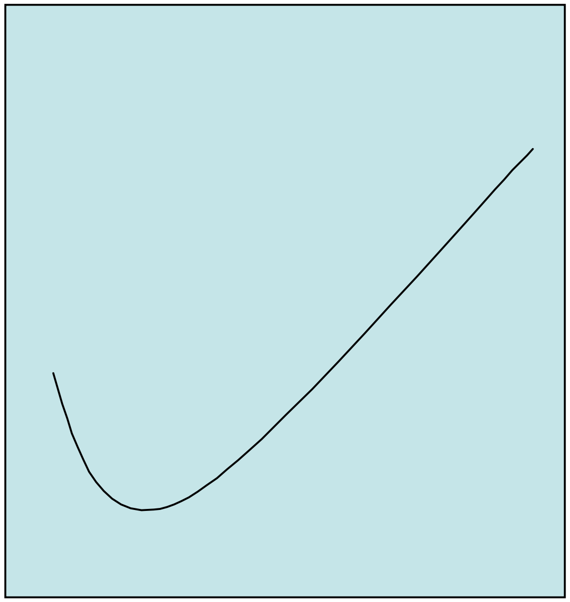
Total cross-sections: cross-talk between HERA, LHC and LC



Giulia Pancheri

INFN Frascati

LCWS2004, Paris

In collaboration with A. de Roeck, R.M. Godbole, A. Grau and Y.N. Srivastava

Why and how do we study total cross-sections?

- To make realistic predictions for $e^+e^- \to$ hadrons at LC

- To understand the role played by QCD in the energy behaviour of total cross-sections

How?

- **LHC** data for total cross-sections can restrict the range of QCD parameters in the **proton** behaviour

  ⇒ Form factors,overlap functions, Pomeron(s), minijets,...

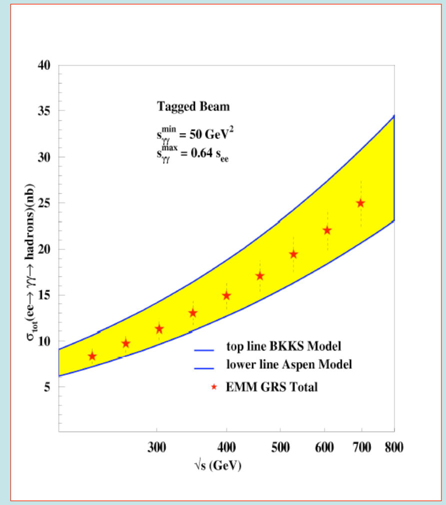
- **HERA** data can do the the same for the **photon**

- Photon-photon cross-sections should then come out with a realistic error and so will e^+e^- $\to$ hadrons at **LC**

Realistic Predictions at LC?

