Quarkonium Measurements at the SPHENIX experiment at RHIC

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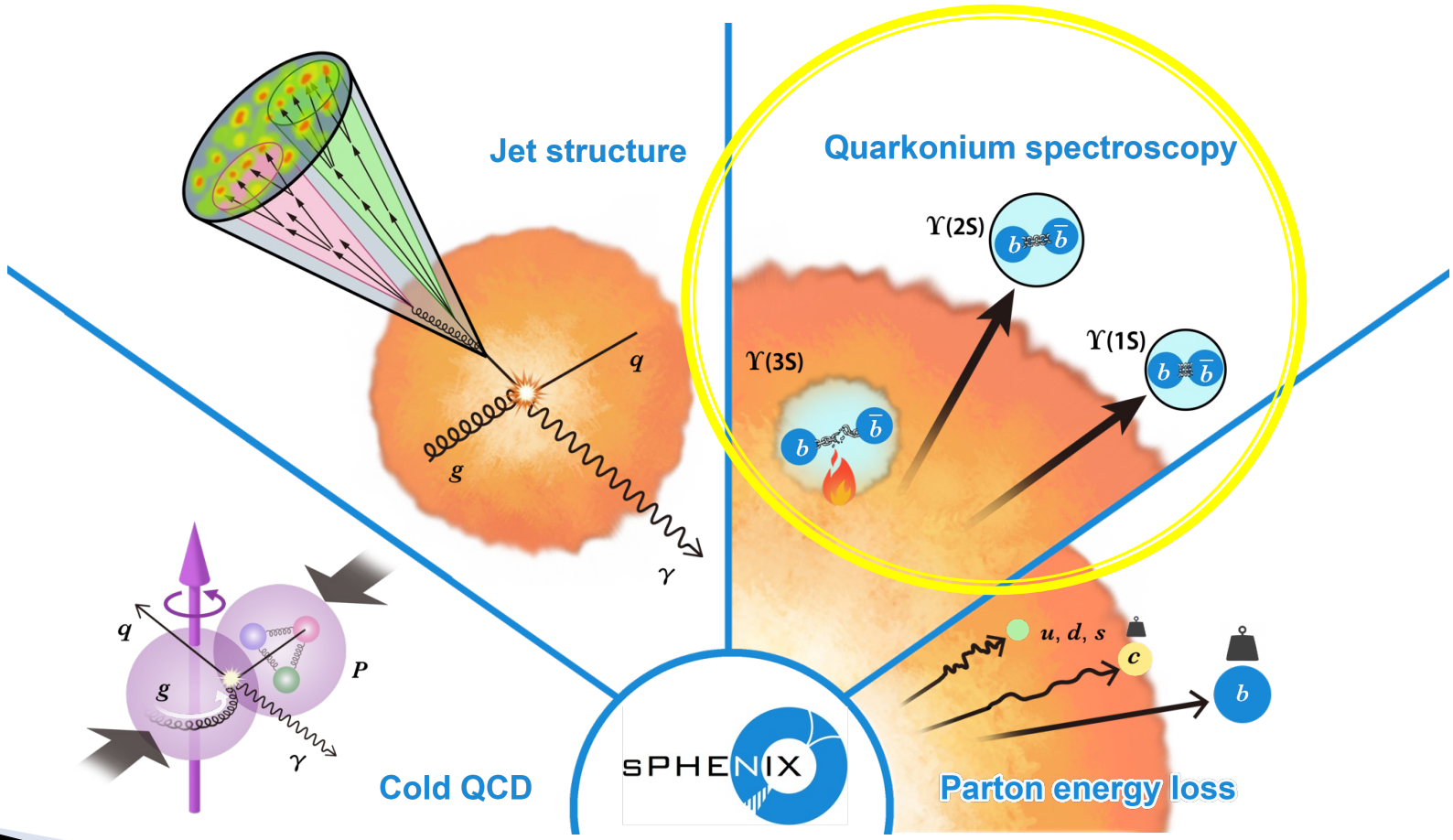
on behalf of sPHENIX Collaboration

RHIC/AGS Users Meeting Workshop – June 12, 2024

Outline

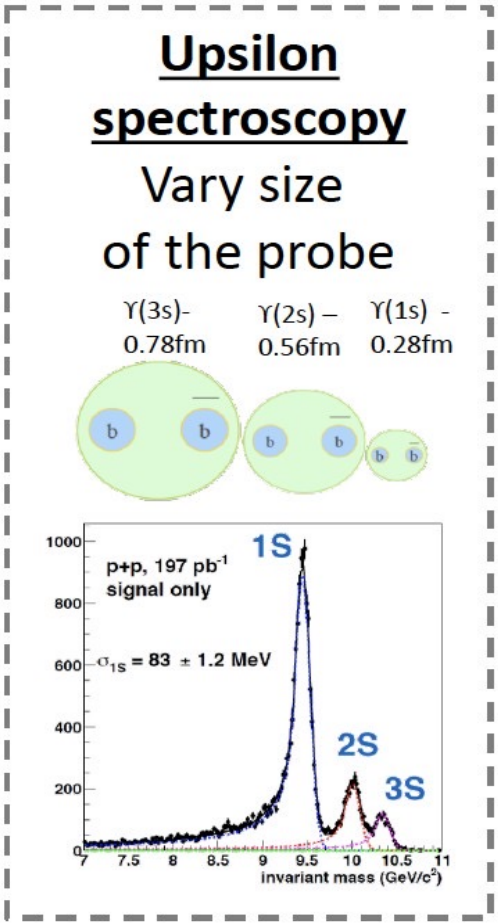
- sPHENIX science mission and sPHENIX detector
- Detecting Quarkonium Dielectron decays
- Projected results and commissioning update

Pillars of the sPHENIX Scientific Program



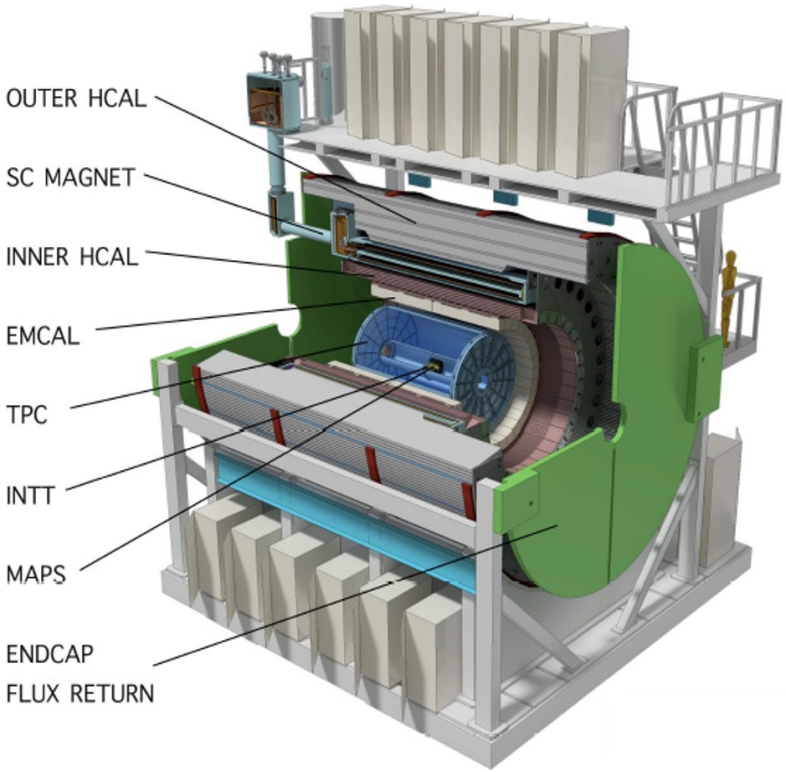
Courtesy of Misaki Ouchida

sPHENIX Core Physics Program



- Guided by the science mission, sPHENIX aims to : probe the QGP in different ways :
  - Vary probe's momentum and angular scale
  - Vary probe's mass and momentum
  - Vary probe's size

sPHENIX Detector Overview



Calorimetry

- Outer Hadronic Calorimeter (oHCAL)
- Inner Hadronic Calorimeter (iHCAL)
- Electromagnetic Calorimeter (EMCAL)

