Spectrometer Design

CEBAF Injector Experiment

Meeting at JLab

Wednesday April 11, 2018

Spectrometer Design

- Radiative Moller Experiment at MIT High Voltage Research Lab
- CEBAF Spectrometer Design Specifications
- Current Status of Magnet Design

Darklight Experiment Simulation

- Simulation showed significant Møller rates (red)
- Needed to understand radiative Møllers to have meaningful Darklight measurement

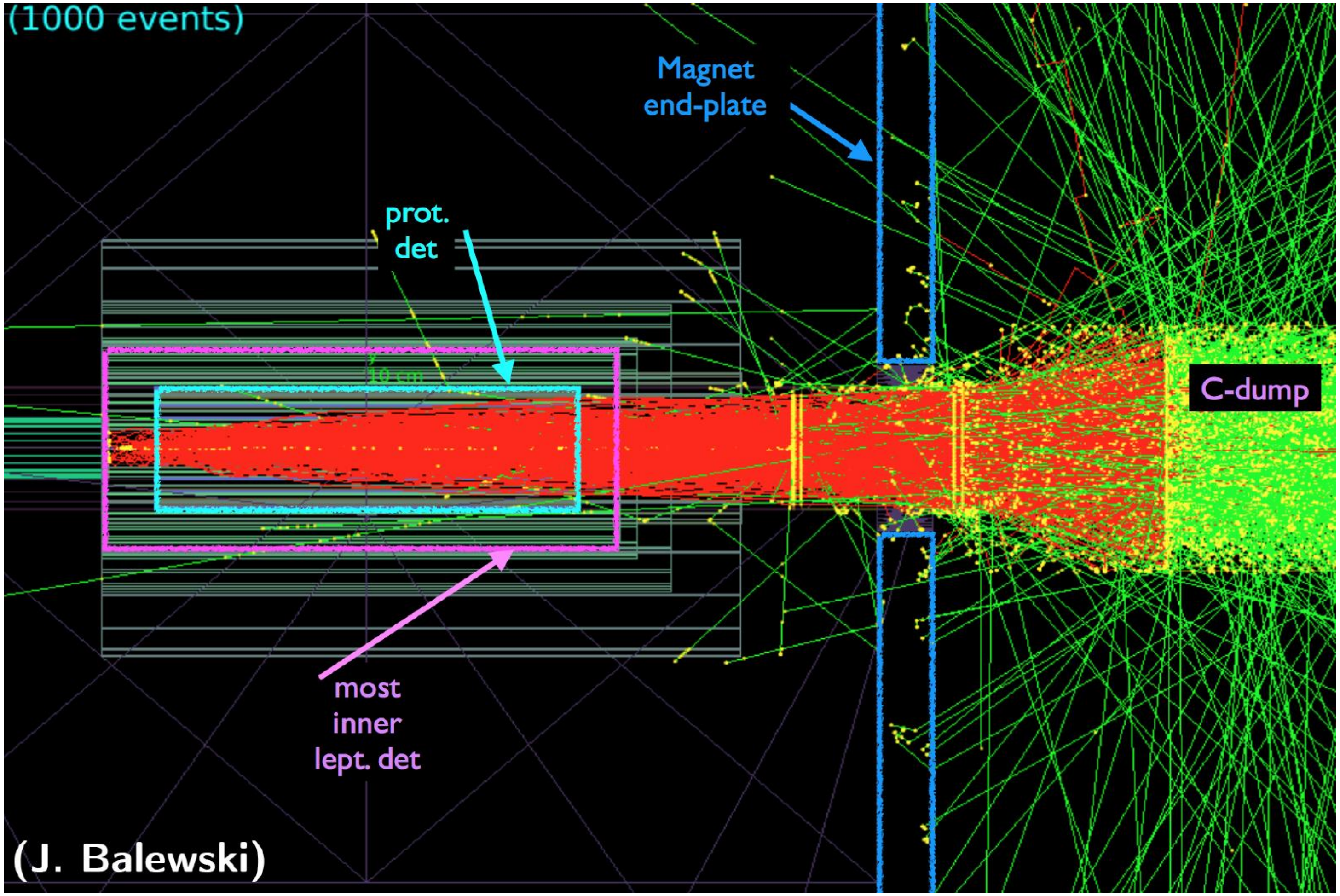

Image from Richard Milner

Radiative Møller Correction Calculations

PHYSICAL REVIEW D **94**, 033004 (2016)

QED radiative corrections to low-energy Møller and Bhabha scattering

Charles S. Epstein* and Richard G. Milner

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(Received 25 February 2016; published 10 August 2016)

We present a treatment of the next-to-leading-order radiative corrections to unpolarized Møller and Bhabha scattering without resorting to ultrarelativistic approximations. We extend existing soft-photon radiative corrections with new hard-photon bremsstrahlung calculations so that the effect of photon emission is taken into account for any photon energy. This formulation is intended for application in the OLYMPUS experiment and the upcoming DarkLight experiment but is applicable to a broad range of experiments at energies where QED is a sufficient description.

