Polarimetry: Update at the Hall A Winter 2019 Collaboration Meeting

Simona Malace
On behalf of the Hall A Compton & Moller Polarimetry Groups

(Compton slides from D. Gaskell)

Beam Polarization via Moller

$$A_{beam} = A_{zz}\, P_{foil}\, P_{beam}$$

measured

from simulation

from theory

needed

Table taken from talk by K. Paschke

Achieved

PREX-I
E=1.1 GeV, 5°
A=0.6 ppm

Charge Normalization	0.2%
Beam Asymmetries	1.1%
Detector Non-linearity	1.2%
Transverse Asym	0.2%
Polarization	1.3%
Target Backing	0.4%
Inelastic Contribution	<0.1%
Effective Q^2	0.5%
Total Systematic	**2.1%**
Total Statistical	**9%**

PREX-II
E=1.1 GeV, 5°
A=0.6 ppm

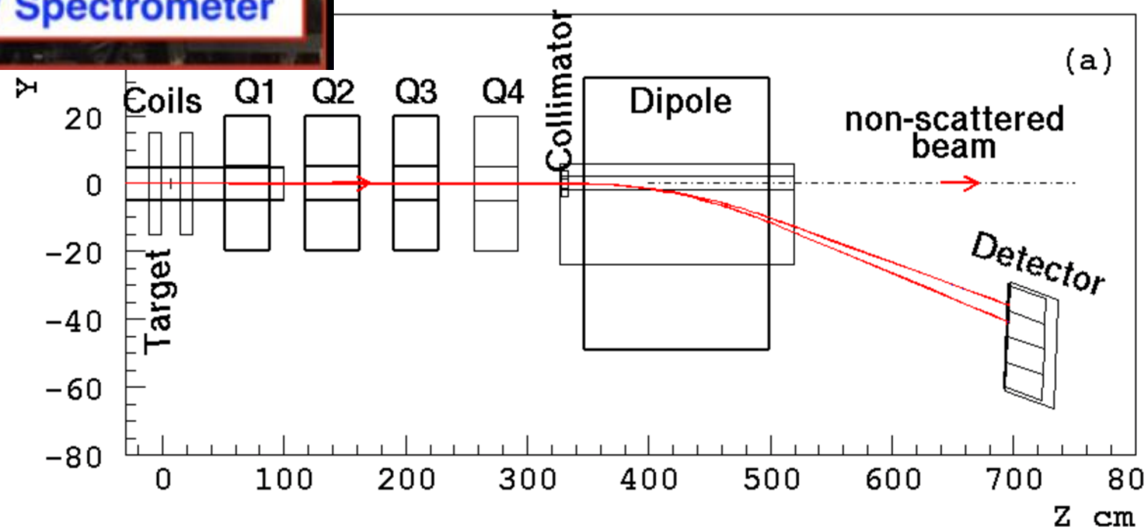
Charge Normalization	0.1%
Beam Asymmetries*	1.1%
Detector Non-linearity*	1.0%
Transverse Asym	0.2%
Polarization*	1.1%
Target Backing	0.4%
Inelastic Contribution	<0.1%
Effective Q^2	0.4%
Total Systematic	**2%**
Total Statistical	**3%**

CREX
E=2.2 GeV, 4°
A = 2 ppm

Charge Normalization	0.1%
Beam Asymmetries	0.3%
Detector Non-linearity	0.3%
Transverse Asym	0.1%
Polarization	0.8%
Target Contamination	0.2%
Inelastic Contribution	0.2%
Effective Q^2	0.8%
Total Systematic	**1.2%**
Total Statistical	**2%**

Table from talk by from Bill Henry

Hall A Moller Overview

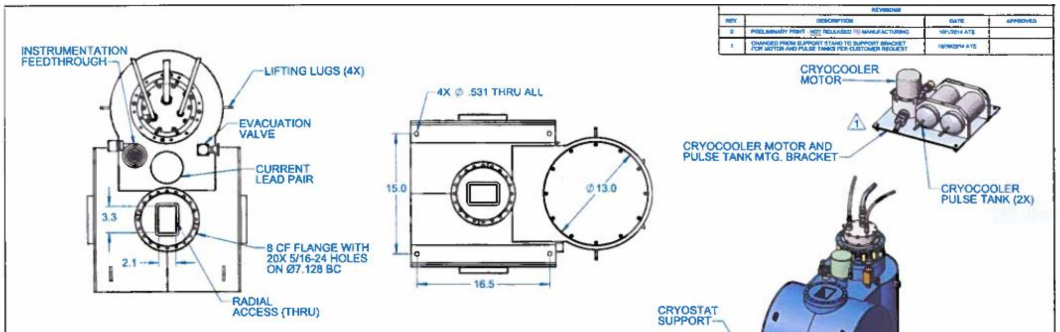


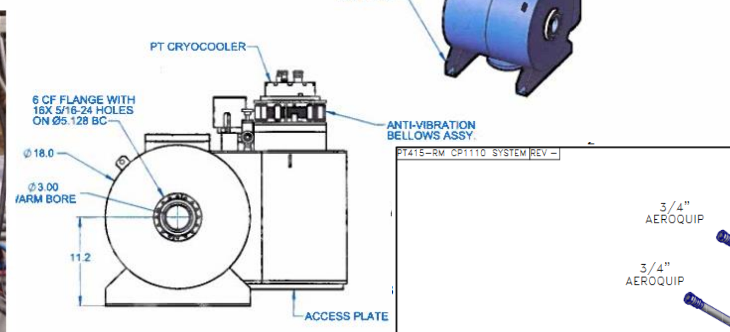
Need to know/have:

→ Target polarization
→ Target magnet field map (field map in simulation)
→ Moller spectrometer acceptance (fields of QQQQD, apertures, precise location of detectors)
→ Levchuk effect in simulation
→ Radiative corrections in simulation
→ Good simulation for good optics solutions
→ ….

Hall A Moller Update: Target Magnet

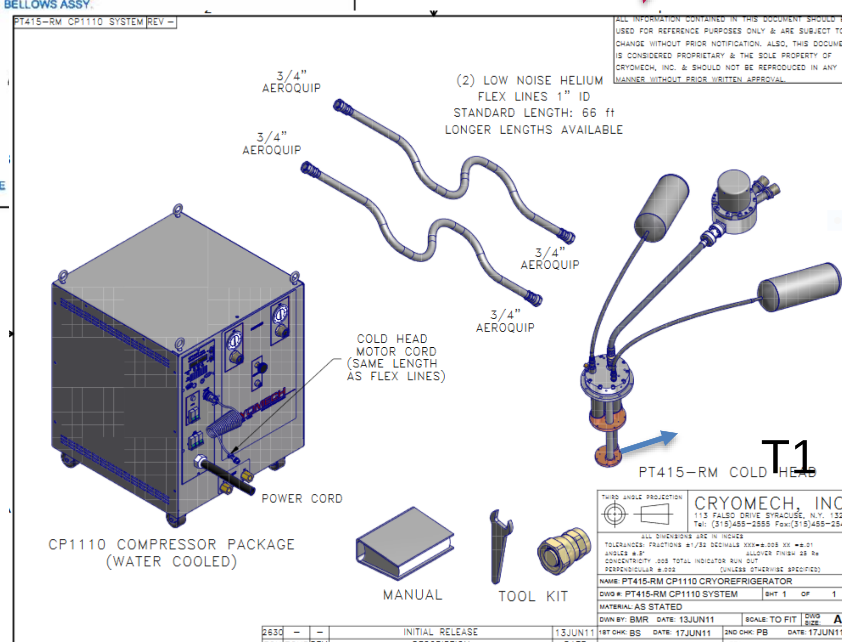
→ Used to saturate the Fe foils; field up to 4 T





