MOLLER Update

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for the MOLLER Collaboration

June 8, 2012

MOLLER Update

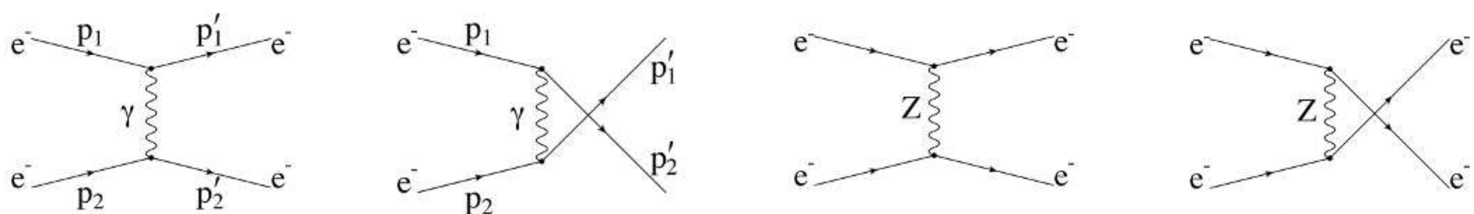
Outline

- Introduction
- Motivation (Indirect search for new physics)
  - –Search for new contact interactions
  - –Sensitivity to SUSY radiative effects, super-massive Z', and light “dark” Z bosons
  - –Precision electroweak test of $\sin^2\theta_W$
  - –Higgs Mass Constraints
- Update to Experimental Design
  - –Layout of target, spectrometer, and detectors
  - –Hybrid torus coil design
  - –Tracking and integrating detectors
- Status and Future Plans

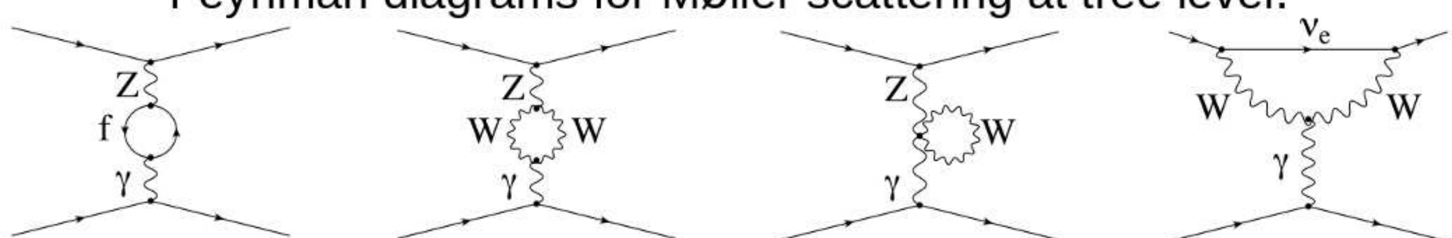
Møller Scattering, A_{PV} Measurement

- MOLLER aimed at precision measurement of parity-violating asymmetry A_{PV} in polarized electron-electron scattering.
- According to SM, A_{PV} results from interference between electromagnetic and weak neutral current amplitudes.

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \frac{A_\gamma A_Z}{A_\gamma^2} = m_e E_{lab} \frac{G_F}{\sqrt{2}\pi\alpha} \frac{4 sin^2\theta}{(3 + cos^2\theta)^2} Q_W^e, \quad (1)$$



Feynman diagrams for Møller scattering at tree level.



– Z mixing diagrams and W-loops. "Hard" radiative corrections involving the massive vector bosons--modify the tree level prediction quite significantly.

Møller Scattering, A_{PV} Measurement

- At proposed kinematics: 11GeV e^-_{beam} (75μA, 80% polarization), and 5mrad $< \theta_{lab} <$ 20mrad:

  $\rightarrow$ Predicted $\langle A_{PV} \rangle$ = 36ppb at $\langle Q^2 \rangle$ = 0.0056 (GeV/c)^2

- For 49 (PAC) week run: $\delta(A_{PV})$ = 0.74ppb:

  $\rightarrow \delta(Q^e_W)/Q^e_W = \pm 2.1\%(\text{stat}) \pm 1.0\%(\text{syst})$

  $\rightarrow \delta(\theta_W) = \pm 0.00026(\text{stat}) \pm 0.00012(\text{syst}) \sim 0.1\%$ precision!

Very challenging measurement requiring:

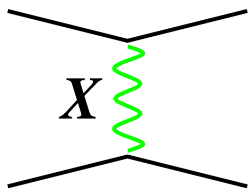
- Unprecedented precision matching of electron beam characteristics for Left versus Right helicity states
- Precision non-invasive, redundant continuous beam polarimetry
- Precision knowledge of luminosity, spectrometer acceptance (Q^2) and backgrounds

$\rightarrow$ **There have already been 3 generations of parity experiments at Jlab with progressively challenging experimental designs.**

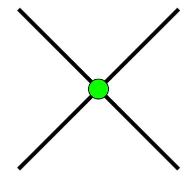
Establishing Limits for New Contact Interactions (Off the Z Resonance)

Important component of indirect signatures for"new physics"

consider



$$A_X \propto \frac{1}{Q^2 - M_X^2} \longrightarrow \sim \frac{4\pi}{\Lambda^2}$$



