PROCEEDINGS OF SCIENCE

The low Q^2 chicane and Compton polarimeter at JLEIC

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The JLAB EIC (JLEIC) design includes a chicane after the interaction point to detect electron associated with production of quasi-real photon at the interaction. This chicane layout can also be used for Compton polarimetry to measure the electron beam polarization. This proceeding will present the layout of the low Q^2 chicane and the implementation and current R&D of a Compton polarimeter which would be located in the middle of this chicane.

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†Jefferson Laboratory and BNL EIC R&D eRD15 Compton Electron Polarimeter for EIC

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1. Introduction

The future Electron Ion Collider will feature availability of both polarized electron and ion beams coupled with a high luminosity from $10^{33} cm^{-2} s^{-1}$ up to a few $10^{34} cm^{-2} s^{-1}$. Energy of the electrons will be similar to the existing CEBAF from 3 to 10 GeV. The protons or ions will have an energy from 20 to 100 GeV [2].

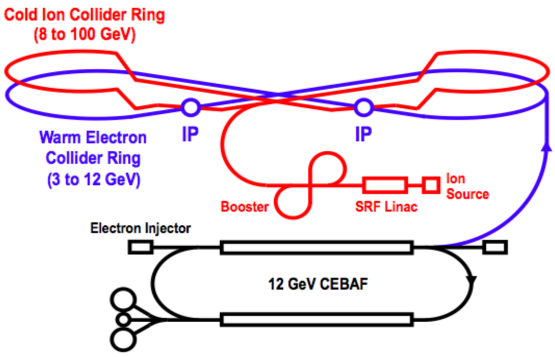


Figure 1: Figure of 8 layout of the JLEIC electron ring with the chicane after in the interaction point

Polarization measurement is important since the machine is designed to run at high luminosity, many measurements will be limited by systematic errors. In the case of inclusive electron measurement, electron polarization can be a major contribution. Polarization also enters the photon production cross-section which can be used to determine the luminosity needed for all the cross section measurements.

1.1 Layout

The Jefferson Laboratory EIC design (JLEIC) is a ring ring collider design in a figure of 8 [3] which makes it easier to conserve polarization of ions and electrons since the precession cancels at first order at the interaction point a thorough description of the design can be found in [1].

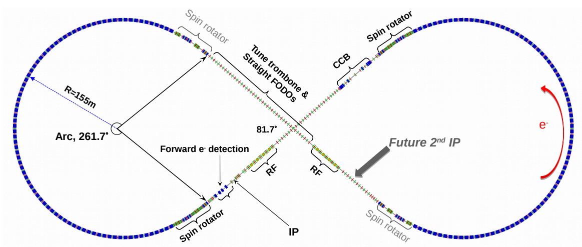


Figure 2: Figure of 8 layout of the JLEIC electron ring with the chicane after in the interaction point

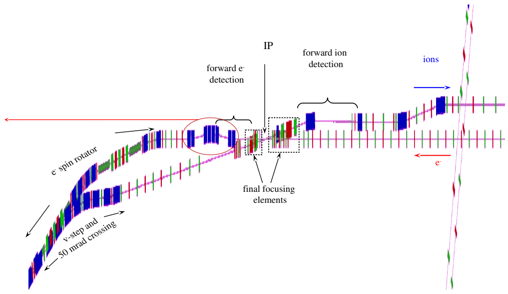


Figure 3: Detailed layout of the magnet lattice of the chicane at the interaction point with the forward electron detection chicane

Two interactions points are planned, the main interaction point is based on a solenoidal magnet giving an almost hermetic detection as show in Fig. 4 where on can see the detector with the magnets for the final focusing and the low Q^2 chicane.

