



Future plans at BNL: RHIC-II and eRHIC

DIS 2007

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Outline

- Past Performance
- Near-term Outlook
- BNL's Plan for the Future
- Summary and Outlook



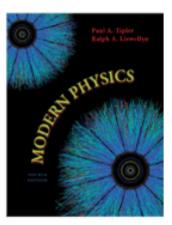
Science performance: 2000-Present

Emergent phenomena in QCD

- Strongly coupled quark-gluon plasma (nearly perfect liquid) produced in RHIC A-A collisions
- "Perfect liquid" was 2005 AIP story of the year

Enormous impact

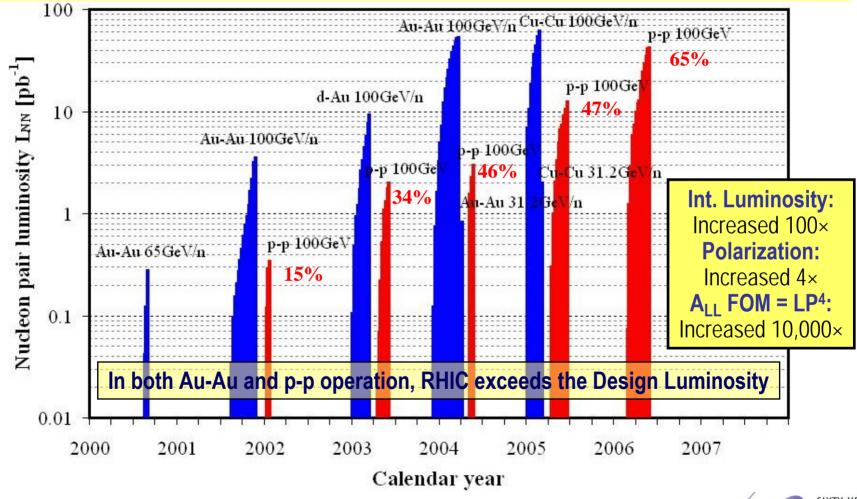
- More than 90 PRLs published, > 7000 citations
- So far, the RHIC program has produced
 29 of the 50 most cited nucl-ex papers of all time
- Text books, popular science press and general media impact







RHIC Accelerator Performance Through Run 6



SIXTY YEARS
OF DISCOVERY
1947-2007

BROOKHAVEN
MATOWAL LABORATORY

Near Term Run Plan

The current plan assumes 20 weeks of cryogenic operations in 2007 and 30 weeks in runs 8-10

| Run | Species | Energy √S _{NN} (GeV) | |
|-----|-----------|----------------------------------|--|
| 7 | Au + Au | 200 | |
| 8 | d + Au | 200 | |
| | p + p | 200 | |
| 9 | Au + Au | TBD | |
| | p + p | TBD | |
| 10 | heavy ion | TBD | |
| | p + p | 500 | |

- In addition to near term run planning, the Program Advisory Committee is looking at
 - Possible new experiments at RHIC
 - Strategic Plans for RHIC spin, A-A at RHIC-II, e-p and e-A at eRHIC

Outlook: 2007 - 2020

- The future of QCD research given what we've learned with RHIC
- BNL plan to enable that research in the mid-term (next 5 years) and long term (the following decade)



Fundamental QCD Questions

- How does ordinary matter get its mass, spin and other intrinsic and dynamical properties?
- How does QCD matter behave at the extraordinary temperatures attained during the first microseconds following the big bang?
- What is the structure of the QCD vacuum, and how is it affected by high temperature and density?
- What are the universal properties of all strongly interacting systems in the limit of high gluon density?



RHIC in the Context of the U.S. Nuclear Science Mission

- LRP Town Meeting on Phases of QCD (Rutgers University, January 2007) (Recommendation #1)
 - "Our central goal is a dramatic advance in our understanding of QCD Matter...The essential requirements for success are...the
 RHIC-II luminosity upgrade..." and "...Strong support for the ongoing theoretical studies of QCD matter..."
- Unanimous recommendation of both Town Meetings on QCD
 - "A high luminosity <u>EIC</u> is the highest priority of the QCD community for new construction after JLab 12 GeV and RHIC II upgrades...This goal requires that <u>R&D resources</u> be allocated for expeditious development of collider and detector design."



