Determination of the Flavor Asymmetry of the Light Quark Sea from Unpolarized Deep Inelastic Scattering at HERMES

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HERMES Collaboration

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- **HERMES experiment**
- **Sea flavor asymmetry from semi-DIS**
- **Fragmentation functions**
- **Sea asymmetry results and conclusions**

The Flavor Asymmetry of the Light Quark Sea

- **light sea quarks from perturbative gluon splitting in the nucleon should be flavor symmetric i.e. as many $u\overline{u}$ pairs as $d\overline{d}$ pairs, *except* for**
  - **Pauli blocking by valence quarks? [F& F, '77].**
  - **pion clouds? (proton emits more $\pi^+ = u\overline{d}$) [AWT, '83]**
  - **anti-symmetrization with valence quarks?**
- **little experimental evidence until...**
- **Gottfried Sum Rule violation indicates a flavor asymmetry:**

$$S_G = \int_0^1 \left(F_2^p(x) - F_2^n(x)\right) \frac{dx}{x}$$

$$S_G = \frac{1}{3}\int_0^1 (u_v(x) - d_v(x))dx - \frac{2}{3}\int_0^1 (\overline{d}(x) - \overline{u}(x))dx = \frac{1}{3}$$

NMC ('91): $S_G = 0.235 \pm 0.026 \neq \frac{1}{3}$

- **now new conclusive data:**
  Drell-Yan and semi-inclusive DIS...

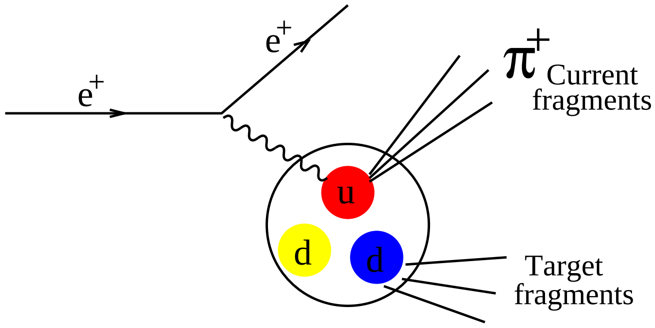
Sea Flavor Asymmetry from DIS

- **Semi-inclusive DIS on a source of protons (hydrogen) and neutrons (deuterium)**
- **flavour-tag the struck quark via identified π^+ and π^-**

