$\gamma\gamma$ total cross-sections and the soft gluon resummation

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LCWS06: International Linear Collider Workshop.

- What gives the energy dependence of total cross-sections?
- A look at $pp, p\bar{p}, \gamma p, \gamma\gamma \rightarrow hadrons$
- A QCD based description of the decrease and the increase of total cross-sections through Soft Gluon Summation (Bloch-Nordsieck Model) and Mini-jets
- Predictions for hadronic backgrounds at future linear colliders.

With G. Pancheri and A. Corsetti, Eikonal Minijet Model for $pp, \gamma p$ and $\gamma\gamma$. PLB **435** (1998) 441, Eur.Phys.J.C19:129-136,2001 1/x in σ_{jet} drives the rise.

With A. de Roeck, A. Grau and G. Pancheri, Testing of models at future Linear colliders LC-TH-2001-030, *and* hep-ph/0305071 JHEP **0306**, 061, pp. 1-15

With A. Grau, G. Pancheri and Y. N. Srivastava Soft Gluon Resummation tames the rise. Phys. Rev. D **72**, 076001, hep-ph/0408355.

With R. Hegde, A. Grau, G. Pancheri and Y. Srivastava hep-ph/yymmnnn, Proceedings of Les Houch Workshop 2005.

Some associated work:

M. Drees and R.M. Godbole, Zeit. Phys. **C59** (1993) 591.
Hadronic backgrounds due to photon structure at
Linear Colldiers

M. Block, E. Gregores, F. Halzen and G. Pancheri for the
Aspen Model Phys.Rev.**D60** (1999) 054024
FACTORIZATION

A. Grau, G. Pancheri and Y. N. Srivastava for the
Bloch-Nordsieck Model PR **D60** (1999) 114020
$\alpha_s(k_t \to 0)$ tames the rise

Summary of the talk

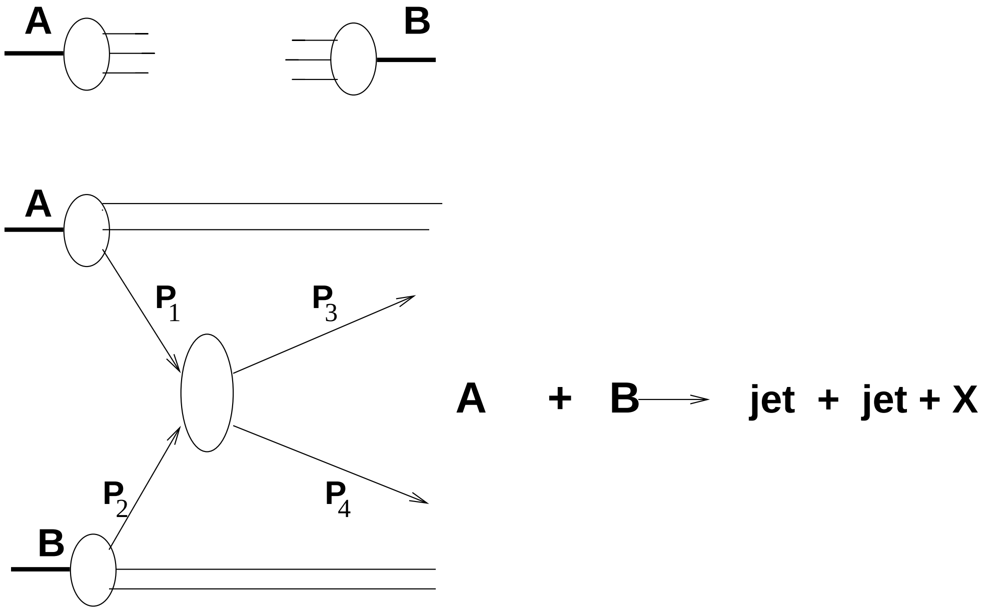
- Predictions for total cross-sections within unified models, embedding QCD processes, using information on proton and photon structure functions as well as those from the model independent extrapolations to higher energies.
- Taming of the high energy rise with the soft gluon resummation in the eikonalised minijet model (EMM).
- Variability of model predictions due to changes in the soft parameters of the $pp/p\bar{p}$ case.

QCD Based approach :

Use perturbative QCD as well as measured str. fns. of p and γ. I.e. in terms of quarks and gluons in p and γ .

Basic philosophy:

Try to explain the rise and the initial fall in terms of partons in the colliding hadrons using experimentally determined parton densities and basic QCD interactions among partons.



$A + B \rightarrow \text{jet} + \text{jet} + X$

Increasing beam energy ⇒ increase in # and energy of collding partons.

$\sigma_{jet} = \sigma(A + B \to jet + jet + X)$

calculated in pQCD rises with increasing $\sqrt{s}$.

Energy rise in σ_{tot} driven by the rise of σ_{jet}.

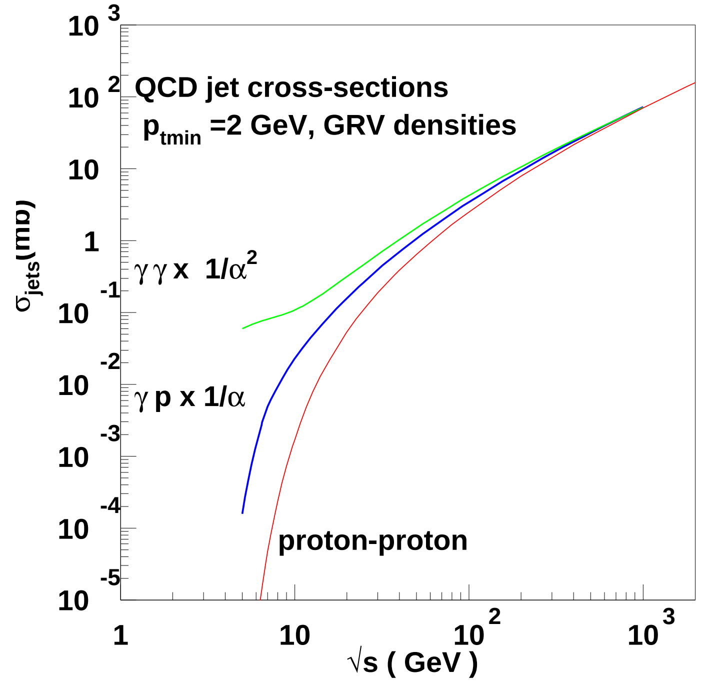
Minijet Model Halzen and Cline (1985)

