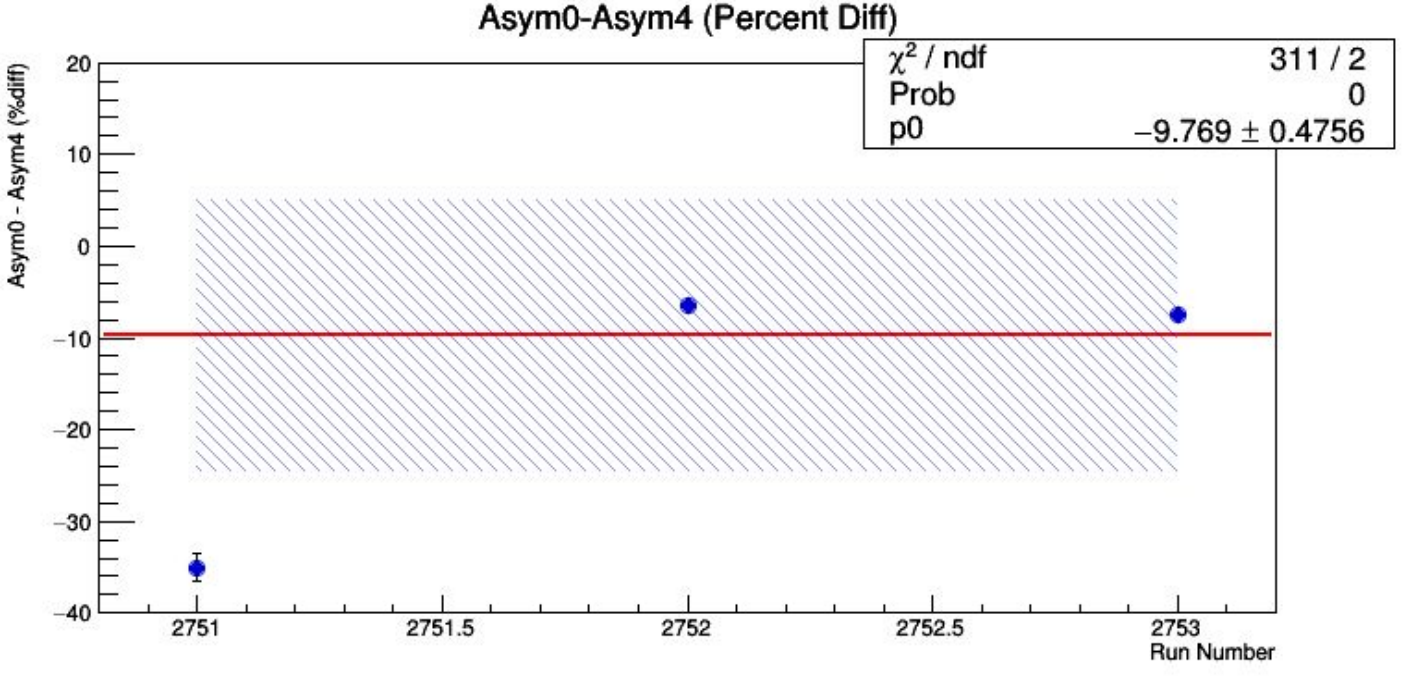
Remember: only Acc4 is sensitive to pedestal.

Acc4 polarization 85-86% which is close to Moller.

I will continue parsing through this data.

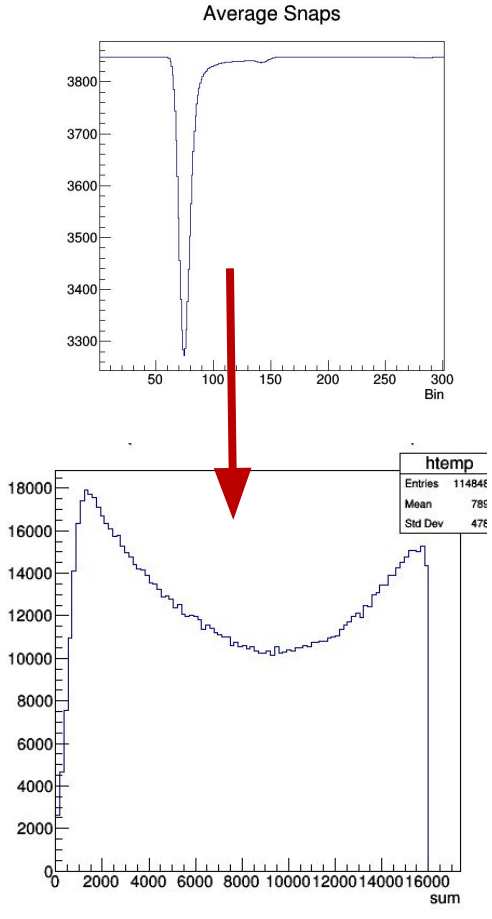
Spring 2016 Pass 5 Overview

- Only 3 data files (2 good, one suspect).
- Same Acc0-Acc4 discrepancy.
- Acc4 gives ~86 % polarization, close to Moller



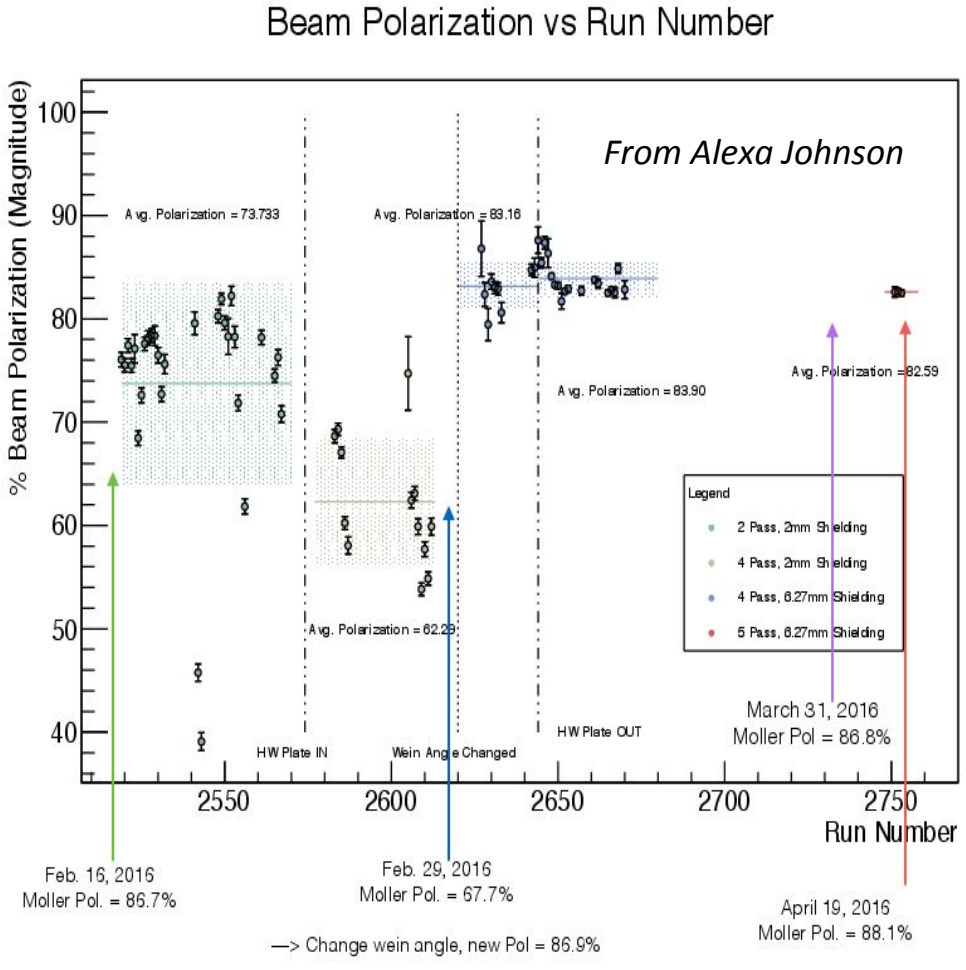
Cross Check Accumulators By Fitting Compton Spectra

- We can perform a cross check on the accumulators by taking the “triggered” data and producing a “Compton spectrum”
- Fit this spectrum directly to Monte Carlo and extract polarization.
- The systematics for this are much harder to deal with.
- Since it is secondary data we do not have very high statistics nor high precision.
- Alexa Johnson used this method to perform a cross check.



