Recent jet physics results from STAR and ALICE

ANPhA 2025 symposium

November 29, 2025, Institute of Physics, Academia Sinica

Saehanseul Oh (Sejong University, LBL)

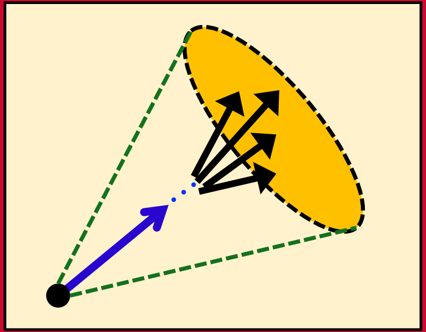
Scope of this talk

Recent Highlights from the STAR Experiment at RHIC (remote) *Institute of Physics, Academia Sinica*	*Chunjian Zhang* 10:20 - 10:45	STAR
Recent results from the ALICE experiment at LHC *Institute of Physics, Academia Sinica*	*Yorito Yamaguchi* 11:05 - 11:30	ALICE
Recent Quarkonia results of CMS heavy ion experiments *Institute of Physics, Academia Sinica*	*Yongsun Kim* 14:00 - 14:25	CMS
PHENIX experiment at RHIC and Japan-Korea collaboration *Institute of Physics, Academia Sinica*	*Yasuyuki Akiba* 09:20 - 09:45	PHENIX
Successful Asian Collaboration in sPHENIX Experiment at RHIC *Institute of Physics, Academia Sinica*	*Itaru Nakagawa* 09:45 - 10:10	sPHENIX

Recent jet physics results from STAR and ALICE *Institute of Physics, Academia Sinica*	*Saehanseul Oh* 10:40 - 11:05

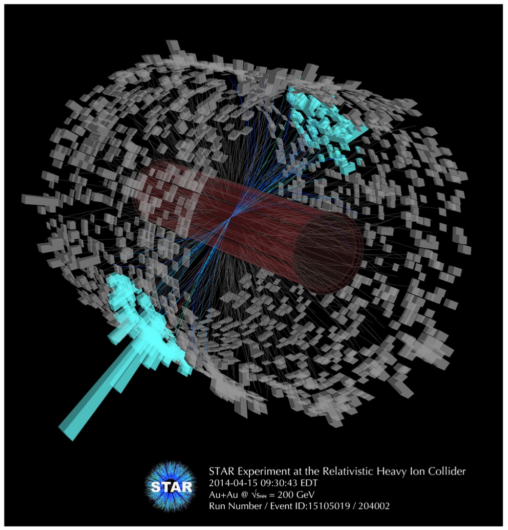
- This talk focuses on **jet physics** results from ALICE and STAR, particularly from **Asian** institutions 

Within ~2 years

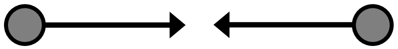


Recent jet physics results from STAR and ALICE

- A collimated spray of particles that emerge from the hadronization of an original high-momentum parton → Jets are **proxies** of **partons**
- Experimentally, jets are defined by a clustering algorithm

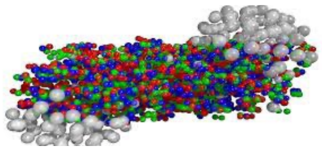


Recent jet physics results from STAR and ALICE



Proton-proton collisions

- Test the predictions of pQCD – a direct manifestation of QCD
- Work as a "vacuum" baseline



Heavy-ion collisions

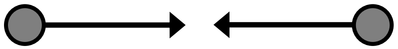
- Interaction between the QGP and jets – Jet quenching
- Probe the inner-working of QGP

Recent jet physics results from STAR and ALICE

Jets in STAR and ALICE

- Access to lower transverse momentum particles relative to CMS/ ATLAS – benefit in substructure studies
- Complementary to each other

Recent jet physics results from STAR and ALICE



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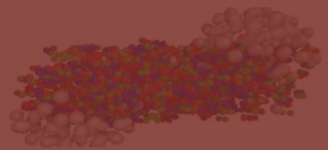


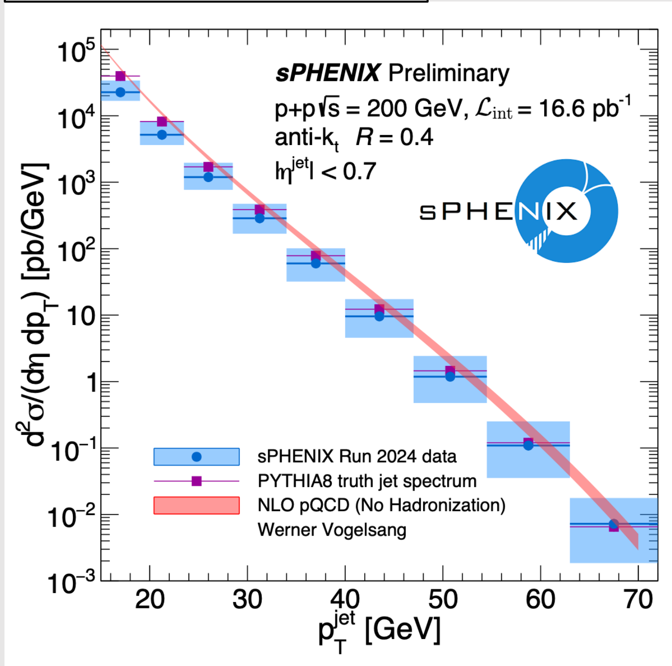
Heavy-ion collisions

- Interaction between the QGP and jets – Jet quenching
- Probe the inner-working of QGP

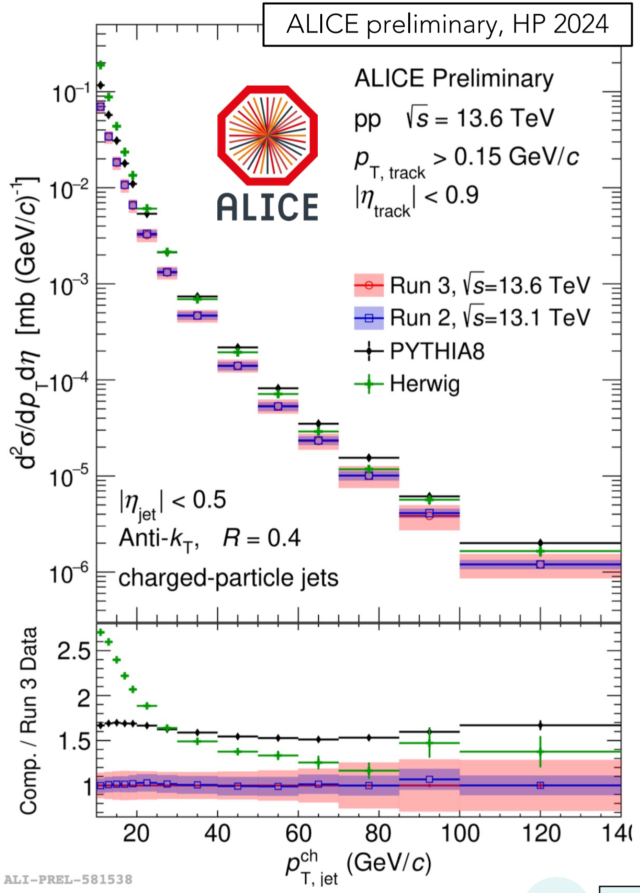
Jet cross section

- **First jet physics results** from **sPHENIX** at RHIC
- ~15% of total luminosity in 2024 *pp* data
- Already significantly higher $p_{T,jet}$ reach than other RHIC results
- Comparison with the PYTHIA 8 Detroit tune, and NLO pQCD calculations without hadronization

