PROPOSAL FOR A RIKEN-BNL WORKSHOP

Current and Future Directions at RHIC

to be held at

Brookhaven National Laboratory
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Organizers

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1 Motivation and plans for the workshop

Our motivation for this workshop is twofold. Firstly, the RHIC experiments (in the "RHIC-I" phase) on A-A and polarized p-p scattering have accumulated a considerable amount of data. In the case of A-A collisions, data has been accumulated at the highest center of mass energy of $\sqrt{s} = 200$ GeV/nucleon. Data have also been accumulated for polarized p-p scattering at the same energy. The data from A-A collisions thus far are remarkable enough to suggest some of our ideas of the dynamics of heavy ion collisions have to be re-thought. Though data from the polarized p-p are yet to be published, it covers a *terra incognita* in polarized scattering. RHIC will provide, with unprecedented detail and accuracy, a wealth of information on the spin structure of the nucleon and on spin phenomena in QCD at high energies, as well as on unpolarized *pp* cross sections. A plan for this workshop would then be to bring together experts at the forefront of the theoretical and experimental communities in both A-A and polarized p-p scattering to understand the wealth of experimental data and to make fresh predictions for the upcoming RHIC runs.

A second motivation for this workshop is that it is not too soon to begin considering future directions at RHIC and the impetus for these from the results obtained from RHIC-I. Under active consideration are the "RHIC-II" upgrades in luminosities and detectors, as well as novel new directions such as eRHIC/EIC. It is important to discuss now the directions that RHIC-II can take. What can we learn from the increased luminosity? Can detector upgrades enable us to study physics in the forward region (particularly important for p-A/d-A scattering) and make feasible measurements of the spectrum of di-lepton, photon and vector meson production? The idea behind eRHIC/EIC is to introduce a high energy electron beam (10 GeV) and to study deeply inelastic scattering off nuclei and polarized eletron-polarized proton scattering at very luminosities. A fair amount of effort has already gone into studying these issues. This workshop will help consolidate and build on this work. We believe that it is very important for the success of the workshop that both theorists and experimentalists interested in such future developments attend and interact closely. This will allow to determine the physics case for each option, weighed against the experimental capabilities and requirements.

To be more specific, the main topics for current and future options that we plan to address are as follows:

- **experimental results and theoretical analysis of A-A results at RHIC** Over the course of this year, RHIC took the first data at full energy, $\sqrt{s} = 200$ A GeV. Following the commisioning run which ran at $\sqrt{s} = 130$ A GeV, the experimental groups have installed additional detectors and have collected one hundred times more data than previously. With additional statistics and experimental tools many of the suprising results of the commisioning run (v_2, HBT, fluctations, transverse energy, to name a few) can be confirmed and studied in unprecedented detail. These experimental results will be reported at Quark Matter 2002 from July 18-24.

  From a theoretical perspective, the months following Quark Matter 2002 may be the most important time of the whole RHIC program. The purpose of this workshop is to discuss the first full energy RHIC data in this singular period.

  Moreover, RHIC experiments have taken data from pp collisions at an energy of $\sqrt{s} =$ 200 GeV, and will soon take data from $d + Au$ collisions at the same energy. Those will provide very important baselines for the interpretation of the $Au + Au$ data. For example, the main source of uncertainty regarding the high-p_t suppression of single-inclusive hadron production, which is the missing baseline from pp and $p + Au$, will be eliminated. A large amount of data and experience from high-energy inelastic pp collisions has already been gathered at the Fermilab-Tevatron. It is important to establish contact between pp, pA, AA and eA communities and discuss how the RHIC pp and pA runs can benefit from the experience gained from the Tevatron and from the eA program at the proposed Electron Ion Collider (EIC).

- **experimental results and theoretical analysis of polarized p-p results at RHIC** Very recently, polarized protons have been collided for the first time. Despite the fact that many technical difficulties had to be overcome, the first, just completed, RHIC-Spin run has been a great success, and first results are expected to be made public within the next months. One motivation for our workshop is to discuss and study these first experimental results. Here, the main focus would be on single-spin asymmetries in large-p_T hadron production, and on spin asymmetries in elastic pp scattering. Note that unpolarized p-p data will be available at $\sqrt{s} = 200$ GeV/n. In addition to providing the calibration for A-A results at the same energy, these results will be interesting in their own right: never before have pp interactions been studied experimentally at center-of-mass energy in excess of 63 GeV! RHIC therefore opens a new window also on unpolarized pp physics. It will provide invaluable testing grounds for theory calculations and broaden our understanding of QCD. On the theoretical side, we will in particular address issues relating to higher-order QCD calculations, QCD resummations, parton distributions, and theoretical uncertainties. There has been a lot of activity in recent years on these topics, one reason being that experimental data and theoretical expectations in pp scattering have not always been in full accord. We plan to analyze the situation, pinpoint open problems, and to work towards their solution. In this way, we hope to obtain "state-of-the-art" theory predictions that can be put to the test at RHIC. We will discuss what particular RHIC measurements are expected to give the most useful pieces of information.