$4 < p_\pi <$ **14 GeV/c**

$z = \frac{E_\pi}{E_{\gamma^*}} > 0.2$

$x_F > 0.25$



- **measure 4 semi-inclusive DIS yields:**

$N_p^{\pi^-}(x,z), N_n^{\pi^-}(x,z), N_p^{\pi^+}(x,z), N_n^{\pi^+}(x,z)$

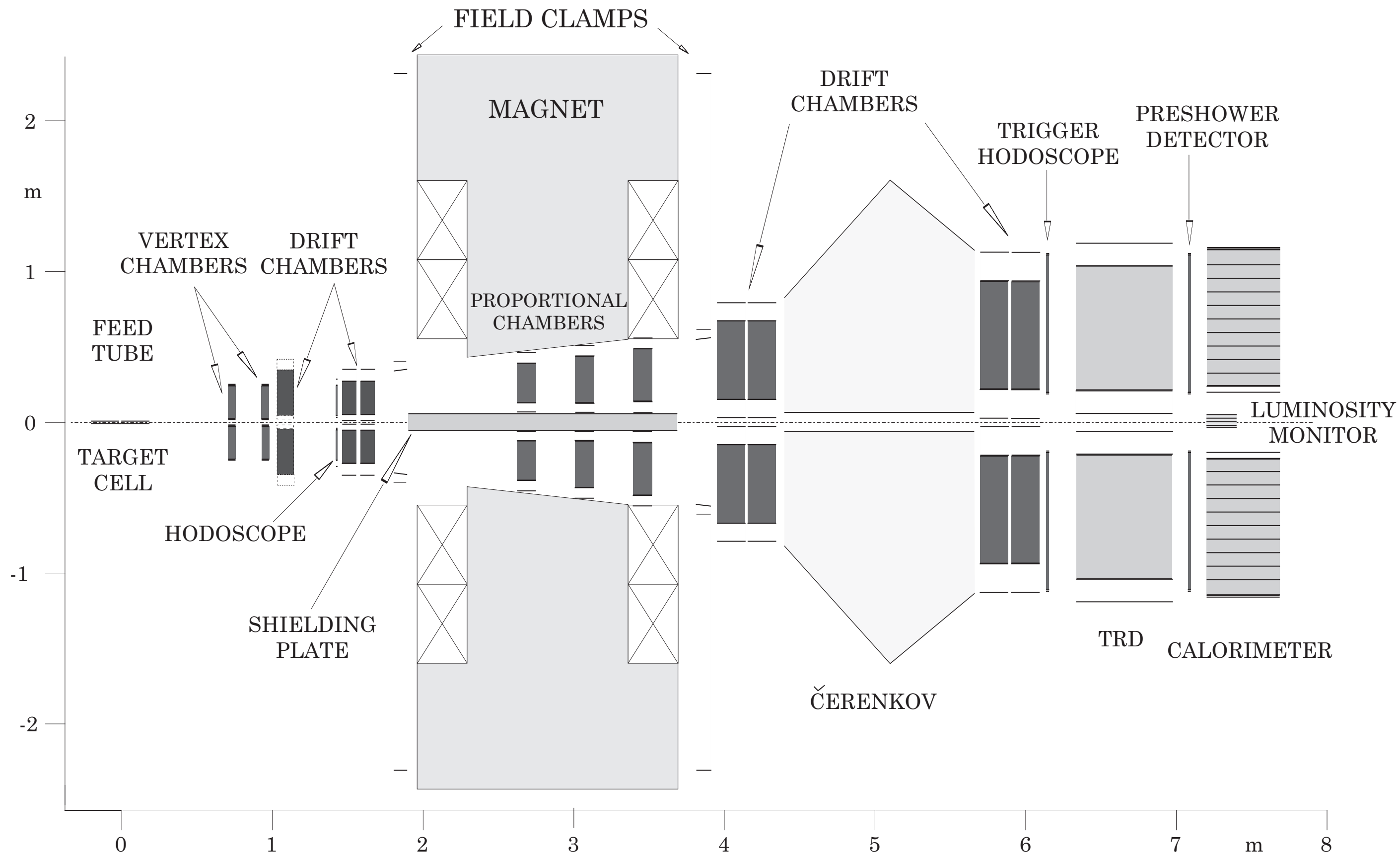
- **solve for unknown sea quark distributions (isospin symmetry $\rightarrow$**

$\overline{u}_p = \overline{d}_n, \overline{d}_p = \overline{u}_n \quad (\& \ s_p = \overline{s}_p = s_n = \overline{s}_n)$

- **use symmetry of the problem to limit the analysis to the light quark sector, and reduce sensitivity to experimental systematics.**

The HERMES experiment

- A deep-inelastic experiment at DESY
- Open-ended target cell internal to HERA e^+ storage ring: polarized and unpolarized gaseous targets, allowing rapid cycling
- Forward spectrometer detects both the scattered DIS e^+ and hadrons (identified pions) in coincidence



In quark parton model, pion yields are:

$$N^{\pi}(x,z) \propto \sum_f e_f^2 q_f(x) D_f^{\pi}(z)$$

Assumptions used:

- **factorization**
- **isospin symmetry:** $u_p = d_n$
- **strange sea the same in proton and neutron**
- **fragmentation functions:**
  - **favoured:**
    $D^+ \equiv D_u^{\pi^+} = D_d^{\pi^-} = D_{\overline{u}}^{\pi^-} = D_{\overline{d}}^{\pi^+}$
  - **disfavored:**
    $D^- \equiv D_d^{\pi^+} = D_u^{\pi^-} = D_{\overline{d}}^{\pi^-} = D_{\overline{u}}^{\pi^+}$

$$N_p^{\pi^\pm}(x,z) - N_n^{\pi^\pm}(x,z) =$$

$$\frac{4}{9}(u-d)D^+ + \frac{4}{9}(\overline{u}-\overline{d})D^- + \frac{1}{9}(d-u)D^- + \frac{1}{9}(\overline{d}-\overline{u})D^+$$

The strange sea conveniently cancels out.