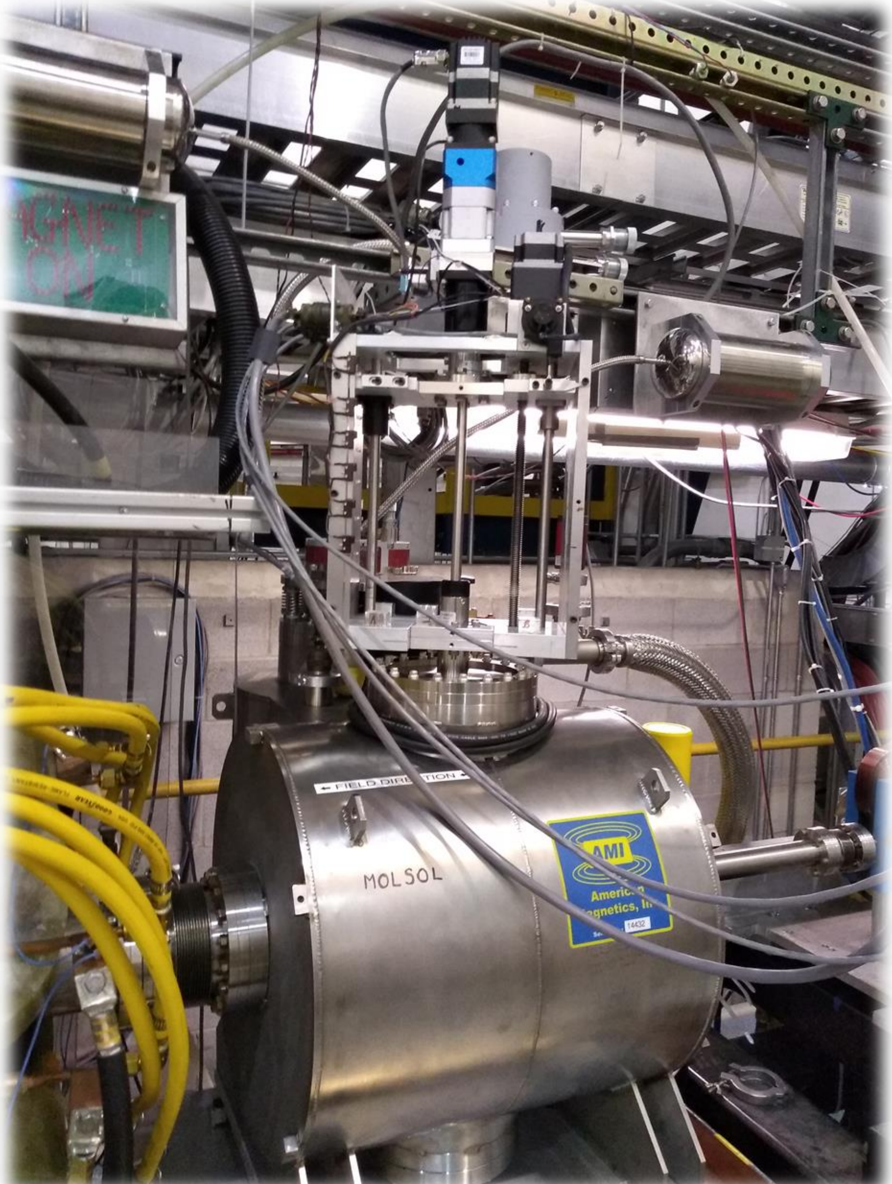
→ Split coil, superconducting magnet from American Magnetics

→ Conduction cooled by a pulse tube cryogenic refrigerator



Water chiller to cool He compressor

Hall A Moller Update: Target Magnet



→ Magnet is working, has been tested/used in the ESB and then moved to the Hall in December (Ethan, Javier, Jack made this magnet work)

→ Installed in the beam line before the holiday shutdown and surveyed and aligned to 300 microns tolerance

→ It was cooled this week and ramped to 10 A (out of 80.5) two days ago (all good)

→ I plan to ramp to 4 T before the hall lockup (for exercise)

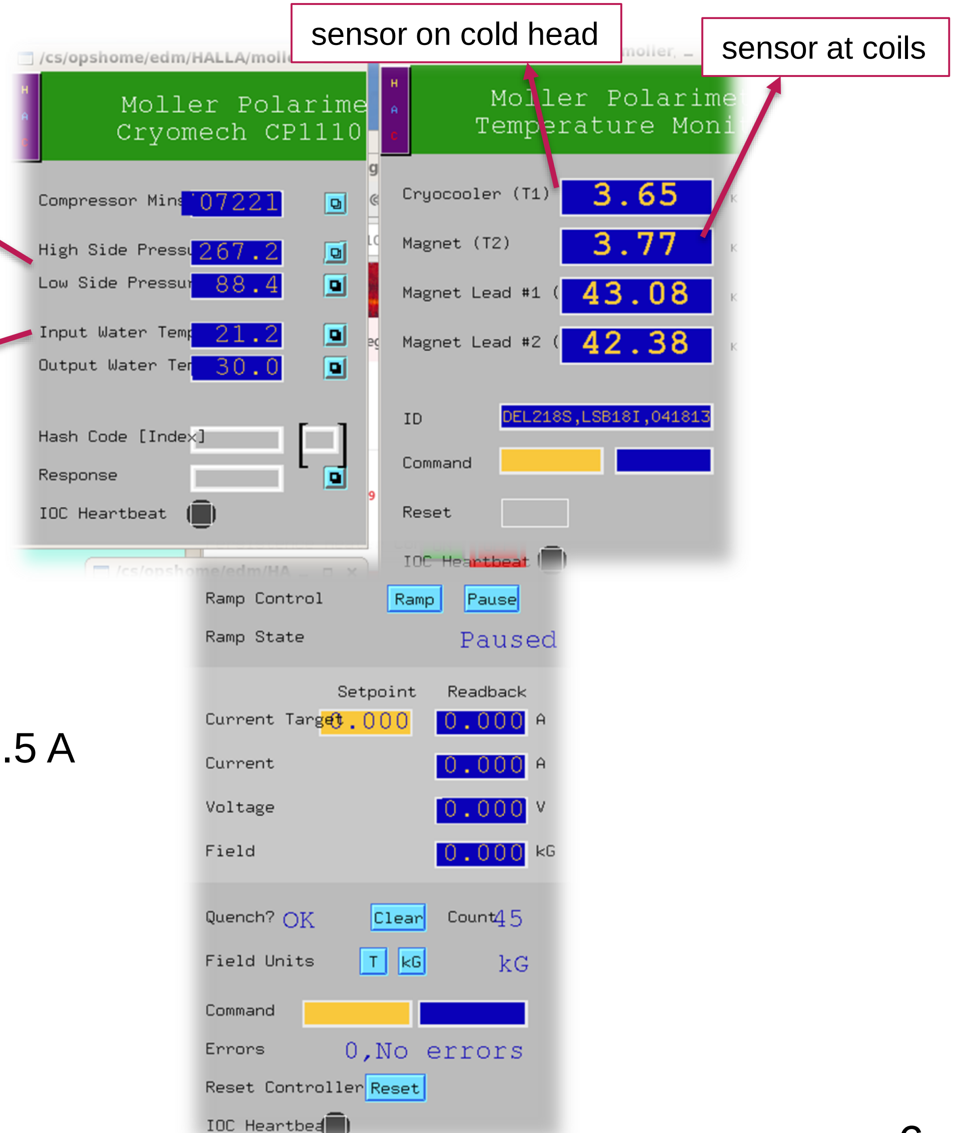
→ A beam test is planned at the end of APEX (during Hall A Polarimetry commissioning) to check the magnet alignment with beam

Hall A Moller Update: Target Magnet

Monitor the magnet/magnet system parameters

Pressures on He lines that run from compressor to the cold head

Temperature of water (from air cooled chiller) that cools the He compressor



Operating the magnet

→ Current limited by the power supply to 80.5 A

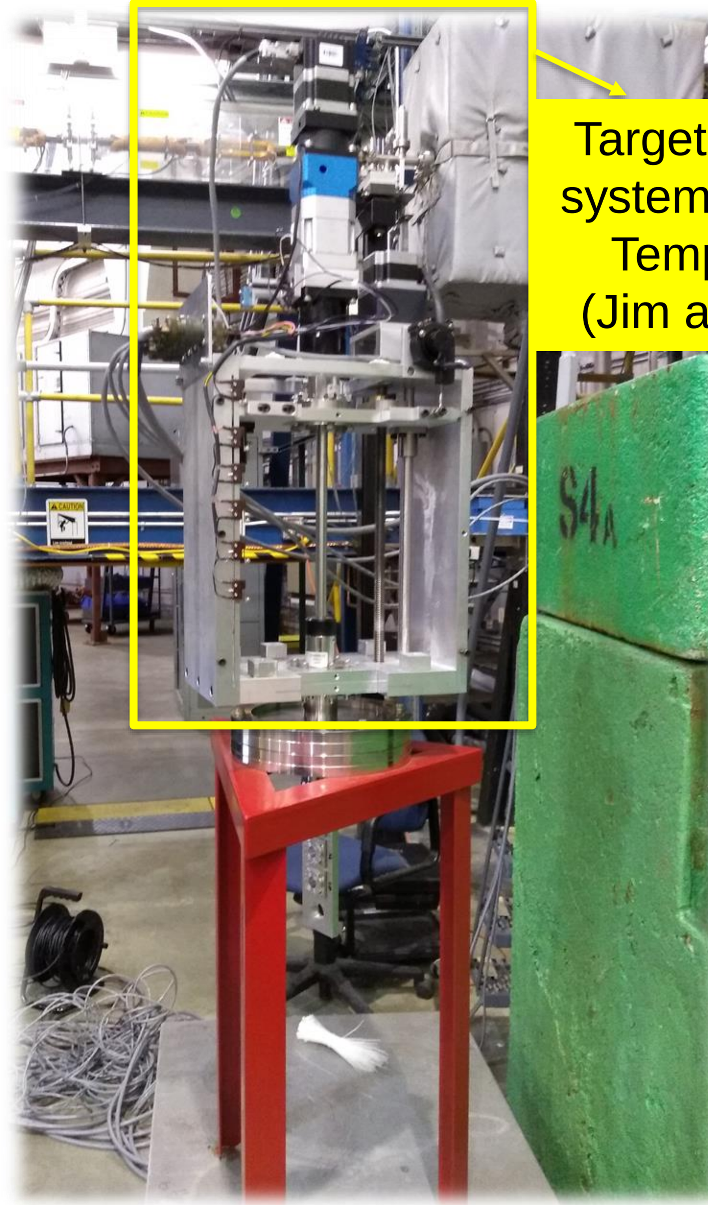
Ramp rates:

→ from 0 to 70 A: 0.0254 A/s
→ from 70 to 80 A: 0.0213 A/s

The field to current ratio is: 0.0536 T/A

Hall A Moller Update: Target

Ladder with 3 Fe foils installed: 1, 4 and 10 microns (1 micron is 99.85 % purity while the other two are 99.99%)



Target motion system built by Temple U. (Jim and Bill)

