sPHENIX Experiment at RHIC

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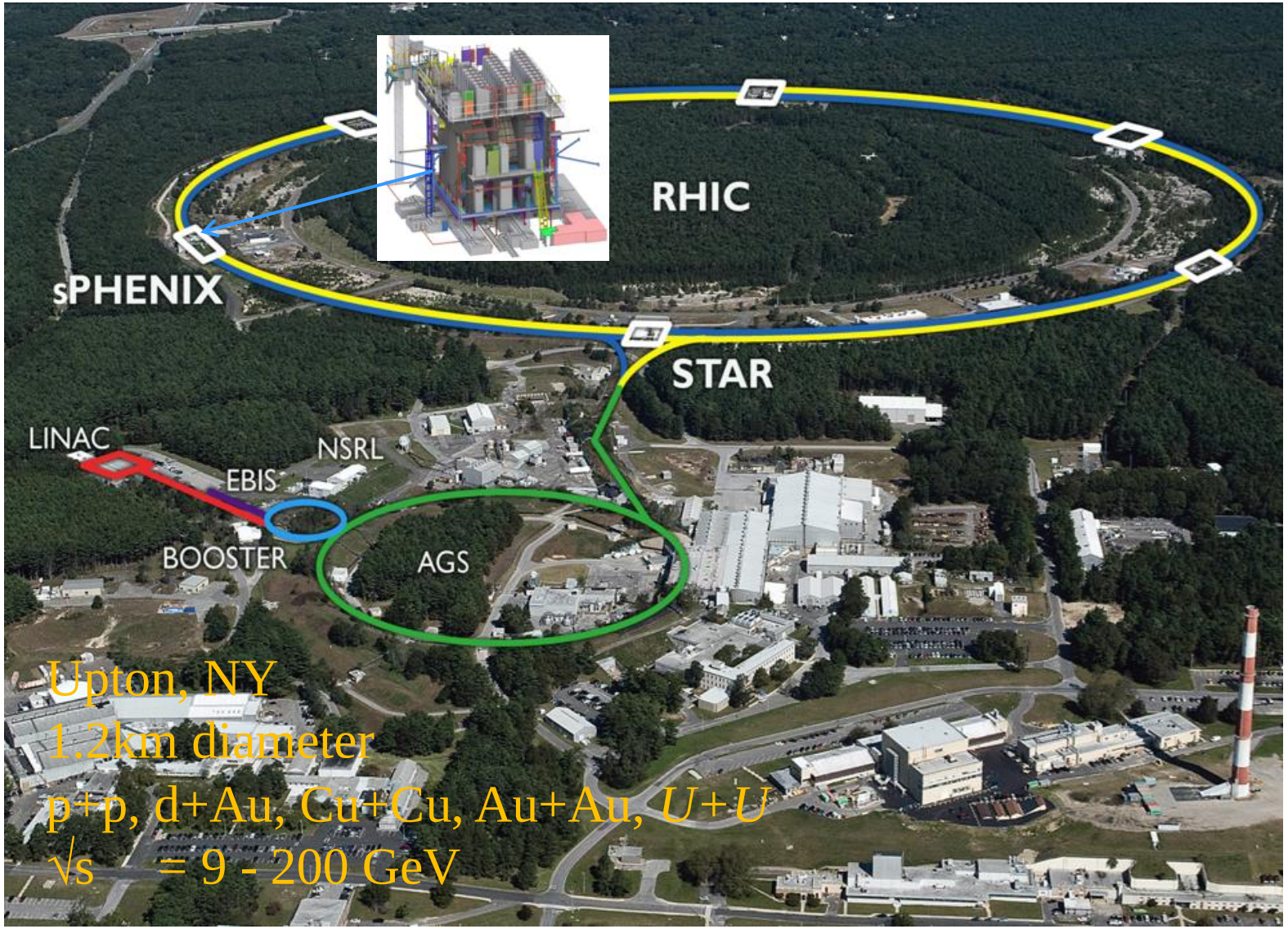
Morgan State University, Baltimore

XIII International Conference on New Frontiers in Physics

The sPHENIX Experiment



sPHENIX is the first new major detector at RHIC in over 20 years

It is a complete tear-down and rebuild of PHENIX which included a full modernization of the experiment complex

sPHENIX Collaboration:

~400 members,

80+ institutions,

14 countries

sPHENIX Detector

sPHENIX is a large-acceptance, high-rate detector optimized to measure jet and heavy quark physics in HI collisions by incorporating **Hadronic** and **EM Calorimetry**, a **Time Projection Chamber**, **Silicon Pixel** and **Strip detectors**, a **Micromegas detector** plus **Global/Trigger detectors** with a **high rate DAQ/Trigger** and a **1.4 T solenoidal magnetic field**.

Features of sPHENIX:

Large, uniform acceptance

- 2π coverage in azimuth
- $-1.1 < \eta < 1.1$ geometric coverage

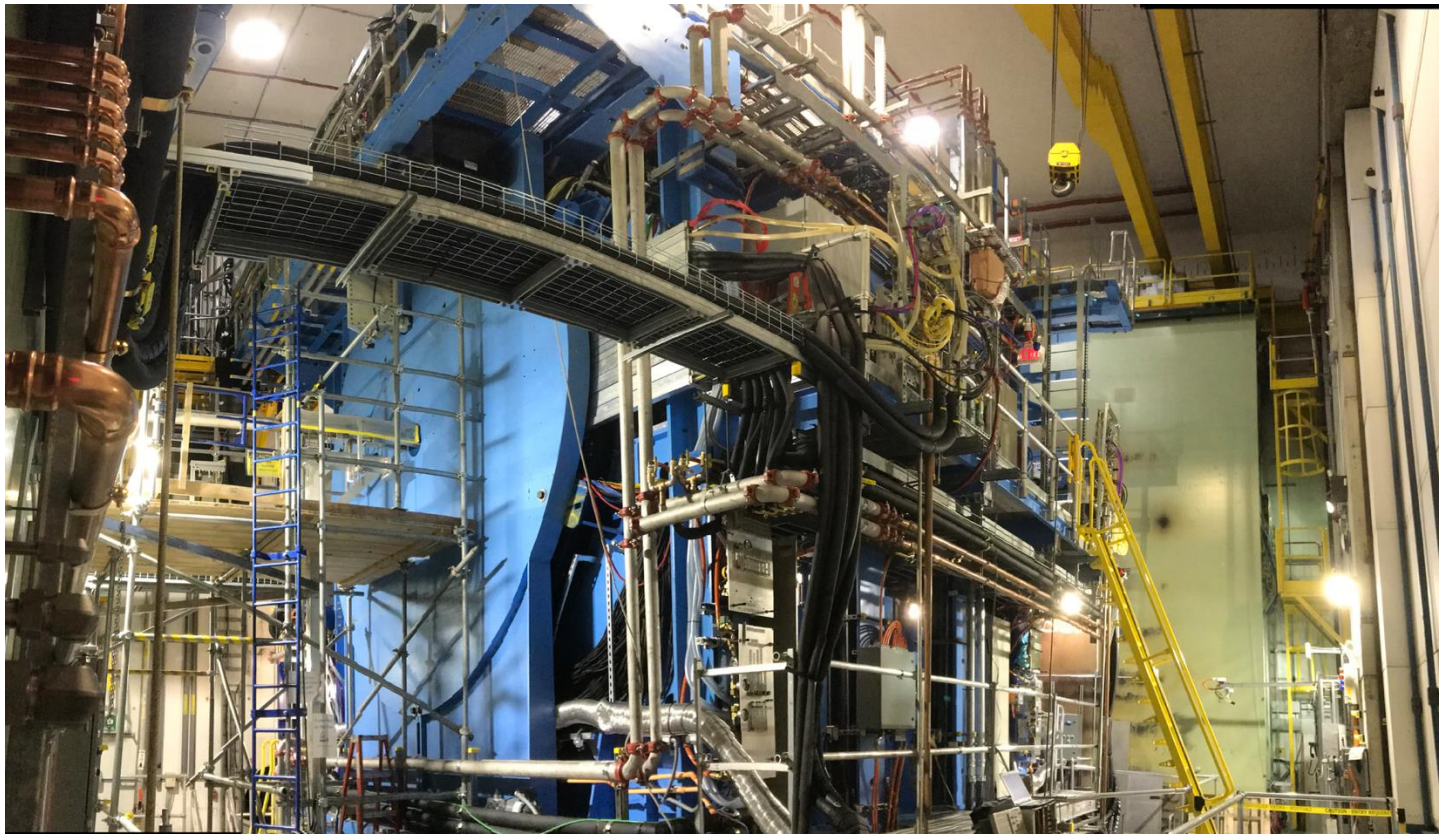
Full EM & hadronic calorimetery

High precision tracking

High precision vertexing, DCA

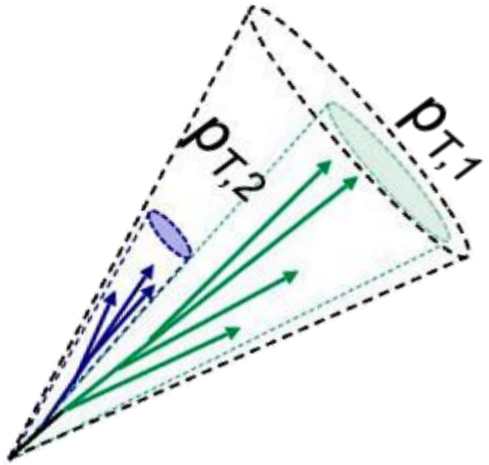
Large AA samples with mini-biased trigger