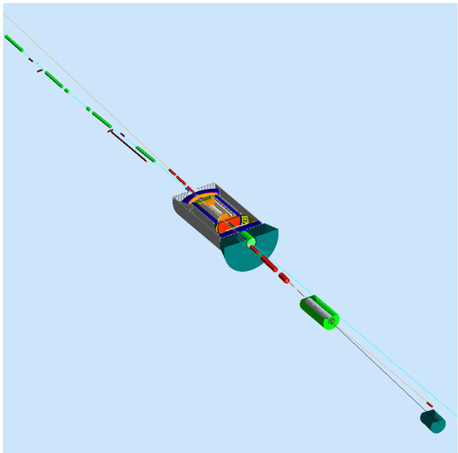


Figure 4: Overview of the interaction point main detector with the final focusing magnets and the low Q^2 chicane

2. The low Q^2 chicane

Quasi-real photons can be produced at the interaction point, since they are almost colinear with the beam the corresponding electrons will not be detected in the main detector. In order to detect those electrons a chicane was designed after the interaction point. It consists of 4 dipoles with the first dipole which takes out electrons corresponding to high photon energy which will be bent out and detected by a tracker detector. The designed momentum resolution is 10^{-3} on the electron energy assuming a 1 mm detector resolution. This will allow to study J/ψ, charm production, real and Time like Compton Scattering for example. The optimization of the chicane acceptance is being studied. All the magnets are modeled in the GEMC simulation. In Fig. 5 one can see electrons deflected in the detector at the first dipole.

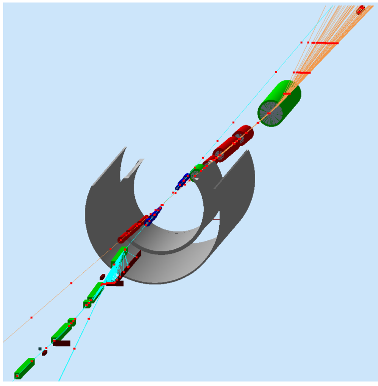


Figure 5: Display of a few events detected in the low Q^2 chicane

The first dipole will be a C magnet to allow off momentum electron to go through a thin window. A scintillating fiber tracker like detector will be used to determine the momentum of the scattered electrons.

3. The JLEIC Compton polarimeter

3.1 Chicane layout

Compton polarimetry is commonly used to measure polarization for experiment where accuracy on the polarization beam is critical, the interaction cross-section of circularly polarized photons with longitudinally polarized electrons is different depending of the direction of the polarization of either the electron or photons. By varying one of the polarization one can measure the Compton asymmetry which is proportional to both photon and electron polarization. Compton polarimeters are considered non invasive meaning they can continuously monitor the beam polarization as long as the amount of Compton interaction is just a fraction of each electron bunch.

The Compton Scattering crosssection can be accurately computed with QED, so one can extract the absolute beam polarization from the measured asymmetry. The Compton asymmetry is particularly well suited for measurement at higher energy where the Compton asymmetry is larger as shown in Fig. 6.

The photon polarization is known accurately to a few tenth of a percent level giving a measurement of the beam polarization. Sub-percent measurement of the polarization was achieved at Jefferson Laboratory in Hall A and Hall C.

The low Q^2 chicane is a good configuration for Compton polarimetry, it allows to separate the Compton electron from the Compton photon. For the current JLEIC design we will rely on a design similar to the one used at Jefferson Laboratory as show in the schematics Fig. 7. The Compton electrons having lost energy during the Compton interaction are bent more after the third dipole and are detected.

The photon source used at Jefferson Laboratory currently is a green CW laser amplified by a Perot Fabry cavity with a typical gain around 1500. It is placed between dipoles 2 and 3 with a small crossing angle with the electron beam.