sPHENIX preliminary, QM 2025



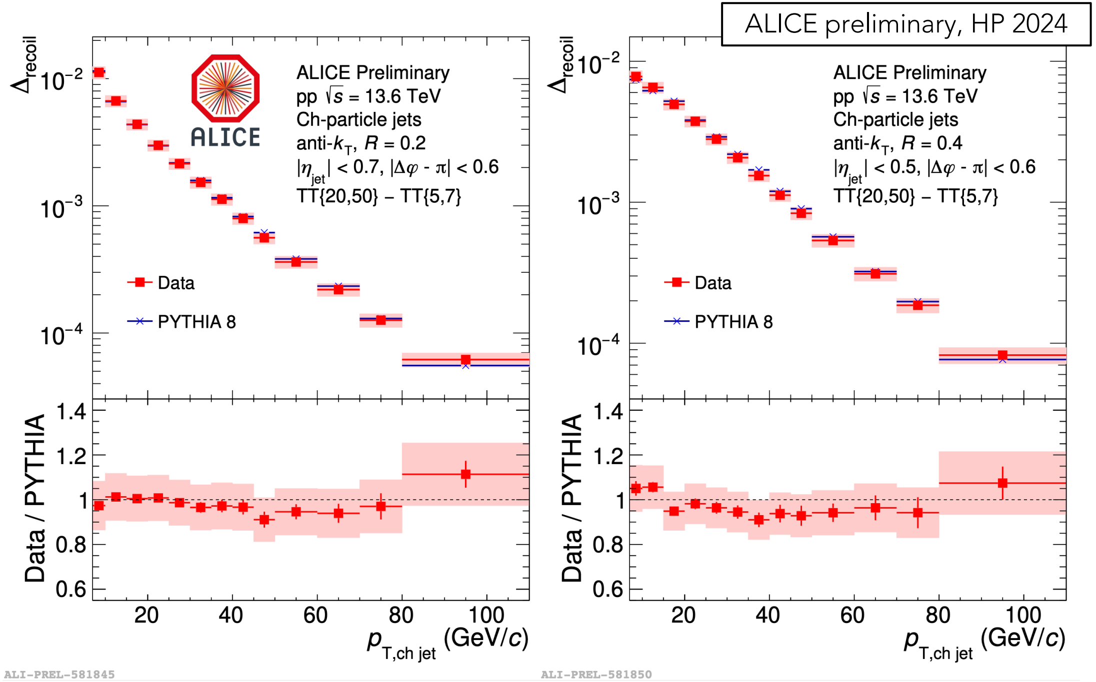
Jet cross section



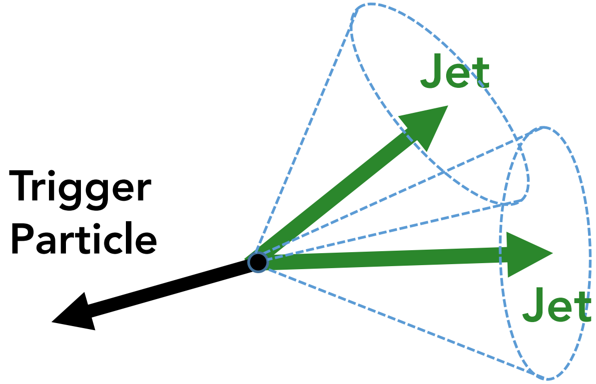
- First jet cross section results with 13.6 TeV *pp* data (Run 3)
  - ✓ Based on small fraction of 2022 data → Further statistics with 2023 and 2024 data
  - ✓ Consistent with 13 TeV (Run 2) results within uncertainties, but theoretical models do not describe the data well

J. Bae (SKKU)

Semi-inclusive jet yield



R = 0.2 **R = 0.4**



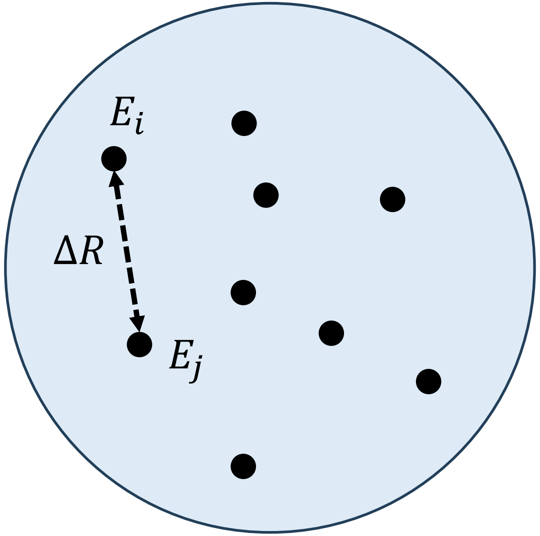
- Semi-inclusive jet yield (h+jet) with Run 3 data (2022 only)
- Good agreement with PYTHIA
- Reference for the upcoming studies in Pb-Pb collisions

Jet substructure – EEC

- Energy-energy correlator (Two-point correlator)

$$\text{Normalized EEC} = \frac{1}{\sum\limits_{jets}\sum\limits_{i\neq j}\left(\frac{E_i E_j}{p^2_{\mathrm{T,jet}}}\right)} \frac{\mathrm{d}\left(\sum\limits_{jets}\sum\limits_{i\neq j}\left(\frac{E_i E_j}{p^2_{\mathrm{T,jet}}}\right)\right)}{\mathrm{d}R_L}$$

- Constituents' pairwise distance weighted with the energy



Jet substructure – EEC

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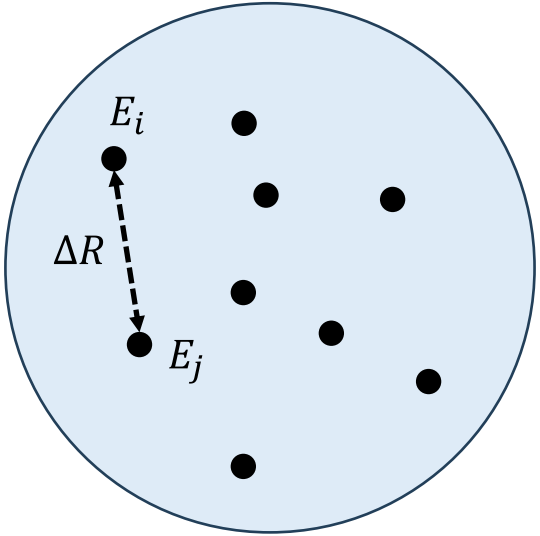


- Constituents' pairwise distance weighted with the energy

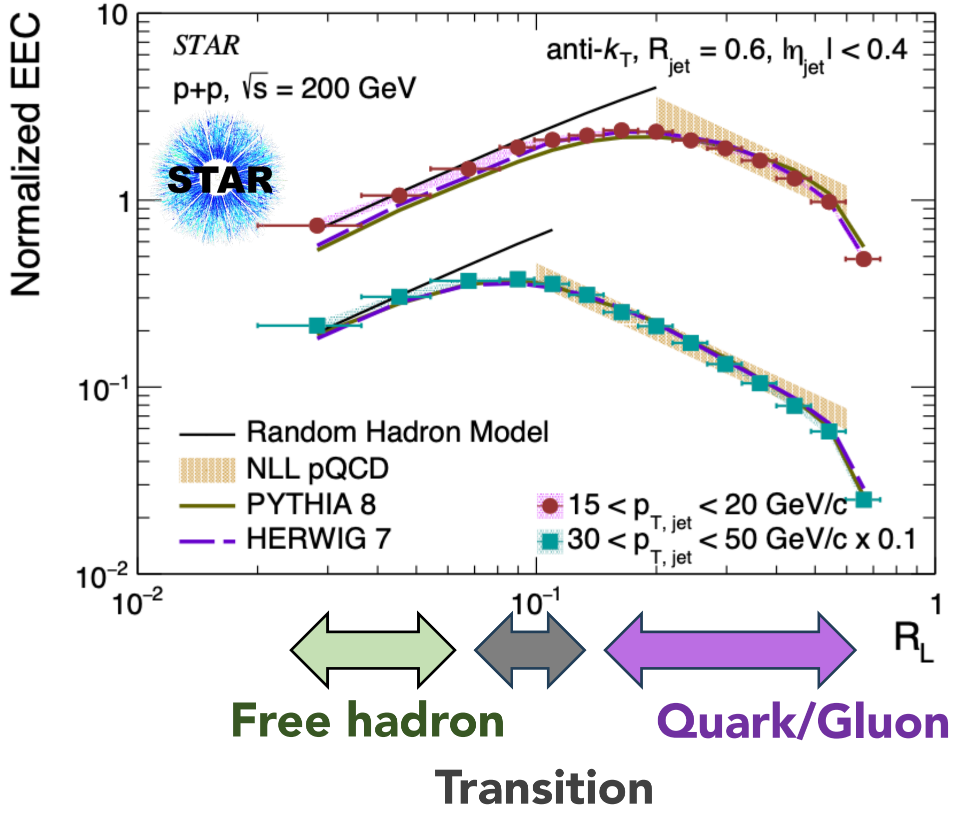
- Why is the observable hyped recently?

