New results for hadronic collisions in the framework of the Parton-Based Gribov-Regge Theory

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We recently proposed a new approach to high energy nuclear scattering, which treats hadronic collisions in a sophisticated way. Demanding theoretical consistency as a minimal requirement for a realistic model, we provide a solution for the energy conservation, screening problems and identical elementary interactions, the so-called ”Parton-Based Gribov-Regge Theory” including enhanced diagrams. We can now present some of our results for SPS and RHIC energies.

1. INTRODUCTION

The most sophisticated approach to high energy hadronic interactions is the so-called Gribov-Regge theory \cite{1}. This is an effective field theory, which allows multiple interactions to happen “in parallel”, with phenomenological objects called \textit{Pomeron}s representing elementary interactions \cite{2}. Using the general rules of field theory, one may express cross sections in terms of a couple of parameters characterizing the Pomeron.

A big disadvantage of GRT implementations was so far the fact that cross sections and particle production are not calculated consistently: the fact that energy needs to be shared between many Pomeron}s in case of multiple scattering is well taken into account when considering particle production (in particular in Monte Carlo applications), but not for cross sections \cite{3}.

Another problem is that at high energies, one also needs a consistent approach to include both soft and hard processes. The latter are usually treated in the framework of the parton model, which only allows the calculation of inclusive cross sections.

We consider now a new approach called Parton-Based Gribov-Regge theory, in order to solve the above-mentioned problems. We use both the language of Pomeron}s (as in Gribov-Regge theory) in order to calculate probabilities (and related to this: cross sections) and the language of strings (to treat particle production). But we treat these

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both aspects in a consistent fashion. This is the really new and attractive feature of our approach. The price to be paid are great technical difficulties which took us a couple of years to solve them. For all the details and applications of the corresponding Monte Carlo program neXus 3 see [4].

2. PARTON-BASED GRIBOV-REGGE THEORY

2.1. Basic ideas

We will discuss the basic features of the new approach in a qualitative fashion. It is an effective theory based on effective elementary interactions. Multiple interactions happen in parallel in proton-proton collisions. An elementary interaction is referred to as Pomeron, and can be either elastic (uncut Pomeron) or inelastic (cut Pomeron). The spectators of each proton form a remnant, see Fig. 1a.

Since a Pomeron is finally identified with two strings, the Pomeron aspect (to obtain probabilities) and the string aspect (to obtain particles) are treated in a completely consistent way. In both cases energy sharing is considered in a rigorous way, and in both cases all Pomerons are identical.

This theory provides also a consistent treatment for hard and soft processes: each Pomeron can be expressed in terms of contributions of different types, soft, hard and semihard, cf. Fig. 1b. A hard Pomeron stands for a hard interaction between valence quarks of initial hadrons. A semihard one stands for an interaction between sea quarks but in which a perturbative process involves in the middle. No perturbative process occurs at all in soft Pomeron.

A Pomeron is an elementary interaction. But those Pomerons may interact with each other at high energy [5 6], then they give another type of interaction called enhanced diagram. There are many types of enhanced diagrams depending on the number of Pomerons for each vertices and on the number of vertices. In our model, effective first order of triple

Figure 1. a) Multiple elementary interactions (Pomerons) in neXus. The energy of each proton (blob) is shared between elastic (full vertical line) and inelastic (dashed vertical line) elementary interactions. A Pomeron b) has soft (blob), hard (ladder) and semihard contributions. c) Enhanced diagrams are included and can give different inelastic contributions d).
and 4-Pomeron vertices (Y and X diagrams see Fig. 1c) are enough to cure unitarity problem which occur at high energy without this kind of diagram [6]. Indeed, Y-type diagrams are screening corrections which are negative contributions to the cross-section. X diagram is anti-screening. The inelastic contributions (cut enhanced diagrams on Fig. 1d) of this diagrams contribute to the increase of the fluctuations in particle production.

2.2. Particle production in NeXus

Thanks to a Monte Carlo, first the collision configuration is determined: i.e. the number of each type of Pomerons exchanged between the projectile and target is fixed and the initial energy is shared between the Pomerons and the two remnants. Then particle production is accounted from two kinds of sources, remnant decay and cut Pomeron. A Pomeron may be regarded as a two-layer (soft) parton ladder attached to projectile and target remnants through its two legs. Each leg is a color singlet, of type $q\bar{q}$, $qqq$ or $q\bar{q}q$ from the sea, and then each cut Pomeron is regarded as two strings, cf. Fig. 2a. It is a natural idea to take quarks and antiquarks from the sea as string ends for soft Pomeron in NeXus, because an arbitrary number of Pomerons may be involved. In addition to this soft Pomerons, hard and semihard Pomerons are treated differently. To give a proper description of deep inelastic scattering data, hard and some of semihard Pomerons are connected to the valence quarks of the hadron.

Thus, besides the three valence quarks, each remnant has additionally quarks and antiquarks to compensate the flavours of the string ends, as shown in Fig. 2c. According to its number of quarks and antiquarks and to the phase space, a remnant decays into mesons, antibaryons and baryons [7]. Therefore, from remnant decay, baryon production is favored due to the initial valence quarks and in particular produce strong leading particle effects (two wings in the rapidity spectra) for proton and $\Lambda$.

3. RESULTS

Considering energy sharing, enhanced diagram and identical elementary interactions, a great number of particle distributions can be calculated within NeXus 3 for any kind of hadronic and nuclear interaction [8]. As an example, Fig. 3 depicts the rapidity spectra...
for proton and anti-proton production for 2 different energies. The different contributions for the particle production (cut Pomeron: dashed-dotted line, remnants: dashed line and dotted line) show that the asymmetry between baryon and anti-baryon production comes from the remnant contributions.

At low energy (158 GeV lab), neXus is in good agreement with NA49 data [8]. For RHIC energy (200 GeV cms), the prediction shows that the cut Pomeron distribution becomes dominant at midrapidity even for the proton, which leads to reduce the asymmetry in this region (ratio closer to 1).

In conclusion, a new realistic model neXus solving most of the existing problems in high energy hadronic interaction models is available [9].

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