Predictions from the statistical parton distributions for various QCD processes

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C. Bourrely, F. Buccella, J.S.

- A Statistical Approach for Polarized Parton Distributions
  Euro. Phys. J. C23, 487 (2002)
- Recent Tests for the Statistical Parton Distributions
  Mod. Phys. Letters A18, 771 (2003)
- The Statistical Parton Distributions: status and prospects
  Euro. Phys. J. C41,... (2005)

Outline

- Basic procedure to construct the statistical polarized parton distributions
- Essential features from the Deep Inelastic Scattering data
- Predictions tested against new data : DIS and hadronic processes
- Conclusions and future

Basic procedure

Use a simple description of the PDF, at input scale Q_0^2, proportional to $[\exp[(x - X_{0p})/\bar{x}] \pm 1]^{-1}$, *plus* sign for quarks and antiquarks, corresponds to a Fermi-Dirac distribution and *minus* sign for gluons, corresponds to a Bose-Einstein distribution. X_{0p} is a constant which plays the role of the *thermodynamical potential* of the parton p and $\bar{x}$ is the *universal temperature*, which is the same for all partons.

We recall that from the chiral structure of QCD, we have two important properties, allowing to relate quark and antiquark distributions and to restrict the gluon distribution:

- The potential of a quark q^h of helicity *h* is opposite to the potential of the corresponding antiquark $\bar{q}^{-h}$ of helicity *-h*

$$X_{0q}^{h} = -X_{0\bar{q}}^{-h} \ .$$

- The potential of the gluon G is zero

$$X_{0G} = 0 \ .$$

The polarized PDF at $Q_0^2 = 4\mathbf{GeV}^2$

For light quarks $q = u, d$ of helicity $h = \pm$, we take

$$xq^{(h)}(x, Q_0^2) = \frac{AX_{0q}^h x^b}{\exp[(x - X_{0q}^h)/\bar{x}] + 1} + \frac{\tilde{A}x^{\tilde{b}}}{\exp(x/\bar{x}) + 1},$$

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consequently for antiquarks of helicity $h = \mp$

$$x\bar{q}^{(-h)}(x, Q_0^2) = \frac{\bar{A}(X_{0q}^h)^{-1} x^{2b}}{\exp[(x + X_{0q}^h)/\bar{x}] + 1} + \frac{\tilde{A}x^{\tilde{b}}}{\exp(x/\bar{x}) + 1}.$$

Note: $q = q^+ + q^-$ and $\Delta q = q^+ - q^-$ (idem for $\bar{q}$)

Strange quarks

For the strange quarks and antiquarks, s and $\bar{s}$, given our poor knowledge on both unpolarized and polarized distributions, we take

$$xs(x, Q_0^2) = x\bar{s}(x, Q_0^2) = \frac{1}{4}[x\bar{u}(x, Q_0^2) + x\bar{d}(x, Q_0^2)] \ ,$$

and

$$x\Delta s(x, Q_0^2) = x\Delta\bar{s}(x, Q_0^2) = \frac{1}{3}[x\Delta\bar{d}(x, Q_0^2) - x\Delta\bar{u}(x, Q_0^2)] \ .$$

Gluons

We use a Bose-Einstein expression given by

$$xG(x, Q_0^2) = \frac{A_G x^{b_G}}{\exp(x/\bar{x}) - 1} ,$$

with a vanishing potential and the same temperature $\bar{x}$. We also need to specify the polarized gluon distribution and we take the particular choice $x\Delta G(x, Q_0^2) = 0$. (Note that $b_G = \tilde{b} + 1$)

Essential features from the DIS data

From well established features of u and d extracted from DIS data, we anticipate some simple relations between the potentials:

- $u(x)$ dominates over $d(x)$, therefore we should have $X^+_{0u} + X^-_{0u} > X^+_{0d} + X^-_{0d}$
- $\Delta u(x) > 0$, therefore $X^+_{0u} > X^-_{0u}$
- $\Delta d(x) < 0$, therefore $X^-_{0d} > X^+_{0d}$.

So we expect X_{0u}^{+} to be the largest potential and X_{0d}^{+} the smallest one. In fact, we have the following ordering (see below)

$$X_{0u}^{+} > X_{0d}^{-} \sim X_{0u}^{-} > X_{0d}^{+} \,.$$

This ordering has important consequences for $\bar{u}$ and $\bar{d}$, namely

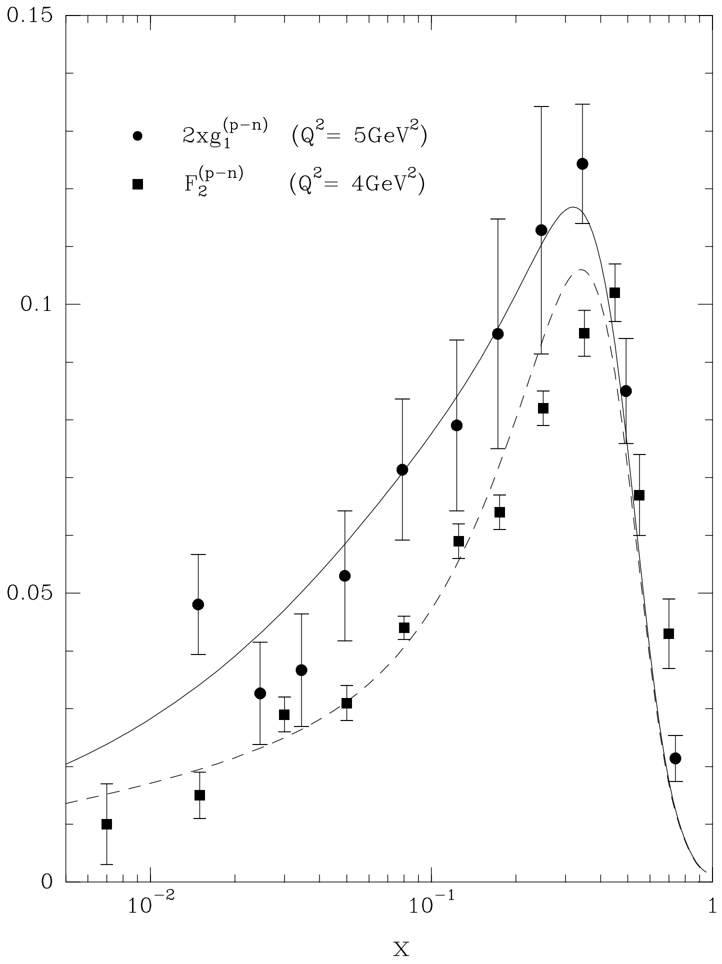
- $\bar{d}(x) > \bar{u}(x)$, flavor symmetry breaking expected from Pauli exclusion principle. This was already confirmed by the violation of the Gottfried sum rule (NMC).
- $\Delta\bar{u}(x) > 0$ and $\Delta\bar{d}(x) < 0$, which remain to be checked and this will be done at RHIC-BNL from $W^{\pm}$ production.

- Note that since $u^-(x) \sim d^-(x)$, it follows that $\bar{u}^+(x) \sim \bar{d}^+(x)$, so we have

$$\Delta\bar{u}(x) - \Delta\bar{d}(x) \sim \bar{d}(x) - \bar{u}(x) \ ,$$

  i.e. the flavor symmetry breaking is almost the same for unpolarized and polarized distributions ($\bar{u}$ and $\bar{d}$ polarizations contribute to about 10% to the Bjorken sum rule).

