Study of identified particle production as a function of transverse event activity classifier, S_T in p-p collisions at √s=13 TeV using Pythia8

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Underlying Events

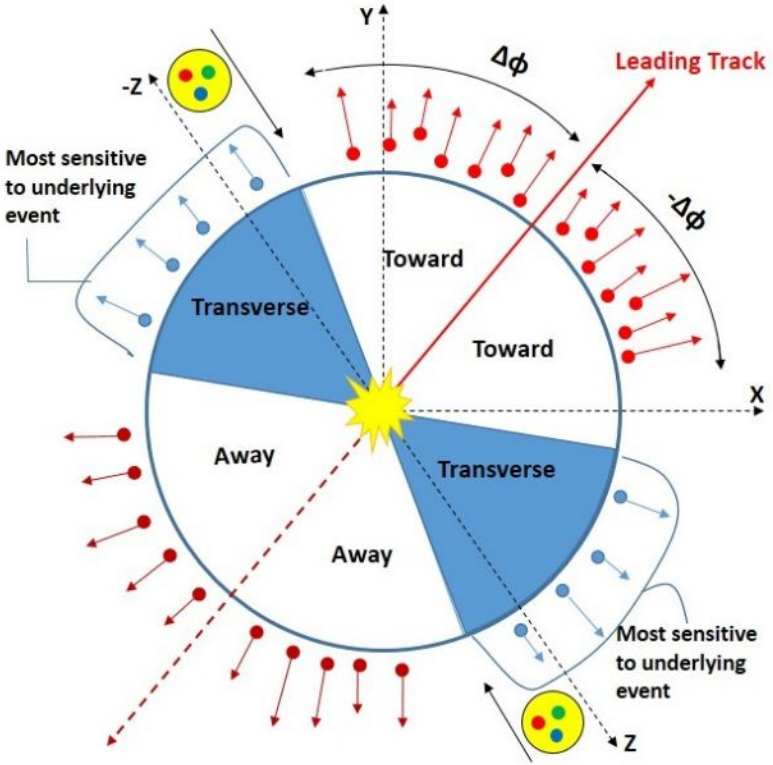
Relativistic Heavy Ion / proton collisions :

➔ **Hard parton-parton interactions** + **Activity from Underlying Events (UE)**

Underlying Event (UE)

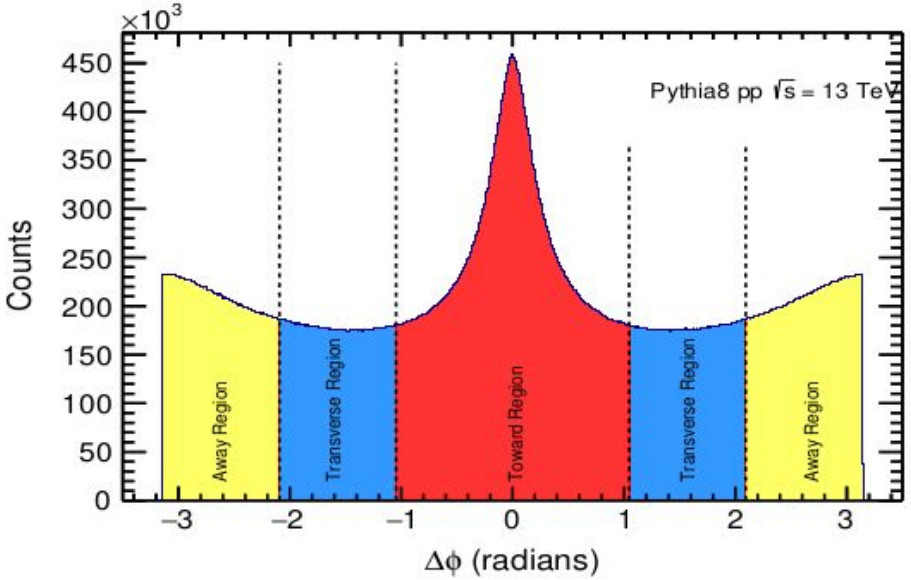
- **Beam-Beam Remnants:** Leftover particles (in AA)/ Leftover partons (in pp) from the initial colliding hadrons that did not participate in the hard scatter.
- **Initial-State Radiation (ISR):** Radiation emitted by the incoming partons before the hard scattering process.
- **Final-State Radiation (FSR):** Radiation emitted by the outgoing partons after the hard scatter interaction.
- **Multiple Parton Interactions (MPI):** Additional partonic interactions between the colliding hadrons beyond the primary interaction.
- **Soft Processes:** Low-energy interactions producing particles with low transverse momentum.

Quantifying UE



Three Topological Regions

Azimuthal angle difference	Region
$\|\Delta\phi\| < 60°$	Toward region
$60° < \|\Delta\phi\| < 120°$	Transverse region
$\|\Delta\phi\| > 120°$	Away region

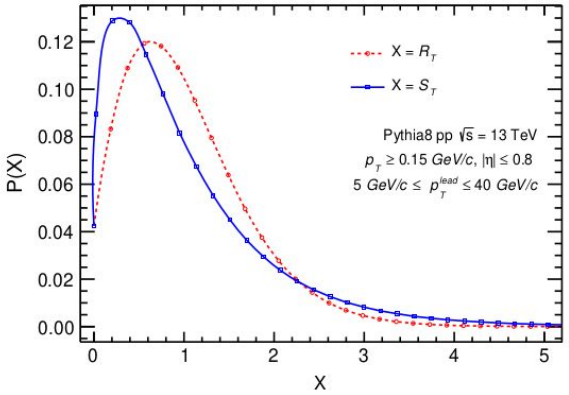


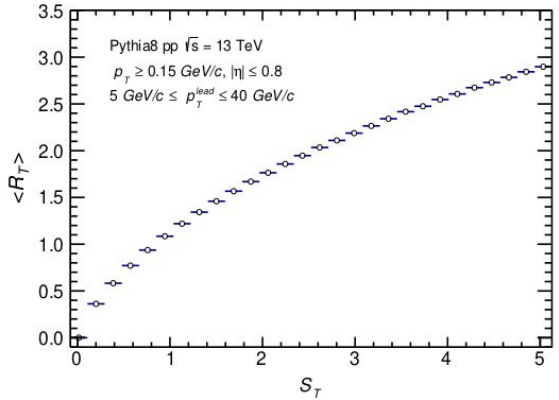
Transverse Activity Classifiers

$$R_T = \frac{N_T^{ch}}{< N_T^{ch} >} \quad [1]$$

$$S_T = \frac{\sum_i p_{T_i}^T}{< \sum_i p_{T_i} >}$$

= 1 : "Average" UE activity
> 1 : ”higher-than-average” UE activity
< 1 : “lower-than-average ” UE activity

