Strange sea asymmetry results from NuTeV

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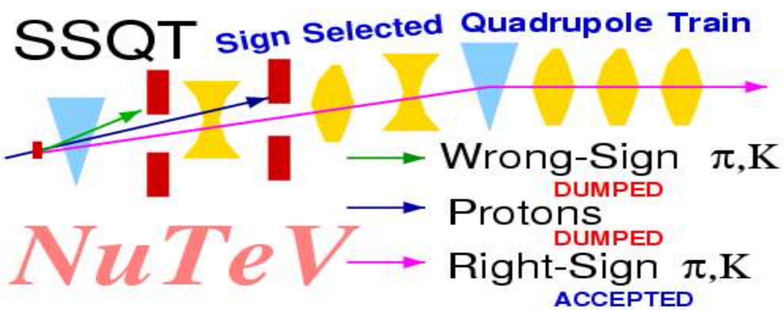
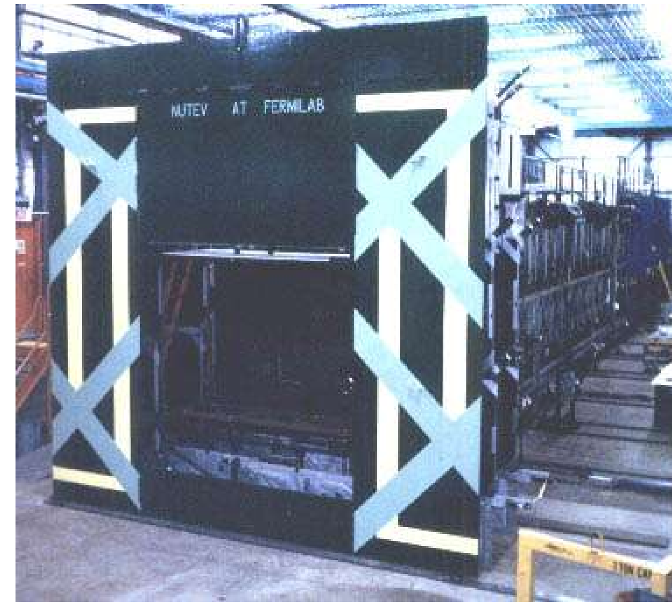
for the NuTeV Collaboration

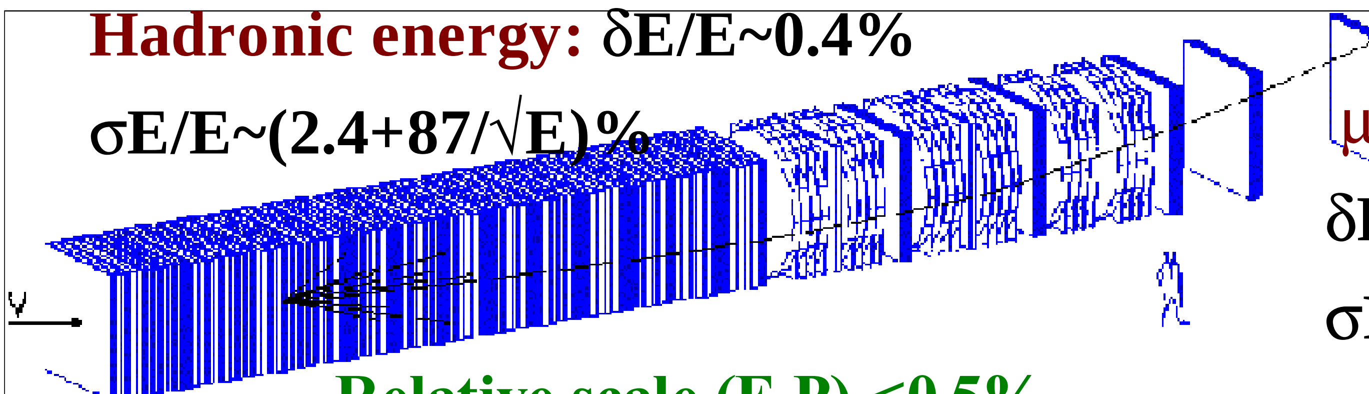
The NuTeV experiment at FNAL

ν-N DIS, sign-selected beam $\langle E_\nu \rangle \sim 120$ GeV
and continuous test beam calibration





Data taken during 1996-97



Hadronic energy: $\delta E/E \sim 0.4\%$

$\sigma E/E \sim (2.4+87/\sqrt{E})\%$

μ momentum

$\delta P/P \sim 1\%$

$\sigma P/P \sim 11\%$

Relative scale (E,P) <0.5%

The NuTeV Collaboration:

