

# Sea quark asymmetries in the nucleon

## A physical model for parton distributions in hadrons

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May 19, 2004

The asymmetries of the nucleon is of special interest since experiments indicate **several asymmetries that are not yet fully understood**:

- The  $\bar{d} - \bar{u}$  asymmetry in the proton sea
- The  $W^+ - W^-$  asymmetry in  $p - \bar{p}$  scattering
- The NuTeV anomaly and possible  $s - \bar{s}$  asymmetry

I will focus on the first and third of these.

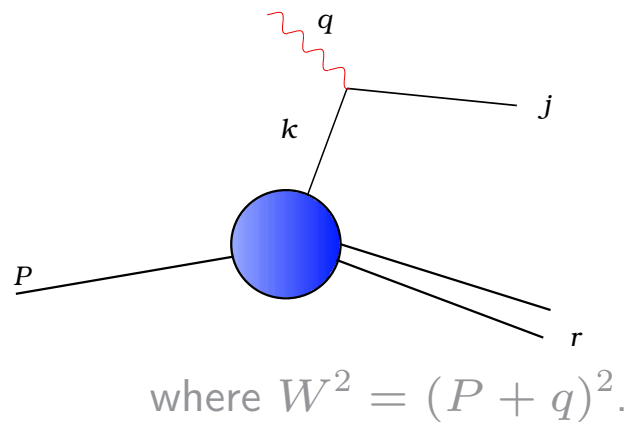
## Working scheme

We want to get a handle on the  $s - \bar{s}$  asymmetry, that can't as yet be probed directly by experiments. This is how we have done it:

- Start from a **reasonably simple, physical model** of the nucleon parton densities that **naturally gives asymmetries in the parton sea**.
- **Fit the model** to available data.
- Make sure the model **correctly describes other asymmetries**.
- Read off the  $s - \bar{s}$  asymmetry.

# A physical model for parton density functions

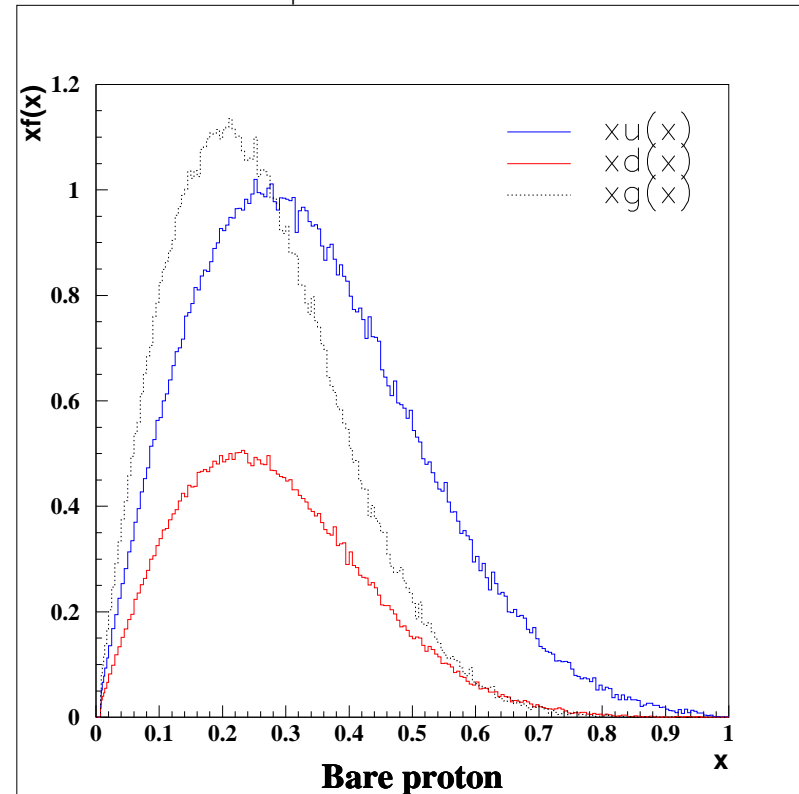
To get the valence distributions, we assume **Gaussian fluctuations** ( $k^\mu \in N(0, \sigma_i)$ ) in the momenta of partons in the rest frame of the hadron and add kinematic constraints:



$$0 < j^2 < W^2$$

$$r^2 > 0$$

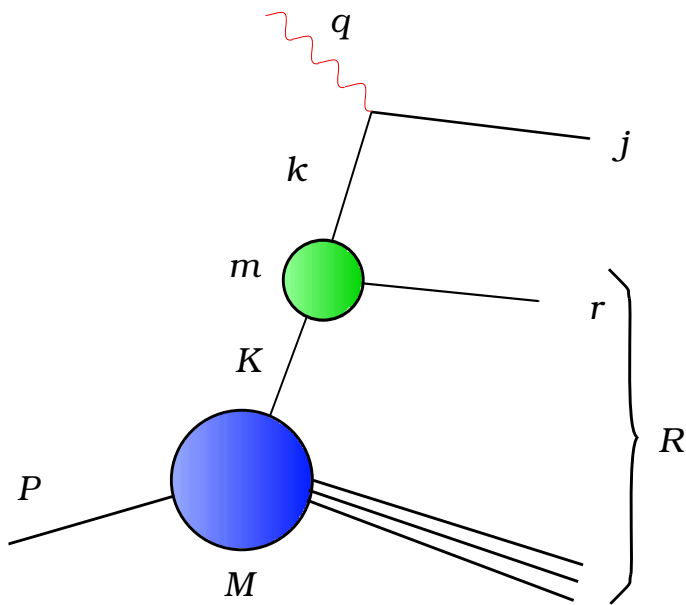
Monte Carlo-simulating using  $x = \frac{k_+}{P_+}$  gives



# Hadronic fluctuations

To get sea partons we assume **hadronic fluctuations** of the nucleon, *i.e.* a sum of quantum states:

$$|p\rangle = \alpha_0|p_0\rangle + \alpha_{p\pi^0}|p_0\pi^0\rangle + \alpha_{n\pi^+}|n\pi^+\rangle + \dots + \alpha_{\Lambda K}| \Lambda K^+\rangle + \dots$$



**Gaussian momentum distributions** for the meson and baryon in the distribution. The probe is interacting with a **parton in the hadronic fluctuation**.

$$x_f = \frac{K_+}{(K + K_{\text{partner}})_+}$$

$$x_i = \frac{k_+}{K_+}$$

$$x = x_f \cdot x_i$$

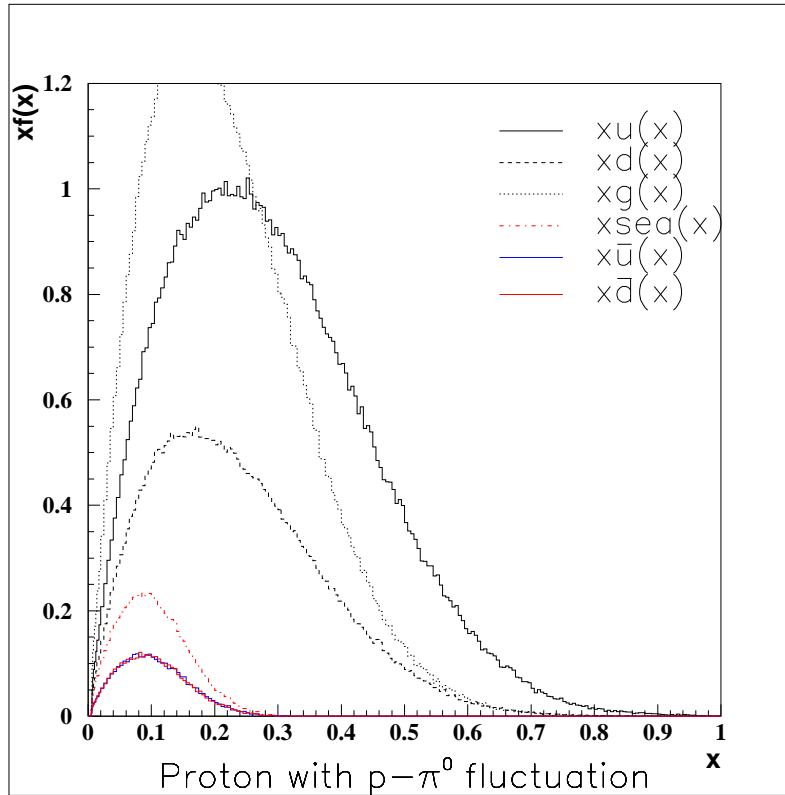
Kinematic constraints (*f* means “fluctuation”):