Cross Check Accumulators By Fitting Compton Spectra

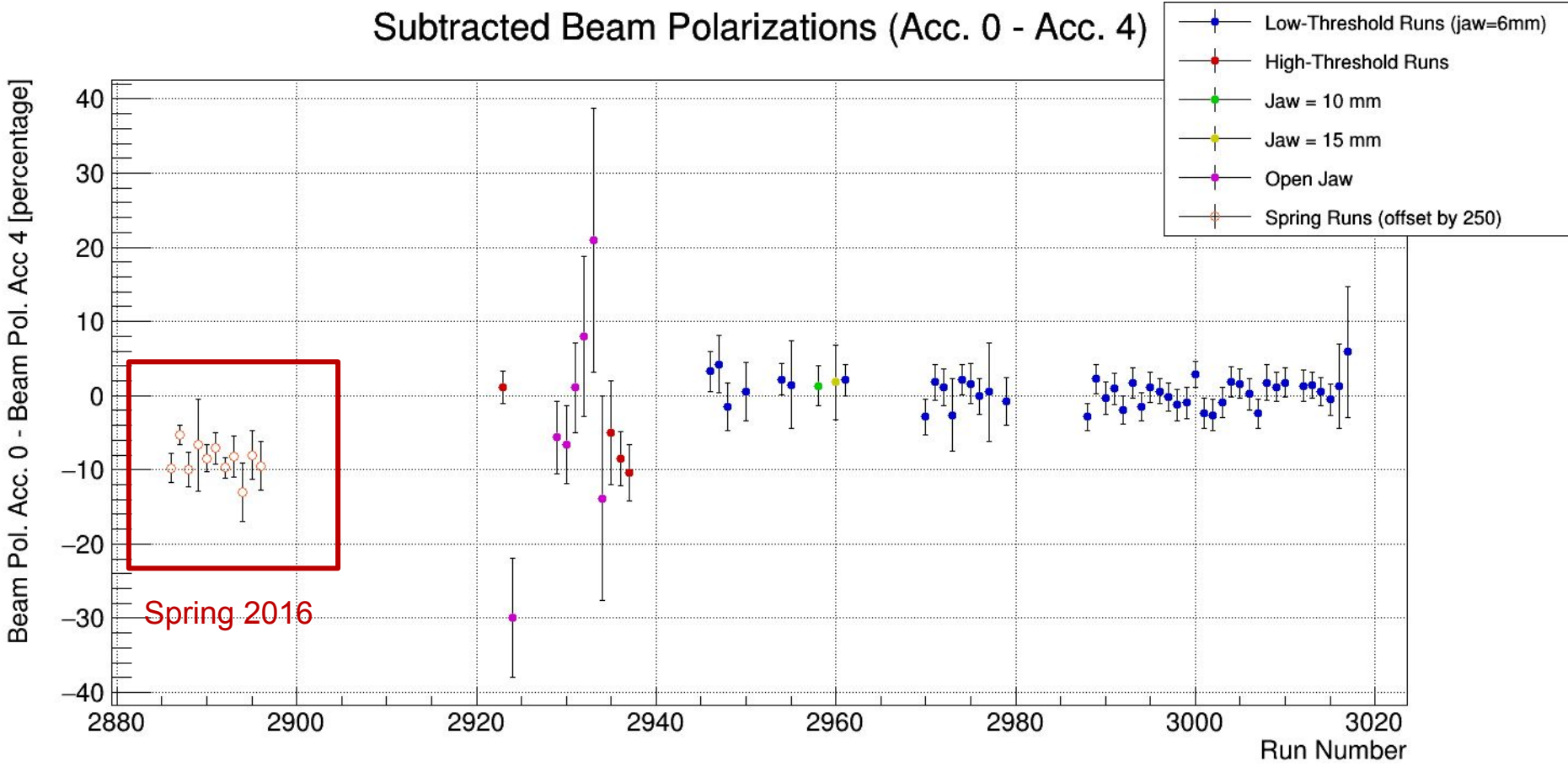
- For Pass 4 and 5 only a few percent below Moller.
- Significantly smaller at Pass2
  - Signal is very tiny at low beam energies.
  - Compton spectra has very poor resolution!
- Gives us hope that Acc4 is **“ok”**



Summary of Fall 2016 Production Running

- Synchrotron radiation (8 GeV beam) issues solved!
  - Fixed a misalignment of beamline (now taken into account by MCC)
  - Installed remote controlled collimator system (Tungsten “Jaws”)
    - Also a much better way of centering detector
  - With synchrotron issue fixed ⟶ lowered Accumulator Threshold
- Accumulator discrepancy has disappeared
  - But do not know why….
  - Undergraduate CMU student **Ian Harris** re-analyzed all of Fall 2016 data.
  - Needed to update pedestal, beam and laser calibrations etc…
- 44 “good” data runs (~2 hours each) @ 8 GeV
- No Pass5 data

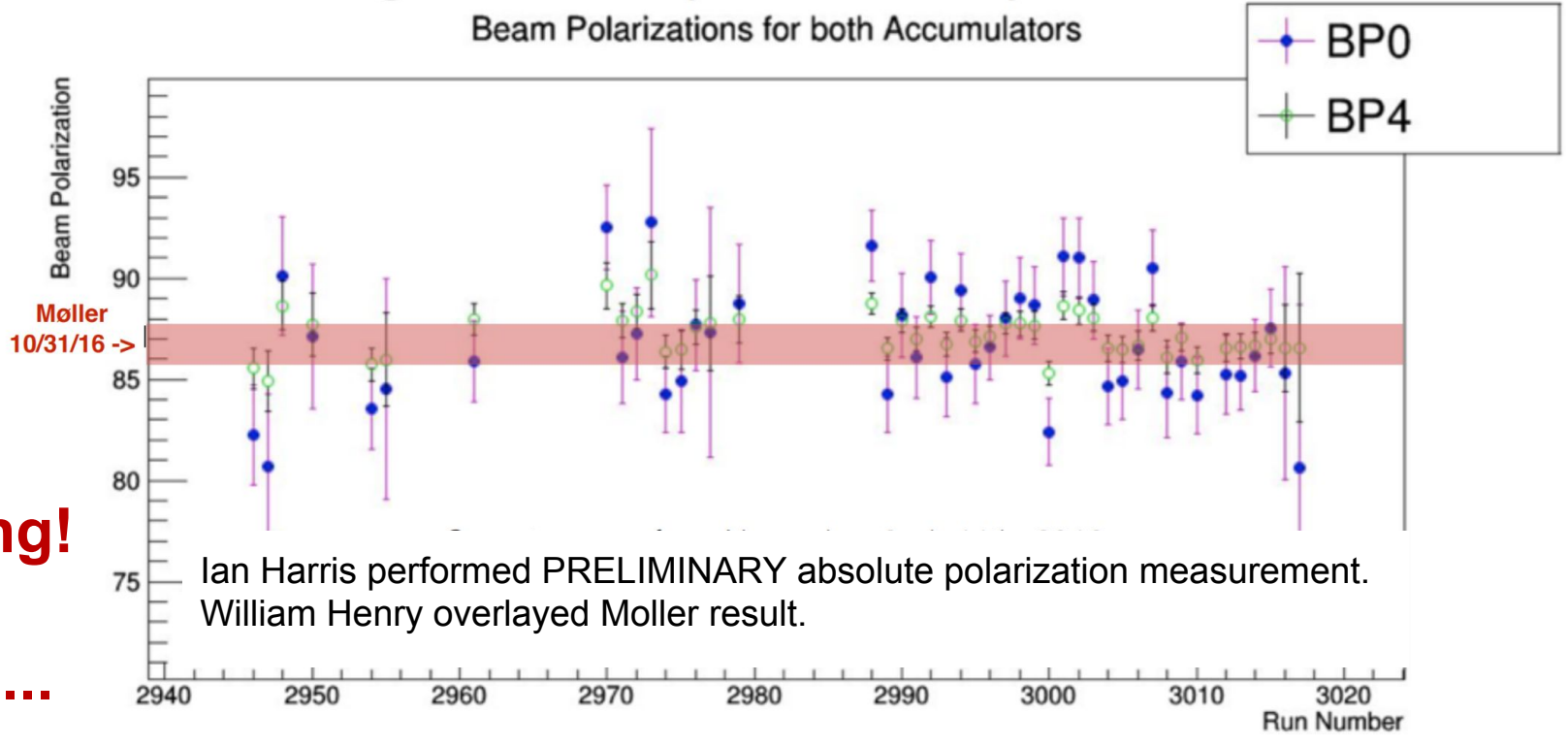
Fall 2016 Data Shows NO Acc0-Acc4 Discrepancy



High threshold shows large scatter. Low threshold shows good agreement between Acc 0 &4

Compton and Moller Finally in Agreement?

Beam polarizations given by accumulators 0 and 4 were in fair agreement (1.13 stdev)



Ian Harris performed PRELIMINARY absolute polarization measurement.
William Henry overlayed Moller result.

Very promising!

Not final...

Summary

- Spring 2016 → a lot of work needs to be done
  - No final polarizations to show you today
  - Needs lots of manual work to clean up data
  - Likely no resolution to Acc0-Acc4 discrepancy.
  - Worst case scenario: use Acc4 to monitor polarization stability, use Moller for absolute polarization value.
- Fall 2016 → Very very promising
  - Thanks to Ian's hard work, got good set of data.
  - Acc0 - Acc4 discrepancy seems to have disappeared.
  - Not mentioned today: need to do some more work to explain sudden change
- No ETA on final analysis, sorry :(
- Stay tuned….

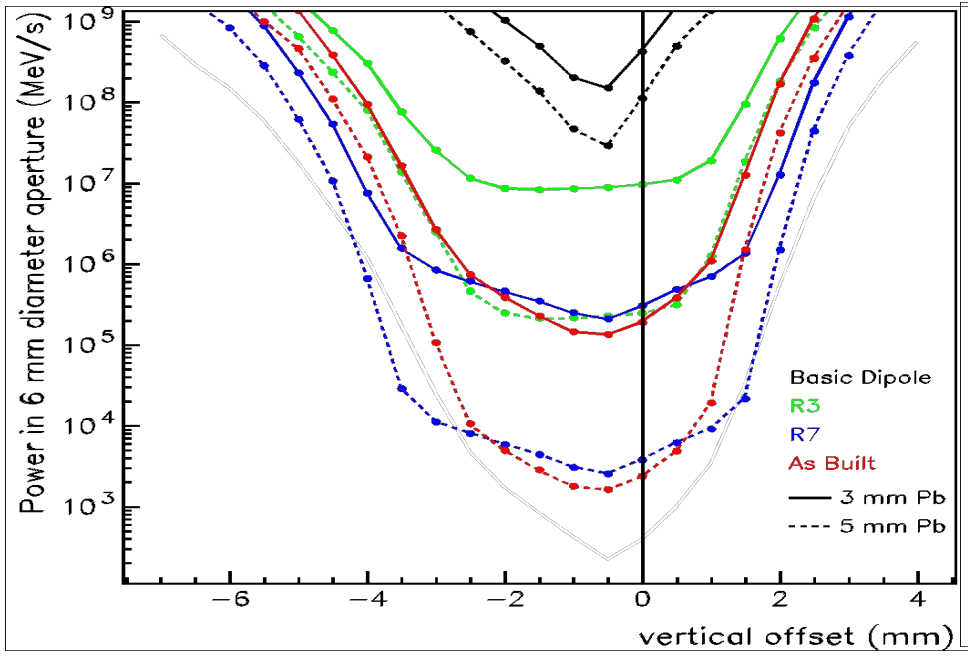
THANK YOU ALL! AND THANKS TO WHOLE POLARIMETRY GROUP.

