Hall A Polarimetry – Future Plans

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Hall A Collaboration Meeting
February 10-11, 2021

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U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Outline

- Hall A Polarimetry
- Improvements to Hall A (and C) Compton Polarimeters (HIPPOL)
  - Laser system
  - Electron detector
- Møller polarimeter
  - Tracking detectors
  - Collimator
  - New target position

Hall A Polarimetry

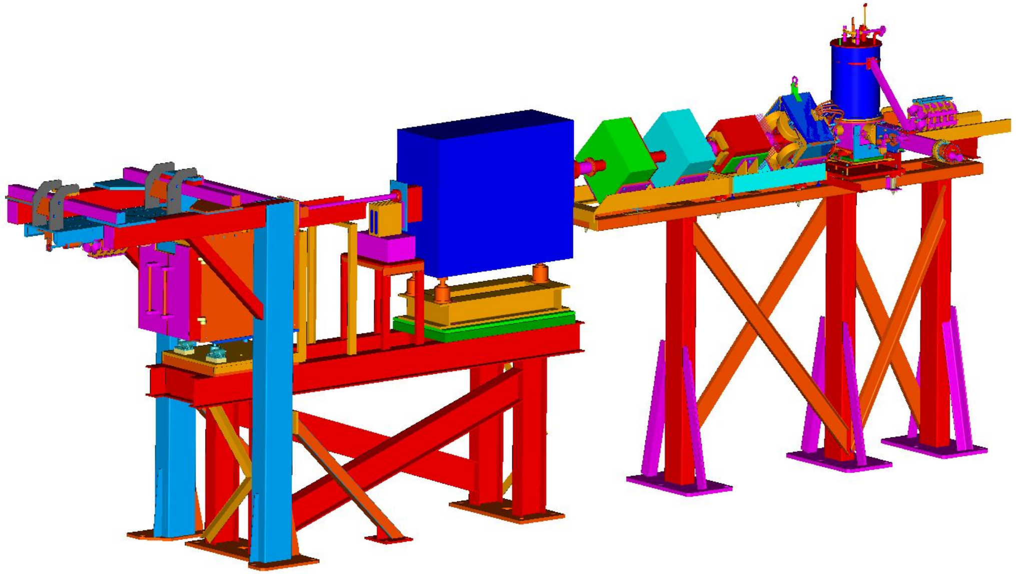
Compton and Moller polarimeters used extensively in 6 GeV era

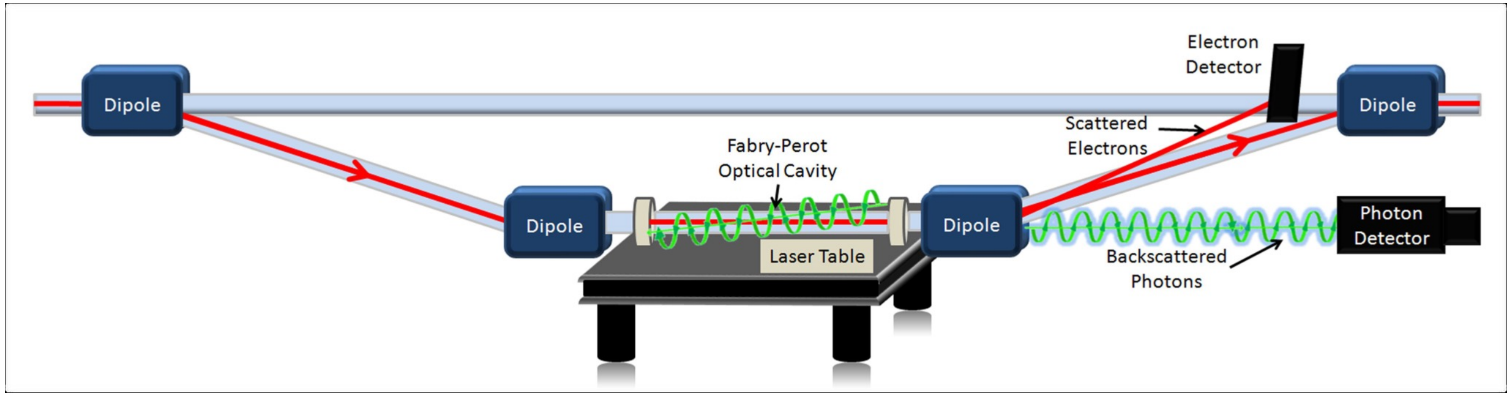
Compton improvements during 6 GeV:

- Laser system → IR to green
- Photon detector → GSO crystal + threshold-less integrating DAQ

Møller improvements during 6 GeV:

- High field target magnet (3-4 T)





Improvements/modifications for 12 GeV

1. Compton chicane modifications (reduced vertical deflection)
2. Moller detectors repositioned (closer to beamline)
3. New, “cryogen-free” magnet for Møller target

Improvements to Hall A and C Polarimetry

- The polarimeters in both Halls A and C have steadily improved precision since the start of the JLab program
- Need for high precision primarily driven by PVES experiments (HAPPEX, PREX, CREX, Q-Weak)
- Precision of dP/P ~ 1% almost "routine"
- Future/ongoing polarimetry improvements driven by:
  - Unprecedented precision required by MOLLER and SOLID
  - Standardization between halls A and C
  - More reliable and robust operation

Experiment	Device	dP/P
HAPPEX-III	Compton (photon)	0.94%
PREX-1	Compton (photon)	1.1%
	Møller	1.2%
Q-Weak	Compton (electron)	0.6%
	Møller	0.85%
PREX-2	Møller	0.89%
CREX	Compton	0.52%
	Møller	0.85%
MOLLER		**0.4%**
SOLID		**0.4%**

0.44% combined!

