Options if there is time…

Alt. 1: (follow-up Rene)
Strangeness correlations

Alt. 2: (follow-up Antonio)
R_T discussion

Alt. 1:
Strangeness correlations

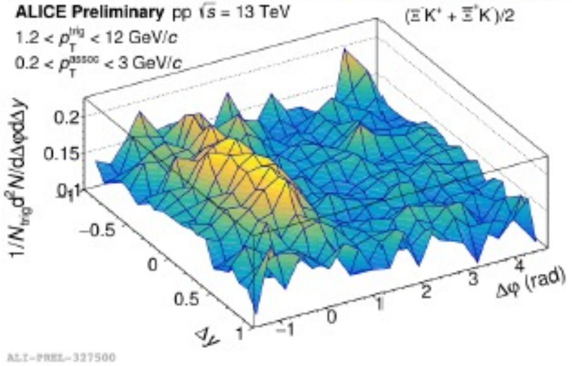
J. Adolfsson

ALICE Thesis Award 2021

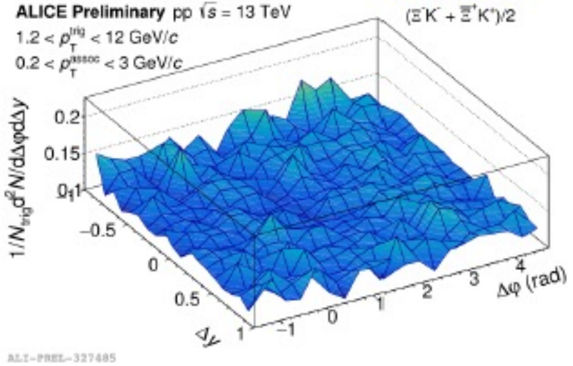
How is strangeness produced in p+p?

- Balance functions: correlation functions indicate where balancing charges end up in ($\Delta\varphi$, $\Delta\eta$)
- Example: $\Xi^{-}K^{+}$ correlations share a s-sbar pair which could come from the same string breaking
  → but there are also $\Xi^{-}K^{+}$ pairs where the s-sbar is not from the same string, model these with $\Xi^{-}K^{-}$ correlations and subtract
- Correlations between Ξ baryon and mesons:
  ΞK → containing a strange quark
  ($\Xi\pi$ → without a strange quark)
- Correlations between Ξ baryon and baryons:
  $\Xi\Lambda$ → containing a strange quark
  (Ξp → without a strange quark)
  $\Xi\Xi$ also measured

$\Xi - \mathrm{K}$ correlations, opposite sign:



$\Xi - \mathrm{K}$ correlations, same sign:



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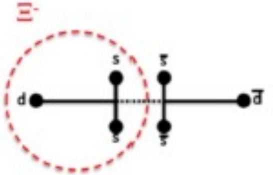
How is strangeness produced in p+p?

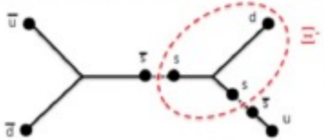
- Balance functions: correlation functions indicate where balancing charges end up in ($\Delta\varphi$, $\Delta\eta$)

Lund string breaking (PYTHIA)

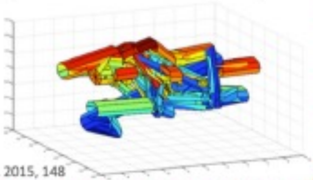
standard:



with junctions:



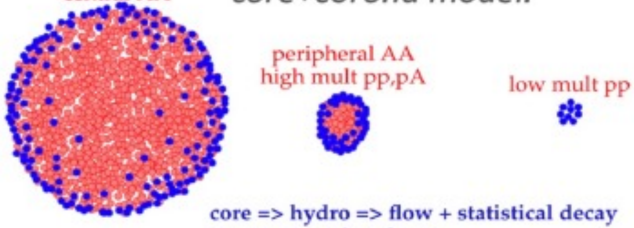
with ropes:



Adolfsson et al. Eur. Phys. J. A 56, 288 (2020), Bierlich et al. J. High Energ. Phys. 2015, 148

EPOS:

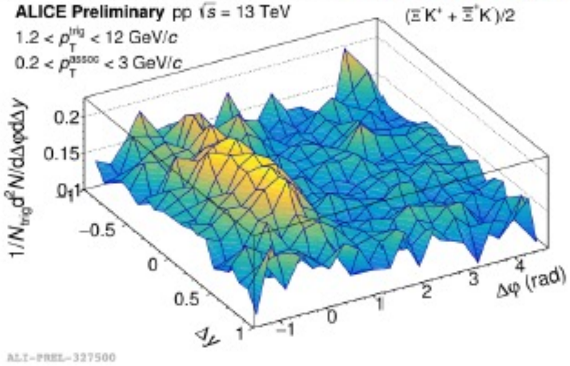
core+corona model:



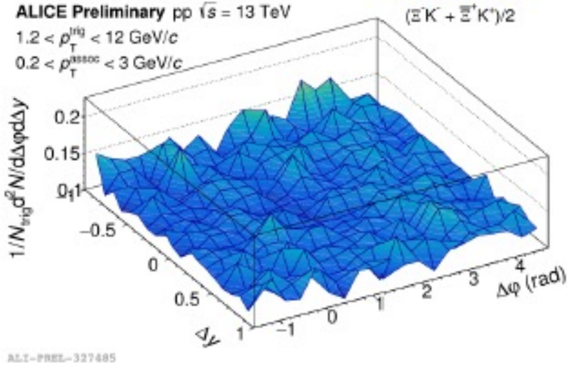
core => hydro => flow + statistical decay
corona => string decay

K. Werner. hal-02434245 (2019)

$\Xi - \mathrm{K}$ correlations, opposite sign:



$\Xi - \mathrm{K}$ correlations, same sign:



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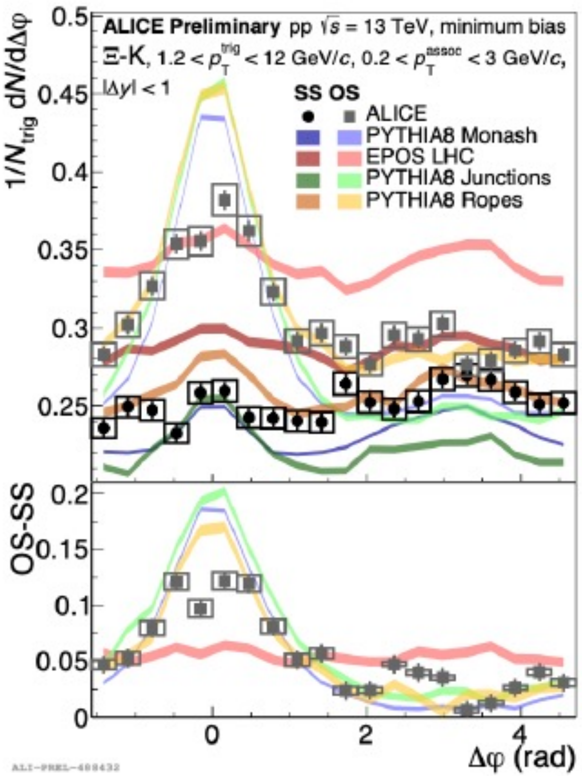
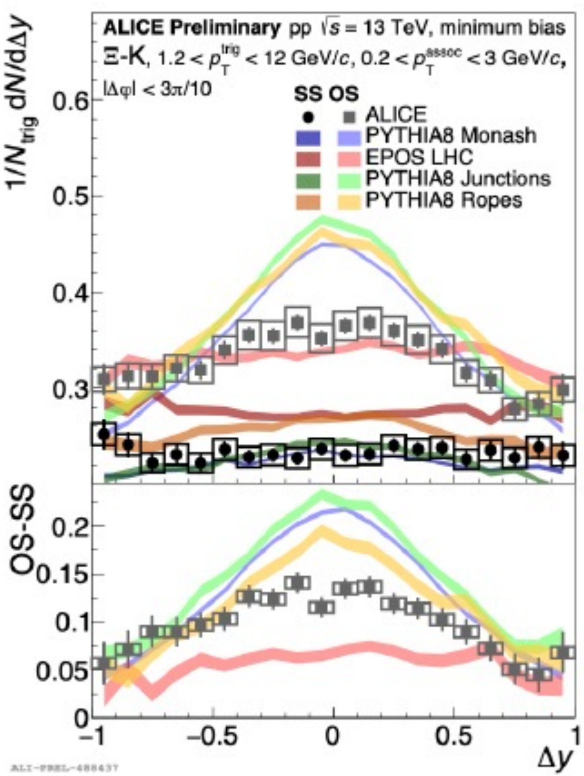
ΞK balance: results

$\Delta\varphi$ projection:



Δy projection, near side:



- Wider NS peak in data than in Pythia → strange quarks produced earlier? more diffusion?
- EPOS has no local conservation of strangeness, predicts flat OS-SS difference, in contradiction to data

Ξp balance: results

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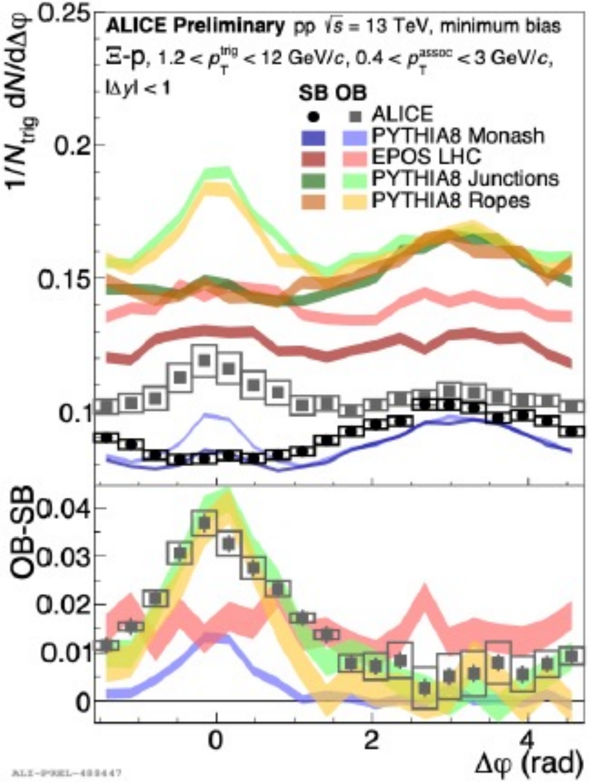
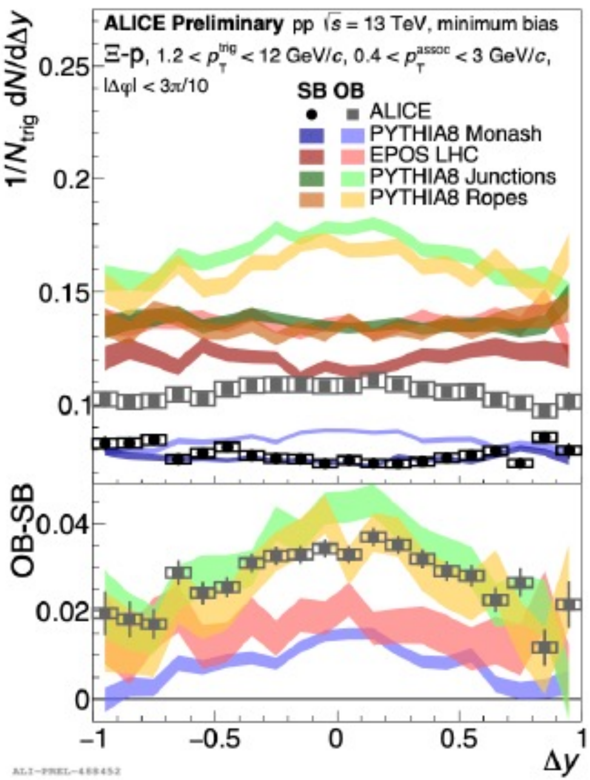
$\Delta\varphi$ projection:



Δy projection, near side:

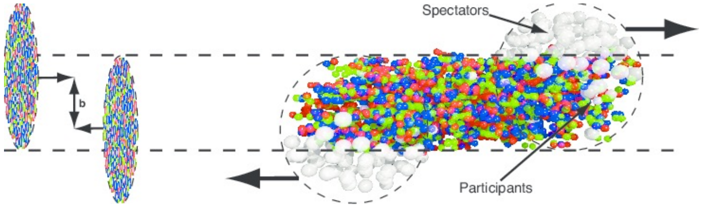


- Junctions and ropes tunes of Pythia are able to get the shape of the OS-SS difference right

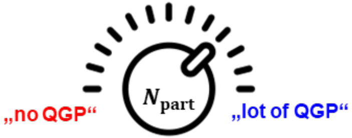
Alt. 2:
R_T discussion

QGP features in small systems – pinning down the origin

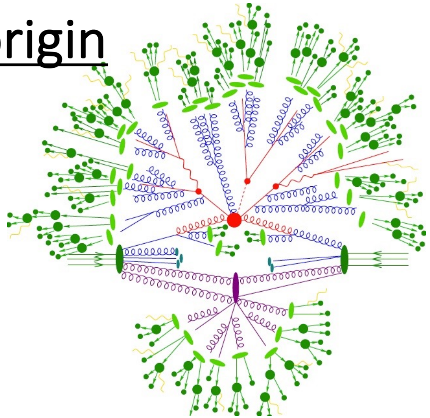
- AA collisions:



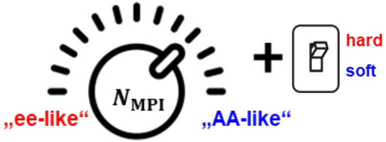
- Multiplicity (N_{ch}) mainly driven by participants (N_{part})



- pp collisions:



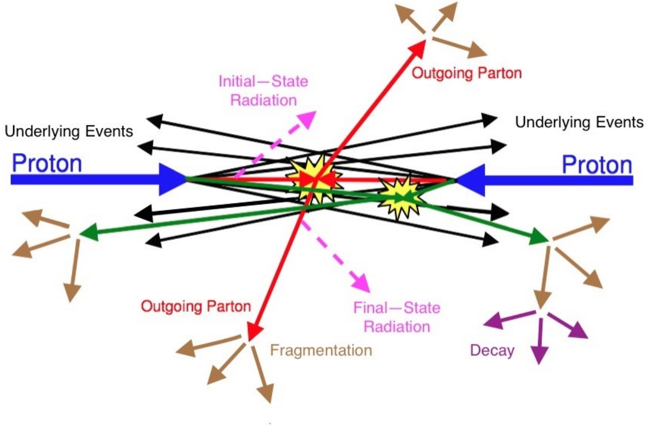
- $N_{\mathrm{part}} = 2$, multiplicity (N_{ch}) sensitive to specific processes!
- „softer“ contribution – from multiple partonic interactions (MPI)
- „harder“ contribution – from the primary process



- pA collisions: a combination of the two scenarios
- *How to go more in depth than studying the dependence on multiplicity?*

We will try to answer this by studying the ***underlying event****!*

The Underlying Event (UE)



- UE: collection of particles NOT originating from the primary hard scattering or the related fragmentation
  - MPI, Initial/final state radiation (ISR/FSR), beam remnants

- Analysis of the UE: measuring particle production in Toward/Transverse/Away, w.r.t. to the highest-momentum track $p_{\mathrm{T}}^{\mathrm{lead}}$
  - Charged particle density: $\frac{1}{\Delta\eta\Delta\varphi}\frac{1}{N_{\mathrm{ev}}}\,N_{\mathrm{ch}}$, often measured as a function of $p_{\mathrm{T}}^{\mathrm{lead}}$

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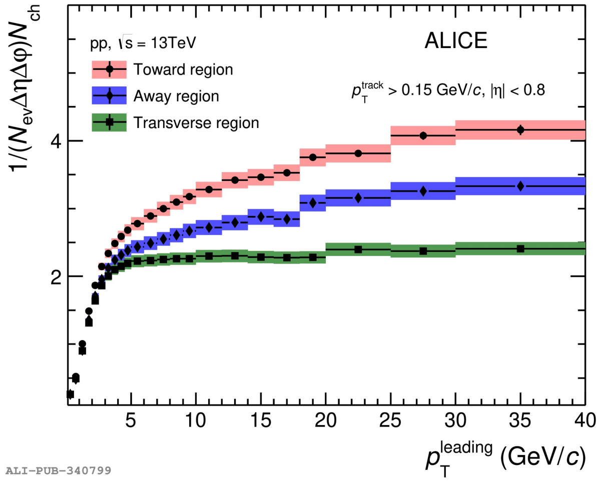
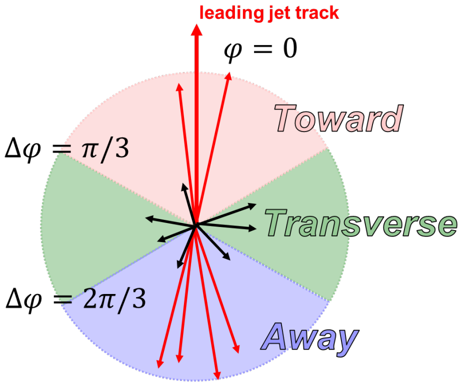


