BRAHMS
Annual RHIC DOE Science and Technology Review
July 24, 2006

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BNL
Overview

- **Science and priorities**
  - How has BRAHMS addressed the program set forth initially, and the science priorities of RHIC

- **Accomplishments**
  - Recent results.
  - Scientific output
  - Run-6 performance

- **Plans**
  - Expected results from ongoing analysis
  - Plans for future analysis.
BRAHMS Experiment and Goals

Physics questions that are being addressed

• How much energy is available for particle production?
• How do particles flow in the transverse & longitudinal direction?
• What is the chemistry of the system?
• What is the rapidity dependence of jet quenching?
• What can we learn about the parton distributions in the Au nuclei at small x?
• What is internal angular momentum in proton?

• The experiment has unique capabilities in terms of precision measurements and particle ID covering a rapidity range of 0-4 and up to moderate high pt (~4 GeV/c)
RHIC Science Questions

BRAHMS has addressed significant questions about strongly interacting matter:

- "How does matter behave at very high temperature and/or density?"
  - Jet-quenching suppression in AA, not d-A
  - Au-Au, Cu-Cu, pp. Bulk properties energy dependence

- "What is the nature of gluonic matter? and how does it appear inside of strongly interacting particles?"
  - d Au at high rapidities (low-x)

- "What is the spin structure of the nucleon?"
  - Single Spin Asymmetries at large $x_F$
Spectra Analysis

Sample of spectra at high rapidity in BRAHMS

protons

pions

y 2.8 -> 4.1

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Rapidity dependence of high-$p_T$ Suppression for identified particles.

$R_{AA}$ depends little on rapidity even for identified particle.

Pions suppressed; protons not

$R_{AA}$ depends on energy-loss, density and underlying reference spectrum.
Elliptic flow in BRAHMS

Flow Ring 3
Z = -11 cm

Flow Ring 2
Si Ring 1
Tile Ring 1

BRAHMS Preliminary

pions
The high rapidity measurements allow to get a handle on baryon transport and stopping via net proton distributions.
NLO pQCD for pions compared to data

Calculations done by W. Vogelsang. Only one scale $\mu = p_T$ and the same fragmentation functions as used for the PHENIX comparison.

KKP has only $\pi^0$ frag. Needed some modification to produce charged pions

KKP FF does a better job compared to Kretzer, Pi and Kaon production still dominated by $gg$ and $gq$ at these rapidities apart from the highest $p_{T\text{cc}}$
Transverse Single Spin Asymmetries measurements in BRAHMS

BRAHMS measures identified hadrons (π, K, p, p̅) in kinematic ranges of 0 < Y < 3.5 and 0.2 < p_T < 4

Data:
- Run-4: First SSA measurements in BRAHMS
- Run-5: pp at $\sqrt{s} = 200$ GeV 2.5 pb⁻¹ recorded
- Run-6: pp at $\sqrt{s} = 62$ GeV planned (Energy dependence)

$A_N(\pi, K, p, p\bar{p})$ in 0.1 < x < 0.35 from Run-5 has been analyzed.

Twist-3 (initial state) calculations by Qiu and Sterman:
Extrapolated to lower p_T region

Phys. Rev D59 014004 (98)
Publications

2000-2006  15  Refereed Journals  
2000-2005  56  Conference proceedings  
2000-2005  105+ Talks at conferences, meetings and workshops  

• Recent Publications  
•  “Rapidity dependence of high $p_T$ suppression at $\sqrt{s_{NN}}=62.4$ GeV”  
  Submitted to Phys.Rev.Lett. nucl-ex/0602018  
•  “Centrality Dependent Particle Production at $y=0$ and $y\sim 1$ in $Au+Au$ Collisions at $\sqrt{s_{NN}} = 200$ GeV”  
•  “Charged Meson Rapidity Distributions in Central $Au+Au$ Collisions at $\sqrt{s_{NN}} = 200$ GeV”  
•  “Forward and Midrapidity Like-particle Ratios from $p+p$ Collisions at $\sqrt{s_{NN}}=200$ GeV”)  
•  “Centrality Dependence of Charged-particle Pseudorapidity Distributions from $d+Au$ Collisions at $\sqrt{s_{NN}}=200$ GeV”  
Citations

