Hall A Compton and Photon Detector Status

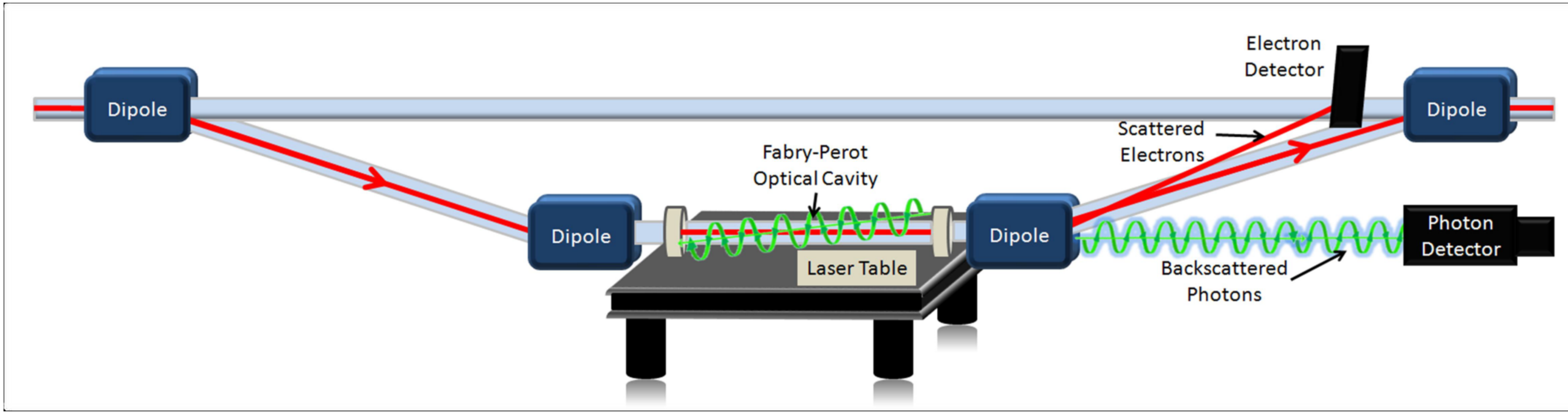
Dave Gaskell & Brian Quinn

PREX/CREX Collaboration Meeting

December 16, 2014

1. Compton Overview and Status
2. Photon Detector (for B.Q.)

Hall A Compton Overview



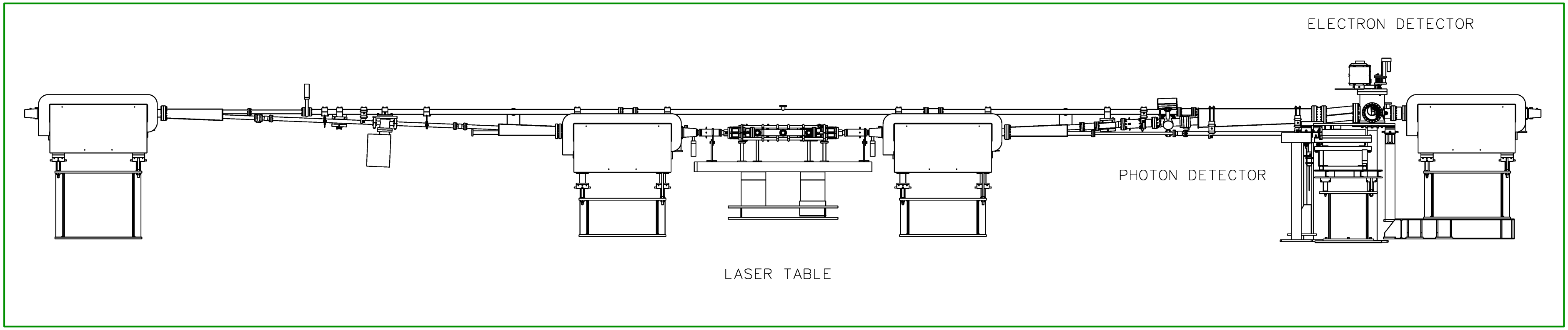
1. Laser system: 1 W green drive laser coupled to high gain Fabry-Perot cavity → several kW intracavity power
2. Photon detector: GSO crystal operated in integrating mode (low energies) → high energy crystal under study: lead-tungstate?
3. Electron detector: silicon strip detector → 240 μm pitch, 192 strips/plane
4. DAQ: CMU, integrating mode photon DAQ. New counting mode photon DAQ + new electron detector DAQ under development

Hall A Compton – 12 GeV Configuration

11 GeV functionality required changing chicane deflection: 30 cm → 21.55 cm

As of January 2014, most of the infrastructure work had been completed
→ Dipole height adjusted
→ New vacuum chambers fabricated and installed
→ Laser table height adjusted (new legs)
→ New electron detector chamber fabricated

Recently completed
→ Modifications for photon detector stand and collimator holder
→ Photon tube



Chicane/Vacuum System

A few modifications have been made to the chicane in the last several months

1. Added new BPM between dipoles 1 and 2 → allow easier beam steering during initial setup. Reduce potential for damaging lasers and optics on table
2. “Backup” shims fabricated for dipoles
3. Electron detector and 4th dipoles vacuum chambers modified to improved clearance for highest energy scattered electrons

Shims for mitigation of synch backgrounds

At higher energies, synchrotron backgrounds in photon detector get uncomfortably large

→ This can be mitigated by adding relatively small shims at ends of dipole to “soften” the bend
→ Shims have been installed as part of the 12 GeV improvements

Shims for mitigation of synch backgrounds

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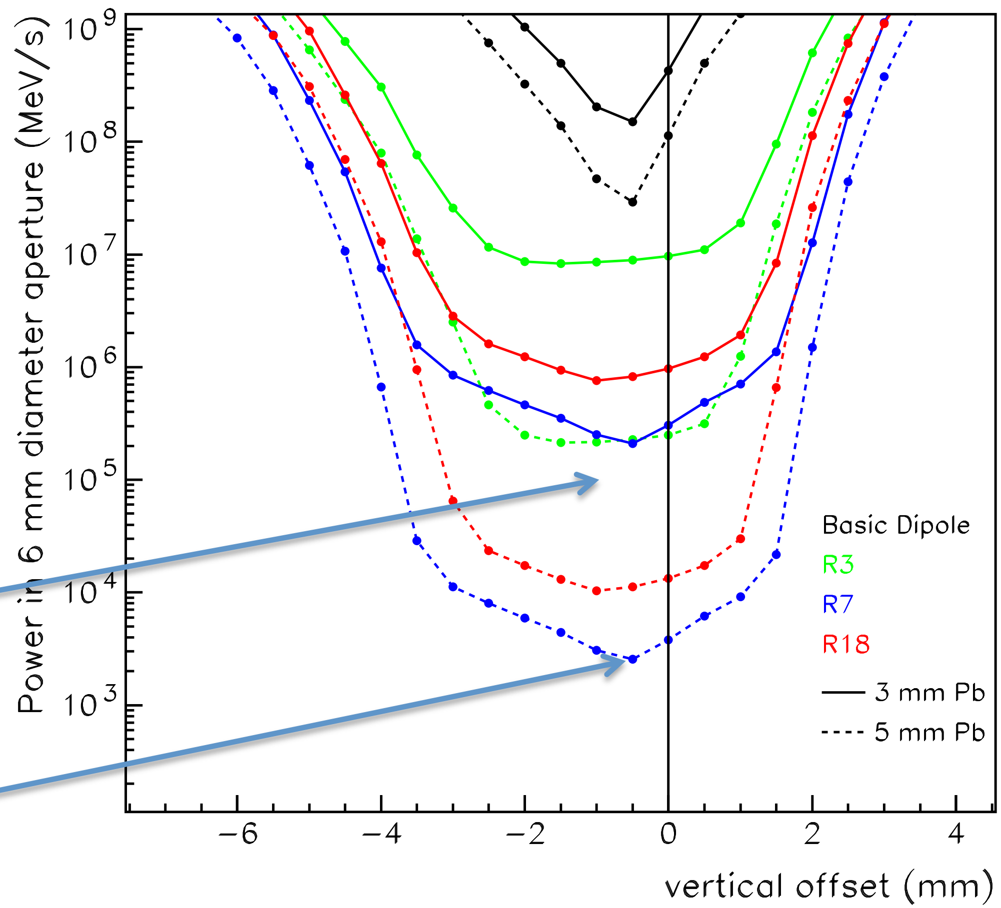
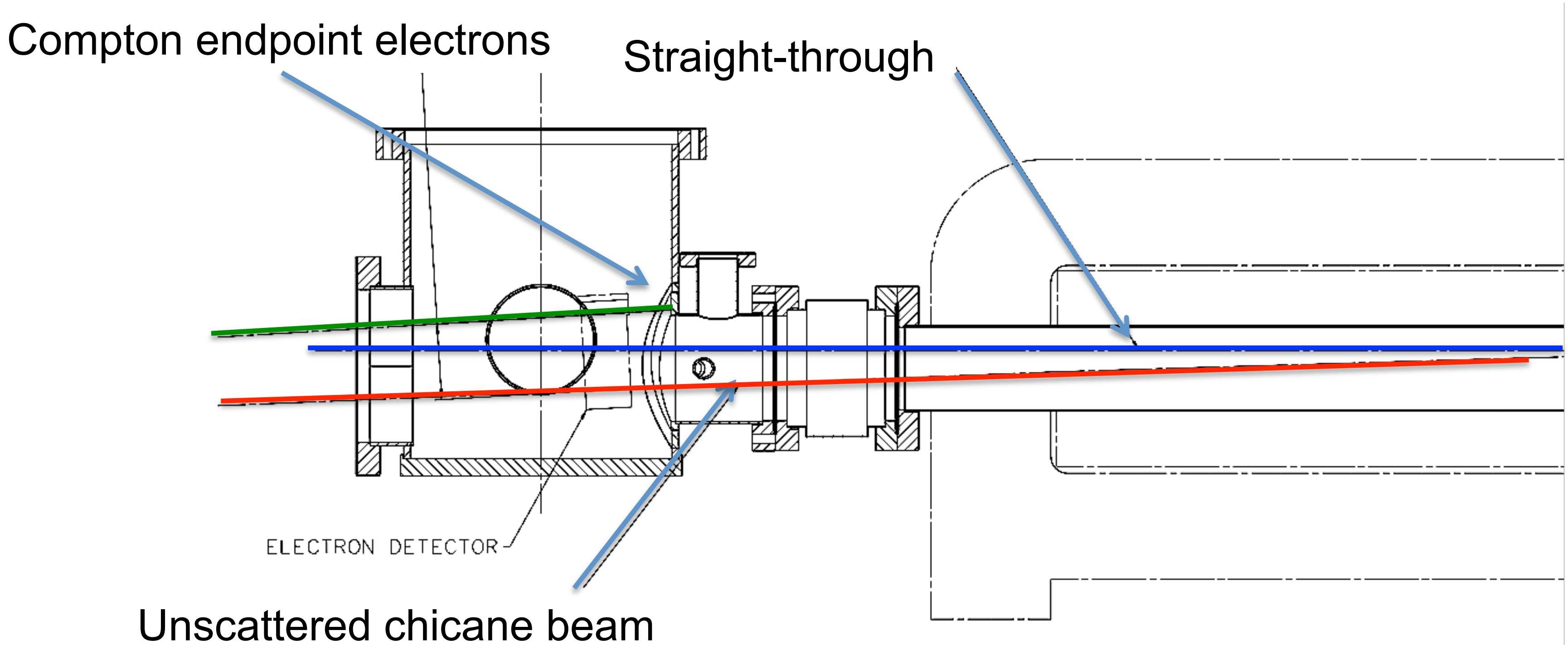
- → This can be mitigated by adding relatively small shims at ends of dipole to "soften" the bend
- → Shims have been installed as part of the 12 GeV improvements
- → Installed shims would yield synch powers larger than optimum design
- → Alternate shims have been fabricated - in case problems are discovered during DVCS run



