Cost of Survival for Large Rapidity Gaps

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In this note we report on calculations of the survival probability of the large rapidity gap (LRG) processes and its energy behaviour.

1. INTRODUCTION

In this note we consider reaction

$$p + p \longrightarrow \tag{1}$$

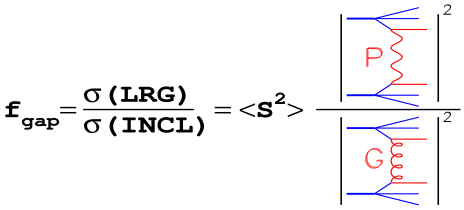
$$X_1 + jet_1(y_1, p_{1,t} \ll \mu) + [LRG] + jet_2(p_{2,t} \ll \mu) + X_2 \, ,$$

where LRG denotes the large rapidity gap between produced particles and X corresponds to a system of hadrons with masses much smaller than the total energy.

The story of LRG processes started from Refs. [1–3], where it was noticed that these processes give us a unique way to measure high energy asymptotic at short distances. Indeed, at first sight the experimental observable

$$f_{gap} \; = \; \frac{\sigma(\; dijet \;\; production \;\; with \;\; LRG \;)}{\sigma_{inclusive}(\; dijet \;\; production \;)} \tag{2}$$

is directly related to the so called "hard" Pomeron exchange. However, this is not the case and the factor (survival probability $\langle \mid S \mid^2 \rangle$ appears between the "hard" Pomeron exchange and the experimental observable.



Actually, this factor $\langle \mid \; S \; \mid^2 \rangle$ is a product of two survival probabilities

$$\langle \mid S \mid^2 \rangle = \tag{3}$$

$$\langle \mid S_{bremsstrahlung}(\Delta y = |y_1 - y_2| \mid^2 \rangle \times \langle \mid S_{spectators}(s) \mid^2 \rangle$$

which have different meanings.

1. $\langle \mid S_{bremsstrahlung} \mid^2 \rangle$ is *probability that the LRG will not be filled by emission of bremsstrahlung gluons from partons, taking part in the "hard" interaction* (see fig 1-a). This factor is certainly important and has been calculated in pQCD in Refs. [4,5,10]. We are not going to discuss it here;

2. $\langle \mid S_{spectator} \mid \mid^2 \rangle$ is related to *probability that every parton with $x_i > x_1$ will have no inelastic interaction with any parton with $x < x_2$* (see fig. 1-b). The situation with our knowledge of this survival probability is the main goal of this paper.

2. Q & A

Q: Have we developed a theory for $\langle \mid S_{spectators}(s) \mid^2 \rangle$?

A: No, there are only models on the market (see Refs. [6–10]).

Q: Can we give a reliable estimates for the value of $\langle \mid S_{spectator} \mid^2 \rangle$?

A: No, we have only rough estimates based on the Eikonal - type models.

Q: Can we give a reliable estimates for the energy behaviour of $\langle \mid S_{spectator} \mid^2 \rangle$?

A: No, but we understood that $\langle \mid S_{spectator} \mid^2 \rangle$ could steeply decreases with energy.

Q: Why are you talking about $\langle \mid S_{spectator} \mid^2 \rangle$ if you can do nothing ?

A: Because dealing with models we learned what questions we should ask experimentalists to improve our estimate and what problems we need to solve theoretically to provide reliable estimates.

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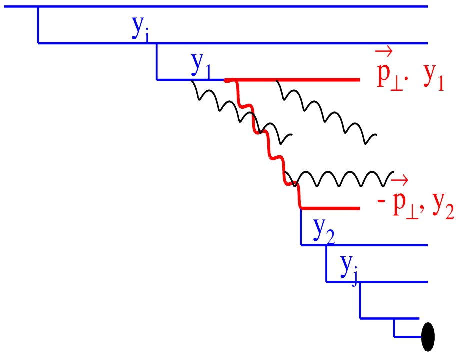

Fig.1-a

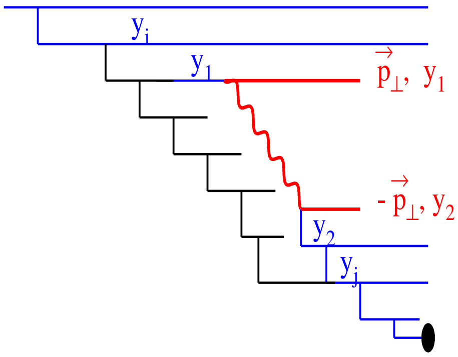

Fig. 1 -b

Figure 1. *Two sources of survival probability: (a) emission of gluons from the partons taking parts in "hard" interaction and (b) emission due to "soft" interaction of spectator quarks (partons).*