Extras

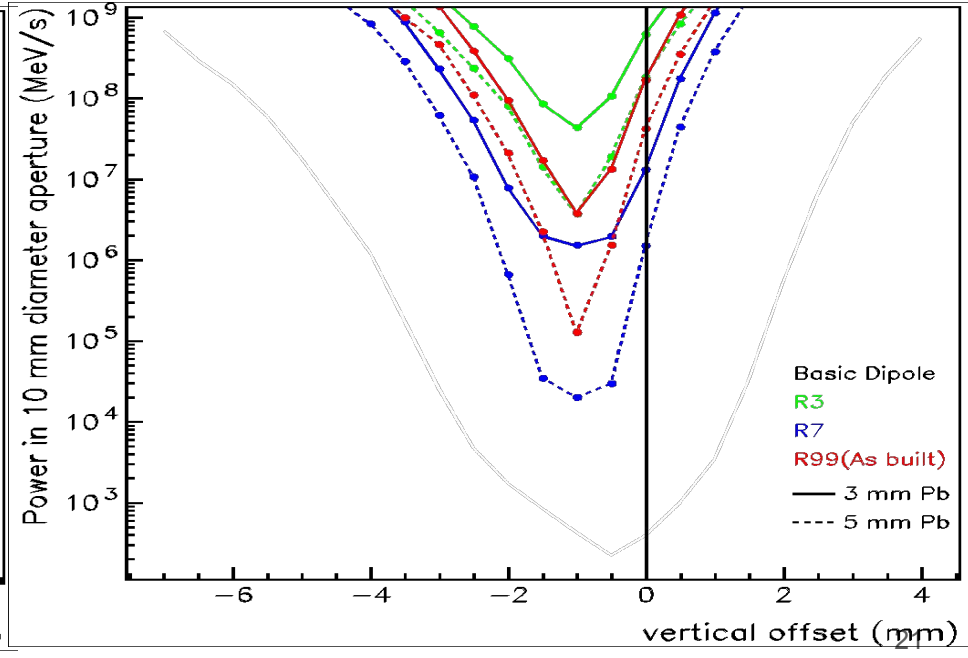
Photon Detector Experience with DVCS

- Spring 2016 → saw **significant** synchrotron radiation
  - Trouble centering beam on Photon Detector → used larger aperture collimator
  - Unexpected discrepancy between “accumulators”

