Minijets, soft gluon resummation and photon cross-sections

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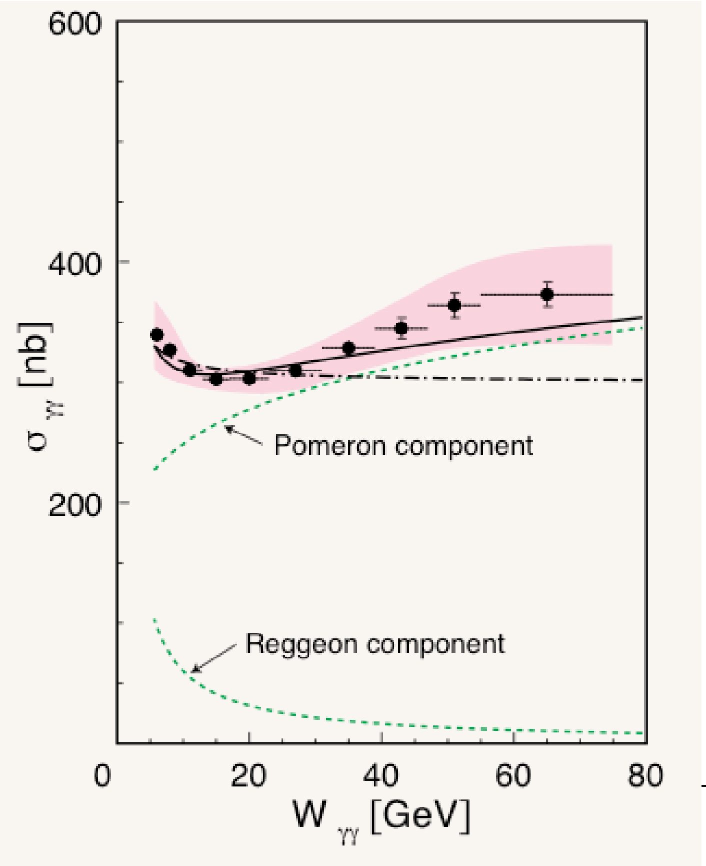
AdA : Where e+e- collisions were born

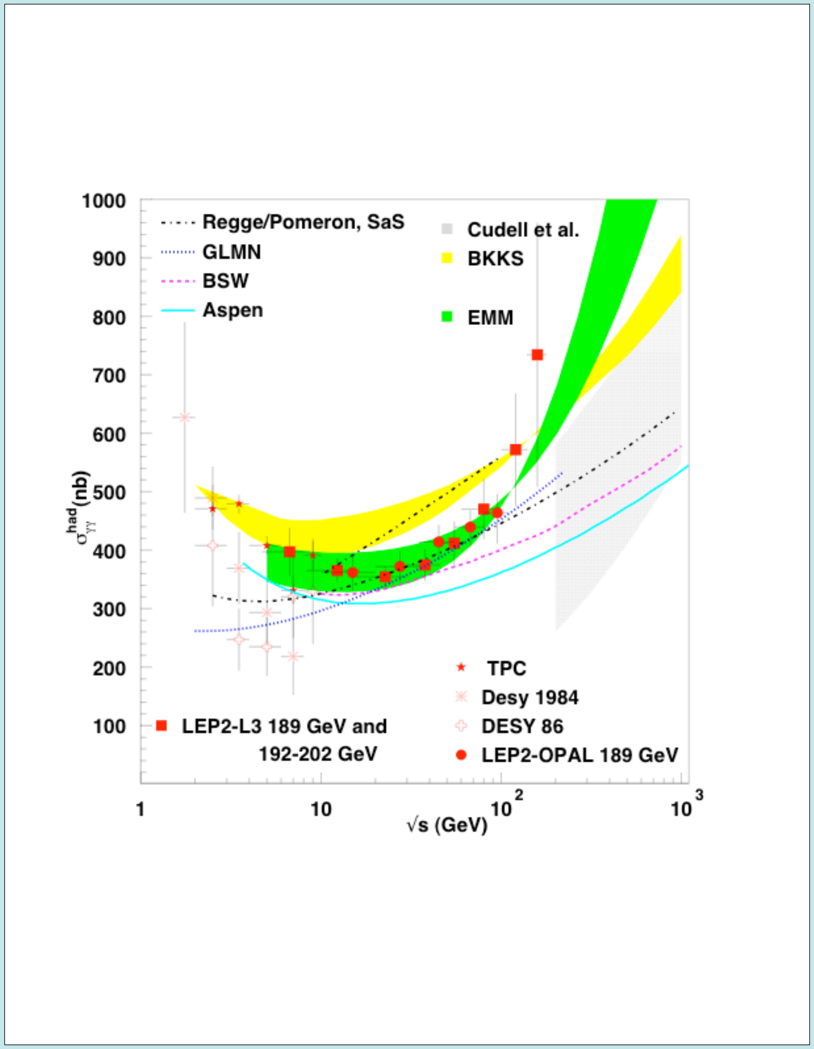
Total cross-sections are a testing ground of our understanding of QCD beyond perturbative regime

- A popular models for total cross-section



Models for total cross-section

- The interest lies in QCD role
- What is the Pomeron? The Reggeon?
- Are these concepts universal?
- Or do they just phenomenologically describe our ignorance?
- How can ILC/LPC help ?



