Total cross-section and Rapidity Gap survival Probability at LHC

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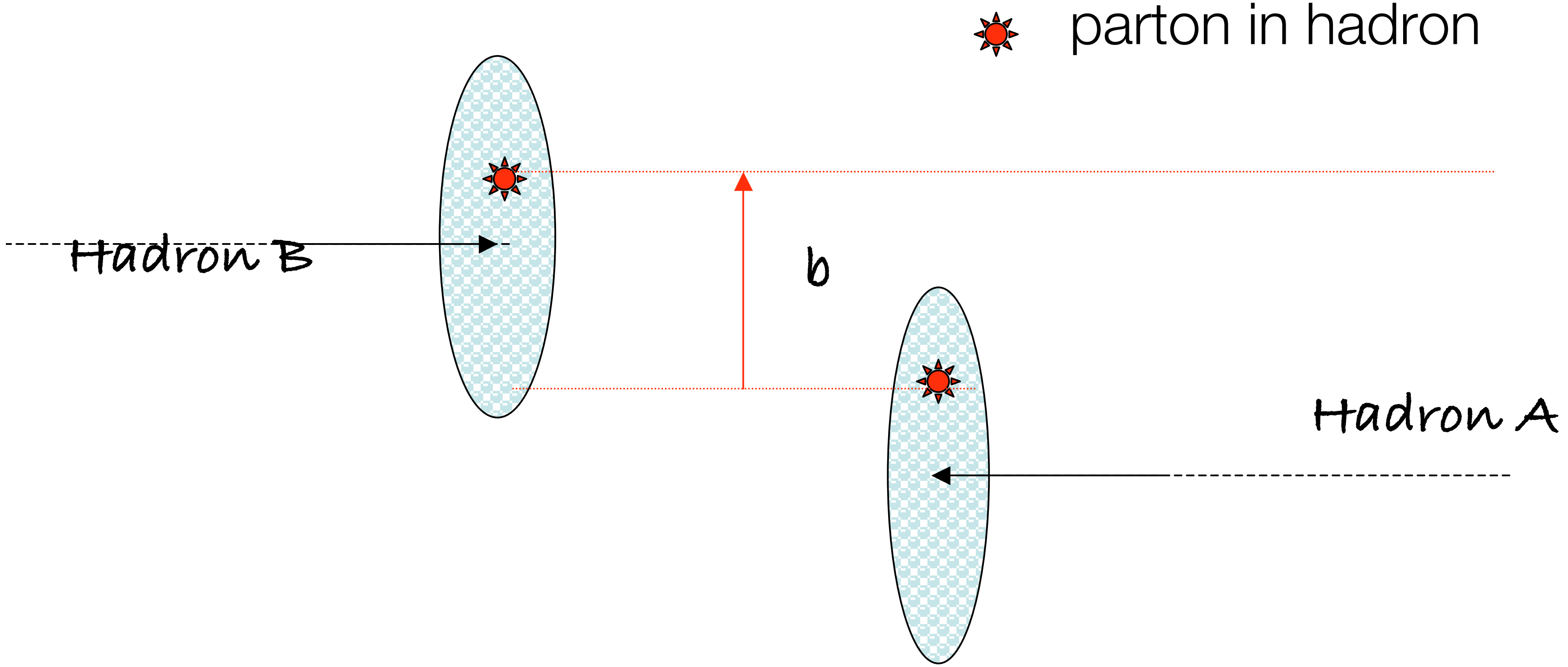
Impact parameter picture of hadronic collisions

$\sqrt{s}$= c.m. Energy hadrons AB



What is needed to calculate the Survival Probability for Large Rapidity Gaps

Vector boson Vector boson to Higgs or other VV state

$\mathcal{P}_{no\text{-}inel}$=probability of no inelastic interactions

- Only very low-pt particle emission can take place

$A(b,s)$ =probability to find partons which will not undergo hard collisions

$\mathcal{P}_{\text{NO-INEL}}(b,s)$

- Poisson distributed (independent) collisions

$$\Pi\{k,\bar{n}\} = \frac{\bar{n}^k e^{-\bar{n}}}{k!}$$

- Now sum on all possibile distributions

$$\boxed{\sum_k \Pi\{k,\bar{n}\} = 1 - e^{-\bar{n}}}$$

In Eikonal representation

- $\sigma_{inel} = \int d^2\vec{b}[1 - e^{-n(b,s)}]$

Average number of collisions at given energy and impact parameter

- $n(b,s) = n_{soft}(b,s) + n_{hard}(b,s)$

$P_t > 1\text{-}2$ GeV

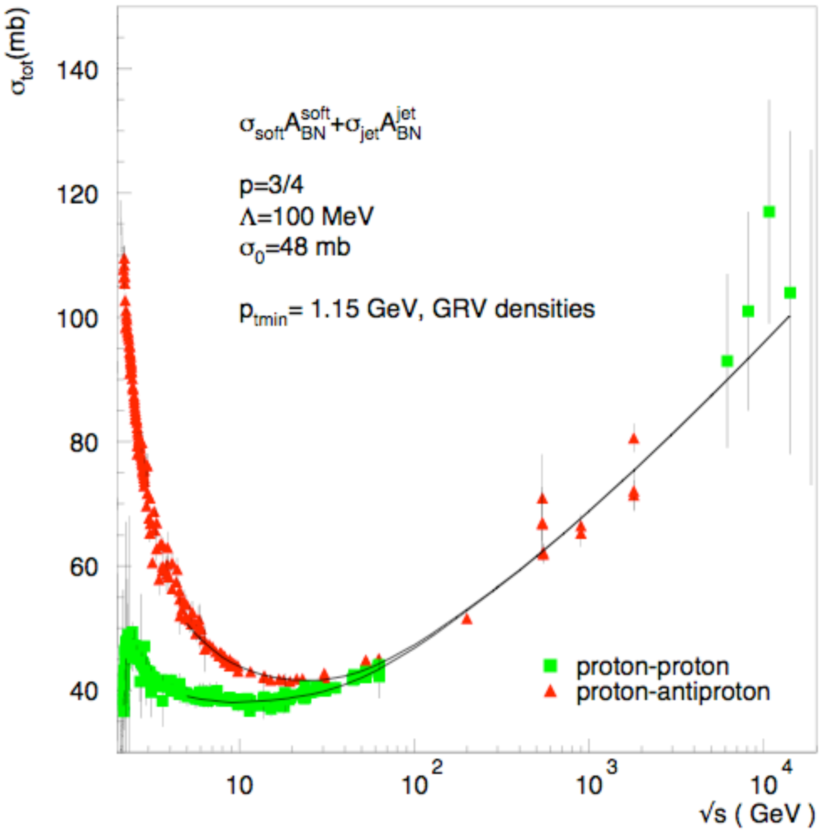
- $n_{soft/hard}(b,s) = A_{BN}^{soft/hard}(b,s)\sigma_{soft/hard}(s)$

