

PHENIX overview and Data Release Plan

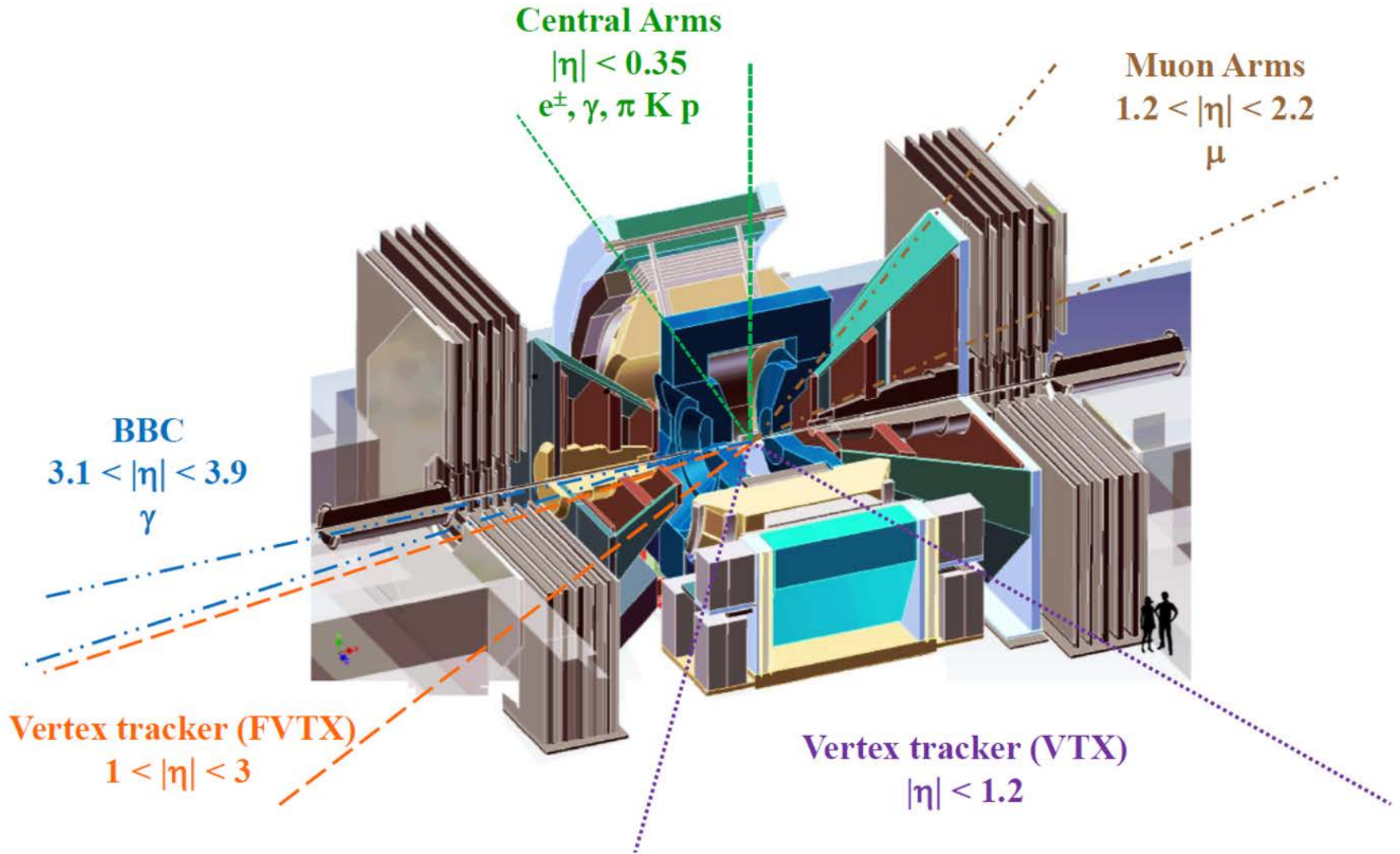
Y. Akiba (RIKEN/RBRC)
for PHENIX Collaboration

PAC2016
2016/06/16

Outline

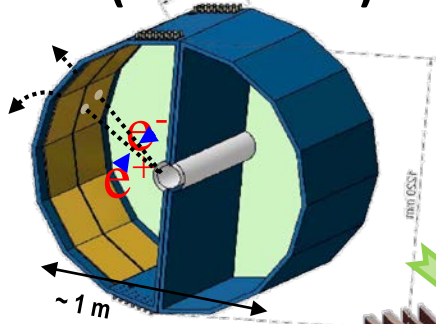
- PHENIX Detector
- Recent accomplishments
 - Highlights of Publication in the past 12 months
 - Recent preliminary results
- RUN16 Data Taking Report
 - Au+Au 200 GeV
 - d+Au BES
- Data Analysis and release plan

PHENIX Detector



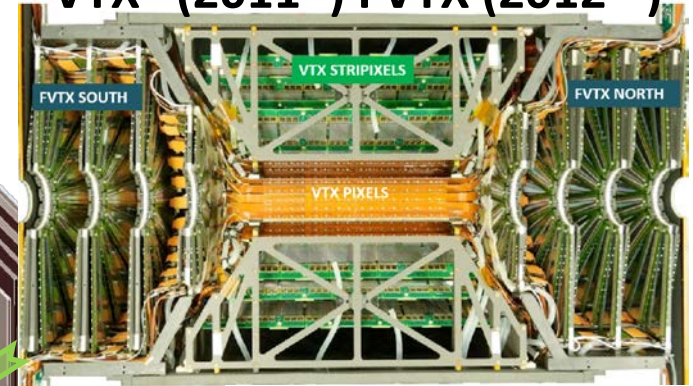
PHENIX Detector Upgrades

HBD (2009-2010)



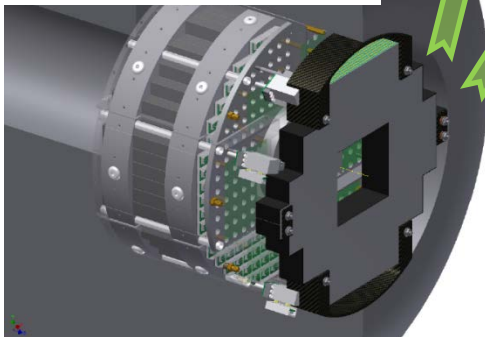
Low mass e^+e^-

VTX (2011-) FVTX (2012 -)



Heavy flavor
 $B, D \rightarrow e, \mu, B \rightarrow J/\Psi$

MPC-EX (2015 -)



Direct photon, π^0 in forward

W-Trigger (2012 -)

$W \rightarrow \mu A_L$
 $\Delta\bar{u}, \Delta\bar{d}$

Data Sets (2010-)

Energy GeV	Colliding System							
	U+U	Au+Au	Cu+Au	3He+Au	d+Au	p+Au	p+Al	p+p
500/510								2011 2012 2013 2015
200		2010 2011 2014 2016		2014	2016	2015	2015	2012
193	2012		2012					
62.4		2010			2016			
39		2010			2016			
27		2011						
20		2011			2016			
7.7		2010						

- Varieties of collision systems and beam energy
- Au+Au golden data sets
- Geometry study U+U, Cu+Au
- p+A, d+Au CNM effects and small system QGP
- p+p W physics (510 GeV) and transverse spin

PHENIX publications

- **163 physics papers published**

– Phys. Rev. Lett.	69
– Phys. Rev. C	64
– Phys. Rev. D	25
– Phys. Letter B	4
– Nucl. Phys. A	1

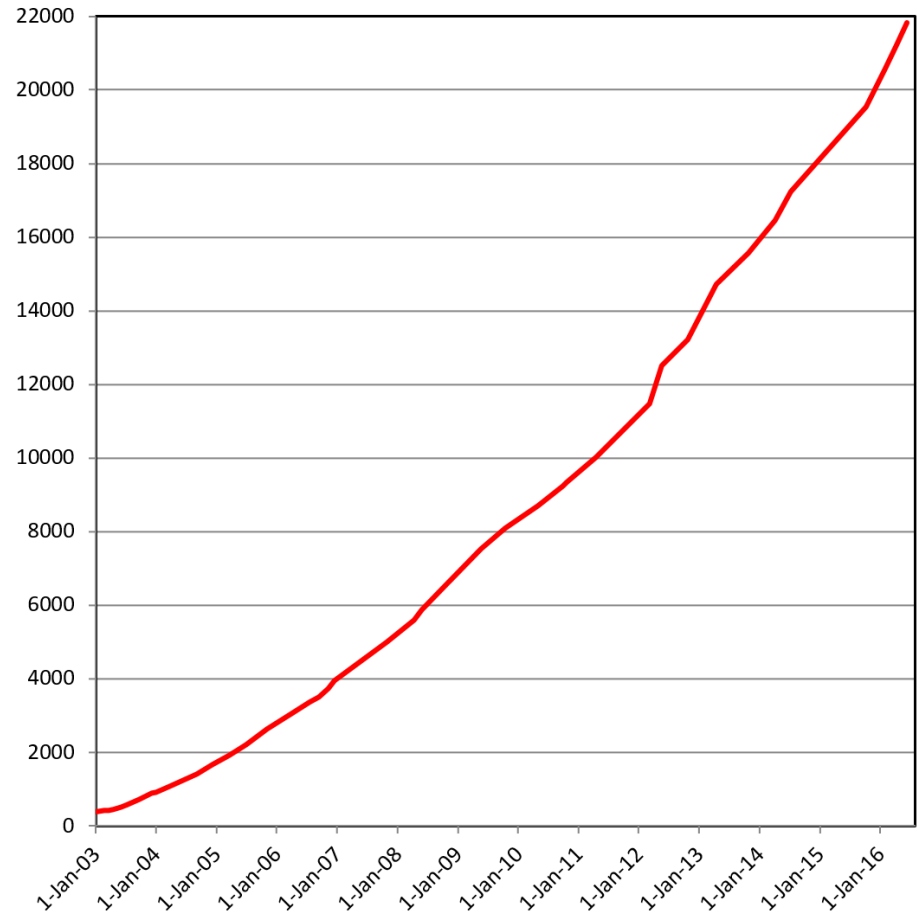
- **Total citation: ~22000**

– Topcite 1000+	1
– 500-1000	7
– 250-500	15
– 100-250	37
– 50-100	40

PHENIX White Paper: ~2200 cites

**100 papers in topcite 50+
(118 if proceedings and NIM
papers are included)**

Cumulative Citations of PHENIX papers



15 papers published in the last 12 months

1. "Measurements of identified particle higher harmonic flow in Au+Au collisions at $\sqrt{s_{NN}}=200\text{GeV}$ "
Physical Review C93, 051902 (2016)
2. "Forward J/psi production in U+U collisions at $\sqrt{s_{NN}}=193\text{ GeV}$ "
Physical Review C93, 034903 (2016)
3. Measurement of parity-violating spin asymmetries in W production at mid-rapidity in longitudinally polarized p+p collisions"
Physical Review D93, 051103(R) (2016)
4. "Single electron yields from semileptonic charm and bottom hadron decays in Au+Au collisions at $\sqrt{s_{NN}}=200\text{ GeV}$ "
Physical Review C93, 034904 (2016)
5. "Centrality dependent Modification of Jet-Production Rates in Deuteron-Gold Collisions at $\sqrt{s_{NN}}=200\text{GeV}$ "
Physical Review Letters 116, 122301 (2016)
6. "Transverse energy production and charged-particle multiplicity at midrapidity in various systems from $\sqrt{s_{NN}}=7.7\text{ to }200\text{ GeV}$ "
Physical Review C93, 024901 (2016)
7. "Scaling properties of fractional momentum loss of high-pT hadrons in nucleus-nucleus collisions at $\sqrt{s_{NN}}=62.4\text{GeV to }2.76\text{ TeV}$ "
Physical Review C93, 024911 (2016)
8. "phi meson production in the forward/backward rapidity region in Cu+Au collisions at $\sqrt{s_{NN}}=200\text{GeV}$ "
Physical Review C93, 024904 (2016)
9. "Measurement of higher cumulants of net-charge multiplicity distributions in Au+Au collisions at $\sqrt{s_{NN}}=7.7\text{-}200\text{GeV}$ "
Physical Review C93 011901(R) (2016)
10. "Dielectron production in Au-Au collisions at $\sqrt{s_{NN}}=200\text{ GeV}$ "
Physical Review C93, 014904 (2016)
11. "Inclusive cross section and double-helicity asymmetry for pi0 production at midrapidity in p+p collisions at $\sqrt{s_{NN}}=510\text{ GeV}$ "
Physical Review D93, 011501 (R)
12. "phi meson production in d+Au collisions at $\sqrt{s_{NN}}=200\text{ GeV}$ "
Physical Review C92, 044909 (2015)
13. "Measurement of Elliptic and Triangular flow in He3+Au collisions at $\sqrt{s_{NN}}=200\text{ GeV}$ "
Physical Review Letters 115, 142301 (2015)
14. "Systematic study of azimuthal anisotropy in Cu+Cu and Au+Au collisions at $\sqrt{s_{NN}}=200\text{ GeV}$ "
Physical Review C92,034913(2015)
15. "Systematic study of charged-pion and kaon femtoscopy in Au+Au collisions at $\sqrt{s_{NN}}=200\text{ GeV}$ "
Physical Review C92,034914(2015)