High rate (15 kHz) DAQ



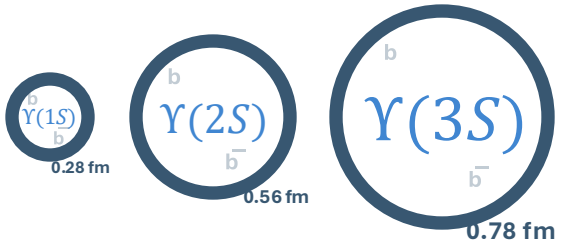
sPHENIX Physics Programs

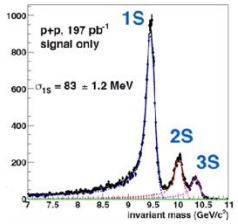
Jet Physics



- Jet correlations
- Nuclear Modification Factor R_{AA}
- Jet structure
- Jet flavor dependencies

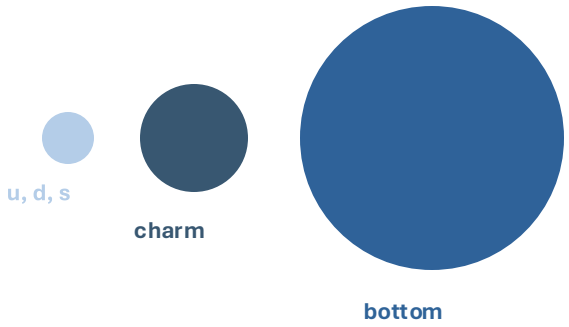
Quarkonium Spectroscopy





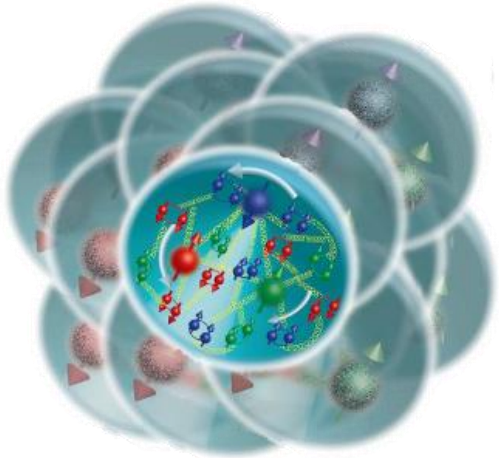
- Sequential quarkonia melting: Suppression of quarkonium depending on the state

Heavy flavor



- Flavor (mass) dependence of parton energy loss in QGP

Cold-QCD



- Origin of the transverse single spin asymmetries
- Nucleon structure
- Fragmentation functions

Plan and status

sPHENIX Beam Use Proposal 2023 (not all shown)

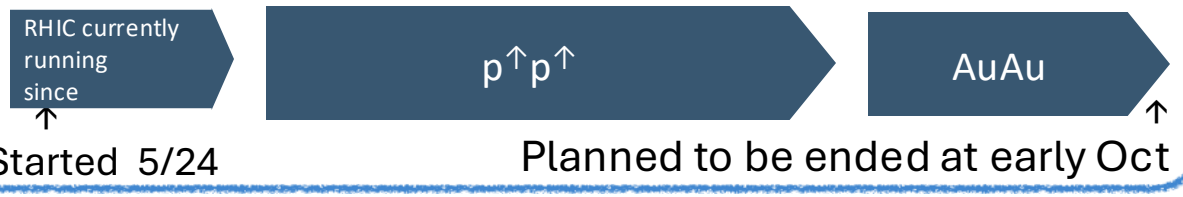
Year	Beam	$\sqrt{s_{NN}}$ (GeV)	Data taking (week)	Luminosity, $\int L_{SEP}$ ($\|z\| < 10$ cm)	
				Recorded	Sampled
2023	Au + Au	200	~~9~~	~~3.7 nb^{-1}~~	~~4.5 nb^{-1}~~
2024	$p^{\uparrow}$+ $p^{\uparrow}$	200	17	0.44 pb^{-1} (5 kHz)	45 (62) pb^{-1}
2024	Au + Au	200	3	0.4 nb^{-1}	0.11 pb^{-1}
2025	Au + Au	200	24.5	6.3 nb^{-1}	21 (25) nb^{-1}

2023: Commissioning

- The construction was finished in April/2023.
- The first beam came in May/2023.
- 2023/08/01: Beam was stopped.
- 2023/08-09: Commissioning with cosmic ray measurements

2024: $p^{\uparrow}$+$p^{\uparrow}$, Au + Au

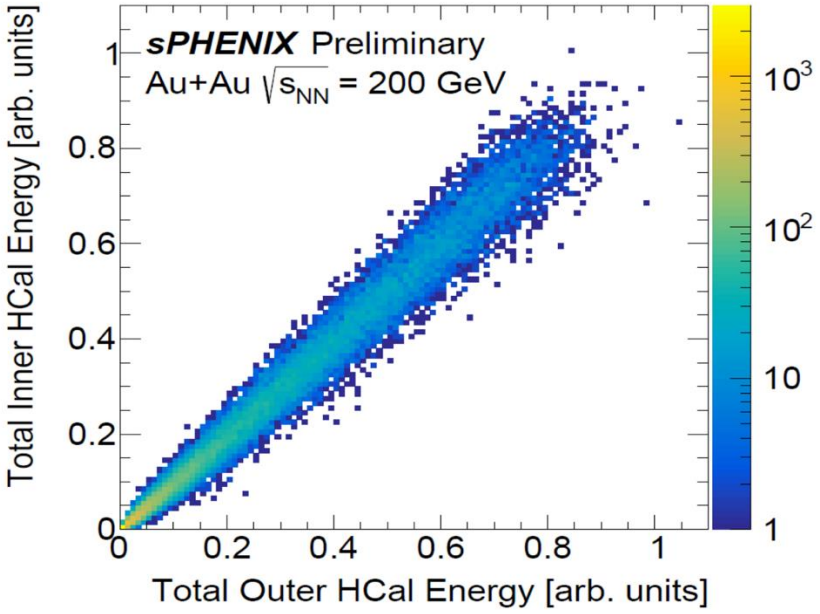
- Transversely polarized proton $p^{\uparrow}$ + $p^{\uparrow}$ (~60% polarization) collision at $\sqrt{s}$ = 200 GeV
- Commissioning with Au + Au for 3 weeks carried over from 2023 to check background & other cross checks



2025: Au + Au

sPHENIX Sub-systems

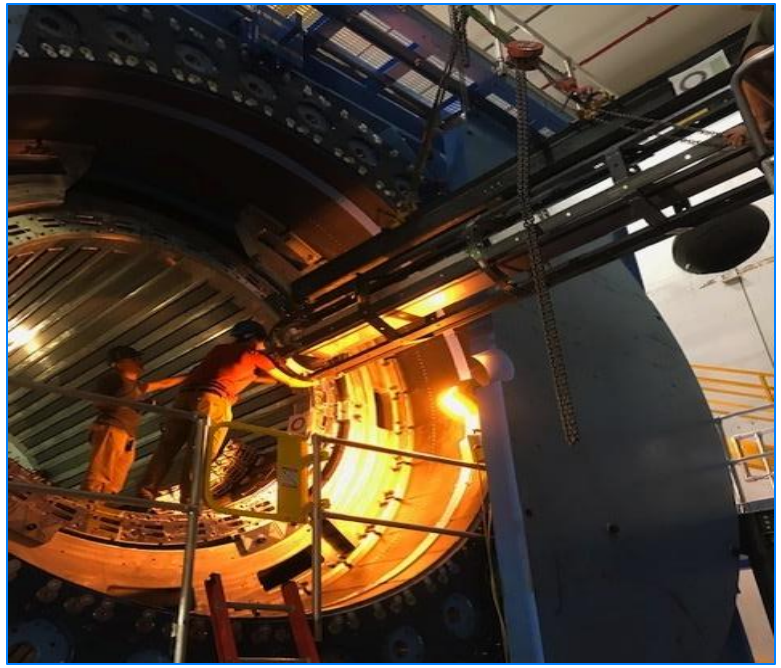
Hadronic Calorimeter

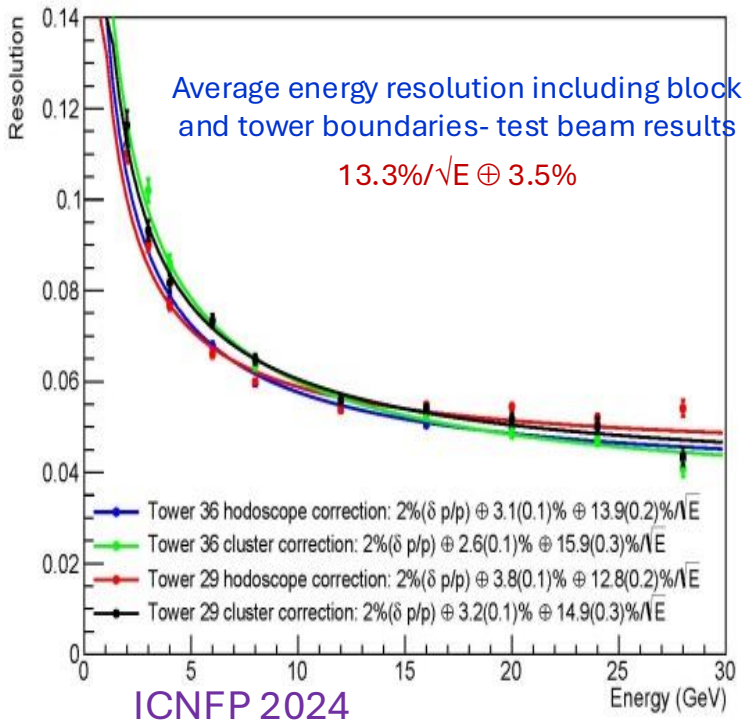


- **Outer HCal** is a steel-scintillator, "tilted plate" calorimeter.
  - Outer HCal (outside the solenoid) and Inner HCal (inside the solenoid)
- Doubles as the support for EMCal. i.e. Sector are supported off the Inner HCAL
- SiPMs readout
- Full calorimeter (EM+H) sys=4.7 λ_I,
- Avg jet E res < 150%/$\sqrt{E} \oplus$ 3.5%
- Measures the energy of hadrons (such as protons, neutrons, and pions)

