

QCD and Total Cross-Sections

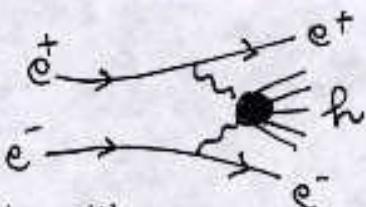
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INFN Frascati National Laboratories

April 27th, 2000

LEP@Trieste

- ◆ Proton-proton total cross-sections
- ◆ Photoproduction
- ◆ Photon-photon

$\hookrightarrow e^+e^- \rightarrow e^+e^- \text{ hadrons}$



In Collaboration with

M. Block, E. Gregores and F. Halzen for the Aspen Model PRD **58**
(1998) 1750.hep-ph/9903248

R. Godbole for the Eikonal Minijet Model PLB **435** (1998) 441.
hep-ph/9908220

A. Grau and Y. N. Srivastava for the Block-Neudischock Model PR **D60**
(1999) 114020. hep-ph/9905228

Supported in part by EEC-TMR98-00169

~~~~> Predictions for  $\sigma_{\gamma\gamma}^{\text{tot}}(s)$  from various models

- proton-like

- Regge-Pomeron  $\propto s^\eta + \propto s^\epsilon$

Sjostrand & Schuler  
'92

- VMD and QPM scaled

Block, Gregores, Fajfer,  
G.P. '97

- factorized

$$\frac{\sigma_p}{\sigma_{pp}}$$

Bourely, Soffer  
TWu '95

- QCD models

- from  $F_2^0$

Badalek, Kwieciński,  
Staszo '95

- $\frac{d\sigma^{\text{jet}}}{dt}$  drives the rise

PYTHIA, PHOJET  
Goddard, G.P.

- NLO QCD models (work still in progress)

- soft gluon summation } -  $\int \alpha_s(R_t) dR_t$   
Keeps the rise at bay } via C

A. Grau, G.P.  
T. Srivastava

The "photon is like a proton" Models