Electron Detector Can

At 11 GeV, maximally scattered (Compton endpoint) electrons will strike electron detector can (green laser)
→ Will create backgrounds in electron detector
→ Shifting can and dipole chamber will shift collision point further downstream, away from electron detector

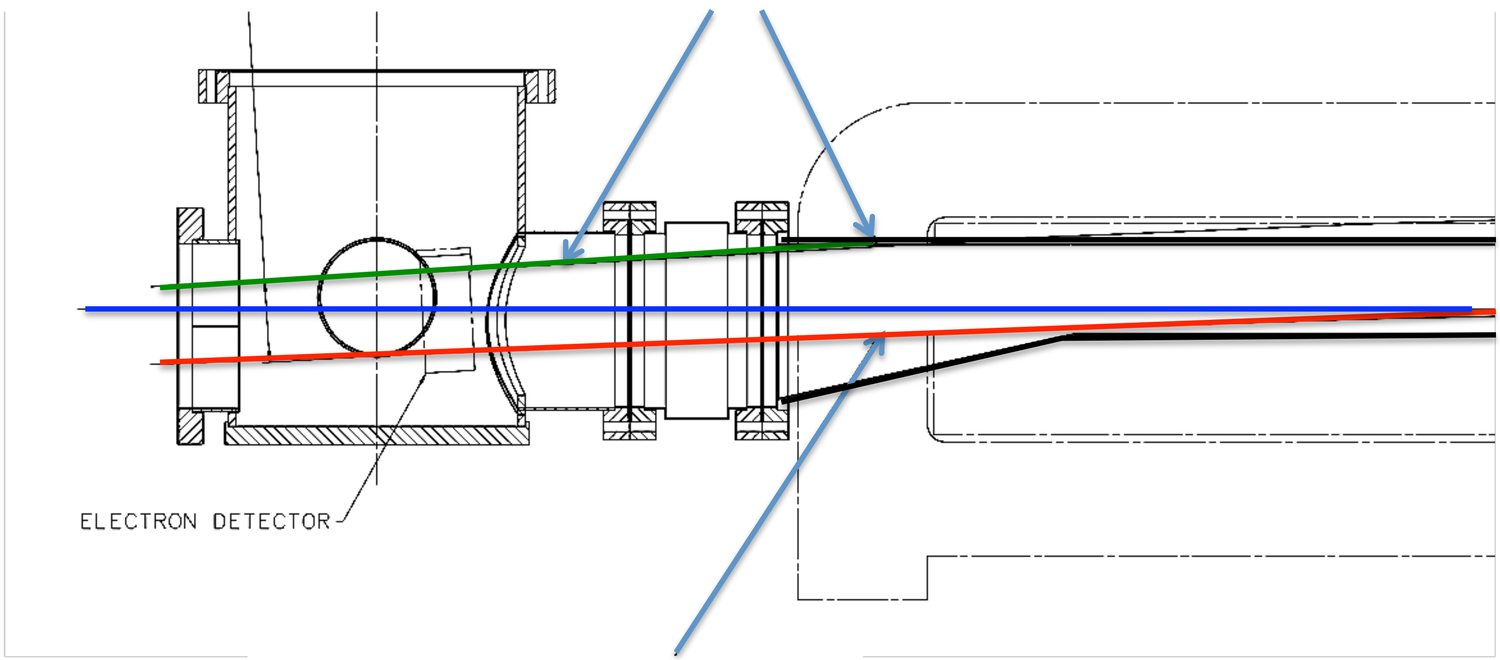


Electron Detector Can

At 11 GeV, maximally scattered (Compton endpoint) electrons will strike electron detector can (green laser)

Modifications:
1. Increase opening and bellows to 8 inches
2. Flip dipole 4 chamber, add “flair” on the upstream side

Compton endpoint electrons



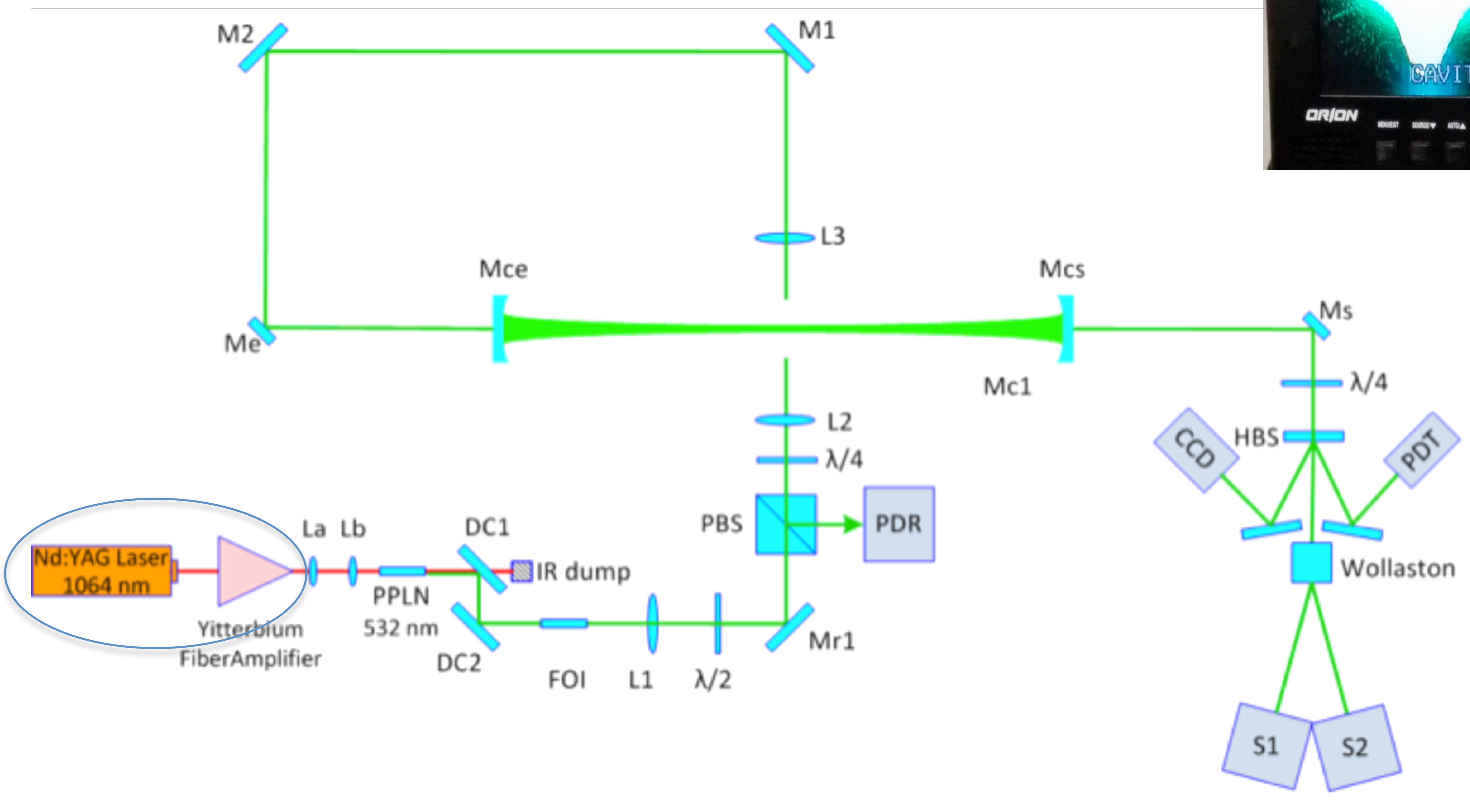
Unscattered chicane beam

Other Compton “infrastructure”

