Compton Polarimetry for the MOLLER Experiment

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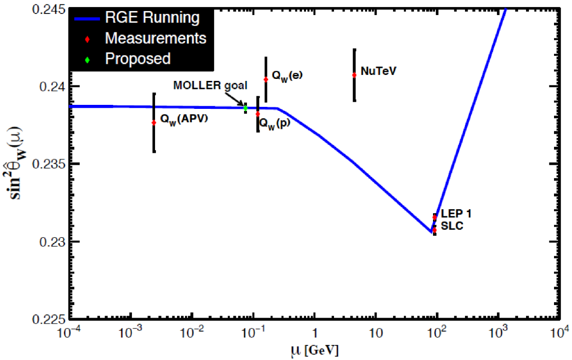
MOLLER Experiment

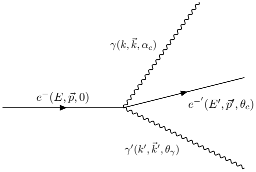
MOLLER is an experiment to measure the parity violating asymmetry A_{PV} in **polarized** electron-electron (Møller) scattering.

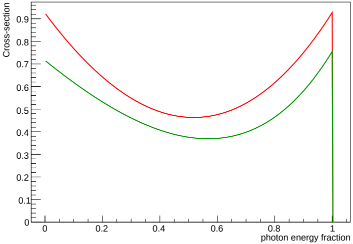
- MOLLER's proposed sensitivity of $\delta(\sin^2\theta_W) = 0.00028$. This is competitive with high energy collider measurement at z-pole.
- Best contact interaction reach for leptons at low OR high energy.



Precision Goal

- MOLLER requires the polarimetry precision of 0.4%.
- This is built on the success of compton polarimeter CREX with quoted precision of 0.4% at low energy.
- Requires
  - New Photon Detector.
  - Electron Detector.
  - Robust laser polarimetry.
  - Control of synchrotron background.

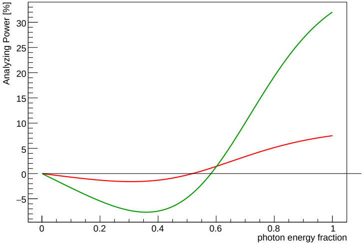




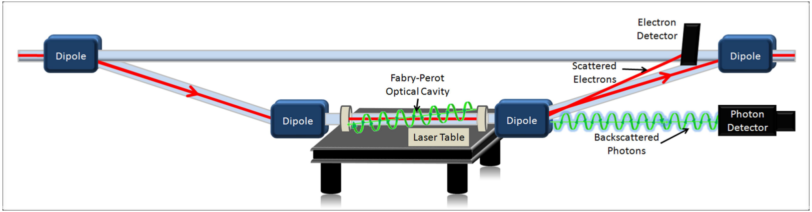
- This technique is non-destructive.
- It can be used for energies larger than ≊1GeV.

$$k' = k \frac{E + p\cos\alpha_c}{E + k - p\cos\theta_\gamma + k\cos(\alpha_c - \theta_\gamma)}.$$

$$\mathcal{A}_c = \frac{\sigma_l - \sigma_l}{\sigma_l + \sigma_l}$$



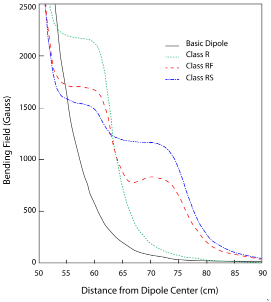
Compton Polarimeter

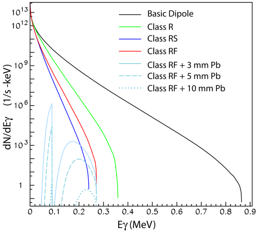


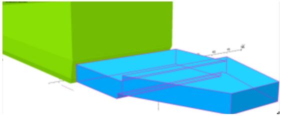
- 4-dipole chicane – deflects beam by 215mm to interact with laser system
- Electron detector – between dipoles 3 and 4. Two parallel techniques for electron detector under development.;
  - Diamond strip detectors.
  - HVMAPS.
- Photon Detector - lead-tungstate (PbWO4). Was used during the DVCS running in Hall A.
- Both electron detector and photon detector simultaneously independently used for polarization measurement.

