The APEX Experiment at Jefferson Lab: A Search for a New Vector Boson

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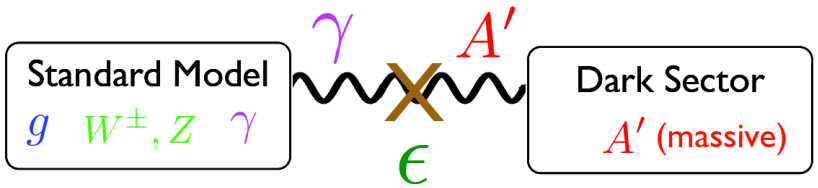
Outline

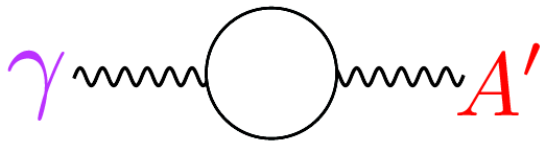
- Brief Motivation
- Experiment Overview
- Status and Plans

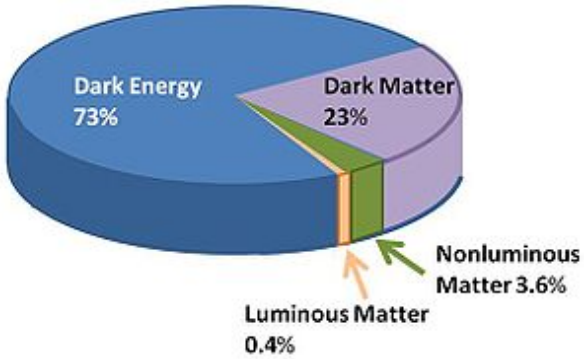
New Vector Boson Motivation

- New vector bosons well motivated extension to standard model
- Could coupling weakly to known fermions through kinetic mixing
- Scenarios could offer portal to dark sector physics
- Theory gives large possible mass and relative coupling ranges - broad phase space to search

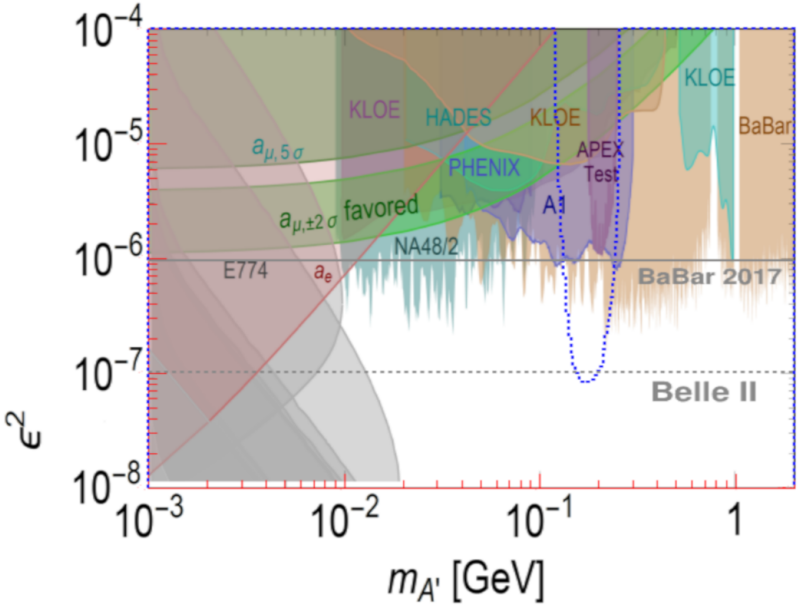
$$\Delta\mathcal{L} = \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu}$$

