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Study of K^0_S production via high-p_T dihadron correlations in pp collisions with ALICE

L. A. HUSOVA(*)

IKP, Westfälische Wilhelms-Universität Münster - Münster, Germany

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Summary. —
Complementary to jet reconstruction, two-particle correlations in $\Delta\eta$ and $\Delta\varphi$ can be used to study jets, in particular, their particle composition. While in Pb–Pb collisions, this is done to characterize the quark-gluon plasma, pp and p–Pb collisions serve as a reference and are of interest on their own for their input into the understanding of particle production mechanisms. Recent ALICE results on the production of strange particles in small systems (pp and p-Pb collisions) reveal the possibility of having similar strange hadron production mechanisms in all collision systems. We study the production mechanism of strange K^0_S meson in jets via two-particle correlations between the K^0_S and charged primary hadrons (h) in pp collisions at $\sqrt{s} = 13\,\text{TeV}$ collected with the ALICE experiment at the LHC. In this paper, the per-trigger yields of K^0_S and charged hadrons will be presented on both the near-side and away-side of the h-K^0_S and K^0_S- h correlation functions. These yields will be shown depending on the transverse momenta of the trigger and associated particles, as well as on the event multiplicity. Moreover, the ratios of these yields to the yields extracted from the h-h correlation function will be shown. In addition, a comparison to different MC generators will be presented, which will allow us to better understand strangeness production in jets.

1. – Introduction

The enhanced production of strange hadrons was observed in heavy-ion collisions and was established to be one of the major characteristics of the deconfined quark-gluon plasma. Lately, new measurements in small systems (pp and p-Pb collisions) with ALICE have shown that the production of strange hadrons over pions increases continuously with event multiplicity [1]. Moreover, this trend is more pronounced for hadrons consisting of more strange quarks. The open question still remains: what kind of mechanism causes this behaviour in small systems?

(*) E-mail: `lucia.anna.husova@cern.ch`

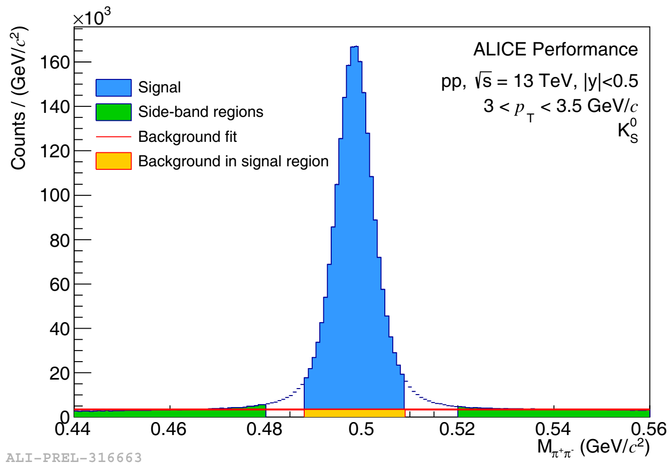

Fig. 1. – Invariant mass distribution for $\pi^+\pi^-$ pairs.

One of the possible approaches how this phenomenon can be studied is the dihadron correlation method with identified strange hadrons. In this method, a particle with high transverse momentum (trigger particle) is associated with other particles within the same event. A correlation function is built with the angular difference between trigger and associated particles in $\Delta\eta$, $\Delta\varphi$ space. With this approach, the jet contribution can be separated from the underlying event. For this purpose, $\mathrm{K^0_S}$ mesons and charged primary hadrons (h), a sample dominated by charged pions, were studied in pp collisions at $\sqrt{s} = 13$ TeV using ALICE data. Three correlations functions were considered, namely, h-h, $\mathrm{K^0_S}$-h and h-$\mathrm{K^0_S}$ (where the first particle in a pair is a trigger), all with transverse momentum ranges $3 < p_{\mathrm{T}}^{\mathrm{trigg}} < 15$ GeV/c and 1 GeV/$c < p_{\mathrm{T}}^{\mathrm{assoc}} < p_{\mathrm{T}}^{\mathrm{trigg}}$. The two-dimensional correlation function is normalised by the number of trigger particles and afterwards projected on the $\Delta\varphi$ axis where two peaks are present (near- and away-side). By the integration of the distribution, the per-trigger yields are calculated. From this, it can be estimated, how the h/$\mathrm{K^0_S}$ ratio in jets depends on multiplicity in small systems and how the presence of strange particle changes the jet-peak yield.

