

PHENIX Data analysis and data preservation

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for PHENIX Collaboration

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Recent highlights and publication status

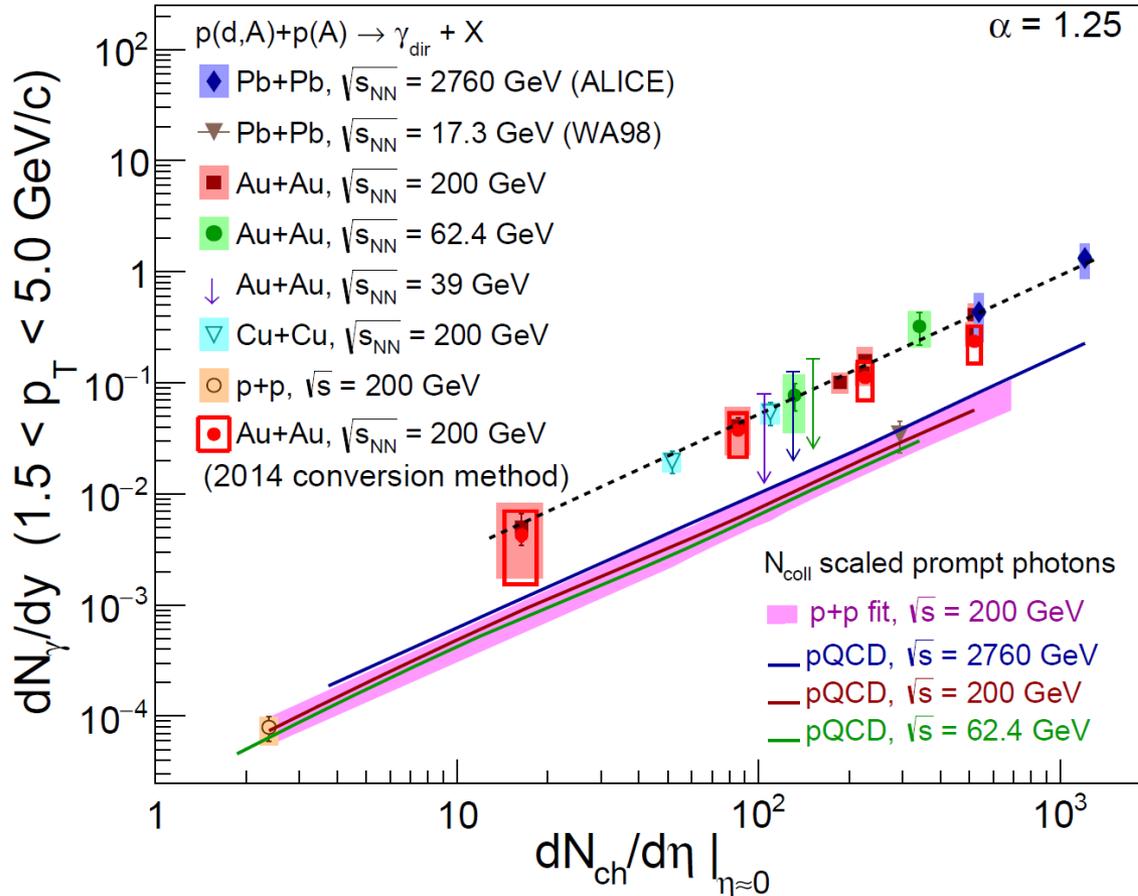
PHENIX papers since last September

PRD102,032001	(2020)	Charged pion A_{LL} in pp at 510 GeV
PRD101,052006	(2020)	Forward J/ψ and $\psi(2S)$ production in pp at 510 GeV
PRC102,014902	(2020)	Forward and Backward J/ψ in $pp, pA, {}^3\text{HeAu}$ at 200GeV
PRC101,034910	(2020)	Forward hadron R_{pA} at 200 GeV
PRL123,122001	(2019)	Suppression of A_N in pAu at 200 GeV
arXiv:2005.14686		π^0, η in U+U at 192GeV
arXiv:2005.14276		$b\bar{b}$ production at forward in $p + p$ at 510GeV
arXiv:2005.14273		Polarization and cross section of J/ψ in $p + p$ at 510 GeV
arXiv:2005.14270		direct photon-hadron correlation in dAu, AuAu at 200GeV
arXiv:1805.04066		$\mu\mu, e\mu, ee$ correlations in $p + p$ 200 GeV

