2021 GHP Topical Group Meeting

News from BNL

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Agenda

• RHIC Beam Energy Scan II
• Highlights of RHIC New Results
• Next steps: RHIC detector upgrades
• Progress on the EIC
COVID-19

• COVID-19 pandemic affected our lives and activities in major ways
  • ~3 months laboratory min-safe mode in March-June 2020
  • ~30% of staff on site daily since June 2020

• We minimize impact by following federal, State and DOE rules and regulations
  • Safety of our staff and their families is our highest priority
  • We developed ways to progress in the challenging new environment
    • Full success of RHIC 2020 run
    • Exemplary progress with sPHENIX upgrade
    • Strong science analysis and publications

• BNL provided strong support in fighting the virus

• The pandemic is not over yet
• High sensitivity search for structure in phase diagram as a function of baryon doping
  • Enabled by upgrades to accelerator and detector
Status from BES I: Critical Point Search

- Final BES I based result
- Non-monotonic variation of moments of net-baryon number distribution
  - Related to correlation length, suggested as a signature of a critical point

\[ (2) \kappa \sigma^2 \]

\[ \sqrt{s_{\text{NN}}} \text{ (GeV)} \]

\[ \text{Net-proton High Moments} \]

- STAR Data
  - 0 - 5%
  - 70 - 80%
- Stat. uncertainty
- Syst. uncertainty
- Projected BES-II
- Stat. uncertainty

kurtosis \times \text{variance of the net-proton number: non-monotonic variation as a function of collision energy observed} (3.1\sigma)
# Beam Energy Scan II Data Collection

<table>
<thead>
<tr>
<th>Beam Energy (GeV/nucleon)</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>$\mu_B$ (MeV)</th>
<th>Run Time</th>
<th>Number Events Requested (Recorded)</th>
<th>Date Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.5</td>
<td>27</td>
<td>156</td>
<td>24 days</td>
<td>560 M</td>
<td>Run-18</td>
</tr>
<tr>
<td>9.8</td>
<td>19.6</td>
<td>206</td>
<td>36 days</td>
<td>400 M (582 M)</td>
<td>Run-19</td>
</tr>
<tr>
<td>7.3</td>
<td>14.6</td>
<td>262</td>
<td>60 days</td>
<td>300 M (324 M)</td>
<td>Run-19</td>
</tr>
<tr>
<td>5.75</td>
<td>11.5</td>
<td>316</td>
<td>54 days</td>
<td>230 M (235 M)</td>
<td>Run-20</td>
</tr>
<tr>
<td>4.59</td>
<td>9.2</td>
<td>373</td>
<td>102 days</td>
<td>160 M (162 M)$^1$</td>
<td>Run-20+20b</td>
</tr>
<tr>
<td>31.2</td>
<td>7.7 (FXT)</td>
<td>420</td>
<td>0.5+1.1 days</td>
<td>100 M (50 M+112 M)</td>
<td>Run-19+20</td>
</tr>
<tr>
<td>19.5</td>
<td>6.2 (FXT)</td>
<td>487</td>
<td>1.4 days</td>
<td>100 M (118 M)</td>
<td>Run-20</td>
</tr>
<tr>
<td>13.5</td>
<td>5.2 (FXT)</td>
<td>541</td>
<td>1.0 day</td>
<td>100 M (103 M)</td>
<td>Run-20</td>
</tr>
<tr>
<td>9.8</td>
<td>4.5 (FXT)</td>
<td>589</td>
<td>0.9 days</td>
<td>100 M (108 M)</td>
<td>Run-20</td>
</tr>
<tr>
<td>7.3</td>
<td>3.9 (FXT)</td>
<td>633</td>
<td>1.1 days</td>
<td>100 M (117 M)</td>
<td>Run-20</td>
</tr>
<tr>
<td>5.75</td>
<td>3.5 (FXT)</td>
<td>666</td>
<td>0.9 days</td>
<td>100 M (116 M)</td>
<td>Run-20</td>
</tr>
<tr>
<td>4.59</td>
<td>3.2 (FXT)</td>
<td>699</td>
<td>2.0 days</td>
<td>100 M (200 M)</td>
<td>Run-19</td>
</tr>
<tr>
<td>3.85</td>
<td>3.0 (FXT)</td>
<td>721</td>
<td>4.6 days</td>
<td>100 M (259 M)</td>
<td>Run-18</td>
</tr>
<tr>
<td>3.85</td>
<td>7.7</td>
<td>420</td>
<td>11-20 weeks</td>
<td>100 M</td>
<td>Run-21$^2$</td>
</tr>
</tbody>
</table>

$^1$ This run included a commissioning phase.