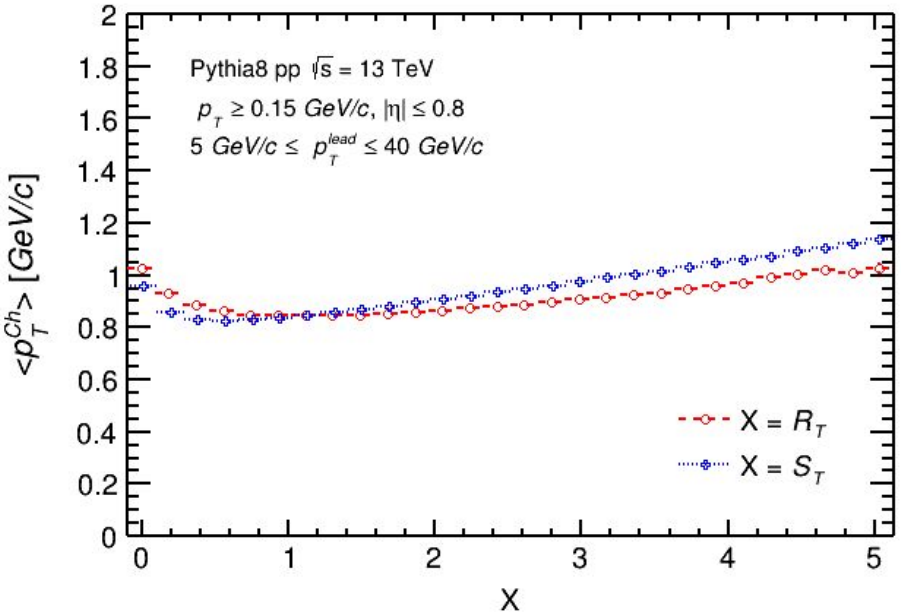


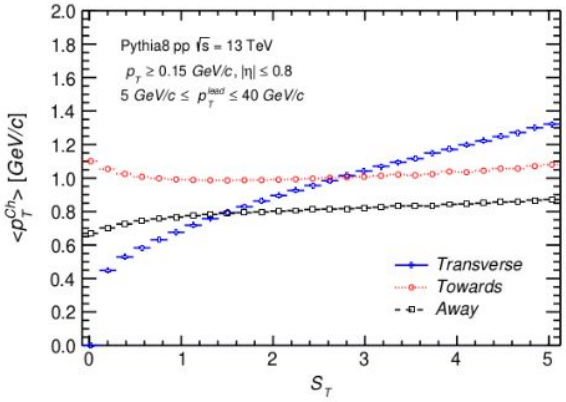


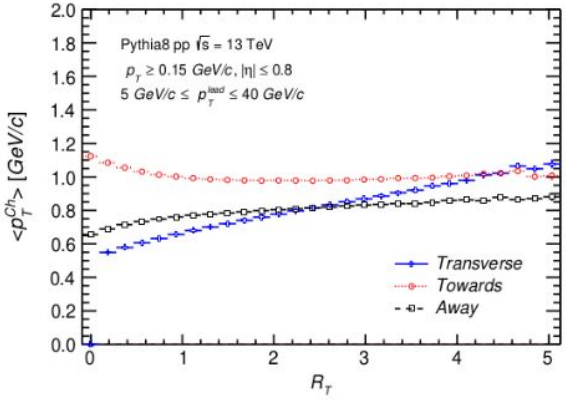
- Events with higher S_T (or R_T) are rarer : high UE activity events are rarer than low UE activity events.
- Positive correlation between S_T and R_T
- < R_T > and S_T are approximately linear upto 1.5, after 1.5 the relationship deviates from linearity.

[1] T. Martin, P. Skands, and S. Farrington, Eur.Phys. J. C 76, 299 (2016)

Charged Particles : Mean p_T







Charged Particles : Mean p_T

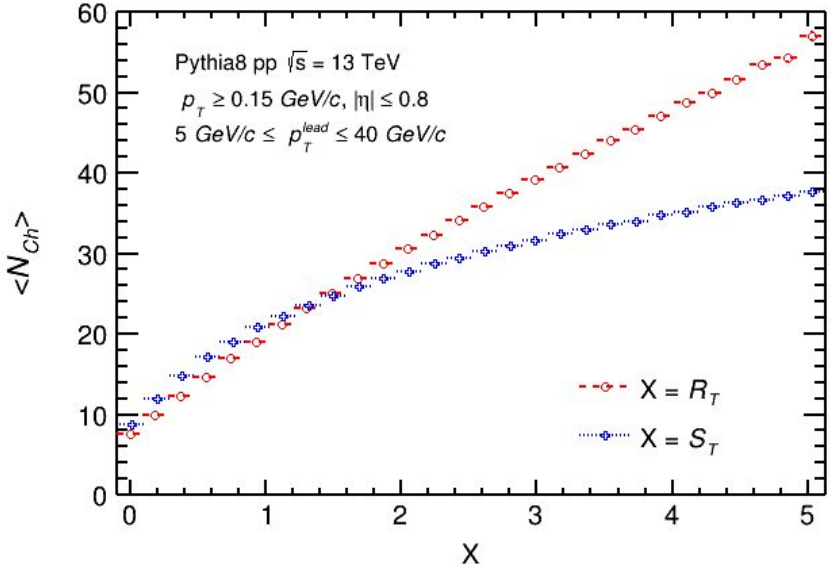
- $< p_T^{ch} >$ is consistently higher in towards region than away region.
- In the toward region, $< p_T^{ch} >$ of the charged particles is largest for lowest for R_T and S_T regime, due to dominance of jets fragmenting into numerous particles. It slowly decreases and saturates for S_T (and R_T) values > 1.5.

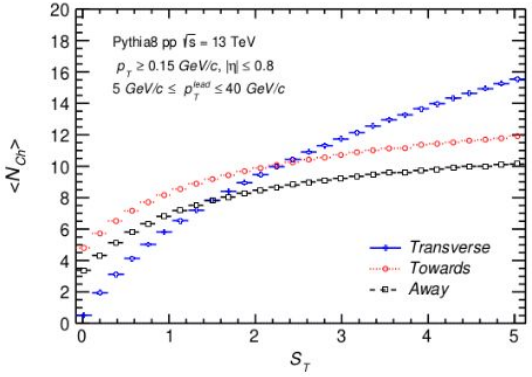
- In the away side region, which is dominated by away-side jet, the $< p_T^{ch} >$ slightly increases with R_T and S_T

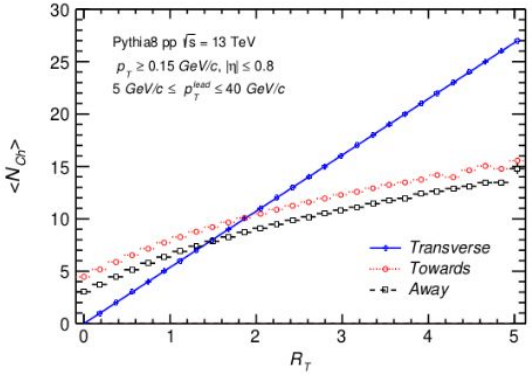
- In the transverse region, $< p_T^{ch} >$ values are lower than toward and away regions for lower ranges of S_T and R_T . It increases with R_T and S_T due to dominance of UE activity.