DOI: 10.1103/PhysRevD.94.033004

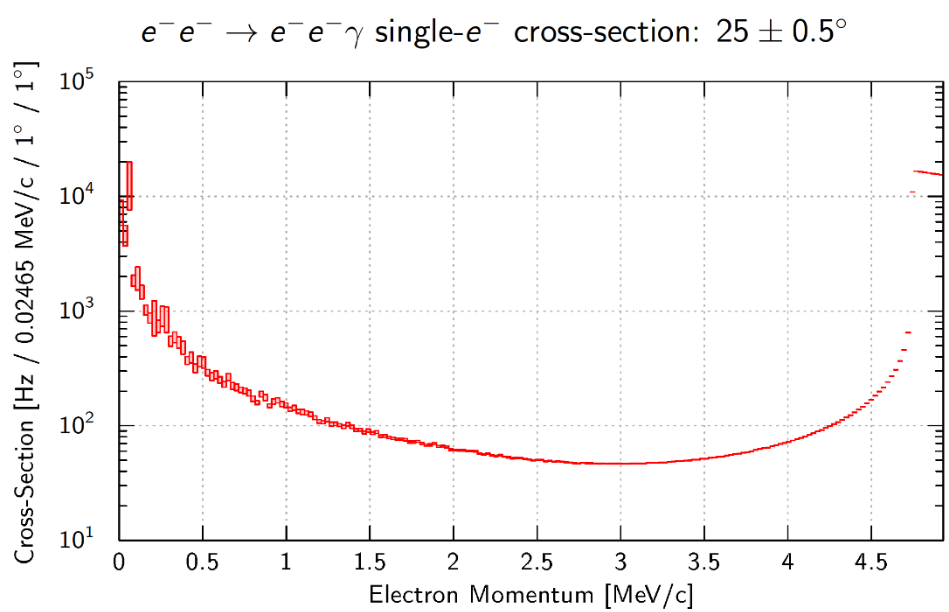
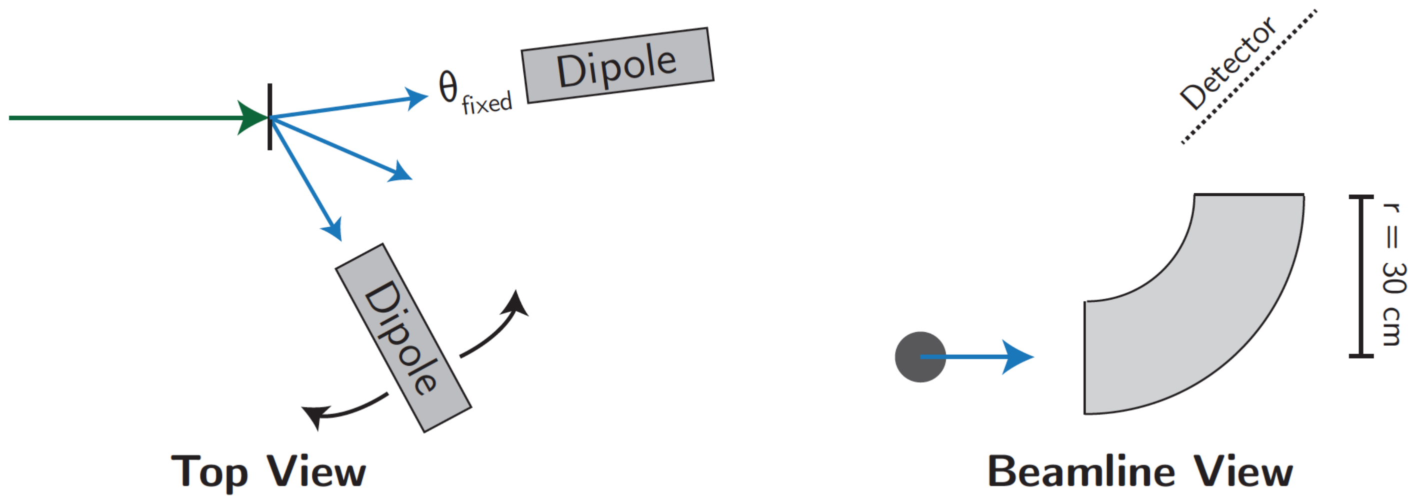


Image from Richard Milner

Initial Experimental Configuration for Radiative Moller Measurements

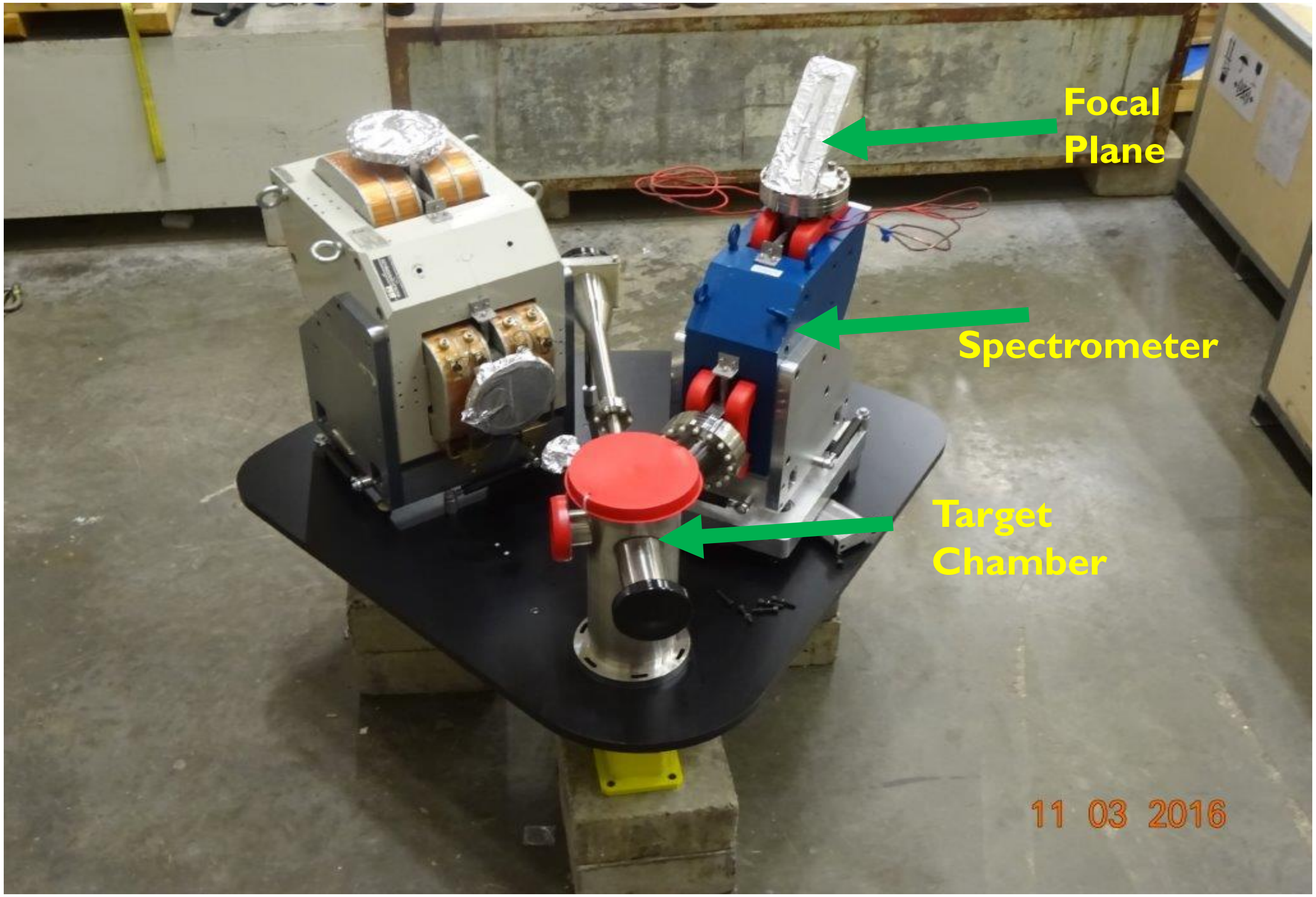
Two Spectrometers



- Pointlike target: 5μm diamond-like carbon foil
- 90° bending dipole magnet, scintillating fiber detector
- Map out electron energy spectrum at various θ
- Relative luminosity monitor: elastic e-C scattering