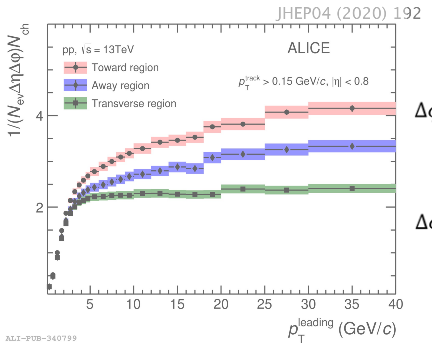


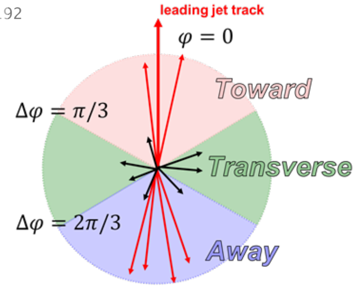
- In Toward/Near (NS), Away (AS):
  - N_{ch} scales with hardness of the process
- In Transverse region (TS):
  - From $p_{\mathrm{T}} \gtrsim 5$ GeV/c, N_{ch} mostly insensitive to the hard component and dominated by N_{MPI}

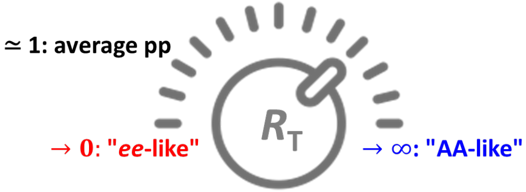
Particle density in the Transverse region ≡ $\mathrm{N_T}$
(UE activity or transverse activity)

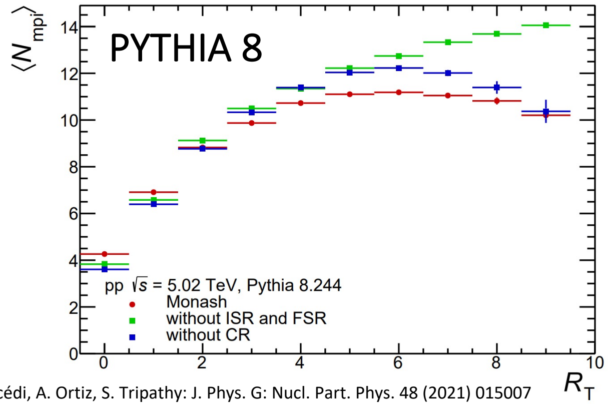
Event shape observable: relative underlying event activity R_{T}

- $R_{\mathrm{T}} = N_{\mathrm{T}} / \langle N_{\mathrm{T}} \rangle$, where N_{T} is charged particle density in Transverse (transverse activity) (introduced in P. Skands et. al., Eur. Phys. J. C **76,** 299 (2016))
  - Defined in events with $p_{\mathrm{T}}^{\mathrm{lead}} > 5\ \mathrm{GeV}/c$ → plateau region









G. Bencédi, A. Ortiz, S. Tripathy: J. Phys. G: Nucl. Part. Phys. 48 (2021) 015007

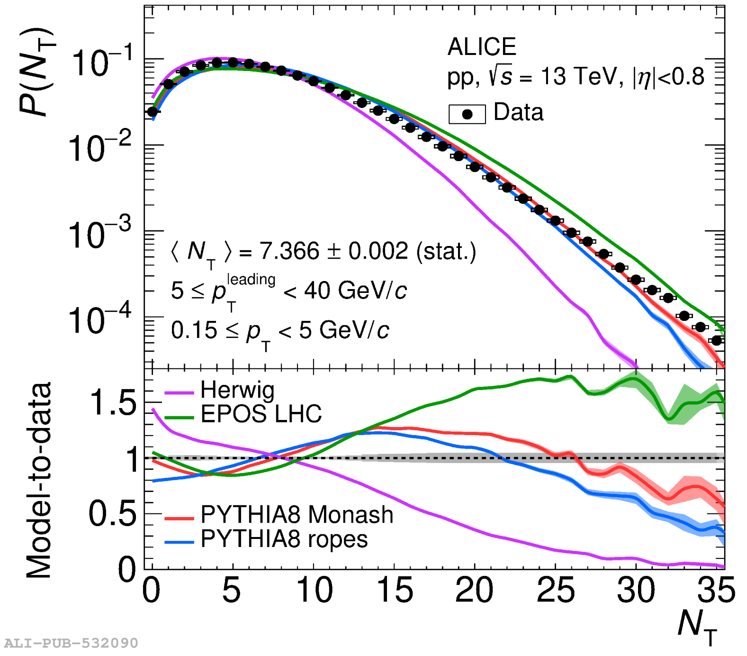
- R_{T} selects different event composition:
  - $R_{\mathrm{T}} \to 0$: event dominated by jet, $N_{\mathrm{MPI}} \to 1$, dominated by pQCD
  - $R_{\mathrm{T}} \to \infty$: event dominated by UE, $N_{\mathrm{MPI}} > \sim 10$, softer processes

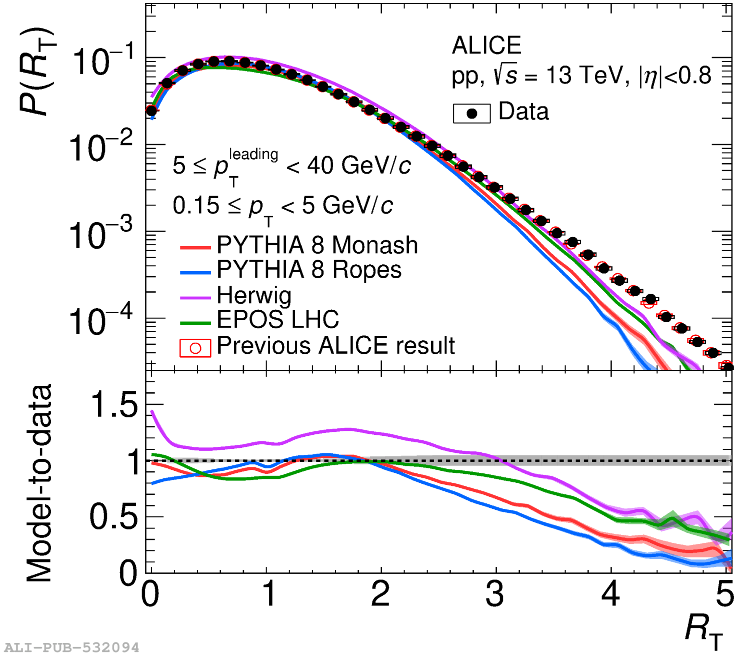
- Analysing particle production in the different regions:
  - Transverse, we test the dependence on $\langle N_{\mathrm{MPI}} \rangle$
  - Toward (Away), we test the dependence on the amount of interplay between jet- and UE-dominated production

N_T & R_T

arXiv:2301.10120

- N_T : number of charged particles per event in Transverse region. $R_T = N_T / \langle N_T \rangle$

