

# PHENIX Status and Plan

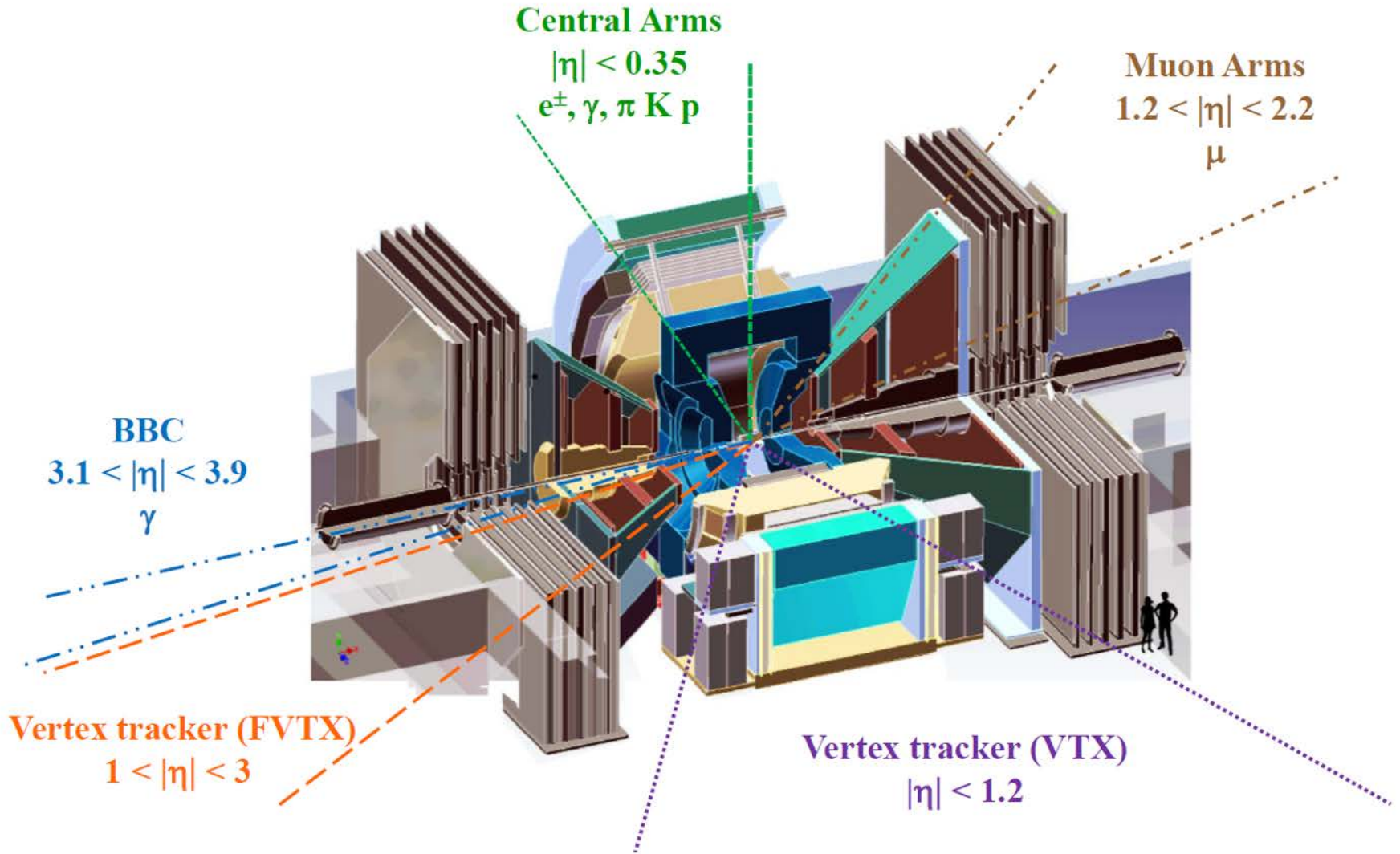
Y. Akiba (RIKEN/RBRC)  
for PHENIX Collaboration

PAC2017 2017/06/15

# Outline

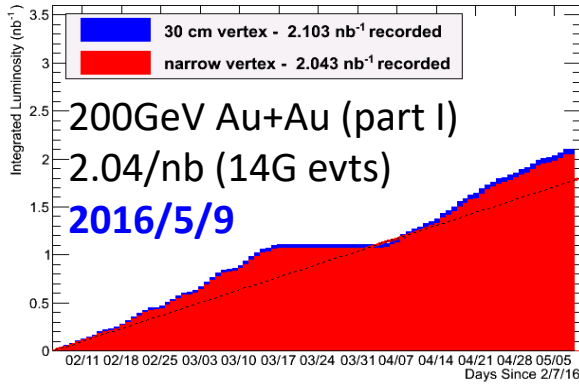
- PHENIX completed data taking
  - RUN16
  - Removal and Repurposing
- Recent accomplishments
  - Highlights of Publication in the past 12 months
  - Recent preliminary results
- Data Analysis status and plan

# PHENIX Detector

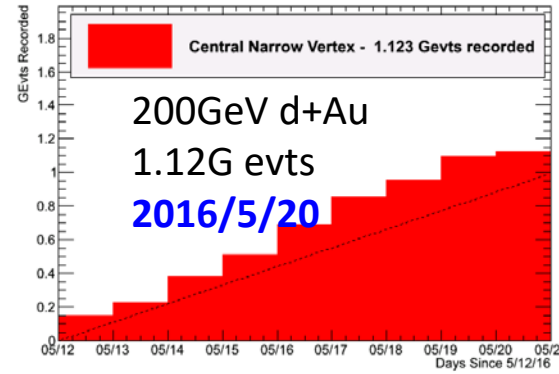


# RUN16: Completion of PHENIX data taking

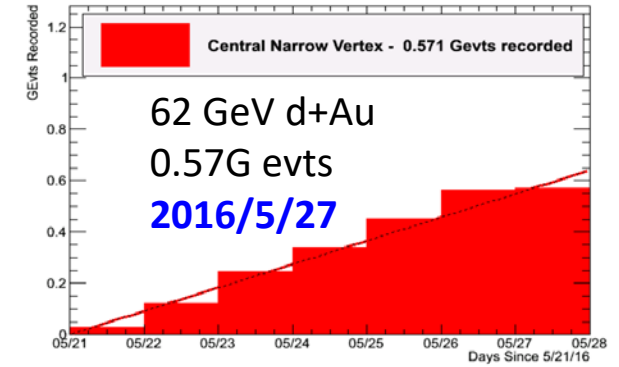
PHENIX Integr. Sampled Lumi vs Day **Mon May 9 06:01:20 2016**



