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LETTER

ANTIBARION TO BARION PRODUCTION RATIOS IN Pb-Pb AND p-p COLLISION AT LHC ENERGIES OF THE DPMJET-III MOMTE CARLO

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

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DPMJET is a Monte Carlo program for the study of 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 prediction we refer to the Ranft's CERN talk [1]. Here the focus is on a particular aspect and the baryon stopping is addressed.

There are different components to baryon stopping. *We consider the component without actual leading quarks.* When the flavor decomposition is not dominated by the final state interactions, this leading-quark-less component can be enhanced by considering strange baryon ratios.

One motivation for looking for a baryon stopping component with a flattish rapidity distribution comes from the simple color evaporation concepts. If soft gluons can arbitrarily arrange colors, a configuration can appear in which the baryonic charge ends up moved to the center. The actual transport is just an effect of the orientation of the color-compensation during the soft hadronisation.

There are many approaches to heavy-ion physics, and baryon transport can appear in many scenarios. It is generally agreed that *there is an initial phase and* *there are subsequent phases in an interaction.* The *initial phase* contains hard partonic interactions. In the models like ours it also contains softer, sometimes multi-peripheral interactions leading to the production of color singlet strings. The *subsequent phases* always contain hadronisation of singlets formed in the initial phase. In many models, they also contain a statistical partonic and hadronic multiple-scattering phase. The concepts are not easy to distinguish as there is an intrinsic relation between the multi-peripheral propagator and the statistical partition function leading e.g. to a similar $m_\perp = \sqrt{p_\perp^2 + m^2}$ dependence.

These are controversial aspects which we want to avoid by considering baryons. Also, for the baryon stopping, alternative ideas were proposed, but most people will agree that fast baryon stopping, as part of the initial process, is a valid attractive option.

Baryon stopping is not a new idea. The phenomenology was developed 30 years ago in "*Dual*" models in a "*Topological*" framework [2]. Critical are various baryonium Regge intercepts

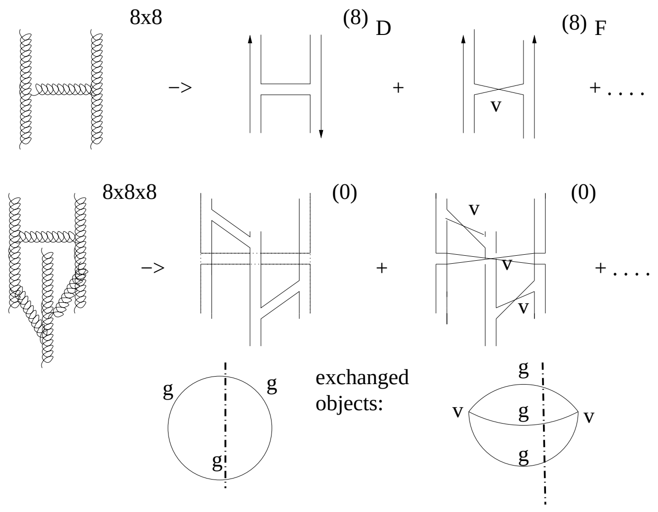
$$\alpha^0_{\mathrm{Barionium}},\ \alpha^1_{\mathrm{Barionium}},\ \text{or}\ \ \alpha^2_{\mathrm{Barionium}}$$

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 $\alpha^2_{\mathrm{Barionium}}$ 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 and so on. Eventually a flattish $\alpha^0_{\mathrm{Barionium}}$ contribution will survive. The intercepts were estimated using the energy dependence of annihilation cross sections and the inclusive baryonic charge distributions. Some ambiguity remains for 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 principle, these soft effects include the color compensating mechanism usually modeled as two strings neutralizing triplet colors.

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 and offer in this way a stringent guidance for modelling the non-perturbative region. Also, the relevant scale of minimum bias interaction is not determined by decay momenta. For high energies, the minimum bias events involve string ends with respectable $O(1-2\,\mathrm{GeV})$ transverse momenta closely neighboring the perturbative range. The separation of soft and hard processes is often exaggerated.

However, there is a problem. Beside the Pomeron, this theory predicts a three gluon Odderon exchange [3]. It is a necessary ingredient of the approach. In comparison to the Pomeron, it has a similar but somewhat lower intercept. Parameterizations of available cross sections require a much smaller coupling to nucleons.



