Photon Total Cross-Sections

Giulia Pancheri
INFN Frascati National Laboratories

April 8th, 2003
Photon 2003, Frascati

- Present predictions on $\gamma\gamma \to hadrons$
- Why predictions differ
- Which predictions to trust?
- A work program to reach stable predictions : Towards a QCD Description of the decrease and the increase of total cross-sections through Soft Gluon Summation (Bloch-Nordsieck Model) and Mini-jets

With A. de Roeck, R.M. Godbole, A. Grau and Y.N. Srivastava

With input from

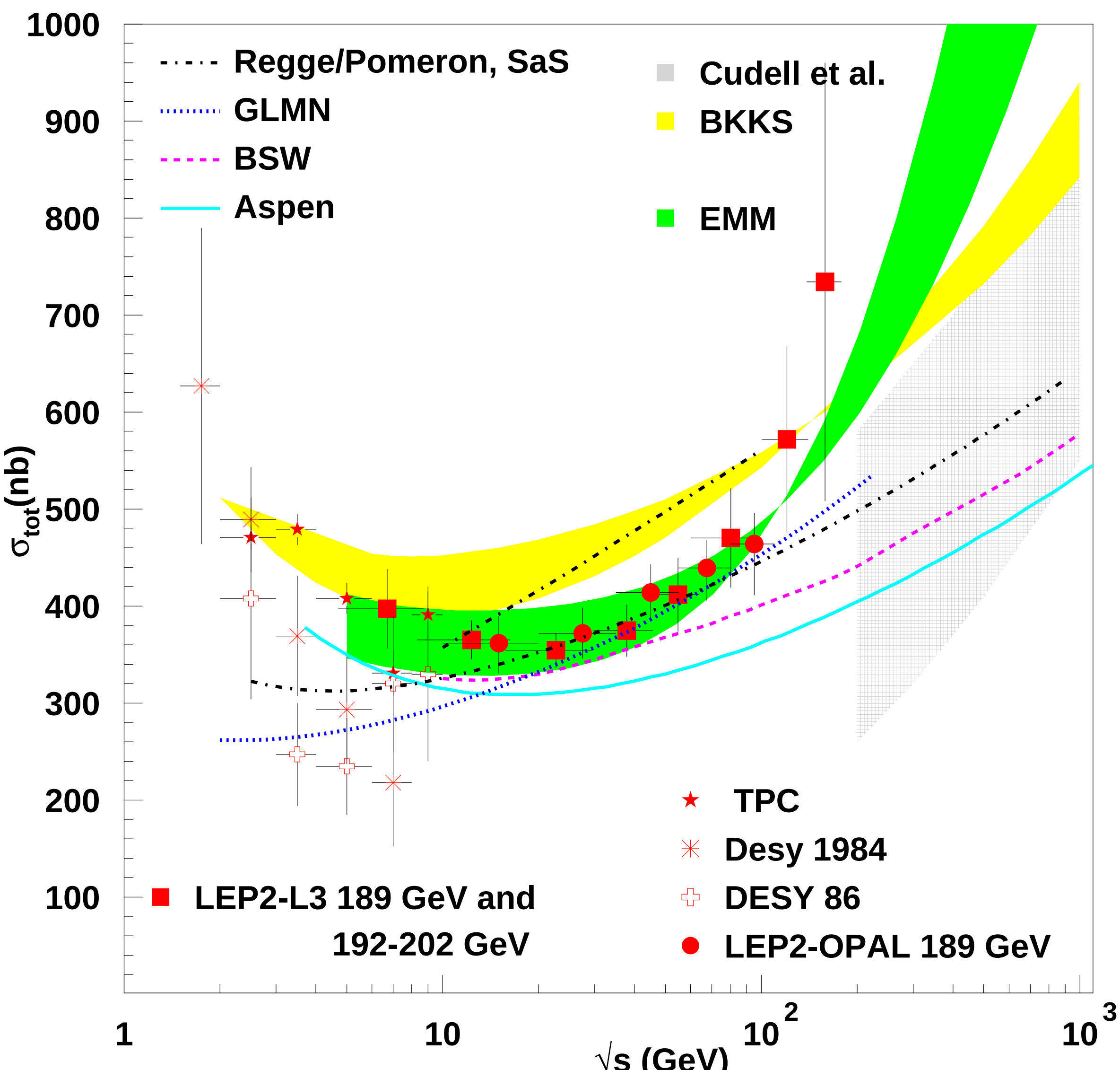
M. Block, E. Gregores and F. Halzen and G.P.,Phys.Rev.**D60** (1999) 054024

