



**Brookhaven**  
National Laboratory

# sPHENIX DETECTOR

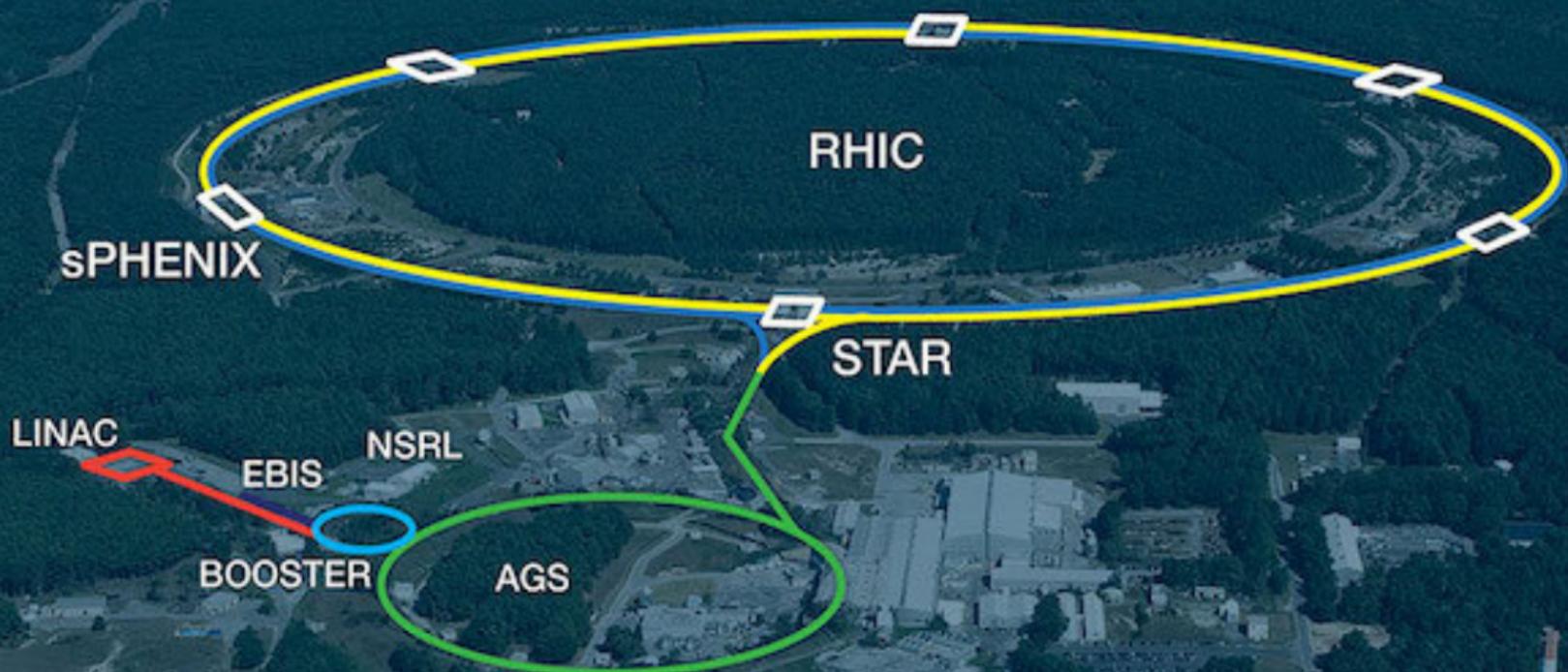
SCIENCE MISSION, INSTALLATION, AND COMMISSIONING

**Ejiro Umaka (BNL), on behalf of sPHENIX Collaboration**

RHIC & AGS Annual Users' Meeting

August 2, 2023





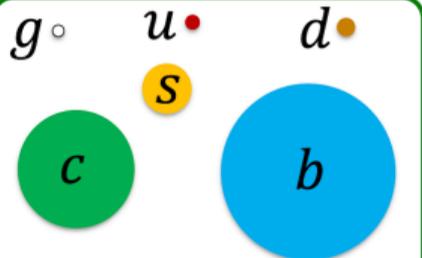
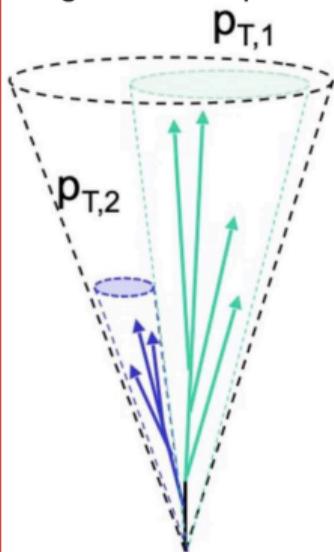
*sPHENIX is a first new detector in RHIC in over 20 years!*

*Required to complete RHIC's scientific mission of probing the inner workings of quark-gluon plasma (QGP)*

# sPHENIX PHYSICS PROGRAM

## Jet Correlations & Structure

vary momentum & angular size of probe

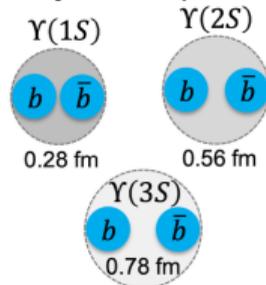


## Heavy Flavor

vary mass & momentum of probe

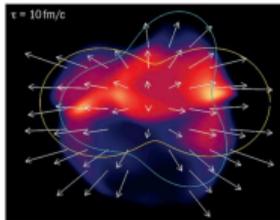
## Quarkonia

vary size of probe



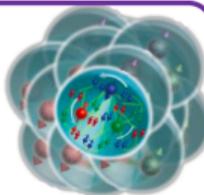
## Bulk

collective behavior in large & small systems



## Cold QCD

vary temperature of QCD matter, study proton spin, transverse momentum, & nuclear effects



sPHENIX will measure QGP probes such as:

- Jet correlations and structure
- Heavy flavor
- Quarkonia

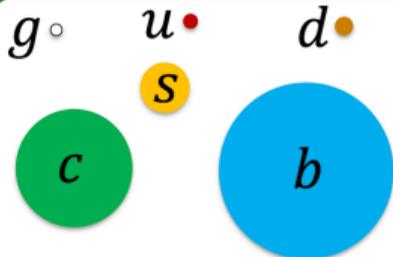
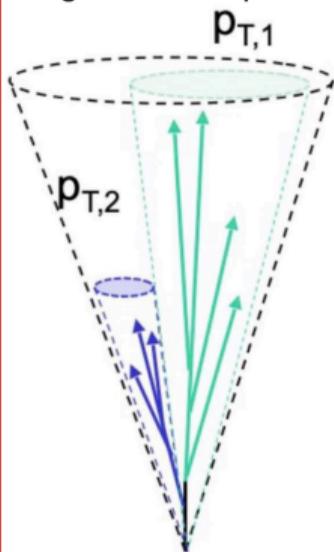
Measurements are also planned for:

- Bulk physics
- Cold QCD

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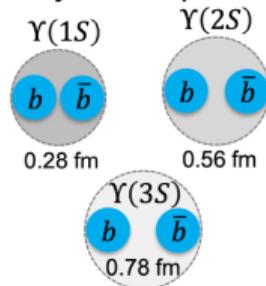


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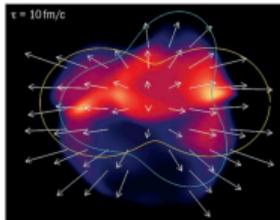
## Quarkonia

vary size of probe



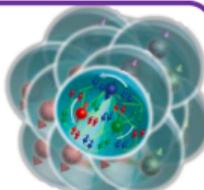
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vary temperature of QCD matter, study proton spin, transverse momentum, & nuclear effects



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Measurements are also planned for:

- Bulk physics
- Cold QCD

# *s*PHENIX Detector Overview

sEPD

MVTX

TPC

MAGNE

oHCAL

FMCAL

ihCAL

MinBIAS

INTT

TPOT

TPOT

• Barrel detectors:  $|\eta| < 1.1$ , full azimuth

• 1<sup>st</sup> hadronic calorimetry at mid-rap at RHIC

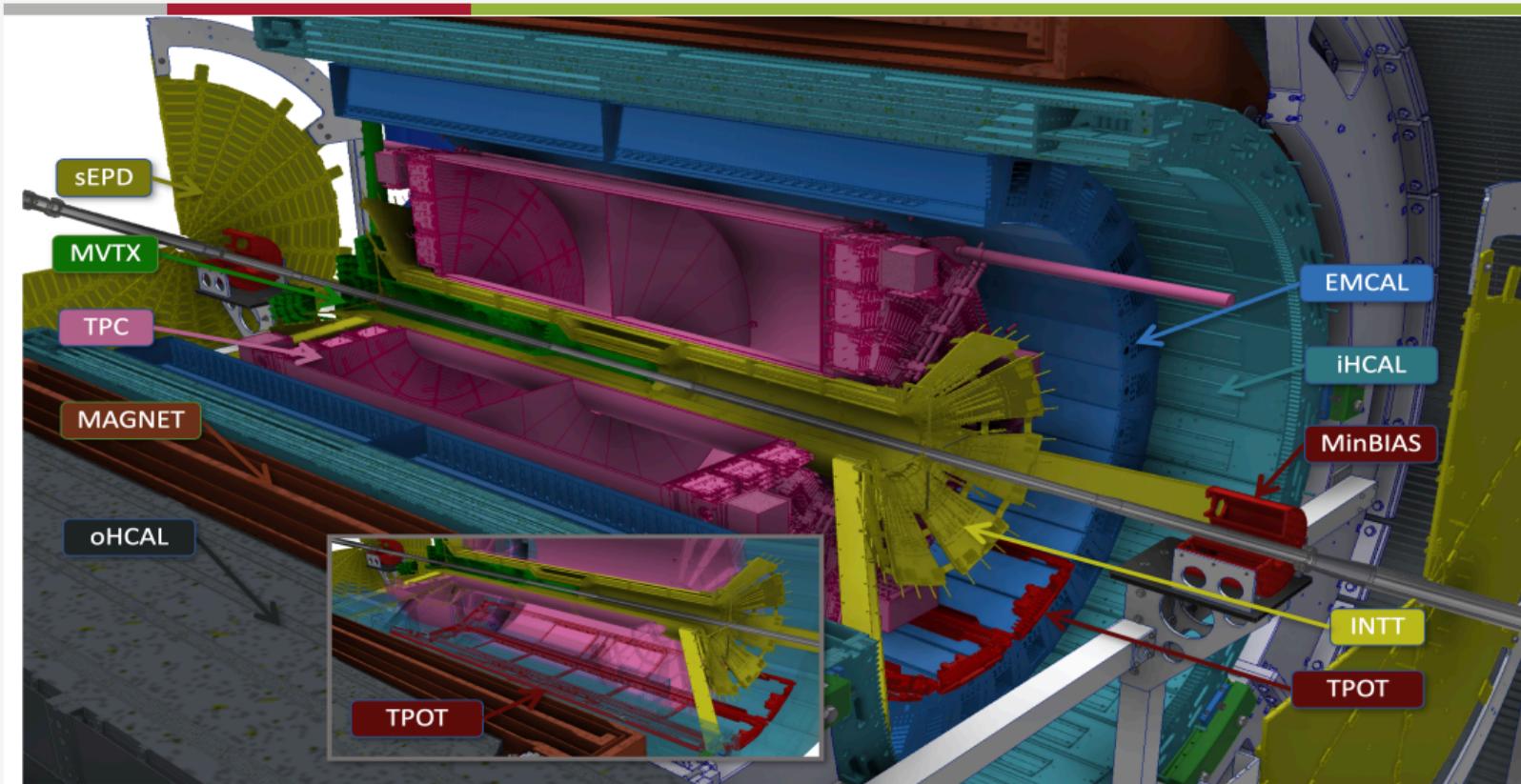
• High DAQ rate of 15kHz

• Triggered readout for the calorimeters

• Streaming readout for tracking

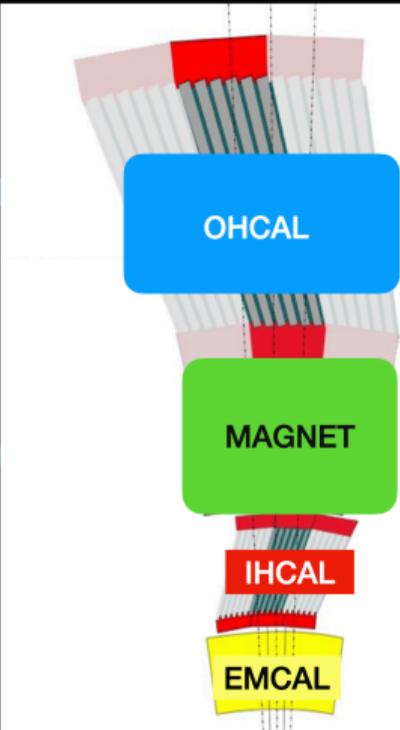
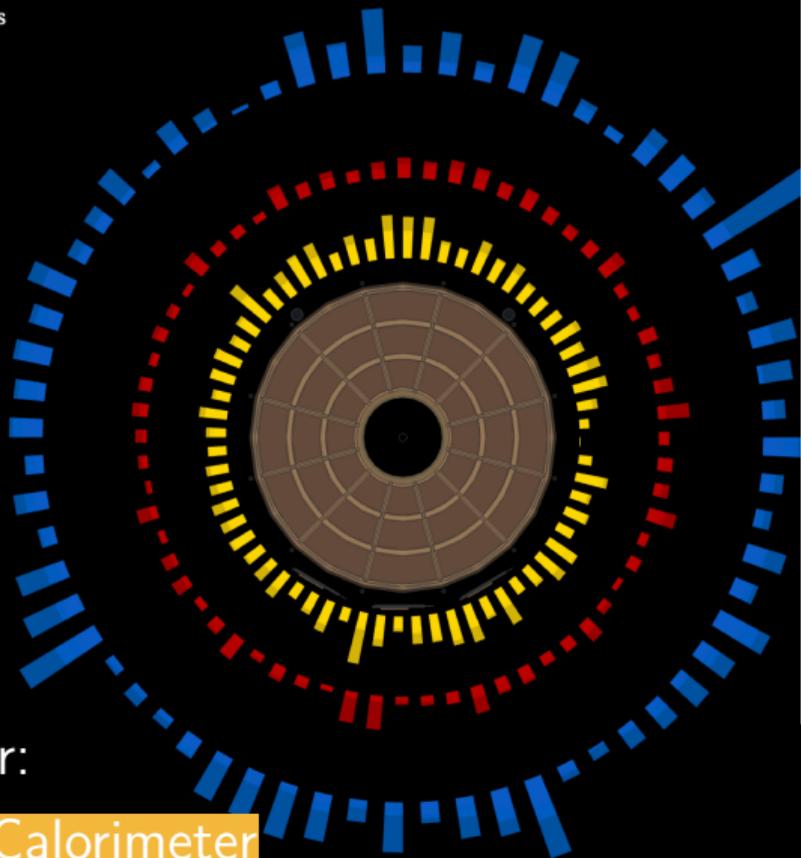
• Forward detectors for event characterization