Predictions for e+e- at LC suffer from uncertainties

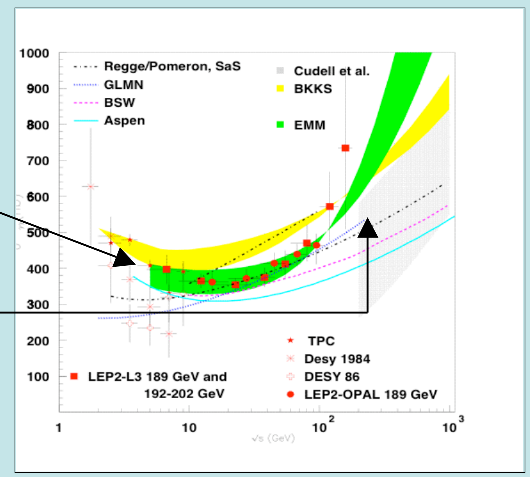
in the gg cross-section data



• the low energy region, i.e. normalization

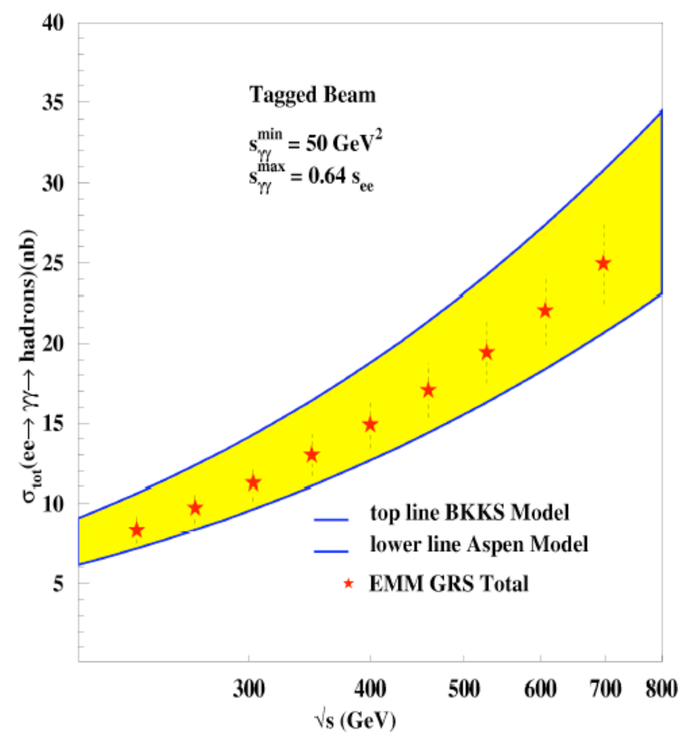
and

• the high energy, i.e. how much gg will rise in the 100-200 GeV c.m.



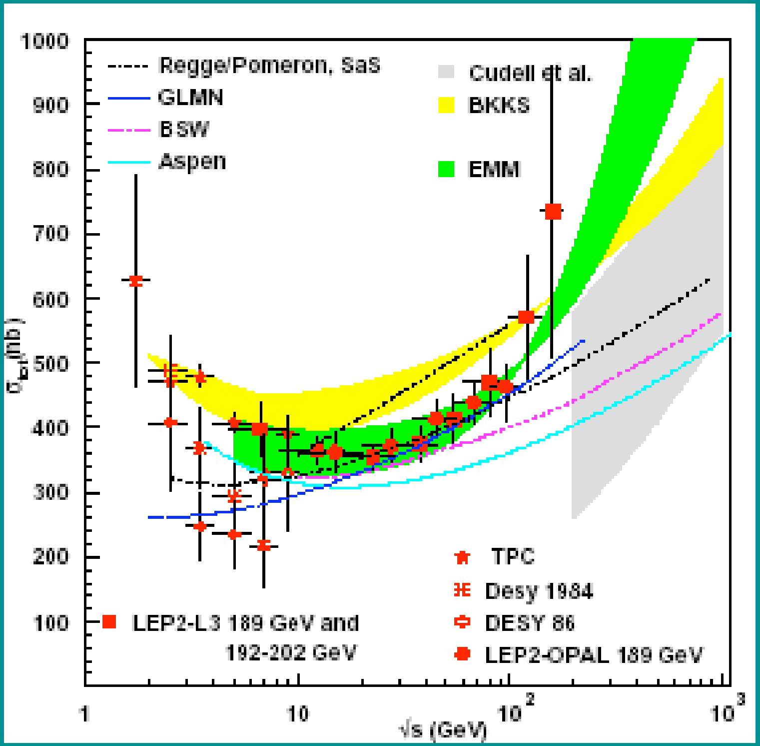
LC and □□scattering

- At LC we need □□ data
- Differences in predictions of total cross-sections at Linear Photon Colliders affect background studies



The photon-photon problem

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



Why such differences for photons ?

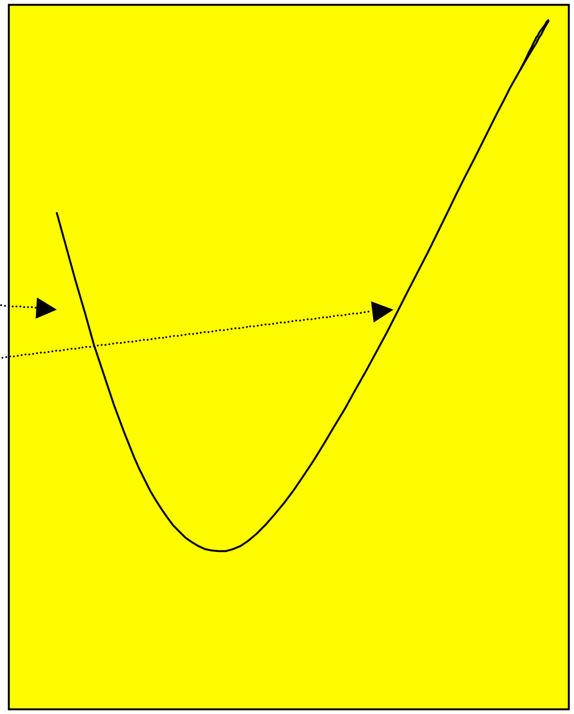
- Uncertainties from proton cross-sections and lack of trustworthy guidance from theoretical models lead to large variations

- Choice of model :QCD or Regge-Pomeron exchanges or factorization a' la Gribov ?

- And anyway which QCD model?