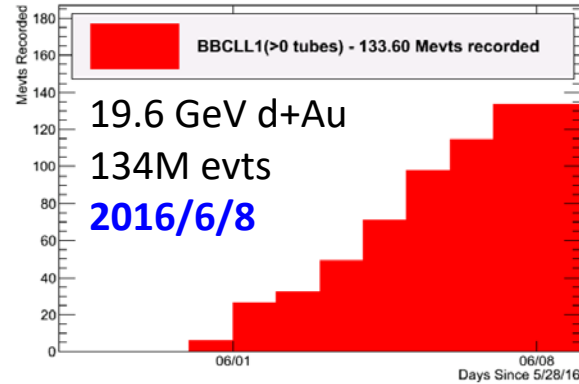
PHENIX GEvts vs Day **Fri May 20 09:00:14 2016**



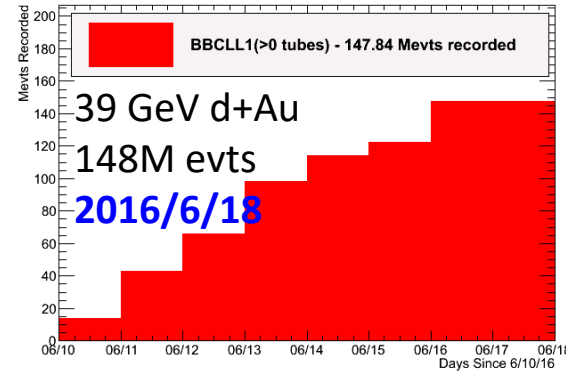
PHENIX GEvts vs Day **Fri May 27 06:00:11 2016**



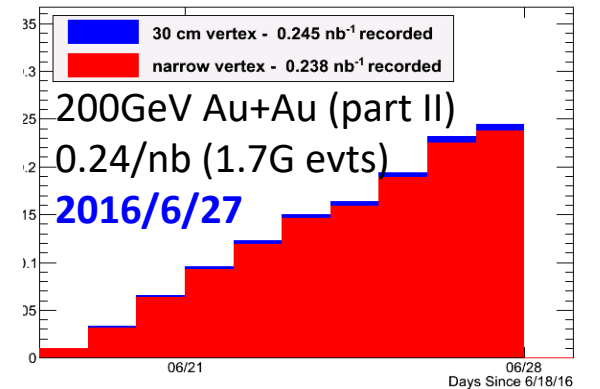
PHENIX Mevts vs Day **Wed Jun 8 09:00:14 2016**



PHENIX Mevts vs Day **Fri Jun 17 09:24:00 2016**



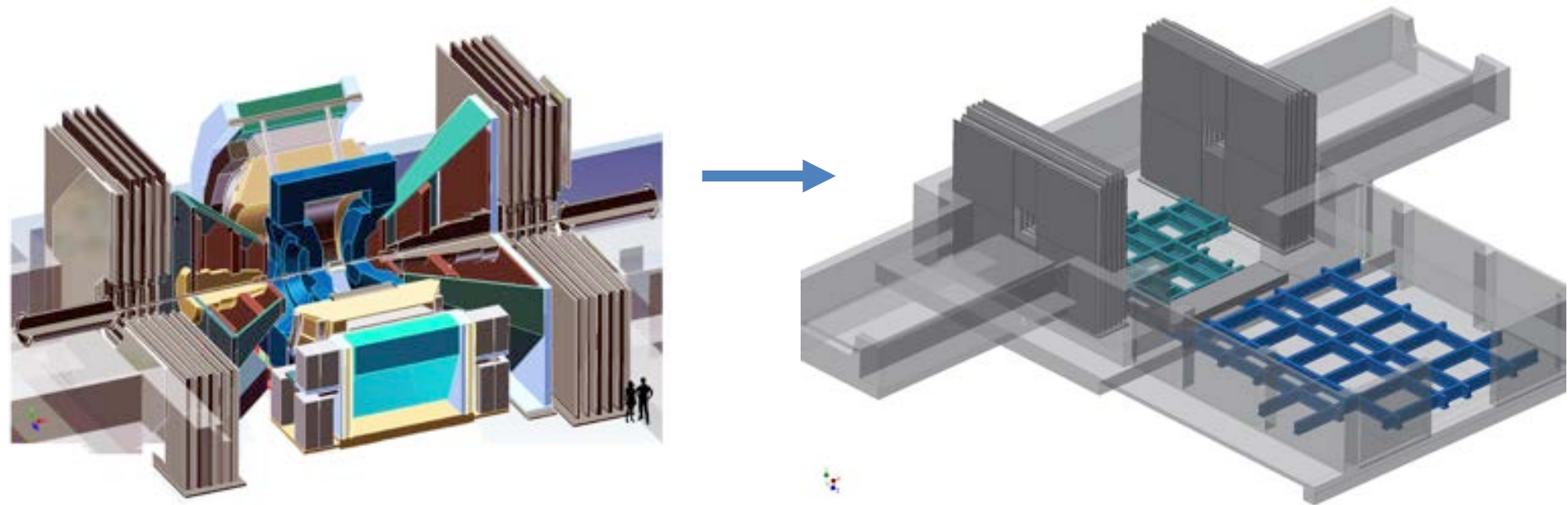
PHENIX Integr. Sampled Lumi vs Day **Mon Jun 27 08:06:26 2016**



RUN16 was the last data taking run of PHENIX detector

- 200 GeV Au+Au      2.3/nb 15.7G evts    Heavy flavor in QGP
- dAu Beam Energy Scan    Study of QGP in small systems

# Removal and Refurbishment (R & R) of the PHENIX Experiment at 1008, July 2016 – December 2018



sPHENIX Magnet Installation Start in 2019 Shutdown

# Removal & Repurposing Schedule

Major Tasks	Start Date	Finish Date
<b>R&amp;R Engineering, Prep and Planning</b>	<b>In Progress</b>	<b>10/1/17</b>
<b>Initial Tasks Following Run 16</b>	<b>6/27/16</b>	<b>7/29/16</b>
<b>Disassemble East Carriage</b>	<b>8/1/16</b>	<b>11/23/16</b>
<b>Disassemble Muon Magnet South</b>	<b>8/1/16</b>	<b>4/30/17</b>
<b>Disassemble Central Magnet</b>		
<b>Part 1 (things that can be done early)</b>	<b>8/1/16</b>	<b>7/3/17</b>
<b>Part 2 (everything else)</b>	<b>7/10/17</b>	<b>11/31/17</b>
<b>Remove Temporary Beampipe</b>	<b>7/10/17</b>	<b>7/24/17</b>
<b>Disassemble West Carriage</b>	<b>7/28/17</b>	<b>6/30/18</b>
<b>Restore Temporary Beampipe for Run18</b>	<b>12/1/17</b>	<b>12/31/17</b>
<b>Disassemble Muon Magnet North</b>	<b>7/1/18</b>	<b><u>12/31/18</u></b>