- **5 papers published**
 - **1 PRL: Suppression of AN of forward hadrons**
- **5 papers in journal review**

Low p_T direct photons

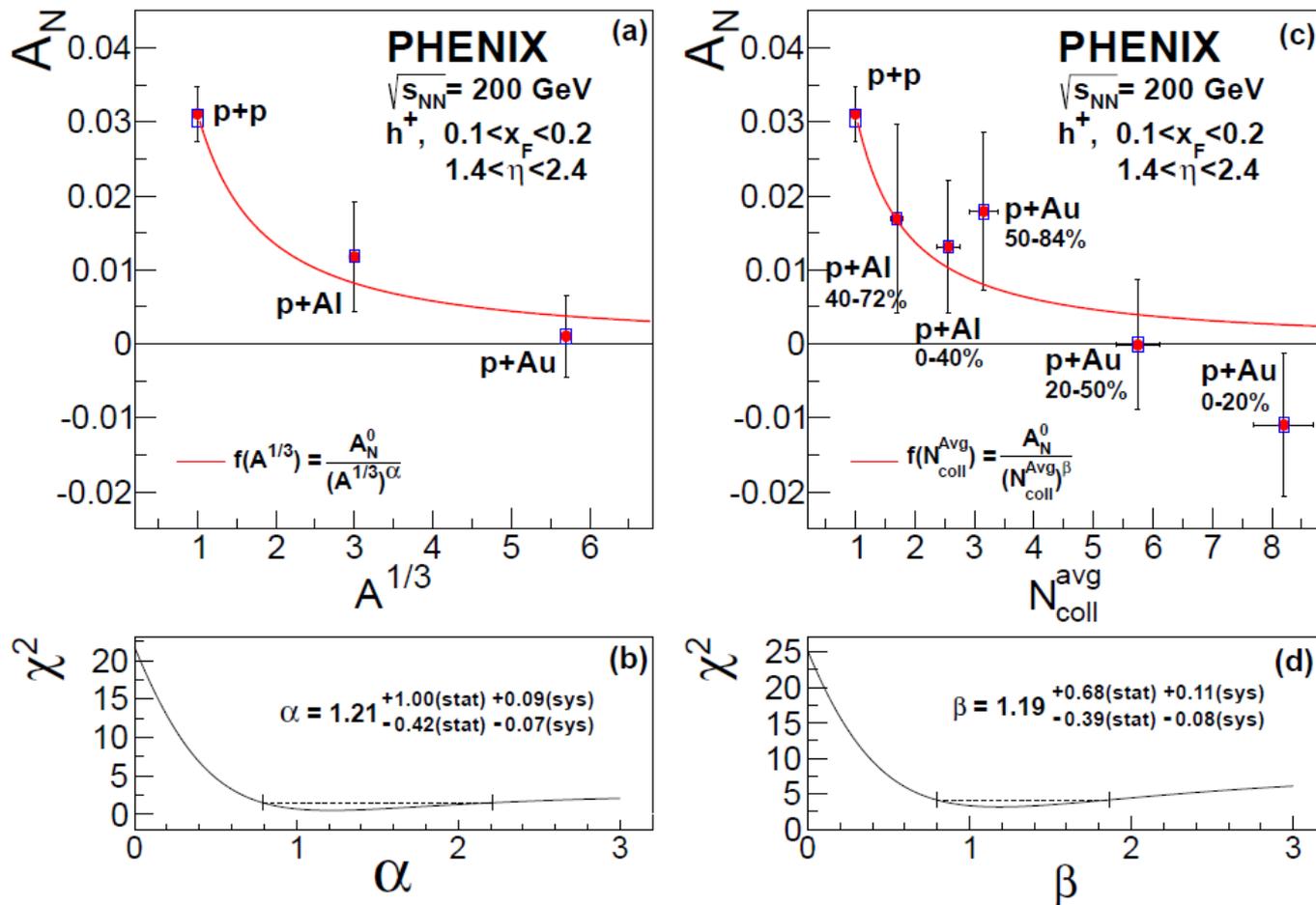
PRL123, 022301(2019) + RUN14 Preliminary



