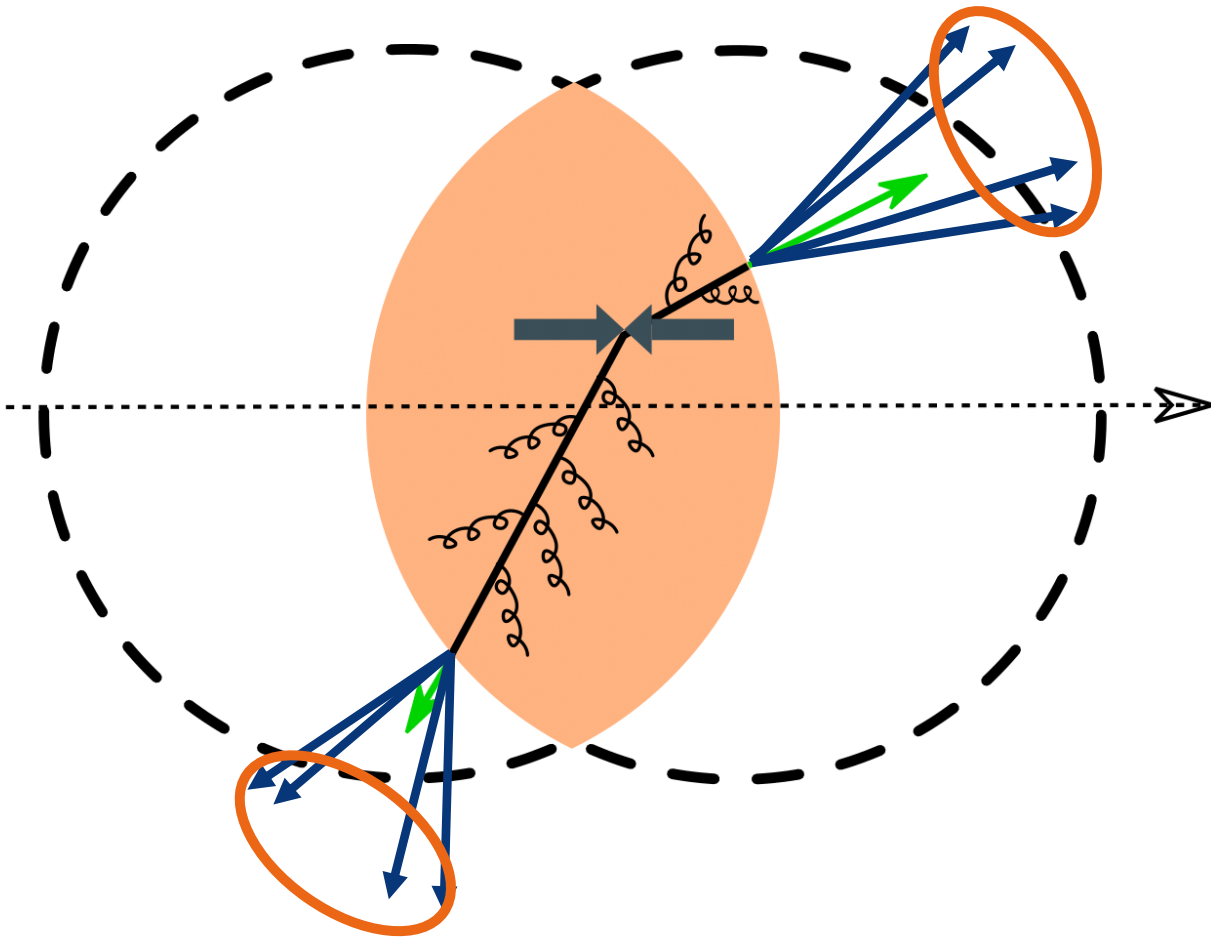# Jet probes of the QGP from RHIC to the LHC

Virginia Bailey
2024 RHIC/AGS User's Meeting
June 12, 2024

MPS Ascend Fellow

Jets as probes of the QGP

- High energy scatterings in collision can produce outgoing high energy quarks or gluons

- These will traverse and interact with the QGP

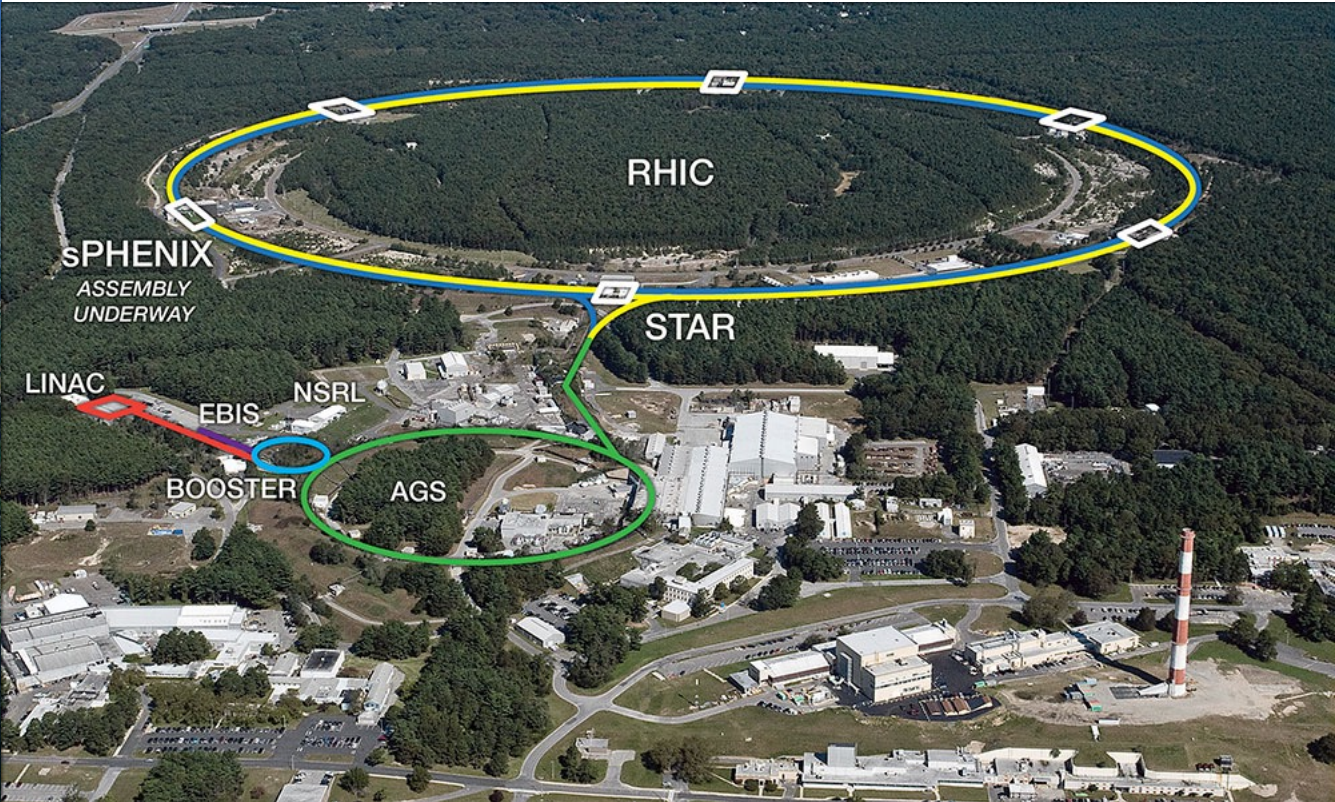- Outgoing parton fragments into spray of particles we measure, called a jet

Studying QGP in the lab

Large Hadron Collider (LHC) at CERN
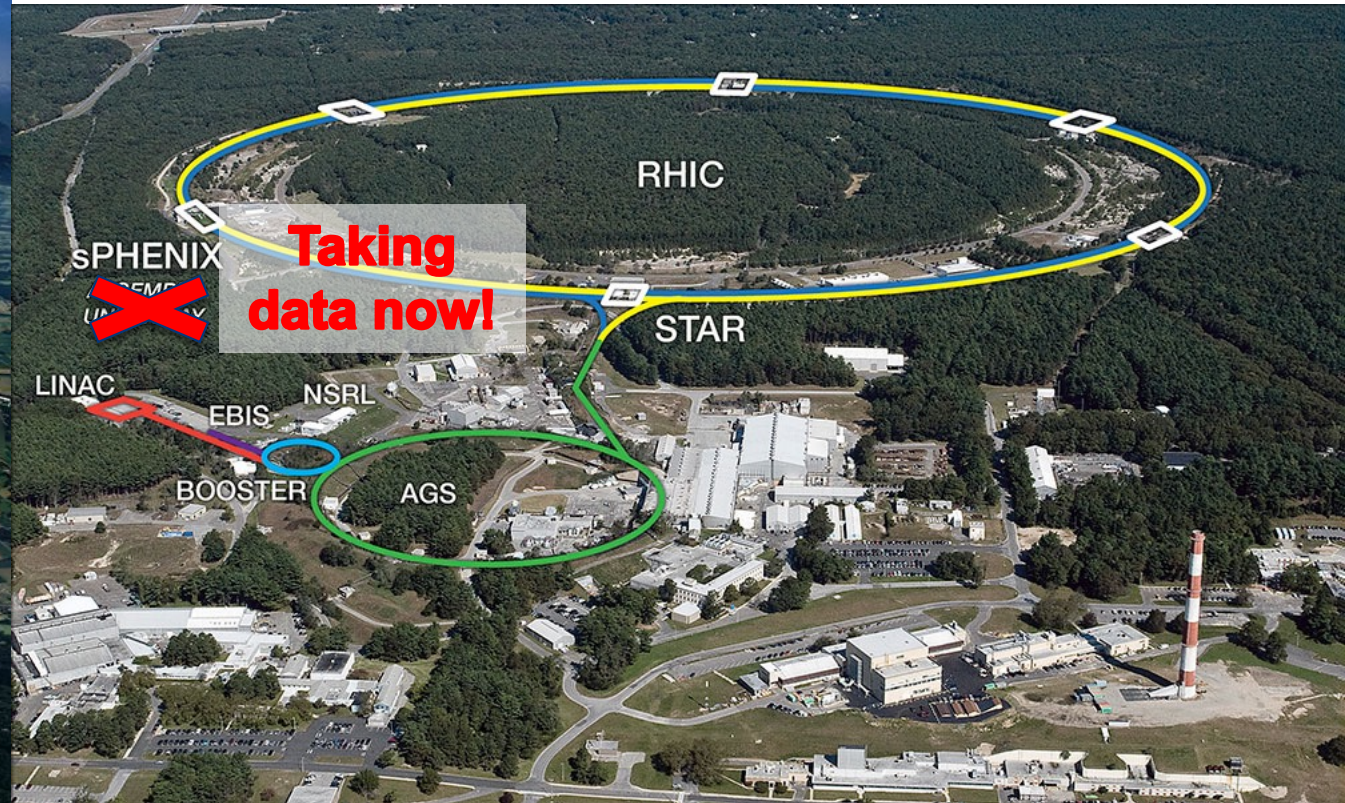
Relativistic Heavy Ion Collider (RHIC) at BNL