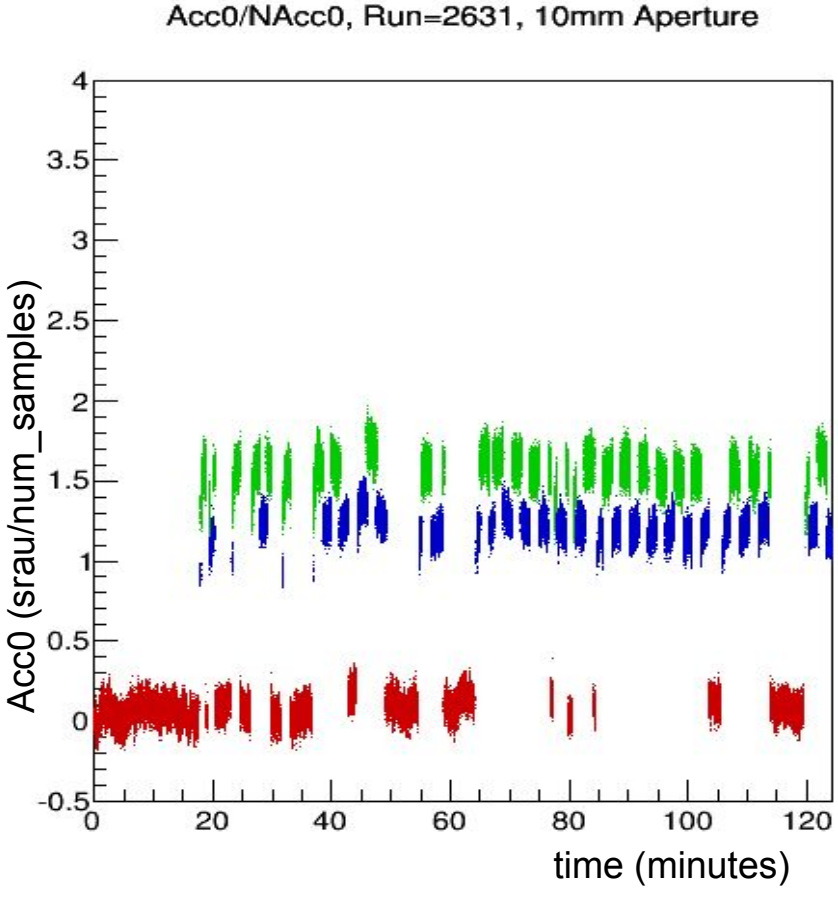
6 mm aperture

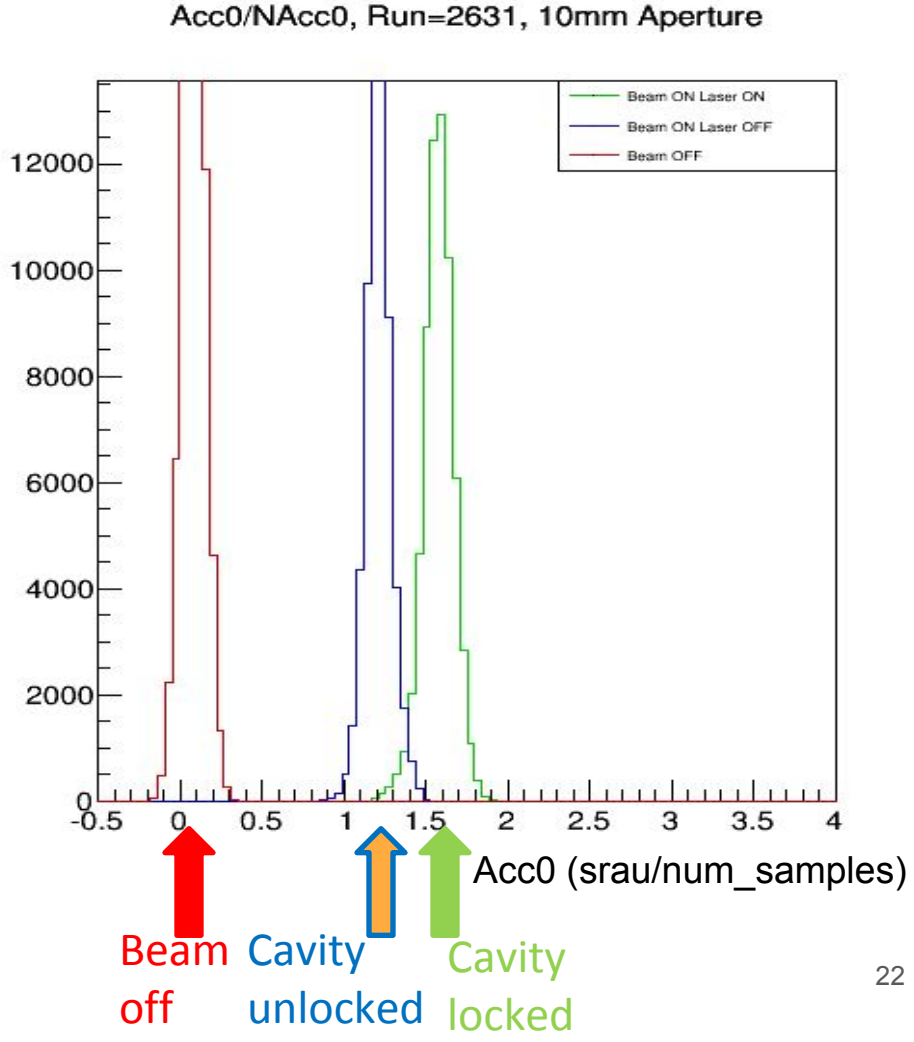


10 mm aperture

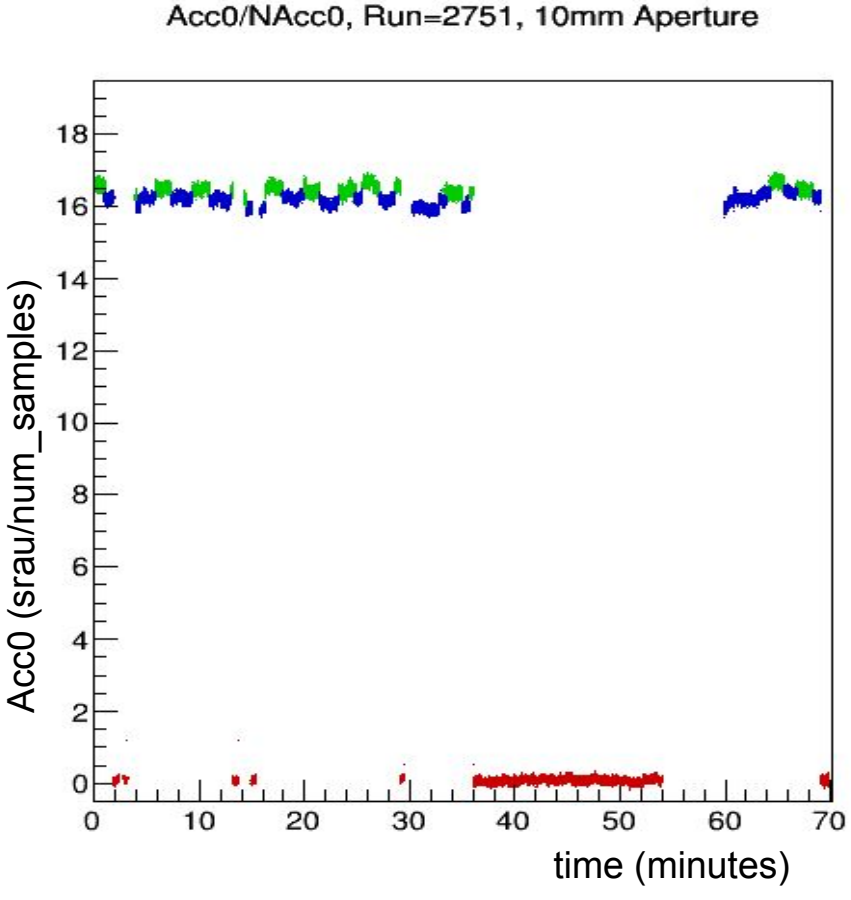


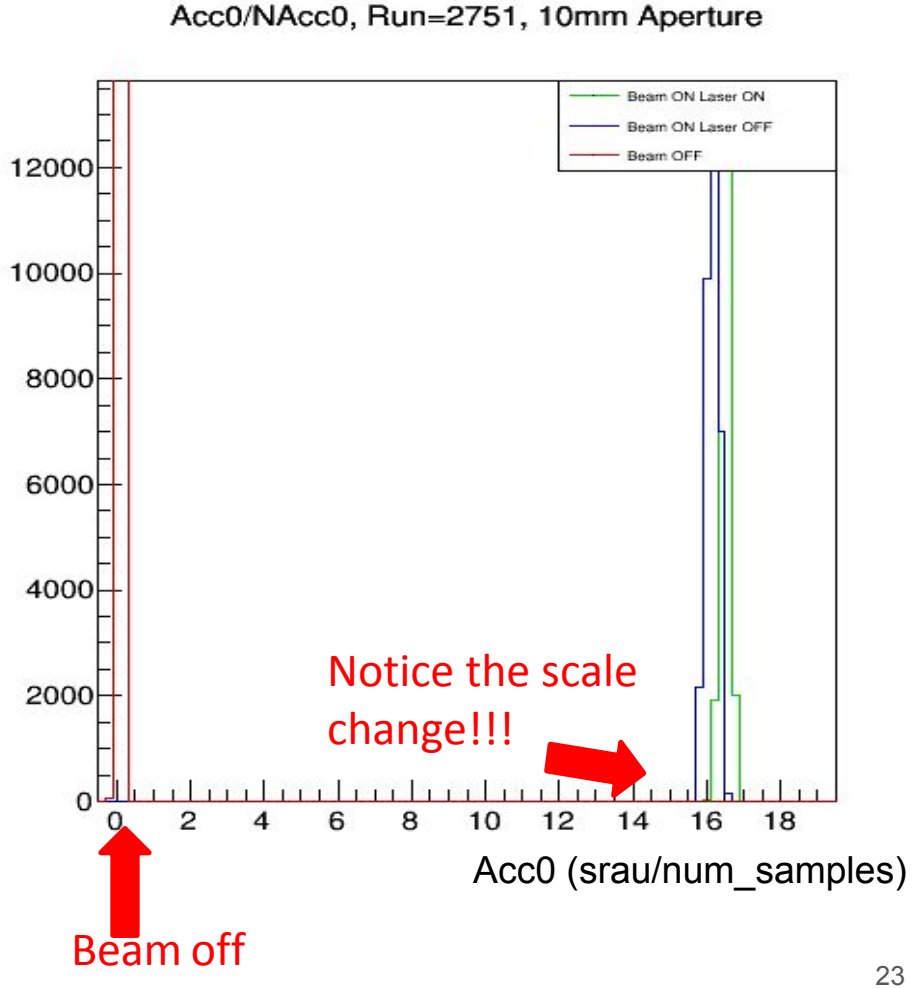
Spring 2016 4-pass running (@15 μA)



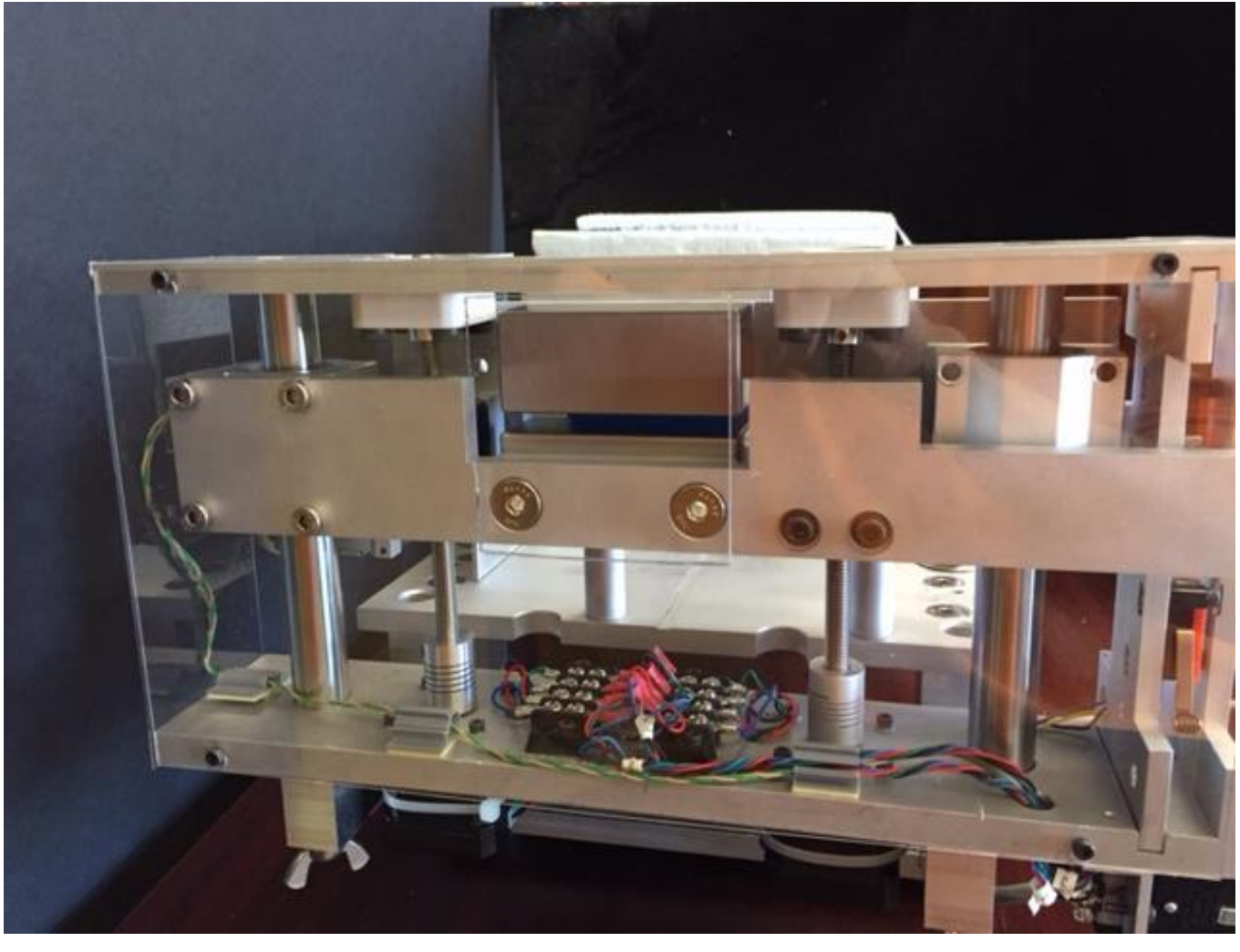


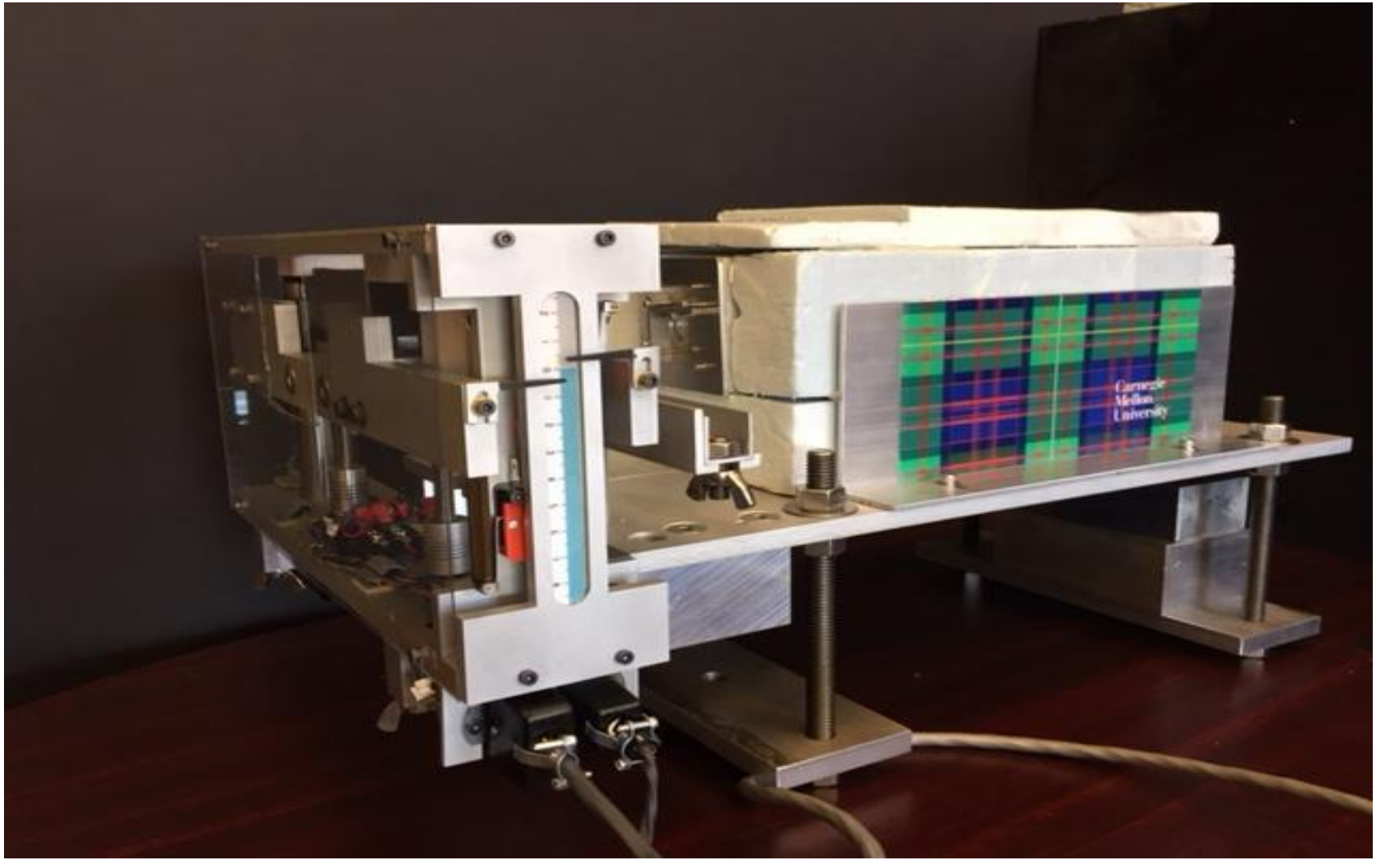
Spring 2016 5-pass running (@15 µA)