- New RUN14 preliminary results confirms earlier measurements
- Consistent with thermal photons from hot QGP
- Property of the QGP is similar for wide range of collision systems

Suppression of A_N in p+A

PRL123, 122001(2019)



A_N of positive hadrons in pAu is suppressed compared with p+p
 A-independence hypothesis of TSSA is clearly disfavored

PHENIX publications

- **199 physics papers published**

– Phys. Rev. Lett.	74
– Phys. Rev. C	81
– Phys. Rev. D	38
– Nature Physics	1
– Phys. Letter B	4
– Nucl. Phys. A	1

- **Total citation: ~29000**

- Topcite 1000+ 2
 - 500-1000 7
 - 250-500 18
 - 100-250 54
 - 50-100 46

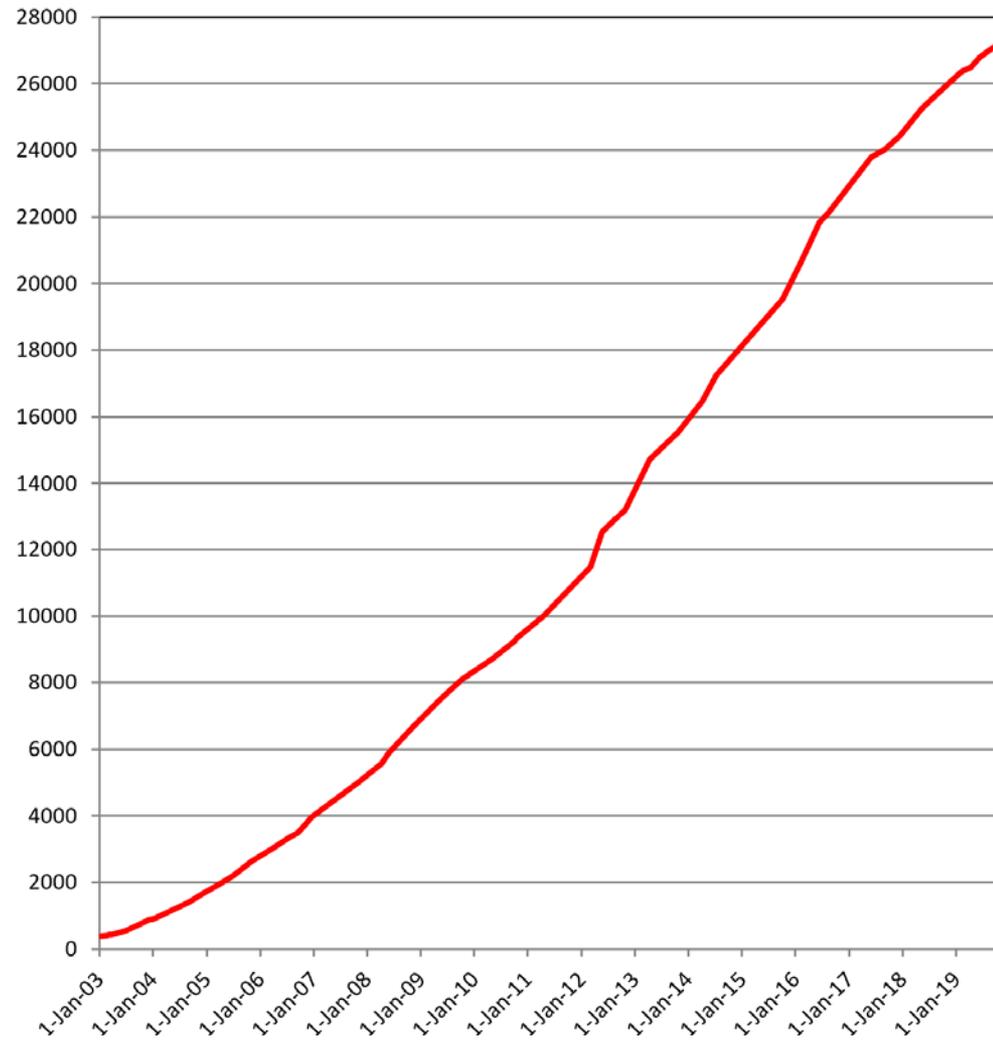
PHENIX White Paper: 2926 cites

Jet quenching discovery: 1083 cites

Nature P paper: 109 citations

**127 physics papers in topcite 50+
(149 if proceedings and detector
papers are included)**

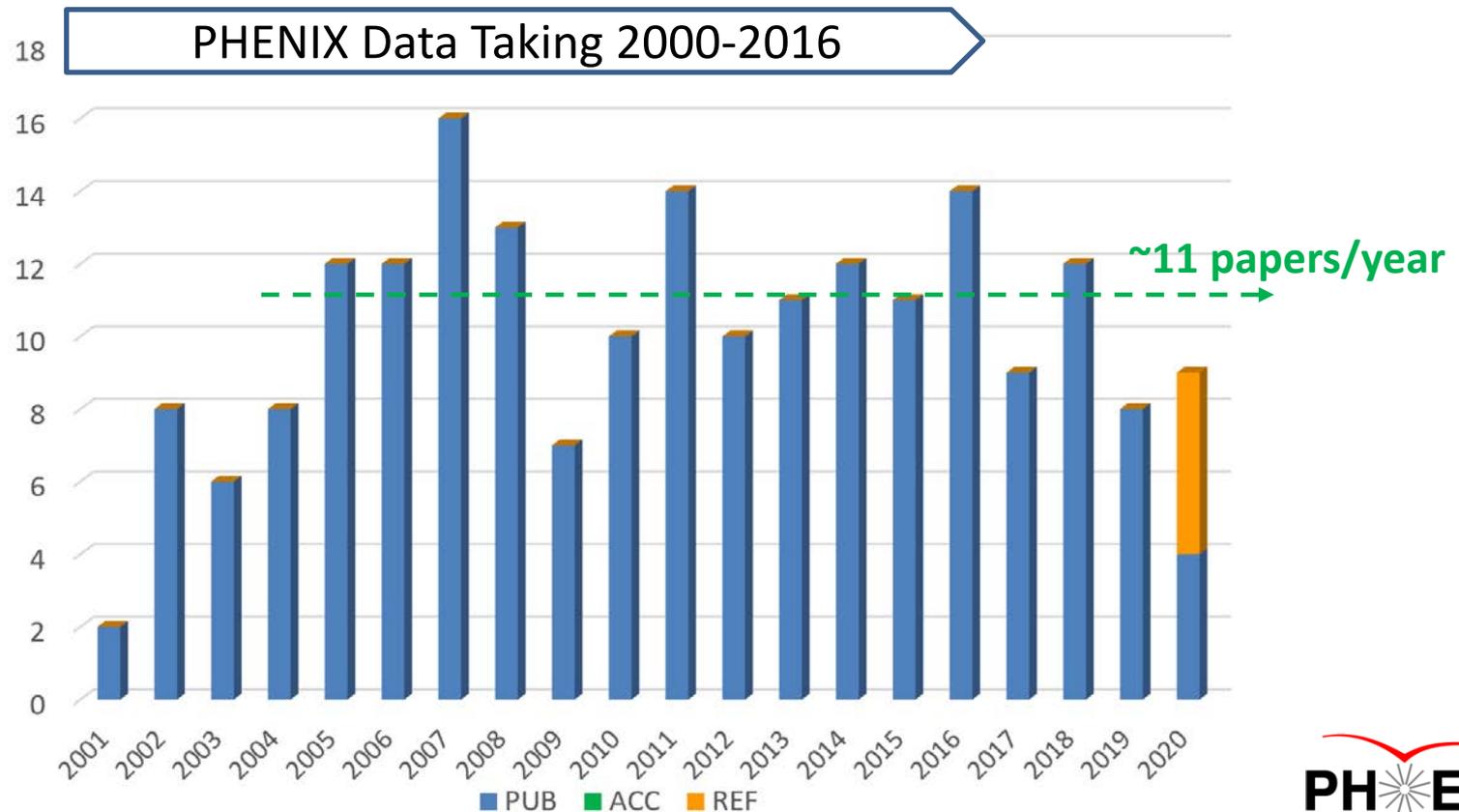
Cumulative Citations of PHENIX papers



PHENIX publications

- ~11 papers per year since 2005
- 4 papers published + 5 papers in journal review in 2020
- Complete publication of major results by 2023

Published PHENIX papers in each year



Data analysis Status

Golden datasets of PHENIX

