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Production of strange particles in jets and underlying events in pp collisions at $\sqrt{s} = 13$ TeV with ALICE

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Abstract. The production of strange (K^0_S, Λ) and multi-strange ($\Xi^\pm$ and $\Omega^\pm$) particles in jets and the underlying event in pp collisions at $\sqrt{s} = 13$ TeV has been studied with ALICE at the LHC. The p_T-differential density of the particles produced in a jet is compared to the inclusive distribution. The corresponding $(\Lambda + \overline{\Lambda})/2K^0_S$ and $(\Xi^- + \overline{\Xi}^+)/(\Lambda + \overline{\Lambda})$ ratios in jets as a function of p_T are also reported in this work. The p_T-differential density distribution of hadrons associated with jets decreases slower than the one reported for inclusive particle production. The ratios measured in jets show a clear difference when compared to the inclusive ones at the intermediate p_T range. The results provide an opportunity to test the strange and multi-strange particle production mechanisms with hard scattering.

1 Introduction

The transverse momentum (p_T) dependence of the baryon-to-meson yield ratio in hadronic and nuclear collisions is sensitive to the collective expansion of the system, the partonic recombination into hadrons, the jet fragmentation, and hadronization. A significant enhancement of such ratio has been observed at intermediate-p_T ($2 < p_T < 6$ GeV/c) in high multiplicity pp and p–Pb collision events with respect to lower multiplicity events [1]. However, the origin of the enhancement still remains an open question. The ALICE collaboration has furthermore investigated production of the V^0 particles (K^0_S and Λ) in jets reconstructed in pp collisions at $\sqrt{s} = 7$ TeV and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [2]. In this contribution, we explore the connection between the baryon-to-meson ratio enhancement and jet production via the measurement of the p_T-differential spectrum of strange and multi-strange particles (K^0_S, Λ, and Ξ) in pp collisions at $\sqrt{s} = 13$ TeV done both inclusively and within energetic jets. The results set new constraints on the particle production mechanisms in jets and provide new insight into the understanding of the origin of flow-like correlations observed in small colliding systems.

2 Analysis Strategy

This analysis is based on 240 million pp collision events at $\sqrt{s} = 13$ TeV collected by the ALICE detector [3] at the LHC. The event selection used the minimum bias trigger which was defined by time coincidence of signals coming from the V0 arrays which cover the forward

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and backward rapidity. Track reconstruction is based on spatial data points measured by the Inner Tracking System (ITS) and Time Projection Chamber (TPC) detectors. ITS is a silicon tracker providing necessary spatial resolution required for reconstruction of primary interaction vertices and secondary vertices of hadron decays. Besides tracking, TPC provides in addition also information about particle type obtained through measurements of $\mathrm{d}E/\mathrm{d}x$.

Charged particle tracks can be measured in the pseudorapidity range $|\eta| < 0.9$ and their p_{T} is constrained from below by 0.15 GeV/c. These tracks are used to reconstruct charged-particle jets, which are used to tag a hard process. The charged-particle jets are reconstructed with the anti-k_{T} algorithm [6] for $R = 0.4$ using the E-recombination scheme. Pseudorapidity of the anti-k_{T} jets is constrained to $|\eta_{\mathrm{jet}}| < 0.35$. In order to reconstruct (multi-)strange particles the following decay channels are used: $\mathrm{K}^0_{\mathrm{S}} \rightarrow \pi^+ + \pi^-$, $\Lambda \rightarrow \mathrm{p} + \pi^-$, and $\Xi^- \rightarrow \Lambda + \pi^- \rightarrow \mathrm{p} + \pi^- + \pi^-$.

The strange particles were matched with a jet when the angular distance within the η–φ plane between the particles and the jet axis is smaller than the resolution parameter, $\Delta R(\text{particle}, \text{jet}) < R$. In some cases particles from the underlying event (UE) are matched to the jet. This component is subtracted from the p_{T} differential density spectra on a statistical basis. The UE contribution is estimated by perpendicular cone (PC) yields. The PC indicates the cone in the η–φ space located at the perpendicular direction with respect to the jet axis in azimuth at the same η. The density of strange particles in a jet cone (JC) or a perpendicular cone is defined as:

$$\rho^{\mathrm{str}}(p_{\mathrm{T}}) = N^{\mathrm{str}}(p_{\mathrm{T}})/A^{\mathrm{str}}, \tag{1}$$

where N^{str} is the number of strange particles and A^{str} is the acceptance in pseudorapidity and azimuthal angle. The density distributions were measured as a function of particle p_{T}. The distributions were normalized per selected event and bin width in p_{T} to obtain, p_{T} differential density $\mathrm{d}\rho/\mathrm{d}p_{\mathrm{T}}$. The density of particles coming from jet fragmentation is estimated by JE = JC − UE = JC − PC, where JE, JC, and UE denote the corresponding p_{T}-differential densities.