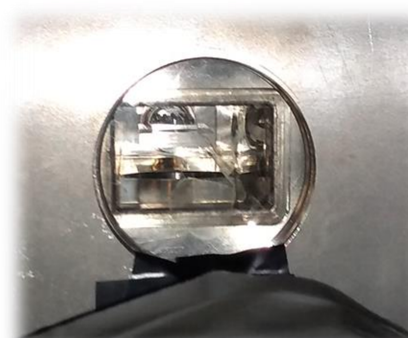
Hall A Moller Update: Target

→ Foils were installed on the ladder ~the day of survey; target was installed in magnet and vacuum pump down started within ~48 h from foil installation

→ The ladder and foils were surveyed w.r.t. the beam line

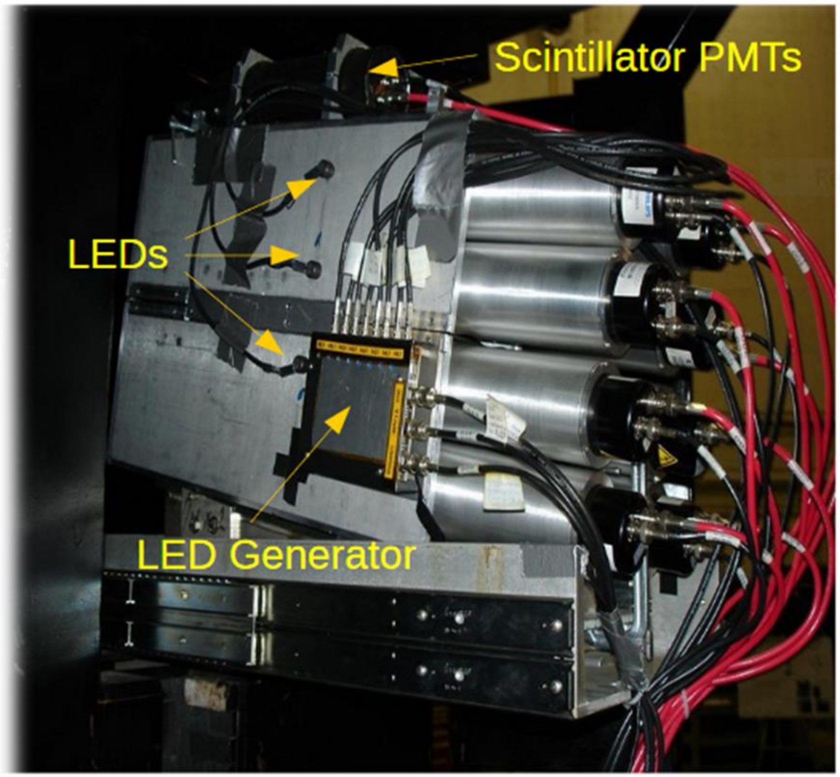
→ Once target was installed in the magnet very little adjustment was needed to position ladder perp to beam

→ Survey results will be available very soon to update the target motion software

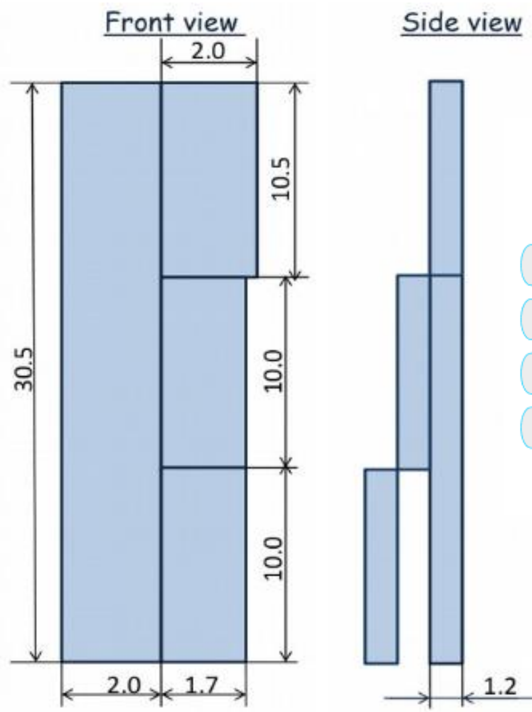


Jefferson Lab

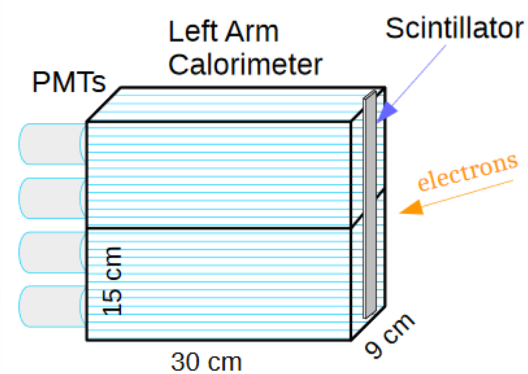
Hall A Moller: Detectors



Scintillators



Calorimeter

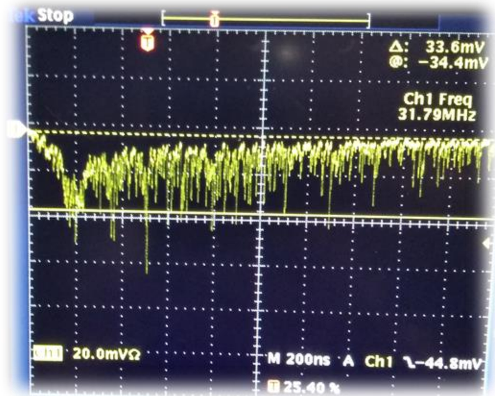


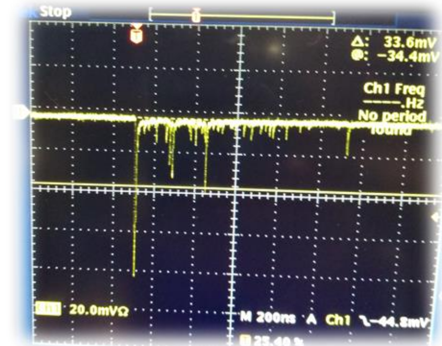
→ Scintillators: 4 paddles per side connected via light guides to Hamamatsu 1 inch PMTs (Hamamatsu R4124)

→ Calorimeter: lead+scintillating fiber, 2 bocks per side each block connected to two 2 inch PMTs (Photonis XP2282B)

Hall A Moller Update: Detectors

→ Checked all PMTs few months ago and found that the PMTs attached to the scintillators exhibit behavior consistent with vacuum contamination (the calorimeter ones look good)

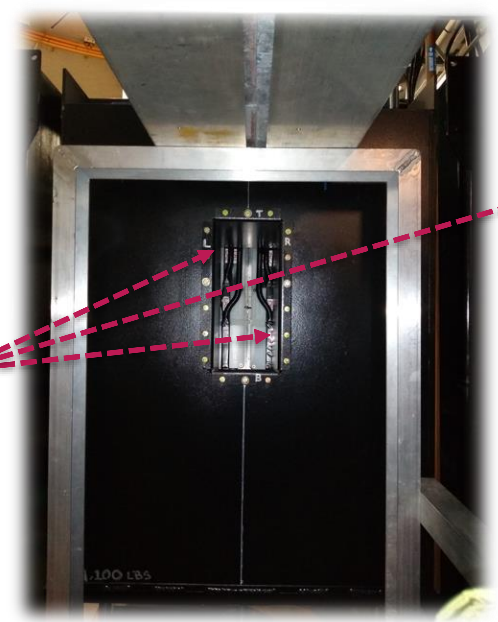


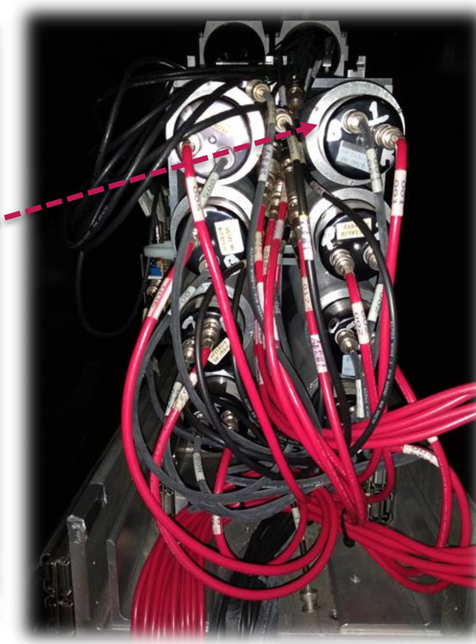


→ At the end of last year placed order for 9 R4124 PMTs (will replace before PREX)

<u>Surveys</u>:

→ To improve the accuracy of the simulation few surveys were done in December 2018 and this month (it remains to be decided whether any realignment will be needed)

