PHENIX and sPHENIX Introduction

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PHENIX and sPHENIX

- PHENIX
  - PHENIX history
  - PHENIX detector
  - Recent results
  - Data sets and physics topics
- sPHENIX
  - sPHENIX detector
  - Physics goals
  - INTT Si tracker

Brief history of PHENIX

1990 Call for LOI of RHIC experiments

1991 RHIC PAC → RE2 (PHENIX) formed as merger of 3 proposals

1992 PHENIX pCDR

2000 RHIC RUN-1 → Jet quenching and strong elliptic flow

2005 RHIC Whit Papers (QGP discovery)

2007 PHENIX: heavy quark energy loss & flow

2010 PHENIX: thermal photons($T_{ini} \simeq 300MeV$)

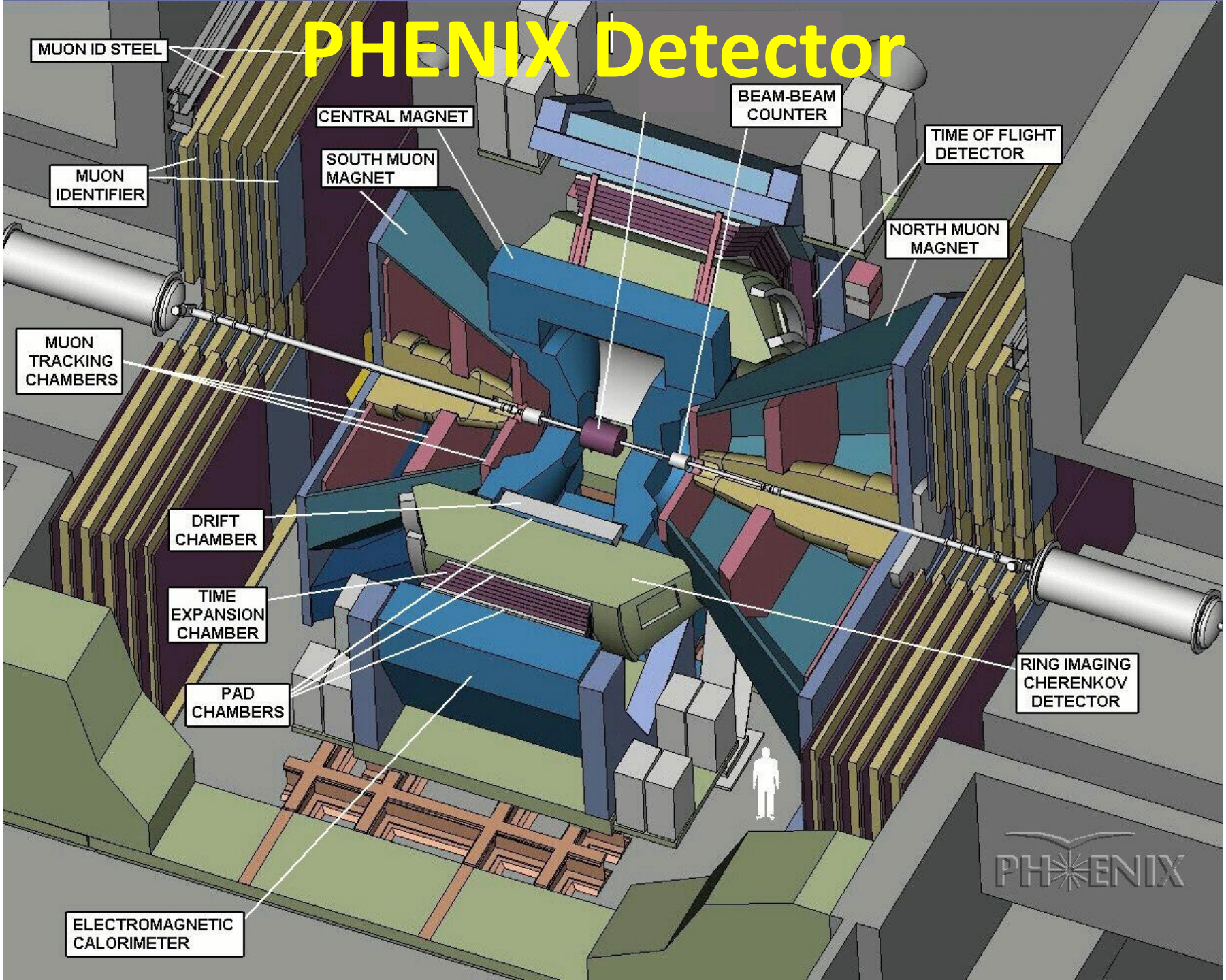
2010 LHC: the first Pb+Pb run. Direct jet measurement

sPHENIX upgrade to measure jets

2015 NSAC Long Range Plan endorse sPHENIX

2016 Last run of PHENIX

2023 sPHENIX will start taking data

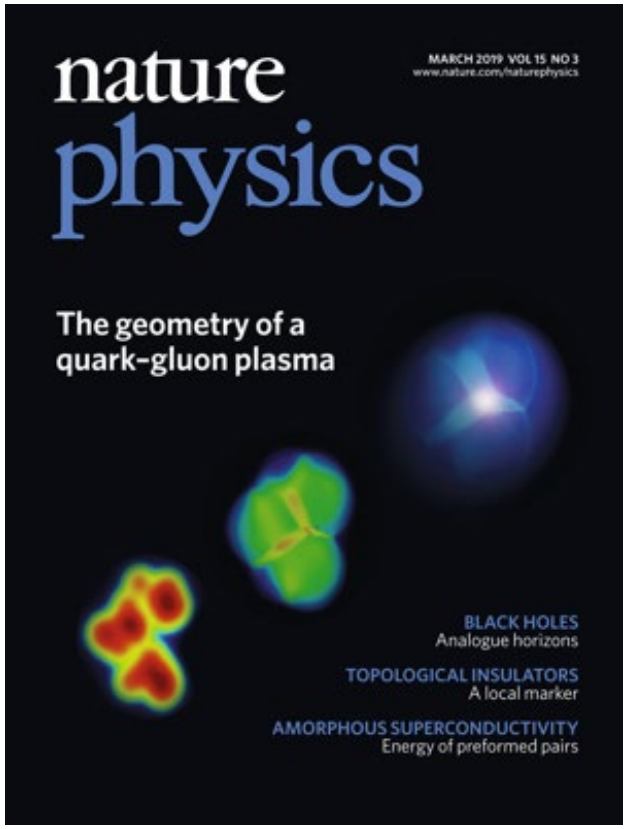

PHENIX Detector
MUON ID STEEL
CENTRAL MAGNET
BEAM-BEAM COUNTER
TIME OF FLIGHT DETECTOR
MUON IDENTIFIER
SOUTH MUON MAGNET
NORTH MUON MAGNET
MUON TRACKING CHAMBERS
DRIFT CHAMBER
TIME EXPANSION CHAMBER
RING IMAGING CHERENKOV DETECTOR
PAD CHAMBERS
ELECTROMAGNETIC CALORIMETER
PHENIX

