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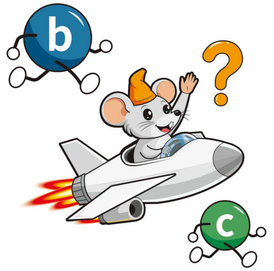

Jet transport and emergence of thermal recoil jets in heavy-ion collisions

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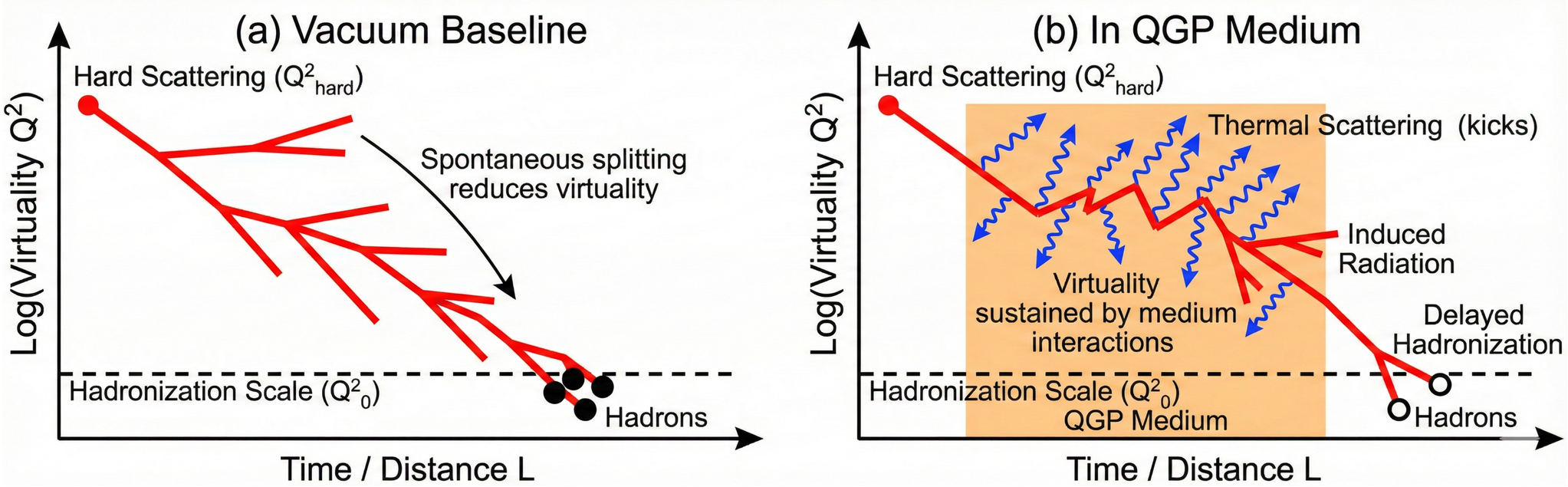
In collaboration with **Peng Jing, Yang He, Shanshan Cao, Li Yi** and **Xin-Nian Wang**

Wuhan, January 24, 2026

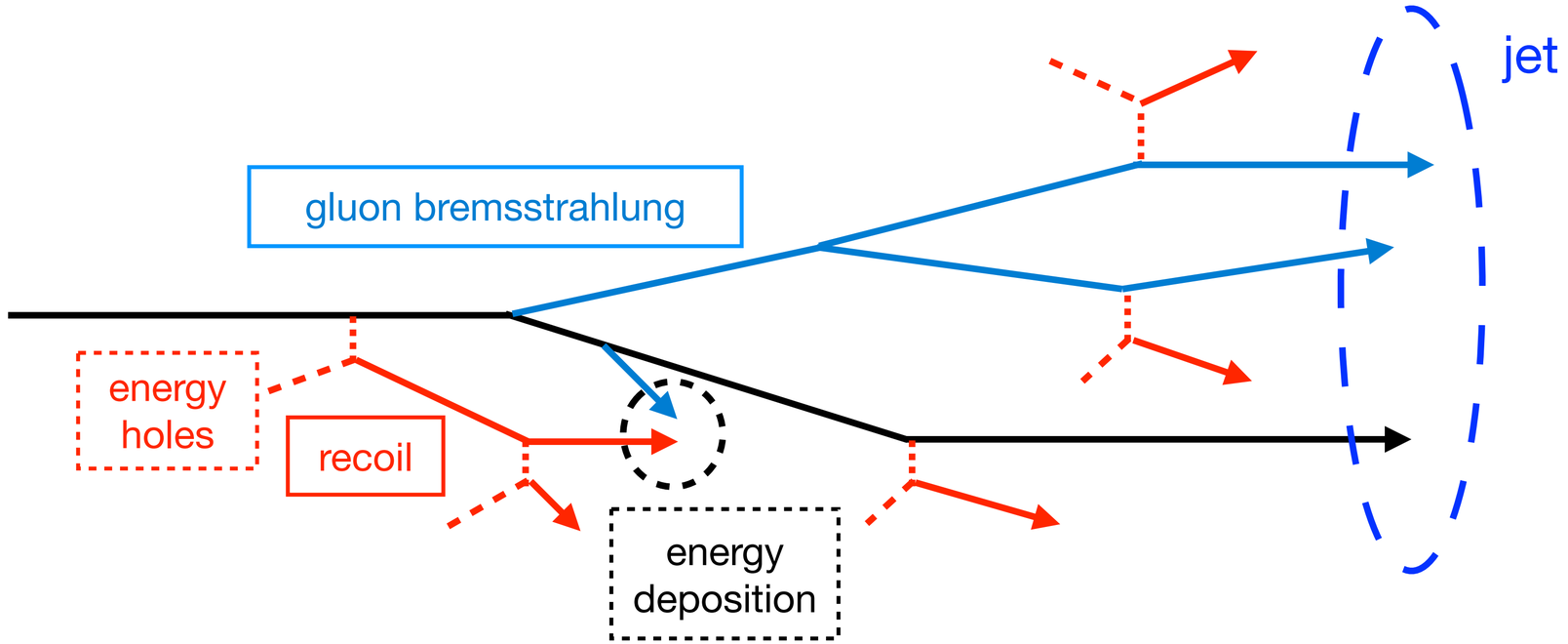
arXiv:2512.12715

Heavy ion collision



- Final-state partons (jet particles) produced by initial hard scattering carry high virtuality.
- Jet partons maintain a certain virtuality scale Q^2_{m} through the medium.
- Jet partons hadronize into hadrons when their virtuality evolves down to the hadronization scale, Q^2_0.