Extraction of the Fragmentation Functions

For hydrogen target:

$$2F_1^{\mathrm{H}}(x,Q^2) = \sum_f e_f^2 q_f(x,Q^2)$$

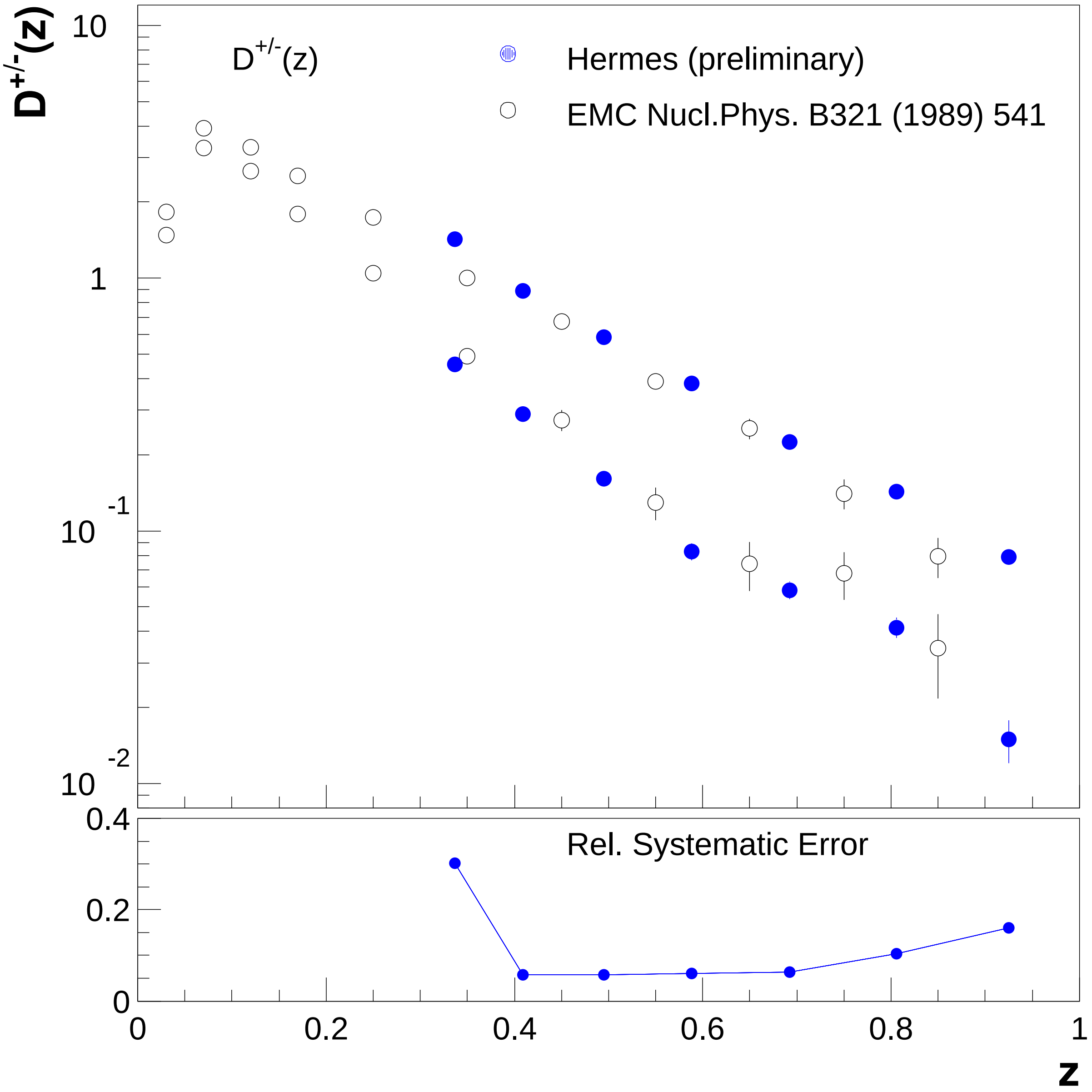
$$F_f^{\mathrm{H}} \equiv \frac{e_f^2 q_f(x,Q^2)}{2F_1^{\mathrm{H}}(x,Q^2)}$$