Energy dependence

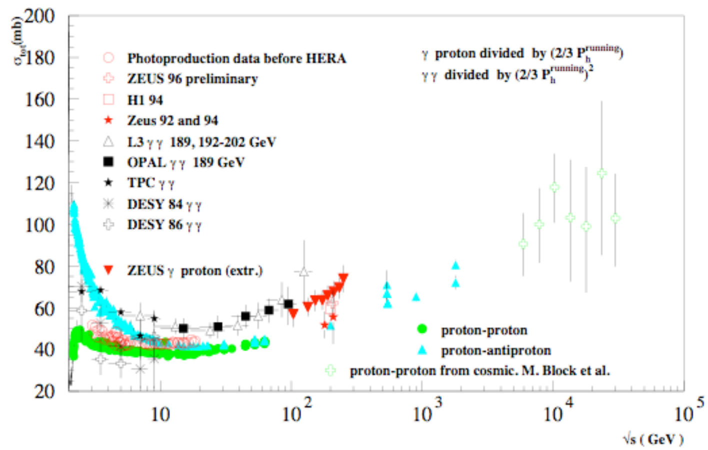
- All total cross-sections show similar energy dependence
- Up to c.m. energies less than 5-10 GeV, the cross section decreases
- At c.m.. energies beyond 20-50 GeV all cross-sections increase
- In the intermediate region, cross-sections exhibit a minimum, and thus an apparently constant behaviour



Comparing the energy dependence of pp, p□,□□ total cross-sections

To compare them scale with

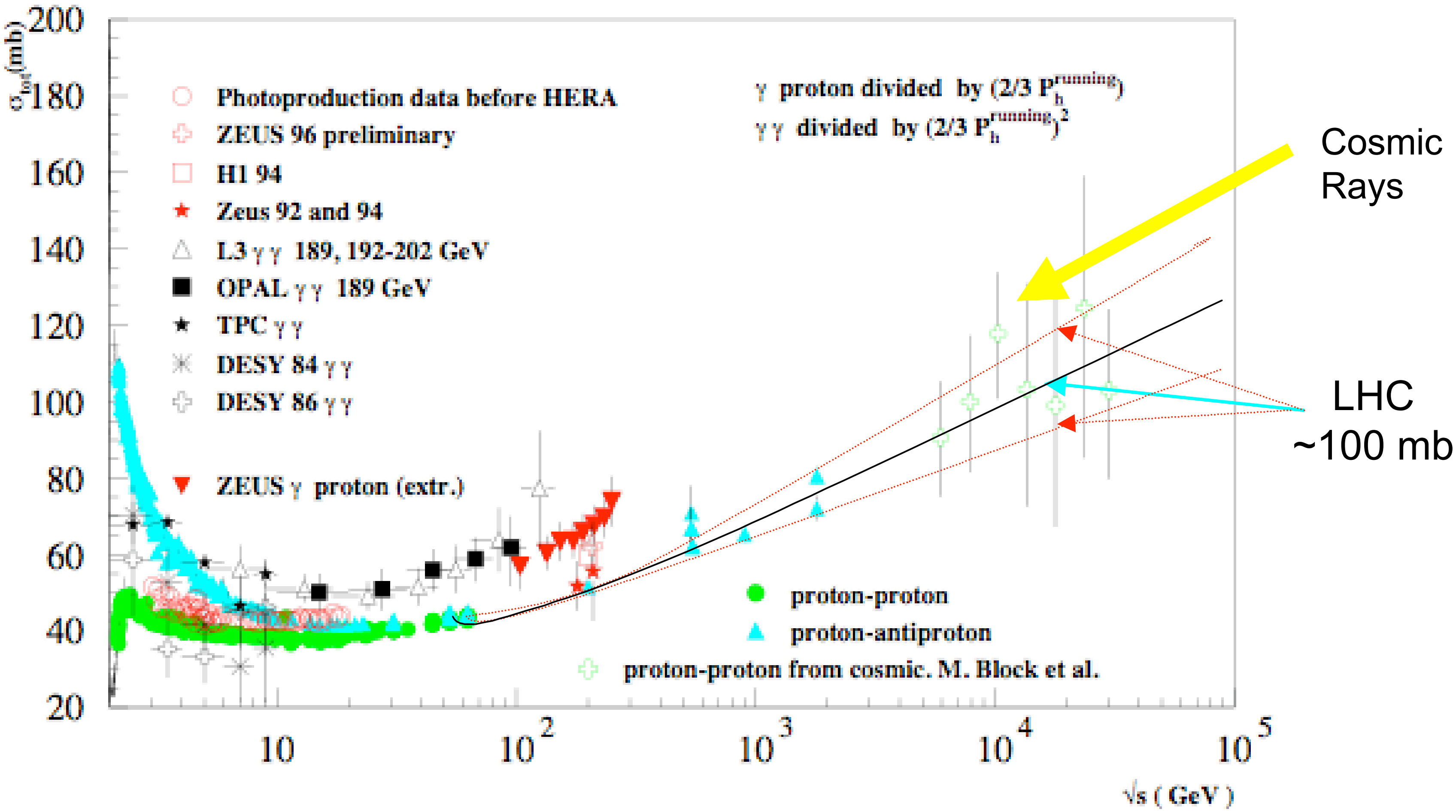
- quark content factor ; 2/3 to go from proton to photon
- Vector Meson Dominance factor