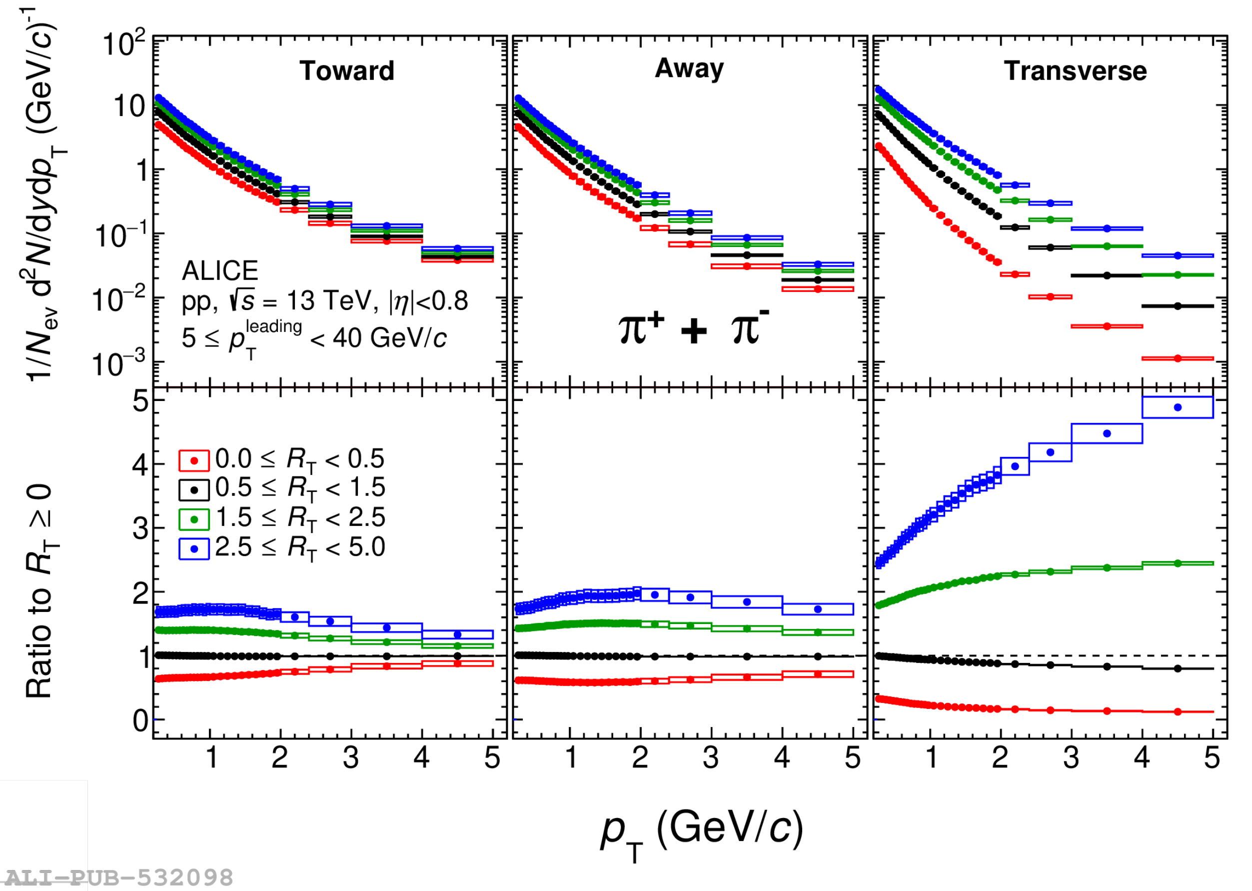




- N_T and R_T probability distributions : challenging for models to describe

Pion p_T spectra : 4 R_T intervals

arXiv:2301.10120



<u>Toward & Away</u>:

Depletion of low p_T increasing with R_T

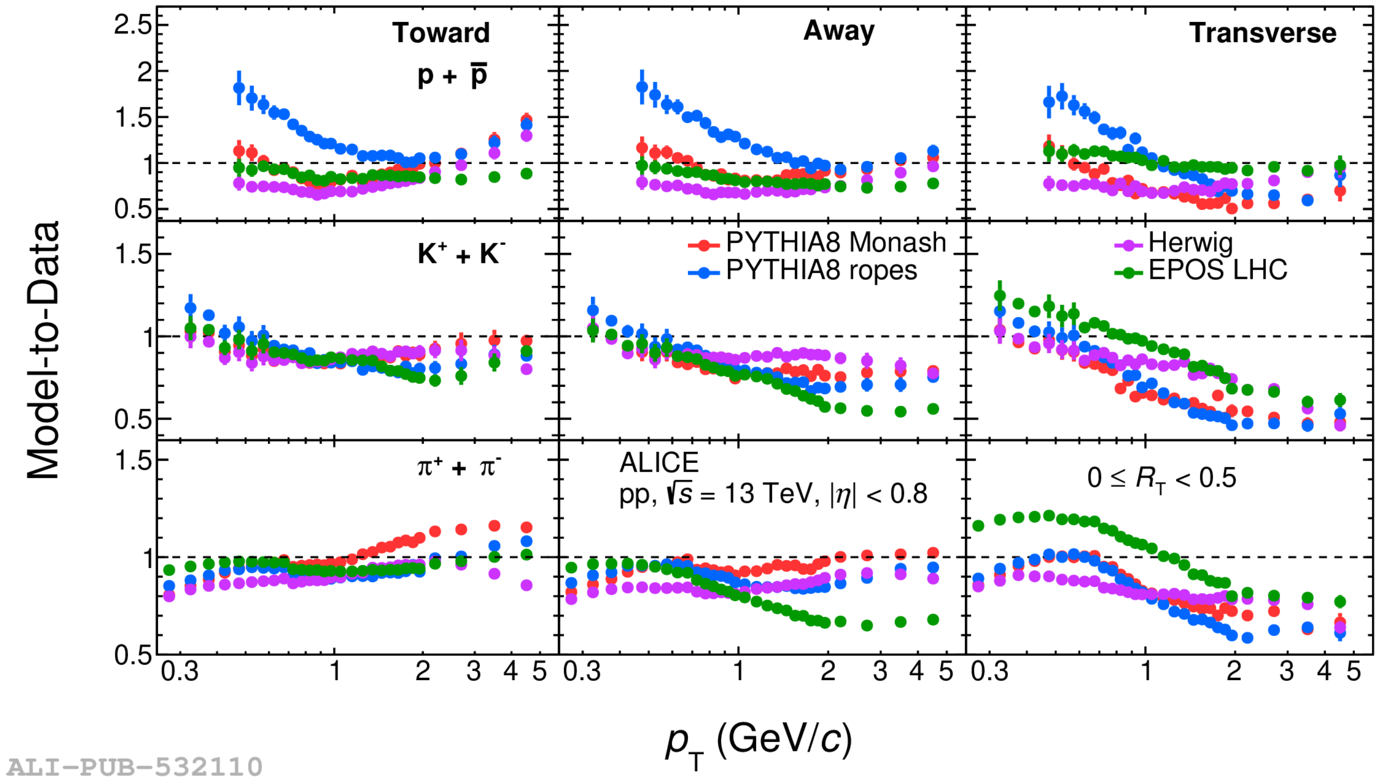
High R_T :

Spectral shapes *soften* with increasing R_T

<u>Transverse</u>: spectra *harden* with increasing R_T

Model-to-Data vs p_T : low R_T

arXiv:2301.10120



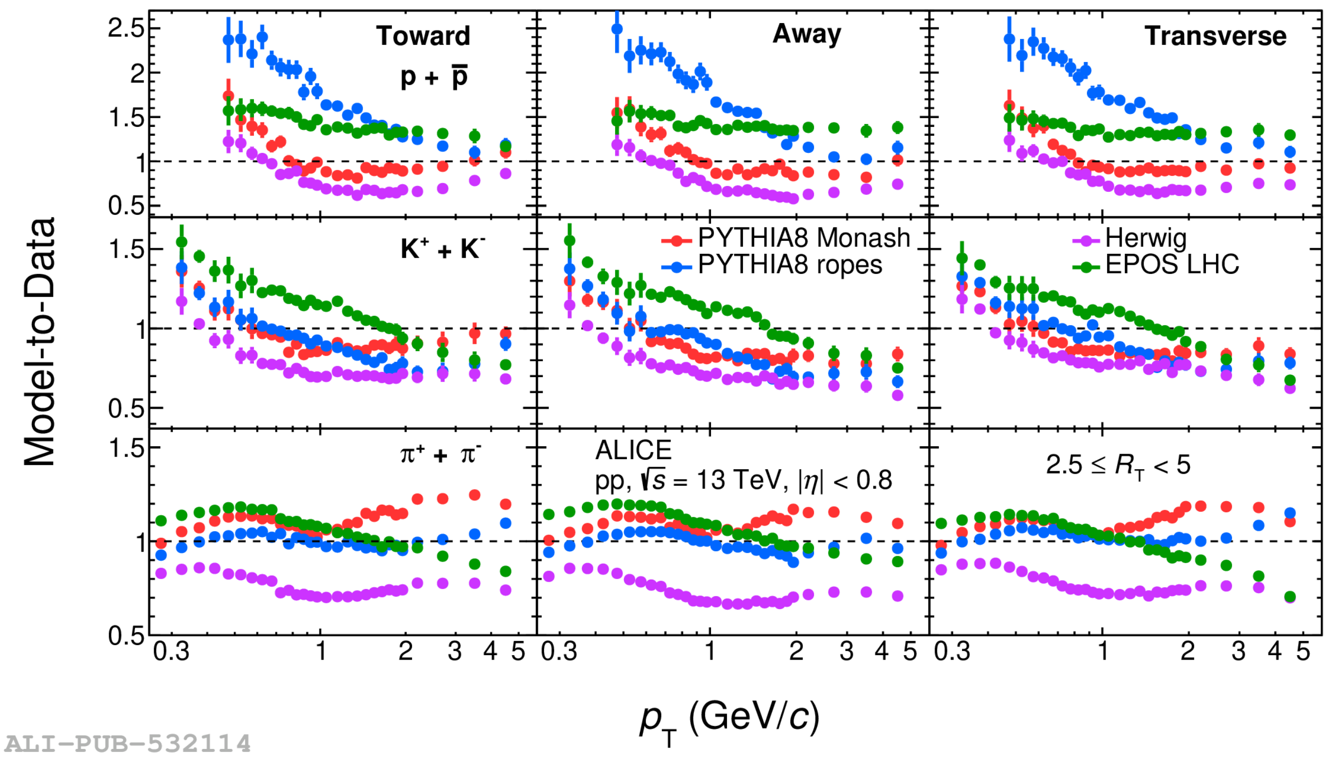
Toward (& Away):

π,K qualitatively reproduced by models at $p_T > 2$ GeV/c

Models generally underestimate soft particle production, while Pythia8 with ropes seem to overestimate production of protons

