Study of path-length dependent energy loss of jets in p-Pb and Pb-Pb collisions with ALICE

Caitie Beattie

On Behalf of the ALICE Collaboration

Quark Matter

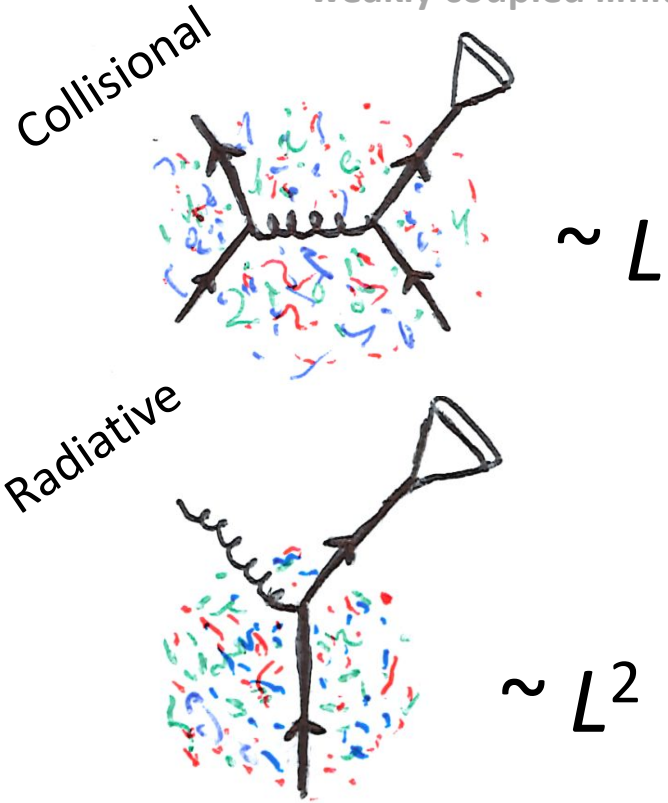
6.4.2022

Funded in part by:

Jet energy loss

Assuming a static medium in the weakly coupled limit…

- Jets lose energy due to interactions with the QGP!
- Microscopic mechanism is well-studied theoretically.
- Theoretical relationship between mechanism and path-length dependence.



M. Djordjevic, et. al., Phys. Rev. C, 2019.

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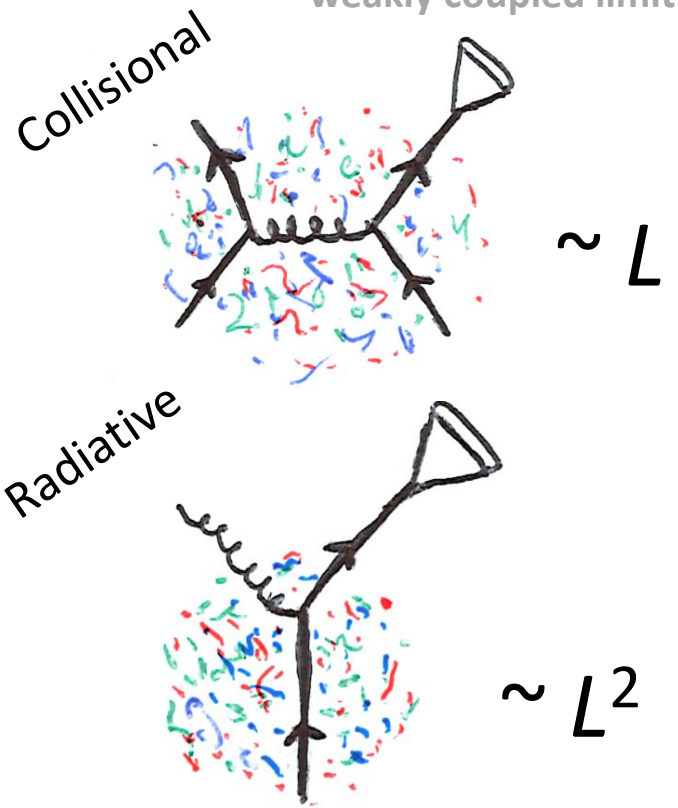
But how can we access this experimentally?



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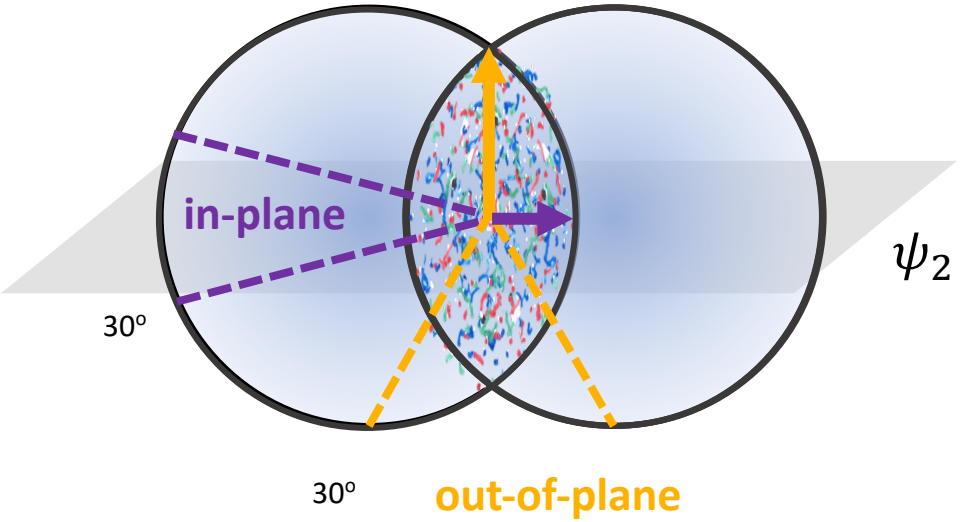
Event-plane angles

Semicentral collisions generate an anisotropic overlap region.



It is expected that the **in-plane** axis will be shorter than the **out-of-plane** axis.

Parton **energy loss** is expected to be greater along the **out-of-plane axis** if path-length dependence is a leading effect.

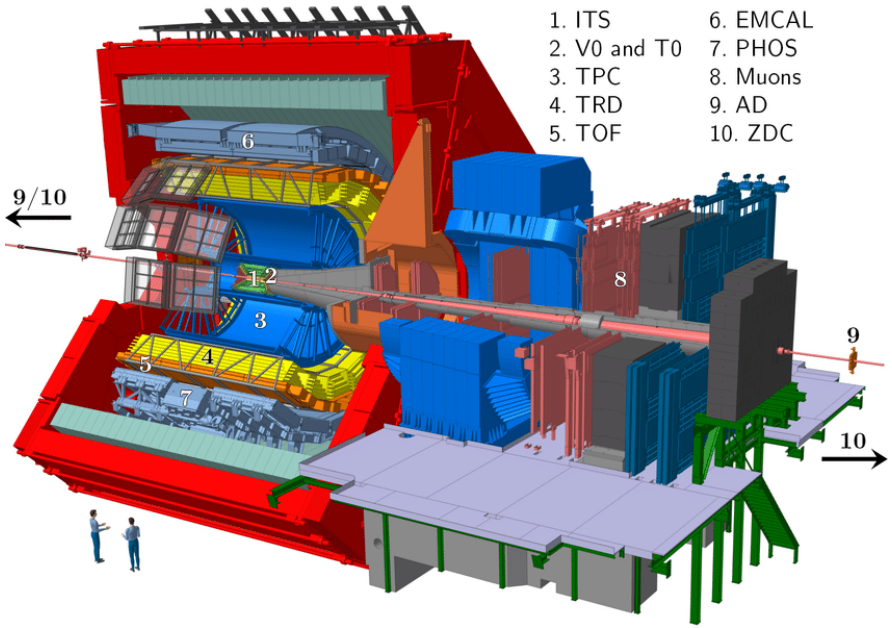
The ALICE detector

ALICE is well-suited to measure soft-hard correlations of interest.

1. **Time Projection Chamber**
   Excellent tracking of charged particles.

2. **EMCal**
   Used for measurement of neutral constituents.

3. **V0**
   Forward detector used to measure event-plane angles.



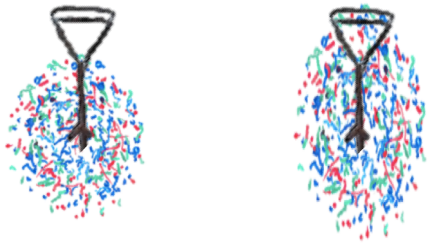
Pb-Pb, p-Pb, $\sqrt{s_{NN}}$ = 5.02 TeV

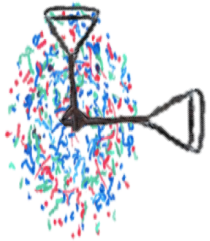
Approaches to constraining path-length dependence

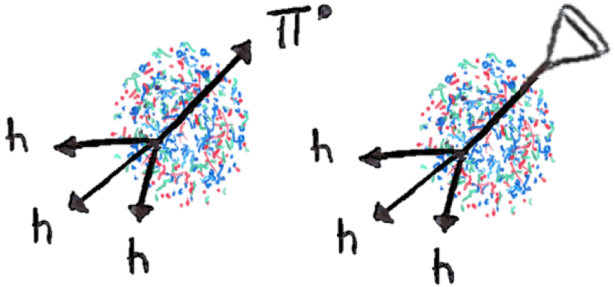
1. Event-Shape Engineering
2. v_2 Measurements
3. Correlation Studies

   π^0- hadrons

   jet - hadrons







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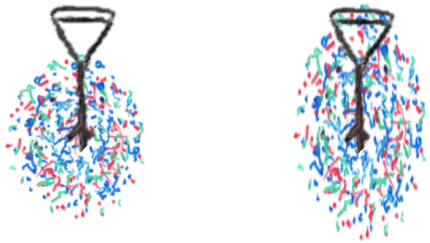

1. **Event-Shape Engineering**

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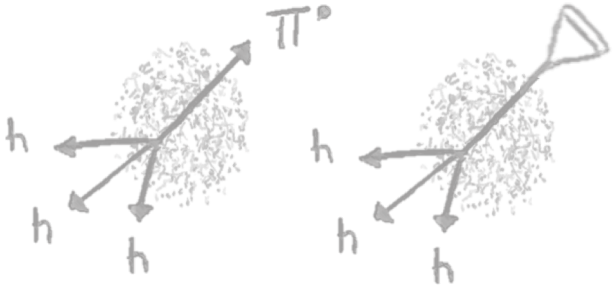