$$\frac{1}{N^{\mathrm{evts}}}\frac{dN^{\pi^+}}{dz} = (F_u^{\mathrm{H}} + F_{\bar{d}}^{\mathrm{H}})D^+ + (F_{\bar{u}}^{\mathrm{H}} + F_d^{\mathrm{H}} + F_s^{\mathrm{H}} + F_{\bar{s}}^{\mathrm{H}})D^-$$

$$\frac{1}{N^{\mathrm{evts}}}\frac{dN^{\pi^-}}{dz} = (F_{\bar{u}}^{\mathrm{H}} + F_d^{\mathrm{H}})D^+ + (F_u^{\mathrm{H}} + F_{\bar{d}}^{\mathrm{H}} + F_s^{\mathrm{H}} + F_{\bar{s}}^{\mathrm{H}})D^-$$

Taking F_f^{H} from published parameterizations, solve for D^+, D^-

Fragmentation Functions from HERMES



Extraction of the sea flavor asymmetry

Construct a pion ratio sensitive to the effects of a flavor asymmetric sea:

$$r(x,z) = \frac{N_p^{\pi^-}(x,z) - N_n^{\pi^-}(x,z)}{N_p^{\pi^+}(x,z) - N_n^{\pi^+}(x,z)}$$

Relating this pion ratio to parton distributions:

$$\frac{\overline{d}(x) - \overline{u}(x)}{u(x) - d(x)} = \frac{\frac{3}{5}\left(\frac{1+D'(z)}{1-D'(z)}\right)(1 - r(x,z)) - (1 + r(x,z))}{\frac{3}{5}\left(\frac{1+D'(z)}{1-D'(z)}\right)(1 - r(x,z)) + (1 + r(x,z))}$$

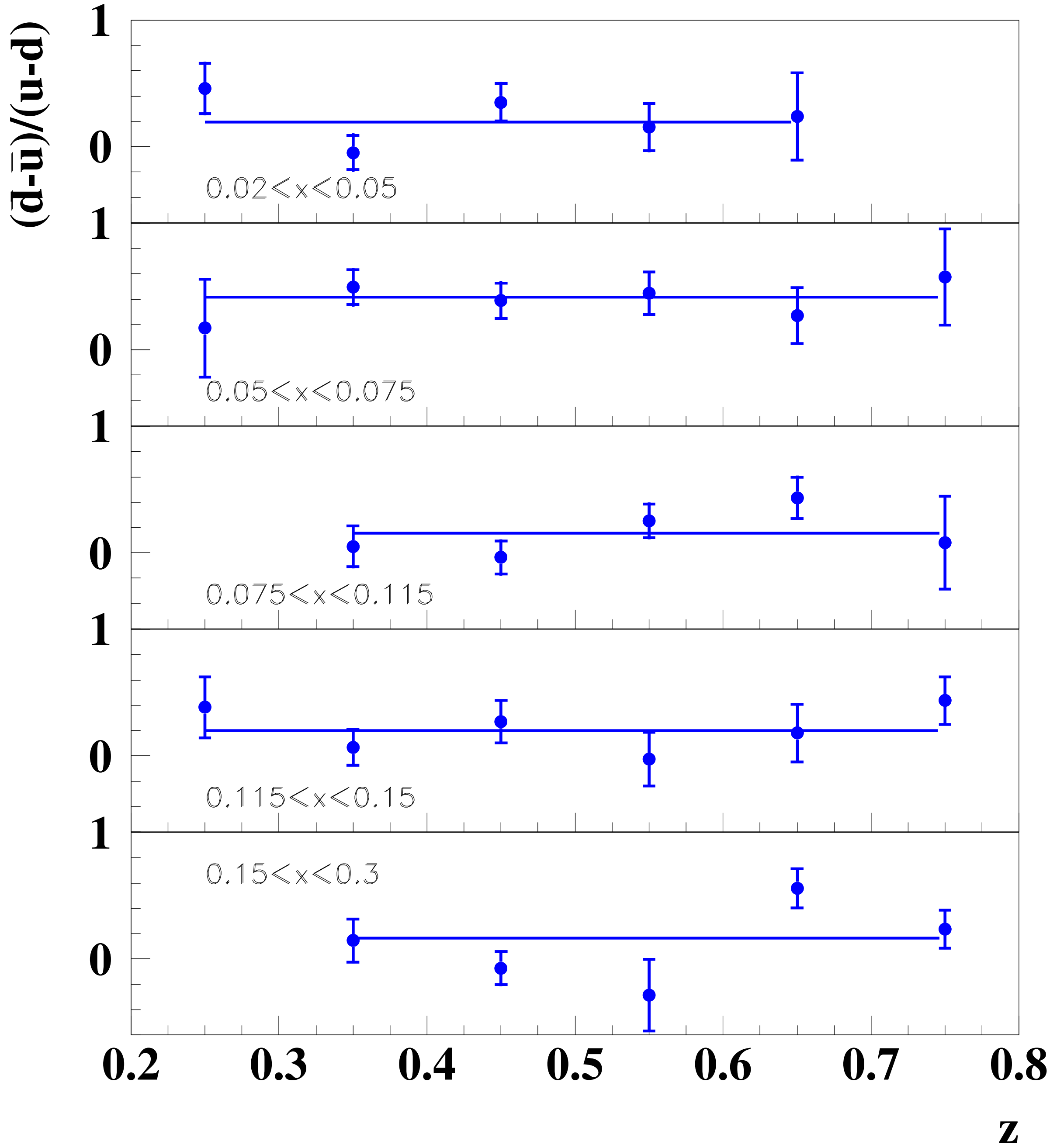
where $D'(z)$ is the ratio of the disfavored to favored fragmentation functions

