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New developments in EPOS: Parton saturation

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Abstract. We discuss latest developments in EPOS concerning parton saturation and its relation with energy conservation in the multiple scattering framework.

Inclusive cross sections are particularly simple, quantum interference helps to provide simple formulas referred to a "factorization". Although factorization is widely used, strict mathematical proofs exist only in very special cases, and certainly not for hadron production in pp scattering. To go beyond factorization and to formulate a consistent multiple scattering theory is difficult. A possible solution is Gribov's Pomeron calculus, which can be adapted to our language by identifying Pomeron and parton ladder. Multiple scattering means that one has contributions with several parton ladders in parallel.



Figure 1. Multiple scattering

We indicated several years ago inconsistencies in this approach, proposing an "energy conserving multiple scattering treatment". The main idea is simple: in case of multiple scattering, when it comes to calculating partial cross sections for double, triple ... scattering, one has to explicitly care about the fact the partons ladders which happen to be parallel to each other (see figure 1) share the collision energy. This energy sharing has been implemented in EPOS, which is a multiple scattering approach corresponding to a marriage of Gribov-Regge theory and perturbative QCD (for details see [1]). An elementary scattering corresponds to a parton ladder, containing a hard scattering calculable based on pQCD, including initial and final state radiation.

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Figure 2. Nuclear modification factor in pPb at 5 TeV/c.

The energy sharing scheme generalizes straightforwardly to proton-nucleus collisions. Here one expects (and observes) the so-called binary scaling, which means that the scaled AA cross section (cross section divided by the number of binary collisions) is equal to the proton-proton one,

$$\frac{1}{N_{\text{coll}}} \left. \frac{dn}{dp_t} \right|_{AA} = \left. \frac{dn}{dp_t} \right|_{pp}$$

or in other words, the nuclear modification factor (ratio l.h.s. to r.h.s.) should be unity.

In figure 2, we show the results for the nuclear modification factor in pPb at 5 TeV. The data are represented as black points, the calculations as red dotted line. Whereas the data are close to unity above two GeV/c, the simulations are clearly below. In fig. 3, we plot the scaled parton p_t distributions for different centralities in pPb at 5 TeV/c. In case of binary scaling all these curves should coincide, which is clearly not the case. So the simulations show a strong violation of this scaling, due to the imposed energy conservation.

After many attempts, we finally found a solution to the problem: The usual constant "soft scale" Q_0^2 (the lower cutoff of virtualities in the parton ladder) has to be replaced by a centrality dependent saturation scale [3, 4, 5, 6, 7, 8],

$$Q_s^2 = Q_0^2 \left(1 + B_{\text{satur}} N_{\text{part}}(i, j) \right),$$

where $N_{\text{part}}(i, j)$ is the number of participating nucleons connected to a given parton ladder between projectile nucleon *i* and target nucleon *j*. So each parton ladder has "its own" saturation scale! This new procedure (implemented in EPOS3, with a single free parameter B_{satur}) allows to completely recover binary scaling, see figure 4.

Also in PbPb collisions we obtain binary scaling at large p_t . So for the first time energy sharing is compatible with binary scaling in a multiple scattering scheme.

I is no surprise that the nuclear modification factor is now close to unity, as seen in fig. 6.



Figure 3. Scaled parton p_t distributions for different centralities in pPb at 5 TeV/c, using a constant soft scale Q_0 .



Figure 4. Scaled parton p_t distributions for different centralities in pPb at 5 TeV/c, using a saturation scale Q_s .

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Figure 5. Scaled parton p_t distributions for different centralities in PbPb at 2.76 TeV/c, using a saturation scale Q_s .



Figure 6. Nuclear modification factor in pPb at 5 TeV/c.

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