Production of (un-)identified light-flavour hadrons as a function of Underlying Event activity in pp collisions with the ALICE detector

Omar Vázquez

for the **ALICE Collaboration**

PRAHA PRAGUE PRAGA PRAG

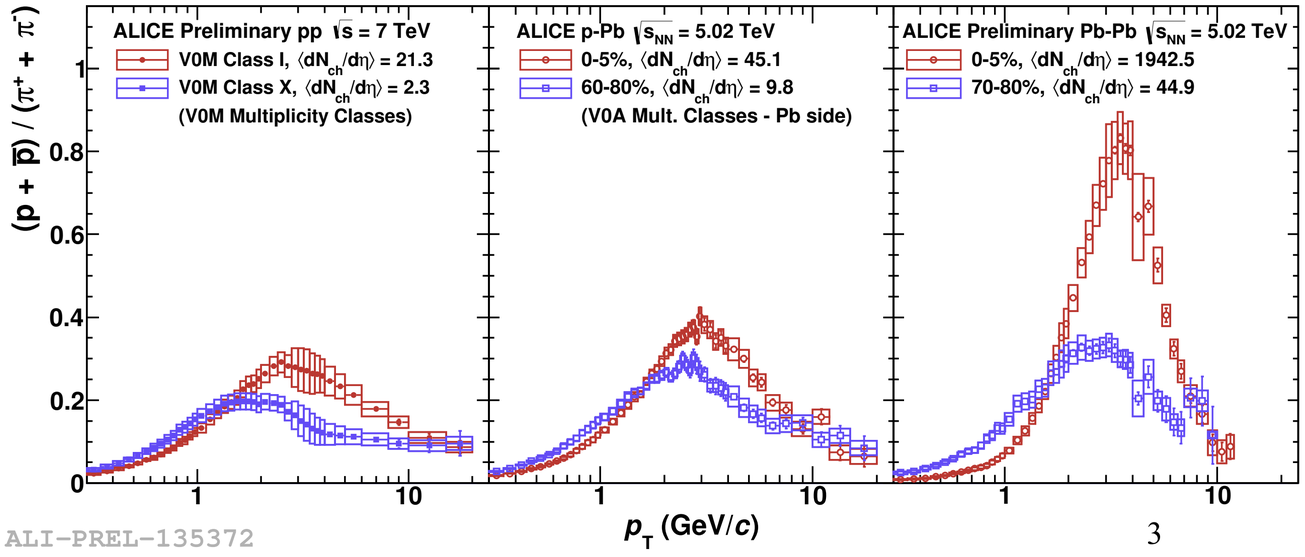
11th International Workshop on Multiple Partonic Interactions at the LHC

Motivations (1/2)

- High-multiplicity pp and p-Pb collisions show effects similar to the ones observed in heavy-ion collisions (attributed to the formation of a QGP) such as:

Motivations (1/2)

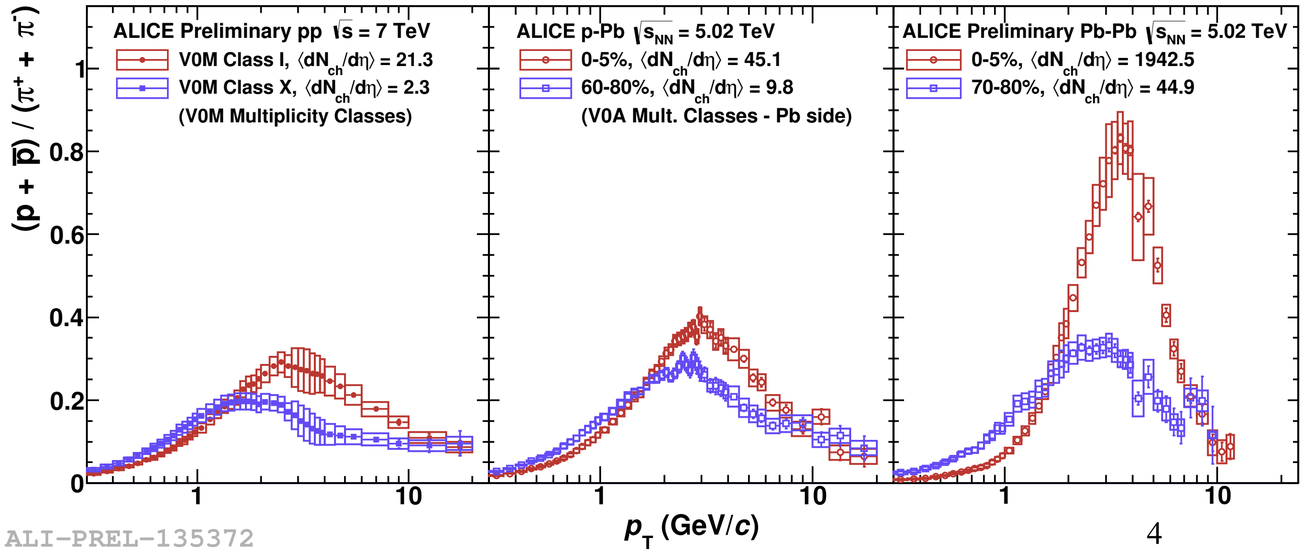
- High-multiplicity pp and p-Pb collisions show effects similar to the ones observed in heavy-ion collisions (attributed to the formation of a QGP) such as:
  - Radial flow

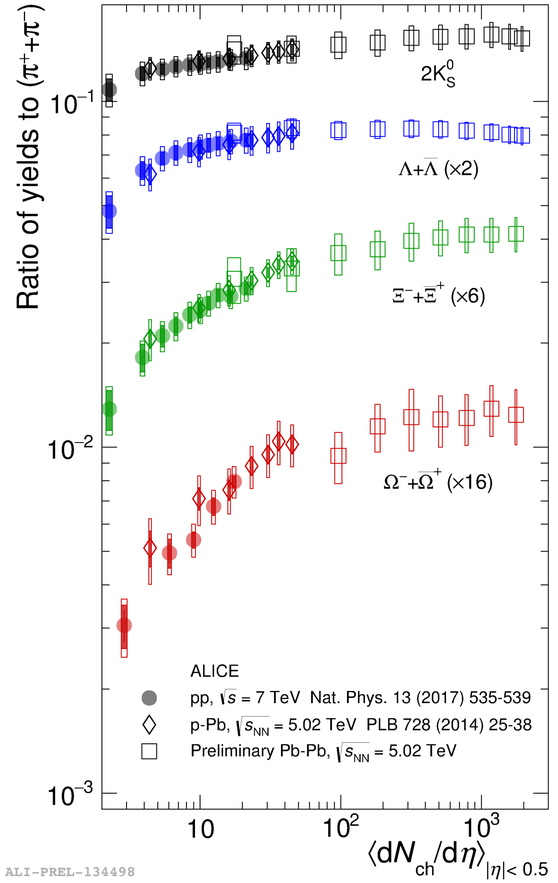


ALI-PREL-135372

Motivations (1/2)

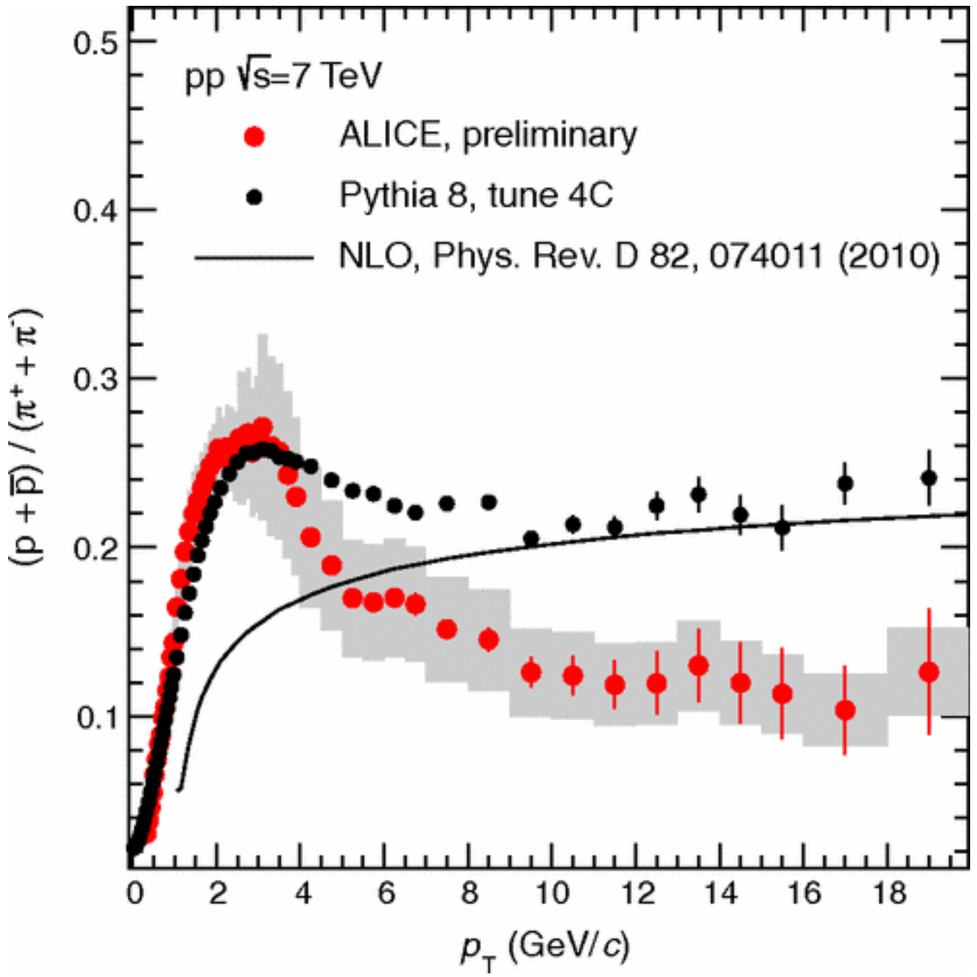
- High-multiplicity pp and p-Pb collisions show effects similar to the ones observed in heavy-ion collisions (attributed to the formation of a QGP) such as:
  - Radial flow
  - Strangeness enhancement





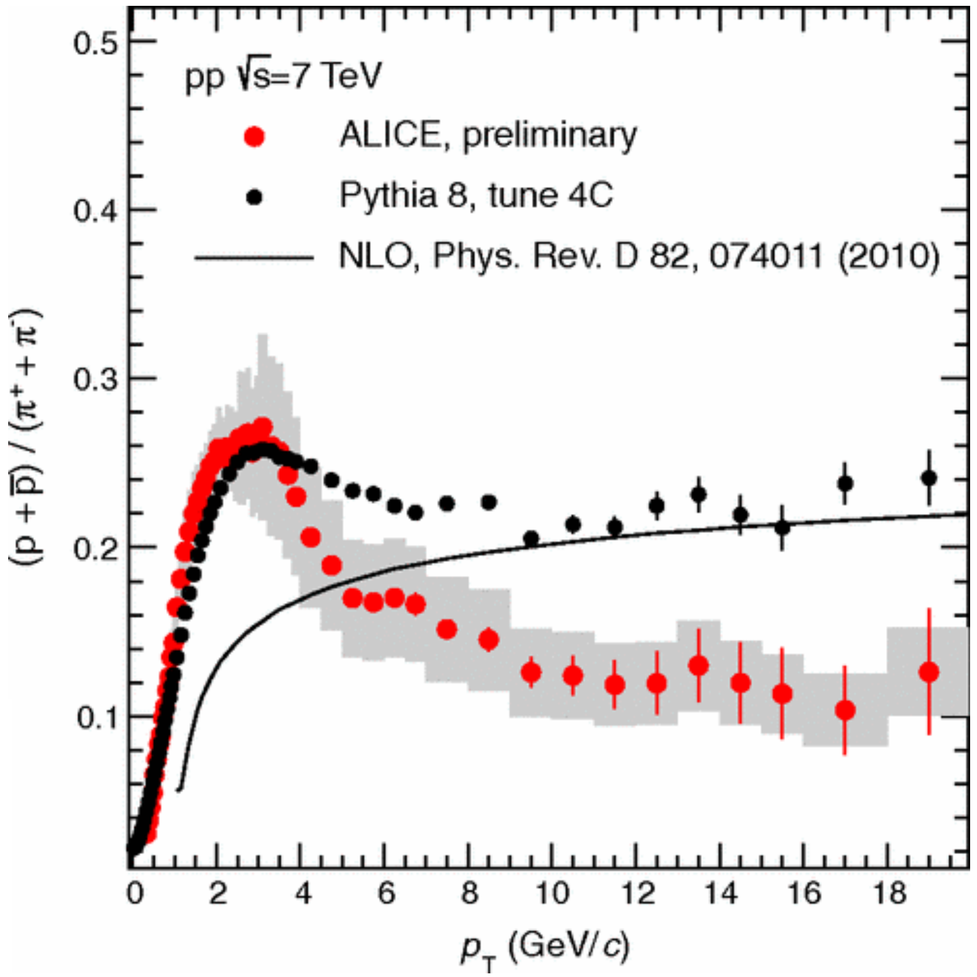
Motivations (2/2)

- The Colour Reconnection (CR) mechanism of PYTHIA, models the interactions between partons at different p_T scales just before the hadronisation.
  - In events with several Multiple Parton Interactions (MPIs), it enhances flow-like patterns in pp collisions.
    Phys. Rev. Lett. 111, 042001
  - It is also important to reproduce the rise of the average transverse momentum with the event multiplicity.
    arXiv: 1307.1094



Motivations (2/2)

- The Colour Reconnection (CR) mechanism of PYTHIA models the interactions between partons at different p_T scales just before the hadronisation.
  - In events with several Multiple Parton Interactions (MPIs), it enhances flow-like patterns in pp collisions.
    Phys. Rev. Lett. 111, 042001
  - It is also important to reproduce the rise of the average transverse momentum with the event multiplicity.
    arXiv: 1307.1094
- We want to test how these effects (strangeness enhancement, radial and anisotropic flow) depend on the MPI activity.



