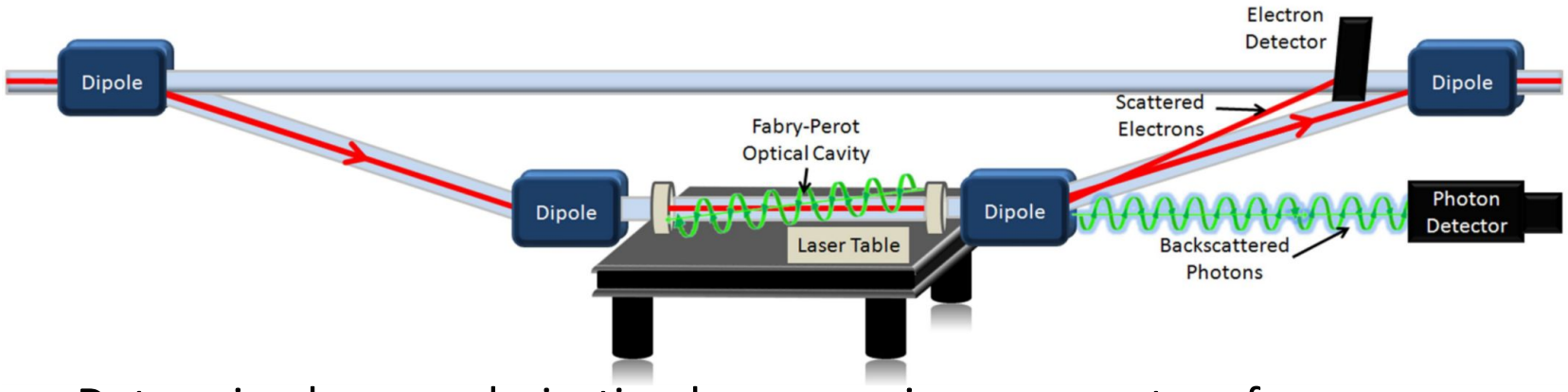
Compton Photon Detector Update

Juan Carlos Cornejo

PREX2/CREX Collaboration Meeting

October 02, 2017

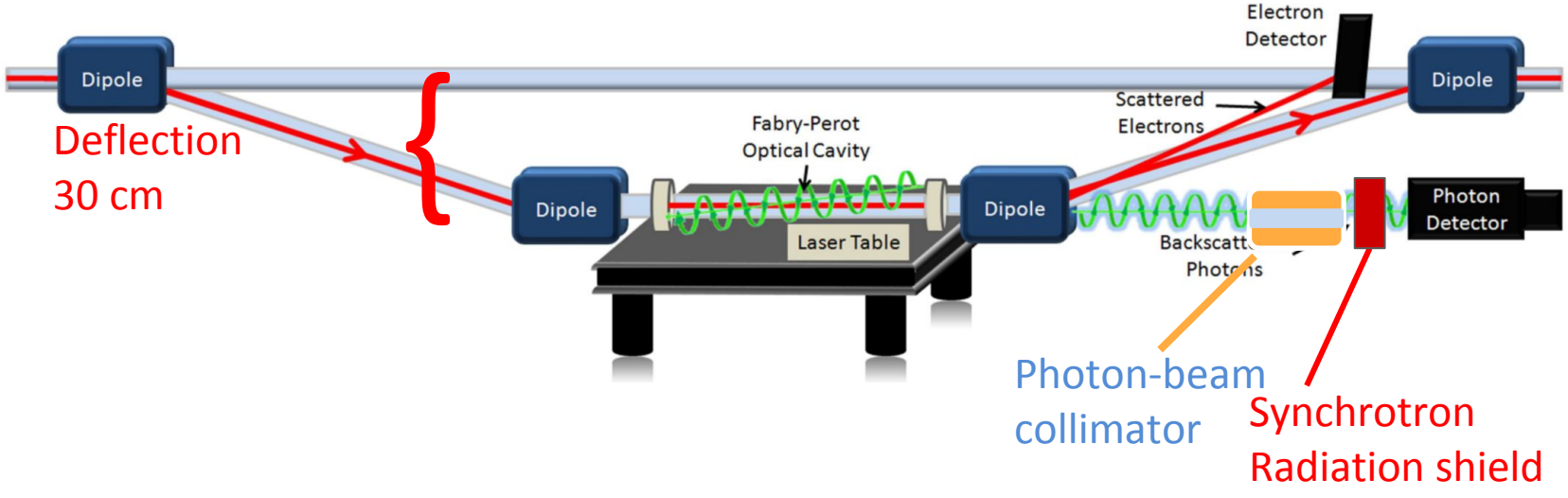
Overview of the Hall A Compton Polarimeter



- 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 Detector: GSO ($PbWO_4$ tested for other "high energy" experiments)
- Electron detector: silicon strip detector (evaluating other options)
- 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 Chicane during 6 GeV Era

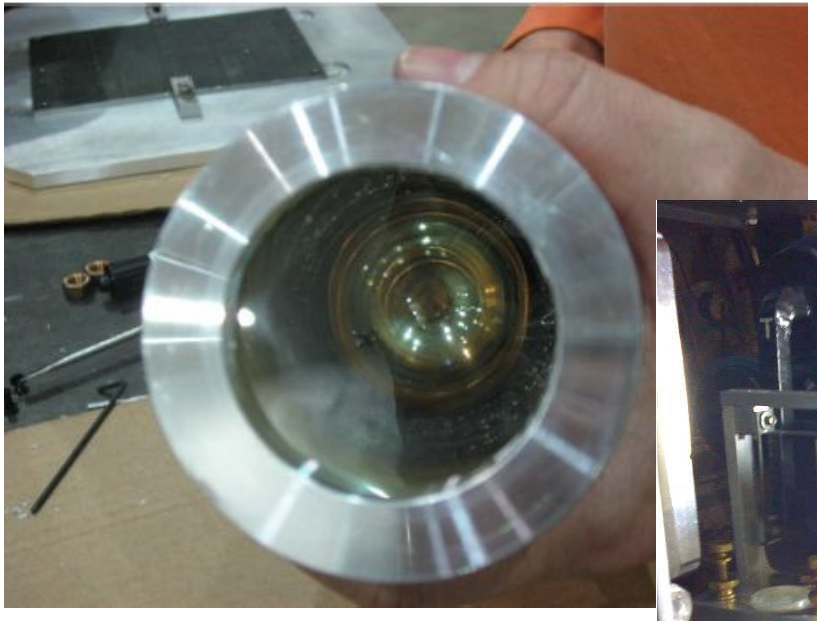
- Vertical chicane ~30 cm
- Cylindrical collimator and thin Pb “shield” used to minimize synchrotron



Compton Photon Detector for “Low Energy” Experiments

Single GSO crystal manufactured by Hitachi Chemical

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



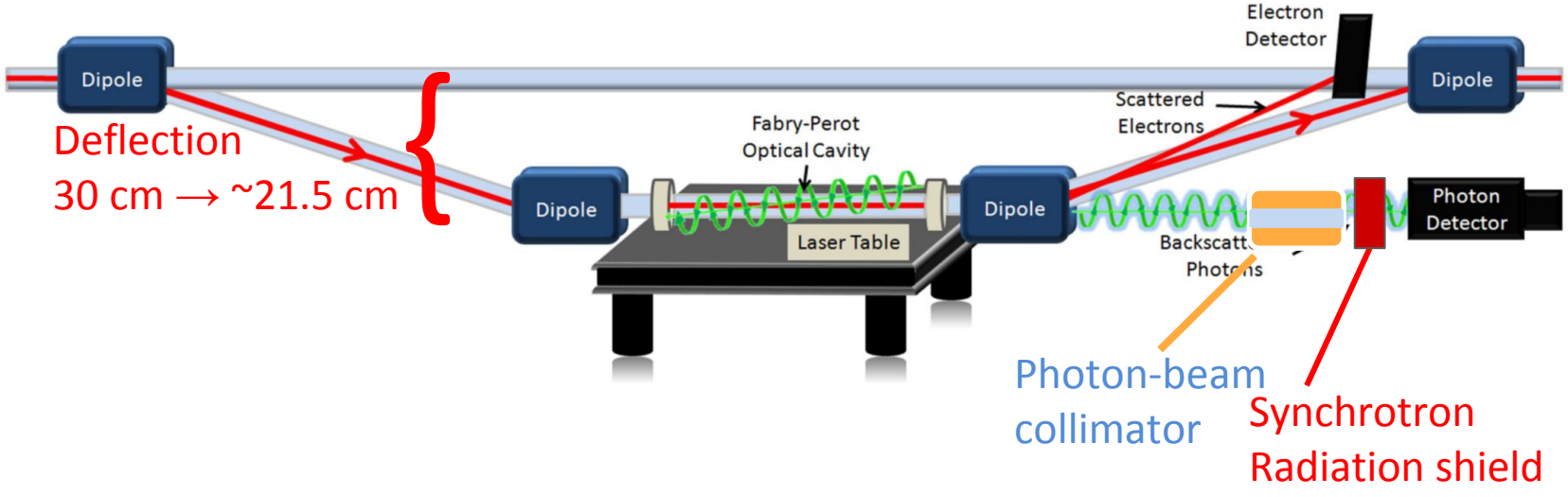
Flash ADC integrating DAQ:

- 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.

