Radiative Møller Scattering with DarkLight

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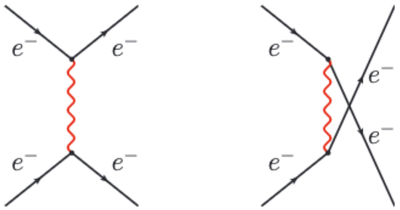
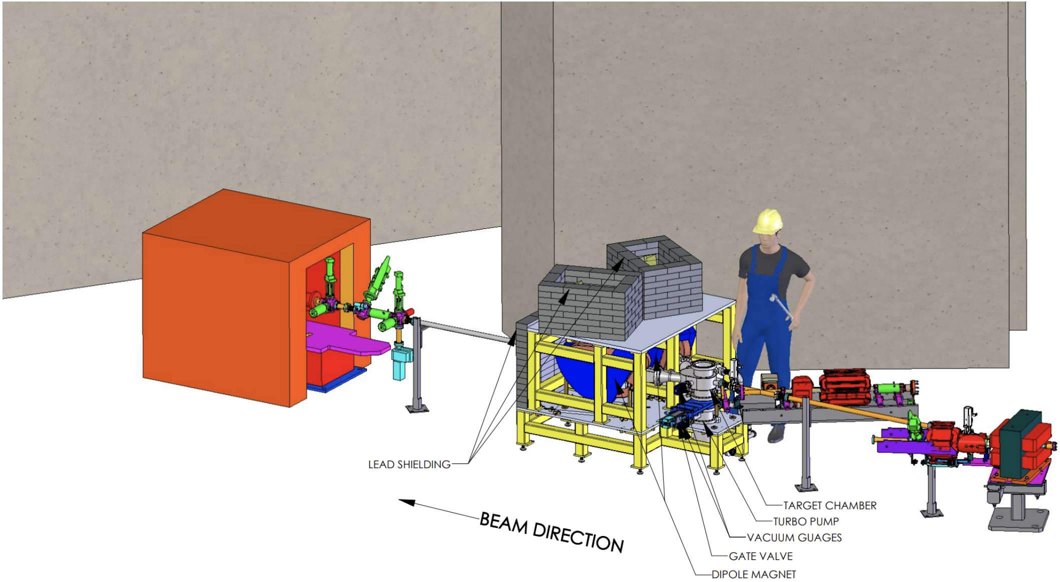
Møller Scattering

- Møller scattering is background or luminosity measurement in many experiments
- Radiative Møller scattering not measured to high precision
- Test size and validity of radiative corrections



Lowest order Møller scattering diagrams

DarkLight at ARIEL



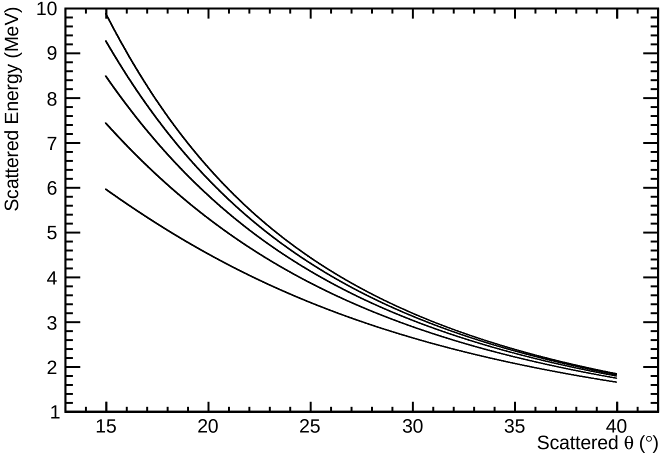
DarkLight at ARIEL

- DarkLight Experiment at ARIEL uniquely suited to test radiative Møller scattering
- Two fixed angle spectrometers: 20° and 36°
- 20% momentum acceptance
- 1 μm C target, 10 μA current
- Variable beam energy (30 - 10 MeV)
- Have the Epstein-Milner $ee \to ee\gamma$ event generator, Phys. Rev. D 94, 033004

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{2s}\left\{\frac{1}{t^2}(s^2 + u^2 - 8m^2(s+u) + 24m^2) + \frac{1}{u^2}(s^2 + t^2 - 8m^2(s+t) + 24m^4) + \frac{1}{tu}(s^2 - 8m^2 s + 12m^4)\right\}$$

