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NSF

Heavy Flavor and Jet Physics with the sPHENIX Detector

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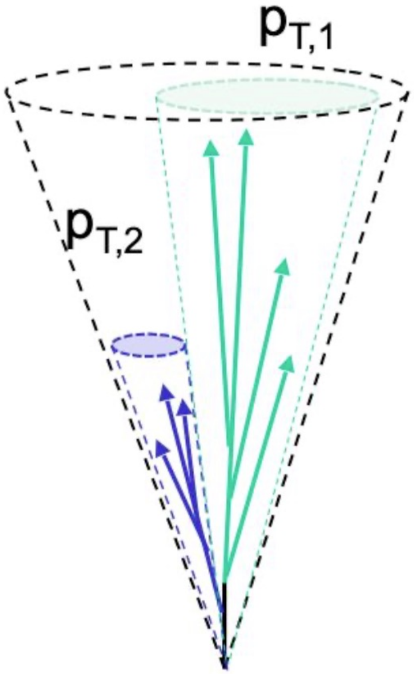
Georgia State University
on behalf of the **sPHENIX** collaboration

2022 RHIC/AGS Annual Users Meeting
June 8th 2022

Georgia State University

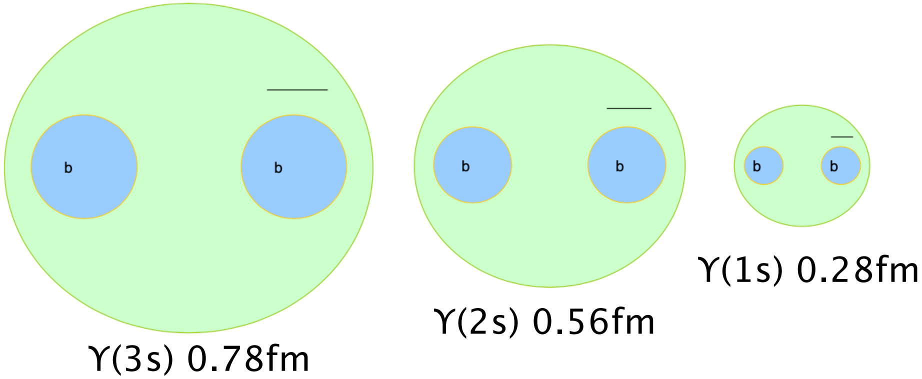
sPHENIX

The sPHENIX Physics Program



Jet structure

vary momentum/angular scale of probe

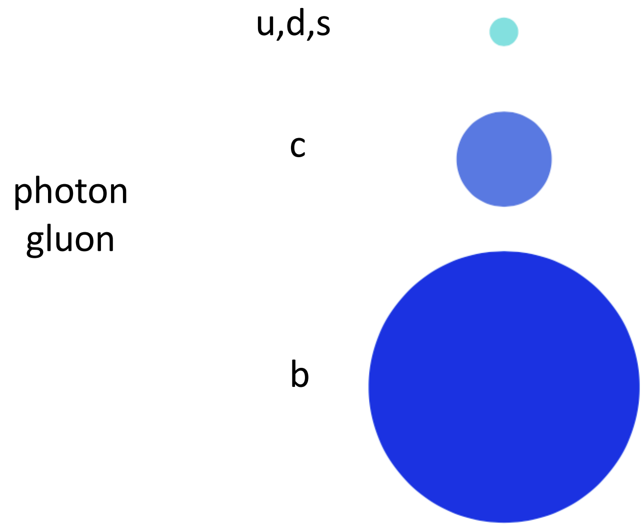


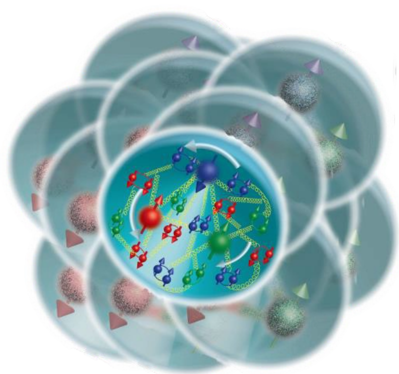
Quarkonium spectroscopy

vary size of probe

Parton energy loss

vary mass/momentum of probe





Cold QCD

study proton spin,
transverse-momentum,
and nuclear effects

sPHENIX Detector

The **sPHENIX** detector at the Relativistic Heavy Ion Collider is designed to measure high transverse momentum probes of the quark-gluon plasma such as jets and heavy-flavor probes, which can offer insight into the small-scale structure of the QGP.

Tracking:

- MAPS-based Vertex Tracker (MVTX)
- Intermediate Silicon Tracker (INTT)
- Time Projection Chamber (TPC)
- TPC Outer Tracker (TPOT)

Event Characterization (Not Pictured):

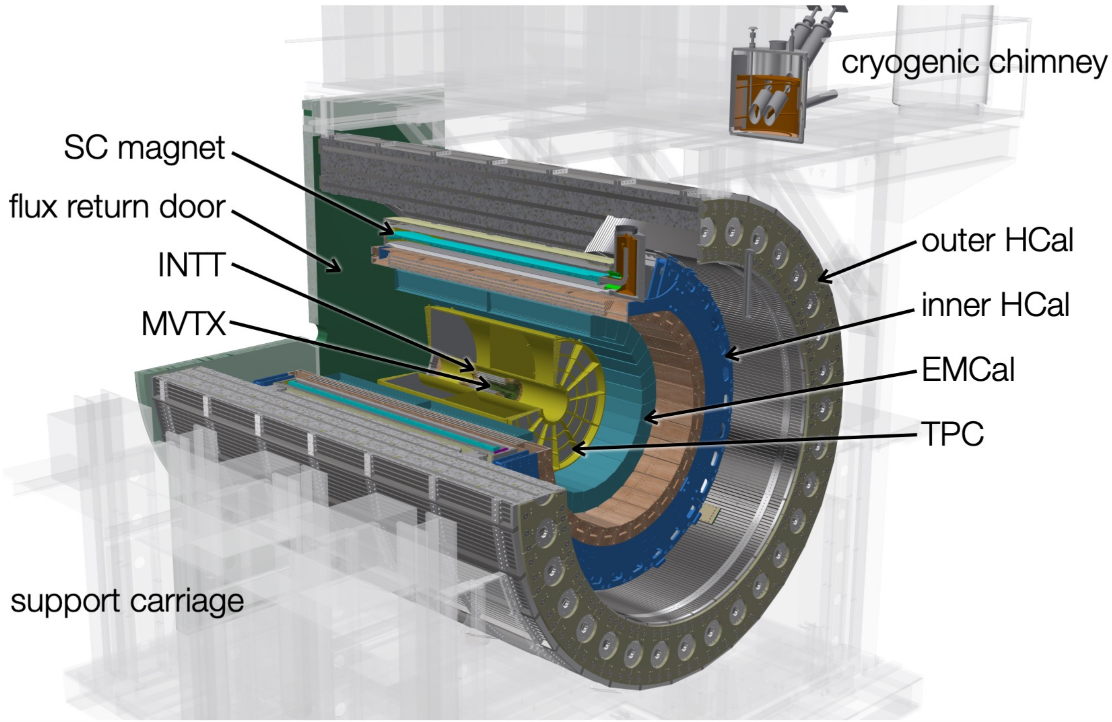
- Minimum Bias Detector (MBD)
- Event Plane Detector (sEPD)

