

The sPHENIX Open and Close Heavy Flavor Program

Zhaozhong Shi

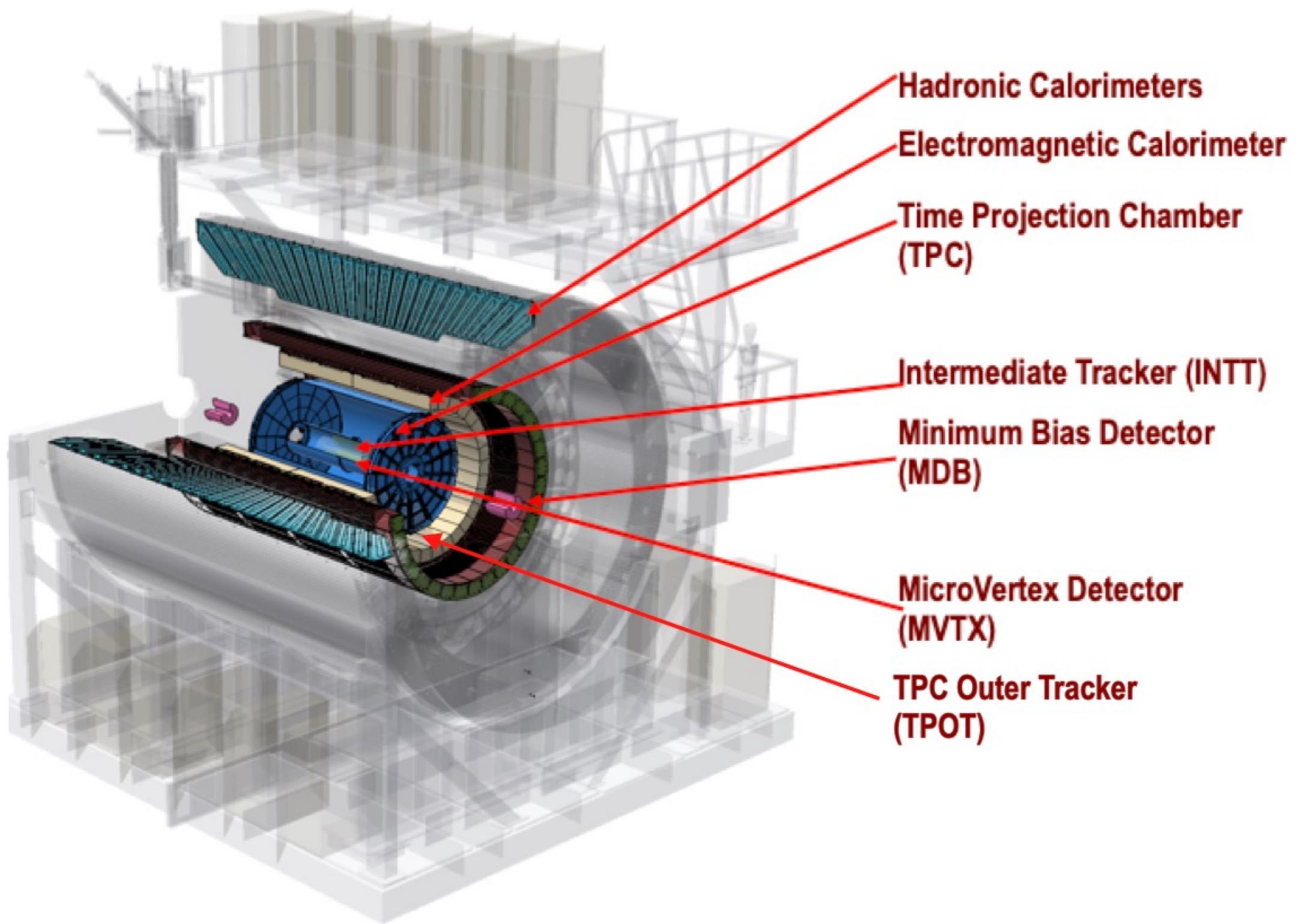
on behalf of the sPHENIX collaboration

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**QNP2022 - The 9th International Conference on Quarks
and Nuclear Physics**

5-9 September 2022, Tallahassee, Florida, USA (Virtual)

The sPHENIX Experiment at RHIC



2015 NSAC Long range Plan for Nuclear Science: sPHENIX Experiment at RHIC

- Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales
- Complementary to LHC experiments

sPHENIX Recent Milestones and Plan



Year 2022

Jan Feb Mar Apr May Jun Jul Aug



MCD II Starts:
Software
Milestone
Outer HCAL
Installation
Complete

Inner HCAL
Installation
Complete

RBBC
Workshop

Year 2023

Sep Oct Nov Dec Jan Feb Mar Apr



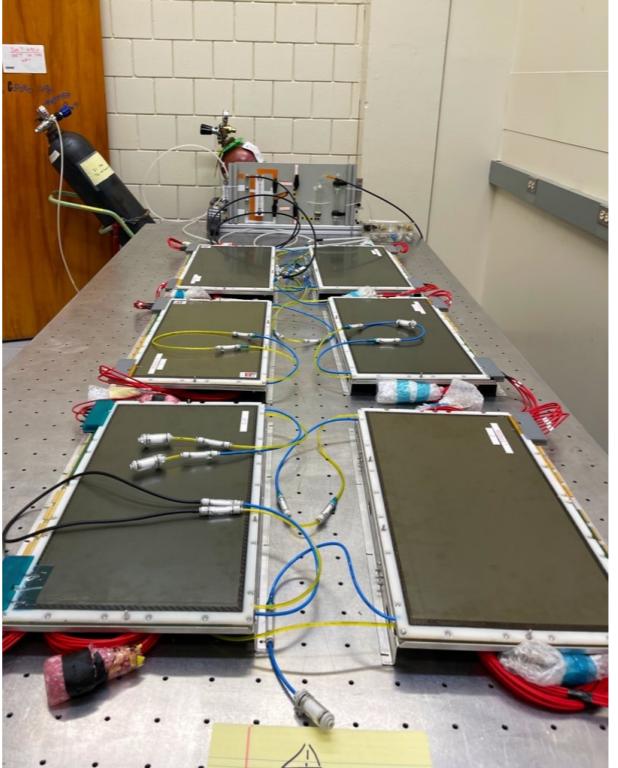
Start first data taking! (< 6 months)

- Collective efforts of international collaboration from 85 institutions in 14 countries
- Intense preparation to ensure timely and high quality data taking in 2023

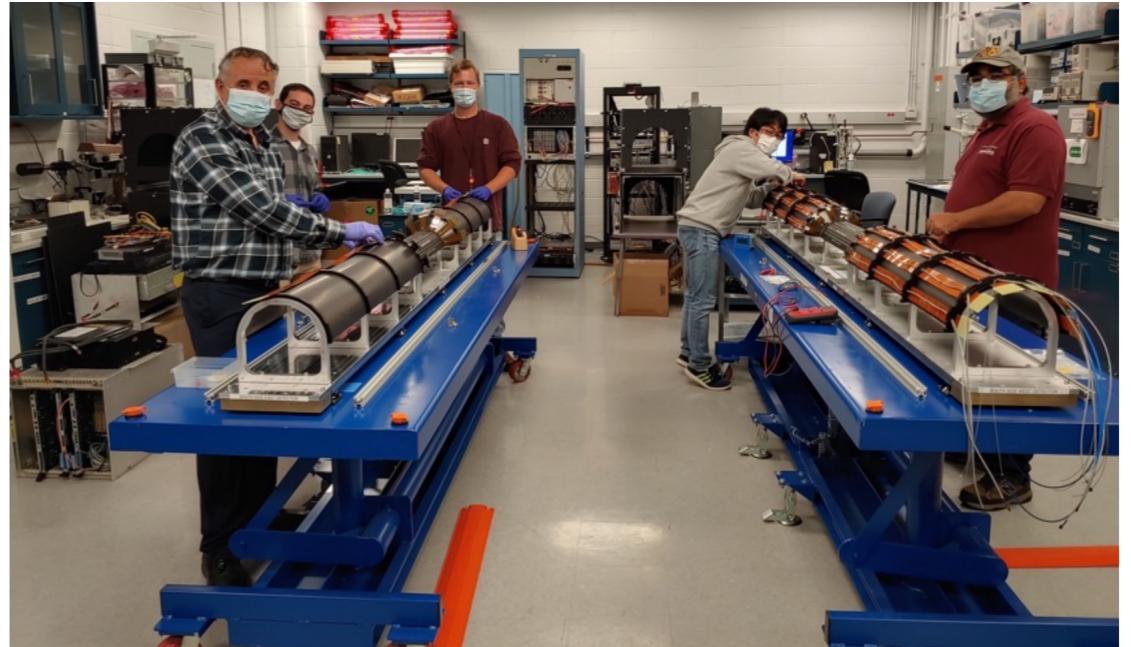
sPHENIX Detector Commissioning



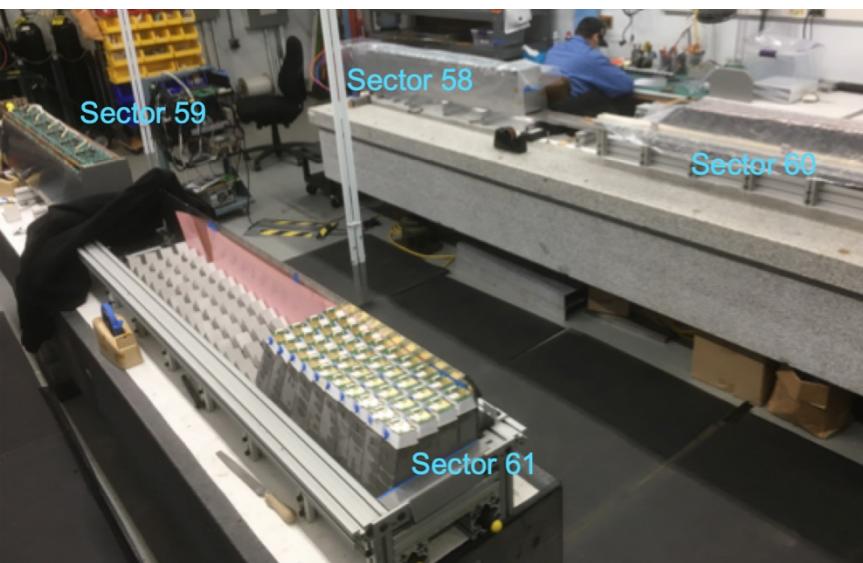
TPC construction at Stony Brook University



TPOT effort By LANL/Stony Brook



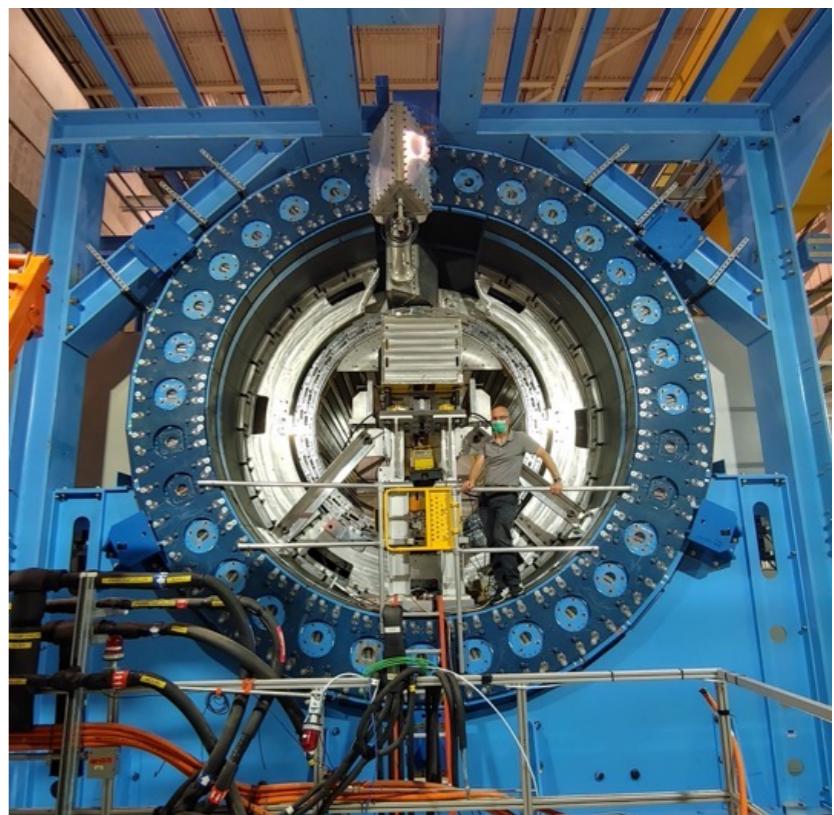
INTT stave completed, carbon fiber parts at BNL