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Compton Polarimetry - HIPPOL

- **Hi**gh **P**recision **Pol**arimetry capital project
- Ultimate goal: Compton polarimeters in Halls A and C with similar capabilities
  - Leverage available beamtime for systematic, functional tests
  - Use of same components allows for easier access to spares (fiber amplifiers, DAQ components, etc.)
- Scope:
  - Improve Hall C laser system to be similar to Hall A system (low gain cavity → high gain cavity) → components in hand
  - Larger electron detector for Hall C → needed for 11 GeV operation
  - New electron detector in Hall A
  - Update Hall C electron detector DAQ (VETROC system) → components in hand

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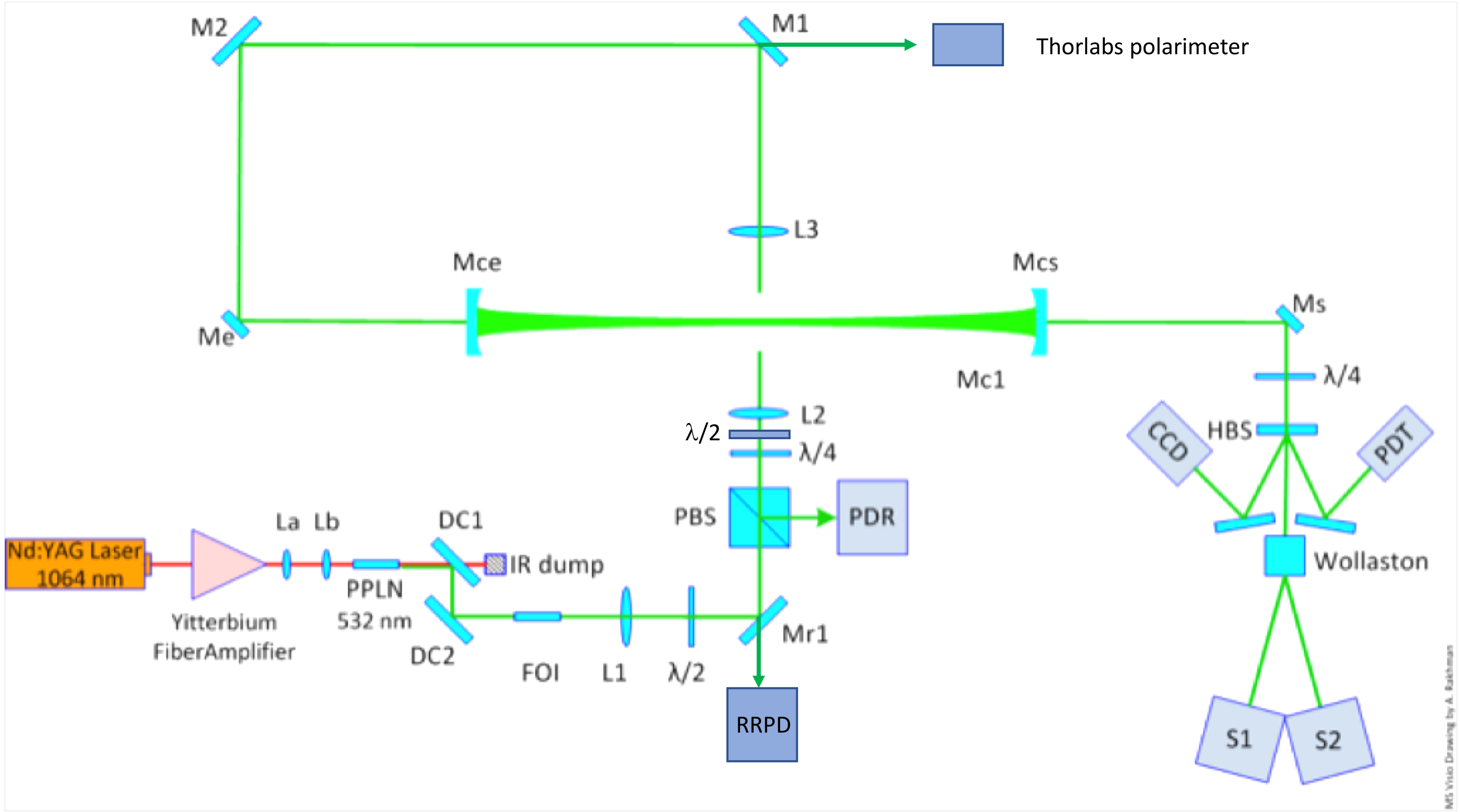
Hall A Laser System

Main components:

- Narrow linewidth 1064 nm seed laser
- Fiber amplifier (>5 W)
- PPLN doubling crystal
- High gain Fabry-Perot cavity
- Polarization manipulation/monitoring optics



Properties:

- 1 W laser power from doubling system
- Mirror reflectivity > 99.98%
- Cavity finesse >=13,000
- Stored power 2-10 kW

HIPPOL: seed laser, fiber amplifier, high reflectivity mirrors for Hall C

Other Laser system updates (not HIPPOL)

Locking electronics:

Hall A still using same custom cavity locking electronics from late 90's

→ Locking electronics live upstairs in CH, VME/EPICS interface in hall

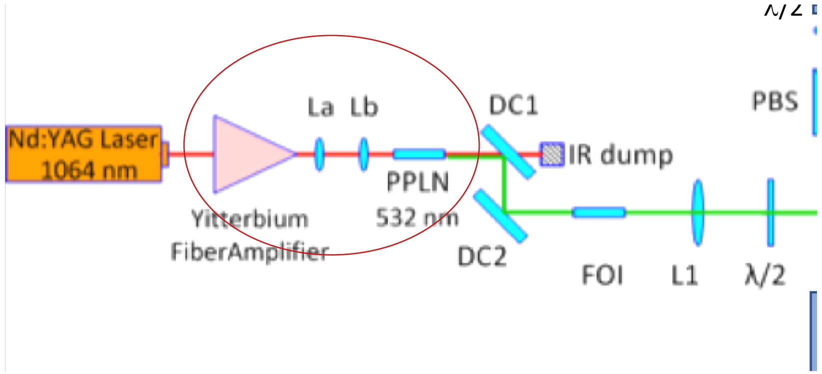
→ CH electronics have already been replaced with spare modules