Magnet

- 1.4T superconducting solenoid used by the BaBar experiment

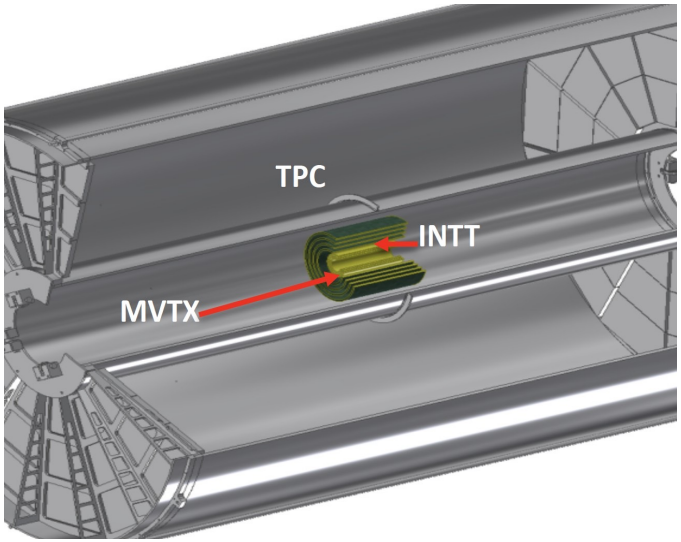
Tracking

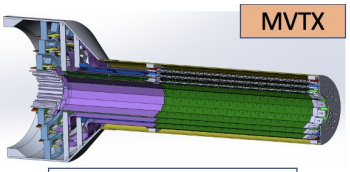
- Time Projection Chamber (TPC)
- Intermediate Silicon Tracker (INTT)
- MAPS-based Vertex Tracker (MVTX)

Performance

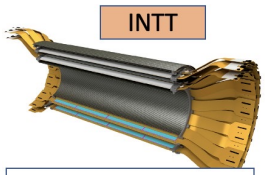
- **High data rate :** read out rate of 15 kHz for all subdetectors
- **Acceptance :** hermetic coverage over full azimuth & pseudorapidity $|\eta| \leq 1.1$ for the tracking & calorimeter systems

sPHENIX Tracking System

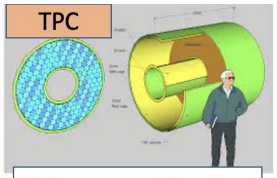




2.3 cm < r < 3.9 cm



6 cm < r < 12 cm



20 cm < r < 78 cm

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 μm for tracks with $p_T > 1$ GeV

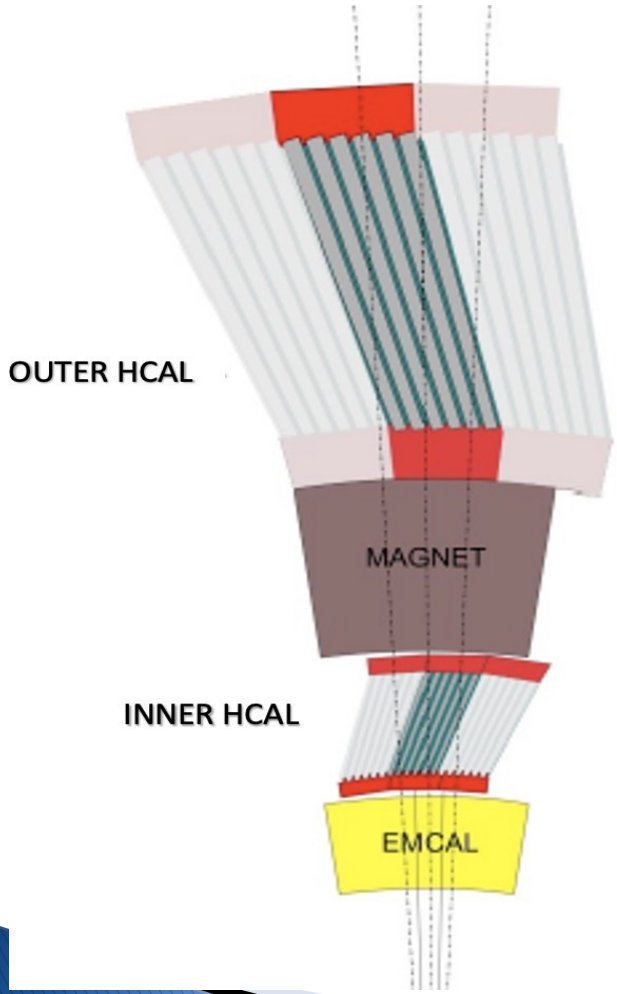
INTT : *pileup event separation*

- Silicon strip detector surrounding the MVTX
- Associates fully reconstructed tracks with the event that produced them

TPC : *momentum measurement*

- Compact (r = 80 cm) & main tracking element filled with Ne-CF_4 gas mixture
- Ungated, with GEM-based read out, spatial resolution of < 200 μm

sPHENIX Calorimeter System



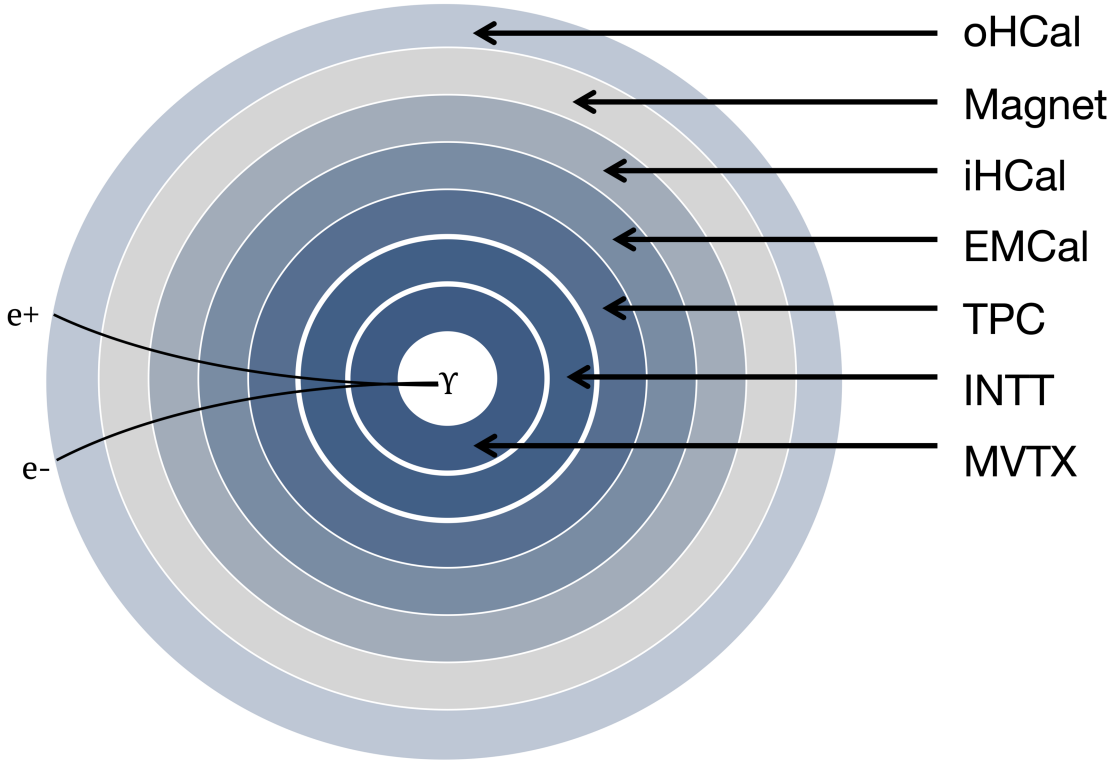
Hadronic calorimetry

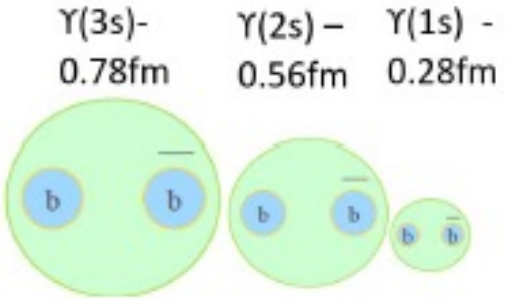
- First at RHIC (at mid-rapidity)
- Plastic scintillating tiles + tilted steel plates with embedded WLS fibers (oHCAL) ; scintillating tiles + Al plates for the iHCAL
- Overall tile segmentation of $\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$