EMCAL assembly at BNL



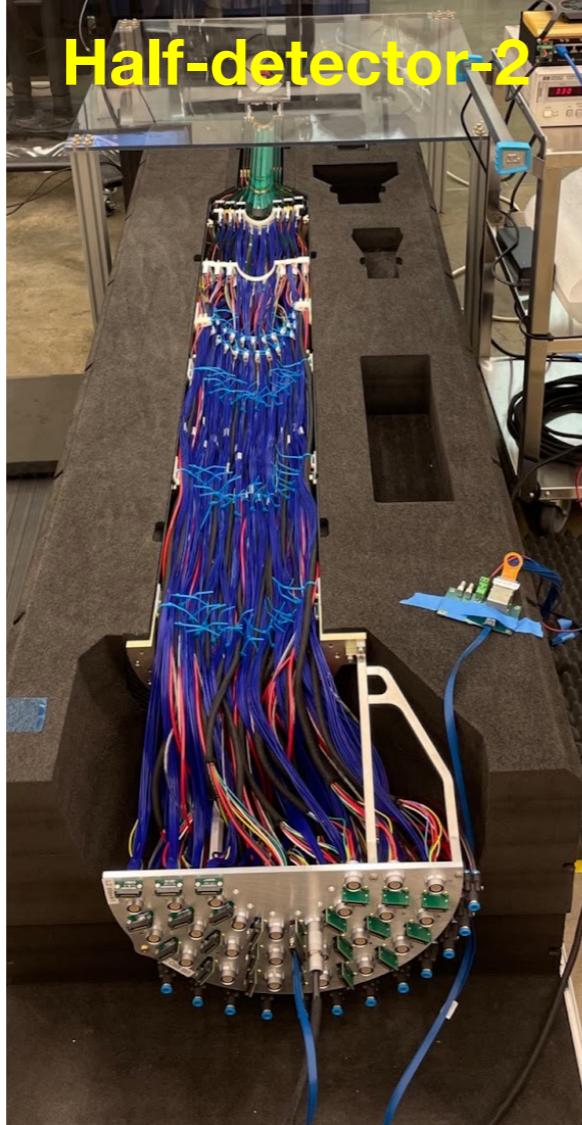
Commissioning task force



sPHENIX detector with HCAL in the PHENIX hall

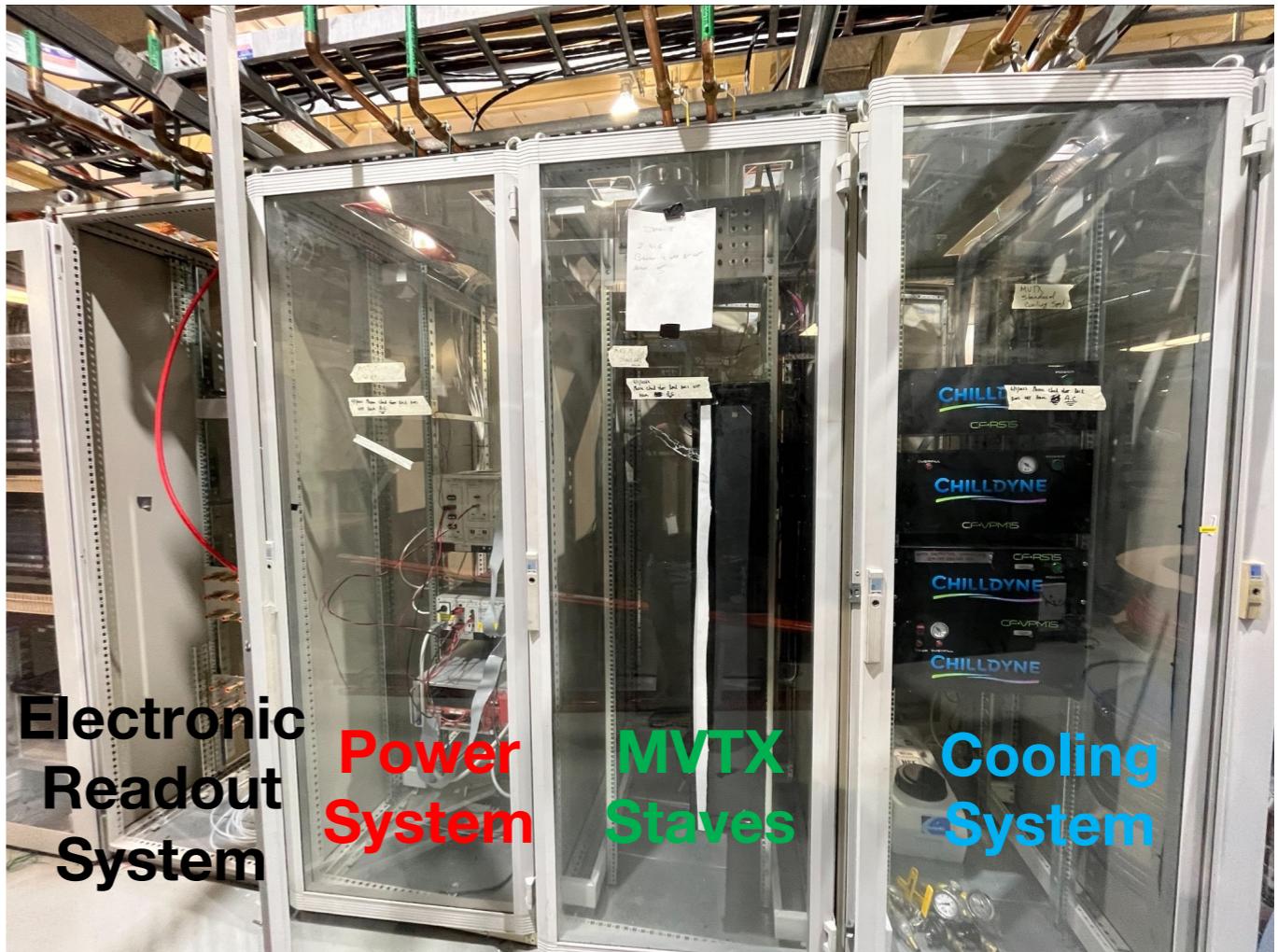
- Lots of construction activities of detectors ongoing in many places
- Collaborative and diverse workforce of students, postdocs, staff, and faculty
- Install the sPHENIX detector from outermost to innermost in the PHENIX hall at BNL

MVTX Commissioning Status



BNL Commissioning

- Clean tent setup
MOSAIC system to test the staves performance
- Entire MVTX system testing
Readout chain test
Detector alignment with cosmic ray data and machine learning
Online monitoring and slow control system
Ensure MVTX functionality for data taking



LBNL MVTX Detector Assembling

- Precision placement of staves at around $50 \mu m$ obtained by CMM
- Stave gluing to carbon structure
- Half detector fully assembled
- Power system and cabling preparation
- Readout mechanical structure

sPHENIX Beam Use Proposal



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

- Extensive **3-year** data taking starting in < 6 months

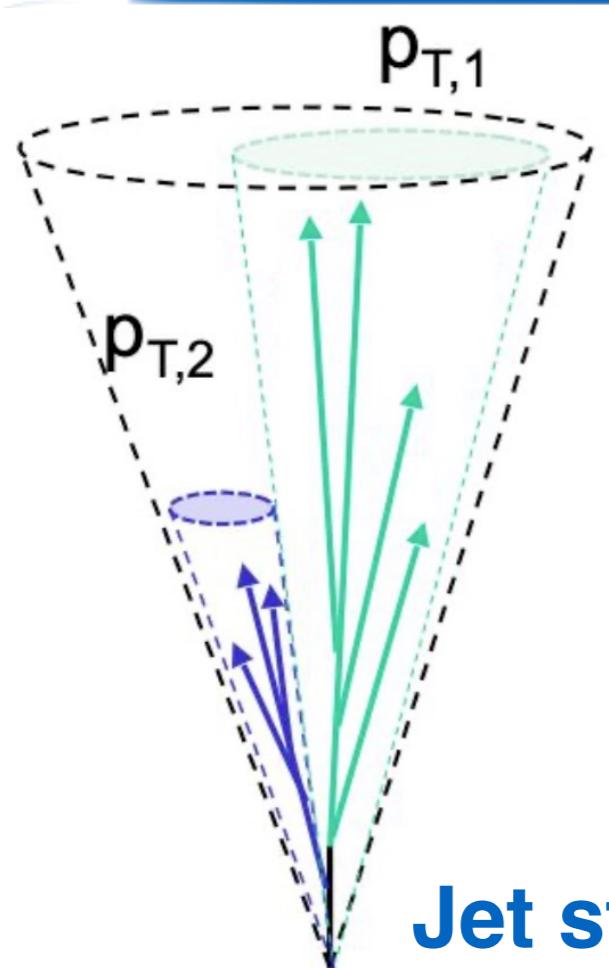
Year-1: commissioning and first physics in Au+Au

Year-2: p+p and p+Au runs for heavy-ion reference and cold QCD physics

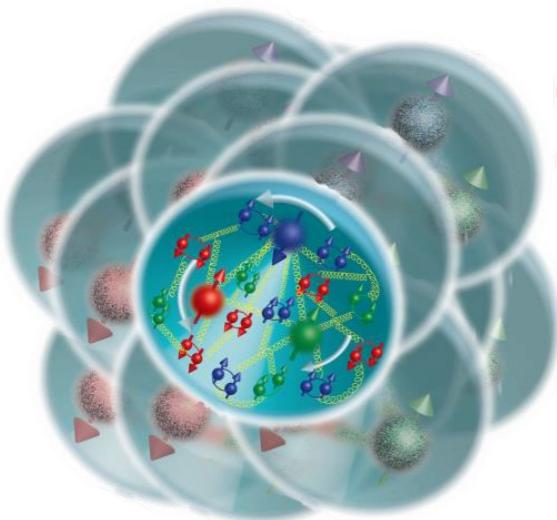
Year-3: very large Au+Au dataset (141B events in total)

[sPHENIX Beam Use Proposal](#)
 endorsed by the BNL NPP
 (Nuclear and Particle Physics)
 PAC (Physics Advisory
 Committee)

The sPHENIX Physics Program



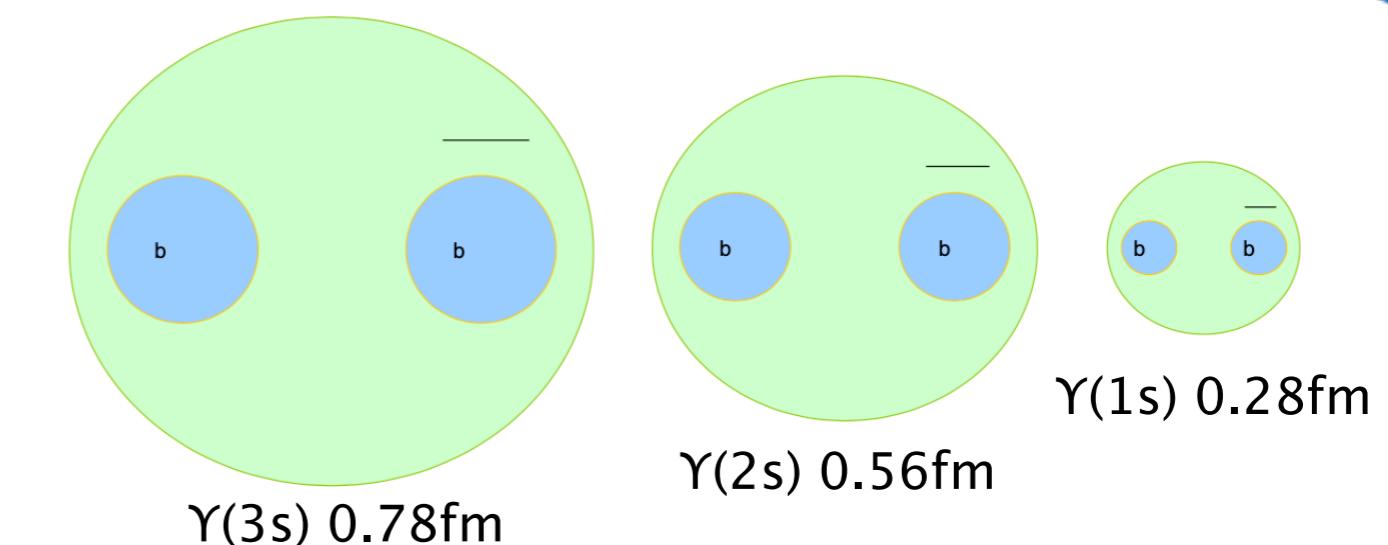
Jet structure
vary momentum/angular scale of probe