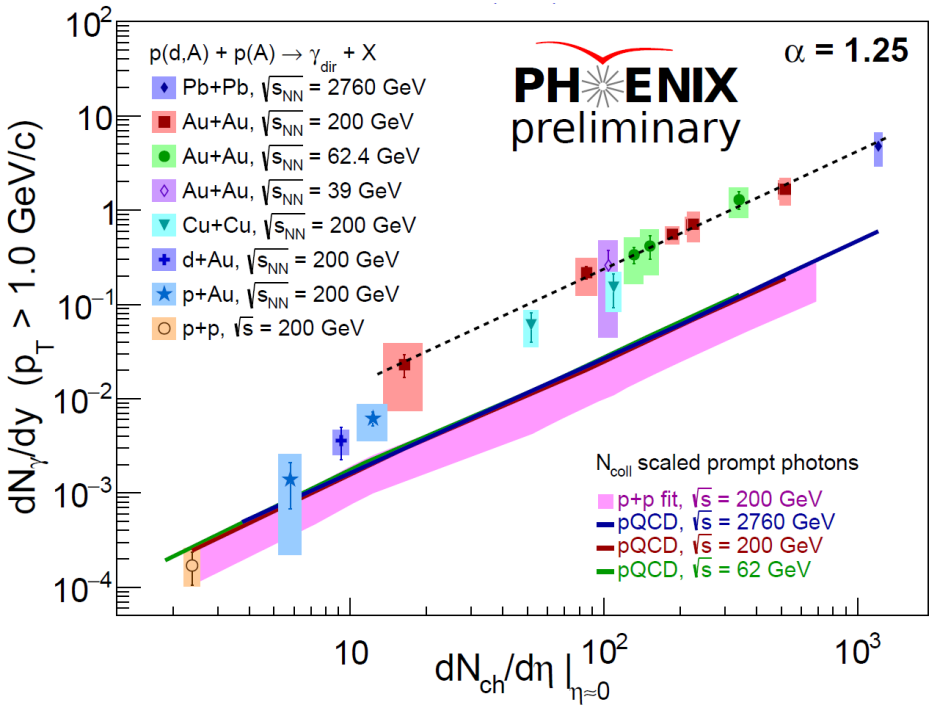
Phenix in 2010

Physics goals of PHENIX

- Study of Quark Gluon Plasma in nucleus-nucleus collisions at RHIC
  - Discovery of QGP → achieved
    - High pT suppression aka jet quenching
    - Strong flow effects (v2, v3,…)
  - Study of QGP properties
    - Direct photon, heavy quark, J/ψ
    - Small systems --- how small a QGP can be
- Study of spin structure of proton in the polarized p+p (and p+A) collisons at RHIC.
  - Gluon polarization $\Delta G(x)$ from A_{LL} measurements
  - Anti-quark polarization $\Delta q(x)$ from the W
  - Study of single spin asymmetries A_N

Recent highlights: small QGP droplets?





- Recently, we have strong evidence that small QGP droplets can be formed in p/d/He+Au collisions
  - Flow in small systems
  - Photon enhancement in central p+Au

PHENIX papers since June 2020

PRD103,052009	**(2021)**	**π^0 A_N in $p+p$ at 200GeV**
PRD103,032007	**(2021)**	**$A_N(p_T)$ of very forward neutrons**
PRC102,054910	**(2020)**	**direct photon-hadron correlation in dAu, AuAu at 200GeV**
PRD102,092002	**(2020)**	**$b\bar{b}$ production at forward in $p+p$ at 510GeV**
PRD102,072008	**(2020)**	**Polarization and cross section of J/ψ in $p+p$ at 510 GeV**
PRC102,064905	**(2020)**	**π^0, η in U+U at 192GeV**
PRD102,032001	**(2020)**	**Charged pion A_{LL} in pp at 510 GeV**
PRC102,014902	**(2020)**	**Forward and Backwoard J/ψ in pp, pA, ^{3}HeAu at 200GeV**

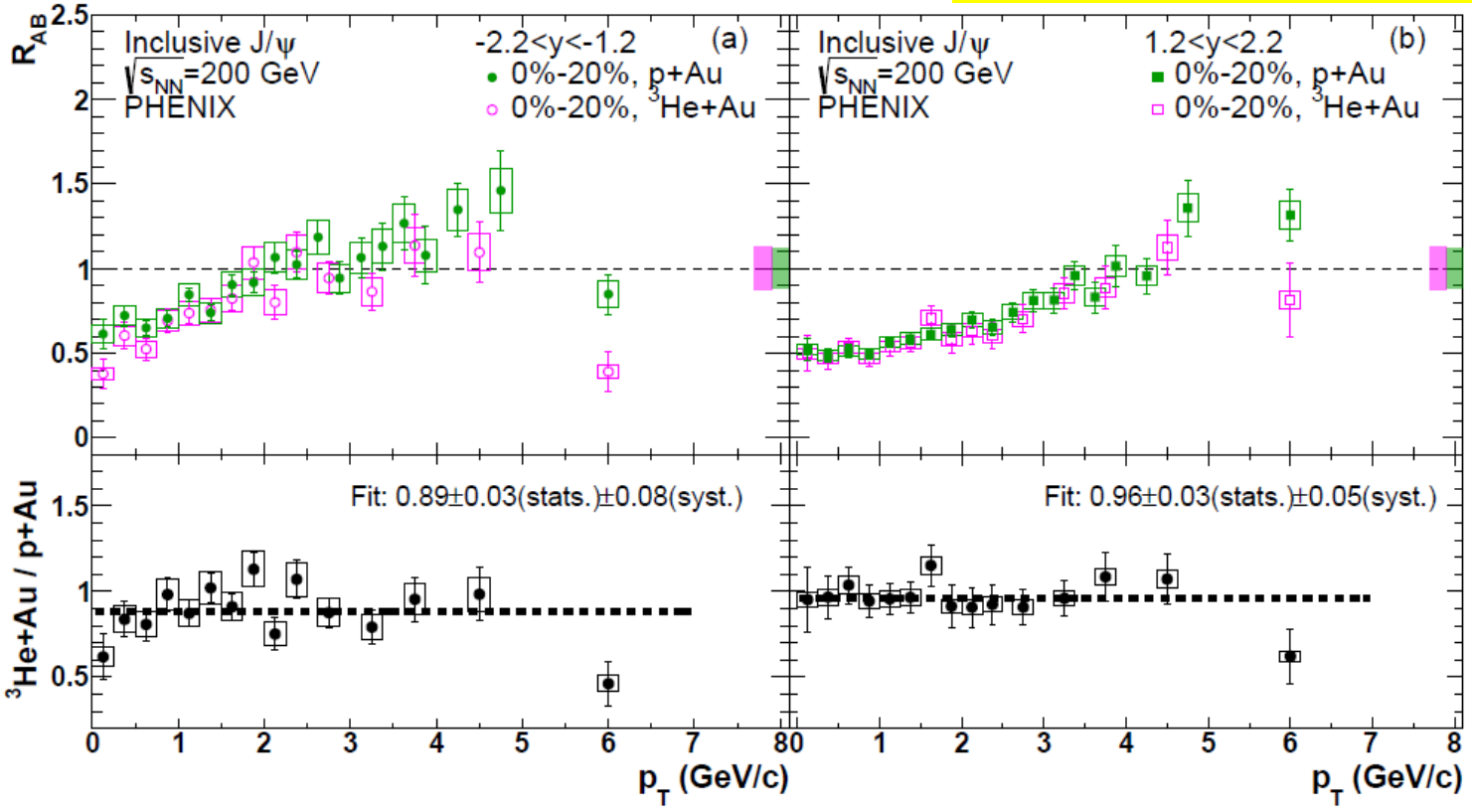
arXiv:2102.13585	A_N of direct photons in $p+p$ at 200 GeV
arXiv:1805.04066	$\mu\mu, e\mu, ee$ correlations in $p+p$ 200 GeV