Electromagnetic calorimetry

- Scintillating fibers in tungsten and epoxy
- High segmentation for HI collisions : $\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$
- Good energy resolution : $\sigma_E/E < 15\%/\sqrt{E}$

Quarkonium Dielectron Decays

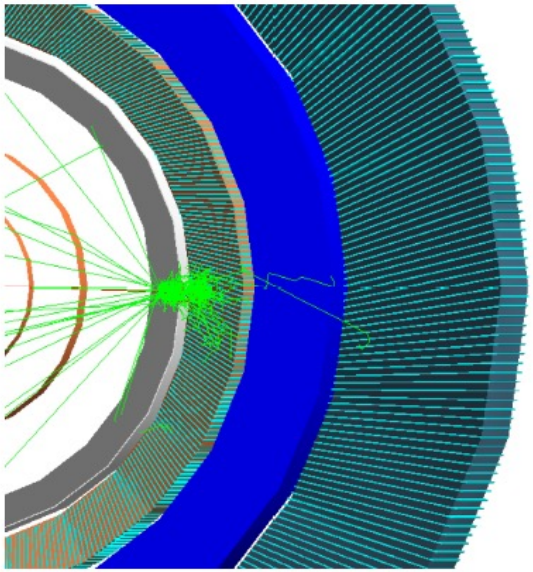




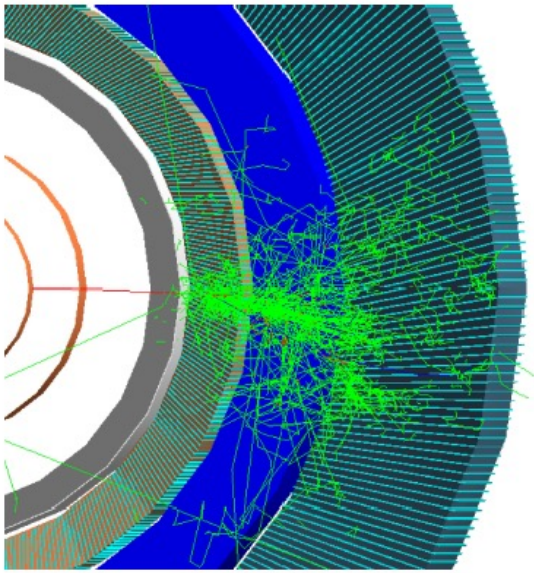
ϒ (1S, 2S, 3S) measurements probe QGP at different length scales.

Electron/Pion Separation

10Gev electron

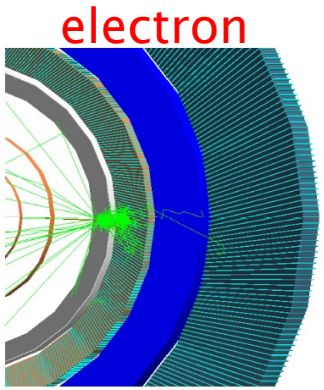


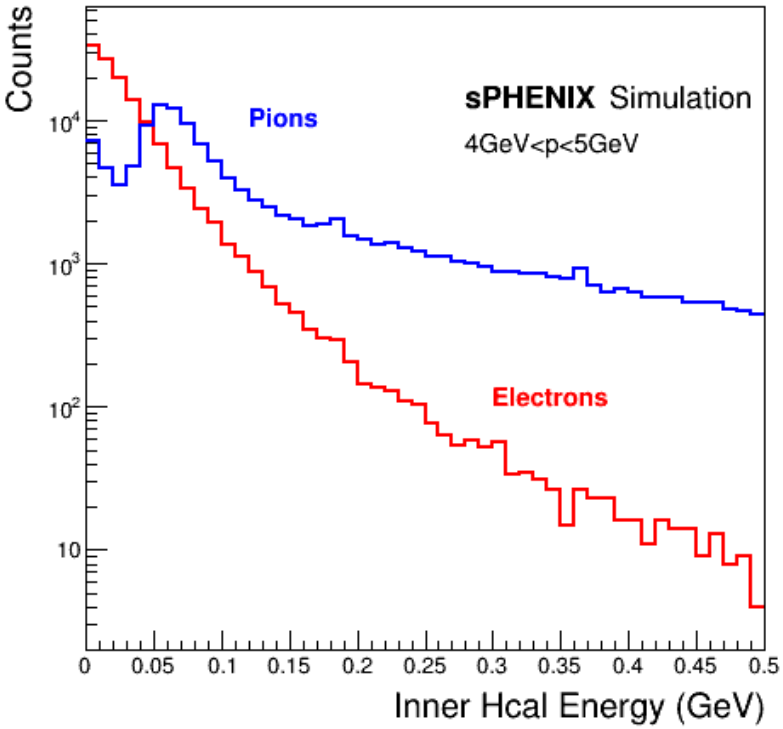
10Gev pion

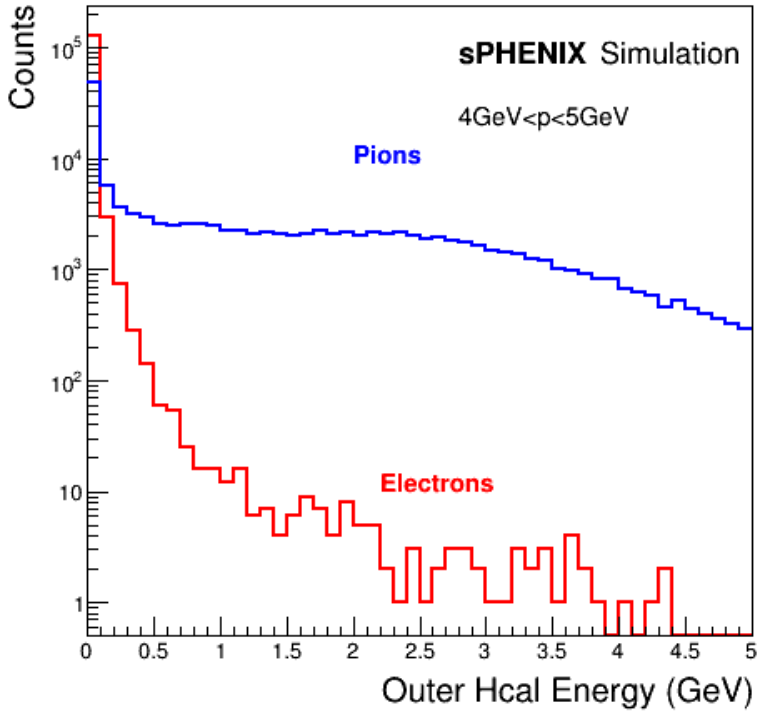


- Electron deposit most of the energy in EmCal (grey) while pion start showering in the Inner HCal