b and s need not be factorized

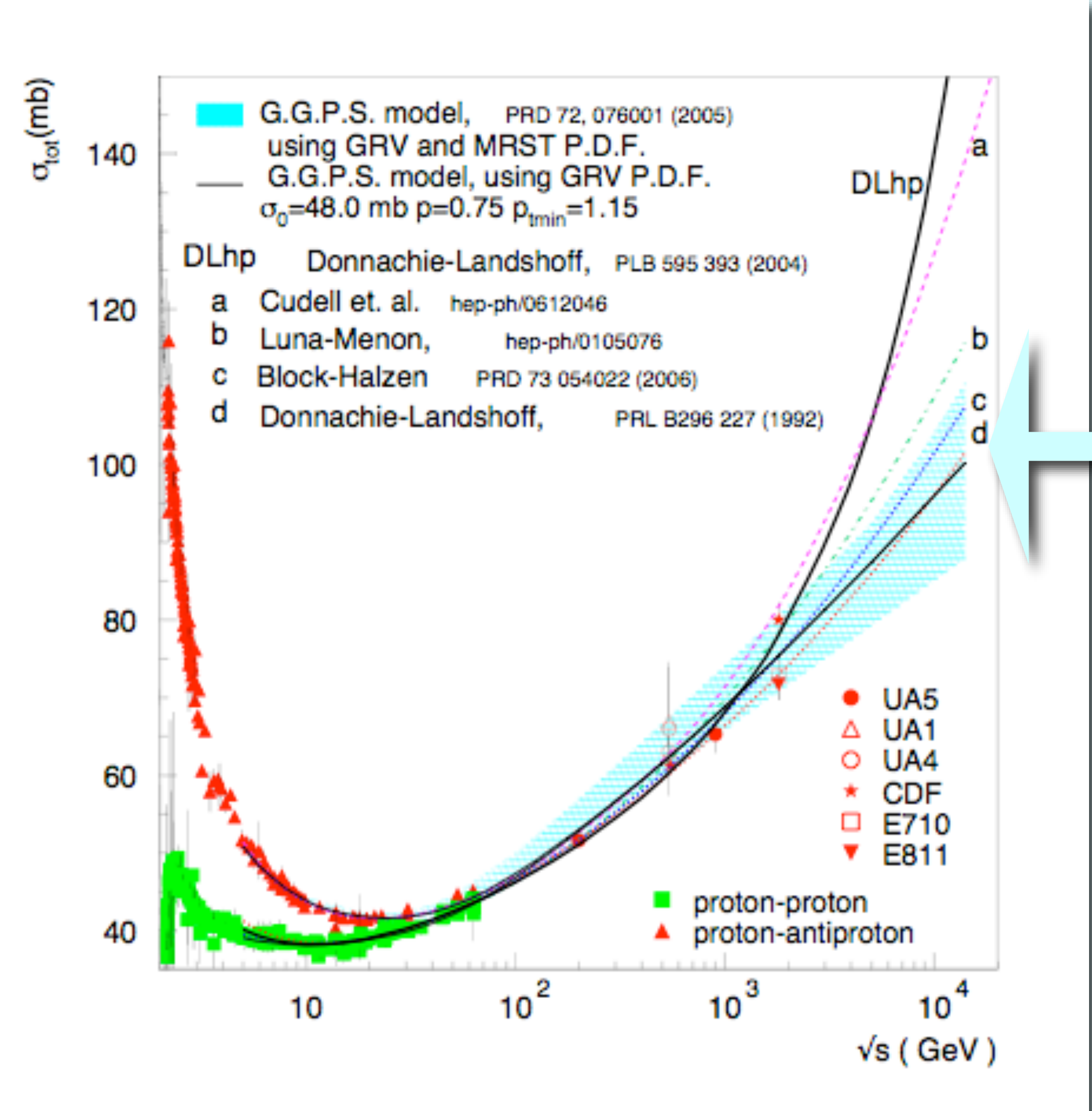
Model for hard and soft interactions

- Eikonal mini-jet model with soft gluon resummation
  - A. Corsetti, A. Grau, G. P.,Y.N. Srivastava, PLB 1996
  - A. Grau, G.P, Y.N. Srivastava, PRD60 1999, hep-ph/9905228
  - A. Achilli, R.M. Godbole, A. Grau, R. Hedge, G.P., Y.N. Srivastava, hep-ph/ 07083626, to appear in PLB