- Laundry list of many other small issues addressed over the last several months (entropy + 12 GeV reconfiguration related)
  - Compton laser-hut: lots of work required to make it light-tight again (Chuck Long)
  - Cavity mirrors – where did they all go?
  - Replacement mirror holders fabricated
  - Laser slow controls: VME CPUs too old – plan in place for replacement
  - Laser slow controls: broken cables, dead amplifier power supplies, dead QPD power supply…
  - Photon detector table motion revived! (thanks Brian)

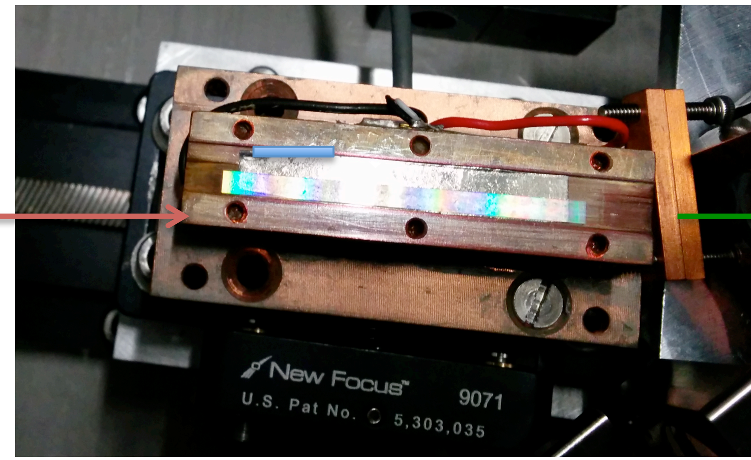
Compton Laser Status

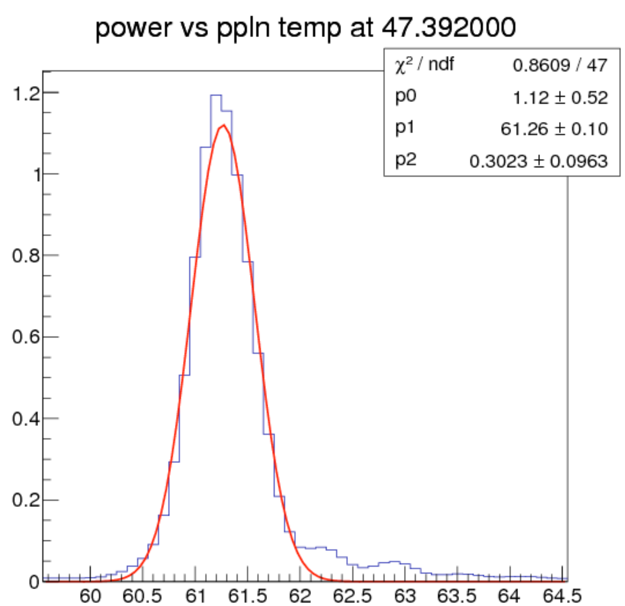
Compton laser system approaching full functionality
→ Components on laser table functioning and aligned
→ Slow controls restored
→ Fabry-Perot cavity locking, but low gain



Compton Laser: Frequency Doubling System

Nd:Yag (200 mW) → Fiber amplifier (5 W) →





Green laser light provided by single-pass, frequency doubling system

→ Good doubling efficiency requires proper alignment of doubling (PPLN) crystal, optimum temperature

→ We are routinely achieving ~20% doubling efficiency, sometimes better

Compton Laser: Fabry-Perot Cavity

- Key component of system is locking the laser to the (high gain) Fabry-Perot cavity
- Before start of DVCS/GMp run, spent a lot of time working on laser-cavity alignment, matching the spatial profile, and achieving lock
- Work was complicated by the power infrastructure work and our unfamiliarity with the details of this system
- In the end, we chose to install low reflectivity mirrors (R=99.83%) to simplify alignment
- FP cavity lock was achieved but at lower gain than expected for these mirrors → 100 W vs. 500 W

See talk by Ciprian Gal

Compton Electron Detector

Existing system suffers from excessive noise, low efficiency

→ For experiments with high luminosity (and/or very long run times), silicon microstrips may not be sufficiently radiation hard

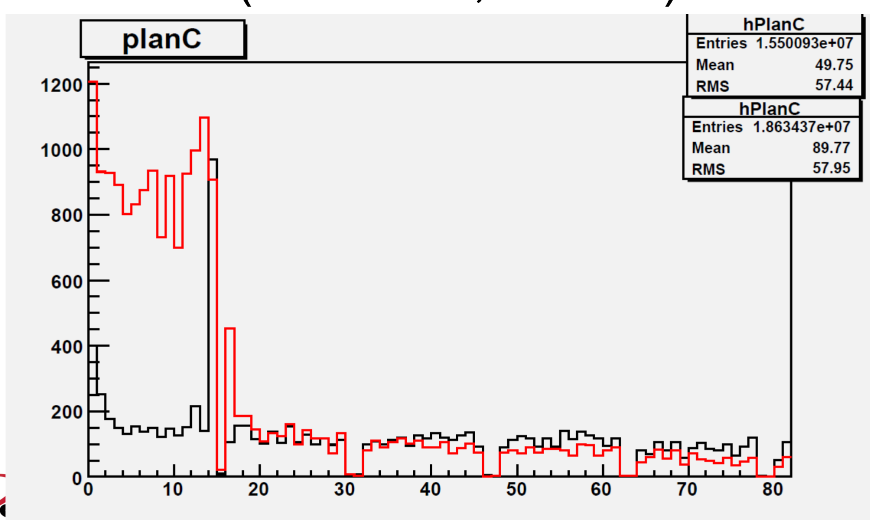
Near term improvement plan (JLab/Manitoba/MSU):

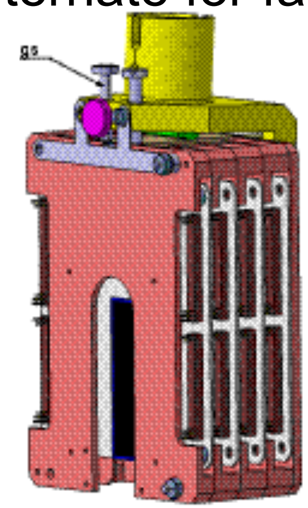
→ Investigate shorter PCB board to couple detector to amplifier-discriminator – improve signal size before discrimination

→ Install thicker silicon plane (?)

Longer term plans:

→ Investigate diamond strips (similar to Hall C) as an alternate for far future experiments (MOLLER, SOLID)





See talk by Alexandre Camsonne

Compton Photon Detector

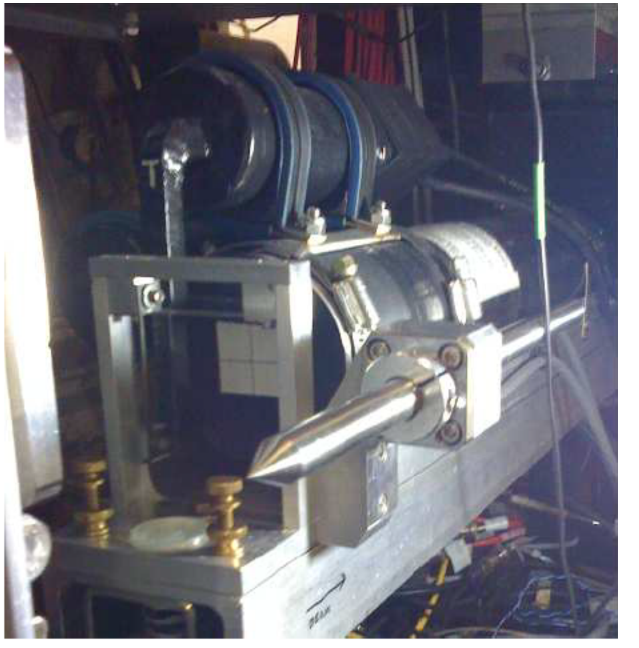
CMU spearheaded the development of the new "integrating mode" photon detector system

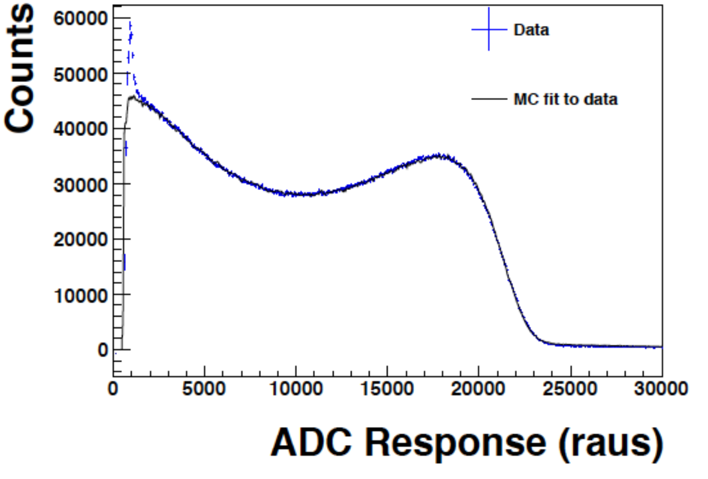
→ High resolution GSO detector + integrating DAQ provided sub-1% photon detector polarization measurements

