Emergence of thermal recoil jets in high-energy heavy-ion collisions

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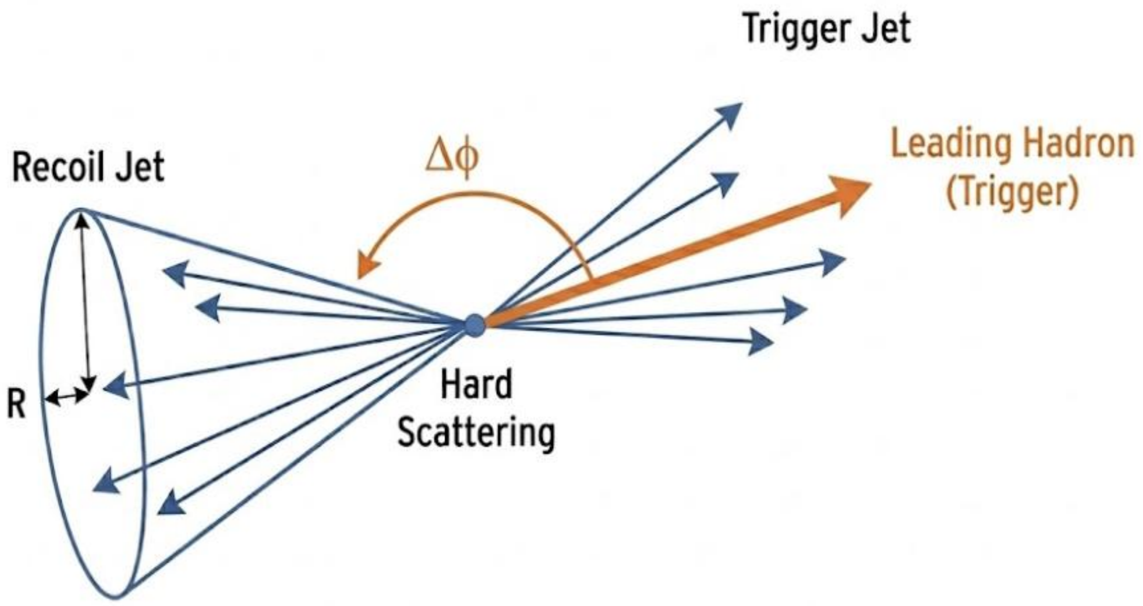
arXiv:2512.12715

Outline

- Motivation: the recoil-jet puzzle
- Framework: from medium response to thermal recoil jets
- Evidence: yield, jet shape, and transverse mass
- Summary

Hadron-Triggered Recoil Jets (h-jet)

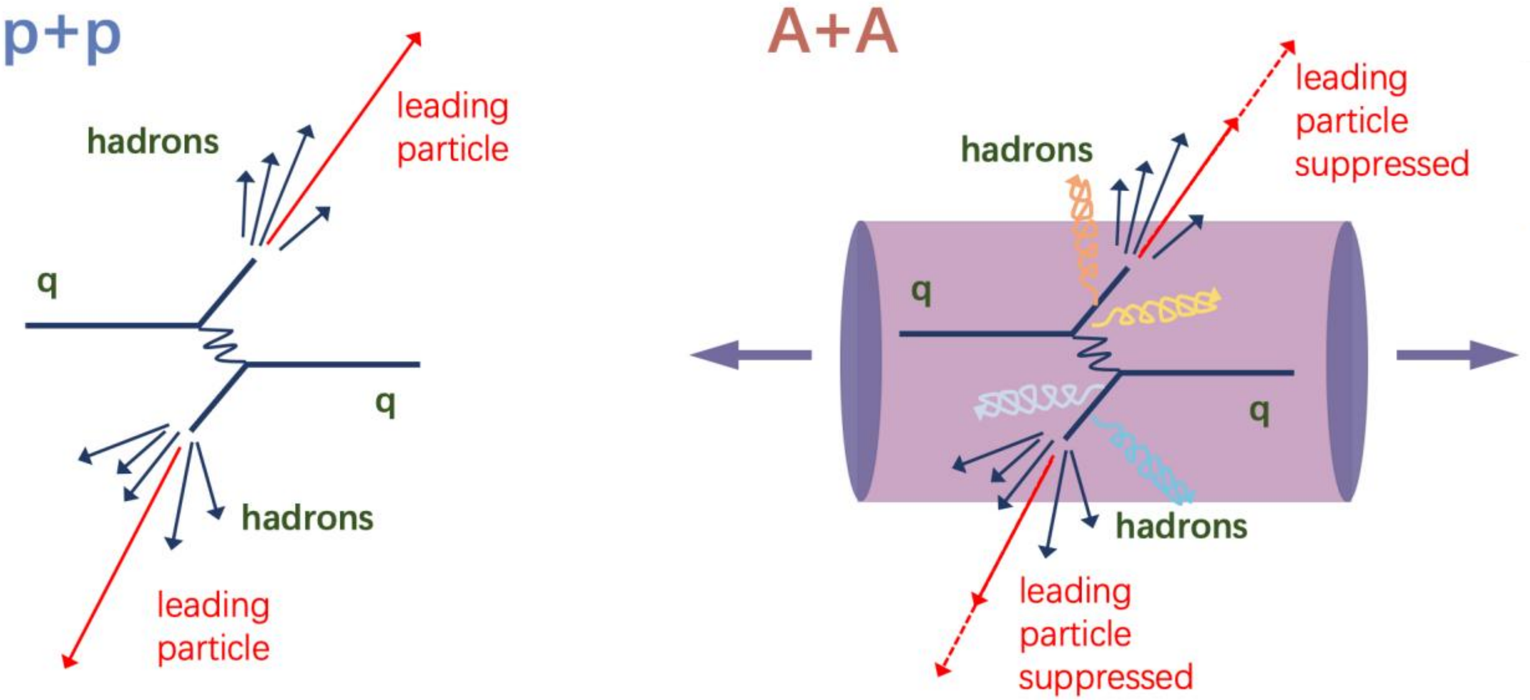
Jets recoiling from a high-p_T trigger hadron



Trigger-normalized recoil jet yield:

$$Y = \frac{1}{N_{trig}} \cdot \frac{d^3 N_{jet}}{dp_{T,jet}^{ch}\, d\Delta\phi\, d\eta_{jet}}$$

Recoil jet yield modification (I_{AA})

