Status of the sPHENIX experiment

Audrey Francisco

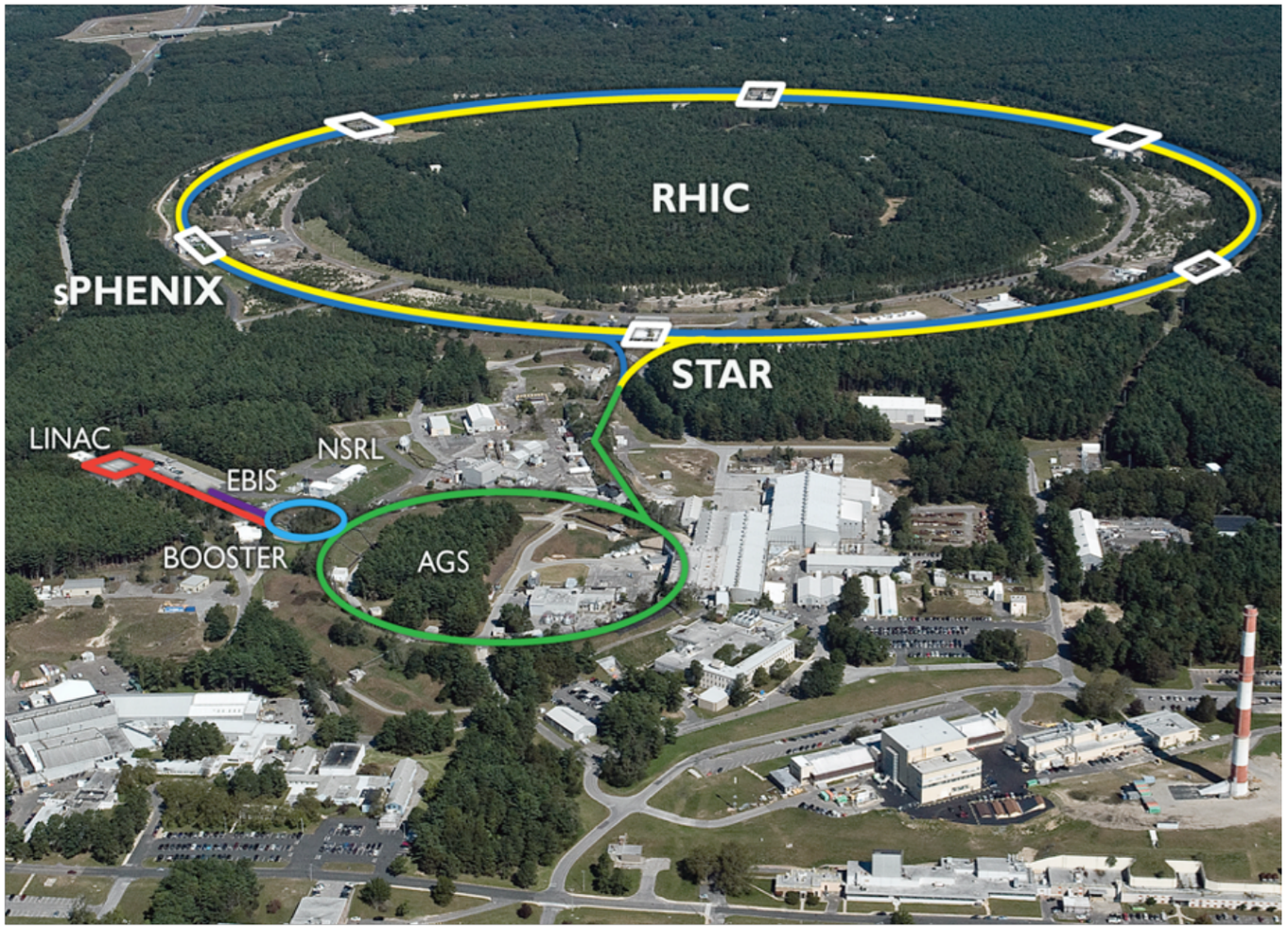
Most of the material was taken from Ejiro Umaka and Ed O'Brien past presentations

Assemblée Générale du GDR de QCD

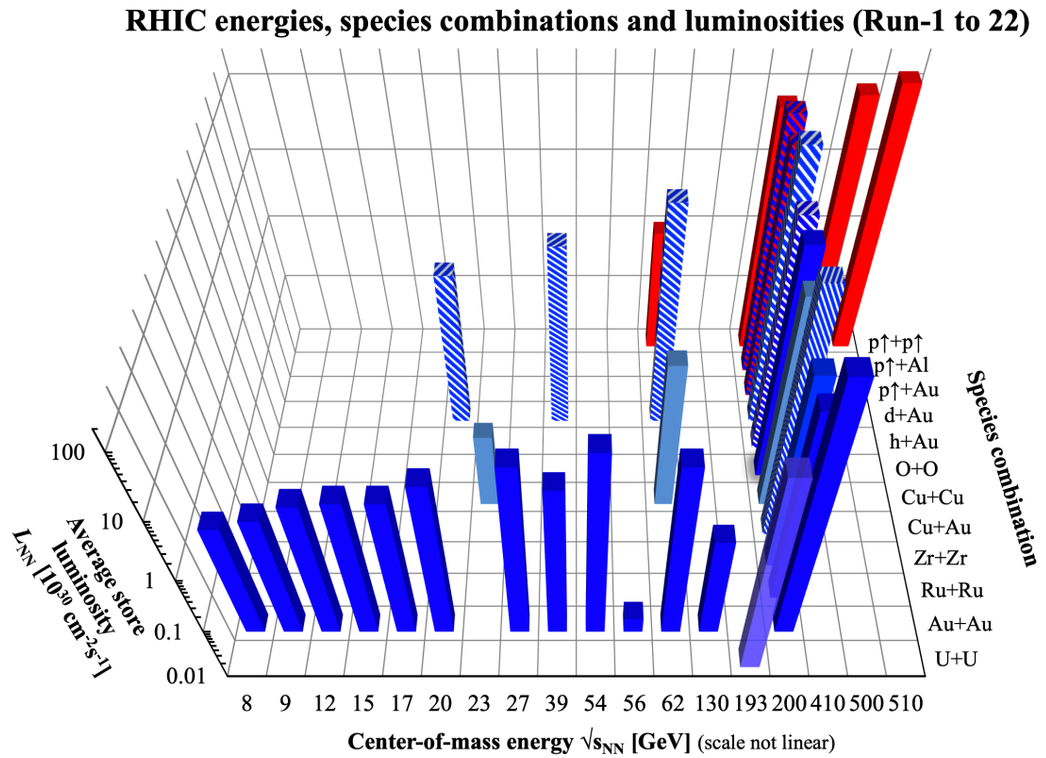
29 September 2023, Strasbourg, France

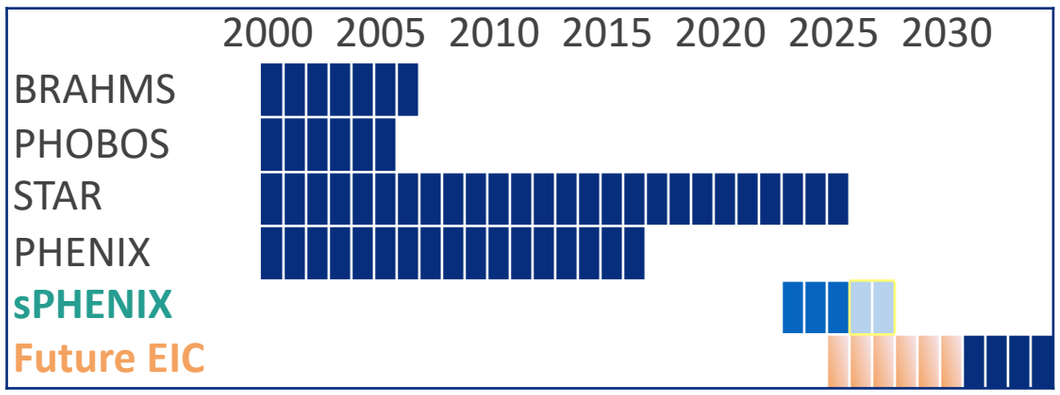
Relatistic Heavy Ion Collider

Located at Brookhaven National Laboratory (Long Island NY, USA)



Past and future data taking





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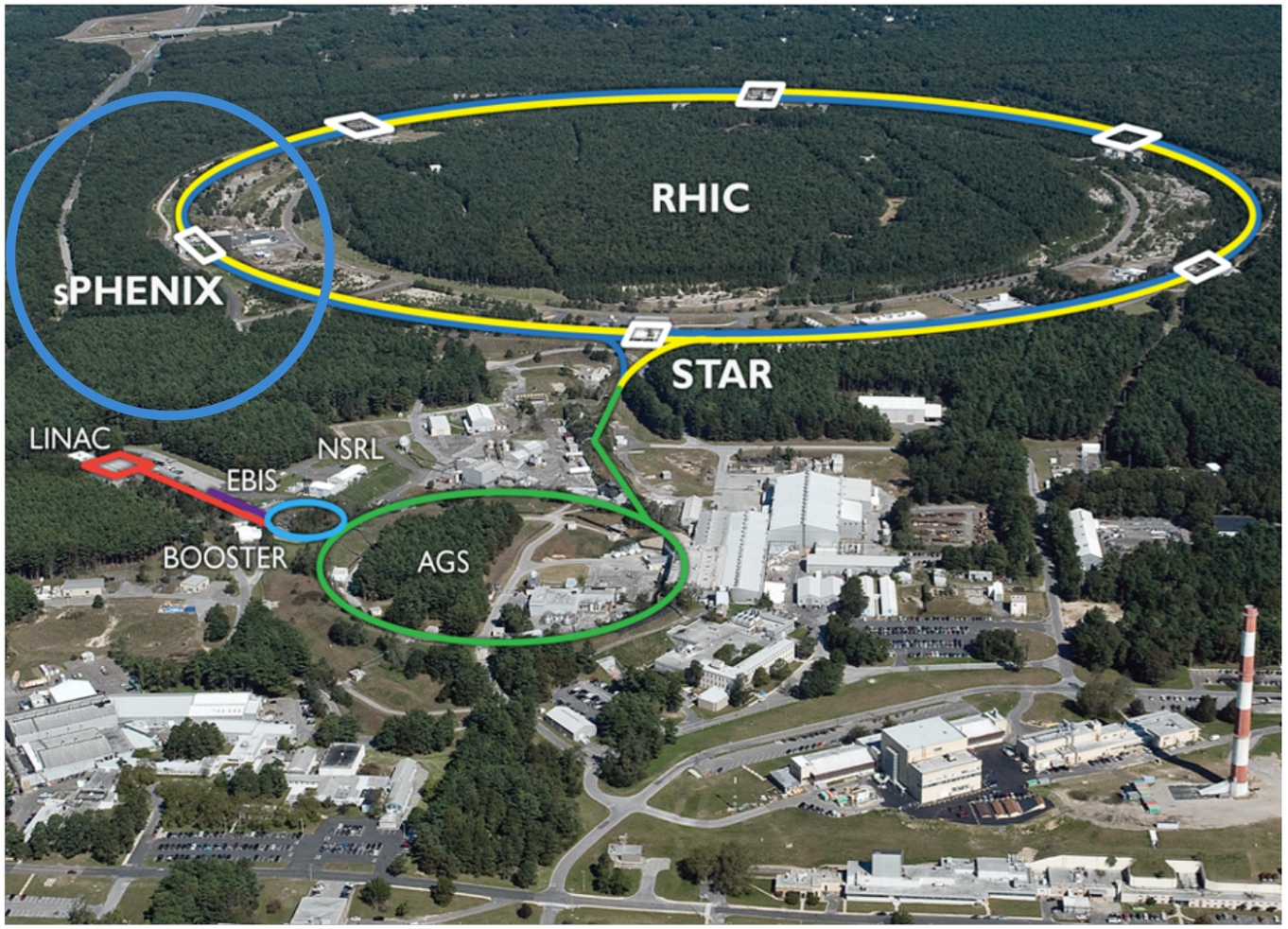

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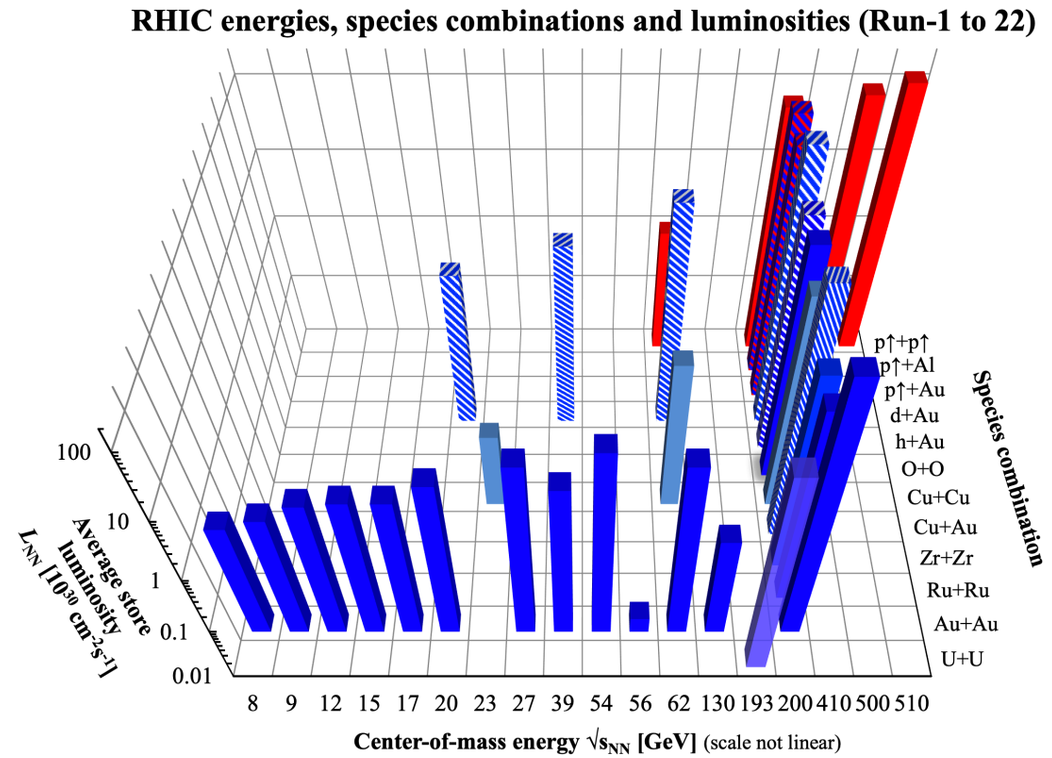
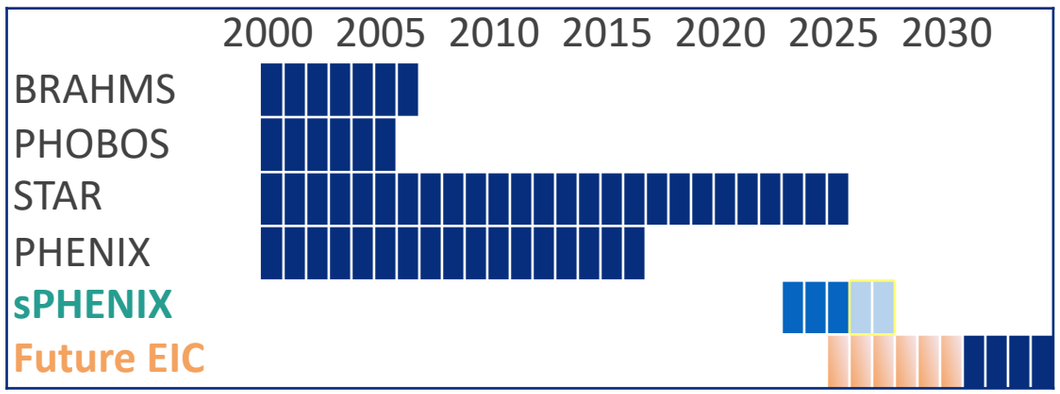


sPHENIX is the first new major detector at RHIC in over 20 years

358 Members

83 Institutions



sPHENIX in a nutshell

Mission: In-depth study QCD phenomena discovered at RHIC

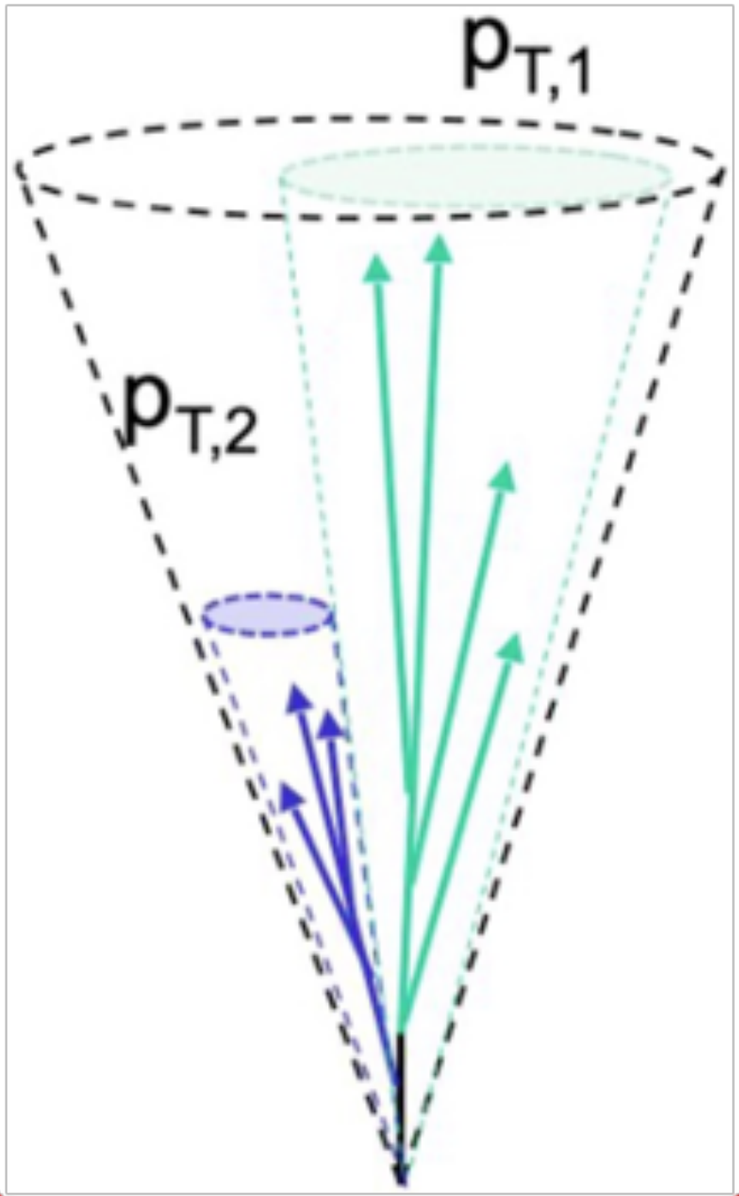
- Focus on **hard probes** (jets and heavy flavor)
- Kinematic reach and capabilities to allow direct comparison to LHC
- Affirmed by DOE 2015 Long Range Plan, BNL RHIC Program Advisory Committee

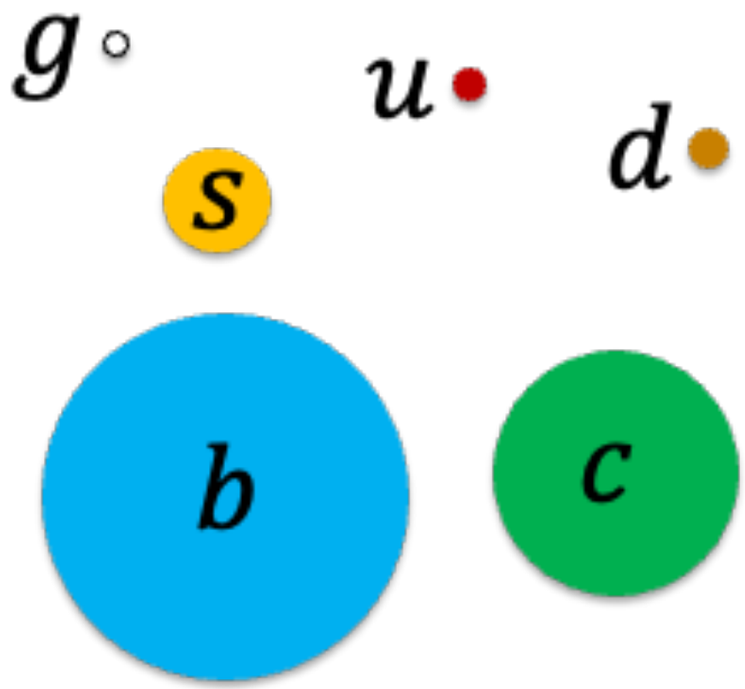
Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo weeks	Physics weeks	$\mathscr{L}_{samp}$ ($\lvert z\rvert < 10$ cm)
2023	Au+Au	200	24	9	4.5 nb^{-1}
2024	p+p	200	24	12	45 pb^{-1}
2024	p+Au	200	-	5	0.11 pb^{-1}
2025	Au+Au	200	24	20.5	21 nb^{-1}

