STAR’s Beam Use Request for BES-II

Helen Caines - Yale
on behalf of the STAR Collaboration
Is there a Critical Point?

Latest from the lattice: Cross-over starts at $T_0 = 156.5 (1.5) \text{ MeV}$

$\varepsilon_0 \sim 1 \text{ GeV/fm}^3$

No indication of CP for $\mu_B < 250 \text{ MeV}$
Is there a Critical Point?

Cross-over starts at $T_0 = 156.5 \pm 1.5$ MeV

$\epsilon_0 \sim 1$ GeV/fm$^3$

No indication of CP for $\mu_B < 250$ MeV

Patrick Steinbrecher QM18

Helen Caines - PAC - June 2018
The Phases of QCD

Critical Point?

Quark-Gluon Plasma

Hadron Gas

Vacuum

Color Superconductor

Nuclear Matter

Baryon Chemical Potential $\mu_B$ (MeV)

Temperature (MeV)

$\sqrt{s} = 62.4$ GeV
Nuclear matter phase diagram

The Phases of QCD

Quark-Gluon Plasma

Color Superconductor

Hadron Gas

Vacuum

Nuclear Matter

Critical Point?

1\textsuperscript{st} Order Phase Transition

We are focusing in on the right region
The BES-II upgrades

- **Enhanced Acceptance**
- **Enhanced PID mid and forward**
- **Enhanced Event Plane Resolution**
- **Enhanced Centrality Definition**

### iTPC upgrade
- Continuous pad rows
- Replace all inner TPC sectors

### EPD upgrade
- Replace Beam Beam Counter

### eTOF upgrade
- Add CBM TOF modules and electronics (FAIR Phase 0)

#### iTPC:
- $|\eta| < 1.5$
- $p_T > 60$ MeV/c
- Better $dE/dx$ resolution
- Better momentum resolution

#### EPD:
- $2.1 < |\eta| < 5.1$
- Better trigger & b/g reduction
- Greatly improved Event Plane info (esp. 1st-order EP)

#### eTOF:
- $-1.6 < \eta < -1.1$
- Extend forward PID capability
- Allows higher energy range of Fixed Target program
The BES-II upgrades

- Enhanced Acceptance
- Enhanced PID mid and forward
- Enhanced Event Plane Resolution
- Enhanced Centrality Definition
- Enhanced $\sqrt{s}$ range

- iTPC, EPD, eTOF (from CBM)
- Fixed target

One iTPC sector has been installed
Full EPD has been installed
3 eTOF modules have been installed
**iTPC: enhanced acceptance**

Excellent MWPC bench test performance

- Gas gain uniformity < 1.5% (RMS)
- E resolution < 20% (FWHM)

Reasonable stability under X-ray tests
- 500nA leakage current
- no trips or sparks

One sector has been installed and operated this year

**Performance so far reaching expectations**

- Hits/track 45—> 72
- $p_T$ threshold 60 MeV/c
- $\eta$ coverage to 1.7
**EPD: enhanced event plane resolution**

Full EPD installed for Run 18  
All 744 tiles are good

Extremely uniform tile operation

Average TAC timing resolution 0.35ns

EP resolution better especially in peripheral events

Timed in and operational within first day of operation  
EPD in main data stream for whole run

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Directed flow changes sign in EPD

Spectators ($\eta > 3.4$) positive $v_1$
Participants ($\eta < 3.4$) negative $v_1$

Deflections in EPD in opposite direction

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**EPD: directed flow over 10 units**

27 GeV $y_{beam}=3.4$
EPD $2.1 < |\eta| < 5.1$

Directed flow changes sign in EPD

Spectators ($\eta > 3.4$) positive $v_1$
Participants ($\eta < 3.4$) negative $v_1$

Deflections in EPD in opposite direction

Corrected $v_1$ 30-60%

**Congratulations to the EPD team**
eTOF: enhanced forward PID

Run 17 commissioning
- Interface to STAR data completed
- Engineering design completed

Participating 3 modules in data taking in Run 18

- Successfully commissioned in 2017 (one module)
- Interface to STAR event builder & barrel TOF
- Engineering design for STAR module completed
- Mounting scheme, HV distribution, Gas system layout, etc.
- System integration successful → participating in data taking in 2018

- Reasonable $\eta$-\phi hit distribution → eTOF working properly
- Time resolution: 59 ps
- System time resolution: 83 ps
- Counter time resolution: 59 ps