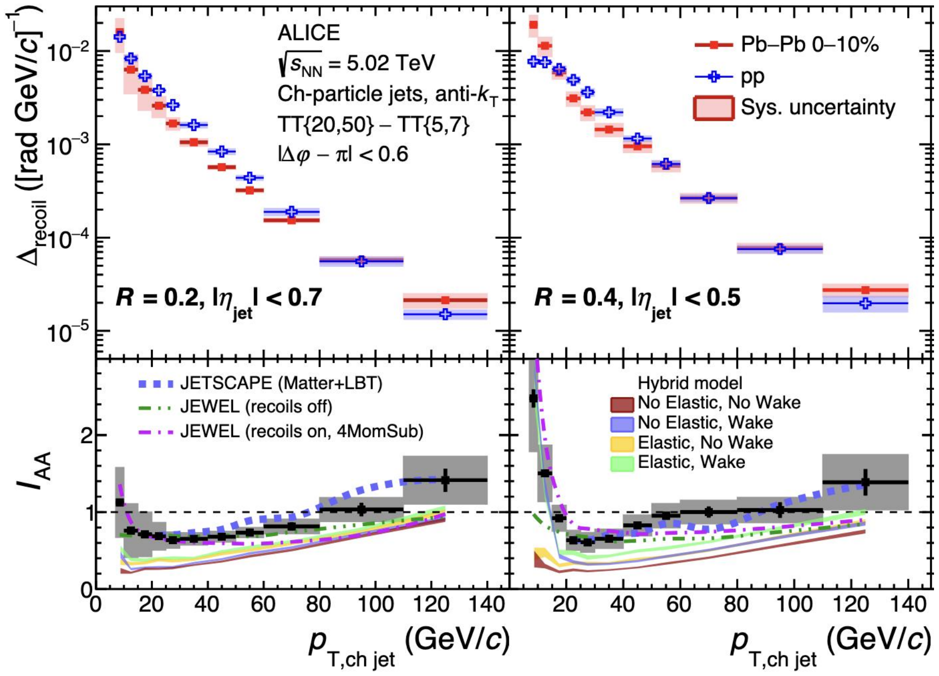


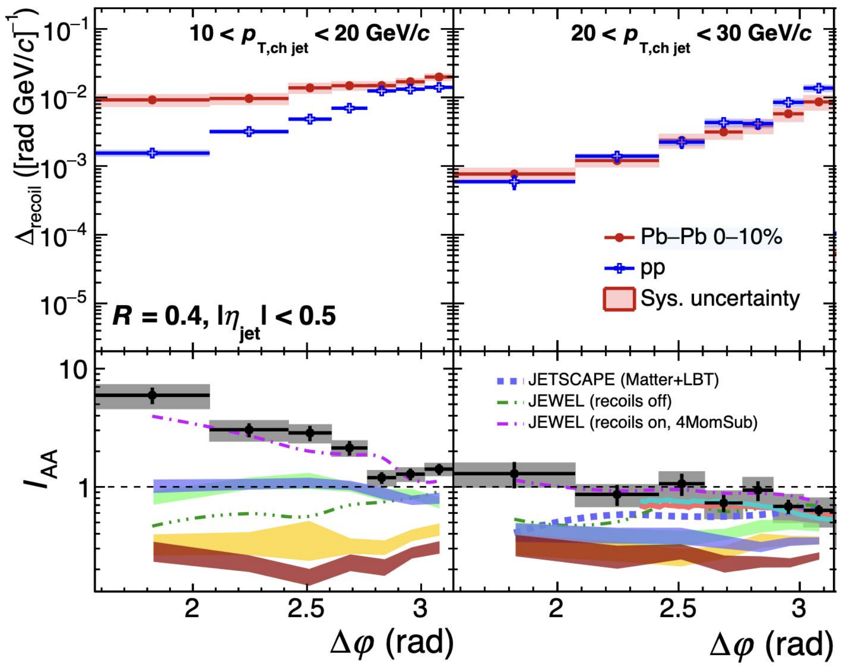
$$I_{AA} = \frac{Y|_{AA}}{Y|_{pp}}$$

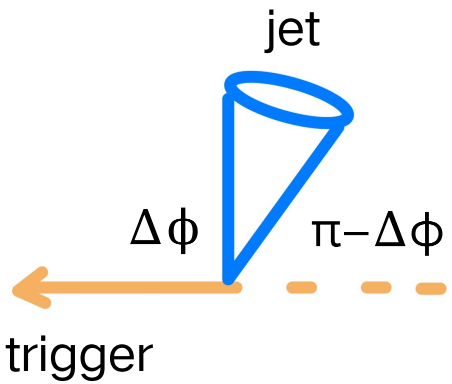
Jet quenching observables: $I_{AA}(p_T)$, $I_{AA}(\Delta\phi)$, jet substructure