- Regge-Pomeron exchange

power law rise  $s^\epsilon$

but is  $\epsilon$  really same?

$\epsilon = 0.0808$  in  $p\bar{p}$

$0.115\dots$  in  $\gamma\gamma$

- simple scaling

$$\sigma_{\gamma\gamma} = A \sigma_{pp}$$

$$\left(\frac{\sigma_{\gamma\gamma}}{\sigma_{pp}}\right)^2 = \left(\frac{\sigma_{pp}}{\sigma_{pp}}\right)^2$$

$$\left(\frac{2}{3}\right)^2 \left(\frac{1}{240}\right)^2$$

↑                           ↑

QPM                      VMD

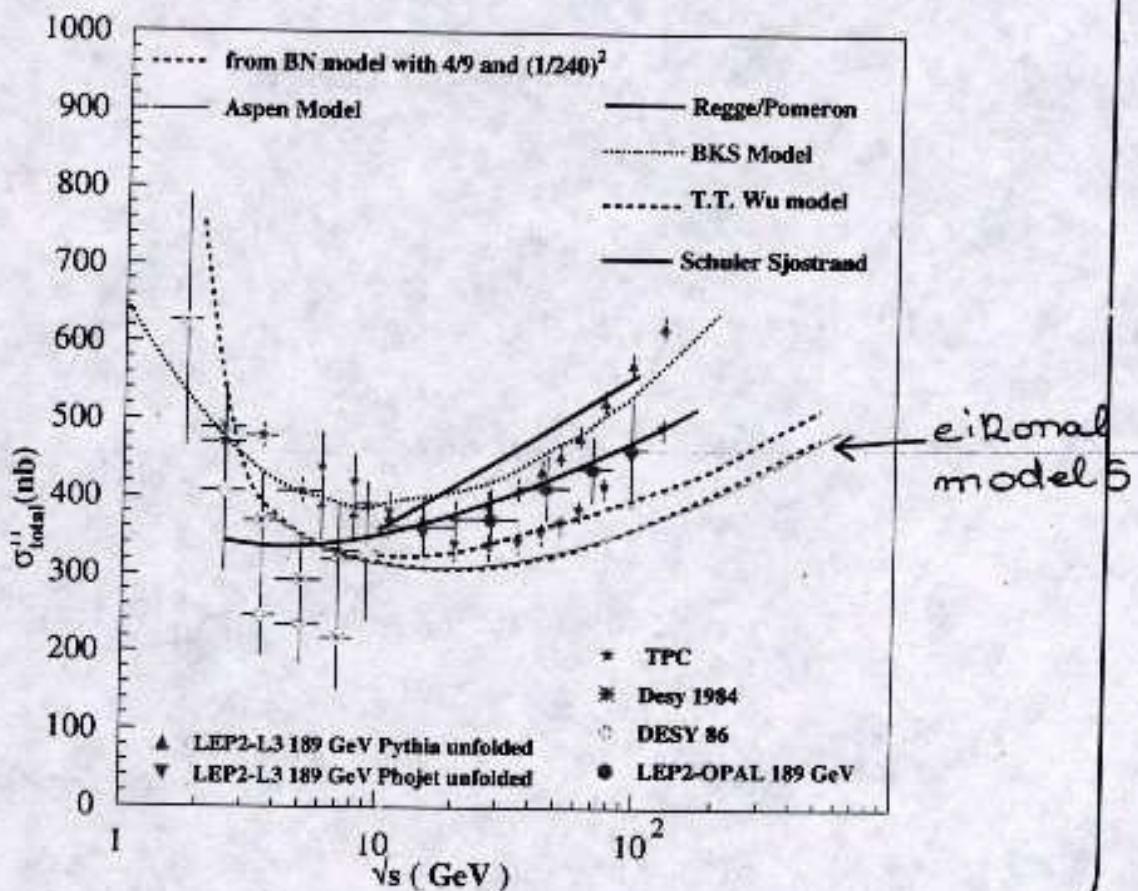
- Eironal formulation

$$\sigma_{\gamma\gamma} \propto \int d^2 b (1 - e^{-\chi_i(b,s)} \cos \chi_R)$$

$$\chi_i(b,s) \Big|_{pp} \sim \text{simple scaling} \sim \gamma\gamma$$

These Models obtain the  $\gamma\gamma$  total cross-section through extrapolation of some/all of the proton properties.

- ◆ Regge/Pomeron  $\sigma^{tot} = Y_{ab}s^{-\eta} + X_{ab}s^{\epsilon}$  with  
 $X_{\gamma\gamma}X_{pp} = X_{\gamma p}^2$   $\eta = 0.467, \epsilon = 0.079$  A.Donnachie and  
 P.V. Landshoff, PLB 296(1992) 227
- ◆ BKS  $\equiv$  B.Badelek, J.Kwiecinski, A.M.Stasto  
 hep-ph/9903248
- ◆ C. Bourely, J. Soffer and T.T.Wu  $\sigma_{\gamma\gamma} = A\sigma_{pp}$   
 hep-ph/9903438
- ◆ G. Schuler and T.Sjöstrand also have a predictions like  
 Regge-Pomeron ZPC73 (1997) 677



