SURVIVAL PROBABILITY OF LARGE RAPIDITY GAPS

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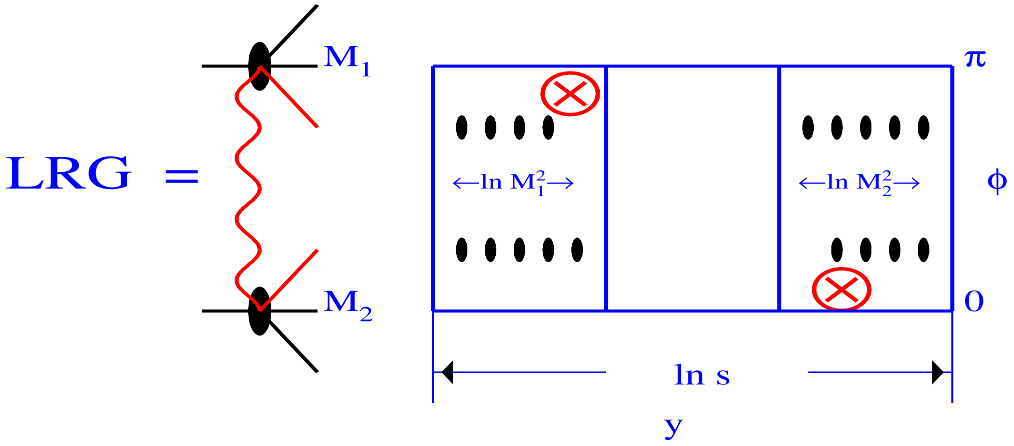
1. **What is survival probability of LRG processes ?**
2. **What is the value of survival probability ?**
3. **How well can we estimate this value ?**
4. **What is the energy dependence of survival probability ?**



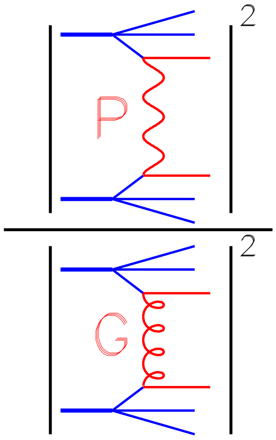
∗ ∗ ∗ **LRG processes $\Longrightarrow$ a unique way**
∗ ∗ ∗ **to measure high energy asymptotic**
∗ ∗ ∗ **at short distances**

Run II QCD WS, "Diffractive Physics and Color Coherence" WG – Fermilab, March 4 - 6,1999

Definitions:

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

$$\mathbf{f_{gap}} = \frac{\sigma\,(\mathbf{LRG})}{\sigma\,(\mathbf{INCL})} = \langle \mathbf{S^2} \rangle$$

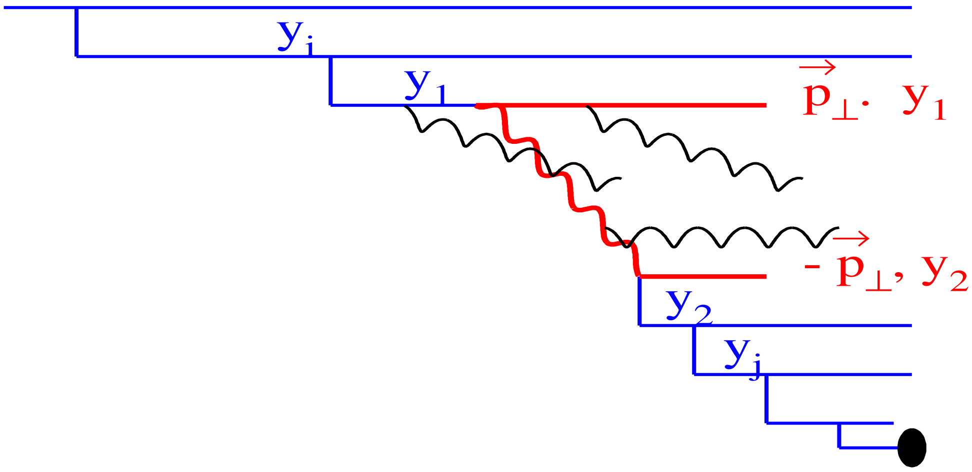


Data :