2 Physical Review Letter

11 Physical Review C

2 Physical Review D

+ 3 papers submitted

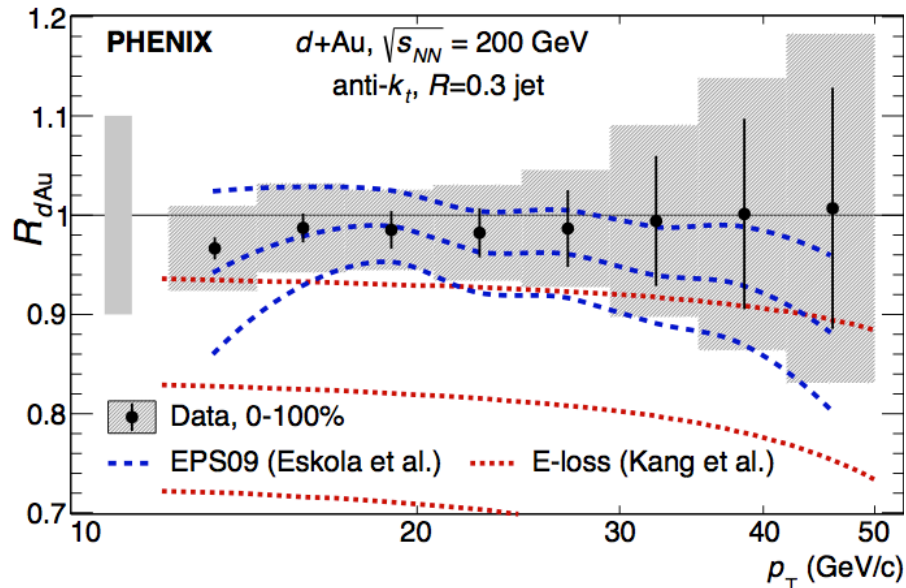
Jets in d+Au (2008)

PRL **116**, 122301 (2016)

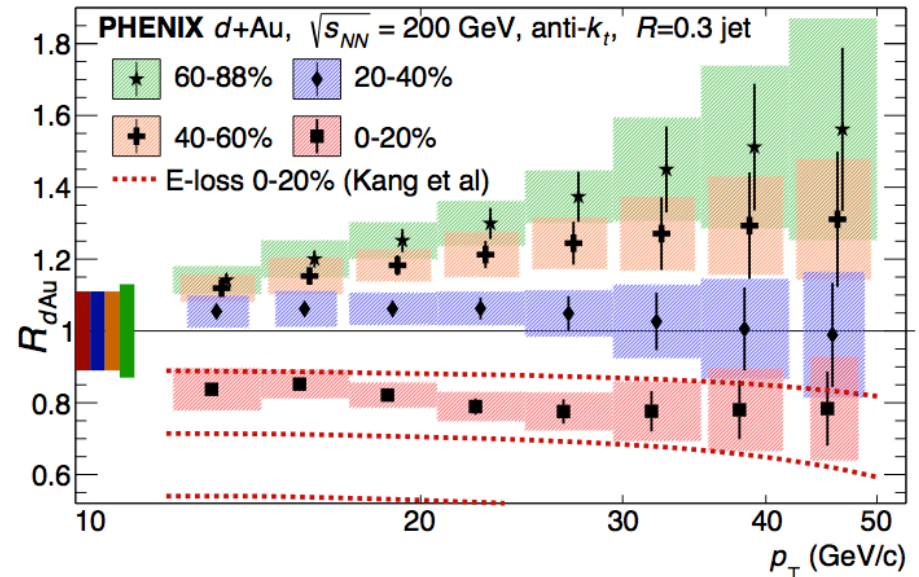
PHYSICAL REVIEW LETTERS

week ending
25 MARCH 2016

Centrality-Dependent Modification of Jet-Production Rates in Deuteron-Gold Collisions at $\sqrt{s_{NN}} = 200$ GeV



Minimum bias jets show no energy loss



Surprising centrality dependence

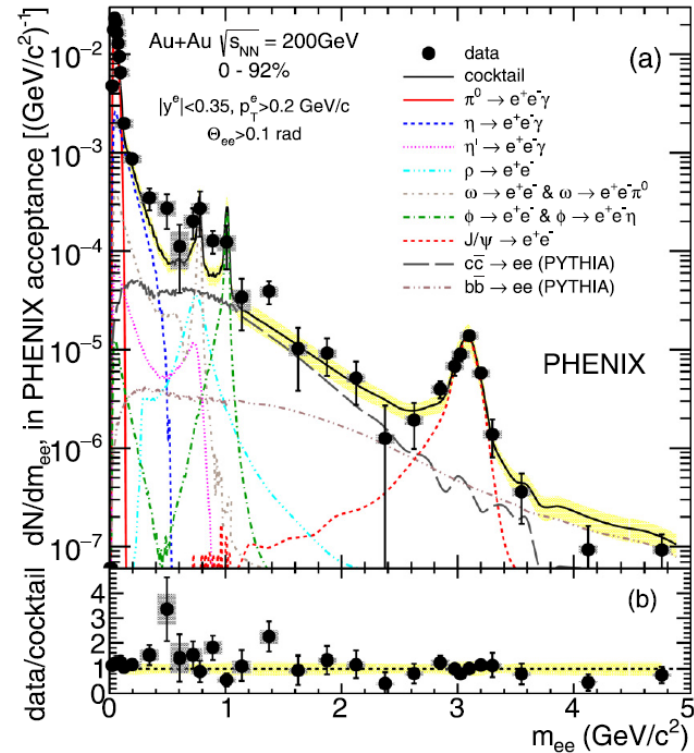
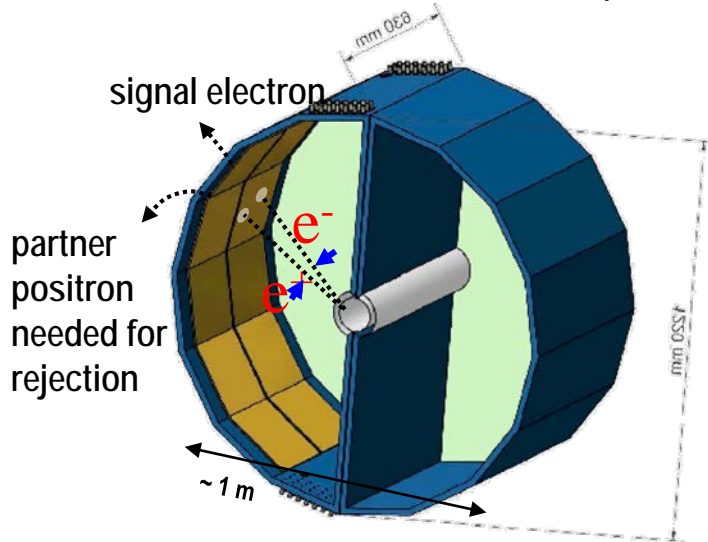
- *Enhancement* at high p_T in peripheral collisions
- Challenge to the conventional models

Final results of low mass ee (2010)

PHYSICAL REVIEW C 93, 014904 (2016)

Dielectron production in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV

- Final Results of 2010 run with Hadron Blind Detector (HBD)

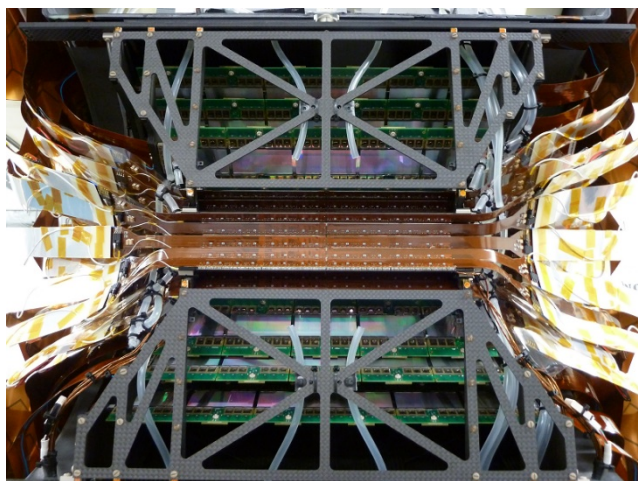
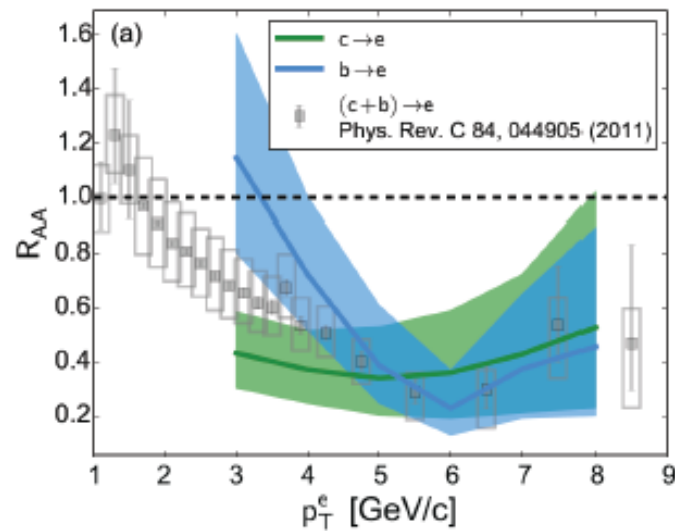
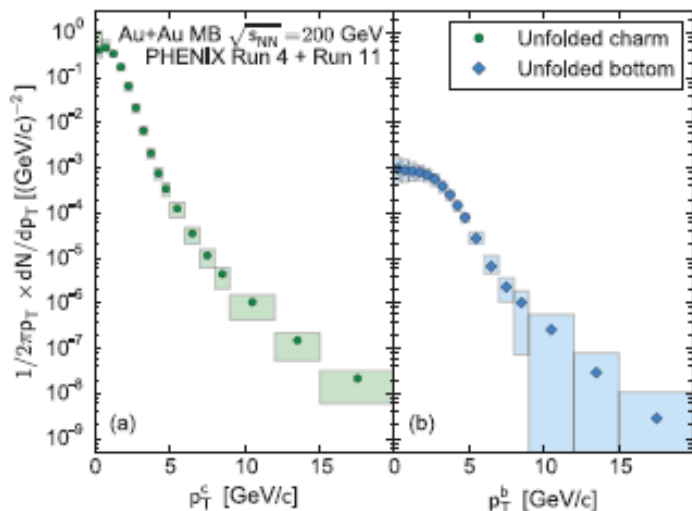


- Moderate enhancement
- Consistent with STAR data
- ρ broadening model can reproduce the data

First publication from VTX (2011)

PHYSICAL REVIEW C 93, 034904 (2016)

Single electron yields from semileptonic charm and bottom hadron decays
in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV



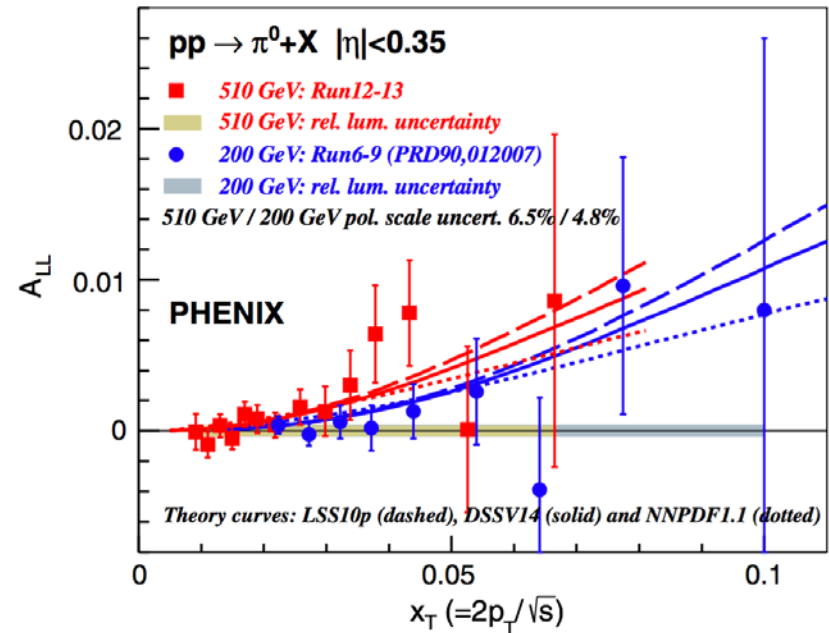
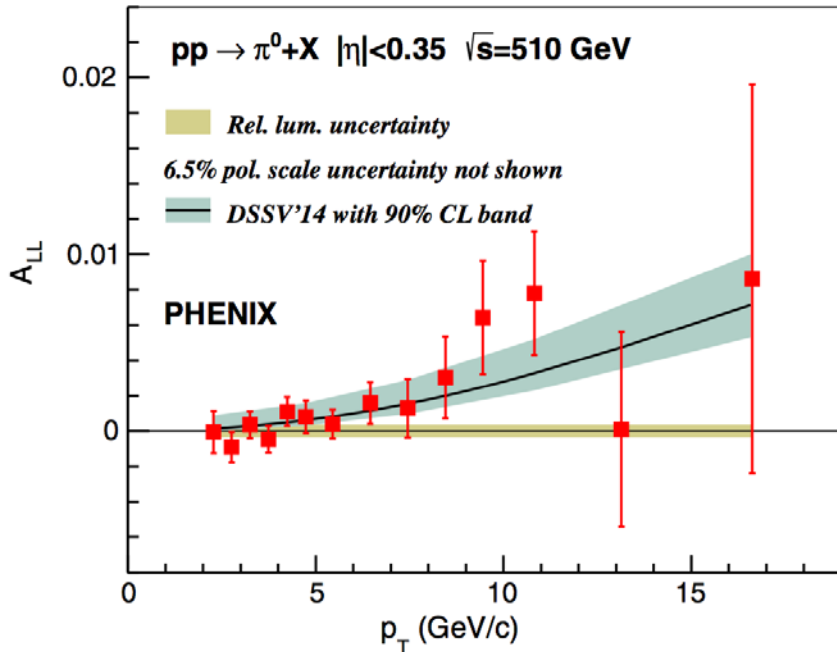
Results from the first run with VTX in 2011

- First observation of Suppression of $b \rightarrow e$
- $b \rightarrow e$ is less suppressed than $c \rightarrow e$ for $3 < p_T < 4$ GeV/c

$\pi^0 A_{LL}$ at 510 GeV (2013)

PHYSICAL REVIEW D 93, 011501(R) (2016)

Inclusive cross section and double-helicity asymmetry for π^0 production at midrapidity in $p + p$ collisions at $\sqrt{s} = 510$ GeV