## Eikonal

## Models

$$f(\theta) = \frac{iR}{2\pi} \int d^2 b e^{i\vec{q} \cdot \vec{b}} [1 - e^{-i\chi(b,s)}]$$

- $\sigma_{el} = \int d^2 b |1 - e^{-i\chi(b,s)}|^2$

- $\sigma_{TOT} = 2 \int d^2 b [1 - e^{-\chi_I(b,s)} \cos \chi_R]$

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

$\chi_R \approx$  small

$$\chi_I \sim A(b) \sigma(s)$$

matter  
distribution

collision  
probability

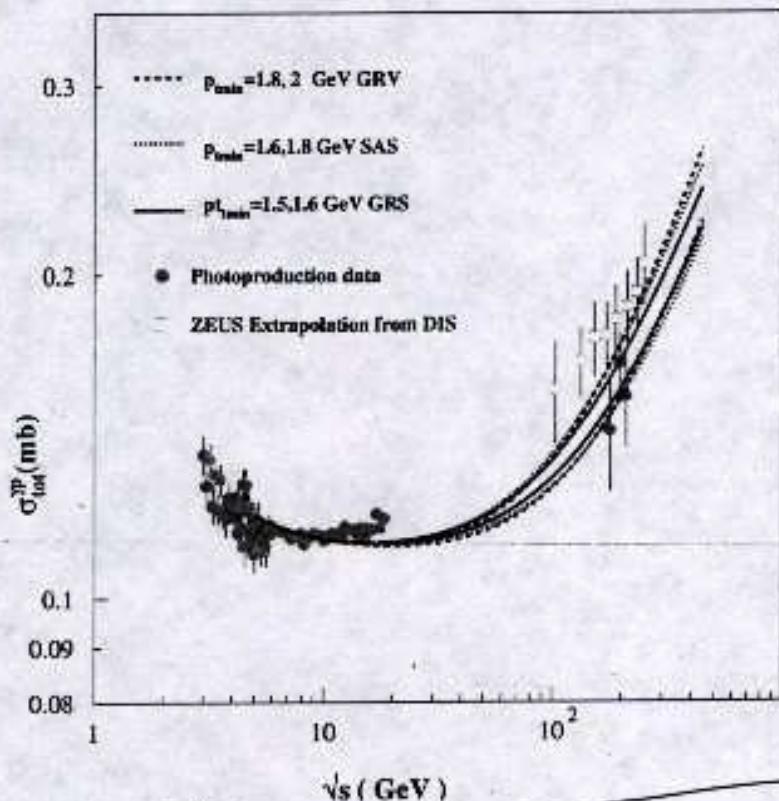
In the Eikonal Minijet Model (EMM) with R. Godbole

$$\sigma_{tot}^{\gamma p} = 2P_{had} \int d^2\vec{b} [1 - e^{-x_I} \cos \chi_R]$$

with

$$P_{had} = \sum_{V=\rho,\omega,\phi} \frac{4\pi\alpha}{f_V^2} \approx \frac{1}{240}, f_\rho = 5.64, \frac{f_\rho}{f_\omega} = \frac{1}{3}, \frac{f_\rho}{f_\phi} = \frac{-\sqrt{2}}{3}$$

and  $\alpha$  evaluated at the  $M_Z$  scale.

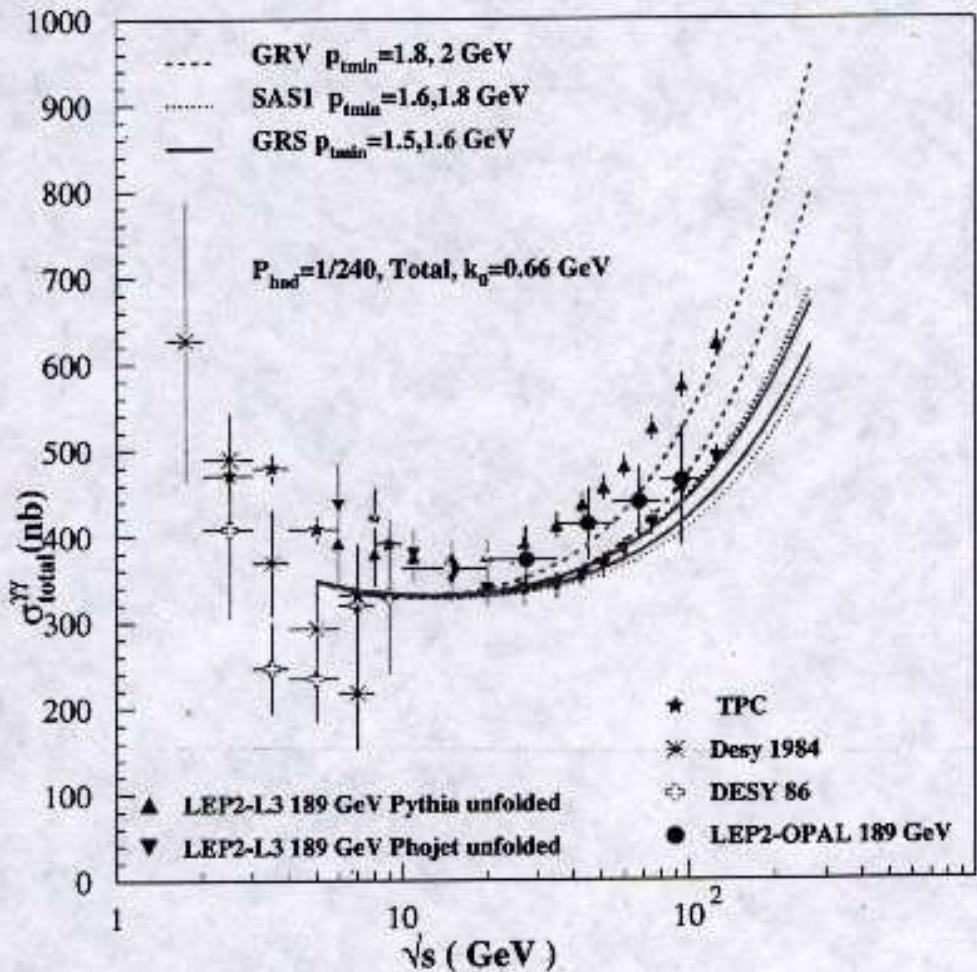


$\chi_R \approx 0$  and  $\chi_I/2 = A(b)(\sigma_{soft}(s) + \sigma_{jet}(s, p_{tmin})/P_{had})$

$A(b)$  modelled through Fourier transform of product of the  
e.m. Form Factors

Using same parameter set for photon Form Factor and

- ◆  $\sigma_{soft}^{\gamma\gamma} = 2/3 \sigma_{soft}^{\gamma p}$
- ◆  $P_{had} = (P_{had}^{\gamma p})^2$
- ◆  $\sigma_{jet}$  with same densities and  $p_{tmin}$  values



N.B. changing  $k_o$  in A(b) will move the curves  $\uparrow$  as  $k_o \downarrow$   
