DPC-SMF

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Charged-particle production as a function of R_{T} in pp, p-Pb, and Pb-Pb collisions

based on: JHEP 01 (2024) 56

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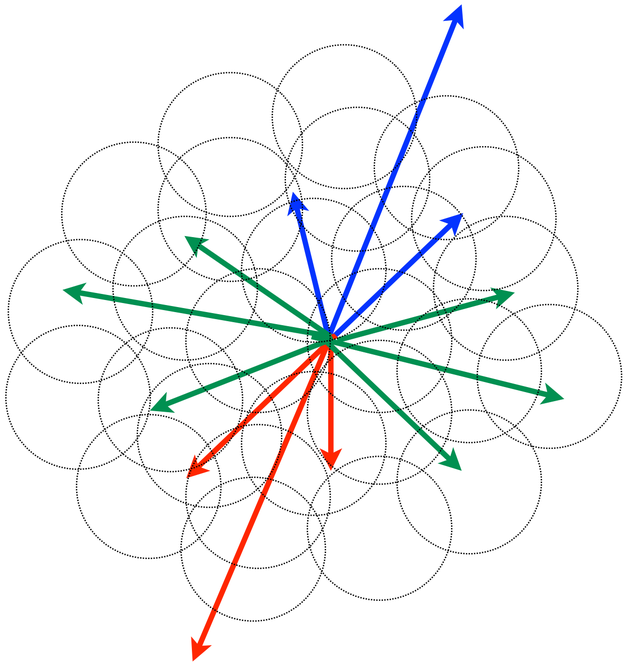
Outline

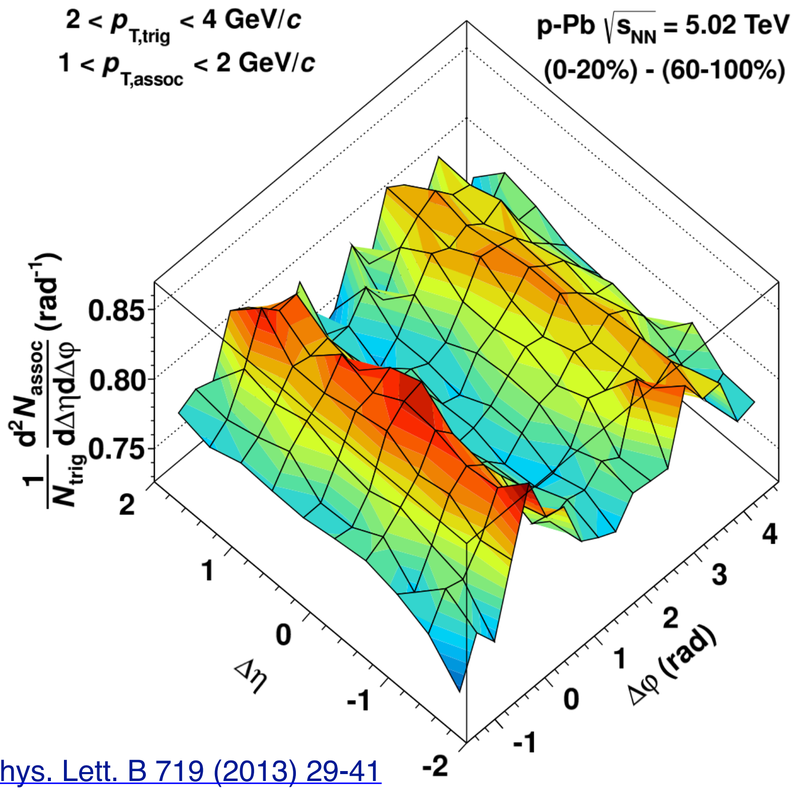
- **Introduction**
  - Collectivity in small systems
  - Selection biases
  - Underlying event and R_{T}
- **Analysis procedure**
  - The ALICE detector in Run 2
  - Analysis details
- **Results**
  - p_{T}-spectra as a function of R_{T}
  - $\langle p_{\mathrm{T}} \rangle$ as a function of R_{T}
  - Integrated yields as a function of R_{T}
- **Summary**



QGP in small systems?

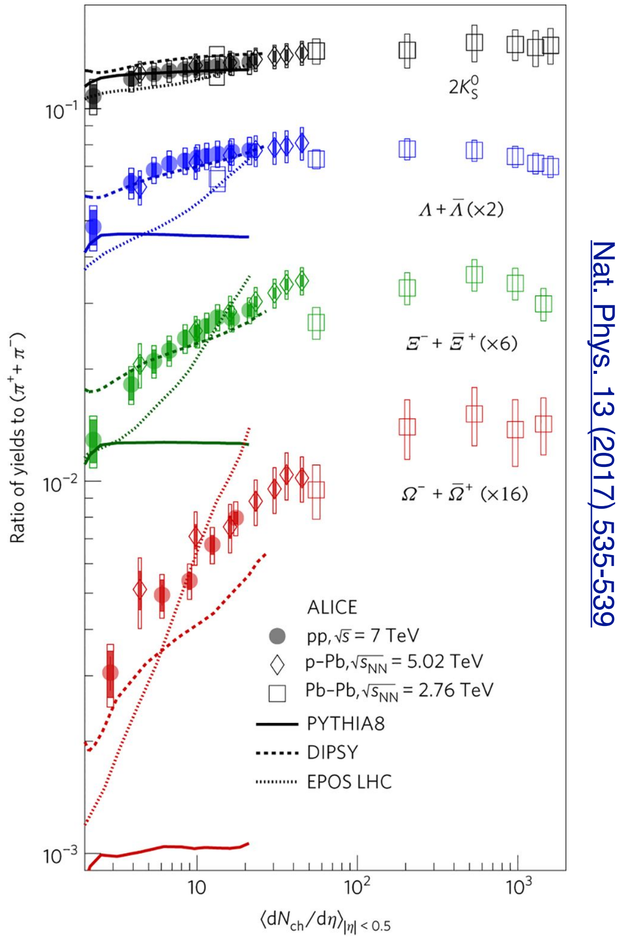
Double ridge structure

$$\Delta\eta = \eta^{a} - \eta^{b} \qquad \Delta\varphi = \varphi^{a} - \varphi^{b}$$



Phys. Lett. B 719 (2013) 29-41

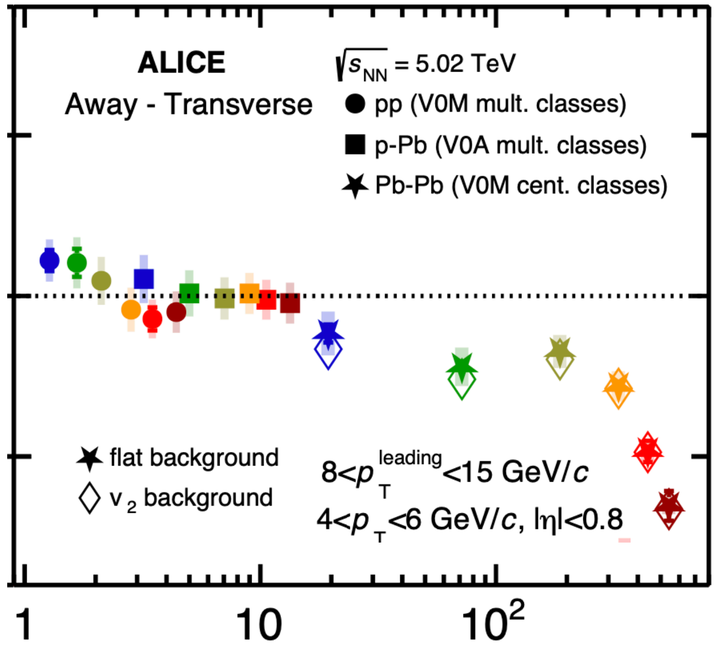
Strangeness Enhancement



Nat. Phys. 13 (2017) 535-539

Jet quenching

$$I_X^{away} = \frac{Y_X^{away} - Y_X^{T}}{Y_{pp}^{away} - Y_{pp}^{T}}$$



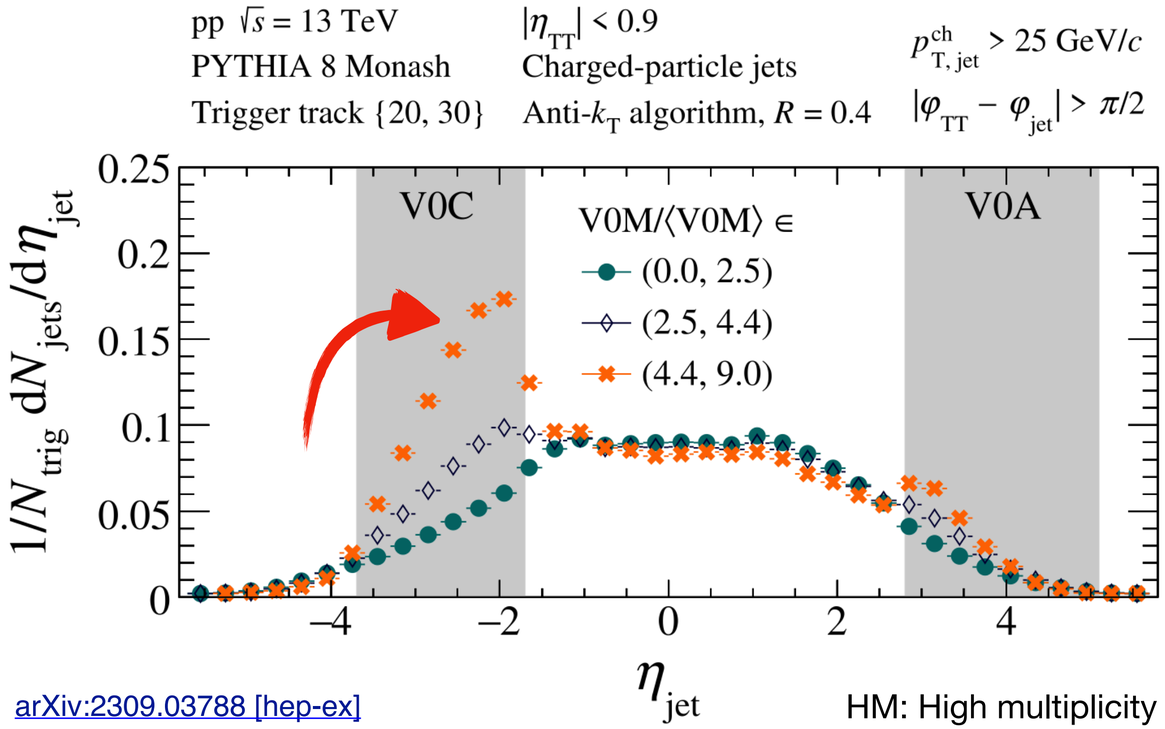
Phys. Lett. B 843 (2023) 137649

Are these effects caused by quark-gluon plasma (QGP), as in heavy-ion collisions, or by other mechanisms like multiparton interactions (MPI)?

