Determination of strange sea distributions from νN DIS

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[arXiv:0812.4448]

Motivation

- the strange sea contribution is comparable to the non-strange one at small x, in particular for the W-production at the LHC
- an accurate estimate of the all sea quark uncertainties is impossible without the species disentangling
- a precise determination of the strange sea is necessary for the precision physics – the NuTeV anomaly can be explained by the small charge asymmetry in the strange distribution, $(s - \bar{s})$

(Davidson-... 01)

The νN DIS charm production

$$\frac{d\sigma^{\overset{(-)}{\nu}N}_{charm}}{dxdy} = \frac{G_F^2 M E_{\overset{(-)}{\nu}}}{\pi(1+Q^2/M_W^2)^2}\left[\left(1-y-\frac{Mxy}{2E}\right)F^{\overset{(-)}{\nu}N}_{2,c}(x,Q) + \right.$$

$$\left. + \frac{y^2}{2}F^{\overset{(-)}{\nu}N}_{T,c}(x,Q) \genfrac{}{}{0pt}{}{+}{(-)} y\left(1-\frac{y}{2}\right)xF^{\overset{(-)}{\nu}N}_{3,c}(x,Q)\right]$$

In the leading order of QCD

$$F_{2,c}^{\overset{(-)}{\nu}N}(x,Q) = 2\xi\left[|V_{cs}|^2\,\overset{(-)}{s}(\xi,\mu) + |V_{cd}|^2\,\frac{\overset{(-)}{u}(\xi,\mu) + \overset{(-)}{d}(\xi,\mu)}{2}\right]$$

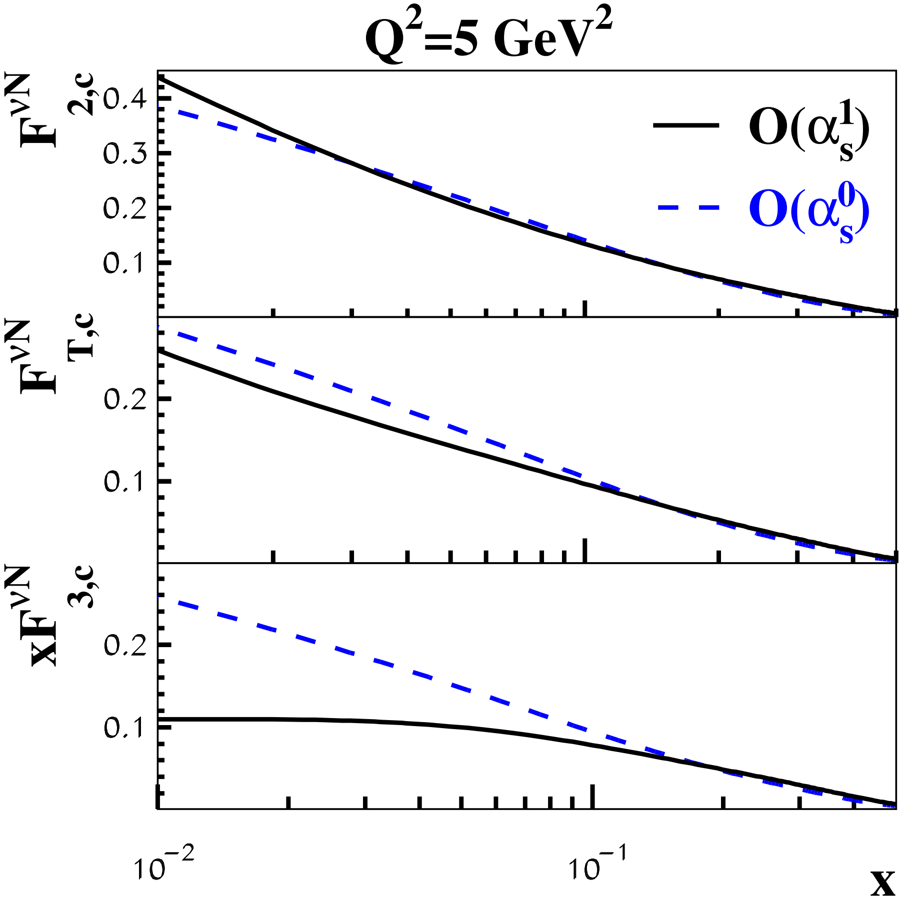
$$F_{T,c}^{\overset{(-)}{\nu}N} = \genfrac{}{}{0pt}{}{+}{(-)} xF_{3,c}^{\overset{(-)}{\nu}N} = \frac{x}{\xi}F_{2,c}^{\overset{(-)}{\nu}N}$$

$$|V_{cs}| \gg |V_{cd}|$$

The NLO QCD corrections

(Gottschalk 81)

