

Status of the DarkLight Experiment

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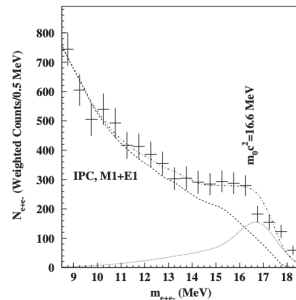
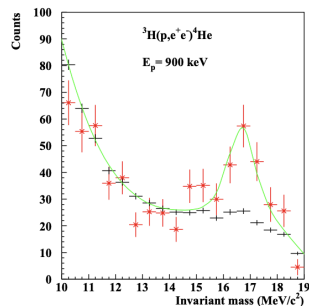


Stony Brook University

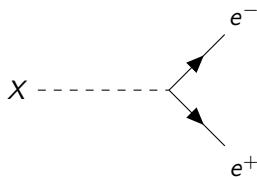
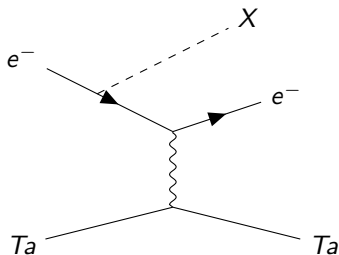


Anomalies: X17

- Excess in e^+e^- invariant mass spectra in ^8Be , ^4He , and ^{12}C
- Corresponds to a mass of $\approx 17 \text{ MeV}/c^2$
- Seen at different angles and different experimental setups
- Proto-phobic boson could explain excess
- Fine-tuned couplings



Dark Boson: Measurable in an Accelerator!



- Measure the produced $e^+ e^-$ spectrum and reconstruct invariant mass
- $m(e^+ + e^-) = m(X)$
- Need a high current, low energy electron accelerator
- Sensitive to leptonic-only coupling models!

DarkLight!



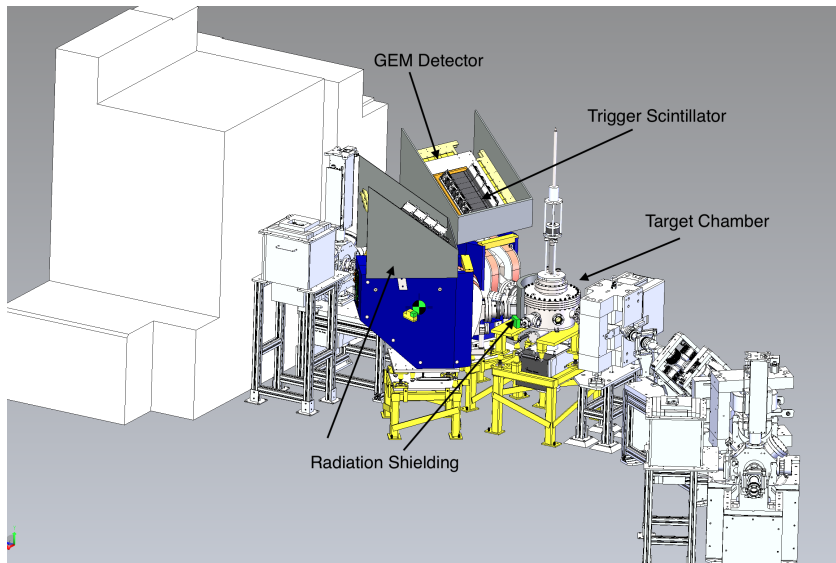
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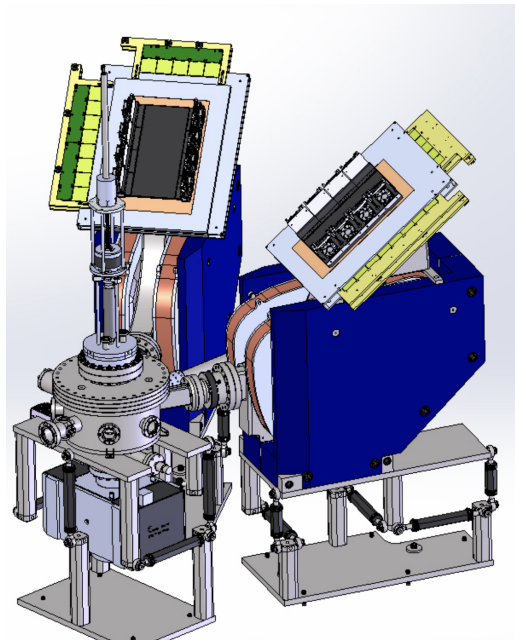


The DarkLight Experiment



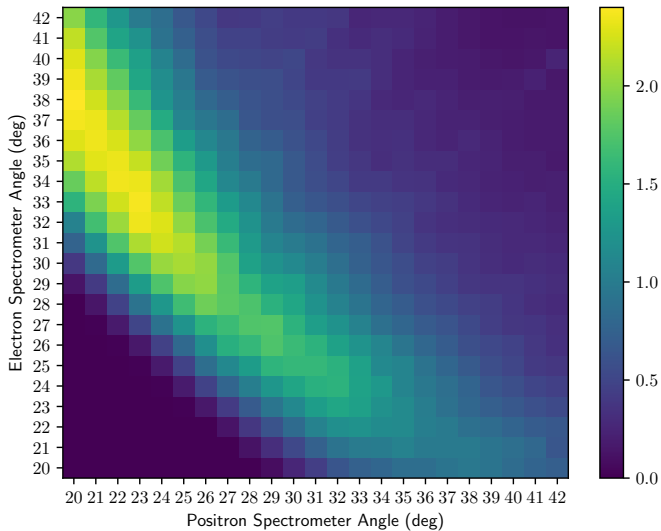
DarkLight Sketch

- 1 μm thick Ta foil target
- 1 μm C foil for calibration and parasitic measurements
- 300 μA beam, 30 MeV $\rightarrow$ 8 W heating
- Target ladder allows “empty space” configuration
- Installed at TRIUMF