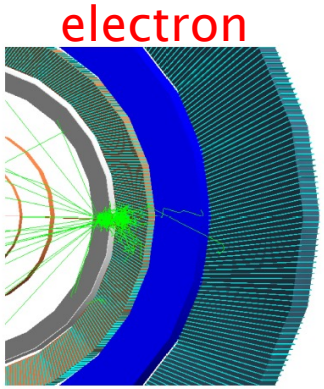
Hadronic Calorimeters

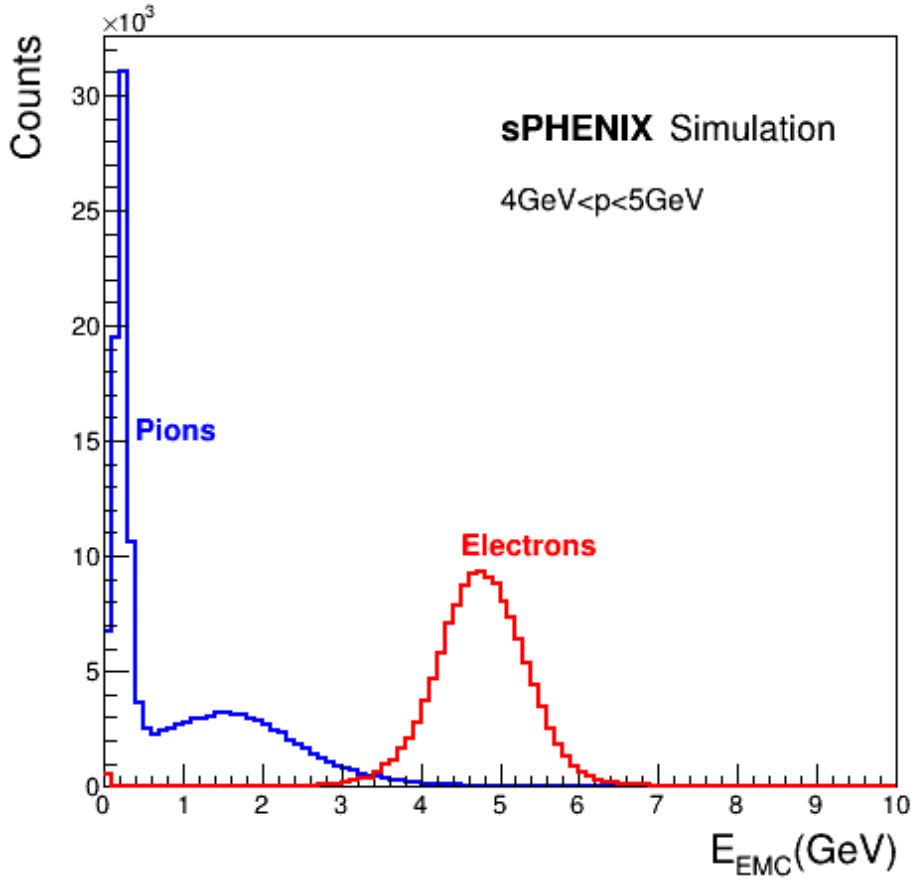






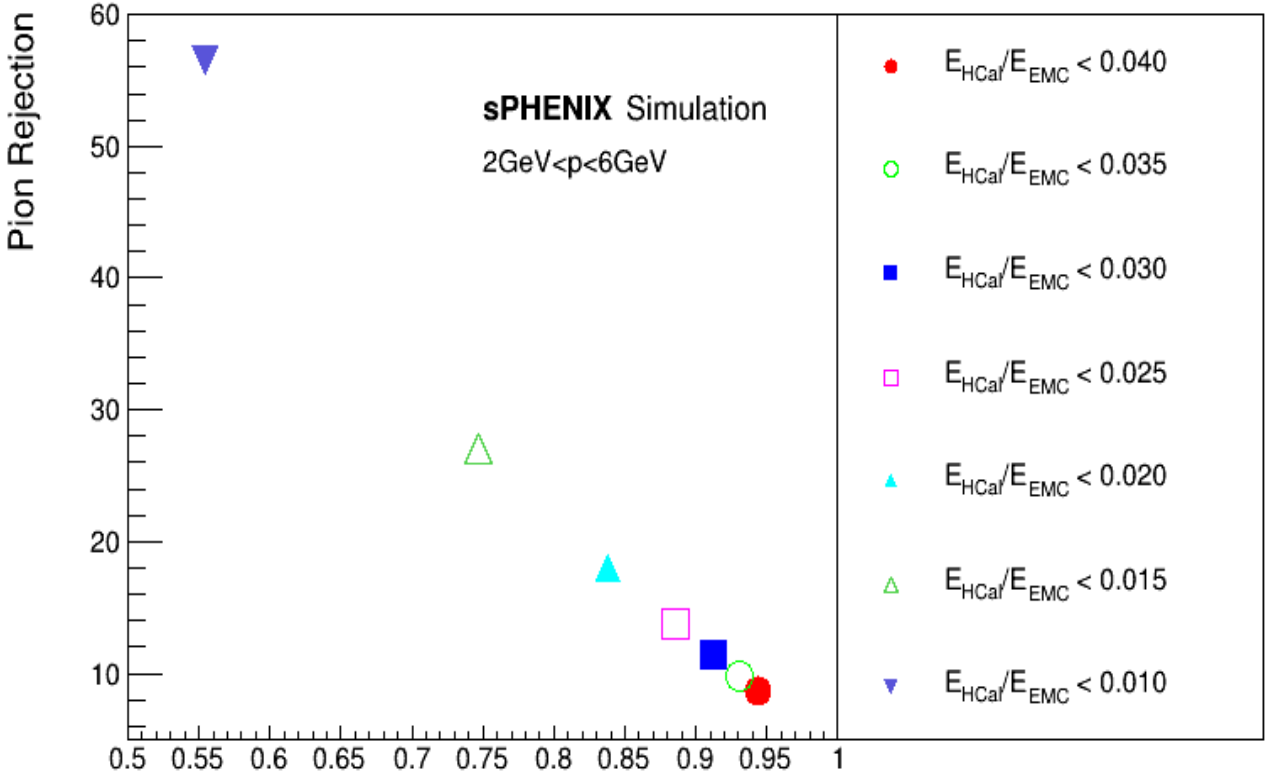
Electromagnetic Calorimeter



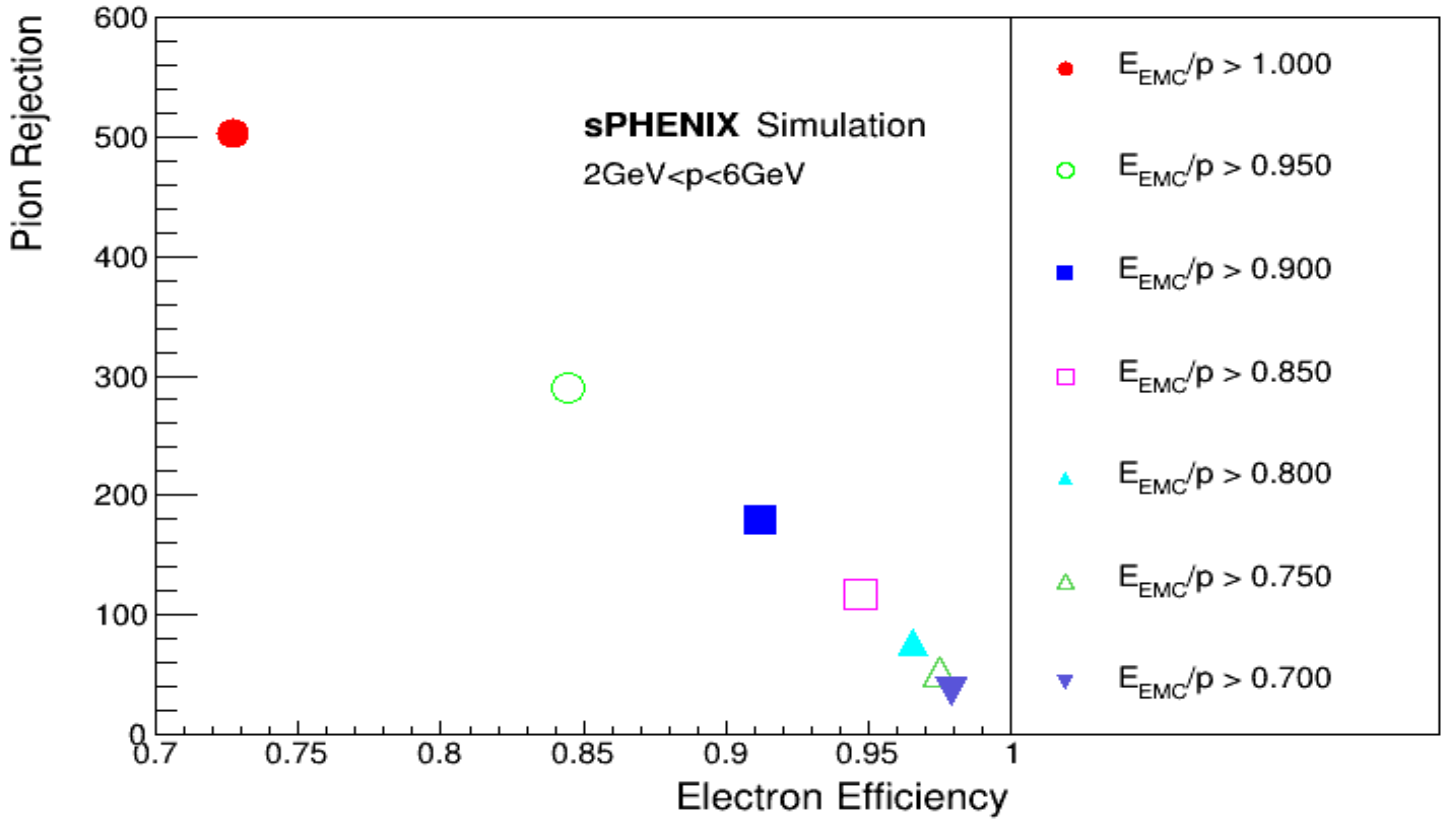


Pion Rejection with Calorimeters

Using the hadronic to electromagnetic energy ratio we evaluate pion rejection vs electron identification efficiency

