

Measurement of strange hadron production in and out of jets in proton-proton collisions with ALICE

C. DE MARTIN⁽¹⁾⁽²⁾

⁽¹⁾ *INFN, Sezione di Trieste - Trieste, Italy*

⁽²⁾ *Dipartimento di Fisica, Università di Trieste - Trieste, Italy*

received 28 January 2022

Summary. — In pp collisions, the ratio of strange hadron yields to charged pion yields increases with the multiplicity of produced particles. To understand if this phenomenon is related to soft or hard processes, the strange hadron production in and out of jets was studied by exploiting the angular correlation between high- p_T particles and strange hadrons identified with the ALICE detector. In this article, the near-side jet yield and the out-of-jet yield of K_S^0 and Ξ^\pm are shown as a function of the multiplicity of charged particles produced in pp collisions at $\sqrt{s} = 13$ TeV. The results suggest that soft processes give the dominant contribution to strange particle production in pp collisions.

1. – Introduction

Heavy-ion collisions are a unique tool to study the quark-gluon plasma (QGP) [1], a state of matter in which quarks and gluons are deconfined. QGP is expected to form when high energy density and temperature conditions are reached, as in ultra-relativistic heavy-ion collisions. One proposed signature of the QGP formation is the strangeness enhancement effect [2], which consists of an increase in the ratio of strange to non-strange hadron yields in Pb-Pb collisions with respect to minimum bias pp collisions. This effect has been further investigated by studying its dependence on the multiplicity of charged particles produced in the collisions [3-7].

Results show that the ratios of different strange hadron yields to pion yields increase with the multiplicity of charged particles, reaching in high-multiplicity pp collisions values comparable to those measured in peripheral Pb-Pb collisions. The smooth transition observed across different collision systems is striking, since different particle production mechanisms are expected to be involved in the different collision systems. In addition, the ratios do not show any dependence on the centre-of-mass energy at the energy scale of the LHC collisions (\sim TeV), suggesting that the driving factor of the observed strangeness enhancement is the multiplicity of charged particles produced in the final state of the

collisions. Results also show that the strangeness enhancement effect is larger for particles with larger strangeness content.

The strangeness enhancement observed in pp collisions is only qualitatively reproduced by state-of-the-art phenomenological models implemented in general-purpose Monte Carlo generators [8, 9].

In this article, the production of K_S^0 and Ξ^\pm in jets and out of jets in pp collisions at $\sqrt{s} = 13$ TeV with the ALICE detector [10] is presented. The results provide new insights into the contribution of hard scattering events and of soft particle production processes to the strangeness enhancement effect in small collision systems.

2. – Analysis strategy

In order to separate strange hadrons produced in jets from those produced out of jets, the angular correlation between high- p_T charged tracks (trigger particles) and strange hadrons is exploited.

The trigger particle is defined as the highest- p_T charged particle found in the event, satisfying the kinematic selection $p_T > 3$ GeV/ c . In this study, trigger particles are considered as a proxy for the jet axis. Strange hadrons are reconstructed via their weak decays: $K_S^0 \rightarrow \pi^+\pi^-$, and $\Xi^- \rightarrow \Lambda\pi^- \rightarrow p\pi^-\pi^-$ together with its charge conjugate. Charged pion and proton tracks are reconstructed and identified using the Time Projection Chamber (TPC) [11] of the ALICE detector. Topological and kinematic selections are applied to reduce the combinatorial background. The K_S^0 and Ξ^\pm signals are extracted from fits to the invariant-mass distributions of their decay products.

Strange hadrons produced in jets are expected to be found at a small angular distance from the trigger particles, and therefore the angular-correlation distribution in a $(\Delta\eta, \Delta\varphi)$ region centred at $(0, 0)$ is used to extract the near-side jet yield, after proper subtraction of the out-of-jet contribution. The out-of-jet yield is obtained from larger values of $\Delta\eta$ and $\Delta\varphi$ ($0.75 < \Delta\eta < 1.2$, $1 < \Delta\varphi < 2$), where no contribution from jet production is expected. The whole angular-correlation distribution ($|\Delta\eta| < 1.2$, $-\pi/2 < \Delta\varphi < 3/2\pi$) is used to obtain the full production yield.