59 ps timing resolution established
Detector upgrades improve STAR PID and acceptance performance, for FXT energies up to 7.7 GeV, overlap energy with the collider mode.
Executive summary

STAR’s goal is the collection of all the data outlined below

<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</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.8</td>
<td>19.6</td>
<td>205</td>
<td>4.5 weeks</td>
<td>400M</td>
</tr>
<tr>
<td>7.3</td>
<td>14.5</td>
<td>260</td>
<td>5.5 weeks</td>
<td>300M</td>
</tr>
<tr>
<td>5.75</td>
<td>11.5</td>
<td>315</td>
<td>5 weeks</td>
<td>230M</td>
</tr>
<tr>
<td>4.55</td>
<td>9.1</td>
<td>370</td>
<td>9.5 weeks</td>
<td>160M</td>
</tr>
<tr>
<td>3.85</td>
<td>7.7</td>
<td>420</td>
<td>12 weeks</td>
<td>100M</td>
</tr>
<tr>
<td>31.2</td>
<td>7.7 (FXT)</td>
<td>420</td>
<td>2 days</td>
<td>100M</td>
</tr>
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<td>19.5</td>
<td>6.2 (FXT)</td>
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<td>100M</td>
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<td>5.2 (FXT)</td>
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<td>100M</td>
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<tr>
<td>9.8</td>
<td>4.5 (FXT)</td>
<td>589</td>
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<td>7.3</td>
<td>3.9 (FXT)</td>
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<td>100M</td>
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<td>5.75</td>
<td>3.5 (FXT)</td>
<td>666</td>
<td>2 days</td>
<td>100M</td>
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<td>4.55</td>
<td>3.2 (FXT)</td>
<td>699</td>
<td>2 days</td>
<td>100M</td>
</tr>
<tr>
<td>3.85</td>
<td>3.0 (FXT)</td>
<td>721</td>
<td>2 days</td>
<td>100M</td>
</tr>
</tbody>
</table>

Roughly equal spacing in $\mu_B$ given energies RHIC can circulate Measure 7.7 in both collider and FXT mode

Numbers updated from white paper given upgrades
Disappearance of QGP?

Several standard signals disappear at $\sqrt{s} < 15$ GeV

B-M $v_2$ separation gone

High $p_T$ suppression gone

$\phi$ $v_2 \sim 0$

$v_3 \sim 0$
2.5.2 Nuclear Modification Factor

Another broadly discussed result from BES-I related to the onset of deconfinement is the $R_{CP}$ measurement shown in Fig. 40 (for all BES-I energies) and Fig. 42 (for 7.7, 11.5 and 19.6 GeV). The high-$p_T$ suppression observed at the top RHIC energies is seen as an indication of the energy loss of partons in a colored medium, and the $R_{AA}$ measurements are one of the clearest signatures for the formation of the quark-gluon plasma. This suppression is expected to vanish at low collision energies, where the energy density becomes too low to produce a significantly large and long-lived QGP. Because there was not a comparable pp energy scan, the BES analysis has had to resort to $R_{CP}$ measurements as a proxy. Still the study of the shape of $R_{CP}(p_T)$ will allow us to quantitatively address the evolution of jet-quenching to lower beam energies.

Average channeling behavior as function of energy is seen in the data (see Fig. 40); at the lowest energies (7.7 and 11.5 GeV) there is no evidence of suppression for the highest $p_T$ values that are reached. This plot demonstrates the turn-off of net suppression for high-$p_T$ hadrons produced in central collisions (0-5 %), relative to those produced in peripheral collisions, (60-80 %), as expected for this signature of QGP formation. Fig. 40 clearly demonstrates that enhancement effects become very large at lower energies. This does not exclude the possibility of QGP formation in the 7.7 and 11.5 GeV datasets, but simply demonstrates that enhancement effects (Cronin type interactions, radial flow, and the relative dominance of coalescence versus fragmentation for hadronization) might increase faster than quenching effects at these energies.

