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eRHIC: The electron ion collider at BNL

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Abstract. Addition of a high intensity & high energy polarized electron/positron beam facility to the already existing Relativistic Heavy Ion Collider (RHIC) complex so that electrons/positron from that facility could collide with the RHIC hadron beams, would significantly enhance RHIC's ability to explore fundamental and universal aspects of QCD. We present here the high lights of the physics program that could result as a result of such a RHIC upgrade.

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1 Introduction

In the past few years considerable interest has developed in the experimental and theoretical nuclear physics community to study the scope of a physics program that could be pursued if a high energy electron beam facility is built at BNL and that beam is made to collide with the already existing hadron beams from RHIC. Such a facility is called eRHIC [1]. If the electron beam is polarized then not only could one study unpolarized deep inelastic scattering (DIS) using the unpolarized protons (e-p) or heavy ions (e-A) at RHIC, but also polarized DIS ($\mathbf{e} \cdot \mathbf{p}$) using the polarized protons from RHIC. No other experimental facility planned in near or distant future would have possibility of such a wide scope of experimental program.

2 What is eRHIC?

The nominal electron beam energy for this future facility under consideration is about 10 GeV, but it could be varied between 5 and 10 GeV. The variation of the hadron beam energy is already possible in the RHIC accelerators today. Using the highest possible value of the proton beam energy possible in the present RHIC of 250 GeV and a 10 GeV electrons from a new facility one could envision DIS with $\sqrt{s} \sim 100$ GeV. For polarized DIS which till now has only been pursued in fixed target mode this would be a factor of ~ 3 to ~ 20 increase in the value of $\sqrt{s}$. The facility will deliver at least 10^{33} cm^{-2}sec^{-1} luminosity. For unpolarized DIS off of heavy ions, it is expected that RHIC would provide beams of 100 GeV/nucleon. This implies that using a 10 GeV electron beam one could attain $\sqrt{s} \sim 60$ GeV for e-A collisions. Using the electron, proton beam energies mentioned above and the the simple relation between the kinematic variables it is obvious that with eRHIC one can reach x as low as few $\times 10^{-4}$ and as high as 0.8 for $Q^2 \geq 1$ GeV^2. If the requirement of $Q^2 > 1$ is removed, eRHIC could access (in photo-production region, for example) $x \sim 10^{-5}$. For a nuclear beam one could reach $x \sim 10^{-3}$ values for $Q^2 > 1$ GeV^2. Figure 1 shows the $x - Q^2$ kinematic reach of the eRHIC (e-p) compared to the fixed target experiments of the past and present.

3 The polarized e-p physics at eRHIC

In the case of polarized DIS off of proton beams the program for such a collider facility is well defined [2,3,4]: eRHIC will enable accucrate measurement of the spin struc-

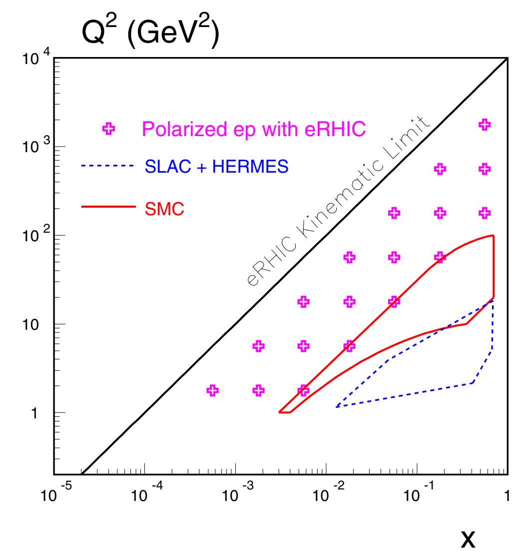

Fig. 1. The $x - Q^2$ kinematic coverage of the eRHIC compared with the present and past fixed target polarized DIS experiments

