# PHENIX
# Status and Data analysis plan

**Yasuyuki Akiba (RIKEN)**
PHENIX Spokesperson

RHIC Site Visit
18 September 2018

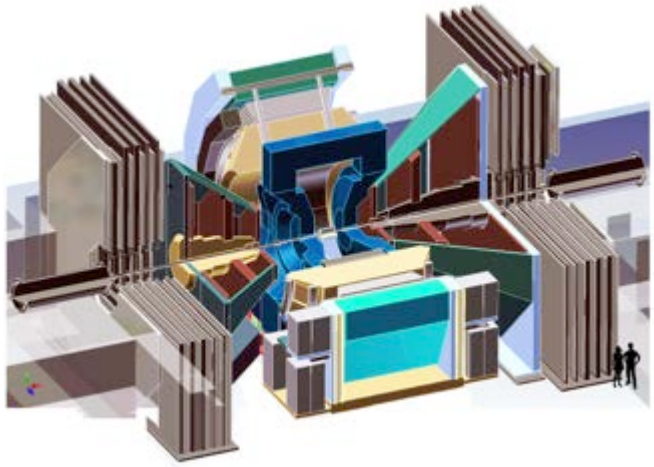
BROOKHAVEN NATIONAL LABORATORY

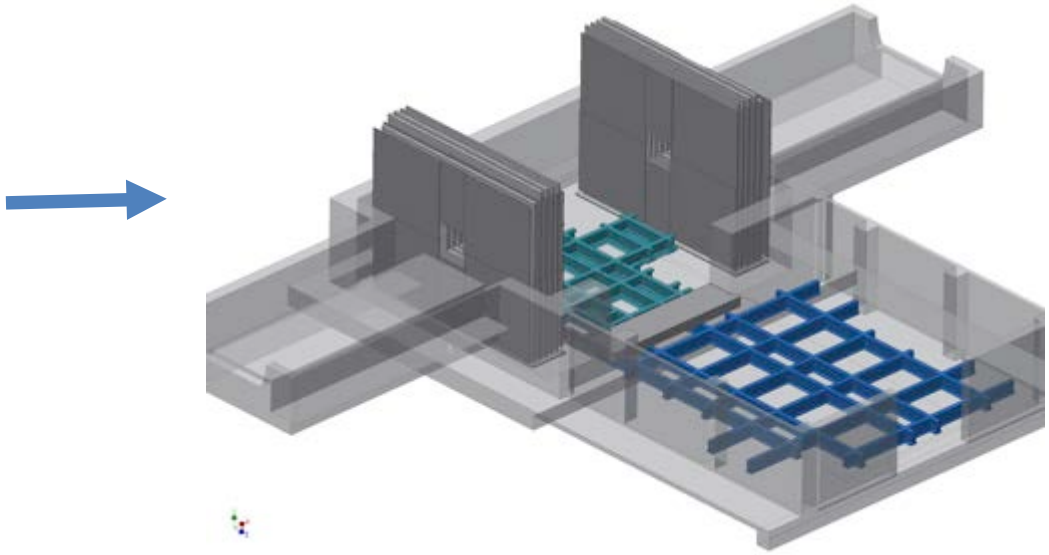
U.S. DEPARTMENT OF ENERGY

# 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





# PHENIX Removal & Repurposing (R&R)

PHENIX July 2016

PHENIX Sept 2018


- 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

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

# Publication status

# Discovery of Jet quenching paper has 1000 citations

INSPIRE HEP

Welcome to INSPIRE, the High Energy Physics information system. Please direct questions, comments or concerns to feedback@inspirehep.net.