  ✓ Final-state jet constituents are used as they are ← No additional clustering or grooming required

  ✓ Potential separation of scales → Non-perturbative, perturbative, and transition regions → Crucial for physics with multi-scale processes

Jet substructure – EEC

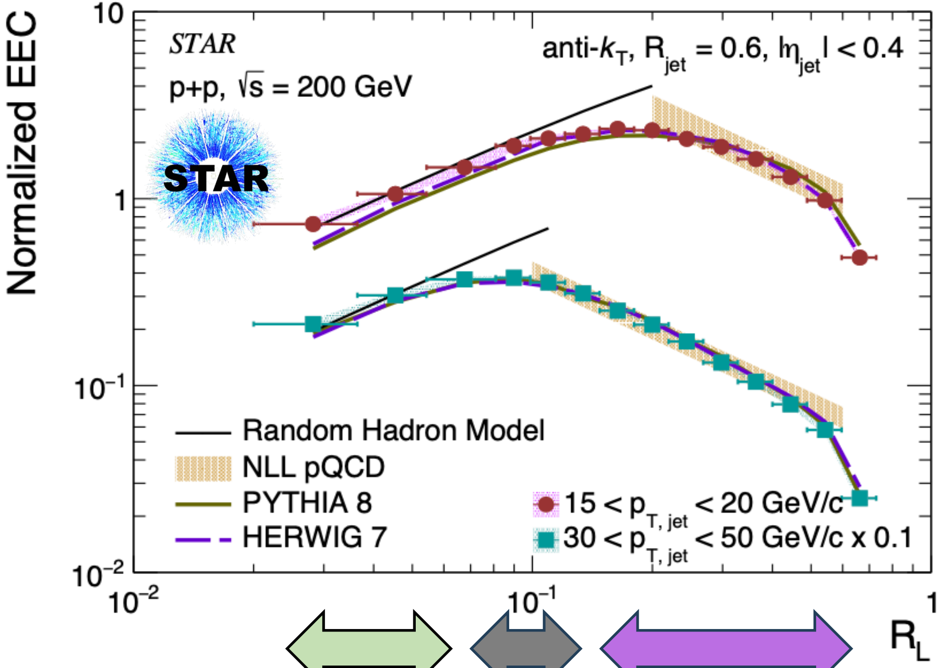
STAR, Phys. Rev. Lett. 135 (2025) 111901



- Theoretical predictions well agree with the data
  - ✓ pQCD for perturbative regime
  - ✓ Random hadron model for non-perturbative regime

Jet substructure – EEC

STAR, Phys. Rev. Lett. 135 (2025) 111901

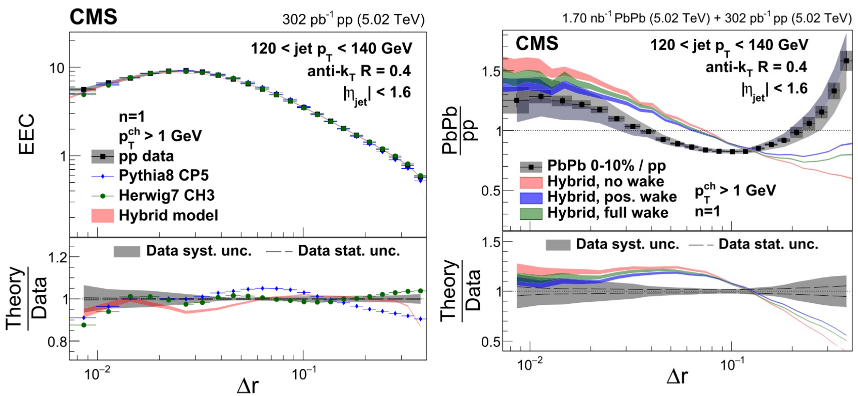


Free hadron

Transition

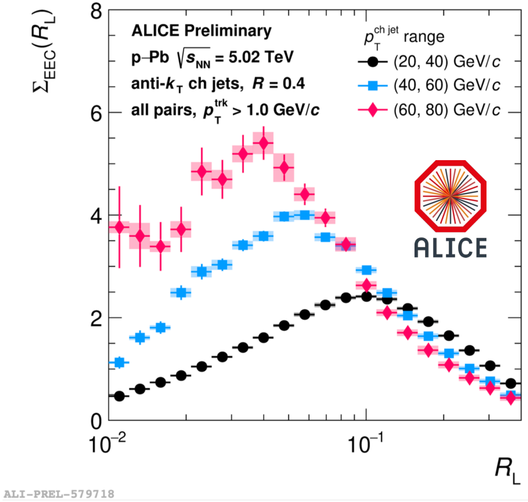
Quark/Gluon

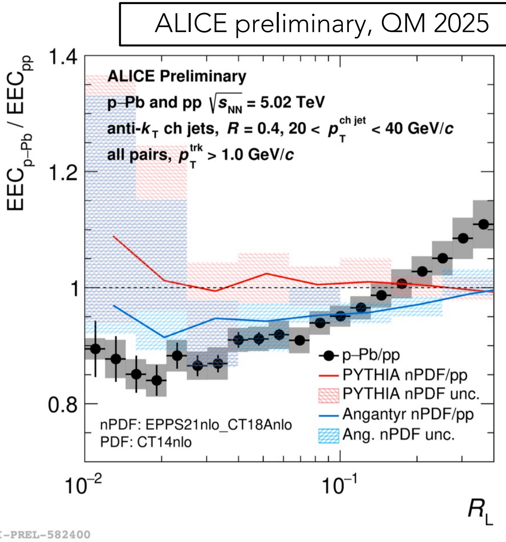
CMS, PLB 866 (2025) 139556



- Further measurements in AA are expected at RHIC

Jet substructure – EEC

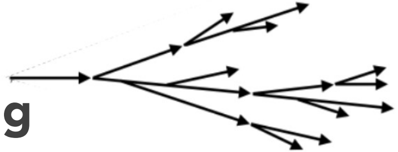




- EEC in p-Pb collisions
  - ✓ Different initial state / Final interaction coming into play?

- Significant difference between pp and p-Pb observed at low $p_{T,jet}$
- nPDF models do not explain the data
- Modification could come from a relative increase in high constituent multiplicity jets

Heavy-flavor jet tagging



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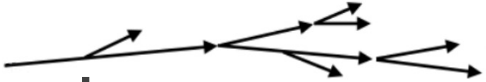
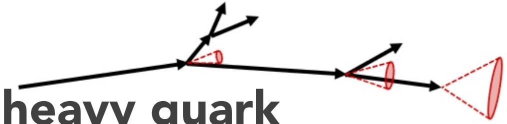
- Broader shower profile, more emissions
- Cassimir color factor (Different amount of color charge carried by quarks and gluons)



quark

- Narrower shower profile

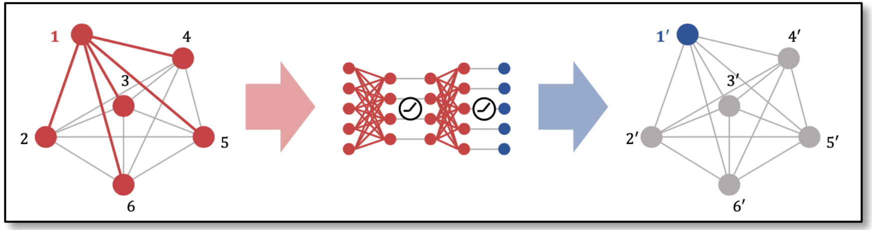


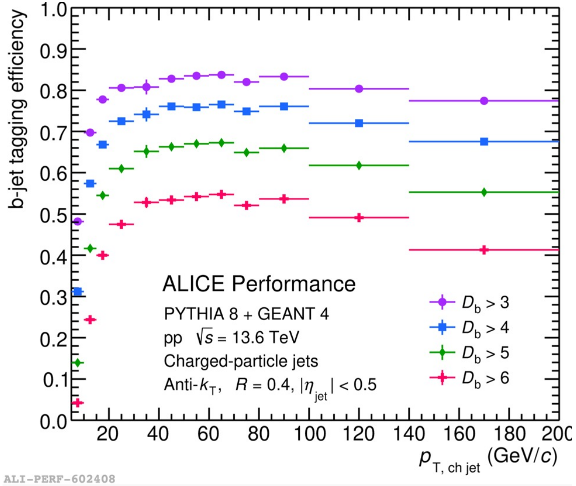
heavy quark

- Suppression of small angle emissions (dead-cone effect)
- Harder fragmentation

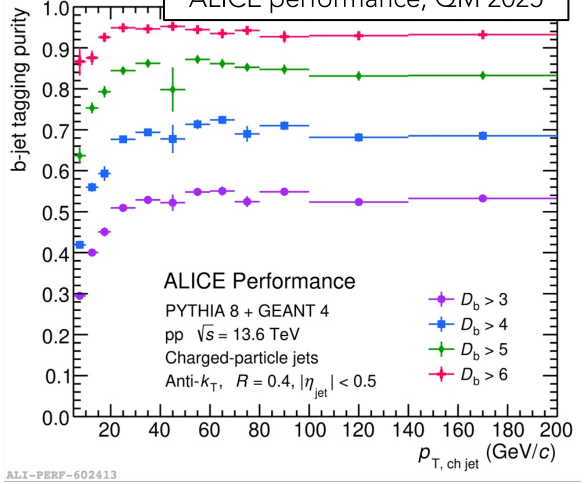
How to better identify heavy-flavor jets?

