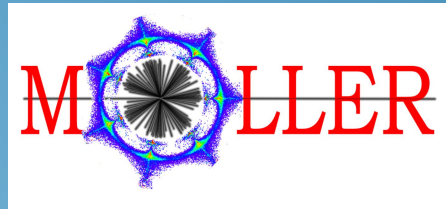


Scanning Beam Monitor Sensitivities for the MOLLER Experiment

Andrew M. Gunsch



Jefferson Lab



1

Thurs. 06-15-2023

Andrew M. Gunsch



Jefferson Lab

VIRGINIA TECH

Outline

- **MOLLER Overview**
 - The MOLLER Experiment
 - The MOLLER Apparatus
- **Scattered Beam Monitors**
 - LAMs
 - SAMs
 - Sensitivity to Magnetic Fields
 - Sensitivity to Beam Position

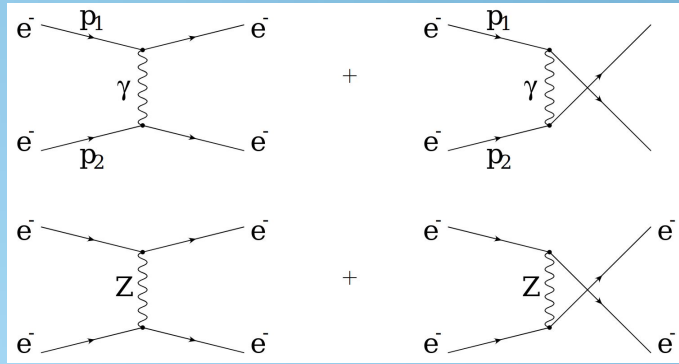


The MOLLER Experiment

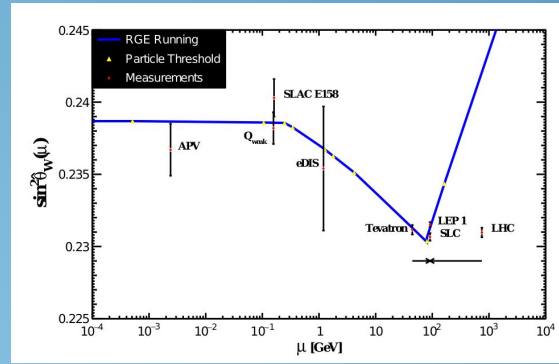
Seeks to obtain an ultra-precise measurement of the **Weak Mixing Angle** at low energy via the **parity-violating asymmetry** of elastic electron-electron (**Møller**) scattering.

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \quad [2]$$

Measurement
Of a
Lepton-
Lepton
Electroweak
Reaction



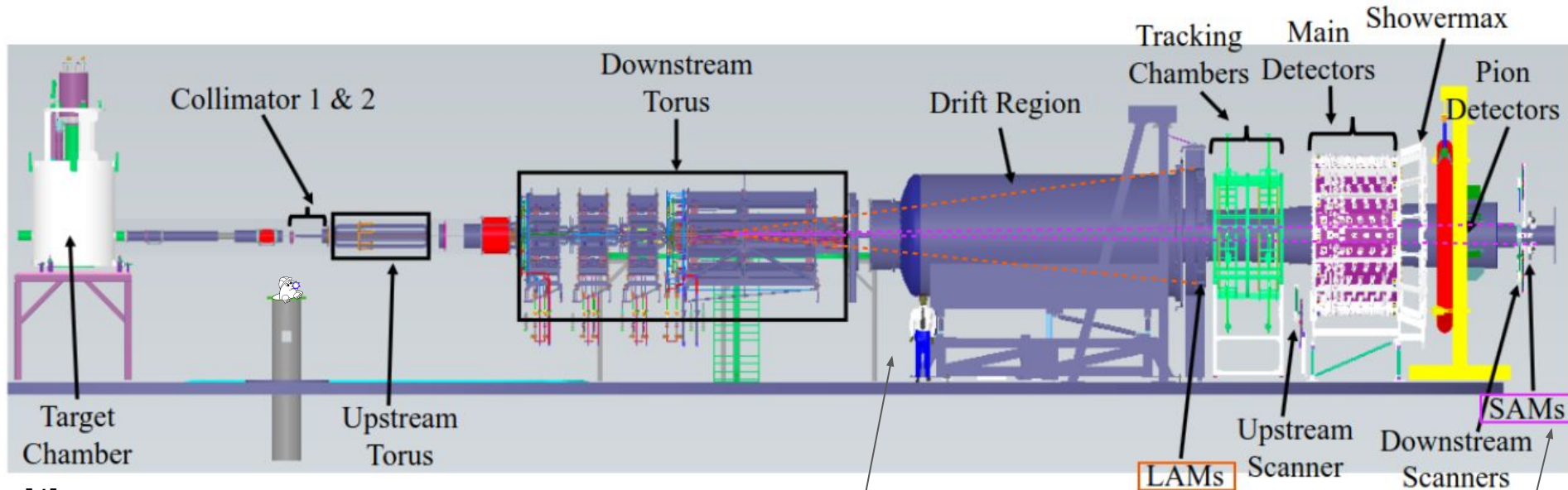
[1]



[3]



The MOLLER Apparatus: Overview



[4]