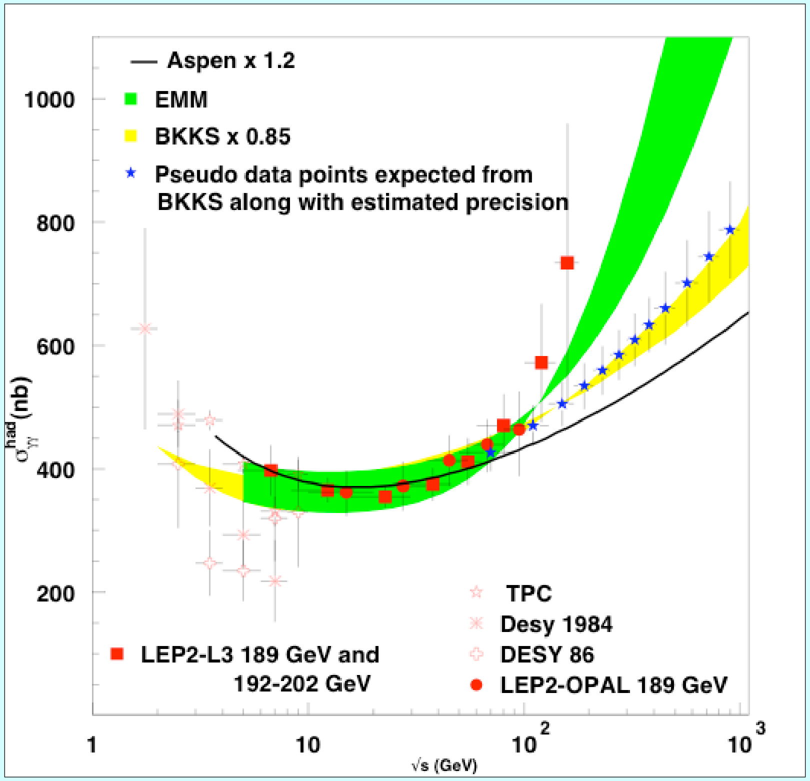
A.de Roeck, R. Godbole, A. Grau, G.Pancheri, JHEP 2003

s^{ε} : Should ε be the same for all hadronic cross-sections?

- Yes if the model
  - is based on Regge poles and a universal Pomeron pole exchange

    $\sigma = Bs^{-\eta} + As^{\varepsilon}$

- Not necessarily if
  - The model has some connection with QCD and parton densities play a role



A fit to LEP data shows that ε is not the same for proton and photon cross-sections

$\sigma = Bs^{-\eta} + As^{\varepsilon} + Cs^{\varepsilon_1}$

- Fit3

C≠ 0 ε=0.093

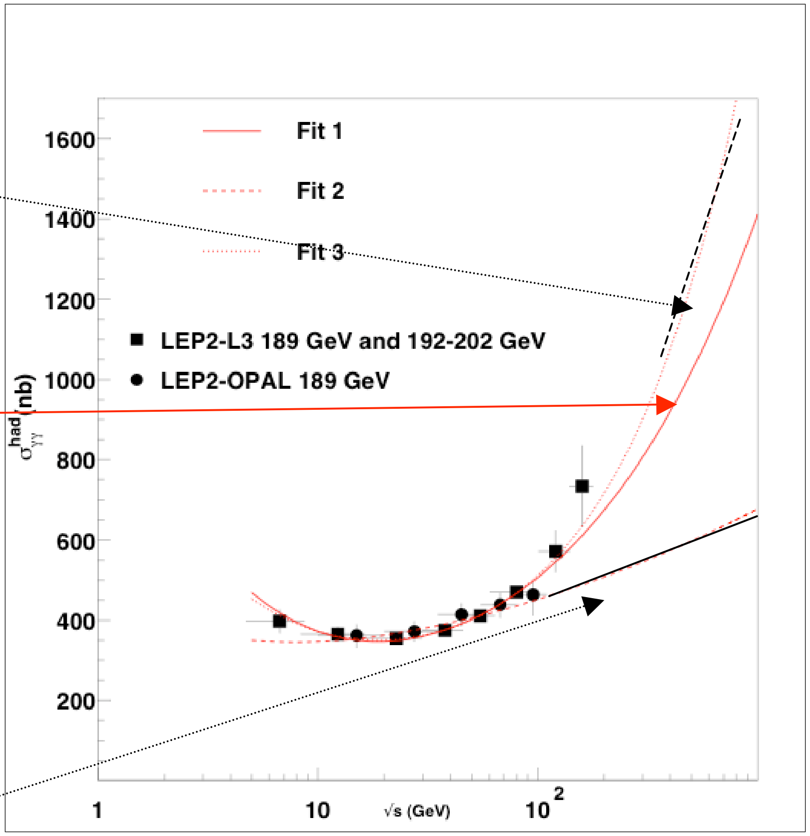
ε_1=0.418

- Fit 1

C=0 ε=0.250

- Fit2

C=0 ε=0.093 as in pp



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A realistic QCD model should relate the fit to QCD phenomenological inputs quantities like densities etc.

The Bloch-Nordsiek Eikonal Minijet model includes k_t resummation

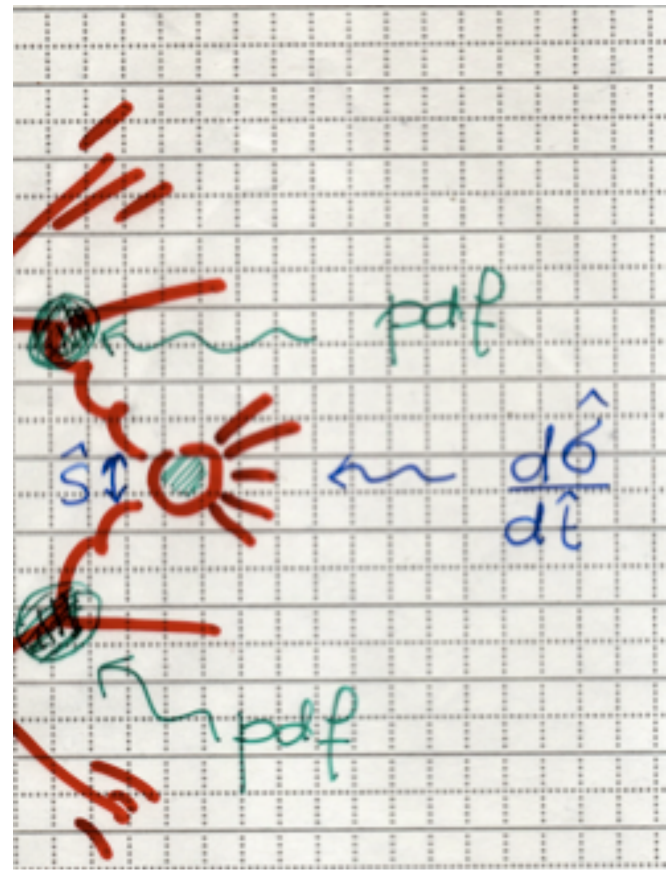
R.Godbole, A. Grau, G.Pancheri, Y.Srivastava PRD 2005
A. Corsetti, A. Grau, G.Pancheri, Y. Srivastava PLB 1996

1. Multiple parton interactions : optical theorem and eikonal representation for $T_{el}(s,t)$
2. Hard scattering to drive the rise due to 1/x
3. Soft gluons down to zero momentum to tame the rise