A. Grau, R.M. Godbole and Y.N. Srivastava Phys. Rev. D 72, 076001 (2005)



With hard pomeron models



Minijets + Soft gluons

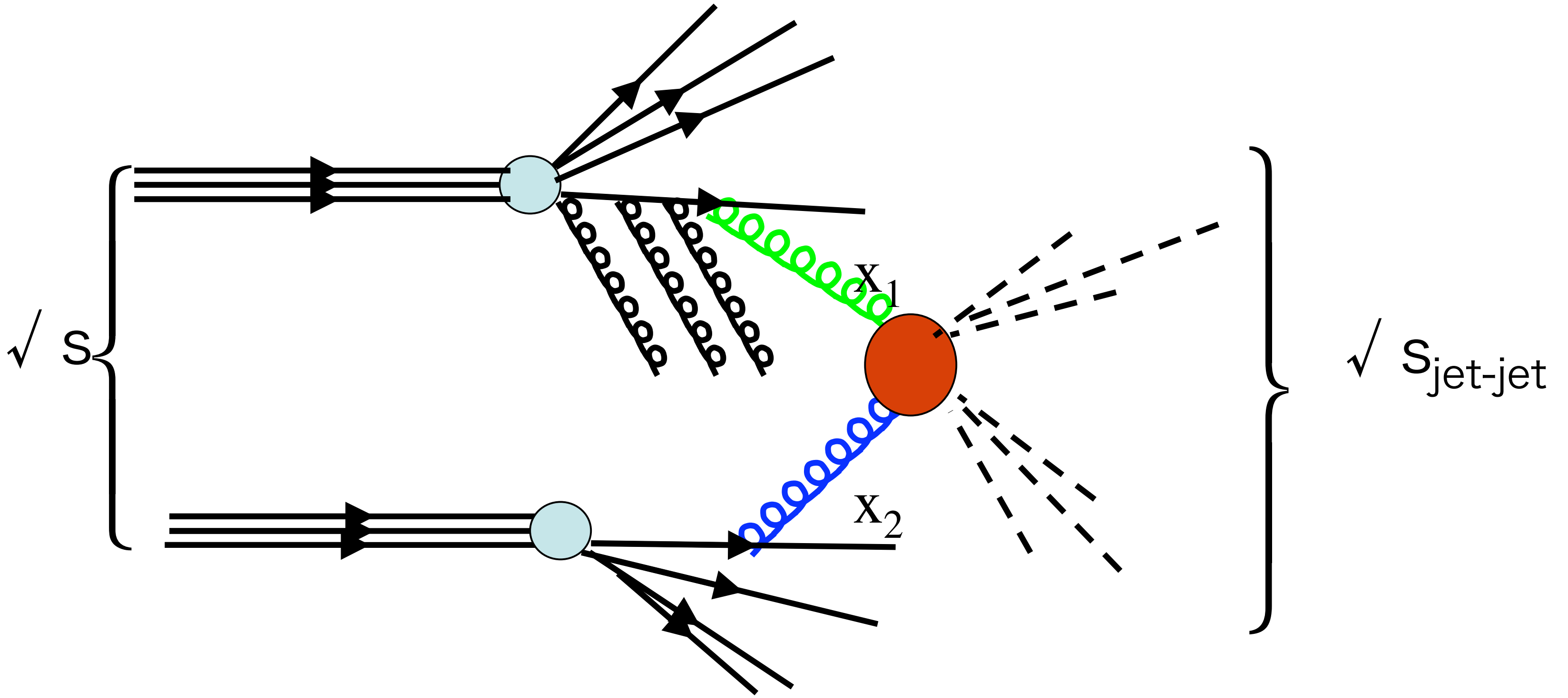
Our model is based on

1. eikonal transformation which implies multiple scattering and requires impact parameter distributions inside scattering particles and basic scattering cross-sections

2. hard component of scattering responsible for the rise of the total cross-section

3. soft gluon emission from scattering particles which softens the rise and gives b-distribution

3. SOFT GLUON EMISSION FROM SCATTERING PARTICLES WHICH SOFTENS THE RISE AND GIVES B-DISTRIBUTION



3. SOFT GLUON EMISSION FROM SCATTERING PARTICLES WHICH SOFTENS THE RISE AND GIVES B-DISTRIBUTION

$$A_{BN}(b,s) = N \int d^2K_\perp \; e^{-iK_\perp \cdot b} \frac{d^2P(K_\perp)}{d^2K_\perp}$$

$$\frac{d^2P(K_\perp)}{d^2K_\perp} = \frac{1}{(2\pi)^2} \int d^2\vec{b} \; e^{iK_\perp \cdot b - h(b,q_{max})}$$

$$h(\vec{b}, q_{max}) = \int_0^{q_{max}} d^3\bar{n}(k)[1 - e^{-ik_t \cdot b}]$$

$$\approx \int_0^{q_{max}} \frac{\alpha_s(k_t^2)}{8\pi} \frac{dk_t}{k_t} \log \frac{2q_{max}}{k_t} [1 - e^{-ik_t \cdot b}]$$

$$\Uparrow$$

Soft gluon emission factor

Soft gluon emission factor

$$\int_0^{q_{max}} \frac{\alpha_s(k_t^2)}{8\pi} \frac{dk_t}{k_t} \log \frac{2q_{max}}{k_t} [1 - e^{-ik_t \cdot b}] \qquad \sim$$

q_{max} is the maximum transverse momentum allowed by kinematics to single soft gluon emission in a given hard collision, averaged over the parton densities.