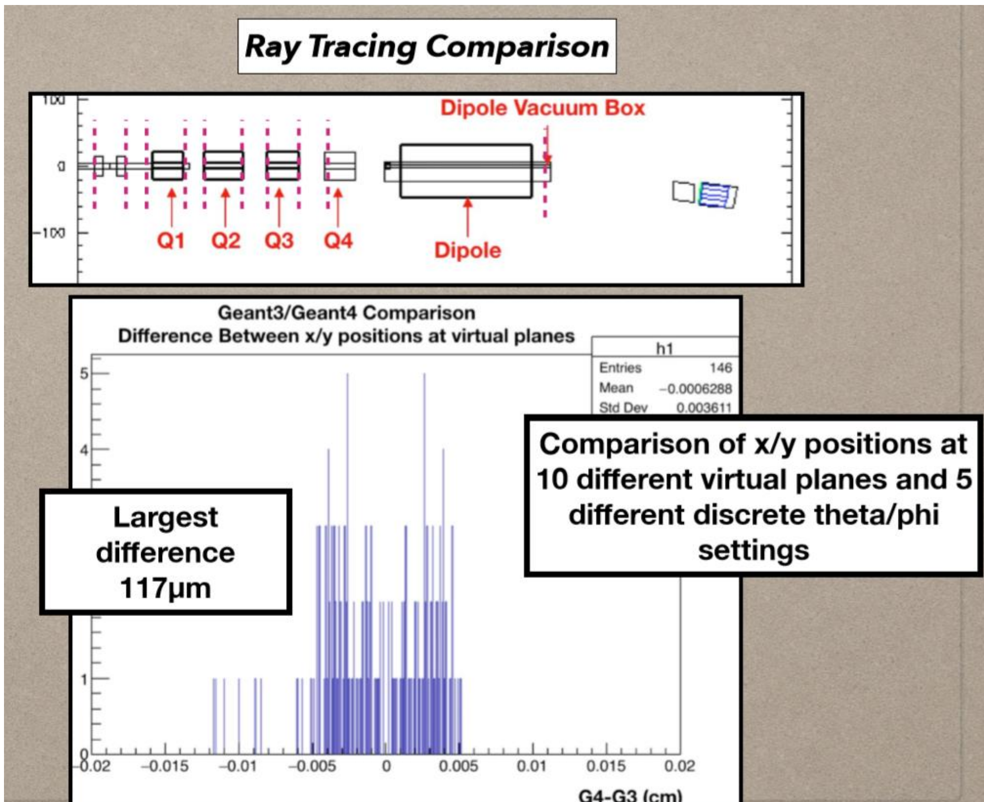


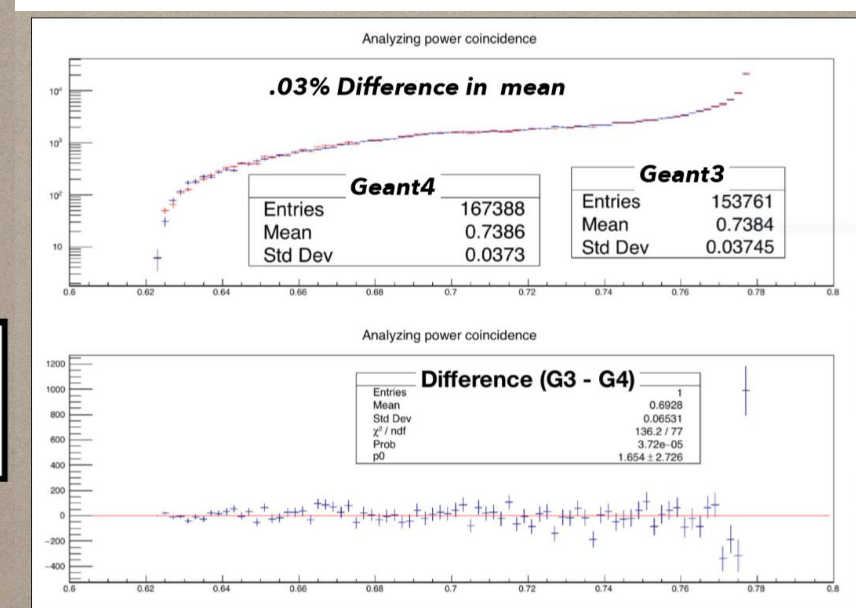


Hall A Moller Update: Simulation

→ Very fruitful effort from users (Don jones, Bill Henry, Eric King, Sanghwa Park…) to write a Geant4 simulation to replace the Geant3 simulation used so far

→ The Geant4 simulation has been validated and will be used to produce optics solutions for future running





Plots from Bill Henry

Hall A Polarimetry: Commissioning

→ Scheduled at the end of the APEX running for 3 days

Moller Plans

→ Check alignment of the target magnet with beam: test developed right now by Yves

→ Detector gains and thresholds tuning

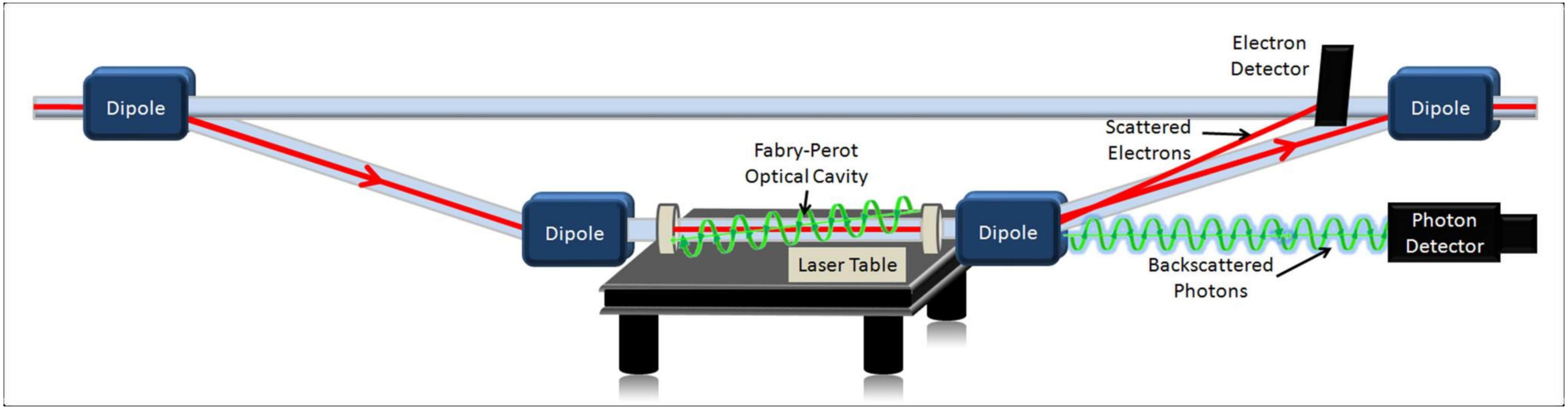
→ Check target foils centering

→ Check target saturation by varying the orientation of foils w.r.t. beam

→ Quads and Dipole scans

→ Holding field reversal study

Hall A Compton Overview



1. Laser system: Few kW stored power in FP cavity, precise knowledge of circular polarization
2. Photon detector: GSO crystal at low energies, PbWO4 at higher energies → LED pulser system to monitor/measure linearity
3. Electron detector: segmented (strip) detector → 240 μm pitch, 192 strips/plane

   → Not presently installed. Hope to install for CREX to test new options

1. DAQ: CMU, integrating mode photon DAQ. New counting mode photon DAQ + new electron detector DAQ under development

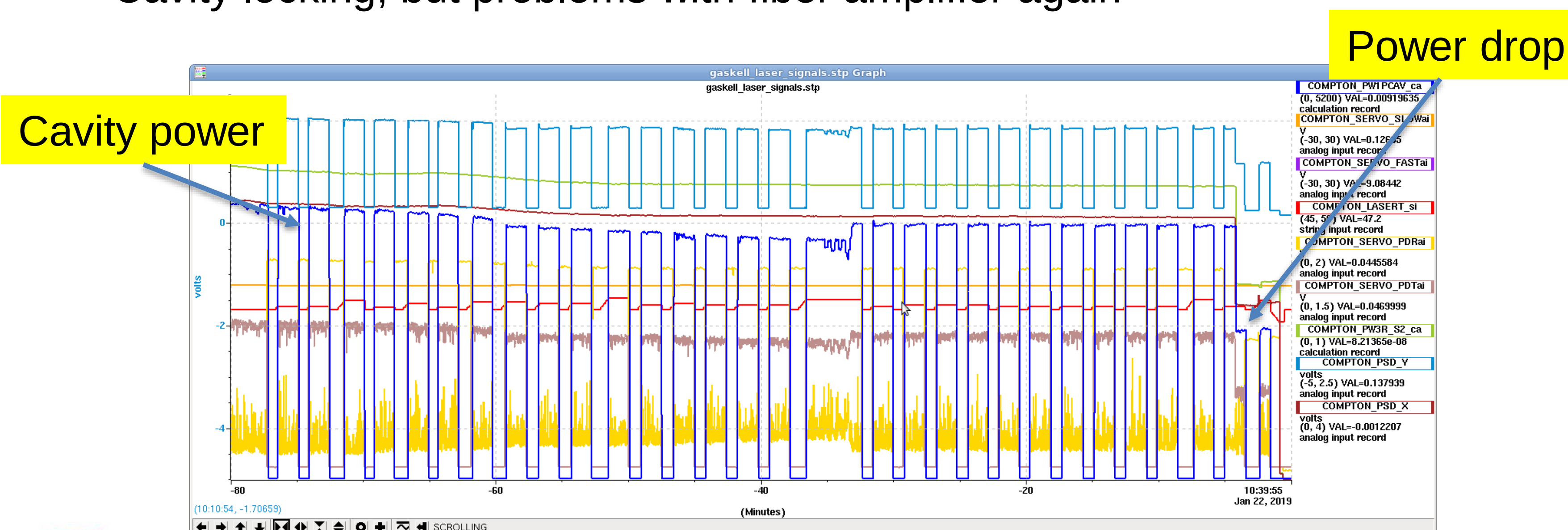
Compton Laser and Cavity Status

Multiple hardware issues over the last few years:

- Replaced seed laser
- Replaced fiber amplifier (5 W amp went bad)
- Remote mirror controller issues
- Cavity mirrors degraded

Preparations for PREX/CREX underway:

- Summer 2018: Installed repaired 5 W fiber amp
- December 2018: Replaced cavity mirrors
- Cavity locking, but problems with fiber amplifier again

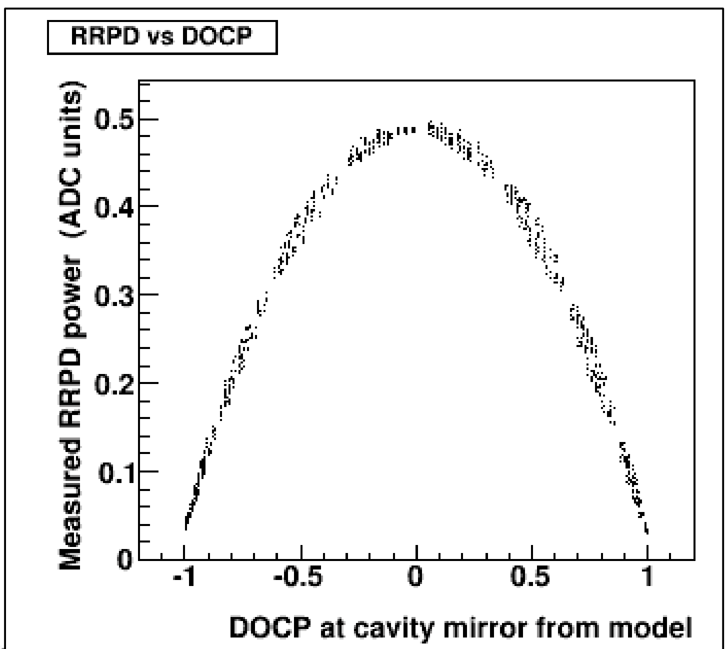


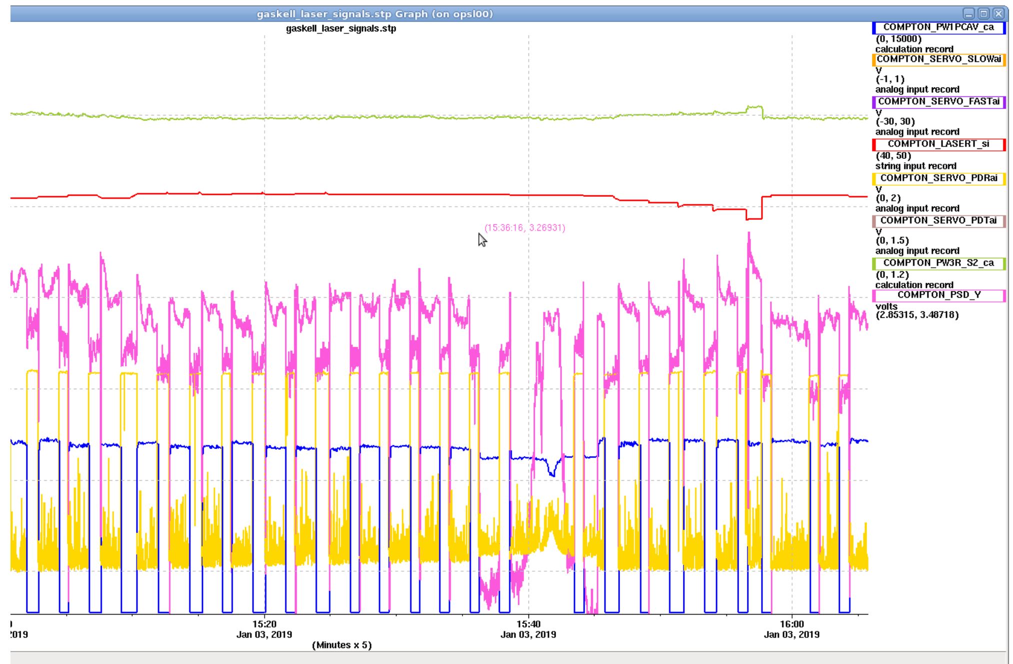
Cavity Polarization Optimization

Optimize degree of circular polarization in cavity by monitoring/analyzing light reflected from cavity, as was done in Hall C (Q-Weak)

→ 1st stage optimization system was done in 2015

QWP/HWP scans give reasonable results – consistent with quality of data obtained in Hall C

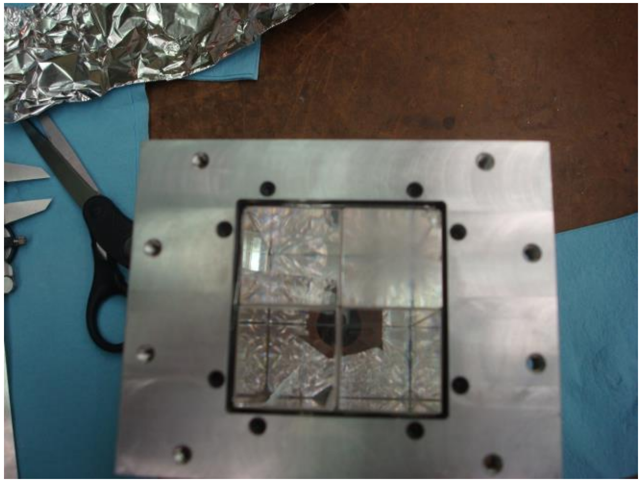


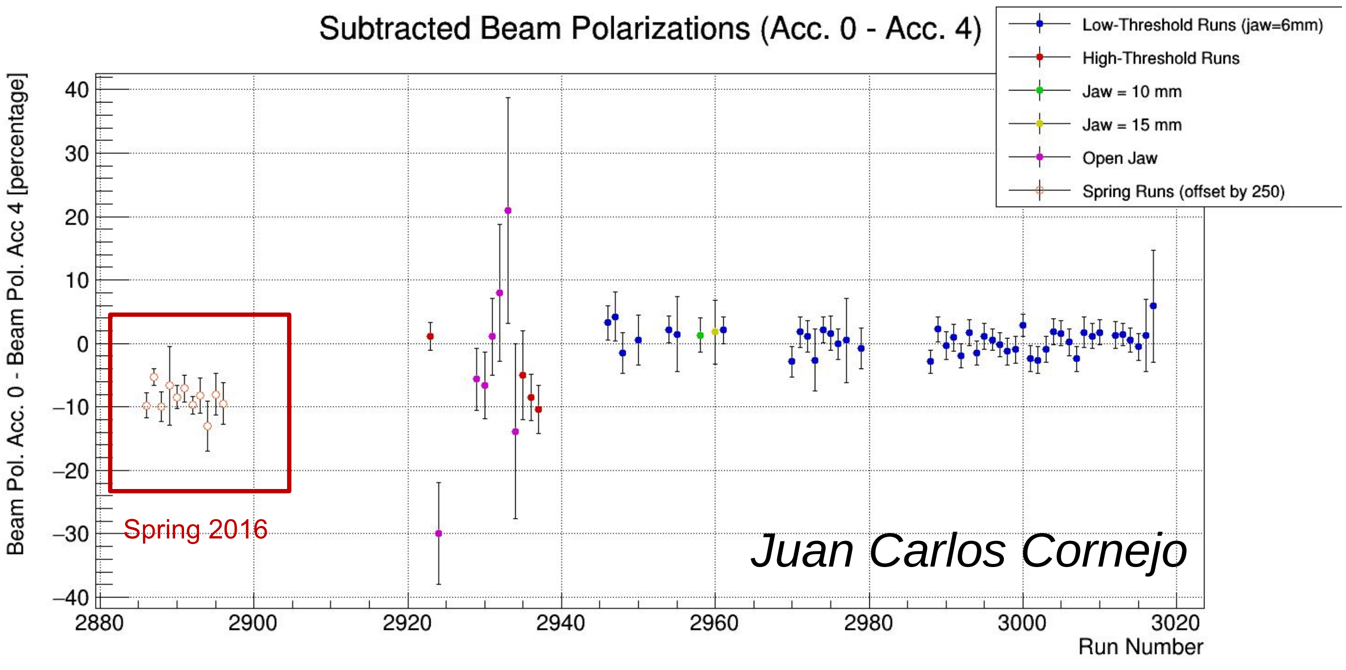


Strange behavior when cavity is locked – power in “RRPD” increases – should get smaller
→ Implies possible polarization effect

