LATEST QCD RESULTS FROM THE ALICE EXPERIMENT*

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ALICE is the LHC experiment dedicated to the study of heavy-ion collisions. Its features also make it an ideal detector for QCD studies in *pp* collisions. Thanks to its excellent particle identification capabilities and low material budget, ALICE can measure hadron and lepton production over a wide momentum range both in *pp* and in Pb–Pb collisions. In this paper, we review recent QCD results, focusing, in particular, on charged-particle multiplicity density, strange particle production, particle ratios, identified particle spectra and heavy flavours in *pp* collisions at $\sqrt{s} = 0.9$, 2.76 and 7 TeV. Results on these observables and on elliptic flow will also be presented for Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

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1. Introduction

The ALICE experiment [1] is the main LHC experiment designed to measure ultrarelativistic Pb–Pb collisions in order to study the properties of a deconfined state of matter, the Quark-Gluon Plasma (QGP), predicted by lattice QCD to be formed at high temperature and energy density. The main difference with respect to the other LHC experiments is its excellent Particle IDentification (PID) capability.

The ALICE experiment studies *pp* interactions to have reference for the understanding of heavy-ion data. This is also useful to check if the models that describe results in elementary collisions at lower energies can reproduce particle production also at LHC energies. In addition, they are important to tune and optimize the Monte Carlo generators commonly used for the description of particle production in high energy collisions.

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In the following, we briefly present a selected set of the latest ALICE QCD results, focusing, in particular, on charged-particle multiplicity density, strange particle production, particle ratios, heavy flavours and elliptic flow.

2. Identified particle production in Pb–Pb collisions

Thanks to its PID performance, the ALICE experiment is able to measure the transverse momentum (p_{T}) spectra of primary particles produced in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. They provide a link to the thermal parameters of the system at chemical and kinetic freezeout.

To obtain information on the thermal properties of the medium at the kinetic freezeout, a global fit of the π, K and p spectra with a Blast Wave function [2], where the kinetic freezeout temperature (T_{fo}) and the radial flow ($\langle\beta\rangle$) are free parameters, is performed. In Fig. 1 (left), the fit parameters for ALICE and STAR [3] in different centrality bins are shown. The radial flow is $\sim 10\%$ higher at $\sqrt{s_{NN}} = 2.76$ TeV than at $\sqrt{s_{NN}} = 0.2$ TeV. The parameter T_{fo}, on the other hand, is affected by some systematics related to the pion fit range (the effect of resonances has to be investigated).

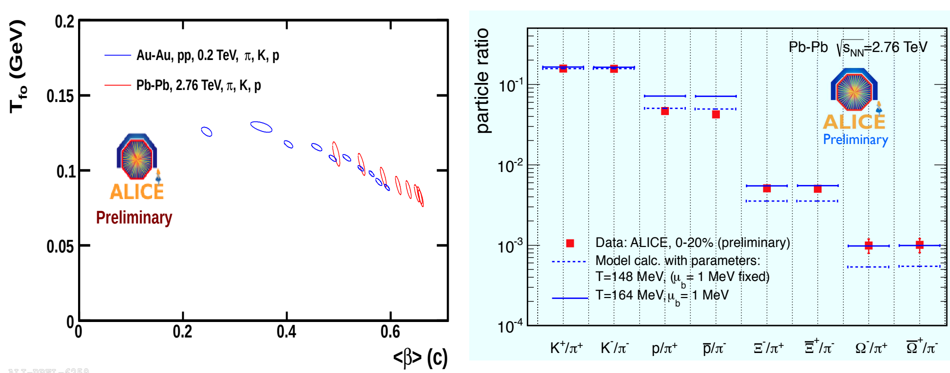

Fig. 1. Left: T_{fo} and $\langle\beta\rangle$ parameters as obtained from a global fit of the spectra with a Blast Wave function for increasing centrality. To be noticed that the first STAR point was obtained in pp collisions. Right: Comparison between particle ratios measured by ALICE in the most central events and thermal model predictions [4].