Because of the neutrality of the $\mathrm{K^0_S}$ meson, it cannot be tracked directly, but can be reconstructed from its decay into two pions: $\mathrm{K^0_S} \rightarrow \pi^+ + \pi^-$ (BR 69%) [2]. The daughter particles were identified via their specific energy loss and the background was suppressed by applying selection criteria based on the $\mathrm{K^0_S}$ decay topology. The final invariant mass spectrum for the momentum range 3–3.5 GeV/c is shown in fig. 1. The residual background was estimated and subtracted with help of the side-band regions.

The collisions were divided into multiplicity classes based on the event activity measured in forward and backward direction by the V0 scintillators of the ALICE detector. In the following, the results labelled with V0M 0–10% (V0M 50–100%) are 10%(50%) of the events with the highest (lowest) multiplicity.

2. – h-h correlations

The h-h correlation function was studied as a base for the identified correlation function. The near- and away-side per-trigger yields are given in fig. 2 as a function of $p_{\mathrm{T}}^{\mathrm{trigg}}$ for three multiplicity classes and the minimum bias sample. An increasing trend with

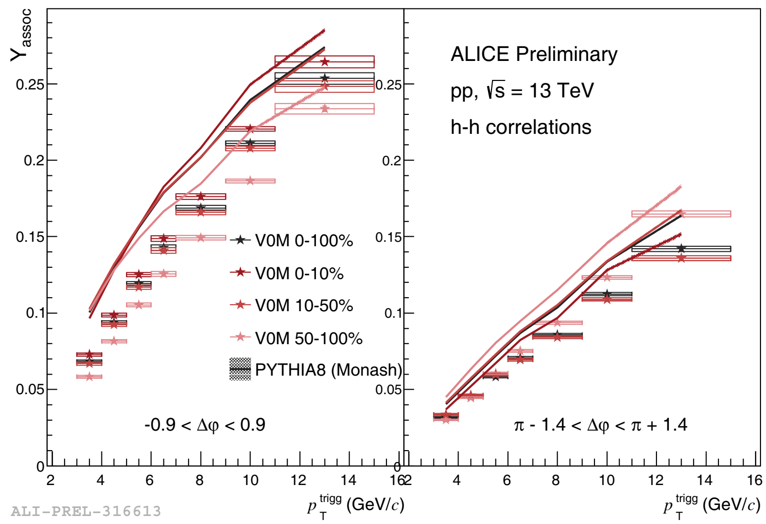

Fig. 2. – The per-trigger yields for the h-h correlation function at the near- (left) and away-side (right) compared with PYTHIA8.

p_T^{trigg} is observed, as more associated particles can be created in more energetic jets. On the near-side a multiplicity ordering is visible, where yields calculated in events with higher multiplicity are bigger than the yields from lower multiplicity class. This could be explained by interplay of softer (ridge present in long-range correlations [3]) and harder processes (fragmentation) differing within these multiplicity classes. On the away-side, this ordering is turned around for hight p_T^{trigg}. This can be understood by considering that the away-side jet can be outside of the pseudorapidity acceptance of the detector. By selecting the high (low) multiplicity events, one is biased towards configurations where the away-side jet is within (outside) the V0 acceptance. This yields into smaller (bigger) away-side yields for high (low) multiplicity. The yields are compared with PYTHIA8 Monash tune prediction [6]. This model can describe the data qualitatively, but not quantitatively, overestimating the yields both on the near- and away-side.

3. – K^0_S-h and h-K^0_S correlations

The $\Delta\varphi$ projection of the h-K^0_S correlation function in the lowest p_T^{trigg} region (fig. 3) was compared with three MC models: standard PYTHIA8 Monash tune with color reconnection (CR) [6], PYTHIA8 without CR and EPOS LHC [5]. None of these models can describe the shape of the correlation function in the whole $\Delta\varphi$ region. Both PYTHIA8 settings overestimate the near-side peak and describe the away-side peak reasonably well. On the other hand, EPOS underestimates both peaks, but overestimates the width of the near-side peak.

The yields as a function of p_T^{trigg} from h-K^0_S and K^0_S -h correlation functions are given in fig. 5 for both near- and away-side. An increasing trend is observed similar to the yields from h-h correlation function as described above. The yields were compared to the same three models as the $\Delta\varphi$ projection, and the behaviour can be derived from the previous one. Namely, both PYTHIA8 tunes overestimate the yields at the near-side while they are underestimated by EPOS. The model description is similar for the yields from both h-K^0_S and K^0_S -h correlation functions.