$$P_{VMD} = \Sigma_{V=\rho,\omega,\phi} \frac{4\pi\alpha}{f_V^2}$$

Some differences in

- Normalization
- Initial decrease
- Slope of rise with energy


σ_tot(mb)
200
180
160
140
120
100
80
60
40
20
Photoproduction data before HERA
ZEUS 96 preliminary
H1 94
Zeus 92 and 94
L3 γ γ 189, 192-202 GeV
OPAL γ γ 189 GeV
TPC γ γ
DESY 84 γ γ
DESY 86 γ γ
ZEUS γ proton (extr.)
γ proton divided by (2/3 P_h^running)
γ γ divided by (2/3 P_h^running)^2
Cosmic Rays
LHC
~100 mb
proton-proton
proton-antiproton
proton-proton from cosmic. M. Block et al.
10
10^2
10^3
10^4
10^5
√s (GeV)

What makes a cross-section?

For point-like systems

- Strength of interaction => coupling constant
- Head-on collisions, i.e. collinearity

For composite systems

✓ Flux of point-like particles undergoing collision

Models for total cross-section

- Bounds from analiticity and unitarity
- Regge-Pomeron exchange
- Eikonal approximation
- Minijets from QCD
- Eikonal Minijet Model (EMM)
- Bloch-Nordsieck resummation for EMM

Up to c.m. energies less than 5-10 GeV, the cross section decreases

- The initial decrease differs in different processes: most notable difference seen in proton proton and proton-antiproton
- Regge - Pomeron behaviour derived from optical theorem and analyticity in the angular momentum plane describes it well

- With $\alpha_R(0)=1/2$ and $\alpha_P(0)=1$ one has 1/sqrt(s) for the Regge term and a constant for the Pomeron term.
- Duality implies that pp with no resonances in the s-channel will have no residual Regge exchange, so only constant term survives, while for proton-antiproton both survive.

QCD is not yet able to describe this behaviour quantitatively

BUT

Soft Gluon Bremstrahlung from initial state reduces the parton-parton cross-sections through an induced initial transverse momentum

acollinearity

The normalization

- A constant and a 1/sqrt(s) term describe well the low energy region
- For proton processes there is a clear minimum which indicates when the rise overcomes the decrease
- From protons to photons the normalization is well described by the scale factor P_{had} for each photon

•Regge exchange can explain qualitatively why two such terms

  •For proton-proton an almost constant behaviour because the s-channel is exotic

  •For proton-antiproton there is a □-trajectory in the t-channel

•The parton model explains $_{\text{Phad}}$

QCD : what it says about energy dependence in total cross-sections

- Perturbative QCD can be used when a_{strong}/p is small, practically for parton momenta around 1-2 GeV (2 rather than 1..)
- At low energies of the hadron-hadron system, a 2 GeV parton in a proton corresponds to fractional energies of x=0.4 => very few partons carry this energy, most protons cannot undergo hard scattering, i.e. scattering described by pQCD
- As the hadrons c.m. energy increases , a perturbative parton, i.e. a 2 GeV parton will carry a 0.1,0.01, 0.001 fractional energy and the flux of such partons available from the hadrons increases=>the cross-section from such processes wil increase

Perturbative QCD provides a natural mechanism for the increase of total cross-sections

All the models have parameters, either for the soft (low energy part) or the high energy or both

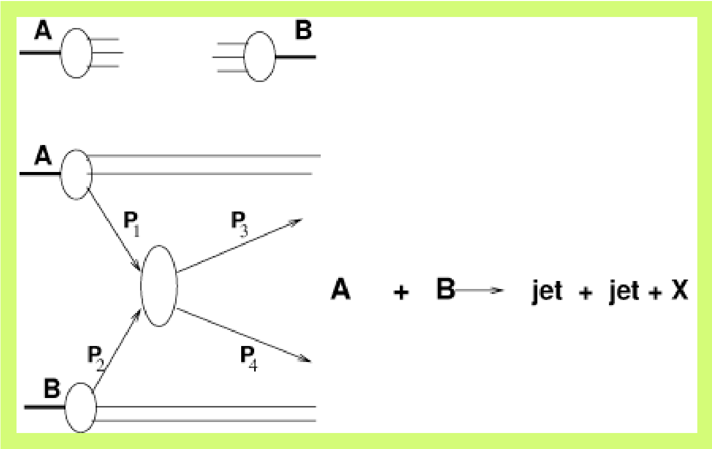
Soft : one fits the data in pp with power laws and then extrapolates to gamma p

