STAR’s progress on physics analyses
Outline

• Overview of STAR’s activities since last PAC
• Highlights
  • publications since last PAC
  • preliminary results since last PAC
• Computing progress highlights
• Summary

Beam Energy Scan – Phase I Results:
• Seen the turn-off of QGP signatures.
• Seen suggestions of the first order phase transition.
• Not seen conclusive evidence of a critical point.

The most promising region for refining the search is in the lower energies $\sqrt{s} = 19.6, 15, 11.5, 7.7,$ and lower.
The iTPC Upgrades strengthen the BES II physics program, and enables new key measurements:
• Rapidity dependence of proton kurtosis
• Dilepton program (sys. errors and intermediate mass region)
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State of STAR

Collaboration meeting May ’17:

Co-spokesperson’s elected: Helen Caines and Zhangbu Xu

New management begins July 1, 2017

3 new institutions applied to join:

Fudan - China, Lead rep.: Chuan Zheng
Heidelberg - Germany, Lead rep.: Norbert Herrmann
Rutgers - U.S.A., Lead rep.: Sevil Salur

From 2014-2017 (Zhangbu’s first term):

45 refereed publications (18 PRL, 2 Nature)
50 Ph.D. Theses (18 since last PAC meeting)
14 new institutions
6 upgrades installed or under construction
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2016:
11 publications
(3 PRL, 1 PLB, 7 PRC)

2017:
4 publications
3 accepted
(2 PRL, 2 PLB, 1 PRC, 1 PRD, 1 Nature)

6 papers in journal review

HEPData: STAR’s footprint has increased from 7 to 35 papers
submission now included in STAR’s paper publication process
working ongoing supplying data from previous papers
Publications since last PAC

- Elliptic flow of electrons from heavy-flavor hadron decays in Au+Au collisions at $\sqrt{s} = 200, 62.4, \text{ and } 39$ GeV
  - Subm: 5/23 '14; Acc: 3/17 '17
- Measurement of elliptic flow of light nuclei at $\sqrt{s} = 200, 62.4, 39, 27, 19.6, 11.5, \text{ and } 7.7$ GeV at RHIC
  - Subm: 1/26; Acc: 9/23 2016
- $J/\psi$ production at low transverse momentum in p+p and d+Au collisions at $\sqrt{s} = 200$ GeV
  - Subm: 2/6; Acc: 9/23 2016
  - *Phys. Rev. D* 93 (2016) 064904
- Measurement of the cross section and longitudinal double-spin asymmetry for di-jet production in polarized pp collisions at $\sqrt{s} = 200$ GeV
  - Subm: 10/24 '16; Acc: 4/28 '17
  - *Phys. Rev. D* 95 (2017) 71103
- Near-side azimuthal and pseudorapidity correlations using neutral strange baryons and mesons in d+Au, Cu+Cu and Au+Au collisions at $\sqrt{s} = 200$ GeV
  - Subm: 3/17; Acc: 7/28 '16
- Jet-like Correlations with Direct-Photon and Neutral-Pion Triggers at $\sqrt{s} = 200$ GeV
  - Subm: 4/7; Acc: 7/22 2016
- Charge-dependent directed flow in Cu+Au collisions at $\sqrt{s} = 200$ GeV
  - Subm: 8/13 2016; Acc: 1/5 2017
- Upsilon production in U+U collisions at 193 GeV with the STAR experiment
  - Subm: 8/24; Acc: 12/15 2017
- Direct virtual photon production in Au+Au collisions at $\sqrt{s} = 200$ GeV
  - Subm: 7/6 '16; Acc: 4/28 '17
- Measurement of D$^0$ azimuthal anisotropy at mid-rapidity in Au+Au collisions at $\sqrt{s} = 200$ GeV
  - Subm: 1/23 '17; Acc: 4/28 '17
- Energy dependence of $J/\psi$ production in Au+Au collisions at $\sqrt{s} = 39, 62.4, \text{ and } 200$ GeV
  - Accepted by PLB (subm: 7/26 '16)
- Global Lambda hyperon polarization in nuclear collisions: evidence for the most vortical fluid
  - Accepted by Nature (subm: 1/21 '17)
- Di-jet imbalance measurements at $\sqrt{s} = 200$ GeV at STAR
  - Accepted by PRL (subm: 9/15 '16)

+7 Submitted: 2 LFSUPC, 3 BulkCorr, 1 JetCorr, 1 HF

All PWGs active and publishing

Helen Caines - BNL-PAC - June 2017
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Citation rate per paper continues linear trend

Renowned and Famous Papers:

2017: 11 + 14
2016: 11 + 11
2015: 9 + 10
2014: 6 + 9
Constraining polarized gluon distribution