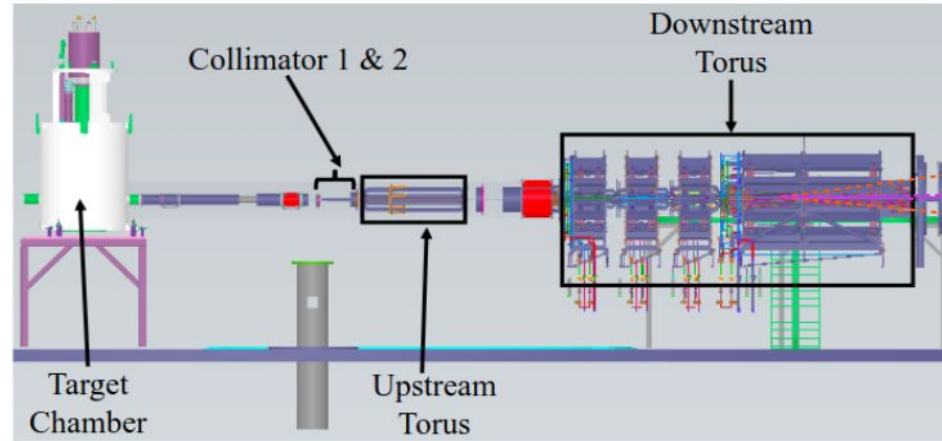
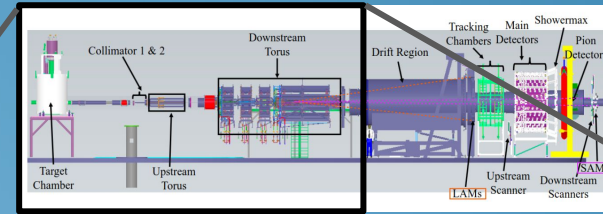
Person for scale

Scattered Beam Monitors



The MOLLER Apparatus: Target and Spectrometer

- Electrons in 11 GeV longitudinally polarized beam scatter off of electrons in the liquid hydrogen target
- Collimators and toroidal magnets define the azimuthal acceptance.



[4]

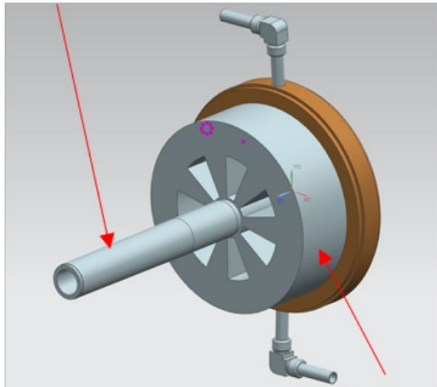


The MOLLER Apparatus: Spectrometry

- Collimator 1 catches the beam
- Collimator 2 defines acceptance of scattered electrons in seven sectors

- The magnet toroids pull the scattered electrons away from the beam

Collimator #1



[5]

Collimator #2

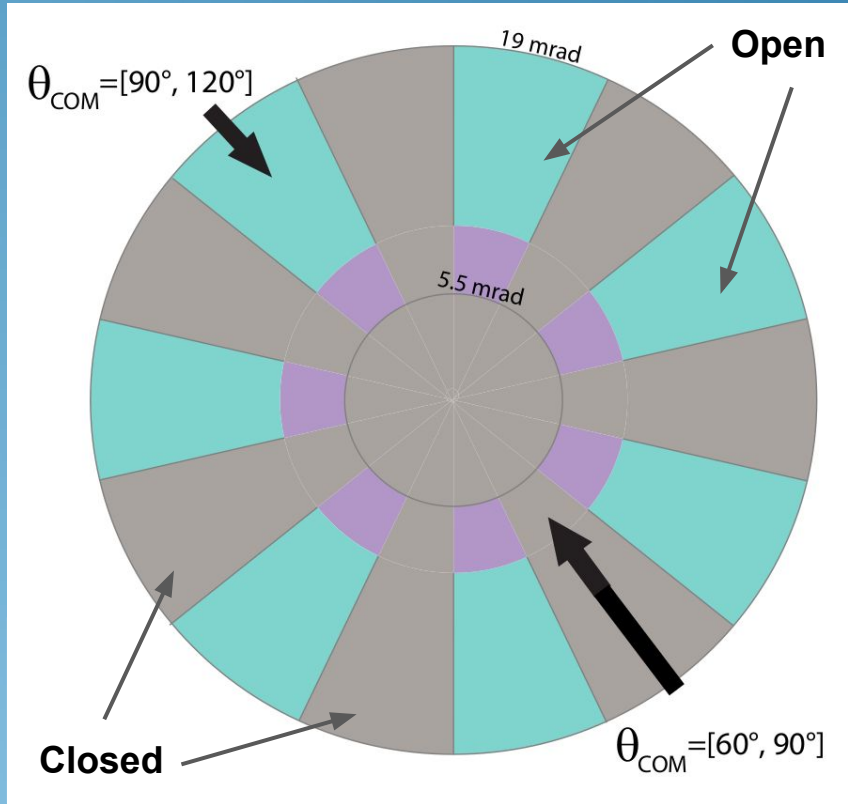


[5]



The MOLLER Apparatus: Spectrometry

- Seven “Open” sectors through which scattered particles may pass
- Seven “Closed” sectors which block scattered particles
 - Locations of toroidal magnetic coils
- Each Møller electron blocked by the closed sector will have a counterpart in the open sector
 - Complete azimuthal acceptance of Møller events