- The increase is steeper in case of S_T, as a consequence of the autocorrelation effect due to the structure of the observable.

Charged Particles : Mean multiplicity







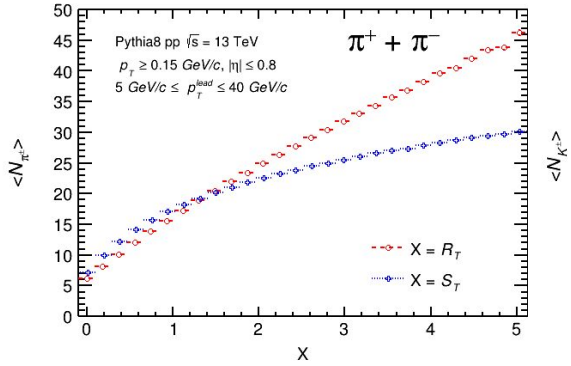
Charged Particles : Mean multiplicity

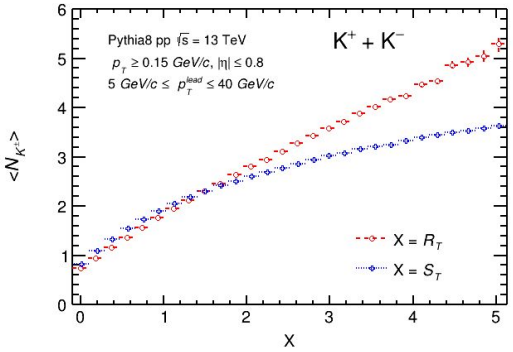
- $< N_{ch} >$ in towards region, is consistently higher than away region.

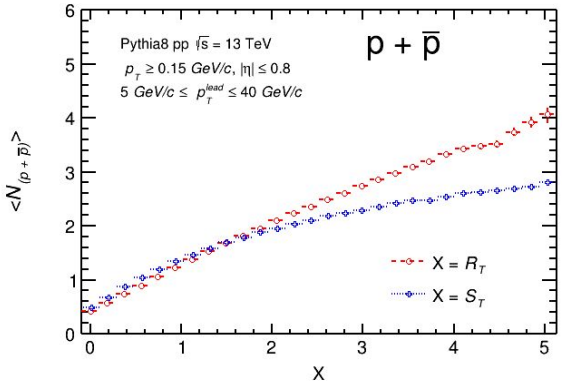
- In the transverse region, for lower values of S_T (and R_T) the $< N_{ch} >$ is lower than both towards and away region. With increasing R_T and S_T values $< N_{ch} >$ increases and there is a crossing over with the towards and away region.
- There is a strong rise in $< N_{ch} >$ in the transverse region for values of $S_T > 1.5$ which signals towards an increase in transverse activity emanating primarily from underlying events.

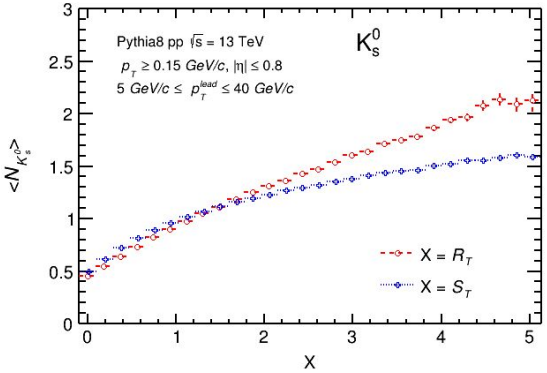
- The increase is a strong in case of R_T due to autocorrelation effect due to structure of the variables.

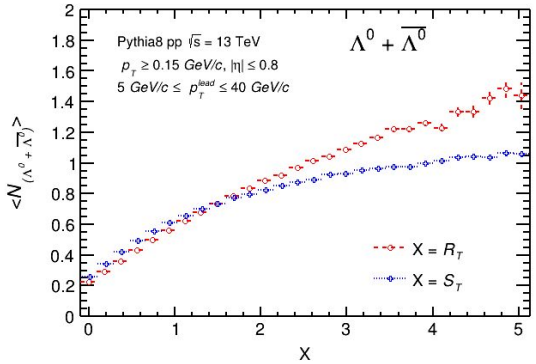
Identified particles: Multiplicity





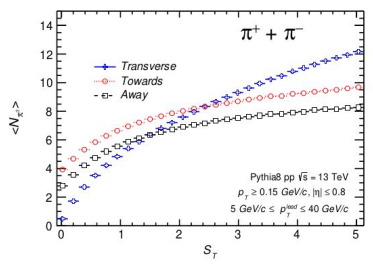


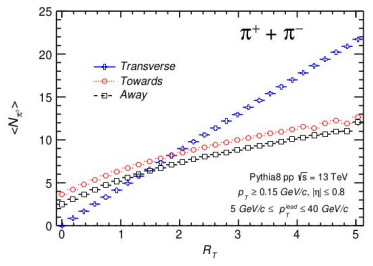


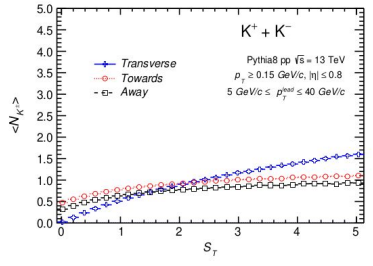


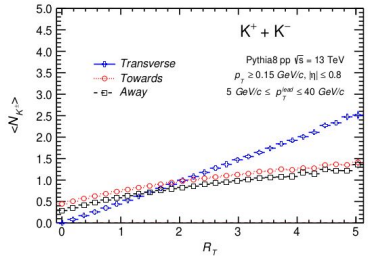
- Trend is similar to that observed for charged multiplicity case.

