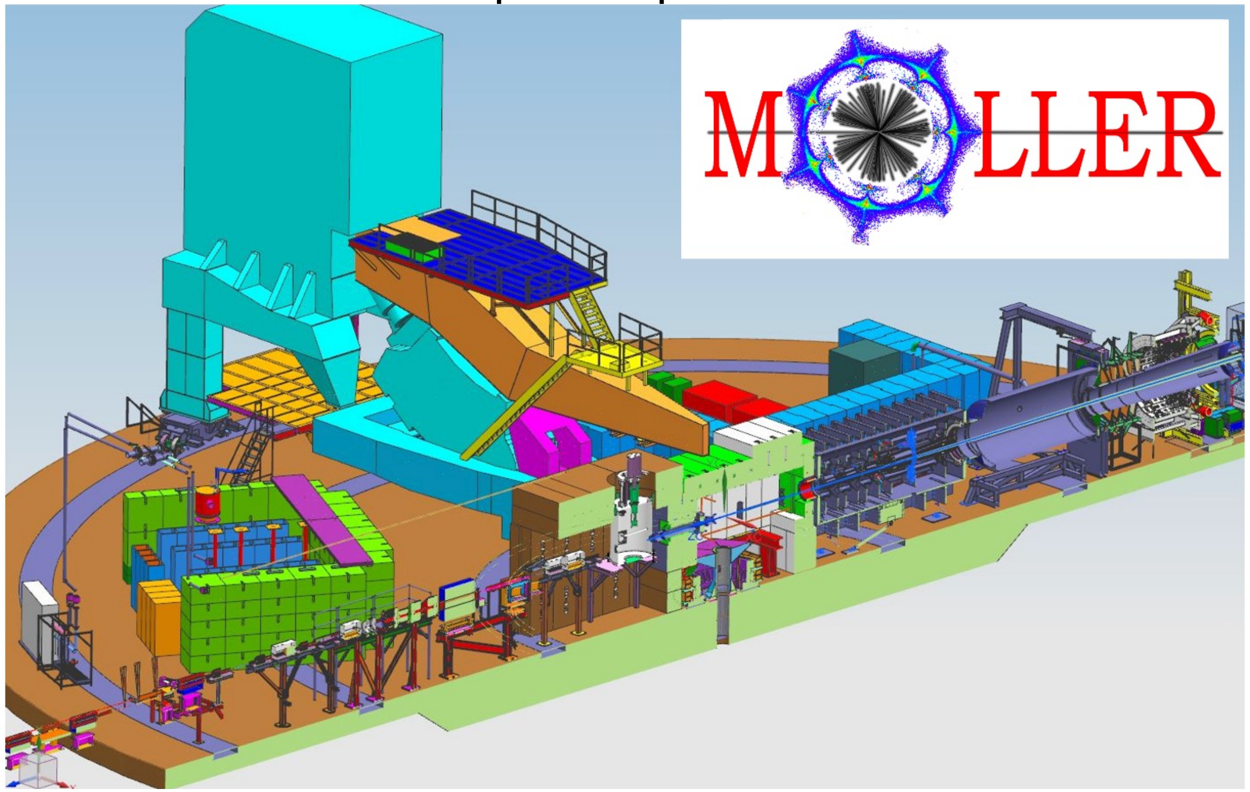
An Overview of the MOLLER Experiment at Jefferson Lab

Measurement **O**f a **L**epton **L**epton **E**lectroweak **R**eaction



APS | JOINT MARCH MEETING AND APRIL MEETING
Global Physics Summit

March 17, 2025

Zuhal Seyma Demiroglu (CFNS, Stony Brook University)

on behalf of the MOLLER Collaboration

Construction Funding: DOE (MIE), NSF, CFI/RM
Research Funding: DOE, NSF, NSERC

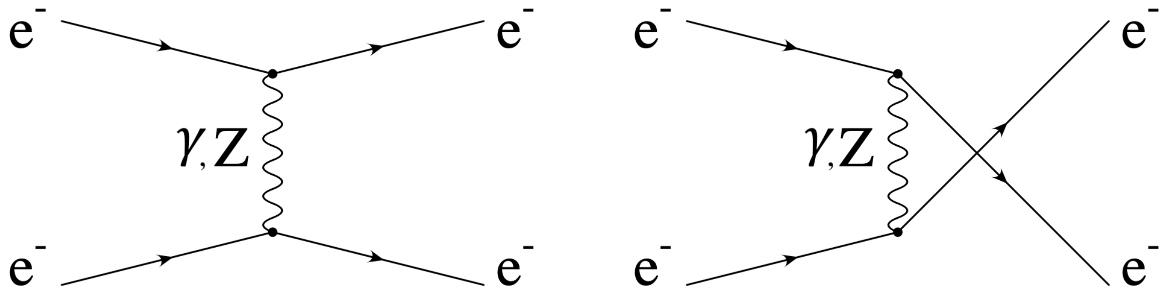
Stony Brook University

Center for Frontiers in Nuclear Science

Jefferson Lab

Parity Violation – A Precision Test of the Standard Model

- Parity-Violating Electron Scattering (PVES):
  - Measures left-right asymmetry in electron scattering.
  - Sensitive to weak interaction's violation of parity.

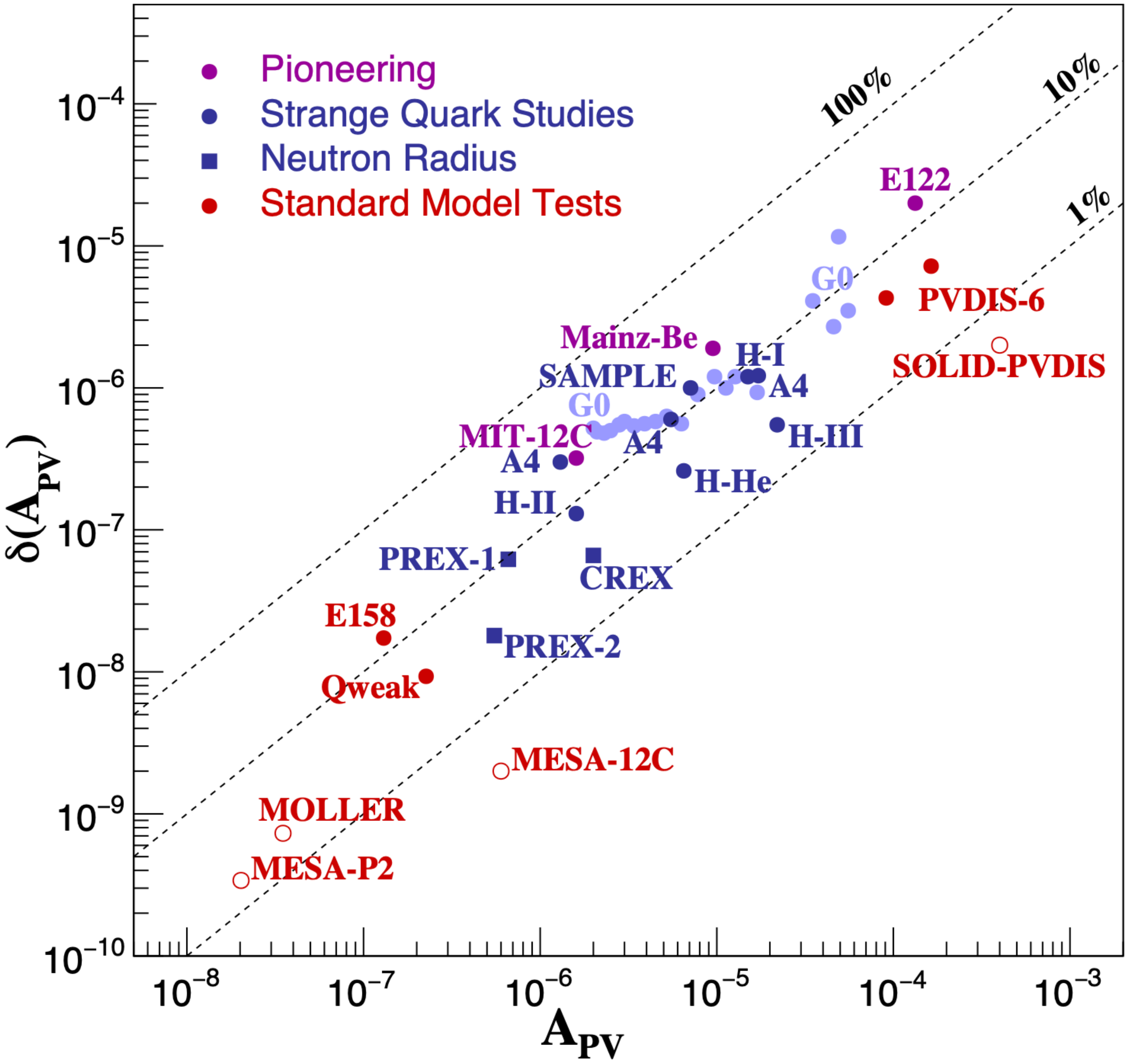


- Interference of electromagnetic and weak amplitudes:

$$\sigma \propto |A_{em} + A_{weak}|^2, \; A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \simeq \frac{|A_{em}A_{weak}|}{|A_{em}|^2 + |A_{weak}|^2} \simeq \frac{|A_{weak}|}{|A_{em}|} \simeq \frac{G_F Q^2}{4\pi\alpha}$$

- Purely leptonic system → minimal theoretical uncertainty.
- Tiny asymmetry → high-precision test of SM.

Evolution of PVES Precision



- PVES is a key tool for precision tests of electroweak interactions.
  - beam stability & polarimetry
  - radiation-hard detectors & cryotargets

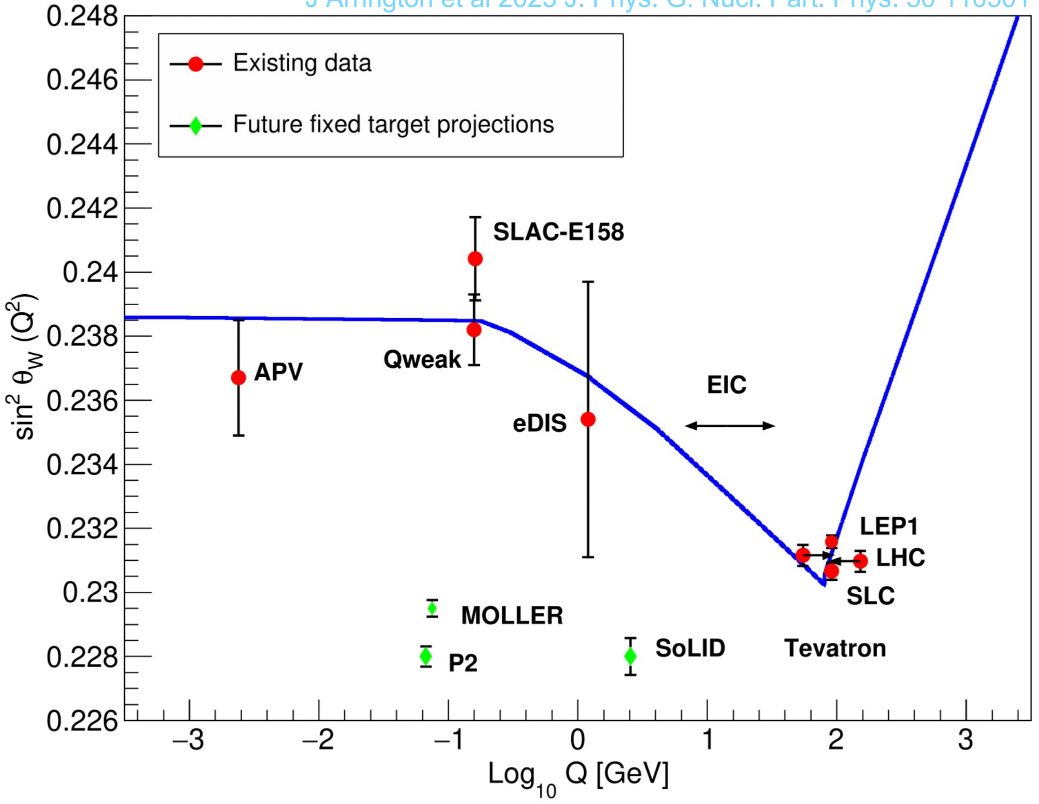
- Evolution of PVES Precision
  - Early experiments: E122, E158 at SLAC
  - More recent: Qweak, PREX, CREX
  - **MOLLER Goal:** Measure $A_{PV} \approx 33$ ppb at with an uncertainty of 0.8 ppb.

Weak Mixing Angle at Low Q² – MOLLER's Impact

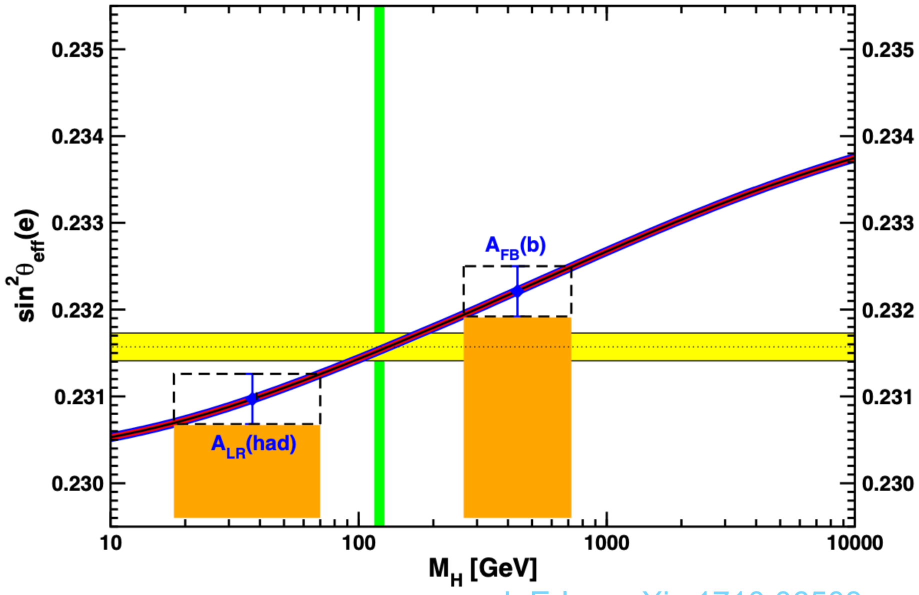
$$A_{PV} = -mE\,\frac{G_F}{\sqrt{2}\pi\alpha}\,\frac{4\sin^2\theta}{(3+\cos^2\theta)^2}\,Q_W^e, \qquad Q_W^e = 1 - 4\sin^2\theta_W \sim 0.075$$

- $\sin^2\theta_W$ measurement at low Q^2 provides precision test of SM.