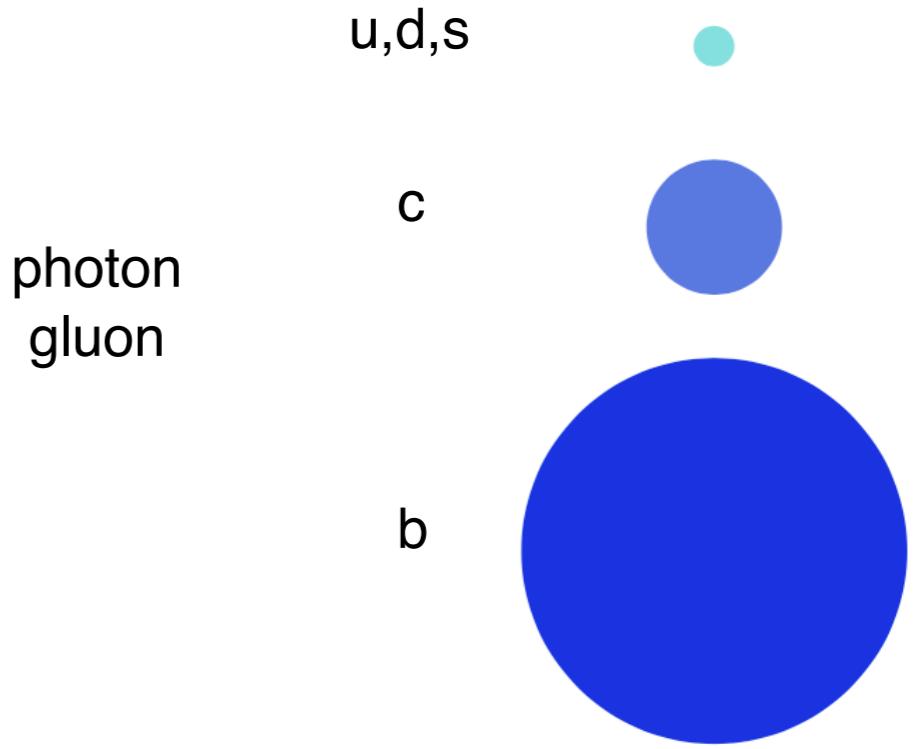
Cold QCD
study proton spin,
transverse-momentum,
and cold nuclear effects



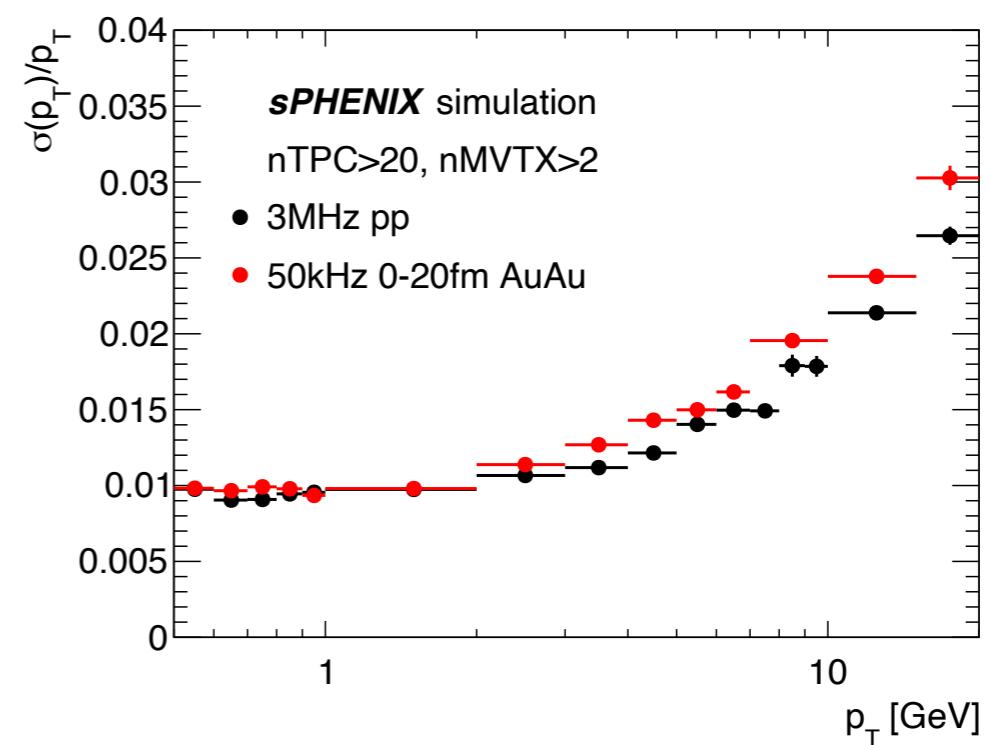
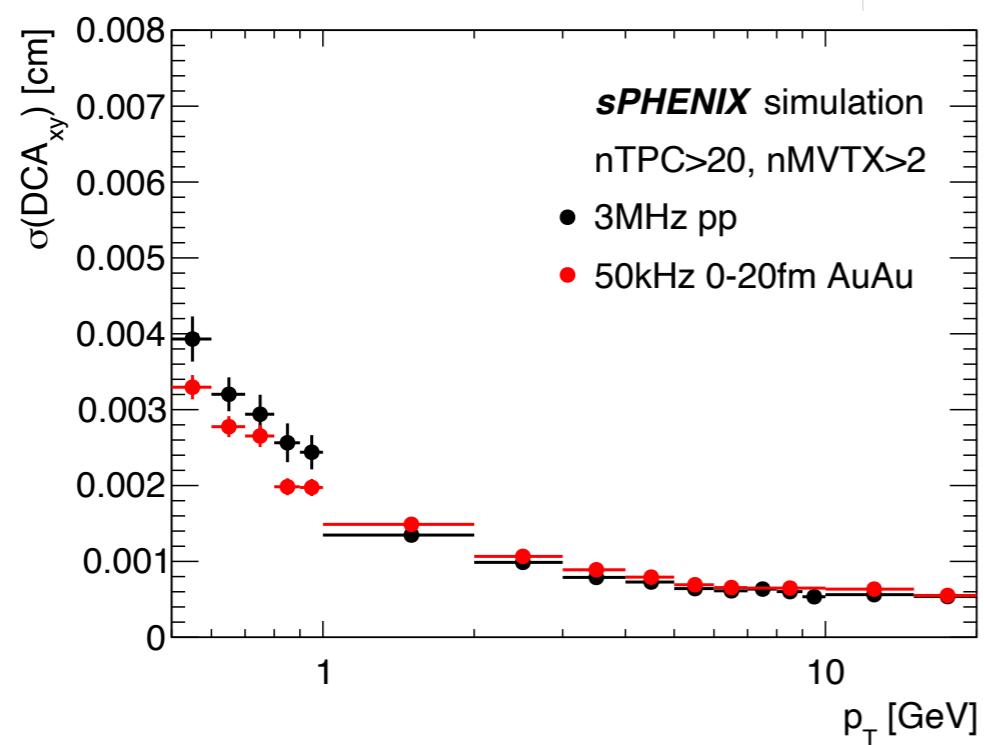
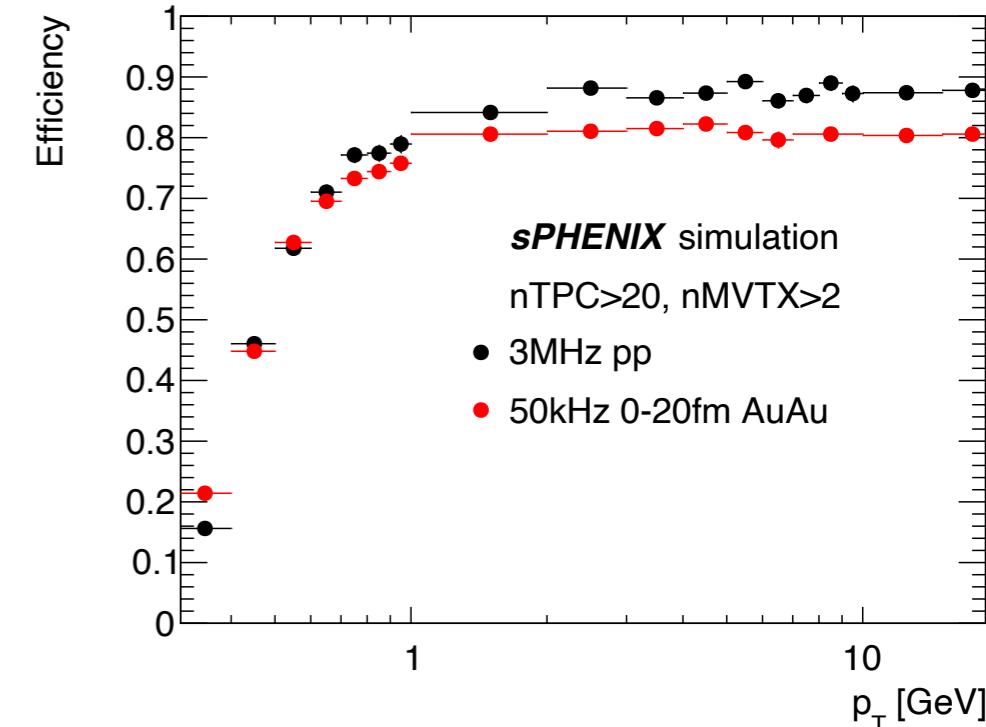
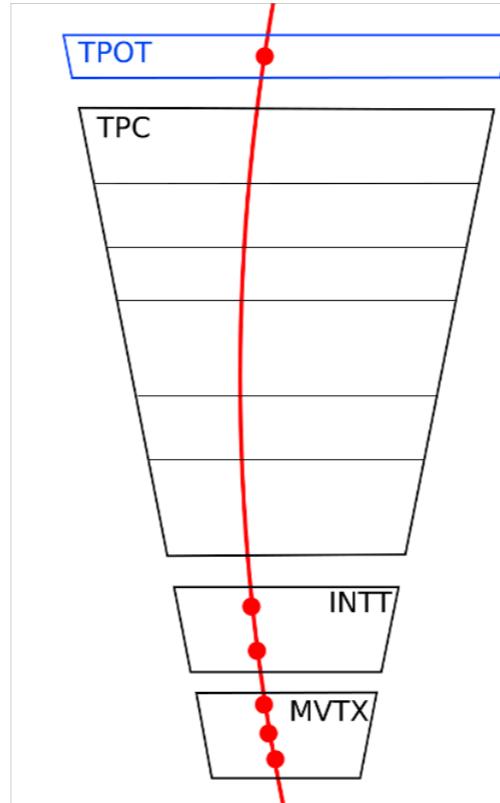
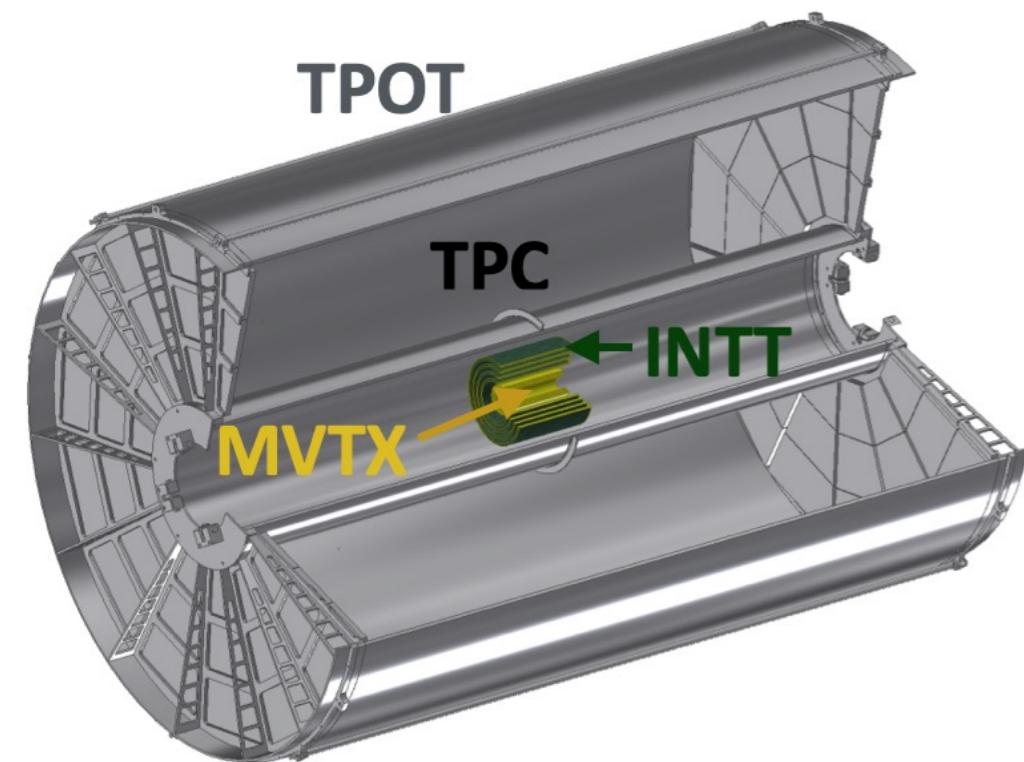
Quarkonium spectroscopy
vary size of probe



