# Precision Bottom Physics Program at sPHENIX with inner vertex detector upgrade

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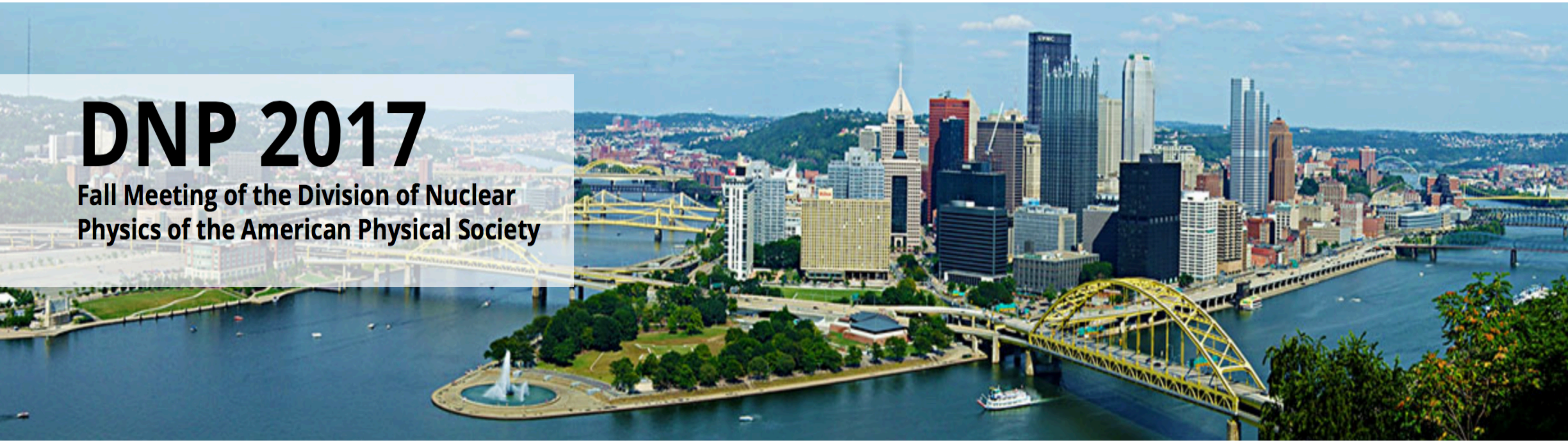
for the sPHENIX collaboration

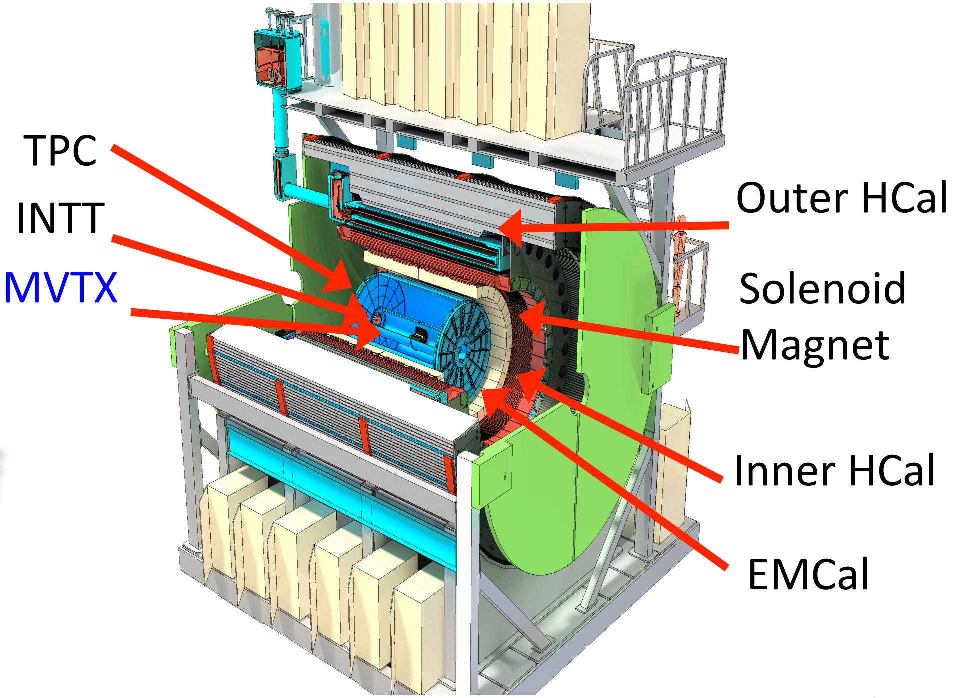


# Outline

- Uniqueness of the sPHENIX open heavy flavor program.
- sPHENIX tracking system:
  - MVTX: critical to the open heavy flavor measurements.
- Physics performance and projections.
- Summary and Outlook.

**sPHENIX:**

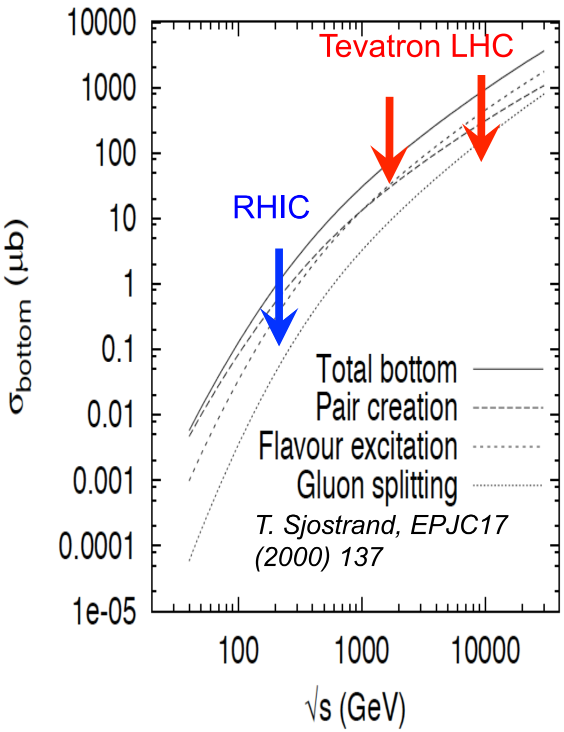
The new state of the art jet and heavy flavor detector at RHIC to explore the microscope structure of the Quark Gluon Plasma (QGP).



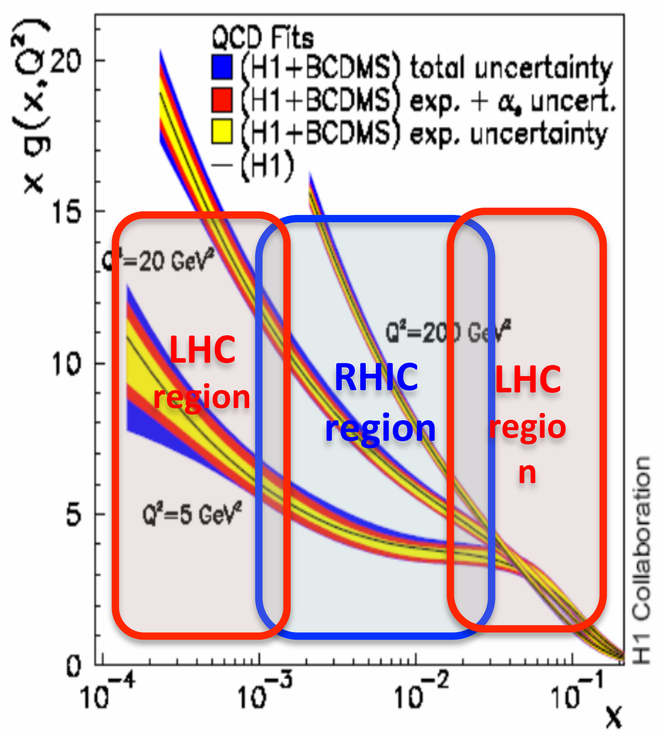
# Uniqueness of sPHENIX heavy flavor program (I)