0-80% Au+Au Collisions at RHIC

Precision measurement of the $\phi$ (and other) flow
**Softer point in EOS**

Recent calculations consistent with original 2005 prediction

- JAM 1.0pt: First order phase transition
  - strong “wiggle”
- JAM X-over - Cross over
  - weaker “wiggle”
- JAM - No transition
  - no “wiggle”

Theoretical calculations do not yet match data

Fine centrality binning possible with BES-II data

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Coalescence of “produced” particles

Assumptions:
- $v_1$ is developed in prehadronic stage
- Hadrons are formed via coalescence: $(v_n)_{\text{hadron}} = \Sigma(v_n)_{\text{constituent quarks}}$
- $(v_1)_{\bar{u}} = (v_1)_{d}$ and $(v_1)_{s} = (v_1)_{\bar{s}}$

anti-$\Lambda$ predicted from quark values deduced from K and p

Fails for 7.7 GeV - At least one assumption incorrect

What happens at lower $\sqrt{s}$? Finer centrality bins?
**FXT directed flow**

**ν₁ at 4.5 GeV:**
- p and Λ similar values
- First identified π results
- Suggestion of difference between π⁺ and π⁻
  - Transported quarks have stronger effect on π⁻

Run 18 (with EPD):
- 1 B events at 7.2 GeV
- 100 M events at 3.0 GeV

Fluctuation measurements below 7 GeV


**BES-II: directed flow improvements**

Current data: Double sign change of $v_1$

**Precision measurement of $dv_1/dy$ as function of centrality**

![Graphs](image1)

**iTPC+ eTOF:**

Enhanced coverage at forward $y$

Signal larger - role of baryon stopping
BES-II: directed flow improvements

Current data: Double sign change of $v_1$

Precision measurement of $dv_1/dy$ as function of centrality

![Graphs showing $v_1$ as a function of $y$ for different $p_T$ ranges.

**BES-I Data**

- BES-II: directed flow improvements
- iTPC+ eTOF:
  - Enhanced coverage at forward $y$
  - Signal larger - role of baryon stopping
- EPD:
  - Enhanced 1st order EP resolution
  - Reduced systematics

![Graph showing $v_1$ vs centrality with error bars.

[Simulation: UrQMD at 19.6 GeV]

- $1.3 \leq |\eta| \leq 1.4$
- TPC
- iTPC

![Graph showing $dv_1/dy$ vs $\sqrt{s_{NN}}$ (GeV).

- 10-40% BES-I
- 10-15% BES-I
- 10-15% BES-II
- 10-15% BES-II+EPD

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Presence of Critical Point?

Critical Points:
- divergence of susceptibilities
  e.g. magnetism transitions
- divergence of correlation lengths
  e.g. critical opalescence

Top 5% central collisions:
Non-monotonic behavior

Peripheral collisions:
smooth trend

Hints of Critical fluctuations

Correlation lengths diverge →

Net-\(\rho\) \(\kappa\sigma^2\) diverge
BES-II: Critical fluctuations

Current data: Suggestive of non-trivial $\sqrt{s}$ dependence of net proton cumulant ratios

**iTPC:**
- Increase $\Delta y_p$ acceptance
- $\Delta y_p > \Delta y$ correlation

**EPD:**
- Improved centrality selection
- Use all TPC for measurement

Establish true nature of correlation
Subject actively pursued theoretically

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Light-ion FXT target?

Question:

Does baryon stopping dominate net-proton fluctuation measurements?

Proposed Test:

Au+light ion collisions
   No QGP created but significant baryon stopping
   If stopping is poisson in nature - correlation random

Under discussion:

Insert a Be target above the current FXT Au target
   - needs more detailed discussion with CAD
Can measure fluctuations in the target rapidity region

Determine if fluctuations all due to stopping
Low mass di-lepton excess

Above 20 GeV
Total baryon density ~ constant

Low mass excess \propto \text{fireball lifetime}
for large range of beam energies and centralities

Excess driven by convolution of \textbf{total baryon} density, \textbf{hot dense} medium effects and the medium’s \textit{lifetime}

Need to add more low energy data

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**BES-II: change total baryon number**

HADES Prelim.0-40%
0.3<M_{ee}<0.7 GeV/c^2

Low Mass Region:
**iTPC:** Significant reduction in sys. and stat. uncertainties

Disentangle total baryon density effects

ρ-meson broadening:

different predictions for di-electron continuum (Rapp vs PHSD)

**iTPC:** Significant reduction in sys. and stat. uncertainties

Enables to distinguish between models for $\sqrt{s} = 7.7$-19.6 GeV
Global Λ polarization

Non-zero measurement now demonstrated 200 GeV
Also as function of centrality

Consistent polarization for particle and anti-particle (within statistical precision)
Non-zero measurement now demonstrated 200 GeV
Also as function of centrality

Consistent polarization for particle and anti-particle (within statistical precision)

Difference $\propto B\text{-field}/T$

10% on y axis corresponds to $8 \times 10^{14}$ T

BES-II resolve $>5\sigma$ difference
**Updated event statistics requirements**

**Table 8:** Event statistics (in millions) needed in BES-II for various observables. This table updates estimates originally documented in Ref. [45].