- Parameters for pp and pbar-p :
  - power exponents
  - normalization
- Parameters for gamma p : normalization (VMD+QPM)

High Energy : one can use power laws (Pomeron/s) and/or QCD jets or "QCD" inspired behaviour

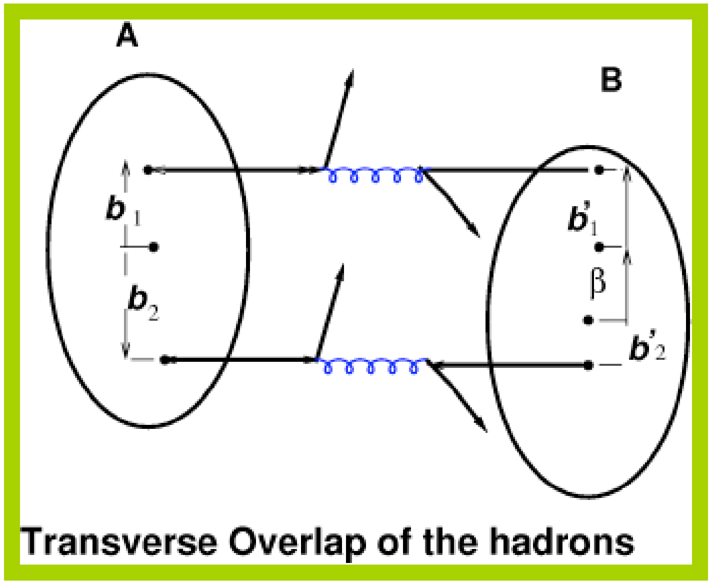
- Power laws should not change from protons to photons
- In QCD cum eikonal, parameters like minimum jet transverse momentum should not change, while different parton densities and parton content may indicate that protons are different from photons

QCD model for total cross-sections : Minijets, eikonal formalism and and Bloch-Nordsieck resummation

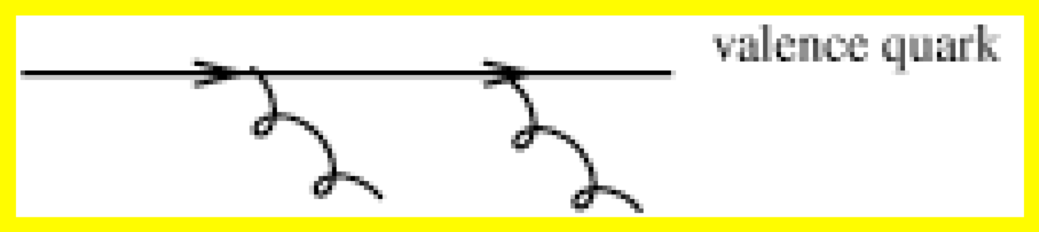


QCD Minjets drive the rise

Overlap in b-space and Eikonal Representation ensure unitarity



Soft gluon emission gives extra energy dependence



The Real Question in any QCD approach to total cross-sections

- The real question in studying σ_{tot} with QCD is

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

- Why?
- Because of soft physics
  - At low energy of course
  - At high energy as well because high energy parton-parton scattering needs soft gluon effects, treated with resummation, which means to integrate (there are many such soft photons) from $k_t = 0$ (they are soft!) to some kinematically determined maximum value