Image from Richard Milner

Experimental Apparatus



Designed and constructed at MIT-Bates

Image from Richard Milner

Installation MIT High Voltage Research Laboratory with 2.5 MeV beam

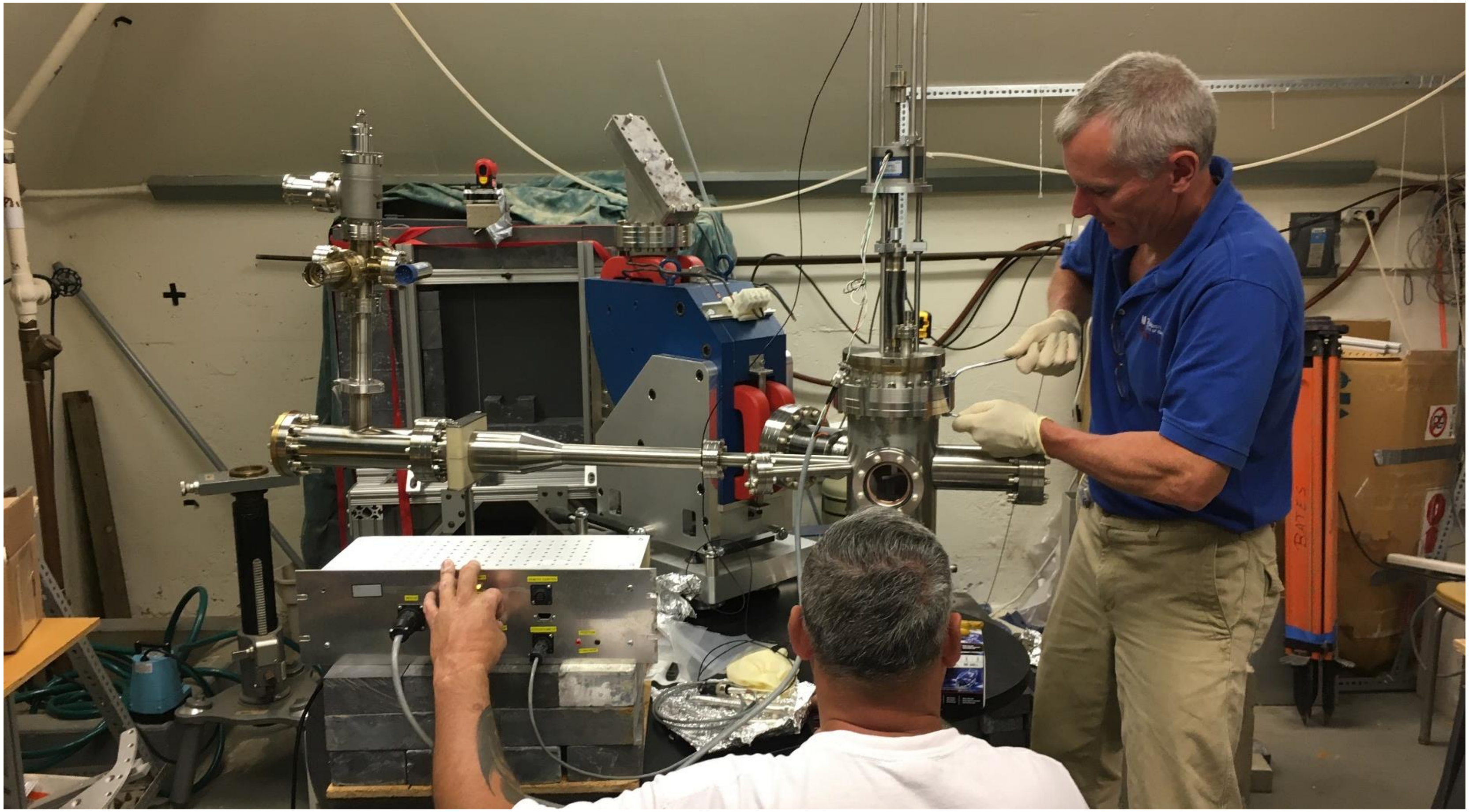
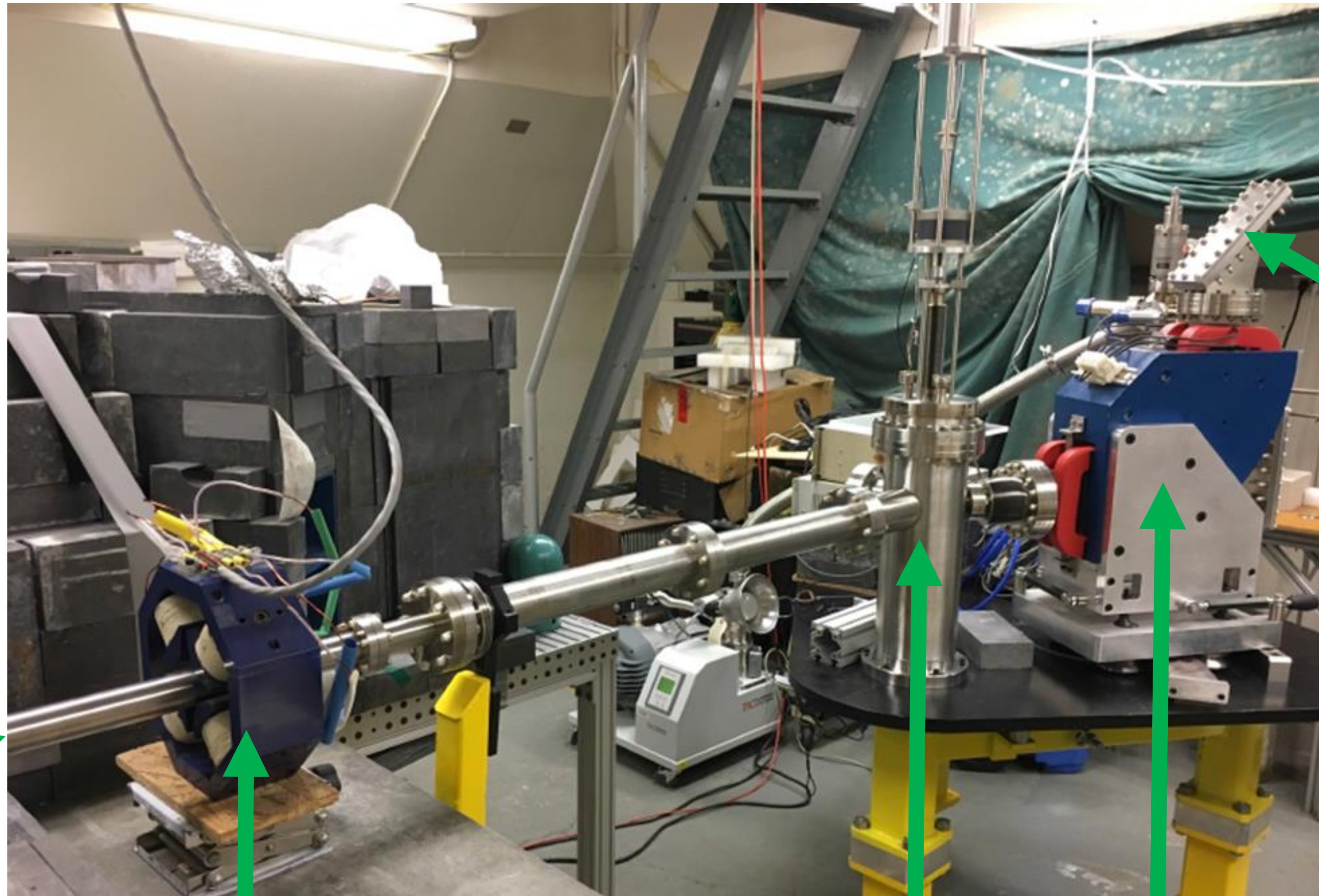