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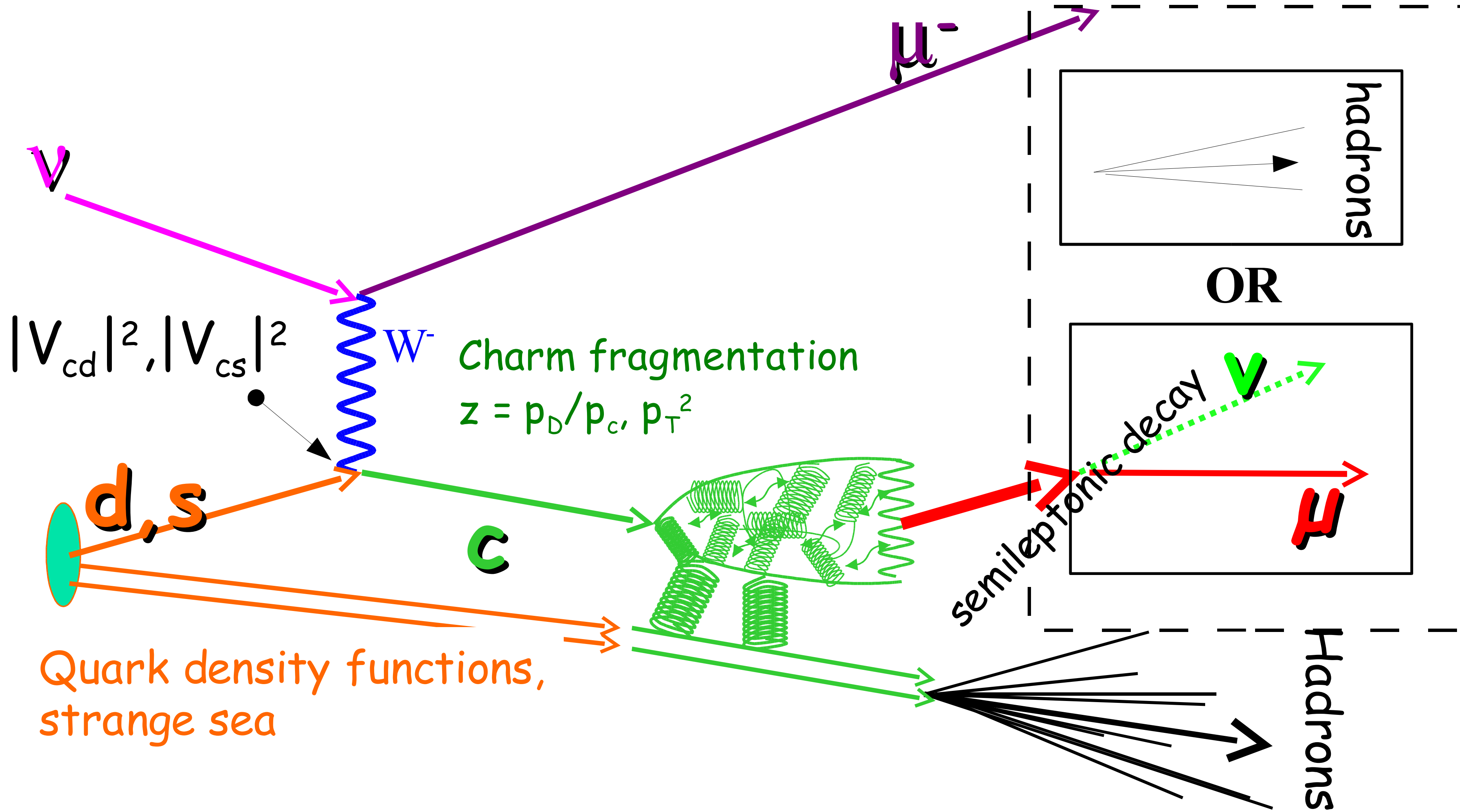
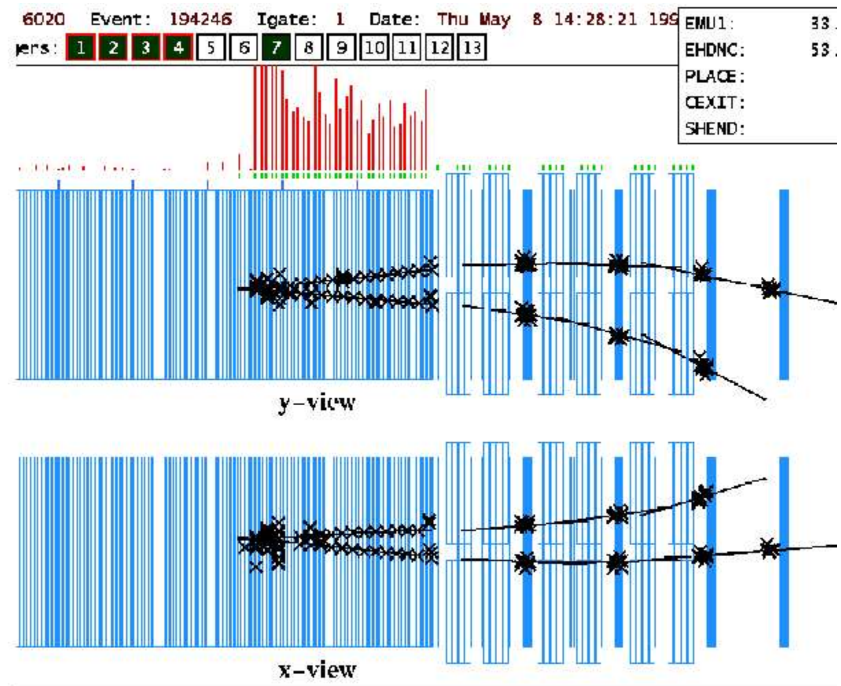
Charm production in ν-N DIS



Charm production detection → dimuons

- Opposite sign dimuons provide clear experimental signature:
  - » extract strange sea
  - » could study charm mass & fragmentation
- Complication from large corrections due to missing energy from decay. So,
  - » measure forward dimuon cross-section ($E_\mu > 5$ GeV)
- Low statistics...



largest dimuon data sets

CCFR	CDHS	Charm II	Nomad	NuTeV	
5030	11041	4111	3590	5012	ν
1060	3684	871	1004	1458	$\bar{\nu}$

NuTeV dimuon cross-section

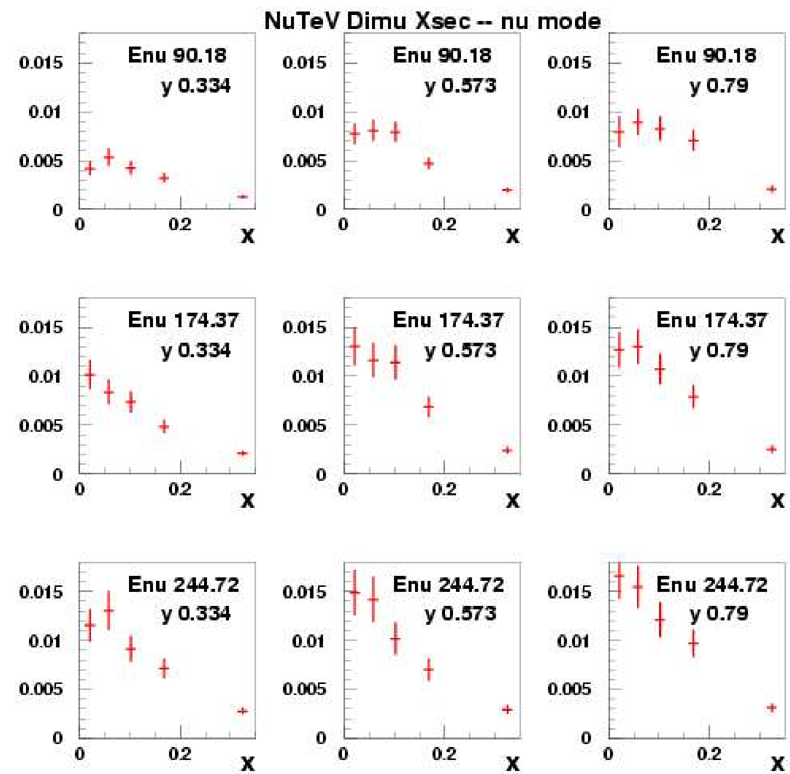
$$\frac{d\sigma_{charm}(E_\nu,x,y)}{dx\,dy}\quad EMC(x)\quad B_c\quad A(E_\nu,x,y;\epsilon,m_c)\rightarrow\frac{d\sigma_{2\mu}(E_\mu,x,y)}{dx\,dy}$$