J Arrington et al 2023 J. Phys. G: Nucl. Part. Phys. 50 110501



The most precise Z-pole measurements of $\sin^2\theta_W$ differ from each other by $\sim 3\sigma$



J. Erler, arXiv:1710.06503

MOLLER precision: Achieve a 2.4% measurement of Q_W^e.

$$\delta(\sin^2\theta_W) = \pm 0.00023(stat) \pm 0.00012(syst) \implies \sim\mathbf{0.1\%}$$

MOLLER: Indirect Searches for New Physics at the TeV Scale

- **Precision Asymmetry Measurements:** Indirect probe of MeV–TeV scale forces (e.g. light Z′, electron compositeness, doubly charged scalars…)
- **Reach**: Sensitivity to contact interaction up to ~25–30 TeV
- Complements collider searches – can reveal hidden quantum effects of new physics.

- Experimental Reach Comparisons:

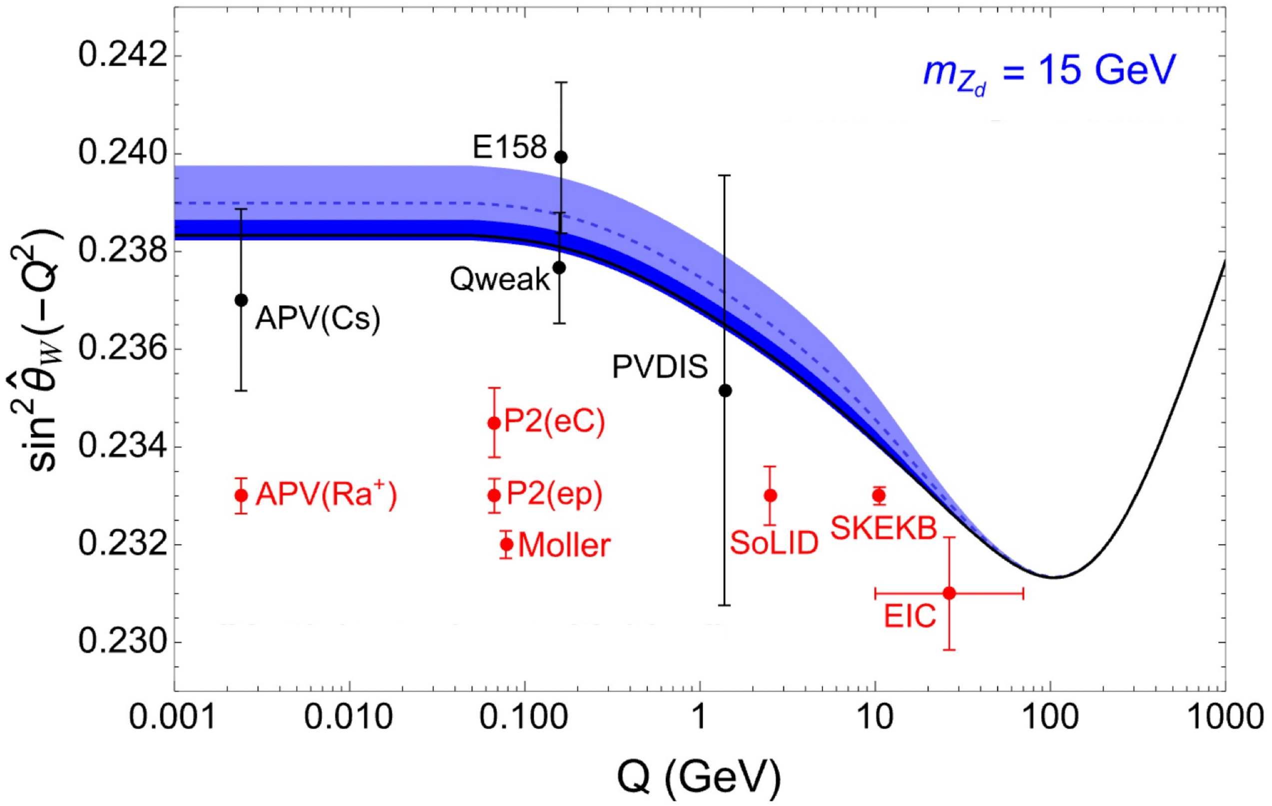
  e^+e^- Collisions

  $\Lambda_{LL}^{ee} \sim 8.3\ TeV$ (LEP200 reach)

  Fixed Target

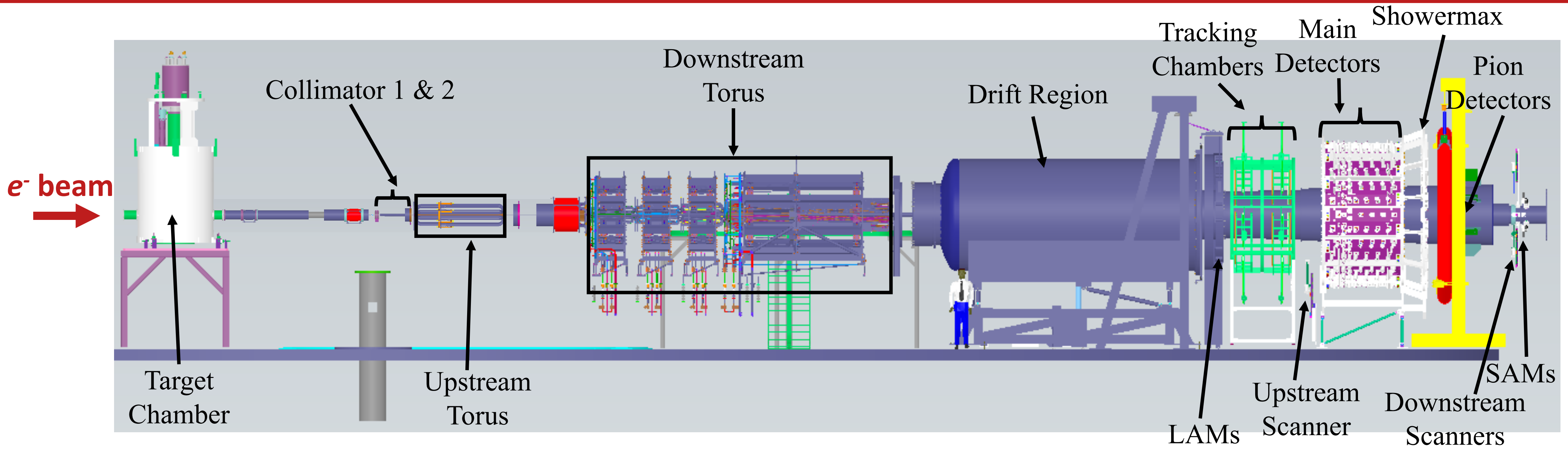
  $\Lambda_{LL}^{ee} \sim 12\ TeV$ (E158 reach)

  $\Lambda_{LL}^{ee} \sim 27\ TeV$ (MOLLER reach)



Adapted from H. Davoudiasl et al., Phys. Rev. D 108, 115018

MOLLER Experiment Design and Parameters



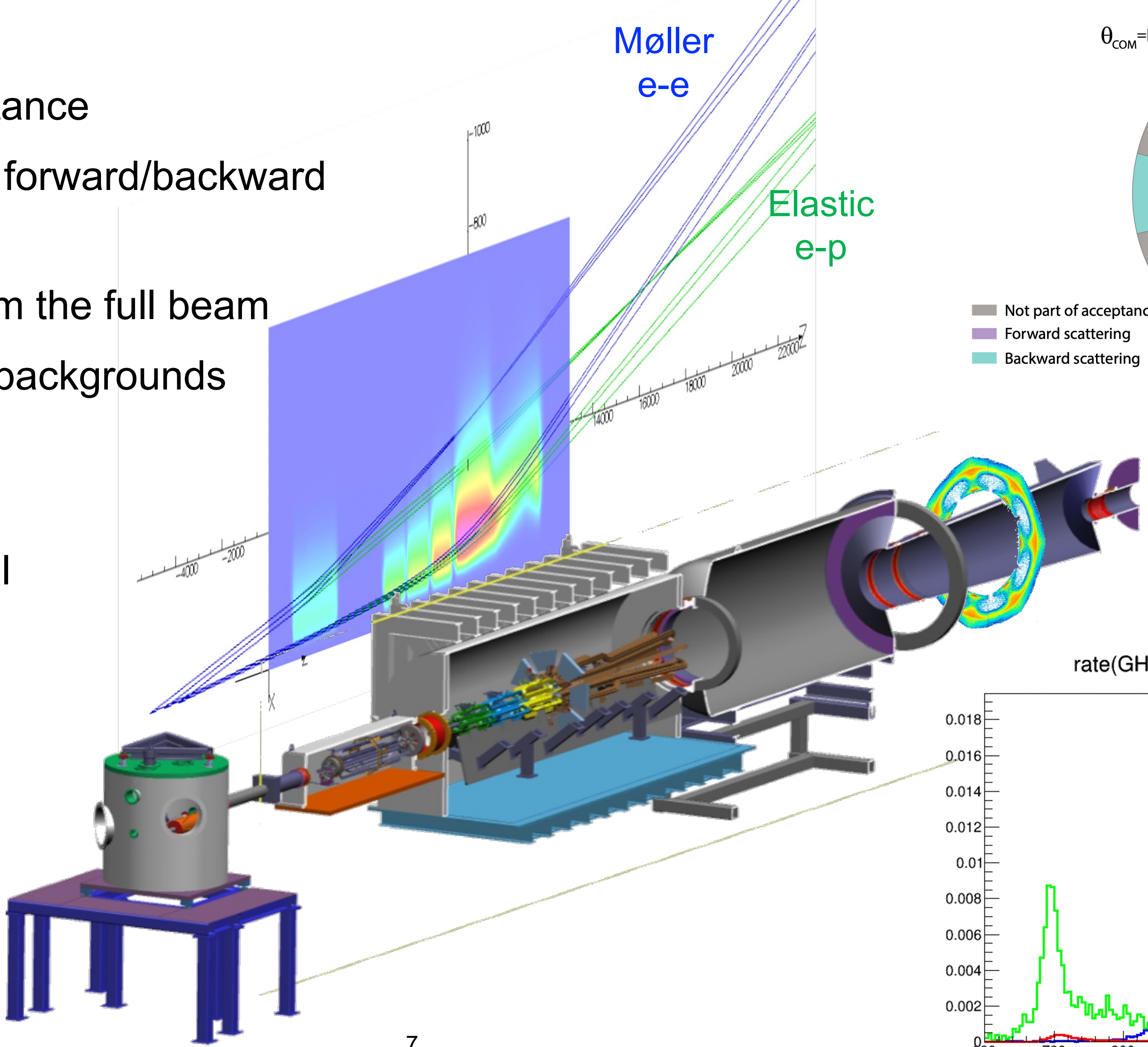
- **High luminosity and acceptance:**
  - 65 μA beam current at 11 GeV beam, 90% polarization
  - 1.25m, 4.5kW LH_2 target
  - Møller rate ~ 134 GHz
  - Max Luminosity: $2.4\times10^{39}cm^{-2}s^{-1}$
  - Full azimuth acceptance: 5-21mrad
- Integrate time: 344 beam days → 8256 h
- $\langle Q^2 \rangle$: 0.0058 GeV^2

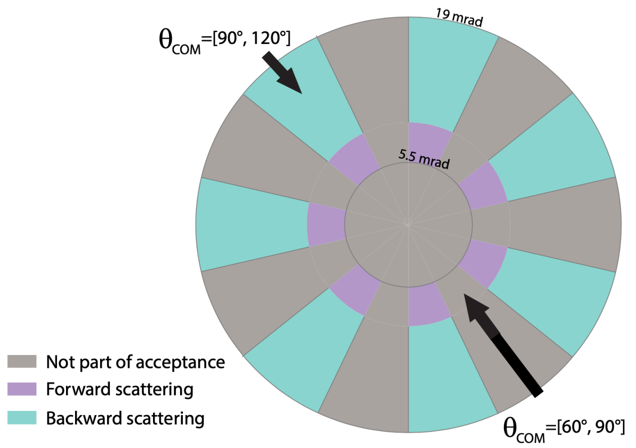
- **Controlling Noise and Systematic Uncertainty**
  - Rapid helicity flipping
  - Stable beam and target conditions
  - Precision calibration of detectors, optics, and acceptance
  - Extensive background monitoring and correction strategies

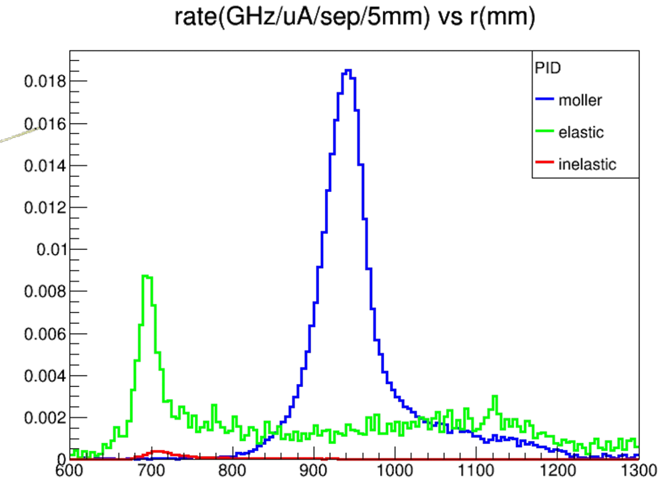
Spectrometer & Collimation – Ensuring Clean Signals

- Collimation System
  - Defines experiment's acceptance
  - Specially designed to select forward/backward scattering in the COM frame
  - Protects magnet regions from the full beam
  - Shapes signal and reduces backgrounds

- Spectrometer
  - Two 7-fold symmetry toroidal magnets
  - ~100% acceptance for identical-particle Møller scattering