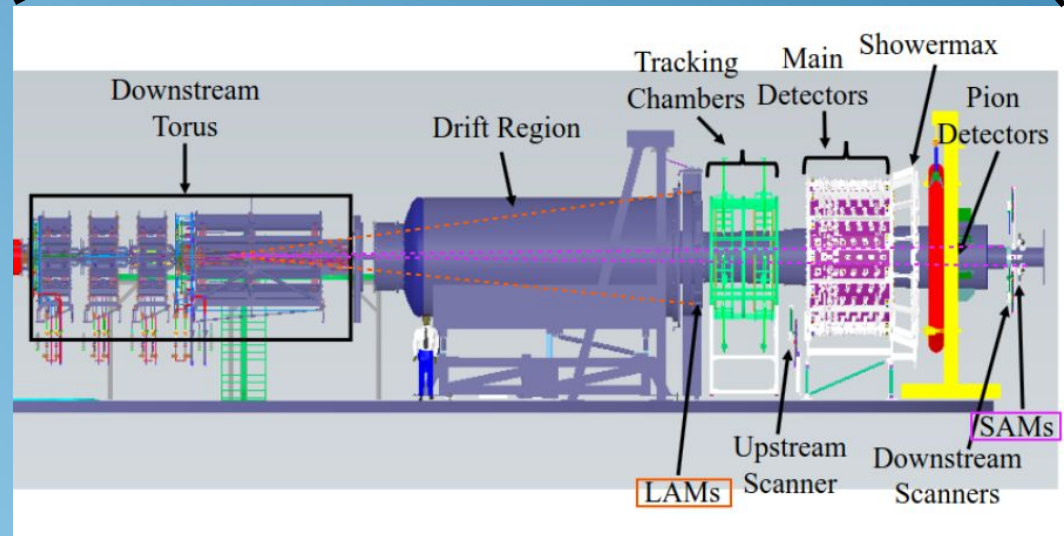
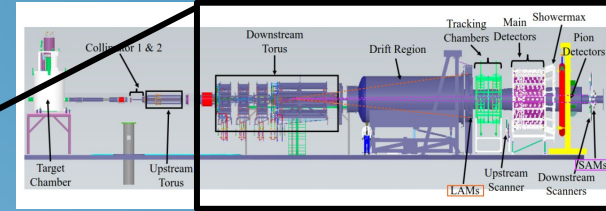


[5]



The MOLLER Apparatus: Detectors

- The scattered electrons drift into the detectors.
- The **Large Angle Monitors (LAMs)** and **Small Angle Monitors (SAMs)** are Scattered Beam Monitors

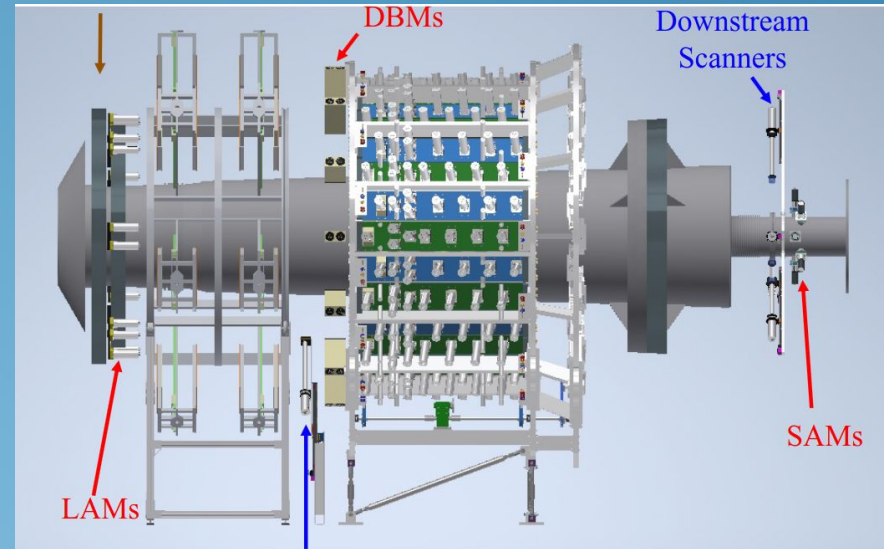


[4]



Scattered Beam Monitors

- Rescattering particles can contribute to false asymmetries
- The Scattered Beam Monitors will watch these backgrounds in order to preserve the integrity of the Møller measurement.

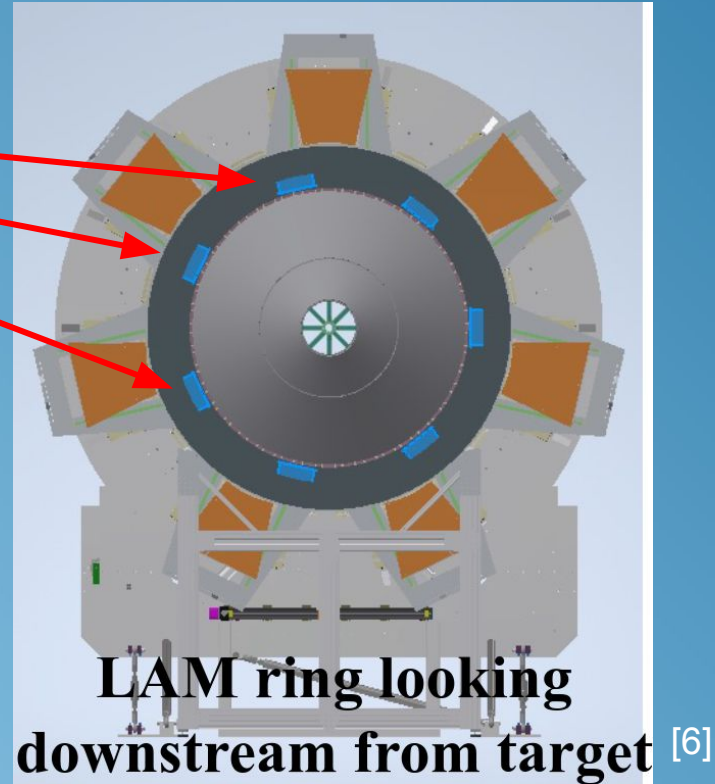
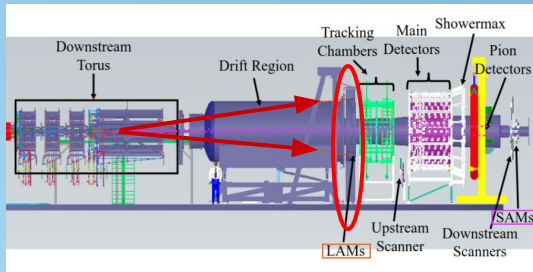


