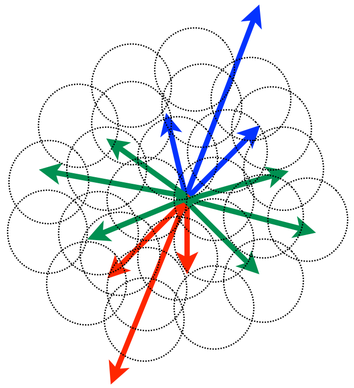


14th International workshop on Multiple Partonic Interactions at the LHC
20-24 November 2023

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

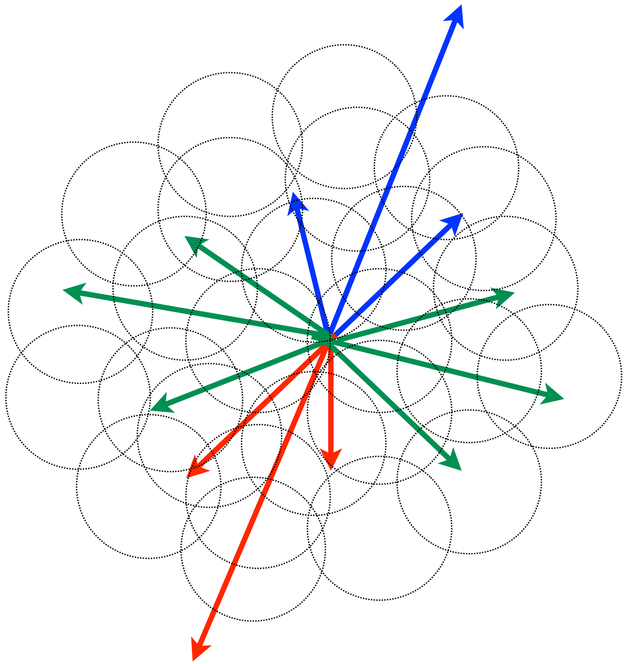
based on: arXiv:2310.07490

Paola Vargas, for the ALICE collaboration

Instituto de Ciencias Nucleares UNAM

Outline

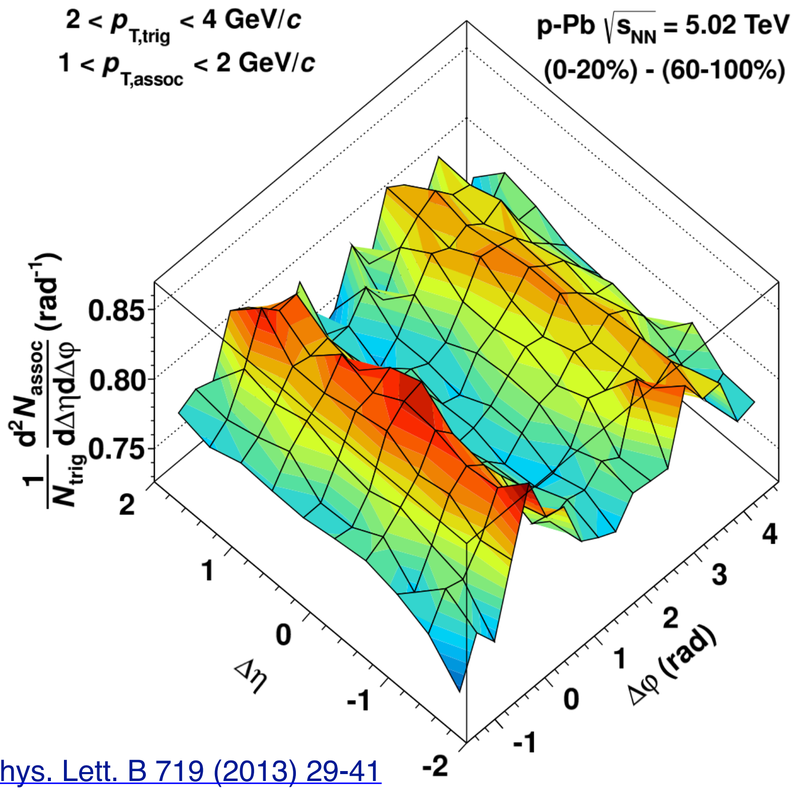
- **Introduction**
  - Collectivity in small systems
  - Selection biases
  - Underlying event and R_{T}
- **Analisys procedure**
  - The ALICE detector in Run 2
  - Analysis details
- **Results**
  - p_{T}-spectra as a function of R_{T}
  - $\langle p_{\mathrm{T}} \rangle$ as a function of R_{T}
  -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



Collectivity in small systems

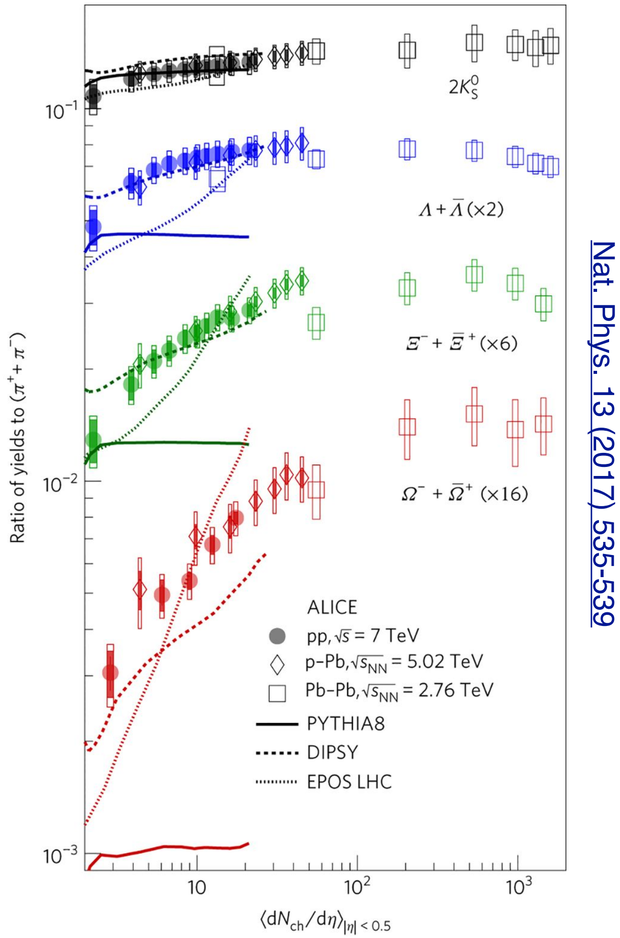
Double ridge structure

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



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

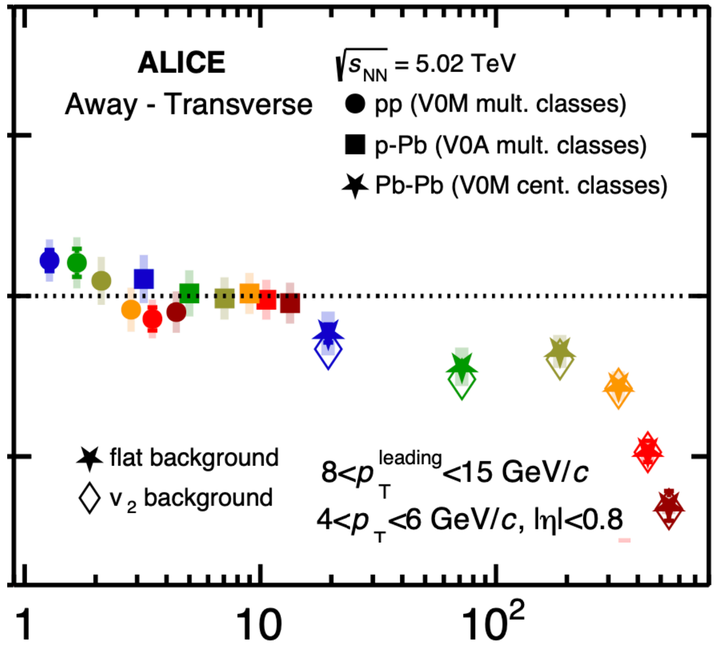
Strangeness Enhancement



Nat. Phys. 13 (2017) 535-539

Jet quenching

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



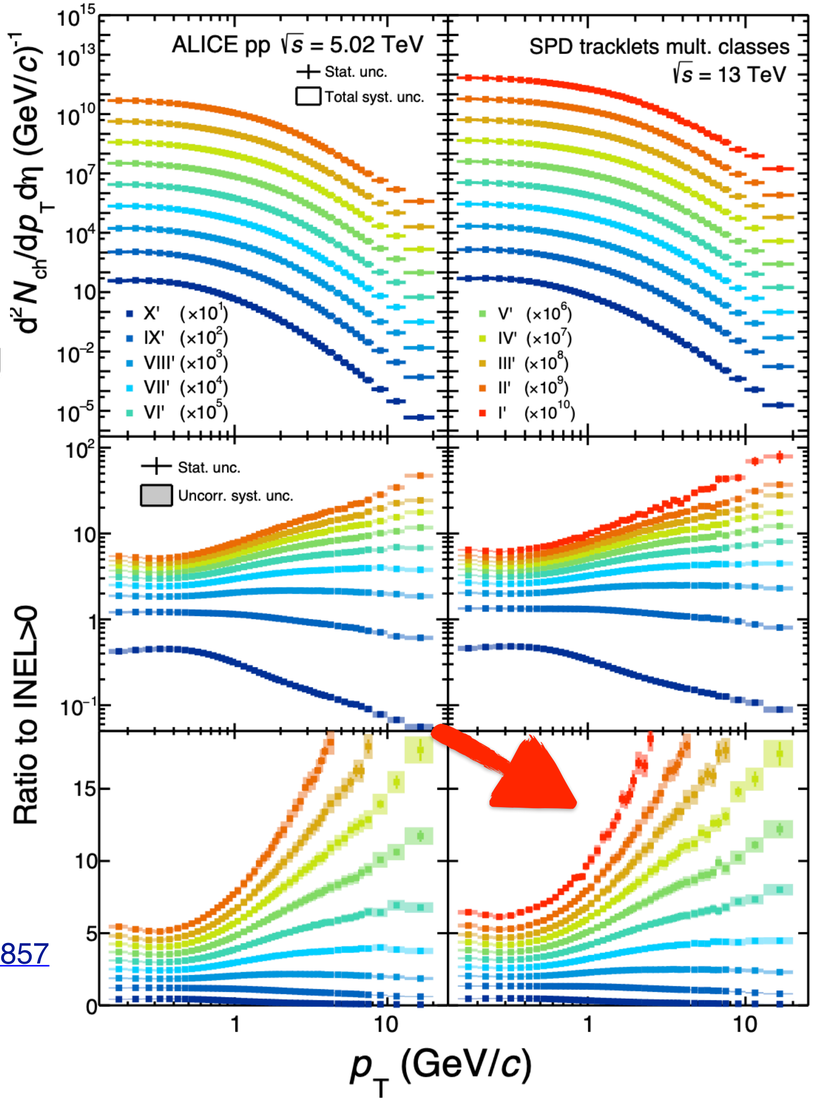
Phys. Lett. B 843 (2023) 137649

Do these effects have the same origin like in heavy-ion collisions? Or, are they caused by other mechanisms? In this work we investigate the MPI option

