

A 3D cutaway diagram of the sPHENIX detector at RHIC. The diagram shows the internal components of the detector, including the SC magnet, flux return door, INTT, MVTK, outer HCal, inner HCal, EMCal, TPC, and support carriage. A cryogenic chimney is also visible at the top right. The text "Heavy-flavor physics with the sPHENIX detector at RHIC" is overlaid in the center.

# Heavy-flavor physics with the sPHENIX detector at RHIC

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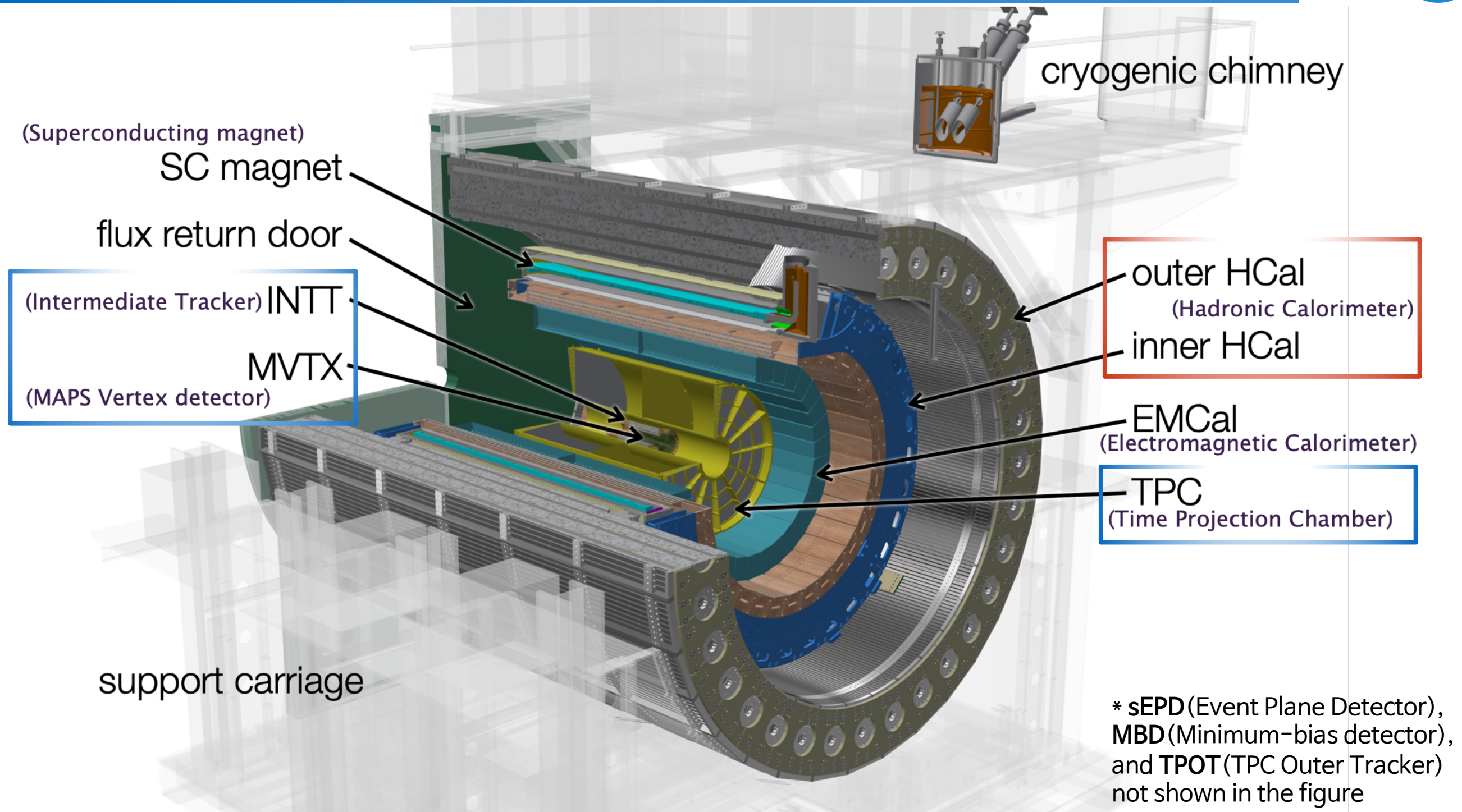
on behalf of the sPHENIX collaboration

**DIS2022 - XXIX International Workshop  
on Deep-Inelastic Scattering and Related Subjects  
2-6 May 2022, Santiago de Compostela, Spain**



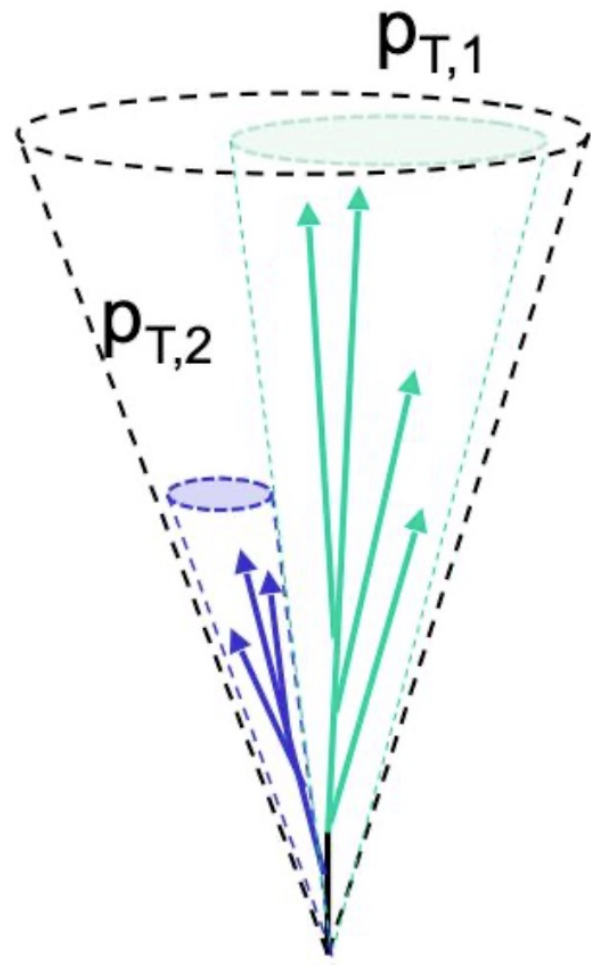
**부산대학교**  
PUSAN NATIONAL UNIVERSITY





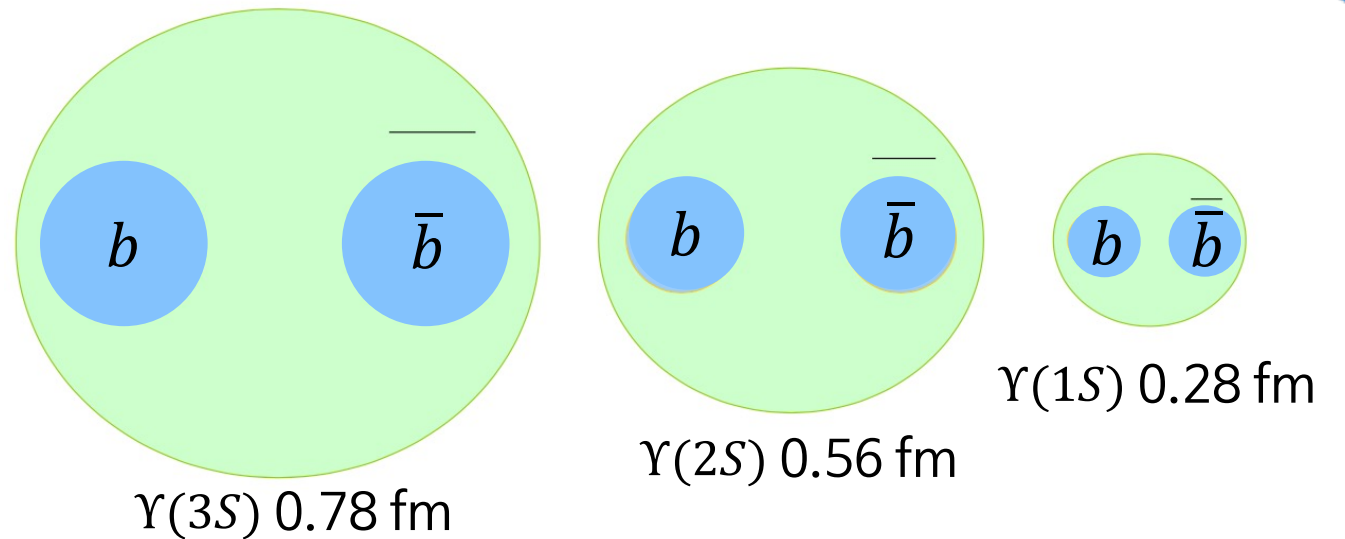
- **First HCal at RHIC for jet measurement**
- **Precise tracking and vertexing with the tracking system for heavy-flavor physics**
- **Large data sample (15 kHz trigger rate)**