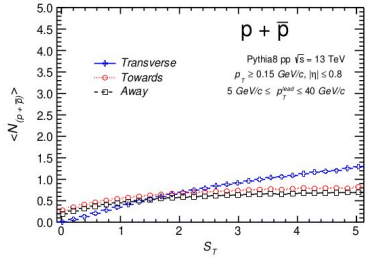
Identified particles: Multiplicity

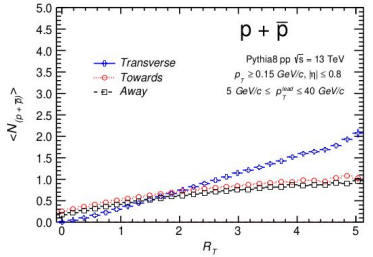


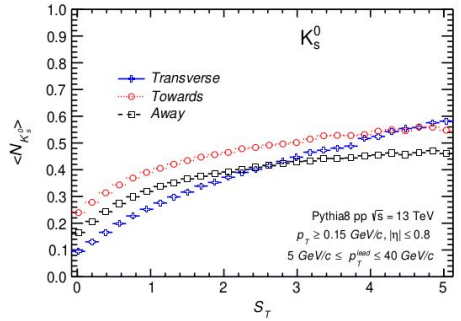


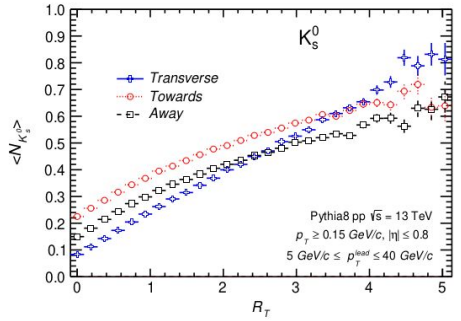


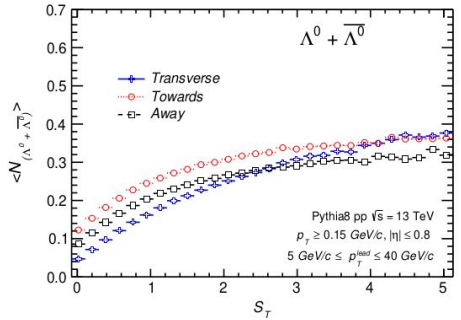


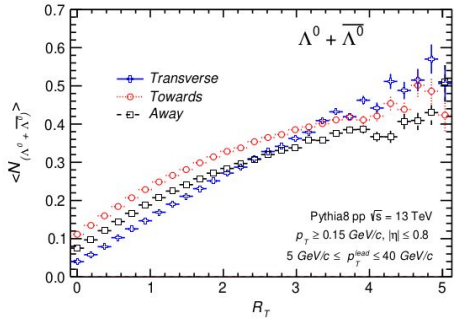












Identified particles: Multiplicity

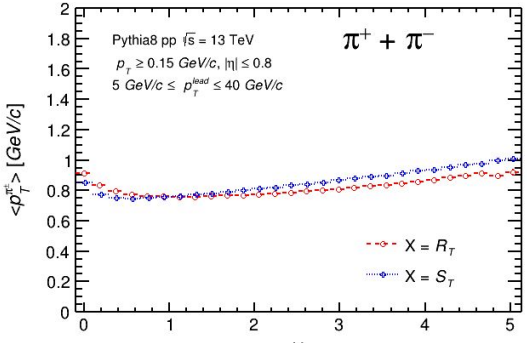
- For Charged particles like pion, kaon and protons the trend is similar to that observed for charged multiplicity case.

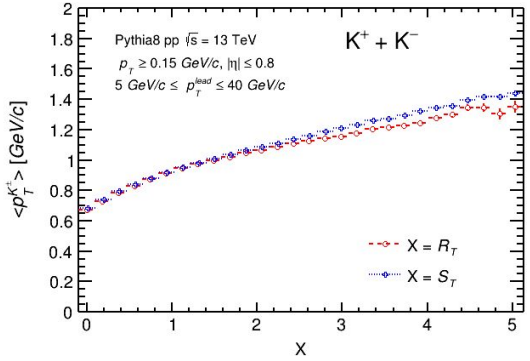
- For neutral V^0 particles like K_0^S and Λ^0 , do not exhibit autocorrelation effects as both S_T and R_T are defined in terms of charged particles.

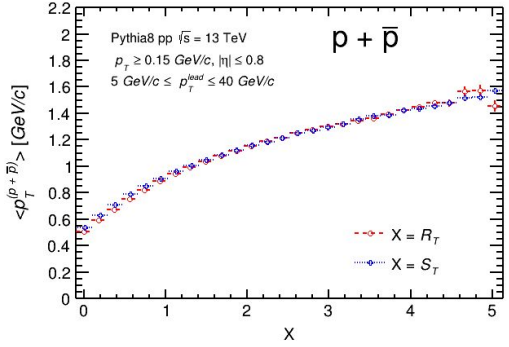
- In V^0 particles the values for toward region remain consistently higher than the other regions up to S_T and R_T ~ 2.0 indicating the dominance of V^0 production by fragmenting jets.

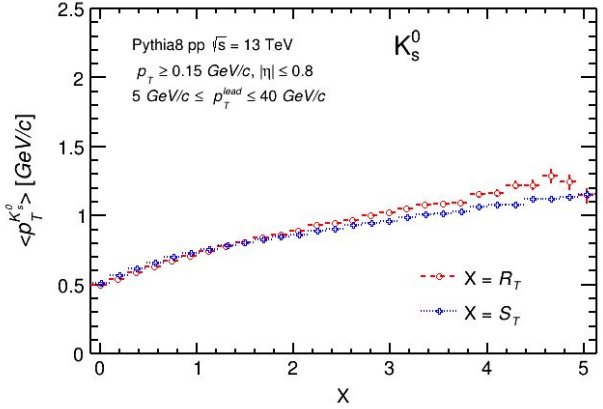
- The gradual increase for transverse region with increase in S_T values, indicates that hadronization mechanism which is sensitive to the non-perturbative effects, affects the strangeness and baryon content of the final state.