Superconducting Magnet

- 1.4T solenoid magnet

Calorimetery:

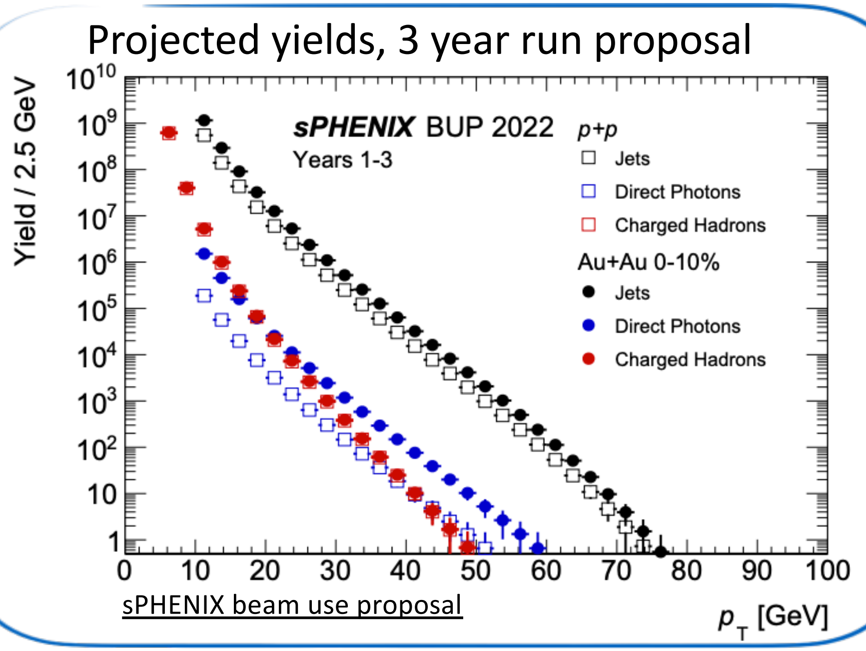
- Electromagnetic calorimeter
- Inner hadronic calorimeter
- Outer hadronic calorimeter

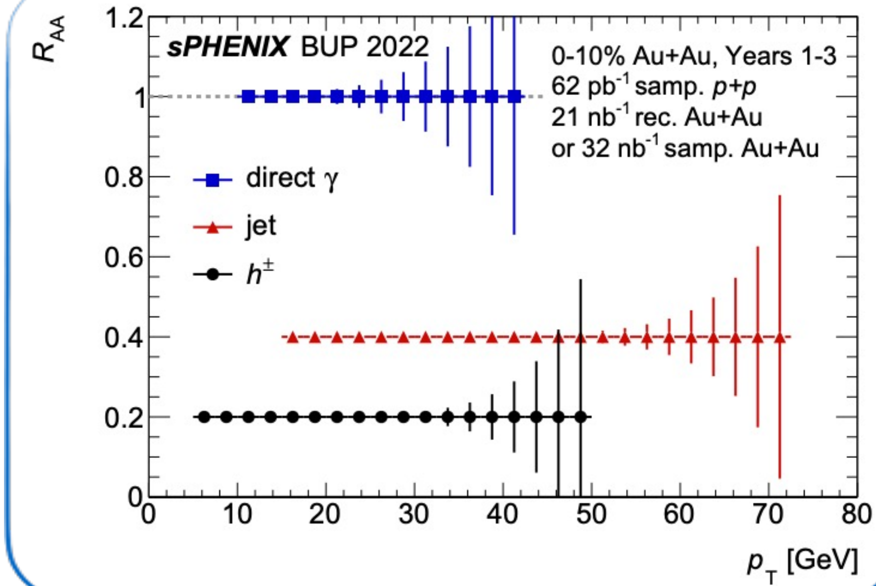


High rate DAQ and trigger systems

- 15 kHz trigger + streaming readout in pp/pA

Jet Physics



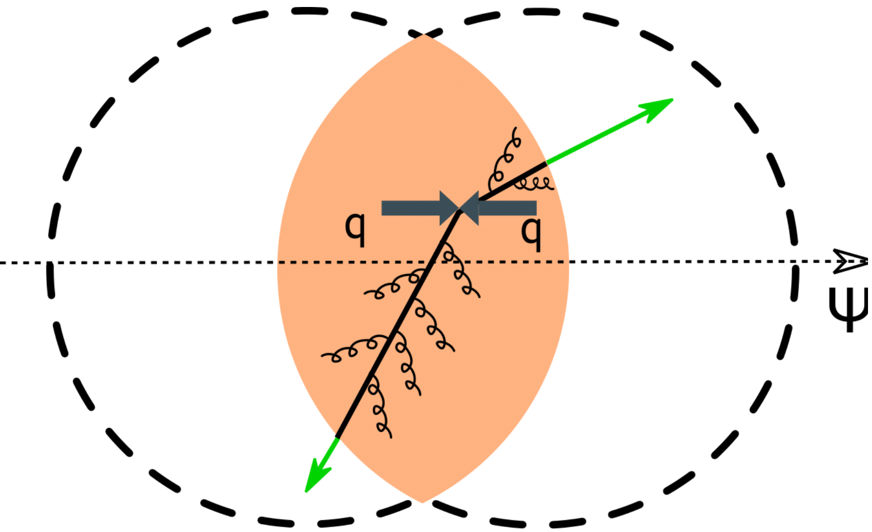


- Jet measurements out to 70 GeV
  - overlap with LHC measurements
- Precision measurements at low p_T
- High stats also for
  - photons (γ-jet measurements)
  - charged hadrons (fragmentation functions, substructure)