Underlying Event in pp collisions at 13 TeV

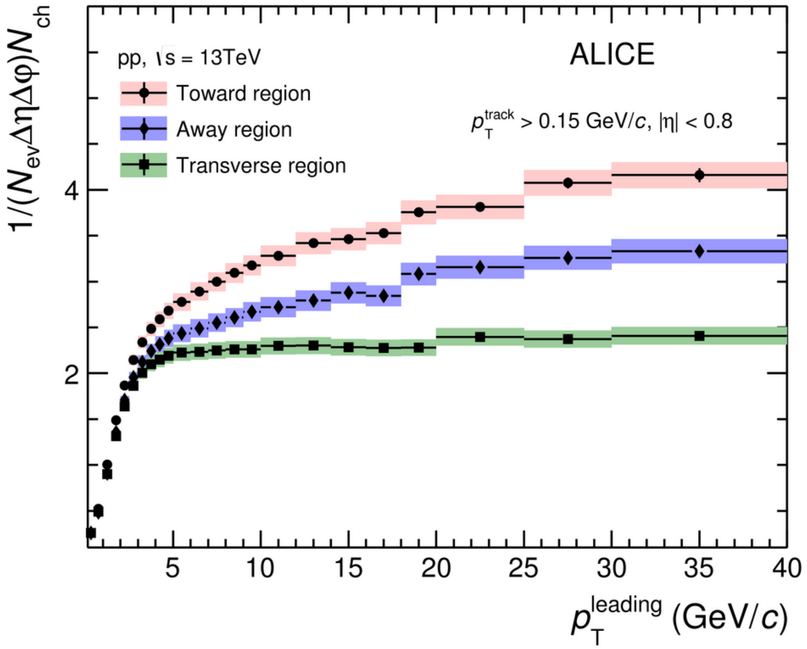
Underlying Event in pp collisions at 13 TeV

- The Underlying Event (UE) is defined as the collection of particles **not** originating from the primary hard parton-parton scattering or the related fragmentation.

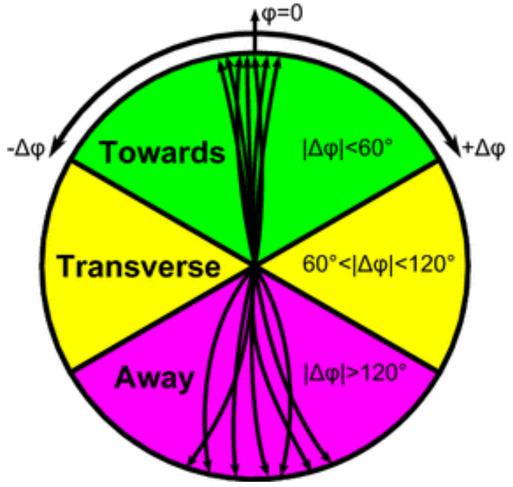
  - The main contribution to the UE comes from additional parton-parton interactions (MPIs) and from initial-state radiation (ISR)

Underlying Event in pp collisions at 13 TeV

- The Underlying Event (UE) is defined as the collection of particles **not** originating from the primary hard parton-parton scattering or the related fragmentation.
  - The main contribution to the UE comes from additional parton-parton interactions (MPIs) and from initial-state radiation (ISR)

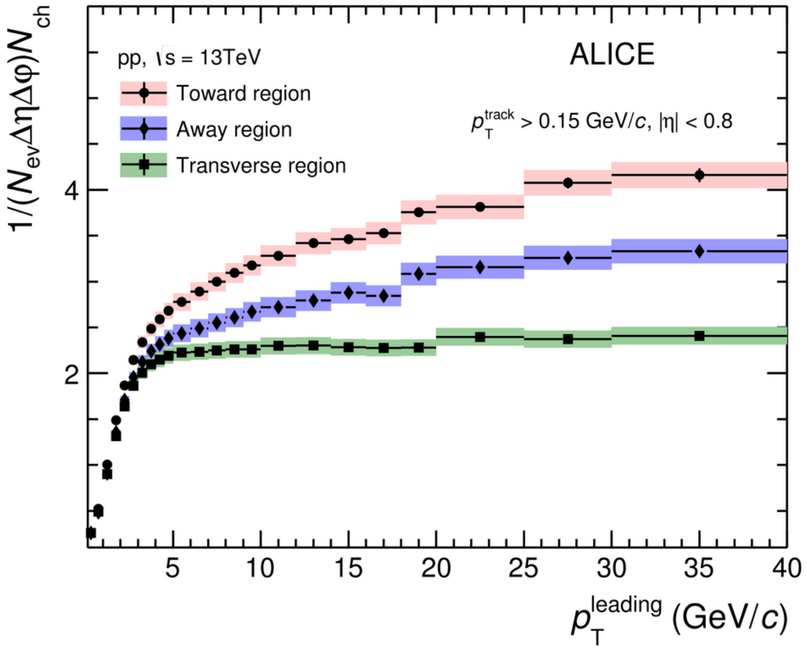


arXiv:1910.14400

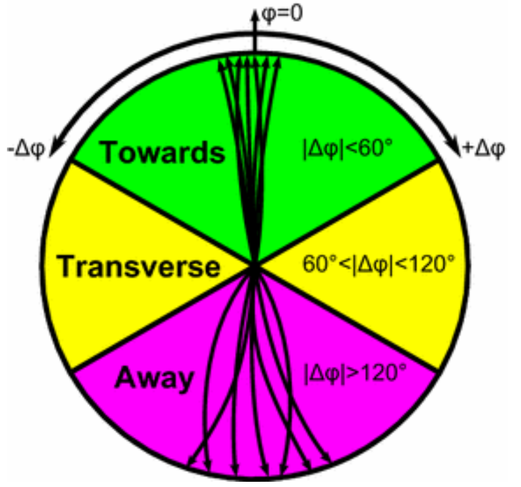


Underlying Event in pp collisions at 13 TeV

- The Underlying Event (UE) is defined as the collection of particles **not** originating from the primary hard parton-parton scattering or the related fragmentation.
  - The main contribution to the UE comes from additional parton-parton interactions (MPIs) and from initial-state radiation (ISR)
- A steep rise of the UE activity at low $p_{\mathrm{T}}^{\mathrm{leading}}$ ($\lesssim 5$ GeV/c) is observed followed by a change of the slope with increasing $p_{\mathrm{T}}^{\mathrm{leading}}$ in the three different regions.
- In the jet pedestal region $p_{\mathrm{T}}^{\mathrm{leading}}$ ($\gtrsim 5$ GeV/c) the number density in the Transverse region becomes almost independent of $p_{\mathrm{T}}^{\mathrm{leading}}$ while it continues to rise in the Toward and Away regions.

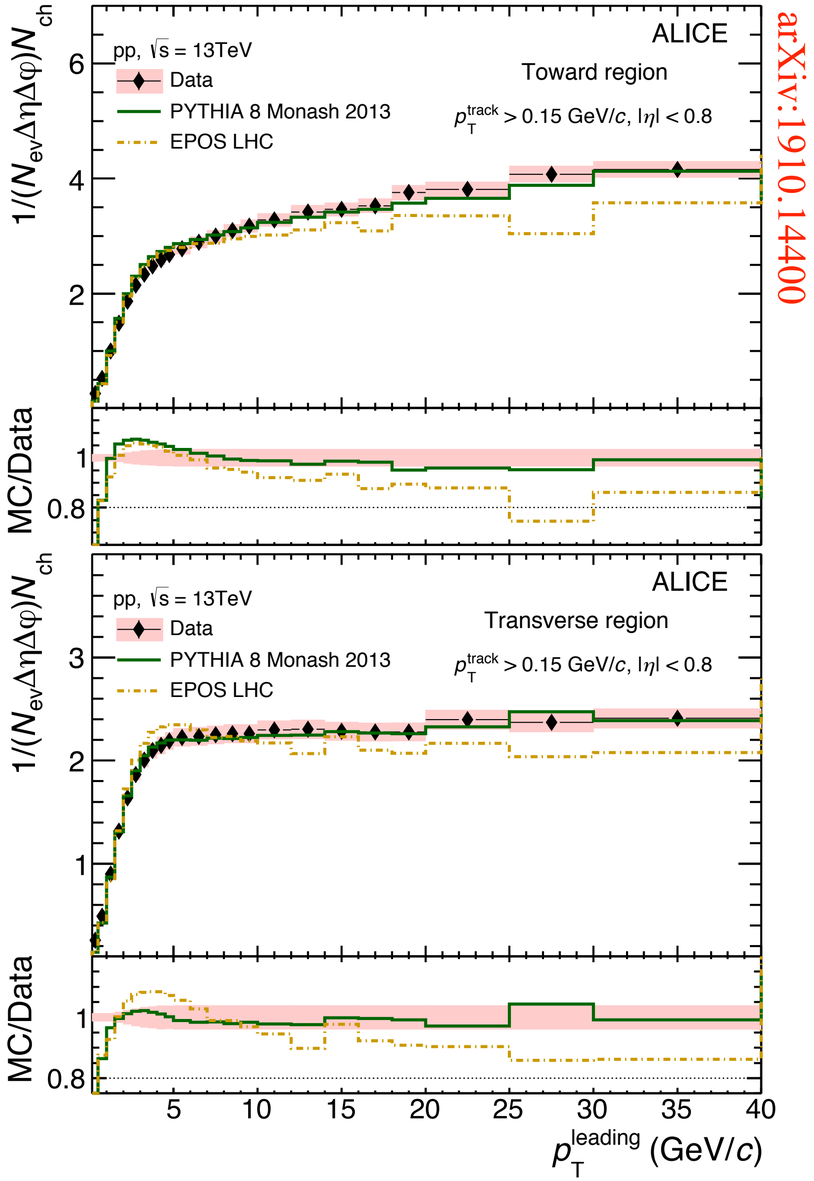


arXiv:1910.14400



Underlying Event in pp collisions at 13 TeV

- PYTHIA8 Monash 2013 gives a good description of the number density in both regions, Toward and Transverse.