Model-to-Data vs p_T : high R_T

arXiv:2301.10120

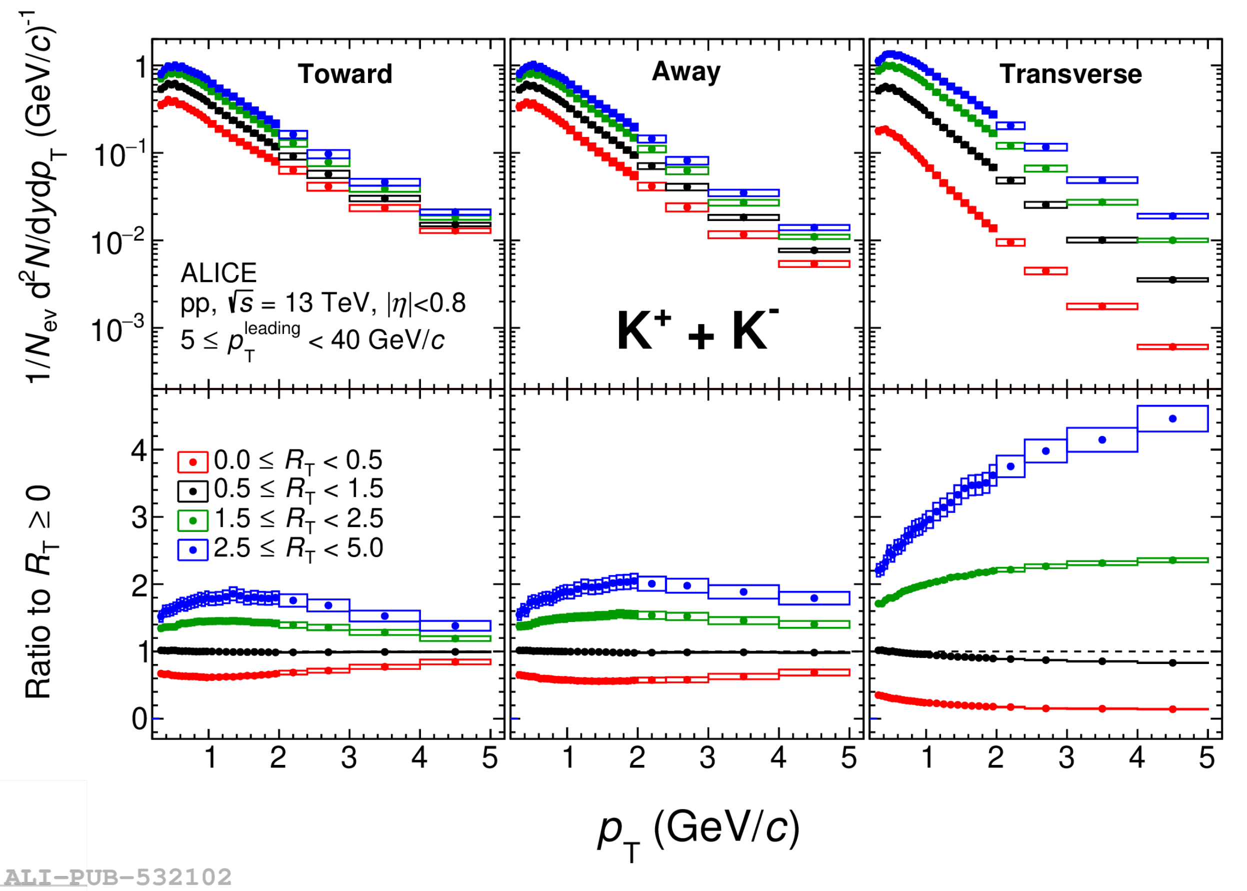


Less agreement between models and data in high R_T interval

EXTRAS

Kaon p_T spectra : 4 R_T intervals

arXiv:2301.10120



Toward & Away:

Depletion of low p_T increasing with R_T

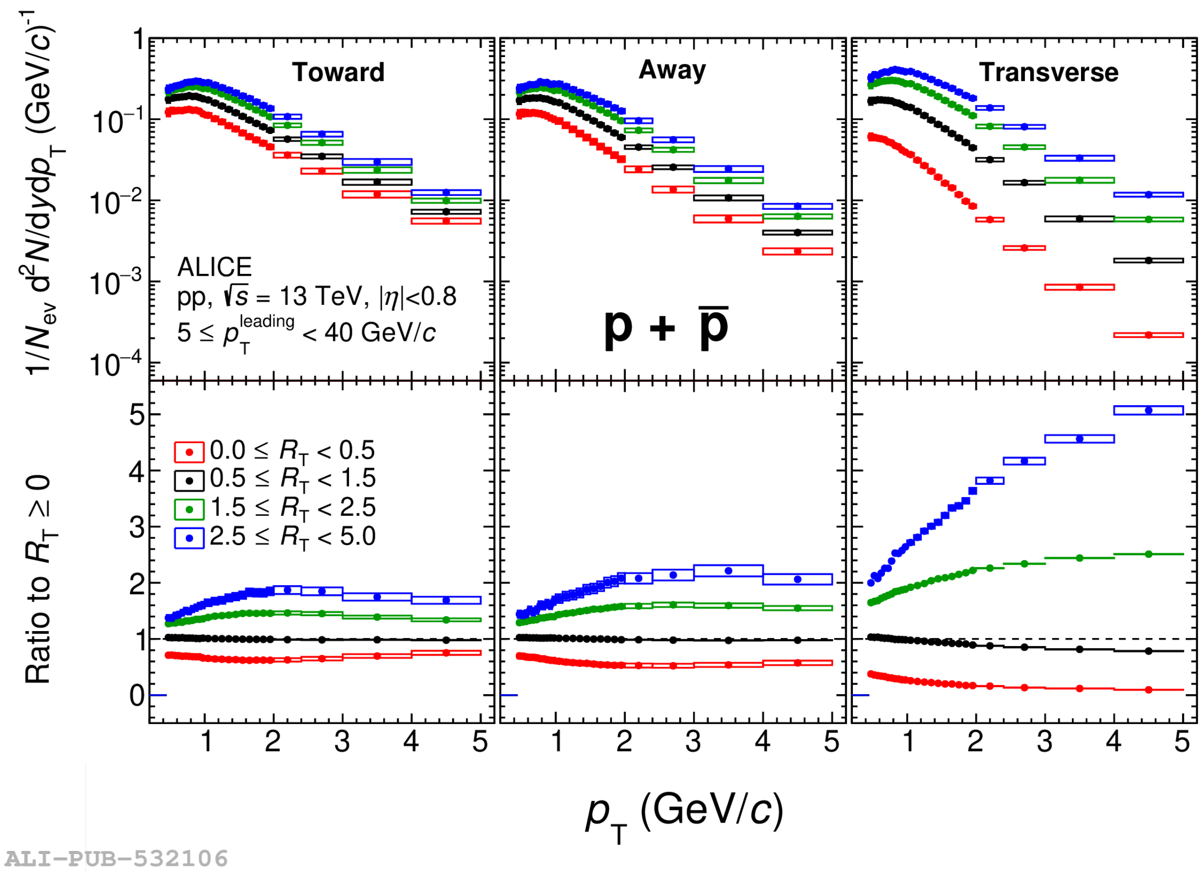
High R_T :

Spectral shapes *soften* with increasing R_T

Transverse: spectra *harden* with increasing R_T

Proton p_T spectra : 4 R_T intervals

arXiv:2301.10120



Same trends as observed for π, K

Mass-ordering: clearer hardening of transverse spectra with increasing R_T as particle masses increase

