

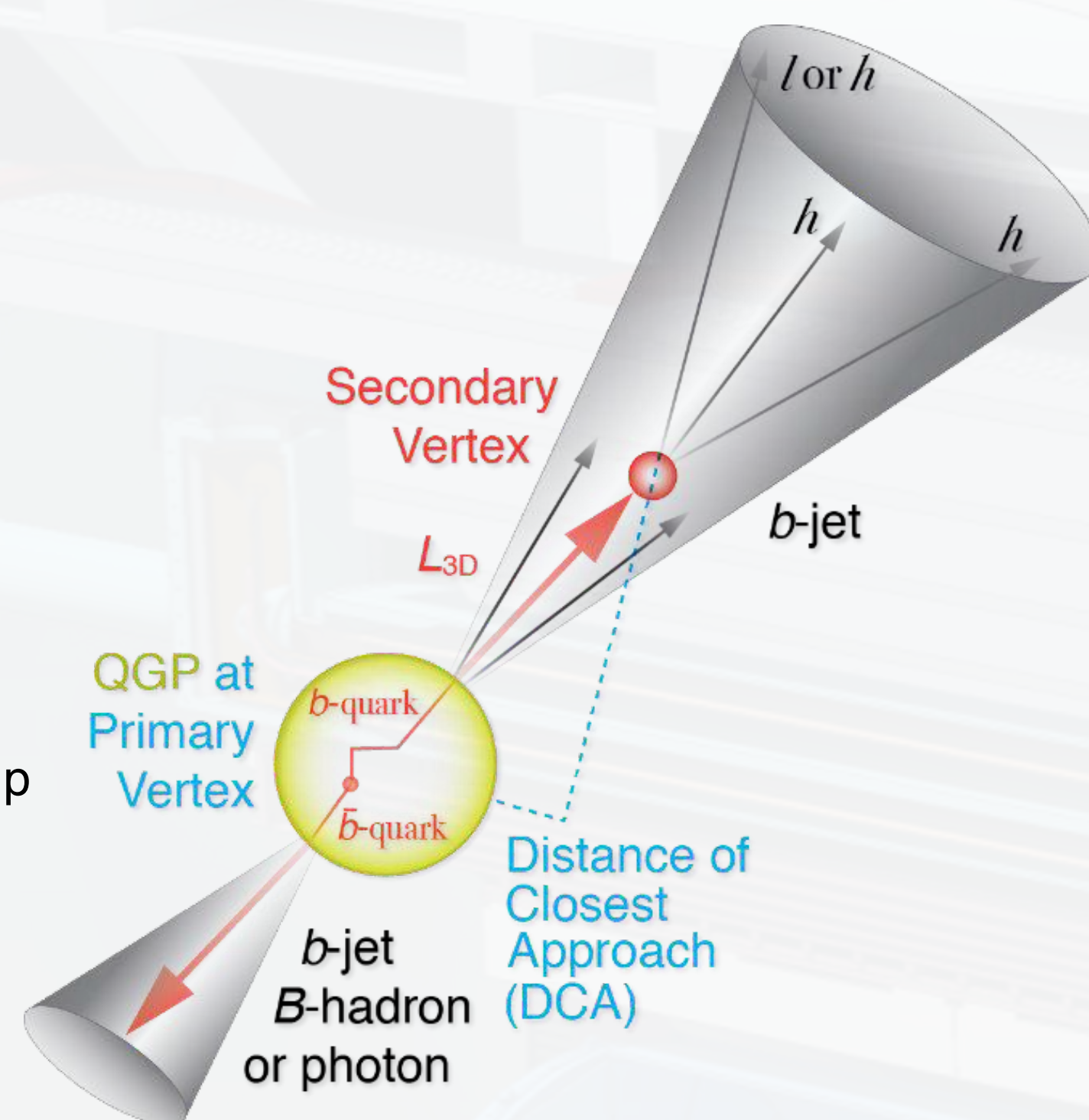
## Zhaozhong Shi, Los Alamos National Laboratory for the sPHENIX Collaboration