arXiv:1910.14400

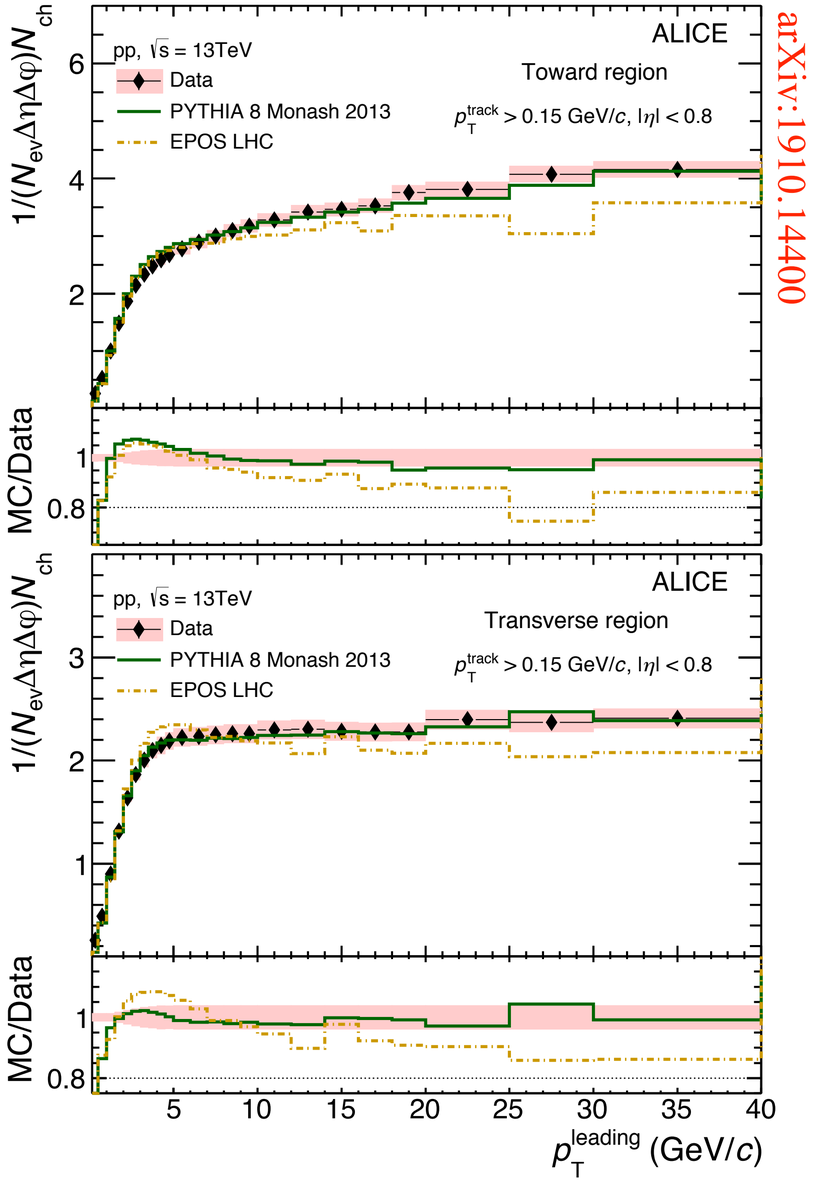
Underlying Event in pp collisions at 13 TeV

- PYTHIA8 Monash 2013 gives a good description of the number density in both regions, Toward and Transverse.

  - In the MPI implementation of PYTHIA, tagging hard scatterings with high-p_T particles biases the events towards low impact parameter collisions, and, hence higher number density.

Phys. Rev. D 36, 2019

  - Low impact parameter pp collisions yields saturation of the MPI activity.



arXiv:1910.14400

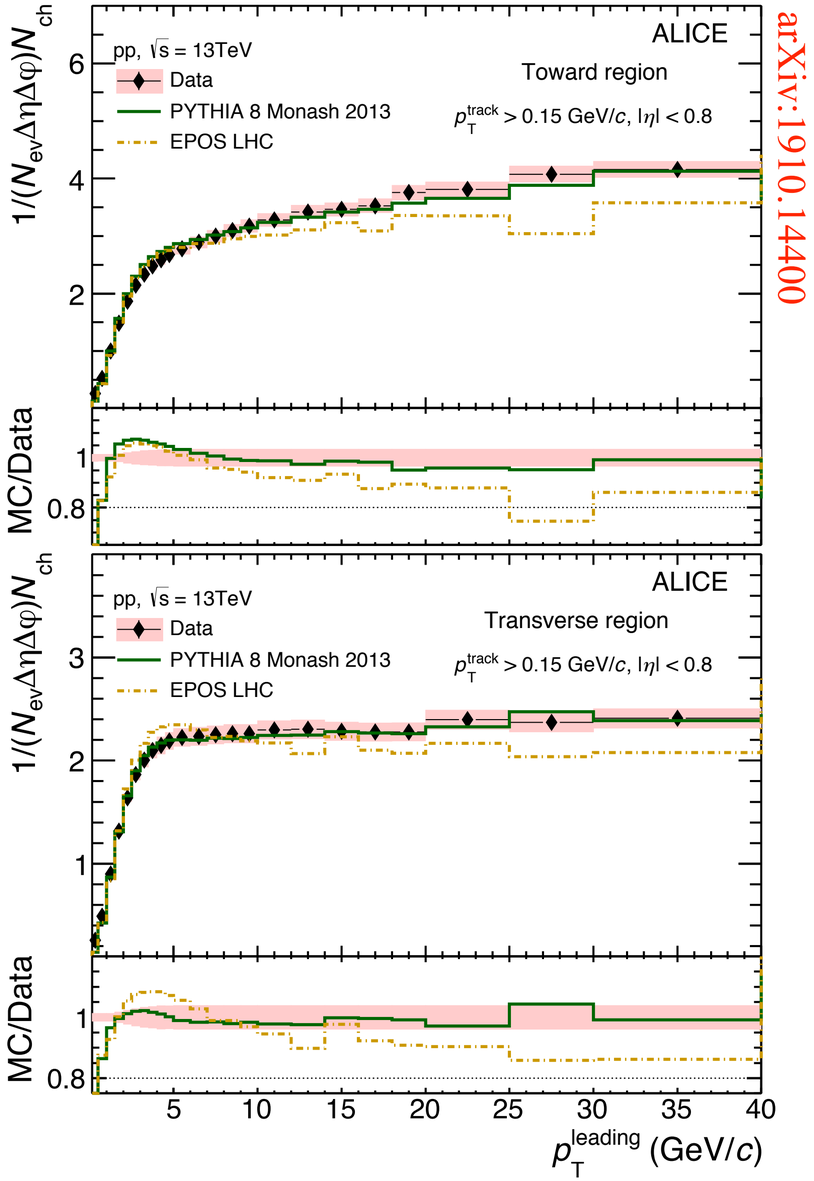
Underlying Event in pp collisions at 13 TeV

- PYTHIA8 Monash 2013 gives a good description of the number density in both regions, Toward and Transverse.
  - In the MPI implementation of PYTHIA, tagging hard scatterings with high-p_{T} particles biases the events towards low impact parameter collisions, and, hence higher number density.

    Phys. Rev. D 36, 2019
    - Low impact parameter pp collisions yields saturation of the MPI activity.

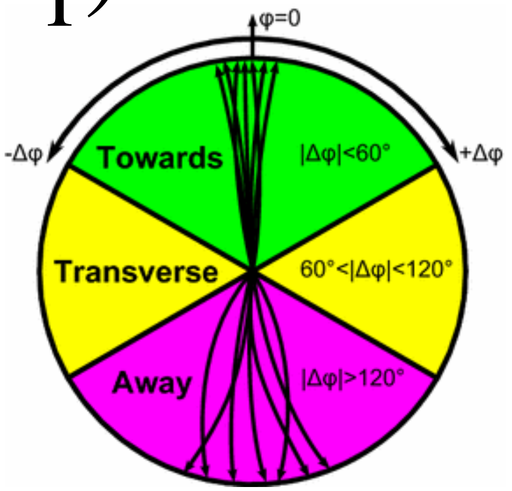
- A recent study showed that both, data and PYTHIA still show a rise of the UE activity with increasing $p_{\mathrm{T}}^{\mathrm{jet}}$ and how CR contributes to that behaviour.

  arXiv:1809.01744

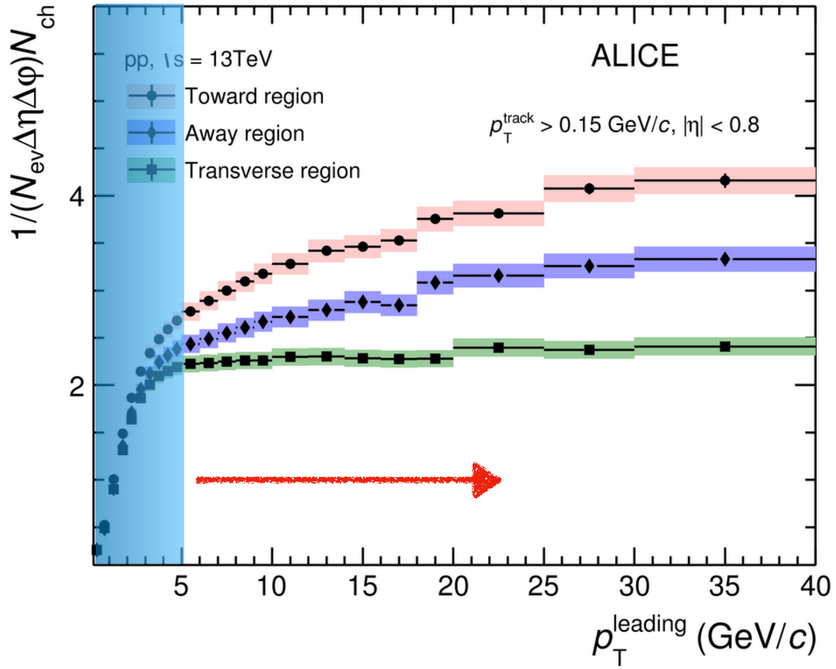


arXiv:1910.14400

Relative Transverse activity(R_{T})



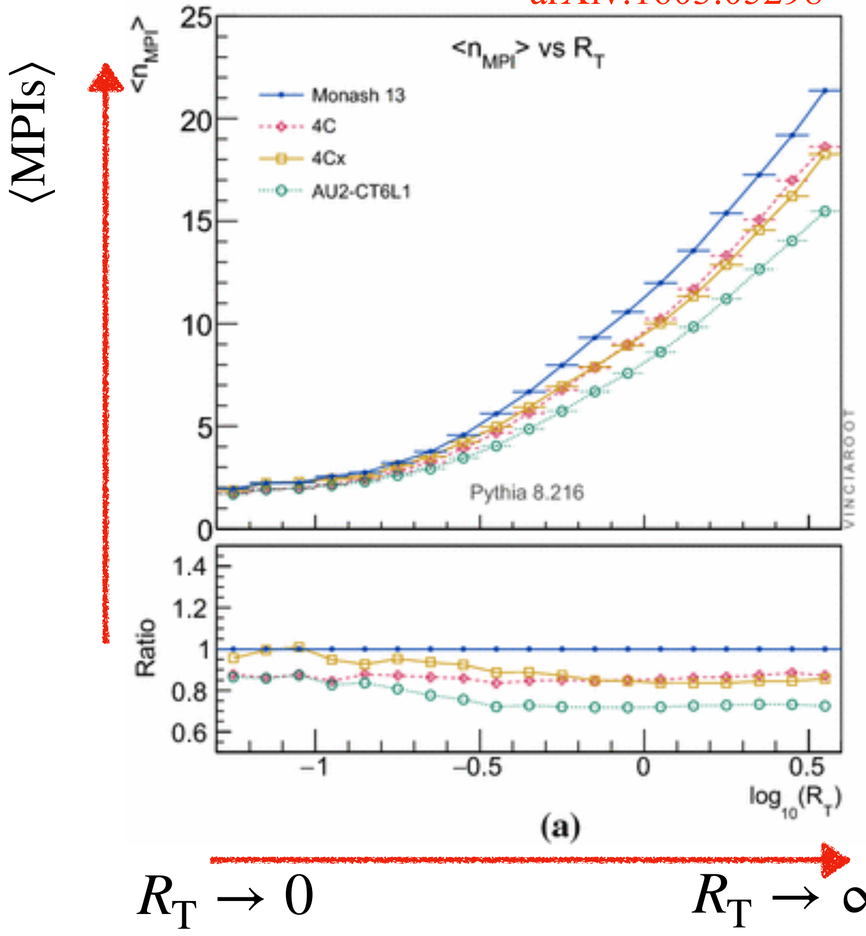
- Based on a publication by P. Skands: arXiv:1603.05298
- Is an event-activity classifier in the Transverse region.
- It is only measured for events that have a leading charged-particle in the jet pedestal ($5 < p_{\mathrm{T}}^{\mathrm{leading}} < 40$ GeV/c).
- $R_{\mathrm{T}} = N_{\mathrm{ch}}/\langle N_{\mathrm{ch}} \rangle$
  - N_{ch} is the charged-particle density in the Transverse region
  - Kinematic cuts of N_{ch}:
    - $p_{\mathrm{T}}^{\mathrm{track}} > 0.15$ GeV/c, $|\eta| < 0.8$
- R_{T} properties have been studied in Phys.Rev. D96 (2017) no.11, 114019



Relative Transverse activity(R_T)

- R_T as a control of the number of MPIs in the Transverse region.