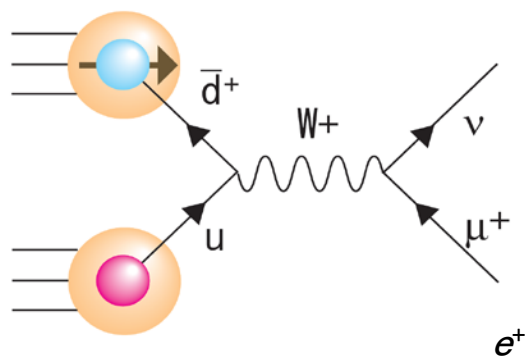


- First observation of Non-vanishing A_{LL} of π^0
- Gluons contribute a significant fraction of the proton spin
- New data provides constraint down to $x \sim 10^{-2}$

Final result of $W \rightarrow e A_L$ (2011-2013)

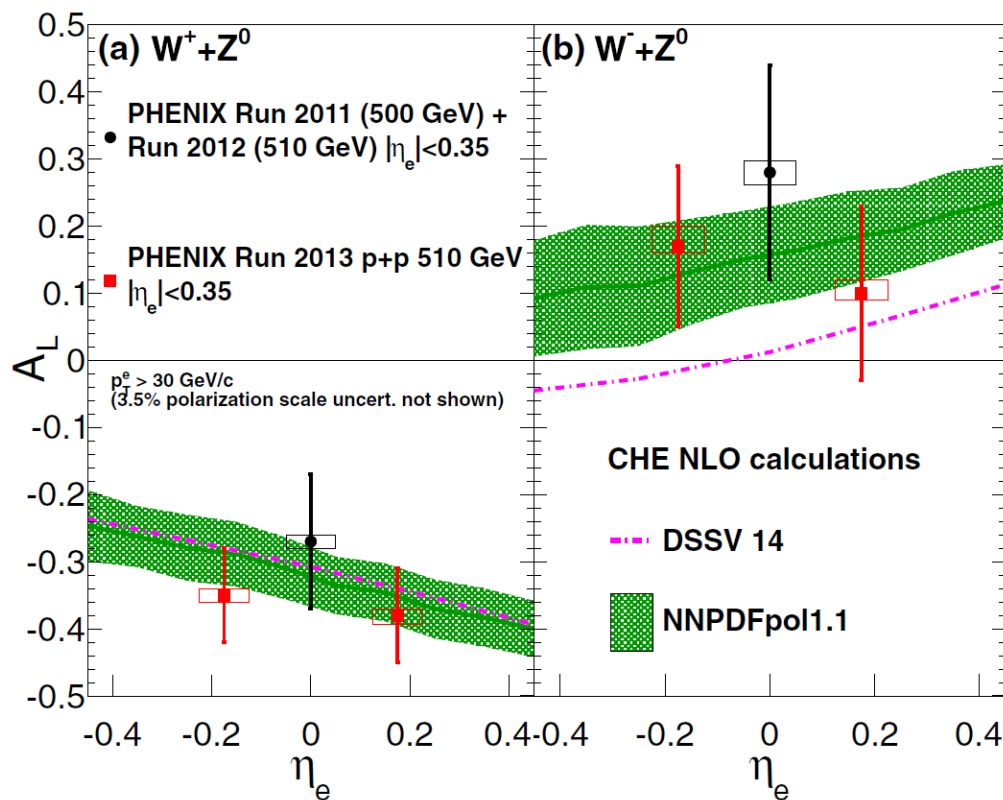
PHYSICAL REVIEW D 93, 051103(R) (2016)

Measurement of parity-violating spin asymmetries in W^\pm production at midrapidity in longitudinally polarized $p+p$ collisions



$$A_L = \frac{N^+(e) - N^-(e)}{N^+(e) + N^-(e)}$$

$$A_L^{W^+} = \frac{-\Delta u(x_1)\bar{d}(x_2) + \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}$$



- Strong constraint on anti-quark polarization $\Delta\bar{u}$, $\Delta\bar{d}$
- Next: $W \rightarrow \mu$ in forward rapidity

$^3\text{He}+\text{Au}$ flow (2014)

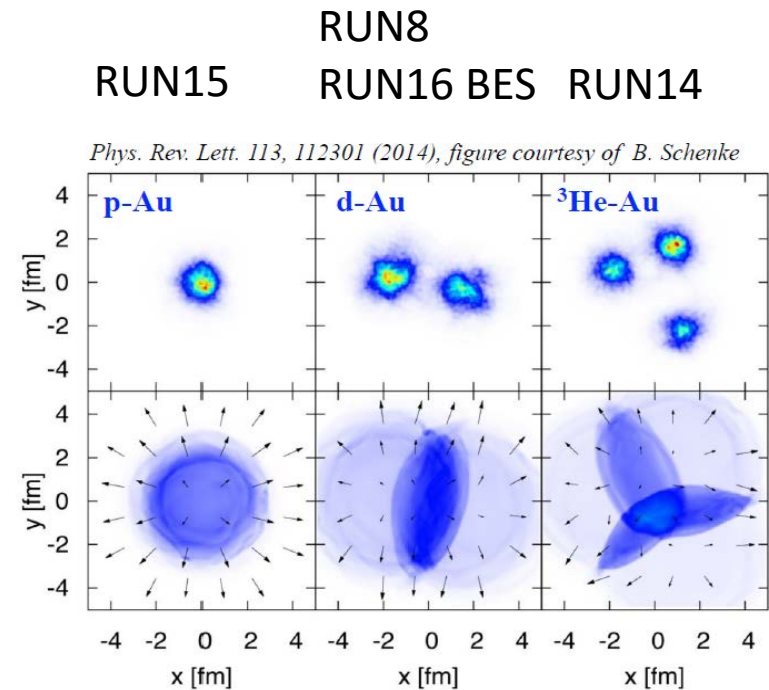
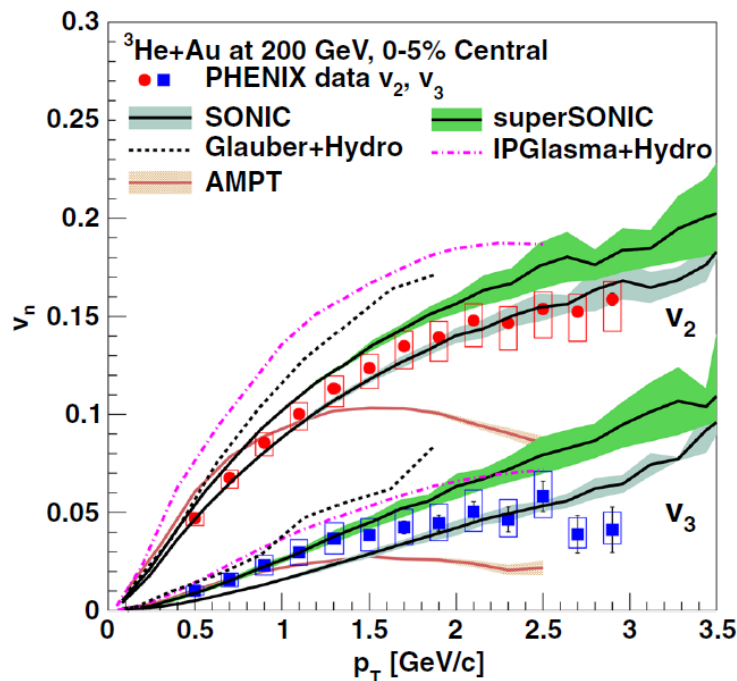
PRL 115, 142301 (2015)

PHYSICAL REVIEW LETTERS

week ending
2 OCTOBER 2015



Measurements of Elliptic and Triangular Flow in High-Multiplicity $^3\text{He} + \text{Au}$ Collisions at $\sqrt{s_{NN}} = 200$ GeV



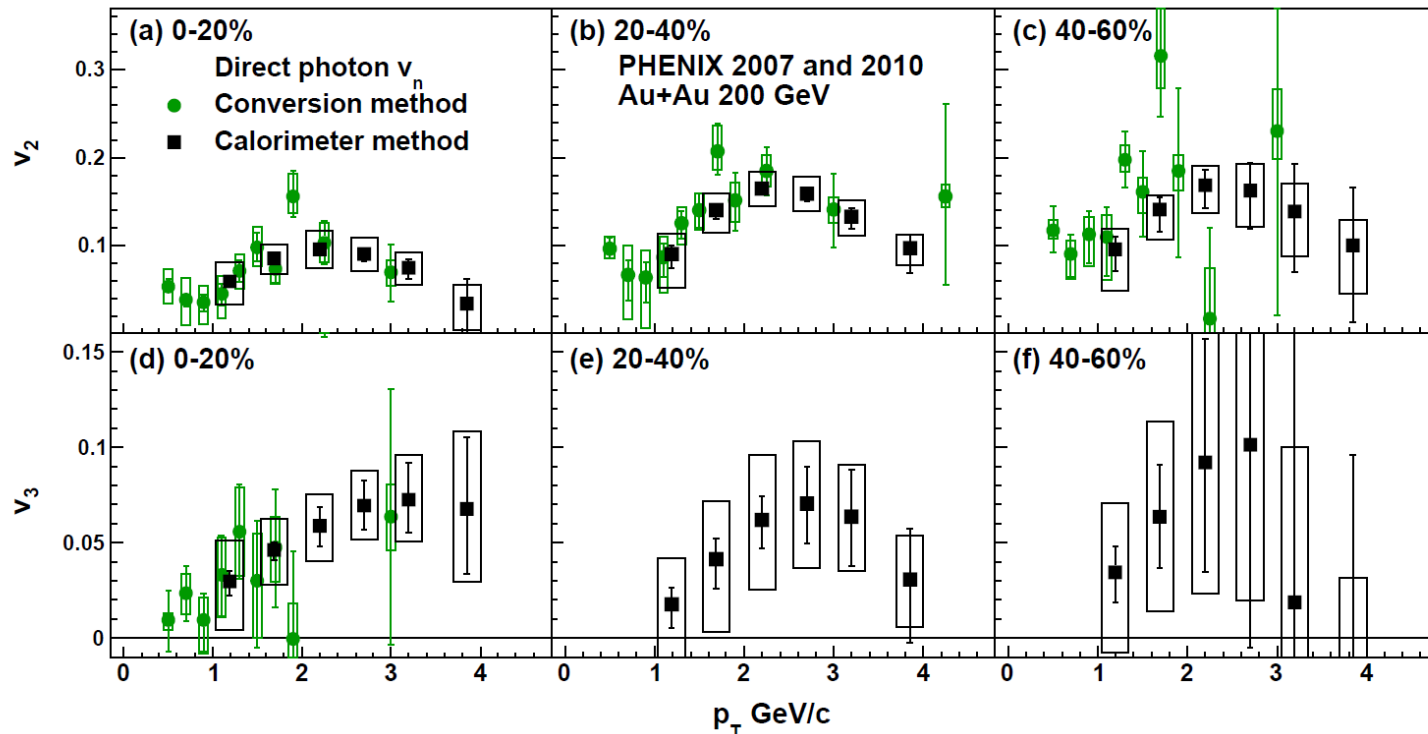
- Results of the short 2014 He3 run
- v_2 and v_3 in $^3\text{HeAu}$ --- hydro at work at small system?
- Next \rightarrow dAu Beam Energy Scan in 2016

Direct photon v_2/v_3 (2010)

arXiv.org > nucl-ex > arXiv:1509.07758

Nuclear Experiment

Azimuthally anisotropic emission of low-momentum direct photons in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV



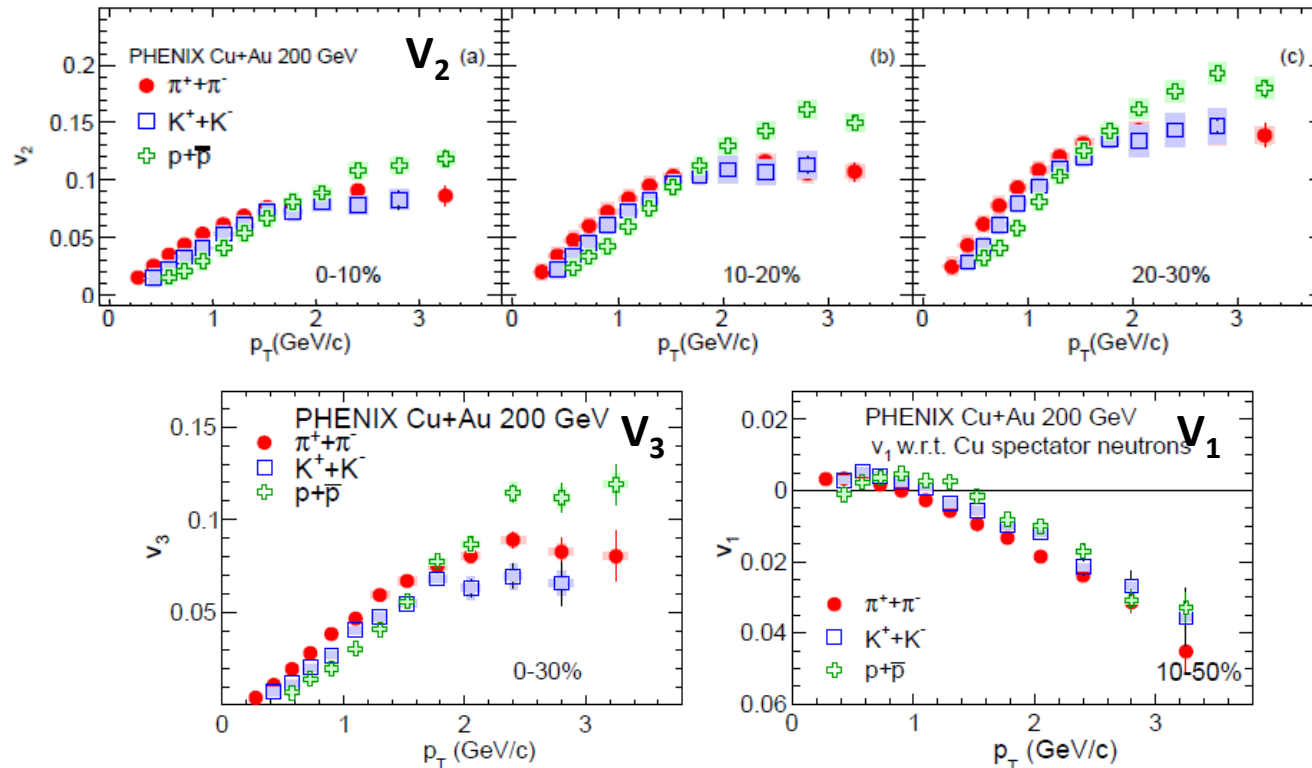
- Low p_T direct photons show large v_2 and v_3
- Challenge to the theory