Event-shape engineering

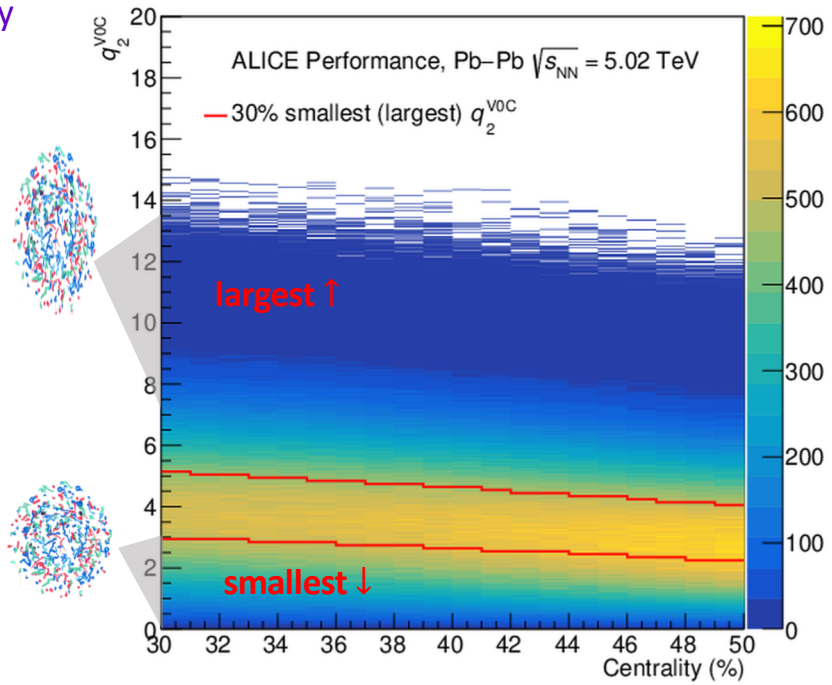
Event-Shape Engineering (ESE) classifies events according to their anisotropy **within a centrality class**.

M = multiplicity

$$q_2 = |\mathbf{Q}_2|/\sqrt{M}$$

$$\mathbf{Q}_2 = \left(\sum_{i=1}^{M} \cos(2\varphi_i), \sum_{i=1}^{M} \sin(2\varphi_i)\right)$$

φ_i = azimuthal angle of ith particle



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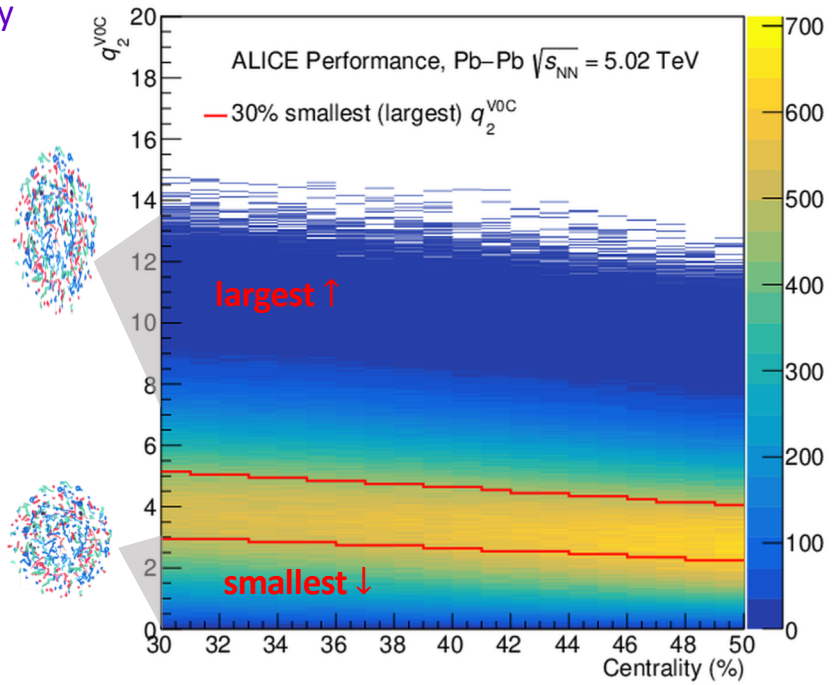
How can we exploit this to study **path-length dependent energy loss**?



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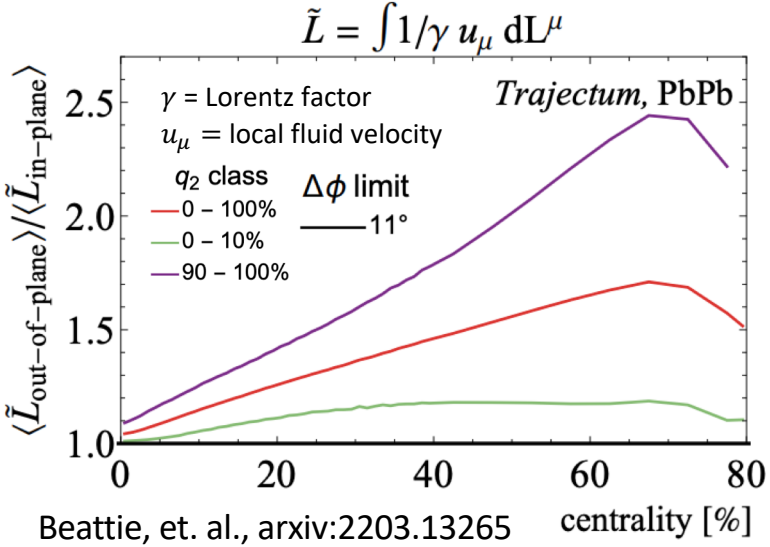
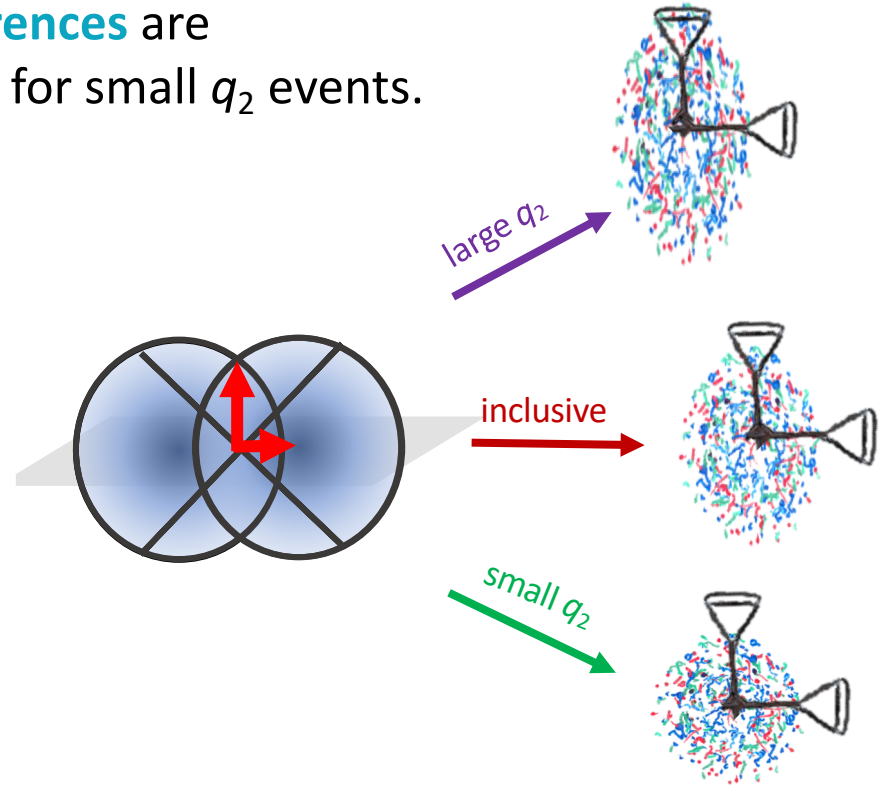
Greater **in- vs. out-of-plane differences** are predicted for large q_2 events than for small q_2 events.



Beattie, et. al., arxiv:2203.13265



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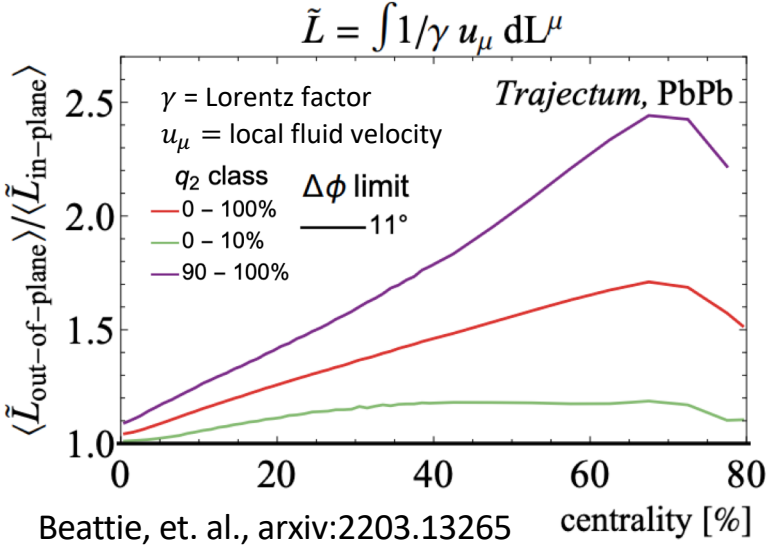