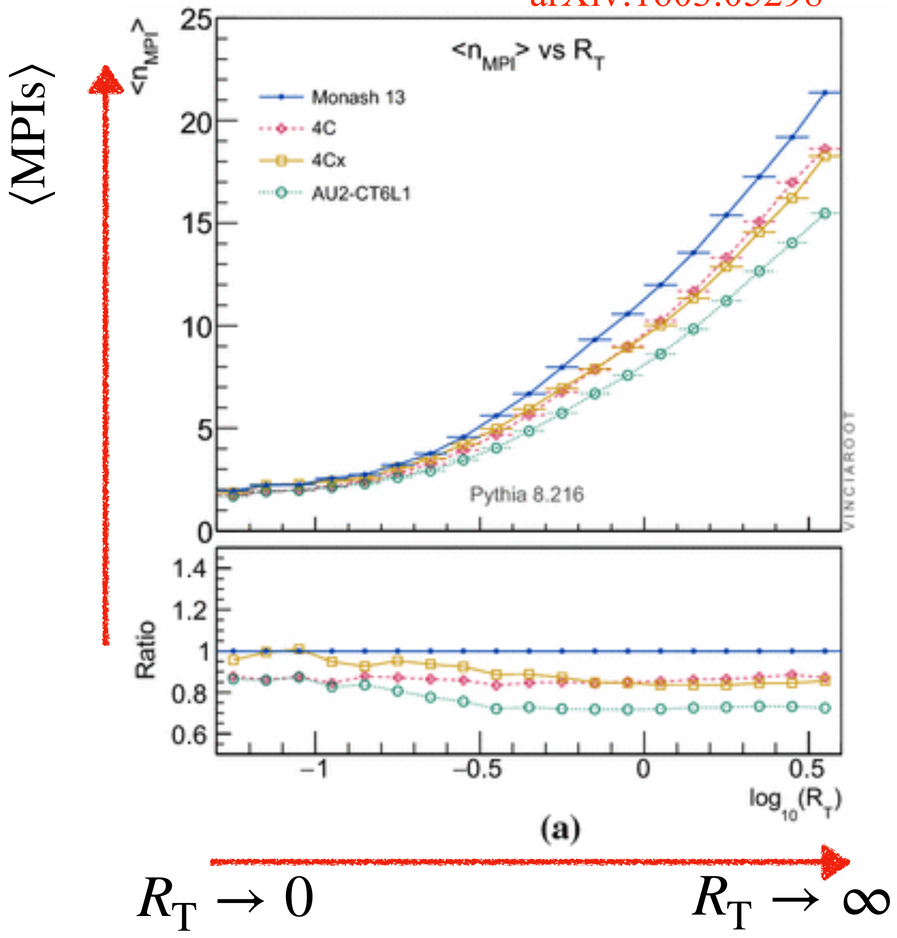
arXiv:1603.05298



Relative Transverse activity(R_T)

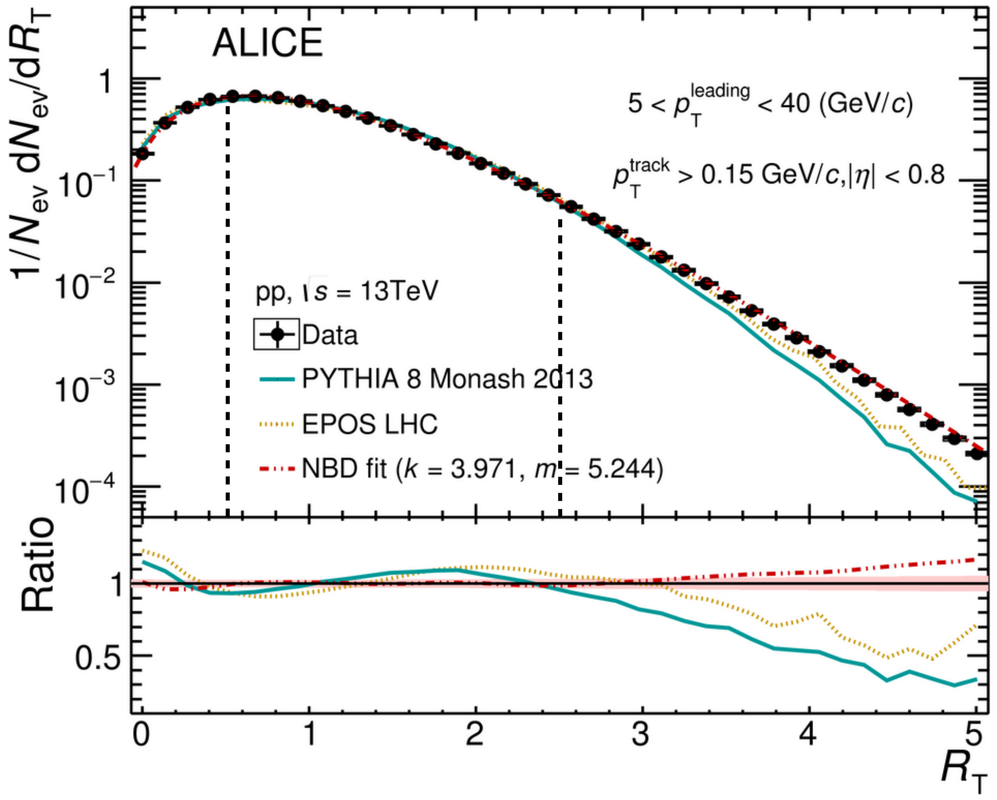
- R_T as a control of the number of MPIs in the Transverse region.

arXiv:1603.05298

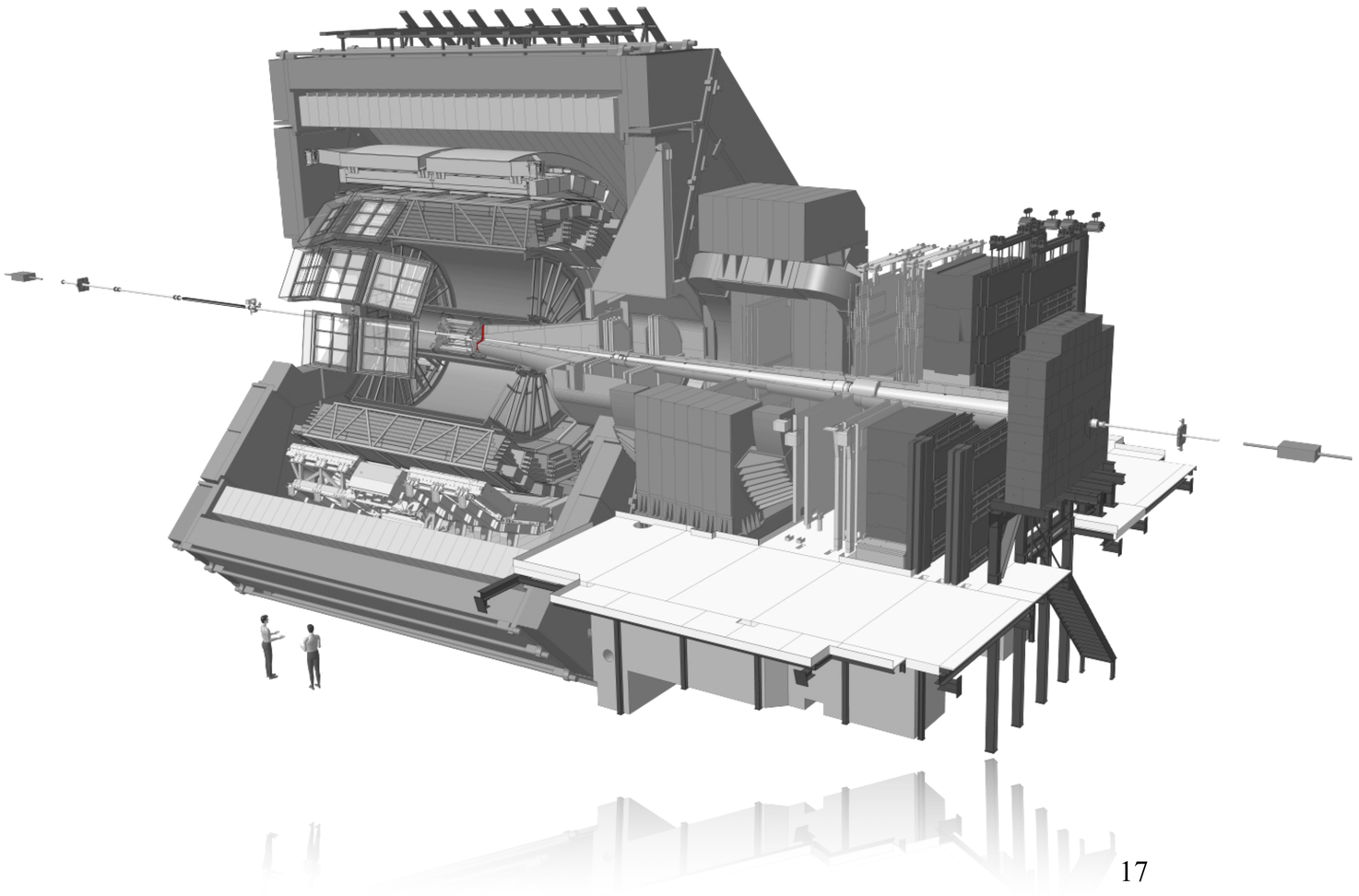


- R_T is used to measure the production of (un-)identified particles in the Toward, Away and Transverse regions as a function of the event activity.