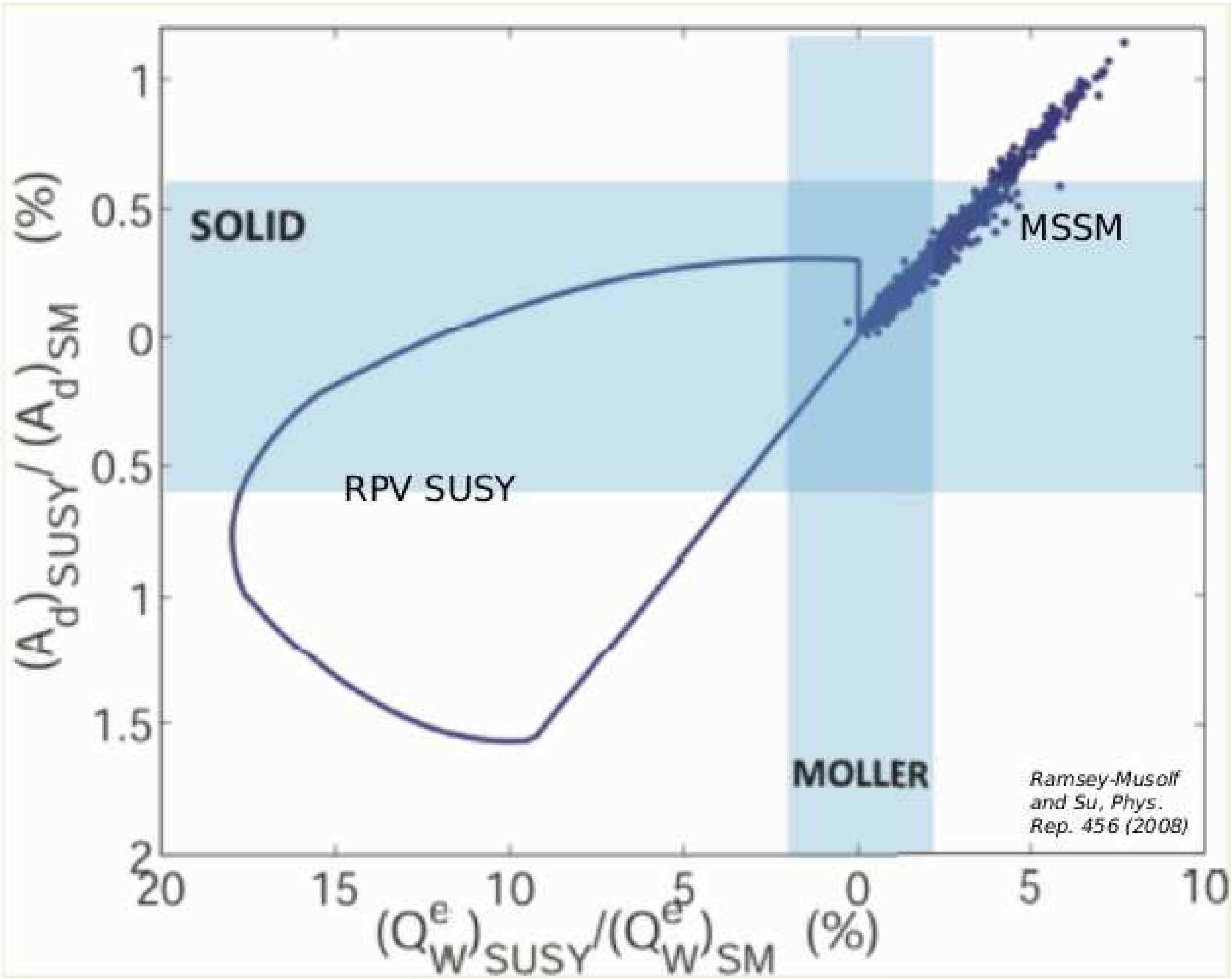
Contact interaction

$Q^2 \sim M_Z^2$ **on resonance:** A_Z *imaginary* $\longrightarrow A_Z^2 \left[1 + \frac{A_X^2}{A_Z^2}\right]$

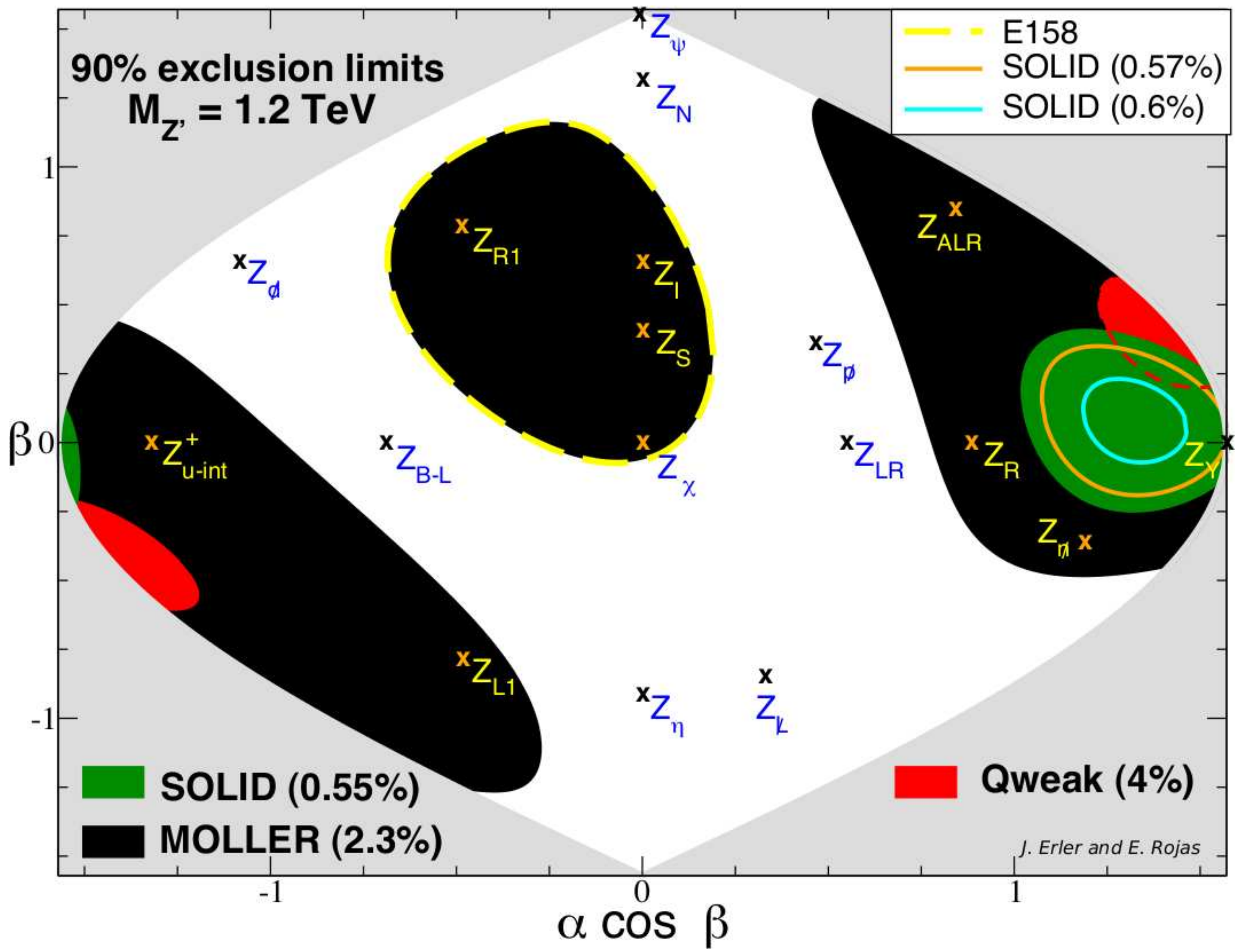
no interference!

- Proposed meas. sensitive to new neutral current amp. as weak as $\sim 10^{-3} \cdot G_F$ from undiscovered high energy dynamics ($\Lambda_{new} \sim 7.5$TeV)
- Current best limits on 4e$^-$ contact interac. come from LEP, LEPII: Probed $\Lambda_{new} \sim 5$ TeV, but was insensitive to $|g_{RR}^2 - g_{LL}^2|$
- Near the Z resonance, new physics interactions (e.g. Z'_X exchange) don't visibly mix with standard model A_Z (Collider Experiments)
- This underscores importance of low energy measurements of Q_W: E158, Qweak, PVDIS, MOLLER, and Mainz P2