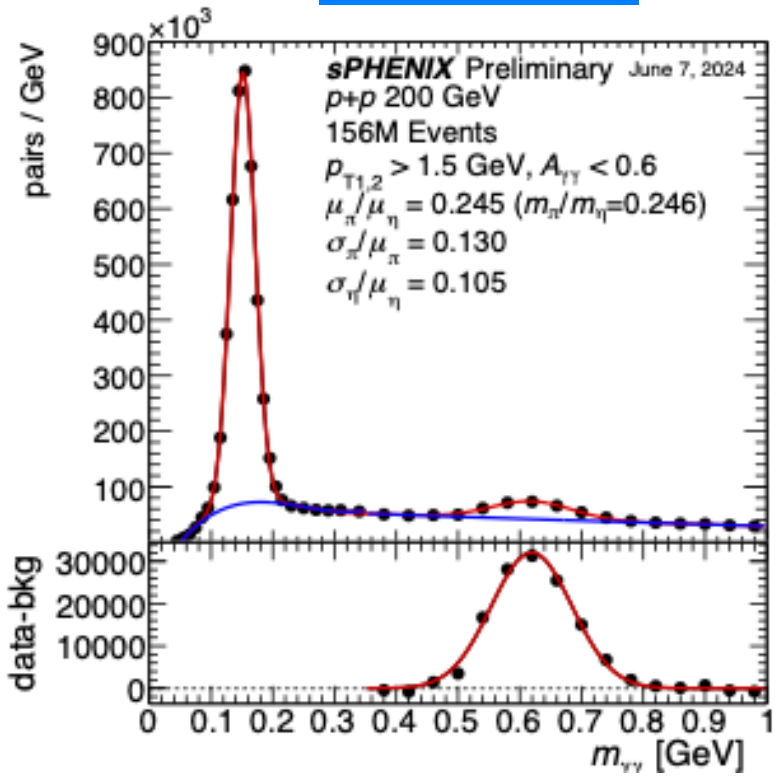
Electromagnetic Calorimeter

- EMCal blocks made of tungsten powder/epoxy composite encasing 2500 scintillating fiber/blocks
- Blocks segmented for HI collision $\Delta\eta \times \Delta\phi \approx 0.025 \times 0.025$
- 4 tower/block 96 blocks/sector, ~24k towers
- Good energy resolution





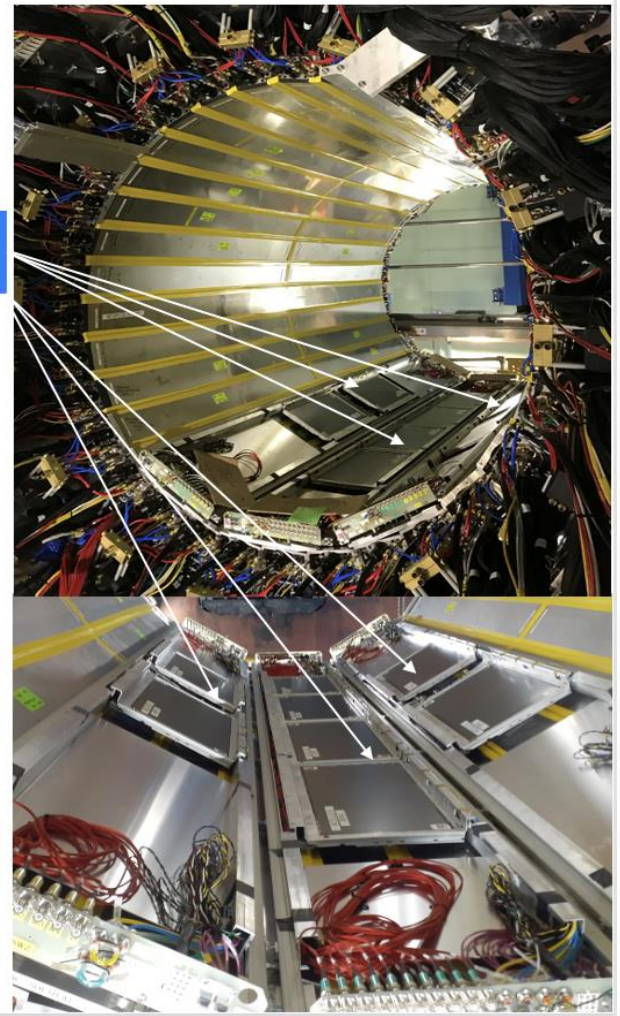
π^0 mass peak



Di-photon mass from p+p Run 24

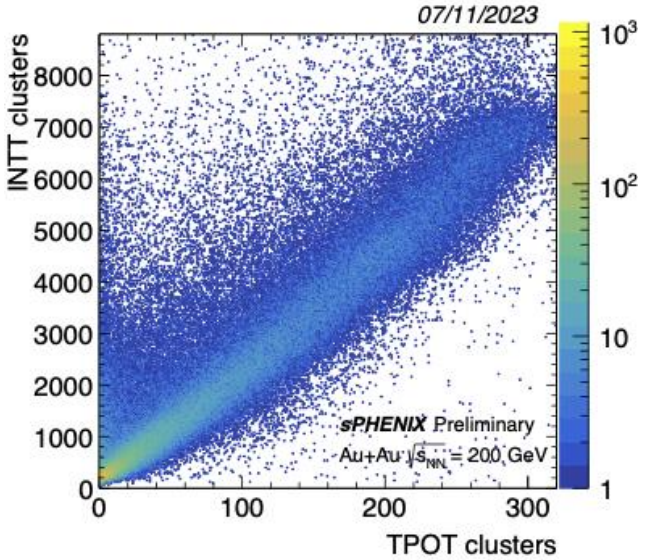
Time Projection Outer Tracker (TPOT)

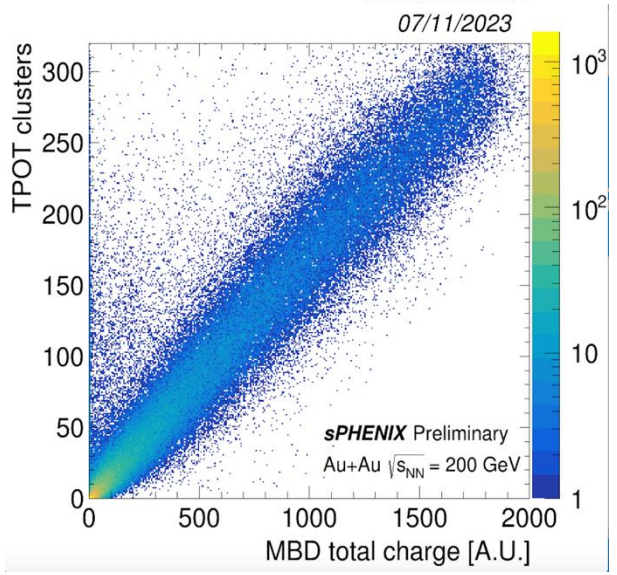
TPOT



- The TPOT consists of eight identical Micromegas modules, two detectors/module, grouped in three sectors. The three sectors are mounted to the EMCal at the bottom of the TPC.
- One sector has four modules, two sectors have two modules.

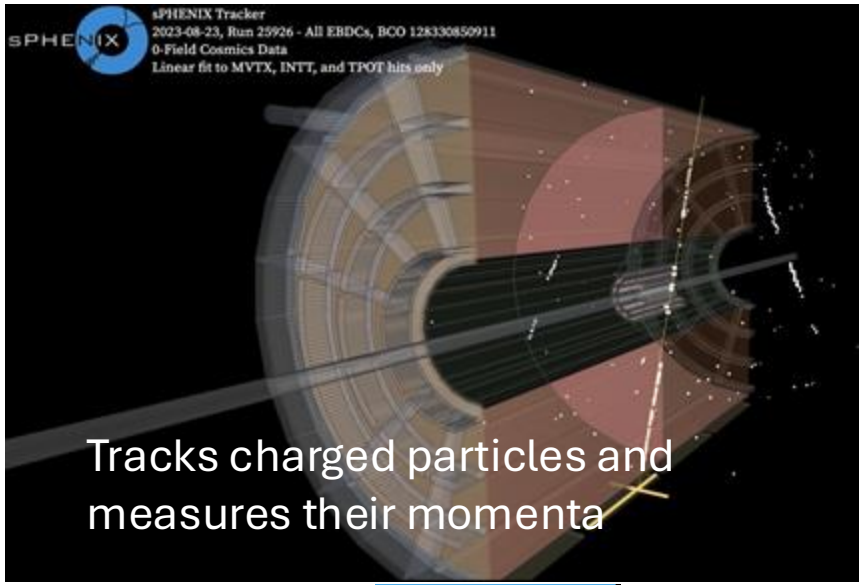
The TPOT's function is to provide tracking distortion correction information for the TPC.