R. M. Godbole and G.P., PLB **435** (1998) 441, Eur.Phys.J.C19:129-136,2001

A. Grau, G.P. and Y.N. Srivastava, PR **D60** (1999) 114020

Present Predictions

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



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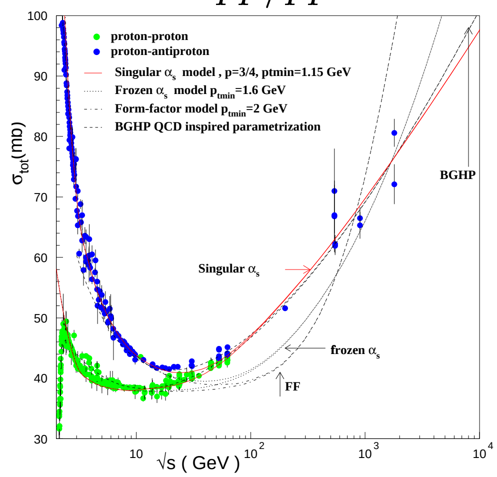
Why predictions differ?

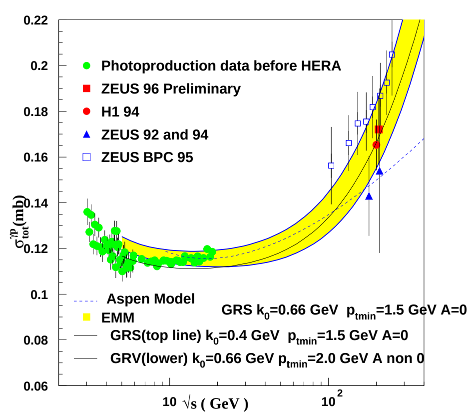
1. There is no calculation from first principles but this would not necessarily be a deterrent from making correct predictions as the $pp/p\bar{p}$ case shows



2. All models for $\gamma\gamma$ do some degree of extrapolation from
   - $pp/p\bar{p} \Longrightarrow$ thus doubling the errors
   - from $\gamma p \Longrightarrow$ as ther are differences among data at high energy

3. At low energies old $\gamma\gamma$ data have large errors and even LEP data probably have a 10% normalization error

4. Data do not reach a high enough energy to pinpoint how the cross-section rises (unlike the $pp/p\bar{p}$ case)



Which predictions to trust

(a) is the photon like a proton ?

Then models based on Gribov factorization

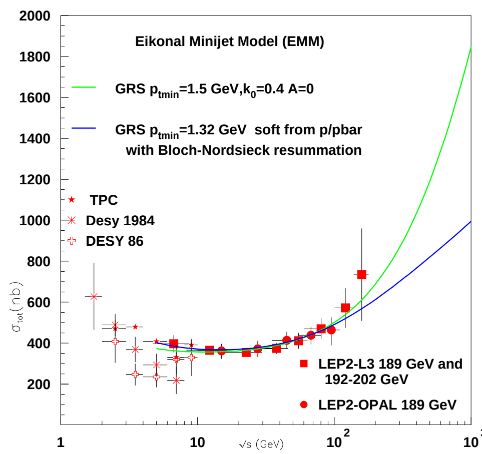
$$\sigma_{\gamma\gamma} = \frac{\sigma^2_{\gamma p}}{\sigma_{pp/\bar{p}}}$$

or similar extensions

$$\Longrightarrow \sigma_{\gamma\gamma}(\sqrt{s} = 1\ TeV) = 500 \div 700\ nb$$

(b) QCD models $\sigma_{jet} \Longrightarrow$ Eikonal Minijet Model

$$\Longrightarrow \sigma_{\gamma\gamma}(\sqrt{s} = 1\ TeV) = 1000 \div 1500\ nb$$