$^2$ This run is an extension of Run-18.
Low Energy RHIC Electron Cooling

- First bunched beam electron cooling
- Targeted at two lowest energies of BES II
- Enabling upgrade to complete in reasonable beamtime
STAR: First Quantitative s-sbar Symmetry Test

No deviation from expected exact matter-antimatter binding energy symmetry observed

B_Λ differs from widely used predictions assuming hypertriton a weekly bound d-Λ system

Stringent constraints on hyperon-nucleon interactions
- Implications for neutron star interior studies where strange matter might exist

Continues string of hypernuclei results
Future: Fixed target adds further opportunities at high baryon density
W and Z Cross Sections

**W and Z Cross Sections**

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**W⁺/W⁻ cross section ratio:**
- Sensitive to unpolarized $\bar{d}/\bar{u}$ quark distribution
- Complementary to the Drell-Yan data with high $Q^2 \sim M_W^2$
- Insights into $\bar{d}$ and $\bar{u}$ at $x > 0.05$

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**W/Z cross section ratio:**
Sensitive to strange quark content of the proton

Serve as input into global analyses to provide constraints on the sea quark distributions
Highlights of PHENIX publication in 2020

PRC102, 054910 (2020)

- Direct-photon and hadron correlation in AuAu and dAu are compared
- Medium modification of jet fragmentation in AuAu

PRC102, 014902 (2020)

- Comprehensive study of $J/\psi$ production in small systems (pAu, dAu, $^3$HeAu) in forward and backward directions
- Cold Nuclear Matter effects on $J/\psi$
STAR Forward Upgrade

Physics target: measurements in $\uparrow p + \uparrow p$ and $\uparrow p + A$ complementary to future measurements at EIC
  - Partonic kinematics similar

- 4 new detector systems $2.5 < \eta < 4$
  - ECal, HCal, Silicon and sTGC tracker
  - First data taking during Run 22

- Calorimeter systems installed in January 2021
  - Commissioning with beam in full swing

- Trackers
  - Full system prototype tests in Run 2020 and 2021
  - Production started

On track for Run 2022
sPHENIX

Physics target: multiscale probe of QGP structure using jets, quarkonia, and heavy flavor

Construction continuing on track for first physics run in 2023

Collaboration has grown to 83 institutions across 4 continents
## RHIC Runs 2021-25

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
</table>
| 2021 | Completion of Beam Energy Scan II  
Precision investigation of structure of QCD phase diagram |
| 2022 | \(^{1\text{p}+^{1\text{p}}} 500 \text{ GeV}  
First run with STAR Forward Upgrade  
Transverse spin measurements complementary to EIC |
| 2023 | \(^{1\text{p}+1\text{p}} \text{ Au}+\text{Au} 200 \text{ GeV}  
First physics run with sPHENIX  
First high energy heavy ion run with extended range from STAR BES II and Forward Upgrades |
| 2024 | \(^{1\text{p}+1\text{p}} \text{ and }^{1\text{p}+1\text{Au}} \text{ runs at }200 \text{ GeV}  
Reference data for 2023 run  
Further spin and cold QCD measurements complementary to EIC |
| 2025 | High statistics \(^{1\text{p}+1\text{p}} \text{ Au}+\text{Au} 200 \text{ GeV}  
Realize sPHENIX capabilities |
Electron Ion Collider Project

Joint project between BNL and TJNAF
DOE CD-1 Review in January 2021
EIC Physics and Detectors

- Yellow Report: major effort guided by the EIC Users’ Group
  - Released March 2021,

- Call for Collaboration Proposals for Detectors at the Electron-Ion Collider
  
  Deadline for submission: December 1, 2021

https://www.bnl.gov/eic/CFC.php
News from BNL

- COVID affected many of our plans
  - Progressing safely
  - RHIC Run and detectors upgrades are on schedule
- Rate of RHIC publications is strong
  - Many new exciting results
- RHIC plans for 2022-2025 runs are developed
  - Based on sPHENIX and STAR upgrades
- Electron Ion Collider is rapidly progressing toward implementation
  - In close cooperation between BNL and TJNAF
Beam Energy Scan II Status

- Currently ~60% through last BES II energy
  - Orders of magnitude increase in statistical power
- Since LRP 2015 target of opportunity
  - Day-scale fixed target runs to extend to higher baryon density