### Abstract

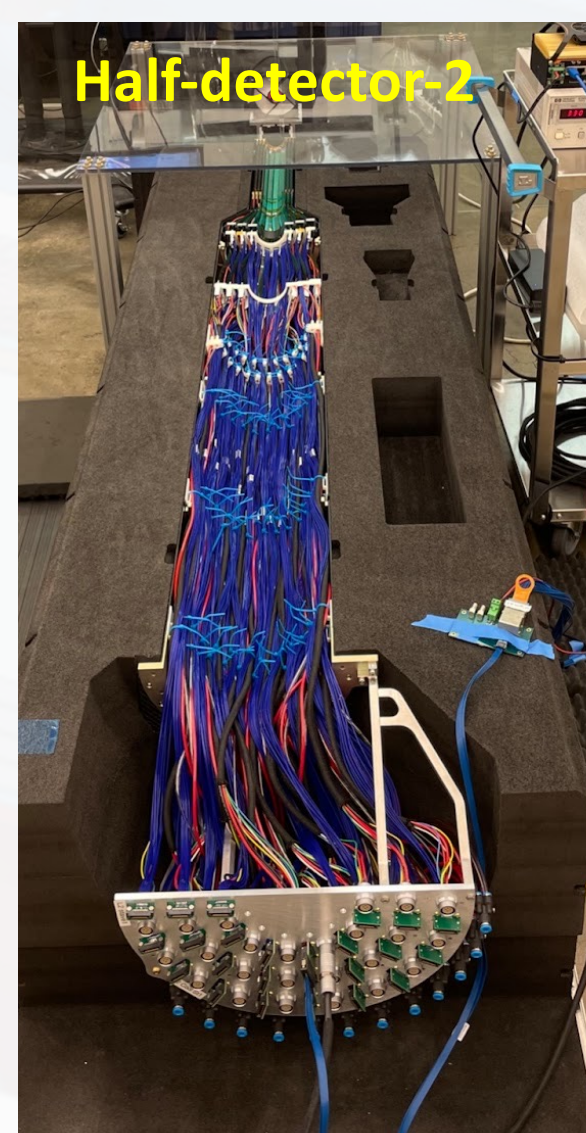
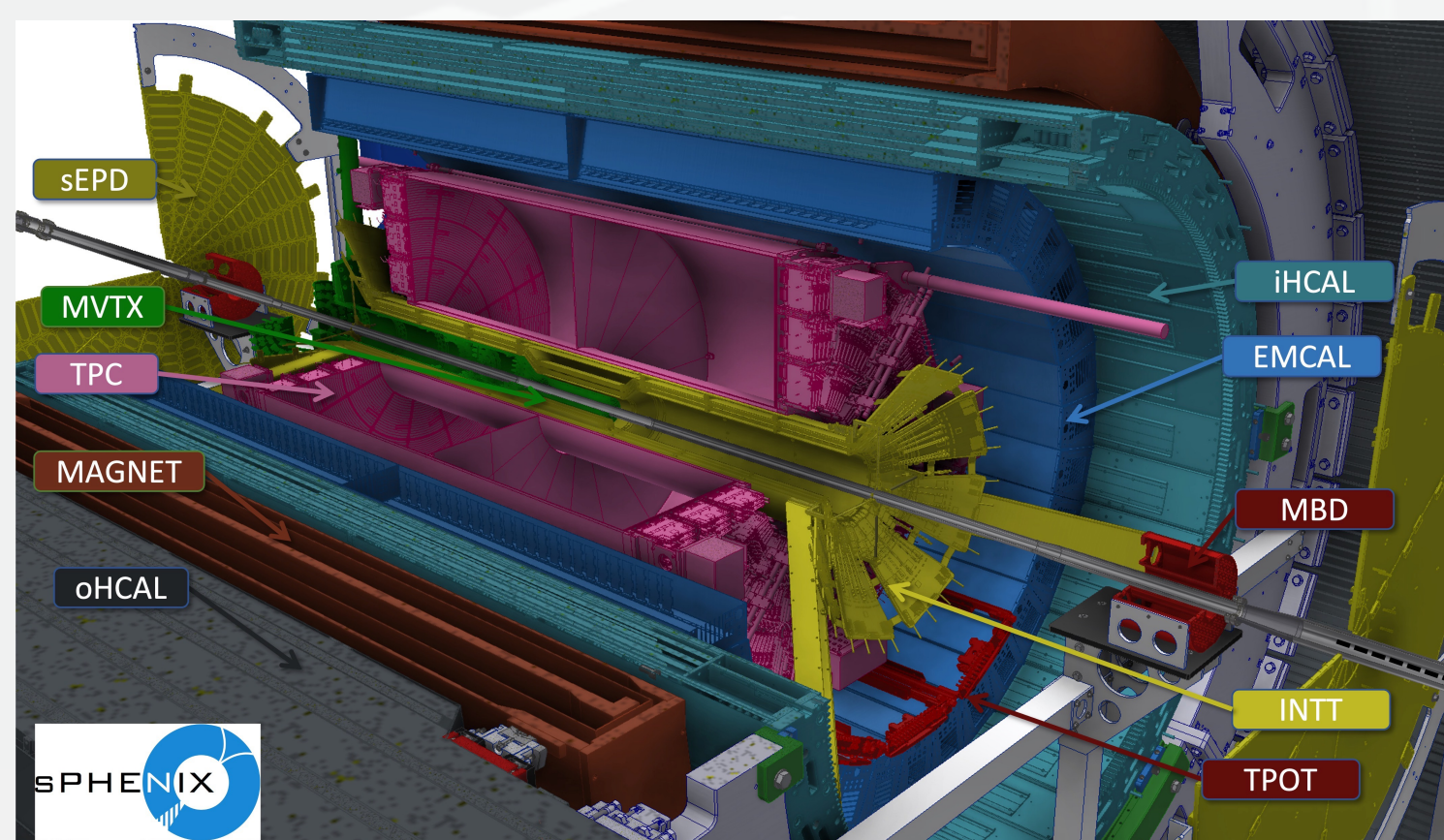
The beauty quark is a unique probe to study the properties of quark-gluon plasma thanks to its large mass and relatively long thermal relaxation time compared with lighter partons. Traditional experimental observables such as elliptic flow  $v_2$  and nuclear modification factor  $R_{AA}$  of fully reconstructed beauty hadrons have been measured at the LHC. Moreover, indirect measurements on non-prompt D-mesons and heavy flavor decayed leptons have been carried out extensively at both the LHC and RHIC. The sPHENIX experiment at RHIC is a state-of-the-art heavy flavor and jet detector. sPHENIX began commissioning with Au + Au collisions in Spring 2023. The Monolithic-Active-Pixel-Sensor (MAPS) based VerTeX detector (MVTX) is a high precision silicon pixel detector. The MVTX provides excellent position resolution and capability of operating in continuous streaming readout mode, allowing precise vertex determination and recording a large data sample, both of which are particularly crucial for b-hadron measurements. We will demonstrate projections of inclusive b-hadron  $v_2$  and  $R_{AA}$  measurements and show the expected constraints on theoretical models.