Energy rise in the Minijet cross-section

Integrated jet cross-sections

$$\sigma_{jet} = \int_{p_t min} \frac{d^2\sigma_{jet}}{d^2\vec{p}_t} d^2\vec{p}_t =$$

$$= \sum\nolimits_{partons} \int_{p_t min} d^2\vec{p}_t \int f(x_1)dx_1 \int f(x_2)dx_2 \frac{d^2\sigma^{partons}}{d^2\vec{p}_t}$$



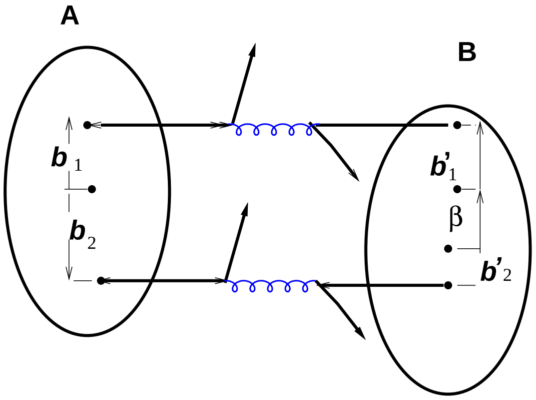
Minijet cross-sections dominated by gluons and similar for $pp, \gamma p$ and $\gamma\gamma$ at high energies when appropriately scaled by $1/\alpha_{em}$

σ_{jet} depend on the densities and very dramatically on p_{tmin} the transverse momentum cut-off

Unitarising mini-jets

- σ_{jet} rises with s as a power in violation Frossiart Bound too fast towards σ_{tot}.
- Unitarization essential. Done using eikonal formalism
- The steep rise of σ_{jet} with s is NOT reflected in the energy rise of $\sigma_{tot}, \sigma_{inel}$.

With increasing energy the probability of multiple parton scattering (MPS) in a given hard scatter increases



Transverse Overlap of the hadrons

$\sigma^{jet}_{AB}(s) =< n^{jet}_{pair} > (s)\sigma^{inel}_{AB}(s)$

Rising MPS $\Rightarrow$ rising jet pair multiplicity

Need to calculate the s dependence of $< n^{jet}_{pair} >$.

Perhaps need to go beyond pQCD.

s dependence related to that of the MPS probability.

This in turn decided by the overlap of the partons in the transverse plane.

$A_{AB}(\beta) = \int d^2b_1 \rho_A(\vec{b_1})\rho_B(\vec{\beta} - \vec{b_1})$

Governing quantity # of collisions:

$$\boxed{n(b,s) = A_{AB}(b,s)\sigma(s) = 2\chi_I(b,s)}$$

$\chi(b,s)$ :: EIKONAL function.

The Eikonal Minijet Model **EMM** *in LO QCD*

Calculate then $\sigma^{\rm inel}$ for **for example** $A, B = p, \bar{p}$,

$$\sigma^{\rm inel}_{pp(\bar{p})} = 2\int d^2\vec{b}[1 - e^{-n(b,s)}]$$

Build n(b,s) for σ^{inel} and use it for

$$\sigma^{\rm tot}_{pp(\bar{p})} = 2\int d^2\vec{b}[1 - e^{-n(b,s)/2} cos(\chi_R)],\ \ \chi_R = 0 \text{ in EMM}$$

b is impact parameter $\Longrightarrow$ transverse momentum of partons in hadrons

Approximations

- separate Pert. Vs Nonpert. terms
  $\rightarrow n(b,s) = n_{NP}(b,s) + n_P(b,s)$
- Further factorize b vs. s behaviour
  $\rightarrow n(b,s) \approx A(b)\sigma(s)$

simplest model $n(b,s) = A(b)[\sigma_{soft} + \sigma_{jet}]$

$\Uparrow$

matter distribution

- Model for A(b).
- σ_{soft} parametrized
- σ_{jet} LO QCD jet x-sections
- Eikonal model not restricted to calculate ONLY c.sections also used to calculate properties of hadronic events. pioneering: T. Sjostrand , More recent : M. Seymore + Borozan JHEP (2002).

At low energies and small σ^{jet}

$\sigma_{AB}^{\text{inel}} = 2\int d^2\vec{b}[1 - e^{-n(b,s)}] \simeq \sigma_{AB}^{soft} + \sigma_{AB}^{jet}$

At high energies, the eikonalisation softens the energy rise of σ^{inel} compared to that of σ^{jet}.

- Eikonal $\chi(b, s)$ contains information on the energy and the transverse space distribution of the partons in the hadrons.
- σ^{jet} depends on the parton densities $f_{q/A}(x_1), f_{q/B}(x_2)$ x_i the longitudinal mmtm fraction
- Overlap function on the transverse space (momentum) distribution.