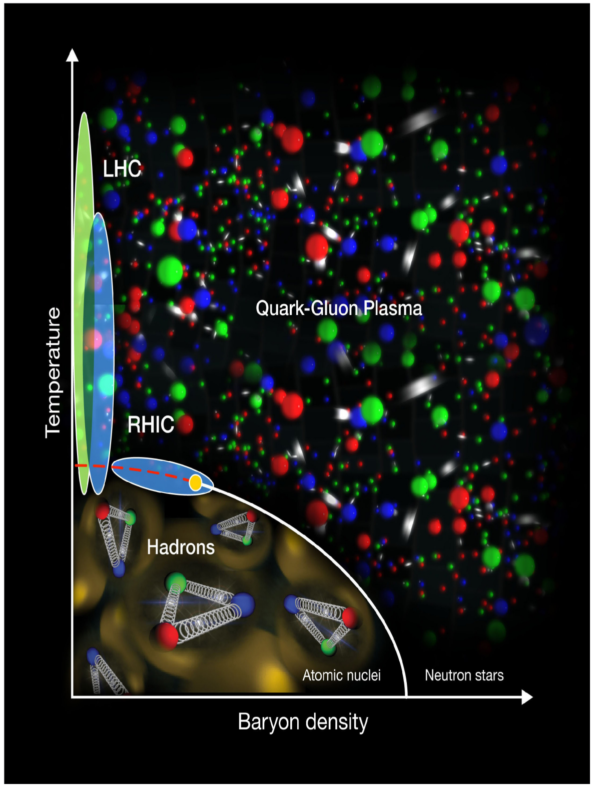
- Through new studies of close and open heavy flavor products at RHIC to probe complementary kinematic region and different temperature of the QGP from the LHC measurements.

Bottom production

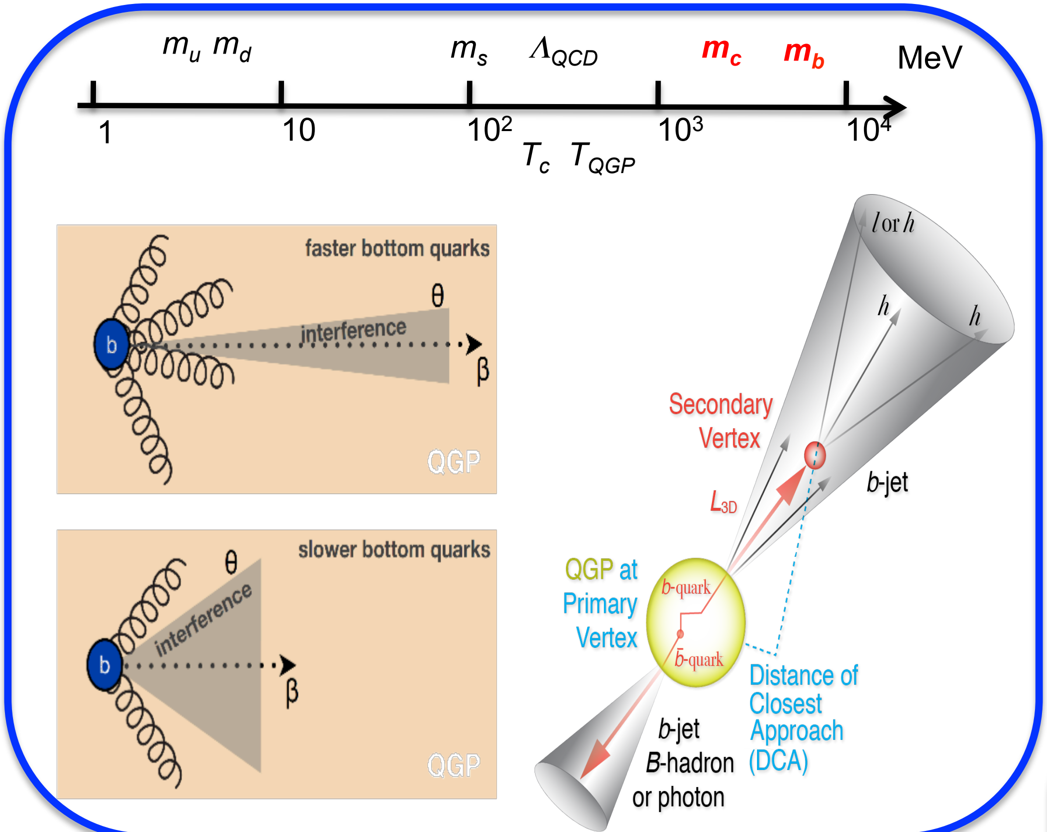



Nucleon Gluon PDF



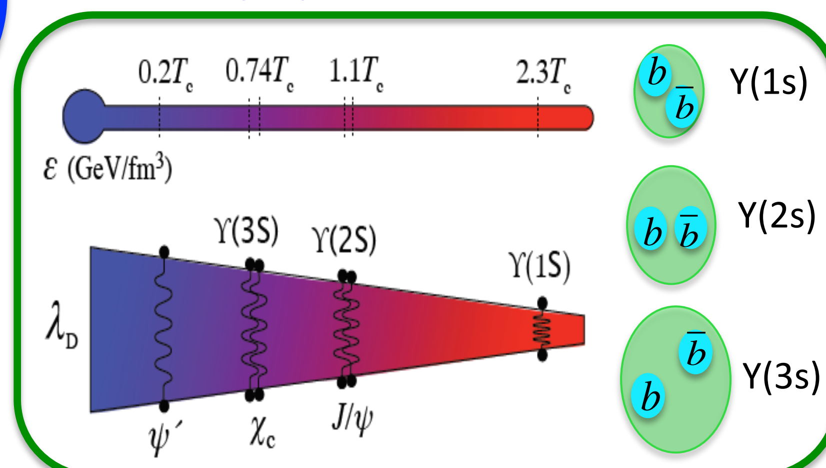



# Uniqueness of sPHENIX heavy flavor program (II)



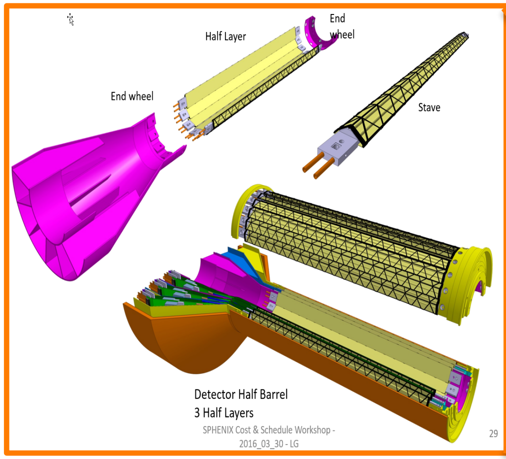

- Open heavy flavor production such as the b-jets and B hadron for the mass/flavor dependent parton energy loss study.
- Collisional VS radiative energy loss determination by accessing fast and slow heavy quarks.