$$D'(z) = D^-(z)/D^+(z)$$

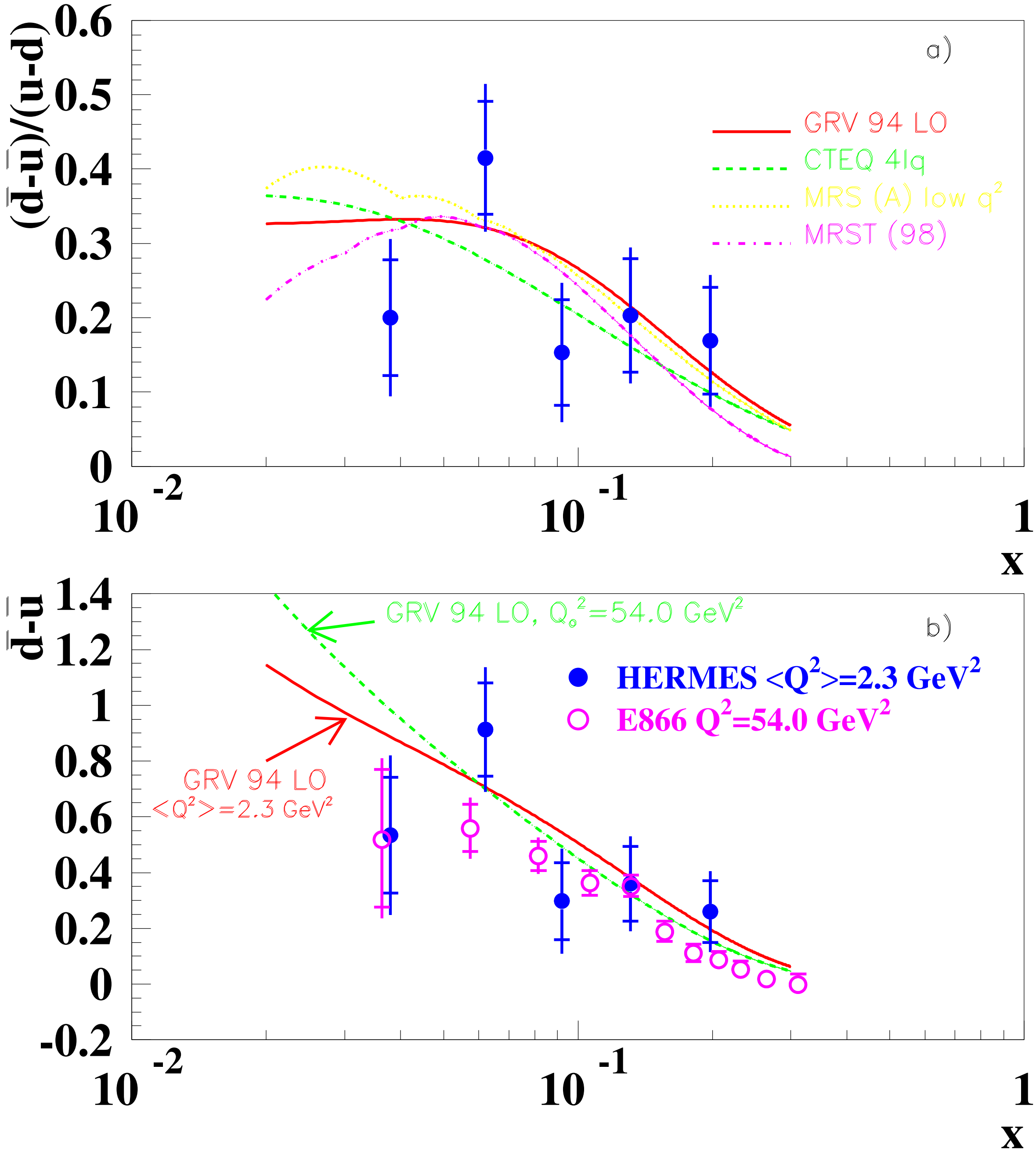
$\frac{\overline{d}(x)-\overline{u}(x)}{u(x)-d(x)}$, **hence RHS also, independent of z**