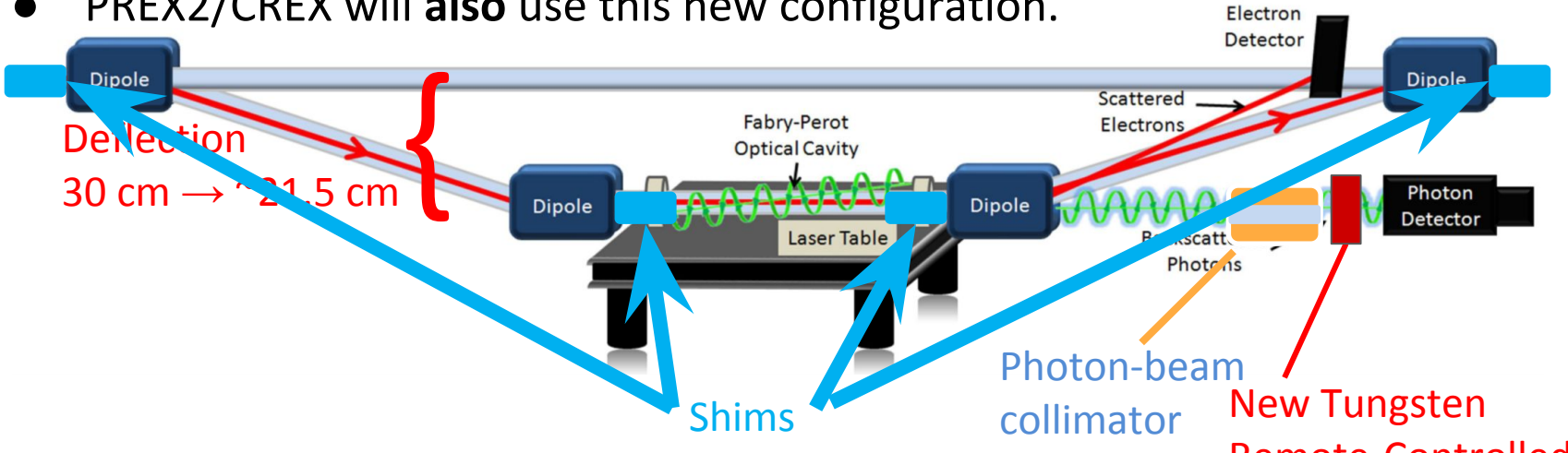
Compton Chicane at 12 GeV

- 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)

Experiences at Higher Energy

(Compton Status Update)

- Recommissioned Compton during DVCS Spring & Fall ‘16
  - Used $PbWO_4$ detector due to higher scattered photon energies.
- Ran into some difficulties
  - Component failures
  - Found unexpected systematic effect on measured asymmetries.
- **Some issues resolved.**
- **Have plan for remaining issues to be resolved by the time PREX2/CREX has to run.**

Compton Laser and Cavity Status

Slides provided by Dave Gaskell

Recent hardware issues:

- Near end of spring 2016 run – Compton laser had 2 component failures
  - → 5 W fiber amplifier “sick”, resulting in noisy output
  - → Seed laser non-functional

  Replaced 300 mW IR seed with 700 mW spare (last used in 2009)

  Replaced 5 W fiber amplifier with 30 W “spare”

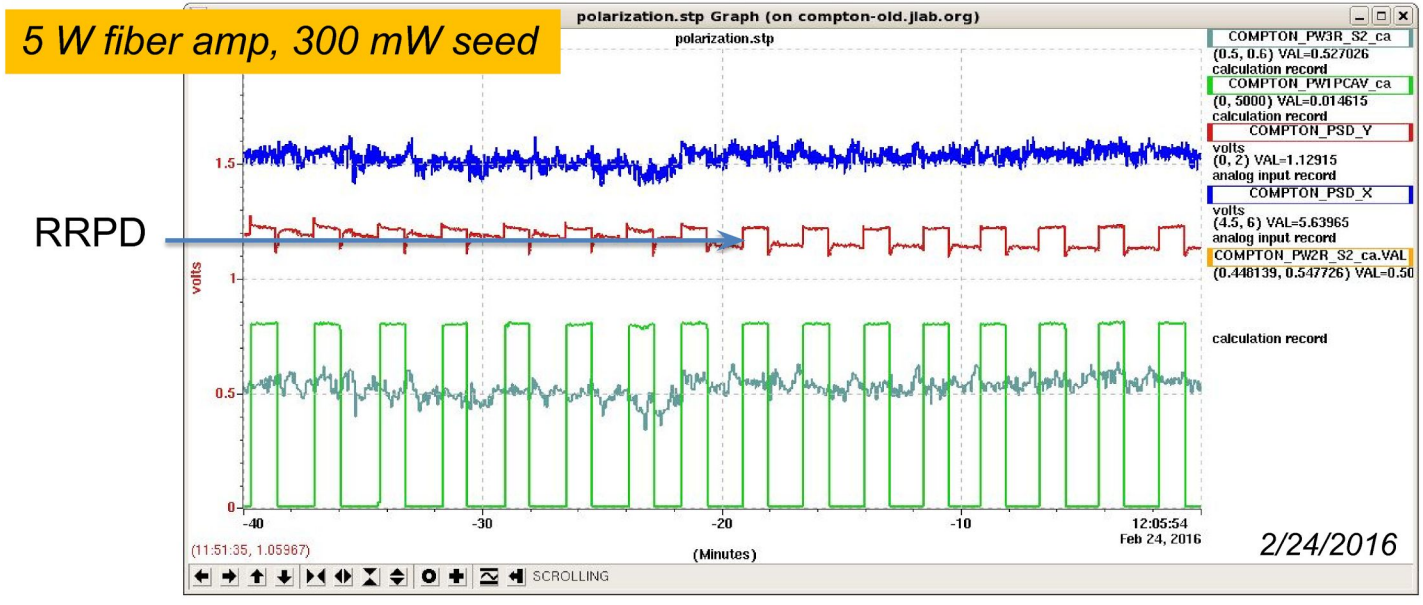
- Fall 2016 run – remote steering mirror issues. Could not use laser near end of experiment
  - → Steering mirrors repaired after run (replaced encoder)

Issues:

- → No spare IR seeds
- → 30 W fiber amplifier not well suited to running at ~ 5 W
- → Cavity was locking at about 2 kW rather than 5 kW → mode matching
- → No spare motors, motor controllers

→ Hope to purchase critical spares in FY18 – waiting on budget guidance

Reflected Power Monitoring



QWP/HWP settings for maximum DOCP optimized with cavity unlocked

→ Monitor RRPD to track polarization with time

→ Use locked cavity to help determine (small) pedestal (low power going back to RRPD)

→ Problem: In Hall A system, signal in RRPD is larger when cavity locked! Apparently, output laser power very sensitive to light reflected back into doubling crystal (issue persists with replaced seed and fiber amplifier)

Slides provided by Dave Gaskell

Laser status

- Plan for this down
  - Restore laser alignment and cavity locking after mirror actuator repair
  - Understand reflected power issues in new polarization optimizaton scheme
  - Install improved isolation/RRPD scheme → requires a few new components
- Was not able to restore lock after steering laser to last, best positions
- Possible issues
  - Mirror alignment of cavity proper has changed
  - Mode matching has changed dramatically (unlikely)
  - Increased loss in cavity mirrors → radiation damage, or issues from vacuum event?

Slides provided by Dave Gaskell

Laser plans

- Before start of Fall 2017 run, would like to understand reason we can't lock/align cavity
  - Easy to check to mode matching
  - Harder to check mirror losses, alignment of cavity proper
- Next down (Spring/summer 2018)
  - Install lower power seed laser, 10 W fiber amp
  - Improve optical isolation
  - Optimize polarization monitoring