- **8 papers published in the last 1 year**
- **2 papers in journal review**

PHENIX

J/ψ in small systems

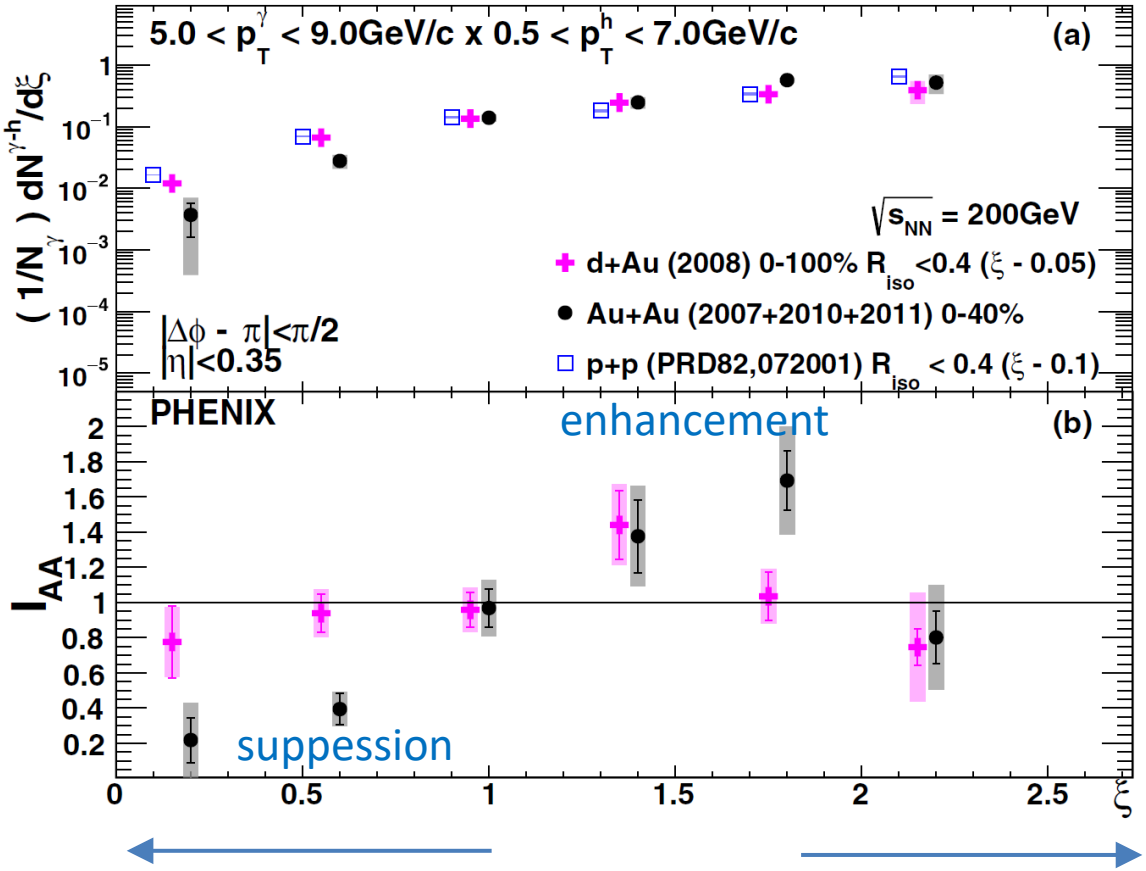
PRC102, 014902 (2020)



- Comprehensive study of J/ψ production in small systems (pAu, dAu, ^{3}HeAu) in forward and backward directions
- Cold Nuclear Matter effects on J/ψ

QGP medium response from direct γ-h correlation

PRC102, 054910 (2020)



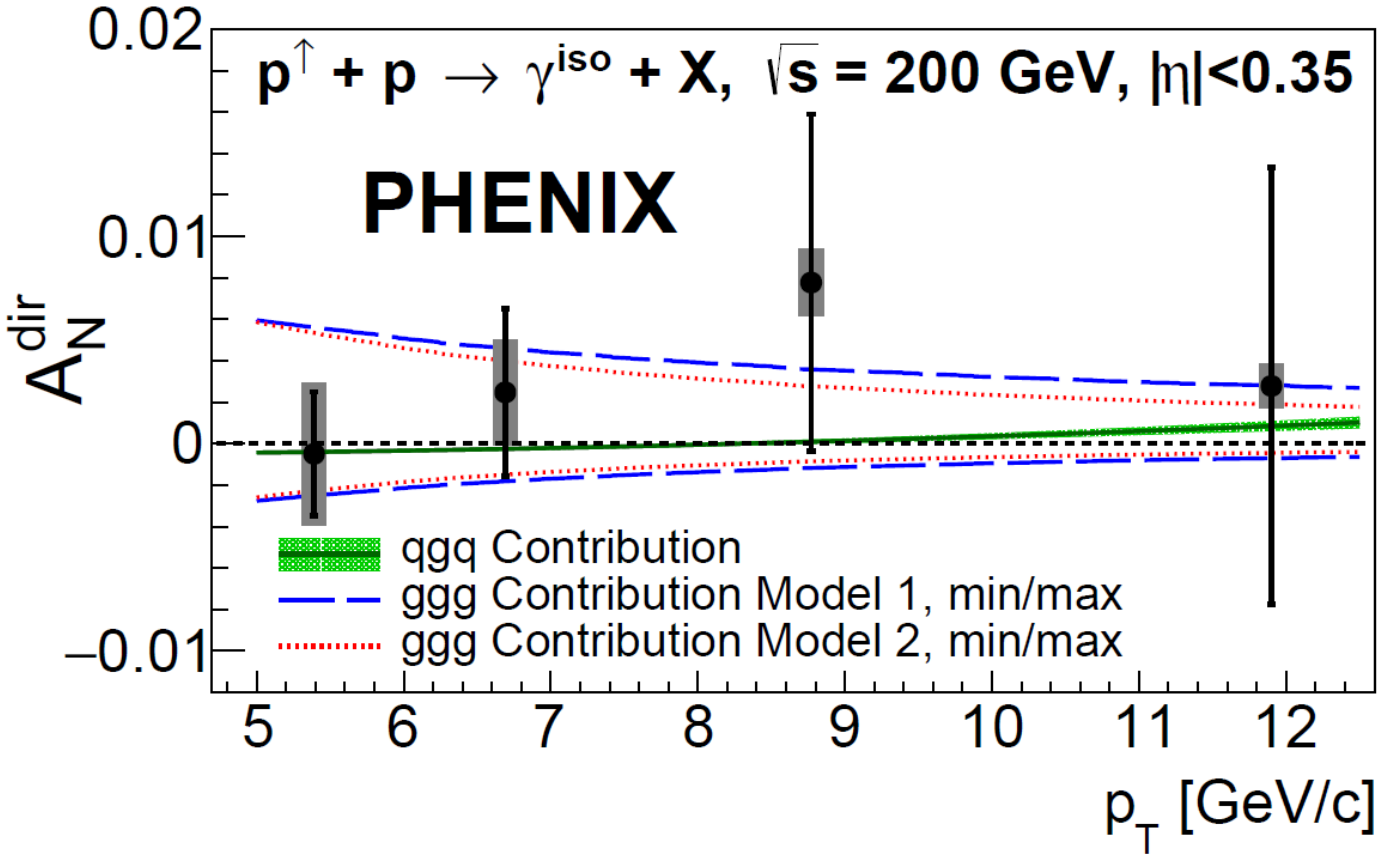
large small

Fractional energy of jet

- Direct-photon and hadron correlation in Au+Au and d+Au are compared
- Medium modification of jet fragmentation in Au+Au is seen
- Hadrons with large jet energy fraction is suppressed
- Low energy hadrons are enhanced as medium response to energy deposited by jets

Direct photon AN

arXiv:2102.13585



- First precision measurement of $A_N(p_T)$ of direct photons
- Direct photons is a very clean probe of proton structure
- The data give constraints on tri-gluon correlation model of A_N

PHENIX publications

- **205 physics papers published**
  - Phys. Rev. Lett. 74
  - Phys. Rev. C 83
  - Phys. Rev. D 42
  - Nature Physics 1
  - Phys. Letter B 4
  - Nucl. Phys. A 1
- **Total citation: ~30000**
- Topcite 1000+ 2
  - 500-1000 7
  - 250-500 21
  - 100-250 52
  - 50-100 46

