Hard-Soft Pomeron Transition from QCD Saturation in the Dipole Picture

Michael Lublinsky

DESY/Theory

Based on:

- M. L., E. Gotsman, E. Levin, and U. Maor, *Nucl. Phys.* **A 696** (2001) 851;
- E. Gotsman, E. Levin, M. L., and U. Maor, *Eur. Phys. J.* **C** 27, (2003) 411;
- J. Bartels, E. Gotsman, E. Levin, M. L., and U. Maor, *Phys. Lett.* **B 556**, (2003) 114.
- J. Bartels, E. Gotsman, E. Levin, M. L., and U. Maor, hep-ph 0304166.

Main Research Goals:

New Global QCD analysis based on Non-Linear Evolution

Balitsky-Kovchegov equation (BKE)

BKE $=$ LO BFKL $+$ Unitarization (non-linearity)

Motivation:

- DGLAP evolution predicts a steep growth of parton distributions at low x which will eventually violate the unitarity constraints;
- The twist OPE breaks down at low x, when the higher twists become of the same order as the leading one;
- DGLAP evolution is totally unable to describe low Q^2 data.

NLO corrections do not solve these problems.

Non-linear evolution is a solution to these problems!

- It accounts for the saturation effects due to high parton densities;
- It sums high twist contributions;
- It allows extrapolation to large distances.

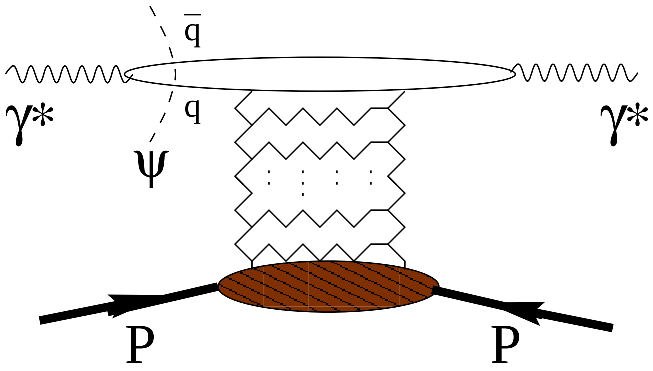
The question to be addressed in this talk:

How far can we push the QCD Dipole Model and the idea of QCD Saturation to the kinematical regions traditionally associated with Soft Nonperturbative Physics.

Strategy:

- Construct a new Saturation Model by solving BK equation and fitting free parameters to the low x F_2 data.
- Use the Model beyond the limits of its formal applicability.

• Color Dipole Approach to DIS



$$x \;=\; Q^2\,/\,W^2$$

The total DIS cross section:

$$\sigma^{DIS}_{tot} \;=\; \int d^2 r_\perp\, d\,z\; P^{\gamma^*}(\,Q,\, r_\perp,\, z\,)\;\; \sigma_{dipole}\,(\,r_\perp,\, x\,)\,; \qquad\qquad \sigma_{dipole} \;=\; 2\int d^2 b\; N\,(\,r_\perp,\, x;\, b\,)\,.$$

$$N\,(\,r_\perp,\, x;\, b\,) \;=\; Im\, a^{el}_{dipole}\,(\,r_\perp,\, x;\, b\,)\,.$$

pQCD: $N \;\sim\; r^2_\perp\, xG(\,r_\perp,\, x\,;b\,)$

(xG - gluon density)

Unitarity: $N \;\leq\; 1$

$N \;\longleftarrow$ Balitsky-Kovchegov NLE + DGLAP corrections

New procedure for extrapolation of parton distributions

Two steps:

- Solve the BK non-linear evolution equation.
  - it takes into account high twist contributions;
  - but only in the leading $\ln(1/x)$ approximation of pQCD;
  - and without a correct short distance description.
- Introduce a correcting function for which a DGLAP-type linear equation is proposed and solved.