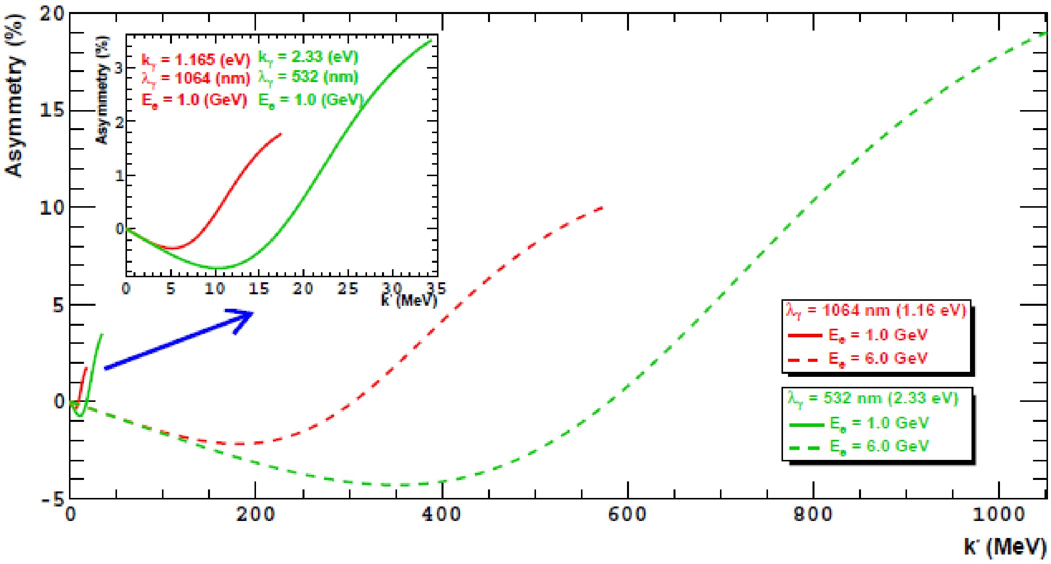


Figure 6: Compton asymmetry for different laser and beam energies

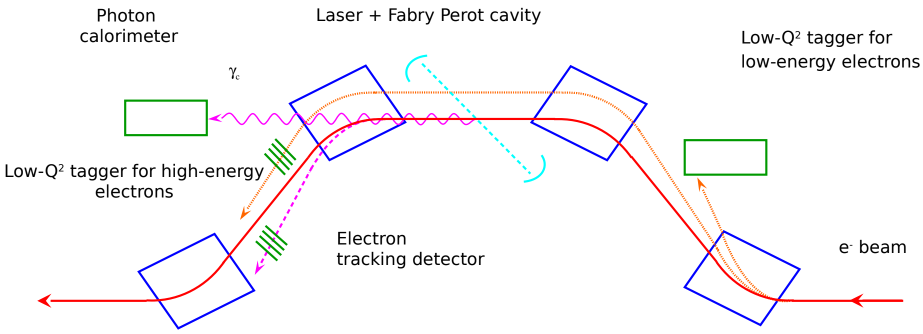


Figure 7: Schematic of the low Q^2 chicane layout including the Compton polarimeter

Compton polarimetry can be done by detecting either the Compton Photon or Compton Electron, both methods have different systematic and are sensitive to different backgrounds. They can give two independent measurement of the polarization which is a good crosscheck.

3.2 Hall C QWeak diamond electron detector

Jefferson Laboratory has already experience of operating Compton Polarimeter in the 1 to 6 GeV range. A strip detector is placed in the dispersion plane then the electron energy is directly proportional to the position in the detector. In Hall C, a 4 planes with 96 strips per plane diamond detector was used as shown in Fig. 8 and installed as in Fig. 9a. The detector can be inserted at different distances from beam.