Sensitivity

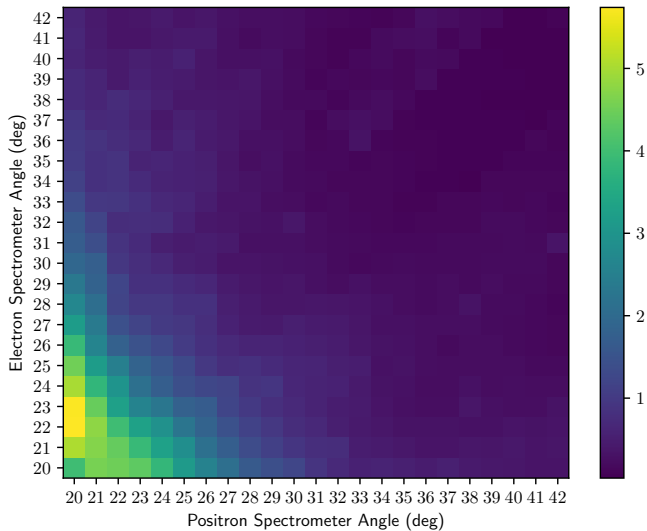
Sensitivities (1000 hrs run time), 13@30
 $\varepsilon = 0.001$



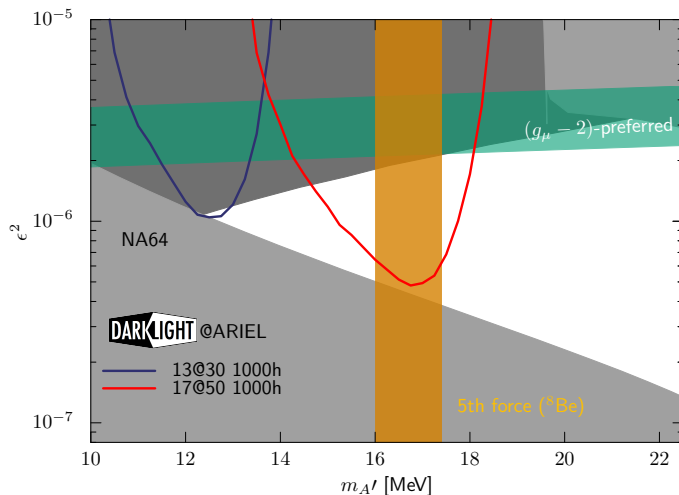
Sensitivity

Sensitivities (1000 hrs run time), 13@32

$$\varepsilon = 0.001$$



Projected Reach



If theory groups can bring $g_\mu - 2$ into better agreement with experiment, the $g_\mu - 2$ preferred band will move down in this figure.

A. Alarcon, *et al.*, <https://arxiv.org/abs/2609.05674>.

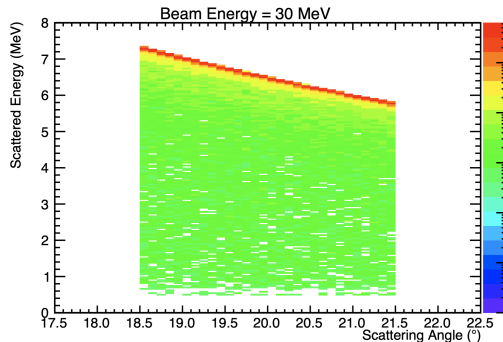
Commissioning and Calibrating

Lets get into some of the details of commissioning and calibrating the experiment!

The analysis here is all preliminary, and we are still working on low-level detector calibrations, cluster-finding, noise-suppression, background rejection, etc.

Stepping into the Light

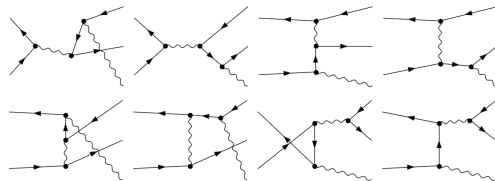
- Radiative Møller scattering tests event generators in regime where electron mass is not negligible
- Performed measurements with beam energies from 10 - 30 MeV
- Simulation work underway
- Also have results from radiative carbon scattering to analyze
- Low-level detector calibration analysis to be done first



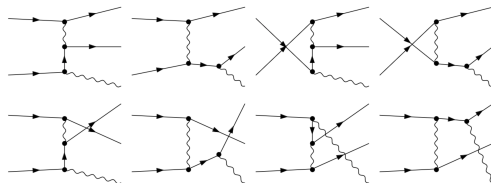
Simulation of Møller scattering at 30 MeV.