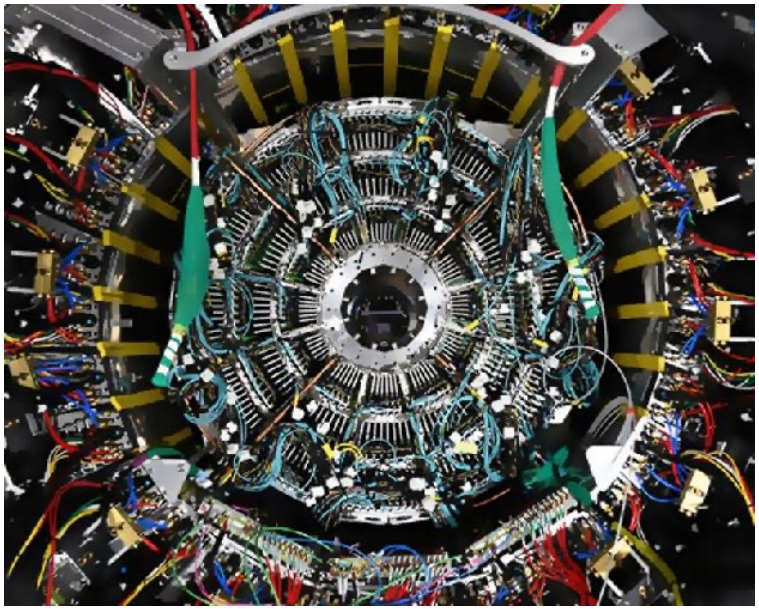


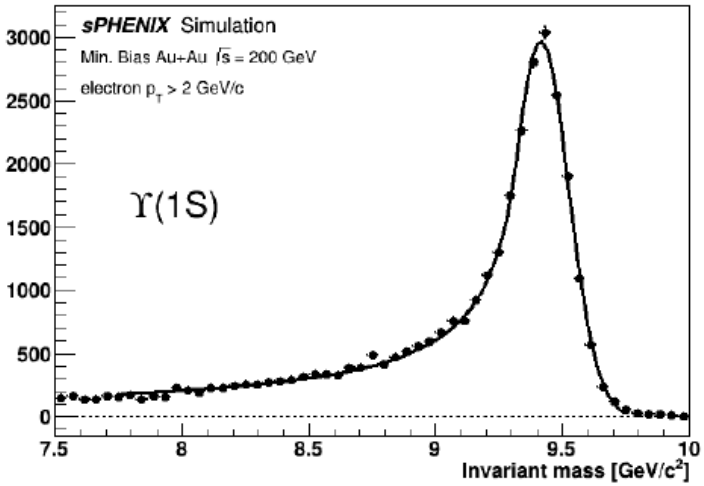
Pion Rejection with Calorimeters And Tracking



For more details see Andrew Clarke's **poster** tomorrow

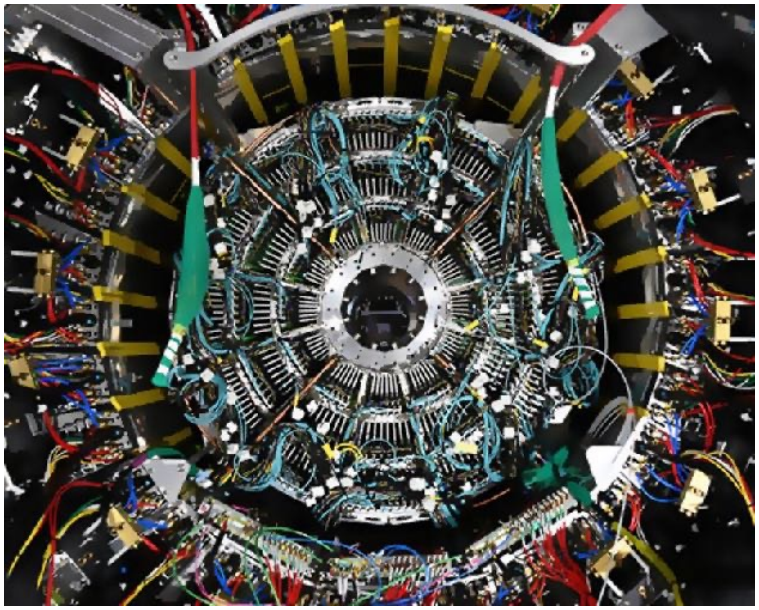
ϒ mass resolution

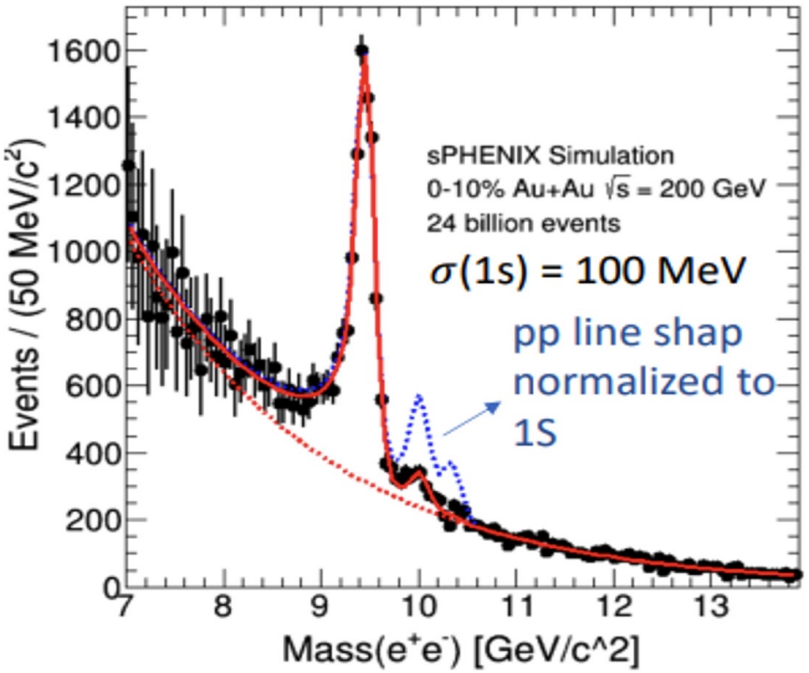




sPHENIX TPC provides invariant mass resolution better than 100 MeV/c^2 for the ϒ di-electron channel.