### Jet structure

vary momentum/angular scale of probe



### Quarkonium spectroscopy

vary size of probe

### Parton energy loss

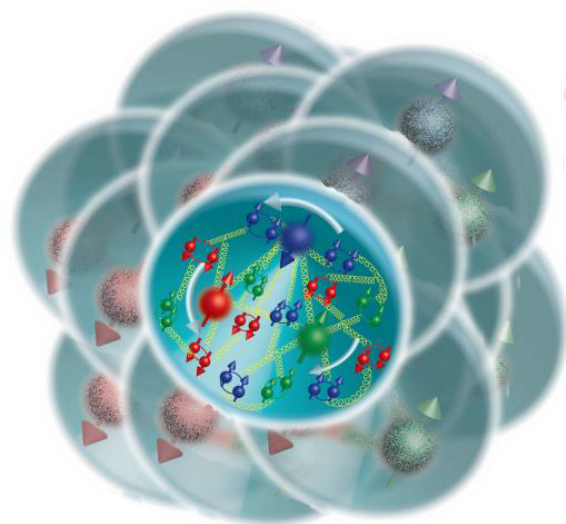
vary mass/momentum of probe

$u, d, s$

$c$

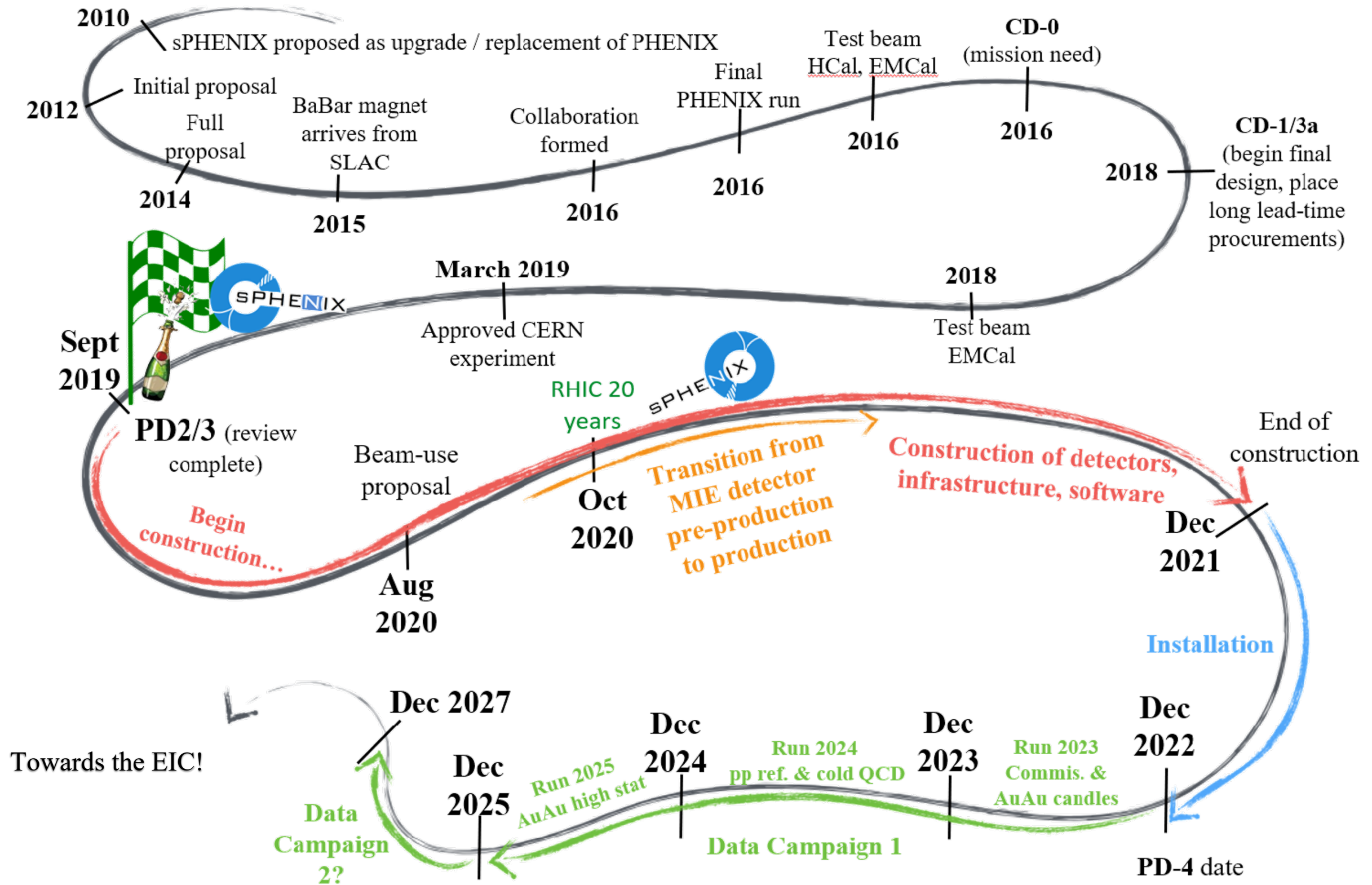
$b$

photon  
gluon



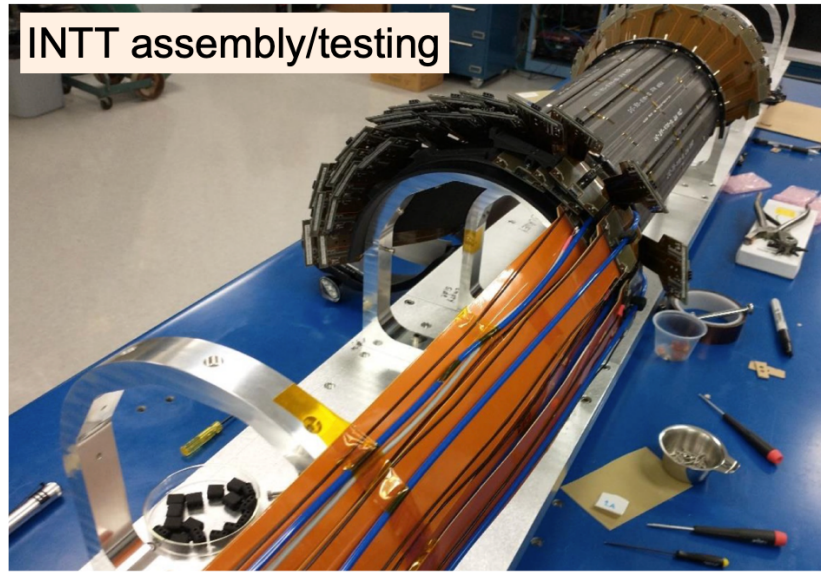
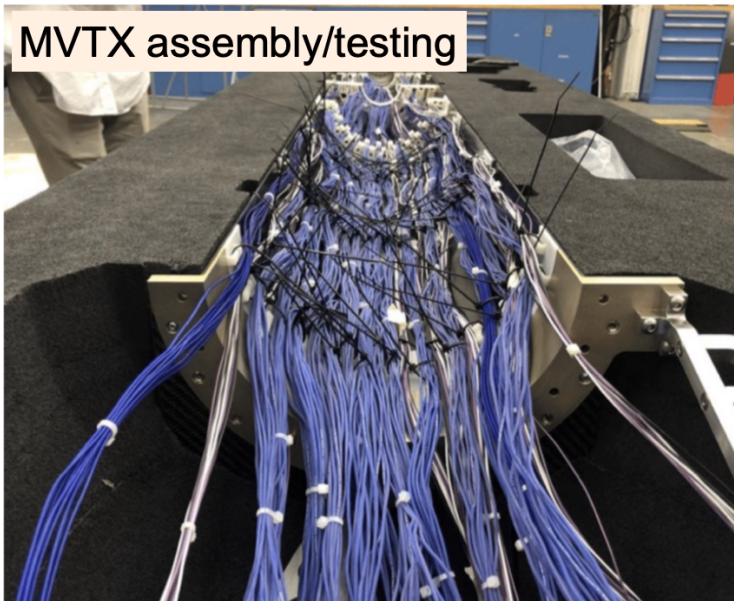
### Cold QCD

study proton spin,  
transverse-momentum,  
and nuclear effects



**First data in early 2023!**

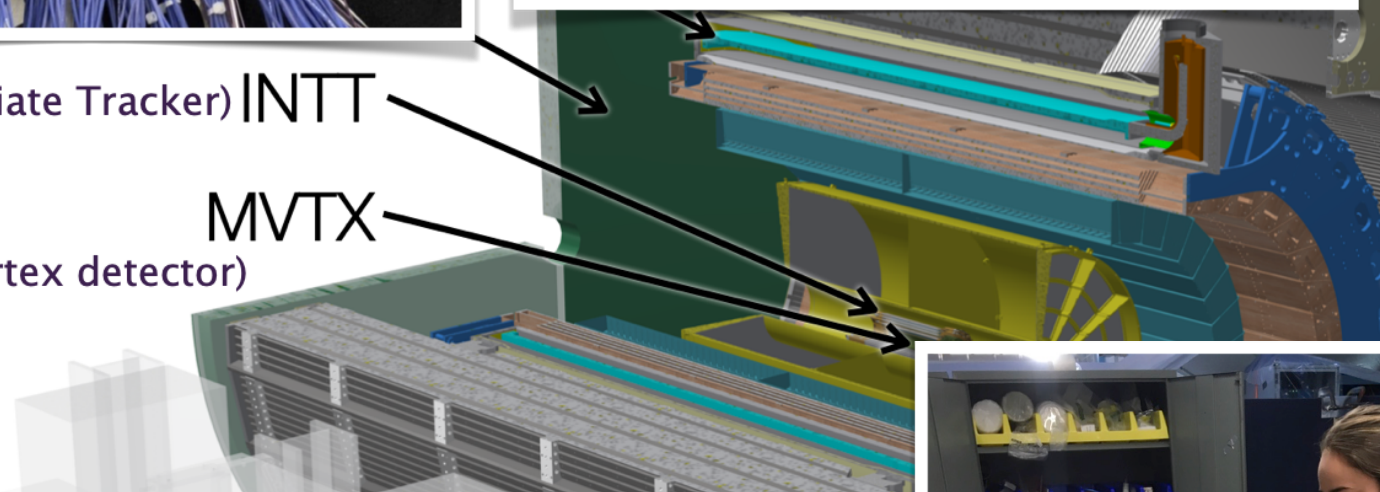




(Intermediate Tracker) INTT

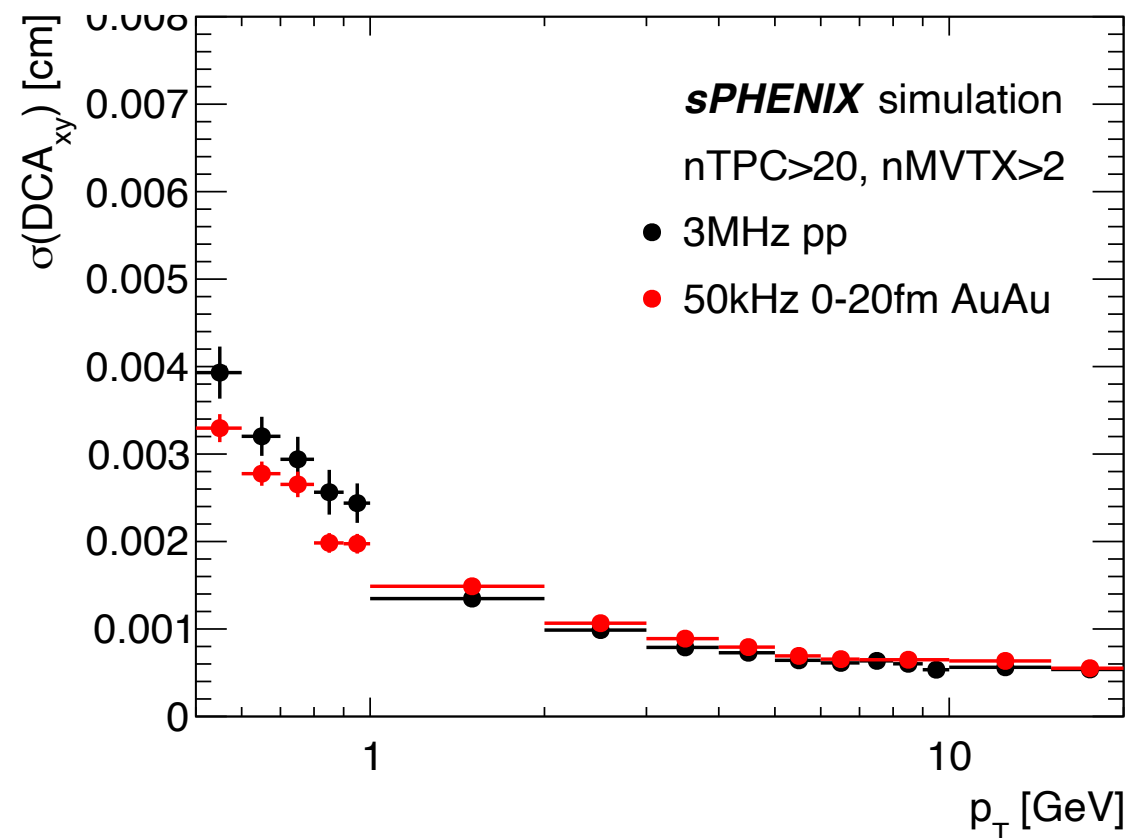
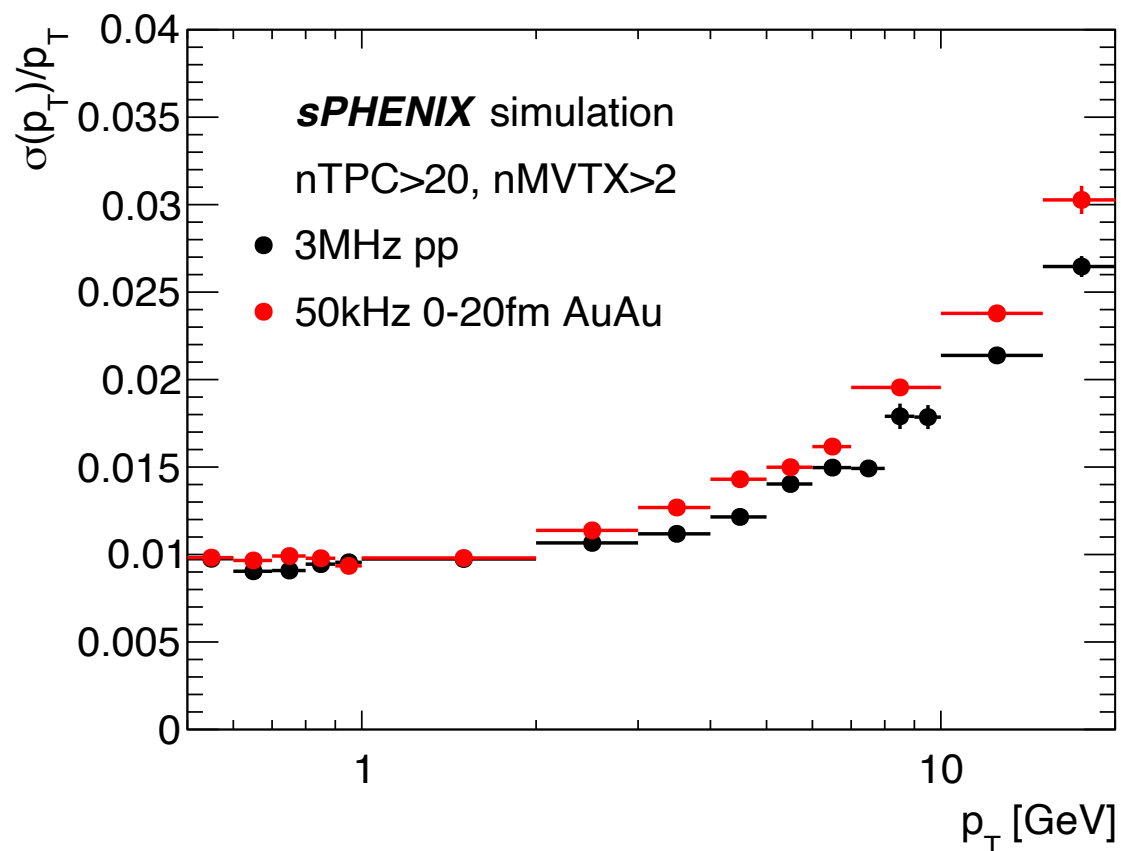
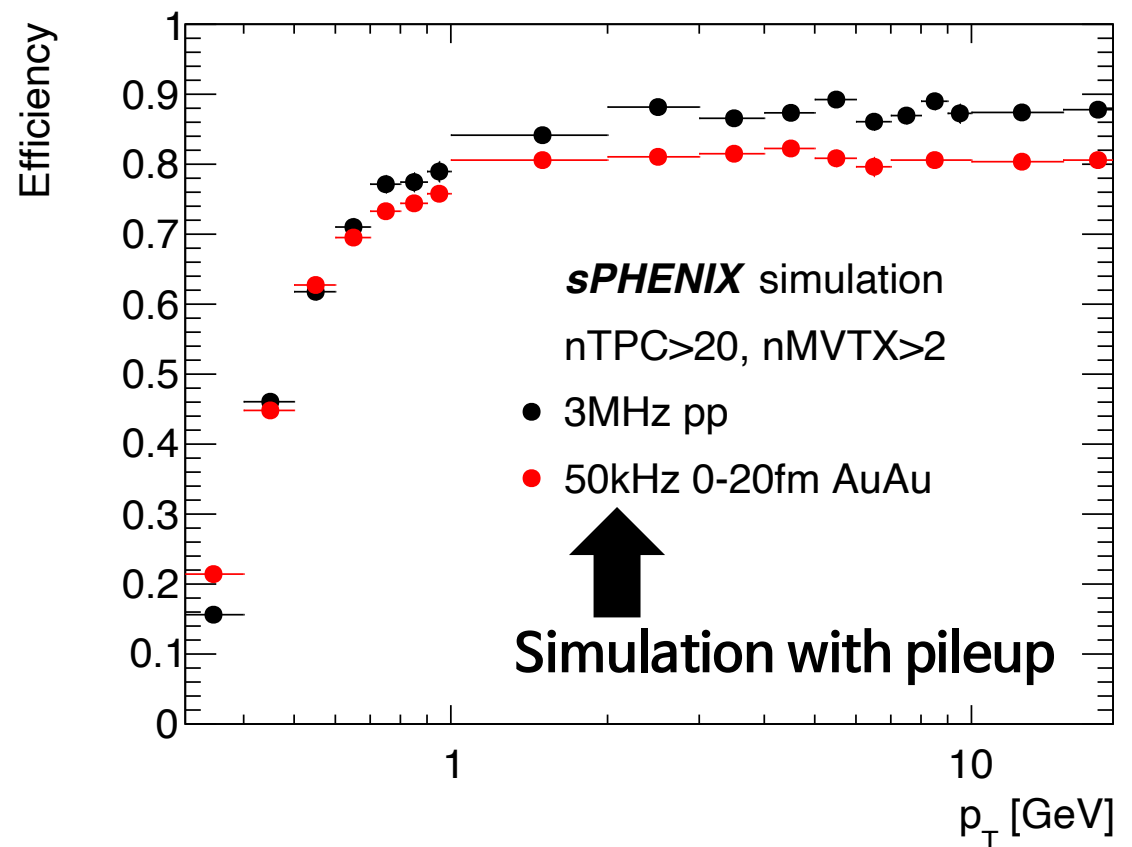
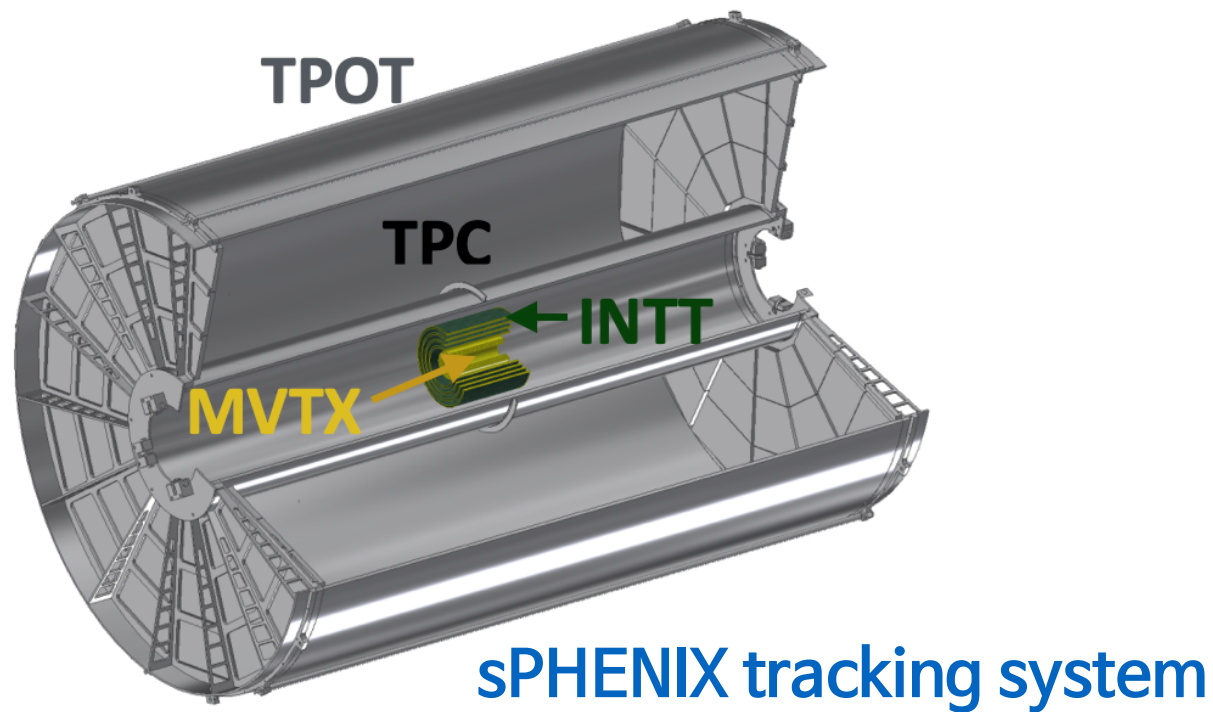
MVTX