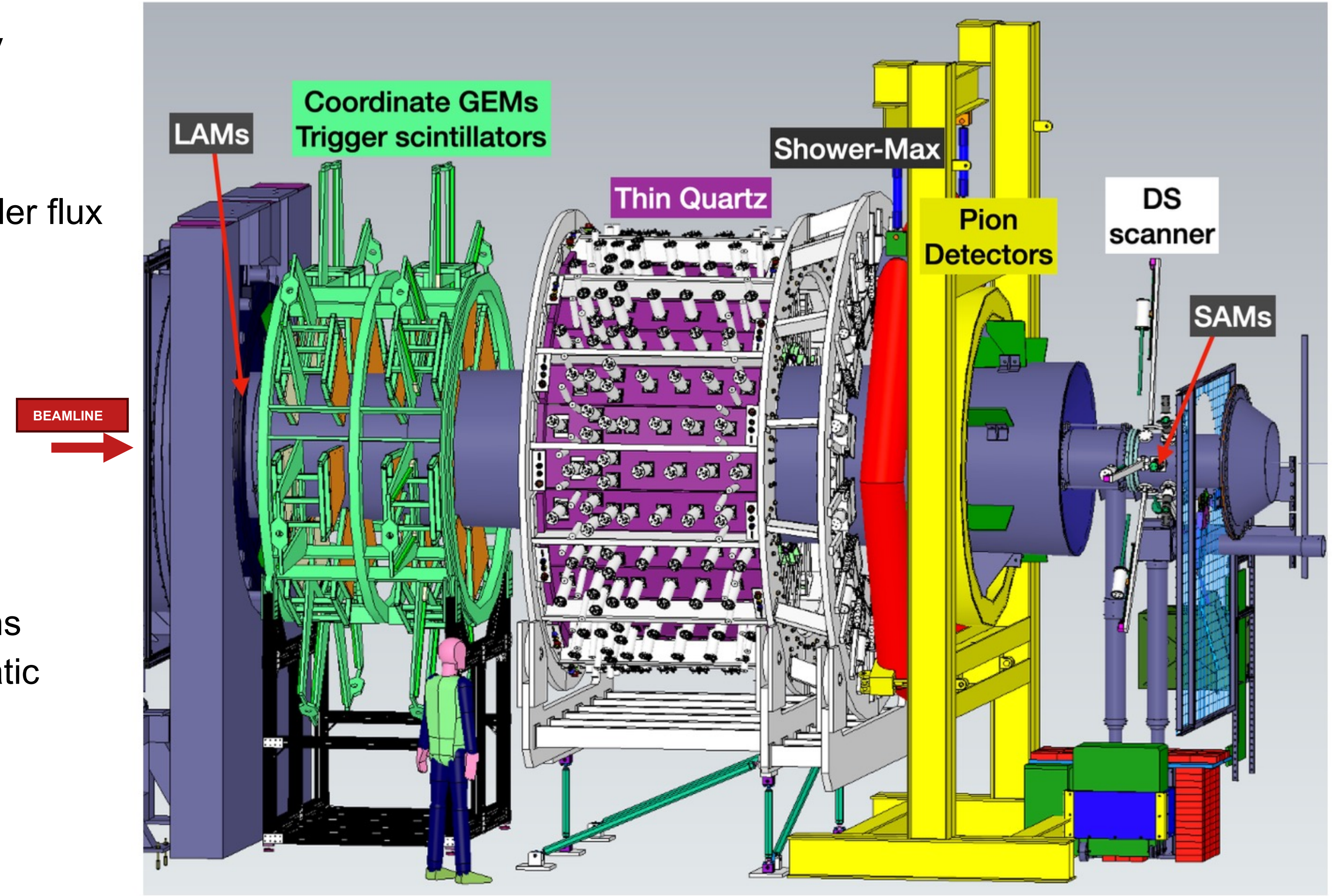






Integrating and Tracking Detectors

- **Thin Quartz Detector:**
  - Six concentric rings; Ring 5 is primary Møller signal
- **Shower-Max Detector:**
  - Additional measurement of integrated Møller flux
- **Pion Detector**
  - Measures pion asymmetries
- **Integrating Monitors**
  - Monitor beam conditions
  - Check for anomalous helicity correlations
- **Tracking Detectors (GEMs)**
  - Precision tracking at low-current beam runs
  - Improve background subtraction & kinematic reconstruction



MOLLER: Status and Timeline

MOLLER Collaboration

~180 authors, 37 institutions, 6 countries

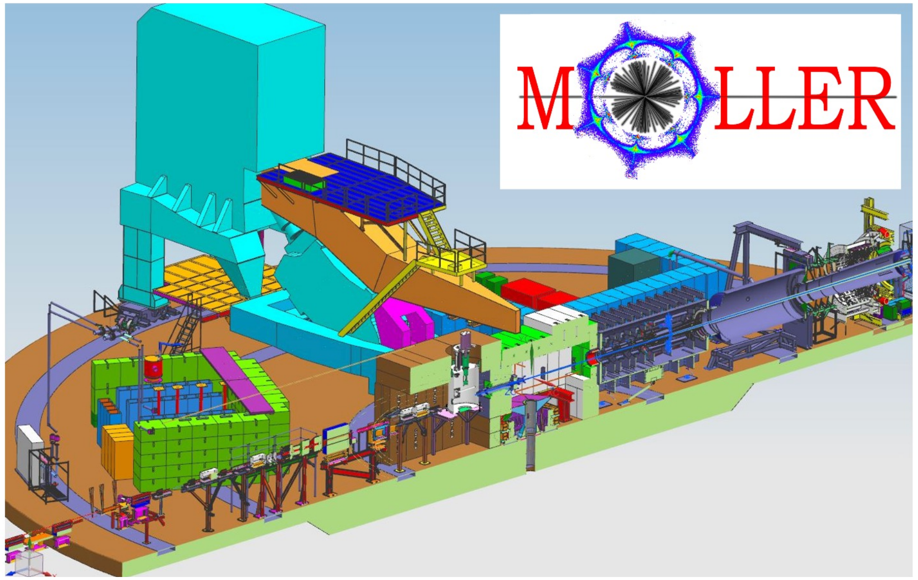
Spokesperson: Krishna Kumar (UMass, Amherst)

Project Manager: Ruben Fair (Jefferson Lab)

- Fabrication and qualification activity underway at Jefferson Lab.
- Will be ready for assembly later this year!
- Ready for physics in early 2027.
- The first physics results are anticipated by mid-2027.

Summary

- MOLLER provides a high-precision test of electroweak theory in a low-energy setting.
  - Can help resolve discrepancies in $\sin^2\theta_W$ measurements.
  - With a projected sensitivity to new contact interactions up to ~25–30 TeV scales, MOLLER offers discovery potential for new physics that is complementary to the LHC and future colliders.
- The experiment's construction is on track.
  - Key components are being built and tested in 2024–2025.
  - Installation/Assembly in Hall-A is targeted to begin later this year!
  - First data is expected by 2027, meaning the physics results are just around the corner after two decades since E158's pioneering measurement.
- MOLLER's results will inform theory and guide the direction of particle physics, demonstrating the power of precision experiments in the quest for new physics.



Thank You!

Backup

Weak Mixing Angle Measurements at Low Energy

- Effective weak mixing angle:

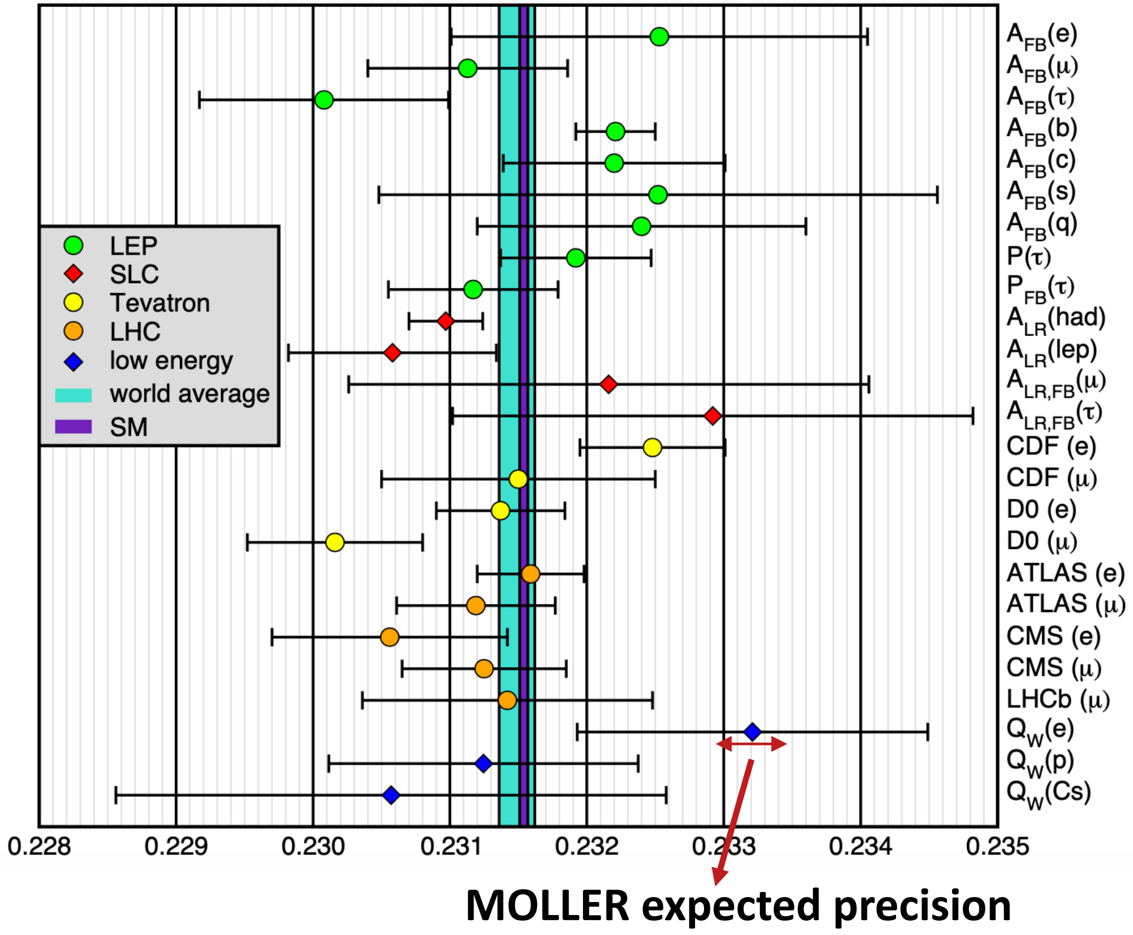
$$\sin^2\theta^l_{eff} \equiv \frac{1}{4}\left(1 - \frac{v_l}{a_l}\right)$$

- MOLLER A_{PV} would be the first low Q^2 measurement to match the precision of the single best high energy measurement at the Z^0 resonance.

- MOLLER projection:

$$\delta(\sin^2\theta_W) = \pm 0.00023(stat) \pm 0.00012(syst)$$
$$\rightarrow \sim 0.1\%$$

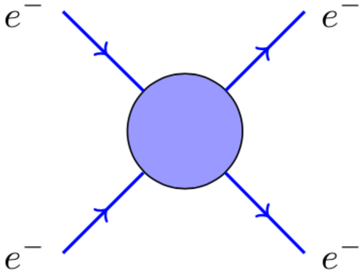
J. Erler, arXiv:1908.07346v1

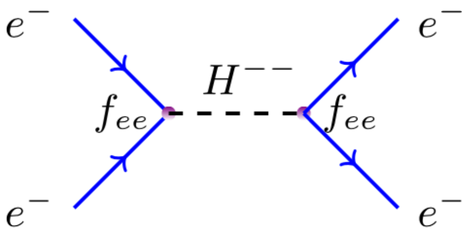


All measurements of the effective leptonic weak mixing angle.

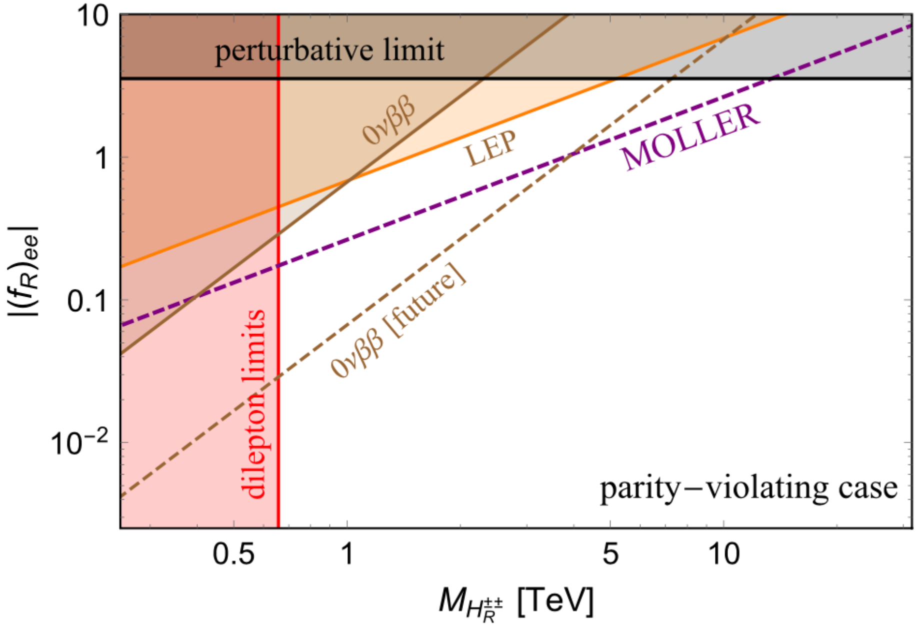
New Physics Beyond the Standard Model

- Most sensitive probe of new flavor and CP-conserving neutral current interactions over next decade.
  - high energy (multi-TeV) scale dynamics (Z’, electron compositeness, supersymmetry, **doubly charged scalars**,…)





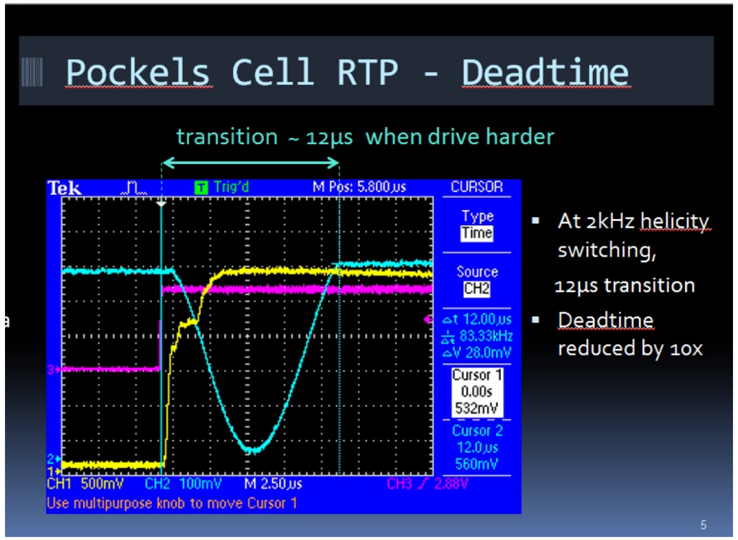
P. S. B. Dev, M. J. Ramsey-Musolf, Y. Zhang
PHYSICAL REVIEW D 98, 055013 (2018)



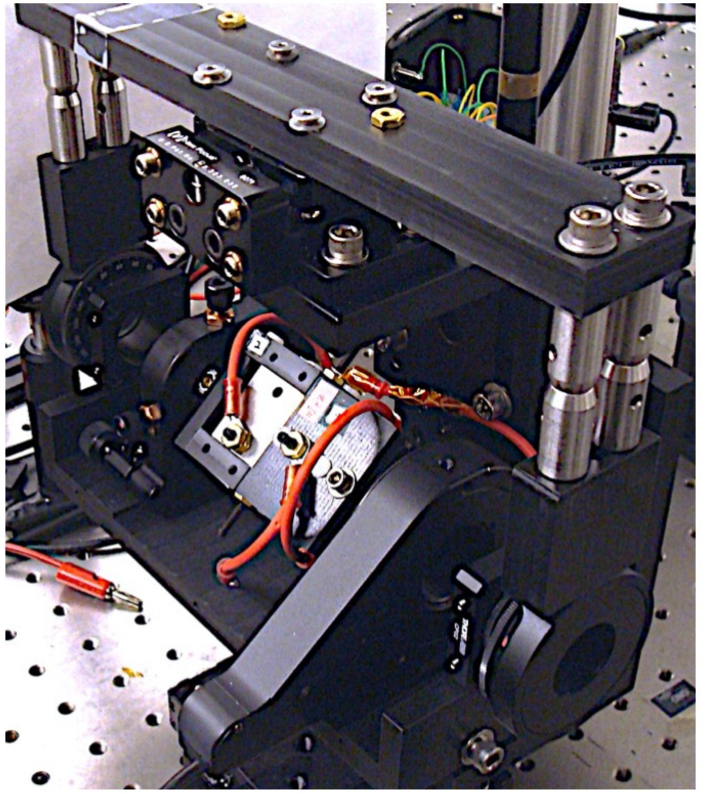
MOLLER prospect for the RH doubly-charged scalar mass $M_{H_R^{\pm\pm}}$ in the parity-violating LRSM and the coupling $|(f_R)_{ee}|$

- $M_{H_R^{\pm\pm}}$ could be probed up to ≃10 TeV for a $\mathcal{O}(1)$ Yukawa coupling by MOLLER → This is far beyond the direct search capability of LHC or even future 100 TeV colliders.