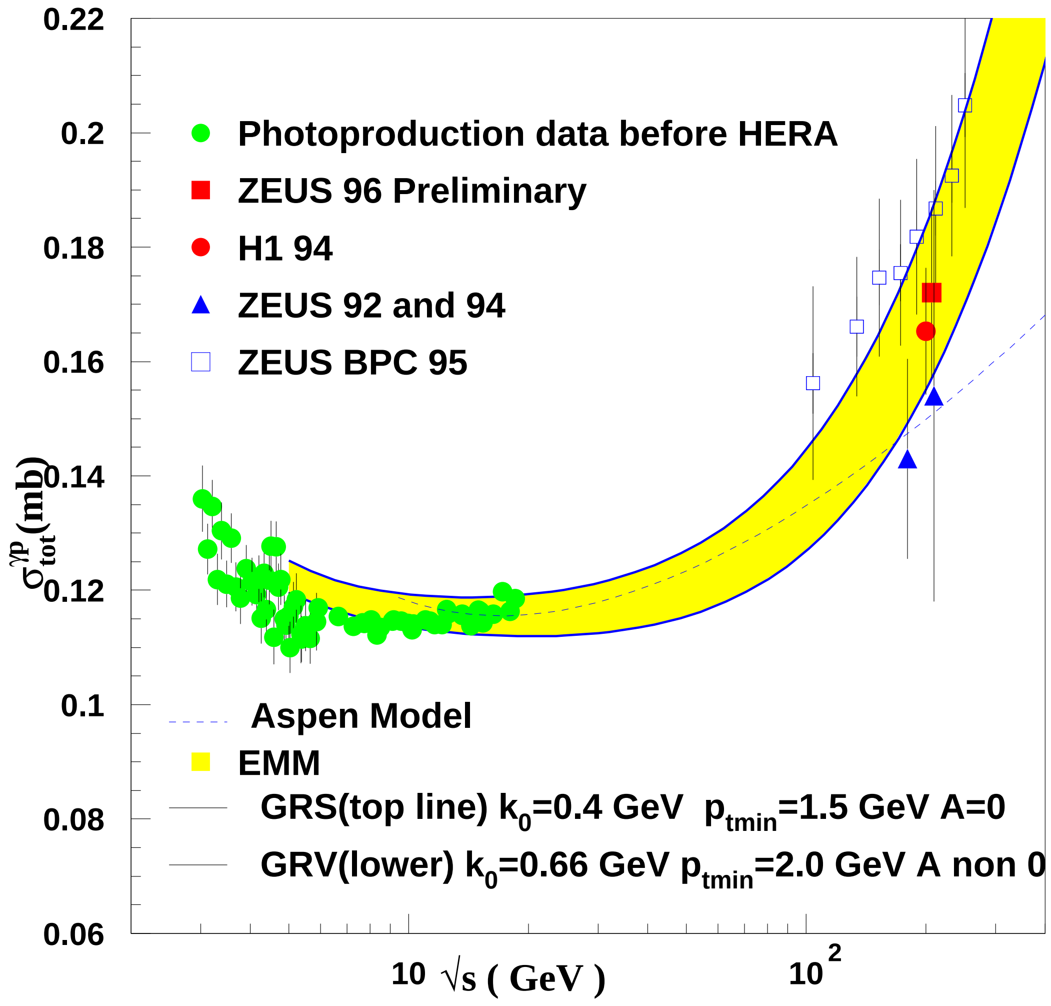
Thus simplest formulation with minijets to drive the rise and eikonalization to ensure unitarity :

$2\chi_I(b, s) \equiv n(b, s) = A(b)[\sigma_{soft} + \sigma_{jet}]$

The normalization depends both on σ_{soft} and on the b-distribution.

How to calculate the transverse overlap function in terms of 'measured' quantities?

Photo-production and extrapolated datas from DIS can be described through the Eikonal Minijet Model with Form Factors and QCD densities : low energy scaled from proton proceses.



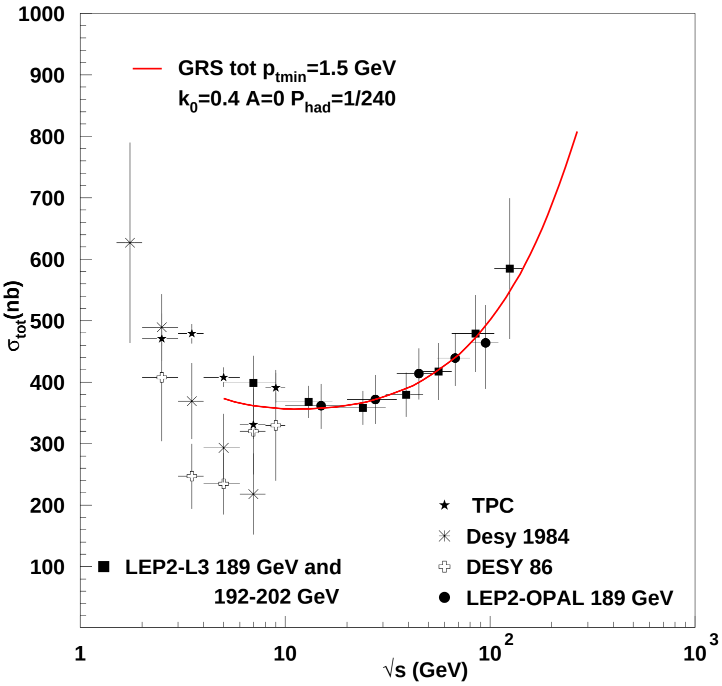
The band is corresponds to $k_0 = 0.66 \pm 0.22$ GeV (ZEUS measurement)

EMM for $\gamma\gamma$

Then

- Using **EMM**, with VMD and Quark Counting at low energy, and same set of parameters which fit γp
- adjusting the overall normalization 10% upwards,
- $k_0 = 0.4$ corresponds to the upper edge in the γp band.