# sPHENIX DETECTOR





sPHENIX Experiment at RHIC  
sPHENIX Simulation  
Au+Au HIJING, 15% central collisions

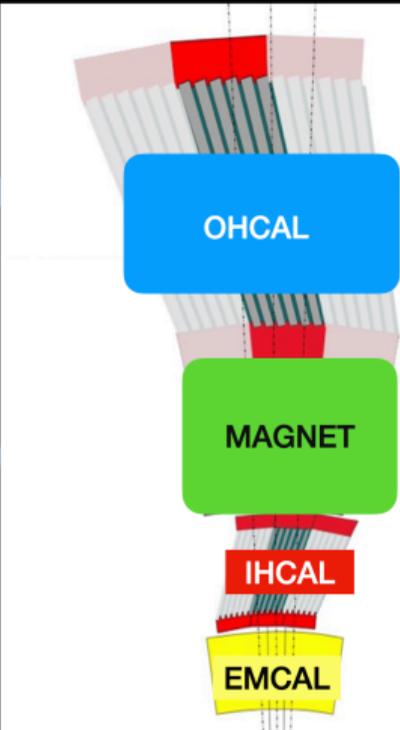
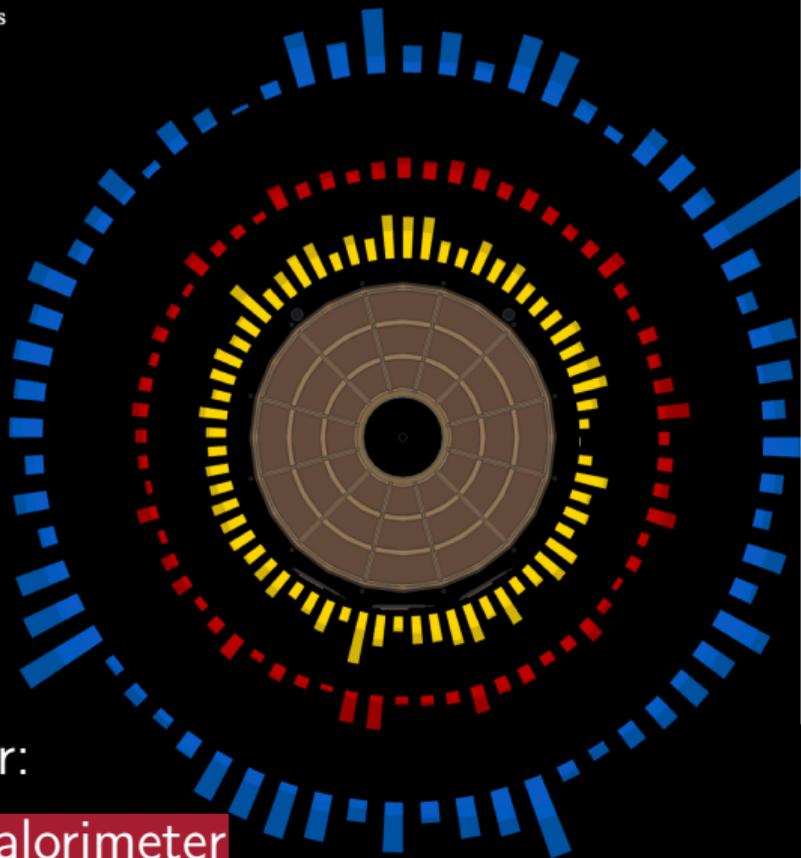


sPHENIX Calorimeter:

- Electromagnetic Calorimeter



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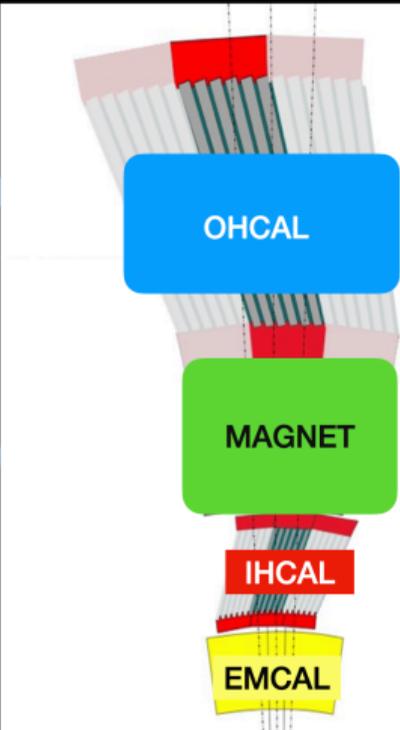
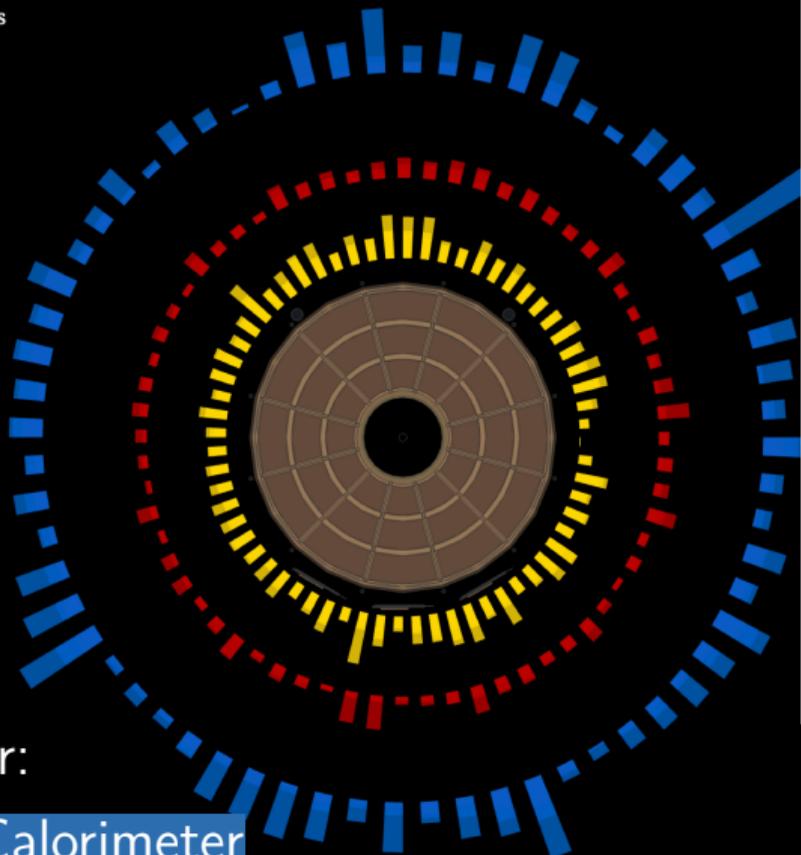


sPHENIX Calorimeter:

- Inner Hadronic Calorimeter



sPHENIX Experiment at RHIC  
sPHENIX Simulation  
Au+Au HIJING, 15% central collisions



sPHENIX Calorimeter:

- Outer Hadronic Calorimeter

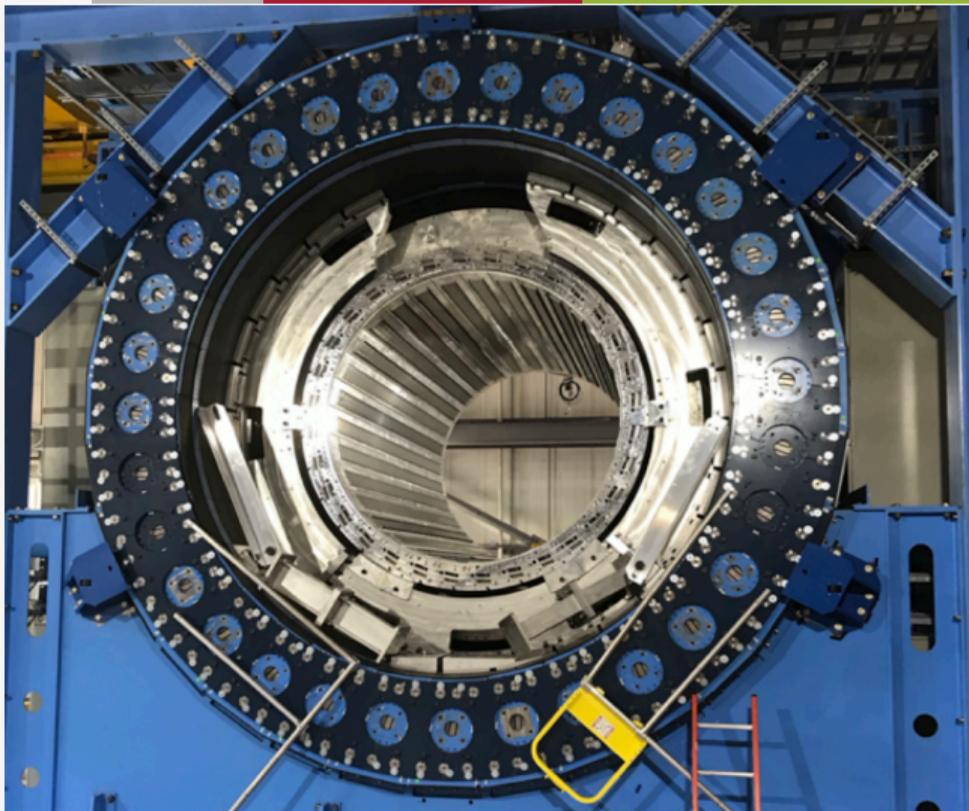


- 1.4T superconducting solenoid repurposed from Babar experiment



INSTALLED SEPTEMBER 30, 2021

# HADRONIC CALORIMETERS



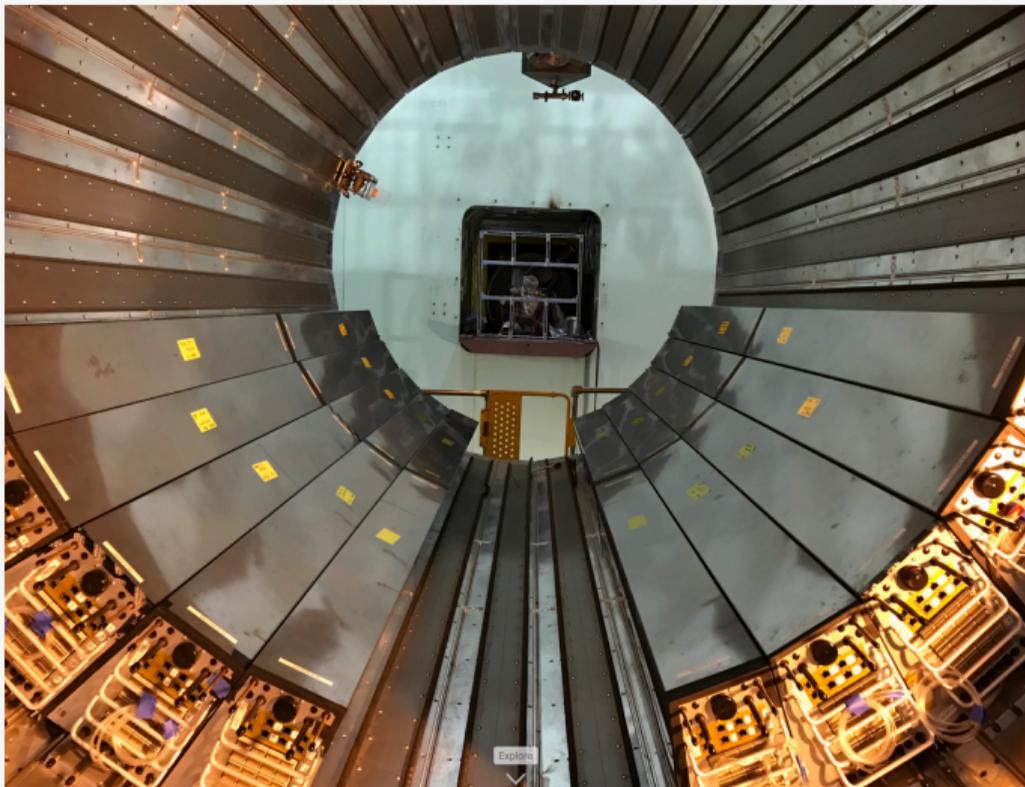
- First at RHIC (at mid-rapidity)
- **OHCAL**: plastic scintillating tiles plus tilted steel plates with embedded WLS fibers
- **IHCAL**: aluminum plates instead of steel
- Overall tile segmentation of  $\Delta\phi \times \Delta\eta \approx 0.1 \times 0.1$
- Crucial for full jet measurement