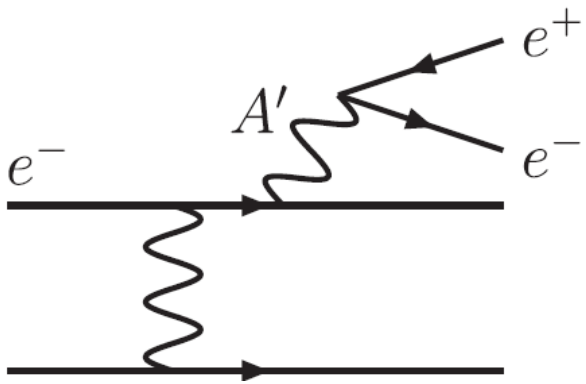




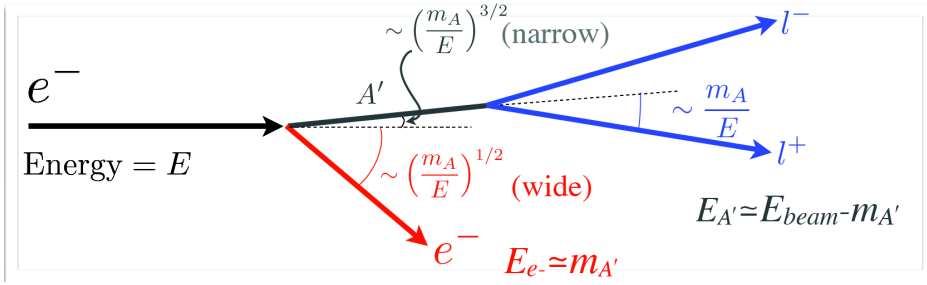


Search Method

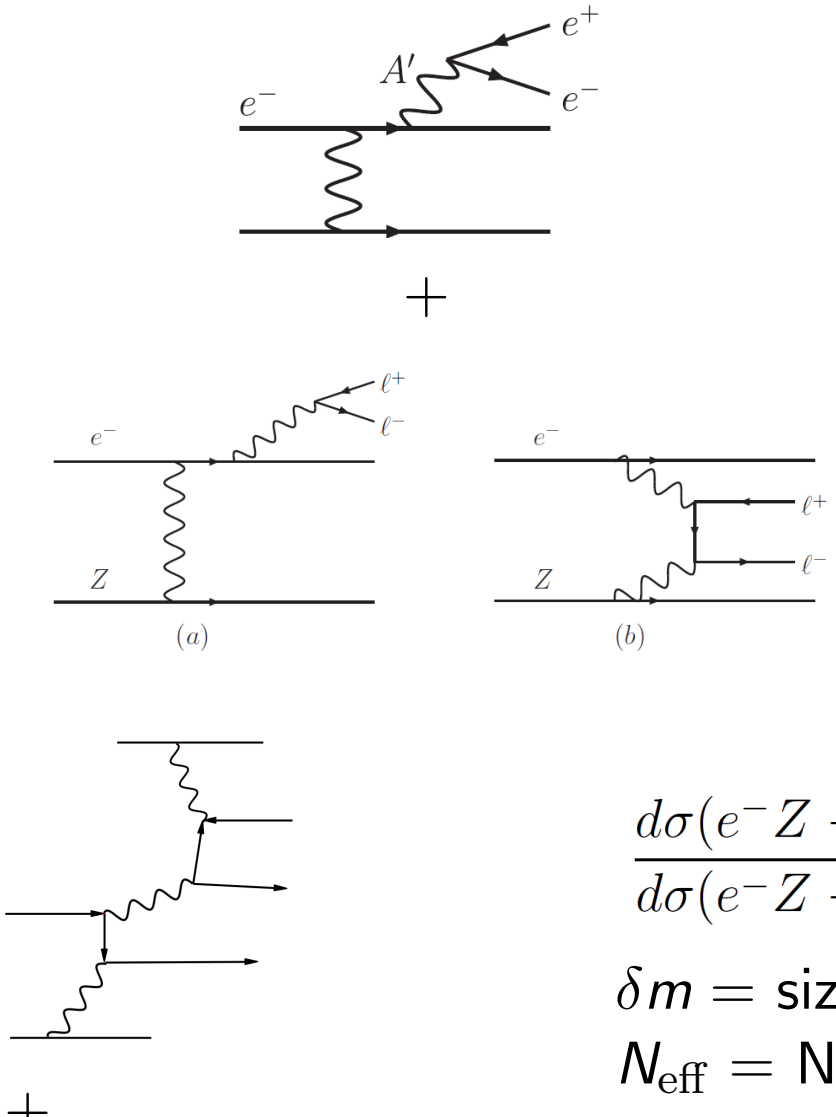




- Invariant mass spectrum through fixed e^+e^- attractive experimentally
- Look for narrow resonance over background (resolution limited)
- A' brem carries most of the energy of incident e^-
- Production angle smaller than decay opening angle



Background Processes



- Several SM backgrounds contribute
  - Radiative Trident
  - Bethe-Heitler Trident
  - Incoherent brem pair

$$\text{Rate} \sim \epsilon^2 \frac{m_e^2}{m_A'^2}$$

- Relative rate to background have similar kinematic factors which cancel:

$$\frac{d\sigma(e^- Z \to e^- Z(A' \to \ell^+\ell^-))}{d\sigma(e^- Z \to e^- Z(\gamma^* \to \ell^+\ell^-))} = \left(\frac{3\pi\epsilon^2}{2N_{\text{eff}}\alpha}\right)\left(\frac{m_{A'}}{\delta m}\right)$$