An interesting observation



Eight free parameters

By performing a NLO QCD evolution of these PDF in 2002, we were able to obtain a good description of a large set of very precise data on $F_2^p(x,Q^2), F_2^n(x,Q^2), xF_3^{\nu N}(x,Q^2)$ and $g_1^{p,d,n}(x,Q^2)$, in correspondance with eight free parameters: the four potentials

$X_{0u}^+ = 0.46128, \; X_{0u}^- = 0.29766,$
$X_{0d}^- = 0.30174, \; X_{0d}^+ = 0.22775,$ and

$$\bar{x} = 0.09907, \; b = 0.40962, \; \tilde{b} = -0.25347, \; \tilde{A} = 0.08318.$$

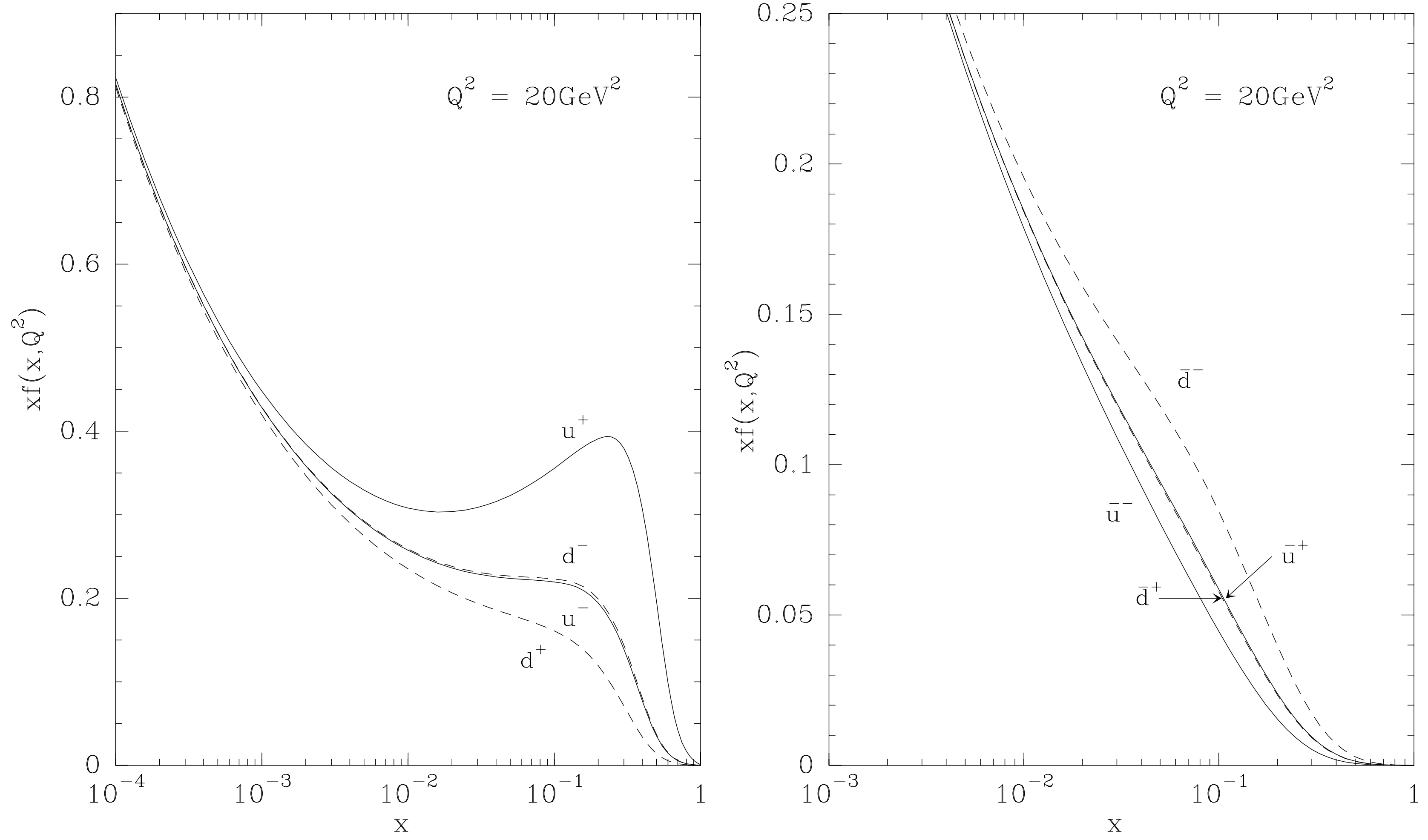
We also have three additional parameters, which are fixed by normalization conditions

$$A = 1.74938, \;\; \bar{A} = 1.90801, \;\; A_G = 14.27535\,.$$

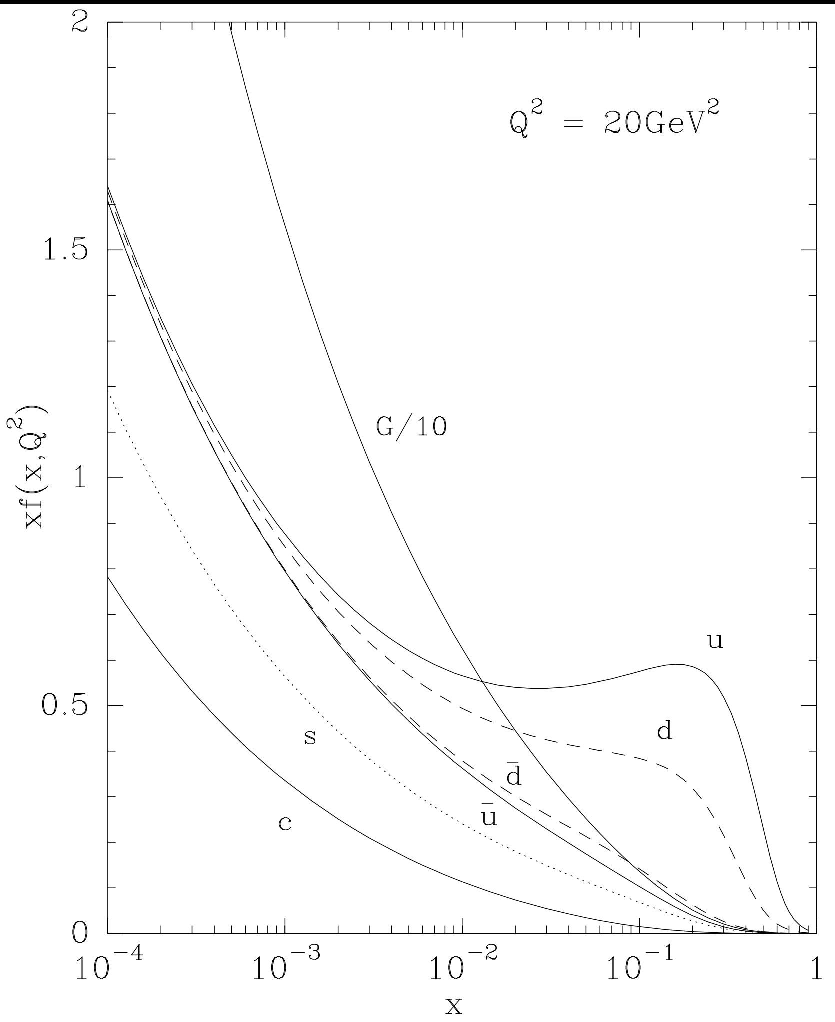
$$u - \bar{u} = 2, \quad d - \bar{d} = 1$$

