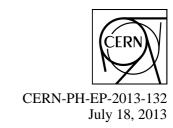
# EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH





# $K_S^0$ and $\Lambda$ production in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76 \text{ TeV}$

ALICE Collaboration\*

#### **Abstract**

The ALICE measurement of  $K_S^0$  and  $\Lambda$  production at mid-rapidity in Pb-Pb collisions at  $\sqrt{s_{\rm NN}}=2.76\,{\rm TeV}$  is presented. The transverse momentum  $(p_{\rm T})$  spectra are shown for several collision centrality intervals and in the  $p_{\rm T}$  range from 0.4 GeV/c (0.6 GeV/c for  $\Lambda$ ) to 12 GeV/c. The  $p_{\rm T}$  dependence of the  $\Lambda/K_S^0$  ratios exhibits maxima in the vicinity of 3 GeV/c, and the positions of the maxima shift towards higher  $p_{\rm T}$  with increasing collision centrality. The magnitude of these maxima increases by almost a factor of three between most peripheral and most central Pb-Pb collisions. This baryon excess at intermediate  $p_{\rm T}$  is not observed in pp interactions at  $\sqrt{s}=0.9\,{\rm TeV}$  and at  $\sqrt{s}=7\,{\rm TeV}$ . Qualitatively, the baryon enhancement in heavy-ion collisions is expected from radial flow. However, the measured  $p_{\rm T}$  spectra above 2 GeV/c progressively decouple from hydrodynamical-model calculations. For higher values of  $p_{\rm T}$ , models that incorporate the influence of the medium on the fragmentation and hadronization processes describe qualitatively the  $p_{\rm T}$  dependence of the  $\Lambda/K_S^0$  ratio.

<sup>\*</sup>See Appendix A for the list of collaboration members

Collisions of heavy nuclei at ultra-relativistic energies are used to investigate a deconfined high temperature and density state of nuclear matter, the quark-gluon plasma. The transverse momentum  $(p_T)$ spectra of identified hadrons and their ratios provide a means for studying the properties of this state of matter and the mechanisms that transform quasi-free partons into observed hadrons. It was observed at the Relativistic Heavy Ion Collider (RHIC) [1, 2], that the  $\Lambda/K_S^0$  and  $p/\pi$  ratios at intermediate  $p_T$  (from about 2 to about 6 GeV/c) are markedly enhanced in central heavy-ion collisions when compared with the peripheral or pp results. A similar observation was also made at the Super Proton Synchrotron [3]. These observations led to a revival and further development of models based on the premise that deconfinement opens an additional mechanism for hadronization by allowing two or three soft quarks from the bulk to combine forming a meson or a baryon [4, 5]. The baryons then appear at a higher  $p_T$  than the mesons, since their momentum is the sum of the momenta of three quarks, instead of only two. If the (anti-)quarks generated by (mini)jet fragmentation are also involved in recombination [6], the baryon enhancement could extend to even higher momenta, up to 10-20 GeV/c [7]. At lower  $p_T$ , the hydrodynamical radial flow also contributes to the baryon enhancement, because the baryons, being heavier, are pushed to higher  $p_T$  than the mesons. But the applicability of such models is limited to transverse momenta below 2 GeV/c, above which the observed  $p_T$  spectra start to deviate from hydrodynamical calculations.

The evolution of the baryon to meson ratio with collision energy, comparisons with pp events and a study of the centrality dependence in nucleus–nucleus collisions provides additional information about this "baryon anomaly" [8]. In Pb–Pb collisions at the Large Hadron Collider (LHC) energies, that are around 14 times higher than those at RHIC, the maximum of the  $\Lambda/K_S^0$  ratio is expected to be shifted towards higher  $p_T$ , because of an increased partonic radial flow [4, 5]. In contrast, the  $\Lambda/K_S^0$  ratio measured in elementary pp collisions should not change significantly with the center-of-mass energy, since the particle production is presumably dominated by fragmentation processes.

The relative contribution of different hadronization mechanisms changes with hadron momentum. While at intermediate  $p_T$  recombination might be dominating, fragmentation could take over at higher  $p_T$ , depending on the underlying momentum distributions of the quarks. For this reason it is important to identify baryons and mesons in a wide momentum range. The topological decay reconstruction of  $K_S^0$  and  $\Lambda$  provides an opportunity to extend the baryon and meson identification from low to high transverse momenta, which can not easily be achieved using other particle identification methods without introducing additional systematic effects.