[6]



Large Angle Monitors (LAMs)

- LAM modules positioned in each of the seven Open Sectors.
- Detect particles that scatter at wide angles
- Current detector quartz geometry:
 - Inner radius 1031.5mm
 - Outer radius: 1196.5mm



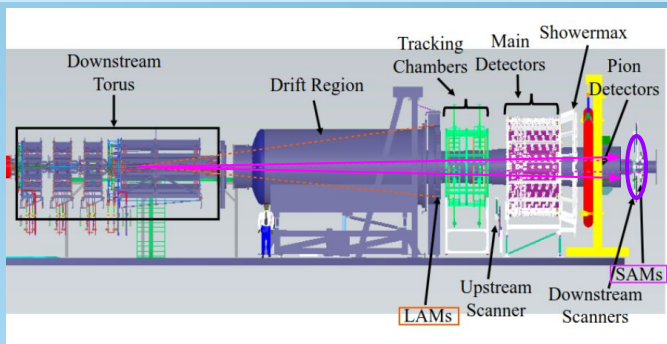
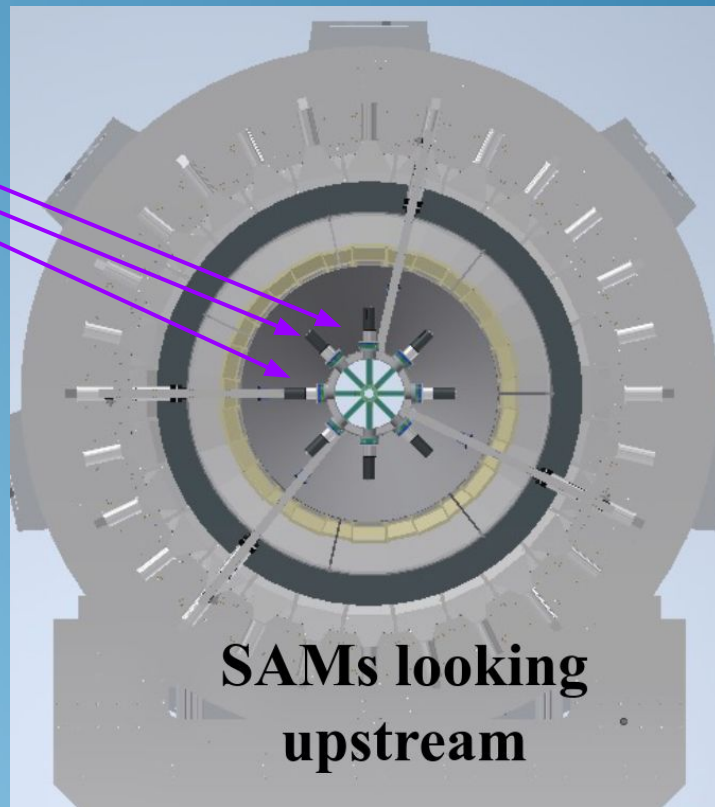
[4]

[6]



Small Angle Monitors (SAMs)

- Eight SAM modules positioned symmetrically about the azimuth
- Current detector quartz geometry:
 - Inner radius: 50mm
 - Outer radius: 66mm
- SAMs do not line up with the Open/Closed Sectors



[4]

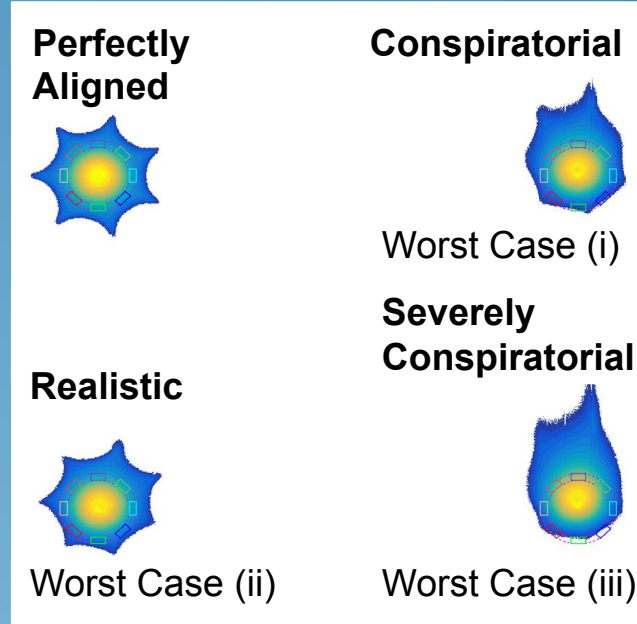
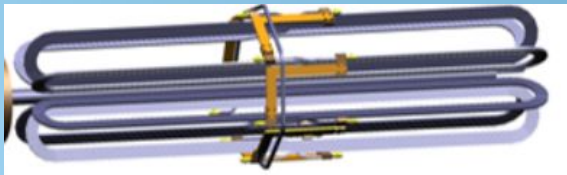
[6]