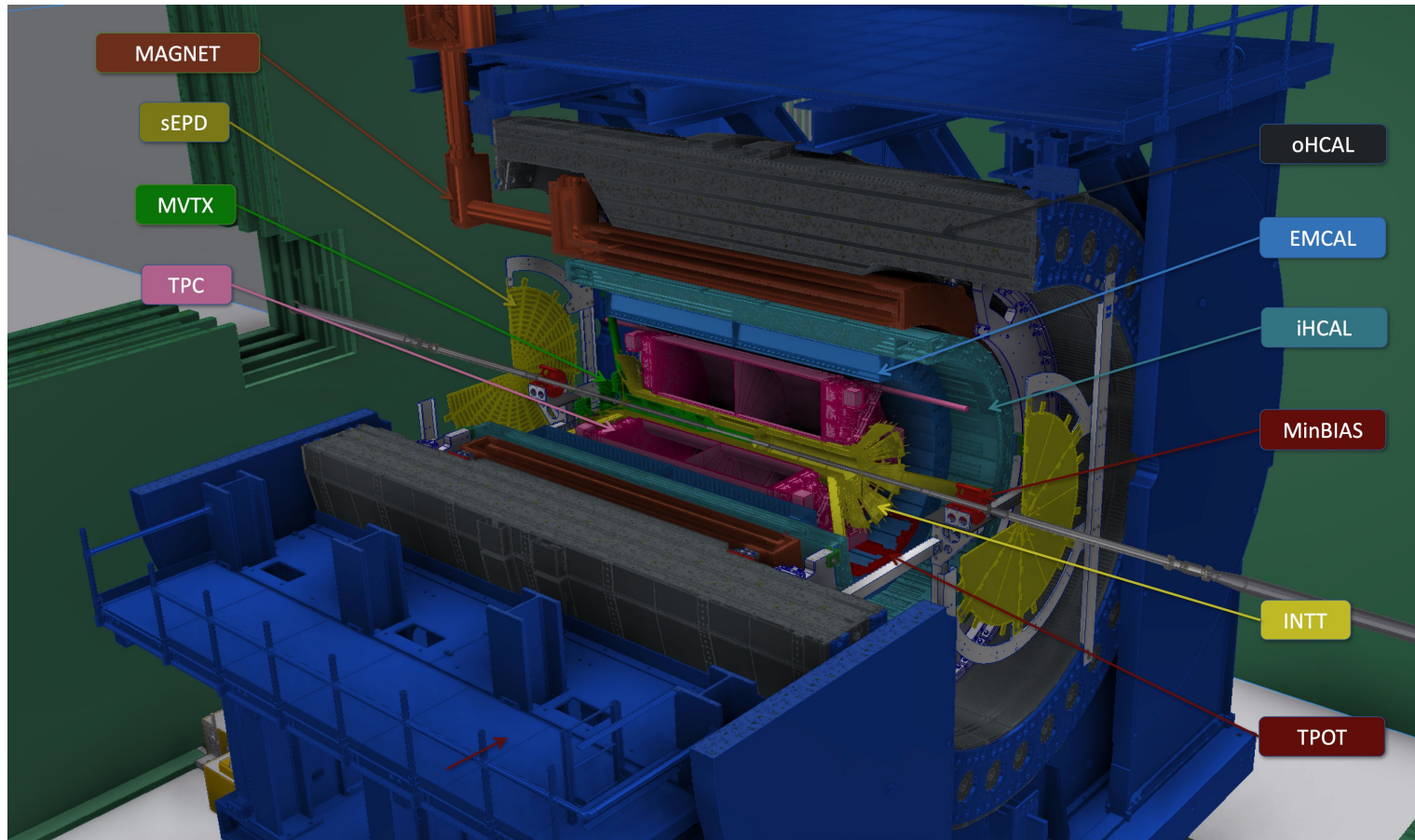# Studying QGP in the lab

Large Hadron Collider (LHC) at CERN

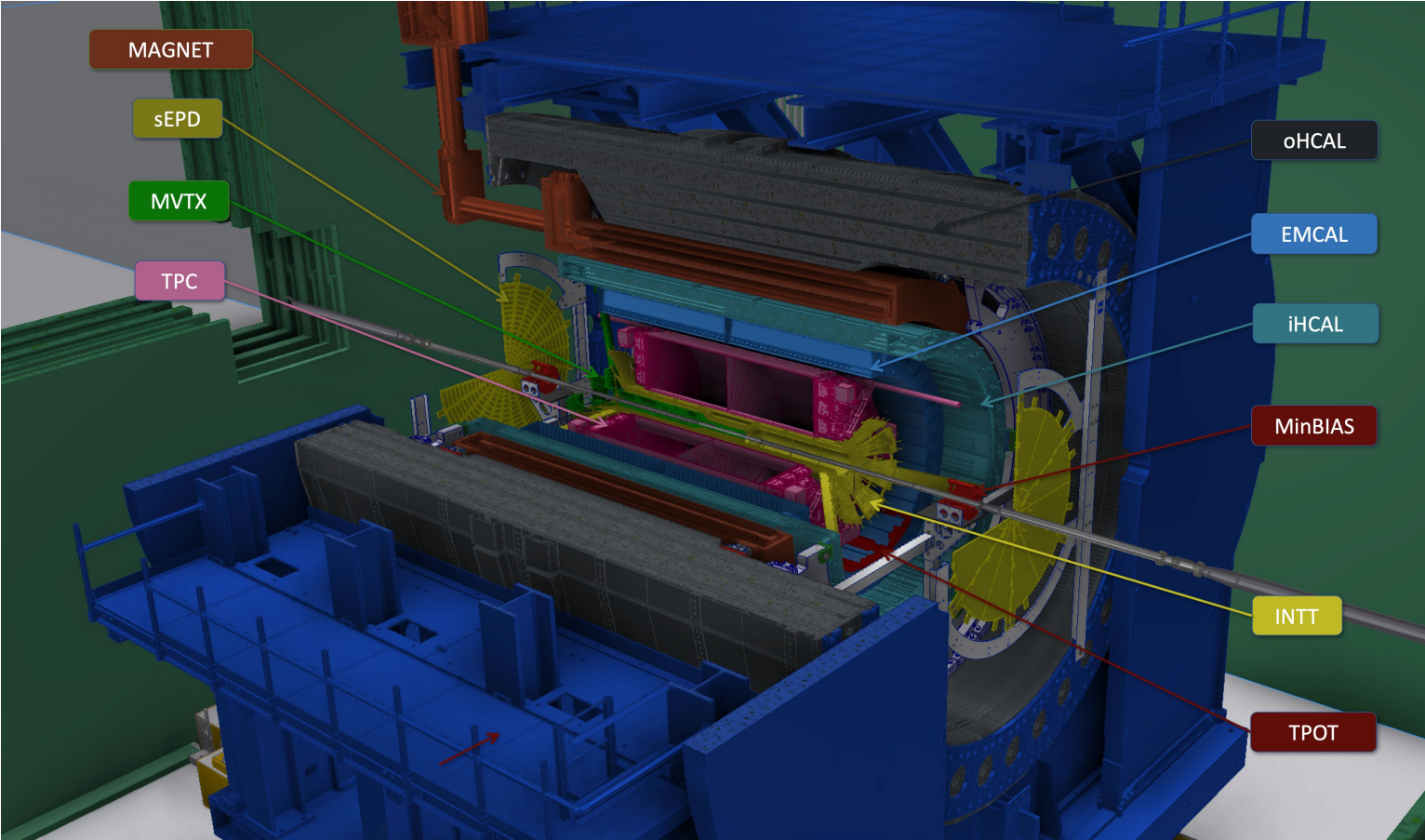Relativistic Heavy Ion Collider (RHIC) at BNL

sPHENIX at RHIC

First new detector at RHIC in 20 years!

sPHENIX at RHIC

First new detector at RHIC in 20 years!

First hadronic calorimeters at RHIC at midrapidity!

Streaming readout for tracking detectors

15 kHz triggered readout calorimeter jet and photon triggers in pp

MAGNET
sEPD
MVTX
TPC
oHCAL
EMCAL
iHCAL
MinBIAS
INTT
TPOT

Why jet measurements at RHIC *and* LHC?

❑ Different QGP:
  ❑ Temperature/temperature evolution different between LHC and RHIC

arXiv:1501.06197

Why jet measurements at RHIC *and* LHC?
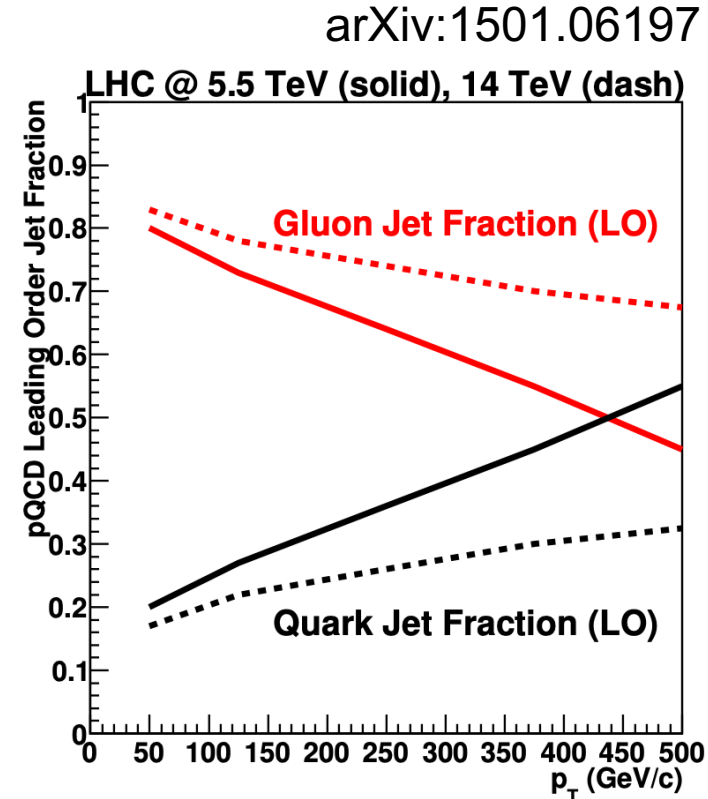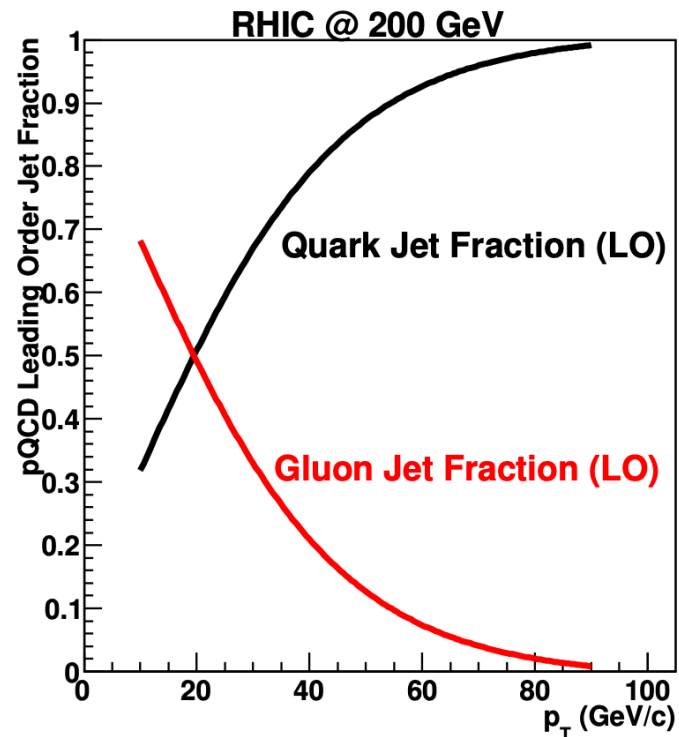
arXiv:1501.06197
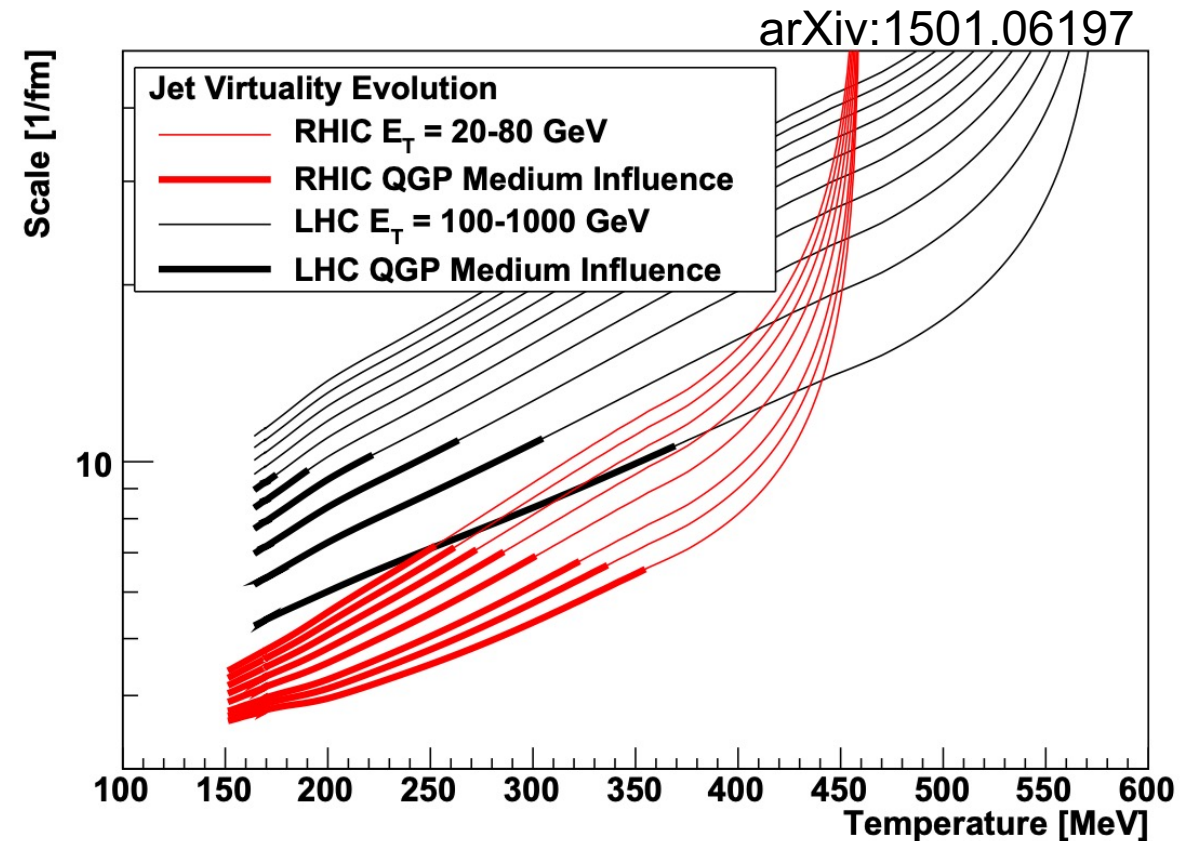
- ❑ Different QGP:
  - ❑ Temperature/temperature evolution different between LHC and RHIC