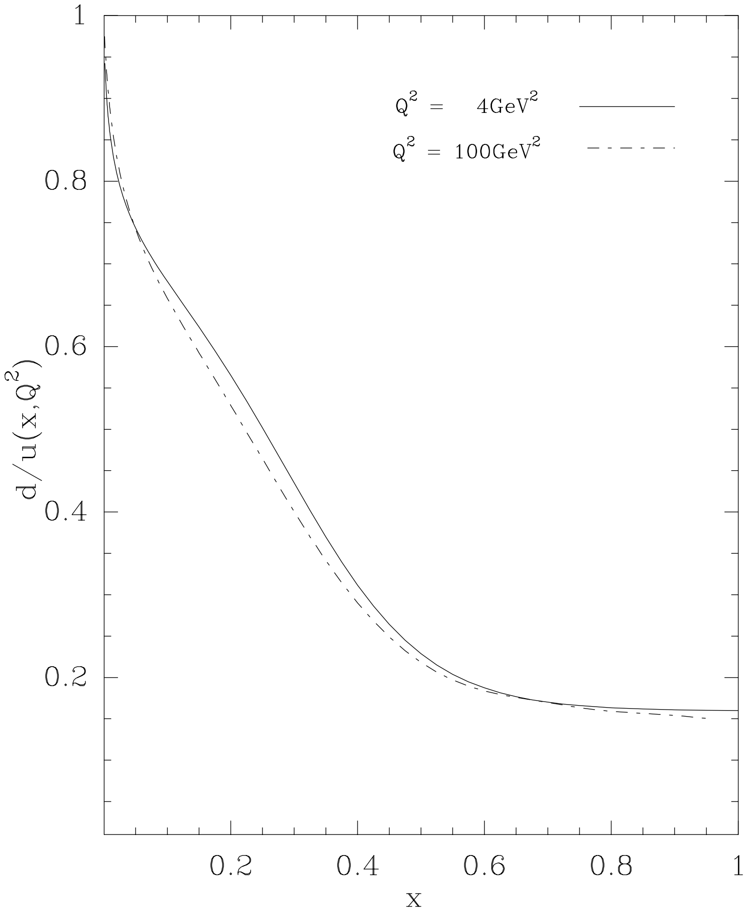
and the momentum sum rule.

Pol. Light quarks distri. (vs. x)