Sensitivity to Magnetic Fields

- The magnetic coils will not be perfectly aligned
- Simulations were performed for cases of misaligned magnetic fields
- Misaligned “Worst Case” magnetic field maps:
 - Conspiratorially misaligned fields: (i) & (iii)
 - Realistically misaligned fields: (ii)

[5]



Histogram rootfiles generated by Devi L. Adhikari

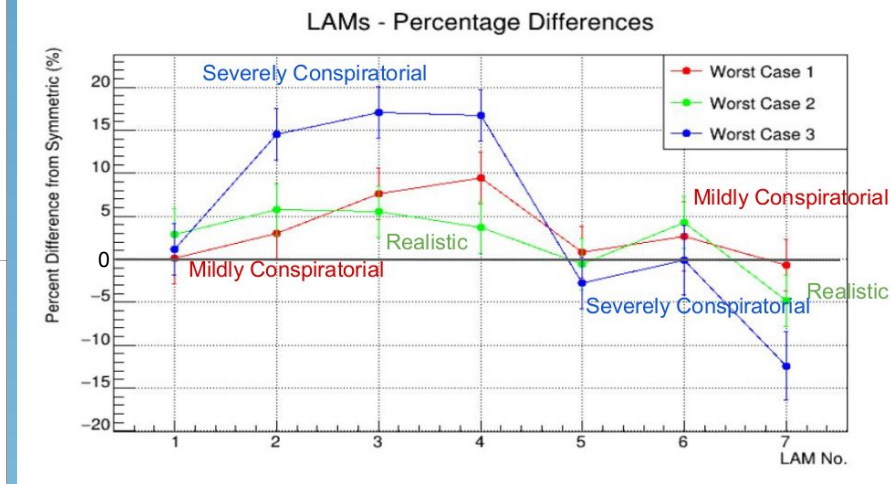
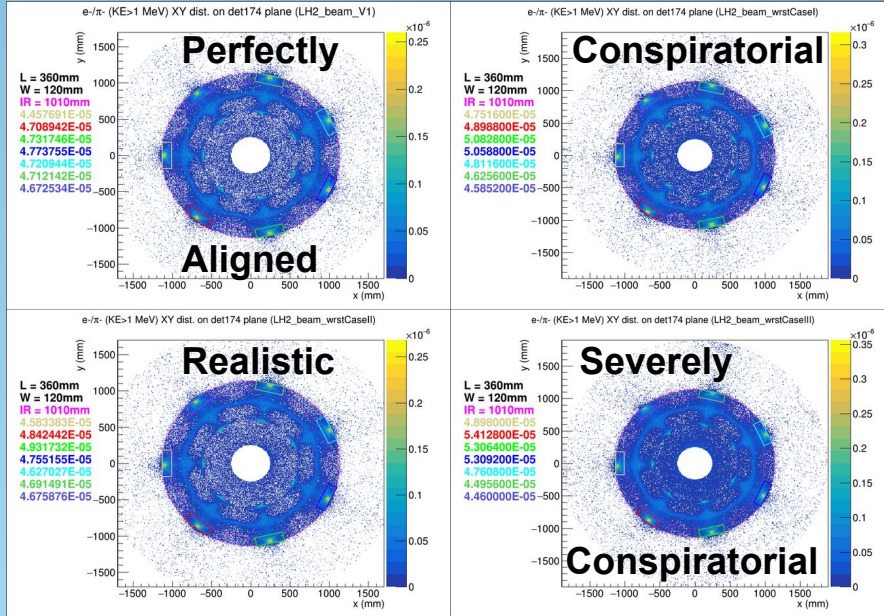


LAM = Large Angle Monitor

LAM Sensitivity to Magnetic Fields

The LAMs respond only weakly to a realistic misalignment of the coils.

$$\text{Percent Difference} = \frac{\text{rate}_{\text{misaligned}} - \text{rate}_{\text{symmetric}}}{\frac{\text{rate}_{\text{misaligned}} + \text{rate}_{\text{symmetric}}}{2}}$$