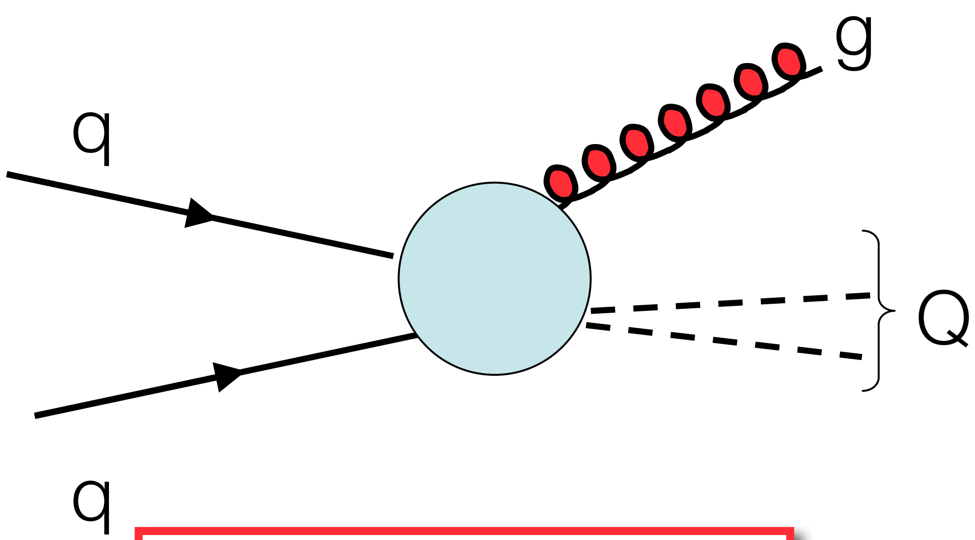
M. Greco and P. Chiappetta

Kinematical constraints on single gluon emission

$q(p_1) + q(p_2) \longrightarrow g + Q$

$Q^2 = s_{jet\text{-}jet}$

$\hat{s} = (p_1 + p_2)^2$

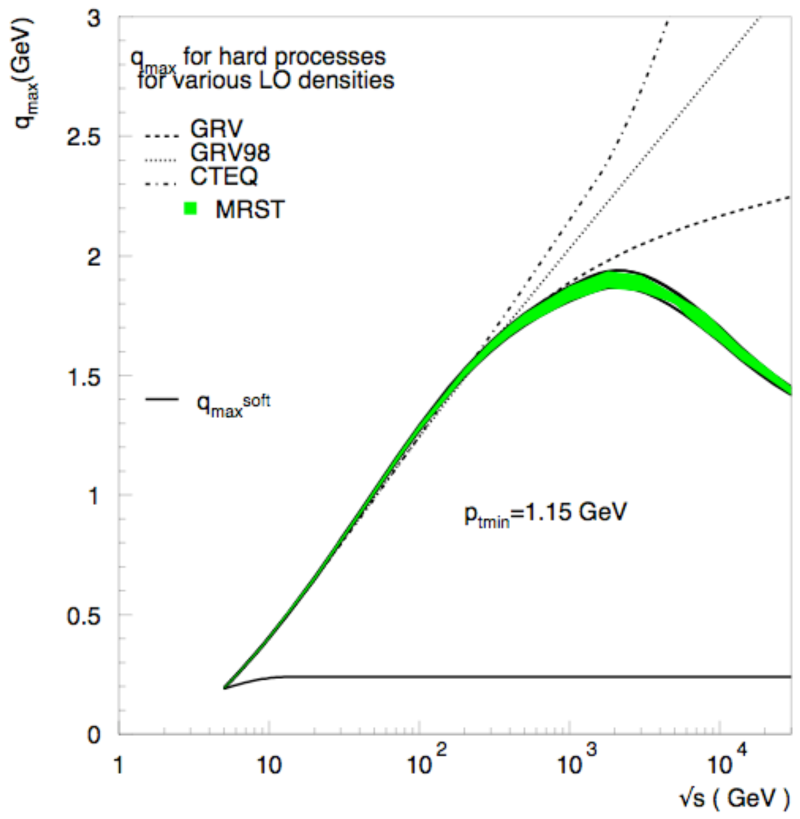


$$\boxed{q_{max} = \frac{\sqrt{s}}{2}\left(1 - \frac{Q^2}{\hat{s}}\right)}$$

Averaging over the densities

$$q_{max}(s) = \frac{\sqrt{s}}{2} \frac{\sum_{i,j} \int \frac{dx_1}{x_1} f_{i|A}(x_1) \int \frac{dx_2}{x_2} f_{j|B}(x_2) \sqrt{x_1 x_2} \int_{z_{min}}^{1} dz(1-z)}{\sum_{i,j} \int \frac{dx_1}{x_1} f_{i|A}(x_1) \int \frac{dx_2}{x_2} f_{j|B}(x_2) \int_{z_{min}}^{1} (dz)}$$

Soft gluon scale



Average over same PDF as for σ_{jet}

$$\int_0^{q_{max}} \frac{\alpha_s(k_t^2)}{8\pi} \frac{dk_t}{k_t} \log \frac{2q_{max}}{k_t} [1 - e^{-ik_t \cdot b}]$$

What about the $k_t \rightarrow 0$ limit for α_s ?