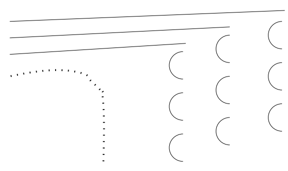


Fig. 1 (left). Structure of Odderon. *Fig. 2. Exchange contribution.*

We now consider the Odderon more closely to the leading $1/N_c$ order in Fig. 1. Two gluons can couple into an octet in an even or odd way (line 1). With a third gluon they can then couple to a C even or C odd singlet (line 2). The exchanged topological object is a cylinder or a baryonium (line 3). In inelastic collision, this object can be cut in the way indicated by the dashed line. The central observation is that a vortex line can remain on each side. In inelastic exchanges, Odderons will therefore contribute to the baryonic charge exchange with three strings as shown in Fig. 2.

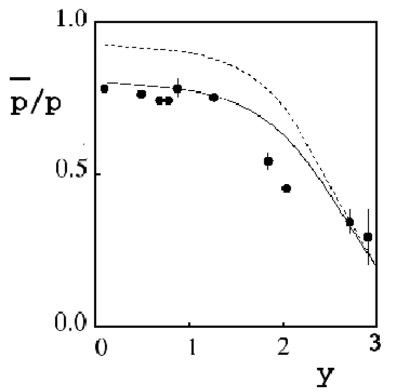
The first experimental indication for a flat component came from preliminary H1 data at HERA [4]. As RHIC runs pp or heavy ions instead of $p\bar{p}$, the central asymmetry allows to address this question much better than before, and the data seem to require a flat contribution as seen in Fig. 3.

To understand the data, we turn to the Dual-Parton/Quark-Gluon-String model. In a factorizing inclusive approximation of the model (QGS-calculation) [5], the best fit to RHIC BRAHMS pp data at $\sqrt{s} = 200$ GeV [6] required diquarks with a probability of $\epsilon = 0.024$ to involve a quark-less baryonium-exchange with an intercept $\alpha_{\{SJ\}} = 0.9$ (solid line). The dotted line corresponds to no such contribution. At LHC the rapidity extends two units more, allowing considerable clarification.

In the full microscopic generator of the model, DPMJET III [7], there are several components affecting the position of the net baryon charge:

initial diquark structure function
during the string decay: qq →meson+qq
during the string decay: qq →baryonium+qq
string fusion effects

The baryonium (line 3 of the table) is just a wide two meson state like the $f_0(600)$ of Krupa [8]. The transport mechanisms from these contributions are not sufficient.



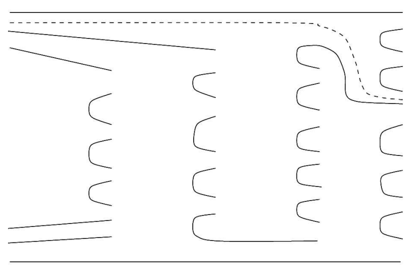


Fig. 3 (left). RHIC BRAHMS pp data at $\sqrt{s} = 200$ GeV compared with the QGS-calculations (lines). The dotted line corresponds to no SJ.

Fig. 4 The flipped configuration.

To obtain a long-range baryon transport, we introduced a new string interaction, reshuffling the initial strings configuration in a certain way indicated in Fig. 4. Two cases are thereby considered:

string rearrangements with Glauber sea quarks
string rearrangements with unitary sea quarks

It introduces an exchange with a conservative intercept of $\alpha_{\{SJ\}} = 0.5$.

Again, a good fit is obtained for the BRAHMS data on the ratio p̄/p as function of $y_{\rm cm}$ (Fig. 5 left). However, as shown, at this energy for nucleons, the contribution actually mainly comes from the non-flipping effects. Fig. 5 (right) shows there is no visible $p_\perp$ dependence in the considered soft range as found in BRAHMS and STAR[9] collaborations data. The same applies to the centrality dependence.

For strange baryons, Fig. 6 (left) shows the net Λ's distribution compared with the data from the STAR collaboration.The Ω-asymmetry measured by the E798 collaboration [19] in πp scattering is shown in Fig. 6 (right). The inclusion of the baryonium production moves the result from the (blue) circles to the (blue) crosses

