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Nuclear PDF studies with proton-lead measurements with the ALICE detector

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The proton-lead programme at CERN's Large Hadron Collider allowed the study of cold-nuclear matter effects from the initial state, such as Cronin enhancement, nuclear shadowing and gluon saturation. They result in a modification of the production cross section and thus provide crucial tests of predictions from perturbative Quantum-Chromodynamics. Furthermore, these control measurements are needed to characterise the extent to which initial-state effects can be differentiated from effects due to final-state interactions in the so-called quark-gluon plasma, produced in high-energy collisions of heavy atomic nuclei.

In this contribution, recent results from the ALICE experiment on the measurements of light-flavour production and jets will be presented. Especially, the multi-strange baryon yields allow the study of the canonical suppression in small systems, whereas jets have been studied in term of the acoplanarity between full and charged jets and the nuclear modification factor as a function of collision centrality. The impact of these measurements in terms of modifications of the PDFs in nuclear matter will be discussed and compared with models.

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1. Introduction

The ALICE experiment has recorded proton-lead collisions, which allow the study of cold nuclear matter effects from the initial state, such as the nuclear modification of the parton distribution functions (PDF) [1]. It is expected that shadowing is dominant at low Bjorken-x at the Large Hadron Collider. Furthermore, gluon saturation effects from the evolution equations (DGLAP and BFKL), k_{T} broadening and Cronin enhancement from multiple parton scatterings, and initial-state energy loss [2, 3, 4] should play a role. These initial-state effects result in a modification of the production cross section [5] and provide crucial tests of perturbative Quantum-Chromodynamics (pQCD). Final-state effects, if present, are expected to origin from energy loss and interactions between the final-state particles in a possible collective expansion. Both effects are important for the interpretation of the results from heavy-ions collisions
The data presented in this contribution are obtained from collisions of a lead beam ($^{208}_{82}$Pb) with an energy of 1.58 TeV per nucleon and opposing proton beam with an energy of 4 TeV during the run-1 data taking in 2013. In each direction 13 bunches were circulating with about 10^{10} protons and 6×10^7 Pb ions per bunch. The resulting centre-of-mass energy of the proton-lead system is $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. The recorded data has an integrated luminosity of $\approx$ 50 μb^{-1}. Due to the energy asymmetry of the proton and lead colliding beams at the LHC, the centre-of-mass system of nucleon-nucleon collisions is shifted by Δy = 0.465 in the direction of the proton beam, with respect to the laboratory frame. Experimental data have been collected with two beam configurations (p–Pb and Pb–p) by inverting the orbits of the two particle species.
Recent results from the ALICE experiment on the measurements of light-flavour production and jets in p-Pb collisions will be presented. ALICE results on open heavy-flavour production are reported in [6] and on the energy dependence of exclusive J/Ψ photoproduction in p-Pb collisions in [7].
The ALICE experiment has measured the pseudorapidity density of charged particles over four units of pseudorapidity in non-single diffractive (NSD) p–Pb collisions [8]. Most model predictions agree within 20% of the data. However, saturation models rise too steeply with the pseudorapidity density, whereas pQCD-based Monte Carlo models such as HIJING and DPMJET describe the pseudorapidity density dependance.

2. Multi-strange baryons

The multi-strange baryon yields in lead-lead collisions have been shown to exhibit an enhancement relative to pp reactions. The Ξ and Ω production rates in proton-lead collisions have been measured with the ALICE detector as a function of transverse momentum [9]. The results cover the kinematic ranges 0.6 GeV/c $< p_{\mathrm{T}} <$ 7.2 GeV/c and 0.8 GeV/c $< p_{\mathrm{T}} <$ 5 GeV/c, for Ξ and Ω respectively, in the common rapidity interval -0.5 $< y_{\mathrm{CMS}} <$ 0. Multi-strange baryons have been identified by reconstructing their weak decays into charged particles. The p_{T} spectra are analysed as a function of event charged-particle multiplicity, which in p–Pb collisions ranges over one order of magnitude and lies between those observed in pp and Pb–Pb collisions. Figure 1 (right panel) shows the $(\Xi^- + \Xi^+)/\pi^- + \pi^+)$ ratio as a function of charged particle multiplicity for the colliding systems pp, p–Pb and Pb–Pb together with theoretical model calculations. The ratios for the seven multiplicity classes

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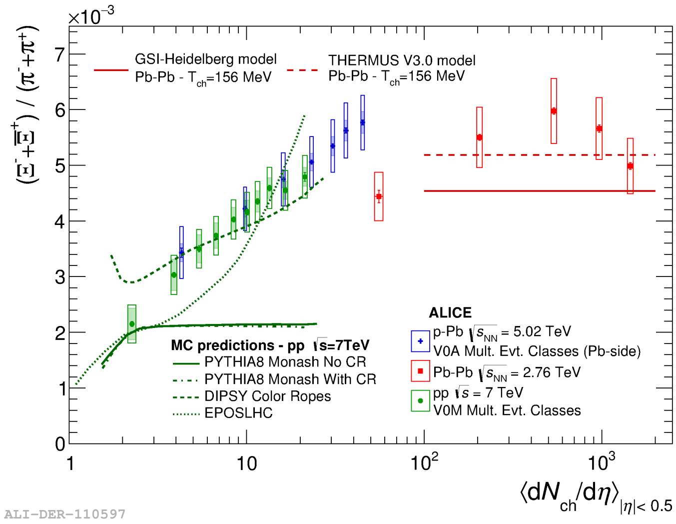