Stepping into the Light

- Additional measurements in addition to BSM search
- Commissioning data provides this measurement
- Møller scattering commonly used as luminosity measurement
- Radiative Møller scattering is easily measurable in checkout period
- Multiple beam energies on C target



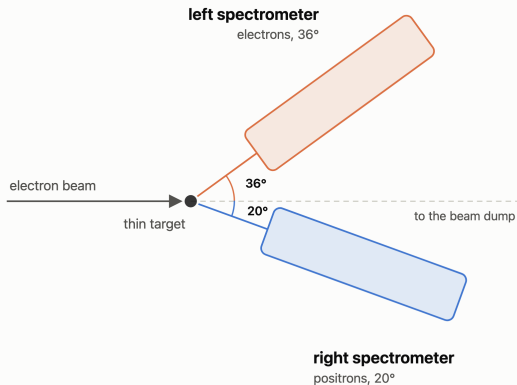
Radiative Bhabha Diagrams



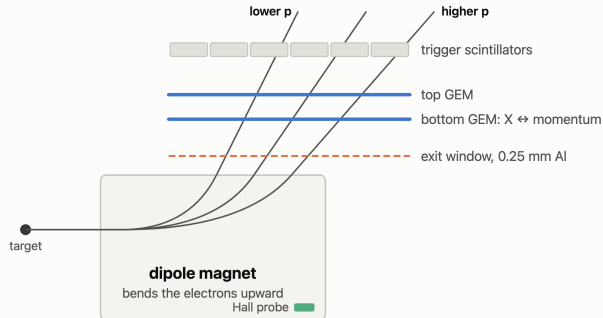
Radiative Møller Diagrams, [Phys. Rev. D 94, 033004](#)