### b-physics at sPHENIX

- Beauty quark as a golden probe for QGP
  - $m_b \gg \Lambda_{QCD}$  and  $m_b \gg T_{QGP}$ , predominantly produced in hard scatterings at the early stage of heavy-ion collisions
  - Relatively long thermal relaxation time  $\rightarrow$  may not reach complete thermal equilibrium and retain memory through the medium
  - Good separation of secondary vertex from primary vertex thanks for long decay lifetime
- Precision measurement of fully reconstructed beauty hadrons such as  $B^+$ ,  $B^0$ , and  $B_s^0$  in exclusive decay channels in p + p to Au + Au collisions
  - Inclusive  $b\bar{b}$  cross section at midrapidity in p + p to test pQCD calculations
  - Constrain beauty quark transport coefficient at RHIC energy
  - Understand b-quark hadronization mechanism
  - Study beauty energy loss mechanism in QGP

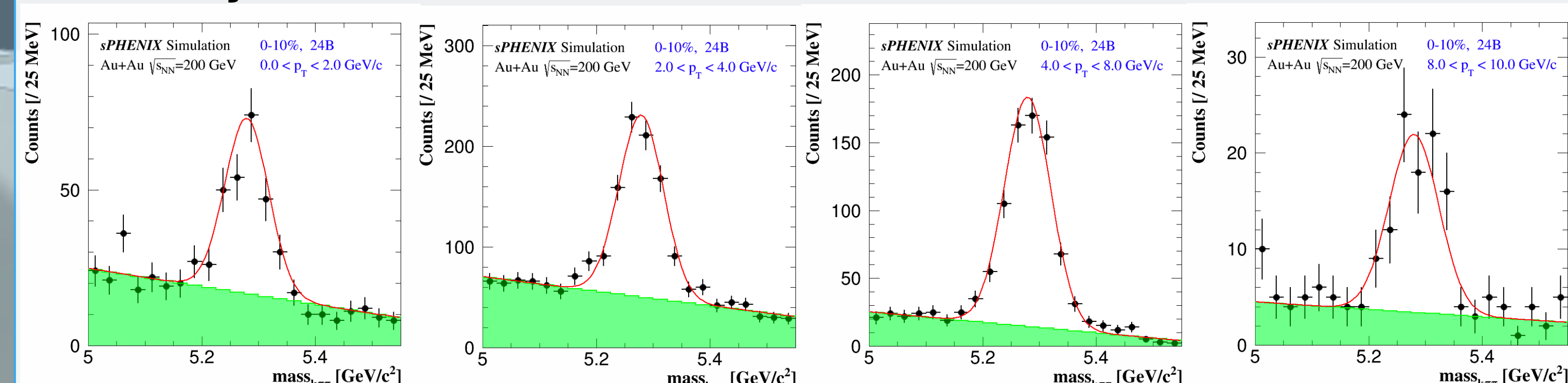


### sPHENIX MVTX Detector



- sPHENIX detector capability for b-physics
  - Excellent tracking and precise vertexing
  - Continuous streaming readout for tracking detectors
  - High luminosity recording
- MVTX: Monolithic Active Pixel Sensor (MAPS)-based-vertex detector
  - Adapting the inner most 3 layers of the ALICE Inner Tracking System (ITS)
  - High granularity of pixels with excellent position resolution ( $\sim 5 \mu\text{m}$ )
  - Continuous streaming readout mode available to maximize data taking capacity
- Track vertex distance of closest approach (DCA) resolution  $< 30 \mu\text{m}$  for track  $p_T > 1 \text{ GeV/c}$
- Enable heavy-flavor jets and open heavy flavor hadron measurements

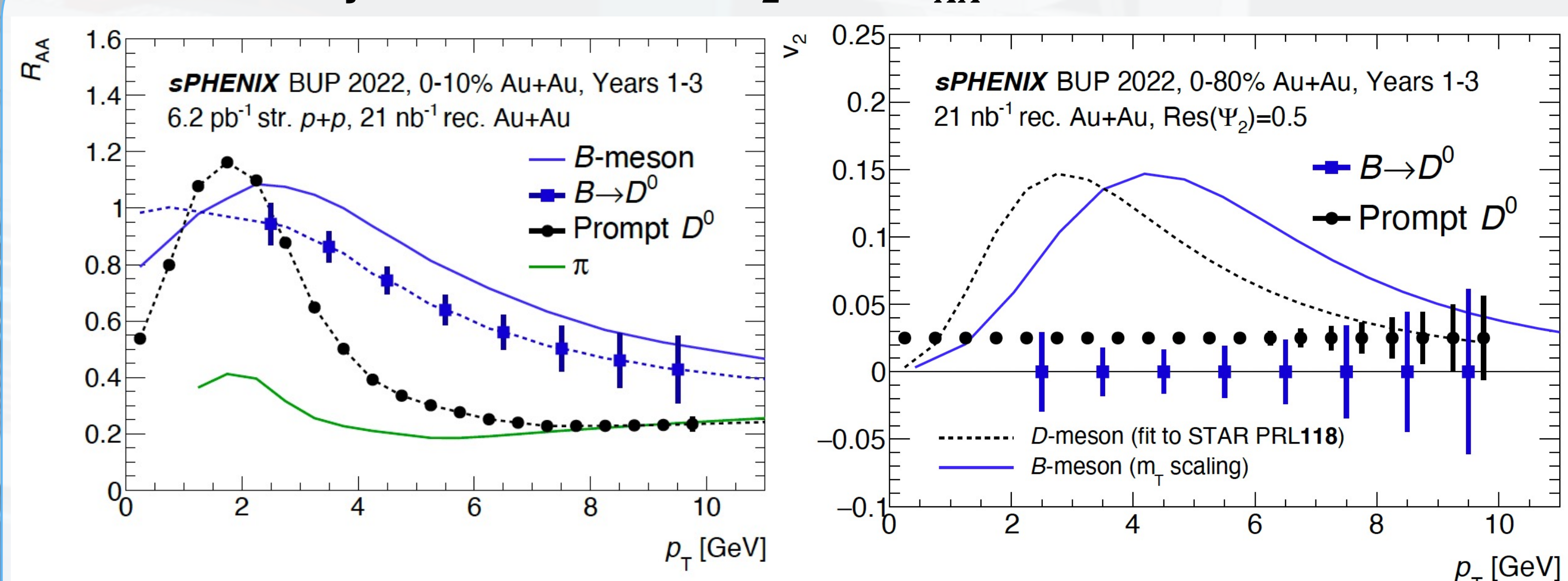
### Fully Reconstructed $B^+ \rightarrow \bar{D}^0 \pi^+$ Simulation Performance