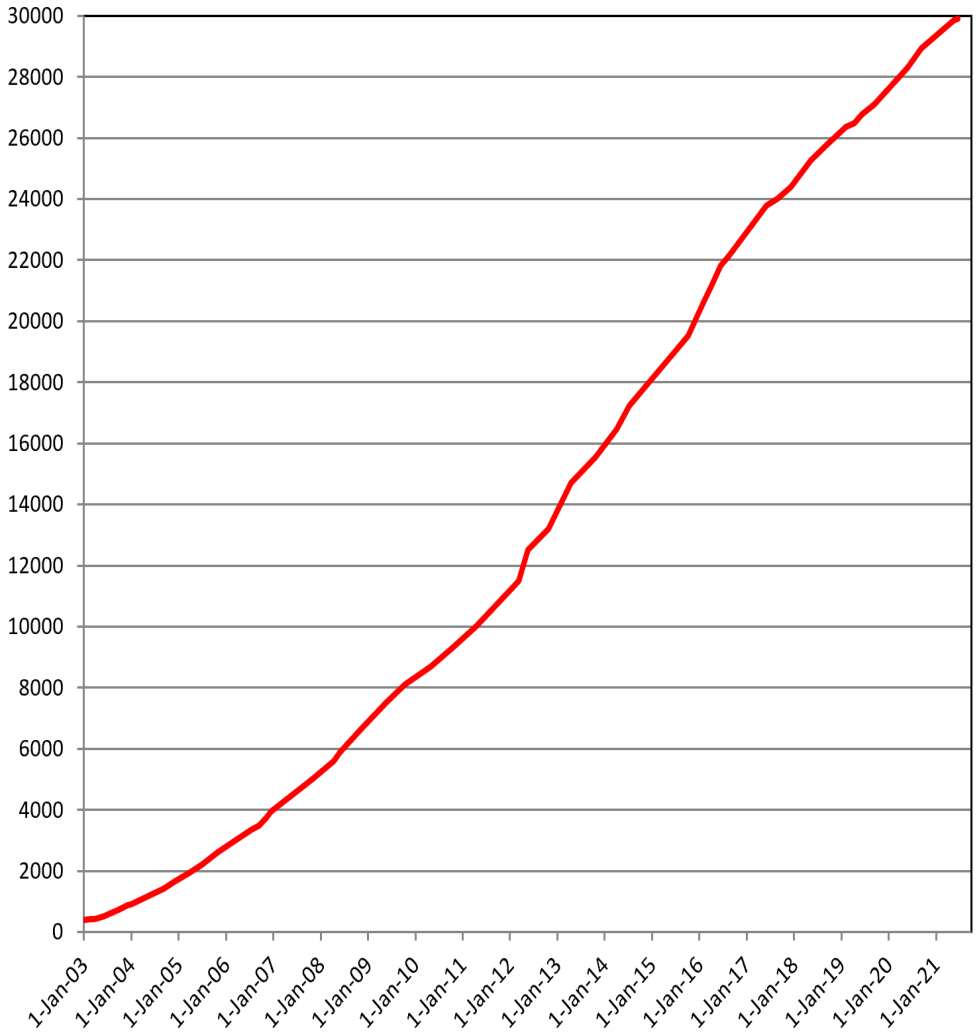
PHENIX White Paper: 3055 cites

Jet quenching discovery: 1112 cites

Nature P paper: 154 citations

128 physics papers in topcite 50+

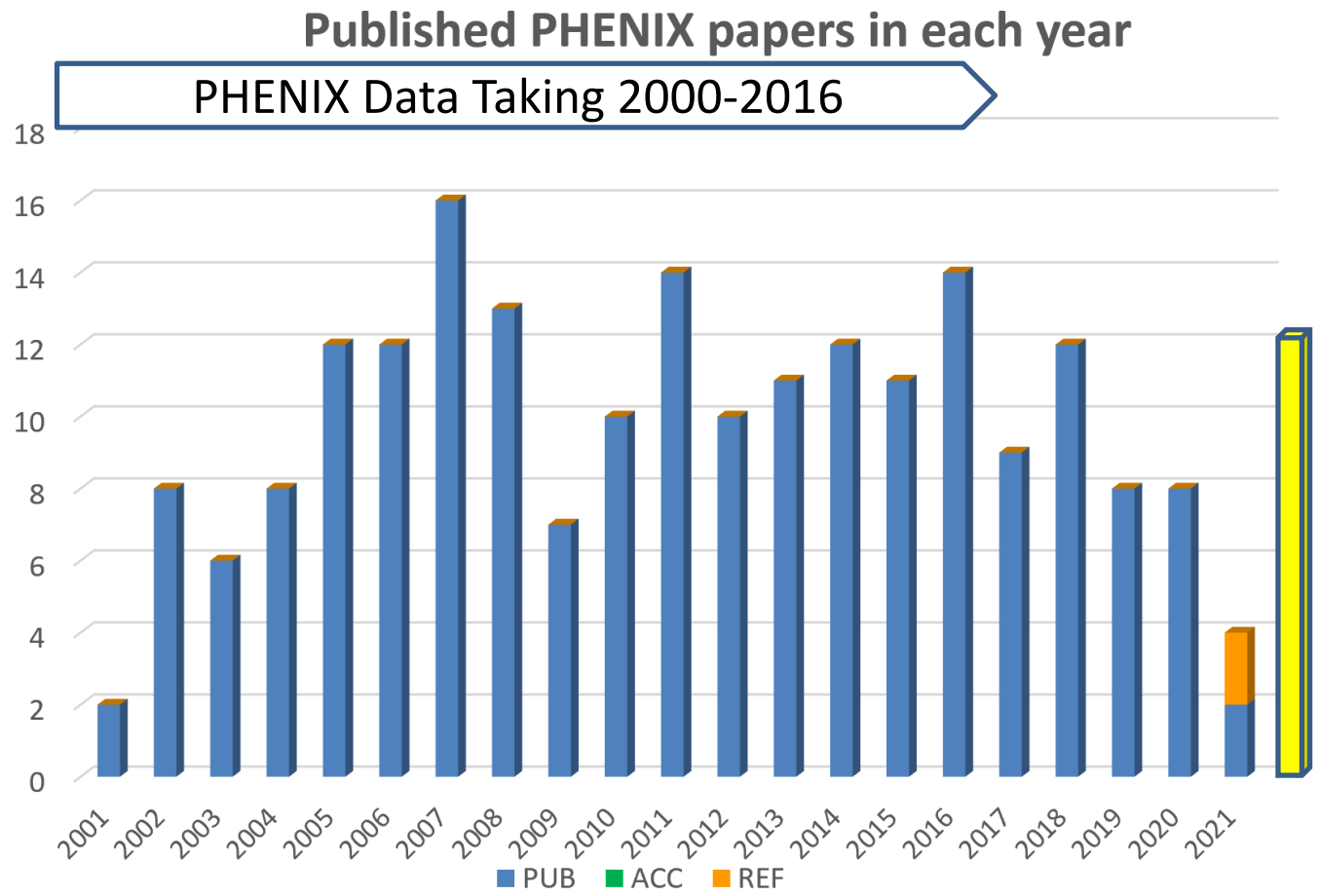
Cumulative Citations of PHENIX papers



PHENIX

PHENIX publications

- 8 papers published in 2020, 2 papers published in 2021 so far.
- Complete publication of major results by 2023 (sPHENIX start)
- Working on the data and analysis preservation



~12 papers in preparation.
2 papers are in internal reveiw

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)
16	Au+Au 200	VTX: DONE FVTX: starting	DONE	DONE
	d+Au BES	DONE	DONE	DONE
15	p+p 200	DONE	DONE	DONE
	p+Au 200	DONE	DONE	DONE
	p+Al 200	N/A	DONE	DONE
14	Au+Au 200	DONE	DONE	DONE
	3He+Au 200	2019	DONE	DONE

On going analyses

- $A_N(p_T)$ of very forward neutron in $p + A$
- Direct photons cross sections and A_{LL}
- $A_N(p_T)$ of heavy-flavor decay electrons
- Direct photons in RUN14 Au+Au
- flow in small systems
- R_{AA} of $b \rightarrow e$ and $c \rightarrow e$
- v_2 of $b \rightarrow e$ and $c \rightarrow e$
- Jets in Cu+Au
- J/ψ and $\psi(2S)$ in small systems
- π^0 in $p + A$ and ^{3}He+Au
- $\pi^{\pm}, \bar{p}$ in p +Au
- $\pi^{\pm}, K^{\pm}, \bar{p}$ in p +Al
- $\pi^{\pm}, K^{\pm}, p, \bar{p}$ in ^{3}He+Au
- ϕ in in $p + A$ and ^{3}He+Au
- K^*in p +Au