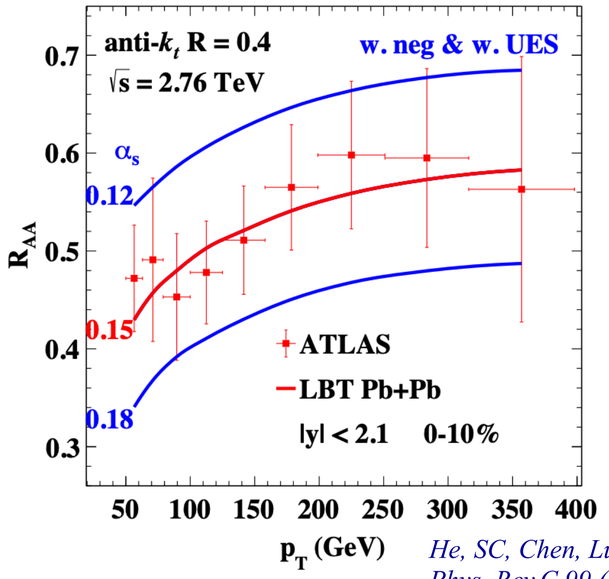
Simulations in linear Boltzmann transport model



- Jet partons and medium background cannot be cleanly separated in reality
- Medium response (energy deposition + depletion) is naturally included in all jet observables
- Jet-medium interactions: medium modification of jets + medium response

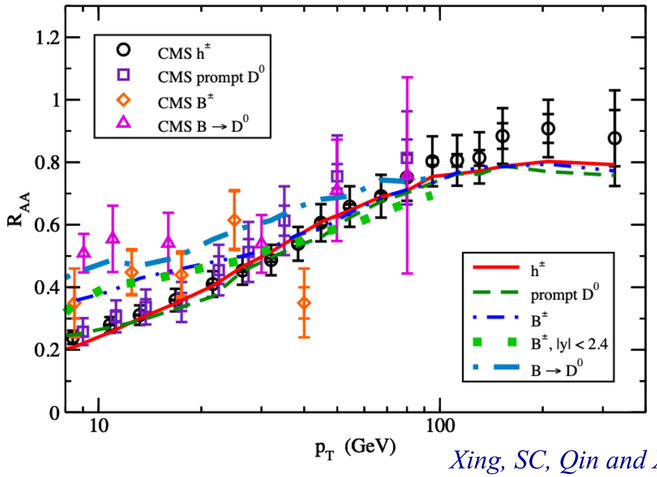
A challenge in simultaneously describing hadrons and jets

jets R_{AA}



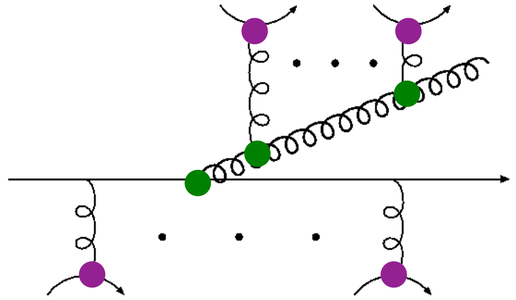
He, SC, Chen, Luo, Pang, Wang
Phys. Rev.C 99 (2019) 054911

hadron R_{AA}



Xing, SC, Qin and Xing
Phys. Lett. B805 (2020) 135424

- **For jets, a fixed $\alpha_s = 0.15$ is sufficient**
- **For hadrons, an additional running α_s is required**

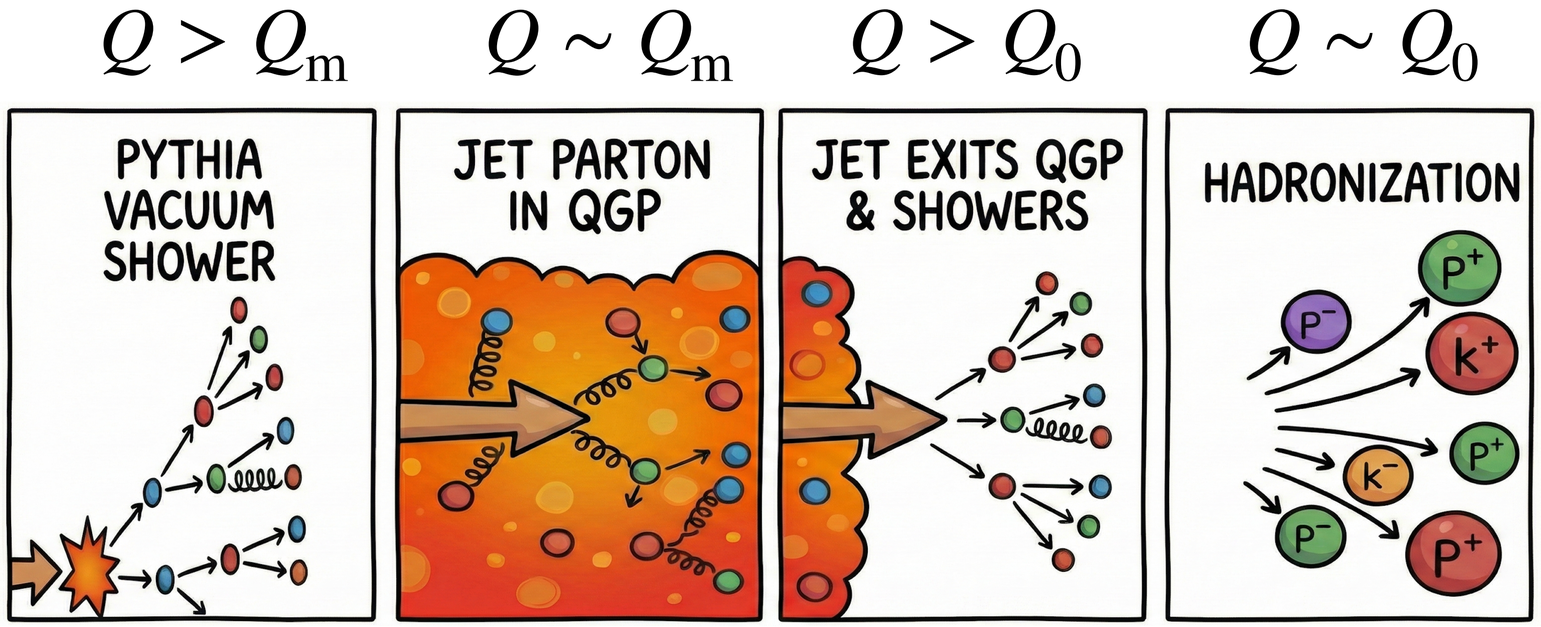


- $\alpha_s^{\mathrm{run}} = 4\pi/[9\ln(2ET/\Lambda^2)]$
- $\alpha_s^{\mathrm{fixed}} = 0.2$

Why the difference?

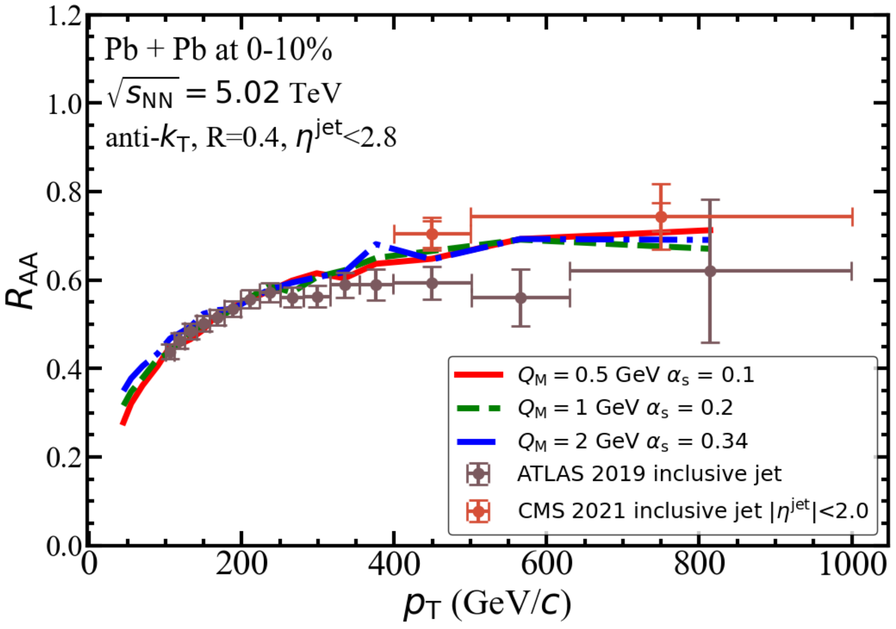
- **Jet partons span a wide range of energy scales**
- **Hadron spectrum is dominated by high-energy partons**
- **Jet spectrum is sensitive to both high- and low-energy partons**