BNL's Plan for the Future in Nuclear Science

- Evolve the RHIC facility to address the QCD questions
 - A main BNL strategic thrust at the institutional level
- Four key elements of the Plan
 - Near-term upgrades to RHIC (discussed earlier)
 - Detector upgrades, EBIS, enhanced luminosity and polarization
 - RHIC-II
 - e-Cooling (maintain small hadron beam emittance at top energy)
 - Factor 10 increase in average luminosity
 - Feasibility established, theory, simulation & benchmarking done
 - CD-0 on the horizon (needs DOE/NSAC buy-in)
 - eRHIC (EIC @ BNL)
 - Theory and computational QCD



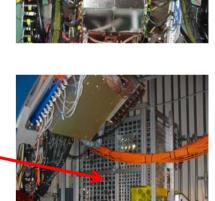
RHIC Upgrades - Detectors

PHENIX

- Hadron Blind Detector (C)
- Muon Trigger (O)
- Silicon Vertex Barrel (VTX) (O)
- Forward Silicon (FVTX) (E)
- Forward EM calorimeter (NCC) (E)

STAR

- Forward meson spectrometer (C)
- DAQ & TPC electronics (O)
- Full ToF barrel (O)
- Heavy Flavor Tracker (HFT) (I)
- Intermediate Silicon Tracker (IST) (I)
- Forward GEM Tracker (FGT) (I)



Projected Cost: \$35M

C = Completed; O = Ongoing; E = Expect FY08 funding; I = In preparation

Red = components focused on high rapidity



Computing Upgrades

- SBU/BNL IBM BlueGene/L 100Tflops
 - Funded by New York State
 - New York Center for Computational Sciences formed
 - NYS Consortium (BNL, SUNY, Columbia, Cornell, RPI, NYU)
 - Now on site and being installed;
 operational in May or June
 - 28Tflops of BlueGene/P coming later
- Expanded Central Computing Facility being planned to accommodate RCF and BlueGene growth



RHIC Upgrades - EBIS

- Will replace Tandems
 - Improved beam intensity
 - Allow for masses to Uranium and polarized ³He
 - Lower operating costs
- Joint DOE and NASA Project
- NASA is providing \$4.5M
 - In progress



- ~\$20M to build EBIS, RFQ and Linac
- Commissioning in late FY2009, operations in FY 2010



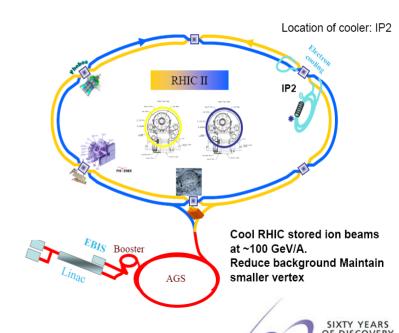
Science of RHIC-II

- What are the properties of the new state produced at RHIC?
 - What is the mechanism of the unexpectedly <u>fast thermal equilibration</u>?
 - What is the initial temperature and thermal evolution of the medium?
 - What is the <u>equation of state</u> of the medium? What is its <u>viscosity</u> and other <u>transport coefficients</u>?
 - Is there direct evidence for <u>deconfinement</u>, color screening, and a partonic nature of the hot, dense medium? What is the screening length?
 - Is <u>chiral symmetry</u> restored, as predicted by QCD?
 - How does the new form of matter <u>hadronize</u> at the phase transition?
- Where is the QCD critical point?
- What is the initial state in heavy ion collisions?
- How does the nucleon get its spin?



RHIC II (e-Cooling)

- Electron cooling will provide a 10-fold luminosity increase needed to answer key QCD questions
 - Requires new technologies based on BNL R&D
 - Low emittance superconducting photocathode electron gun
 - Superconducting ERL
 - R&D on ERL to be completed in FY2008
- Theory, simulation & benchmarking
 - Done
- Ready for CD-0
- Construction start ~FY2010
- Cost \$94M (TPC, FY 2007 dollars)
- ERL technology important for eRHIC



Science of EIC/eRHIC

- Does the self-limiting growth of color field strengths in QCD lead to universal behavior of all nuclear and hadronic matter in the vicinity of these limits?
- How does the nuclear environment affect the distribution of gluons in momentum and space?
- What is the internal landscape of a nucleon in the region dominated by sea quarks and gluons?
- How do hadronic final states form from light quarks and massless gluons in QCD?