V1/v2/v3 in CuAu (2012)

arXiv.org > nucl-ex > arXiv:1509.07784

Nuclear Experiment

Measurements of directed, elliptic, and triangular flow in Cu+Au collisions at $\sqrt{s_{NN}} = 200$ GeV



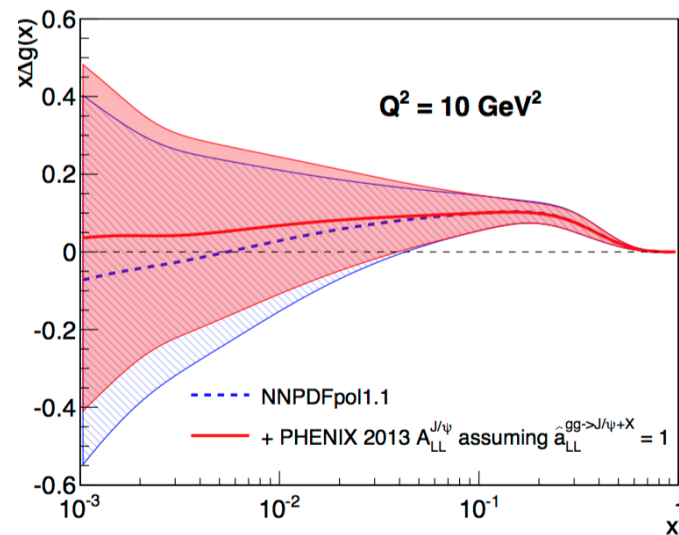
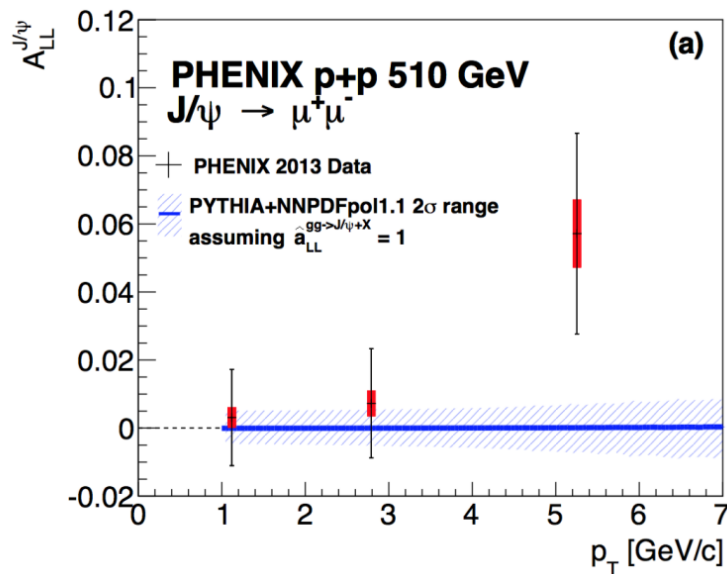
- $V_1/v_2/v_3$ of $\pi/K/p$ are measured
- Mass ordering and $\varepsilon_n N^{1/3}$ scaling is observed

ALL of J/Psi at 510 GeV (2013)

arXiv.org > hep-ex > arXiv:1606.01815

High Energy Physics - Experiment

Measurements of double-helicity asymmetries in inclusive J/ψ production in longitudinally polarized $p + p$ collisions at $\sqrt{s} = 510$ GeV

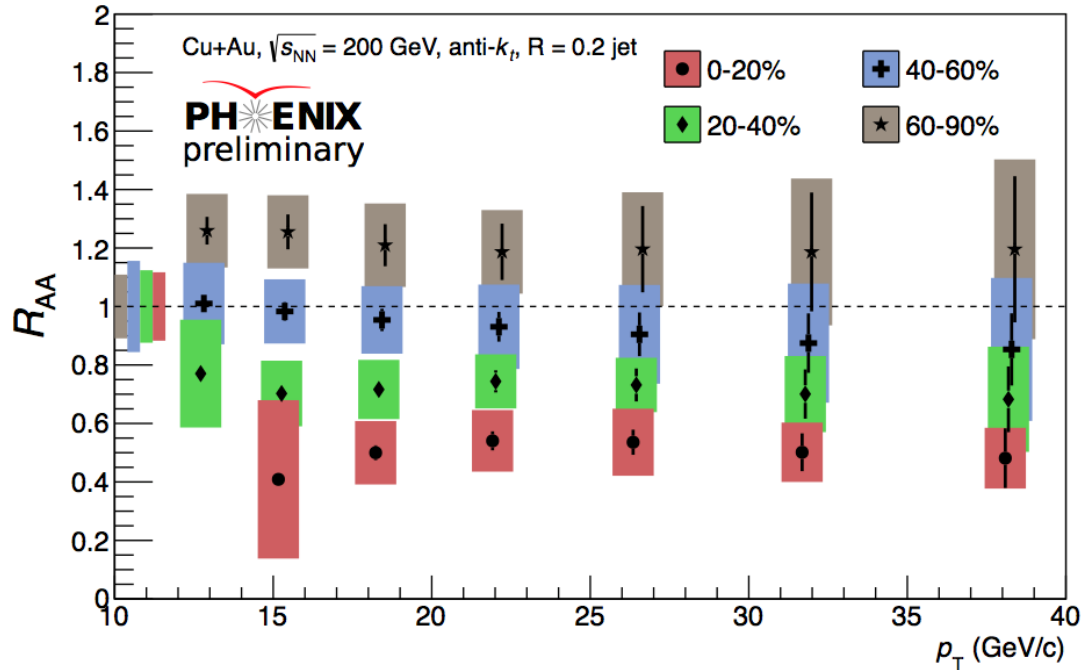


- New paper just submitted earlier this month
- First measurement of A_{LL} of J/Psi
- Consistent with zero, but give new constraint on ΔG at small x

Highlights of Recent Preliminary Results

Jets in Cu+Au (2012)

2016 RHIC/AGS Thesis award Arbin Timilsina

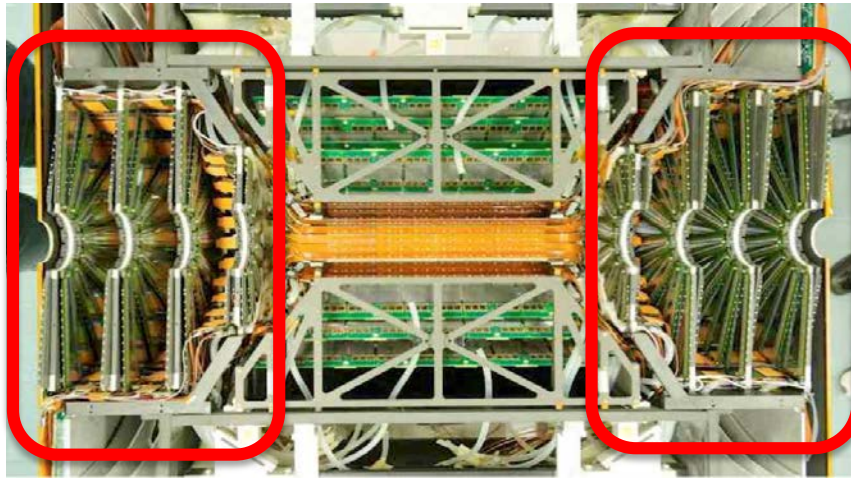
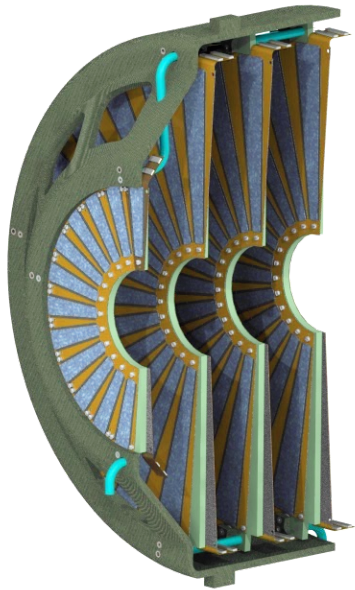


- jets suppressed by \sim factor of 2 in central Cu+Au collisions
- suppression shows no p_T dependence
- PPG was formed.

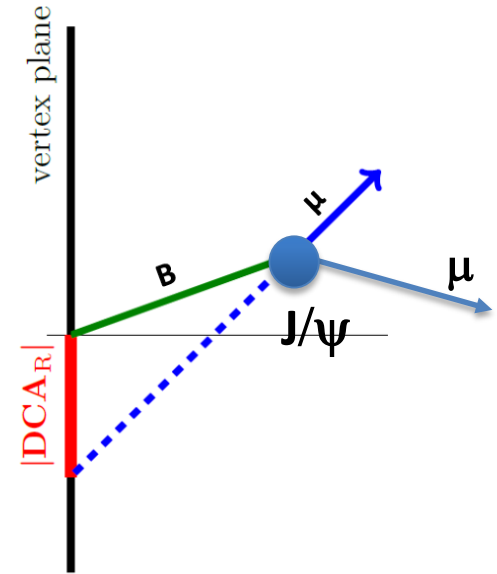
B- \rightarrow J/ ψ in pp and CuAu (2012)

The first B results from FVTX

NEW Release for Users' meeting !



FVTX detector

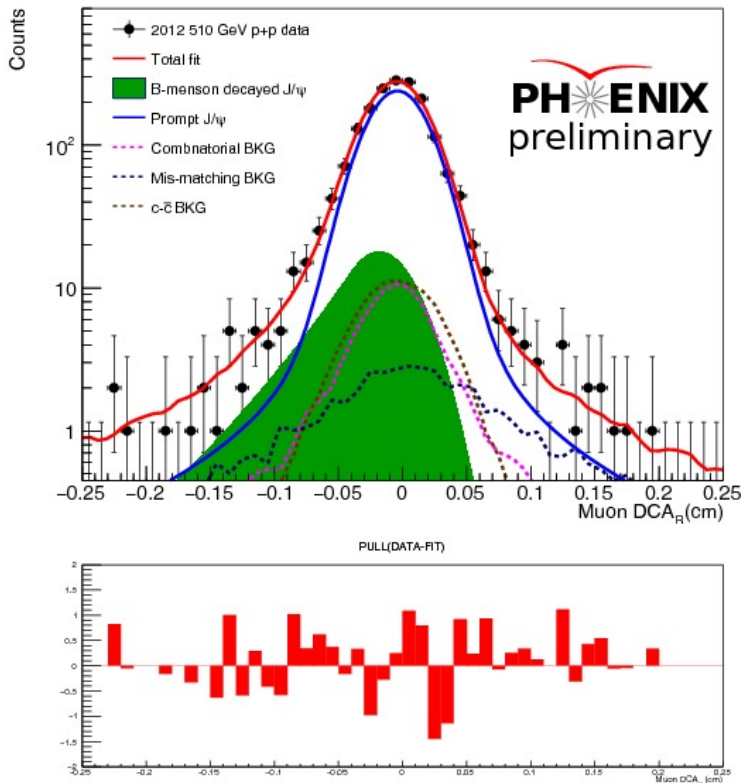


- B \rightarrow J/Psi fraction was measured in pp 510 GeV and Cu+Au 200 GeV from precise measurement of DCA

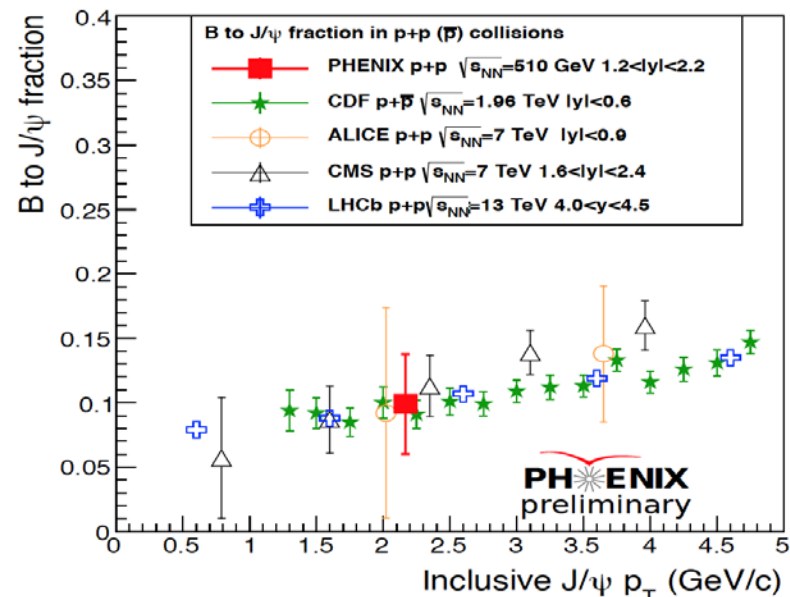
B → J/Psi in pp 510GeV (2012)

NEW Release for Users' meeting !