<table>
<thead>
<tr>
<th>Collision Energy (GeV)</th>
<th>7.7</th>
<th>9.1</th>
<th>11.5</th>
<th>14.5</th>
<th>19.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_B$ (MeV) in 0-5% central collisions</td>
<td>420</td>
<td>370</td>
<td>315</td>
<td>260</td>
<td>205</td>
</tr>
<tr>
<td>Observables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{CP}$ up to $p_T = 5$ GeV/$c$</td>
<td>-</td>
<td>160</td>
<td>125</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Elliptic Flow ($\phi$ mesons)</td>
<td>80</td>
<td>120</td>
<td>160</td>
<td>160</td>
<td>320</td>
</tr>
<tr>
<td>Chiral Magnetic Effect</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Directed Flow (protons)</td>
<td>20</td>
<td>30</td>
<td>35</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Azimuthal Femtoscopy (protons)</td>
<td>35</td>
<td>40</td>
<td>50</td>
<td>65</td>
<td>80</td>
</tr>
<tr>
<td>Net-Proton Kurtosis</td>
<td>70</td>
<td>85</td>
<td>100</td>
<td>170</td>
<td>340</td>
</tr>
<tr>
<td>Dileptons</td>
<td>100</td>
<td>160</td>
<td>230</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>$&gt;5\sigma$ Magnetic Field Significance</td>
<td>50</td>
<td>80</td>
<td>110</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Required Number of Events</td>
<td>100</td>
<td>160</td>
<td>230</td>
<td>300</td>
<td>400</td>
</tr>
</tbody>
</table>

+100M for each FXT energy

Typically factor 20 more than for BES-I

dileptons drive the event request
With guidance from the Collider-Accelerator Department, each scenario has cryo-weeks assigned to commissioning of Low-Energy RHIC electron Cooling (LEREc): six weeks in Run 19 and five weeks in Run 20. For all scenarios we have to assume a third year of RHIC running to follow, in order to allow the completion of the BES-II physics mission. Specifically, the request of twelve weeks for $\sqrt{s_{NN}} = 7.7$ GeV will need to be collected in a third year of BES-II. Moreover, some scenarios necessitate this third run to address parts of the requests for the $\sqrt{s_{NN}} = 9.1$ GeV. Run 21 would thus combine the remainder of BES-II with the start of STAR’s forward physics program which would see a $\sqrt{s} = 500$ GeV polarized $pp$ run that year as proposed in [2, 3].

For more details about running at 500 GeV see Elke’s talk
Run 19

Table 2: Scenarios 1, 2, 3, and 4 - Run 19 assuming nineteen cryo-weeks of running, including six weeks of LEReC commissioning, and two weeks of cool-down/set-up time

<table>
<thead>
<tr>
<th>Single-Beam Energy (GeV/n)</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>Run Time</th>
<th>Species</th>
<th>Events</th>
<th>Priority</th>
<th>Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.8</td>
<td>19.6</td>
<td>4.5 weeks</td>
<td>Au+Au</td>
<td>400M</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9.8</td>
<td>4.5 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7.3</td>
<td>14.5</td>
<td>5.5 weeks</td>
<td>Au+Au</td>
<td>300M</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>7.3</td>
<td>3.9 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>31.2</td>
<td>7.7 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Expect installation and commissioning of upgrades to last until Feb 27th

See Flemming’s talk for more details
Run 20

Table 3: Scenario 1 - Run 20 assuming twenty-four cryo-weeks of running, including five weeks of LEReC commissioning, and two weeks of cool-down/set-up time.¹

<table>
<thead>
<tr>
<th>Single-Beam Energy (GeV/n)</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>Run Time</th>
<th>Species</th>
<th>Events</th>
<th>Priority</th>
<th>Sequence Spring 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.75</td>
<td>11.5</td>
<td>5 weeks</td>
<td>Au+Au</td>
<td>230M</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5.75</td>
<td>3.5 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4.55</td>
<td>9.1</td>
<td>7 weeks²</td>
<td>Au+Au</td>
<td>118M²</td>
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<td>3</td>
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<tr>
<td>4.55</td>
<td>3.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19.5</td>
<td>6.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>13.5</td>
<td>5.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>3.85</td>
<td>3.0 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

¹ The BES-II request includes a 7.7 GeV run which requires 12 cryo-weeks. This data set will need to be collected in a third year of BES-II.