Image from Richard Milner

Current Experimental Setup at HVRL



Recent Preliminary Data

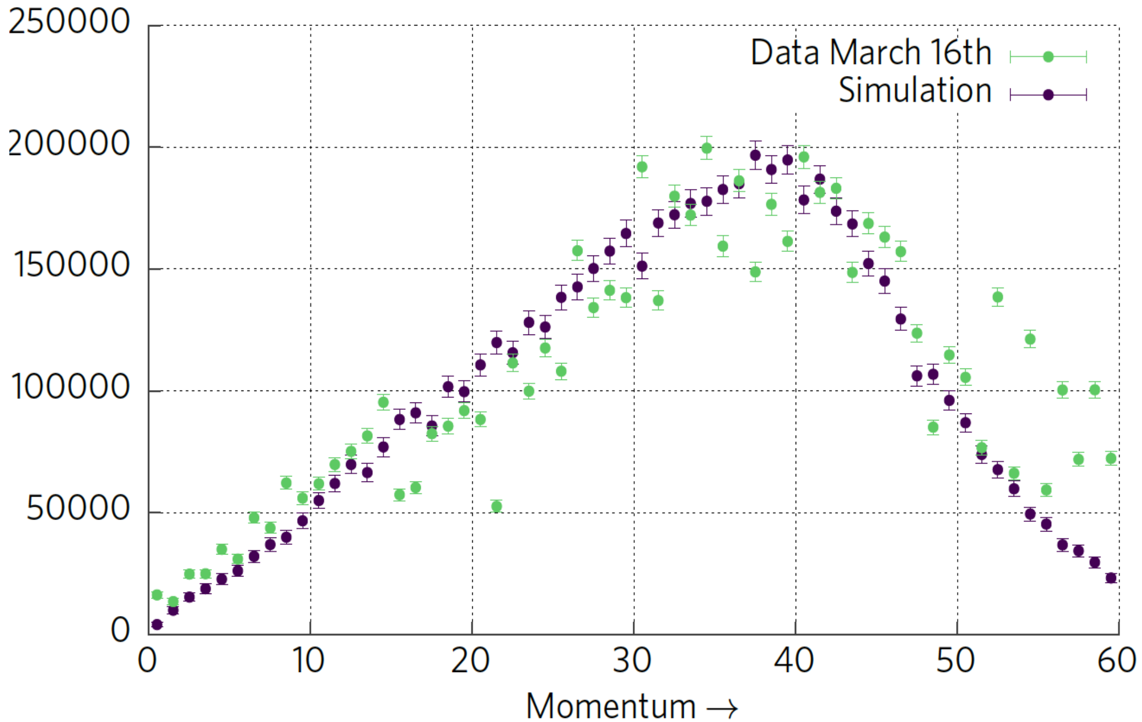
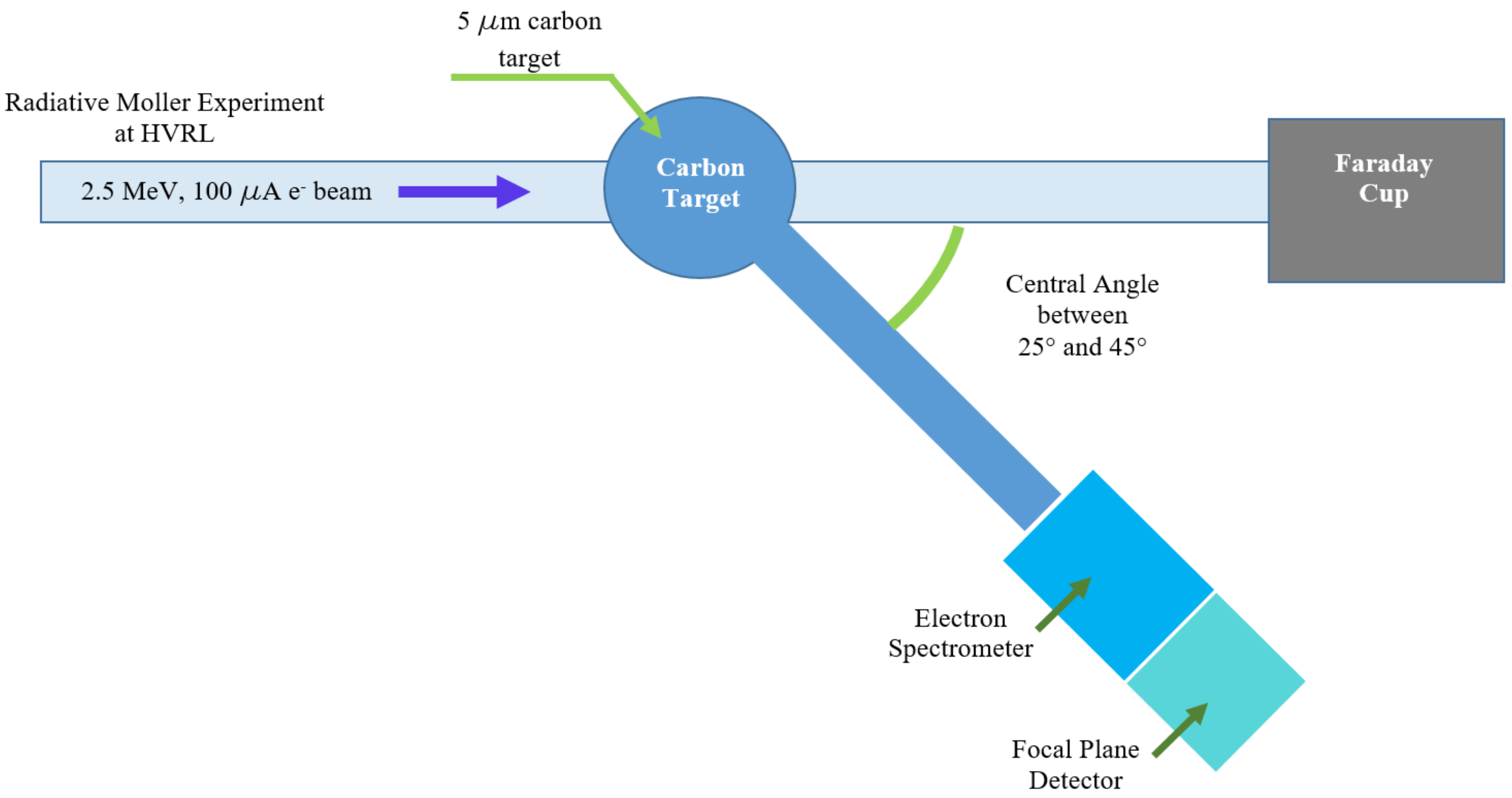