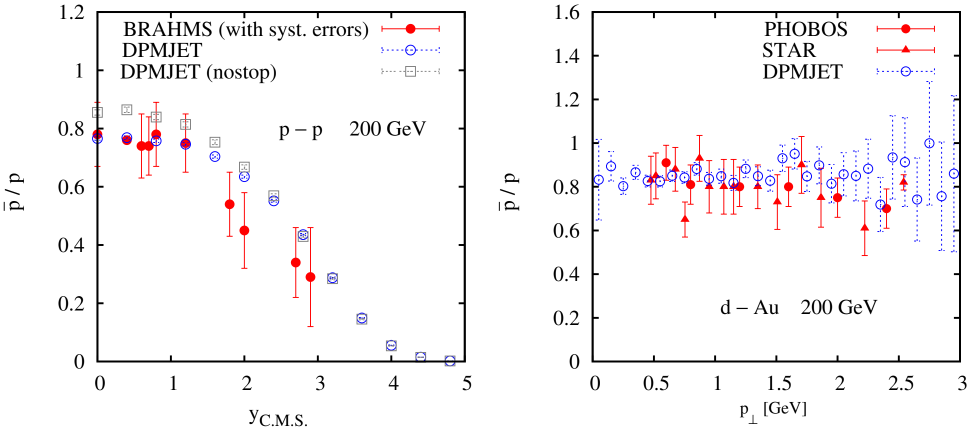


Fig. 5 . RHIC data compared with the DPMJET results.

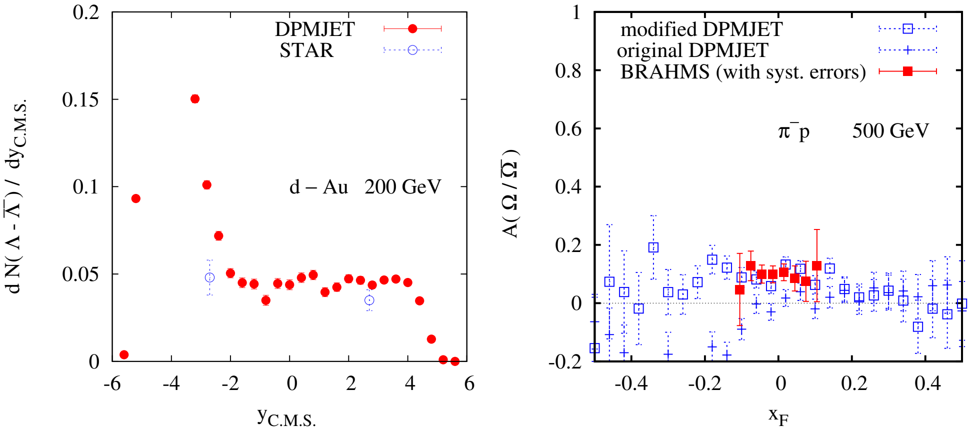


Fig. 6. Net strange baryon distribution.

to reproduce the undashed data. Not shown is the Ξ asymmetry, which is also available [19]. It indicates a backward peak which is not reproduced.

Now turning to LHC predictions, the DPMJET III prediction for the pseudo rapidity of p, $\bar{\mathrm{p}}$, and p$-\bar{\mathrm{p}}$ is shown in Fig. 7. The new baryon stopping process is now also in pp scattering a 40% effect. Of course, 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 $\eta = 4$.

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

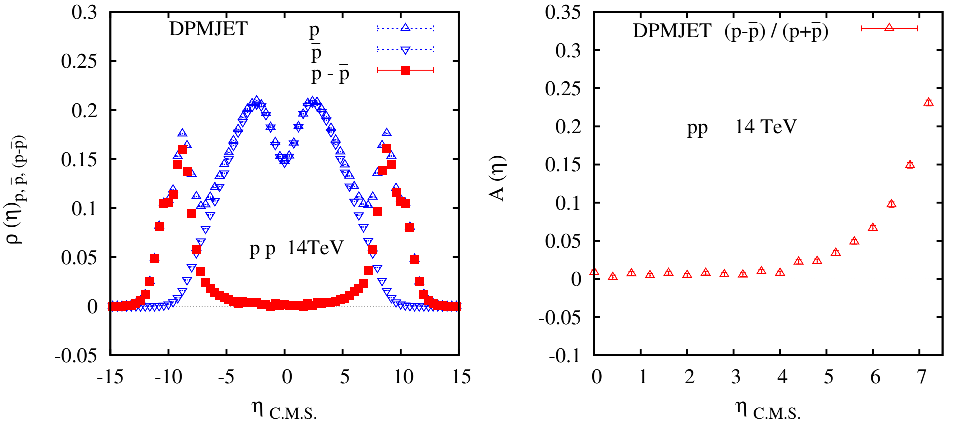


Fig. 7. pp – *LHC predictions for* p *and* $\bar{\mathrm{p}}$.