The hard cross-section

- Mini-jet cross-section

$\Sigma\int$ densities $\int dp_t \, d\sigma/dp_t$



In all mini-jet models densities make all the difference between photon and proton processes

Proton-proton and proton-antiproton

Most commonly used densities

- GRV
- CTEQ
- MRST

γ–proton and $\gamma\gamma$

Most commonly used densities

- GRV
- GRS
- CJKL

Soft resummation

Probablity of total K_T from infinite # of soft gluons

$$\int d^2b\, e^{iK_T b} \exp\{-\int d^3n(k)[1-e^{-ik_t b}]\}$$

depends upon single gluon energy

- maximum : use Kinematics
- minimum : 0 from Bloch-Nordsieck theorem

Role of resummation

An infinite number of soft quanta

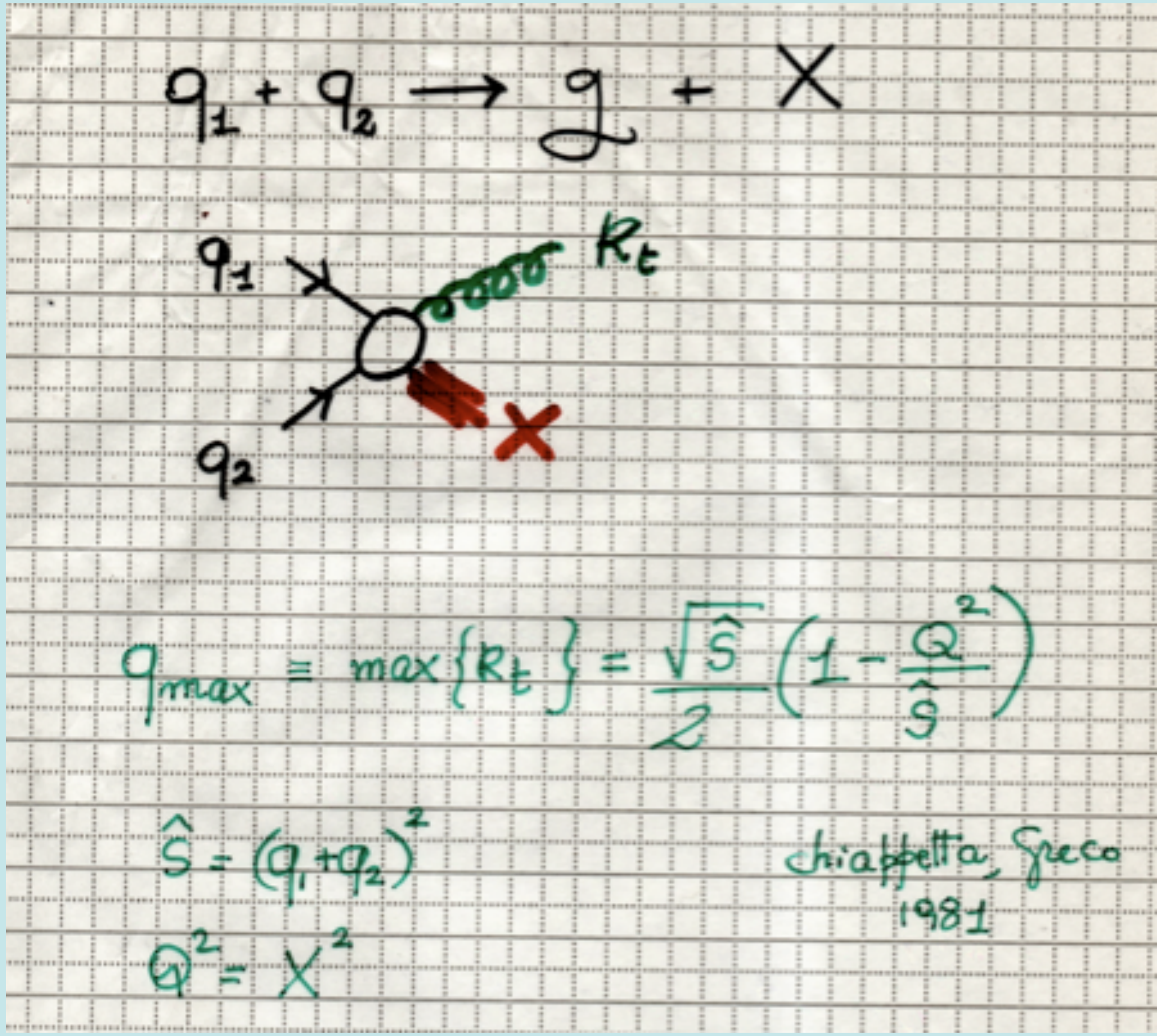
- down to zero momentum but how?

    next slides

- Up to an energy dependent limit q_{max}
    - Higher hadron energy ⇒ possibility of more small x partons with "high energy" (≈1-2 GeV) ⇒ higher q_{max}

Maximum soft gluon energy

- q_1 and q_2 : any two partons
- X : the 2-jet final state
- $Q^2 \geq 4\, p^2_{tmin}$
- q_{max} depends on x_1, x_2
- We average over densities



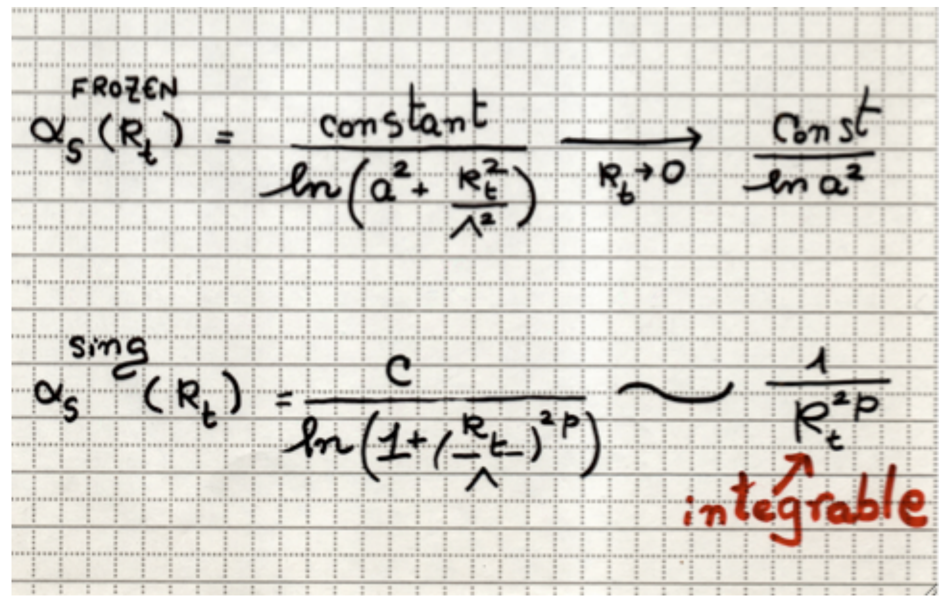
Zero momentum quanta

- Soft gluons need to be resummed if they are indeed soft ≈1/k
- Resummation implies integration over dk_t