But it is time
to get serious

QCD vs. stable predictions

A work program to reach stable predictions may be based on

- at low energy $\Longrightarrow$ The photon is like a proton
- at high energy Minijets+Resummation
- low and high with a unified description

$$\sigma_{tot}^{\gamma\gamma} = 2P_{had}^{\gamma\gamma} \int d^2\vec{b}[1 - e^{-\chi(b,s)}/2]$$

with

$$\chi(b,s) = \frac{4}{9}\frac{[\chi_{pp} + \chi_{p\bar{p}}]_{soft}}{2} + A_{BN}(b,s,p_{tmin})\sigma_{jets}^{\gamma\gamma}(s,p_{ptmin})$$

Resummation of soft gluons takes place through
Fourier transform of
resummed soft gluon transverse momentum distribution

$$A_{BN}(b,s,p_{tmin}) = \frac{e^{-h(b,s,p_{tmin})}}{\int d^2\vec{b}e^{-h(b,s,p_{tmin})}}$$

- first obtain soft eikonal from analogous QCD minijets+resummation for protons
- fix jet parameters from γp
  - parton densities
  - p_{tmin}

Technically rather challenging

- $h(b,s) = \int_{k_{min}}^{k_{max}} d^3\bar{n}_{gluons}(k)\ [1 - e^{ik_t \cdot b}]$

- $k_{max} \Longrightarrow$ *average over densities* $\Uparrow$ *as* $\sqrt{s}$ $\Uparrow$

- $k_{min} = 0$ in principle but one needs a model for

vfil

$$\alpha_s(k_t) \text{ as } k_t \to 0$$

Modelling for α_s in the infrared limit

We choose α_s from Nakamura, GP, Srivastava, Z.Phys.C21:243,1984 such that it is

- Integrable

  but

- singular

- inspired by the Richardson potential for quarkoniumn bound states

$$\tilde{\alpha}_s(k_\perp^2) = \frac{12\pi}{(33-2N_f)} \frac{p}{\ln[1+p(\frac{k_\perp}{\Lambda_{QCD}})^{2p}]}$$

- for $K_\perp \gg \Lambda_{QCD}$ $\quad \tilde{\alpha}_s \rightarrow \alpha_s^{AF}$
- for $K_\perp \ll \Lambda_{QCD}$ $\quad \tilde{\alpha}_s \rightarrow (k_\perp^2)^{-p}$

If p is smaller than 1 the integral can be done

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

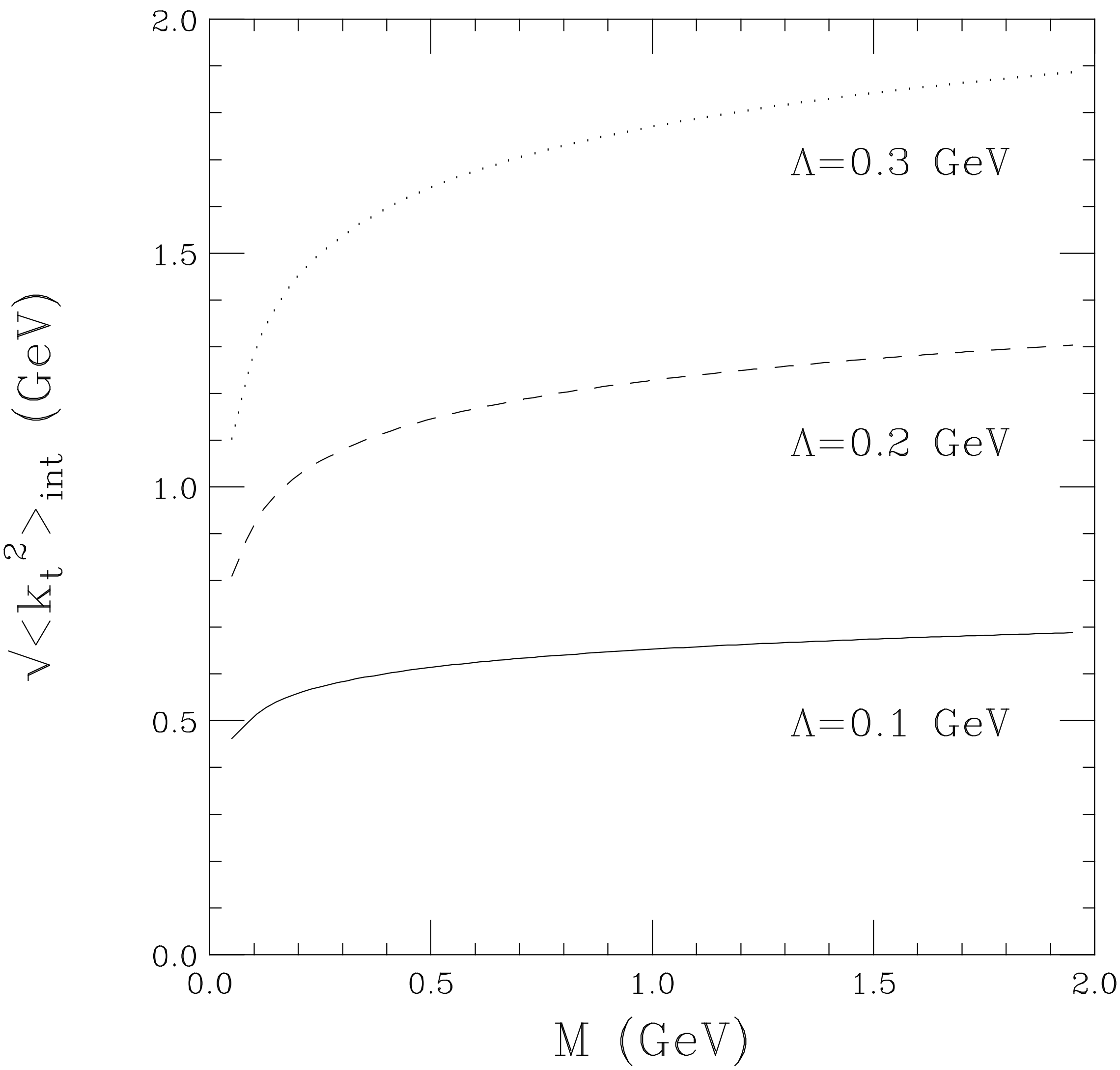
- $\hat{s}$ the energy of the initial parton-parton subprocess
- the jet-jet invariant mass $\sqrt{\hat{s}_{jet}}$,

