Resolution studies for the ECCE EIC detector proposal

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As the preparation for the electron-ion collider, EIC, is progressing, detector proposals were submitted in December 2021 to the EIC Project. One of these proposals is the ECCE consortium[1] that has based its proposal around re-using the 1.5 T BaBar magnet that is currently prepared for the sPHENIX experiment and also the outer sPHENIX hadronic calorimeter. Re-using these two components allows for more resources to concentrate on the main detector components needed for a deeply inelastic scattering (DIS) collider experiments, namely tracking, electromagnetic calorimetry and particle identification. Given the ongoing involvement of Japanese groups in PHENIX and sPHENIX, it is only natural to continue on the ECCE proposal.

The main part of the proposal concentrated on the technical solutions to fulfill the scientific goals that were formulated in the EIC white paper,[2] the National Academy of Science report and the Yellow Report.[3] All of the key measurements were studied in full GEANT4 simulations of the ECCE detector. In DIS, the main process is the incoming lepton scattering off a quark from the incoming proton or nucleus. As such, the simplest way to reconstruct the hard interaction is by measuring the scattered lepton energy and scattering angle and reconstruct the momentum transfer Q^2 and the momentum fraction x that the quark carried relative to the proton momentum. Figure 1 shows the fraction of events that get reconstructed in the same x and Q^2 bin as the true kinematics (bin retention fraction) for a fine binning that was used in many impact studies of the Yellow Report. As can bee seen, the DIS kinematics can be reconstructed very well over a large range of the phase space, but toward the bottom right corner (at low inelasticity y) the resolution suffers at very small scattering angles. Here other reconstruction methods that also make use of the hadronic final state are preferable.

Next, for many studies related to the spin and three-dimensional structure of the nucleon, semi-inclusive DIS measurements also make use of detecting at least a final-state hadron as well. One of the most important quantities is the momentum fraction z this final-state hadron carries relative to the struck quark. At higher z the hadron is more likely to carry the struck quark and therefore acts as flavor analyzer. Other relevant variables are the transverse momentum relative to the virtual photon from the hard lepton-quark interaction and the azimuthal angles of hadron and incoming proton spin orientation relative to the scattering plane.

In Fig. 2 the average resolution of z for pions in the same fine x and Q^2 binning can be seen. It also suffers somewhat at lower z due to the scattered lepton reconstruction but otherwise is very well reconstructed. The other semi-inclusive variables are even more robust. Using these resolution studies the same impact studies as in the Yellow Report were revisited using a realistic detector simulation and show that the ECCE proposal is capable to carry out these measurements successfully.

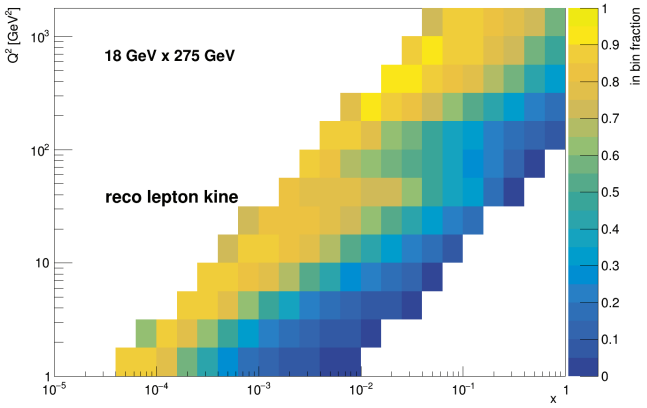

Fig. 1. Bin retention fractions in DIS events of 18 GeV on 275 GeV e-p collisions in bins of x and Q^2 when using the scattered lepton to calculate the DIS kinematics.

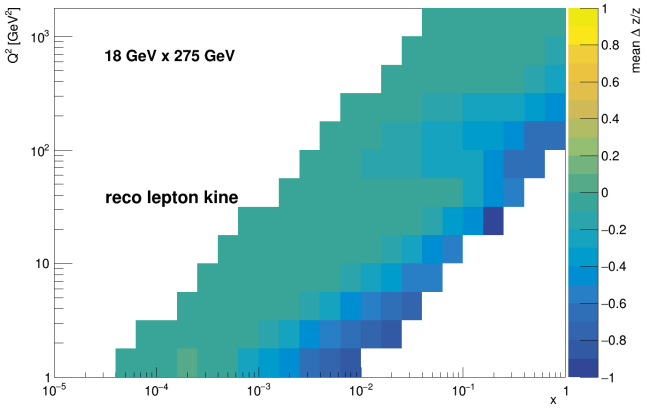

Fig. 2. z resolutions for pions in DIS events of 18 GeV on 275 GeV e-p collisions in bins of x and Q^2 when using the scattered lepton to calculate the DIS kinematics.

References

1) https://www.ecce-eic.org/.
2) A. Accardi *et al.*, Eur. Phys. J. A **52**, 268 (2016).
3) R. Abdul Khalek *et al.*, arXiv:2103.05419.

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