ϒ mass resolution





sPHENIX TPC provides invariant mass resolution better than 100 MeV/c^2 for the ϒ di-electron channel.

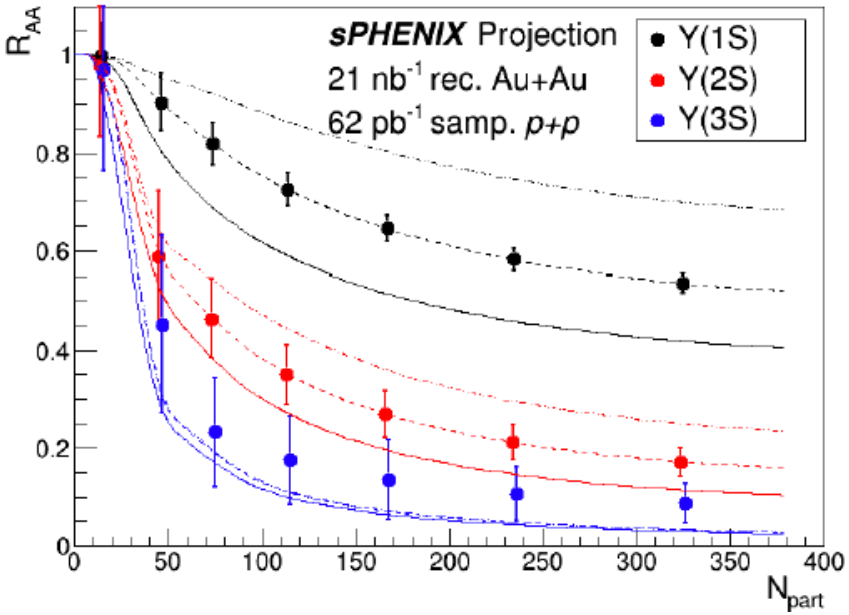
Quarkonium Projections

- Nominal Run Plan and Reality

Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z\rvert$ <10 cm	Samp. Lum. $\lvert z\rvert$ <10 cm
2023	Au+Au	200	24 (28)	9 (13)	3.7 (5.7) nb^{-1}	~~4.5 (6.9) nb^{-1}~~
2024	$p^{\uparrow}p^{\uparrow}$	200	24 (28)	12 (16)	0.3 (0.4) pb^{-1} [5 kHz] 4.5 (6.2) pb^{-1} [10%-*str*]	45 (62) pb^{-1}
~~2024~~	~~$p^{\uparrow}$+Au~~	~~200~~	~~–~~	~~5~~	~~0.003 pb^{-1} [5 kHz]~~ 0.01 pb^{-1} [10%-*str*]	~~0.11 pb^{-1}~~
2025	Au+Au	200	24 (28)	20.5 (24.5)	13 (15) nb^{-1}	21 (25) nb^{-1}

sPHENIX Probes : Upsilon Spectroscopy

- Three year running plan assumed for the plots
- Y(3S) projection based on Y(3S) suppression reported by CMS at LHC



- Projected statistical uncertainties for the R_{AA} of the Y(1*S*) , Y(2*S*) and Y(3*S*) states as a function of N_{part}

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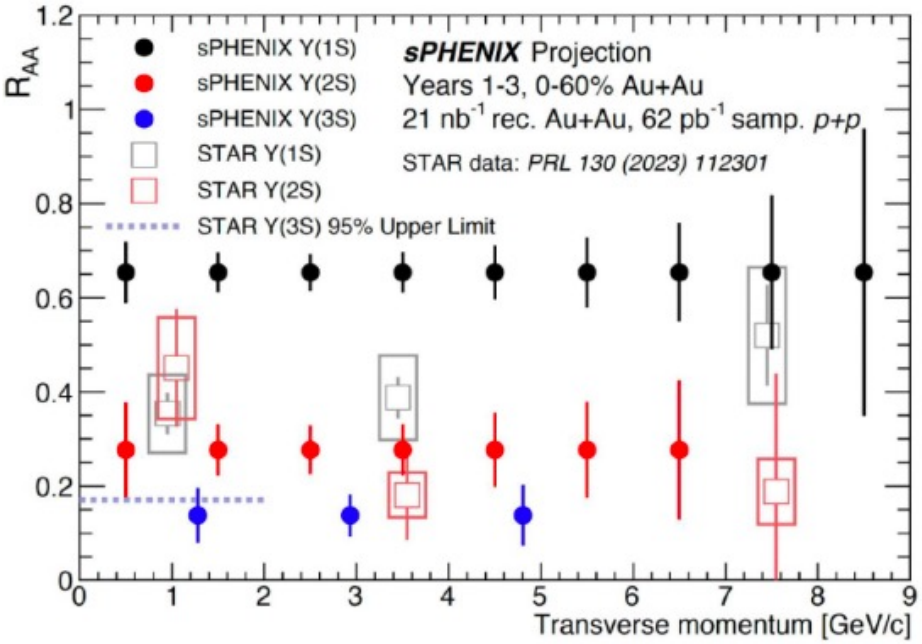

- Projected statistical uncertainties for the R_{AA} of the Y(1*S*) , Y(2*S*) and Y(3*S*) states as a function of *Transverse Momentum*

sPHENIX Probes : Upsilon Spectroscopy

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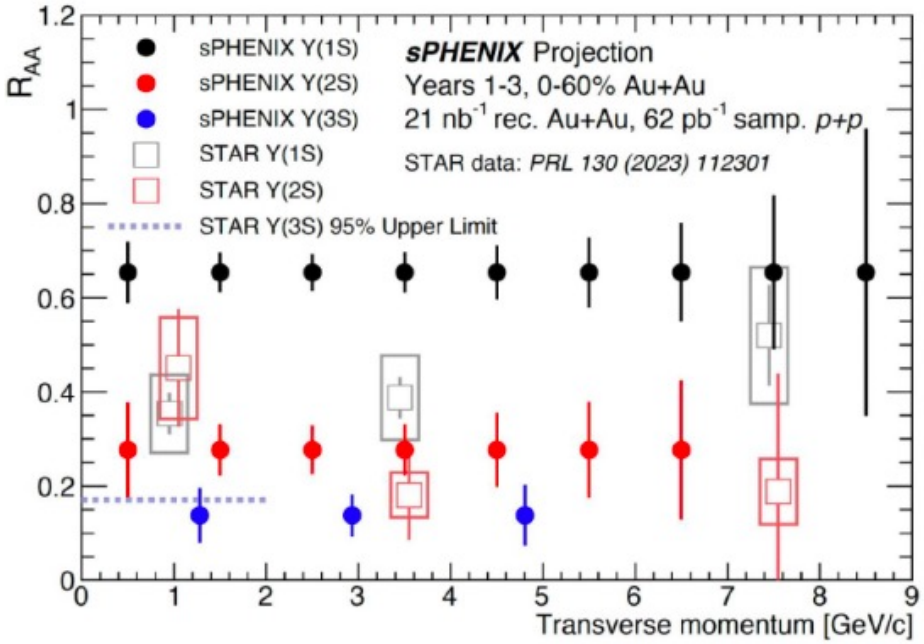
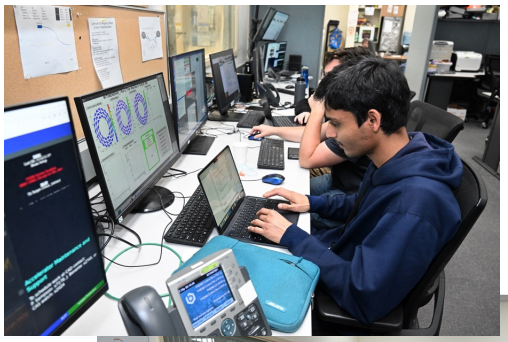