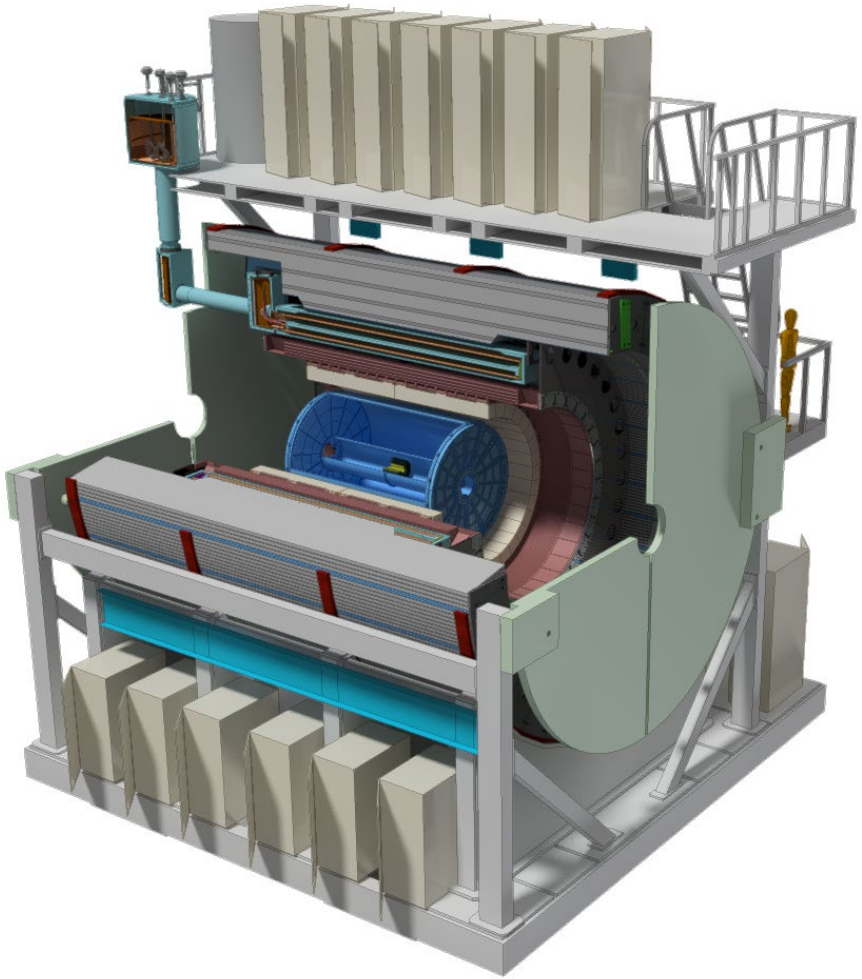
Many analysis topics waits for analyzers

RUN14 AuAu (~15 billion) and RUN16 AuAu (~15 billion) has not been analyzed.

High impact analysis topics of RUN14+16 data sets

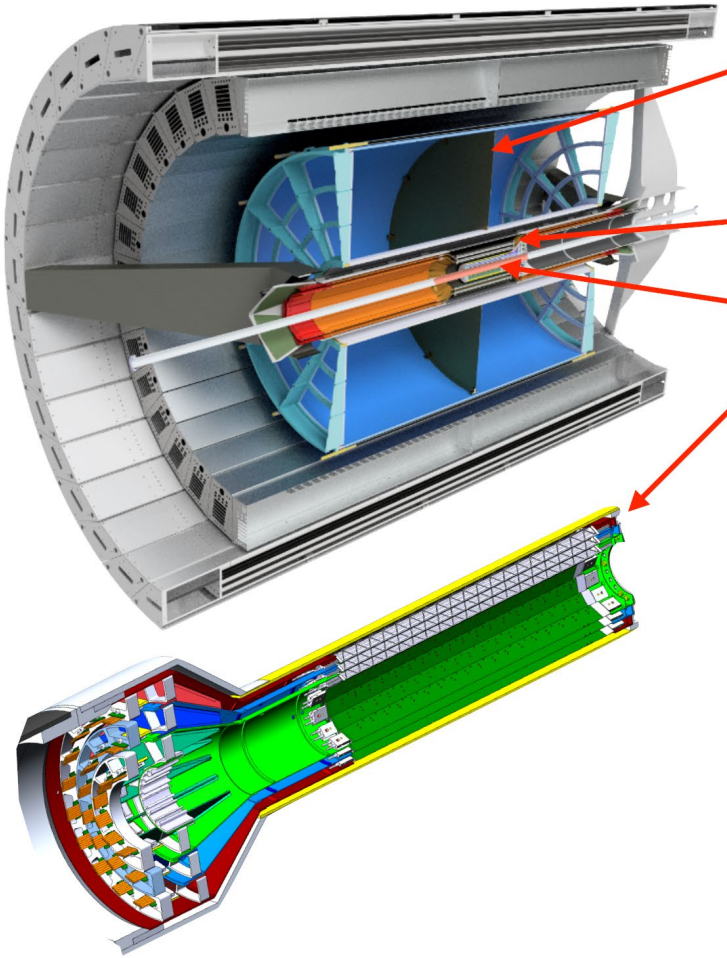
- Direct photons with wide pT range
  - ~1GeV/c to ~10 GeV/c with (internal) conversion
  - ~3 GeV/c to >20 GeV/c with EMCAL
- Thermal dileptons → direct measurement of initial temperature of QGP at RHIC
- Heavy flavor (b, c) RAA and flow at midrapidity with VTX
- Heavy flavor (b,c) RAA and flow in forward/backward with FVTX
- Direct photon+hadron correlations
- Quarkonia (J/Psi, Upsilon)

sPHENIX



- New and the last experiment at RHIC
- Large solid angle detector consisting of
  - MVTX silicon pixel tracker
  - INTT silicon tracker
  - TPC
  - EMCAL
  - HCAL
- The detector measures jets, direct photons and Upsilon
- Start taking data in 2023 to complete RHIC mission.

sPHENIX subsystems: tracking and calorimetry



Continuous readout TPC (R = 20-78cm)
- shares many concepts with ALICE TPC upgrade

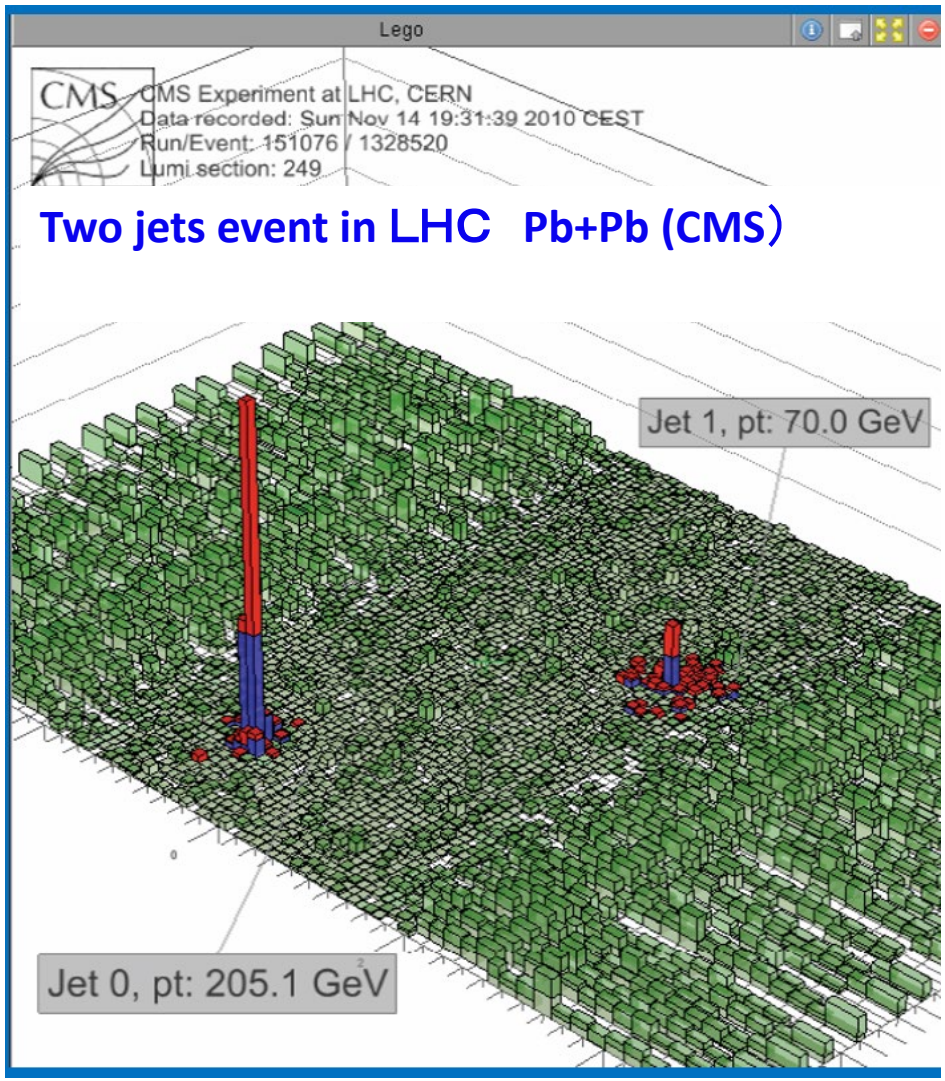
Si strip intermediate tracker (INTT, R = 7-11cm)