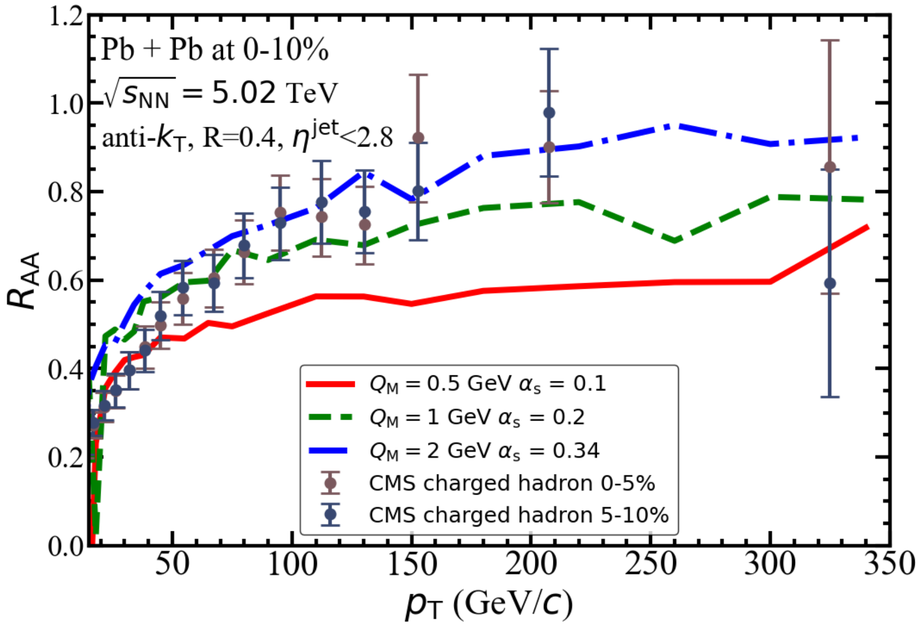
Energy scale dependence in in-medium evolution

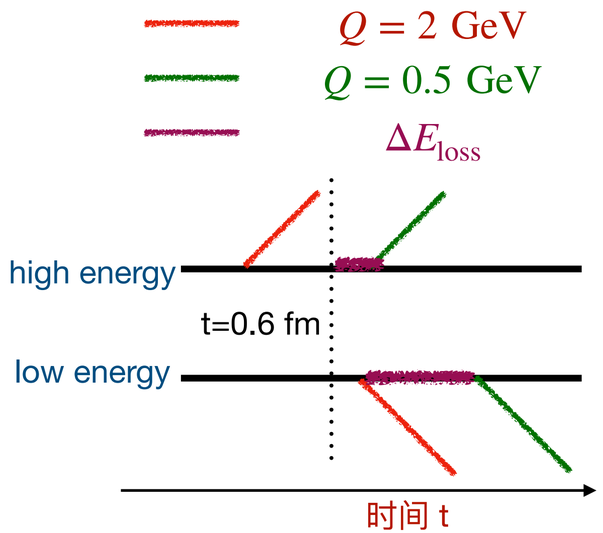


- Previous setting: $Q_m = Q_0 = 0.5$ GeV; now: $Q_m > Q_0$ can be varied [as in JETSCAPE, LIDO]
- Partons start scattering with QGP after a time $\tau_0^{\text{scatt.}}$, which depends on Q_m
- Increasing Q_m enhances energy loss for soft partons while leaving hard partons less affected

Effect of medium scale on jet vs. hadron R_{AA}



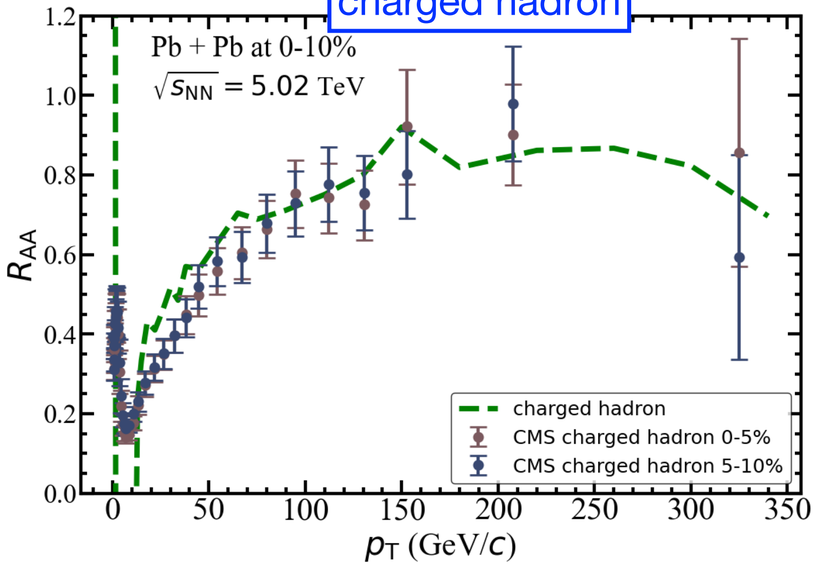




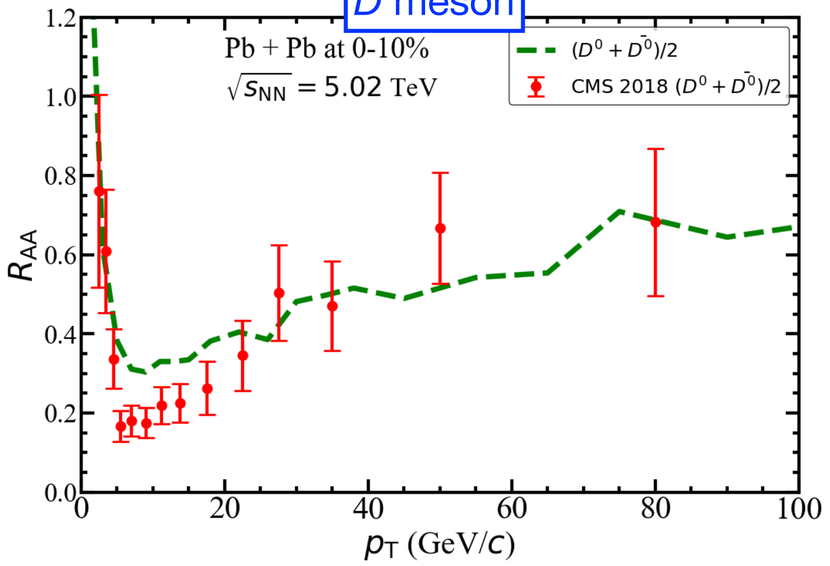
- Adjust α_{s} for the jet R_{AA} and examine the hadron R_{AA}
- Increasing Q_{m} enhances energy loss for soft partons while leaving hard partons less affected
- As Q_{m} increases, the total energy loss decreases because fewer jet partons undergo the evolution
- Setting $Q_{\mathrm{m}} = 2$ GeV provides a simultaneous description of jet and hadron R_{AA}