Heavy-flavor jet tagging





ALICE performance, QM 2025



- Graph Neural Network (GNN)
  - ✓ Superior b-jet tagging performance compared to traditional tagging methods

C. Choi (PNU)

Heavy-flavor jet tagging

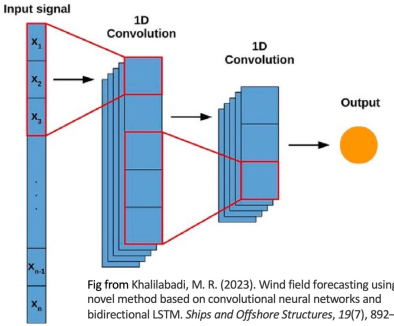
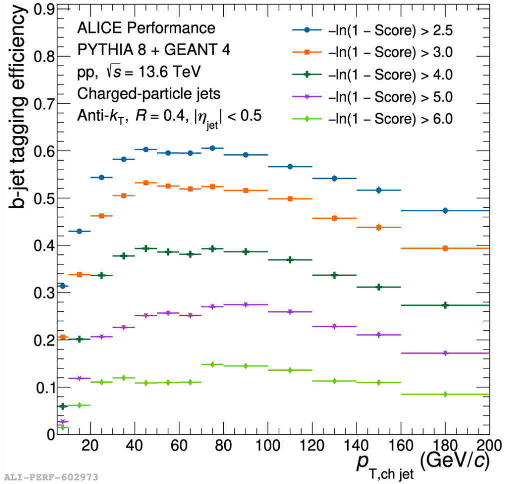
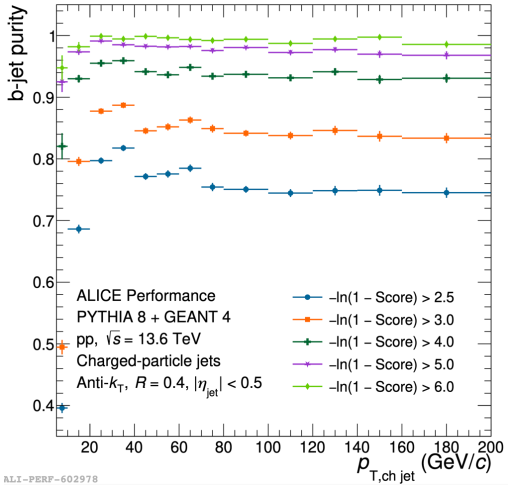


Fig from Khalilabadi, M. R. (2023). Wind field forecasting using a novel method based on convolutional neural networks and bidirectional LSTM. *Ships and Offshore Structures*, *19*(7), 892–900.

ALICE performance, QM 2025



H. Park (Tsukuba U)



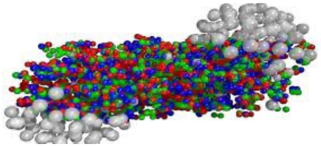
- 1-D convolutional Neural Network (CNN)
  - ✓ Superior b-jet tagging performance compared to traditional tagging methods

These results will be a basis for the next b-jet measurements

Recent jet physics results from STAR and ALICE

Proton-proton collisions

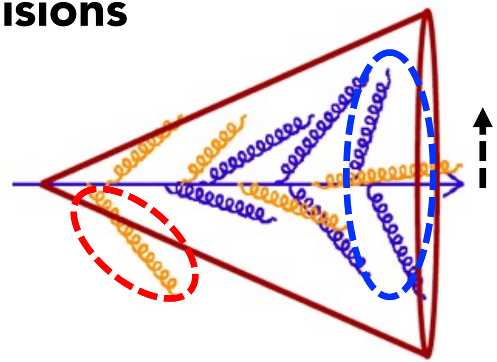
- Test the predictions of pQCD – a direct manifestation of QCD
- Work as a "vacuum" baseline



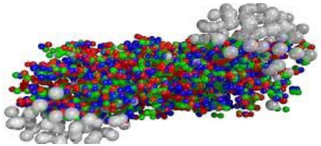
Heavy-ion collisions

- Interaction between the QGP and jets – Jet quenching
- Probe the inner-working of QGP

Jet quenching in heavy-ion collisions



- Jet energy loss
- Jet substructure modification
- Jet deflection



Heavy-ion collisions

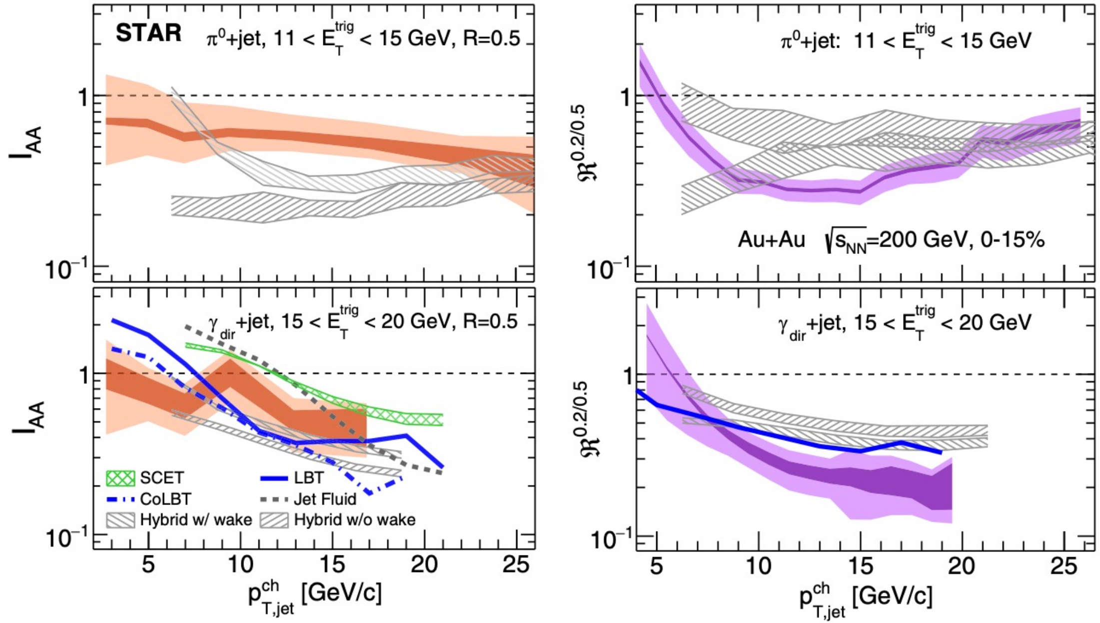
- Interaction between the QGP and jets – Jet quenching
- Probe the inner-working of QGP

Direct γ/π^0+jet

Jet energy loss
Jet substructure modification
Jet deflection

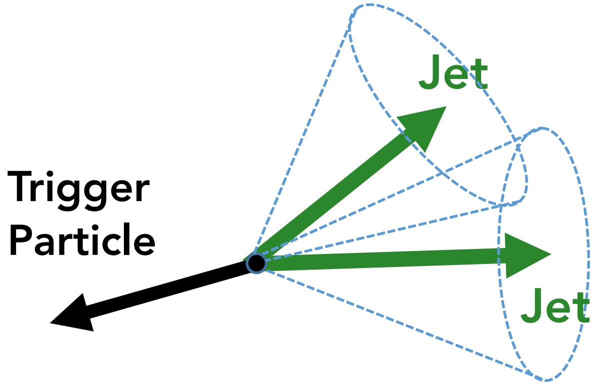
STAR, PRL 134 (2025) 232301

STAR, PRC 111 (2025) 64907



N. Sahoo (Shandong U., IISER)

- Semi-inclusive γ+jet and π^0+jet
  - ✓ Parton content (q vs. g)
  - ✓ Path length