Sensitivity to SUSY particle radiative loop effects

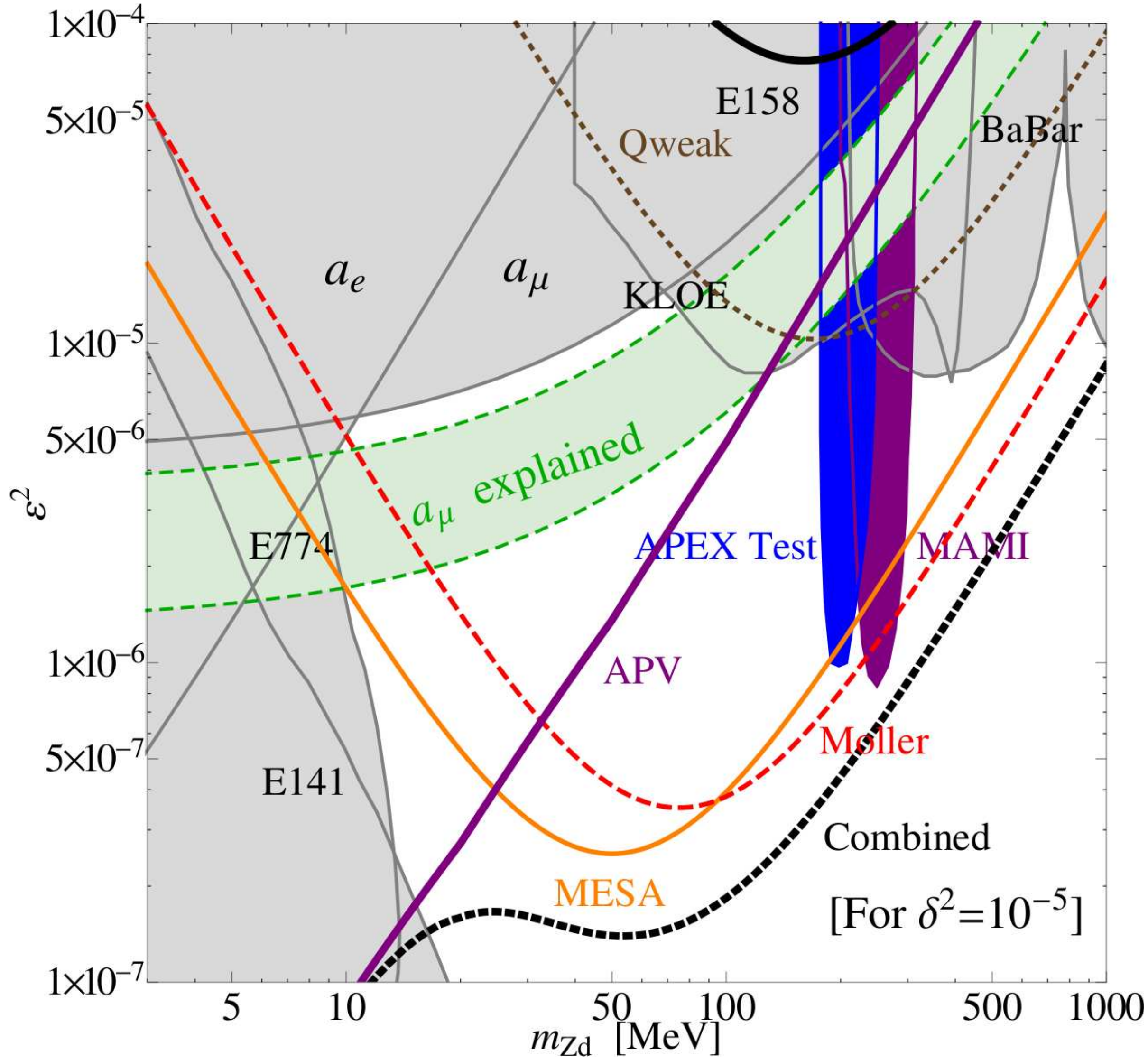


Complimentary Measurement to LHC



Sensitivities for "Dark" Z Coupling to explain a_μ

(*from Davoudiast, Lee, and Marciano, arXiv:1205.2709v1*)



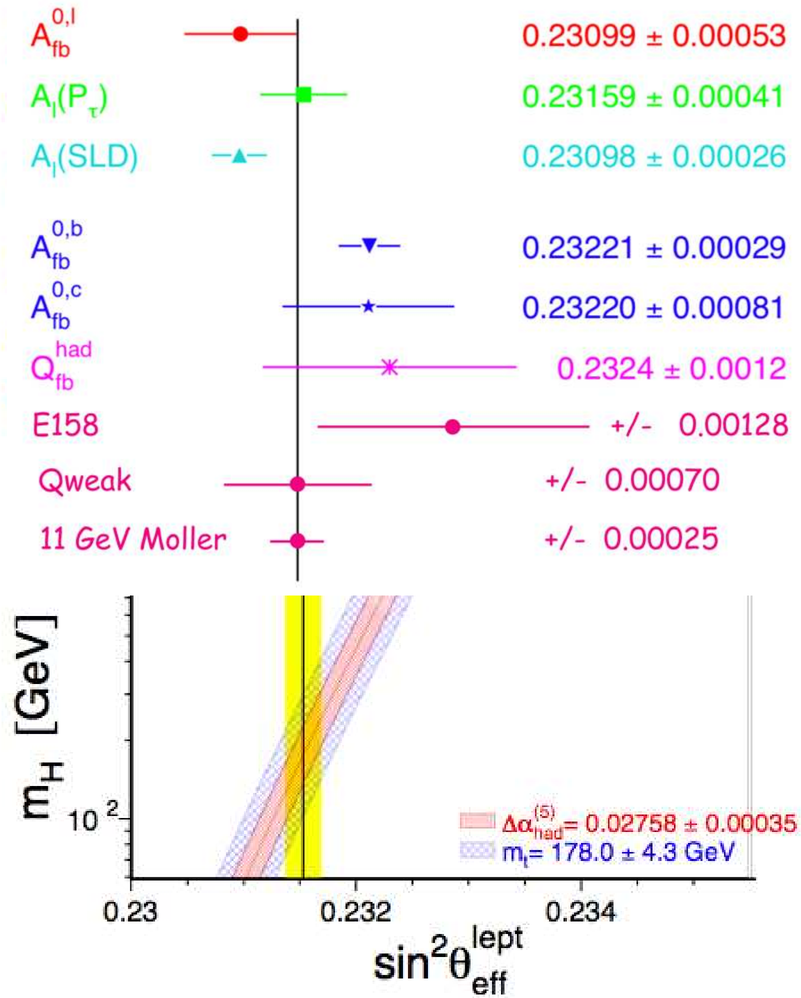
Precision Electroweak Tests of $\sin^2\theta_W$ and the Higgs Mass

- World data avg: $sin^2\theta_W$ = 0.23122(17)
  => $m_H = 89^{+38}_{-28}$ GeV
  (favors SUSY, rules out Technicolor)
- Avg dominated by two measurements separated by 3σ:

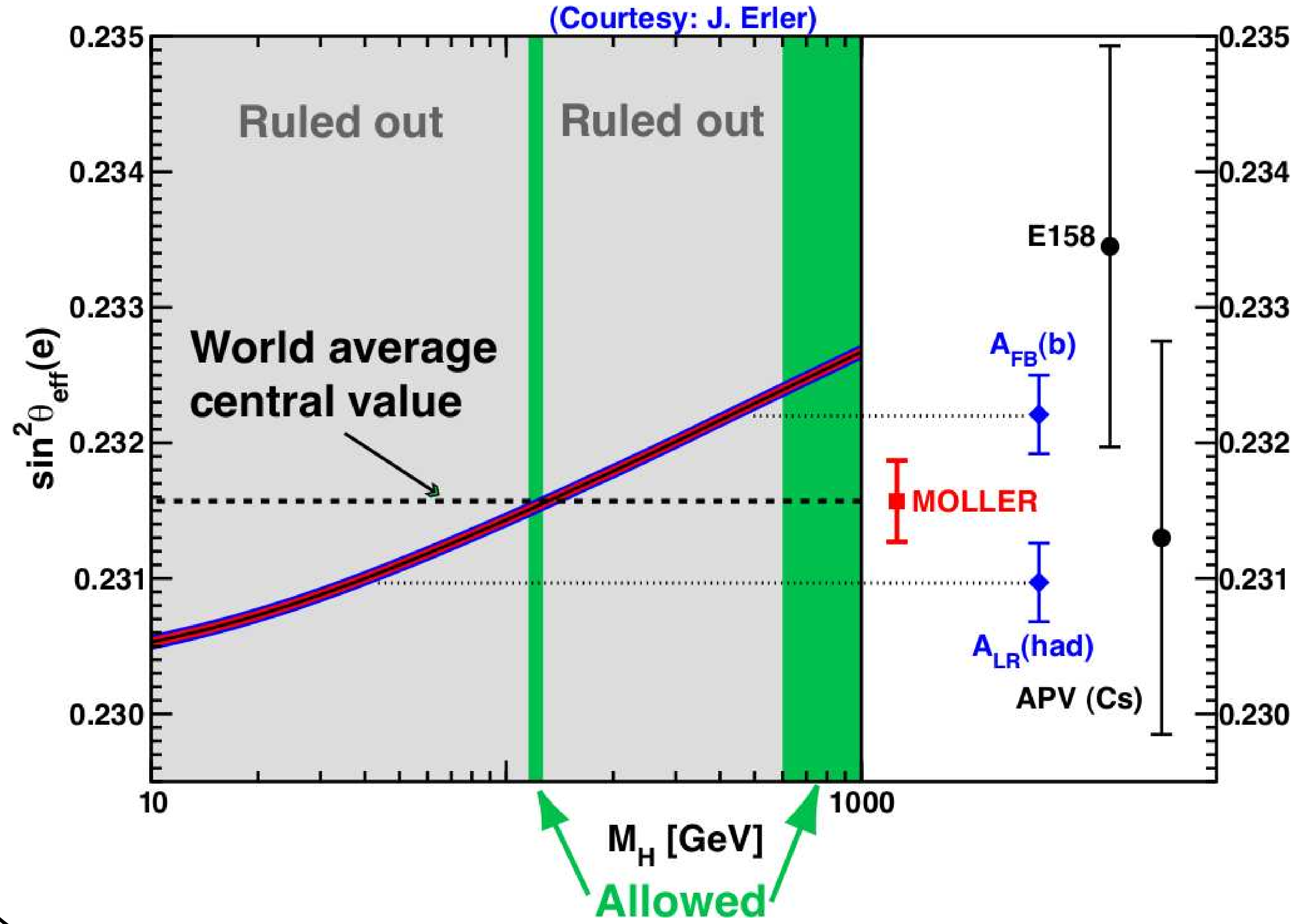
→ A_l(SLD) : 0.2310(3), => $m_H = 35^{+26}_{-17}$ GeV
rules out SM!

→ $A_{fb}^{0,1}$: 0.2322(3), => $m_H = 480^{+350}_{-230}$ GeV
rules out SUSY, favors Technicolor

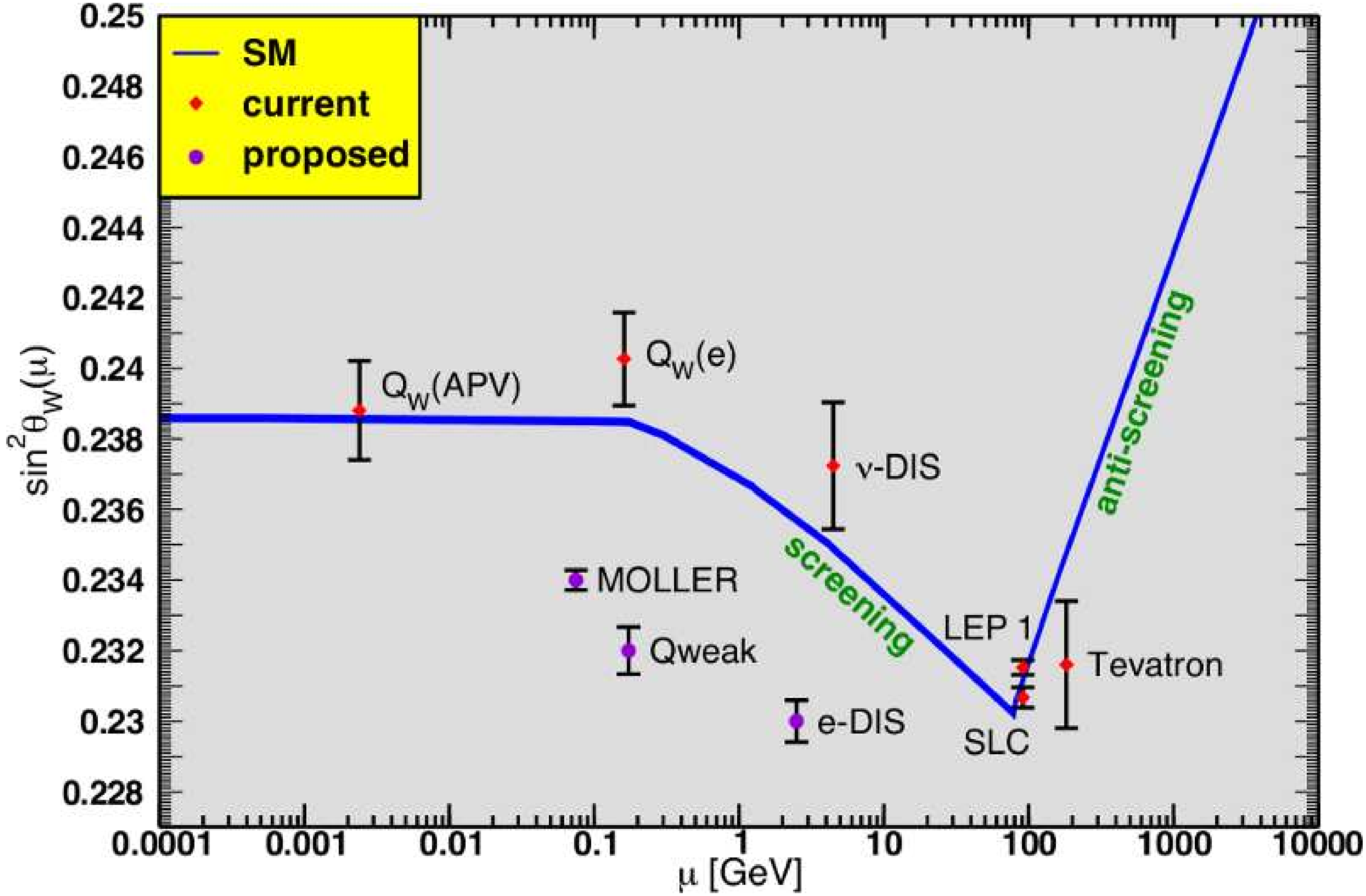
- Proposed measurement precise enough to effect the central value of $sin^2\theta_W$ and provide new indirect evidence for the range of allowed m_H values