HEP :: HEPNAMES :: INSTITUTIONS :: CONFERENCES :: JOBS :: EXPERIMENTS :: JOURNALS :: HELP

find cn phenix and topcite 1000+ | Brief format | Search | Easy Search | Advanced Search

find j "Phys.Rev.Lett.,105*" :: more

2018/05/09

Sort by: earliest date | desc. | - or rank by - | Display results: 25 results | single list

**HEP** **2** records found Search took 0.55 seconds.

1. **Formation of dense partonic matter in relativistic nucleus-nucleus collisions at RHIC: Experimental evaluation by the PHENIX collaboration**
   PHENIX Collaboration (K. Adcox (Vanderbilt U.) *et al.*). Oct 2004. 127 pp.
   Published in **Nucl.Phys. A757 (2005) 184-283**
   DOI: 10.1016/j.nuclphysa.2005.03.086
   e-Print: **nucl-ex/0410003** | **PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service
   Detailed record - Cited by 2512 records 1000+

2. **Suppression of hadrons with large transverse momentum in central Au+Au collisions at $\sqrt{s_{NN}}$ = 130-GeV**
   PHENIX Collaboration (K. Adcox (Vanderbilt U.) *et al.*). Sep 2001. 6 pp.
   Published in **Phys.Rev.Lett. 88 (2002) 022301**
   DOI: 10.1103/PhysRevLett.88.022301
   e-Print: **nucl-ex/0109003** | **PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service
   Detailed record - Cited by 1000 records 1000+

