Antibaryon to Baryon Production Ratios in Pb-Pb and p-p collision at LHC energies of the DPMJET-III Monte Carlo

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Abstract

A sizable component of stopped baryons is predicted for pp and $PbPb$ collisions at LHC. Based on an analysis of RHIC data within the framework of our multi-chain Monte Carlo DPMJET-III the LHC predictions for pp and $PbPb$ are presented.

1 Introduction

DPMJET is a Monte Carlo program for the scattering of hadrons or nuclei. It utilizes PHOJET for the scattering of individual hadrons and parts of PYTHIA for the decay of partonic strings. The present version is DPMJET III. For the most recent general LHC predictions we refer to Ranft's CERN talk [1,2]. Here the focus is on a particular aspect and baryon stopping is addressed [3,4].

There are different components to baryon stopping. Most interesting we consider *the component without leading quarks.* The actual baryon transport is here just an effect of the orientation of the color-compensation during the soft hadronisation.

Baryon stopping is not new. The phenomenology was developed 30 years ago [5] in "*Dual*" models in a "*Topological*" framework [6]. Critical are various baryonium Regge intercepts

$$\alpha^0_{Barionium},\ \alpha^1_{Barionium},\ \text{or}\quad \alpha^2_{Barionium}$$

of processes in which the exchanged baryonia respectively contain 0, 1 or 2 quark pairs transporting 0, 1 or 2 valence quarks. The idea is that $\alpha^2_{Barionium}$ is dominant in the leading region. As it has a low intercept it will not reach very far and the next baryonium will take over in a more central region. Eventually a flattish $\alpha^0_{Barionium}$contribution will survive. The intercepts were estimated using the energy dependence of annihilation cross sections [5] and the inclusive baryonic charge distributions [7]. Some ambiguity remains for the intercept of the long range component and a confirmation of the flattish distribution indicated by HERA and RHIC data at LHC would be useful.

Today such baryon processes are still of fundamental interest. Many people are convinced that under specified conditions very high energy hadronic scattering can be understood with BFKL Pomeron exchanges described by ladders of dispersion graphs. In these graphs soft effects are thought to be contained in effective gluon exchanges calculated in a self-consistent way. In

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principle these soft effects include the color compensating mechanism usually modeled as two strings neutralizing triplet colors.

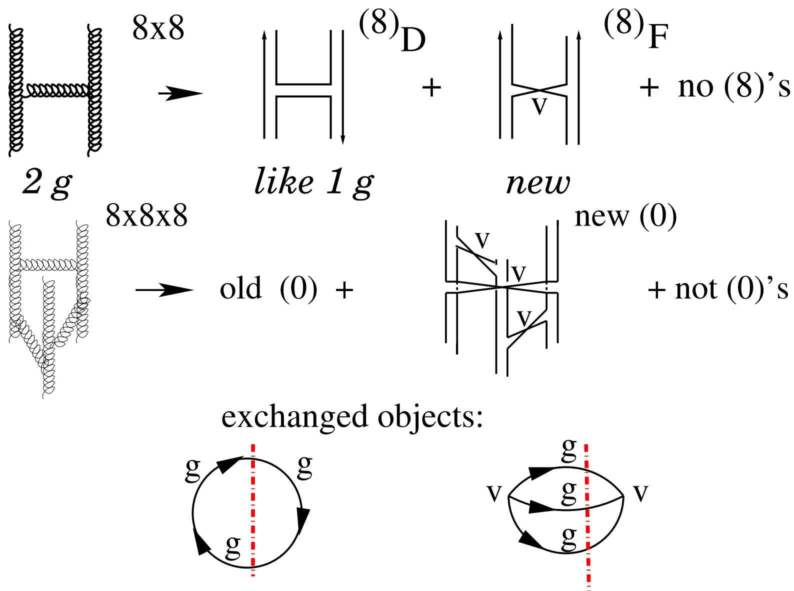


Fig. 1: Structure of Odderon

In string phenomenology it is assumed that these predictions somehow apply to minimum bias physics. The idea is that BFKL QCD results extrapolate smoothly into the minimum bias region where a suitable truncation has to be modeled.