year	Beam, E(GeV)	Recorded data (pp equiv)	upgrade	Physics
2016	AuAu 200 dAu 200 dAu 62,39,20	2.3/nb (90/pb) 15B events 1G & 73/nb (29/pb) 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 ³ HeAu 200	2.3/nb (90/pb) 15 B events 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

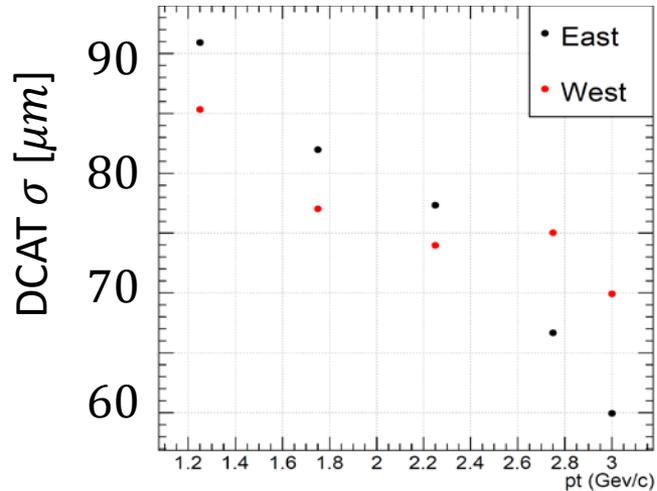
Data Production Status

RUN	beam	VTX/FVTX/Muon (heavy flavor)	Central Arm flow	Central Arm EM (γ , e)	MPC/EX (small-x)
16	Au+Au 200	VTX geometry calibration	DONE	DONE	N/A
	d+Au BES	DONE	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	DONE	DONE	DONE	N/A
	3He+Au 200	2019	DONE	DONE	

