eRD12 Progress Report - Status Update on Polarimeter, Luminosity Monitor and Low Q^2-Tagger for Electron Beam

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This document describes the progress made since the last July 2014 report [1, 2] on the polarimeter, luminosity monitor and low Q^2-tagger projects and the general integration within the interaction region (IR). More information can be found in the eRHIC design study report [3]

1 Overall Progress Summary

Progress has been made since the last report. The last report listed four points of topic which are repeated here:

1. Hire a postdoc for the project
2. Develop a Monte Carlo code, which calculates small and wide angle bremsstrahlung taking into account polarization dependencies
3. Improve the IR design to integrate all the requirements coming from physics in the hadron and electron beam direction
4. Integrate the IR design in the EicRoot simulation framework

The progress towards completing each item will be discussed in more detail below.

1.1 Hiring of the PostDoc

This has been completed. Richard Petti was hired to take on this project, and started on August 11^{th}, 2014.

1.2 Monte Carlo code to simulate polarized Bremsstrahlung

No new progress has been made on this front since the July report.

1.3 IR-Design

Significant progress has been made on this topic, as this has been the major current effort of Richard Petti since August. A new iteration of the IR design has been released by Brett Parker. The major design change from the last report is the inclusion of dipole magnets on the hadron beam beyond 25m to bend the beam to fit around the ring. There are also more focusing quad magnetics added to the electron beam not shown in the figure, but included in the EicRoot framework. A schematic of the current IR design is shown in Fig. 1.

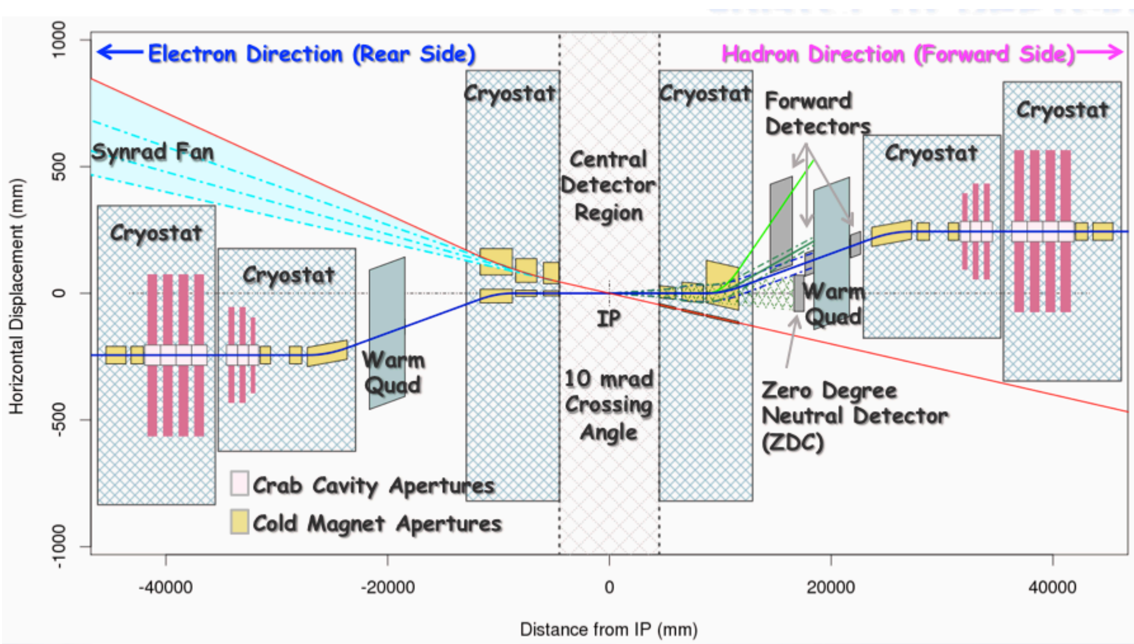

Figure 1: Schematic layout of the eRHIC interaction region.