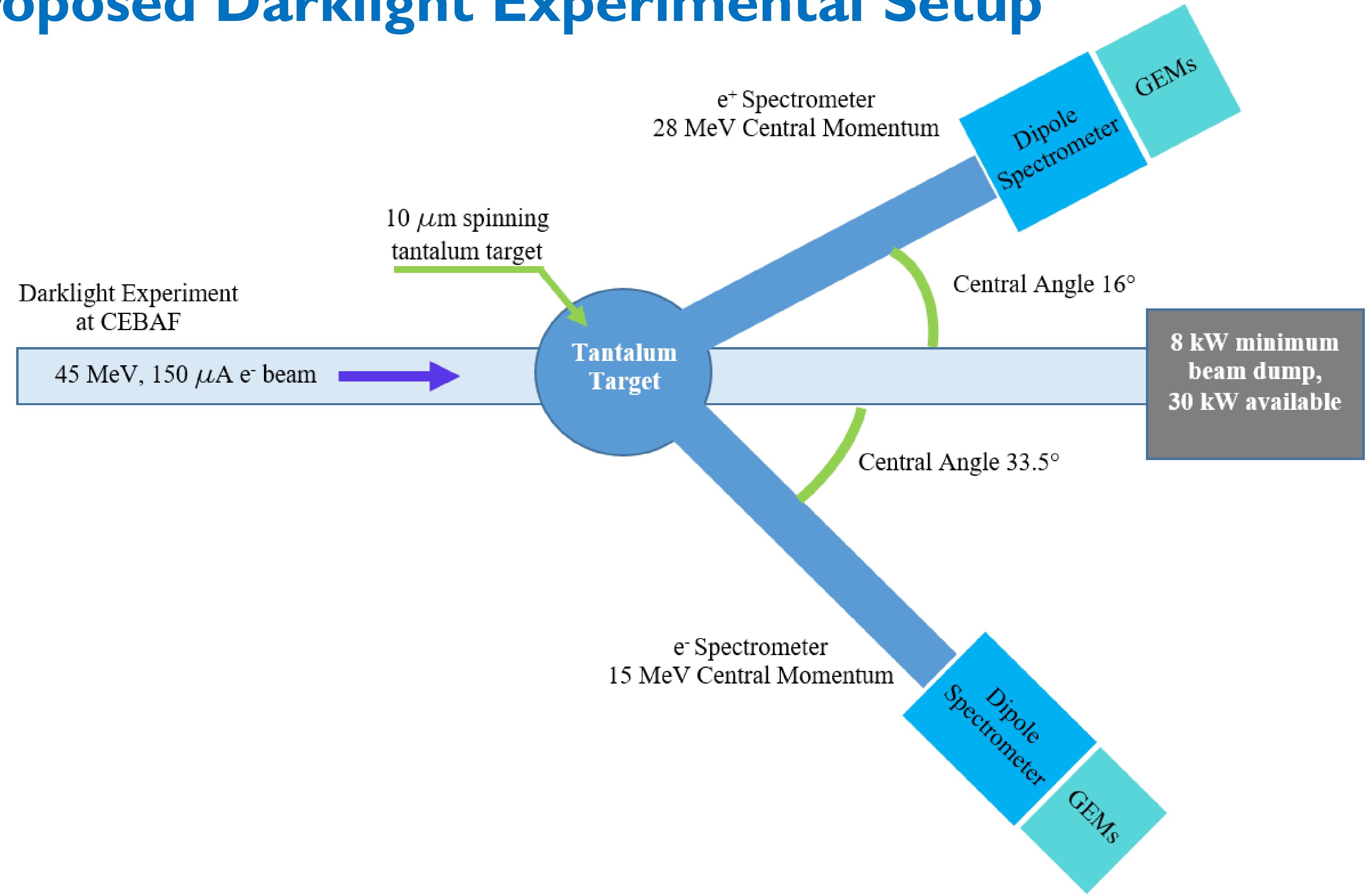
Figure 3.7: Measured focal plane momentum distribution for radiative Møller electron scattering from carbon at 2.5 MeV compared with simulation [18].

Image from Richard Milner

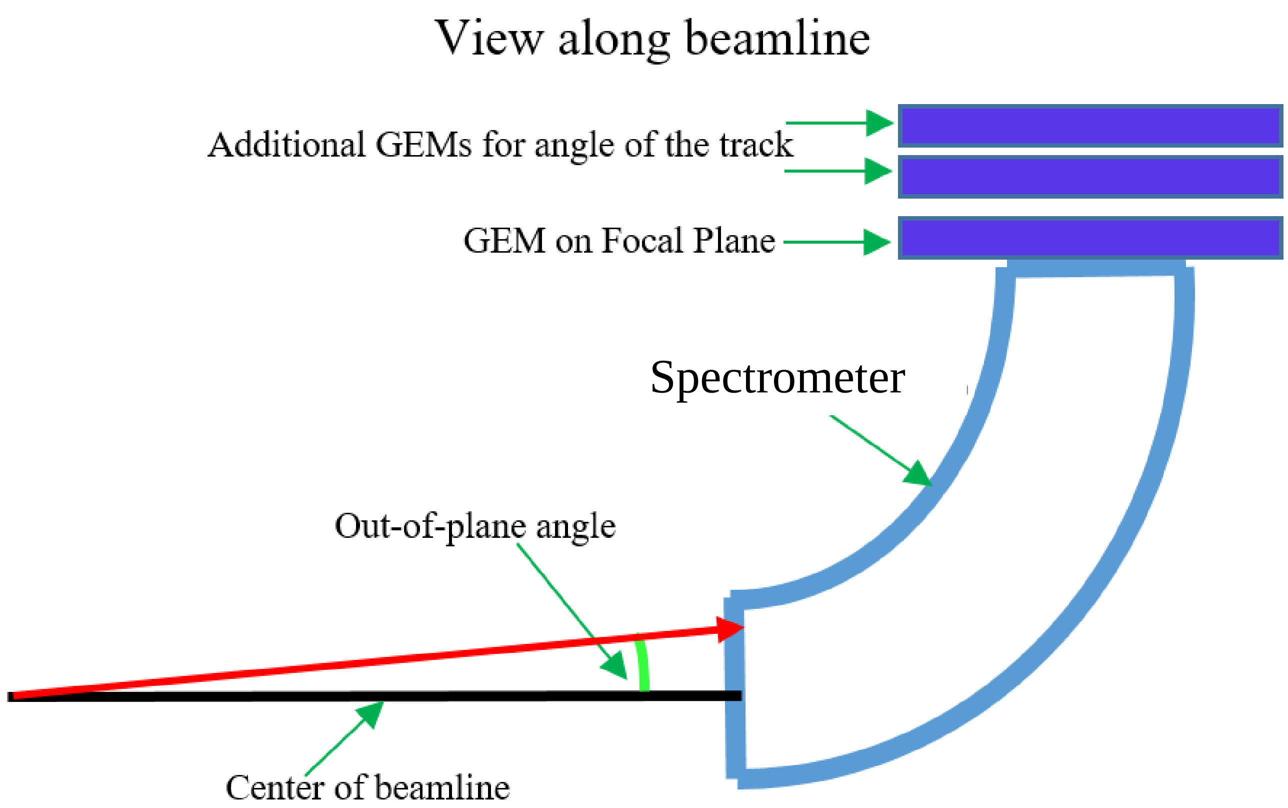
Present Radiative Moller Experimental Setup