Parton energy loss
vary mass/momentum of probe
u,d,s

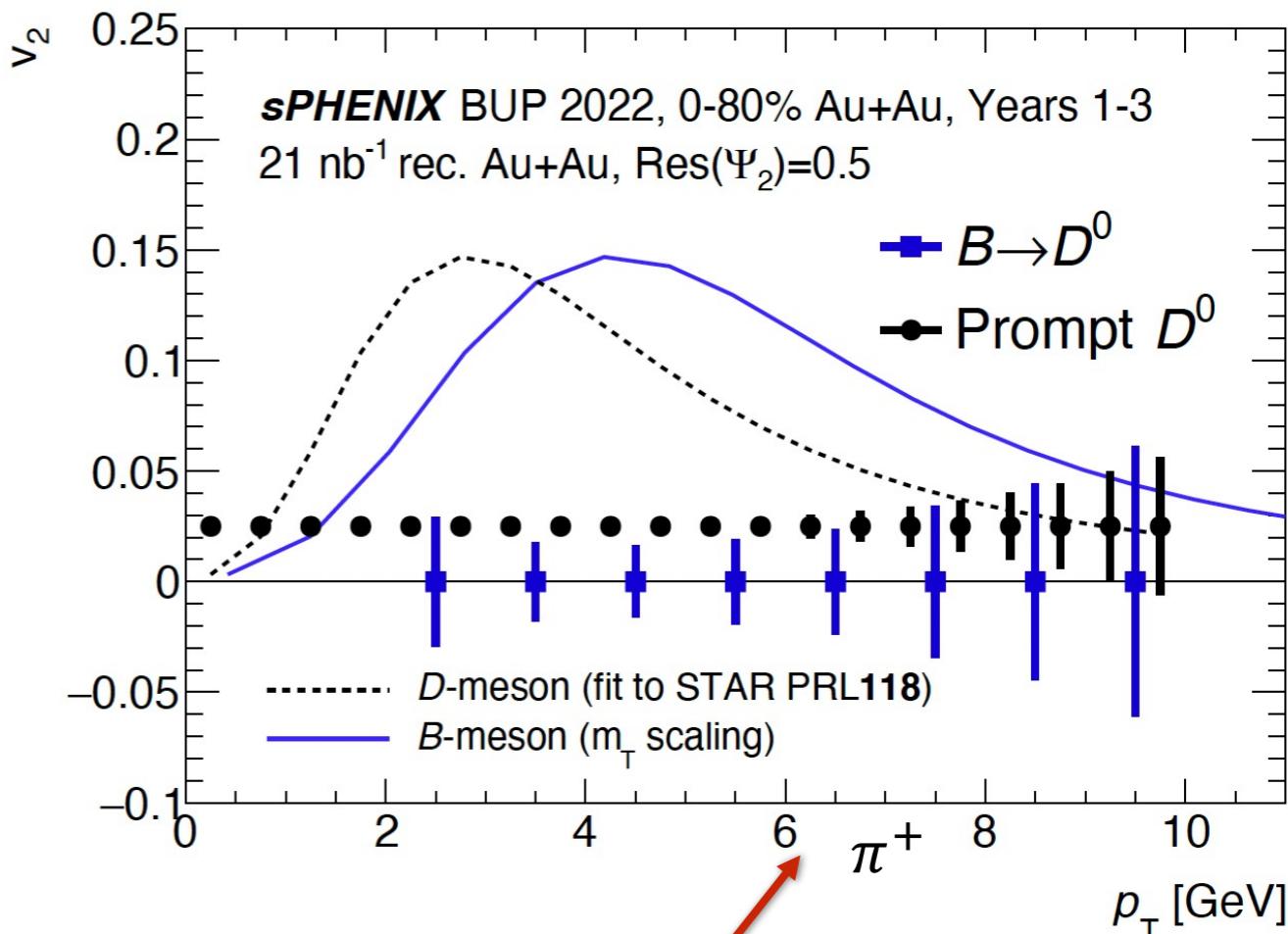
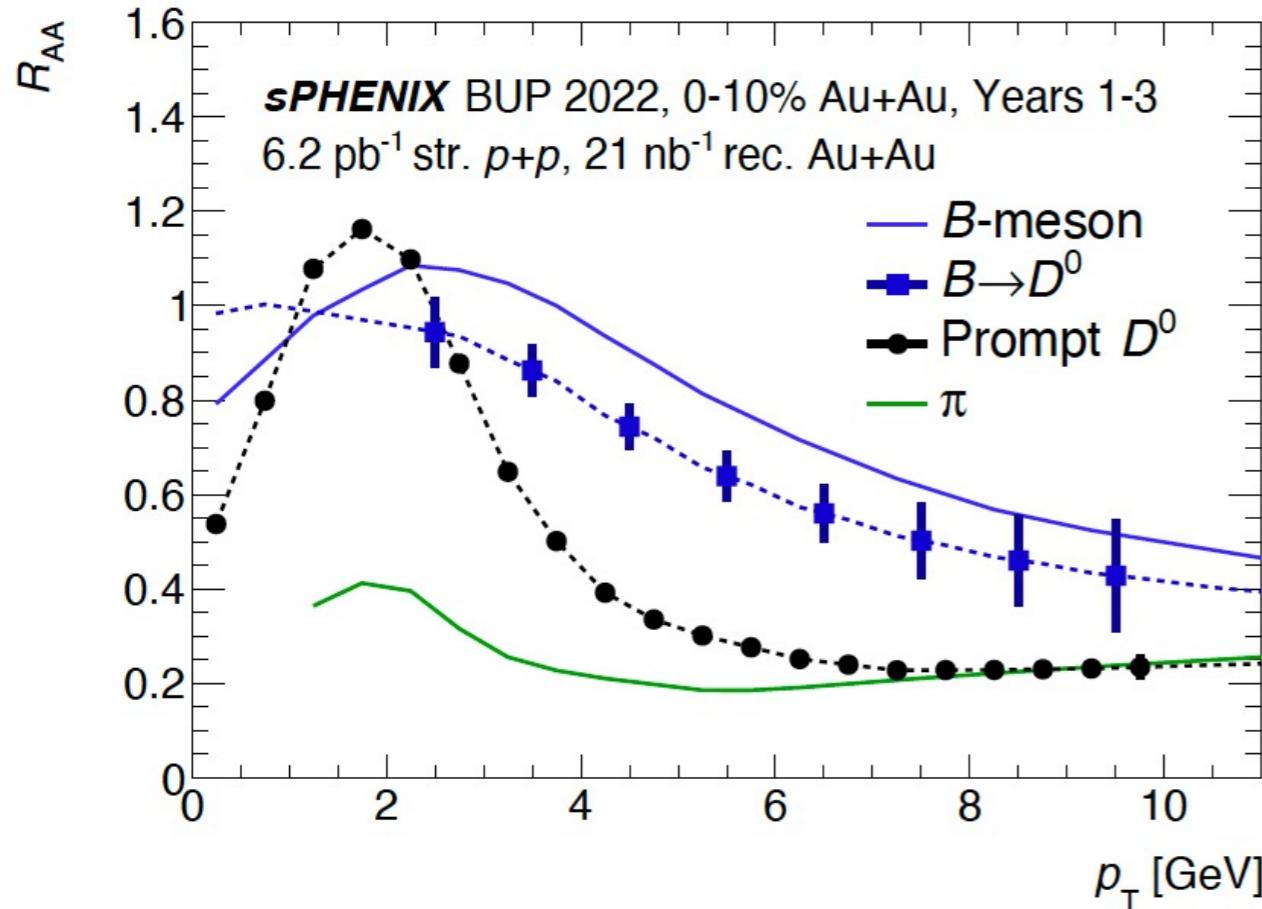


Tracking System and Performance

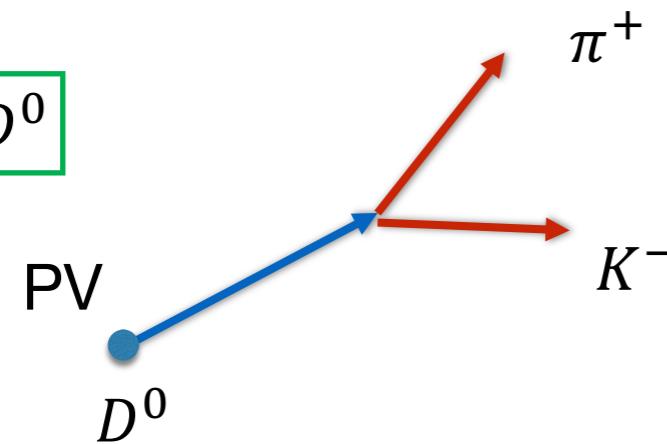


- MVTX and INTT operating in continuous streaming readout mode with advanced electronics
- TPC + TPOT for main for outer tracking for momentum determination
- Excellent tracking reconstruction and vertexing performance for HF physics studies