Remote (arduino) controlled Tungsten “JAWS”




Carnegie
Mellon
University

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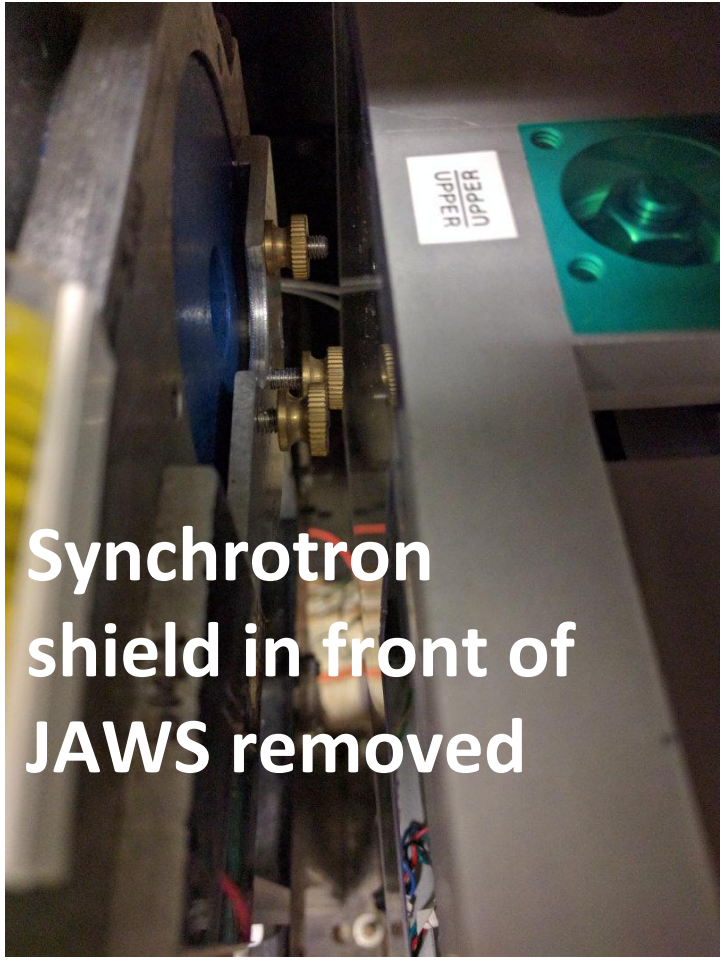
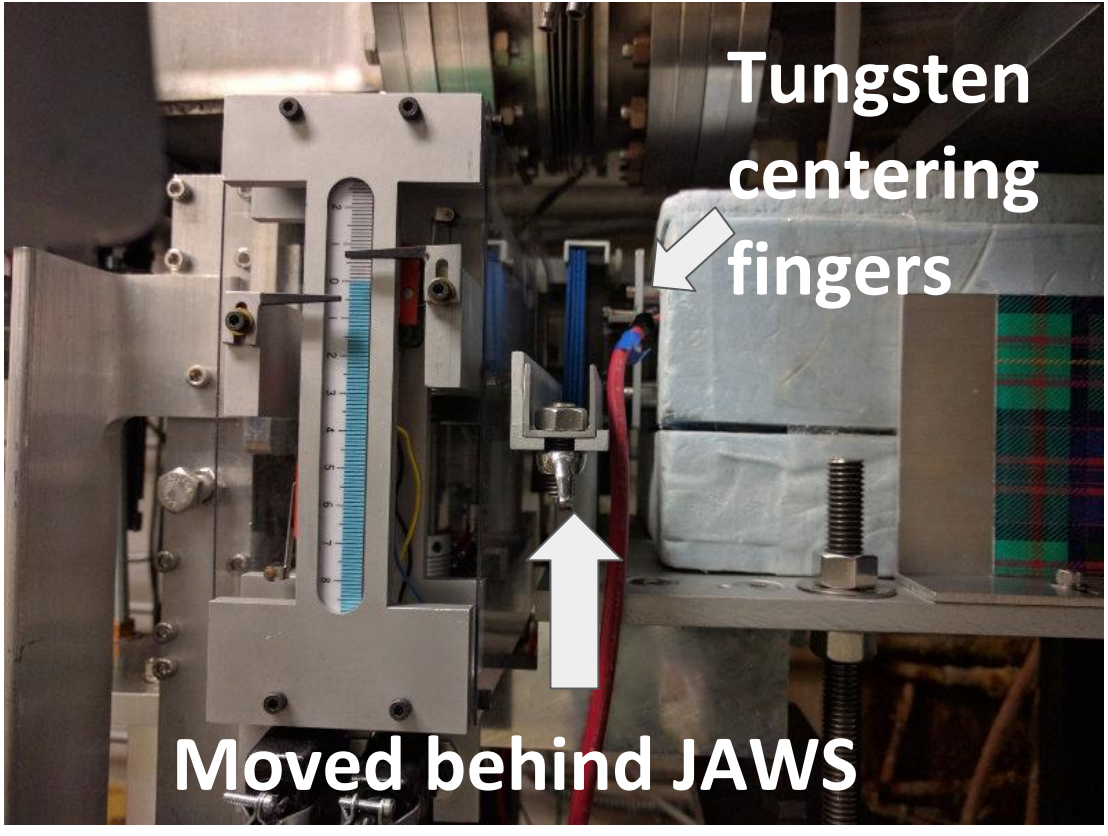
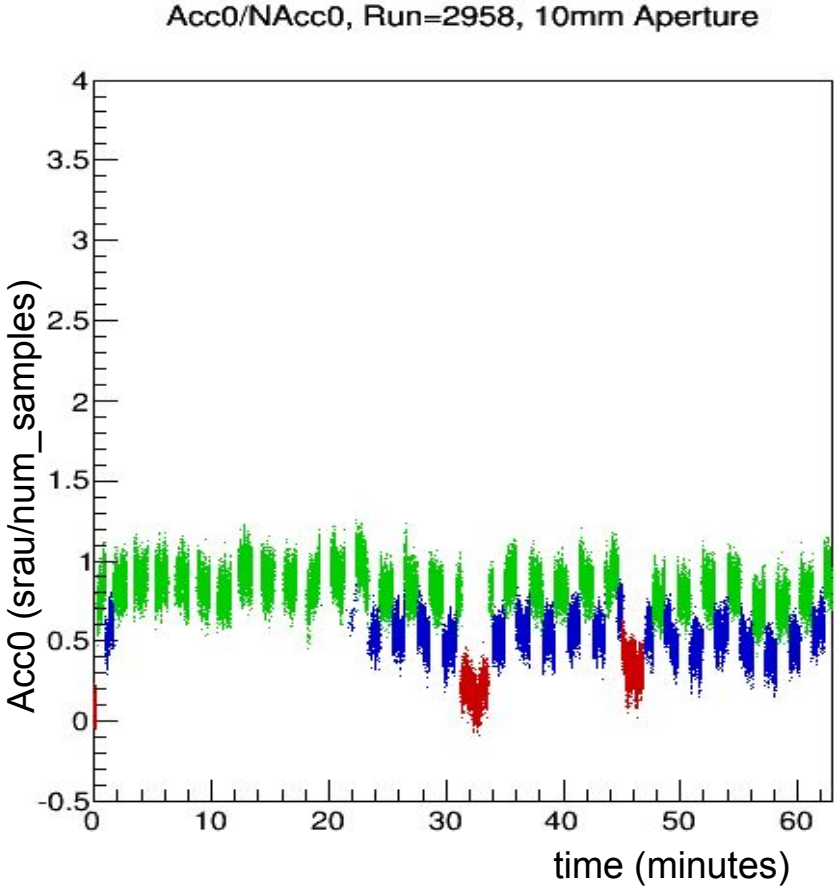
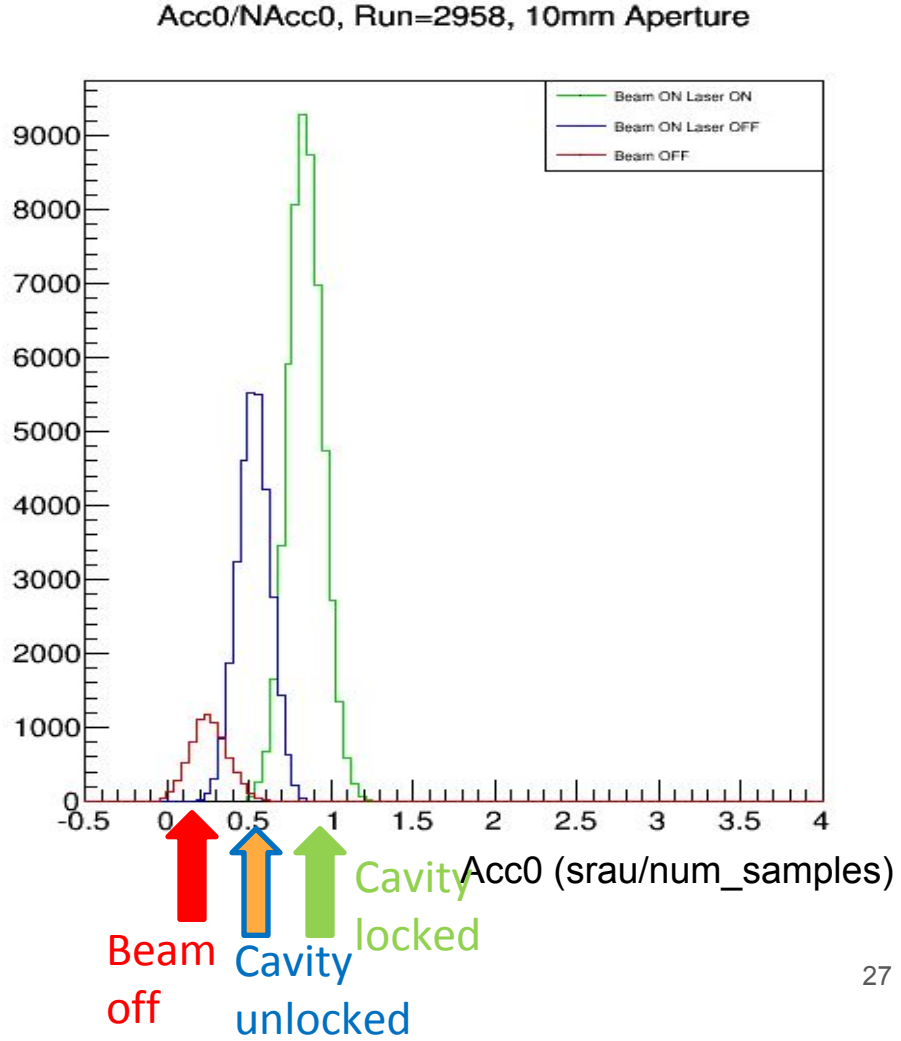




