Electron Detectors for the MOLLER Experiment

Nafis Niloy (on behalf of the MOLLER Collaboration)
University of Manitoba

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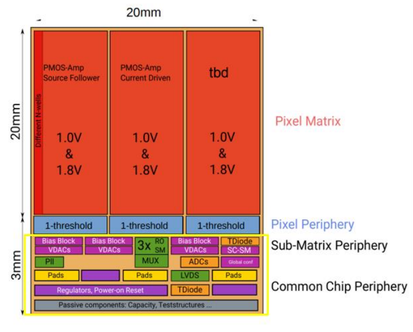
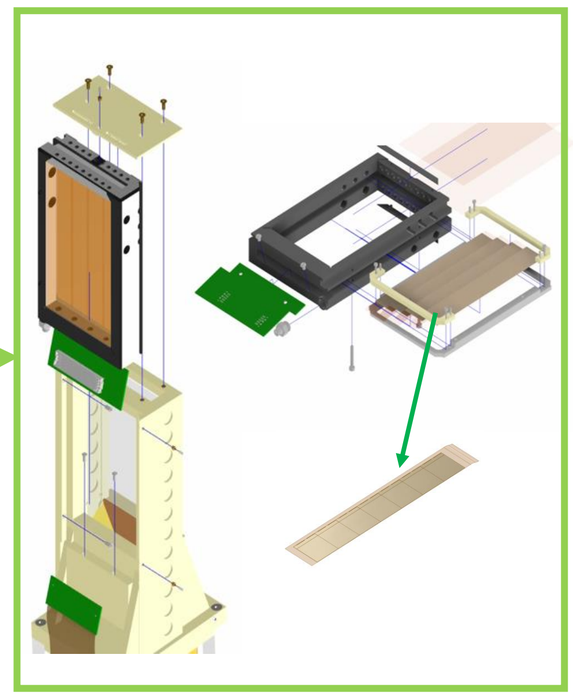
HVMAPS

- HVMAPS (High Voltage Monolithic Active Pixel Sensors) are based on HV-CMOS technology [1]
- Each active pixel is 80 x 80 μm^2 with readout electronics, filters and amplifiers all integrated into the chip
- Overall size of detectable region is 2 x 2 cm^2
- Can be manufactured as thin as 50 microns (low material budget)
- Timing resolution of 16 ns with peak detection rate of 30 MHz
- Generates about 1W of heat during peak operation
- Operating temperature should not exceed 75^0 C, so will require cooling solutions if used in vacuum or confined spaces.



Main Integrating Detectors

- Consists of 224 Cherenkov detectors operating in integration mode [2]
- Ring 5 detectors will have HVMAPS to map scattered electron profile as well as diagnostic purposes
- HVMAPS will be glued and wire-bonded to Kapton flex-prints with signal and power traces
- Each Ring 5 quartz will have 7 x 4 = 28 HVMAPS placed behind it
- Constant airflow needs to be maintained across the HVMAPS planes to prevent overheating of the HVMAPS