Now 1013 citations

PHENIX

# 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

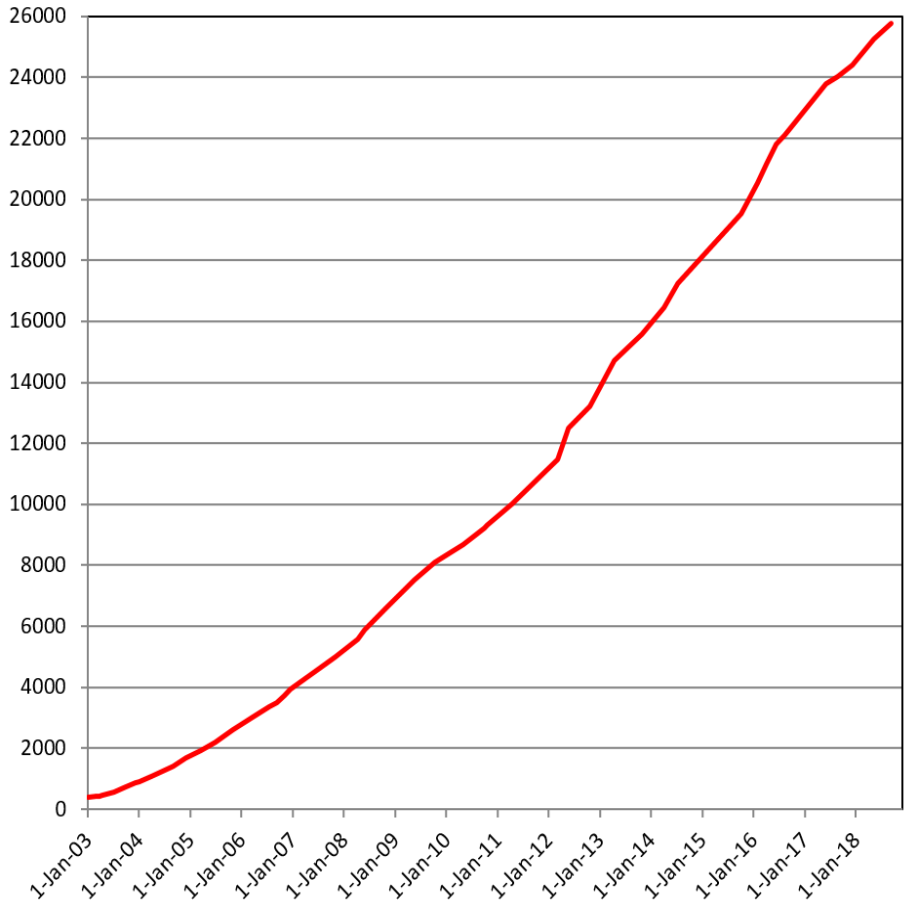
**PHENIX White Paper: ~2600 cites**

**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**

**Cumulative Citations of PHENIX papers**




PHENIX

# PHENIX papers in the last 12 months

| | |
|---|---|
| **PRD98,032007 (2018)** | **$A_L$ of $W \to \mu$** |
| **PRD98,012006 (2018)** | **$A_N$ of forward $J/\psi$ in p+A** |
| **PRC98,014912 (2018)** | **Long range correlation of high $p_T$ hadrons in $p+p$ and d+Au** |
| **PRC97,064911 (2018)** | **HBT Levy fit analysis** |
| **PRC97,064904 (2018)** | **Identified hadron $v_2$ in pAu and $^3$HeAu** |
| **PRL120, 062302 (2018)** | **Collectivity in d+Au Beam Energy Scan and $p$ +Au 200GeV** |
| **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)** | **$B \to J/\psi$ 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 | $\phi \to \mu\mu$ in $p+p$ 510 GeV |
| arXiv:1803.01749 | Two particle correlation with respect to event plane |
| arXiv:1804.10024 | Event-by-event elliptic flow in AuAu 200 GeV |
| 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 |