Modeling the infrared behaviour

- frozen
- Our choice : singular but integrable, phenomenological choice

SOFT GLUON RESUMMATION EFFECTS

$$h(b,s) = \int d^3 n_g(k)[1 - e^{-i\mathbf{k}_t \cdot \mathbf{b}}]$$

Virtual gluons

Energy-momentum conservation factor for real soft gluons

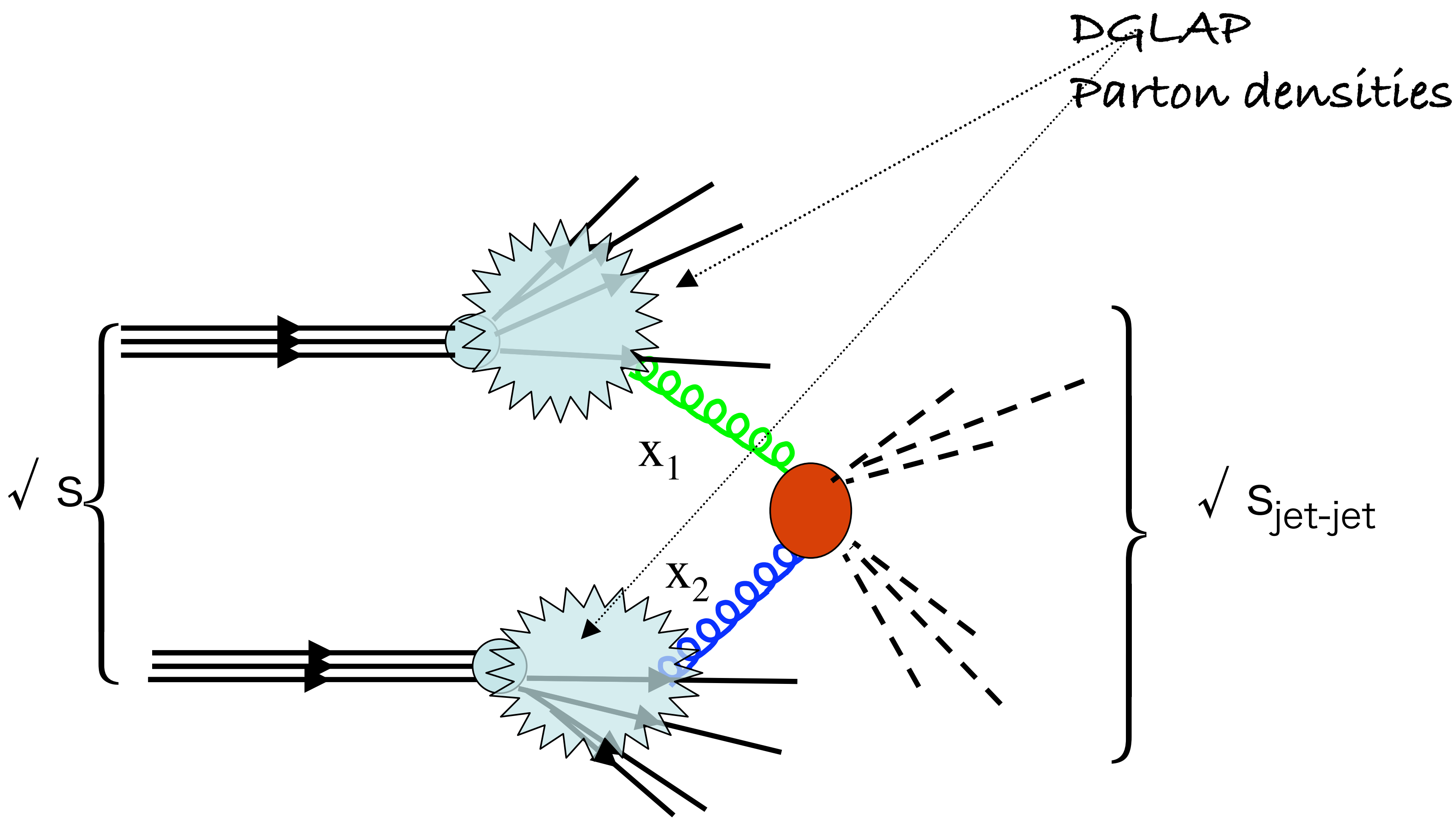
$$d^3 n_g(k) \propto \alpha_s(k_t^2)$$

Model

$$\boxed{A_{hard}(b) \propto e^{-(b\Lambda)^{2p}}}$$

$$\alpha_s(k_t) \approx \frac{1}{k_t^{2p}} \qquad as \quad k_t \to 0 \qquad p < 1$$

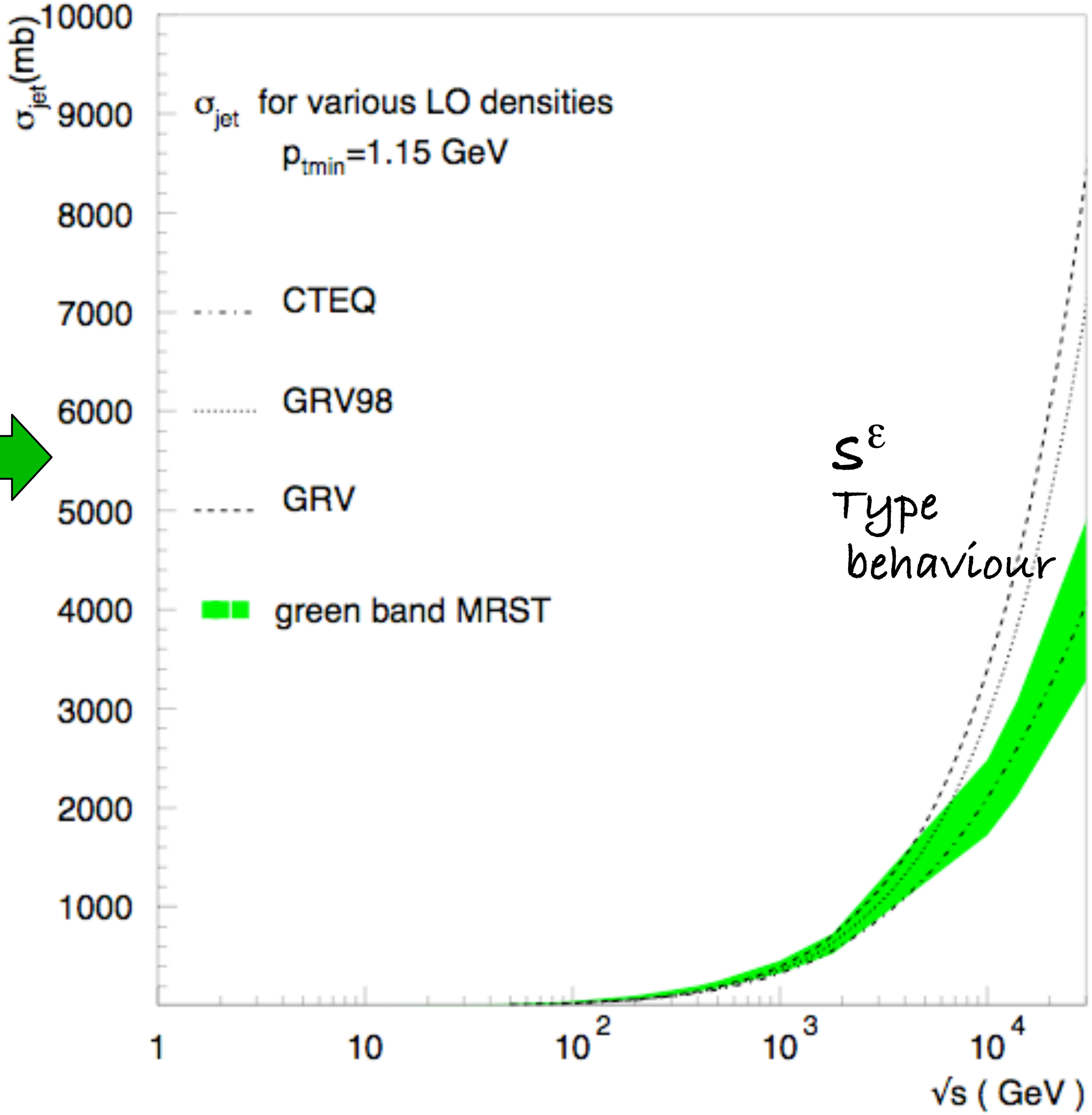
2. Hard component of scattering responsible for the rise of the total cross-section



2.