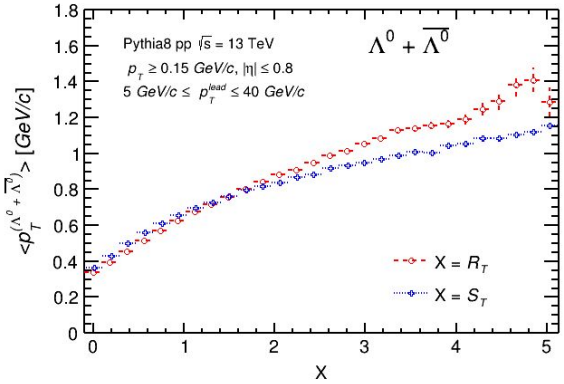
Identified particles: Momentum



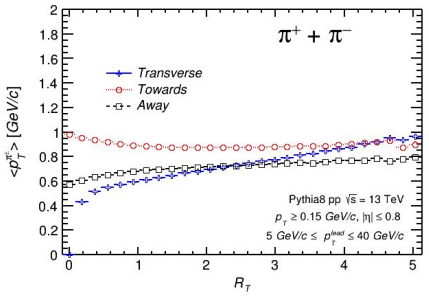


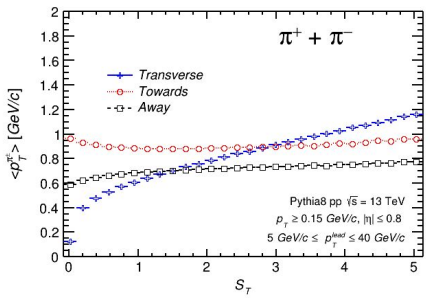


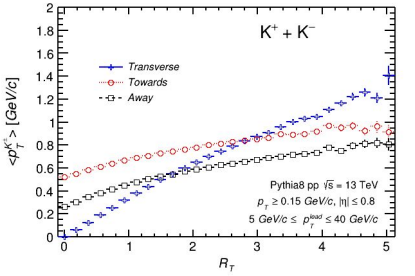


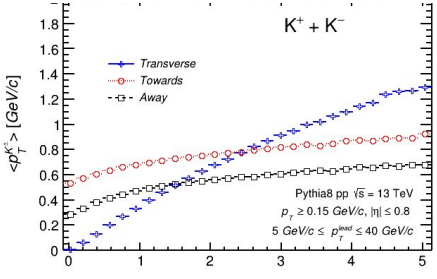


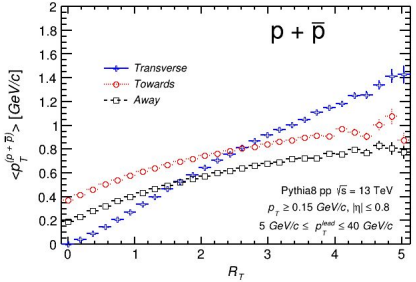
Identified particles: Momentum

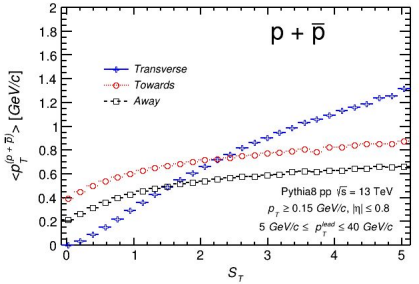


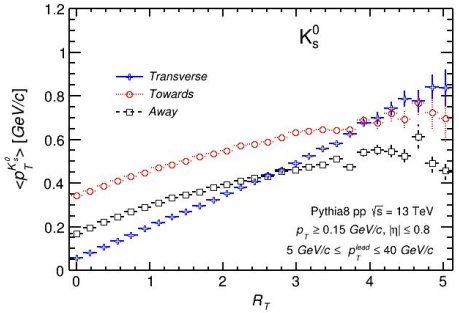


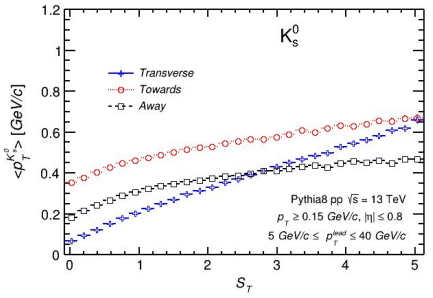


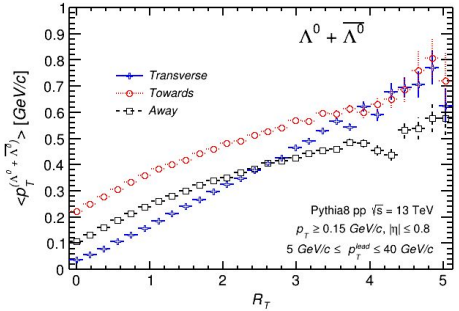


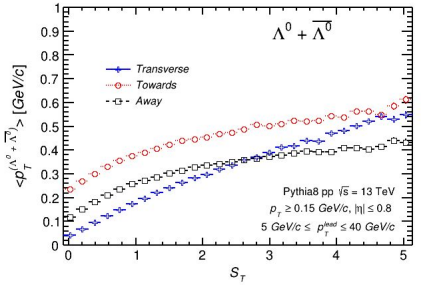








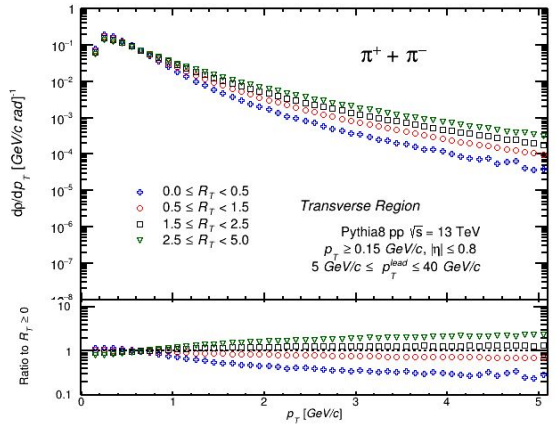


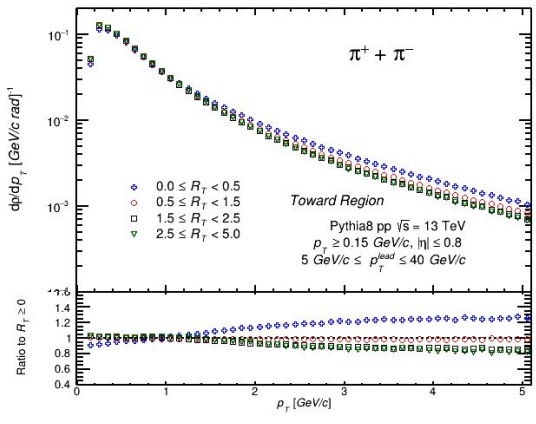


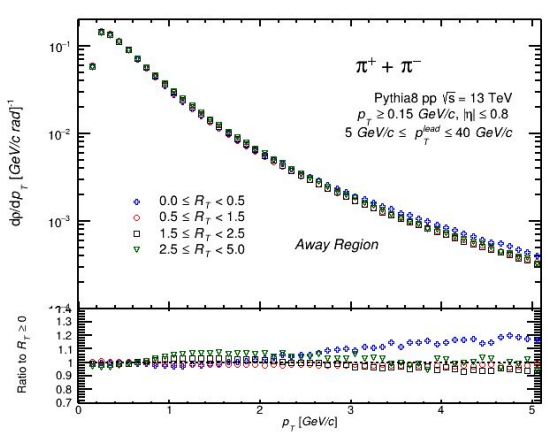
Identified particles: Momentum

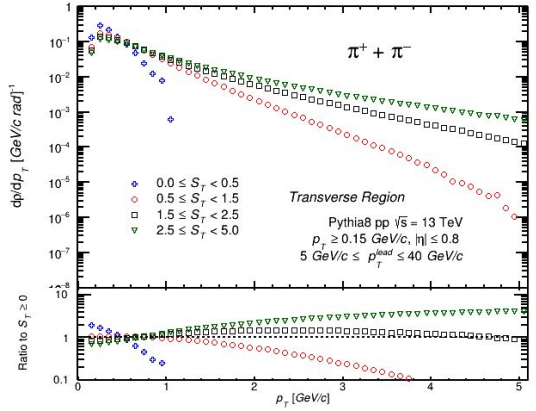
- $< p_T >$ in towards region is always higher than away region.
- $< p_T >$ of the toward region is consistently higher for all the identified particles for lower ranges of S_T and R_T . The values for away region is also higher than transverse region for lower ranges. Because the are dominated by particle production via jet fragmentation and hence carry the highest p_T .
- The trend observed for pions is different than other identified particles. The $< p_T >$ of pions are considerably higher for lower ranges showing a slight decrease with S_T (and R_T) and remains more or less uniform throughout.
- The values for other particles show a consistent increasing trend with S_T (and R_T). The values of $< p_T >$ of identified charged particles are highest in the transverse region for higher ranges of S_T and R_T where the transverse activity due to underlying events dominates.
- For charged particles, there is a smooth crossing over of the $< p_T >$ in transverse region with the one of away and toward region for S_T ~ 1.5 and R_T ~ 1.5.
- The same is not observed for the neutral particles for which the contribution from toward region dominates throughout. The crossing point for the V0 particles with away region is seen at S_T , R_T ~ 2.5 but with towards region happen at larger values. This indicates that the contribution to $< p_T >$ is essentially driven by jet fragmentation for neutral particles while the charged particles are affected by underlying events.