Direct γ/π^0+jet

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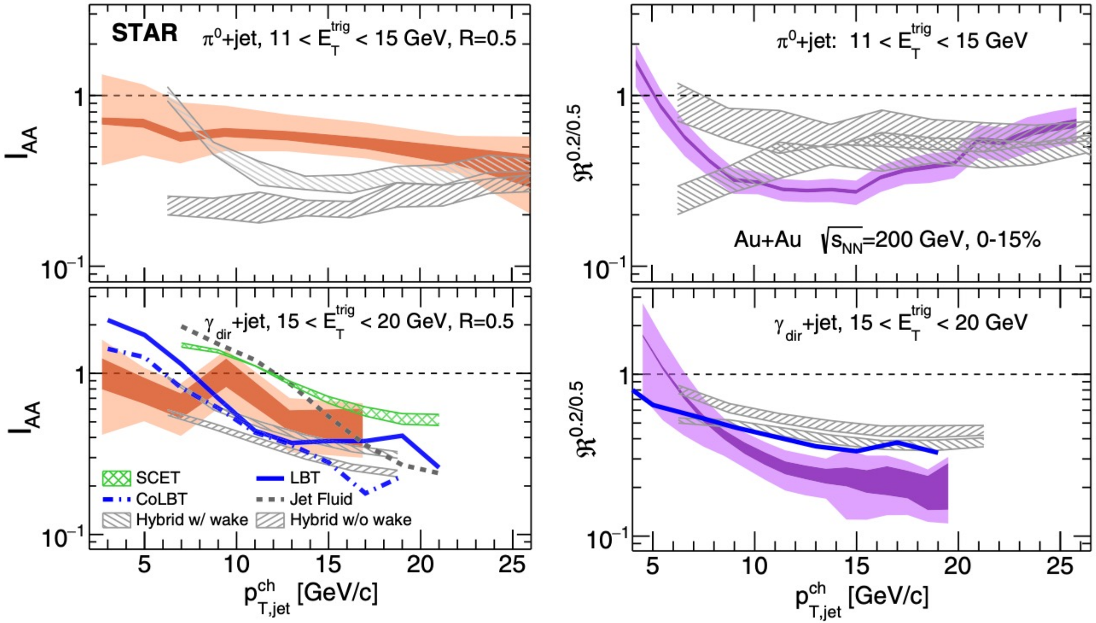
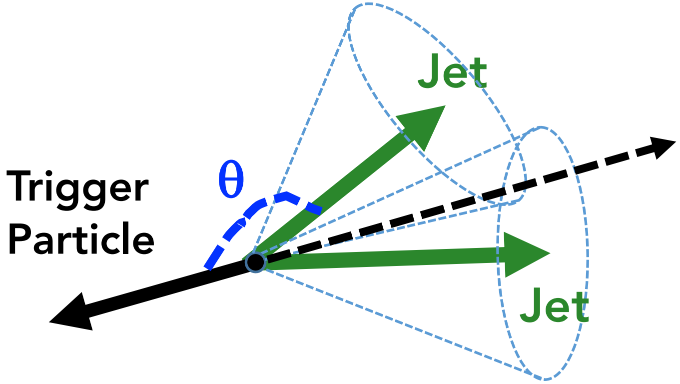
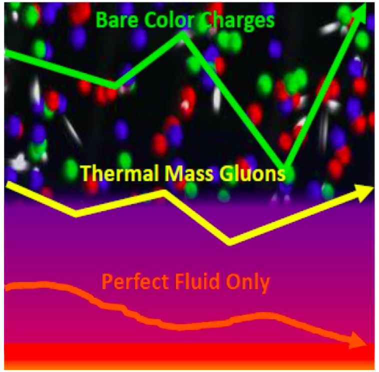


- Semi-inclusive γ+jet and π^0+jet
  - ✓ Parton content (q vs. g)
  - ✓ Path length

- Significant intra-jet broadening, not fully consistent with model calculations
- No significant difference observed between two triggers

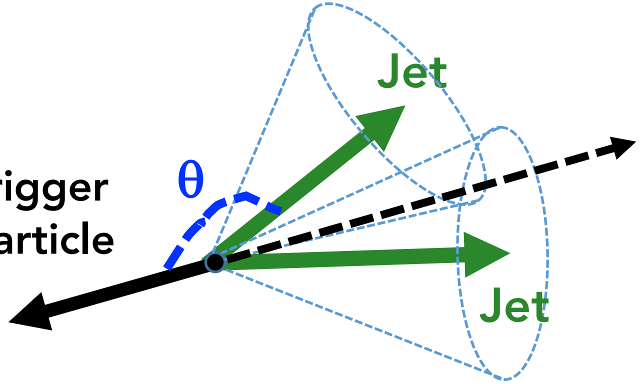
Jet acoplanarity





- Jet acoplanarity – Azimuthal deviation from the trigger axis
  - ✓ Single Rutherford-like scattering off of QGP quasiparicles or response of the QGP medium by a jet (jet wake)?

Jet acoplanarity



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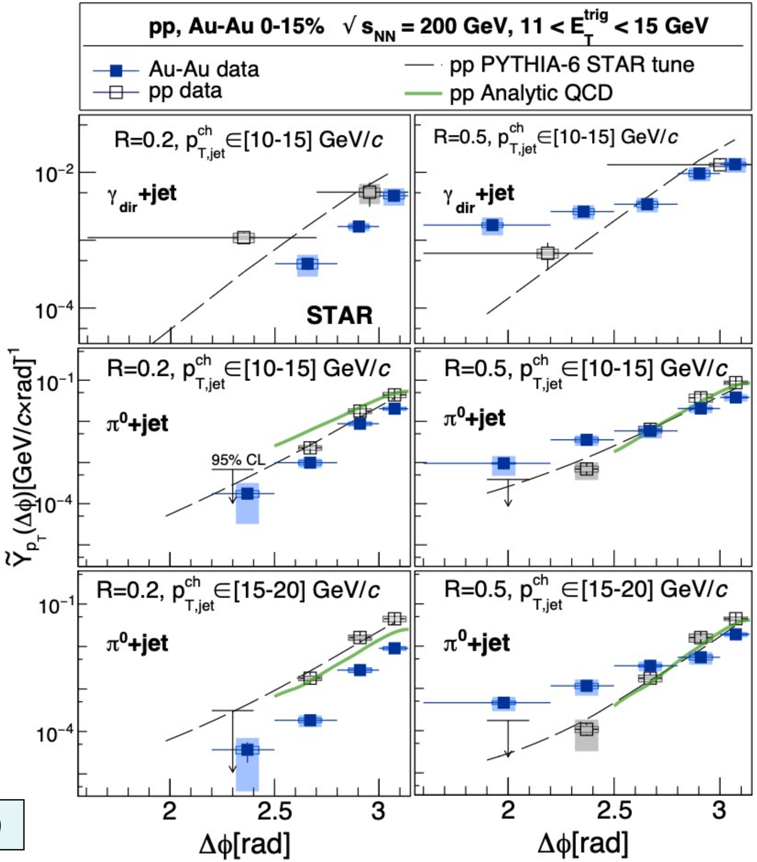
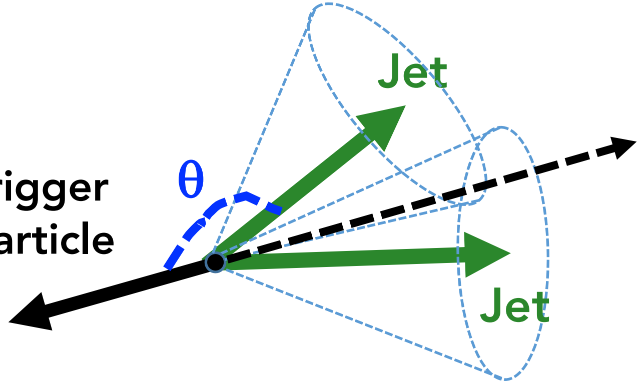
STAR, PRC accepted



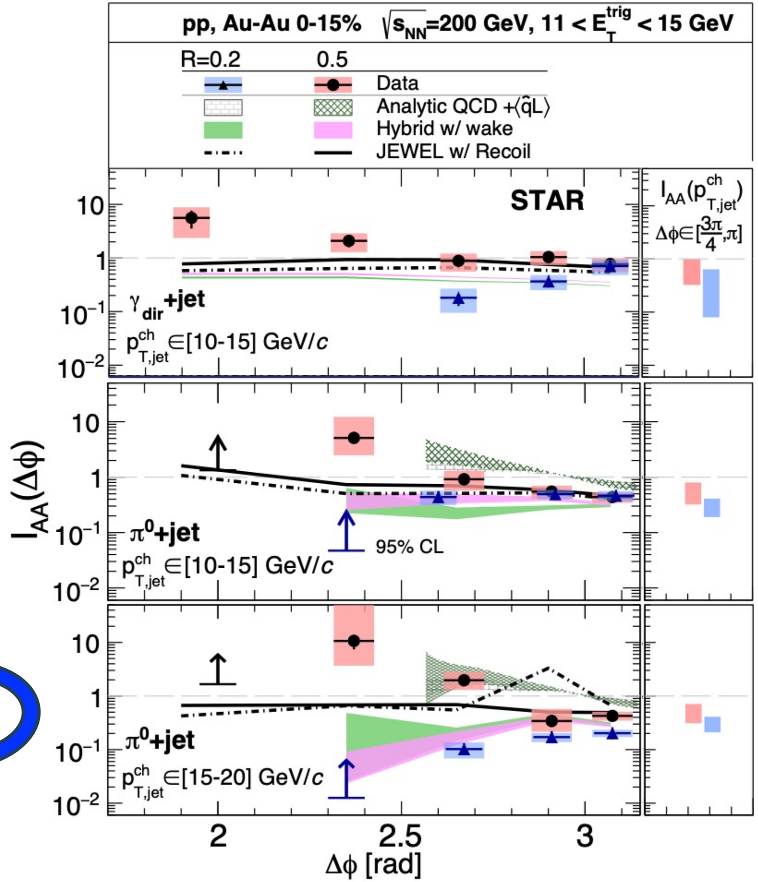
N. Sahoo (Shandong U., IISER)