Rapid Communications PRD

Run 9 Longitudinal p+p at 200 GeV

STAR 2009 Di-jet Cross Section

STAR's first mid-rapidity di-jet publication

Gluon polarization 0.2 for x>0.05
Extending to lower x

Preliminary release

Run 9 Longitudinal p+p at 200 GeV

First forward di-jet $A_{LL}$ result

Access to lower $x$

Good agreement with DSSV & NNPDF NLO QCD global analyses
And even lower $x$

Preliminary release

Run 13 Longitudinal $p+p$ at 510 GeV

$$\text{sign}(\eta_1) = \text{sign}(\eta_2)$$

$$\text{sign}(\eta_1) \neq \text{sign}(\eta_2)$$

Run 13 data: largest impact $0.02 \leq x \leq 0.05$

Good agreement between 200 and 510 GeV data

$A_{LL}$ indicates positive trend with invariant mass

Further constraining $\Delta G$ via higher statistical precision
**Probing sea quark polarization**

Preliminary release

**Run 13 Longitudinal p+p at 510 GeV**

\[ \vec{p} + p \rightarrow W^\pm \rightarrow e^\pm + \nu \]
\[ \sqrt{s}=510 \text{ GeV} \hspace{1cm} 25 < E_T < 50 \text{ GeV} \]

$W A_L$:

- Good agreement with previous results
- Statistical precision improved by 40%

Measured asymmetry larger than that expected from DSSV fits

Results already impactful in reweighting NNPDF fits

(E. Nocera, arXiv:1702.05077)

Tightest constraints to date on $\Delta \bar{u}$ and $\Delta \bar{d}$ distributions
**Λ (Λ̅) transverse spin transfer**

Preliminary release  
Run 12 Transverse p+p at 200 GeV

ΔTT: Sensitive to (anti-)s-quark transversity and spin dependent fragmentation distributions

First measurement of mid rapidity Λ ΔTT in p+p collisions
Clear mass ordering $p_T < 2\text{GeV/c}$
Consistent with NCQ scaling

Helen Caines - BNL-PAC - June 2017
HFT: Enhanced charm baryons

Preliminary release  Run 14 Au+Au at 200 GeV

Charm B/M ratio similar to light and strange species
Coalescence of charm?

First charm baryon measurement in HI

Helen Caines - BNL-PAC - June 2017
MTD: Charmonia

Preliminary release

Run 14 Au+Au at 200 GeV
Run 15 p+p and p+Au

Low $p_T$: RHIC < LHC —> Less regeneration at RHIC
High $p_T$: RHIC > LHC —> Less color screening at RHIC

Lower temperature QGP at RHIC
MTD: Bottomonia

Preliminary release

Run 14 Au+Au at 200 GeV
Run 15 p+p and p+Au

First measurement: \( \Upsilon(2S+3S) \)
\( R_{AA} \Upsilon(1S): \text{LHC} \sim \text{RHIC} \)
\( R_{AA} \Upsilon(1S) > R_{AA} \Upsilon(2S+3S) \)

Results consistent with sequential melting
Harcore jet quenching

PRL - Editors choice

Preliminary release

Dijet asymmetry
p+p balance recovered for R=0.4 (not R=0.2) when soft particles included

Jets are quenched but lost energy can be recovered and first hard splitting not modified
Recoil jet quenching

**RHIC:** Jet $p_T = 10$-20 GeV

R=0.2: $p_{T,\text{Shift}} \sim -4.4 \pm 0.2 \pm 1.2$ GeV
R=0.5: $p_{T,\text{Shift}} \sim -2.8 \pm 0.5 \pm 1.2$ GeV

**LHC:** Jet $p_T = 60$-100 GeV

R=0.5: $p_{T,\text{Shift}} \sim -8 \pm 2$ GeV

Larger energy loss at LHC

Run 11 Au+Au at 200 GeV

Examine jets recoiling of high $p_T$ charged hadron

Removal of combinatorial jets via event mixing allows access to low $p_T$ jets

Recoil jets highly suppressed
**BES-I results**

Spectra: Submitted PRC

R_{cp}: Submission PRL this week

**BES-I data including 14.5 GeV**

Chemical, kinetic, and high p_T analyses of BES-I data completed

Strangeness analysis nearly ready for submission to journal

Most BES-I results (close to being) published

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**Helen Caines - BNL-PAC - June 2017**
Global \( \Lambda \) polarization

Accepted by Nature

(still under embargo)

Unpredicted BES-I analysis

Both \( \Lambda \) and \( \bar{\Lambda} \) polarized

Hint that polarization different for anti-particle

Due to coupling to magnetic field?