To extract the *strange sea*, we need:

- charm production model (LO, NLO)
- nuclear correction function
- branching ratio
- correction due to 5 GeV cut on muon energy. Correction depends on

* decay and fragmentation models

but not on any experimental details



cross-section results (PRD64 (2001) 112006)

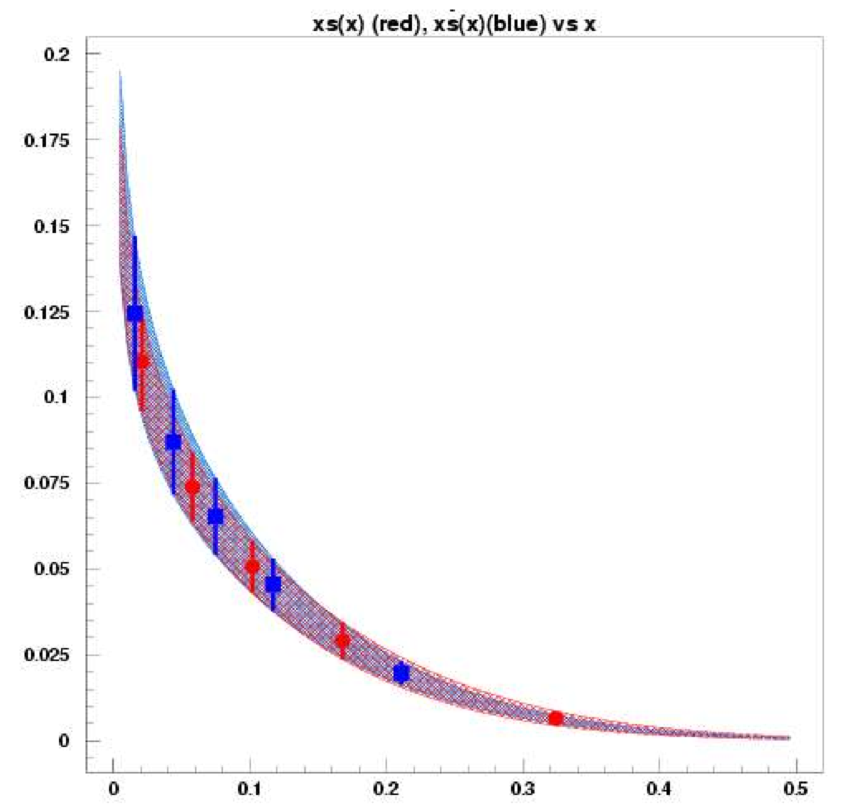
Leading order fits to the dimuon cross-section

- Historically, the following parameterization has been used:

$$s(x,Q) = \kappa(1-x)^{\alpha}\left[\frac{\bar{u}(x,Q)+\bar{d}(x,Q)}{2}\right] \quad \text{(fit for } \kappa, \alpha, \bar{\kappa}, \bar{\alpha} \text{)}$$

$$\bar{s}(x,Q) = \bar{\kappa}(1-x)^{\bar{\alpha}}\left[\frac{\bar{u}(x,Q)+\bar{d}(x,Q)}{2}\right]$$

- Published LO fits with CTEQ4, GRV94 and Buras-Gaemers parameterization -BGPAR- (PRD64)
  - » BGPAR also fitted to inclusive data
- To establish connection with more modern pdfs, new LO fits using CTEQ5L, for ν and ν-bar



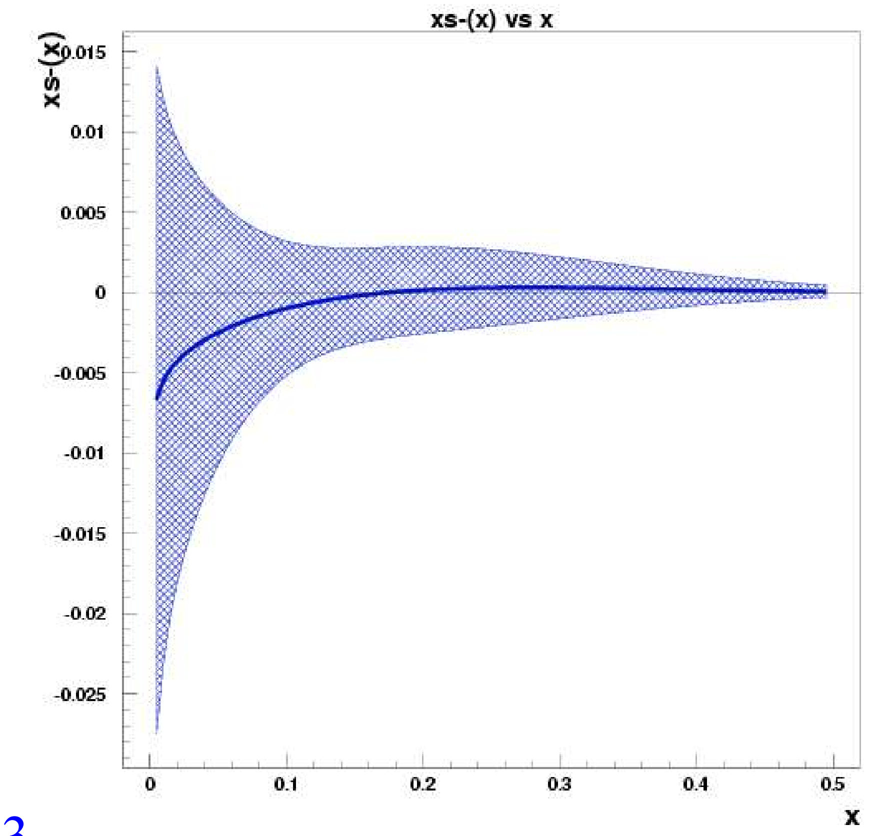
LO Asymmetry

The measurement of the strange sea asymmetry

$$xs^{-}(x) = xs(x) - x\bar{s}(x)$$

has its own merit and is relevant to the NuTeV Electroweak result (PRL88 091892)

A ***positive*** asymmetry of +0.006 could account for difference from other EW results.



