Particle production in ultra-relativistic heavy-ion collisions at the LHC

E. Fragiacomo[1]*
[1] *Istituto Nazionale di Fisica Nucleare, Sezione di Trieste, ITALY*

on behalf of the ALICE Collaboration

Introduction

In this talk, mechanisms of particle production at the LHC energies are discussed in the light of the most recent results obtained by the ALICE experiment. We present ratios of particle yields, transverse momentum spectra and mean transverse momenta of light-flavour particles, including resonances and light nuclei, measured for different collision systems (pp, p–Pb, Pb–Pb and Xe–Xe) and centre-of-mass energies.

Particle yields and thermal production

At the LHC energies, particle production is dominated by soft QCD processes and therefore modelling the underlying dynamics remains a challenge. In nucleus-nucleus collisions the production of most light-flavour hadrons and light (anti-)(hyper-)nuclei can be described by thermal models with few parameters, as the chemical freeze-out temperature and volume [1]. The most notable discrepancy between data and models, namely the over-prediction of the proton yield, finds still several possible explanations [2], whereas the measured lower yield for the short-lived K^{*0} resonance is attributed to the presence of rescattering effects in the hadronic phase [3]. Indeed, short-lived resonances have long been recognized as good probes to investigate the late-stage evolution of ultra-relativistic heavy-ion collisions [4]. Unlike hadronic resonances, light (anti-)(hyper-)nuclei have yields which are in agreement with the thermal model predictions at chemical freeze-out [1], thus excluding effects in the hadronic phase. This seems counterintuitive, considering that they have small binding energies. Coalescence after kinetic freeze-out is evoked as explanation [5], but detailed transport calculations are still awaited.

Evolution of the hadro-chemistry with system size

An interesting feature which has emerged is the smooth evolution of particle chemistry from small to large systems. This is shown

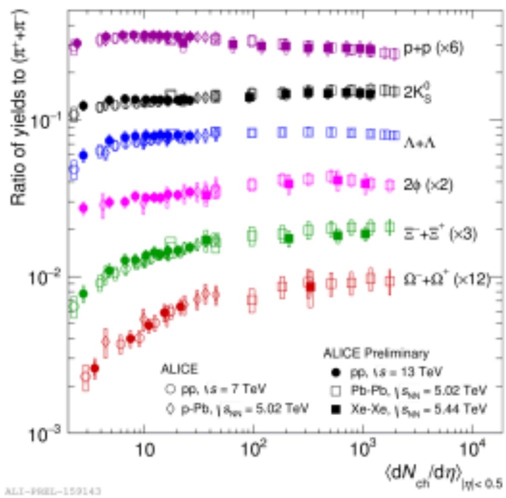

FIG. 1: Particle yield ratios to the pion yield as function of the charged-particle multiplicity density.

in Figure 1 where a compilation of yield ratios to the pion yield is presented as function of charged-particle multiplicity density for several hadrons, including strange mesons and strange and multi-strange hyperons. The

*Electronic address: enrico.fragiacomo@ts.infn.it

newly available data for Xe–Xe at 5.44 TeV and pp at 13 TeV are in agreement with previous findings. What is observed is that the ratios seem to depend only on the multiplicity, irrespective of the collision system and the energy. For strange particles an increasing trend from small to large systems is observed, which saturates at the grand-canonical limit. This increase is larger for multi-strange hadrons. The canonical suppression of strangeness production in small systems, a consequence of local strangeness conservation [6], explains in the context of thermal models the relative enhancement of strangeness production in heavy-ion collisions, historically proposed as a signature of quark-gluon plasma formation [7]. This explanation, however, fails the test of the ϕ/π ratio. Indeed, for the strangeness-neutral ϕ meson a flat dependence as function of the multiplicity is expected, whereas a clear increase by almost a factor two is observed [8].

Transverse momentum spectra and hydrodynamics

Figure 2 shows the average transverse momentum as function of the charged-particle multiplicity for Pb–Pb and Xe–Xe collisions.

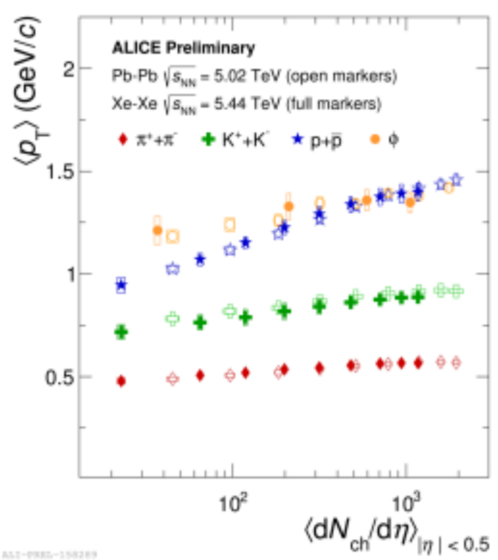

FIG. 2: Average transverse momentum as function of the charge-particle multiplicity density.

For all presented hadrons an increasing trend is observed which reflects the hardening of transverse momentum spectra with increasing centrality. The average p_{T} follows a mass ordering in central collisions, being larger for particles with larger mass and similar for particles with comparable mass, such as the proton and the ϕ meson [9]. These observations are consistent with expectations from hydrodynamical models, as particles in the expanding system experience the same radial velocity field.

The effect of hydrodynamics in shaping the transverse momentum spectra is further explored with the baryon-to-meson ratio [9]. Three ratios, namely p/ϕ, p/π and Λ/K^0_S will be presented for Pb–Pb and Xe–Xe collisions. The flatness of the p/ϕ ratio is consistent with hydrodynamics expectations (particles with similar mass have similar spectral shapes) and, at the same time, it is reproduced by models including recombination [10]. The enhancement of proton and Λ over π and $\mathrm{K}^0_{\mathrm{S}}$ respectively, is understood as due to radial flow.

References

[1] S. Acharya *et al.* (ALICE Collaboration), Nucl. Phys. A971 (2018) 1-20
[2] M. Floris, Nucl. Phys. A 931 (2014) 103112
[3] B. Abelev *et al.* (ALICE Collaboration), Phys. Rev. C91 (2015) 024609
[4] G. Torrieri and J. Rafelski, Phys. Lett. B509 (2001) 239-245
[5] S. Cho *et al.*, Prog. Part. Nucl. Phys. 95 (2017) 279-322
[6] K. Redlich and A. Tounsi, Eur. Phys. J. C24 (2002) 589–594
[7] J. Rafelski and B. Muller, Phys. Rev. Lett. 48 (1982) 1066–1069
[8] V. Vislavicius and A. Kalweit, arXiv:1610.03001
[9] F. Bellini, Proc. Quark Matter 2018, arXiv:1808.05823
[10] V. Minissale, F. Scardina, V. Greco, Phys. Rev. C92 (2015) 054904