Histogram rootfiles generated by Devi L. Adhikari

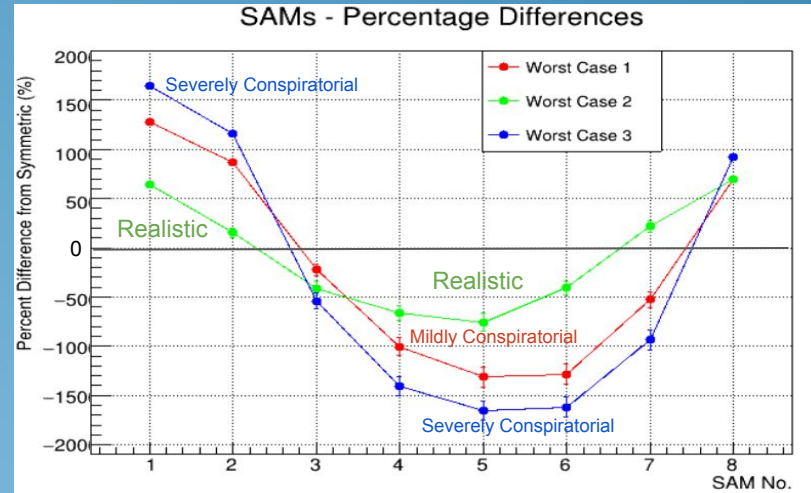
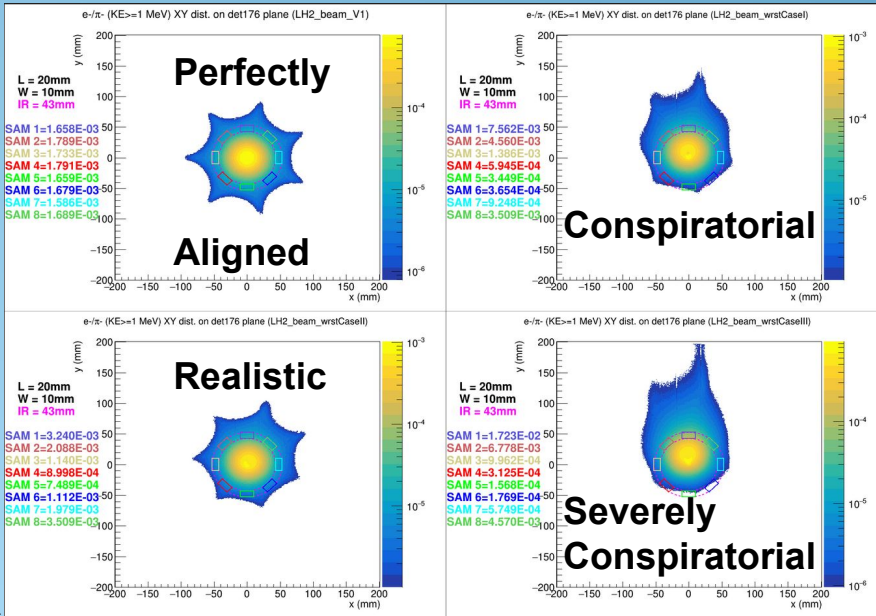


SAM Sensitivity to Magnetic Fields

SAM = Small Angle Monitor

The SAMs respond dramatically to even a realistic misalignment of the coils.

$$\text{Percent Difference} = \frac{\text{rate}_{\text{misaligned}} - \text{rate}_{\text{symmetric}}}{\frac{\text{rate}_{\text{misaligned}} + \text{rate}_{\text{symmetric}}}{2}}$$

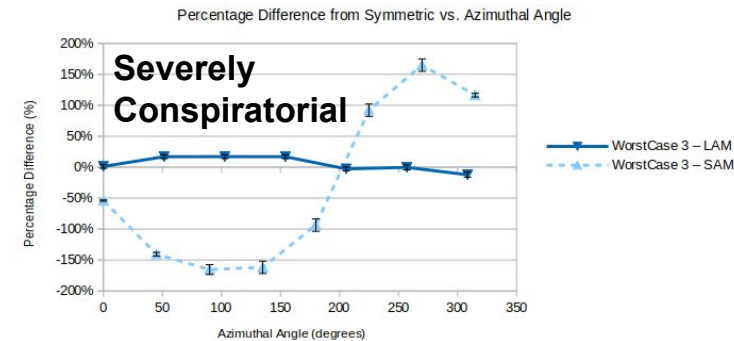
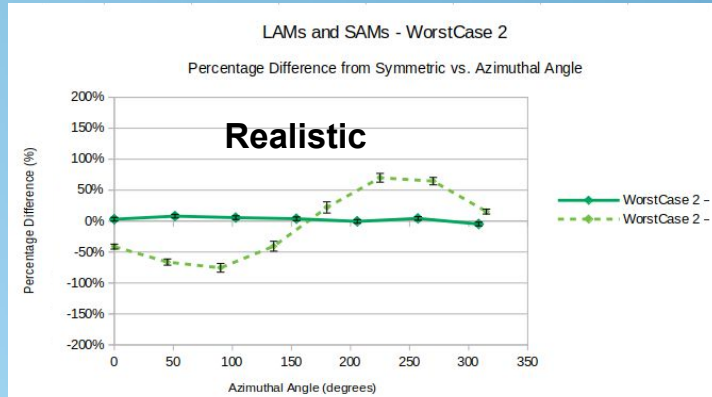
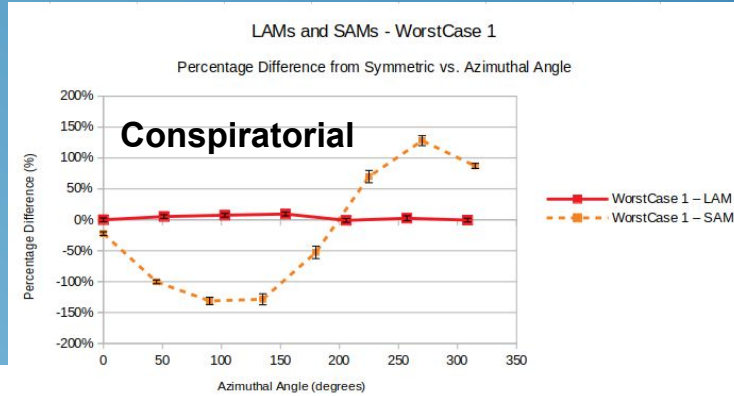


Histogram rootfiles generated by Devi L. Adhikari



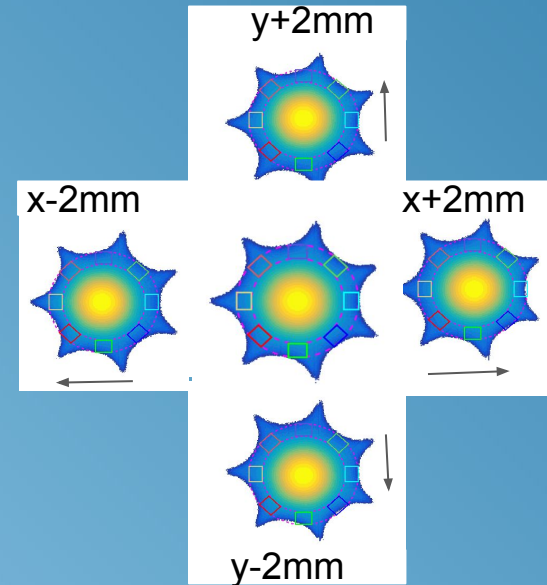
Comparing LAMs and SAMs Percentage Differences

- LAM and SAM percent differences were plotted with respect to angular position on the azimuth
- The SAMs respond much more dramatically to a misaligned magnetic field than the LAMs.



