Baryon–antibaryon asymmetry in the central region at $\sqrt{s} = 0.9$ and 7 TeV with ALICE

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In this article, we discuss the results from the analysis of p+p collisions at $\sqrt{s} = 0.9$ and 7 TeV recorded by the ALICE experiment at the LHC. We concentrate on the baryon transport studies which are of great importance for the determination of the carrier of the baryon number. In particular, the rapidity and transverse momentum dependence of the $\overline{\mathrm{p}}$/p ratio is presented. The results are compared with different theoretical predictions. Finally, the energy dependence of the mid-rapidity ratios is discussed.

1 Introduction

The carrier of the baryon number (BN) is a topic that has been debated theoretically for some time [1, 2, 3, 4, 5, 6]. Based on the Quark-Gluon String Model (QGSM) [2] the BN is associated with its valence quarks. On the other hand, there are models describing the baryon structure with the picture of three strings starting at the valence quarks and joining together in the center, at a virtual point called "string junction" (J) [1, 3]. These two concepts result in a significantly different BN distribution with rapidity (BN transport), when the proton interacts inelastically at high energies. Experimentally, the BN transport over very large rapidity intervals is addressed by measuring the antiproton-to-proton production ratio at mid-rapidity, $R = N_{\overline{\mathrm{p}}}/N_{\mathrm{p}}$, or equivalently, the proton–antiproton asymmetry, $A = (N_{\mathrm{p}} - N_{\overline{\mathrm{p}}})/(N_{\mathrm{p}} + N_{\overline{\mathrm{p}}})$. In this article, we describe the measurement of the $\overline{\mathrm{p}}$/p ratio at midrapidity in pp collisions at center-of-mass energies $\sqrt{s} = 0.9$ TeV and 7 TeV ($\Delta y \approx 6.9$–8.9), with the ALICE experiment at the LHC [7].

2 Data analysis – results

Data recorded during the first LHC runs (December 2009 and March–April 2010) were used for this analysis. The trigger required a hit in one of the VZERO counters or in the SPD detector [8], in coincidence with the signals from two beam pick-up counters, one on each side of the interaction region, indicating the presence of passing bunches. The momentum as well as the particle identification relied for this analysis on the information from the TPC detector. The phase space of the analysis was restricted to the rapidity and momentum range of $|y| < 0.5$ and $0.45 < p < 1.05$ GeV/c, respectively. The corrections that are applied were the following:

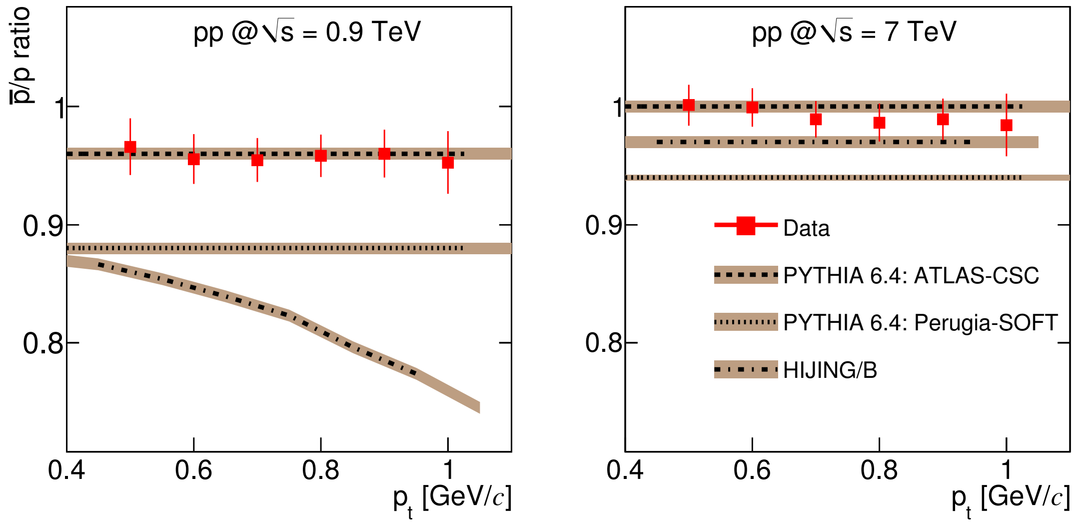

Figure 1: The p_t dependence of the $\overline{\mathrm{p}}/\mathrm{p}$ ratio integrated over $|y| < 0.5$ for pp collisions at $\sqrt{s} = 0.9$ TeV (left) and $\sqrt{s} = 7$ TeV (right). See also [8].

