Production of strange particles in charged jets in Pb–Pb and p–Pb collisions measured with ALICE

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Abstract. Measurements of spectra of identified particles produced in jets in heavy-ion collisions can provide further important insights into the interplay of various hadronisation processes which participate in the particle production in the hot and dense medium. In this contribution, we present the measurements of the p_{T} spectra of Λ baryons and $\mathrm{K}^0_{\mathrm{S}}$ mesons produced in association with charged jets in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV and in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The results are obtained with the ALICE detector at the LHC, exploiting the excellent particle identification capabilities of this experiment. Baryon-to-meson ratios of the spectra of strange particles associated with jets are studied in central collisions and are compared to the ratios obtained for inclusive particles and for particles coming from the underlying event.

1. Introduction

An enhancement of the baryon-to-meson ratio is observed for inclusive spectra of light-flavour particles produced at intermediate transverse momenta (p_{T}) ($2\ \mathrm{GeV}/c < p_{\mathrm{T}} < 6\ \mathrm{GeV}/c$) in heavy-ion collisions when compared to the ratio in proton–proton (pp) collisions. It was first observed at the Relativistic Heavy Ion Collider [1, 2] and later at the Large Hadron Collider (LHC) as well [3]. The ratio of the p_{T} spectrum of Λ baryons to the spectrum of $\mathrm{K}^0_{\mathrm{S}}$ mesons measured in lead–lead (Pb–Pb) collisions with the ALICE experiment is increasing dramatically with centrality and reaching values three times greater than the ratio in pp collisions. This phenomenon also manifests in proton–lead (p–Pb) collisions and depends on particle multiplicity [4]. This enhancement is still not fully understood.

Parton fragmentation and hadronisation is a well-known concept of hadron production in perturbative QCD describing how a high-p_{T} parton, produced in a hard scattering process, fragments in vacuum into a collimated spray of hadrons called a jet. Fragmentation in vacuum cannot explain the observed enhancement. However, this process might be modified by interaction of the fragmenting partons with constituents of the hot and dense strongly interacting matter created in ultra-relativistic heavy-ion collisions.

Another frequently discussed scenario proposed to explain the shape of the observed baryon-to-meson ratio is parton recombination which assumes that multiple partons (close to each other in phase space) cluster together to form a hadron. In such case, a quark clusters with an anti-quark to form a meson and a baryon is produced when three quarks cluster which gives rise to a harder p_{T} spectrum of baryons with respect to that of mesons.

We aim to understand the origin of the $\Lambda/\mathrm{K}^0_\mathrm{S}$ enhancement by separating hadrons produced in jets from hadrons produced in the thermalised bulk. Results of this analysis will allow us to tell whether the baryon-to-meson ratio is enhanced due to the bulk effects in the plasma, like for example parton recombination or radial flow, or whether it is a phenomenon caused (also) by a modification of the jet fragmentation in the medium.

2. Analysis

The analysis is performed on data recorded in the ALICE detector at the LHC during the Pb–Pb and p–Pb runs with collisions at the centre-of-mass energies of $\sqrt{s_\mathrm{NN}} = 2.76$ TeV and 5.02 TeV respectively. Tracking of charged particles in the central barrel is provided by the Inner Tracking System and the Time Projection Chamber, both placed in a magnetic field of 0.5 T. Centrality in Pb–Pb collisions and multiplicity classes in case of p–Pb collisions are estimated from the multiplicity of charged particles measured in the V0 detectors at forward rapidities [5].

The analysis of neutral strange particles in charged jets is based on two main parts: reconstruction of charged jets and reconstruction of neutral strange particles.

The charged jets are reconstructed using tracks of charged primary particles having $p_\mathrm{T}^\mathrm{track} > 150\,\mathrm{MeV}/c$ and uniform distribution in azimuth and in pseudorapidity of range $|\eta_\mathrm{track}| < 0.9$. These tracks are used as input for the anti-k_t algorithm (implemented in the FastJet package [6]). Values used for the resolution parameter of the jet algorithm are $R = 0.2, 0.3$ in case of the Pb–Pb collisions whereas for the p–Pb collisions, it is feasible to use also $R = 0.4$ since the background from soft processes is not as large as in the Pb–Pb case. The definition of charged jets implies that neutral primary particles are not included in the jet constituents and do not contribute to the reconstructed jet momenta. Clusters reconstructed by the k_t algorithm are used to estimate the average level of background in each event which is then subtracted from the momenta of reconstructed jets [7]. In order to further reduce the contribution of fake jets, cuts are applied on jet p_T ($p_\mathrm{T}^\mathrm{jet,ch}$), p_T of the leading jet constituent and jet area ($A_\mathrm{jet,ch}$).