3 years

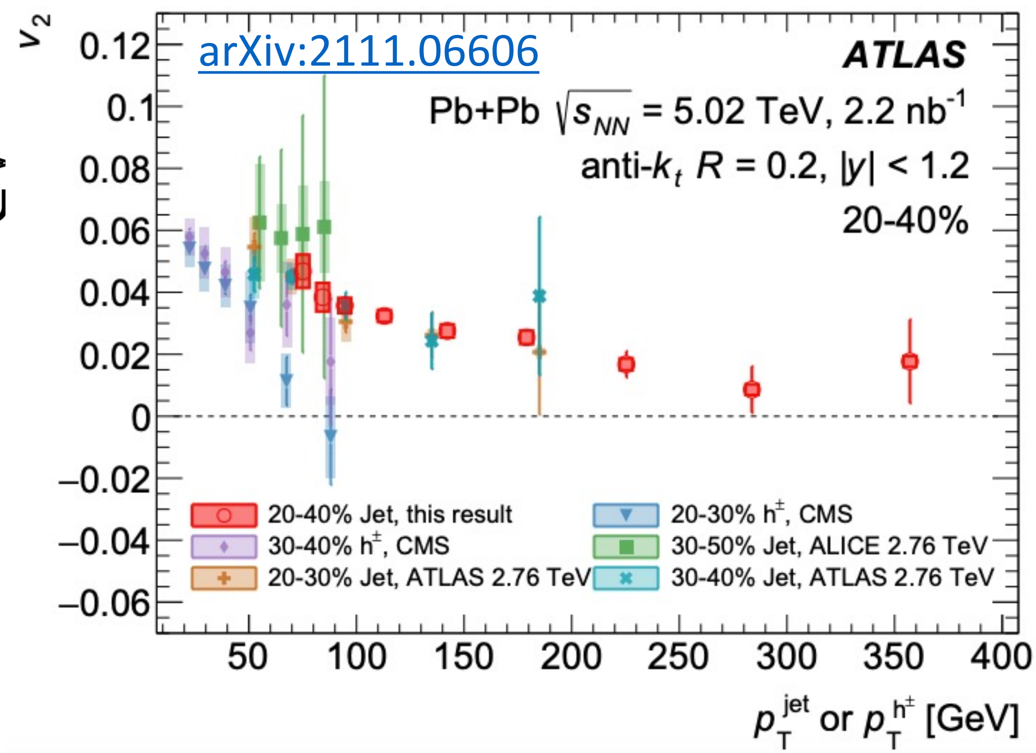
Signal	Au+Au 0–10% Counts	$p+p$ Counts
Jets $p_T > 20$ GeV	22 000 000	11 000 000
Jets $p_T > 40$ GeV	65 000	31 000
Direct Photons $p_T > 20$ GeV	47 000	5 800
Direct Photons $p_T > 30$ GeV	2 400	290
Charged Hadrons $p_T > 25$ GeV	4 300	4 100

Open question: What is the path-length dependence of energy loss?



Cartoon from M. Rybar

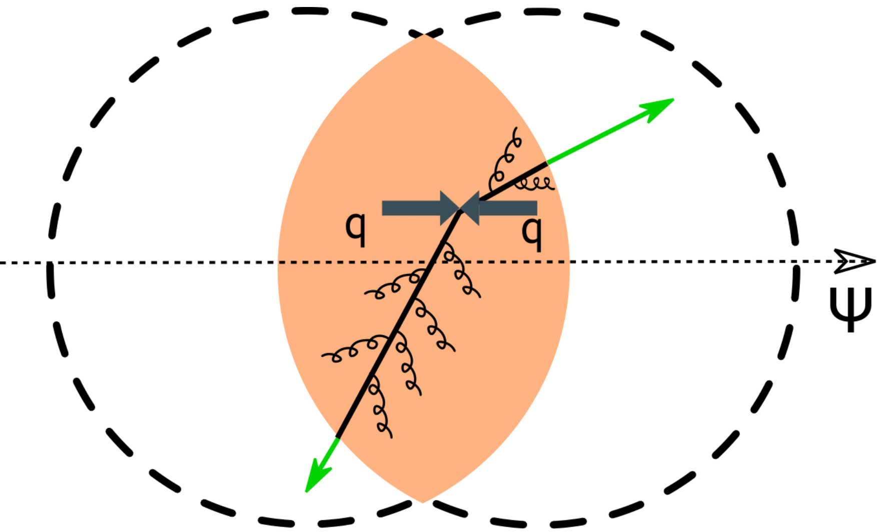
From the LHC



- v_2 at low p_T → flow
- v_2 at high p_T (i.e. jet v_2) → energy loss correlations with initial geometry
  - path-length dependence of energy loss
- Precision measurements of jet v_2 at ***high*** p_T

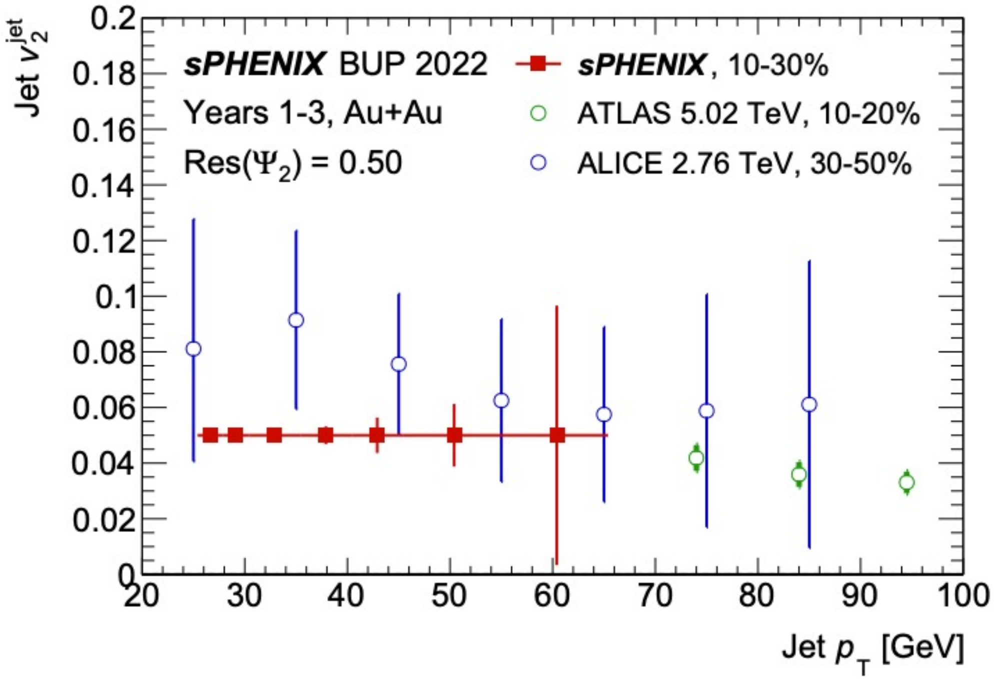
What we can learn at sPHENIX: Jet v_2

Open question: What is the path-length dependence of energy loss?