Note: mass not negligible for these energies

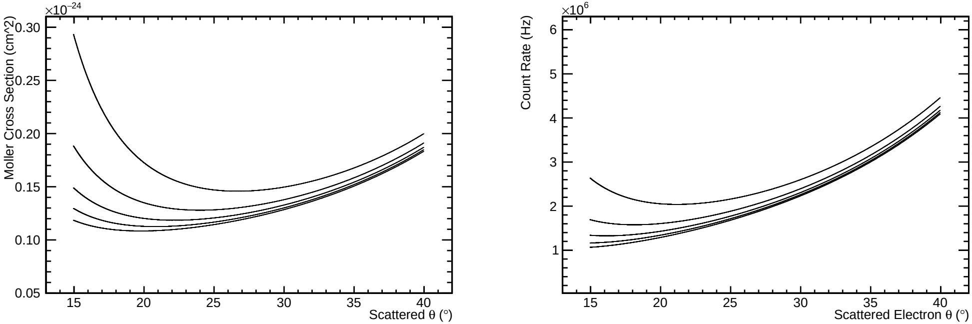
Kinematics



Energy vs scattering angle, 30 MeV to 10 MeV from top to bottom in steps of 5 MeV

Energy too low for 36° spectrometer, but could be used for luminosity measurement

Cross Section and Count Rate



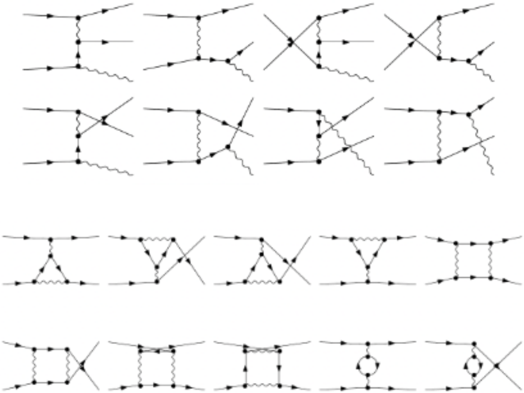
Left: Cross Section as a function of scattering angle. **Right:** Count rate, folding in acceptance, as a function of scattering angle. Lowest energy corresponds to highest rate.

Timing resolution determined by GEM detectors. Multi-frame readout allows us to distinguish events 100 ns apart, leading to 10 MHz maximum rate.
Using Ta here would increase rate by $\approx$100x.

Background Processes

- Elastic carbon scattering is at ≈30 MeV
  - Initial indication is $d\sigma/d\Omega$ is ≈Møller
  - Would need to be far down in radiative tail to not worry about background, not sure where we sit
  - Not sure about the background rate from elastics that make it into the spectrometer
- Carbon has several relevant low lying nuclear states
  - 4.4 MeV - 30 MeV
  - Need to check cross sections of these states, but lower than elastics
- Quasi-elastic scattering needs to be studied
  - Written simple Geant4 MC to test the energy distribution of these states