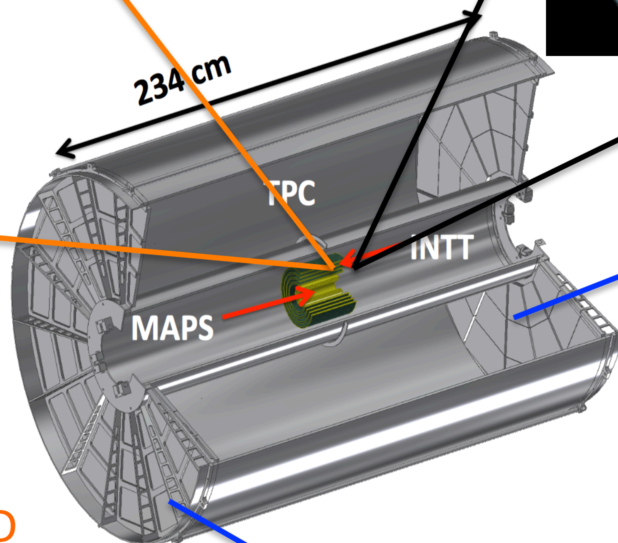
- Sequential melting of the Υ(1s,2s,3s) in the QGP due to different bind energies.
- The QGP thermometer: Υ(1s,2s,3s).

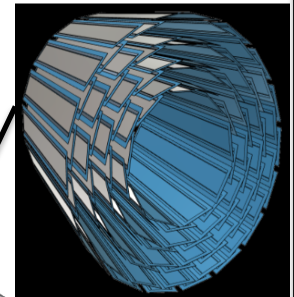


# sPHENIX tracking system

- MVTX, INTT and TPC:



## INTT:

- 4 layers of Si strips.
- Pattern recognition, track reconstruction etc. Reject pile up events.

## MVTX:

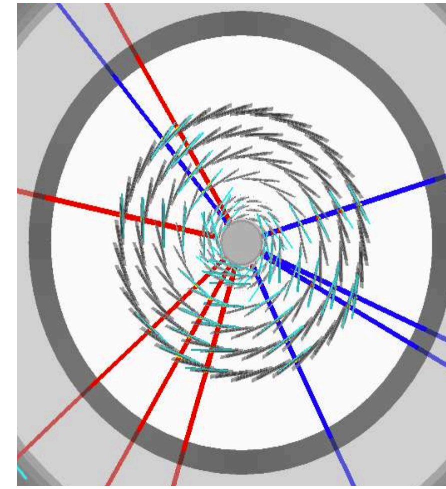
- 3 layers of Si pixels.
- Precise primary and displaced vertex, 2D/3D DCA etc determination.
- **Crucial for the open heavy flavor measurements.**

## TPC:

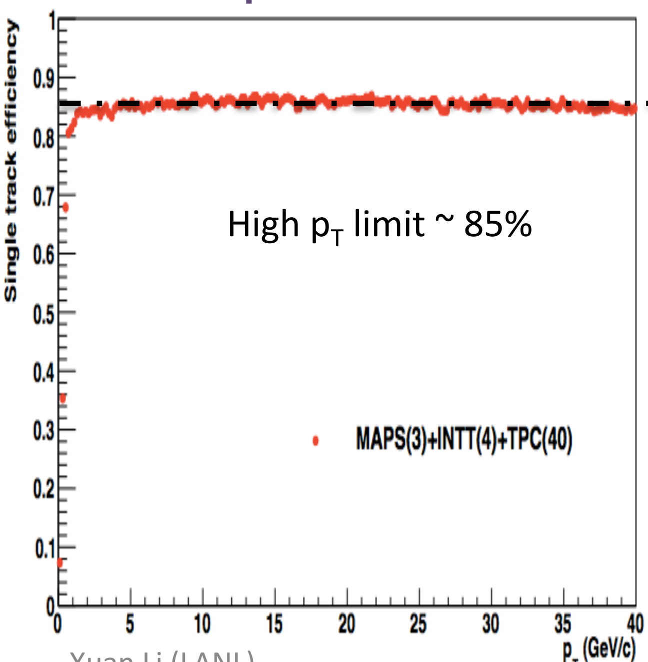
- Length 234 cm, radius 20-78 cm.
- Pattern recognition, track reconstruction in the 0.2-40 GeV/c $p_T$ region etc.

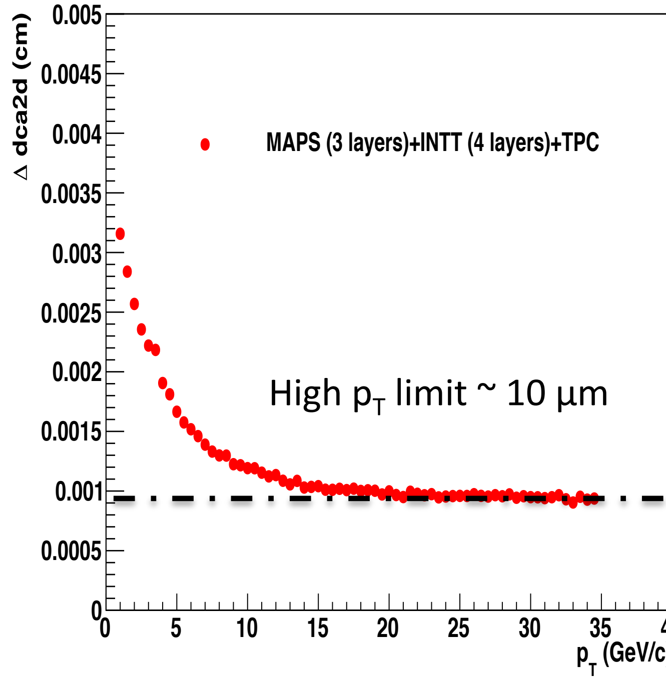
# sPHENIX tracking performance in MC

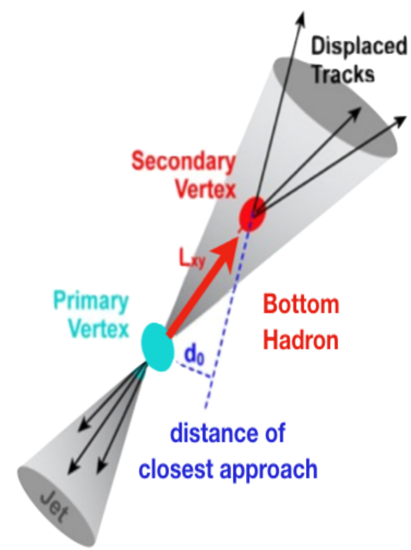
- Tracking efficiency and DCA resolution in 200 GeV 0-10% Au+Au collisions.
  - Tracking efficiency 85% at high $p_T$ and 80% at $p_T$ ~1 GeV/c.
  - The 2D Distance of Closes Approach ($DCA_{2D}$) resolution is ~10 μm at high $p_T$ and < 35 μm down to $p_T$ ~1 GeV/c.