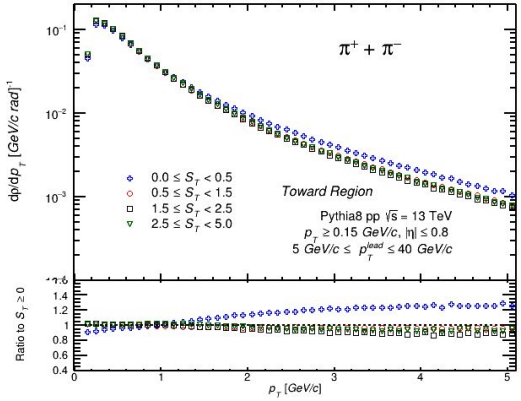
p_T Spectra - Pion

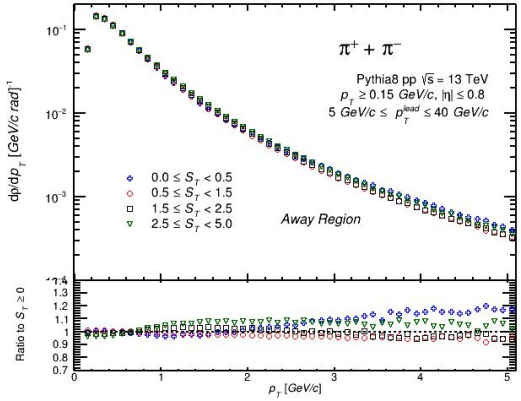




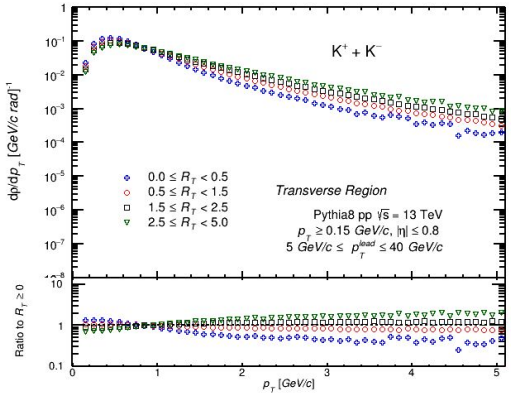


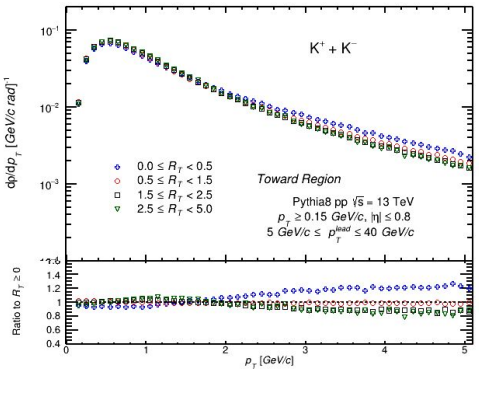


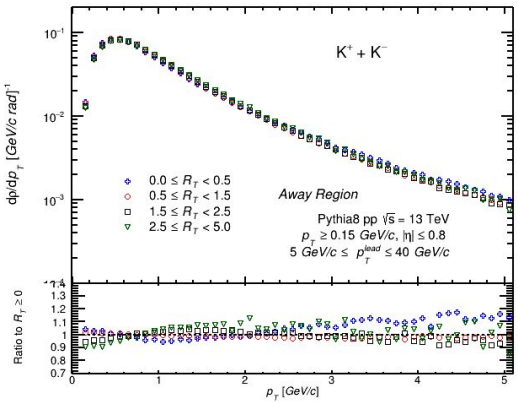


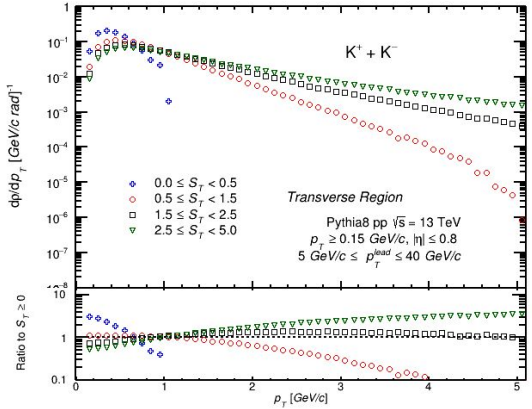


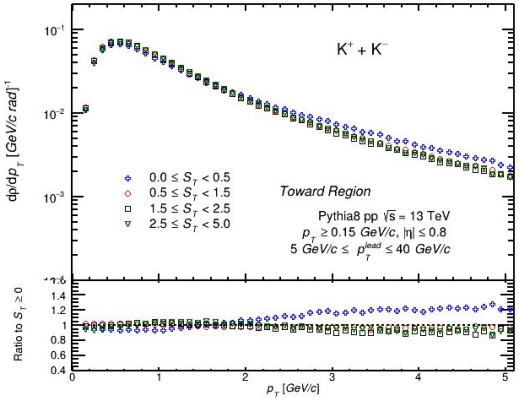
p_T Spectra - Kaon

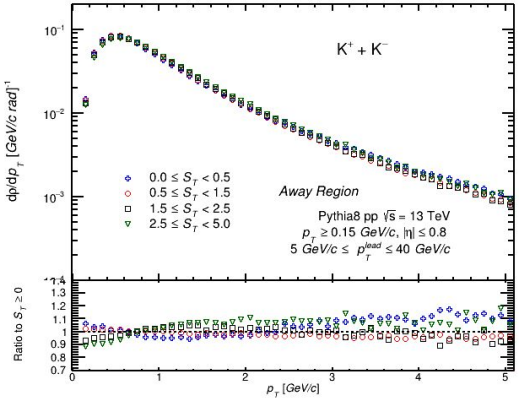




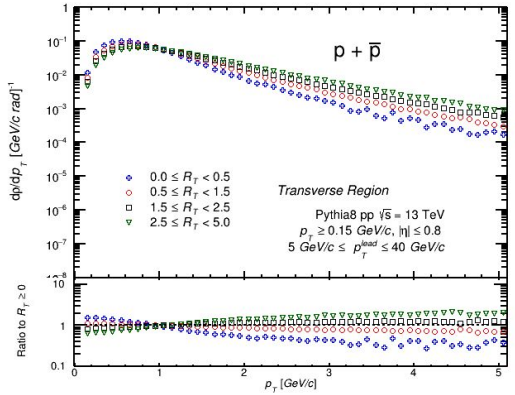


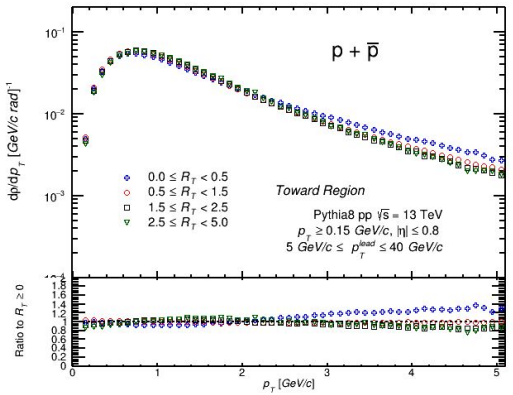


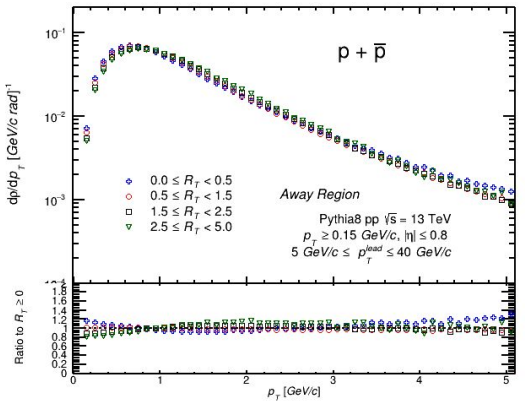


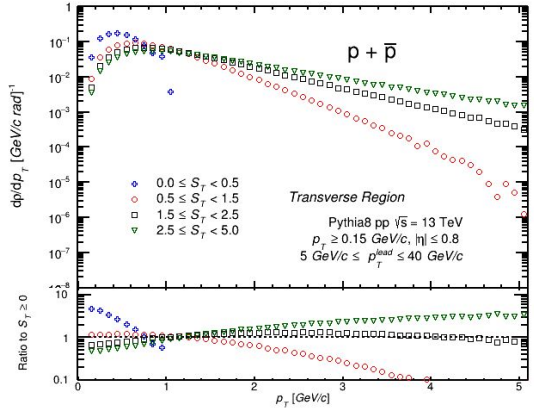


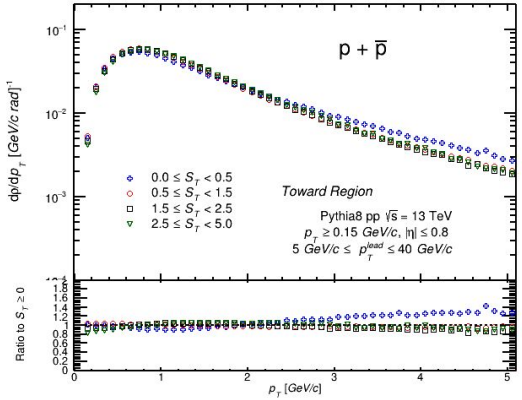
p_T Spectra - Proton

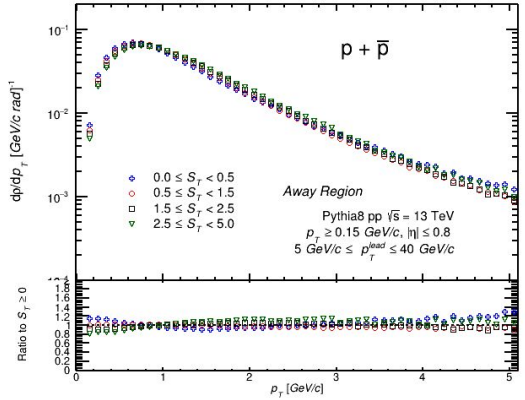




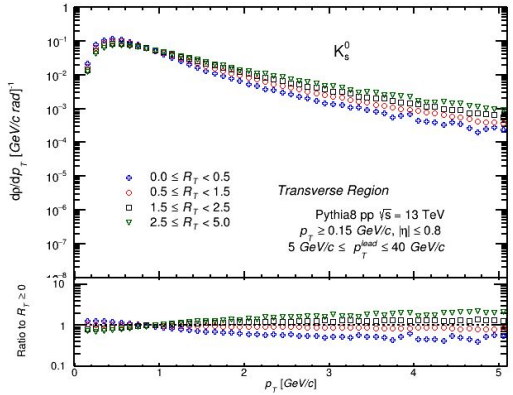


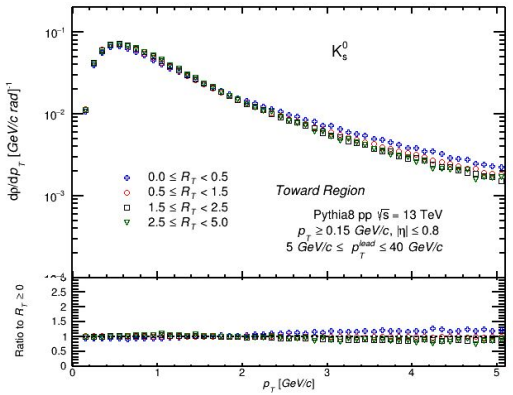


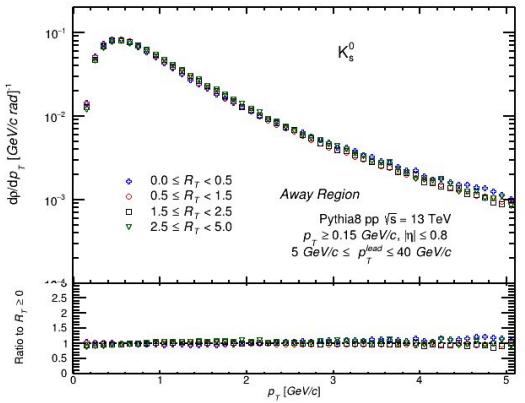


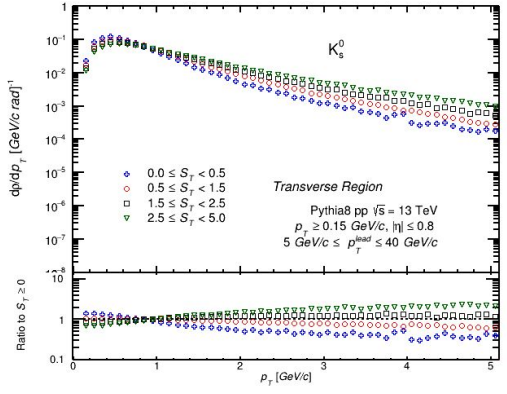


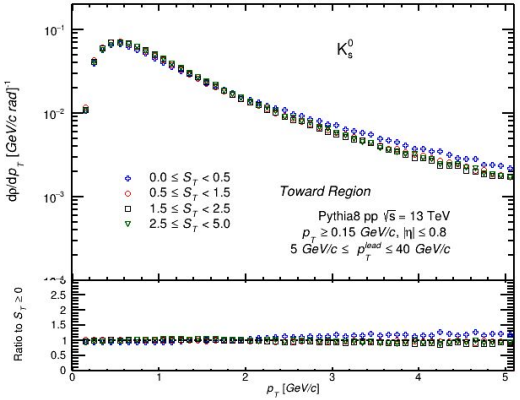
p_T Spectra - K^0 Short

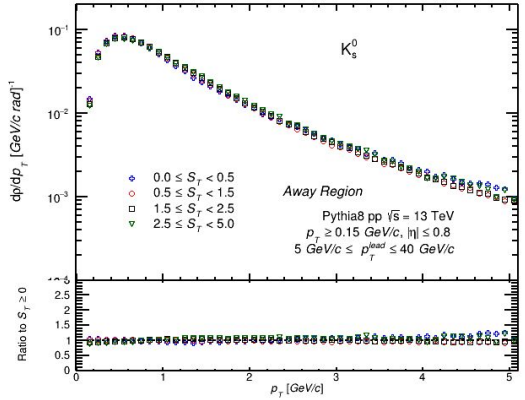




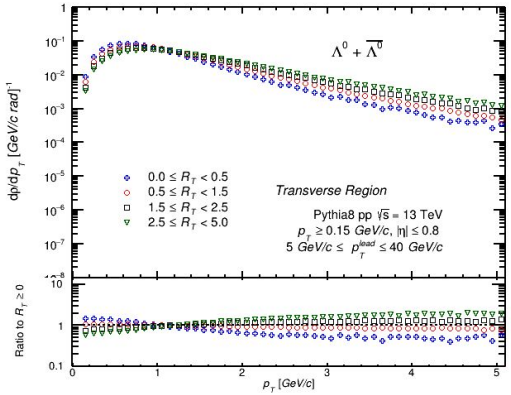


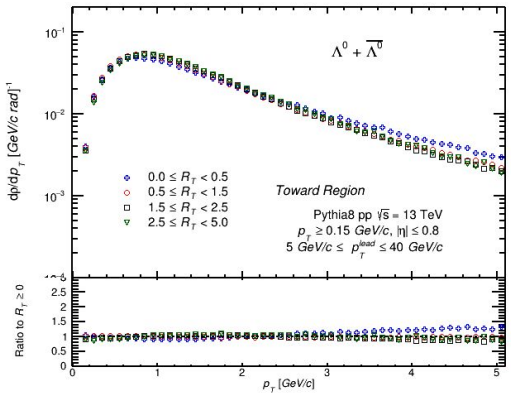


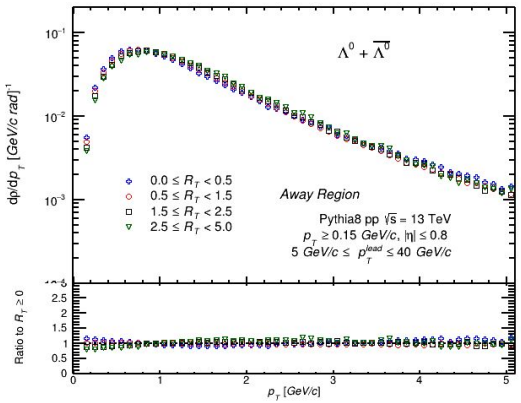


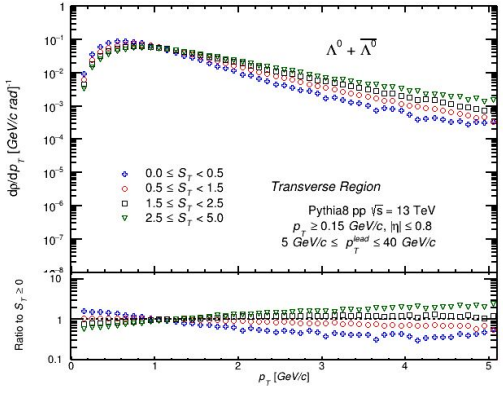


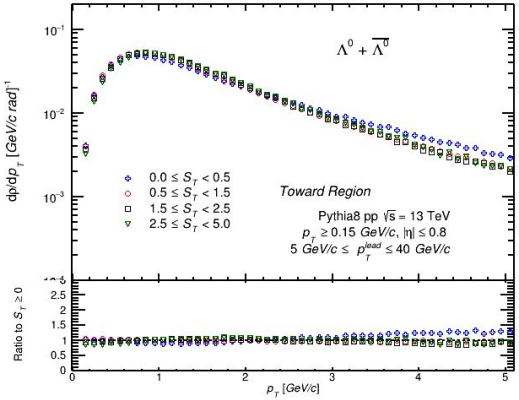
p_T Spectra - Lambda

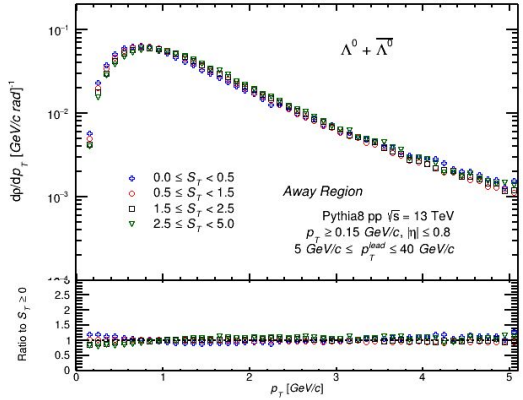