(MAPS Vertex detector)

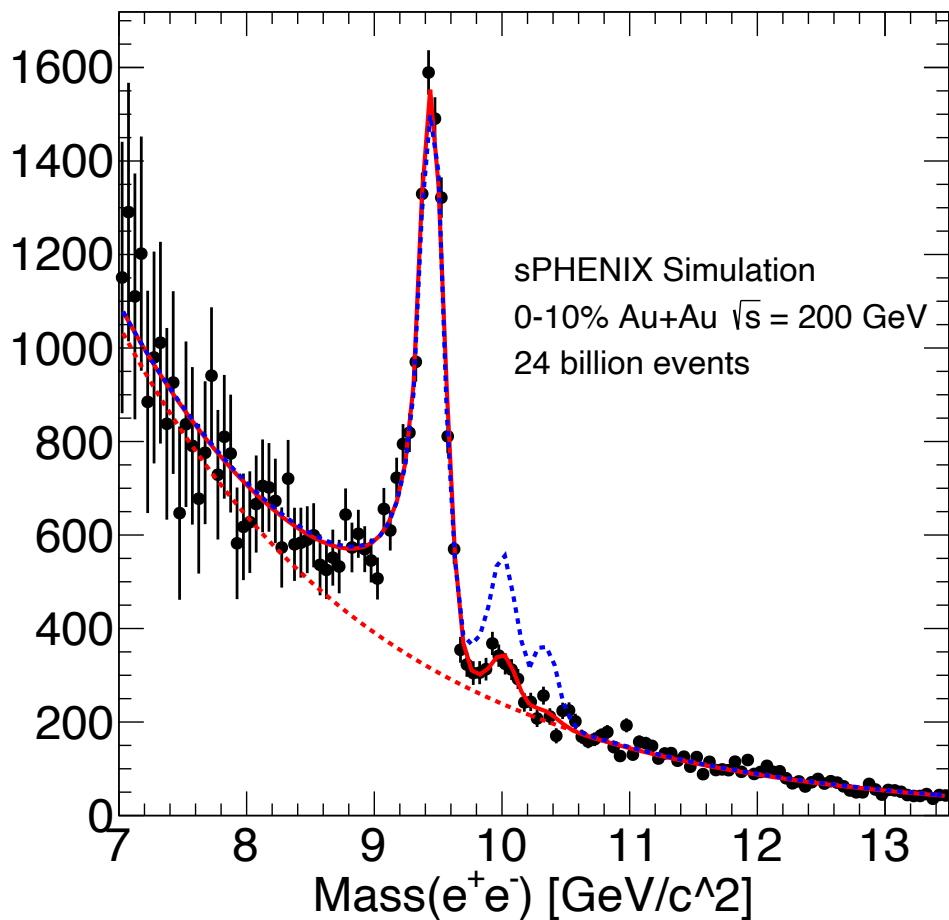
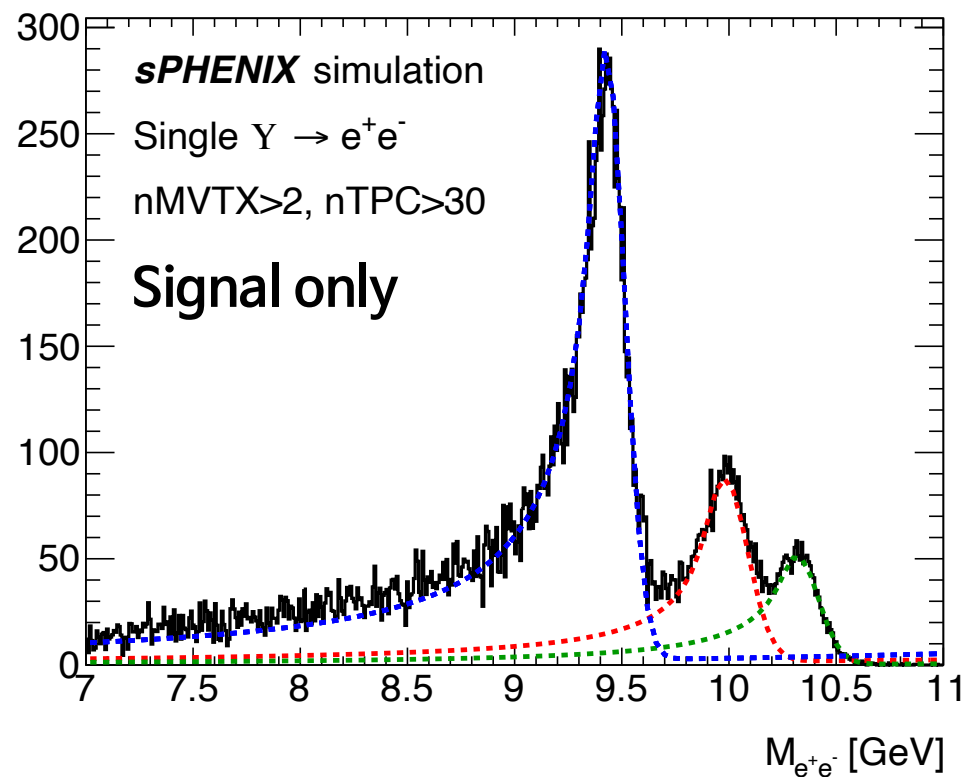




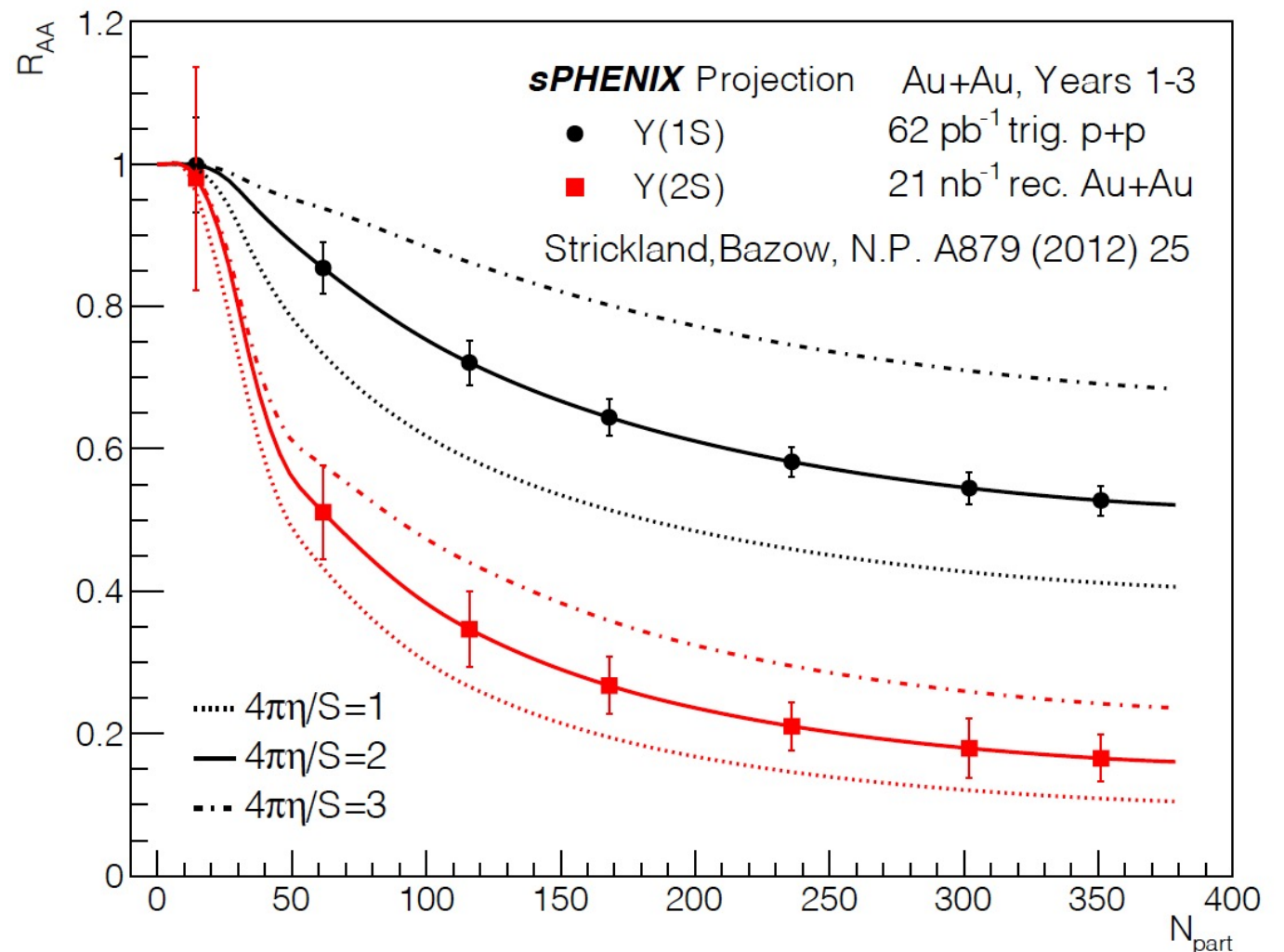
- Tracking and vertexing based on the ACTS package  
*Computing and Software for Big Science 5, 23 (2021)*