Higher backscattered photon energies in the 12 GeV era require a new crystal

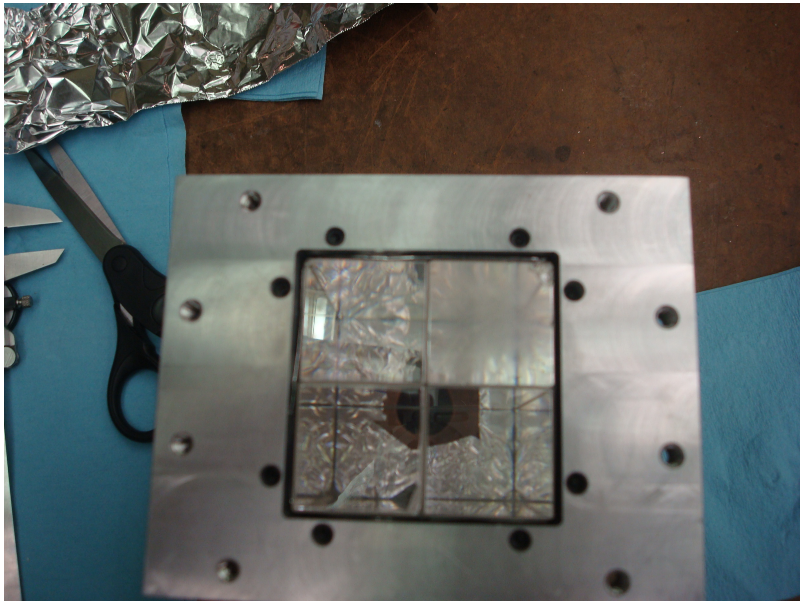
Requirements:
→ "Good" energy resolution
→ Dense enough to contain full (or most) of the backscattered photon energy

Hoping to test lead-tungstate during DVCS/GMp run

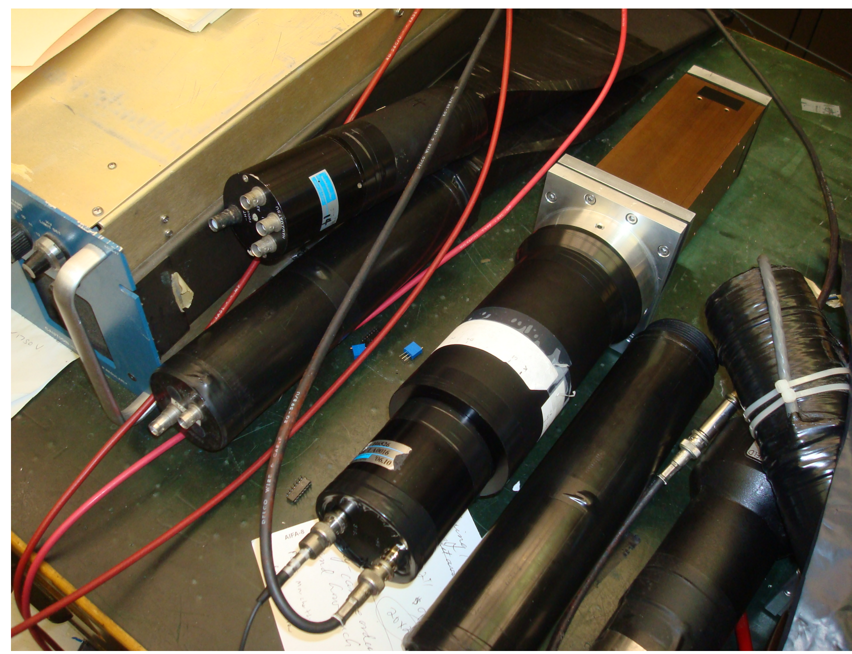




Lead Tungstate Test Detector



Have installed a 4-block, lead-tungstate detector to test during DVCS/GMp run
→ CMU DAQ needs to be revived



Lead-tungstate crystals on loan from Yerevan/Hall C

Crystal size = 3 x 3 x 20 cm

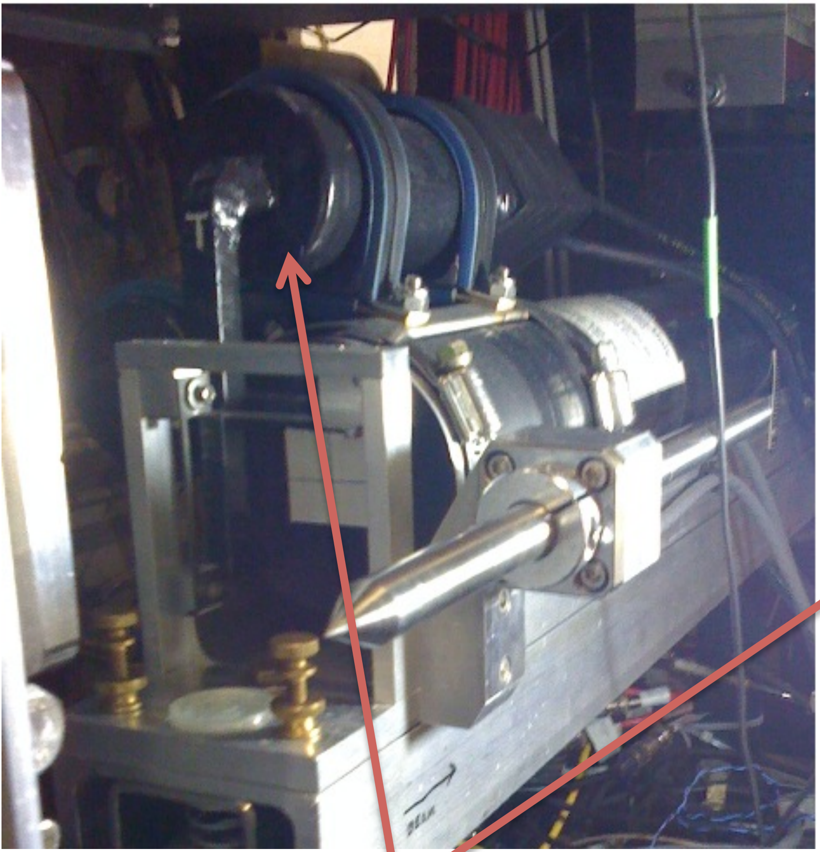
Detector assembled, PMT optimized by CMU (B. Quinn)

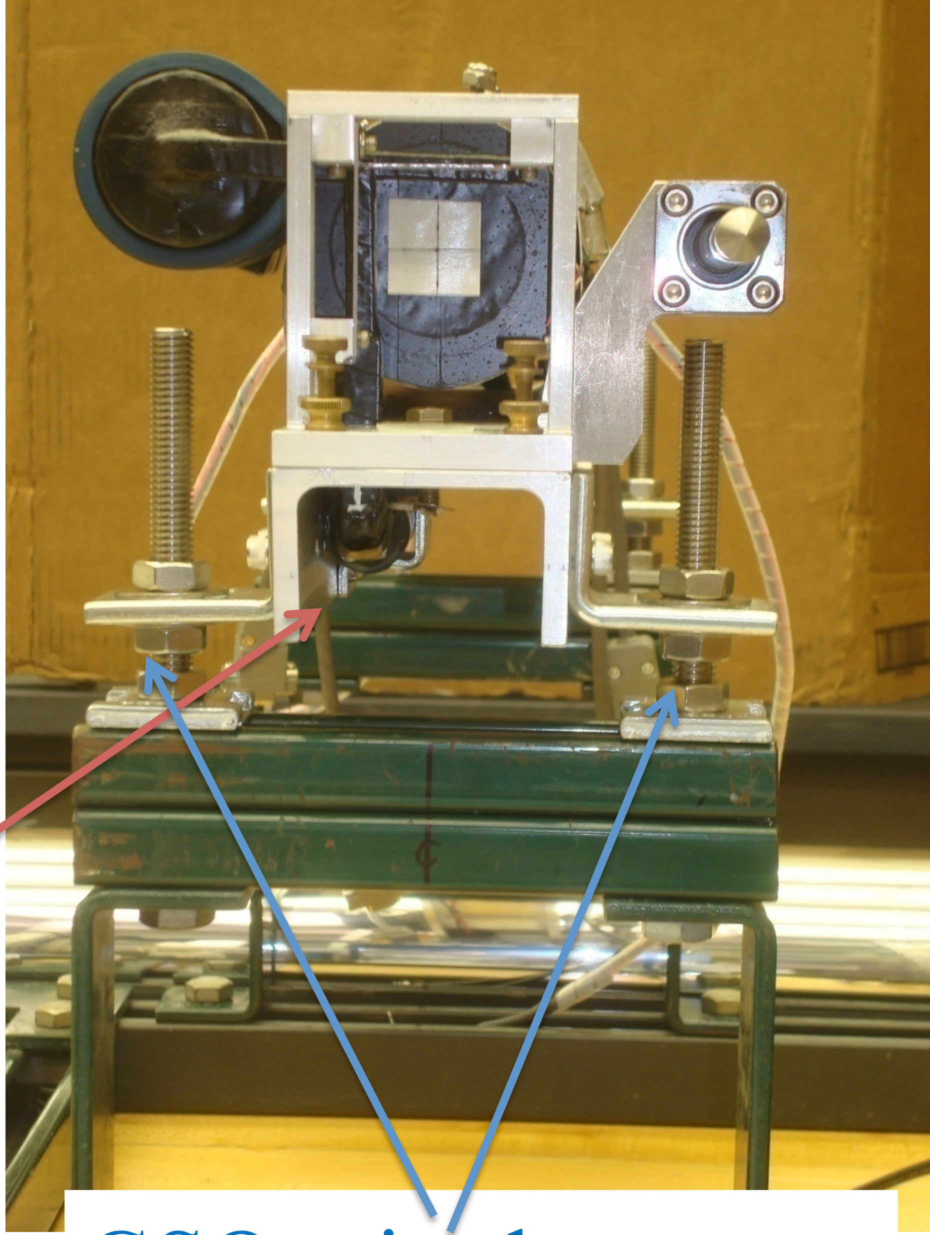
Photon detector status / plans (PREX/CREX)

-New beam height
-Lower photon energy than HAPPEX 3

(Discussed last time:
-Lessons learned from Megan's analysis of HAPPEX 3 Compton)