one gets a very good fit to the present data



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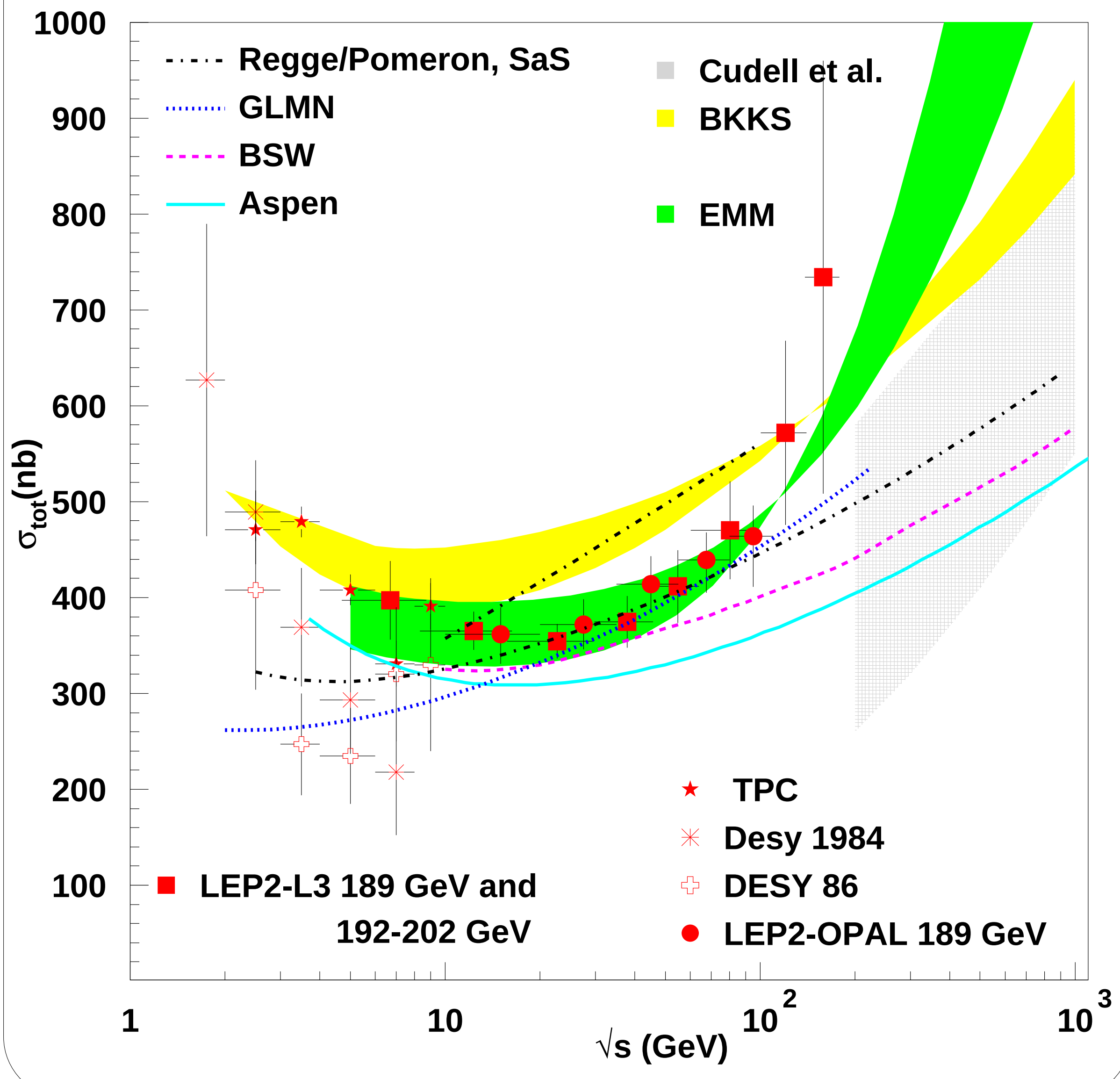
Data for $\gamma\gamma$ total x-sections show a fast rise which can be reproduced with EMM

Use of 'measured' properties of the γ, p and factorisaation, simple quark counting rule to connect γp parameters to $\gamma\gamma$ case.