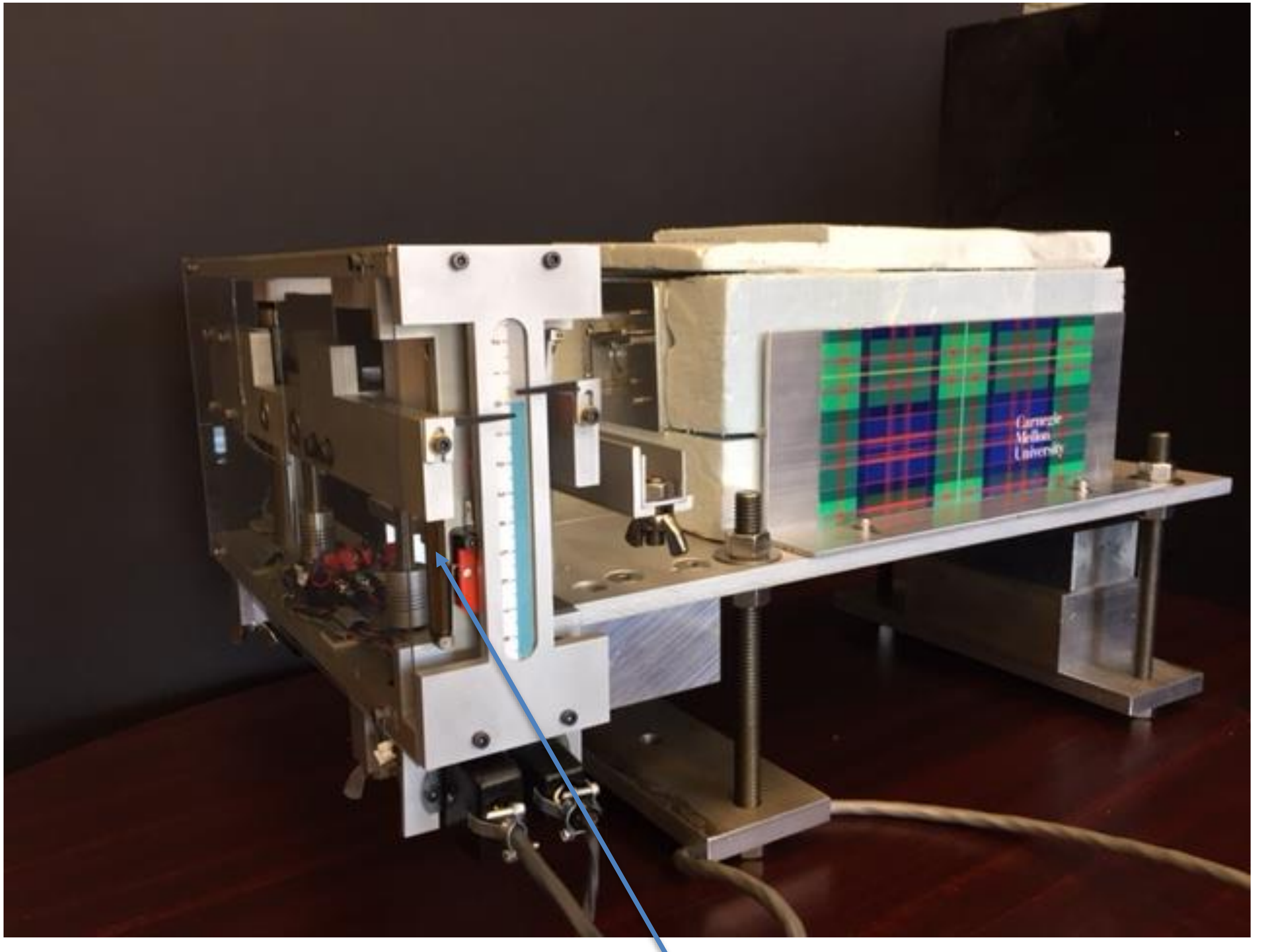
Integrating Photon Detector – PbWO4

During DVCS running, used lead tungstate
→ GSO not suitable for higher energies – backscattered photons ~ 3 GeV at 11 GeV
→ Read out using CMU integrating DAQ
→ Initially, saw differences in asymmetry between "thresholdless" readout, and asymmetry from readout with "low" threshold
→ This difference went away after installation of adjustable synchrotron shield (JAWS)





Remotely adjustable collimator



Remote (arduino) – controlled Tungsten "JAWS"

Integrating Photon Detector - GSO

GSO will be used for upcoming PREX and CREX experiments

Preparations:

→ Linearity tests and PMT/base optimization (CMU, UVa)

→ CMU integrating DAQ resuscitation and checkout (CMU, Stony Brook)

→ GSO stand adjustment and fitting (accommodate new 12 GeV Compton chicane geometry)

GSO installed in hall – will be used if there is opportunity during tests after APEX

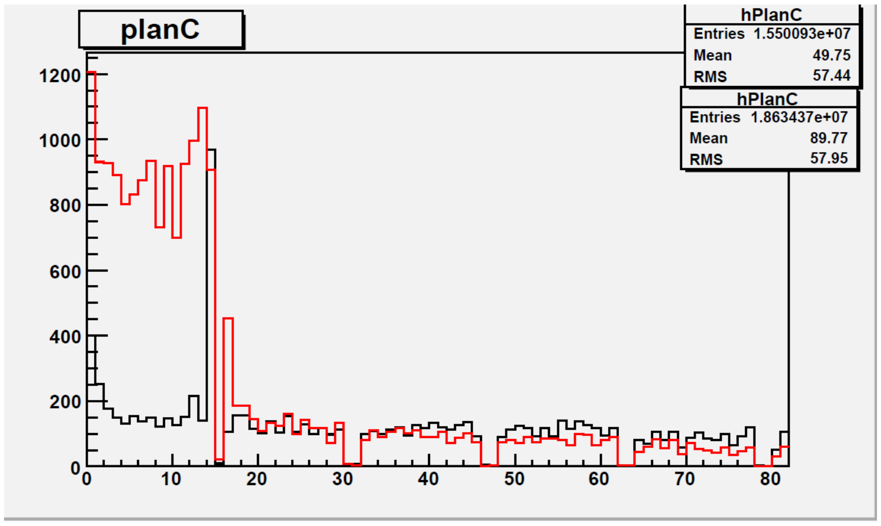
Electron Detector

Existing electron detector system has not worked well in 12 GeV era

→ Excess noise, signal too small

→ Likely culprit is path to get small signals from silicon strip detectors to amplifier discriminators (capacitance too large)

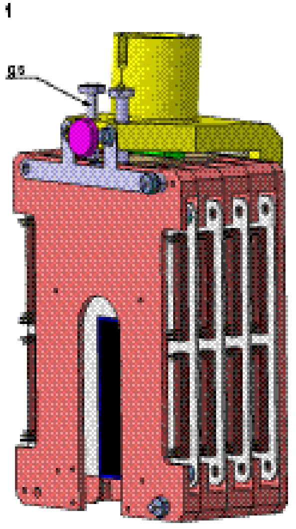
→ Existing amplifier discriminators also operate in "fixed width" mode – 1 μs pulse for any hit



For CREX run, hope to try a couple alternatives

→ Amplify signal from strips on carrier board (in vacuum chamber)

→ Test Hall C amplifier-discriminator (QWAD), signal with proportional to time above threshold



Hall A Polarimetry: Commissioning

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Moller Plans

- → Check alignment of the target magnet with beam: test developed right now by Yves
- → Detector gains and thresholds tuning
- → Check target foils centering
- → Check target saturation by varying the orientation of foils w.r.t. beam
- → Quads and Dipole scans
- → Holding field reversal study

Compton Plans

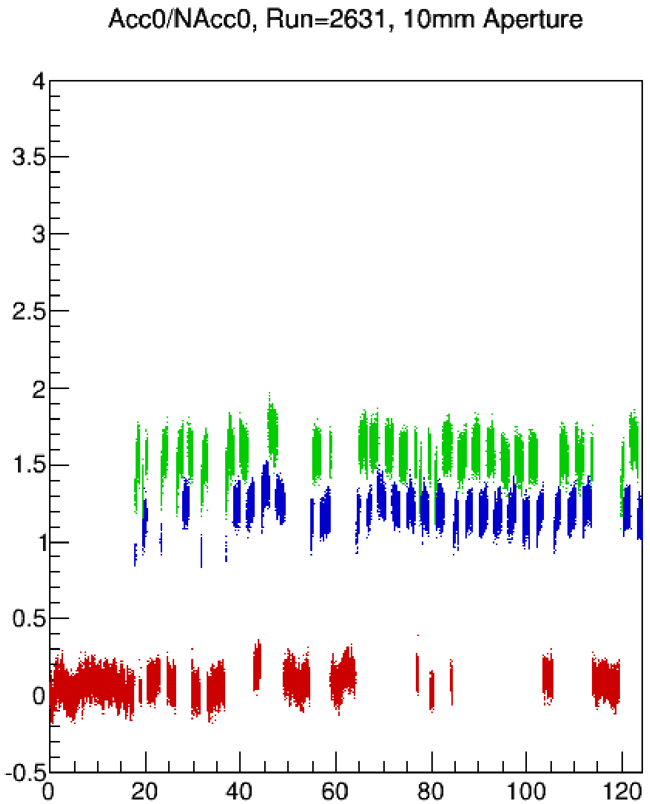
- → Test the GSO detector

Summary

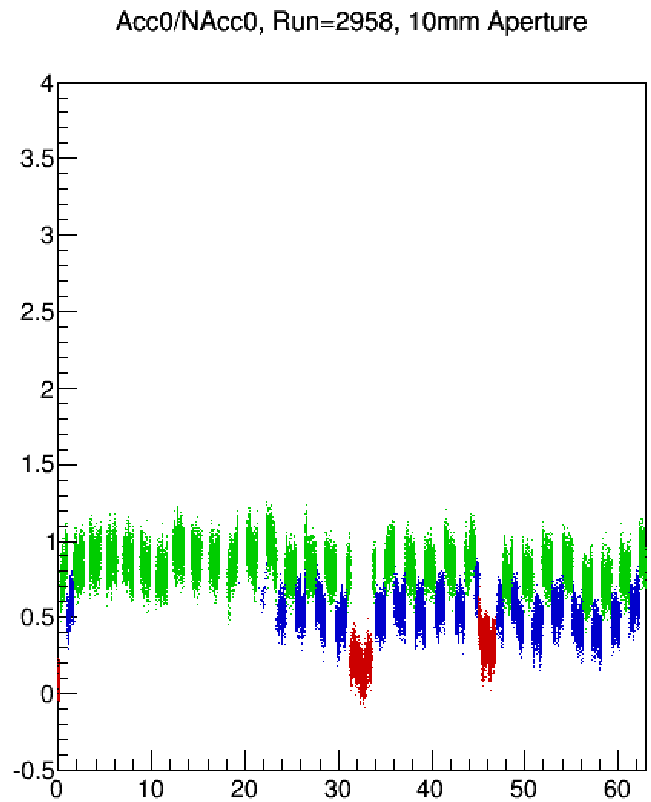
Hall A Compton and Moller Polarimeters are on track to be ready for PREX/CREX and beyond