Selection biases

Hard process

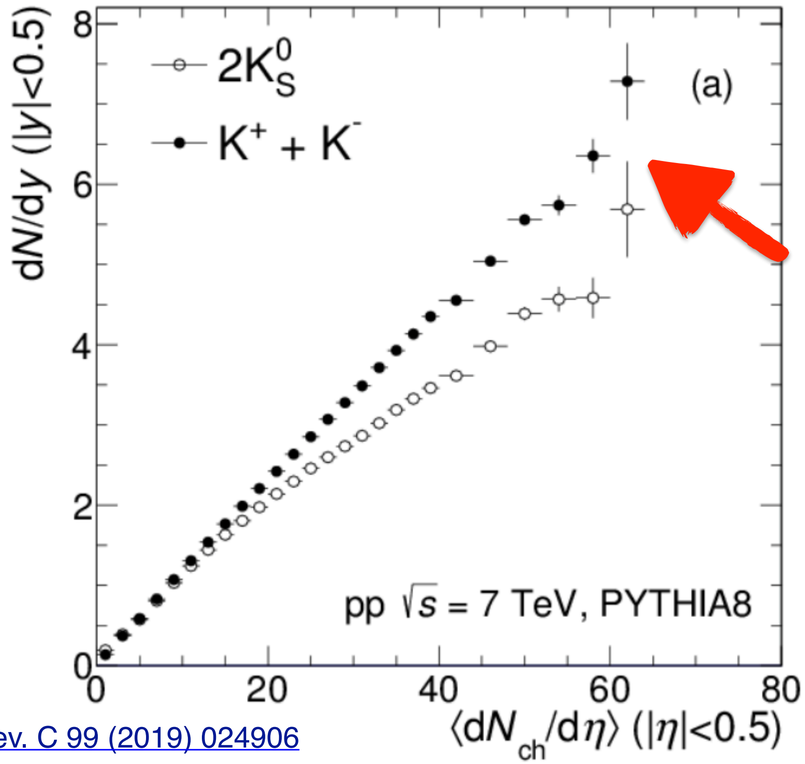
Selecting multiplicity classes and measuring particle spectra in the same pseudo rapidity interval biases the sample towards hard pp collisions



Eur. Phys. J. C79 (2019) no.10, 857

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

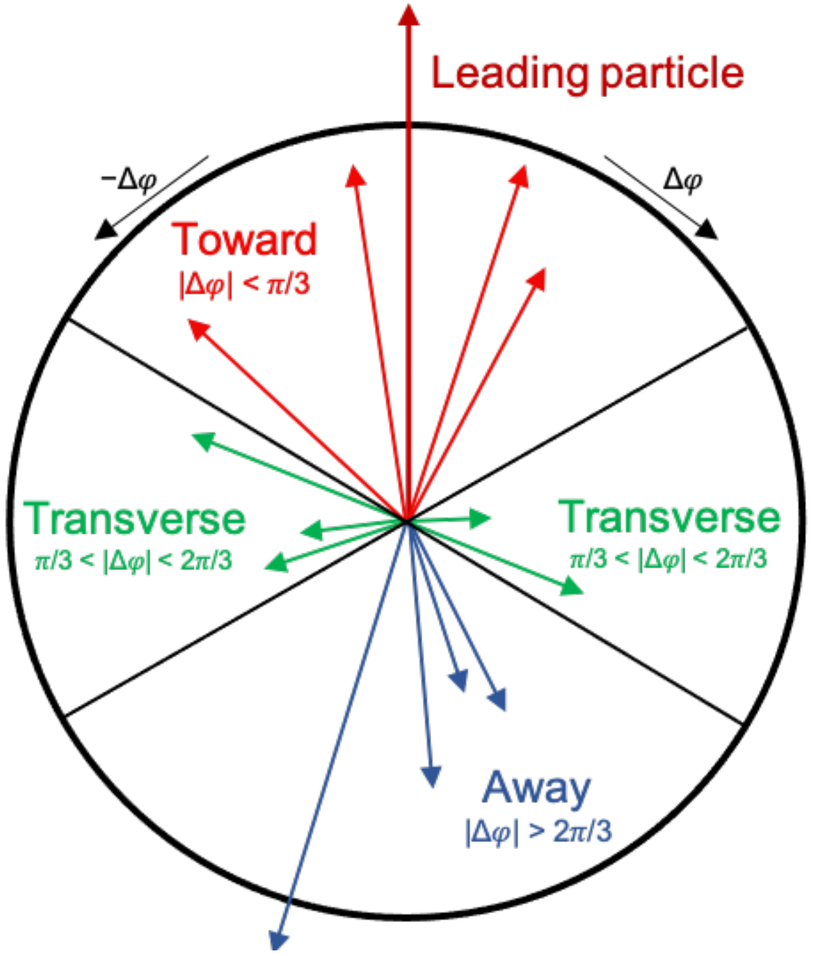
Relative transverse activity classifier

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

!

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

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

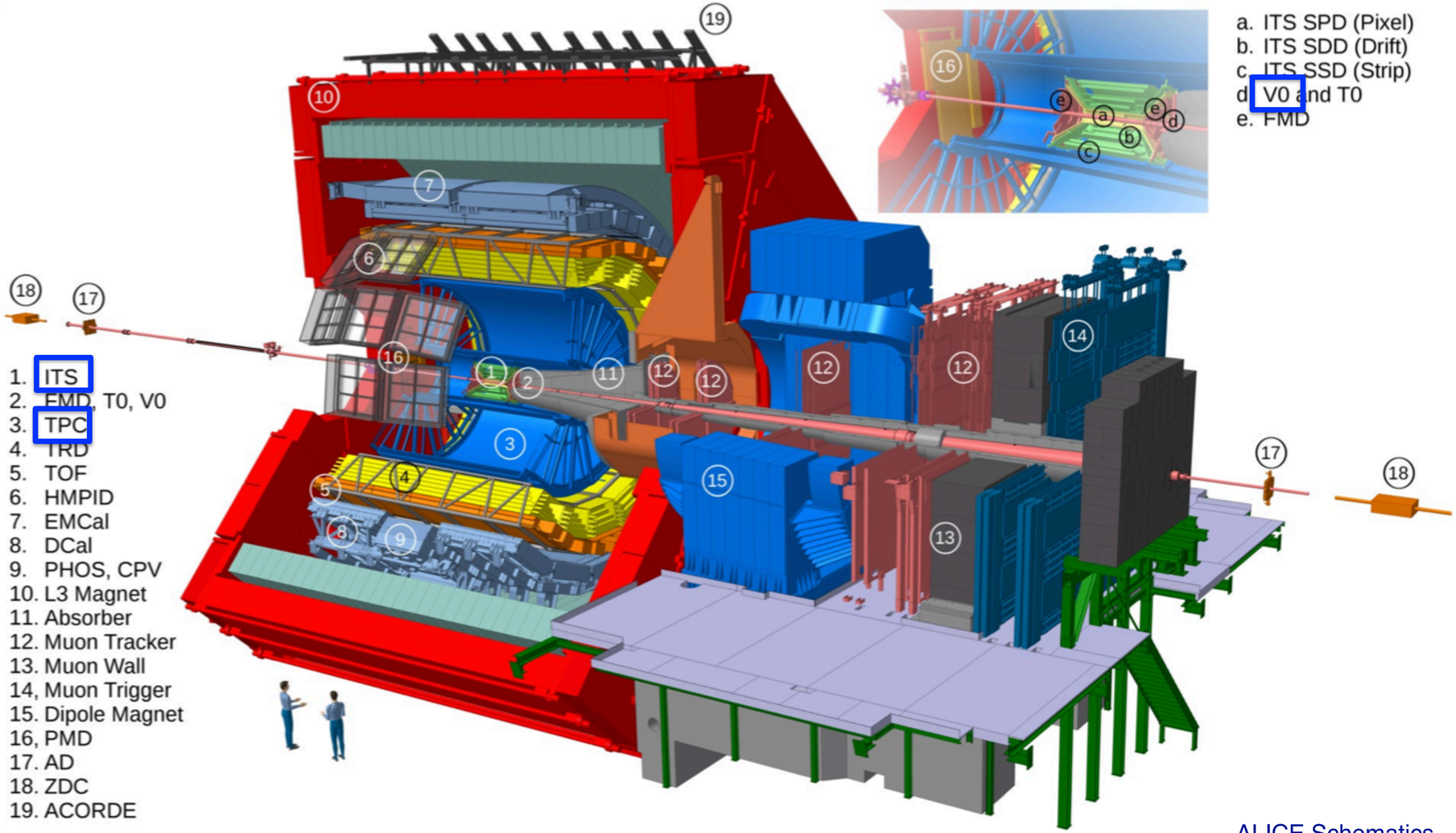


$$|\Delta\varphi| = |\varphi^{\mathrm{assoc}} - \varphi^{\mathrm{trig}}|$$

- By definition R_{T} is expected to be a “jet-free” multiplicity estimator
- The neutral-to-charged particle yield in the toward and away region is not biased at high-R_{T} values

More details about multiplicity estimators in Sushanta Tripathy’s talk (11/20 at 9:50 h)

The ALICE detector in Run 2



ALICE Schematics

Main detectors used in this work

ITS: primary vertex, pile up rejection and tracking

TPC: tracking

V0: triggering and background rejection

Analysis details

Corrections

The raw p_{T} spectra as a function of track multiplicity were corrected for multiplicity using a Bayesian unfolding

The raw p_{T} spectra as a function of R_{T} fully corrected multiplicity were further corrected for:

Efficiency: Data-driven-tracking efficiency

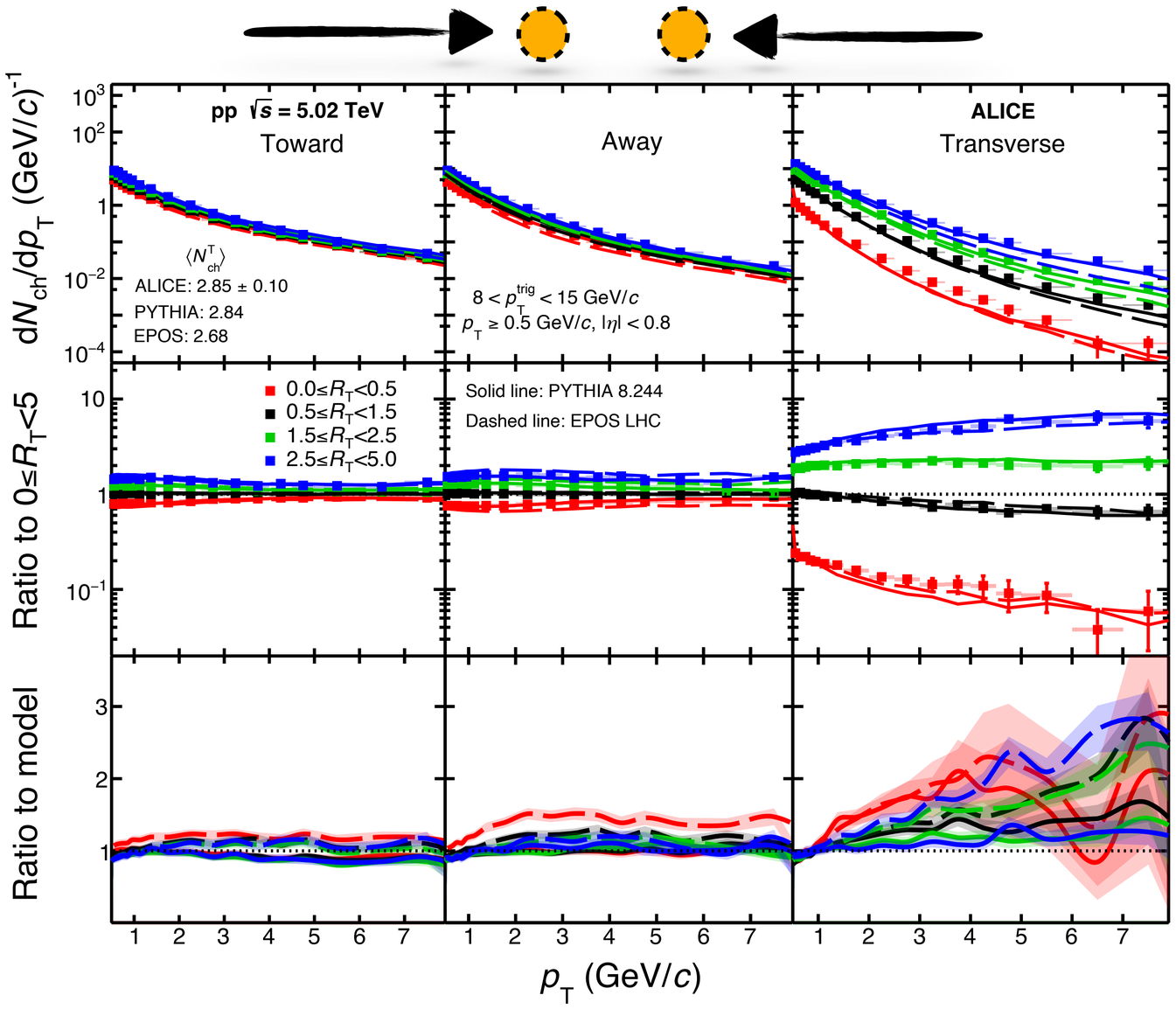
Secondary contamination: from different sources such as weak decays and material interactions

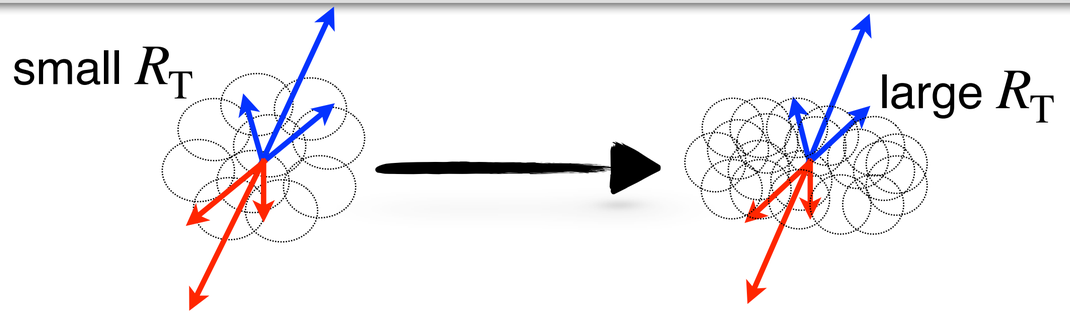
Systematic uncertainties

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

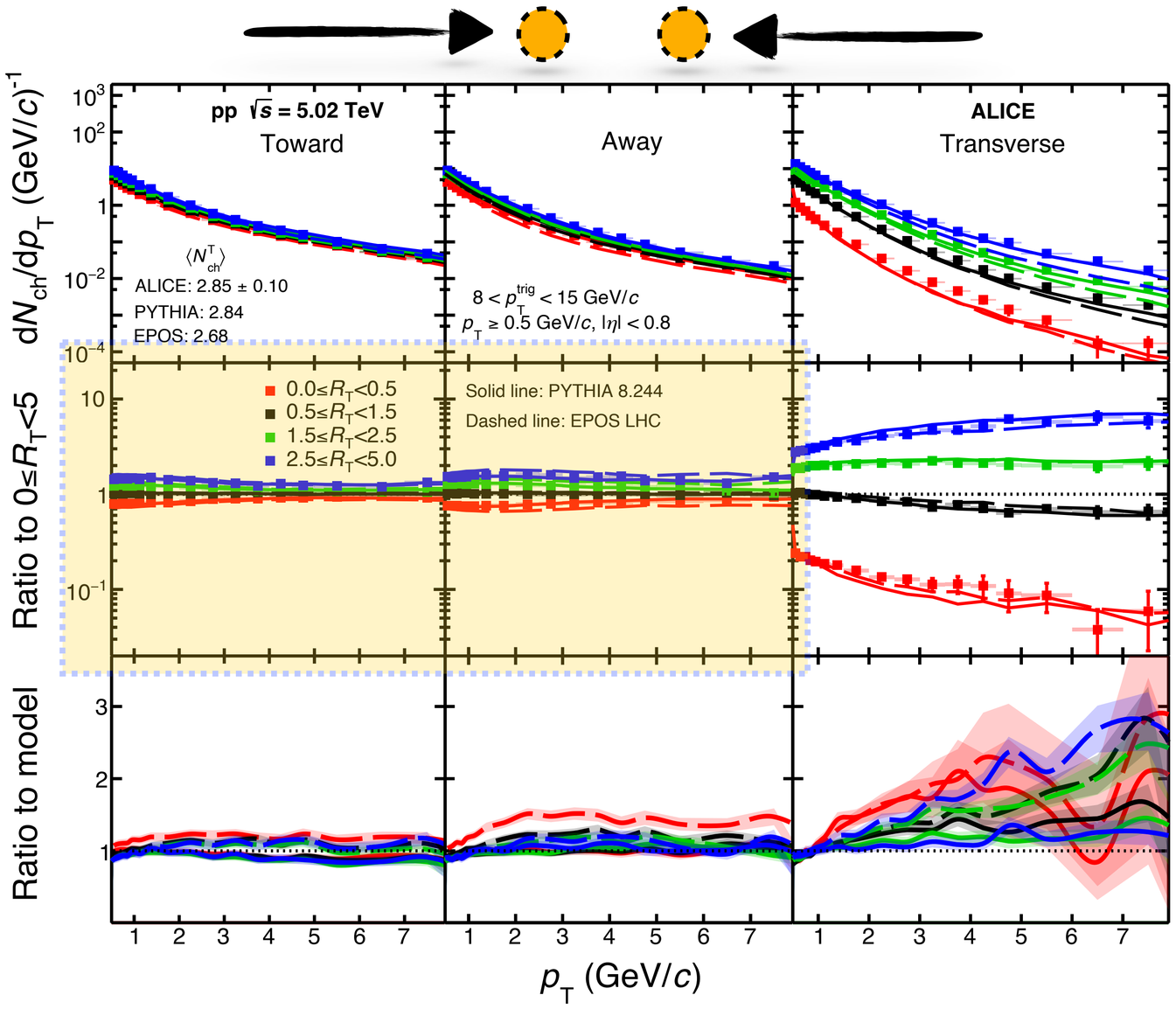
Source	uncertainty (%)					
	pp		p–Pb		Pb–Pb	
p_{T} (GeV/c)	0.5	7.0	0.5	7.0	0.5	7.0
track reconstruction and selection*	1.5	3.5	1.4	1.2	2.5	1.4
mult. dependence of tracking efficiency*	3.0	3.0	3.0	3.0	3.0	3.0
MC non-closure*	3.0	3.0	3.0	3.0	3.0	3.0
matching efficiency	0.4	0.3	1.1	0.6	0.8	0.9
particle 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