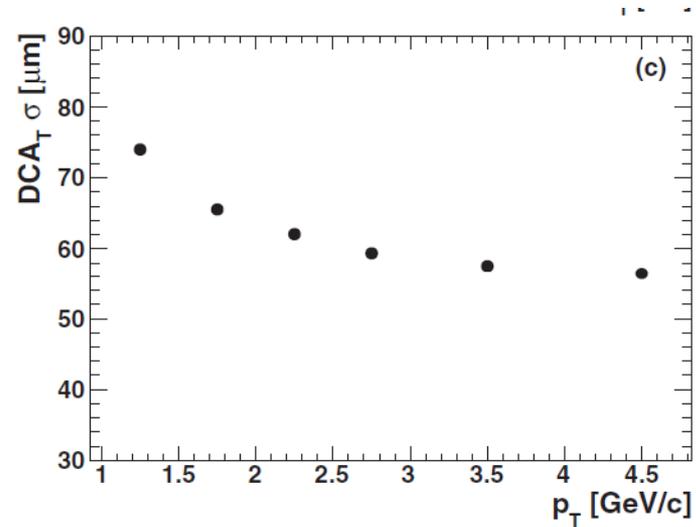
- Run16AuAu ~ 6 months of CPU

RUN16 DST production status

Present DCA resolution in RUN16



Nominal VTX DCA resolution



- One of 4 layers of West half of VTX was lost due to a beam accident in RUN15 pAu.
- VTX was rebuilt before RUN16 and reinstalled, but the one lost layer makes VTX geometry calibration more difficult
- Geometry calibration is almost complete, and better than 90 μm resolution is achieved.
- We can start RUN16 DST production after the calibration.
- ~6 months of CPU to complete the RUN16 production

Data analysis review in Dec 2019

- Review of PHENIX data analysis and workforce on 2019/12/12
 - Review panel:
 - J.Nagle, P. Steinberg, U. Heinz, and D. Arkhipin
 - PHENIX requested for additional resource to complete key analyses (HF with VTX, HF with FVTX, and thermal dilepton) and data/analysis preservation
- Review report
 - Endorses importance of the three key analyses topics
 - Supports for data preservation effort
- BNL provided additional resource
 - 1 new Postdoc at BNL for PHENIX analysis
 - 50% for analysis support + 50% for one of the key analyses
 - Hiring process started (delayed by COVID-19). Selection will start soon.
 - 0.5 FTE from NPPS to support data preservation effort in future
- Feasibility study of key analyses for additional support from DOE NP (FVTX b/c separation complete)

Workforce for PHENIX analysis

- Current workforce (updated August 2020)

PhD students	33.4	FTE
Postdocs	7.3	FTE
Senior Scientist	4.8	FTE
Total	44.5	FTE
- These numbers are similar to those reported in the S&T review 1 year ago.
- PHENIX have yearly survey of active members. In 2020, we have 86 members taking the survey. The same number of members took the survey in 2019.
- Small number of senior members in analysis is a concern. New analyzers (students/Postdocs) cannot learn from the analysis know-how from experienced members.
- PHENIX is developing a new Data Analysis/Preservation page to preserve the analysis knowledge

Data Preservation

PHENIX Data analysis and Preservation page



PHENIX, the Pioneering High Energy Nuclear Interaction eXperiment, is an exploratory experiment for the investigation of high energy collisions of heavy ions and protons. It is the largest of the four experiments that have taken data at the Relativistic Heavy Ion Collider. Data-taking was finished in 2016 and the PHENIX Collaboration is now analyzing large data samples collected, prioritizing those with a unique physics reach.

This website has been created by the PHENIX Collaboration to support its long-term Data and Analysis Preservation effort. Materials are being collected from legacy web resources, systematized and curated. Please do not hesitate to examine [the list of work items](#) and [let us know](#) if you can help.

- We are developing PHENIX Data analysis and preservation web site
- “reference manual” for PHENIX data analysis
- Aim to preserve full analysis chain of one of key analyses in future

PHENIX DAP page (2)

Central Arm Detectors

Name

- Drift Chamber
- Pad Chambers
- Ring Imaging Cherenkov
- Hadron Blind Detector
- Time Expansion Chamber
- Time-of-Flight
- Aerogel Cerenkov Counter
- Time-of-Flight West
- Electromagnetic Calorimeter
- Silicon Vertex Tracker

Role

- Measures the position and momentum of charged particles.
- Measures the position of charged particles with precision.
- Identifies Electrons.
- Identifies electrons without detecting hadrons.
- Measures the position and momentum of charged particles. Identifies particles.
- Measures the position of charged particles. Identifies particles.
- Identifies particles at high transverse momentum.
- High resolution particle identification.
- Measures the position and energy of charged and neutral particles. Identifies photons and charged particles.
- Charged particle tracking near the collision vertex.