Proposed Darklight Experimental Setup



Proposed Darklight Experimental Setup - Detectors



Overview of Darklight at CEBAF Experiment

- Experiment will use two dipole spectrometers to search in the 17 MeV e^+e^- invariant mass region for a dark photon candidate
- 45 MeV, 150 μA electron beam on a 10 μm spinning tantalum foil
- Instantaneous luminosity of 52 $nb^{-1}s^{-1}$ = 0.275 fb^{-1} s^{-1} hydrogen equivalent

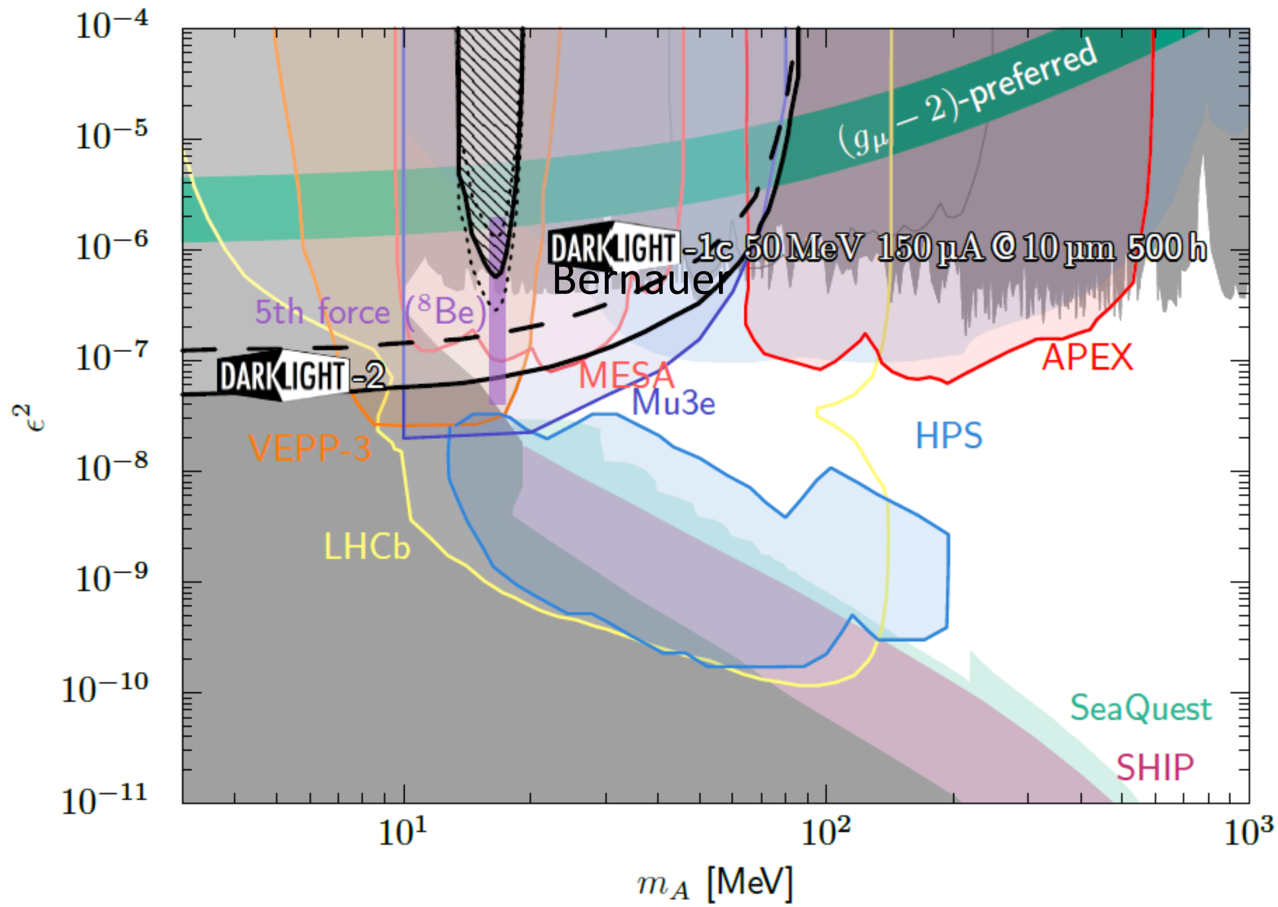


Image from Jan Bernauer

Design Specifications for CEBAF Dipole Spectrometers

	Spectrometer	
Parameter	e^+	e^-
In-plane acceptance	$\pm 2°$	
Out-of-plane acceptance	$\pm 5°$	
Momentum acceptance	$\pm 20\,\%$	
Central angle	$16°$	$33.5°$
Central momentum	28 MeV	15 MeV

- Similar to Radiative Møller Spectrometer, but with different specifications
- Additional physical size limitation determined by space available in detector hall

Preliminary Design Work

- Iterative program created by Jan Bernauer gives approximate shape of dipole magnet for a given focal plane length
  - Specify a focal plane length and magnetic field strength
  - Program assumes a polynomial form for dipole geometry
  - Iterates to find dipole shape needed to create focal plane
- Code does not have fringe fields or other higher order effects included
- These effects need to be included for the final design