B → J/ψ Fit (-2.2 < y < -1.2)



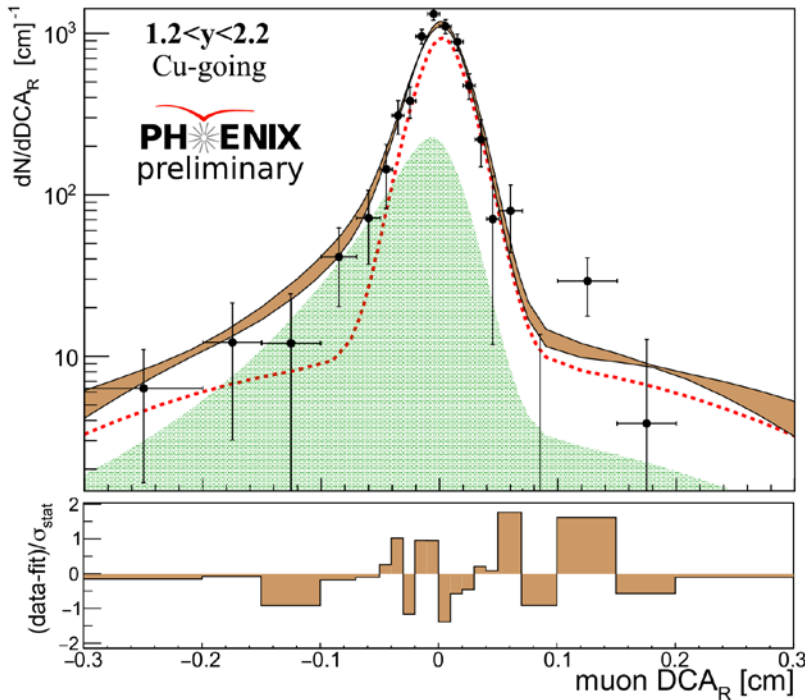
Run12 510 p+p B to J/ψ fraction



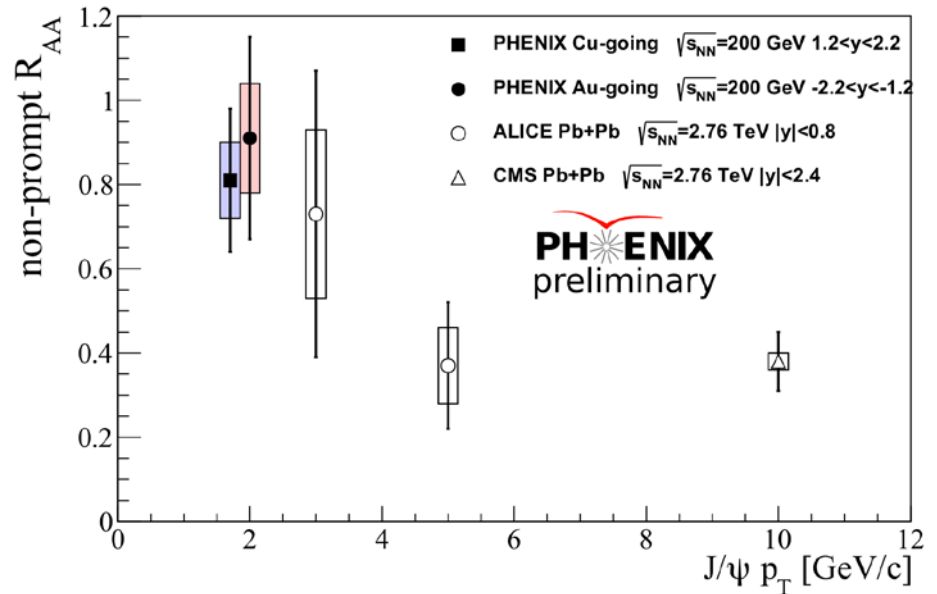
- The first measurement of B → J/Psi fraction in p+p at RHIC and below 1TeV
- Use precision DCA measurement with FVTX
- B fraction consistent with higher energy data
- PPG was formed. Expect paper submission in a half year

B→J/ψ in CuAu 200 GeV (2012)

NEW Release for Users' meeting !

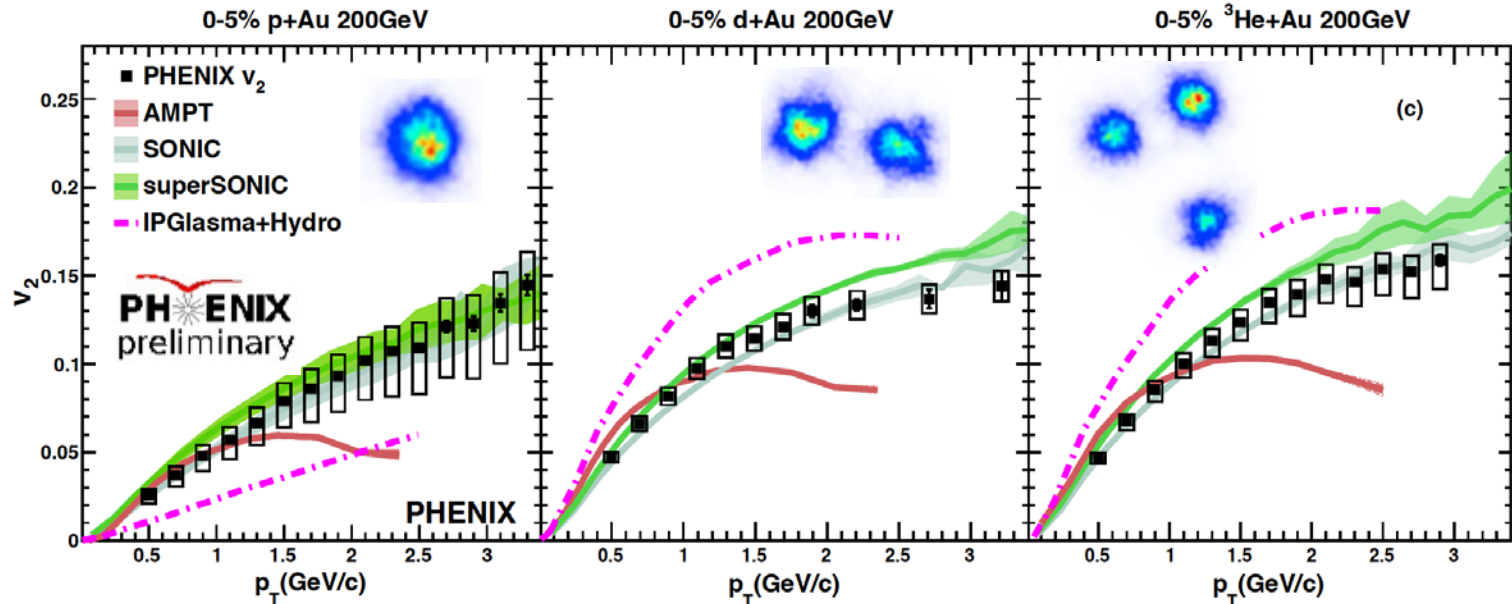


$$R_{AA}^{B \rightarrow J/\psi} = \frac{F_{B \rightarrow j/\psi}^{AA}}{F_{B \rightarrow j/\psi}^{pp}} R_{AA}^{J/\psi} = \frac{F_{B \rightarrow j/\psi}^{AA}}{0.1} R_{AA}^{J/\psi}$$



- Measure B→J/Psi fraction in Cu+Au with FVTX
- Convert the B→J/Psi fraction to RAA assuming that B→J/Psi fraction in p+p is 0.1
- PPG was formed. Expect paper submission in a half year

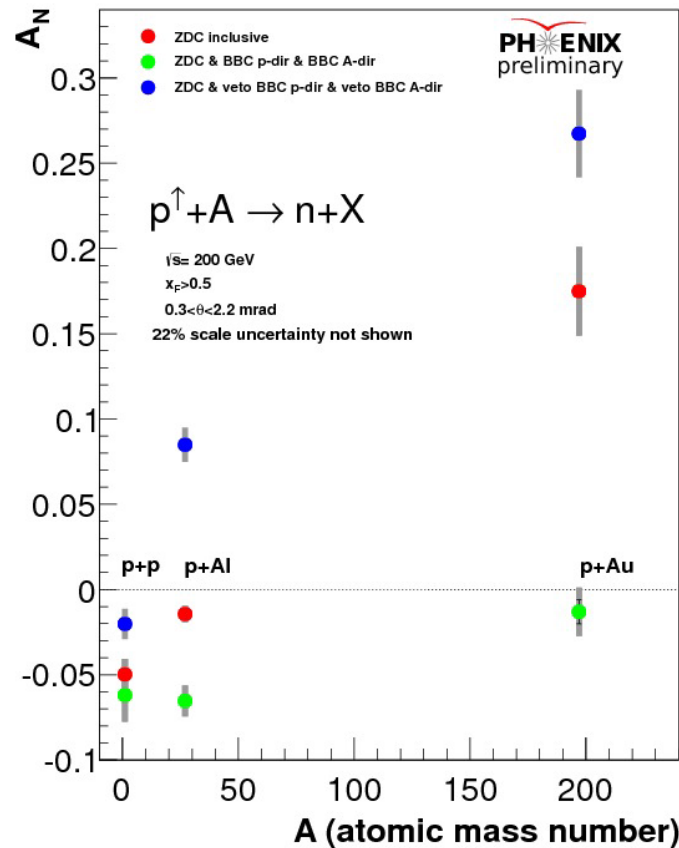
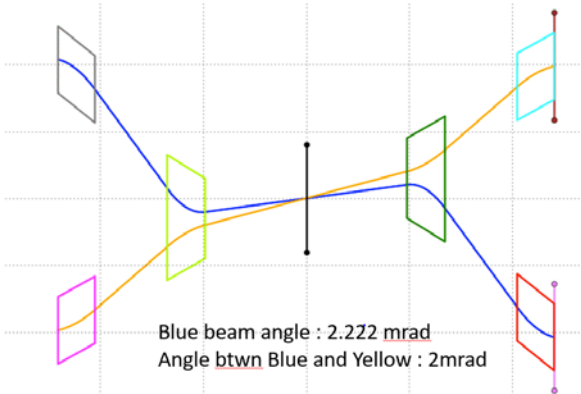
p+Au flow (2015)



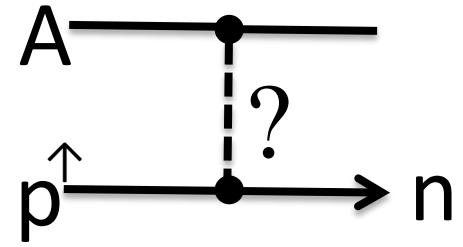
- Observation of v_2 in central p+Au at RHIC energy
- Hydro-model can reproduce the v_2 in p+Au, d+Au, and He+Au
- PPG was formed. Expect the paper submission in a half year.

A_N of forward neutron (2015)

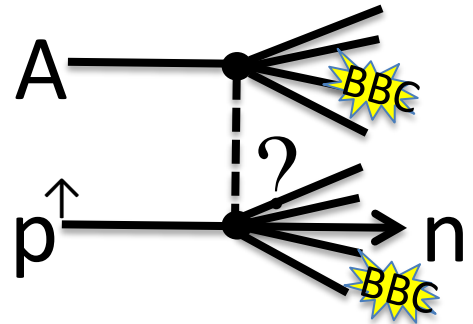
Dedicated p+Au/p+Al runs to hit the center of ZDC



Both BBC veto



Both BBC Fired



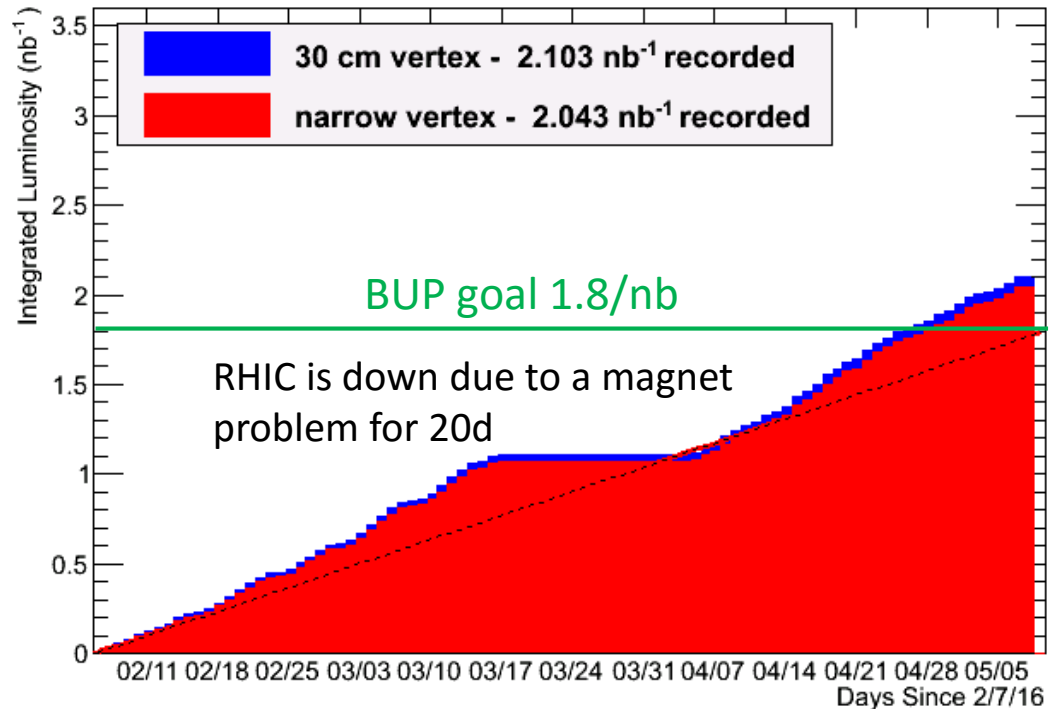
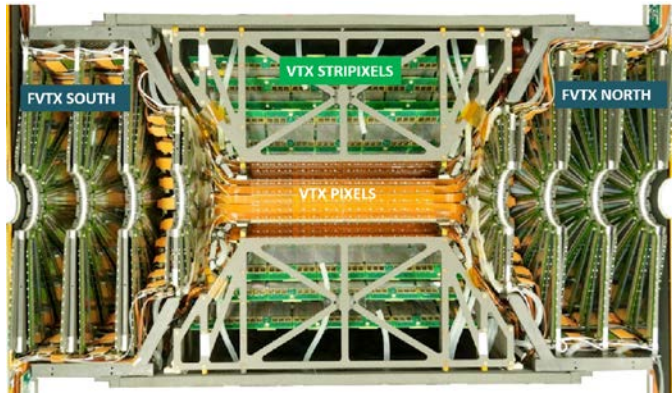
- Surprisingly large A_N in p+A
- A_N is suppressed if both BBCs are hit ($3.1 < |\eta| < 3.9$)
- No firm theoretical explanation yet
 - Interference between UPC photon and π^0 ?
- Discovery thanks to the unique p+A capability of RHIC and support of CAD and STAR to dedicated “PHENIX p+Au/p+Al” runs.