$$0 < j^2 < x_f W^2$$

$$r^2 > 0, R^2 > 0$$

## Hadronic fluctuations, contd.

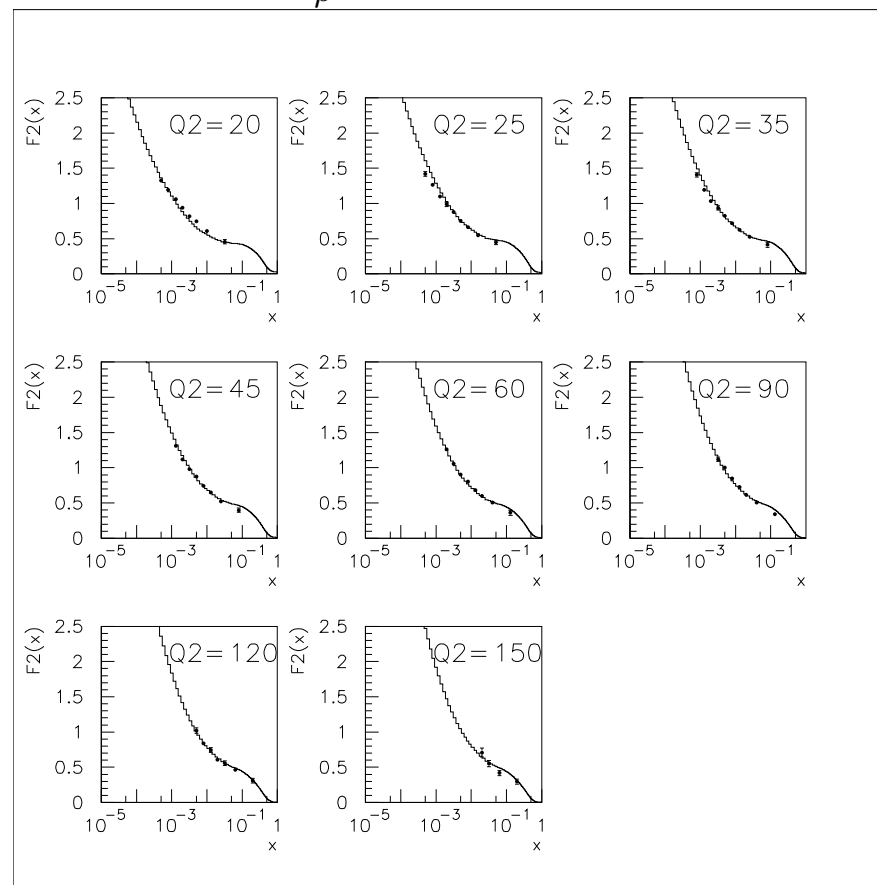
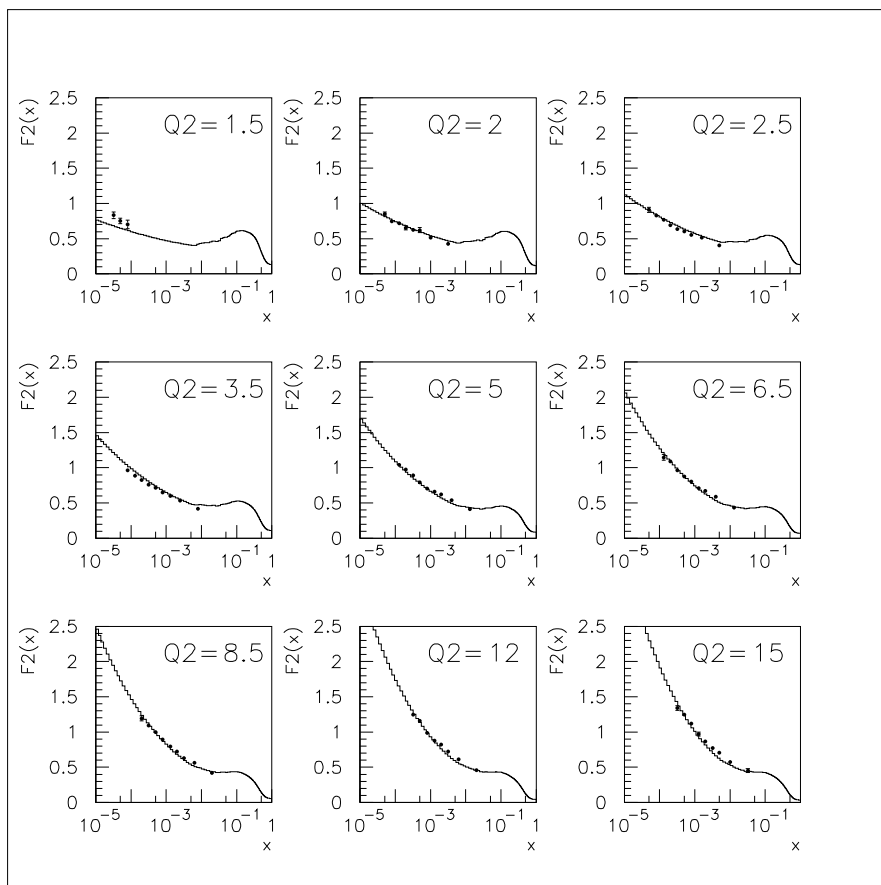
The resulting sea distribution using the dominant  $|p_0\pi^0\rangle$  fluctuation:



## Fit to HERA $F_2$ data

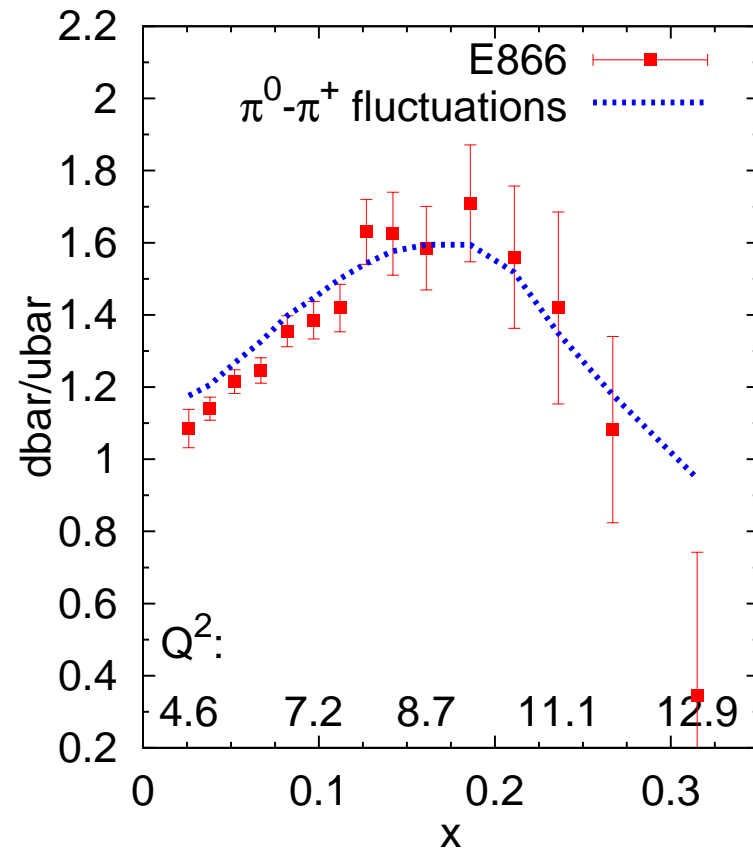
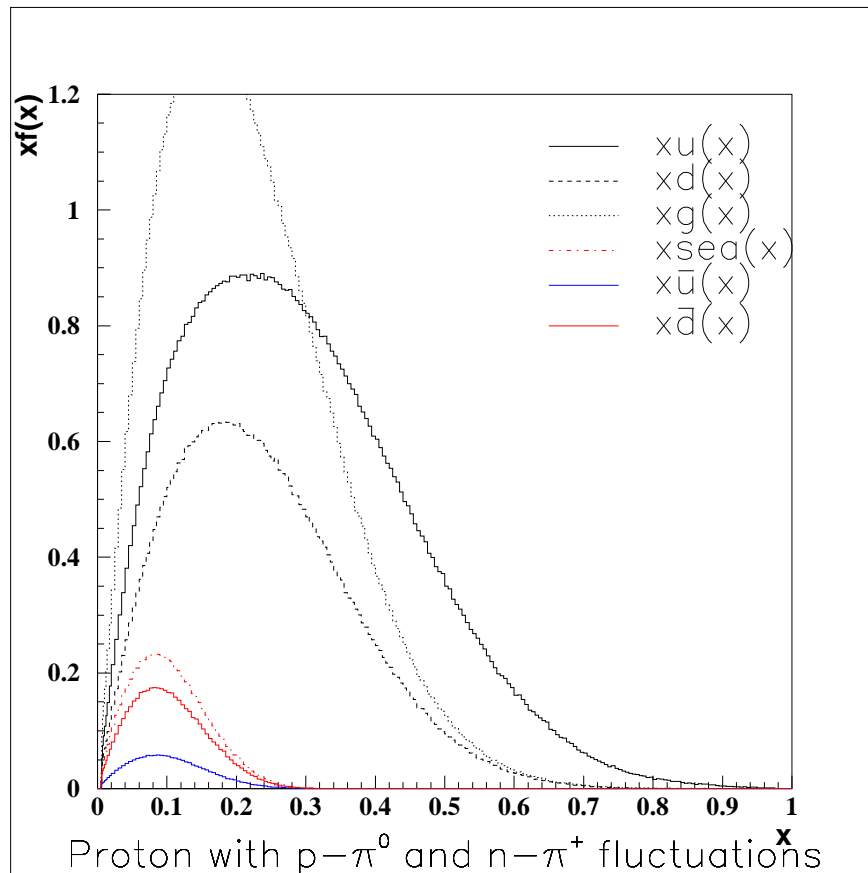
$$Q_0 = 0.8 \text{ GeV}, \sigma_u = 180 \text{ MeV}, \sigma_d = 150 \text{ MeV}, \sigma_g = 135 \text{ MeV},$$