→ VME modules in hall have had component failures in the last few years - repaired by Spectrometer Support

For reliable long term operation, need spares/backup system

→ Hall C used commercial, FPGA-based locking system (Digilock) – may not be fast enough for high gain cavity

→ Tests with Hall A cavity planned



Laser frequency doubling system

→ Existing system uses separate fiber amplifier + PPLN crystal

→ Replacing PPLN crystal requires significant alignment + downtime

→ Combined-function amplifier-doubler will be tested for compatibility with high finesse cavity

Other Laser system updates (not HIPPOL)

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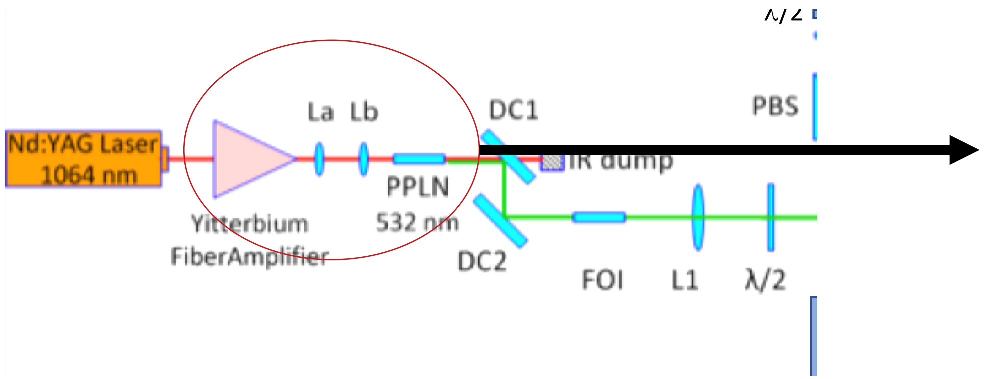
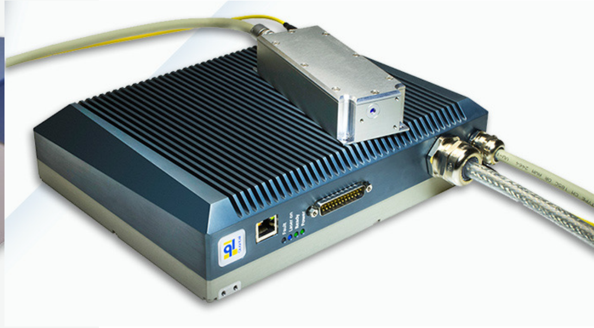


Keopsys CVFA



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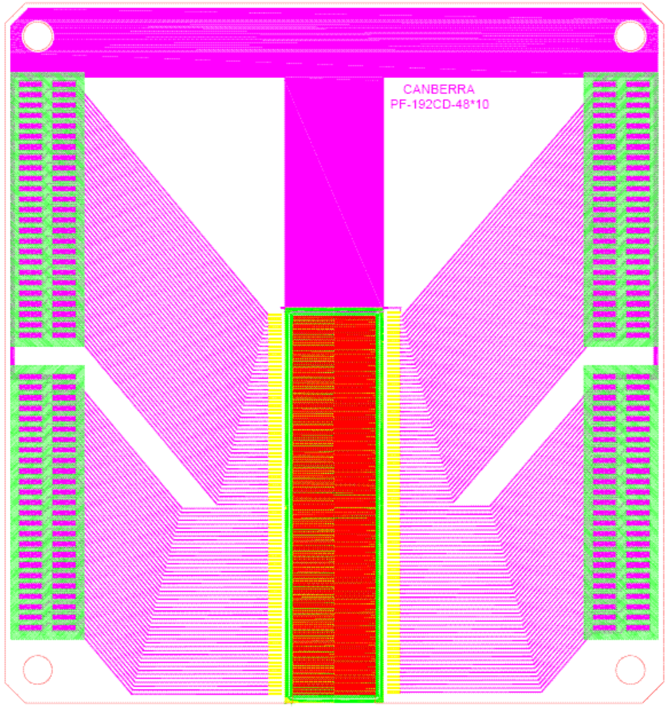
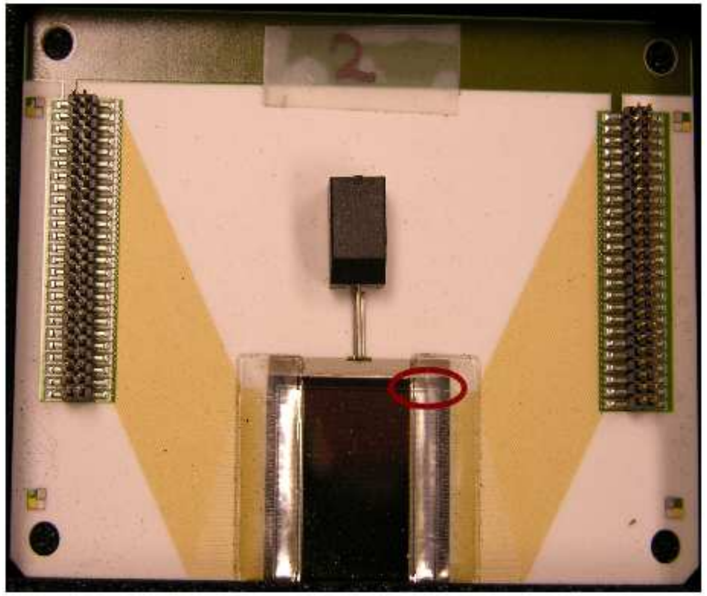
Compton Electron Detector