HARD COMPONENT OF SCATTERING RESPONSIBLE FOR THE RISE OF THE TOTAL CROSS-SECTION

$$\sigma_{hard} \equiv \sigma_{\rm jet}^{AB}(s, p_{tmin})$$



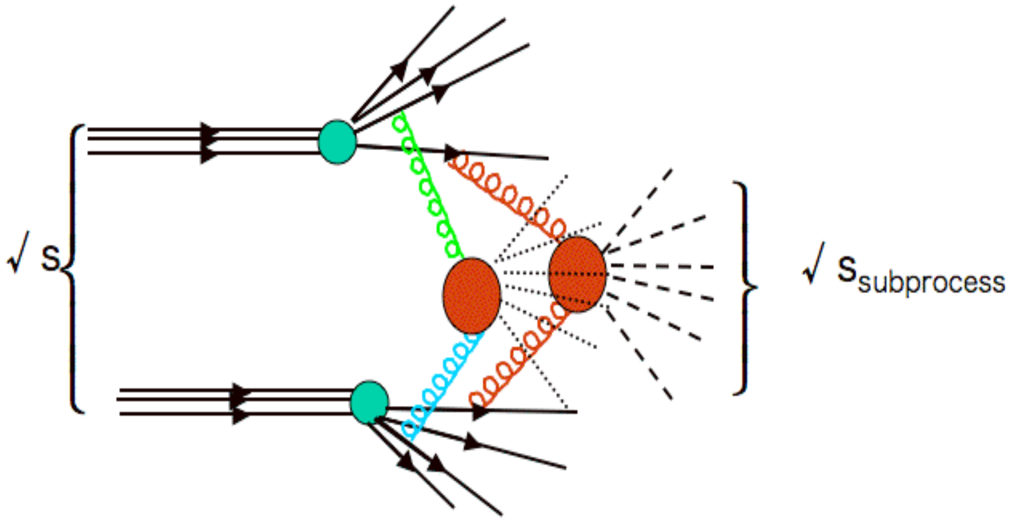
1. Eikonal transformation

$$\sigma_{total} = 2\int d^2\vec{b}[1 - e^{-\chi(b,s)}]$$

With $\Re\chi(b,s) \approx 0$ and $\Im\chi(b,s) = n(b,s)/2$

- $\sigma_{inel} = \int d^2\vec{b}[1 - e^{-n(b,s)}]$
- $\sigma_{total} = 2\int d^2\vec{b}[1 - e^{-n(b,s)/2}]$

1. EIKONAL TRANSFORMATION IMPLIES MULTIPLE SCATTERING



Survival probability

Probability of not having an inelastic collision

$$P_{no-inel} = e^{-n(b,s)}$$

Can be used to calculate the survival probability of Large Rapidity Gaps for collisions at given b-value in a colorless exchange

V. Khoze, J. Bjorken,…

Survival probability

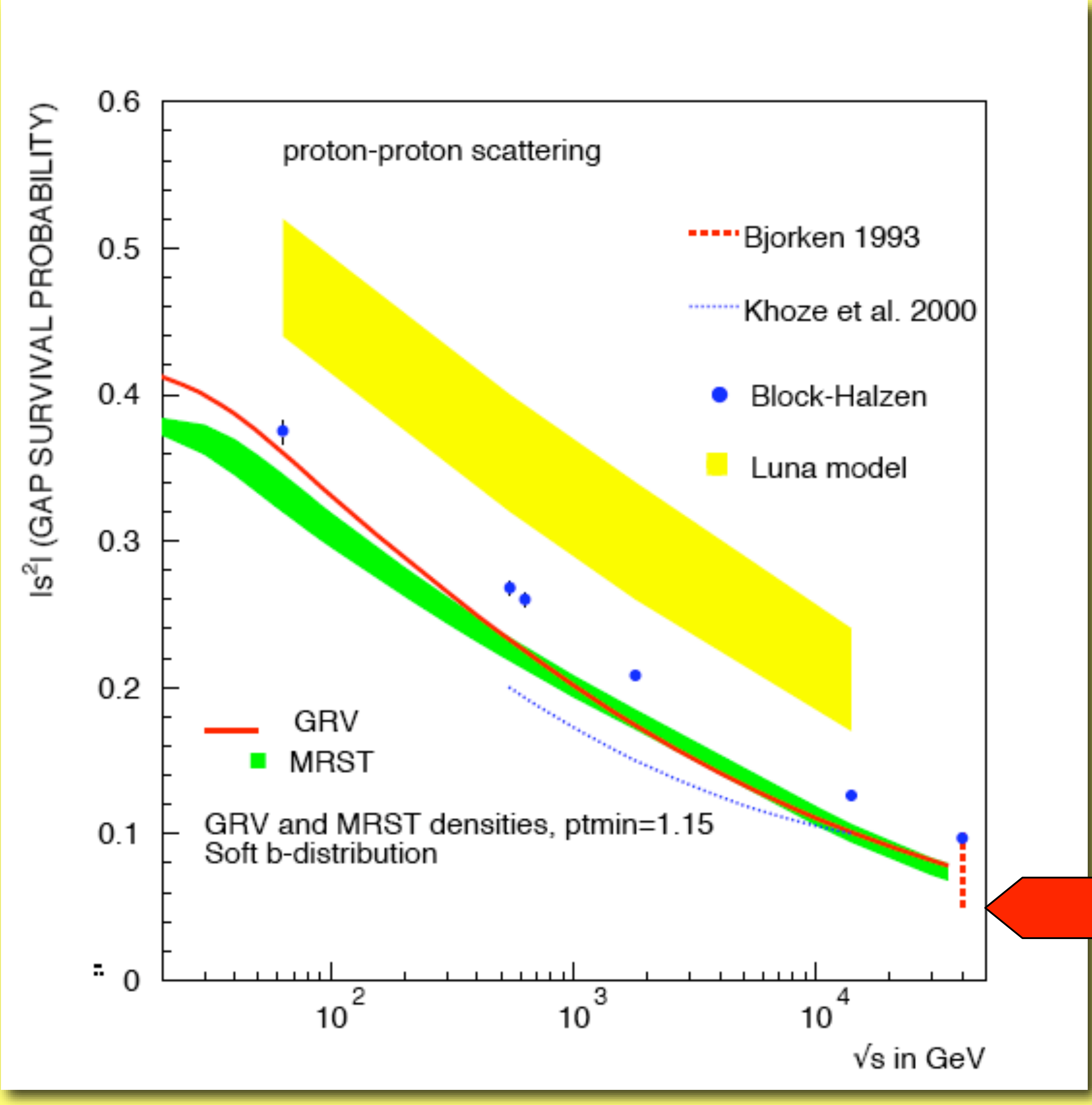
$$< |S|^2 >= \int d^2\vec{b} A(\vec{b}, q_{max}^{soft}) |S(\vec{b})|^2$$