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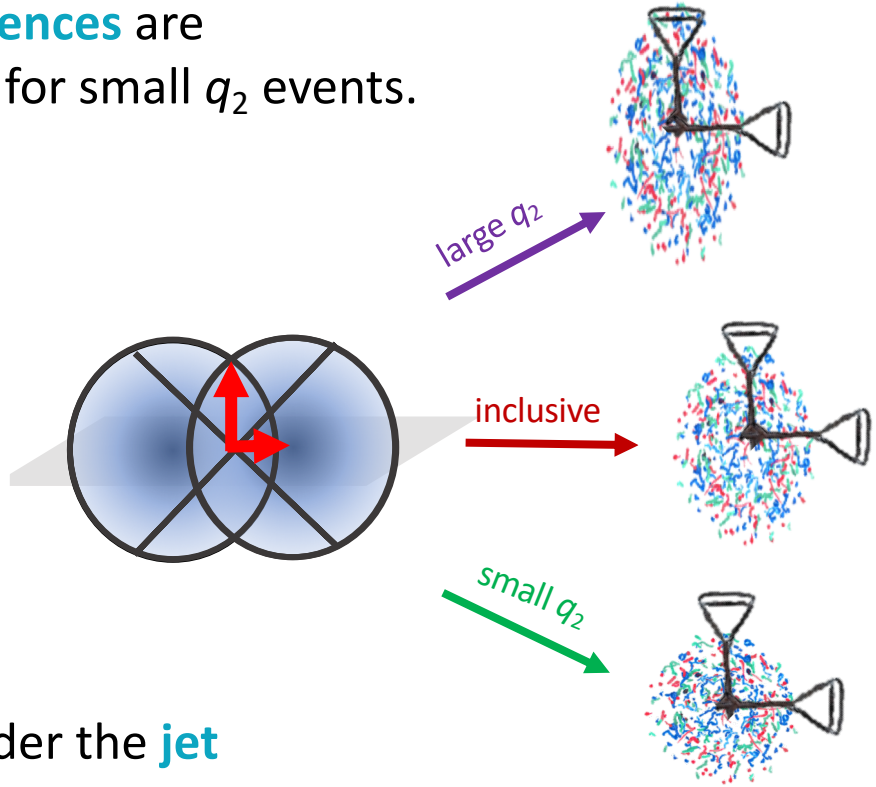
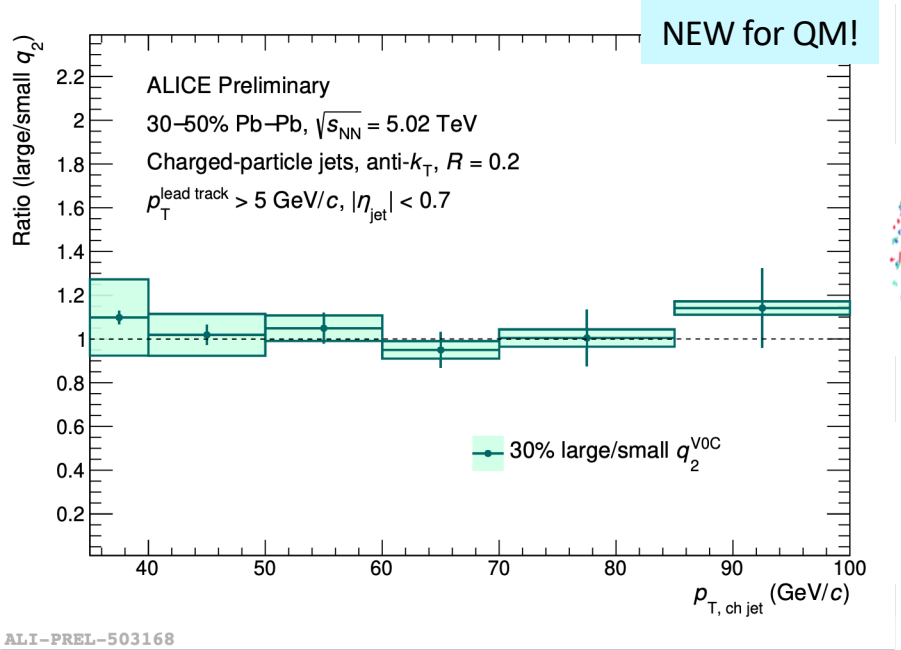
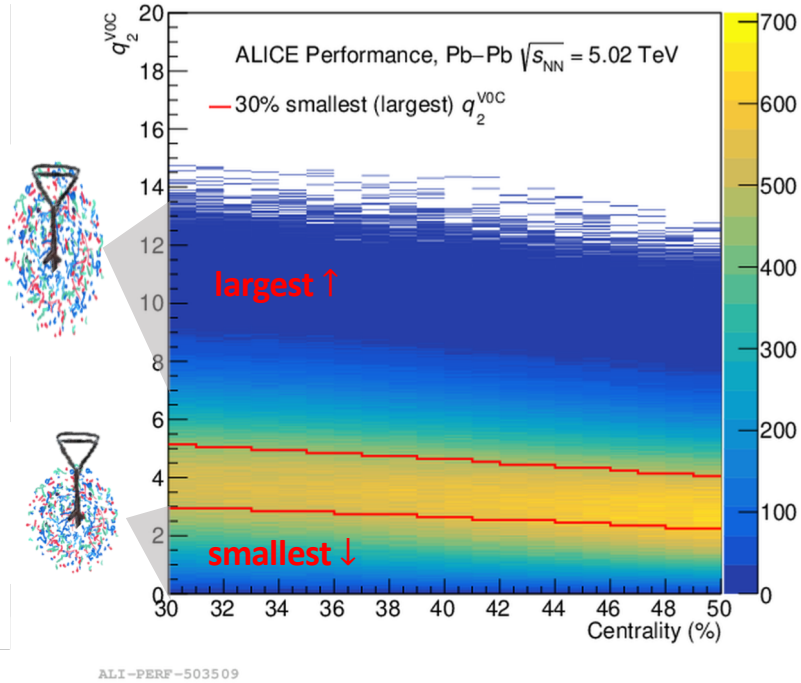


To study this in data, we can consider the **jet spectra** separated by ESE class.

Event-shape engineering

Comparison of jet spectra from large and small q_2 events is consistent with unity.

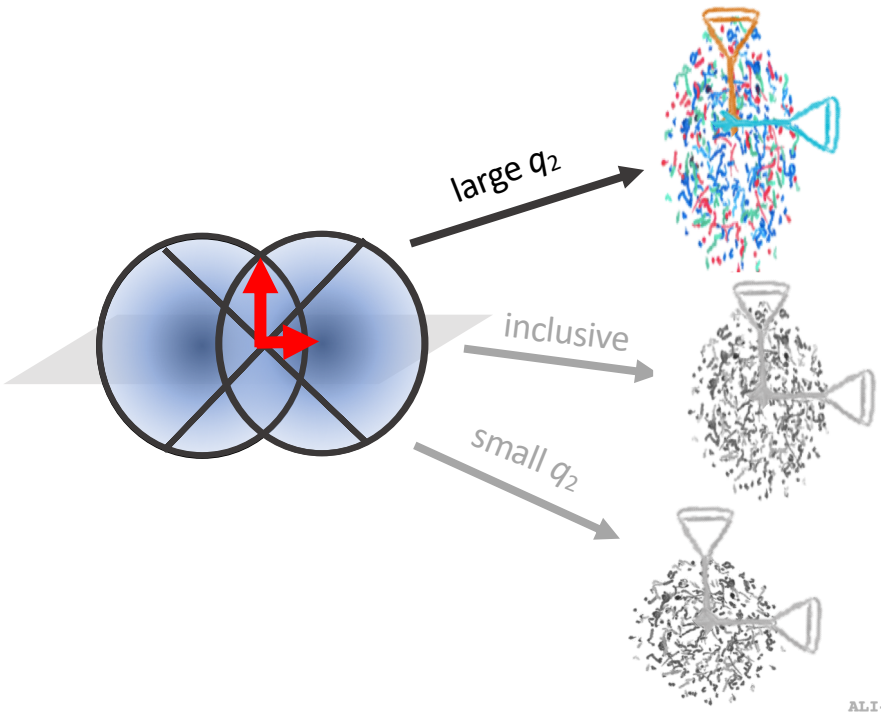


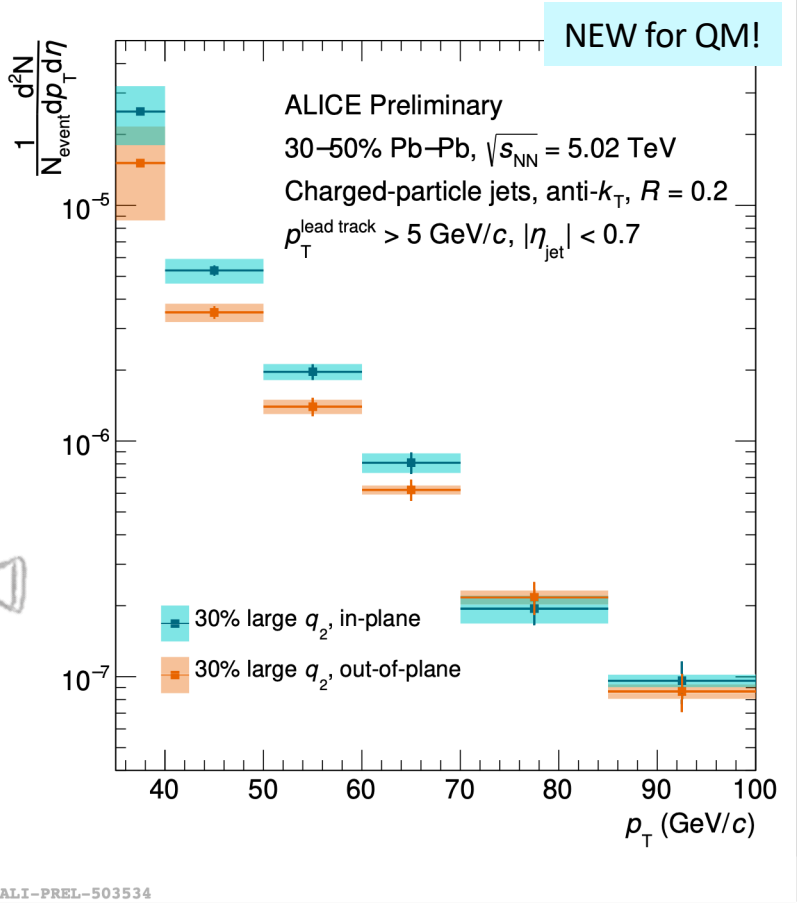


Additional q_2^{V0A} cut imposed for autocorrelations.