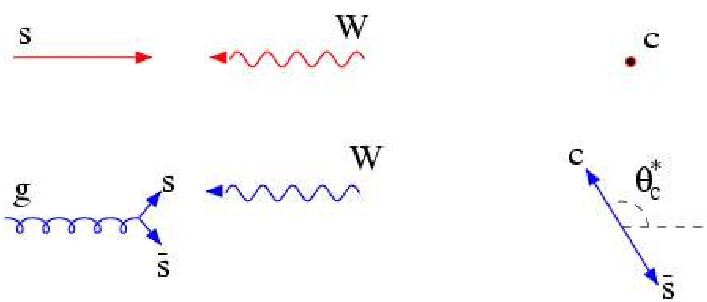
CTEQ5 “κ, α” result consistent with 0:

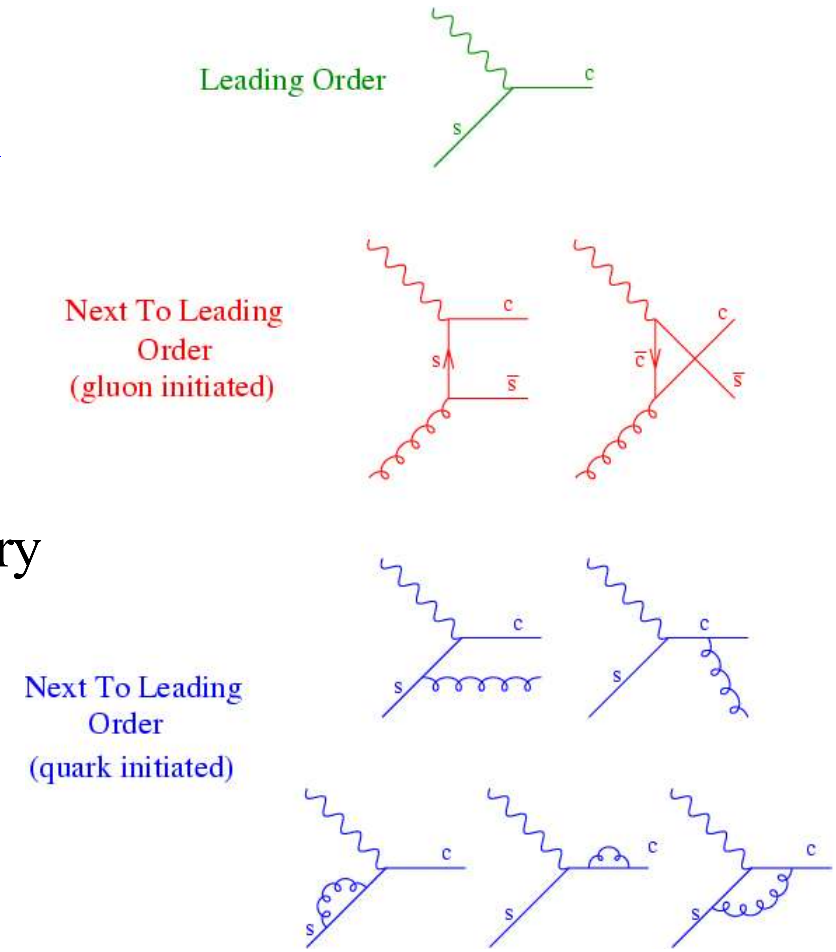
$$\int x s^{-}(x)\, dx = -0.0003 \pm 0.0011$$

previous LO results ranged from -0.0027±0.0013 (with BGPAR fitting both NuTeV and CCFR) to ~ -0.0005 (using other LO sets)

Fits using NLO charm production model

- NLO strange sea of global interest
  - » charm production has large gluon contribution
- but extraction more complicated than LO:
  - » fragmentation requires convolution integral with cross-section
  - » the acceptance correction for muon energy cut now depends on the charm $p_\perp$ at the primary vertex:



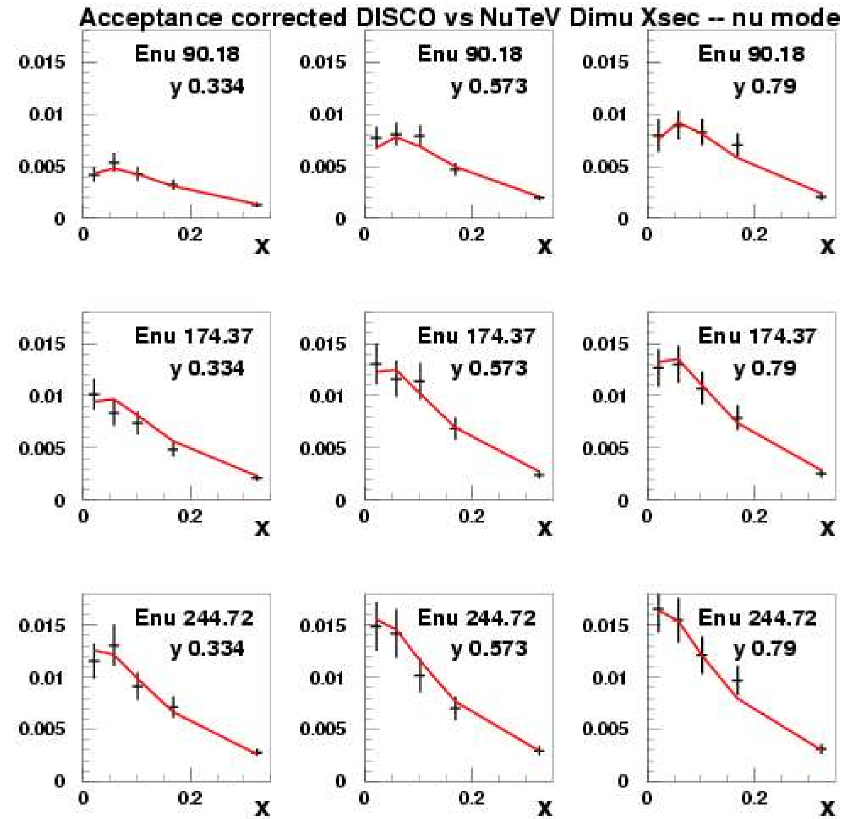


New NLO results

- Fit NuTeV dimuon cross-section tables
- Acceptance calculation from DISCO
  (S. Kretzer, F. Olness, D. Mason PRD65 (2002))
- Use CTEQ6M as the starting pdf set
- Use Collins Spiller fragmentation
  - » do not fit for shape fix ε to 0.75 ($\pm$0.25 for error estimates) from MC/data scans
- B_c fixed at 0.093 (E531), range $\pm$0.008

$\Rightarrow$ try different parameterizations for the strange sea

NLO fits to ν x-section

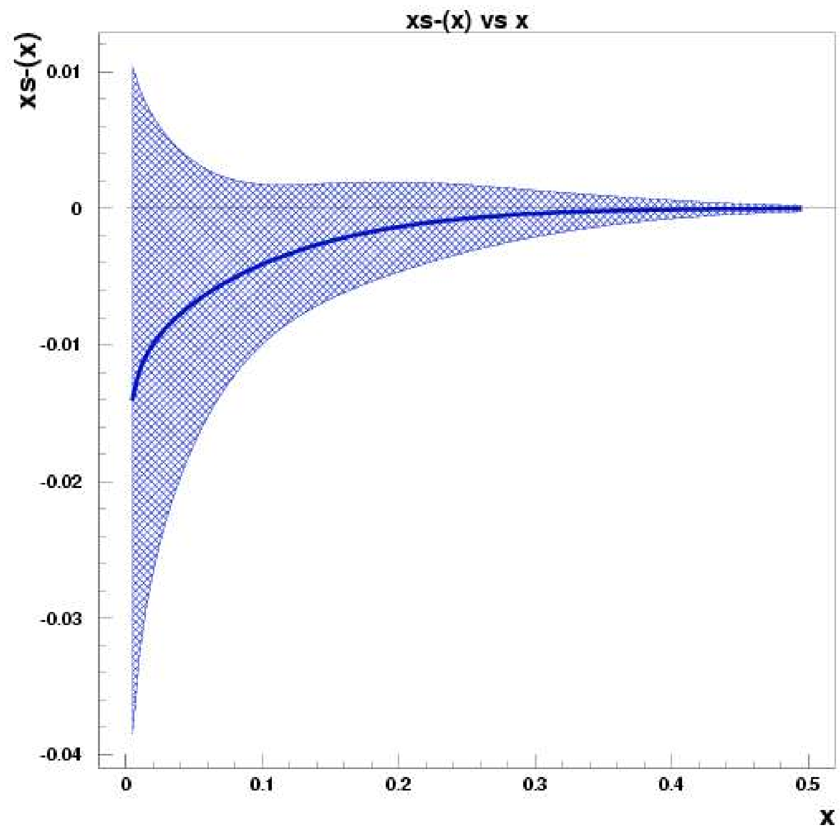


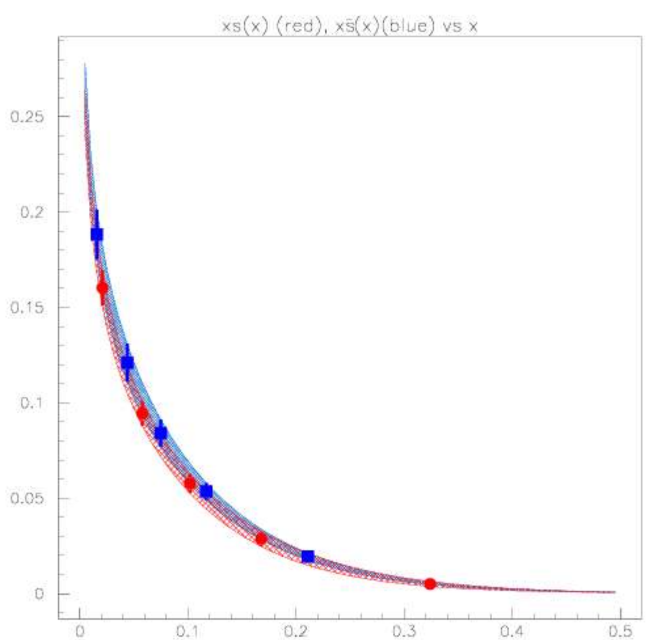
NLO strange sea

- First, use the [κ, α] parameterization:
  - » $\chi^2 = 38/39$ NDF

$\longrightarrow \quad \int x\, s^{-}(x)\, dx = -0.0011 \pm 0.0014$

result similar to LO fits.