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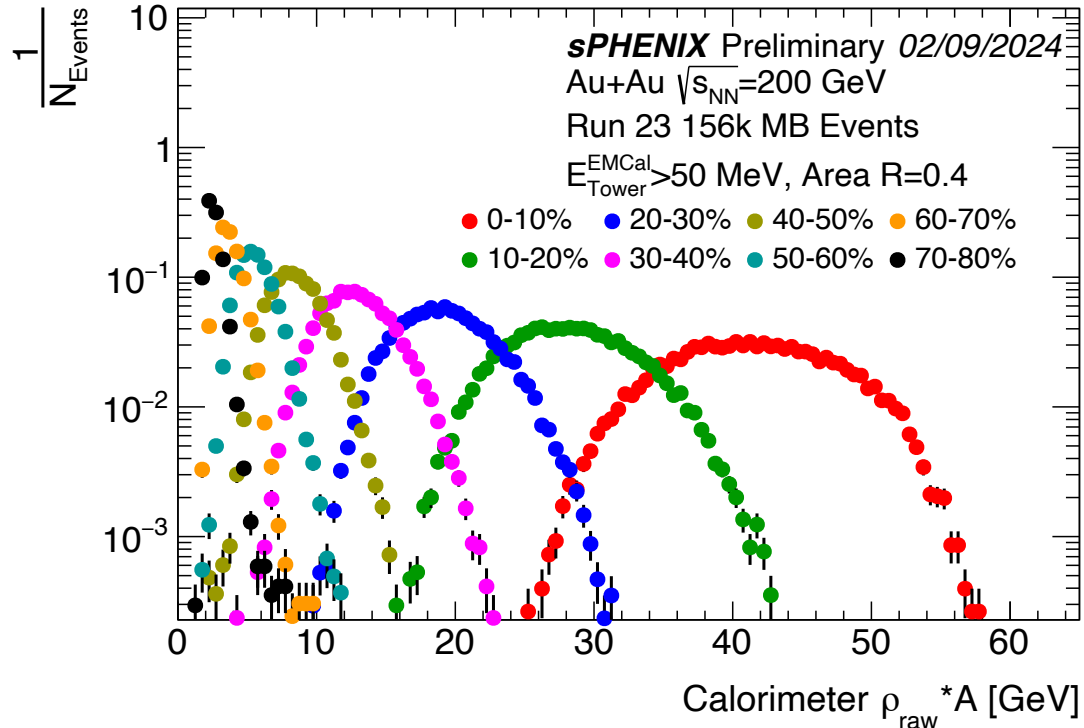 - ❑ Different quark vs. gluon jet mixture
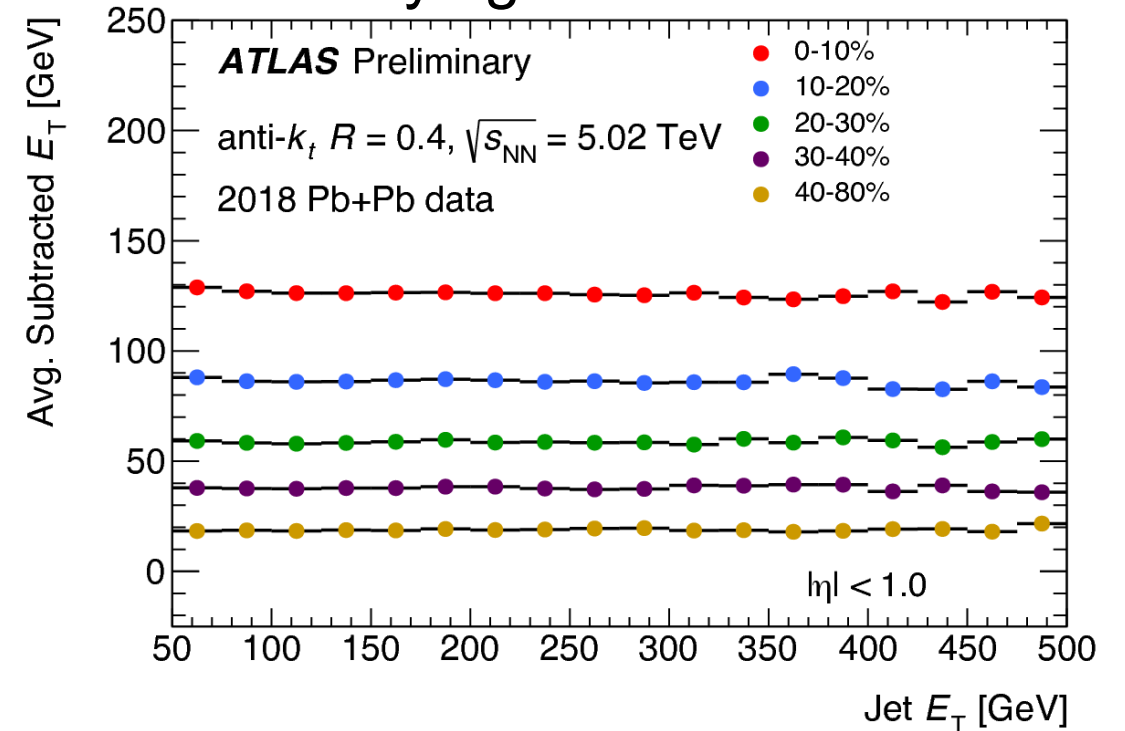 - ❑ Lower kinematic range- radiation close to the QGP medium scale early in collision

RHIC @ 200 GeV

Quark Jet Fraction (LO)

Gluon Jet Fraction (LO)

LHC @ 5.5 TeV (solid), 14 TeV (dash)

Gluon Jet Fraction (LO)

Quark Jet Fraction (LO)

Underlying event at RHIC vs. LHC

Underlying event at **RHIC**
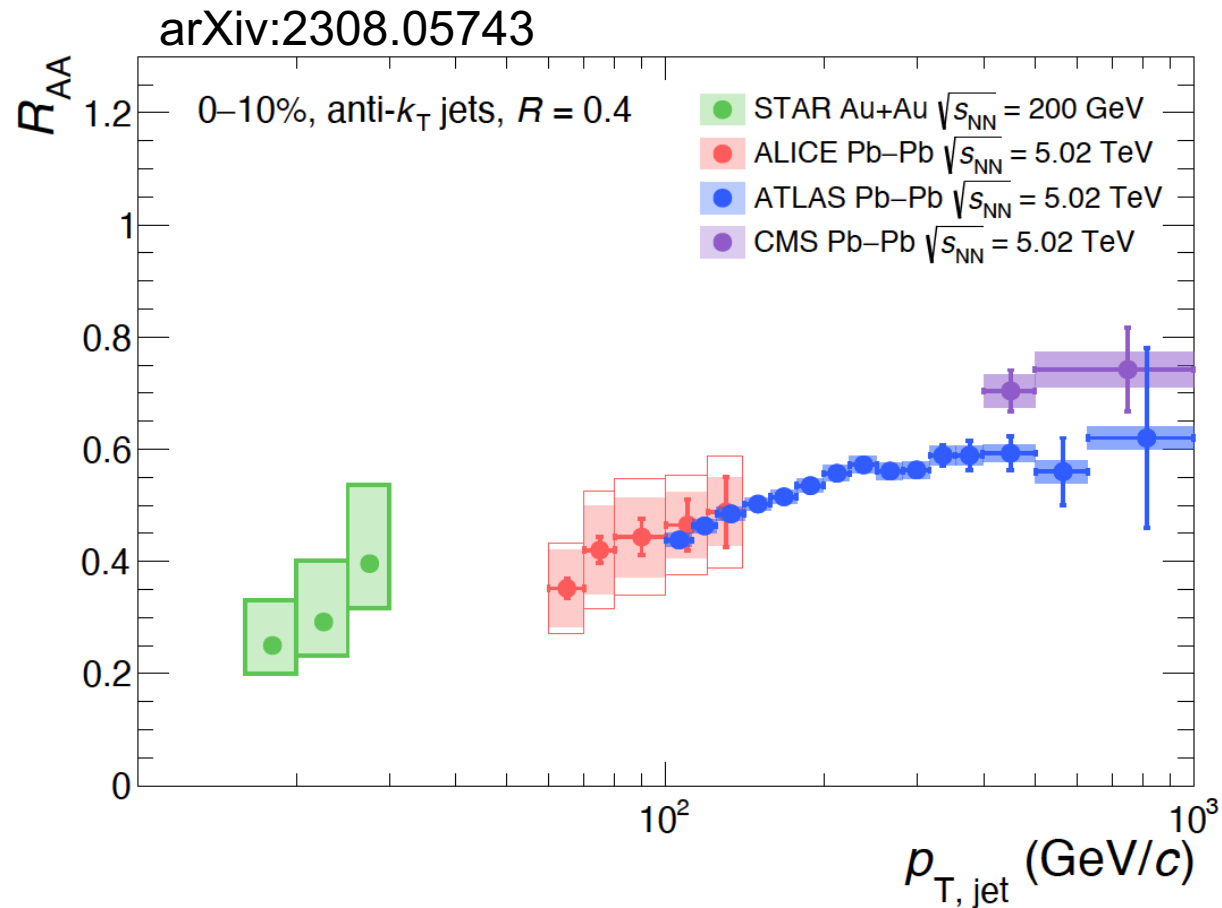

Underlying event at the **LHC**

Underlying event at RHIC is significantly smaller than at the LHC- RHIC can measure jets at low energy

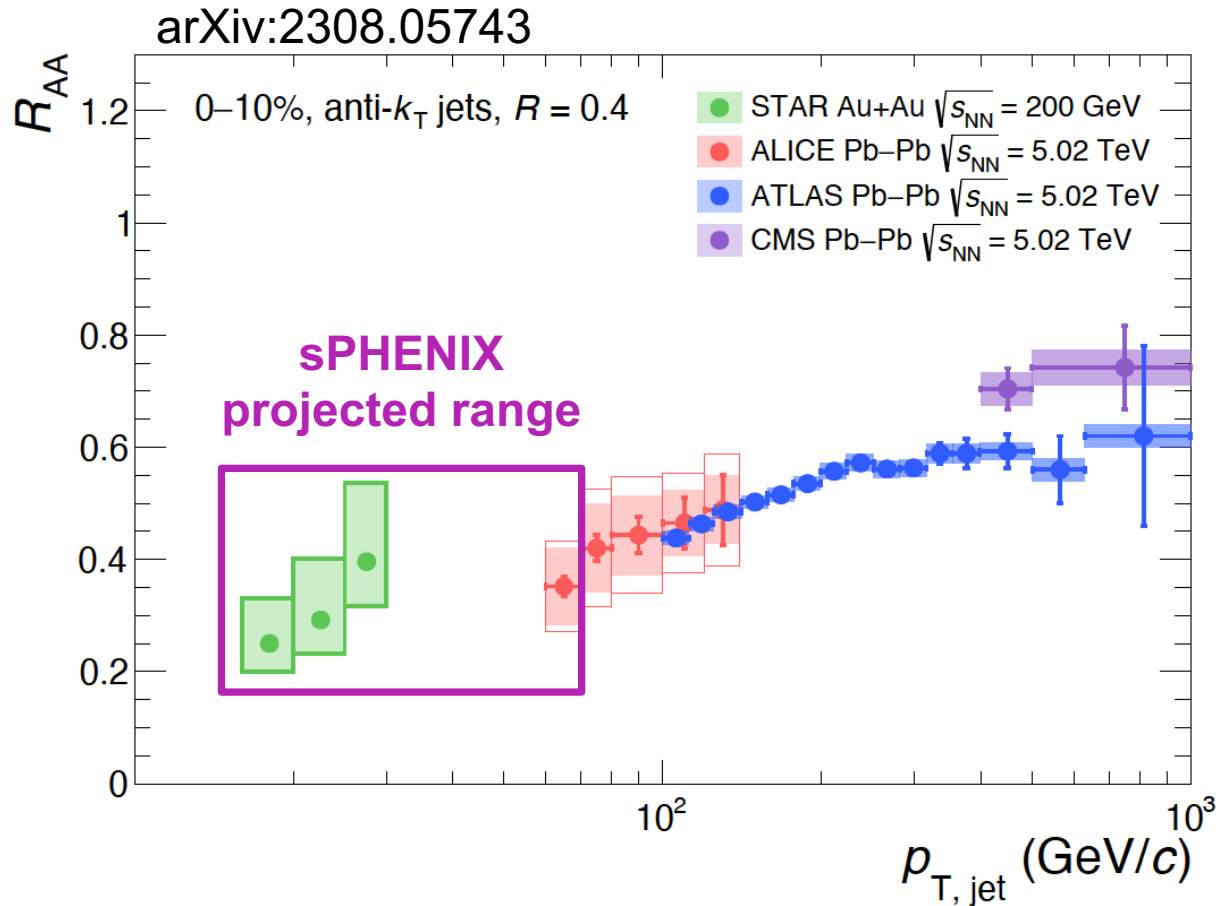# Jet yields are suppressed...