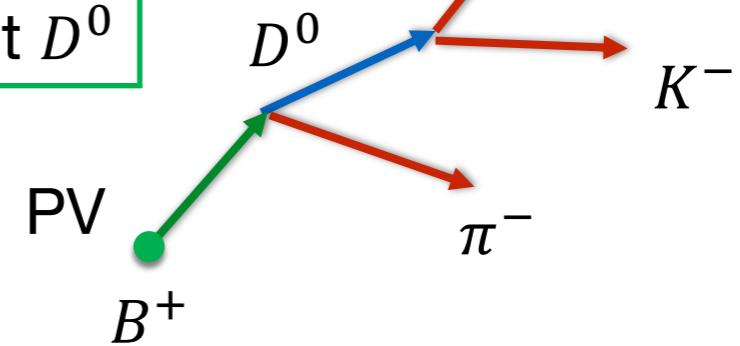
Fully reconstructed D^0 mesons



Prompt D^0

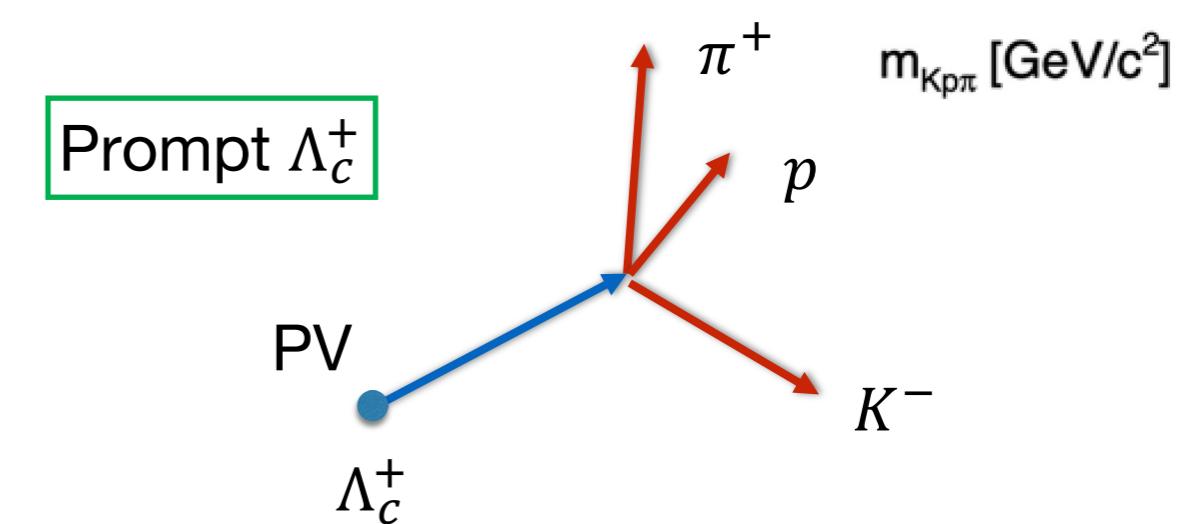
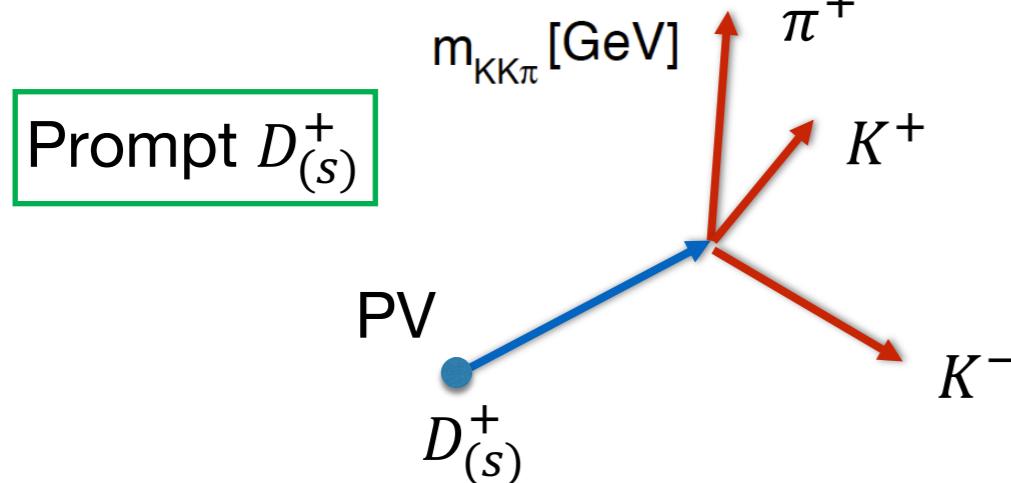
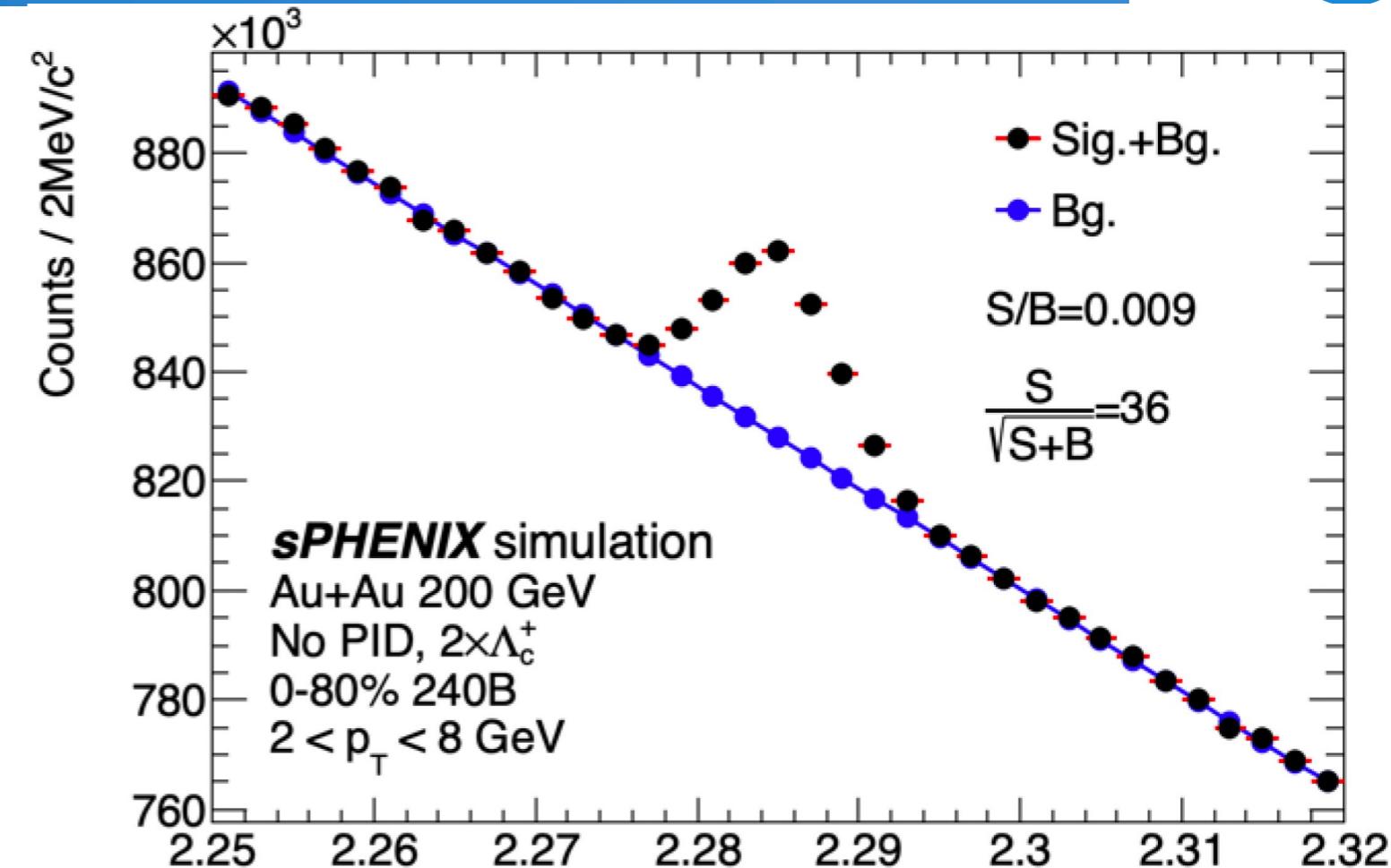
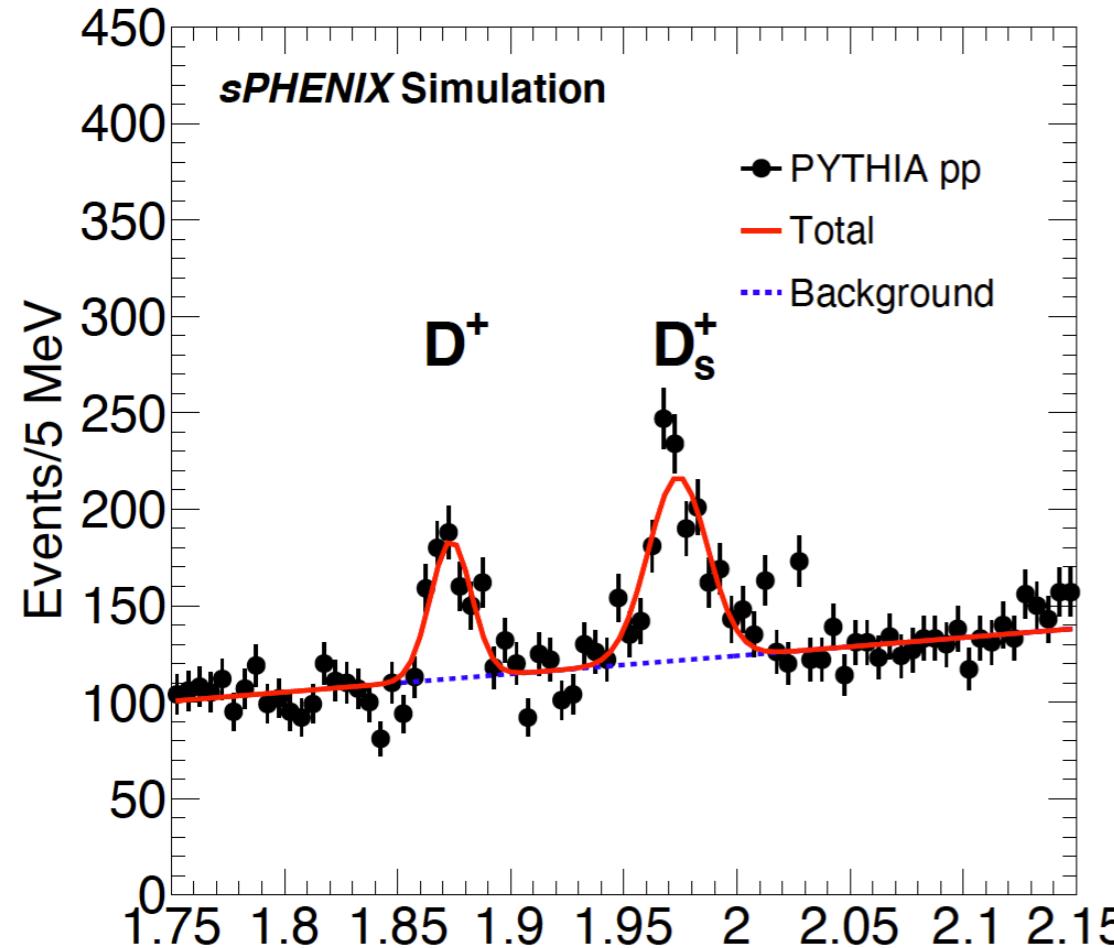


Non-Prompt D^0



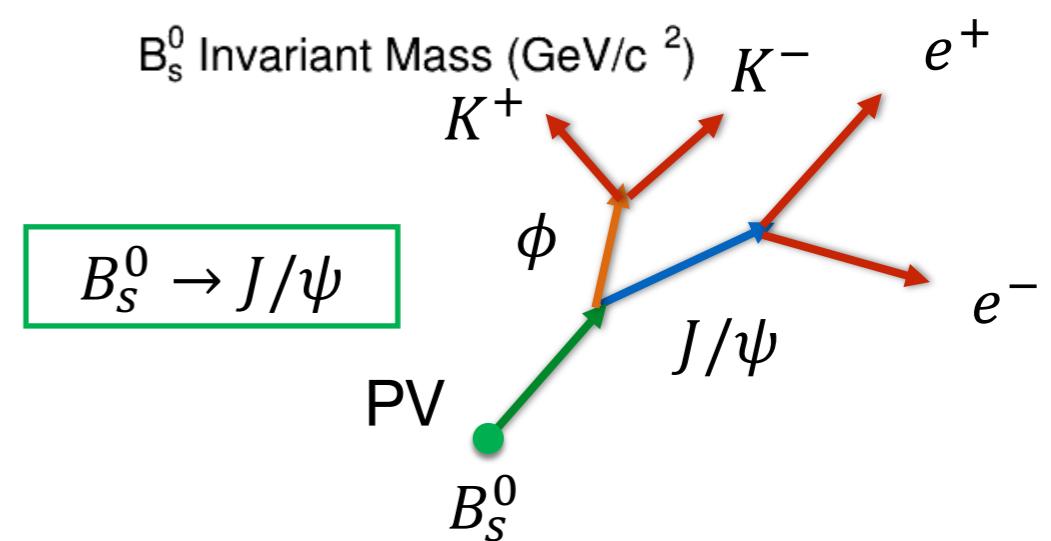
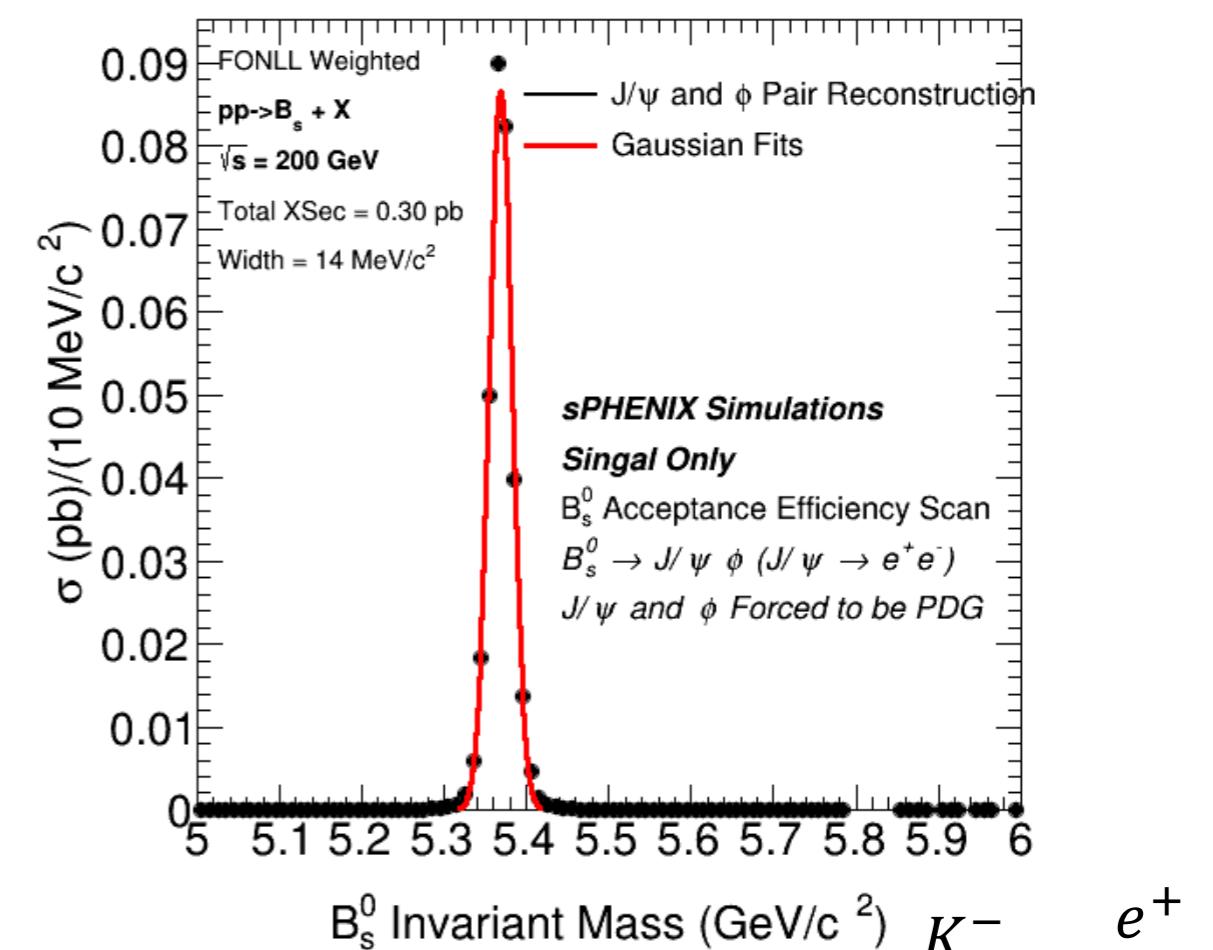
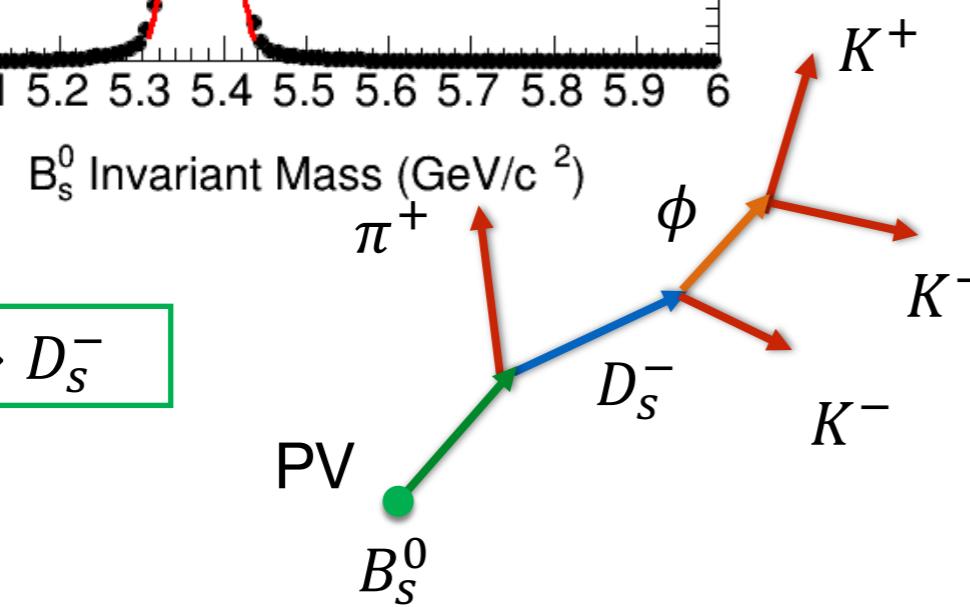
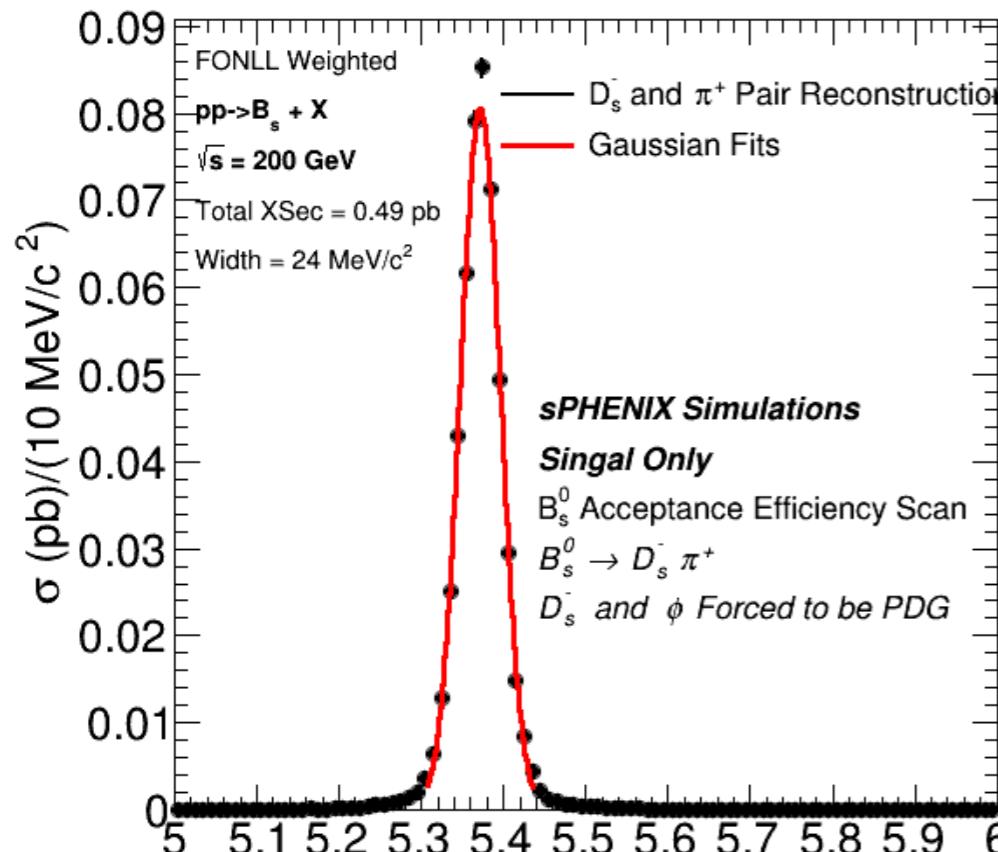
- Fully reconstructed D^0 via $D^0 \rightarrow K^- \pi^+$ without hadronic PID
- Charm quark energy loss mechanism to probe the internal structure of QGP
- Diffusion coefficient for charm quarks in QGP at RHIC energy
- Data-driven method to separate of prompt and non-prompt D^0 with DCA