To Orient Ourselves for Calibration

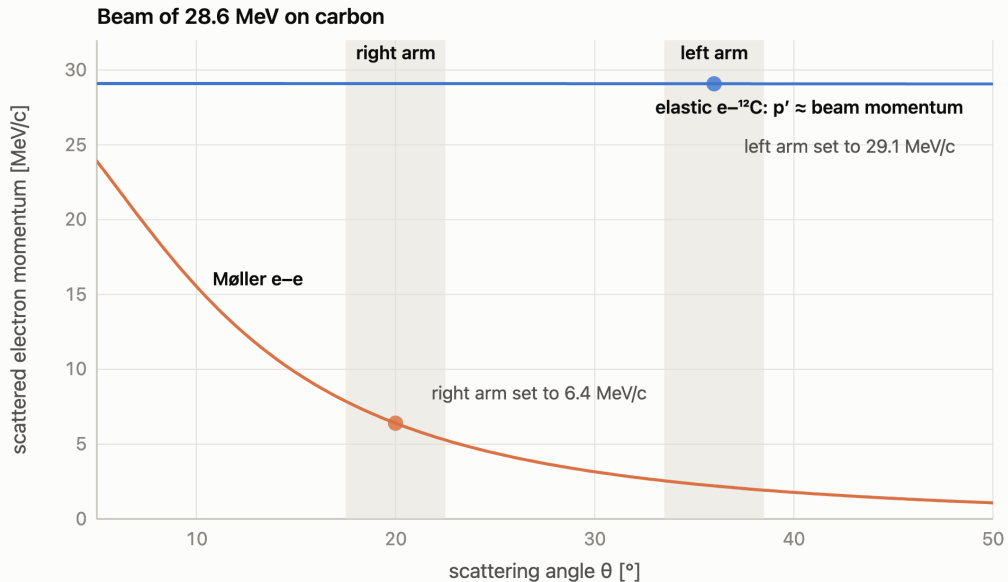
Seen from above



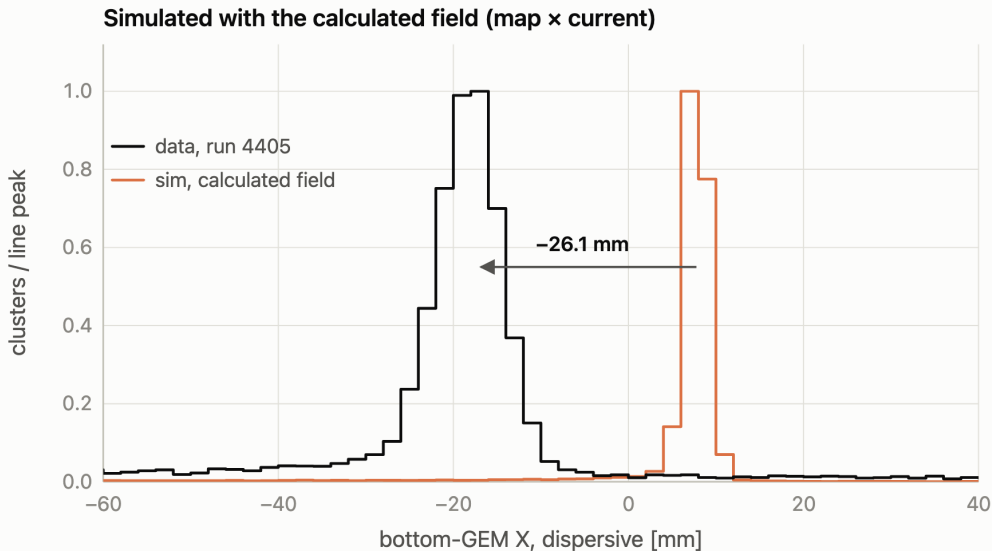
One spectrometer from the side



Calibration Processes

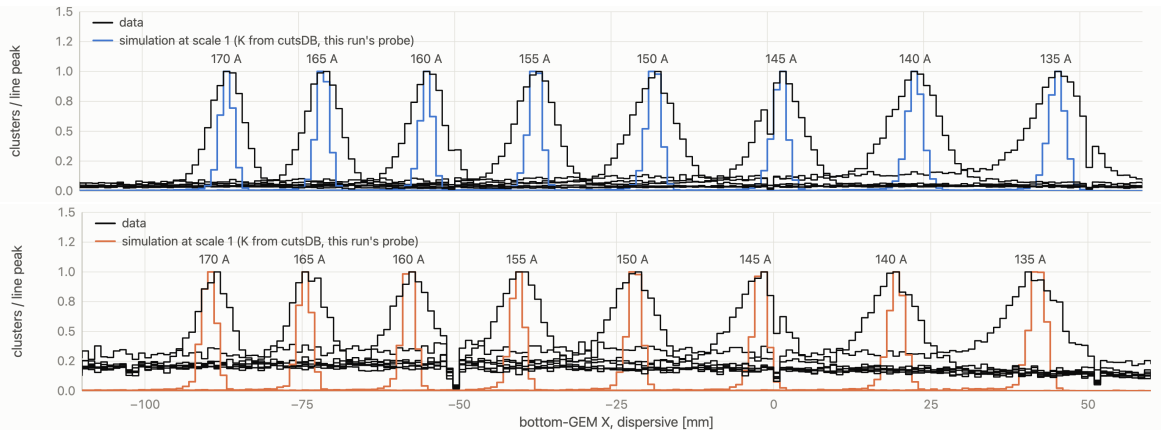


Elastic Line Calibration



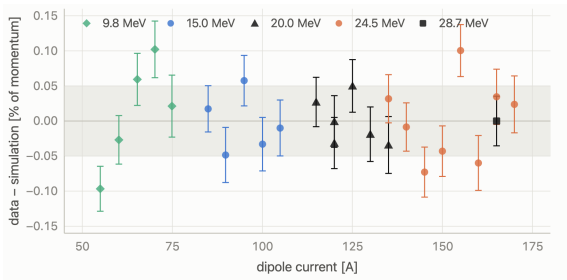
We found a 4 % disagreement in scale between measured and calculated field maps.

Elastic Line Calibration

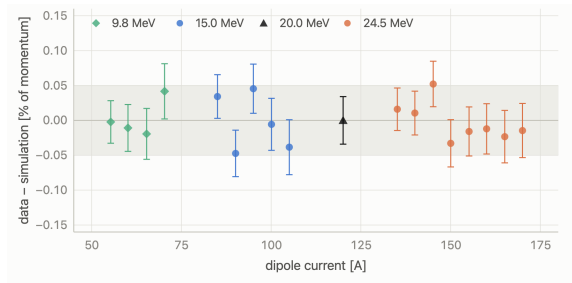


Feeding the measured hall probe field into the simulation captures run-by-run field variations.

Elastic Line Calibration



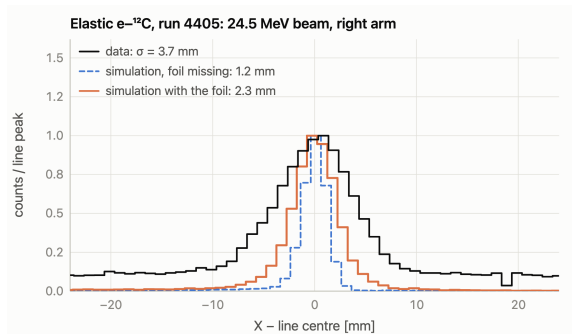
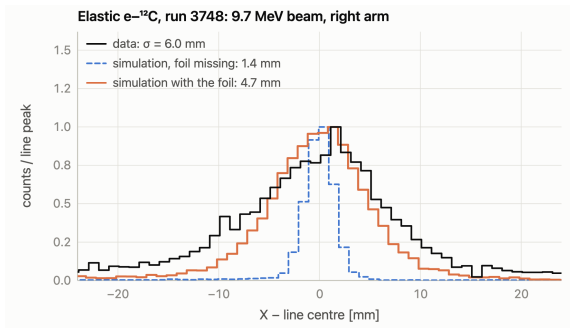
Left arm



Right arm

With probe calibration we see good agreement between simulation and data.

Multiple Scattering Matters!

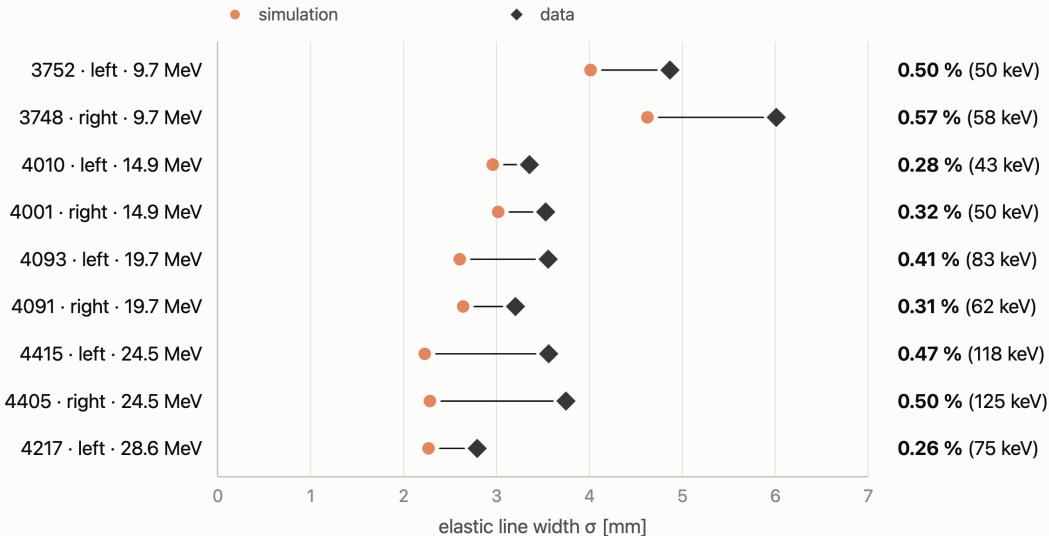


Multiple scattering dominates our line widths, but does not explain all of it. If the simulation is right, what remains is beam effects.