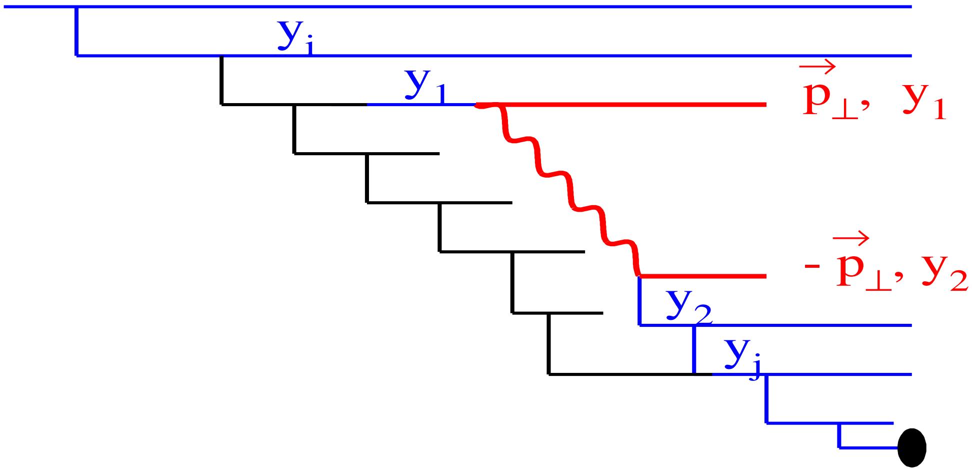
	D0	CDF
$f_{gap}(\sqrt{s} \;=\; 1800\,GeV\;)$	$0.6 \pm 0.1\,\%$	$1.13 \pm 0.16\,\%$
$f_{gap}(\sqrt{s} \;=\; 630\,GeV\;)$	$1.6 \pm 0.2\,\%$	$2.7 \pm 0.9\,\%$
$R_{gap} \;=\; \frac{fgap(\sqrt{s}\,=\,630\,GeV\,)}{fgap(\sqrt{s}\,=\,1800\,Gev\,)}$	2.67 ± 0.38	2.4 ± 0.9
$R_S \;=\; \frac{\langle \lvert S \rvert^2 \rangle(\sqrt{s}\,=\,630\,GeV\,)}{\langle \lvert S \rvert^2 \rangle(\sqrt{s}\,=\,1800\,GeV\,)}$	2.2 ± 0.8	???

What is $\langle | \mathbf{S} |^2 \rangle$:

$$\langle | \mathbf{S} |^2 \rangle \quad = \quad \begin{array}{c} \langle | S_{bremsstrahlung}(\Delta y = |y_1 - y_2| \; |^2 \rangle \\ \times \\ \langle | S_{spectators}(s) \; |^2 \rangle \end{array}$$

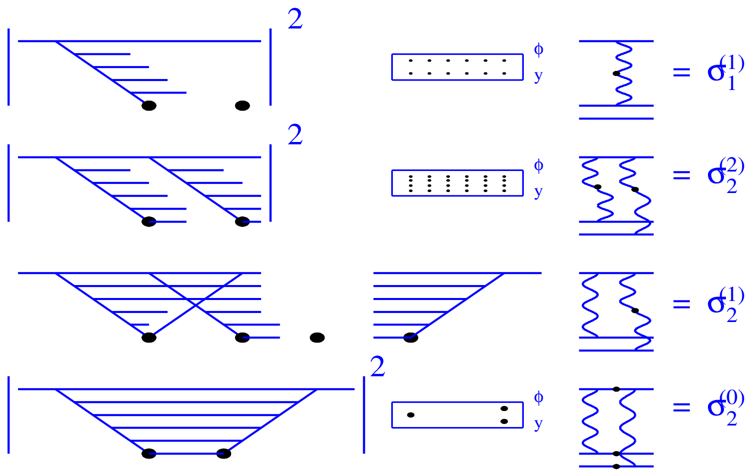


$\langle | \mathbf{S_{bremsstrahlung}} \; |^2 \rangle$: Probability that the LRG will not be filled by emission of bremsstrahlung gluons from partons, taking part in the "hard" interaction.



$\langle |\ \mathbf{S_{spectator}}|\ |^2\rangle$: Probability that every parton with $x_i\ >\ x_1$ will have no inelastic interaction with any parton with $x\ <\ x_2$

For inclusive dijet production all interactions between these groups of parton cancel due to Abramovski-Gribov -Kancheli cutting rules



$$\sigma_2^{(0)} \; : \; \sigma_2^{(1)} \; : \; \sigma_2^{(2)} \; = \; 1 \; : \; -4 \; : \; 2$$

- .For inclusive cross section:

$$\sigma_2^{incl} \; = \; \sigma_2^{(1)} \; + \; 2\, \sigma_2^{(2)} \; = \; 0$$

References :

DAWN:

1. Yu.L. Dokshitser, V. Khoze & S.I. Troyan : *" Collective QCD effects in the structure of final multi-hadro111n states"*, Sov.J.Nucl.Phys. 46 (1987) 116.
2. Yu.L. Dokshitser, V.A. Khoze & T. Sjostrand: *"Rapidity gaps in Higgs production"*, Phys.Lett. B274 (1992)116.
3. J.D. Bjorken: *"A plumber's view of perturbative QCD"*, Phys.Rev.D45 (1992) 4077.
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$\langle | \, S_{\mathbf{bremsstrahlung}} \, |^2 \rangle$:

1. A.D. Martin, M.G. Ryskin & V.A. Khoze: *"Dijet hadroproduction with rapidity gaps and QCD double logarithmic effects"*, Phys.Rev.D56 (1997) 5867.
2. A.D. Martin, M.G. Ryskin & V.A. Khoze: *"The rapidity gap Higgs signal at LHC"*, Phys. Lett B401 (1997) 330.
3. G. Oderda & G. Sterman: *"Energy and color flow in dijet rapidity gaps"*, Phys.Rev. Lett. 81 (1998) 3591.

$\langle | \mathbf{S_{spectator}} |^2 \rangle$:

1. J.D. Bjorken: *"Rapidity gaps and jets as a new physics signature in very high-energy collisions"*, Phys.Rev.D47 (1993) 101.
2. E. Gotsman, E. L. & U. Maor: *"Large rapidity gaps in proton - proton collisions"*, Phys.Lett.B309 (1993) 199-204.
3. E. Levin: *"Rapidity gaps in DIS"*, Phys.Rev.D48 (1993) 2097.
4. R.S. Fletcher: *"Rapidity gap signals in Higgs production at the SSC"*, Phys.Rev.D48 (1993) 5162 .
5. E. Gotsman, E. L. & U. Maor: *" Diffractive leptoproduction of small masses in QCD""*', Nucl.Phys.B493 (1997) 354-396,1997.
6. A. Rostovtsev & M.G. Ryskin: *"How to estimate the number of Pomerons/rescatterings.* Phys. Lett. B390 (1997) 375).
7. E. Gotsman, E. L. & U. Maor: *"Energy dependence of the survival probability of large rapidity gaps"*, Phys. Lett. B438 (1998) 229.
8. E. Gotsman, E. L. & U. Maor: *"The survival probability of large rapidity gaps in a three channel model"*, TAUP 2561 - 99,hep-ph/9902294

Q & A:

Q: Have we developed a theory for $\langle | \, S_{spectator} \, |^2 \rangle$?
A: No, there are only models on the market .

Q: Can we give a reliable estimates for the value of $\langle | \, S_{spectator} \, |^2 \rangle$?
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 $\langle | \, S_{spectator} \, |^2 \rangle$?
A: No, but we understood that $\langle | \, S_{spectator} \, |^2 \rangle$ could steeply decreases with energy.

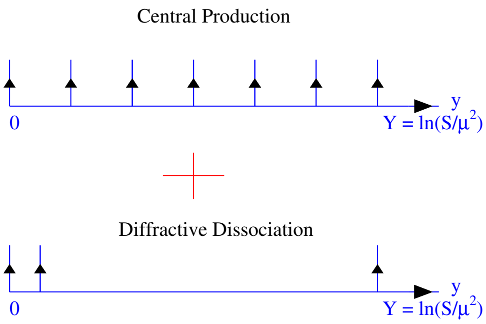
Q: Why are you talking about $\langle | \, S_{spectator} \, |^2 \rangle$ if you can do nothing ?
A: Because:

- Dealing with models we have learned what questions we should ask experimentalists to improve our calculations;
- We learned what problems we need to solve theoretically to provide reliable estimates;
- We understood what kind of questions could be answered in LRG experiments;
- We are on the way to understanding in what experiments our accuracy is enough to get an interesting information on the high energy scattering amplitude at short distances.

Eikonal Model:

Main assumptions:

- Only the fastest parton interacts with "wee" partons
- Hadrons are correct degrees of freedom at high energy
- $\frac{\sigma_{SD}+\sigma_{DD}}{\sigma_{el}} \ll 1$
- Oversimplified final state



- Simple form of unitarity :

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

- Solution (only one arbitrary function $\Omega(s,b)$!?) :

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

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

- Simple parameterization :

$$\Omega(s,b) = \frac{\sigma_0}{\pi R^2(s)}\,(\frac{s}{s_0})^{\Delta_P}\,e^{-\frac{b^2}{R^2(s)}} = \nu(s)\,e^{-\frac{b^2}{R^2(s)}}$$

- Analytical formulae for "soft" observable :