RHIC records + PHENIX run summary table

Run	Species	Energy (GeV/nucleon)	Integrated Luminosity (Polarization L/T)	IE
01	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	65.2	1b^{-1}	
02	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	100.0	24b^{-1}	
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	9.8	-	
	polarized p+p	100.2	$\sim 1.015\text{pb}^{-1}$	
03	$d + ^{197}\text{Au}^{78+}$	100.7+100	2.74nb^{-1}	
	polarized p+p	100.2	0.35pb^{-1}	
04	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	100.0	241pb^{-1}	
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	31.2	9pb^{-1}	
05	$^{63}\text{Cu}^{28+} + ^{63}\text{Cu}^{28+}$	100.0	3nb^{-1}	
	$^{63}\text{Cu}^{28+} + ^{63}\text{Cu}^{28+}$	31.2	0.19nb^{-1}	0.38
	$^{63}\text{Cu}^{28+} + ^{63}\text{Cu}^{28+}$	11.2	2.7nb^{-1}	3.78
	polarized p+p	100.2	$3.4/0.2\text{pb}^{-1}$	858
06	polarized p+p	100.2	$7.5/2.7\text{pb}^{-1}$	2338
	polarized p+p	31.2	$0.08/0.02\text{pb}^{-1}$	288
07	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	100.0	813pb^{-1}	5.18
08	$d + ^{197}\text{Au}^{78+}$	100.7+100	80nb^{-1}	160B
	polarized p+p	100.2	$\sim 15.2\text{pb}^{-1}$	115B
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	4.6	-	45k
09	polarized p+p	249.9	$14/-\text{pb}^{-1}$	
	polarized p+p	100.2	$16/-\text{pb}^{-1}$	
10	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	100.0	1.5nb^{-1}	5.7B
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	31.2	0.11nb^{-1}	0.7B
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	19.5	40nb^{-1}	0.25B
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	3.85	0.3nb^{-1}	1.7M
11	polarized p+p	249.9	$18/-\text{pb}^{-1}$	
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	9.8	2pb^{-1}	13M
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	100.0	1.7nb^{-1}	2.18/5.2B
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	13.5	7pb^{-1}	45M
12	polarized p+p	100.2	$\sim 110\text{pb}^{-1}$	
	polarized p+p	254.9	$32/-\text{pb}^{-1}$	
	$d + ^{197}\text{Au}^{78+} + ^{208}\text{Pb}^{82+}$	96.4	0.2nb^{-1}	1.28/0.8B
	$^{63}\text{Cu}^{28+} + ^{197}\text{Au}^{78+}$	99.9+100.0	5nb^{-1}	0.88/8.1B
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	2.5	-	Very short
13	polarized p+p	254.9	$155/-\text{pb}^{-1}$	
14	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	7.3	4pb^{-1}	23M/10M
	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	100.0	7.5nb^{-1}	3.5B/19B
	$^3\text{He}^{2+} + ^{197}\text{Au}^{78+}$	103.5+100.0	24nb^{-1}	
15	polarized p+p	100.2	$\sim 160\text{pb}^{-1}$	
	polarized p + $^{197}\text{Au}^{78+}$	103.9+98.6	$\sim 10.2\text{pb}^{-1}$	
	polarized p + $^{27}\text{Al}^{13+}$	103.9+98.7	$\sim 10.5\text{pb}^{-1}$	
16	$^{197}\text{Au}^{78+} + ^{197}\text{Au}^{78+}$	100.0	7nb^{-1}	0.8B/15B
	$d + ^{197}\text{Au}^{78+}$	100.7+100	50nb^{-1}	
	$d + ^{197}\text{Au}^{78+}$	31.1+31.1	5nb^{-1}	
	$d + ^{197}\text{Au}^{78+}$	9.9+9.8	0.08nb^{-1}	
	$d + ^{197}\text{Au}^{78+}$	19.6+19.4	2nb^{-1}	