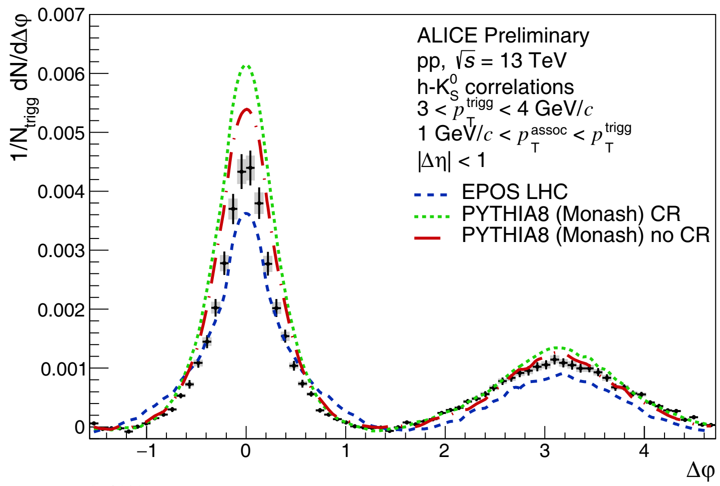

Fig. 3. – $\Delta\varphi$ projection of the h-K^0_S correlation function for the lowest p_T^{trigg} interval compared with MC models.

4. – Comparison of hadron- and strangeness-triggered yields

In order to compare the effect of strange and non-strange trigger and associated particles, the ratios to the yields from h-h correlation function were calculated.

These ratios for the K^0_S meson being the trigger particle are shown in fig. 6 as a function of p_T^{assoc}. A decreasing trend of the yield ratios with p_T^{assoc} is observed, which suggests that the probability for production of high-p_T associated particle within a jet triggered with K^0_S meson is smaller than within a jet triggered with an unidentified

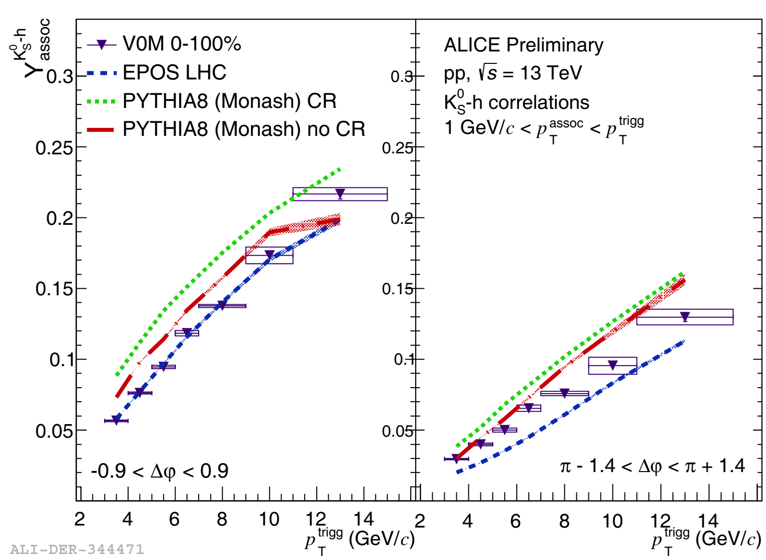

Fig. 4. – The per-trigger yields of K^0_S -h correlation functions as a function of p_T^{trigg} compared with MC models.

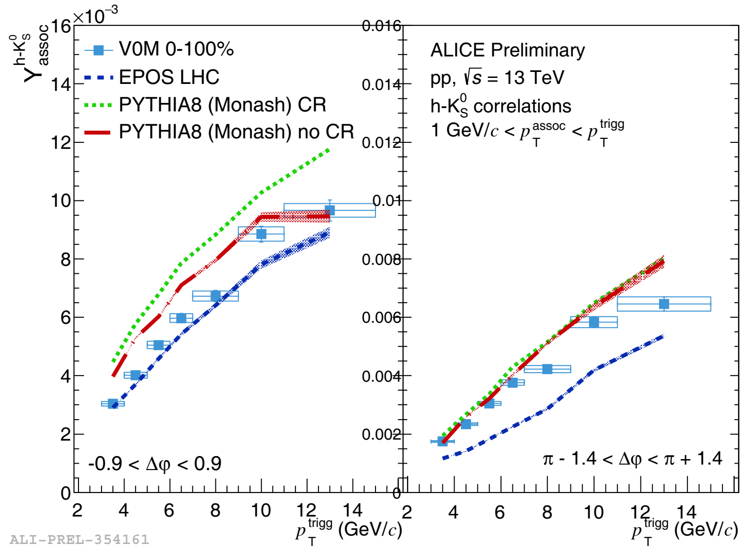

Fig. 5. – The per-trigger yields of h-K^0_S correlation functions as a function of p_T^{trigg} compared with MC models.

particle ($\pi^{\pm}$) and the difference becomes bigger with increasing of p_T^{assoc}. The results are also compared with MC models, which can reproduce the ratios the best for the highest p_T^{trigg} interval, while EPOS LHC and the standard PYTHIA8 Monash tune overestimate the ratios at low p_T^{trigg}.