Slides provided by Dave Gaskell

Photon Detector Experience with DVCS

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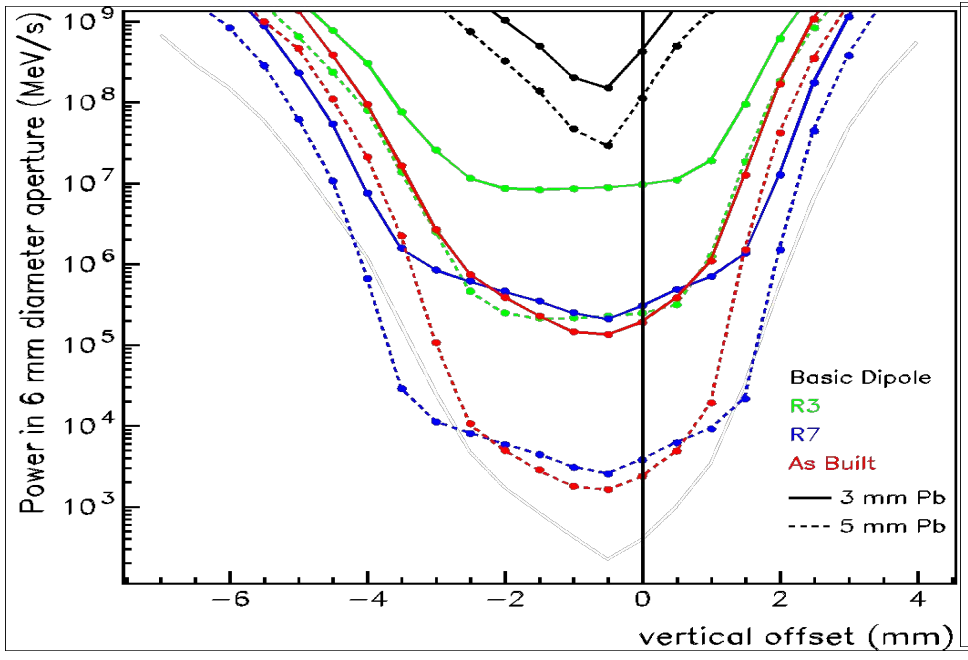
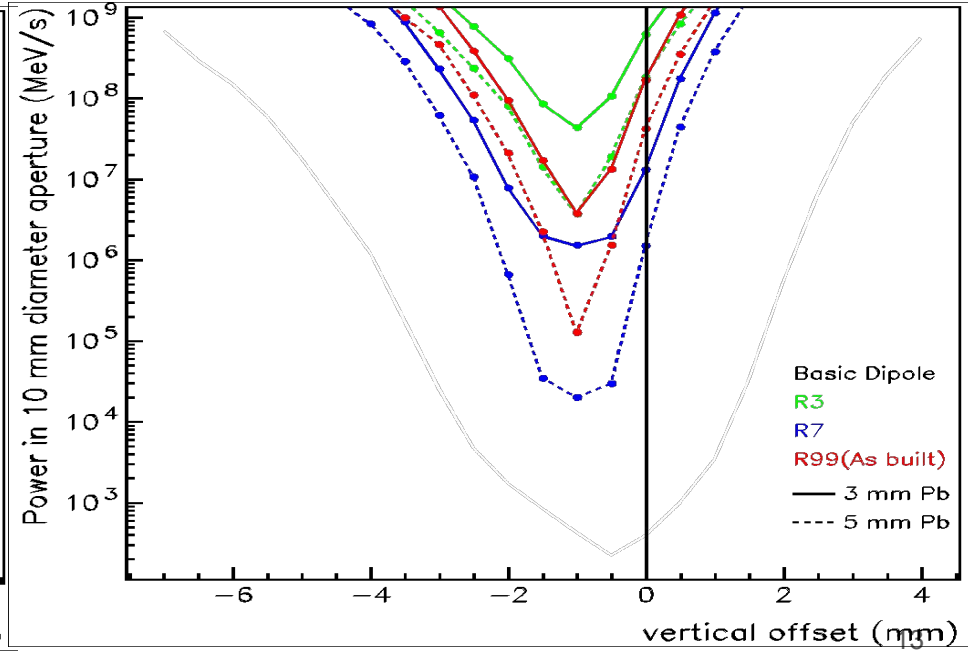
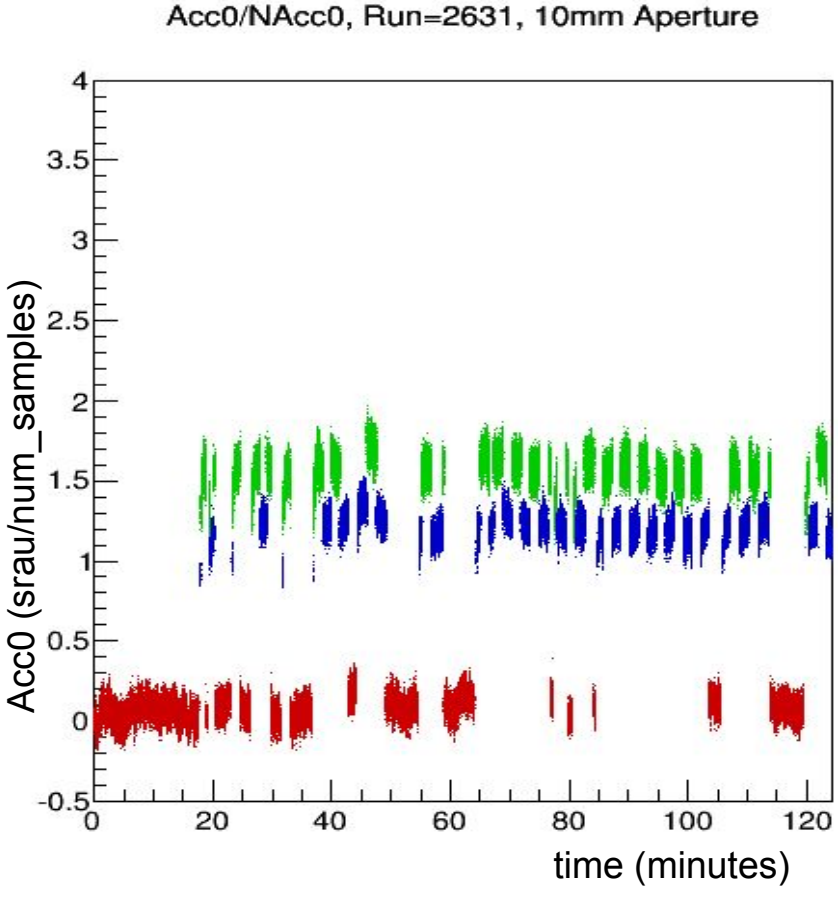
6 mm aperture