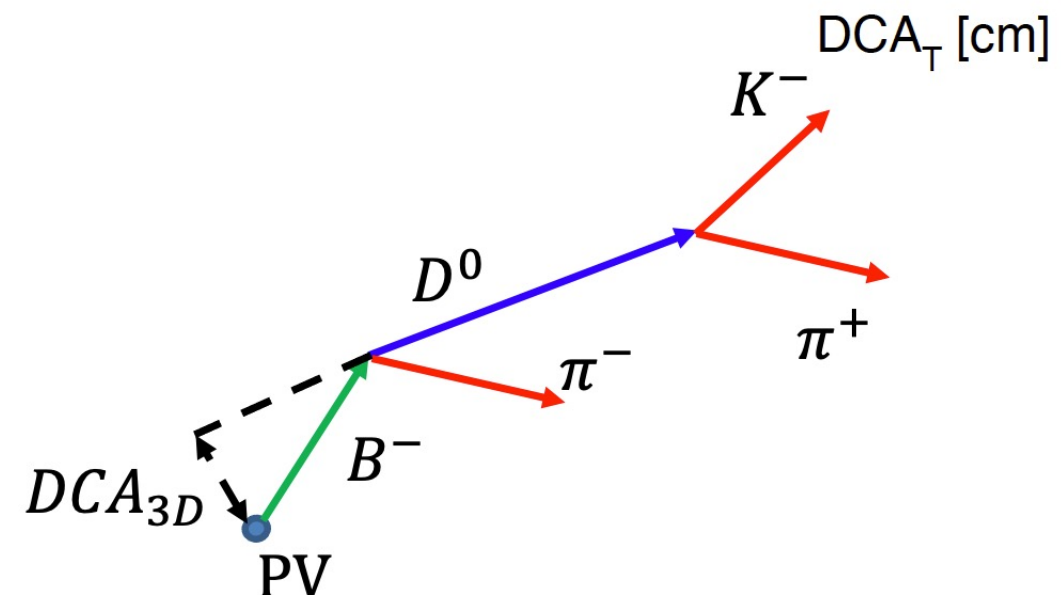
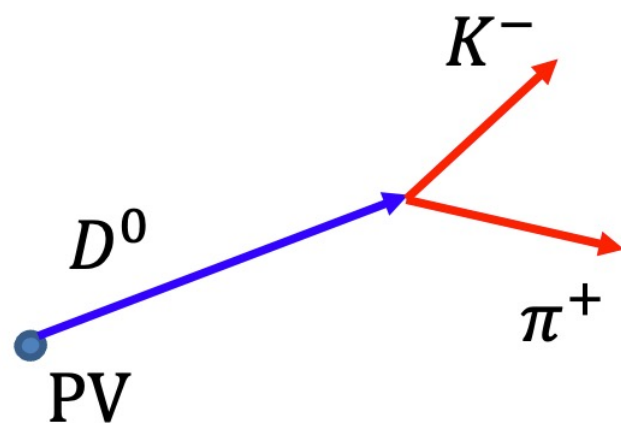
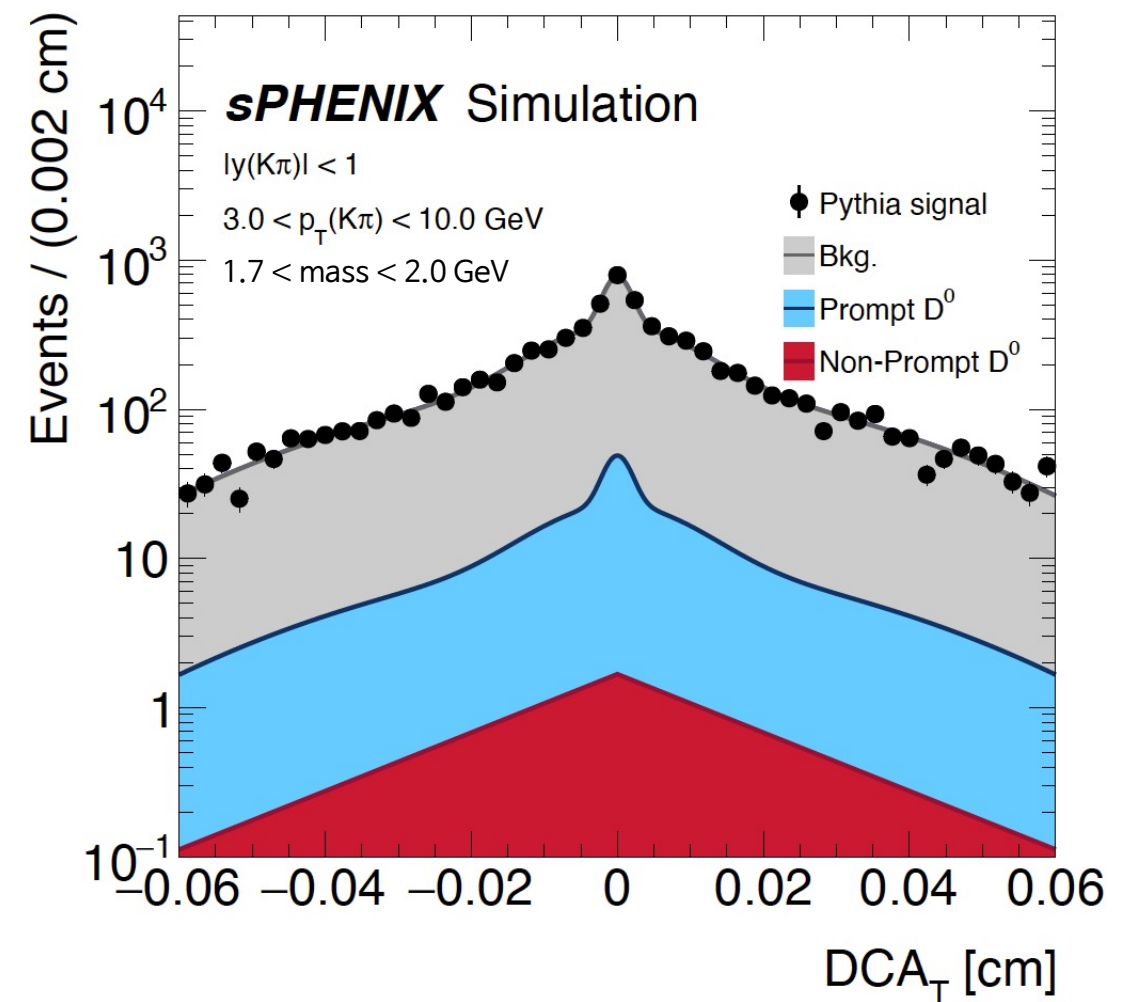
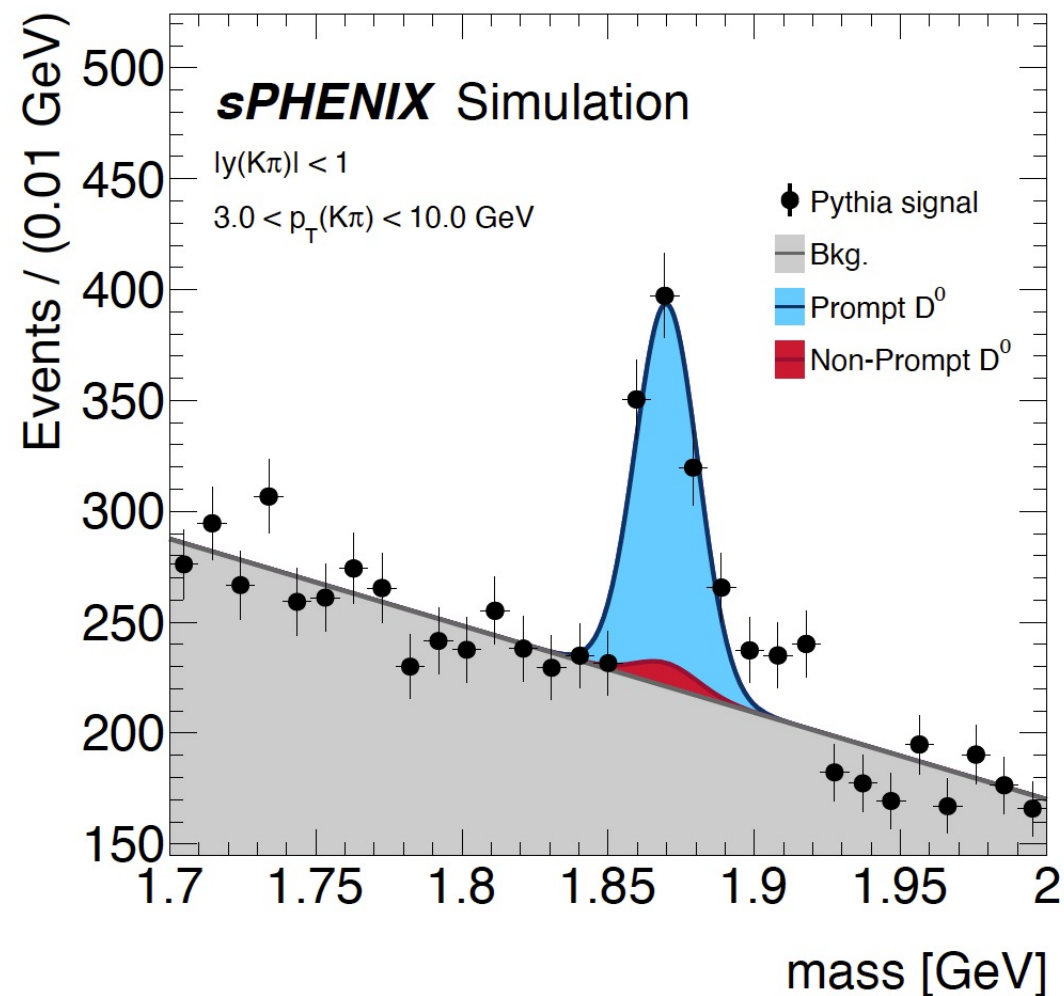




- Upsilon measurement via di-electron channel
- Clear separation of three Upsilon states
- Precise study of sequential suppression in the QGP  
- Only chance to observe the fate of  $\Upsilon(3S)$  at RHIC!