Scope of EIC/eRHIC

To address these questions

the program needs:

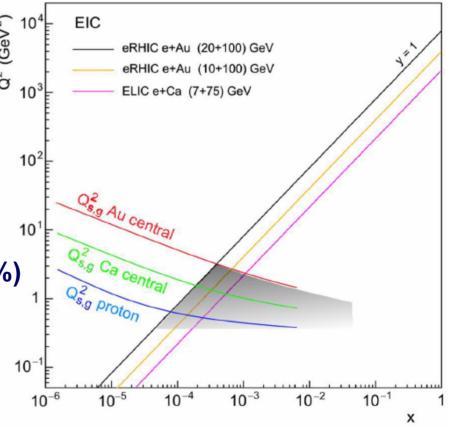
Integrated luminosity of

~ 50 fb⁻¹ in a decade 100×HERA

Achievable with average luminosities ~ 10³³/cm²sec

• Beams of interest include 50-250 GeV protons (Pol. ≥ 70%) Up to 100 GeV/n Au Up to 167 GeV/n polarized ³He

Colliding with
 3-20 GeV polarized e[±]



eRHIC Capabilities

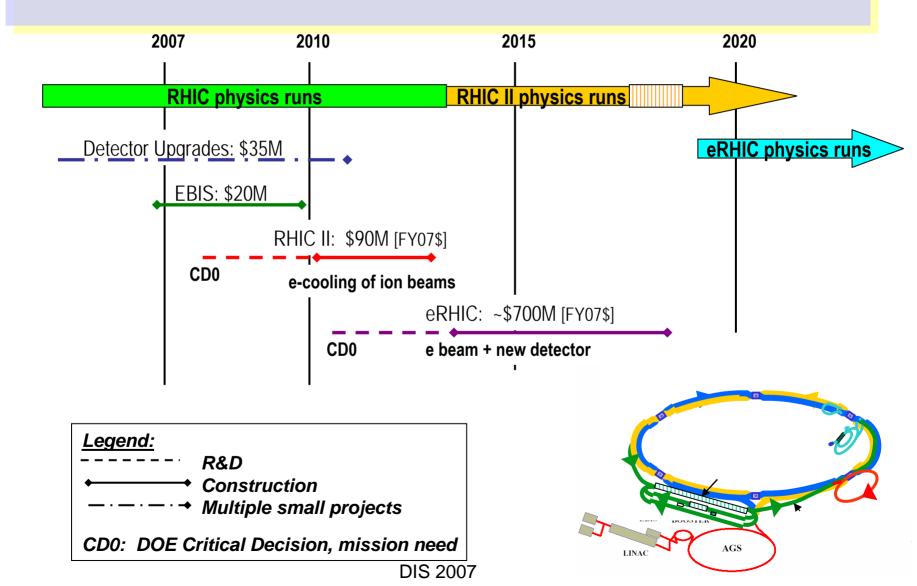
- eRHIC is being developed with realistic performance parameters, based on experience with high luminosity heavy ion beams & detectors, and with high energy highly polarized proton beams:
 - RHIC is the world's only collider capable of producing both high-energy heavy ion and polarized proton beams
 - This uniqueness is not likely to be challenged anytime soon
 - 100 GeV proton beams with ~ 65% polarization operational
 - First test at 250 GeV protons reached ~ 45% polarization
 - First stochastic cooling of high energy bunched beams demonstrated in RHIC
- eRHIC would build naturally on other RHIC R&D and upgrades:
 - e-cooling ERL
 - EBIS, which is designed to provide the polarized ³He beams



R&D Plan for eRHIC

- BNL's R&D plan for eRHIC is well-defined:
 - Two design options developed in parallel (2004 ZDR):
 - Final decision will be driven by experimental requirements, cost & time
 - An ERL-based design ("Linac-Ring") is presently the most promising:
 - Superconducting energy recovery linac (ERL) for the ↑e- beam
 - Peak luminosity of $2.6 \times 10^{33} \ \text{cm}^{-2} \text{s}^{-1}$ with potential for upgrade
 - R&D for a high-current polarized electron source needed to achieve the design goals
 - Estimated TPC = \$600M + \$100M detector trust fund, 5 year construction
 - Detector design simulation & technology:
 - BNL is working with MPI-Munich (A. Caldwell) and MIT (B. Surrow) on detector simulation with a focus on e-A

A Long Term Strategic View of RHIC



Outlook

- The RHIC programs are spectacularly successful
 - There is a clear and rich path forward in QCD research, both in the phases of QCD and in fundamental hadron structure
- The QCD community's recommendations recognize the high priority of the nuclear physics questions that could be addressed at the RHIC facility with the new capabilities outlined here. In particular
 - The EIC is the QCD community's highest priority for the next new construction after RHIC II and CEBAF – 12 GeV
 - It could be operational at BNL within a decade
 - · It is the crucial next step in QCD for the nuclear science community