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 $z_{min} = 4p_{tmin}^2/(sx_1x_2)$.


2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
Λ=0.3 GeV
Λ=0.2 GeV
Λ=0.1 GeV
$\sqrt{\langle k_t^2 \rangle_{int}}$ (GeV)
M (GeV)

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

In the proton-proton and proton-antiproton fit with the Bloch-Nordsieck (BN) model , the eikonal takes 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 :

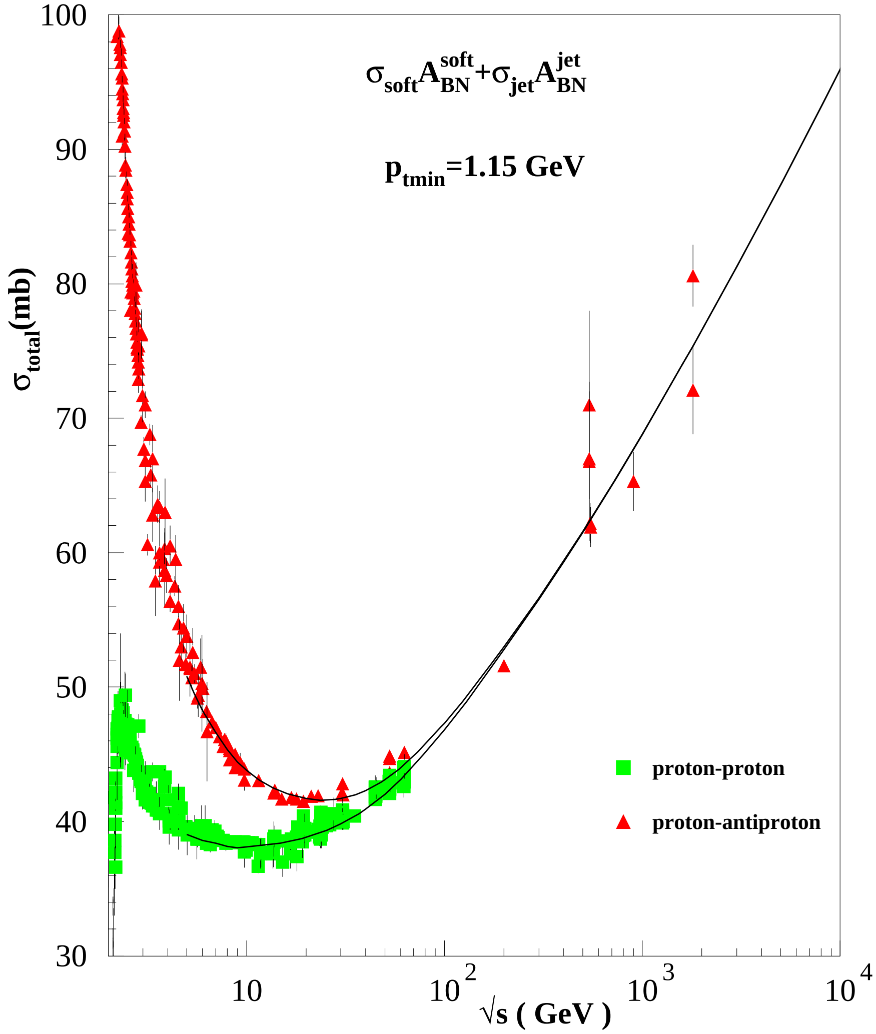
- with σ_{soft} constant or $\Downarrow$ $\sigma_{soft} A_{BN}^{soft} \Downarrow$
- with $\sigma_{jet} \Uparrow$ $\sigma_{jet} A_{BN}^{jet} \Uparrow$ but not as much as without soft gluons