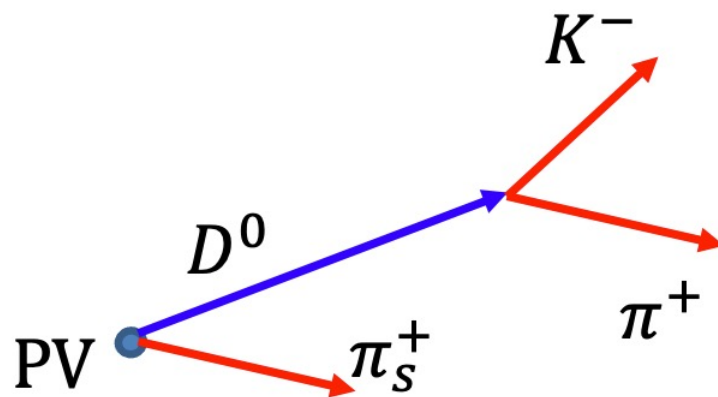
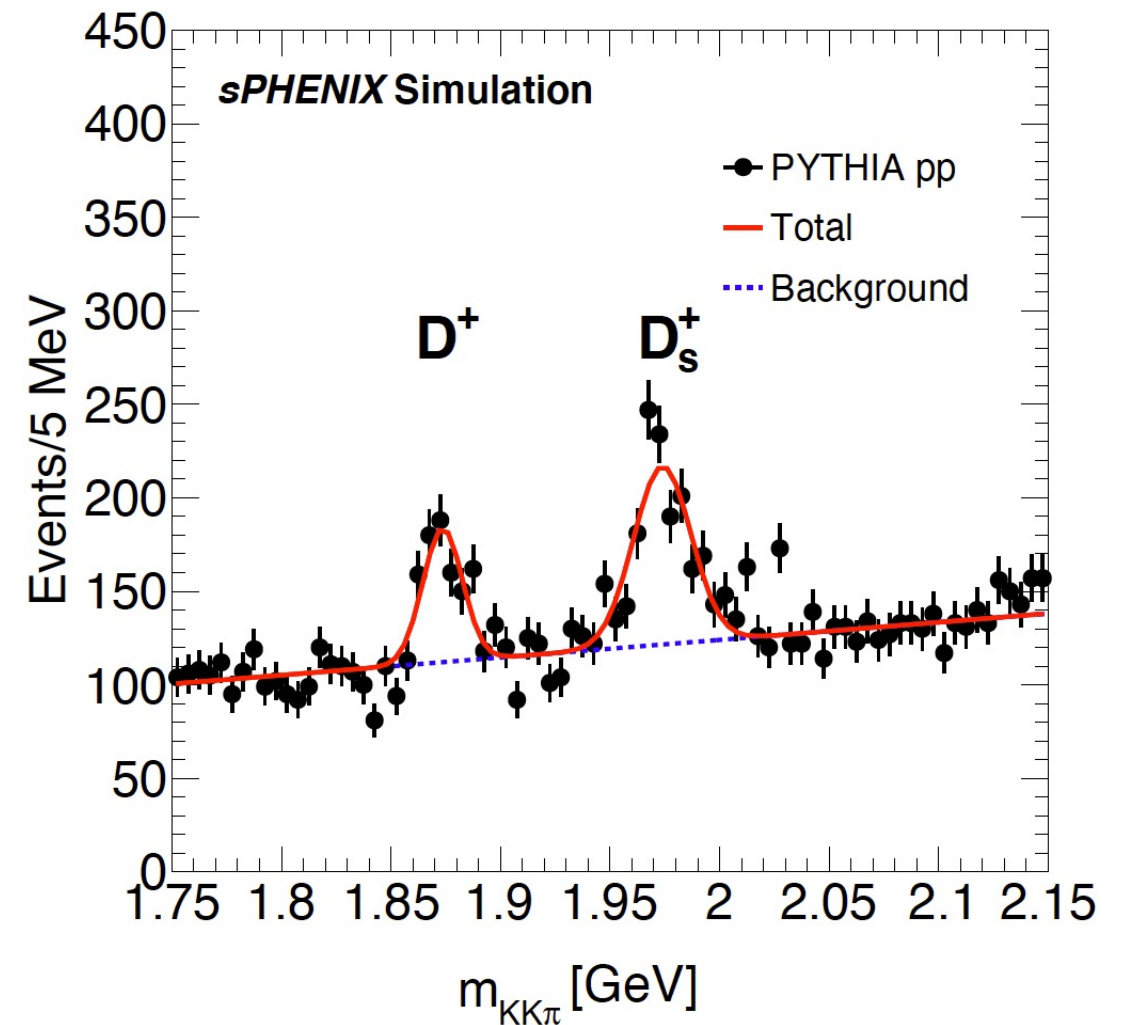
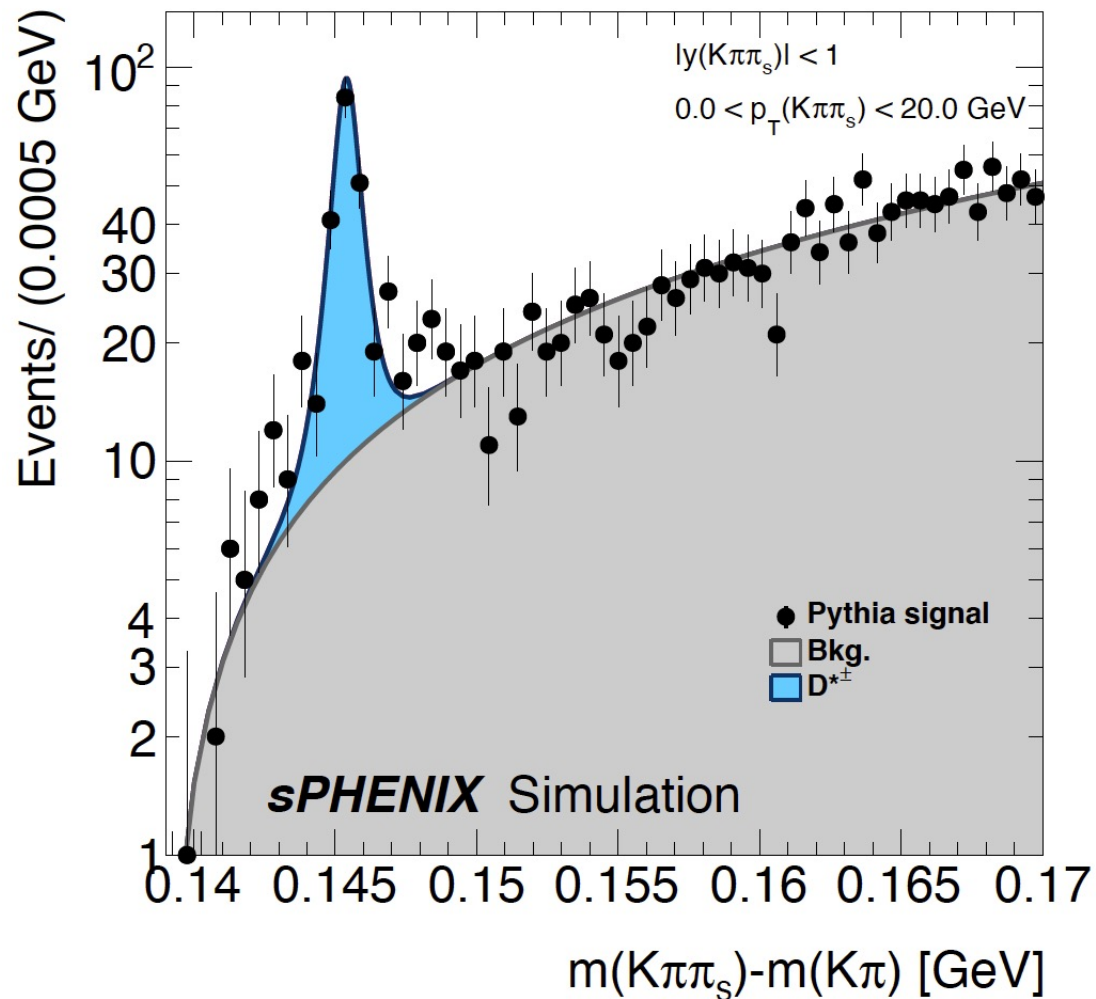


- Heavy-flavor hadron reconstruction with KFParticle and kinematic selections
- Non-prompt hadrons can be further separated with DCA

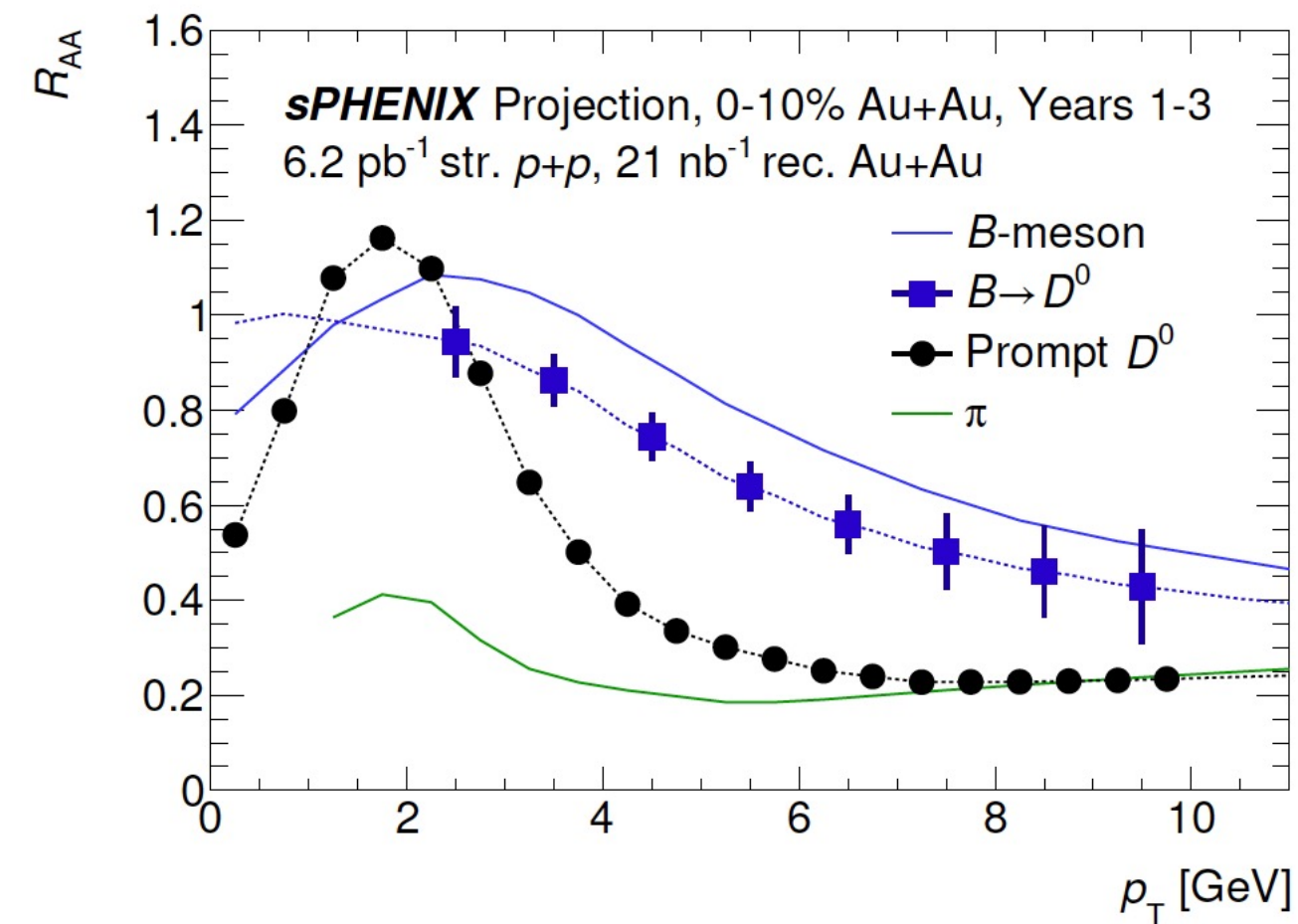




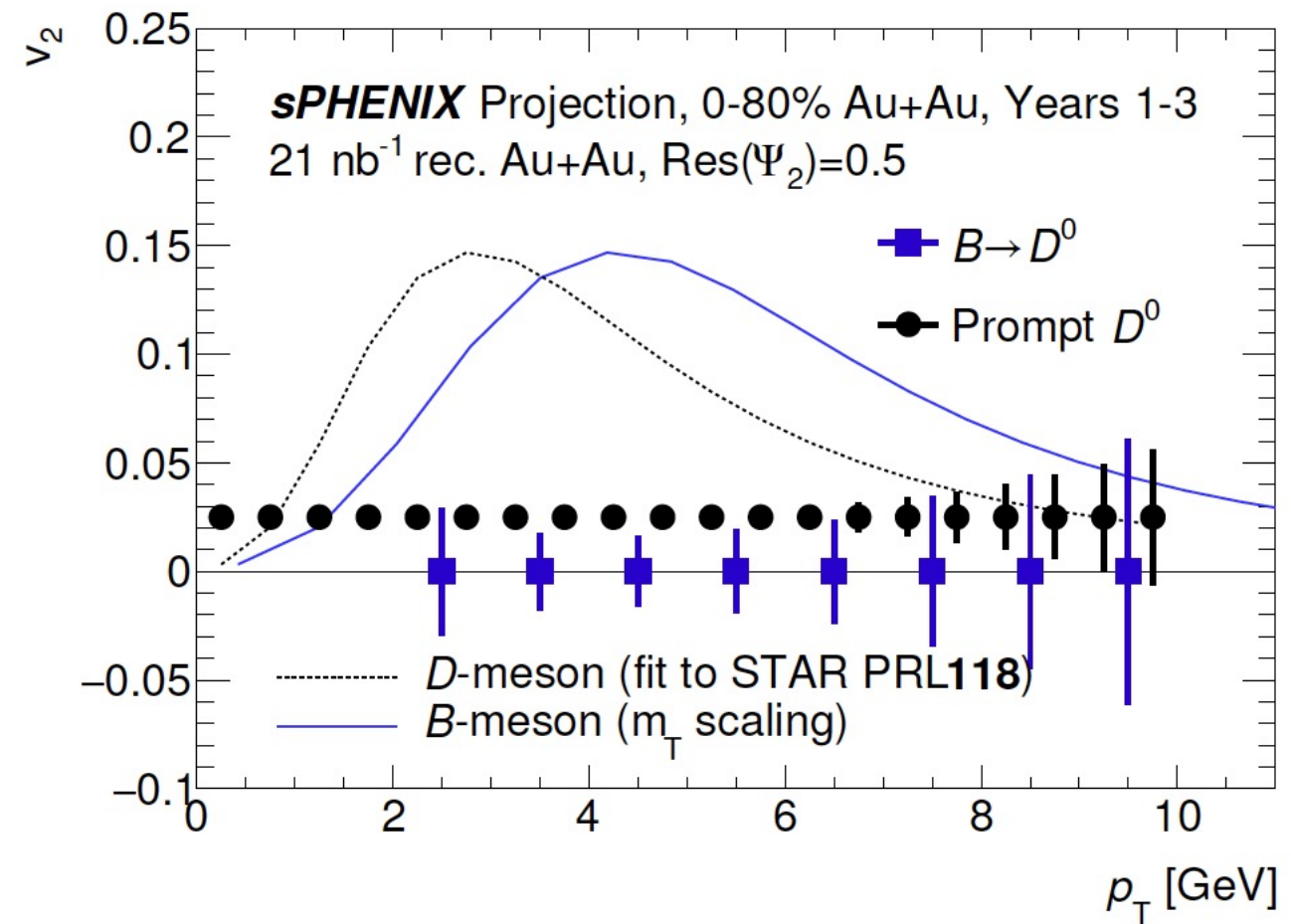
- Heavy-flavor hadron reconstruction with KFParticle and kinematic selections
- Feasible to reconstruct  $D^*$  and  $D_s^+$  with three daughters