To get information on the thermal properties of the medium at the chemical freezeout, the ratios between the integrated yields of different particle species are compared with thermal model predictions [4] (see Fig. 1 (right)). At the temperature $T = 164$ MeV the agreement is good for kaons and multistrange particles while p/π is not well described. Setting the temperature at $T = 148$ MeV helps the description of protons but underestimates the multi-strange production.

In Fig. 2 (left), the $p_{\rm T}$ dependent $\Lambda/K^0_{\rm s}$ ratio measured by ALICE in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV is shown for different collision centralities. The strong centrality dependence and the enhancement with respect to *pp* interactions are evident. The maxima are higher in magnitude and shifted towards higher momenta compared with RHIC results [5] as can be seen in Fig. 2 (right).

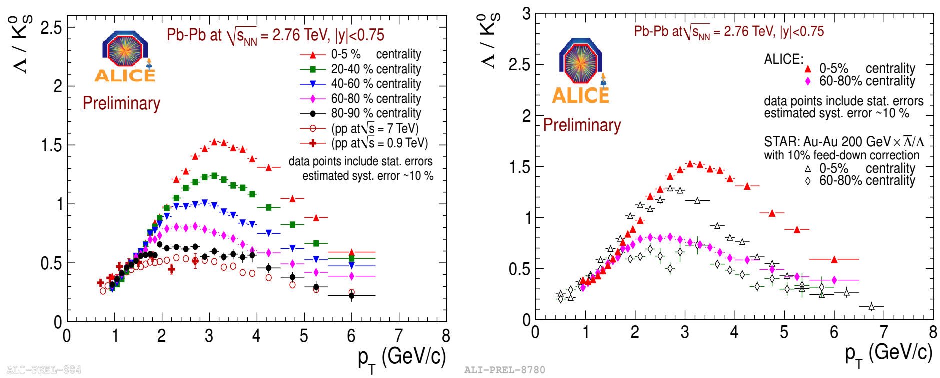

Fig. 2. Left: $\Lambda/K^0_{\rm s}$ ratio measured by ALICE in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV for different centrality bins compared with the same ratio in *pp* collisions at $\sqrt{s} = 0.9$ and 7 TeV. Right: Comparison between ALICE and RHIC $\Lambda/K^0_{\rm s}$ ratios for two selected centrality bins.

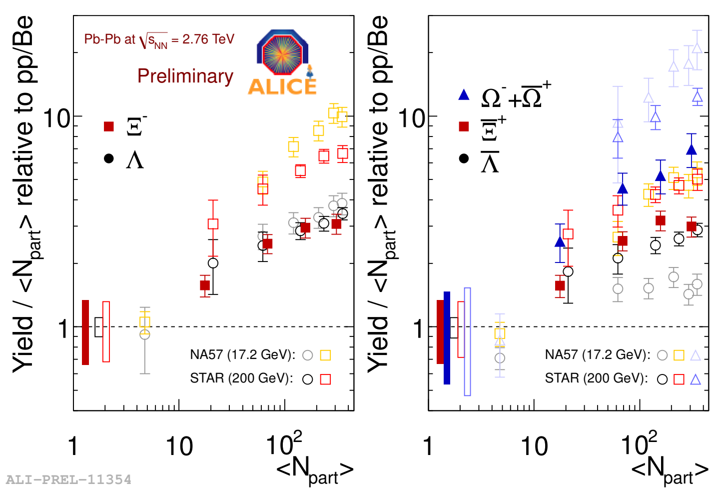

Fig. 3. Integrated yields of strange baryons produced in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV normalised to the yields obtained in *pp* events at the same energy scaled with the mean number of participants $\langle N_{\rm part}\rangle$ as a function of $\langle N_{\rm part}\rangle$. The ALICE results are compared with the SPS and RHIC ones.