At some level an untruncated soft or collinear QCD calculation would operate in phantasy space as the end entropy can never be exceeded. In hadronic string models the scattering is assumed to end with the production of independently decaying strings. Such a few string state contains comparatively low entropy. In this way the required truncation is taken to be sufficiently servere to allow for no really separate non perturbative contribution as the effective radius of convergence is not crossed.

In this way semihard calculations offer a stringent guidance for modeling the non-perturbative region. With few added assumptions the very successful Dual-Parton / Quark-Gluon-String model [8] description of all relevant data is obtained.

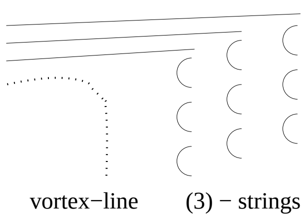


Fig. 2: Proton contribution

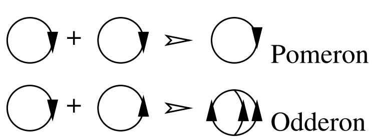


Fig. 3: Fusion contribution

However, there is a problem. Beside the Pomeron semihard theory predicts *a three gluon Odderon exchange* [9, 10]. It is a necessary ingredient of the approach. In comparison to the Pomeron it has to have a similar but somewhat lower intercept. Parameterizations of available cross sections require a small coupling to nucleons.

In Fig. 1 we consider the Odderon to the leading $1/N_c$ order. Two gluons can couple into an octet with even or odd C parity (line 1). With a third gluon they can then couple to an even or odd C parity singlet (line 2). The exchanged topological object is a cylinder or a baryonium (line 3). In inelastic collisions this object can be cut in the way indicated by the dashed line through the reggeized gluons.

The central observation is that a vortex line can remain on each side. In inelastic exchanges Odderons can contribute to baryonic charge exchange with three strings as shown in Fig. 2 .

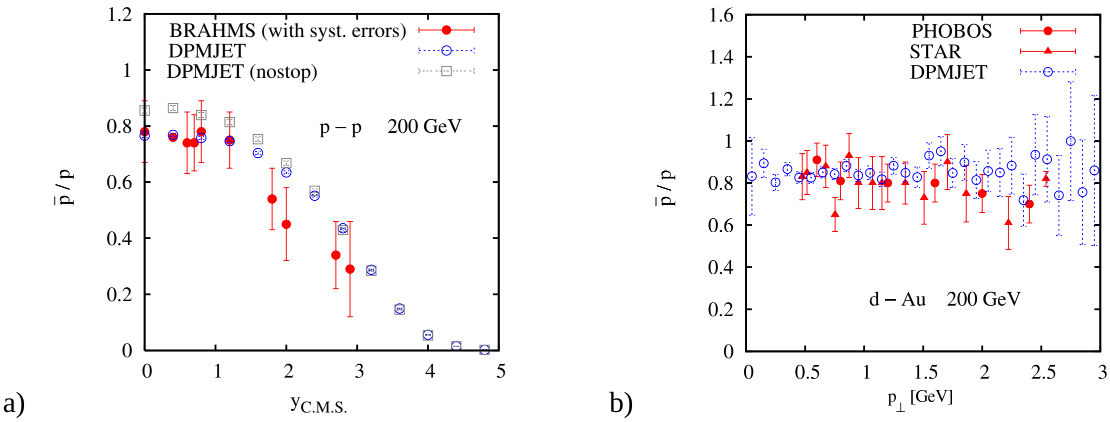


Fig. 5: RHIC data compared with the DPMJET results

That the Odderon has to be attached exactly to the vortex line might explain why the Odderon coupling to the proton is considerable smaller than the Pomeron coupling. Guided by Kwiecinski's and Balitskij's, Kovchegov's calculations for semihard processes *strings can fuse*. Topologically there are two posibilities (Fig. 3). The fusion probability should here be mainly determined by geometry. There should be plenty of Odderons in Pomeron fusion processes.