Cartoon from M. Rybar

In sPHENIX



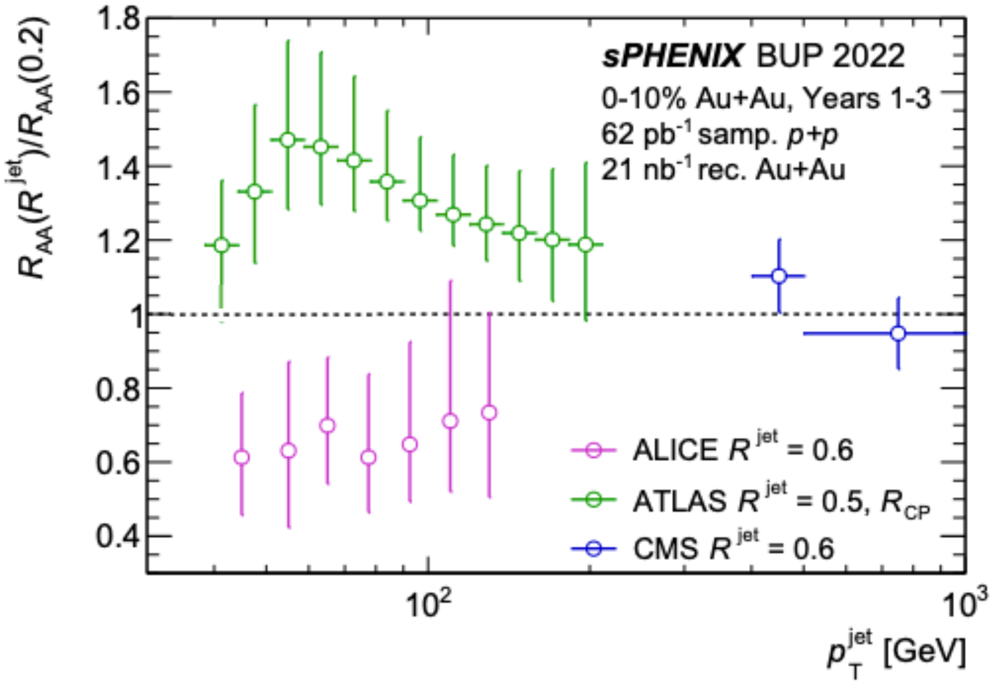
- v_2 at low p_T → flow
- v_2 at high p_T (i.e. jet v_2) → energy loss correlations with initial geometry
  - path-length dependence of energy loss

- Precision measurements of jet v_2 at ***low*** p_T
  - Constrain models of path-length dependence of energy loss for jets near QGP medium scale

What we can learn at sPHENIX: *R* dependence

Open question: What is the interplay between out of cone energy loss and medium response vs. jet structure dependence?

From the LHC

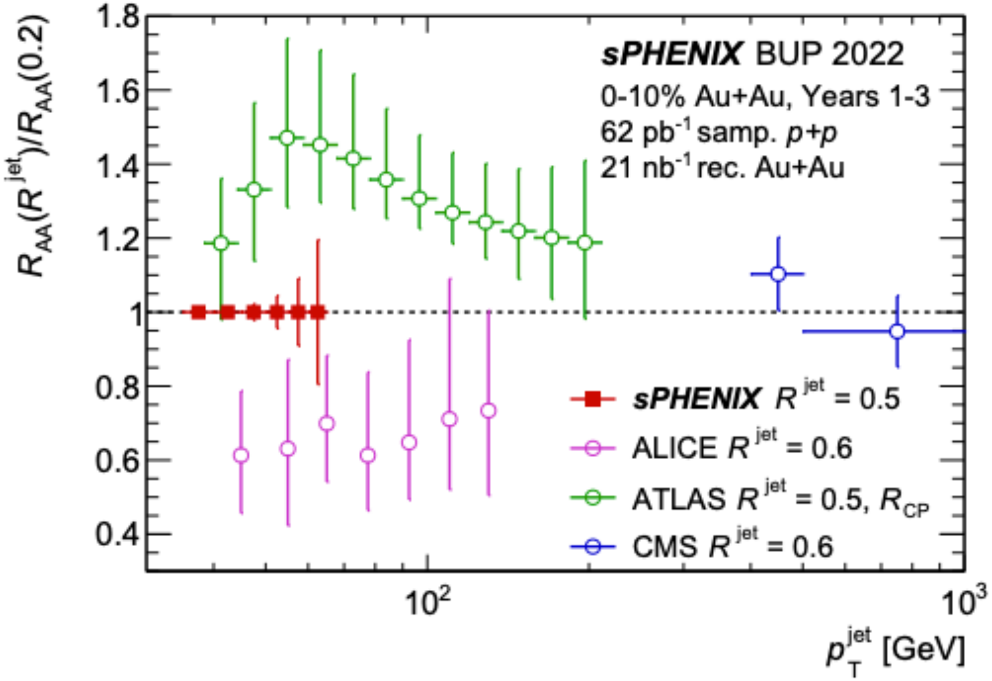


- Competing effects can lead to larger or smaller suppression for large R jets:
  - Recovery of out of cone energy
  - Inclusion of medium response
  - Jets with wider splittings lose more energy
- Models need input from experiment to balance these effects
- Tension in LHC results at low p_T

What we can learn at sPHENIX: *R* dependence

Open question: What is the interplay between out of cone energy loss and medium response vs. jet structure dependence?