Figure 1: $(\Xi^- + \Xi^+)/\pi^- + \pi^+)$ ratio as a function of charged particle multiplicity for the colliding systems pp, p–Pb and Pb–Pb. The ratios for the seven multiplicity classes in p–Pb data lie between the Minimum Bias pp and peripheral Pb–Pb results. The chemical equilibrium model predictions by the GSI-Heidelberg [10] and the THERMUS 2.3 [11] models and PYTHIA calculations with different tunes are represented by the coloured curves.

in p–Pb data lie between the Minimum Bias pp and peripheral Pb–Pb results. A similar multiplicity dependence in pp and p–Pb collisions with increasing multiplicity is observed. Neither PYTHIA 6 nor 8 reproduce these data in any of the tunes tested. Calculations from EPOS predict an increase but does not fit the data. DIPSY shows a relatively good description of the data. A statistical model is employed, which describes the change in the ratios with volume using a canonical suppression mechanism, in which the small volume causes a species-dependent relative reduction of hadron production. The calculations, in which the magnitude of the effect depends on the strangeness content, show good qualitative agreement with the data.

3. Jets

The acoplanarity between full and charged jets has been studied by the ALICE Collaboration [12]. Jets are reconstructed from charged particles measured in the central tracking detectors and neutral energy deposited in the electromagnetic calorimeter. The transverse momentum of the full jet (clustered from charged and neutral constituents) and charged jet (clustered from charged particles only) is corrected event-by-event for the contribution of the underlying event, while corrections for underlying event fluctuations and finite detector resolution are applied on an inclusive basis. A projection of the dijet transverse momentum, $k_{\mathrm{Ty}} = p_{\mathrm{T,jet}}^{\mathrm{ch+ne}} \sin(\Delta\phi_{\mathrm{dijet}})$ with $\Delta\phi_{\mathrm{dijet}}$ the azimuthal angle between a full and charged jet and $p_{\mathrm{T,jet}}^{\mathrm{ch+ne}}$ the transverse momentum of the full jet, is used to study nuclear matter effects in p–Pb collisions. This observable is sensitive to the acoplanarity of dijet production and its potential modification in p–Pb collisions with respect to pp collisions. Measurements of the dijet k_{Ty} as a function of the transverse momentum of the full and recoil charged jet and the event multiplicity are depicted in Figure 2. No significant modification of k_{Ty} due to nuclear

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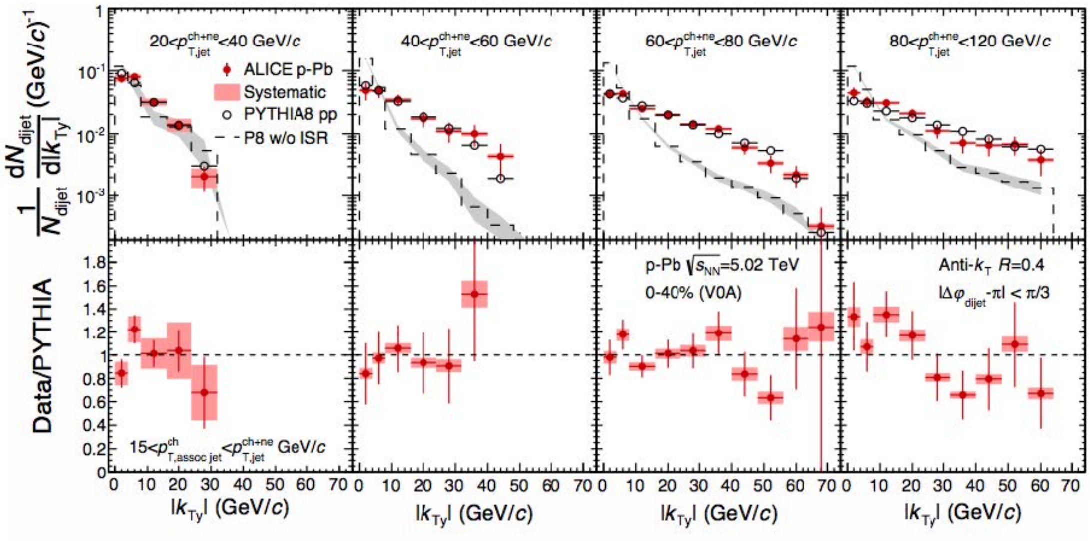

Figure 2: ALICE measurement [12] of the dijet $|k_{Ty}|$ distributions in the most central 40% p–Pb collisions for different kinematic regions of the full jet ($p_{T,jet}^{ch+ne}$), compared to PYTHIA8 (tune 4C and K = 0.7) with and without initial state radiation. The lower panels show the ratio between the measurement and PYTHIA8 including initial state radiation.

matter effects in p–Pb collisions with respect to the event multiplicity or a PYTHIA8 reference is observed. So, the p_T imbalance of jet correlations in Pb–Pb results are unlikely to originate from multiple scatterings in the nuclear target.