PDF (vs. x) and d/u ratio: 3 regions

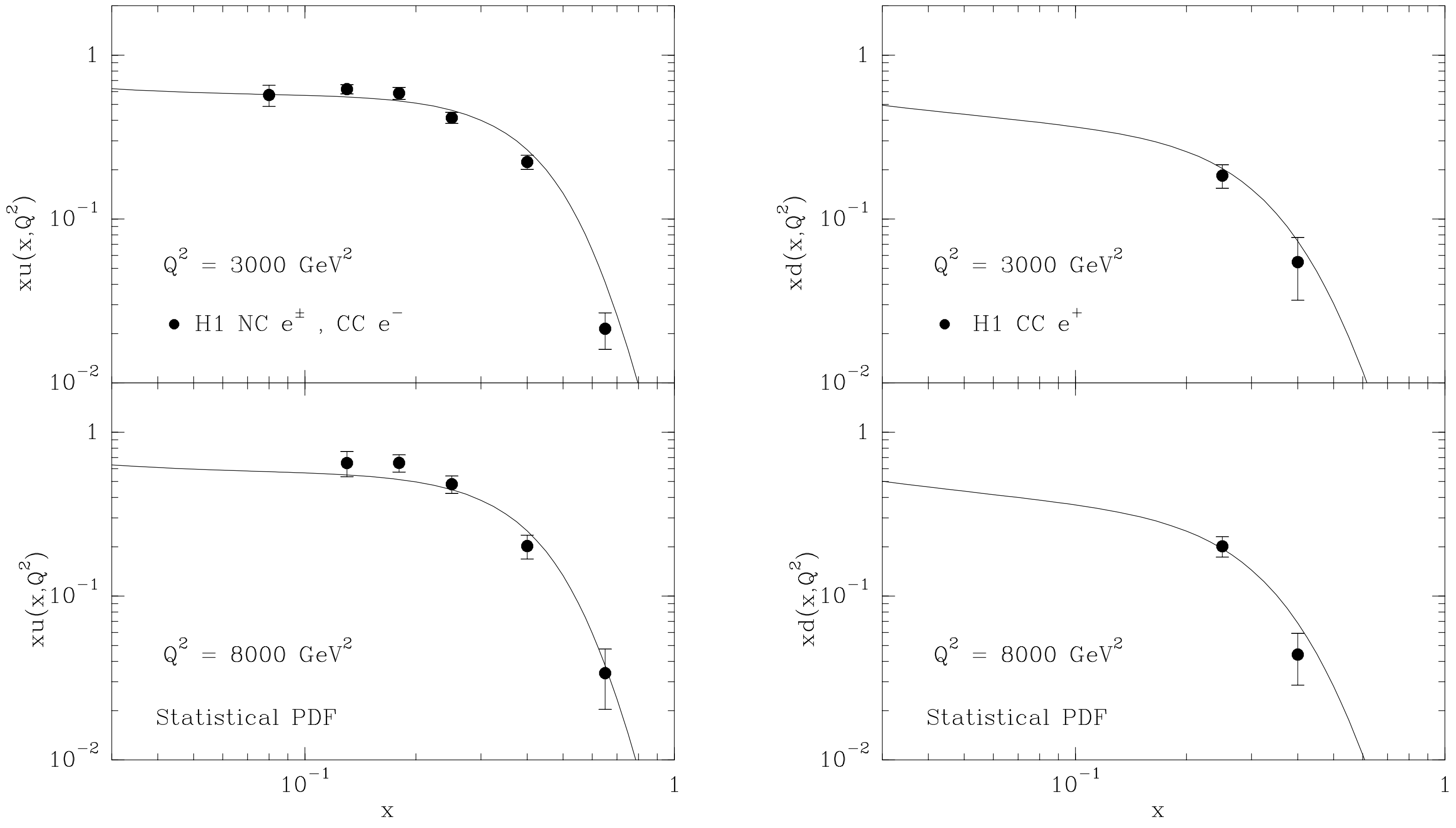




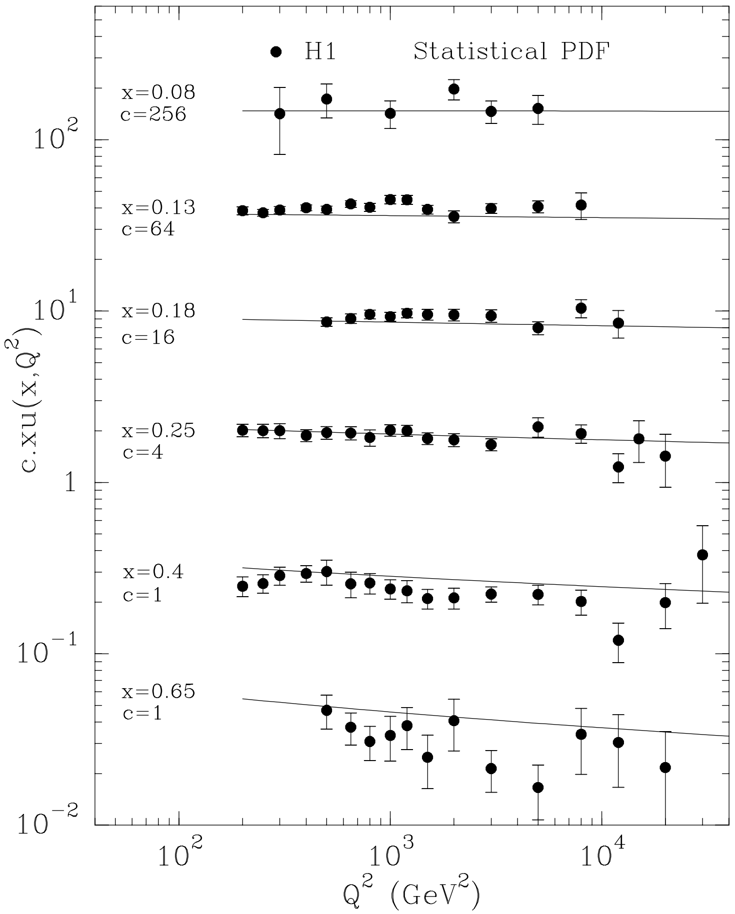
Predictions tested against new data

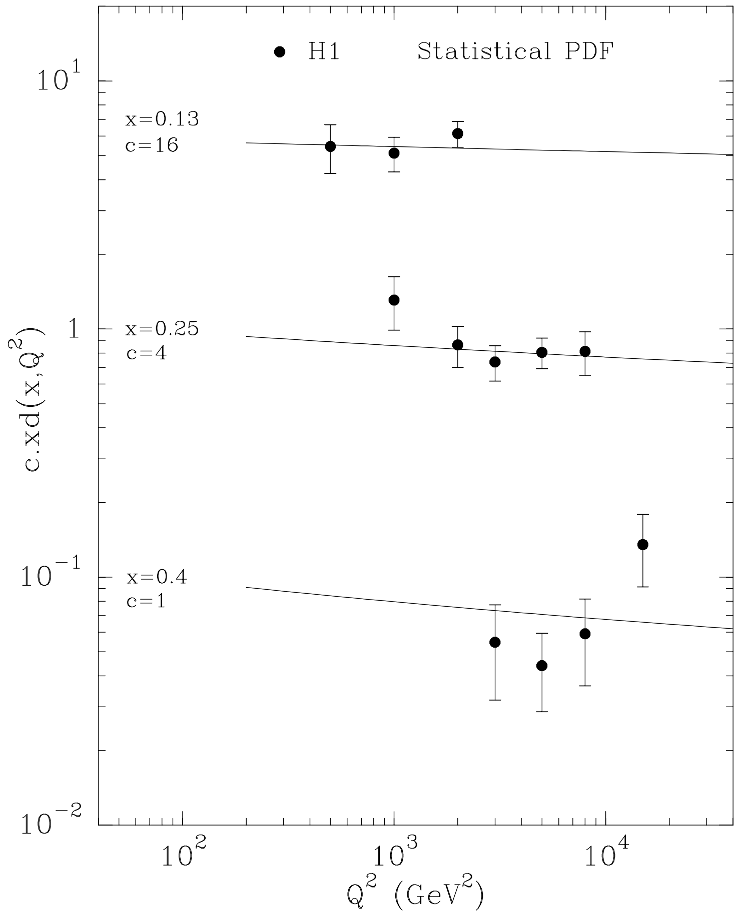
- Deep Inelastic Scattering
- Hadronic Collisions

Light quarks distributions (vs. x)

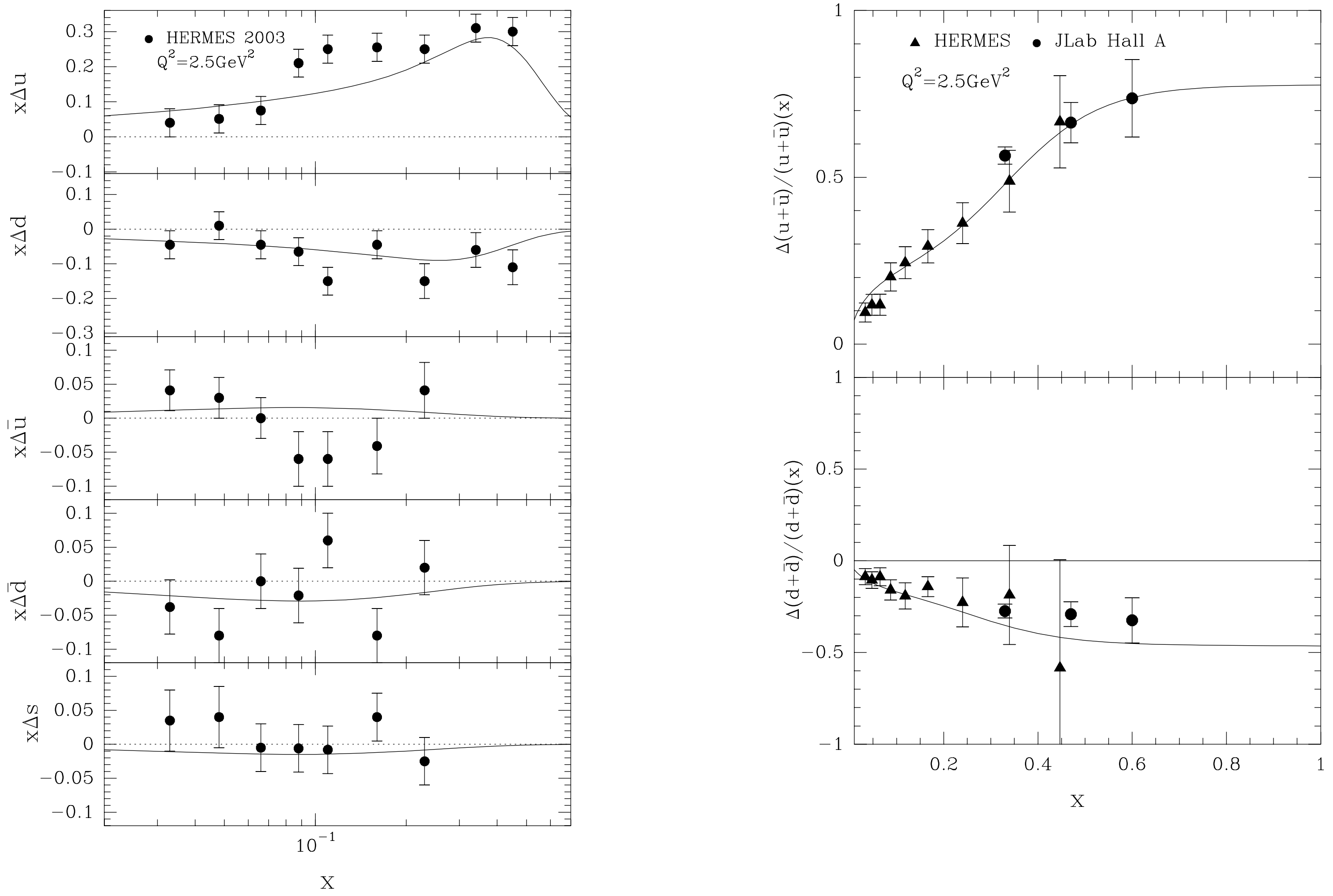


Light quarks distribu. (vs. Q^2)