PHENIX

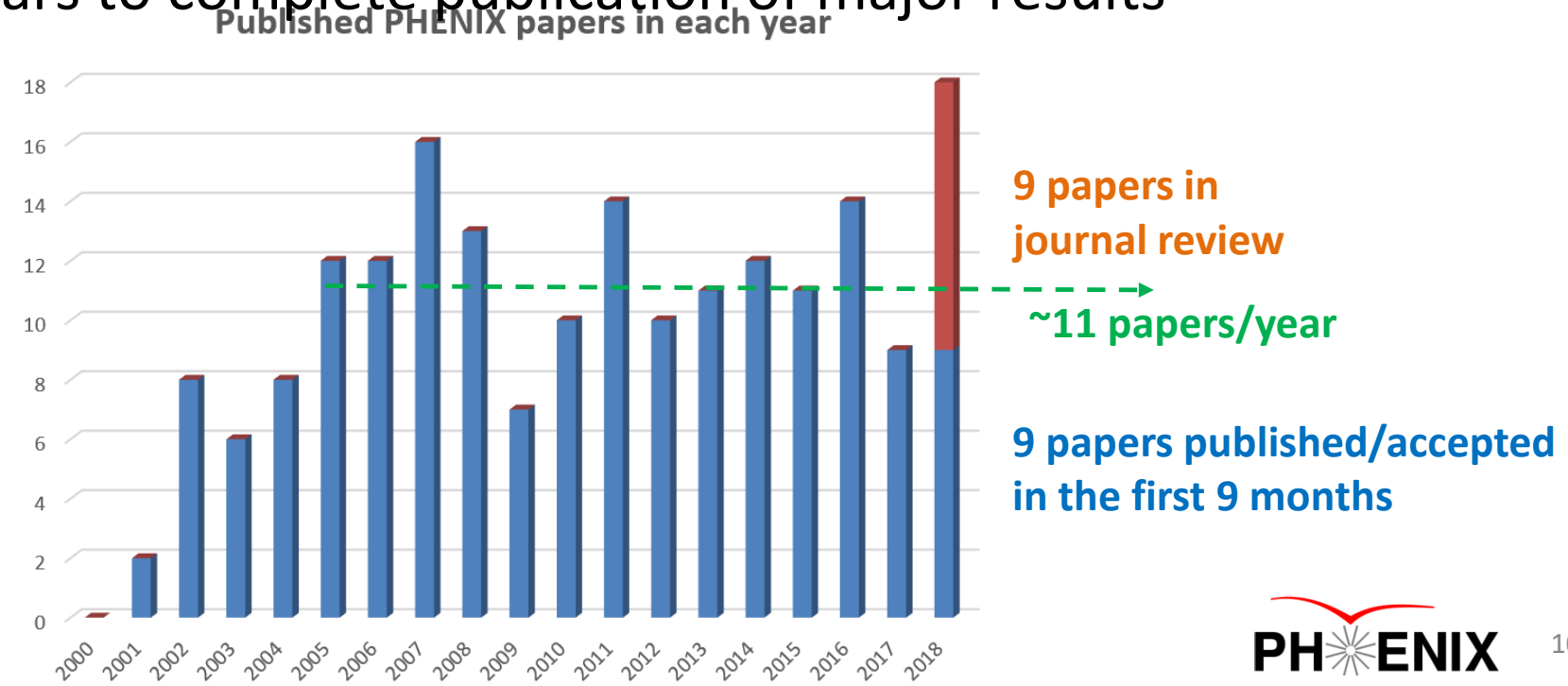
# Publication in the last 12 months

- 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 pAu, dAu, $^3$HeAu

PHENIX

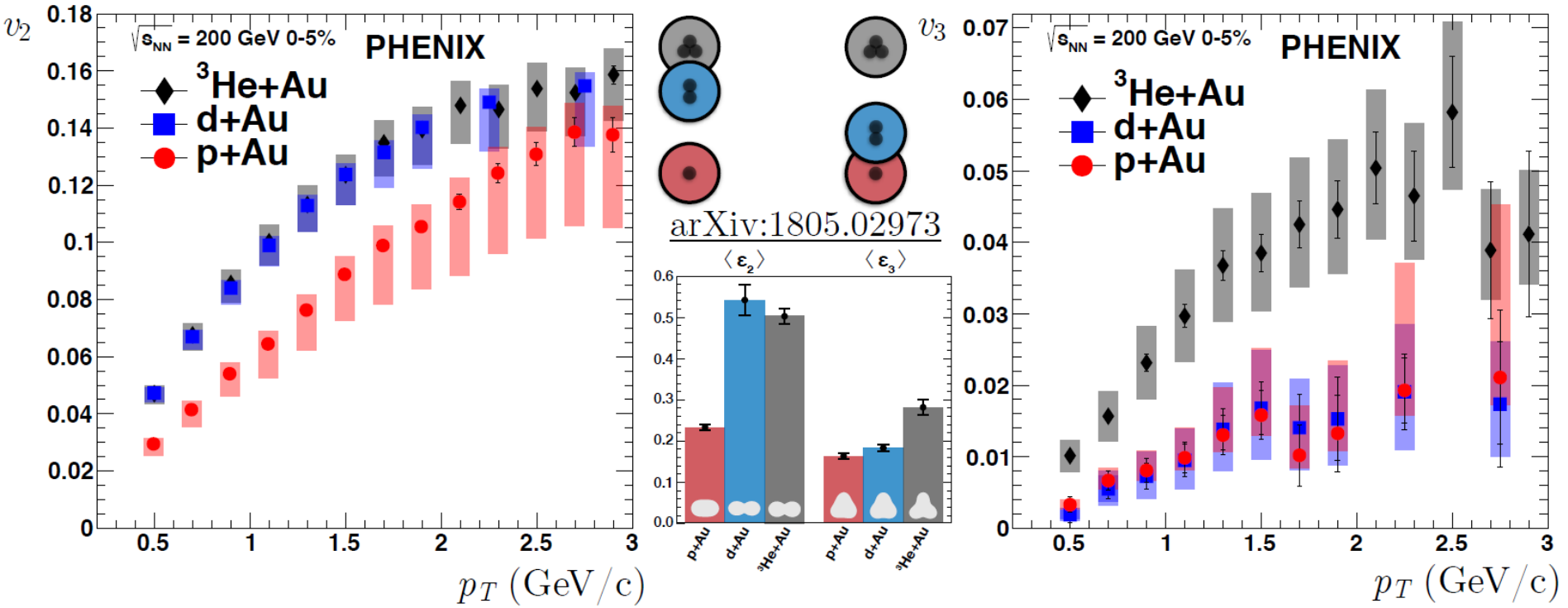