Physics program

Jet Correlations & Structure

vary momentum & angular size of probe



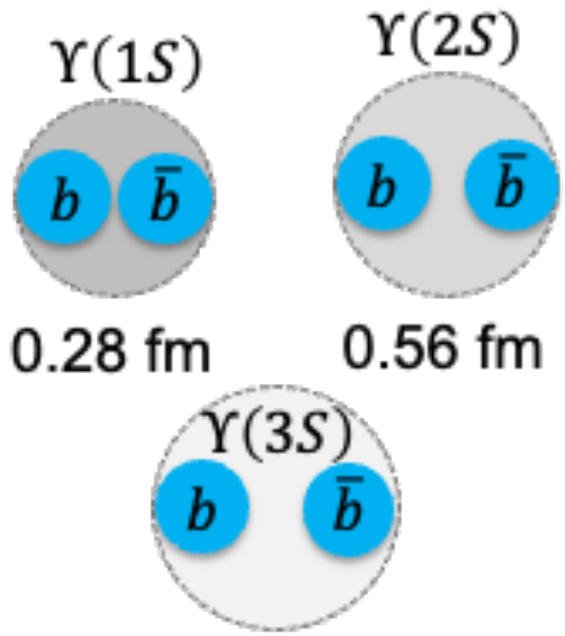


Parton Energy Loss

vary mass & momentum of probe

Quarkonium Spectroscopy

vary size of probe

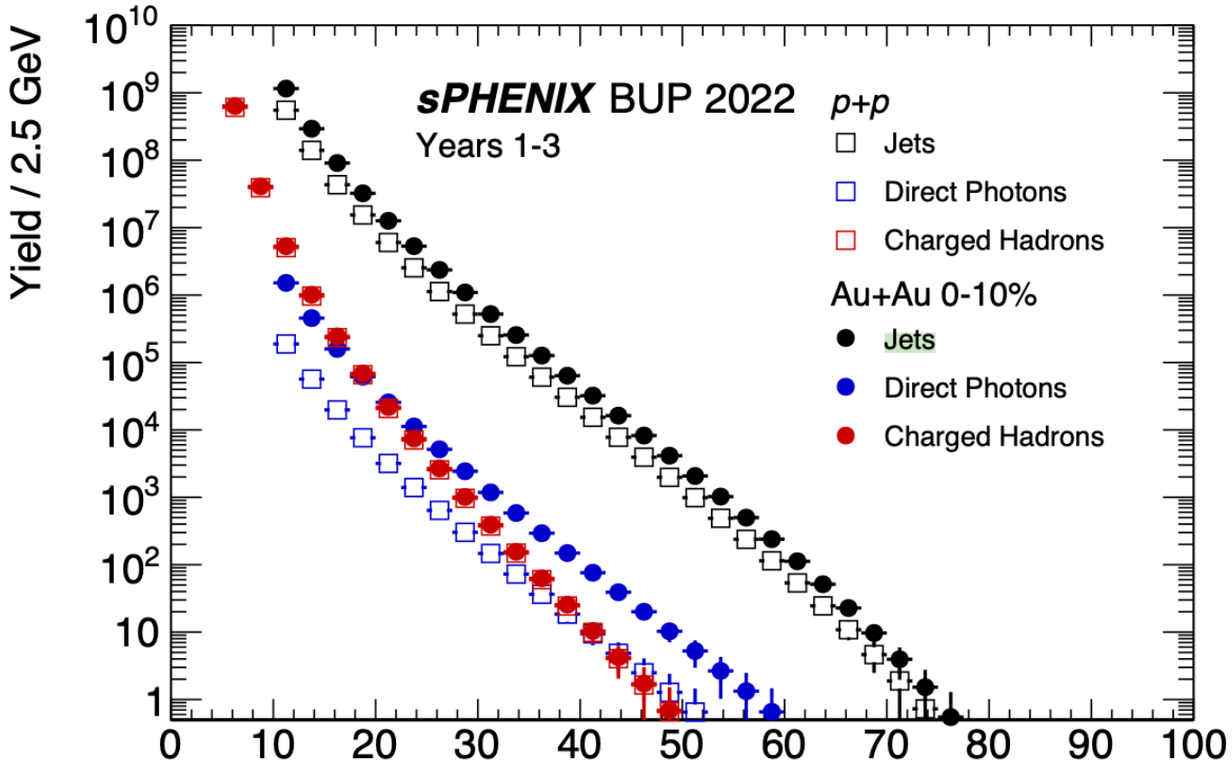


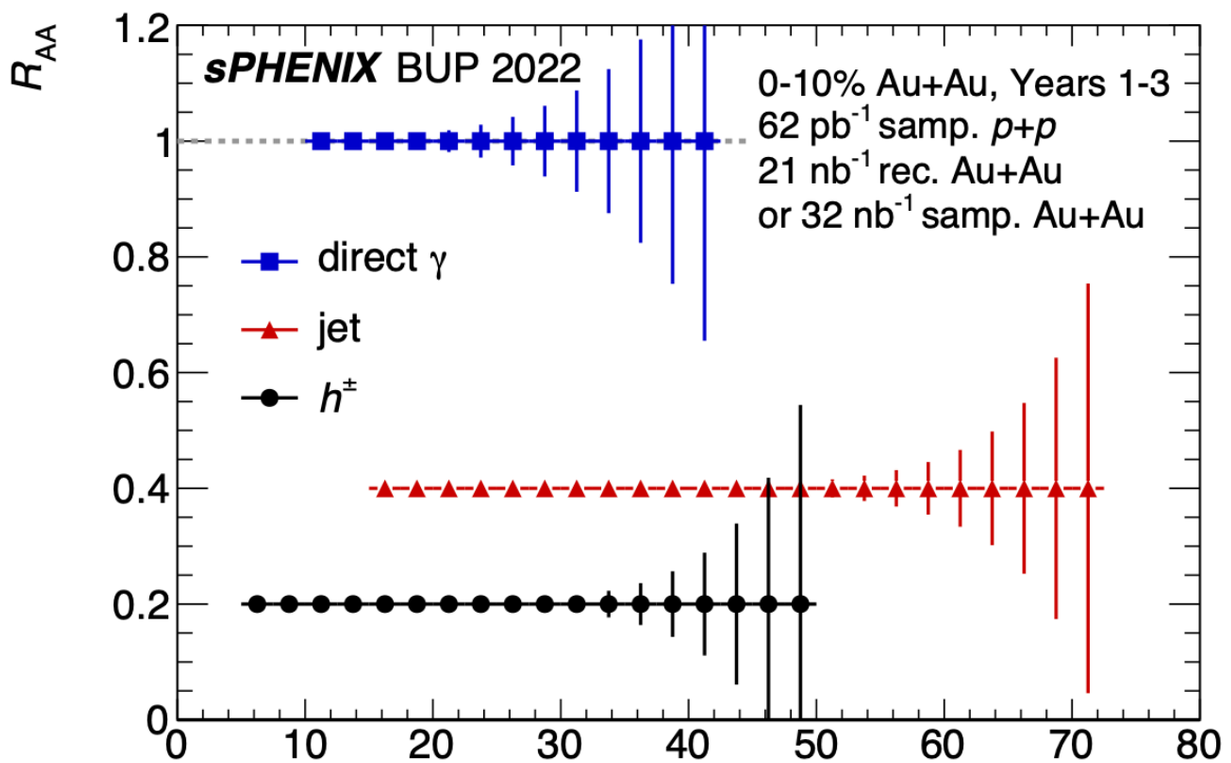
Cold QCD

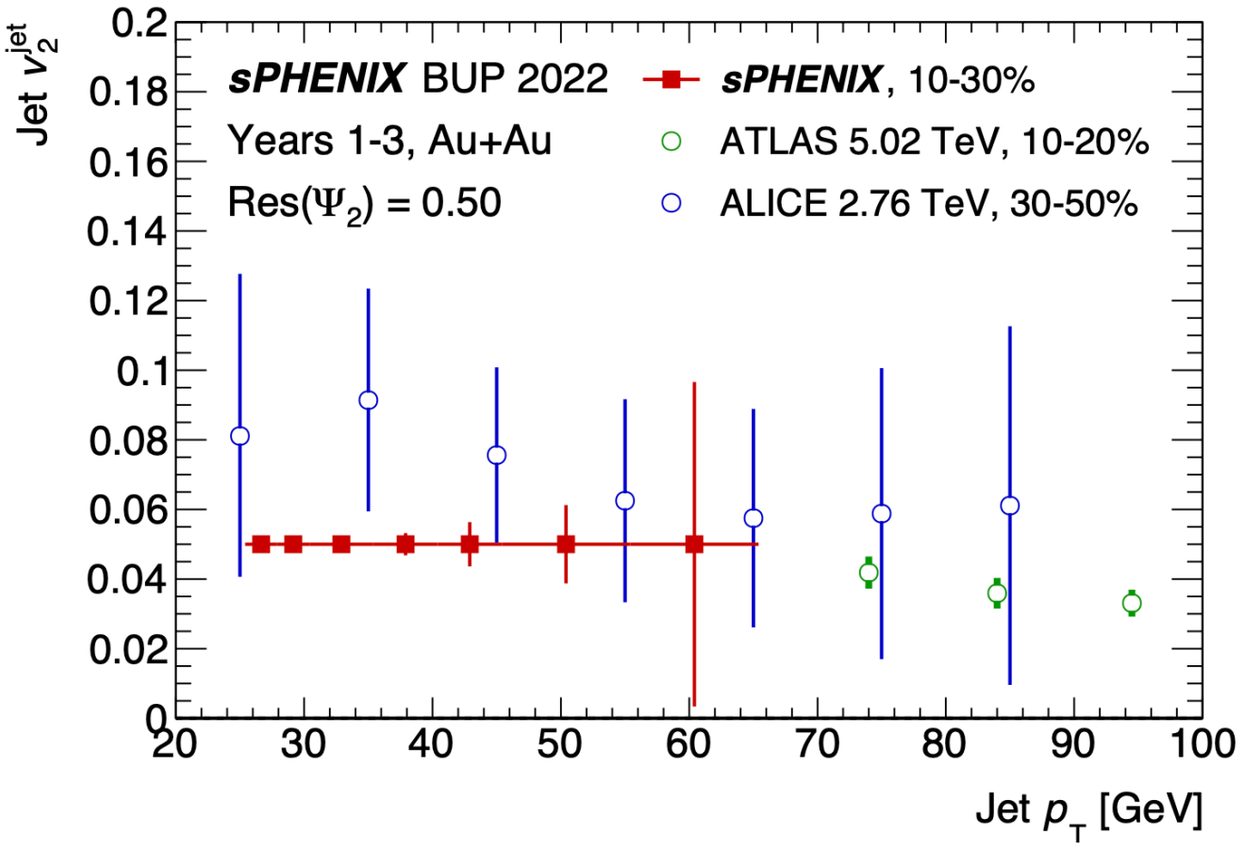
vary temperature of QCD matter
study proton spin, transverse momentum, & nuclear effects

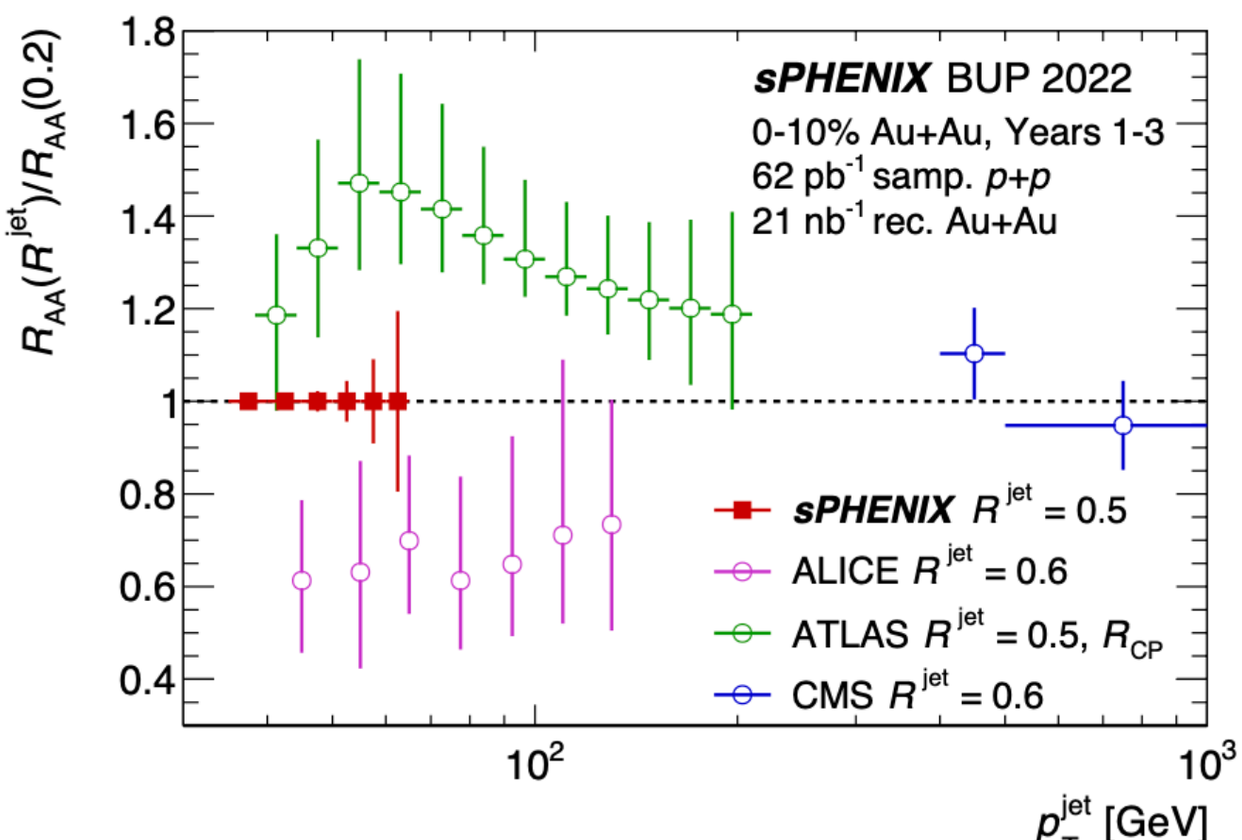
Plots from BUP 2022/23

Selected highlights from the physics program









Plots from BUP 2022/23

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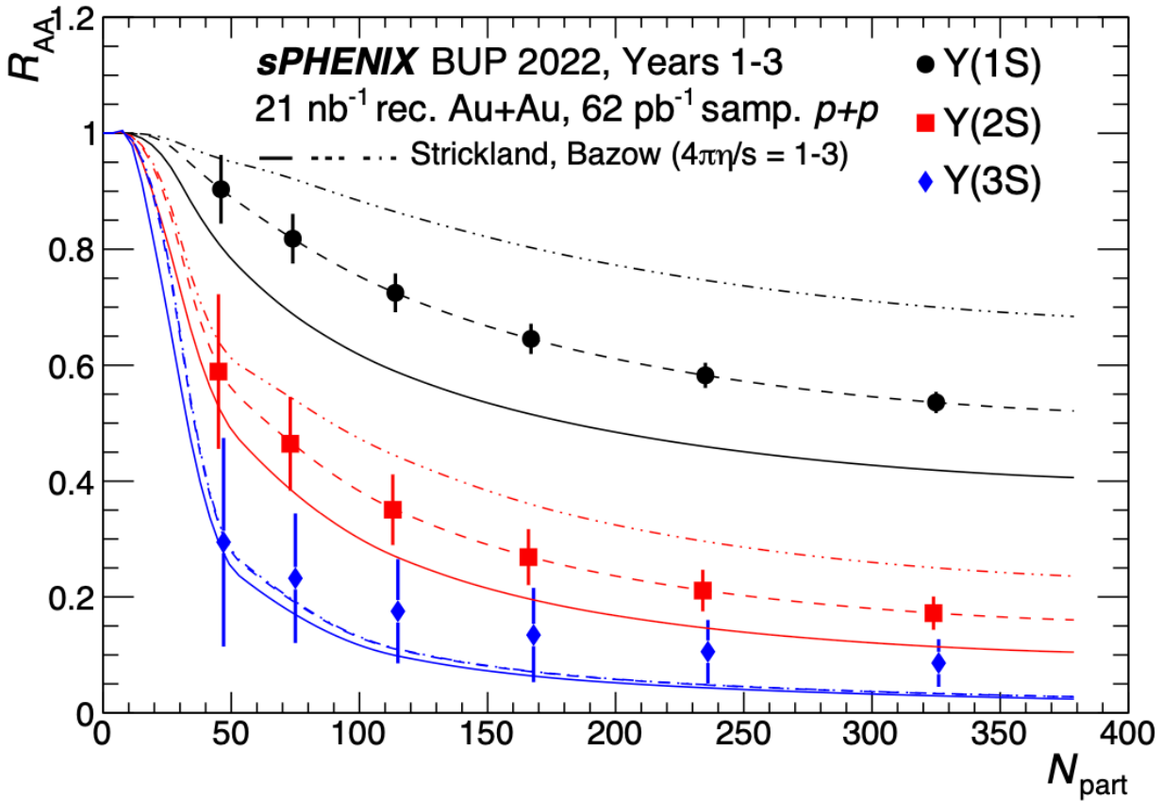

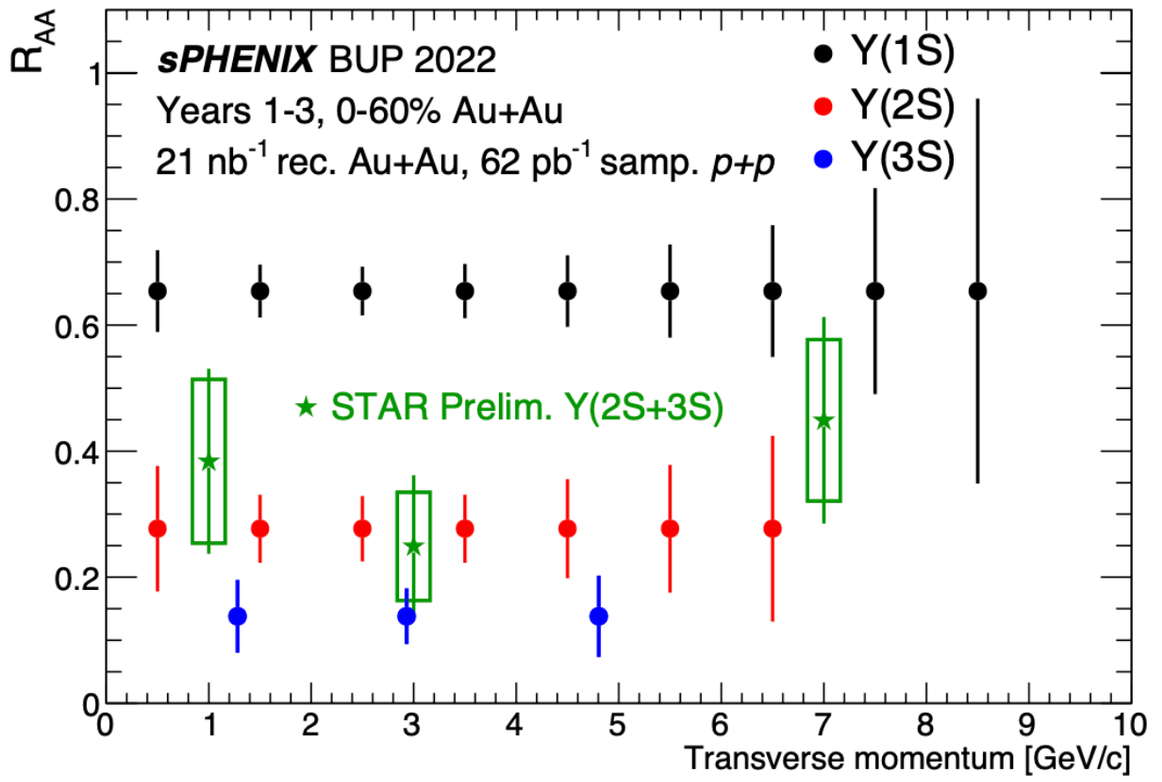

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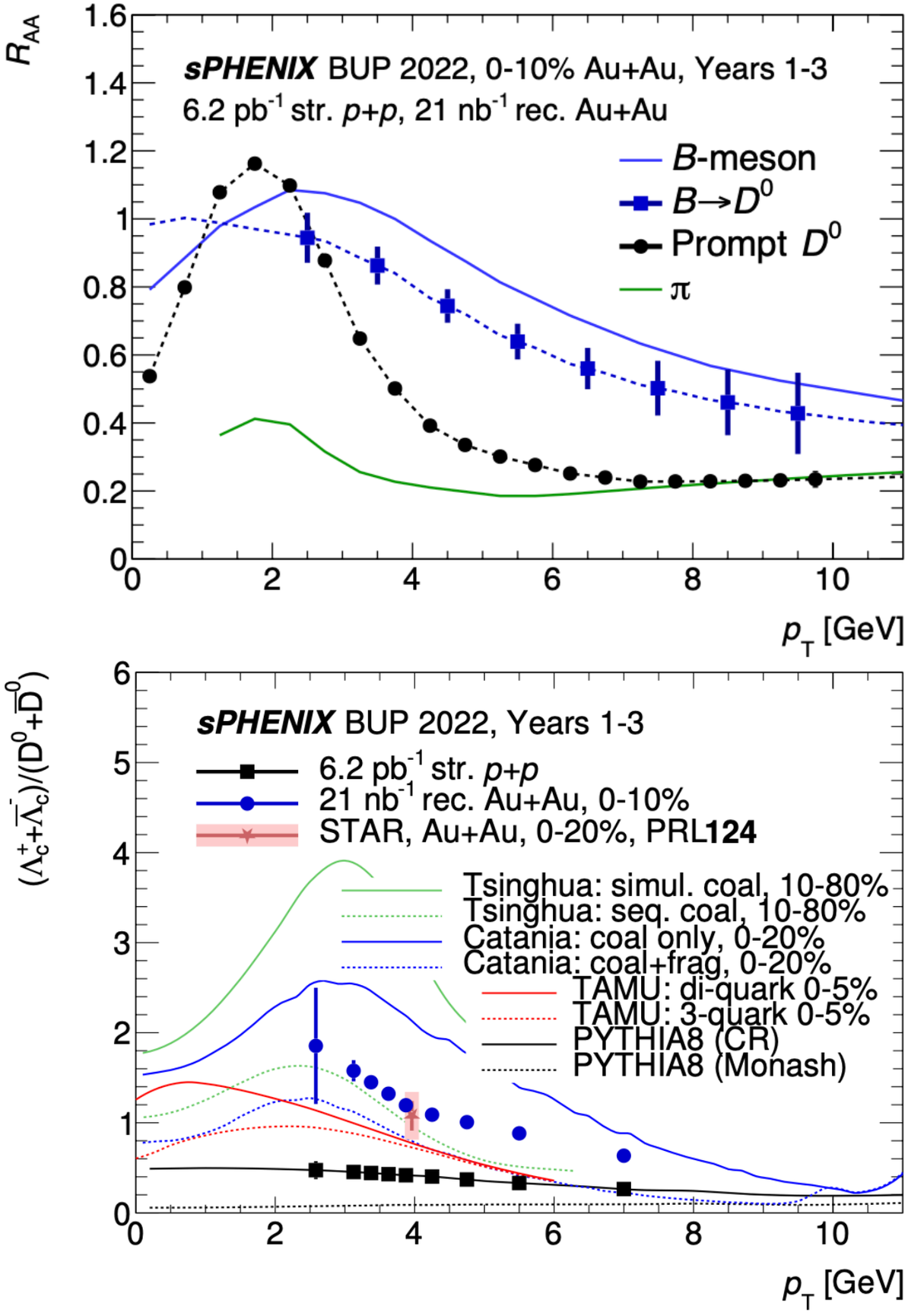
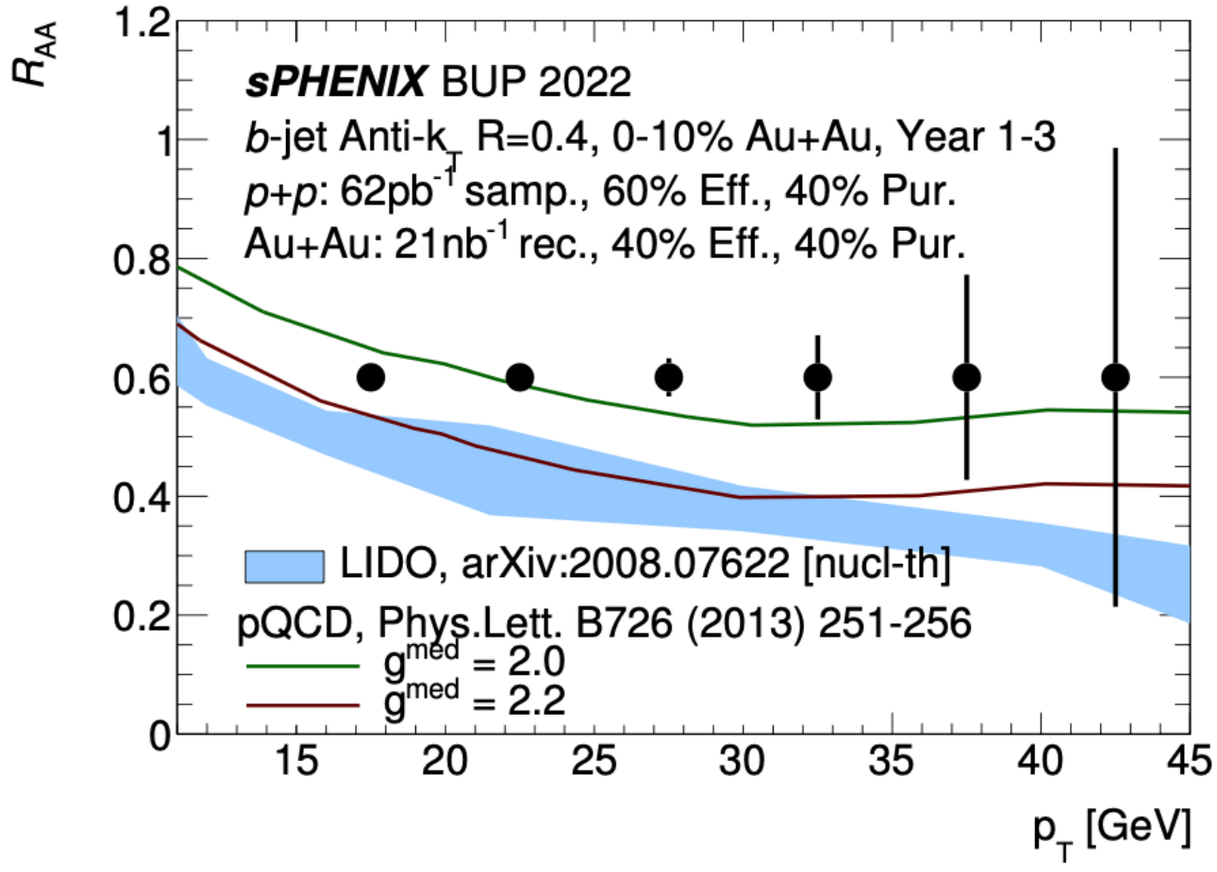
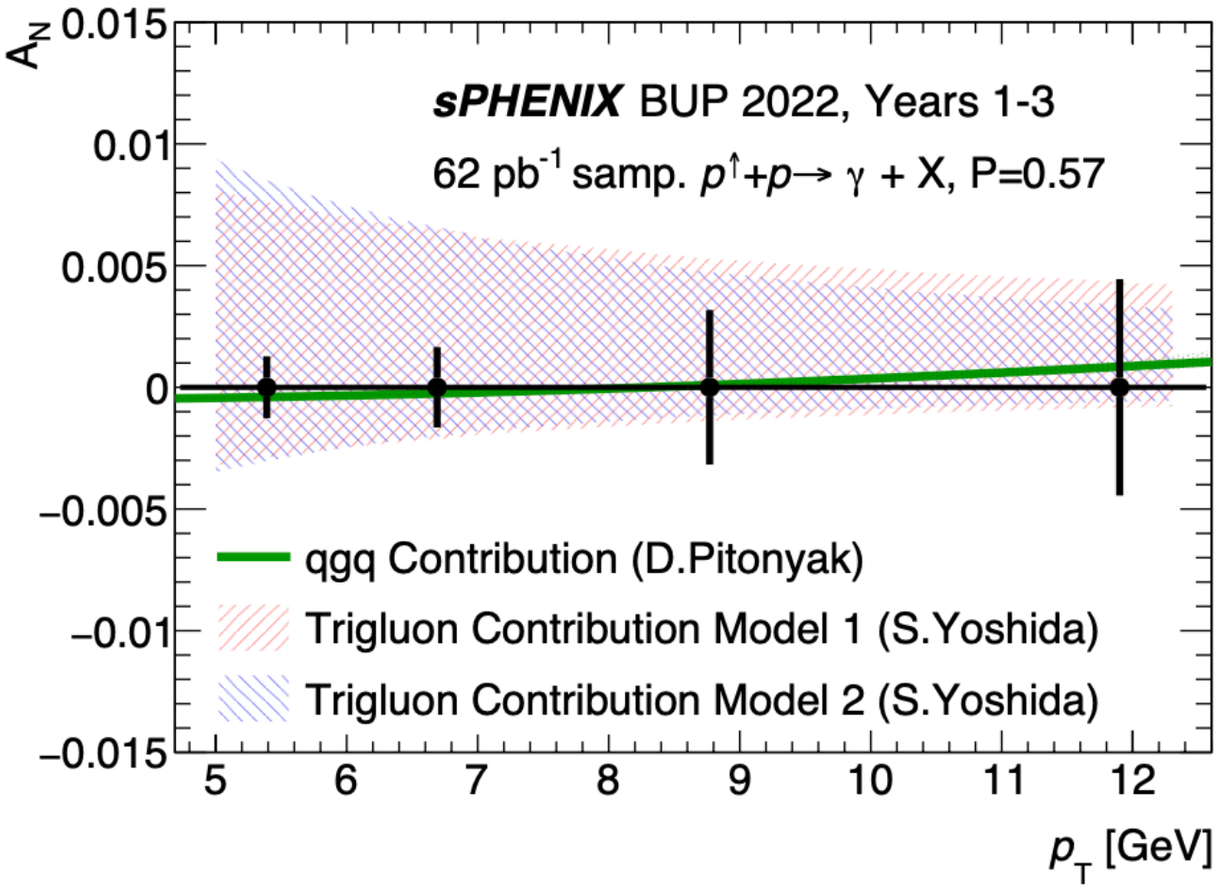
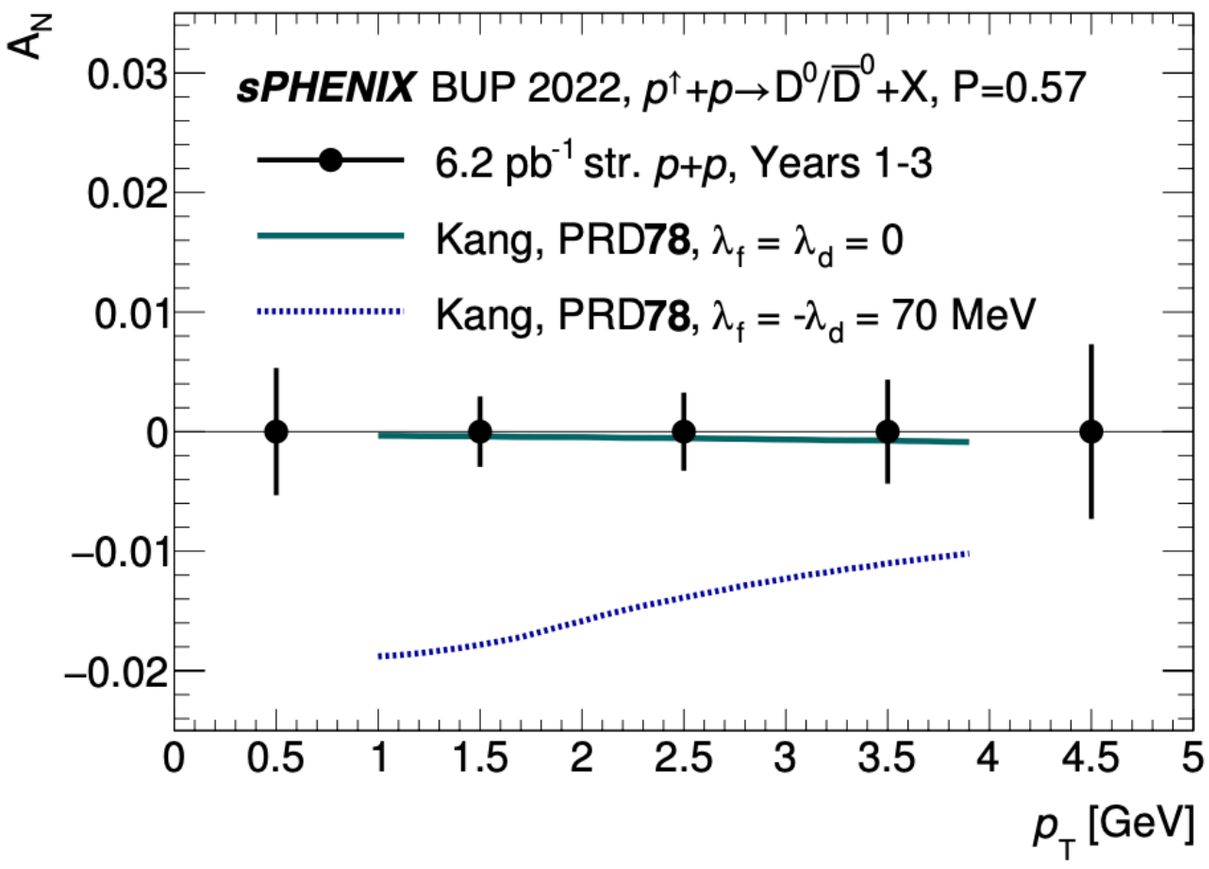