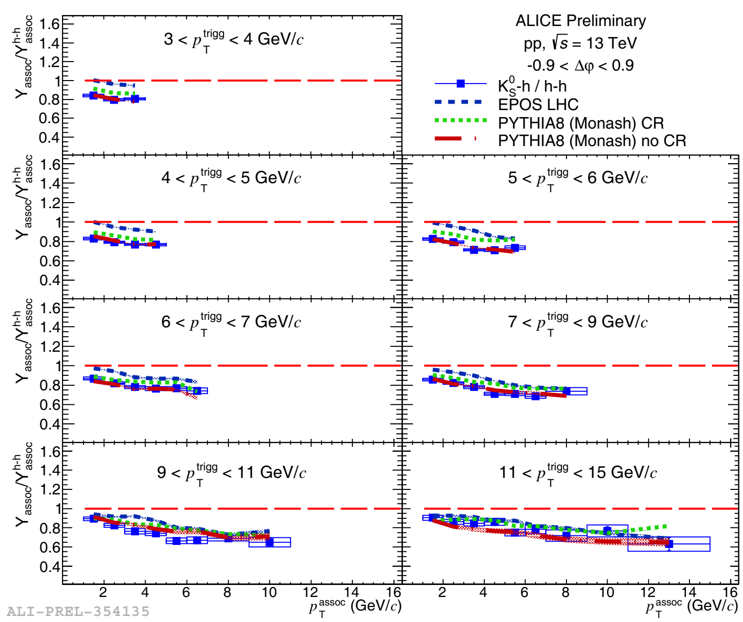

Fig. 6. – The ratios of near-side yields from K^0_S -h correlation function over the ones from h-h correlation function as a function of p_T^{assoc} compared with MC models.

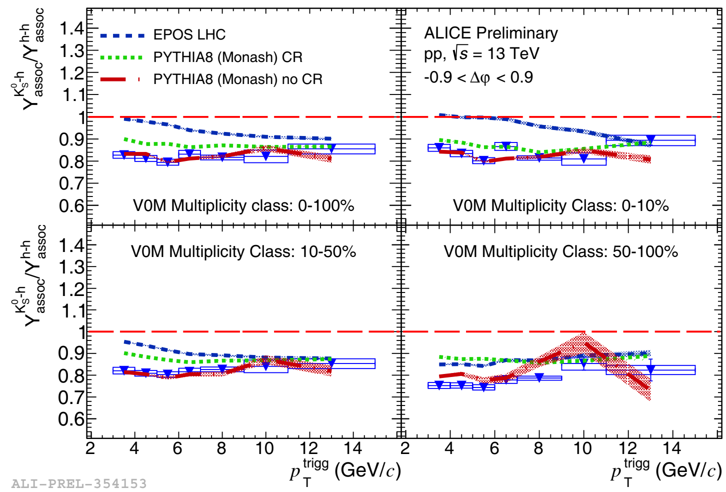

Fig. 7. – The ratios of near-side yields from K^0_S -h correlation function over the ones from h-h correlation function as a function of p_T^{trigg} compared with MC models.

In fig. 7, these ratios are plotted as a function of p_T^{trigg} and multiplicity. The ratios show no dependence on p_T^{trigg} in any of the multiplicity classes and are below unity, which indicates that the jets triggered with K^0_S meson have smaller associated yields. In the low p_T^{trigg} region, a small dependence on the multiplicity is observed. The ratios are well described with PYTHIA8 without CR while EPOS LHC predicts more pronounced dependence on the multiplicity than observed in the data.