2 Comparing with RHIC and Tevetron Results

The first experimental indication for a flat component came from preliminary H1 data at HERA [11]. As RHIC runs pp or *heavy ions* instead of $p\bar{p}$ the central asymmetry allows to address the asymmetry better than the SPS or Tevatron collider and the data seem to require a rather flat contribution [12].

In the Dual-Parton-Model generator, DPMJET III [13], there are several components affecting the position of the net baryon charge. The transport mechanisms from these contributions are not sufficient. To obtain the needed long range baryon transport we introduced a new string interaction reshuffling the initial strings configuration in a certain way indicated in Fig. 4. It effectively introduces a baryonium exchange at the top with an intercept of $\alpha^0_{Barionium} = 0.5$.

A good fit is obtained for the BRAHMS data on the ratio $\bar{p}/p$ as function of y_{cm} (Fig. 5a) [14]. However, for nucleons at this energy the contribution comes mainly from non flipping effects. The empty squares show the result without flipping,

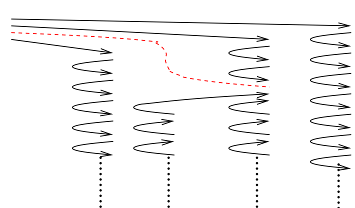


Fig. 4: The flipped configuration

This changes for nuclei where multiple Pomeron exchanges appear as required by Glauber theory. For nuclear scattering fusion of complete strings which are geometrically close (< 0.75fm) is needed to reduce the spectral density. It also can lead to effective quarkless baryonium exchanges.

Fig. 5b shows agreement with PHOBOS and STAR [15, 16] collaborations data. No $p_\perp$ dependence is visible in the considered soft range. The same applies to the centrality dependence.

For strange baryons good agreement is obtained with the net Λ's distribution compared with data from the STAR collaboration. For the Ξ asymmetry - which is also available - a possibly observed backward peak is not reproduced. The Ω-asymmetry measured by the E791 collaboration [17] in πp scattering is shown in Fig. 6 . The inclusion of the baryonium production (Fig. 6 insert) moves the result from the crosses to the squares to reproduce the filled square data.

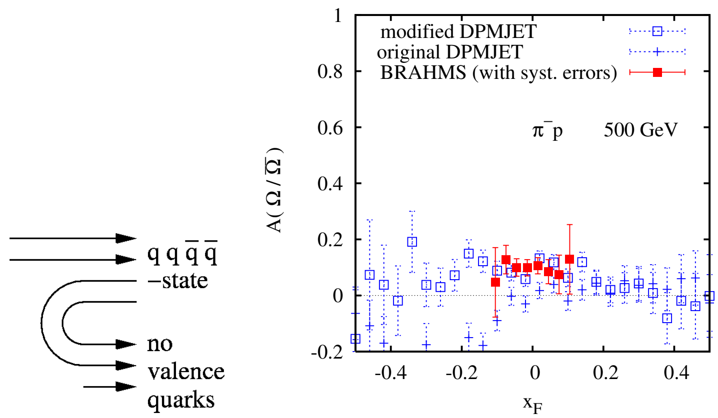


Fig. 6: Net Ω distribution and Tevatron data where the asymmetry

$$A(\Omega/\bar{\Omega}) = (N_\Omega - N_{\bar{\Omega}})/(N_\Omega + N_{\bar{\Omega}})$$

3 Prediction for LHC Data

Turning to LHC the DPMJET III prediction for the pseudo rapidity of p, $\bar{p}$, and $p - \bar{p}$ and the asymmetry are shown in Fig.7 . The new baryon stopping process is now stronger than before as the Pomeron number increased with energy. With the effective intercept of 0.5 the present implementation of the baryon stopping is a rather conservative estimate. For an intercept of 1.0 the value at $\eta = 0$ would roughly correspond to the present value of $\eta = 4$