3 layer MVTX vertex tracker (R = 2.3, 3.1, 3.9cm)
- based on ALICE ITS IB detector

First @ RHIC: Large acceptance high-rate tracking

Challenges:
- track reconstruction CPU time
- TPC distortion correction

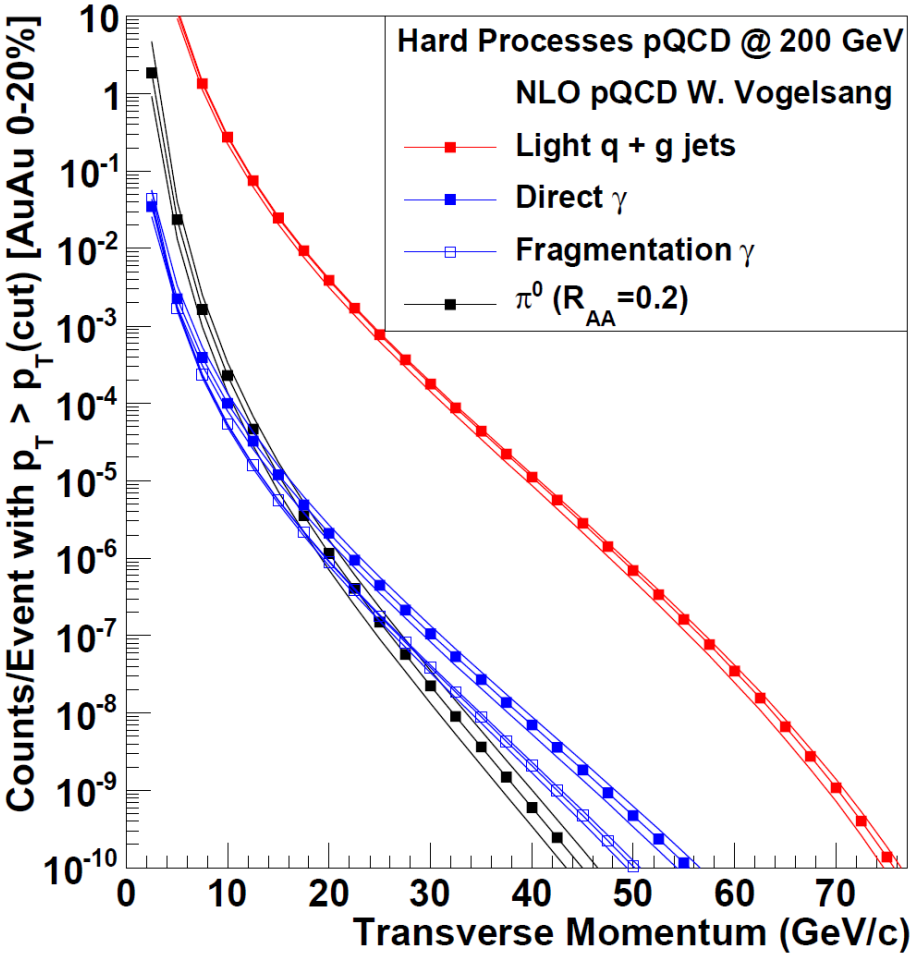
Why measuring jets with sPHENIX



- LHC experiments demonstrates that direct jet reconstruction in heavy on collisons is possible and very useful too to study QGP
  - Direct reconstruction of jets *was not* in the scope of RHIC experiment when RHIC started
- Energy loss of parton in QGP can be studied by jets measurement at RHIC
- 2015 NSAC Long range plan called for the state of the art jet detector RHIC → sPHENIX

Jets and direct photons with sPHENIX

Yield of Jets and direct photons measured with sPHENIX in one year

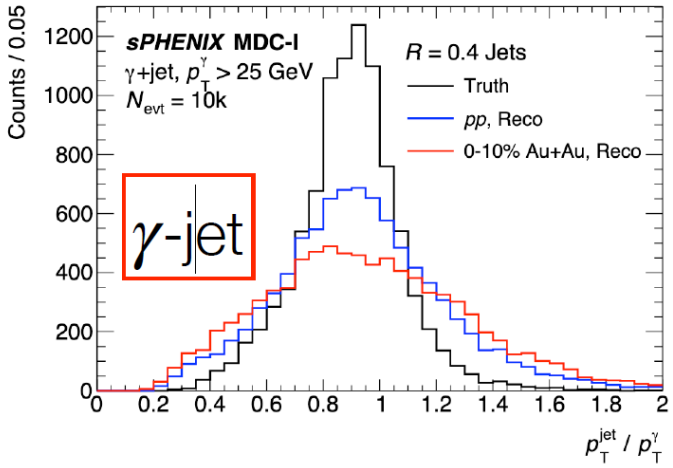


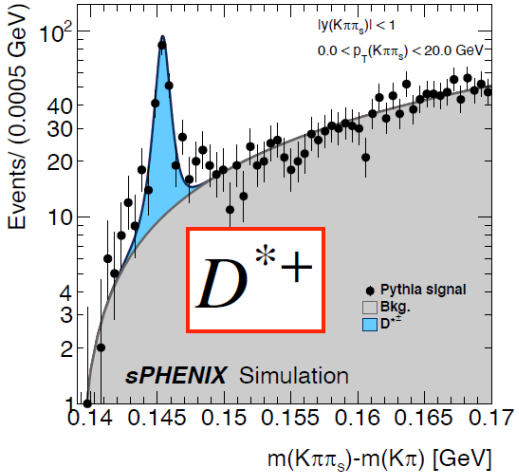
- sPHENIX will record 100 billion AuAu collisions per year
  - 100M jets with pT>20 GeV
  - 1 M γ_{direct} + jets with pT>10 GeV

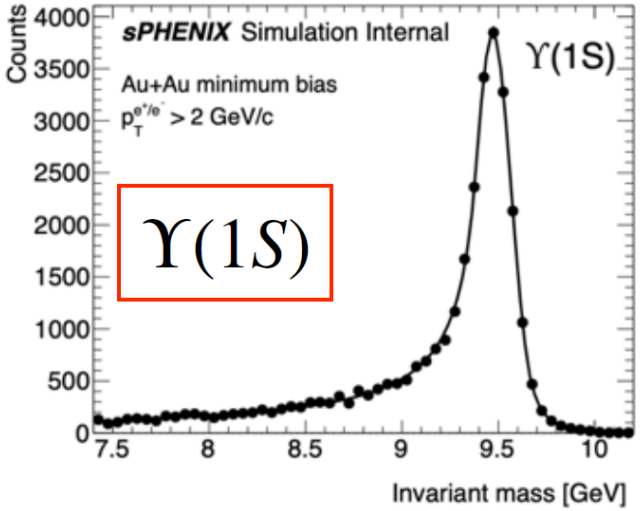
  → High statistic study of energy loss in QGP
- b-jet tag with MVTX+INTT