The analysis is performed in five multiplicity classes based on the distribution of the total charge deposited in the two V0 detectors placed at forward rapidity [12]. For each V0M multiplicity class, an average number of charged particles produced at midrapidity $\langle dN/d\eta \rangle_{|\eta| < 0.5}$ is assigned.

3. – Results

The out-of-jet and near-side jet p_T spectra of the Ξ^\pm baryon in the different multiplicity classes are shown in the left and right panels of fig. 1, respectively. The out-of-jet spectra, which are related to soft particle production, are less hard than the near-side jet spectra. The same is observed for the K_S^0 meson. In order to compute the p_T -integrated yield, the p_T spectra are interpolated. The fits allow extrapolating the yield in the p_T intervals where it cannot be measured, while in the complementary p_T interval the measured values are used.

The left (right) panel of fig. 2 shows the K_S^0 (Ξ^\pm) yields per trigger particle normalised to the corresponding $\Delta\eta\Delta\varphi$ area as a function of $\langle dN/d\eta \rangle_{|\eta| < 0.5}$. For both strange hadrons, the out-of-jet yield increases with the multiplicity of charged particles, while the near-side jet yield shows a milder evolution, suggesting that the relative contribution

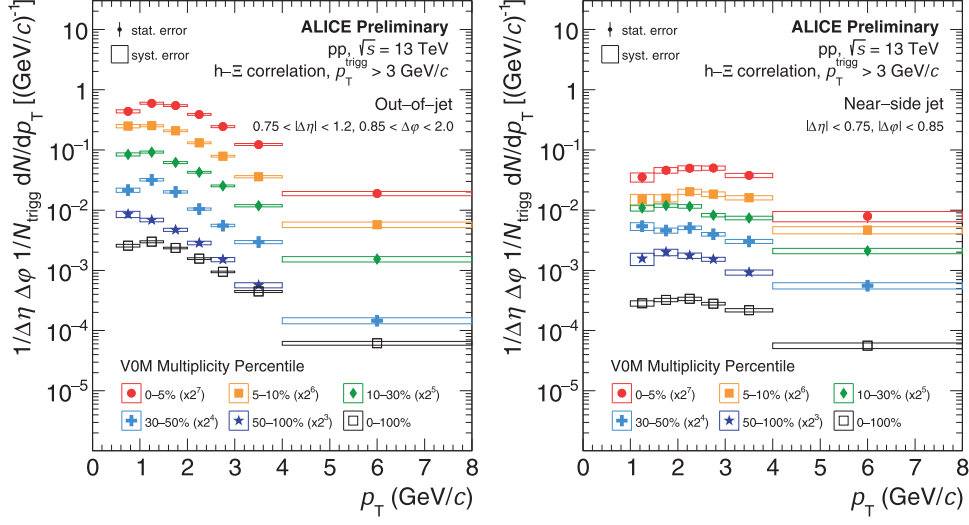


Fig. 1. Ξ^\pm p_T spectra for out-of-jet (left) and near-side jet (right) production. The statistical and systematic uncertainties are represented by vertical lines and boxes, respectively.

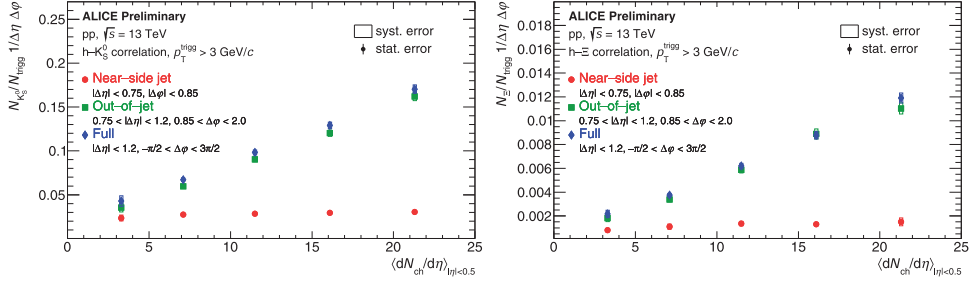


Fig. 2. K_S^0 (left) and Ξ^\pm (right) yields per trigger particle and per unit of $\Delta\eta\Delta\phi$ area *vs.* charged-particle multiplicity at midrapidity $\langle dN_{ch}/d\eta \rangle_{|\eta|<0.5}$ for near-side jet (red markers), out-of-jet (green markers) and full (blue markers) production. The statistical and systematic uncertainties are represented by vertical lines and boxes, respectively.

of soft processes increases with multiplicity. The full yield is observed to be driven by the out-of-jet production.