Existing electron detectors



Hall A: silicon strip
→ 4.6 cm vertical coverage
→ 192 strips, 240 μm pitch
→ ***Suffers from small signal size/excess noise leading to low efficiency***



Hall C: diamond strips
→ 2 cm vertical coverage
→ 96 strips, 200 μm pitch
→ ***Undersized for ideal 11 GeV operation***
→ ***Efficiency ok, but could be improved***

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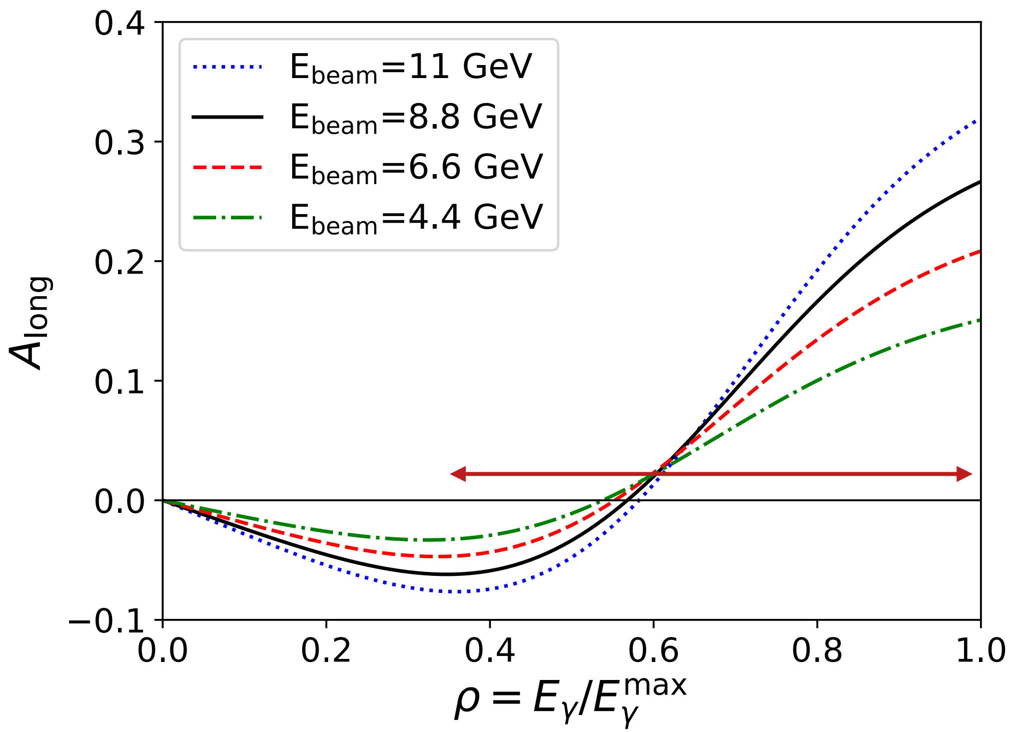
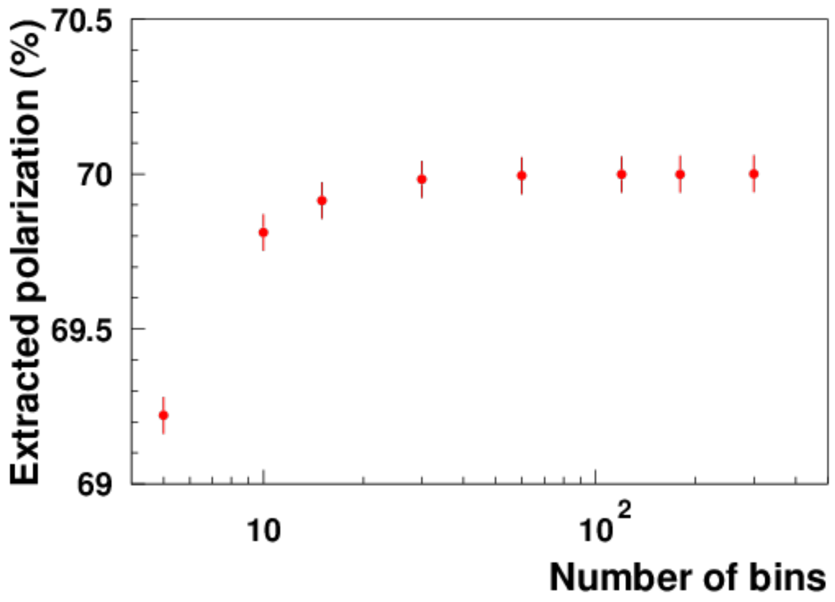
Detector Requirements





Need ~ 30 bins/strips between endpoint and zero-crossing to reliably extract polarization

Needs to cover from Compton edge to at least zero crossing, asymmetry minimum preferred