• 5 top citations from BRAHMS
  – (144) Quark gluon plasma and color glass condensate at RHIC? The Perspective from the BRAHMS experiment. Published in Nucl.Phys.A757:1-27,2005
  – (112) ON THE EVOLUTION OF THE NUCLEAR MODIFICATION FACTORS WITH RAPIDITY AND CENTRALITY IN D + AU COLLISIONS AT S(NN)**(1/2) = 200-GEV. Published in Phys.Rev.Lett.93:242303,2004
  – (85) PSEUDORAPIDITY DISTRIBUTIONS OF CHARGED PARTICLES FROM AU+AU COLLISIONS AT THE MAXIMUM RHIC ENERGY. Published in Phys.Rev.Lett.88:202301,2002

• Total citations (- self citations) 874
### Collaboration

#### Educational Output

- 11 Institutions in 5 Countries.
- 36 Scientists, 3 Post Docs, 6 Ph.D students, 5 MS students

<table>
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<th>Year</th>
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*In addition ~15 M.S. thesis*
Run-6 pp Data Taking

Goals for 62 GeV were

- Reference spectra for AA at $y \sim 0$ and $y \sim 3$
- Single Spin Asymmetries out to $x_F=0.55$

Experiment was unchanged from and setup tuned on a small number of stores at 200 GeV (Feb+June)

- 0.21 pb$^{-1}$ recorded as of 12 pm today since June 7th
- RBUP Goal: 0.85 pb$^{-1}$
- 123.5 hours of data taking
- Calculated by min-bias trigger ("CC trigger") covering ~50% of pp inelastic cross-section of 36 mb at 62.4 GeV
- Goal Assumed: Recorded/Delivered ~0.6

Calibrations and reconstruction are in progress.
Analysis Status

• BRAHMS Measurements are completed with the extended high luminosity runs of Au-Au, Cu-Cu and pp at 200 and 62.4 GeV
• The focus has been on unique forward coverage
  – Transverse spectra of $\pi$, K, p
  – Elliptic Flow
  – Small-x physics
  – Transverse flow
  – Suppression of high $p_T$ particles
  – Transverse spin measurements at $x_F=0.2$ to 0.4 (200 and 62 GeV)
  – Data production have been completed, detailed
  – Analysis and publication of data will take ~1.5 additional years (based on experience with similar size experiments)
• This matches the time-scale for several students and post docs, involvement of European groups that go to ALICE, US groups that will/is be involved in STAR, CMS and ATLAS.
Analysis priorities

- **AuAu 62 and 200 GeV**
  - Differential flow analysis for identified hadrons.
  - Rapidity and centrality dependence of pt-suppression
  - Rapidity and centrality dependence of soft physics
- **CuCu 62 and 200 GeV**
  - Comparison of particle production and pt dependence at 62 GeV and 200 GeV
  - Comparison of jet-quenching via Rcp and RAA to AuAu
  - Volume and geometry dependence of AA.
- **Pp at 200 GeV**
  - Spin Asymmetries $A_N$ (bulk of data)
  - High pt flavor dependence of hadron production
- **Pp at 62 GeV**
  - Reference spectra for AA and SSA at large $x_F$
- **dA at 200**
  - Revisiting identified spectra at large $\eta$. 
Conclusions

• BRAHMS has performed an extensive survey of identified hadron production with its unique $y-p_t$ coverage in Heavy Ion reactions at RHIC
• The flexibility of the experiment and RHIC facility allowed for unique measurements in d-Au and spurred extensive interest in low-x physics at RHIC and LHC
• BRAHMS has contributed with significant and unique measurements for the RHIC spin program
• The Collaboration has sufficient resources to complete the remaining bulk of analysis and publications in a time frame of ~1-1.5 years, matching the timeframe of students staff moving to other projects.