Electromagnetic Calorimeter

Write-ups

- [DOI: 10.5281/zenodo.3013206](#) PHENIX Electromagnetic Calorimeter (EMCal) – Detector Basics (G.David)
- [DOI: 10.5281/zenodo.3893772](#) Explanation of PHENIX triggers (A.Bazilevsky)

Theses

- [DOI: 10.5281/zenodo.3805026](#) The Quark-Gluon Plasma probed by Low Momentum Direct Photons in Au+Au Collisions at $\sqrt{s_{NN}}=62.4\text{GeV}$ and $\sqrt{s_{NN}}=39\text{GeV}$ beam energies (Vladimir Khachatryan)
- [DOI: 10.5281/zenodo.3805026](#) Inclusive jet production in proton-proton and copper-gold collisions at $\sqrt{s_{NN}}=200\text{GeV}$ (Arbin Timilsina)

Publications

- [PHENIX Calorimeter](#) (NIM A 499, 2003. doi.org/10.1016/S0168-9002(02)01954-X)
- [High Energy Beam Test of the PHENIX Lead-Scintillator EM Calorimeter](#) High Energy Beam Test of the PHENIX Lead-Scintillator EM Calorimeter

Presentations

- [DOI: 10.5281/zenodo.4007111](#) PHENIX Focus: Electromagnetic Calorimeter (Gabor David)

Variables and Accessors under PHCentralTrack Node (used for charged particle analyses)

Type	Name	Description
float	get_pemcx	x-component of the projection of the cgl track onto the EMC (cm)
float	get_pemcy	y-component of the projection of the cgl track onto the EMC (cm)
float	get_pemcz	z-component of the projection of the cgl track onto the EMC (cm)
float	get_plemc	path length following particle trajectory from vertex to EMC
float	get_temc	time of the EMC hit. This time has been back-corrected in PHCentralTracks to be the physical time instead of the photon flash time. The reason is that the former is more useful for calculating properties of a charged track.
float	get_emcdphi	difference in phi (rads) between the track model projection and the hit in emc
float	get_emcdz	difference in z (cms) between the track model projection and the hit in emc
float	get_emcsdphi	emcdz variable normalized to SIGMAS (after calibrations)
float	get_emcsdz	emcdz variable normalized to SIGMAS (after calibrations)
float	get_emcsdphi_e	position resolution of the EMCal depends upon the shower type. emcdphi variable in SIGMAS assuming the resolution appropriate for EM showers (after calibrations)
float	get_emcsdz_e	position resolution of the EMCal depends upon the shower type. emcdz variable in SIGMAS assuming the resolution appropriate for EM showers (after calibrations)
float	get_ecore	energy deposited in the EMC "shower core"
float	get_dep	reduced variable for (ecore/nomE0) that is centered at zero, with sigma around one. It is convenient cut as the known pt and charge dependence is fully accounted for
float	get_ecorr	EMC corrected energy (after calibrations)
float	get_ezent	energy deposited in the central tower

PHENIX DAP page (3)

- In new DAP page, we preserve knowledge of how to analyze PHENIX data. It includes
 - Data set summary
 - How to access data in RCF and to run analysis jobs
 - Reference manual of analysis software
 - Reference manual for simulation and embedding
 - Analysis tutorials and example
 - And more
- Short term goal of the DAP page is to help current analyzers and new analyzers
- It will take another > 6 months to complete the page
- Long term goal is to preserve an entire analysis chain of one of the three key analysis proposed in Dec 2019 review
 - New Postdoc of BNL PHENIX group will be assigned to this task

Summary

- PHENIX completed its data taking in RUN16
 - Removal and Repurposing is basically completed
- Publication status
 - PHENIX continues to produce high impact results
 - Publishing ~11 papers per year, ~2000 citations/year
- Towards completion of Data analysis and preservation
 - VTX geometry calibration is about to complete, and RUN16 DST production will start soon
 - Data analysis review in Dec 2019
 - New DAP page
 - Preserving the knowledge of PHENIX data analysis