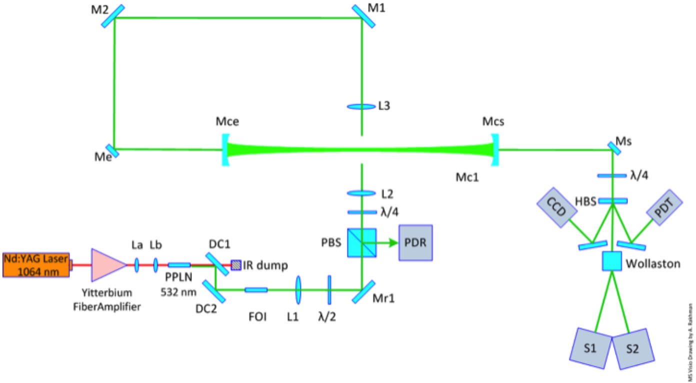
Dipole Shims

- Background from synchrotron radiation in the photon detector is a primary concern.
- Shims are added to chicane dipoles to mitigate synchrotron radiation at higher energies
- Implementing these shim designs is challenging due to constraints.



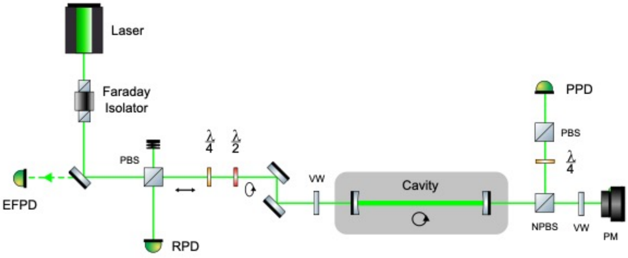


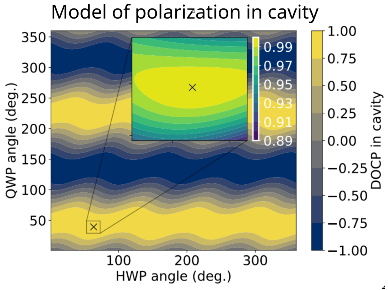




- Laser system – high finesse/high-gain Fabry-Perot cavity, pumped by narrow linewidth 1064 nm laser, frequency doubled to 532 nm.
- Laser system components: 1064 nm seed + 5-10 W fiber amplifier + PPLN doubling system generates 1 W green power

Laser Polarization Determination

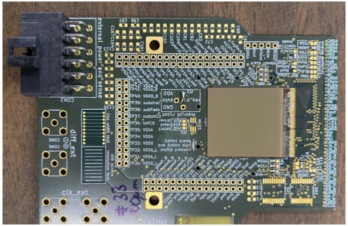


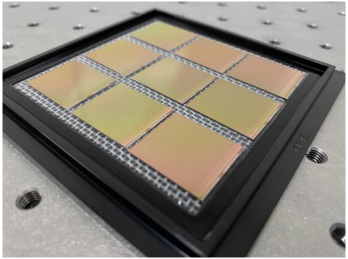


- Use back reflection to optimize the cavity.
- Use the outgoing beam to measure the polarization in the cavity.