Charm Hadronization



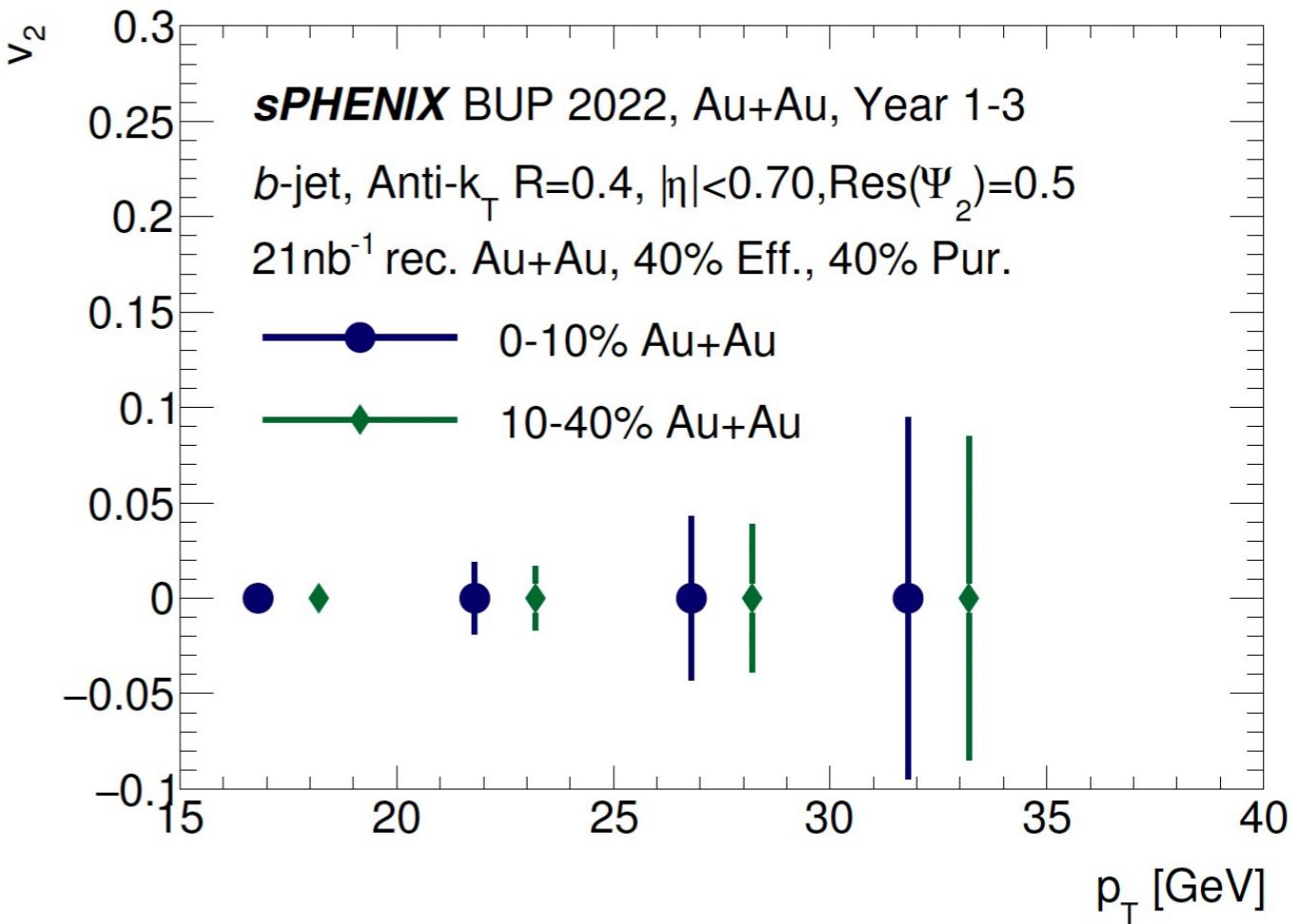
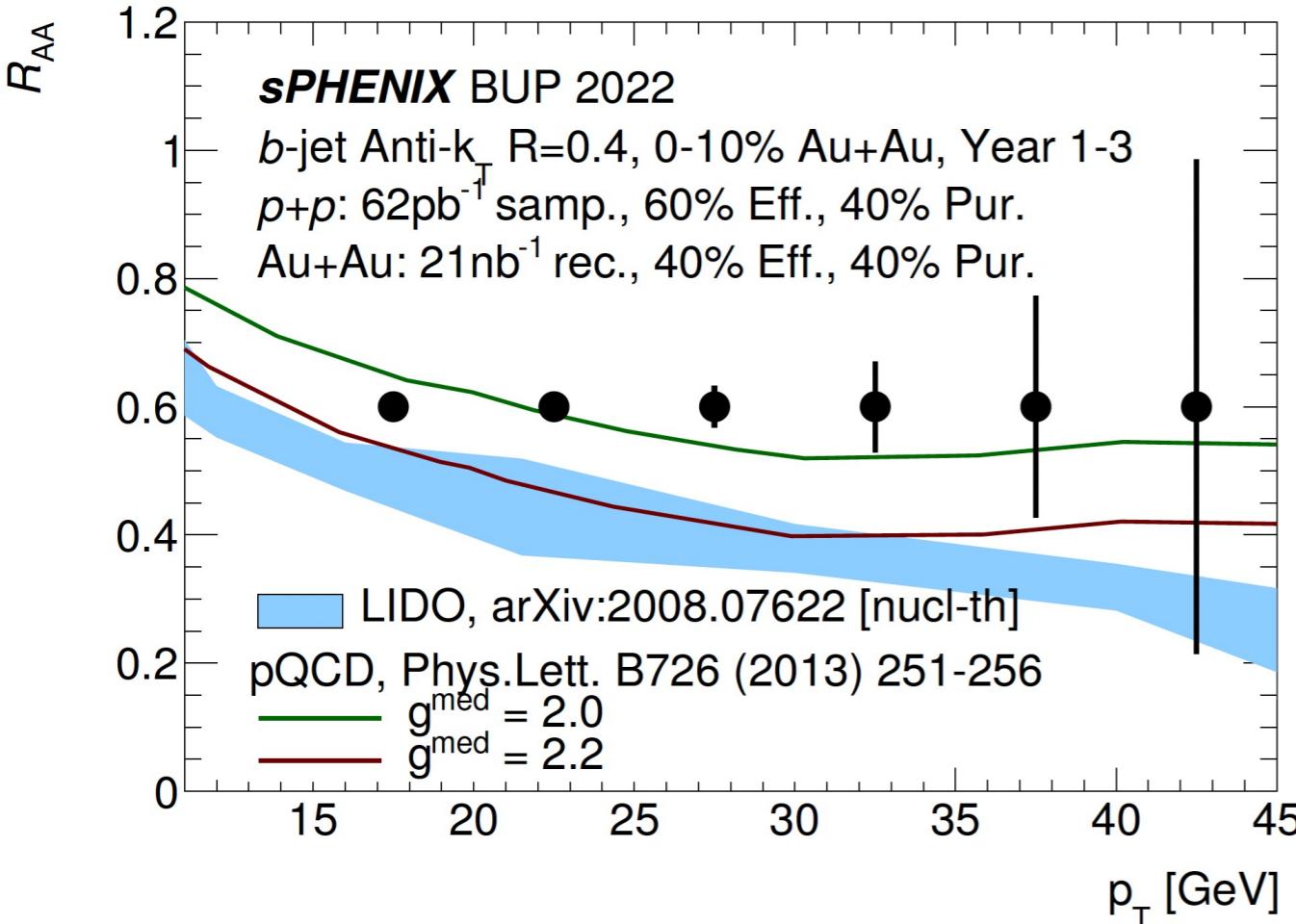
- More complex 3-prong decays
- High precision measurement thanks to streaming readout data taking and tracking
- Study charm hadronization from vacuum to QGP via the measurements of D_s^+/D^+ and Λ_c^+/D^0 as a function of event multiplicity