The experimental physicists are currently working with and providing feedback to the machine developers on the current design and we are beginning the iteration process to converge on a design that meets the requirements posed by the EIC physics on the IR design [3, 4, 5].

1.4 Integration of the IR design in the eRHIC simulation framework

Alexander Kiselev, Brett Parker, and Stephen Brooks have finished the implementation of the importing of the CAD files and magnetic field maps into the EicRoot framework. Stephen Brooks encodes the information into .csv files, which contain the beam line element geometries of the apertures and the magnetic field implementation. Alexander Kiselev further developed the EicRoot code to read in these files, add magnet yokes to the configuration, and increased the functionality for easily selecting various components of the beam line to be installed during the simulation. An event display of the setup in EicRoot is shown in Fig. 2. The physical beam lines are omitted for clarity, leaving only the magnet yokes and detectors visible in the display. For more information on the EicRoot simulation framework, please see the wiki [6].

2 Beyond the four points of action from the last report

Progress has been made on the experiment side of the project. All of the work thus far has been focused on the low Q^2-tagger design. This will be completed shortly and the next task is to move on to the polarimeter and luminosity detector design and integration.

2.1 IR design of the electron beam and the low Q^2-tagger

An initial design of a low Q^2-tagger has been implemented in the EicRoot framework, including a dedicated class object for the detector. The current design is shown in Fig. 2. Panel (a) of the figure shows the low Q^2-tagger in relation to the entire IR setup. It is the small detector to the left of the figure. Panel (b) shows a zoomed in view of the detector so that some details can be resolved.

As can be seen, the planned detector is compact and should be able to meet our needs with a relatively simple design. The current design is roughly 20cm x 30cm x 40cm in size. It consists of two tracking layers (in yellow in panel (b) of the figure) followed by an electromagnetic calorimeter (in violet in panel (b) of the figure). We are considering adding a third tracking layer for redundancy. This simple design would allow the reconstruction of the scattering angle, θ, and energy of the scattered electrons. The detector is placed roughly 15m down the beam line in the electron going direction. To maximize acceptance at low angle, the detector will be placed as close to the beam pipe as possible. The placement in the current simulation is at 2cm from the nominal beam center. A beam pipe with a thin exit window must be designed to minimize energy loss off electrons. This will be done in collaboration with BNL-CAD. The expected synchrotron radiation fan of the beam (indicated in Fig. 1) is on the other side of the beam from where the tagger will be placed, and so should have minimal effect.

An initial scattering angle reconstruction algorithm has been developed, which makes use of look up histograms to map out the phase space of θ as a function of particle energy,