GSO modified for new beam height





Vertical finger PMT would collide with shelf above

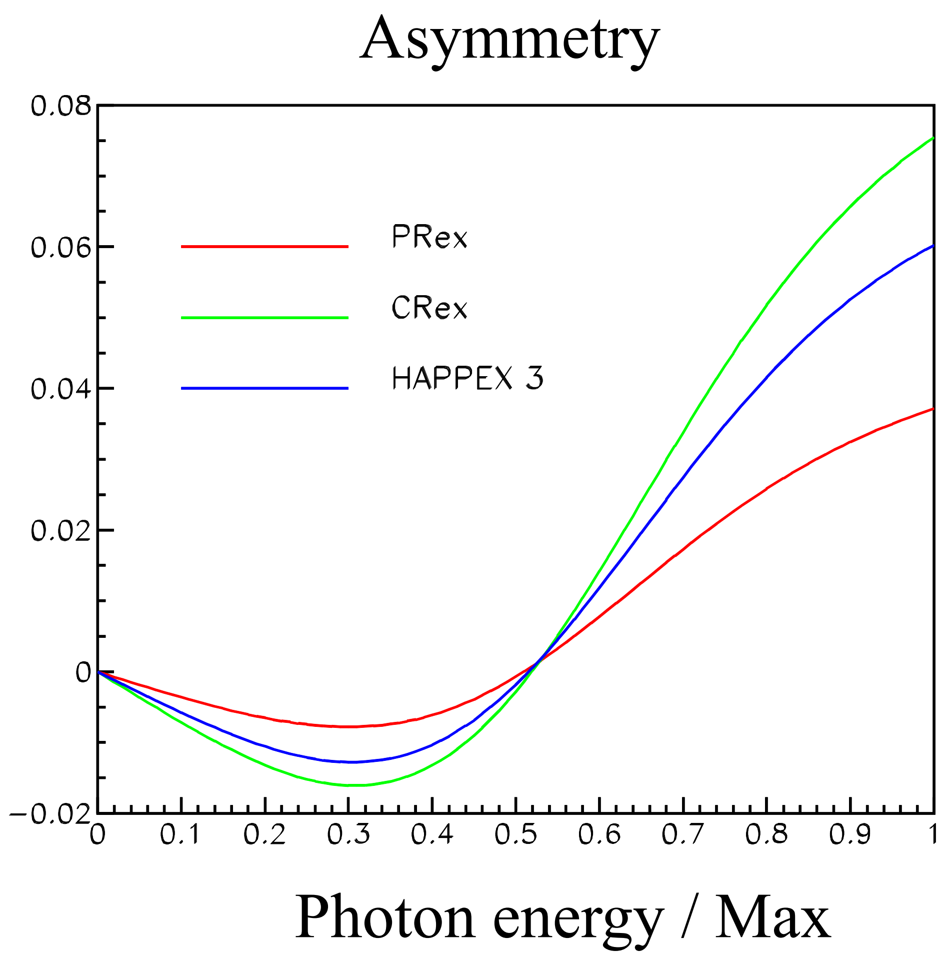
GSO raised 2.75” and adjustable

Duplicate linearity-measurement system (mini-Megan, micro-Megans) operational at CMU including:

- ✓ pulse sequencing,
- ✓ PMT readout,
- ✓ Event replay,
- ✓ Linearity analysis

Used to measure (and tweek) response of PMT on PbWO4 detector

Lower photon energy than HAPPEX 3



Max photon energy: 204 MeV, 160 MeV, 38.6 MeV

GSO PMT base customized to optimize linearity at gain appropriate for HAPPEX 3.

Integrating DAQ requires good understanding of PMT response to determine analyzing power

PREX-I ran with same gain
→ five times smaller pulses.

Modifying 2nd base for linearity at high current. If successful, will try to optimize performance at five times higher gain

Existing PMT/base as spare

Near-term plans:

-Test linearity of existing PMT/base and gain stability vs. load (at higher gain)

-Prepare PMT/base combination optimized for operation at higher gain

From last meeting:

-Find collimator inserts

-Modify Accumulator 4 & 5 definitions?

-Run mini-Megan under beam loading conditions

Global Compton Status

- Chicane: No beam through “new” chicane yet. Likely won’t happen until spring run.
- Laser system: low-gain cavity locking. Path towards high-gain cavity SHOULD be straightforward
- Electron detector: not installed. Path forward not 100% clear – more tests required to decide on ultimate solution for PREX/CREX
- Photon detector: Test lead-tungstate detector installed. In principle, GSO detector is ready to go
  - CMU integrating DAQ not yet ready

Compton Plans

- Near term (January down)
  - Restore CMU photon DAQ functionality – test lead-tungstate prototype in spring
  - Swap out low gain mirrors in FP cavity → aim for few kW level powers in cavity
  - Further characterization of laser and optics
- Longer term plans
  - Improve laser polarization monitoring/setup scheme (replicate Hall C system for < 0.2% level systematic error) → this will require some new equipment, controls, and software. Summer 2015?
  - Improve electron detector performance
  - Continue development of Compton DAQ Upgrade
  - Make better logo?

Hall A Compton Subsystems and Contributors

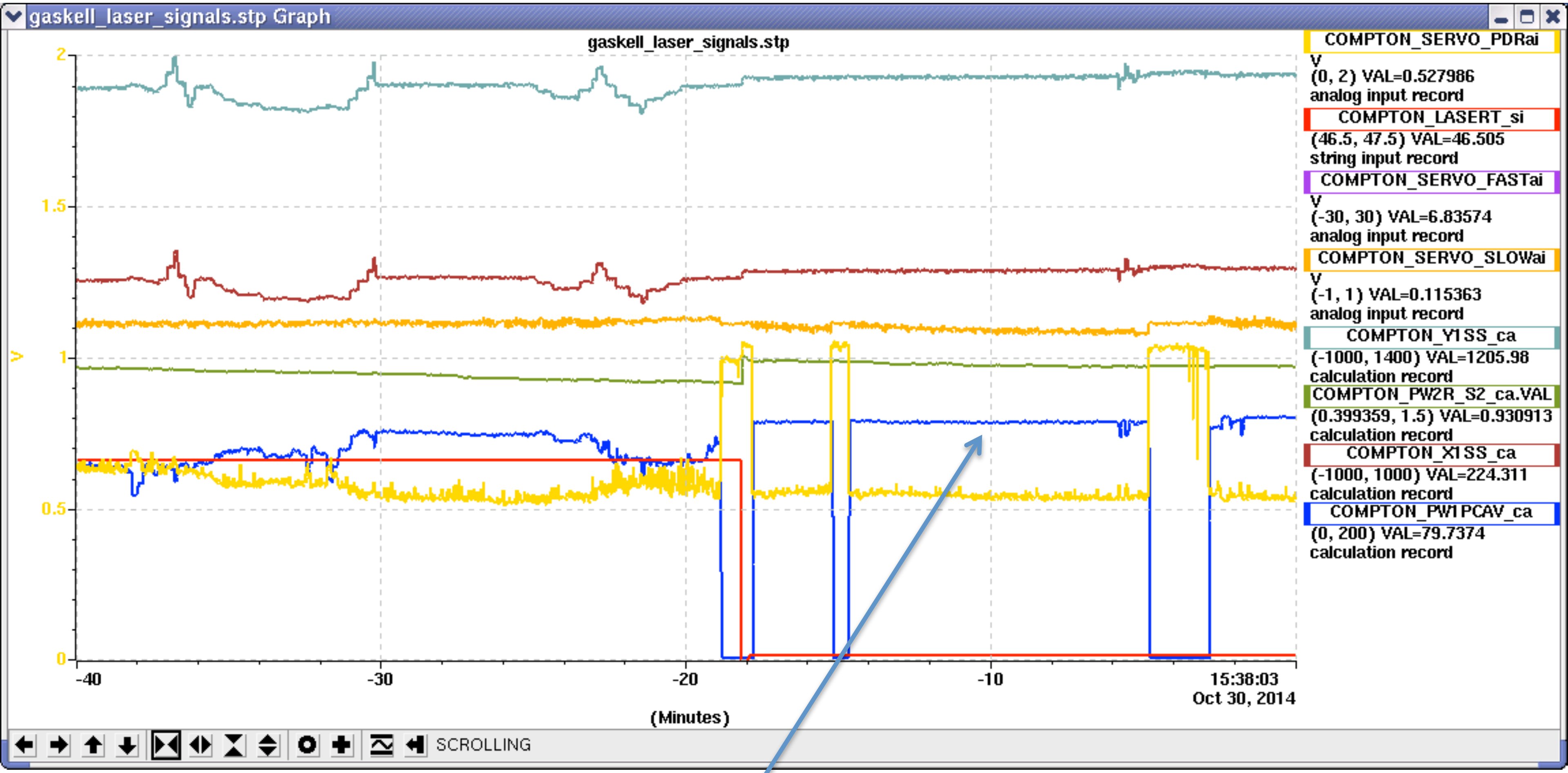
- Coordination: JLab (Gaskell)
- Laser System: JLab (Gaskell, Dalton), UVa (Gal, Paschke)
- Photon Detector: CMU (Quinn, Franklin)
- Electron Detector: Manitoba (Mammei, Spies, Shabestari), JLab (Camsonne), Miss. State (Dutta), Clermont-Ferrand
- DAQ: CMU (Franklin, Quinn), JLab (Michaels, Camsonne)