Legend: **Done**, **In progress**, **Target Completion Date**, Not yet Started

- Shield Wall will open up around July 3<sup>rd</sup>, 2017, and Central Arm will be rolled out soon after
- West Carriage can be worked on, but will need Central Arm removed before full disassembly is possible. Will roll out and complete disassembly during Run18.
- Above schedule is based on current understanding of run schedule. If Run18 and Run19 are combined, we would endeavor to remove north magnet before Run18/19 Start

# PHENIX Removal and Repurposing Status

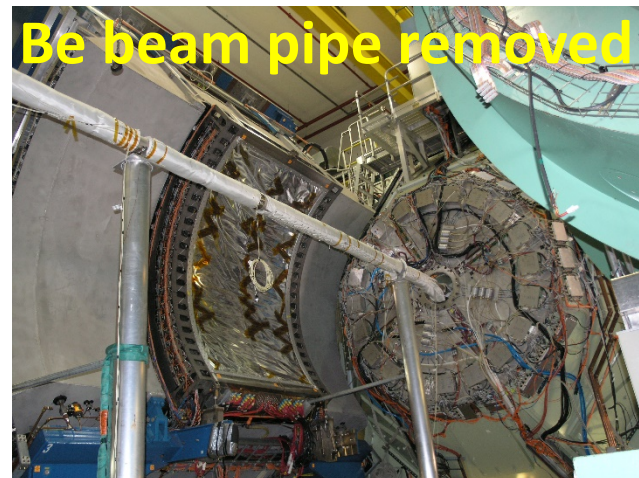
East Arm



South Muon



Be beam pipe removed



- East arm was completely removed
- South muon is completely disassembled
- Shield wall was closed for RUN17, but removal work on Central Arm inside IR during maintenance days
- Removal & Repurposing will resume after RUN17
- Hardest Parts (Central and North Arm) Still to Come

# PHENIX publications

- **172 physics papers published**

– Phys. Rev. Lett.	69
– Phys. Rev. C	67
– Phys. Rev. D	31
– Phys. Letter B	4
– Nucl. Phys. A	1