RUN16 Report

Au+Au at 200 GeV (2/7-5/9)

PHENIX Integr. Sampled Lumi vs Day

Mon May 9 06:01:20 2016



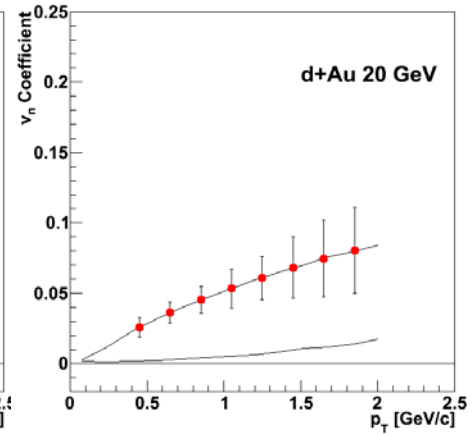
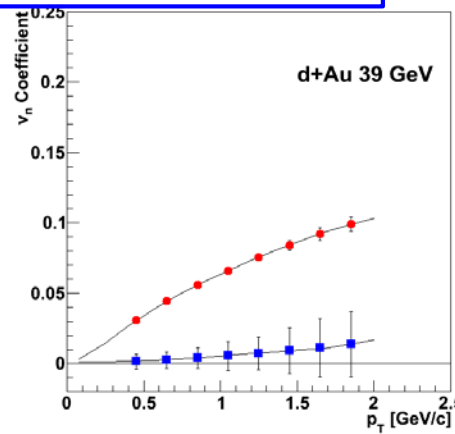
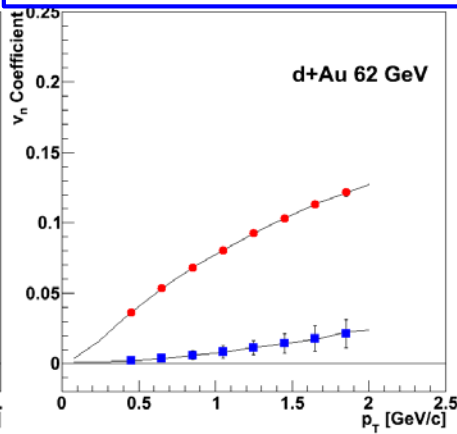
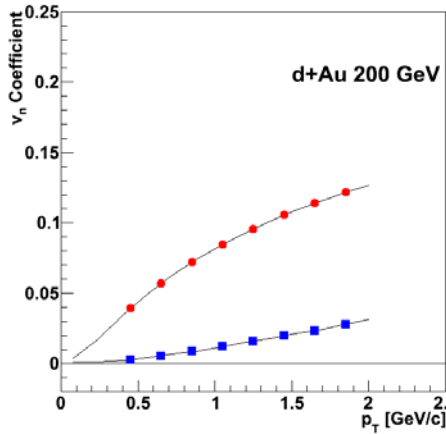
Very successful Au+Au run at 200 GeV

- 20 days of RHIC down time due to a magnet problem
- Recorded $>2/\text{nb}$ of data in $|z| < 10\text{cm}$. 110% of BUP goal
- Additional $\sim 10\%$ of data will be recorded in the last week of RUN16

RUN16 doubles the heavy flavor data with VTX/FVTX

d+Au Beam Energy scan

0-5% central events within $|z_{vtx}| < 10$ cm



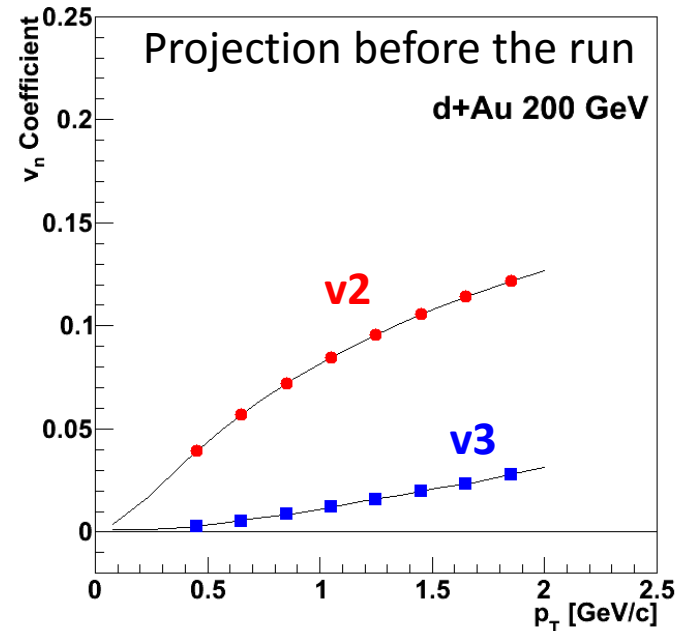
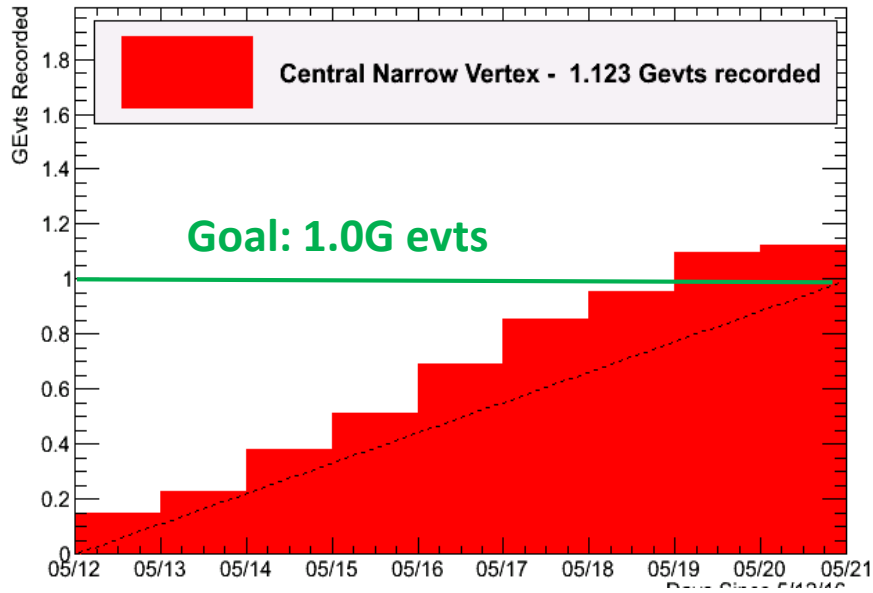
1 week, 1.0 B evts	1 week, 160 M evts	1.5 weeks, 110M	1.5 weeks, 9M
robust baseline v_2 and v_3 measurements	All 3 lower energies for robust v_2 measurements to establish <ul style="list-style-type: none"> • role of pre-equilibrium stage • role of hadronic stage 		
Factor of ~ 20 stat increase from Run8 FVTX improved EP	v_3 at lower energy: more sensitive to time spent in QGP	Does v_3 collapse at lower energy ? upper limits of v_3 can be established	
same detector conditions= \Rightarrow systematics control in the BES	Statistically significant measurements for both v_2 and v_3	Transition region for v_3 collapse	Largest lever arm for v_2 measurements

- Measure v_2 at all 4 energies; v_3 at 2 top energies.

dAu at 200 GeV (5/20-5/27)

PHENIX GEvts vs Day

Fri May 20 09:00:14 2

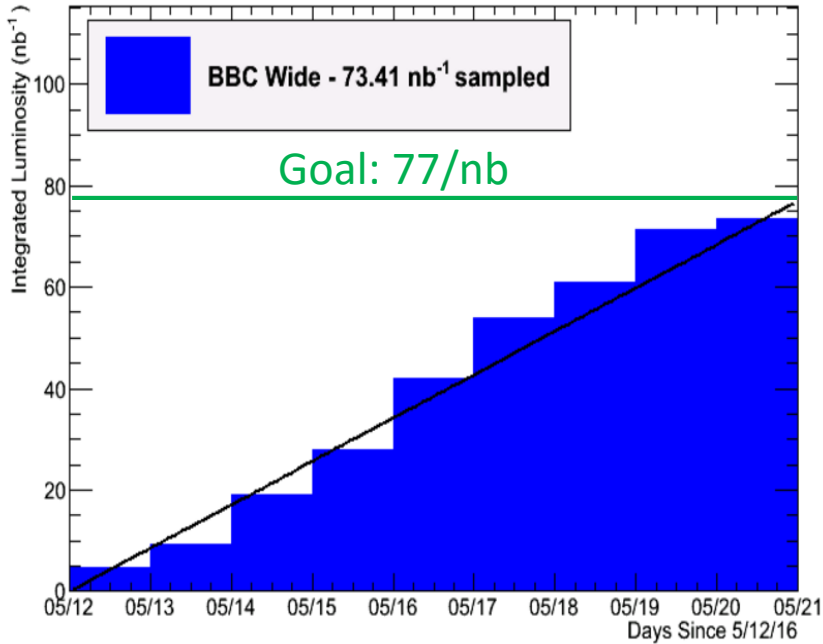


- Very successful run
- First goal of d+Au at 200 GeV is to record 1G evts in top 5% centrality to measure v_2 and v_3
- Recorded >1.1 G evts of top 5%, >110% of the goal
- Semi-online analysis shows v_2 and v_3 !

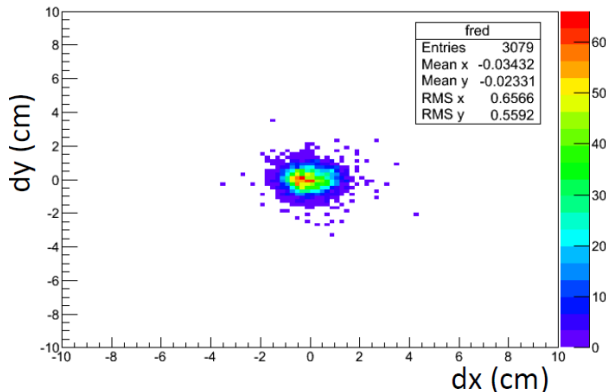
dAu at 200 GeV: Ldt for MPC-EX

PHENIX Integr. Sampled Lumi. vs Day

Fri May 20 09:00:13 2016

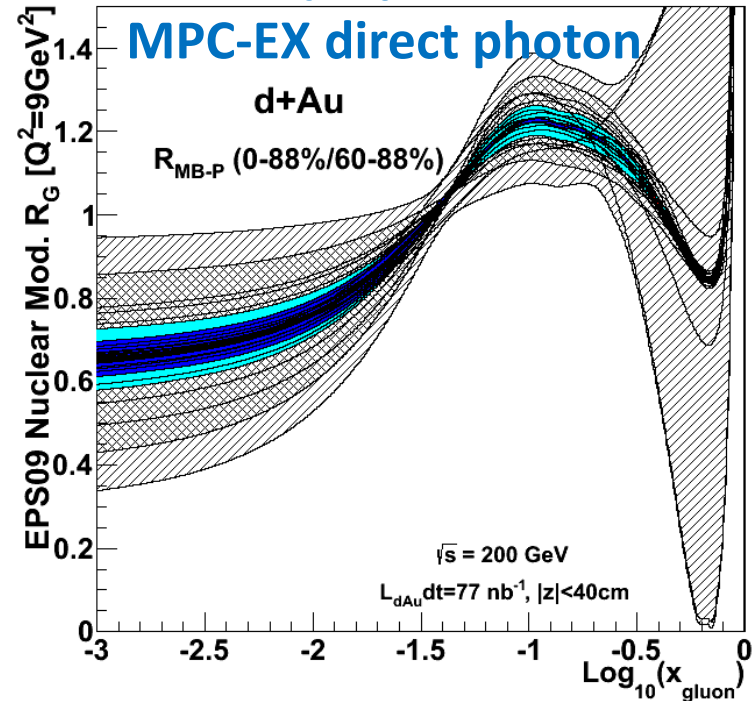


MPC & MPC-EX hit position correlation



RUN16 projection

MPC-EX direct photon

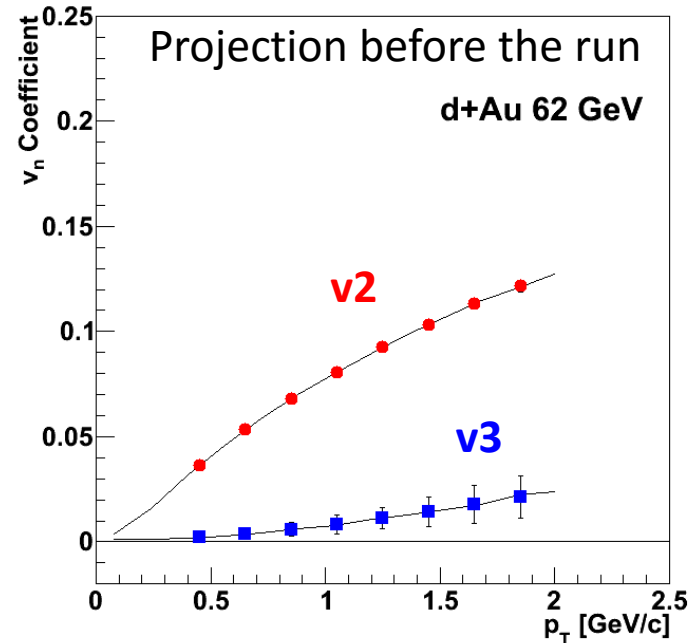
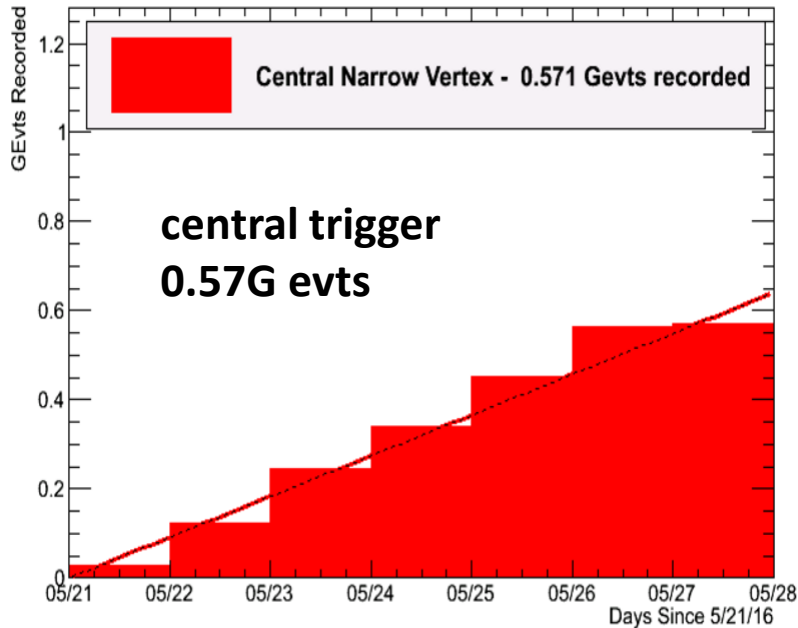