δm = size of mass search window

N_{eff} = Number of available ℓ decays

APEX Collaboration

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Natalia Toro	SLAC

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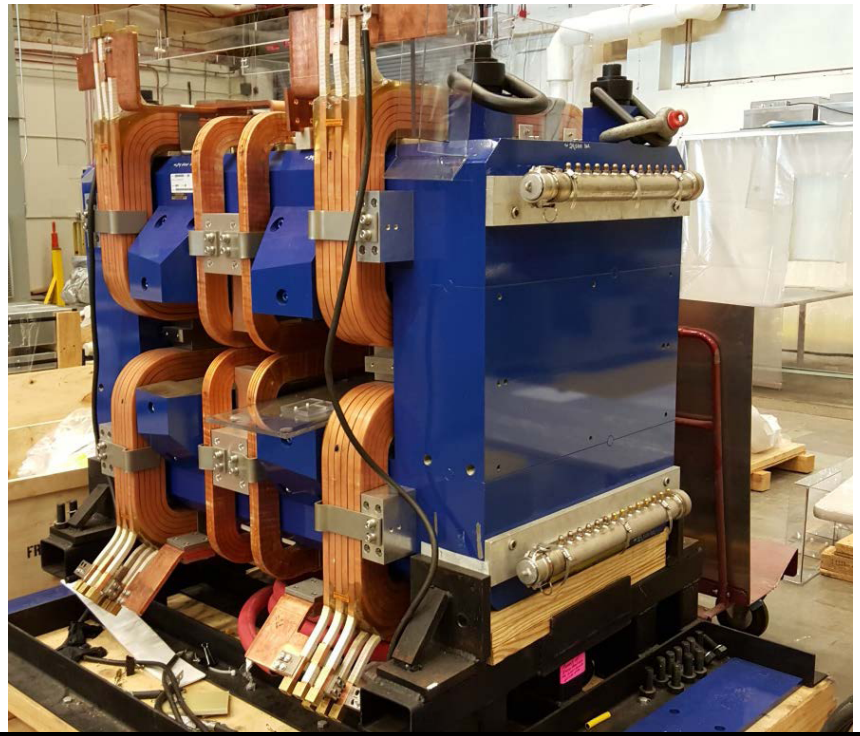
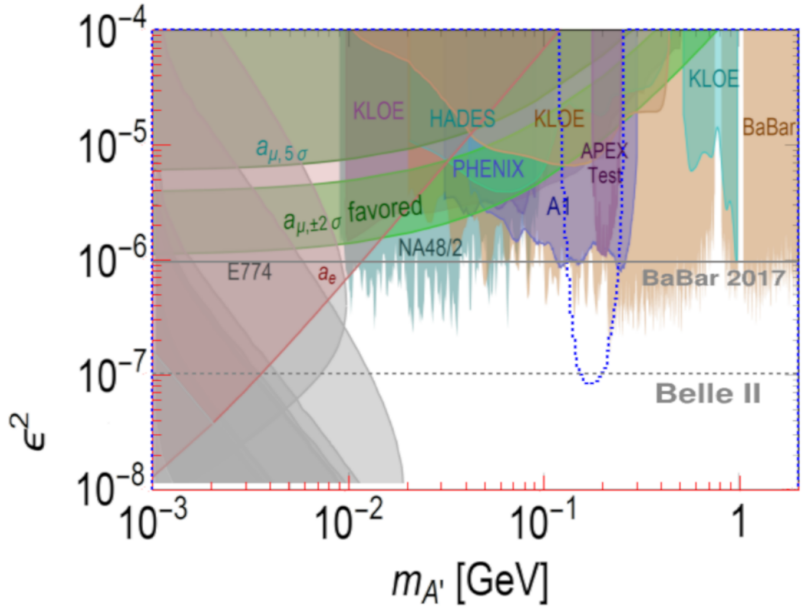
Experiment Overview



- Probing ∼100-250 MeV range to $\epsilon^2 \sim 10^{-7}$ (originally 65-525 MeV)
- 30 PAC days of 2.2 GeV e^- on multiwire target high-Z target
- New wire target
- New septum magnet to optimize acceptance down to $\sim 4.5^\circ$
- Scintillating fiber tracker for acceptance calibration



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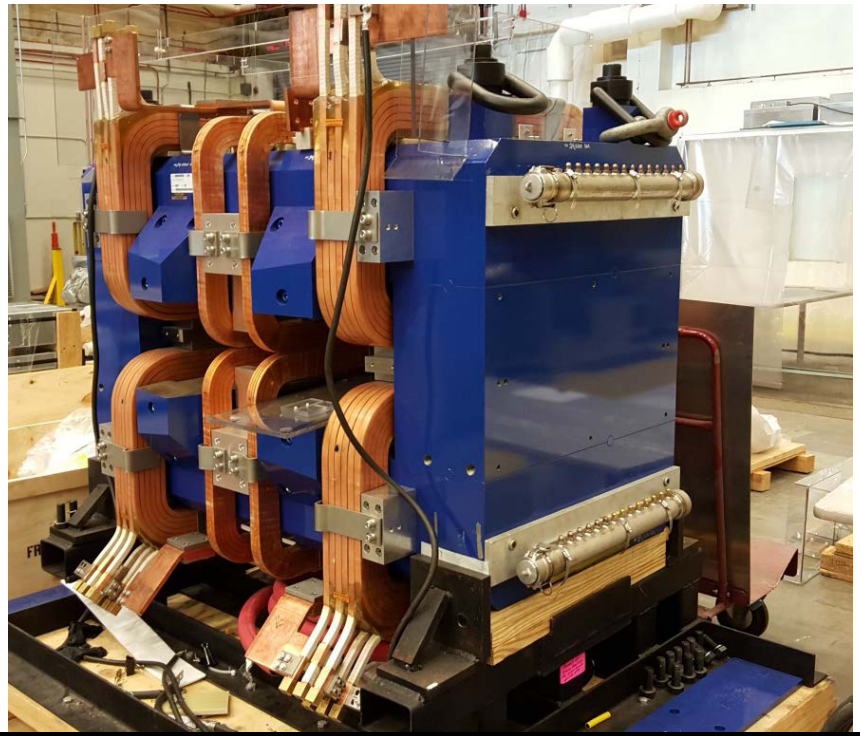