3. EIKONAL-TYPE MODELS

3.1. Eikonal model

In eikonal model we assumed that the correct degrees of freedom at high energies are hadrons, and, therefore, the scattering amplitude is diagonal in the hadron basis. Practically, it means [6] that we assume that the ratio σ^{SD}/σ^{el} ‘ $\ll 1$. In this model the unitarity constraint looks simple, namely,

$$Im a_{el}(s,b) = | a_{el}(s,b) |^2 + G_{in}(s,b) \; , \tag{4}$$

which has solution in terms of arbitrary real function - opacity $\Omega(s,b)$:

$$a_{el} \; = \; i \left[1 - e^{-\frac{\Omega(s,b)}{2}} \right] \; ; \tag{5}$$

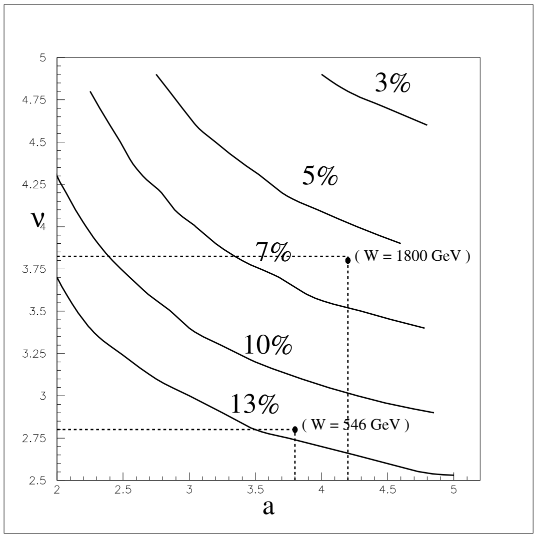

Figure 2. *Survival probability in the eikonal model.*

$$G_{in}(s,b) \; = \; 1 - e^{-\Omega(s,b)} \; ; \tag{6}$$

$$\Omega(s,b) \; = \; \nu(s) \; e^{-\frac{b^2}{R^2(s)}} \; ; \tag{7}$$

where Eq. (7) is Pomeron-like parameterization that has been used for numerical estimates. The formula for survival probability looks as [3] [6]

$$<| \, S \, |^2>= \frac{\int d^2 b e^{-\frac{b^2}{R_H^2}} \, e^{-\Omega(s,b)}}{\int d^2 b e^{-\frac{b^2}{R_H^2}}} \tag{8}$$

where R_H^2 is radius for the hard processes. In Ref. [6] the values of R_H^2 and $R^2(s)$ were discussed in details. The main observation is that the experimental value of the ration σ^{el}/σ_{tot} depends only on the value of ν. This gives us a way to find the value of ν directly from the experimental data. The result is plotted in Fig.2 and shows both the small value of the survival probability and its sharp energy dependence.

3.2. Three channel model.

The assumption that σ^{SD}/σ^{el} ‘ $\ll 1$ is in contradiction with the experimental data, therefore, it is interesting to generalize the eikonal model to include processes of the diffractive dissociation. It was done in Ref.[7], where the rich diffractive final state was described by one wave function orthogonal to the hadron

$$\Psi_{hadron} = \alpha \, \Psi_1 + \beta \, \Psi_2 \; ; \qquad \Psi_D = - \beta \, \Psi_1 + \alpha \, \Psi_2 \; , \tag{9}$$

where $\alpha^2 + \beta^2 = 1$. The scattering amplitude is diagonal with respect functions $\Psi_{1,2}$ and we used Eq. (5)-

Eq. (7) -type parameterization to describe it. The result of our calculation is given in Fig.3.

4. CONCLUSIONS

The experimentally observed value of the survival probability appear naturally in these two models.

The parameters that have been used are in agreement with the more detailed fit of the experimental data.

It turns out that the scale of $\langle | S_{spectator} |^2 \rangle$ is given by ratios $R_{el} = \frac{\sigma_{el}}{\sigma_{tot}}$, $R_{SD} = \frac{\sigma_{SD}}{\sigma_{tot}}$ and $R_{DD} = \frac{\sigma_{DD}}{\sigma_{tot}}$, but not the ratio $R_D = \frac{\sigma_{el} + \sigma_{SD} + \sigma_{DD}}{\sigma_{tot}}$, which does not show any energy dependence.