Take-away #1

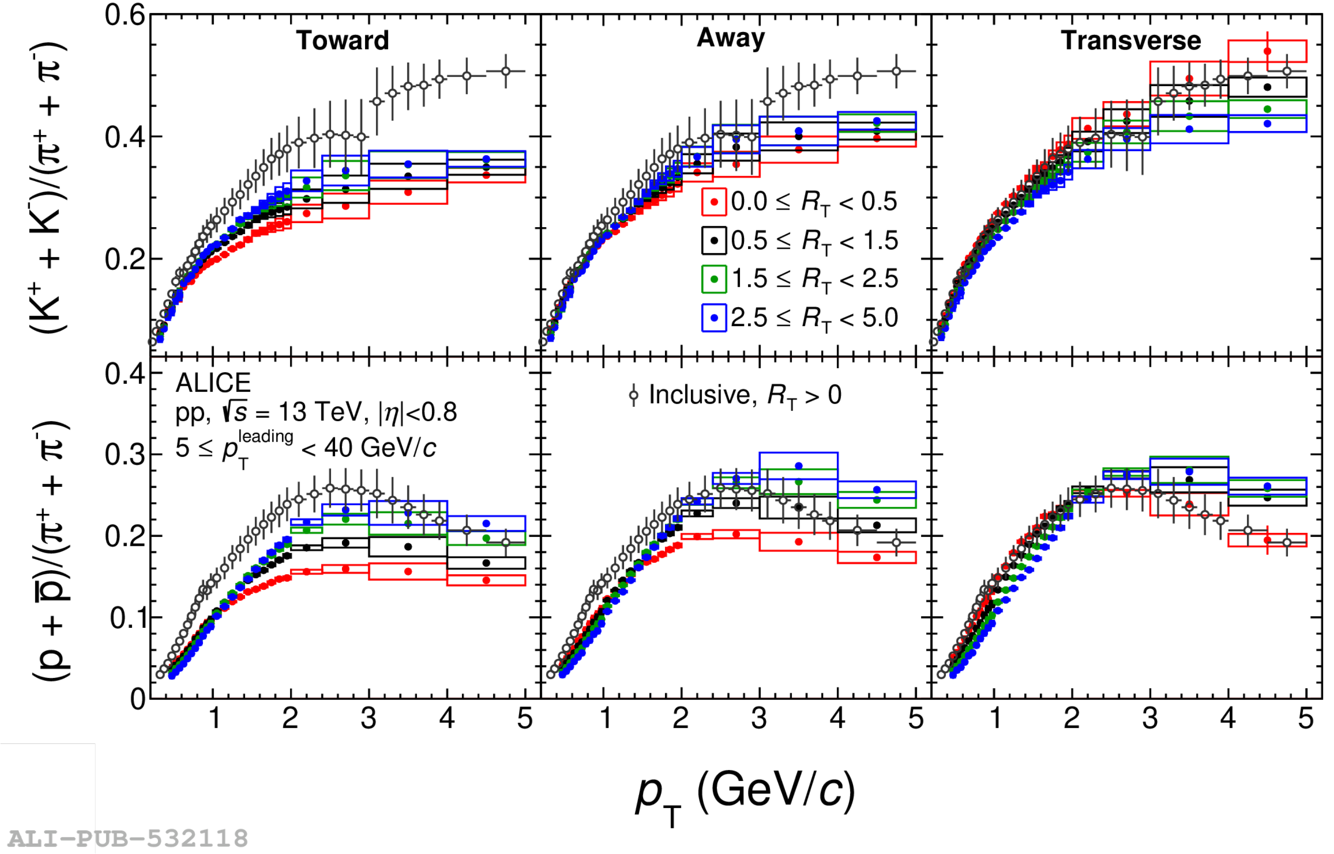
- Generally room for improvement in model descriptions of particle p_T spectra for different R_T intervals (particularly high R_T): trust data will be useful for model authors

- Observed some common trends in data for π, K, p

- Next: study K/π and p/π ratios, and compare with models

Particle ratios vs p_T

arXiv:2301.10120



Toward & Away;

K/π and p/π ratios: increase with increasing R_T

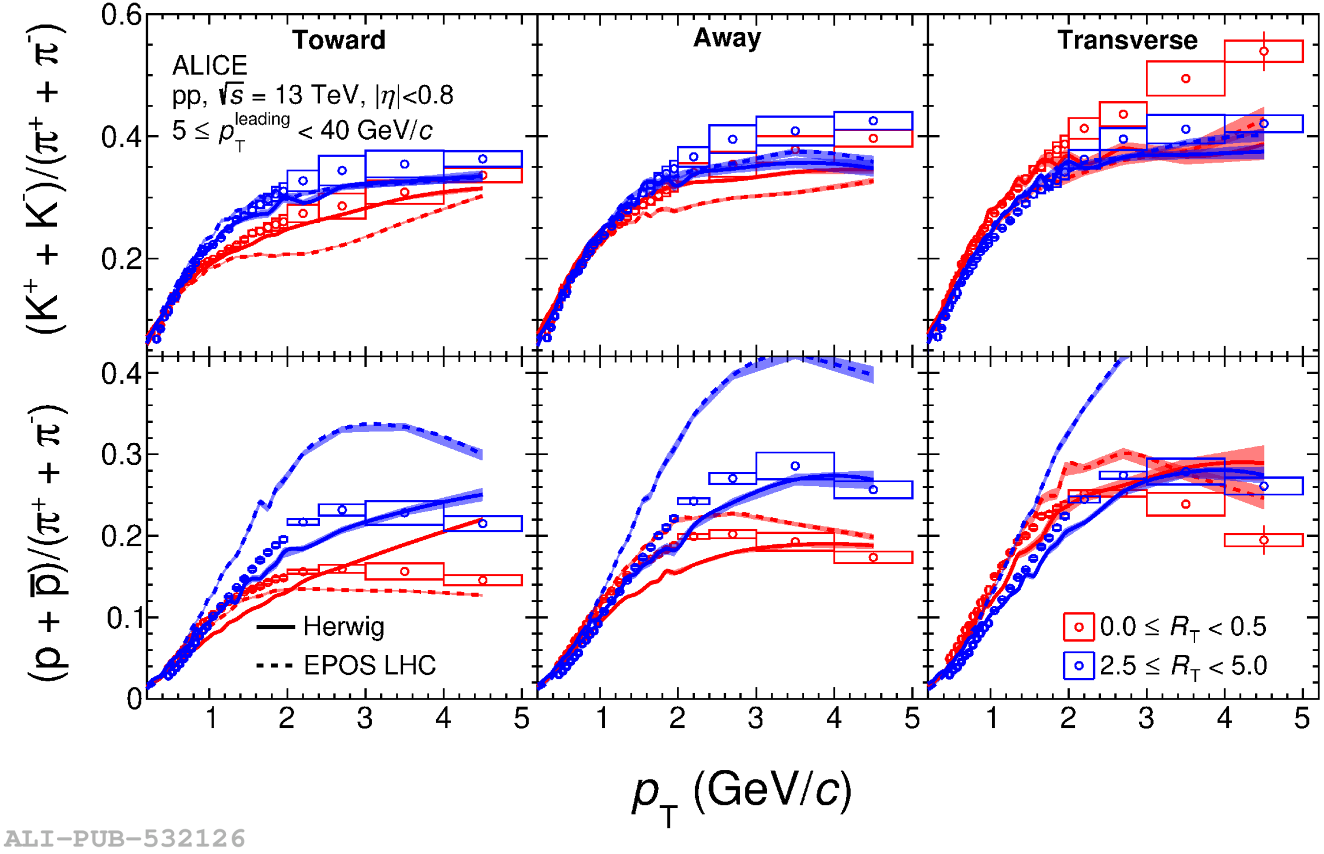
Transverse;

p/π ratio: (small) increase with increasing R_T

Increase at intermediate p_T reminiscent of radial flow effects

Particle ratios vs p_T : Herwig & EPOS

arXiv:2301.10120



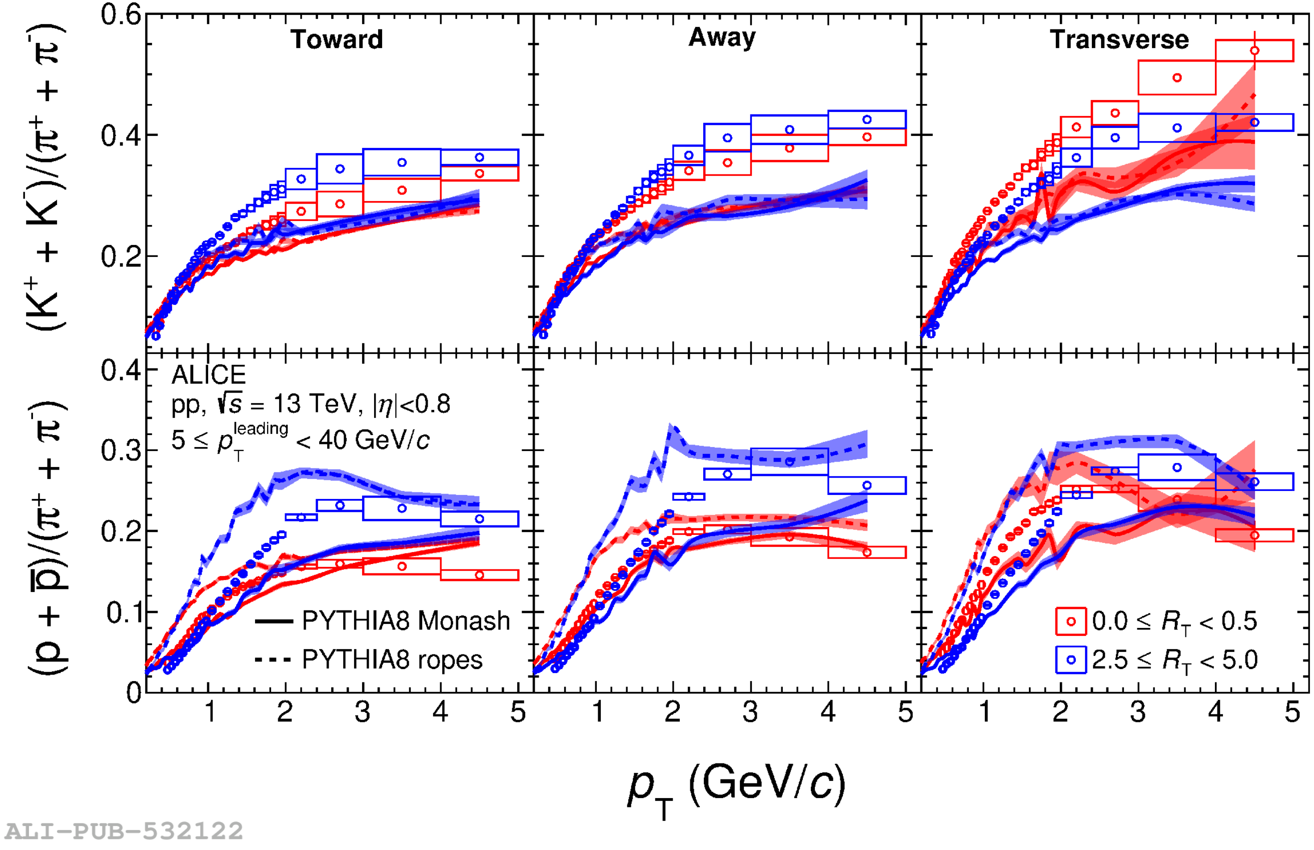
K/π Ratio: reasonably described by Herwig & EPOS LHC