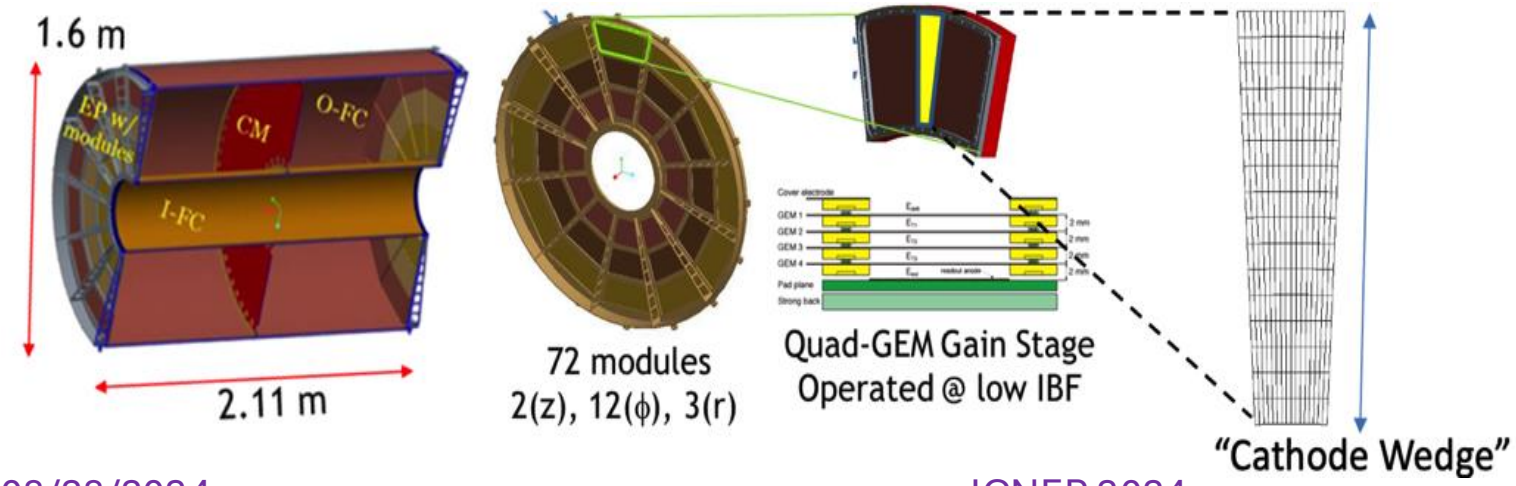


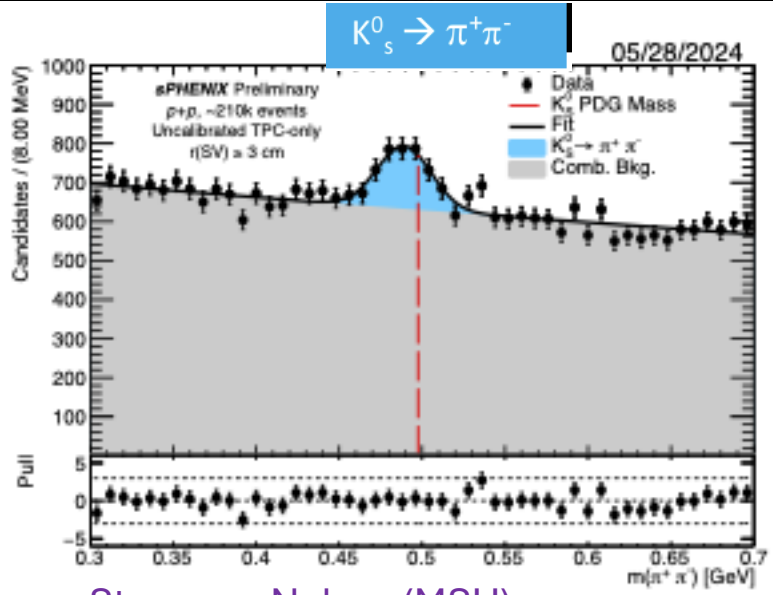


Time Projection Chamber

- Field cages are Kapton-carbon fiber
- End caps are aluminum
- Central membrane is G-10-honeycomb sandwich
- Internal chamber volume is filled with Ar-CF-Isobutane 75/20/5 gas
- GEM foils provided by CERN
- Electronics readout on each end
- ASIC modified SAMPA chip from ALICE

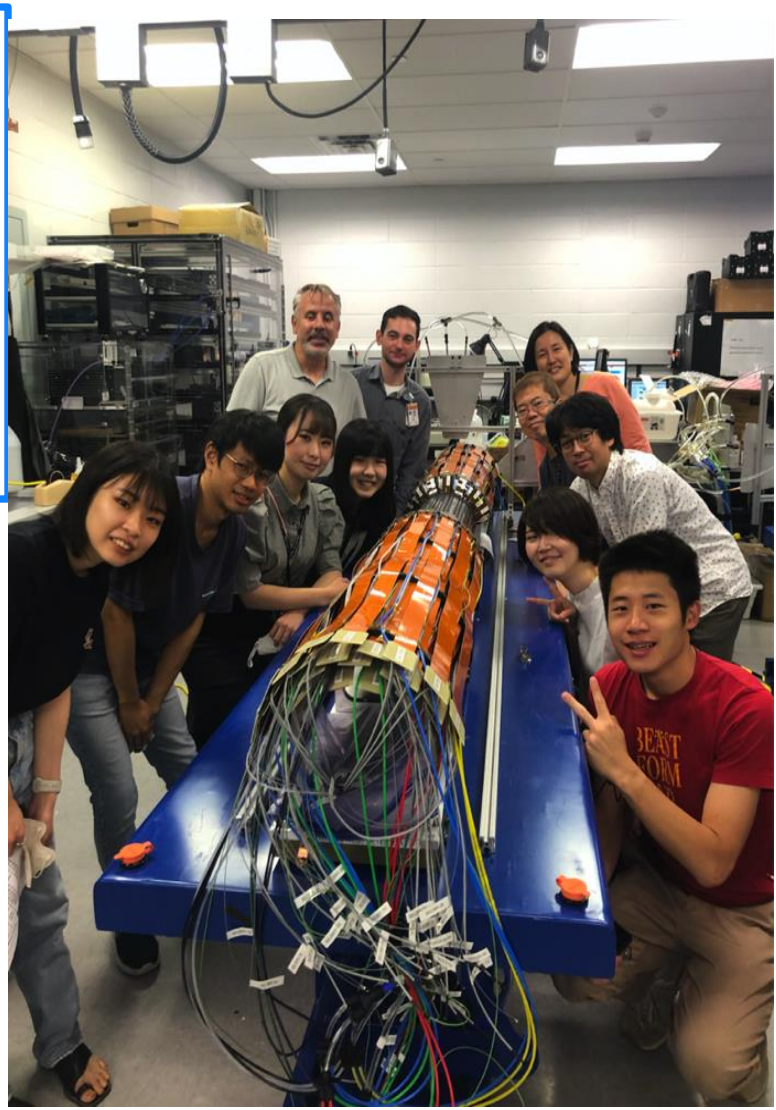


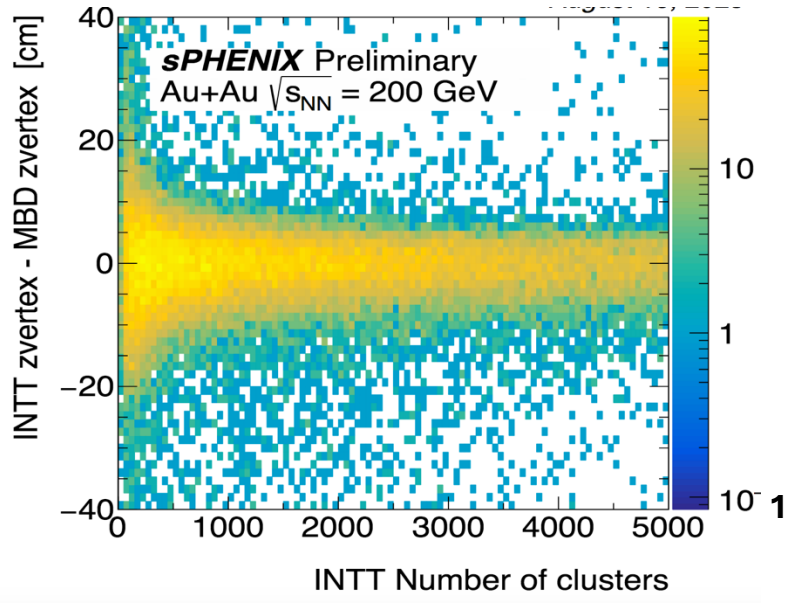


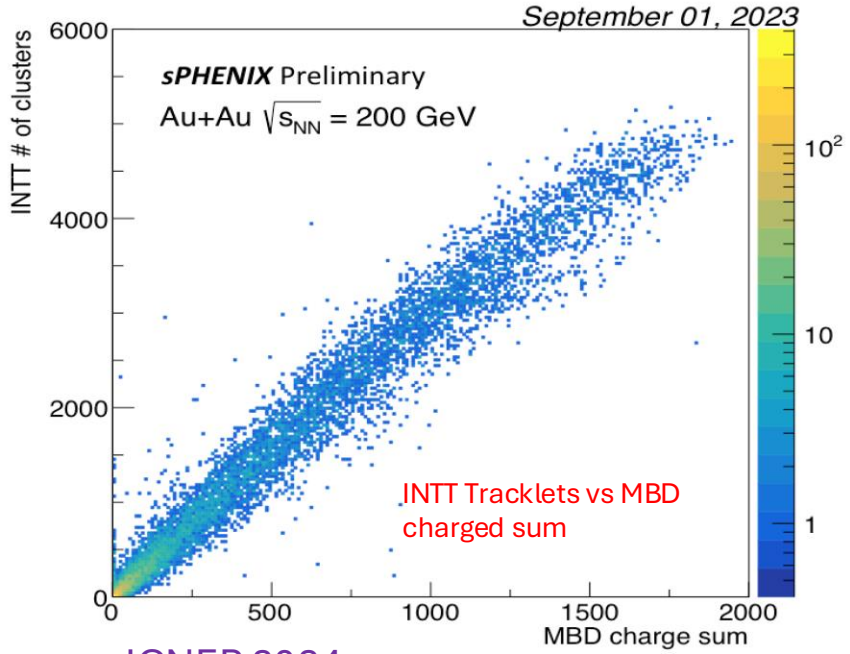


InTermediate Tracker(INTT)

- Two-layer silicon-strip detector for Tracking and vertex determination with acceptance: $|\eta| < 1.1$ and $\phi = 2\pi$
- tracking between TPC and MVTX with good timing resolution
- Fast time response of 60ns allowing to readout collisions each data from each single RHIC's beam bunch-crossing and suppress event-pileup background.
- 78 um pitch, provides timing tag resolving bunch crossing