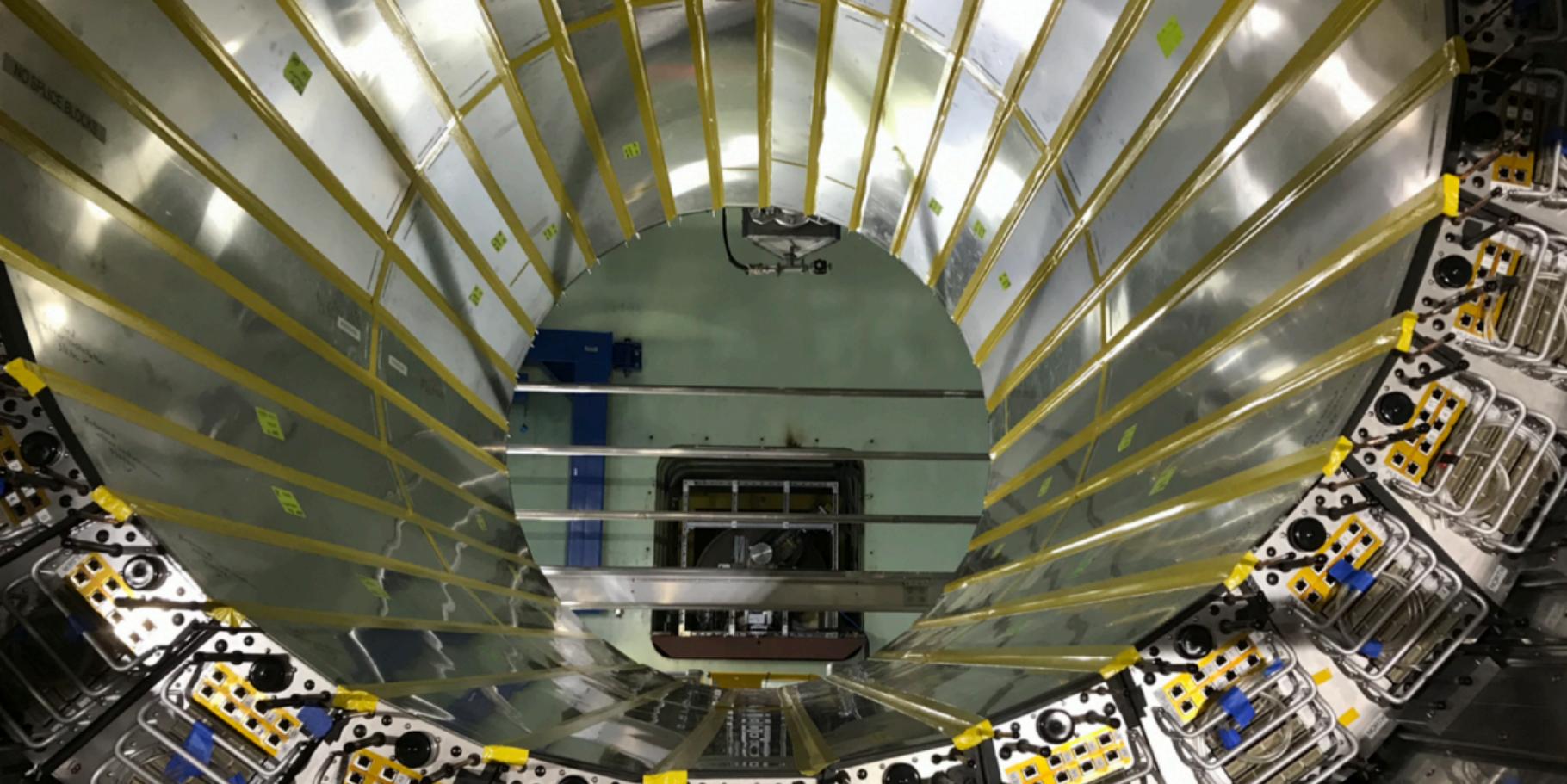
OHCAL INSTALLED ON FEBURARY 28, 2022

IHCAL INSTALLED ON JUNE 9, 2022

# ELECTROMAGNETIC CALORIMETER



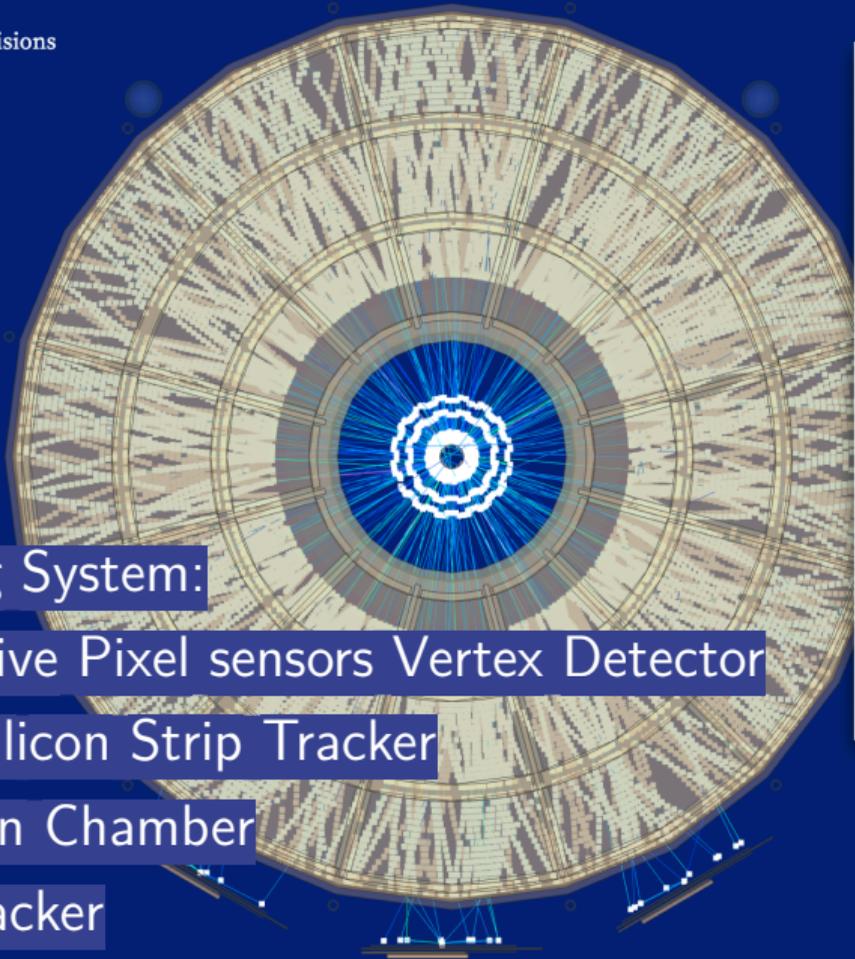
- Made with scintillating fibers in tungsten and epoxy
- High segmentation for HI collisions:  $\Delta\phi \times \Delta\eta \approx 0.025 \times 0.025$
- Good energy resolution:  $\sigma_E/E < 15\%/\sqrt{E}$  for photons ( $\gamma$ , jets), electrons ( $\Upsilon$  spectroscopy)



EMCAL INSTALLED ON DECEMBER 2, 2022

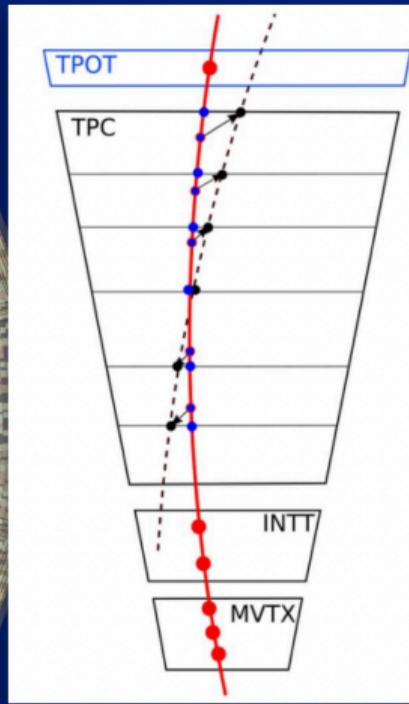


sPHENIX Experiment at RHIC  
sPHENIX Simulation  
Au+Au HIJING, 5% central collisions

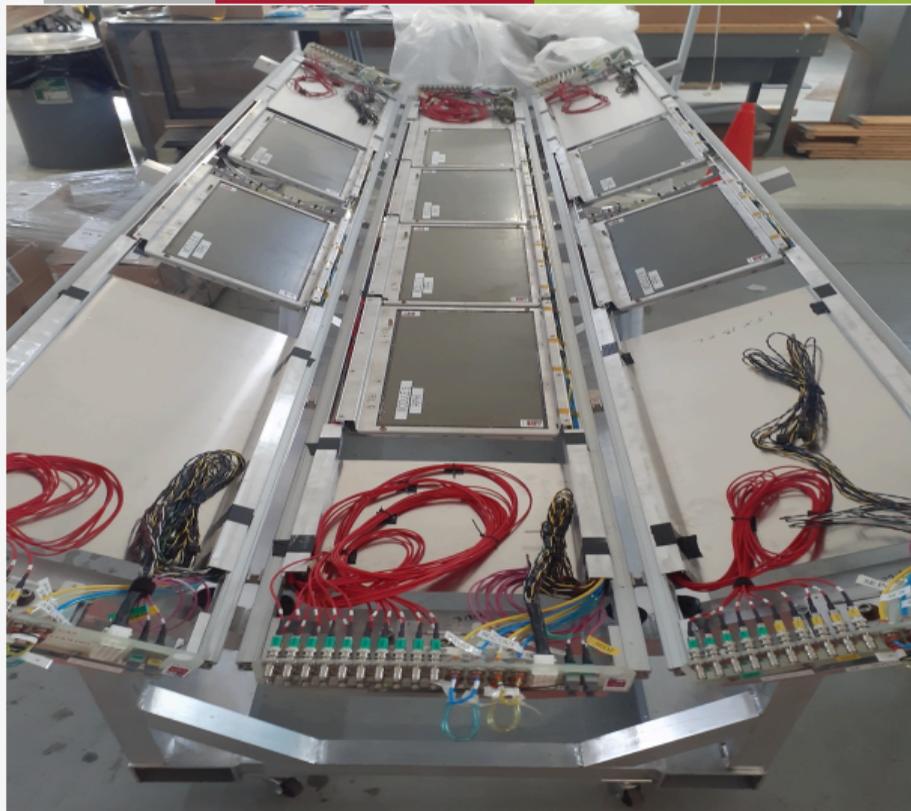


### sPHENIX Tracking System:

- Monolithic Active Pixel sensors Vertex Detector
- Intermediate Silicon Strip Tracker
- Time Projection Chamber
- TPC Outer Tracker



# TPC OUTER TRACKER



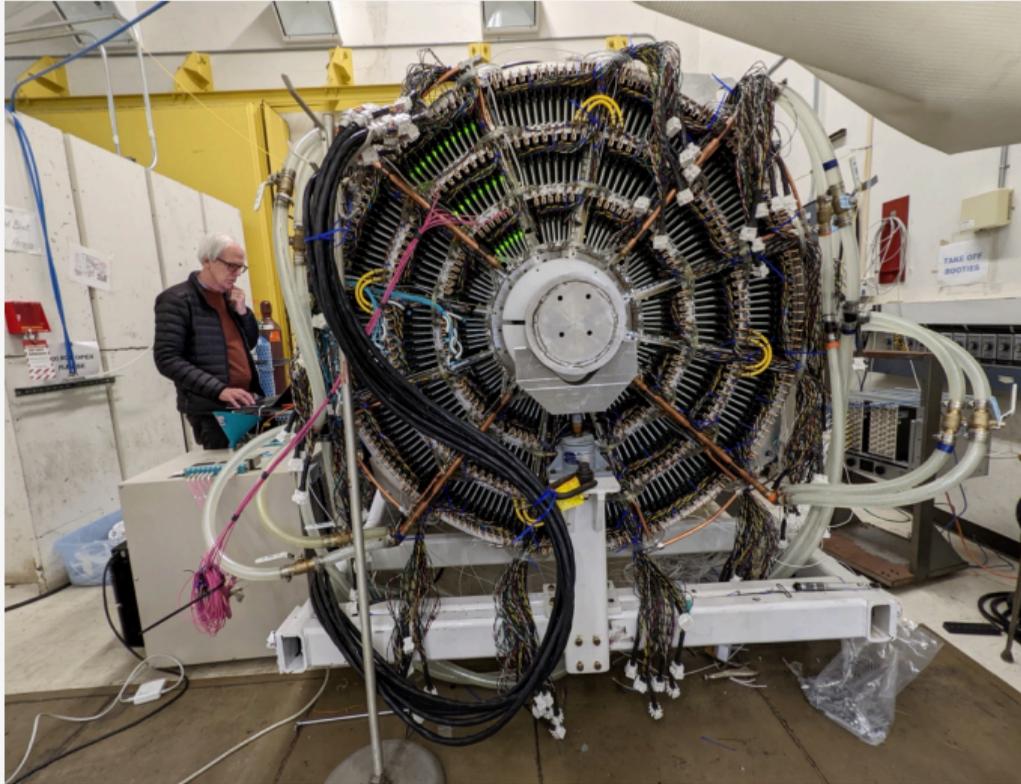
## TPOT: tracking calibration

- Micromegas-based detector with 8 sectors
- Situated underneath the TPC
- Corrects for beam-induced space charge distortions of the TPC