arXiv:1910.14400

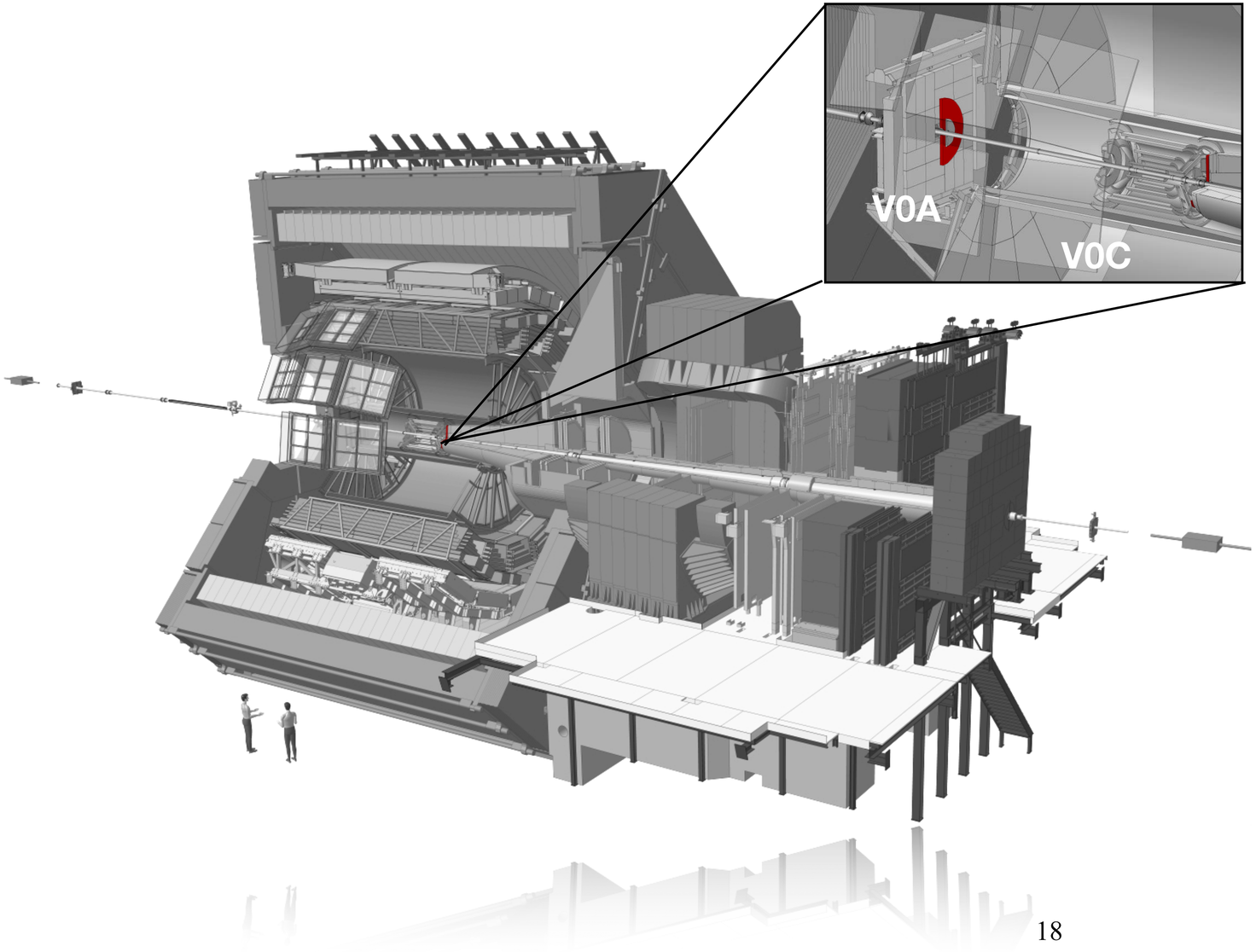


ALICE at the LHC



The dedicated detector at the LHC for tracking and PID from ~150 MeV/*c* up to 20 GeV/*c* in high-multiplicity environments

ALICE at the LHC

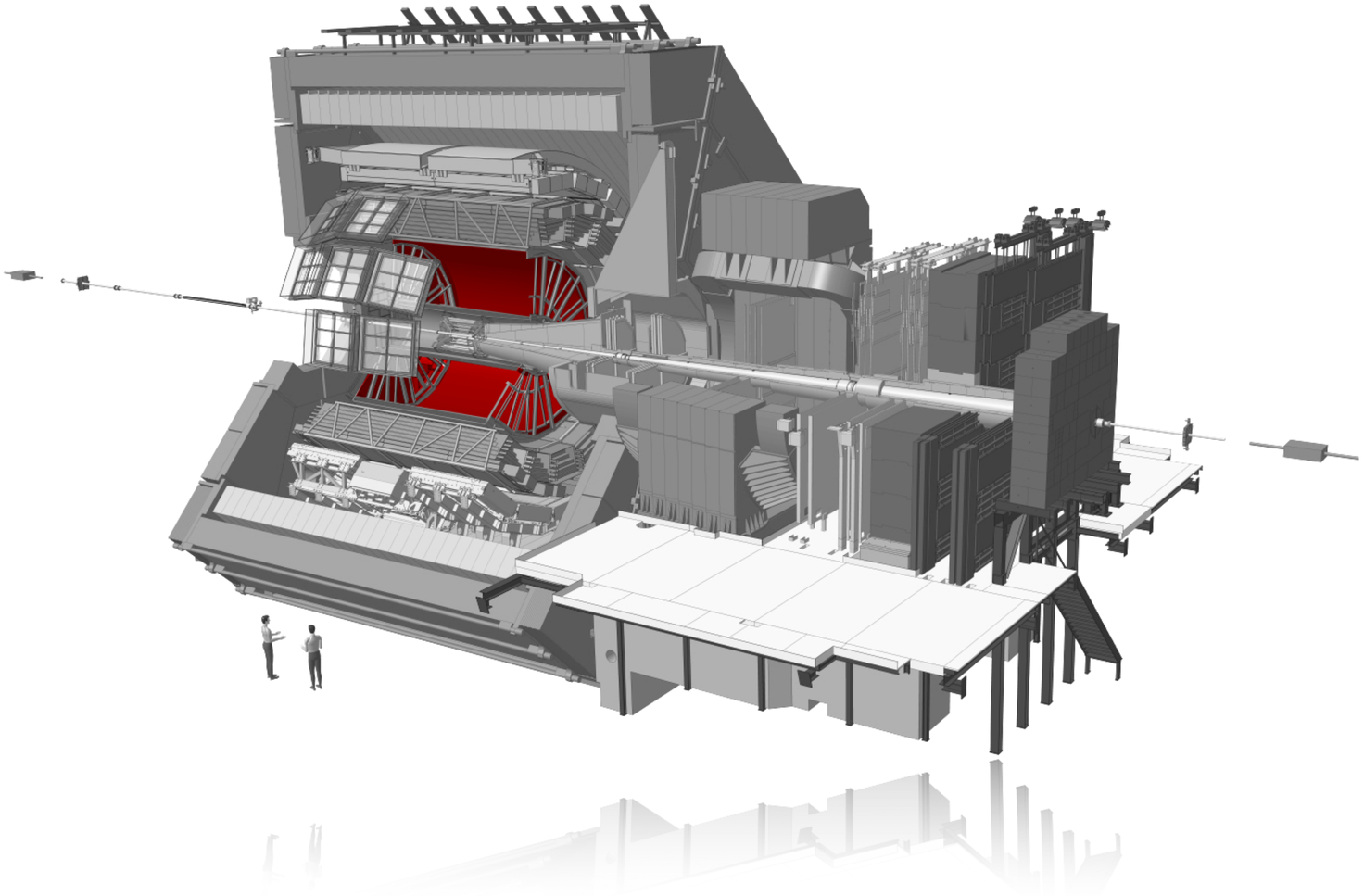


The dedicated detector at the LHC for tracking and PID from ~150 MeV/c up to 20 GeV/c in high-multiplicity environments

V0 = V0A + V0C

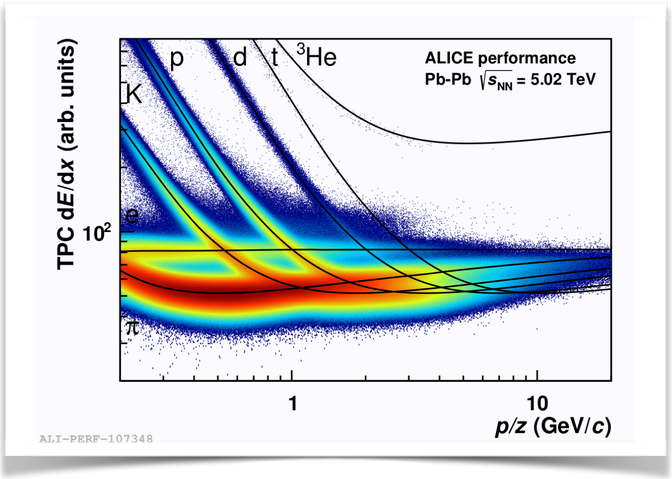
- Forward scintillator hodoscopes
  - V0A ($2.8 < \eta < 5.1$)
  - V0C ($-3.7 < \eta < -1.7$)
- Triggering, background suppression and event classification

PID with ALICE at the LHC



TPC

- Gas-filled cylindrical volume
- PID based on dE/dx
- $|\eta| < 0.9$



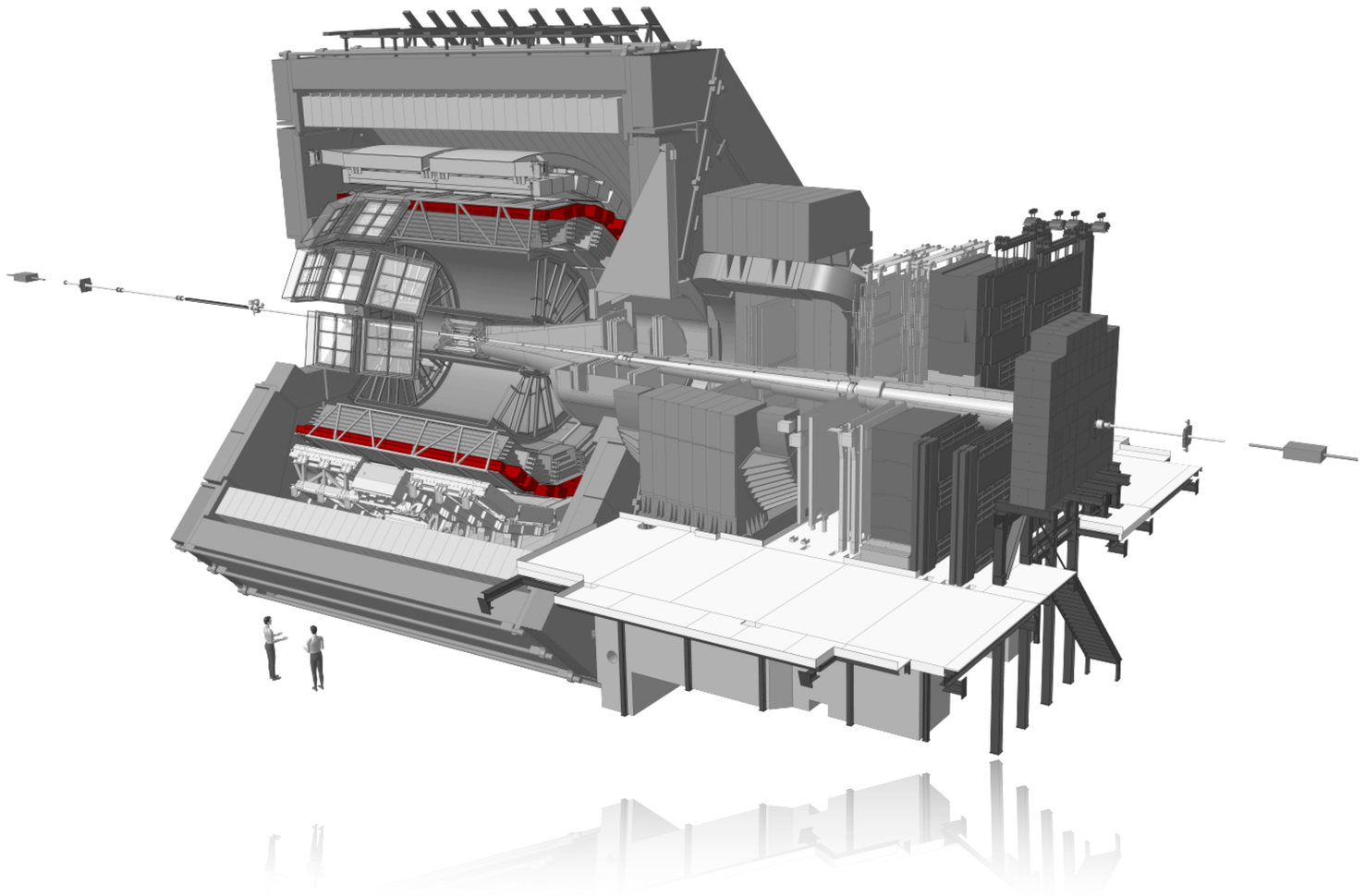
Results of identified particles shown in this presentation

π/K/p

$\phi \rightarrow \mathrm{K}^{+}\mathrm{K}^{-}$

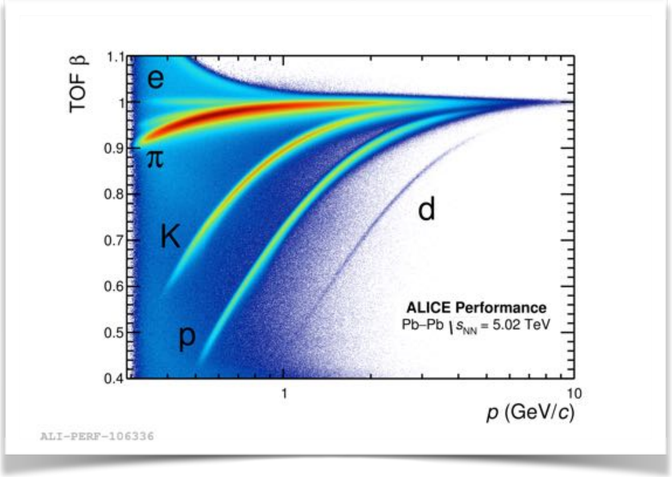
$\Xi^{-}(\overline{\Xi}^{+}) \rightarrow \Lambda(\overline{\Lambda}) + \pi^{-}(\pi^{+})$