Normalization here is 10% off what you get from γp

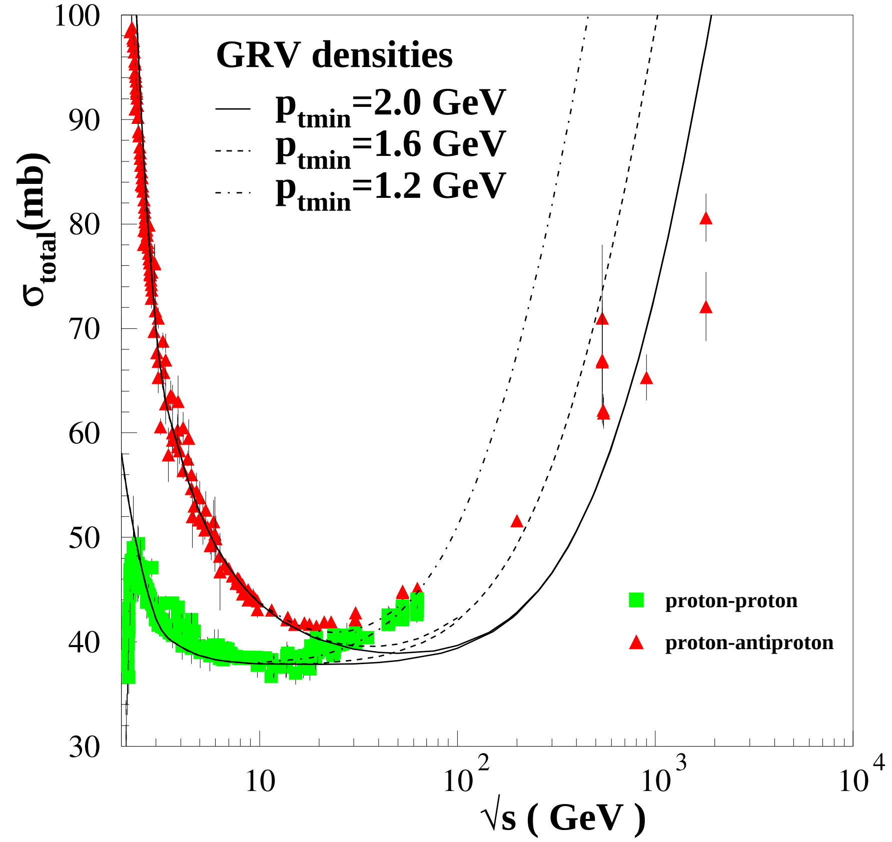
Present Predictions

Already at $\sqrt{s} = 500\ GeV$
predictions differ by a factor 3



Form Factors + minijets in $pp(p)$

It is possible to describe the early rise, which takes place around $10 \div 30\ GeV$ for proton-proton and proton-antiproton scattering, using GRV densities and a $p_{tmin} \simeq 1\ GeV$, but then the cross-sections start rising too rapidly, whereas a $p_{tmin} \approx 2\ GeV$ can reproduce the Tevatron points but it misses the early rise.



- The rise for $pp/\bar{p}p$ is too rapid for $p_{Tmin} \simeq 1$ GeV and miss early rise if $p_{Tmin} \simeq 2$ GeV.
- The best fit to the $\gamma\gamma$ data require 10 % upward normalisation relative to γp data .
- No explanation for the initial decrease.

Beyond simple EMM

EMM model does O.K. qualitatively but is certainly not the whole story.

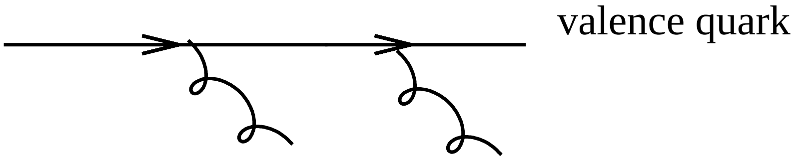
Improve the model by removing the approximations used.

Recall **assumed** $n(b,s) = A(b)[\sigma_{soft} + \sigma_{jet}]$.

- The separation between s and b dependence only an approximation.

- Writing the overlap function as a $\mathcal{F}.\mathcal{T}.$ of measured distributions does not allow for a s dependence of A

Pancheri and Collab. developed a model based on semi-classical method to calculate the impact parameter space distribution of partons in a hadron using resummation of soft gluon emissions.



$A(b,s) = A(b, M(s))$.

Here $M =< q_{max}(s) >$ is the average of the 'maximum' energy allowed for single soft gluon emission.

More about the rise

EMM needs further refinements,
including
full LLO resummation to tame the rise

$$n(b,s) = n_{soft}(b,s) + A_{PQCD}(b,s)\sigma_{jet}^{LO}$$

$$\Uparrow$$

Soft gluons can tame the rise

$A(b) \Longrightarrow$
$A(b,s) \simeq \int d^2\vec{K}_t e^{i\vec{K}_t\cdot\vec{b}}\ \Pi(K_t\ \mathit{from\ initial\ partons}\ )$

Bloch Nordsieck
Resummation

$$A_{PQCD}(b,s) \equiv \frac{e^{-h(b,s)}}{\int d^2\vec{b}\ e^{-h(b,s)}}$$

- $h(b,s) = \int_{k_{min}}^{k_{max}} d^3\bar{n}_{gluons}(k)\ [1 - e^{ik_t\cdot b}]$
- $k_{max} \Longrightarrow \mathit{average\ over\ densities}\ \Uparrow\ \mathit{as}\ \sqrt{s}\ \Uparrow$
- $k_{min} = 0$ in principle but one needs a model for

$\alpha_s(k_t)$ as $k_t \to 0$

Soft Gluon Emission and Energy Dependence

The Bloch Nordsieck model

- is like EMM model with σ_{jet}^{QCD} driving the rise

  and in addition

  Soft Gluon Emission from Initial State Valence Quarks in k_t-space to give impact parameter space distribution of colliding partons

- introduces energy dependence in the **b-distribution** of partons in the hadrons $\Longrightarrow$ which depends on
  1. p_{tmin}
  2. parton densities

Two main results :

1. softening effect
2. dependence of hard scattering parameters is reduced

The softening effect happens

- as $\sqrt{s} \Uparrow$ the phase space available for soft gluon emission also $\Uparrow$
- the transverse momentum of the initial colliding pair due to soft gluon emission $\Uparrow$
- more straggling of initial partons $\Rightarrow$ less probability for the collision

Energy dependence in impact parameter b

The energy dependence which ultimately will soften the rise due to mini-jets comes from the

maximum transverse momentum allowed to a single gluon.

$$q_{max}(\hat{s}) = \frac{\sqrt{\hat{s}}}{2}(1 - \frac{\hat{s}_{jet}}{\hat{s}})$$

with integration to be done over

- $\hat{s}$ the energy of the initial parton-parton subprocess
- the jet-jet invariant mass $\sqrt{\hat{s}_{jet}}$,

Averaging over densities

$$< q_{max}(s) >=$$

$$= \frac{\sqrt{s}}{2} \frac{\sum_{i,j} \int \frac{dx_1}{x_1} f_{i/a}(x_1) \int \frac{dx_2}{x_2} f_{j/b}(x_2) \sqrt{x_1 x_2} \int dz(1-z)}{\sum_{i,j} \int \frac{dx_1}{x_1} f_{i/a}(x_1) \int \frac{dx_2}{x_2} f_{j/b}(x_2) \int (dz)}$$

with the lower limit of integration in the variable z given by $z_{min} = 4p_{tmin}^2/(sx_1x_2)$.