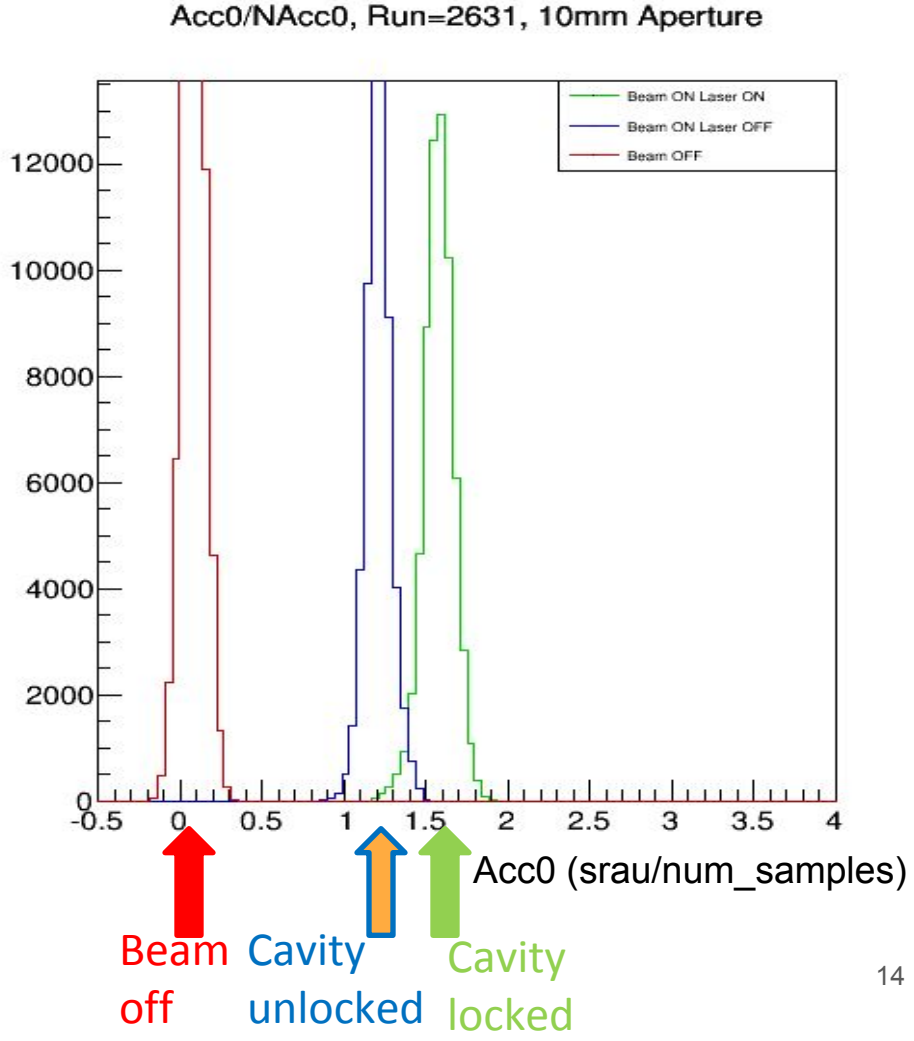


10 mm aperture

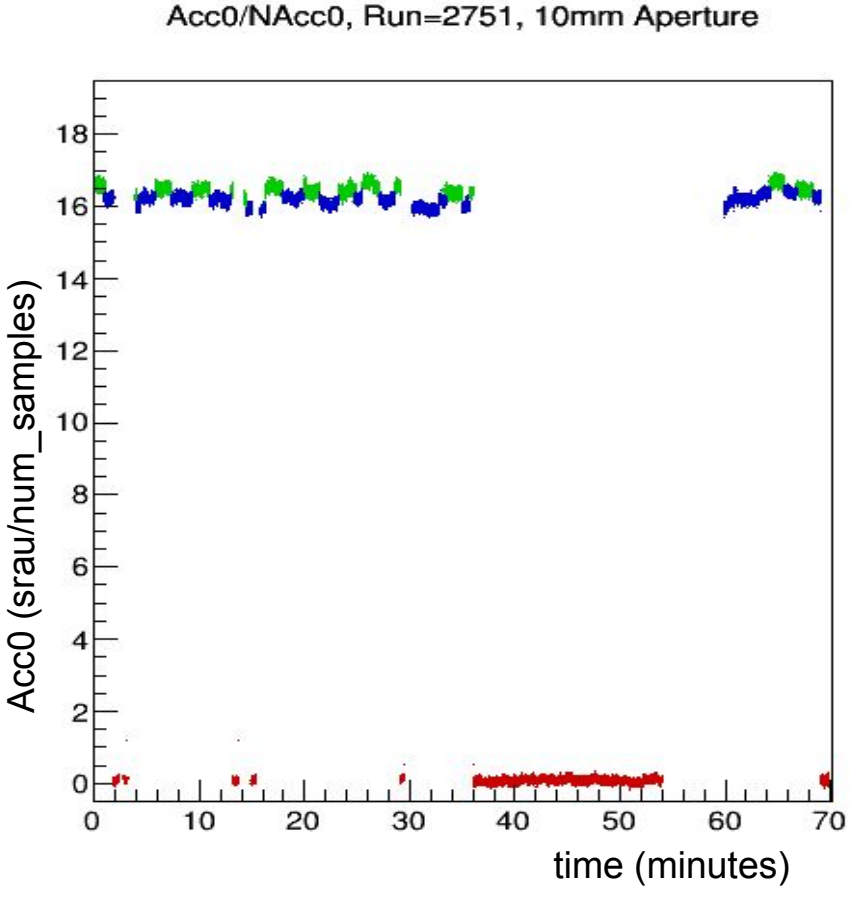


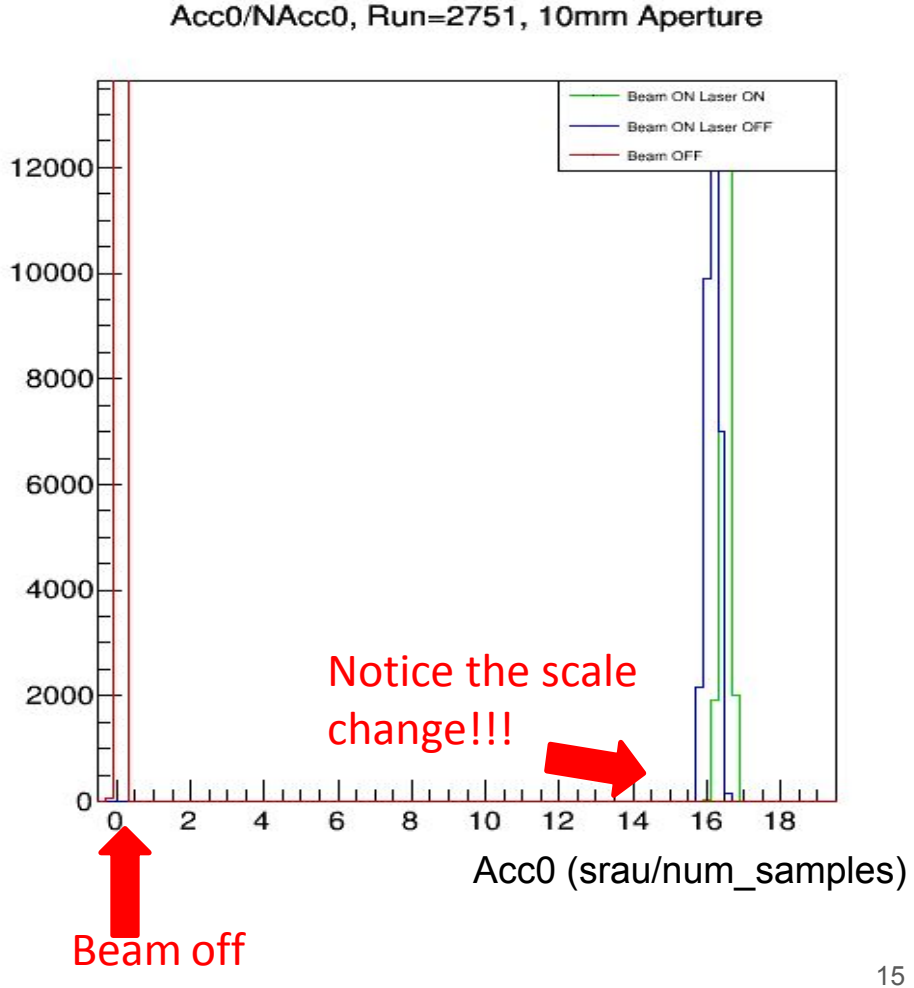
Spring 2016 4-pass running (@15 μA)





Spring 2016 5-pass running (@15 µA)





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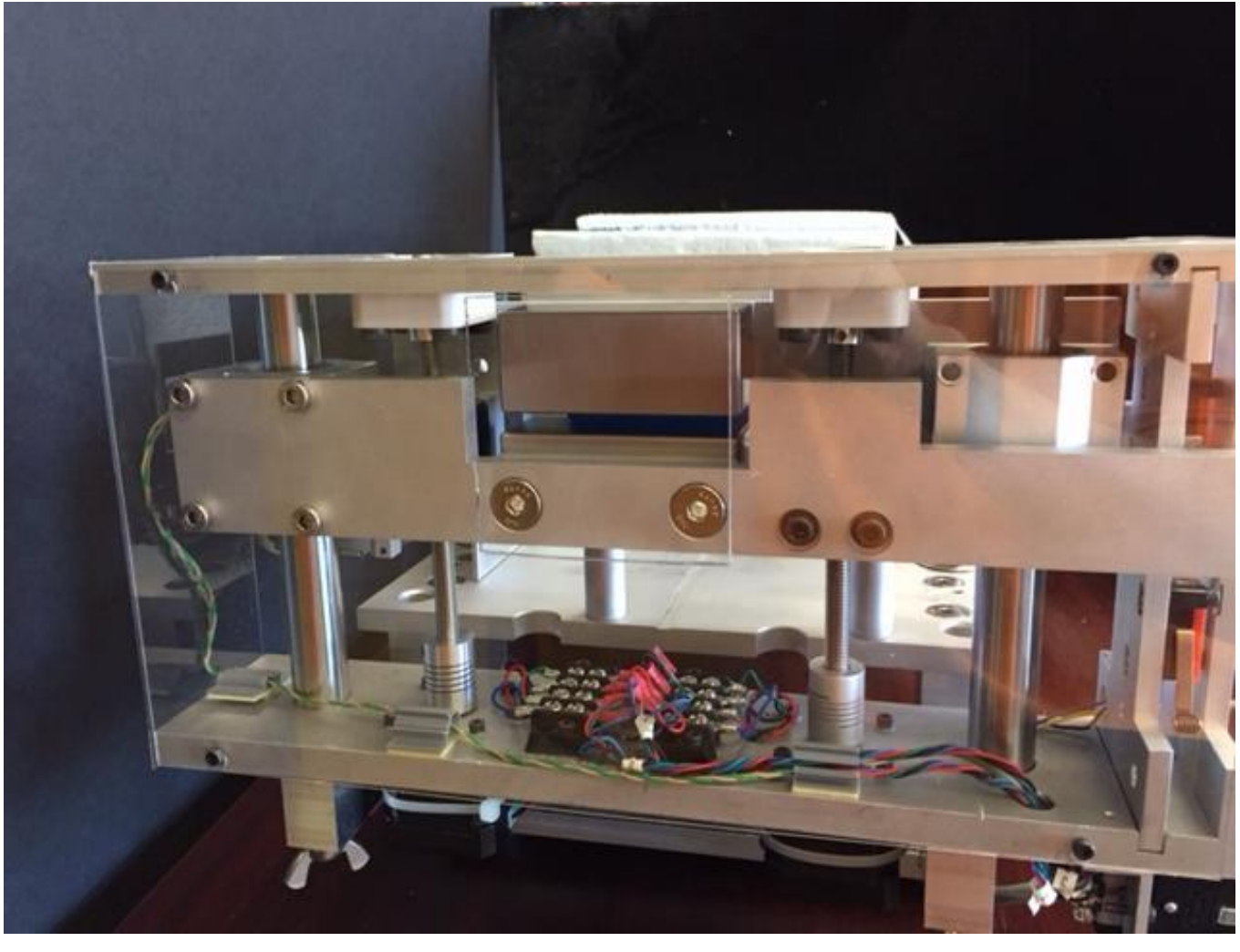
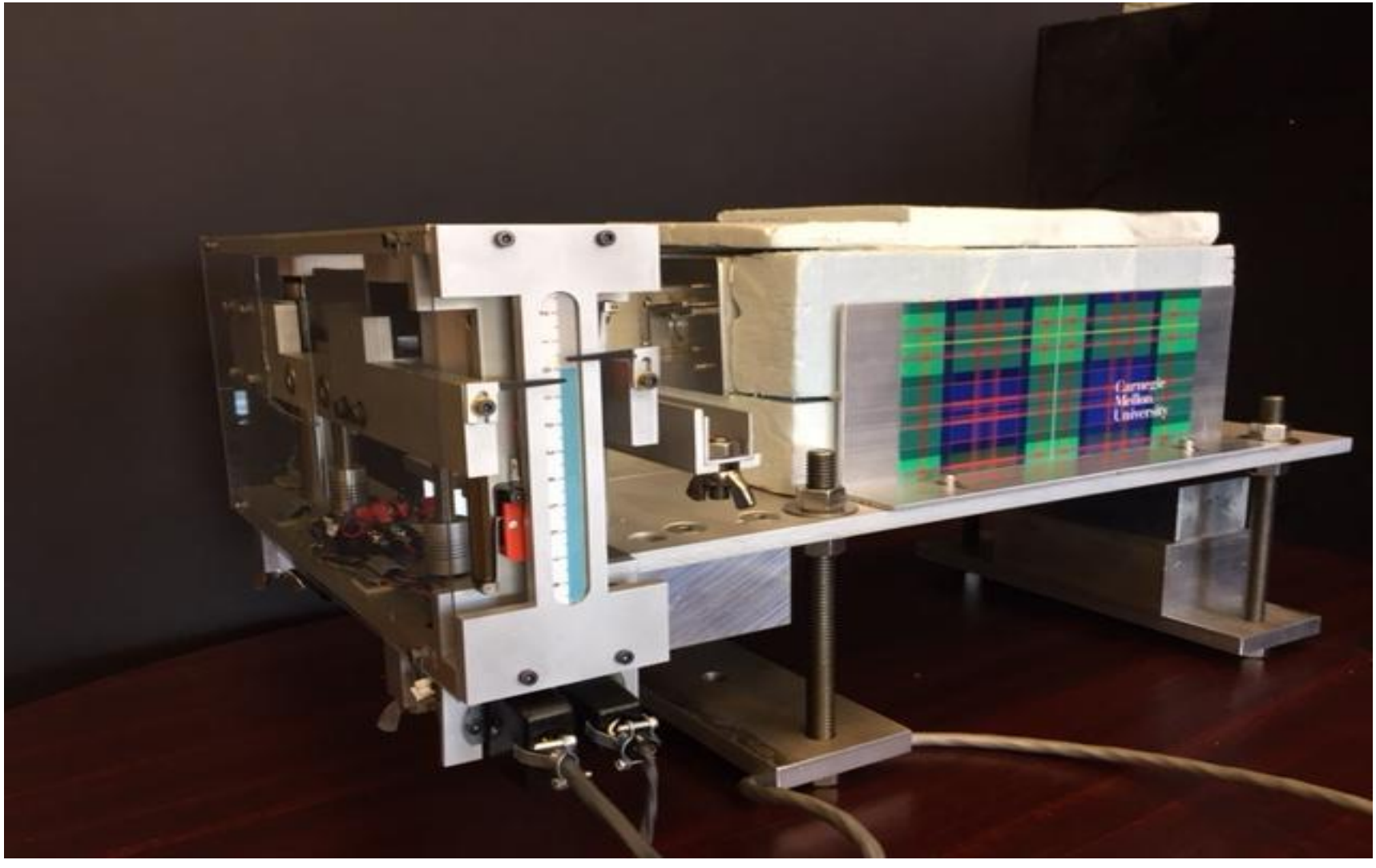
Remote (arduino) controlled Tungsten “JAWS”