Event-shape engineering

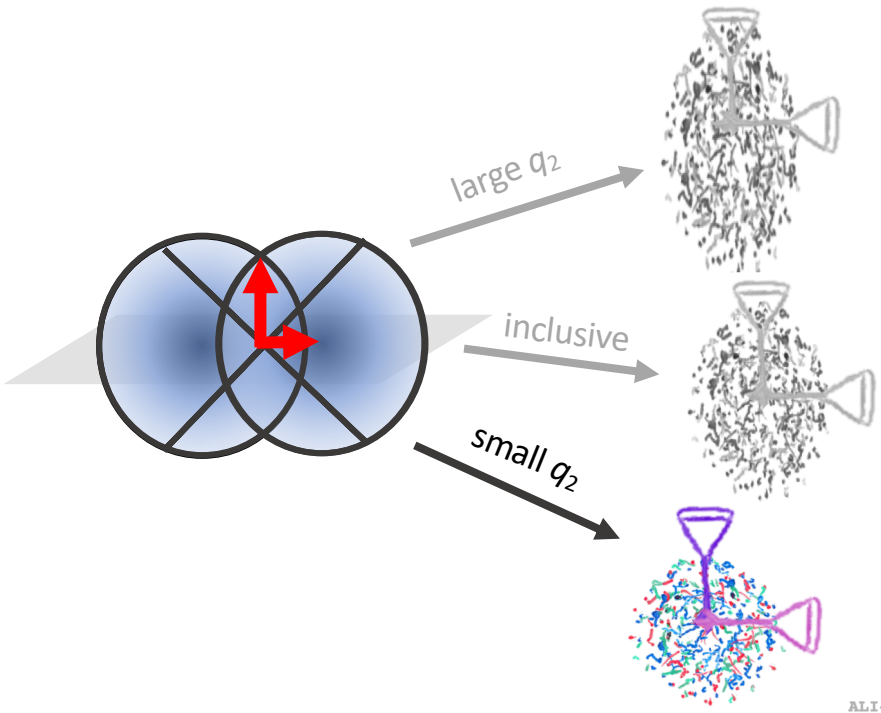
Large q_2 events show significant out vs. in plane difference at mid p_T

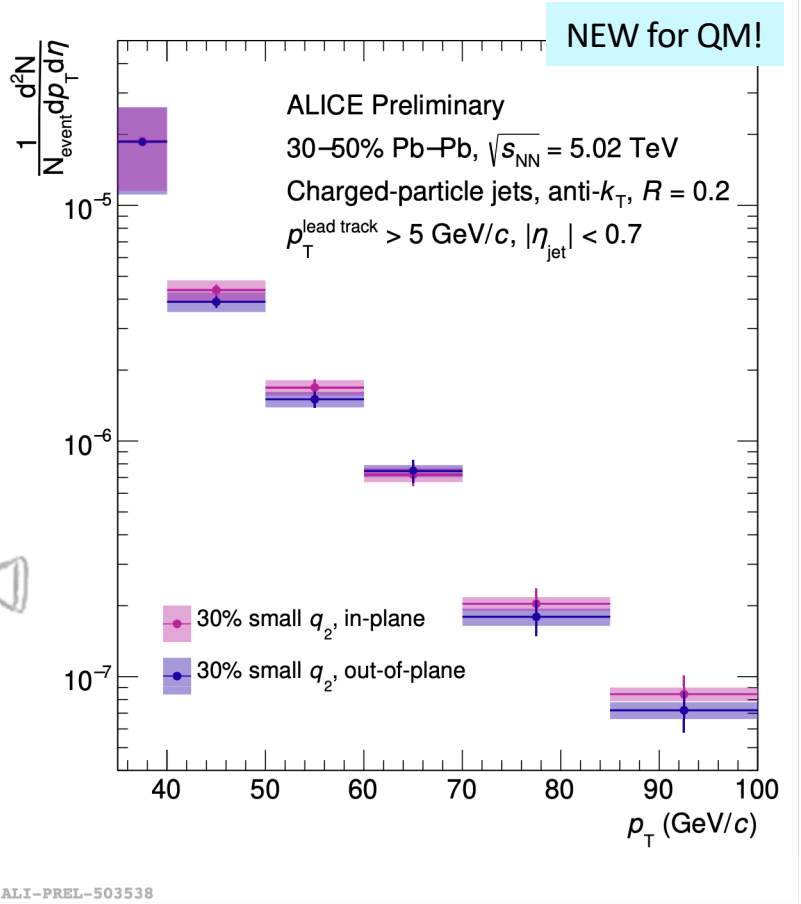




Event-shape engineering

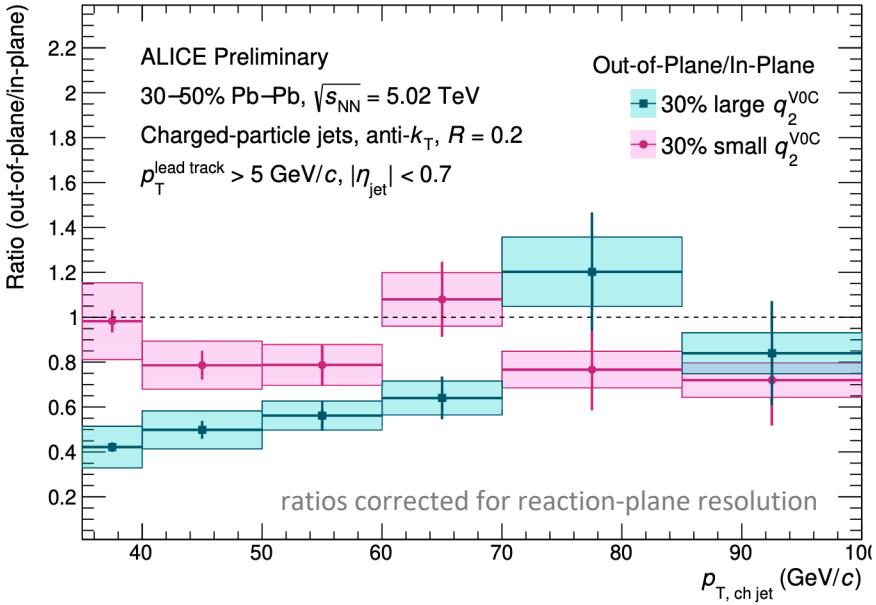
Small q_2 events show less out vs. in plane difference at mid p_T





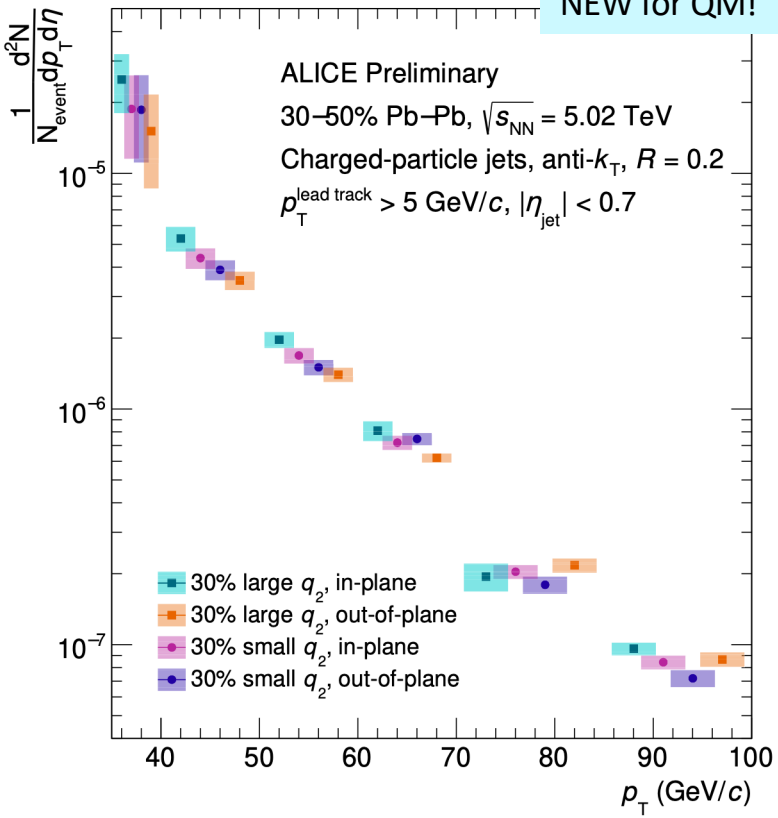
Event-shape engineering

Suppression of out-of-plane yields relative to in-plane, more significant for large q_2!



ALI-PREL-503397

NEW for QM!



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Additional q_2^{V0A} cut imposed for autocorrelations.

Approaches to constraining path-length dependence

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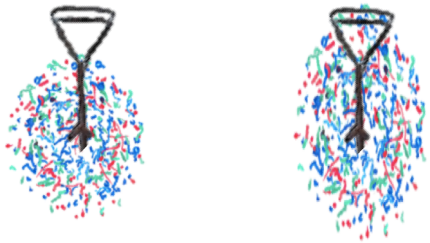

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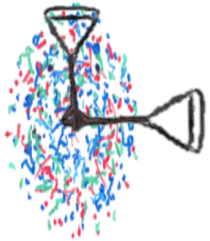

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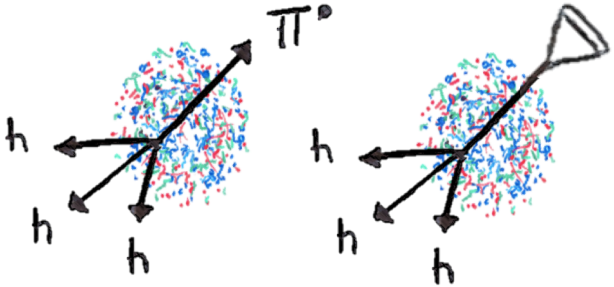

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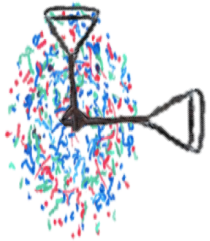

