Beam Use Proposal for Runs 7 and Beyond

Barbara Jacak
for the PHENIX Collaboration

Deputy Spokespersons:
   Yasuyuki Akiba
   Matthias Grosse-Perdekamp
   Richard Seto

Operations Manager: Ed O’Brien
Upgrades Manager: Axel Drees
Run-7 Coordinator: Mike Leitch
Communications Coordinator: Brant Johnson

Outline

1. Collaboration Status
2. PHENIX Achievements & Discoveries
3. PHENIX Physics goals for Run 7-10
   200 GeV/A Au+Au (x10 integrated luminosity)
   d+Au (58 pb⁻¹ → reference for Au+Au)
   200 GeV p+p (≥ 71 pb⁻¹ → measure ∆G)
   500 GeV p+p
      (W production → quark, antiquark polarization)
   Au+Au energy scan (search for critical point)
   additional heavy ion system(s)

4. Beam Use Proposal
   Boundary conditions & issues
PHENIX Collaboration

University of São Paulo, São Paulo, Brazil
Academia Sinica, Taipei 115, China
China Institute of Atomic Energy (CIAE), Beijing, China
Peiking University, Beijing, P.R. China
Charles University, Faculty of Mathematics and Physics, Karlova, 135 23, Charles University, Faculty of Mathematics and Physics, Ke Karlovu 3, 121 17 Prague, Czech Republic
Czech Technical University, Faculty of Nuclear Sciences and Technical Engineering, Siedlce 7, 180 00 Prague, Czech Republic
Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 23 Prague, Czech Republic
University of Joskele, P.O. Box 430, 40414, Åred, Sweden
Laboratoire de Physique Corpusculaire LPC, Université de Clermont-Ferrand, F-63178 Aubière, Clermont-Ferrand
DAPNIA, CE Saclay, F-91191 Gif-sur-Yvette, France
IPNL, Université de Nice-Sophia Antipolis, CS 34049, 06304 Nice Cedex 02, France
Laboratoire Legrois-Ringuet, Ecole Polytechnique, CS 70679, Route de Saclay, F-91128 Palaiseau, France
SUBATECH, Ecully des Illèmes de Nantes, F-44807 Nantes, France
University of Rhodes, Rhodes, Greece
IPPE, Research Institute for High Energy Physics at the Russian Academy of Sciences, Protvino, Russia
14 Countries; 68 Institutions; 550 Participants

Athenea Christchurch University, Christchurch, New Zealand
Brookhaven National Laboratory (BNL), Chemical Dept., Upton, NY 11973, USA
Brookhaven National Laboratory (BNL), Collider-Accelerator Dept., Upton, NY 11973, USA
Brookhaven National Laboratory (BNL), Physics Dept., Upton, NY 11973, USA
University of California - Riverside (UCR), Riverside, CA 92521, USA
University of Colorado, Boulder, CO, USA
Columbia University, New York, NY, USA
Florida Institute of Technology, Melbourne, FL, USA
Florida State University, Tallahassee, FL, USA
Georgetown University (GU), Washington, DC, USA
University of Illinois-Chicago, Chicago, IL, USA
Iowa State University (ISU) and Ames Laboratory, Ames, IA 50011, USA
Los Alamos National Laboratory (LANL), Los Alamos, NM 87545, USA
Lawrence Livermore National Laboratory (LLNL), Livermore, CA 94550, USA
University of Maryland, College Park, MD 20742, USA
Department of Physics, University of Massachusetts, Amherst, MA 01003-2327, USA
Old Dominion University, Norfolk, VA 23529, USA
University of New Mexico, Albuquerque, NM 87131, USA
New Mexico State University, Las Cruces, NM 88003, USA
Department of Physics, State University of New York at Stony Brook (USSTB), Stony Brook, NY 11794, USA
Department of Physics and Astronomy, State University of New York at Stony Brook (USSTB), Stony Brook, NY 11794, USA
Oak Ridge National Laboratory (ORNL), Oak Ridge, TN 37831, USA
University of Tennessee (UT), Knoxville, TN 37996, USA
Michigan State University, East Lansing, MI 48824, USA
University of Wisconsin, Madison, WI 53706, USA

PHENIX is, and will remain, strong
PHENIX is fantastically productive

1. 51 Papers published to date + 4 others accepted
   + 7 in review process
   
   *Impact of our papers is enormous!*

1. PHENIX has
   20% of the 50 most cited nucl-ex papers *of all time!*
   22% of the 50 most cited nucl-ex papers in 2006

   2nd most cited nucl-ex paper in 2006
   50th most cited of “all HEP” in 2006
   (316 citations)

1. Most cited paper, with 374 citations is
   “Suppression of hadrons with large transverse momentum in central
   Au+Au collisions at $s(NN)^{1/2} = 130$-GeV”

---

4 upgrades in place for Run-7 *

- Hadron Blind, Reaction Plane detectors
- Muon Piston Calorimeter (N)