Polarized Electron Source



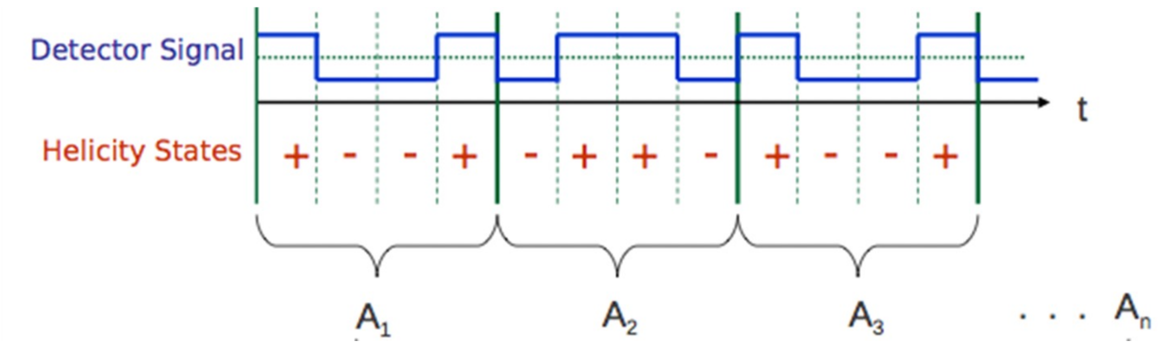
- Generated with a circularly polarized laser beam.
  - Pockels cell controls the spin of the electron beam.
- New technology needed: RTP (Rubidium Titanyl Phosphate) cell
  - Requiring high ~2kHz flip rates, ~11μs transitions
  - Two crystals, transverse field
  - No piezo-electric ringing artifacts
  - Much faster and more stable



The requirements for helicity-correlated beam asymmetries during MOLLER

	HAPPEX-II (achieved)	Q_{weak} (achieved)	PREX-2 (achieved)	CREX (achieved)	MOLLER (required)
Intensity asymmetry	400 ppb	30 ppb	25 ppb	-88 ppb	10 ppb
Energy asymmetry	0.1 ppb	0.4 ppb	0.8 ± 1 ppb	0.1 ± 1.0ppb	< 1.4 ppb
position differences	1.7 nm	4.4 nm	2.2 ± 4 nm	-5.2 ± 3.6nm	0.6 nm
angle differences	0.2 nrad	0.1 nrad	$< 0.6 \pm 0.6$ nrad	-0.26 ± 0.16nrad	0.12 nrad
size asymmetry (quoted)	–	$< 10^{-4}$	$< 3 \times 10^{-5}$	$< 3 \times 10^{-5}$	$< 10^{-5}$

How Do We Take the Bulk of Our Data?



Parameter	Random Noise (65 μA)
Statistical width (0.5 ms)	**$\sim$ 82 ppm**
Target Density Fluctuation	30 ppm
Beam Intensity Resolution	10 ppm
Beam Position Noise	7 ppm
Detector Resolution (25%)	21 ppm (3.1%)
Electronics noise	10 ppm
Measured Width (σ_{pair})	**91 ppm**

MOLLER specification is 10 ppm resolution for relative beam intensity measurement for 1 kHz window pairs.

- The raw signal from the detectors integrated for each helicity window (0.52 ms) and asymmetry formed from in a single helicity patterns.
  - MOLLER is designing around a helicity flip rate of 1.92 kHz.

$$A_i = \left(\frac{F_R - F_L}{F_R + F_L}\right)_i \cong \left(\frac{\Delta F}{2F}\right)_i ;\ A_{raw} = \langle A_i \rangle$$

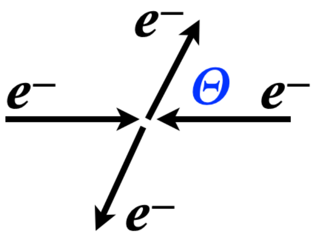
- Remove the correlations of flux to beam intensity, position, angle, and energy fluctuations:

$$A_i = \left(\frac{\Delta F}{2F} - \frac{\Delta I}{2I}\right)_i - \sum \left(\alpha_j (\Delta X_j)_i\right)$$

- Repeat 30 billion times to get desired statistical error.

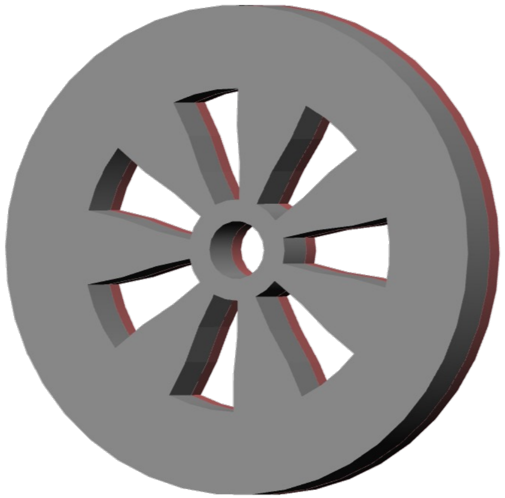
MOLLER Kinematics and Acceptance

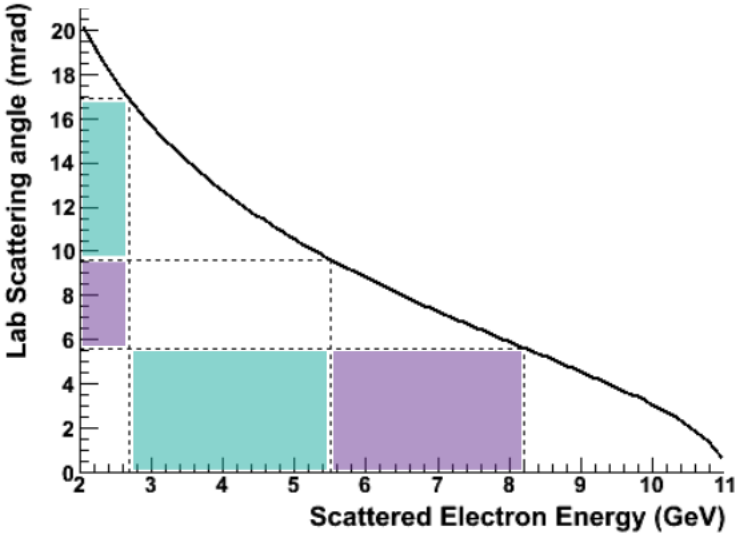
- Identical particles.

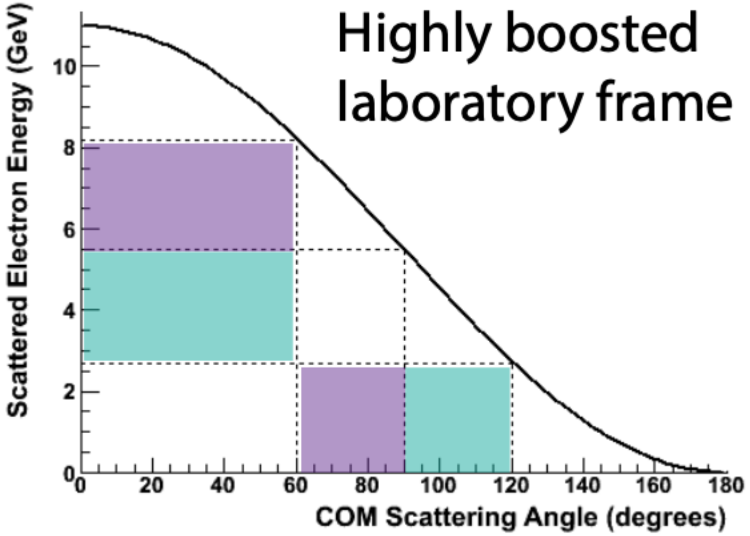


- Measure either forward or backward scattering in CM frame.
- Full azimuthal acceptance for Møller scatters from 6 $<\theta_{lab}<$ 20 mrad

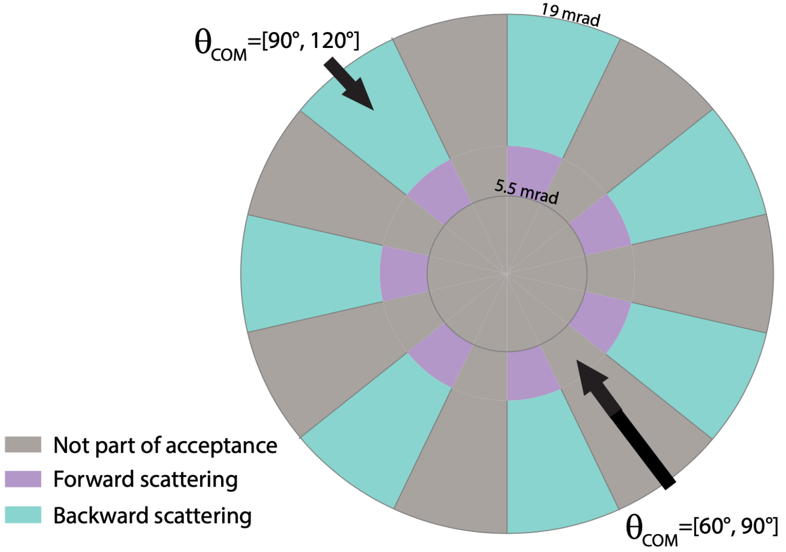
Acceptance defining collimator
7-fold symmetry