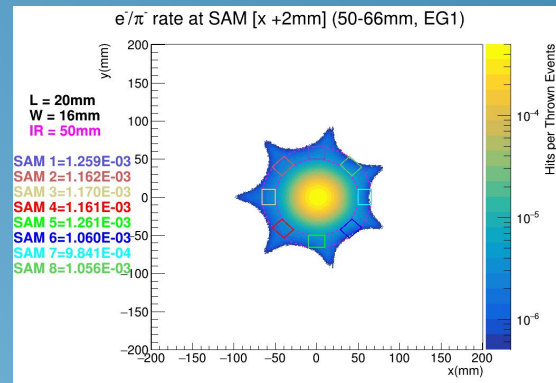
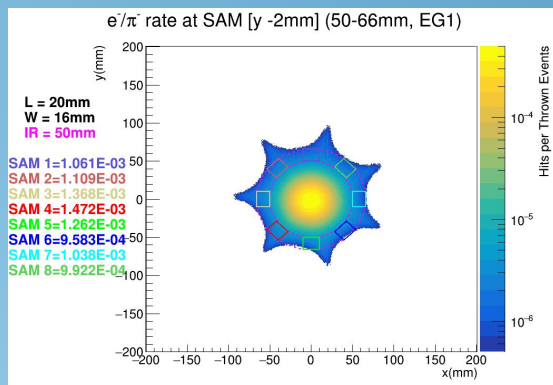
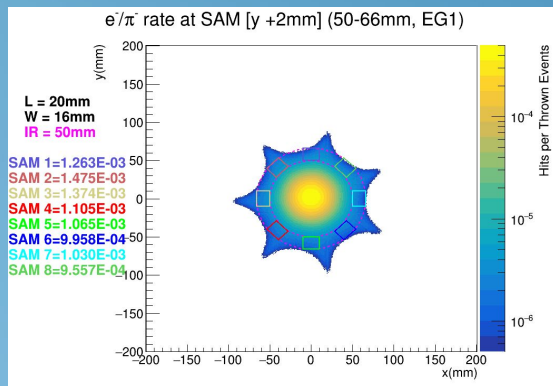
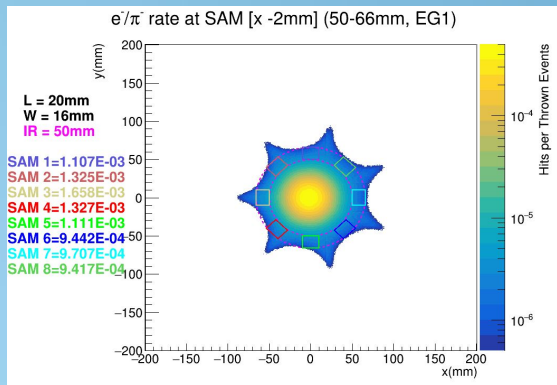
Sensitivity to Beam Position

- Simulations were also performed for the electron beam being offset by 1mm and 2mm in various directions
- It is unlikely that the beam would be offset any more than 2mm.



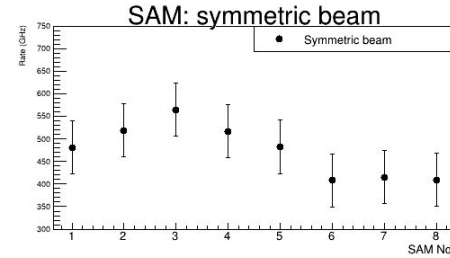
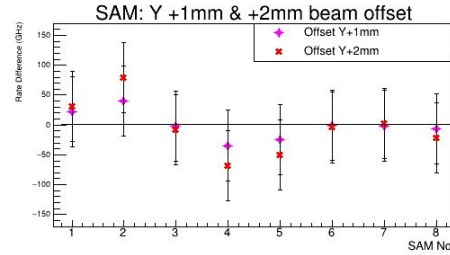
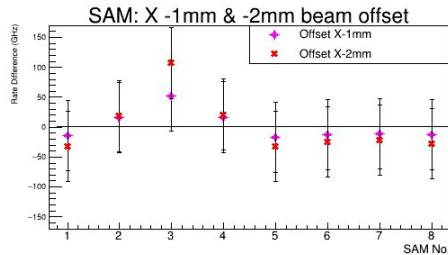
SAM Sensitivity to Beam Position (+/- 2mm)

SAM = Small Angle Monitor

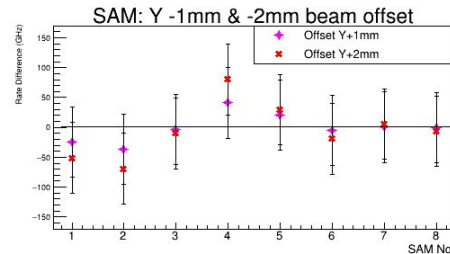
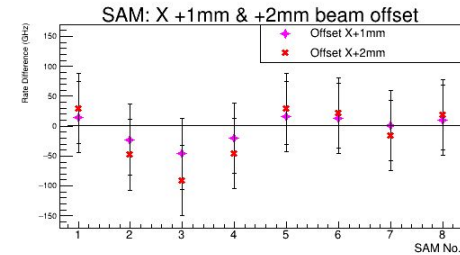