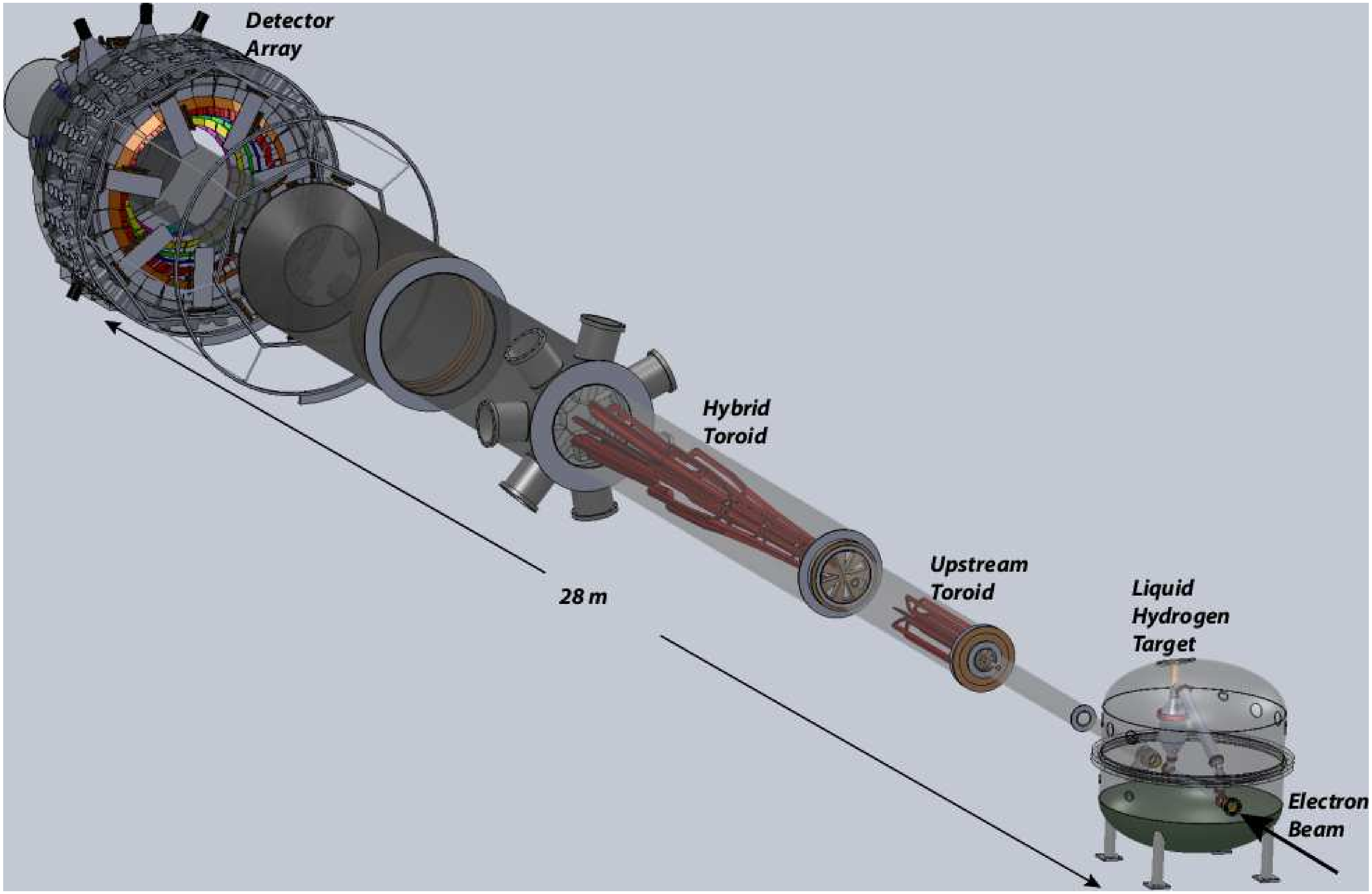
Higgs Mass Constraints



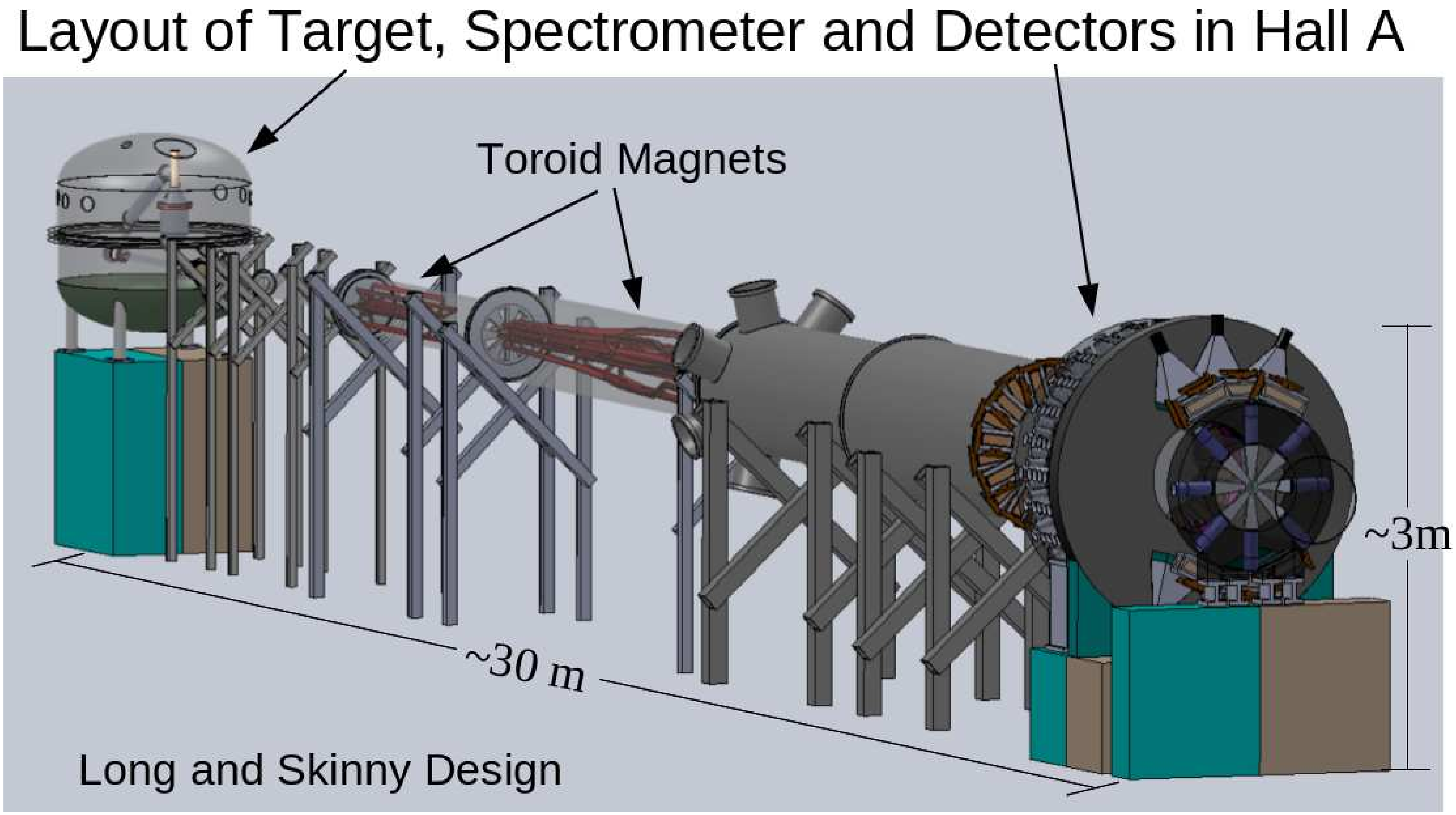
Current and Future $sin^2\theta_W$ Measurements