Hadrons and jets with different flavors

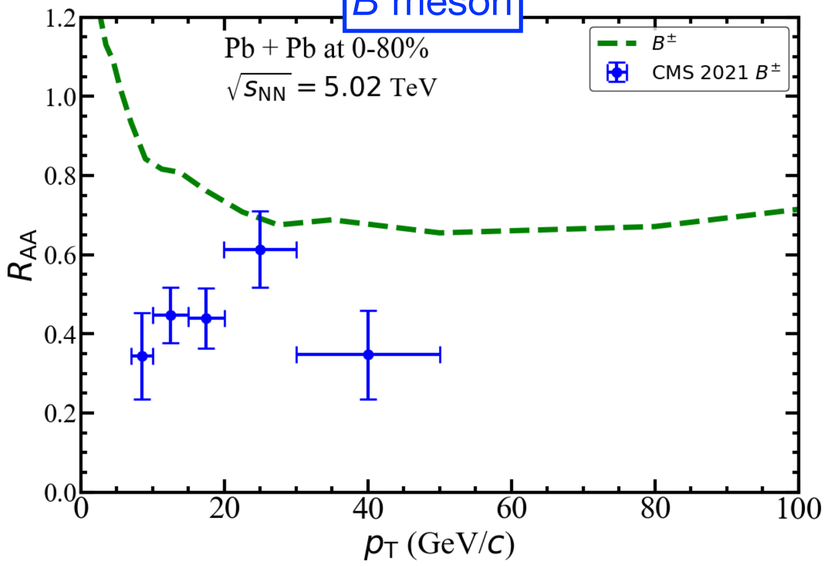
charged hadron



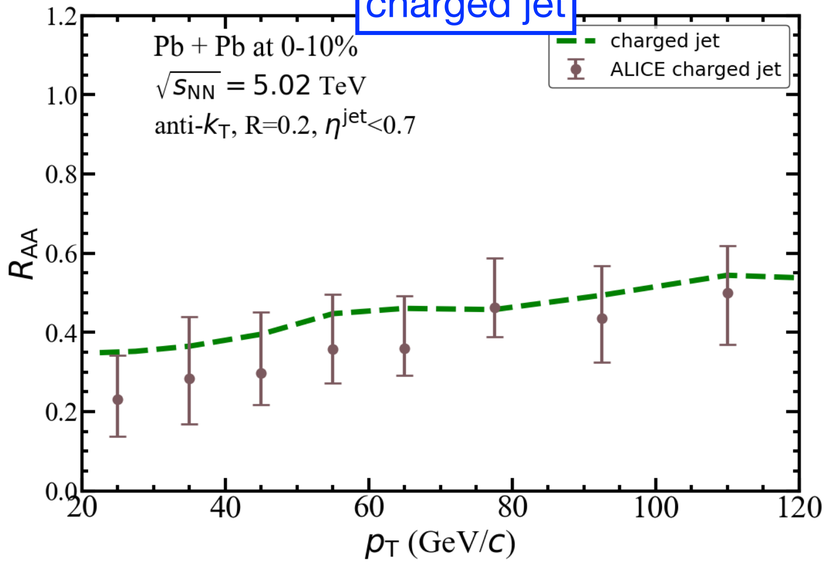
D meson



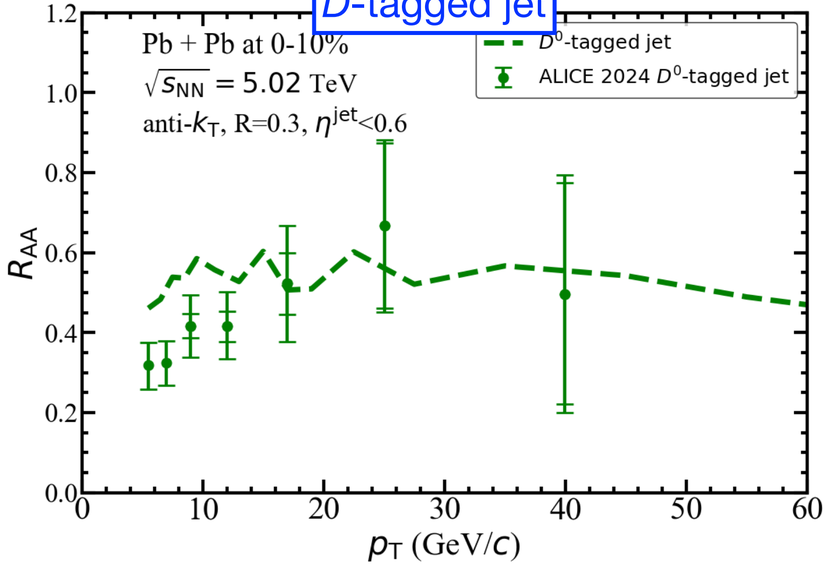
B meson



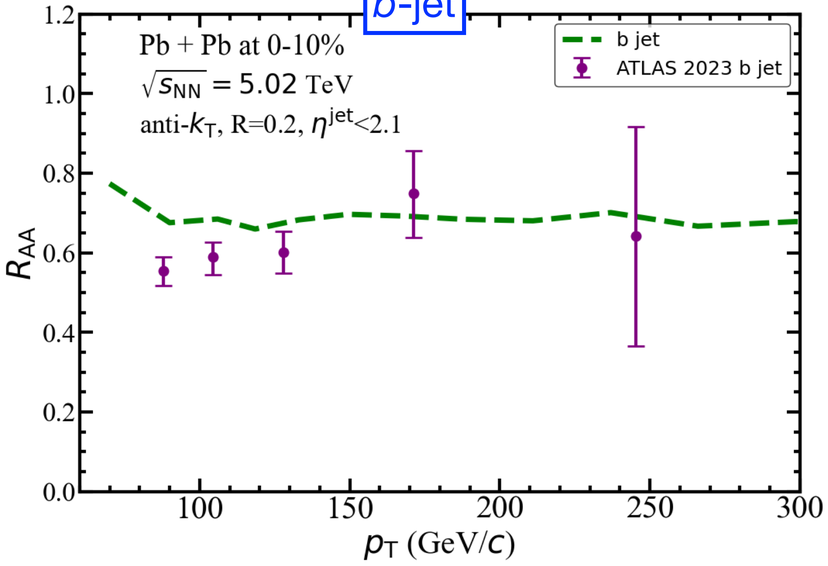
charged jet



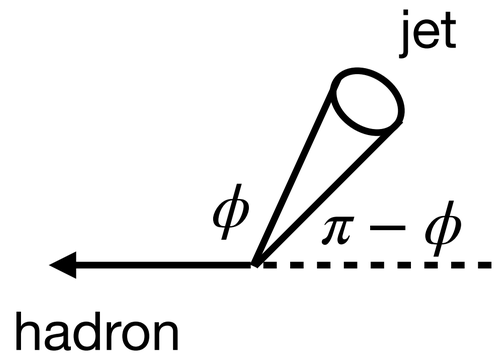
D-tagged jet



b-jet



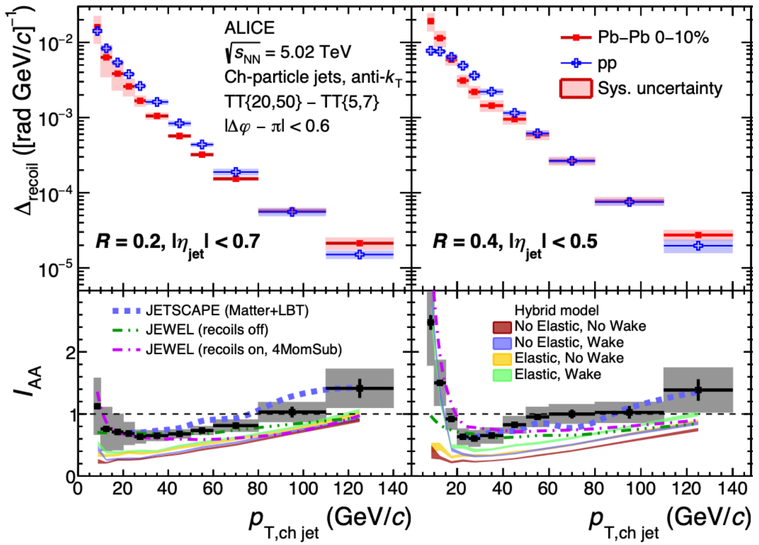
Anomalous enhancement of the nuclear modification factor I_{AA}



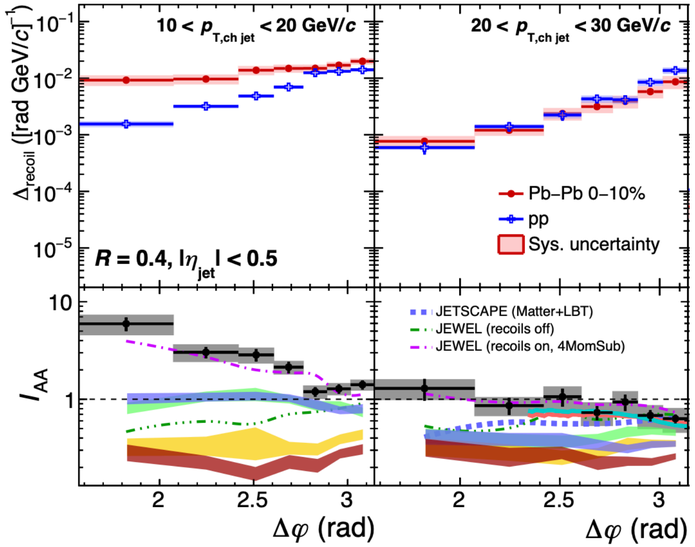
