High-gradient Wien spin rotators at Jefferson Lab

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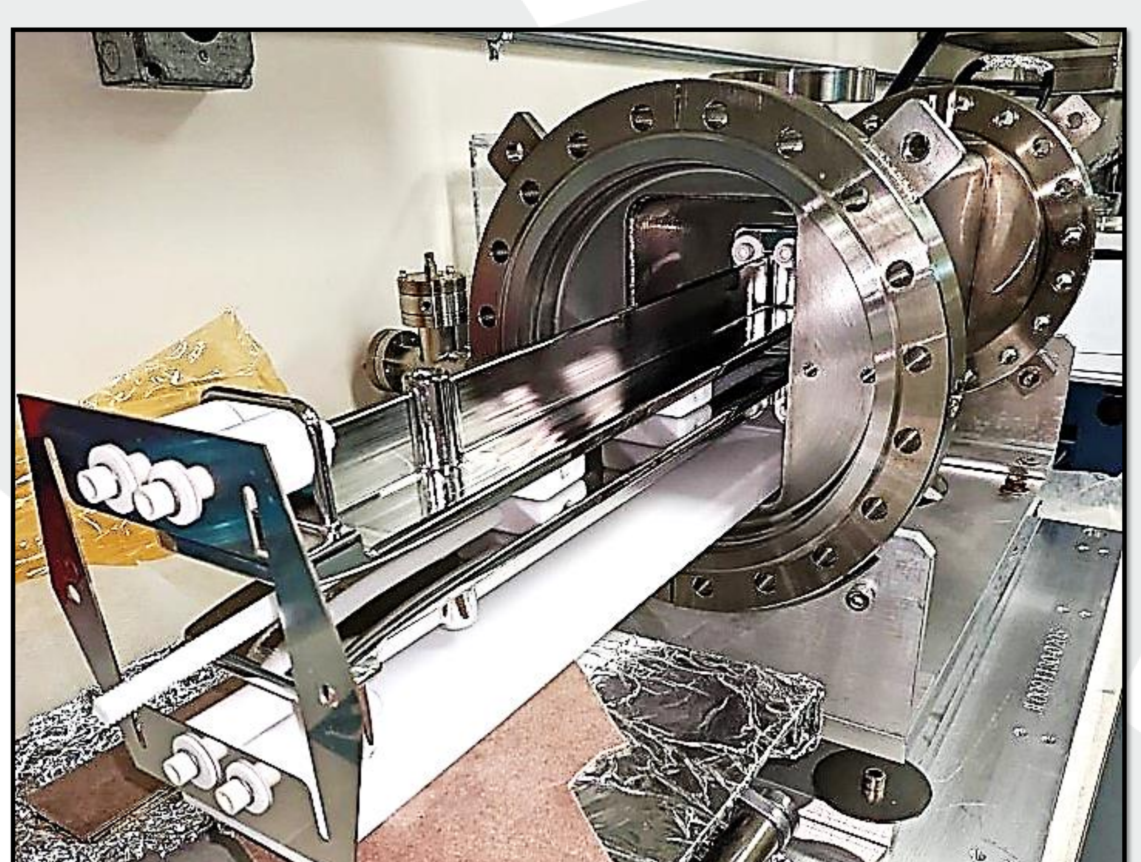
ABSTRACT