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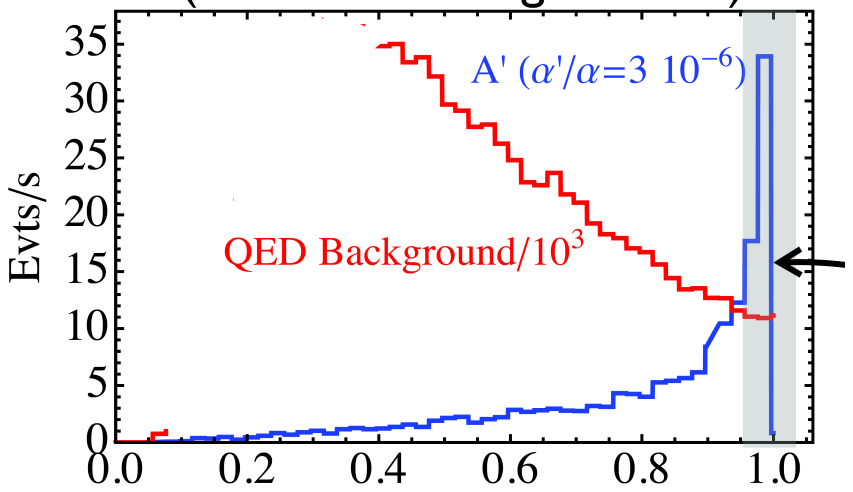
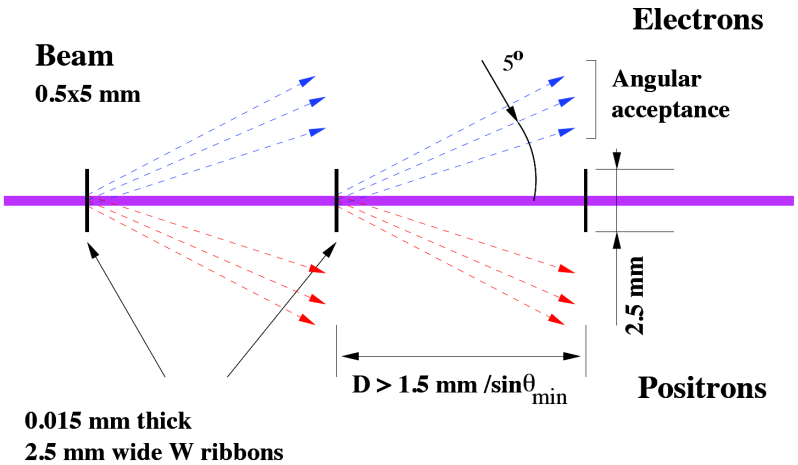
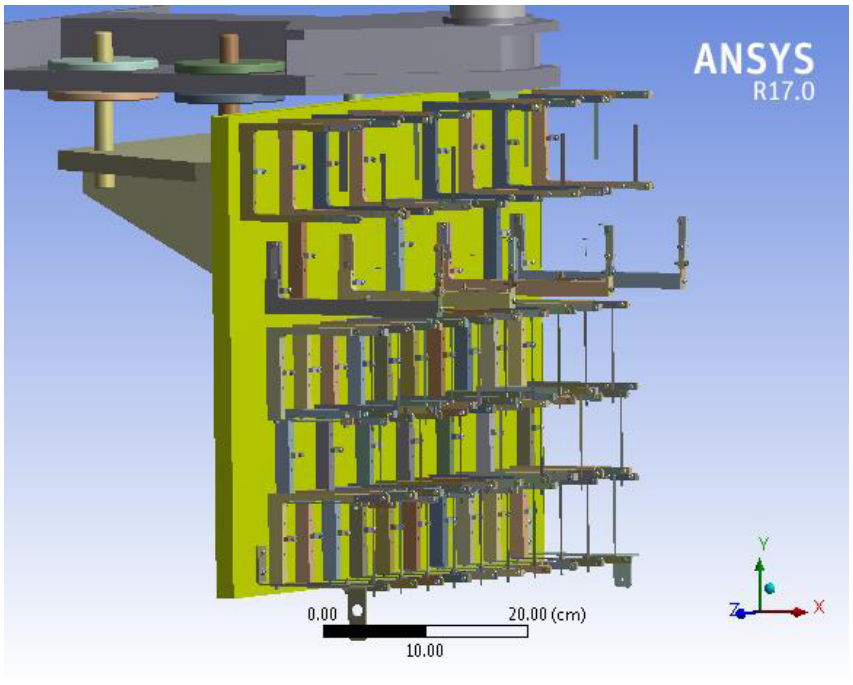
(rates before angular cuts)



