Outline

• PHENIX Removal and Repurposing
• Publication status
• Highlights of recent results
• Data analysis status and plan
Removal and Refurbishment (R & R) of the PHENIX Experiment at 1008
Project start in 2016, scheduled completion in 2018
  – On track for final component removal (MMN) in 2018, after which IR is suitable for sPHENIX preparation and installation

Huge savings in repurposing (IR and associated infrastructure, Racks, Cables, Gas Facilities, etc)

Repurposed detectors:
  – BBC to be reused for sPHENIX MBD
  – PbSc for STAR and possibly ePHENIX forward EMCAL, and for FNAL Dark photon search
  – RICH PMTs, TOF.E, and AGEL returned to US-J for use at J-PARC
# Remaining PHENIX R&R Schedule, 2018

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Major Task</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 7-8</td>
<td>Move racks from 912 to 1008</td>
<td>DONE</td>
</tr>
<tr>
<td>May 9-11</td>
<td>Re-arrange remaining racks in 912</td>
<td>DONE</td>
</tr>
<tr>
<td>May 14-31</td>
<td>Construct cart for MuTr steel removal</td>
<td>DONE</td>
</tr>
<tr>
<td>June 18</td>
<td>Run 18 ends, Roll out Shield Wall</td>
<td>DONE</td>
</tr>
<tr>
<td>June 20-25</td>
<td>Riggers take down Shield Wall</td>
<td>DONE</td>
</tr>
<tr>
<td></td>
<td>Remove racks and yellow scaffold in NE IR corner</td>
<td>DONE</td>
</tr>
<tr>
<td>July 16-27</td>
<td>Remove Beam Pipe</td>
<td>DONE</td>
</tr>
<tr>
<td>July 5-18</td>
<td>Pull out cable, roll up/cut</td>
<td>DONE</td>
</tr>
<tr>
<td>Aug 9-Sept 5</td>
<td>Remove 1\textsuperscript{st} Layer of North MuID Chambers</td>
<td>DONE</td>
</tr>
<tr>
<td>Aug 28-Sept 13</td>
<td>Remove “dog house ledge”</td>
<td>In Progress</td>
</tr>
<tr>
<td>Aug 28-Sept 15</td>
<td>Install Lifting Blocks on MuTr Piston</td>
<td>In Progress</td>
</tr>
<tr>
<td>Sept 6-14</td>
<td>Remove MuTr “donut”</td>
<td>In Progress</td>
</tr>
<tr>
<td>Sept 17-28</td>
<td>Remove MuTr Piston</td>
<td></td>
</tr>
<tr>
<td>Oct 1-30</td>
<td>Remove MuTr Support Steel</td>
<td></td>
</tr>
<tr>
<td>Nov 1-15</td>
<td>Remove 1\textsuperscript{st} Layer of South MuID Chambers</td>
<td></td>
</tr>
</tbody>
</table>
Publication status
Discovery of Jet quenching paper has 1000 citations

Now 1013 citations
PHENIX publications

- **184 physics papers published/accepted**
  - Phys. Rev. Lett. 71
  - Phys. Rev. C 74
  - Phys. Rev. D 33
  - Nature Physics 1
  - Phys. Letter B 4
  - Nucl. Phys. A 1

- **Total citation: ~26000**
  - Topcite 1000+ 2
    - 500-1000 6
    - 250-500 17
    - 100-250 50
    - 50-100 39

**PHENIX White Paper:** ~2600 cites

114 physics papers in Topcite 50+
(134 if proceedings and NIM papers are included)

The paper of jet quenching discovery is the first regular article of RHIC that has more than 1000 citations
PHENIX papers in the last 12 months

PRD98,032007 (2018)  $A_L$ of $W \rightarrow \mu$
PRD98,012006 (2018)  $A_N$ of forward $J/\psi$ in p+A
PRC97,064911 (2018)  HBT Levy fit analysis
PRC97,064904 (2018)  Identified hadron $v_2$ in pAu and $^3$HeAu
PRL120, 022001 (2018)  $A_N$ of very forward neutrons in $p + A$ 200 GeV
PRC96,064905 (2017)  $v_2$ in d+Au Beam Energy Scan
PRC96,064901 (2017)  $B \rightarrow J/\psi$ in CuAu
arXiv:1805.04084  Low $p_T$ direct photons in Cu+Cu (accepted by PRC)
arXiv:1805.02973  small QGP droplet (accepted by Nature Physics)
arXiv:1710.01656  $\phi \rightarrow \mu\mu$ in $p + p$ 510 GeV
arXiv:1803.01749  Two particle correlation with respect to event plane
arXiv:1805.02448  Direct photon and hadron correlation in $p + p$ 200 GeV
arXiv:1805.02450  dimuons from Drell Yan and bb cecays in $p + p$ 200 GeV
arXiv:1805.04066  $\mu\mu, e\mu, ee$ correlations in $p + p$ 200 GeV
arXiv:1805.04075  Scaling of low $p_T$ direct photon yield
arXiv:1805.04389  $\pi^0$ and $\eta$ in Cu+Au 200 GeV
arXiv:1807.11928  $dN_{ch}/d\eta$ and $v_2$ in small systems
Publication in the last 12 months