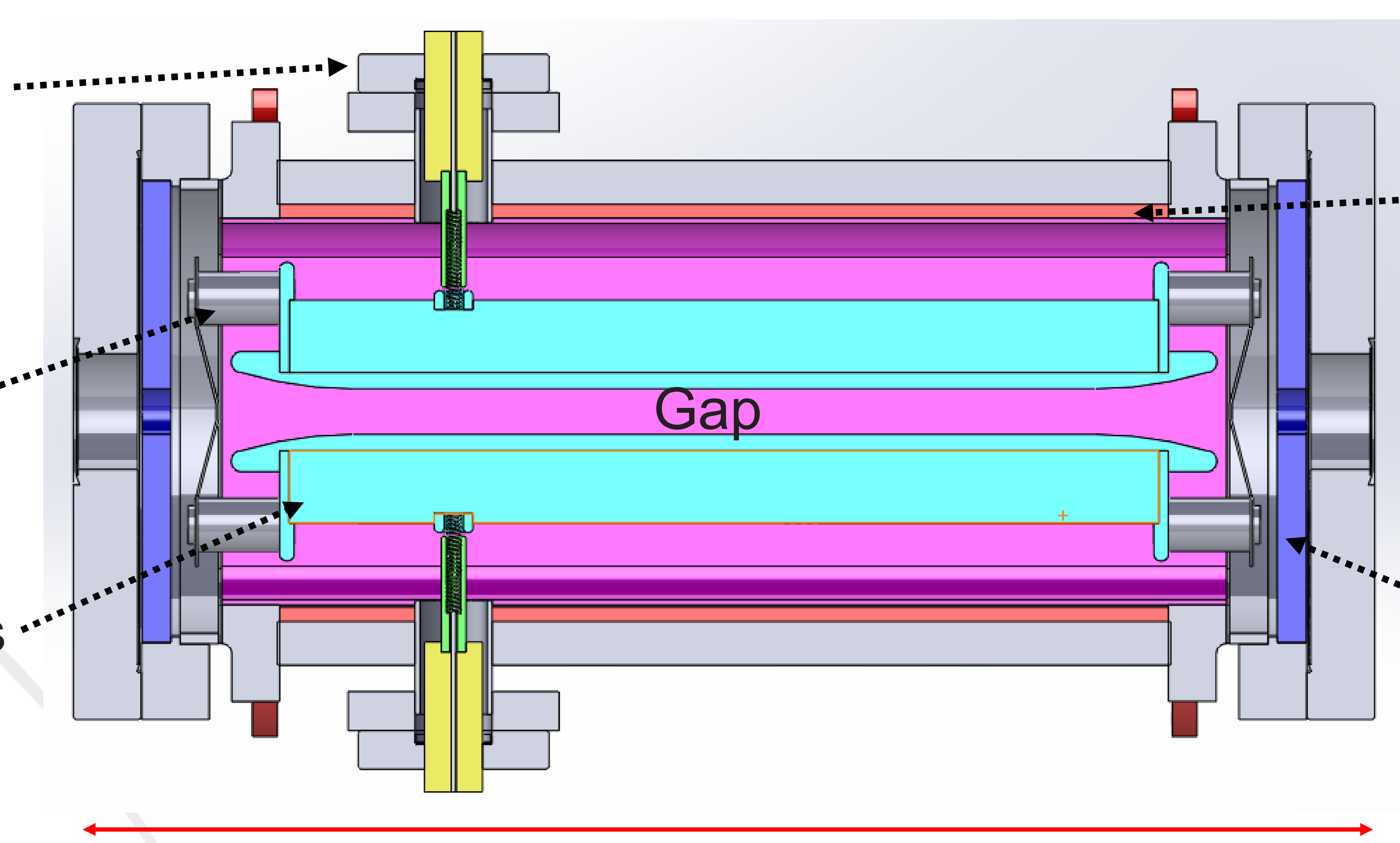
Nuclear physics experiments performed in the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory (JLab) require spin manipulation of electron beams. Two Wien spin rotators in the injector keV region are essential at CEBAF to establish longitudinal polarization at the end station target, and to flip the polarization direction by π rad to rule out false asymmetries. In a Wien filter, the homogeneous and independent electric and magnetic fields, along with the velocity vectors of the electrons that traverse it, form a mutually orthogonal system. The magnitude of the electrostatic field, established by biasing two highly-polished electrodes, defines the desired spin angle at the target yet deviates the beam trajectory due to the Lorentz force. The beam trajectory in the Wien is then re-established by adjusting the magnetic field, induced by an electromagnet encasing the device vacuum chamber. This contribution describes the evolution design and high voltage testing of Wien filters for spin manipulation at increased beam energies in the keV injector region, required by high precision parity violation experiments like MOLLER.

- **OBJECTIVE:** Modify the existing CEBAF Wiens to provide ±π/2 rad spin rotation plus 10% margin, compatible with an electron beam of 300 keV maximum energy.
- **MOTIVATION:** The planned MOLLER experiment at the JLab requires 65 µA current, 90% longitudinally-polarized, and highly stable 11 GeV electron beam, for which the photogun was upgraded to provide 200 keV beam. Wien filter spin rotation depends on beam energy, so the CEBAF Wiens must be upgraded to produce a higher gradient. This could also benefit upcoming projects like EIC and ILC.