Beam Background

Line width: simulation (with all material) and data

beam momentum spread



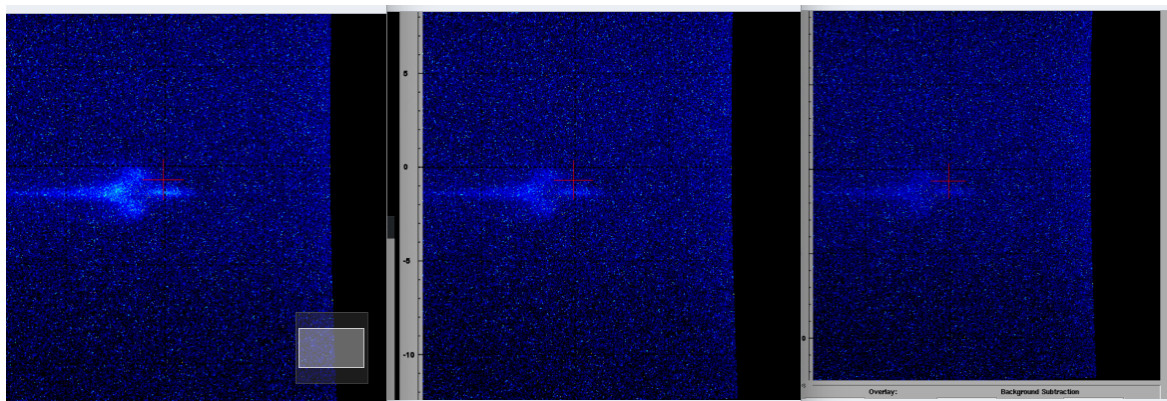
Estimated beam energy spread from elastic line data.

Commissioning and Calibrating

Not only are we commissioning and calibrating our experiment, but also the accelerator!

The unfortunate reality: We do not know our beam energy better than 1 %, and our beam current is completely unknown.

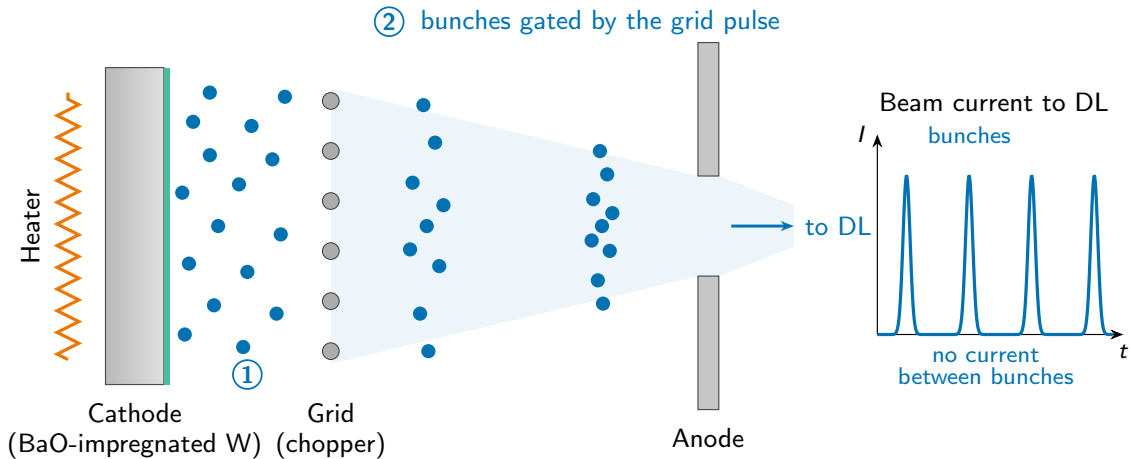
Beam Background



Left: Cathode set to 5.3 V. Middle: Cathode set to 5.2 V. Right: Cathode set to 5.0 V.

Viewscreen just upstream of the DarkLight scattering target.

