PROCEEDINGS OF SCIENCE

Polarized internal target experiments based on EIC beams

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The Electron-Ion Collider is under construction at BNL. It will have high-energy high-intensity polarized beams of electrons and hadrons. These beams will allow a high accuracy investigation of nucleon structure in the low- to very-low-x DIS regime. At the same time, similar to the realization at HERA, these beams could be used with an internal target for a very productive investigation of medium- to high-x nucleon structure. Due to a novel regime of electron beam operation and its high polarization and intensity, the Figure-of-Merit of an internal target experiment at EIC will be 500+ times higher than was obtained by HERMES.

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1. Introduction

Experiments with an electron beam and an internal target in the storage rings were proposed a long time ago, see e.g. Ref. [1]. They are productive due to fast damping of the beam particle oscillations thanks to intense synchrotron radiation. The important features of the internal target method were formulated soon after [2–4]. These include a continuous electron beam on the target, high luminosity for data taking, reduced interaction of the produced particles in the target, the possibility of using polarized atoms as a target, and the use of unique beams of positrons and antiprotons. Internal targets were used at BINP to study the light nuclei and a polarized deuteron [5–9].

In the 1980s, with the construction of the multi GeV electron storage rings at SLAC and DESY, two large scale experiments were proposed [10, 11]. They were motivated by the discovery of a nucleon “spin puzzle" by the EMC collaboration and the wide physics program on the meson and hadron structure which could be realized. The proposal for HERA [12, 13], focused on spin structure functions, was accepted and led to many key advances in hadron physics [14].

The physics program on PEGASYS included 14 topics shown in Fig. 1 taken from Ref. [15]. After experiments at HERMES, SLAC, Compass and JLab, most of these topics were advanced very significantly. Several of them, e.g. J/ψ production and Tagged structure functions, have become hot topics in recent years. At the same time, as is typical in science, with higher experimental productivity the next level of understanding of the hadron nature could be achieved.

The EIC Yellow Report [16] briefly indicated “opportunities from fixed target mode operation". The experiment productivity or Figure-of-Merit is defined by a product of the beam intensity, the square of the beam polarization, the target thickness (nucleon/cm^2), and the square of the nucleon polarization (including dilution factor): FOM $= I_e \times P_e^2 \times t_N \times P_N^2$. We show here that the EIC electron beam allows a huge increase in the experimental Figure-of-Merit, see also Ref. [17]. The EIC electron beam also allows us to create a tagged photon beam with energy up to 18 GeV which is now not available anywhere since the closing of the SLAC fixed target program.

2. Electron beam of the Electron-Ion Collider

According to the EIC CDR, the accelerator system includes the Rapid Cycling Synchrotron, which will provide a polarized electron beam into the electron ring where beam polarization as a function of time is shown in Fig. 2 taken from Ref. [18]. It also allows maintaining high beam current limited primarily by the RF power.

3. Luminosity and Figure-of-Merit of the internal-target-based experiment at EIC

For comparison of the Figure-of-Merit in a potential experiment (called for now “Heracles") at EIC and the one which had been achieved in HERMES we used information from the EIC accelerator report [18, 19] and from Ref. [20]. For HERMES we used average beam current 25 mA, luminosity of 1.2×10^{31} electron-nucleon/cm^2 (in the case of the deuteron target), 40% electron beam polarization and 85% target polarization [21]. The target thickness in the case of He-3 was 1×10^{15} nucleons/cm^2 with polarization 54%, limited by the required lifetime of the beam of 45 hours [22].

III. PHYSICS EXPERIMENTS

III.A Quark Hadronization in Deep Inelastic Scattering

III.B Nuclear Transparency in Exclusive Electroproduction Reactions

III.C Azimuthal Distributions of Leading Hadrons from the Nucleon

III.D Cumulative Production; Tagged Structure Functions

III.E Study of Inelastic and Quasi-elastic Scattering at Large x_{Bj}

III.F Nuclear Response to Deep Inelastic Scattering

III.G Inclusive Virtual Compton Scattering

III.H Exclusive Virtual Compton Scattering

III.J Precision Measurement of Internal Bremsstrahlung

III.K J/ψ Production

III.L Open Charm Production

III.M Exclusive Kaon Production from the Proton and Deuteron

III.N Search for New Particles Coupling only to Leptons

III.O Bose-Einstein Correlations in $eA \to e'\pi^{\pm}\pi^{\pm}X$

Figure 1: Physics program of PEGASYS [15].