Measurements at **RHIC** and the **LHC**

arXiv:2308.05743

Measurements cover
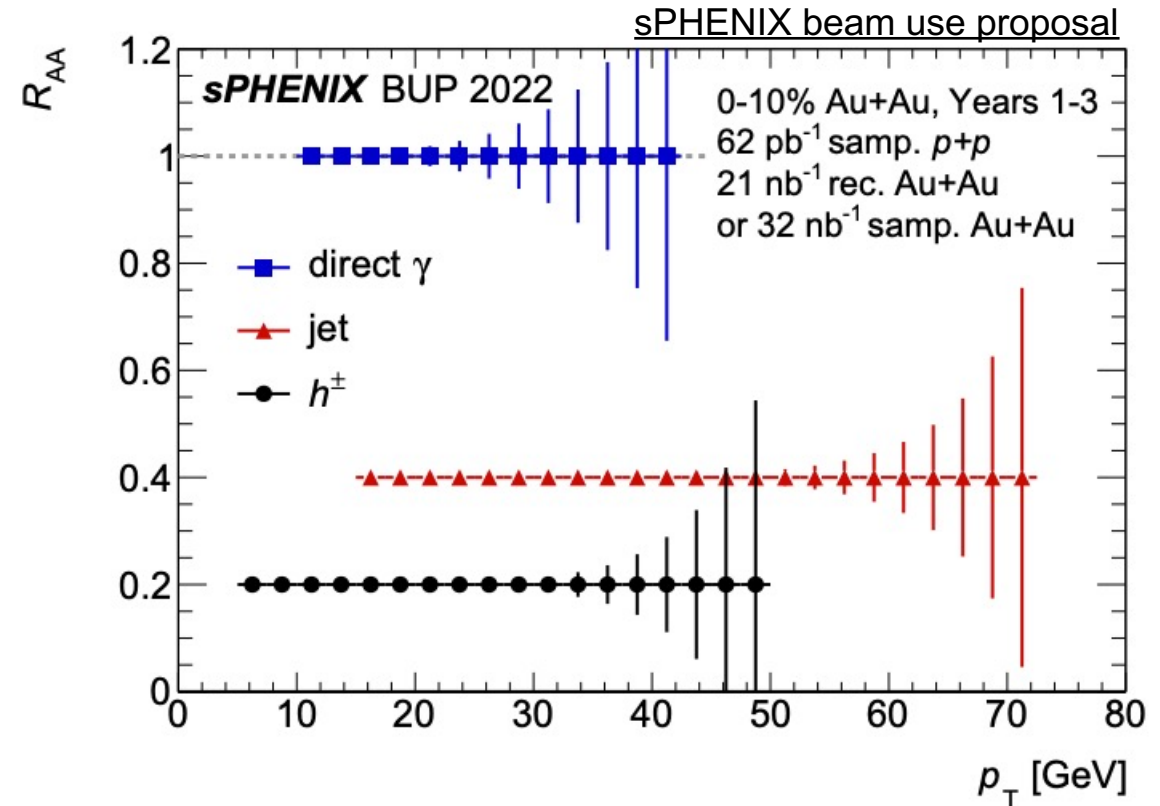kinematic range
10s of GeV to TeV!

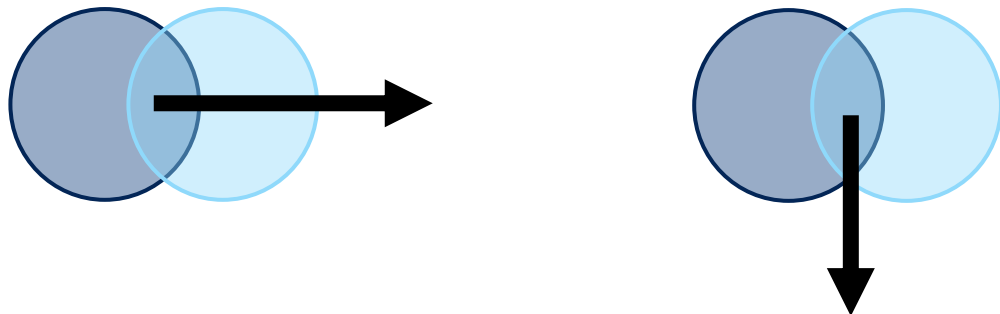# Jet yields are suppressed...

Measurements at RHIC and the LHC

Future RHIC measurements
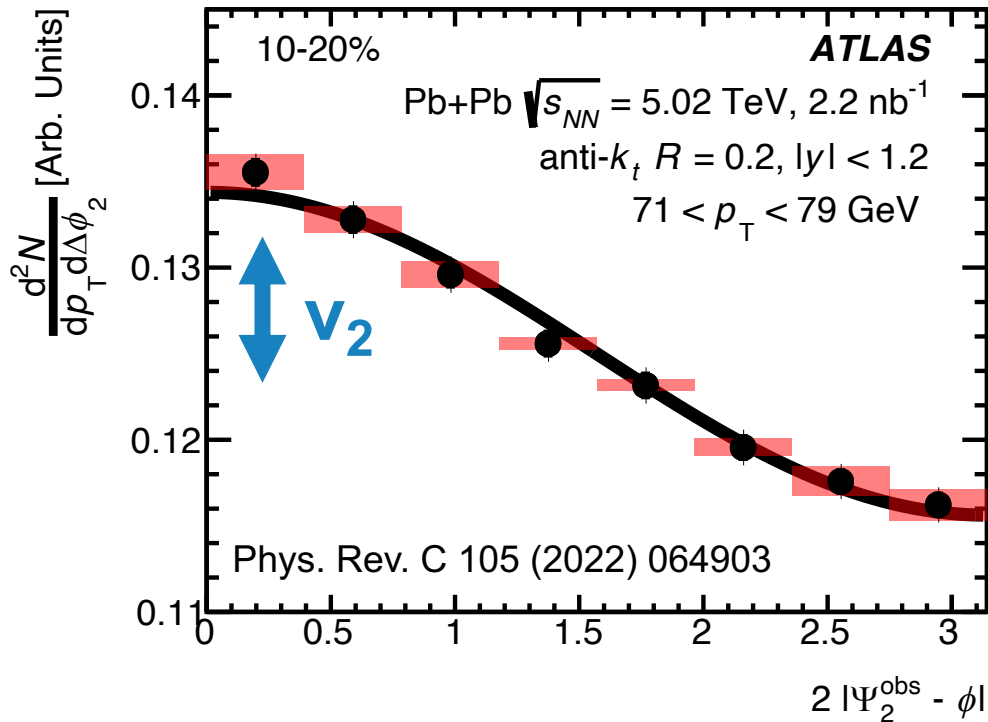
…as a function of path-length

...as a function of path-length

Measurements at **RHIC**

Future RHIC measurements

RHIC provides high precision at low p_T

...as a function of flavor

Measurements at the **LHC**

2018 Pb+Pb 1.7 nb^{-1}, 2017 *pp* 260 pb^{-1}, $\sqrt{s_{NN}}$ = 5.02 TeV

ATLAS

Phys. Lett. B 846 (2023) 138154

anti-k_T R = 0.4 jets
$|\eta^{jet}|$ < 2.8

For γ-tagged jets
p_T^γ > 50 GeV, $|\eta^\gamma|$ < 2.37
$\Delta\phi(\gamma,\text{jet})$ > 7π/8

[PLB 790 (2019) 108]

Inclusive jet 0-10%

γ-jet 0-10%

More likely
to be a
quark jet
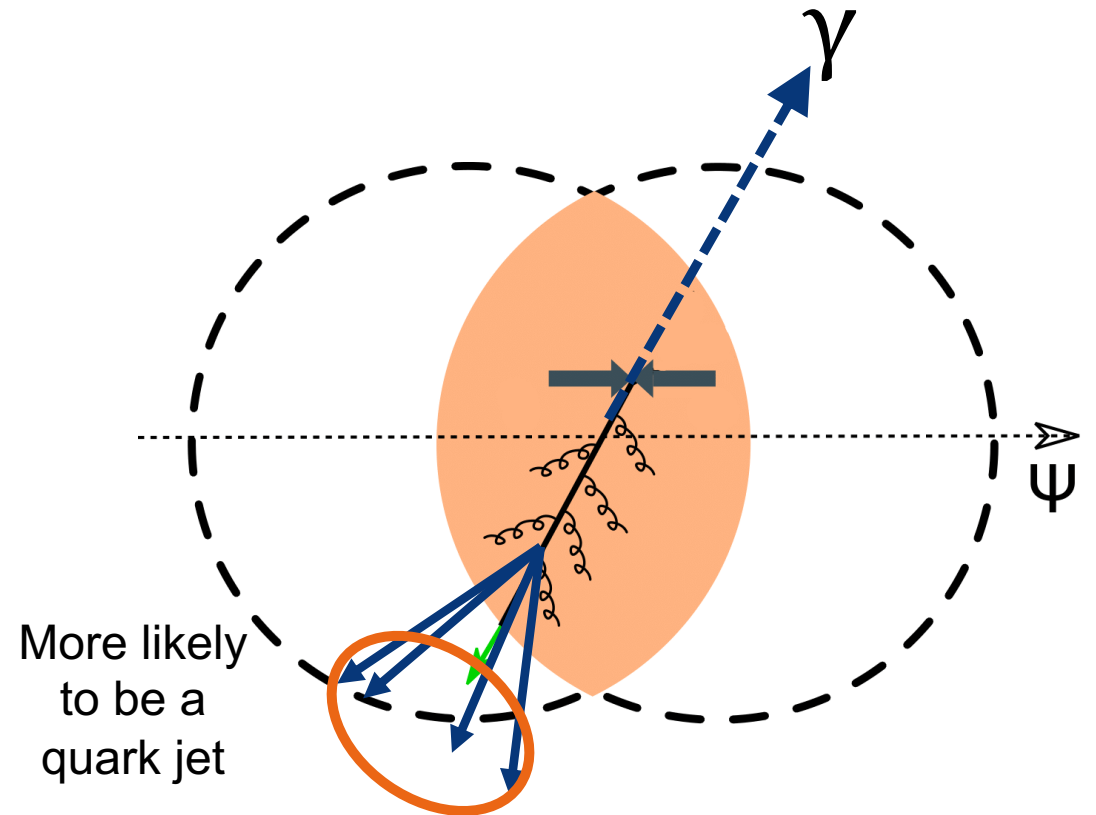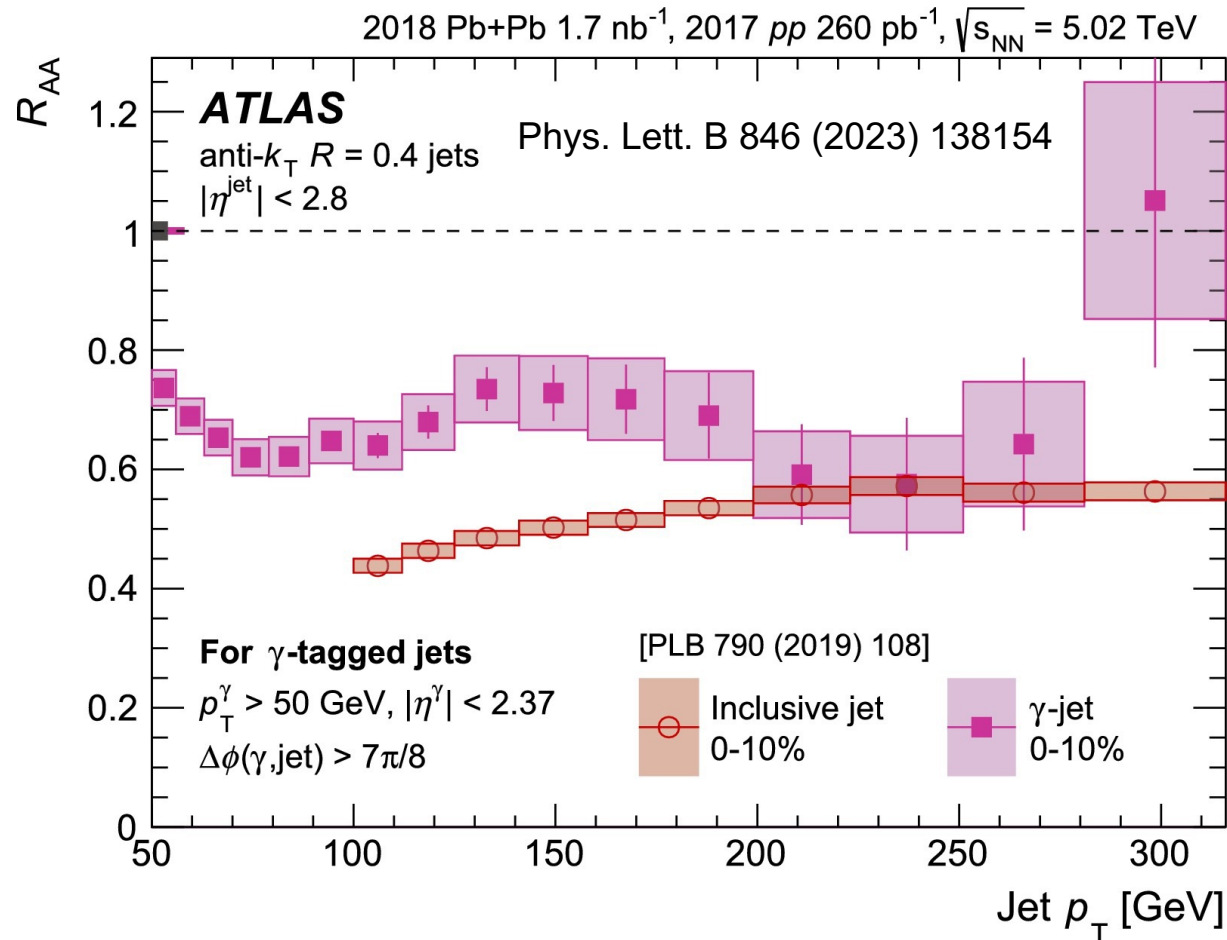
…as a function of flavor