In sPHENIX



Precision measurement in region of tension from LHC

- Competing effects can lead to larger or smaller suppression for large R jets:
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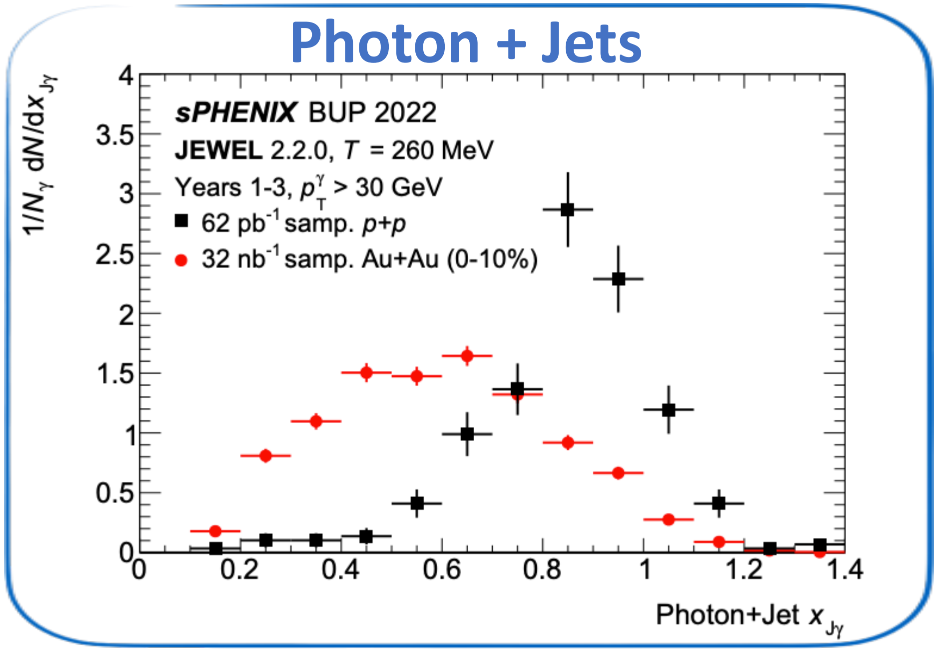
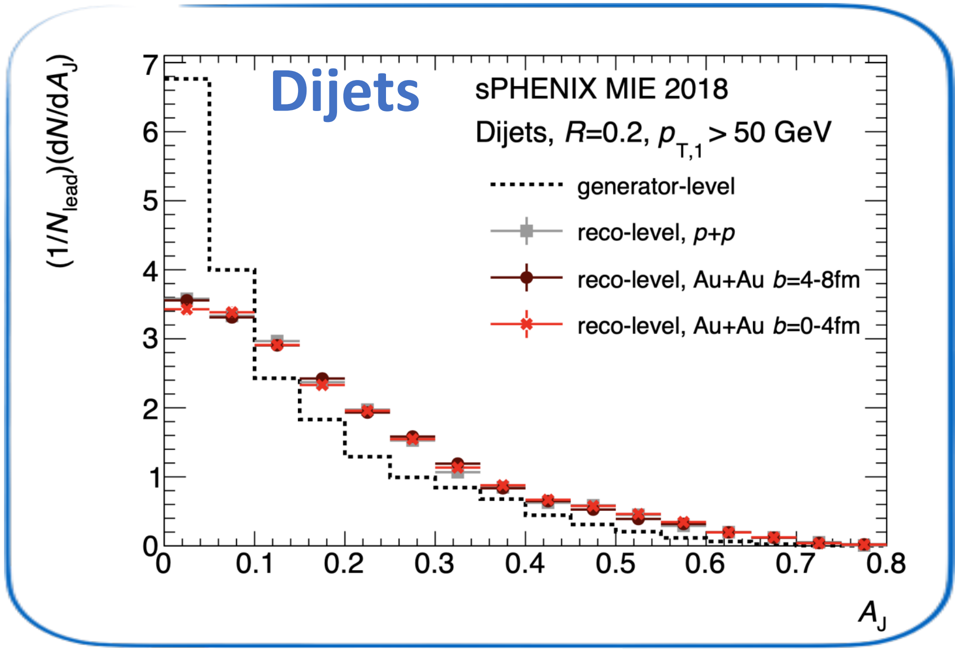
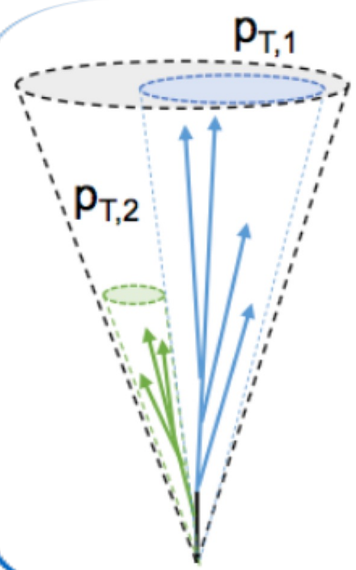
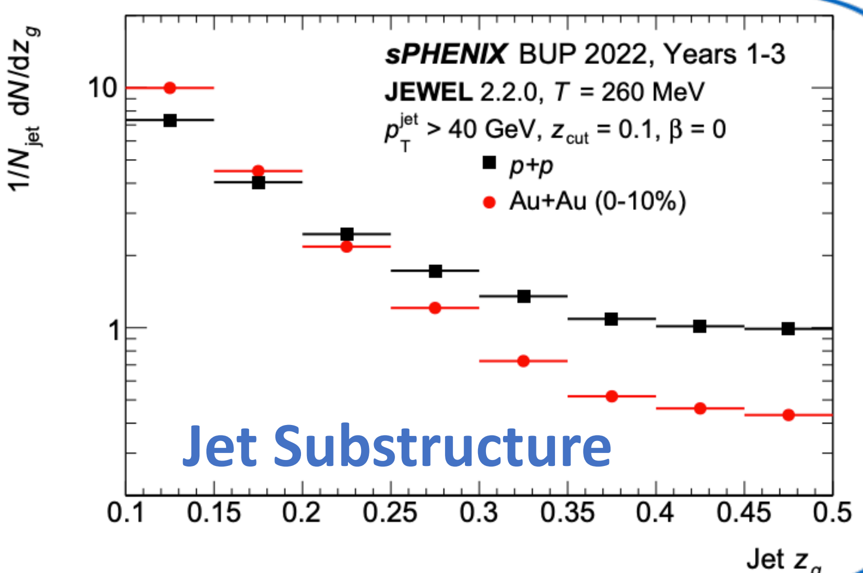
Other jet measurements in sPHENIX