Experimental puzzle: I_{AA} enhancement

I_{AA} vs. p_T *ALICE, PRL 133 (2024) 2, 22301* I_{AA} vs. $\Delta\phi$



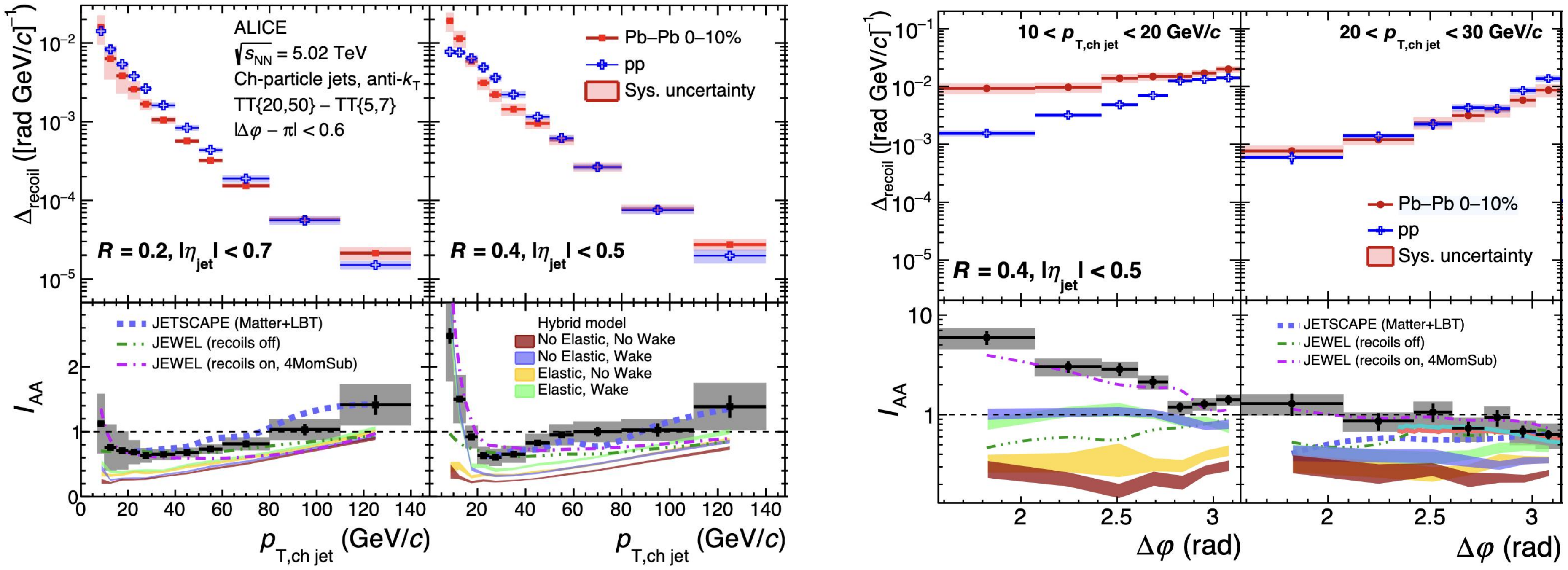


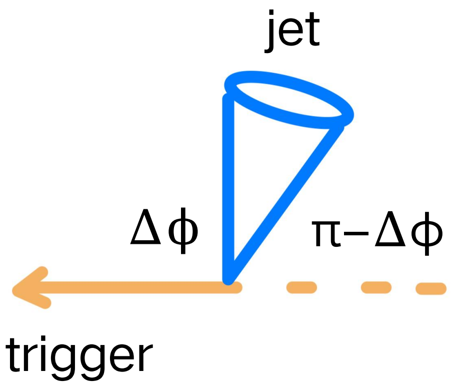


- Enhancement at large π-Δϕ (for small p_T,and large R jets)

Experimental puzzle: I_{AA} enhancement

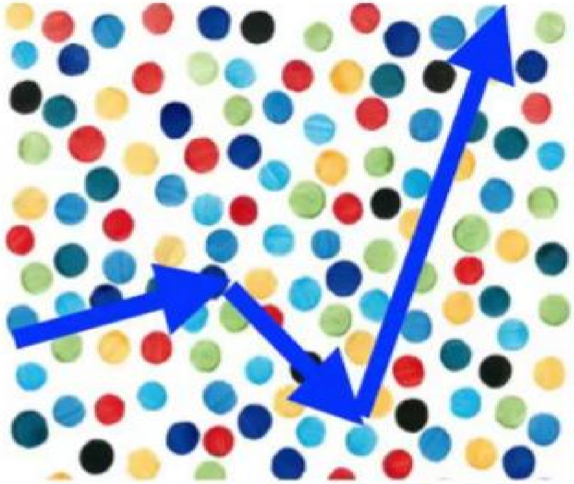
I_{AA} vs. p_T *ALICE, PRL 133 (2024) 2, 22301* I_{AA} vs. $\Delta\phi$





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

From modified hard-jet to medium response



Modified hard-jet

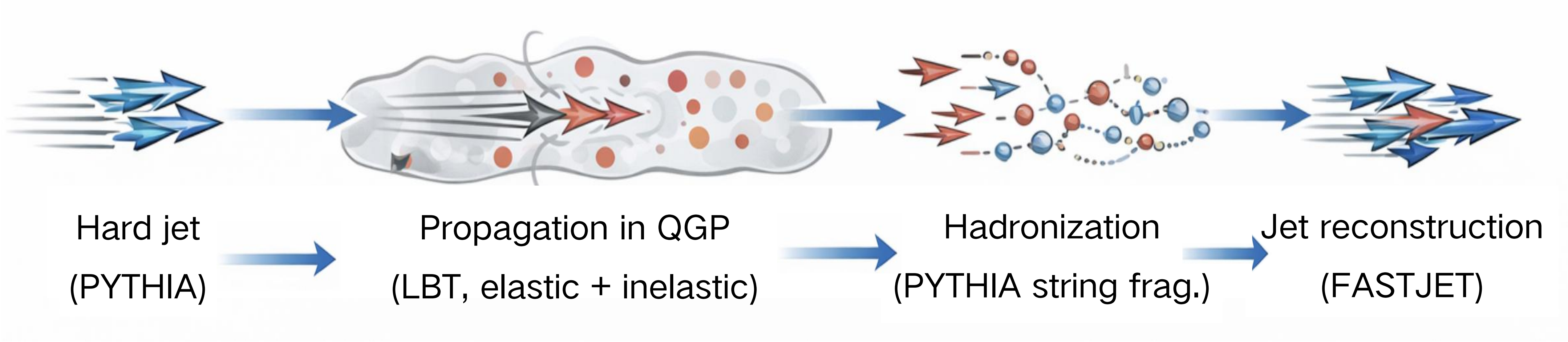
- Hard jet deflection
- Few energetic particles
- Cannot explain R-dependence

Medium response

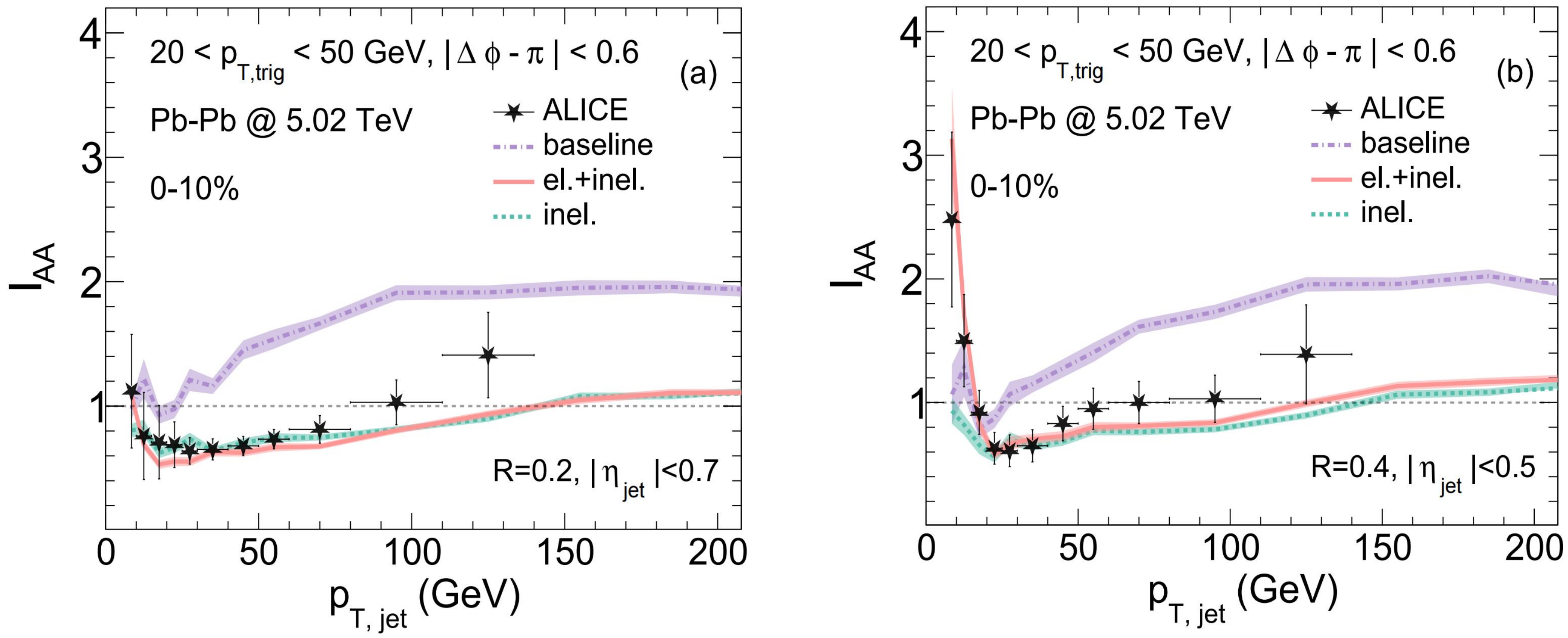
- Energy deposition
- Many soft recoil partons
- Explains R-dependence