The full solution is

$$N(r_\perp, x; b) = \tilde{N}(r_\perp, x; b) + \Delta N(r_\perp, x; b)$$

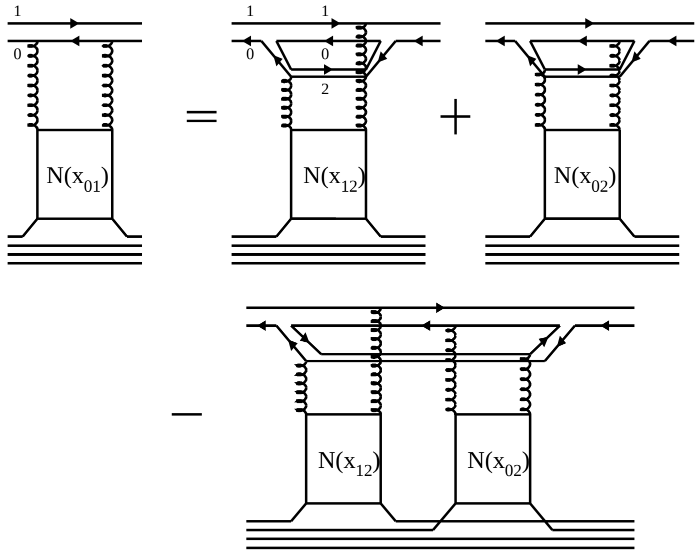
$\tilde{N}(r_\perp, x; b) \leftarrow$ BK non-linear equation;

$\Delta N(r_\perp, x; b) \leftarrow$ DGLAP-type linear equation;

where

$$N(r_\perp, x; b) = Im\, a^{el}_{dipole}(r_\perp, x; b).$$

Non-linear evolution



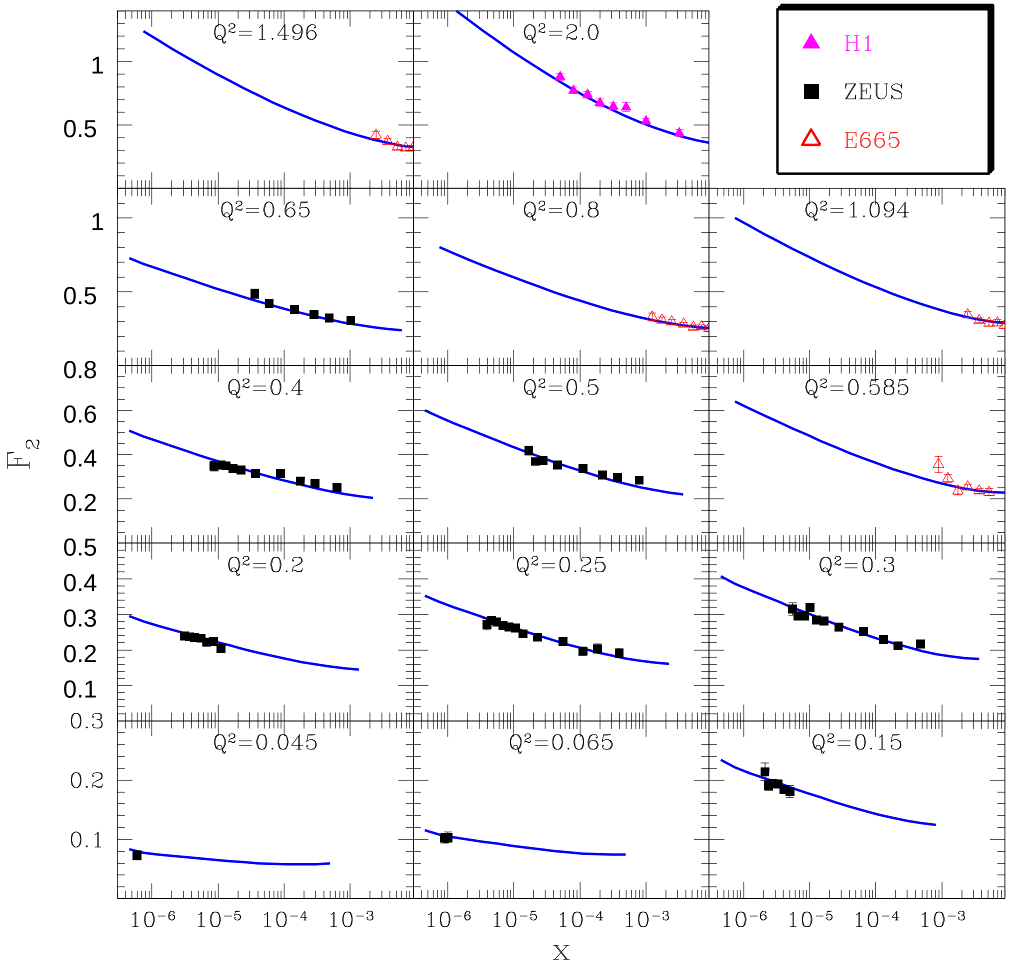
GLR (81)
Mueller & Qiu (86)
....
Balitsky (95)
Kovchegov (99)
Braun (2000)
Iancu, Leonidov & McLerran (2000)