Jet acoplanarity



- Jet acoplanarity – Azimuthal deviation from the trigger axis
  - ✓ Single Rutherford-like scattering off of QGP quasiparicles or response of the QGP medium by a jet (jet wake)
- *R*-dependent medium-induced acoplanarity broadening

STAR, PRC accepted

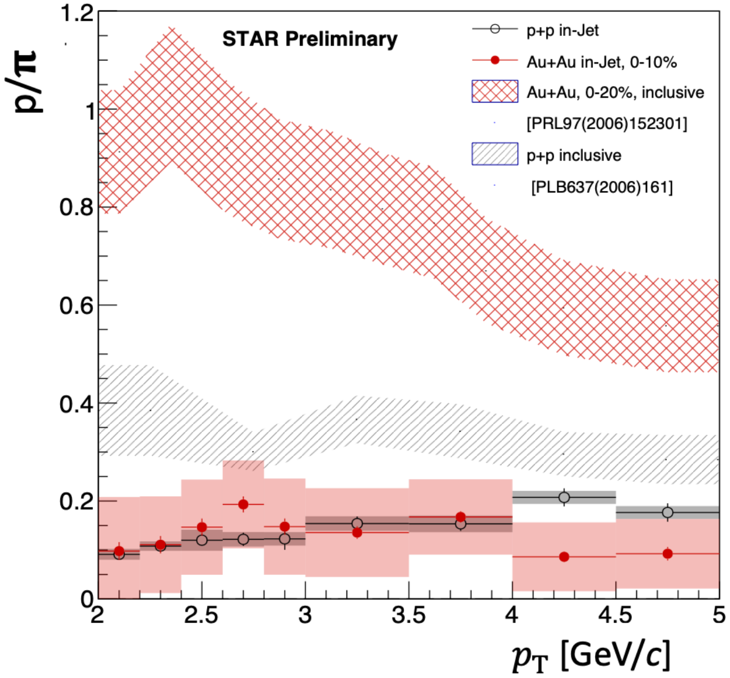


Jet hadrochemistry

- Jet hadrochemistry – p/π ratio in jets
  - ✓ Baryon enhancement + jet quenching?
  - ✓ Theoretical predictions from a while ago
    (Hwa, Yang PRC (2004) / Sapeta, Weidemann, EPJ (2008) / Luo, et al., PLB (2023))

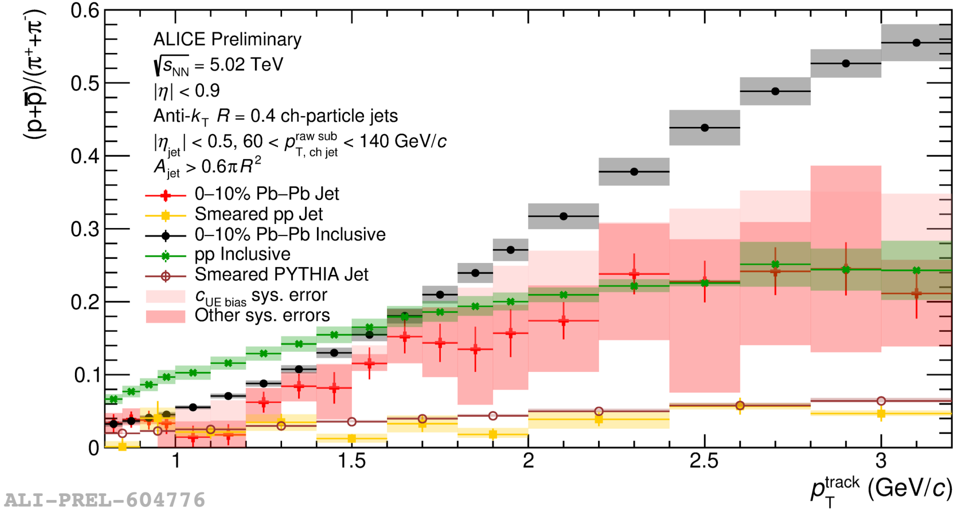
- Similar p/π ratios in jets in *pp* and Au+Au collisions observed, contrasting to the inclusive ratios at 200 GeV

STAR preliminary, QM 2025



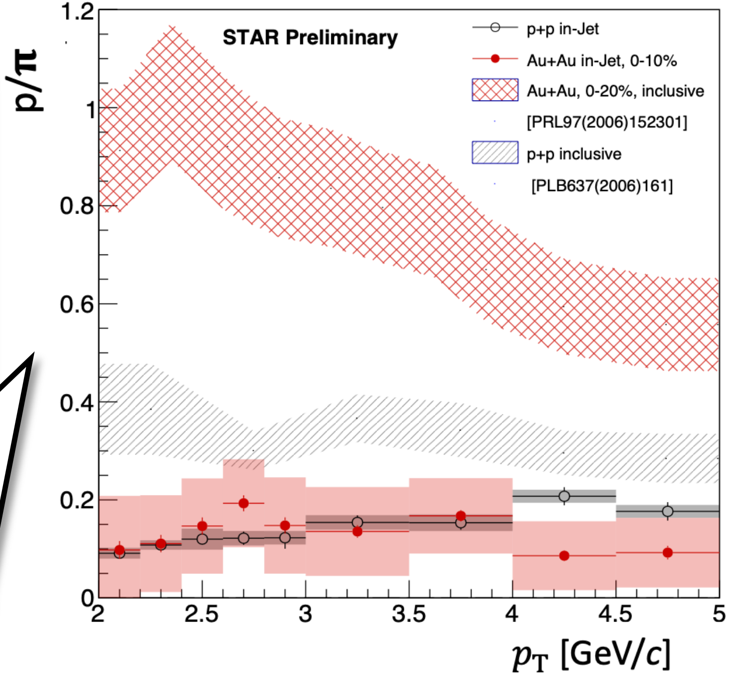
Jet hadrochemistry

ALICE preliminary, QM 2025



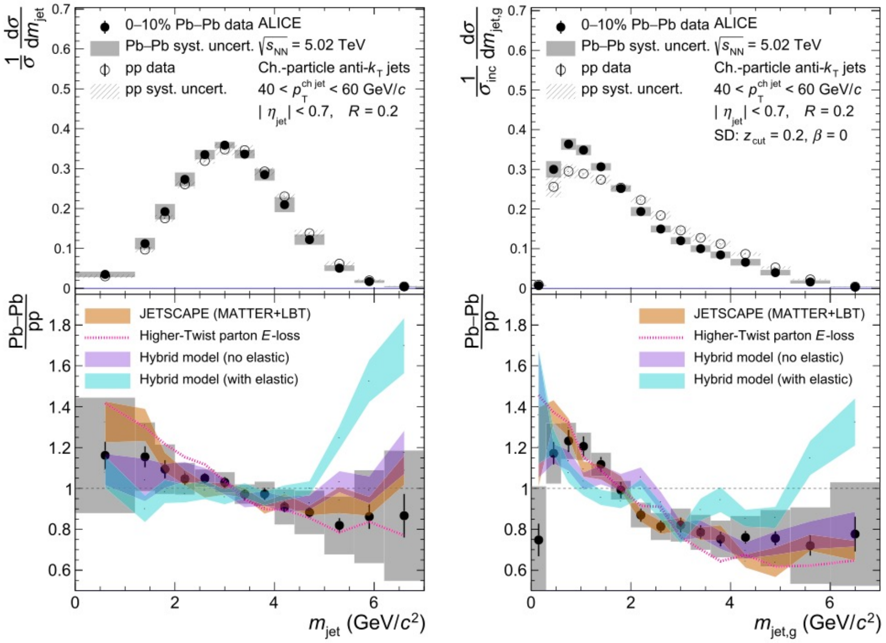
- Baryon enhancement in jets at 5.02 TeV?