In this Letter we present the  $K_S^0$  and  $\Lambda$  transverse-momentum spectra and the  $\Lambda/K_S^0$  ratios from Pb–Pb collisions at  $\sqrt{s_{\rm NN}}=2.76$  TeV recorded in November 2010's heavy-ion run of the LHC. The  $p_{\rm T}$  dependence of the  $\Lambda/K_S^0$  ratios is compared with pp results obtained at  $\sqrt{s}=0.9$  and 7 TeV, that bracket the Pb–Pb measurements in energy.

A description of the ALICE apparatus can be found in [9]. For the analysis presented here, we used the Time Projection Chamber (TPC) and the Inner Tracking System (ITS) to reconstruct charged particle tracks within the pseudo-rapidity interval of  $|\eta| < 0.9$ . Particle momenta were determined from the track curvature in a magnetic field of 0.5 T. The two VZERO scintillator counters, covering pseudorapidity ranges of  $2.8 < \eta < 5.1$  (VZERO-A) and  $-3.7 < \eta < -1.7$  (VZERO-C), provided a signal proportional to the number of charged particles in these acceptance regions. The VZERO detectors together with the two innermost Silicon Pixel Detector (SPD) layers of the ITS, positioned at radii of 3.9 and 7.6 cm (acceptance  $|\eta| < 2.0$  and  $|\eta| < 1.4$  respectively), were used as an interaction trigger. To select a pure sample of hadronic interactions, only events with at least one particle hit in each of the three trigger detectors (SPD, VZERO-A and VZERO-C) were accepted offline. The selected events were required to have reconstructed primary vertices with a position along the beam direction within  $\pm 10$  cm of the nominal center of the detector to ensure a uniform acceptance in pseudo-rapidity for the particles under study. The events were then classified according to the collision centrality, based on the

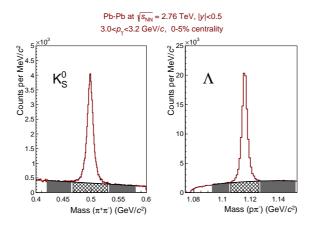


Fig. 1: Examples of invariant mass distributions for  $K_S^0$  and  $\Lambda$ . The filled areas to the sides of the peaks were used to fit the background in order to estimate the background level under the peaks, indicated as the light shaded areas.

sum of the amplitudes in the VZERO counters fitted with a Glauber model description of the collisions, as discussed in [10]. After these selections, we retained for the final analysis 13 million events in the collision centrality range from 0 to 90% of the nuclear cross-section.

The weakly decaying neutral hadrons ( $K_S^0$  and  $\Lambda$ ) were reconstructed using their distinctive V-shaped decay topology in the channels (and branching ratios)  $K_S^0 \to \pi^+\pi^-$  (69.2%) and  $\Lambda \to p\pi^-$  (63.9%) [11]. The reconstruction method forms so-called V0 decay candidates and the details are described in [12]. Because of the large combinatorial background in Pb-Pb collisions, a number of topological selections had to be more restrictive than those used in the pp analysis. In particular, the cuts on the minimum distance of closest approach between the V0 decay products and on the minimum cosine of the V0 pointing angle (the angle between the line connecting the primary and V0 vertices and the V0 momentum vector) [12] were changed to one standard deviation and to 0.998, respectively. In addition, we retained only the V0 candidates reconstructed in a rapidity window of |y| < 0.5, with their decay-product tracks within the acceptance window  $|\eta| < 0.8$ . To further suppress the background, we kept only V0 candidates satisfying the cut on the proper decay length  $l_T \cdot m/p_T < 3 c\tau (4 c\tau)$ , where  $l_T$  and m are the V0 transverse decay length and nominal  $\Lambda$  ( $K_S^0$ ) mass [11], and  $c\tau$  is 7.89 cm (2.68 cm) for  $\Lambda$  ( $K_S^0$ ) [11]. For the  $\Lambda$ candidates with  $p_T < 1.2 \text{ GeV/}c$ , a conservative three-standard-deviation particle-identification cut on the difference between the specific energy loss (dE/dx) measured in the TPC and the expected energy loss as defined by a momentum-dependent parameterization of the Bethe–Bloch curve was applied for the proton decay-product tracks. To reduce the contamination of  $\Lambda$  reconstructed as  $K_S^0$ , an additional selection was applied in the Armenteros-Podolanski variables [13] of  $K_S^0$  candidates, rejecting candidates with  $p_{\rm T}^{\rm arm} < 0.2 \times |\alpha^{\rm arm}|$ . Here,  $p_{\rm T}^{\rm arm}$  is the projection of the positively (or negatively) charged decay-product momentum on the plane perpendicular to the V0 momentum. The decay asymmetry parameter  $lpha^{arm}$  is defined as  $\alpha^{\rm arm} = (p_{\parallel}^+ - p_{\parallel}^-)/(p_{\parallel}^+ + p_{\parallel}^-)$ , where  $p_{\parallel}^+(p_{\parallel}^-)$  is the projection of the positively (negatively) charged decay-product momentum on the momentum of the V0. The minimal radius of the fiducial volume of the secondary vertex reconstruction was chosen to be 5 cm to minimize systematic effects introduced by efficiency corrections. It was verified that the decay-length distributions reconstructed within this volume were exponential and agreed with the  $c\tau$  values given in the literature [11].