Plots from BUP 2022/23

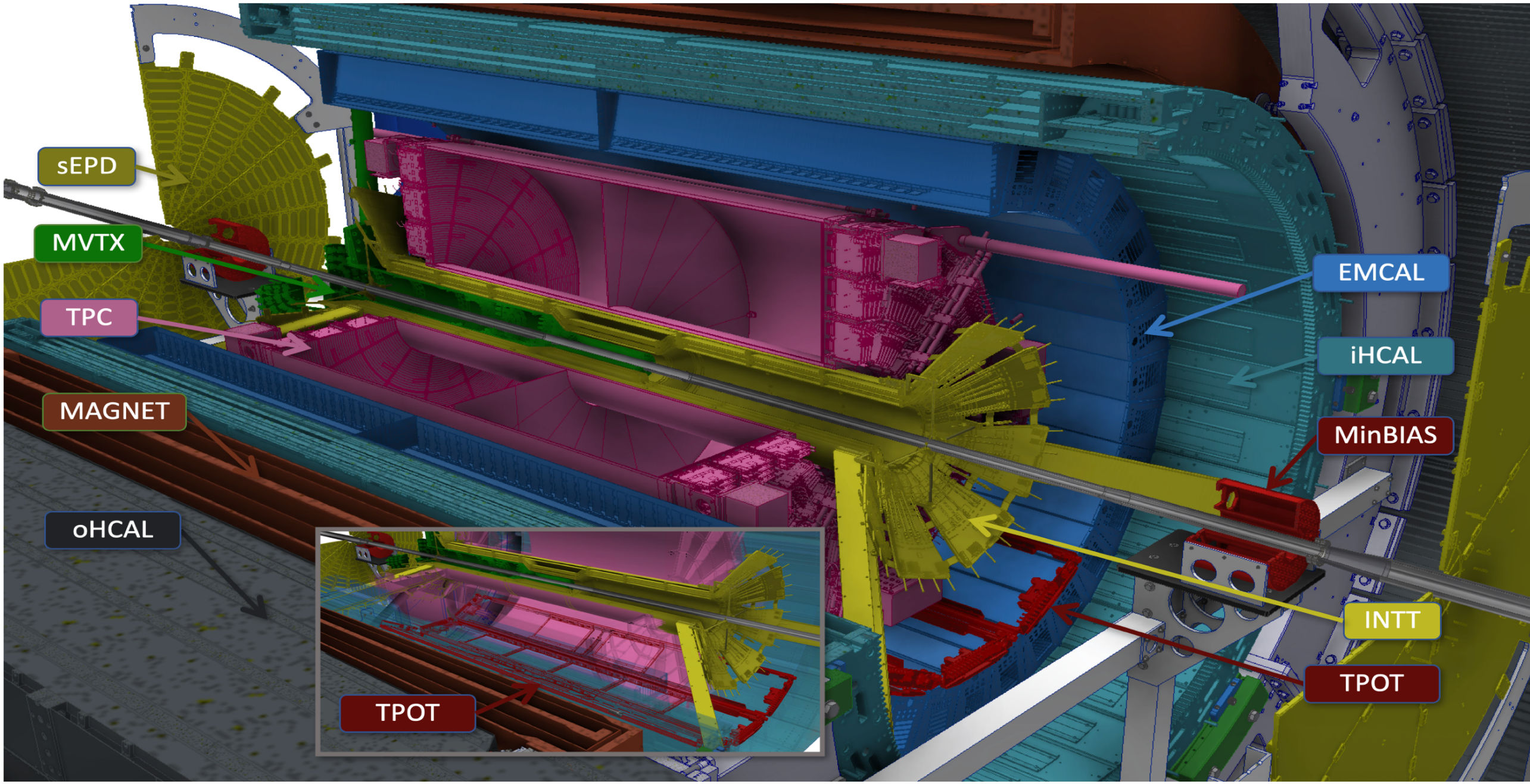
Selected highlights from the physics program





sPHENIX detector

- Barrel detectors: **|η|< 1.1, full azimuth**
- **1st hadronic calorimetry** at mid-rap at RHIC
- High **DAQ rate of 15kHz**
- Triggered readout for the calorimeters
- **Streaming readout for tracking**

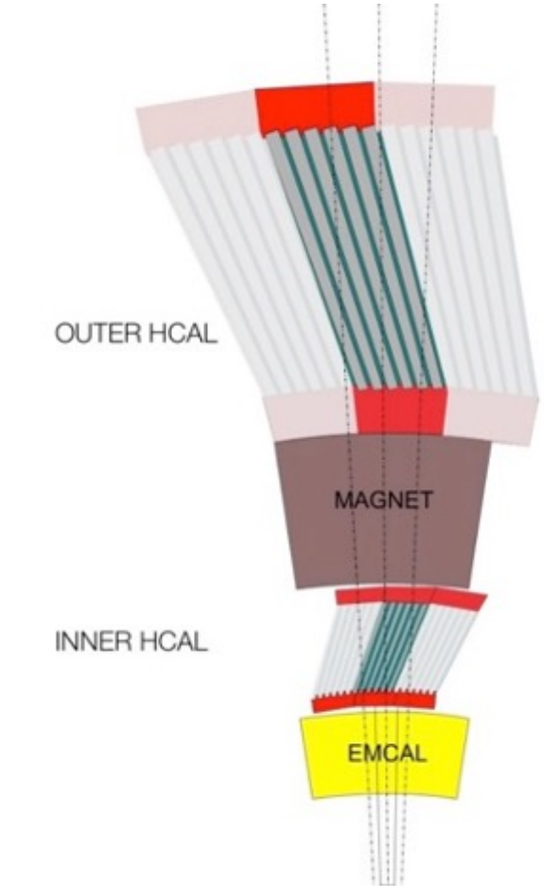


Magnet

1.4T superconducting solenoid repurposed from Babar experiment

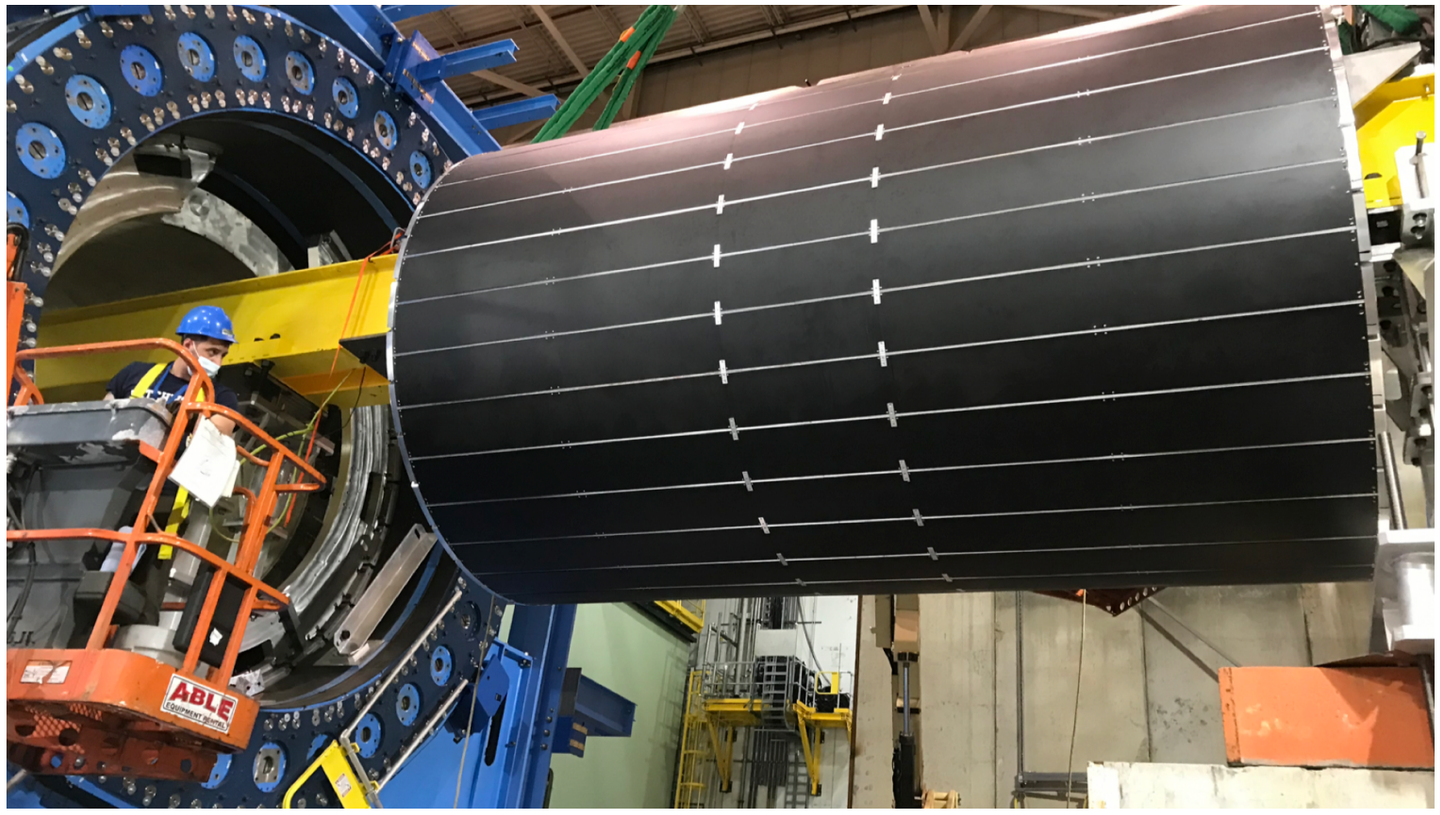
Installed September 30, 2021

Hadronic calorimeters

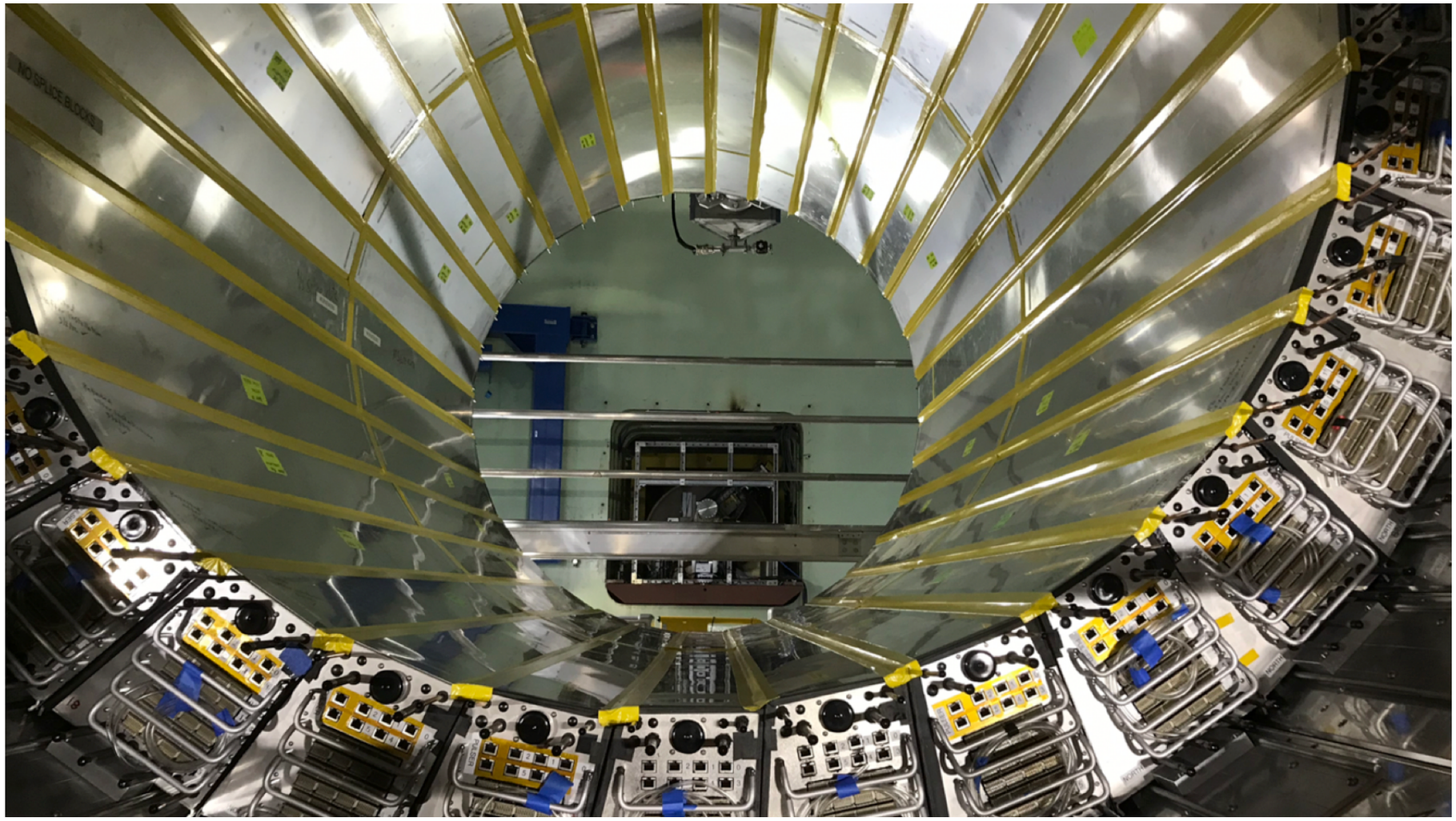


- OHCAL: plastic scintillating tiles plus tilted steel plates with embedded WLS fibers
- IHCAL: aluminum plates instead of steel
- Overall tile segmentation of $\Delta\phi \times \Delta\eta \approx 0.1 \times 0.1$
- Performance requirements driven by jet physics in HI collisions
  - Uniform fiducial acceptance $-1<h<1$ and $0<\phi<2\pi$
  - Absorb >95% of energy from a 30 GeV jet
- OHCAL created by instrumenting barrel magnetic flux return

OHCAL installed on February 28 2022
IHCAL installed on June 9 2022



Electromagnetic calorimeter

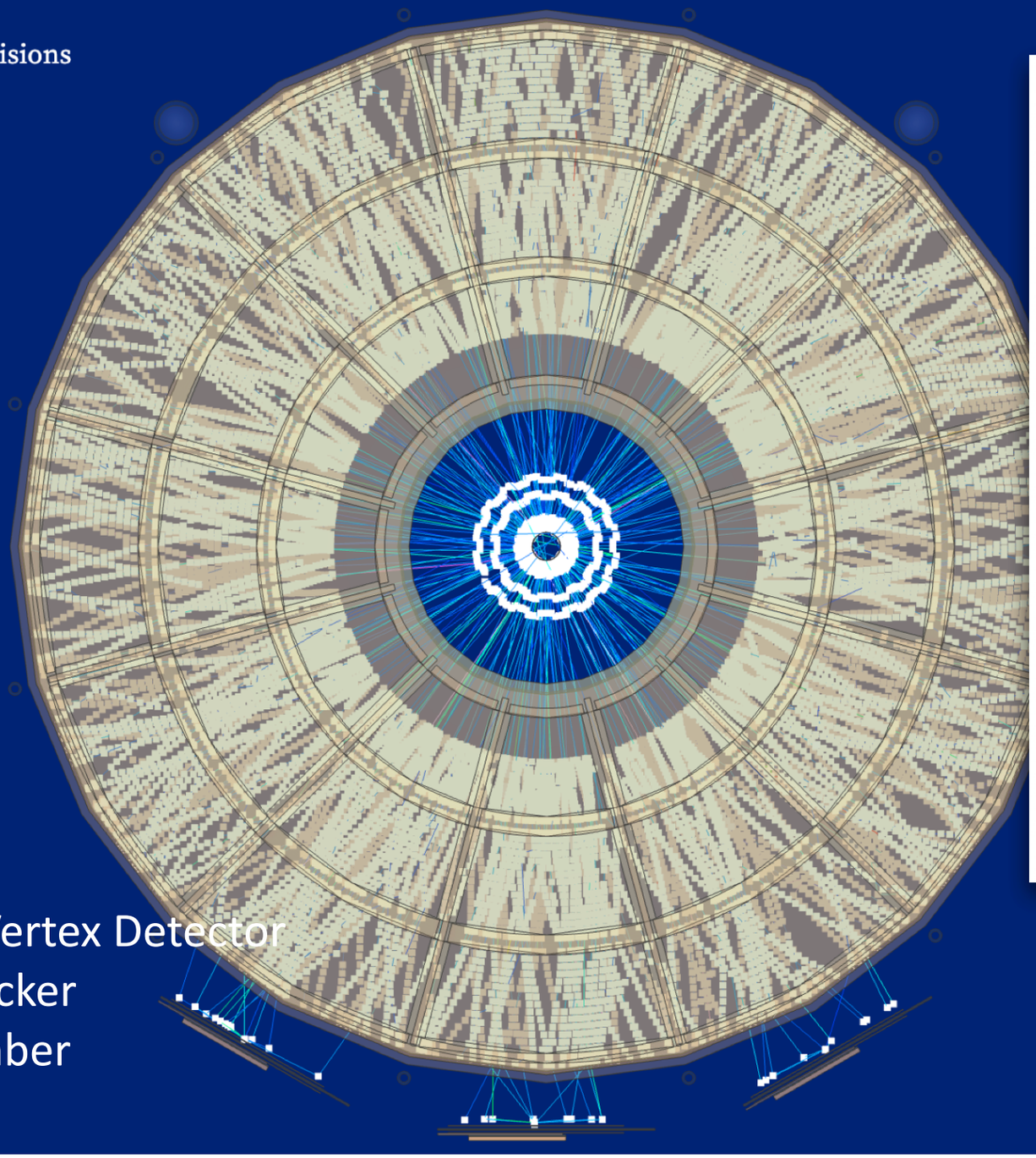


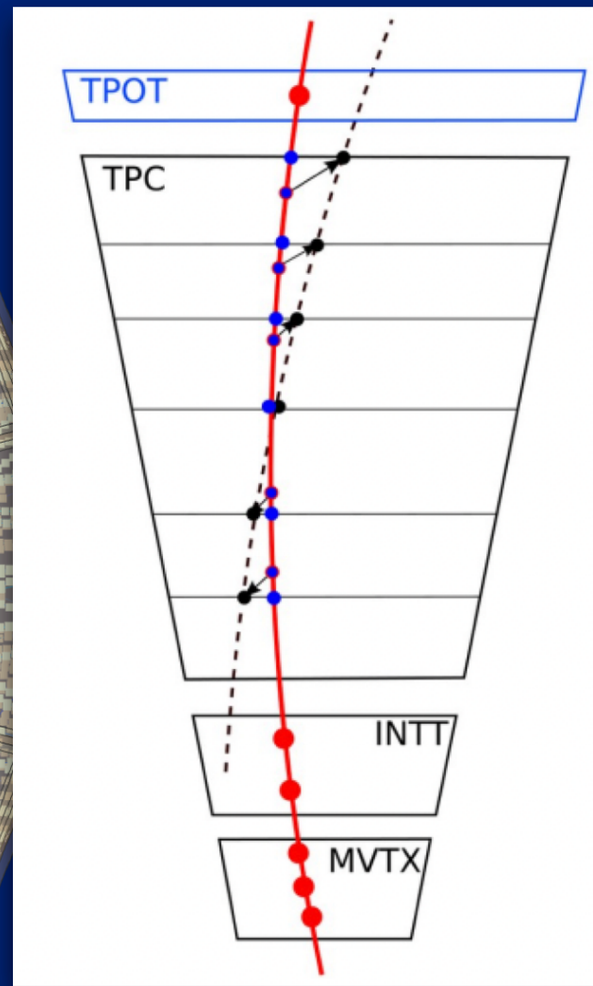
Installed September 2, 2022

- 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 (γ, jets), electrons (Y spectroscopy)

sPHENIX tracking system

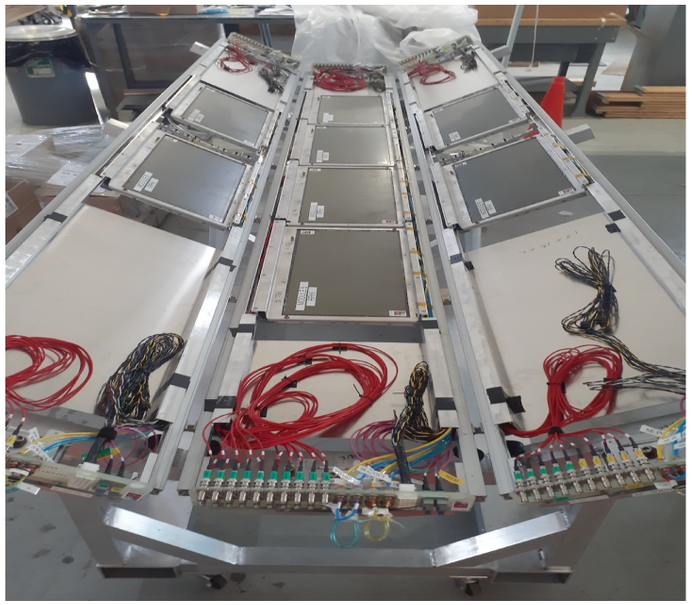
sPHENIX Experiment at RHIC
sPHENIX Simulation
Au+Au HIJING, 5% central collisions



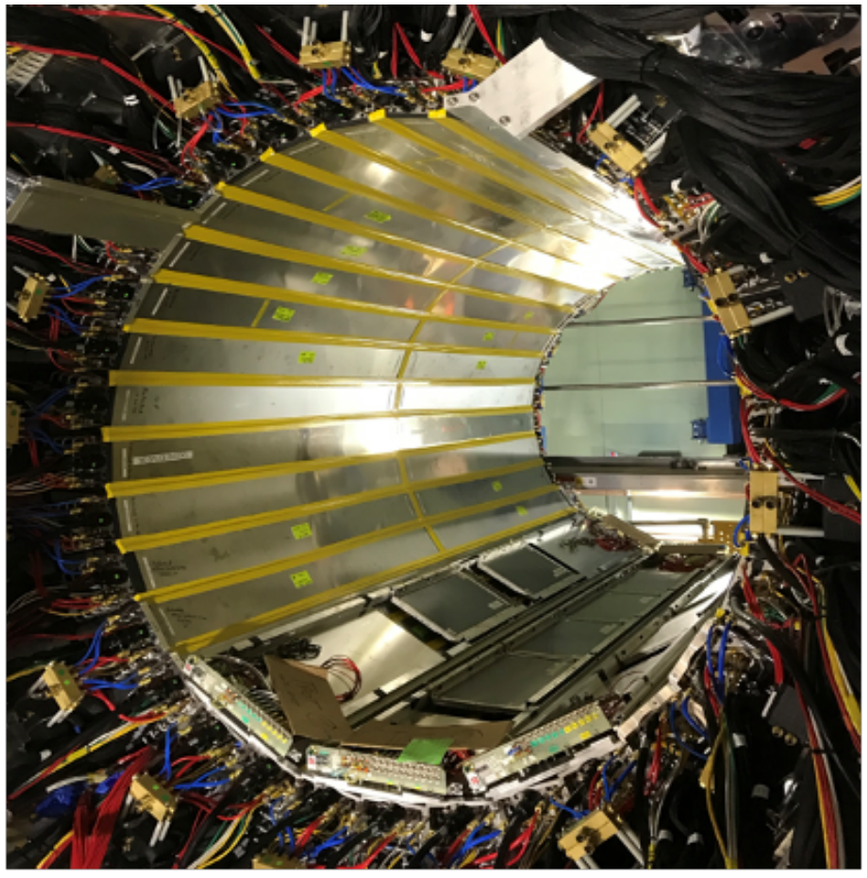


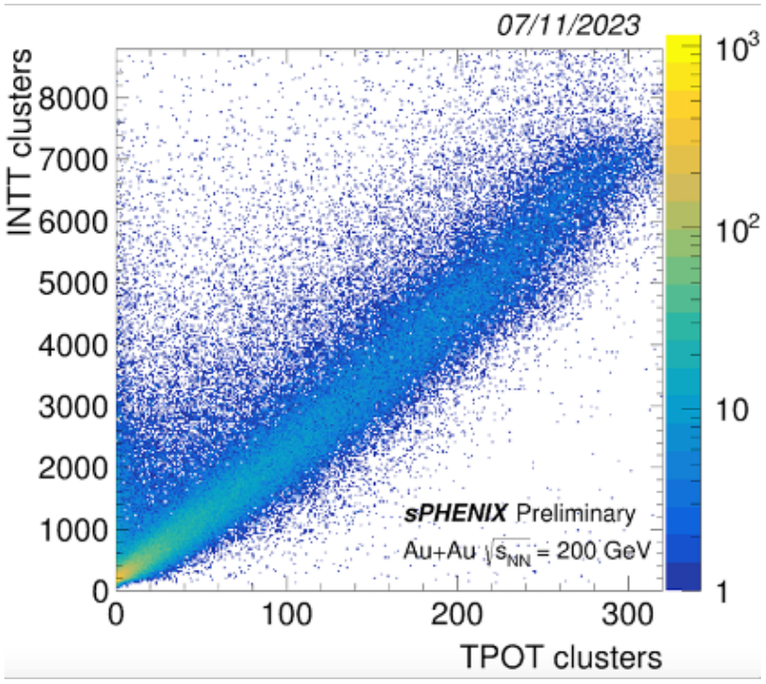
Monolithic Active Pixel sensors Vertex Detector
Intermediate Strip Tracker
Time Projection Chamber
TPC Outer Tracker