PID with ALICE at the LHC



TOF

- MRPC detector
- PID based on the Time-Of-Flight
- $|\eta| < 0.9$



Results of identified particles shown in this presentation

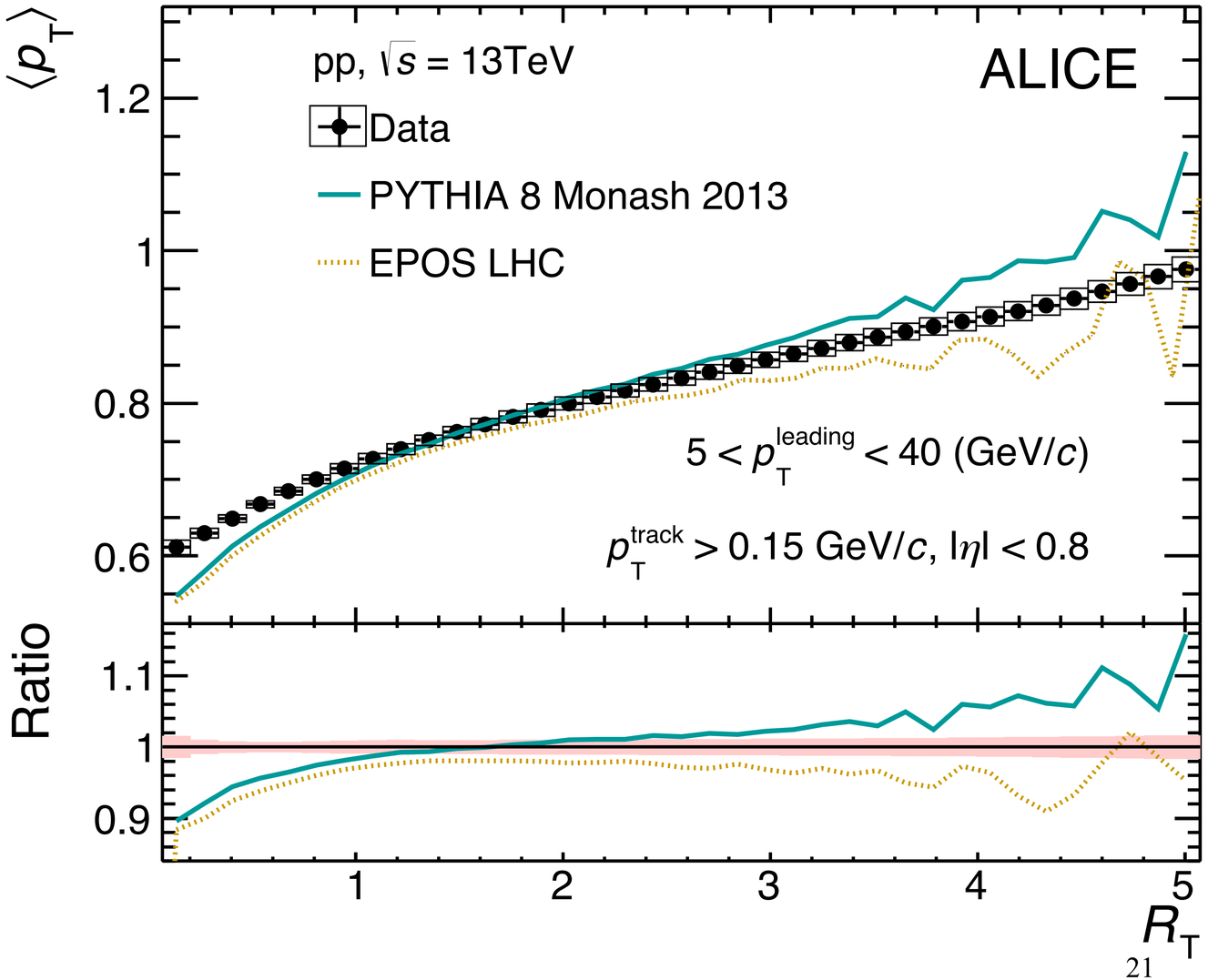
π/K/p

$\phi \rightarrow K^+K^-$

$\Xi^-(\overline{\Xi}^+) \rightarrow \Lambda(\overline{\Lambda}) + \pi^-(\pi^+)$

$\langle p_{\mathrm{T}} \rangle$ vs R_{T}

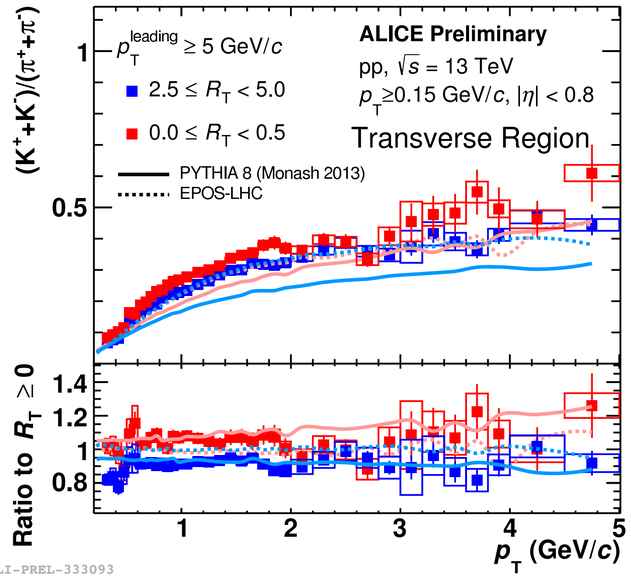
arXiv:1910.14400



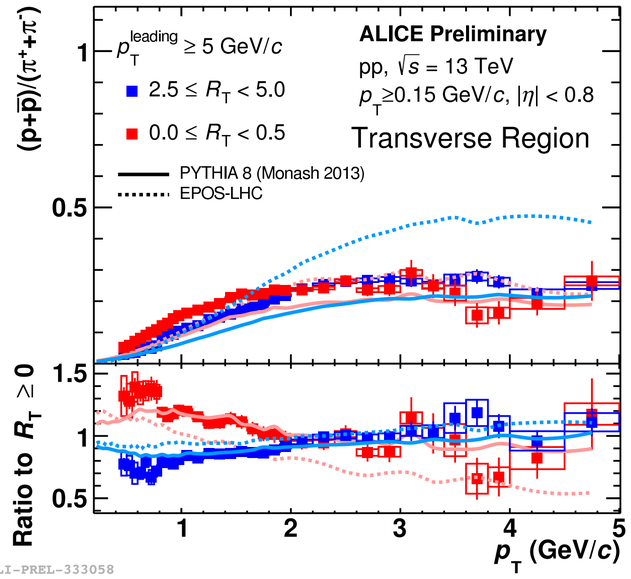
- The average transverse momentum in the Transverse region rises steadily as a function of the UE multiplicity.
- While at low UE multiplicity, PYTHIA and EPOS LHC predict compatible average transverse momentum, both predict softer activity than data.
- In the limit of high UE, both MC generators fail to describe the data. Furthermore, the deviations have opposite signs for the two models.

Particle ratios in the Transverse side

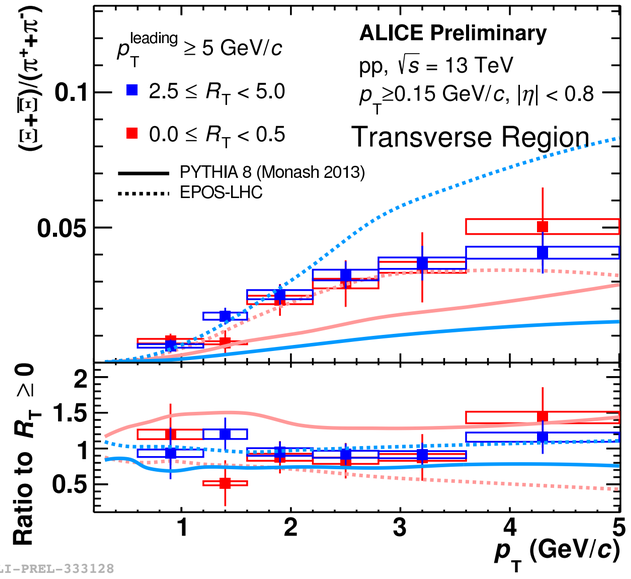
New



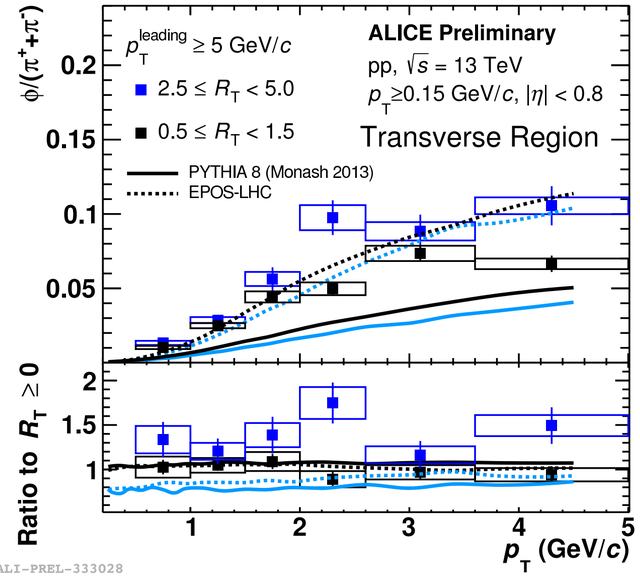
ALI-PREL-333093



ALI-PREL-333058



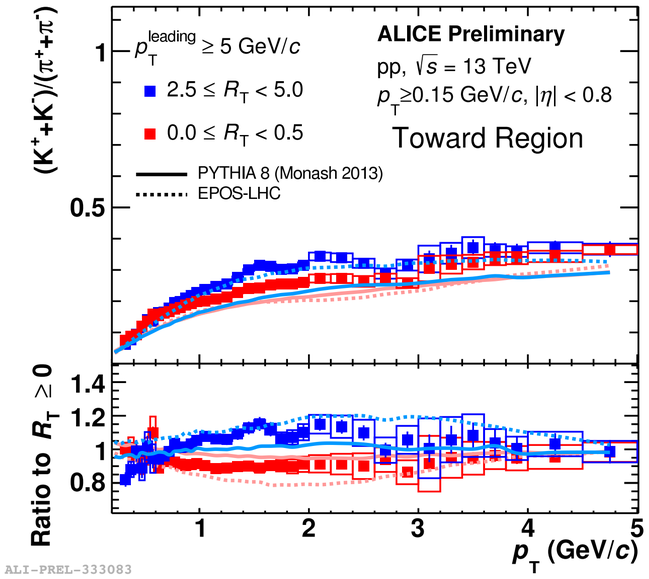
ALI-PREL-333128



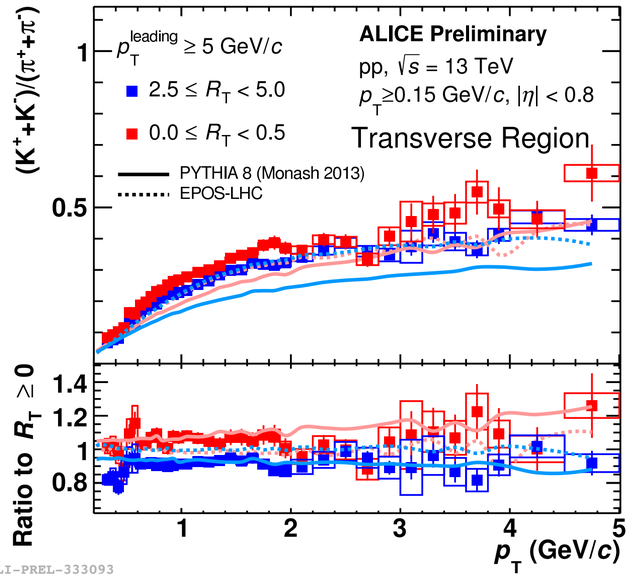
ALI-PREL-333028

- The p_T-differential kaon-, proton-, Xi- and phi-to-pion ratios in the Toward, Away and Transverse regions were measured.
- It was observed that the particle ratios in the Transverse side behave qualitatively similar among the different species and in general no dependence on R_T was observed.
- One could conclude that the particle production in the UE do not depend on the number of MPIs.
- Overall, model predictions in the Transverse side fail to describe the data.