Selection bias in pp collisions

Hard process

The selection of high-multiplicity events affects the distribution for recoil jets showing a higher rate of hard-recoil jets in HM events compared to MB events

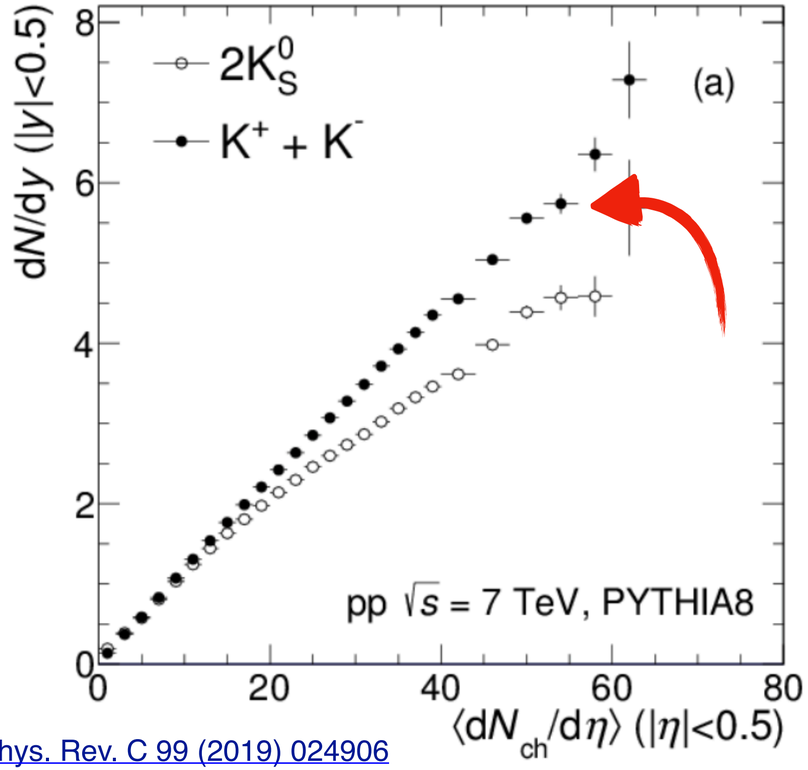


arXiv:2309.03788 [hep-ex]

HM: High multiplicity
MB: Minimum bias

Charged particles

The neutral-to-charged particle yield is biased by requiring high charge-particle multiplicity



Phys. Rev. C 99 (2019) 024906

Underlying event and R_{T}

In pp collisions, the underlying event (UE) refers to everything that does not come from the hard partonic scattering

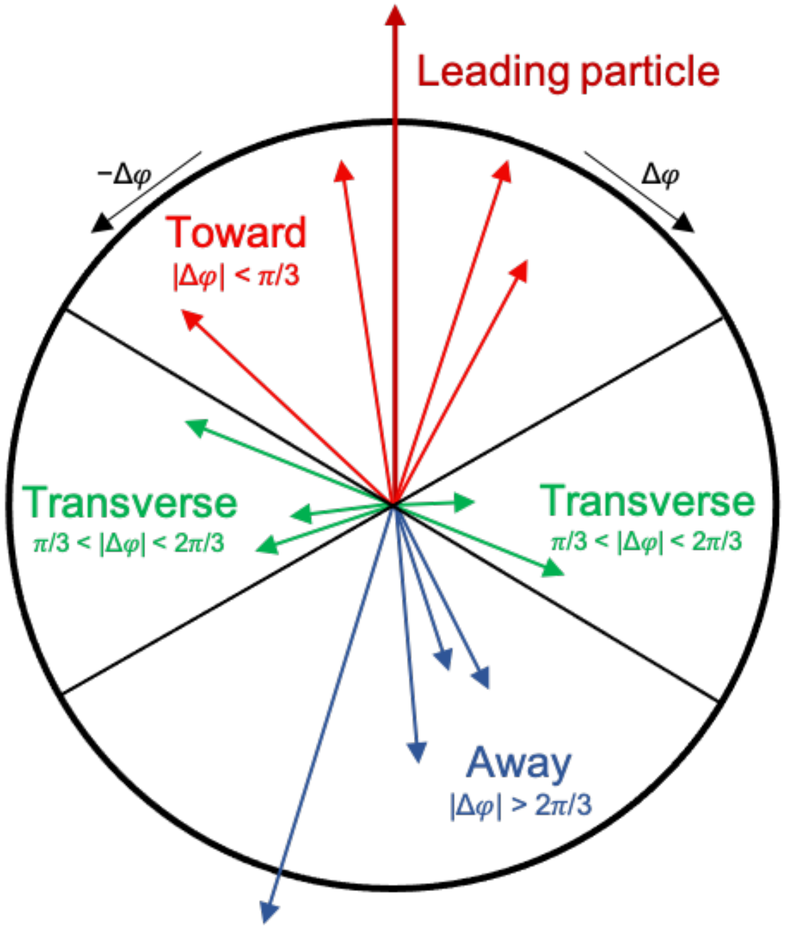
The topological regions are defined relative to the direction of the charged particle with the highest transverse momentum ($p_{\mathrm{T}}^{\mathrm{trig}}$) in the event

Relative transverse activity classifier

$$R_{\mathrm{T}} = \frac{N_{\mathrm{ch}}^{\mathrm{T}}}{\langle N_{\mathrm{ch}}^{\mathrm{T}} \rangle}$$

with $N_{\mathrm{ch}}^{\mathrm{T}}$: multiplicity in the transverse region

Eur. Phys. J. C 76 (2016) 1-12

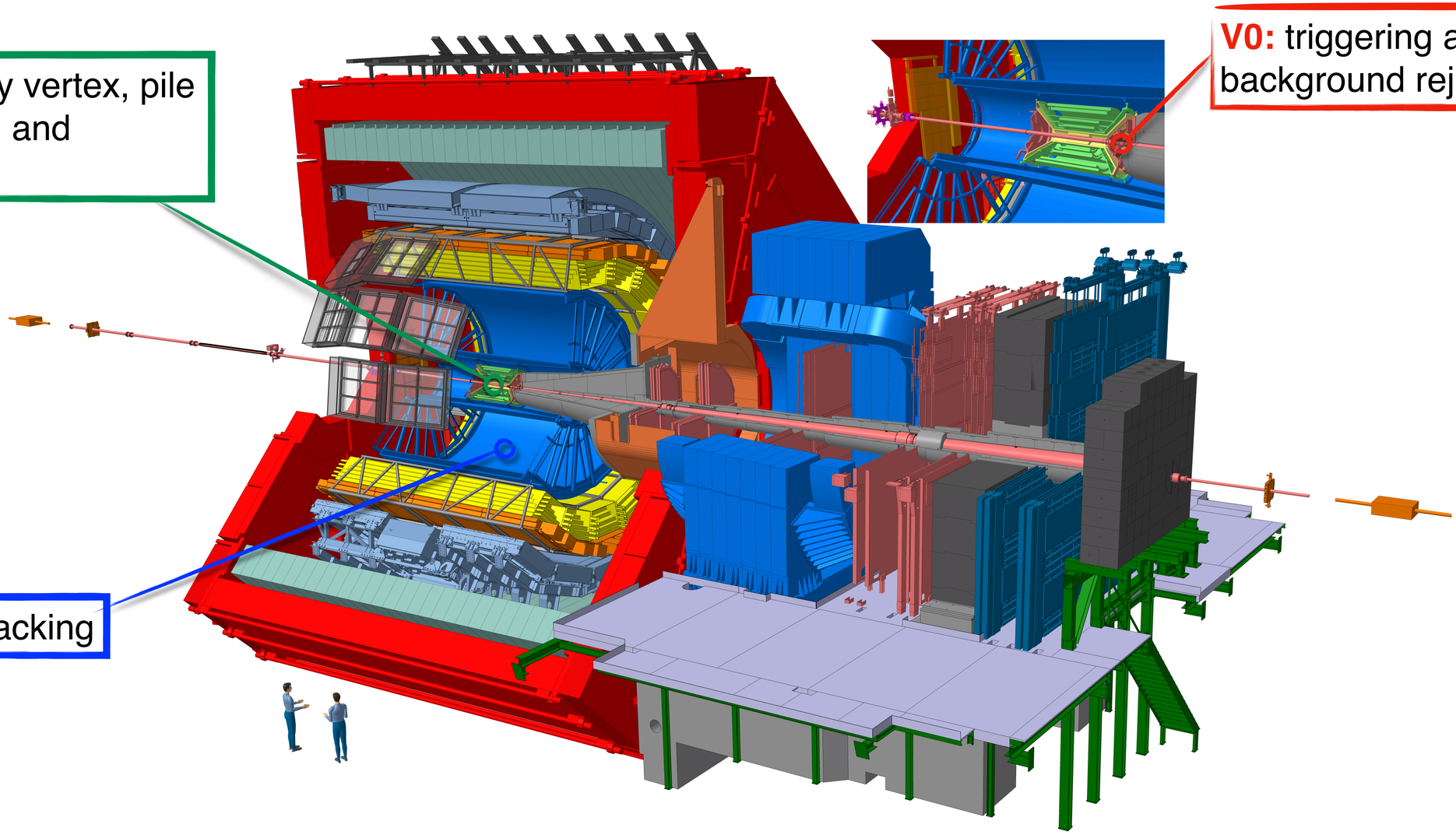


$$|\Delta\varphi| = |\varphi^{\mathrm{assoc}} - \varphi^{\mathrm{trig}}|$$

- By definition the multiplicity estimator R_{T} excludes the jet fragments
- The neutral-to-charged particle yield in the toward and away region is not biased at high-R_{T} values

The ALICE detector in Run 2

Main detectors used in this work



Analysis details

Corrections

The uncorrected p_{T} distributions as a function of the fully corrected multiplicity are obtained using a Bayesian unfolding

The resulting p_{T} distributions were further corrected for:

Efficiency: A data-driven-tracking efficiency approach, which considers the particle composition measured by ALICE, was used