*Thanks to the ever-impressive 1008 staff!*
Hadron Blind Detector

novel concept for $e^+D \rightarrow$ Dalitz rejection

- windowless $\text{CF}_4$ Cherenkov detector
- 50 cm radiator length
- CsI reflective photocathode
- Triple GEM with pad readout

2 side covers with frame
2 vertical panels
HV panels
window support
6 active panels
HBD Commissioning Underway

Gas gain:
(assuming a primary charge of 19e in the 1.5mm drift gap and a conversion of 10 ADC counts/IC)

\[ G = 2900 \]

Hadrons selected in central arm projected onto HBD

Upgrade path increases PHENIX acceptance

(i) \( \pi^0 \) and direct \( \gamma \) with additional EM calorimeters (NCC, MPC)
(ii) heavy flavor with silicon vertex tracker (VTX, FVTX)

(i) + (ii) for large acceptance \( \gamma \) jet

(iii) low mass dileptons (HBD)
Upgrade Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase</td>
<td>R&amp;D Phase</td>
<td>Construction Phase</td>
<td>Ready for Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerosol</td>
<td>Flavor Tagged high pT Physics</td>
<td>Flavor Tagged high pT Physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOF-W</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HBD</td>
<td>Low mass di-electrons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VTX-barrel</td>
<td>γ-jet, jet tomography, heavy quark spectroscopy</td>
<td></td>
<td>2007 DOE start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VTX-endcap</td>
<td>γ-jet, CGC, jet tomography, heavy quark spectroscopy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIC</td>
<td>γ-jet, CGC, jet tomography, heavy quark physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MuTrigger</td>
<td>Quark spin structure, W-physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAQ</td>
<td>New subsystems, higher luminosity, higher data rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heavy Ion Physics: Recent Achievements

Run 4 + 5 show:

Hadronization → final state coalescence of constituent quarks from a flowing medium

accepted in PRL

19 citations already!

submitted to PRL:

φ scales as a meson
PHENIX achievements & discoveries (2)

1. Medium response to deposited energy - shock front? *

PRL 97, 052301 (2006) (105 citations) and nucl-ex/0611019 (5 cites already) accepted in PRL

many calculations of medium response, including by string theorists

Heavy Quarks do interesting things, too

Au+Au nucl-ex/0611020 (14 cites)

J/Ψ suppressed i.e. color screening

(but only somewhat)

cc coalescence?
sequential melting of charmonia?
Furthermore, open charm loses energy & flows!

Radiative energy loss only fails to reproduce $v_2^{HF}$.

Heavy quark transport model has better agreement with both $R_{AA}$ and $v_2^{HF}$.

Small relaxation time $\tau$ or diffusion coefficient $D_{HO}$ inferred for charm.

$$D = \frac{1}{3} \frac{\lambda_{mfp}}{\langle v \rangle} = \frac{\langle v \rangle}{3 \rho \sigma}$$

$$D = \frac{\eta}{\rho} \sim \frac{\eta}{S}$$

Small $D$ $\rightarrow$ small $\eta/S$ independent measure!

Compelling questions

1. Does $J/\psi$ flow (final state coalescence says yes...)?
   $J/\psi$ $v_2$, fate of direct $\gamma$

2. How efficient is transport in the medium?
   $\pi^0$ at high $p_T$, di-jets, $\gamma$jet correlations

3. Is hadronization really so simple?
   Extend light hadron measurements: $\pi/K/p$ to 10 GeV/c

4. Is there evidence for chiral symmetry restoration and/or thermal radiation in low mass dileptons?
   $\rightarrow$ Extend sensitivity for new and rare channels via upgrades + increased integrated luminosity!

Order of magnitude $\mathcal{L}$ over existing Run-4!

Collect in Run-7 + Run-9
Precision of J/$\psi$ v$_2$ measurement

Run-7 will tell if J/$\psi$ v$_2$ is zero or not

Need better statistics at high p$_T$

C. Loizides
hep-ph/0608133v2

FGM Model, (\bar{q}) values

6 \leq \langle \bar{q} \rangle \leq 2.4 \text{ GeV}^2/\text{fm}  
(Probability > 10\%)

\bar{q} \sim \langle k_T \rangle^2/\lambda
Increase $p_T$ range & errors

Run-7 + 9

Runs 7+9: from limit to measurement of $q$-hat

Simulation study, using $q$-hat = 13.2
d+Au request for Run-8

1. With recent p+p runs, d+Au data are the limiting factor for precision statements about the (small) nuclear modifications.