[κ, α] parameterization, as implemented has problems

» evolution via ubar & dbar "not quite right" QCD

(but limited x and Q range)

Evolve properly

- Define s, sbar at Q_0 then evolve:

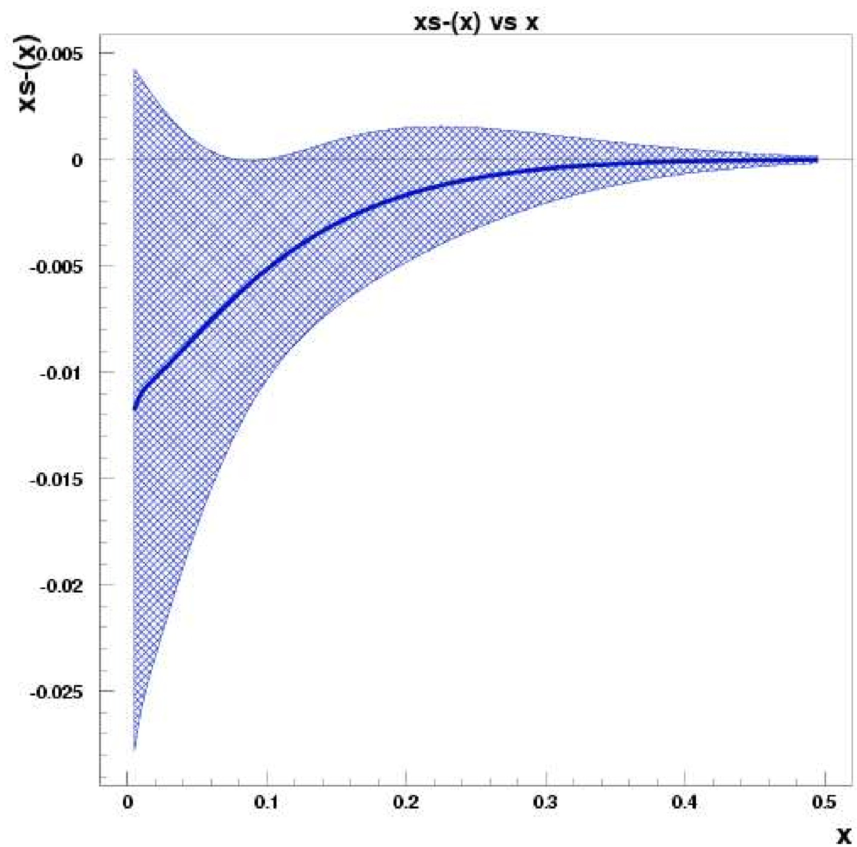
  requires evolution code which treats sbar and s independently

→ obtain CTEQ code (thanks!)

→ $\int x s^{-}(x)\,dx = -0.0013 \pm 0.0013$

similar result as before, but

→ parameterization still does not constrain the total strangeness to $\int s^{-}(x)\,dx = 0$



Further satisfying QCD requirements

Adopt a "CTEQ inspired" parameterization (hep-ph/0312323):

$$s^+(x,Q_0) = \kappa^+ (1-x)^{\alpha^+} x^{\gamma^+} \left[\bar{u}(x,Q_0) + \bar{d}(x,Q_0)\right]$$

$$s^-(x,Q_0) = s^+(x) \tanh\left[\kappa^- (1-x)^{\alpha^-} x^{\gamma^-} \left(1-\frac{x}{x_0}\right)\right]$$

$$s = \frac{s^+ + s^-}{2}, \qquad \bar{s} = \frac{s^+ - s^-}{2}$$

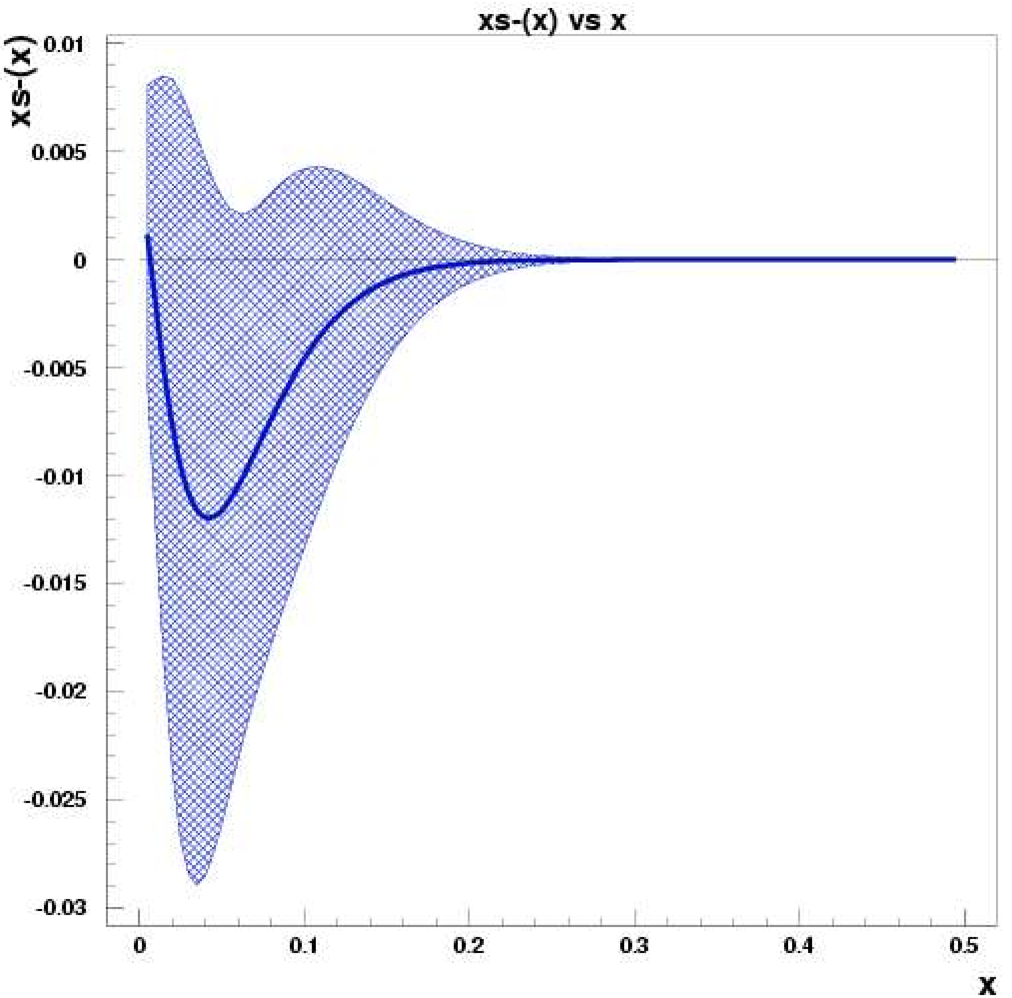
with x_0 constrained by $\int s^-(x,Q_0)\,dx = 0$

In our procedure we do not impose a momentum sum rule constraint (but we check the effect). This is to avoid fixing $\int xs^+\,dx$ (our only constraint option). There is no effect on the non-strange pdfs or the asymmetry.