Carnegie
Mellon
University

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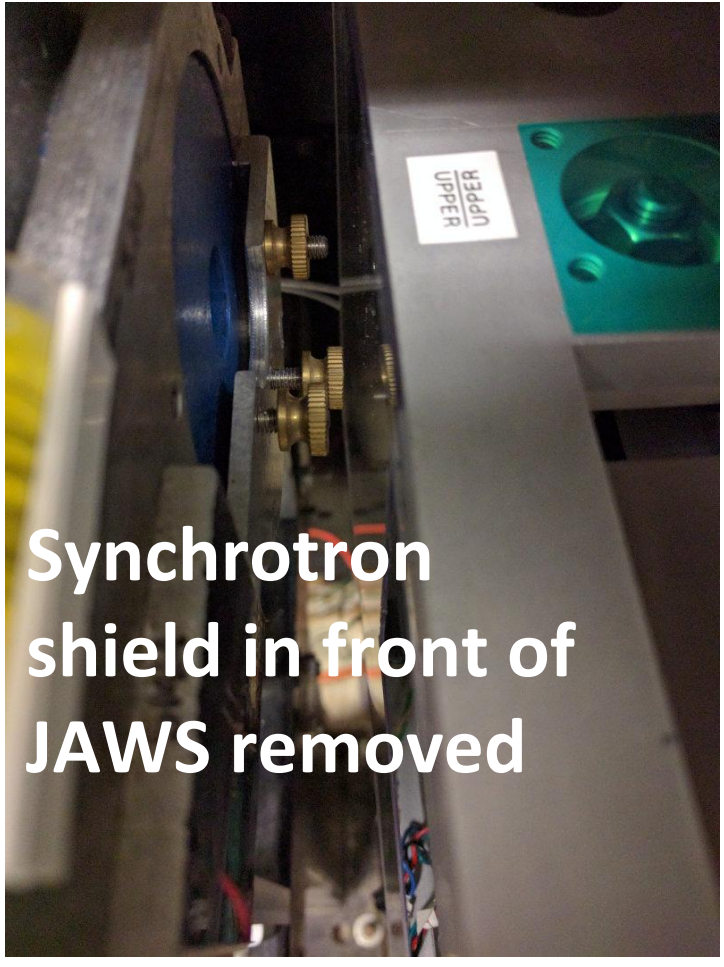
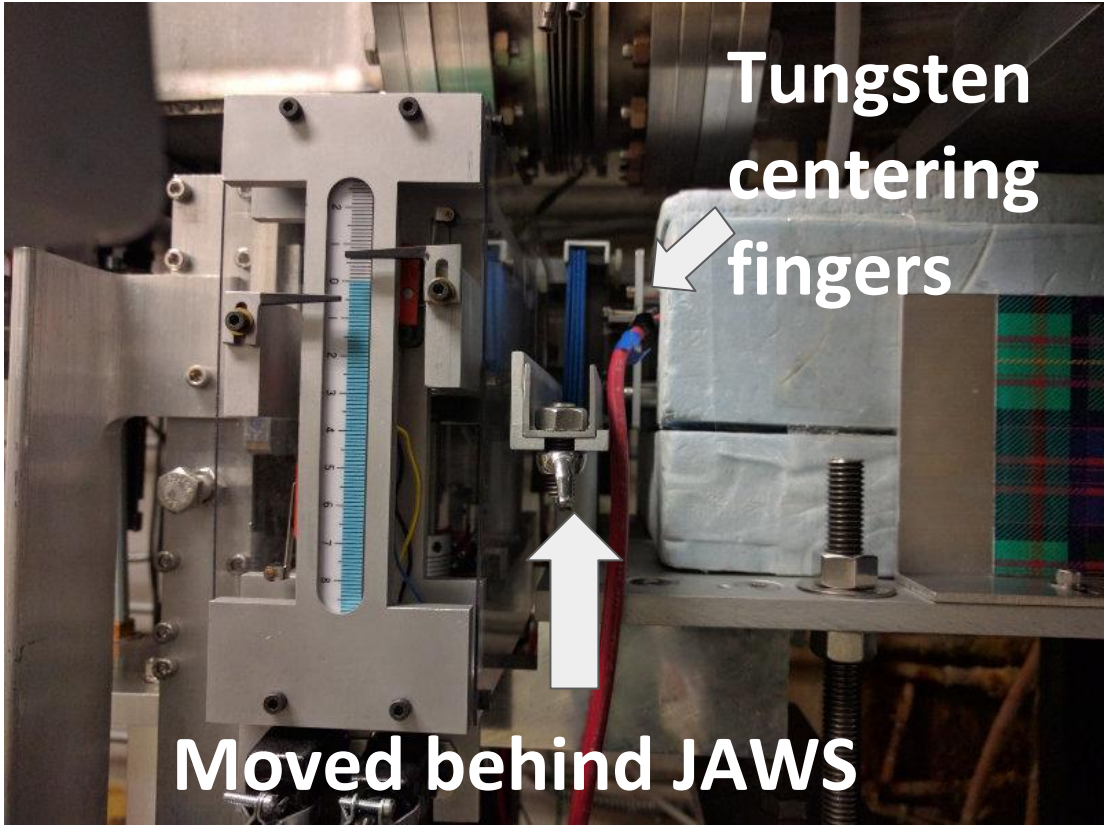
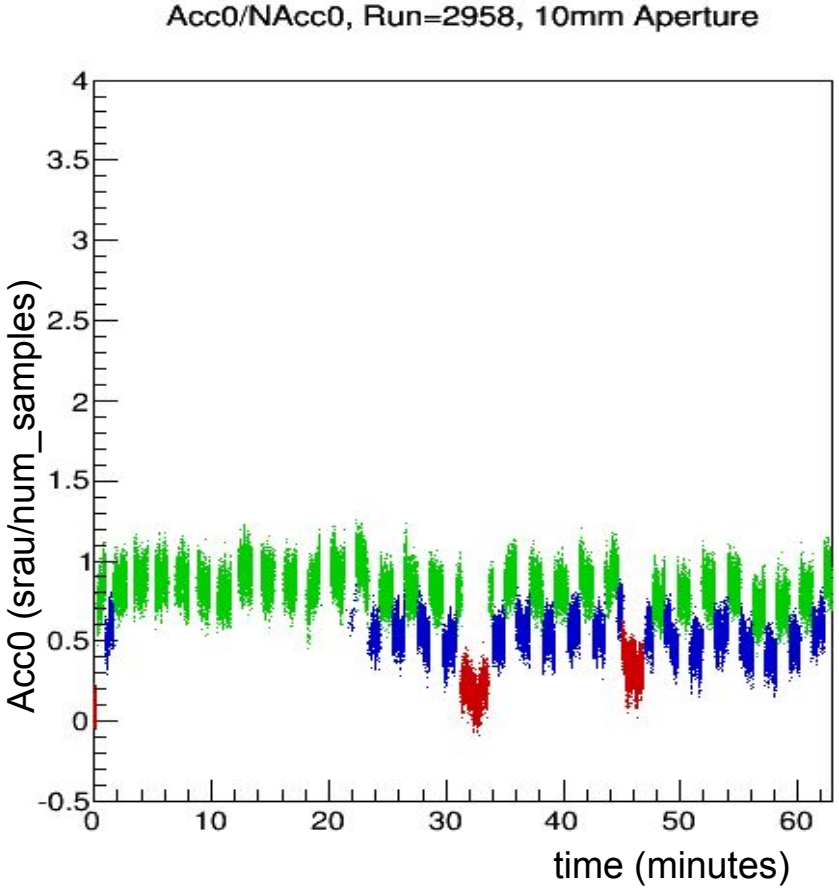
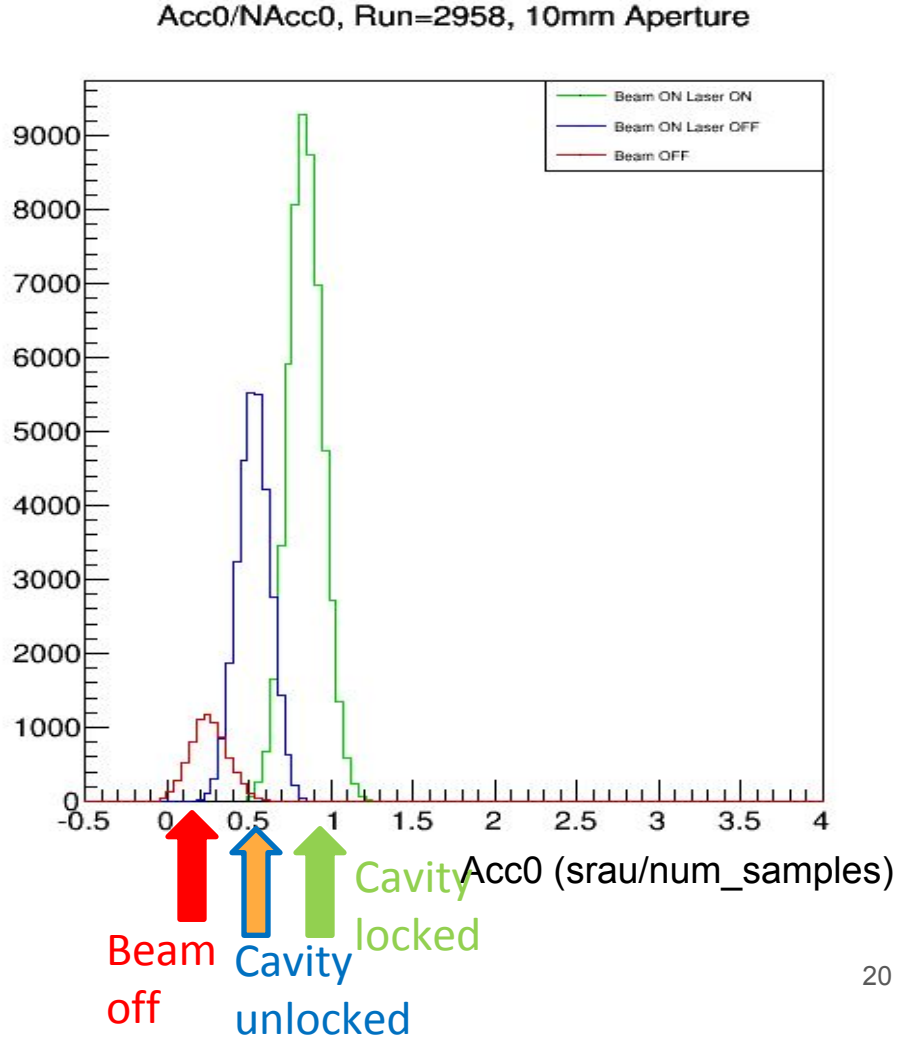