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

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

$$\sigma_{el} = \sigma_{tot}-\sigma_{in} = \pi R^2(s)[ln(\frac{\nu(s)}{4})+C+Ei(-\nu(s))-2Ei(-\frac{\nu(s)}{2)}]$$

- Simple formula for survival probability :

$$<\mid S\mid^2>=\frac{\int d^2b\Gamma_H(b)P(s,b)}{\int d^2b\Gamma_H(b)}$$

with

$$\Gamma_H(b) = \frac{1}{\pi R_H^2}e^{-\frac{b^2}{R_H^2}}$$

- Analitycal form of $<\mid S\mid^2>$:

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

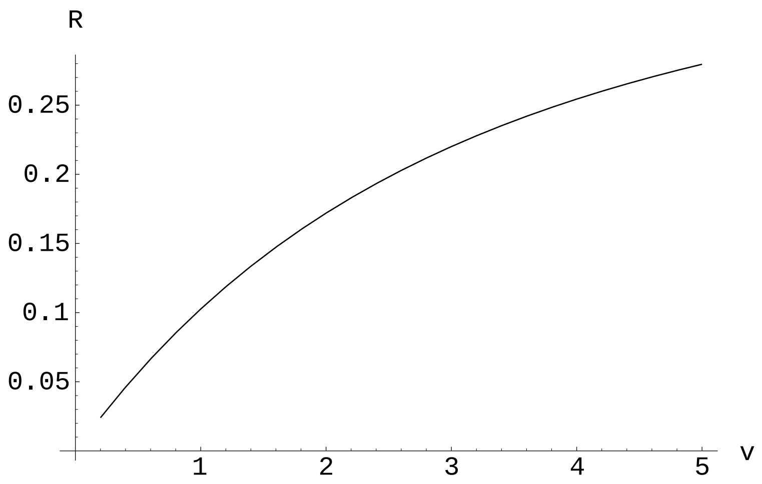
with

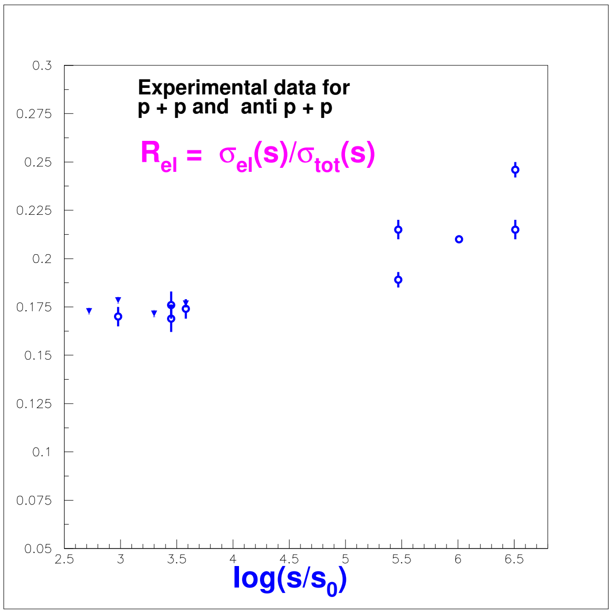
$$a(s) = \frac{R_S^2(s)}{R_H^2}$$

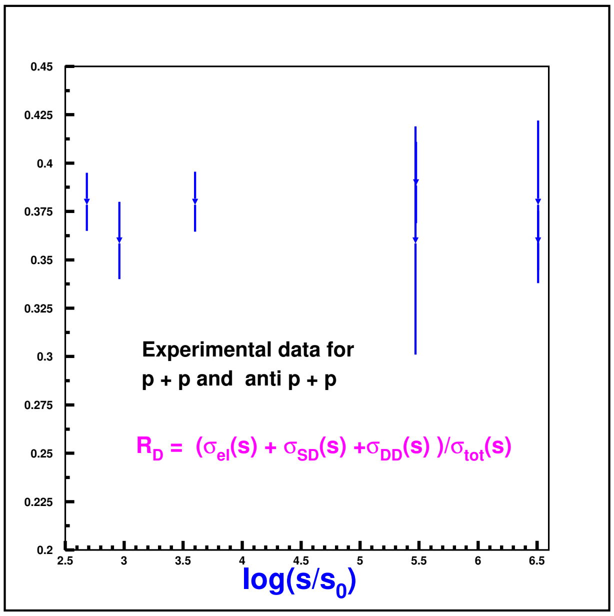
Results :