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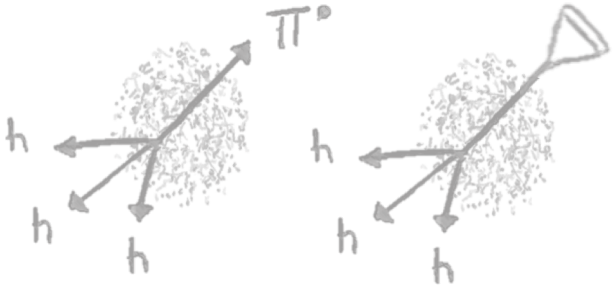
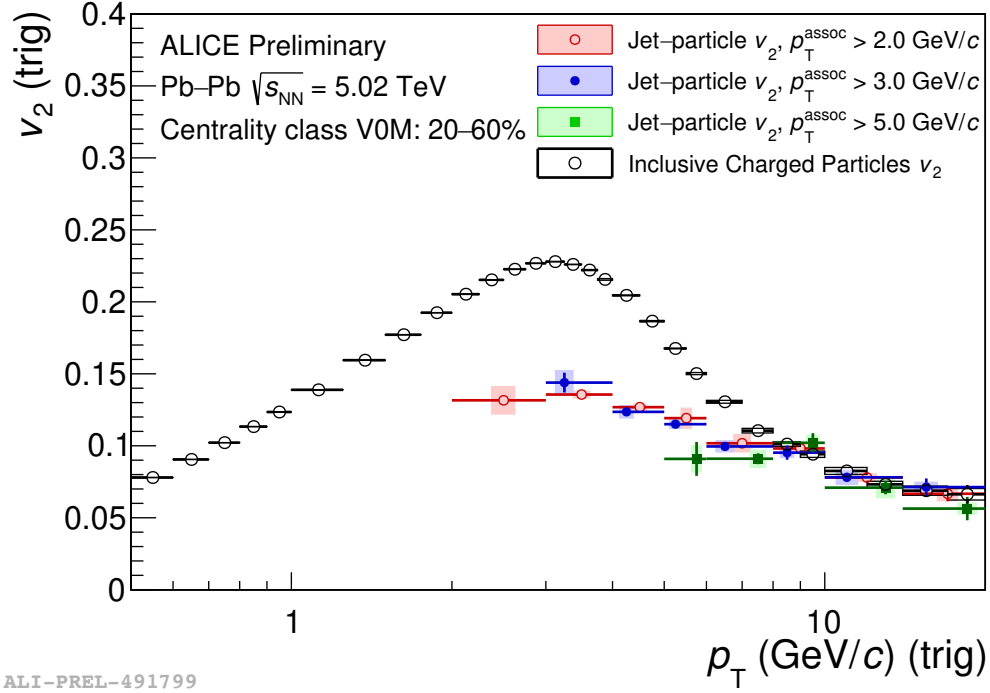
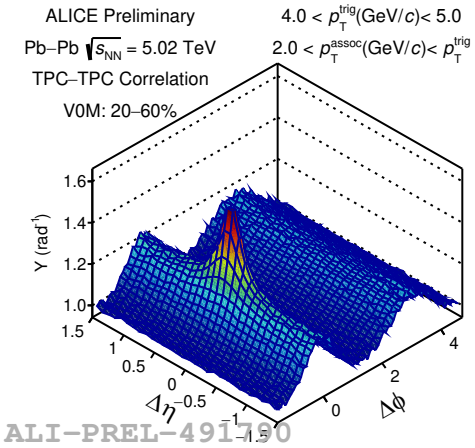


Jet-particle v_2

We can explore lower in p_T by considering the **jet particle v_2**.





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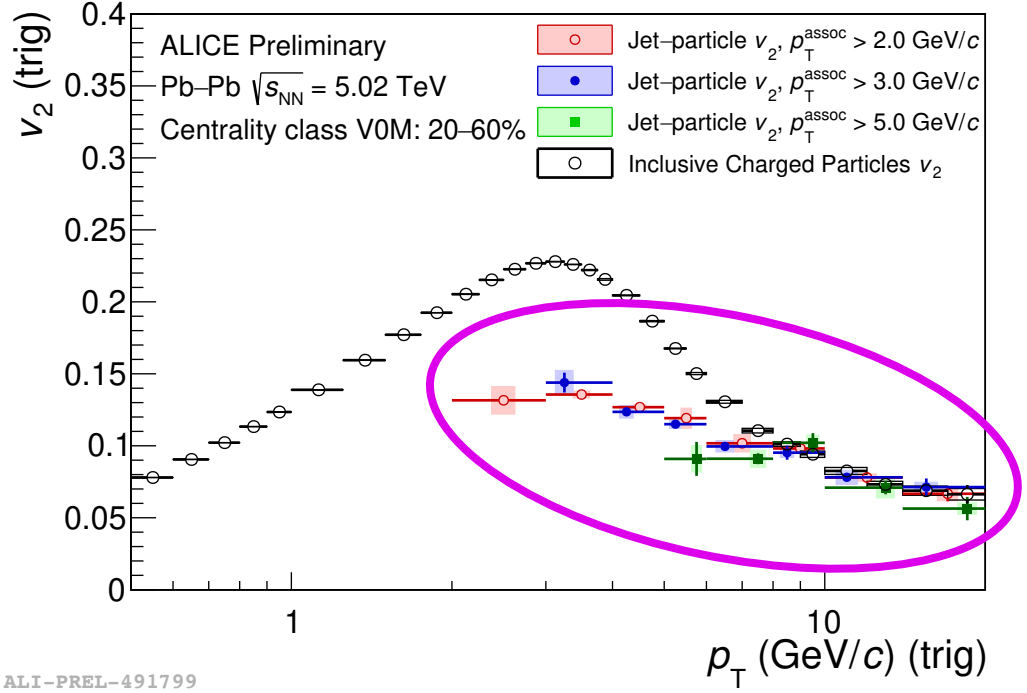
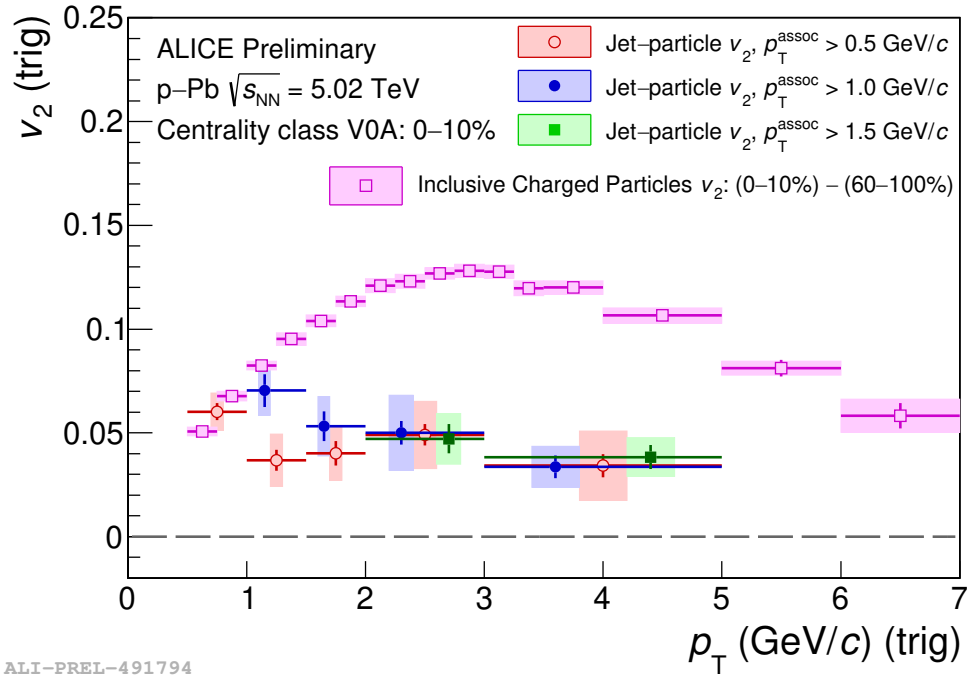


Non-zero v_2 is indicative of suppressed out-of-plane jet activity, consistent with path-length dependence.

Jet-particle v_2

But when we look in p-Pb, we also see non-zero v_2!



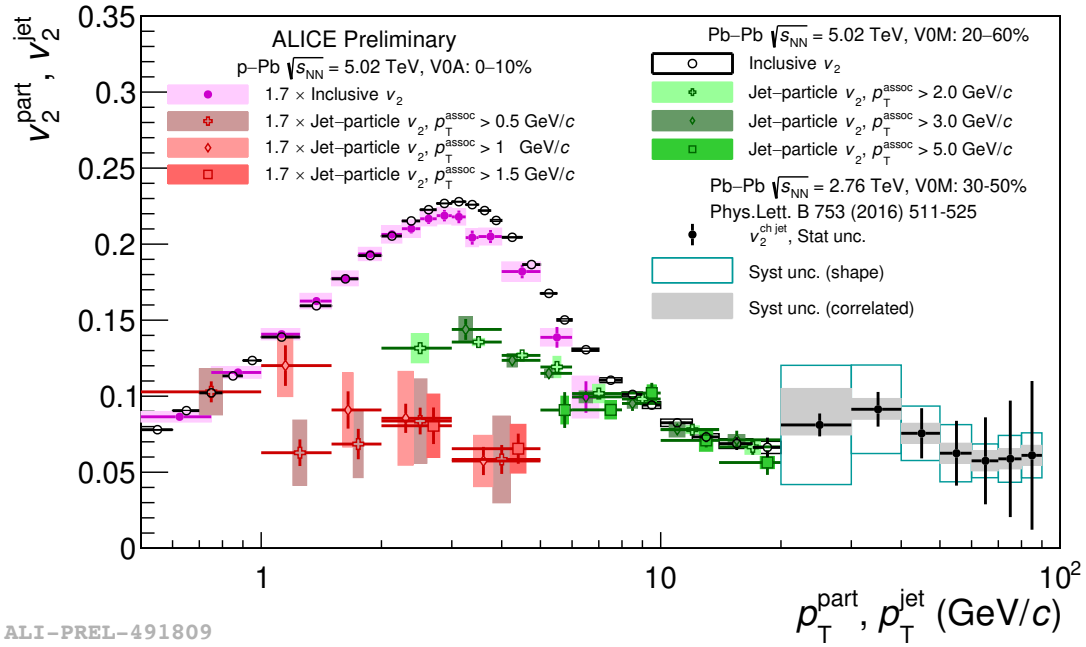
Is the jet particle v_2 indicative of jet quenching, or something else?

See talks by Filip Krizek and Marianna Mazzilli!

Jet-particle v_2

Stay tuned for upcoming paper!

When comparing p-Pb and Pb-Pb, we see the v_2 magnitude is different but comparable.