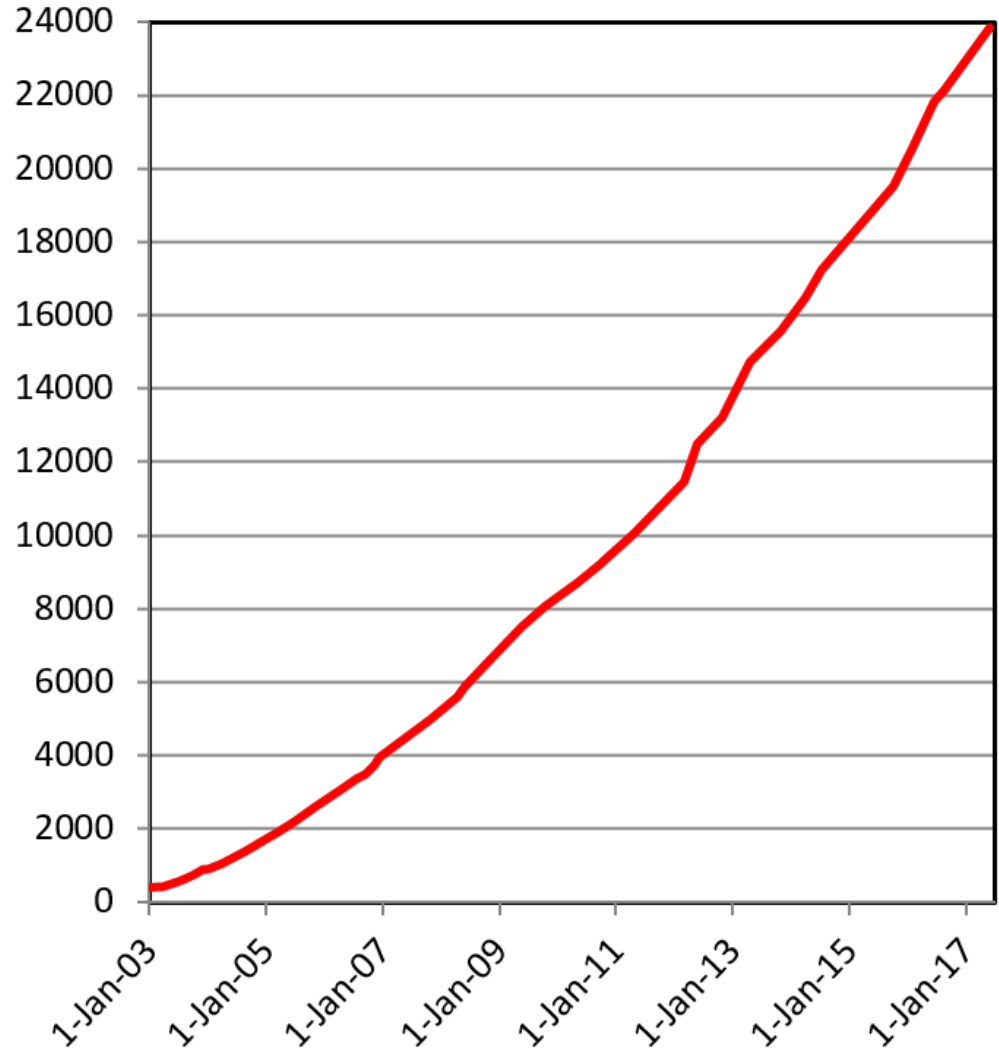
- **Total citation: ~24000**

– Topcite 1000+	1
– 500-1000	7
– 250-500	17
– 100-250	41
– 50-100	43

**PHENIX White Paper: ~2400 cites**

**109 papers in topcite 50+  
(127 if proceedings and NIM  
papers are included)**

**Cumulative Citations of PHENIX papers**





# 9 papers published in the last 12 months

1. Cross section and transverse single-spin asymmetry of muons from heavy-flavor decays in polarized p+p collisions at  $\sqrt{s} = 200$  GeV. **PRD95,112001 (2017)**
2. Angular decay coefficient of  $J/\psi$  mesons at forward rapidity from p+p collisions at  $\sqrt{s} = 510$  GeV. **PRD95, 092003 (2017)**
3. Measurements of  $B \rightarrow J/\psi$  at forward rapidity in p+p collisions at  $\sqrt{s} = 510$  GeV. **PRD95, 092002 (2017)**
4. Nonperturbative-transverse effects and evolution in dihadron and direct photon-hadron angular correlation in p+p collisions at  $\sqrt{s} = 510$  GeV. **PRD95, 072002 (2017)**
5. Measurement of long range angular correlations and azimuthal anisotropy in high multiplicity p+Au collisions at  $\sqrt{s_{NN}} = 200$  GeV. **PRC95, 034910 (2017)**
6. Measurement of the relative yields of  $\psi(2S)$  to  $\psi(1S)$  mesons produced at forward and backward rapidity in p+p, p+Au, and  $^3\text{He}+\text{Au}$  collisions at  $\sqrt{s_{NN}}=200\text{GeV}$ . **PRC95, 034904 (2017)**
7. Measurements of double-helicity asymmetries in inclusive  $J/\psi$  production in longitudinally polarized p+p collisions at  $\sqrt{s} = 200$  GeV. **PRD94, 112008 (2016)**
8. Azimuthally anisotropic emission of low momentum direct photons in Au+Au collisions at  $\sqrt{s_{NN}}=200$  GeV **PRC94, 064901 (2016)**
9. Measurements of directed, elliptic, and triangular flow in Cu+Au collisions at  $\sqrt{s_{NN}}=200$  GeV. **PRC94,054910 (2016)**

Plus

3 papers in journal review

6 papers in PHENIX internal review

# Highlights of recent results

## Heavy Flavor measurement

- $B \rightarrow J/\psi$  in p+p
- $B \rightarrow J/\psi$  in Cu+Au
- $b \rightarrow e$  and  $c \rightarrow e$  in RUN14

Published in PRD  
Submitted to PRC  
Preliminary

## Flow in small Systems

- $v_2$  in p/d/3He+Au
- Flow measurement in RUN16 d+Au  
Beam Energy Scan

Published in PRC  
Two papers under  
internal review

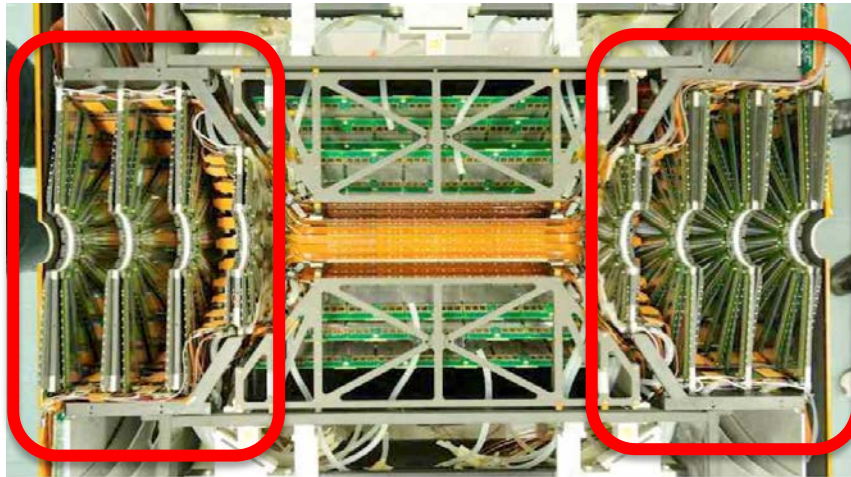
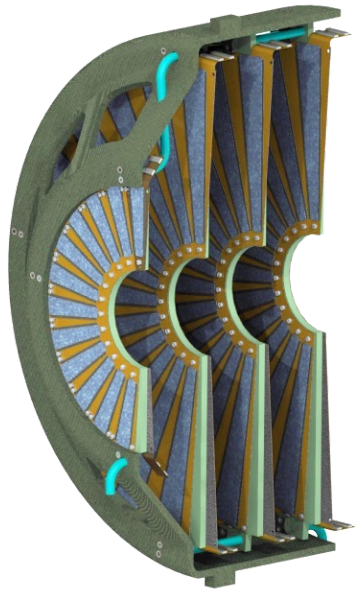
## Spin physics

- $A_N$  of very forward neutron in p+A
- $A_N$  of forward  $J/\psi$  in pAu

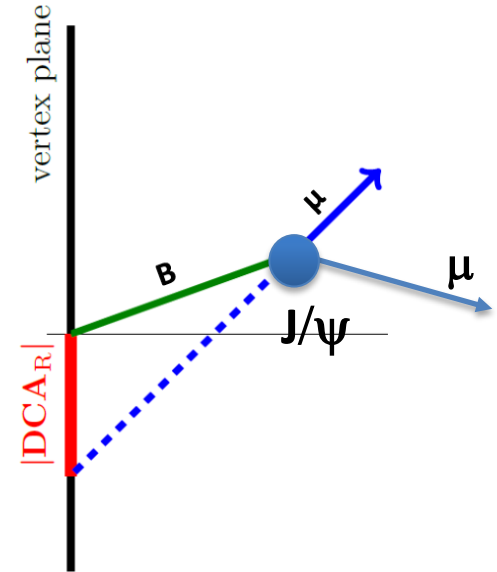
Submitted to PRL  
Preliminary

# B $\rightarrow$ J/ $\psi$ in pp and CuAu (2012)

## The first B $\rightarrow$ J/ $\psi$ results at RHIC



FVTX detector



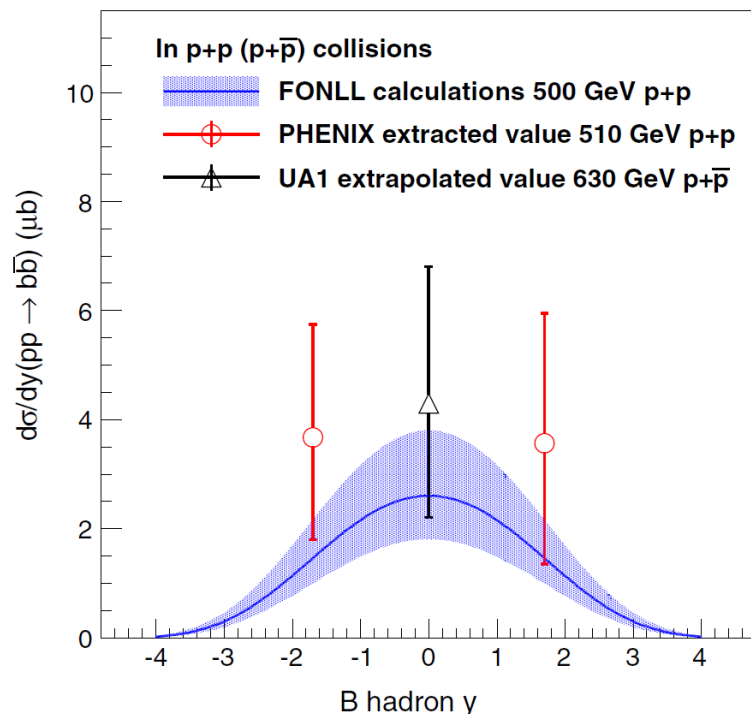
- B $\rightarrow$  J/ $\psi$  fraction was measured in pp 510 GeV, pp 200 GeV and Cu+Au 200 GeV
- Results in pp at 510 GeV was published in PRD
- Results in pp and CuAu at 200 GeV was submitted to PRC