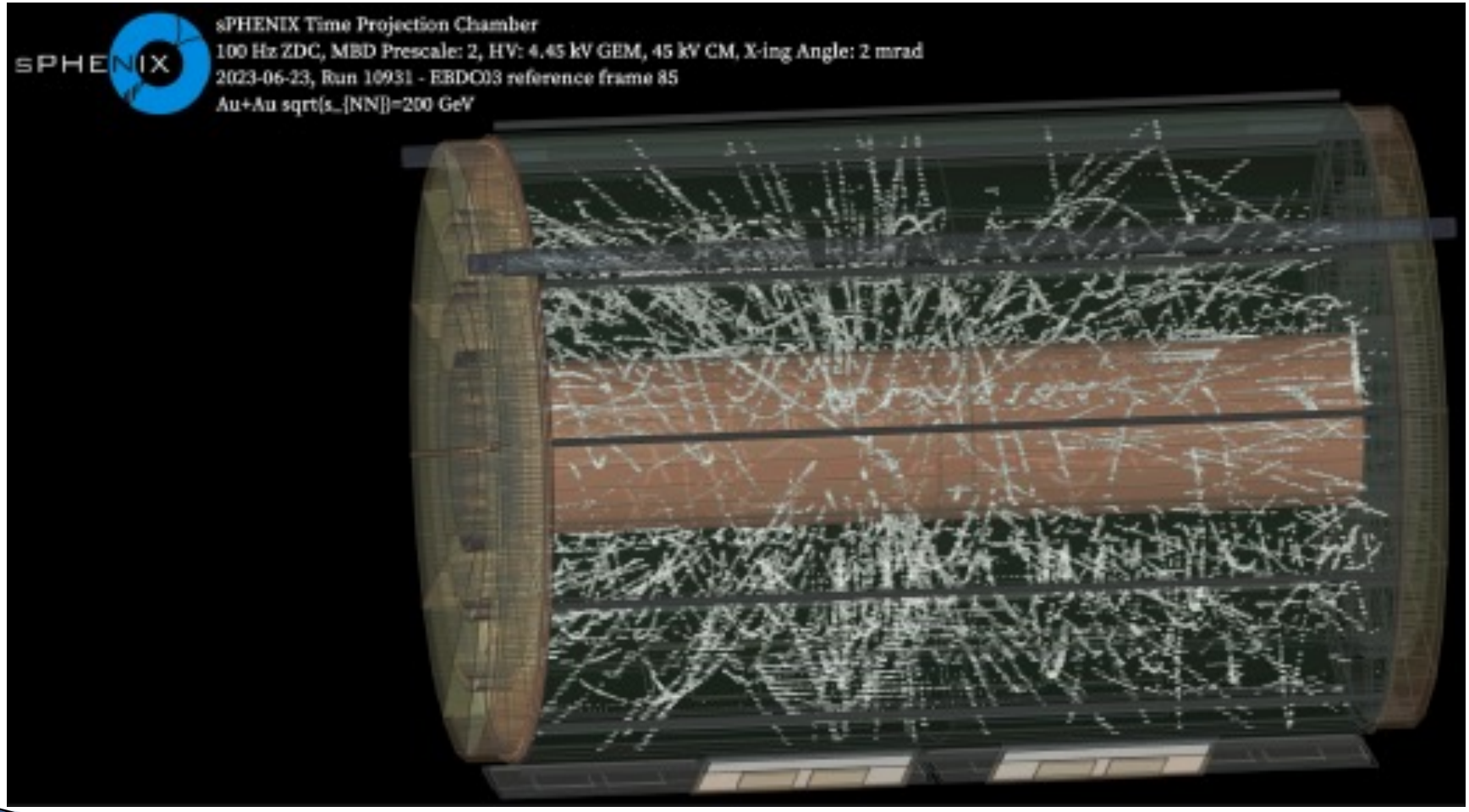
- Clear separation of Υ states allows for comparison between RHIC and LHC measurements
- Crucial measurement, since the temperature profiles from hydrodynamic calculations show important differences with collision energy

Detector Commissioning

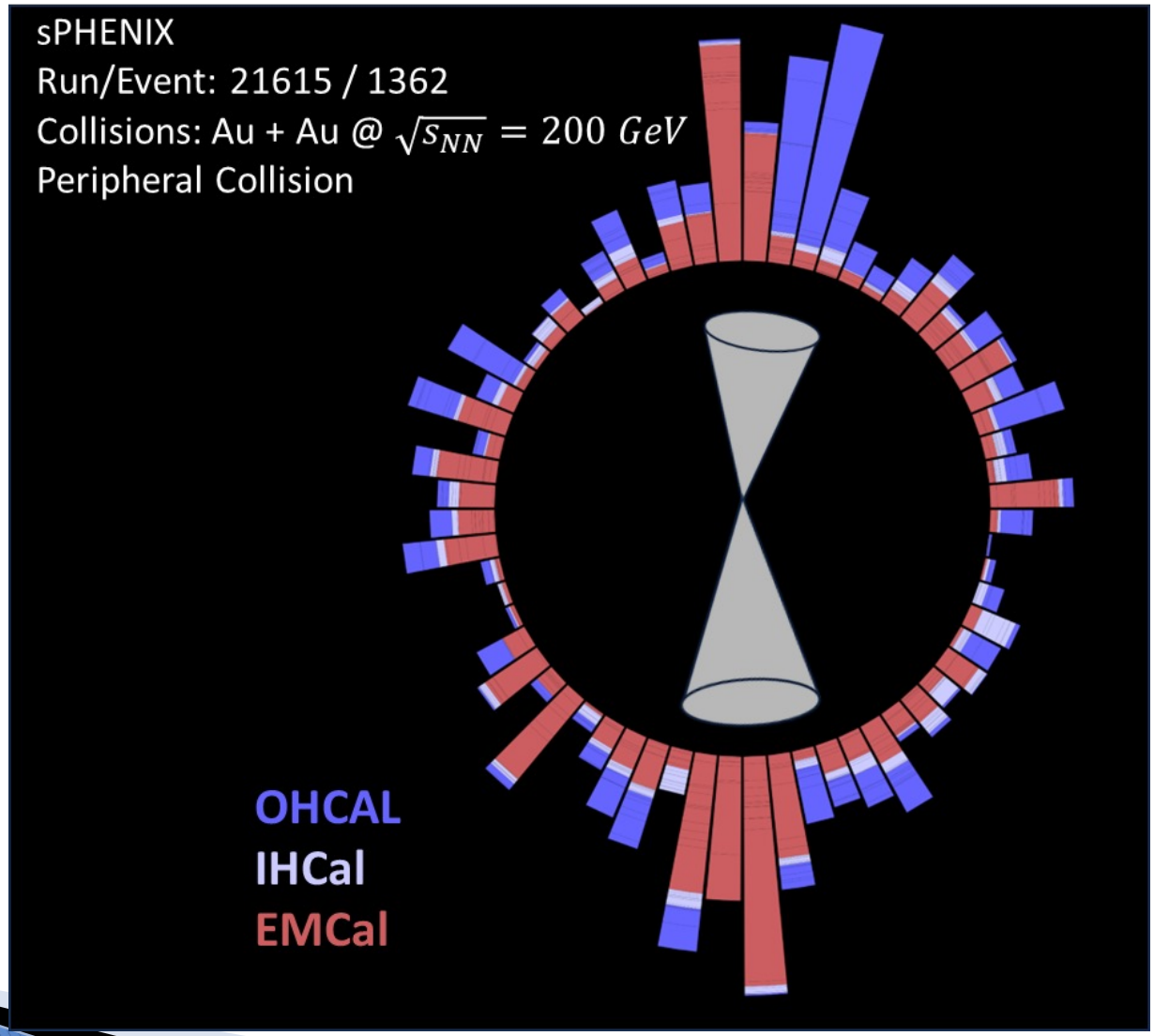
- Significant progress achieved during RHIC Run23 despite the early termination of the run with collision data observed by each of the detector subsystem.
- Commissioning effort is continuing into Run24 and we are nearing completion of the process