Measurements at the LHC

Measurements at RHIC

Jet measurements at RHIC inherently quark dominated
➤ quark vs. gluon differences must be considered when comparing RHIC vs. LHC

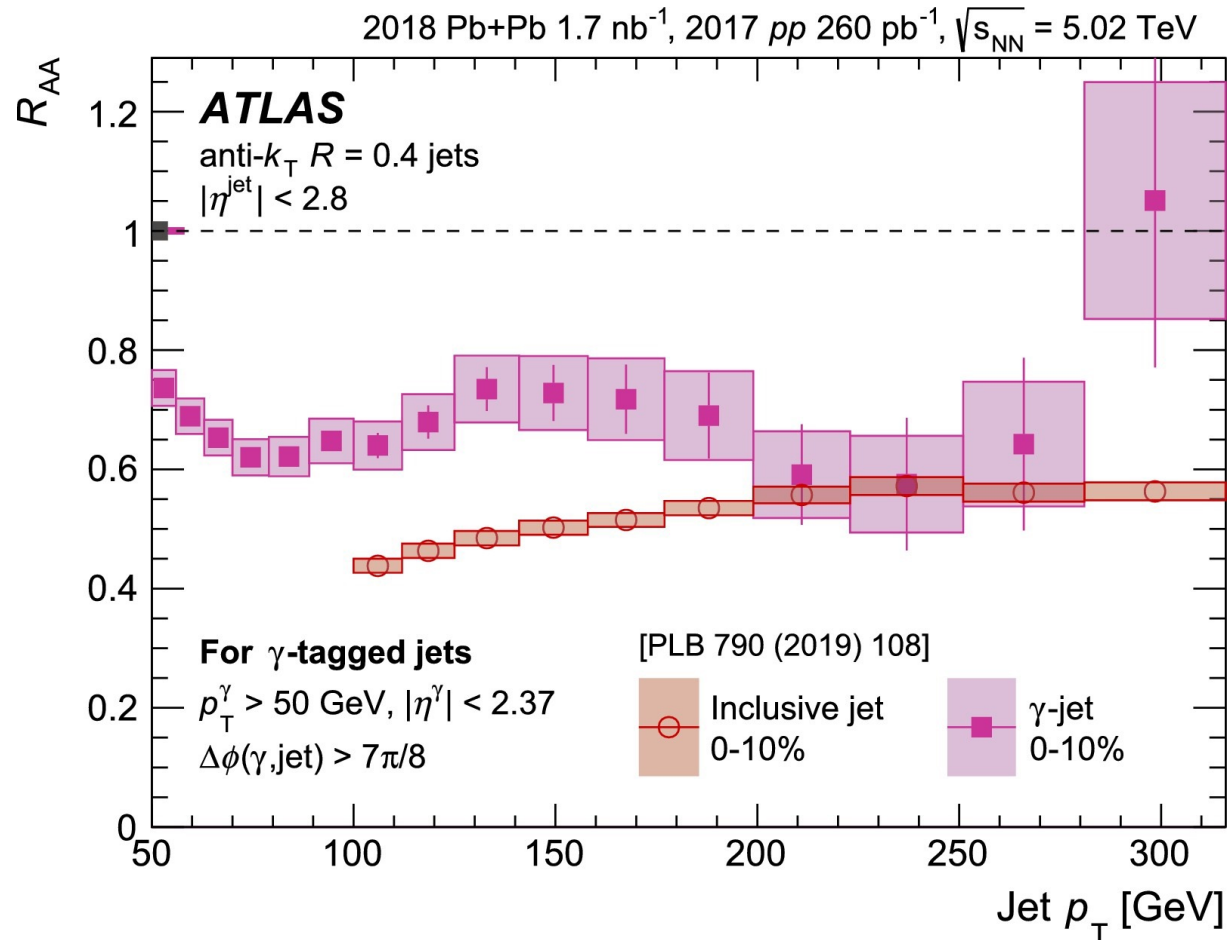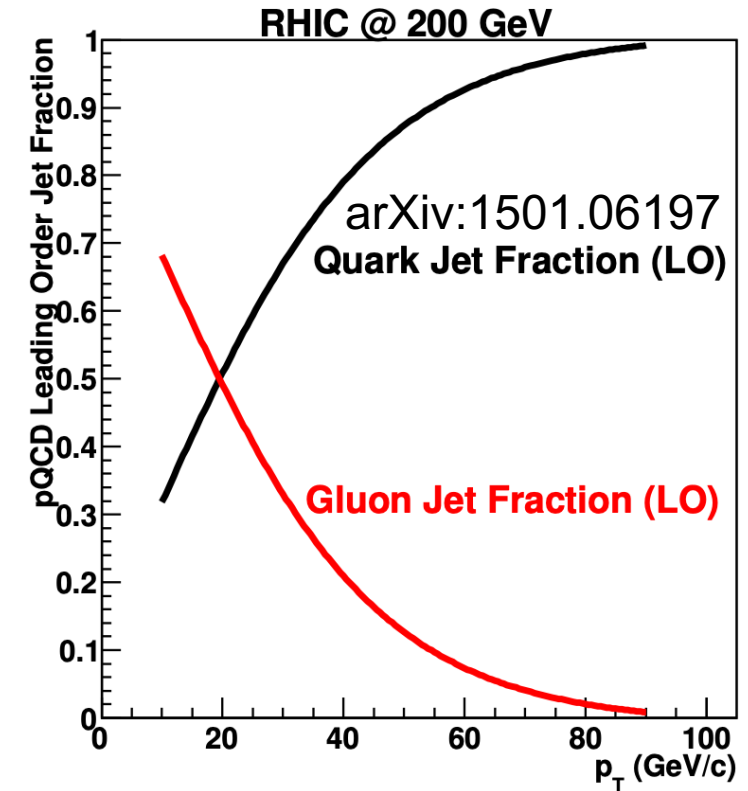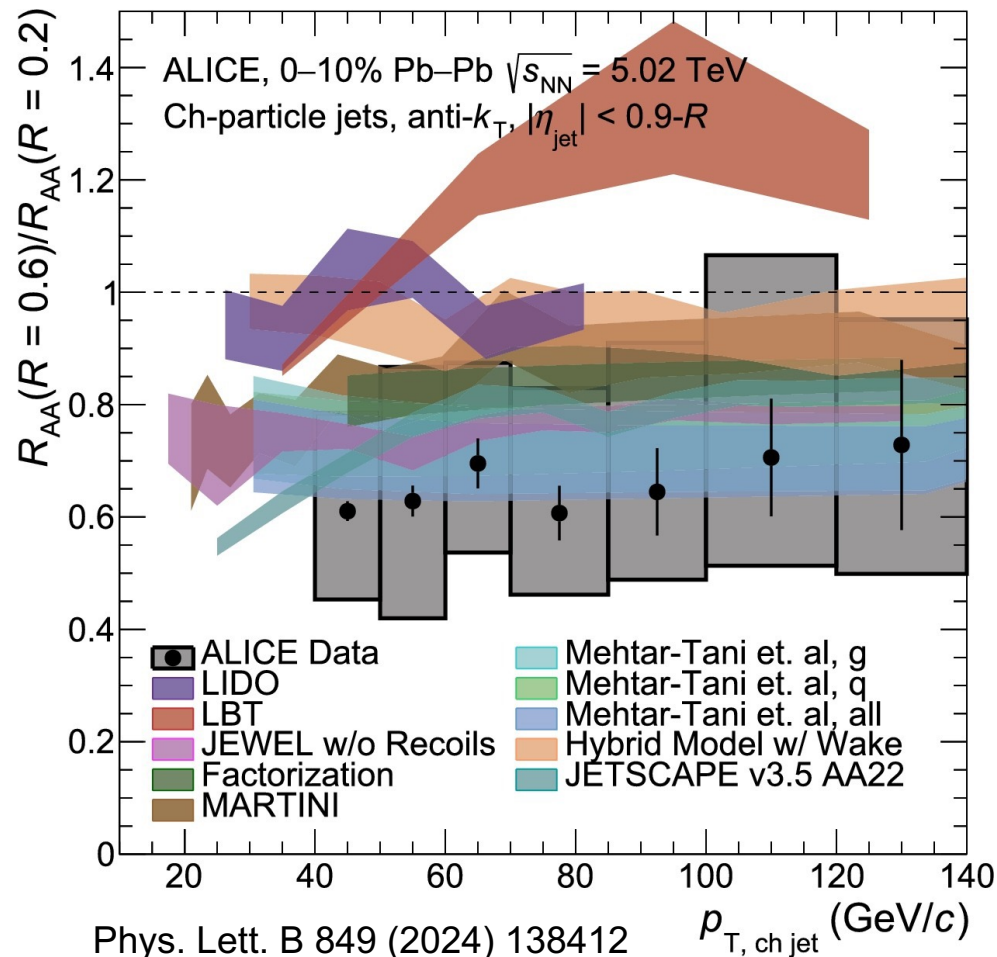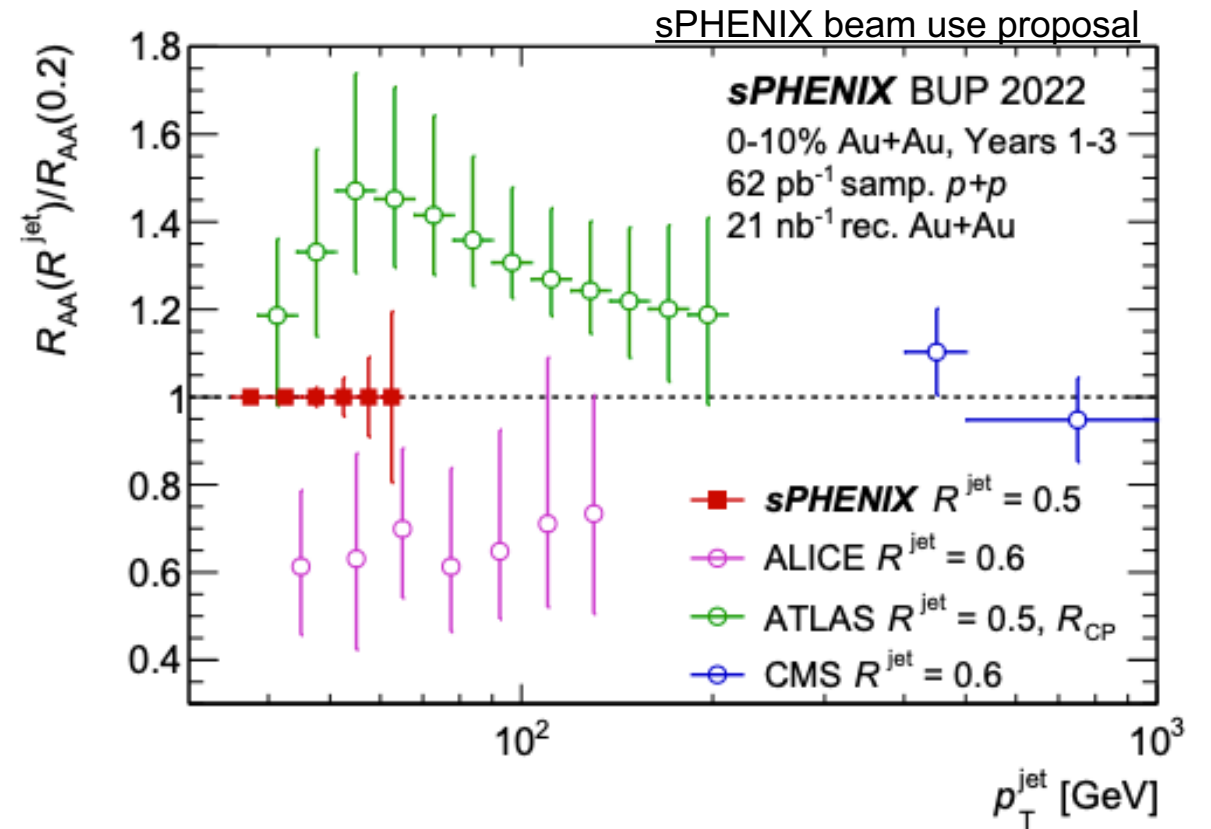# …as a function of (sub)structure