**100 pions embedded in central Au+Au Hijing simulation**

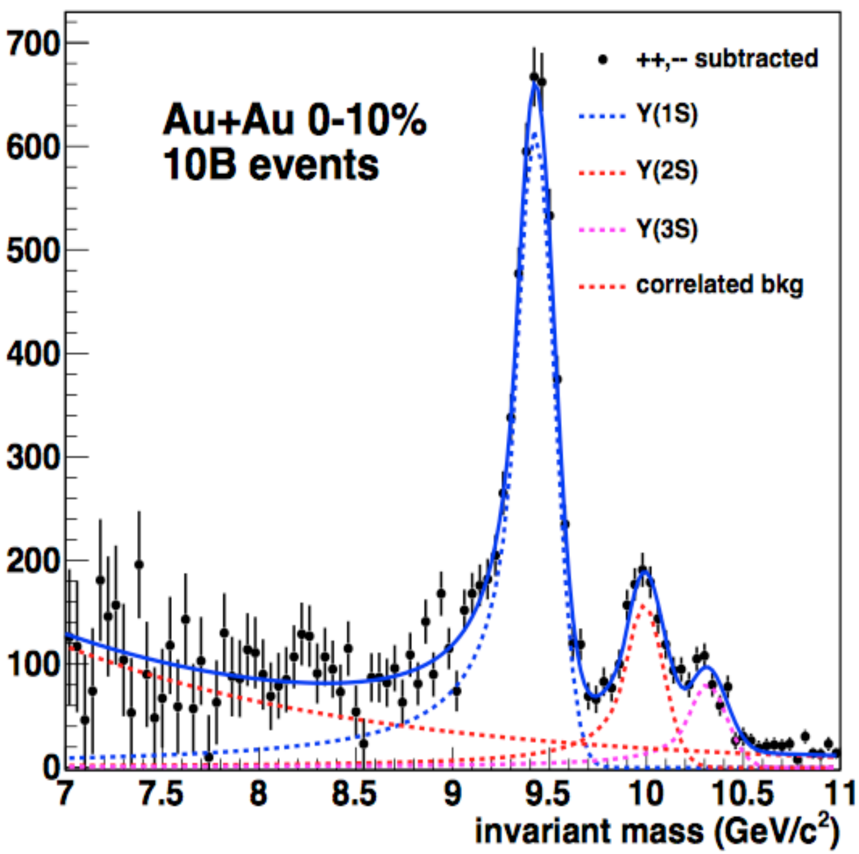


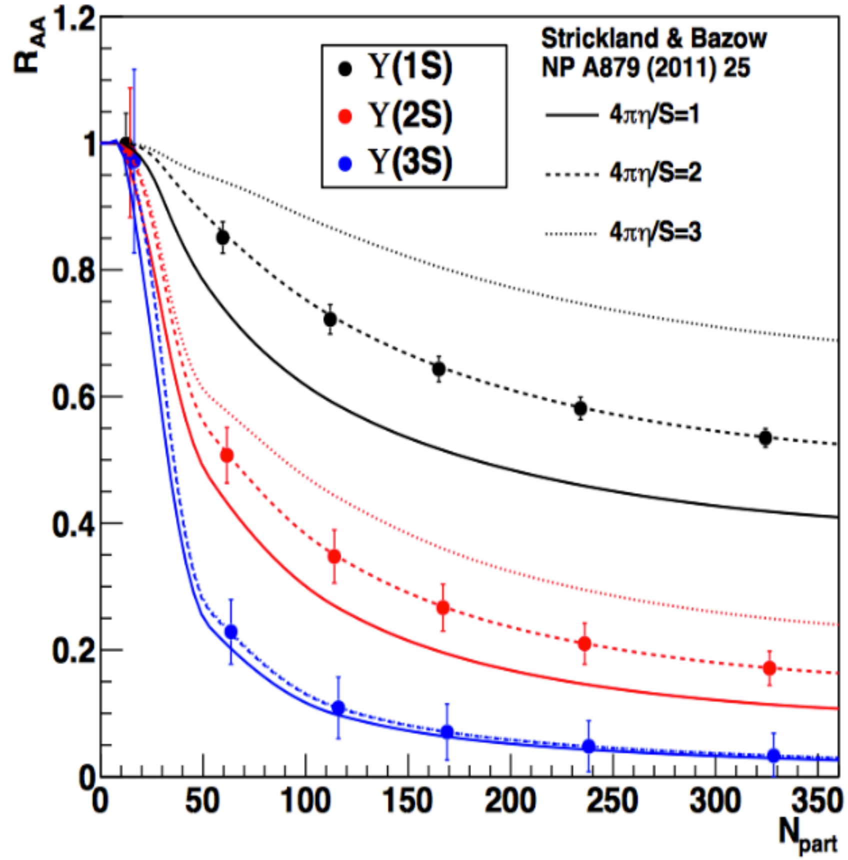



# Upsilon measurement projection at sPHENIX

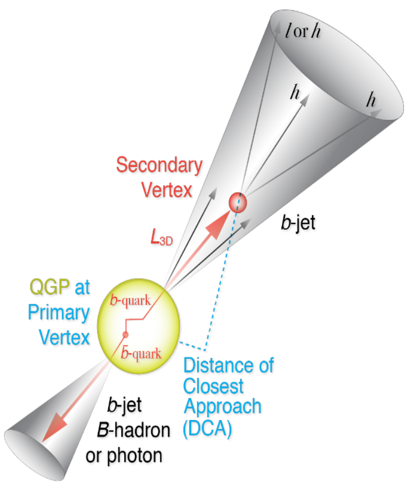
- Di-electron mass sepction: Clear separation of Υ(1s), Υ(2s) and Υ(3s) in central Au+Au collisions with expected sPHENIX luminosity.
- Υ(1s,2s,3s) $R_{AA}$ projection: would provide tight constraints on theoretical descriptions of RHIC data.

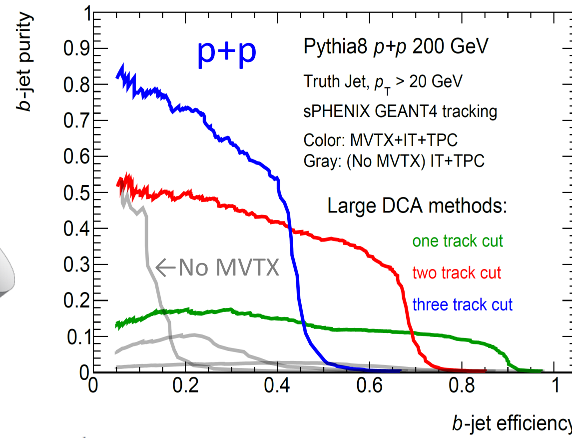


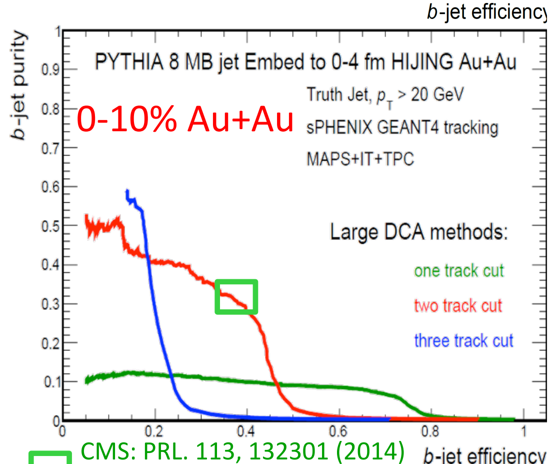



# b-jet measurement projection at sPHENIX

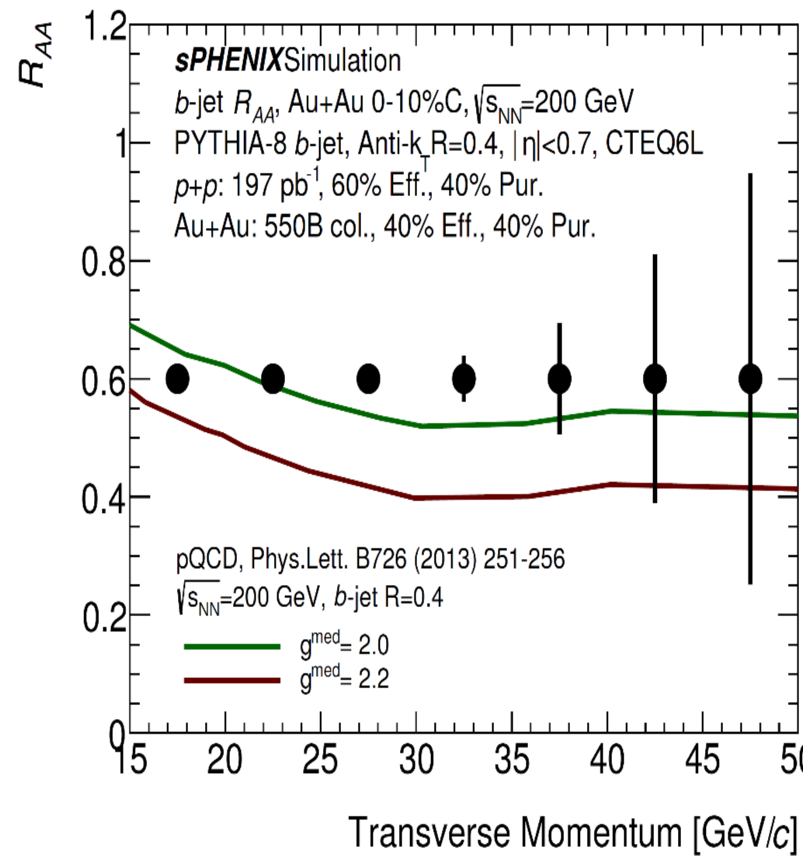
- b-jet tagging: purity is 40% (40%) and efficiency is 40% (60%) in central Au+Au (p+p) collisions. MVTX is crucial to tag b-jets.
- b-jet $R_{AA}$ projection: improve the understanding of b quark energy loss in QGP.