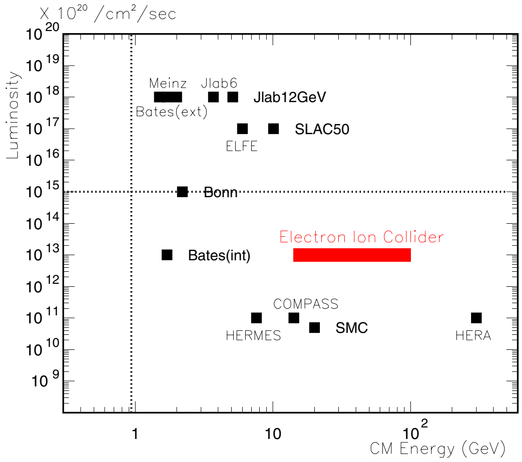

Fig. 2. The center of mass energy vs the e-p luminosity plot for past and some future DIS facilities

ture function of the proton and of neutron (if $^3\mathrm{He}^{+2}$ can be stored in the RHIC ring) in the low-x region which is the source of the largest uncertainty in the first moments $\Gamma_1^{p/n}$ and the Bjorken sum rule. The spin carried by the polarized gluon inside a nucleon is a yet unmeasured quantity. eRHIC would measure that unambiguously and using theoretically and experimentally clean techniques of pQCD analysis at NLO, the photon-gluon-fusion process resulting in di-jet or 2 high p_T oppositely charged tracks, and using photoproduction of di-jets and high p_T tracks. Further eRHIC facility would be unique in its ability to study and resolve the polarized parton distribution inside a polarized photon. Investigations based on charged current e-p scattering would allow a first and unique measurement of the parity violating structure function $g_5^{\pm}$. There would also be other measurements possible with eRHIC that would be semi-inclusive and exclusive in nature, which will help resolve the spin structure of the nucleon along with the above mentioned measurements with much better accuracy than possible in present day DIS experiments and by those planned to be operational in a few years.

4 Unpolarized e-A physics at eRHIC

With the eRHIC, one can also perform unpolarized DIS using the heavy ions in RHIC. The most interesting kinematic region indicating unusual nuclear phenomena is at low x [5]. In the last decade, experiments at HERA have provided hints of saturation of unpolarized F_2 structure functions at low x. However, exploration of even higher gluonic density kinematics is necessary to confirm these observations. With eRHIC's lower CM energy compared to HERA's, this is not possible with protons, however, one could use a heavy ion to enhance the gluon densities and expect to see saturation phenomena using the RHIC beams in e-A DIS. Some theorists have boldly described this saturation phenomenon as indicate formation of a new and unique state of matter, and called it the Color Glass Condensate (CGC). Indirect evidence for its existance seen from HERA data could be confirmed with direct measurements of e-A at eRHIC. Properties of CGC can be probed by measuring both the inclusive as well as exclusive processes in e-A scattering. Understanding the CGC would be critical in the investigations of QGP underway at RHIC and at LHC in future. Experimental signatures for this kind of unusual phenomena have been predicted in various recent publications [5]. The eRHIC will be a unique place to study this physics in detail as a function of A (e.g. the atomic number) of the beam. Also, the variable energies for each nuclear beam will allow a study of the onset of saturation physics. Other unpolarized DIS phenomena which have been studied in the past in the fixed target environment have been mainly related to color transparency, EMC effect and other intermediate low-x related phenomena. These could also now be studied at eRHIC with ease.

5 Outlook

Various subgroups are now being formed to realize the EIC project and its physics [1]. The activities of the accelerator working group formed principally by the collaboration of MIT/Bates and BNL have resulted in a preliminary design for the electron ring that could realize the EIC at BNL. A small group of people met recently at BNL to discuss the electron beam polarimetry and its into the electron ring accelerator design. Physics groups have continued their activities in smaller subgroups and are expected to present their investigations at regular intervals. EIC collaborations meetings are presently planned at a frequency of once a year. The detector development activity is about to start. Integration of the detector with the accelerator lattice is one of the issues of particular interest to the EIC community because of the particular interest in low x physics and the demanding particle ID requirements posed by exclusive physics interests [1,3].

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