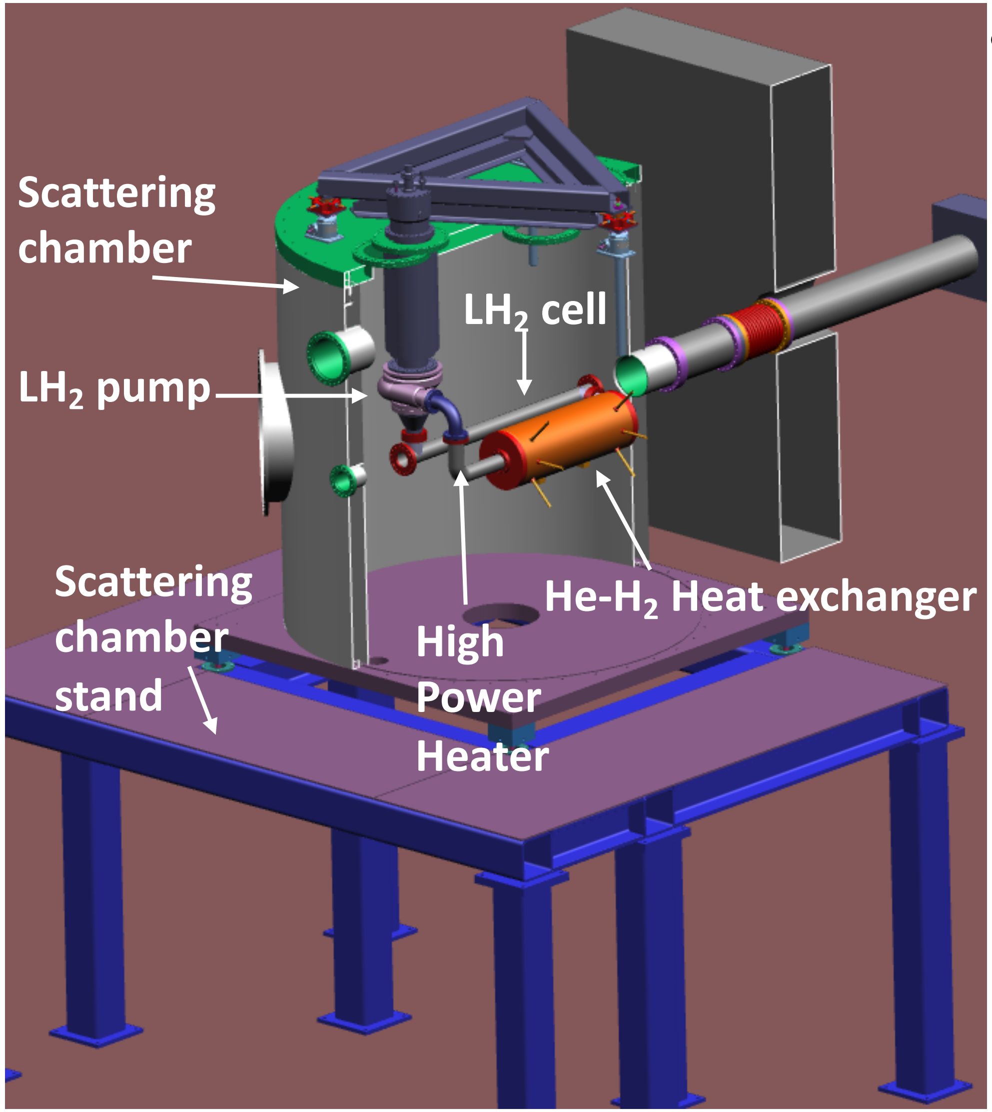




Highly boosted laboratory frame

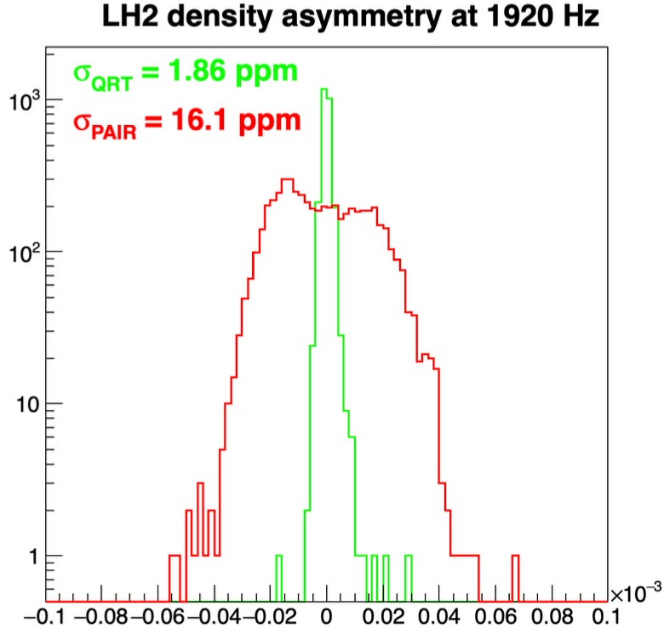


Liquid Hydrogen Target

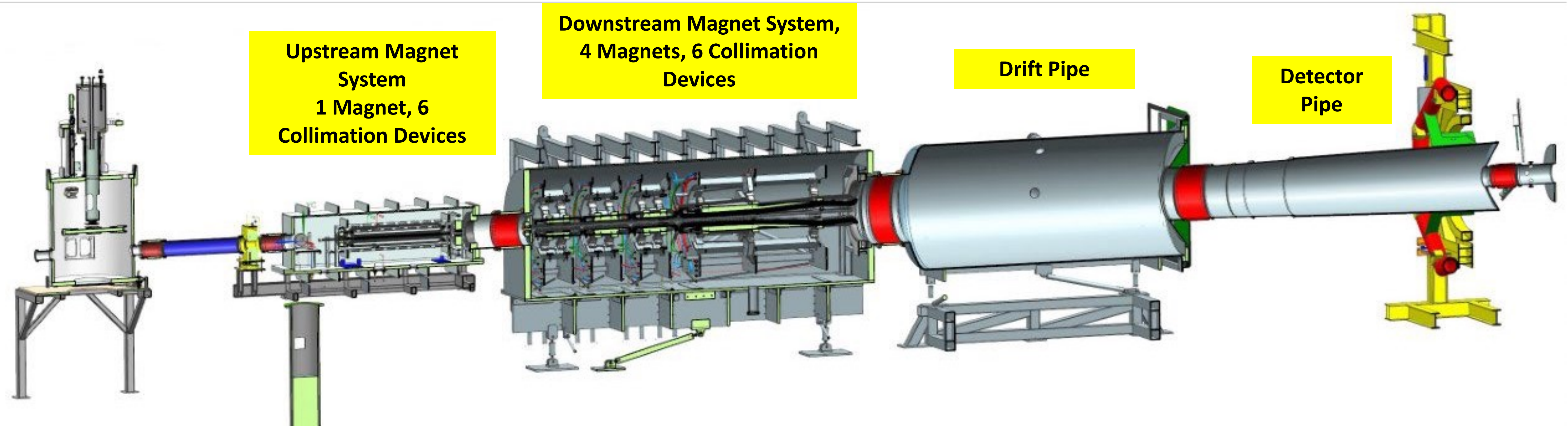


- The MOLLER target is designed using CFD to meet the demanding requirements:
  - Target power: 4 kW, Target flow: 25 l/s, Density fluctuation: <30 ppm
  - The Q_{weak} target (3kW, 17 l/s) demonstrated the capability of high-power, high-stability targets and CFD design tools.

Target Parameters	
Cell length	125 cm
Cell thickness	8.93 g/cm^2
Radiation length	14.6%
p, T	35 psia, 20K
ϕ acceptance	5 mrad (0.3°)
Target power	4000 W

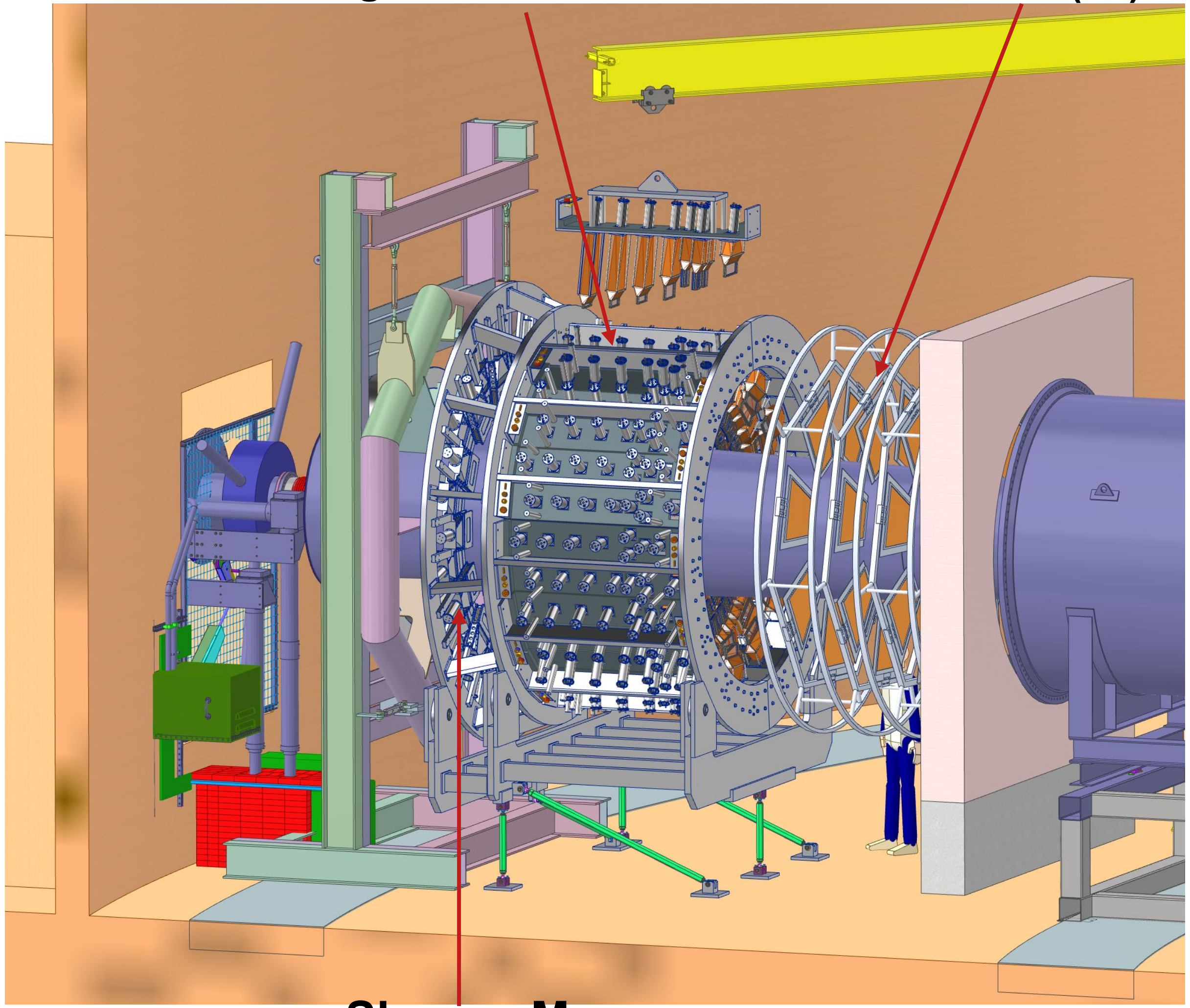


MOLLER Spectrometer



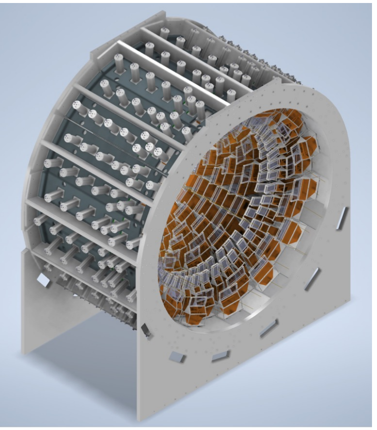
- Extent of spectrometer scope is 26.5 m.

Integrating and Tracking Detectors Overview



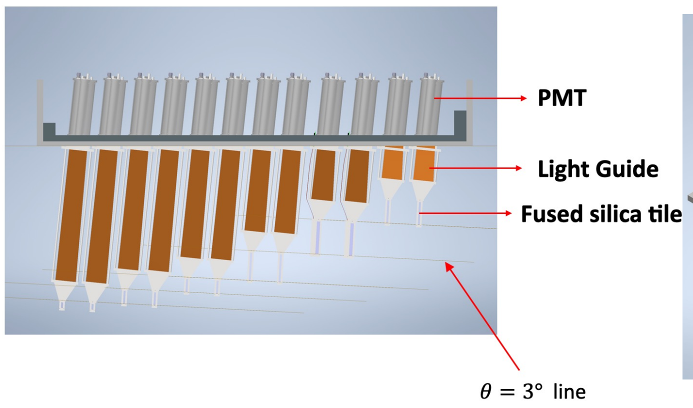
- **Integrating detectors** are an array of detectors based on quartz as the active element.
  - Asymmetry measurements of both signal and background, and beam and target monitoring.
  - 6 concentric rings. Ring 5 primarily capturing the Møller electron signal.
- **Shower-Max detector** concept uses a layered "stack" of tungsten and fused silica (quartz) to induce EM showering and produce Cherenkov light
  - Provides additional measurement of Ring 5 integrated flux $\Longrightarrow$ less sensitive to low energy and hadronic backgrounds.
  - Will also operate in tracking mode to give additional handle on background pion identification.
  - Will have good resolution over full energy range ($\lesssim$ 25%), radiation hard with long term stability and good linearity.
- **Pion detector**
  - Hadronic dilution/asymmetries
- **Integrating monitors** are "canaries", looking for a variety of anomalous helicity correlations
  - Small Angle (SAMs); Large Angle (LAMs); Diffuse Background (DBMs); Scanners (remotely controllable)
- **GEMs**
  - Spectrometer calibration, electron scattering angle distribution and background measurements.

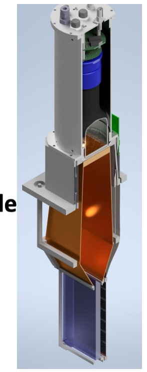
Detector Plane Segmentation

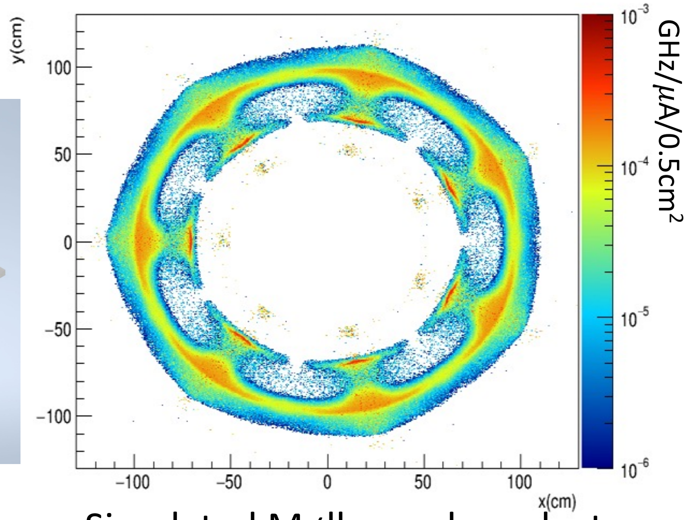


Detector assembly

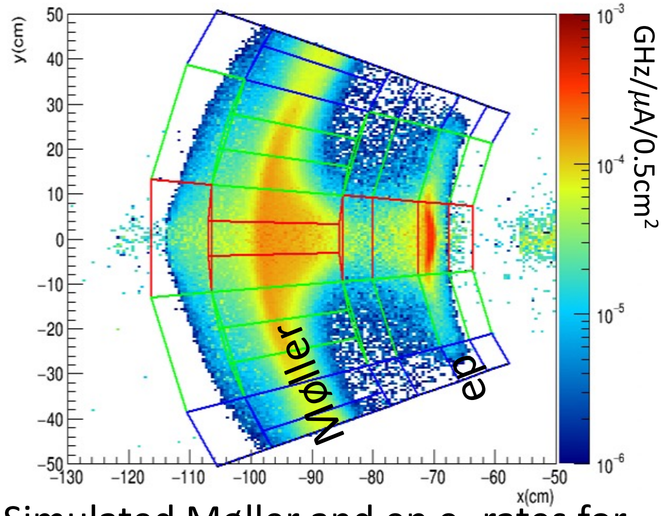
Beam left view





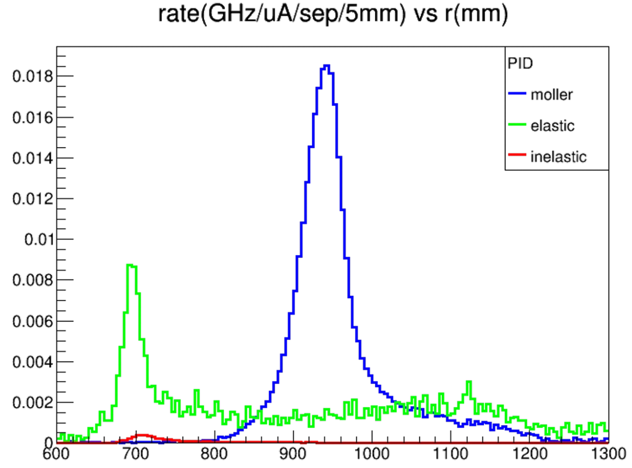


Simulated Møller and ep electron rates



Simulated Møller and ep e- rates for superimposed azimuthal and radial bins in one toroidal sector.

