Semi-inclusive deep inelastic scattering at the Electron Ion Collider

R. Seidl*1

The electron-ion collider, EIC, will be a newly build accelerator at Brookhaven National Laboratory to collide polarized electrons with polarized protons and light ions, as well as unpolarized heavier nuclei. It will be the perfect place to study the strong interaction with collision energies between $\sqrt{s} = 29$ to 141 GeV and luminosities that are expected to be three orders of magnitude higher than achieved at the HERA ring in Germany. In early 2020 the US DOE office of science acknowledged the EIC officially as a project that will be built in the next 10 years. A large community of more than 1000 members has already formed with interest in the EIC, organized as the EIC user group.[1)] Within this group a call for a comprehensive Yellow report was formed that updates earlier publications on the physics goals[2,3)] and closely looks at the technological options for EIC detectors to have in order to fulfill these physics goals. The main process at the EIC is deeply inelastic lepton-nucleon (or nucleus) scattering, DIS, in which only the scattered lepton is detected. The kinematic variables x, which is the momentum fraction of the nucleon a parton has, and the momentum transfer of the process Q^2 can be extracted. Typically scales of $Q^2 > 1$ GeV^2 are considered as in that case the extracted cross sections and spin asymmetries can be factorized into hard scattering processes between partons that can be described by perturbative QCD and nonperturbative parton distribution functions, PDFs. PDFs describe the distribution of quarks and gluons within the nucleon as a function of the momentum fraction x at a given scale Q^2. In semi-inclusive DIS at least one final state hadron is also detected and the type, charge, momentum fraction z and transverse momentum relative to the boson mediating the lepton-parton scattering informs on the flavor, spin and intrinsic transverse momentum of the struck parton with the help of fragmentation functions. These semi-inclusive DIS processes cover most of the main physics goals of the EIC. For example, the spin contribution by individual sea quark flavors to the total nucleon spin can be probed this way. Also the three-dimensional momentum picture of the nucleon can be obtained via SIDIS measurements and the closely related Sivers function and the tensor charges for quarks, sea-quarks and gluons (gluons only for the Sivers function).

As an example of the work by the SIDIS group of the yellow report, the four-dimensional coverage of SIDIS hadrons was studied at all envisioned collision energies taking into account a potential detector configuration ranging from $-3.5 < \eta < 3.5$ with varying particle identification (PID) ranges depending on suitable technologies. Figure 1 displays the coverage for pions. One can see that at intermediate x and Q^2 the maximum PID momentum of only 6 GeV limits the expected coverage while elsewhere the coverage is sufficient. This is caused by the fact that at central rapidities no compact PID detector can cover a larger momentum range. Using these detector coverages and realistic smearing, pseudo-data was created resembling actual measurements extrapolated to about 10 fb^{-1}, which corresponds to about a year of EIC running. This pseudo-data was then used in global fits by theorists to extract the impact on various physics goals of the EIC such as the tensor charges that potentially relates to physics beyond the standard model,[4)] the Sivers function,[5)] as well as the expected scale dependence of the functions that relate to the three-dimensional momentum picture of the nucleon. The Yellow Report is now publicly available[6)] and provides the basis for the ongoing review process of the DOE.

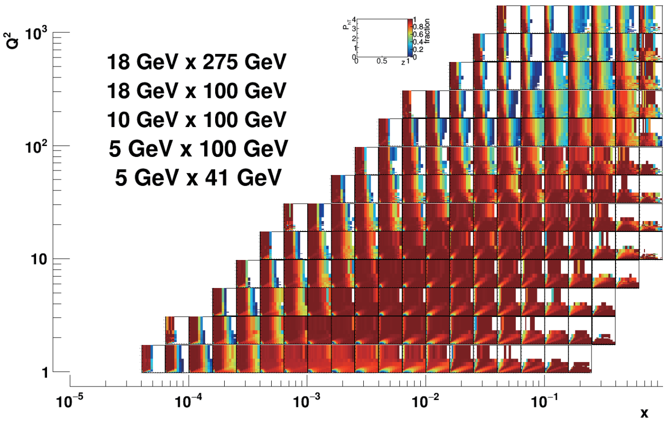

Fig. 1. Particle identification acceptance ratios for pions from semi-inclusive events at the EIC as a function of momentum fraction z and transverse momentum P_T, in bins of x and Q^2.

References
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*1 RIKEN Nishina Center