or  $\downarrow$  as  $k_o \uparrow$

# A QCD Model for the overlap A(b)

A. CORSE  
A. GRAD  
G. P.  
Y. SRIVAS  
PLB, AU

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

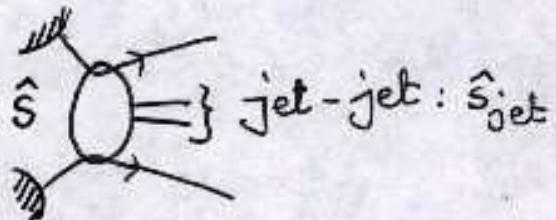
$$n_{\text{hard}}(b, s) = A(b) \sigma_{\text{jet}}(s) \quad \text{factorized model}$$

$\downarrow$   
av # of  
collisions

$\downarrow$   
\* scatterers  
per unit  
area

$\downarrow$   
cross-section

$$\int \frac{d\hat{\sigma}}{dp_T^2} \times \text{partonic distribution}$$



$$(F_{\text{sum factor}})_{\text{particle a}} \\ \otimes (F_{\text{sum factor}})_{\text{particle b}}$$

parton model improved

$$n_{\text{hard}}(b, s) = \int \dots A(b; \hat{s}, \hat{s}_{\text{jet}}) \frac{d\hat{\sigma}}{dp_T^2} \quad \text{no-factorization}$$

$\downarrow$   
b-distribution of subprocess

ANSÄTZE



$\tilde{f}_{\text{LO}}$  ( transverse momentum )  
distribution of initial  
 $q\bar{q}$  system extracted  
from colliding "hadrons"

- We need the instantaneous picture of where the partons are at any given  $b$ -value for each  $\sqrt{s}$
- Starting point:
  - the position of each parton is known through the interaction which pulled it out
  - no interaction  $\leftrightarrow ?$
  - collisions  $\leftrightarrow$  partons are kicked out of their collinearity because of multiple soft gluon emission