p/π ratio: larger R_T interval more challenging, especially for Herwig

[N.B.: models tuned to e^+e^-]

Particle ratios vs p_T : Pythia

arXiv:2301.10120



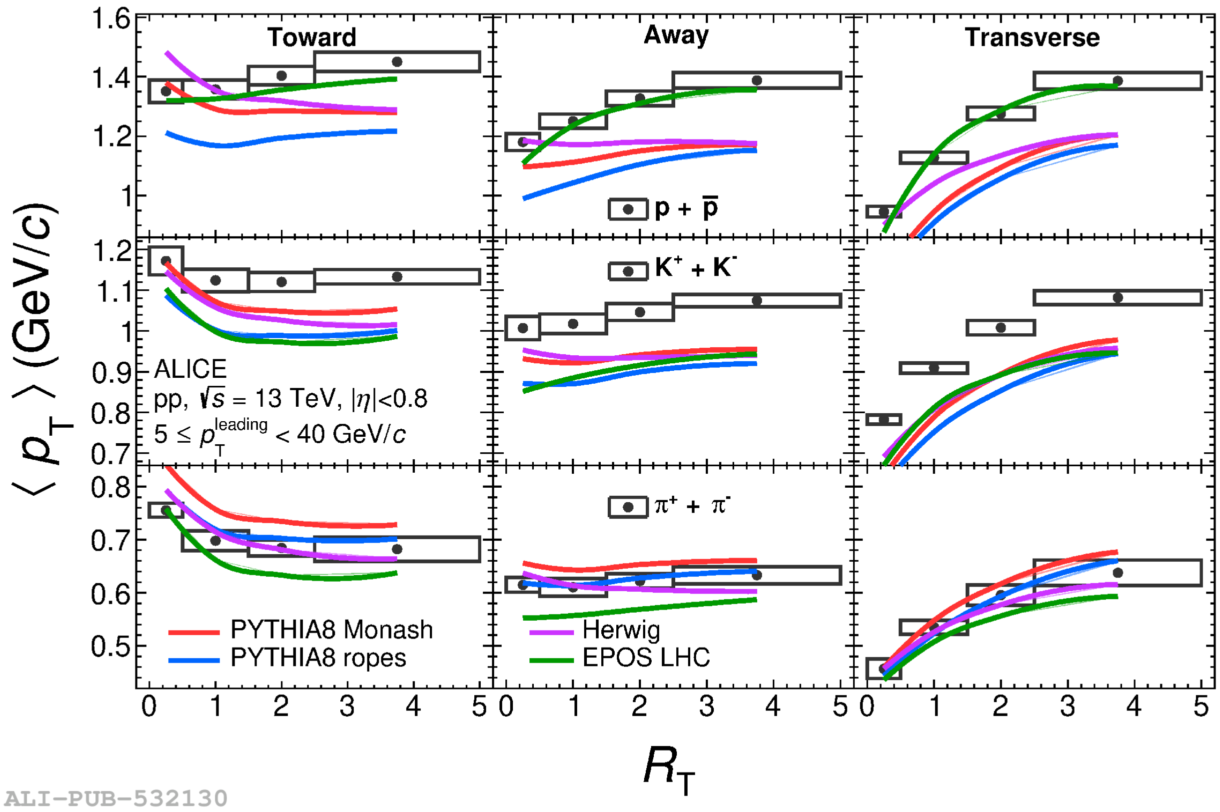
K/π Ratio: PYTHIA systematically lower than data

p/π ratio: larger R_T interval more challenging, especially for PYTHIA8 ropes

[N.B.: models tuned to e^+e^-]

$<p_T>$ vs R_T & Models

arXiv:2301.10120



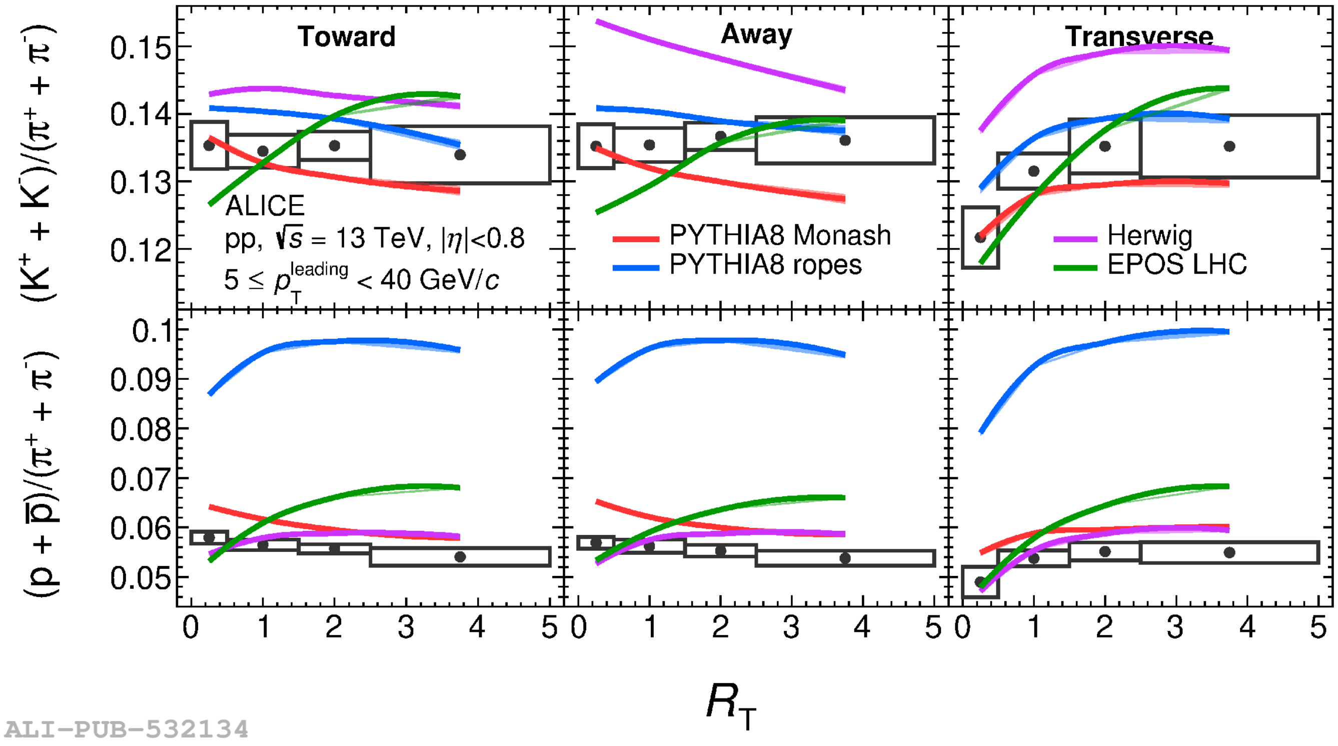
Proton data best described by EPOS LHC

Kaon data challenging for all

π data qualitatively described by all models

Particle ratios vs R_T & Models

arXiv:2301.10120



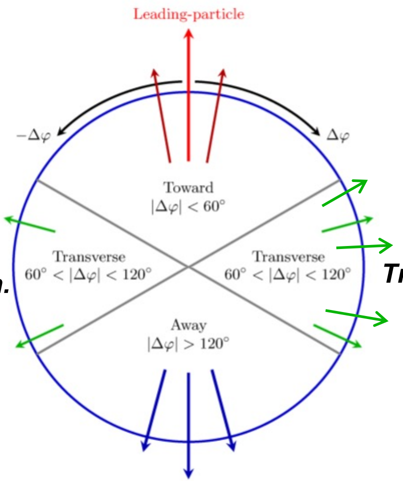
K/π Ratio: qualitatively described by several models (Herwig predicts a higher ratio)

p/π ratio: qualitatively described by several models (PYTHIA8 ropes predicts a significantly higher ratio)