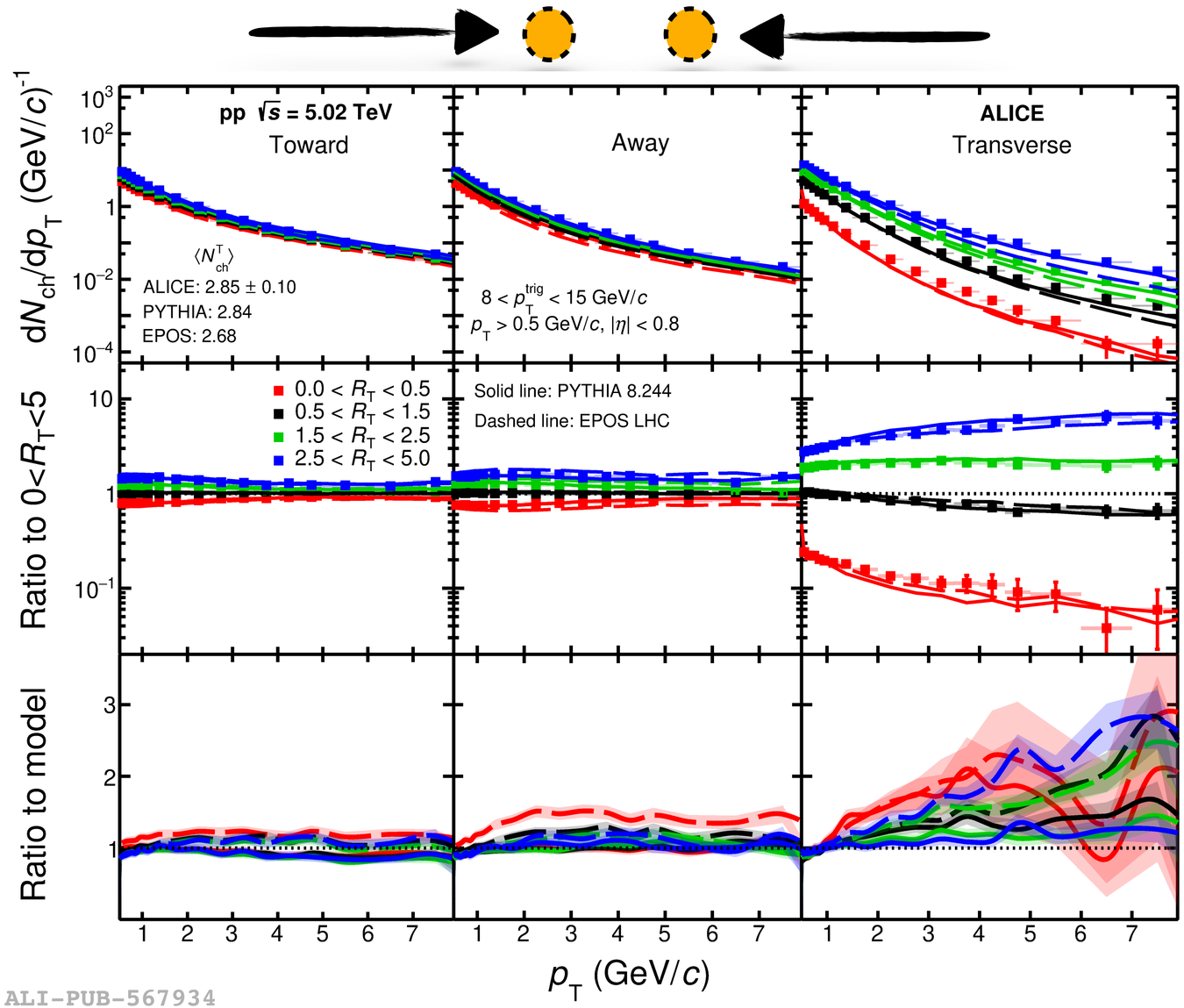
Feed-down contamination: from material and decays

Systematic uncertainties

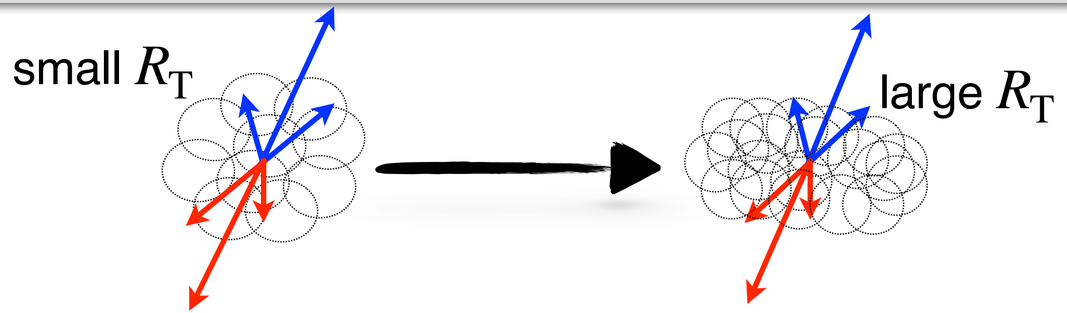
These were divided in R_{T}-dependent uncertainties (*) and R_{T}-independent uncertainties

Source	uncertainty (%)					
	pp		p–Pb		Pb–Pb	
p_{T} (GeV/c)	0.5	7.0	0.5	7.0	0.5	7.0
track reconstruction and selection*	1.5	3.5	1.4	1.2	2.5	1.4
mult. dependence of tracking efficiency*	3.0	3.0	3.0	3.0	3.0	3.0
MC non-closure*	3.0	3.0	3.0	3.0	3.0	3.0
matching efficiency	0.4	0.3	1.1	0.6	0.8	0.9
particle composition	0.3	1.3	0.5	1.2	0.3	0.7
secondary contamination	0.1	negl.	0.3	negl.	negl.	negl.
material budget	0.3	0.2	0.3	0.2	0.3	0.2
Total	4.5	5.7	4.6	4.6	5.0	4.6

p_{T}-spectra as a function of R_{T}



ALI-PUB-567934



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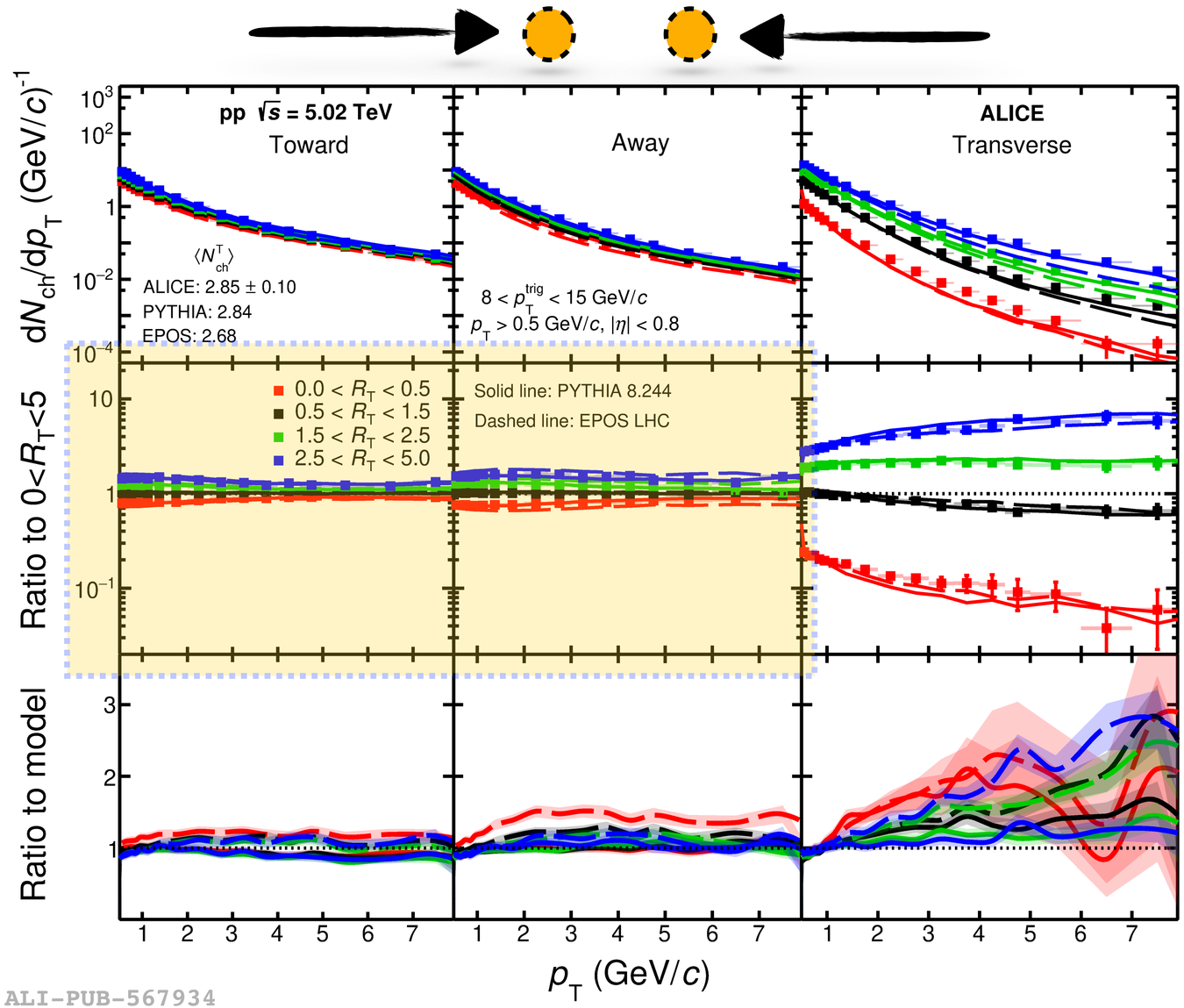