# Semiclassical argument for soft-radiation model for $A(b)$

- Assume a constant  $b$ -distribution  $A_0$  in absence of interaction
- change in  $b$ -distribution  
⇒ entirely due to soft gluon emission stimulated by interaction

$$A(b) = A_0 \int d^2 k_{\perp} e^{ik_{\perp} \cdot b} P_{\text{soft}}(k_{\perp})$$

{  
all the  
small  $k_{\perp}$ s  
which change  
the paths

$$\bullet \int A(b) d^2 b = 1 \Rightarrow A_0 = \frac{1}{P_{\text{soft}}(0)}$$

A proposal for a Soft Gluon Summation  
model

A. Consoli  
A. Grau  
G. P.  
Y. Srivastava  
PLB 382(1996)  
282  
LNF-96/010

$$A(b) = \frac{e^{-h(b)}}{2\pi \int b db e^{h(b)}}$$

$e^{-h(b)}$  =  $\mathcal{F}$  (  $k_t$ -distribution of  
soft gluons  
in  $q\bar{q} \rightarrow X + \text{jet jet}$  )

→ A PICTURE OF

- multiparton collisions

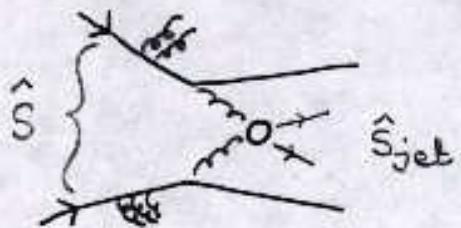
L. Ametller  
N. Paolelli  
D. Treleani

- each collision dressed by soft gluons

→  $A(b) \rightarrow A(b, s)$

energy dependence  
softens the rise in  $\sigma_{\text{jet}}$

$$A(b) = \frac{e^{-\bar{h}(b)}}{2\pi \int b db e^{-\bar{h}(b)}}$$



$$\bar{h}(b) = \frac{8}{3\pi} \int_0^{q_{max}} \frac{dk_t}{R_t} \alpha_S(R_t^2) \ln \frac{q_{max}}{R_t} [1 - J_0(b R_t)]$$

$$q_{max} = q_{max}(\hat{s}, \hat{s}_{jet})$$

