Simulation study of the charged current DIS cross-section measurement at the EIC

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The precise understanding of the proton structure is one of the keys to answering what matter is made of. Precision is also an important factor as an input in the LHC experiments[1,2] that investigate new physics from TeV-scale proton-proton collisions. While recent LHC results have improved the precision, the electron-proton (ep) scattering data from HERA[3] is still the most important input in the determination of the parton distribution in protons.

The primary process of interest at ep scattering is the deep inelastic scattering (DIS). It is an electroweak process via the exchange of a virtual photon or weak boson between the electron and a parton in the proton. The kinematic variables used to describe DIS are the energy scale Q^2, Bjorken x, and the inelasticity y. Charged current (CC) DIS proceeds via a $W^{\pm}$ boson exchange and hence is a charge selective process. It has a sensitivity to the distribution of quarks with the opposite charge of the incoming lepton.

The Electron Ion Collider (EIC) is the next collider scheduled to be built at the Brookhaven National Laboratory in US. The EIC performs collisions of electrons and protons or nuclei. It has a few beam-energy settings and the highest centre-of-mass energy is 141 GeV. The value is smaller than that of HERA; however, the high luminosity allows a measurement at the edge of the kinematic coverage of the EIC. The EIC is expected to have ep DIS cross-section measurements at the region with higher x values than the HERA data.

The ECCE detector[4] is a multi-purpose detector proposed at the EIC. The full detector simulation is available, and the CC DIS analysis is performed using the simulated samples. CC DIS events are generated as the signal events and neutral current DIS and photoproduction events are generated as background events for ep scattering at the highest beam-energy setting of 18 GeV × 275 GeV.

In CC DIS, the incoming electron is scattered as a neutrino and cannot be detected. The kinematic variables are reconstructed only from the information of the hadronic final state.[a] Resolution of the reconstructed variables are found to be typically at 15–25%, except for the region corresponding to the calorimeter edges. A large reconstruction bias is observed, possibly due to the insufficient calibration of the calorimeters.

The escaping neutrino creates an imbalance in transverse momentum (p_{T}) in the detected final state. Events with p_{T} imbalance are selected. Further criteria to ensure the quality of p_{T} imbalance are defined for the background rejection. The measurement is restricted to the region $Q^2 > 100$ GeV^2 and $y < 0.9$. The extraction of the cross section is conducted in bins of (x, Q^2). Owing to the large reconstruction bias, a coarse binning is set to avoid unreasonably large event migration. The uncertainties in the energy scale, energy resolution, and background estimation are propagated to the extracted cross section. The values of ±2% and 5% are *arbitrarily* assigned as the scale and resolution uncertainties, respectively.

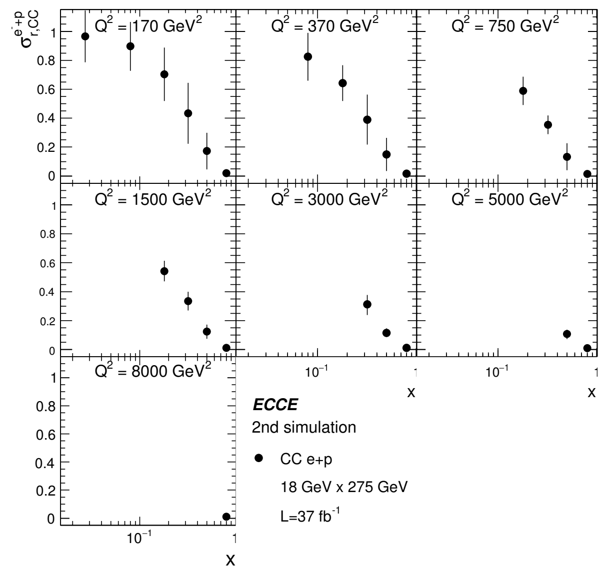

Fig. 1. Reduced CC DIS cross section for $e + p$ collisions at 18 GeV × 275 GeV extracted from the ECCE 2nd simulation samples. The total uncertainties are shown by vertical error bars. The statistical uncertainties are smaller than the size of markers.

Figure 1 shows the resulting cross section for 37 fb^{-1} of simulated collisions. The measurement reaches $(x, Q^2) = (0.8, 8000\ \mathrm{GeV}^2)$. The statistical uncertainty is small and the maximum value is given as 4% at $(x, Q^2) = (0.8, 170\ \mathrm{GeV}^2)$. The study covers a region of higher x values than that of the HERA data,[3] especially at the mild Q^2 region.

The EIC explores a region of high x, offering further information on the proton structure. Once the detector is adequately understood and properly calibrated, the measurement would be substantially improved with finer binning and smaller uncertainties.

References
1) ATLAS collaboration, J. Instrum. **3**, S08003 (2008).
2) CMS collaboration, J. Instrum. **3**, S08004 (2008).
3) H1 and ZEUS collaborations, Eur. Phys. J. C **75**, 580 (2015).
4) `https://www.ecce-eic.org/`.

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a) Calorimeter clusters are used with zero-mass assumption. In the future, tracking information could be included.