Simulations showed lead-synch shield spread photon beam and JAWS would clip Compton Spectrum.

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





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Unanticipated Discrepancy in No-Threshold vs Threshold

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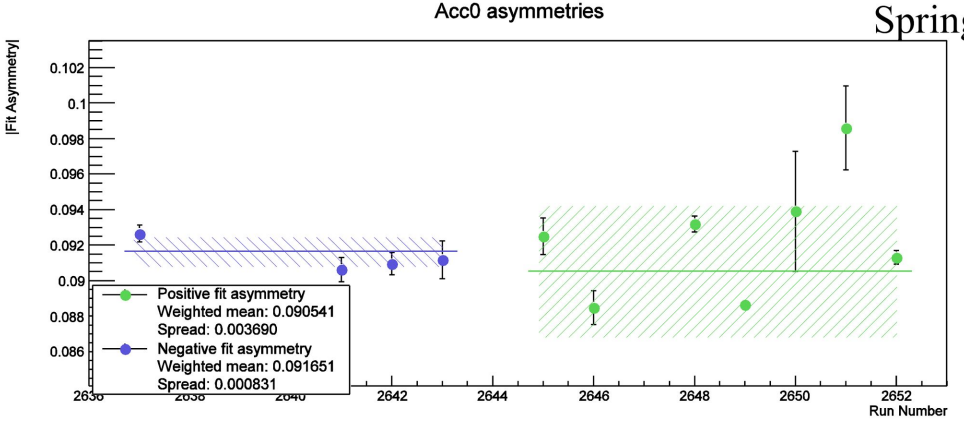
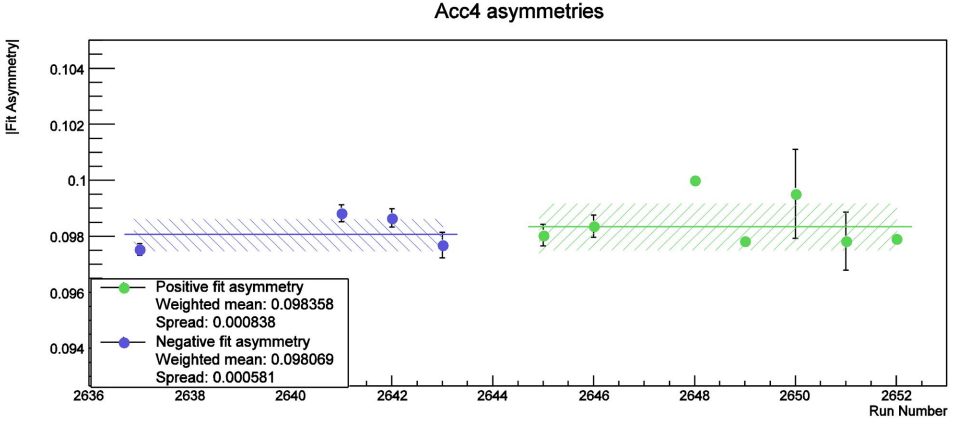
From Brian Quinn's March PREX2/CREX Update

Spring '16 4-pass



Acc0
A=9.1%



Acc4
A=9.8%

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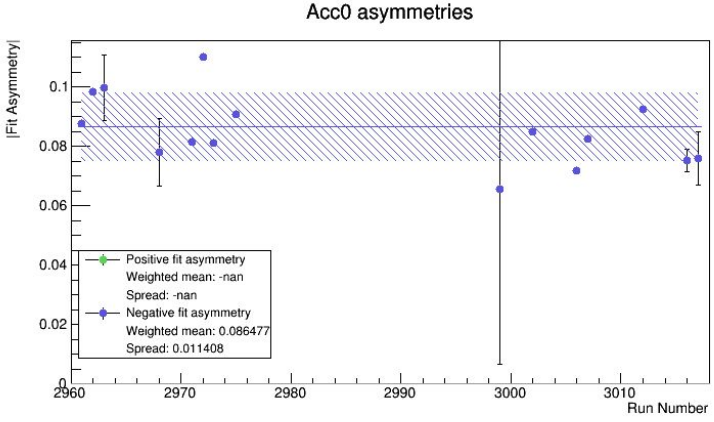

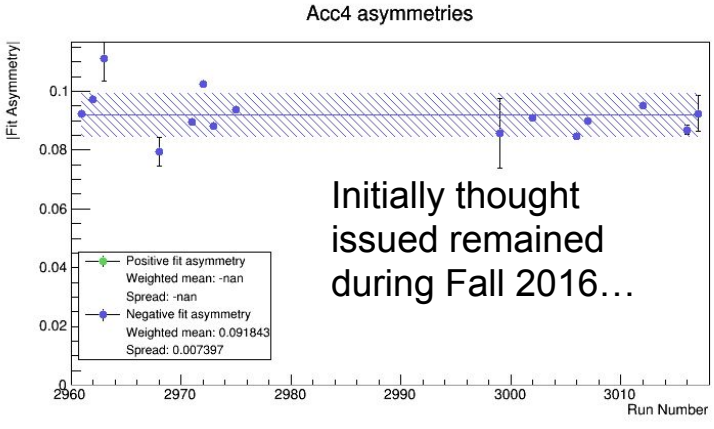

Initially thought issued remained during Fall 2016…

- 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.