- 2nd goal is to record 77/nb for direct photon measurement with MPC-EX
- PHENIX achieved >95% of the goal
- MPC-EX worked well in the run

dAu at 62 GeV (5/20-5/27)

PHENIX GEvts vs Day

Fri May 27 06:00:11 2016

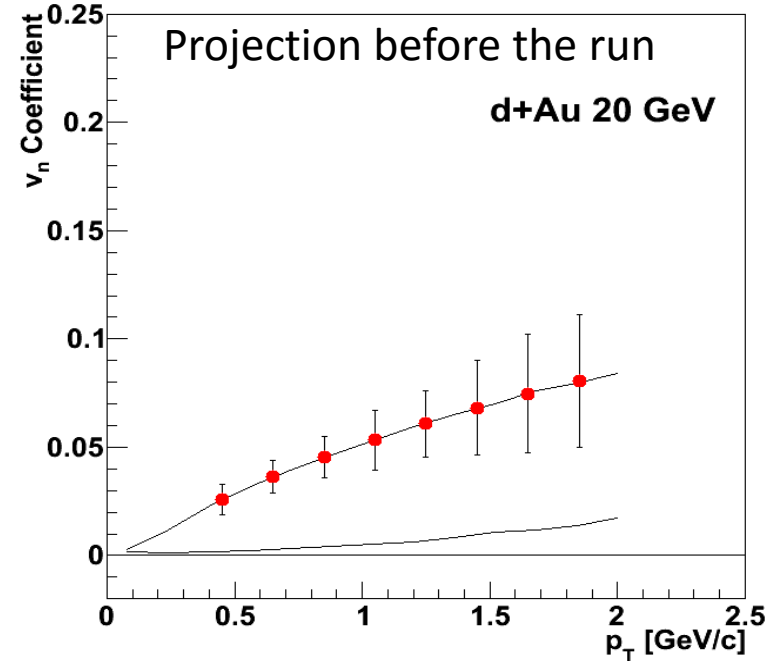
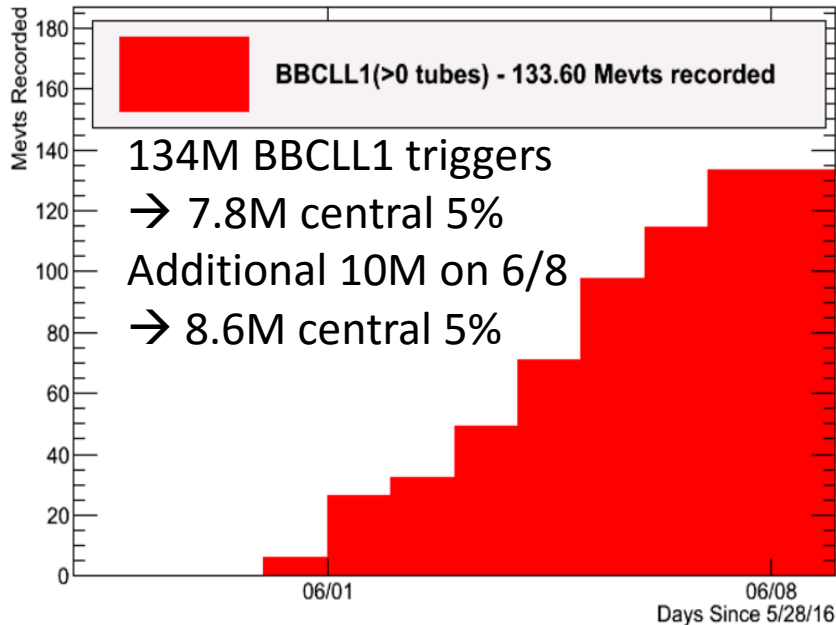


- Very successful
- Recorded 0.57G evts in top 10%
→ 285M evts in top 5% centrality
- This is >120% of BUP goal of 230M in top 5%

dAu at 19.6 GeV (5/28-6/8)

PHENIX Mevts vs Day

Wed Jun 8 09:00:14 2016

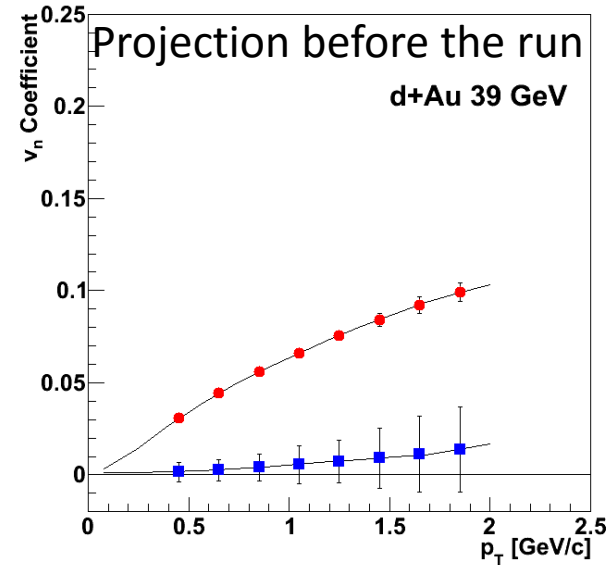
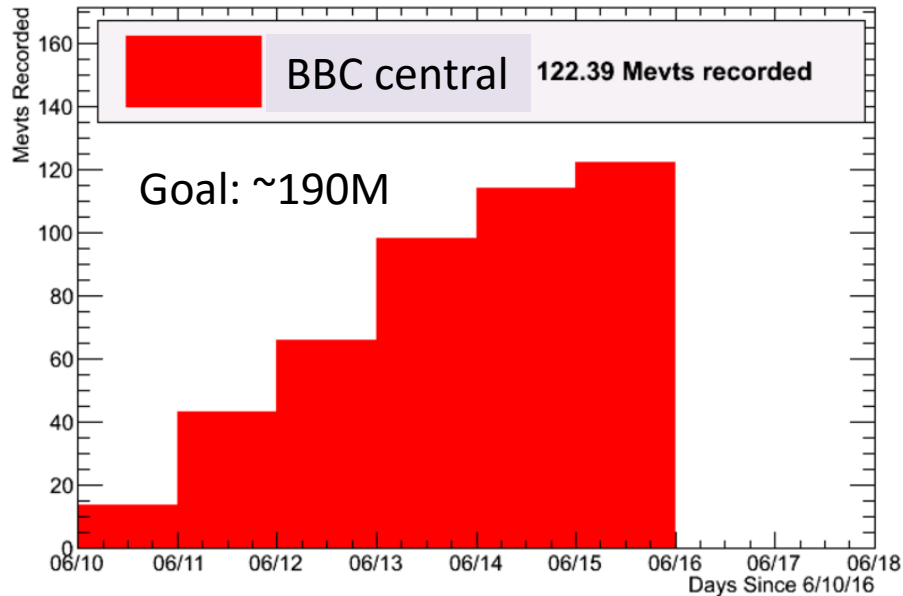


- Difficult start due to low energy and small system
- Recorded ~8.6M evts in top 5%
>120% of the BUP goal of 7M evts

dAu at 39 GeV (6/10-6/17)

PHENIX Mevts vs Day

Wed Jun 15 18:00:11 2016



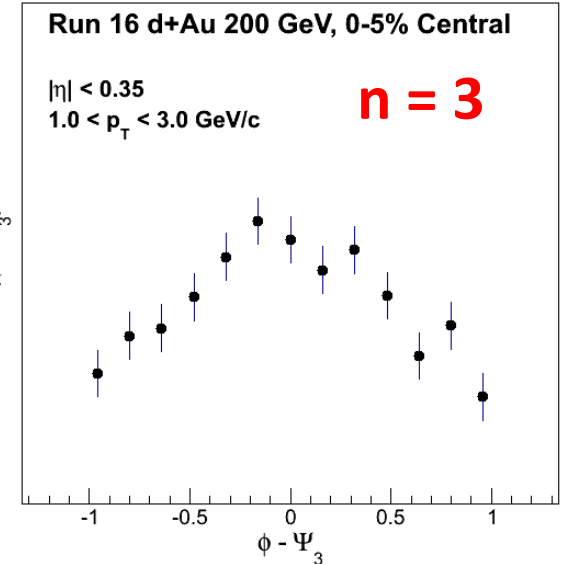
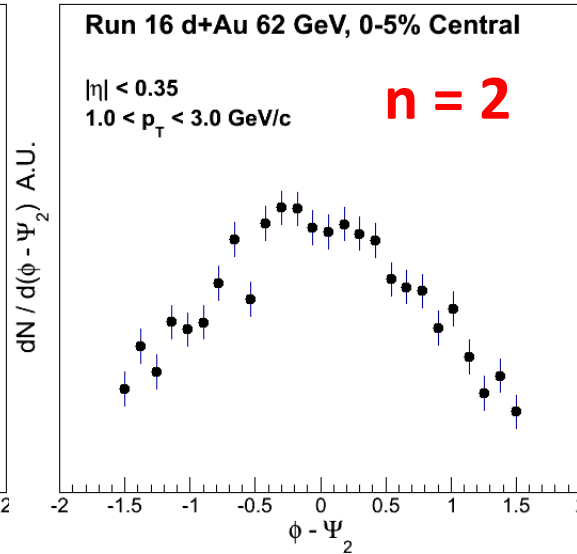
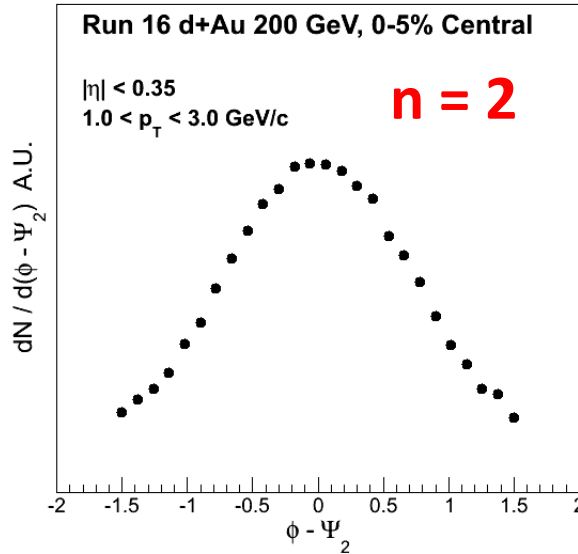
- 39 GeV run is in progress
- Goal is to record 110M evts in top 5% centrality (~190M BBC central trigger)
- We project that ~80% of goal will be achieved by the end of the run

Quick look at Run 16 d+Au data

d+Au 200 GeV

d+Au 62 GeV

d+Au 200 GeV



- Great enthusiasm for the d+Au BES physics
- (almost) Online data production, and online analysis !
- First signs of v_2 at 200 GeV and 62 GeV
- First indication of non-zero v_3 in d+Au at 200 GeV!