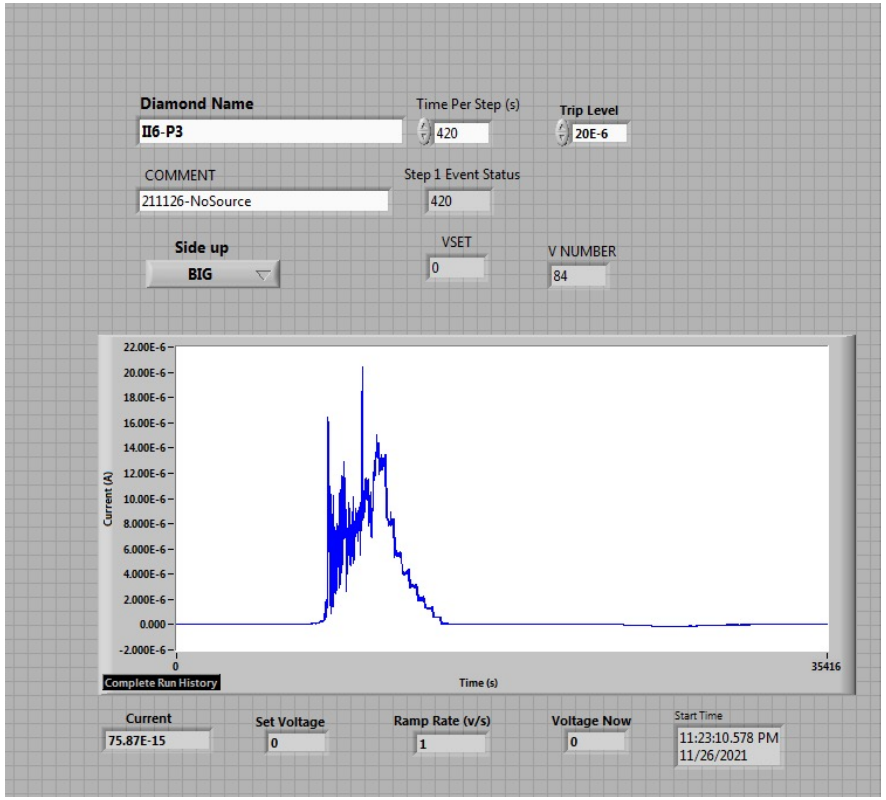
A pitch of 245 μm will allow good performance down to 4.4 GeV in both Hall A and C

Hall A → 5.75 cm
Hall C → > 2 cm

2 x 3 cm or 6 cm plane for Hall A
3 cm plane for Hall C

Electron Detector

- Existing Hall A/C detectors will be replaced with new diamond strip detectors
  - In parallel, U. Manitoba working on HVMAPS electron detector
- Hall C diamond detector worked for Q-Weak but suffered from non-uniform, modest efficiency
  - Analogue pulses carried out of vacuum via flex cables
  - QWAD amplifier-discriminators just outside vacuum can
- New diamond detectors will use ASICS on detector board in place of QWADS outside of vacuum can
- Candidate ASICs under consideration
  - SAMPA (ALICE)
  - SALT (LHCb)
  - Calypso (Ohio State)
- Test diamond substrates procured for tests with above
  - JLab Fast Electronics has designed SALT/SAMPA test boards, Ohio State will design/fabricate Calypso boards



<u>Status</u>

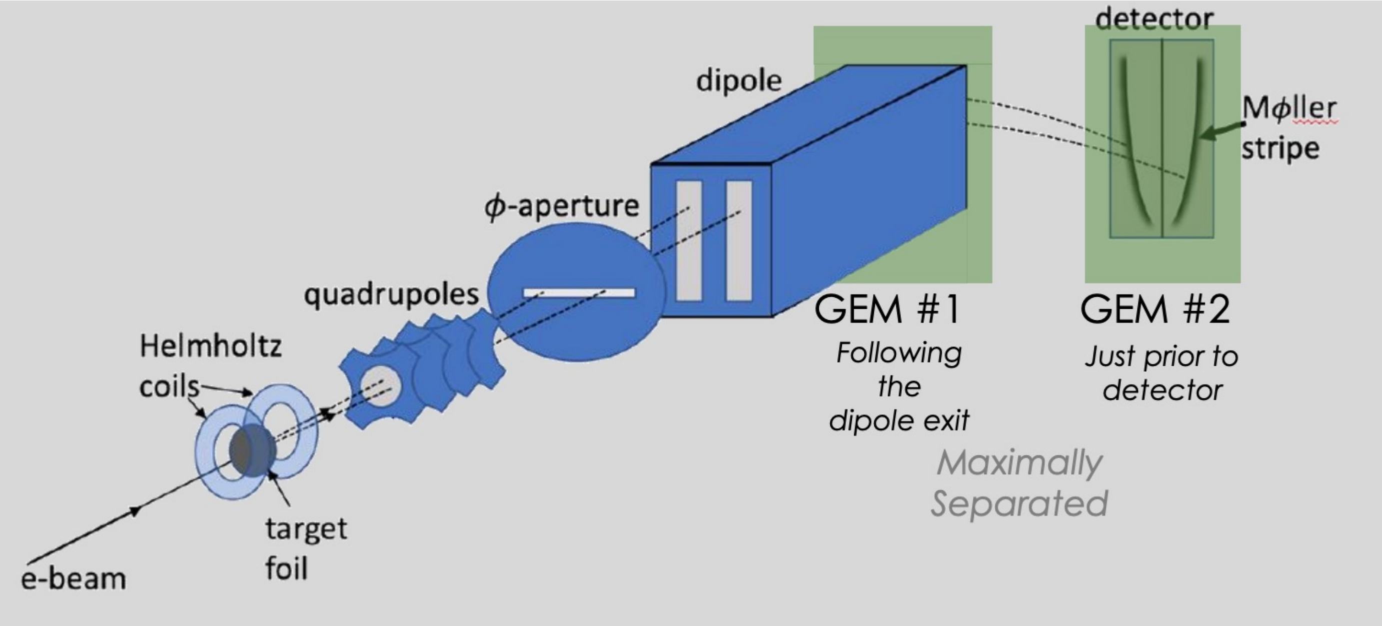
- Test diamond planes obtained from II-VI, sent to Ohio State for characterization
- High leakage currents (µA instead of pA) → boards will be replaced