Present results based only on 1996 data sample → again as much data from 1997 to be analyzed.

Sea flavor asymmetry vs z



Sea flavor asymmetry vs x



$$\overline{d}(x) - \overline{u}(x) = \frac{\overline{d}(x) - \overline{u}(x)}{u(x) - d(x)} [u(x) - d(x)]_{GRV\ \ 94\ \ LO}$$

Comparing with other data

To compare to the NMC Gottfried Sum:

From present data:

$$\int_{0.02}^{0.3}(\overline{d}(x)-\overline{u}(x))dx = 0.107 \pm 0.018(\mathrm{stat}) \pm 0.015(\mathrm{sys})$$

$$(Q_o^2 = 2.5\ \mathbf{GeV}^2)$$

Extrapolating using GRV 94 LO: $\rightarrow$

$$\int_0^1(\overline{d}(x)-\overline{u}(x))dx = 0.16 \pm 0.03$$

(NMC result $= 0.147 \pm 0.039$**)**

Drell-Yan experiments determine $\overline{d}/\overline{u}$

E866 used $[\overline{d}+\overline{u}]_{CTEQ\ 4M}$ **to get** $\overline{d}-\overline{u}$**:**

$$\int_{0.02}^{0.345}(\overline{d}(x)-\overline{u}(x))dx = 0.068 \pm 0.007(\mathrm{stat}) \pm 0.008(\mathrm{sys})$$

$$(Q_o^2 = 54\ \mathbf{GeV}^2)$$

Extrapolating using CTEQ 4M: $\rightarrow$

$$\int_0^1(\overline{d}(x)-\overline{u}(x))dx = 0.100 \pm 0.007 \pm 0.017$$

Conclusions

- **a substantial fraction of NMC GSR deficit must come from a flavor asymmetry of the light quark sea**

- **Drell-Yan experiments measure $\overline{d}/\overline{u}$**
  Semi-inclusive DIS measures $\frac{\overline{d}-\overline{u}}{u-d}$
  $\rightarrow$ complementary

- **Drell-Yan and semi-DIS results are consistent, while Q^2 different by a factor of $\sim$20**
  $\rightarrow$ no unexpected evolution due to non-perturbative effects