Fully Reconstructed B_s^0 Meson

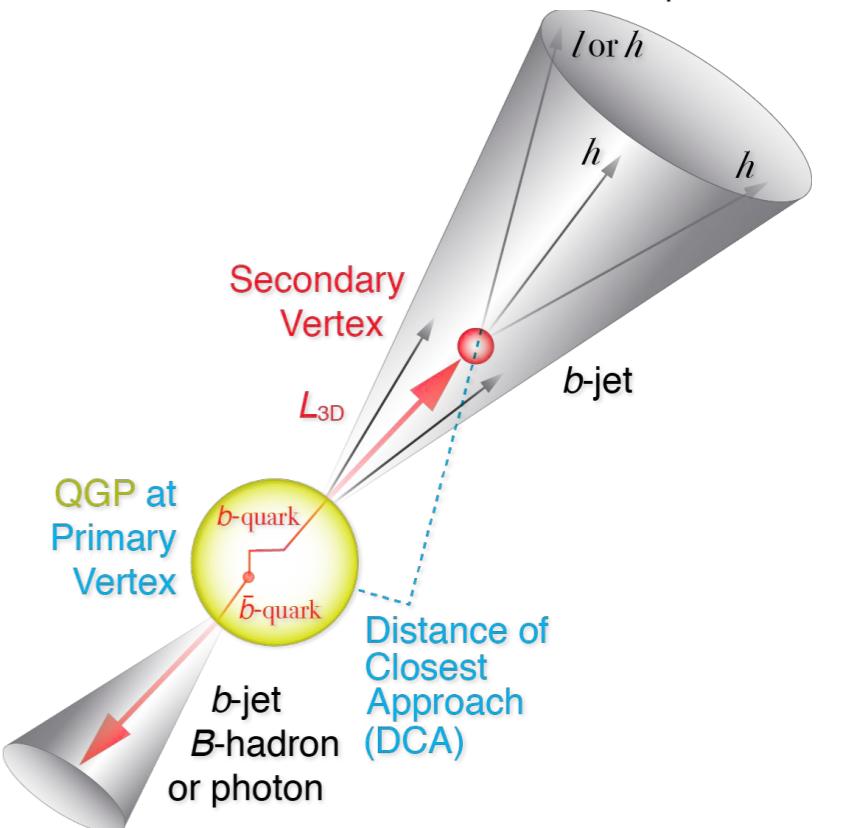


- Exotic-hadron like complex 4-prong decays
- FONLL weight B_s^0 in GEANT simulation for signal only prediction
- First observation of fully reconstructed B-meson in nuclear collisions at RHIC
- Study beauty quark hadronization mechanism with B_s^0/B^+ ratio
- Test QCD factorization theorem at RHIC energy in the beauty sector

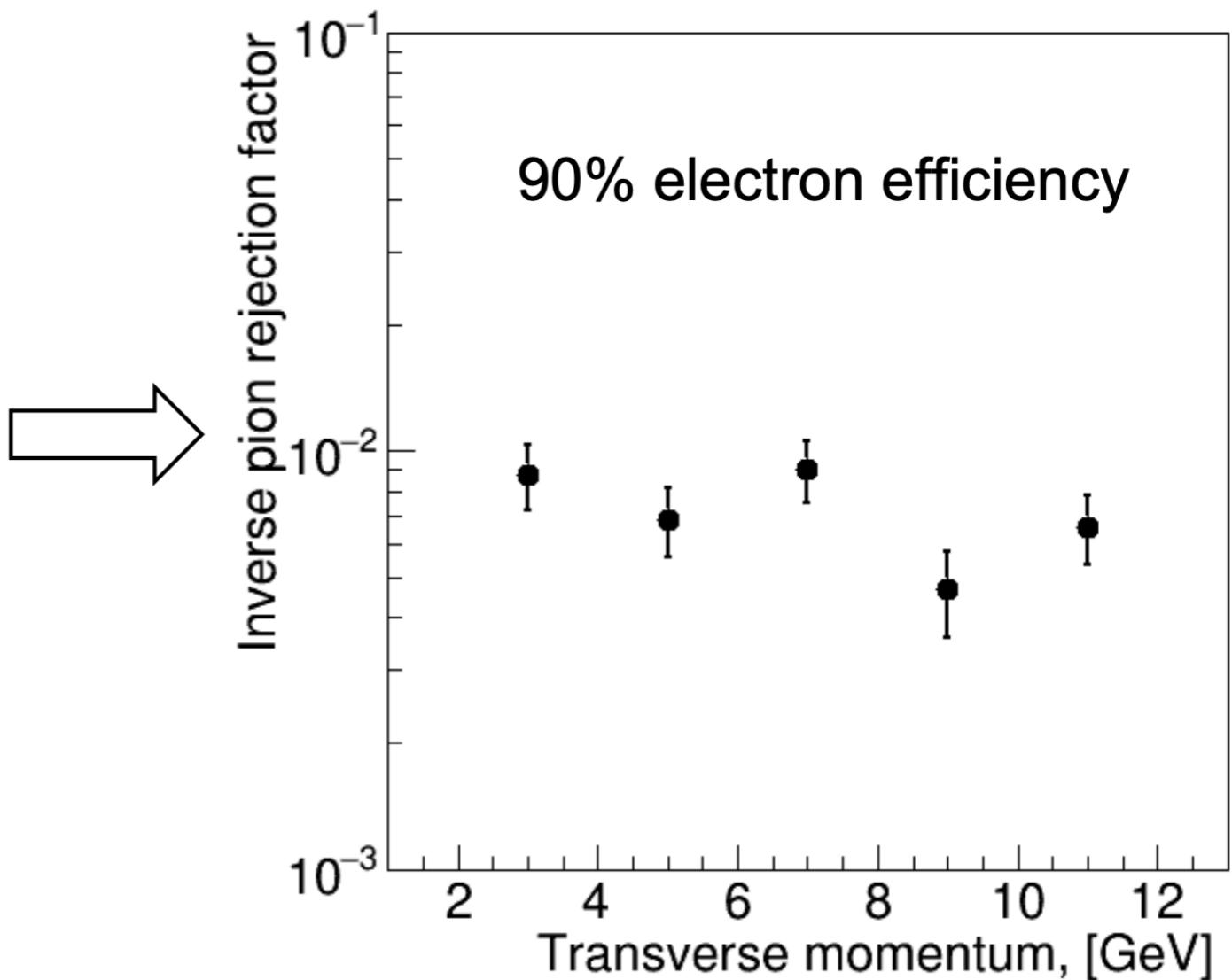
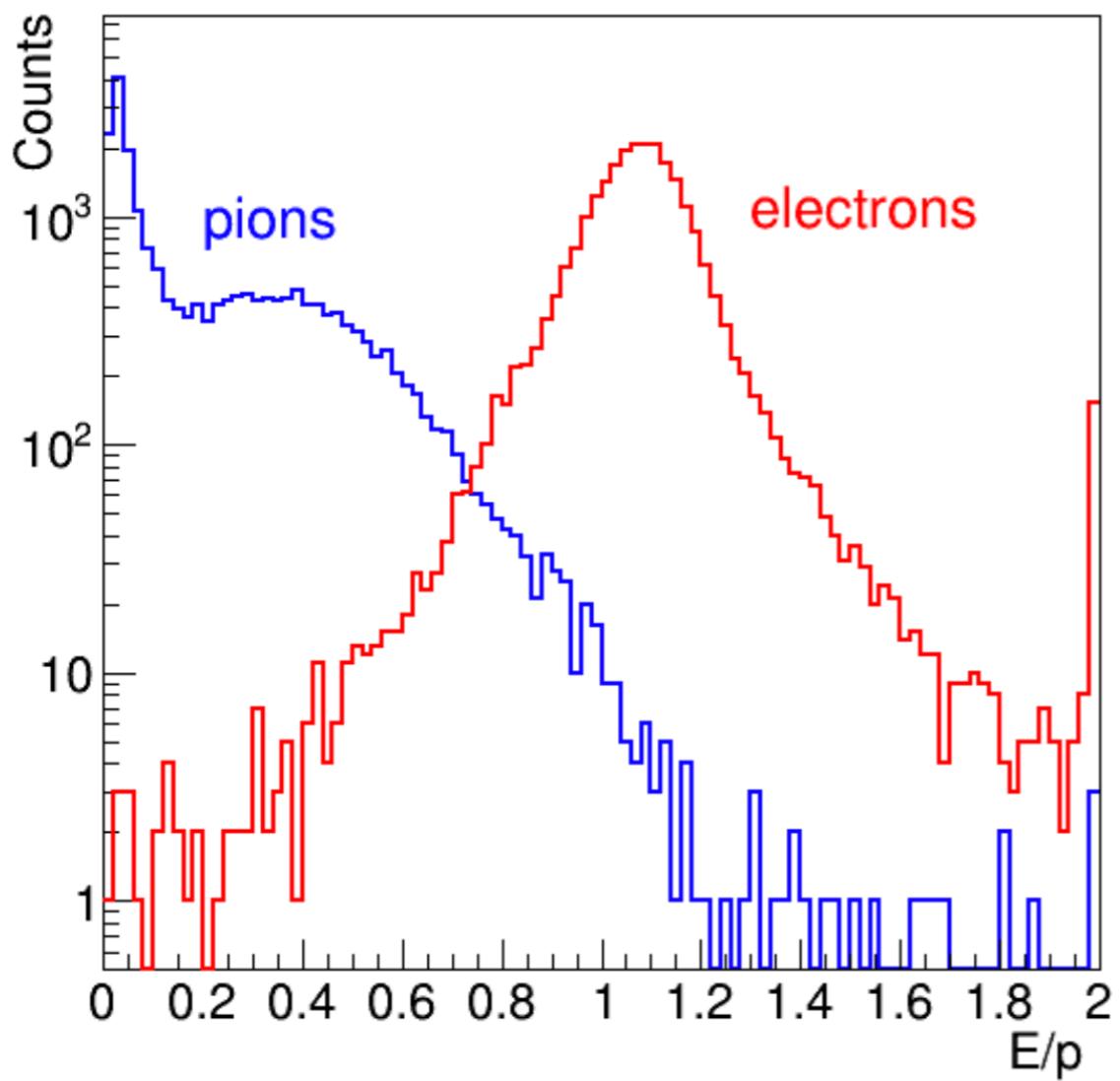
b-jet R_{AA} and v_2 Measurement



- Utilization of MVTX to reconstruct secondary vertex within the jet cone
 - Jets with displaced vertex to tag the b quarks
 - Inclusive measurement with better statistics
- First b-jet measurement at RHIC
- Sensitive to heavy-quark collisional and radiative in-medium energy loss
- Constrain beauty quark diffusion coefficient at RHIC energy
- Complementary to LHC with better measurements at lower p_T