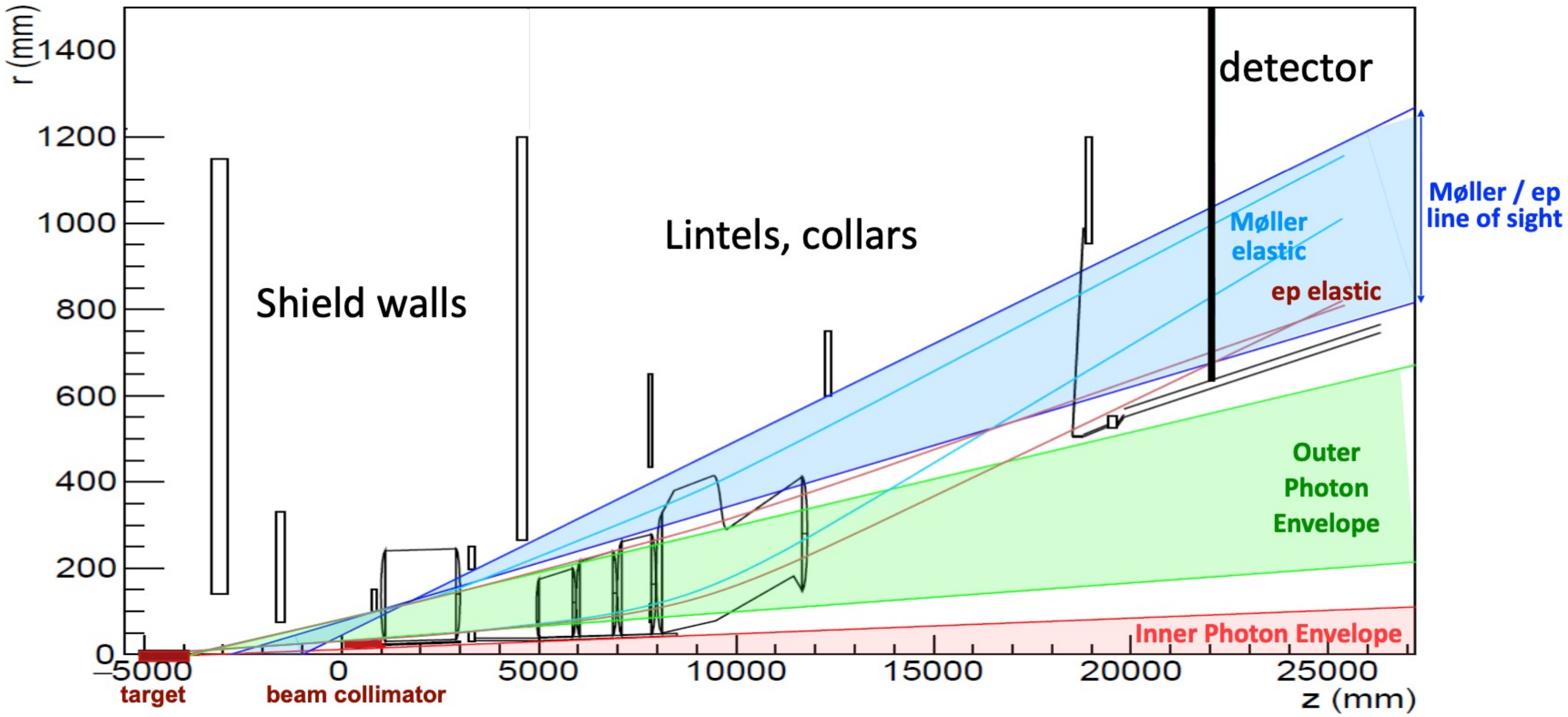
- The thin detector array consist of 6 rings and 224 detectors.
  - 28 segments around the annulus
  - Each segment has a total of 8 detector modules
  - 84 detectors in Ring 5 and 28 in each of the other rings
  - Each detector module consists of a quartz, tile, an air-core light guide, and a PMT.
- High level of segmentation separates irreducible backgrounds from Møller signal.
  - The modules must overlap slightly, to cover the azimuth so that the rings need to staggered along the beam direction. They also need to be spaced such that assembly and access to quartz tiles is possible.



Radial dist. at detector plane 26.5m from target, all φ includes rad. eff.

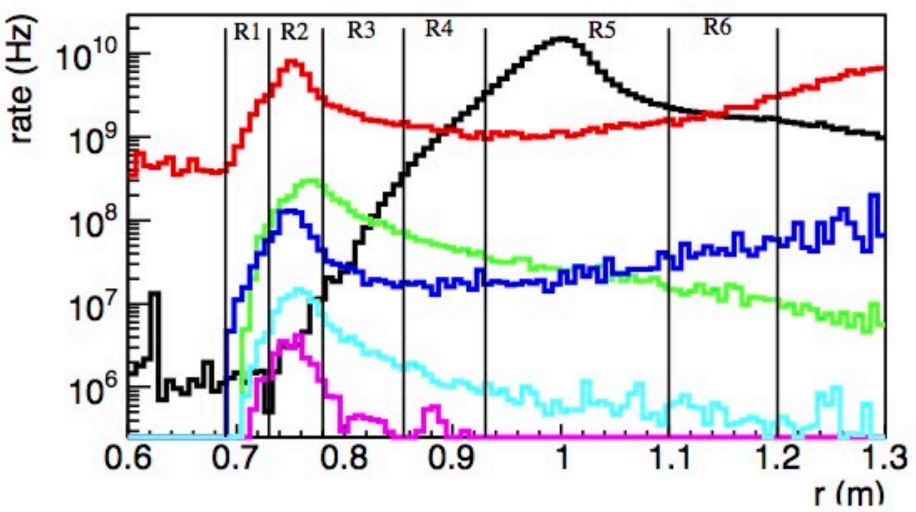
MOLLER Backgrounds

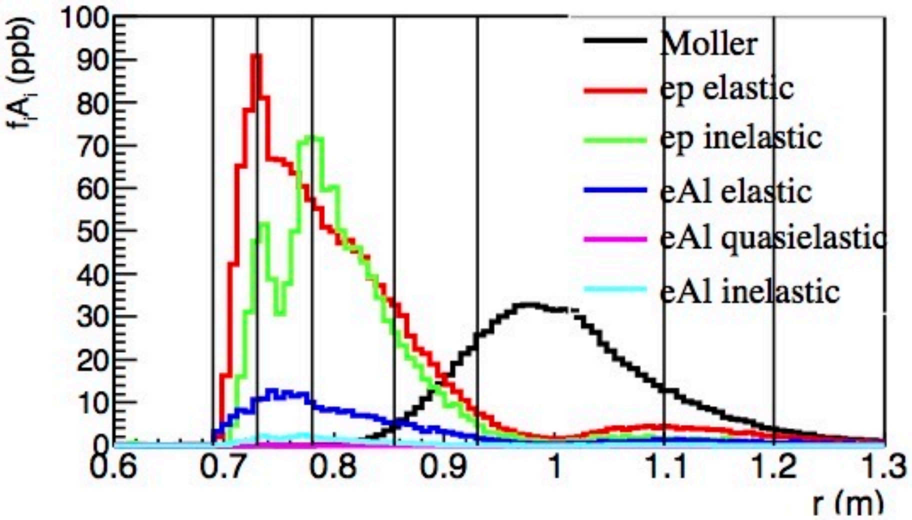
- Irreducible backgrounds arise from scattering off the target material that will pass through the spectrometer and arrive at the detector plane.
  - The principal irreducible background under the Møller “peak” is radiative elastic ep scattering.
- Other background sources
  - Photons and neutrons from 2 bounce collimation system.
  - Pions and muons: photo-production and DIS



Background Deconvolution

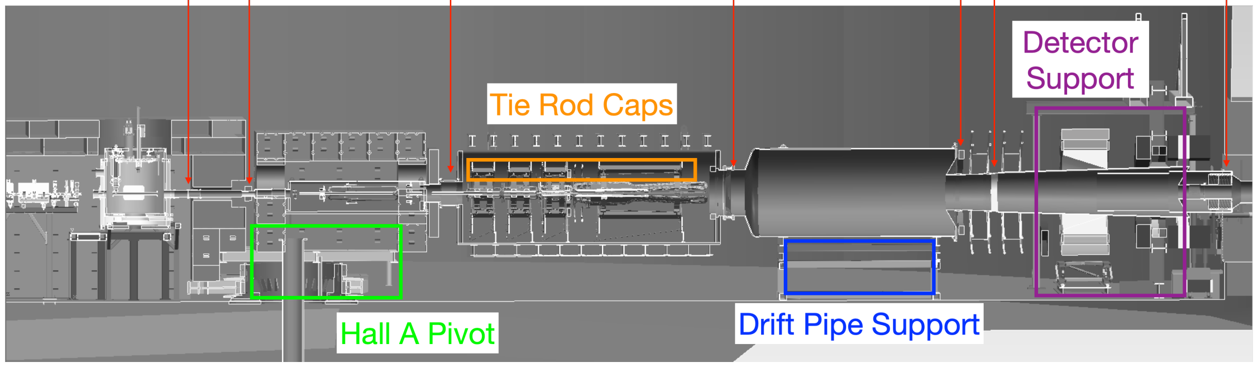
Kent Paschke





- Deconvolute the signal from the background using the segmented detector plane.
- Elastic ep: ~10% of the signal, asymmetry is well known.
- Inelastic ep: <0.3% of the signal but asymmetry is ~20x larger, not well known.
- The inelastic contribution is prominent in Rings 2 and 3, will be measured there.

Potential Background Asymmetries from Ferrous Materials



Elevation view of the MOLLER spectrometer, marked up from JLab CAD drawings.
The locations of potentially ferromagnetic materials are indicated.

Bellows: Inconel 625
Hall A Pivot, Tie Rod ends,
Detector support: mild steel
Drift pipe and downstream torus support: mild steel

- Potential backgrounds to the Møller scattering asymmetry due to scattering from polarized materials along the beam line or elsewhere in the Hall. → polarized materials are most likely due to ferromagnetic materials/components.
- Estimate false asymmetry A_f as;

$$A_f = f_r P_e P_s A_n$$

f_r: rate fraction of process
P_e: incident electron polarization
P_s: material electron polarization
A_n: analyzing power

- Goal: $A_f < 10^{-11}$
- In ~1G ambient field:
  - Mild steel: $P_s \sim 10^{-2}$
  - Stainless steel: $P_s \sim 10^{-5} \sim 10^{-7}$
  - Inconel 625: $P_s \sim 10^{-8}$
  - Aluminum (paramagnetic): $P_s < 10^{-9}$
  - Conservative estimate: $P_e A_n \sim 10^{-3}$

The Projected Statistical and Systematic Uncertainties

Error Source	Fractional Error (%)	
	Run1	Ultimate
Statistical	**11.4**	**2.1**
Absolute Norm. of the Kinematic Factor	3	0.5
Beam (second moment)	2	0.4
Beam polarization	1	0.4
$e + p(+\gamma) \rightarrow e + X(+\gamma)$	2	0.4
Beam (position, angle, energy)	2	0.4
Beam (intensity)	1	0.3
$e + p(+\gamma) \rightarrow e + p(+\gamma)$	0.6	0.3
$\gamma^{(*)} + p \rightarrow (\pi, \mu, K) + X$	1.5	0.3
$e + Al(+\gamma) \rightarrow e + Al(+\gamma)$	0.3	0.15
Transverse polarization	2	0.2
Neutral background (soft photons, neutrons)	0.5	0.1
Linearity	0.1	0.1
Total systematic	**5.5**	**1.1**

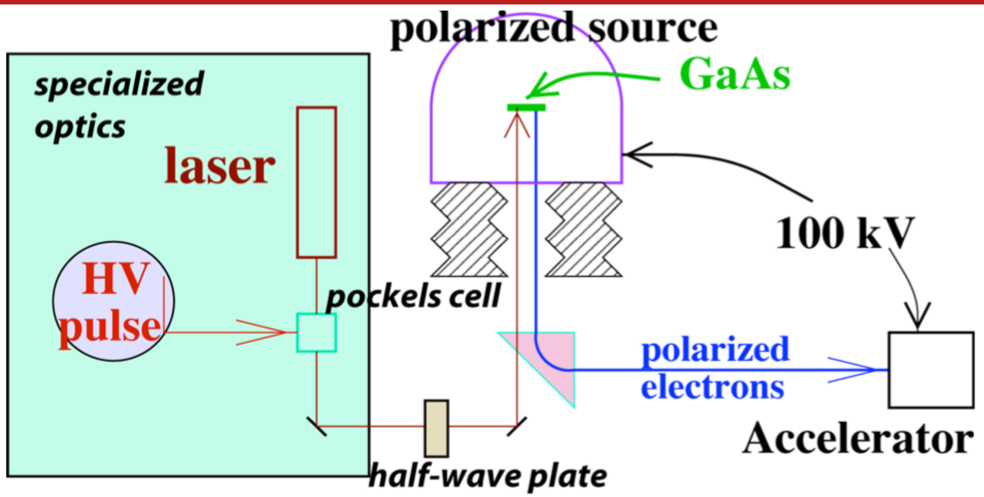
$$A_{PV} = \frac{\frac{A_{expt}}{P_b} - f_b A_b}{1 - f_b}$$

Run	PAC Days	Stat Error		Efficiency
Period	(prod)	$\sigma(A_{meas})$	$\sigma(A_{PV})$	
I	14	2.96ppm	11.4%	40%
II	95	1.08ppm	4.2%	50%
III	235	0.65ppm	2.5%	60%

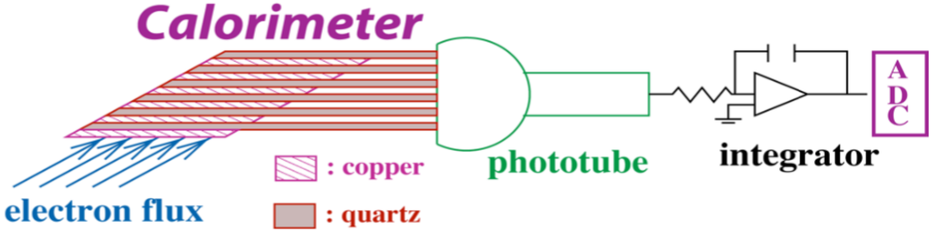
Summary of notional run phases, with production and calibration estimates used for collaboration planning, to achieve the ultimate precision goals of the MOLLER experiment.

Conceptual Overview of the Experimental Technique

Krishna Kumar



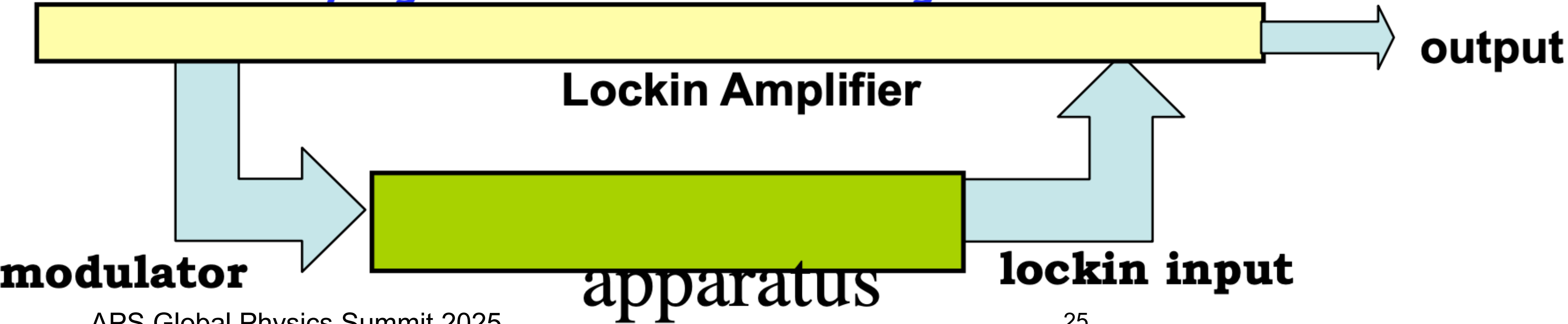
- Optical pumping of a GaAs wafer: "black magic" chemical treatment to boost quantum efficiency
- Rapid helicity reversal: polarization sign flips > 100 Hz to minimize the impact of drifts
- Helicity-correlated beam motion: under sign flip, beam stability at the sub-micron level



"Flux Integration": very high rates

direct scattered flux to background-free region

Tiny signal buried in known background



Apparatus:

beam, target, spectrometer, detectors and accelerator all interconnected!