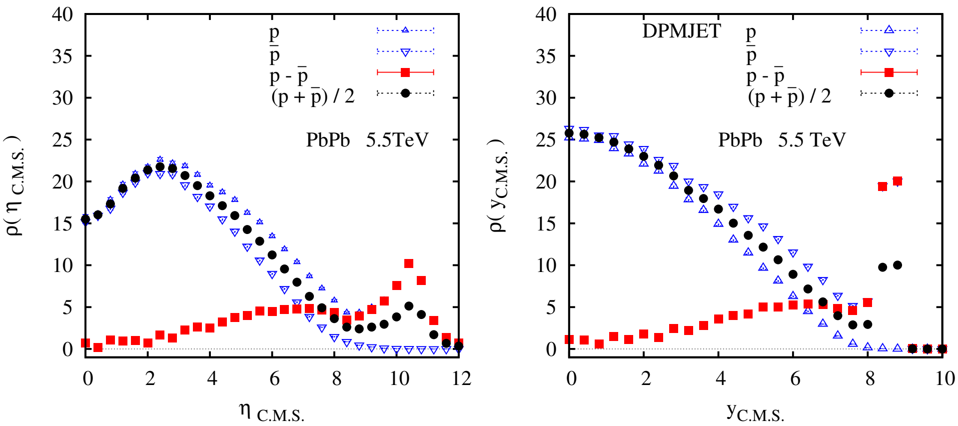


Fig. 8. PbPb – *LHC predictions for* p *and* $\bar{\mathrm{p}}$.

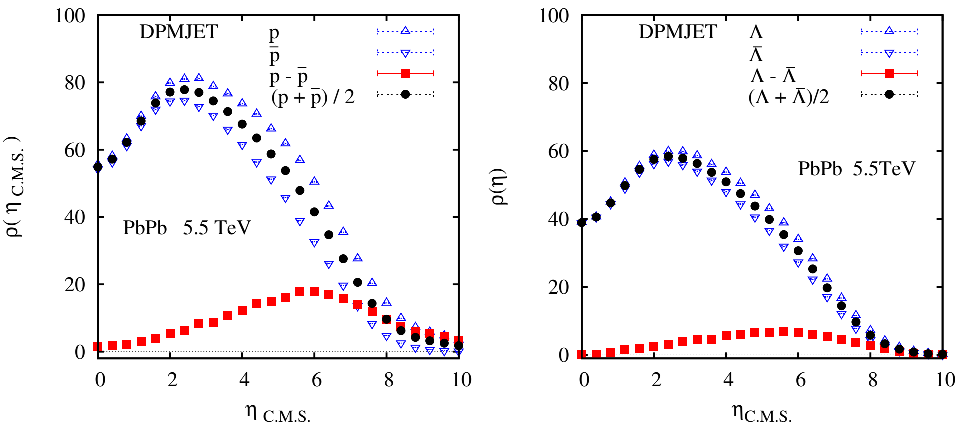


Fig. 9. PbPb – *central LHC predictions for* p *and* $\bar{\mathrm{p}}$, *resp.* Λ *and* $\bar{\Lambda}$.

The DPMJET III prediction for the especially interesting most central 10% of the events for the pseudorapidity proton and Λ distributions are shown in Fig. 9. Of course these most central results are somewhat uncertain, as the model is so far not well tested in this region.

The asymmetry for the 10% most central events is plotted in Fig. 10. The line drawn corresponds to an $\alpha^0_{\mathrm{Barionium}} = 0.5$ with an arbitrary normalisation. It is a safe, quite conservative estimate and it could be considerably flatter.

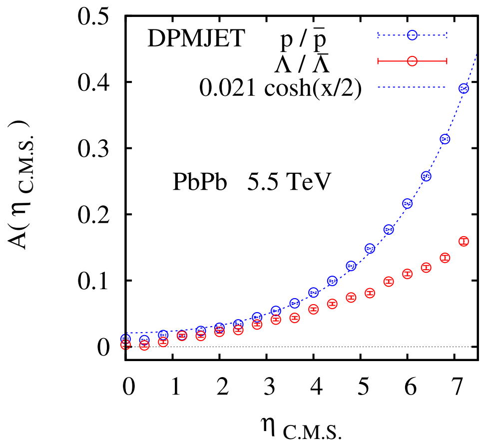


Fig. 10. PbPb – *central LHC predictions for* p, *resp.* Λ *asymmetry.*

To conclude there is a strong evidence for the baryon stopping component. It moderately depends on the density. There is still some uncertainty how flat the intercept has to be.

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OMJER TVORBE ANTIBARIONA I BARIONA U SUDARIMA Pb-Pb I p-p NA ENERGIJAMA LHC PROGRAMOM DPMJET-III MOMTE CARLO

Predviđamo poveću komponentu zaustavljenih bariona u pp i PbPb u LHC mjerenjima. Predstavljamo LHC predviđanja za pp i PbPb sudare dana nasim više-niznim Monte Carlo DPMJET-III simulacijama zasnovanim na analizama RHIC podataka.