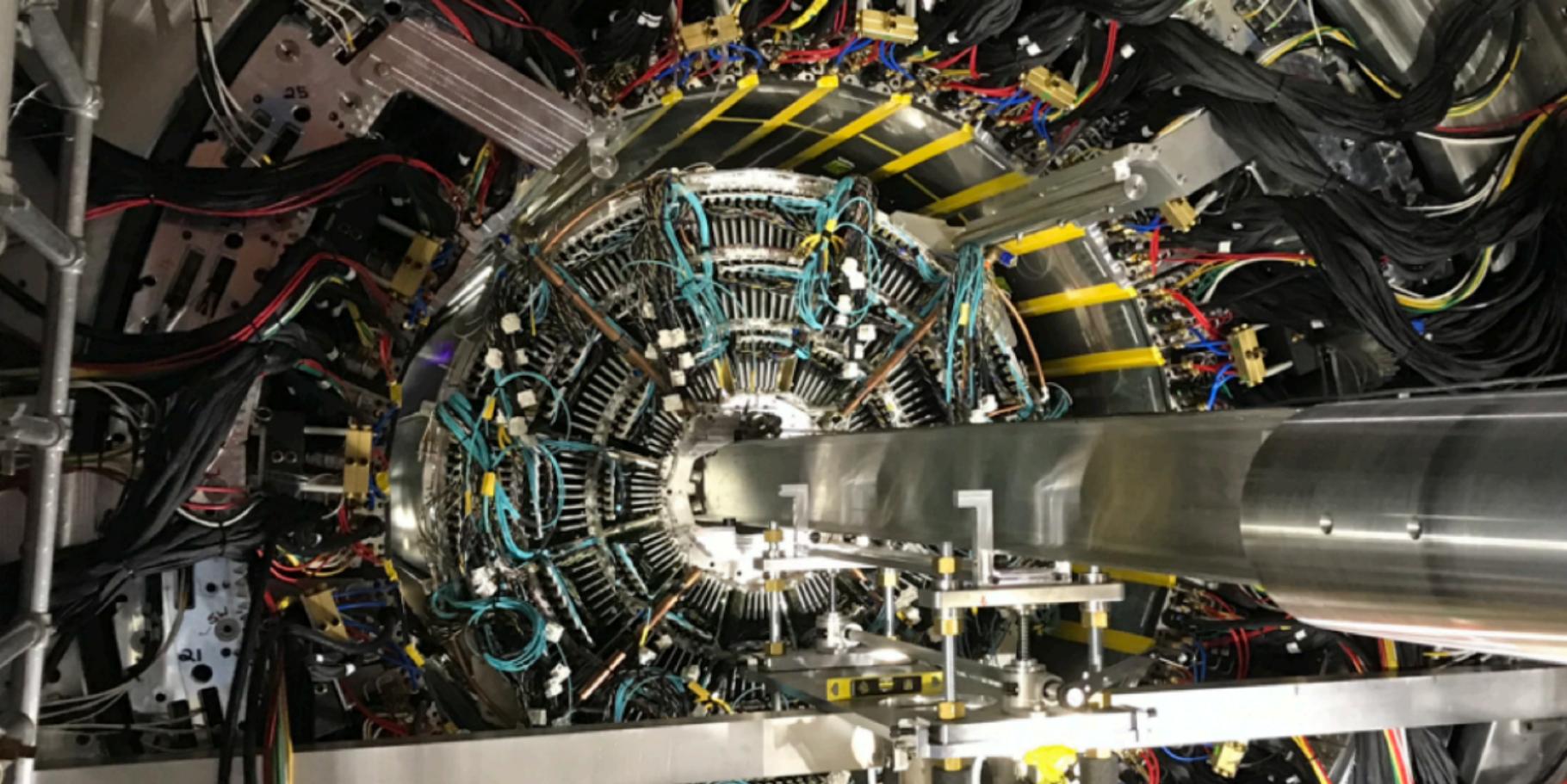
TPOT INSTALLED ON DECEMBER 9, 2023

# TIME PROJECTION CHAMBER



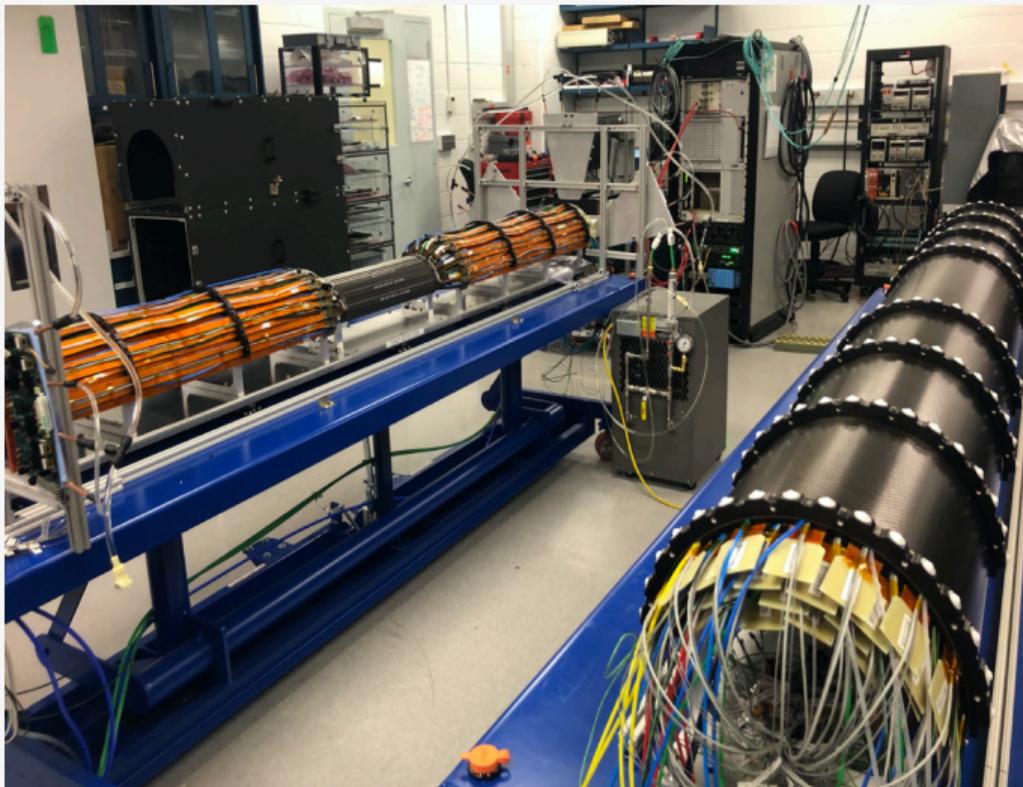
## TPC: momentum measurement

- Compact ( $r \approx 80$  cm) and main tracking element filled with Ar-CF<sub>4</sub> gas mixture
- Ungated, with GEM-based read out, spatial resolution of  $< 200 \mu\text{m}$



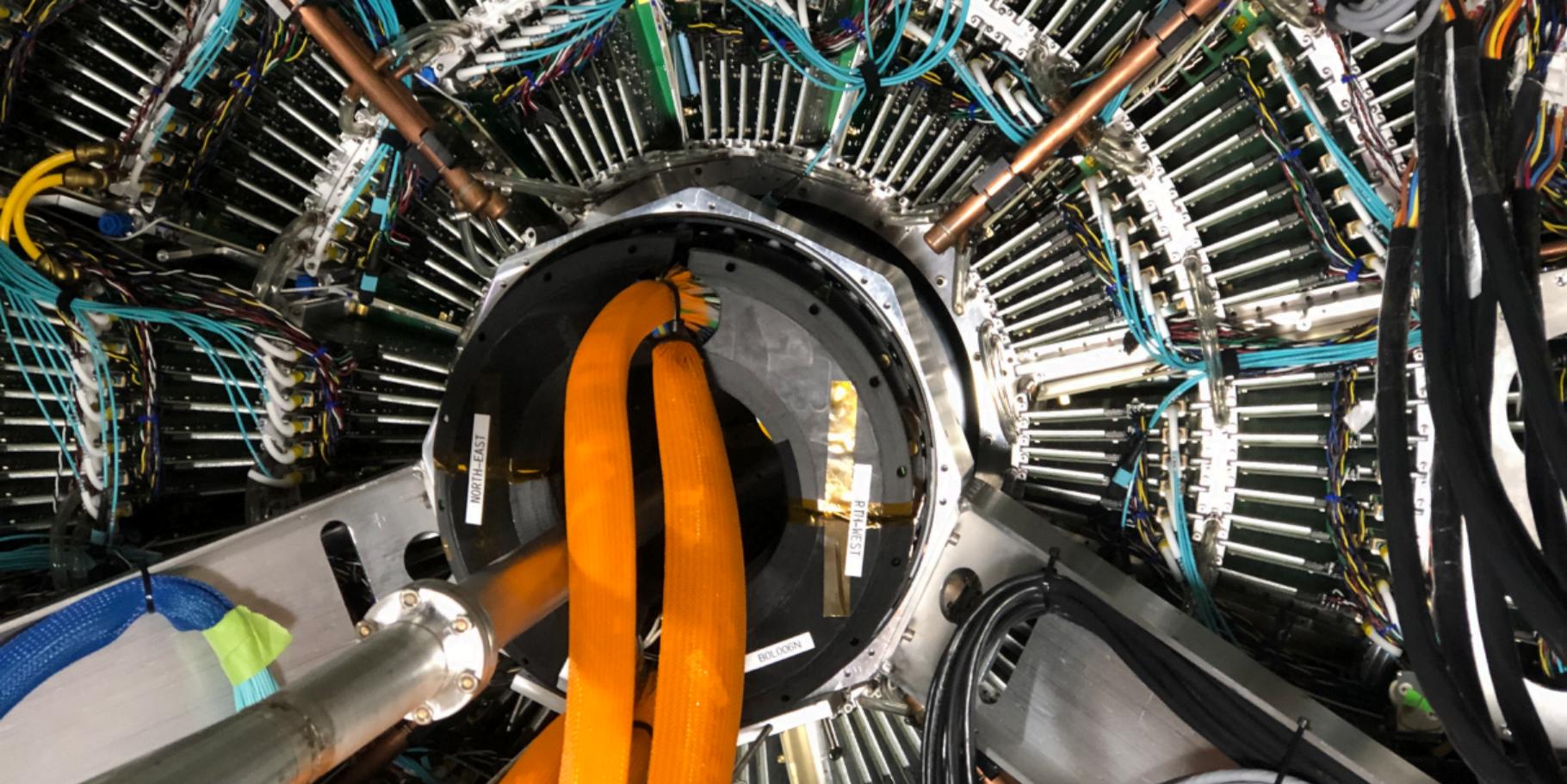
TPC INSTALLED ON JANUARY 19, 2023

# INTERMEDIATE SILICON STRIP TRACKER



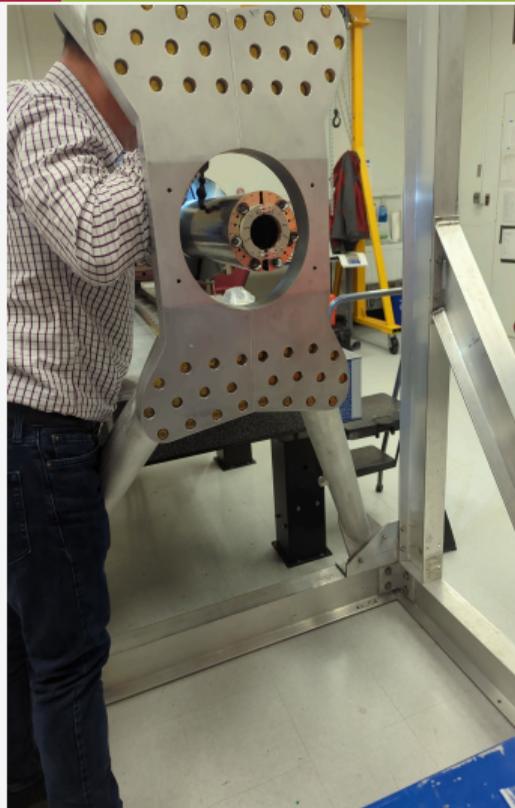
## INTT: pileup event separation

- Silicon strip detector surrounding the MVTX
- Associates fully reconstructed tracks with the event that produced them
- Timing resolution  $\approx 100\text{ns}$