• 9 papers published + 2 accepted since 2017/9/6
  – PRL: $A_N$ of very forward neutron in $p + A$
  – PRL: $v_2$ in $d$+Au Beam Energy Scan and $p$+Au
  – Nature Physics (accept): small QGP droplets
    • First PHENIX paper accepted by Nature Physics

• 16 papers were submitted since 2017/9/6

• 12 papers were submitted in 2018
  – 3 papers submitted to PRL
    • Scaling of Low $p_T$ direct photon
    • Correlations of dileptons from $b$ decay
    • $dN_{ch}/d\eta$ and $v_2$ in small systems
  – 1 paper accepted by Nature Physics
    • Evidence for small QGP droplets in $p$Au, dAu, $^3$HeAu
Publish the results of PHENIX

- Publish the results from the “golden” datasets
  - RUN14+16 has effectively >20 times of RUN11 for heavy-flavor measurement
- Unique, high statistics datasets have long impact
  - Example: we published 12 papers in 2014-17 from 2008 d+Au data
- 3 years to complete publication of major results

Published PHENIX papers in each year

9 papers in journal review
~11 papers/year
9 papers published/accepted in the first 9 months
Highlights of recent results
Evidence for small QGP droplets

- $\nu_{2}^{p+Au} < \nu_{2}^{d+Au} \approx \nu_{3}^{^{3}\text{He}+Au}$ and $\nu_{3}^{p+Au} \approx \nu_{3}^{d+Au} < \nu_{3}^{^{3}\text{He}+Au}$
- Order of $\nu_{2}$ and $\nu_{3}$ is the same as that of $\varepsilon_{2}$ and $\varepsilon_{3}$
- Presence of QGP droplets best describes the data
- Accepted by Nature Physics
Thermal photons: transition to QGP?

Scaling means similar photon source across beam energies

→ Most photons are emitted at the phase transition

A paper submitted to PRL

• Evidence for Photon enhancement in $p + A$ and $d + Au$

→ Support QGP formation in small systems
Flow of charm and bottom

\( v_2^c(\text{c} \rightarrow \text{e}) \) vs \( v_2^b(\text{b} \rightarrow \text{e}) \)

- Preliminary results from Run14 data (~20 B events)
- First measurement of \( v_2 \) of \( b \rightarrow e \)
  - Hint of non-zero \( v_2 \) of bottom
  - Hint that \( v_2 \) of \( b \) and \( c \) are different.
- Run16 data will double the statistics
The final results of 2012+2013
Concluded $W A_L$ program with PHENIX
Contribution to global fit to helicity PDF

$A_N$ of positive hadrons in pAu is suppressed compared with p+p!
Consistent with CGC in large nuclei
Status of the data analysis and plan
Coming up papers

Paper writing groups for 9 papers formed
• Direct photon hadron correlation in $p + A$
• $R_{pA}$ of forward hadrons
• $\pi^0$ in $p + A$ and $^3$He+Au
• $A_N$ of $\pi^0$ in $pp$ and $p + A$
• Direct photon-hadron correlation in $p + p$, $d+Au$, $Au+Au$
• $\pi^0 - h$ correlation in $p + p$ and $p + A$
• $A_N$ of forward hadrons in $p + A$
• $J/\psi \rightarrow \mu\mu$ $p + p$ at 510GeV
• $b \rightarrow e$ and $c \rightarrow e$ in $pp$ 200 GeV

Papers from QM2018 preliminary results
• $R_{AA}$ of $b \rightarrow e$ and $c \rightarrow e$ in $Au+Au$
• $v_2$ of $b \rightarrow e$ and $c \rightarrow e$
• Low $p_T$ photons in $p +Au$ and central $d+Au$
• Low $p_T$ photons in 39, 62 GeV $Au+Au$
## Data Production Status

<table>
<thead>
<tr>
<th>RUN</th>
<th>beam</th>
<th>VTX/FVTX/Muon (heavy flavor)</th>
<th>Central Arm flow</th>
<th>Central Arm EM (γ, e)</th>
<th>MPC/EX (small-x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Au+Au 200</td>
<td>Needs calibration, 2019</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>d+Au BES</td>
<td>Needs calibration, 2019</td>
<td>DONE</td>
<td>DONE</td>
<td>calibration</td>
</tr>
<tr>
<td>15</td>
<td>p+p 200</td>
<td>DONE</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p+Au 200</td>
<td>DONE</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p+Al 200</td>
<td>N.A.</td>
<td>DONE</td>
<td>DONE</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Au+Au 200</td>
<td>VTX ~90% DONE, FVTX ~90% DONE</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>3He+Au 200</td>
<td>2019</td>
<td>DONE</td>
<td>DONE</td>
<td></td>
</tr>
</tbody>
</table>