Radiative Events



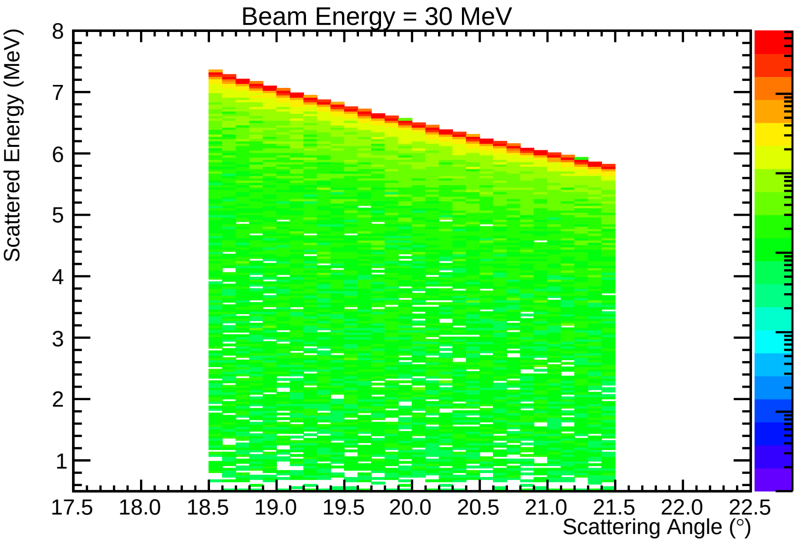
Diagrams courtesy of Charles Epstein

Slide courtesy of Douglas Hasell

Generated Events

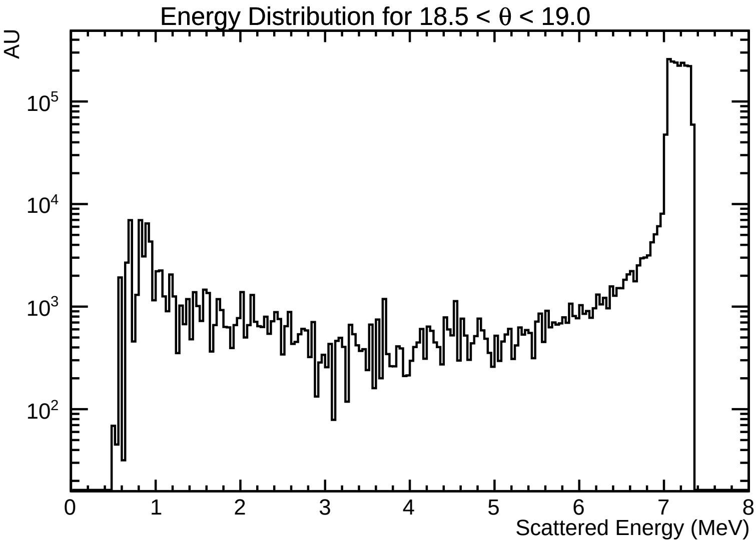
- Run EM generator for 1 M events
- Set generator to have 3/4 events radiate
- Minimum photon energy is 1E-4 MeV
- $E_{\mathrm{Beam}} = 30$ MeV
- Accept events that end up within $18.5^\circ < \theta < 21.5^\circ$
- "Default" settings

Angular Distribution



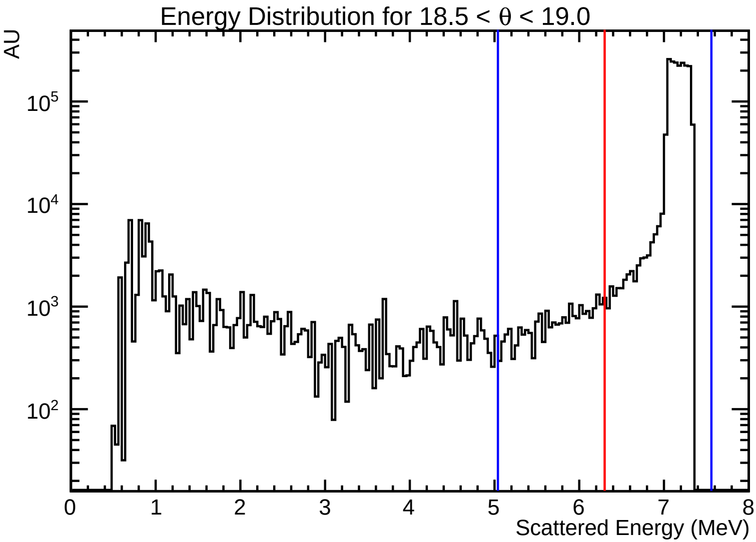
Assuming nominal ±1.5 degree nominal θ acceptance

Energy Distribution



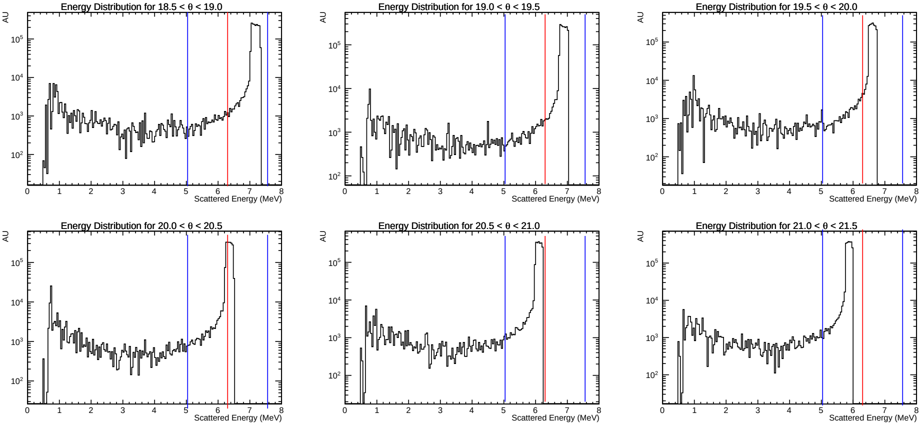
Assume we have 0.5° bins.

Energy Distribution



Red line indicates central momentum, blue lines indicate acceptance.

Energy Distribution



Six bins for each energy with a 30 MeV beam.

Questions

- Can we have our thin carbon target and low current?
- Want two GEMs to form tracks, will they be instrumented together?
- What is p_{min} that will make it into our spectrometers?
- Can we use the other spectrometer for something if no GEMs?
- Will we have trigger scintillators for both spectrometers?

Outlook

- At each momenta we can do six measurements assuming 0.5° binning
- At lower momenta, picture does not change from what I've shown except the energy range becomes compressed
- Depending on p_{min}, maybe able to reduce p_{central} and do several measurements
- "Nominal" measurement is 30 spectra, six bins $\times$ five energies
- Lower current than 10 μA is great!