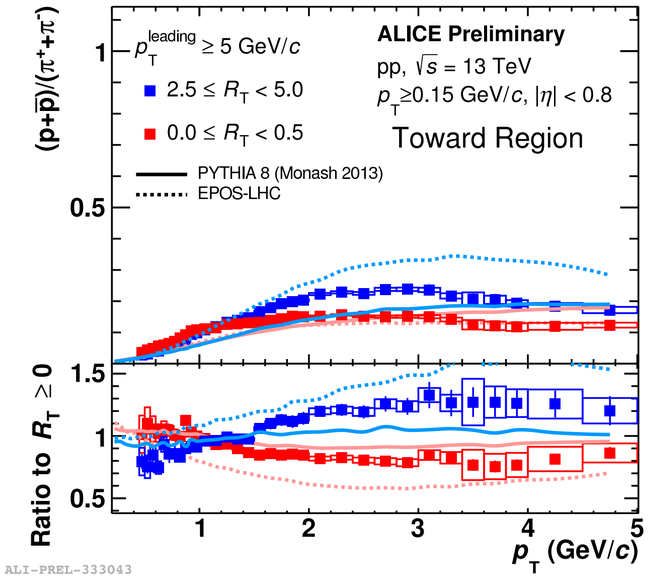
Particle ratios in the Toward vs Transverse side



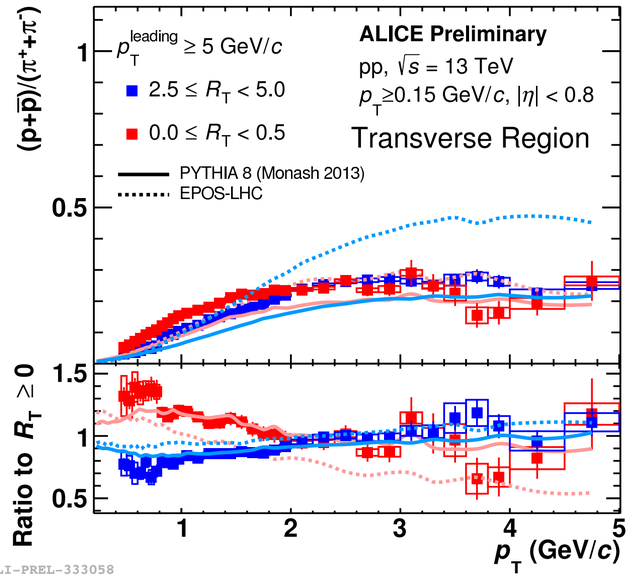
ALI-PREL-333083



ALI-PREL-333093



ALI-PREL-333043

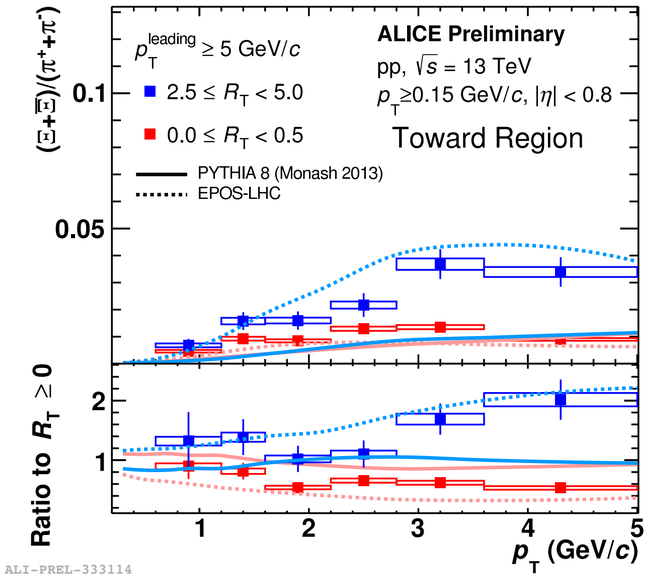


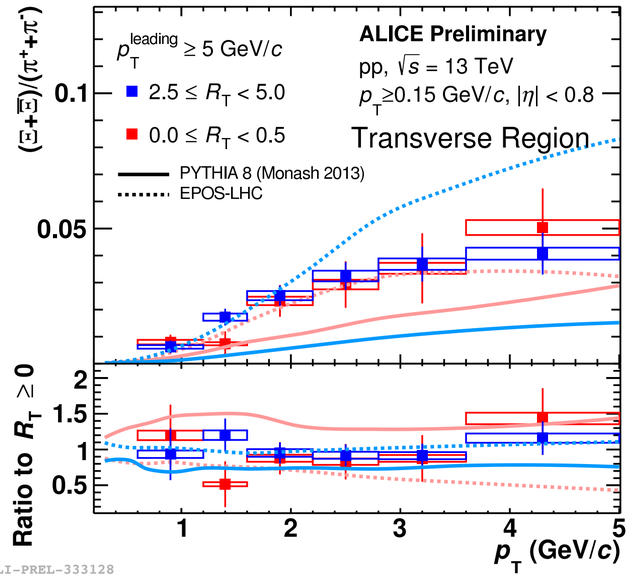
ALI-PREL-333058

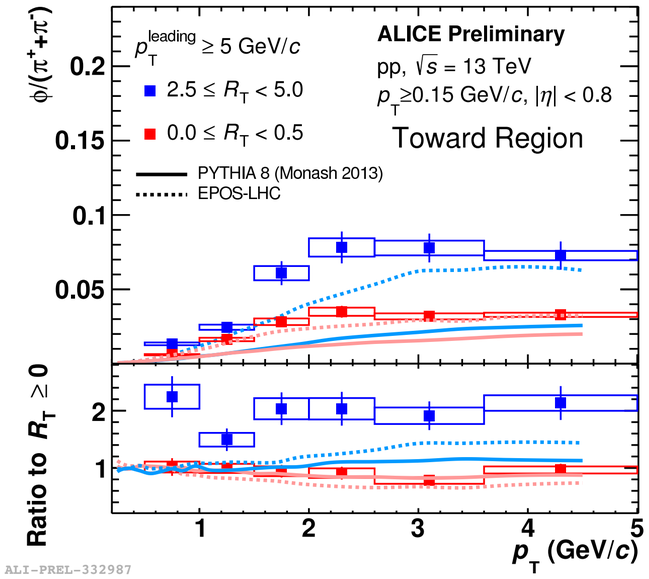
New

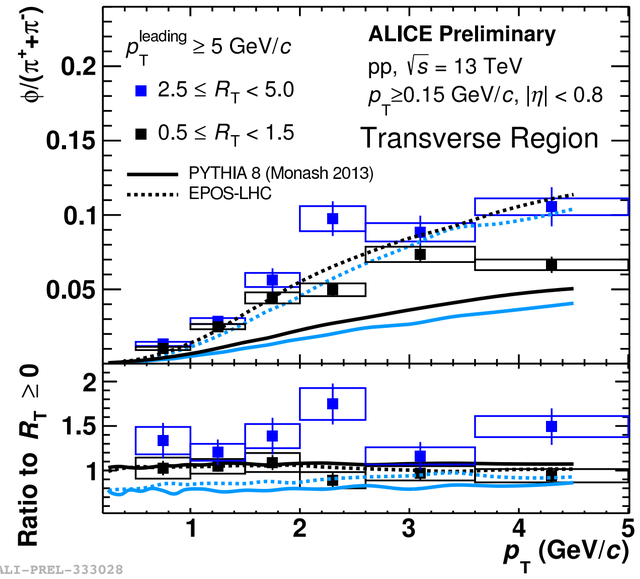
- $(K^+ + K^-)/(\pi^+ + \pi^-)$
  - Little dependence on R_T in both regions was observed.
  - In general, PYTHIA and EPOS-LHC undershoot the data measurements.
- $(p + \bar{p})/(\pi^+ + \pi^-)$
  - Clear evolution in the Toward region as a function of R_T.
  - Both MC predictions fail to describe the baryon-to-meson ratio.

Particle ratios in the Toward vs Transverse side









New

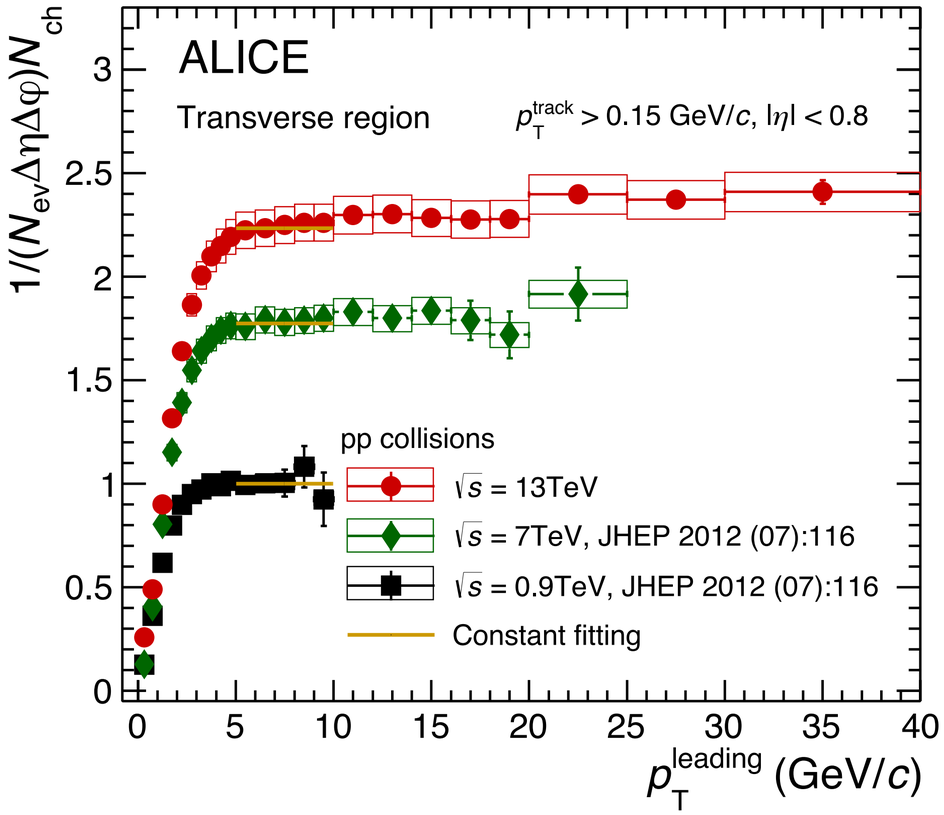
- $(\Xi + \bar{\Xi})/(\pi^+ + \pi^-)$
  - It was observed that the hard component is much lower in the Toward region and it grows towards the Transverse MPI limit with R_T.
  - In general, both models fail to describe the data in the Toward and Transverse regions.
- $\phi/(\pi^+ + \pi^-)$
  - Similar to the Xi-to-pion ratio in the Toward region, the Transverse MPI limit is reached with increasing R_T.

Summary

- The ALICE Collaboration has reported measurements of the Underlying Events as a function of $\sqrt{s}$.
- The height of the jet pedestal increases with the collision energy. In fact, it was observed that it increased about 30% between $\sqrt{s} = 7$ TeV and $\sqrt{s} = 13$ TeV.
- R_{T} can be used to quantify the UE activity in the Transverse region.
- Ratios of identified particle yields in the Toward and Transverse regions were measured as a function of R_{T}.
  - In general, no dependence of the particle production on R_{T} was observed in the Transverse region.
  - The hard component in the Toward region increases with the number of MPIs in the Transverse region, with increasing R_{T}.