The further measurement all ratios mentioned above will specify the model and will provide a better predictions for the survival probability. For example, new data on R_{DD} [11] will specify the value of β which will lead to more definite predictions for $\langle | S_{spectator} |^2 \rangle$ (see Fig. 3).

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REFERENCES

1. Yu.L. Dokshitser, V. Khoze and S.I. Troyan,Sov.J.Nucl.Phys. 46 (1987) 116.
2. Yu.L. Dokshitser, V.A. Khoze and T. Sjostrand, Phys.Lett. B274 (1992)116.
3. J.D. Bjorken, Phys.Rev. D45 (1992) 4077; D47 (1993) 101.
4. A.D. Martin, M.G. Ryskin and V.A. Khoze, Phys.Rev.D56 (1997) 5867; Phys. Lett B401 (1997) 330.
5. G. Oderda and G. Steman, Phys.Rev. Lett. 81 (1998) 359; Talk at ISMD'99, Providence,RI, 9-13 Aug 1999, `hep-ph/9910414`;
6. E. Gotsman, E. Levin and U. Maor, Phys.Rev.D48 (1993) 2097; Nucl.Phys.B493 (1997) 354; Phys. Lett. B438 (1998) 229.
7. E. Gotsman, E. Levin and U. Maor, Phys.Rev. D60 (1999) 094011; Phys. Lett. B438 (1998) B452 (1999) 387, B438 (1998) 229-234.
8. R.S. Fletcher, Phys.Rev.D48 (1993) 5162; Phys.Lett.B320 (1994) 373.
9. A. Rostovtsev and M.G. Ryskin, Phys. Lett. B390 (1997) 375).
10. E. Levin, A.D. Martin and M.G. Ryskin. J.Phys.G25 (1999) 1507.
11. K. Goulianos, talk at this WS.

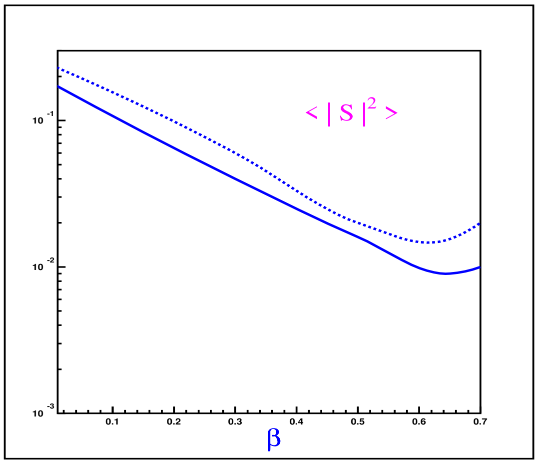

Fig.3-a

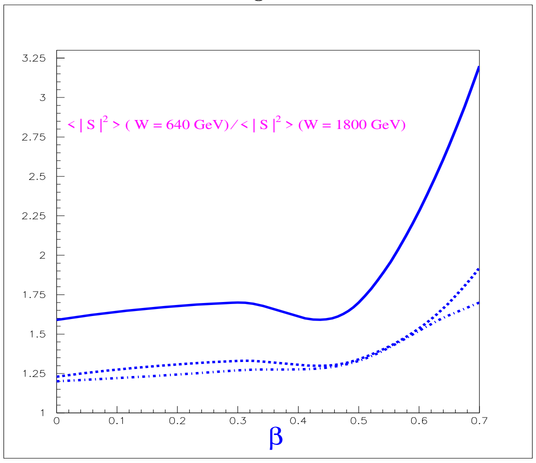

Fig. 3-b

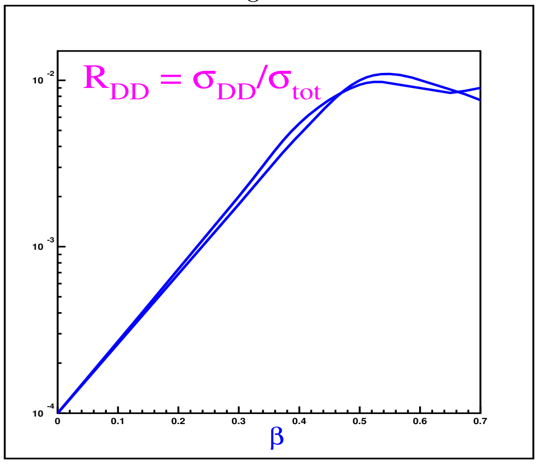

Fig. 3-c

Figure 3. *The value of survival probability (Fig.3-a), its energy dependence (Fig.3-b) and prediction for the ratio of double diffraction dissociation to the total cross section (Fig.3-c) versus β.*