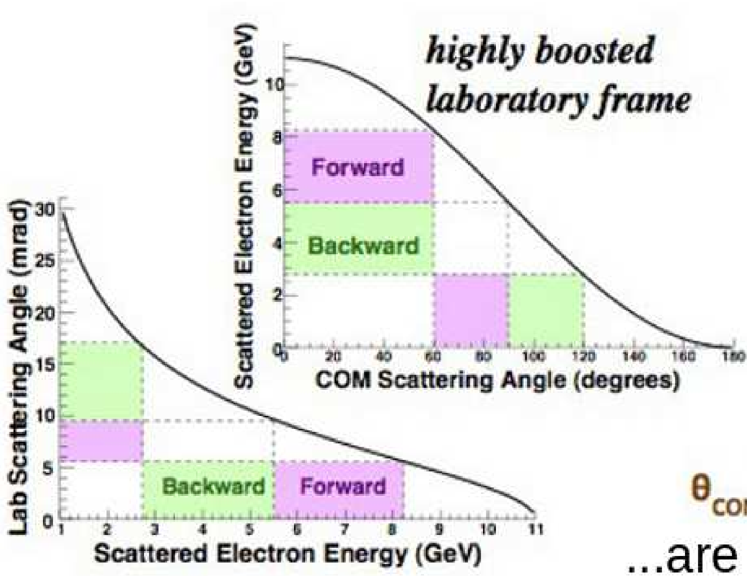
Experimental Design Update

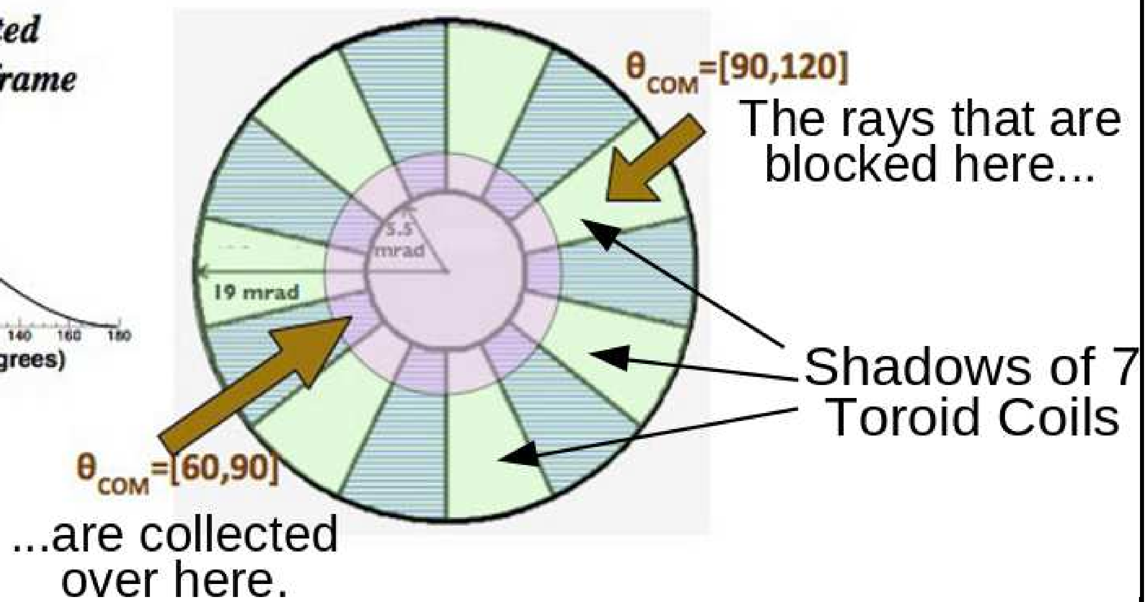


Experimental Design (Perspective View from Downstream)



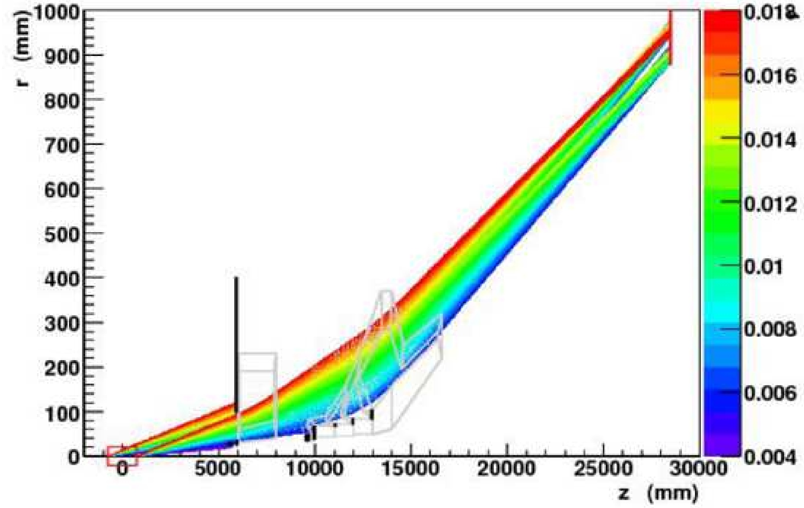
Optimized Spectrometer ($\sim$ 100% Acceptance)



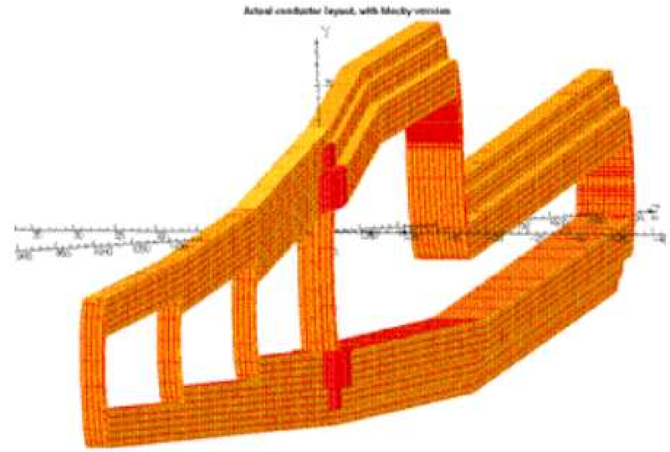


- The combination of a toroidal magnetic system with an odd number of coils together with the symmetric, identical particle scattering nature of the Møller process allows for $\sim$ 100% azimuthal acceptance

Toroid Design Concept



Projected radial coordinate of scattered Møller electron trajectories. Colors represent θ_{lab} (rad). Magnet coils (grey) and collimators (black) are overlaid.