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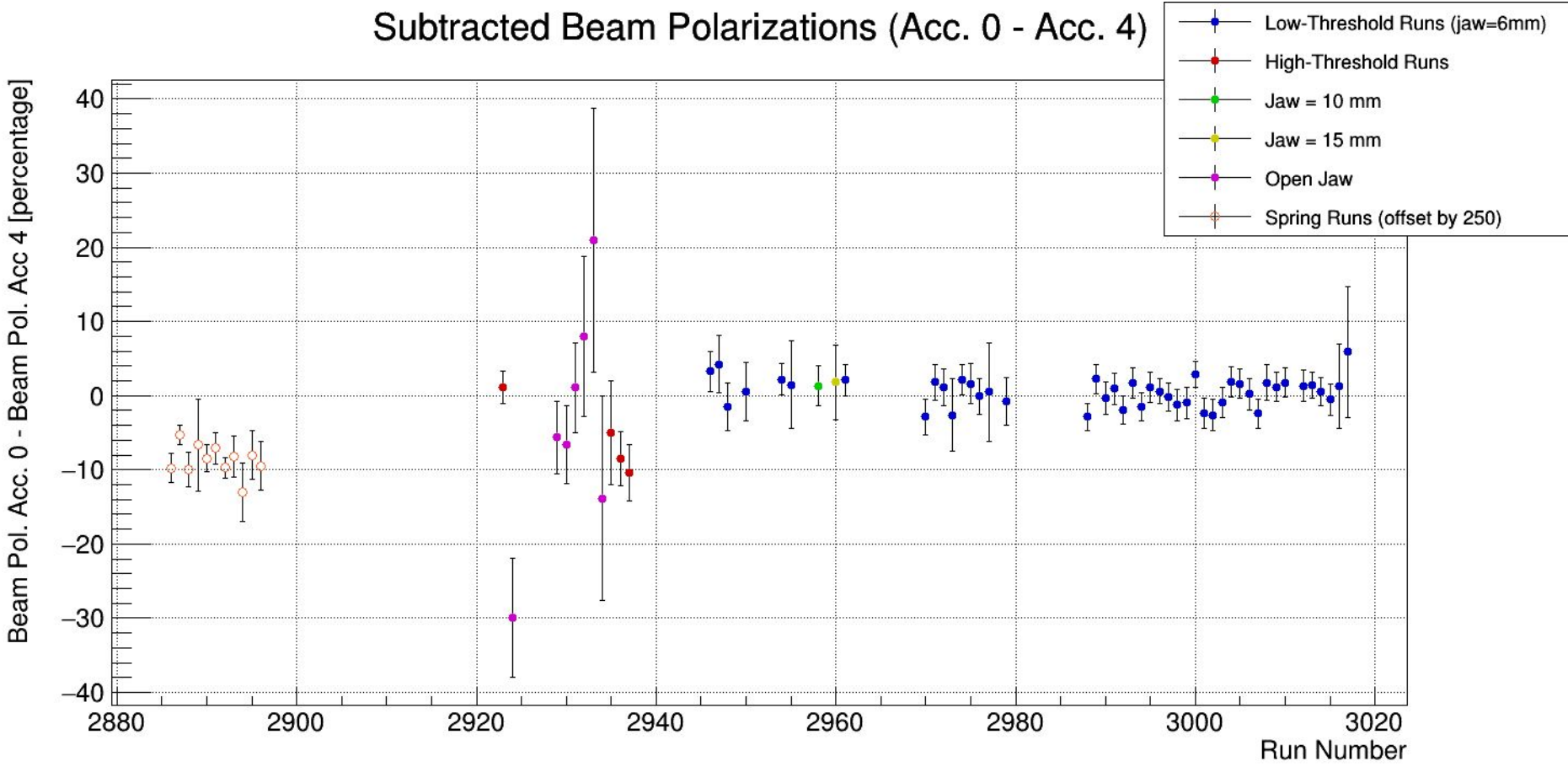
    - Undergraduate CMU student Ian Harris re-analyzed all of Fall 2016 data.
    - Needed to update pedestal, beam and laser calibrations etc...

Fall 2016 Data Shows NO Acc0-Acc4 Discrepancy



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

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    - 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)

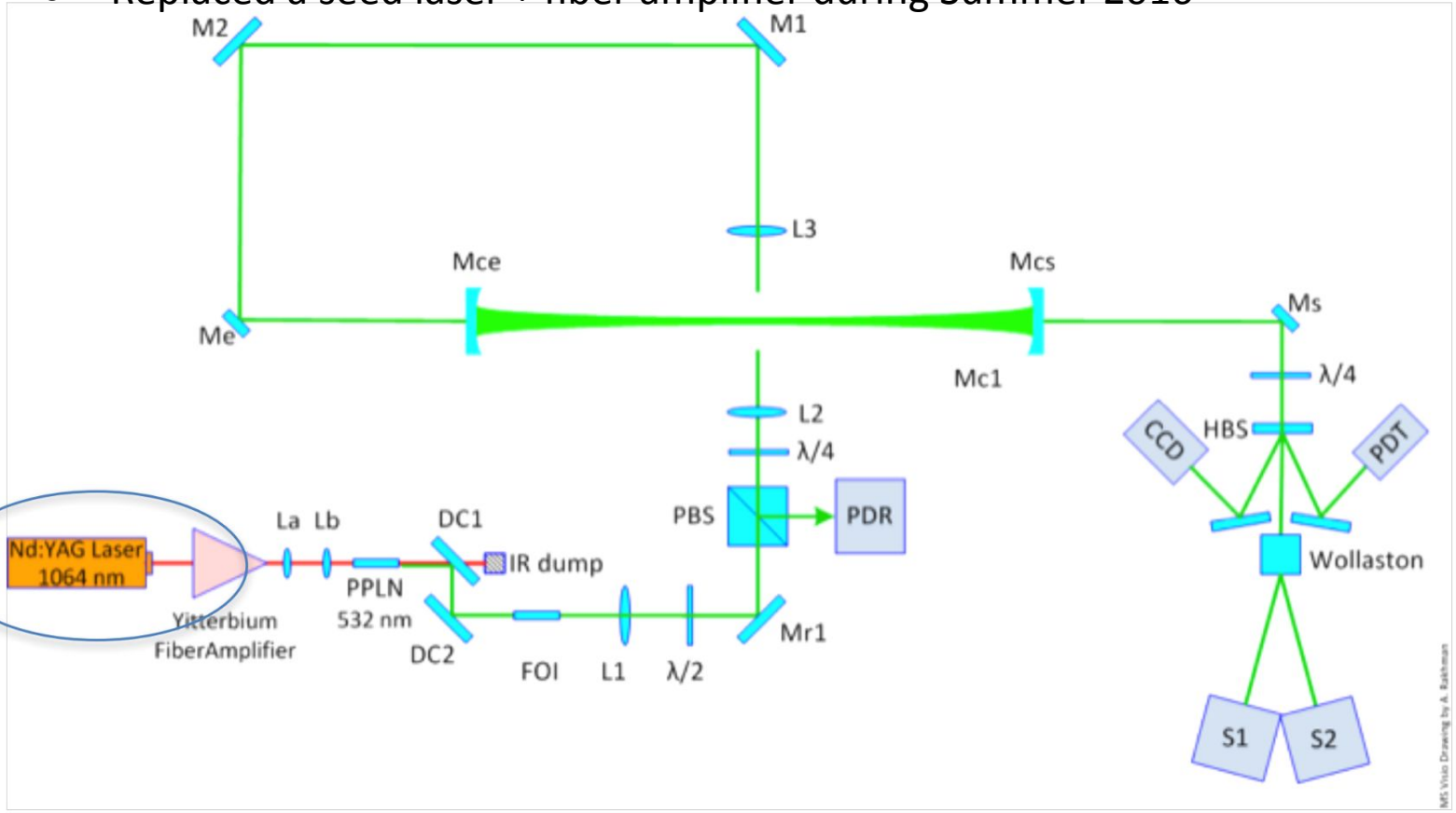
Summary

- 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.