$$\nu(s) \;=\; ?$$

Observation: $R(\nu) \;=\; \frac{\sigma_{el}}{\sigma_{tot}}$

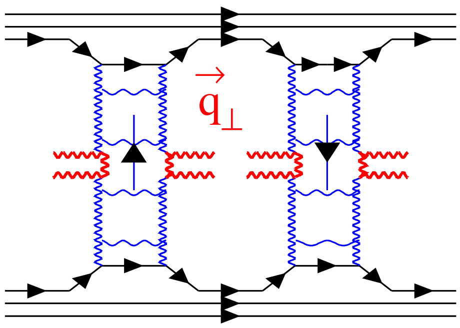


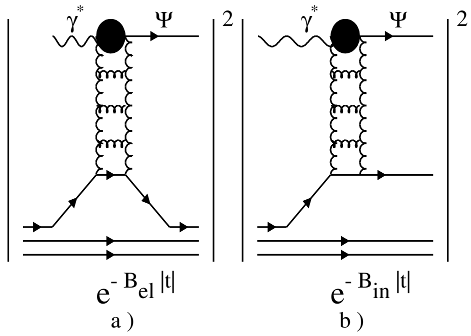




$\mathbf{a}(s) \;=\; ?$

Double Parton Interaction (CDF): $\qquad$ J/Ψ production at HERA:





$$\sigma_{DP} \;=\; m\,\frac{\sigma_{incl}(2jets)\,\sigma_{incl}(2jets)}{2\,\sigma_{eff}}$$