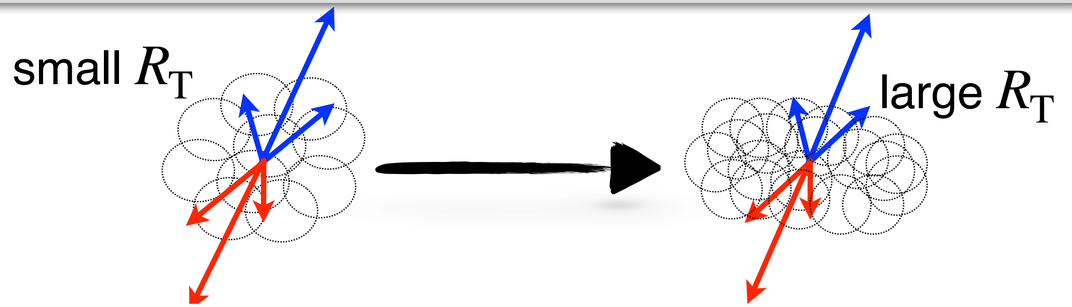
p_{T}-spectra as a function of R_{T}





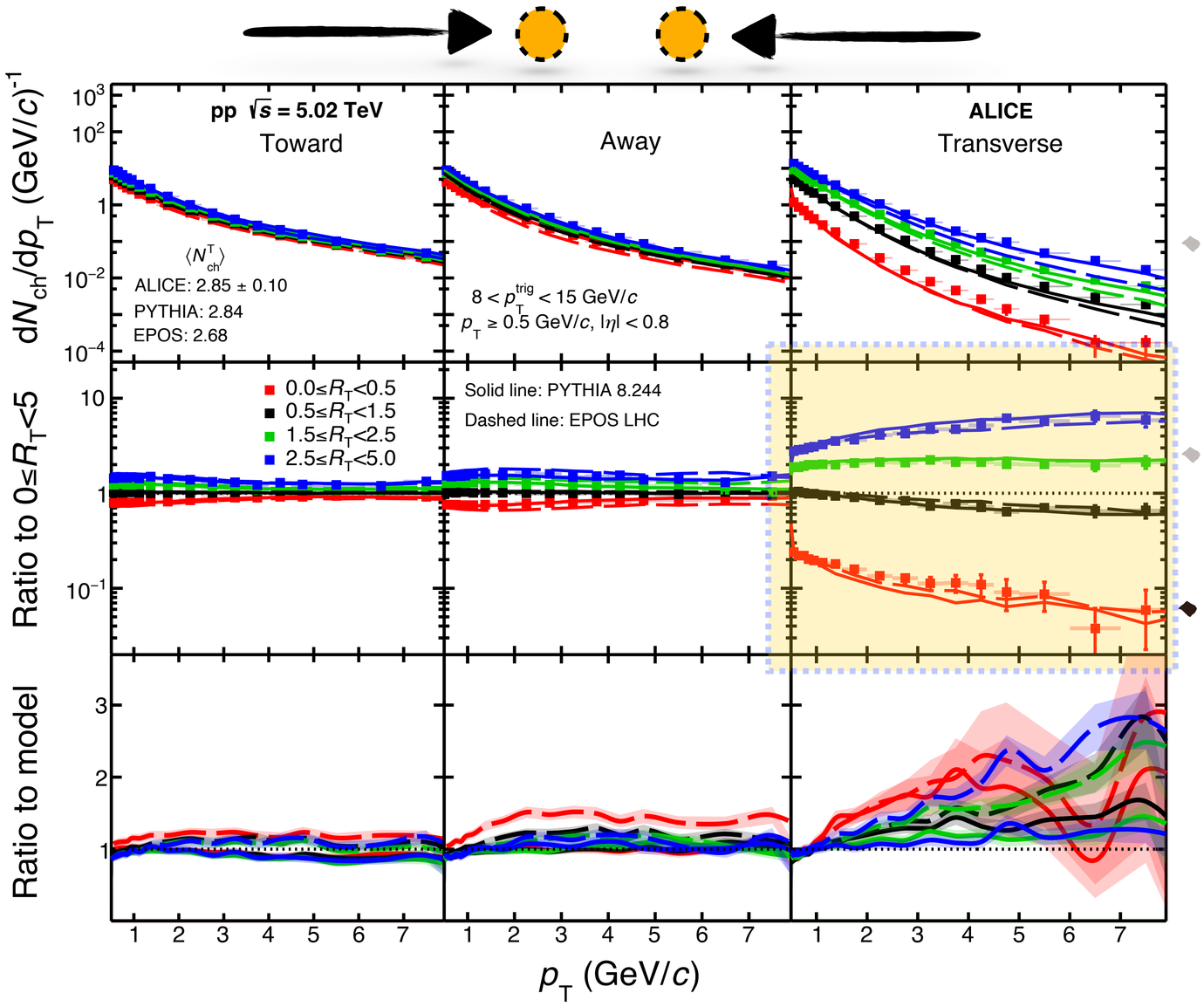
p_{T}-spectra as a function of R_{T}

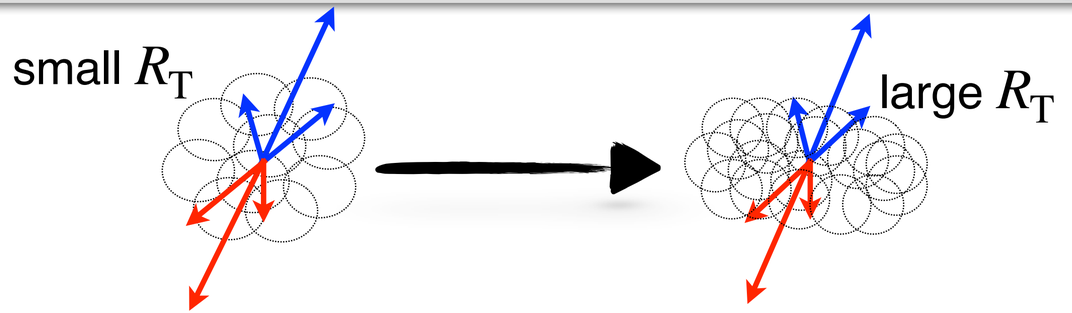




- For $p_{\mathrm{T}} < 4$ GeV/c, the p_{T} spectra in the away and toward regions relative to the R_{T}-integrated event class exhibit a R_{T}-dependence. **This effect can be attributed to the presence of collective radial flow**
- For $p_{\mathrm{T}} > 4$ GeV/c, the spectral shapes in the away and toward regions are found to be almost independent of R_{T}

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





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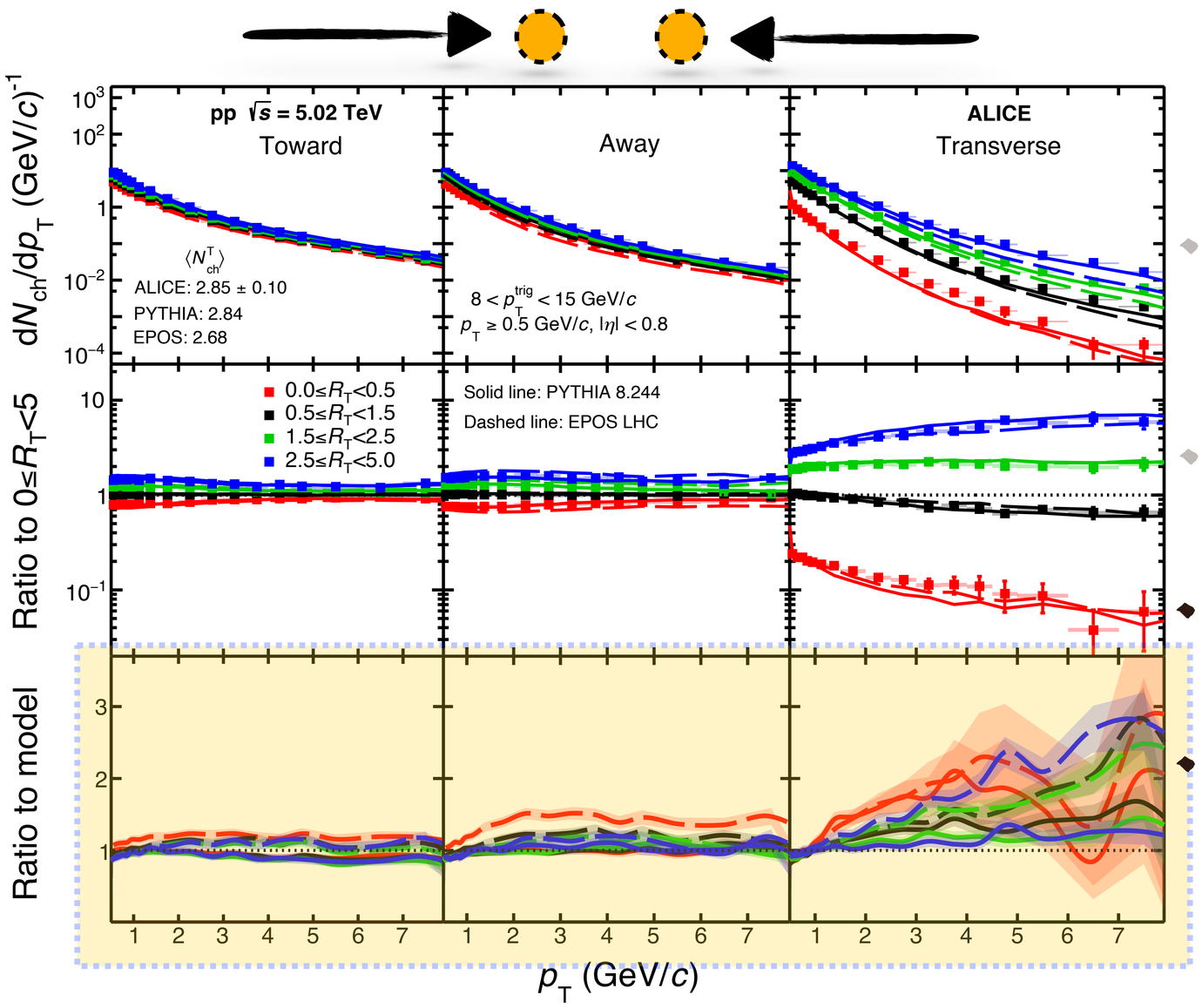
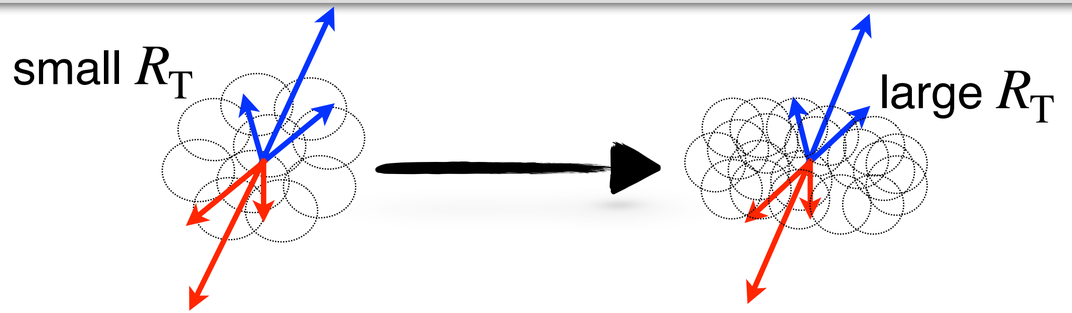
- For $p_{\mathrm{T}} > 4$ GeV/c, the spectral shapes in the away and toward regions are found to be almost independent of R_{T}
- The p_{T} spectra in the transverse region harden with increasing R_{T}. **Autocorrelations are relevant in this region**