# $B \rightarrow J/\psi$ in p+p and Cu+Au

PHYSICAL REVIEW D 95, 092002 (2017)

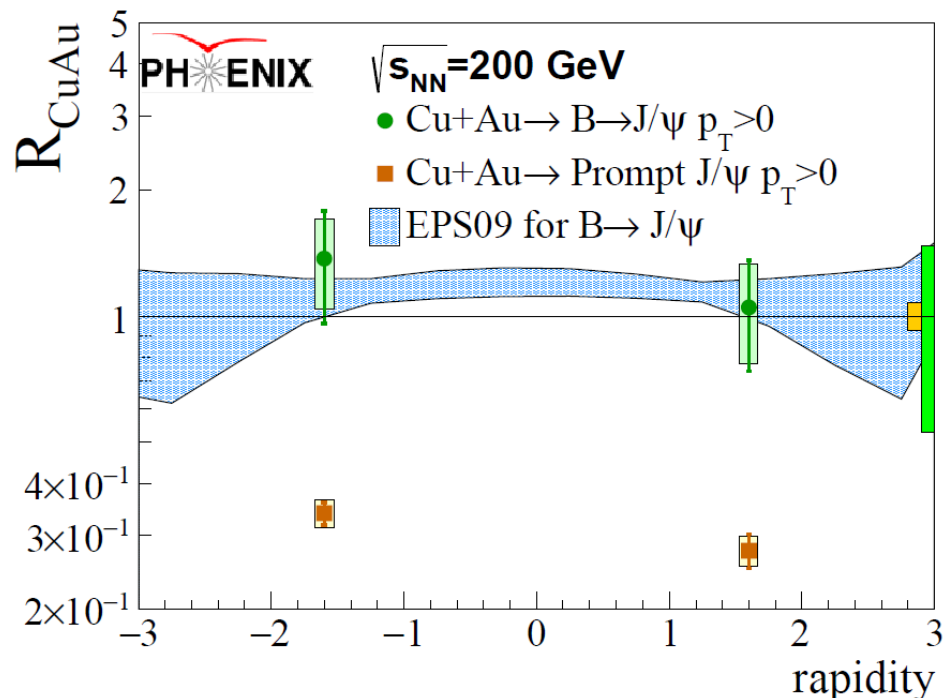
arXiv:1702.01085v1

Measurements of  $B \rightarrow J/\psi$  at forward rapidity  
in  $p+p$  collisions at  $\sqrt{s}=510$  GeV



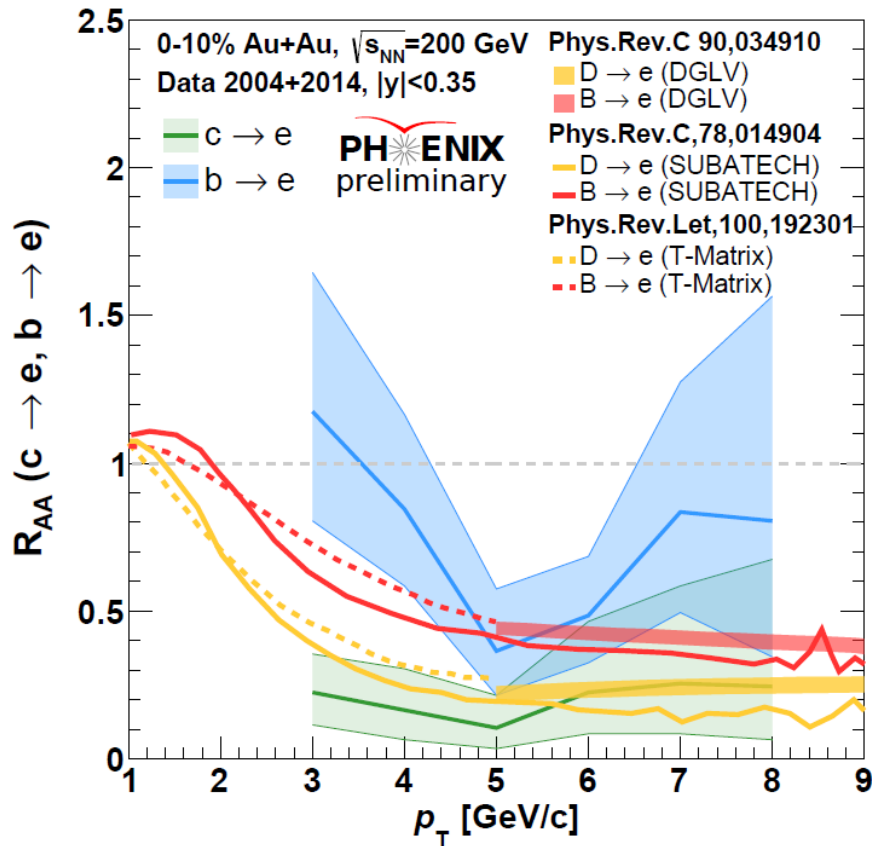
The first measurement of  
 $B \rightarrow J/\psi$  at RHIC

$B$ -meson production at forward and backward rapidity  
in Cu+Au collisions at  $\sqrt{s_{NN}} = 200$  GeV