we use the soft b-distribution $A(\vec{b}, q_{max}^{soft})$

$$\int d^2\vec{b} A(\vec{b}, q_{max}^{soft}) = 1$$

$$|S(\vec{b})|^2 = P_{no-inel}$$

Comparing with other models



Bjorken

CONCLUSIONS

- We have built a model for the total cross-section which
  - Incorporates hard and soft gluon effects
  - Satisfies the limits from the Froissart bound
  - Can be used to study other minimum bias effects like Survival Probability of Large Rapidity Gaps
  - Easily extended to γ p and γ γ

Extra transparencies

The questions are :

- What makes the cross-section rise?

- What makes the cross-section rise within the limits imposed by the Froissart bound?

Two mechanisms

- Rise is due to increasing number of gluons which undergo “hard|” collisions, namely PQCD calculable interactions

- Saturation of Froissart bound is due to increasing acollinearity of “hard” partons because of initial state energy dependent soft gluon emission

Model for hard and soft interactions

- Work with A. Achilli, A. Grau, R.M. Godbole, Y.N. Srivastava
- Eikonal mini-jet model with soft gluon resummation

Jet cross-sections at LO

Using current

DGLAP evoluted

PDF's :

GRV, MRST, CTEQ

$$\sigma_{\text{jet}}^{AB}(s, p_{tmin}) =$$

$$\int_{p_{tmin}}^{\sqrt{s/2}} dp_t \int_{4p_t^2/s}^{1} dx_1 \int_{4p_t^2/(x_1 s)}^{1} dx_2 \times$$

$$\sum_{i,j,k,l} f_{i|A}(x_1) f_{j|B}(x_2) \frac{d\hat{\sigma}_{ij}^{kl}(\hat{s})}{dp_t}.$$

Softening the rise

- Soft gluons change the parton collinearity
- Higher energy → more emission

more acollinearity

smaller x-section

Soft gluon emission

According to our model, soft gluon emission down to zero momentum modes is responsible for the initial

decrease in p p , as well as for the

transformation of the sharp rise due to the increase in gluon-gluon interactions

into a smooth behavior

3. SOFT GLUON EMISSION FROM SCATTERING PARTICLES WHICH SOFTENS THE RISE AND GIVES B-DISTRIBUTION

$$A_{BN}(b,s) = N \int d^2K_\perp \; e^{-iK_\perp \cdot b} \frac{d^2P(K_\perp)}{d^2K_\perp}$$

$$\frac{d^2P(K_\perp)}{d^2K_\perp} = \frac{1}{(2\pi)^2} \int d^2\vec{b} \; e^{iK_\perp \cdot b - h(b,q_{max})}$$

$$h(\vec{b}, q_{max}) = \int_0^{q_{max}} d^3\bar{n}(k)[1 - e^{-ik_t \cdot b}]$$

$$\approx \int_0^{q_{max}} \frac{\alpha_s(k_t^2)}{8\pi} \frac{dk_t}{k_t} \log \frac{2q_{max}}{k_t} [1 - e^{-ik_t \cdot b}]$$

$\Uparrow$

Soft gluon emission factor

What one needs to calculate A(b,s)

- Limits of integration

for soft gluon factor $\int dn_g(k)[1-e^{ikb}]$

- upper limit $q_{max}^{(s)}$

- lower limit k=0 but then need to model

$\int dk\, \alpha_s(k)$ down into the infrared region

Our model in the infrared

- Singular but integrable

$$\alpha_s(k_t^2) = \frac{12\pi}{33 - 2N_f} \frac{p}{\log[1 + p(\frac{k_t^2}{\Lambda^2})^p]}$$

- Singularity regulated by $p < 1$

How about N_{soft}?