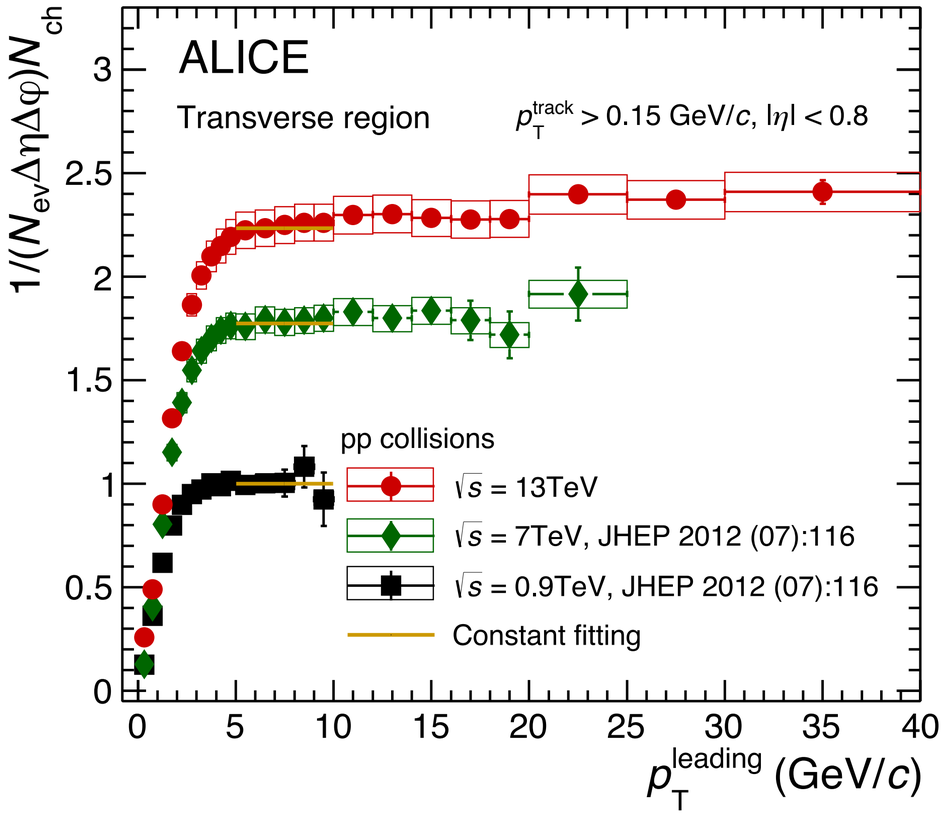
Backup

Number density as a function of $\sqrt{s}$

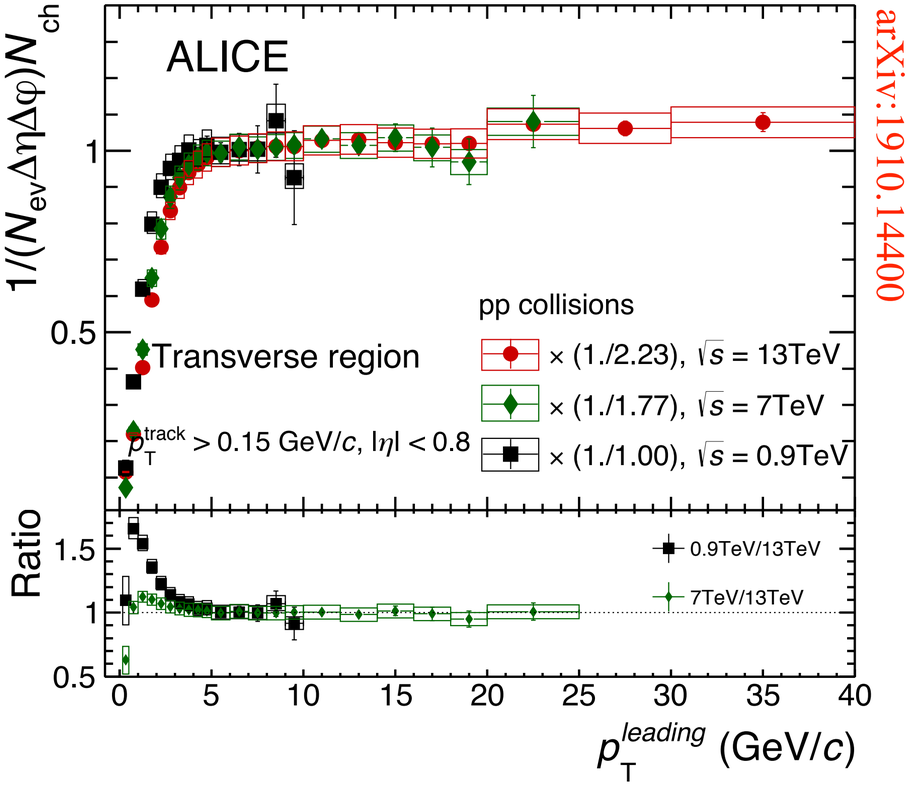


- Clear dependence of the number density in the jet pedestal region as a function of $\sqrt{s}$

Number density as a function of $\sqrt{s}$



Normalise the number density by the respective height of the jet pedestal

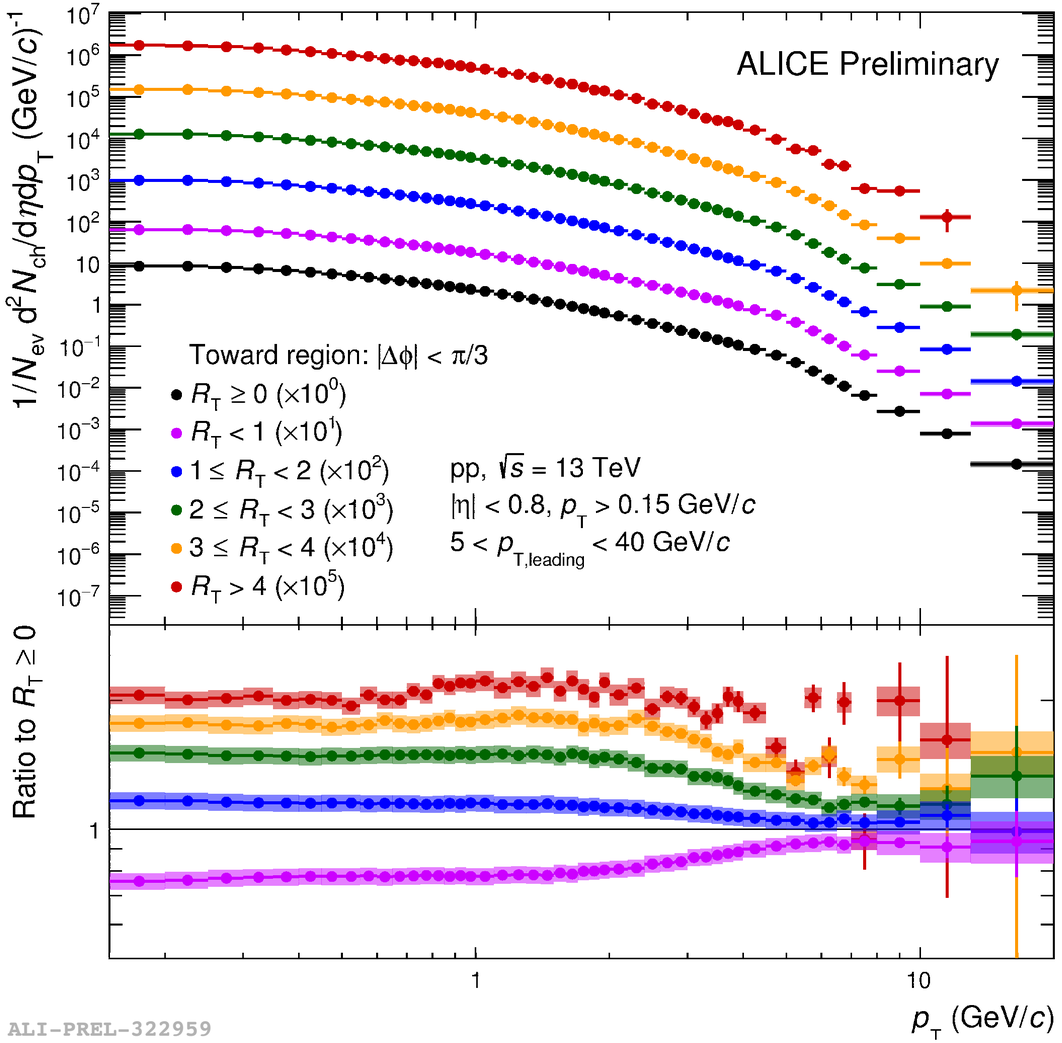


arXiv:1910.14400

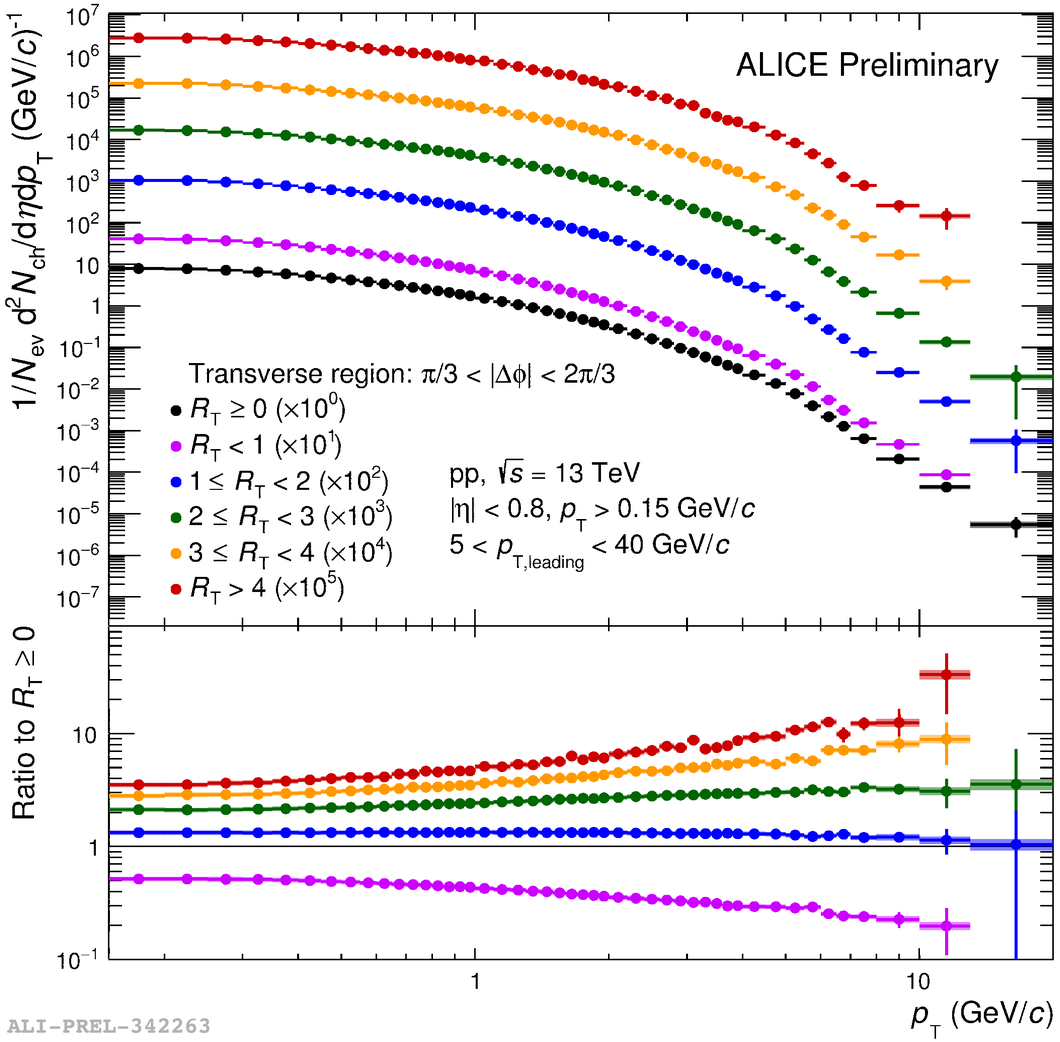
- Clear dependence of the number density in the jet pedestal region as a function of $\sqrt{s}$

- An ordering in the region below 5 GeV/c among the three collision energies is observed. The lowest energy has the highest number density relative to the plateau.

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



ALI-PREL-322959



ALI-PREL-342263