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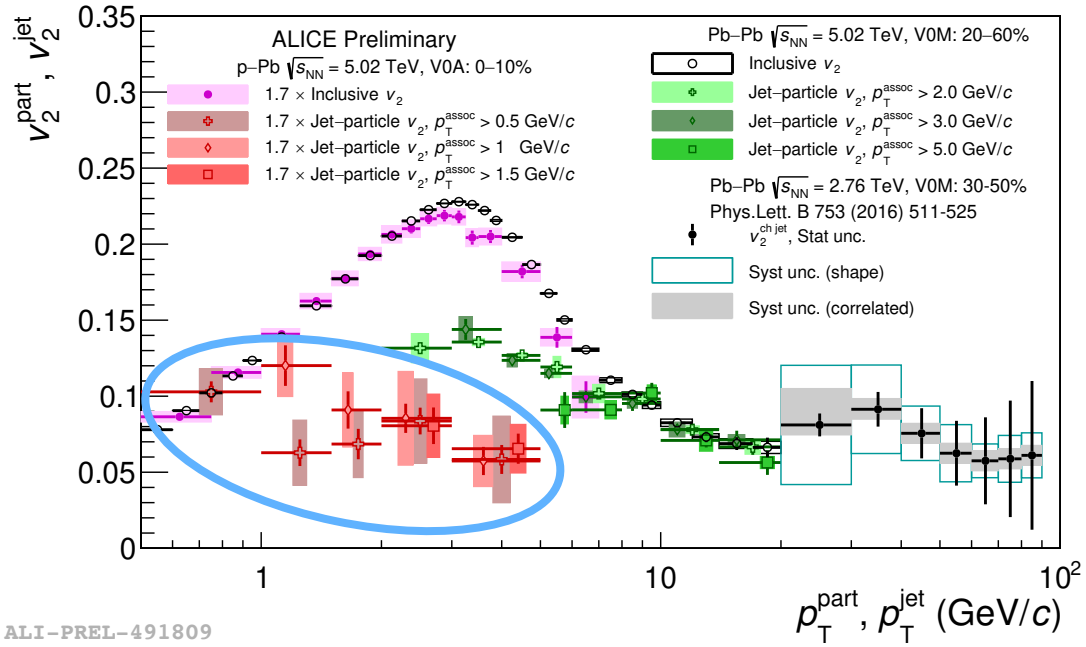

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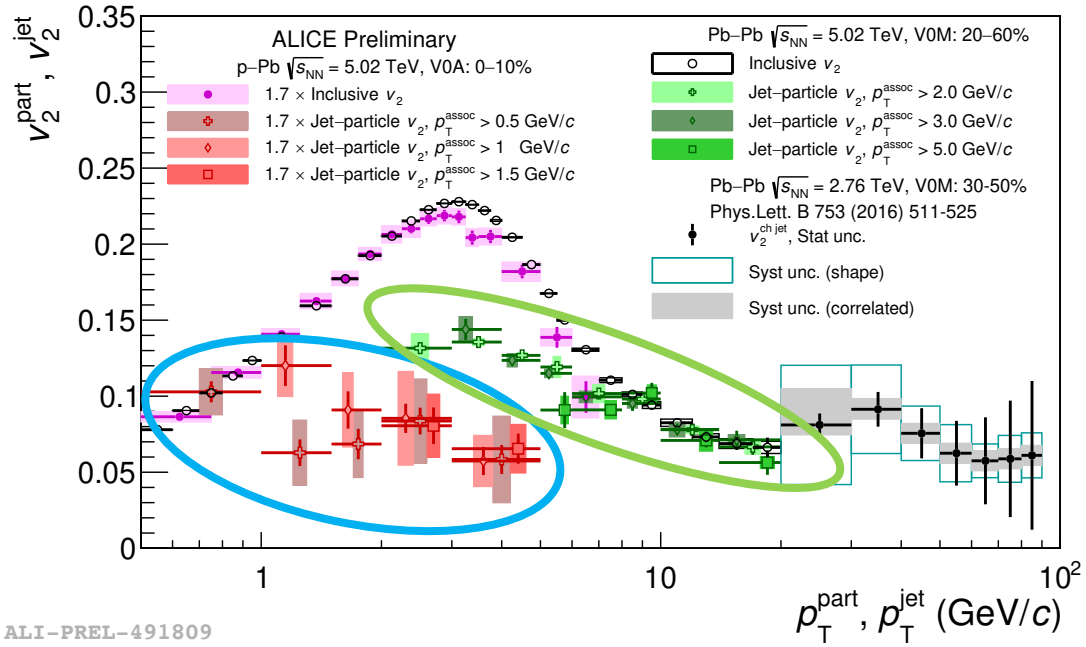

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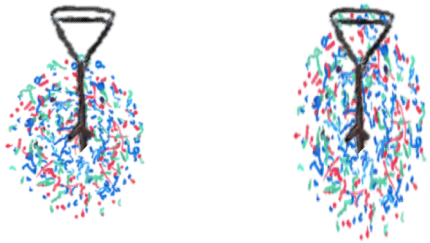

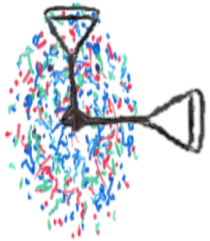

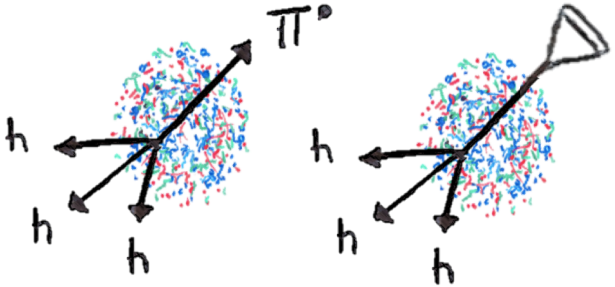

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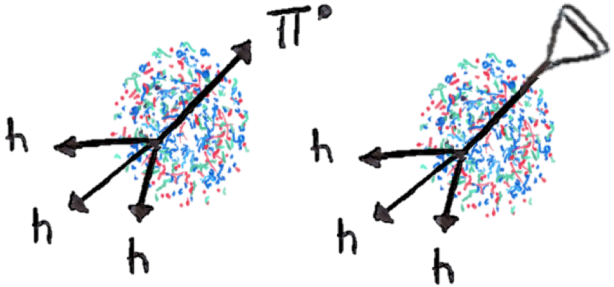
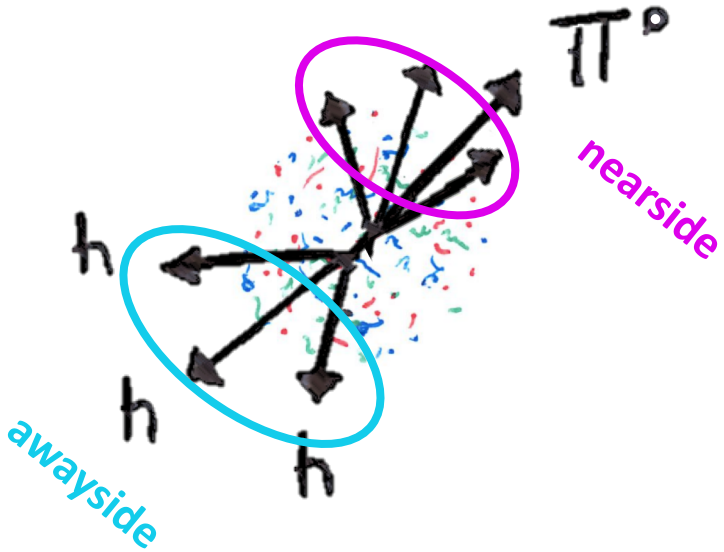


Correlation studies

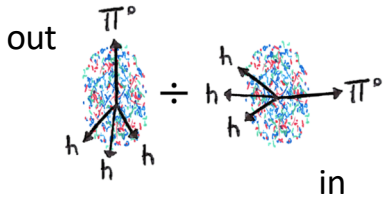
We can look for high-p_T π^0s (or jets), and study the modification of associated hadrons.



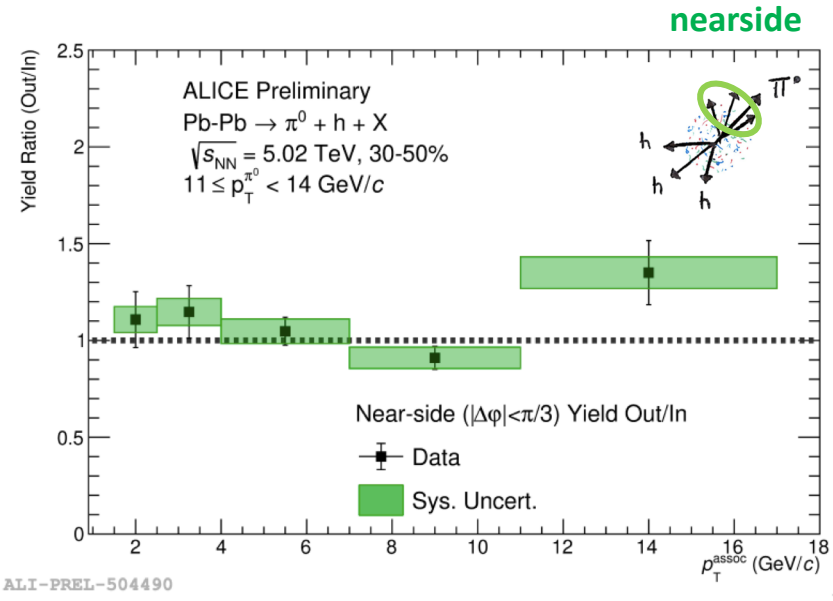
Look first at near-side and away-side yields.

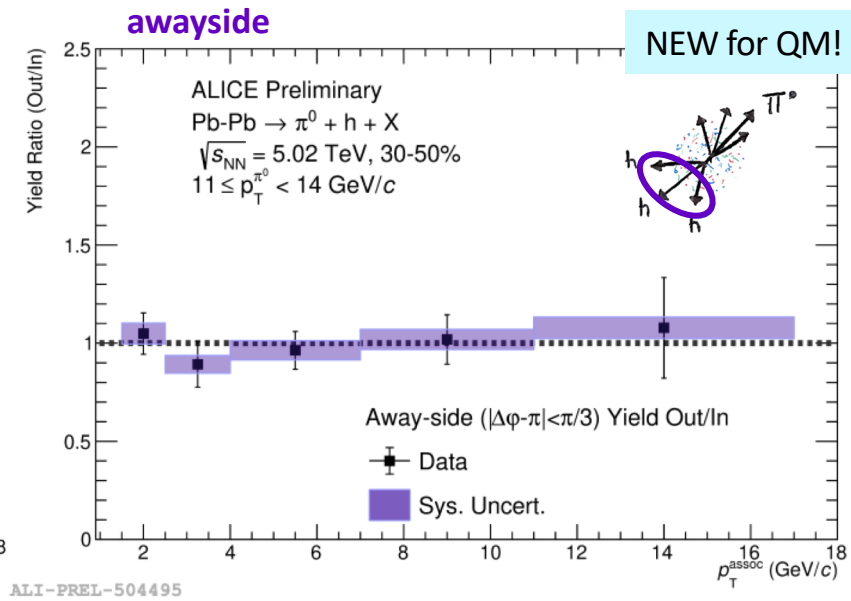
Then consider how these comparisons vary with event-plane.