A model with medium response

arXiv:2602.10395

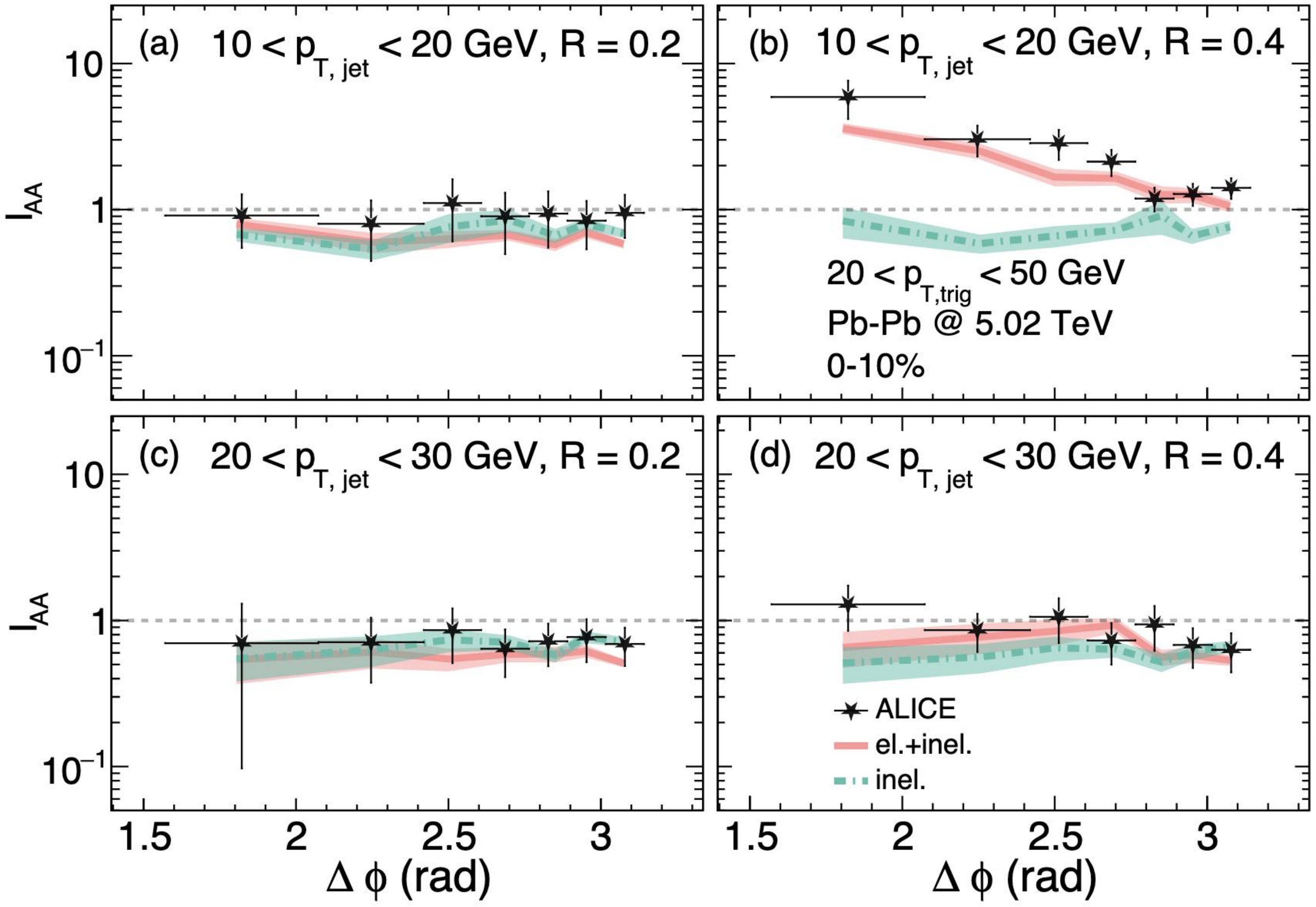


p_T dependence of I_{AA}



- Trigger bias → $I_{AA} > 1$ at high p_T
- Medium response → $I_{AA} > 1$ at low p_T for large R