# Publish the results of PHENIX

- 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



# Highlights of recent results

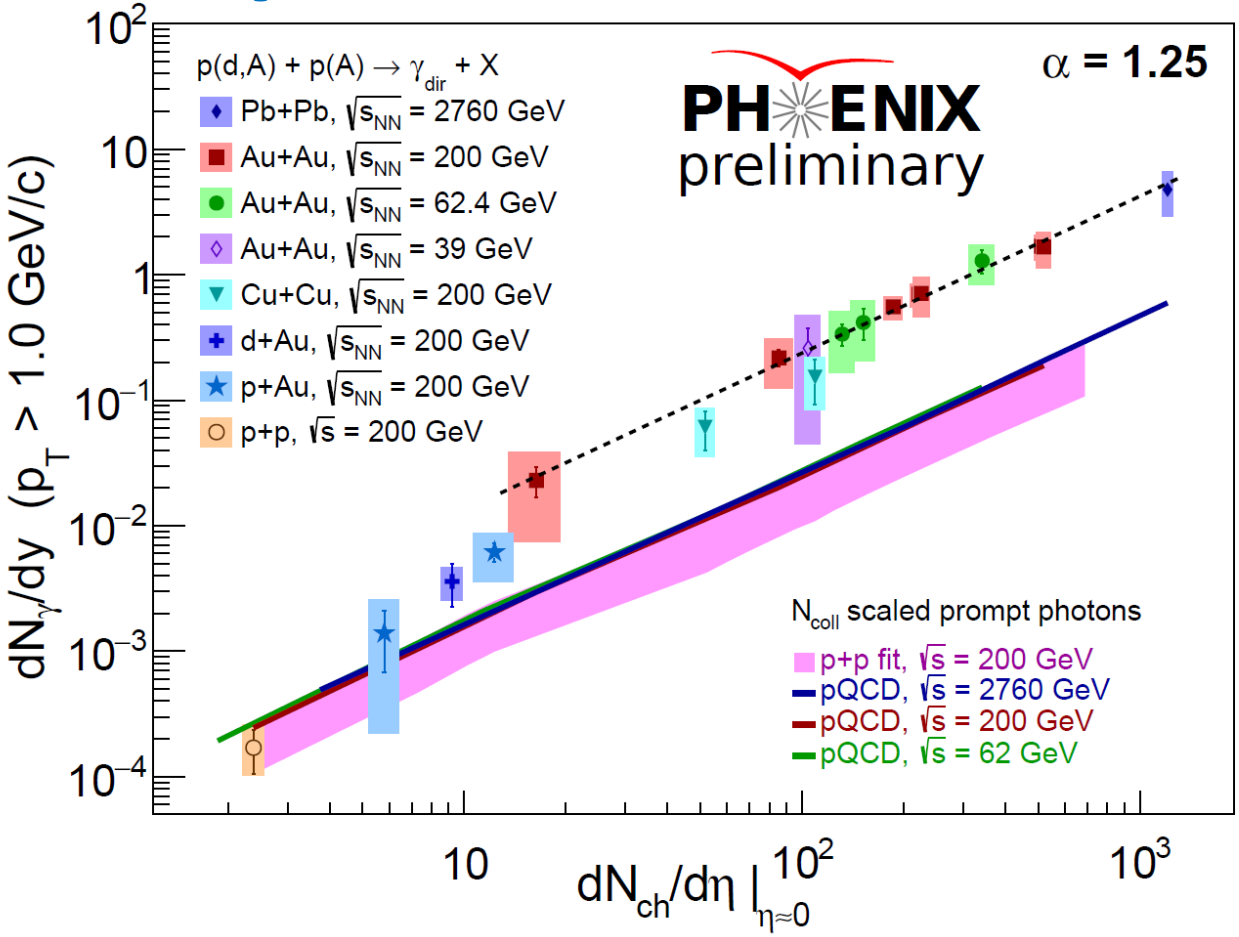
# Evidence for small QGP droplets




- $v_2^{p+Au} < v_2^{d+Au} \simeq v_3^{^3He+Au}$ and $v_3^{p+Au} \simeq v_3^{d+Au} < v_3^{^3He+Au}$ order of $v_2$ and $v_3$ is the same as that of $\varepsilon_2$ and $\varepsilon_3$
- Presence of QGP droplets best describes the data
- Accepted by Nature Physics