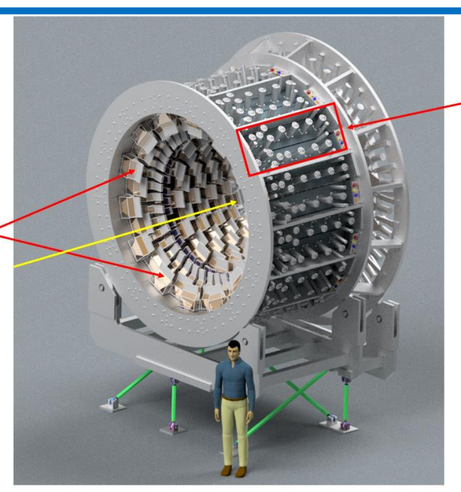


The MOLLER Experiment

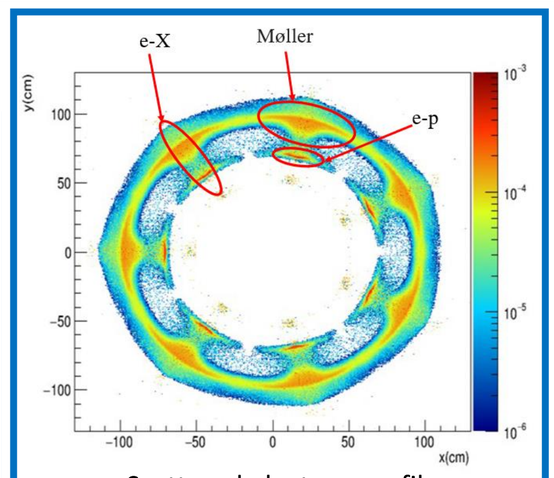
- MOLLER will measure A_{PV} in Moller scattering (due to EM and weak neutral currents) to an uncertainty of 0.8 ppb [2]
- Will give the weak charge of the electron to within 2.4%, and the weak mixing angle to ± 0.00028
- Measured Asymmetry, $A_{meas} = Pe(f_p A_{PV} + \sum_b A_b f_b) + Ab_{eam} + Ai_{nst}$

$$\text{where } A_{PV} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \left[mE \frac{G_F}{\sqrt{2}\pi\alpha} \frac{4\sin^2\theta}{(3+\cos^2\theta)^2} \right] Q_W^e$$

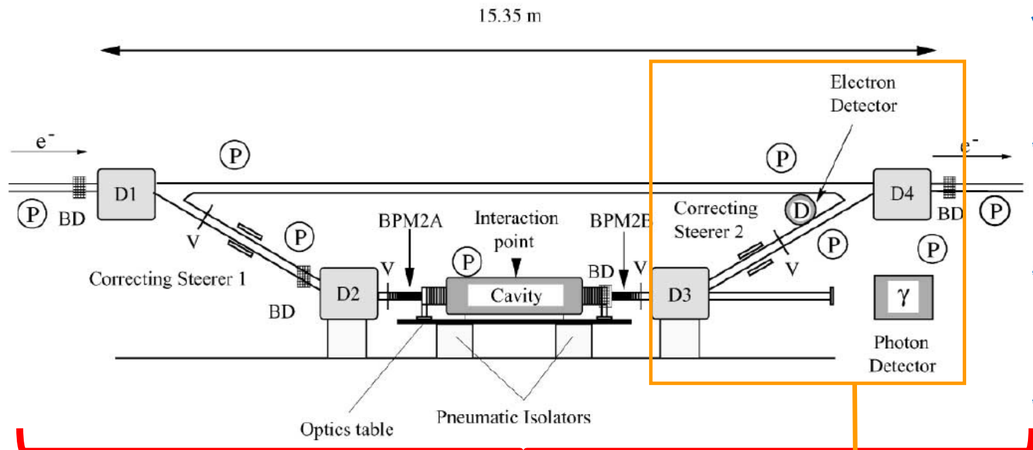
- Will use JLab's Continuous Electron Beam Accelerating Facility (CEBAF) with a beam helicity flip rate of 1.92 kHz