(Glück-Kretzer-Reya 96)



LO: $Wq \to c$

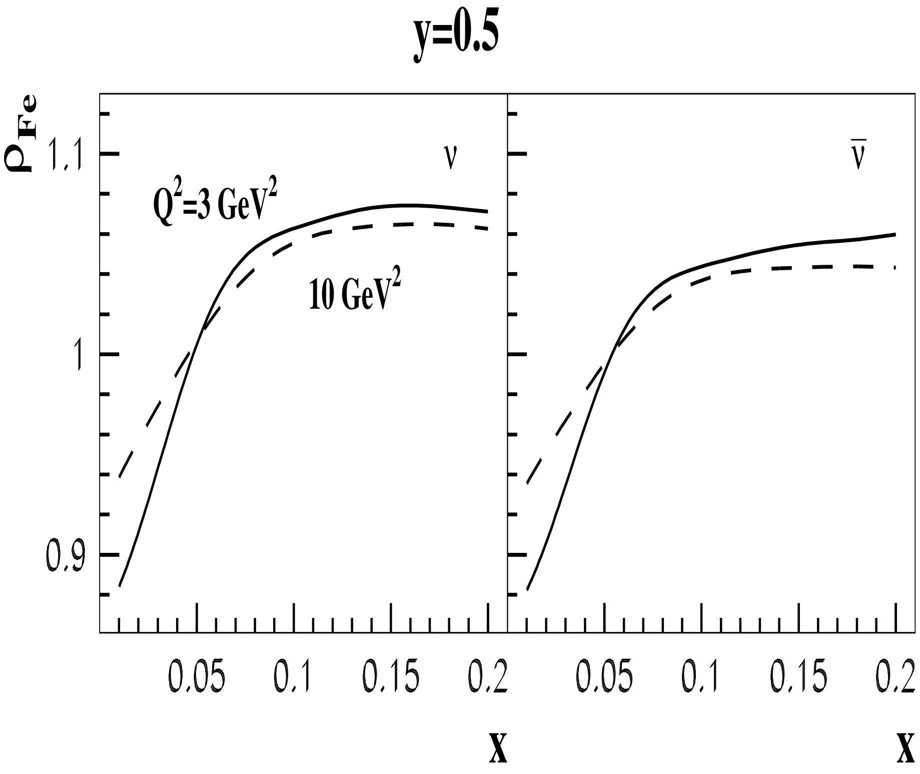
NLO: $Wq \to cg$

$Wg \to cq$

The magnitude is similar for the ν- and $\bar{\nu}$-beam.

The nuclear corrections

(Kulagin-Petti 07)



The nuclear corrections depend on the beam type and momentum transfer Q.

The νN DIS dimuon production

$$\frac{d\sigma^{\overset{(-)}{\nu}N}_{\mu\mu}}{dxdy} = B_\mu \frac{d\sigma^{\overset{(-)}{\nu}N}_{\text{charm}}}{dxdy}$$

$$B_\mu = \sum f_h Br(h \to \mu X)$$

B_μ depends on the neutrino beam type and energy through the charmed-hadrons production rates f_h. For the rates measured by the E-531 emulsion experiment $B_\mu = (9.2 \pm 0.9)\%$, averaged over beam type at $E_\nu > 30$ GeV

(Bolton 97)

A simultaneous fit of B_μ and $s(\bar{s})$ is possible due to the cross section slope is sensitive to the strange sea magnitude through the QCD evolution

$$\frac{ds(x,\mu)}{d\ln\mu} \sim \int_x^1 \frac{dy}{y}\left[P_{qq}(x/y)s(y,\mu) + \ldots\right]$$

The basic features of the fit

- The dimuon NuTeV and CCFR data, both for the ν- and $\bar{\nu}$-beams with similar energy, are combined with the fixed-target Drell-Yan data (constraint on the non-strange sea) and the world inclusive charged-leptons DIS data (constrain the gluons and valence quarks).