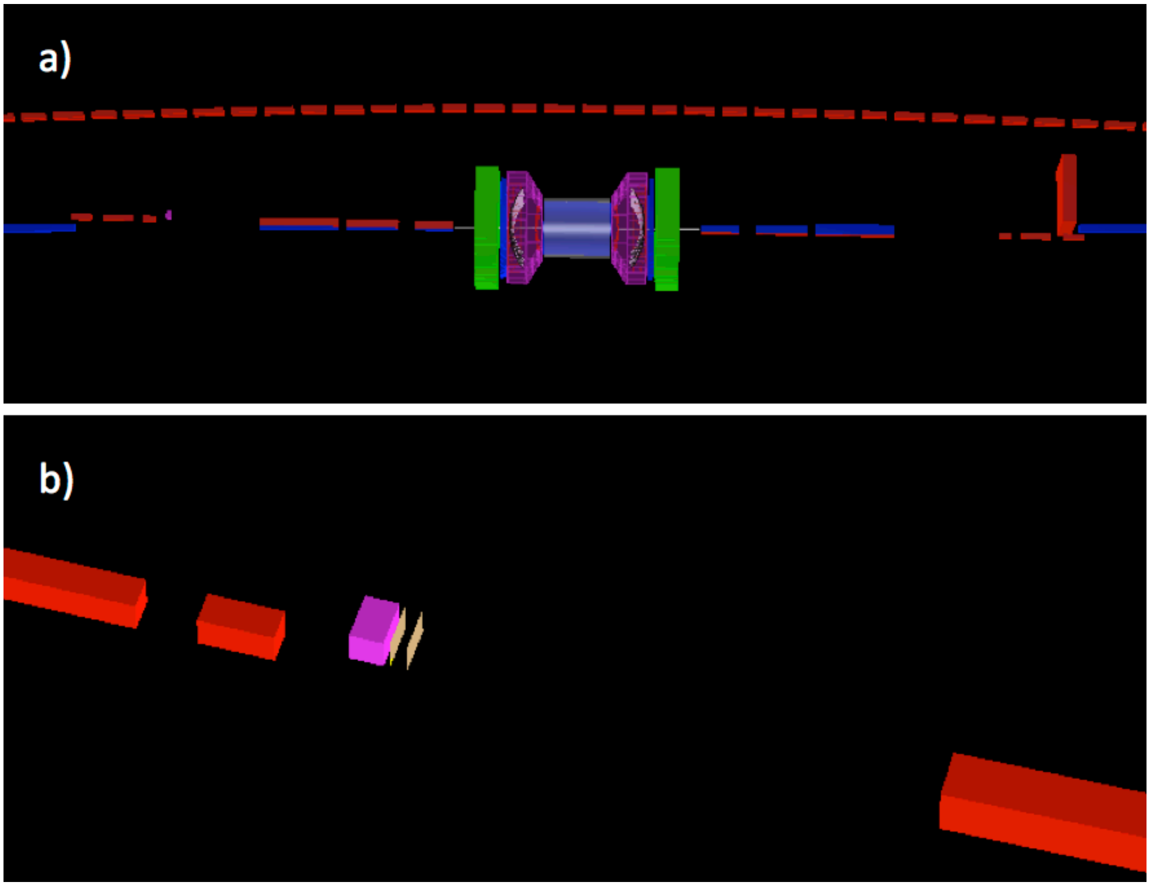

Figure 2: Panel (a): An event display showing the IR setup in the EicRoot framework. The main detector is seen in the center of the figure. The electron beam (center red), FFAG bypass (top red), and hadron beam (blue) lines are all implemented in the simulation. The low Q2-tagger is shown as the small detector on the left (at about 15m). The placement of the Roman Pot detector is also shown by the red block on the right side of the figure (at 18m). Panel (b): A zoomed in view of the low Q^2-tagger.

hit position in the first layer, and slope of the track as calculated by the hits in the two layers. The initial idealized performance is good, with a resolution on the order of 1.5%, shown in Fig. 3. Realistic position and energy resolutions need to be included to truly asses the expected scattering angle resolution of the detector.