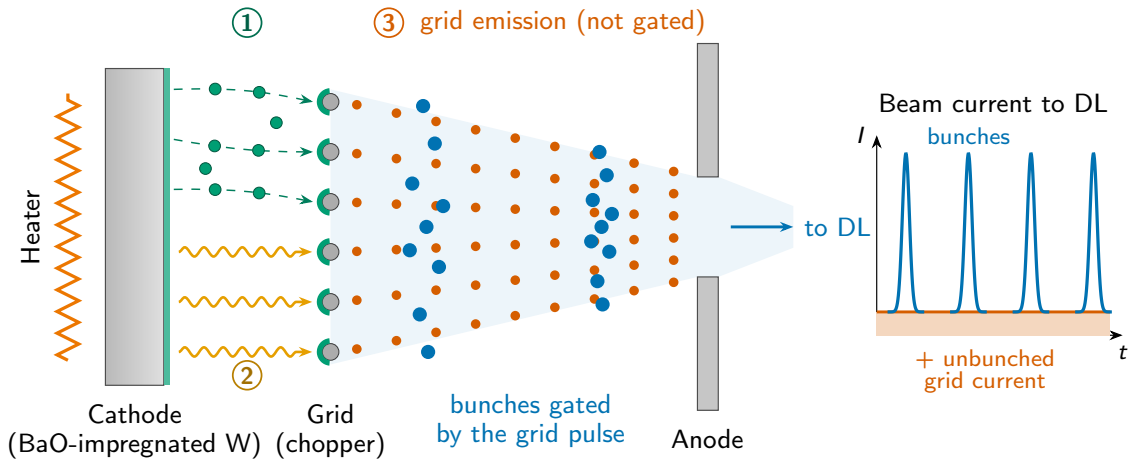
Beam



① Hot cathode emits electrons

② Grid pulse lets a bunch through

Beam Background

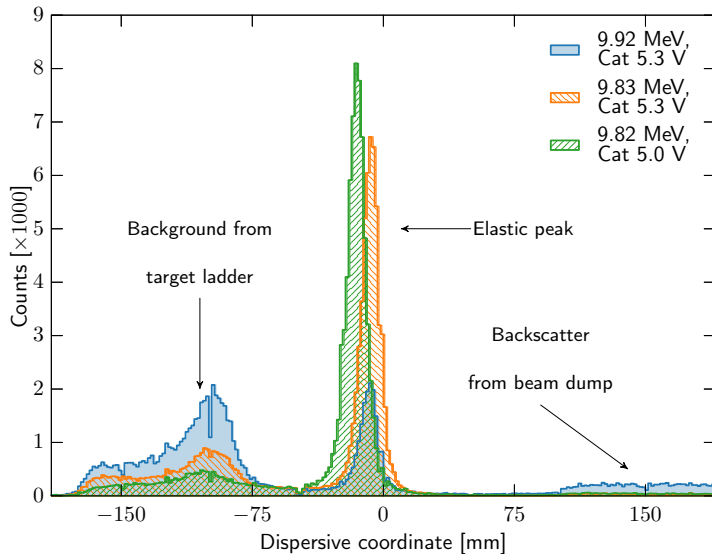


① BaO evaporates from cathode and deposits on the grid

② Heat from cathode, keeps grid hot

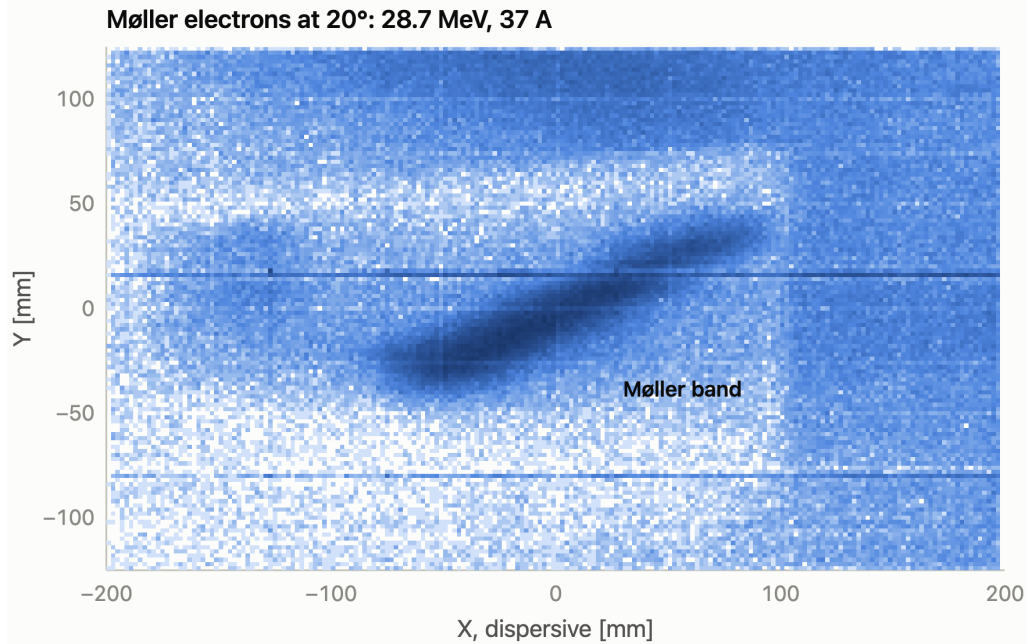
③ The BaO-coated grid emits electrons continuously

Beam Background

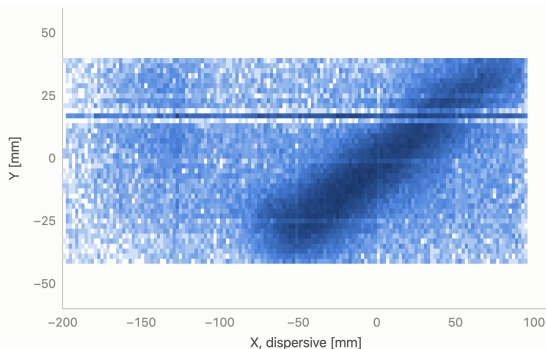


With beam tuning and close collaboration with the accelerator group, we can minimize but not eliminate background.

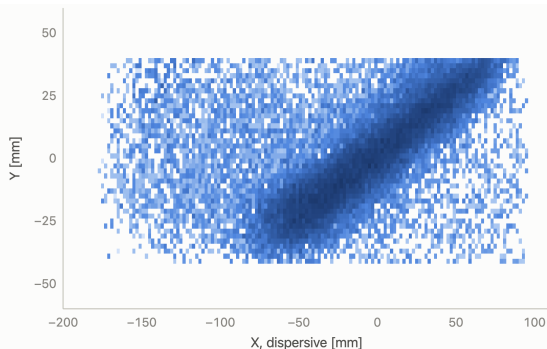
Møller Plus Background



Moving Toward Møller



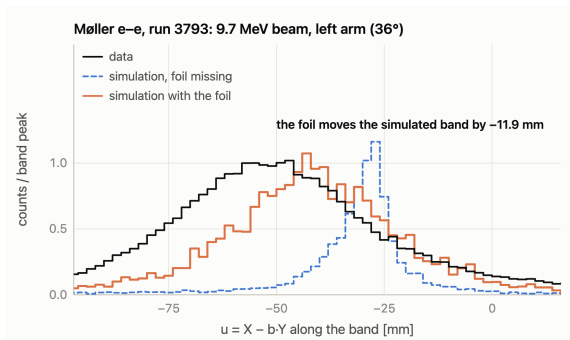
Left: data.