$$I_{\mathrm{AA}}(p_{\mathrm{T}}, \Delta\phi) = \frac{Y_{\mathrm{AA}}(p_{\mathrm{T}}, \Delta\phi)}{Y_{\mathrm{pp}}(p_{\mathrm{T}}, \Delta\phi)}$$

ALICE,Phys. Rev. Lett. 133 (2024) 022301

I_{AA} vs. $p_{\mathrm{T,\,jet}}$

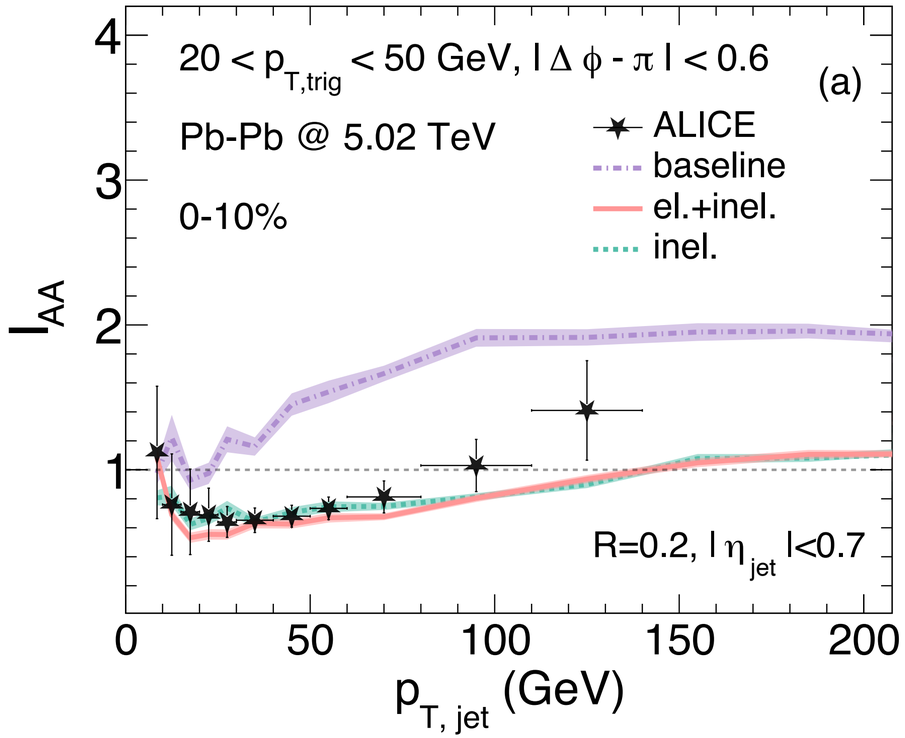


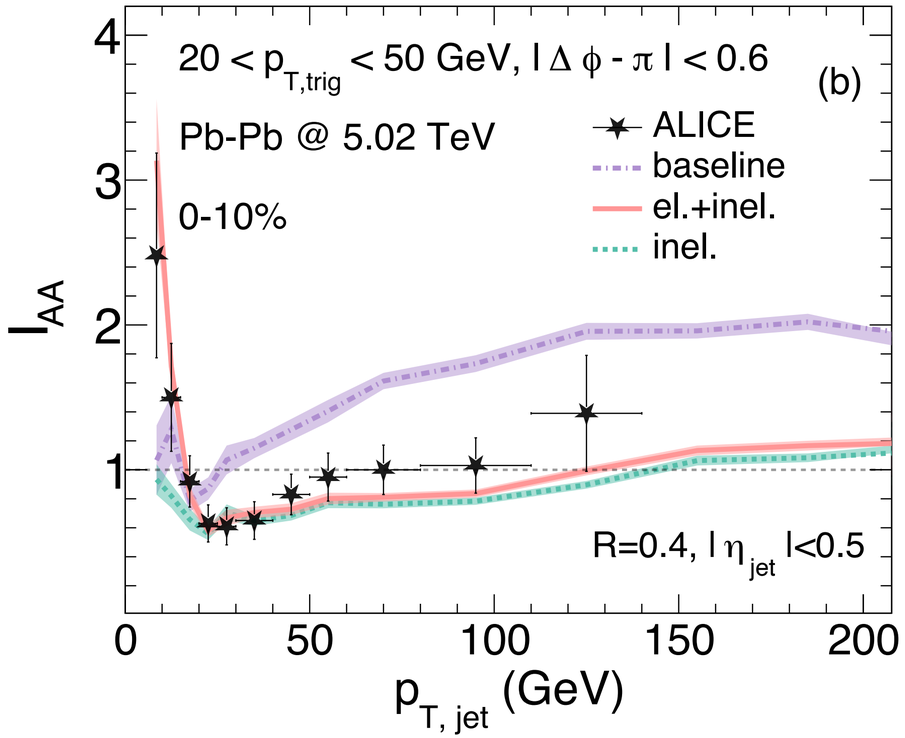
I_{AA} vs. $\Delta\phi$



- No existing model can quantitatively describe both data
- No qualitative explanation of the enhancement at large $\pi - \phi$, and its disappearance for jets with small R or high p_{T}