Beam Corrections

Kent Paschke

Remove correlations to beam intensity, position, angle, and energy fluctuations:

$$\left(A_{cxpt}\right)_i = \left(\frac{\Delta F}{2F} - \frac{\Delta I}{2I}\right)_i - \sum_j \left(\alpha_j \left(\Delta X_j\right)_i\right)$$

Creates noise and also a systematic false asymmetry from average difference

Monitor resolution
Calibration imprecision

Parameter	Noise (65 μA)
Statistical Width	**~82 ppm**
Beam Intensity Resolution	10 ppm
Beam Position Noise	7 ppm

Error Source	Fractional Error (%)
Beam (position, angle, energy)	0.4
Beam (intensity)	0.3

Keep beam asymmetries small

- Special techniques with the polarized source laser optics
- Beam transport configuration to avoid exacerbating differences
- “slow reversals” that flip the sign of beam asymmetries
- feedback

Beam Property	Assumed Sensitivity	Accuracy of Correction	Required 1 kHz random fluctuations	Required cumulative helicity-correlation	Systematic contribution
Intensity	1 ppb / ppb	$\sim$1%	$<$ 1000 ppm	$<$ 10 ppb	$\sim$ 0.1 ppb
Energy	-0.7 ppb / ppb	$\sim$5%	$<$ 108 ppm	$<$ 1.4 ppb	$\sim$ 0.05 ppb
Position	1.7 ppb / nm	$\sim$5%	$<$ 47 μm	$<$ 0.6 nm	$\sim$ 0.05 ppb
Angle	8.5 ppb / nrad	$\sim$5%	$<$ 4.7 μrad	$<$ 0.12 nrad	$\sim$ 0.05 ppb
Spot Size	0.012 ppb / ppm	-	-	$<$ 10 ppm	$\sim$ 0.1 ppb

Beam correction analysis

Two calibration techniques

- beam modulation for calibration
- linear regression

Combined, for precision and accuracy in the PREX-2 analysis

- Removed >90% noise
- 4% precision on total correction

BCM Resolution

Kent Paschke

Parameter	Noise (65 μA)
Statistical Width (1016 μs)	**~82 ppm**
Target Density Fluctuation	30 ppm
Beam Intensity Resolution	10 ppm
Beam Position Noise	7 ppm
Detector Resolution (25%)	21 ppm
Electronics Noise	10 ppm
Measured Width	**91 ppm**

Existing BCM receivers
- Bench tests with well known receivers = 42 ppm
- Seven monitors (for MOLLER), average to get ~ 16 ppm resolution
- Would imply 92ppm ultimate pair width (instead of 91ppm) if not improved

Would prefer to do better, to enable systematic studies with better resolution

Two strategies for improvement
- New version of JLab electronics has been fielded
  - Expect 2x better (~22 ppm) resolution for single monitor
  - Bench tests suggest further improvements by improving local oscillator
- LBNL digital processor prototype (Kolomensky and group)
  - Uses fast sampling ADC's capable of direct RF sampling
  - Eliminates need for local oscillator
  - Initial bench studies give ~ 10 ppm resolution for 960 Hz window pairs

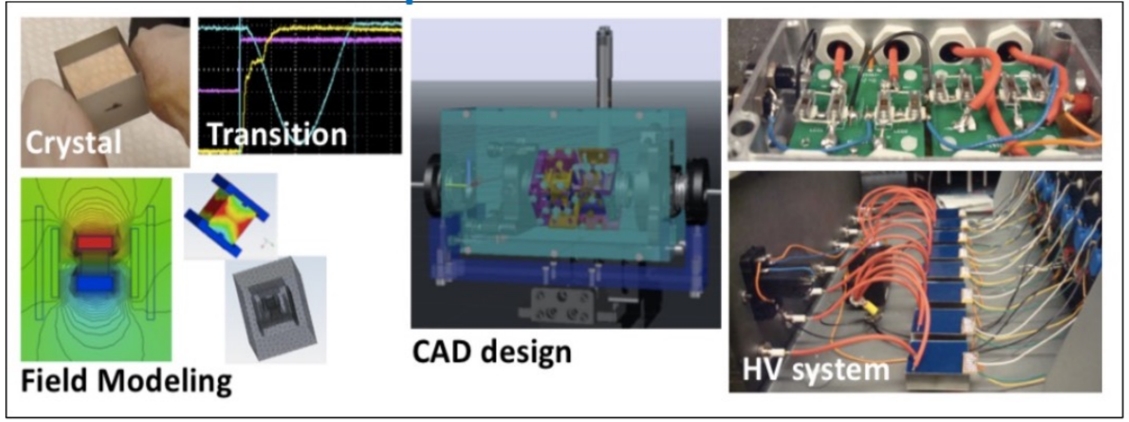
LBNL prototype receiver

Readout
- Existing receivers use Digital-to-Analog Convertor ⟶ Integrators, matching detector readout chain
- Option to use digital readout favored, still being explored

Technical and Operational Experience from 3rd Generation PV Experiments

Careful configuration of the polarized source kept beam difference averages very small during PREX-2

RTP Pockels Cell: Improved control of beam fluctuations

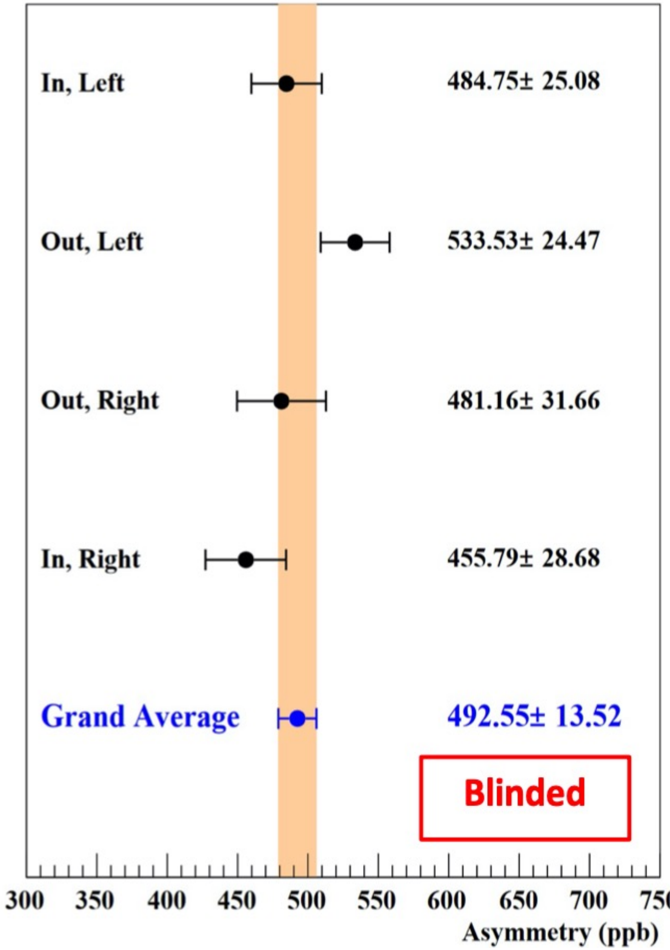


	MOLLER (344 PAC days)	MOLLER Run 1 (25 PAC days)	PREX-2 achieved (19 PAC days)
Intensity	<10 ppb	<30 ppb	25 ppb
Energy Asymmetry	<1.4 ppb	<7 ppb	0.8 ppb
Position Difference	<0.6 nm	<3 nrad	2.2 ppb
Angle Difference	<0.13 nrad	<0.6 nrad	0.6 nrad

Beam correction calibration, analysis and cross-checks

type	Mean(ppb)
X1	-22.33
Y1	22.5
E	-70.44
Y2	-2.84
X2	9.7
	1.27
	-0.01
	1.06
	0.26
	0.24
	0.18
	0.06
	-60.38

Total beam corrections:
(60.4 ± 2.5) ppb



Polarimetry in the Experimental Hall

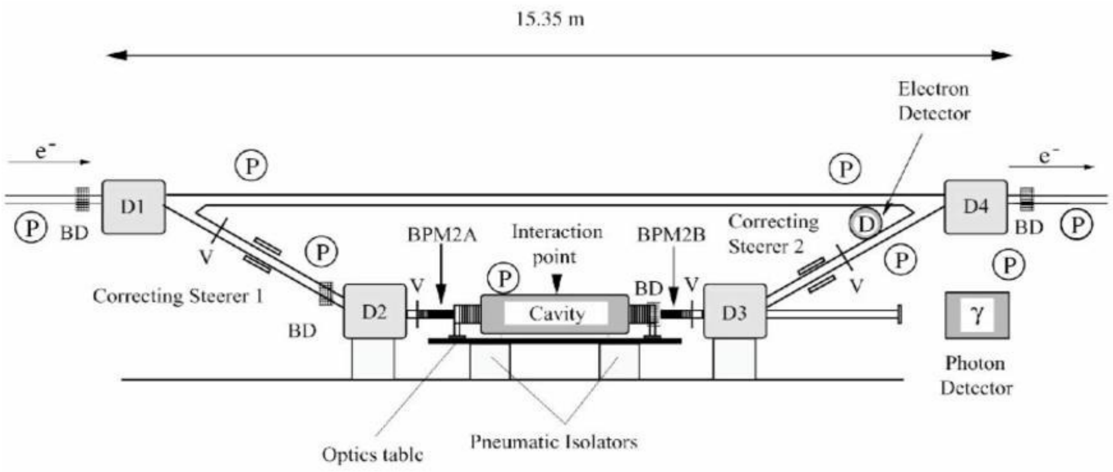
- Two independent measurements which can be cross checked.
- Continuous monitoring during production (protects against drifts, precession)
- Statistical power to facilitate cross normalization (get to systematic limit in about 1 hour)

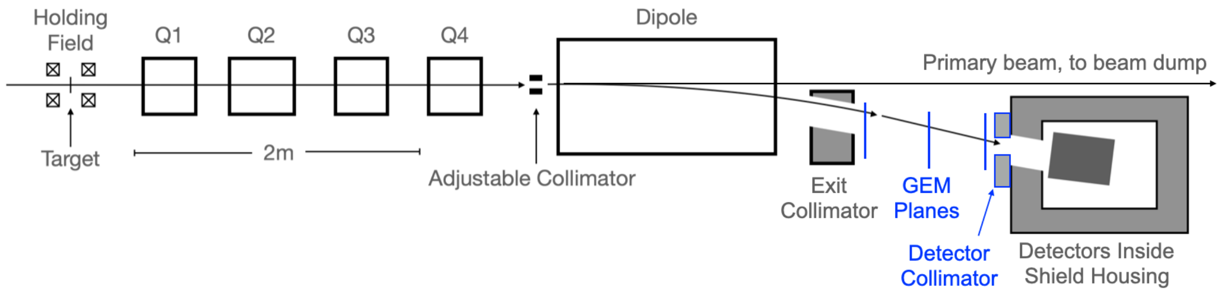
Compton Polarimetry

- Continuous, non-invasive measurement
- Utilized integrating technique with photon detector
- Polarimeter runs will be taken continuously alongside the main detector

Moller Polarimetry

- Low-current, invasive measurement
- 0.5% instrumental precision for Hall C polarimeter
- Polarimeter runs will be taken approximately every week





Meeting MOLLER beam differences

Kent Paschke

Source configuration

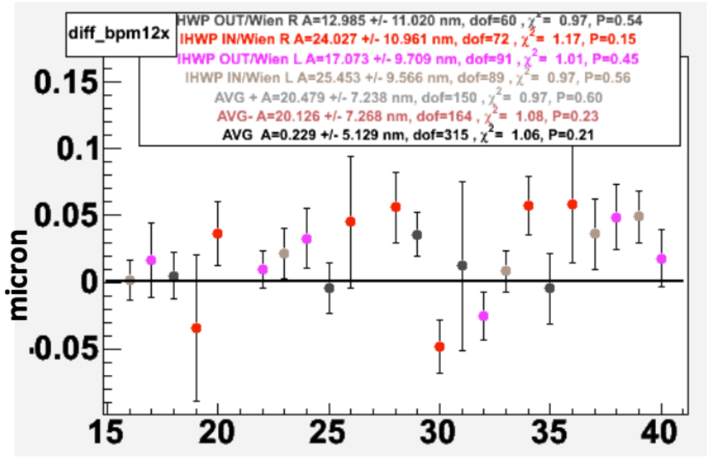
Adiabatic Damping

- Good beam match keeps variation small

Slow Reversals

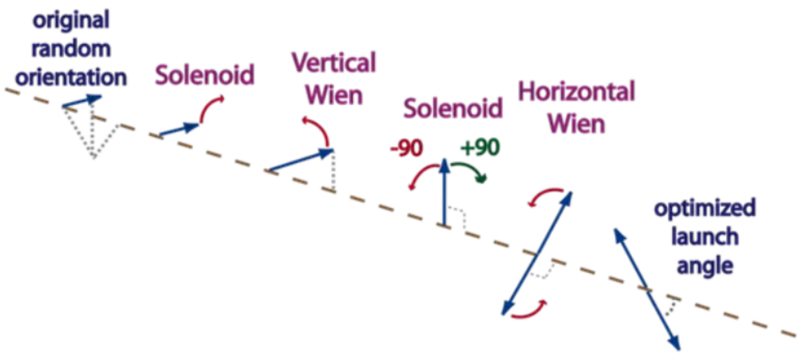
- Laser optics reversals (e.g. IHWP)
- Injector Spin Manipulation ("Wien" rotators)
- g-2 precession
- Net factor ~10 suppression of beam asymmetries

PREX-II showed ISM cancellation of position differences



Injector Spin Manipulation

- Solenoids + 2 Wien rotations
- ~80 reversals during run phase 2&3 (weekly)



g-2 rotation

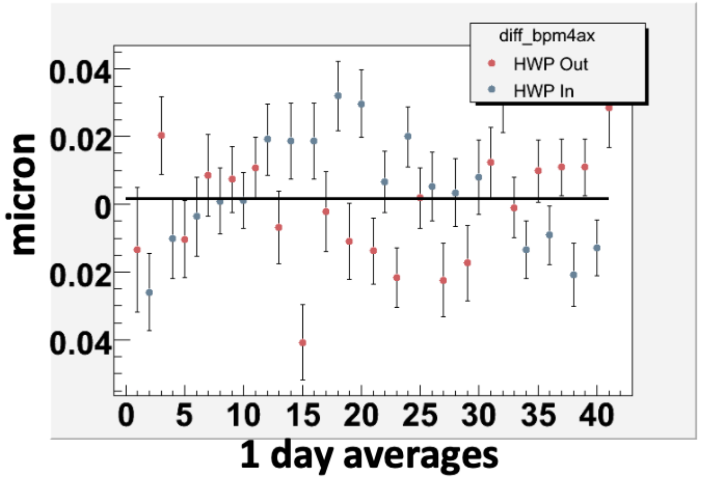
- Beam energy (ΔE~100 MeV)
- ~few reversals during run phases 2 and 3