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

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



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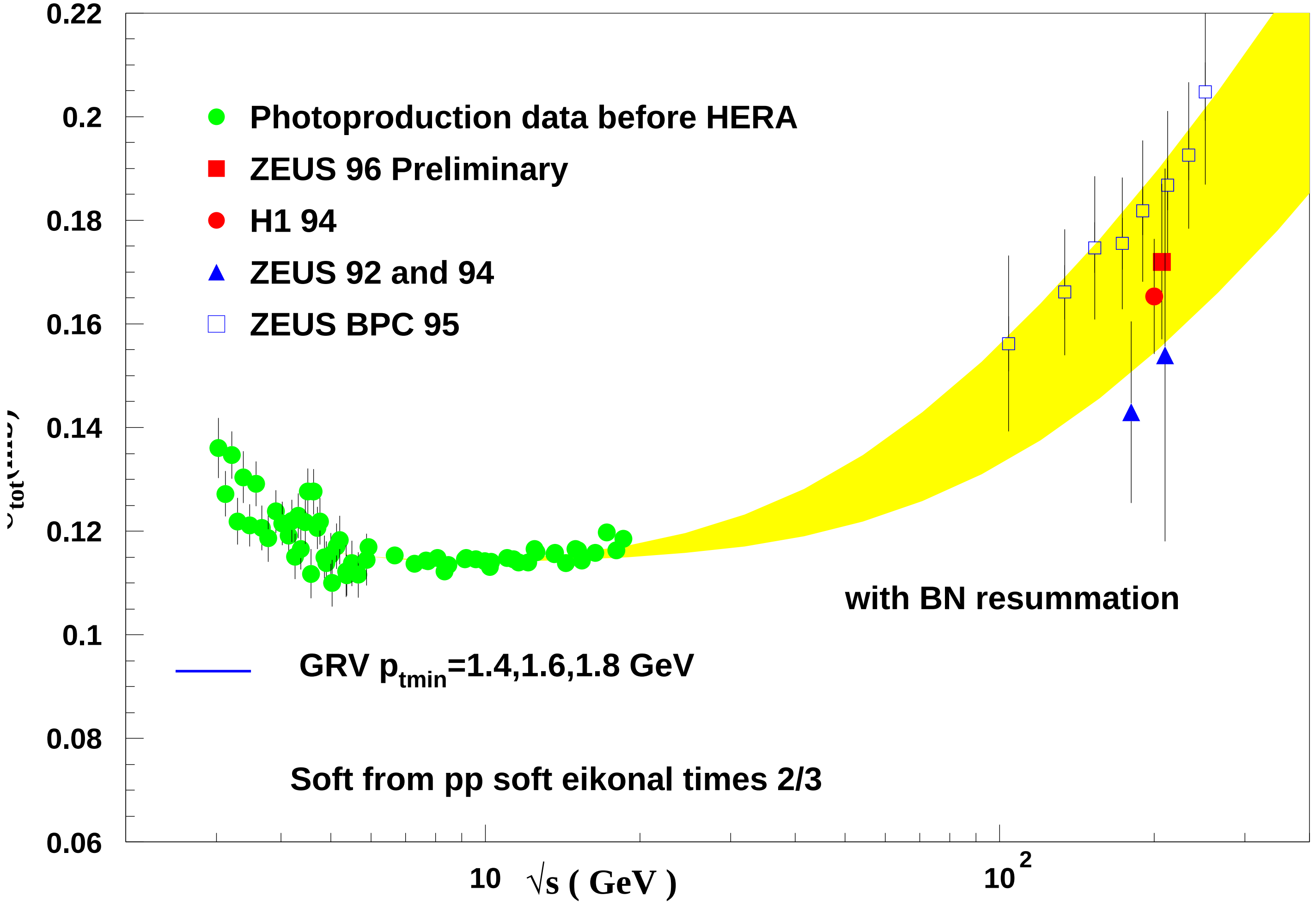
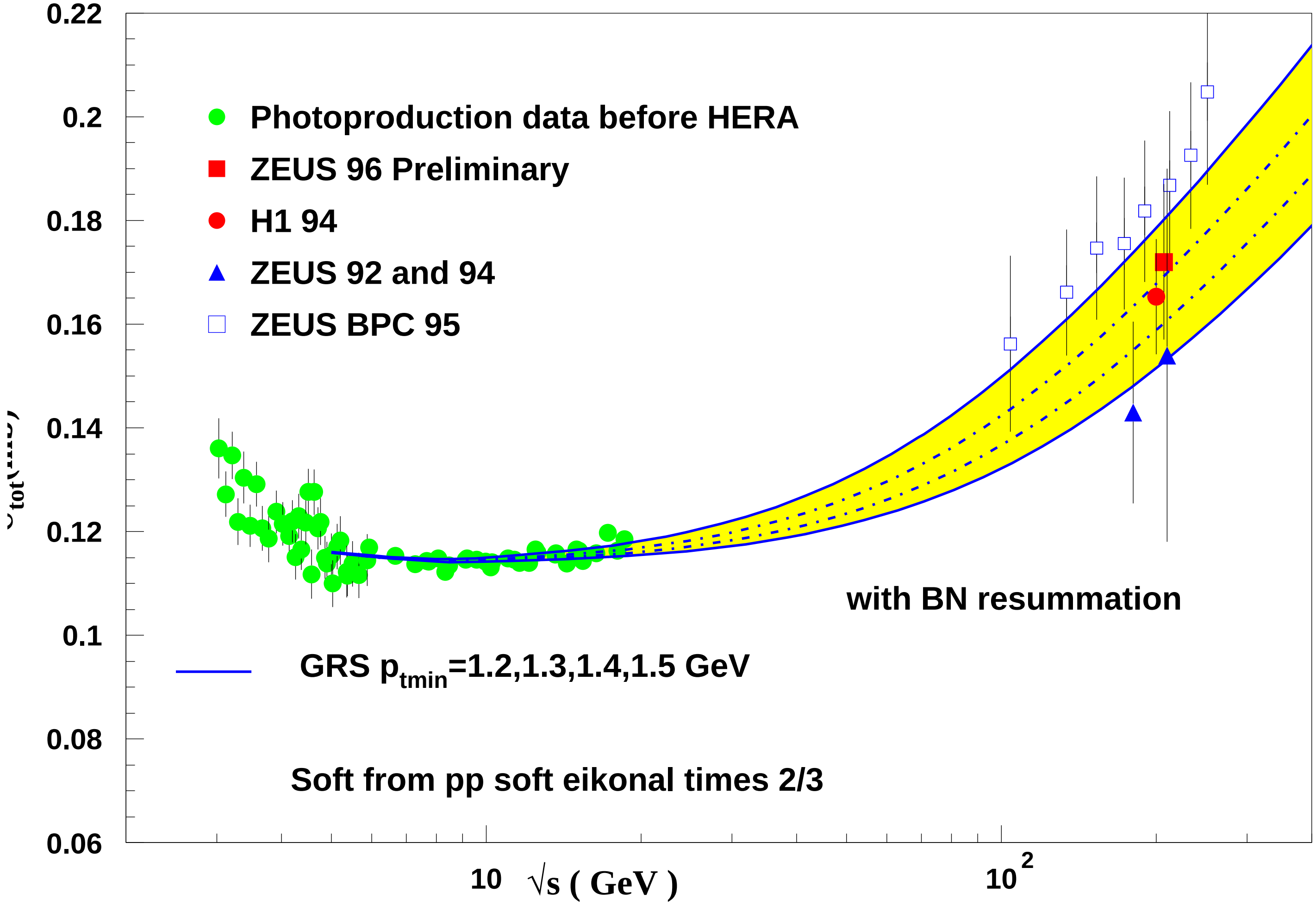