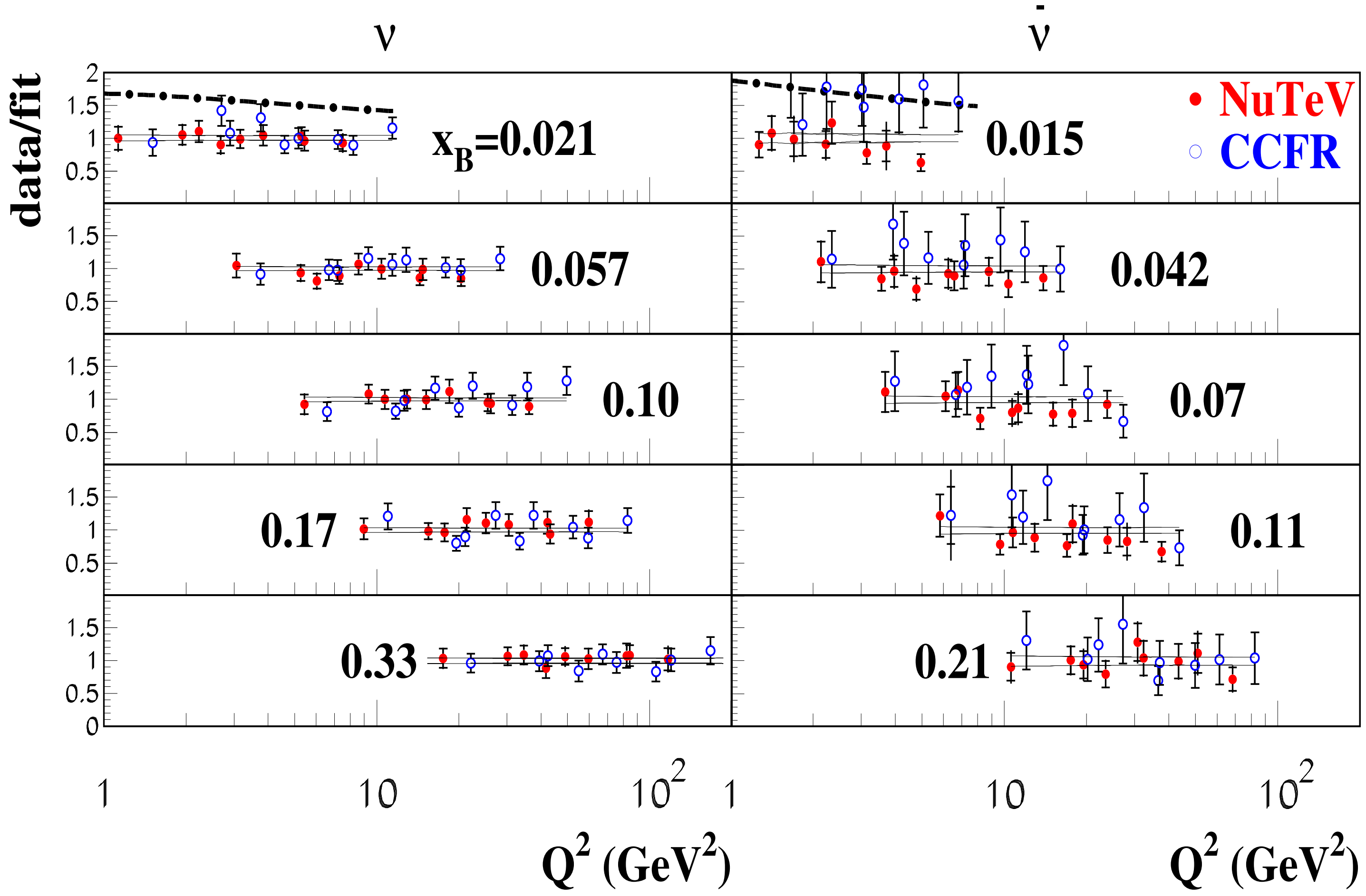
- B_μ is fitted simultaneously with

$$x\overset{(-)}{s}(x,Q_0^2) = \overset{(-)}{A_s}\; x^{\overset{(-)}{a_s}}\,(1-x)^{\overset{(-)}{b_s}}$$

  and other PDFs.