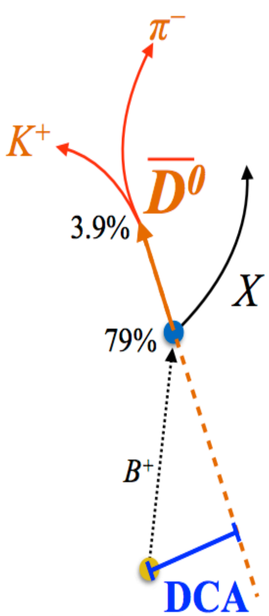

CMS: PRL. 113, 132301 (2014)

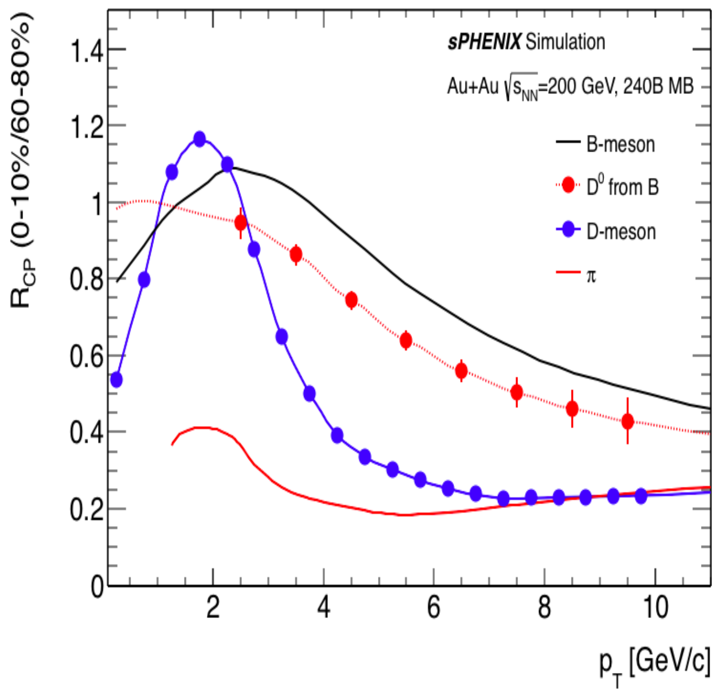


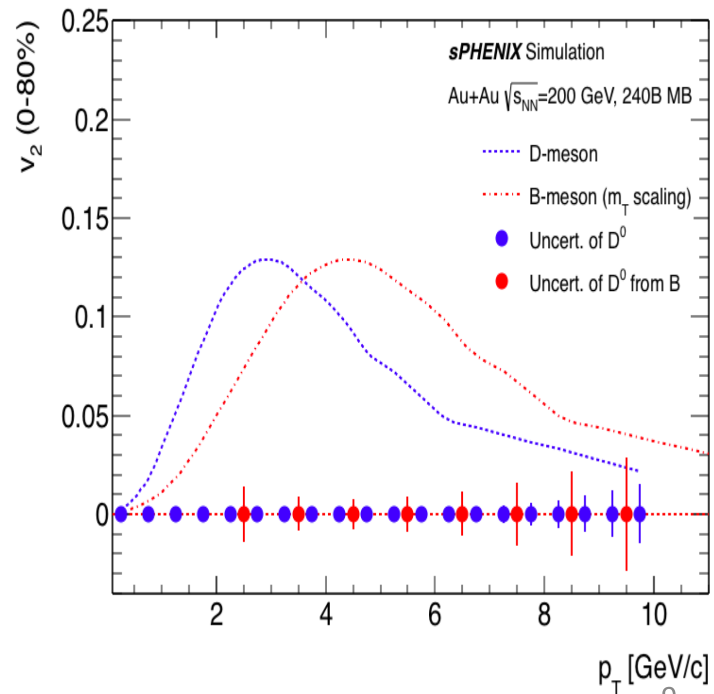
# B-hadron measurement projection at sPHENIX

- B-hadron tagging: tag B-hadron with non-prompt D meson.
- Non-prompt D meson projection:
  - $R_{CP}$ ($R_{AA}$): precisely study the mass hierarchy of parton energy loss up to 10 GeV/c.
  - $v_2$ : determine the bottom quark collectivity up to 8 GeV/c.