Data comparison and analysis with improved LBT





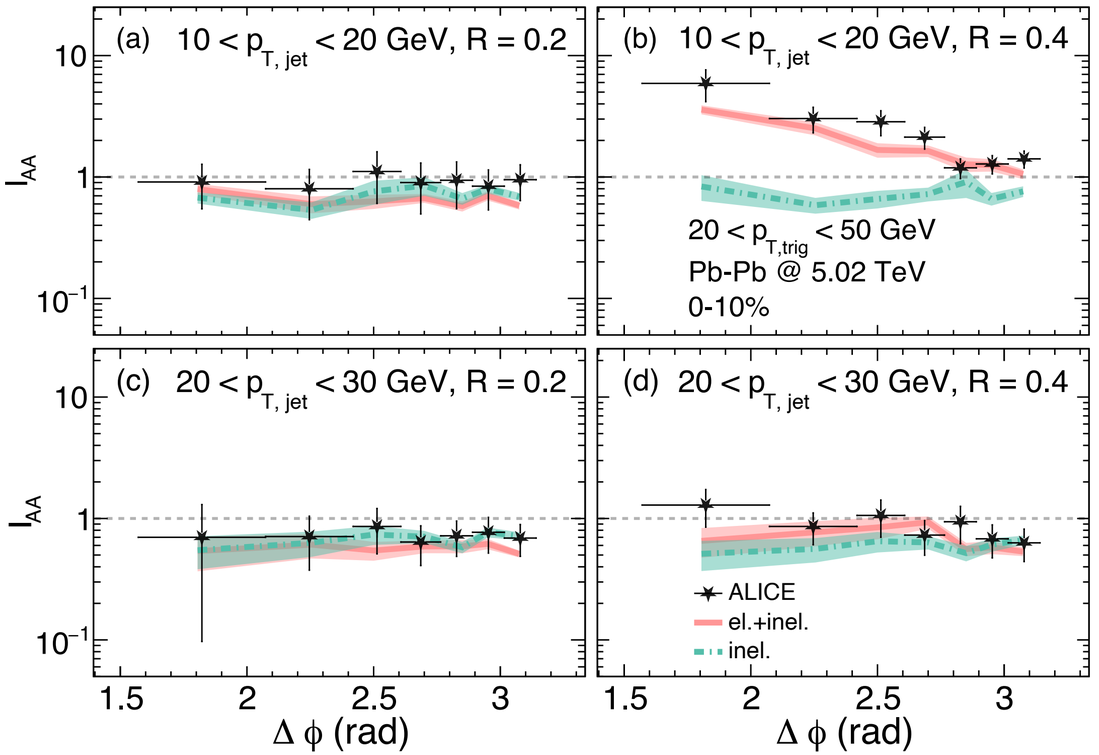
- Simultaneous description of hadron and jet is crucial for understanding hadron-triggered jets
- Enhancement at high-$p_{\mathrm{T,jet}}$: enhancement of baseline by trigger bias
- What is the physical origin of the low-$p_{\mathrm{T,jet}}$ enhancement?

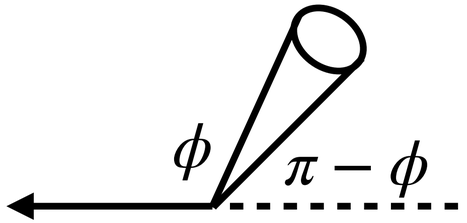
Jet Deflection or Medium Response?