Results with new parameterization

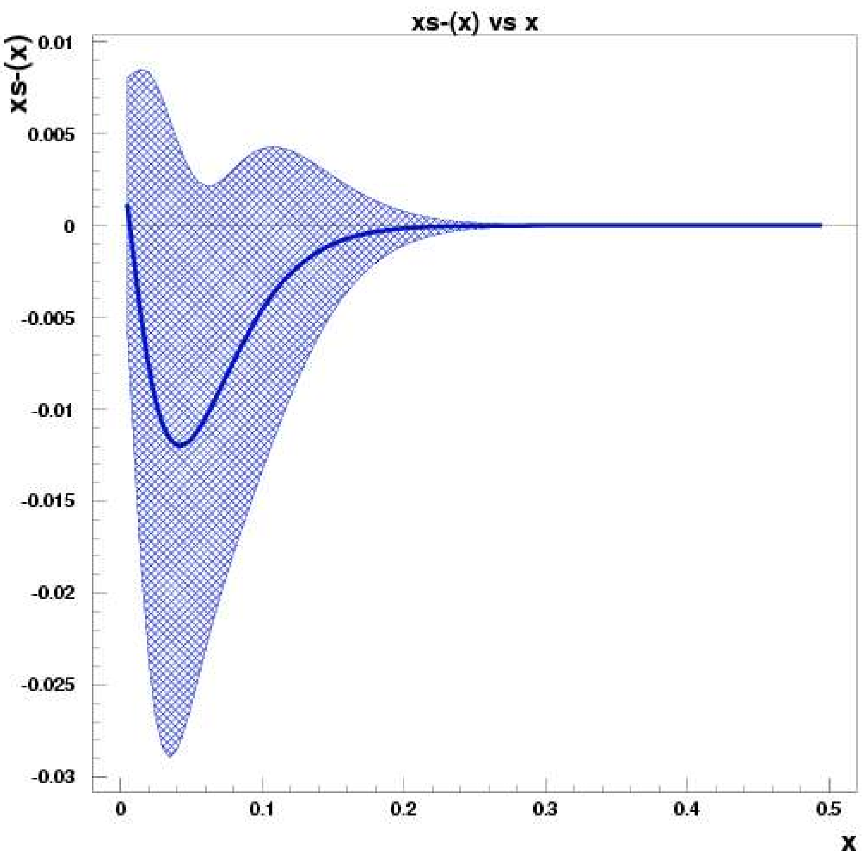
$$\int x s^{-}(x) dx = -0.0009 \pm 0.0014$$

$\chi^2 = 37/37$ NDF
number sum rule satisfied by s^- going positive below lowest x data point.

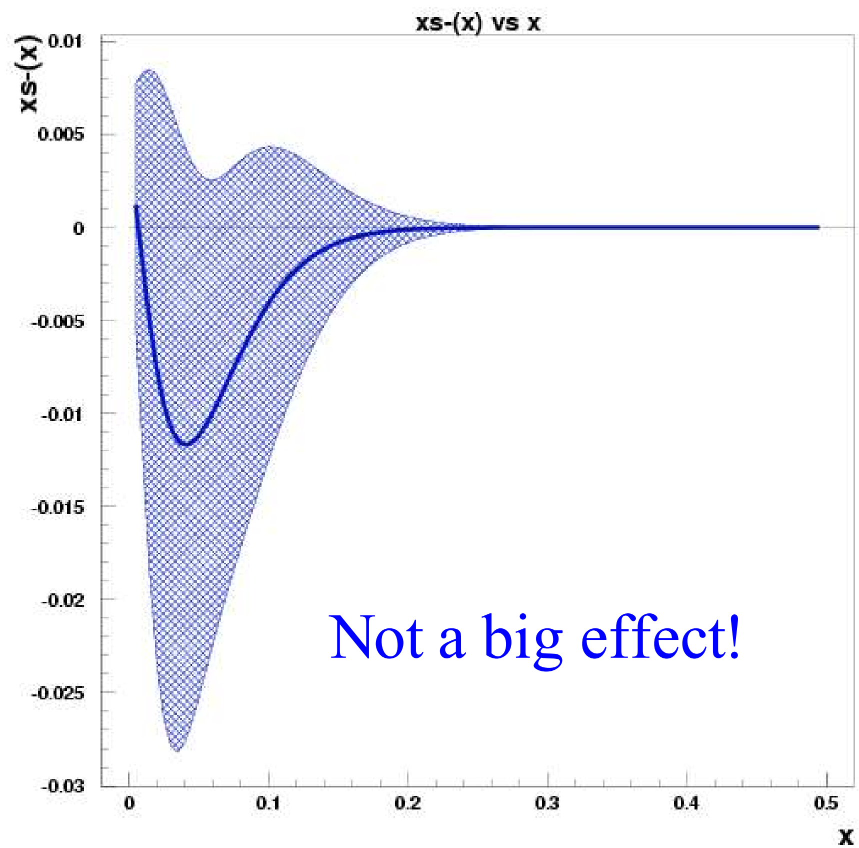


How about momentum sum rule effect?

no sum rule constraint
$\chi^2 = 37/37$



with sum rule constraint
$\chi^2 = 38/38$



What about positive asymmetry?

