Survival Probability of Large Rapidity Gaps (LRG) in Diffractive Dijet Production at LHC

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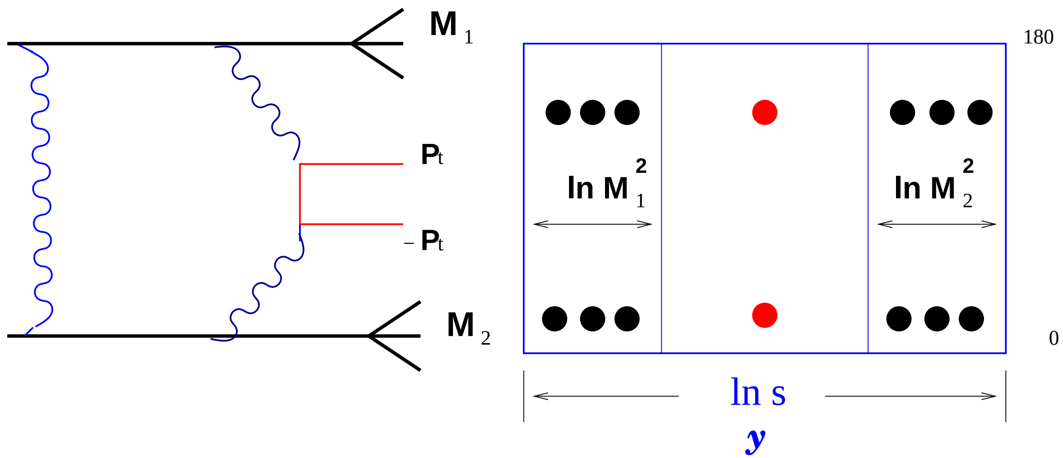
A joint project of DESY (S.Bondarenko and H.Kowalski)
and
TAU (E.Gotsman, E.Levin, U.Maor, A.Prygarin)

- discussion of an energy dependence of LRG survival probability
- some quantitative estimations based on the "impact parameter model"
- proper parameterization from H. Kowalski and D. Teaney (2003)

LRG =



- Eikonal Model
- LRG
- Higgs Production

- *Yu. L. Dokshitzher, V.A. Khoze, T. Sjöstrand*
  Phys. Lett. B274 *(1992) 116*
  “Rapidity gaps in Higgs production”

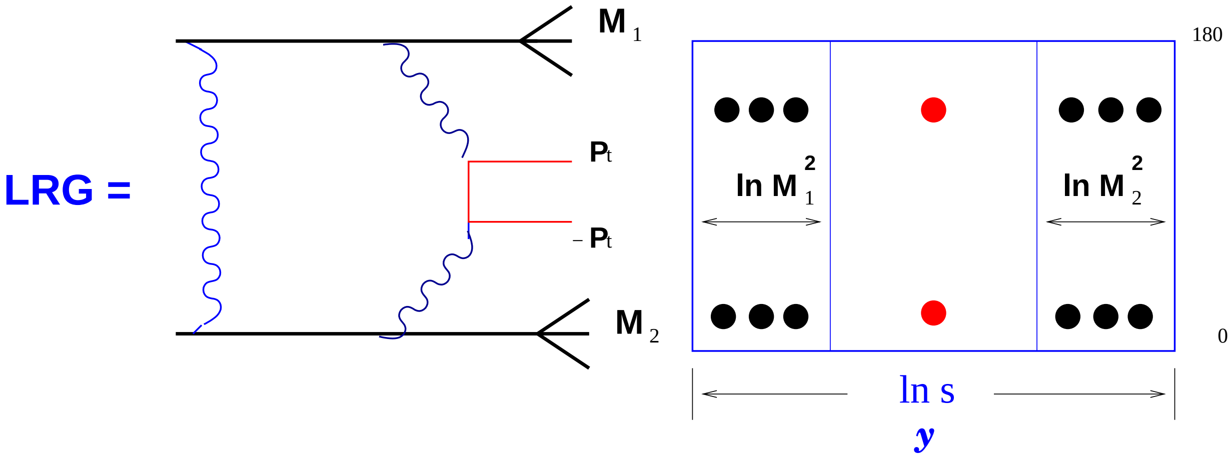
- *J.D. Bjorken*
  Int. J. Mod. Phys. A7 *(1992) 4189 ; Phys. Rev.* D47 *(1993) 101*
  “Rapidity gaps and jets as a new physics signature in very high-energy hadron hadron collisions”

- *E. Gotsman, E. Levin, U. Maor*
  *Phys.Rev.*B39 *(1993) 199*
  “Large rapidity gaps in pp collisions ”

- *H. Kowalski, D.Teaney*
  *Phys.Rev.*D68 *(2003) 114005*
  “An impact parameter dipole saturation model ”

History:

Bjorken (1992) and Dokshitzer (1992) et al., suggested utilizing rapidity gaps as a signature for Higgs production, in the W-W fusion process in hadron-hadron collisions.



$$p(1) + p(2) \longrightarrow$$
$$M_1[hadrons] + LRG + [jet_1(p_t), jet_2(-p_t)] + LRG + M_2[hadrons]$$

Bjorken (1992) :

$$f_{gap} = < |S|^2 > \cdot F_s$$

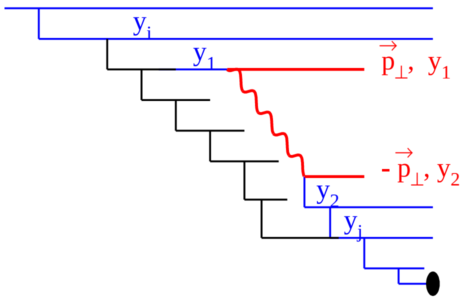
Experimental definition

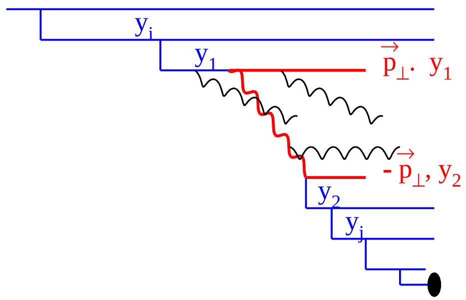
$$f_{gap} = \frac{cross\ section\ for\ dijet\ production\ with\ LRG}{inclusive\ cross\ section\ for\ dijet\ production}$$

F_s - fraction of events due to t-channel color singlet exchange.

$< |S|^2 >$ - the survival probability of LRG not to be filled by

produced particles (hadrons) **bremsstrahlung gluons**





$< |S_{spectator}|^2 >$ $< |S_{Bremsstrahlung}|^2 >$

LRG survival probability
using eikonal model in impact parameter representation

Elastic amplitude

$$\frac{d\sigma}{dt} = \pi |f(s,t)|^2$$

$$\sigma_{total} = 4\pi Im f(s,0)$$

In impact parameter representation

$$a_{el}(s,b) = \frac{1}{2\pi} \int d^2q \; e^{-i\overline{q}\cdot\overline{b}} f(s,t)$$

$$\sigma_{tot} = 2 \int d^2b \; Im \; a_{el}(s,b) \qquad \sigma_{el} = \int d^2b |a_{el}(s,b)|^2$$

s-channel unitarity constraint implies $|a(s,b)| \leq 1$

Assuming hardrons are eigenstates of scattering matrix

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

where $G_{in}(s,b)$ is the inelastic cross section

$$\sigma_{in} = \int d^2b\; G_{in}(s,b)$$

In this form the unitarity constraint has a simple analytical solution

We assume that $a(s, b)$ is purely imaginary, we have

$$a_{el}(s, b) = i[1 - e^{-\Omega(s,b)/2}]$$

and

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

where $\Omega(s, b)$ is an arbitrary real function.

Hence $P(s, b) = e^{-\Omega(s,b)}$ is the probability that no inelastic interaction takes place at impact parameter b.

We use $\Omega(s,b)$ approximated by a Gaussian

$$\Omega(s,b) = \nu(s)\Gamma(s,b)$$

where

$$\nu(s) = \frac{\sigma_0}{\pi R^2(s)}(\frac{s}{s_0})^{\Delta}$$

and the profile function

$$\Gamma(s,b) = e^{-\frac{b^2}{R_H^2(s)}}$$

In Regge framework the "soft" radius is of the form

$$R_s^2(s) = 4R_0^2 + 4\alpha'(0)\ln(\frac{s}{s_0}) = 2B_{el}(s)$$

where $B_{el}(s)$ denotes the forward slope of the elastic cross section

$$\frac{d\sigma}{dt} \sim e^{B_{el}(s)\, t}$$

In this formalism the required integrals could be done analytically

$$\sigma_{tot} = 2\int d^2b(1-e^{\Omega/2}) = 2\pi R^2(s)[\ln(\nu(s)/2) + C - Ei(-\nu/2)]$$

$$\sigma_{in} = \int d^2b(1-e^{\Omega}) = \pi R^2(s)[\ln(\nu(s)) + C - Ei(-\nu)]$$

$$\sigma_{el} = \sigma_{tot} - \sigma_{in} = \int d^2b(1-e^{\Omega}) =$$
$$\pi R^2(s)[\ln(\nu(s)/4) + C - Ei(-\nu) - Ei(-\nu/2)]$$

where

$$Ei(x) = \int_{-\infty}^{x} \frac{e^t}{t} dt$$

and C=0.5773 .
The ratio $\frac{\sigma_{el}}{\sigma_{tot}}$ only depends on the factor $\nu(s)$.