## $D$ -meson modification factor



## $D$ -meson elliptic flow

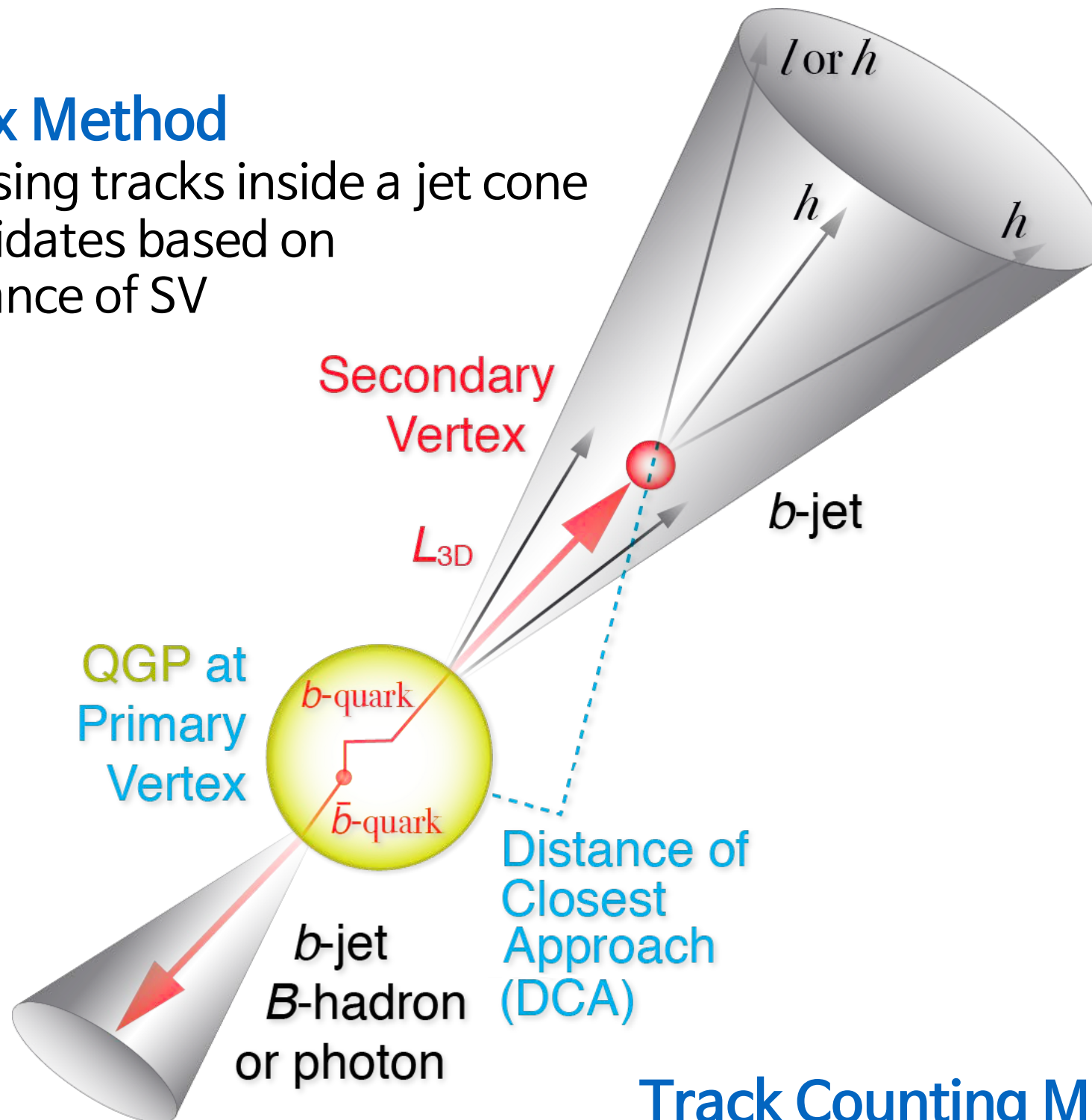


- Precise measurement of prompt and non-prompt  $D$ -meson at  $p_T < 10$  GeV/ $c$  to study mass-dependent energy loss and collectivity inside the QGP
- Significant constraints on diffusion coefficient and temperature dependence



## Secondary Vertex Method

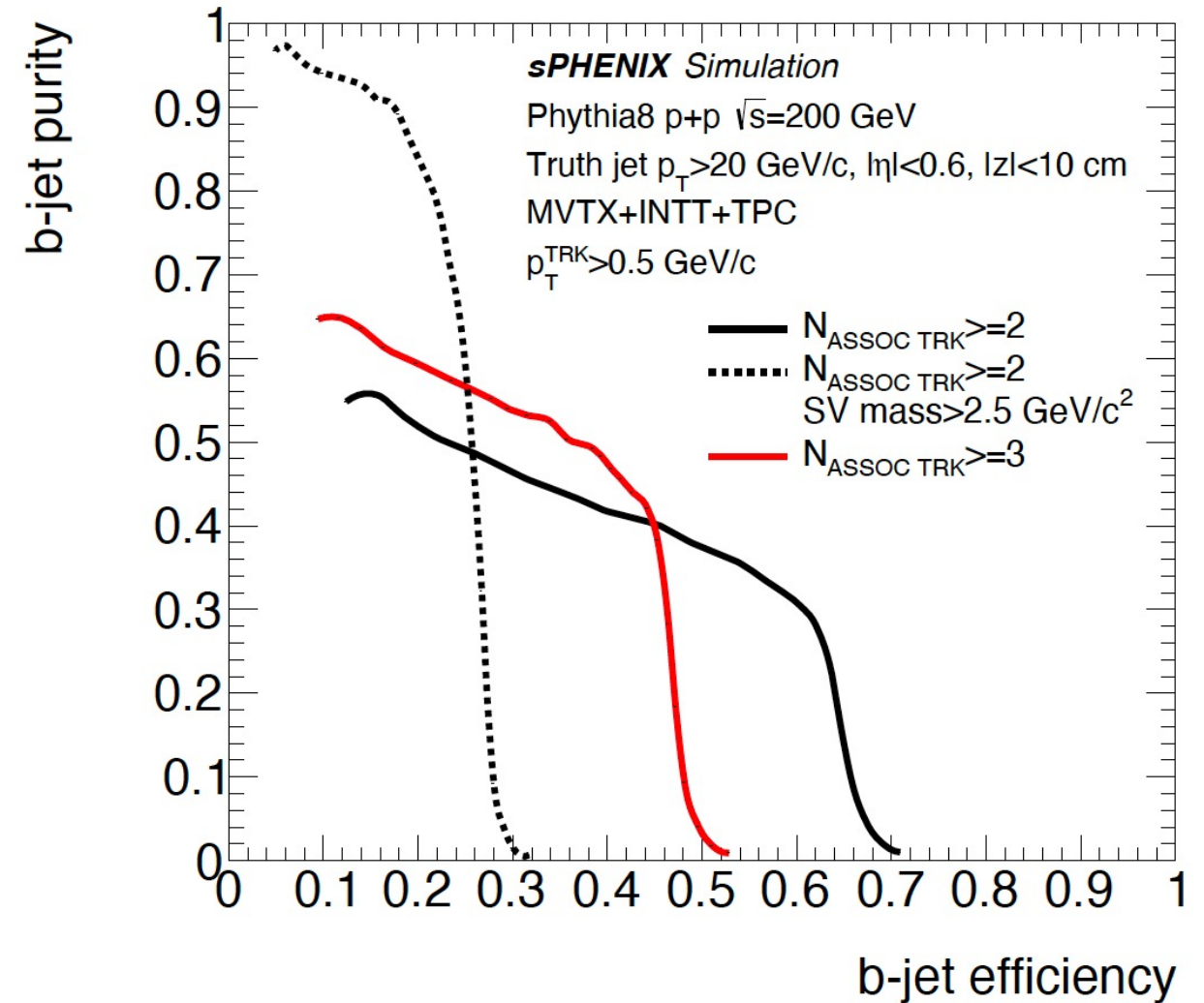
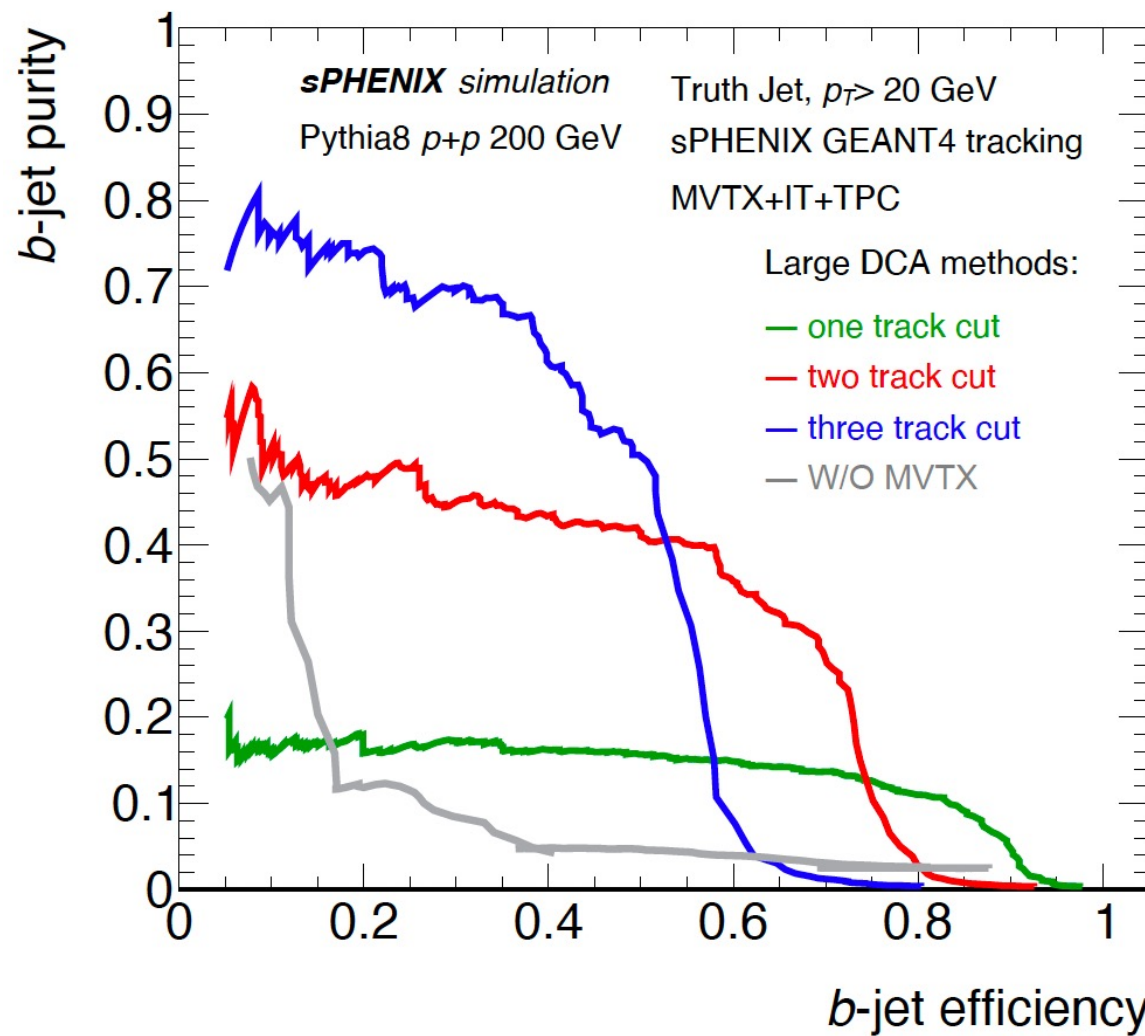
- Reconstruct SV using tracks inside a jet cone
- Select  $b$ -jet candidates based on the 3D flight distance of SV