In Fig. 3, the enhancement of strange baryons produced in Pb–Pb collisions (scaled with the number participating in the interaction $\langle N_{\rm part}\rangle$) with respect to pp collisions at the same energy is shown. It is evident that the enhancement increases with the strangeness content and decreases with the collision energy when comparing the ALICE measurements with those from SPS and RHIC.

3. Heavy flavour and quarkonia production

In heavy-ions collisions, the study of heavy quark production gives information on the QGP medium through several processes: quarkonium production suppression by colour screening, charmonium regeneration due to the recombination of initially uncorrelated c and $\bar{c}$ quarks and in-medium energy loss of heavy quarks.

In Fig. 4, the ratio between D mesons $p_{\rm T}$ spectrum measured in Pb–Pb and pp collisions scaled by the number of nucleon–nucleon collisions expected in heavy-ion interactions (R_{AA}) is shown for central (left) and semi-peripheral (right) events [6]. R_{AA} agrees for D^0, D^+, D^{*+}, increases in more peripheral collisions and reaches a suppression of a factor of 3–4 in central collisions for $p_{\rm T} > 5$ GeV$/c$. The strong suppression observed is likely to be a final state effect with strong in-medium energy loss for charm quarks.

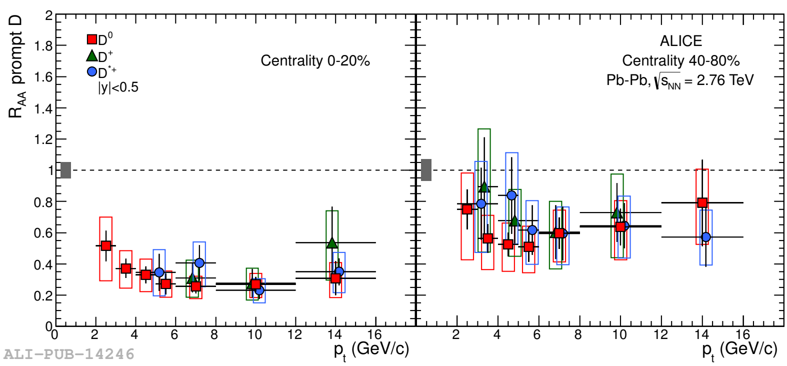

Fig. 4. R_{AA} for prompt D^0, D^+, D^{*+} as a function of $p_{\rm T}$ in 0–20% and 40–80% centrality classes [6].

In Fig. 5 (left), the average R_{AA} of D mesons is compared to R_{AA} of charged hadrons [6]. ALICE preliminary results showed that charged pion R_{AA} coincides with charged hadron R_{AA} for $p_{\rm T} > 5$ GeV$/c$. Hence there are indications that the prediction that heavy quarks would lose less energy than gluons, hence $R_{AA}^{D} > R_{AA}^{\rm charged}$ is correct even if the results are not conclusive. The comparison with CMS non prompt J/ψ R_{AA} [7] shows that the J/ψ suppression is weaker than that of charged hadrons.