Nuclear effects are typically quantified using the *nuclear modification factor* R_{AA} where the particle yield in nucleus-nucleus collisions is divided by the yield in pp interactions, scaled by the averaged number of binary collisions. The latter is obtained from Glauber calculations. An R_{AA} of one would indicate that no nuclear effects, neither "cold" (such as Cronin, shadowing or gluon saturation) nor "hot" (parton energy loss) are present and that nucleus-nucleus collisions can be considered as an incoherent superposition of nucleon-nucleon interactions.
The centrality-dependent nuclear modification factor Q_{pPb} for charged and full jets, measured by the ALICE [13] and ATLAS Collaboration [14], respectively, is illustrated in the left panel of Figure 3. The jet production in p–Pb collisions is consistent with the production expected from binary scaling from pp collisions. The ratio of jet yields reconstructed with the two different resolution parameters is also independent of the centrality selection, demonstrating the absence of major modifications of the radial jet structure in the reported centrality classes.

3.1 Summary

The ALICE experiment has studied cold-nuclear effects such as shadowing and gluon saturation in proton-lead collisions at the CERN-LHC. Recent results on the measurement of light-flavour production and jets were presented. The strange hadron results give a clear indication for a continuous reduction of canonical suppression with increasing multiplicity. Jet fragmentation exhibits

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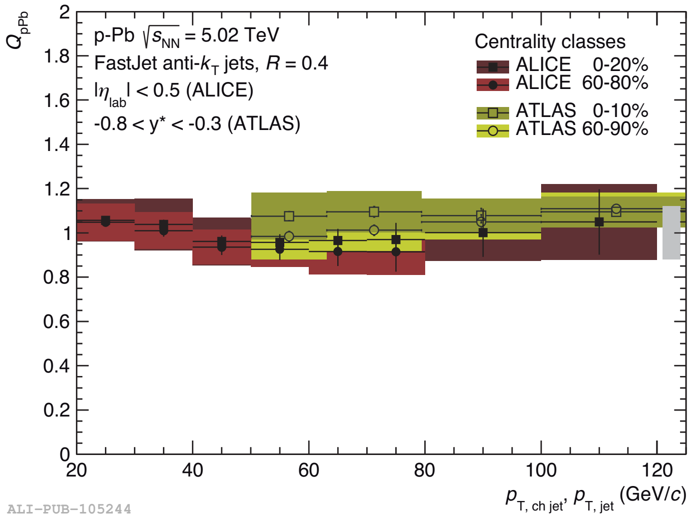

Figure 3: Left panel: Nuclear modification factor Q_{pPb} of charged jets measured by ALICE [13], compared to the nuclear modification factor for full jets as measured by ATLAS [14]. Note that the underlying parton p_T for fixed reconstructed jet p_T is higher in the case of charged jets.

no modification in proton-lead collisions. More results are expected from the Run-2 data taking at $\sqrt{s_{NN}}$ = 5.02 TeV and $\sqrt{s_{NN}}$ = 8.16 TeV with an integrated luminosity of ≈ 0.36 nb^{-1} (7-8 times larger than those from Run-1) and ≈ 0.06 nb^{-1}, respectively.

References

[1] C. A. Salgado et al., J. Phys. G 39, 015010 (2012).

[2] J. W. Cronin, H. J. Frisch, M. J. Shochet, J.P. Boymond, P. A. Piroue and R. L. Sumner, Phys. Rev. D 11, 3105 (1975).

[3] A. Accardi, arXiv: hep-ph/0212148.

[4] R. C. Hwa and C. Yang, Phys. Rev. Lett. 93, 082302 (2004).

[5] K. J. Eskola, H. Paukkunen, C. A. Salgado, JHEP 0904, 65 (2009).

[6] R. Vertesi for the ALICE Collaboration, these proceedings.

[7] J. G. Contreras for the ALICE Collaboration, these proceedings.

[8] ALICE Collaboration, Phys. Rev. Lett. 110, 032301 (2013).

[9] ALICE Collaboration, Phys. Lett. B 758 (2016) 389 and Phys. Lett. B 728 (2014) 25.

[10] A. Andronic, P. Braun-Munzinger, and J. Stachel, Phys. Lett. B 673 (2009) 142.

[11] S. Wheaton, J. Cleymans, and M. Hauer, Computer Physics Communications 180 (2009) 84.

[12] ALICE Collaboration, Phys. Lett. B 746 (2015) 385.

[13] ALICE Collaboration, Eur. Phys. J. C76, 271 (2016) and Phys. Rev. C91, 064905 (2015).

[14] ATLAS Collaboration, Phys. Lett. B 748, 392 (2015).

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