Δϕ dependence of I_{AA}

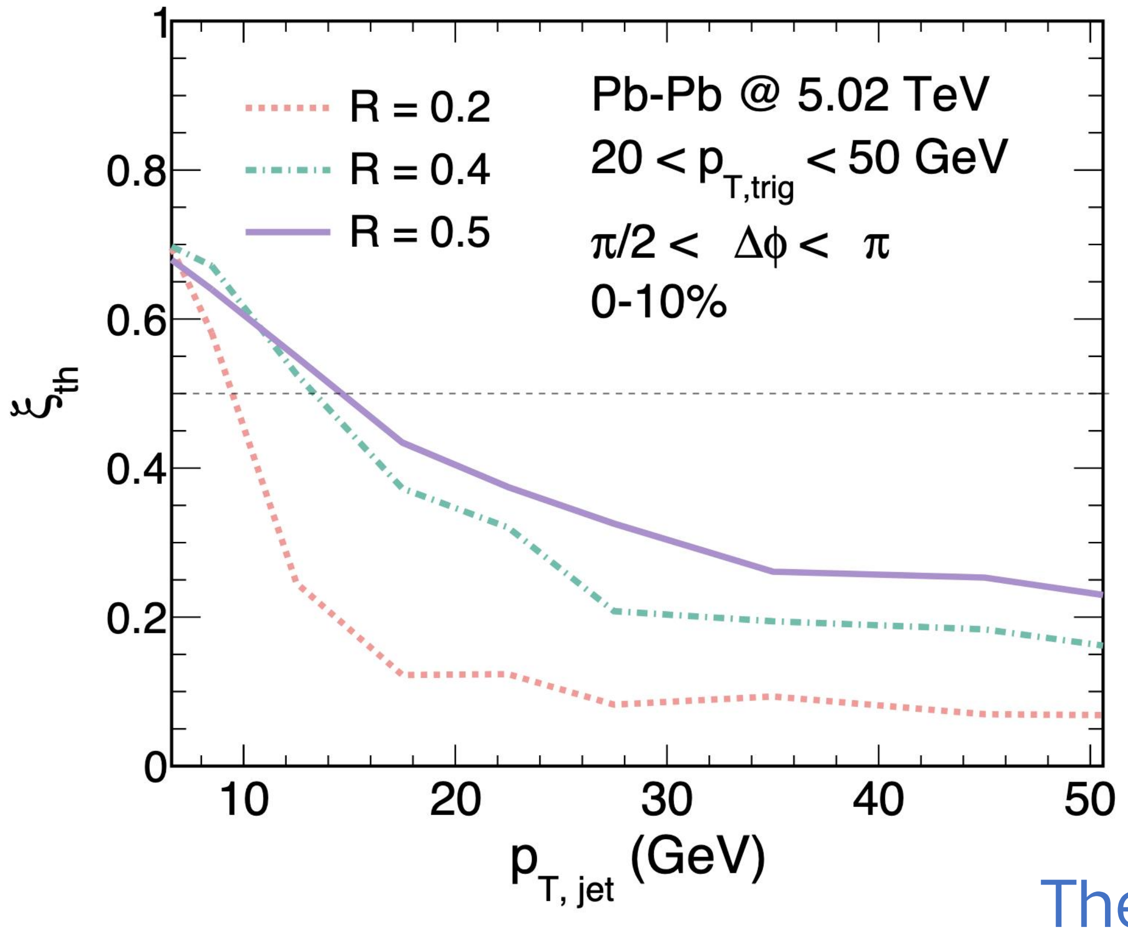


- Enhancement appears at large π−Δϕ for jets with large R and low p_T
- Enhancement disappears for small R or high p_T

What we learn from turning off elastic scattering

turning off elastic scattering → suppress recoil partons production → remove medium response source → large angle enhancement disappears

Thermal origin of the enhanced jet yields

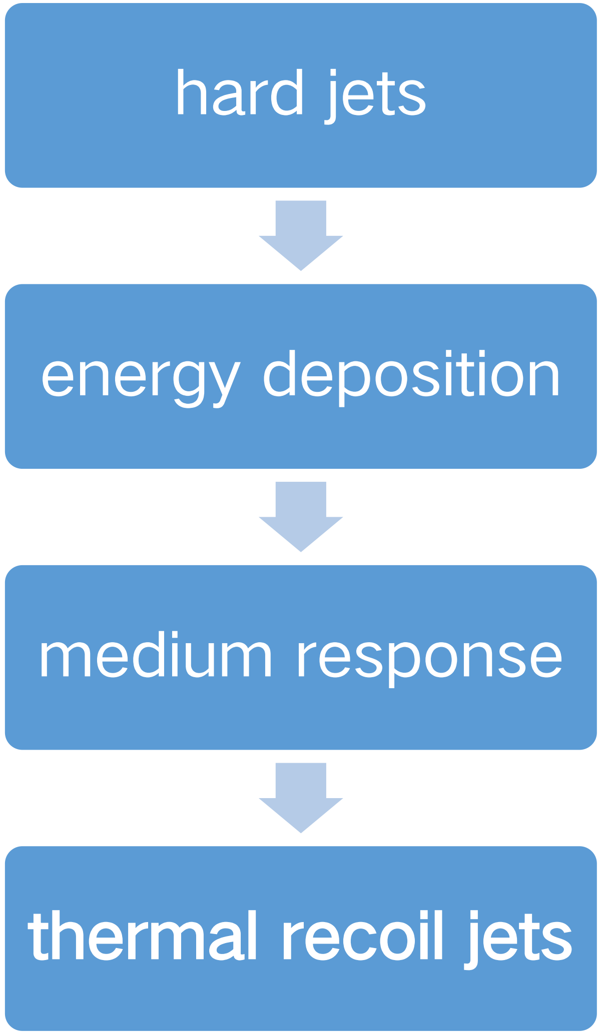


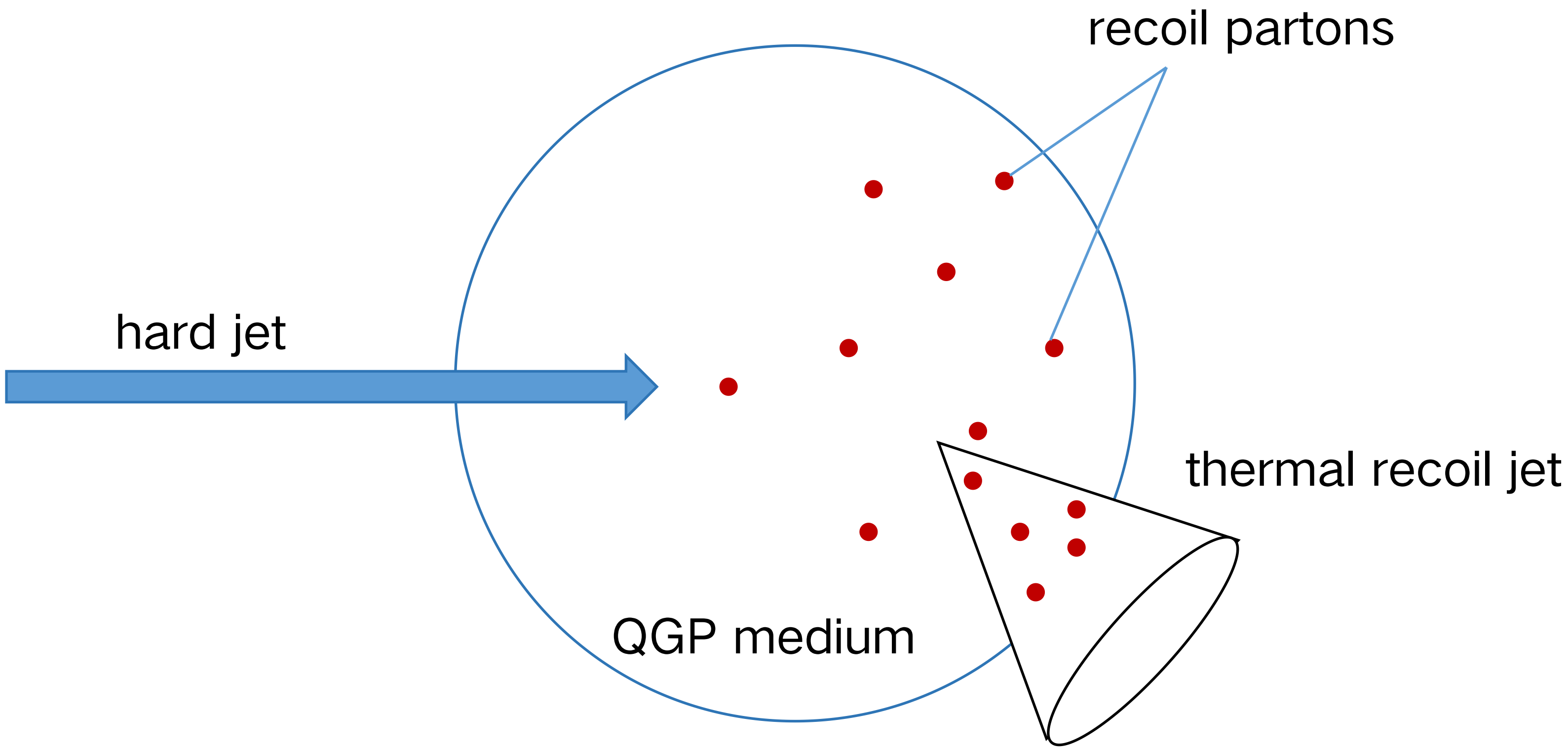
$$\xi_{th} = \frac{\left|\vec{p}_T^{\,recoil} - \vec{p}_T^{\,negative}\right|}{\left|\vec{p}_T^{\,recoil} - \vec{p}_T^{\,negative}\right| + \vec{p}_T^{\,jet-shower}}$$