- Two variants of the fit are considered: with and without a constraint on B_μ from the emulsion data.

The pulls for unconstrained fit



$\chi^2/NDP = 63/89$ for CCFR and $38/89$ for NuTeV.

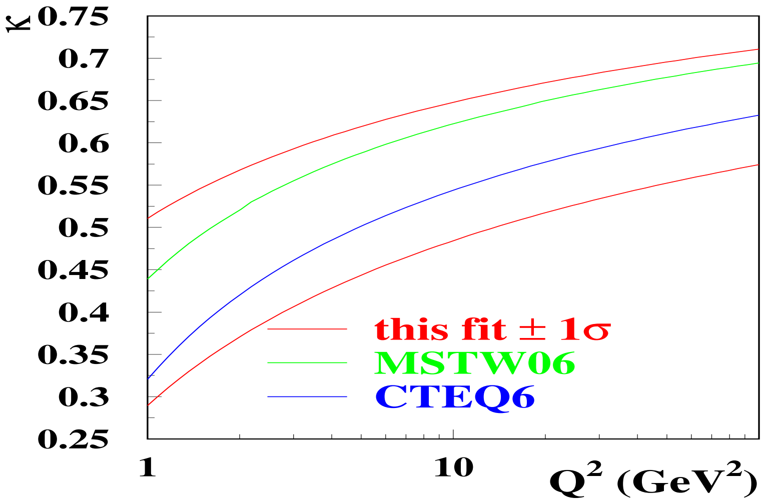
Check of the data consistency

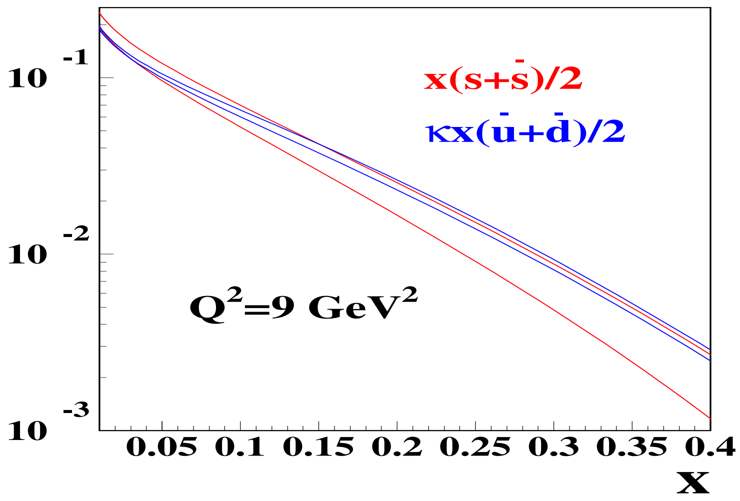
- The value of $B_\mu = (9.1 \pm 1.0)\%$ (averaged over the beam type and energy) obtained in our fit is consistent with one obtained by Bolton, $B_\mu = (9.2 \pm 0.9)\%$.

- No beam type dependence of B_μ is observed: $B_\mu = (9.4 \pm 1.1)\%$ for neutrino and $(8.9 \pm 2.2)\%$ for antineutrino.

- No energy dependence of B_μ is observed: the fitted energy slope of B_μ is consistent with zero.

- The NuTeV and CCFR data demonstrate some inconsistency: $B_\mu = (7.2 \pm 1.7)\%$ for the variant of fit with the NuTeV data only and $(9.7 \pm 1.1)\%$ for CCFR.