- **plans and physics prospects for a new RHIC detector,** specifically adapted to the pp collider situation. The present RHIC detectors are capable devices for measuring the final states relevant for investigating the nucleon spin structure. On the other hand, neither of the two big detectors (PHENIX and STAR) are classic hadron collider detectors, such as CDF or D0 at the Tevatron. In particular, the RHIC detectors are limited in angular acceptance, examples being photon or jet detection at PHENIX, or muon detection. Many spin physics measurements could be performed with much higher accuracy and detail, were the detectors more strongly dedicated to the pp situation. This would also allow to learn a great deal more about QCD and nucleon structure through detailed measurements of unpolarized cross sections. It has therefore been proposed to add a new detector to RHIC which would focused on the investigations of pp physics that will be missed by the presently available RHIC detectors even after their upgrades, in the RHIC II era, because of their principle focus on the heavy ion collisions. A possibility of adding an electron beam facility to the RHIC accelerator complex has been discussed recently (see below) which would enable collisions between that electron beam and the polarized proton and heavy ion beams at RHIC. It would require a new detector at the new collision point. The new pp detector mentioned in the above paragraph could be modified at the appropriate time to make it more suited for the asymmetric electron-ion collisions. Feasibility of such ideas could be discussed in this workshop.

- **RHIC upgrades in luminosity.** The accuracy of many measurements in spin physics at RHIC will be limited by statistics. Examples are the prompt photon spin asymmetry, or transversity measurements through Drell-Yan dimuon production. It is clear that an upgrade in luminosity would mean an important advance in this context. It is not even inconceivable that signals of physics beyond the standard model may just become visible at RHIC – again, this is also a question of statistical accuracy and hence of luminosity. Luminosity upgrades at RHIC by factors as large as 20 are currently discussed and appear not impossible. Again, their physics implications, as well as their technical aspects would be discussed at the workshop.

- **RHIC upgrades in energy.** Possibilities of increasing RHIC's top energy to 650 GeV have been discussed. This would open several new possibilities: first, it would enable measurements of cross sections and spin asymmetries in different kinematic regimes. For instance, a photon produced with transverse momentum $p_T = 10$ GeV at $\sqrt{s} = 200$ GeV mainly probes $x \sim 0.1$ in the parton distribution functions, while at $\sqrt{s} = 650$ GeV it will access $x \sim 0.03$. One will therefore obtain information on parton distribution functions over larger domains, and it will also be interesting to see whether measurements at various energies ($\sqrt{s} = 200, 500, 650$ GeV) will be mutually consistent, within QCD. In addition, it should be recalled that even in the unpolarized case measurements in *pp* collisions are limited to only $\sqrt{s_{\max}} = 63$ GeV, as mentioned above. RHIC at 650 GeV would therefore open a new window on QCD studies. Higher energies may also be crucial for seeing physics beyond the standard model. All these issues will be addressed in the workshop.

- ***ep* and *eA* physics at the EIC.** As mentioned earlier, it has been proposed to build a new electron-ion collider at BNL. To appreciate the general value of such a machine at Brookhaven, one simply needs to recall the way in which lepton-hadron and hadron-hadron colliders have provided complementary invaluable information on many aspects of nuclear and particle physics in the past. An electron-ion collider of the format currently discussed would open new windows on studies of nuclear structure and high-density regimes. It would be constructed in such a way that also polarized *ep* collisions could be studied – the resulting prospects for spin physics are enormous: precise measurements of spin structure functions, deeply-virtual Compton scattering, polarized photon structure, to mention just a few of the many possibilities that would arise.

  Considerable effort has already gone into physics and design studies for such a facility. In particular, a major workshop on the EIC was held here at Brookhaven this February, in which an exhaustive collection of topics, possibilities, but also challenges, was on the agenda. It was agreed to continue focused discussions on physics questions relevant for the EIC in the framework of long-term working groups. The workshop we propose here would be an ideal venue for coordinating and starting the efforts relating to (polarized) *ep* physics at the EIC. Two of us (A.D. & R.V.) hold a BNL Program Development Fund (PDF), which could be used to fund this part of the workshop.

Collider physics of the future need not necessarily be confined to RHIC. With LHC, an entirely new domain in particle physics will open up. Recently, discussions have begun whether, given a successful polarized p-p and A-Aera at RHIC, polarization of the proton beams in LHC is possible and/or desirable. Such studies are only in their infancy, but it is clearly conceivable that many aspects relating to "new physics" may be investigated in more detail at LHC. Given the proximity of this topic to RHIC physics, we plan to briefly address also LHC in our workshop. Once again, we think this is timely in view of the length of time such developments in particle physics take.

2 Format and timing of the workshop

We propose to format the workshop to have a duration of about three weeks. We propose that the workshop start August 5th and end August 24th, with a few participants arriving a little earlier or staying a little longer. The workshop is timed to follow the "Quark Matter" 2002 conference to be held in Nantes, France, from July 18-24 and to precede the "Spin-2002", which takes place here at Brookhaven, Spetember 9-14. Both of these conferences are the major conferences in their field.