- What matters will be $\int \alpha_s(k_t)dk_t f(k_t)$

and not $\alpha_s(0)$

Models for infrared behaviour



Soft gluons give b-distributions

In eikonal representation

$$\sigma_{tot} \approx 2\int d^2b\, [1-e^{-n(b,s)/2}]$$

- $n(b,s)$=average # of collisions at distance b, at energy $\sqrt{s}$
- b-distribution is needed

Our ansatz:

b-distribution =
Fourier transform of soft gluon K_t distribution

Resummation of soft gluons down to k_t=0

- Gluon emission in k_t changes the collinearity of initial partons
- And for same energy and p_{tmin}, acollinearity of initial partons will bring loss of luminosity of the parton beams and parton-parton cross-sections will decrease
- As the energy available for soft gluon emission increases, so does the acollinearity of the parton-parton collision
- The rate of rise of total cross-sections due to rising minijet cross-section is reduced (softened by) by soft gluon emissions.
- Softening effect more important the more singular α_s

We shall illustrate how the model works for the proton-proton case and then show its application to $\gamma\gamma$

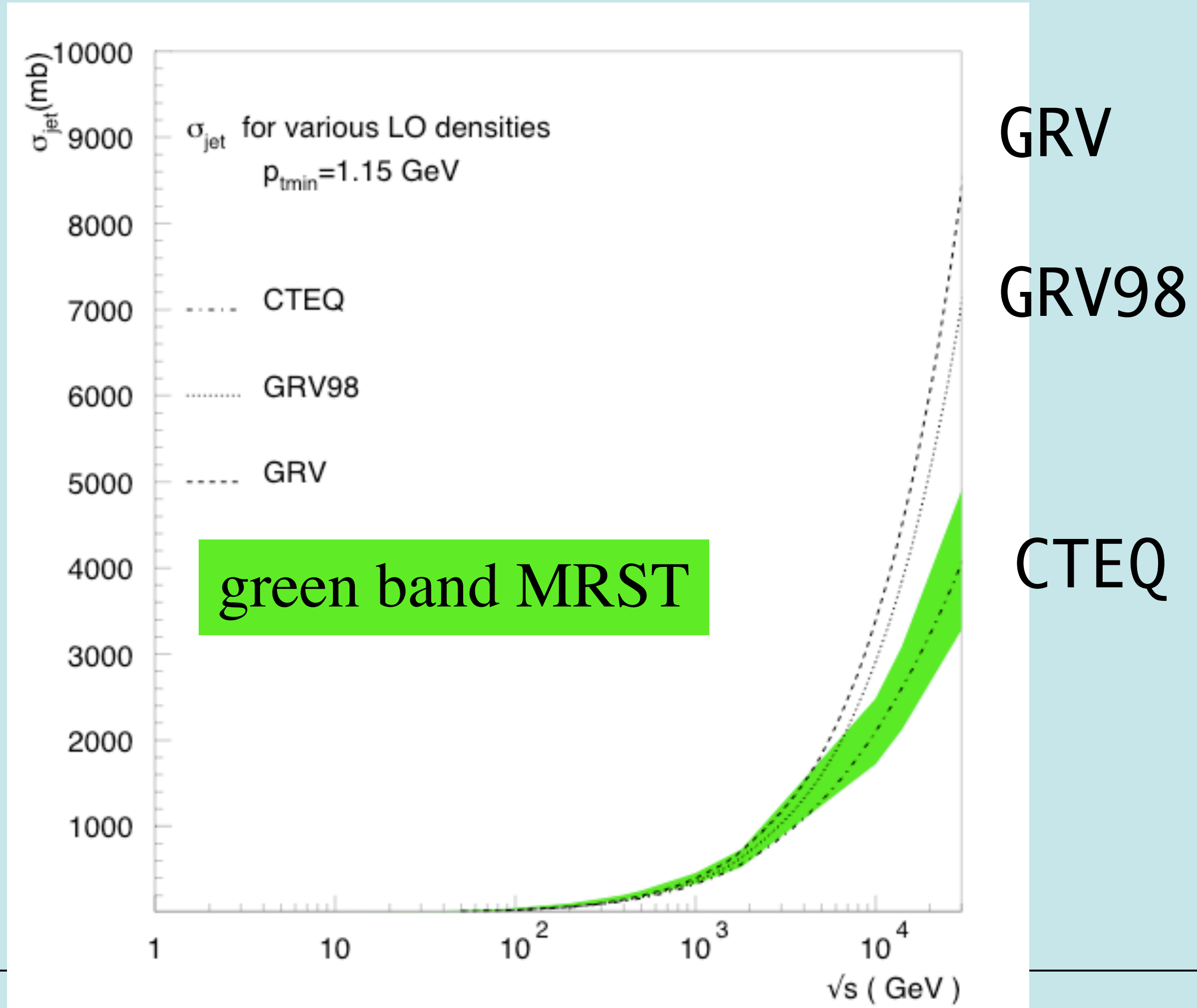
How the model works

- Choose p_{tmin} = 1÷2 GeV for mini-jets

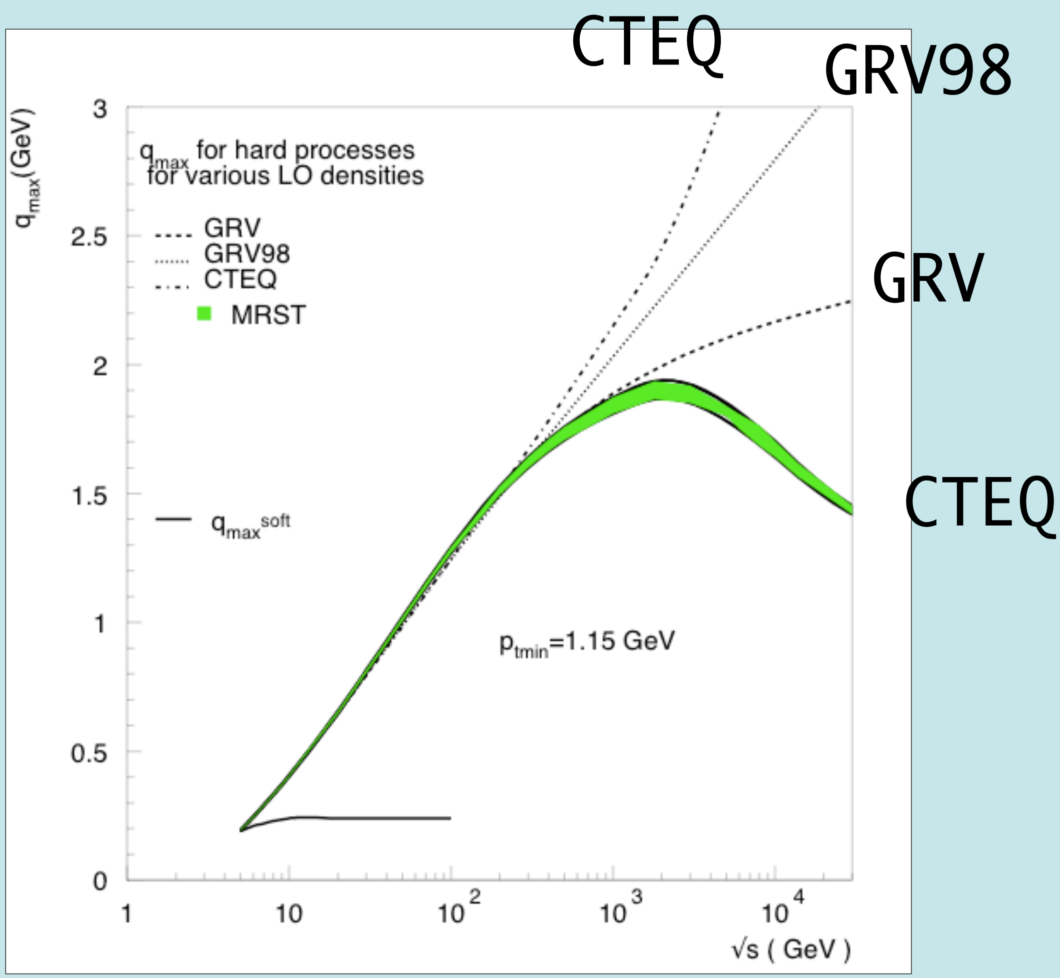
- Choose parton densities
- Calculate minijet x-section
- Calculate q_{max} for soft gluons
- Calculate A(b,s) for given q_{max}
- Calculate n_{hard} (b,s)=A(b,s) $\sigma_{jet}(p_{tmin},s)$
- Parametrize n_{soft}
- Evaluate n(b,s)= n_{soft} + n_{hard}

- Eikonalize $\sigma_{tot} \approx 2\int d^2b\, [1-e^{-n(b,s)/2}]$

σ_{jet} for p_{tmin}=1.15 GeV



q_{max} for ptmin=1.15 geV

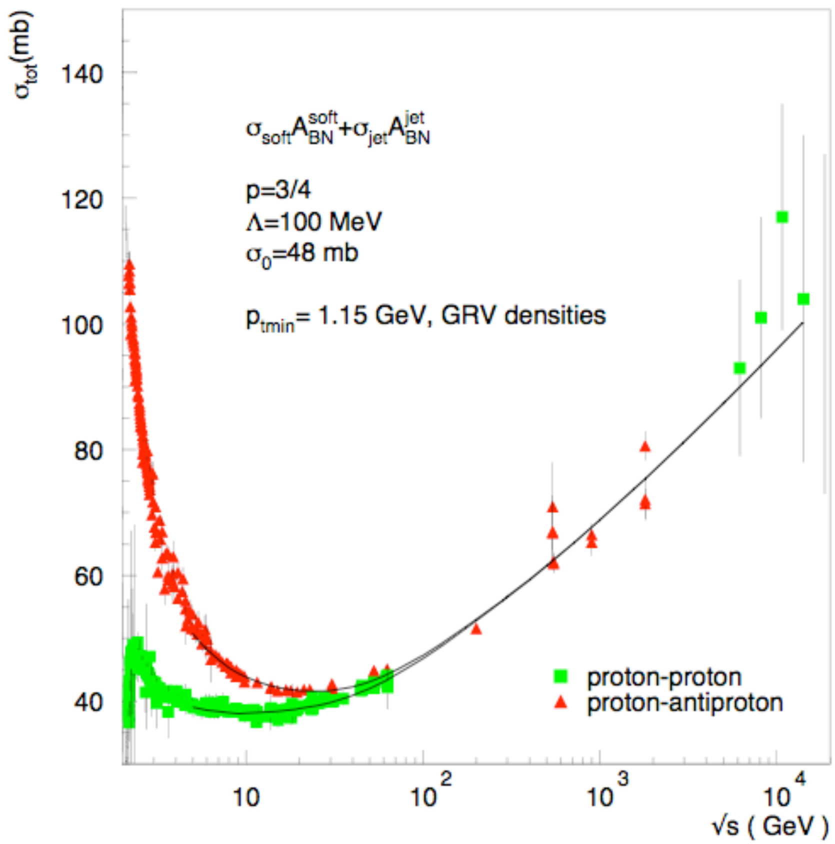


Which parameters in soft emission?

p_{tmin} and **p** regulate how large is the maximum energy , but PDF's also play a role

