Overview of the DAQ Systems for the MOLLER Experiment

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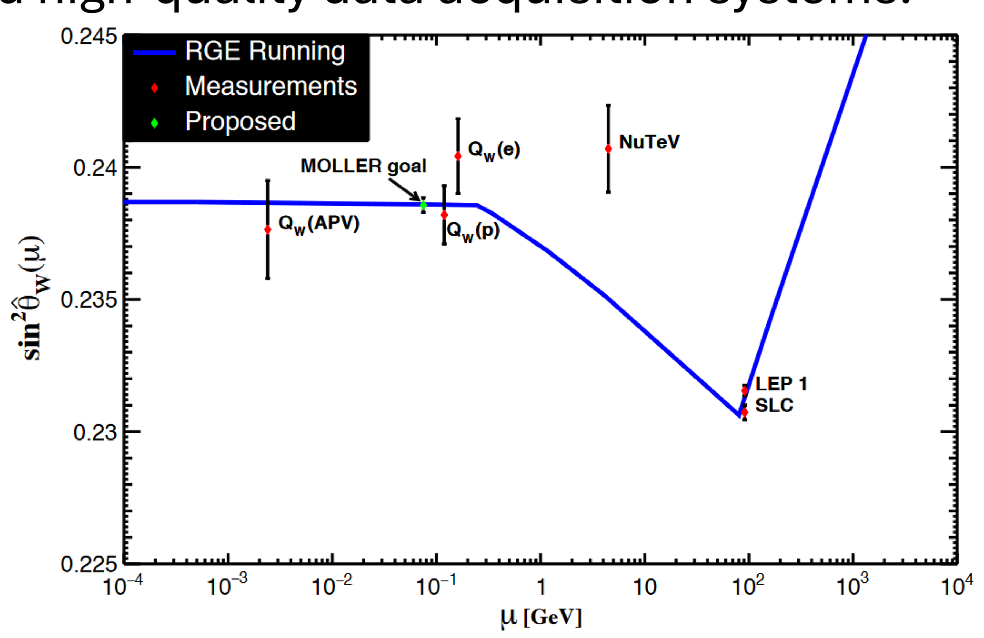
Abstract

The MOLLER (Measurement Of Lepton-Lepton Electroweak Reaction) experiment is an ultra-precise measurement of the parity-violating asymmetry, A_{PV}, in Møller interactions between longitudinally polarized electrons and unpolarized electrons in a liquid hydrogen target at momentum transfer $Q^2 \ll m_Z$ (mass of the Z^0 boson). The A_{PV} measurement is predicted to be ~33 ppb and will be measured to an overall uncertainty of ~0.8 ppb. Ultimately, the MOLLER experiment's goal is to measure the weak charge of the electron, which with this level of precision, would give insight into new physics beyond Standard Model at the TeV scale. To ensure such a precision can be met, MOLLER requires reliable and high-quality data acquisition systems.



Motivation

In Electroweak Unification, the two neutral current bosons, Z^0 and γ, are described as a linear combination of two orthogonal bases:

$$|\gamma\rangle = \cos\theta_W|B\rangle + \sin\theta_W|W^3\rangle\,,$$

$$|Z^0\rangle = -\sin\theta_W|B\rangle + \cos\theta_W|W^3\rangle$$

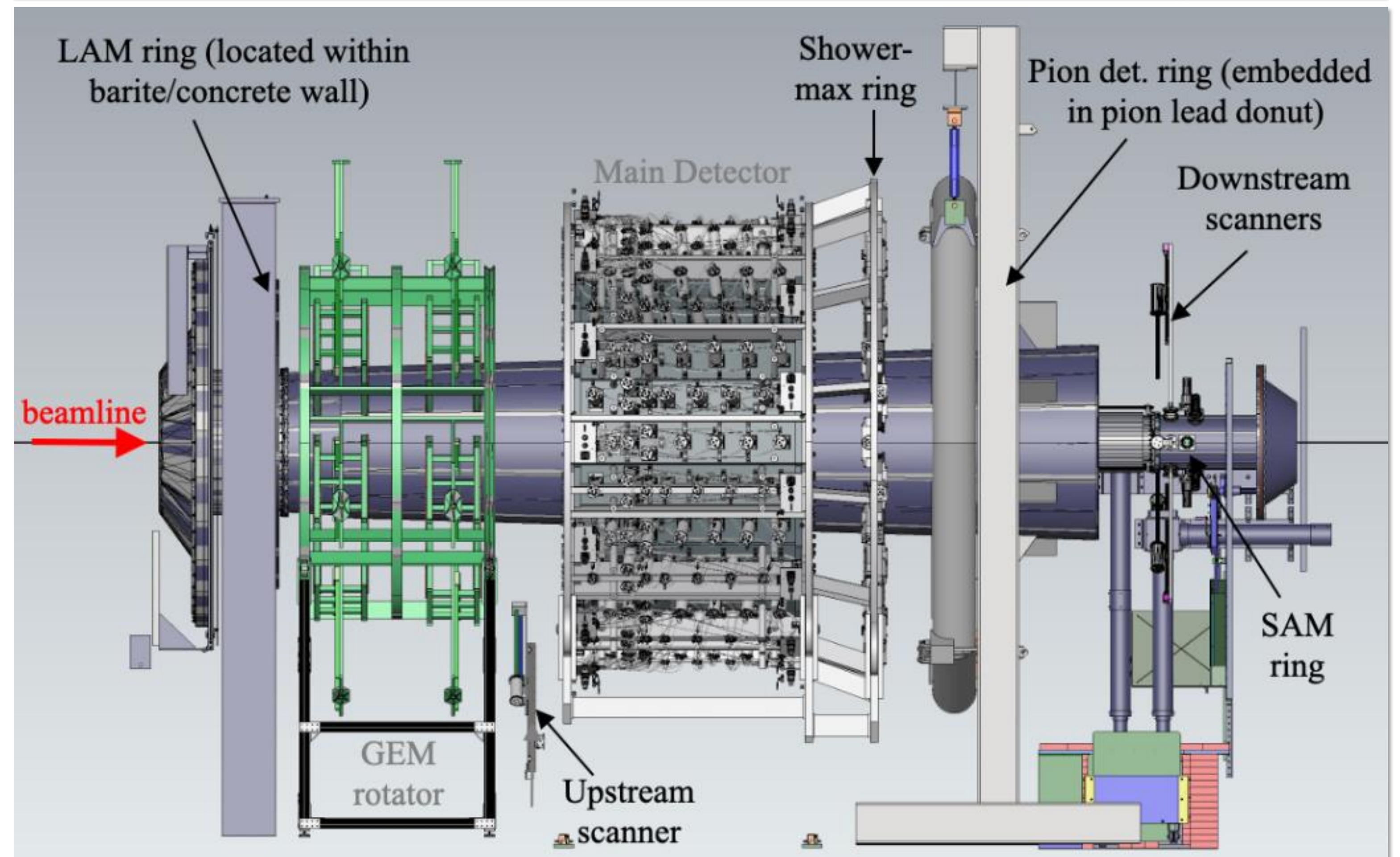
However, γ exchange preserves parity symmetry whereas the Z^0 exchange violates parity. By measuring the parity-violating asymmetry, we can extract information about the weak mixing angle and the weak charge of the electron. In scattering of longitudinal polarized electrons from a unpolarized target, we can express the asymmetry by:

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = mE\frac{G_F}{\sqrt{2}\pi\alpha}\frac{4\sin^2\theta}{(3+\cos^2\theta)}Q_w^e$$

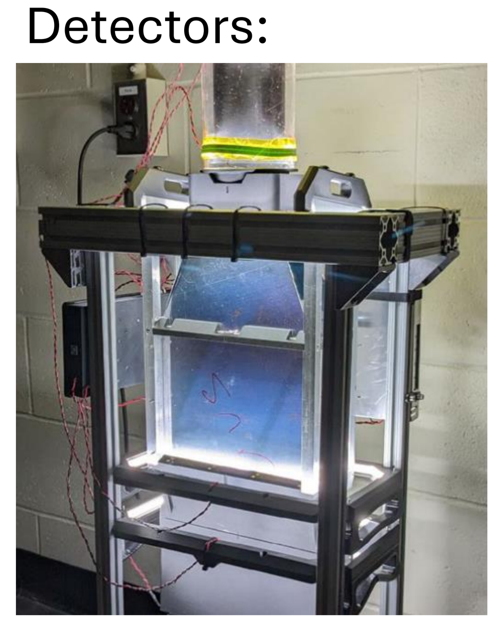
At tree-level, $Q_w^e = 1 - 4\sin^2\theta_w$.

To measure this asymmetry, the difference in detector response is averaged over many helicity windows with a resolution of less than 10 ppm. Two DAQ systems will be used, an integrating system designed for high luminosity and a counting system for low luminosity measurements. Both systems need to operate at 100% throughout.