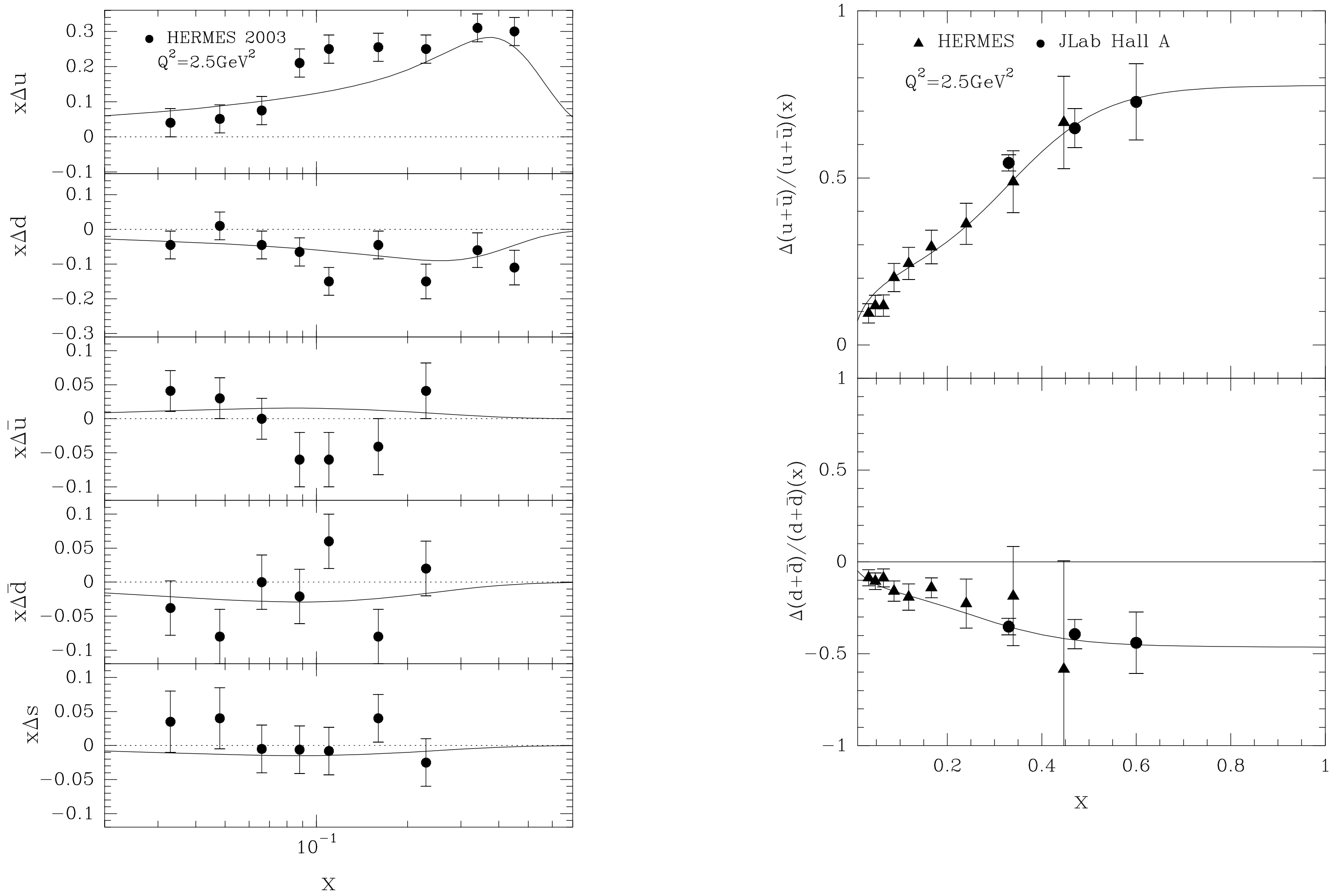




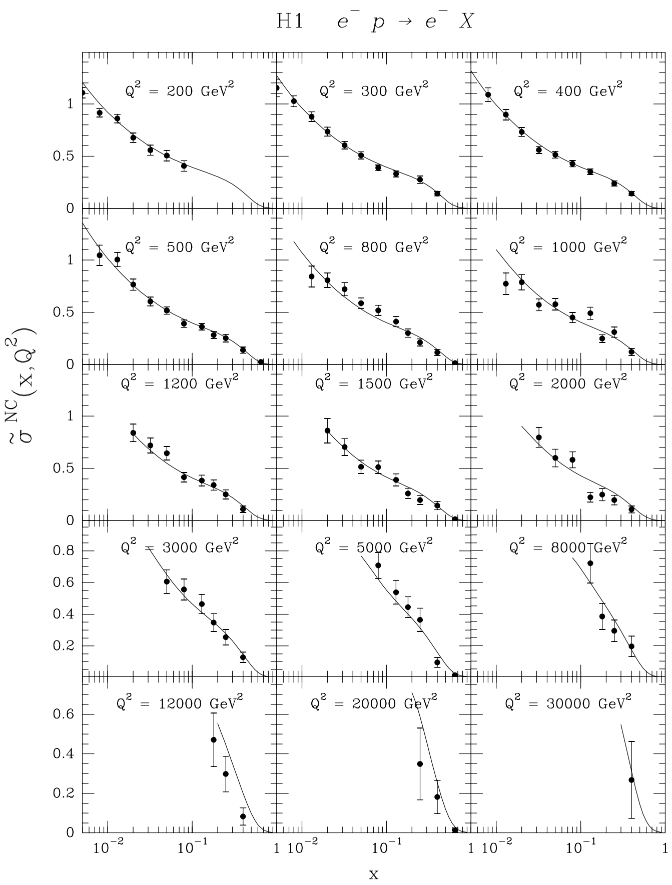
Polarized quarks distributions

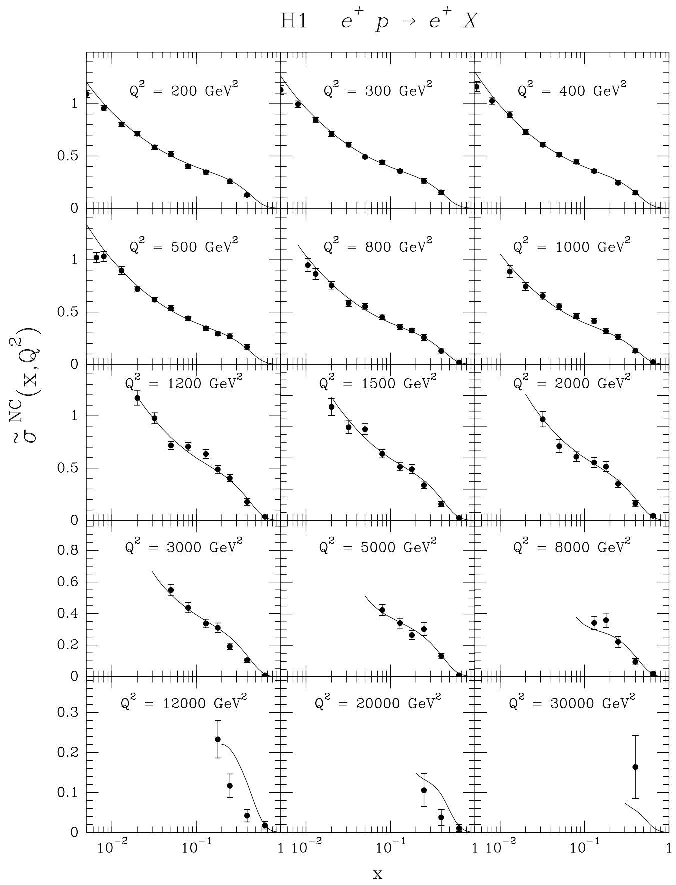


but final data move down!!!