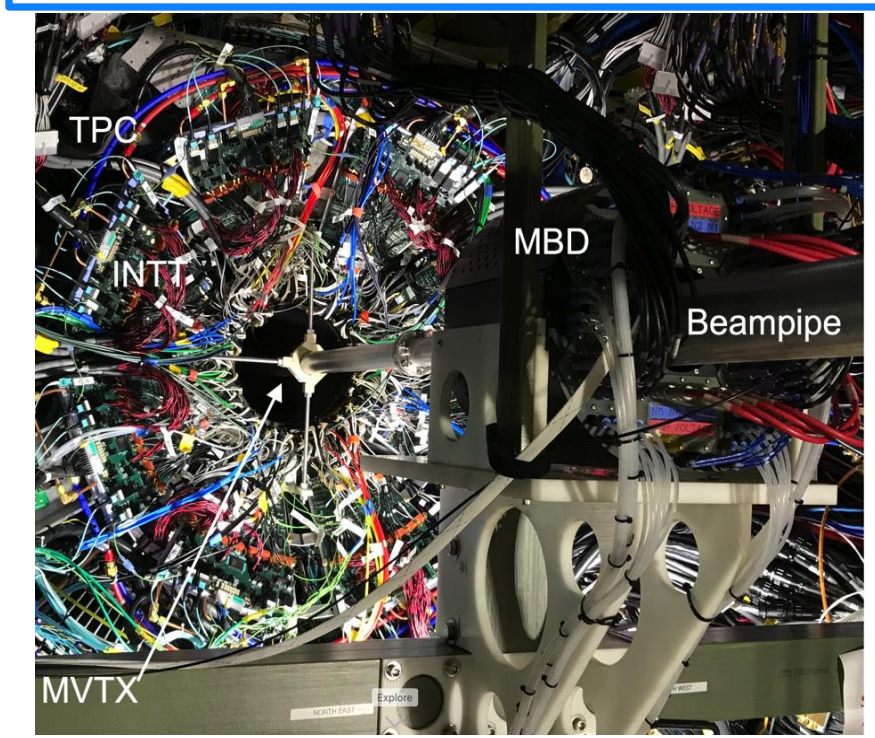


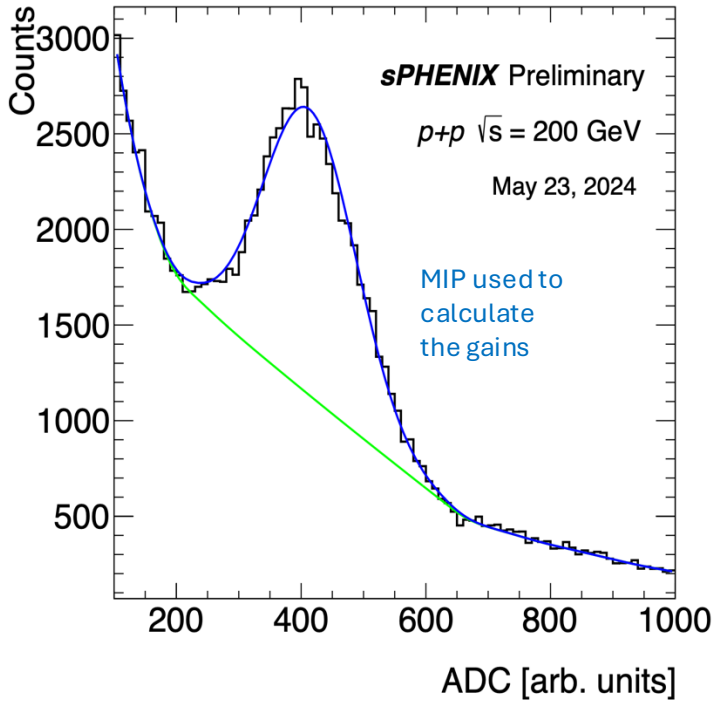


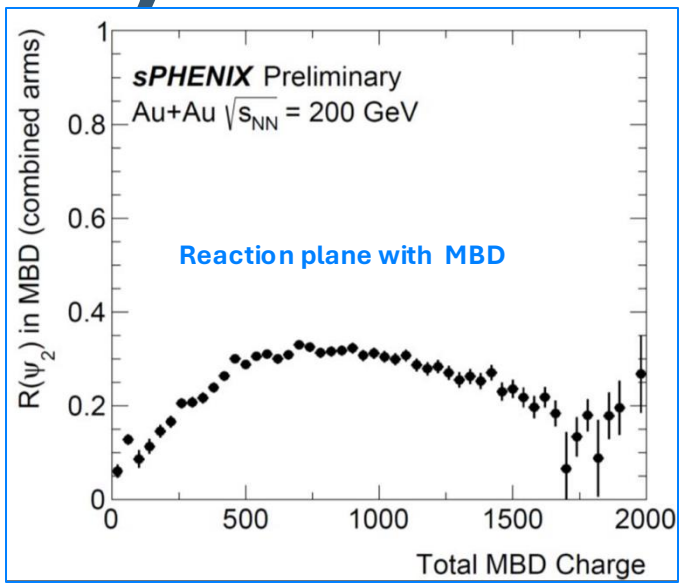


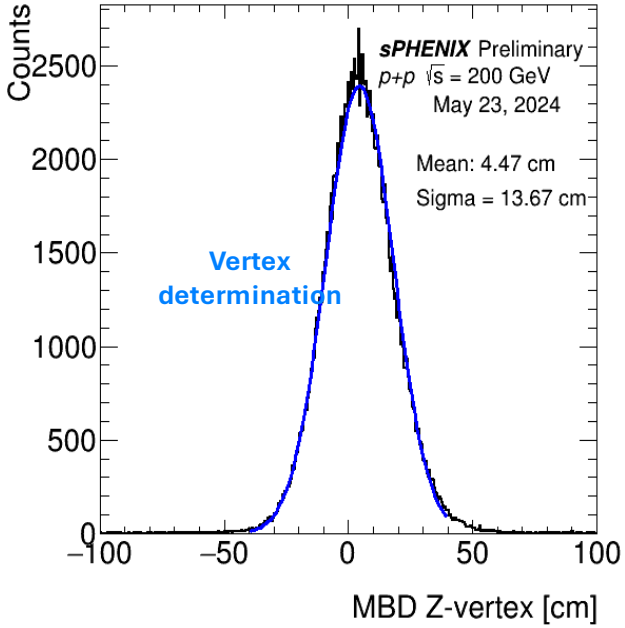
Minimum Bias Detector (MBD)

- MBD based on original PHENIX Beam Beam Counter with new electronics.
- Min-Bias trigger detector
- Two arrays of 64 custom PMTs with quartz radiator windows.
- MBD system timing resolution = 50 ps.
- centrality and reaction plane determination



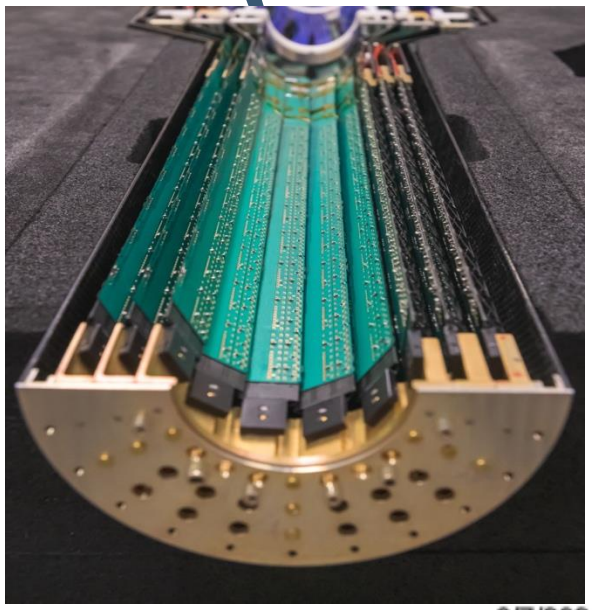




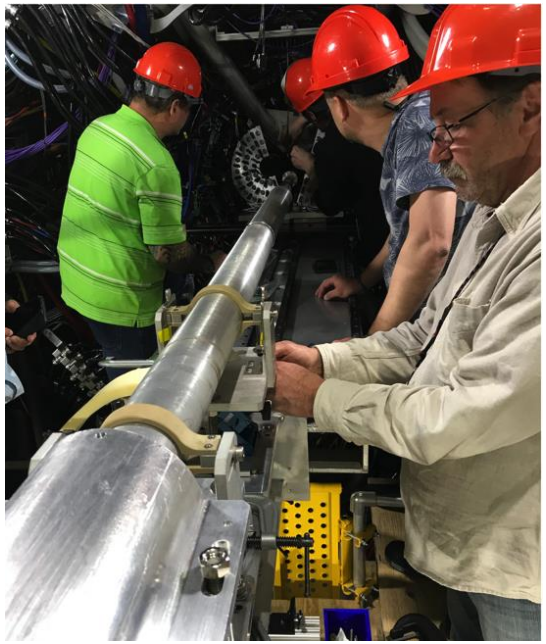


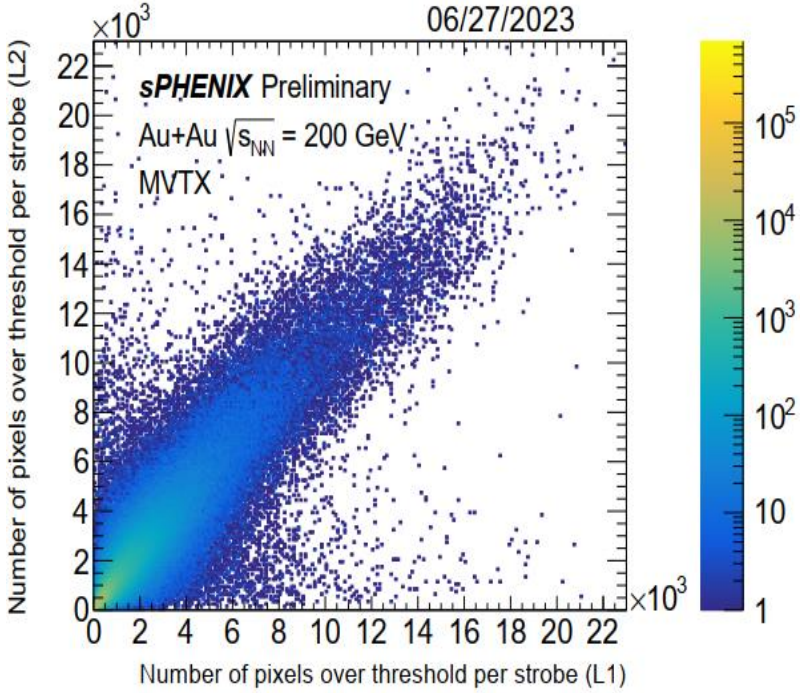
Monolithic Active Pixel Vertex (MVTX)