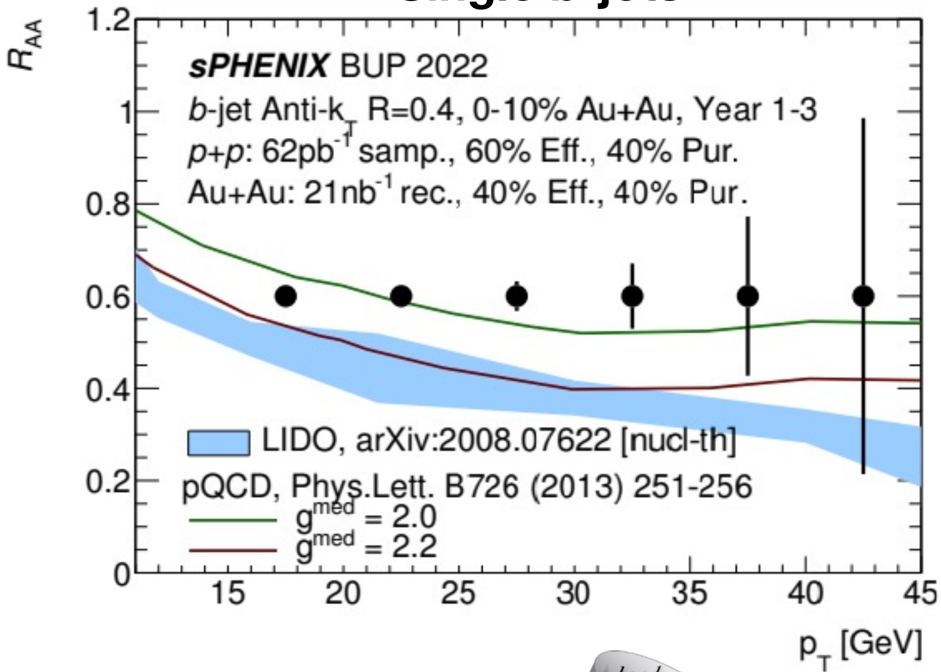




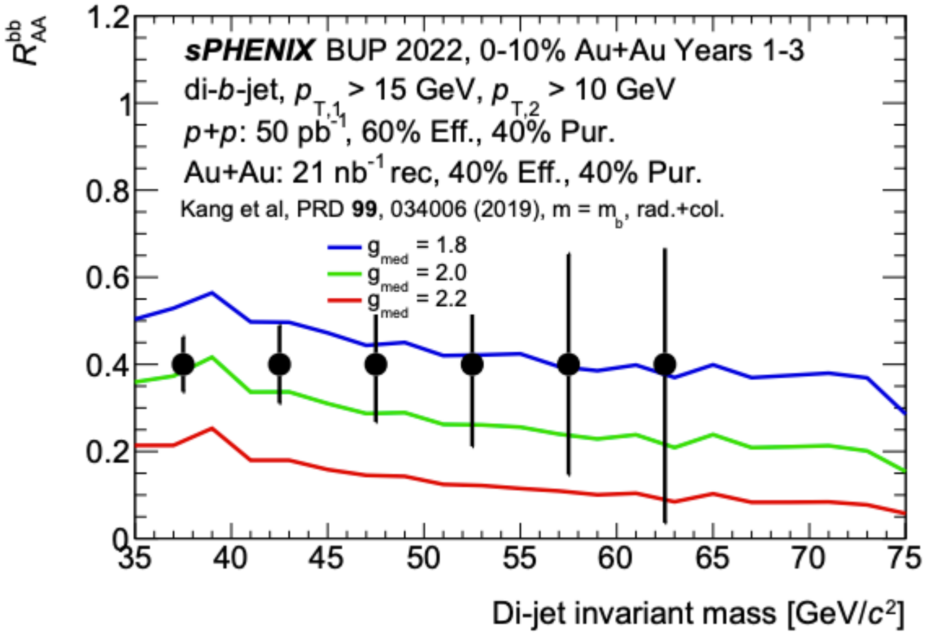


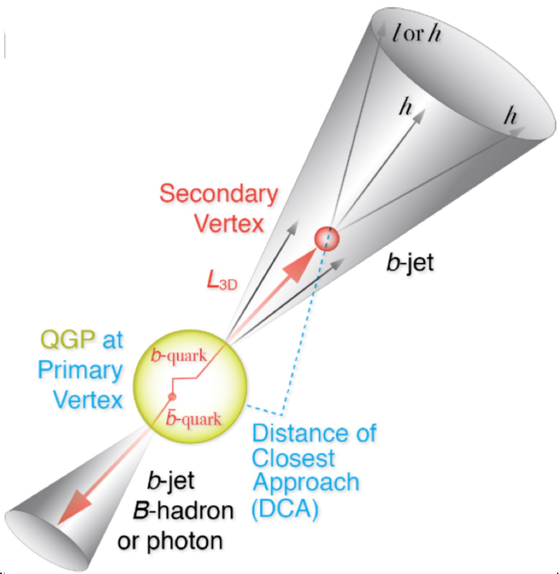
Heavy Flavor Jets

Single b-jets



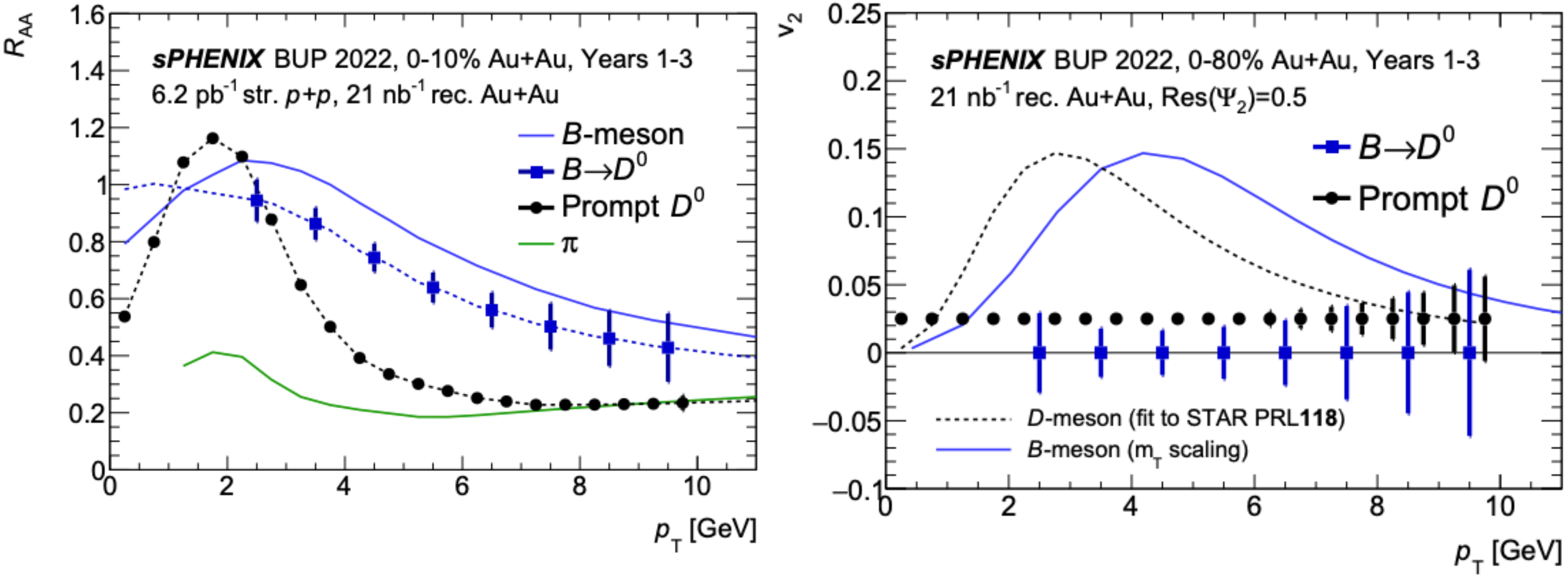
di-b-jets





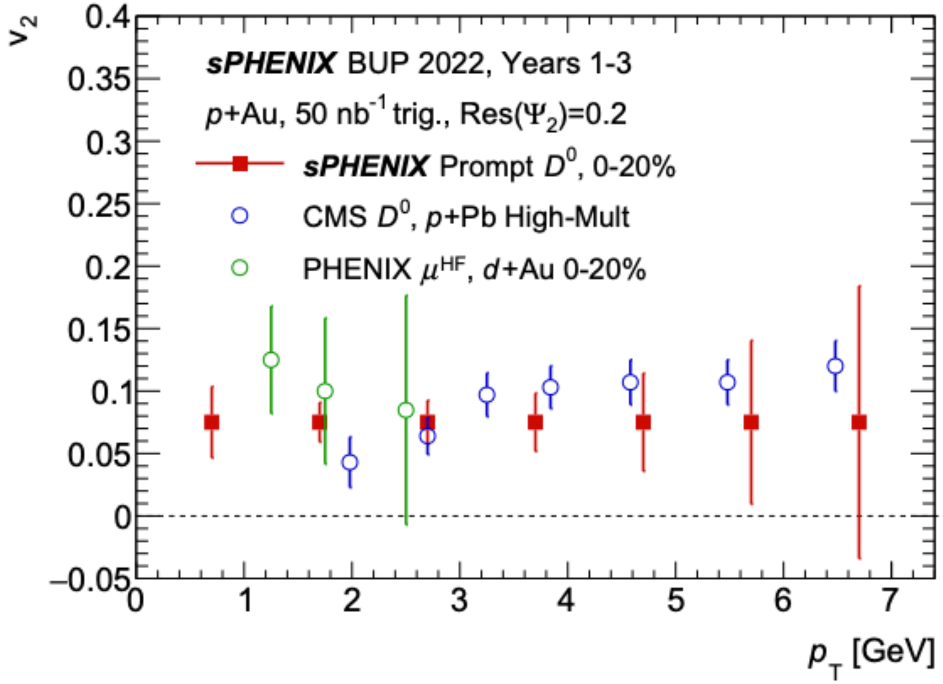
- b-jet tagging using DCA tagger for secondary vertices
  - mass dependence of energy loss
  - back-to-back b-jet measurement reduces contribution from gluon splitting