Eikonal Minijet Model +Bloch-Nordsiek resummation

⇒ IEMM

Improved Eikonal Minijet Model

For protons

High Energy parameters

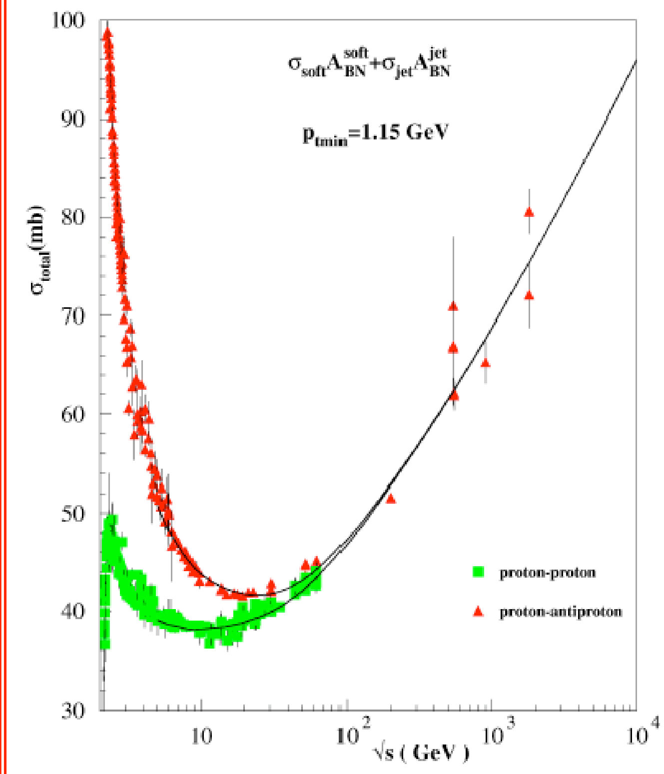
- Minimum jet transverse momentum
- Parton densities
- Infrared behaviour of α_s for *soft* gluon emission resummation in k_t (linked to partonic b-distribution)

Low energy parameters

- Normalization
- Low energy impact parameter distribution (b-distribution)

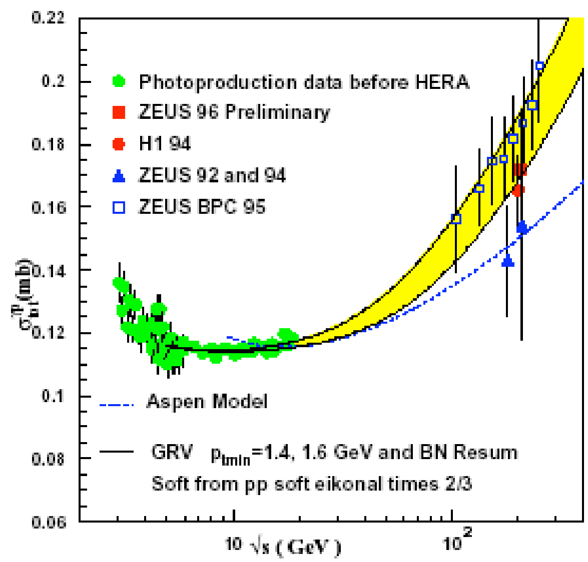
The Proton Case

- Tevatron data allow for both log and $\log^2$ and more than simple Regge + 1 Pomeron
- The EMM + BN model predicts **98 mb** at LHC
- Range of model parameters, like p_{tmin} and soft IR behaviour, still needs to be determined

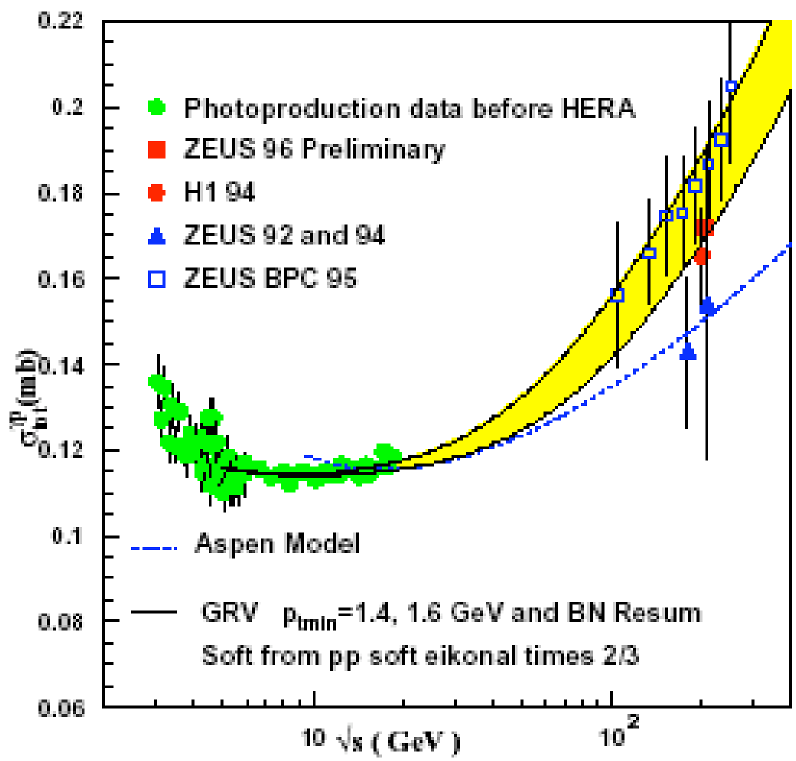


The rise

- Power law may be different in various processes
- Predictions for cross-sections at future accelerators like Linear Collider may vary by large factors
- for □p case