MOLLER Main Integrating Detectors

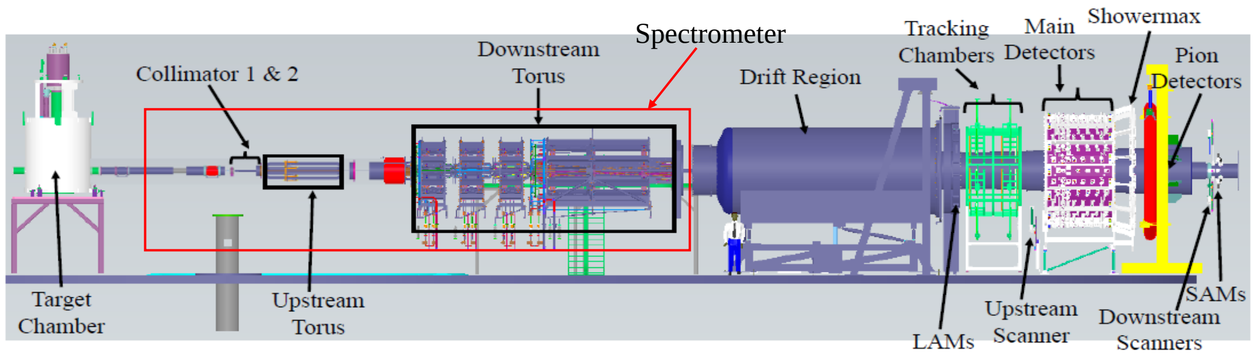


Scattered electron profile



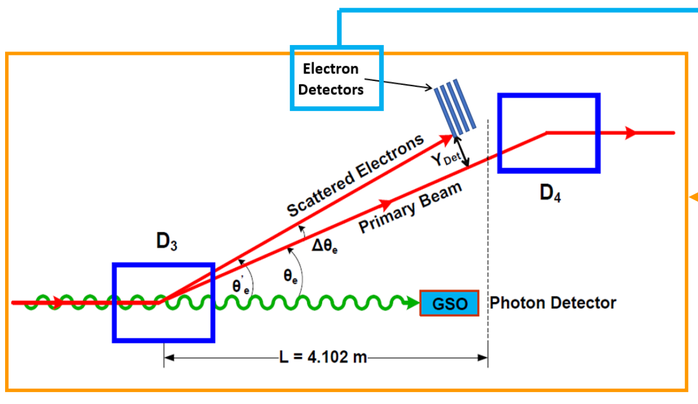
Compton Polarimeter

(not to scale)

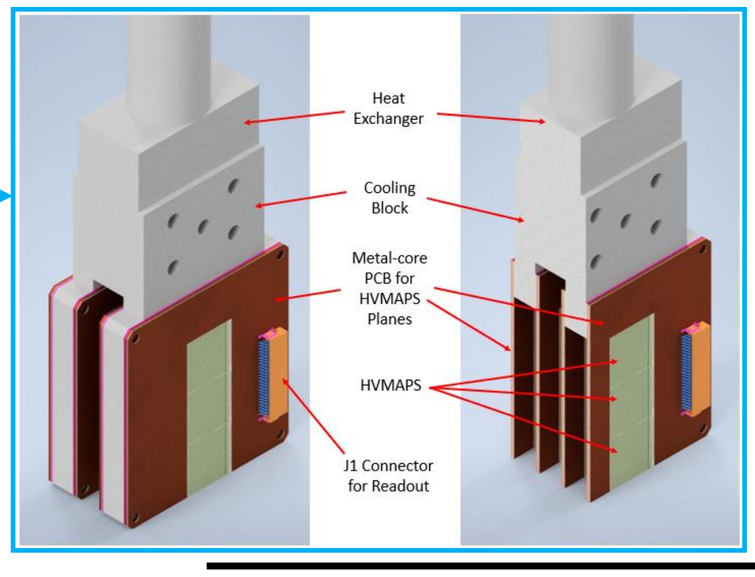


MOLLER experimental setup in Hall A

Compton Polarimeter



- Accurately measures the polarization of the electron beam
- Relies on Compton Scattering between electrons and photons in a Fabry-Perot cavity [3]
- Polarization is measured as a function of scattered photon and electron energy
- $A_{exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_\gamma P_e A_l$
- 4 parallel planes of 3 x 1 HVMAPS placed between dipoles D3 and D4 to accurately measure electron deflection



- HVMAPS for Compton Polarimeter will be under vacuum and must rely on passive (mostly conductive) cooling
- Chips will be glued and wire-bonded to metal-core PCBs to aid heat dissipation
- Copper cooling blocks will transfer heat generated by HVMAPS to the heat exchanger
- LCW will be circulated through channels inside the heat exchanger to carry away the heat

References

1. Niklaus Berger, Mu3e Collaboration, et al. The mu3e experiment. Nuclear Physics B-Proceedings Supplements, 248:35–40, 2014.

2. Mammei, Juliette. "The MOLLER experiment." *arXiv preprint arXiv:1208.1260* (2012).

3. Rakhman, A., et al. "A high-finesse Fabry–Perot cavity with a frequency-doubled green laser for precision Compton polarimetry at Jefferson Lab." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 822 (2016): 82-96.