Neutral strange particles (V^0) are measured by reconstructing their weak decays into two charged daughter particles, namely $\mathrm{K}^0_\mathrm{S} \to \pi^+ + \pi^-$ and $\Lambda \to \mathrm{p} + \pi^-$. Cuts on parameters of the decay topology are used to suppress combinatorial background in the sample of V^0 candidates and the signal yield is extracted from the resulting invariant-mass distribution.

If a V^0 candidate is accepted, its distances from the axes of selected jets in the event are calculated to check whether it is in a jet cone. A jet is selected only if its cone is fully contained within the acceptance region of V^0 particles: $|\eta_\mathrm{jet,ch}| < |\eta_{\mathrm{V}^0}|^\mathrm{max} - R$. The candidate is considered to be inside a jet cone if the distance, calculated in azimuth and pseudorapidity, is less than the resolution parameter of the jet finder:

$$\sqrt{(\varphi_{\mathrm{V}^0} - \varphi_\mathrm{jet,ch})^2 + (\eta_{\mathrm{V}^0} - \eta_\mathrm{jet,ch})^2} < R. \tag{1}$$

Spectra of associated particles are studied for two intervals of jet momentum: $p_\mathrm{T}^\mathrm{jet,ch} > 10\,\mathrm{GeV}/c$ and $p_\mathrm{T}^\mathrm{jet,ch} > 20\,\mathrm{GeV}/c$. Raw spectra of V^0 particles associated with cones of charged jets in central Pb–Pb collisions, normalised per unit area in the ($\varphi \times \eta$)-space, are presented in Fig. 1. Area used for normalisation is the area of the region of associated particles.

Particles in jet cones do not originate only from the jet fragmentation but also from underlying event (UE). In order to estimate this contribution, the V^0 particles are also associated with regions where only underlying event is expected to be present. In case of Pb–Pb collisions, these regions are defined by five different methods (e.g. perpendicular or randomly placed cones).

Prior to subtraction of the contribution from UE, we apply the efficiency correction of the V^0 reconstruction, using the inclusive simulated particles. The pseudorapidity distribution of the simulated jets in the Monte Carlo sample does not correspond to the distribution of real selected

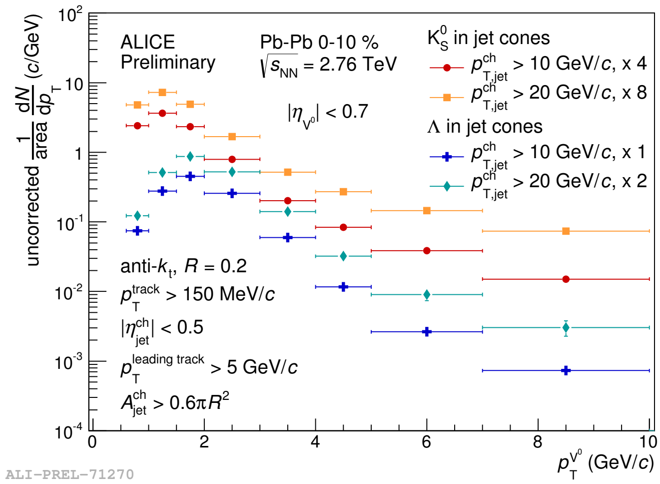

Figure 1. Raw spectra of V^0 particles associated with charged jets with $R = 0.2$ above a given $p_{\mathrm{T}}^{\mathrm{jet,ch}}$ threshold in central Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV.

jets. Since the efficiency correction is applied only as a function of $p_{\mathrm{T}}^{\mathrm{V}^0}$, the η distributions of simulated V^0 particles associated with jet cones and with the UE regions have to be reweighted in order to match the shapes observed in real data.

After the efficiency correction, spectra of V^0 particles in jets are obtained by subtracting the UE contribution from the spectra of particles in jet cones.