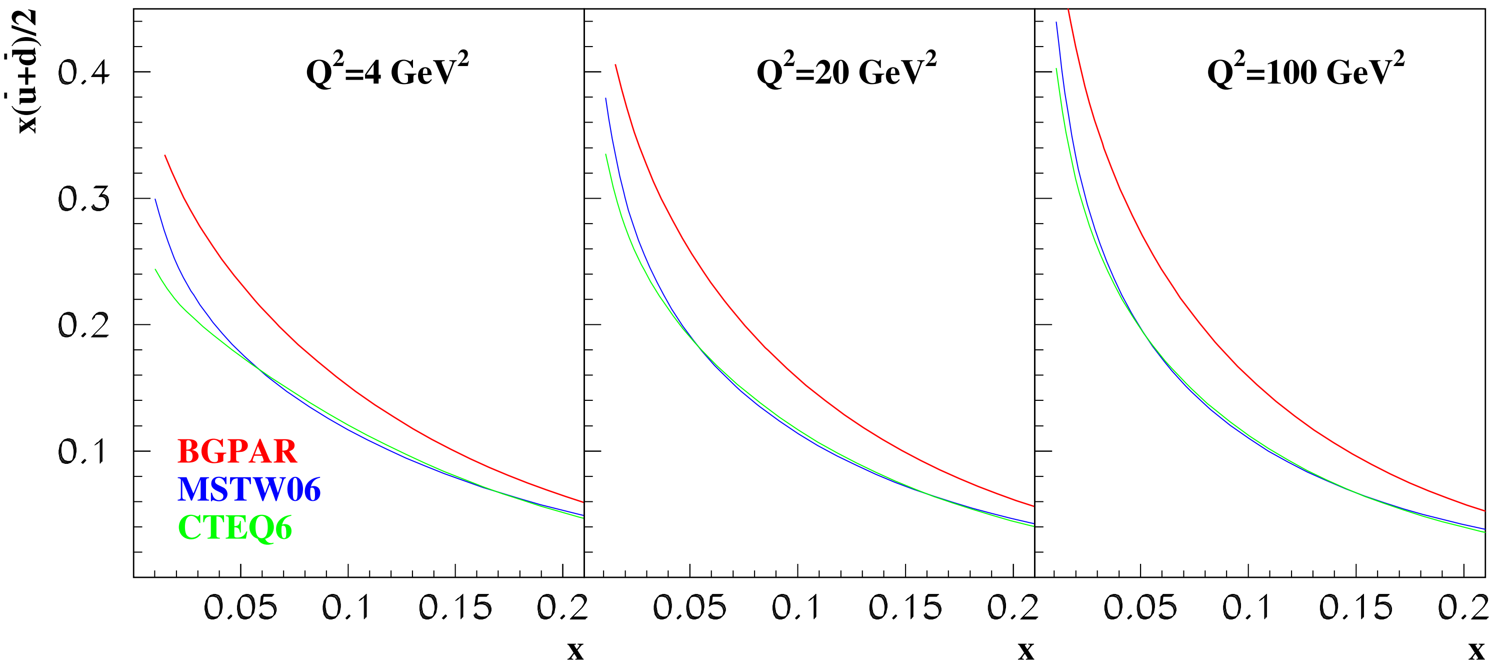


- The value of strange sea suppression factor

$$\kappa = \frac{\int_0^1 x\,[s(x)+\overline{s}(x)]\,dx}{\int_0^1 x\left[\overline{u}(x)+\overline{d}(x)\right]dx}$$

depends on Q and $\kappa(Q^2 = 20\ \mathrm{GeV}^2) = 0.59\pm0.08$. This is bigger than $\kappa(20\ \mathrm{GeV}^2) = 0.48^{+0.06}_{-0.05}$ obtained in the CCFR NLO QCD fit.

- The x-shape of strange sea is some softer than the non-strange one.