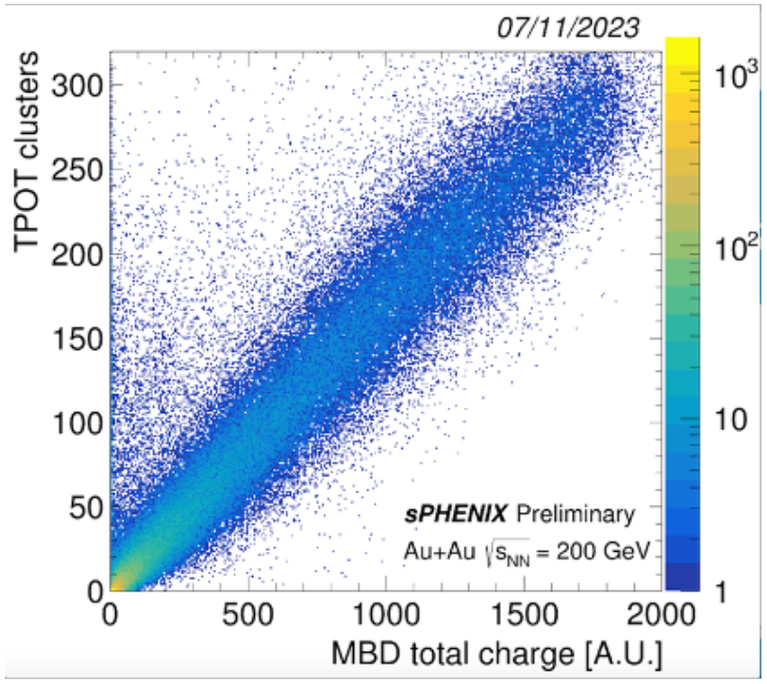
TPC Outer Tracker (TPOT)



- 8 Micromegas modules (2 detectors/module for 2D information)
- Below the TPC
- One sector = 335 x 42 x 11 cm. Gas is 95/5 Ar/iC4H10
- Provides tracking distortion correction information for the TPC





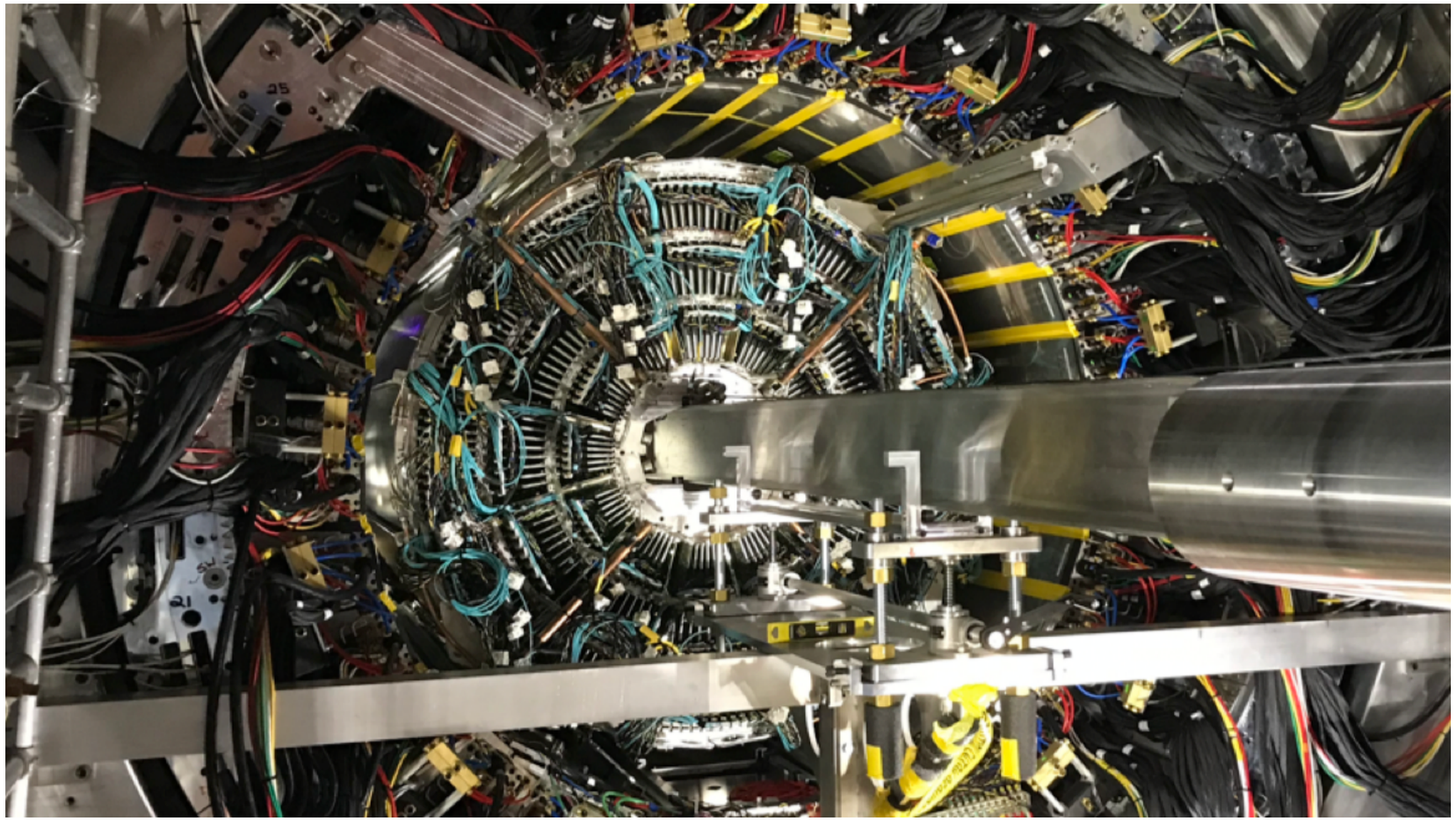


Installed December 9, 2022

Time projection chamber

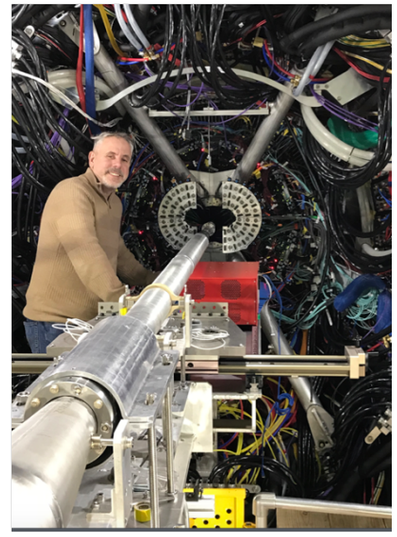
- Compact (r ≈ 80 cm) and main tracking element filled with Ar-CF4 gas mixture
- Ungated, with GEM-based read out, spatial resolution of < 200 µm
- ASIC modified SAMPA chip from ALICE

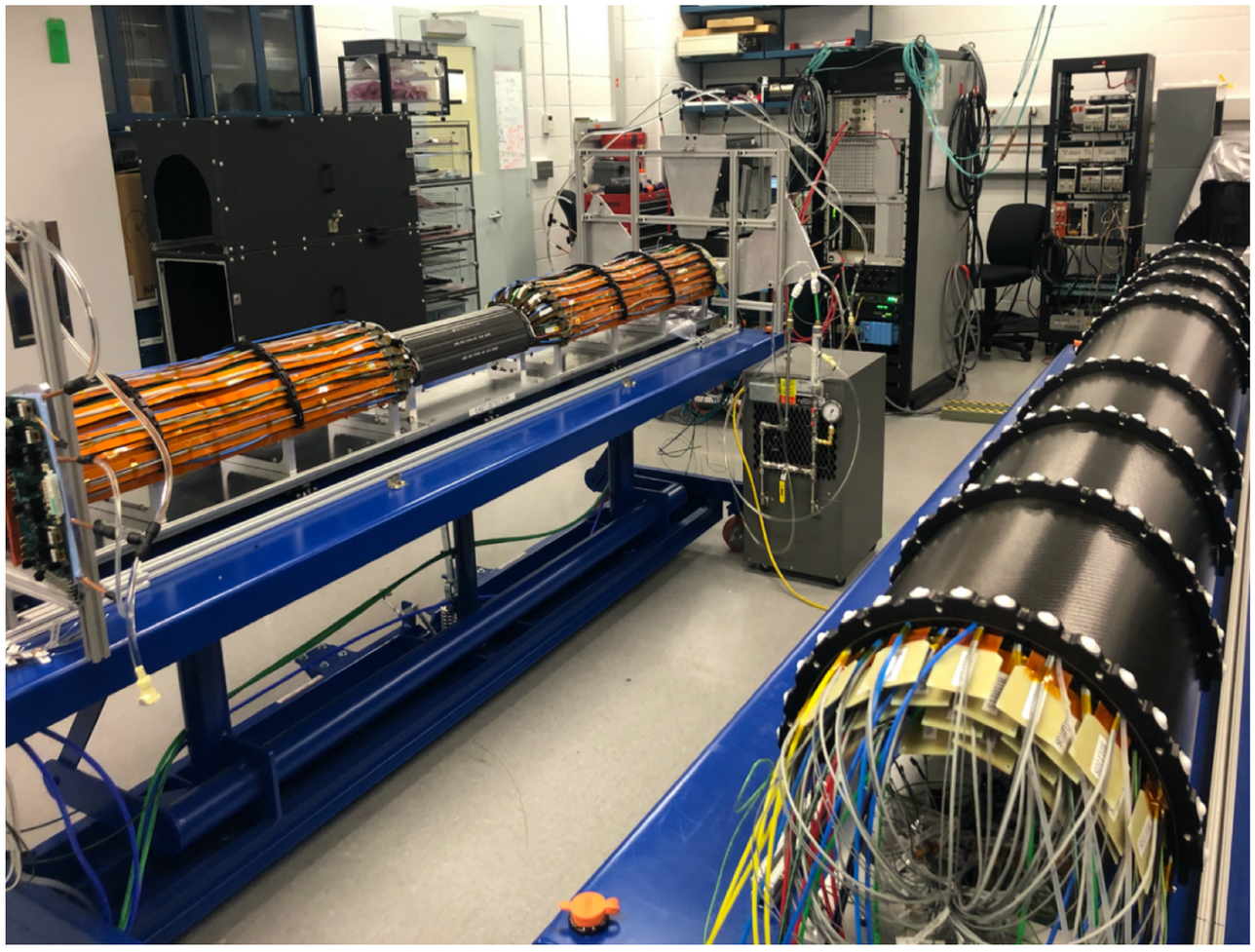
Installed January 19, 2023

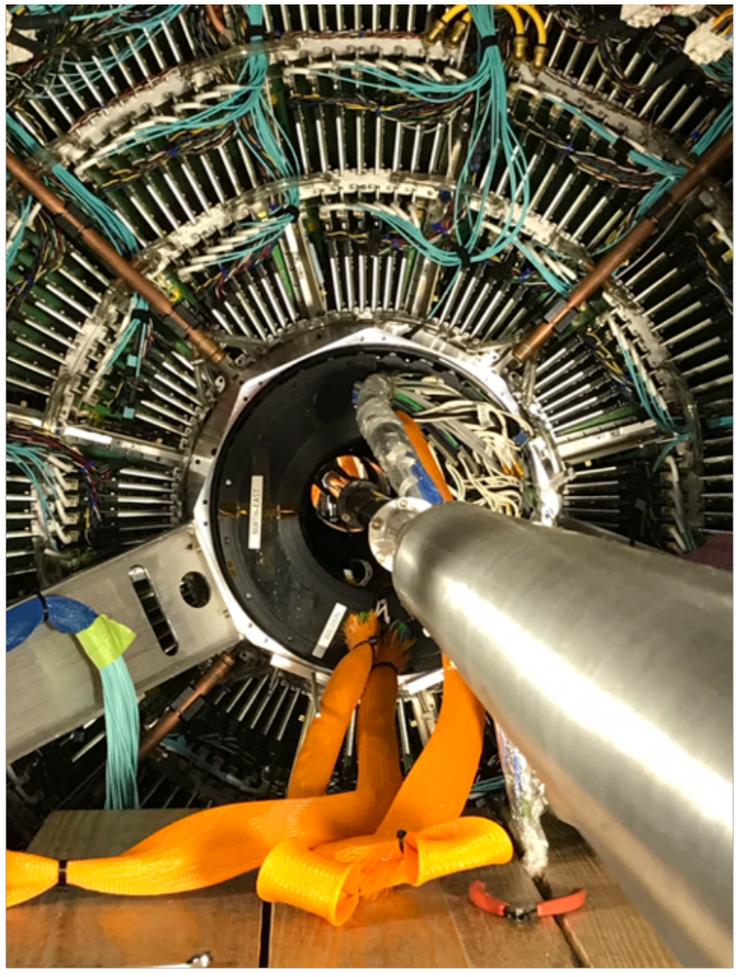


Intermediate Silicon Strip Tracker

- INTT: pileup event separation
- 2-layer silicon strip detector surrounding the MVTX
- Associates fully reconstructed tracks with the event that produced them
- Timing resolution ≈ 100ns

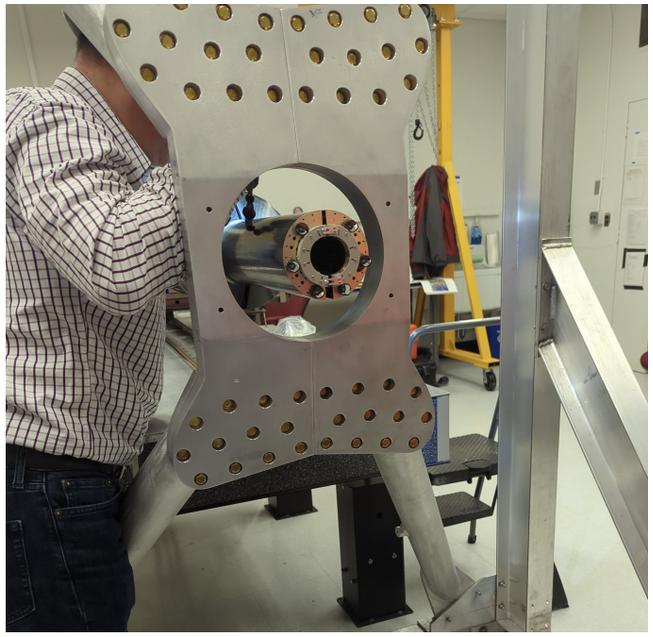






Installed February 28, 2023

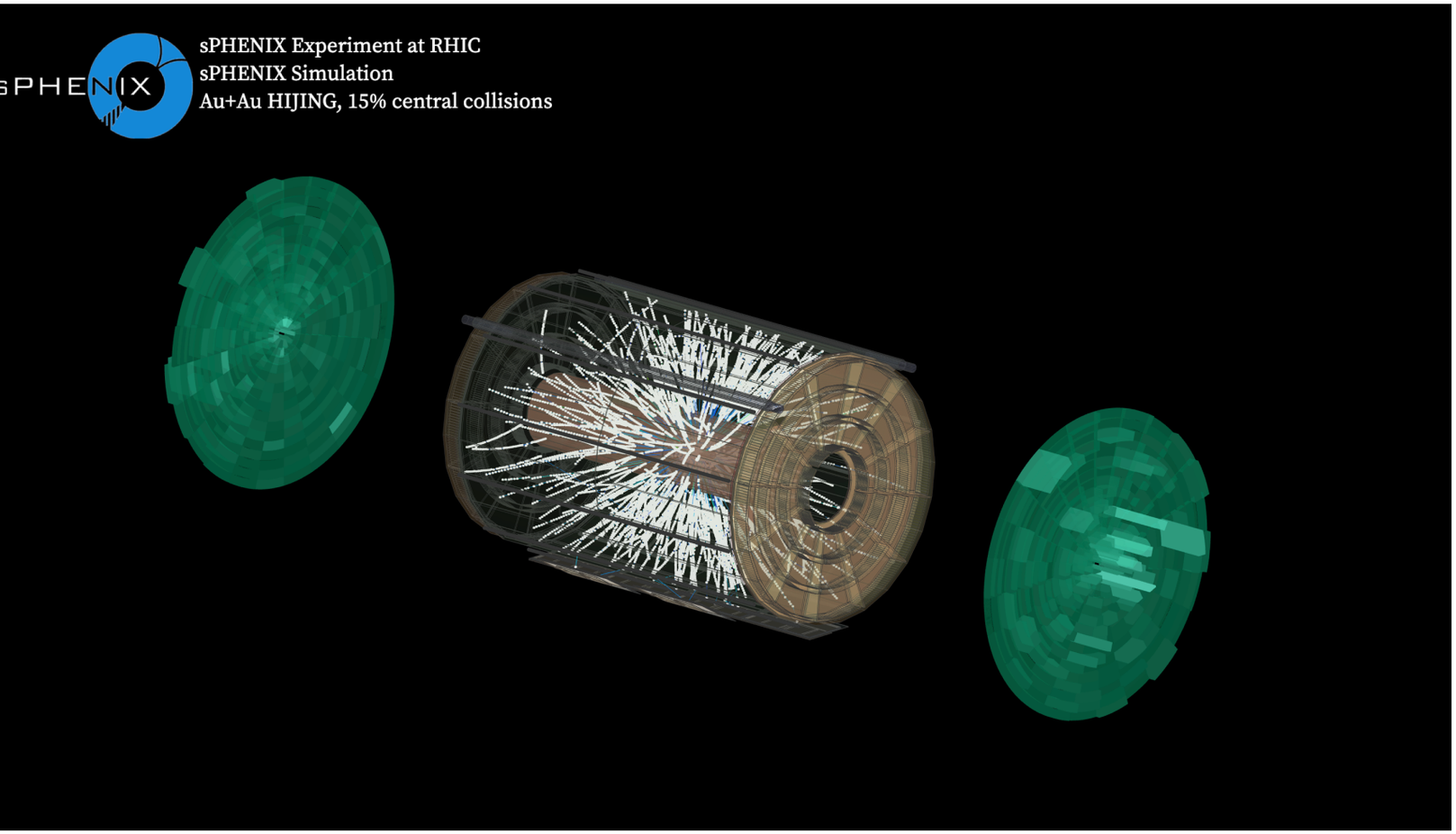
MAPS vertex detector

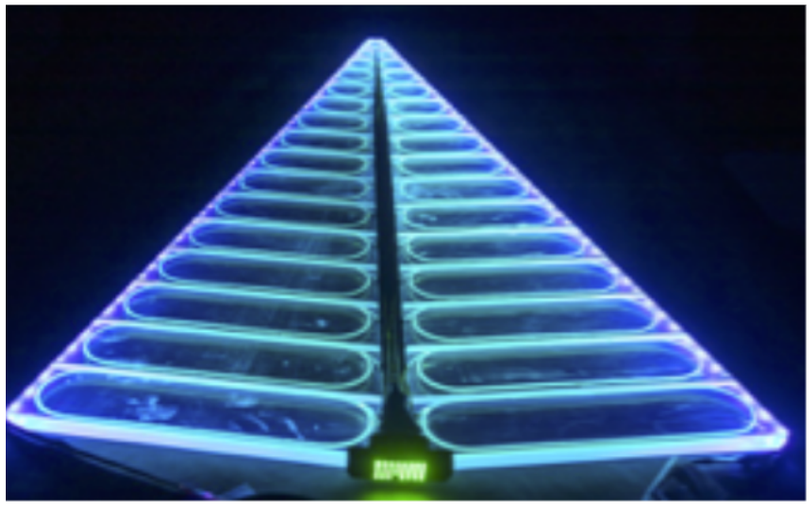


- MVTX: high resolution vertexing
- 270M channel, 3-layer MAPS-based pixel detector.
- The MVTX is a copy of inner 3 layers of the ALICE ITS w/ a custom design of service supports to meet sPHENIX needs
- Nearest to the collision point, spatial resolution of 5 µm for tracks with p_T>1GeV

Installed March 30, 2023

Event Plane Detector

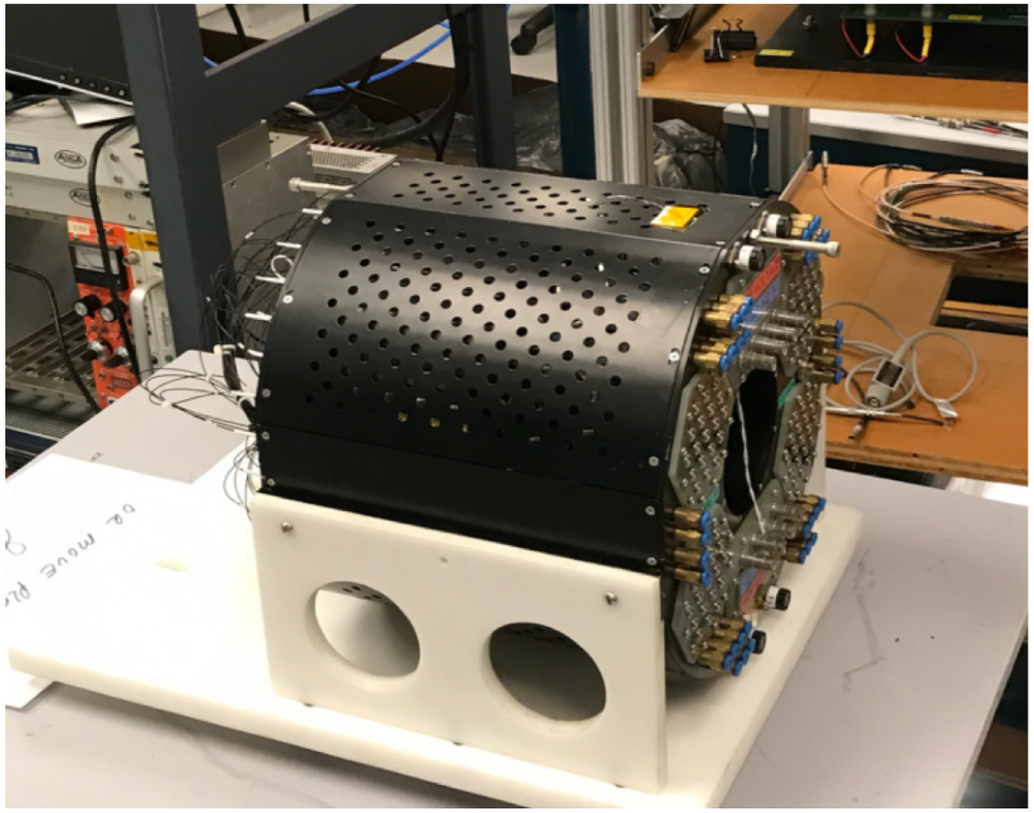




- 2 wheels of 12 sectors, $2.0 < |\eta| < 4.9$, 1.2cm thick plastic scintillators with embedded WLS fibers
- 744 total tiles
- Used for centrality and event plane measurement

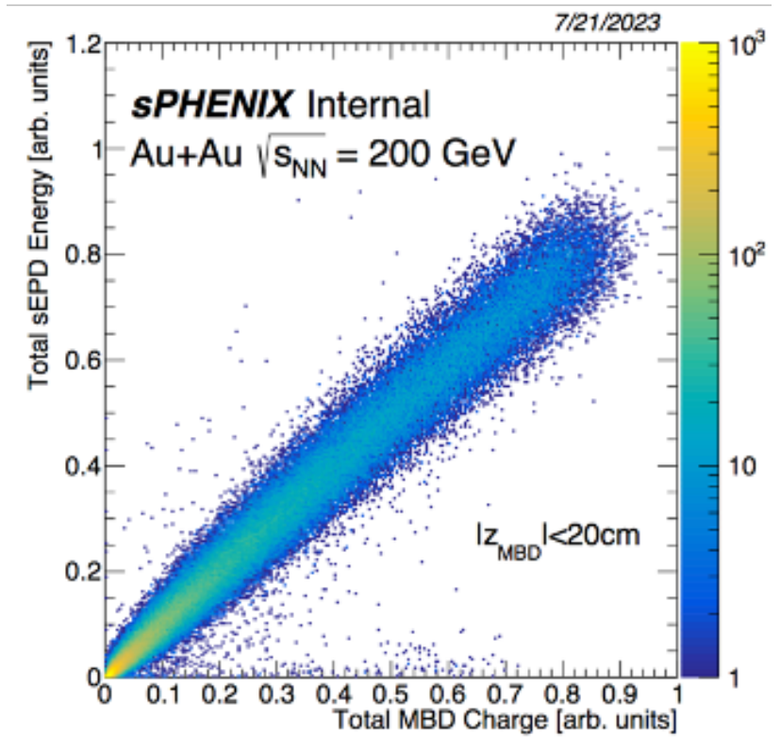
Installed June 2023

Minimum bias detector



- Based on original PHENIX Beam Beam Counter w/ new electronics.
- Custom PMTs w/ 30 ps timing resolution.