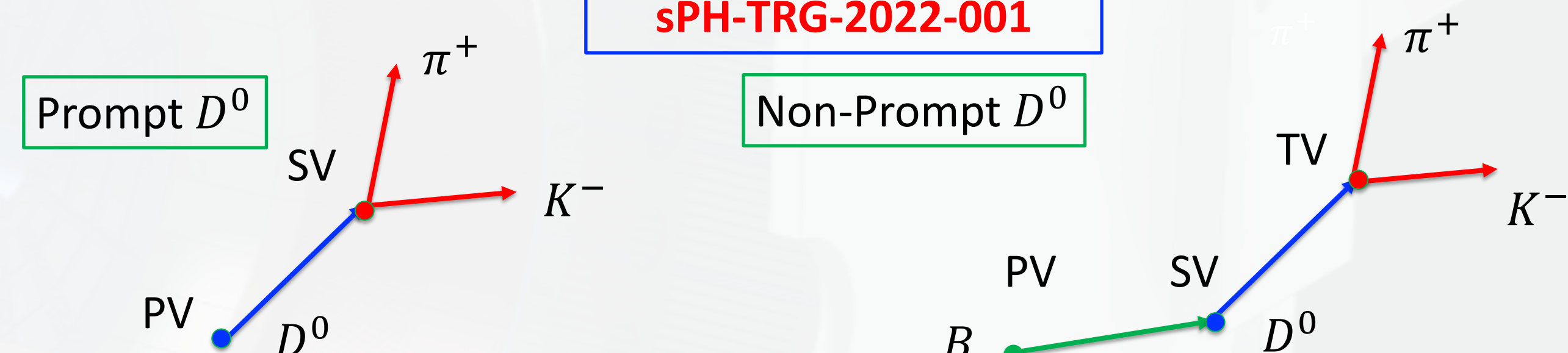
sPH-HF-2017-002

- 100  $\pi/K/p$  embedded in central HIJING Au + Au events with full sPHENIX detector in GEANT 4
  - Fast simulation: FONLL weighted  $B^+$  signal and detector effects smeared with tracking performance extracted from GEANT 4 simulation and reconstruction
  - Assume 5 years of data taking: an integrated luminosity corresponding to 240 billion MB events
- Fully reconstructed  $\bar{D}^0$  and  $B^+$  from the decay daughters without using hadronic PID
- Clear  $B^+$  signal observed for  $p_T$  from 0 – 10 GeV/c
  - First fully reconstructed b-hadron from exclusive decays in heavy-ion collisions at RHIC
  - Application of machine learning techniques on topological variable selections