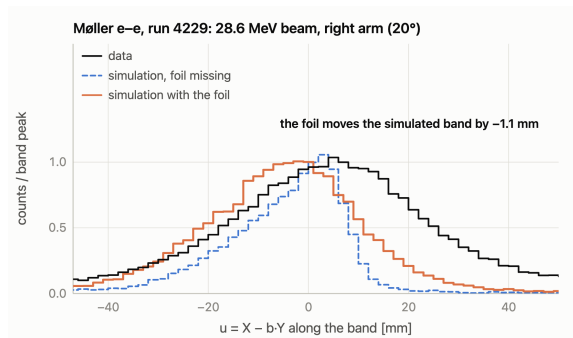
Right: simulation.

Right arm, ≈ 6 MeV Møller scattering, data and simulation with fiducial cuts applied and full multiple scattering effects.

Moving Toward Møller



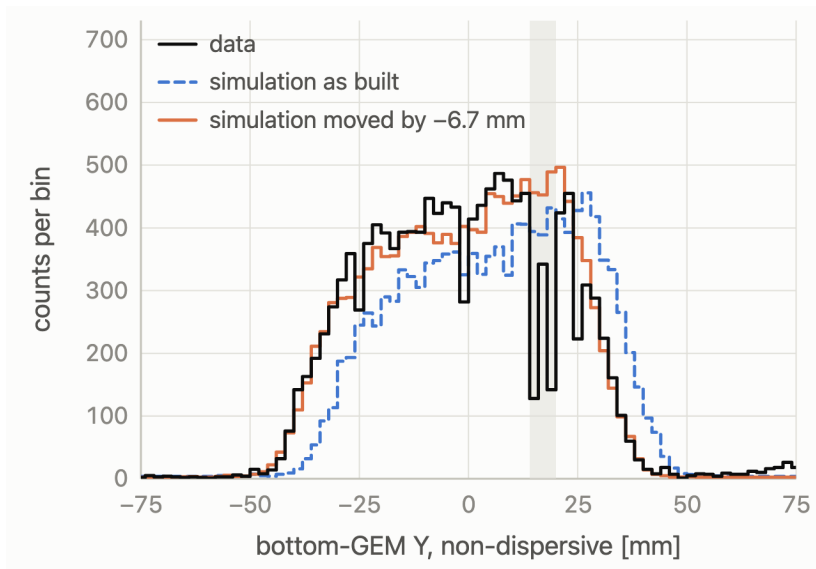
Left arm, ≈ 2 MeV Møller scattering.



Right arm, ≈ 6 MeV Møller scattering.

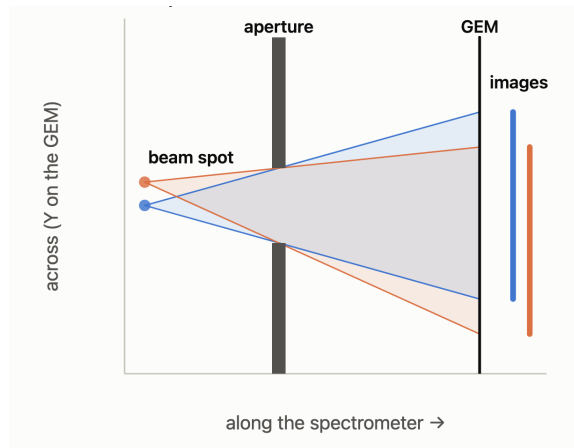
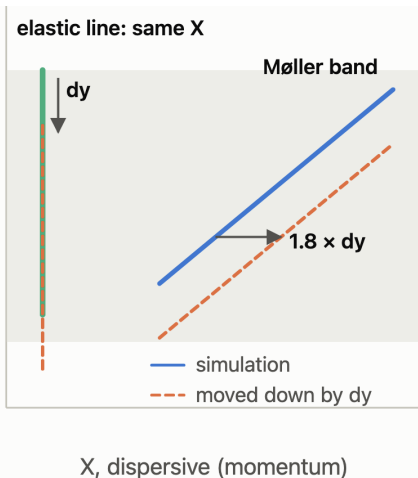
There are still offsets! What do we do?

Elastic Offsets



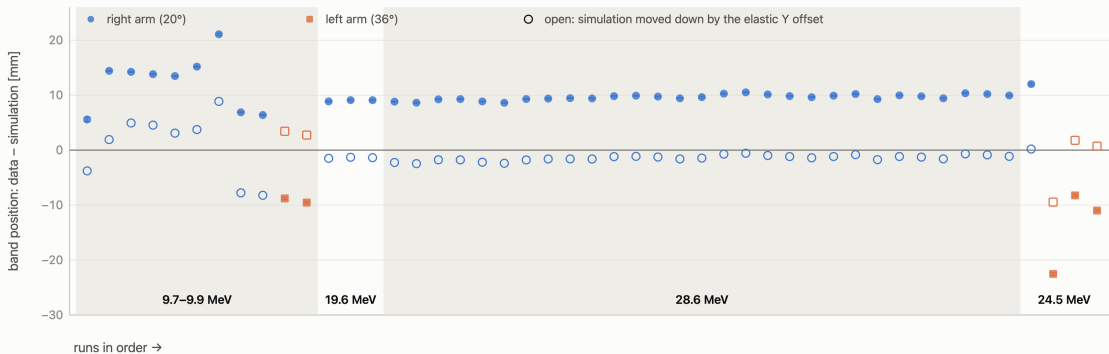
The elastic line non-dispersive coordinate y , does not match in sim and data. Fit this and apply to Møller. Gray band denotes dead region in data.

A Pinhole



The spectrometer behaves like a pinhole camera, even though the width is set by the chamber, a beam offset can move y . Opposite for each spectrometer.