$$\sigma_{eff} \;=\; 14.5 \,\pm\, 1.7 \,\pm\, 2.3 \; mb$$

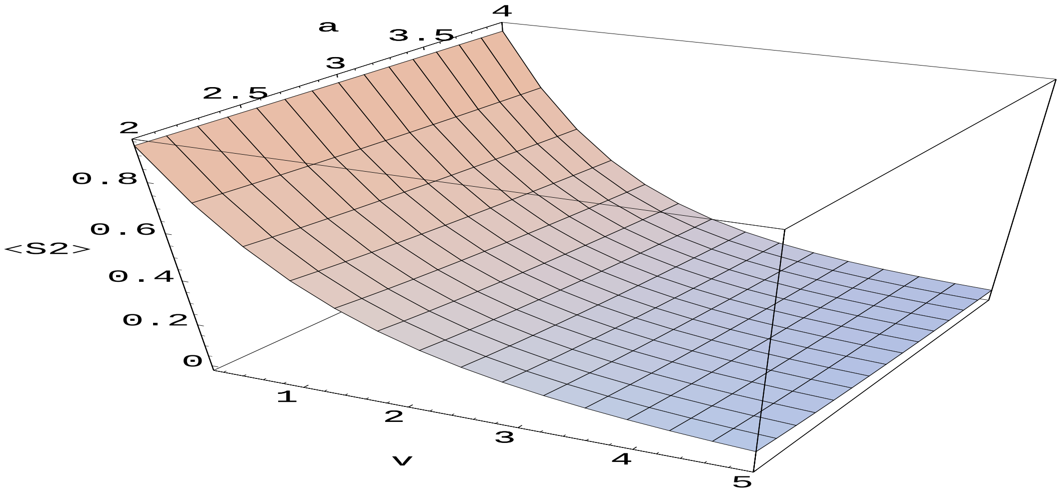
$$\sigma_{eff} \;=\; 2\,\pi\,R^2_H$$

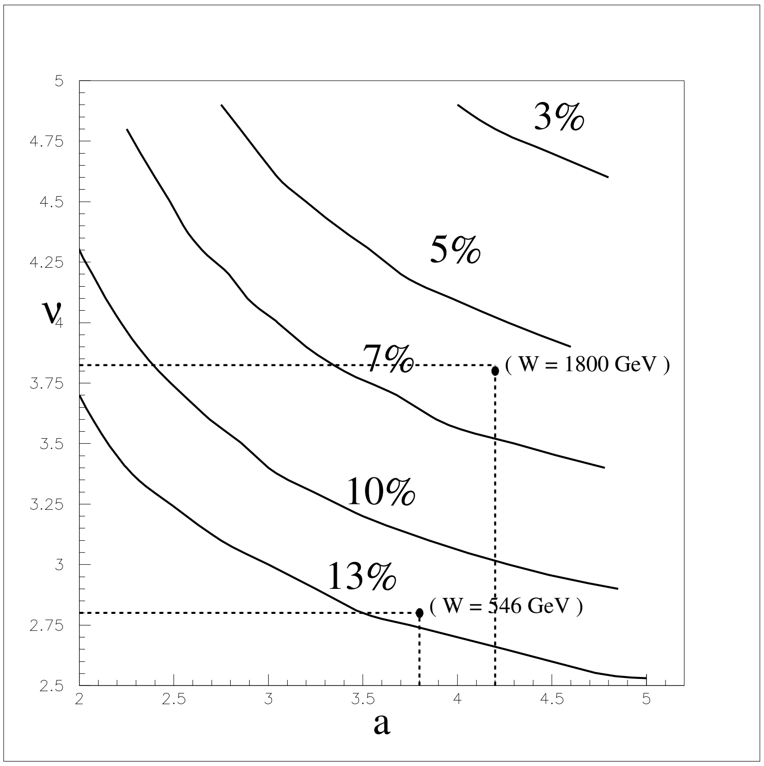
$$B_{el} \;=\; 4 \; GeV^{-2}$$

$$B_{in} \;=\; 1.66 \; GeV^{-2}$$

$$R^2_H \;=\; 8 \; GeV^{-2}$$

$\langle \mid S_{spectator}(s) \mid^2 \rangle$?





Three channel model :

Three channels :

elastic scattering
single diffractive production
double diffractice production

Main assumptions:

- Only the fastest parton interacts with the target ;
- Hadrons are not correct degrees of freedom ;
- $\frac{\sigma_{DD}(\,M > M_0\,)}{\sigma_{el}} \ll 1$;
- Oversimplified final state: central production (uniform in rapidity) and elastic + diffractive production with small masses.

- Ψ_n with $n = 1, 2 \longrightarrow$ the wave functions of correct degrees of freedom

$$< \Psi_n \times \Psi_m | \mathbf{T} | \Psi_{n'} \times \Psi_{m'} > \;=\; A_{n,m}(s, b_t)\, \delta(n - n')\, \delta(m - m')$$

- Unitarity can be written only for A_n in the form:

$$2\ Im\ A_{n,m}(s, b_t) \;=\; |A^2_{n,m}(s, b_t)|^2 \;+\; G^{in}_{n,m}(s, b_t)$$