### Projected b-hadron $v_2$ and $R_{AA}$ Measurements

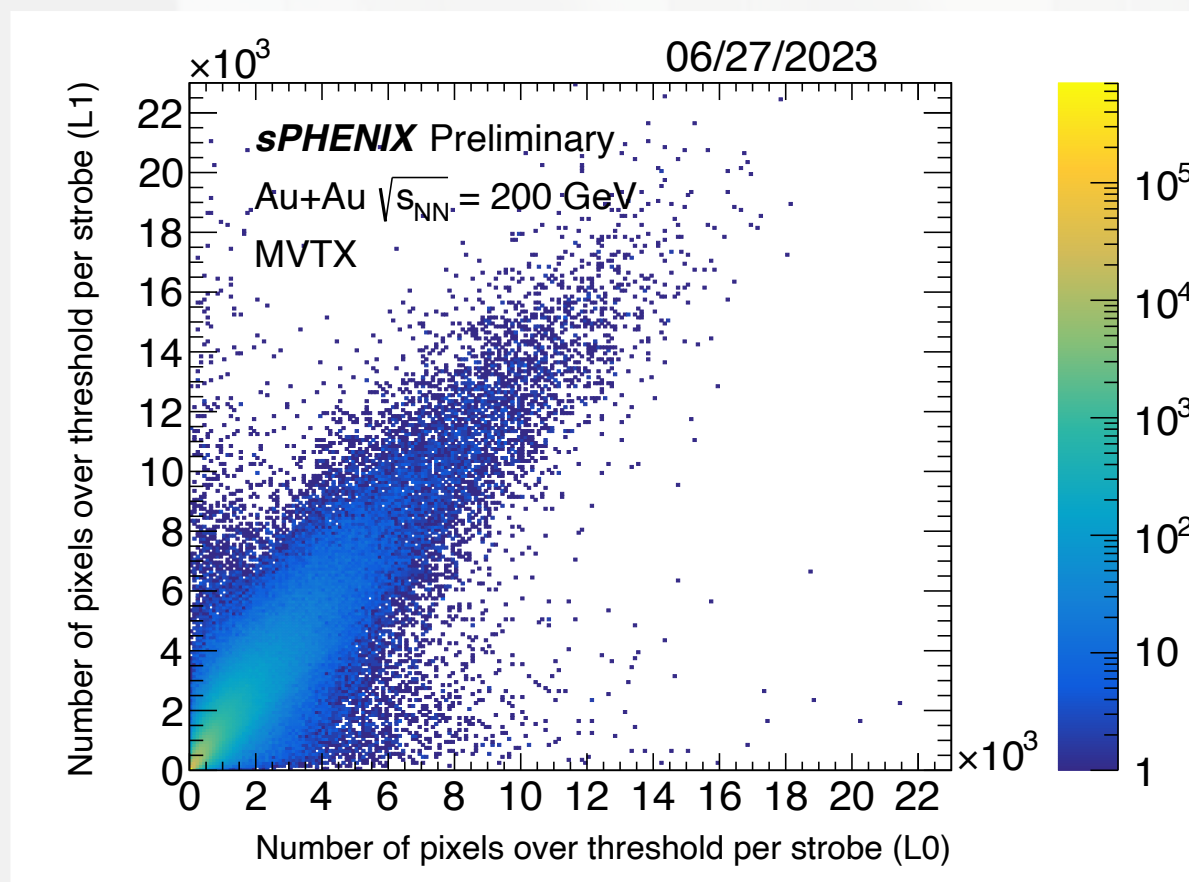