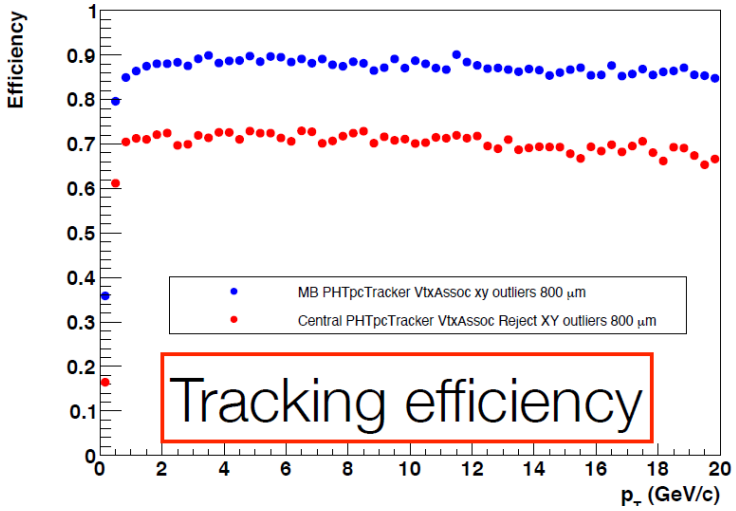
  → quark mass dependence of energy loss

Recent simulation (MDC-1) results of sPHENIX

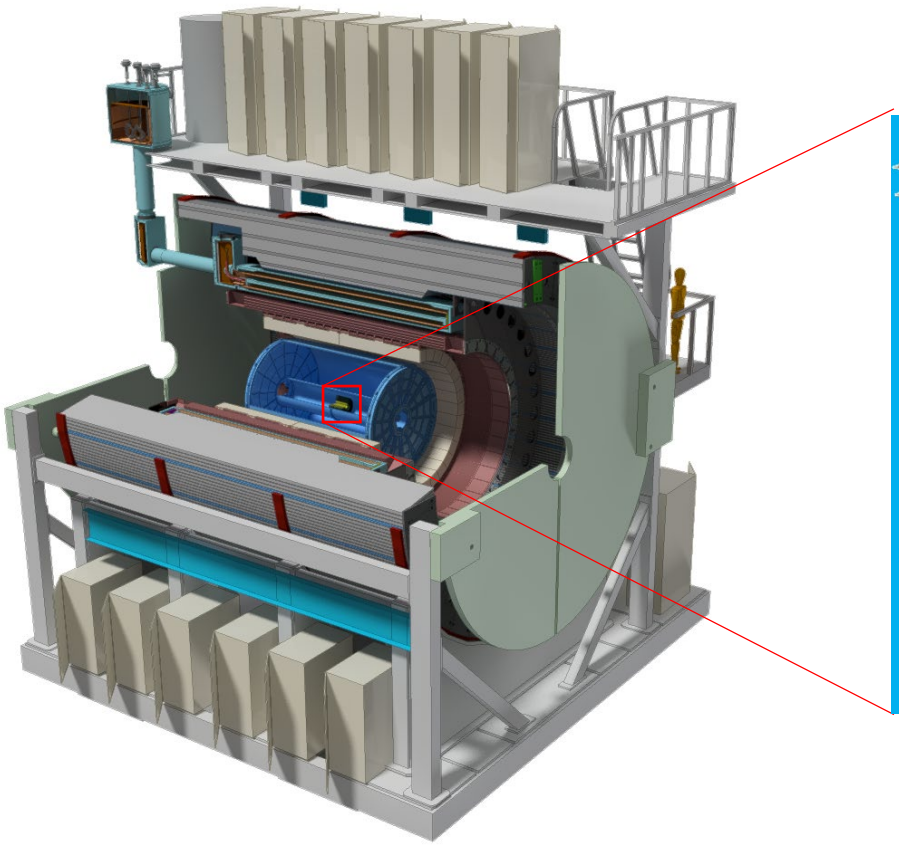


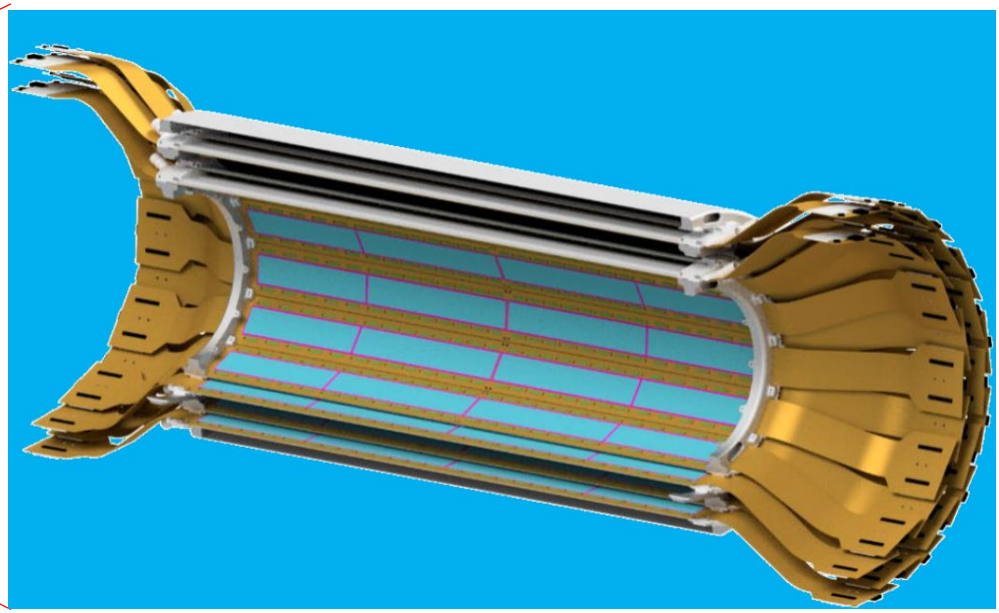






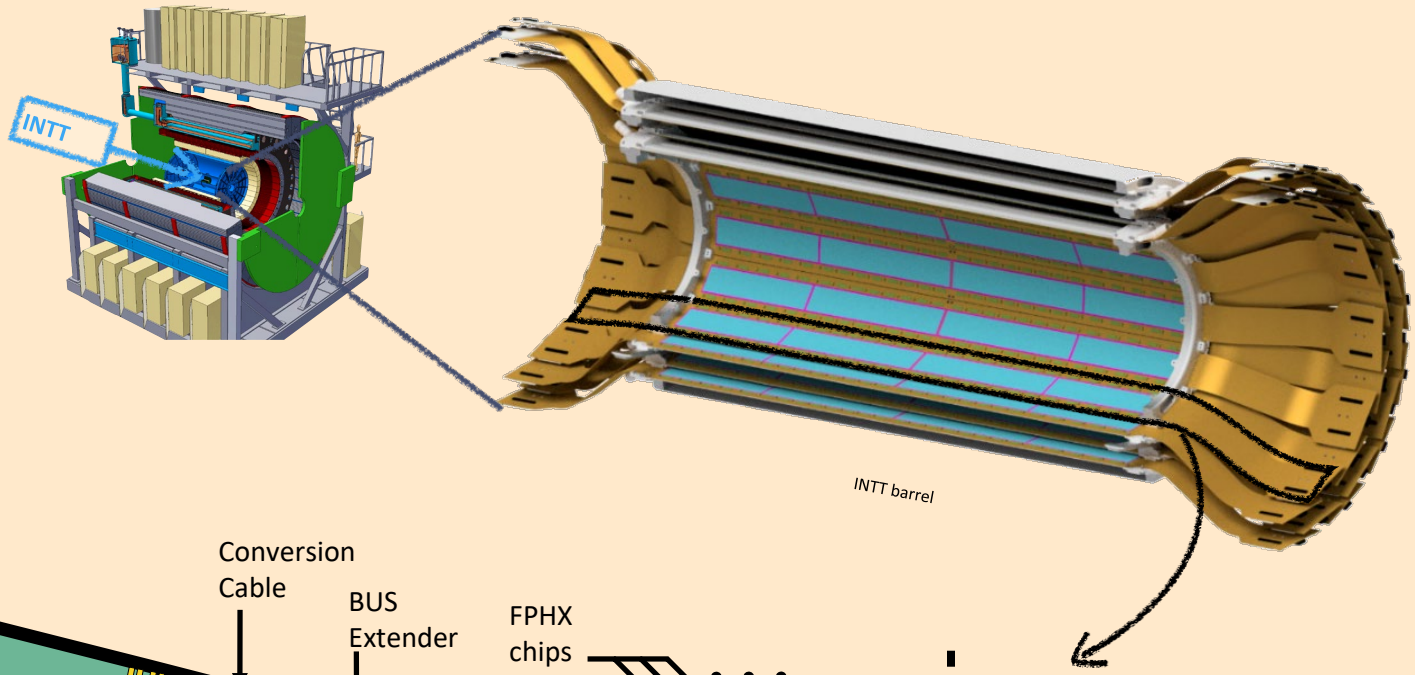
sPHENIX Intermediate Silicon Tracker (INTT)

