Energy dependence of anti-proton/proton ratio in p+p collisions

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Introduction

Protons (p) and anti-protons ($\bar{p}$) are the most abundantly produced baryons in high energy collisions. These have been measured at various center of mass energies ($\sqrt{s}$) in hadron-hadron collisions at ISR, STAR and ALICE experiments as a function of rapidity (y) and transverse momentum ($p_{\rm T}$). In this paper, we compare the experimentally measured anti-proton to proton ratio at midrapidity in p+p collision at various center of mass energy ($\sqrt{s}$ = 23 to 7000 GeV) with models PYTHIA [1], PHOJET [2] and HIJING/B-$\bar{\rm B}$ [3] to understand the baryon production mechanism in these collisions. We also present the asymmetry for proton and anti-proton production at midrapidity for p+p collisions as a function of $\sqrt{s}$.

Data and Models

Figure 1 shows the increase of the $p_{\rm T}$ integrated $\bar{p}/p$ ratio at midrapidity with increase in $\sqrt{s}$ for p+p collisions. The experimental data are compared to three models,viz, PYTHIA (Ver. 6.4), PHOJET (Ver. 1.12) and HIJING/B-$\bar{\rm B}$ (Ver. 1.34),all with default settings. All models studied show that the $\bar{p}/p$ ratio increases with $\sqrt{s}$ and approaches unity for higher energies (LHC). Infact, the PYTHIA and PHOJET models give very similar values at the LHC energies, while HIJING/B-$\bar{\rm B}$ under predicts the $\bar{p}/p$ ratio.

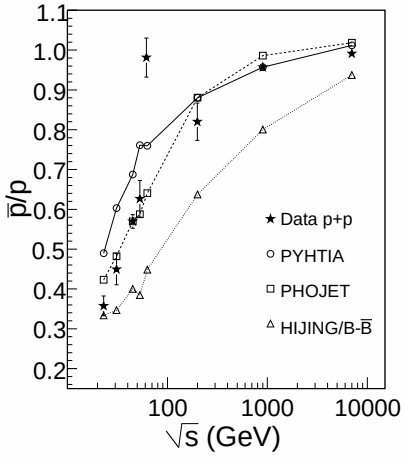

FIG. 1: $\bar{p}/p$ ratio at midrapidity as a function of $\sqrt{s}$ for p+p collisions. The experimental data are compared to model calculations from PYTHIA [1], PHOJET [2] and HIJING/B-$\bar{\rm B}$ [3] with default settings.

The basic difference between PYTHIA and PHOJET lies in their approach towards an event formation. The starting point of particle production in PYTHIA is through the description of possible hard interactions in $e^+ + e^-$, p+$p(\bar{p})$ or e+p colliders and then combines several ideas for the soft hadronic interactions, whereas in PHOJET model it initializes the event generation by describing the soft component of hadron-hadron, photon-hadron or photon-photon interactions at high energies. The hard component is introduced later and calculated by perturbative QCD at the partonic level. The abnormality of the ratio at $\sqrt{s} = 63$ GeV is out of the scope of this paper and hence not discussed here.

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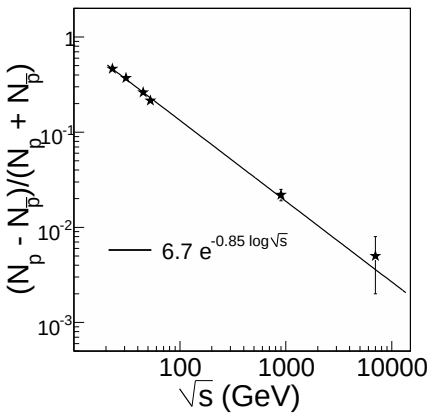

FIG. 2: Asymmetry for proton and anti-proton production at midrapidity for p+p collisions as a function of $\sqrt{s}$. The solid line is a fit to the data, with the functional form shown.

Different baryon production mechanisms could lead to an asymmetry in the production of protons and anti-protons. This asymmetry can be measured by constructing the following ratio,

$$\frac{N_p - N_{\bar{p}}}{N_p + N_{\bar{p}}}, \tag{1}$$

where N_p and $N_{\bar{p}}$ are the number of protons and anti-protons. As pair production would lead to same number of protons and anti-protons, the asymmetry will have a value of zero. Any non-zero value indicates the fraction of protons in midrapidity due to effects such as stopping. Figure 2 shows the asymmetry ratio for protons and anti-protons as measured in p+p collisions for various $\sqrt{s}$ ranging from 23 GeV to 7 TeV. The asymmetry is found to decrease with increase in $\sqrt{s}$, indicating the decreasing contributions of protons due to stopping at midrapidity. The ratio changes from about 46% at $\sqrt{s} = 23$ GeV to 0.5% at the top LHC energy of 7 TeV. The solid line in Fig. 2 is a fit ($\chi^2/ndf = 3/4$) to the experimental data with the function $Ae^{-Blog\sqrt{s}}$, with the parameters $A = 6.7 \pm 0.9$ and $B = 0.85 \pm 0.04$.

Summary

In summary, we have presented a compilation of the available data for $\bar{p}/p$ ratio at midrapidity for p+p collisions as a function of $\sqrt{s}$. We have compared the $\bar{p}/p$ ratio vs. $\sqrt{s}$ to results from various models with different baryon production mechanisms, such as PYTHIA, PHOJET and HIJING/B-$\bar{\text{B}}$ with default settings. It is observed that PHOJET gives the best description of the data for all $\sqrt{s}$, PYTHIA gives higher values of the $\bar{p}/p$ ratio for $\sqrt{s} < 200$ GeV and HIJING/B-$\bar{\text{B}}$ under predicts the ratio for all beam energies. The asymmetry, a measure of proton stopping at the midrapidity in p+p collisions are presented. The fraction of protons stopped around midrapidity varies from 46% at $\sqrt{s} =$ 23 GeV to 0.05% for $\sqrt{s} = 7$ TeV. This energy range corresponds to a range in $y_{\rm beam}$ from 3 to 9 units, respectively.

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References

[1] T. Sjostrand, *et al.*, Computer Physics Commun. 135, 238 (2001); T. Sjostrand and M. van Zijl, Phys. Rev. D 36, 2019 (1987); T. Sjostrand and P. Skands, Eur. Phys. J. C 39, 129 (2005); T. Sjostrand and P. Skands, JHEP 0605, 026 (2006).

[2] R. Engel, Z. Phys. C 66, 203 (1995); R. Engel, J. Ranft and S. Roesler, Phys. Rev. D 52, 1459 (1995).

[3] S.E. Vance, M. Gyulassy,and X.N. Wang, Phys. Lett. B 443, 45 (1998).