0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
Photoproduction data before HERA
ZEUS 96 Preliminary
H1 94
ZEUS 92 and 94
ZEUS BPC 95
with BN resummation
GRV p_{tmin}=1.4,1.6,1.8 GeV
Soft from pp soft eikonal times 2/3
10
10^2
$\sqrt{s}$ (GeV)



Photoproduction data before HERA
ZEUS 96 Preliminary
H1 94
ZEUS 92 and 94
ZEUS BPC 95
with BN resummation
GRS p_{tmin}=1.2,1.3,1.4,1.5 GeV
Soft from pp soft eikonal times 2/3
0.22
0.2
0.18
0.16
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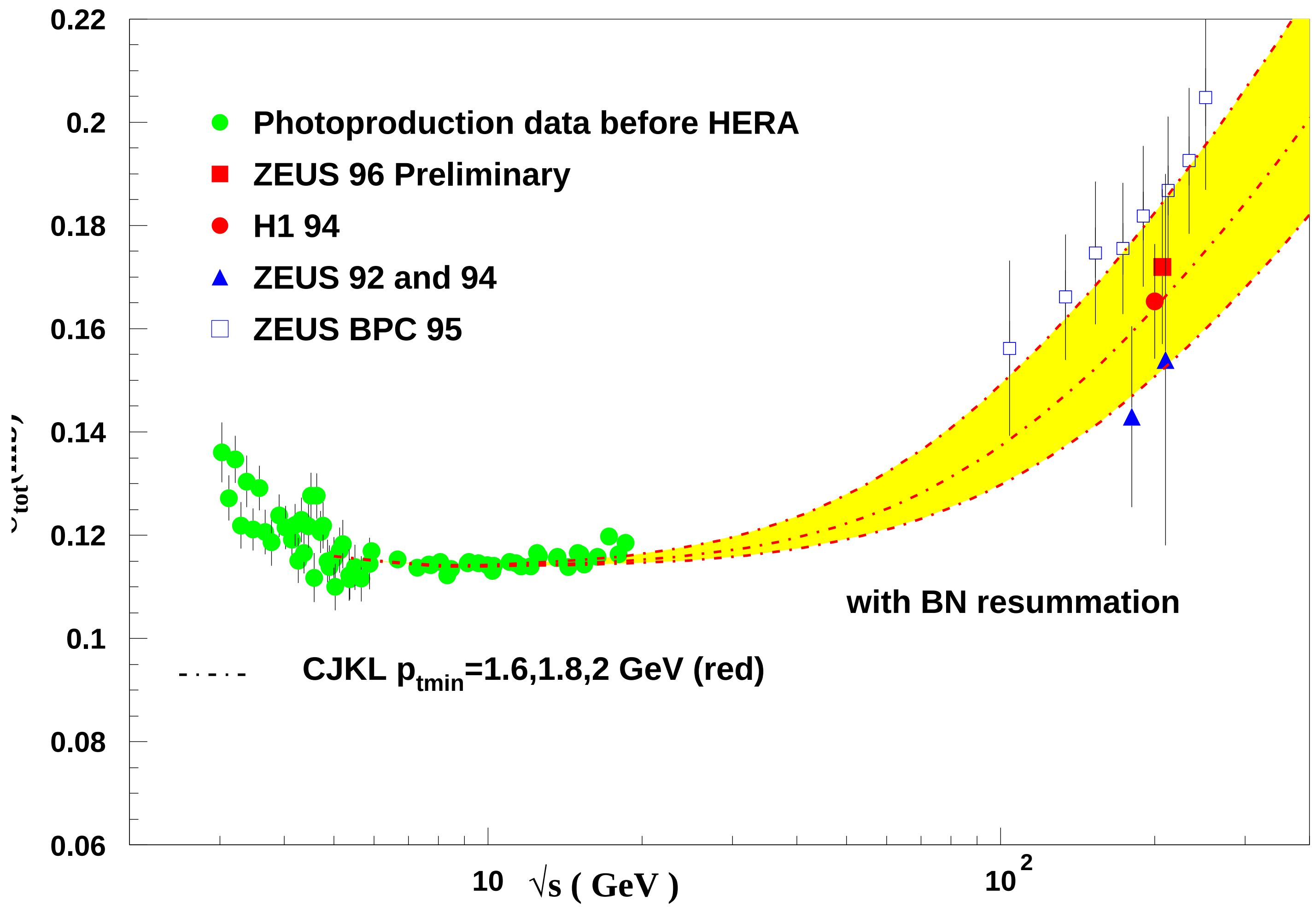
0.12
0.1
0.08
0.06
10
10^2
$\sqrt{s}$ (GeV)