- $\xi_{th} \approx 0$: hard-shower dominated
- $\xi_{th} > 0.5$: response-dominated

The thermal contribution is more prominent for lower-p_T and larger-R jets.

Emergence of Thermal Recoil Jets



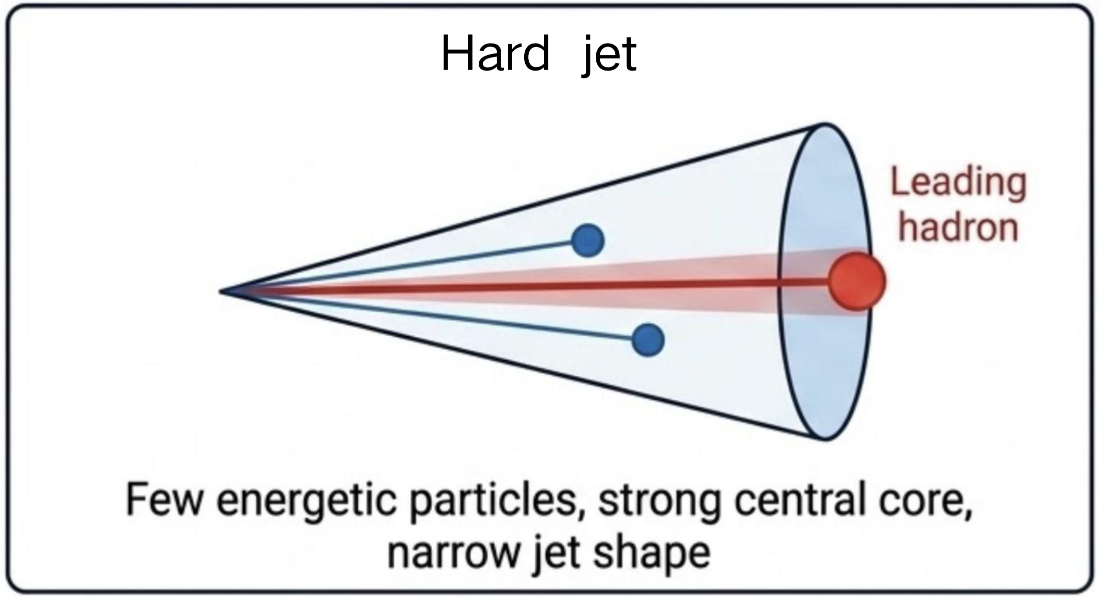


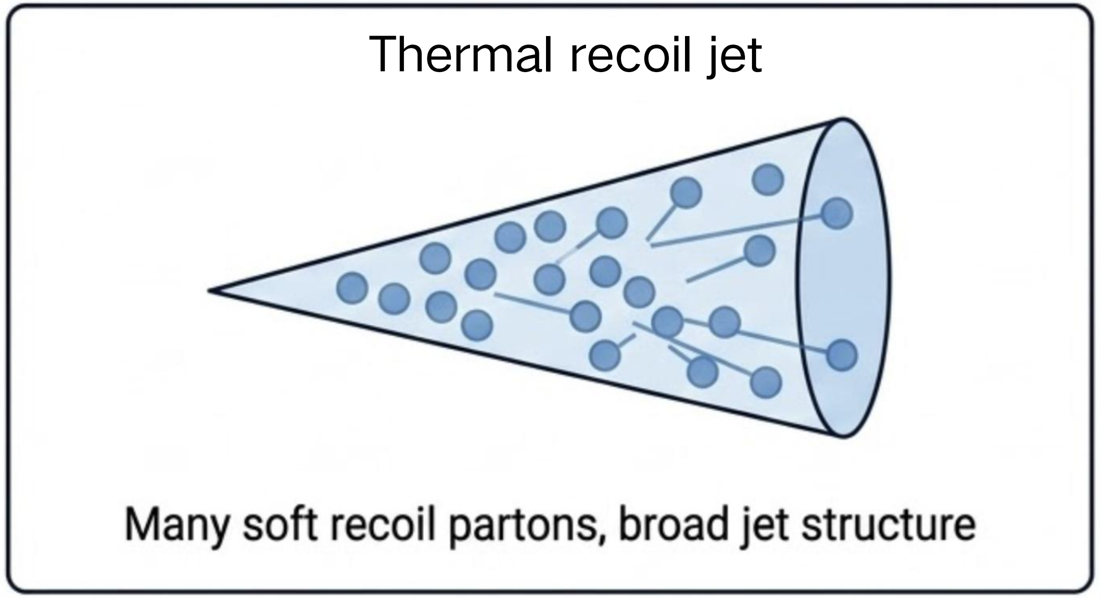
The medium can reorganize into a reconstructable jet-like object.