$$\frac{d\tilde{N}\,(\,x_{01}\,,\;y\,;\,b\,)}{dy} \;=\; -\,\frac{2\,C_F\,\alpha_S}{\pi}\;\tilde{N}\,(\,x_{01}\,,\;y\,;\,b\,)\;\ln\,\frac{x_{01}^2}{\rho^2}\;+$$

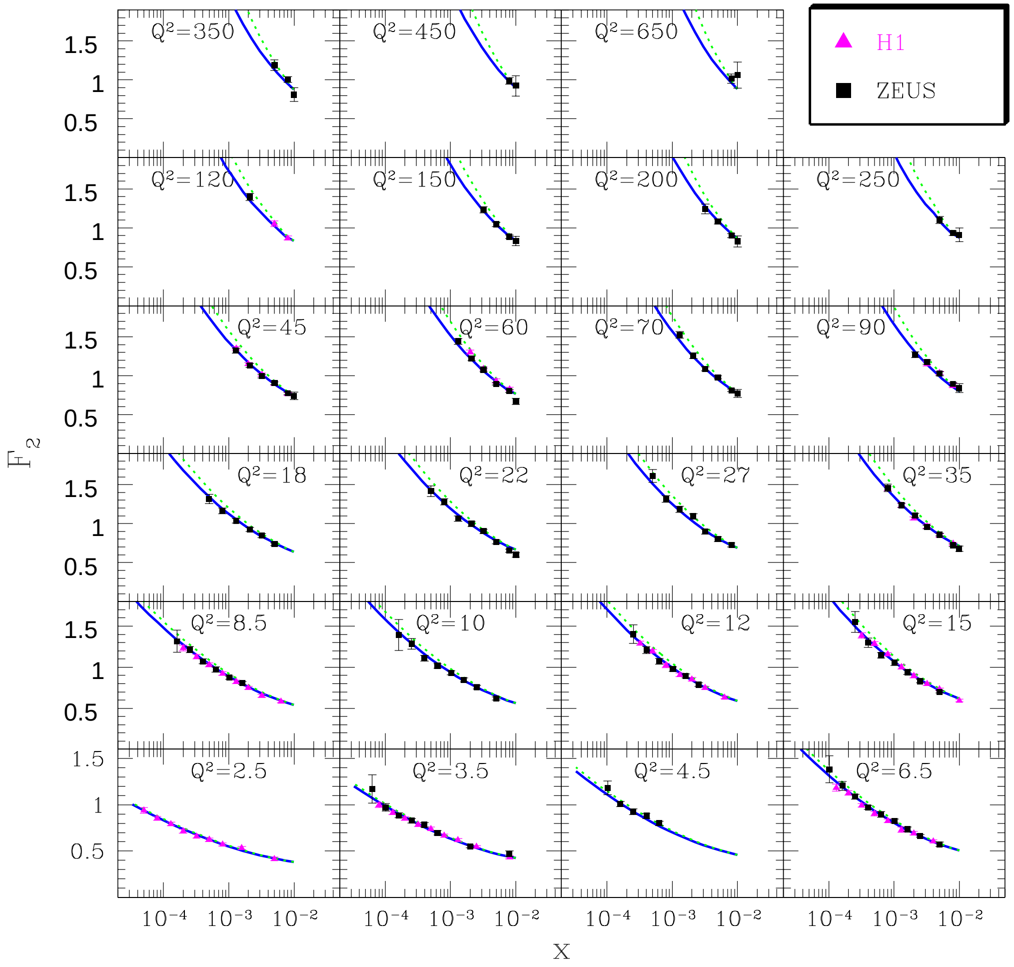
$$\frac{C_F\,\alpha_S}{\pi^2}\;\times\;\int_\rho d^2\,x_2\,\frac{x_{01}^2}{x_{02}^2\,x_{12}^2}\;\times\;\Big(\,2\,\tilde{N}\,(\,x_{02}\,,\;y\,;\,b\,)\;-\;\tilde{N}\,(\,x_{02}\,,\;y\,;\,b\,)\,\tilde{N}\,(\,x_{12}\,,\;y\,;\,b\,)\Big)$$