STAR preliminary, QM 2025



Jet mass

- **Jet mass** in heavy-ion collisions ← Probe of the modification of parton virtuality evolution in heavy-ion collisions



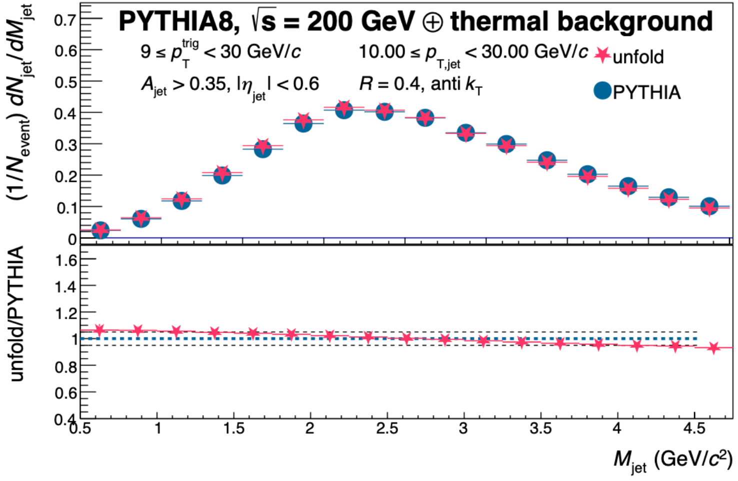
ALICE, PLB 864 (2025) 139409

- ✓ ALICE, Ungroomed and groomed jet mass with R = 0.2
- ✓ Consistent picture of narrowing as jet transverse the QGP
- ✓ Results prefer no in-medium elastic Moliere scattering

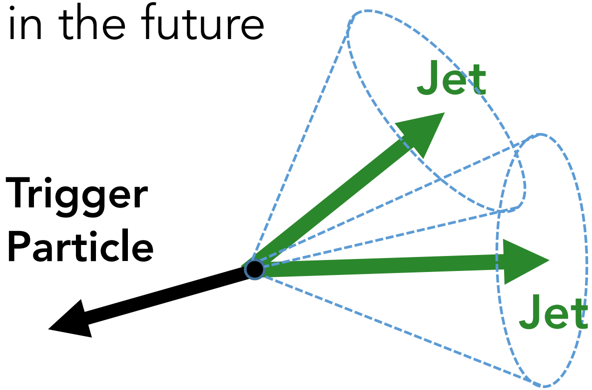
Jet mass

- **Jet mass** in heavy-ion collisions ← Probe of the modification of parton virtuality evolution in heavy-ion collisions

STAR performance, RHIC-AGS meeting 2025



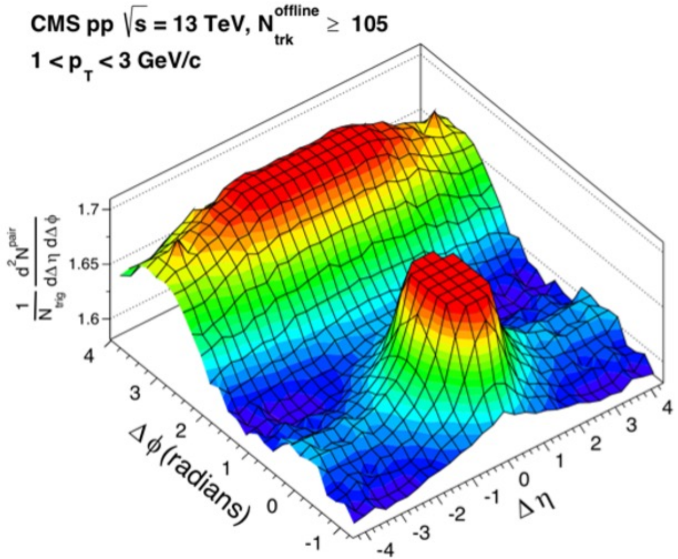
- ✓ STAR – Semi-inclusive jet mass
- ✓ Measurement/correction methods developed
- ✓ Good closure results→ New results coming in the future

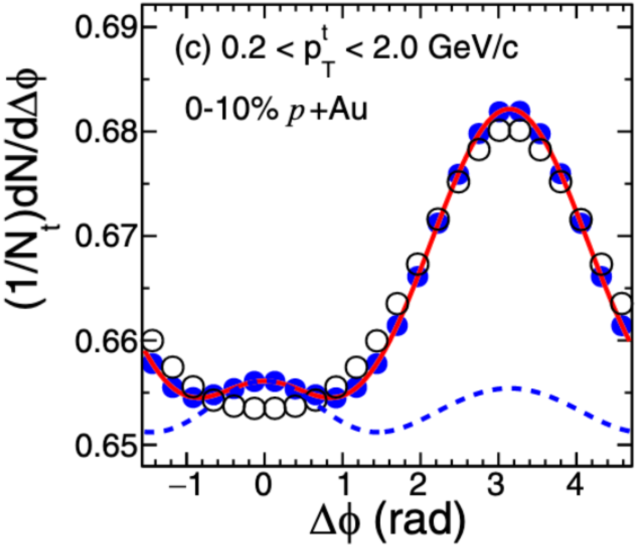


J. Kang (Sejong U)

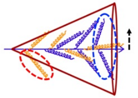
Jet quenching in O+O collisions

- While QGP-like collective behaviors have been observed in high-multiplicity pp and p+A collisions, no clear jet-quenching signal was reported in such small systems





Jet quenching in O+O collisions

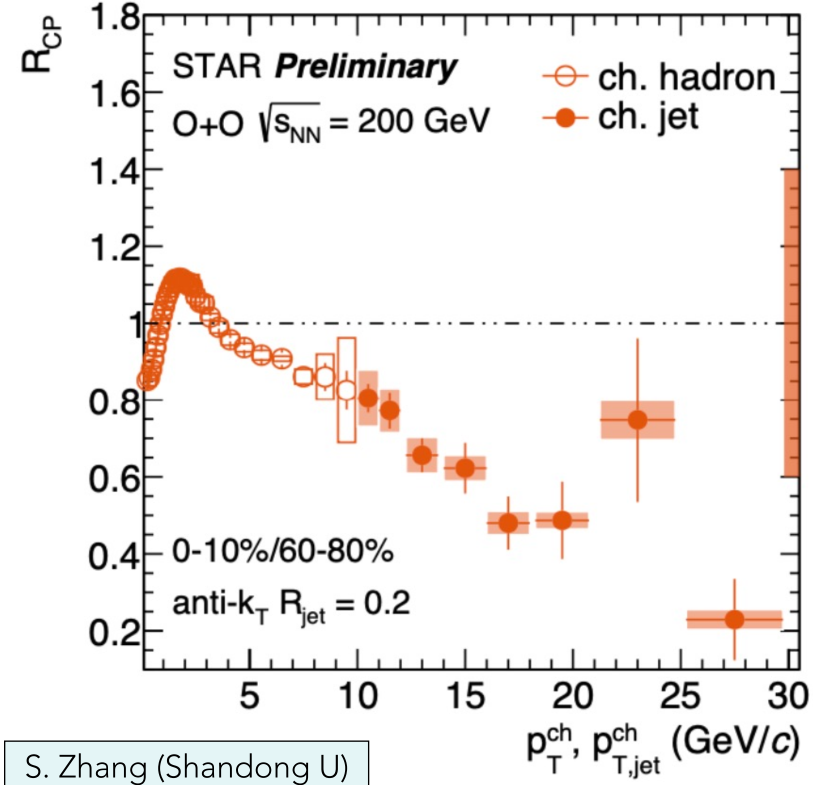


- While QGP-like collective behaviors have been observed in high-multiplicity pp and p+A collisions, no clear jet-quenching signal was reported in such small systems

- Clear collective flow signal is observed in 200 GeV O+O collisions
  → What about jet quenching?