Phys. Rev. D 104 (2021) 016017

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



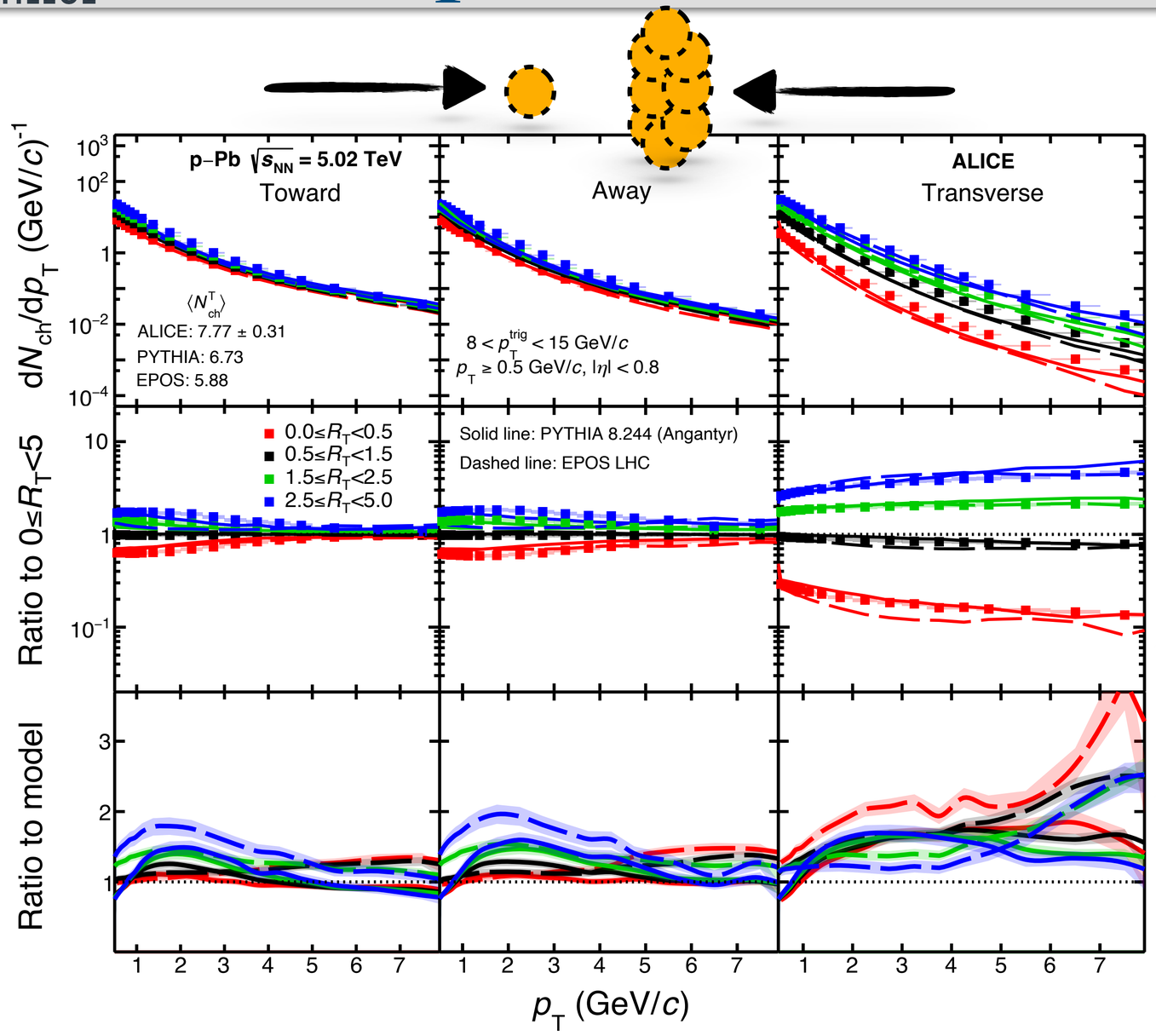


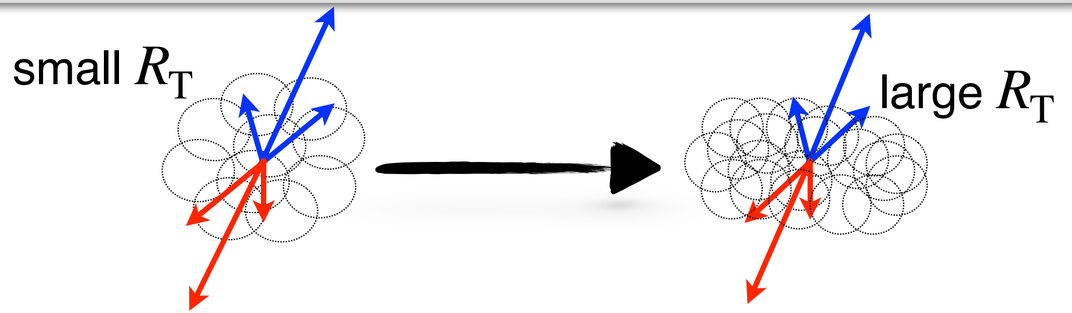
- For $p_{\mathrm{T}} < 4$ GeV/c, the p_{T} spectra in the away and toward regions relative to the R_{T}-integrated event class exhibit a R_{T}-dependence. **This effect can be attributed to the presence of collective radial flow**
- For $p_{\mathrm{T}} > 4$ GeV/c, the spectral shapes in the away and 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 describes data better than EPOS-LHC

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





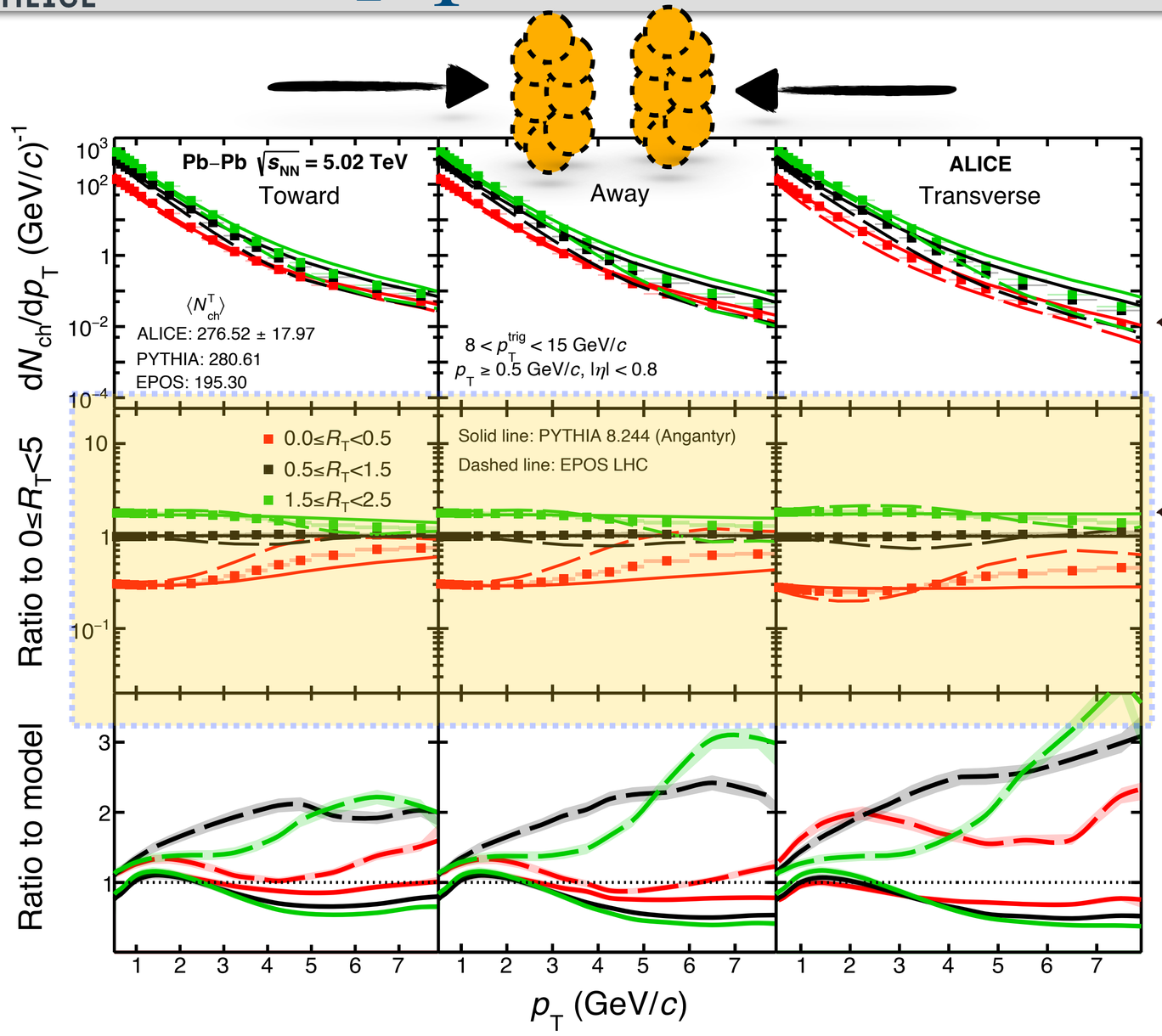
- For $p_{\mathrm{T}} < 4$ GeV/c, the p_{T} spectra in the away and toward regions relative to the R_{T}-integrated event class exhibit a R_{T}-dependence. **This effect can be attributed to the presence of collective radial flow**
- For $p_{\mathrm{T}} > 4$ GeV/c, the spectral shapes in the away and 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**