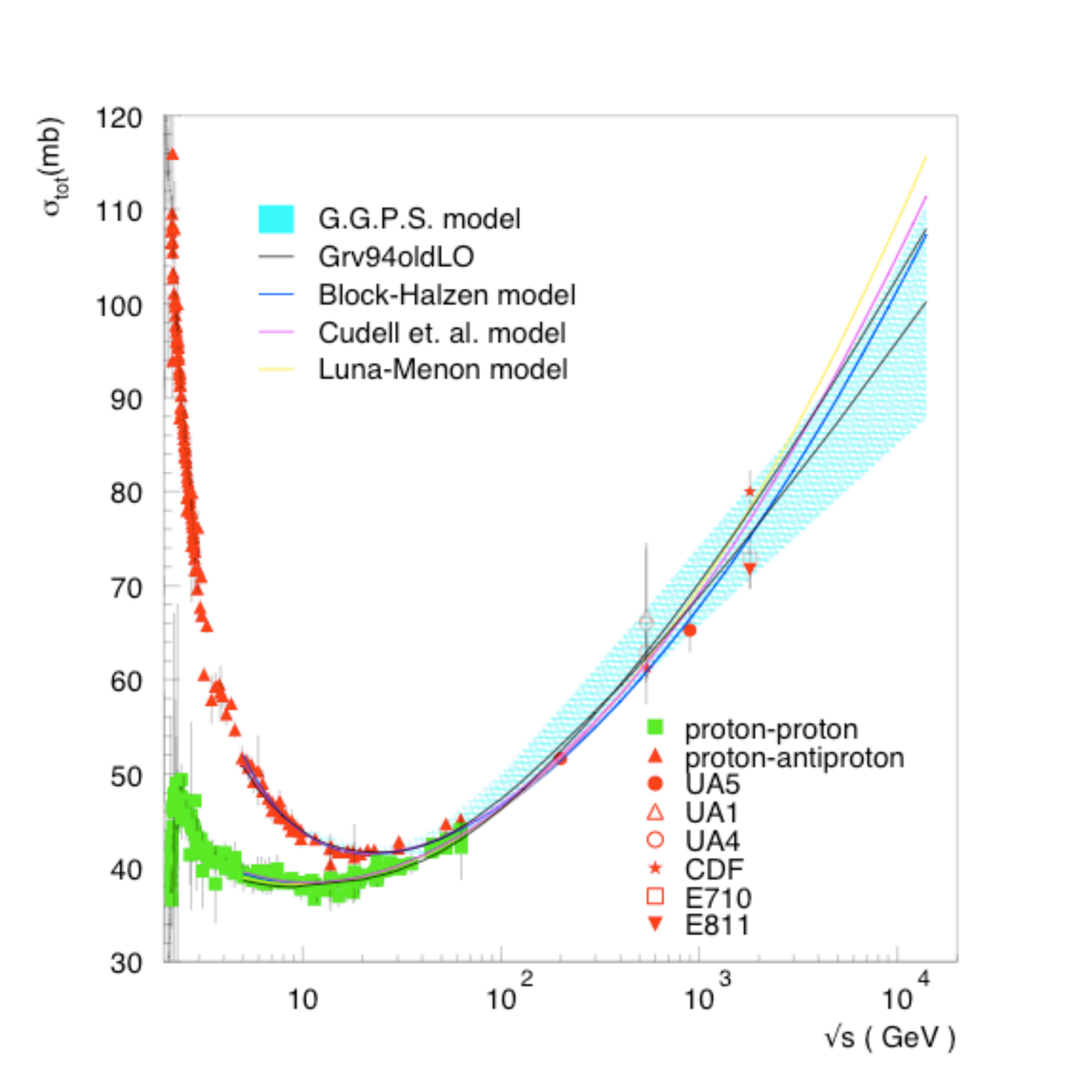
- P_{tmin} ⟷ hard scattering lowest scale
- **p** ⟷ infrared (integrable) behaviour

σ_{tot}=102 mb
at LHC



GRV

Comparison with proton data(I)



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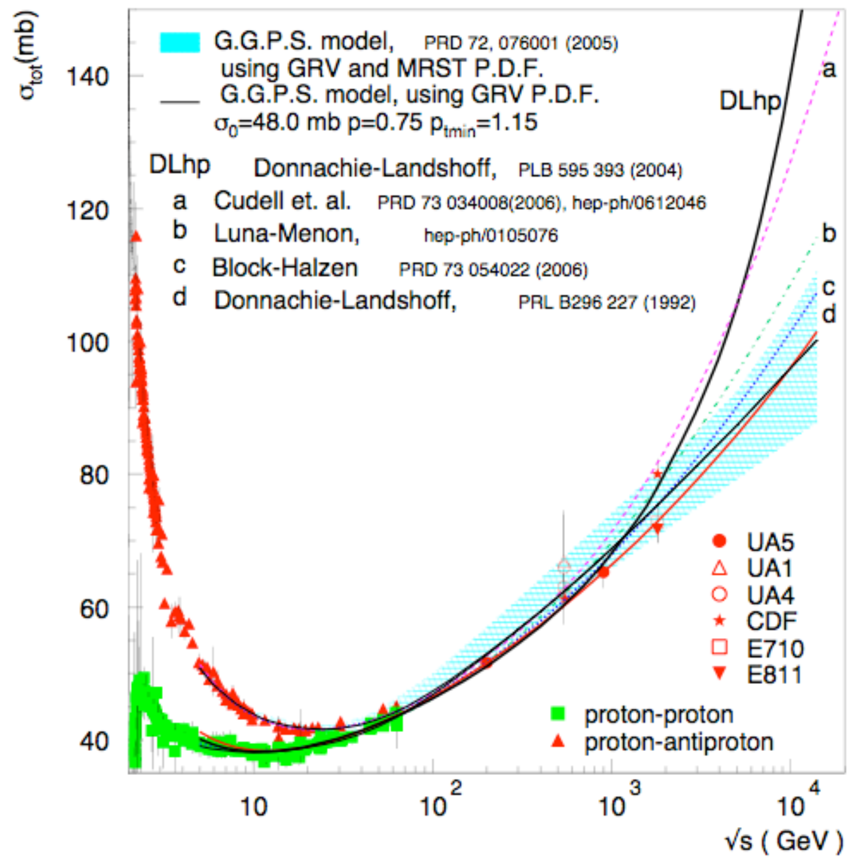