**240B MB Au+Au collisions at 200 GeV**

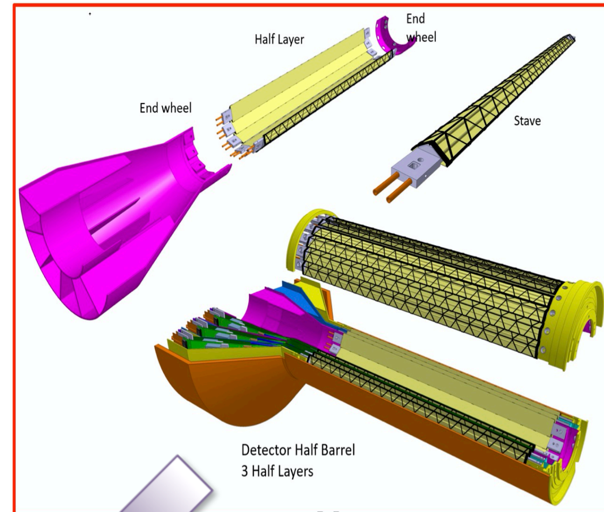


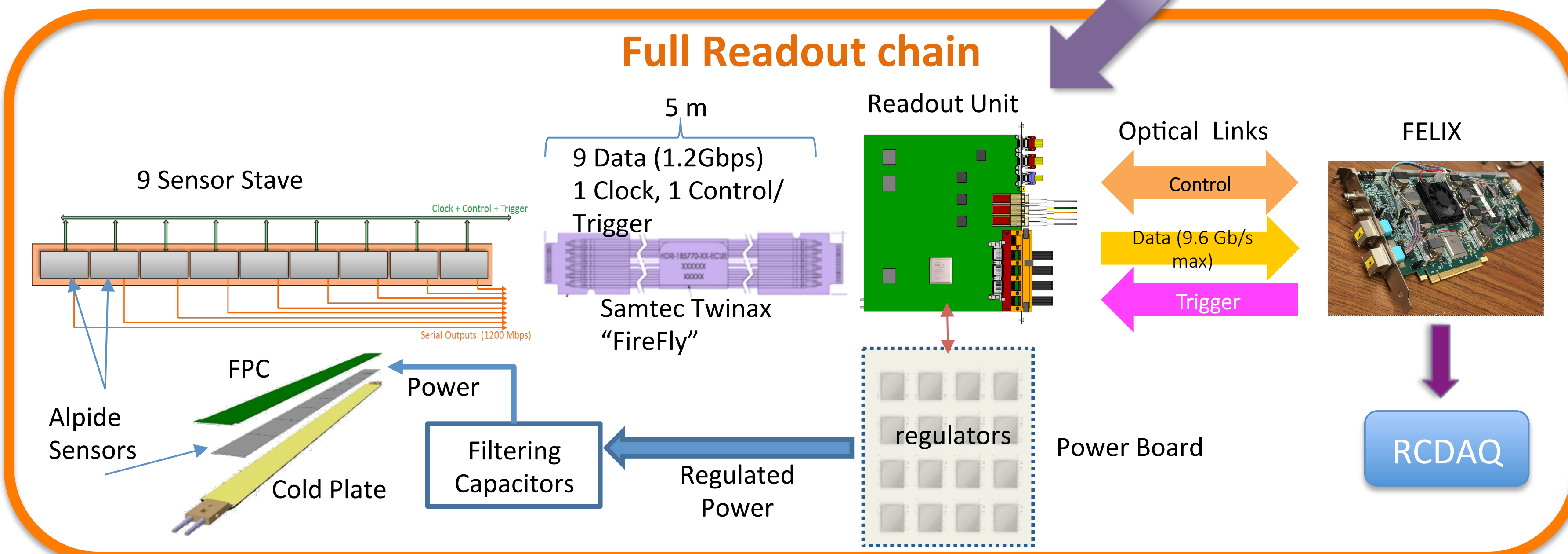



# Inner tracking detector upgrade - MVTX

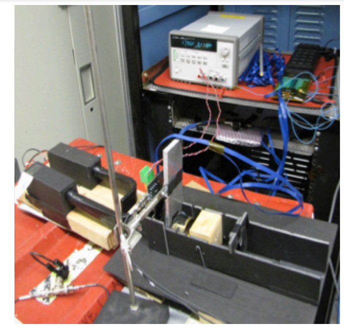
- The MVTX detector R&D:
  - Testing and debugging each component of the MVTX full readout chain.
  - Mechanical design for the sPHENIX integration is ongoing.

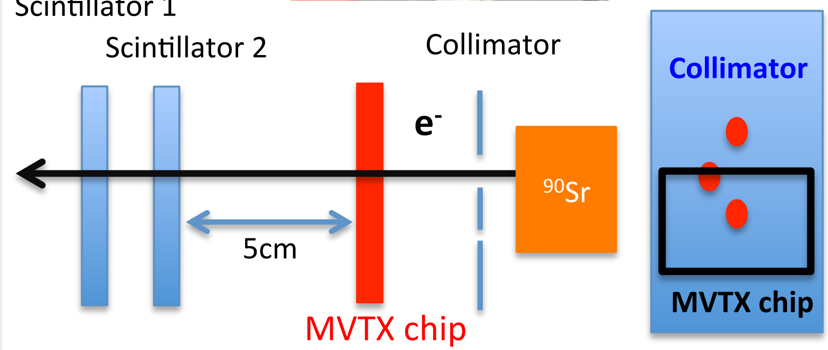


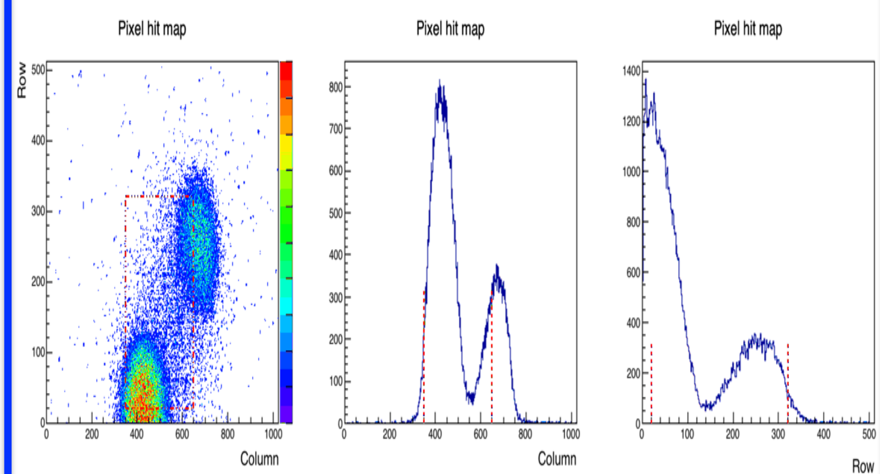



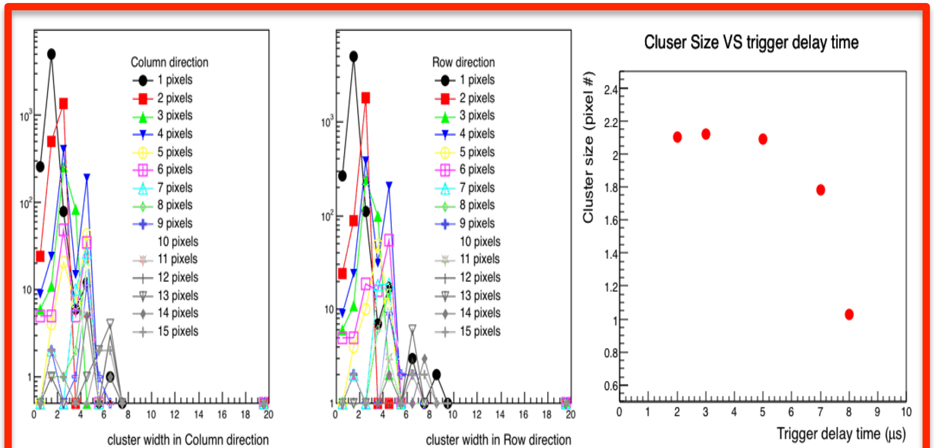
# Inner tracking detector upgrade - MVTX

- Preliminary test results:
  - Achieve triggered events from $^{90}$Sr source and cosmic ray.
  - Characterize the cluster size from physical signal (90Sr electrons, cosmic ray) with different configuration such as the trigger delay.
  - Optimization is under way.



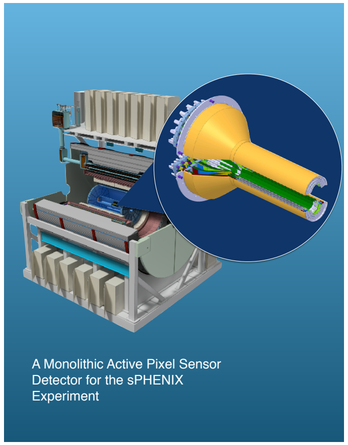


# Summary and Conclusions

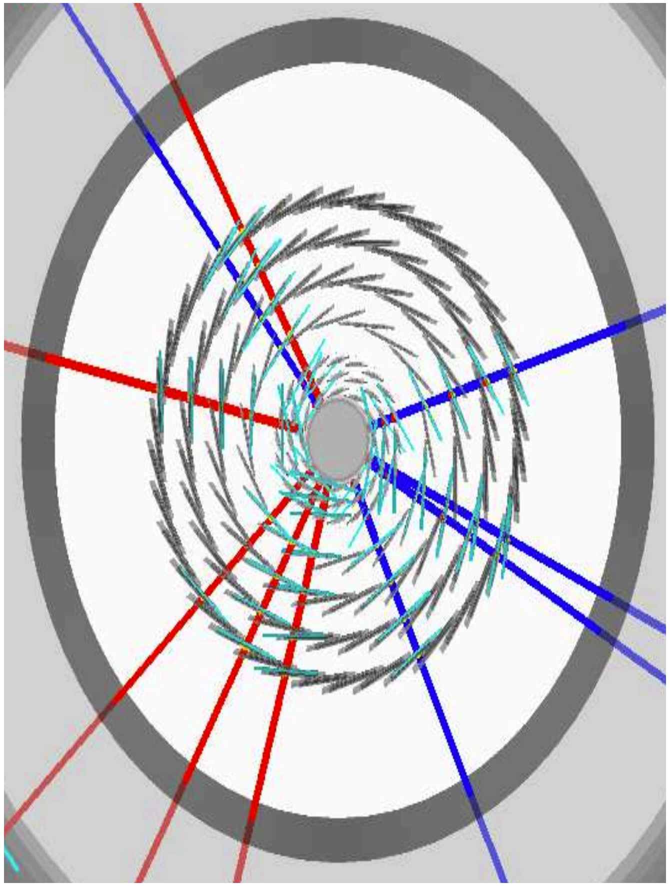
- The sPHENIX tracking system can support the heavy flavor physics program at RHIC from 2022 to 2026:
  - Study the Upsilon(1s,2s,3s) as the QGP thermometer.
  - Precise open heavy flavor measurements to study the mass/flavor dependent parton energy loss mechinism and to constrain the heavy quark diffusion coefficient.
  - Feasibilities of correlation studies beyond inclusive measurements is under exploration.
  - The MVTX is key upgrade to achieve the open heavy flavor measurements.
- Look forward to the DOE proposal submission to support the full MVTX construction.