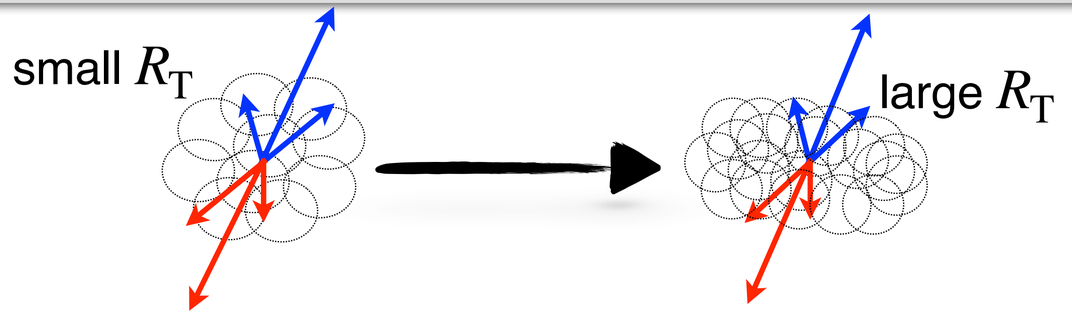
Phys. Rev. D 104 (2021) 016017

- 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

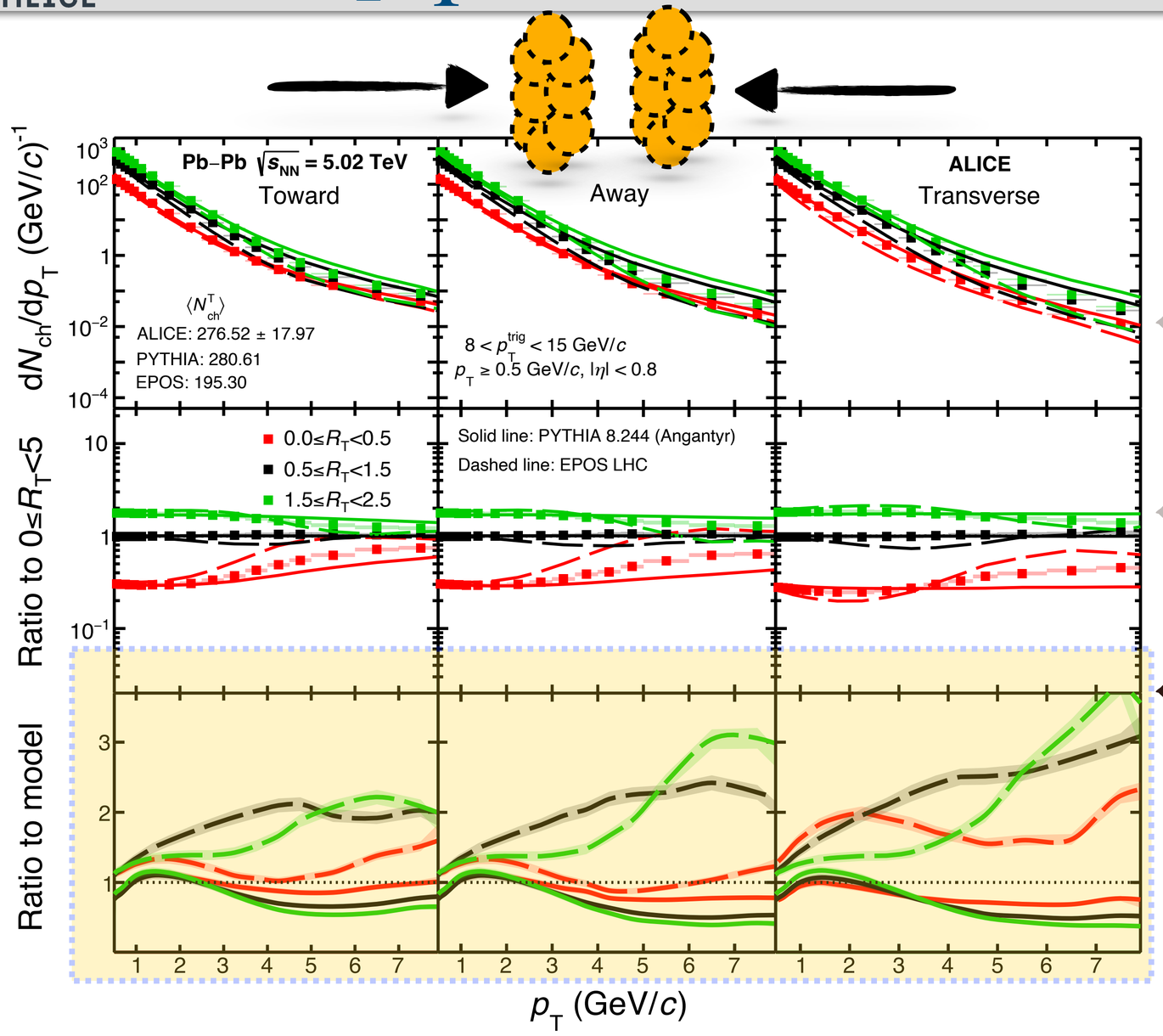
p_{T}-spectra as a function of R_{T}

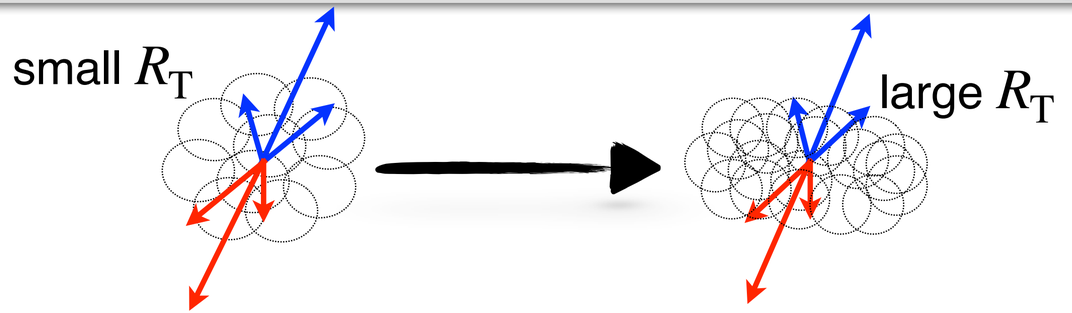




- For $p_{\mathrm{T}} < 6$ GeV/c, the p_{T} spectra for all three topological regions are qualitatively similar to that of pp and p-Pb collisions.
- For $p_{\mathrm{T}} > 6$ GeV/c, the spectral shapes for all three topological regions are found to be almost independent of R_{T}

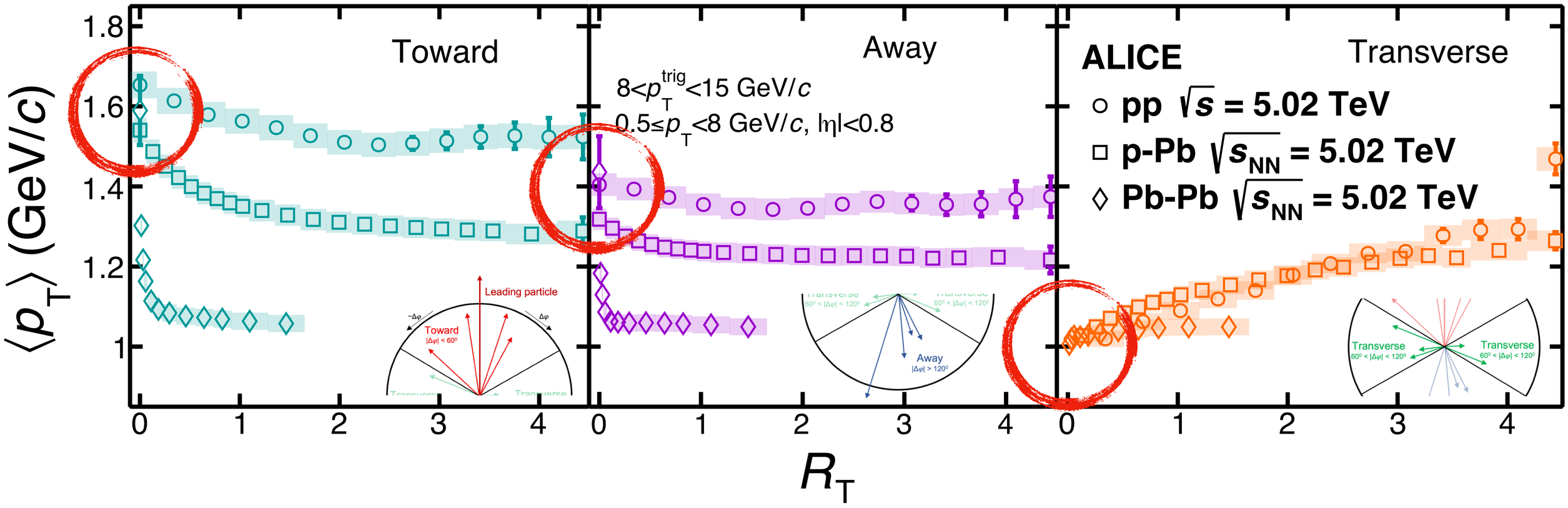
p_{T}-spectra as a function of R_{T}





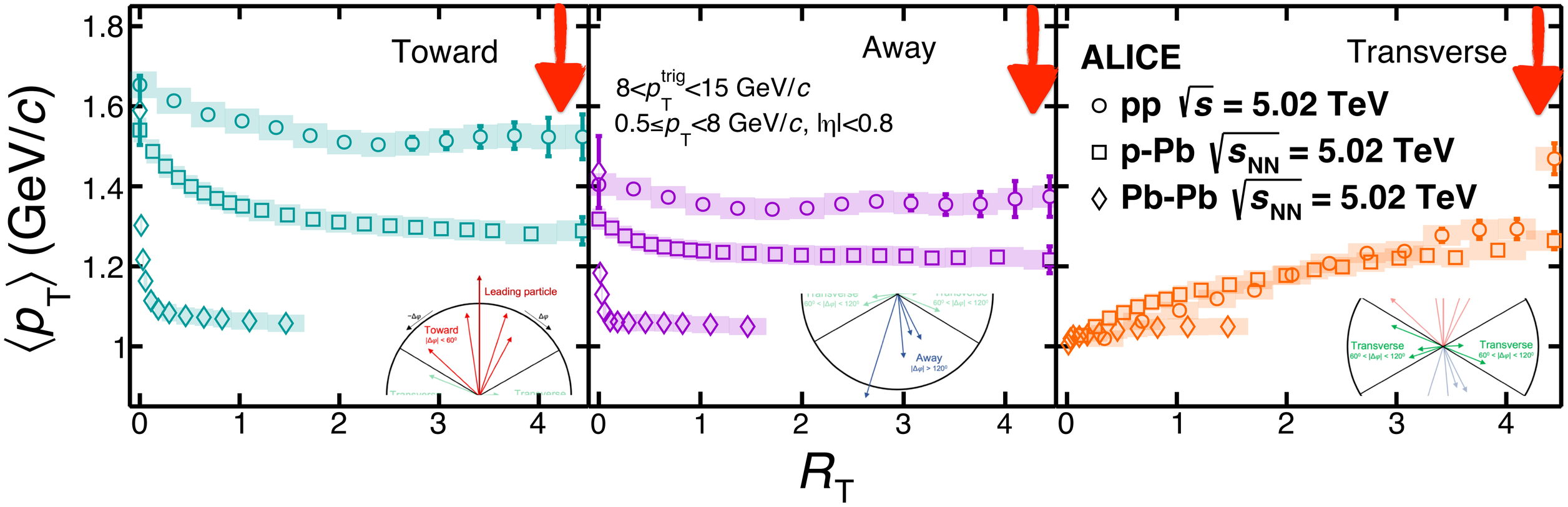
- For $p_{\mathrm{T}} < 6$ GeV/c, the p_{T} spectra for all three topological regions are qualitatively similar to that of pp and p-Pb collisions.
- For $p_{\mathrm{T}} > 6$ GeV/c, the spectral shapes for all three topological regions are found to be almost independent of R_{T}
- In general, PYTHIA8/Argantyr 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 fail the description up to 10% for higher R_{T}-bins.