PHENIX

# Thermal photons: transition to QGP?




- Scaling means similar photon source across beam energies

→ Most photons are emitted at the phase transition

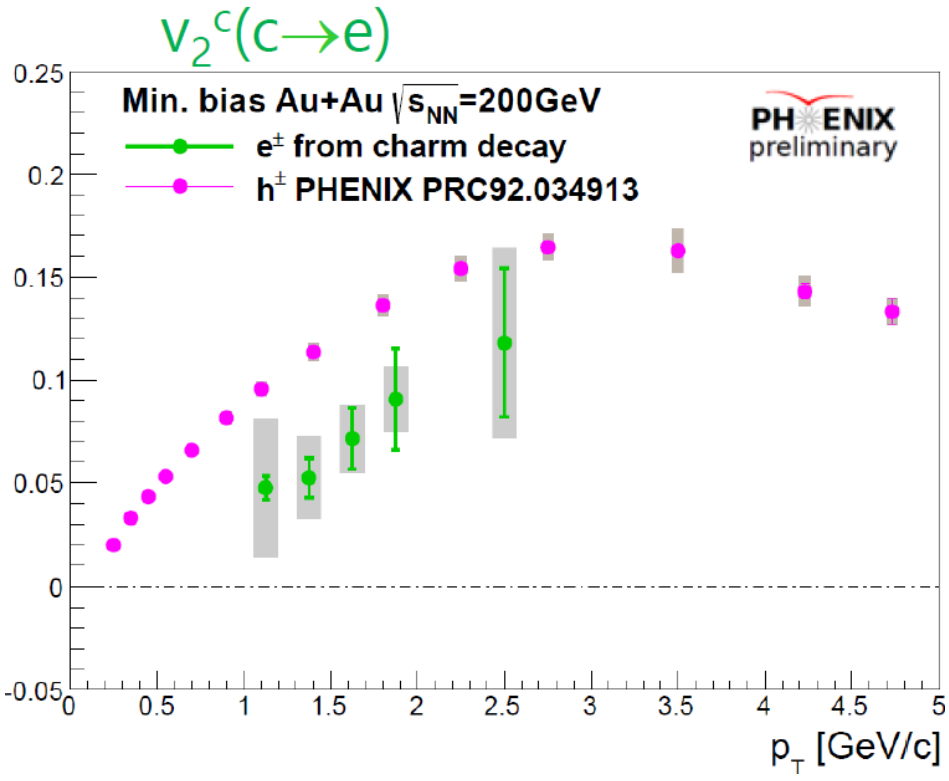
A paper submitted to PRL

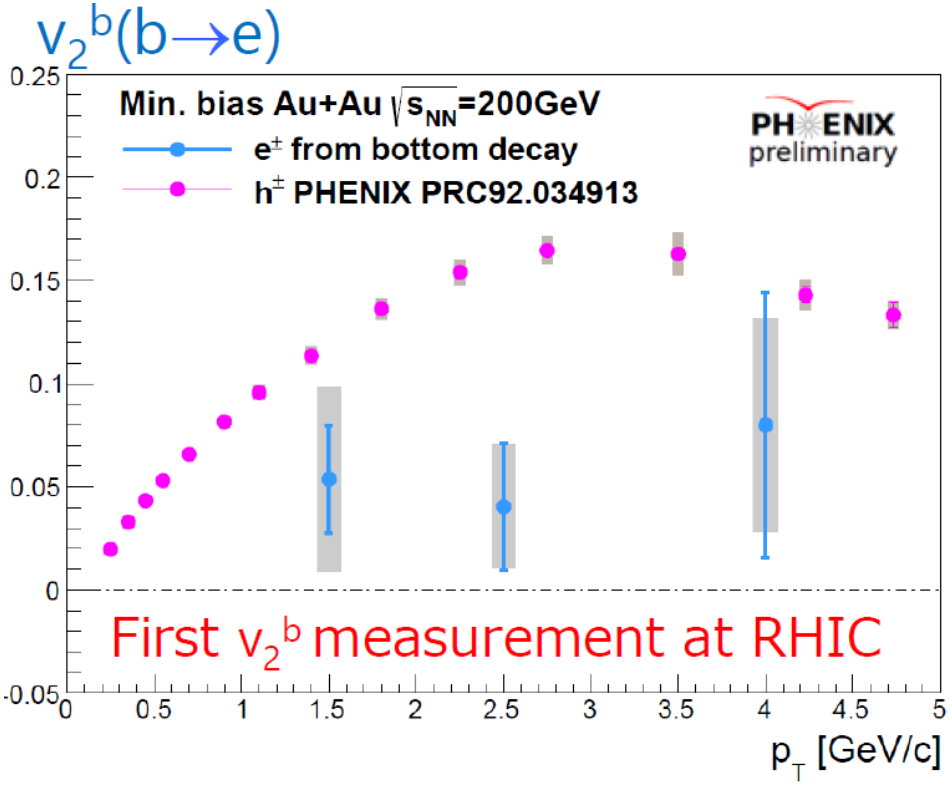
- Evidence for Photon enhancement in $p + A$ and $d$+Au