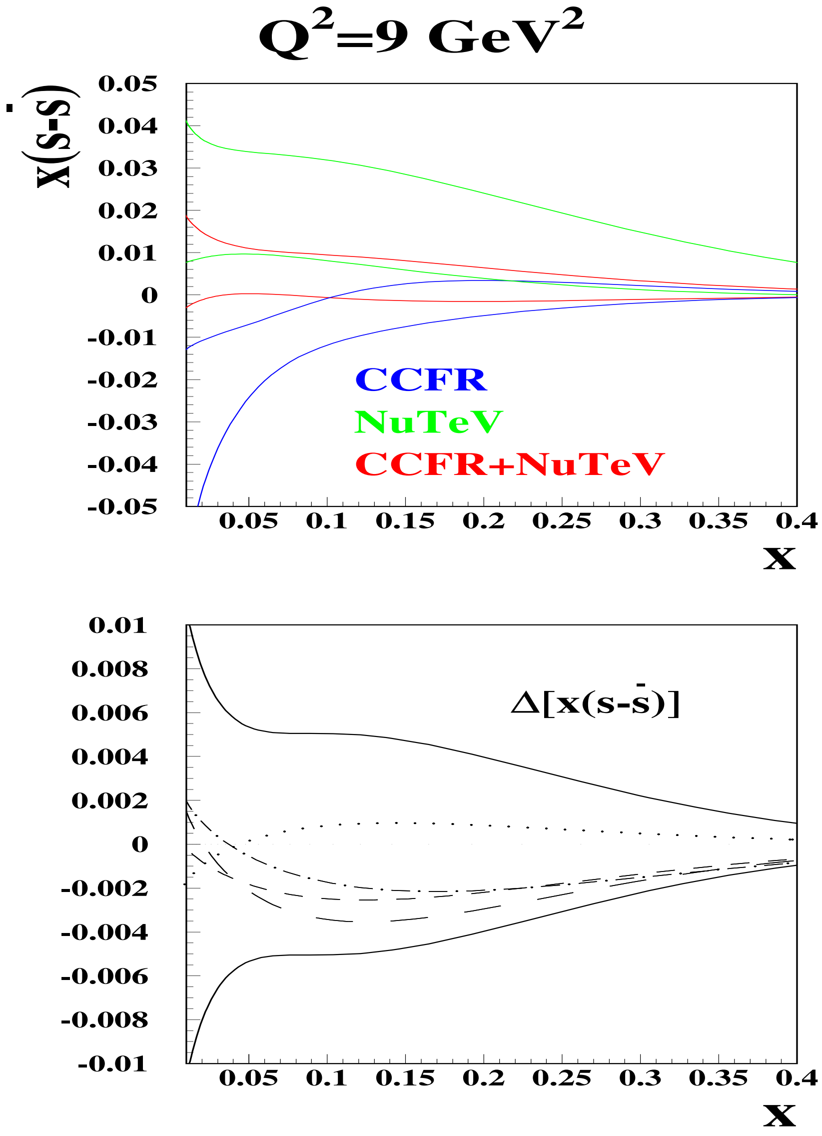
The non-strange quark distribution given by the BGPAR parameterization used in the CCFR analysis is much bigger than for other modern PDFs sets.

The constraints on B_μ from the emulsion experiments

With B_μ fixed $\kappa(20\ \mathrm{GeV}^2) = 0.594 \pm 0.026$
(compare with 0.59 ± 0.08 for B_μ fitted).