- **Next:** Run16AuAu ~ 6 months of CPU
### Golden datasets of PHENIX

<table>
<thead>
<tr>
<th>year</th>
<th>Beam, E(GeV)</th>
<th>Recorded data</th>
<th>upgrade</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>AuAu 200 dAu 200 dAu 62,39,20</td>
<td>2.3/nb (90/pb) 1G &amp; 73/nb 0.6G 0.1G, 8M</td>
<td>VTX,FVTX MPC-EX</td>
<td>Heavy Flavor Gluon nPDF Small QGP</td>
</tr>
<tr>
<td>2015</td>
<td>pp 200 pAu 200 pAl 200</td>
<td>23/pb 80/nb (16/pb) 275/nb (7.4/pb)</td>
<td>VTX, FVTX</td>
<td>Heavy Flavor Transverse spin CNM, small QGP</td>
</tr>
<tr>
<td>2014</td>
<td>AuAu 200, 15 $^3$HeAu 200</td>
<td>2.3/nb (90/pb) 25/nb (15/pb)</td>
<td>VTX, FVTX</td>
<td>Heavy Flavor Small QGP</td>
</tr>
<tr>
<td>2013</td>
<td>pp 510</td>
<td>240/pb</td>
<td>W-trigger</td>
<td>Anti-quark spin Gluon spin</td>
</tr>
<tr>
<td>2012</td>
<td>pp 510 pp 200 CuAu 200 UU 193</td>
<td>50/pb 4/pb 5/nb (60/pb) 0.17/nb (10/pb)</td>
<td>W-trigger VTX, FVTX</td>
<td>Anti-quark spin Transverse spin Heavy flavor Geometry</td>
</tr>
<tr>
<td>2011</td>
<td>pp 510 AuAu 200 AuAu 19, 27</td>
<td>28/pb 0.8/nb (32/pb)</td>
<td>W-trigger VTX</td>
<td>Anti-quark spin Heavy flavor BES-I</td>
</tr>
<tr>
<td>2010</td>
<td>AuAu 200 AuAu 62,39,7</td>
<td>1.1/nb (44/pb)</td>
<td>HBD</td>
<td>Low mass ee BES-I</td>
</tr>
</tbody>
</table>

**Many physics topics with variety of high statistics datasets**

**Up to 3 years to complete publication of major results**
Need for Long term data preservation

• Unique, high statistics datasets have long impact
  2013 discovery of collectivity in p+Pb at LHC
  → re-analysis of 2008 d+Au data to investigate collectivity at RHIC
  → Renewed interest in other physics topics in d+Au
  → we published 12 papers in 2014-17 from 2008 d+Au

• We need effort for long term data preservation and analyzability
  – Dedicated expert resources and planning for this effort are needed
• Challenge: Keep the number of Ph.D students and postdocs to analyze the data
  – Decline of the number of active collaborators
  – Good news: Two new institutions are to join PHENIX
• We had the 2\textsuperscript{nd} PHENIX School in August to recruit and to train new students and postdocs.
• Focus on important physics topics that PHENIX has strength
  – Flow in large and small system
  – Low $p_T$ direct photons
  – Open HF (VTX/FVTX)
  – Quarkonia
  – Jets and high $p_T$ particles
Summary

• Removal and Repurposing near completion

• Recent achievements
  – PHENIX continues to produce high impact results
    • Publishing ~11 papers per year, ~2000 citations/year
  – Recent highlights
    • Evidence for small QGP droplets
    • Thermal photons: transition to QGP?
    • $v_2$ of $b \rightarrow e$ and $c \rightarrow e$
    • Suppression of $A_N$ in $p+Au$

• Status of Data analysis
  – DST production except for heavy flavor measurement in RUN16 are basically completed
  – Up to 3 more years to publish major results
  – It is essential to maintain the current level of RCF and manpower support
  – Dedicated Manpower needed to preserve analyzability of the data
### Data Production Status

<table>
<thead>
<tr>
<th>RUN</th>
<th>beam</th>
<th>VTX/FVTX/Muon (heavy flavor)</th>
<th>Central Arm flow</th>
<th>Central Arm EM ($\gamma$, e)</th>
<th>MPC/EX (small-x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Au+Au 200</td>
<td>Needs calibration, 2018</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>d+Au BES</td>
<td>Needs calibration, 2018</td>
<td>DONE</td>
<td>DONE</td>
<td>calibration</td>
</tr>
<tr>
<td>15</td>
<td>p+p 200</td>
<td>DONE</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p+Au 200</td>
<td>DONE</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p+Al 200</td>
<td>N/A</td>
<td>DONE</td>
<td>DONE</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Au+Au 200</td>
<td>Started, 2017</td>
<td>DONE</td>
<td>DONE</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>3He+Au 200</td>
<td>2018</td>
<td>DONE</td>
<td>DONE</td>
<td></td>
</tr>
</tbody>
</table>

- Solved: Delay of VTX production due to “event mis-alignment”
- Run14AuAu, Run16AuAu ~ 6 months of CPU each