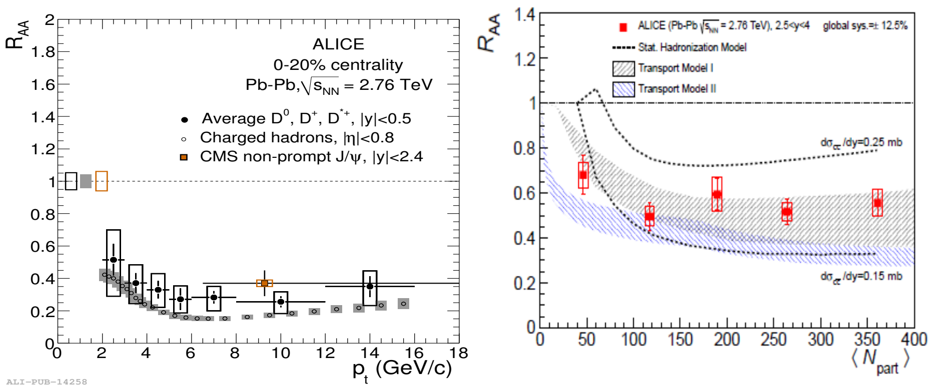

Fig. 5. Left: Averaged R_{AA} of D mesons compared to R_{AA} of charged hadrons and non-prompt J/ψ (CMS data) [6]. Right: Inclusive J/ψ R_{AA} ([11]) compared with the predictions of Stat. Hadronization Model [8], Transport Model I [9] and II [10].

In Fig. 5 (right), the inclusive J/ψ R_{AA} is compared with theoretical models that include J/ψ regeneration. Statistical hadronization and transport models which feature a full or partial J/ψ production from c quarks in the QGP phase can describe the data (see [11] for more details).

4. Elliptic flow

The evaluation of collective phenomena and, in particular, of the anisotropic flow described by the coefficients in the Fourier expansion of the azimuthal particle distribution, gives the chance to get information on the medium produced in Pb–Pb collisions.

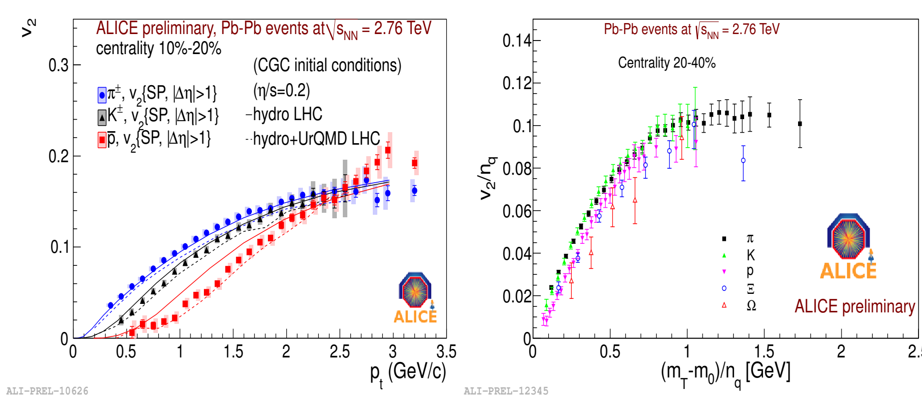

Fig. 6. Left: v_2 for π, K and $\bar{p}$ in the 10%–20% centrality class compared with hydrodynamical models [12]. Right: v_2 scaling with the number of constituent quarks in terms of transverse kinetic energy per quark.

In Fig. 6 (left), the elliptic flow (v_2) for π, K and $\overline{p}$ in the 10%–20% centrality class is compared with hydrodynamic models [12] which correctly predict the mass splitting. The pure hydro disagrees with $\overline{p}$ that are better described by hydro coupled with UrQMD. In Fig. 6 (right), the v_2 scaling with the number of constituent quarks is shown in terms of transverse kinetic energy per quark. It can be seen that the quark scaling does not work for $\overline{p}$ and strange baryons.

5. Conclusions

Thanks to its great tracking and PID performance, the ALICE experiment can study the properties of a deconfined state of matter, the QGP, predicted by lattice QCD to be formed in ultrarelativistic heavy-ion collisions. In this paper, a selection of the latest ALICE results has been shown. We have seen that, studying the properties of the p_{T} spectra, indication on the chemical and kinetic freezeout temperatures as well as on the radial flow can be obtained. From the Λ/K^0_{s} ratio, information on the baryon enhancement can be obtained. ALICE can also extend to higher energies the results obtained at lower energies on the strangeness enhancement and study the properties of QGP looking at the effect that it has on the heavy flavours like quarkonium production suppression, charmonium regeneration and in-medium energy loss of heavy quarks. Finally, from the elliptic flow, information on the collective motion of the medium can be obtained.

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