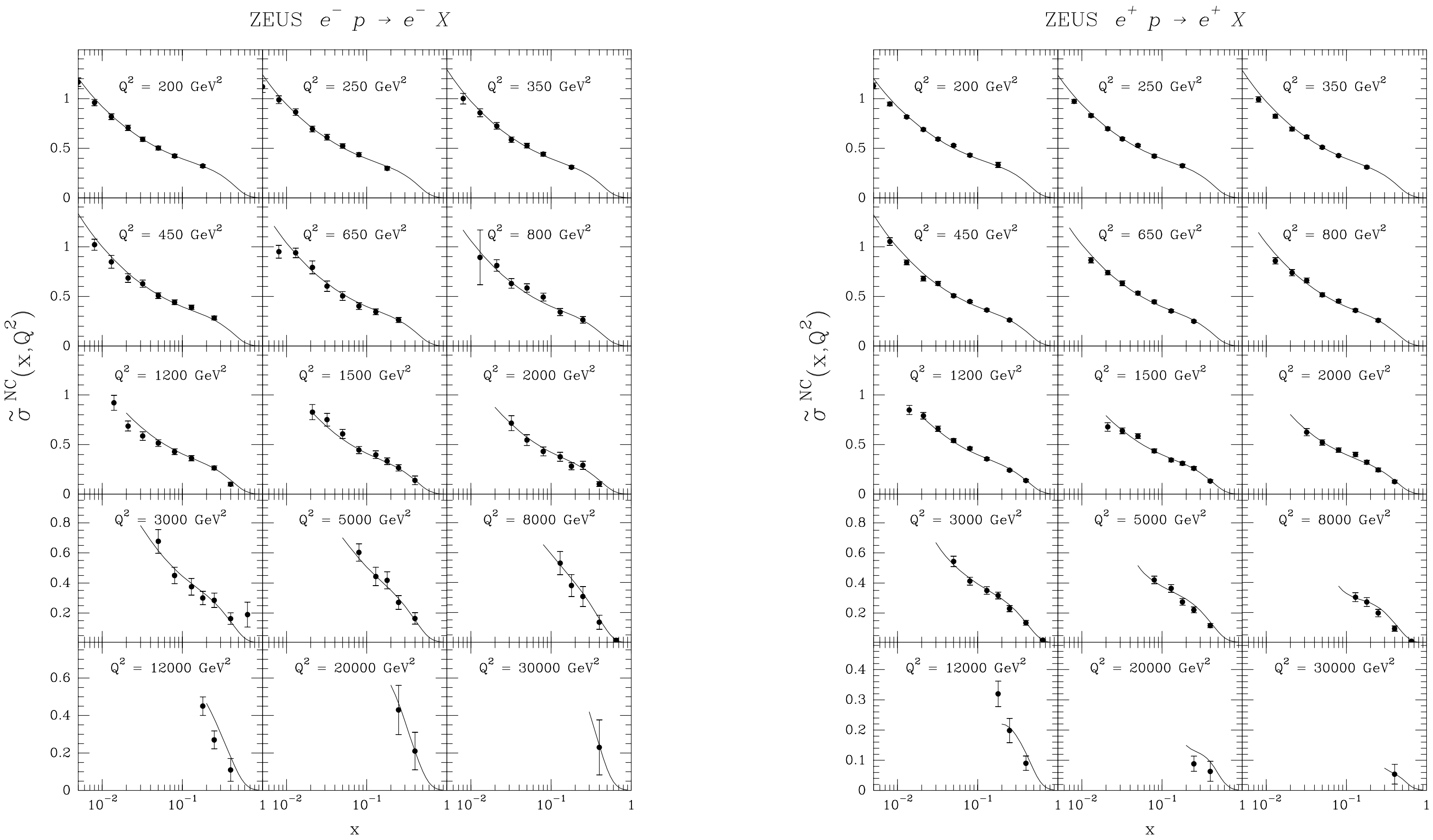


Neutral current in $e^{\pm}p$ collisions (H1)