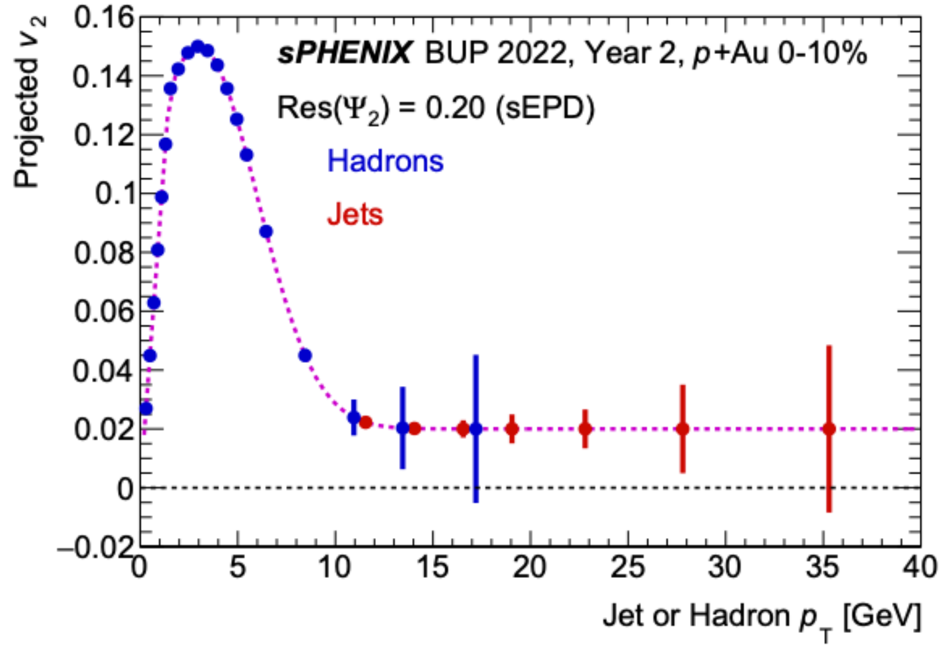
Open Heavy Flavor Physics



- Vary the mass of QGP probes:
  - $m_{c,b} >> \Lambda_{QCD}$ → produced primarily in early hard scatterings
  - Large mass of b-quarks → modeled better theoretically
  - Study mass dependence of collectivity and energy loss
  - Provide constraints on diffusion transport parameter of the QGP

Small Systems





- Heavy flavor flow in p+Au:
  - Collectivity in small systems
- Jet/high p_T hadrons p+Au:
  - Cold nuclear matter effects
  - Potential for energy loss in small systems
  - Cold QCD spin measurements

Detector Status

Carriage installation complete!
- Jun. 2021

Magnet installation complete!
- Oct. 2021

OHCAL installation complete!
- 28th Feb. 2022

IHCAL Barrel assembly complete!
- 18th Mar. 2022

Summary

- sPHENIX detector will provide:
  - Full coverage electromagnetic and hadronic calorimetry
  - High precision tracking and vertexing
  - Fast readout rate
- Design allows for:
  - High statistics samples of hard probes (jets, photons, high p_T charged hadrons, heavy-flavor)
  - Precision reconstruction of secondary vertices for heavy flavor tagging
  - Complimentary measurements to LHC
- Measurements will improve our understanding of small-scale behavior of the QGP
- Data taking to begin in Feb. 2023!

February 28, 2022

sPHENIX is supported by

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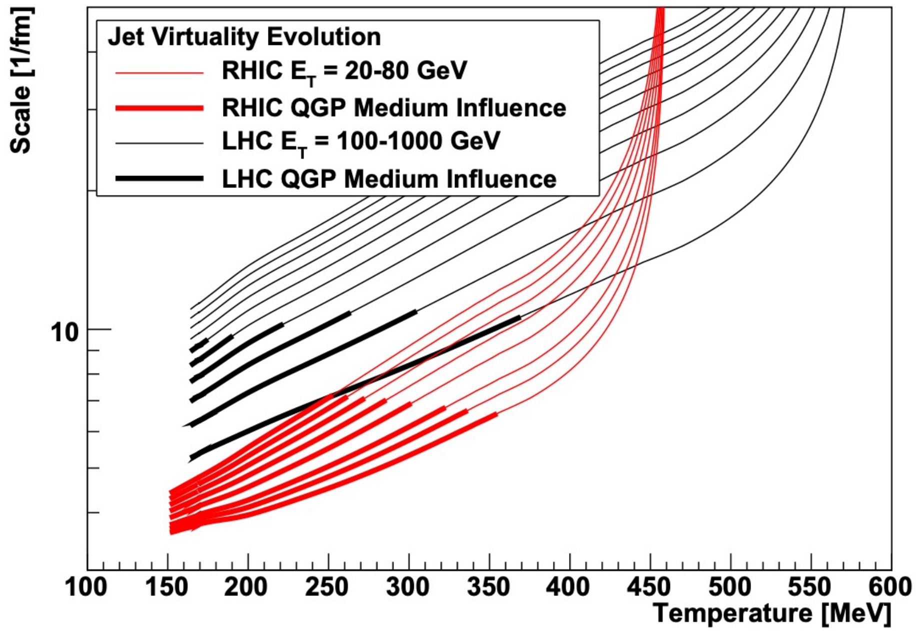
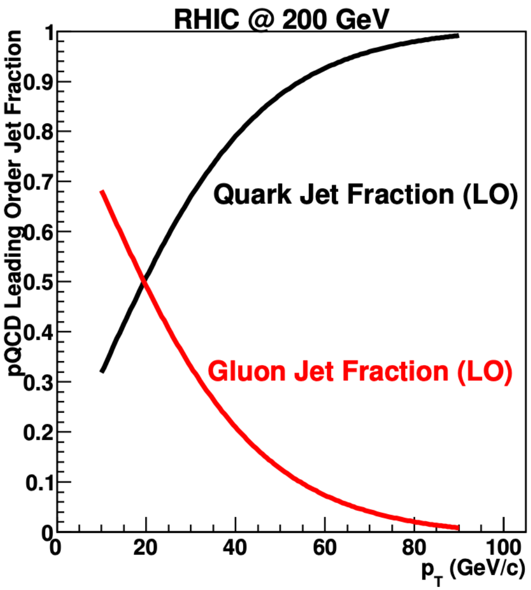
Backup

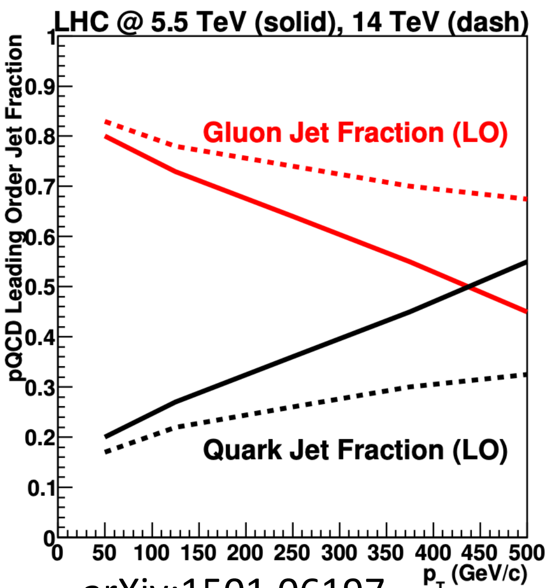
Why Jets in sPHENIX vs. the LHC

- Different QGP:
  - Temperature evolution different between LHC and RHIC



- Different probes:
  - Different quark vs. gluon jet mixture
  - Lower kinematic range- radiation close to the QGP medium scale early in collision