2. Run-3 d+Au provided 2.7 nb⁻¹.

3. Run-8: provide comparison for Run-7 Au+Au
   - 1.1 nb⁻¹Au+Au → 44 pb⁻¹ equivalent p+p collisions
   - J/ψ <R_AA> ~ 0.5 → ~22 pb⁻¹ equivalent p+p collisions
   - → 58 nb⁻¹ d+Au
Run-8: major step for d+Au Physics

→ increased significance in A+A

range of suppression factors allowed by $\sigma_{\text{abs}}$ uncertainty

forward $\pi^0$ $R_{dA}$ with the MPC

Qiu/Vitev, PLB 632, 507 (2006) coherent multiple scattering
Kharzeev, et al, PLB599 CGC
Vitev, hep-ph/0609156 + initial state energy loss

$\pi^0$ spectrum in MPC south
polarized p+p: on the road to determining $\Delta G$

Run 5:

Run 5 (Preliminary)

GRSV-max

GRSV-std

Scaling error of 40% is not included.

$\Delta g = 0$

$\Delta g = -g$

Run-6

1. Reconstruction is essentially complete, analysis underway

1.11

FOM ~7 times Run-5
PHENIX remains committed to yearly p+p running, to develop required luminosity & polarization. Next goal is 500 GeV p+p for W production.

From our previous Run-7 request

for $2.7 + 6.0 \text{ pb}^{-1}$ transverse pol. recorded (<Run-8) di-hadron (+ singles) measurement

Boer and Vogelsang, hep-ph/0312320

approximately what’s expected for Run-8
Basis for time request

1. **RHIC Collider Projections for delivered luminosities**
   *from June 1, 2006*

   30 cryoweeks  * was 32.5 in Sept. 06 plan
     2 weeks cool-down + warm-up
     1.5 week per species set-up (+ 0.5-1 wk for pol. p+p)
     1 week per species ramp-up
   22.5 physics weeks for two species *was 25 weeks

1. **PHENIX efficiency of 42%**
   60% live x 70% of collisions inside Z ± 30cm
   * was 23% in Run-6
   significant backgrounds at store start
   extended vertex distribution (?)
   we anticipate better tune & DAQ start in Run-8

Boundary conditions

1. **Funding constraints**
   30 cryo weeks rather than 32+
   cascading effects of curtailed Run-6 and Run-7 lengths
   *hopefully that era is over…*

1. **Upgrades schedule**
   Beam species, energies tailored to utilize upgrades
   Current plan is to replace HBD by VTX for Run-10

1. **Milestones**
   Polarized gluon distribution in 2008
   First W physics (u,d polarization) in 2011

Realism in what RHIC can deliver

▶ solution: optimal + conservative plans
CAD projections for AuAu luminosity (Run-7)


It is assumed that the peak performance is reached after 1 week of linear ramp up, starting with 35% of the final value. Note that these are weeks of physics running.

need 1.1 nb\(^{-1}\) recorded, 2.6 nb\(^{-1}\) delivered

---

d+Au Run-8

1. 58 nb\(^{-1}\) recorded (138 delivered) = x20 Run-3 comparable J/\(\psi\) statistics to Run-7 Au+Au
Run-8 polarized p+p

71 pb$^{-1}$ recorded (167 delivered)
to measure $\Delta G$ (aim to follow RHIC Spin Plan)

Summary of proposal for Run 7-10

<table>
<thead>
<tr>
<th>RUN</th>
<th>SPECIES</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>PHYSICS WEEKS</th>
<th>$\int L , dt$ (recorded)</th>
<th>p+p Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Au+Au</td>
<td>200</td>
<td>12</td>
<td>1.1 nb$^{-1}$</td>
<td>44 pb$^{-1}$</td>
</tr>
<tr>
<td>8</td>
<td>d+Au</td>
<td>200</td>
<td>10</td>
<td>58 nb$^{-1}$</td>
<td>23 pb$^{-1}$</td>
</tr>
<tr>
<td></td>
<td>p+p</td>
<td>200</td>
<td>15</td>
<td>71 pb$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Au+Au</td>
<td>TBD</td>
<td>25-M</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p+p</td>
<td>500</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>U+U?</td>
<td>200</td>
<td>25-N</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p+p</td>
<td>500</td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Run 9 & 10 plan

Run-9
1 complete large 200 GeV/A Au+Au data set
   → definitive measurements with rarest probes
1 if needed, complete 200 GeV polarized p+p
1 begin 500 GeV polarized p+p for W production
1 aim to begin low energy scan & utilize HBD

Run-10
1 begin commissioning VTX detector (HBD removed)
   → both p+p and heavy ion running
   ion species/energy depend on Runs-7,9 and EBIS
1 significant 500 GeV polarized p+p for W production
   utilizing muon trigger

Concluding Remarks

1 PHENIX (and RHIC) have been extremely successful
   Runs 1-6 analyzed
   publications are done or on the way
   impact is extremely high
1 Extend demonstrated spin physics capabilities to
   higher $p_T$ and to new channels
1 Careful planning and execution of upgrades
   open new physics channels, extend reach for rare
   processes
   help attract new collaborators to PHENIX
   closely coupled to accelerator capability development
   drive Beam Use Proposals for coming years
   will prepare PHENIX for data-taking with RHIC-II