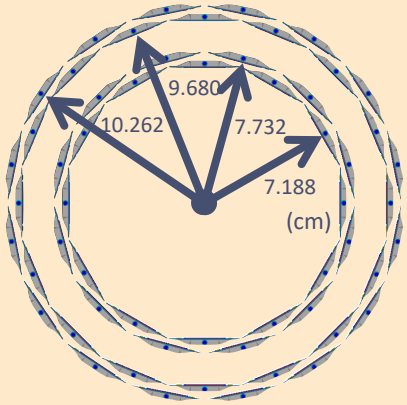




- sPHENIX is the upgrade of PHENIX experiment
- sPHENIX will start taking data in 2023 to complete the scientific mission of RHIC

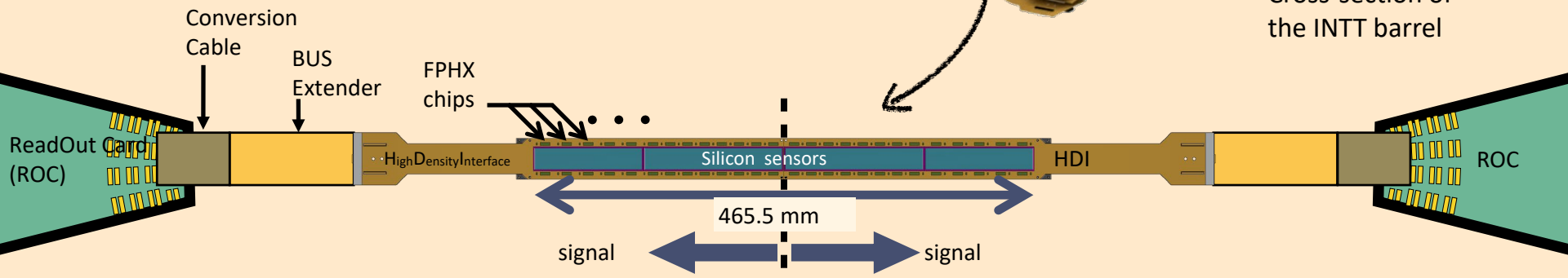
Overview of Intermediate Silicon Tracker (INTT)



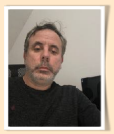


Inner ladders: 12 × 2
Outer ladders: 16 × 2
Total: 56

Cross-section of the INTT barrel

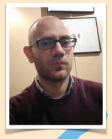


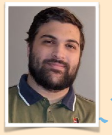
INTT Group

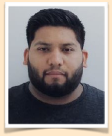


















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Yumika Namimoto, Yuka Sugiyama

NEW MEMBERS


Sioan Zohar

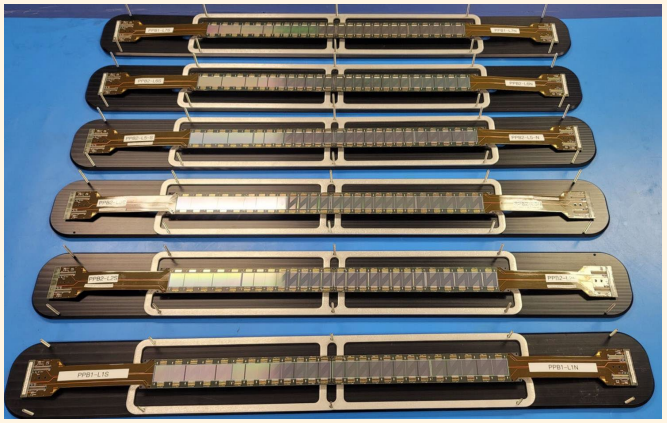
Yusuke Nakamura


Yuka Sugiyama

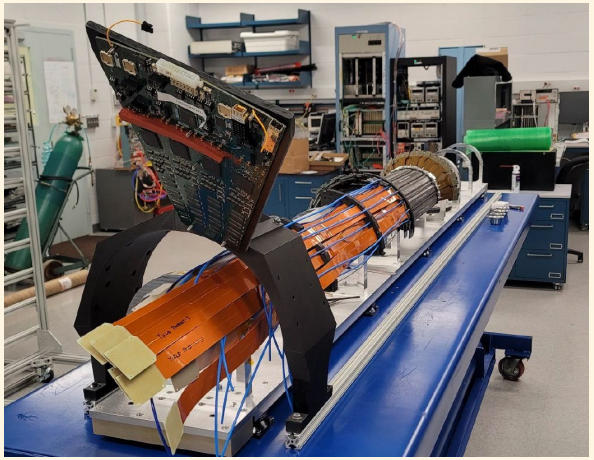

Genta Nakano

Status of INTT detector

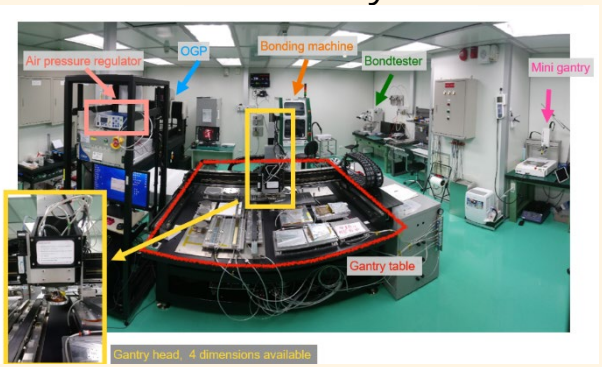
Ladder assembly at BNL



INTT Ladders

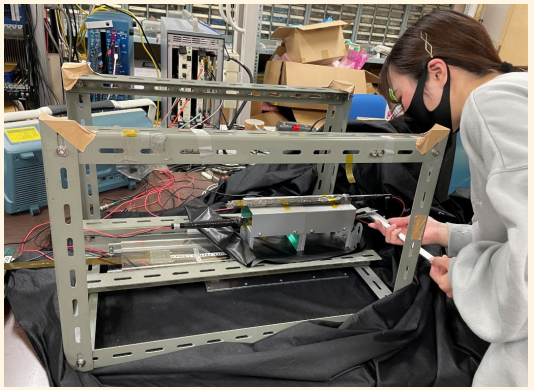


Barrel assembly test at BNL



Ladder assembly in Taiwan

Long data bus extender developed in Japan



Cosmic ray test at Nara

- **Mass production is on-going at RIKEN, Nara, Taiwan, and BNL.**
  - **Minium delay by mitigating the impact of coronavirus**
- **INTT will be completed by the end of this JFY to be ready for installation to sPHENIX**

Summary

- PHENIX
  - Completed data taking in 2016
  - Continue physics publication from the variety of high statistics datasets
  - Very high statistcs AuAu data with VTX/FVTX waits for analyzers to produce high impact physics results
- sPHENIX
  - The first and only large solid angel jet detector at RHIC
  - sPHENIX will start taking data in 2023 for 3 years to complete scientific mission of RHIC
  - INTT silicon tracker