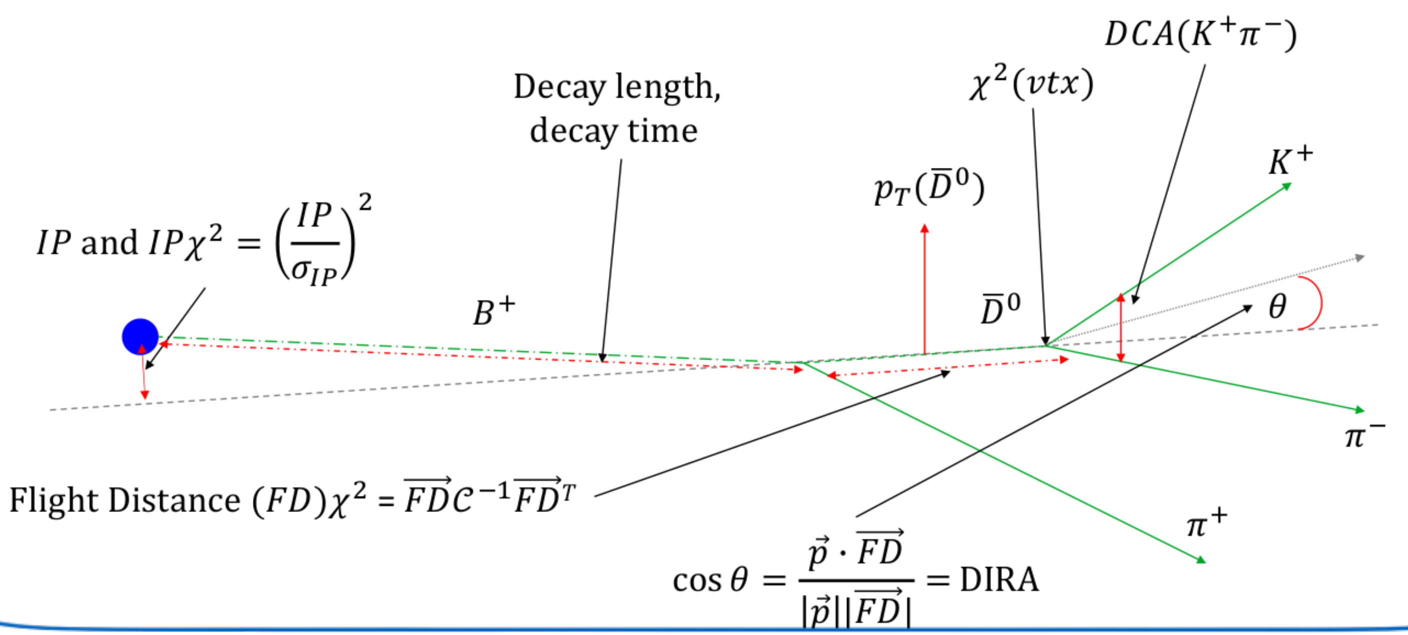




arXiv:1501.06197

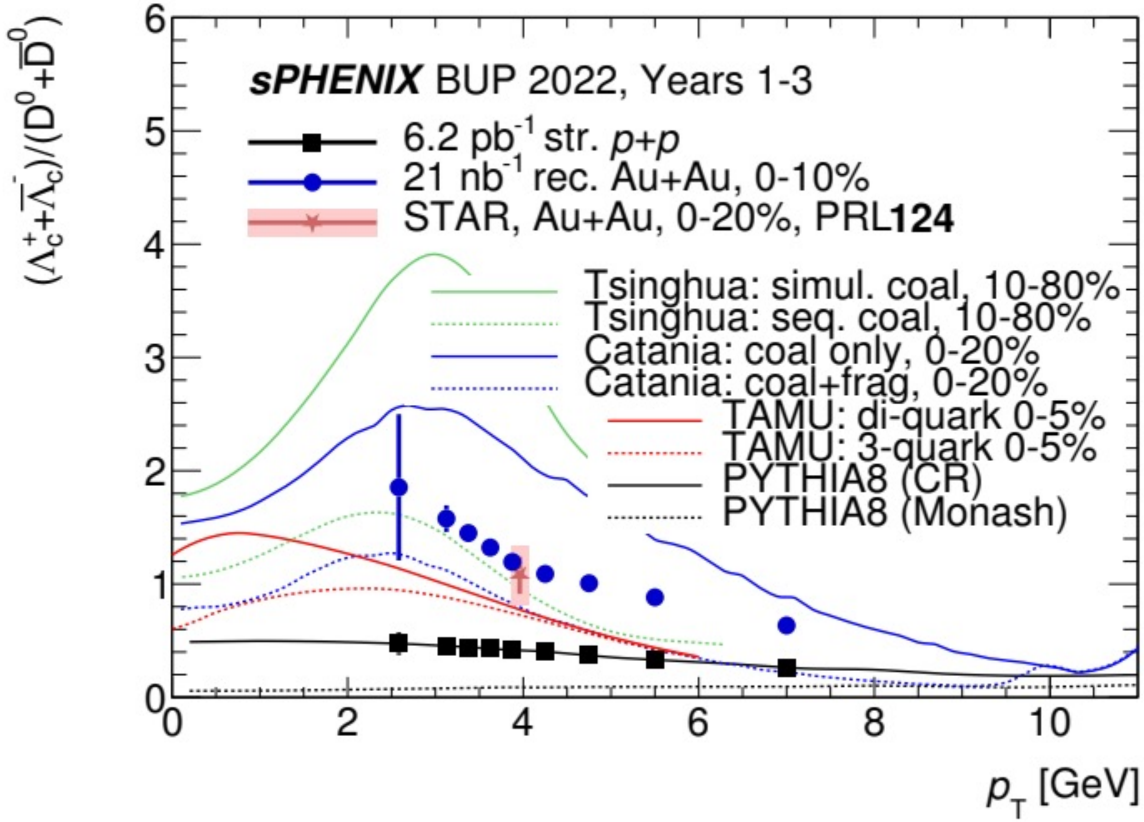
Heavy Flavor Toolkit

- Track reconstruction using [ACTS]
- Heavy flavor reconstruction using KFParticle
  - Developed for CBM experiment and adapted for use in STAR, ALICE, & others
- Tracking, vertexing, & HF reconstruction studied in simulated pp and Au+Au events with pileup



[CBM-SOFT-note-2006-001] [CBM-SOFT-note-2006-002] [CBM-SOFT-note-2007-003] [GSI Talk. Nov 25th, 2008]

Heavy Flavor Hadronization in Medium



- Study effects of medium on hadronization of heavy quarks
- Indications of Λ_c/D^0 enhancement at RHIC
  - Study in detail with sPHENIX
  - Measure *p*+*p* baseline in data
- Discerning power between theoretical models