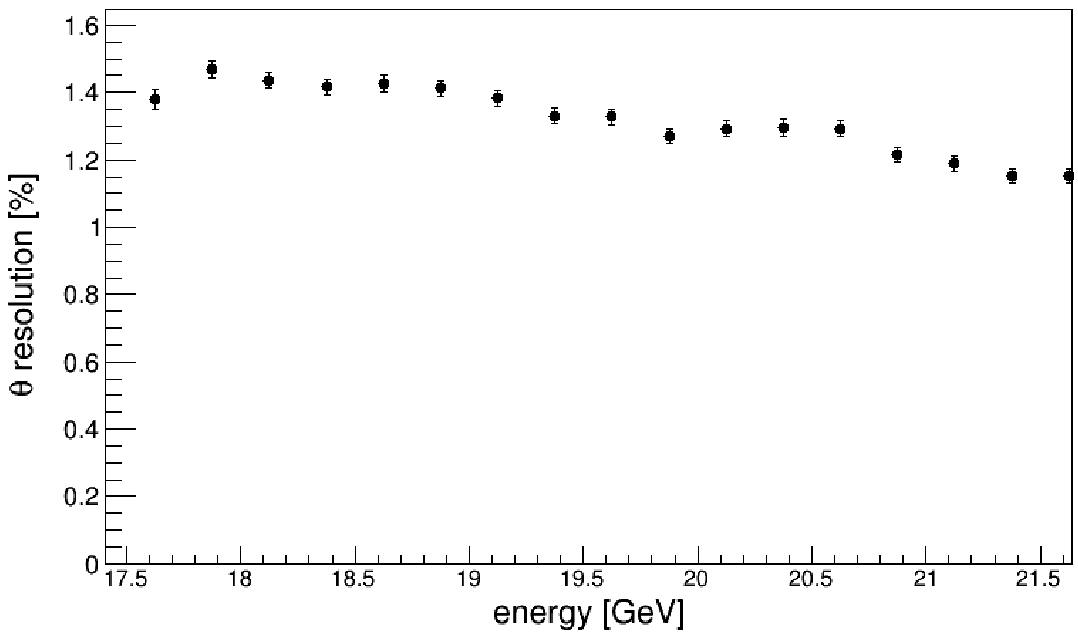

Figure 3: The idealized resolution for θ extracted from the simulation and the described reconstruction algorithm shown as a function of electron energy.

Recommendations based on the simulations have been proposed to the machine designers to further improve the IR. It has been found that the electron beam apertures in the magnet yokes in the current v2.1 design limit the acceptance of low scattering angle electrons. The electron beam aperture is aligned parallel with the hadron beam line, while the electron beam crosses at an angle of 10 mrad at the interaction point. This is not ideal in terms of acceptance. A simple rotation of the orientation of the apertures around the y-axis can significantly increase acceptance in Q^2. This is illustrated in Figs. 4 and 5, where the track hits on the first layer are plotted in the x-y plane. Fig. 4 shows the acceptance in this space for the nominal IR design, while Fig. 5 shows the same acceptance space with the apertures rotated by 30 mrad around the y-axis. A clear improvement is seen in the extension of the acceptance, the θ reach extends from about 2 mrad to 6 mrad. Two example energy bins are shown, which will dominate the collected statistics in real events. We have brought this to the attention of Brett Parker and Vadim Ptitsyn, these are technically straight-forward modifications to be implemented in the next iteration of the design.

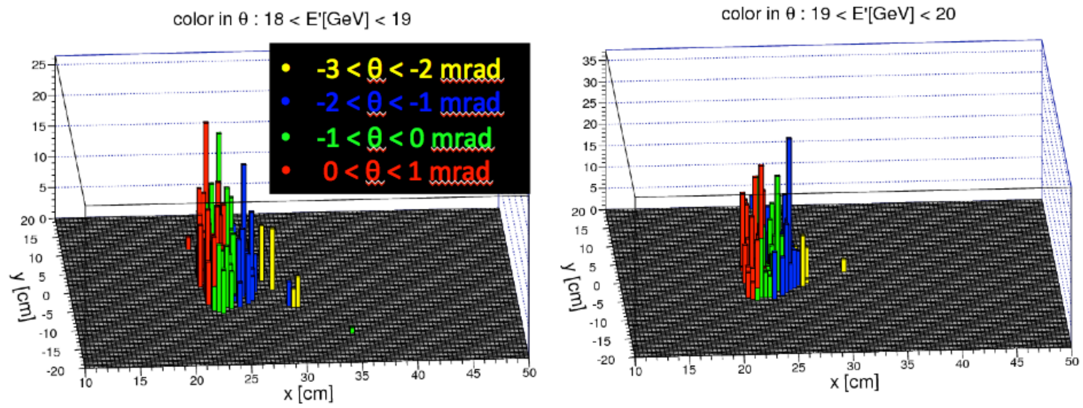

Figure 4: The acceptance of scattered electrons on the xy plane of the detector tracking layer for the nominal IR design. The colors represent bins of θ as shown in the legend. The left plot is for the energy bin 18-19 GeV, the right plot for the energy bin 19-20GeV.