Measurements at the **LHC**

Phys. Lett. B 849 (2024) 138412

Future RHIC measurements

...as a function of (sub)structure
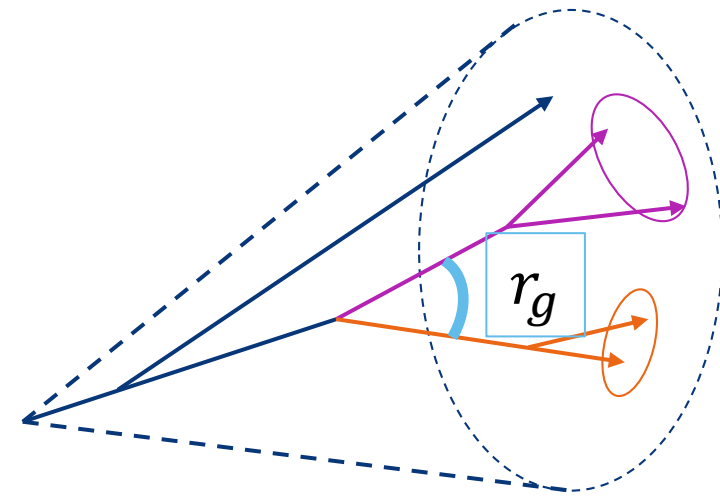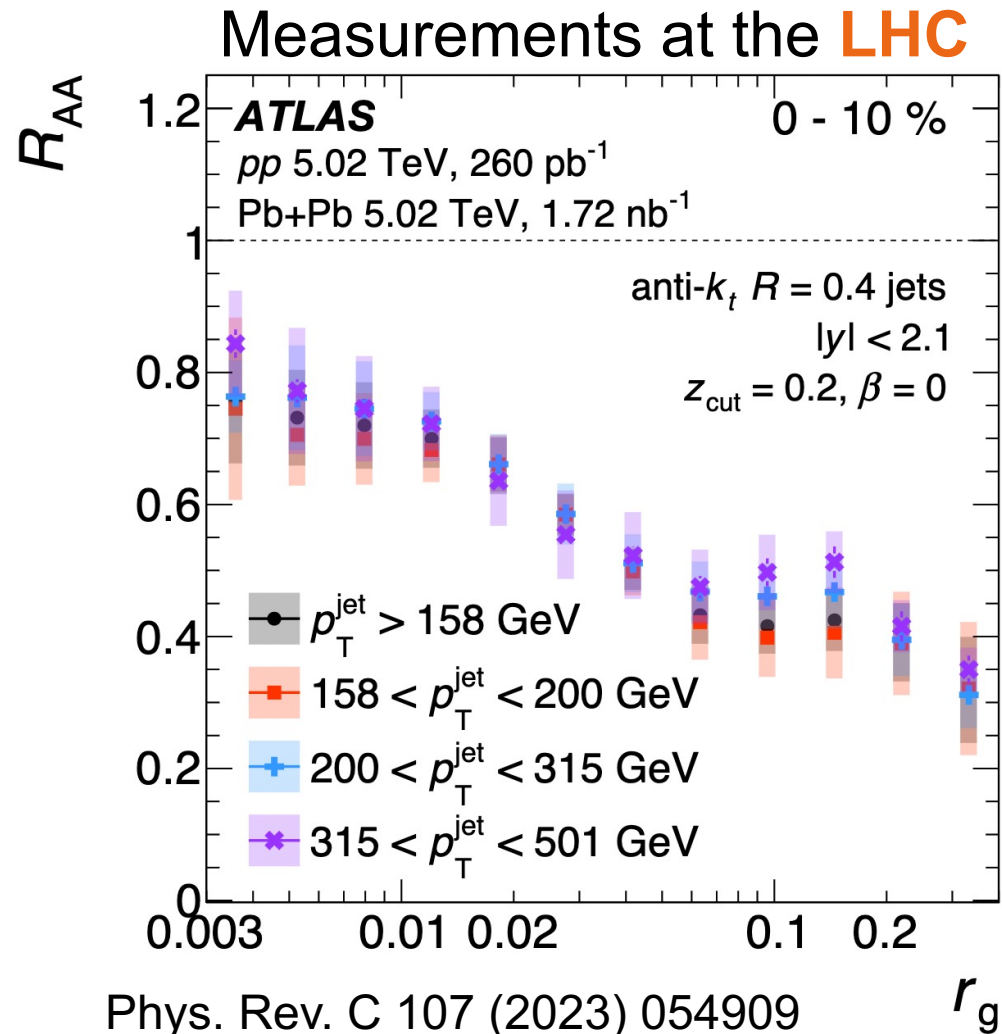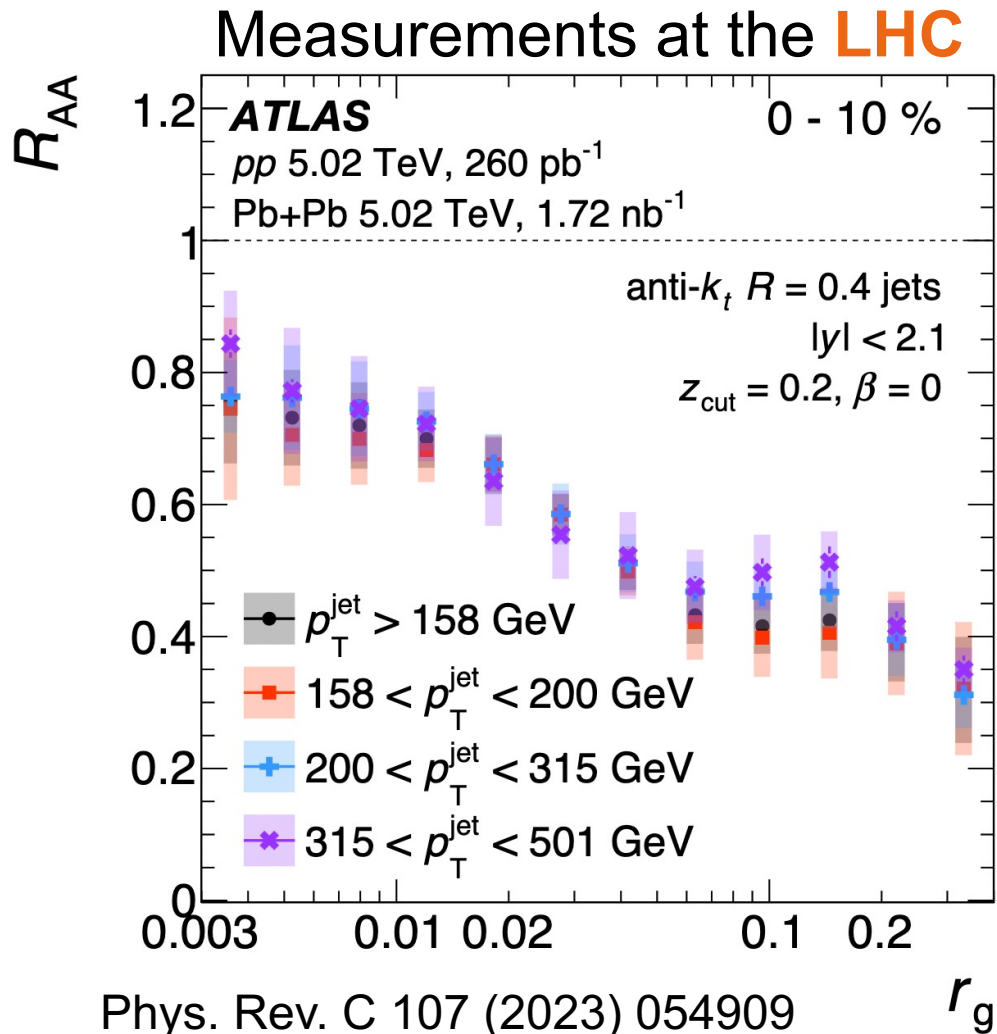
Measurements at the **LHC**

ATLAS

pp 5.02 TeV, 260 pb^{-1}

Pb+Pb 5.02 TeV, 1.72 nb^{-1}

0 - 10 %

anti-k_t R = 0.4 jets

|y| < 2.1

z_{cut} = 0.2, β = 0

- p_T^{jet} > 158 GeV
- 158 < p_T^{jet} < 200 GeV
- 200 < p_T^{jet} < 315 GeV
- 315 < p_T^{jet} < 501 GeV

Phys. Rev. C 107 (2023) 054909

$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

...as a function of (sub)structure

Measurements at the **LHC**

ATLAS · 0 - 10 %
pp 5.02 TeV, 260 pb^{-1}
Pb+Pb 5.02 TeV, 1.72 nb^{-1}

anti-k_t $R = 0.4$ jets
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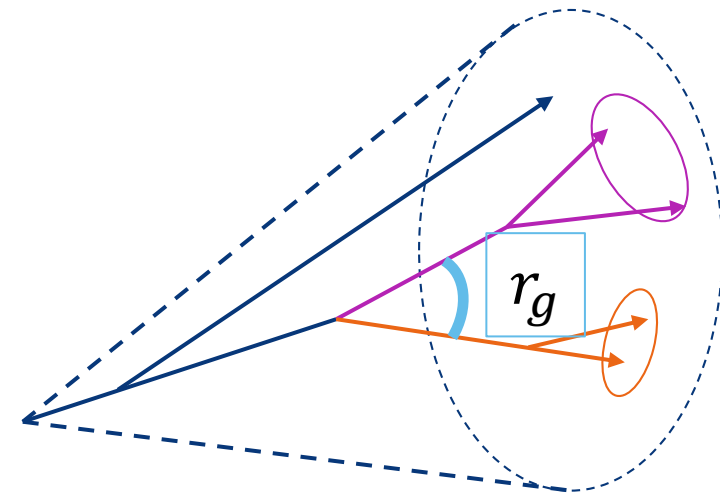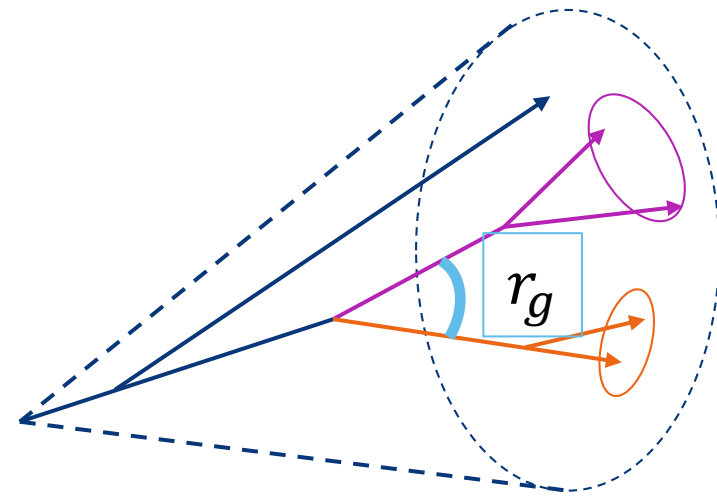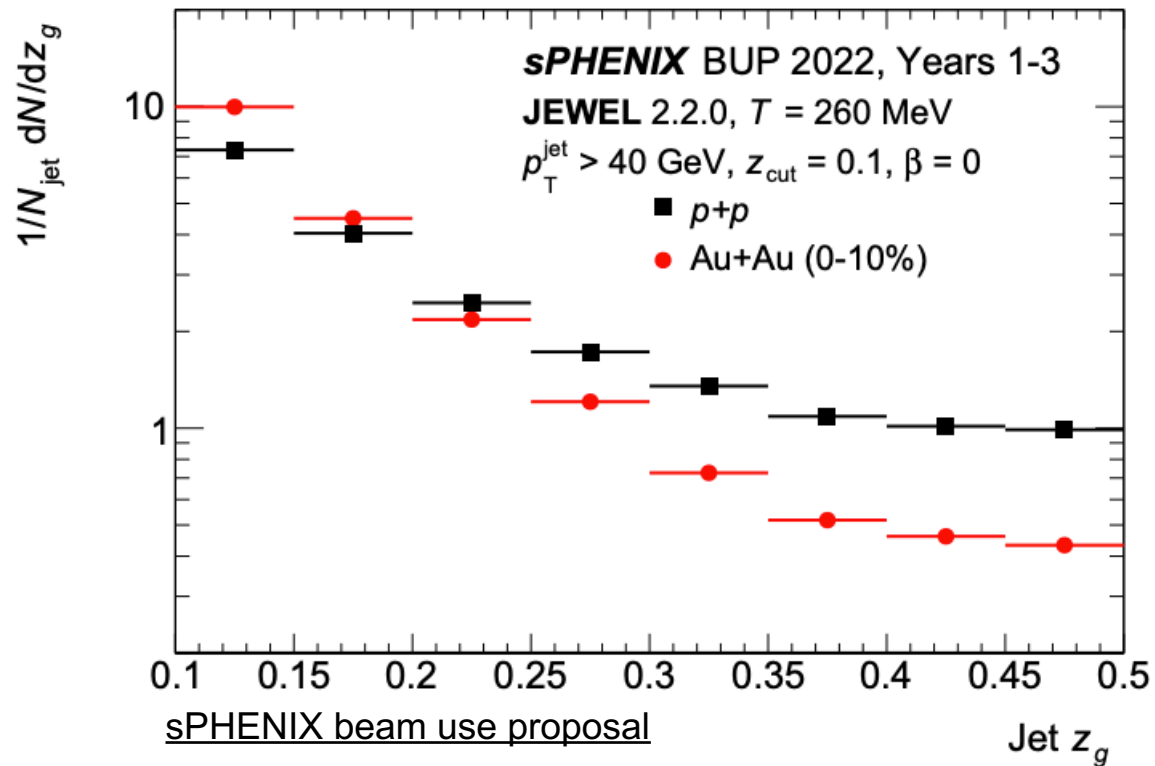
Phys. Rev. C 107 (2023) 054909