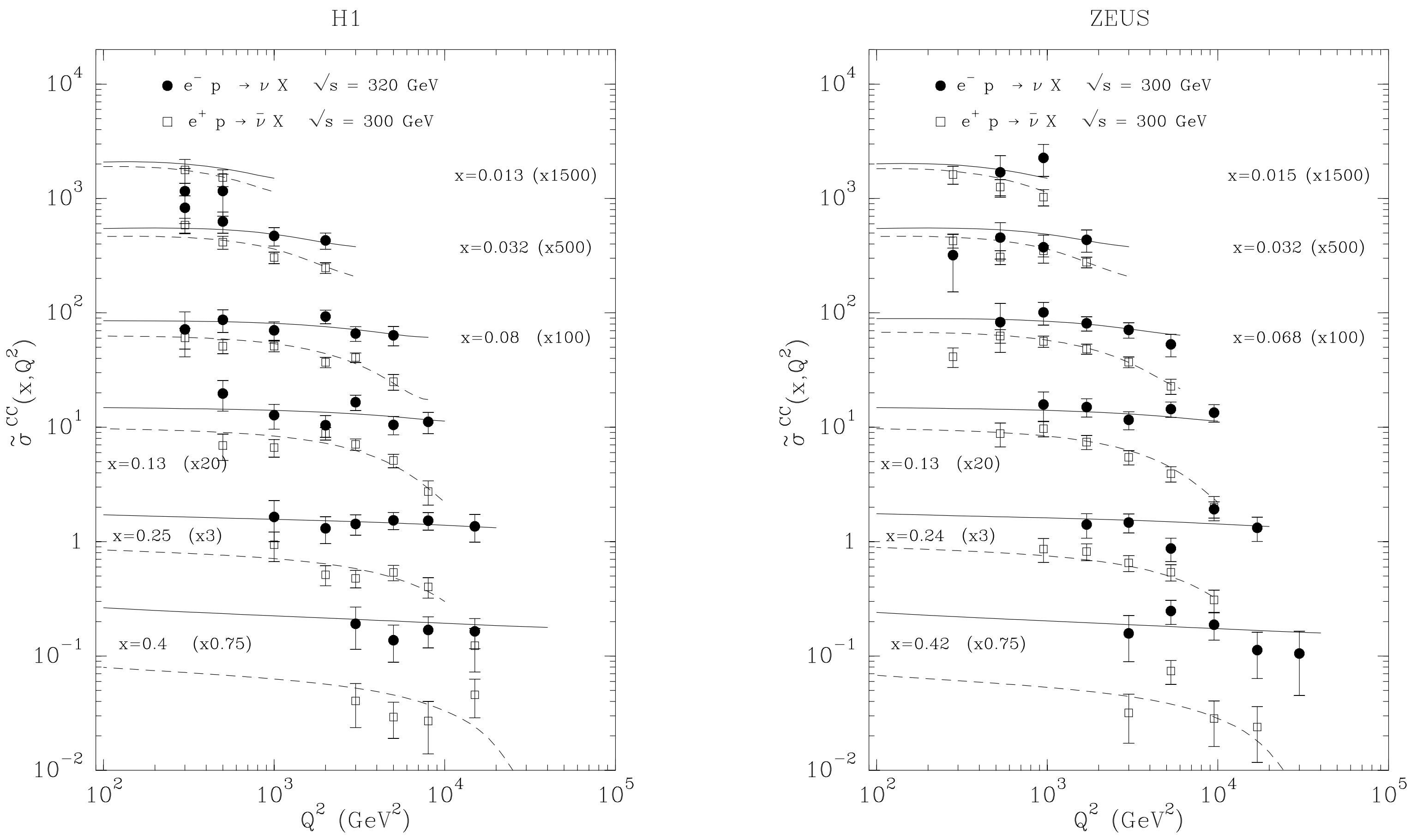




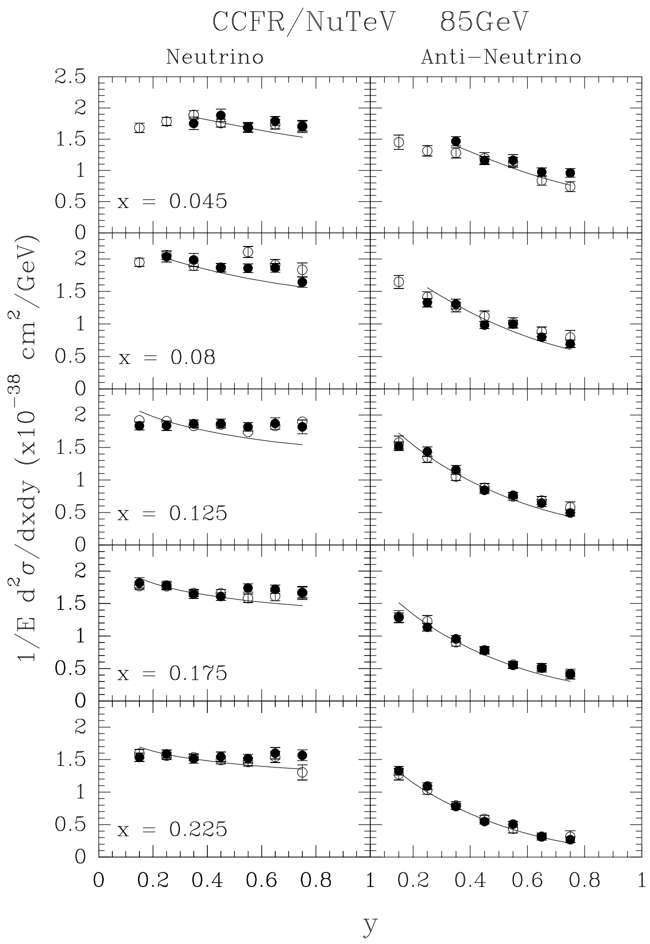
Neut. current in $e^{\pm}p$ collisions(ZEUS)