γp in IEMM



Photoproduction data before HERA
ZEUS 96 Preliminary
H1 94
ZEUS 92 and 94
ZEUS BPC 95
Aspen Model
GRV p_{tmin}=1.4, 1.6 GeV and BN Resum
Soft from pp soft eikonal times 2/3
$\sigma_{tot}^{\gamma p}$(mb)
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
10
$\sqrt{s}$ (GeV)
10^2

Work since Jeju Meeting

- Completed gg and gp studies within the Eikonal minijet Midel with Bloch-Nordsieck soft gluon resummation

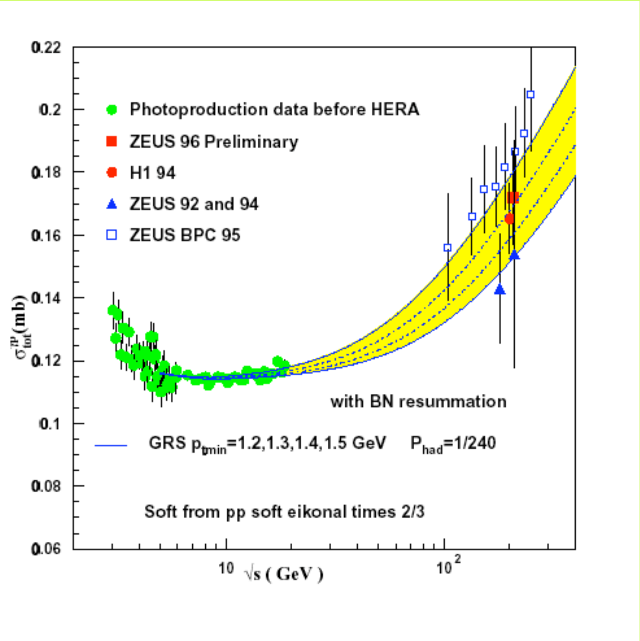
for various photon densities

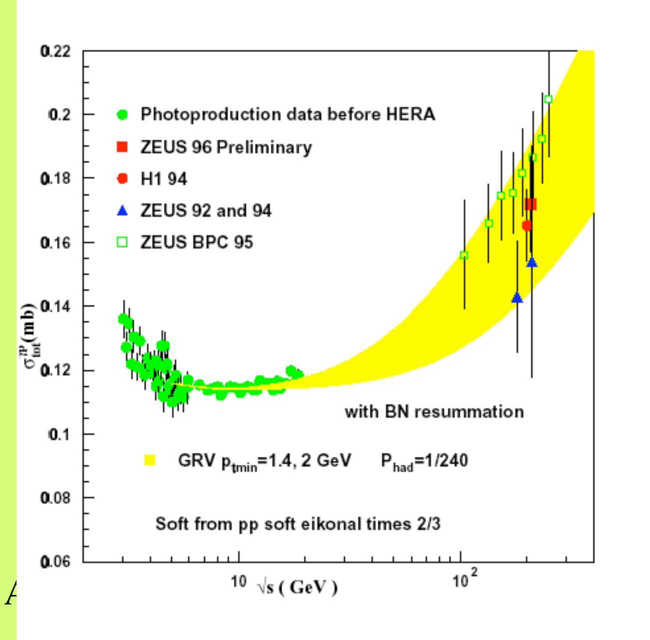
GRV M.Gluck, E.Reya, and A.Vogt
GRS M.Gluck, E.Reya and I.Schienbein
CJKL F.Cornet, P. Jankowski, M.Krawczyk and A. Lorca
Ptmin=1.2 to 2 GeV