Bloch-Nordsieck Model for $p-p$ and $p-p$

Now make fits to the pp and $p\bar{p}$ in the Bloch-Nordsieck (BN) model , the eikonal is of the form

$$\boxed{n(b,s) = \sigma_{soft} A_{BN}^{soft} + \sigma_{jet} A_{BN}^{jet}}$$

Soft gluon emission has here a twofold effect as the energy increases :

- with σ_{soft} constant or $\Downarrow$ $\sigma_{soft} A_{BN}^{soft} \Downarrow$
- with $\sigma_{jet} \Uparrow$ $\sigma_{jet} A_{BN}^{jet} \Uparrow$ but not as much as without soft gluons

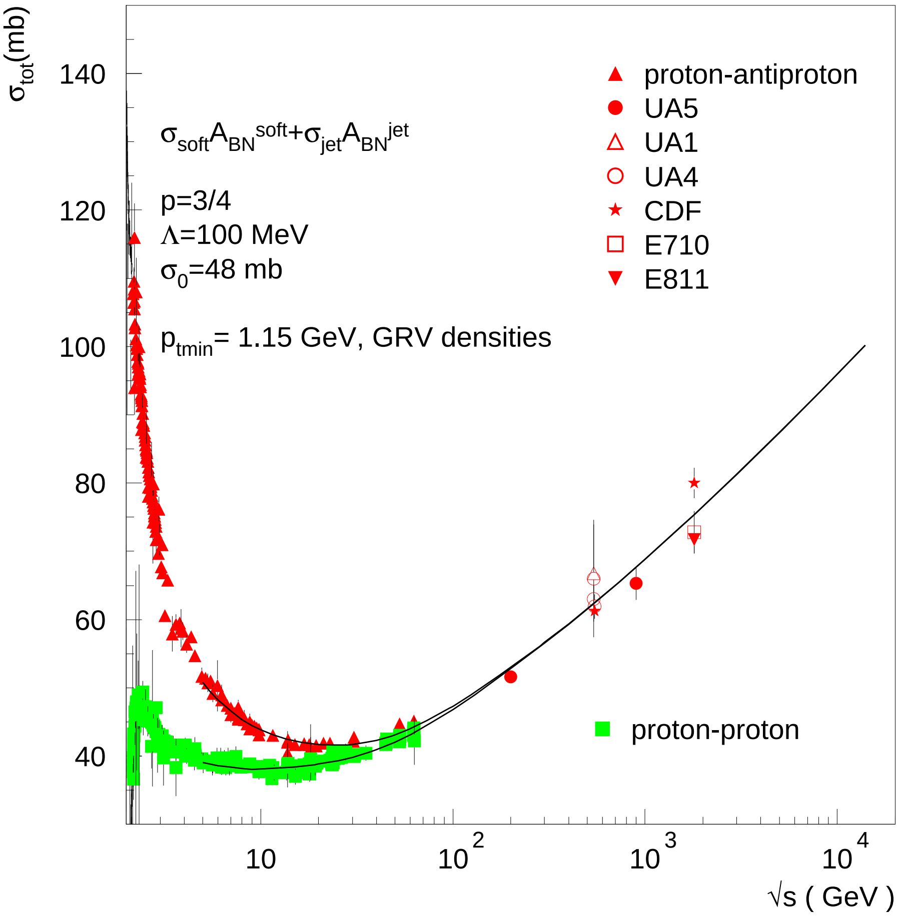
Proton Total cross-sections with BN resummation

A good description is obtained with a soft part given by

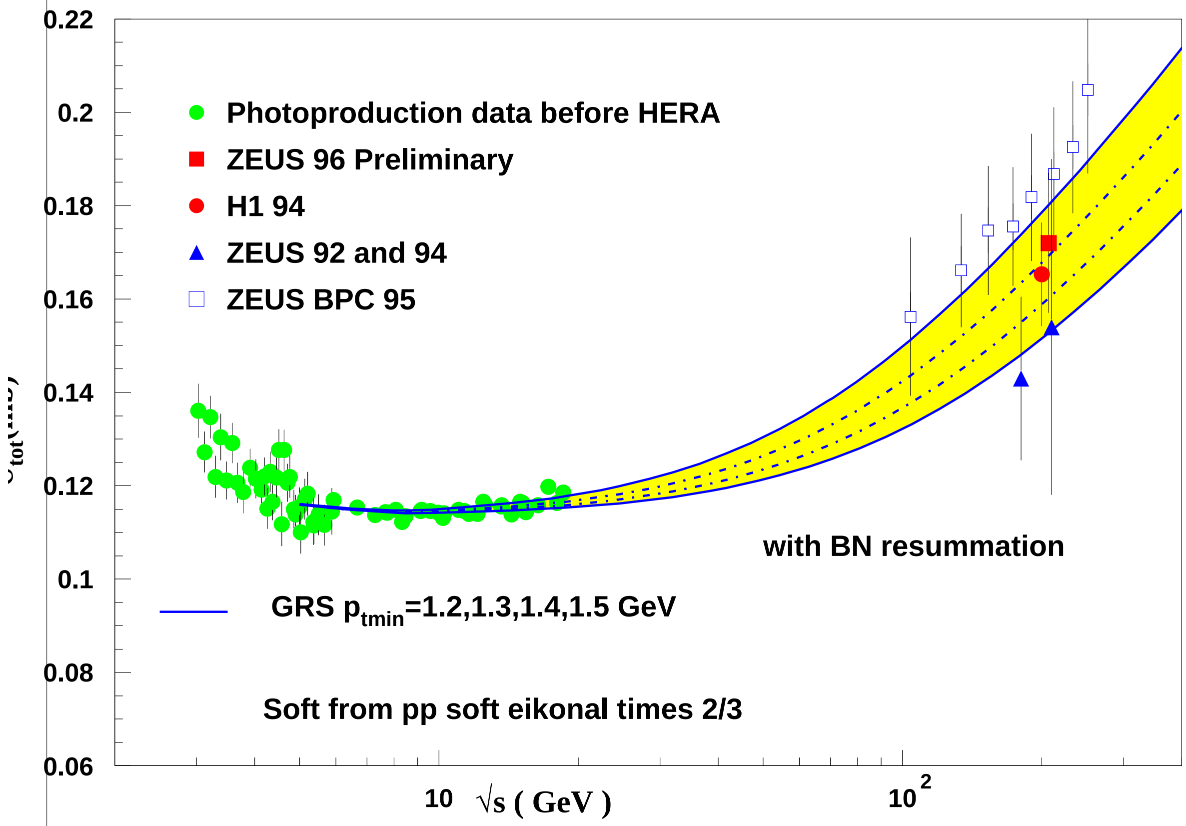
$$\sigma^{pp}_{soft} = \sigma_0 A^{soft}_{BN}(b,s) \qquad \sigma_0 = 48mb$$