$R = 0.2$ $R = 0.4$

$10 < p_{\mathrm{T,jet}} < 20$ GeV

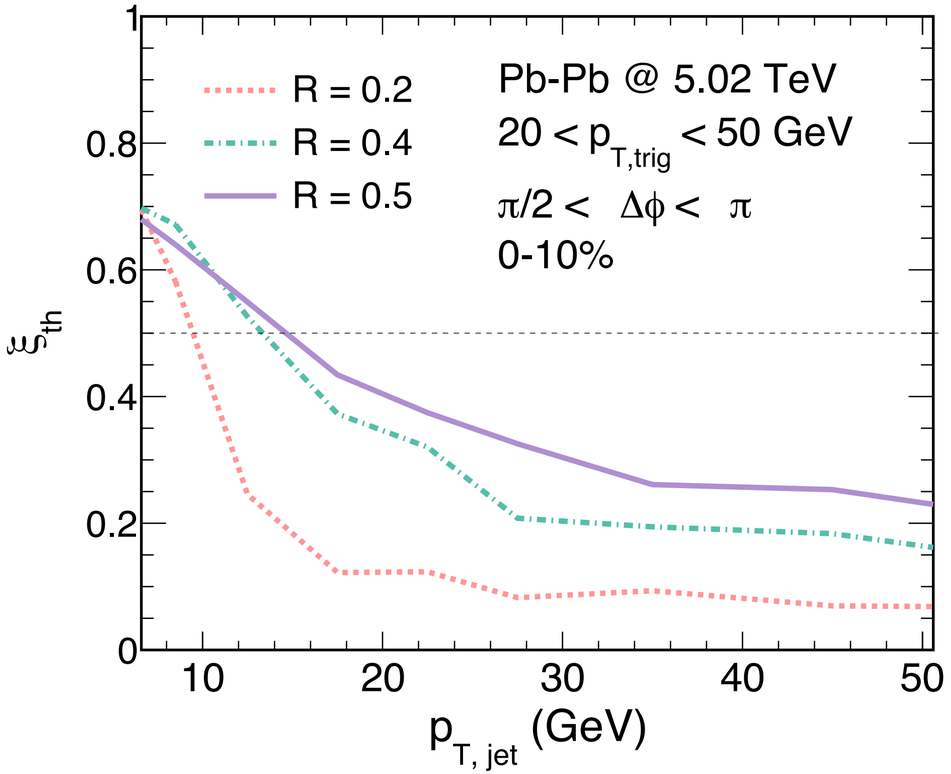
$20 < p_{\mathrm{T,jet}} < 30$ GeV

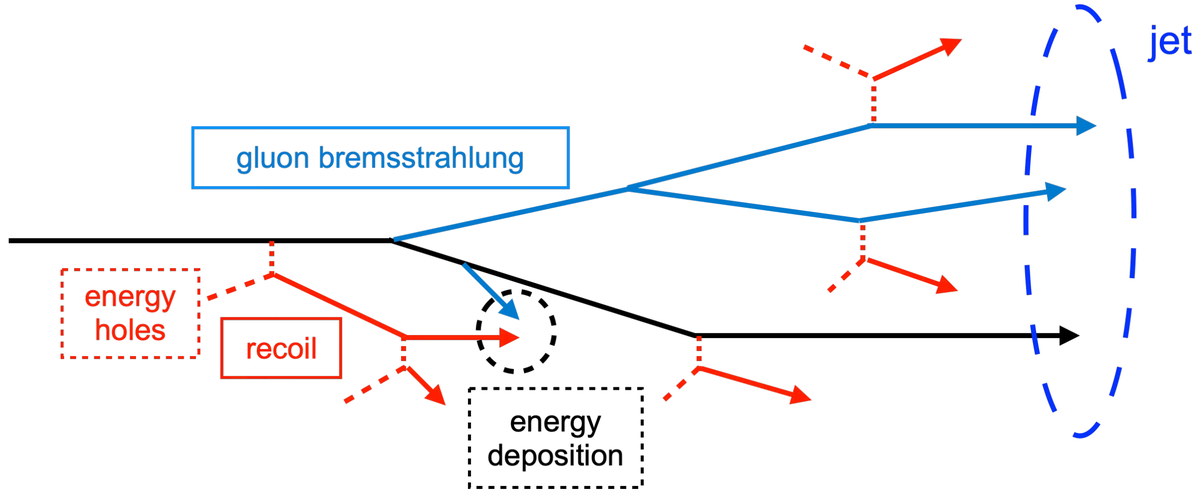




- I_{AA} enhancement is observed only for large-radius, low-energy jets at small angles.
- The additional jet yield in $A + A$ collisions consists of particles that are more widely distributed and carry lower average energy.

What are the jet constituents?

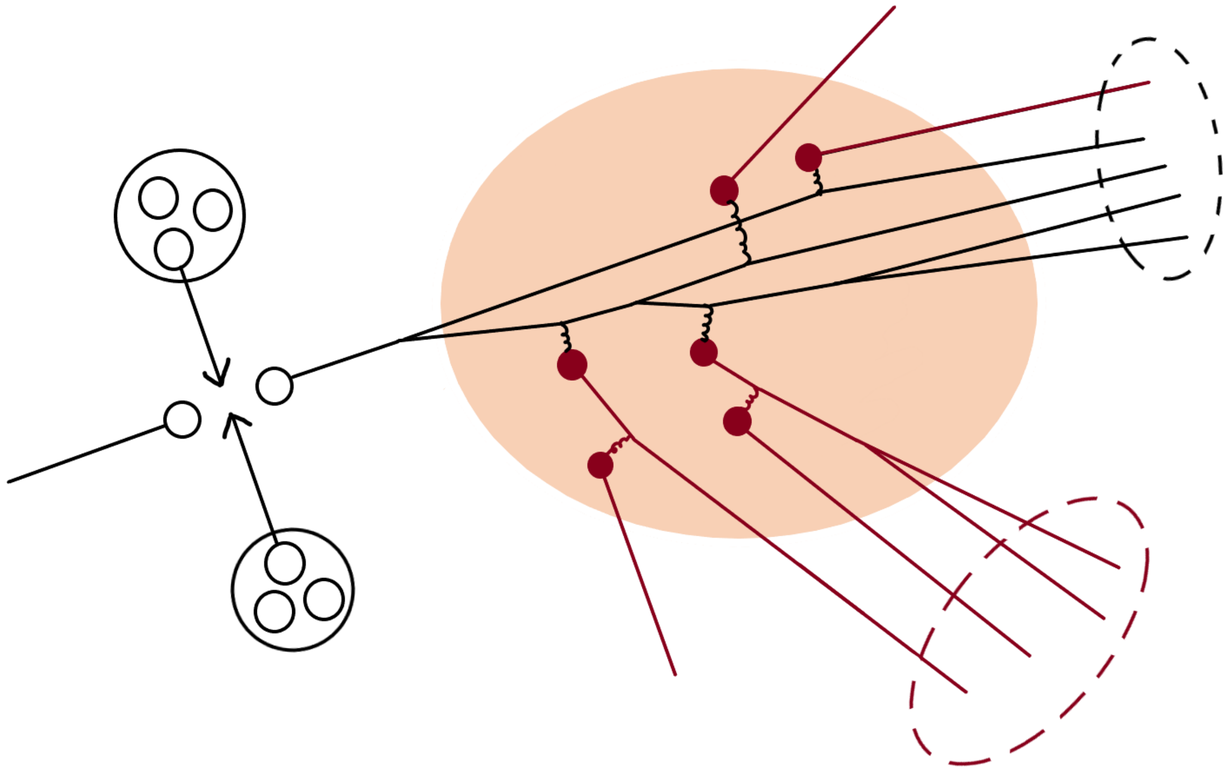




$$\xi_{\mathrm{th}} = \frac{|\vec{p}_{\mathrm{T}}^{\,\mathrm{recoil}} - \vec{p}_{\mathrm{T}}^{\,\mathrm{negative}}|}{|\vec{p}_{\mathrm{T}}^{\,\mathrm{recoil}} - \vec{p}_{\mathrm{T}}^{\,\mathrm{negative}}| + p_{\mathrm{T}}^{\mathrm{jet-shower}}}$$

- Most of the jet energy is contributed by thermalized recoil particles scattered out from the medium (medium response)
- The contribution of recoil particles increases as the jet momentum $p_{\mathrm{T,jet}}$ decreases and the jet radius increases

Emergence of “thermal recoil jets”