Approximations: LLog $1/x$; $N_c \to \infty$; α_s - const.; b - large.

Results

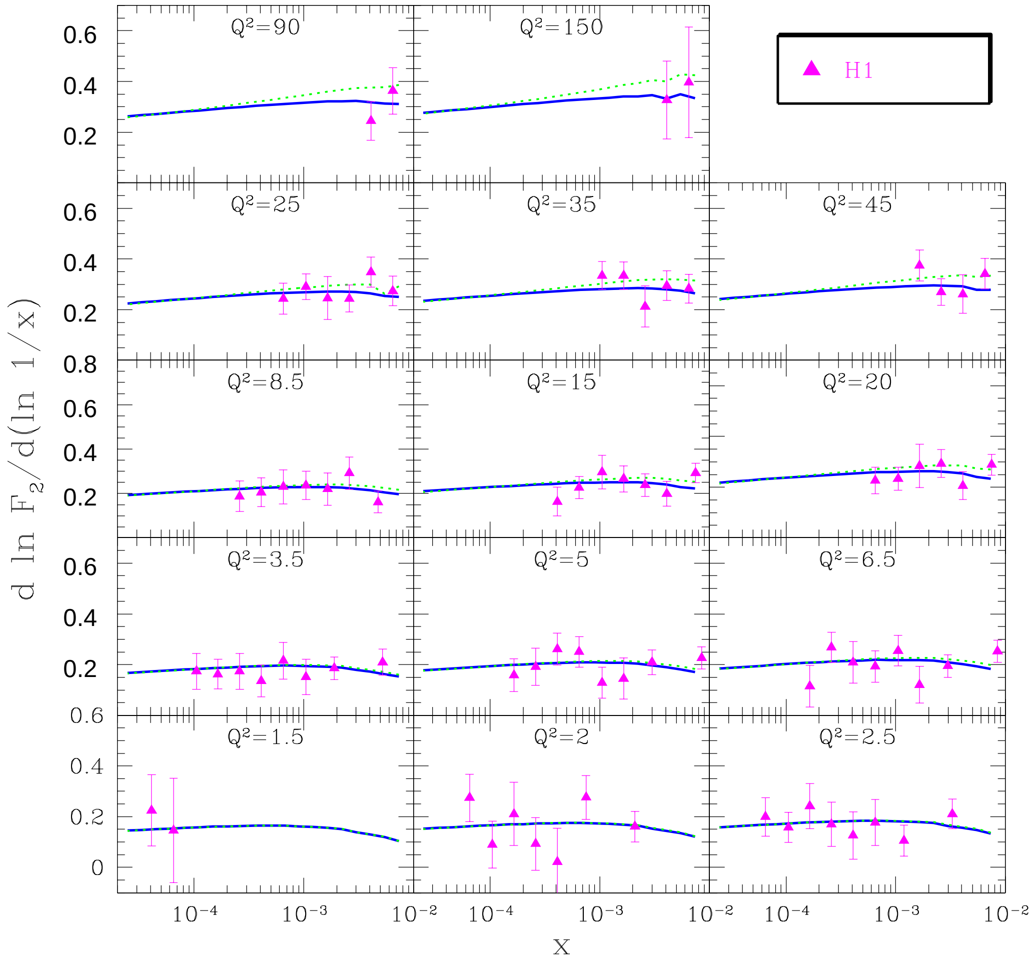


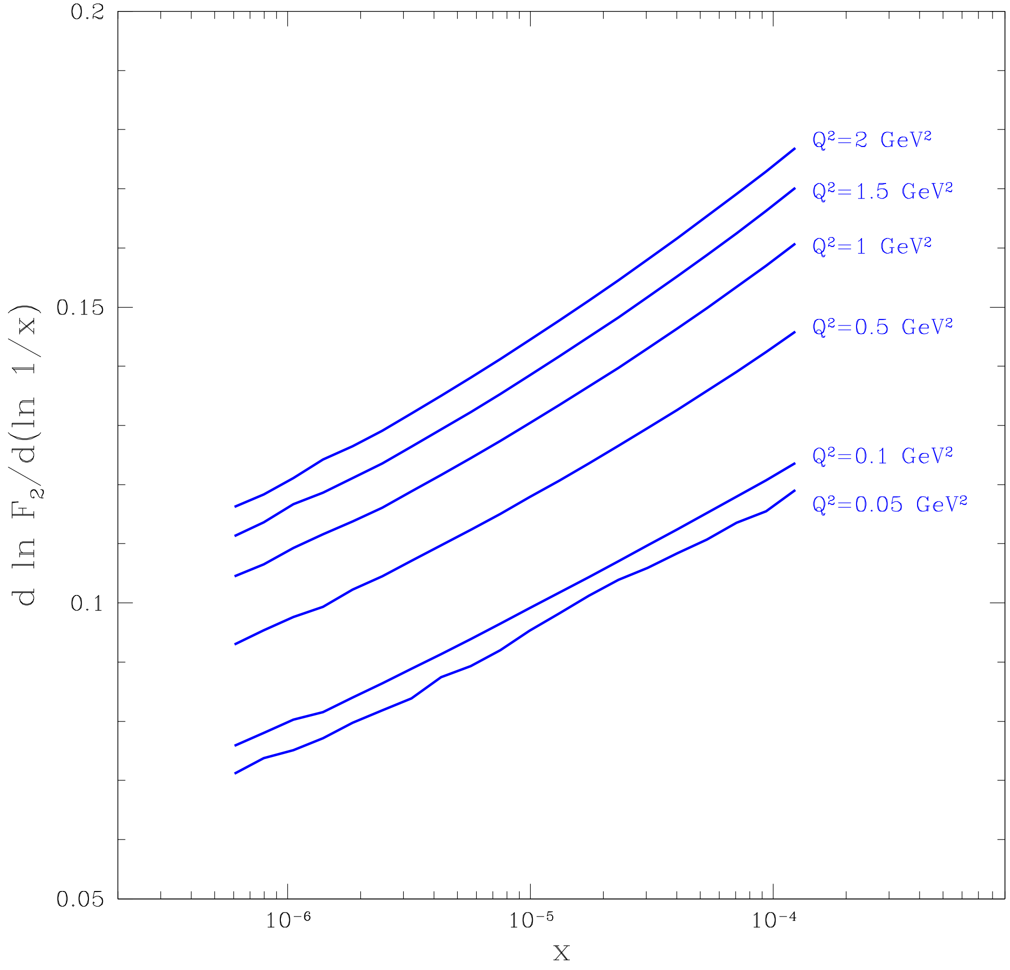
H1
ZEUS
E665
Q²=1.496
Q²=2.0
Q²=0.65
Q²=0.8
Q²=1.094
Q²=0.4
Q²=0.5
Q²=0.585
Q²=0.2
Q²=0.25
Q²=0.3
Q²=0.045
Q²=0.065
Q²=0.15
F 2
X



H1
ZEUS
Q²=350
Q²=450
Q²=650
Q²=120
Q²=150
Q²=200
Q²=250
Q²=45
Q²=60
Q²=70
Q²=90
Q²=18
Q²=22
Q²=27
Q²=35
Q²=8.5
Q²=10
Q²=12
Q²=15
Q²=2.5
Q²=3.5
Q²=4.5
Q²=6.5
F 2
X