Target





- Wire target allows for known point reconstruction - improves angle reconstruction (limiting factor in W resolution)
- Multiple scattering on 1 mrad level at final foil
- Set of 10; 2.5 mm wide, 15 μm thick ($\sim 0.4\% X_0$) tungsten ribbons
- Includes cross wires, carbon foils, and holes to sight beam

APEX Experimental Configuration - HRS

- Pair of High Resolution Spectrometers (HRS) reconstruct invariant mass spectrum, $\Omega \sim$5 msr
  - 3 kHz overall trigger rate (500 Hz from QED tridents)
- In-plane angular resolution ~ 0.5 mrad
  (limiting factor for mass resolution)

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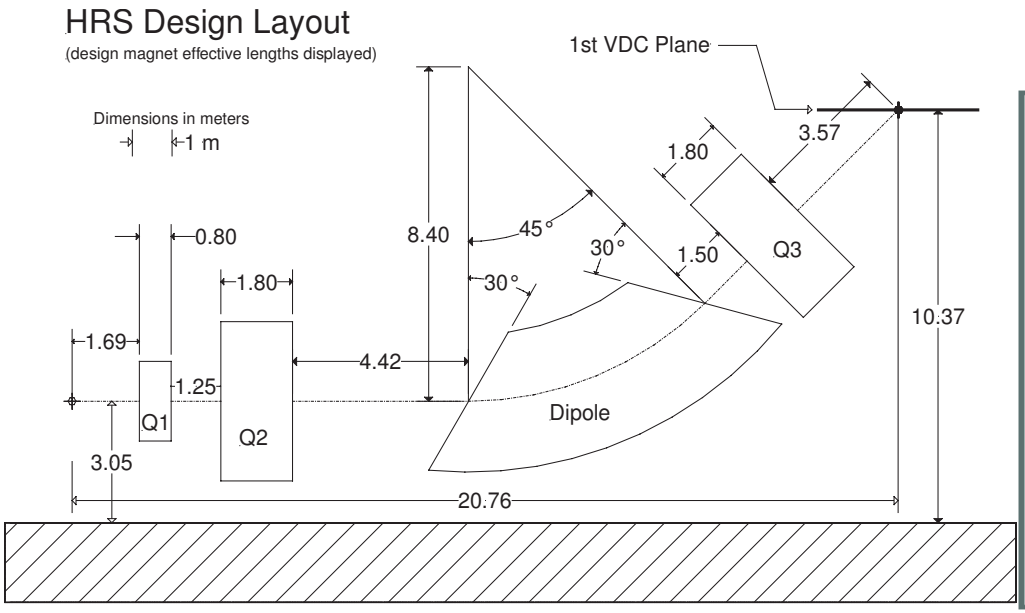
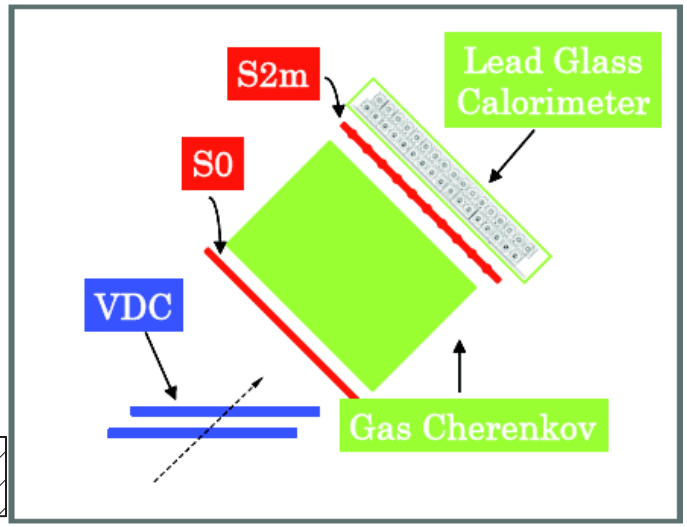
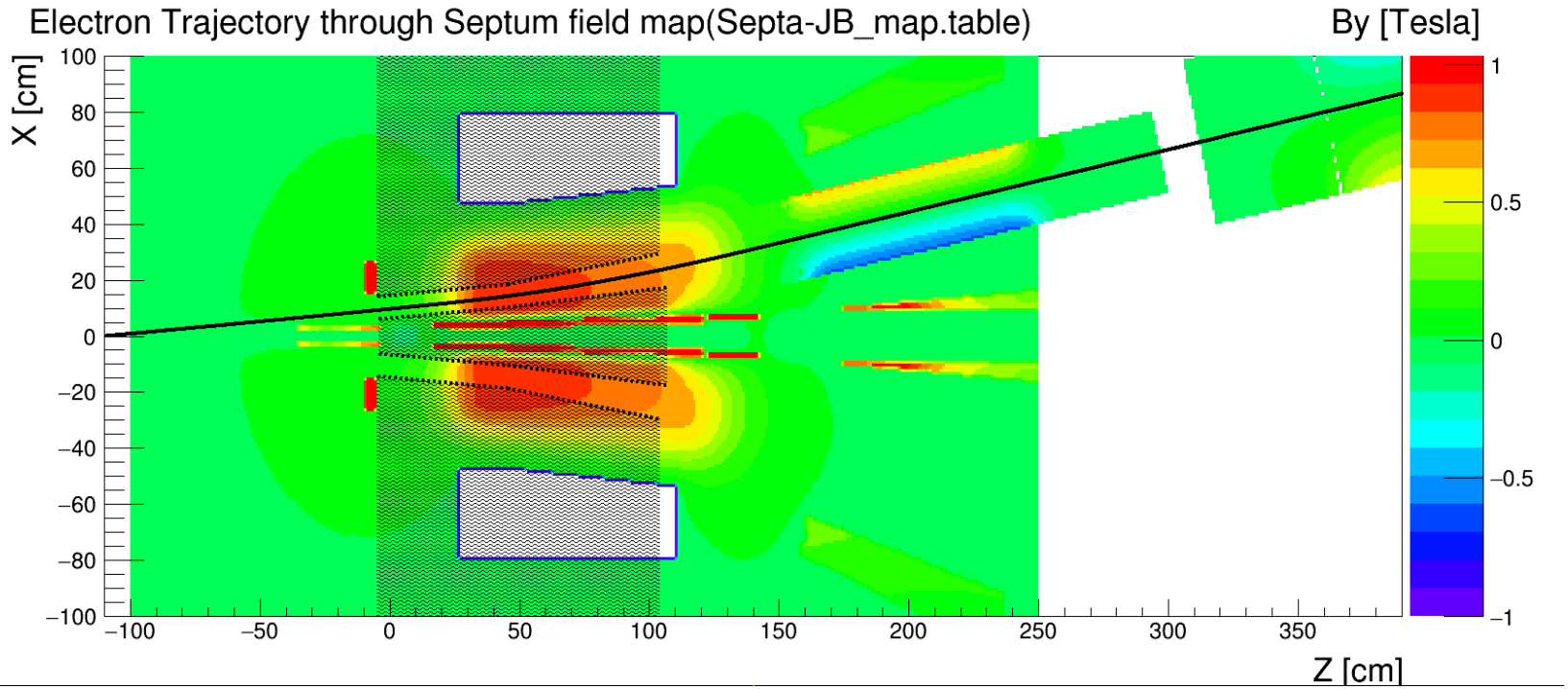
Detectors