Moving Toward Møller



Applying the elastic line shifts bring Møller simulations into better agreement with data.

So What Can We Measure?

	target electrons per carbon nucleus	luminosity beam x target	cross section the physics we test	acceptance from the simulation	efficiency not simulated
$N_{\text{el}} =$		$L \cdot$	$\sigma_{\text{el}} \cdot$	$A_{\text{el}} \cdot$	ϵ_{el}
$N_{\text{M}} =$	$6 \cdot$	$L \cdot$	$\sigma_{\text{M}} \cdot$	$A_{\text{M}} \cdot$	ϵ_{M}

1 data: divide the two counts

$$R_{\text{data}} = N_{\text{M}} / N_{\text{el}} = 6 \cdot \sigma_{\text{M}} A_{\text{M}} \epsilon_{\text{M}} / (\sigma_{\text{el}} A_{\text{el}} \epsilon_{\text{el}})$$

L cancels: no beam current, target thickness or dead time

2 simulation: the same ratio

$$R_{\text{sim}} = 6 \cdot \sigma_{\text{M}} A_{\text{M}} / (\sigma_{\text{el}} A_{\text{el}})$$

generators and Geant4 give $\sigma \cdot A$ for each arm; $\epsilon = 1$

3 compare: the double ratio D

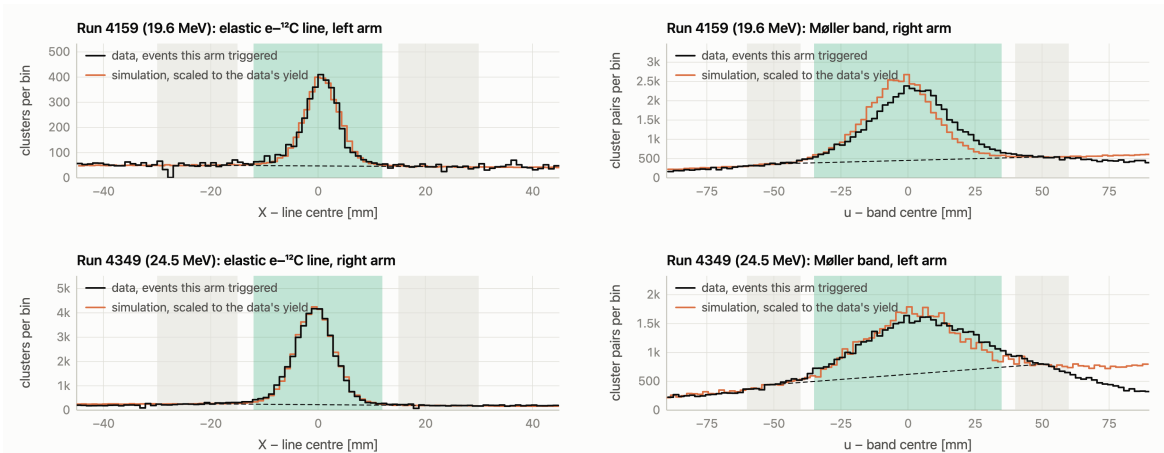
$$D = R_{\text{data}} / R_{\text{sim}}$$

$$= \epsilon_{\text{M}} / \epsilon_{\text{el}} \text{ if the simulated } \sigma \cdot A \text{ are right}$$

$D = 1$: cross sections, acceptances and efficiencies all understood

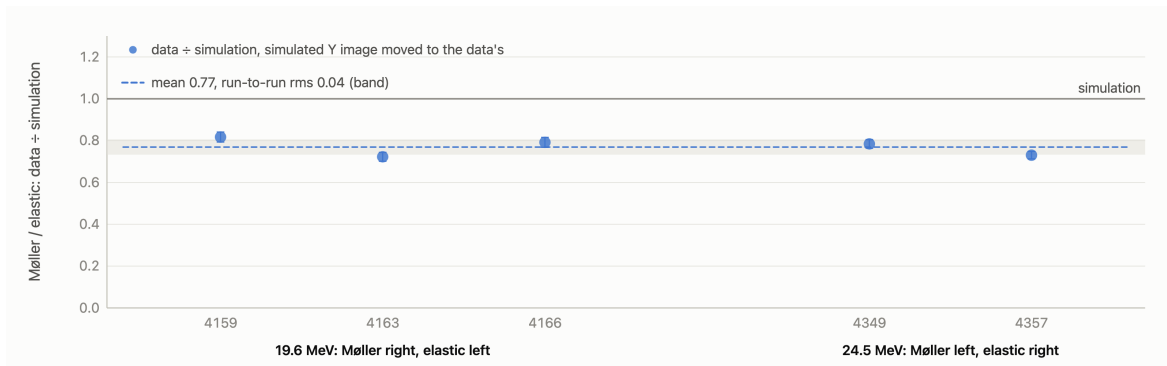
We can measure the ratio of Møller to elastic scattering, which needs no luminosity.

Beginning to Match Simulation and Data for an Extraction



Gray bands denote the sidebands, green bands are the signal regions. The simulation is scaled to match the data in the signal region.

Beginning to Match Simulation and Data for an Extraction



A very preliminary ratio. Given the challenges associated with data taking we are making good progress, but clearly more work to be done.

Summary

- PP-EEC approved for 1300 h of beamtime for DarkLight
- Progress on multiple fronts in the past year
 - Finished experiment commissioning!
 - Analyzing radiative Møller and carbon scattering data
 - Planning on requesting additional commissioning beam time before moving to 1000 h production data taking
- Energy upgrade work in progress, plan to run 50 MeV in 2028/2029