The raw yield in each  $p_T$  bin was extracted from the invariant-mass distribution obtained for this momentum bin. Examples of such distributions are shown in Fig. 1. The raw yield was calculated by subtracting a fit to the background from the total number of V0 candidates in the peak region. This region was  $\pm 5\sigma$  for  $K_S^0$ , and  $\pm (3.5\sigma + 2 \text{ MeV}/c^2)$  (to better account for tails in the mass distribution at low  $p_T$ ) for  $\Lambda$ . The  $\sigma$  was obtained by a Gaussian fit to the mass peaks. The background was determined by fitting polynomials of first or second order to side-band regions left and right of the peak region.

The overall reconstruction efficiency corrections were extracted from a procedure based on HIJING events [14] and using GEANT3 [15] for transporting simulated particles, followed by a full calculation of the detector responses and reconstruction done with the ALICE simulation and reconstruction framework [16]. The estimated efficiency included the geometrical acceptance of the detectors, track reconstruction efficiency, the efficiency of the applied topological selection cuts, and the branching ratios for the V0 decays. The typical efficiencies for both particles were about 30% for  $p_T > 4$  GeV/c, dropping to 0 at  $p_T \sim 0.3$  GeV/c. The efficiencies did not change with the event centrality for  $p_T$  above a few GeV/c. However, at lower  $p_T$ , they were found to be dependent on the event centrality. For  $\Lambda$  at  $p_T < 0.9$  GeV/c the difference is about factor 2 between the 0–5% and 80–90% centrality intervals. This was because the distributions of the topological variables used in the selections were changing with the centrality, whereas the corresponding threshold cut values were kept constant. The effect was well reproduced by the Monte Carlo simulations. The final momentum spectra were therefore corrected in each centrality bin separately.

The spectra of  $\Lambda$  were in addition corrected for the feed-down contribution coming from the weak decays of  $\Xi^-$  and  $\Xi^0$ . For this purpose, a two-dimensional response matrix, correlating the  $p_T$  of the detected decay  $\Lambda$  with the  $p_T$  of the decayed  $\Xi$ , was generated from Monte-Carlo simulations. By normalizing this matrix to the measured  $\Xi^-$  spectra [17], the distributions of the feed-down  $\Lambda$  were determined and subtracted from the inclusive  $\Lambda$  spectra. The phase space distribution and total yield for the  $\Xi^0$  were assumed to be the same as for the  $\Xi^-$ . The feed-down correction thus obtained was found to be a smooth function of  $p_T$  with a maximum of about 23% at  $p_T \sim 1$  GeV/c and monotonically decreasing to 0% at  $p_T > 12$  GeV/c. As a function of centrality, this correction changed by only a few per cent.

Since the ratio  $\Xi^-/\Omega^-$  in Pb–Pb collisions at  $\sqrt{s_{\rm NN}}=2.76$  TeV was measured to be about 6 [18], and taking into account that the branching ratio  $\Omega^-\to \Lambda K^-$  is 67.8% [11], the feed-down contribution from decays of  $\Omega^-$  baryons would be about 1%, which is negligible compared with other sources of uncertainty (see below). Also, we did not correct the  $\Lambda$  spectra for the feed-down from non-weak decays of  $\Sigma^0$  and  $\Sigma(1385)$  family.