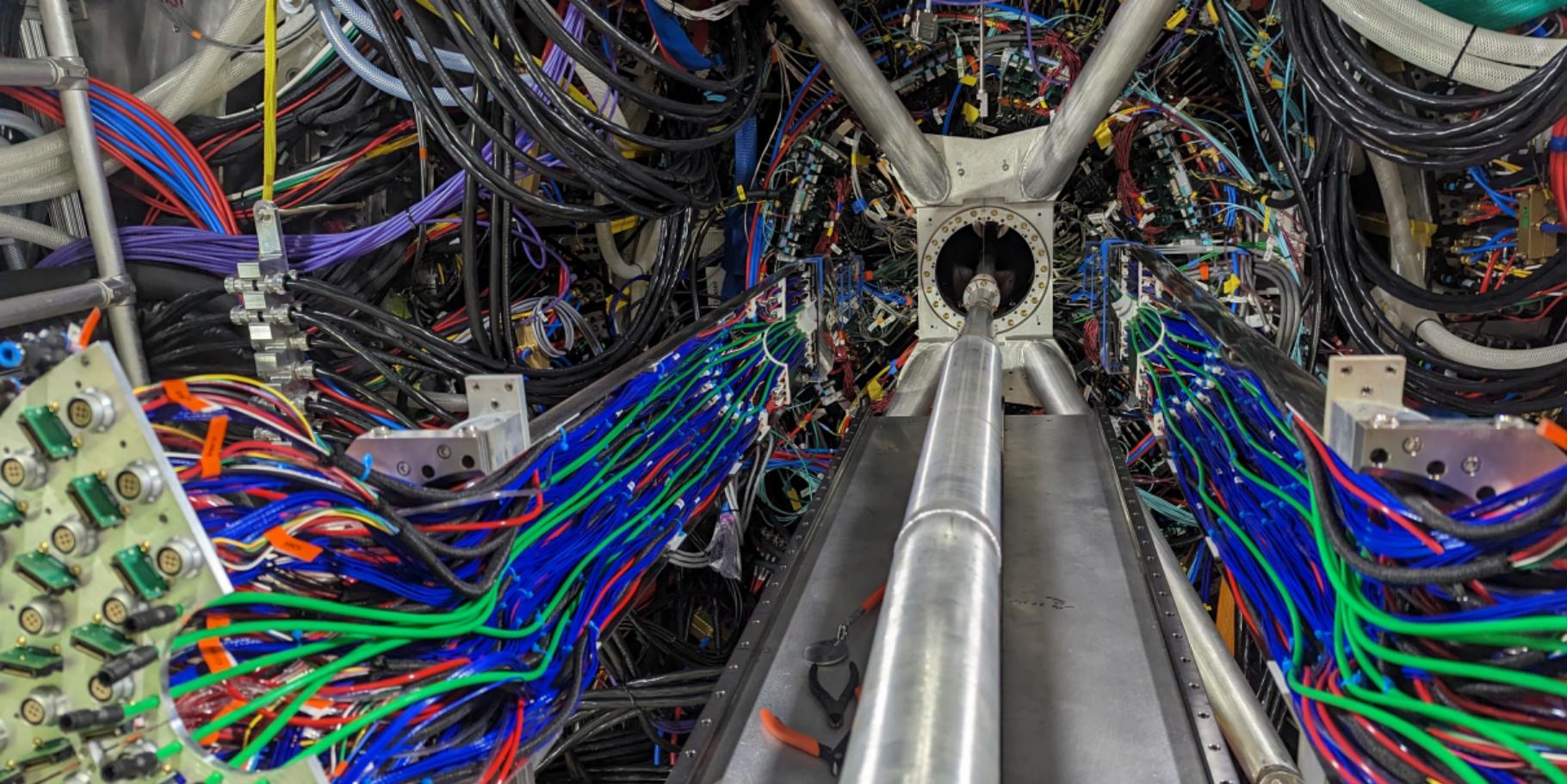
INTT INSTALLED ON FEBRUARY 28, 2023

# MAPs VERTEX DETECTOR



## MVTX: high resolution vertexing

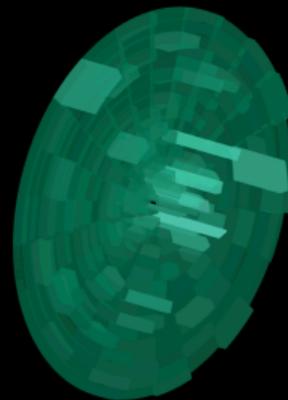
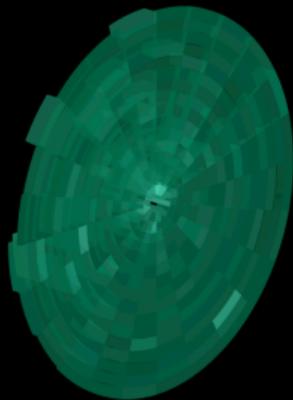
- 3 layers of Monolithic Active Pixel sensors based on ALICE ITS-II
- Nearest to the collision point, spatial resolution of  $5 \mu\text{m}$  for tracks with  $p_T > 1\text{GeV}$
- Essential for the heavy flavor program!



MVTX INSTALLED ON MARCH 30, 2023



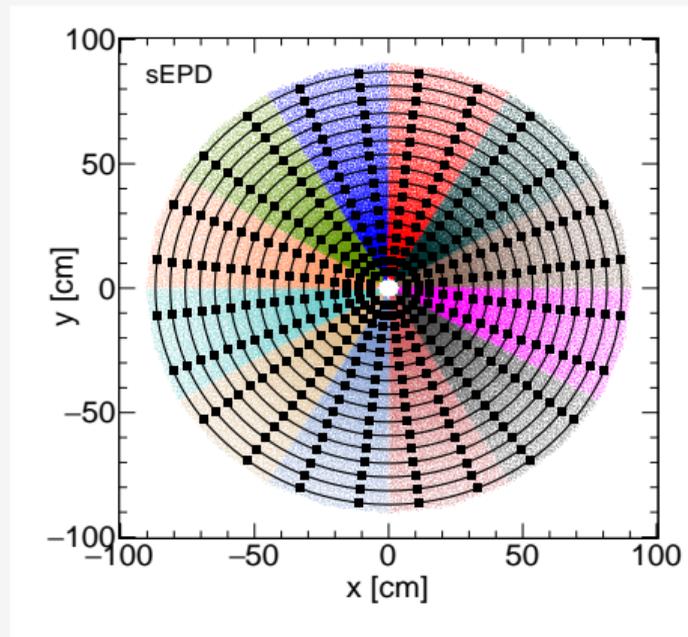
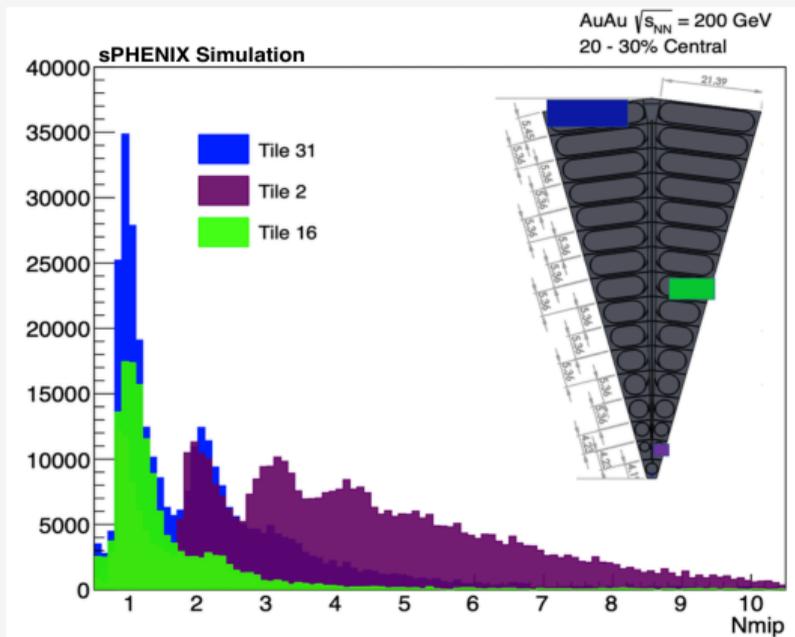
sPHENIX Experiment at RHIC  
sPHENIX Simulation  
Au+Au HIJING, 15% central collisions



## Event Characterization Systems:

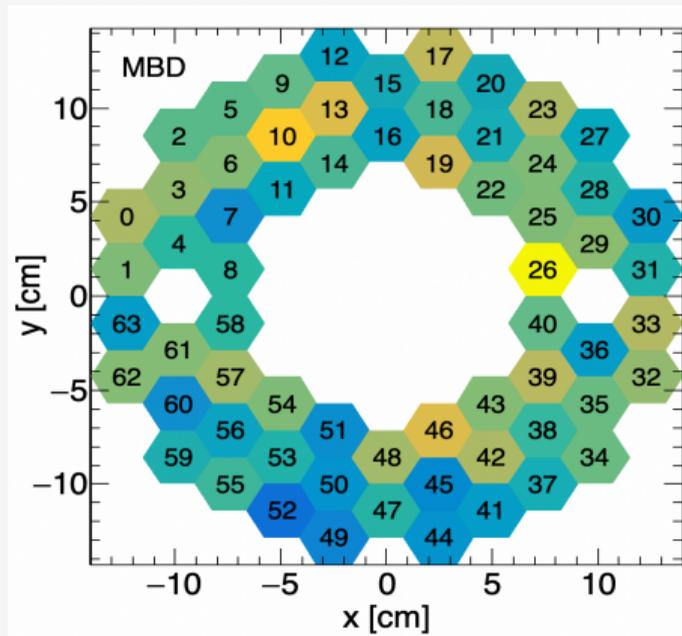
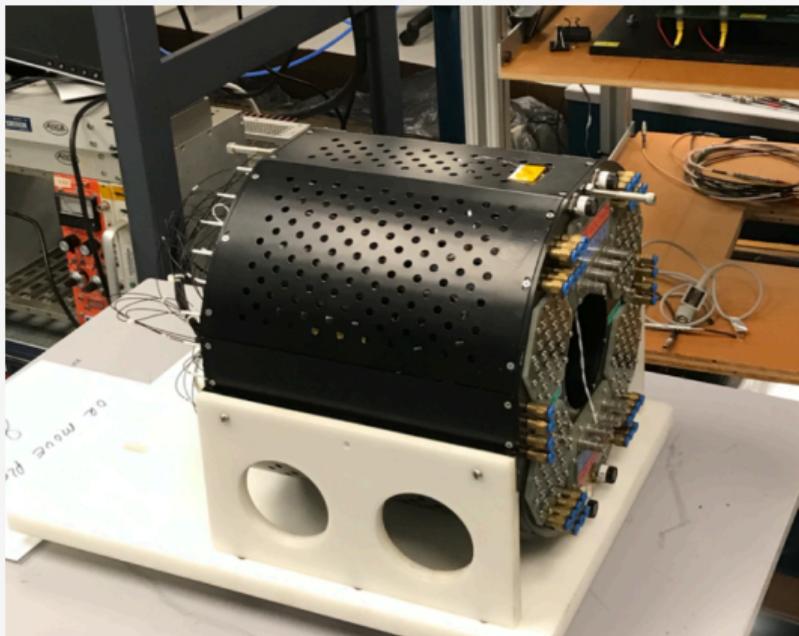
- Minimum Bias Detector (not shown)
- sPHENIX Event Plane Detector (in green)
- Zero Degree Calorimeter (not shown)

# sPHENIX EPD



- 2 wheels of 12 sectors,  $2.0 < |\eta| < 4.9$ , 1.2cm thick plastic scintillators with embedded WLS fibers, 744 total tiles. Used for centrality and event plane measurement

# MINIMUM BIAS DETECTOR



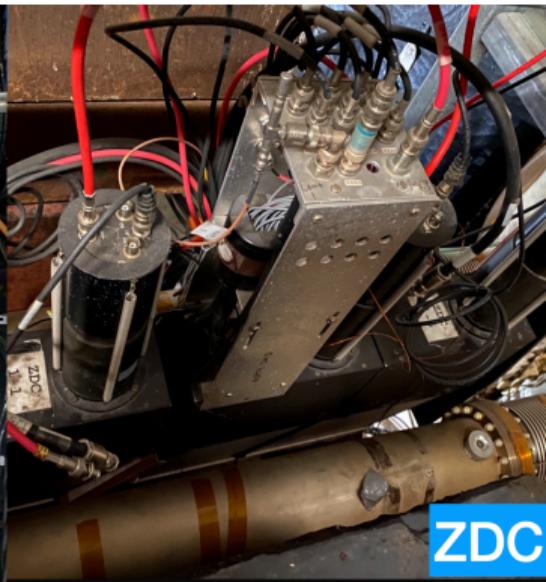
- Covers  $3.51 < |\eta| < 4.61$ , reuse of PHENIX BBC, 128 channels of 3cm thick quartz radiator on mesh dynode PMT, 120ps timing resolution. Measures centrality; provides triggering