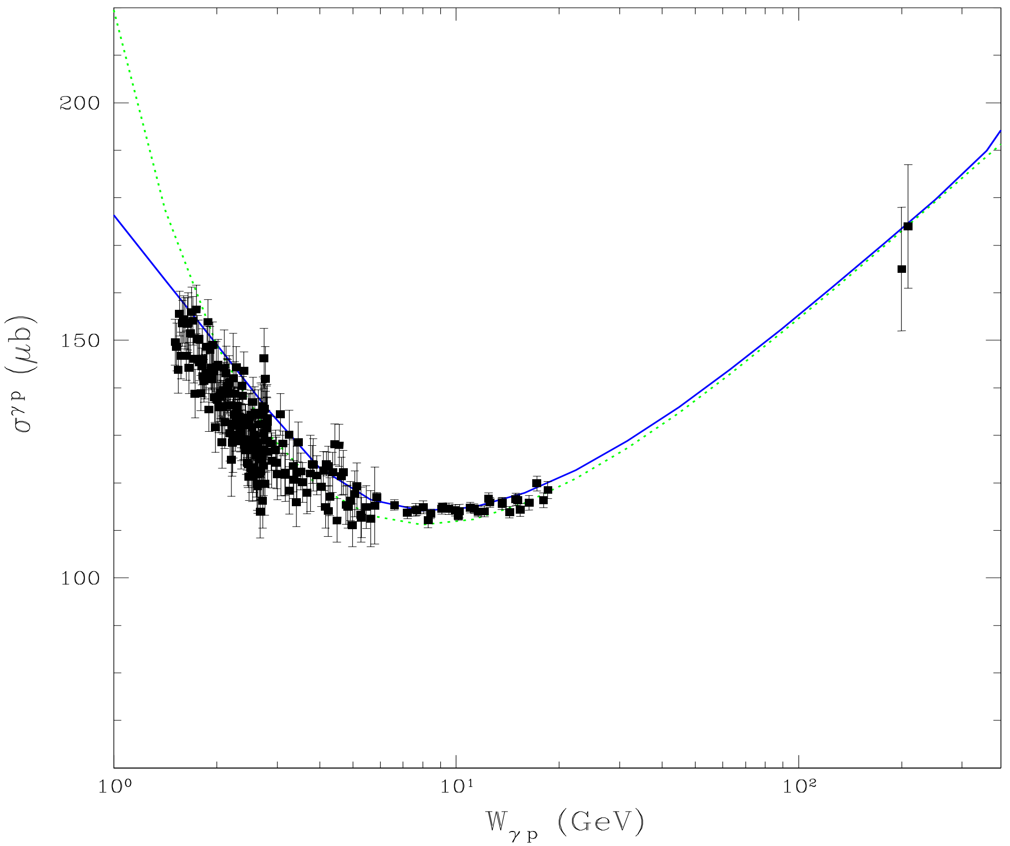
$$\lambda \;=\; \partial \ln \mathbf{F_2} / \partial \ln(\mathbf{1}/\mathbf{x})$$