Strange particles in jets can be produced also by decays of jet constituents, namely in this analysis, we aim to account for the contribution of the Λ production from decays of $\Xi^{0,-}$ baryons. The corresponding feed-down fraction can only be roughly estimated since spectra of Ξ in jets have not been measured yet. We consider two scenarios: feed-down fraction calculated for spectra of inclusive Λ baryons and fraction obtained from Λ baryons in jets simulated in pp at $\sqrt{s} = 2.76$ TeV or 5.02 TeV with PYTHIA 8 tune 4C [8, 9]. These scenarios are taken as an upper and a lower limit of the systematic uncertainty on the feed-down contribution.

3. Results

Figure 2 shows the p_{T} dependence of the ratio of the corrected yields of Λ baryons to that of $\mathrm{K}^0_{\mathrm{S}}$ mesons in charged jets in high-multiplicity p–Pb collisions for two $p_{\mathrm{T}}^{\mathrm{jet,ch}}$ thresholds, compared with the ratios for measured inclusive particles and for particles simulated in PYTHIA 8. The measured baryon-to-meson ratio in jets in p–Pb collisions is below the measured ratio of inclusive particles in p–Pb collisions, below the measured ratio of inclusive particles in pp collisions [10] (not shown) and is also below the ratio of inclusive particles obtained with PYTHIA simulation. Moreover, the measured ratio exhibits a surprising similarity with ratios of particles in jets simulated in PYTHIA and does not evince any significant dependence on R or $p_{\mathrm{T}}^{\mathrm{jet,ch}}$. The results indicate no visible modification of strangeness production in charged jets in p–Pb and the enhancement of the baryon-to-meson ratio thus seems to be due to bulk effects.

4. Summary

We presented the motivation for studying spectra of strange particles in jets in heavy-ion collisions, techniques used in the analysis of the $\Lambda/\mathrm{K}^0_{\mathrm{S}}$ ratio in charged jets in Pb–Pb and p–Pb collisions were described and we showed the first results of such measurement, performed by ALICE in p–Pb collisions. The measured $\Lambda/\mathrm{K}^0_{\mathrm{S}}$ ratio indicates that the enhancement originates

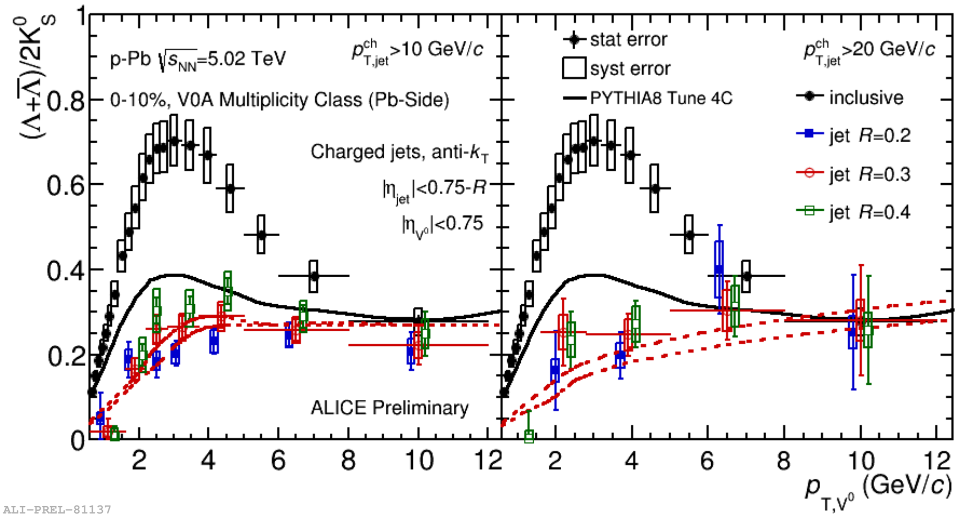

Figure 2. Λ/K^0_S ratio in charged jets with $R = 0.2, 0.3, 0.4$ in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV for $p_T^{jet,ch} > 10$ GeV/c (left) and $p_T^{jet,ch} > 20$ GeV/c (right), compared with the inclusive ratio and simulation results. Black solid line indicates the inclusive ratio from PYTHIA 8. Red dashed lines denote the spread of ratios in PYTHIA jets for all used values of R.

from bulk effects. The determination of final corrections and uncertainties of the results in case of Pb–Pb collisions is under ongoing investigation.

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