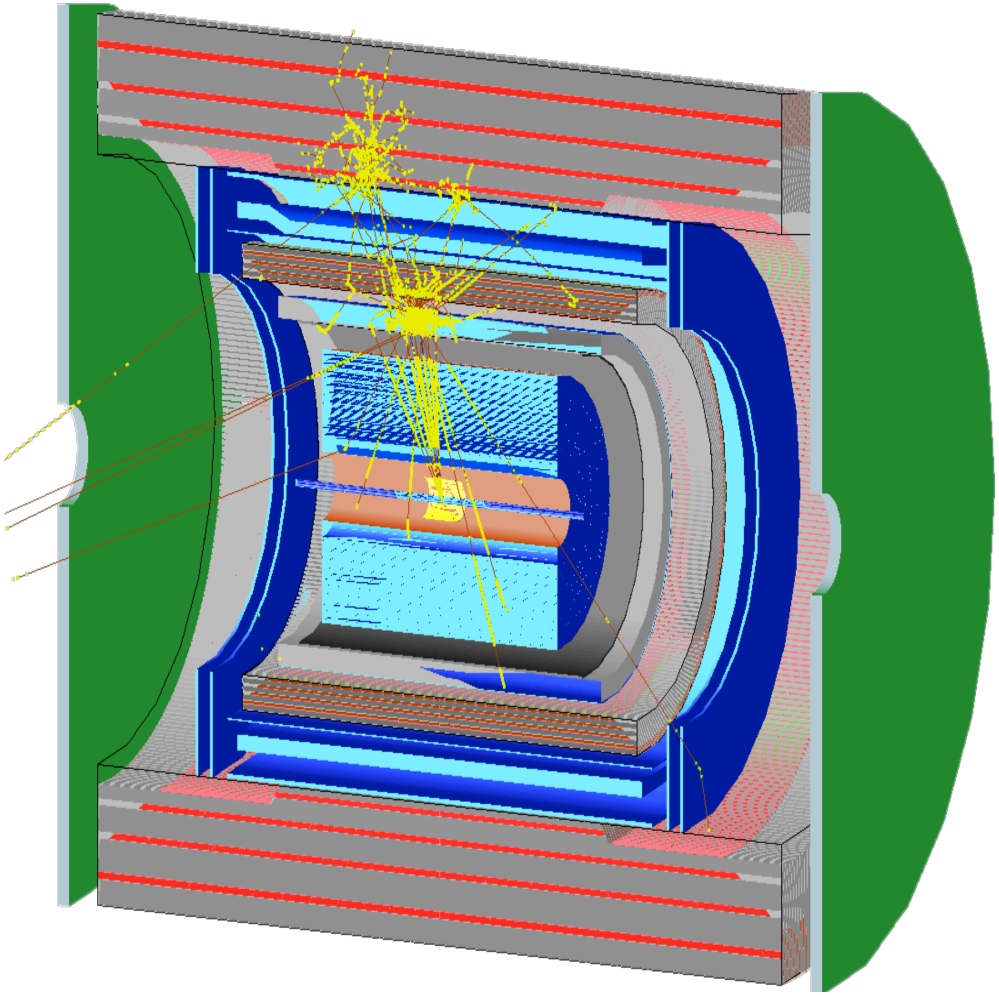
# Backup

# sPHENIX tracking GEANT4 MC

Tracking in G4

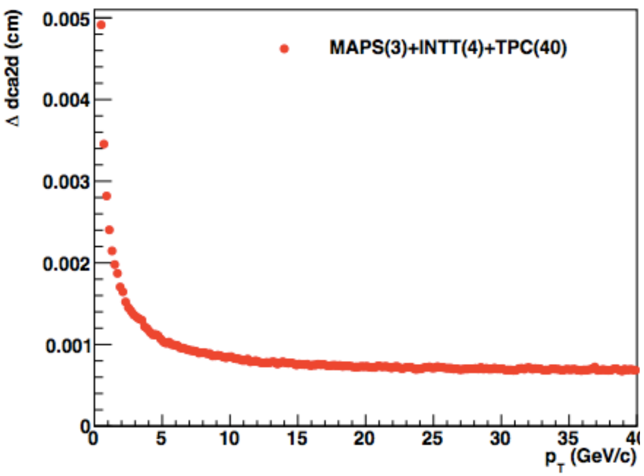


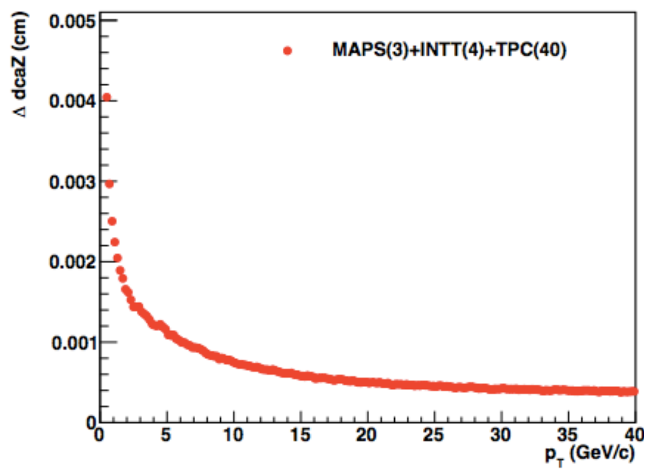
Single B hadron in sPHENIX MC

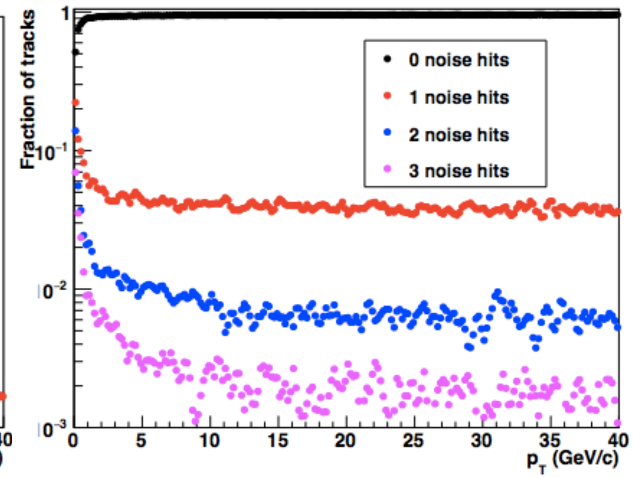


# Tracking Performance w/ and w/o MVTX

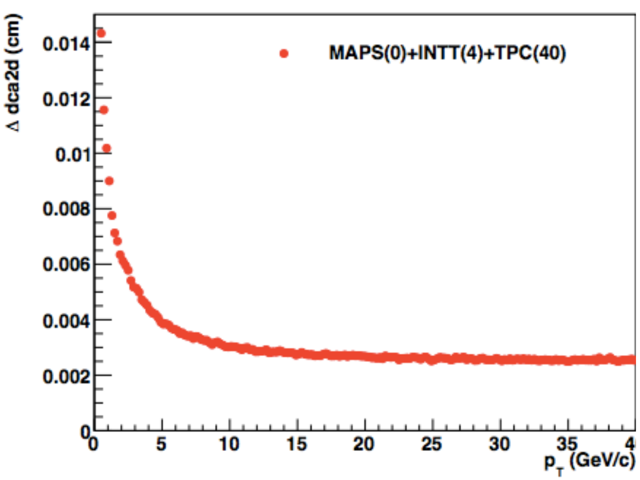
## Simulation + Tracking w/ MVTX

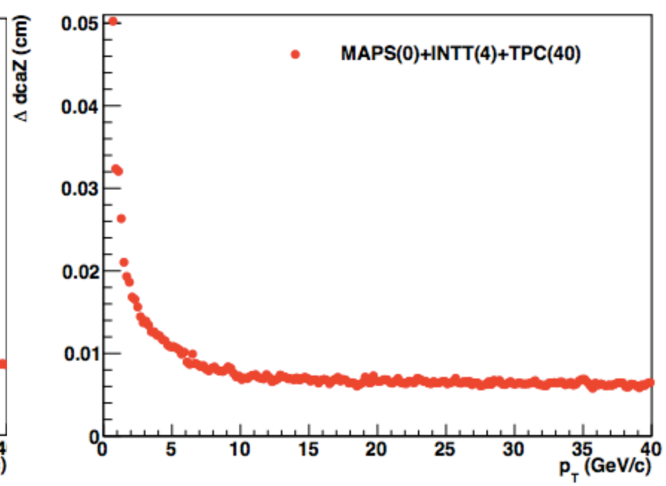


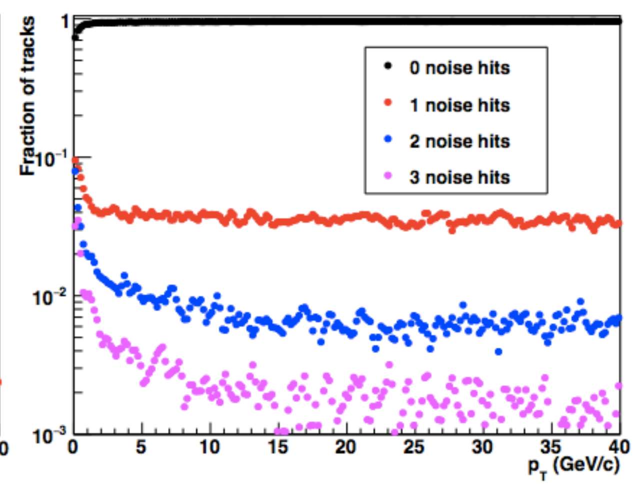



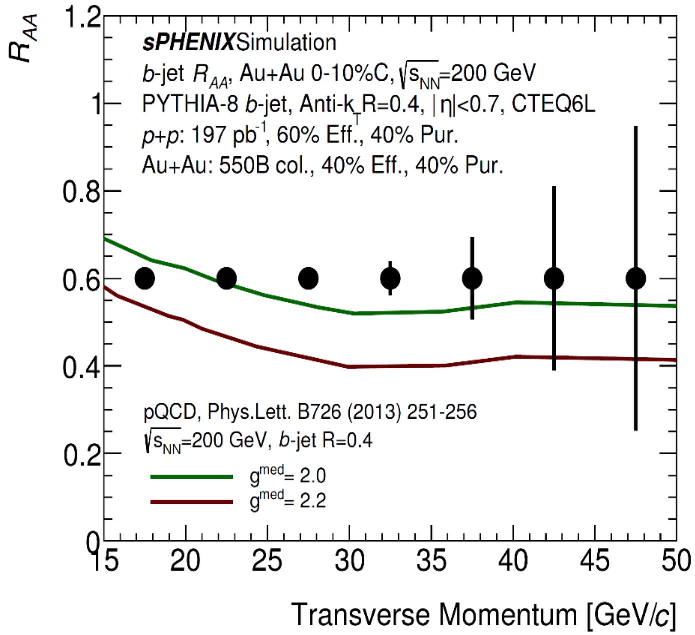

## Simulation + Tracking w/o MVTX

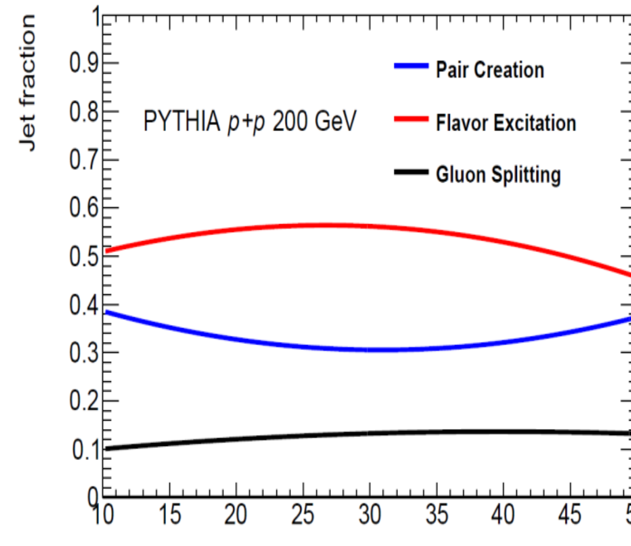


# b-jet $R_{AA}$ performance



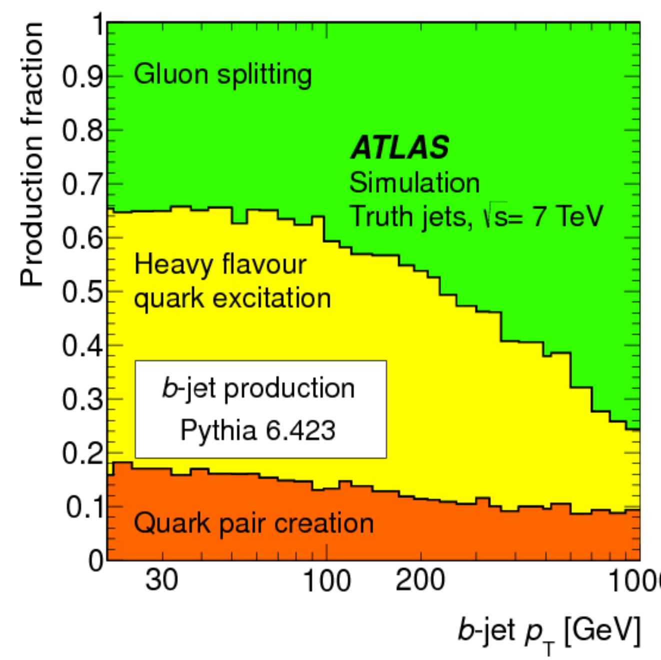




MVTX aiming first b-jet nuclear modification factor @ RHIC, covering ~15-40 GeV/c

- Mass dependence of parton energy loss
- Cleaner access to partonic kinematics

Uniqueness at RHIC (vs. LHC)

- Gluon splitting contribution is much less (~10%)
- Access to lower $p_T$ → larger $m_b/p_T$ (cover 3-10)



# Tagging $B$-mesons with Non-Prompt $D^0$

- Impact parameter (DCA) method to tag non-prompt $D^0$ from $B$-meson decays
- Simulation setup – Fast simulation with HIJING+Geant4 tracking performance
    - Single track efficiency and DCA distributions from full HIJING+Geant4 simulations
    - These fed into a fast Monte Carlo package to generate the distributions for signals (prompt and non-prompt $D^0$) as well as combinatorial background
    - Apply comprehensive set of topological cuts based on the STAR/HFT experience