and

$$\sigma^{p\bar{p}}_{soft} = \sigma_0(1 + \frac{2}{\sqrt{s}})A^{soft}_{BN}(b,s)$$

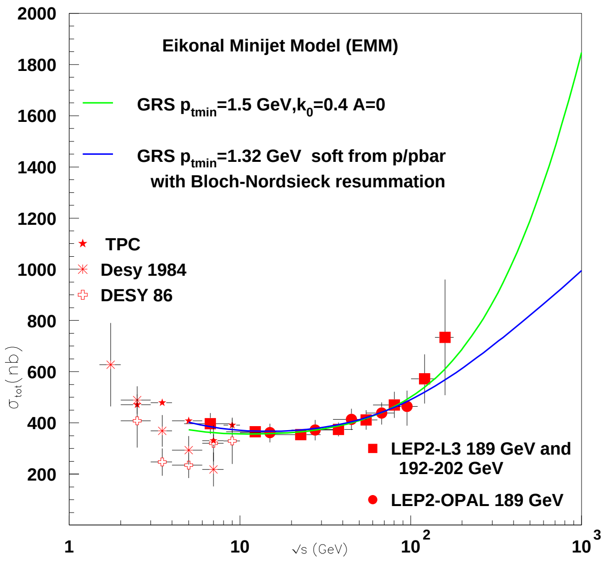


The case for γp



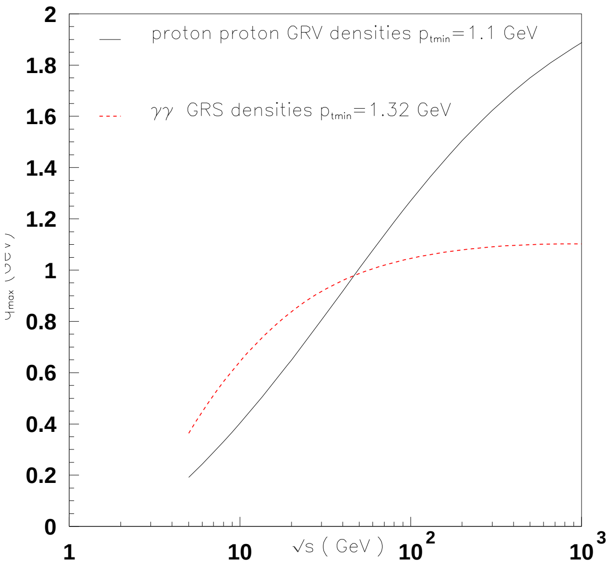
for reasonable range of p_{Tmin} decent description of γp data is possible.

comparison with plain EMM



Recall M depended on the parton densities in the hadron.

BN effect stronger for protons.