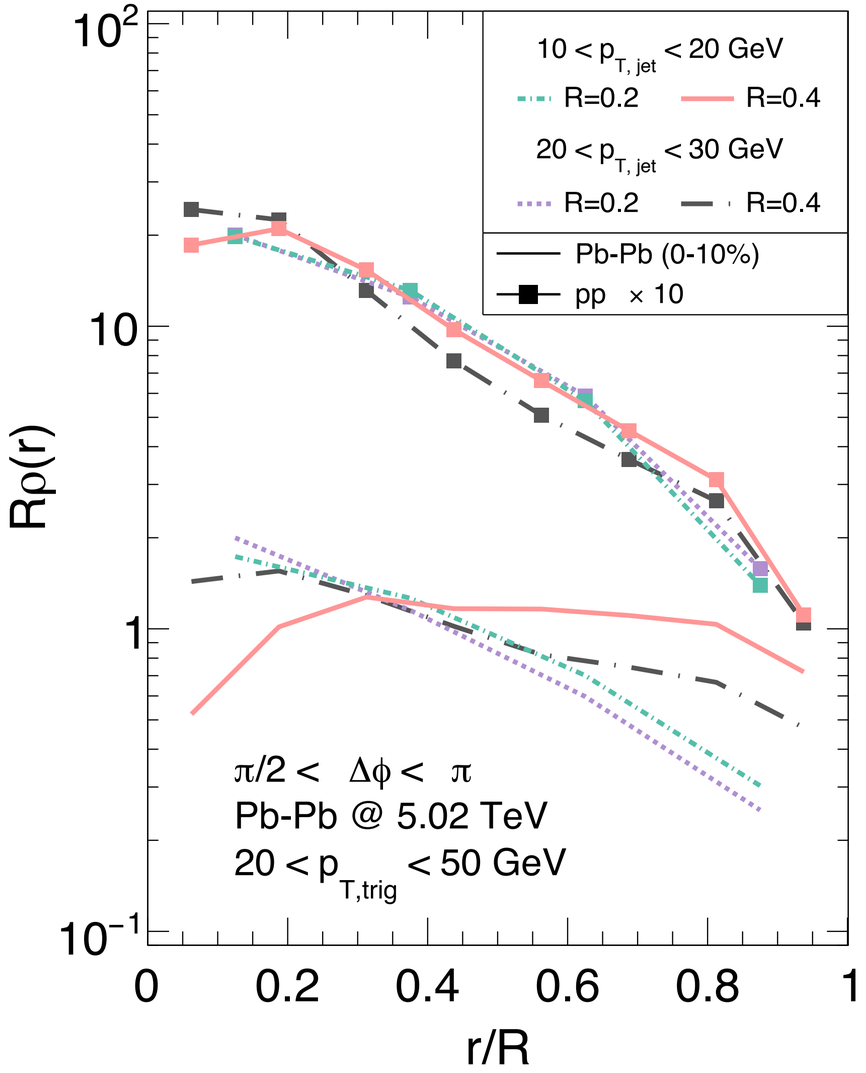
Hard jet

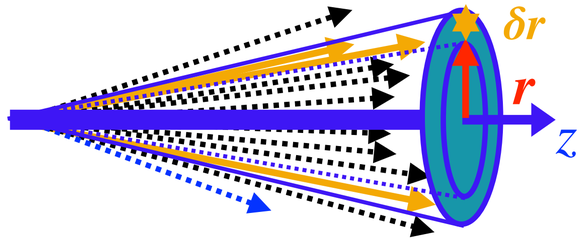
- Hard particles at the core, soft particles around

Thermal recoil jet

- Composed of soft particles sparsely distributed in the momentum space
- Require large R for reconstruction, only present at low jet p_T

Shapes of thermal recoil jets vs. hard jets

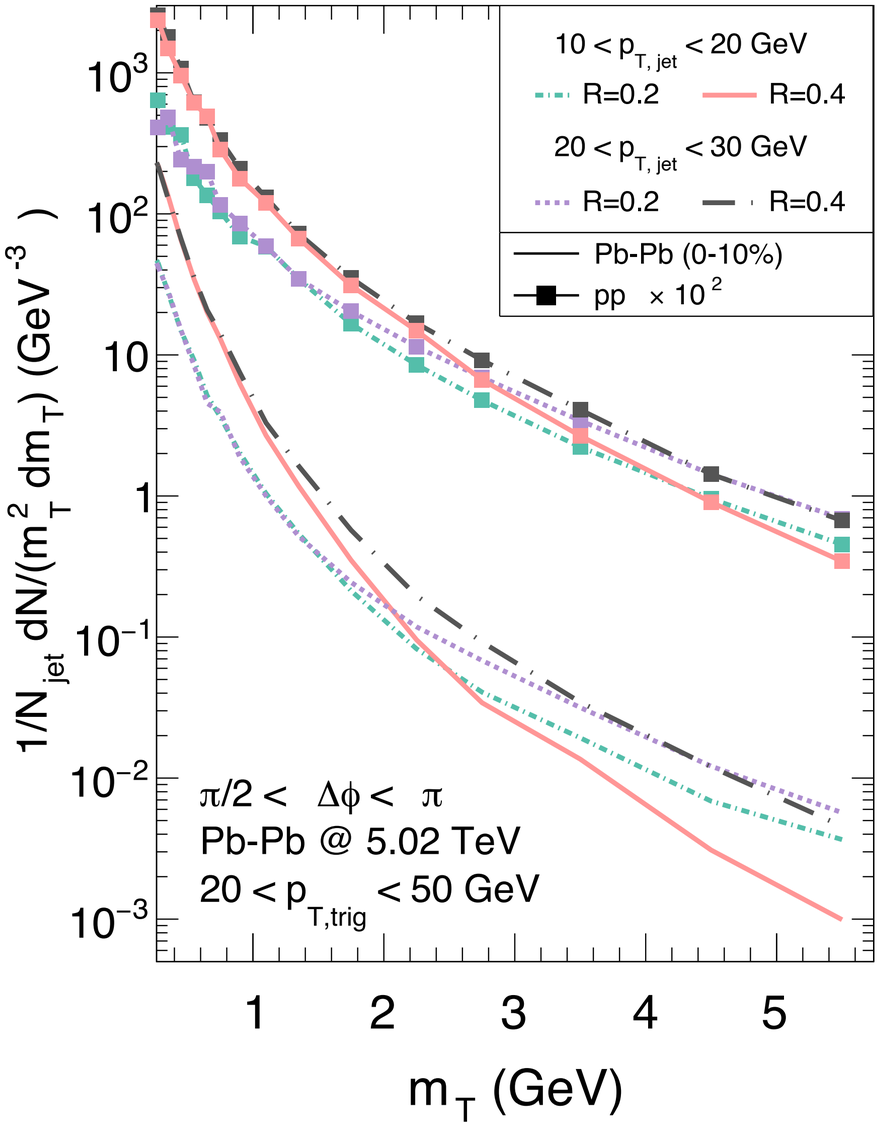




$$\rho(r) = \frac{1}{\delta r} \frac{\sum_{\text{jets}} \sum_{\text{track}\in(r-\frac{\delta r}{2}, r+\frac{\delta r}{2})} p_{\text{T,track}}}{\sum_{\text{jets}} \sum_{\text{track}} p_{\text{T,track}}}$$

- Decreasing ρ with r for small cone-size (R) jet, similar to jets in p+p collisions
  - Feature of hard jet: energetic particles at jet core, soft particles at large r
- Increasing ρ with r for large R jet at low $p_{\text{T,jet}}$
  - Feature of thermal recoil jet: soft particles sparsely distributed in the momentum space

m_{T} distributions of thermal recoil jets vs. hard jets



Thermal distribution: $\frac{1}{m_{\mathrm{T}}^2}\frac{dN}{dm_{\mathrm{T}}} \sim e^{-m_{\mathrm{T}}/T_{\mathrm{eff}}}$

- For R = 0.2 jets in $A + A$ collisions, the constituent distribution still exhibits a power-law tail similar to $p + p$
- For R = 0.4 jets within $10 < p_{\mathrm{T,jet}} < 20$ GeV in $A + A$ collisions, a thermal distribution structure is observed in the constituent spectrum between 0 and 2 GeV

Summary

- A medium scale is introduced to regulate the energy loss of particles at different energy scales, simultaneously describing the suppression of hadrons and jets
- A novel jet production mechanism is proposed: thermal recoil jets
  - naturally explains the p_T, R, $\Delta\phi$ dependencies of the hadron-jet I_{AA}
  - can be straightforwardly tested by experiments

reference:

- https://github.com/dyczzz/A-Color-Tracking-LBT-Model
- https://arxiv.org/abs/2512.12715

Thank you!