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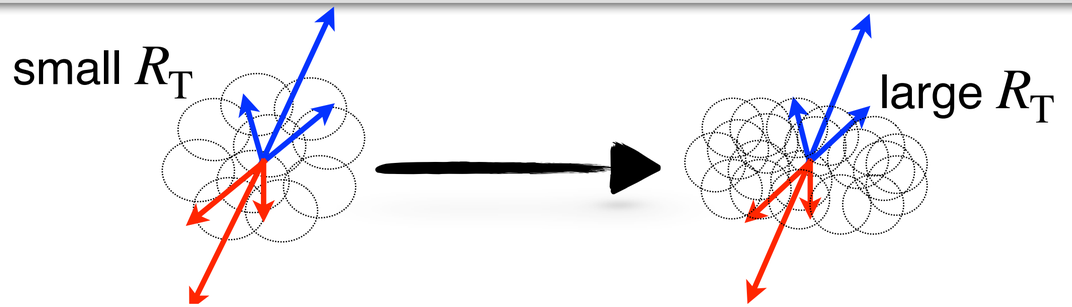
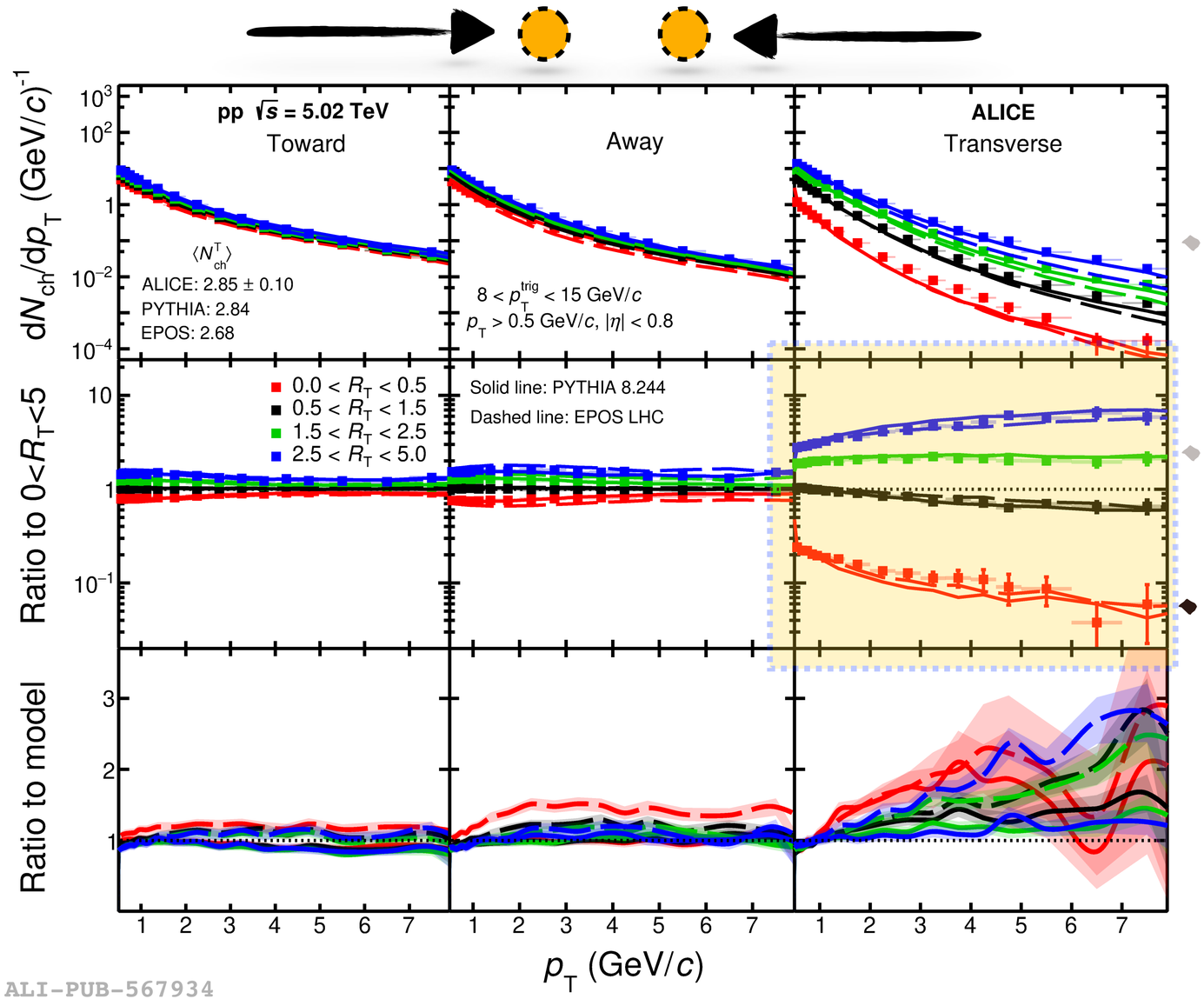


- For $p_{\mathrm{T}} < 4$ GeV/c, the p_{T} spectra in the away and toward regions relative to the R_{T}-integrated event class exhibit a R_{T}-dependence. **In PYTHIA the effect is produced by color reconnection**
- For $p_{\mathrm{T}} > 4$ GeV/c, the spectral shapes in the away and toward regions are found to be almost independent of R_{T}

p_{T}-spectra as a function of R_{T}



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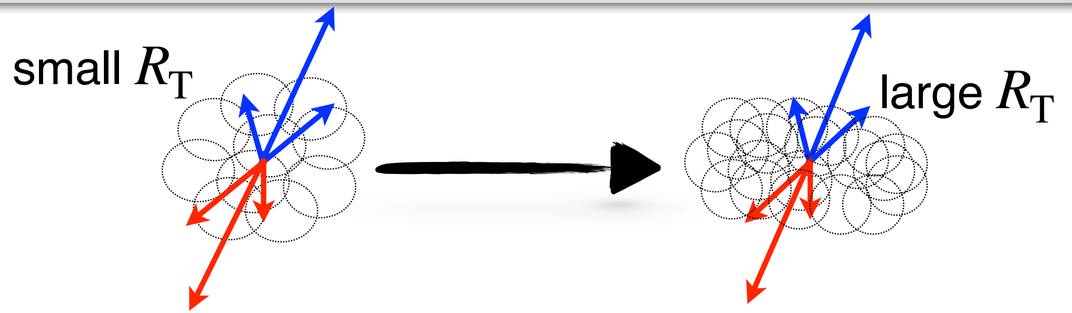

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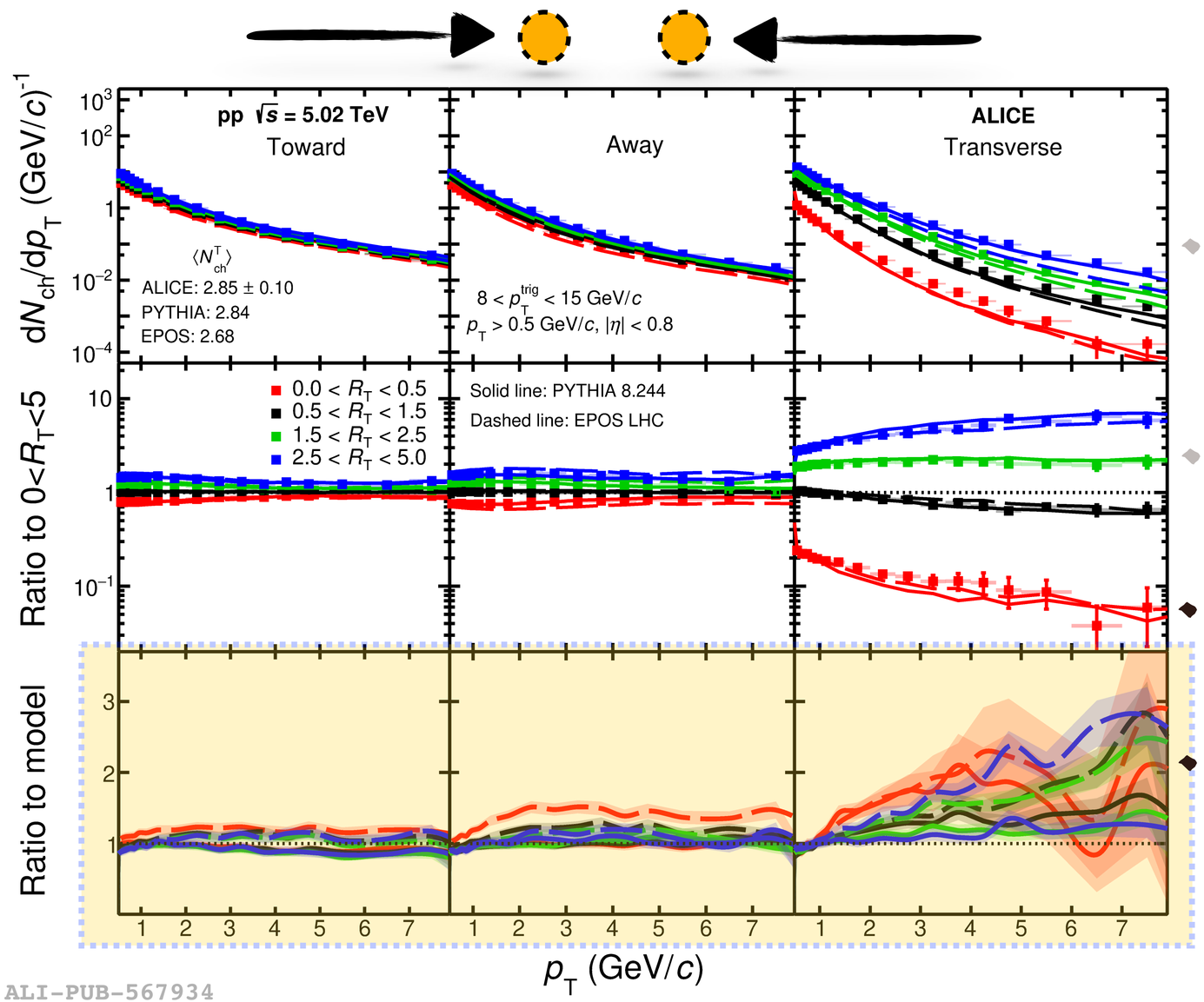
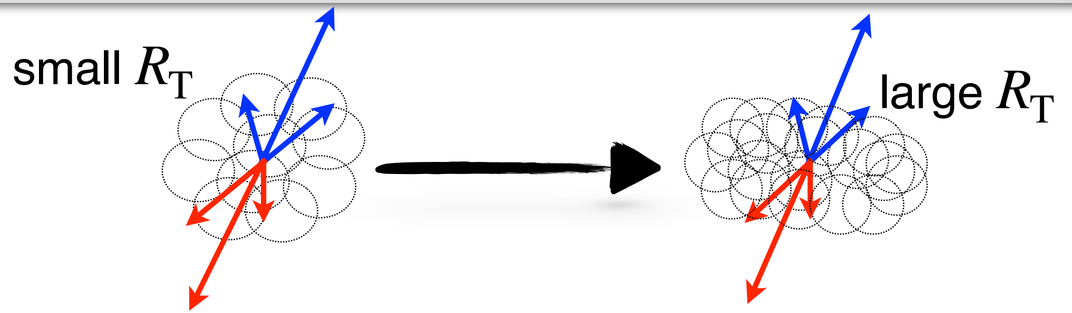
- For $p_{\mathrm{T}} > 4$ GeV/c, the spectral shapes in the away and toward regions are found to be almost independent of R_{T}
- The p_{T} spectra in the transverse region harden with increasing R_{T}. **Autocorrelations are relevant in this region**