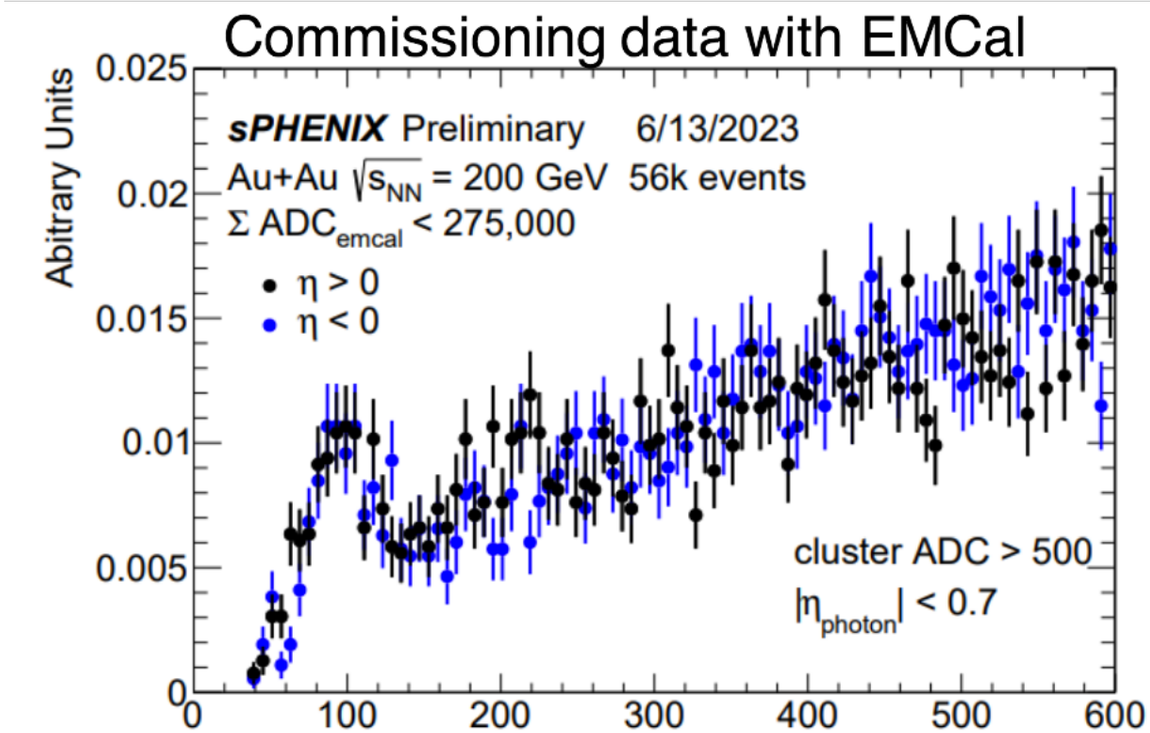
- Covers $3.51 < |\eta| < 4.61$
- Measures centrality; provides triggering

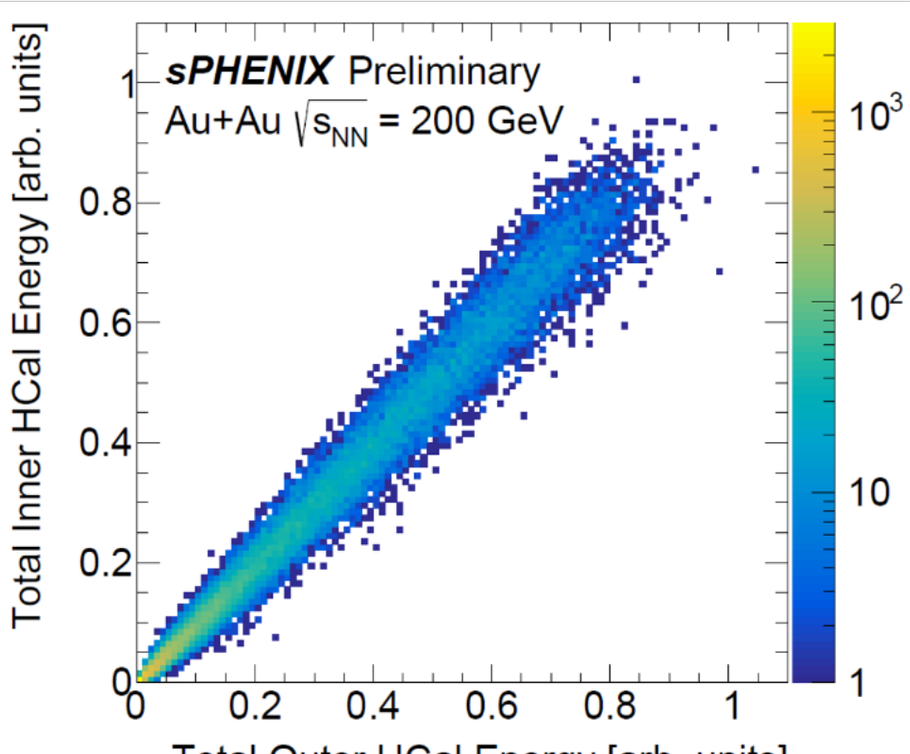


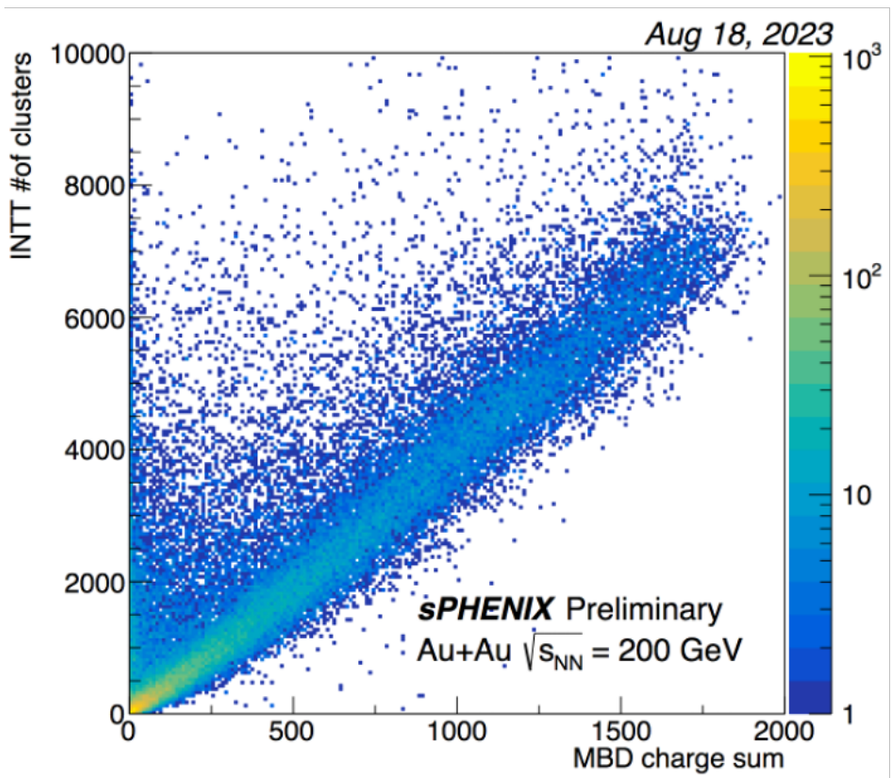
Installed April 2023

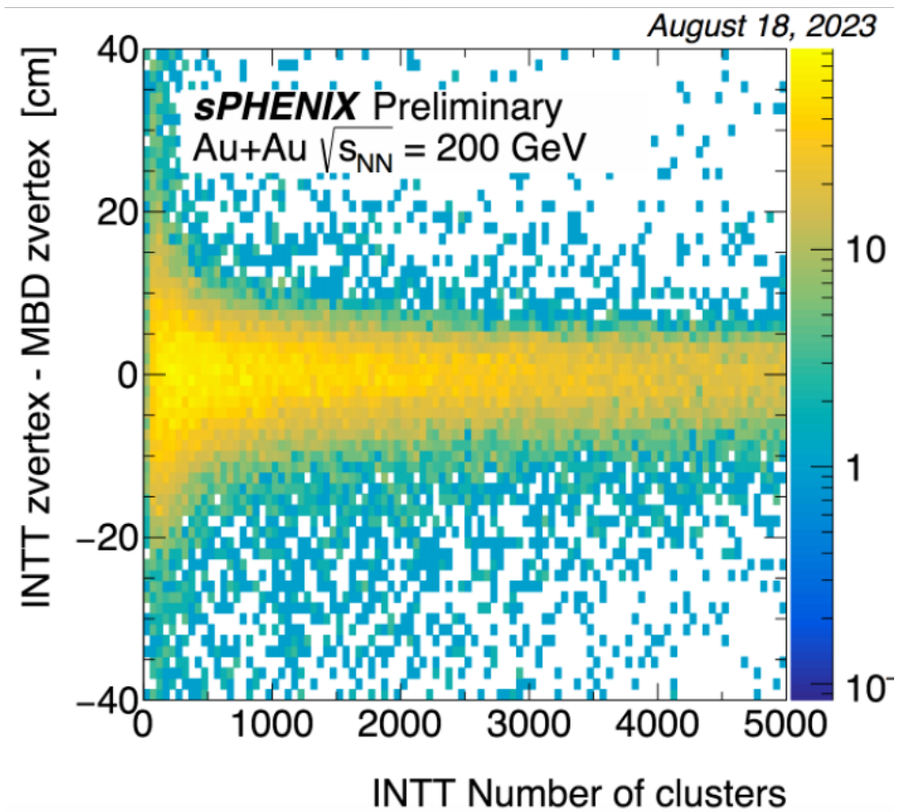
Ready on May 18 2023 for commissioning

Some preliminary performances









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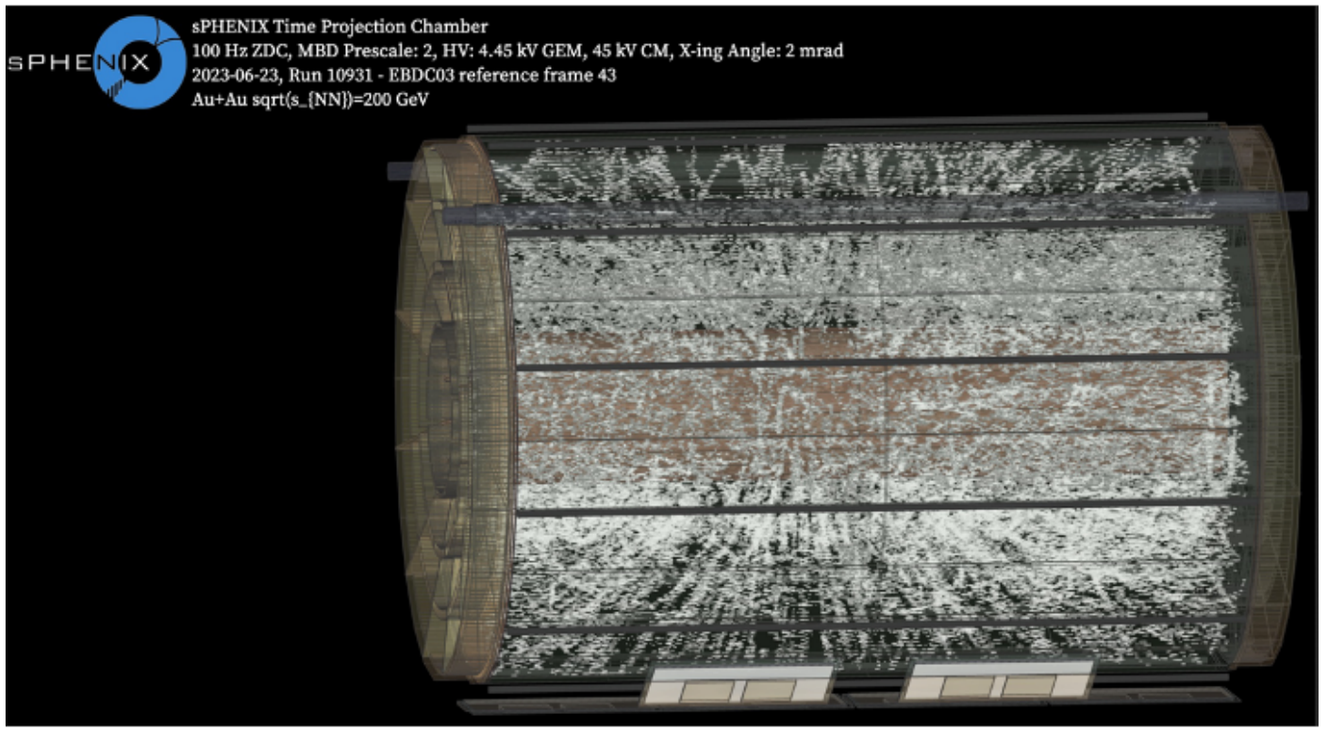

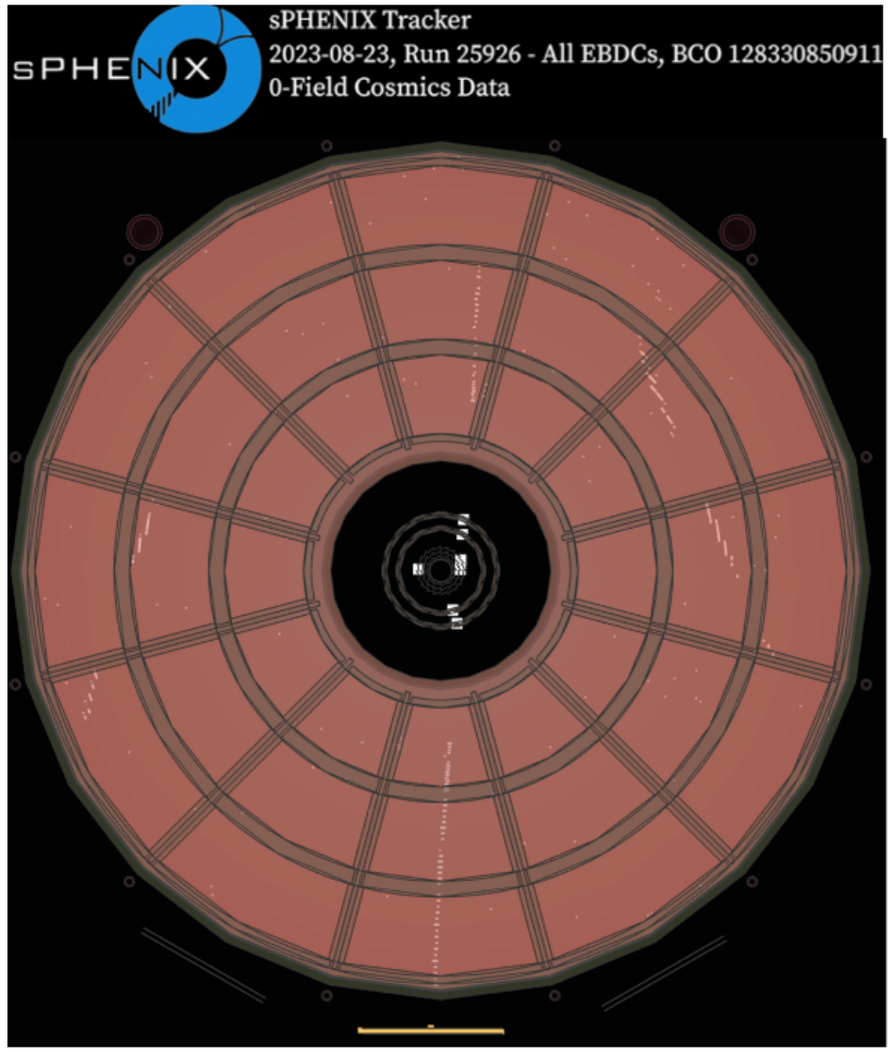

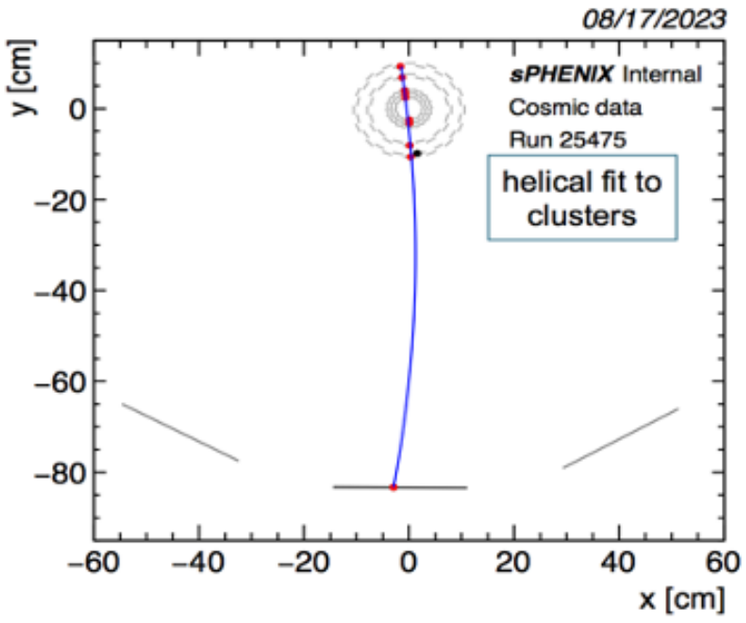

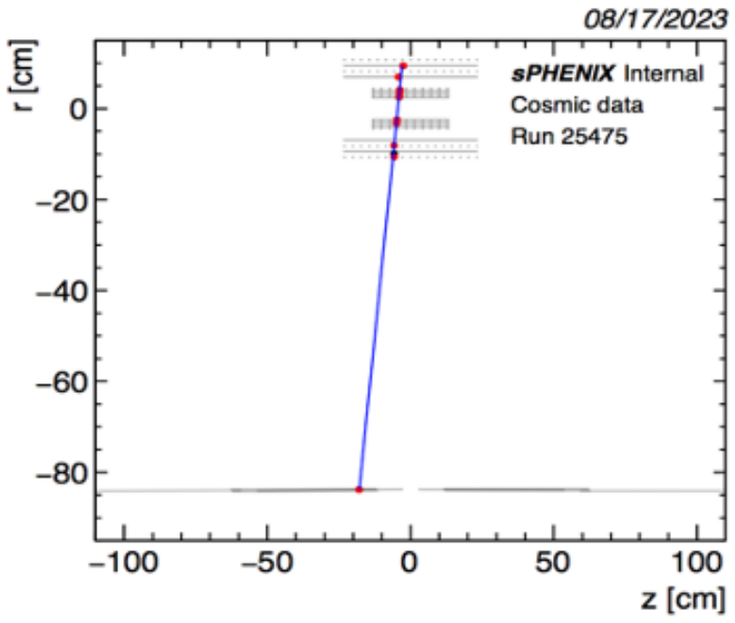

The challenges of constructing a new detector

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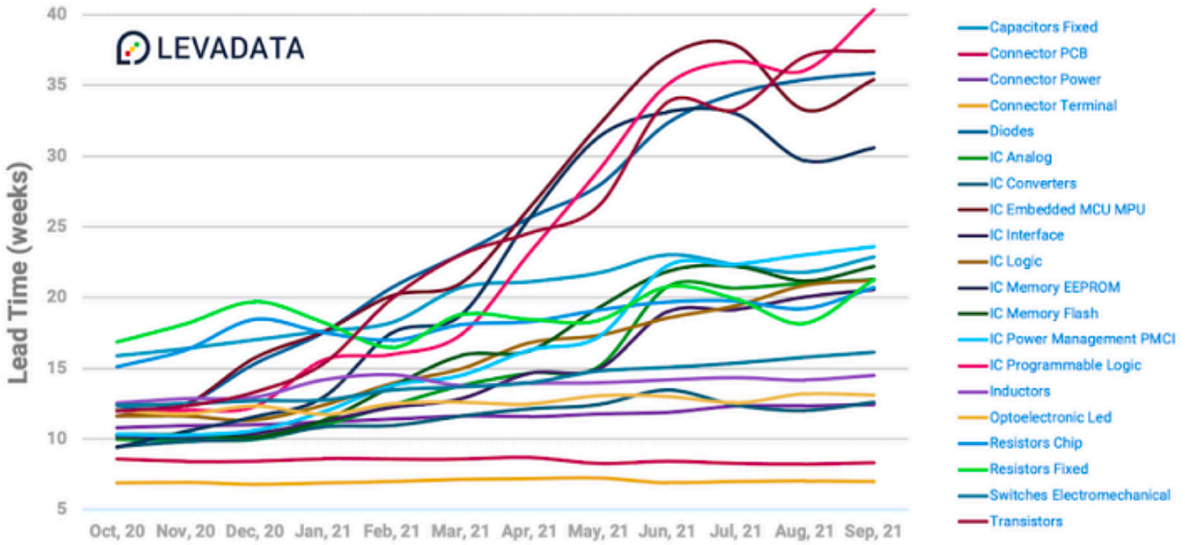
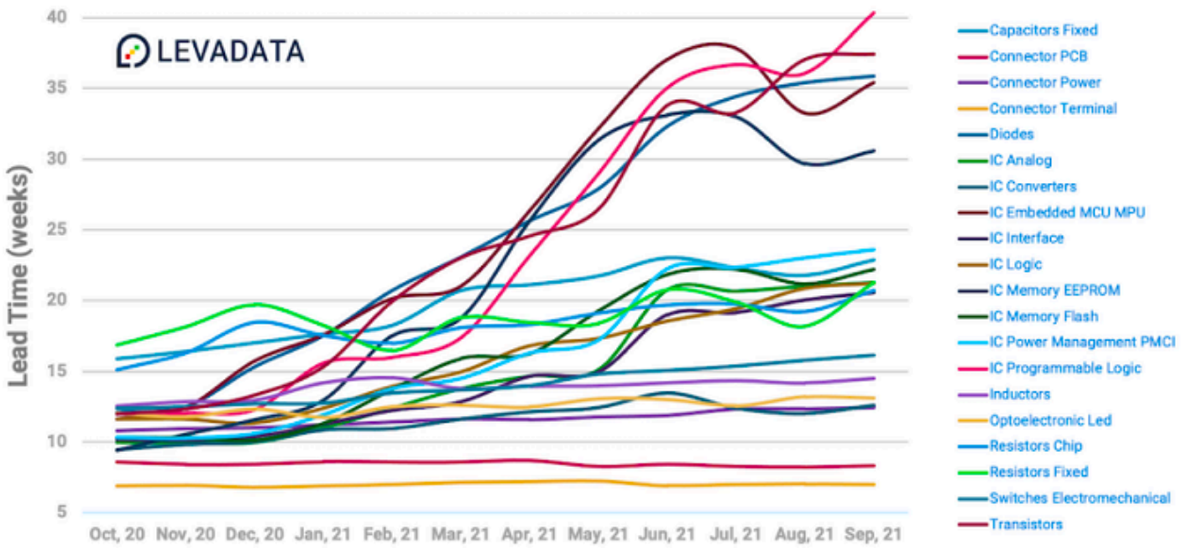
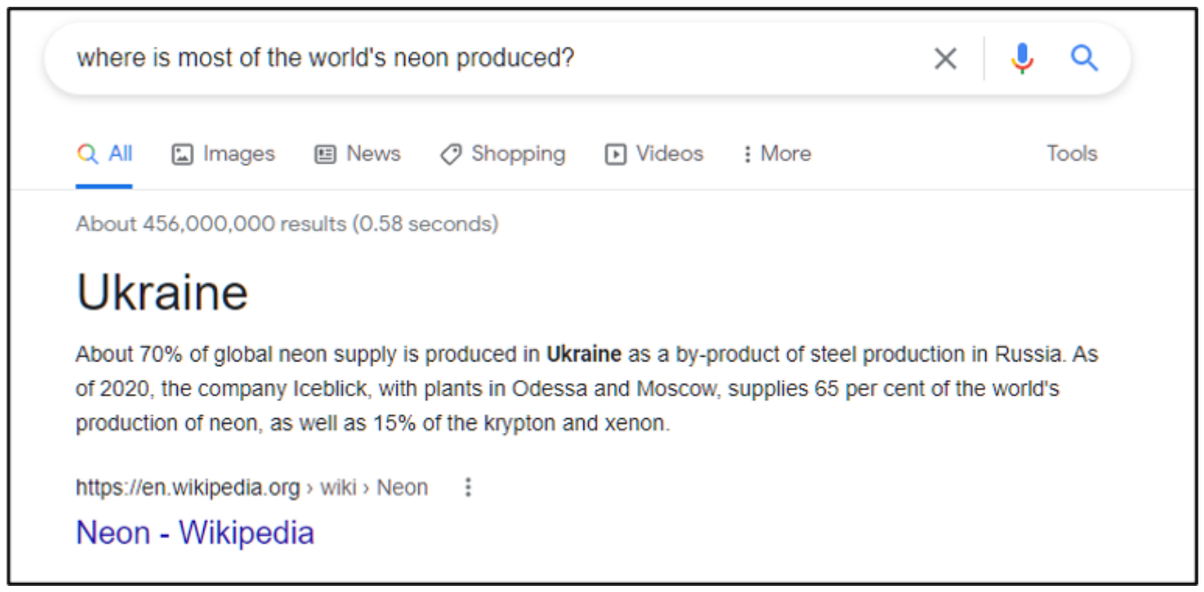