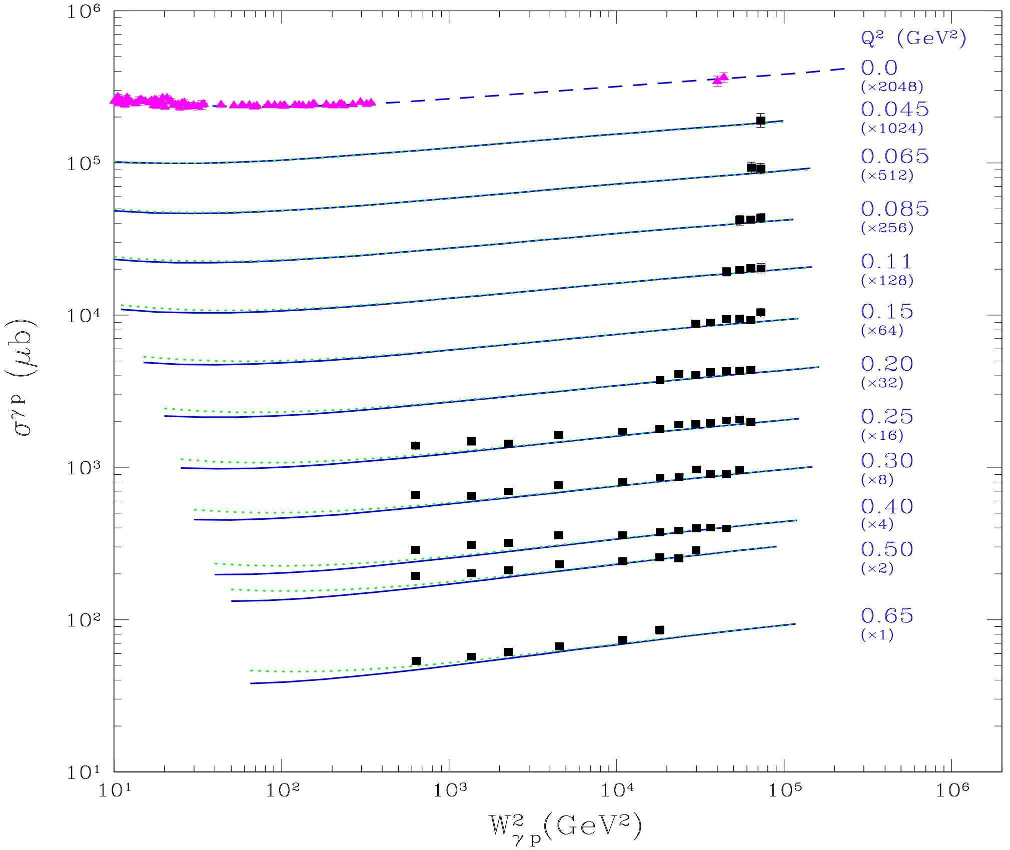




Total Photoproduction

$$x = (Q^2 + Q_0^2)/W^2 \,; \quad Q_0^2 = 4\, m_q^2 \,; \quad m_q = 0.15 \text{ (GeV)}\,.$$