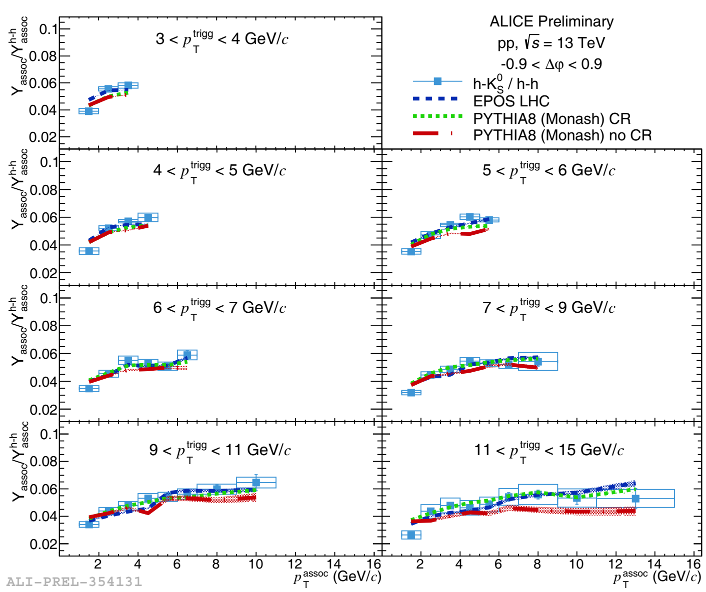

Fig. 8. – The ratios of near-side yields from h-K^0_S correlation function over the ones from h-h correlation function as a function of p_T^{assoc} compared with MC models.

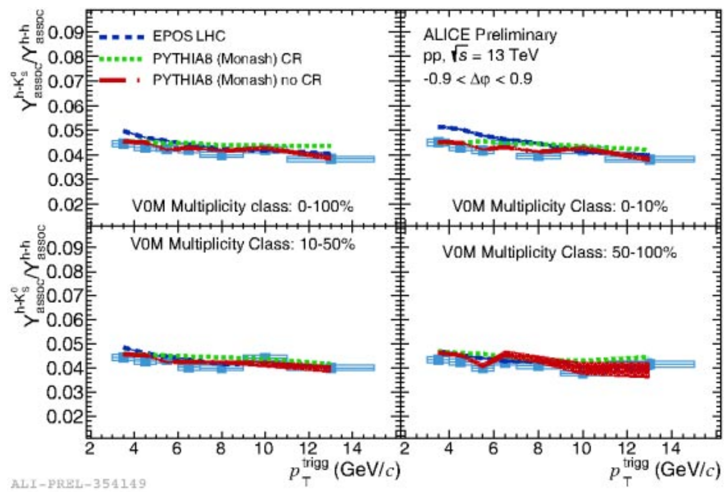

Fig. 9. – The ratios of near-side yields from h-K^0_S correlation function over the ones from h-h correlation function as a function of p_T^{trigg} compared with MC models.

In order to quantify the differences in the production of strange (K^0_S) and non-strange (unidentified) particles within jets, the $\frac{h-K^0_S}{h-h}$ yield ratios were calculated and are shown in fig. 8 as a function of p_T^{assoc}. An increasing trend with p_T^{assoc} is observed which means that the production of K^0_S mesons is, for high-p_T, slightly enhanced in jets. This behaviour is similar to the p_T -integrated yield ratio $2K^0_S/(\pi^+ + \pi^-)$ measurement [4]. The yield ratios are reasonably well described by all used MC models.

The p_T^{trigg} and multiplicity dependence of the yield ratio is shown in fig. 9. The ratios slightly decrease with p_T^{trigg} in all accounted multiplicity classes, but no multiplicity dependence can be observed. From this, it follows that the jet fragmentation process does not contribute to the strangeness enhancement measured in the previous analyses integrated in p_T . The comparison to the MC models was performed also in this case, and while both PYTHIA8 settings reproduce the data well, the EPOS LHC predicts a small enhancement at small p_T^{trigg} in the 0–10% multiplicity class compared to minimum bias sample or lower multiplicity classes.

5. – Conclusions

The per-trigger yield measurement from h-K^0_S, h-h and K^0_S -h correlation functions was presented. A per-trigger yield dependence on the event multiplicity was observed which can be explained on the near-side with interplay of soft (long-range correlation) and hard (jet fragmentation) processes. On the away-side, this is caused by the position of the away-side jet in psedorapidity which biases the event activity determination. Neither the shape of the h-K^0_S correlation function nor the yield dependence on p_T^{trigg} can be described by the used MC models. A slight dependence of the jet-peak yield ratio on the event multiplicity was observed for the K^0_S -h correlation function. This was not the case for h-K^0_S. An increasing trend of the $\frac{h-K^0_S}{h-h}$ yield ratio with p_T^{assoc} is consistent with previous inclusive $2K^0_S/(\pi^+ + \pi^-)$ measurement.

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