- corrections for absorption (extracted using a complete Monte Carlo production simulating the detector response with GEANT3),
- corrections for the proper p($\overline{\mathrm{p}}$)–A inelastic cross-sections (comparison between GEANT3 and FLUKA),
- corrections for background (mainly protons) and feed–down (parameterization of the distribution of the distance of closest approach– *dca* of the tracks to the primary vertex from data)
- corrections for the differences in the efficiencies of the analysis cuts for the different charges.

For more details about the corrections and the estimation of the systematic uncertainties, see [8].

The final corrected $\overline{\mathrm{p}}/\mathrm{p}$ ratio R rises from $R_{|y|<0.5} = 0.957 \pm 0.006(stat.) \pm 0.014(syst.)$ at $\sqrt{s} = 0.9$ TeV to $R_{|y|<0.5} = 0.991 \pm 0.005(stat.) \pm 0.014(syst.)$ at $\sqrt{s} = 7$ TeV. Within statistical errors, the measured ratio R shows no dependence on transverse momentum (Fig. 1) and rapidity Fig. 2 [8]. The different models studied are also independent of momentum and rapidity, with the exception of HIJING/B, which predicts a decrease with increasing p_t for the lower energy. The data are compared with various model predictions for pp collisions[5, 6, 9] in both Fig. 1 and Fig. 2. Two of the PYTHIA tunes [9] (ATLAS-CSC and Perugia-0) as well as the version of QGSM with the value of the string junction intercept $\alpha_J = 0.5$ [5] describe the experimental values well, for both energies. QGSM without string junctions ($\epsilon = 0$) is slightly above the data. HIJING/B [6] underestimates the experimental results, in particular at the lower LHC energy. Also, QGSM with a value of the junction intercept $\alpha_J = 0.9$ [5] predicts a smaller ratio, as does the Perugia-SOFT tune of PYTHIA, which also includes enhanced baryon transfer.

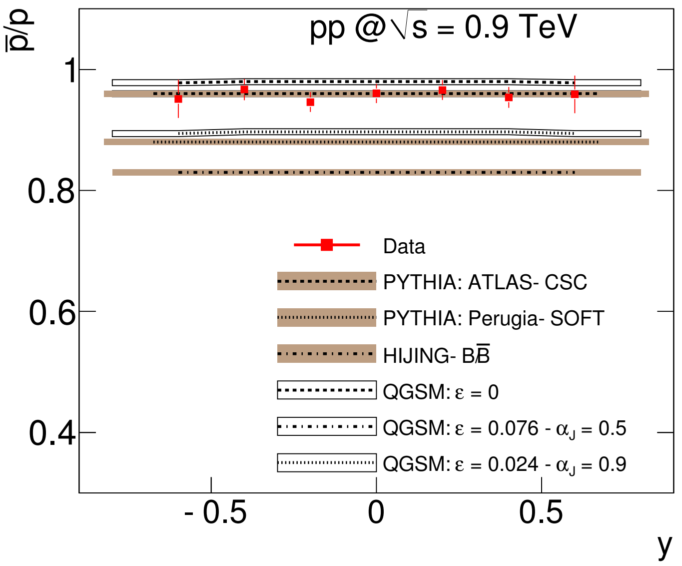

Figure 2: The $\overline{\mathrm{p}}/\mathrm{p}$ ratio as a function of the rapidity y at $\sqrt{s} = 0.9$ TeV. See also [8].