- The following slides show some results from this program

Example Results from Magnetic Field Code

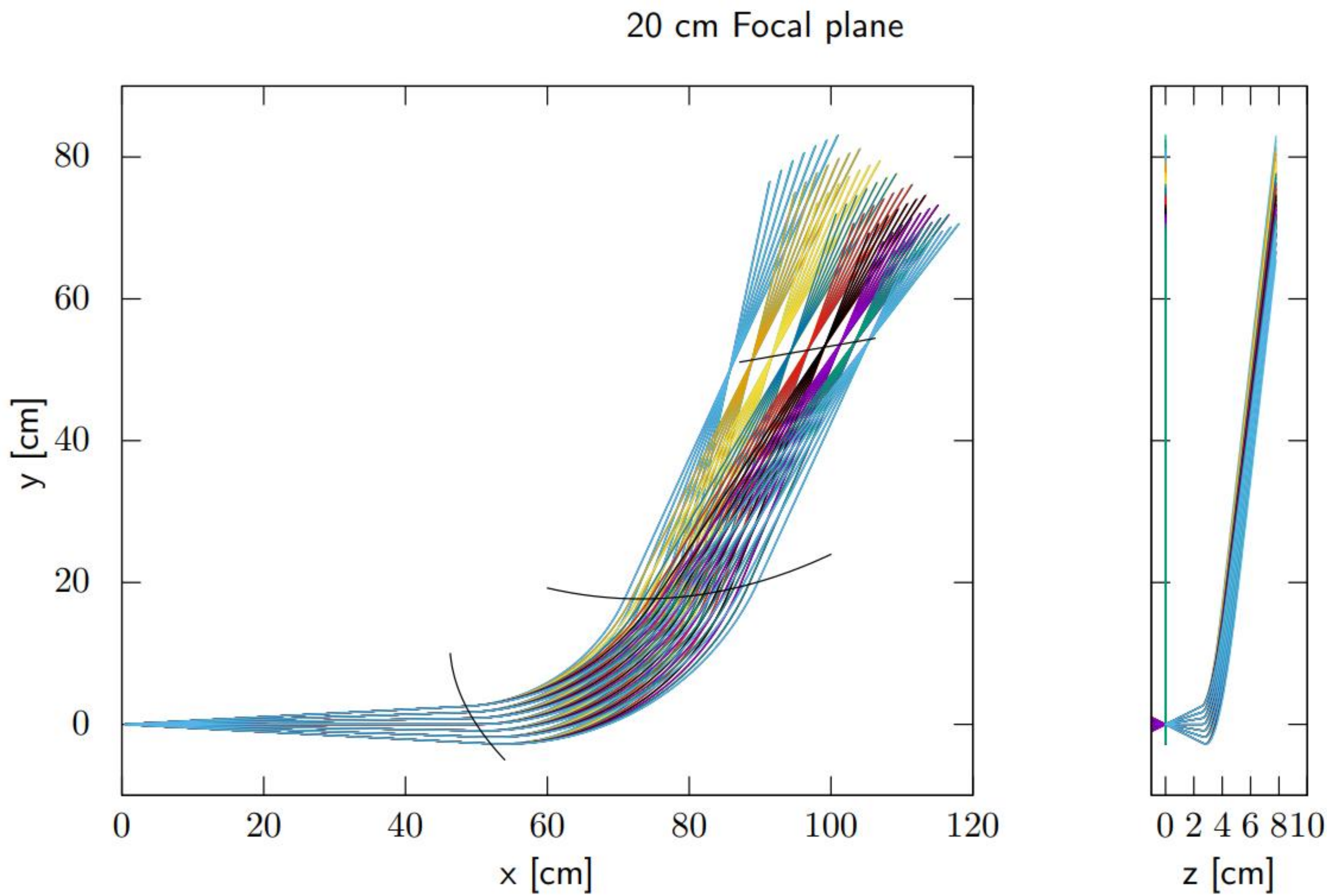


Image from Jan Bernauer

Example Results from Magnetic Field Code

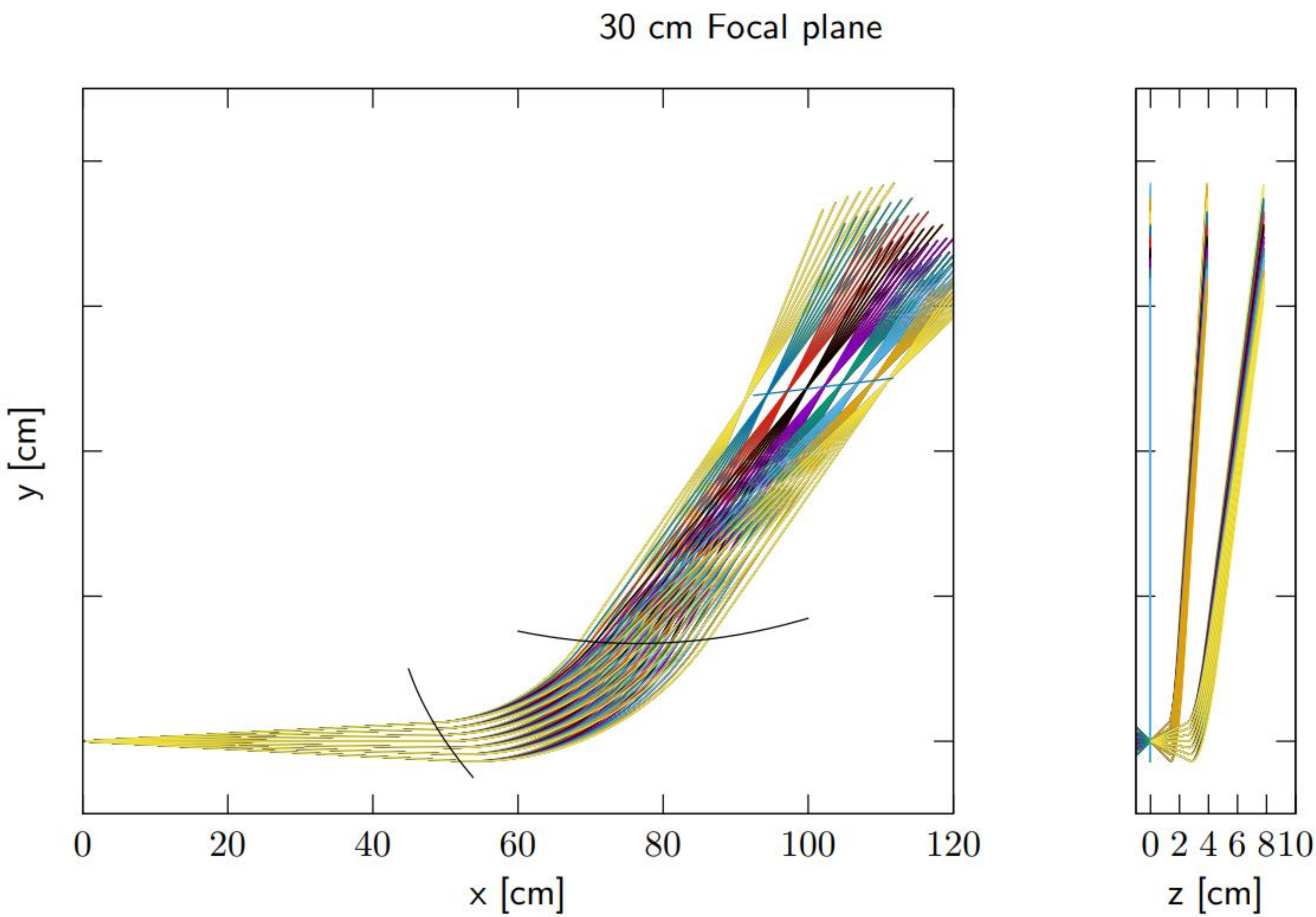


Image from Jan Bernauer

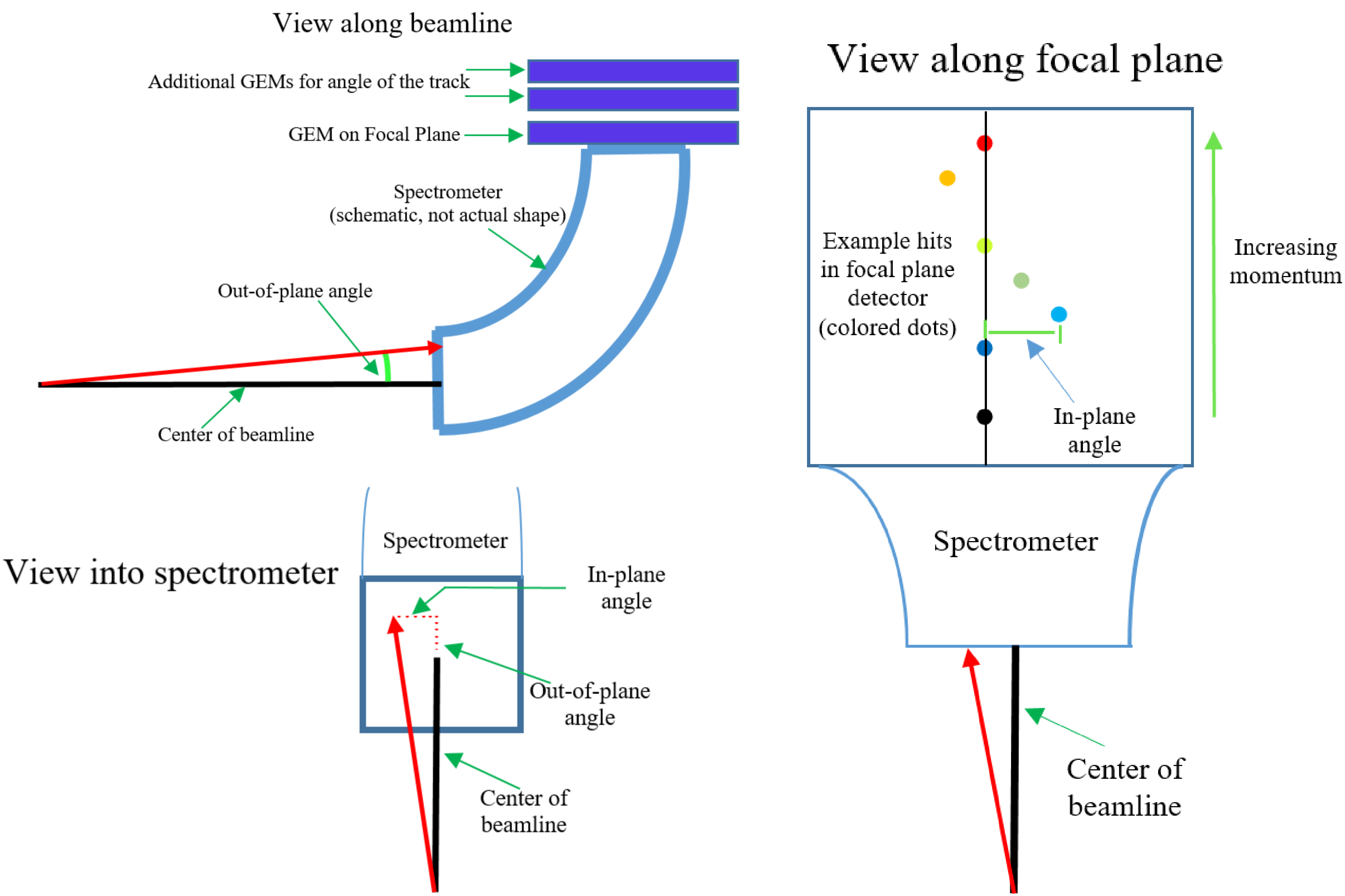
Current Spectrometer Design Status

- Currently have Ernie Ihloff, Chris Tschalaer, and Bobby Johnston collaborating on a final design
- Can handle other issues, such as shielding, after magnet is designed
- Design needs to be finalized by mid-May for proposal

Backup Slides

Backup Slides

$$R = \frac{p}{qB}.$$



Backup Slides

We assume an $e^+ - e^-$ pair to originate from a point target. The geometry of scattering plane and the components p_x, p_y, p_z of the electron momentum $\vec{p^+}$ are shown on Fig. 1. Here, δ is the spread angle and $\theta^{\pm}$ and $\varphi^{\pm}$ are the azimutal and polar emission angles of the

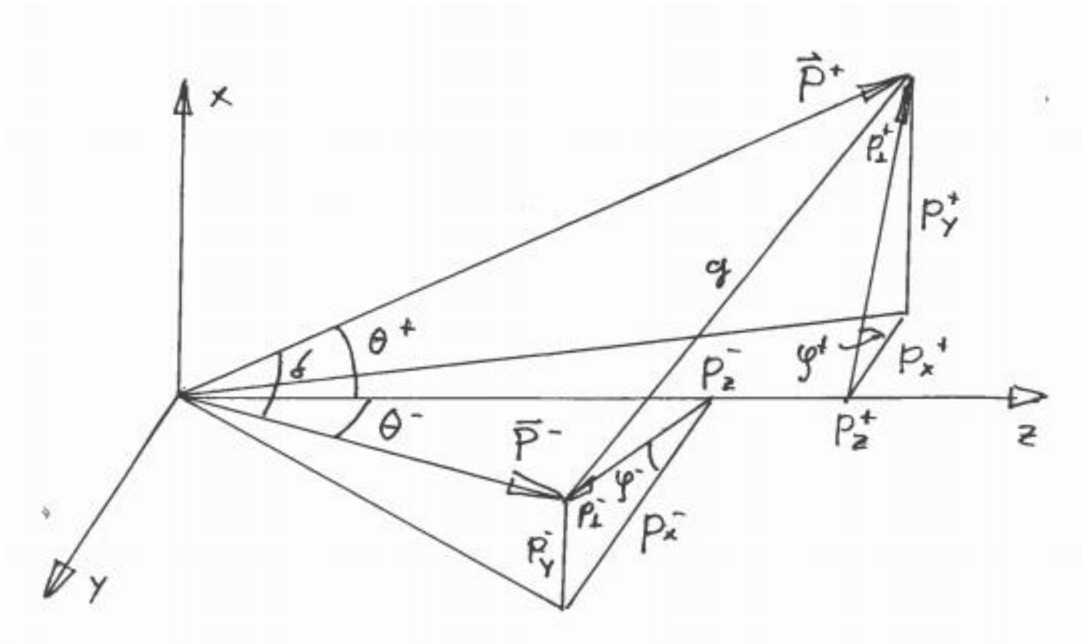


Figure 1: Momentum geometry

Image from Chris Tschalaer

Backup Slides

II. EXPERIMENT DESIGN

A. Overview