HAll

Polarimetry

EXTRA

Compton Laser: Fabry-Perot Cavity



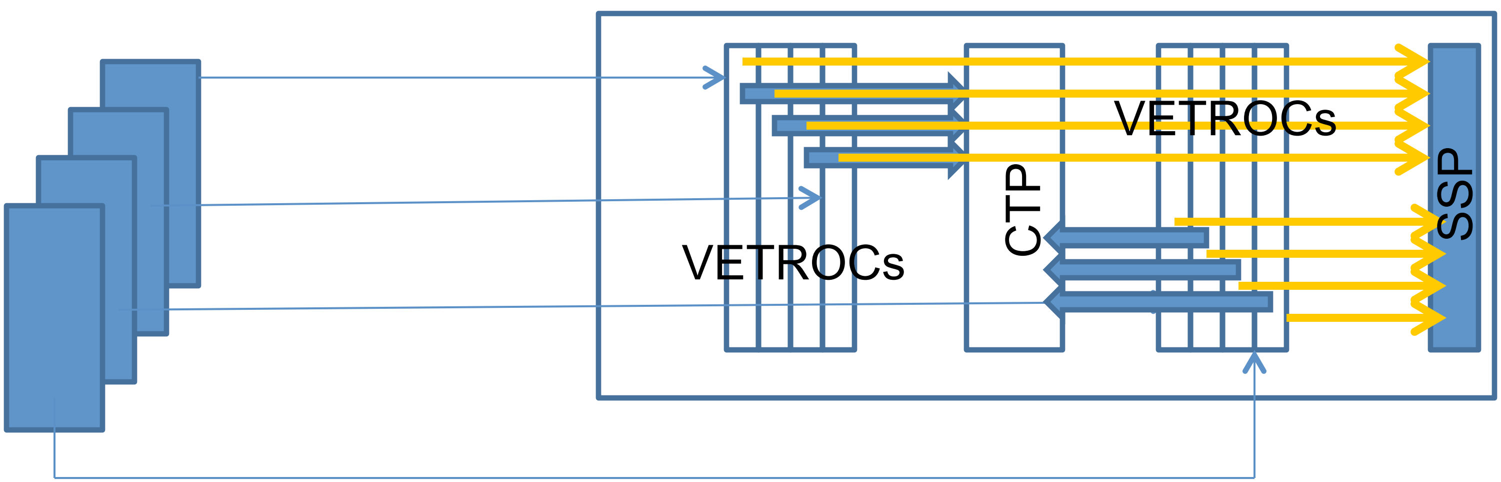
Locked FP cavity

VETROC

Electron detector also needs new, fast readout

→ Fast Electronics group working with Bob Michaels and Alexandre Camsonne to develop new custom logic board – VETROC

→ Similar functionality to CAEN V1495, but "super-charged" – higher rate capabilities, expanded memory/buffer

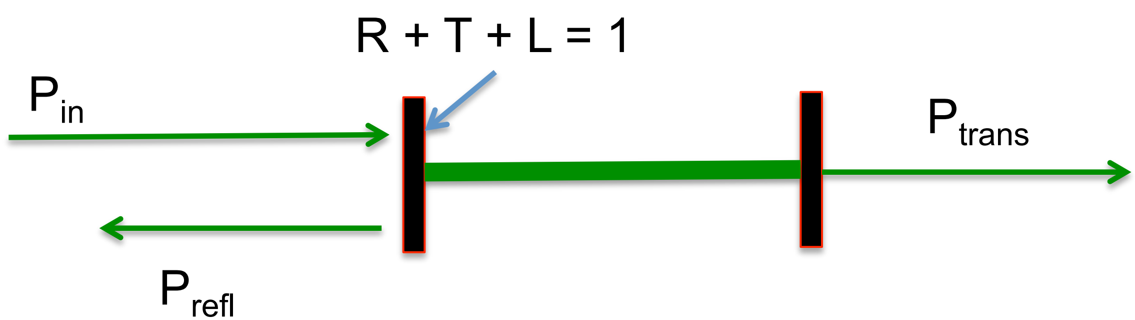


Compton Laser: Fabry-Perot Cavity

Using the incident, reflected, and transmitted power, we can totally characterize cavity properties

Inputs:
P_{in} = 851 mW
P_{refl} = 539 mW
P_{trans} = 120 mW
Mirror T = 0.163%

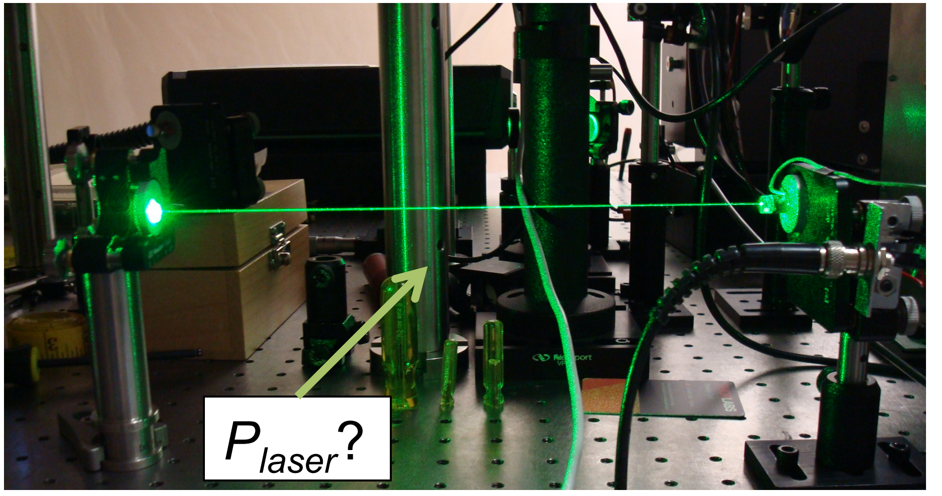
Cavity properties:
Finesse = 1274
Gain = 102
c0 (mode match) = 46%
Total loss = 0.22%

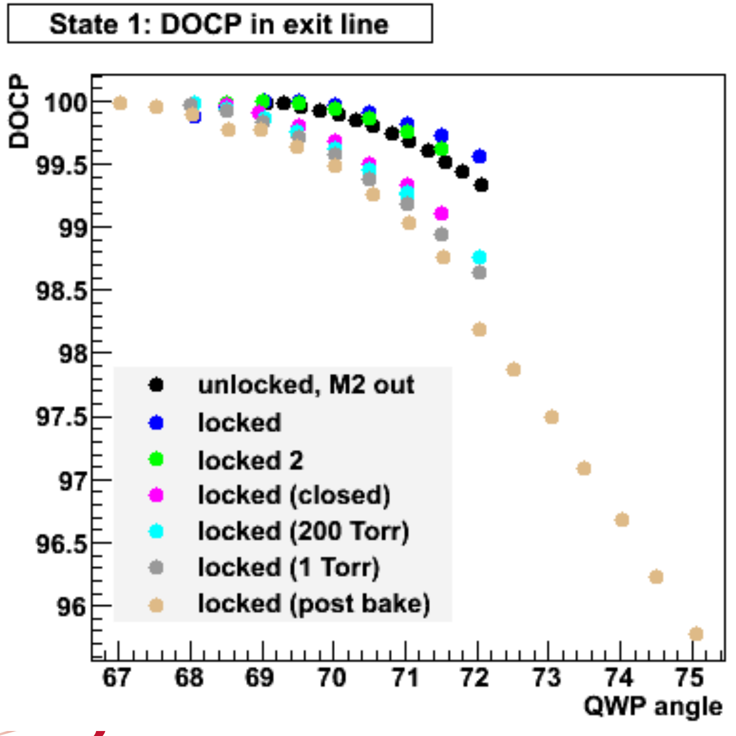


Mode match can be improved via iteration or direct measurement.
Inferred loss MUCH too large! Dirty mirrors? Or other losses on table?

Laser Polarization - the Transfer Function

Knowledge of the laser polarization inside cavity is a key systematic uncertainty
→ Polarization usually inferred from measurements of beam transmitted through cavity, after 2nd mirror





Typically a "transfer function" is measured with cavity open to air

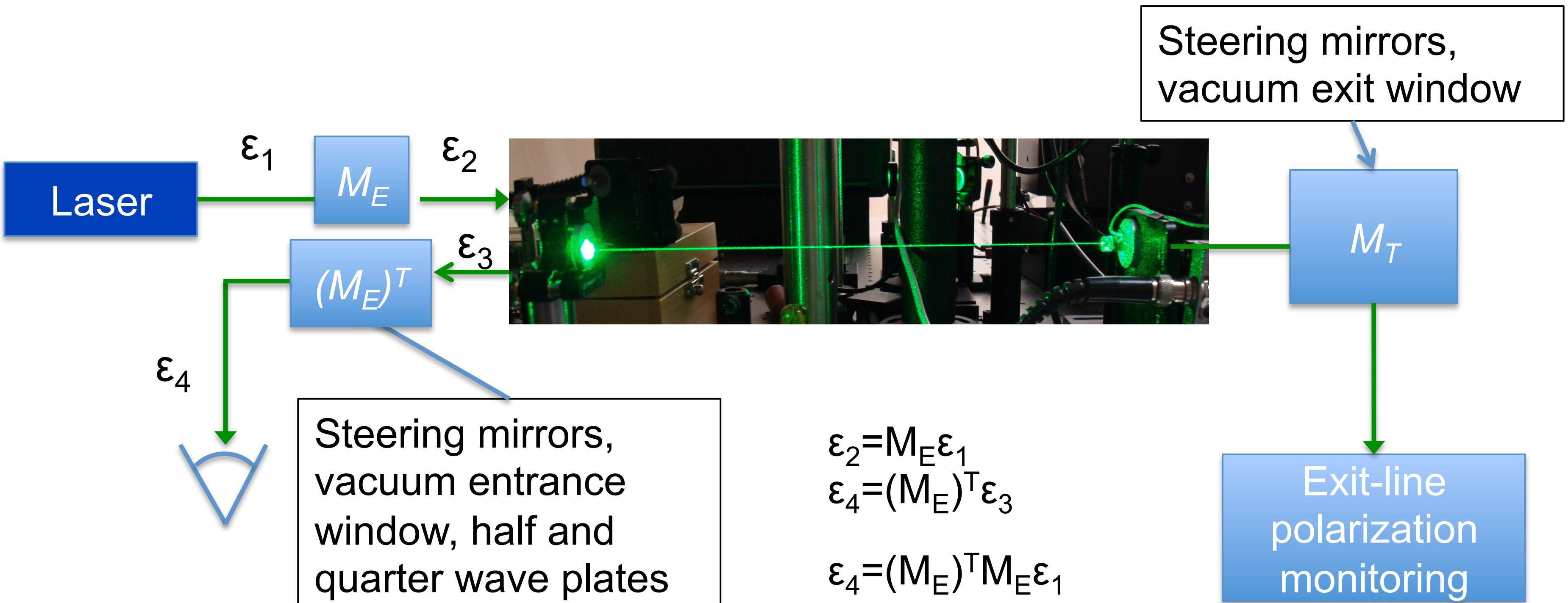
<u>Possible complications due to:</u>
→ Change in birefringence due to mechanical stresses (tightening bolts)
→ Change in birefringence when pulling vacuum