MBD



sEPD



ZDC

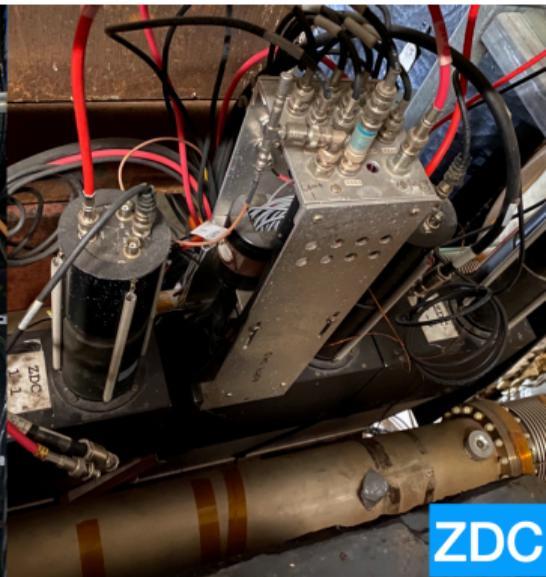
• MBD INSTALLED APRIL 2023



MBD

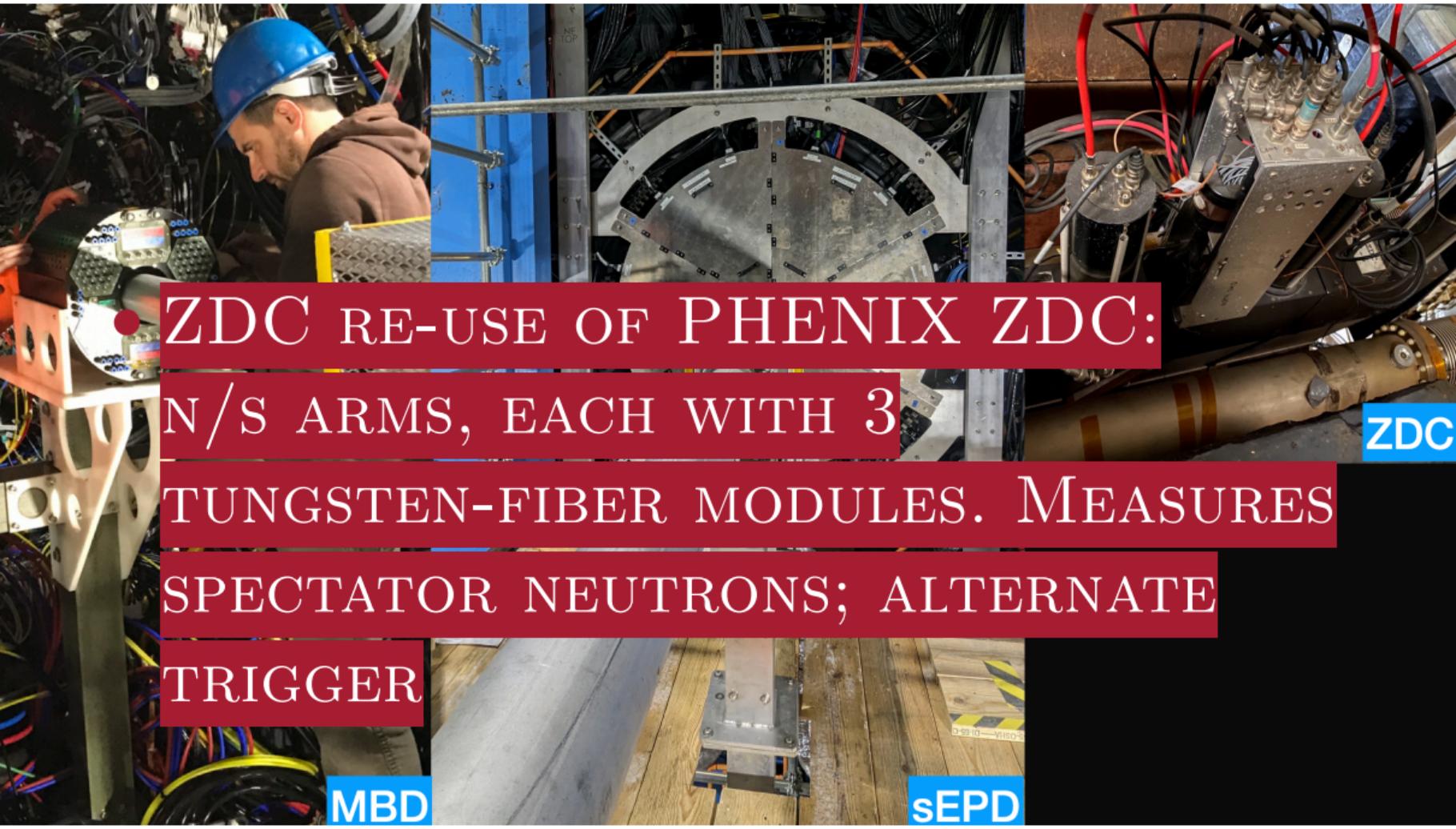


sEPD



ZDC

● SEPD INSTALLED JUNE 2023



• ZDC RE-USE OF PHENIX ZDC:

N/S ARMS, EACH WITH 3

TUNGSTEN-FIBER MODULES. MEASURES

SPECTATOR NEUTRONS; ALTERNATE

TRIGGER

MBD

ZDC

sEPD



MAY 18 2023, START OF COMMISSIONING

# sPHENIX RUN PLAN

Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo weeks	Physics weeks	$\mathcal{L}_{samp}$ ( $ z  < 10$ cm)
2023	Au+Au	200	24	9	$4.5 \text{ nb}^{-1}$
2024	p+p	200	24	12	$45 \text{ pb}^{-1}$
2024	p+Au	200	-	5	$0.11 \text{ pb}^{-1}$
2025	Au+Au	200	24	20.5	$21 \text{ nb}^{-1}$

- Year 1: Currently in commissioning and calibration phase; plans for first physics

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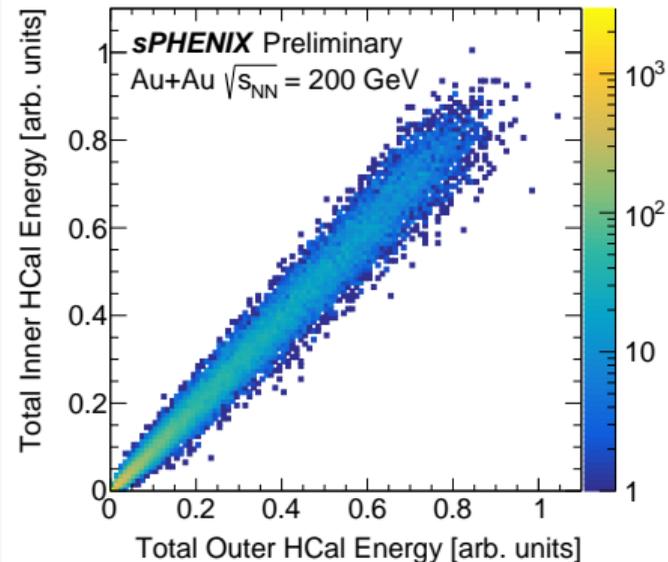
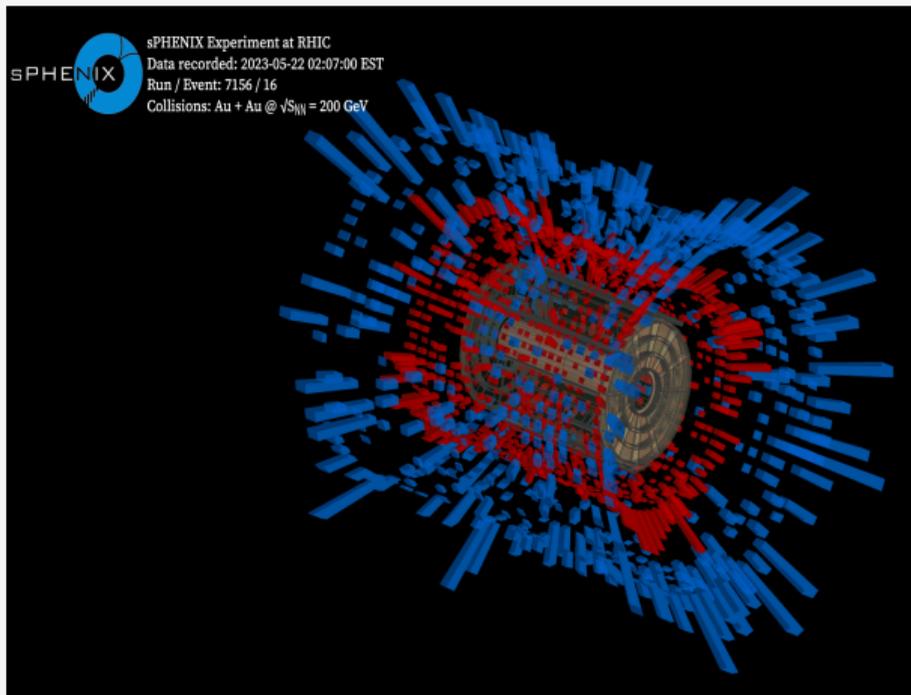
- Year 2: Cold QCD and heavy-ion reference

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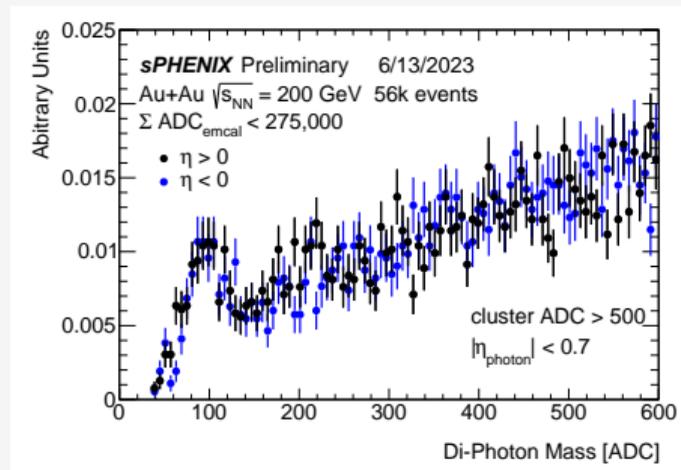
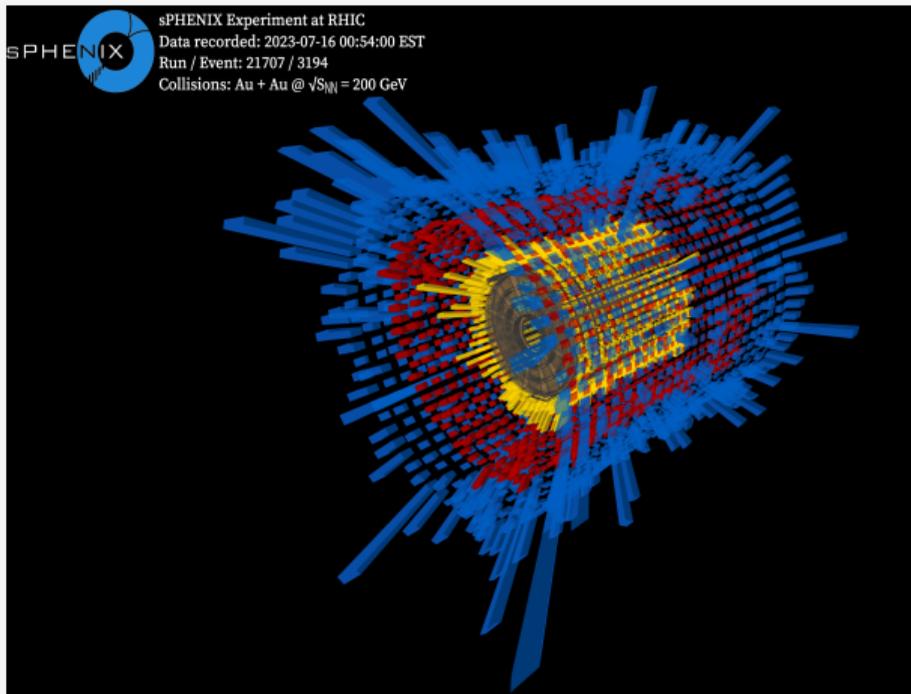
- Year 3: Large Au+Au dataset