→  $n_{hard}(b, s) = \sum \int (\bar{t}_q(x_1) \bar{t}_{\bar{q}}(x_2) dx_1 dx_2 dp_t^2 d\hat{s}_{jet} \frac{d\hat{\sigma}}{dp_t^2} \times$

$\times A(b, \hat{s}, \hat{s}_{jet})$

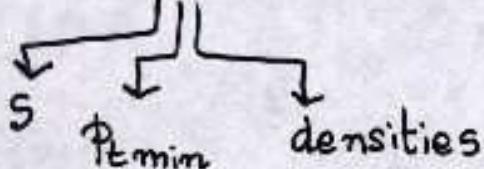
with  $\hat{s}, \hat{s}_{jet}$   
dependence  
to be  
integrated  
over densities  
and subprocesses

APPROXIMATION

$$n_{hard}(b, s) \approx \hat{\sigma}_{jet}(s, p_{tmin}) A(b, \langle q_{max} \rangle)$$

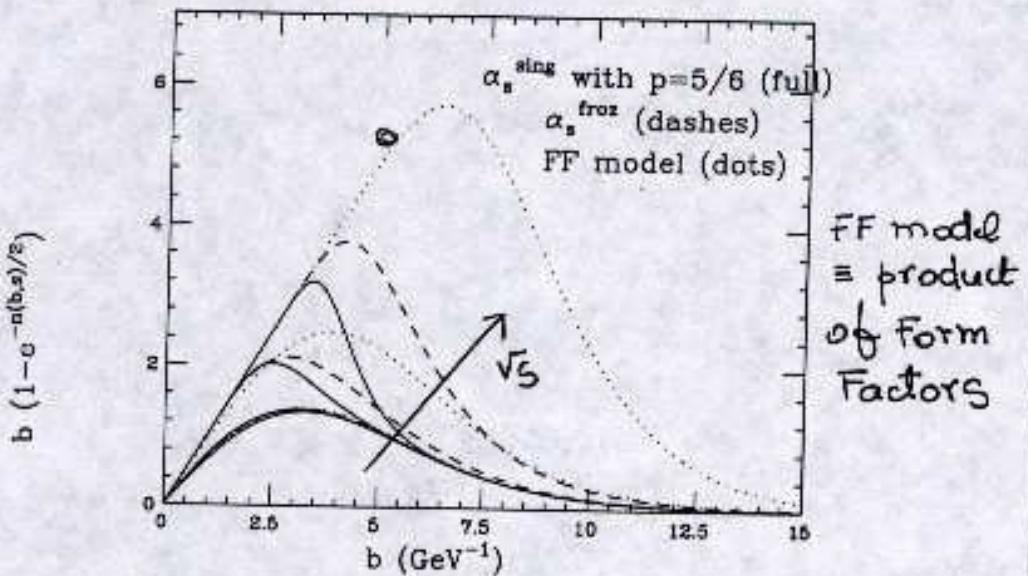
$\langle q_{max} \rangle$  = average over parton densities

↑ as  $\sqrt{s}$  ↑



The Effect of the Soft Gluon Summation model can be observed in the

Integrand of the eikonal formulation for  $\sigma_{tot}$   
in the three different models



The integrand is peaked at different  $b$ -values as the energy increases, but also as the model for  $A(b)$  changes.

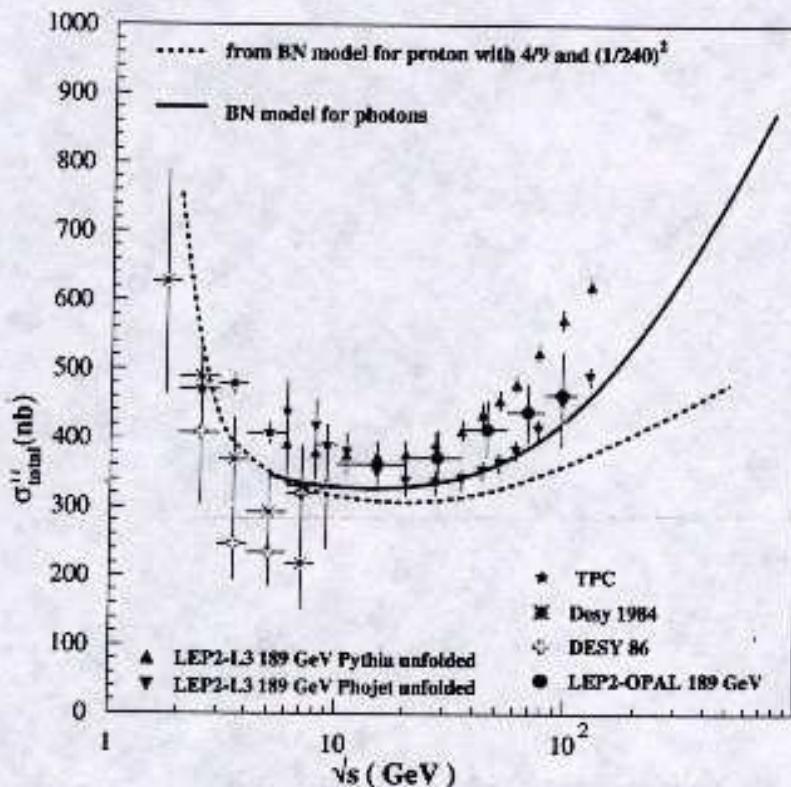
The rise with energy of the area under the curve, i.e. the cross-section, ~~at this stage energy~~ shrinks for the more singular  $\alpha_s$  behaviour.

This is like EMM model with  $\sigma_{jet}^{QCD}$  driving the rise  
and in addition

Soft Gluon Emission from Initial State Valence Quarks in  
 $k_T$ -space used to give the impact parameter space  
distribution of colliding partons

$$A(b) = \frac{e^{-h(b,s)}}{\int d^2\vec{b} e^{-h(b,s)}}$$

Preliminary Result with GRV densities and  $p_{tmin} = 2 \text{ GeV}$