Signature I: jet shape

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

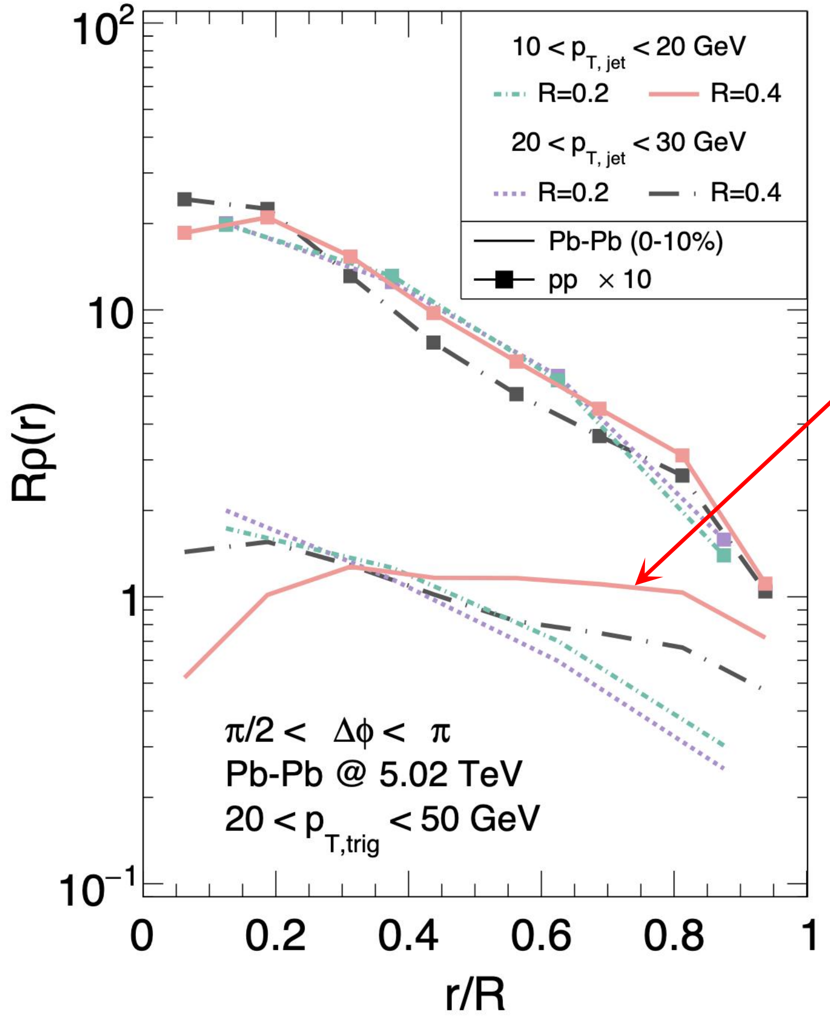
- Energy distribution relative to jet axis
- Distinguishes hard jets from thermal recoil jets





Jet shape tests whether the jet energy is concentrated near the axis or spread over large angles.

Signature I result: broad jet shape



For large R, low-p_T recoil jets

- Weaker central core compared with pp
- Show a broadened shape

A broad jet shape supports medium-response-dominated jets.

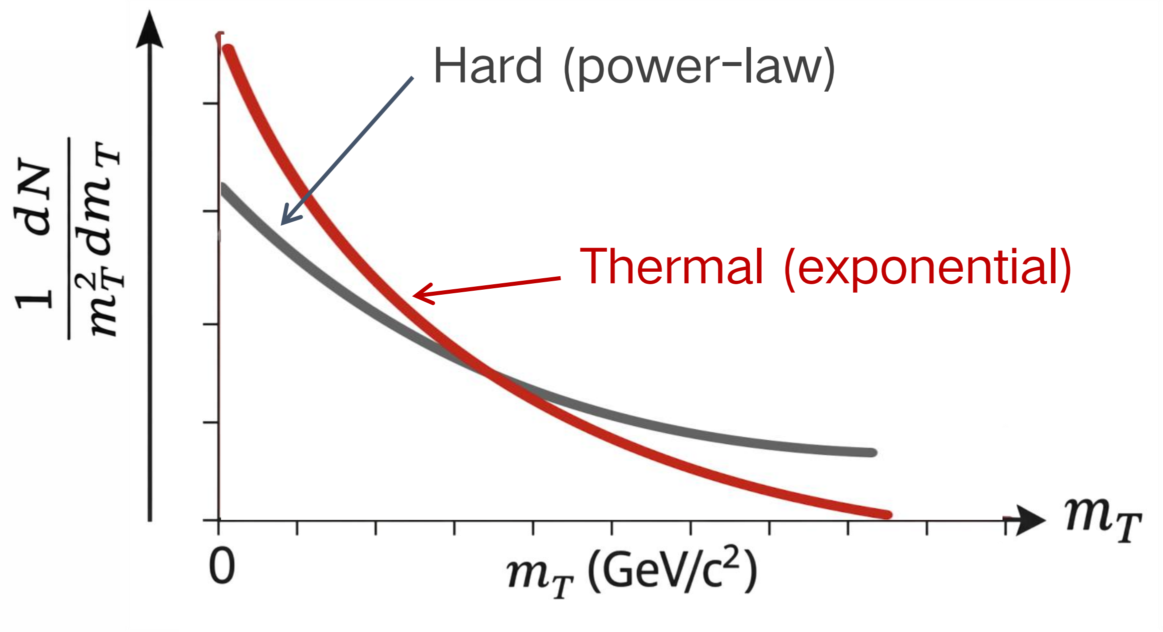
Signature II: transverse mass (m_T)

$$m_T = \sqrt{p_T^2 + m^2}$$

Thermal expectation:

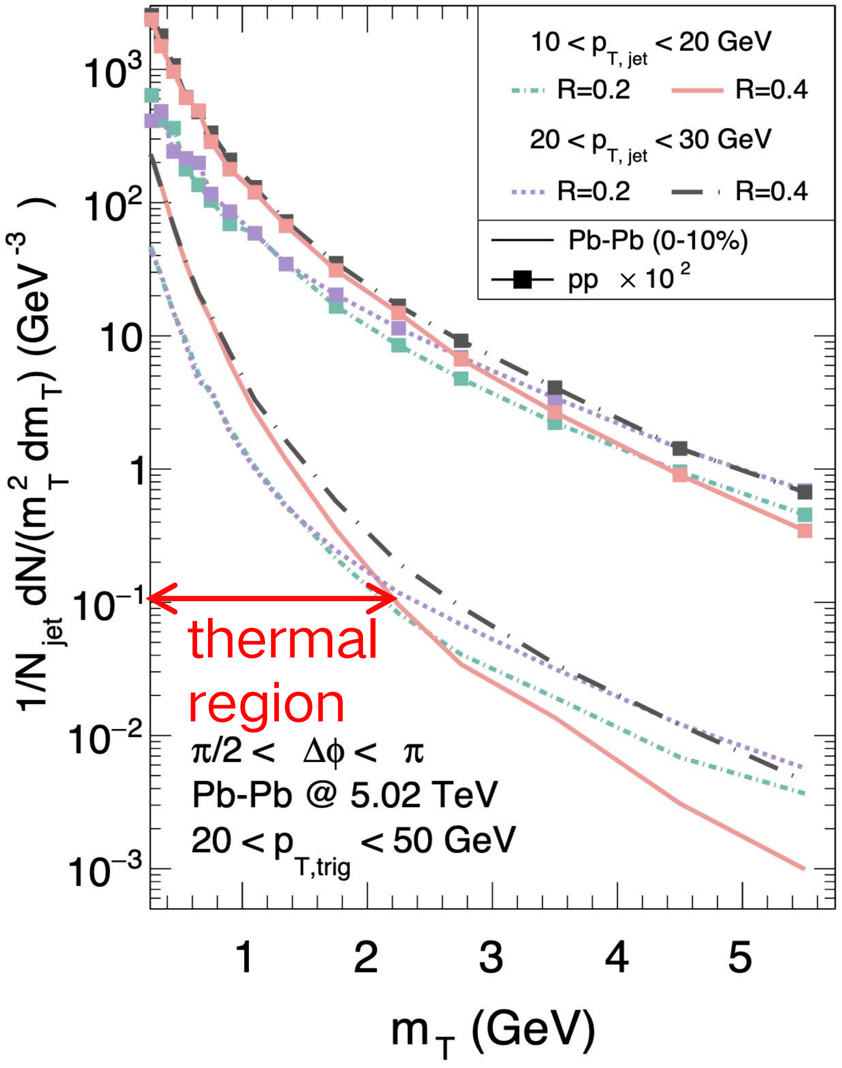
$$\frac{1}{m_T^2}\frac{dN}{dm_T} \propto exp(-\frac{m_T}{T})$$

- Slope parameter → temperature T



Thermal recoil jets → exponential-like m_T spectrum of jet constituents

Signature II result: soft thermal-like spectrum

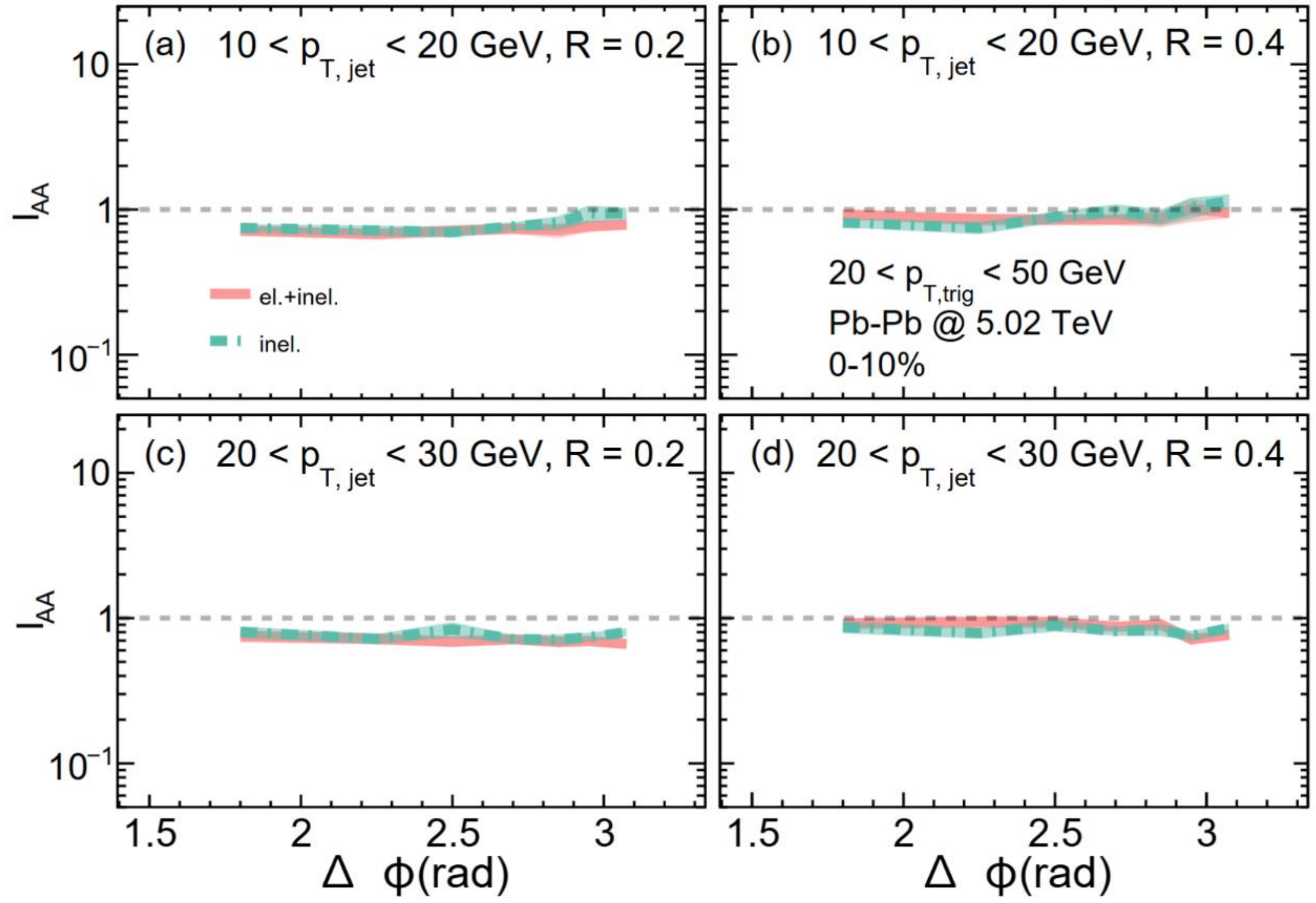


For large R, low-p_T recoil jets

- The constituent spectrum becomes softer
- A thermal-like behavior persists up to m_T ~ 2 GeV
- Small-R jets remain more power-law-like

The constituent spectrum supports the thermal origin of the enhanced recoil-jet yield.

HQ-jet: I_{AA} vs $\Delta\phi$



- No enhancement of I_{AA} at large $\pi-\Delta\phi$
- Medium response (elastic) has negligible impact on HQ-jet yield

One mechanism, multiple signatures

hard jets -> energy deposition -> medium response -> thermal recoil jets

Yield-level signatures

- low p_T I_{AA} enhancement
- large-angle I_{AA} enhancement
- strong large-R dependence

Substructure signatures

- broad jet shape
- soft thermal-like constituents

Summary

- A transport model is developed to simultaneously describe the recoil-jet observables
- A novel jet production mechanism is proposed: thermal recoil jets
  - ✓ Naturally explains the p_T, R, and Δϕ dependence of the hadron- triggered recoil-jet I_{AA} enhancement
  - ✓ Can be straightforwardly tested by jet substructure measurements

back up

RHIC:Au-Au @ 200GeV