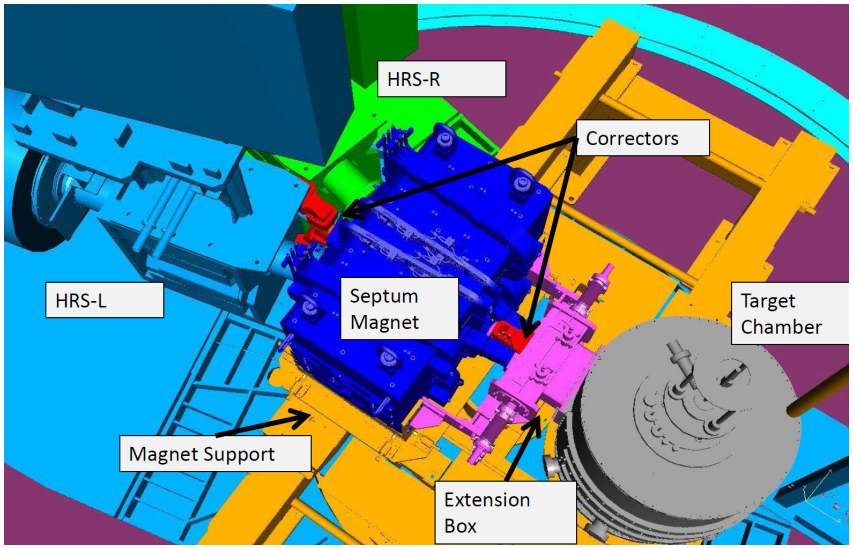
- 20 ns coincident window between arms to reduce false coincidence
- Cerenkov in e^+ arm included for π^+ rejection
- 5 MHz VDC operation (highest for production)