The challenges of constructing a new detector





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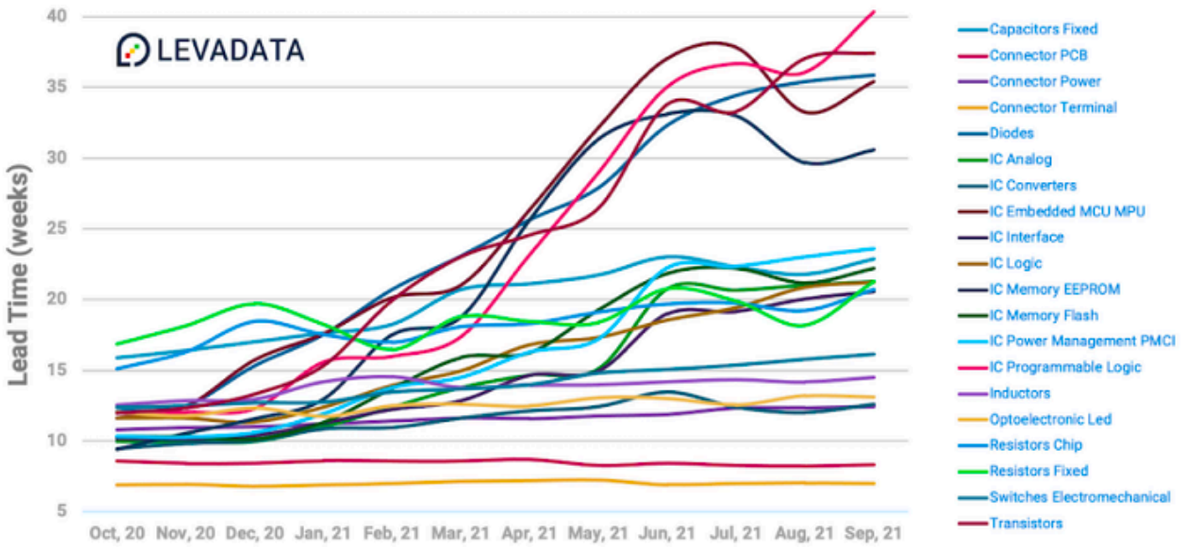
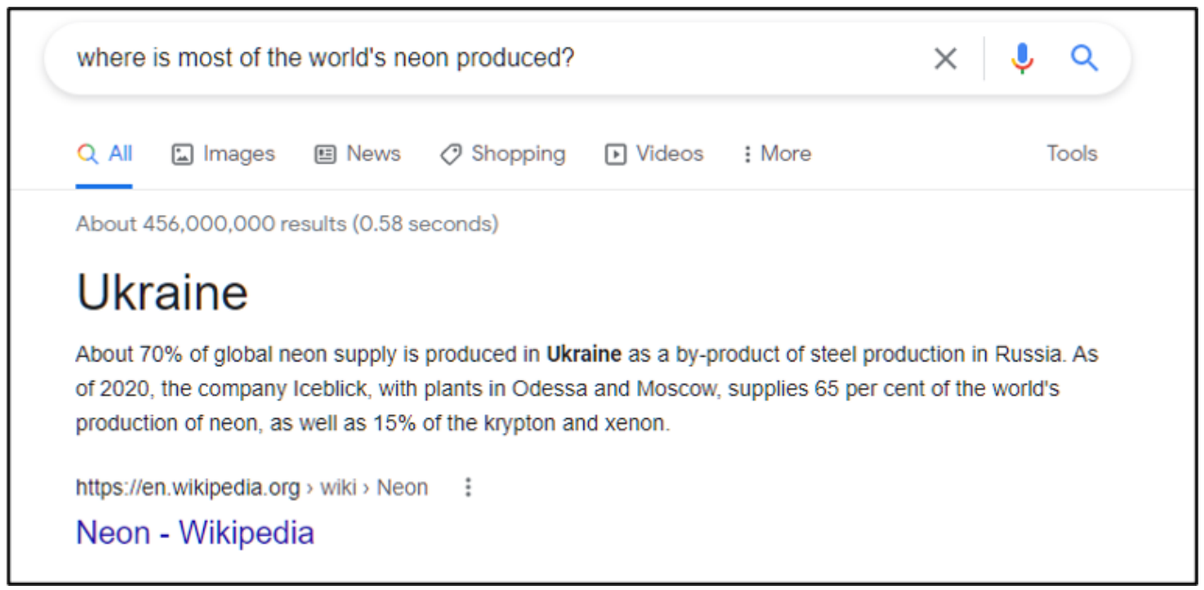


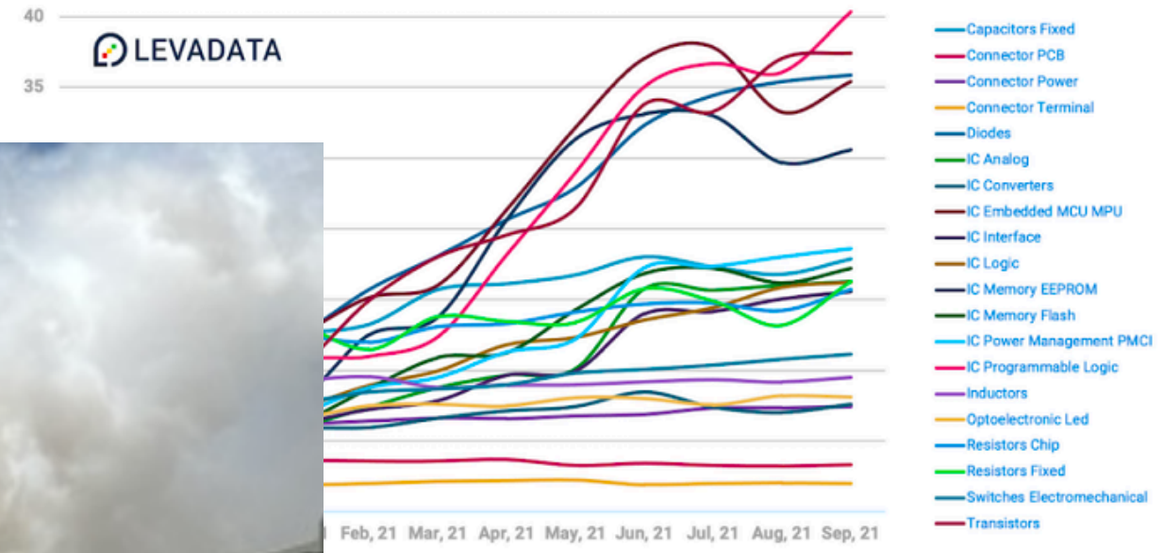


Multiple UPS trucks destroyed by flames when fire breaks out at California facility

There is no word of any injuries, and it's unclear what caused the fire.

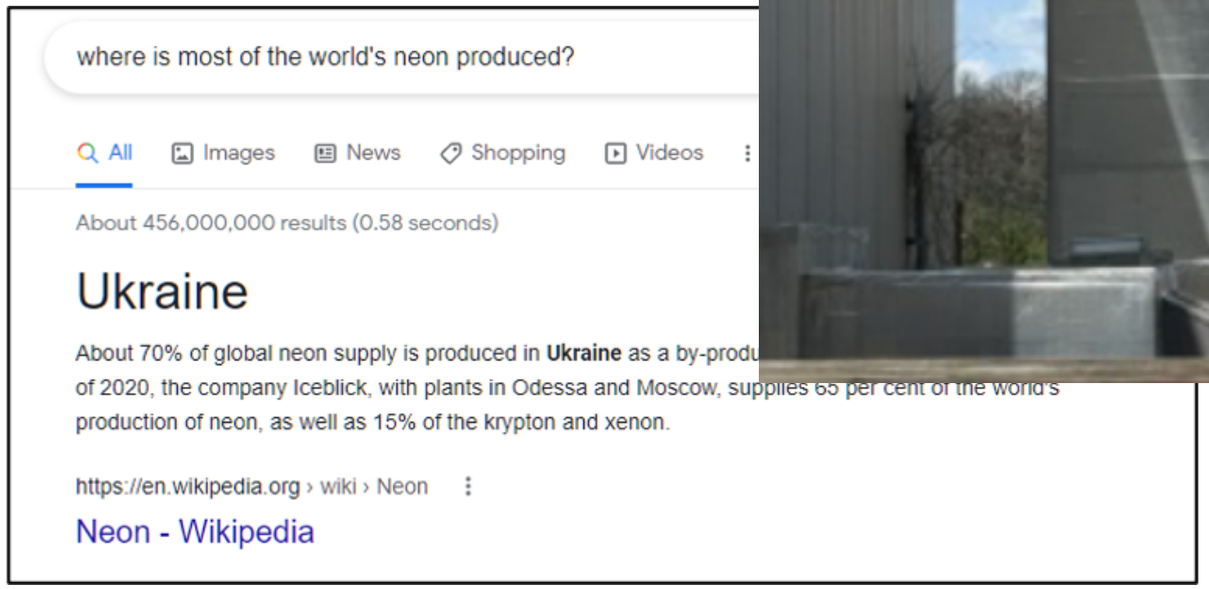
Monday, April 11, 2022

The challenges of constructing a new detector



PS trucks destroyed by flames
breaks out at California facility

y injuries, and it's unclear what caused the fire.



Status

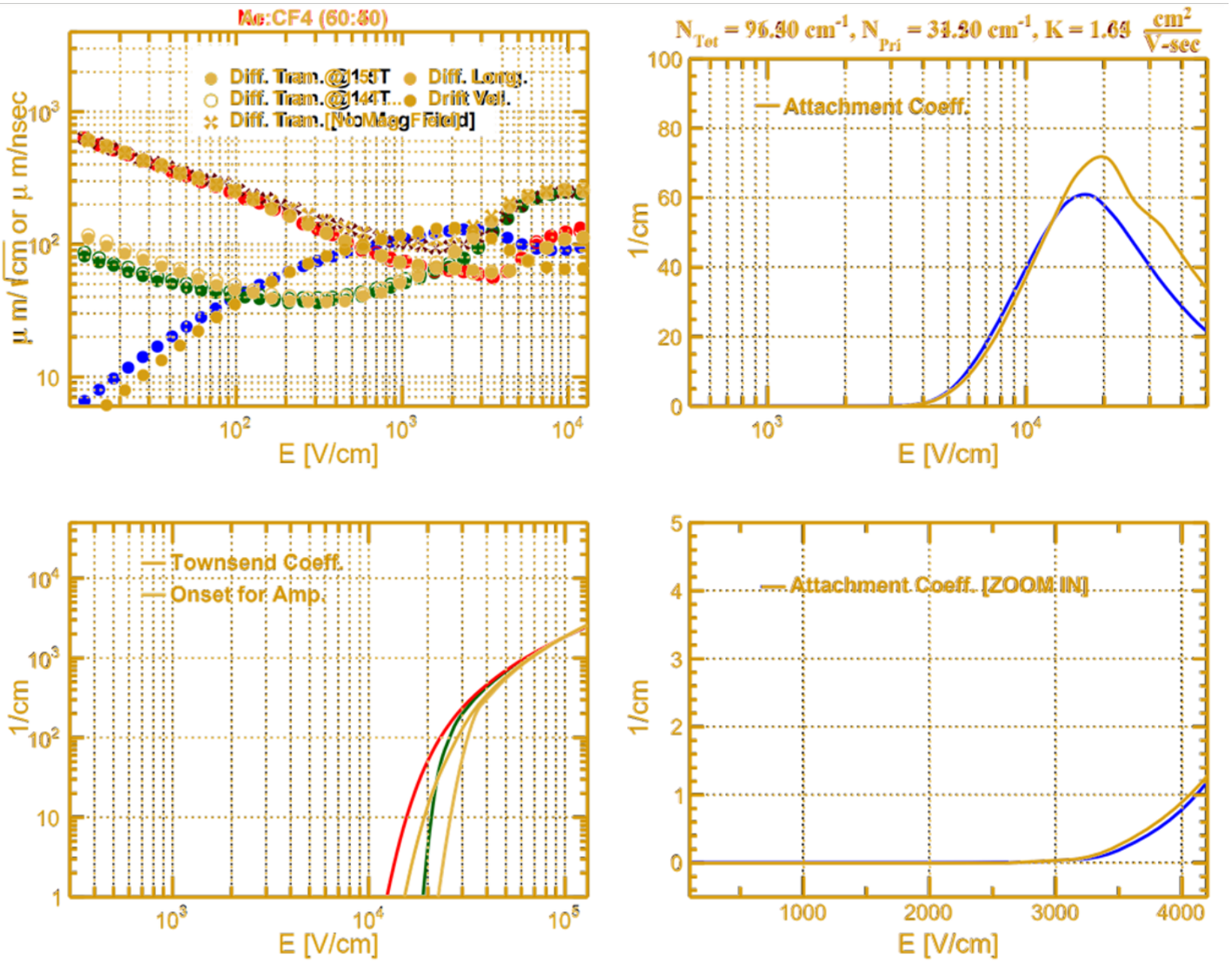
- **A lot of work has already been done**
  - sPHENIX is fully installed and was operational in RHIC Run 2023.
  - Detector subsystem performance is consistent with expectations
- **Some still remains**
  - Commissioning work prior to and during the early weeks of RHIC Run 204
  - A lot of physics coming in the next years!

Start of a new experiment always is an interesting adventure!

Back-up

TPC gas change

Ar:CF_4 60:40

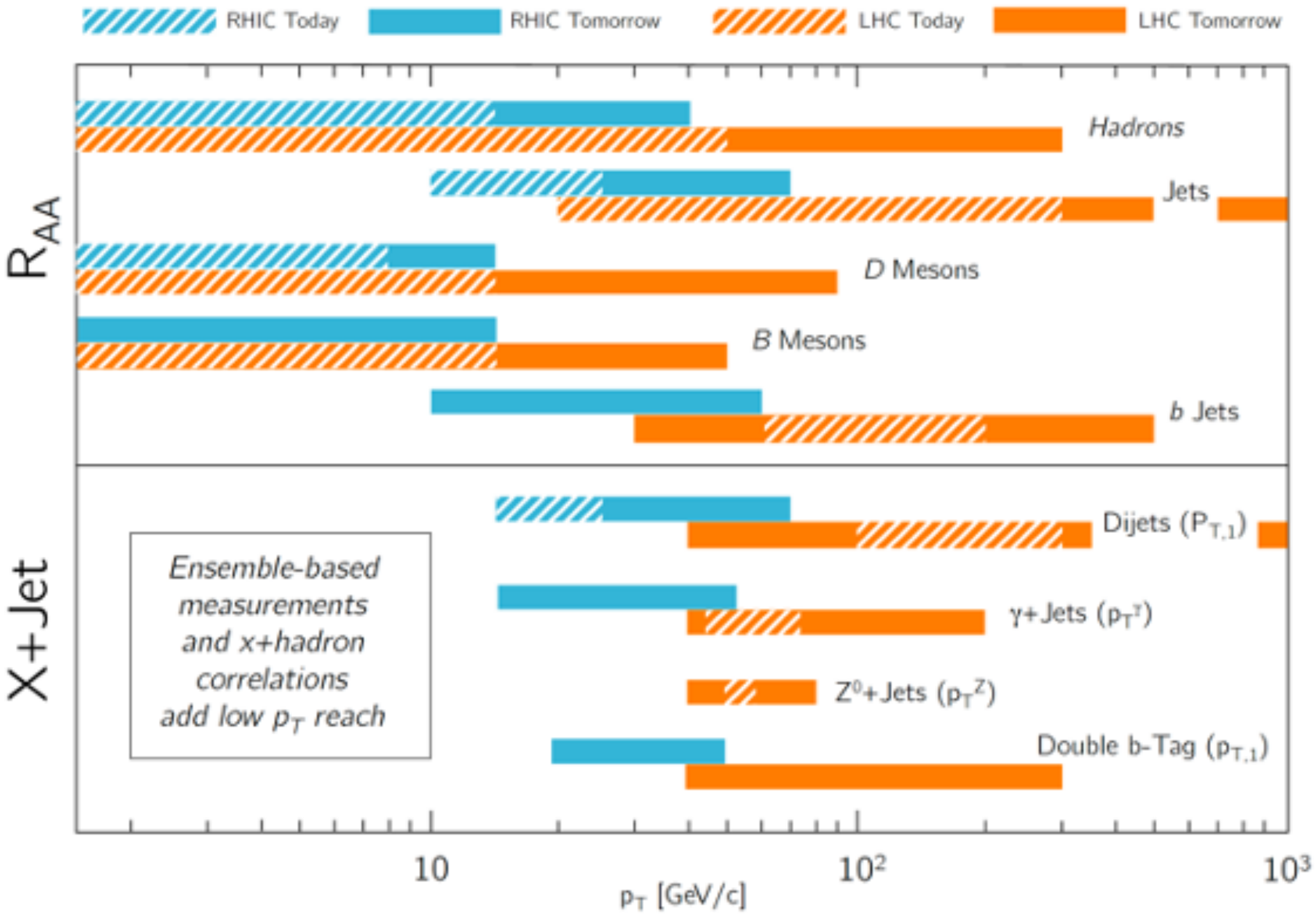


- Near perfect match in transverse diffusion, longitudinal diffusion, electron drift velocity, and attachment
- The Townsend coefficient is a bit lower -> need for higher voltages to produce the same gain
- The ion mobility is down by 23%...indicating 23% higher space charge.

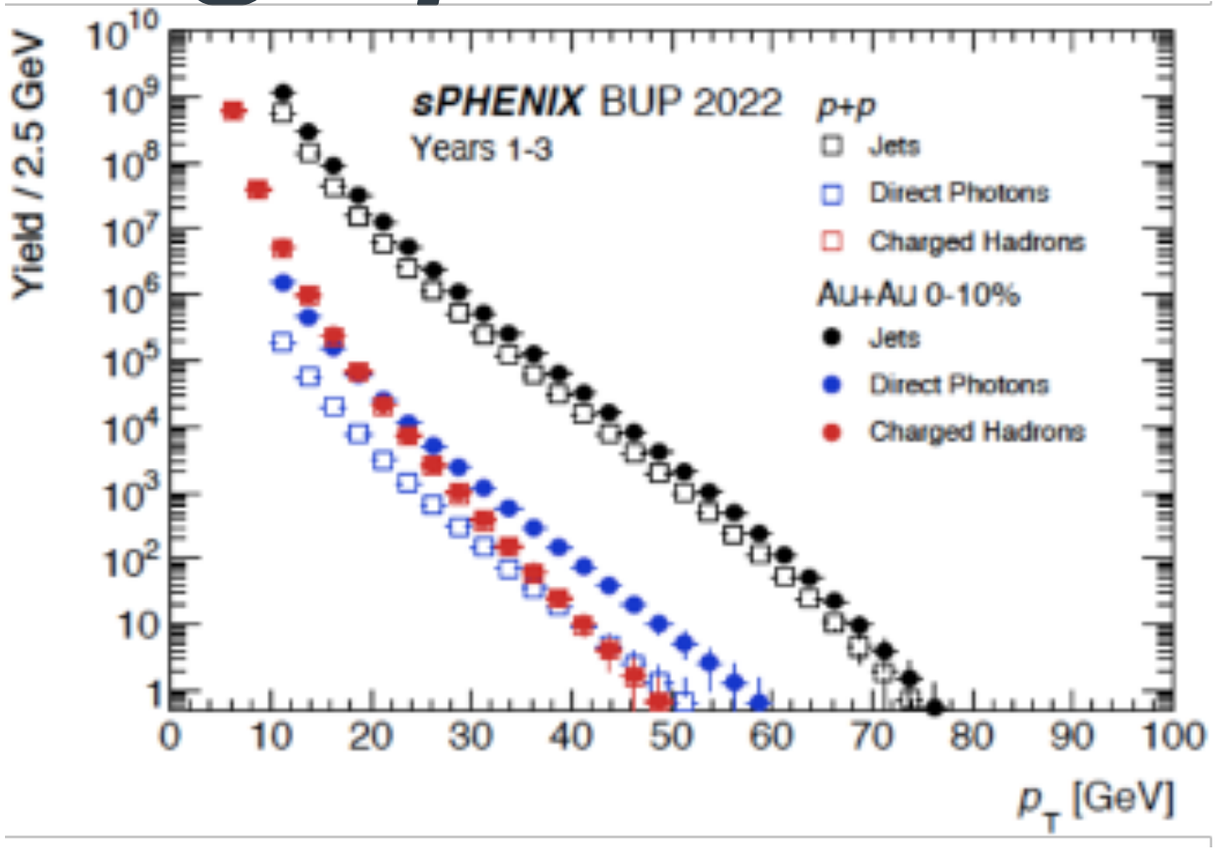
Missing commissioning taks

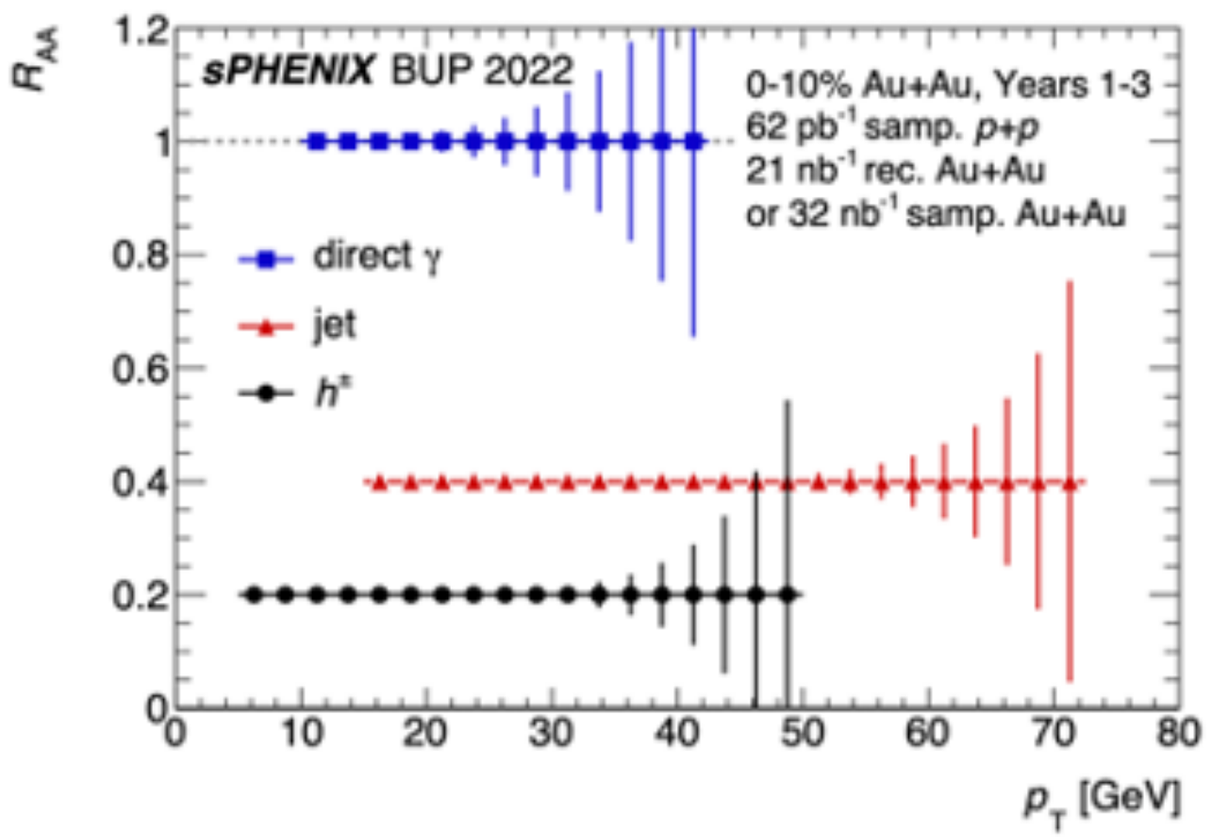
System	Before Run 2024	During Run 2024
Trigger	Firmware and software development of calorimeter triggers	First operation of calorimeter triggers with beam
TPC	• FEE firmware completion • tests of zero suppression • completion of MJACK to mitigate SEU • development of digital current • cosmic ray data with and without zero suppression	• Stable operation with HV • collision data with and without zero suppression • testing of digital current and SEU mitigation
DAQ	• Tests with zero suppression in calorimeters and TPC • Throughput and livetime tests with multievent buffering • Development of offline event building • Any additional development needed to achieve routine 15 kHz • Improvements in reliability, data integrity, and error handling	• Tuning of zero supression • Timing of detectors to new triggers • Spin: integrate ZDC, SMD and MBD digital scaler information into GL1
MVTX	• Field off cosmic data for tracking development and alignment • Development of mitigation strategies for background and lock-up	• Field off and field on collision data for tracking development and alignment • Tests of mitigation strategies for background and lock-up
INTT	Field off cosmic data for tracking development and alignment	Field off and field on collision data for tracking development and alignment
EMCal HCal	(HCal) tower-by-tower cosmics analysis	Demonstration of design energy resolution and response uniformity