Outlook/Using the $R_{\mathrm{T}}^{\mathrm{min(max)}}$ to disentangle ISR/FSR

- The two transverse regions are further classified *min.* and *max.* based on the number of charged particles
- Then $R_{\mathrm{T}}^{\mathrm{min(max)}} = \frac{N_{\mathrm{T}}^{\mathrm{min(max)}}}{\langle N_{\mathrm{T}}^{\mathrm{min(max)}} \rangle}$

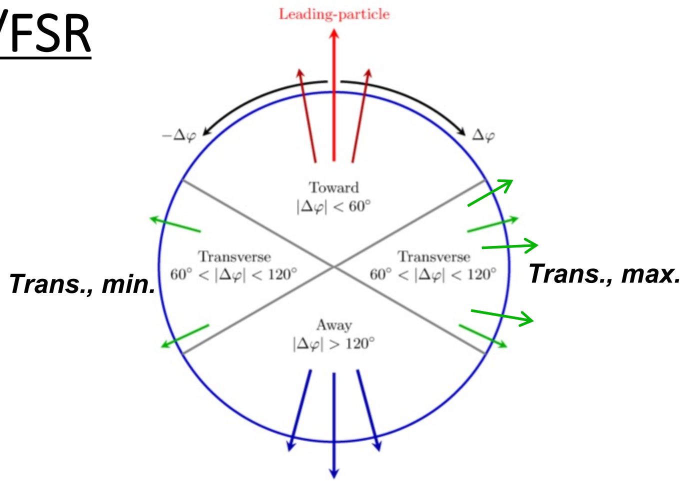
Trans., min.

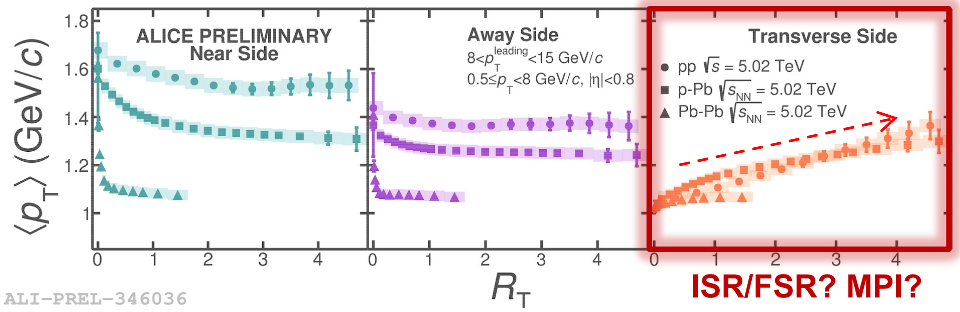


Trans., max.

Outlook/Using the $R_{\mathrm{T}}^{\min(\max)}$ to disentangle ISR/FSR

- The two transverse regions are further classified *min.* and *max.* based on the number of charged particles
- Then $R_{\mathrm{T}}^{\min(\max)} = \dfrac{N_{\mathrm{T}}^{\min(\max)}}{\langle N_{\mathrm{T}}^{\min(\max)} \rangle}$
- Can be used to disentangle the radial flow-like effects and the ISR/FSR contamination ($R_{\mathrm{T}}^{\min} \propto N_{\mathrm{MPI}}$, $R_{\mathrm{T}}^{\max} \propto \mathrm{ISR/FSR}$)





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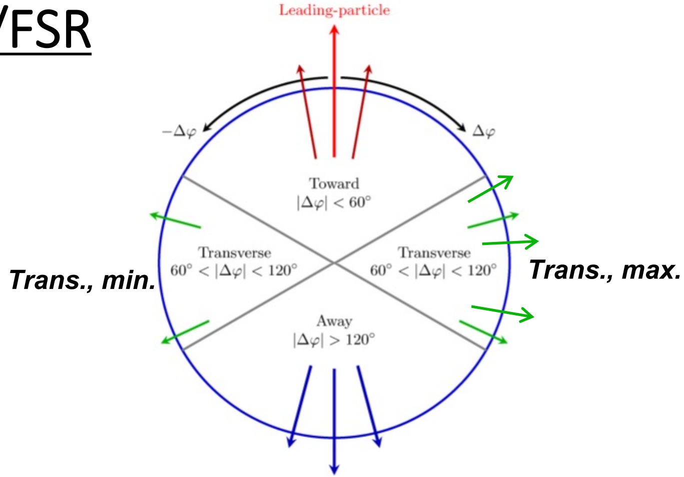
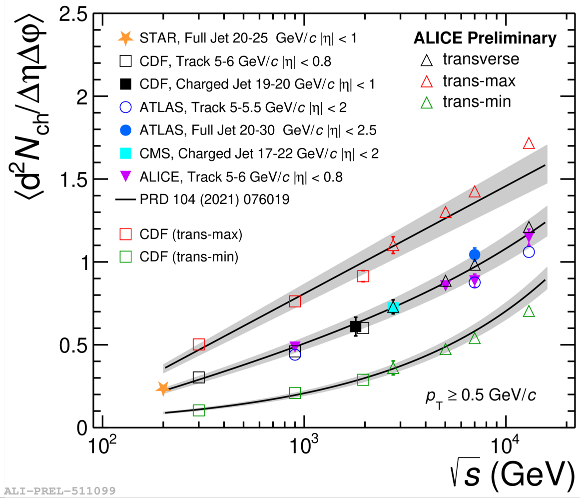
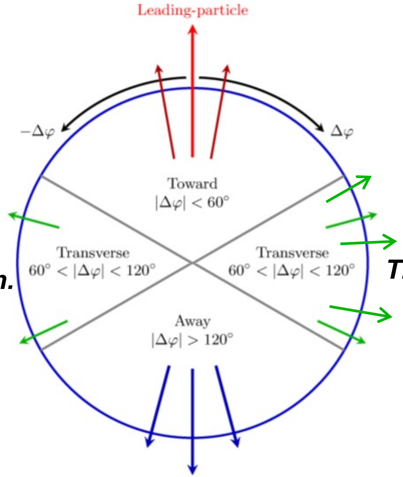




- ALICE now has preliminary results on charged particle densities in Trans., min and Trans., max regions in pp collisions at $\sqrt{s} = 2.76,\ 5.02,\ 7,\ 13\ \mathrm{TeV}$

Outlook/Using the $R_{\mathrm{T}}^{\mathrm{min(max)}}$ to disentangle ISR/FSR



- The two transverse regions are further classified *min.* and *max.* based on the number of charged particles
- Then $R_{\mathrm{T}}^{\mathrm{min(max)}} = \dfrac{N_{\mathrm{T}}^{\mathrm{min(max)}}}{\langle N_{\mathrm{T}}^{\mathrm{min(max)}} \rangle}$
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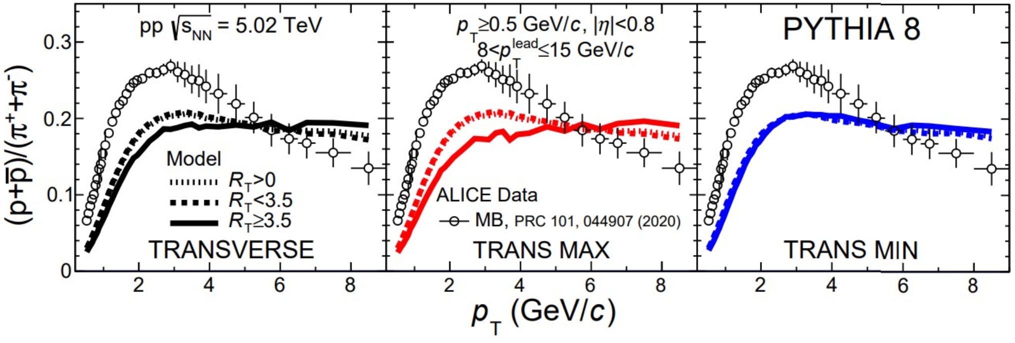
Ortiz, G. Bencedi, A. Paz, Phys.Rev.D 104 (2021) 1, 016017



- ALICE now has preliminary results on charged particle densities in Trans., min and Trans., max regions in pp collisions at $\sqrt{s} = 2.76,\ 5.02,\ 7,\ 13$ TeV
- Results on identified particle spectra in Trans., min regions vs $R_{\mathrm{T}}^{\mathrm{min(max)}}$ will be key in understanding the role of MPI
  - Currently underway!