The fraction of  $\Lambda$ 's produced in hadronic interactions with the detector material was estimated using the detailed Monte Carlo simulations mentioned above. Since this fraction was found to be less than 1%, it was neglected.

The following main sources of systematic uncertainty were considered: raw yield extraction, feed-down, efficiency corrections, and the uncertainty on the amount of crossed material. These were added in quadrature to yield the overall systematic uncertainty on the  $p_T$  spectra for all centralities.

The systematic uncertainties on the raw yields were estimated by using different functional shapes for the background and by varying the fitting range. Over the considered momentum range, the obtained raw yields varied within 3% for  $K_S^0$  and 4–7% for  $\Lambda$ .

As a measure for the systematic uncertainty of the feed-down correction, we used the spread of the values determined for different centrality ranges with respect to the feed-down correction estimated for minimum bias events. This deviation was found to be about 5% relative to the overall  $\Lambda$  yield.

The systematic uncertainty associated with the efficiency correction was evaluated by varying one-byone the topological, track-selection and PID cuts. The cut variations were chosen such that the extracted uncorrected yield of the  $K_S^0$  and  $\Lambda$  would change by 10%. To measure the systematic uncertainty related to each cut, we used as a reference the corrected spectrum obtained with the nominal cut values. For  $\Lambda$ , the feed-down correction was re-evaluated and taken into account for every variation of the cut on the cosine of the pointing angle. The overall  $p_T$ -dependent systematic uncertainty associated with the efficiency correction was then estimated by choosing the maximal (over all cut variations) deviation between varied and nominal spectra values obtained in each momentum bin. For the momentum range

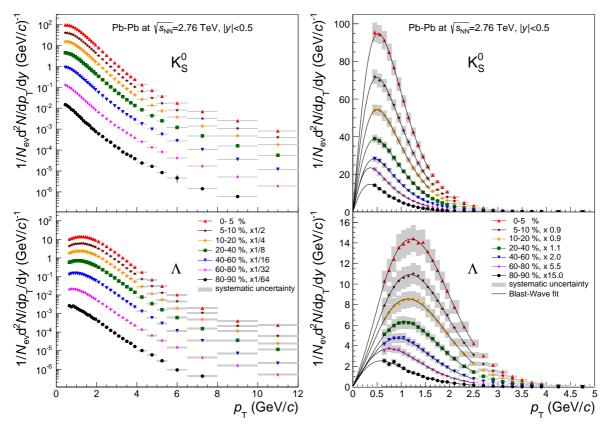
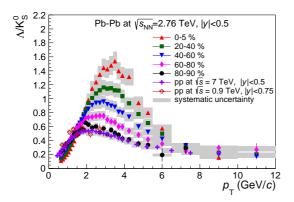


Fig. 2:  $K_S^0$  and  $\Lambda$  transverse momentum spectra for different event centrality intervals shown in logarithmic (left) and linear (right) scale. The curves represent results of blast-wave fits [19].



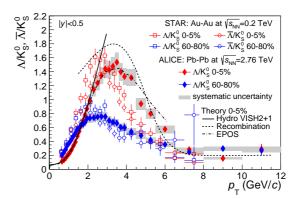


Fig. 3: Left:  $\Lambda/K_S^0$  ratios as a function of  $p_T$  for different event centrality intervals in Pb–Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV and pp collisions at  $\sqrt{s} = 0.9$  [12] and 7 TeV [20]. Right: Selected  $\Lambda/K_S^0$  ratios as a function of  $p_T$  compared with  $\Lambda/K_S^0$  and  $\bar{\Lambda}/K_S^0$  ratios measured in Au–Au collisions at  $\sqrt{s_{NN}} = 200$  GeV [21]. The solid, dashed and dot-dashed lines show the corresponding ratios from a hydrodynamical model [22, 23, 24], a recombination model [25] and the EPOS model [26], respectively.

considered, this systematic uncertainty was determined to be 4–6% for both  $K_S^0$  and  $\Lambda$ .

The systematic uncertainty introduced because of possible imperfection in the description of detector material in the simulations was estimated in [12] and amounted to 1.1–1.5% for  $K_S^0$  and 1.6–3.4% for  $\Lambda$ .