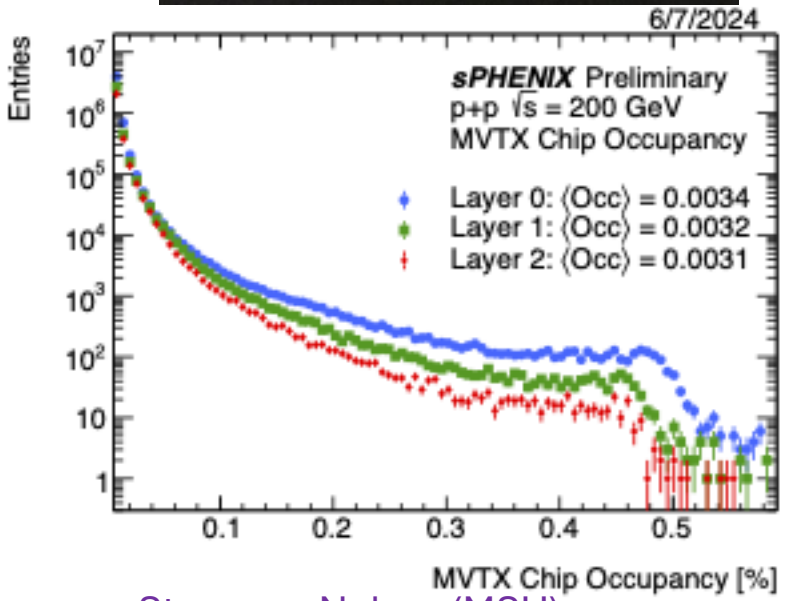
- The MVTX is a 230M channel, 3-layer MAPS-based pixel detector
- The MVTX is a copy of inner 3 layers of the ALICE ITS w/ a custom design of service supports to meet sPHENIX needs
- Staves and Readout Units produced at CERN w/ participation from sPHENIX collaborators



precise vertexing

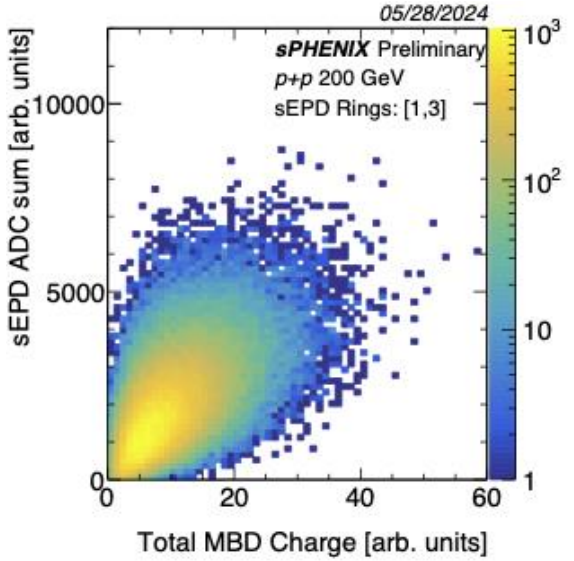


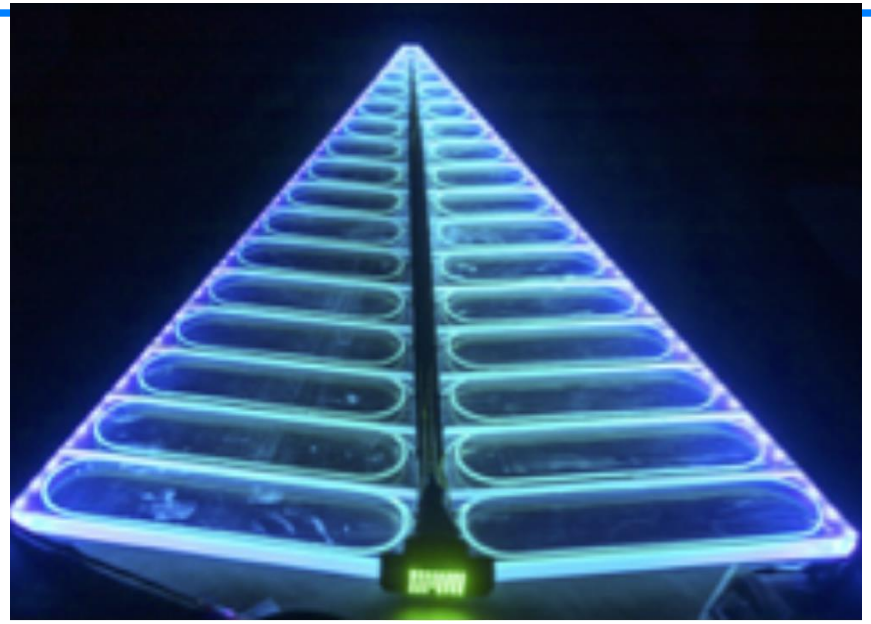


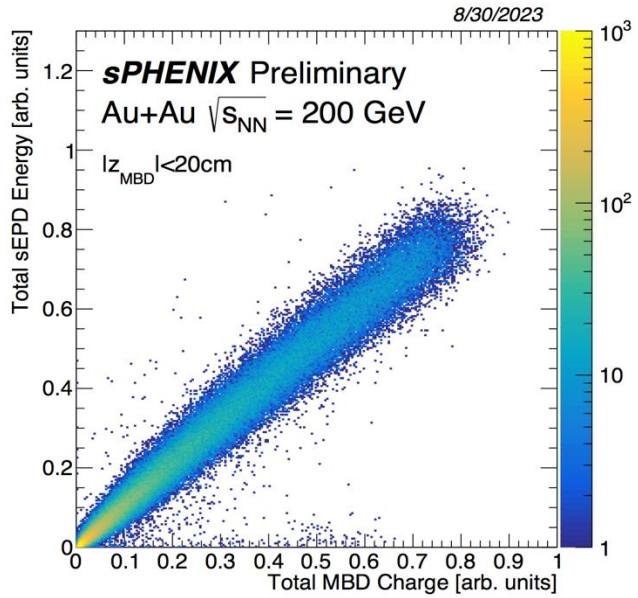


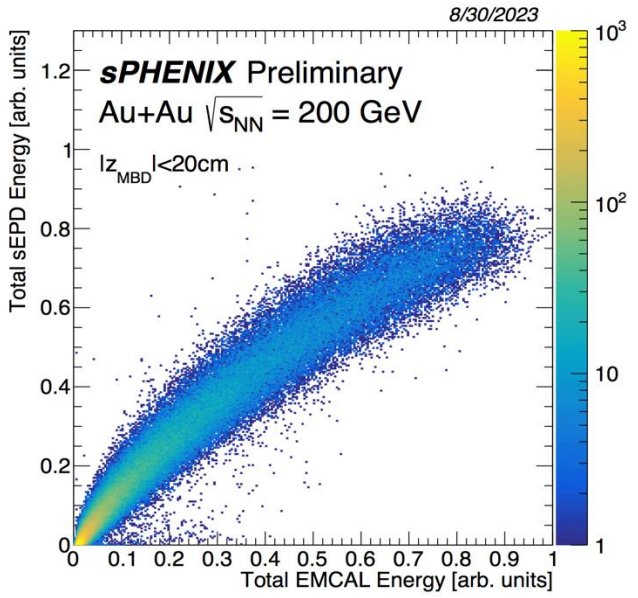
sPHENIX Event Plane Detector (sEPD)

- Two forward disks of scintillator tiles w/ WLS readout into SiPMs
- Covers both forward & backward rapidity region in 2.1<|η|<4.9
- 12 sectors/disk each subdivided into 31 tiles
- Total 744 channels with 16 segments in η and 24 in ϕ
- Essential role for event plane determination w/ high resolution
- Observe correlations between sEPD-MBD, sEPD-EMCal in RHIC data