Phys. Rev. D 104 (2021) 016017

p_{T}-spectra as a function of R_{T}



ALI-PUB-567934



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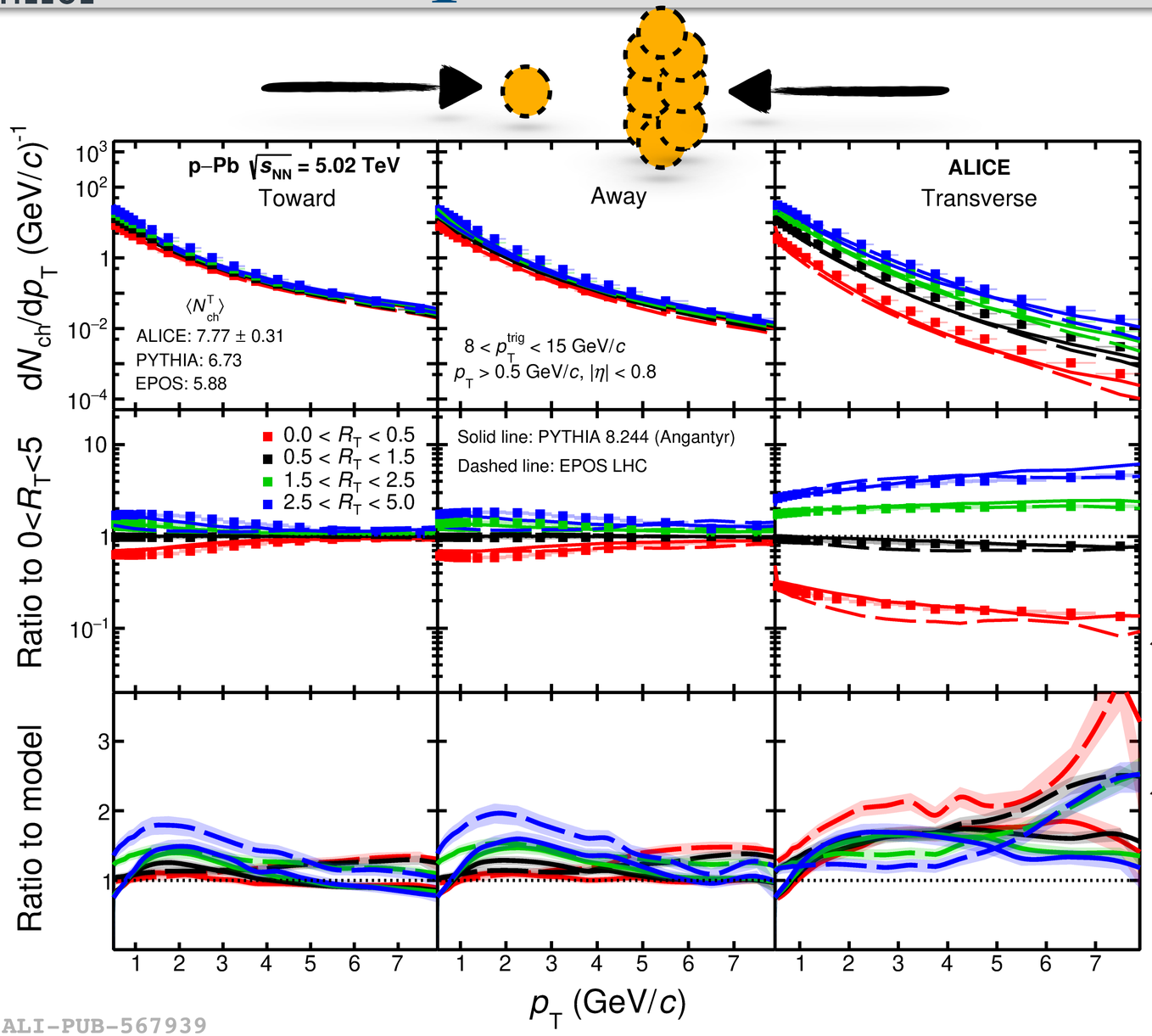
- The p_{T} spectra in the transverse region harden with increasing R_{T}. **Autocorrelations are relevant in this region**

Phys. Rev. D 104 (2021) 016017

- In general, PYTHIA8 describes data better than EPOS LHC

p_{T}-spectra as a function of R_{T}



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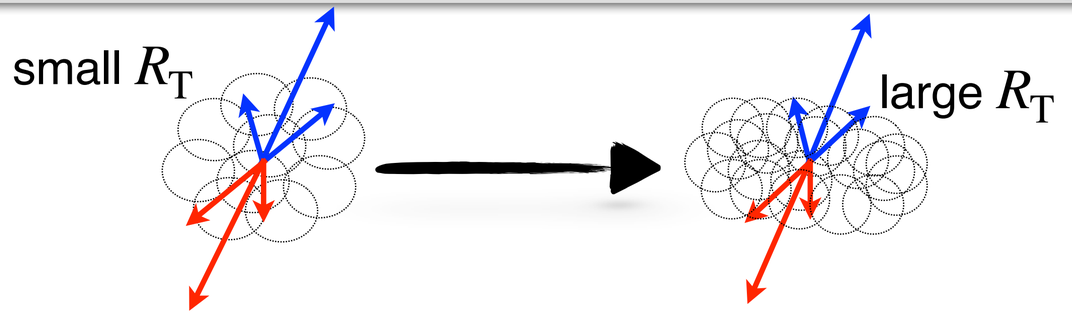


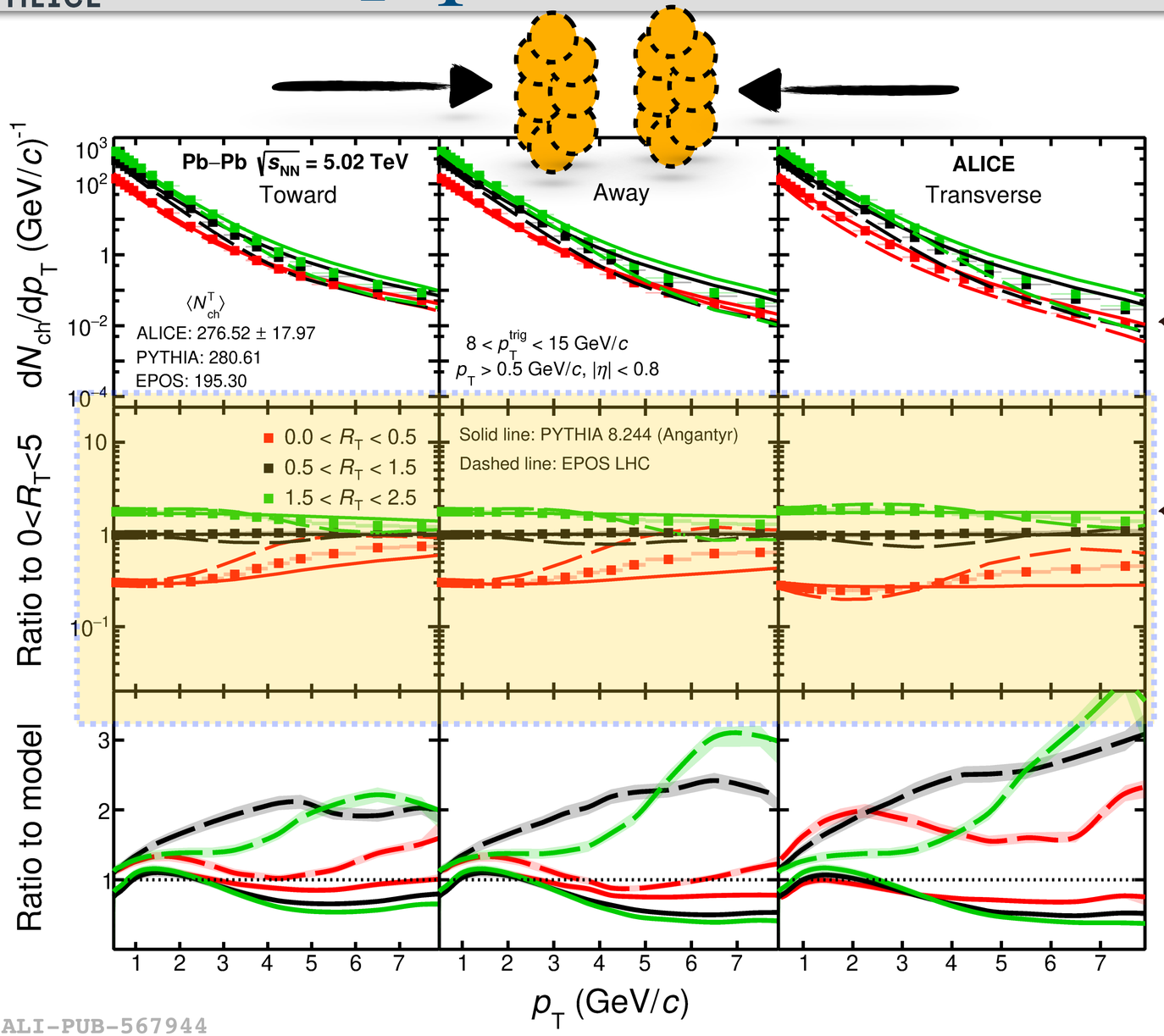
- For $p_{\mathrm{T}} < 4$ GeV/c, the p_{T} spectra in the away and toward regions relative to the R_{T}-integrated event class exhibit a R_{T}-dependence. **In PYTHIA the effect is produced by color reconnection**
- For $p_{\mathrm{T}} > 4$ GeV/c, the spectral shapes in the away and toward regions are found to be almost independent of R_{T}
- The p_{T} spectra in the transverse region harden with increasing R_{T}. **Autocorrelations are relevant in this region**

Phys. Rev. D 104 (2021) 016017

- In general, PYTHIA8/Argantyr describes data better than EPOS LHC except for the transverse region