Detector Overview

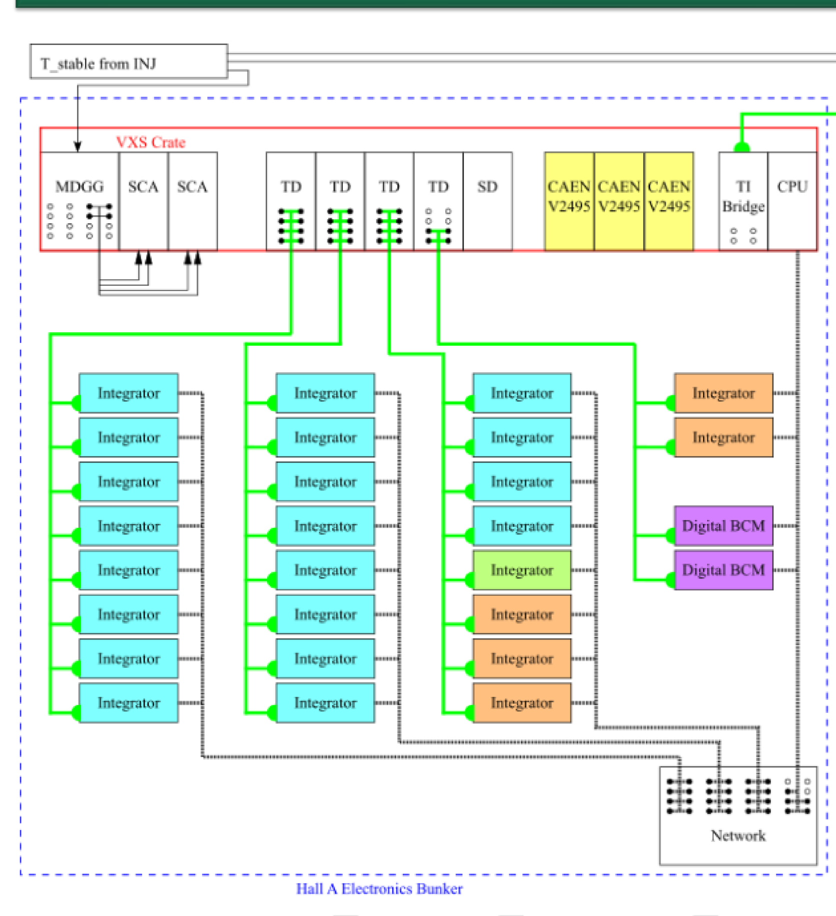


Location:	Hall A
Electron Beam:	Up to 70 μA of 11 GeV beam with 90% polarization and capable of 2kHz helicity flip rate
Target:	Liquid Hydrogen (LH_2)
Detectors:	



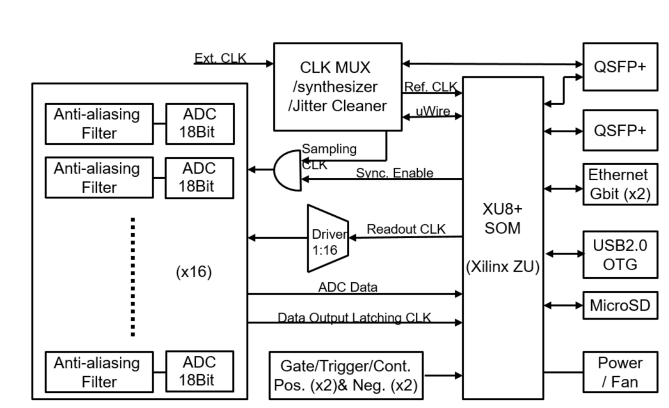
224	Thin Quartz Detectors	(Main)
28	GEM Modules	(Tracking)
28	Pion Detectors	(Aux)
28	Shower Max	(Aux)
28	Large Angle Monitors	(Aux)
14	Diffuse Beam Detectors	(Aux)
8	Small Angle Monitors	(Aux)
2	Scanner Detectors	(Aux)

Integrating Mode DAQ



$R = \mathcal{L}\sigma \rightarrow$ 134 GHz

0.52 ms 'helicity windows'