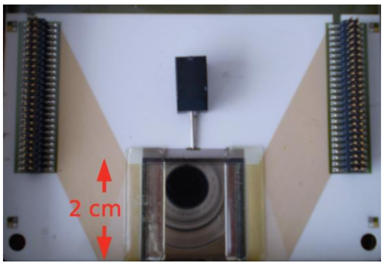
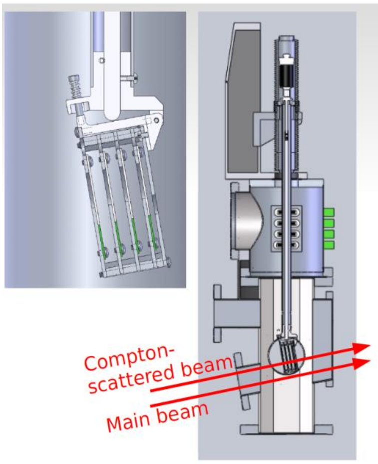
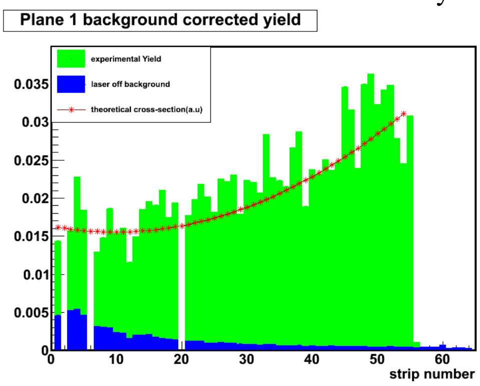


Figure 8: One of the Hall C Compton diamond detector plane



(a) Layout of the Hall C Compton Electron detector

Compton spectra are recorded for each beam helicity as shown in Fig. 9b.



(b) Typical Compton energy spectrum

The Compton asymmetry can then be computed Fig. 10 strip by strip and by fitting the asymmetry one has access to the beam polarization.

Beam polarization was measured for the QWeak experiment at 0.6 % accuracy [4] at electron energy of 1 GeV.

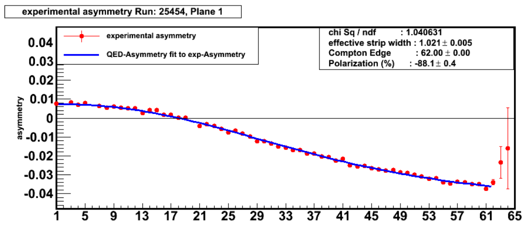


Figure 10: Compton electron detector asymmetry as a function of strip number (energy)

3.3 EIC Compton electron detector design

With the successful experience of the Hall C detector the JLEIC baseline detector is also diamond strip detector which proved to be able to sustain radiation doses greater than 10 MRad without hint of damages during the QWeak experiment. Conditions at EIC are very different to the current JLAB setup in terms of current, while 80 μA of current is available at JLAB, JLEIC will run high current going from 0.72A up to 3A. At such high currents, background from the electron beam can be significant, shielding and cooling might be needed to protect the detector from the large amount of RF power deposited from the beam. Such additional material can affect the shape of the detector response and introduce systematic errors on the polarization measurement. A current effort on studying the feasibility of a Compton Electron polarimeter is being co-funded by Jefferson Laboratory and BNL EIC R&D fund as proposal eRD15 [5]. We are currently investigating a detector design similar to the Hall C detector with a motion allowing to adjust the distance from the beam depending on the energy. A Roman Pot configuration as shown in Fig. 11 is being studied would allow for cooling, placing the amplifiers close to the detector and easy servicing of the detector.

3.4 Simulation

In order to determine the expected background in the detector which would determine the required laser power to do the measurement, a simple implementation of the Compton electron detector was introduced in Geant 4 Monte Carlo (GEMC) JLEIC simulation. Contribution from Bremsstrahlung was evaluated by increasing the gas pressure in the beamline and scaling it back to expected value of the vacuum. Electron were transported from the IP to the end of the Compton chicane and particles reaching the detector were recorded. A Compton event generator was also adapted to the GEMC simulation to be able to determine the expected signal. In Fig. 12, one can see the signal to noise ratio for a 10 W laser and 1 A of 5 GeV electron beam. The signal to noise ration is more than 100 for now so our preliminary option for the laser is a single pass laser.

Additional background source have to be studies such as Synchrotron radiation and effect of additional particles coming from the interaction point. The effect of the Roman Pot thin windows is starting to be studied to see how much it will degrade the accuracy of the measurement. A low statistics comparison is show on Fig. 13.