Tracking Detectors for Hall A Møller

Existing Hall A Møller detector system has no information on event distribution at detectors
→ Event distribution can provide information about spectrometer optics → check Monte Carlo (analyzing power)
→ Additional tracking detector would help reduce systematic error due to acceptance/optics
→ Studies underway to see how tracking detector could help studies of radiative effects and Levchuk effect correction

GEMs will be used to provide this tracking information
→ Funded through MOLLER NSF midscale project (detectors) and DOE project (mechanical supports)

Detector design nearing completion
→ Preliminary design review in January
→ Desirable to install early to allow use/checkout prior to MOLLER run



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Møller GEM Design

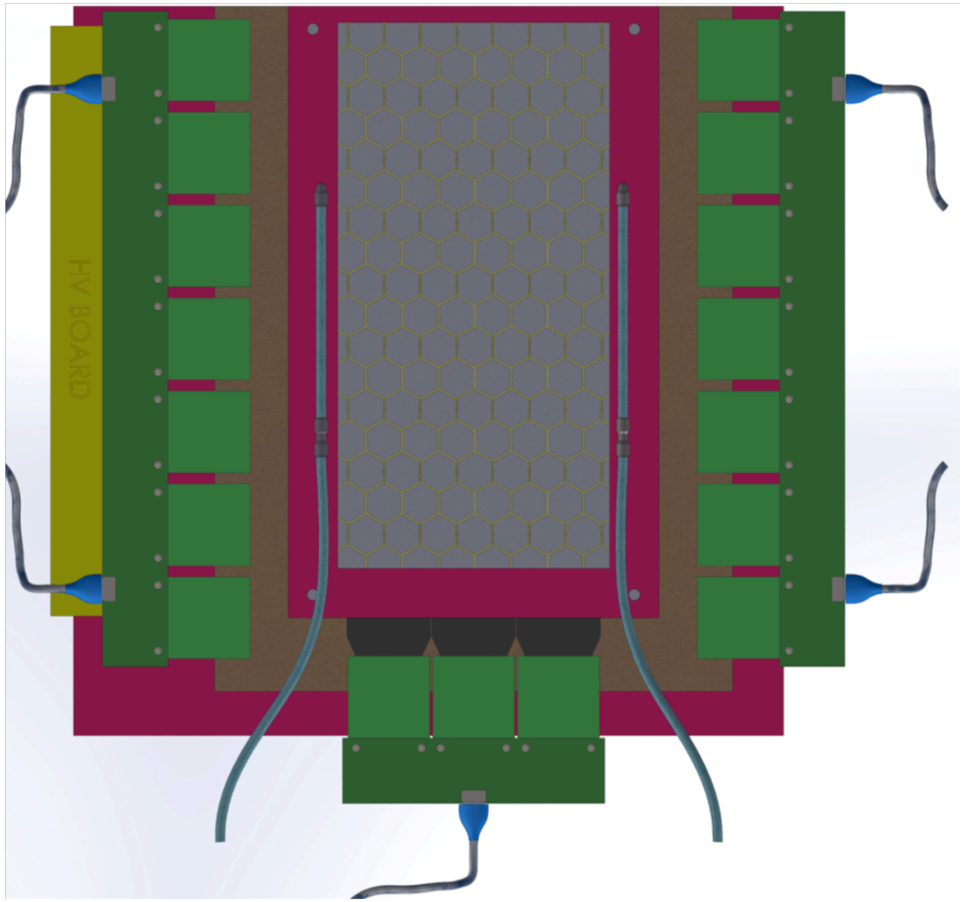
Møller polarimeter GEM detector included in Preliminary Design Review (Jan. 12-14, 2022) held for several MOLLER detectors

Committee recommended adding a 3rd GEM plane (current plan has only 2)

- Final location, number of planes under discussion

Other proposed changes/updates post-review:

- Reduce height of active area for better integration with beamline
- Optimize connectors and cable routing
- Start working with JLab designers to determine plan for detector supports



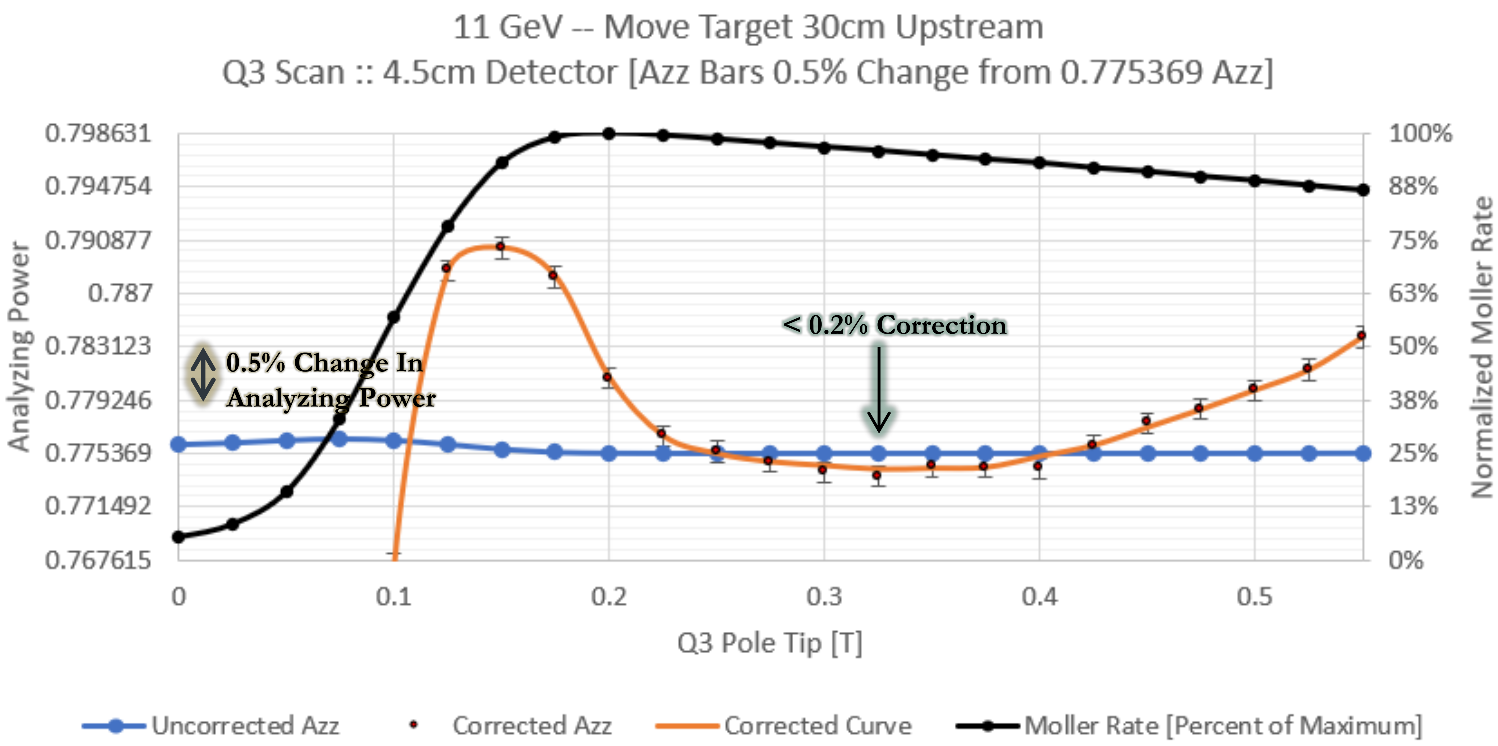
Moller Polarimeter GEM preliminary design, Nilanga Liyanage (Uva)