EXTRA

Synchrotron yield with JAWS



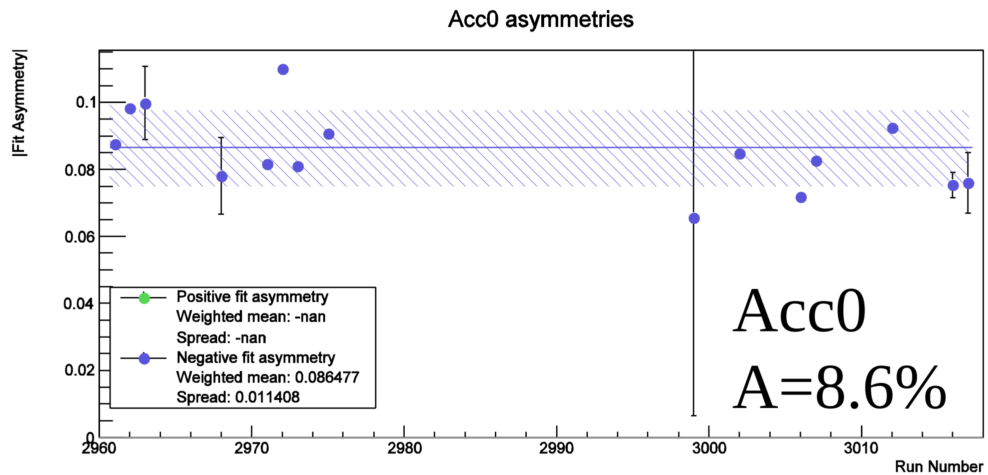
Spring 2016 – 4 pass beam

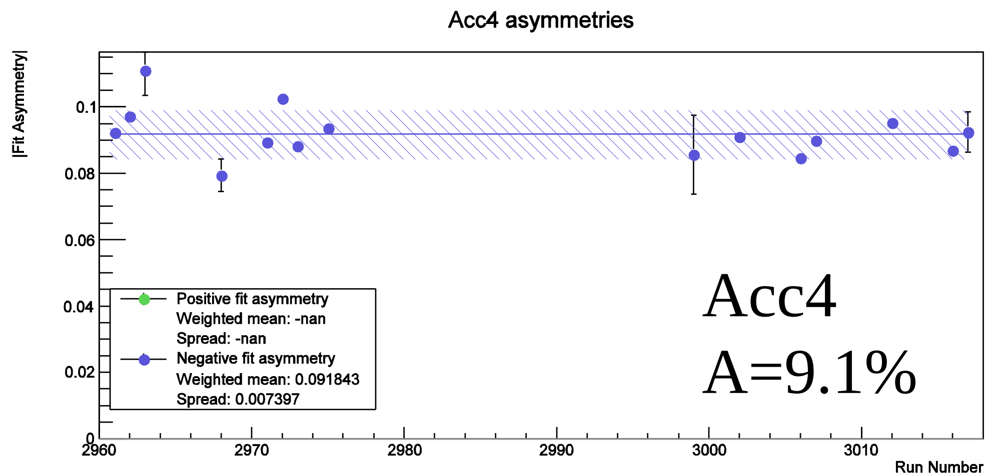


Fall 2016 – 4 pass beam

No 5 pass Compton data in fall 2016

Photon Detector Asymmetries at High Energies





Difference in Asymmetries extracted from Acc0 vs. Acc4

Acc0 integrates fADC for entire MPS
6.7 million bins – very sensitive to pedestal etc.

Acc4 ("stretched window")
Integrates only pulses above threshold
Rejects big pulses (above larger threshold)

Effect persists over multiple run periods w/different backgrounds

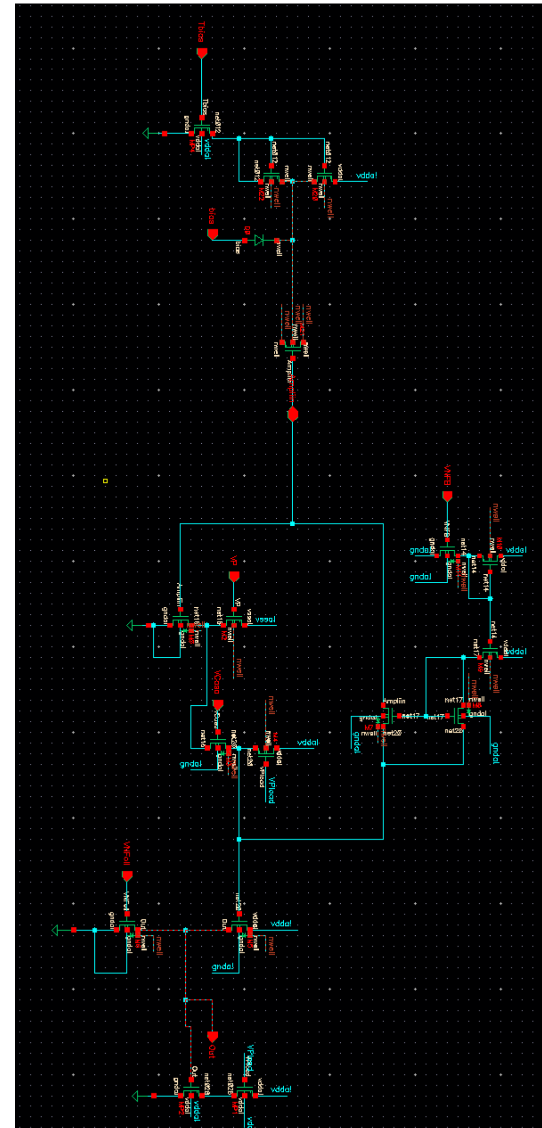
Fall'16 4-pass

HVMAPS as Compton e-Detectors

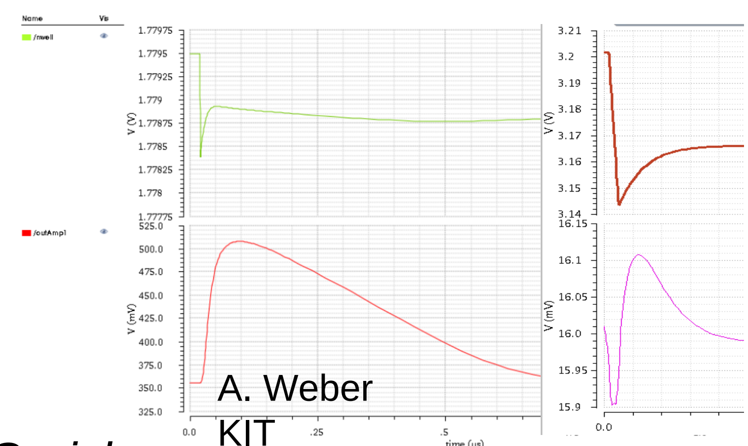
The NSERC proposal to participate in the combined ATLAS/PANDA/Mu3e/P2 HVMAPS production run was funded.

Near term R&D plans (1 Year):

- Participate in July 2-9 DESY beam prototype tests
- Purchase FPGA and carrier boards
- Obtain a few of the current prototype spares and
- Bench-test with sources and learn how to operate
- Establish signal needs and HW interface for Compton
- Complete our own set of simulations and
- Implement possibly needed (small) circuit changes
- Submit design for production (early next year ?)



In-pixel design (right) determines the signal shape and size.