p_T Spectra - Conclusion

- The evolution of the p_T distributions of identified particles in different regions of transverse activity quantified by R_T and S_T can provide additional information about the particle production mechanism.

- The p_T spectra obtained in transverse, towards and away regions are shown in the figures. and the corresponding ratios to the S_T (and R_T) integrated spectra is shown in the bottom section of each figure.
-
- For all particle species, spectral shapes harden with increasing UE activity i.e. with increasing values of S_T and R_T in the transverse region and is reminiscent of radial flow effects.
-
- In the toward and away region, the differentiation of these R_T and S_T classes is not pronounced and the spectra is harder for low values of S_T and R_T for toward as. well as away region. This is observed for all the identified particle species studied and can also be seen from ratio to $S_T \geq 0$ (and $R_T \geq 0$) integrated spectrum in lower panels of the figures.
-
- The p_T spectra in the transverse region is more strongly differentiated by S_T classes than R_T classes for charged particles. This effect seems to be a manifestation of the construction of the observable as this differentiation vanished for neutral particles.

Summary

- The production of various species of particles π , $K \pm$, $p + \bar{p}$, K_s^0 , and Λ^0 in p−p collisions at $\sqrt{s}$ = 13 TeV is studied as a function of transverse activity classifier, S_T , in the three topological regions using pQCD inspired PYTHIA 8 event generator.
- The classifier S_T was introduced and its performance with R_T was gauged.
- The evolution of mean multiplicity and mean transverse momentum for identified particles were studied as a function of S_T .
- It was observed that, in the transverse region, charge particle production at higher S_T ranges is predominantly driven by underlying events. However, for V0 particle production, a dominance of hard processes was observed.
- The p_T spectra of the considered particle species were found to be sensitive to underlying event (UE) activity. It was noted that p_T spectra of identified charged particles were more strongly differentiated by S_T classes than by R_T classes.
- The obtained results provide a baseline for upcoming experimental measurements at LHC energies and can be used to help constrain Monte-Carlo models.

Thank you for your Attention