Au+Au “event” in TPC

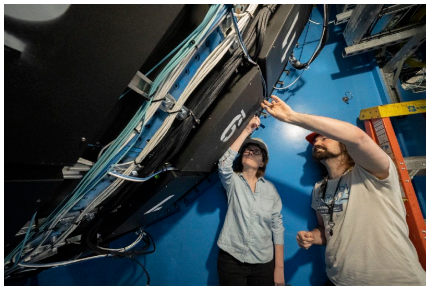


Full calorimeter jets event display



sPHENIX Collaboration Meeting May 2024

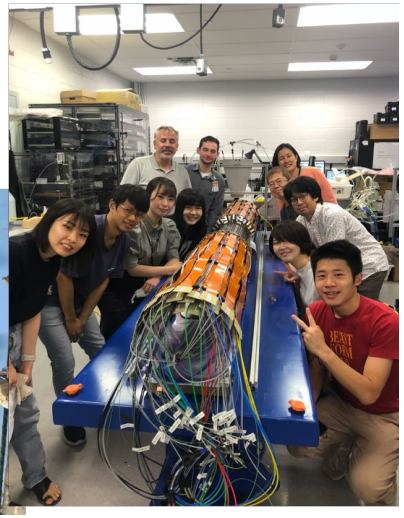
Conclusions


- sPHENIX adds new capabilities to measure bottomonium and high p_T J/ψ at RHIC providing a broad program that is complementary to LHC
- sPHENIX first quarkonium data just around the corner thanks to the efforts of many dedicated Collaborators

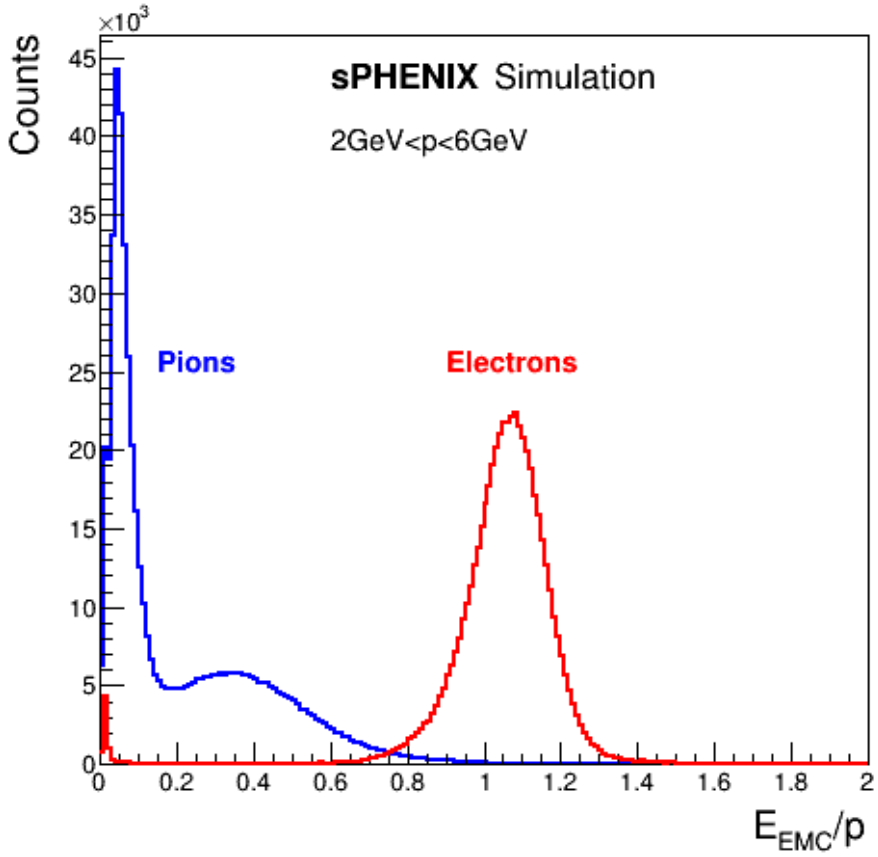
Full set of current and future sPHENIX results:
https://www.sphenix.bnl.gov/PublicResults



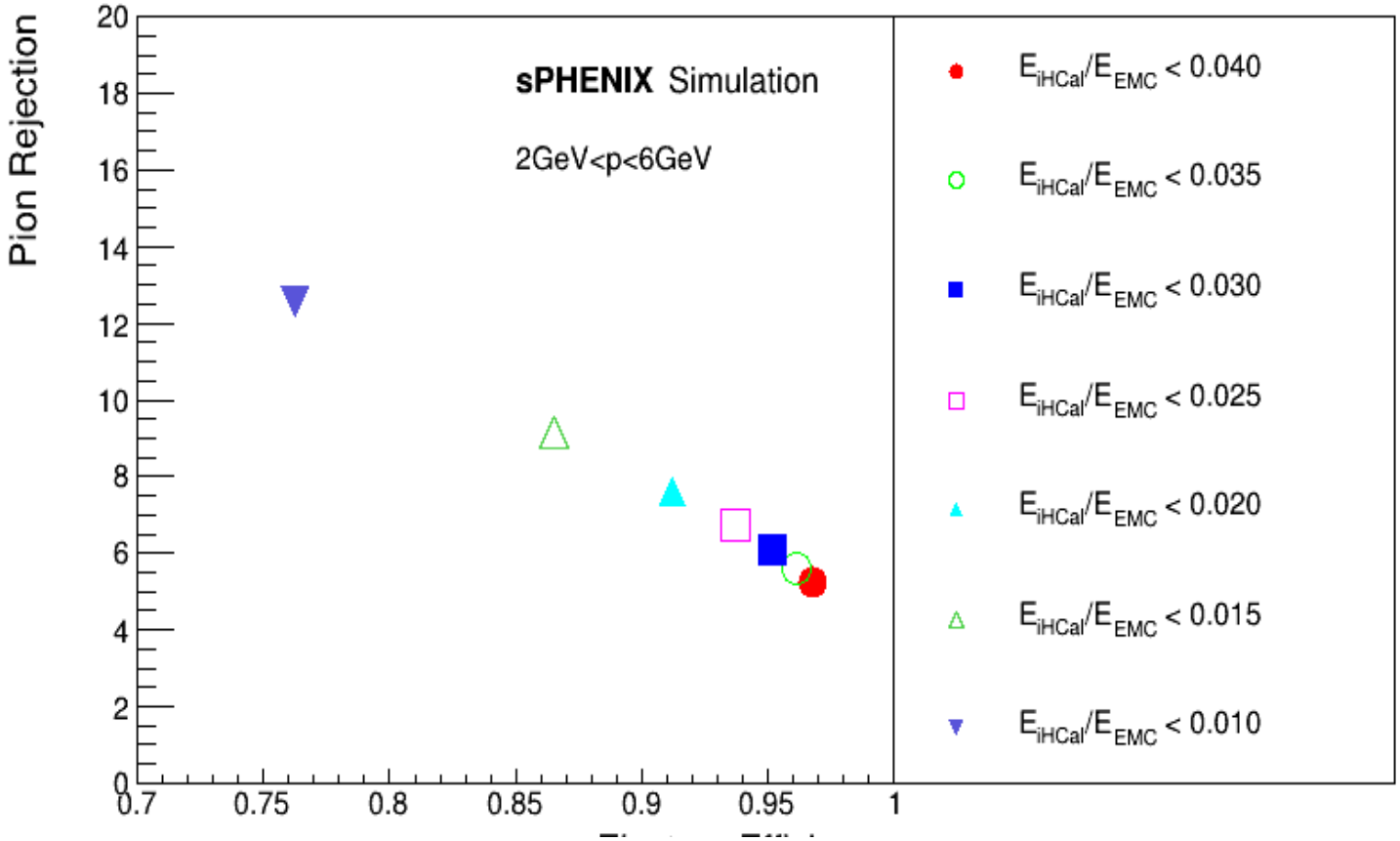



BACKUP

EMCal Energy and Momentum



Inner HCal and EMCal



Inner HCal and EMCal