Electron Detector (HVMAPS)

- Hybrid pixel sensors based on HV-CMOS technology
- Each pixel dimension is 80 x 80 μm^2, spread across a 250 x 256 grid
- Approximately 2 x 2 cm^2 detectable area.
- Readout electronics, filters and amplifiers all integrated into the chip.
- Timing resolution of 16ns with peak detection rate of 30 MHz per readout line





This is being developed at the University of Manitoba. **More details on next talk by Shefali.**

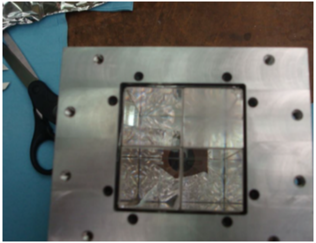
Electron Detector(Diamond Strip)

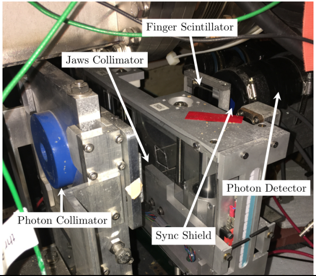
- New electron detector is required to meet precision goal for MOLLER.
- Diamond detectors being developed/fabricated.
- Previously successfully used for Hall-C Compton polarimeter during the Q_{weak} experiment.
  (Phys. Rev. X, 6(1):011013, 2016.)
- Plans to improve the performance during Q_{weak} by putting amplification electronics on the detector board.
- Substrates ordered from II-VI. Which is now delivered and perform suitably.

The SenseIC in Columbus Ohio is developing new FLAT-32 ASIC and Ohio State University is making the diamond sensors.

Photon Detector

- Lead tungstate calorimeter read out with a single PMT.
- 6m downstream from the compton interaction point.
- Can use threshold-less energy integration technique similar to low energy measurements.
- Will be able to calibrate response function with concidence electron detection.



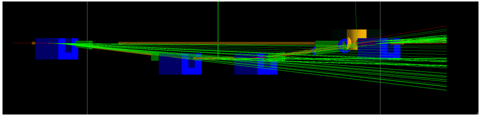


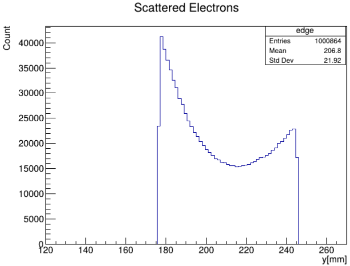
Expected Uncertainty

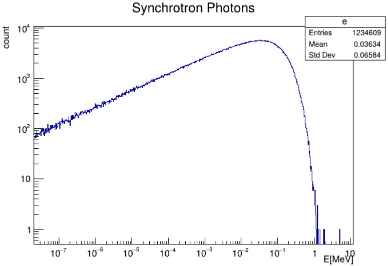
Relative error (%)	electron	photon
Position asymmetries*		
E_{Beam} and λ^*_{Laser}	0.03	0.03
Radiative Corrections*	0.05	0.05
Laser polarization*	0.20	0.20
Background / Deadtime / Pileup	0.20	0.20
Analyzing power Calibration / Detector Linearity	0.25	0.35
Total:	0.38	0.45

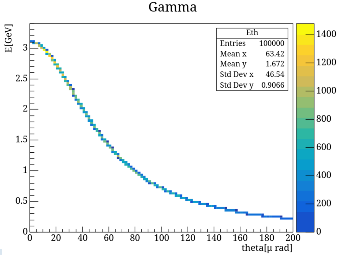
Topics marked $*$ are common systematic uncertainties between the photon and electron analyses, while the others are largely independent between the detector systems.

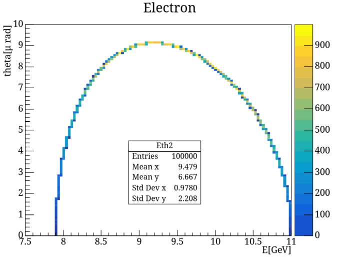
Geant4 Simulation











- Simulation will be used to study synchrotron light and Compton event and background detection.

Summary

- MOLLER has very stringent requirement on precision. Precise knowledge of electron polarization is very important to achieve that requirement.
- Combination of electron detector and photon detector provides very precise measurement of polarization using compton polarimetry.
- Experience from past experiments; PREX-II and CREX have provided essential insights that help improve technique to achieve expected 0.4% precision in polarimetry.