Survival probability

Probability of not having an inelastic collision

$$P_{inel} = e^{-n(b,s)}$$

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

V. Khoze, J. Bjorken,…

Survival probability

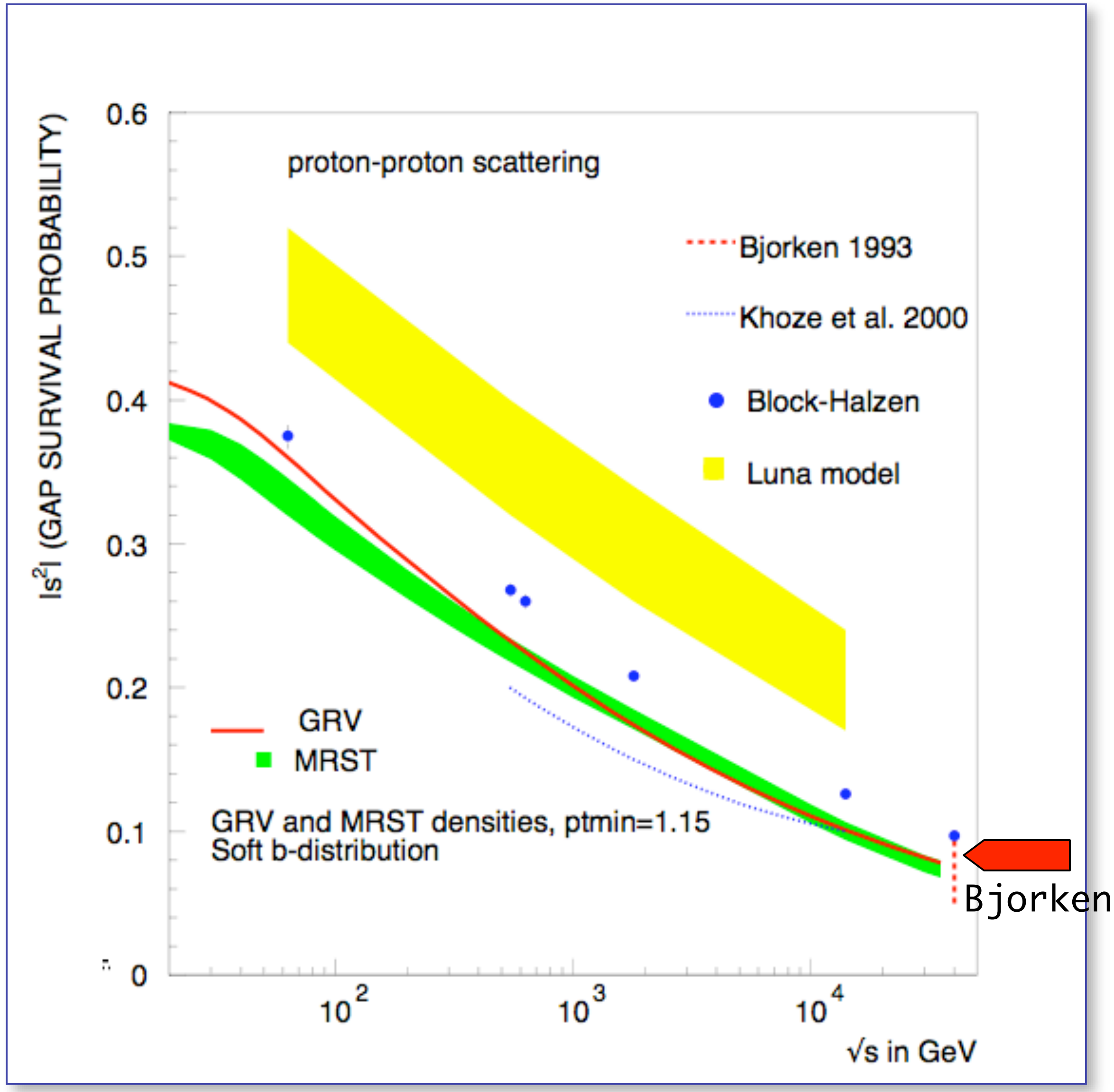
$$< |S|^2 >= \int d^2\vec{b} A(\vec{b}, q_{max}^{soft}) |S(\vec{b})|^2$$