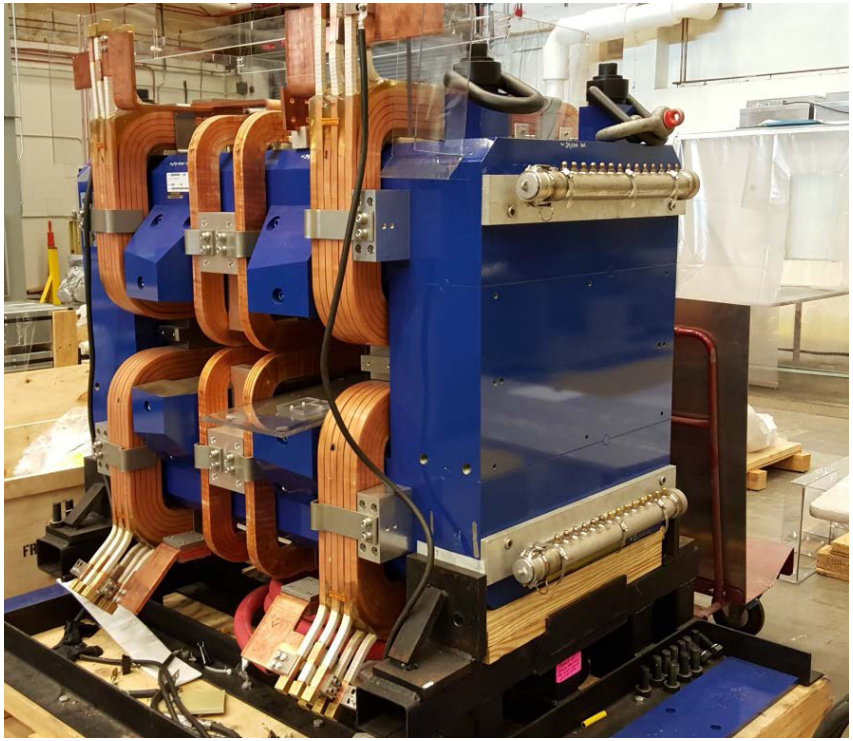
Septum Magnet



- HRS minimum 12.5°, for ∼5° insert ∼ 0.5 T·m dipole
- HRS only go to 12.5° where 4.5-5.5° acceptance needed
- Additional dipole with $\int Bdl$ ∼0.5 T· m ("septum") provides additional bend immediately after target

Septum Magnet II



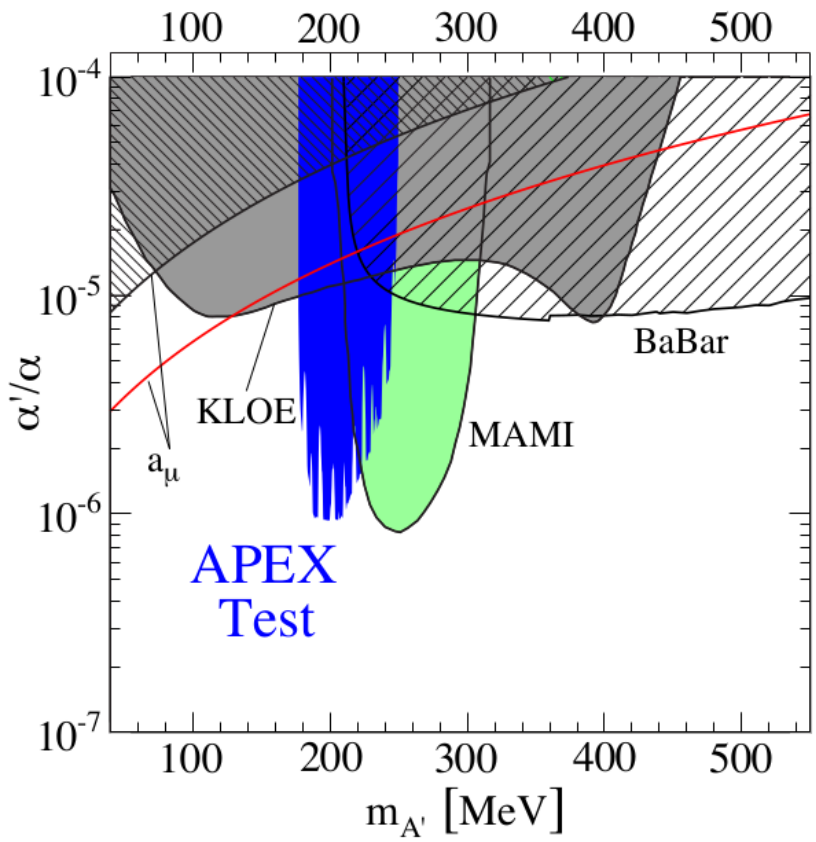


- Newly constructed for this experiment to optimize acceptance at small angles
- Additional corrector magnets required to keep beam on dump

Scintillating Fiber

- New inserable "active sieve" scintillating fiber detector used to calibrate acceptance
- 32×32 1 mm fiber grid provides active sieve
- 8.8 cm × 10.3 cm active area
- Calibration previously done by flipping polarity
  - Previous inactive sieve rate too low for e^+ side