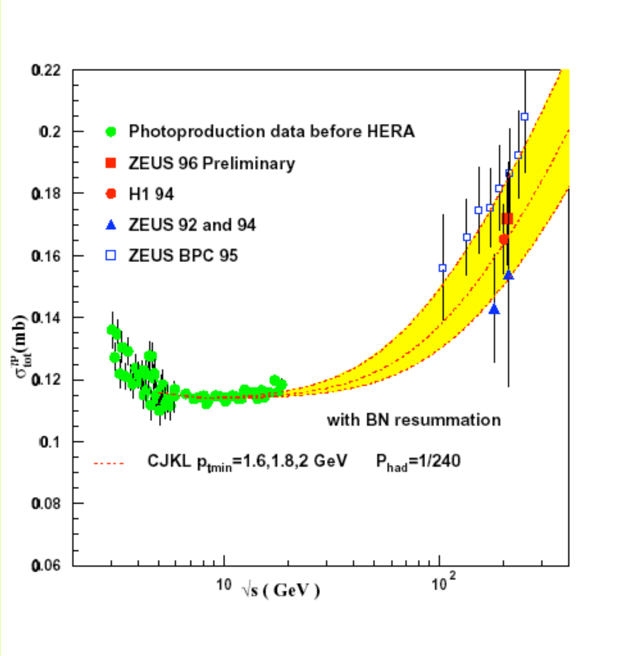
□□for Various Densities and P_{tmin}

GRV, GRS and CJKL Densities：

P_{tmin}=1.2 to 2 GeV



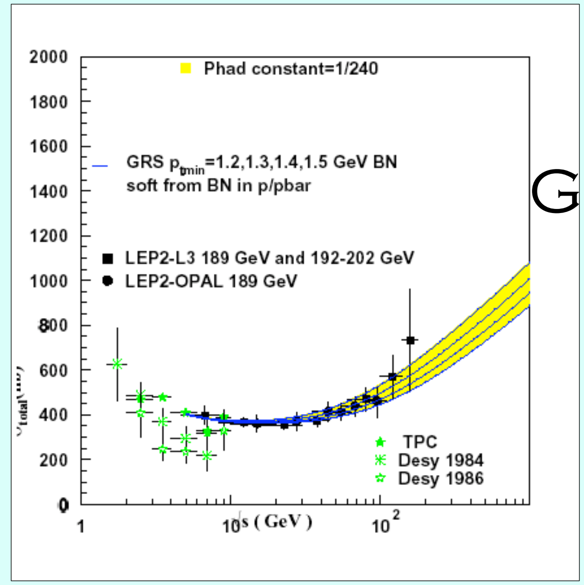




□□for various densities and P_{tmin}

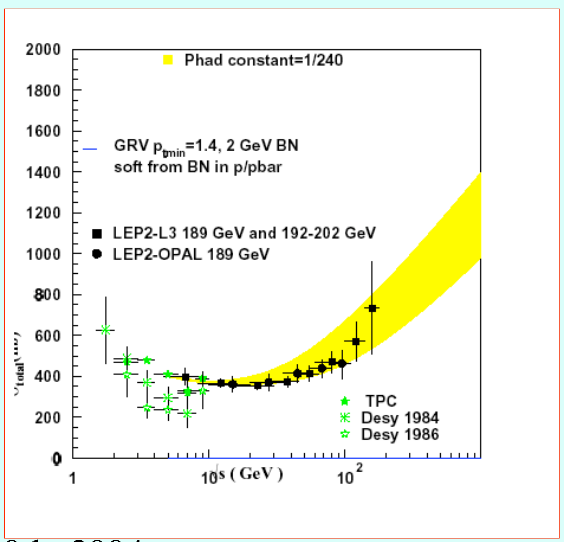
GRV, GRS and CJKL Densities：

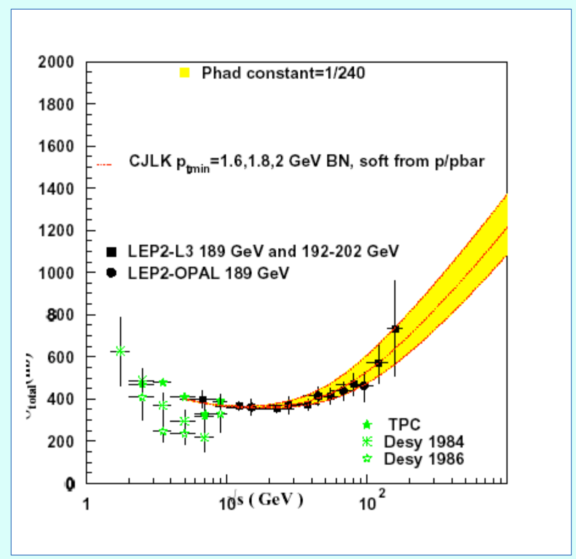
P_{tmin}=1.2 to 2 GeV



GRS

GRV





CJKL

Learning from LHC for LC：
From pp →hadrons to e^+e^- → hadrons

- A work program to reach stable predictions for LC and learn about QCD contribution to $\square_{total}$ needs LHC measurements and an understanding of how much parameters can vary.
- Predictions for e^+e^- → hadrons come from □□ → hadrons
- Model builders must prepare predictions for various paramer sets so as to contrain proton parameters from LHC as much as possible
- From proton to photons : HERA data are crucial in order to constrain the photon parameters
- From □p and pp : □□should come out parameters free