SAM Sensitivity to Beam Position: Rates

SAM = Small Angle Monitor



- SAM #3:
 - greatest response in X
 - small response in Y



- SAM #7:
 - small response in X
 - small response in Y



Conclusion

- The SAMs are much more sensitive to changes in the experiment than the LAMs.
- These simulations did not take into account the physical limitations of the detector modules and signal processing.
- There have been many changes to the geometry of the simulated apparatus since these simulations were run, so they must be run again.
- There is much yet to be done in preparation for assembling the Scanning Beam Monitors and using them to watch for false asymmetries in the MOLLER Experiment.



References: Image Sources

- [1] Czarnevski, A., Marcian, W. J. “Polarized Møller-violating electron scattering”. Int. J. Mod. Phys. A. 15, 16 2365-2375 (2020).
- [2] Kumar, K. S. “Parity-violating Møller scattering”. AIP Conf. Proc. 1182 660-664 (2009).
- [3] Particle Data Group. “Review of particle physics”. Prog. of Theor. and Exp. Physics. 2020, 8, pp. 186 (2020).
- [4] The MOLLER Technical Design Report (2022).
- [5] The MOLLER Conceptual Design Report (2020).
- [6] Adhikari, D. L. “Scattered Beam Monitors (SBM) and Scanner Detectors (SD)”. MOLLER Collaboration Meeting, May 5-6 (2023).

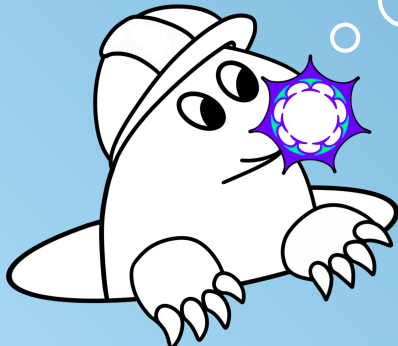


Acknowledgements

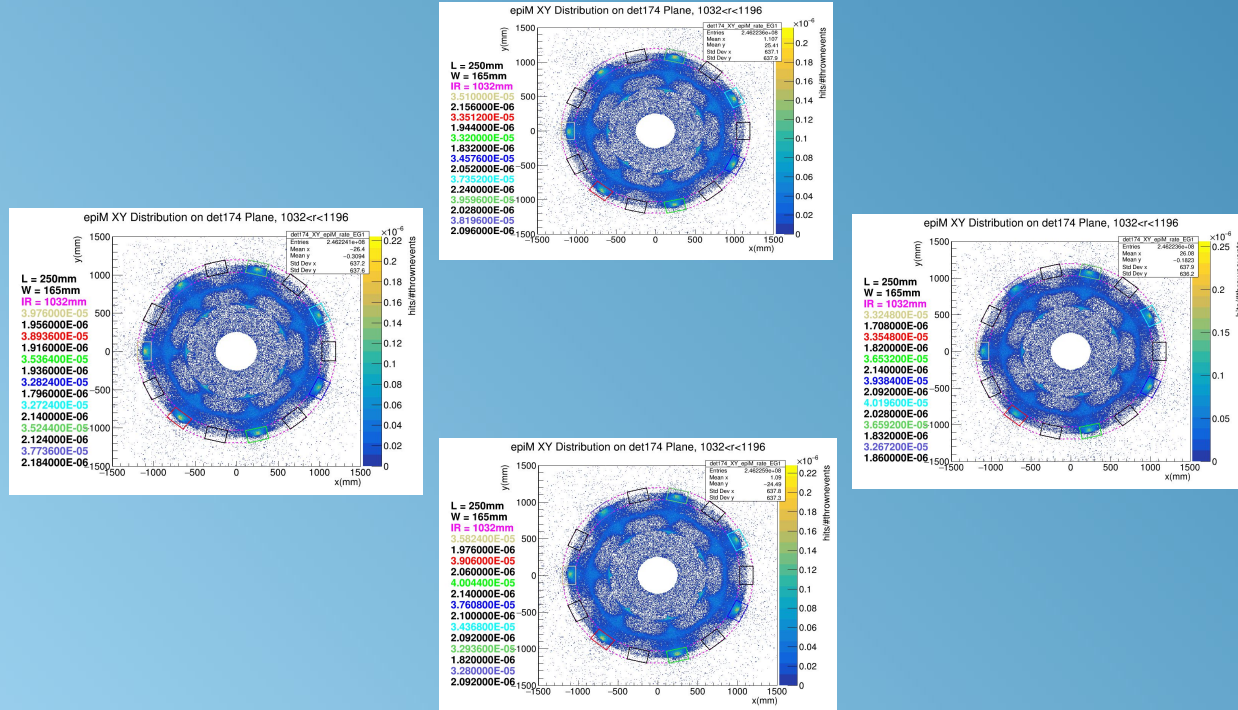
- Research Group: Mark Pitt, Devi L. Adhikari, and Daniel Valmassei
- The MOLLER Collaboration
- Sakib Rahman (“Worst-Case” magnetic field maps)
- This research was supported by NSF Grants: 2013023, 2012995, 1714325



*Thank You For Listening!
Any Questions?*



LAM Sensitivity to Beam Position (+/- 1mm)



LAM Sensitivity to Beam Position