Fig. 6 shows the momentum and scattering angle distribution from a PYTHIA simulation of low $Q^2 < 0.01GeV^2$ e+p events. Using this as a guide we would like to have acceptance to θ <10 mrad.

2.2 IR design of the hadron beam and the Roman Pot

Simulations have been performed testing the acceptance of low angle scattered protons in the current v2.1 IR design in the proton going direction as well. The findings will be communicated to the machine designers for implementation into the next version of the IR design. This work goes beyond the original proposal, but due to space constraints it is useful to optimize both sides simultaneously. The main function of the Roman Pots is the detection of forward scattered protons from exclusive reactions (for more information on the physics requirements, see [7]). Roman Pots are a detector technology used in many other experiments (TOTEM at CERN [8], STAR at RHIC [9], and H1, ZEUS at HERA [10, 11] for example). The key feature of Roman Pots is that they consist of some tracker inside a retractable bellow system, so that the detector can be moved in and out to get as close to the beam as is feasible, allowing detection of particles scattered at very small angles. For these acceptance studies, a very simple detector setup was implemented into the simulation. A single large sensor layer was installed at 18m down the beam line (placed right before the second set of magnet triplets).

One thing immediately obvious from looking at the whole IR setup in the event display (see Panel (a) of Fig. 2) is that there is only room for detector coverage on one side of the beam, the other side is blocked by the electron beam line. This needs to be discussed

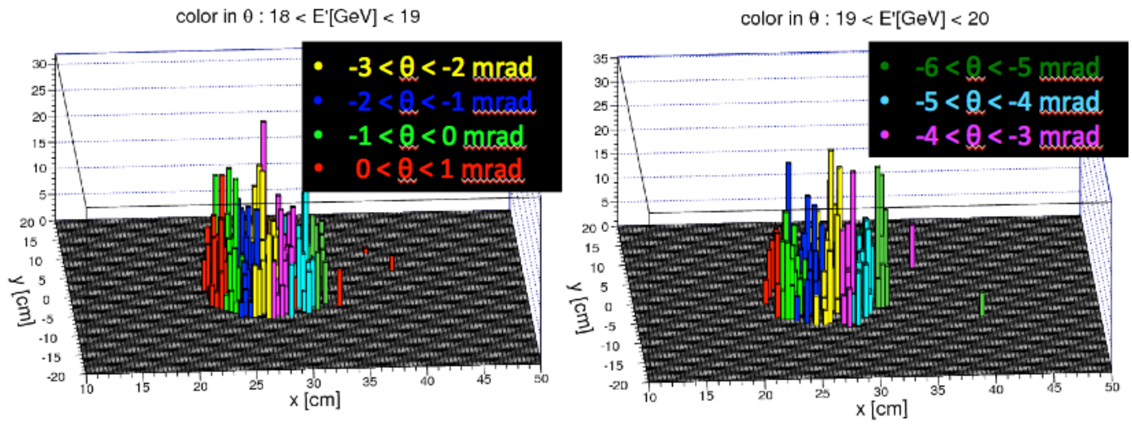

Figure 5: The acceptance of scattered electrons on the xy plane of the detector tracking layer for the modified IR design. The colors represent bins of θ as shown in the legend. The left plot is for the energy bin 18-19 GeV, the right plot for the energy bin 19-20GeV.