$B \rightarrow J/\psi$  is not suppressed in  
Cu+Au

# $b \rightarrow e$ and $c \rightarrow e$ at midrapidity

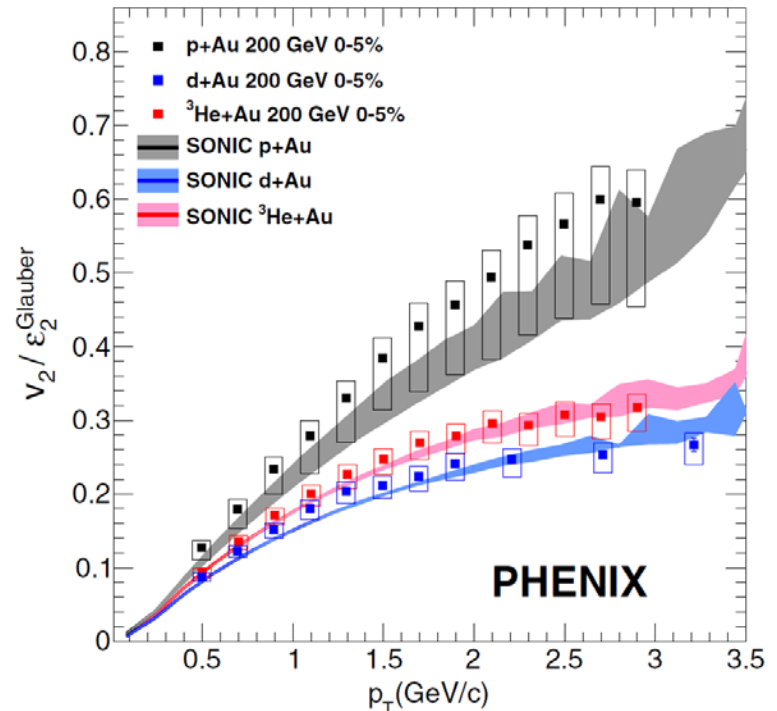
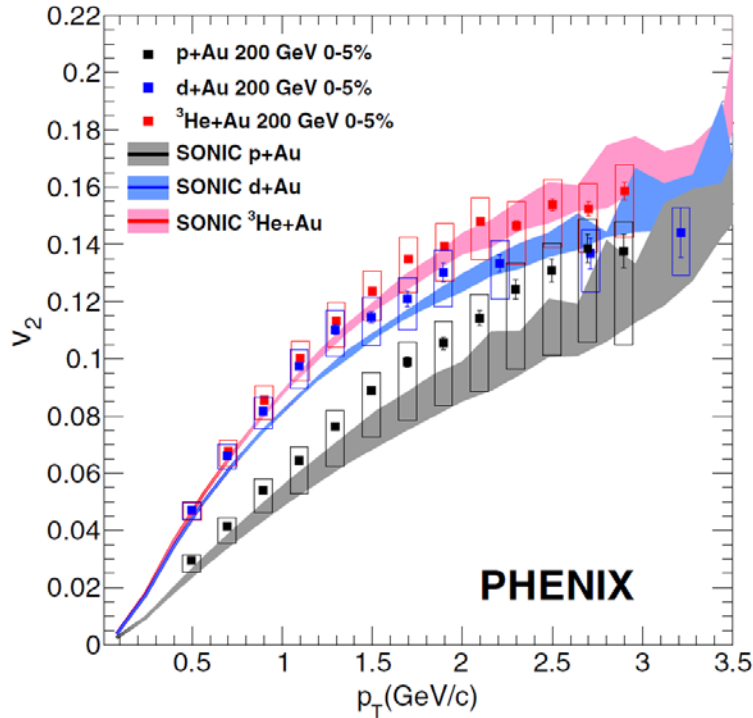


- Preliminary results from  $\frac{1}{4}$  of RUN14 data was presented at Quark Matter 2017 conference
- The results confirm that b quark is less suppressed than c quark in QGP.
- The results will be finalized and published in a year.

# Flow in p/d/<sup>3</sup>He+Au

PHYSICAL REVIEW C 95, 034910 (2017)

Measurement of long-range angular correlations and azimuthal anisotropies  
in high-multiplicity  $p + Au$  collisions at  $\sqrt{s_{NN}} = 200$  GeV



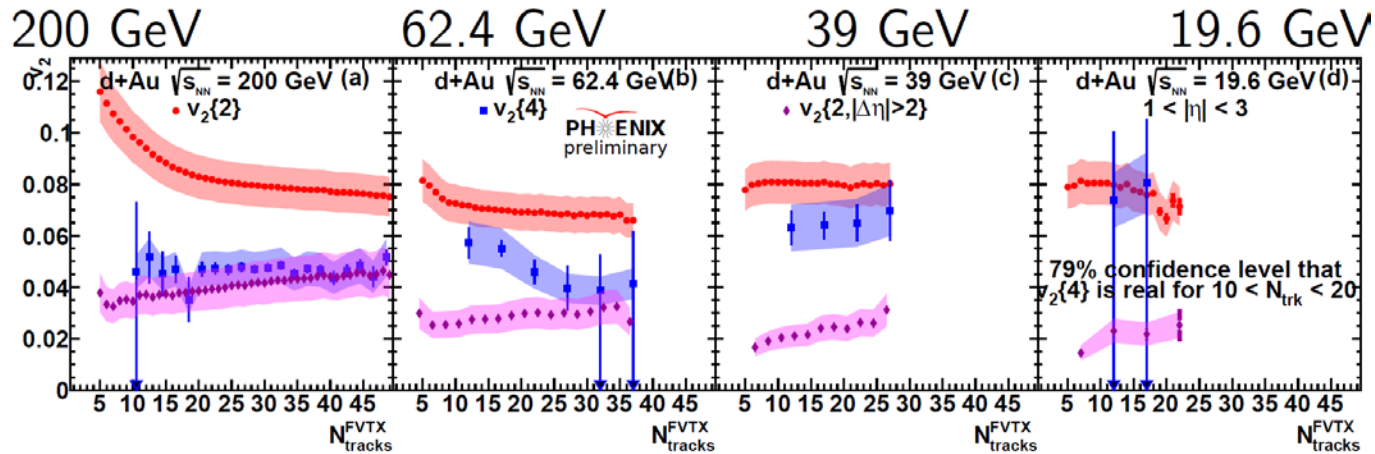
$v_2$ :  ${}^3\text{He}+\text{Au} > \text{d}+\text{Au} > \text{p}+\text{Au}$

$v_2/\epsilon_2$ :  $\text{p}+\text{Au} > \text{d}+\text{Au} > {}^3\text{He}+\text{Au}$