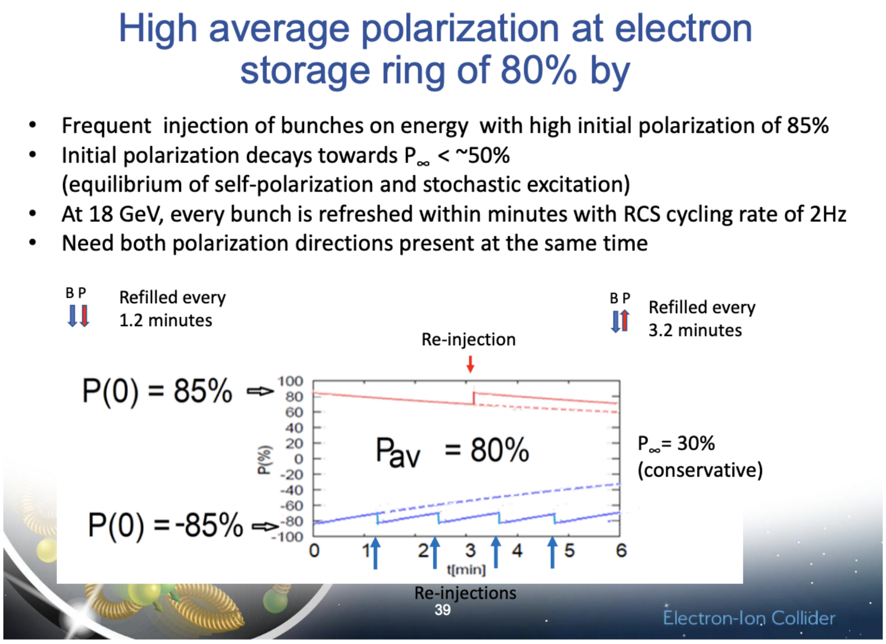

Figure 2: EIC beam polarization and intensity vs. time [18].

At EIC the projected beam current is 227 mA at 18 GeV and 2500 mA at 12 GeV, beam polarization 80%. The target thickness usable at EIC can be much higher because of frequent injection of the polarized beam. It is nine times higher for the triple length of the storage cell (from 40 cm to 120 cm) without significant loss of target polarization. For the He-3 target this leads to the EIC FOM with 18 GeV beam of 2×10^{33} compare to the HERMES FOM of 6×10^{30}, both in units electron-nucleons/cm^2 with the polarizations in square.

One example of a currently needed experiment is connected to the neutron and pion structure function accessible with the soft proton-tagged DIS. Such an experiment effectively deals with a “free" neutron target. This was in item III.D of the PEGASYS program, see Fig. 1. The initial set of data was taken by HERMES during its latest run [23] using a soft proton recoil detector and by BONUS/CLAS at JLab [24, 25]. A specialized setup for such an experiment with luminosity of 10^{36} electron-nucleons/cm^2 is under development by the TDIS collaboration [26] for the unpolarized target. Heracles will allow us to get double polarized data for this process with a deuteron target which will be a clean measurement of the spin-dependent neutron structure functions.

4. Layout of the experiment and detector

The layout of the experiment could follow that of HERMES as shown in Fig. 3 (or LHCb) with a natural upgrade of the tracking and particle identification detectors, as well as the data acquisition electronics, according to the technology developed over the last 30 years. For example, instead of the wire chambers for tracking, Heracles can use modern GEM-based detectors, which already operate in the SBS spectrometer at a luminosity of 10^{38} electron-nucleons/cm^2.

The data will be in the wide range of Q^2-x, defined mostly by the beam energy, which is between JLab and HERMES. However, due to 500+ times higher FOM the data will have 20+ times smaller error bars, which for example allow dramatic advance in high-x meson production physics.

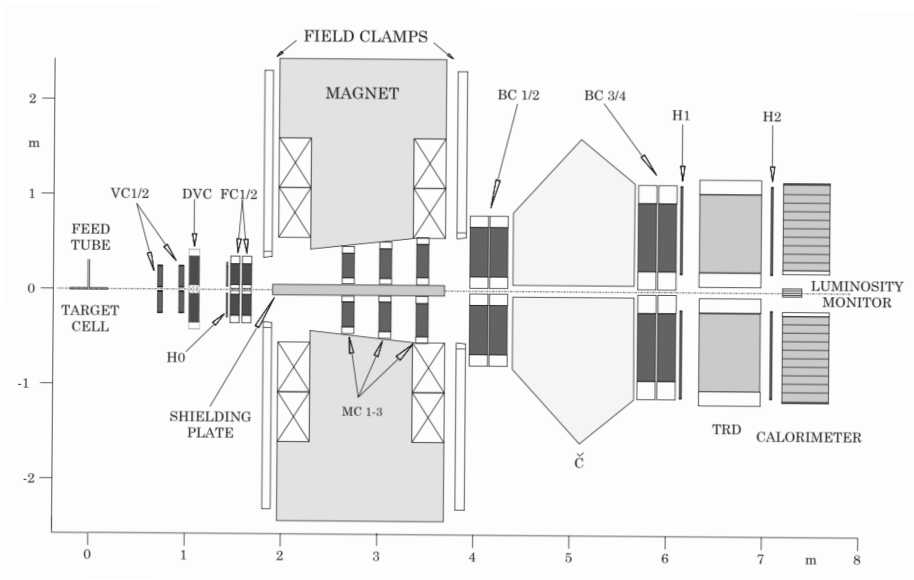

Figure 3: Layout of the HERMES spectrometer [20].

5. Conclusion

The beams of the EIC provide excellent opportunities for double polarized hadron physics experiments, especially with a high intensity 18 GeV polarized electron beam. They could be used for fixed target experiments similar to HERMES with much higher productivity (by a factor of 500+) and also for the tagged photon beam.

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