Figure 3 shows a compilation of central rapidity measurements of the ratio R in pp collisions as a function of center-of-mass energy (upper axis) and the rapidity interval Δy (lower axis). The lower energy data points are taken from [10, 11, 12]. At $\sqrt{s} = 0.9$ TeV there is still a small but significant excess of protons over antiprotons. The ratio at $\sqrt{s} = 7$ TeV is consistent with unity. The curve shown in Fig. 3 corresponds to a parameterization of the ratio taking into account that the baryon pair production at very high energy is governed by Pomeron exchange and baryon transport by string-junction exchange [4]. Following this formulation the $\mathrm{p}/\overline{\mathrm{p}}$ ratio can be described by the simple form $1/R = 1 + C\exp[(\alpha_{\mathrm{J}} - \alpha_{\mathrm{P}})\Delta y]$. The value for the Pomeron intercept is chosen to be $\alpha_{\mathrm{P}} = 1.2$ in accordance with the energy dependence of the rapidity density [13] and $\alpha_{\mathrm{J}} = 0.5$ (intercept of the Reggeon). The parameter C, which determines the relative contribution of the two diagrams, is adjusted to the measurements from ISR, RHIC, and LHC. The fit, shown in Fig. 3, gives a reasonable description of the data with only one free parameter (C), except at lower energies, where contributions of other diagrams (exchange of two junctions at both vertices) cannot be neglected [4]. The contribution of a second string junction diagram with a larger intercept [3], i.e., $1/R = 1 + C\exp[(\alpha_{\mathrm{J}} - \alpha_{\mathrm{P}})\Delta y] + C'\exp[(\alpha_{\mathrm{J'}} - \alpha_{\mathrm{P}})\Delta y]$ with $\alpha_{\mathrm{J'}} = 1$, is compatible with zero ($C \approx 10$, $C' \approx -0.1 \pm 0.1$).

3 Summary

In summary, we have measured the ratio of antiproton to proton production at $\sqrt{s} = 0.9$ and $\sqrt{s} = 7$ TeV. The reported values are $R_{|y|<0.5} = 0.957 \pm 0.006(stat.) \pm 0.014(syst.)$ at 0.9 and $R_{|y|<0.5} = 0.991 \pm 0.005(stat.) \pm 0.014(syst.)$ at 7 TeV. The $\overline{\mathrm{p}}/\mathrm{p}$ ratio is independent of both rapidity and transverse momentum and the results are consistent with standard models of baryon-number transport over very large rapidity intervals in pp collisions.

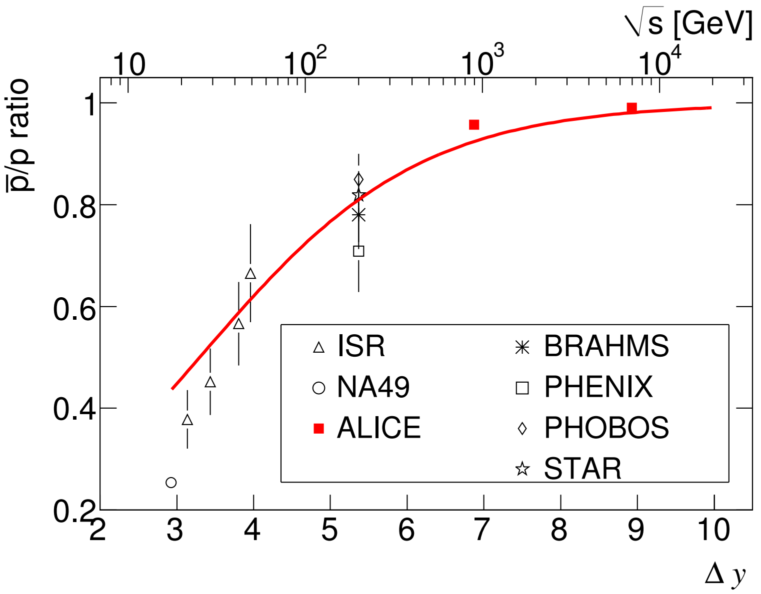

Figure 3: Central rapidity $\overline{\mathrm{p}}/\mathrm{p}$ ratio as a function of the rapidity interval Δy (lower axis) and center-of-mass energy (upper axis). Error bars correspond to the quadratic sum of statistical and systematical uncertainties for the RHIC and LHC measurements and to statistical errors otherwise. See also [8].

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