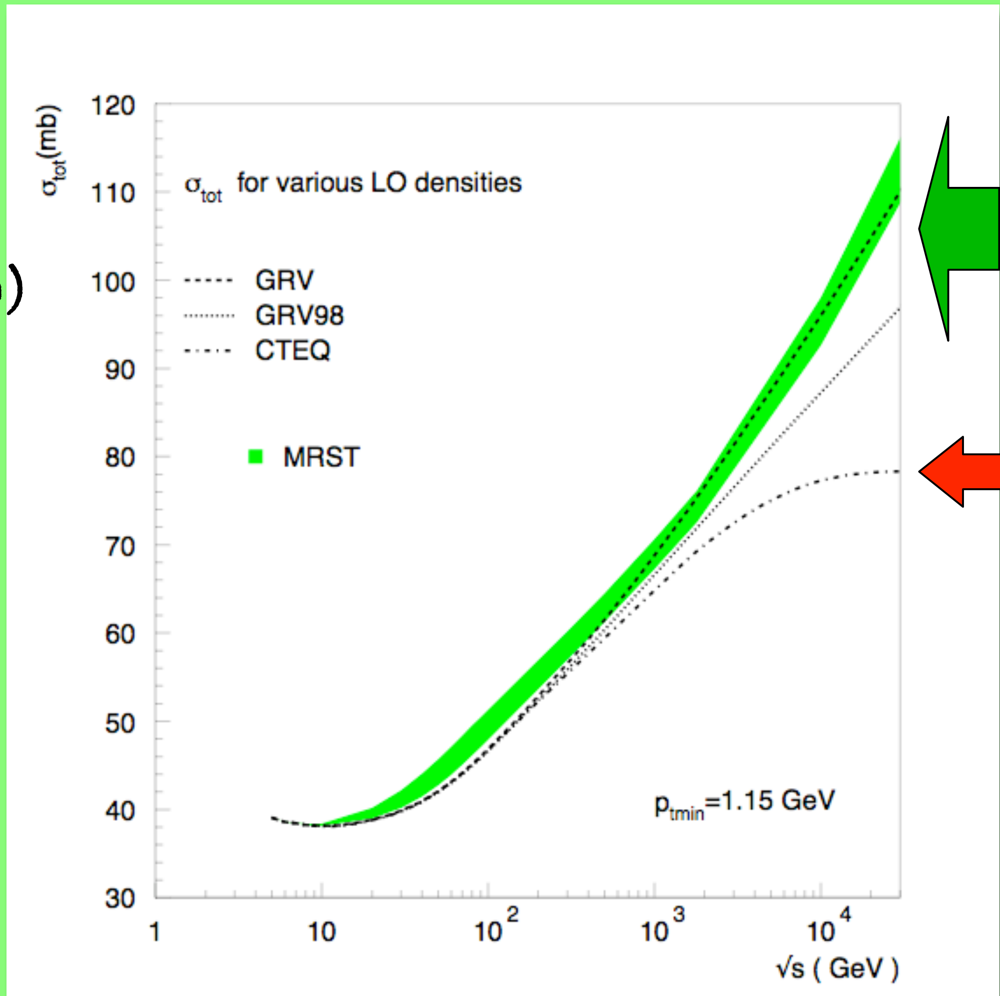
$$n_{soft}(b,s) = A_{BN}^{soft}(b,s)\sigma_0(1+\epsilon\frac{2}{\sqrt{s}})$$

$\epsilon = 0,1$ depending upon the process being pp or $pbarp$

- Parametrized with a constant σ_0
- With p_{tmin} dependence through A(b,s)

For p_{TMIN}=1.15 GeV and a chosen set of low energy parameters

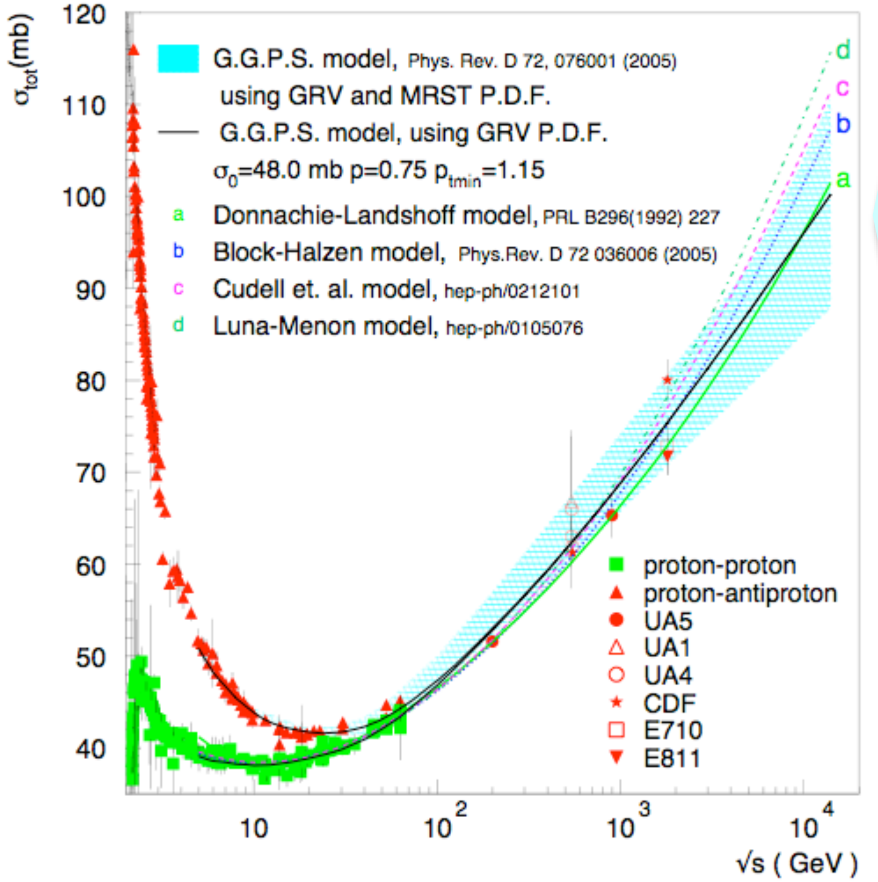
σ_{tot} (mb)



acceptable

Not good

Comparing with data and other models



GRV
MRST

At very large energies :

$$\bar{\sigma}_T(s) \approx 2\pi \int_0^\infty (db^2)[1 - e^{-n_{hard}(b,s)/2}],$$

$$n_{hard}(b,s) = \sigma_{jet}(s) A_{hard}(b,s)$$

$$\sigma_{jet}(s) = (s/s_o)^\epsilon \sigma_1.$$

$$A_{hard}(b,s) \propto e^{-h(b,s)}$$

where

$$h(b,s) = \int d^3 n_g(k)[1 - e^{-i\mathbf{k}_t \cdot \mathbf{b}}]$$

From power law to log behaviour

$$A_{hard}(b) \propto e^{-(bq)^{2p}} \qquad C(s) = A_o(s/s_o)^{\epsilon}\sigma_1$$

$$\bar{\sigma}_T(s) = 2\pi \int_o^{\infty} db^2[1 - e^{-C(s)e^{-(bq)^{2p}}}]$$

$$q^2\bar{\sigma}_T(s)] \rightarrow \ (2\pi)[lnC(s)]^{1/p}$$

Main result

$$\sigma_T(s) \approx\rightarrow [\ln s^{\epsilon}]^{1/p} \approx [\epsilon \ln s]^{(1/p)}$$