² The complete request is for 160M MB events and will take 9.5 cryo-weeks to collect assuming design cooling performance. The remainder of the data will be collected in a third year of BES-II.

The BES-II request includes a 7.7 GeV run which requires 12 cryo-weeks. This data set will need to be collected in a third year of BES-II.

Table 4: Scenario 2 - Run 20 assuming nineteen cryo-weeks of running, including five weeks of LEReC commissioning, and two weeks of cool-down/set-up time.¹

<table>
<thead>
<tr>
<th>Single-Beam Energy (GeV/n)</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>Run Time</th>
<th>Species</th>
<th>Events</th>
<th>Priority</th>
<th>Sequence Spring 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.55</td>
<td>9.1</td>
<td>9.5 weeks</td>
<td>Au+Au</td>
<td>160M</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4.55</td>
<td>3.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5.75</td>
<td>3.5 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>7.3</td>
<td>3.9 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19.5</td>
<td>6.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>13.5</td>
<td>5.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>3.85</td>
<td>3.0 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

¹ The BES-II request includes an 11.5 GeV and 7.7 GeV run which require 5 and 12 cryo-weeks, respectively. These data sets will need to be collected in a third year of BES-II.
**Table 5: Scenario 3** - combined Fall ’19 run with five cryo-weeks from Run 19 and nine cryo-weeks from Run 20 assuming twenty-four cryo-weeks of running, including five weeks of LEReC commissioning, and two weeks of cool-down/set-up time. Followed by a Spring ’20 run of the remaining thirteen cryo-weeks.¹

<table>
<thead>
<tr>
<th>Energy (GeV/n)</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>Run Time</th>
<th>Species</th>
<th>Events</th>
<th>Priority</th>
<th>Sequence Fall 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.75</td>
<td>11.5</td>
<td>5 weeks</td>
<td>Au+Au</td>
<td>230M</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5.75</td>
<td>3.5 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>19.5</td>
<td>6.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>13.5</td>
<td>5.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3.85</td>
<td>3.0 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy (GeV/n)</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>Run Time</th>
<th>Species</th>
<th>Events</th>
<th>Priority</th>
<th>Sequence Fall 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.55</td>
<td>9.1</td>
<td>9.5 weeks</td>
<td>Au+Au</td>
<td>160M</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4.55</td>
<td>3.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

¹ The BES-II request includes a 7.7 GeV run which requires 12 cryo-weeks. This data set will need to be collected in a third year of BES-II.

**Table 6: Scenario 4** - combined Fall ’19 run with five cryo-weeks from Run 19 and eight cryo-weeks from Run 20 assuming nineteen cryo-weeks of running, including five weeks of LEReC commissioning, and two weeks of cool-down/set-up time. Followed by a Fall ’20 run which combines the remaining eleven cryo-weeks with those of a third year of BES-II¹

<table>
<thead>
<tr>
<th>Energy (GeV/n)</th>
<th>$\sqrt{s_{NN}}$ (GeV)</th>
<th>Run Time</th>
<th>Species</th>
<th>Events</th>
<th>Priority</th>
<th>Sequence Fall 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.75</td>
<td>11.5</td>
<td>5 weeks</td>
<td>Au+Au</td>
<td>230M</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5.75</td>
<td>3.5 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>19.5</td>
<td>6.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>13.5</td>
<td>5.2 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3.85</td>
<td>3.0 (FXT)</td>
<td>2 days</td>
<td>Au+Au</td>
<td>100M</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

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<td>4.55</td>
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<td>160M</td>
<td>1</td>
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<td>100M</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

¹ The BES-II request includes a 7.7 GeV run which requires 12 cryo-weeks. This data set will also need to be collected in a third year of BES-II, extending into Spring ’21.
Very smooth running - fills lasted many hours with close to flat luminosity thanks CAD

Exceeded data taking goals for both isobars

Blind analysis procedures in place and data QA underway
Run 18 brief report: FXT

$\sqrt{s} = 3.85$ GeV:

$\sim$300 M events with EPD

Fast offline:

FXT location clear

Good EPD - TPC correlations

Nice agreement with Glauber centrality estimates

($\sqrt{s} = 7.2$ GeV
Recorded during CEC commissioning - $\sim$15M events)
Run 18 brief report: Au+Au 27 GeV