Same features like in pp collisions for all the three topological regions

p_{T}-spectra as a function of R_{T}



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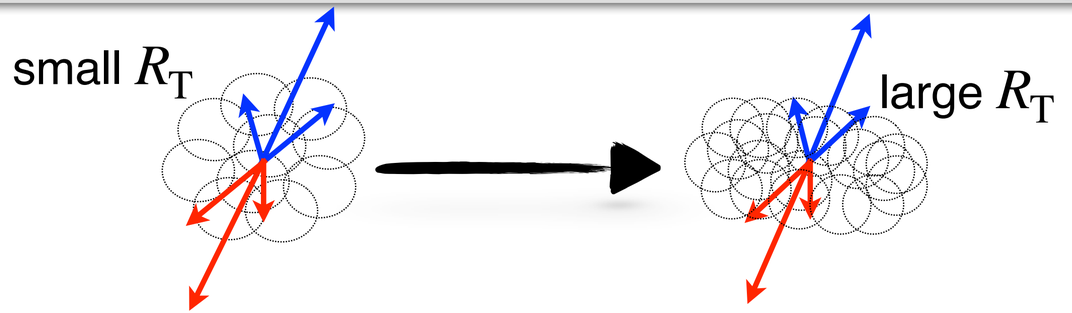
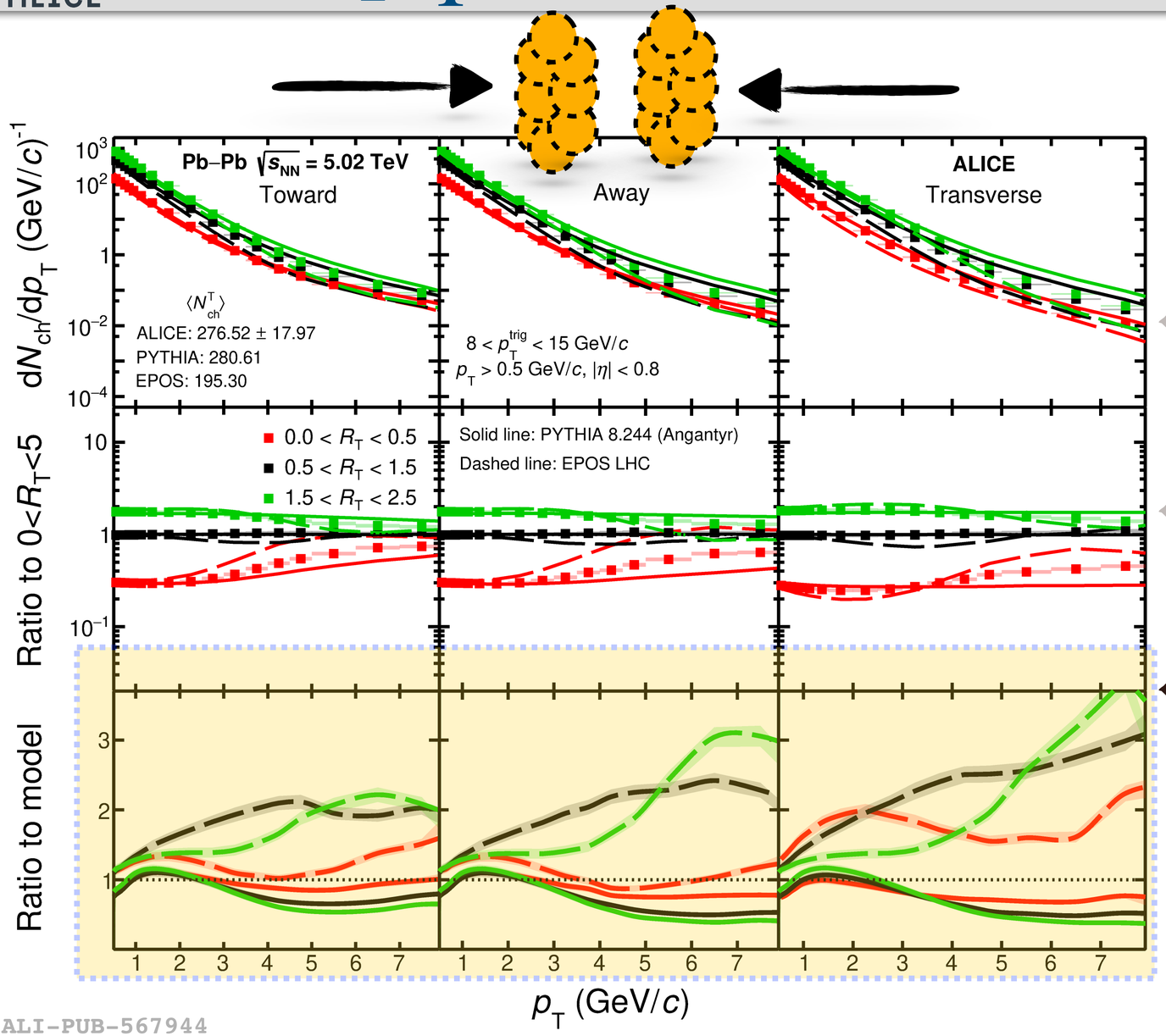


- For $p_{\mathrm{T}} < 6$ GeV/c, the p_{T} spectra for all three topological regions are qualitatively similar to that of pp and p-Pb collisions.
- For $p_{\mathrm{T}} > 6$ GeV/c, the spectral shapes for all three topological regions are found to be almost independent of R_{T}

p_{T}-spectra as a function of R_{T}



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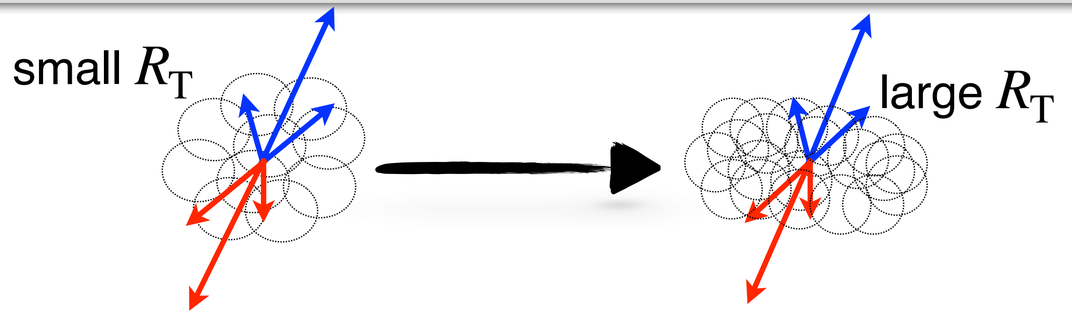
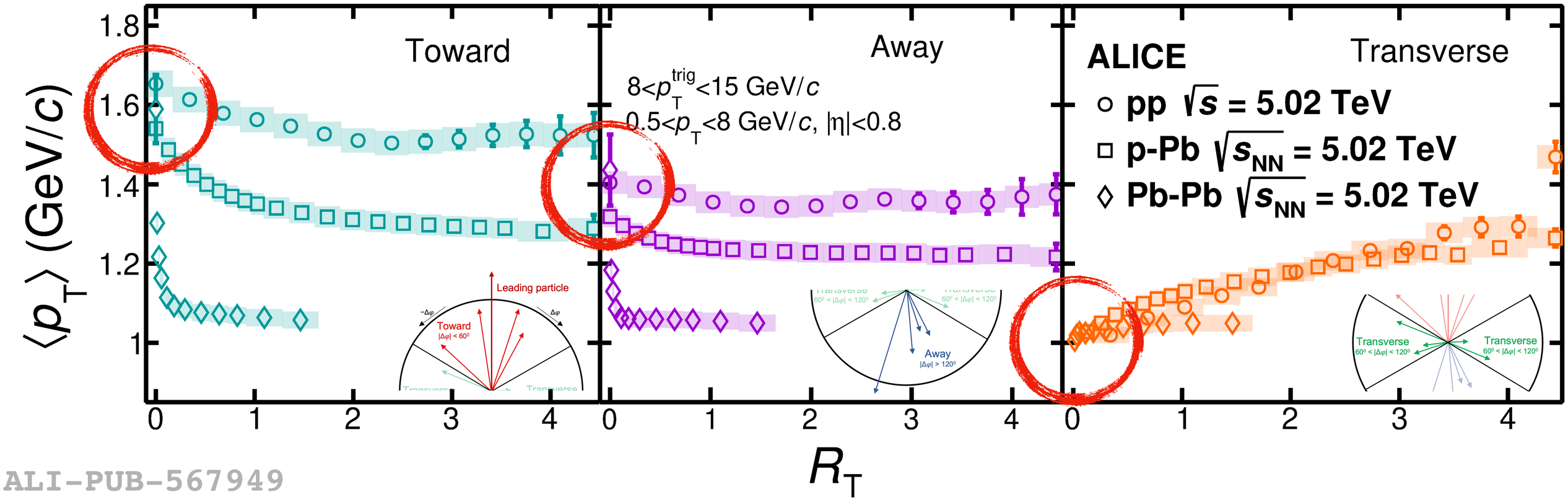


- For $p_{\mathrm{T}} < 6$ GeV/c, the p_{T} spectra for all three topological regions are qualitatively similar to that of pp and p-Pb collisions.
- For $p_{\mathrm{T}} > 6$ GeV/c, the spectral shapes for all three topological regions are found to be almost independent of R_{T}
- In general, PYTHIA8/Argantyr fairly describes the data in the lower p_{T} region and overestimates the high p_{T} yield ($p_{\mathrm{T}} > 3$ GeV/c) for all three topological regions while EPOS LHC fails the description up to 10% for higher R_{T}-bins.

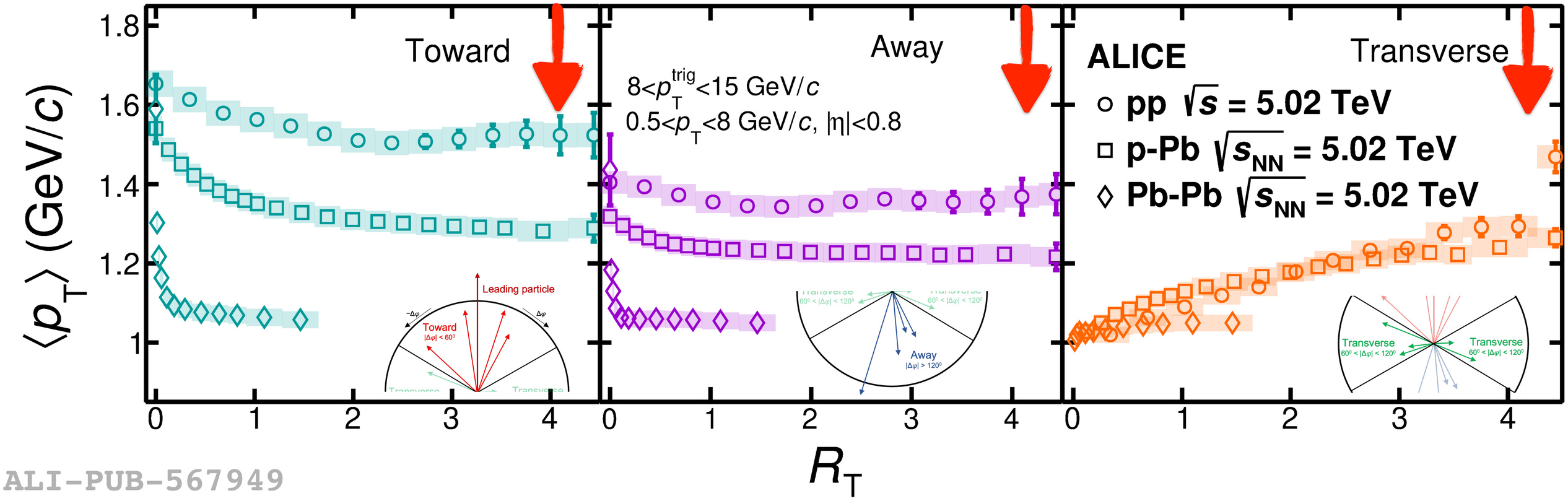
$\langle p_{\mathrm{T}} \rangle$ as a function of R_{T}



ALI-PUB-567949

The jet contribution dominates at low R_{T}, as expected for $R_{\mathrm{T}} \to 0$