3 Results

Figure 1 shows the p_{T}-differential densities for $\mathrm{K}^0_{\mathrm{S}}$ and $\Xi^- + \overline{\Xi}^+$. As expected the density distributions, which are corresponding to jet fragmentation, are considerably harder than the inclusive case. Let us point out that the p_{T}-differential density distribution of inclusive hadrons is lower than that of the PC selection since the latter is obtained from events which contain jets with $p^{\mathrm{ch}}_{\mathrm{T,\,jet}} > 10$ GeV/c.

The $(\Lambda + \overline{\Lambda})/2\mathrm{K}^0_{\mathrm{S}}$ and $(\Xi^- + \overline{\Xi}^+)/(\Lambda + \overline{\Lambda})$ ratio of the p_{T}-differential densities corresponding to jets with $p^{\mathrm{ch}}_{\mathrm{T,\,jet}} > 10$ GeV/c and underlying events are presented in Figure 2. The data suggest that the inclusive and the UE ratios manifest an enhancement at $p_{\mathrm{T}} \sim 3 - 4$ GeV/c. The ratios corresponding to charged-particle jets are significantly lower than those for the inclusive and UE case at low and intermediate p_{T}. In addition, the ratios which are measured in jets are approximately independent of p_{T} in the region above 2 GeV/c. This suggests that the enhancement which is seen in the baryon-to-meson and baryon-to-baryon ratios at intermediate p_{T} is not driven by the jet fragmentation. In Figure 2, these ratios are compared to the PYTHIA 8 simulation with rope model [5]. It is shown that the PYTHIA can simulate the ratio $(\Lambda + \overline{\Lambda})/2\mathrm{K}^0_{\mathrm{S}}$ well but fails to reproduce the $(\Xi^- + \overline{\Xi}^+)/(\Lambda + \overline{\Lambda})$ which carries information about multi-strange particles. The $(\Xi^- + \overline{\Xi}^+)/(\Lambda + \overline{\Lambda})$ ratio obtained with PYTHIA 8 soft QCD shows a strong increase, inconsistent with the data. The $(\Xi^- + \overline{\Xi}^+)/2\mathrm{K}^0_{\mathrm{S}}$ and $(\Omega^- + \overline{\Omega}^+)/2\mathrm{K}^0_{\mathrm{S}}$ ratios were also studied with the PYTHIA 8 rope model, see Figure 3. It can be seen that PYTHIA in the soft QCD mode predicts similar strong increase as observed above.

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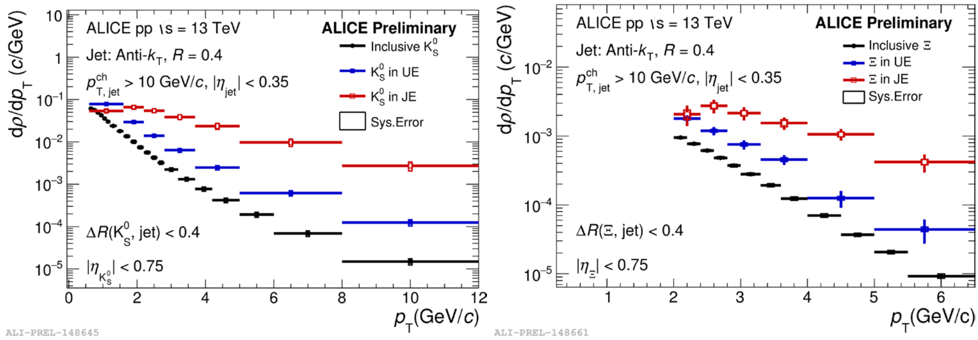

Figure 1. (color online) p_T-differential density of K^0_S (left) and $\Xi^- + \overline{\Xi}^+$ (right) in pp collisions at $\sqrt{s}$ = 13 TeV. The black points represent particles from minimum bias events, the blue points represent particles within a cone perpendicular to the jet, which are associated with the underlying event, and the red points represent the particles from the jet fragmentation.