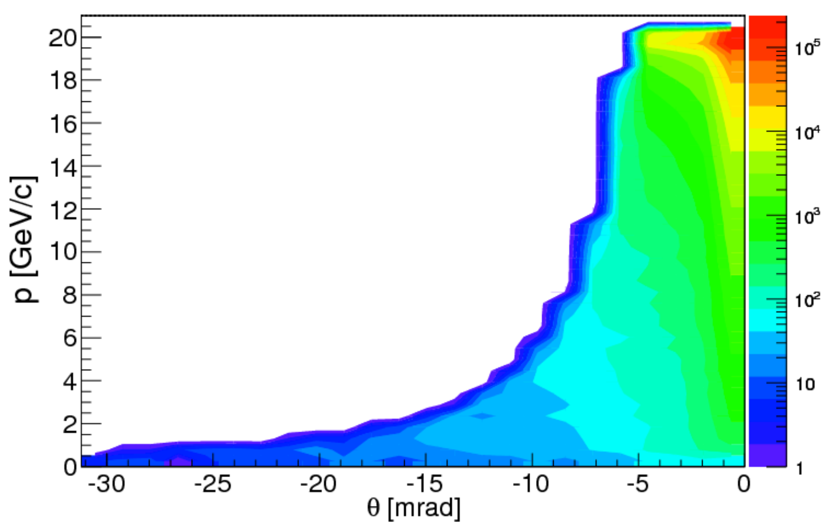

Figure 6: The momentum vs. θ distribution of the scattered electron in PYTHIA simulated e+p collisions from events with $Q^2 < 0.01 GeV^2$.

with the machine designers to find a more optimal placement. Even so, decent acceptance coverage can be achieved by placing sensors on the one side (as implemented in the simulations here) as well as covering directly above and below the beam. To increase acceptance at low scattering angle, it is desirable to place the detector as close to the beam as possible. In this simulation, the sensor is placed 10σ away from the expected beam width, corresponding to 1.8cm as calculated from the latest β-functions of the machine [3].

The acceptance is shown in Fig. 7 as a function of proton momentum and the corresponding $|t|$ of the reaction in panel (a), and as a function of proton momentum and scattering angle, θ in panel (b). In general the coverage is good, with the exception at high $|t|$, where there is virtually no coverage past $|t| = 0.8GeV^2$. As can be seen in panel (b), this loss is driven by scattered protons near beam energy with a relatively large scattering angle hitting the magnet yoke. This can most likely be improved with simple considerations as has been the case with the electron going side of the IR discussed in the last section. Alternatively, it may be beneficial to place a Roman Pot station much earlier in z in between the main detector and the first beam magnets, keeping in mind that the detector must be placed in a warm region of the IR to be of any use. An overall optimization of the location of the Roman Pot stations is a goal of the next iteration.

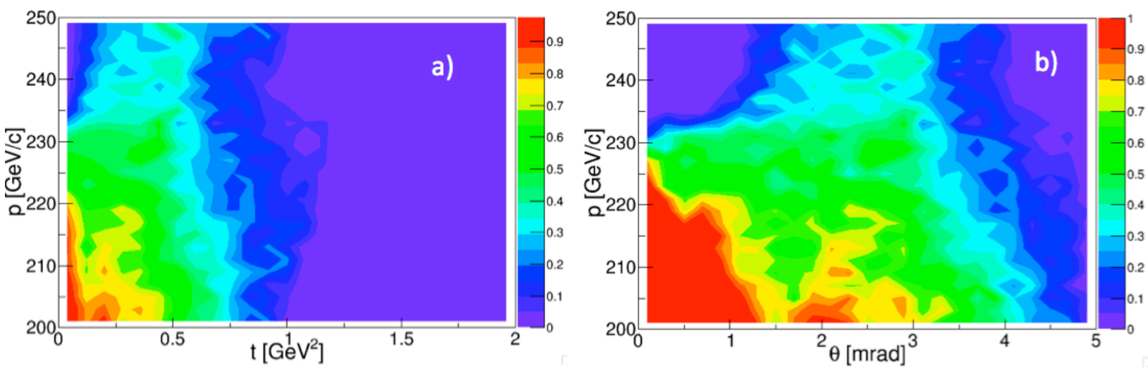

Figure 7: Acceptance plots of a Roman Pot detector placed at z=18m. Panel (a) shows the acceptance in proton momentum and $|t|$ space, panel (b) shows the acceptance in proton momentum and θ space.

3 Towards the next review

The studies concerning the low Q^2-tagger and Roman Pot designs in the IR should be completed in the next few months. Efforts will be ramped up on the polarimeter and luminosity detector designs and a more detailed report on this is expected at the next review.

References

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