Extras

Compton Laser System Experience with DVCS/GMp

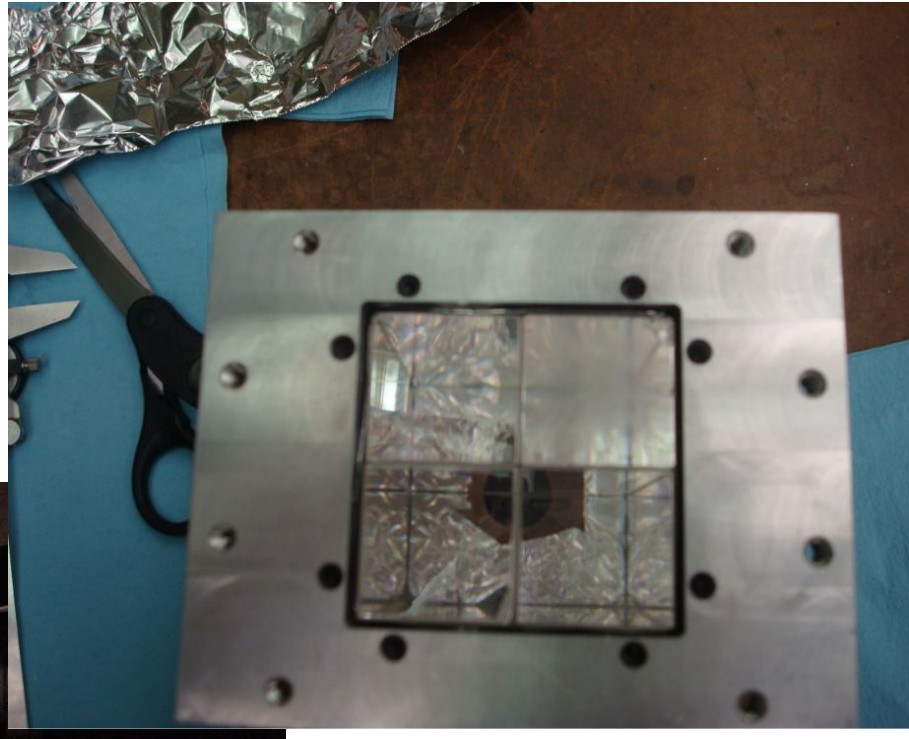
- Compton laser system was fully functional at the start of Fall 2016
  - Replaced a seed laser + fiber amplifier during Summer 2016



Compton Photon 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



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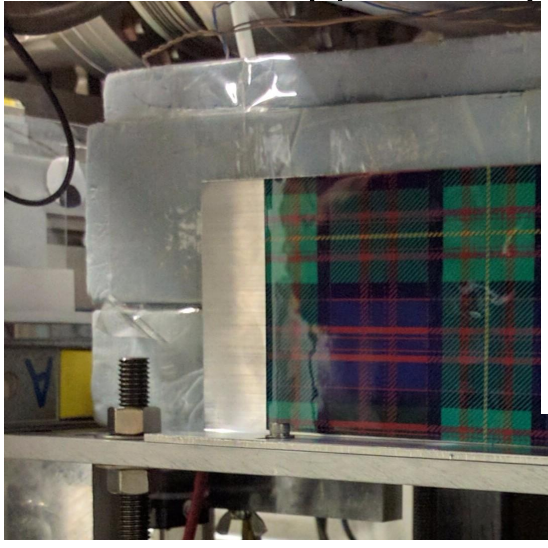
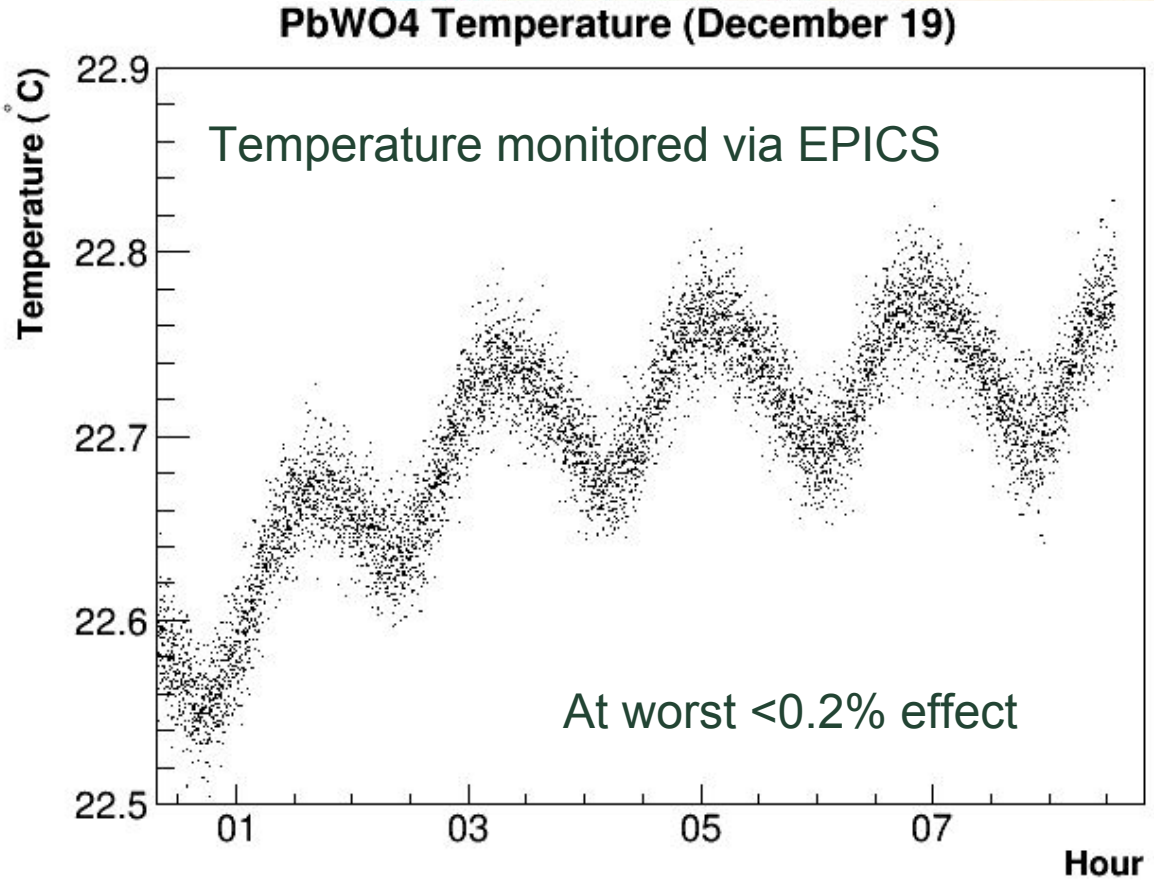
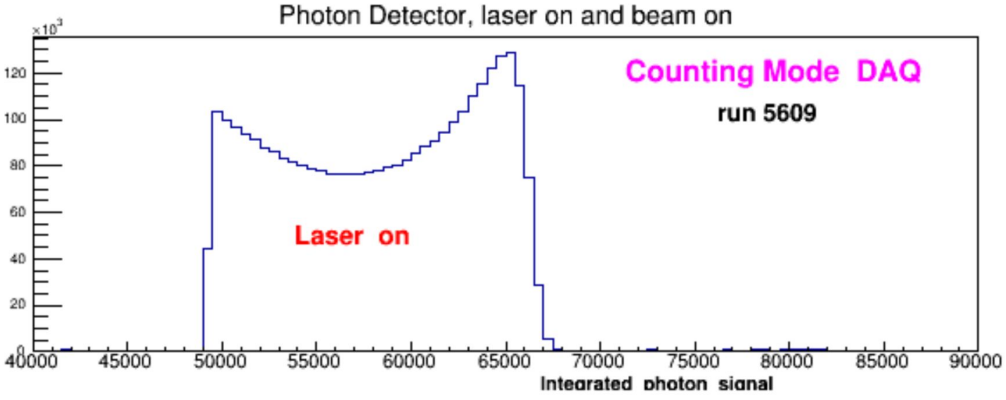


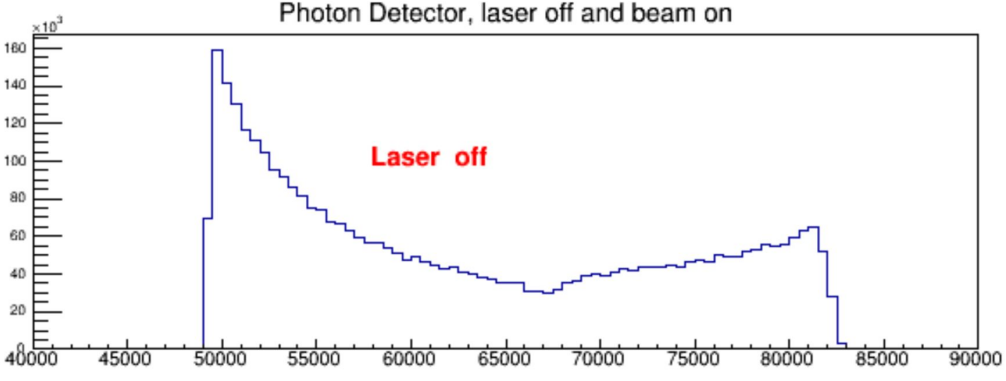


Photon Detector Experience with DVCS

- 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)

Electron Detector Experience and Plans

Silicon strip detector → 240 μm pitch, 192 strips/plane

- Suffering from excessive noise and low efficiency
- Possible excess synchrotron radiation at “high energy”?
  - “Photon stopper” could not be tested in Fall due to a valve being stuck
- Installed one plane of thicker silicon in the Hall for testing (Spring and Fall 2016)
- Tests underway at JLab and Manitoba
  - Check if different amplifier-discriminator or even a better coupling of detector to amplifier-discriminator helps the noise issue
- Evaluating possibility of other detectors for future experimental demands
  - HVMAPS
  - diamond detector (Hall C vendor no longer available)
- Building new DAQ (VETROC) which can also be better integrated with Photon DAQ