Since the systematic uncertainties related to the efficiency correction are correlated for the  $\Lambda$  and  $K_S^0$  spectra, they partially cancel in the  $\Lambda/K_S^0$  ratios. These uncertainties were evaluated by dividing  $\Lambda$  and  $K_S^0$  spectra obtained with the same cut variations and found to be half the size of those that would be obtained if the uncertainties of the  $\Lambda$  and  $K_S^0$  spectra were assumed to be uncorrelated. Altogether, over the considered momentum range, the maximal systematic uncertainty for the measured  $\Lambda/K_S^0$  ratios was found to be about 10%.

The transverse-momentum spectra of  $K_S^0$  obtained in different centrality intervals were compared with the spectra of charged kaons also measured by ALICE [27]. The two sets of spectra agree within the systematic uncertainties.

The corrected  $p_T$  spectra are shown in logarithmic scale in Fig. 2 (left). The spectra were fitted using the blast-wave parameterization described in [19]. The resulting curves are superimposed in Fig. 2 (right), with a linear scale and for a restricted momentum range, to emphasize the low- $p_T$  region. The fit range in  $p_T$  was from the lowest measured point up to 2.5 GeV/c (1.6 GeV/c) for  $\Lambda$  ( $K_S^0$ ). The fitting functions were used to extrapolate the spectra to zero  $p_T$  to extract integrated particle yields dN/dy. The results are given in Table 1. The systematic uncertainties of the integrated yields were determined by shifting the data points of the spectra simultaneously within their individual systematic uncertainties and reapplying the fitting and integration procedure. In addition, an extrapolation uncertainty was estimated, by using alternative (polynomial, exponential and Lévy-Tsallis [28, 29]) functions fitted to the low-momentum part of the spectrum, and the corresponding difference in obtained values was added in quadrature.

The  $p_{\rm T}$  dependence of the  $\Lambda/{\rm K_S^0}$  ratios, formed for each centrality interval by a division of the respective measured  $p_{\rm T}$  spectra, is presented in Fig. 3 (left panel). For comparison, the same ratios measured in minimum bias pp collisions at  $\sqrt{s} = 0.9$  [12] and 7 TeV [20] are plotted as well.

The  $\Lambda/K_S^0$  ratios observed in pp events at  $\sqrt{s} = 0.9$  and 7 TeV agree within uncertainties over the presented  $p_T$  range, and they bound in energy the Pb–Pb results reported here. The ratio measured in the most peripheral Pb–Pb collisions is compatible with the pp measurement, where there is a maximum of about 0.55 at  $p_T \sim 2$  GeV/c. As the centrality of the Pb–Pb collisions increases, the maximum value

**Table 1:** Integrated yields, dN/dy, for  $\Lambda$  and  $K_S^0$  with uncertainties which are dominantly systematic. A blast-wave fit is used to extrapolate to zero  $p_T$ . Fractions of extrapolated yield are specified. Ratios of integrated yields,  $\Lambda/K_S^0$ , for each centrality bin with the total uncertainty, mainly from systematic sources, are shown.

|         |                               | 0–5%            | 5-10%           | 10-20%          | 20-40%          | 40-60%          | 60-80%          | 80–90%          |
|---------|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Λ       | dN/dy                         | $26 \pm 3$      | $22\pm2$        | $17 \pm 2$      | $10\pm1$        | $3.8 \pm 0.4$   | $1.0 \pm 0.1$   | $0.21 \pm 0.03$ |
|         | $p_{\rm T}$ < 0.6 GeV/c frac. | 10%             | 11%             | 12%             | 14%             | 18%             | 24%             | 32%             |
| $K_S^0$ | dN/dy                         | $110 \pm 10$    | 90±6            | 68±5            | $39 \pm 3$      | $14\pm1$        | $3.9 \pm 0.2$   | $0.85 \pm 0.09$ |
|         | $p_{\rm T}$ < 0.4 GeV/c frac. | 20%             | 21%             | 21%             | 23%             | 25%             | 31%             | 33%             |
|         | Ratio $dN/dy \Lambda/K_S^0$   | $0.24 \pm 0.02$ | $0.24 \pm 0.02$ | $0.25 \pm 0.02$ | $0.25 \pm 0.02$ | $0.26 \pm 0.03$ | $0.25 \pm 0.02$ | $0.25 \pm 0.02$ |