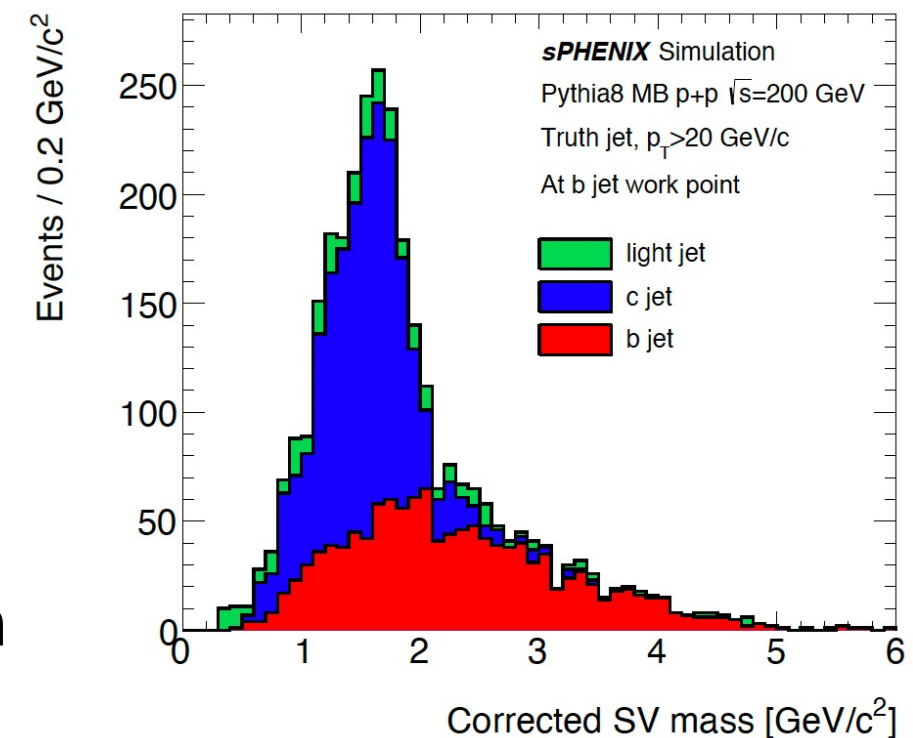
**First  $b$ -jet measurements  
at RHIC with sPHENIX!**

## Track Counting Method

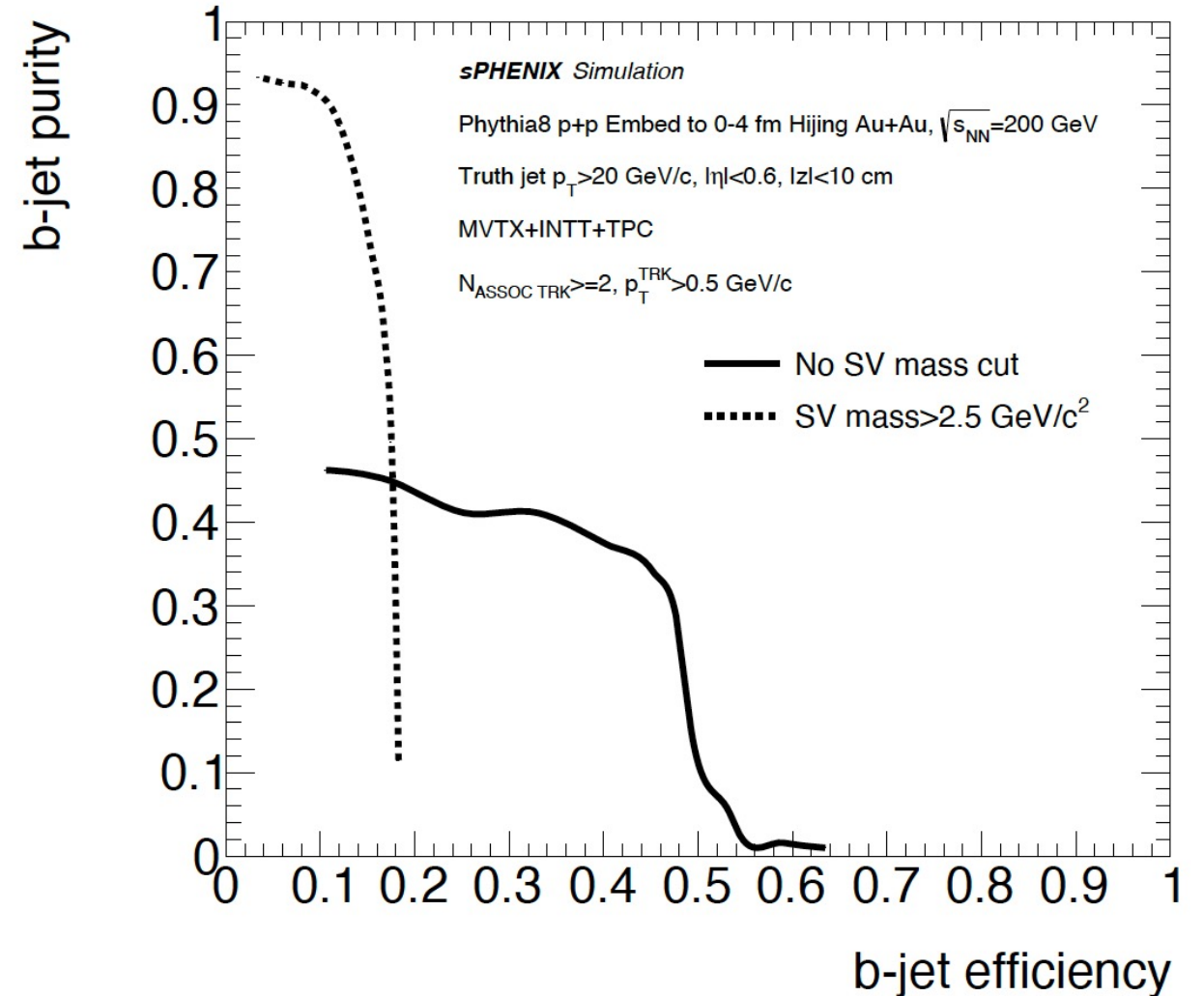
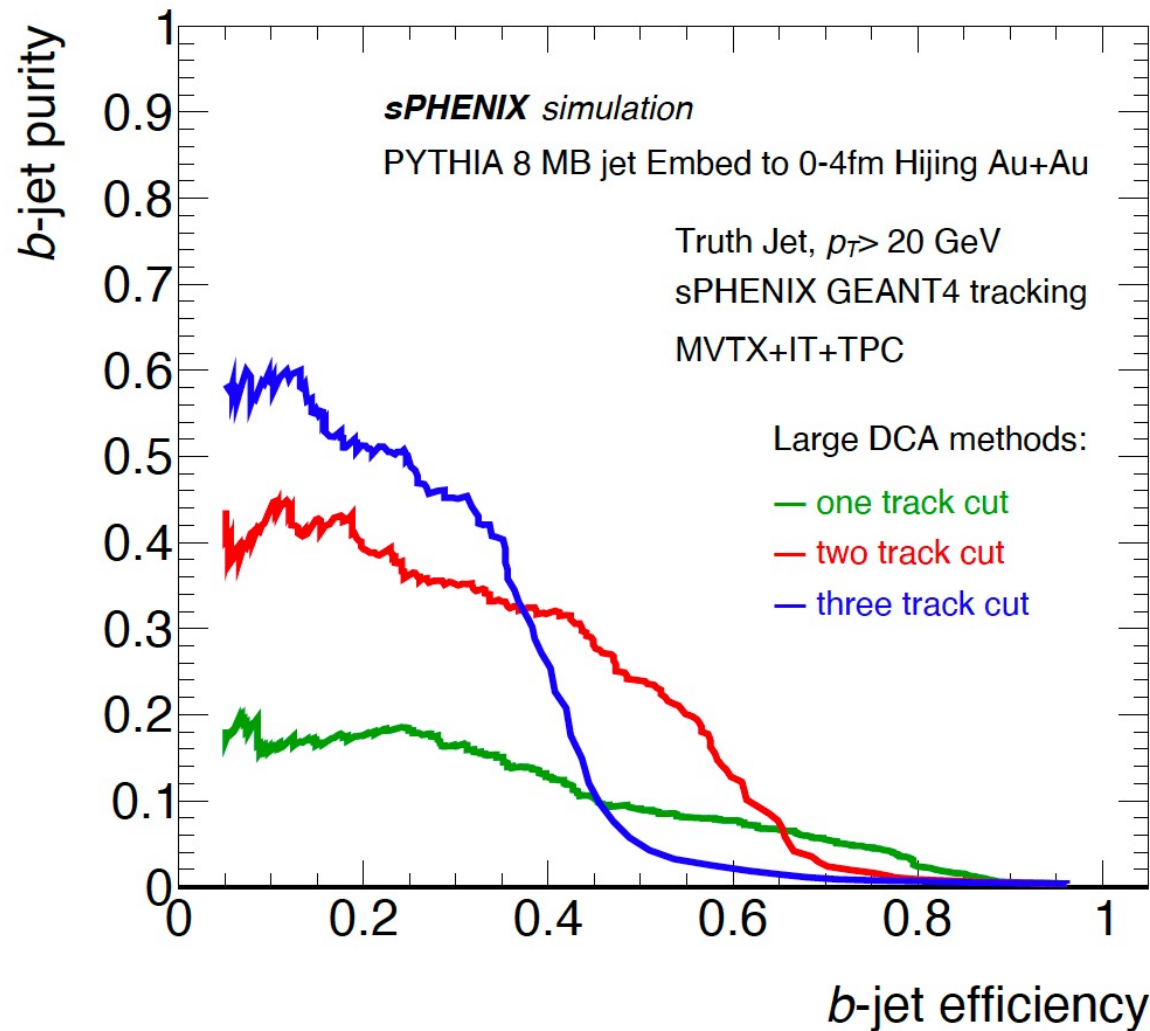
- Tracks from  $b$ -jet likely have large DCA
- Select  $b$ -jet candidates based on the number of tracks with large DCA



- Simulation study with inclusive jets in PYTHIA8
- **~60%  $b$ -jet efficiency and ~40%  $b$ -jet purity** with the track counting method  
→ Performance compatible with CMS
- Properties of SV such as SV mass provides further discrimination power and data-driven validation