# HADRONIC CALORIMETERS CORRELATION



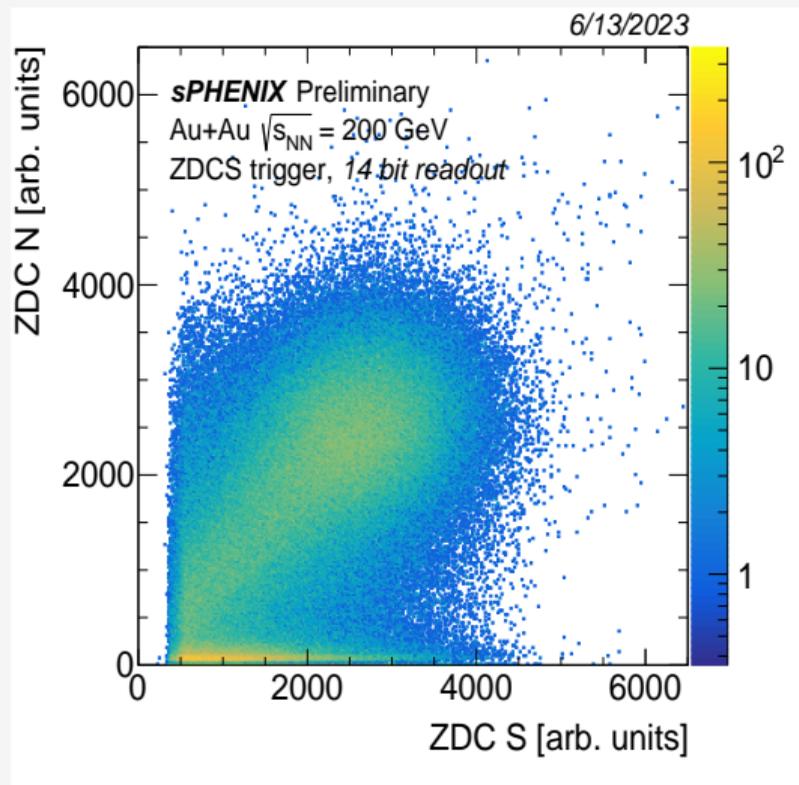
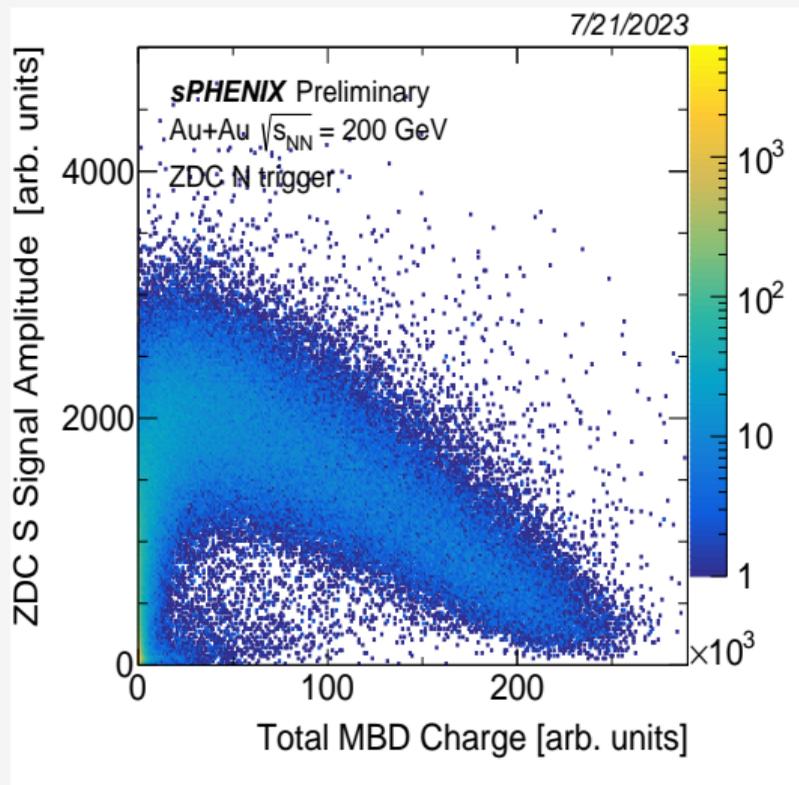
- Tight ihcal-ohcal correlation with commissioning data!

# COMMISSIONING DATA WITH EMCAL

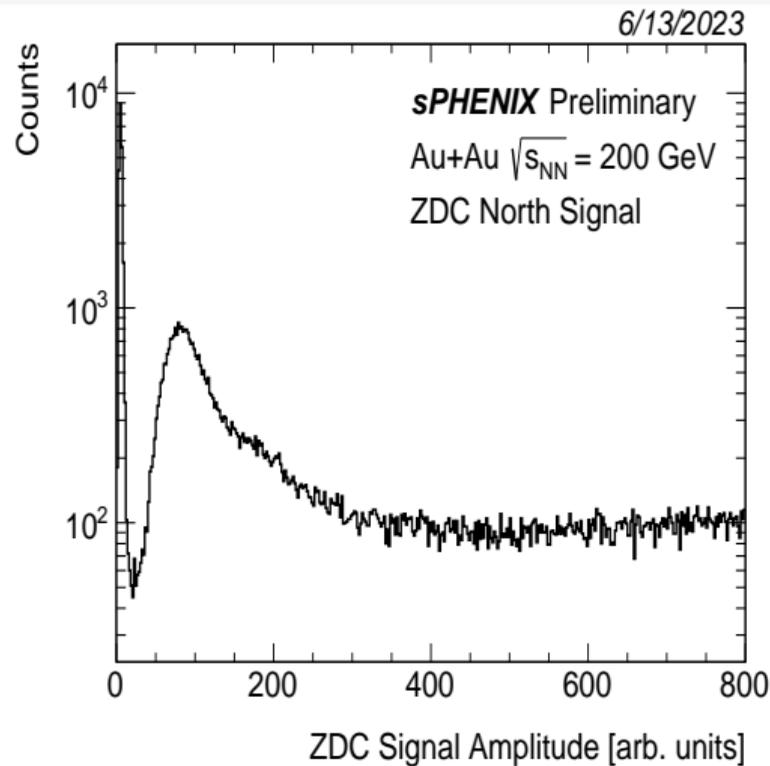
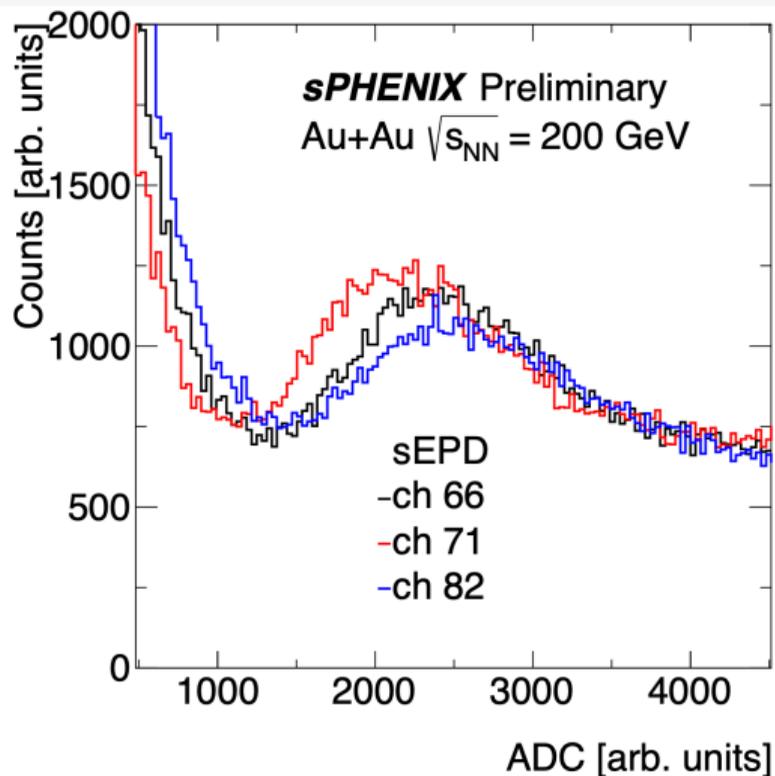


- di-photon mass distribution shows  $\pi^0$  peak

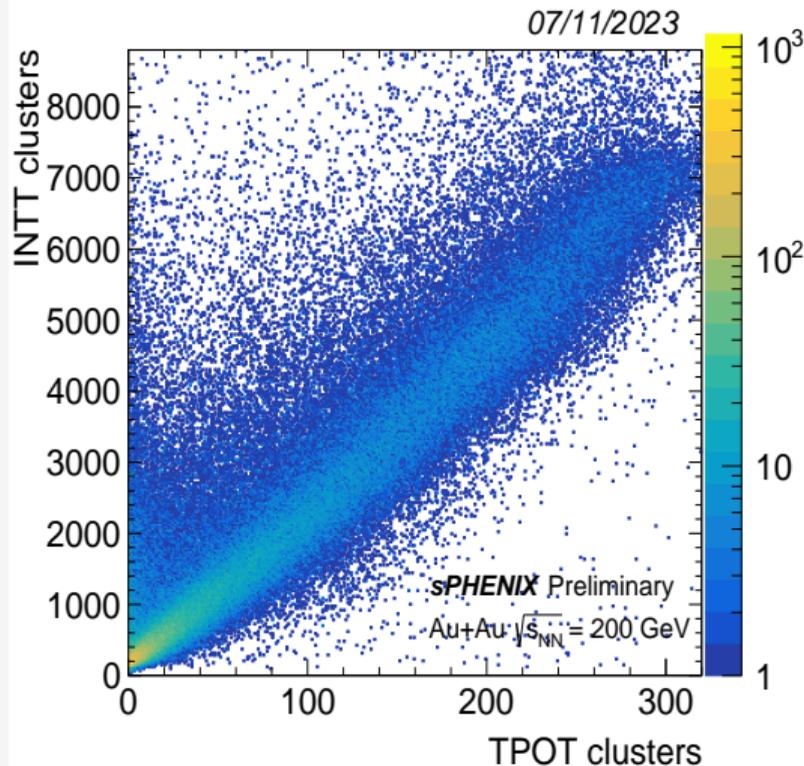
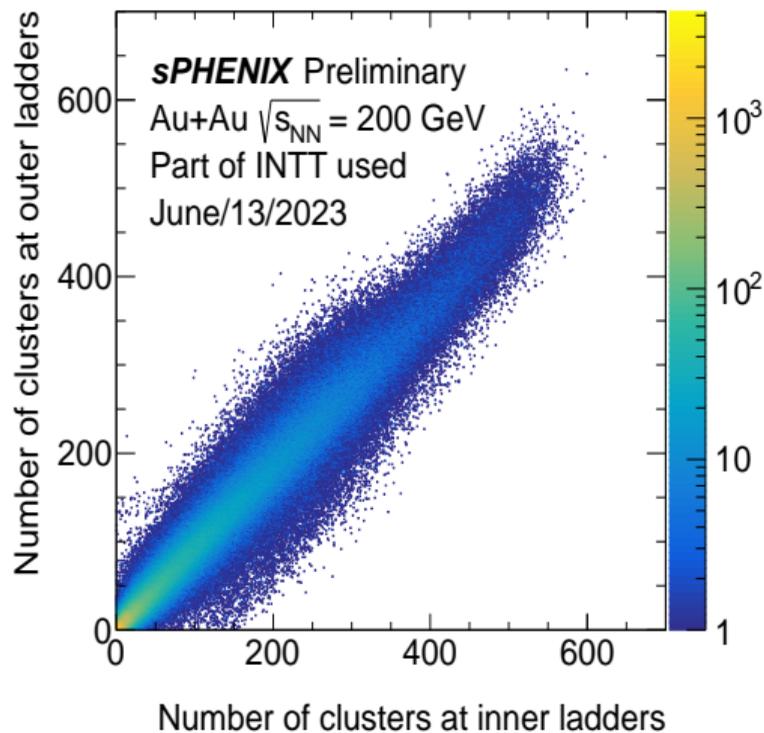
# FORWARD DETECTORS CORRELATION



# SIGNAL IN FORWARD DETECTORS



# TRACKING DETECTORS CORRELATION



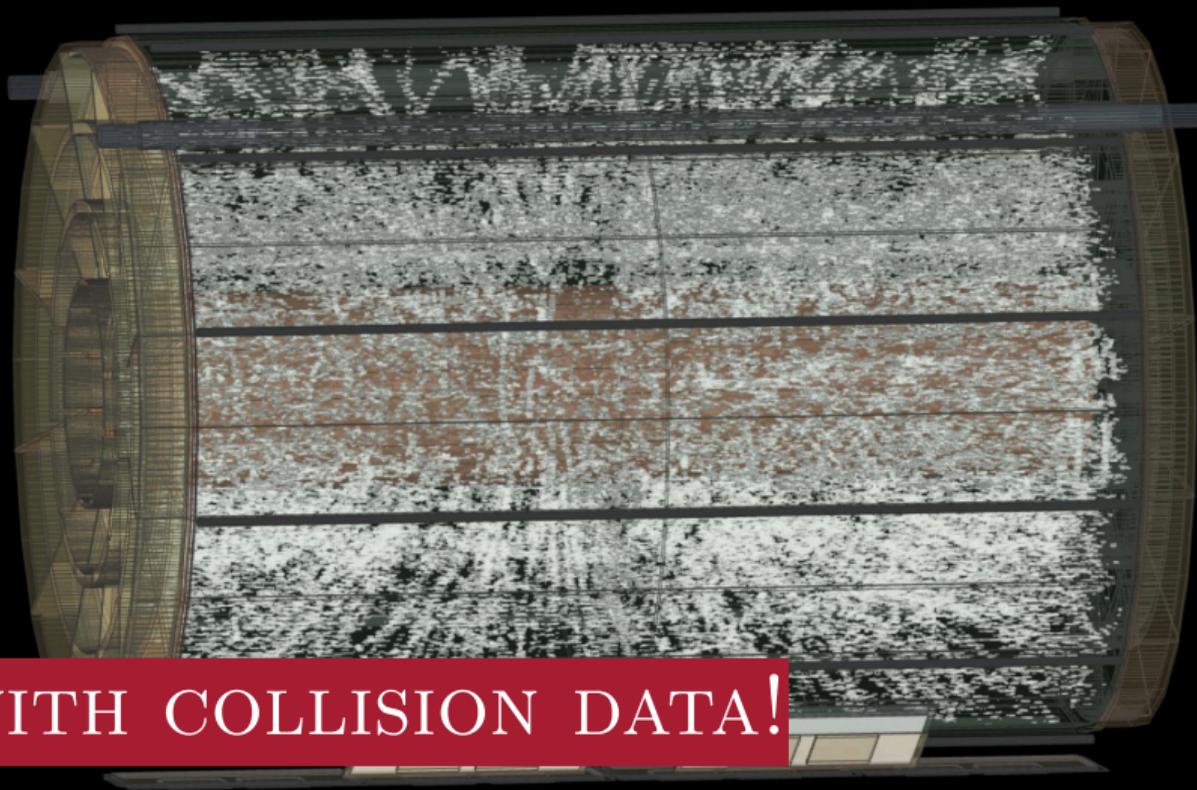


sPHENIX Time Projection Chamber

100 Hz ZDC, MBD Prescale: 2, HV: 4.45 kV GEM, 45 kV CM, X-ing Angle: 2 mrad

2023-06-23, Run 10931 - EBDC03 reference frame 43

Au+Au sqrt(s)=200 GeV

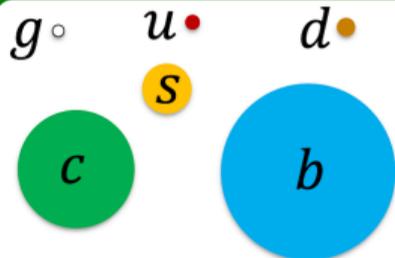
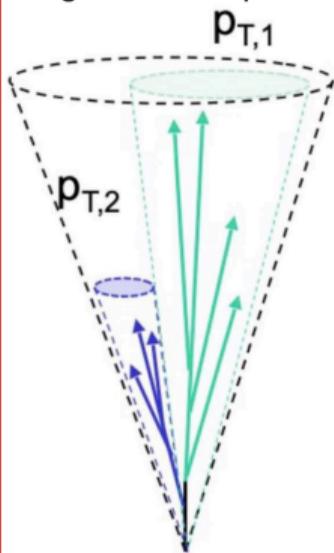


TPC HITS WITH COLLISION DATA!