Laser Polarization – the "Entrance" Function

Propagation of light into the Fabry-Perot cavity can be described by matrix, $\boldsymbol{M_E}$

→ Light propagating in opposite direction described by transpose matrix, $(\boldsymbol{M_E})^T$

→ 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*



$\varepsilon_2 = M_E \varepsilon_1$

$\varepsilon_4 = (M_E)^T \varepsilon_3$

$\varepsilon_4 = (M_E)^T M_E \varepsilon_1$

JINST 5 (2010) P06006

*J. Opt. Soc. Am. A/Vol. 10, No. 10/October 1993

Cavity Polarization via Reflected Power

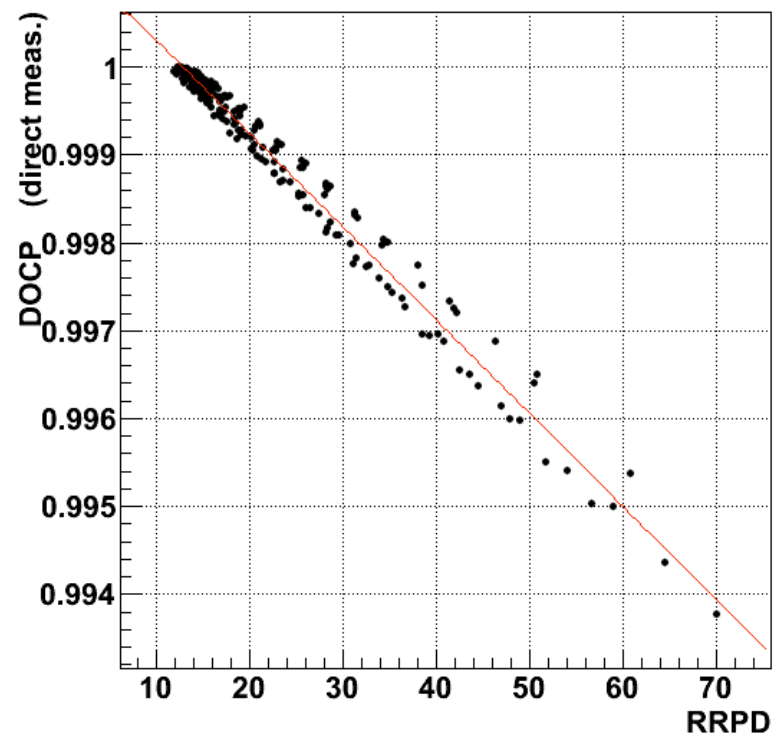
"If input polarization (ε_1) linear, polarization at cavity (ε_2) circular only if polarization of reflected light (ε_4) linear and orthogonal to input"

→ In the context of the Hall C system, this means that the circular polarization at cavity is maximized when retro-reflected light is minimized

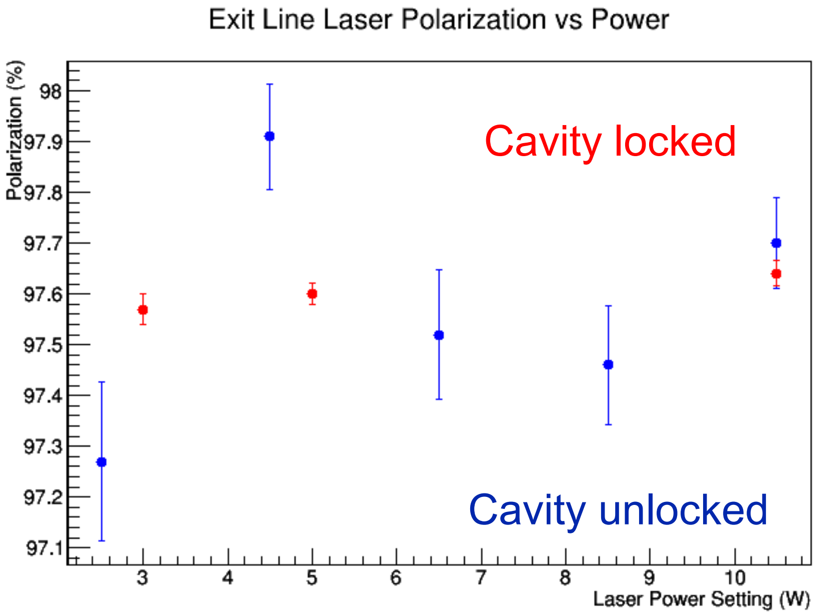
→ Above statement was verified experimentally (with cavity open) by directly measuring circular polarization in cavity while monitoring retro-reflected power

→ Additionally, by fitting/modeling the entrance function we can determine the degree of circular polarization by monitoring the reflected power – even for the case when system is not optimized

Circular polarization in cavity



Laser Polarization Systematic Uncertainty



Cavity polarization optimization scans performed with cavity unlocked
→ No measureable difference in laser polarization when comparing to locked cavity

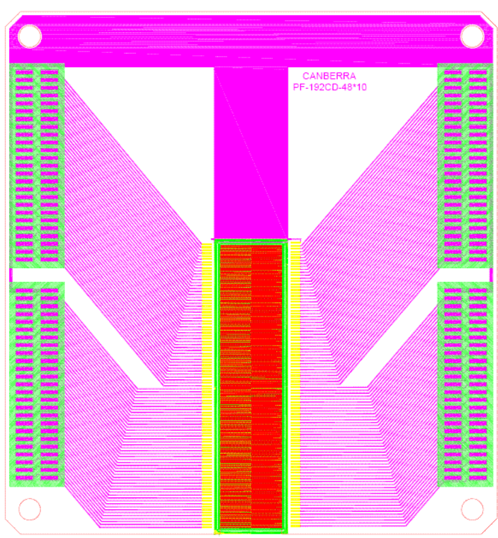
Additional sources of potential uncertainty due to transmission through input cavity mirror and potential laser depolarization
→ Both constrained by measurement to be very small

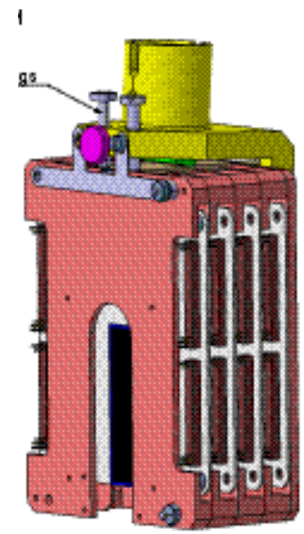
Overall systematic error on laser polarization in cavity ~ 0.1%

Compton Electron Detector*

Current Issues

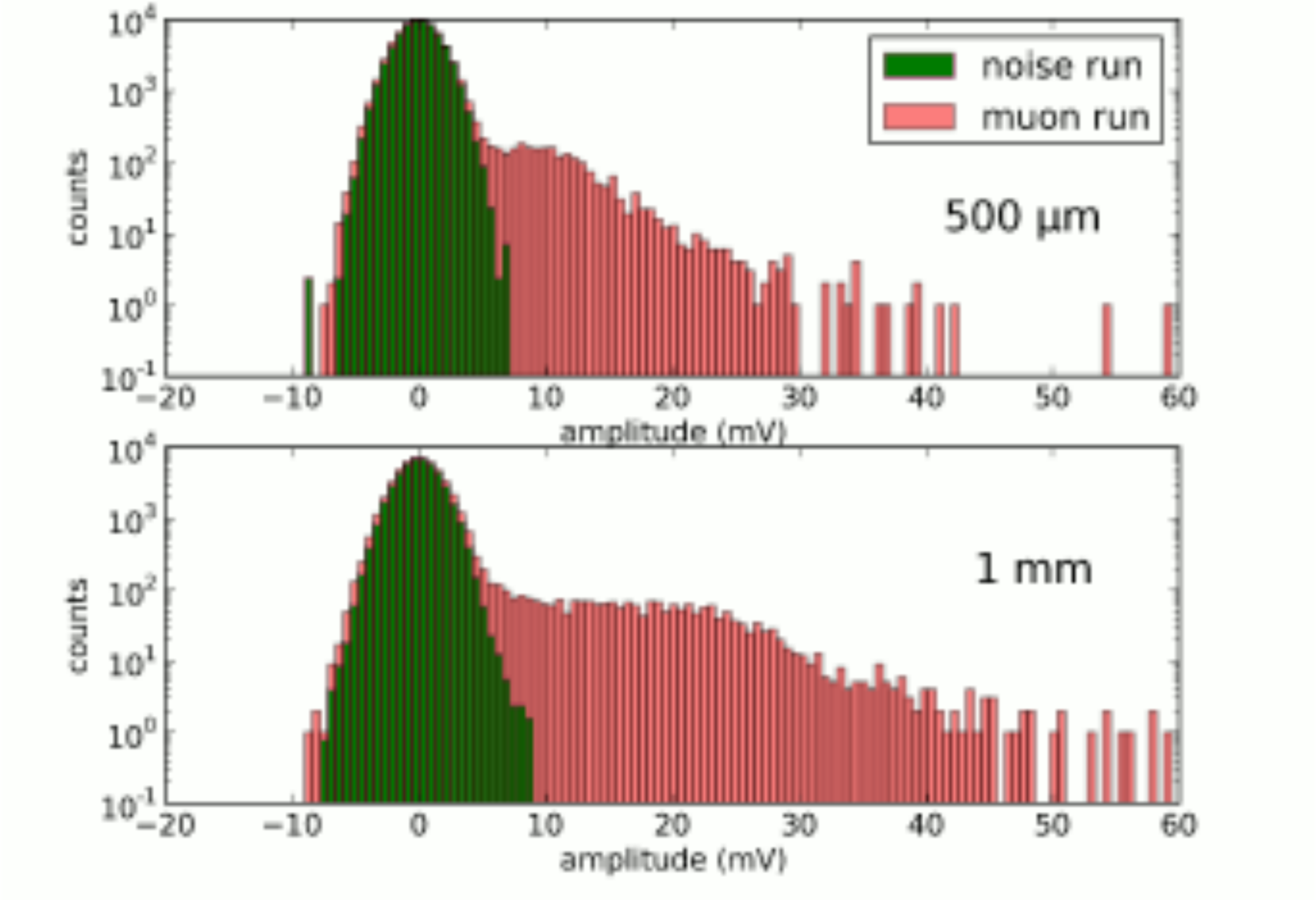
→ Synchrotron radiation (did not work during PVDIS)
→ Contamination of asymmetry by shielding
→ Signal / background ratio
→ Crosstalk - digital with analog (need to be careful of offsets and thresholds)
→ No official support for major development in Clermont
→ Readout with standard Compton DAQ only run at 30 Hz
→ Readout 32 bit BLT only : dead time