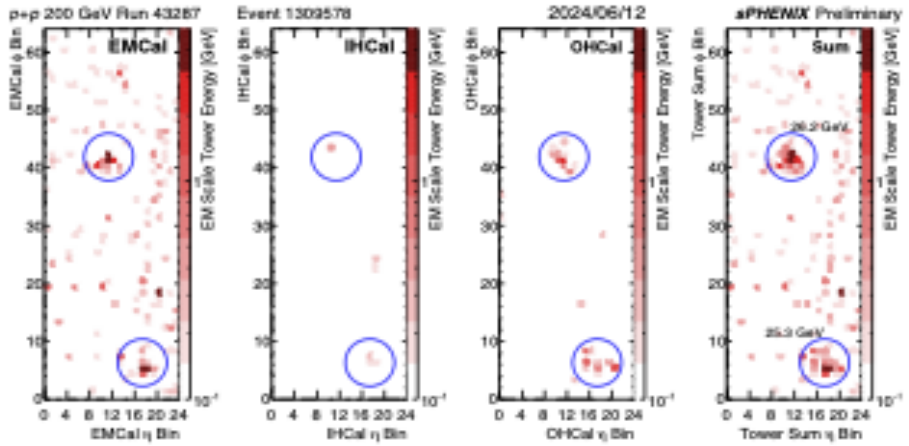


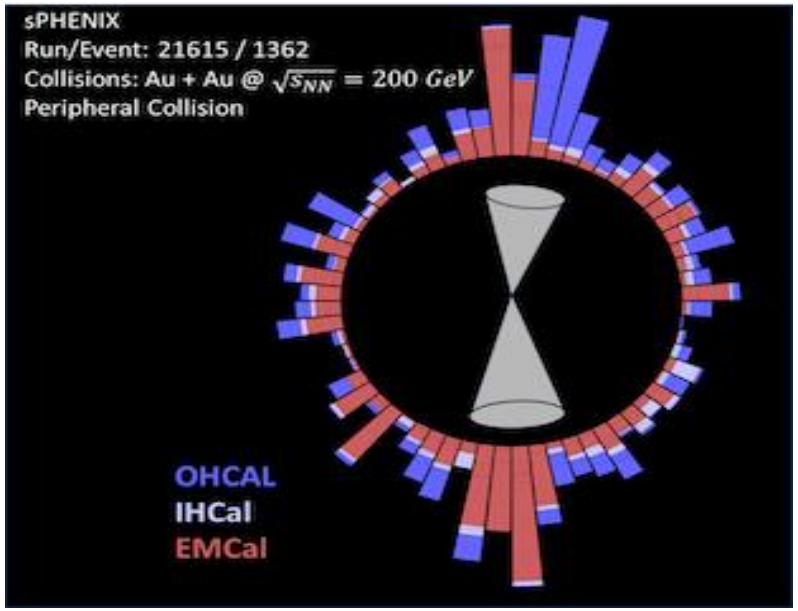


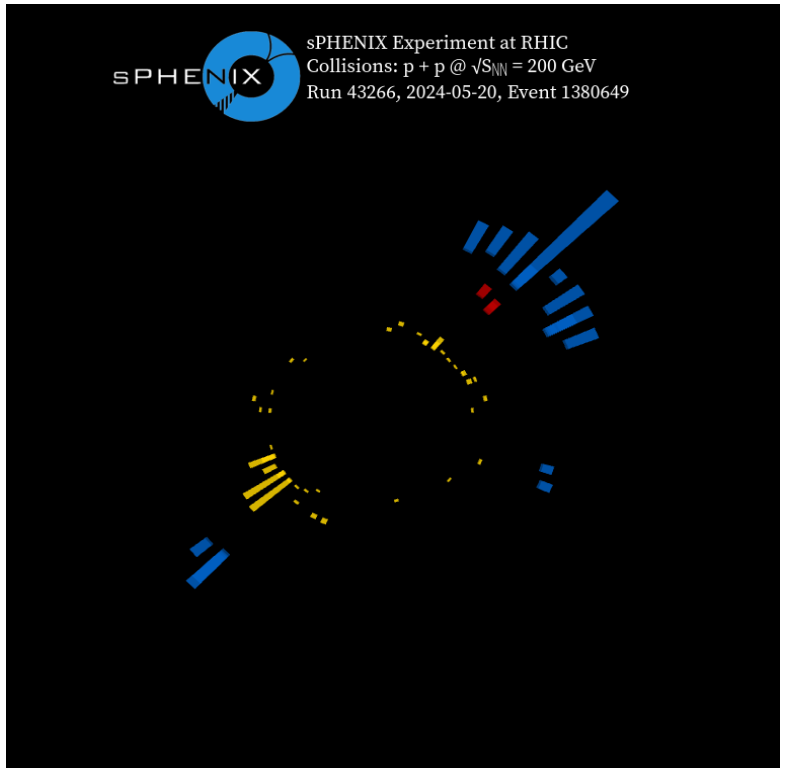
Jet Size and Substructure in sPHENIX

sPHENIX will measure jets as a function of the jet size

- Explore balance of competing increased energy loss and energy recovery effects
- Address tensions between LHC jet results at low pT





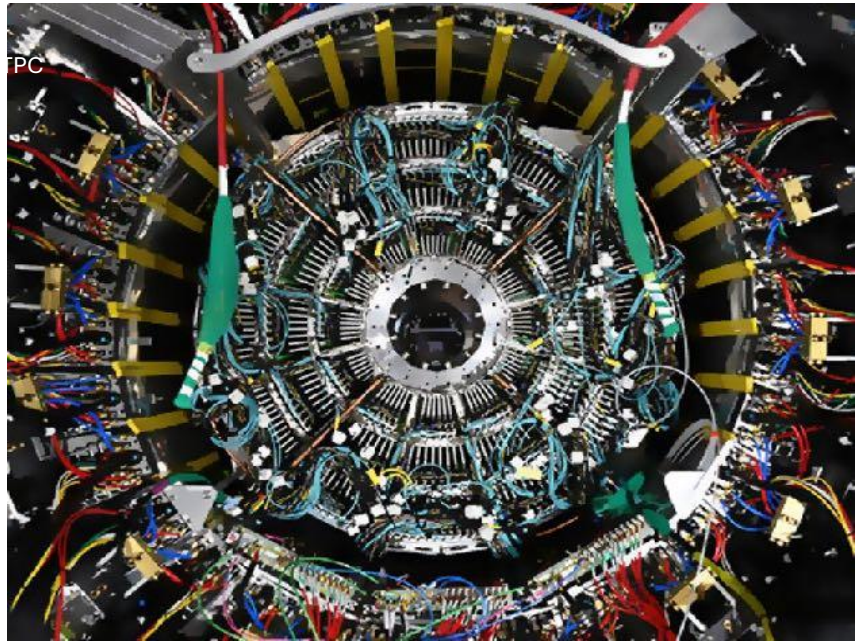


sPHENIX will perform precision measurements of jet (sub)structure using calorimetric and particle flow jet:

- Access to QGP resolving power
- Parton shower dependence to energy

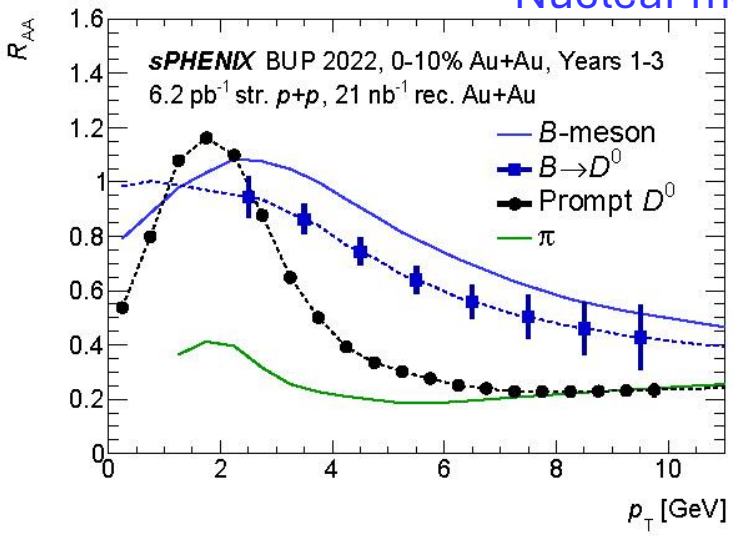
See Tanner Mengel's talk on Underlying event characterization in 200 GeV Au+Au collisions and jet measurements with the sPHENIX detector, Wednesday @ 12 pm

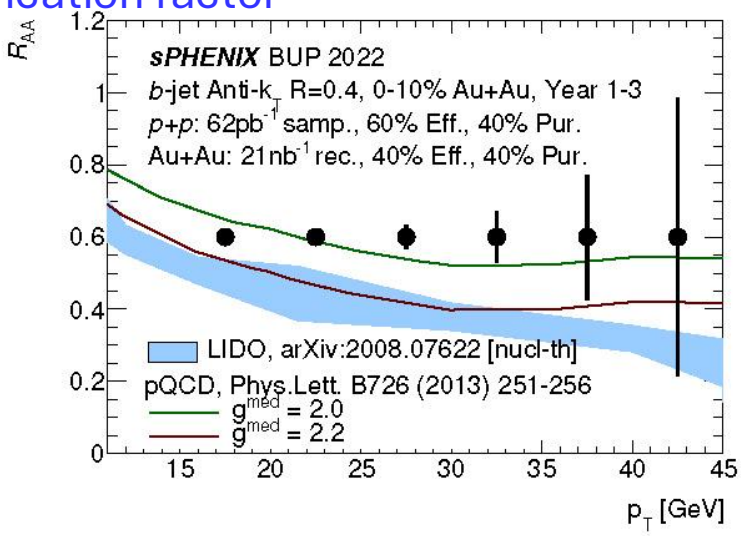
Open Heavy Flavor



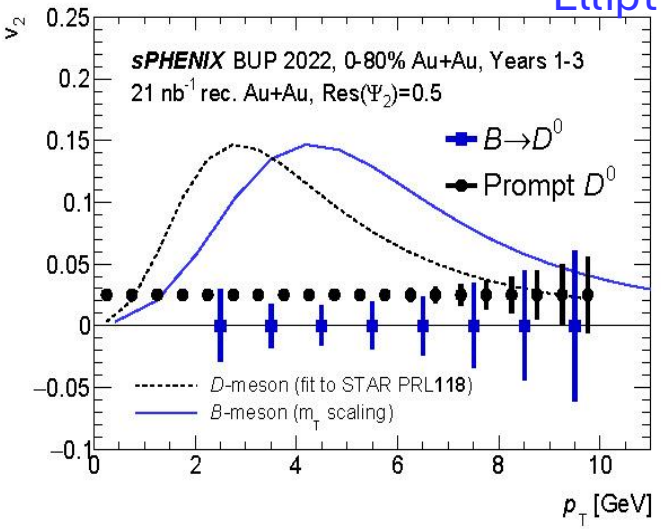
Current p+p running is key for sPHENIX HF program ->boost in streaming readout for higher statistics needed for R_{AA}, Λ_C / D0,
->Reached 10% streaming as planned for Run24