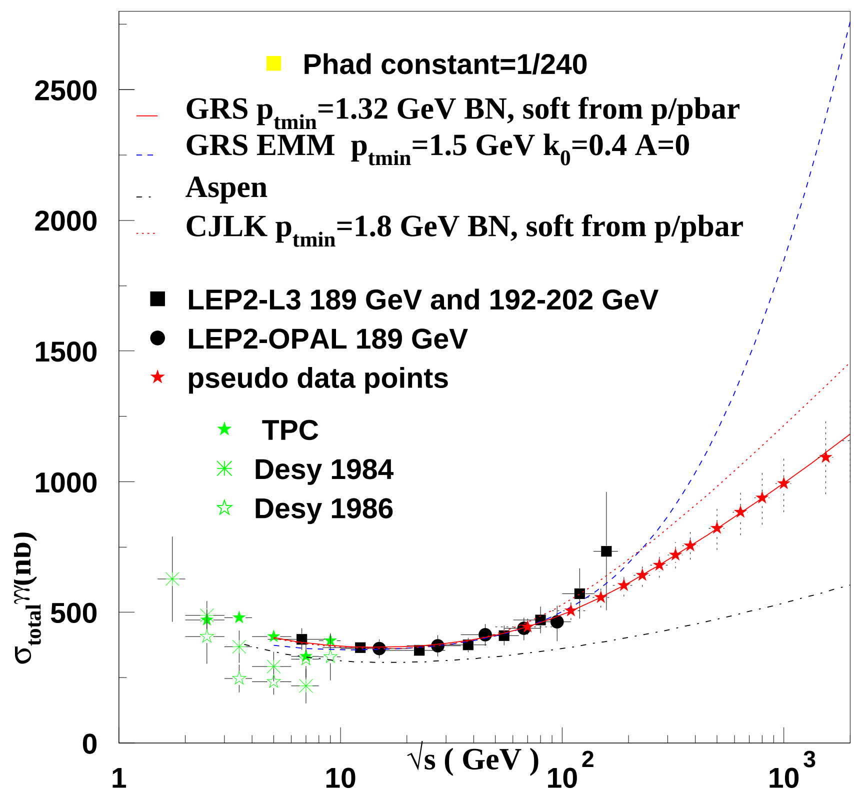


0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
Photoproduction data before HERA
ZEUS 96 Preliminary
H1 94
ZEUS 92 and 94
ZEUS BPC 95
with BN resummation
CJKL p_{tmin}=1.6,1.8,2 GeV (red)
10
$\sqrt{s}$ (GeV)
10^2

Present update is done using following improvements

1. Soft part of the eikonal $n(b,s)$ directly from proton and antiproton processes $\rightarrow n^{\gamma\gamma}_{soft}(b,s)$ given by $\frac{4}{9}\frac{n^{pp}_{soft}+n^{p\bar{p}}_{soft}}{2}$ using fit to protons,
2. soft resummation for hard scattering,
3. two types of densities

- GRS : Glück, Reya and Scheinbein, Phys. Rev. D 60, 054019,1999.
- CJLK: F. Cornet, P. Jankowski, A. Lorca and M. Krawczyk , hep-ph, in preparation.



$\gamma\gamma$: Aspen EMM and resummation