eRHIC

Zero[th]-Order Design Report

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Executive Summary

The scientific case and the scope of a high energy electron-ion collider with high luminosity to study the fundamental structure of matter using the deep inelastic scattering has been discussed in the nuclear physics communities around the world for the past few years. A collider at BNL which adds a new, 10 GeV/c, high intensity polarized electron/positron beam to the existing Relativistic Heavy Ion Collider (RHIC) complex, called "eRHIC", was first presented to NSAC in 2001. NSAC supported this idea enthusiastically and encouraged rapid R&D towards realizing such facility. Since then eRHIC has successfully gone through multiple BNL internal and NSAC sub-panel reviews. It has recently appeared on the list of 28 scientific projects supported by the US Department of Energy Twenty-Year Science Facility Plan.

This report, the eRHIC Zeroth-Order Design Report (ZDR), is the first detailed document reporting studies on the accelerator and the interaction region of this collider. The ZDR results from several months of studies performed jointly by BNL and MIT-Bates, with close collaboration with scientists from BINP (Novosibirsk) and DESY (Hamburg). The principal goals of these studies are to develop an initial design for eRHIC, to investigate accelerator physics issues most important for its design, and to evaluate the luminosities that could be achieved in such a collider if it were to be built in the near future with minimal R&D. Secondary goals include identifying specific accelerator aspects needing varying levels of R&D, which would lead to significantly higher luminosities. It is assumed that the time scale for realizing eRHIC is short enough, that at least one if not two experiments at RHIC are still taking data in an upgraded RHICII collider, using upgraded RHIC detectors. Those experiments and eRHIC would share one of the hadron beams in RHIC.

RHIC proton and heavy ion beams can be stored at design energies of 250 GeV and 100 GeV per nucleon, but they can also be stored at lower energies. eRHIC will provide collisions with variable center-of-mass energies, with longitudinal and/or transverse polarization in the interaction region (IR) for both electron and hadron beams. The main design option for eRHIC presented in the report is based on the construction of a 10 GeV electron/positron storage ring, adjacent to either the 12 or 4 o'clock collision point of RHIC, intersecting with one of the RHIC hadron beams. The electron beam energy will be variable down to ~5 GeV with minimal loss in luminosity and in polarization for collisions. The electron beam injector system will consist of linacs and recirculators fed by a polarized electron source. The study suggests that an e-p collision luminosity of 4×10^{32} $cm^{-2}s^{-1}$ can be achieved for the high-energy mode (10 GeV on 250 GeV), if the electron beam facility is designed using today's established state-of-the-art reliable accelerator technology, without an extensive R&D program. For the electron-gold ions collisions (10 GeV on 100 GeV/u), the same design results in a luminosity of about 4×10^{30} $cm^{-2}s^{-1}$. The potential to go to significantly higher luminosities by increasing the electron beam intensity will be explored in the future. A polarized positron beam of 10 GeV energy and high intensity will also be possible, using the process of self-polarization due to synchrotron radiation in the ring to build up the beam polarization.

eRHIC requires some modifications of the RHIC hadron rings. Most important among them are

a) the addition of electron cooling system, to achieve and maintain small beam emittances (this is also required for the RHICII upgrade plans), and
b) increasing the number of bunches in each ring from 120 to 360, consistent with the RF frequency of the present RF system.

Feasibility of such a total intensity increase requires further studies on topics such as the effect of electron cloud formation and an appropriate injection scheme.

A preliminary design for the eRHIC interaction region has been developed, providing early beam separation for the hadron and electron beams and including spin rotators in both the electron and the ion rings. The non-colliding RHIC ion beam avoids the IR region by a trajectory bypass. Preliminary issues related to the integration of a detector into the IR design have also been considered, anticipating regions of intense synchrotron radiation generated by the bends in the electron beam. An acceptable solution seems possible.

A possible alternative design for eRHIC is also presented as an appendix. This considers an electron accelerator based on an energy recovery superconducting linac (ERL), instead of a storage ring. Preliminary estimates suggest that this design option could produce higher luminosities, but requires significant R&D efforts for the polarized electron source and for the energy recovery technology. Consequently this has a longer time horizon and a larger uncertainty in the estimate of performance and costs involved. Work on both options for eRHIC will continue in the foreseeable future, until the final construction timescale demands freezing the design, and the technology.