$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

…as a function of (sub)structure

Future RHIC measurements

sPHENIX BUP 2022, Years 1-3
JEWEL 2.2.0, T = 260 MeV
p_T^{jet} > 40 GeV, z_{cut} = 0.1, β = 0
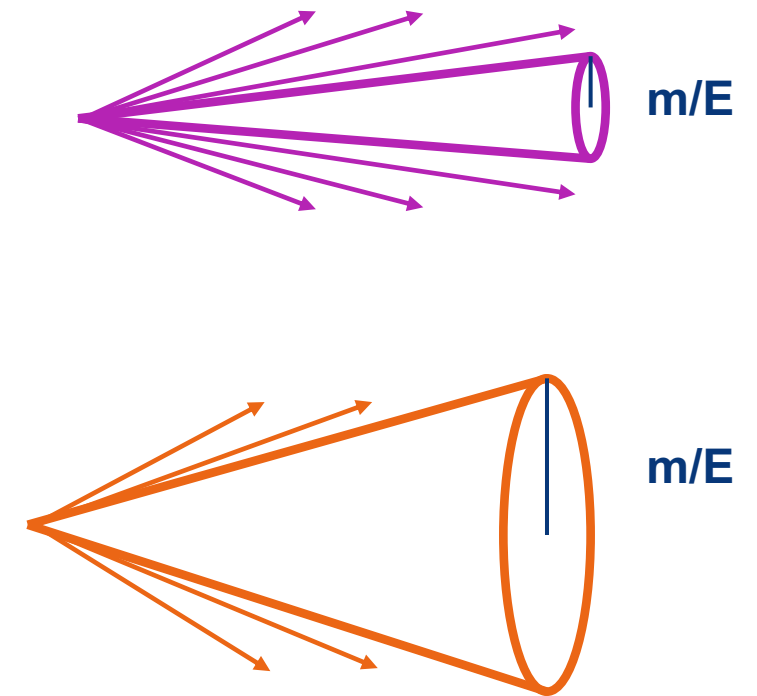■ $p+p$
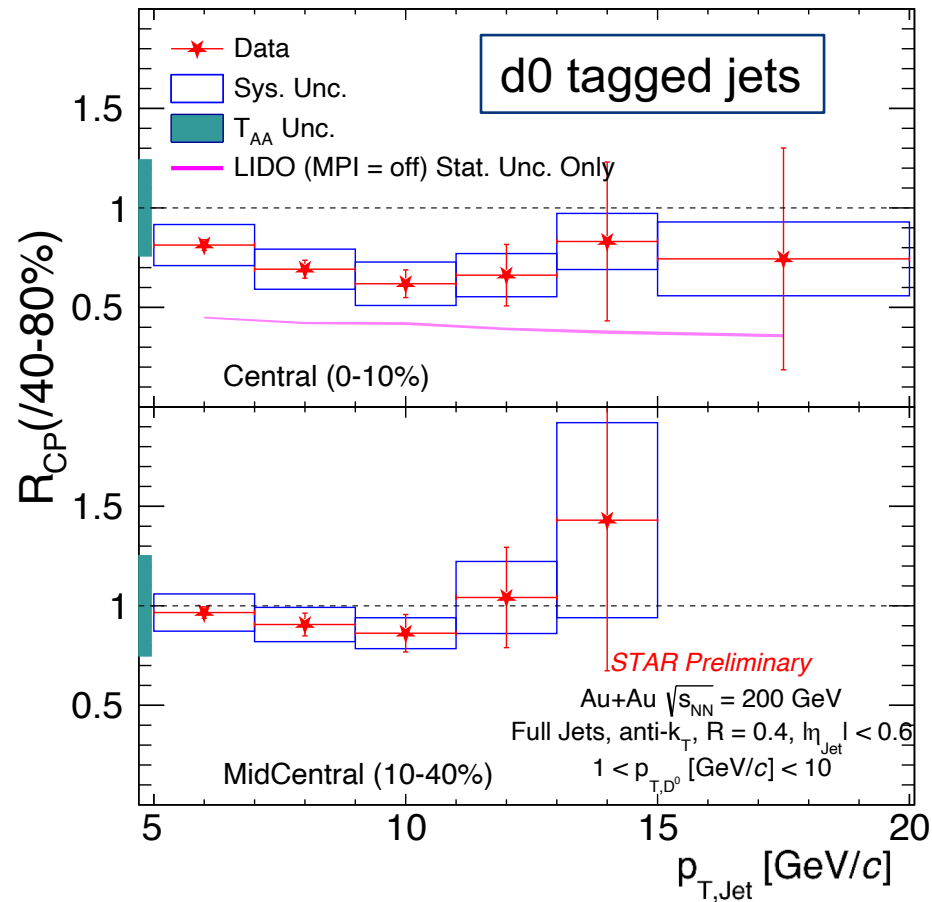● Au+Au (0-10%)

sPHENIX beam use proposal

$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$
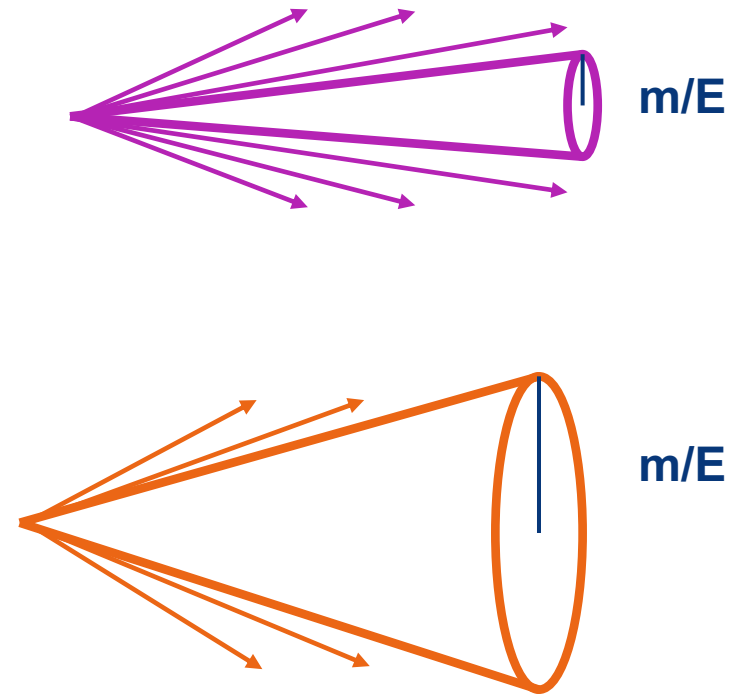
…as a function of mass

Measurements at **RHIC**

…as a function of mass

Measurements at the LHC

ATLAS
Pb+Pb 2018, 1.4(1.7) nb^{-1}
pp 2017, 260 pb^{-1}
anti-k_t $R = 0.2$ jets, $|y| < 2.1$
$\sqrt{s_{NN}} = 5.02$ TeV, Centrality 0-20%

LIDO model b-jets
LIDO model light-jets
Dai et al. b-jets
Dai et al. inclusive jets

● b-jets   ○ inclusive jets

R_{AA} p_T [GeV]

m/E

m/E

Eur. Phys. J. C (2023) 83:438

…as a function of mass

Future RHIC measurements
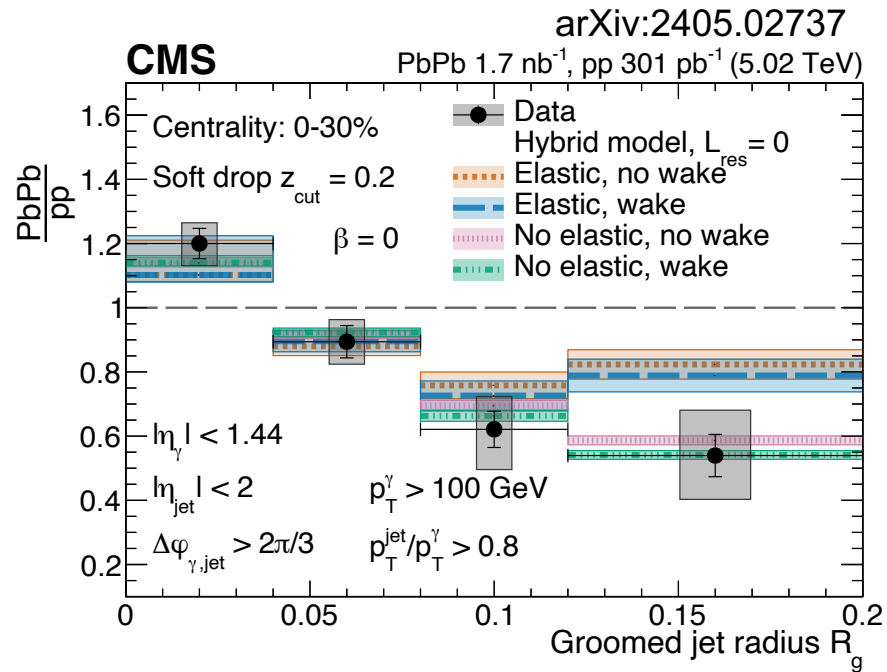
sPHENIX beam use proposal
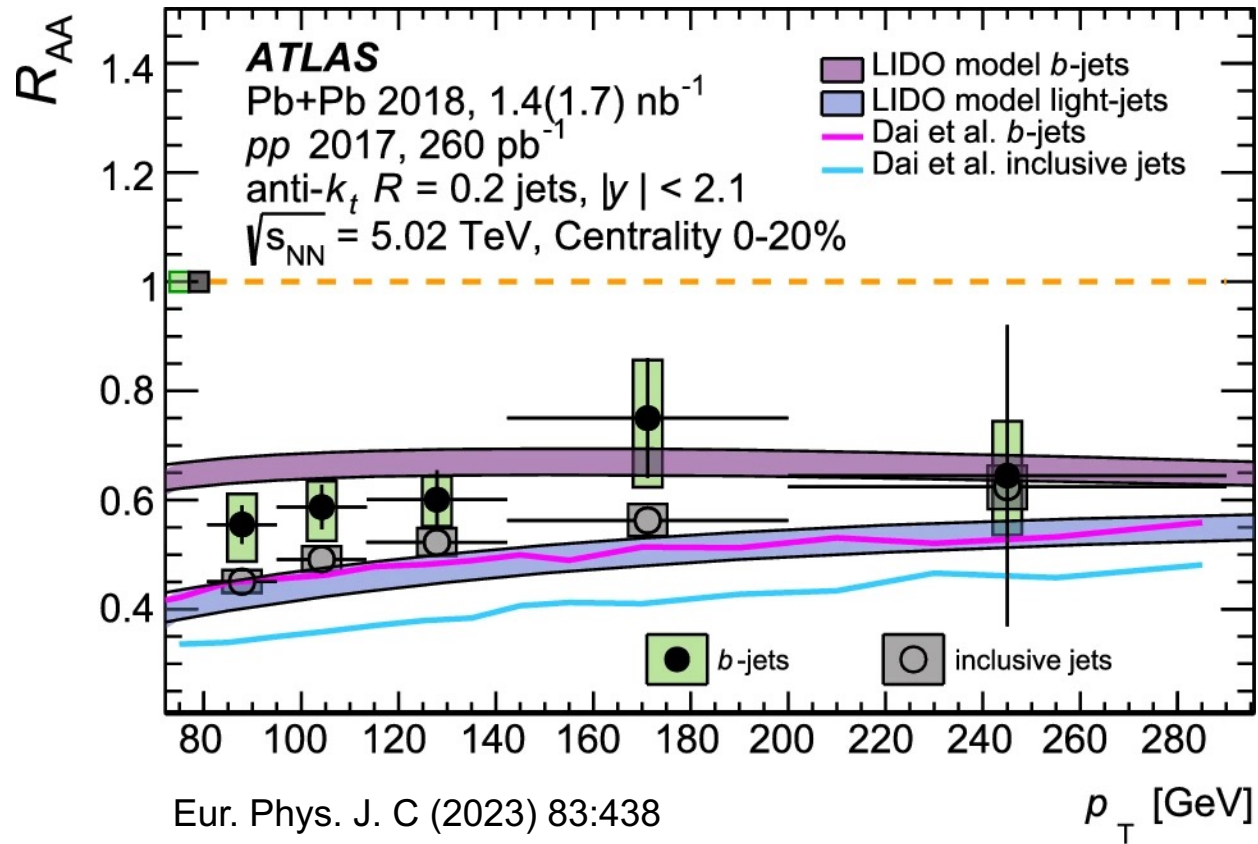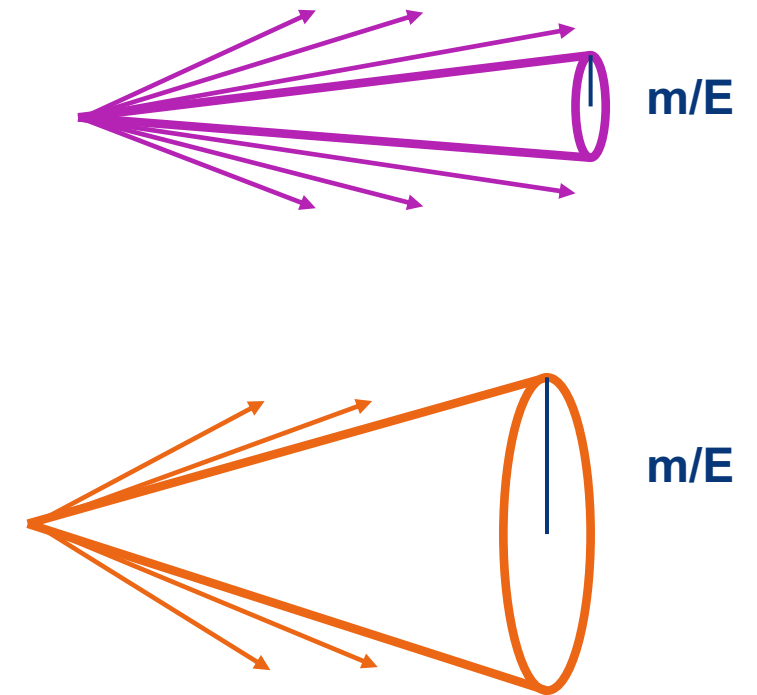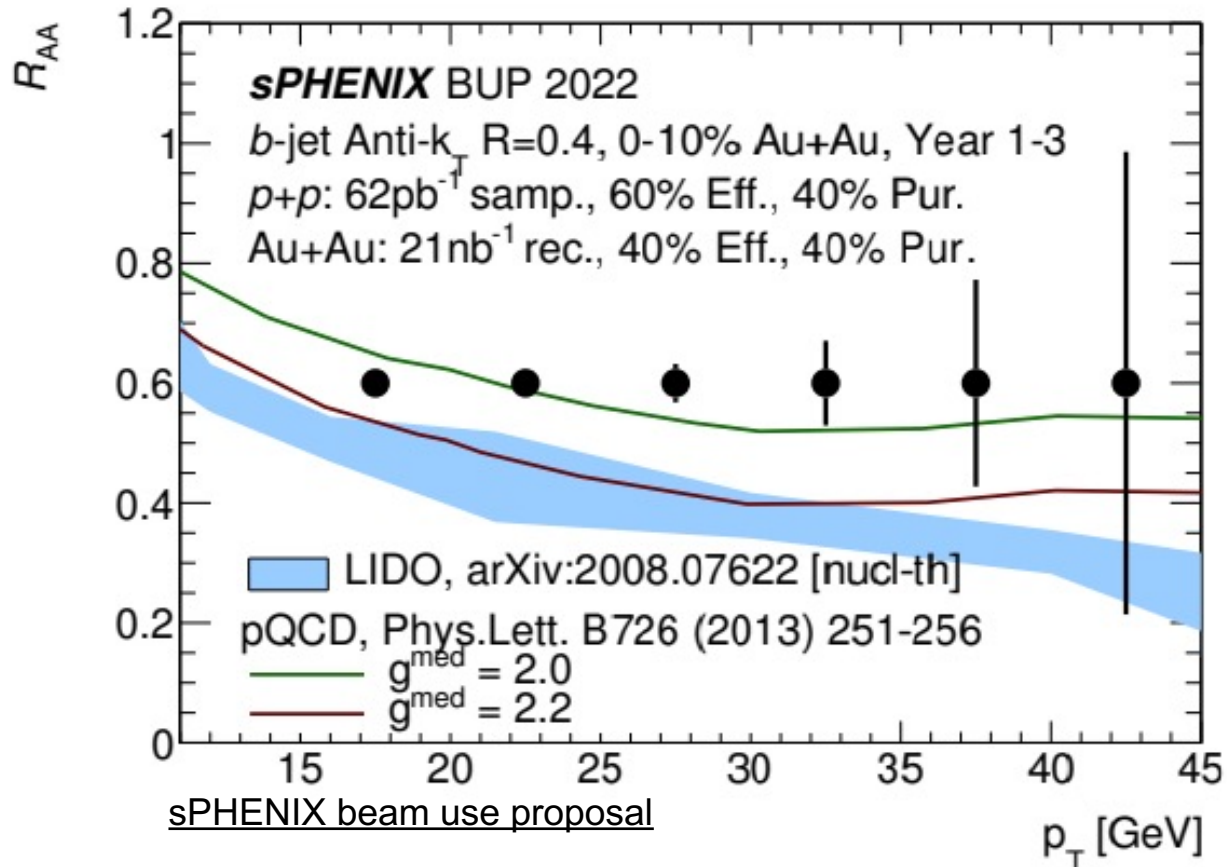
Next generation measurements