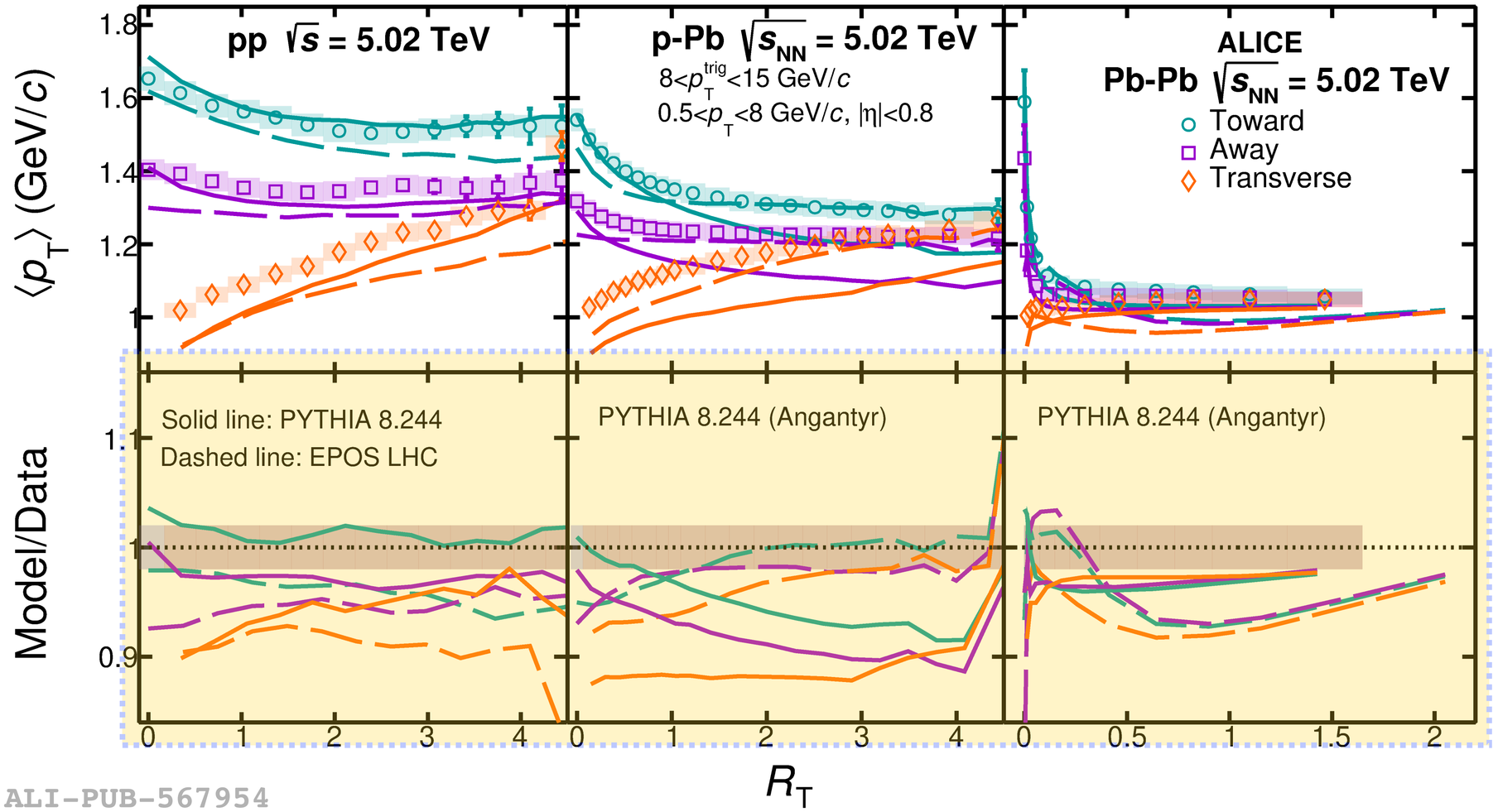
$\langle p_{\mathrm{T}} \rangle$ as a function of R_{T}



ALI-PUB-567949

For large R_{T}, the $\langle p_{\mathrm{T}} \rangle$ is dominated by bulk contribution and exhibits an ordering that depends on the system size

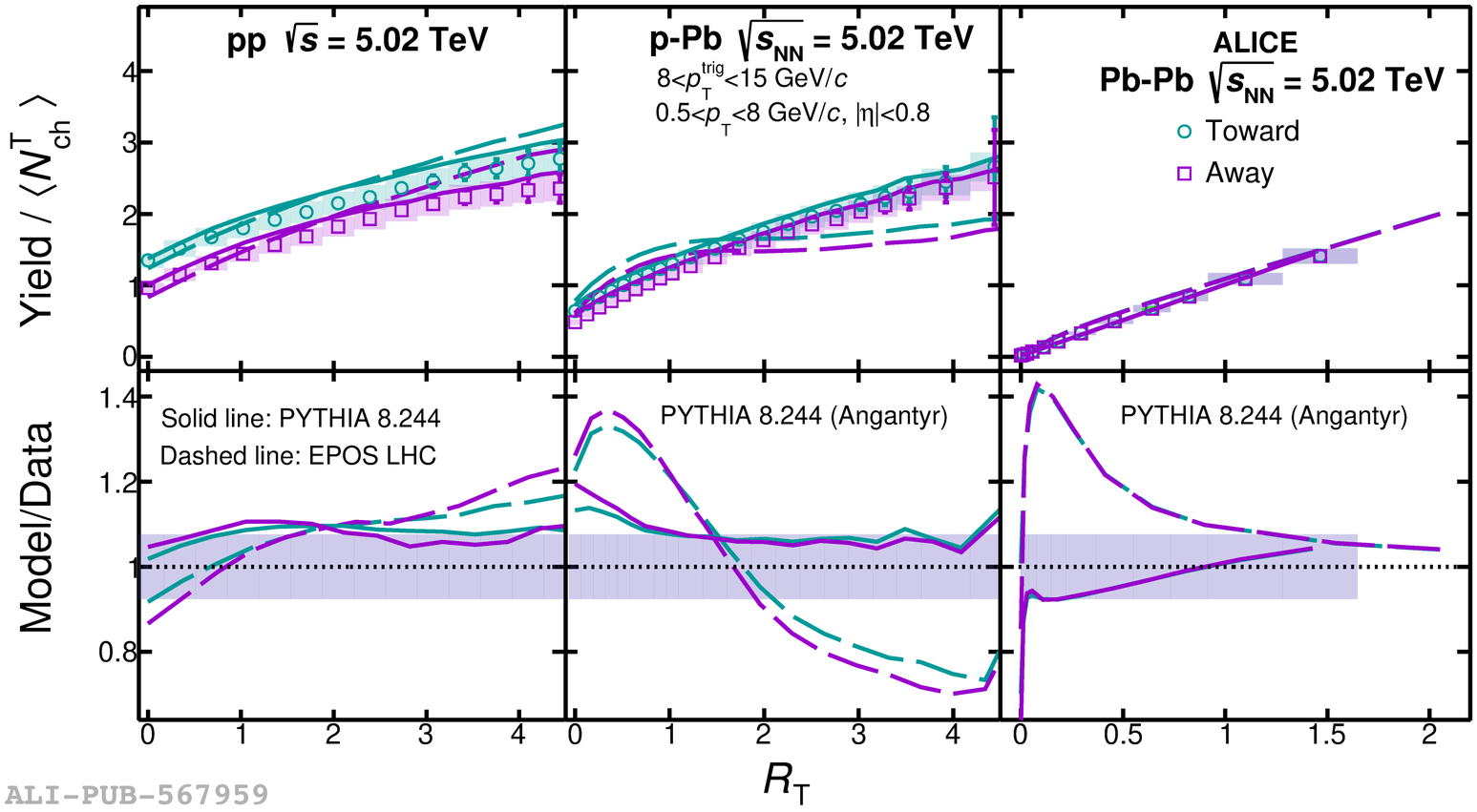
Comparison of $\langle p_{\mathrm{T}} \rangle$ with models



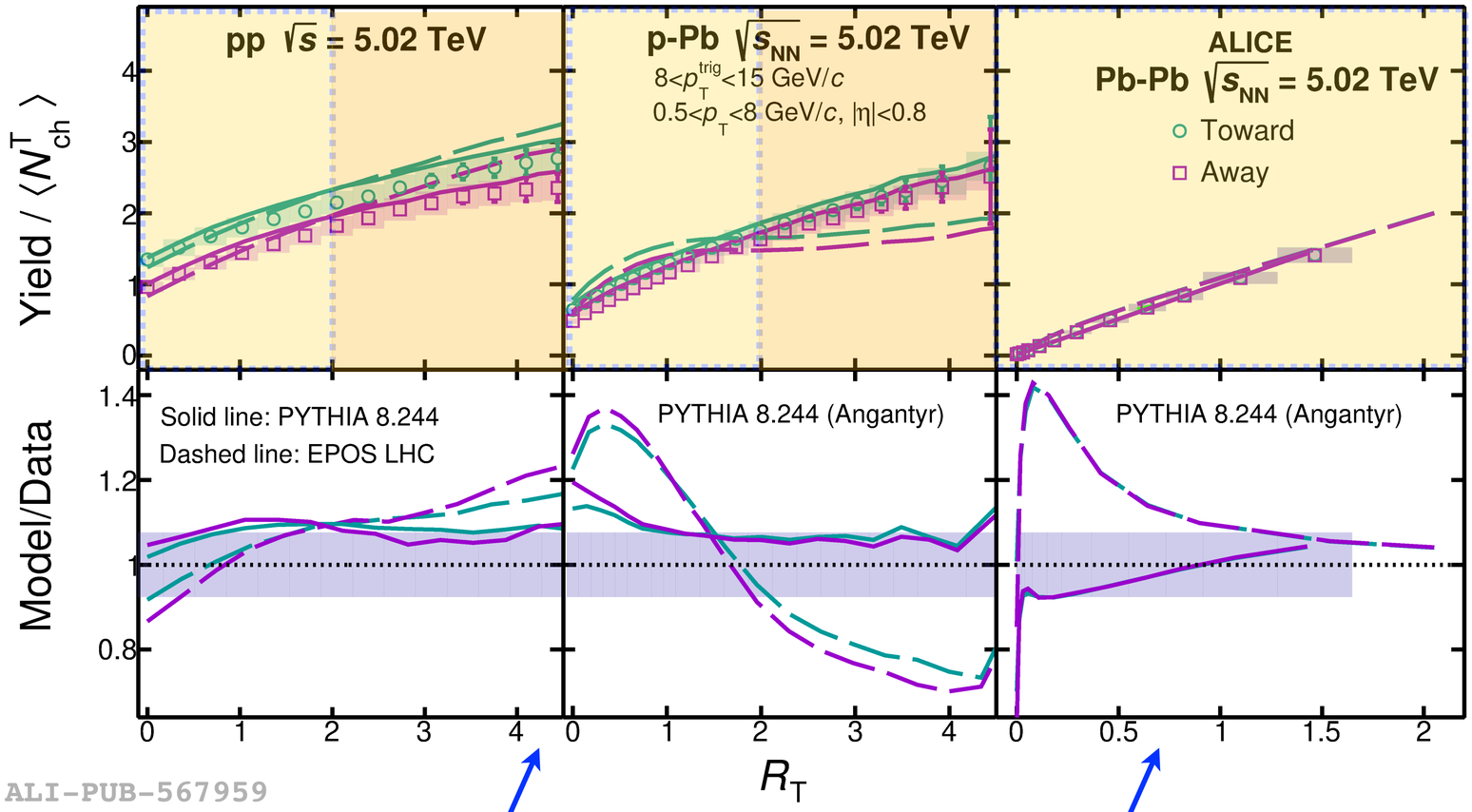
ALI-PUB-567954

- The models deviate by 10% from data, however, they show a trend with R_{T} that is qualitatively similar to the measured one

