The sPHENIX Barrel Upgrade: Jet Physics and Beyond

John Haggerty
Brookhaven National Laboratory
on behalf of the PHENIX collaboration
Quark Matter 2012
The sPHENIX concept

Design a major upgrade to PHENIX to address fundamental questions about the nature of the strongly coupled QGP near $T_c$ at RHIC

- Emphasizes jet physics observables with calorimetry initially
- Provides a solid platform for future upgrades and enhancements
- Takes advantage of the luminosity improvements due to stochastic cooling and the wide range of species and energies available at RHIC
- Designed around new technologies that enable a more compact detector, and reuses as much of the PHENIX infrastructure as possible, both helping to keep costs down
Outline

- Physics motivation
- The detector concept and design goals
- Description of the detector design
- Expected performance of the detector
- Where to get more information
- Summary
• How does $\eta/s$ go from being nearly as small as possible near $T_c$ to the weakly coupled limit?

• The figure shows several state-of-the-art calculations and three generic scenarios approaching $T_c$
Jet observables

- A parton traversing the medium accumulates transverse momentum characterized by
  \[ \hat{q} = d (\Delta p_T^2) / dx \]

- Coupling parameters like \( \hat{q} \) are scale dependent and must approach weak coupling at high energies and strong coupling at thermal energies
Experiment to confront theory

- We have benefitted from the formation of a theoretical collaboration to study these issues.
- The key questions for the feasibility of the experiment are:
  - Are the jet rates large enough at RHIC?
  - Are the jets distinguishable from background fakes?

See Coleman-Smith presentation, Thursday

http://jet.lbl.gov/
Jet rates at RHIC

- At present RHIC luminosity, in a 20 week Au+Au run we would have $10^6$ jets above 30 GeV in 0-20% centrality.

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Fake jets

- Using 750M minimum bias HIJING events
- True jets outnumber fake jets for $p_T > 20$ GeV/c
Design goals for a jet detector at RHIC

• Full azimuthal coverage in a fiducial region $|\eta|<1$

• 2 T solenoid to ultimately allow high resolution tracking in a small volume

• Electromagnetic and hadronic calorimetry
  - Electromagnetic
    • $\Delta \eta \times \Delta \varphi \approx 0.02 \times 0.02$
    • $\sigma_E/E \approx 15%/\sqrt{E}$
  - Hadronic
    • $\Delta \eta \times \Delta \varphi \approx 0.1 \times 0.1$
    • $\sigma_E/E \approx 100%/\sqrt{E}$

• Data acquisition capable of recording $>10$ kHz
sPHENIX concepts

Take advantage of new technologies for a very compact design

• Tungsten-scintillator EMCAL makes detector more compact than previously possible
• SiPM’s or APD’s are small, don’t require high voltage, and work in a magnetic field
• Hadron calorimeter can serve as flux return
• HCAL uses fiber embedded in scintillator for light collection ala T2K
• Commercial electronics when possible, existing ASIC’s when not
• New technologies not available ten years ago minimize costs and build on experience in PHENIX
2 T Solenoid 70 cm inner radius

≈ 1 X_0
Electromagnetic calorimeter

- Optical accordion
- Tungsten absorber
- Scintillating fiber
Hadronic calorimeter

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SiPM

• Design based on existing parts
• Gain stabilization on detector
• Economical in large quantities
GEANT4 simulation

10 GeV/c pion showering in the hadronic calorimeter
Expected performance of calorimeters

Single particle resolution in EMCal+HCal

Jet energy resolution
From GEANT4 in $p+p$

- Better than 65%/√E
- 90%/√E
Jet physics sPHENIX

- Day 1 measurement of inclusive jet spectrum to measure jet quenching
- FASTJET anti-$k_T$ algorithm applied to p+p and Au+Au collisions
  - Fast simulation using results of full detector simulation
  - Additional smearing of the underlying event added
  - Unfolding to recover input spectrum

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$R_{AA}$ resolution

![Graph showing $R_{AA}$ resolution with simulation results and theoretical predictions.](image)
Beyond the baseline

sPHENIX can be extended

- Improved tracking in the magnetic field for high resolution momentum measurement
- A preshower detector which improves the reach of $\gamma/\pi^0$ separation and electron identification
- There is another effort exploring the possibility for forward physics with additional instrumentation
- We have considered from the beginning how it could evolve to a detector at an EIC
More detail

There is much more information in arXiv:1207.6378
sPHENIX posters

- 271 - sPHENIX Jet Upgrade Program: Unraveling Strong vs Weak Coupling, J. Nagle
- 258 - Jet Physics Simulations for the sPHENIX Upgrade, A. Hanks
- 323 - sPHENIX Jet Reconstruction Performance, A. Sickles
- 382 - Photon Reconstruction in the sPHENIX Electromagnetic Calorimeter, M. Purschke
- 171 - Quarkonium measurements with the proposed sPHENIX detector, M. Rosati
- 298 - The Tungsten-Scintillating Fiber Accordion Electromagnetic Calorimeter for the sPHENIX Detector, C. Woody
- 391 - Hadron Calorimetry in the sPHENIX Upgrade Project at RHIC, E. Kistenev
- 288 - A Silicon Photomultiplier (SiPM) Based Readout for the sPHENIX Upgrade, E. Mannel
Next steps

• We submitted a proposal to Brookhaven management on July 1, 2012
• Most of the proposal is available as arXiv:1207.6378
• A laboratory review will take place in October
• We are pursuing an aggressive schedule to review, fund, and construct this detector
Summary

• Jet physics accessible at RHIC complements and extends measurements made at the LHC
• The sPHENIX proposal consists of a small number of well defined components which builds on the experience of building and operating the PHENIX detector to carry out a program of jet physics measurements at RHIC