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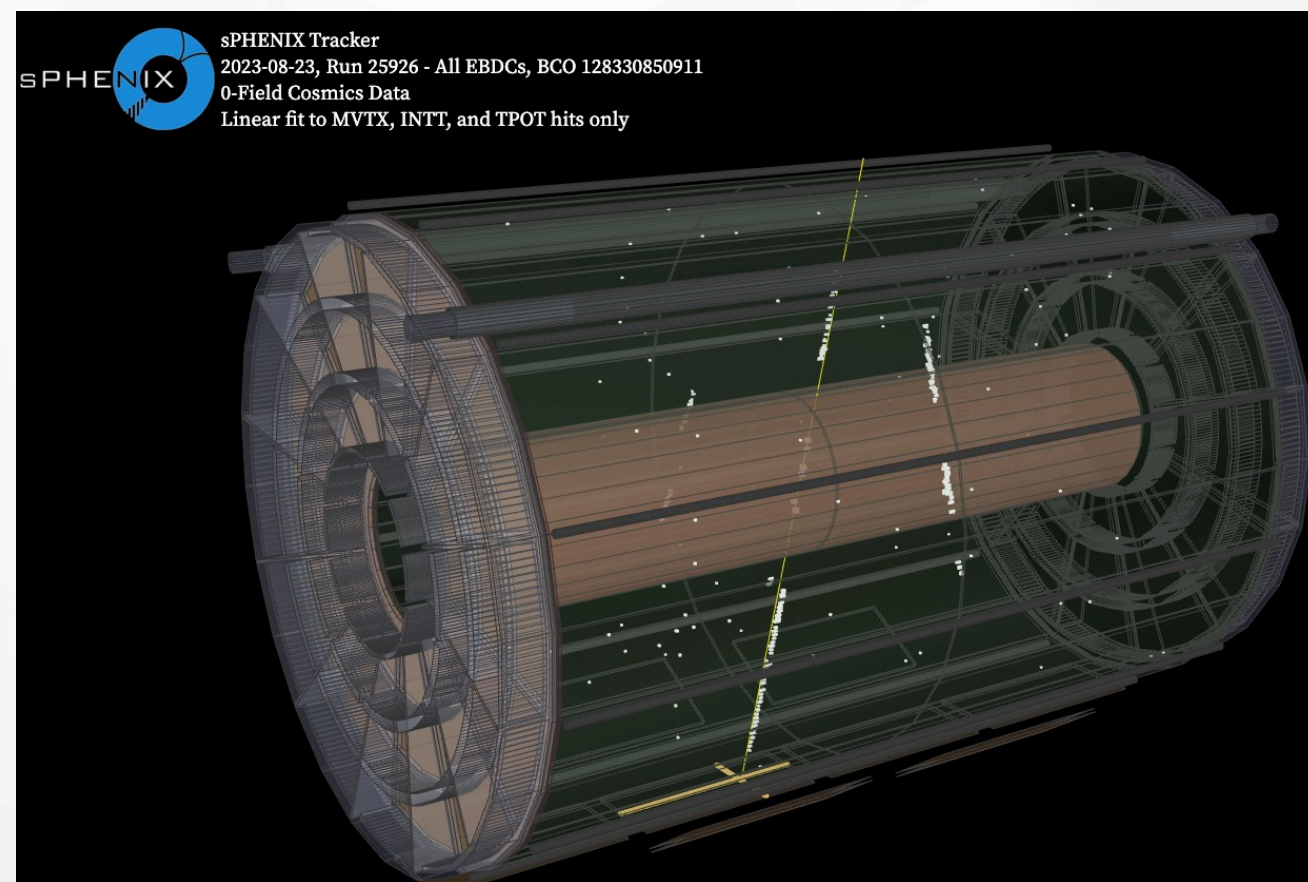