Møller Target Magnet – Position Shift

At 11 GeV, Møller quads not strong enough to totally eliminate impact of so-called Levchuk effect
→ Correction for Levchuk effect model-dependent and tightly coupled with detailed understanding of acceptance

Can be mitigated by shifting the Møller target/magnet upstream by ~30 cm

Target magnet shift included in MOLLER beamline design → also being pursued in the near-term if time and resources allow



Eric King – Temple University

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New Collimator for Moller detectors

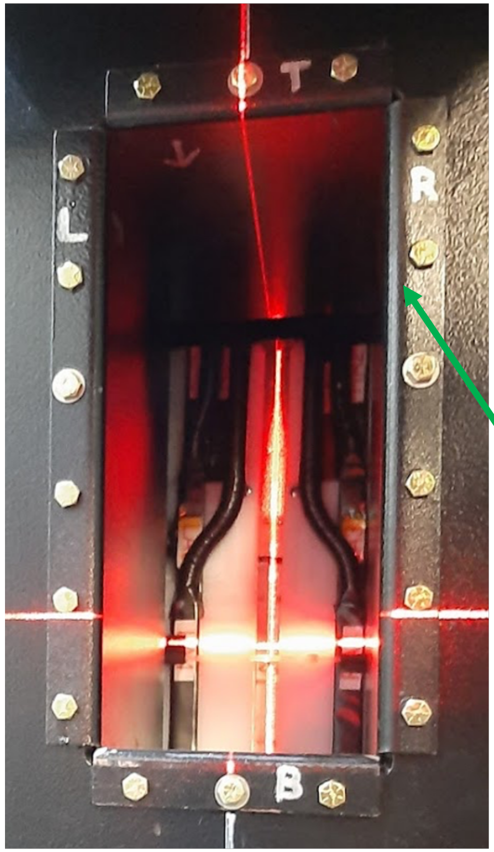
In addition to target position shift, changes to acceptance also required to mitigate Levchuk effect

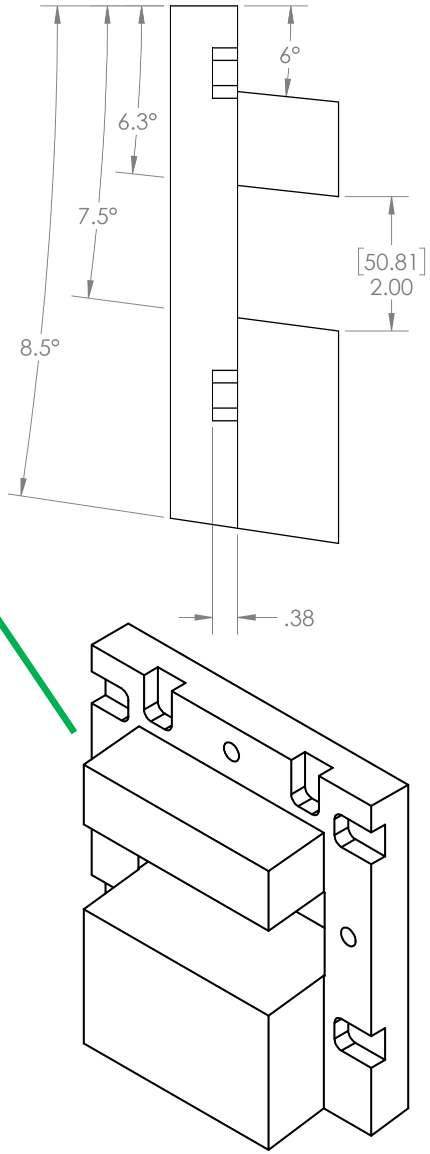
- Limiting vertical acceptance to 5 cm essentially eliminates Levchuk correction
- Full vertical acceptance of Møller detectors is 30 cm (4 rows of PMTs) – reduced in PREX/CREX by turning off rows of PMTs, but minimum coverage is ~7.5 cm → significant Levchuk corrections remains