Picture of Wien filter during assembly.

High gradient Wien filter



- **DESCRIPTION:** A new Wien filter design with HV feedthroughs was equipped with:
  - Single piece 304 stainless steel electrodes.
  - Improved Rogowski profile
  - Reduced electrode gap (15 mm vs 13 mm)
  - Max gap gradient of 3.9 MV/m.

Wien filter electrode Rogowski profile.

- **OPERATION PARAMETERS:** Through the evolution of CEBAF, three versions of the Wien filter design were produced to rotate the spin angle to a maximum of π/2 rad plus a 10% margin, compatible with 130, 200, and 300 keV, respectively.

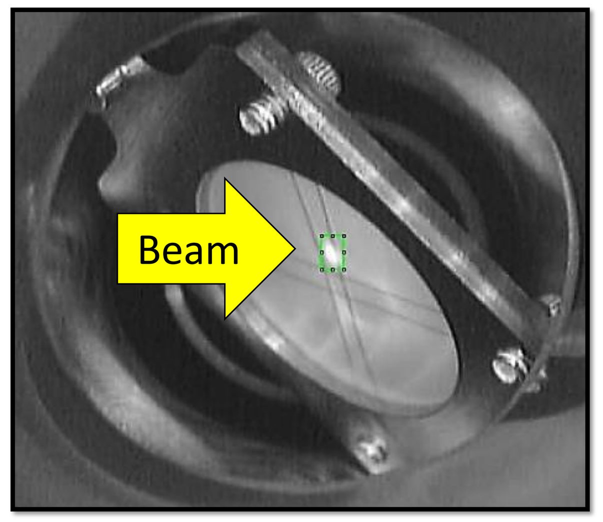
$$\frac{E_y}{B_x v_z} = 1$$

Equilibrium condition

$$\theta = \frac{eL}{m_0 c\beta\gamma^2}\left[\frac{E_y}{v_z}\right]$$

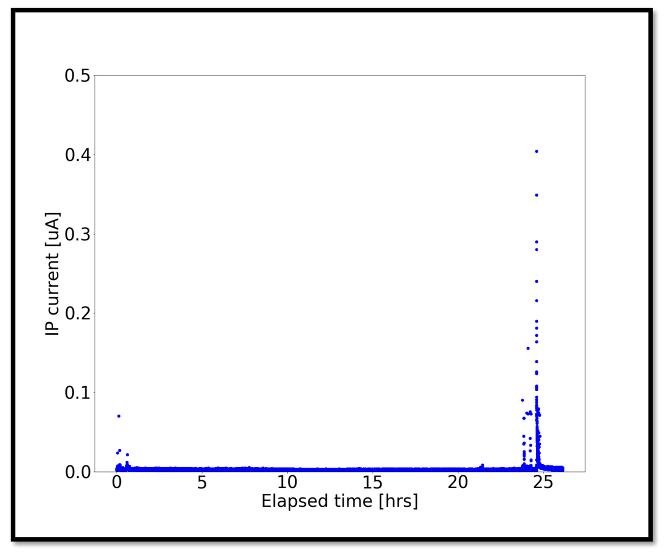
Spin rotation from Thomas- BMT equation

- **HV EVALUATION:**
  - Milestone! Standalone. 90° spin rotation and 300 keV compatible. Magnet off, bias at 26 kV per electrode (3.9 MV/m highest gradient to date sustained 24 hrs).
  - On beamline. >100° spin rotation and 200 keV compatible. Magnet off, bias at 21 kV per electrode (3.2 MV/m sustained 2 hrs).
  - Milestone! On beamline. >100° spin rotation achieved with a 180 keV beam.



180 keV beam on fluorescent screen

Vacuum during operation



- **CONCLUSIONS:**

The device is operational in a 180 keV test bed accelerator and initial tests show that it exceeds its design capabilities, providing spin angle rotation up to 0.694 π rad (125 deg) measured at a Mott polarimeter, with imperceptible impact in beamline vacuum conditions.

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