of the ratio also increases and its position shifts towards higher momenta. The ratio peaks at a value of about 1.6 at  $p_{\rm T}\sim 3.2~{\rm GeV/}c$  for the most central Pb–Pb collisions. This observation may be contrasted to the ratio of the integrated  $\Lambda$  and  $K_{\rm S}^0$  yields which does not change with centrality (Table 1). At momenta above  $p_{\rm T}\sim 7~{\rm GeV/}c$ , the  $\Lambda/K_{\rm S}^0$  ratio is independent of collision centrality and  $p_{\rm T}$ , within the uncertainties, and compatible with that measured in pp events.

A comparison with similar measurements performed by the STAR Collaboration in Au–Au collisions at  $\sqrt{s_{\rm NN}}=200~{\rm GeV}$  is shown in Fig. 3 (right panel). Since the anti-baryon-to-baryon ratio at the LHC is consistent with unity for all transverse momenta [30, 31], the  $\Lambda/{\rm K}_{\rm S}^0$  and  $\bar{\Lambda}/{\rm K}_{\rm S}^0$  ratios are identical and we show only the former. The STAR  $\Lambda/{\rm K}_{\rm S}^0$  and  $\bar{\Lambda}/{\rm K}_{\rm S}^0$  ratios shown are constructed by dividing the corresponding  $p_{\rm T}$  spectra taken from [21]. The quoted 15%  $p_{\rm T}$ -independent feed-down contribution was subtracted from the  $\Lambda$  and  $\bar{\Lambda}$  spectra. The shape of the distributions of  $\Lambda/{\rm K}_{\rm S}^0$  and  $\bar{\Lambda}/{\rm K}_{\rm S}^0$  are the same but they are offset by about 20% and have peak values around 10% higher, and respectively lower, than the ALICE data. This comparison between LHC and RHIC data shows that the position of the maximum shifts towards higher transverse momenta as the beam energy increases. It is also seen that the baryon enhancement in central nucleus–nucleus collisions at the LHC decreases less rapidly with  $p_{\rm T}$ , and, at  $p_{\rm T}\sim 6~{\rm GeV}/c$ , it is a factor of two higher compared with that at RHIC.

Also shown in the right panel of Fig. 3 is a hydrodynamical model calculation [22, 23, 24] for most central collisions, which describes the  $\Lambda/K_S^0$  ratio up to  $p_T$  about 2 GeV/c rather well, but for higher  $p_T$  progressively deviates from the data. Such decoupling between the calculations and measurements is already seen in the comparison of  $p_T$ -spectra [27]. The agreement for other charged particles is improved when the hydrodynamical calculations are coupled to final-state re-scattering model [25]. Therefore it would be interesting to compare these data and their centrality evolution with such treatment. For higher  $p_T$ , a recombination model calculation [5] is presented (Fig. 3, right panel). It approximately reproduces the shape, but overestimates the baryon enhancement by about 15%. In the right panel of Fig.3, we also show a comparison of the EPOS model calculations [26] with the current data. This model takes into account the interaction between jets and the hydrodynamically expanding medium and arrives at a good description of the data.

In conclusion, we note that the excess of baryons at intermediate  $p_{\rm T}$ , exhibiting such a strong centrality dependence in Pb–Pb collisions at  $\sqrt{s_{\rm NN}}=2.76~{\rm TeV}$ , does not reveal itself in pp collisions at the center-of-mass energy up to  $\sqrt{s}=7~{\rm TeV}$ . At  $p_{\rm T}>7~{\rm GeV/c}$ , the  $\Lambda/{\rm K_S^0}$  ratios measured in Pb–Pb events for different centralities all merge together and with the dependence observed in pp collisions. This agreement between collision systems suggests that the relative fragmentation into  $\Lambda$  and  ${\rm K_S^0}$  hadrons at high  $p_{\rm T}$ , even in central collisions, is vacuum-like and not modified by the medium. In future, it would be interesting to extend the measurements to higher transverse momenta to see whether the nuclear modification factor behaves in the same way as the one for charged particles [32].