Rather than fabricating new (smaller) detectors and possibly impacting operation at lower energy, opted to design a small removable collimator

- Tungsten collimator will mount on detector opening (using existing bolts)
- Bottom detectors can be turned off, so no need to extend all the way to the bottom of the detector

Picture of window with frame





Collimator concept: Jim Fast, Don Jones, Eric King

Summary

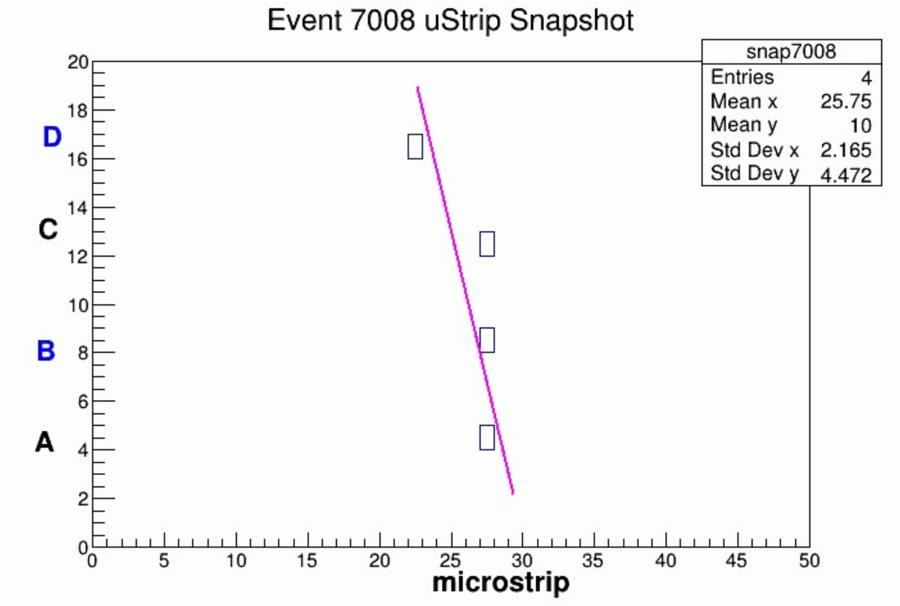
- Several ongoing/planned improvements to Hall A (and C) Compton polarimeters
  - HIPPOL capital project
    - Hall C Compton laser
    - Hall C electron detector DAQ
    - Hall A and C electron detectors
  - Additional improvements being pursued for Compton laser system
    - New locking electronics
    - Combined function amplifier and frequency doubling system
  - Fast counting DAQ also under development → VETROC (electron detector, tested during CREX) and JLab FADC (photon detector)
- Hall A Møller
  - New tracking detectors to better constrain analyzing power and corrections
  - Target shift ~30 cm upstream
  - Acceptance defining collimator

EXTRA

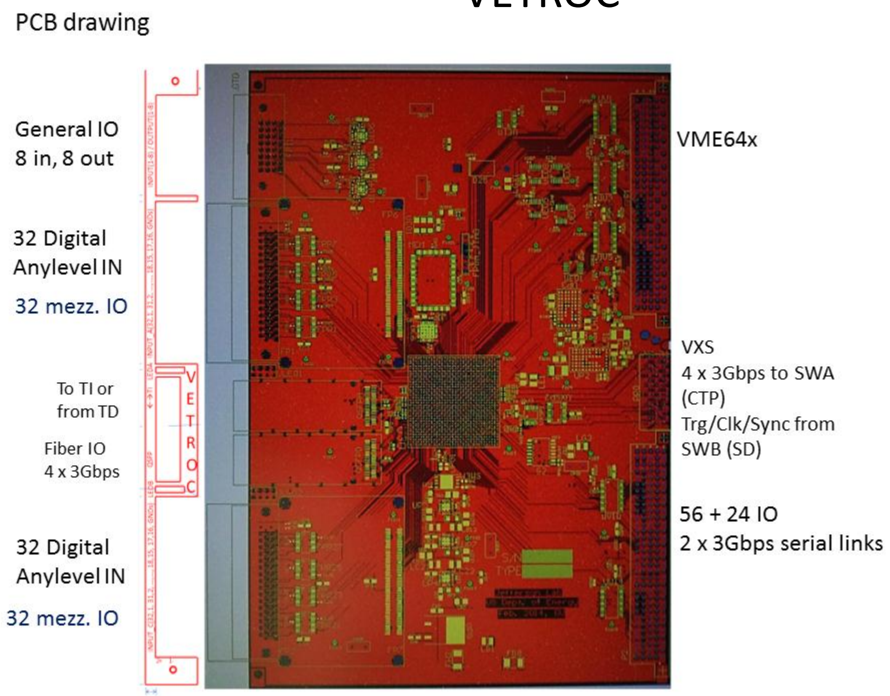
Electron Detector DAQ

Electron detector readout requires processing “tracks” from multiple planes at high rates (order 100s of kHz)

- Hall A has transitioned to using the JLab VETROC modules (first use with beam during CREX)
- Hall C was using CAEN V1495 during Q-Weak
  - V1495 worked well, but can only handle full tracks at very limited rates
  - Required complicated pseudo-tracking based trigger with operation in scaler mode
- Hall C also moving to VETROC–based readout
  - Standardization across Hall A and C
  - Higher rate capabilities – more flexibility



VETROC



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Electron Detector

HIPPOL project:

→ Replace existing electron detectors in Halls A and C with new diamond strip detectors

→ Optimize size and granularity for operation at 11 GeV while retaining low energy capabilities (perhaps slightly reduced precision at lowest energy)

→ Improve on Hall C design with different approach to electronics – amplify signal on detector plane (rather than outside vacuum can)

In parallel, U. Manitoba developing HVMAPS-based detector system (Hall A A only)

→ Prototyping and testing underway