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A new comprehensive detector for RHIC-II

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Abstract

The proposed upgrade to the Relativistic Heavy Ion Collider at Brookhaven National Laboratory will result in a factor of 40 increase in luminosity from that currently available. I present concepts for a comprehensive new detector designed to exploit the wealth of physics that will then become accessible. The design incorporates high rate detectors and particle identification up to a transverse momentum of ~20 GeV/c with complete azimuthal coverage over almost the entire RHIC rapidity range. High statistics quarkonia measurements and a comprehensive jet program are examples of the unique physics made available by this detector design. "Tomographic" measurements of the quark gluon plasma, believed to be formed at RHIC energies, are made possible through the use of hard-scattering probes. The forward region will also be explored providing new insight into initial conditions of RHIC collisions. In addition this detector design is optimal for studies to determine the dynamics and structure of the proton, thus making full use of the polarized proton beams at RHIC.
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1. Introduction

The proposed design for a comprehensive new detector at the future RHIC-II (Relativistic Heavy Ion Collider) complex will allow a unique, in-depth, experimental program to be performed. The exceptional features of the proposal are based on the desire to answer several compelling physics questions:

- There is currently much evidence for a strongly-coupled Quark Gluon Plasma (sQGP) at RHIC. If a sQGP is created what are its precise properties?
- What is the effect of chiral symmetry restoration on hadronization in a dense medium? What is the chiral structure of the QCD vacuum and its influence on the masses of particles?

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- Is there another phase of matter at low Bjorken-x, i.e. the color glass condensate (CGC)? If present, what are its features and how does it evolve into the QGP? If not, are parton distribution functions understood at low Bjorken-x and can they describe particle production?
- What are the structure and dynamics inside the proton, including parton spin and orbital angular momentum? What are the contributions of gluons and the QCD sea to the polarization of the proton. What is the flavor-dependence? Are there tests for new physics beyond the standard model from spin measurements at RHIC-II (such as parity-violating interactions)?

To answer these questions we believe that both an upgrade to the existing RHIC accelerator and a comprehensive new detector are needed.[1] Although both the PHENIX and STAR experiments have several upgrade programs planned [1,2] neither will have as complete an acceptance coverage and/or such a large PID range as this new detector. It is only through the high luminosity of RHIC-II in combination with tracking, particle identification, electro-magnetic/hadronic calorimetry all over a large acceptance and a high rate experiment that they can be studied in an effective and efficient manner.

2. The detector concept

The requirements for the new detector are therefore quite specific and result in a design very similar to existing high energy experiments plus a few features necessary for a heavy ion physics program; where large multiplicities, especially at low p_T, enforce fine granularity tracking and calorimetry. The requirements are:

- High rate detectors, data acquisition and trigger capabilities.
  - Essential, as the proposed program almost entirely involves detailed studies of rare processes.

- Complete hadronic and electromagnetic calorimetry over $\sim 4\pi$.
  - Required for jet, electron and photon reconstruction, triggering and correlation studies.

- Excellent charged particle momentum resolution in the mid-rapidity region up to $p_T \geqslant 40$ GeV/c.
  - For resolving the individual Υ states and jet fragmentation and suppression studies.

- Central and forward rapidity particle identification for π, K, p and lepton separation (e/h and μ/h) out to $p_T \sim 20$–30 GeV/c.
  - Lepton separation is necessary for quarkonia reconstruction. Particle identification (PID) of charged particles is required for jet composition, leading particle identification and to study individual particle species kinematics at small Bjorken-x.

This detector has the ability to be successfully operated in proton–proton (polarized and unpolarized), proton–nucleus and nucleus–nucleus collisions.

The conceptual design for the detector is shown in Fig. 1. The barrel region ($|\eta| < 1.2$) is implemented from the inside out with a small radius, thin, Berylium beam pipe, a silicon microvertex tracker, a primary tracker, a ring imaging cherencov detector (RICH), a time of flight (ToF)/aerogel combination, a high p_T tracker, an electromagnetic calorimeter (EMCal), a hadronic calorimeter (HCal) embedded in the magnet and muon chambers. The $2.5 < \eta < 3.5$ detector layout is similar with forward silicon disk tracking, PID components, calorimetry and muon chambers. At $\eta > 3.5$ a separate forward spectrometer is planned with a silicon disk tracker, in a separate magnetic field. This is supplemented by a RICH, an EMCal, and/or HCal. The location of the RHIC DX magnets limit the forward reach of the spectrome-

[1] I agree with the referee that a detailed comparison between STAR, PHENIX and the new detector would be very interesting. However I do not think I have space in these four pages to make a fair comparison and do not wish to make only s-partial comparison as this would be biased. Therefore I have added references to the upgrade talks from both STAR and PHENIX, which were complete in their details and leave it to the reader to make the comparison him/herself.

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