Simulations showed lead-synch shield spread photon beam and JAWS would clip Compton Spectrum.

Fall 2016 4-pass running with 10 mm aperture (@10 µA)



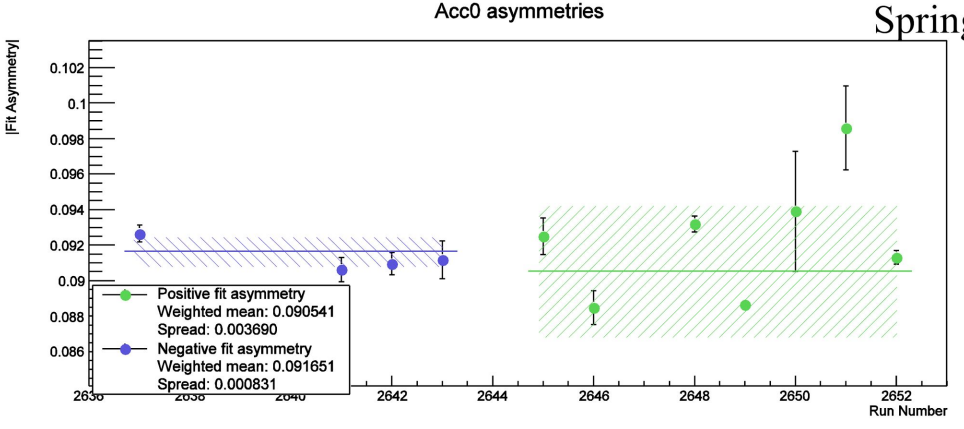


Unanticipated Discrepancy in No-Threshold vs Threshold

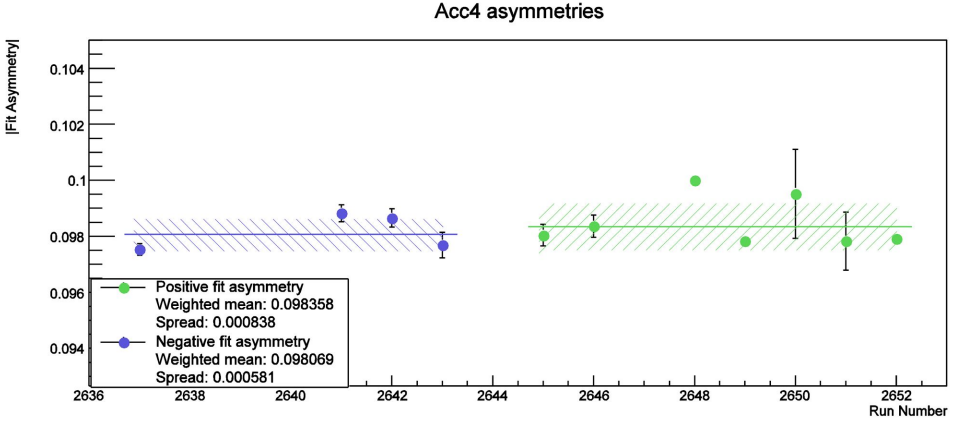
- Acc0 (no-threshold) is as much as 10% lower than Acc4 (threshold)

From Brian Quinn's March PREX2/CREX Update

Spring '16 4-pass

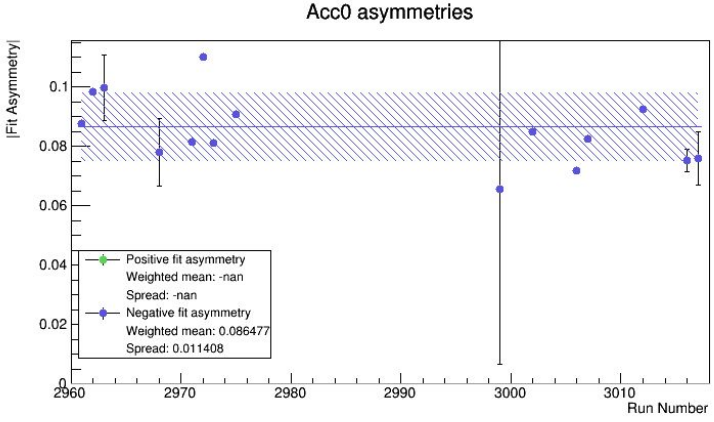


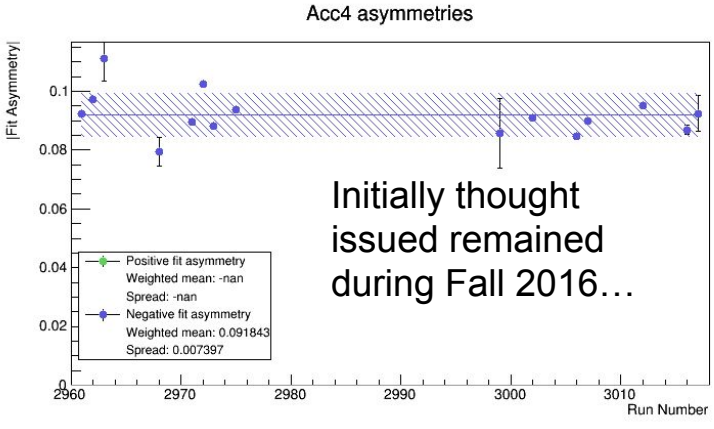
Acc0
A=9.1%



Acc4
A=9.8%

Unanticipated Discrepancy in No-Threshold vs Threshold





Initially thought issued remained during Fall 2016…

- Acc0 (no-threshold) is as much as 10% lower than Acc4 (threshold)
- Many bench tests already performed, including dedicated analysis.
  - Initial primary suspect was a likely “afterglow”
    - R.E Zhu et. al. NIM A 376 (1996) found some crystals with > 15 ms afterglow.
  - Afterglow can be “small” but Acc0 integrates ~6.6 million samples → effect gets amplified.
  - See previous Compton talks for all bench tests that we ruled out.

Photon Detector Experience with DVCS

- Spring 2016 → saw **significant** synchrotron radiation
  - Trouble centering beam on Photon Detector → used larger aperture collimator
  - Unexpected discrepancy between “accumulators”
- Fall 2016 → synchrotron radiation (8 GeV beam) issues solved!
  - ✓ Fixed a misalignment of beamline (now taken into account by MCC)
  - ✓ Installed remote controlled collimator system (Tungsten “Jaws”)
    - Also a much better way of centering detector
  - With synchrotron issue fixed → lowered Accumulator Threshold
  - Accumulator discrepancy…
    - Is gone!
    - Undergraduate CMU student Ian Harris re-analyzed all of Fall 2016 data.
    - Needed to update pedestal, beam and laser calibrations etc…
    - Last nagging issue is strange Acc0 to Acc4 correlation
      - But less worrisome.