A. Weber
KIT

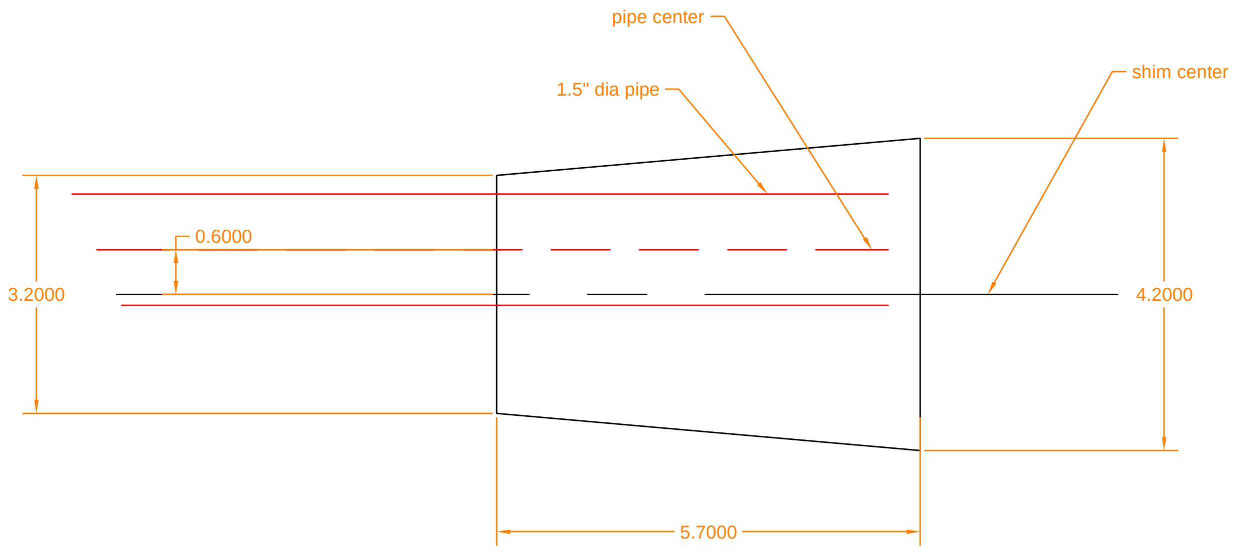
Simulation setup by Preeti Pandey (UofM postdoc) varying the parameters

Chicane and alignment issues

Before DVCS fall 2016 run, re-started chicane alignment “from scratch”
→ DIMAD from Yves
→ Ideals from Survey and Alignment
→ Checked against Joyce Miller’s model

Found dipoles 1 and 4 offset from nominal positions – low by 1 cm
Found shims offset by different amount – low by 1.5 cm

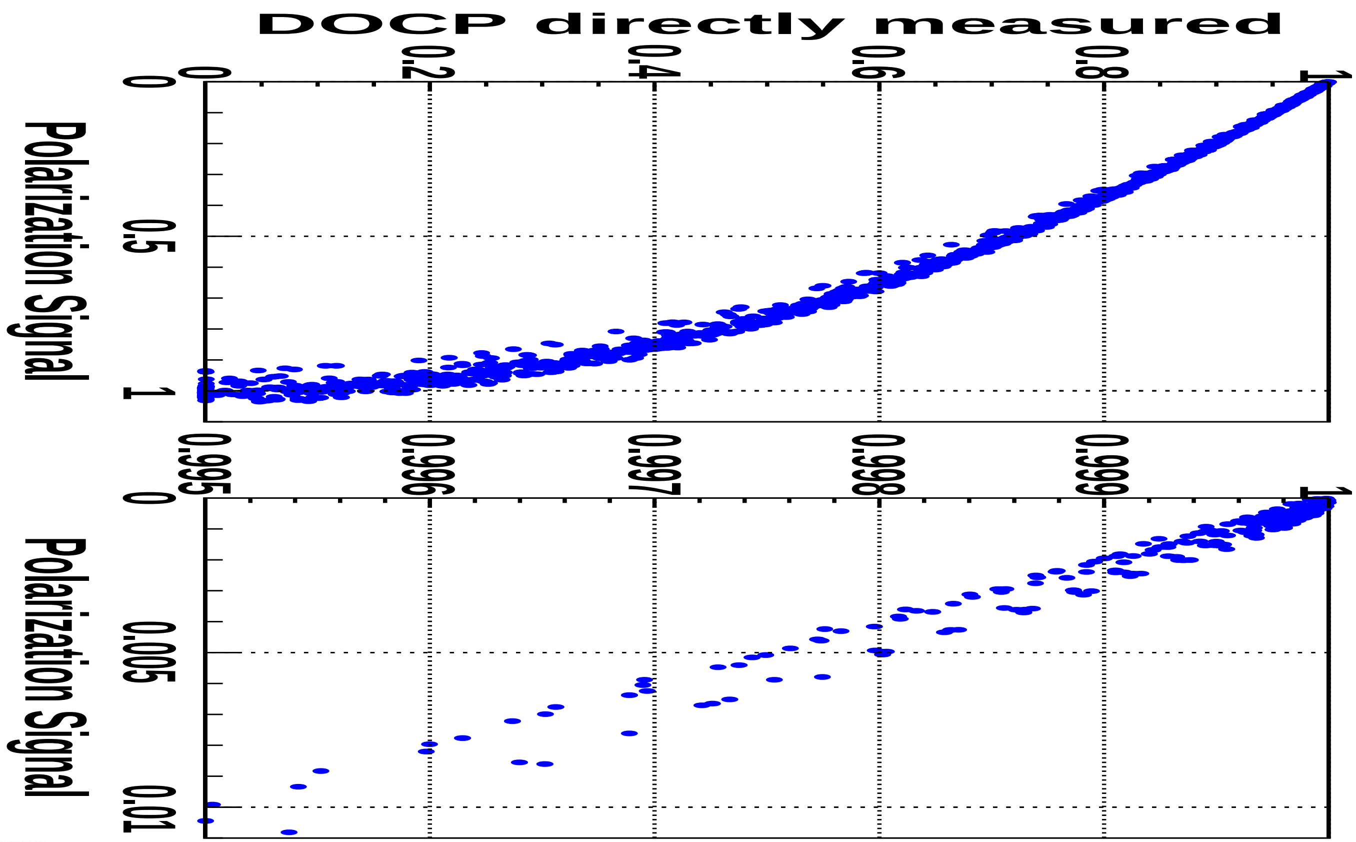
→ Dipoles have been raised – need final alignment



Cavity Polarization via Reflected Power

“If input polarization (ε_1) linear, polarization at cavity (ε_2) circular only if polarization of reflected light (ε_4) linear and orthogonal to input”
→ In the context of the Hall A/C systems, this means that the circular polarization at cavity is maximized when retro-reflected light is minimized

→ Above statement was verified experimentally in Hall C (with cavity open) by directly measuring circular polarization in cavity while monitoring retro-reflected power

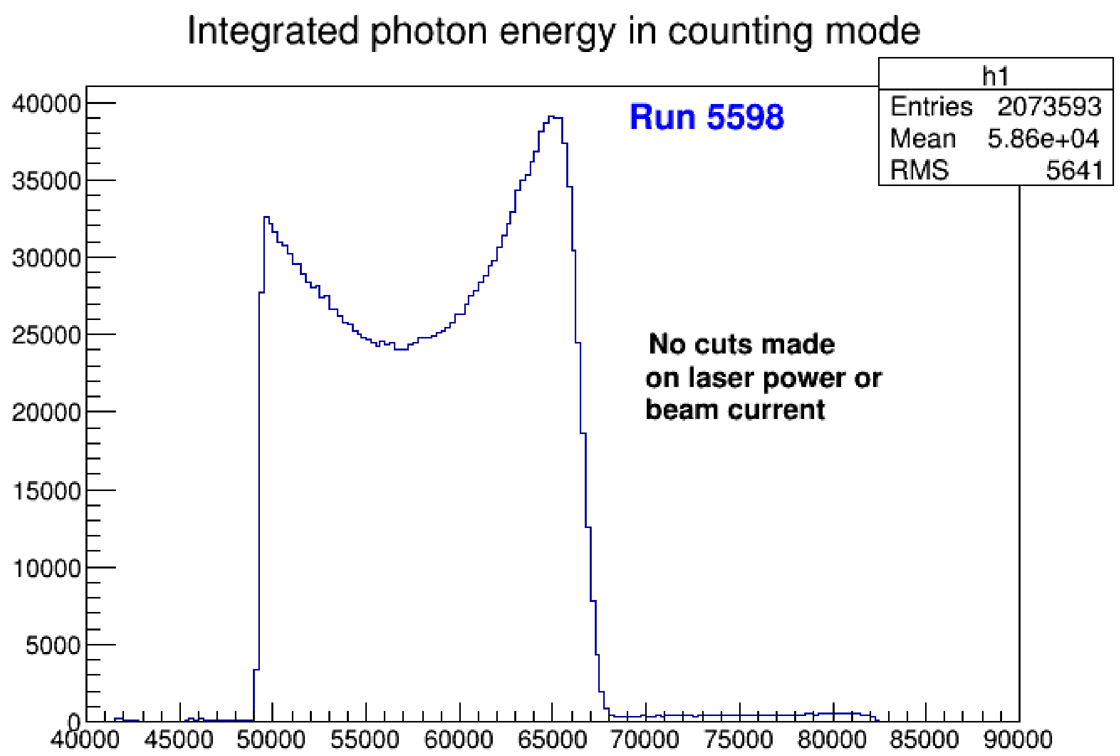


Fast Counting DAQ for Photon Detector

Fast counting DAQ using JLab Flash ADC under development

Goal: Measure differential asymmetry spectrum (event-mode) at high rates (10's of kHz)

→ JLab flash ADC can also be used in "accumulator" mode – perhaps eventually transition from custom SIS module in CMU DAQ to JLab-supported flash ADC



Bob Michaels, Shuji Li (New Hampshire), Hanjie Liu (Columbia)

Compton Laser System Overview

Laser system requirements:
1. 2-10 kW CW green power
2. ~100% circular polarization
→ Known to 0.1% level
3. Periodic laser helicity flipping

Main components of Hall A Compton laser system:
1. Narrow linewidth 1064 nm seed laser
2. Fiber amplifier (>5 W)
3. PPLN doubling crystal
4. High gain Fabry-Perot cavity
5. Polarization manipulation/monitoring optics