Hydro-calculation reproduces imperfect scaling of  $v_2$  with  $\epsilon_2$

– Strong evidence for initial geometry as the source of the flow

# Flow in d+Au Beam Energy Scan

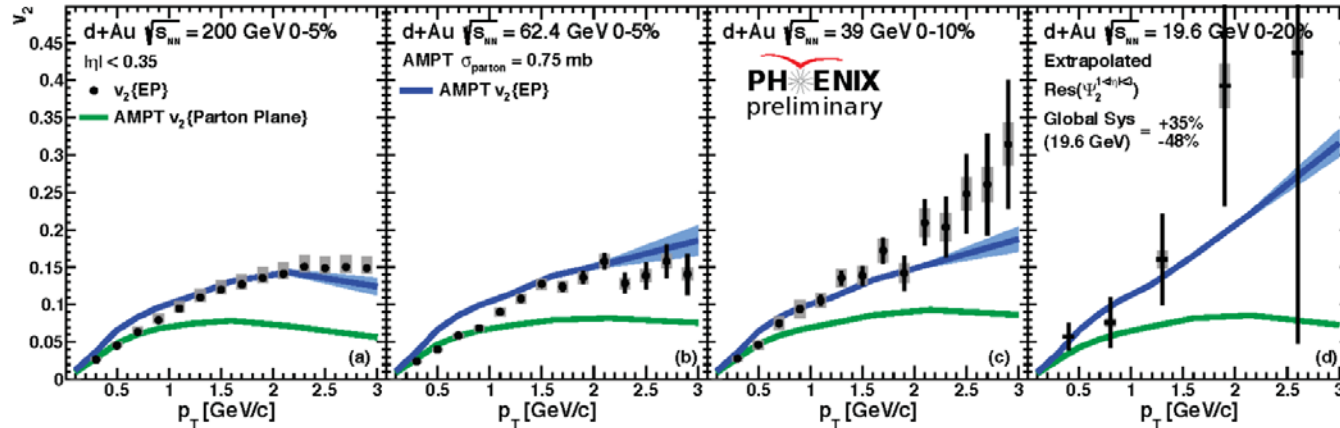


200 GeV

62 GeV

39 GeV

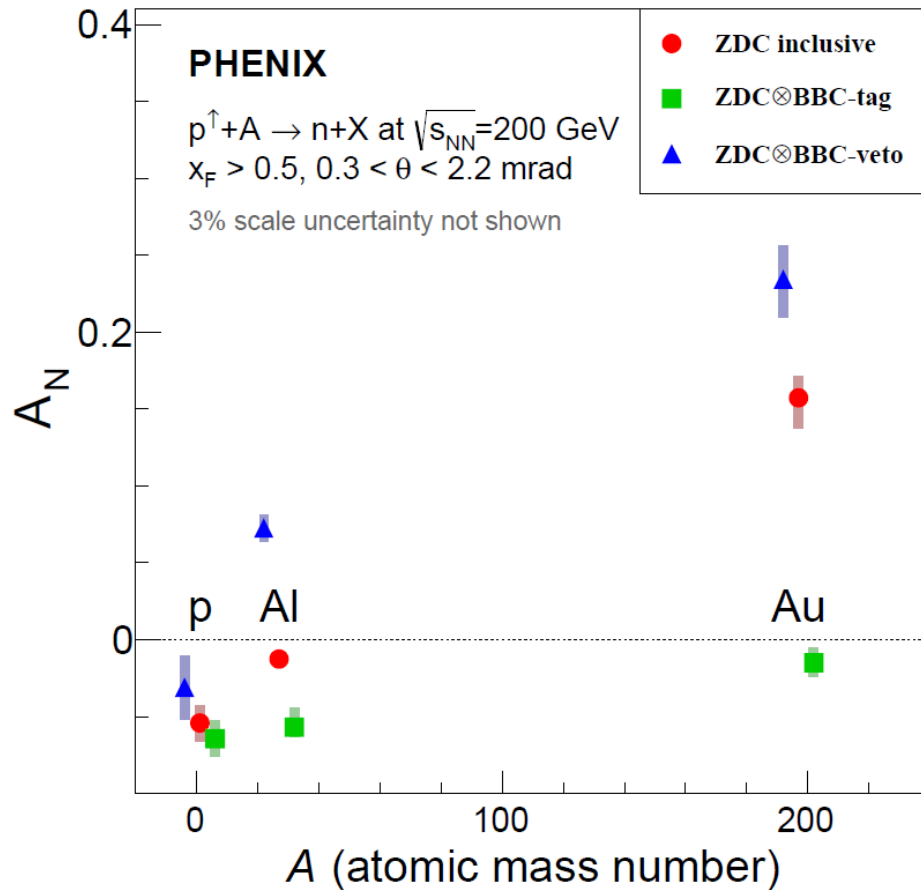
20 GeV



- Flow measurements in Run16 d+Au BES shown in QM2017
- Two papers of the results in PHENIX internal review

# $A_N$ of very forward neutrons in pp/pA

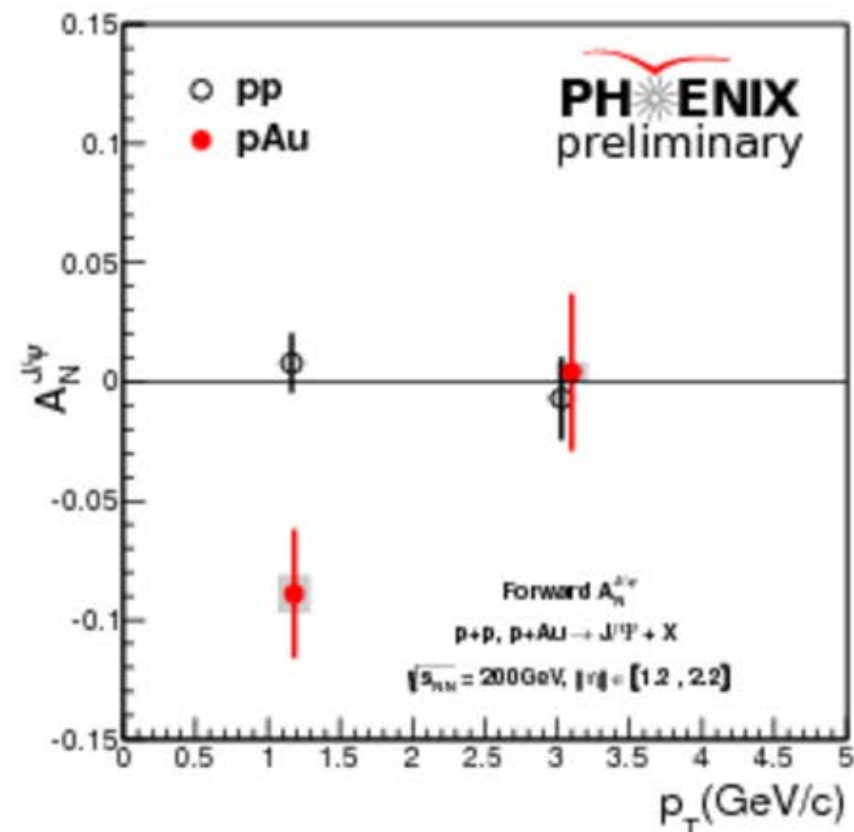
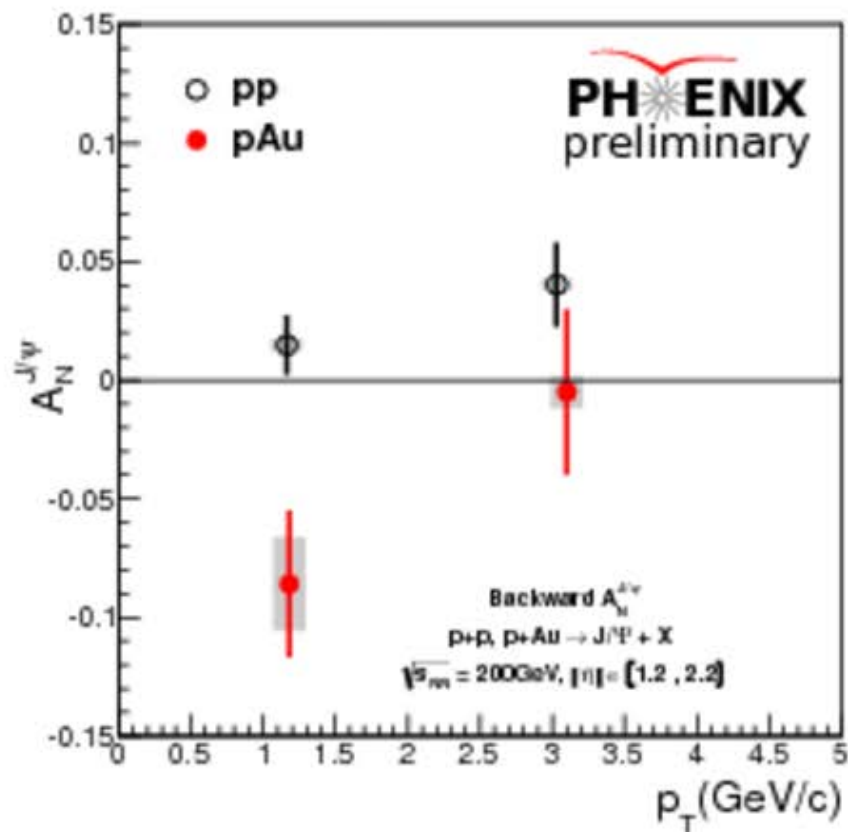
arXiv:1703.10941