Jet quenching in O+O collisions

STAR preliminary, QM 2025

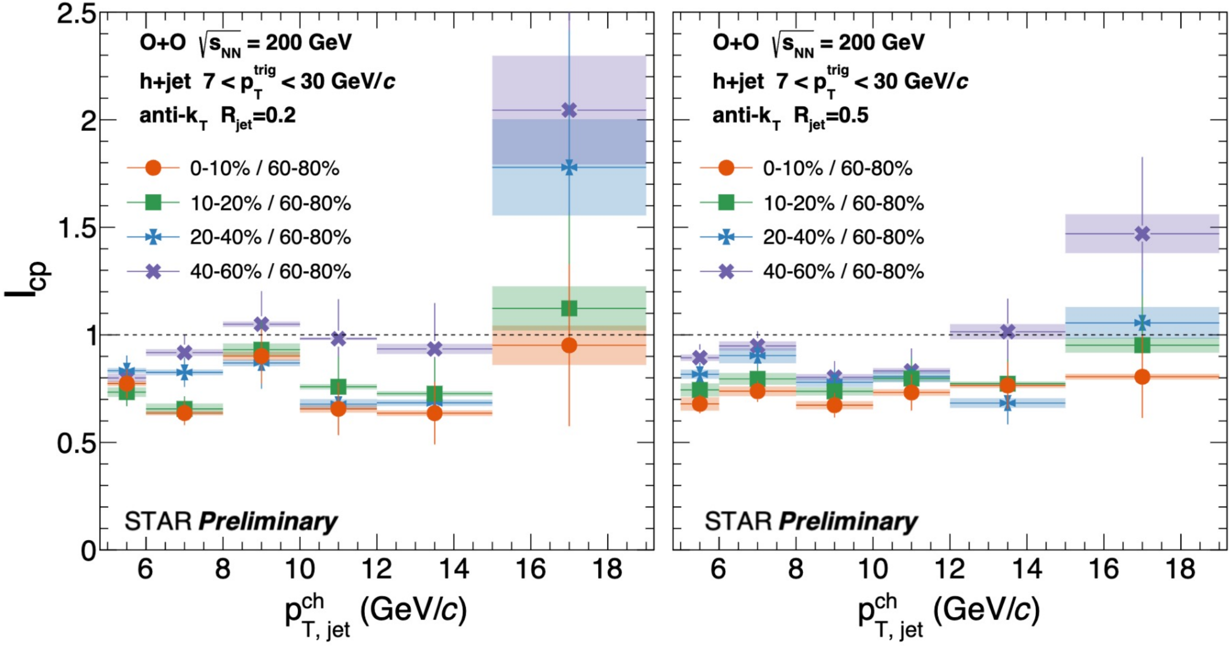


S. Zhang (Shandong U)

- Inclusive jet and hadron R_{CP}
- Similar level of suppression at high p_T is observed, but uncertainty from N_{coll} is very large

Jet quenching in O+O collisions

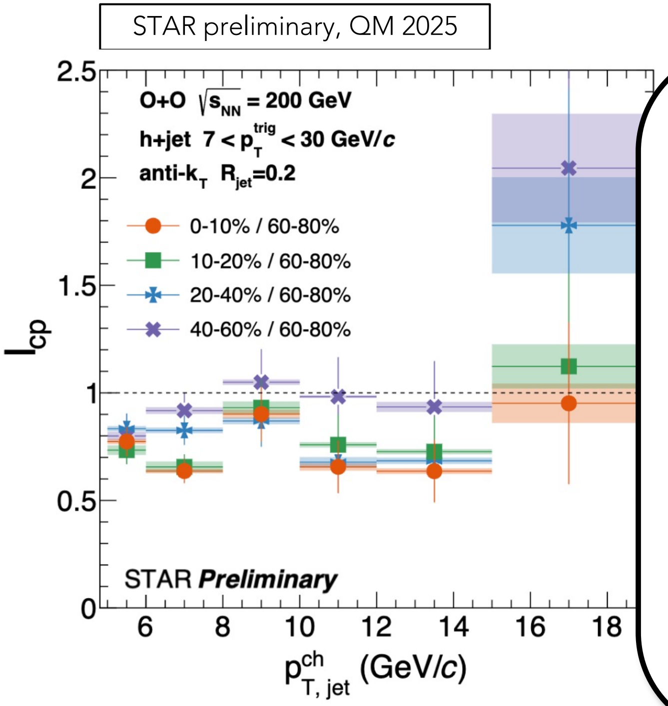
STAR preliminary, QM 2025

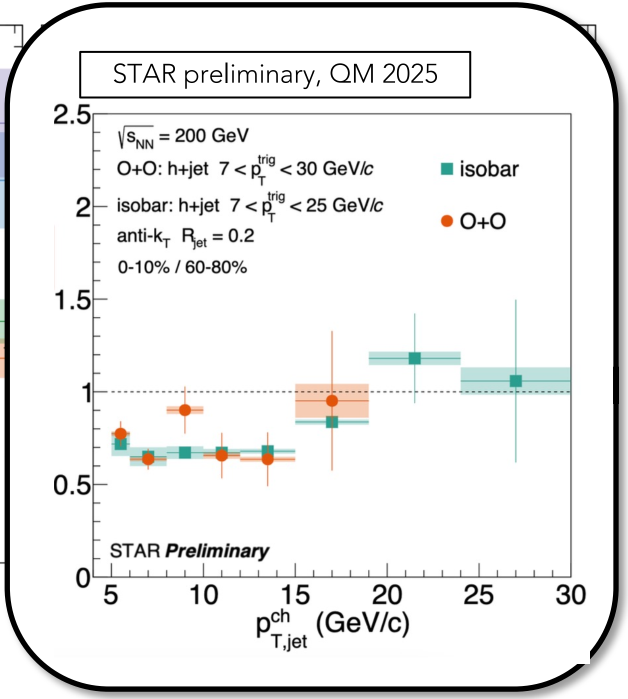


- Semi-Inclusive jet I_{CP}
- Yield suppression observed in central collisions

S. Zhang (Shandong U)

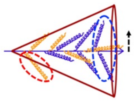
Jet quenching in O+O collisions





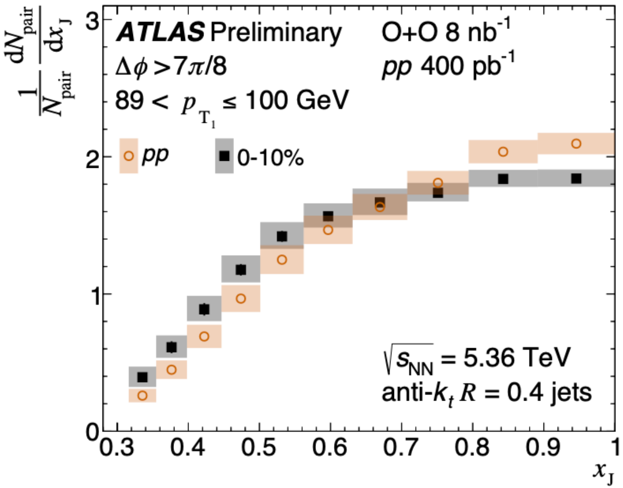
- Semi-Inclusive jet I_{CP}
- Yield suppression observed in central collisions (Similar level with isobar collisions)

Jet quenching in O+O collisions



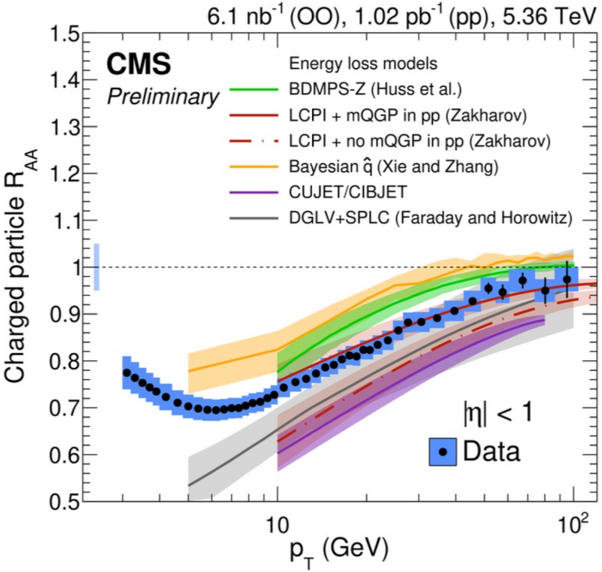
Jet energy loss
Jet substructure modification
Jet deflection

ATLAS preliminary, IS 2025



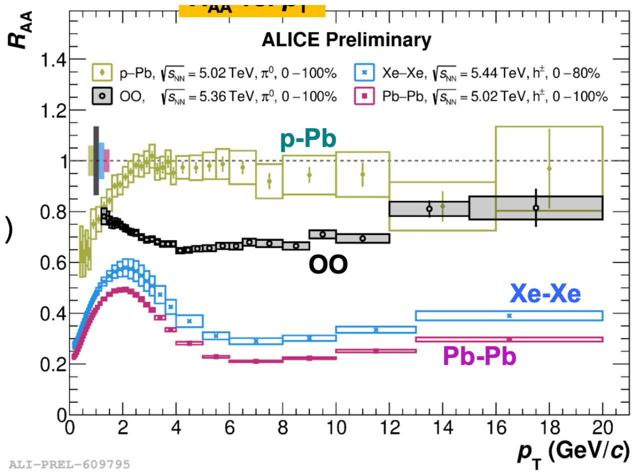
Di-jet imbalance

CMS preliminary, IS 2025



Charged hadron R_{AA}

ALICE preliminary, IS 2025



π^0 R_{AA}

- Measurements of jet quenching in O+O collisions are on-going at the LHC

Summary

- Productive years and rich results in jet physics in the field of relativistic heavy-ion physics
  - Various aspects of jet quenching are investigated
  - Complementary results from RHIC and the LHC
  - Theoretical inputs needed for both *pp* and AA systems

- Asian institutions are involved with multiple key measurements in jet physics, and further contributions are expected in the future