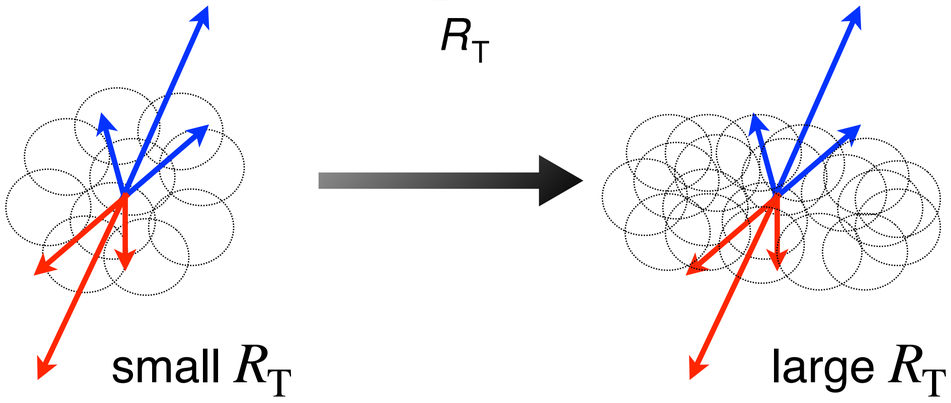
Normalized integrated yield as a function of R_T



Normalized integrated yield as a function of R_T

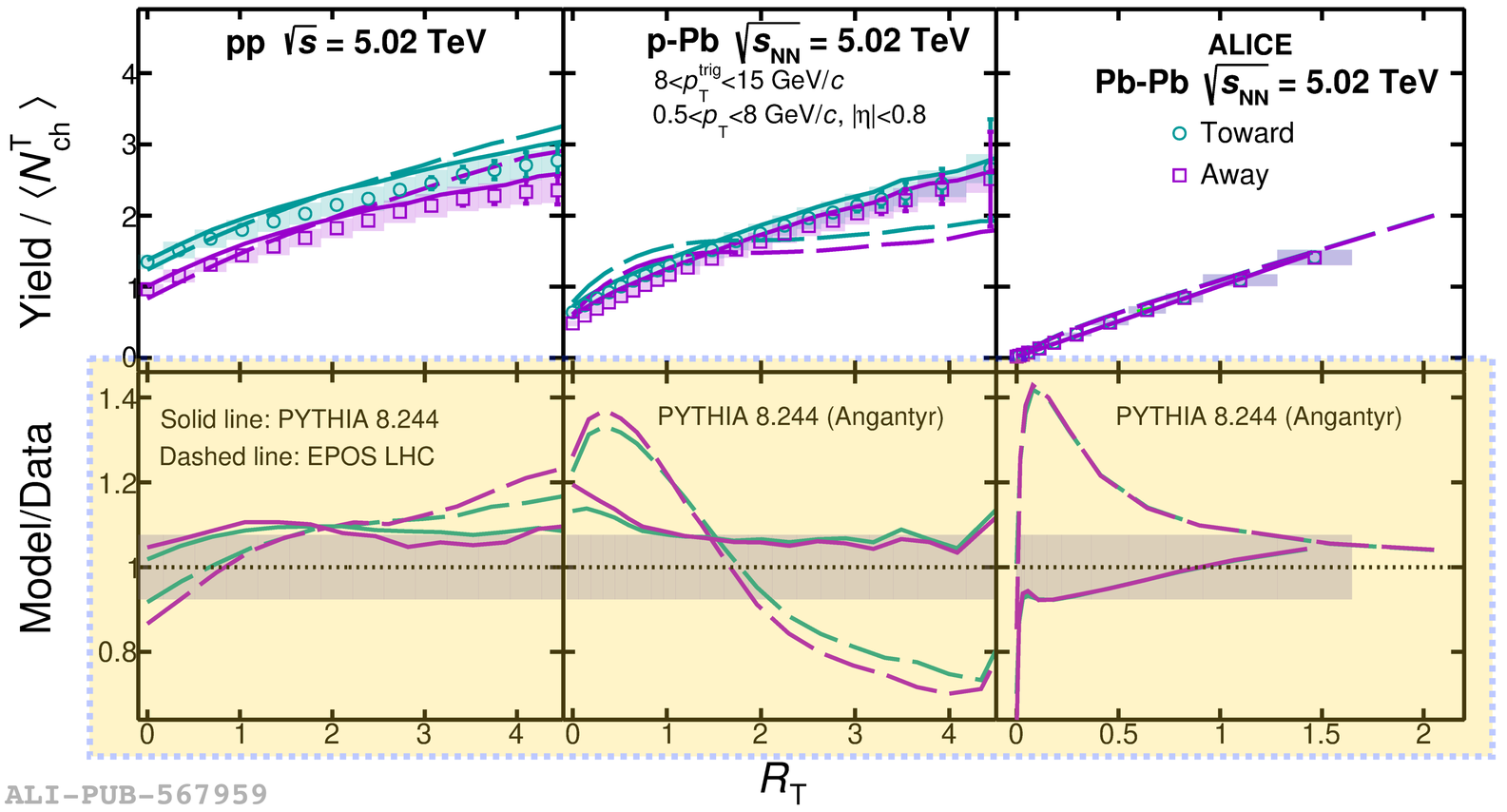


UE is isotropically distributed



More activity in the transverse region

Normalized integrated yield as a function of R_T



For all three collision system, PYTHIA8/Argantyr describes data better than EPOS LHC

Summary

- The p_{T} spectra as a function of R_{T} in pp, p-Pb and Pb-Pb collisions have been presented
  - For $R_{\mathrm{T}} < 2$, the activity in the transverse region is a good proxy for UE
  - For $R_{\mathrm{T}} > 2$, the activity in the transverse region gets biased towards multi-jet final states (probably from hard Bremsstrahlung radiation)
- pp and p-Pb collisions
  - In the toward and away regions the high-p_{T} yield ($p_{\mathrm{T}} > 2$ GeV/c) is nearly R_{T} independent suggesting the absence of high multiplicity effects at high R_{T}
  - The transverse region is affected by autocorrelations: the p_{T} spectra get harder with increasing R_{T}. Similar behavior is seen using the track multiplicity instead of R_{T}
- Pb-Pb collisions
  - Current results are limited to $R_{\mathrm{T}} < 2.5$ therefore results are dominated by the bulk of particle production

- For R_{T} close to zero, the three collision systems exhibit the same value of $\langle p_{\mathrm{T}} \rangle$ while for large R_{T}, it exhibits an system size ordering

- Overall, PYTHIA 8 describes better the data (pp, p-Pb and Pb-Pb) than EPOS LHC supporting the MPI picture

Thanks!

arXiv:2204.13733 [hep-ph]

Flattenicity: a new event classifier to study pp collisions

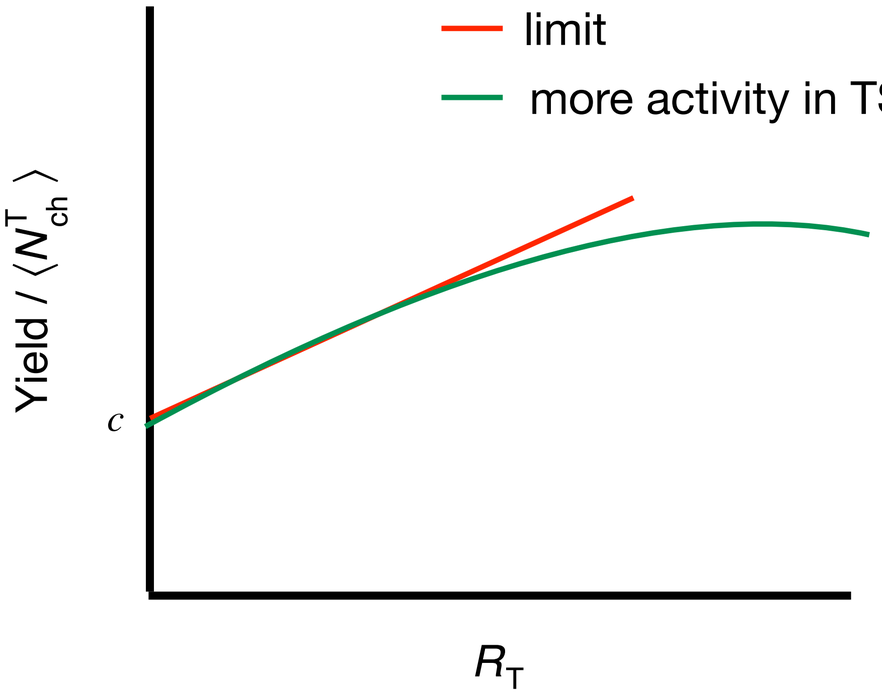
Antonio Ortiz

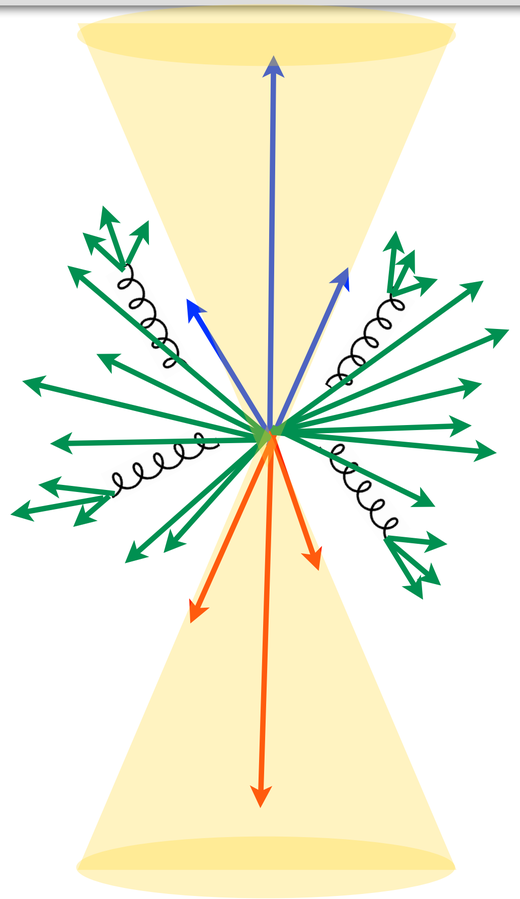
Theoretical Physics Seminar,
Wigner Research Centre for Physics
26/08/2022

Stay tuned, new results as a function of flatenicity are coming!

Backup

Normalized integrated yield explanation





The gluon radiation produce more activity in TS

higher $\langle N_{ch}^{TS} \rangle$ value

$$\frac{\text{Yield}^{\text{toward}}}{\langle N_{ch}^{TS} \rangle} = \frac{N_{ch}^{jet} + N_{ch}^{TS}}{\langle N_{ch}^{TS} \rangle} = \frac{N_{ch}^{jet}}{\langle N_{ch}^{TS} \rangle} + R_T = c + R_T$$