Goal is 700M “Good” events.
(NB: Run 11 68M events
|vz| < 70 cm && >1 primary tracks)

MB trigger very open

Only ~50% are actual events

Only ~50% of those are flagged by HLT as good

|vz| < 50 cm && >4 primary tracks

Currently have ~350M events (as of Wed)
Hope to reach 500—550M good events by end of run
Data taking during Run 18 very successful

Upgrades performing at or beyond expectations

BES-I  24 papers published (1 nature, 9 PRL)
      2 submitted
      5 advanced stages

BES-II will likely run into 2021

Ready for BES-II
BACK UP
PAC recommendation for Run 18

The PAC recommends for Run 18 the following:

- $\sqrt{s_{NN}} = 200$ GeV $^{96}$Ru+$^{96}$Ru and $^{96}$Zr+$^{96}$Zr, 1.2 billion minimum bias events in each system. This program has the potential to clarify a question of major significance in the field – can a signal of the chiral magnetic field be extracted from charge separation measurements in two isobaric systems. This is the highest priority for Run 18.

- 3 weeks of $\sqrt{s_{NN}} = 27$ GeV Au+Au collisions accumulating 1 billion events to measure effects of global polarization of Lambdas and anti-Lambdas with high statistics, assuming RHIC operates with 15 weeks of cryogenic running in 2018.

- 2 days of $\sqrt{s_{NN}} = 3$ GeV Au+Au collisions in fixed-target mode to accumulate approximately 100 million events in order to investigate net proton fluctuations at an energy between its BES I run and the lower energy HADES runs.
**Event Plane Detector: EPD**

2.1 < |\(\eta| < 5.0

Replacing BBCs

16 radial and 24 azimuthal sections

**REAL data**

Note EP resolution much better in peripheral events

**Event Plane Detector**

Greatly improved Event Plane Resolution especially 1\(^{st}\)-order EP

Determine Centrality away from mid-rapidity

Better trigger & background reduction
Lambda polarization statistics

Clearly, very exciting development
Signal and BES dependence need more data
Au+Au 27GeV in run 18 with EPD
To establish if there is a difference
Result will guide BES-II studies

Hint of Bfield:
1.5sigma average for 7.7-39GeV
Significance of Lambda-Anti-Lambda

- 27 GeV (based on BES-I uncertainties)
- Assuming \( R_{EPD} = 2R_{BBC} \)
- Z axis depicts the significance of the gap in between the Lambda and Anti-Lambda Polarizations

\[ BUR (P_\Lambda - P_{\bar{\Lambda}}) \]

Rough avg of data
Projected stats
Today
Above phi mass QGP dominated

400 M factor 2.4 reduction in average uncertainties
700 M factor 3.2 reduction in average uncertainties

First measurement of T at this energy
**Di-lepton error estimates - 27 GeV**

**Error Bars**

- How much will they shrink?
  - Run 11: 68M
  - 390 M \(2.4x\) (cyan)
  - 700 M \(3.2x\) (red)

- \((dN/dy)/(dN_{ch}/dy)\) \([M:0.4-0.75\text{GeV/c}^2]\)
  - Run11: \(5.21552\times10^{-06} \pm 2.13466\times10^{-06}(\text{stat}) \pm 9.84061\times10^{-07}(\text{sys})\)
  - 2Weeks(2.4): \(\pm 8.89e-07\)
  - 3Weeks(3.2): \(\pm 6.67e-07\)

(500M \(\rightarrow\) 2.7x)

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Helen Caines - PAC - June 2018
Endcap Time-Of-Flight: eTOF

Compressed Baryonic Matter Experiment (CBM)
1/10\textsuperscript{th} TOF modules installed inside East pole-tip

Large-scale integration test of system for CBM

Single TOF module for Run-17 - integration test

Forward PID over iTPC $\eta$ range

$-1.6 < \eta < -1.1$

TPC $dE/dx$ effic. drops rapidly in this range due to $p_\text{Z}$ boost
iTPC

Increase in #channels in 24 inner sectors by ~factor 2

Provides near complete coverage

New electronics for inner sectors

Enhanced rapidity coverage

Old

New

better $dE/dx$;

-1 < $\eta$ < 1

-1.5 < $\eta$ < 1.5;

$p_T > 125$ MeV/$c$

$p_T > 60$ MeV/$c$. 