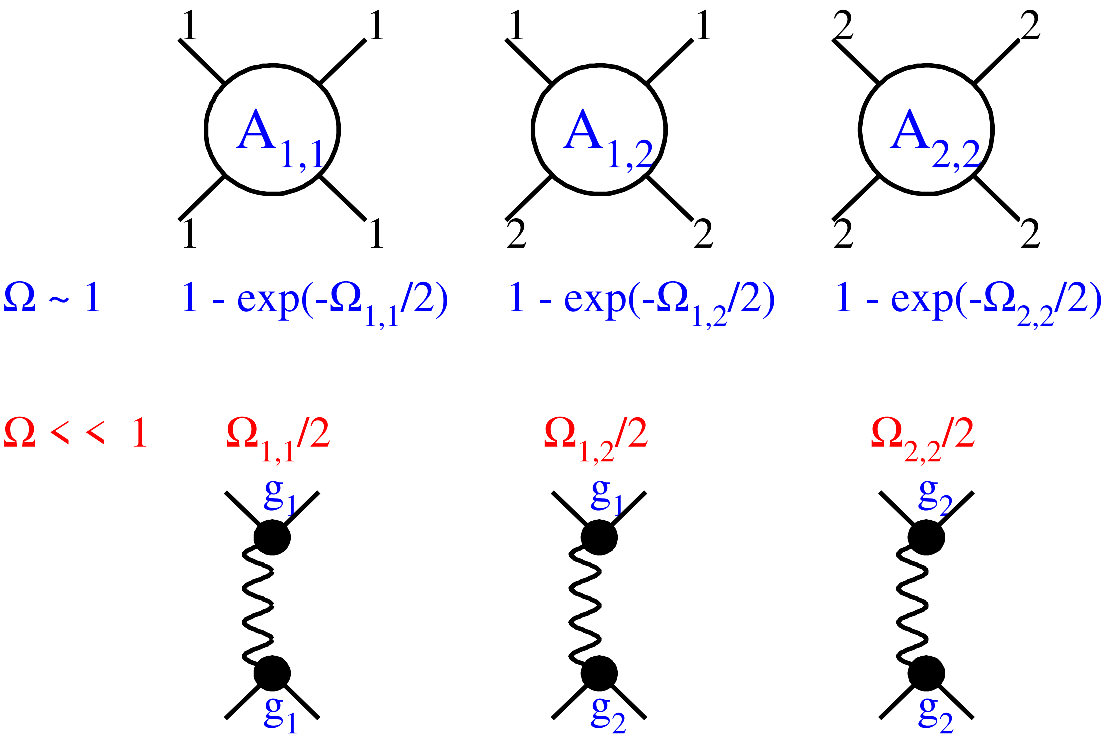
- Therefore, we have

$$A_{n,m}(s,b_t) \;=\; i\,\{\,1\;-\;e^{-\frac{\Omega_{n,m}(s,b_t)}{2}}\,\}$$

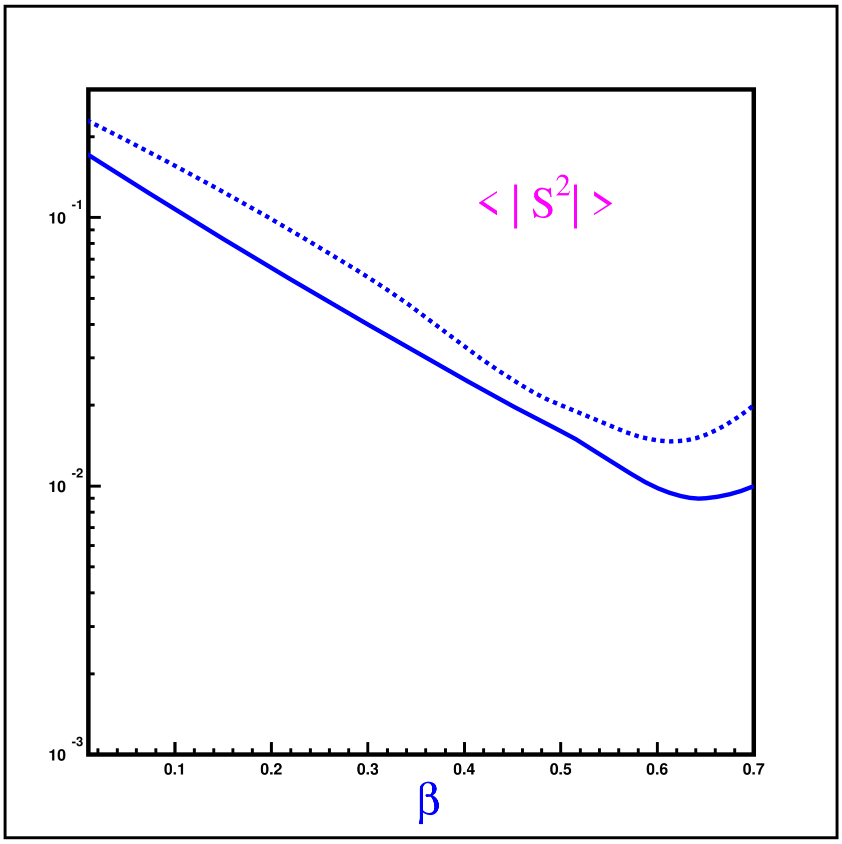
$$G_{n,m}(s,b_t) \;=\; 1\;-\;e^{-\Omega_{n,m}(s,b_t)}\;;$$

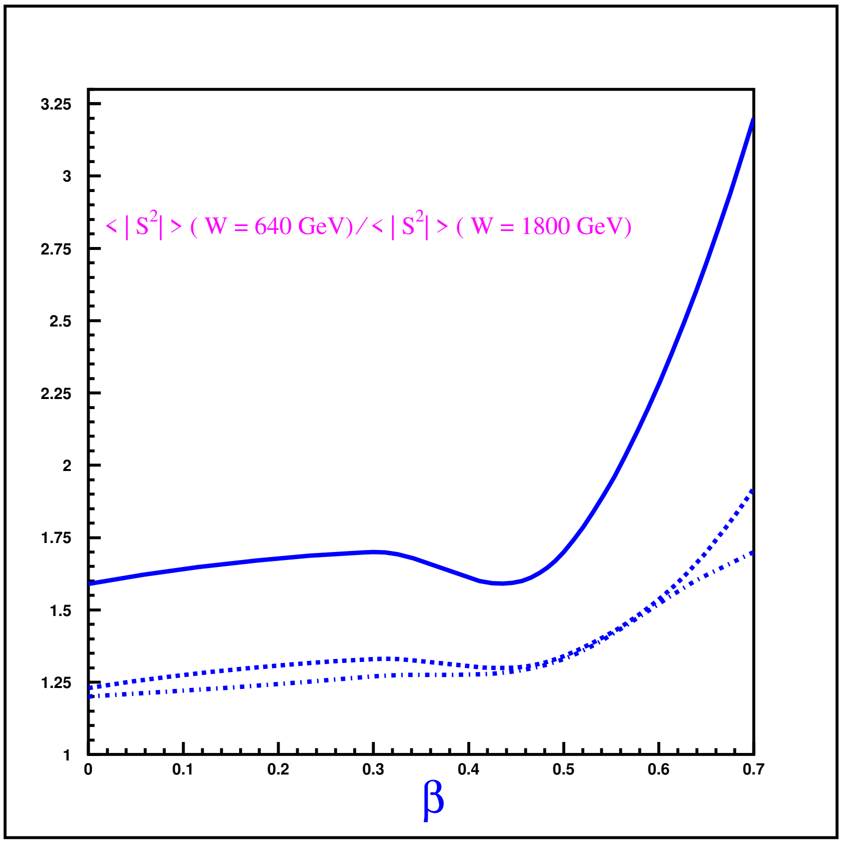
- Produced hadron and diffractive state have:

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



$\langle |\ \mathbf{S_{spectator}(s)}\ |^2 \rangle ?$





- E. Gotsman, E.L. & U. Maor: (hep-ph/9902240)

And what?

- Accuracy, in principle, much better than in Eikonal Model, but still we do not know what to do with diffraction in the region of large mass ($M \approx s$) ;
- The scale of SC is not given by

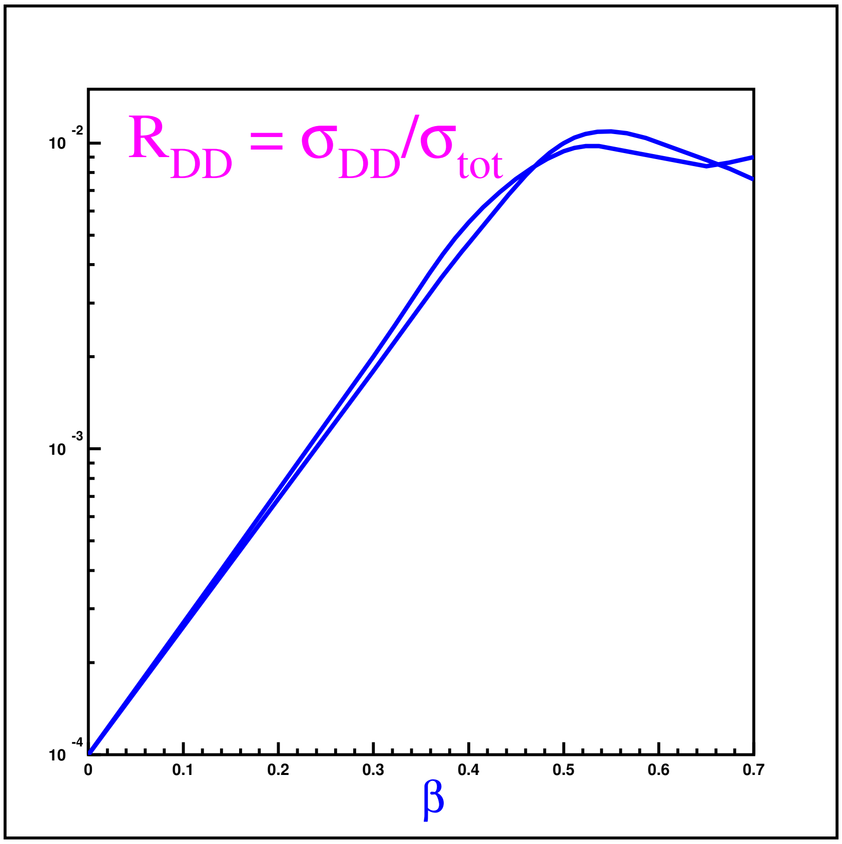
$$R_D = \frac{\sigma_{el} + \sigma_{SD} + \sigma_{DD}}{\sigma_{tot}} ,$$

  but rather by the separate ratios

$$R_{el} = \frac{\sigma_{el}}{\sigma_{tot}} \quad R_{SD} = \frac{\sigma_{SD}}{\sigma_{tot}} \quad R_{DD} = \frac{\sigma_{DD}}{\sigma_{tot}}$$

- The small value of the survival probability as well as its strong energy dependence appear naturally in this approach ;
- The parameters that have been used in agreement with the more detailed fit of the experimental data ;
- Questions to experimentalists:
  1. What is R_{el} at $\sqrt{s}$ equal to 630 GeV?, 1800GeV ?, Tevatron runII energy ?
  2. What is the value for R_{SD} at $\sqrt{s}$ equal to 630 GeV?, 1800GeV ?, Tevatron runII energy ?

3. What is the value for R_{DD} at $\sqrt{s}$ equal to 630 GeV?, 1800GeV ?, Tevatron runII energy ?



4. What is the value of the single diffraction cross section in the region of large masses at $\sqrt{s}$ equal to 630 GeV?, 1800GeV ?, Tevatron runII energy ?