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

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

$$|S(\vec{b})|^2 = P_{inel}$$

Comparison with other models



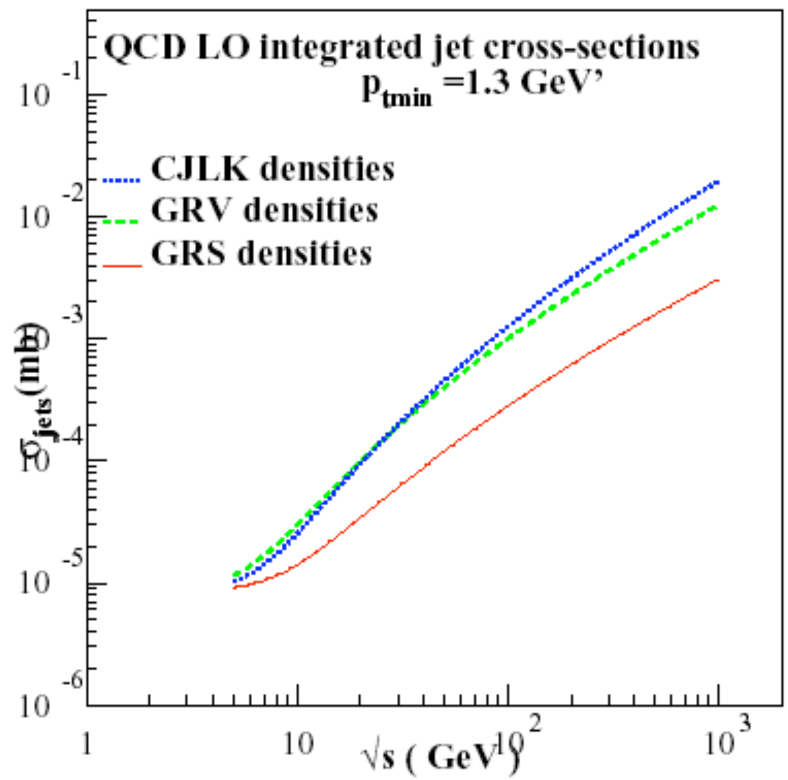
Now apply the model to $\gamma\gamma$

Choose p_{tmin} = 1÷2 GeV for mini-jets and parton densities

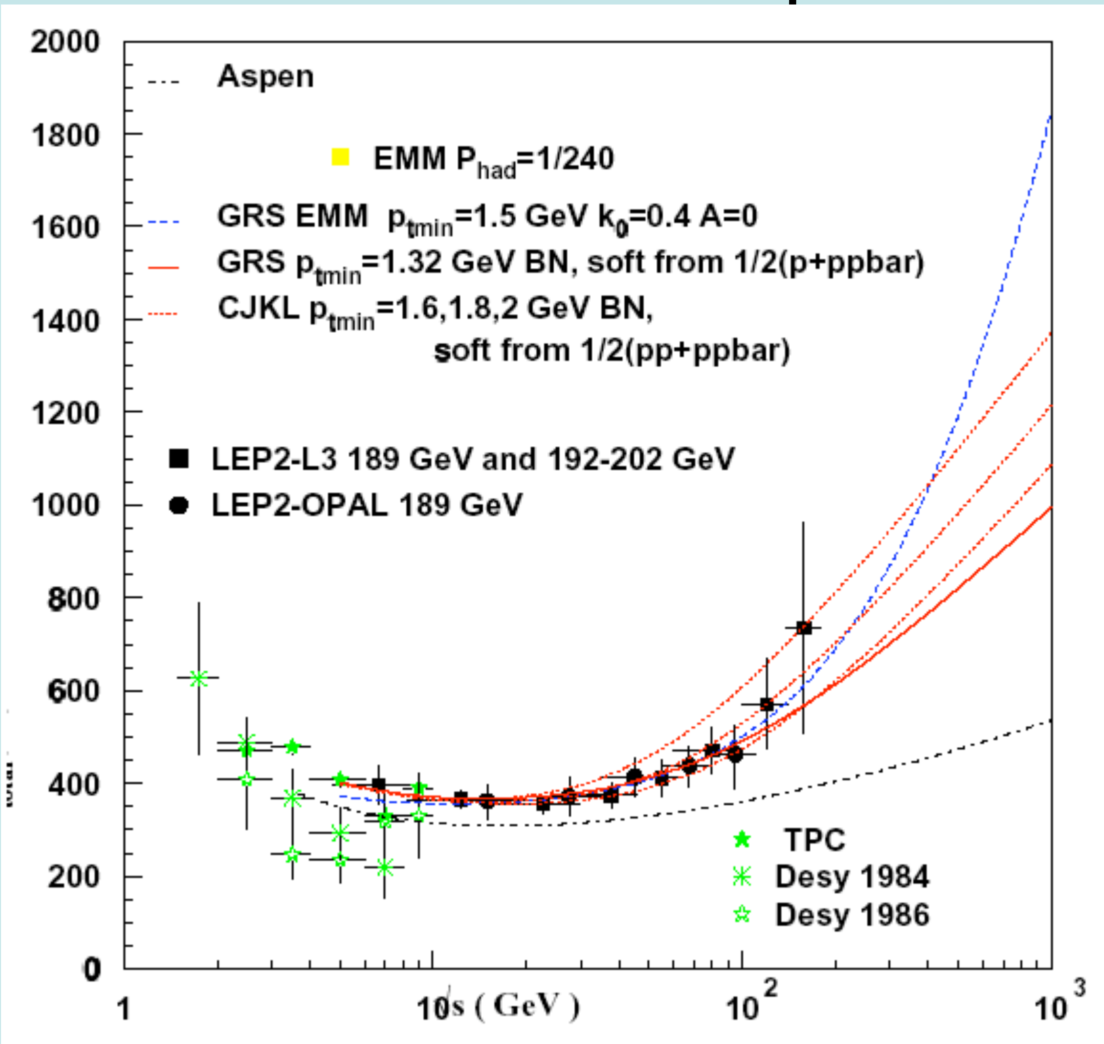
For photons, LEP data suggest

p_{tmin} ~ 1.3 ÷ 1.8 GeV

- Gluck Reya Vogt
- Gluck Reya Shielbein
- Cornet Jankowski Lorca Krawczyk



Eikonalize $\sigma_{tot} \approx 2P_{had} \int d^2b\, [1-e^{-n(b,s)/2}]$ and compare with data



P_{had} is a Phenomenological input describing the hadronic content of the photon in eikonal models

R.Fletcher, T.Gaisser. F.Halzen, 1993

An aside on the Froisart bound and minijet cross-sections

About the Froissart bound and QCD minijets

For all densities we find

$$\sigma_{jet}^{PDF}(s, p_{tmin}) \approx s^{\epsilon}$$

with

$\epsilon \approx 0.4$ for GRV and GRV98 $\rightarrow$ more singular

$\epsilon \approx 0.3$ for CTEQ and MRST $\rightarrow$ less singular

QCD Mini-jets violate the Froissart bound

- Consequence of infinite range of QCD
- One needs to introduce a finite distance of the interaction
- The eikonal does it through the hadron finite size

Minijets : how to reduce their growth?

- Embedding the minijets into the eikonal

  but

- It depends on how A(b,s) $\longrightarrow$ 0 as b $\longrightarrow$ infinity

Finite size of hadrons

- The finite size can be introduced through the Form Factor

  $A(b) \sim e^{-b\ \mathrm{constant}}$ as $b \sim$ very large :

not enough to tame the rise because the growth of

σ_{jet}^{PDF} is too strong!!

or

energy dependent soft gluon emission where satisfaction of the Froissart bound would imply that the the finite range of the interaction is restored through soft gluon emission down into the infrared

For all pdf's

- For different PDF , with soft gluon emission to give an energy dependent size and QCD hard gluon minijets to drive the rise

- All the Bloch-Nordsieck type curves

$$\sigma_{tot}^{pp/p\bar{p}} = a_0 + a_1 s^b + a_2 \ln(s) + a_3 \ln^2(s).$$

even though $\sigma_{jet} \Uparrow s^{\epsilon}$

Conclusions (I)

- We have built a model for the total cross-section which
  - Incorporates **hard** and **gluon** effects
  - Satisfies the limits from the **Froissart** bound
  - Can be used to study other minimum bias effects
  - Easily extended to γ p and $\gamma\gamma$

Conclusions (II)

- Predictions at ILC vary according to which densities better describe the behaviour at low x
- Total cross-sections measurements in Collider mode would allow clean information on $\gamma\gamma$ cross-sections, reducing the errors due to modelling of diffractive components
- Even in regular mode, difference in the model predictions are measurable and can give insights into the soft or non perturbative region of QCD.