Kinematic coverage



High-p_T Probes

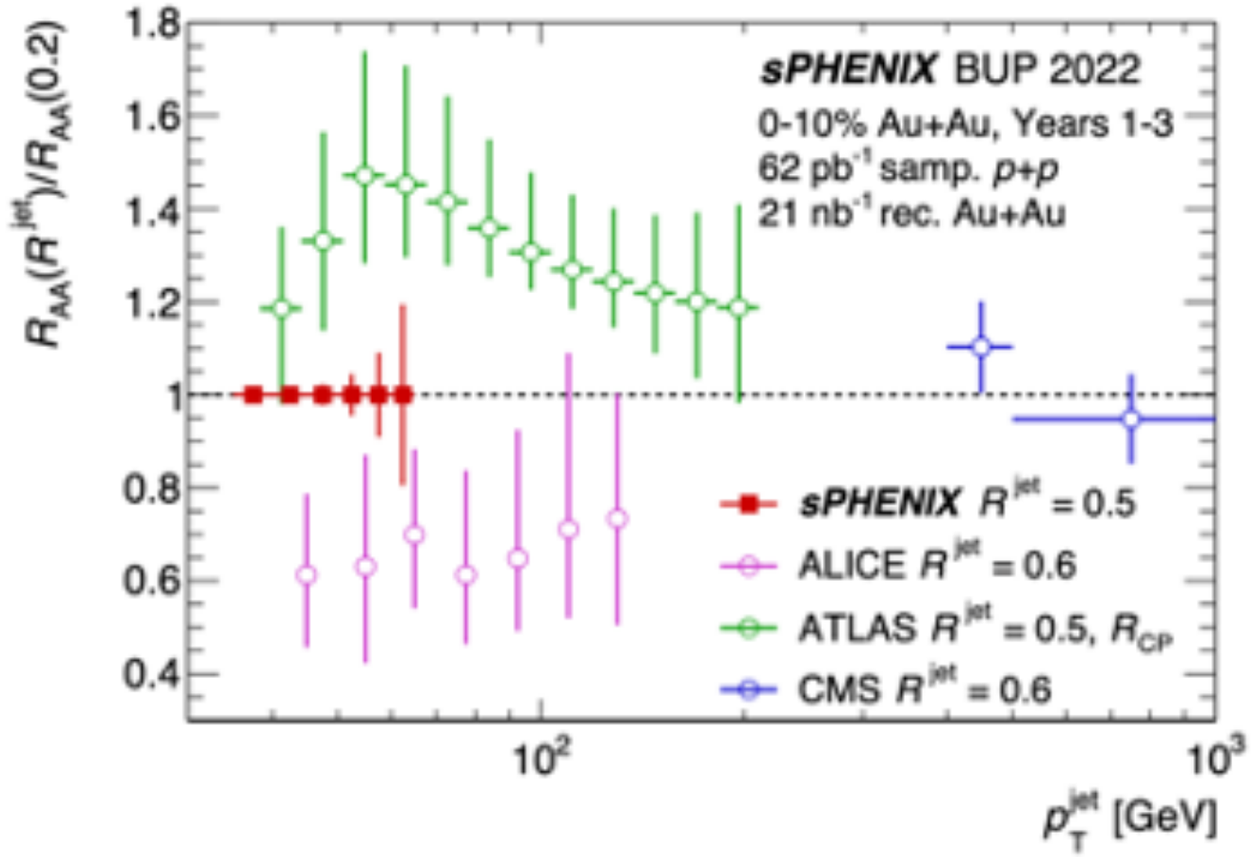


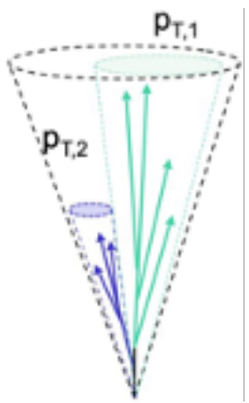


- In 3 years of data taking, sPHENIX will measure
  - Jets out to p_T ~ 70 GeV/c
  - Charged hadrons out to p_T ~ 50 GeV/c
  - Direct photons out to p_T ~ 40 GeV/c
- Kinematic overlap with LHC measurements

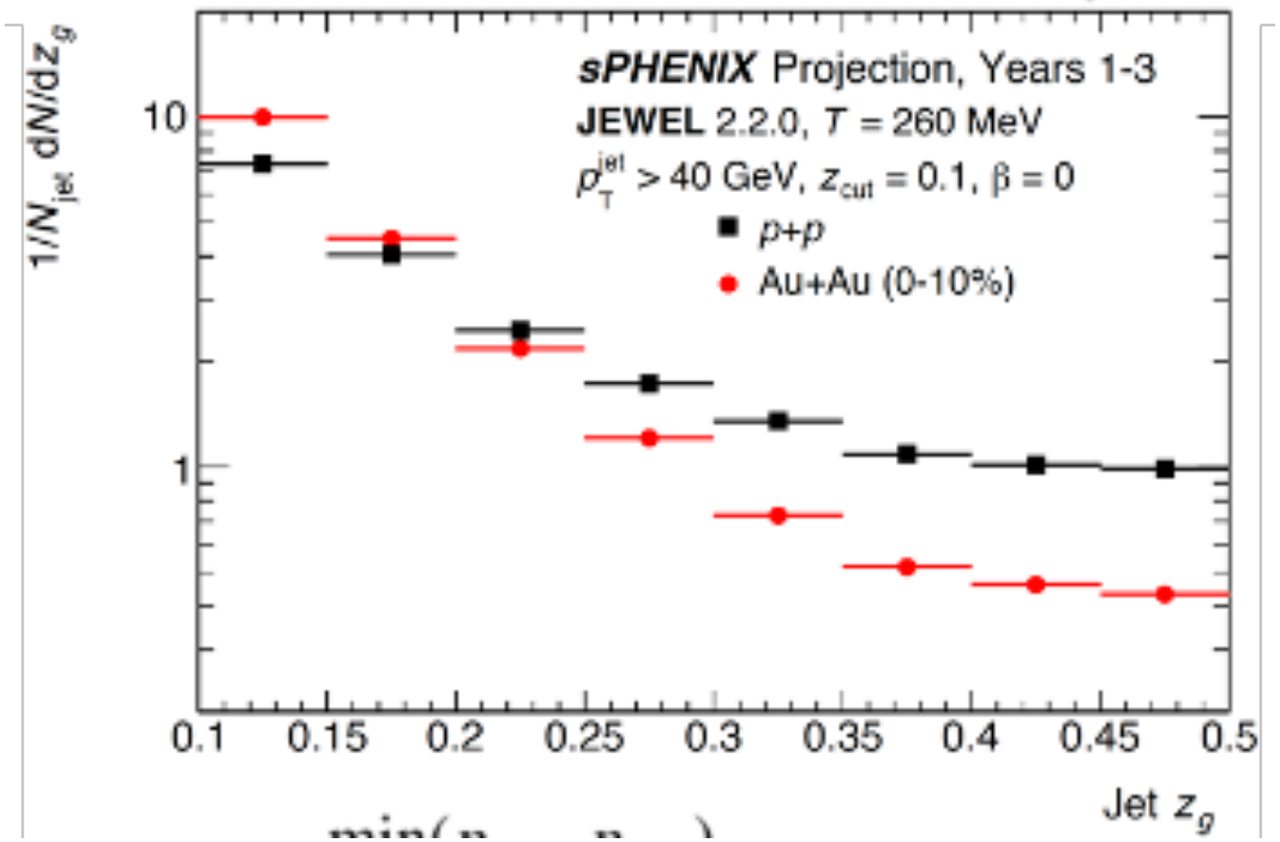
Jets

- Will measure jets for $p_T < 100$ GeV/c: tension in LHC jet results in this region
- Jet grooming will be used to explore evolution of parton shower
  - Connection to fundamental QCD
  - Probe to measure QGP properties



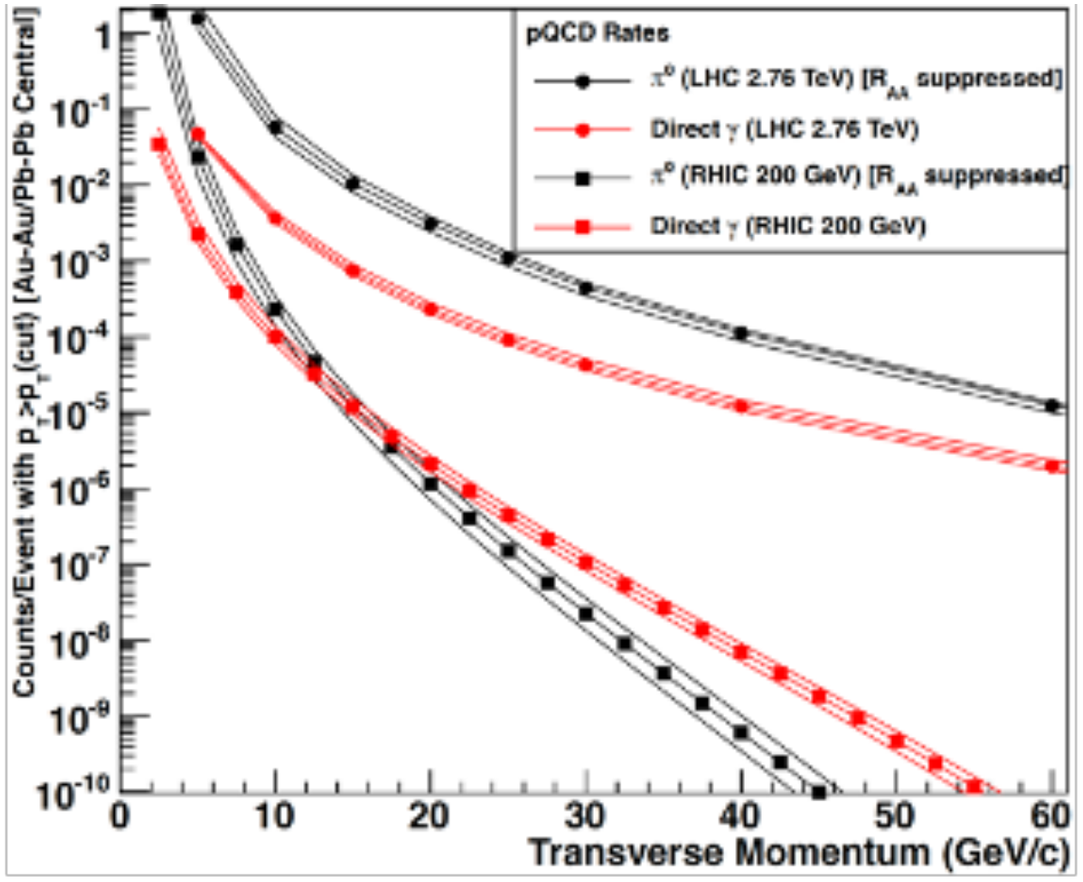


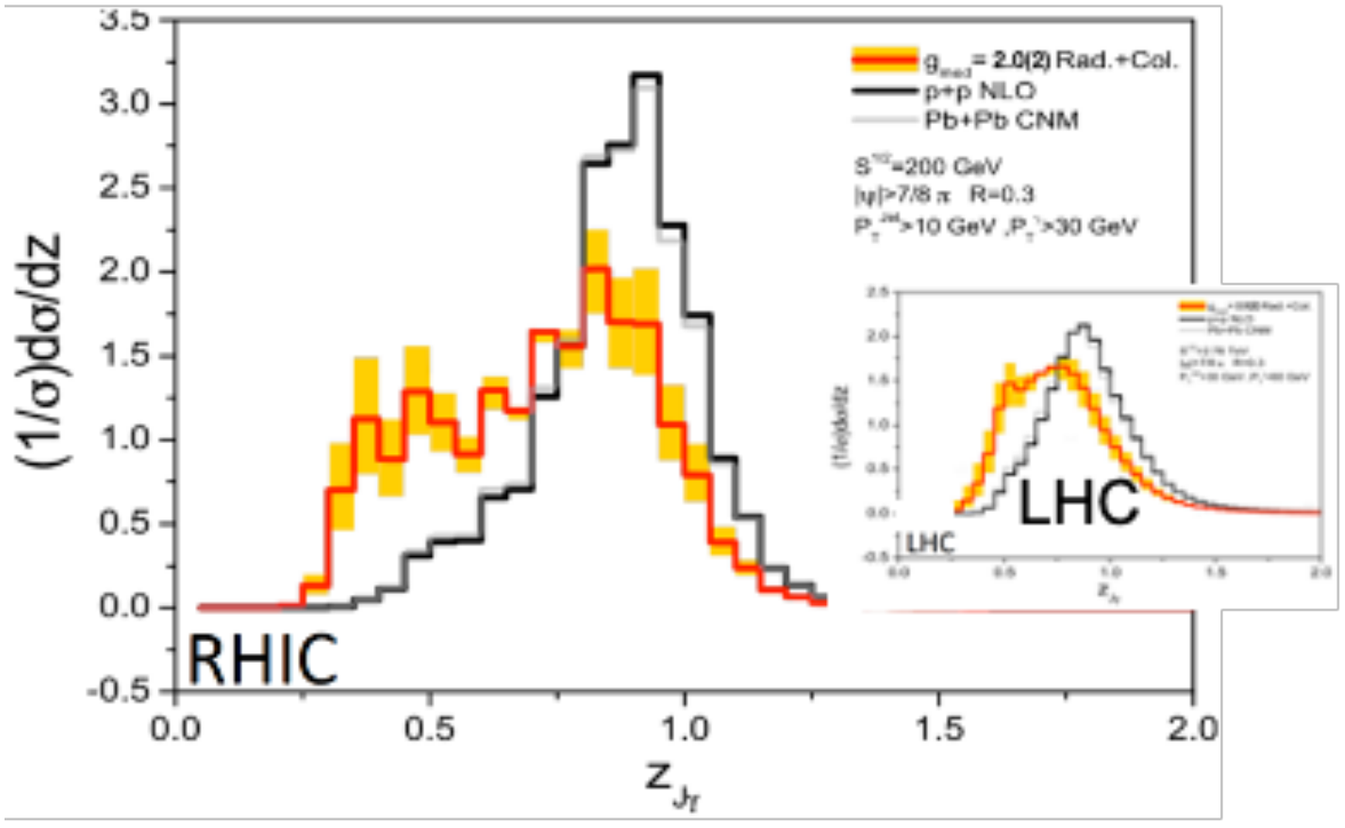
$$z_g \equiv \frac{min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

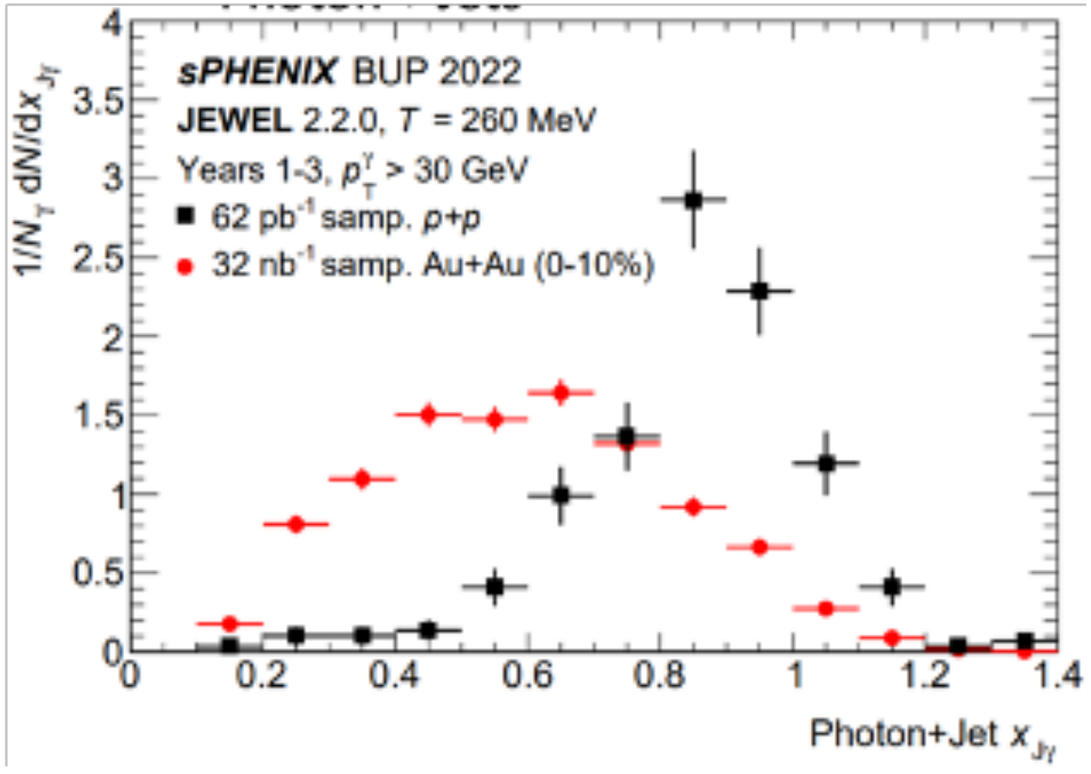


Photon-tagged jets

- Key measurement in sPHENIX physics program
- RHIC is ideal for measuring direct photons.
- Measurements of z_{Jg} may be more sensitive at RHIC

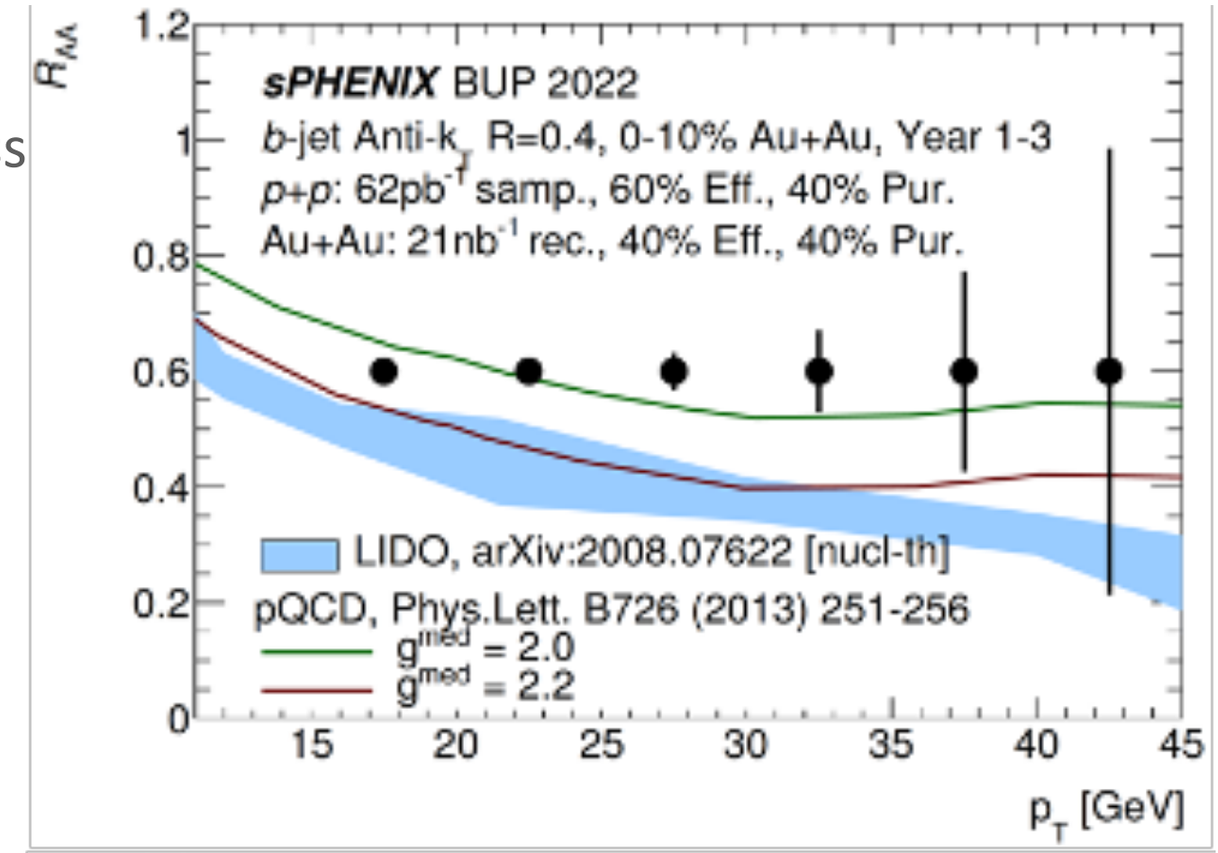


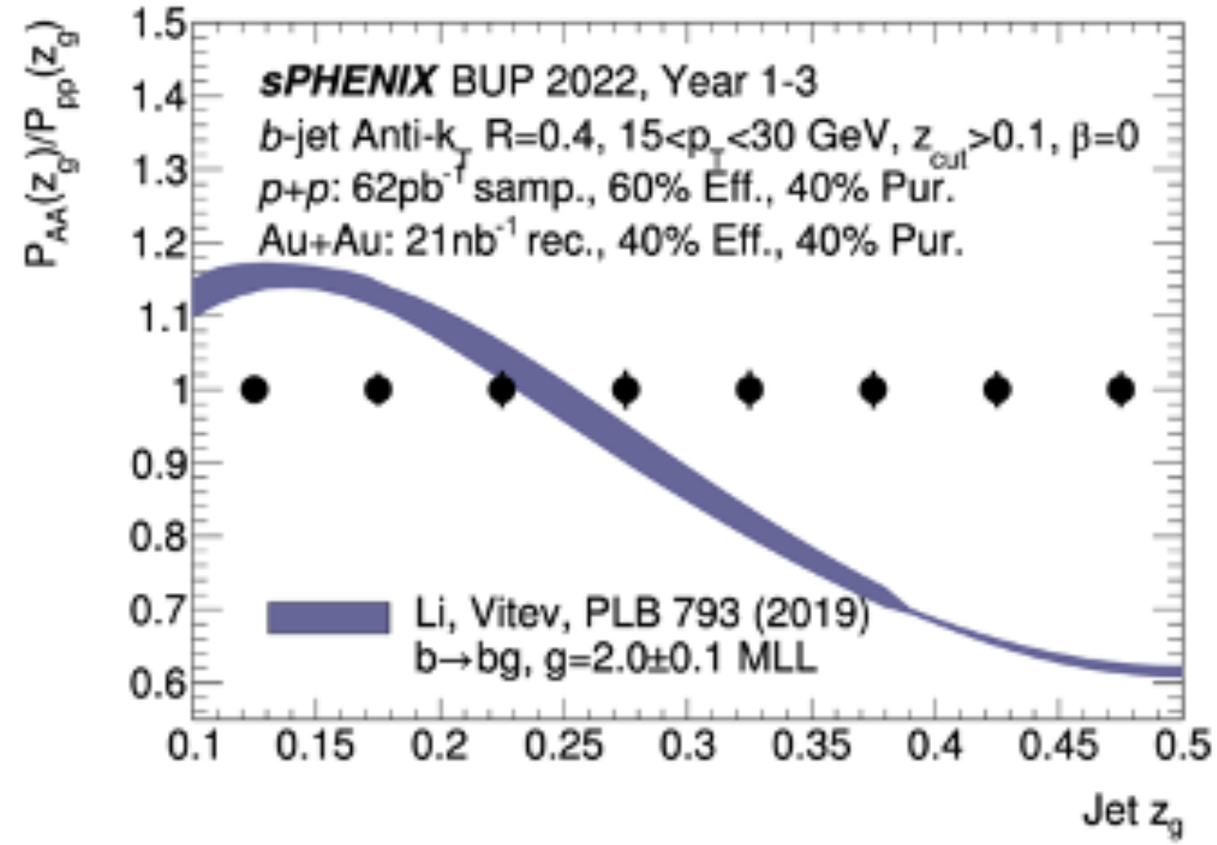


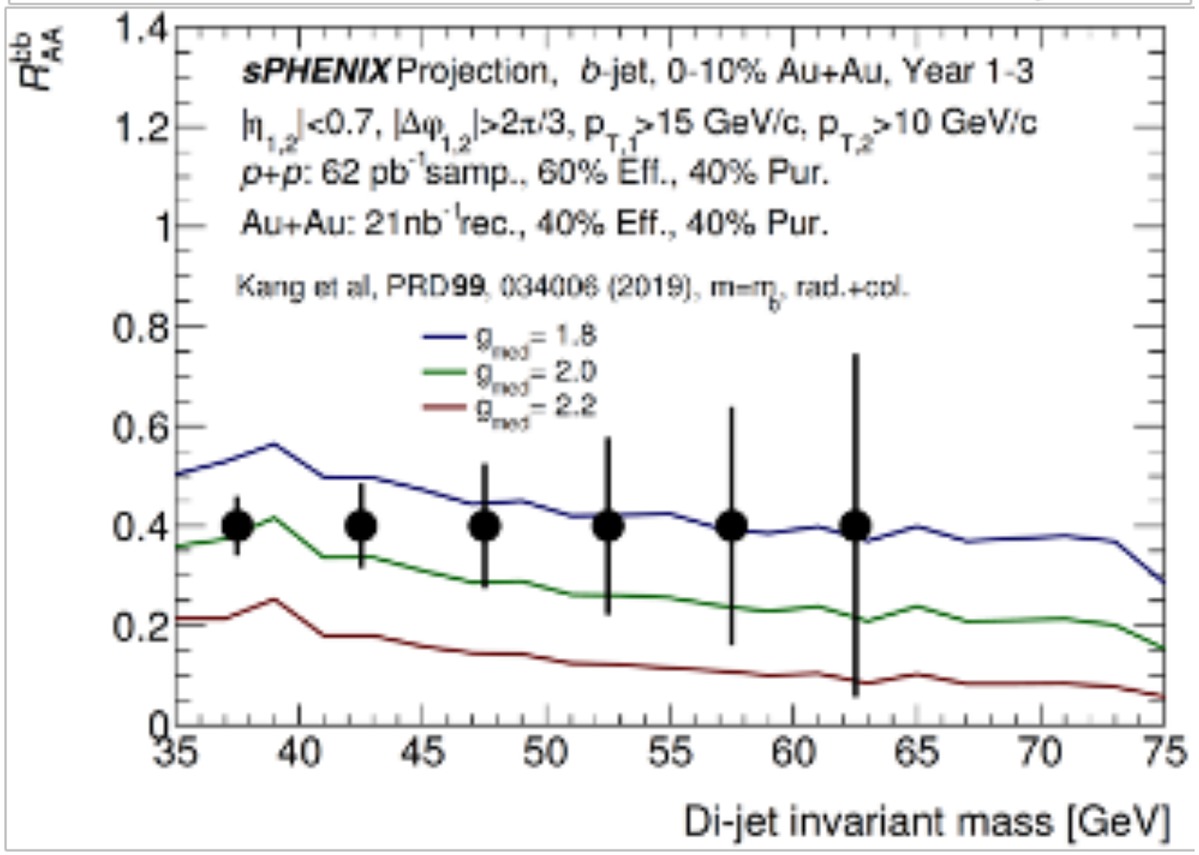


b-tagged jets

- Sensitive to collisional vs. radiative energy loss
- 1st RHIC *b*-jet measurement!
- Lower p_T range than LHC
  - Larger heavy-quark mass effect
- Studies of *b*-jet substructure