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vary momentum & angular size of probe

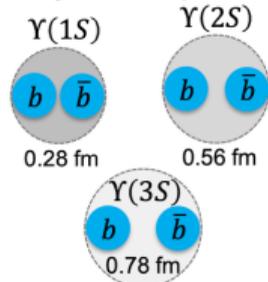


## Heavy Flavor

vary mass & momentum of probe

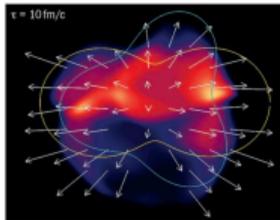
## Quarkonia

vary size of probe



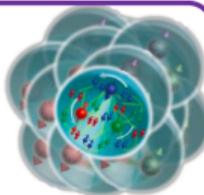
## Bulk

collective behavior in large & small systems



## Cold QCD

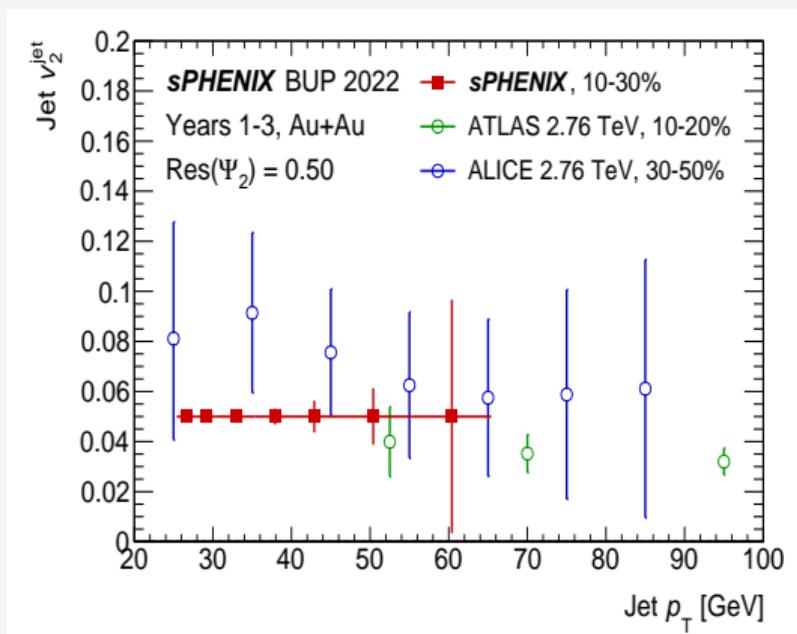
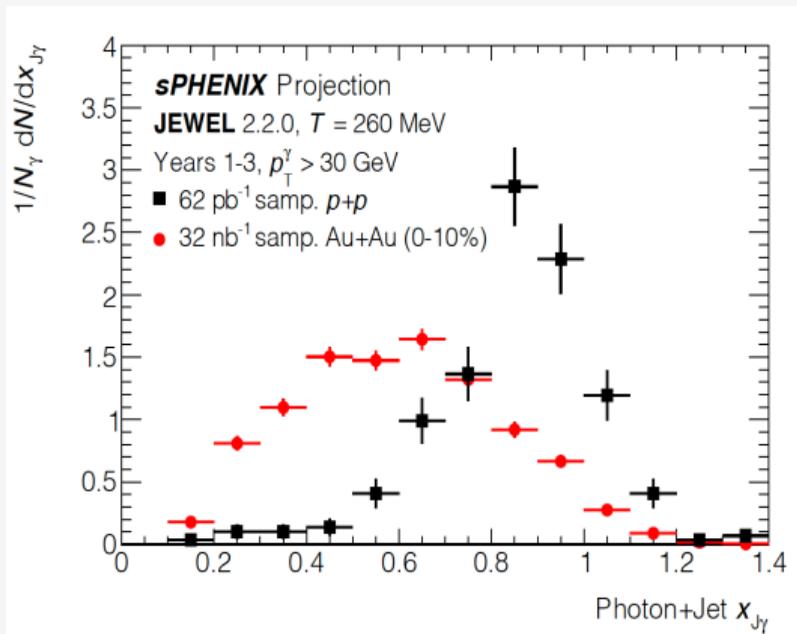
vary temperature of QCD matter, study proton spin, transverse momentum, & nuclear effects



## sPHENIX Physics

- Jets
- Heavy flavor
- Quarkonia
- Collectivity
- Cold QCD

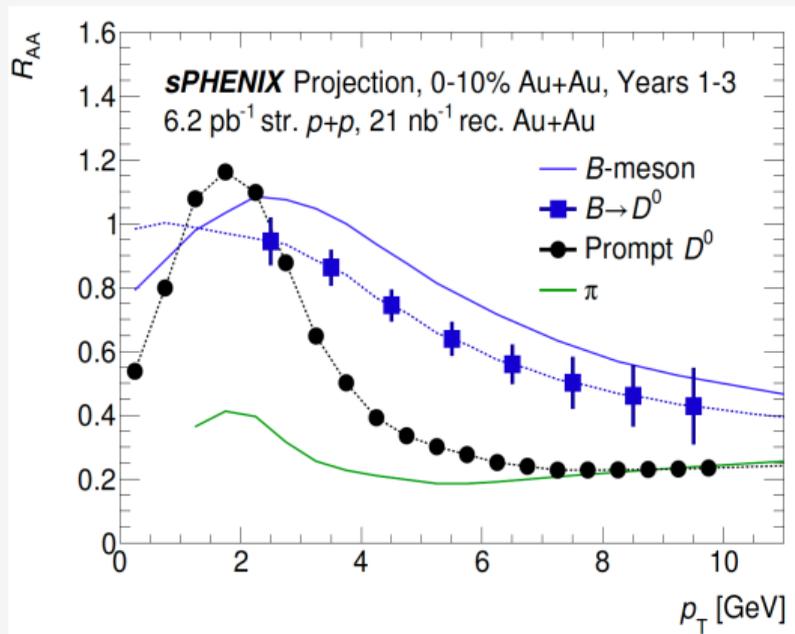
# JET CORRELATION PROJECTIONS



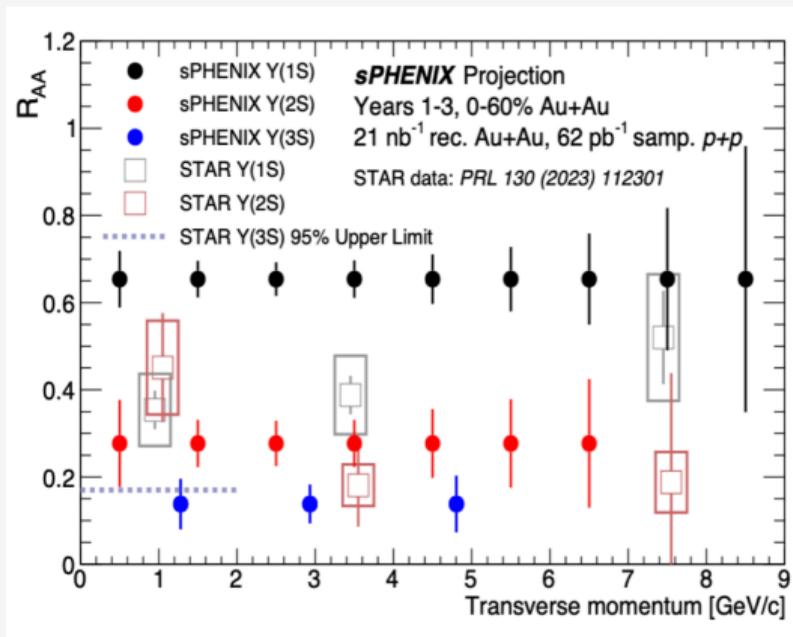
- jet-to-photon  $p_T$  balance in p+p and Au+Au

- jet yield as a function of the azimuthal distance from the event plane

# HEAVY FLAVOR AND QUARKONIA

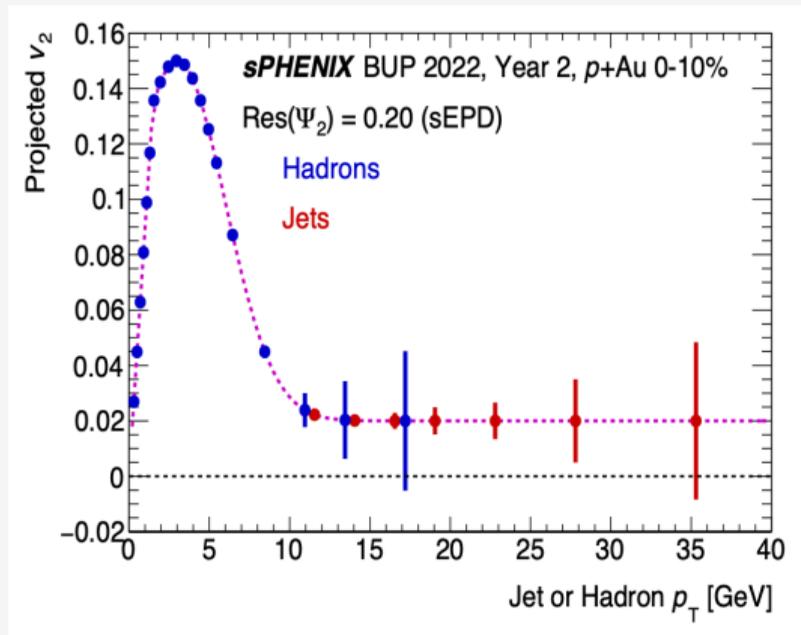


- $R_{AA}$  predictions for non-prompt/prompt  $D^0$  mesons

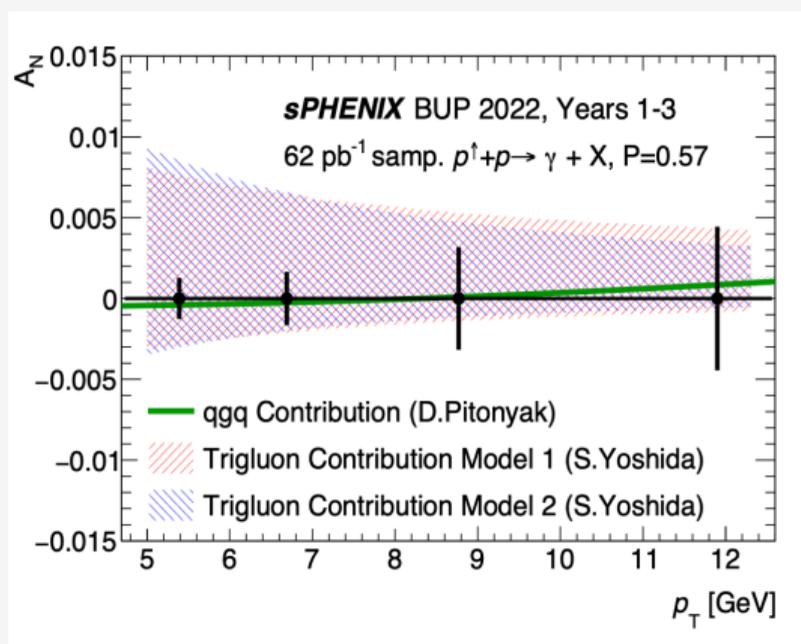


- $R_{AA}$  predictions for all three  $\Upsilon$  states with sPHENIX 3-year run plan

# COLLECTIVITY AND COLD QCD



- projected statistical uncertainties for charged hadrons and jet  $v_2$  in p+Au



- projected statistical uncertainties for direct photon TSSAs

COMMISSIONING BEGAN ON MAY 18,  
ALREADY HAVE FIRST RESULTS WITH COMMISSIONING DATA.  
LOOKING FORWARD TO FIRST PHYSICS RESULTS!