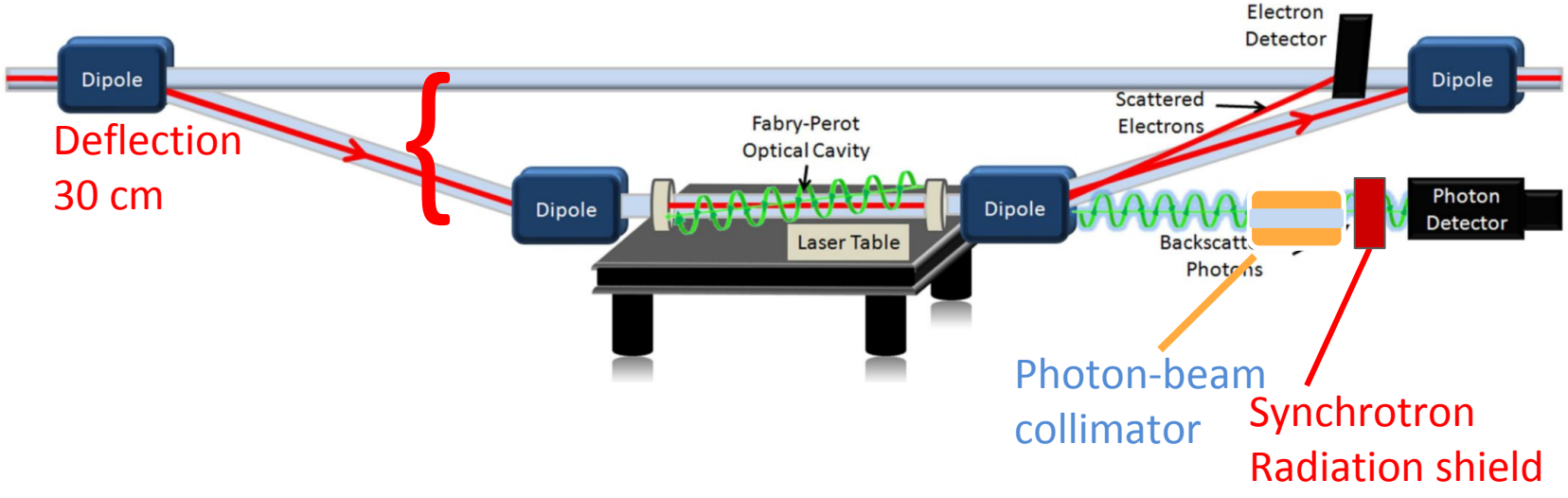
Found nothing that would indicate problem with GSO (PREX2/CREX)

Summary

- Compton had to be recommissioned for 12 GeV running.
  - Hit several bumps along the way.
- Laser system needs some work → have plan to move forward.
- $PbWO_4$ Photon detector tested (will not be used for PREX/CREX2)
- Synchrotron and centering issues no longer a problem → should be smooth experience moving forward.
- Initial Acc 0 & 4 discrepancy caused us to perform lots of bench tests and dedicated analysis
  - Found nothing that indicates a problem for PREX2/CREX.
  - Resolved Acc0/4 issue now less worrisome → but will keep looking into for future experiments.

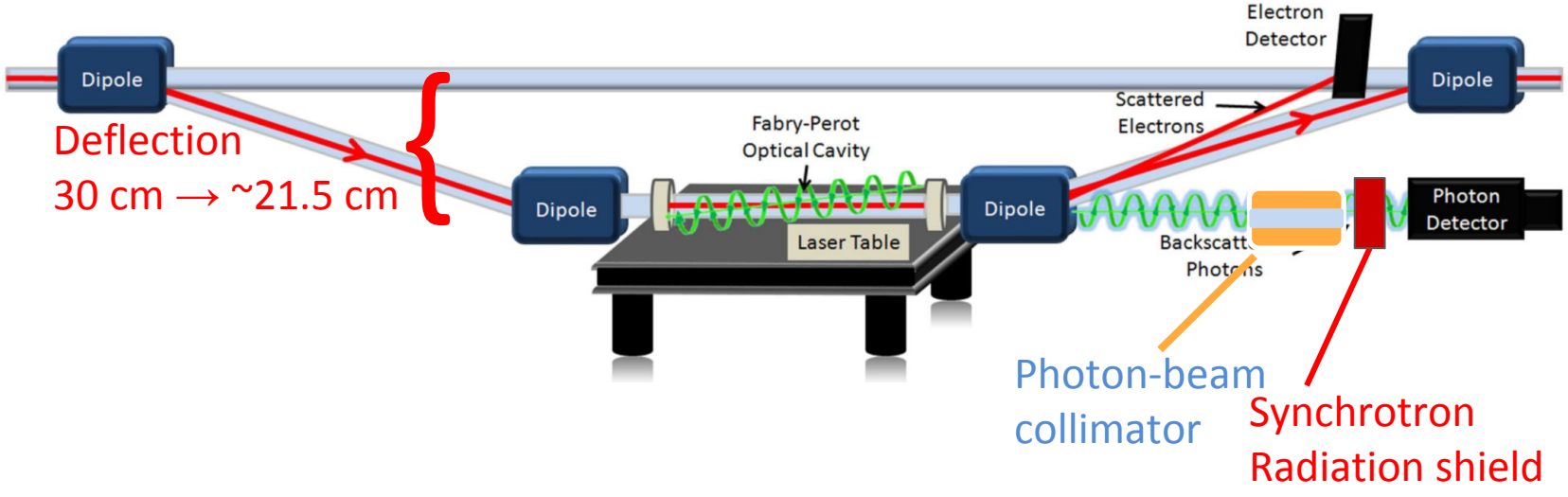
Compton Chicane during 6 GeV Era

- Vertical chicane ~30 cm
- Cylindrical collimator and thin Pb “shield” used to minimize synchrotron



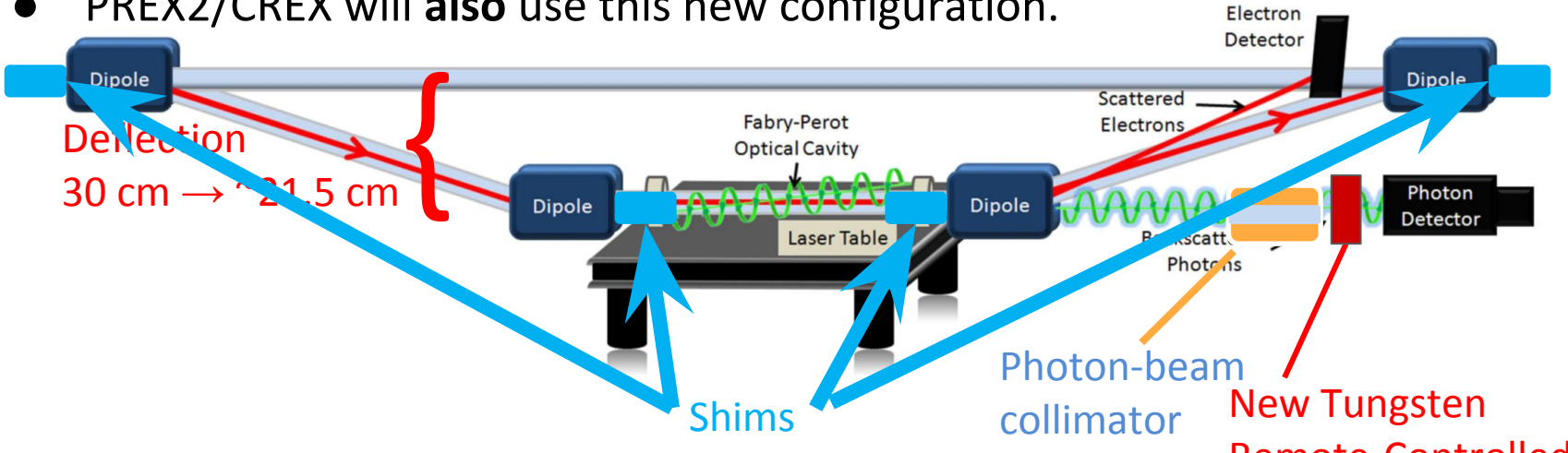
Compton Chicane at 12 GeV

- Vertical chicane deflection decreased (30 cm → ~21.5 cm)
- Expect ~E^4 increase in synchrotron radiation!!!



Compton Chicane at 12 GeV

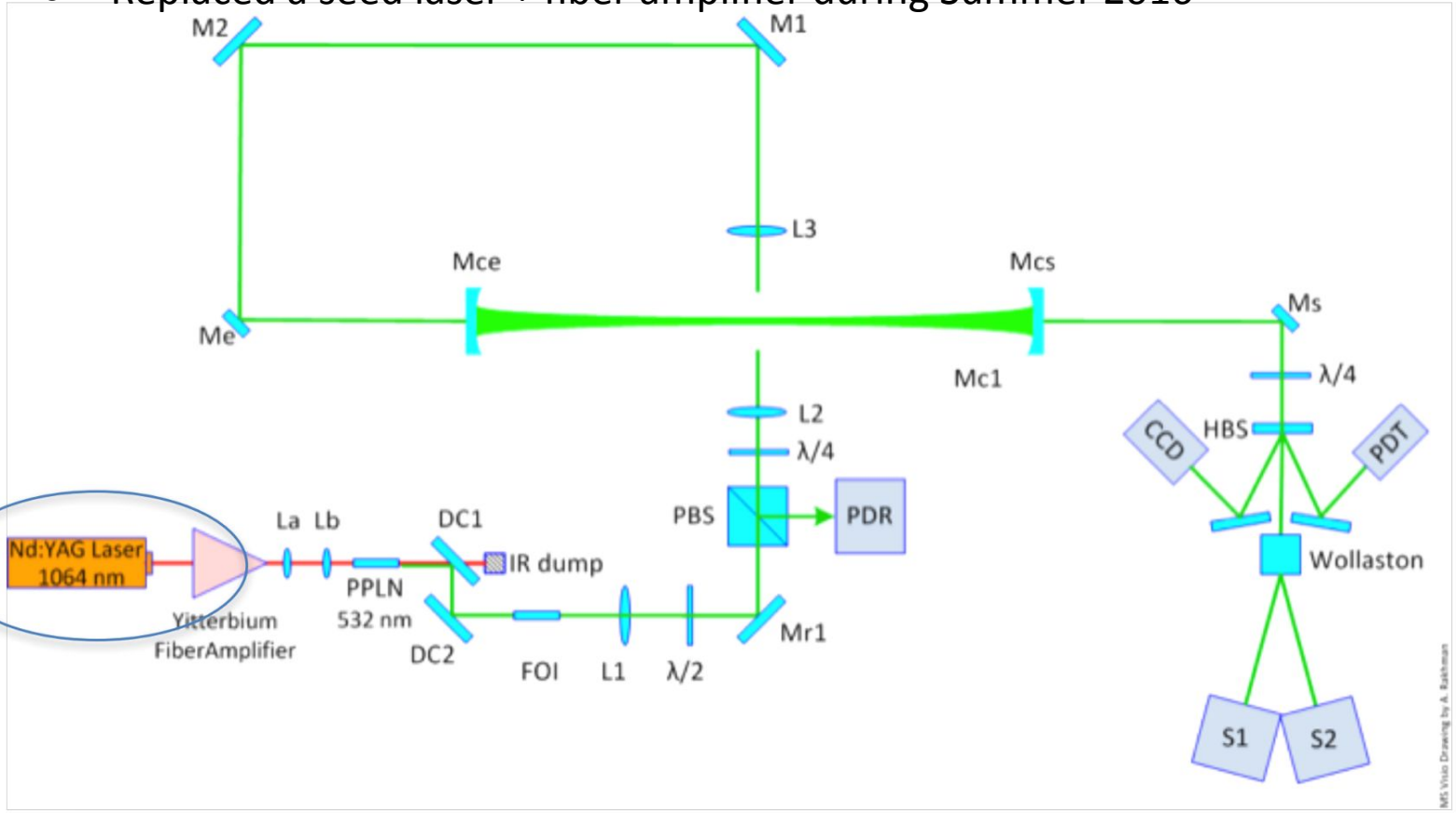
- Vertical chicane deflection decreased (30 cm → ~21.5 cm)
- Expect ~E^4 increase in synchrotron radiation!!!
- Modify fringe field with added ‘shims’.
- PREX2/CREX will **also** use this new configuration.