$$\sigma_f = 58 \text{ MeV}, \alpha^2 = 0.0933, \frac{A}{\pi f_\rho^2} = 1.05$$



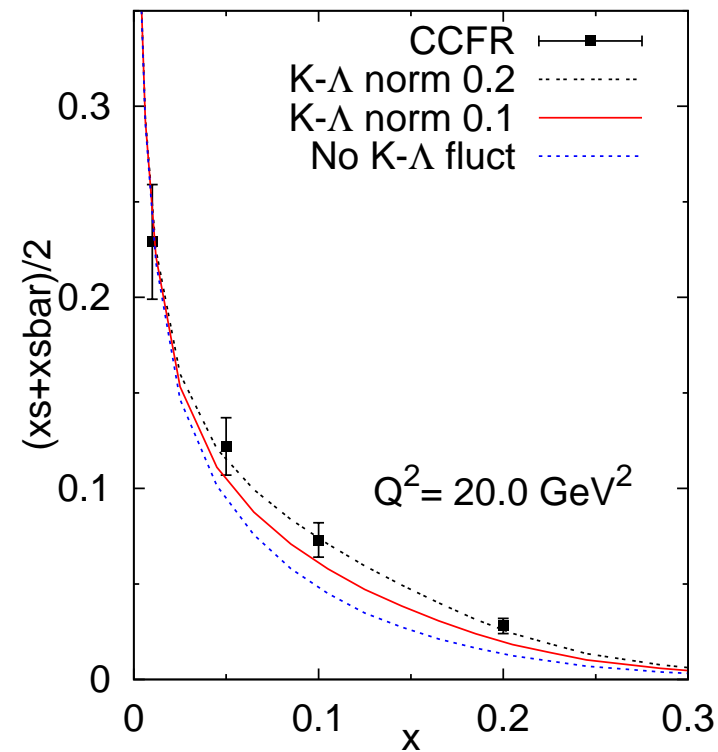
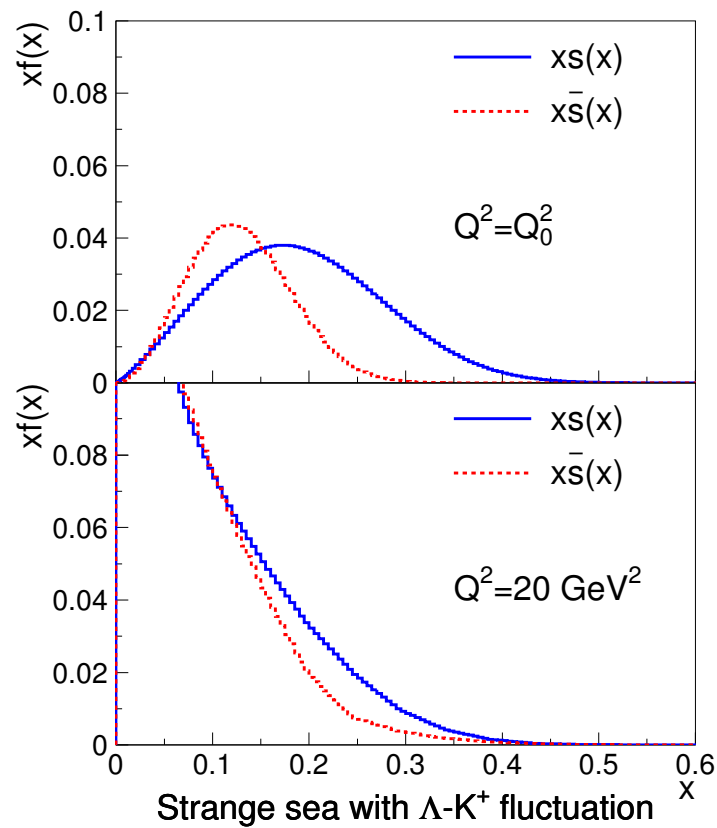
## The $\bar{u} - \bar{d}$ asymmetry