Need better statistics

Most vortical system ever

12 citations already

Helen Caines - BNL-PAC - June 2017
Flow in small system

Preliminary release

p+Au, d+Au, Cu+Cu, Cu+Au, Au+Au, U+U at 200 GeV

$\nu_{1even}$ and $\nu_3$ system independent

$|\eta|<1$ and $|\Delta\eta|>0.7$

$\ln(\nu_2/\epsilon_2)$ scales with $N_{ch}^{-1/3}$ for all systems

$\nu_n/\epsilon_n \propto e^{-A(\frac{n}{s} \frac{n^2}{S^2})}$

All systems have similar $\eta/s$?
Chiral magnetic effects

Preliminary release

Same-sign

Charge separation variable has dependence on correlation conditions

Run 15 p+Au at 200 GeV

\[
\sqrt{s_{NN}} = 200 \text{ GeV}
\]

\[
\gamma_{OS} - \gamma_{SS}
\]

\[
N = \sqrt{N(\alpha) \times N(\beta)}
\]

\[
\cos(\phi_1 + \phi_2 - 2\phi_3) \times N_{\text{part}}
\]

STAR Preliminary

BBC EP  MB  HT

ZDC EP  MB  HT

0-100% p+Au 200 GeV

30-40% U+U 193 GeV

70-80% U+U 193 GeV

0-100% p+Au 200 GeV

Daniel Cebra - Jun - 2015

RHIC Program Advisory Meeting

Brookhaven National Laboratory

BES II – Physics Cases for iTPC

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### Offline production summary

#### Table: Production Summary

<table>
<thead>
<tr>
<th>Species</th>
<th>Total # of events (M)</th>
<th>% tags events completed</th>
<th>Estimate time to delivery (months)</th>
<th>% tags time to completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Au+Au 200GeV</td>
<td>9126.46</td>
<td>70.15</td>
<td>2.95</td>
<td>69.76%</td>
</tr>
<tr>
<td>d+Au 200GeV</td>
<td>6543.26</td>
<td>72.22</td>
<td>2.43</td>
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<tr>
<td>d+Au 62GeV</td>
<td>1181.10</td>
<td>32.15</td>
<td>0.44</td>
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<tr>
<td>d+Au 39GeV</td>
<td>357.91</td>
<td>90.81</td>
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<tr>
<td>d+Au 20GeV</td>
<td>642.12</td>
<td>91.42</td>
<td>0.08</td>
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<tr>
<td>Run 15</td>
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<td></td>
</tr>
<tr>
<td>p+p 200GeV</td>
<td>10997.37</td>
<td>95.26</td>
<td>0.23</td>
<td>95.68%</td>
</tr>
<tr>
<td>p+Au 200GeV</td>
<td>6329.66</td>
<td>96.81</td>
<td>0.10</td>
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</tr>
<tr>
<td>p+Al 200GeV</td>
<td>3647.70</td>
<td>93.29</td>
<td>0.10</td>
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<tr>
<td>Fixed Target 2015</td>
<td>1015.11</td>
<td>92.62</td>
<td>0.03</td>
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<tr>
<td>Run 14</td>
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<td></td>
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<tr>
<td>Au+Au 200GeV</td>
<td>6718.09</td>
<td>84.66</td>
<td>0.39</td>
<td>90.85%</td>
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<tr>
<td>He3+Au 200GeV</td>
<td>5045.59</td>
<td>96.79</td>
<td>0.22</td>
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<tr>
<td>Au+Au 14.6GeV</td>
<td>1260.30</td>
<td>31.29</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Au+Au 200GeV</td>
<td>412.20</td>
<td>99.38</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

**Production of all past dataset essentially completed**

**Use of Cori more efficient than use of unused PHENIX CPU cycles**

**Updated since BUR**
Progress towards picodsts

Run 16 data produced in picots format
  HFT analysis uses picodsts exclusively

Picodsts development nearly finalized for adoption by whole collaboration
  Most recently adding FMS, EMCal, EPD data

In process of converting “active” older datasets
  Since jobs are short and self-contained could be opportunity to use unused PHENIX CPU cycles

Microdst preserved and written directly to tape
  Factor 5-7 larger than picodsts
  Can (re)make picodsts from microdsts
Summary

12 papers published/accepted since last PAC meeting
   including 1 Nature and 3 PRL

18 active GPCs
   6 submitted to journals
   5 PWGC-previewed paper drafts in PWGs + 35 analyses expected for preview within ~12 months

Published or preliminary results from most datasets in circulation
   37 (55) invited talks in 2017 (2016)
   > 60 talks and posters at SPIN16, DIS17, SQM16, HP16, QM17

Essentially all previous datasets produced
   Conversion to picodsts begun
   Significant allocation granted to run on NERSC/Cori
   Successfully running production, and simulation, on HPC resources

Run 17 p+p data mostly calibrated during run
   Final calibration underway before production starts

Another very productive year