π^0- hadron correlations



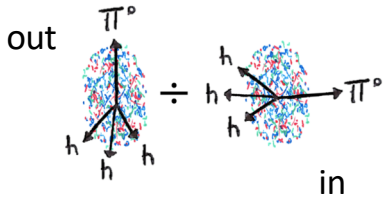
No evidence of modification…



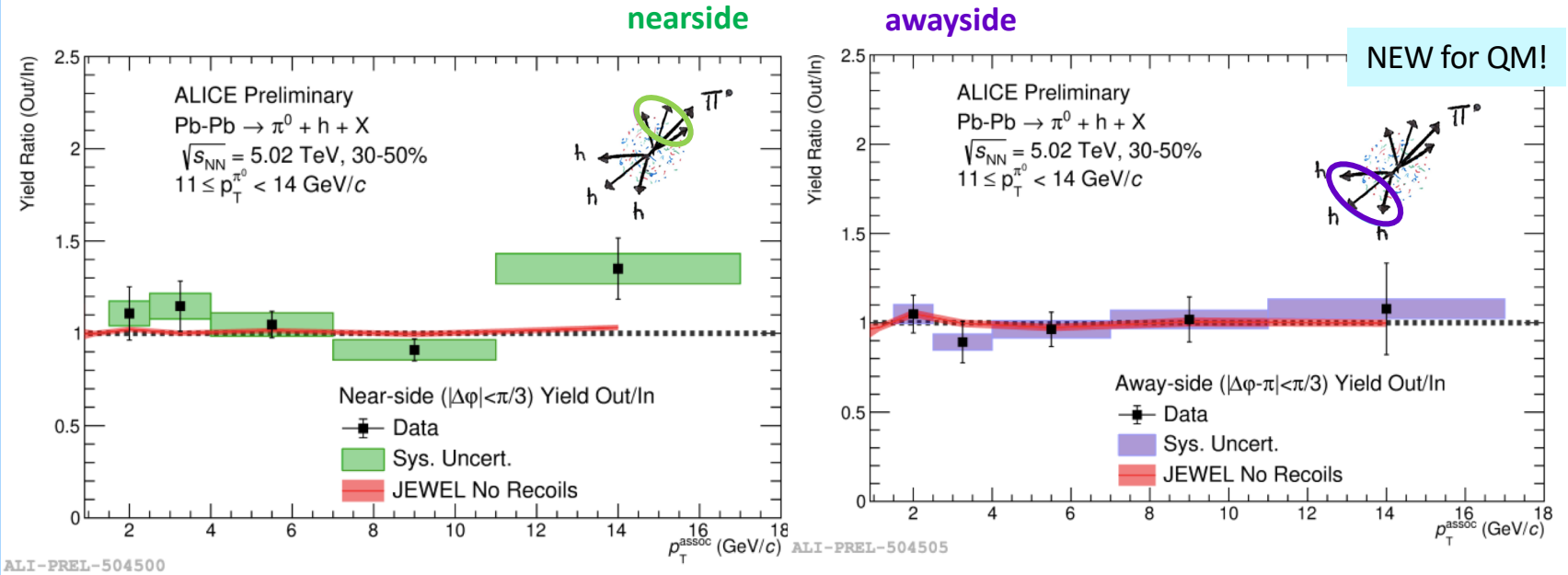


…for wide range of p_T^{assoc} to high precision.

π^0- hadron correlations

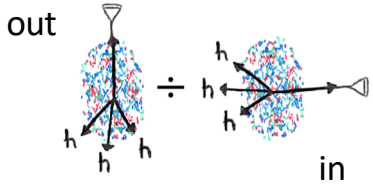


…but none predicted by JEWEL (w/o recoils).

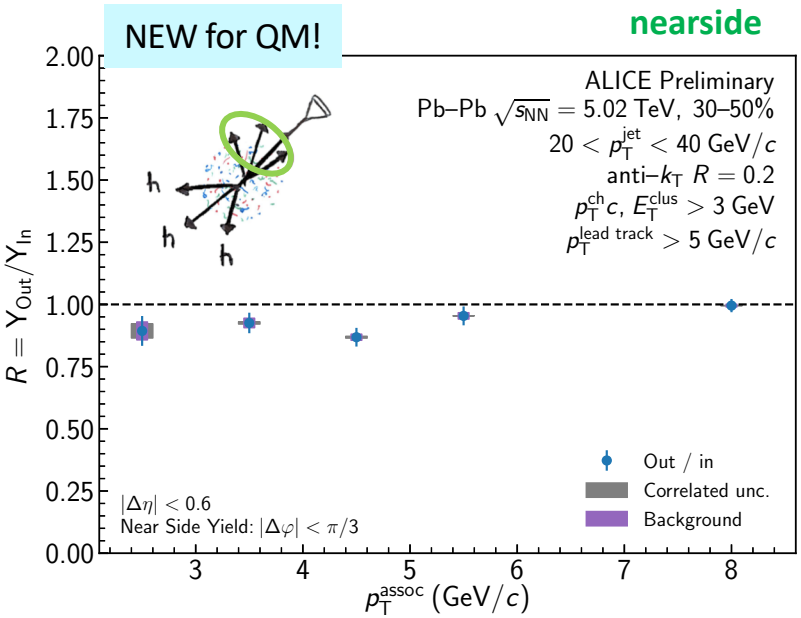


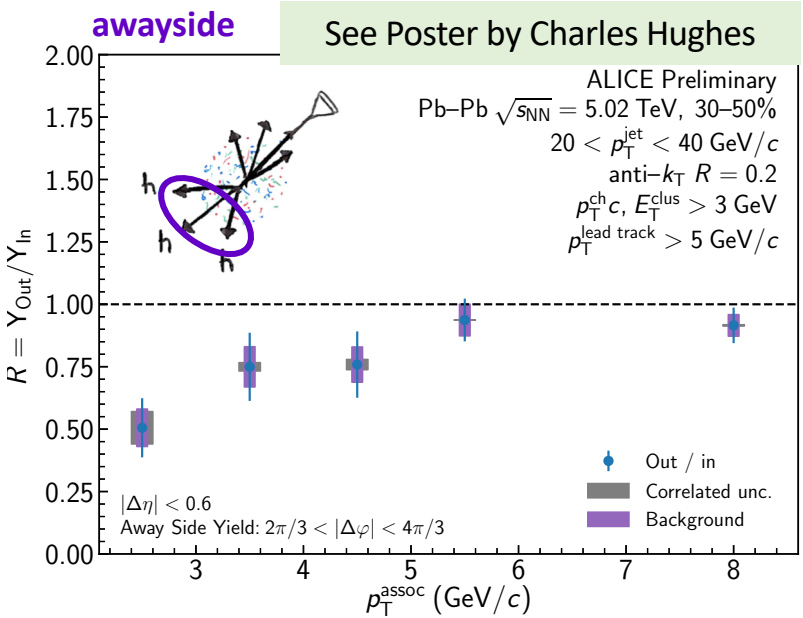
Path-length not the leading contributor for this observable.

Jet-hadron correlations



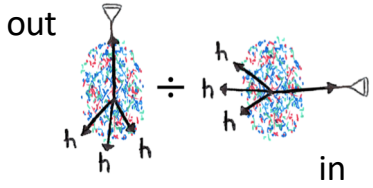
Away-side modification at low p_T^{assoc}...



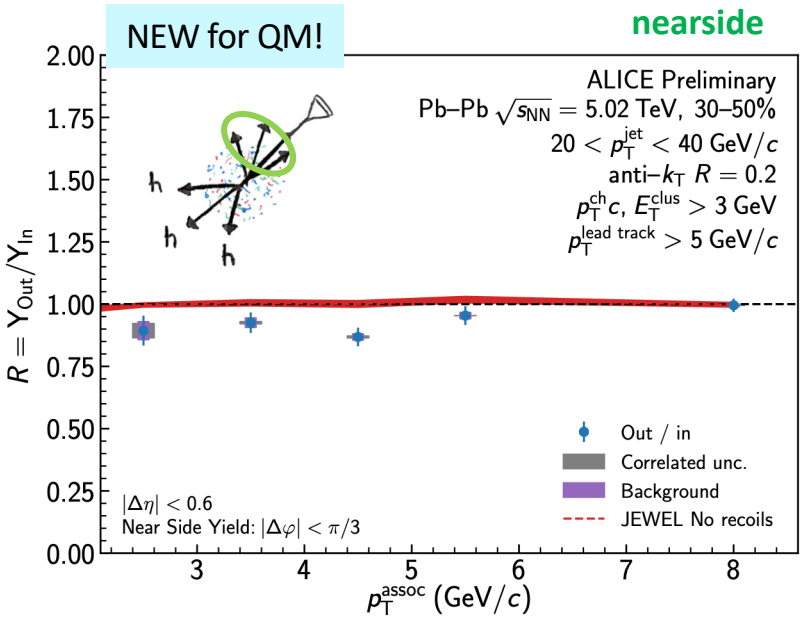


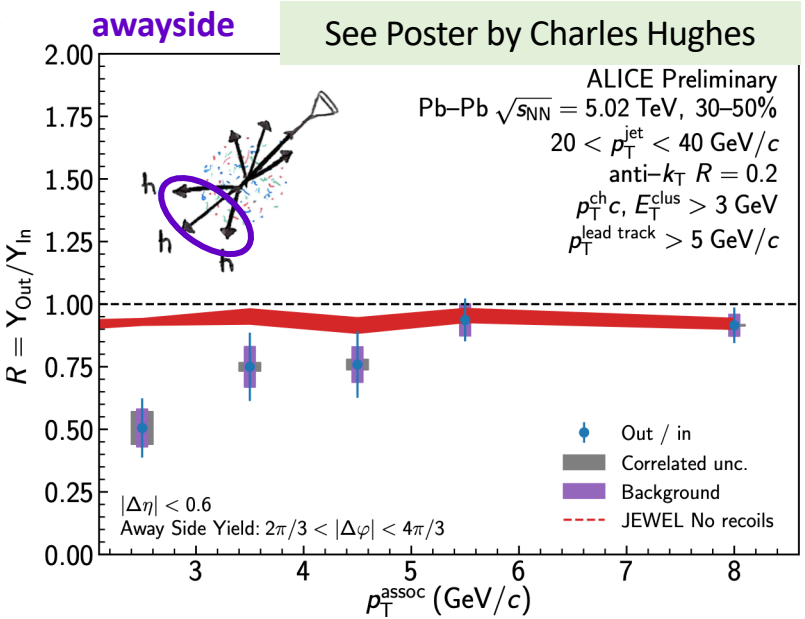
...with work being done to push to lower p_T^{assoc}. Stay tuned!