We expect publication of the flow results from d+Au BES in a relatively short time scale

Data Analysis/Release Plan

Data Sets and Reconstruction Status

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

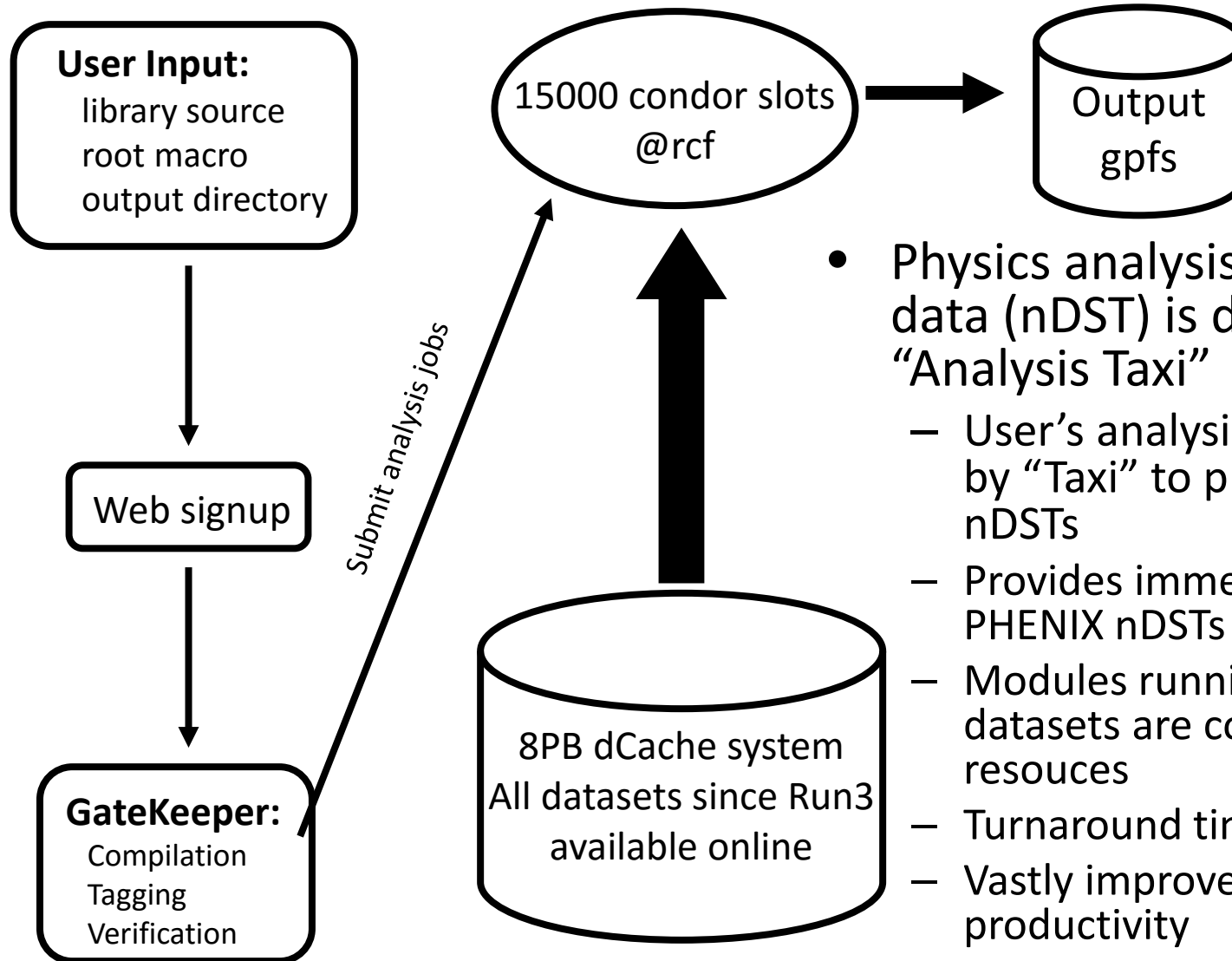


: completed



: needs second pass for VTXP

The Analysis Taxi



- Physics analysis of reconstructed data (nDST) is done through “Analysis Taxi”
 - User’s analysis modules are run by “Taxi” to process available nDSTs
 - Provides immediate access to all PHENIX nDSTs since RUN3
 - Modules running over same datasets are combined to save resources
 - Turnaround time typically hours
 - Vastly improves PHENIX analysis productivity

Required Computing Resources

- Run14/15/16 nDST production timescale is probably the end of 2017
 - CPU time to process all RUN14 Au+Au data is about a half year
- PHENIX part of gpfs filesystems provide sufficient buffer disk space for reconstruction
- Currently 8PB dCache is split into 5PB DST and 3PB raw data storage
- Run14 and Run16 will add 2PB of DSTs, raw data storage will be merged to DST storage
- Not clear yet if the current Analysis Taxi scheme is feasible for PB sized datasets.
 - This can be addressed by, for example, to save multiple smaller filtered datasets. This would increase dCache space needs

PWGs, Preliminary

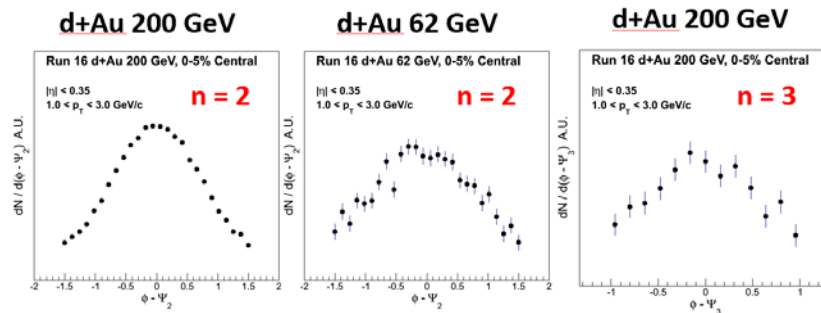
- PHENIX has 3 Physics Working Groups (PWGs)
 - SPIN PWG p+p and spin
 - PLHF PWG Photon, low mass vector meson, hadron, flow
 - HHJ PWG Hard probes, Heavy flavor, JetsEach PWG has several “Topical Analysis Groups”
- All physics analysis are developed under a PWG and reviewed by PWG
- Preliminary results are approved by Collaboration in a monthly meeting
 - Only one Preliminary approval for the same physics observable
- Recently, we have more emphasis on final publication.
 - Many of recent preliminary results are given after Paper Preparation Group (PPG) to publish the final results is formed.

SPIN PWG

- Physics topics under PPG
 - A_{LL} of forward π^0/η at in pp 500 GeV
 - A_N of heavy flavor decay muon in pp at 200 GeV
 - J/Psi polarization in pp at 510 GeV
- Expected PPG in ~ 1 year
 - A_N of forward neutron in pA
 - Final results of $W \rightarrow \mu A_L$ (2011+2012+2013)
- Expected Preliminary results in 1 year
 - ALL of charged pion in pp at 510GeV
 - ALL of direct photon in pp at 510GeV
 - AN of J/Psi in pp/pA at 200 GeV

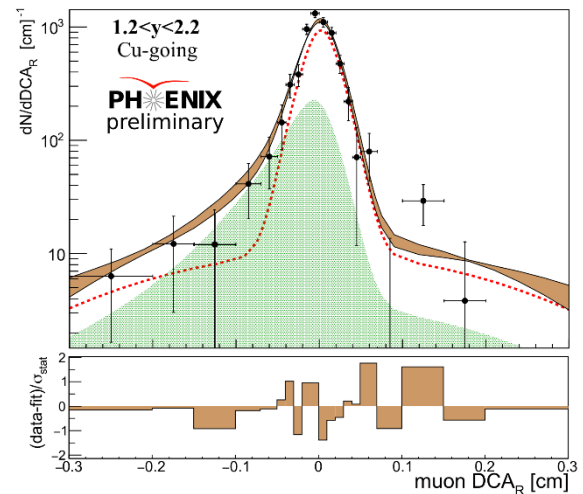
PLHF PWG

- Physics topics under PPG
 - HBT Levy fit in AuAu (Run10)
 - Flow in p+A (Run15)
- Expected PPG in ~ 1 year
 - V_2 and v_3 from d+Au BES
 - System size dependence of v_n in forward/backward rapidity in CuCu/CuAu/AuAu
 - Virtual photon in CuCu
- Expected preliminary in ~ 1 year
 - Low p_T direct photons in Au+Au and p+Au via external conversion



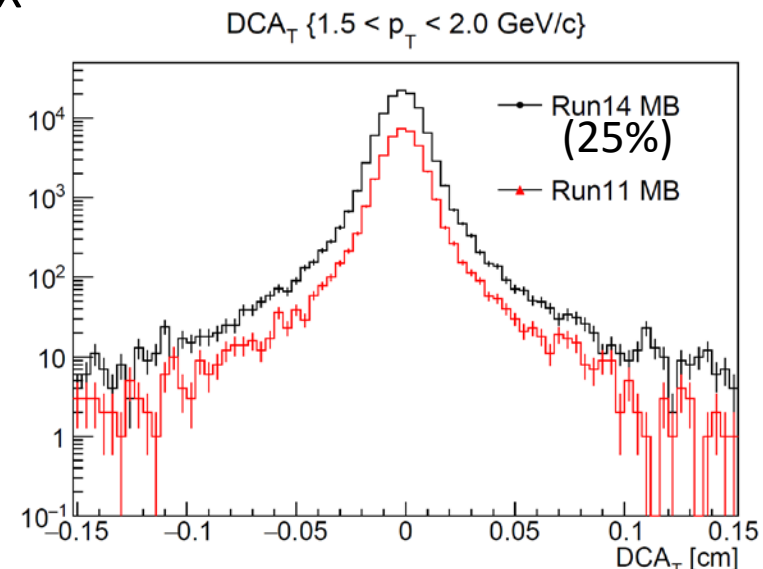
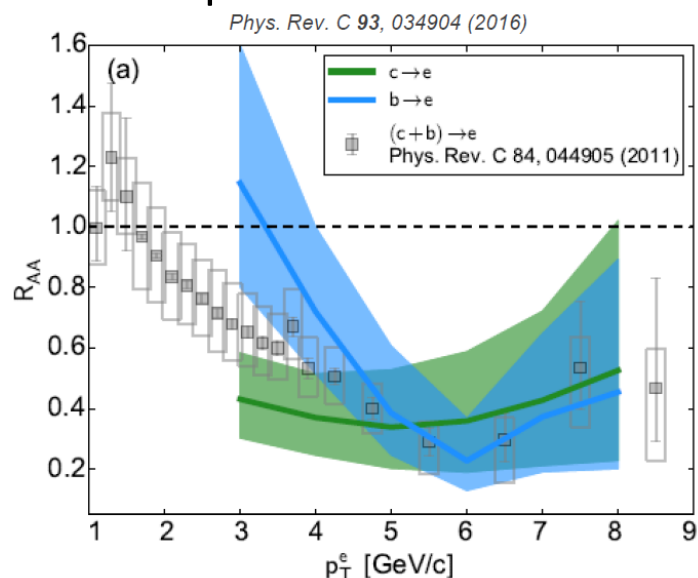
HHJ PWW

- Physics topics under PPG
 - Jet production in CuAu
 - J/Psi and Psi(2S) at forward rapidity in pp at 200GeV
 - e+e- from open heavy flavor in p+p at 200GeV
 - Direct photon – hadron correlation in pp at 200GeV
 - FVTX B \rightarrow J/psi fraction in pp at 510 GeV
 - FVTX B \rightarrow J/psi fraction in CuAu at 200 GeV
- Expected PPG in ~ 1 year
 - Pi0/eta in Cu+Au
 - pi0 in 3He+Au
 - Pi0 in p+A
 - Photon-hadron correlation in d+Au
- Expected preliminary in ~ 1 year
 - FVTX B \rightarrow J/Psi fraction in pp at 200 GeV (Run15)
 - FVTX B \rightarrow J/Psi fraction in pA
 - VTX $b \rightarrow e / (b, c \rightarrow e)$ fraction in pp (Run15)
 - VTX RAA ($b \rightarrow e$) in Au+Au (Run14)
 - VTX v_2 of single e in AuAu (Run14)



Expected improvement over RUN11 HF results

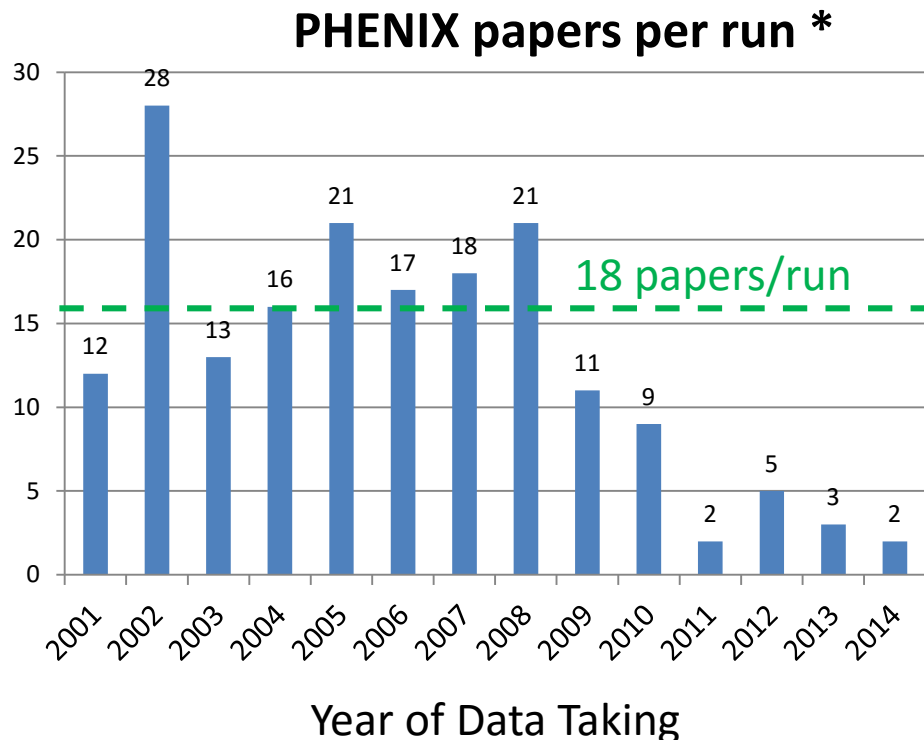
RUN11 published results of VTX



- About 25% of RUN14 data analyzed
 - A factor of ~ 3 increase of statistics in electron DCA distribution
 - $\sim 25\%$ improvement of the efficiency after reprocessing is expected
 - A factor of ~ 15 improvement over RUN11
- RUN16 Au+Au run doubles the dataset.
- Same high statistics data from FVTX
- Definitive results on RAA and v_2 of $b \rightarrow e$, $B \rightarrow J/\Psi$ and many other HF topics from RUN14 and 16 data

Publish the results of PHENIX

- RUN16 is 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 in the past runs



(* as of end of 2015 including submitted papers)

- pp at 500/510 GeV
 - pp at 200 GeV
 - p+Al and pAu at 200 GeV
 - d+Au at 20,39,62, 200GeV
 - Cu+Au at 200 GeV
 - Au+Au at 200 GeV
 - U+U at 193 GeV
- > 5 years to complete publication of all results