As the collision energy and centrality increase, the maximum of the  $\Lambda(\bar{\Lambda})/K_S^0$  ratio shifts towards higher  $p_T$ , which is in qualitative agreement with the effect of increased radial flow, as predicted in [4]. The ratio of integrated  $\Lambda$  and  $K_S^0$  yields does not, within uncertainties, change with centrality and is equal to that measured in pp collisions at 0.9 and 7 TeV. This suggests that the baryon enhancement at intermediate

 $p_{\rm T}$  is predominantly due to a re-distribution of baryons and mesons over the momentum range rather than due to an additional baryon production channel progressively opening up in more central heavy-ion collisions. This centrality dependence may be challenging for theoretical models which try to disentangle the quark-recombination contributions from the radial-flow effect and which, in addition, will need to describe other particle spectra and their  $p_{\rm T}$ -dependent ratios.

The width of the baryon enhancement peak increases with the beam energy. However, contrary to expectations [7], the effect at the LHC is still restricted to an intermediate-momentum range and is not observed at high  $p_{\rm T}$ . This puts constraints on parameters of particle production models involving coalescence of quarks generated in hard parton interactions [33].

Qualitatively, the baryon enhancement presented here as  $p_T$  dependence of  $\Lambda/K_S^0$  ratios, is described in the low- $p_T$  region (below 2 GeV/c) by collective hydrodynamical radial flow. In the high- $p_T$  region (above 7–8 GeV/c), it is very similar to pp results, indicating that there it is dominated by hard processes and fragmentation. Our data provide evidence for the need to include the effect of the hydrodynamical expansion of the medium formed in Pb–Pb collisions on the mechanisms of fragmentation and hadronization.

### Acknowledgements

The ALICE collaboration would like to thank all its engineers and technicians for their invaluable contributions to the construction of the experiment and the CERN accelerator teams for the outstanding performance of the LHC complex.

The ALICE collaboration acknowledges the following funding agencies for their support in building and running the ALICE detector:

State Committee of Science, World Federation of Scientists (WFS) and Swiss Fonds Kidagan, Armenia, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Financiadora de Estudos e Projetos (FINEP), Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP);

National Natural Science Foundation of China (NSFC), the Chinese Ministry of Education (CMOE) and the Ministry of Science and Technology of China (MSTC);

Ministry of Education and Youth of the Czech Republic;

Danish Natural Science Research Council, the Carlsberg Foundation and the Danish National Research Foundation:

The European Research Council under the European Community's Seventh Framework Programme; Helsinki Institute of Physics and the Academy of Finland;

French CNRS-IN2P3, the 'Region Pays de Loire', 'Region Alsace', 'Region Auvergne' and CEA, France:

German BMBF and the Helmholtz Association;

General Secretariat for Research and Technology, Ministry of Development, Greece;

Hungarian OTKA and National Office for Research and Technology (NKTH);

Department of Atomic Energy and Department of Science and Technology of the Government of India; Istituto Nazionale di Fisica Nucleare (INFN) and Centro Fermi - Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Italy;

MEXT Grant-in-Aid for Specially Promoted Research, Japan;

Joint Institute for Nuclear Research, Dubna;

National Research Foundation of Korea (NRF);

CONACYT, DGAPA, México, ALFA-EC and the EPLANET Program (European Particle Physics Latin American Network)

Stichting voor Fundamenteel Onderzoek der Materie (FOM) and the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO), Netherlands;

Research Council of Norway (NFR);

Polish Ministry of Science and Higher Education;

National Authority for Scientific Research - NASR (Autoritatea Naţională pentru Cercetare Ştiinţifică - ANCS);

Ministry of Education and Science of Russian Federation, Russian Academy of Sciences, Russian Federal Agency of Atomic Energy, Russian Federal Agency for Science and Innovations and The Russian Foundation for Basic Research;

Ministry of Education of Slovakia;

Department of Science and Technology, South Africa;

CIEMAT, EELA, Ministerio de Economía y Competitividad (MINECO) of Spain, Xunta de Galicia (Consellería de Educación), CEADEN, Cubaenergía, Cuba, and IAEA (International Atomic Energy Agency);

Swedish Research Council (VR) and Knut & Alice Wallenberg Foundation (KAW);

Ukraine Ministry of Education and Science;

United Kingdom Science and Technology Facilities Council (STFC);

The United States Department of Energy, the United States National Science Foundation, the State of Texas, and the State of Ohio.

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