We naturally get a difference between  $\bar{u}(x)$  and  $\bar{d}(x)$  at intermediate  $x$  when using both  $|p\pi^0\rangle$  and  $|n\pi^+\rangle$  fluctuations, since  $\pi^+$  has only  $\bar{d}$  (no  $\bar{u}$ ) and there is no light fluctuation to  $\pi^-$ :



## The $s - \bar{s}$ asymmetry

The strange fluctuations, *e.g.*  $|\Lambda K^+\rangle$  gives an **asymmetry between  $s$  and  $\bar{s}$** , since  $s$  is always in the baryon and thus **at higher  $x$  than the  $\bar{s}$**  in the meson:



Fit to  
CCFR data  
 $\downarrow$   
 $s/\bar{u}$  ratio in  
accordance with  
fragmentation  
parameters

## The NuTeV anomaly

NuTeV measured the ratio of neutral to charged current interactions in  $\nu - N$  scattering, resulting in a value of the Standard Model  $\sin^2 \theta_W$  which **differs from previous fits** using other interactions by  $3\sigma$ :

$$\sin^2_{\text{NuTeV}} \theta_W = 0.2277 \pm 0.0016 \text{ while } \sin^2_{\text{SM}} \theta_W = 0.2227 \pm 0.0004$$

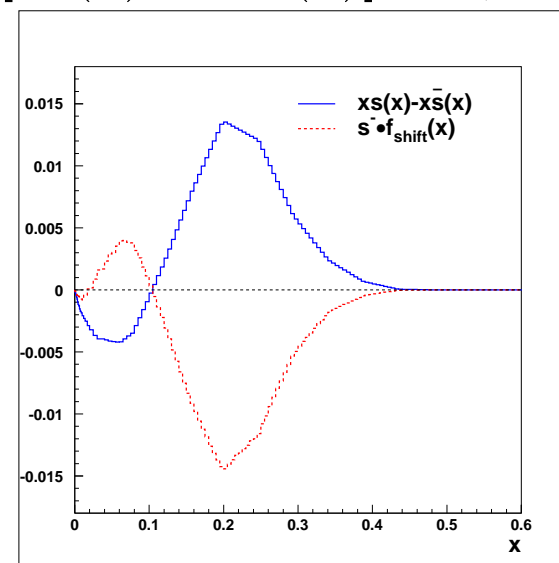
One of the explanations within the SM proposed is that  $s(x)$  and  $\bar{s}(x)$  in the nucleon are **different in shape**:  $s^- = \int_0^1 [xs(x) - x\bar{s}(x)]dx \neq 0$

The NuTeV collaboration has published a function which, folded with  $s^-$ , gives the effect on  $\sin^2 \theta_W$ .

With our model:

$$\Delta \sin^2 \theta_W = -0.0018$$

*i.e.* the **discrepancy is reduced to  $1.9\sigma$** .



# Conclusions

- We have a **physical model** for the  $x$ -shape of parton distribution functions in hadrons.
- We get a  $\bar{u} - \bar{d}$  **asymmetry** at intermediate  $x$ , in agreement with data.
- The model predicts a  $s - \bar{s}$  **asymmetry** sufficient to reduce the NuTeV anomaly **below  $2\sigma$** .