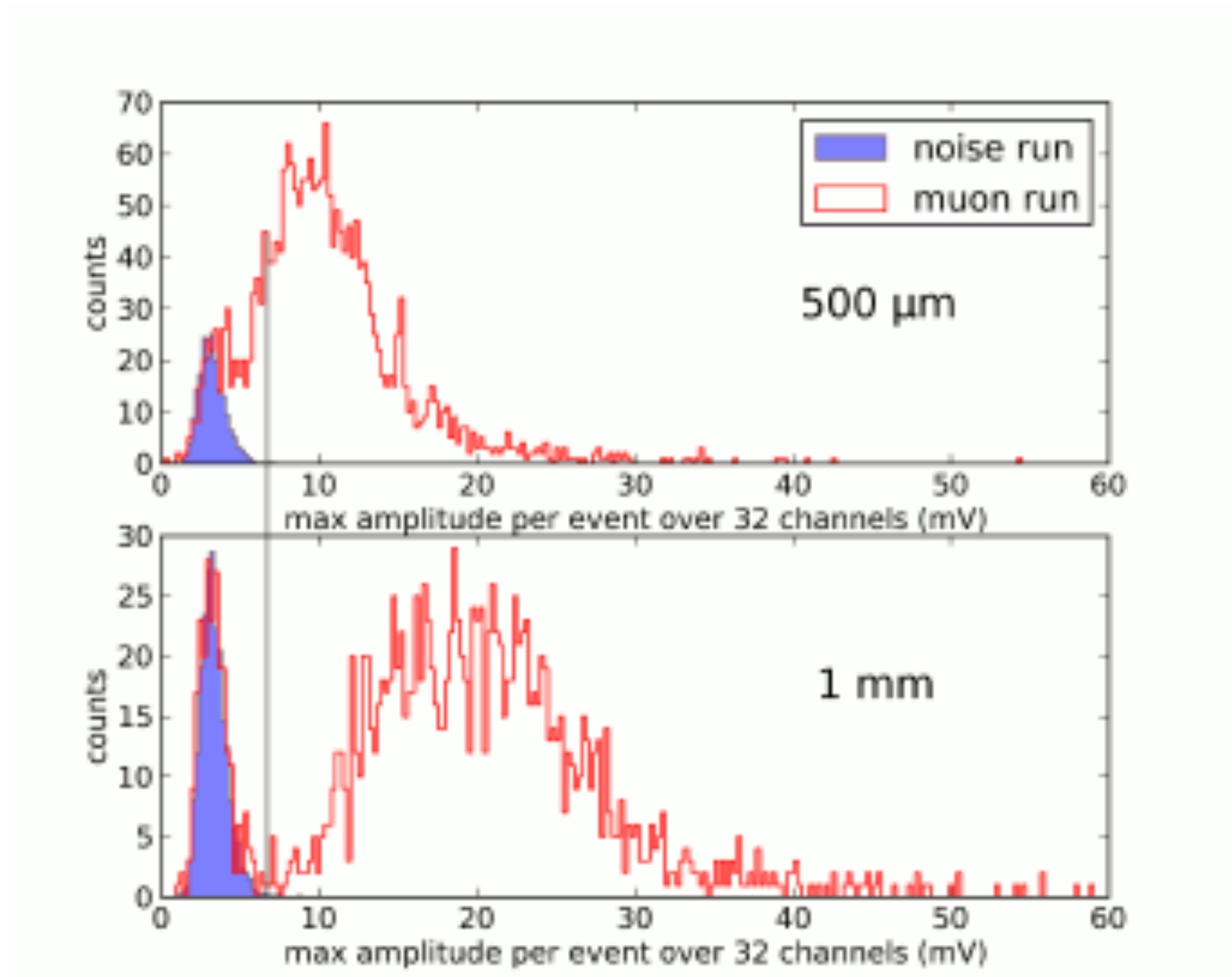
*Courtesy Alexandre Camsonne

Cosmic Tests



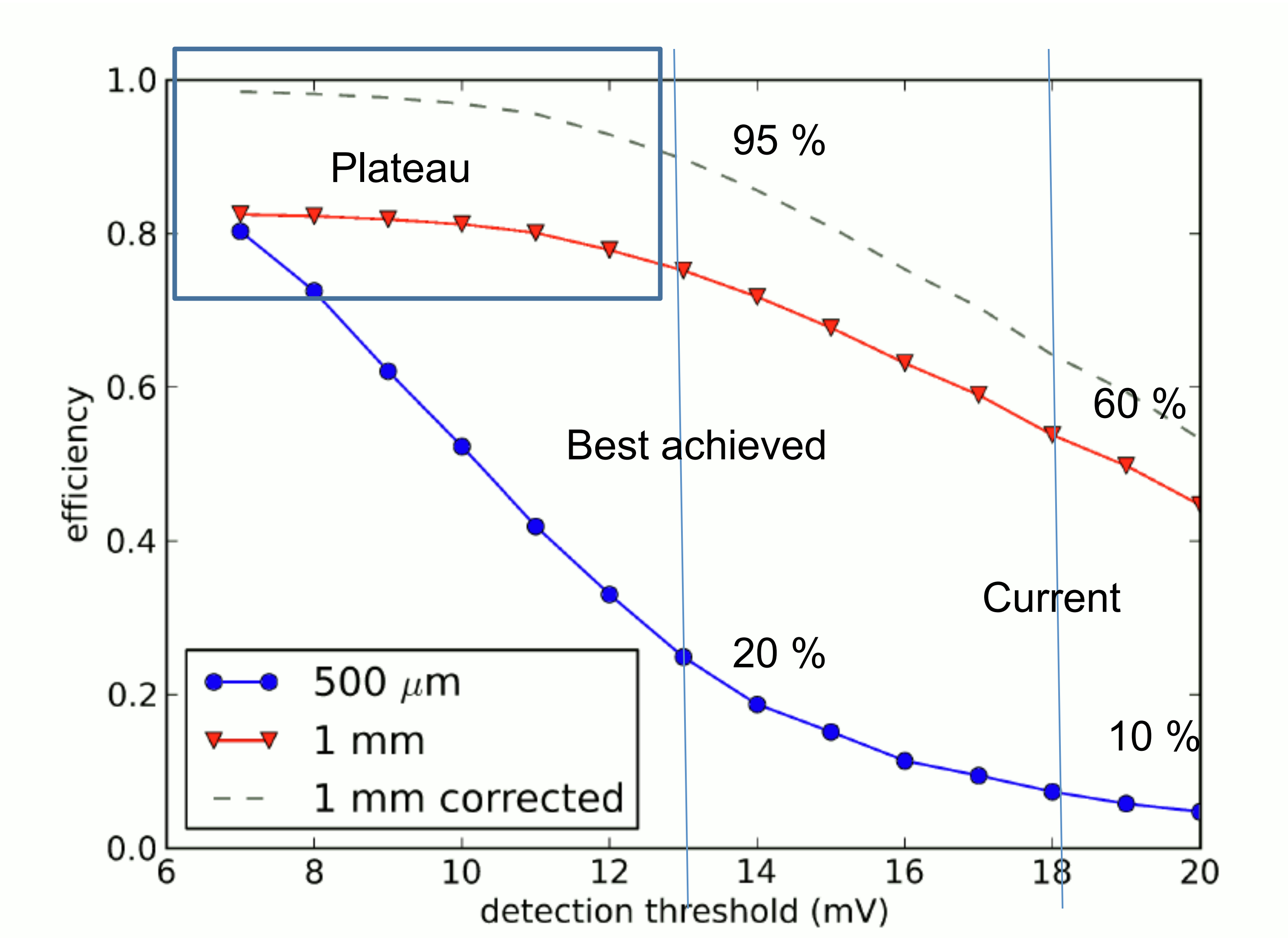
Single channel

Cosmic Tests



All channels (sum)

Efficiency curve



Jefferson Lab