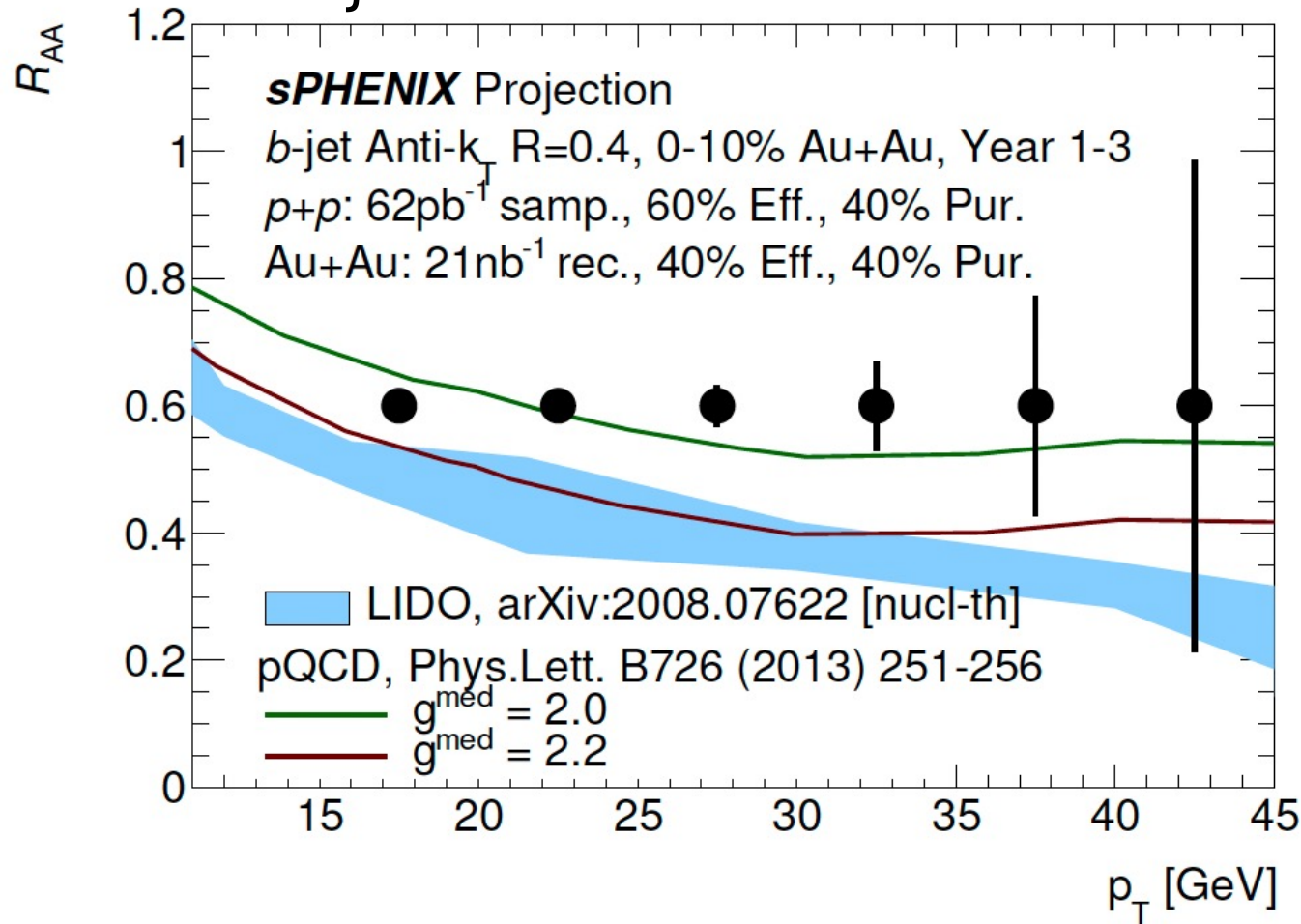




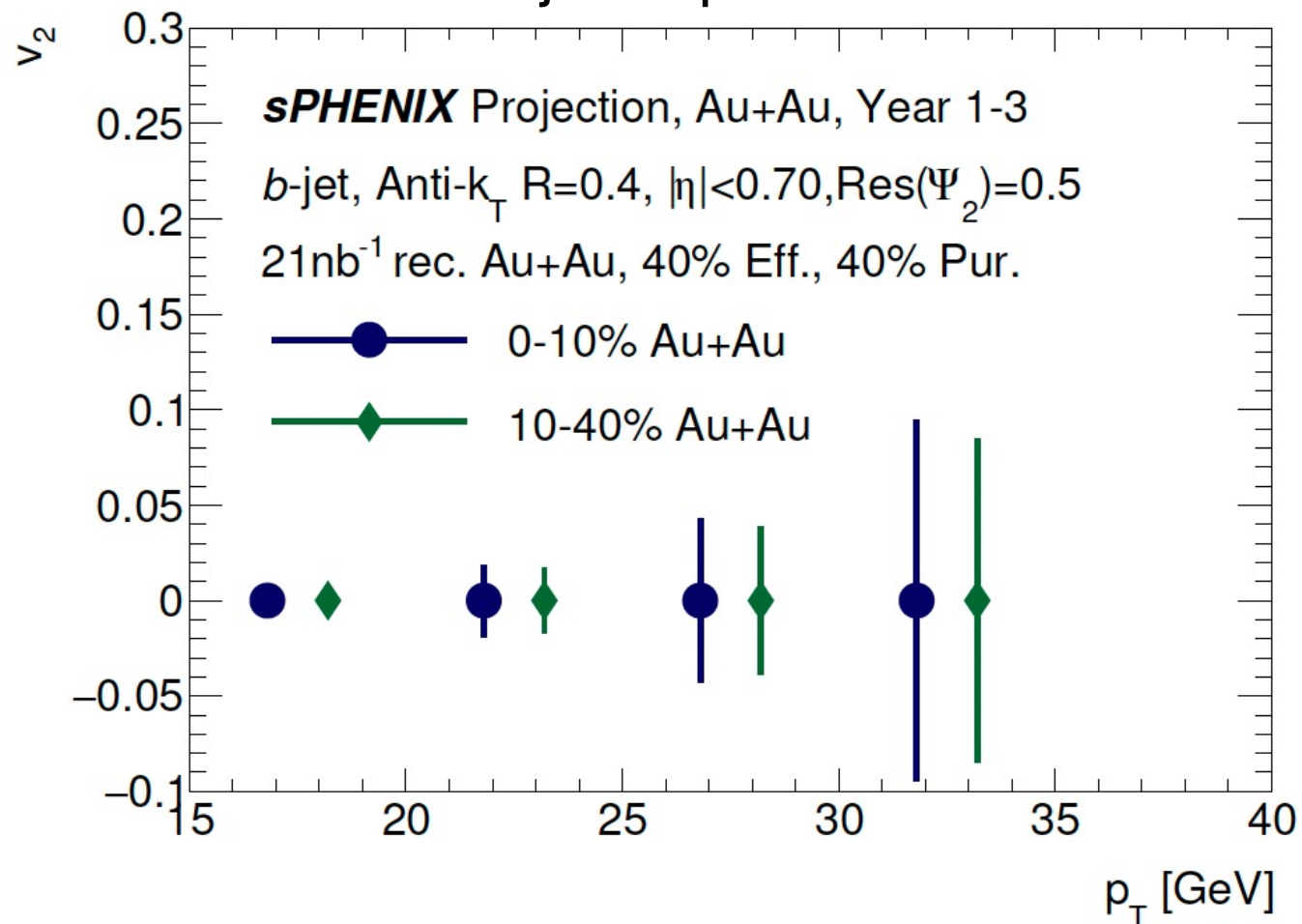


- Simulation study with inclusive jets in PYTHIA8 embedded to background events from HIJING Au+Au of 0-4 fm
- **~40%  $b$ -jet efficiency and ~40%  $b$ -jet purity** with both methods  
 → Performance compatible with CMS
- Very high purity of  $b$ -jet samples can be selected with a SV mass cut

## $b$ -jet nuclear modification factor



## $b$ -jet elliptic flow



- First  $b$ -jet measurements at RHIC with sPHENIX will provide important information on mass-dependent response inside the QGP
- Further study with di- $b$ -jet pairs (mass &  $p_T$  balance) to suppress contribution from gluon splitting



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

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

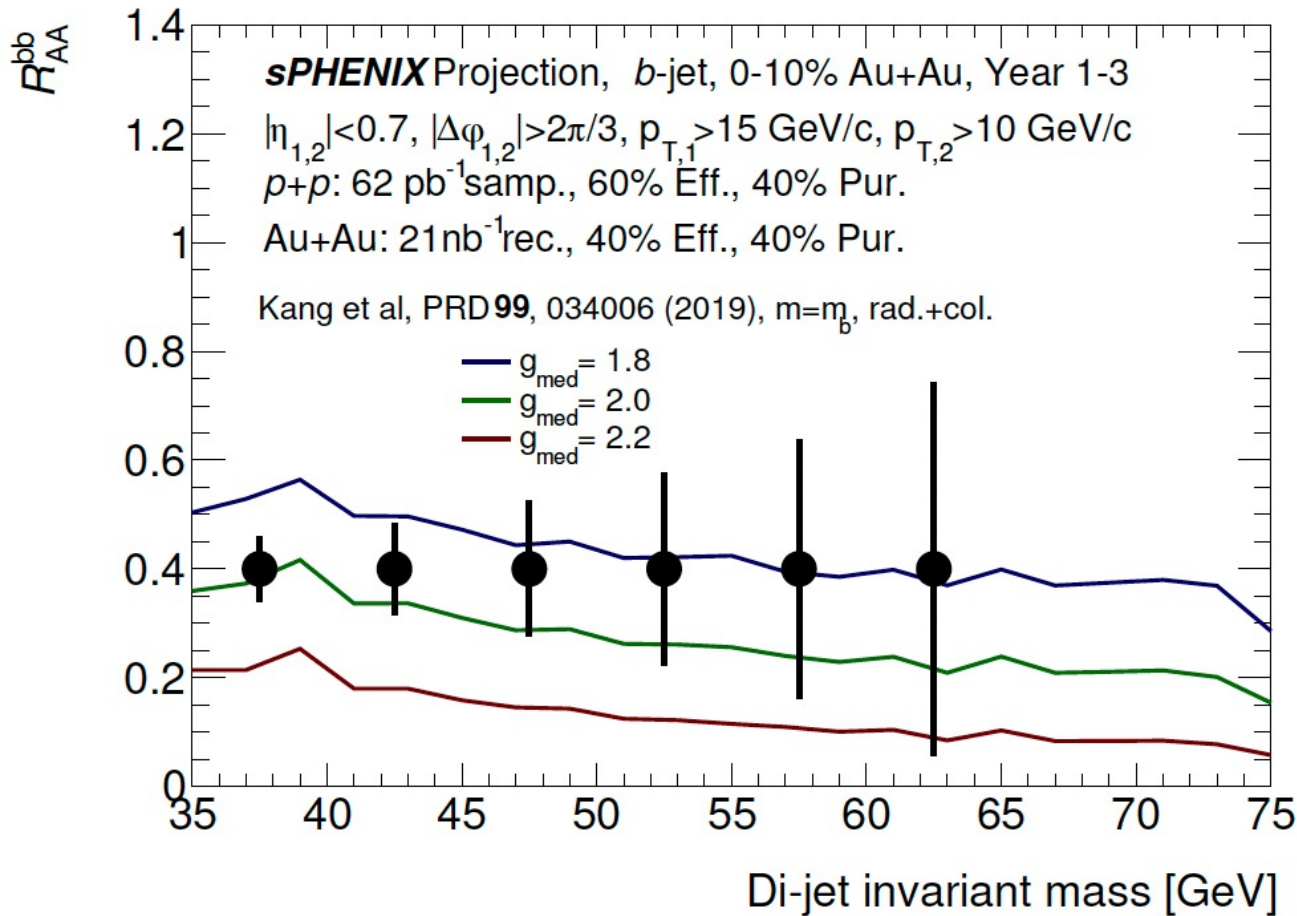
- Extensive **3-year** data taking starting in < 1 year
  - ➔ **Year-1:** commissioning and first physics
  - ➔ **Year-2:** p+p and p+Au runs for heavy-ion reference and cold QCD physics
  - ➔ **Year-3:** very large Au+Au dataset (141B events in total)

**Precise study on heavy-flavor physics with sPHENIX!**

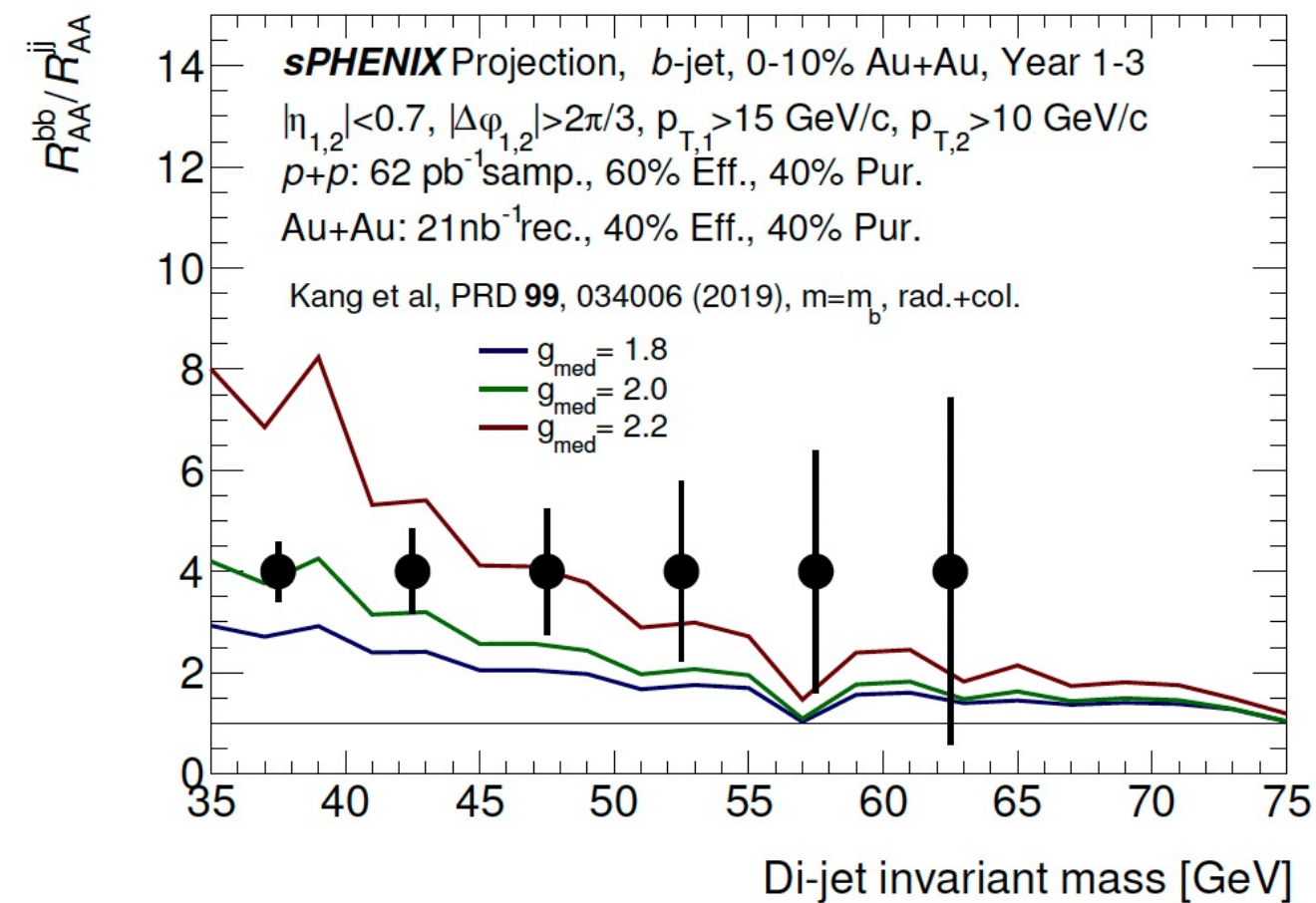
**First data in early 2023!!**

# BACKUP

## di- $b$ -jet nuclear modification factor



## Ratio between di- $b$ -jet and di-light-jet



- Study with di- $b$ -jet pairs (mass &  $p_T$  balance) to suppress contribution from gluon splitting