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



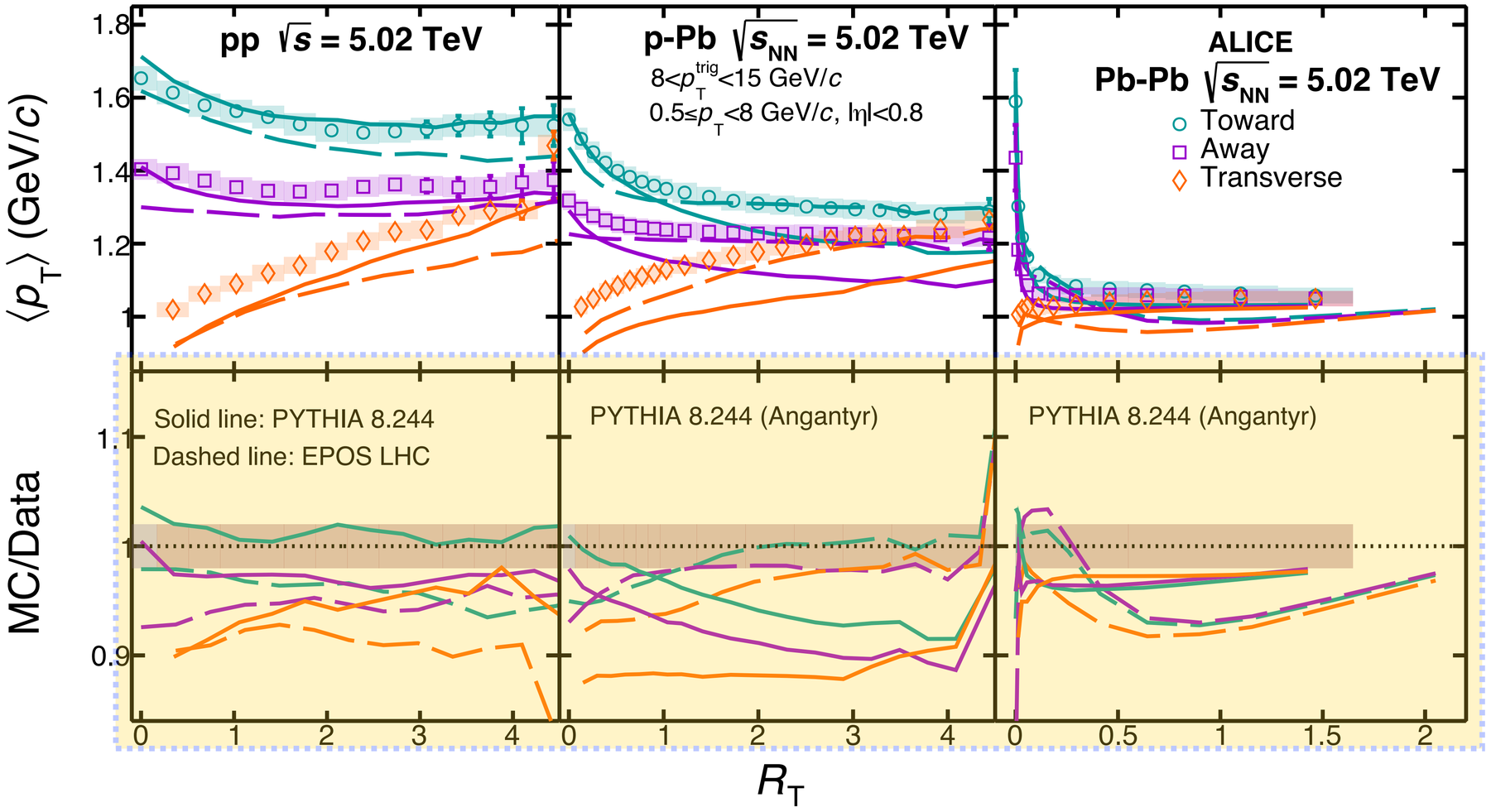
The jet contribution dominates at low R_{T}, as expected for $R_{\mathrm{T}} \to 0$

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



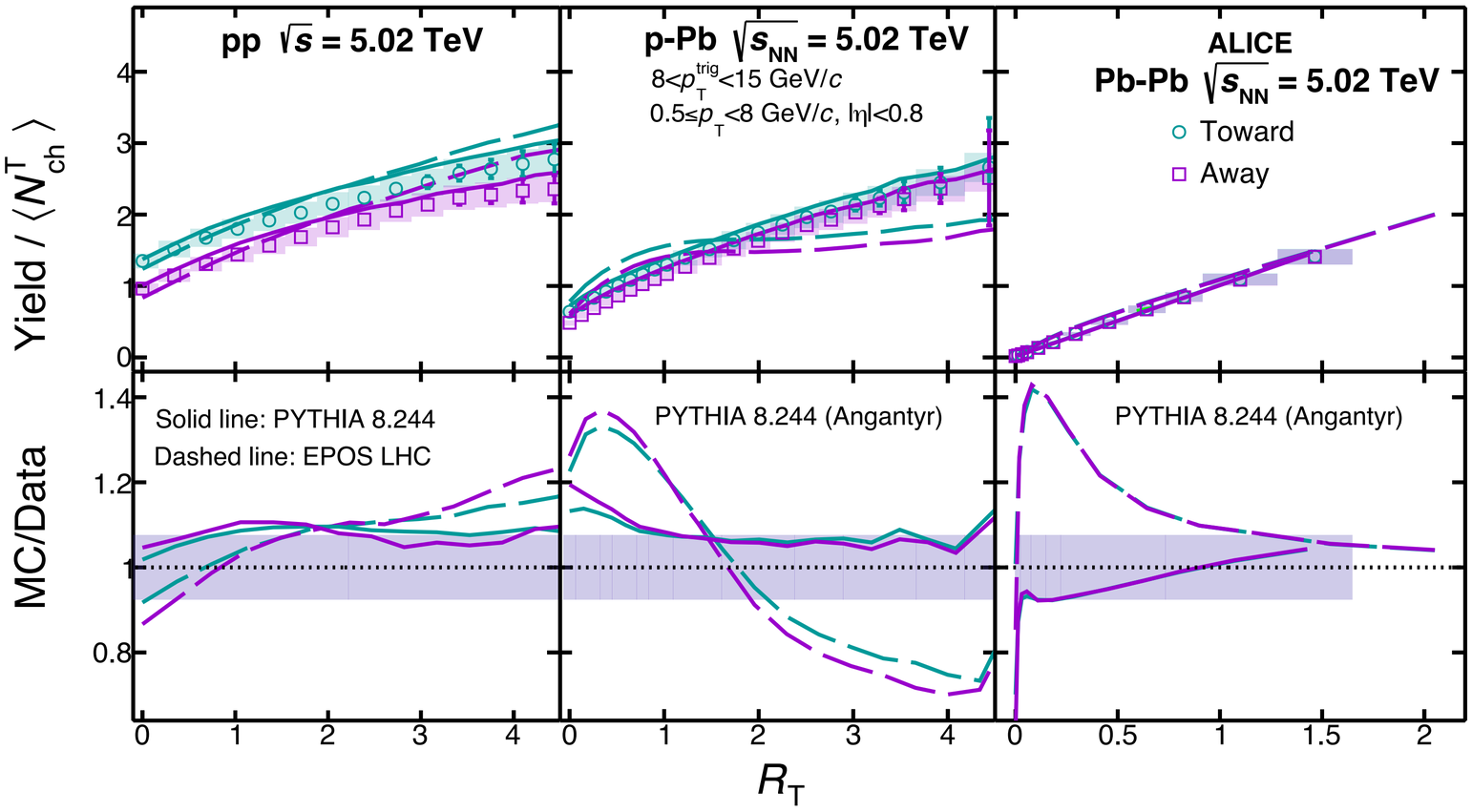
For large R_{T}, the $\langle p_{\mathrm{T}} \rangle$ is dominated by bulk contribution and exhibits an ordering that depends on the system size

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

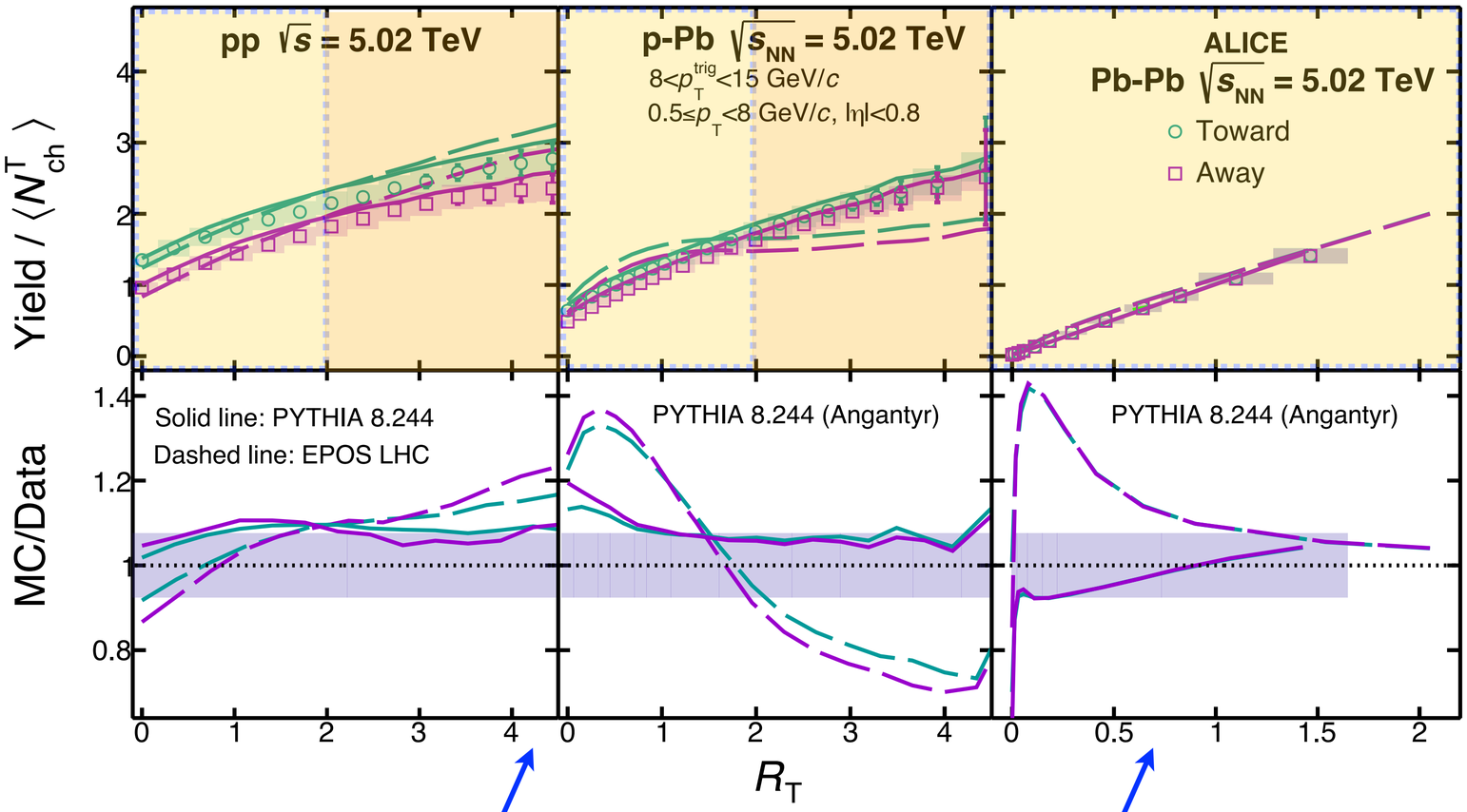


- The models deviate by 10% from data, however, they show a trend with R_{T} that is qualitatively similar to the measured one