- $p_T$  differential measurements with excellent precision for both fully reconstructed prompt and non-prompt  $D^0$ , which comes from b-hadron decay, in the  $D^0 \rightarrow K^-\pi^+$  in p + p and Au + Au collisions
  - Large statistics thanks to the streaming readout capability of the tracking system
  - Achieve separation of prompt and non-prompt  $D^0$  through a data-driven method with DCA precisely determined by MVTX
- Probe the fundamental properties of QGP with beauty quarks
  - Curves: theoretical model predictions
  - Test pQCD in p + p and phenomenological model calculations in Au + Au
  - Prompt  $D^0$   $v_2$  and  $R_{AA}$ : investigate charm thermalization in the QGP medium
  - Non-prompt  $D^0$   $v_2$  and  $R_{AA}$ : indirect study on b-quark diffusion and hadronization
  - Prompt and non-prompt  $D^0$ : flavor dependence of energy loss in the QGP medium
- Fully reconstructed b-hadron studies currently work-in-progress
  - Improved full simulation with detector alignment and calibration performance from data
  - New projected beam luminosity in future runs
  - Latest theoretical model calculations

### First Year Data Taking and Analysis



sPH-MVTX-2023-001



sPH-TRK-2023-001

- sPHENIX detector commissioning with 200 GeV Au + Au beams in Run 23: 05/18/2023 – 08/01/2023
  - Data ready for offline analysis (alignment and calibration)
- All detector systems function properly and are able to readout the data
  - Physics trigger information stored in MVTX streaming readout data to select interesting events
  - Strong correlation among tracking subsystems (MVTX, INTT, TPC and TPOT)
  - Cosmic event display of the full tracking detector system in zero magnetic field

### Summary

- Demonstration of detector functionality and readiness for offline data analysis
  - Validate the synchronization of the subdetectors through correlation studies
  - Beam collisions data taking complete
  - Currently taking and analyzing cosmic data for detector alignment and calibration
- sPHENIX will provide strong model constraints on b-quark transport in QGP at RHIC energy
  - Indirect study through non-prompt  $D^0$
  - Low  $p_T$ : beauty diffusion coefficient and thermalization in QGP
  - Intermediate  $p_T$ : b-quark hadronization
  - High  $p_T$ : flavor dependence of energy loss
  - Enable beauty quark as a novel probe for QGP at RHIC
- New studies on fully reconstructed b-hadron  $R_{AA}$  and  $v_2$  ongoing
- Exciting physics results forthcoming