Jet-hadron correlations



Away-side modification at low p_T^{assoc}...

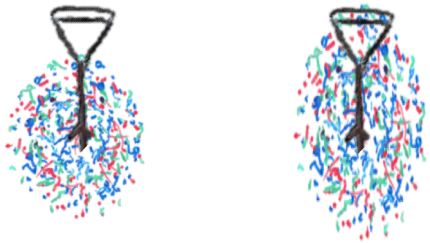




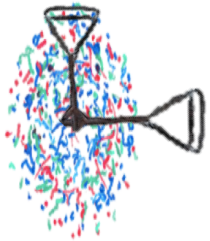
Suppression not seen in JEWEL (w/o recoils).

Approaches to constraining path-length dependence

1. Event-Shape Engineering



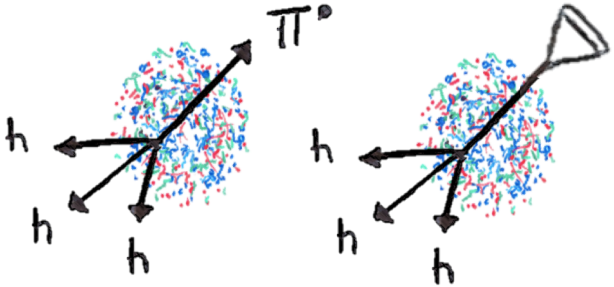
2. v_2 Measurements



3. Correlation Studies

   π^0- hadrons

   jet - hadrons



Summary

- **Event-Shape Engineering** studies show significant event-plane dependence in more anisotropic events.
- Non-zero **jet-particle v_2** shows event-plane dependence in p-Pb and Pb-Pb.
- **Correlation** studies show mixed event-plane dependence, depending on observable.

Not all event-plane observables are sensitive to path-length differences.

Observables that are most sensitive show results consistent with path-length dependent energy loss.

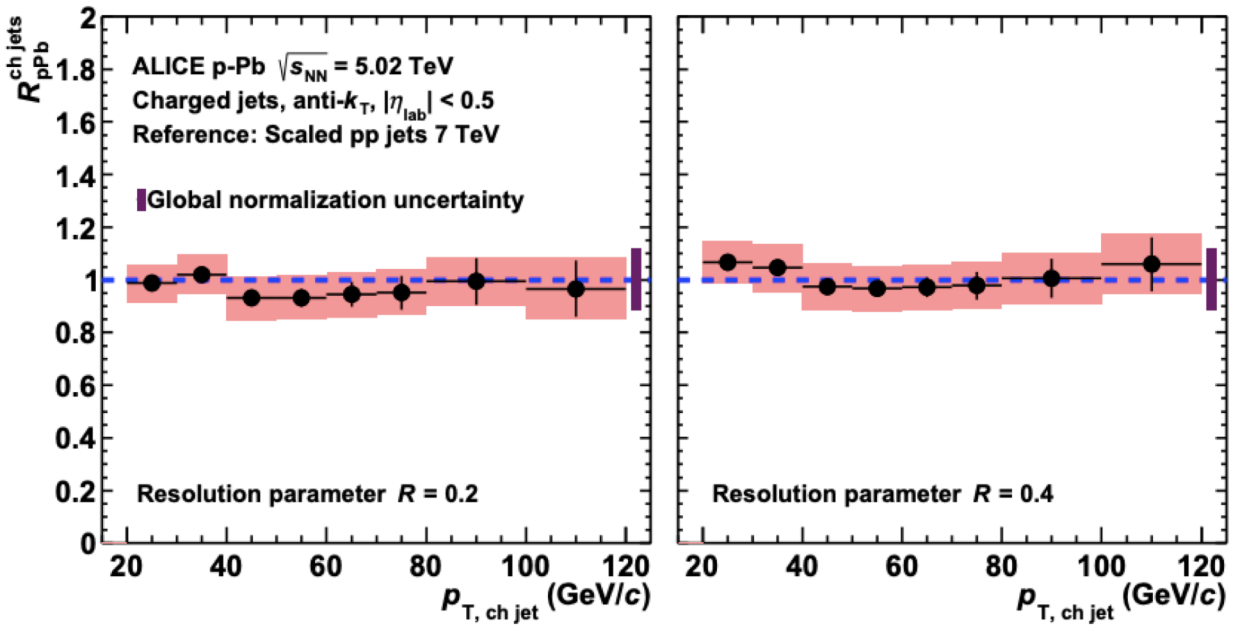
Summary

ALICE Jet Results at QM

	Longitudinal: energy loss, path length dependence	Transverse: wide vs. narrow, quark/ gluon, intrajet broadening	Jet Deflection	Mass/Flavor Dependence	Jet Grooming	Non-Perturbative Effects	Small Systems
Isolated photon-jet correlations: Alwina Liu Tues. 16:30	ALICE		ALICE				
Path length dependence in Pb--Pb and p—Pb collisions: Caitie Beattie Wed. 8:40	ALICE						ALICE
Jet angularity and fragmentation in Pb-Pb: James Mulligan Wed. 10:00	ALICE	ALICE			ALICE	ALICE	
Search for jet quenching in high-multiplicity pp collisions: Filip Krizek Wed. 12:50			ALICE				ALICE
Heavy-flavor jets from small to large systems: Marianna Mazzilli Wed. 14:40	ALICE	ALICE		ALICE		ALICE	ALICE
R-dependence of jet suppression and groomed jet splittings in Pb--Pb: Hannah Bossi Thurs. 18:10	ALICE	ALICE	ALICE		ALICE		
Jet acoplanarity and energy flow within jets in Pb—Pb and pp: Rey Cruz-Torres Thurs. 18:30	ALICE	ALICE	ALICE		ALICE	ALICE	

Backup: The R_{pPb}

The R_{pPb} is consistent with unity.



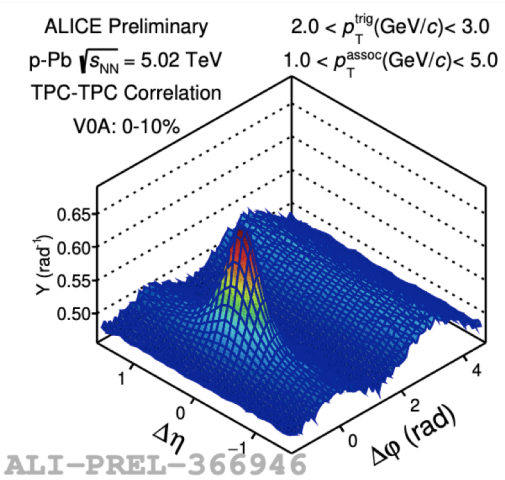
ALICE, Phys. Lett. B749 (2015) 68-81

Backup: Jet-Particle v_2

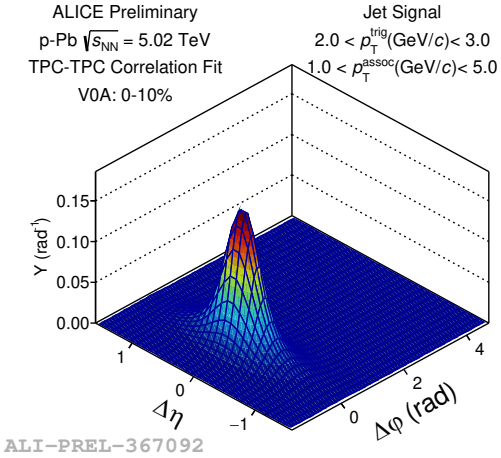
Signal – extracted using double Gaussian

Background – obtained from sum of flow harmonics

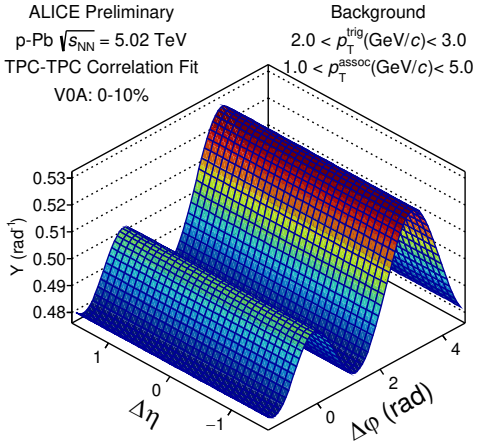
Data



Signal



Background



Backup: Jet-Hadron Analysis - Reaction Plane Fit

$$\frac{d^2 N^{bkgd.}(\Delta\phi, \Delta\eta)}{d\Delta\phi d\Delta\eta} = \pi\tilde{\beta}^R \left(1 + \sum_{n=1}^{\infty} 2\tilde{v_n}^{R,t} v_n^a \cos n\Delta\phi\right)$$

Sharma, et. al., Phys. Rev. C, 2016.

$$\tilde{\beta}^R = B\left(1 + \sum_{k=2,4,6,\ldots} 2v_k^t \cos k\phi_s \frac{\sin kc}{kc} R_n\right) \qquad \tilde{v_n}^{R,t} = \frac{v_n^t + \cos n\phi_s \frac{\sin nc}{nc} R_n + \sum_{k=2,4,6,\ldots}\left(v_{k+n} + v_{|k-n|}\right)\cos k\phi_s \frac{\sin kc}{kc} R_n}{1 + \sum_{k=2,4,6,\ldots} 2v_k^t \cos k\phi_s \frac{\sin kc}{kc} R_n}$$