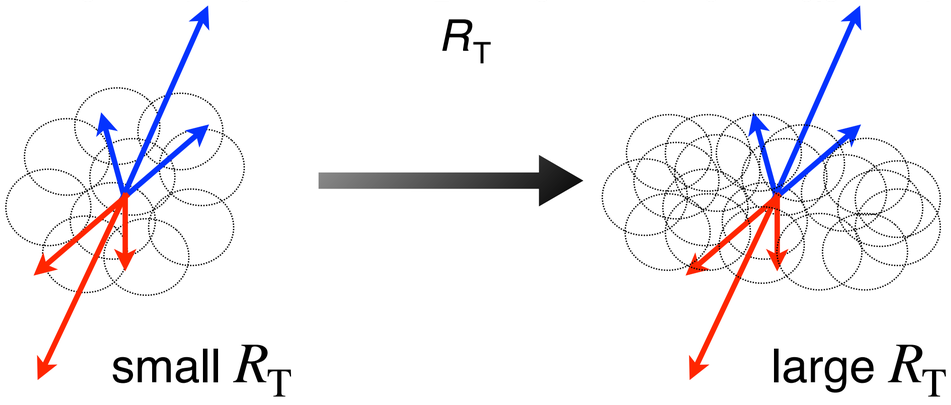
Normalized integrated yield as a function of R_T



Normalized integrated yield as a function of R_T

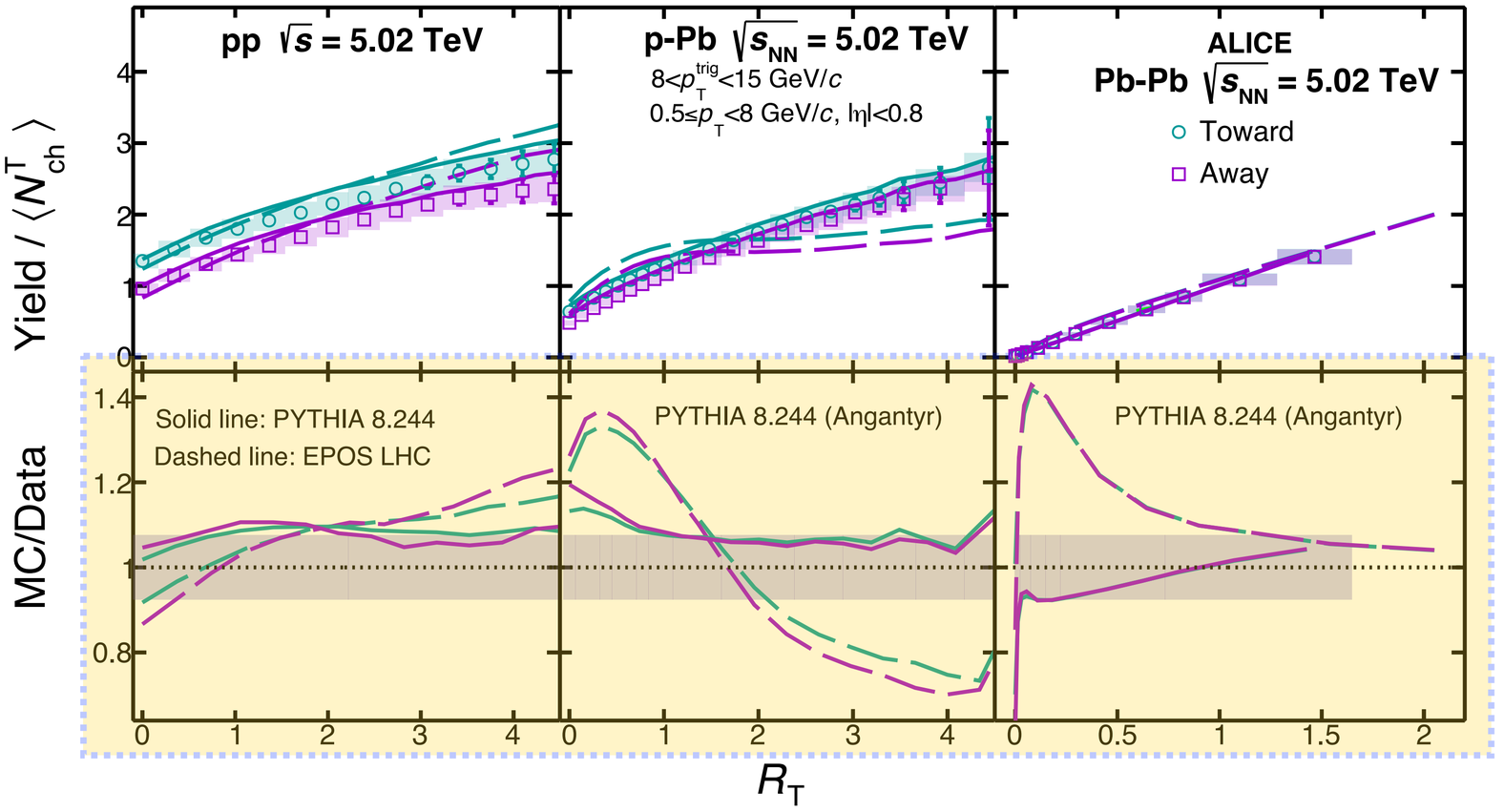


UE is isotropically distributed



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
  - We could only reach $R_{\mathrm{T}} < 2.5$ therefore results are dominated by bulk particle production

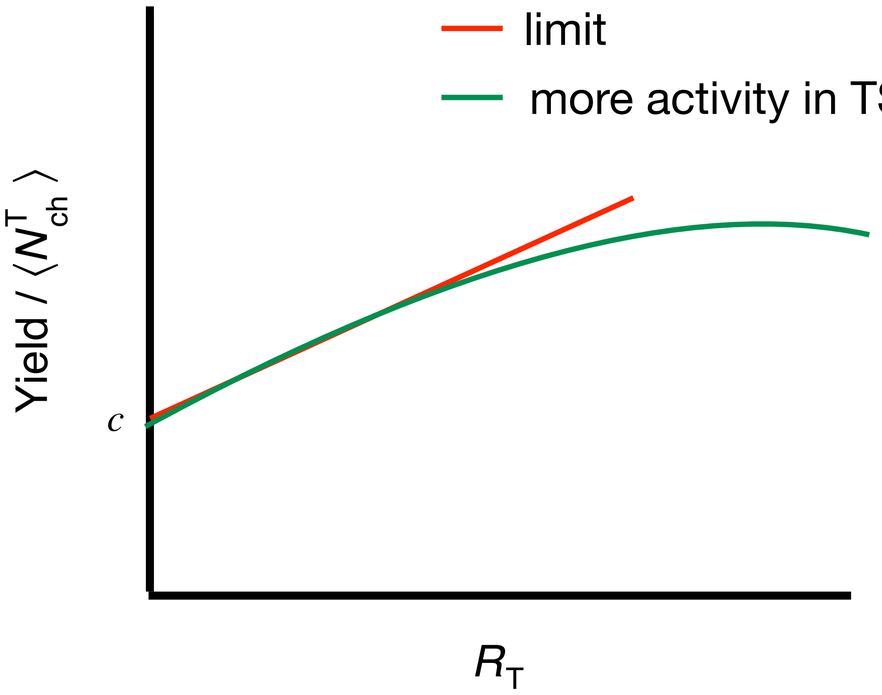
- For R_{T} close to zero, the $\langle p_{\mathrm{T}} \rangle$ is system size independent while for large R_{T}, it exhibits an system size ordering

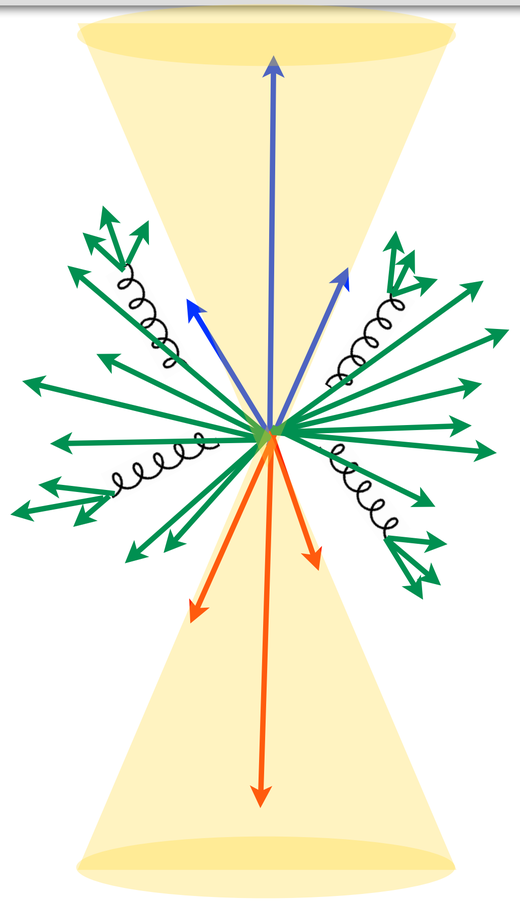
- Overall, PYTHIA 8 describes better the data (pp, p-Pb and Pb-Pb) than EPOS LHC supporting the MPI picture

Results about energy dependence of the R_{T} in Feng Fan's talk (11/23 at 17:20 h)

Backup

Normalized integrated yield explanation





The gluon radiation produce more activity in TS

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

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