Following Bjorken (1992) the survival probability $< |S|^2 >$ is defined as the normalized product of two quantities. The first is the convolution over parton densities, of two interacting projectiles presenting the cross section for the hard parton-parton collisions (dijet production) under discussion. The second term is $P(s,b)$ i.e. the probability that no inelastic interaction takes place in the rapidity interval of interest

In eikonal formalism

$$< |S|^2 > = \frac{\int d^2b \; \sigma_H(s,b) P(s,b)}{\int d^2b \; \sigma_H(s,b)} = \frac{\int d^2b \; d^2b' \Gamma^2_H(s,b-b') \Gamma^2_H(s,b') P(s,b)}{\int d^2b \; d^2b' \Gamma^2_H(s,b-b') \Gamma^2_H(s,b')}$$

where

$$\Gamma_H(b) = e^{-\frac{b^2}{R^2_H(s)}}$$

and

$$P(s,b) = e^{-\Omega(s,b)}$$

In this formalism the LRG survival probability

$$< |S|^2 >= \frac{\int d^2b\ d^2b' \Gamma^2_H(b-b')\Gamma^2_H(b')P(s,b)}{\int d^2b\ d^2b' \Gamma^2_H(b-b')\Gamma^2_H(b')}$$

could be written as

$$< |S|^2 >= \frac{a(s)\gamma[a(s),\nu(s)]}{[\nu(s)]^{a(s)}}$$

where

$$a(s) = \frac{\pi R^2_S(s)}{\pi R^2_H(s)} = \frac{ineraction\ area\ for\ soft\ collisions}{interaction\ area\ for\ hard\ collisions}$$

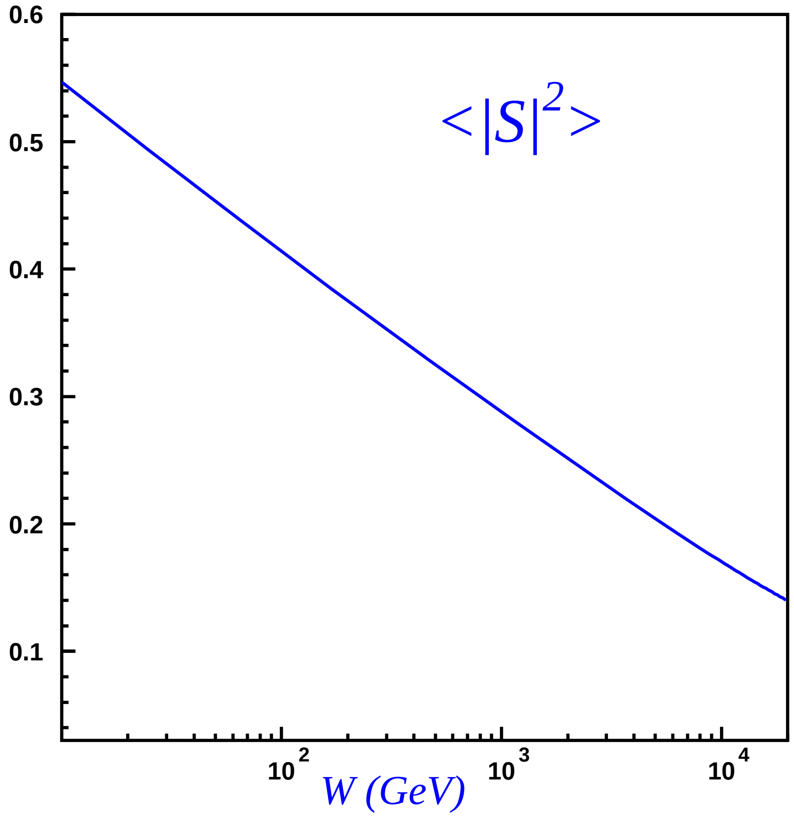
and

$$\nu(s) = \frac{\sigma_0}{\pi R^2(s)}\left(\frac{s}{s_0}\right)^{\Delta}$$

incomplete gamma function $\gamma(a,x) = \int_0^x z^{a-1} e^{-z} dz$

Our calculations

We use a parameterization from H. Kowalski and D. Teaney approach (2003)



$$R^2_{hard} = 8.5\ GeV^{-2}$$

$$\Delta = 0.106$$

$$\alpha'(0) = 0.25\ GeV^{-2}$$

$$R^2_0 = 2.34\ GeV^{-2}$$

$$R^2_s(s) = 4R^2_0 + 4\alpha'(0)\ln(\frac{s}{s_0})$$

$$< |S|^2 > (2000\ GeV) = 0.246$$

$$< |S|^2 > (20000\ GeV) = 0.132$$

Future Plans

- **Parameters in hard interaction**
- **Go beyond the eikonal model for survival probability of LRG (e.g. "additive quark model")**
- **Compare our estimations to experimental data at accessible energy range**

$$R_H \Rightarrow 2 * R_H$$