Bloch Nordsieck

## Conclusions

- Rise with energy of

$$\sigma_{\gamma\gamma}^{\text{TOT}}$$

is in agreement with  
QCD minijet expectations

- $\sigma_{pp}$   $\sigma_{op}$   $\sigma_{\gamma\gamma}$  together

in  $\sim$  energy regions

are still needed for QCD

studies  $\sqrt{s_{\gamma\gamma}} \sim 200 \div 300 \dots \text{GeV}$

Energy Behaviour at  $\bar{pp}, p\bar{p}, \Delta p, \gamma\gamma$

- Scaling Factor

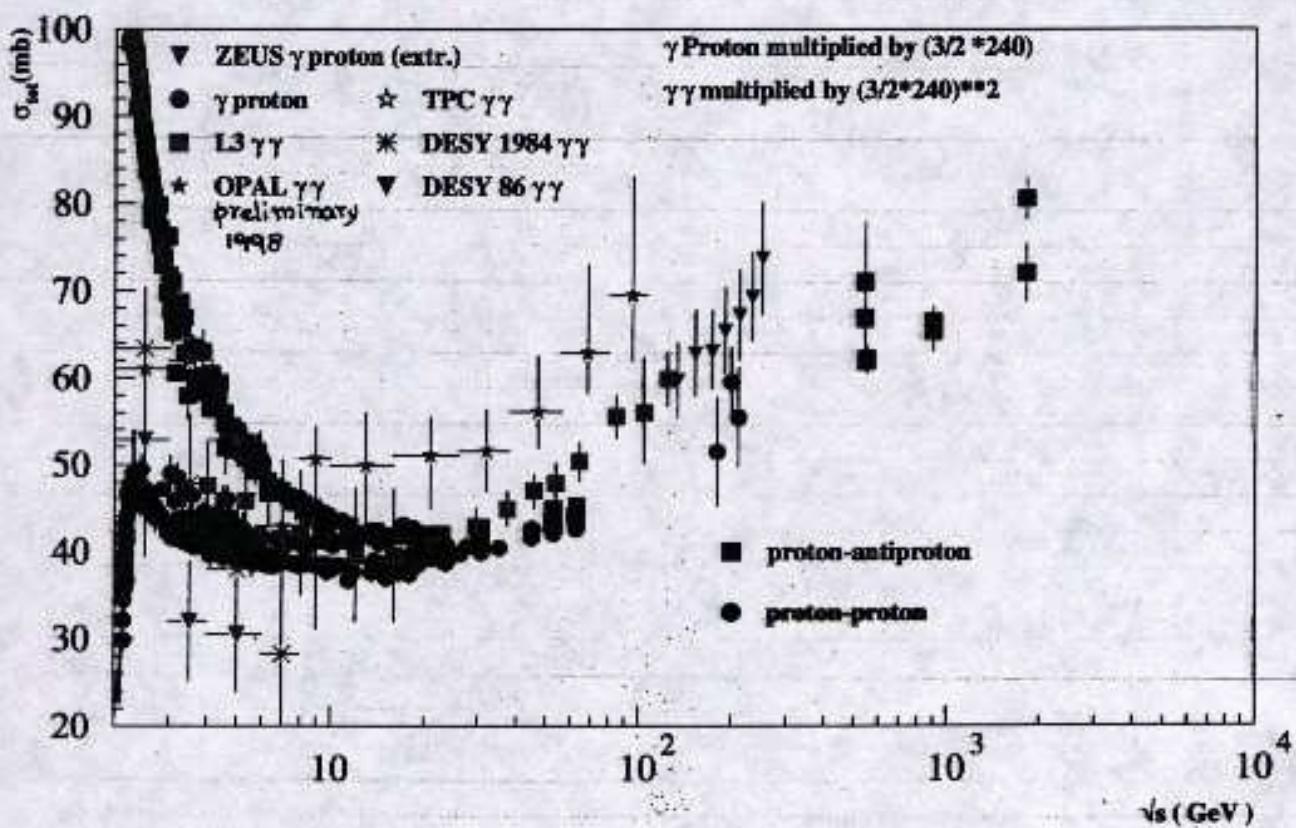
$$3/2$$

$a^{\text{PM}}$

- for each  $\gamma$

$$\sum_v \frac{4\pi a}{\rho^2}$$

$\sqrt{s}$  VMD



~~~ E:Konal Minijet Models

$$\bar{\sigma}_{\text{TOT}} = 2 \int d^2 b (1 - e^{-n(b,s)/2})$$

$$n(b,s) = n_{\text{soft}}(b,s) +$$

↓
basically
fixed the "bulk"

$$A_{\text{FF}}(b) \sigma_{\text{soft}}(s)$$

↓
form factor
model
"a la carte"
VMD, QPM,
Regge-

\mathcal{J} (form factors)

$$\frac{q_0^2}{q^2 + q_0^2} \quad \left(\frac{v^2}{q^2 + v^2} \right)^2$$

$$\downarrow$$

$n_{\text{hard}}(b,s)$

describes the rise

$$A_{\text{hard}}(b,s) \sigma_{\text{jets}}^{\text{QCD}}(s)$$

↓
calculable
from
QCD
GRV, SAS
GRS...
 $p_t \gg 1/2 G$

↓
form
factor
as in
soft

NLO QCD
with soft
gluon
summation

The EMM model for protons using current parton densities like GRV does not reproduce well the initial rise with energy as indicated by the curve labelled FF