→ Support QGP formation in small systems

PHENIX

# Flow of charm and bottom



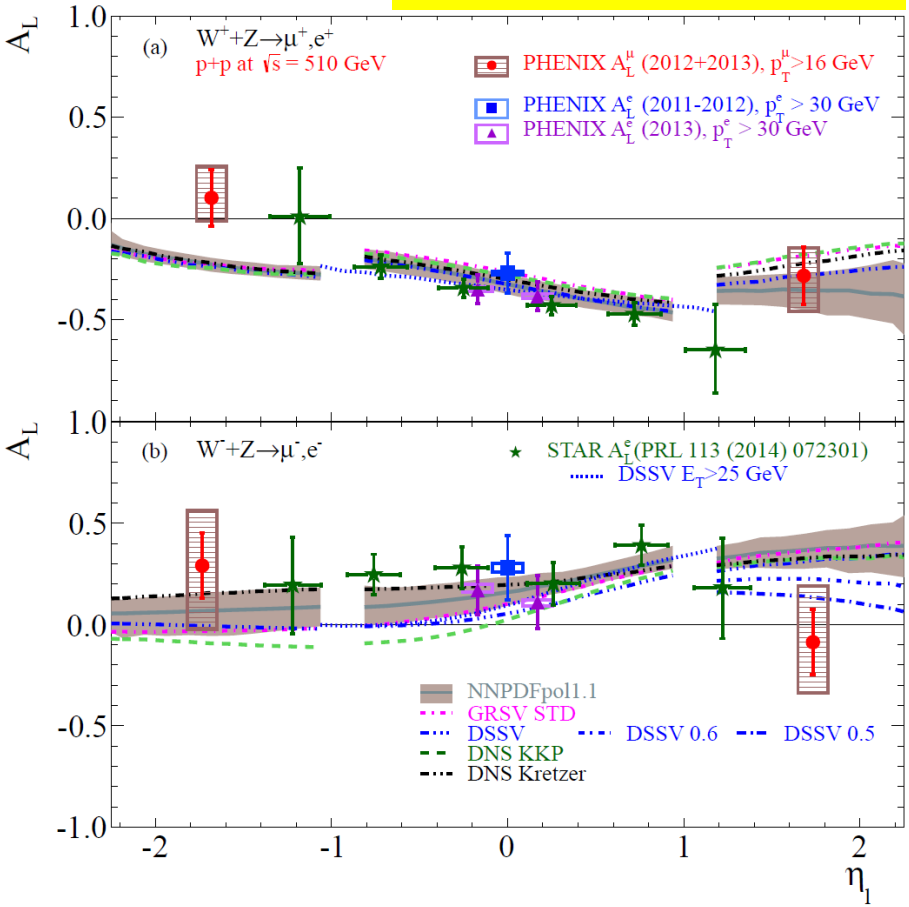



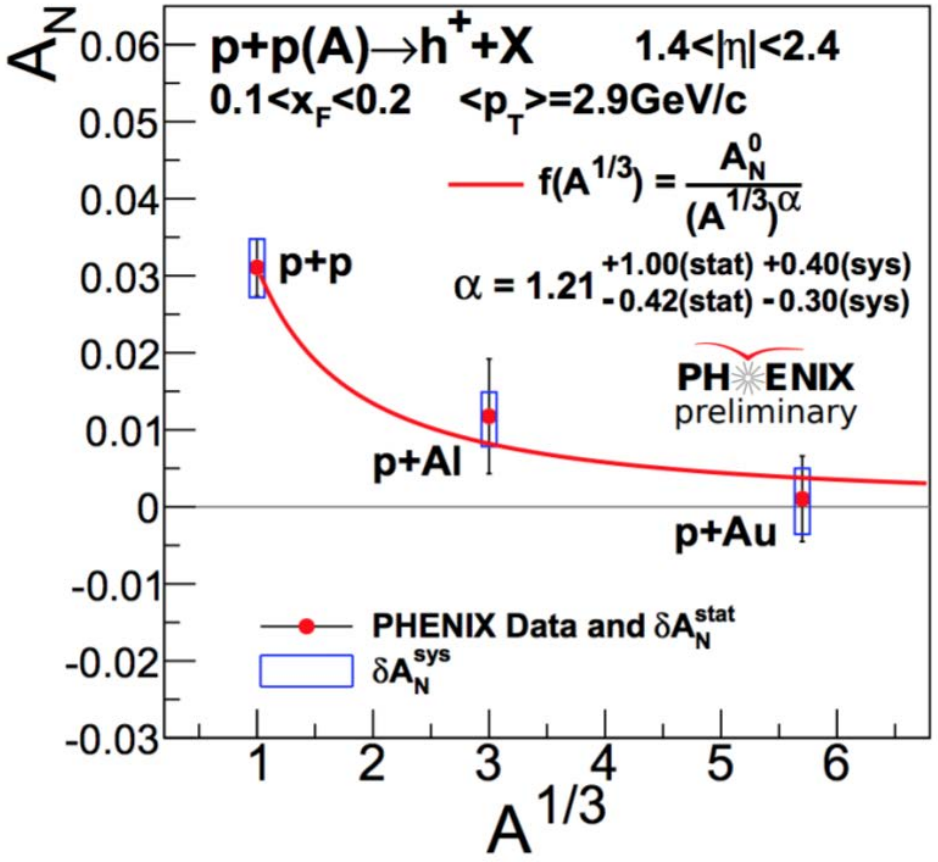

- Preliminary results from Run14 data (~20 B events)
- First measurement of $v_2$ of $b \rightarrow e$
  - Hint of non-zero $v_2$ of bottom
  - Hint that $v_2$ of $b$ and $c$ are different.
- Run16 data will double the statistics

PHENIX

# PHENIX Spin highlights

PRD98 032007 (2018)




**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**

PHENIX

# 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

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

- Next: Run16AuAu ~ 6 months of CPU

# Golden datasets of PHENIX

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

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

**Up to 3 years to complete publication of major results**

PHENIX

# 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 2nd 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

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

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

PHENIX