512 Channels → 32 Modules

~ 130 MB/s

Counting Mode DAQ

Low beam-current measurements

~100 pA → 210 kHz

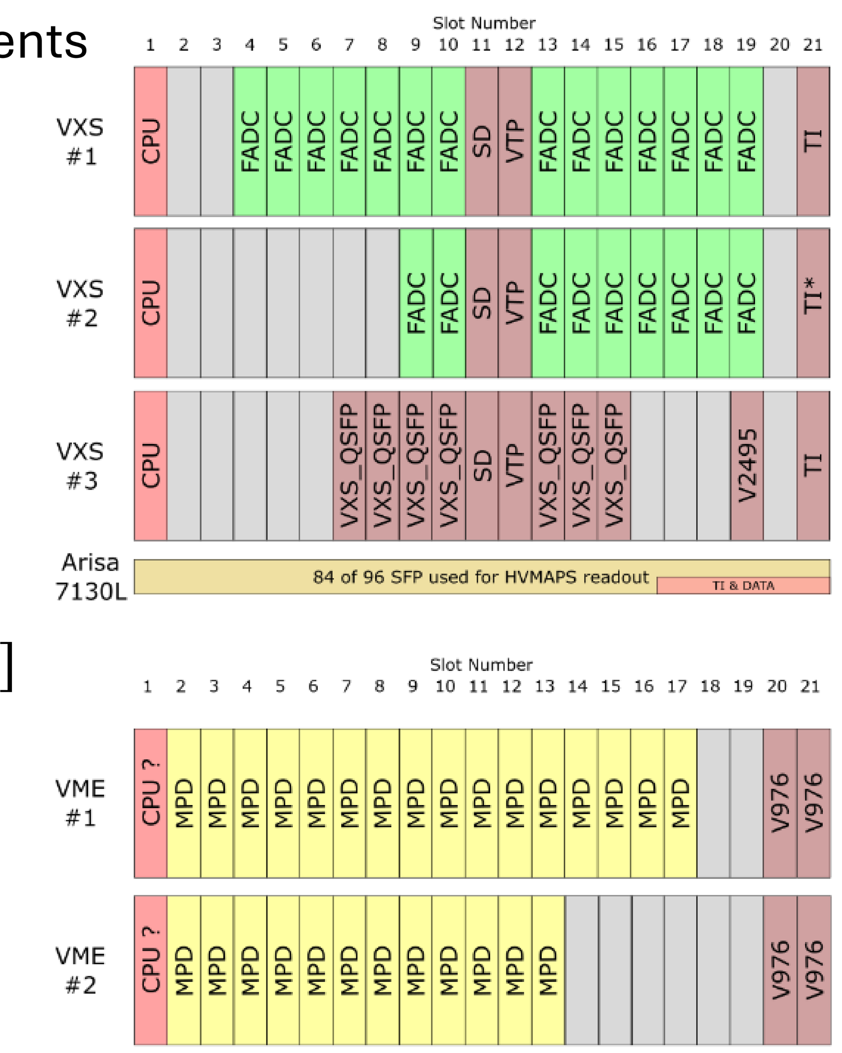
Trigger Conditions:

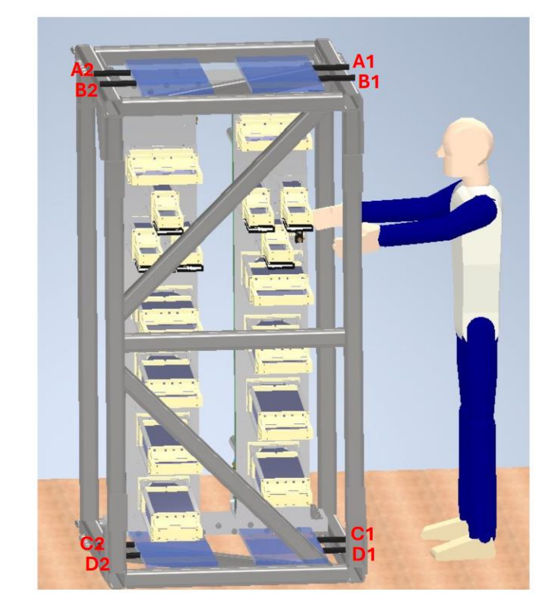
Main { OR $TS_u^i \cdot TS_d^i$

Quartz { OR TQ^i ; OR SM^i

OR PD^i

Pion { OR $PD^i \cdot [TS_u^j \cdot TS_d^j]$





Trigger:
$(A_1 \cdot C_1)$ OR $(B_1 \cdot D_1)$ OR $(A_2 \cdot C_2)$ OR $(B_2 \cdot D_2)$

Future Work

- Set up test stands:
  - Counting Test Stand
  - Integrating Test Stand
- Upgrade the Hall A CH Parity DAQ:
  - New crate & CPU
  - Update to CODA 3
- Upgrade the Injector Crate
  - Set up communication between the Parity DAQ and injector crate
- Online and Offline Analysis:
  - Configure it to work with CODA 3 (EVIO 4)
  - Add EPICS data to mock data stream
  - Update the analysis software as we better understand the actual data stream

References

1. MOLLER Experiment Homepage: *https://moller.jlab.org/moller_root/*
2. J. Benesch et al. (MOLLER), (2014), arXiv:*1411.4088* [nucl-ex].
3. MOLLER Collaboration, Technical Design Report, 2023.
4. Paul King, Integration and Counting Mode DAQ Planning for MOLLER, 2024, *MOLLER Collaboration Meeting 2024*.
5. Arindam Sen, Plan for the W&M Test Setup, 2024, *MOLLER Collaboration Meeting 2024*.