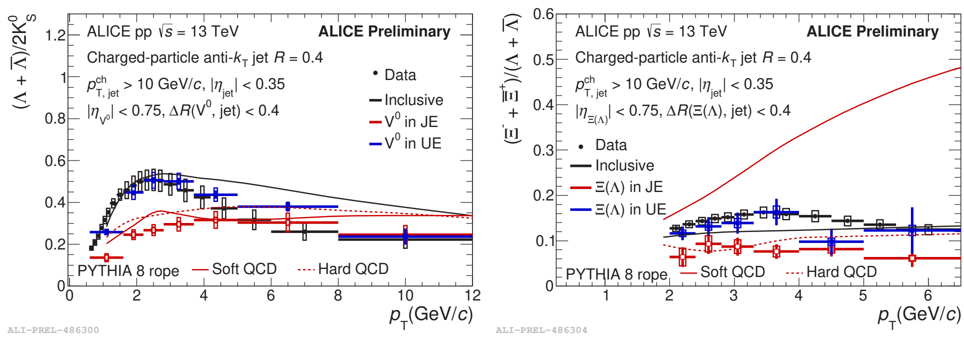

Figure 2. (color online) Ratio of p_T differential densities for $(\Lambda+\overline{\Lambda})/2K^0_S$ (left) and $(\Xi^-+\overline{\Xi}^+)/(\Lambda+\overline{\Lambda})$ (right) as a function of particle p_T in pp collisions at $\sqrt{s}$ = 13 TeV. The black points correspond to the ratio evaluated for particles from minimum bias events, the blue points correspond to the ratio obtained for particles which come from a cone that is perpendicular to the jet, and the red points represent the ratio from the jet fragmentation. Charged-particle jets with $p^{ch}_{T,jet}$ > 10 GeV/c were reconstructed with the anti-k_T algorithm with R = 0.4. The ratios are compared to the corresponding calculation by PYTHIA 8 simulations.

4 Conclusions

The the p_T dependent spectra of K^0_S, $\Lambda + \overline{\Lambda}$ and $\Xi^- + \overline{\Xi}^+$ within jets are considerably less steep than in the case of inclusive particles. In contrast to the inclusive distributions, the $(\Lambda+\overline{\Lambda})/2K^0_S$ and $(\Xi^-+\overline{\Xi}^+)/(\Lambda+\overline{\Lambda})$ ratios measured within jets do not exhibit enhancement at intermediate p_T. The enhancement of baryon to meson ratio in high multiplicity events thus might be attributed to soft processes taking place during the collisions. The $(\Xi^-+\overline{\Xi}^+)/(\Lambda+\overline{\Lambda})$ ratio measured in jets is likewise almost p_T independent. Hence, the enhanced production of multi-strange hadrons in high-multiplicity events [4] may also be explained by the soft processes. The measured ratios are compared with PYTHIA 8 rope model predictions. The

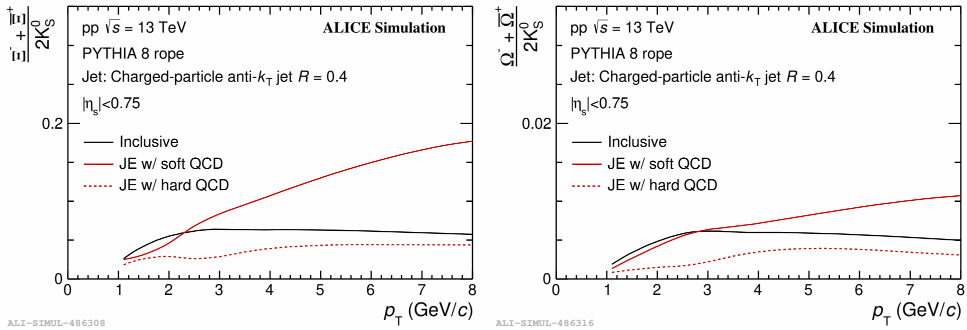

Figure 3. (color online) The $(\Xi^- + \overline{\Xi}^+)/2K^0_S$ (left) and $(\Omega^- + \overline{\Omega}^+)/2K^0_S$ (right) ratios obtained from PYTHIA 8 simulations.

PYTHIA 8 can describe the $(\Lambda + \overline{\Lambda})/2K^0_S$ but fails to reproduce the ratios that involve multi-strange particles ($\Xi^\pm$ and $\Omega^\pm$) with soft QCD.

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References

[1] ALICE Collaboration, B. B. Abelev et al., "Multiplicity dependence of Pion, Kaon, Proton and Lambda Production in p–Pb Collisions at $\sqrt{s_{NN}}$ =5.02 TeV" *Phys. Lett.* B728 (2014) 25–38, arXiv:1307.6796 [nucl - ex].

[2] ALICE Collaboration, S. Acharya et al., "Production of Λ and K^0_S in jets in p–Pb collisions at $\sqrt{s_{NN}}$ = 5 TeV and pp collisions at $\sqrt{s}$ = 7 TeV", arXiv: 2105.04890 [hep - ex].

[3] ALICE Collaboration, B. B. Abelev et al., "Performance of the ALICE Experiment at the CERN LHC," *Int. J. Mod. Phys.* A29 (2014) 1430044, arXiv:1402.4476 [nucl - ex].

[4] ALICE Collaboration, J. Adam *et al.*, "Enhanced production of multi-strange hadrons in high-multiplicity proton-proton collisions", *Nature Phys.* **13** (2017) 535–539, arXiv: 1606.07424 [nucl - ex].

[5] T. Sjöstrand et al., "An introduction to PYTHIA 8.2", *Comput.Phys.Commun.* **191** (2015), arXiv: 1410.3012 [hep-ph].

[6] M. Cacciari, G. P. Salam and G. Soyez, "The anti-k_t jet clustering algorithm," JHEP **04**, 063 (2008) doi:10.1088/1126-6708/2008/04/063 [arXiv:0802.1189 [hep-ph]].