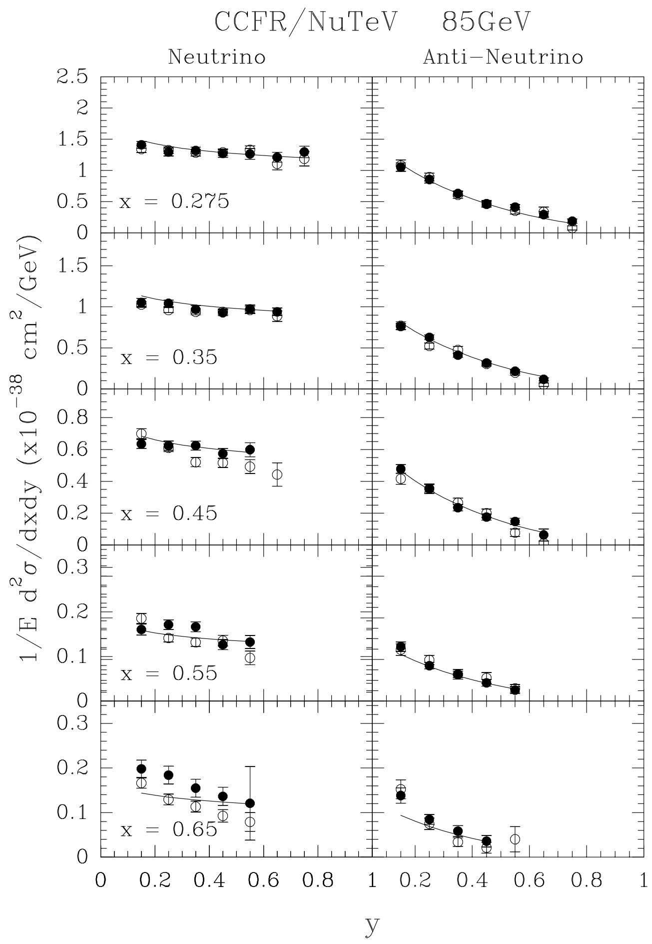


Charged current in $e^{\pm}p$ collisions

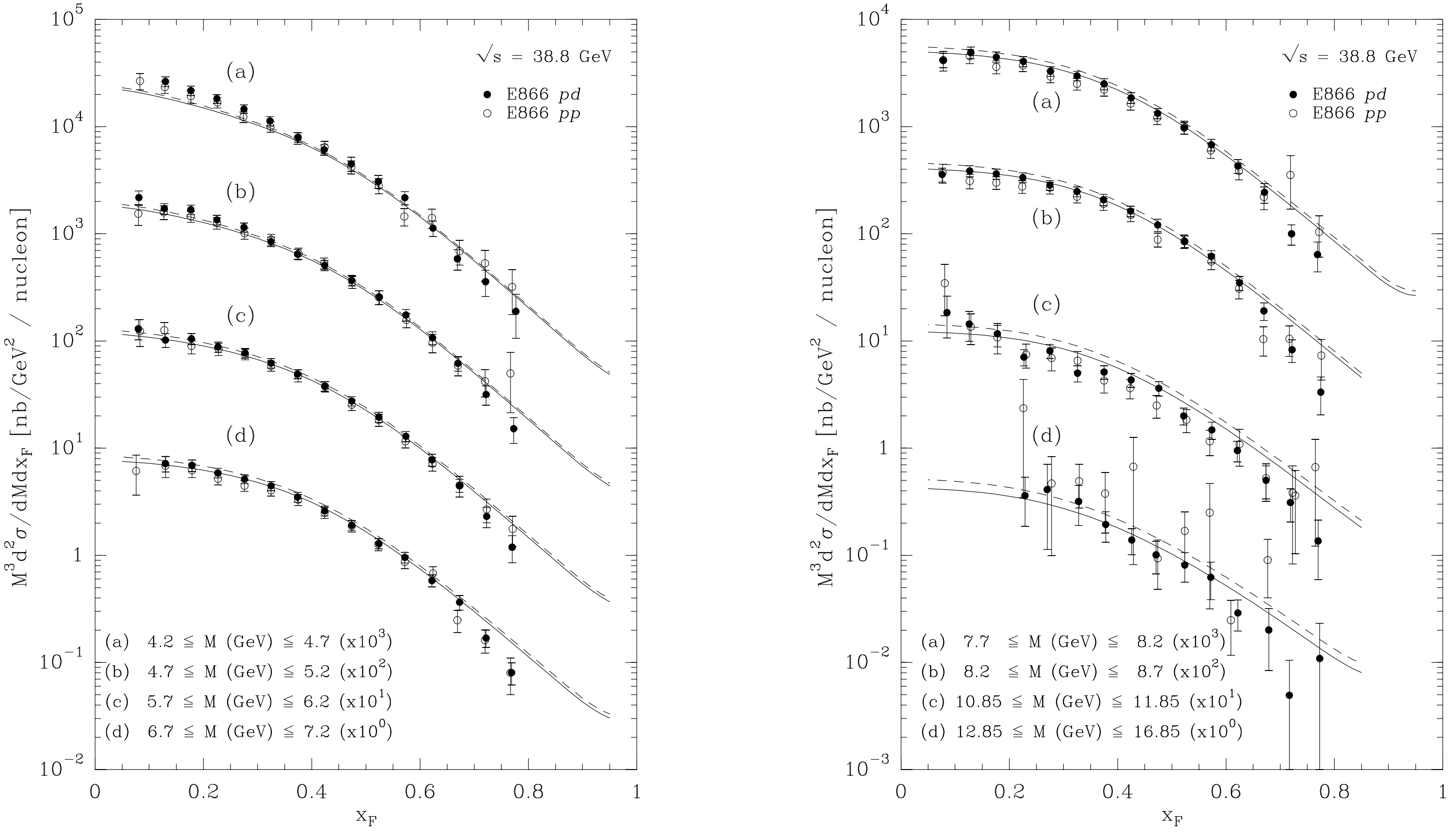


Charged current neutrino c. sections

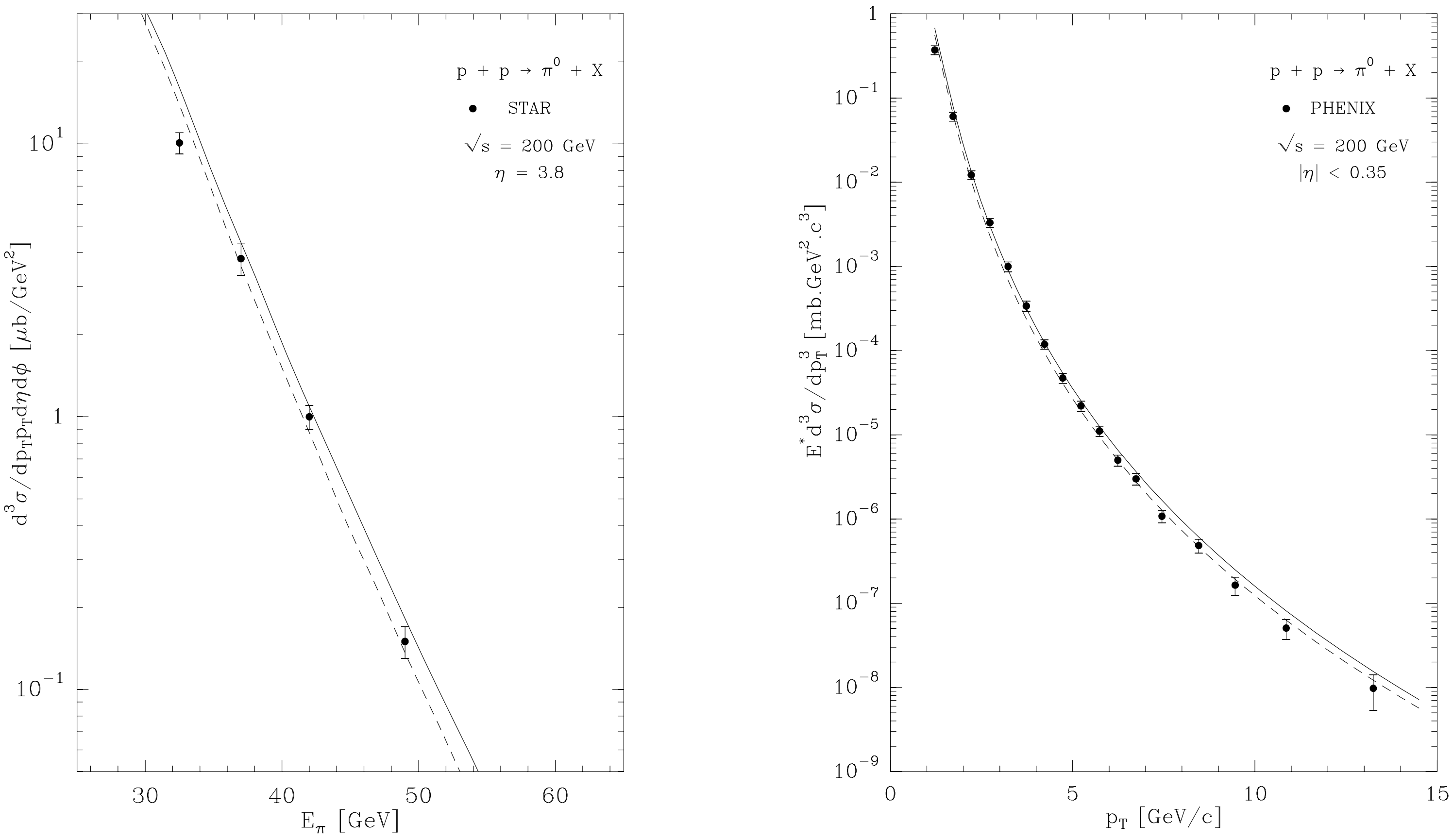




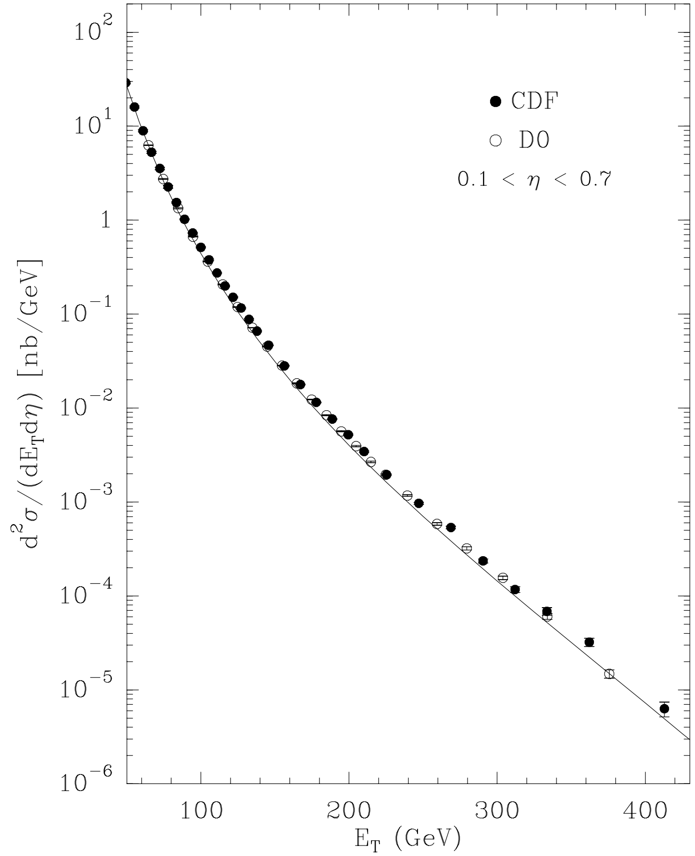
Drell-Yan processes



Inclusive π^0 production in pp collisions



Single-jet production in $\bar{p}p$ collisions



Conclusions and Future

- A new set of PDF is constructed in the framework of a statistical approach of the nucleon
- All unpolarized and polarized distributions depend upon eight free parameters
- New tests against experimental (unpolarized and polarized) data are very satisfactory
- Special features need to be confirmed
- Extension to p_T dependance (see F. Buccella talk)