Meeting MOLLER beam differences

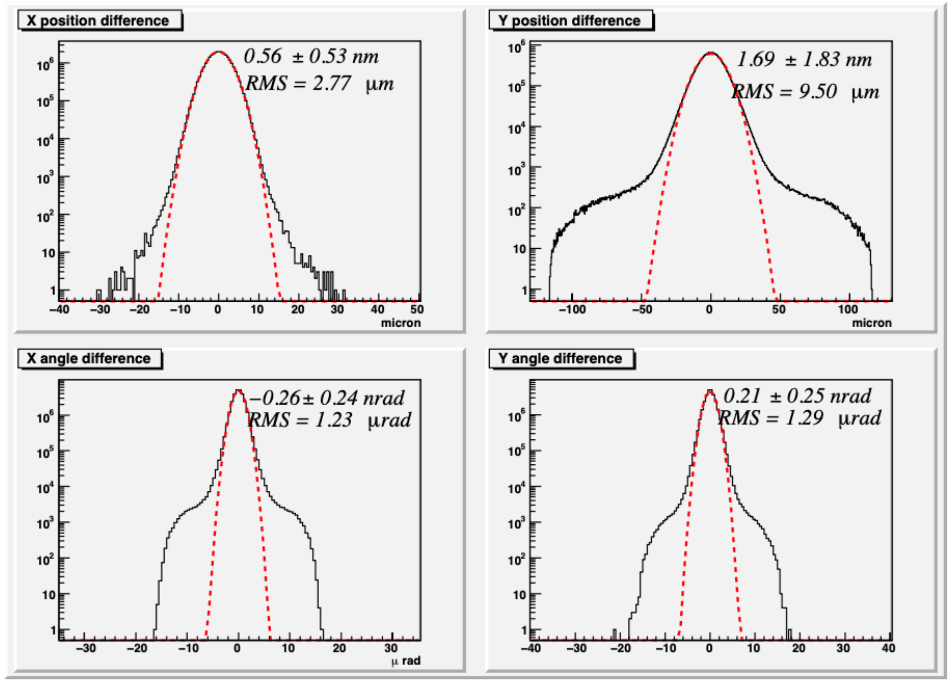
Kent Paschke

- Injector source laser — 20-50 nm in 5MeV injector
- e- beam delivery (adiabatic damping) — factor of 10-100 from adiabatic damping
- cancellation with "slow" reversals — factor of 2-10
- detector symmetry — Factor >10 in sensitivity
- correction calibration (beam modulation) — 10% precision

HAPPEX-II: position difference convergence



HAPPEX-II: Zero position differences



Factor of two in beam position asymmetry
would be a small hit on total error bar

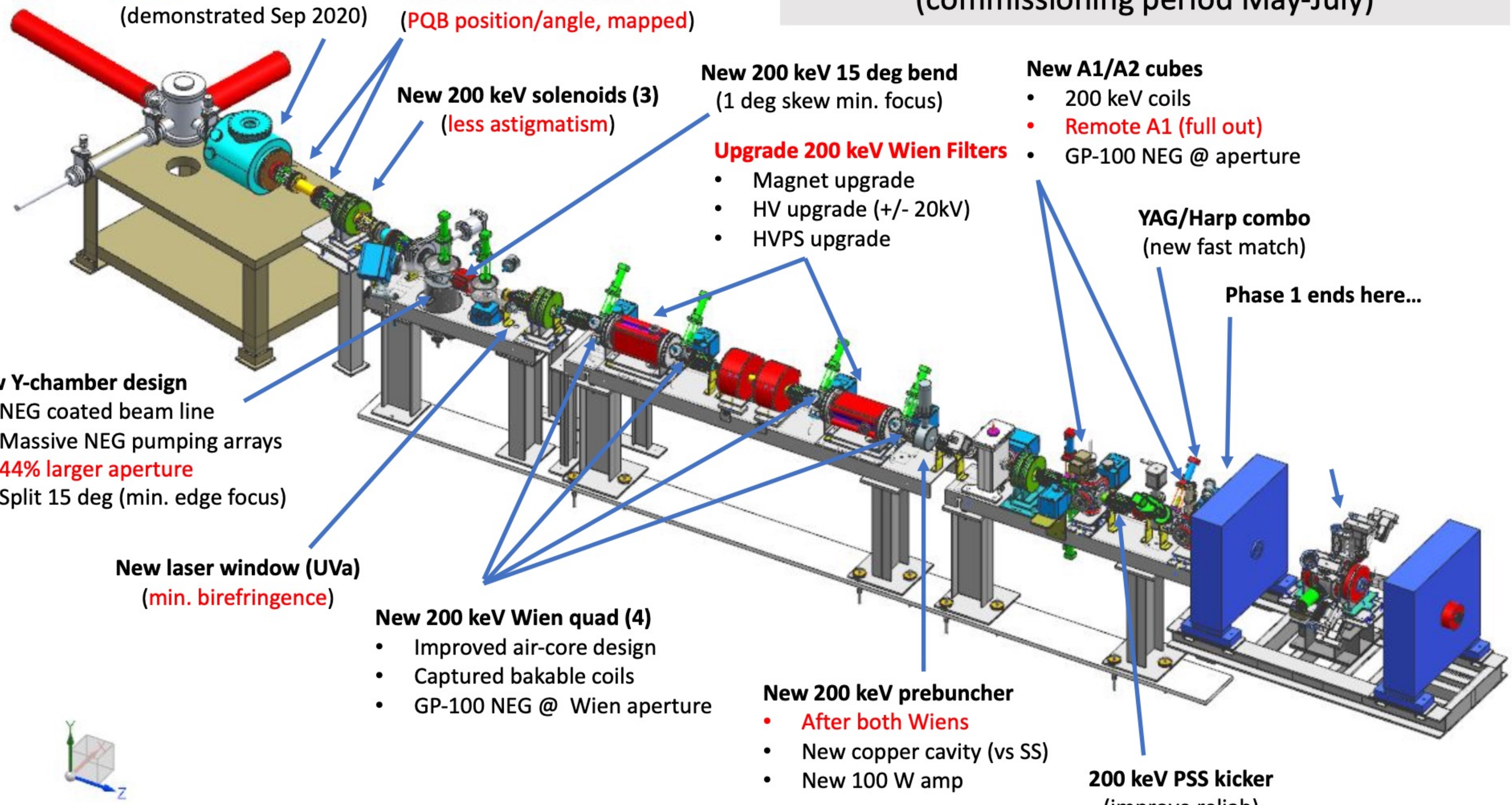
uncertainty		
statistical	2.1%	
systematic (total)	1.1%	
beam (position, angle, E)		0.4%
beam(intensity)		0.3%
beam (2nd moment)		0.4%

→ if doubled, total syst ~1.3%

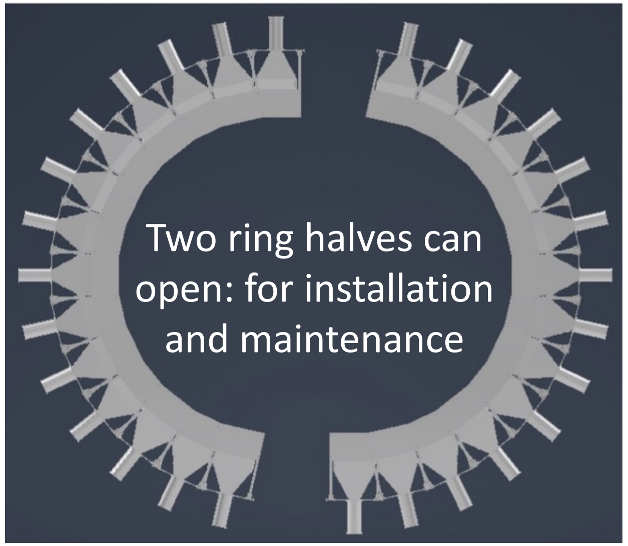
Phase 1 Injector Upgrade

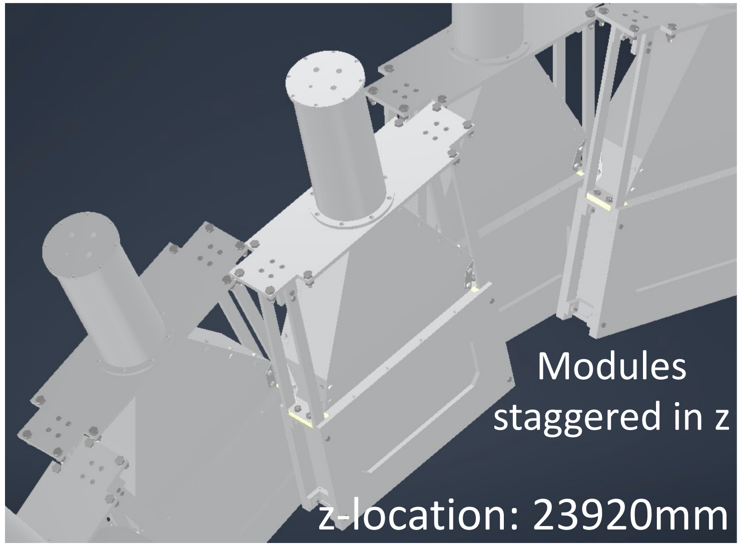
Kent Paschke

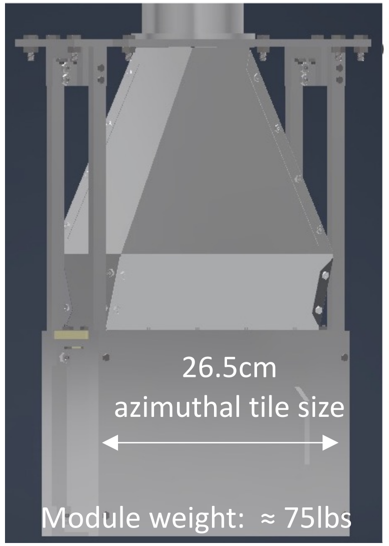
AIPINJ – Phase 1 Installation Completed May 2021
(commissioning period May-July)

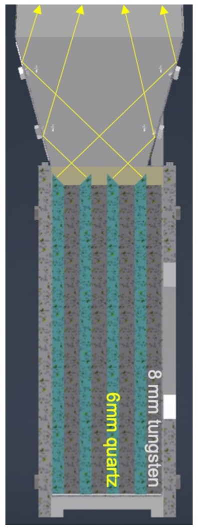


Shower-Max Detector

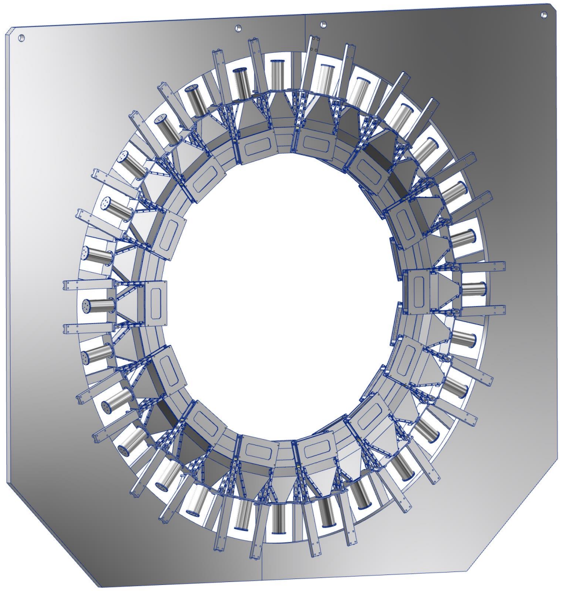




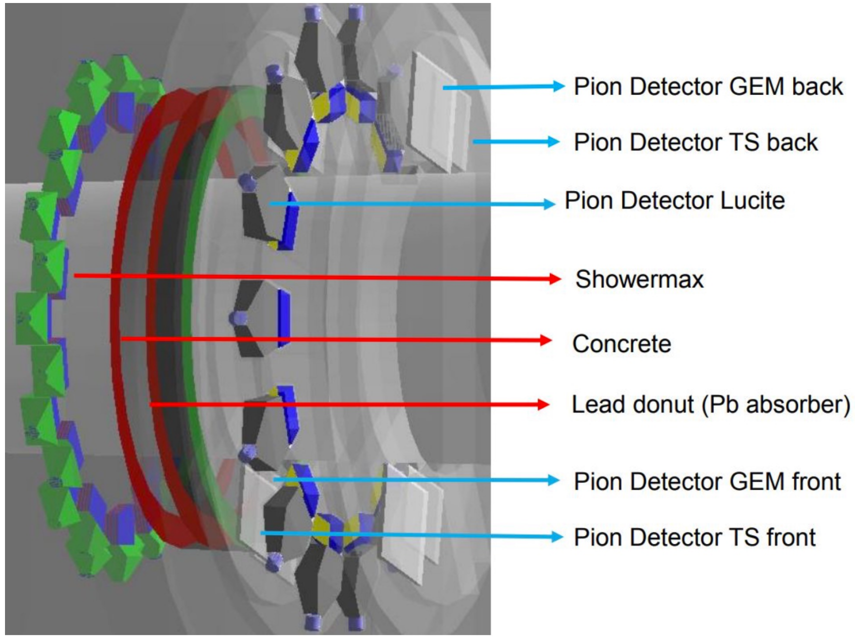


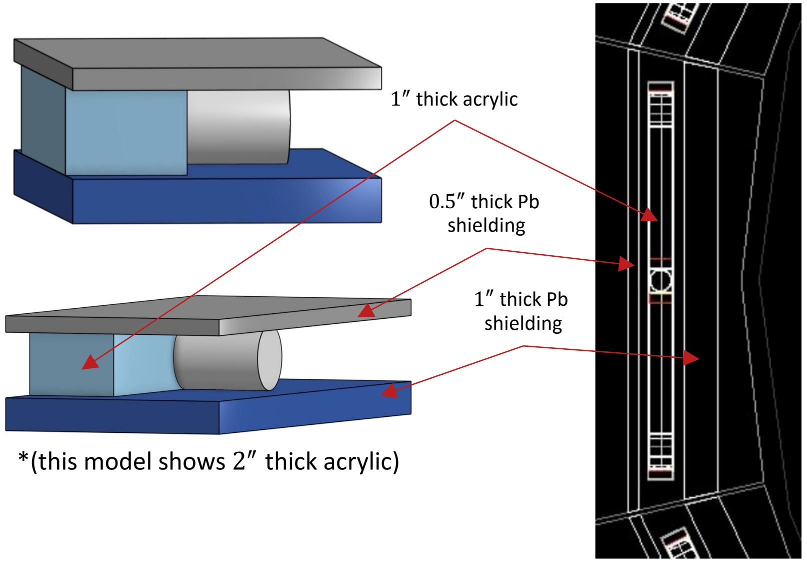


- Goal: second, independent measurement of Møller peak.
- Electromagnetic sampling calorimeter; layered quartz and tungsten
- 28 modules intercepting physics signal flux 1.7 m downstream of Ring 5.



Pion Detector





*(this model shows 2″ thick acrylic)

- Goal: Quantify pion background contamination in Møller signal asymmetries.
- 28 identical acrylic Cherenkov detectors, located downstream of the Shower-max detectors.
- Encased in Pb donut, downstream of shower-max detectors to suppress Møller electrons by > 10^3