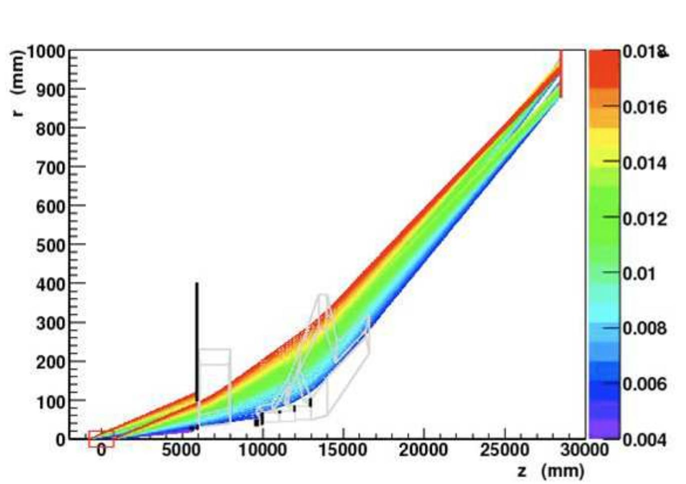
Single Hybrid coil shown with 1/10 scale in z direction. Note the 4 current returns give successively higher downstream fields.

- Spec. employs two back-to-back toroid magnets and prec. collimation:

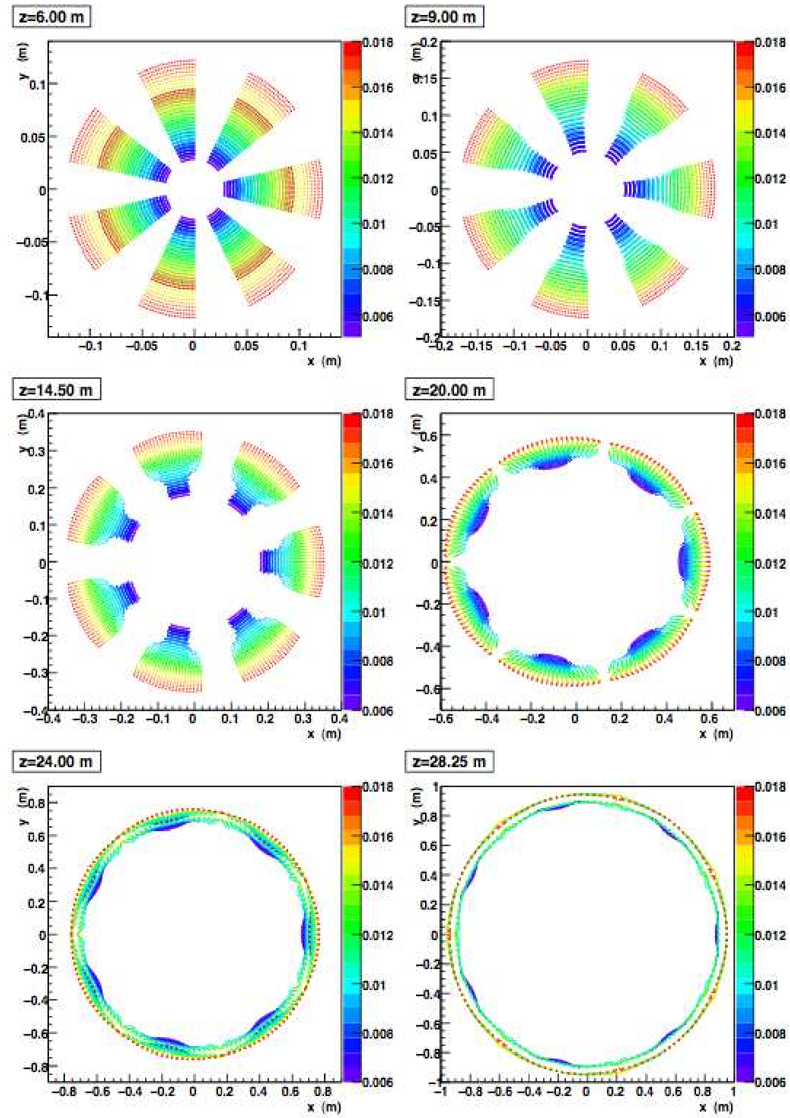
$\rightarrow$ Upstream toroid has conventional geometry

$\rightarrow$ Downstream "hybrid" toroid novel design inspired by the need to focus Møller electrons with a wide momentum range while separating them from e-p (Mott) scattering background