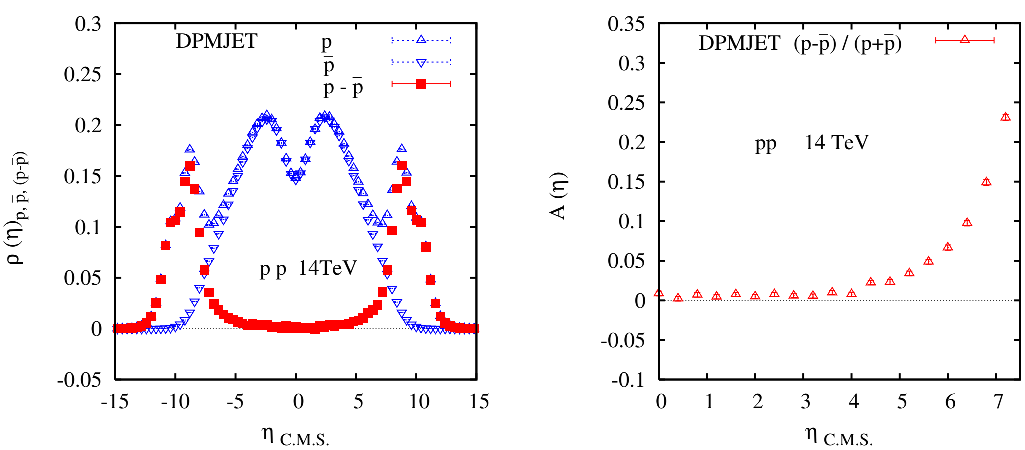
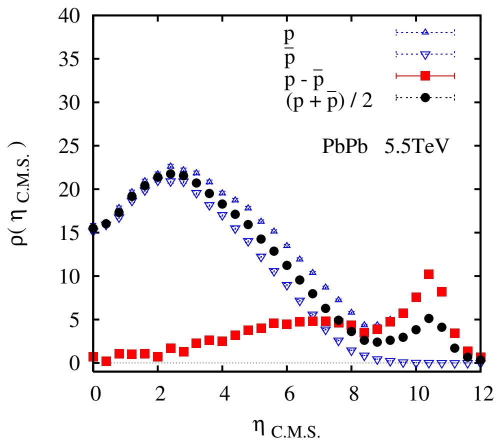


Fig. 7: pp−LHC predictions for p and $\bar{p}$

For heavy ion collisions the baryon stopping gets even stronger. The pseudorapidity proton distributions in $PbPb$ scattering are given in Fig. 8.



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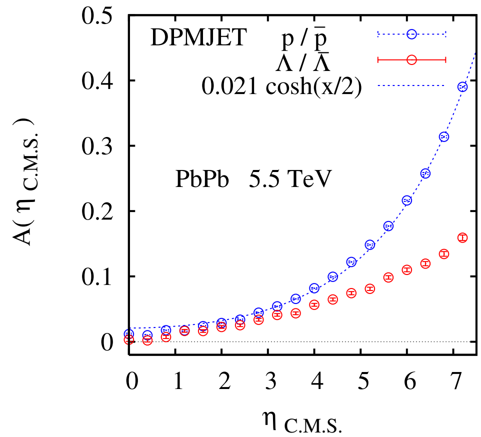

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Fig. 8: $PbPb-$LHC predictions for p and $\bar{p}$

Fig. 9: $PbPb-$central LHC predictions for the p resp. Λ asymmetry

Especially interesting are the most central 10% of the events. The DPMJET III prediction for the proton and Λ asymmetries in such events is shown in Fig 9. There is some uncertainty in this prediction as the model in its present form does not reproduce the full elliptic flow. Hopefully the net baryon distribution is not affected by missing a non-initial state effect. The line drawn corresponds to an $\alpha^0_{Barionium} = 0.5$ with an arbitrary normalization. It is a safe, quite conservative estimate and it could be considerably flatter.

To conclude there is a strong evidence for a significant baryon stopping component. There is still some uncertainty how high the intercept has to be and LHC measurements will be useful.

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