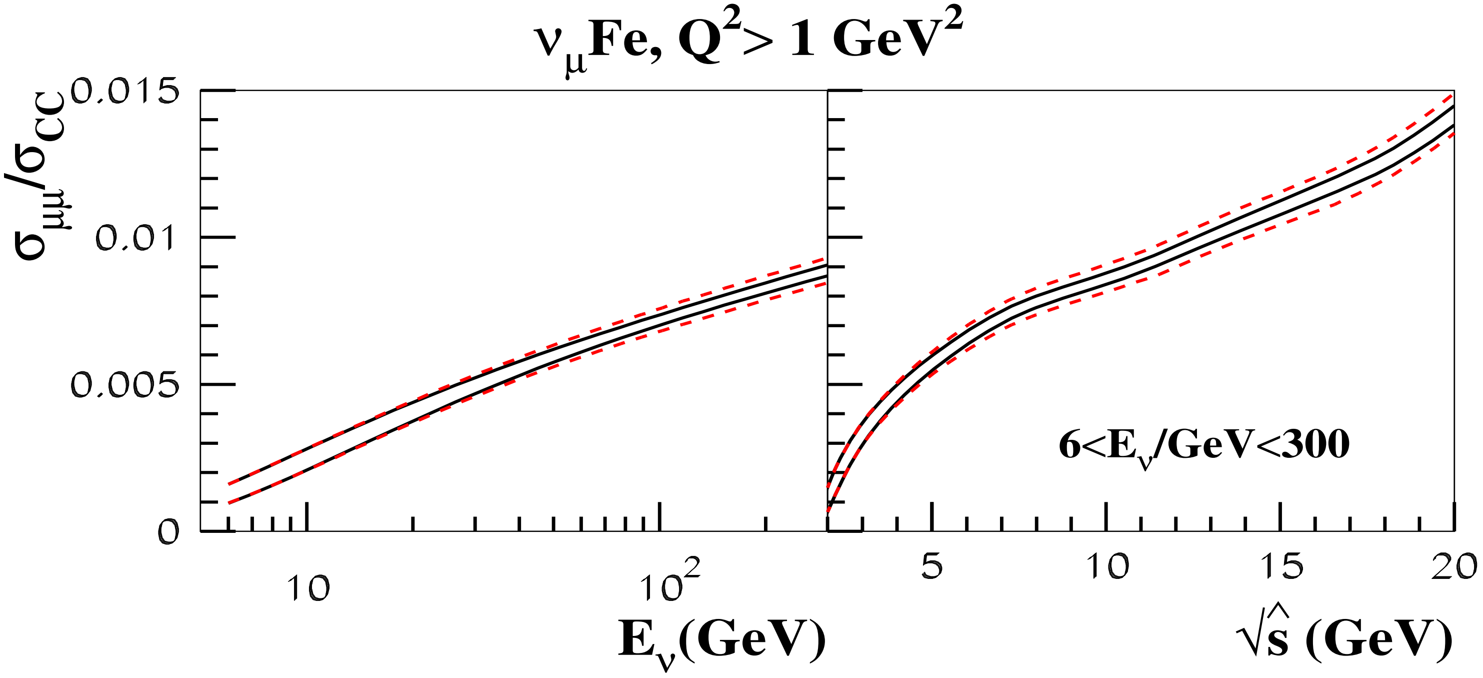
Measurement	$E_\nu > 5$ GeV	$E_\nu > 30$ GeV
CHORUS (KayisTopaksu 05)	$7.30 \pm 0.82\%$	$8.50 \pm 1.08\%$
CHORUS (DiCapua 08)	$9.11 \pm 0.93\%$	
E531 (Bolton 97)	$7.86 \pm 0.49\%$	$8.86 \pm 0.57\%$
Weighted average	$7.94 \pm 0.38\%$	$8.78 \pm 0.50\%$

With the additional input for B_μ we get substantial improvement in the strange sea magnitude, $\kappa(20\ \mathrm{GeV}^2) = 0.62 \pm 0.04$.



- The $s/\bar{s}$ asymmetry is comparable to zero within the errors, at $Q^2 = 20$ GeV^2 $\int_0^1 x[s(x) - \bar{s}(x)]dx = 0.0010(13)$ $(0.0013(9)$ with the additional input for $B_\mu)$.
- The asymmetry has different sign for the CCFR and NuTeV cases and is sensitive to the choice of the QCD scale, value of B_μ, to the nuclear corrections, etc.

Outlook



The NOMAD dimuon data at small E_ν and $\hat{s} = Q^2(1/x - 1)$ are more precise than the current prediction uncertainties. The same is valid for the recent CHORUS emulsion data on the charmed hadron production. In combination, this input would allow to improve the strange distribution(s) at $x > 0.1$.

Summary

- The nucleon strange sea is extracted from a global fit including the (anti)neutrino dimuon data by the CCFR and NuTeV collaborations, the inclusive charged lepton-nucleon DIS and Drell-Yan data. The fit is constrained by the semi-leptonic charmed-hadron branching ratio $B_\mu = (8.8 \pm 0.5)\%$, determined from the inclusive charmed hadron measurements performed by FNAL-E-531 and CHORUS.
- The strange sea suppression factor 0.62 ± 0.04 at $Q^2 = 20~\mathrm{GeV}^2$ is obtained, the most precise value available.
- The x-distribution of total strange sea that is slightly softer than the non-strange sea.
- The asymmetry between strange and anti-strange quark distributions consistent with zero (integrated over x it is equal to 0.0013 ± 0.0009 at $Q^2 = 20~\mathrm{GeV}^2$).