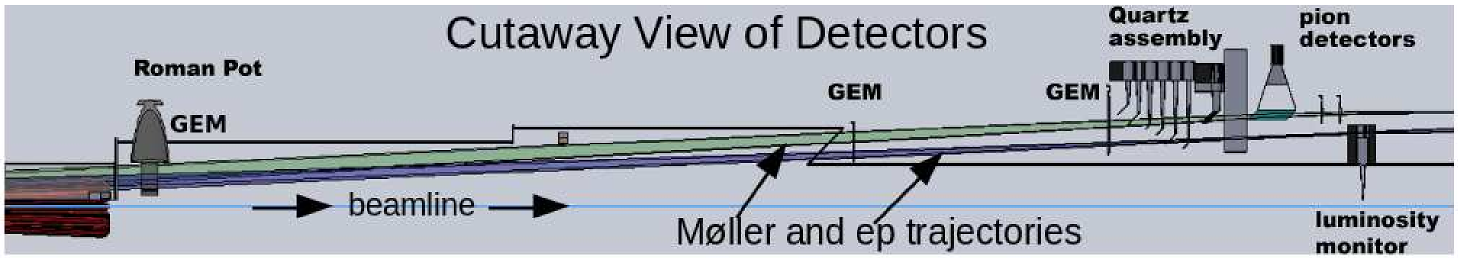
Optics Raytrace

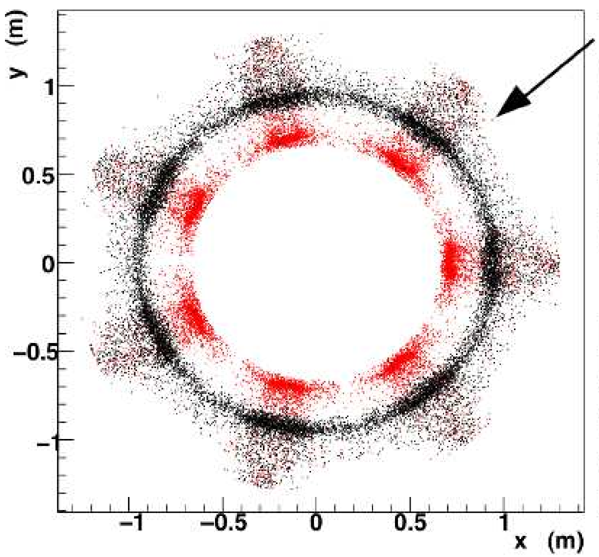


--Defocusing effects results in population of full azimuth



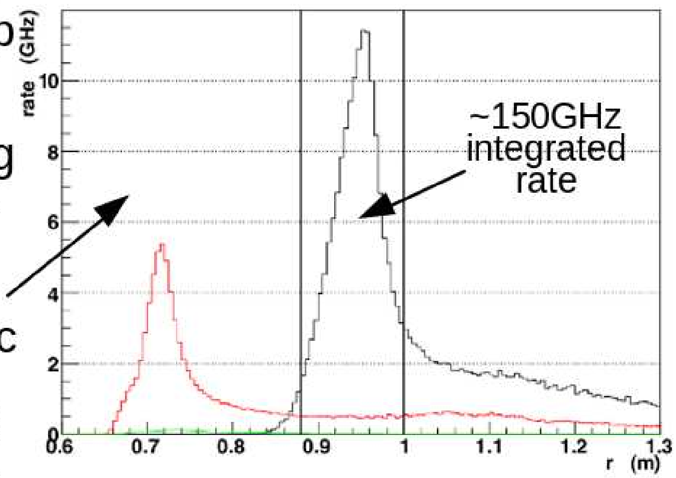
Tracking and Integrating Detectors





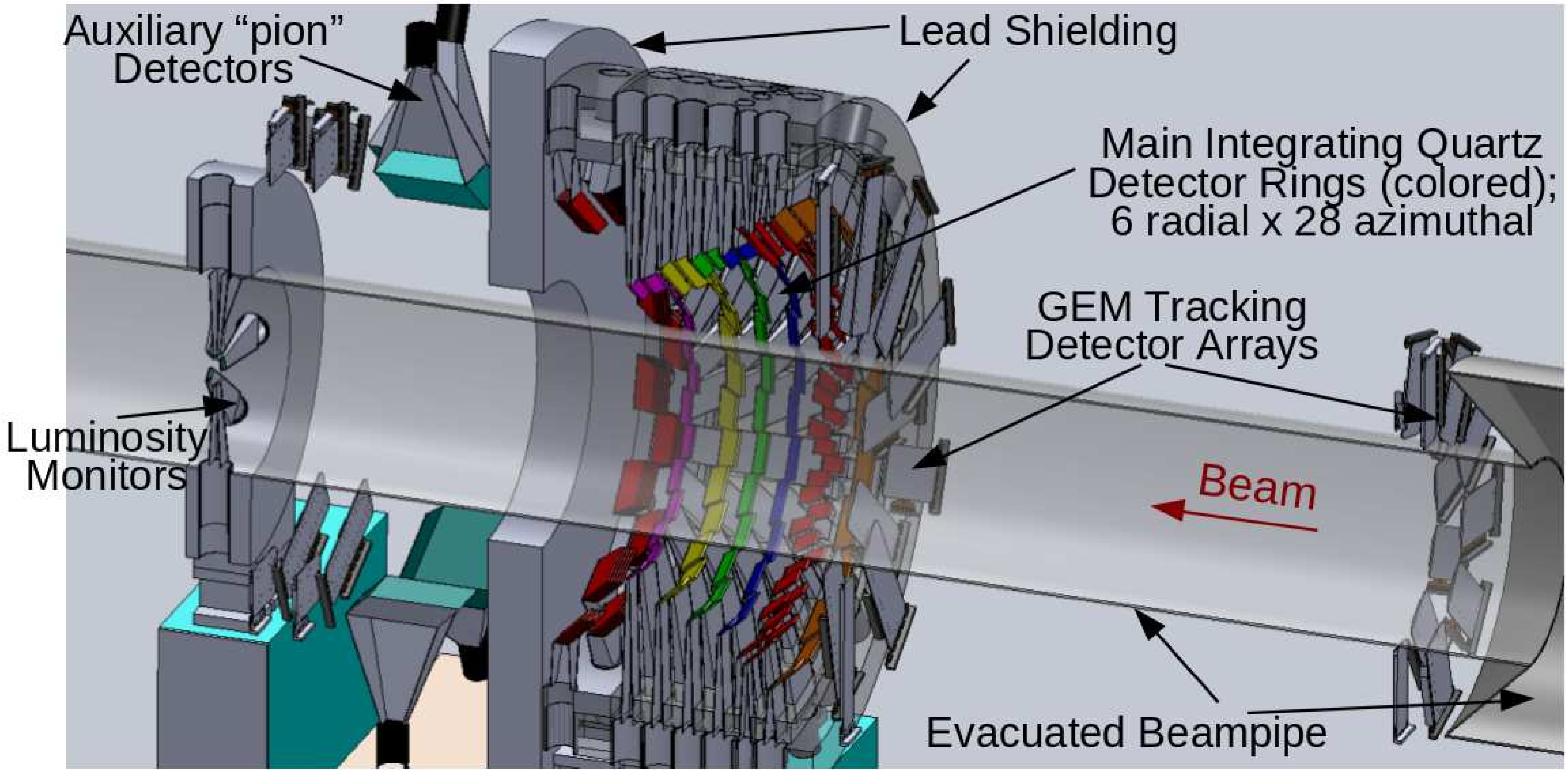
Transverse distribution of Møller (black) and ep (red) electrons 28.5 m downstream of target. Note the phi defocusing of spectrometer optics.

Radial rate distribution of Møller (black), elastic ep (red), and inelastic ep (green) electrons at main detector location.



Tracking and Integrating Detectors

Perspective view of integrating detector assembly



New Challenges

- 150GHz total detected Moller event rate
  $\longrightarrow$ Must flip pockels cell at $\sim$2kHz
  $\longrightarrow$ 80ppm pulse-to-pulse statistical fluctuations
  - Electronic noise and density fluctuations $< 10^{-5}$
  - Pulse-to-pulse beam monitoring res. a few microns at 1kHz
- 0.5nm/0.05nrad control of beam on target
  $\longrightarrow$ Requires improvement on control of pol. src. laser transport
  $\longrightarrow$ Improved methods of “slow helicity reversal” (double wien)
- Target requires $\sim$5kW of cooling power at 85μA I_{beam}
- Full azimuthal acceptance with θ_{lab} between 5 and 17mrad
  $\longrightarrow$ Aggressive spectrometer design
  $\longrightarrow$ Complex collimation and shielding issues
- Robust and redundant 0.4% beam polarimetry
  $\longrightarrow$ Plan to pursue both Compton and atomic Hydrogen techniques

Status and Future Plans

- JLab PAC 34 - full approval - strong endorsement
- This endeavor represents 4^{th} generation JLab parity violation experiment with collaboration consisting of $\sim$ 100 physicists from 30 institutions
- MOLLER MIE proposal submitted by JLab to DOE Nuclear Physics last September–requesting to initiate CD process
- Expecting to start CD process early next year following DOE's NP retrenchment
- 3 - 4 years for Construction/Installation
- 2- 3 years Commissioning/Running
- Approved request of 344 PAC days for production running and 13 commissioning weeks over 3 running periods

Status and Future Plans

- List of key subsystems and institutions interested in their design, construction, and implementation:

  Polarized Source: UVa, JLab, Miss St.

  Hydrogen Target: JLab, VaTech, Miss St.

  Spectrometer: Canada, ANL, MIT, Umass, UVa

  Focal Plane Detectors: Syracuse, Canada, JLab, UNC A&T, VaTech

  Luminosity Monitors: VaTech, Ohio

  Pion Detectors: Umass, LATech, UNC A&T

  Tracking Detectors: W&M, Canada, Umass, UVa, INFN Roma

  Electronics: Canada, JLab

  Beamline instrumentation: Umass, JLab, VaTech

  Polarimetry: UVa, Syracuse, JLab, CMU, ANL, Miss St.,
  Clermont-Ferrand, Mainz, W&M

  Data Acquisition: Ohio, Rutgers

  Simulations: ISU, Umass/Smith, Berkeley, LATech, UVa