The strangeness enhancement effect can be observed in the Ξ^\pm/K_S^0 yield ratio as a function of $\langle dN_{ch}/d\eta \rangle_{|\eta|<0.5}$ (fig. 3). The increase with multiplicity of the ratio of full yields is attributed to the larger strangeness content of the Ξ^\pm ($|S| = 2$) with respect to the K_S^0 ($|S| = 1$). The out-of-jet ratio increases with multiplicity in a similar way. Conclusive statements about the multiplicity dependence of the near-side jet ratio cannot be drawn due to large uncertainties. However, under the assumption that systematic uncertainties are correlated in multiplicity, and considering therefore only statistical uncertainties, a flat trend with multiplicity can be excluded. Moreover, an increase with multiplicity compatible to the one shown by the out-of-jet yield ratio cannot be excluded within statistical uncertainties.

While the out-of-jet ratio is compatible with the ratio of full yields, the near-side jet ratio is smaller for all values of multiplicity, suggesting that soft particle production

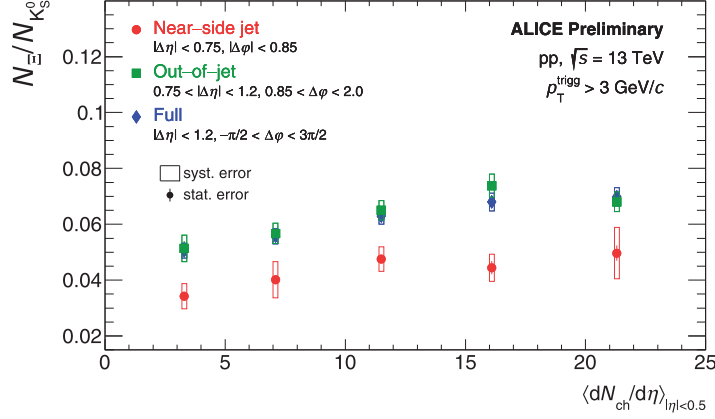


Fig. 3. $-\Xi^\pm/K_S^0$ yield ratio *vs.* charged-particle multiplicity at midrapidity $\langle dN/d\eta \rangle_{|\eta|<0.5}$ for near-side jet (red markers), out-of-jet (green markers) and full (blue markers) production. The statistical and systematic uncertainties are represented by vertical lines and boxes, respectively.

represents the dominant contribution to the strangeness enhancement effect in pp collisions.

4. – Conclusions

The ALICE Collaboration has carried out several multi-differential analyses to investigate the origin of the strangeness enhancement effect in small collision systems. In this article, the near-side jet and out-of-jet production of K_S^0 and Ξ^\pm hadrons was presented as a function of the multiplicity of charged particles produced in pp collisions at $\sqrt{s} = 13$ TeV. The results suggest that soft processes represent the dominant contribution to strange hadron production in pp collisions.

REFERENCES

- [1] PASECHNIK R. and ŠUMBERA M., *Universe*, **3** (2017) 7.
- [2] RAFELSKI J. and MÜLLER B., *Phys. Rev. Lett.*, **48** (1982) 1066.
- [3] ALICE COLLABORATION, *Nat. Phys.*, **13** (2017) 535.
- [4] ALICE COLLABORATION, *Eur. Phys. J. C*, **80** (2020) 167.
- [5] ALICE COLLABORATION, *Phys. Lett. B*, **758** (2016) 389.
- [6] ALICE COLLABORATION, *Phys. Lett. B*, **728** (2014) 25.
- [7] ALICE COLLABORATION, *Phys. Lett. B*, **728** (2014) 216.
- [8] SJOSTRAND T., MRENNNA S. and SKANDS P. Z., *Comput. Phys. Commun.*, **178** (2008) 852.
- [9] WERNER K., GUIOT B., KARPENKO I. and PIEROG T., *Phys. Rev. C*, **89** (2014) 216.
- [10] ALICE COLLABORATION, *Int. J. Mod. Phys. A*, **29** (2014) 1430044.
- [11] ALME J. *et al.*, *Nucl. Instrum. Methods A*, **622** (2010) 316.
- [12] ALICE COLLABORATION, *J. Instrum.*, **8** (2013) P10016.