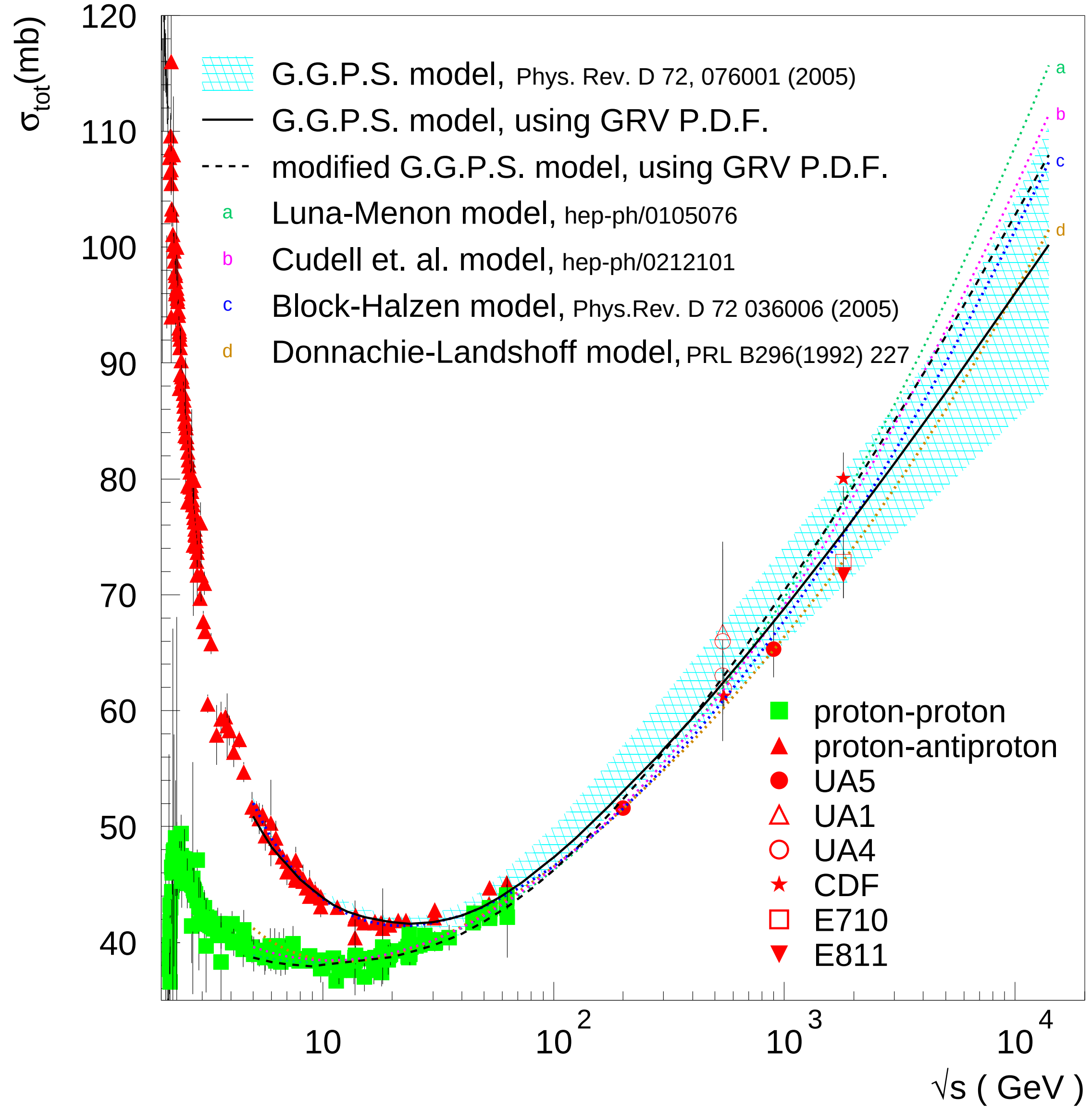


Recall M depends on the parton densities in the target.

'soft' parameters for the proton determined using a given parton density for p and **the soft parameters for the** p **determined using those for** p and **VMD**.

What happens to the fit values of the parameters σ_0, p etc., if we change the p density.

The $p\bar{p}/pp$ cross-sections



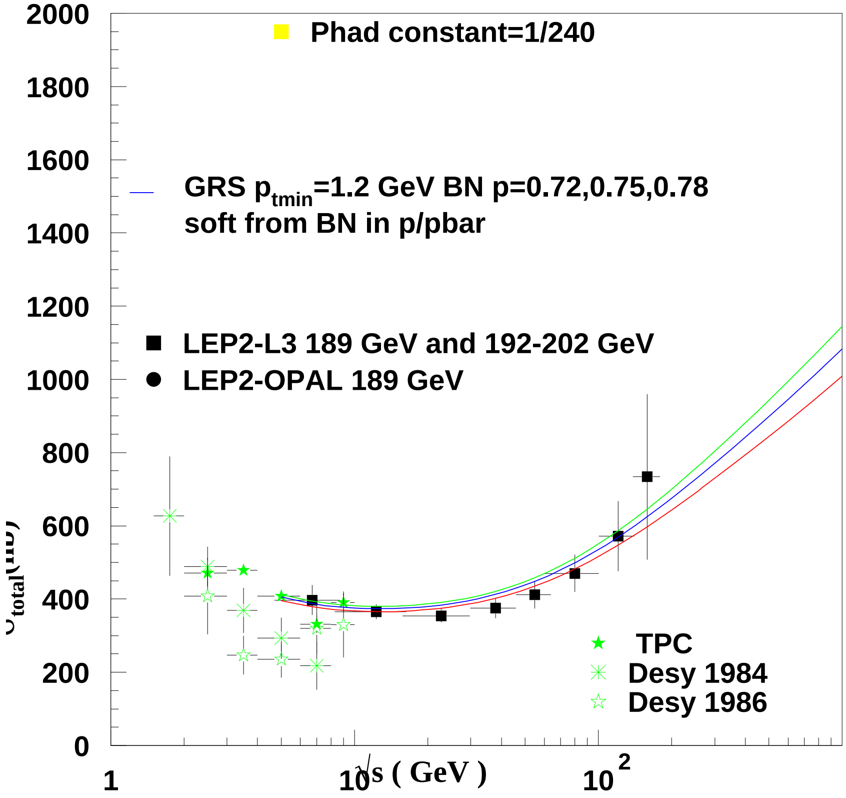
Predictions for total x-sections in various models.

The shaded area: the range of results in the Eikonlaised Mini-jet model with soft gluon resummation (R.G. et al) (the G.G.P.S. model) the solid line: the prediction obtained using the GRV parton densities in the model. The long-dashed dotted curve (d) :the predictions for the DL fit. The dotted(BH) curve (c), the uppermost dashed curve (a): results of analytical models

Parameters changes

PDF	p_{tmin} (GeV)	σ_0 (mb)	p
GRV	1.15	48	0.75
GRV94lo	1.10	46	0.72
	1.10	51	0.78
GRV98lo	1.10	45	0.70
	1.10	50	0.77
MRST[?]	1.25	47.5	0.74
	1.25	44	0.66

Effect on $\gamma\gamma$.



Outlook

The changes seem to cover similar range as by changing p^T_{min}.

My guess is our predictions for the total range is going to be VERY similar.

Work is in progres.