Previous Results

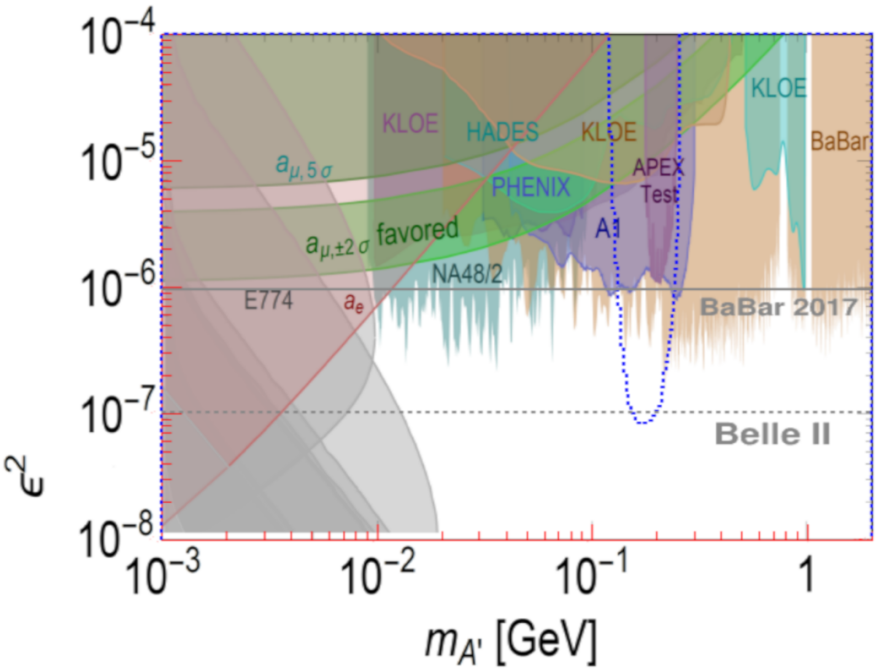


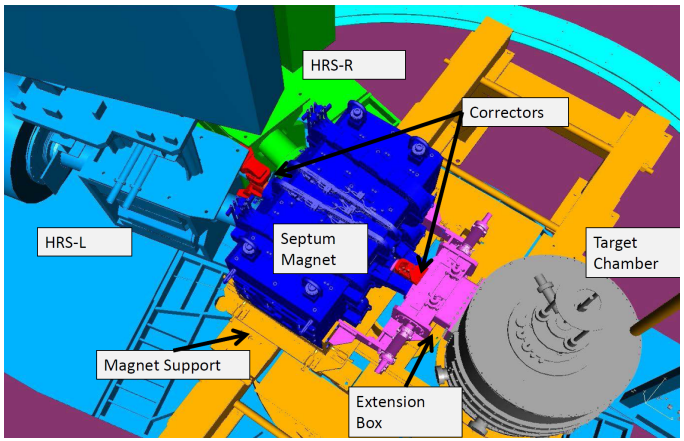
- Successful two week test run in summer 2010
- 150 μ A 2.3 GeV e^- beam
- Single 22 mg/cm^2 Ta foil target
- 5° septum (used for PREX)

Abrahamyan et al, PRL 107 (2011) 191804

- M_A = 175-250 MeV excluded to $\alpha'/\alpha \sim 10^{-6}$ at 90% CL
- Implemented successful 10 ns window trigger between arms
- Demonstrated high rate tracking for VDC, 75 kHz/wire (1 cm spacing)

Upcoming Plans





- Now on schedule for 40 calendar days in February 2019!
- Installation to begin mid-November after Tritium running
- Approved for just 2.2 GeV running to reflect modern landscape
- In principle broader energy range could be probed

New collaborators welcome!!!

Summary

- New vector bosons with weak couplings to standard fermions well motivated and could provide a portal to the dark sector
- APEX at Jefferson Lab aims to search in $\sim$100 MeV range of energies by studying e^+e^- pair invariant mass spectrum with twin symmetric spectrometers
- Running is scheduled to take place early 2019

BACKUP

Settings	**A**	**B**	**C**	**D**
Beam energy (GeV)	2.2	4.4	1.1	3.3
Central angle	5.0°	5.0°	5.0°	5.0°
Effective angles	4.5–5.5	4.5–5.5	4.5–5.5	4.5–5.5
Target T/X_0 (ratio[a])	4%	8%	0.7% (1:3)	8%
Beam current (μA)	70	60	50	80
Central momentum (GeV)	1.095	2.189	0.545	1.634
Singles (negative polarity)				
e^- (MHz)	4.1	0.7	4.5	2.2
π^- (MHz)	0.1	1.7	0.025	0.9
Singles (positive polarity)				
e^+ (kHz)	27	5	18	17
$\pi+$ [p] (kHz)	90	1700	25	900
Trigger/DAQ:				
Trigger[b] (kHz)	3.0	3.1	2.0	3.3
Coincidence Backgrounds:				
Trident: $e^-Z \to e^-e^+e^-Z$ (Hz)	500	110	260	370
e^+e^- from real γ conversion (Hz)	30	16	3	45
Accidentals [c] (Hz)	55	30	40	40