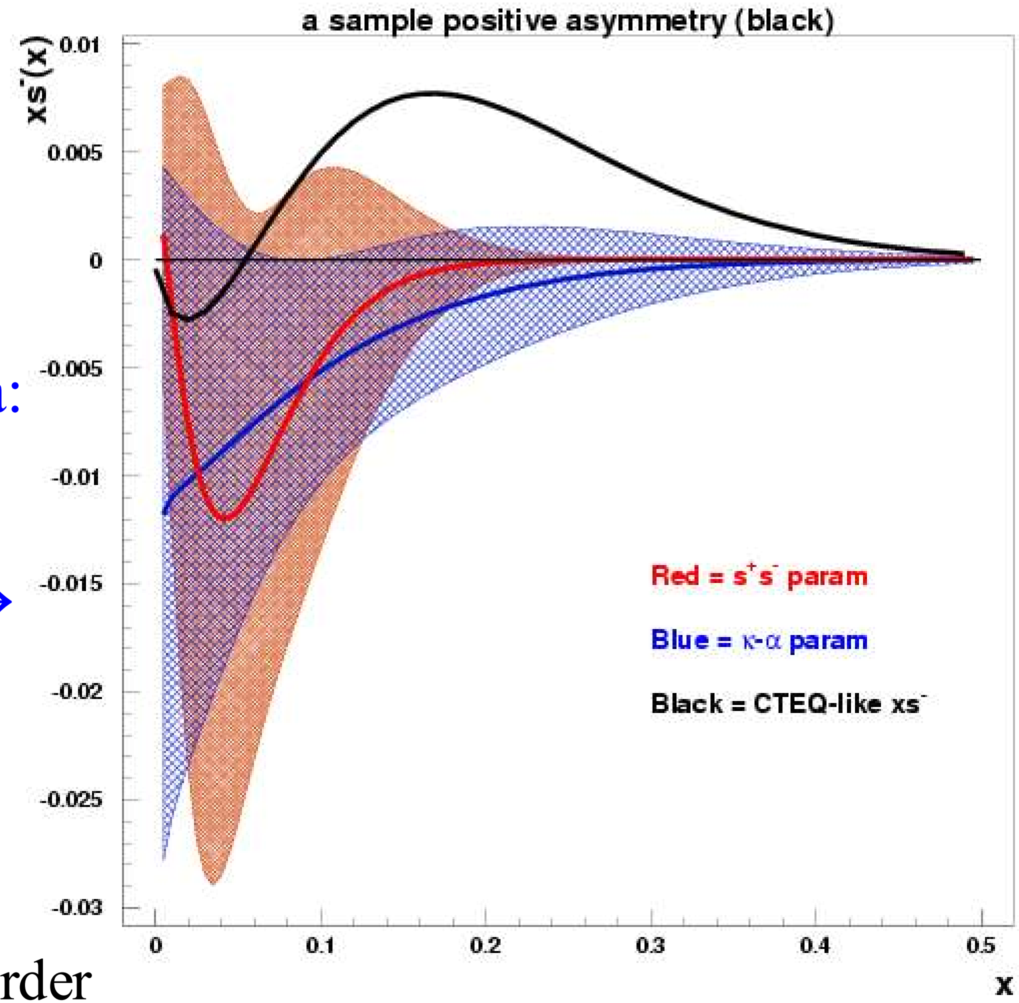
Several global fits find positive asymmetry, with EW implications

We test this possibility with the data:

- constrain s- to be positive

  (black curve as in hep-ph/31/2323) →

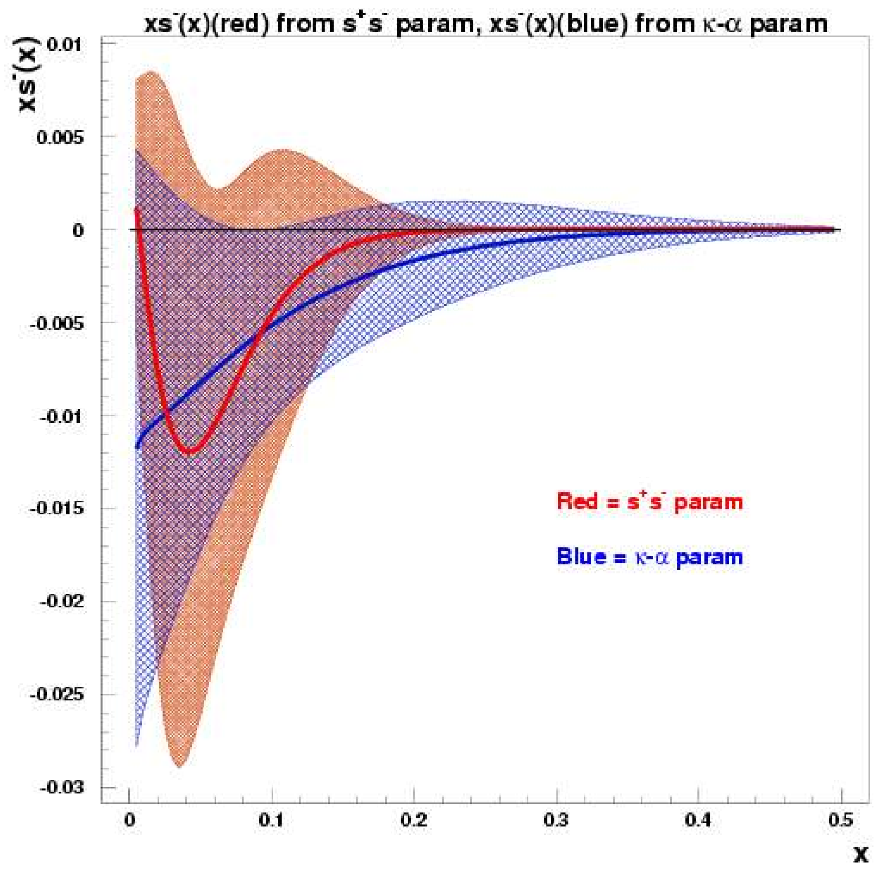
- χ^2 = 55/40 NDF, higher than standard fit (37/37 NDF)
- $\int xs^- (x)\, dx = 0.0016$
- positive asymmetry at higher x even harder



Summary and conclusions

- Our measured asymmetry is at most consistent with zero
  - » both LO and NLO
  - » with different parameterizations
- s- tends toward negative values at the lowest x-bin data points
- number sum-rule forces positive turn
- below lowest x-data-point

Collaboration with phenomenologists (Amundson, Kretzer, Olness, Tung) provided us with necessary tools



Plans for further analysis

It will be interesting to understand global vs just dimuon results.

We will complete our investigation of different effects such as
- » fixing parameters (e.g charm mass)
- » fragmentation

We will assist with implementation of dimuon x-section fitting to global analysis (acceptance, etc)

But so far all indications are that asymmetry is far bellow the level needed for EW result explanation (+0.006)

level needed for EW explanation