J. Benesch, G.B. Franklin, B.P. Quinn, and K.D. Paschke, “Simple modification of Compton polarimeter to redirect synchrotron radiation” PhysRevSTAB.18.112401 (2015)

Compton Laser System Experience with DVCS/GMp

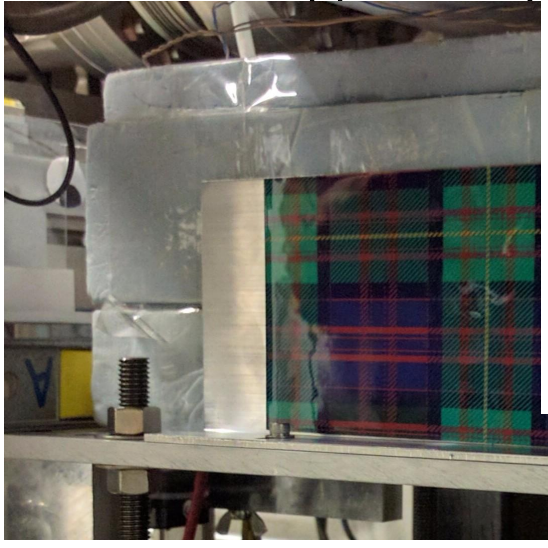
- Compton laser system was fully functional at the start of Fall 2016
  - Replaced a seed laser + fiber amplifier during Summer 2016

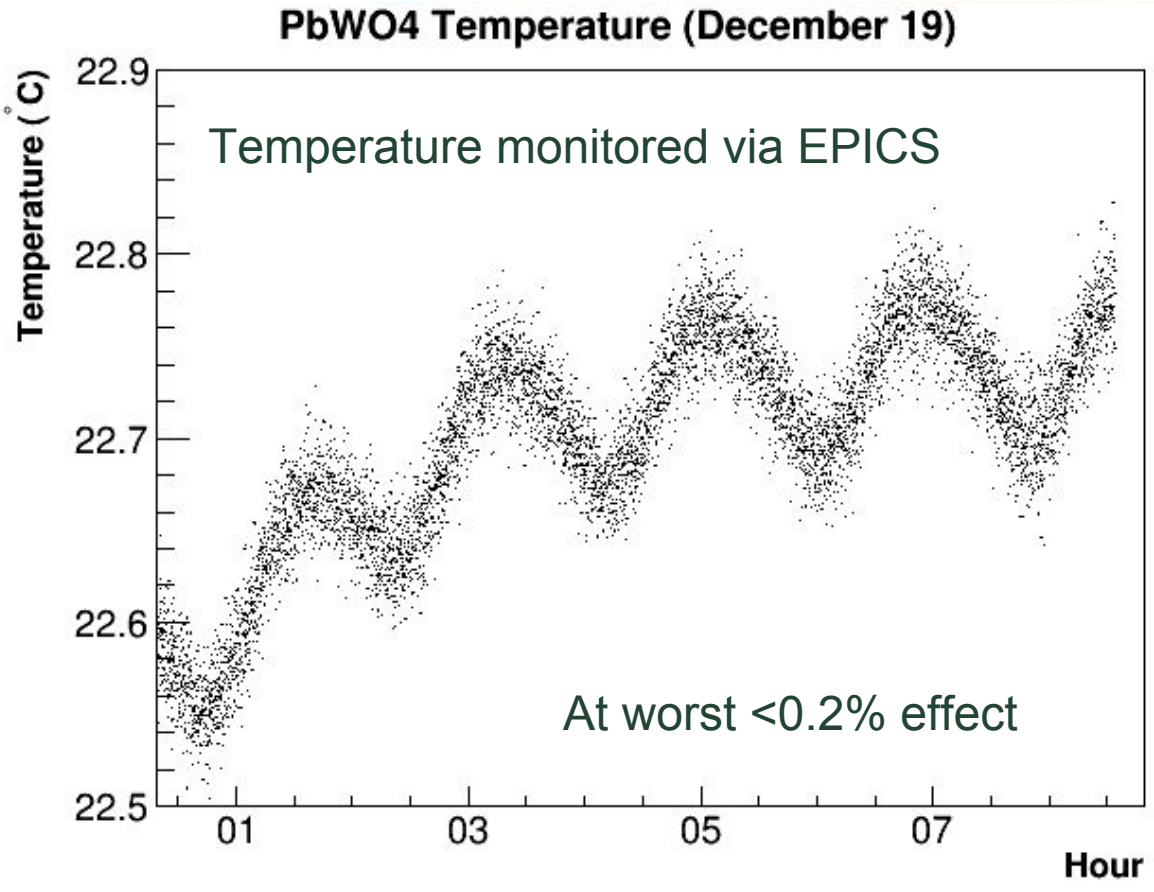


Compton Photon Detectors: “High Energy”

Need denser material tc
of ~3 GeV photon → Pl

- 6x6 cm x 20 cm leng
- On loan from Yerev
- Suitable for > 6 GeV
- Light output change
  - Wrapped in sty

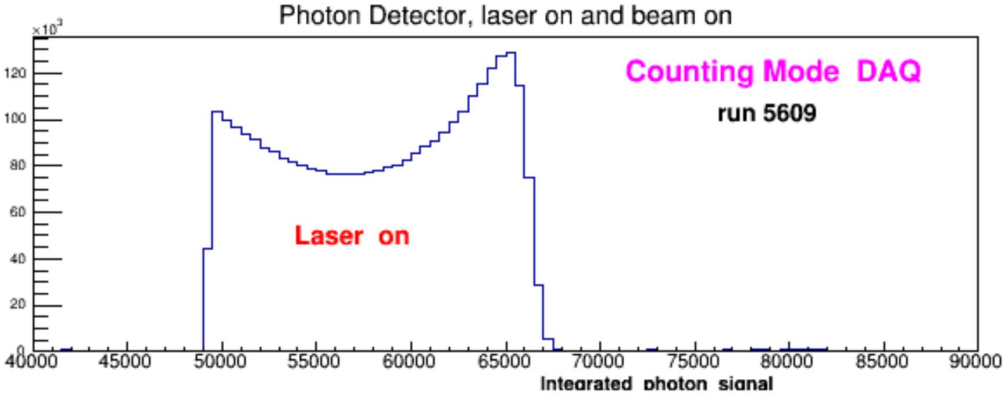


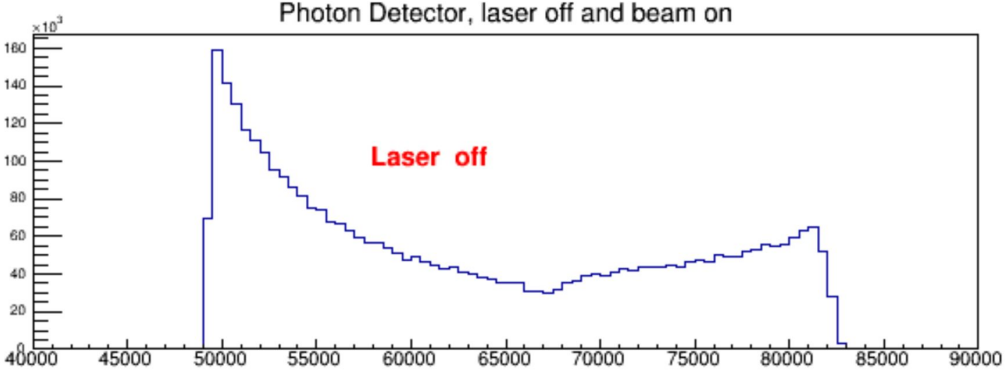


Helicity pickup

- Helicity flip rate (@ 30 Hz) is **not delayed** → significant pickup
  - Helicity correlated difference with no-delay: 0.04 rau/num_samples
  - Modified helicity bit and **manually delayed it till end of MPS window**
  - Helicity correlated difference with manual delay: max 0.001 rau/num_samples
  - Reminds us of why we **need** delayed helicity reporting

Progress on “counting mode” Photon Detector DAQ





From R. Michael

- Progress made during Fall 2016
  - Simultaneously ran integrating and counting DAQ (S. Liu, R. Michaels & A. Camsonne)
- Present status:
  - Readout of individual photons via a single JLab FADC-250
  - Still missing helicity info in order to extract asymmetries.

- Counting mode can be better integrated with electron DAQ (VETROC)