- Unexpectedly large  $A_N$  of very forward neutrons in p+Au was discovered in RUN15
- Very large  $A$  dependence of the asymmetry
- The result is submitted to PRL



# $A_N$ of $J/\psi$ in p+Au



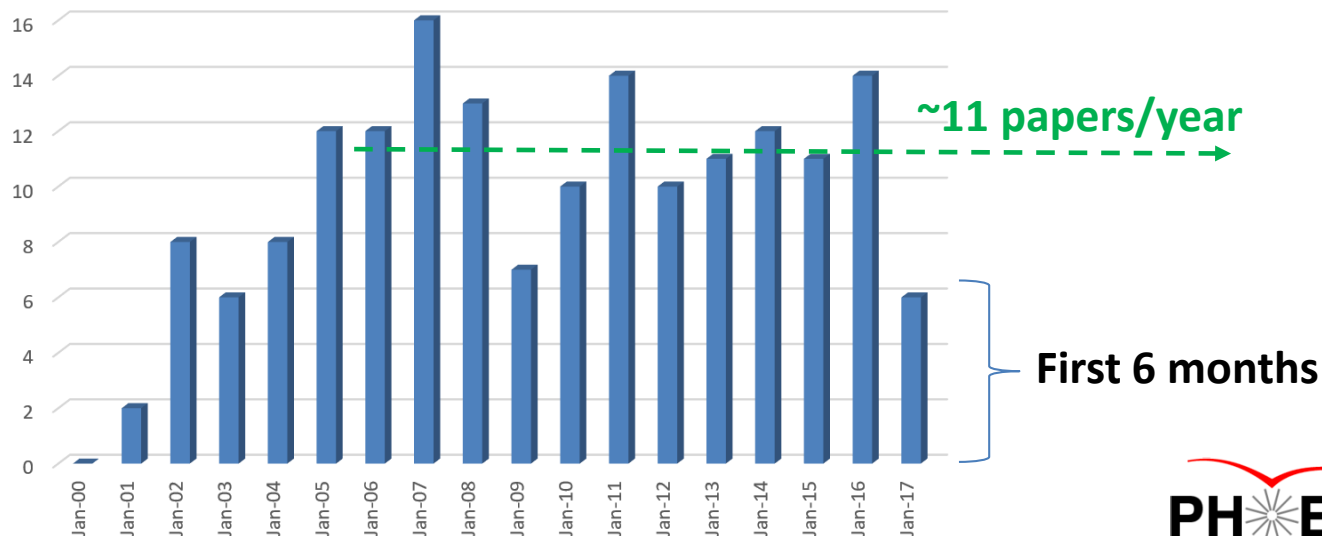
- Hint of non-zero  $A_N$  of  $J/\psi$  in p+Au at 200 GeV
- $> 2\sigma$  effect seen in both of forward and backward rapidity
- Results of two analysis groups are consistent. Paper preparation group will be formed soon

# Data Analysis Status and Plan

# Publish the results of PHENIX

- RUN16 was the last data-taking run with PHENIX detector.
  - Au+Au 200 GeV to complete heavy-flavor measurement
  - d+Au energy scan to complete the study of QGP in small system.
- 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 10 papers in 2014-16 from 2008 d+Au data
- 4 years to complete publication of major results

Published PHENIX papers in each year



# Golden datasets of PHENIX

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

Many physics topics with variety of high statistics datasets

Up to 4 years to complete publication of major results

# 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	Started, ~ 1 month	DONE	DONE	
	p+Al 200	N.A.	DONE	DONE	
14	Au+Au 200	Started, 2017	DONE	DONE	N/A
	$^3\text{He}+\text{Au}$ 200	2018	DONE	DONE	

- Delay of VTX production due to “event mis-alignment” (solved)
- Run14AuAu, Run16AuAu ~ 6 months of CPU each
- p+p, p+A ~2 weeks of CPU each

# Required Computing Resources and Support

- Time scale of completing Run14/15/16 nDST production is the end of 2018
  - CPU time to process each of Au+Au run is about a half year
  - Start of VTX part of AuAu production was delayed due to “event misalignment” problem that requires several steps to fix
- PHENIX part of gpfs filesystems provides sufficient buffer disk space for reconstruction
- Run14 and Run16 will add 2PB of DSTs
- It is essential to maintain
  - (1) the current level of RCF resource, and
  - (2) The support for PHENIX data production to keep the scientific productivity of PHENIX

# Summary

- PHENIX completed its data taking in RUN16
  - Removal and Repurposing is well under way
- Recent achievements
  - PHENIX continues to produce high impact results
    - Publishing ~11 papers per year, ~2000 citations/year
  - Recent highlights
    - Heavy flavor measurements
    - flow in small systems
    - $A_N$  in pAu
- Status of Data analysis
  - DST production except for heavy flavor measurement in RUN14-16 are complete
    - expected to be completed by the end of 2018
  - Up to 4 years to publish major results
  - It is essential to maintain the current level of RCF and manpower support