The experiment aims to measure the process $e^-X \rightarrow$ $^- TaA' \rightarrow e^- Ta(e^+e^-)$ by detecting the produced lepton pair in two dipole spectrometers.

B. Beam and Target

The experiment design assumes a 45 MeV e^- beam provided by the LERF accelerator in external beam mode with a current of 150 µA. It will impinge on a 10 µm tungsten foil. This produces an instantaneous luminosity of $\mathcal{L} = 52\,\mathrm{nb}^{-1}\,\mathrm{s}^{-1}$, i.e., $0.275\,\mathrm{fb}^{-1}\,\mathrm{s}^{-1}$ hydrogen equivalent.

The beam will heat up the foil with about 4 W, which can be dissipated via radiation for practical beam spot sizes. To protect the target from accidental melting, the target will be a spinning foil disc.

Backup Slides

Table 2: For 90° bend, estimate of magnetic field strength and physical size, assuming 0.5 m from target to magnet and 0.5 m path length in the magnet.

Parameter	Specification	Unit
Bending Radius	32	cm
Magnetic Field	5	kGauss
Minimum Gap	11	cm

Measured quantity	Effect on invariant mass resolution
Relative momentum	$\frac{dM_A}{d\Delta p} = 85\,\mathrm{keV}/\%$
In-plane angle	$\frac{dM_A}{d\Delta\Theta} = 22\,\mathrm{keV}/mrad$
Out-of-plane angle	$\frac{dM_A}{d\Delta\Phi} = 5\ keV/mrad$

Backup Slides