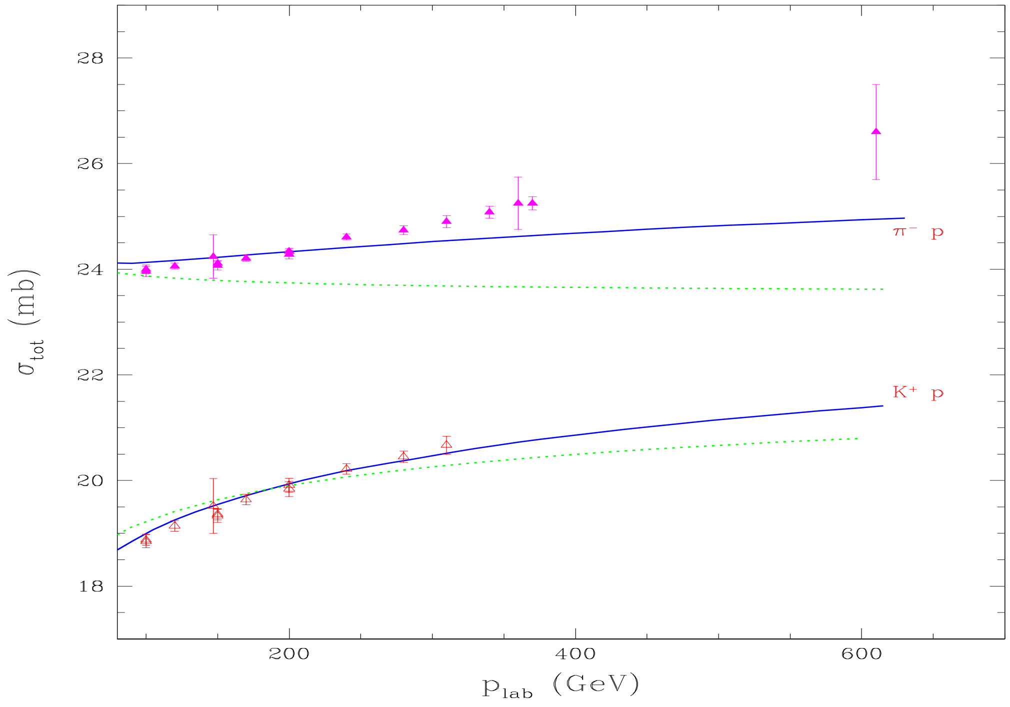


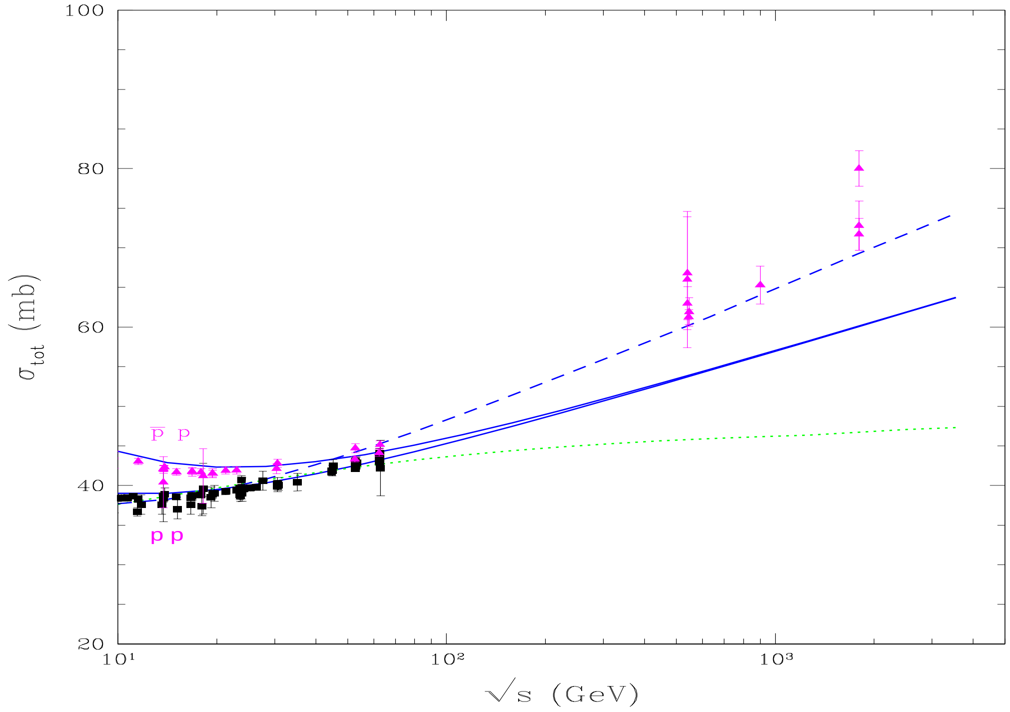


Soft Hadron Interactions

$$\sigma_{H-proton}(x) \;=\; \int d^2 r_\perp |\psi_H(r_\perp)|^2\, \sigma_{dipole}(r_\perp, x)$$

$$x \;=\; Q_0^2 \,/\, s \qquad\qquad Q_0 \;\propto\; M_H$$





Secondary trajectory $\sim\; s^{\,-\,0.45}$ is added.

Summary

- A new approach to global QCD analysis is developed;
- Low x data on the F_2 structure function is reproduced using one fitting parameter; Resulting $\chi^2/ndf = 1$;
- Our method allows extrapolation of the parton distributions to the LHC energies as well as very low photon virtualities $Q^2 \ll 1\, GeV^2$;
- We find $\lambda \simeq 0.25 - 0.4$ at large Q^2 (hard BFKL pomeron) while $\lambda \simeq 0.08 - 0.1$ at very low x and Q^2 well below $1\, GeV^2$. A result which agrees with the "soft pomeron" intercept without soft physics involved;
- The dipole picture pushed to a nonperturbative region works sufficiently well. It describes high energy photoproduction. Soft hadron interaction data are reproduced with quite satisfactory accuracy.

Within the Dipole Picture and QCD Saturation, the Soft Pomeron is a phenomenon of Multiple Rescattering of the Hard (BFKL) Pomeron.