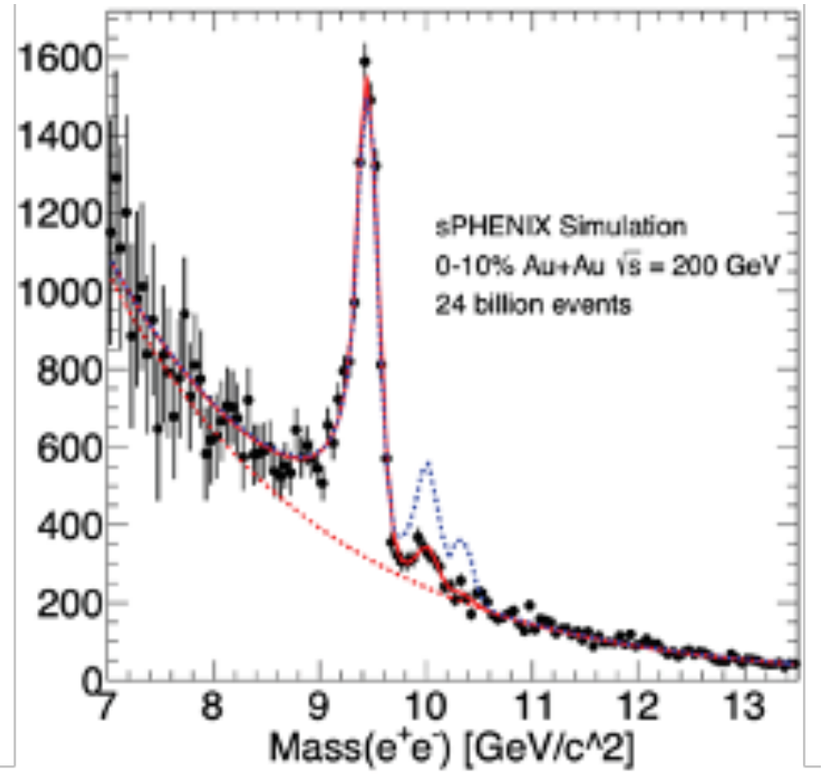


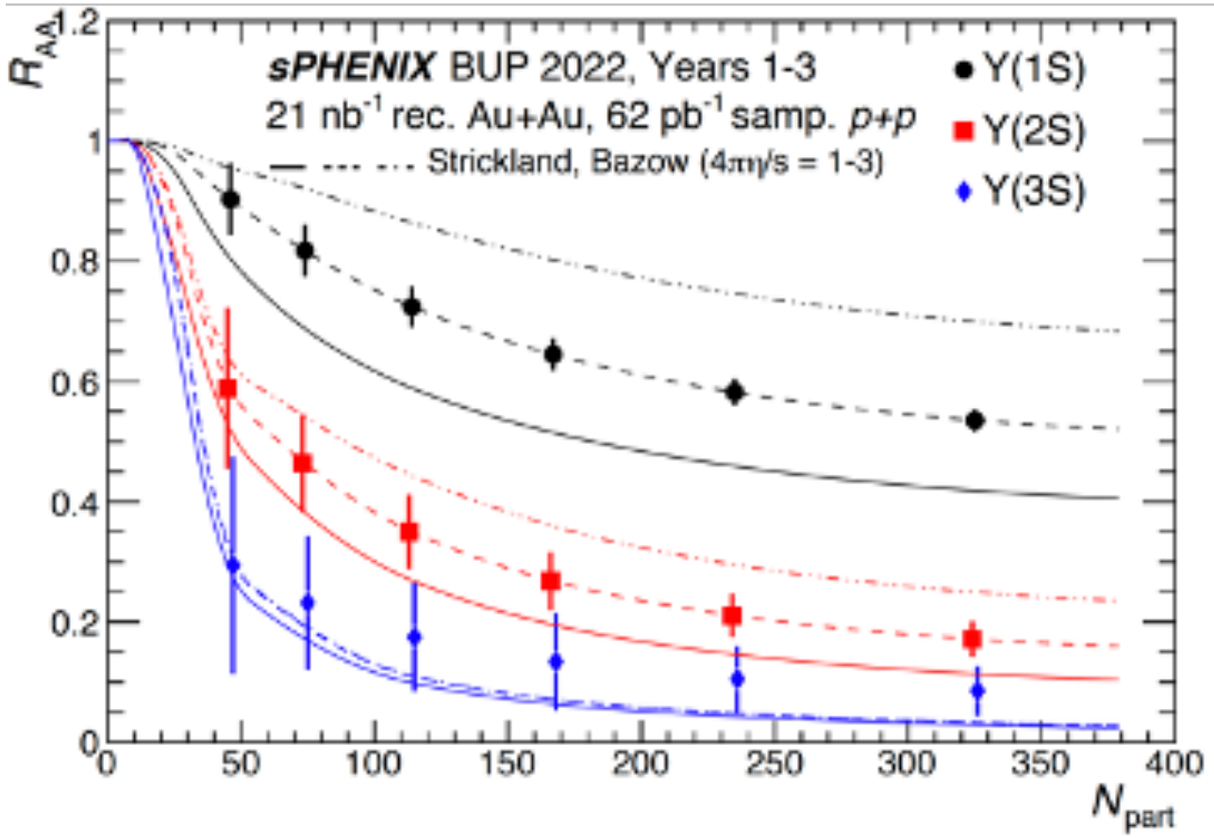


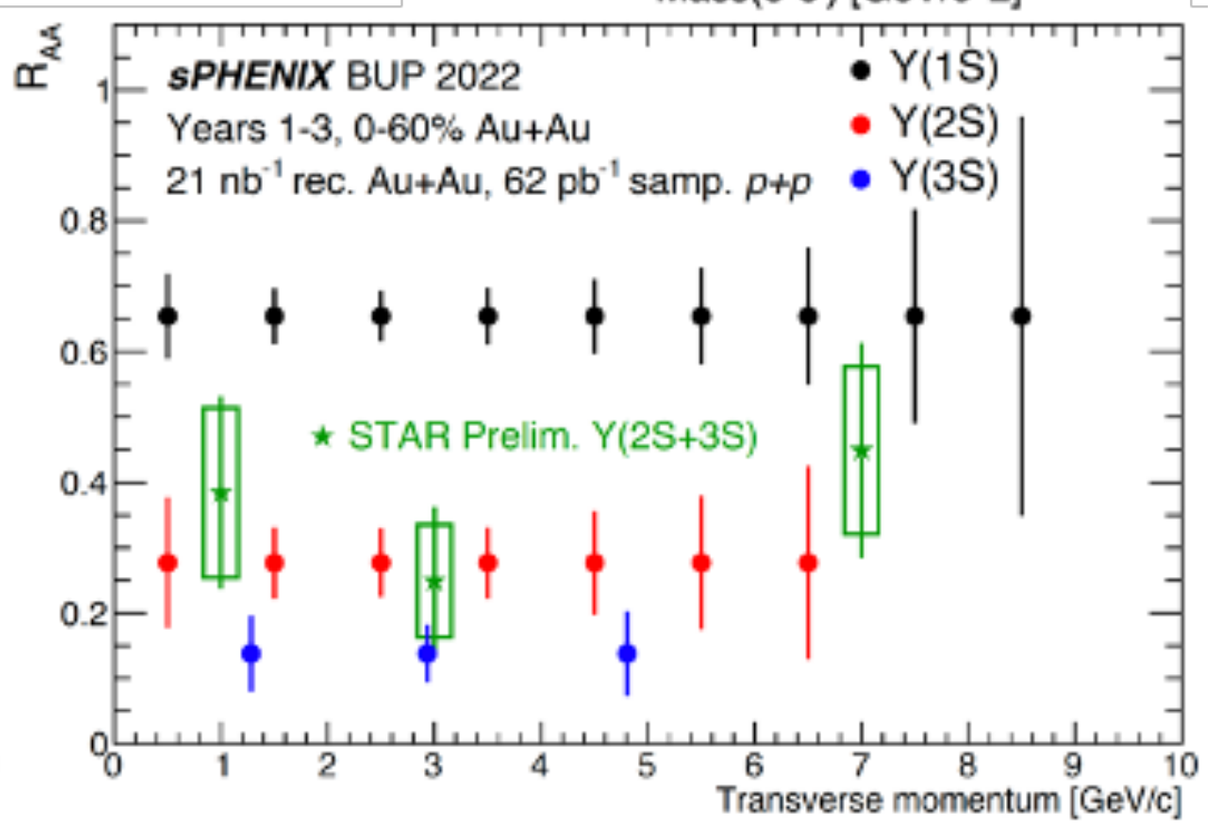


Quarkonia

- Excellent mass resolution will allow clean separation of three U states
  - First time at RHIC!
- Chance for clear measurement of U(3*S*) suppression → test of theoretical predictions

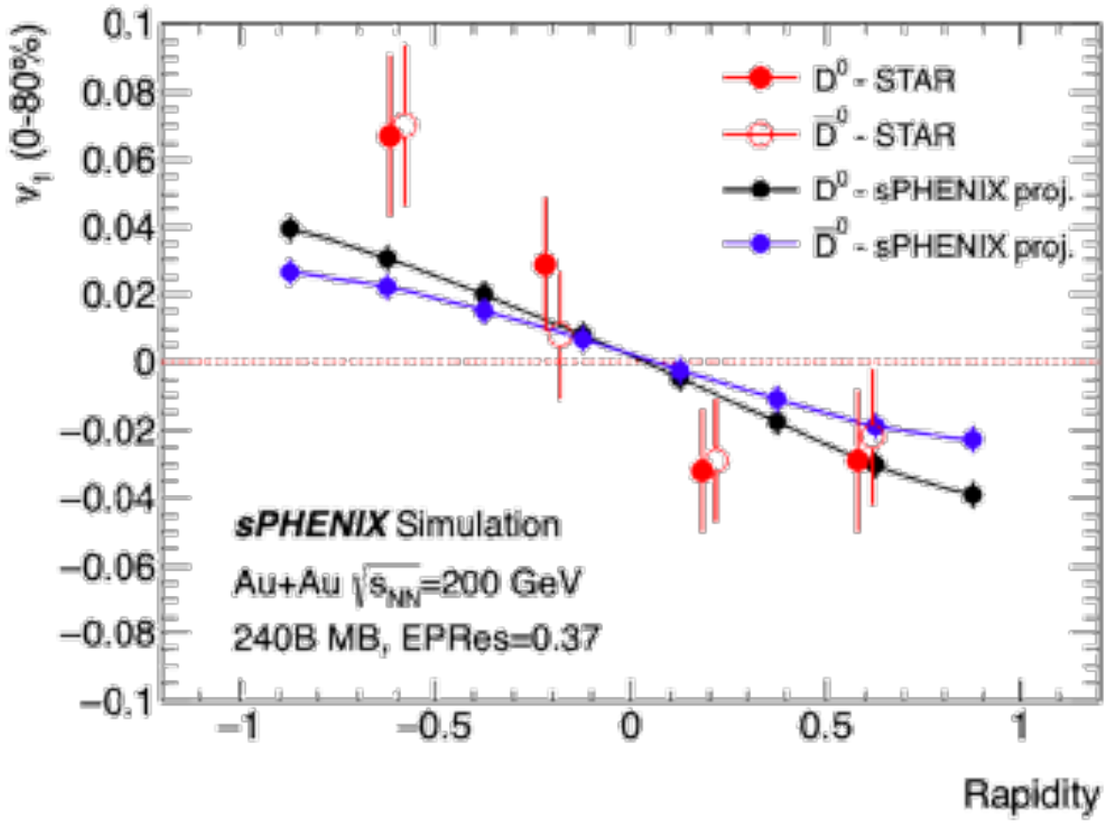


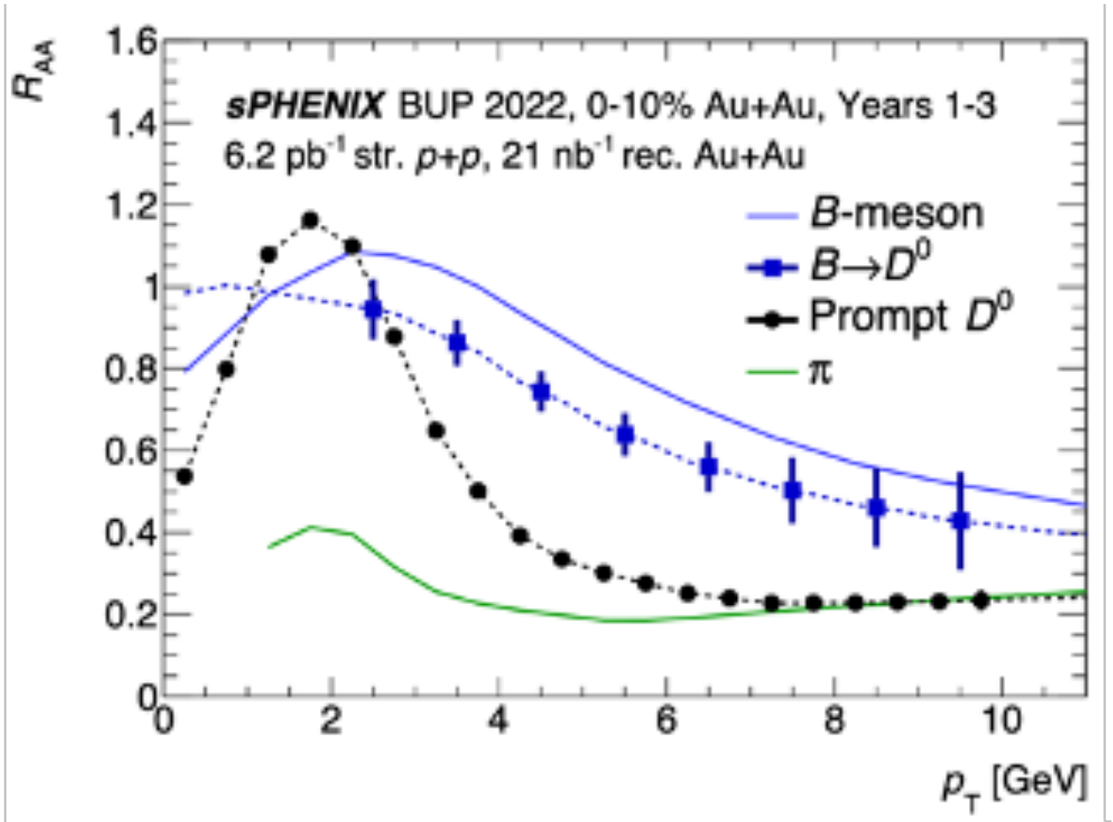


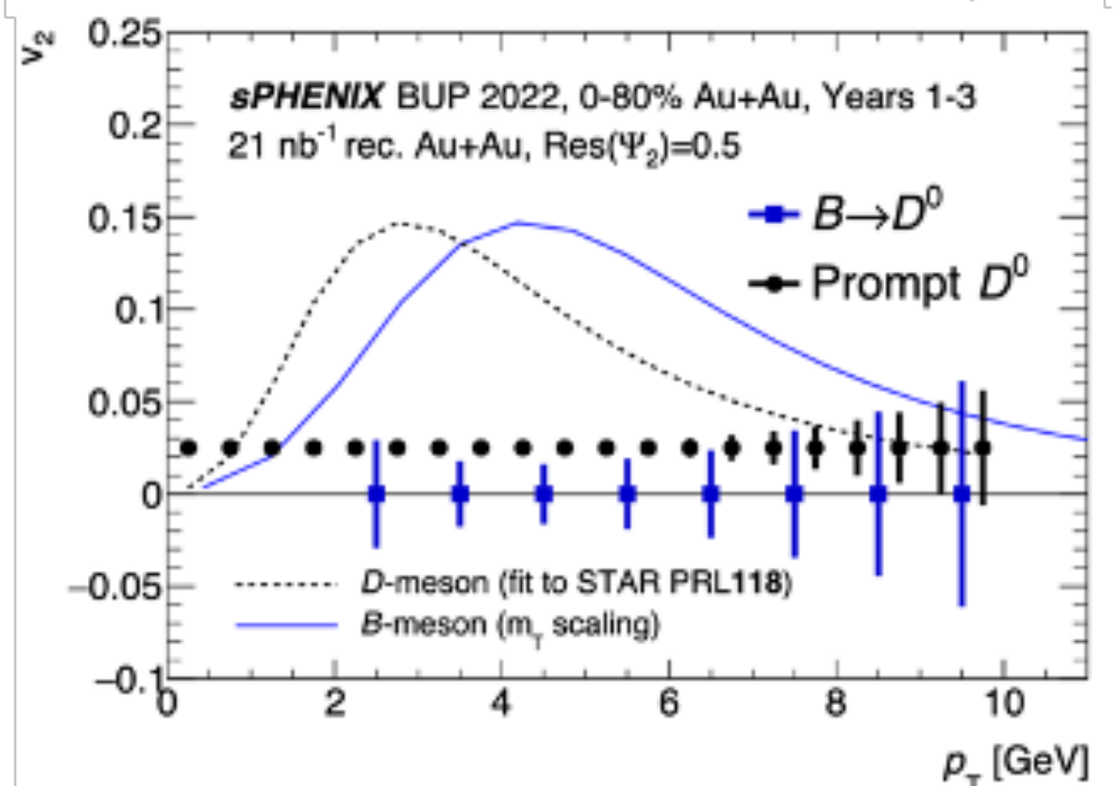


Open Heavy Flavor

- Streaming readout → large min. bias data set & HF measurements down to $p_T = 0$
- Will access *b*-quark R_{AA} & v_2 via non-prompt D^0
- Transient magnetic field may influence v_1 differently for D^0 & $\overline{D}^0$

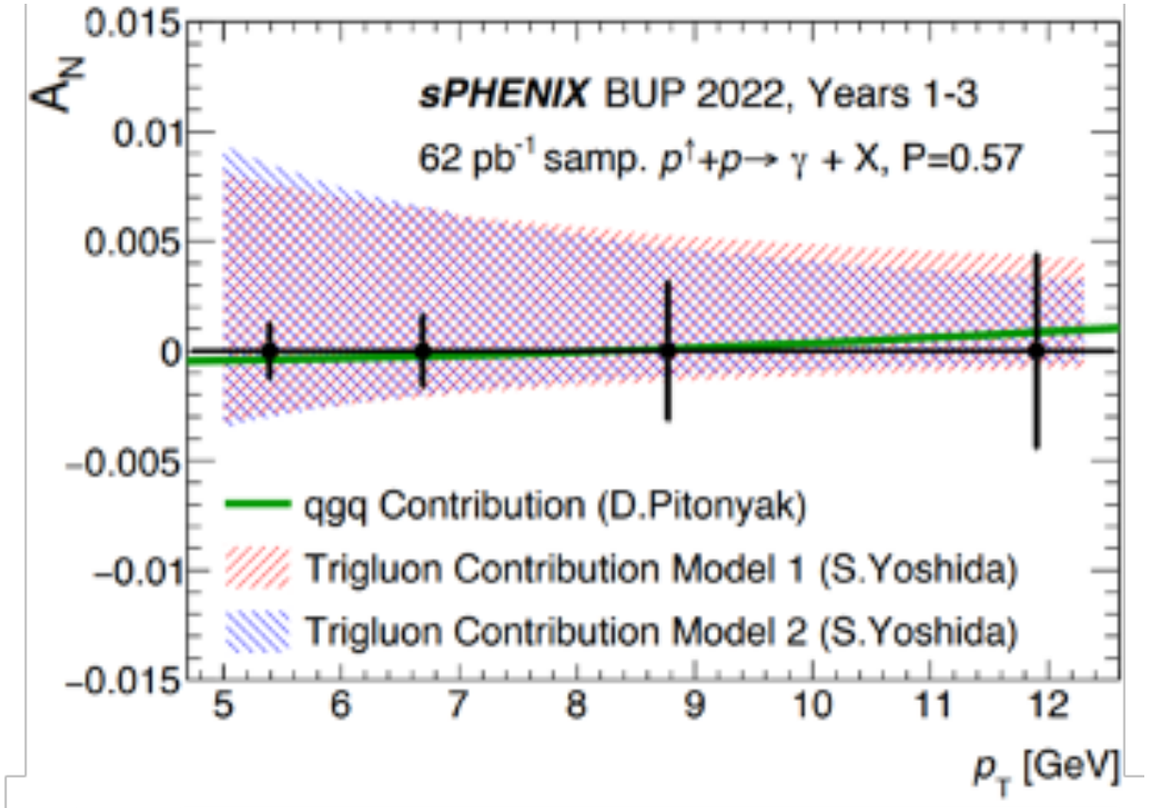


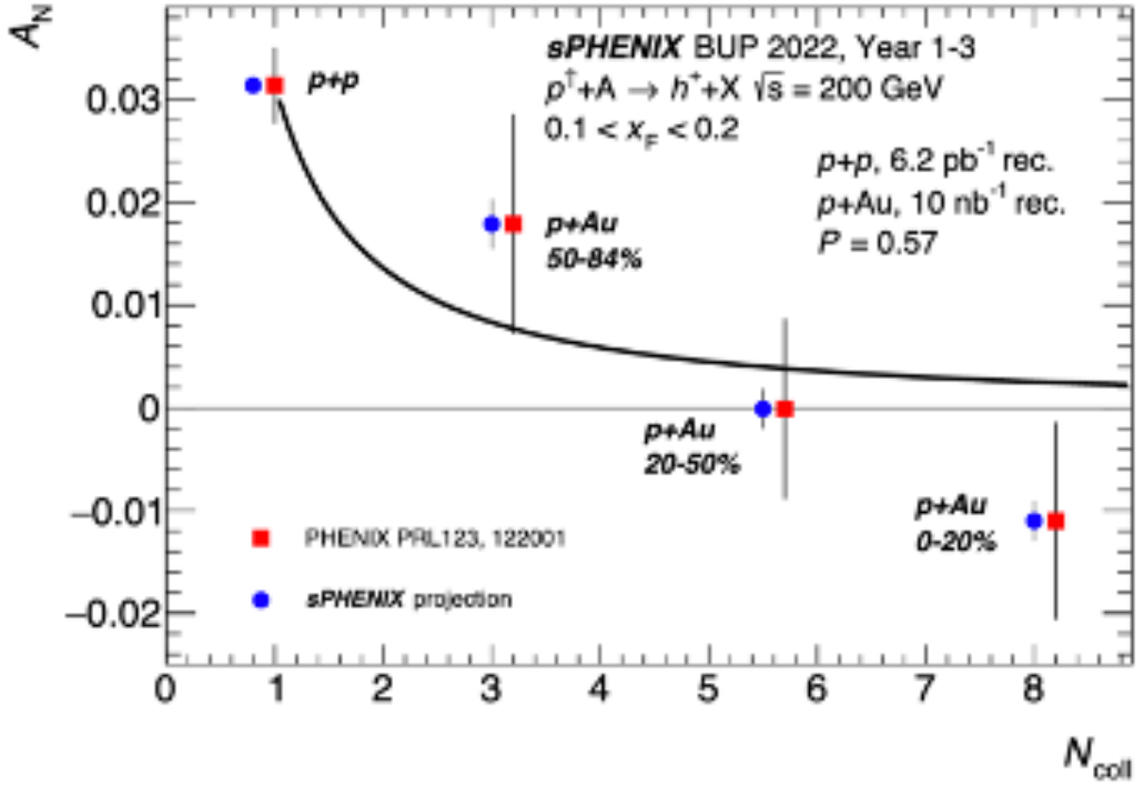


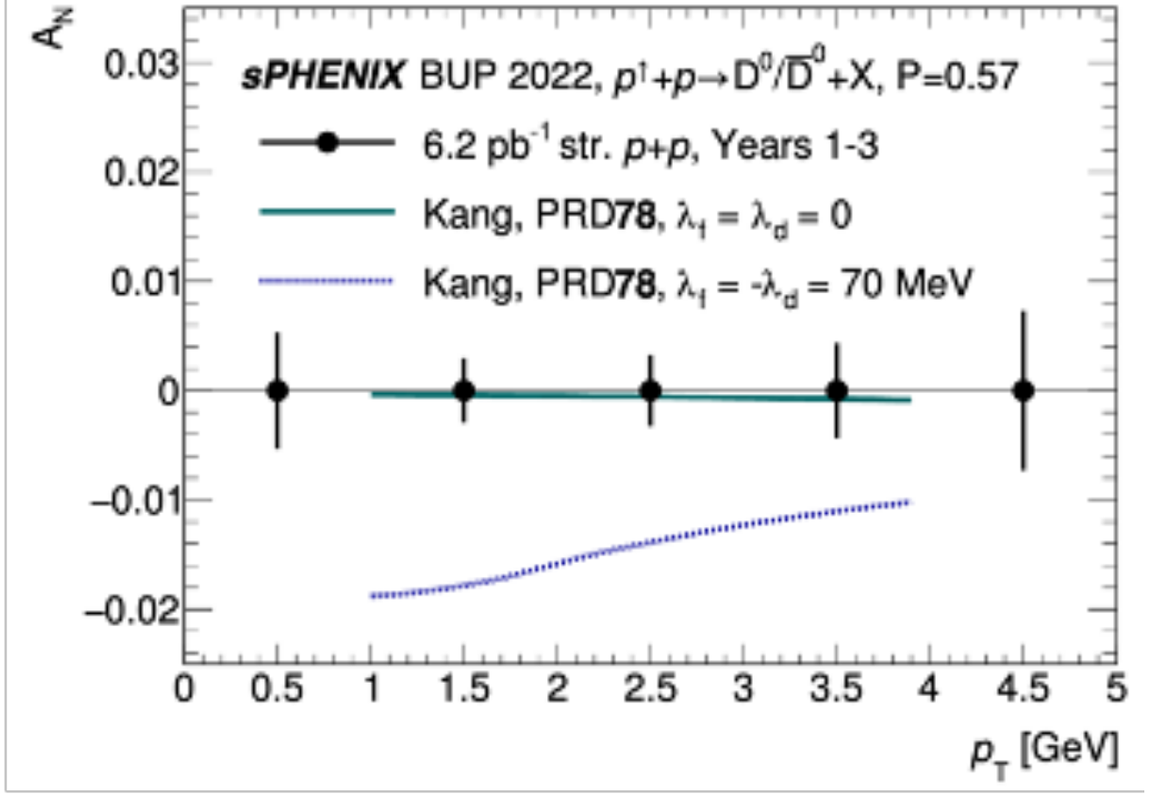


Cold QCD

- Transverse Single-Spin Asymmetry via prompt photons & D^0
- *p*+Au: Measure nuclear dependence of TSSA
- Improved statistics w.r.t. PHENIX







The collaboration

358 Members
83 Institutions
4 Continents