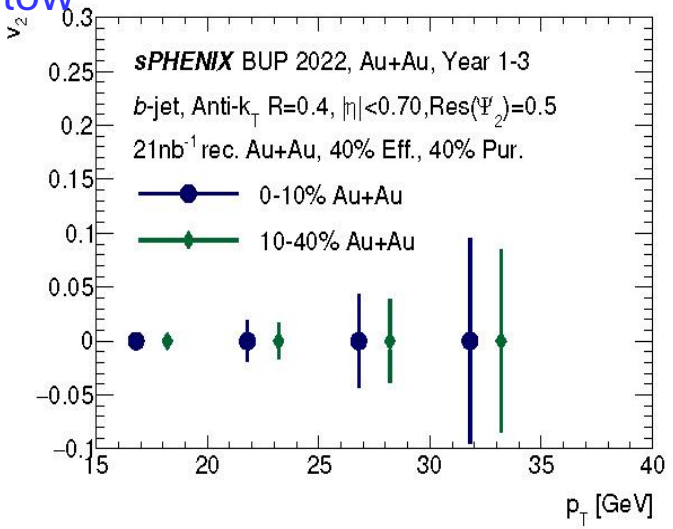
Nuclear modification factor





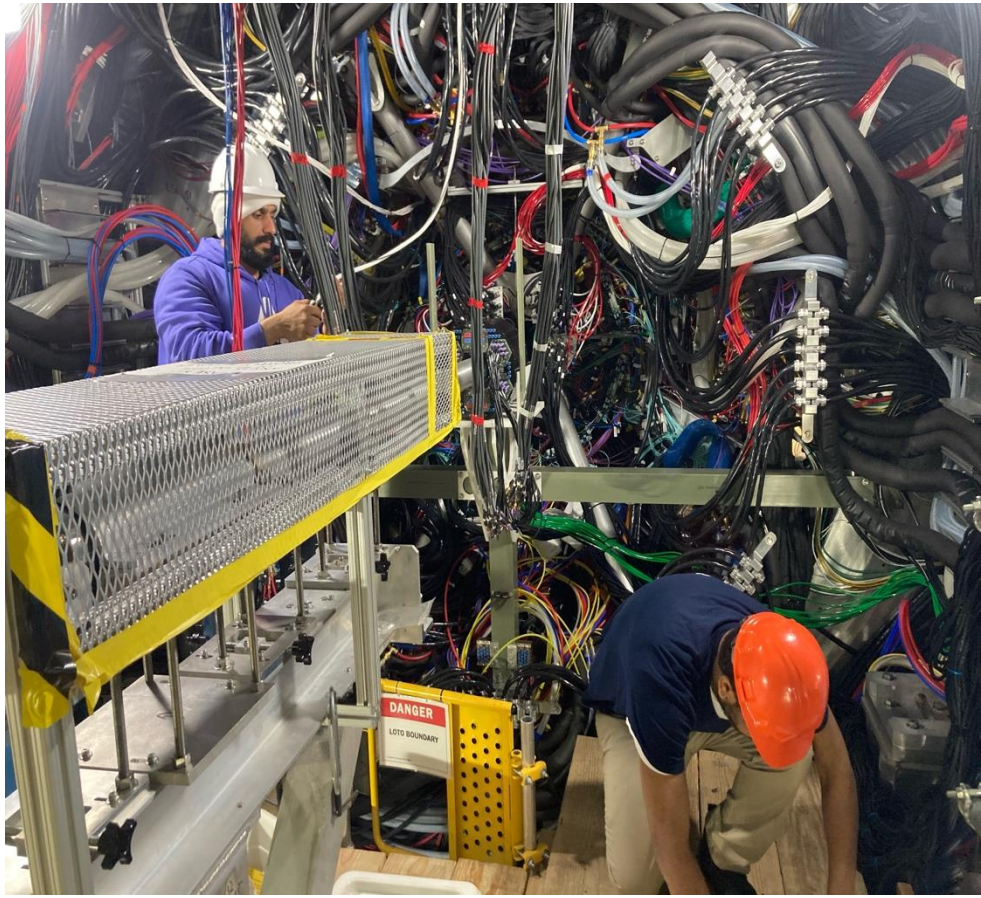
Elliptic Flow





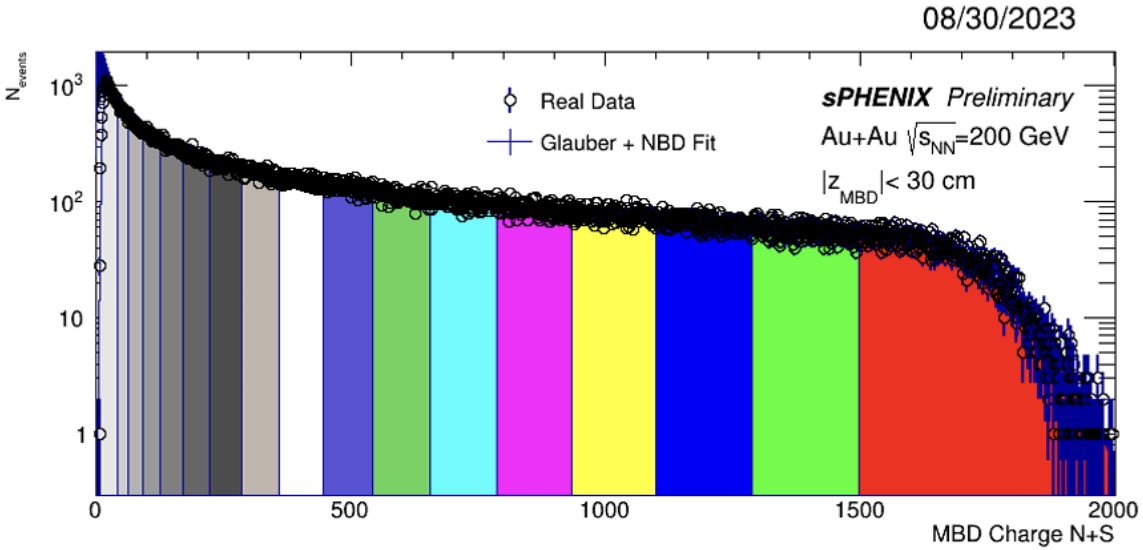
Summary

- sPHENIX studies QGP and Cold-QCD at RHIC in BNL.
  - 2024: $p^{\uparrow}$ + $p^{\uparrow}$ data taking + 3 wks rollover of Au + Au commissioning.
  - 2025: Au + Au data taking (higher statistics)
- Physics: Jet / Heavy flavor / Cold-QCD
- Currently, Run24 is ongoing with all subsystems commissioned

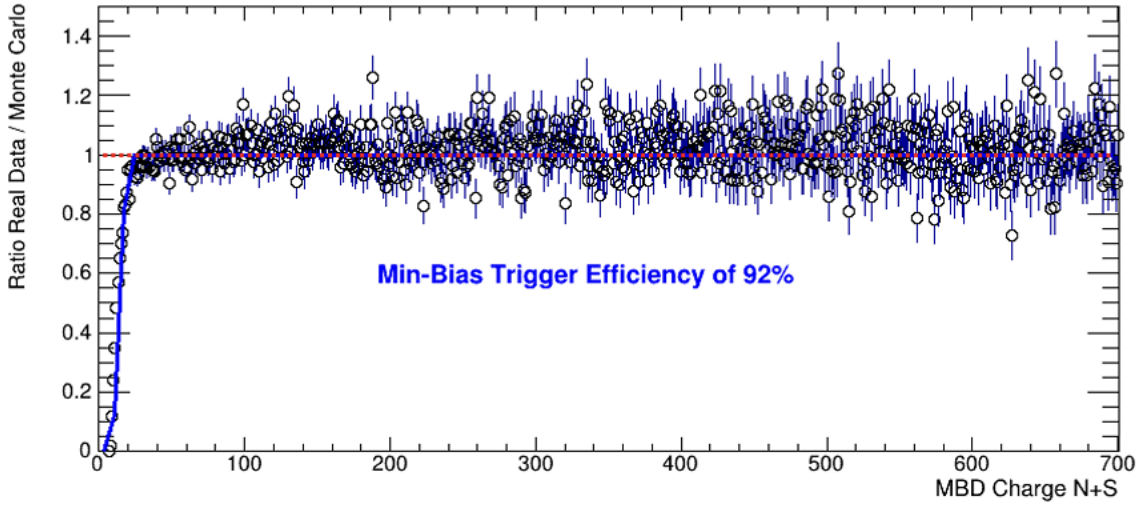


BACKUP

Centrality in sPHENIX

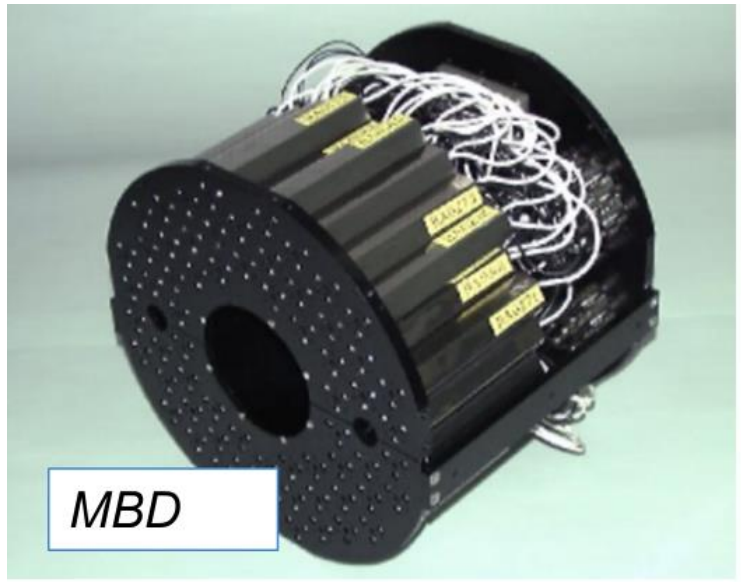


MBD total charge distributions matches well with the NBD-Glauber model



Ratio plot indicates high efficiency of MBD 92%

Global detectors



Three Global detectors used for event characterization:

- Min-bias Detector (MBD)
- Zero Degree Calorimeter (ZDC)
- sPHENIX Event Plane Detector (sEPD)