High statistics data = more differential measurements of jet quenching

Measurements at the LHC

arXiv:2405.02737

Photon tagged substructure

Future RHIC measurements
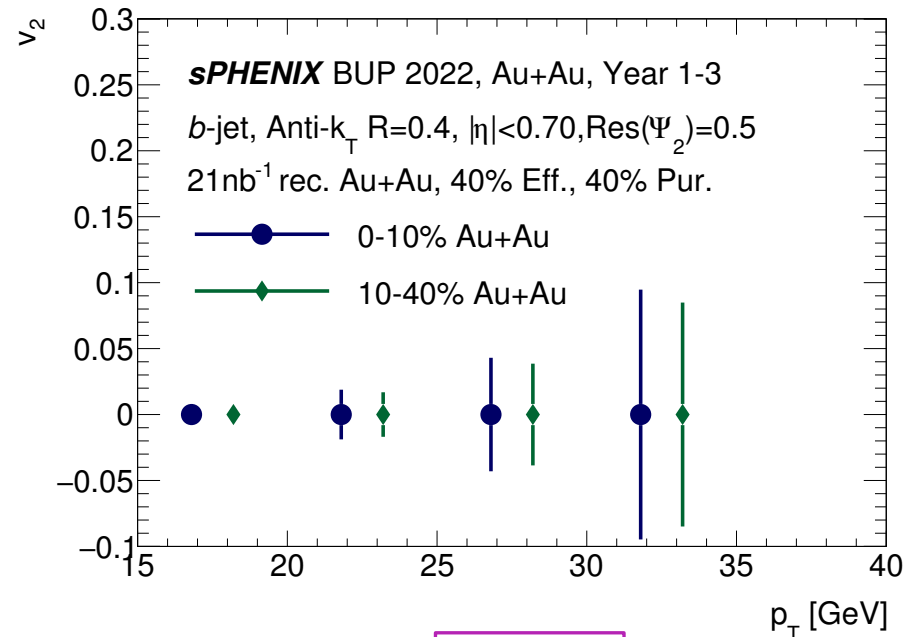
b-jet v_2
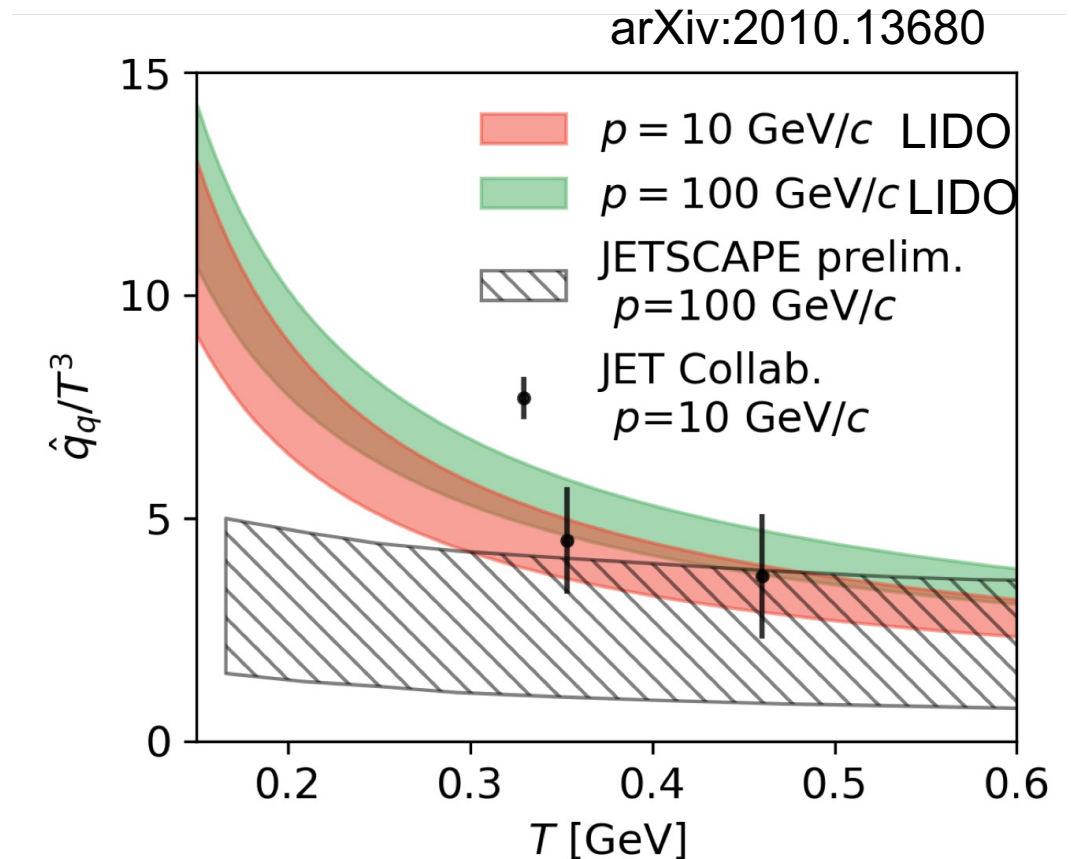
+ much more

How to extract information about QGP?

- Need models to relate measurements to QGP

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- Bayesian analysis allows for extraction of QGP parameters from many measurements

- Can include data from RHIC and LHC

arXiv:2010.13680

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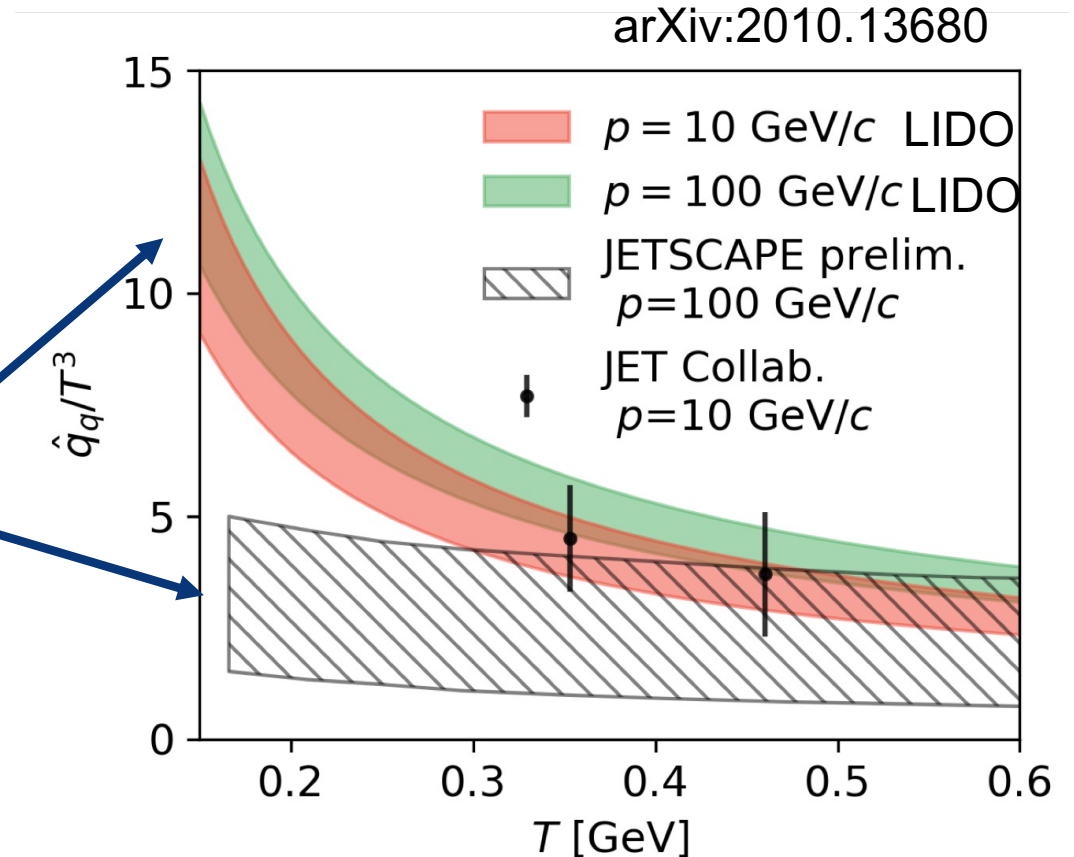
- Can include data from RHIC and LHC

Different models get different temperature dependence

arXiv:2010.13680

Conclusion

- Jet measurements at RHIC and the LHC provide complimentary measurements
  - Vary temperature of QGP
  - Vary jet population
  - Vary kinematic coverage

- Combining measurements from RHIC and the LHC in Bayesian analysis can help extract properties of the QGP

- High statistics data allows for more precise and more differential measurements of jet quenching
  - LHC run 3
  - sPHENIX + continued STAR running at RHIC

sPHENIX Experiment at RHIC
Collisions: p + p @ $\sqrt{S_{NN}} = 200$ GeV
Run 43266, Event 1380649