The running of the simulation is being implemented to be run on the batch farm to allow for high statistics studies and the analysis code used for the QWeak experiment is being adapted to extract a polarization from the pseudo-data to study the systematic error introduced.

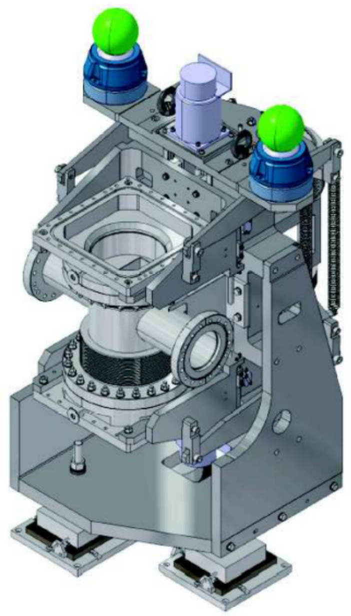


Figure 11: Example of TOTEM Roman Pot at CERN LHC. The detector fits in the rectangular cavity seen at the top in the cylinder allowing for a couple of centimeter of motion.

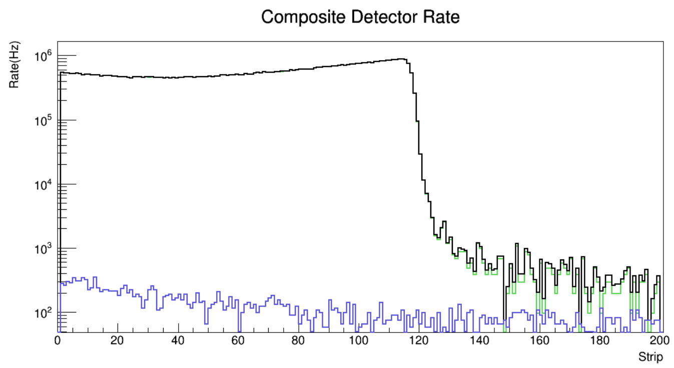


Figure 12: Signal to background ratio for 10 W laser and 1 A of beam current at 5 GeV

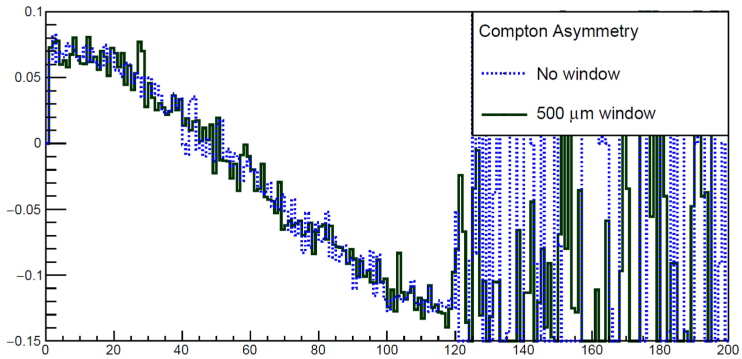


Figure 13: Preliminary comparison of effect of metallic window in front of the electron detector

4. Conclusion

The JLAB EIC is a polarized electron and ion machine. It features a low Q^2 chicane allowing to look at quasi-real photons physics. Expected momentum resolution is 10^{-3}. This chicane will also host a Compton polarimeter. Compton polarimetry is a natural candidate for electron beam polarization measurements at EIC considering the high energy and high current available. Experience from Jefferson Laboratory has shown than sub-percent electron polarization measurements were feasible for both Compton photon and electron detection for an energy ranging 1 to 3 GeV. With the increase current additional shielding of the detector has to be done. An ongoing R&D effort (eRD15) focusing on the Compton electron detection has been funded from the EIC R&D fund. It will evaluate the effect of the shielding on the measurement will be evaluated through simulation. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177 andDE-AC05-06OR23177.

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