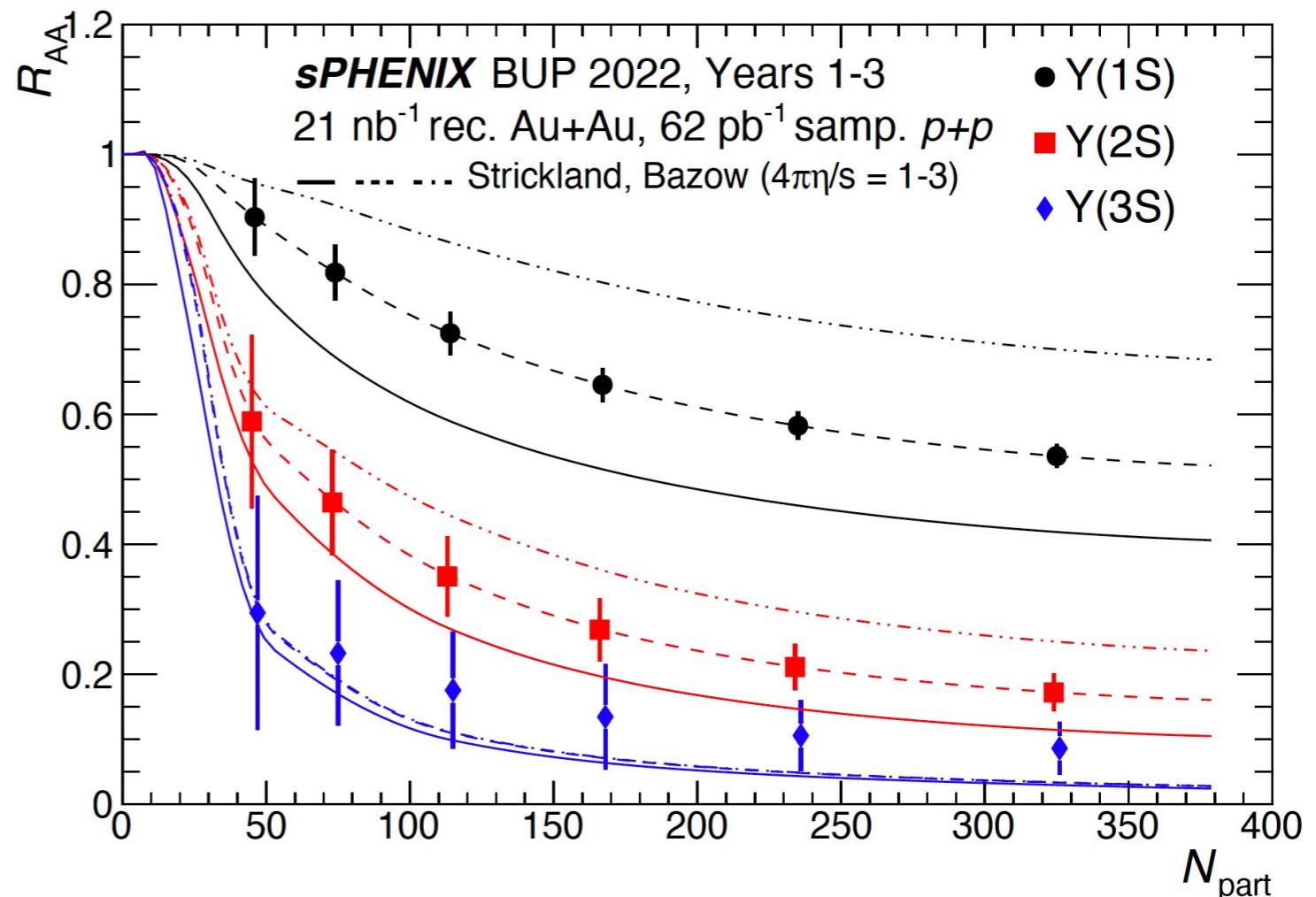
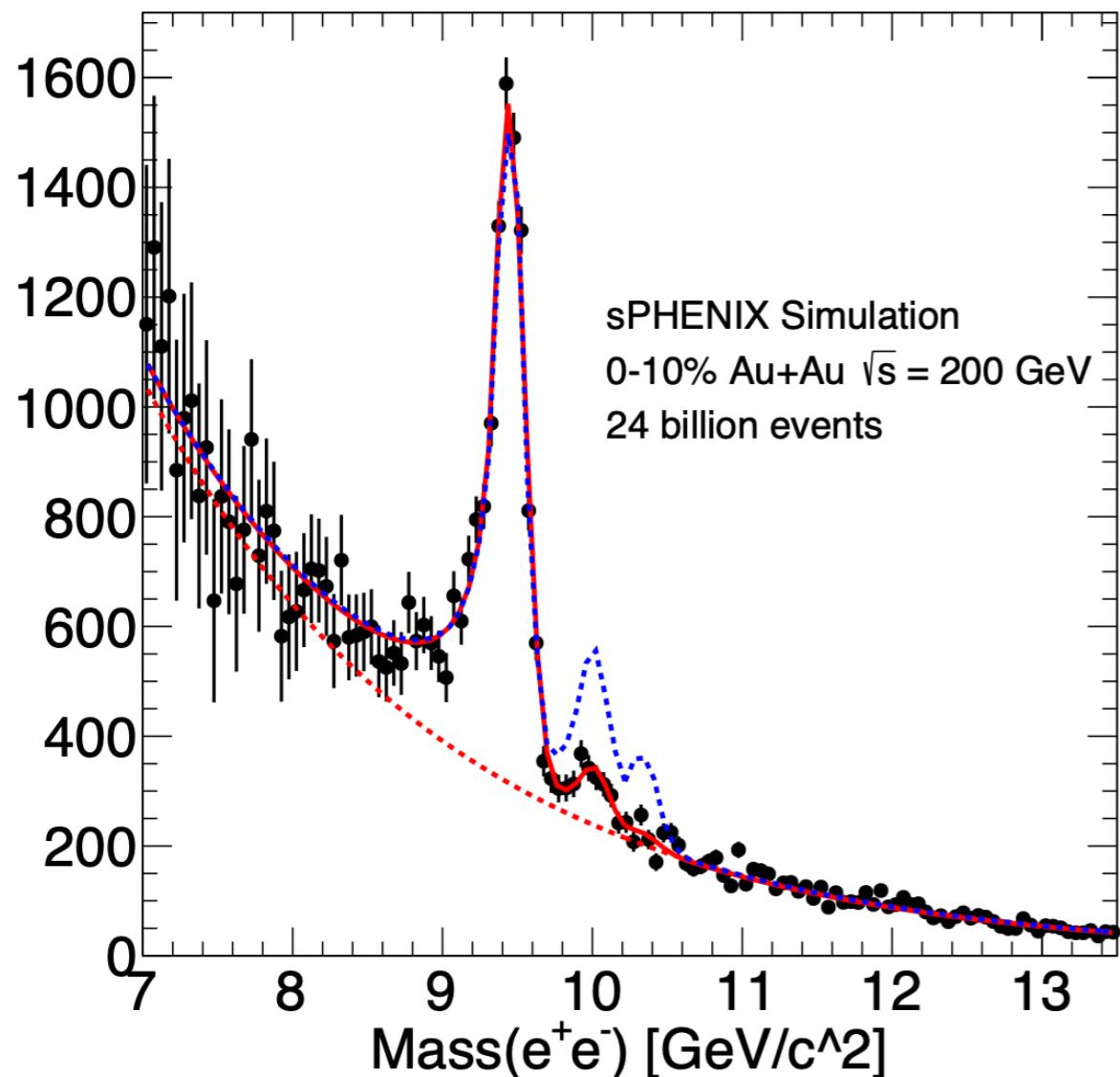


Electron Identification Capabilities

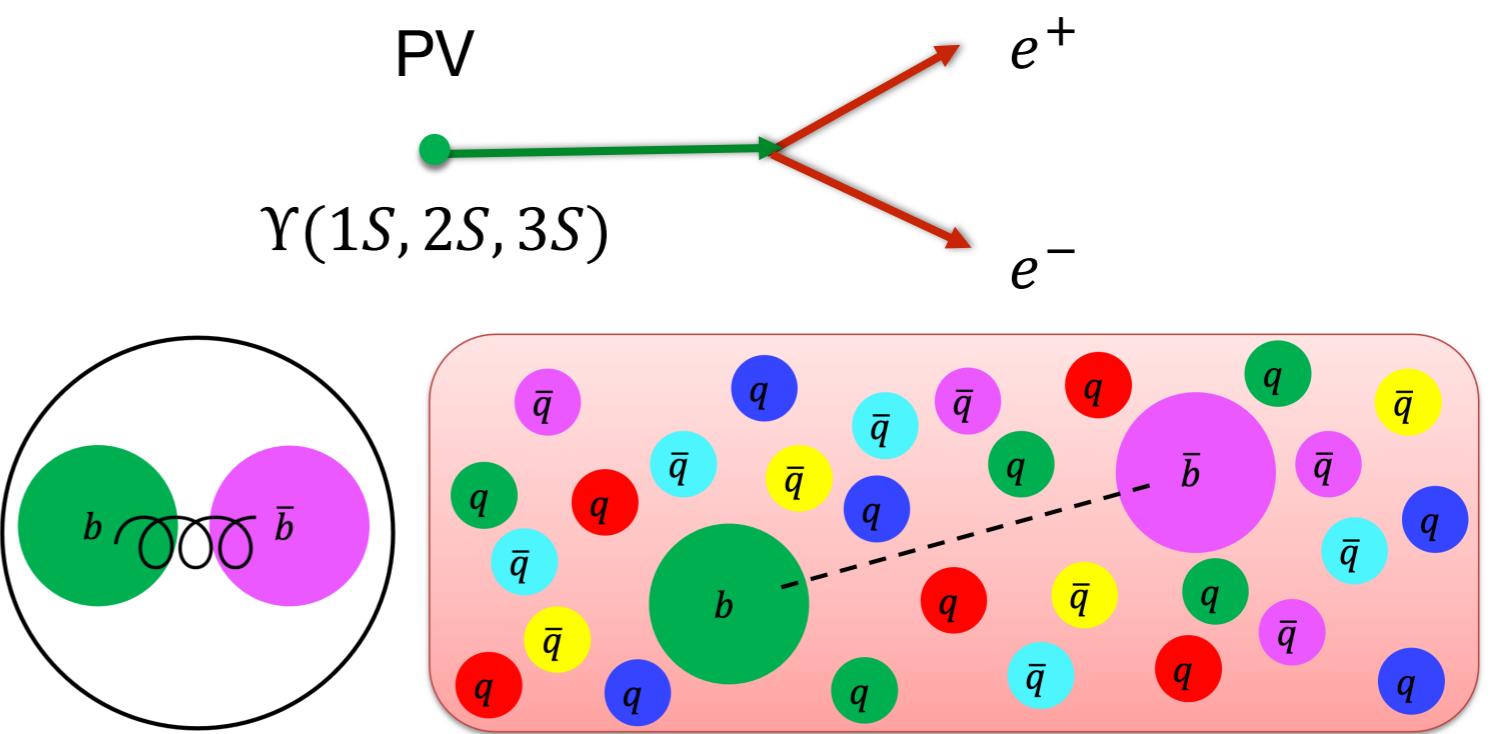


- Use shower core energy information from central EMCAL and HCAL for e/h separation
- Working point: EMCAL/ $p > 0.9$ and iHCAL/EMCAL < 0.2 to maintain 90% electron efficiency
- Excellent electron identification capabilities for quarkonia background rejection
- Improvement with machine learning techniques in development
- Ongoing muons identification studies with machine learning techniques

Upsilon Spectroscopy



- Measuring QGP temperature via color screening effect
- Excellent mass resolution dielectronic decay channel
- R_{AA} measurement with high precision
- Potential observation of $\Upsilon(3S)$ at RHIC, complementary with CMS $\Upsilon(3S)$ measurement at the LHC



Summary

The sPHENIX Experiment at RHIC

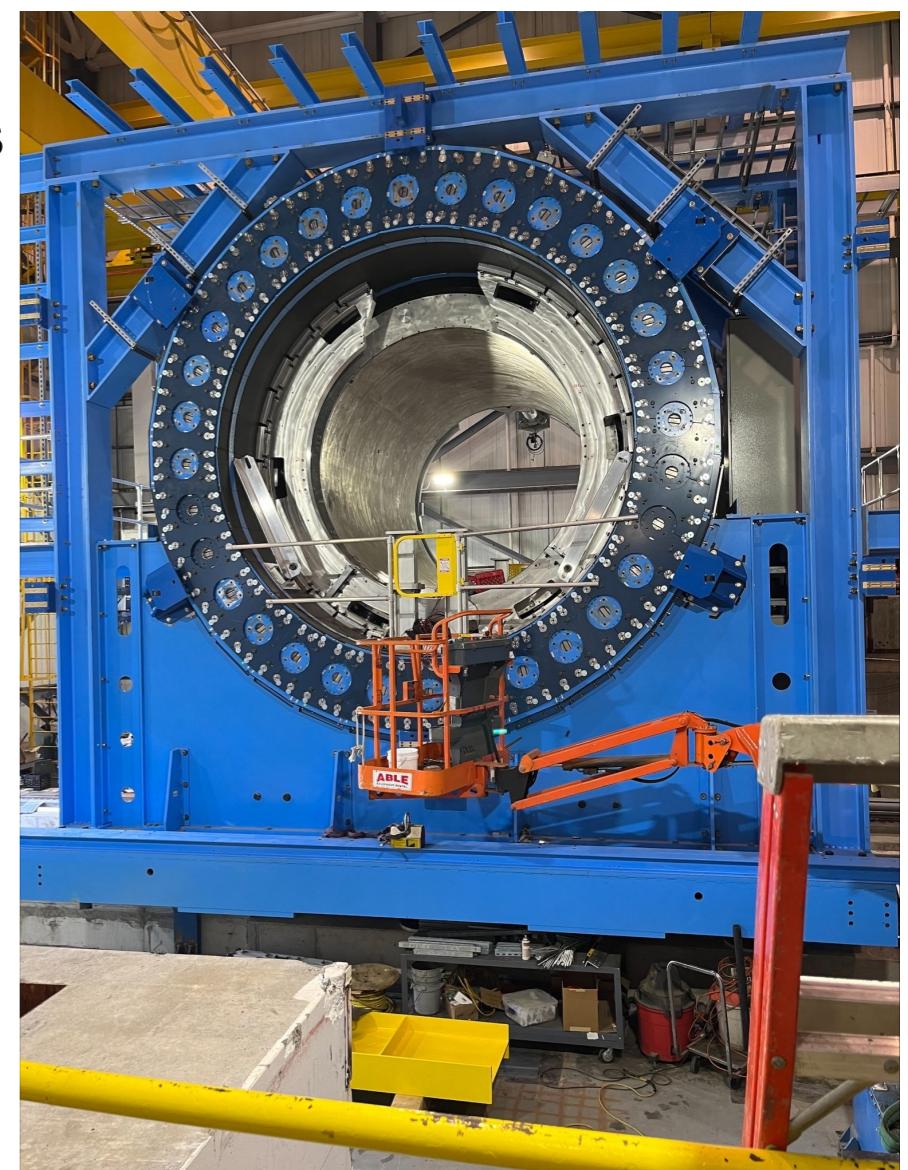
- Physics program: jet, **open heavy flavor, quarkonia, cold QCD**
- Detector commissioning: lots of activities are ongoing right now

Detector Performance

- Excellent tracking and vertexing capabilities for heavy flavor physics measurements
- Good electron identification performance for quarkonia background rejection

Open Heavy Flavor Physics Program

- Fully reconstructed charm and beauty hadron measurements
 - Heavy quark energy loss
 - Heavy quark diffusion
 - Heavy quark hadronization
- First inclusive b-jet measurements
 - Complementary to LHC experiments
 - High precision at low p_T



Hidden Heavy Flavor Physics Program

- Upsilon Spectroscopy
 - measure the temperature of QGP
 - Potential observation of $\Upsilon(3S)$ at RHIC

 **First data taking starts in around 02/2023: STAY TUNE!**



- This work is supported by the United States Department of Energy Office of Science and Los Alamos National Laboratory Laboratory Directed Research & Development (LDRD)
- **Thank you very much for your attention!**



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