Extraction of Δs for D Meson Production in Neutrino DIS

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- I. Introduction
- II. Semi-inclusive $D/\bar{D}$ Production in CC DIS

$$\begin{cases} \nu + \vec{p} \longrightarrow l^- + D + X \\ \bar{\nu} + \vec{p} \longrightarrow l^+ + \bar{D} + X \end{cases}$$

- III. Numerical Results
- IV. Conclusion

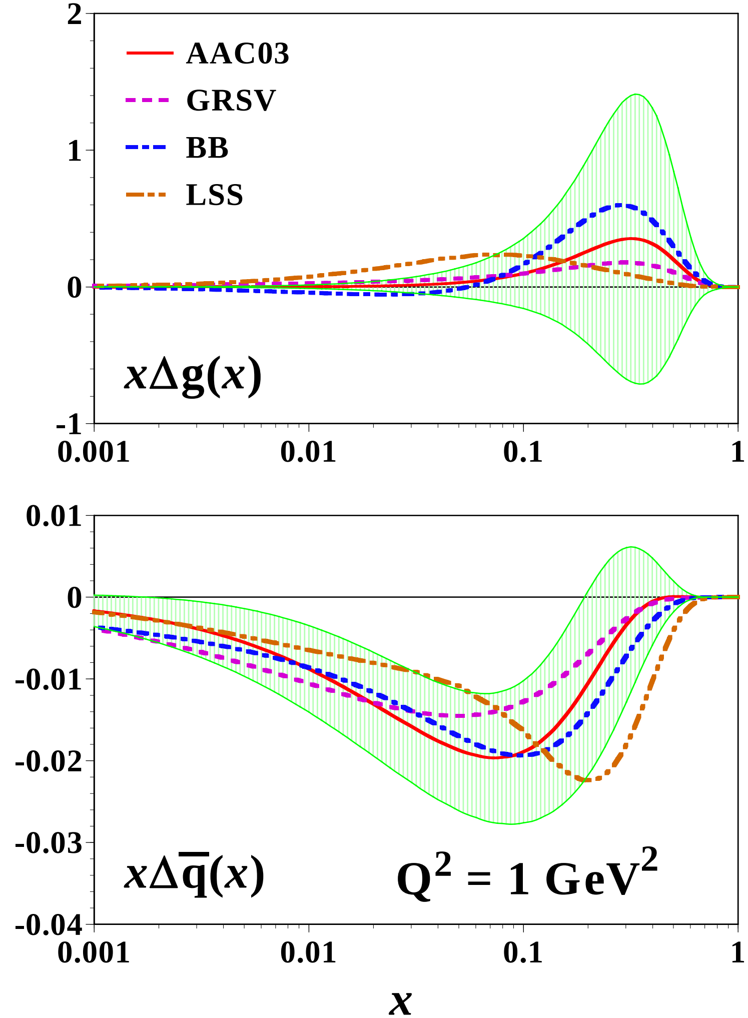
I. Introduction

Pol-PDF: Δs, Δg

- Uncertainties of the polarized sea quark and gluon distributions are still large.
  - Flavor decomposition of $\Delta\bar{q}$
  - Semi-inclusive DIS (HERMES)

- Charged current (CC) DIS is effective to extract the flavor decomposed parton distribution.
  - $W^{\pm}$ couples to parton flavor
  - Through longitudinal single spin asymmetry A_L
  - ★ Neutrino-induced reaction

AAC, PRD69, 054021 (2004)



CC DIS and Flavor Structure of Δq

- **Cross Section:**

$$\frac{d^2\sigma(\nu p \text{ or } \bar{\nu} p)}{dQ^2 d\nu} = \frac{G^2}{2\pi} \cdot \frac{k'}{k}\left[W_2(Q^2,\nu)\cos^2\frac{\theta}{2} + 2W_1(Q^2,\nu)\sin^2\frac{\theta}{2} \pm W_3(Q^2,\nu)\frac{k+k'}{M}\sin^2\frac{\theta}{2}\right]$$

- **How about flavor $SU(3)_f$ structure?**

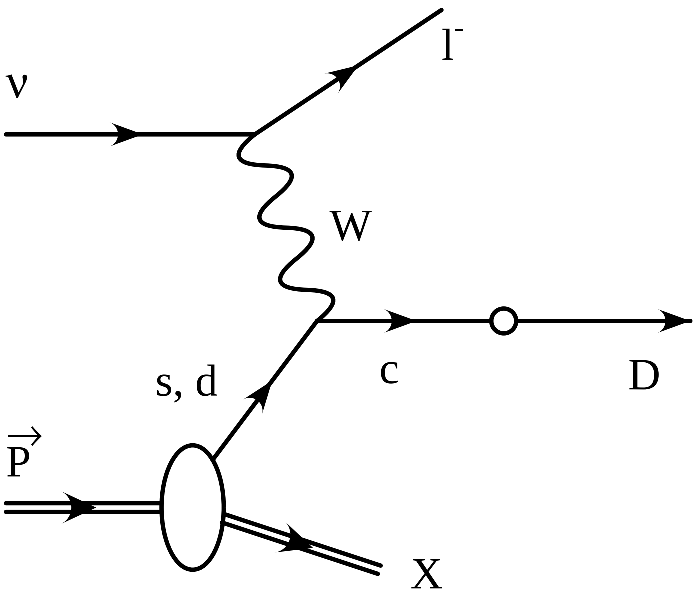
$$\begin{cases} \Delta u_s = \Delta d_s = \Delta s = \Delta\bar{u} = \Delta\bar{d} = \Delta\bar{s} & \text{(Flavor SU(3)}_f\text{)} \\ \Delta\bar{u} = \Delta\bar{d} = \lambda\Delta\bar{s} & \text{(E. Leader, } et\ al., \ Phys.\ Lett. \text{ B462, 189 (1999).)} \end{cases}$$

To examine the polarized s quark distribution, we studied semi-inclusive $D/\bar{D}$ production in $\nu\vec{p}$ scattering.

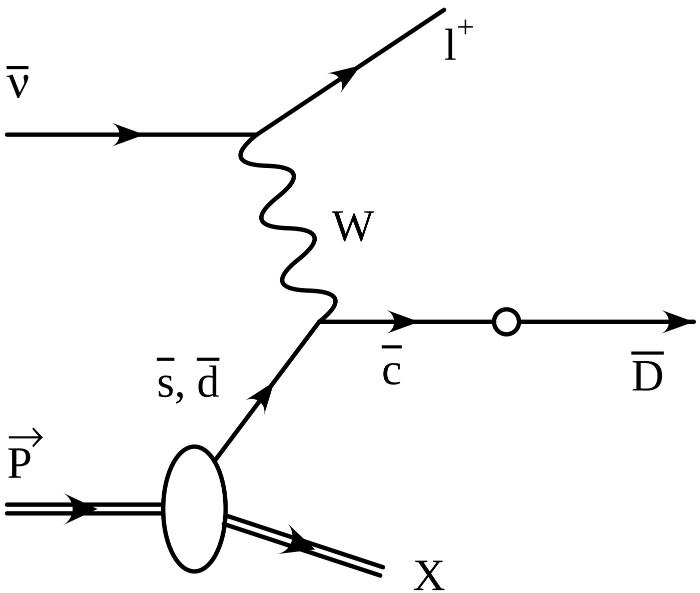
$$\nu + \vec{p} \to l^- + D + X, \quad \bar{\nu} + \vec{p} \to l^+ + \bar{D} + X$$

II. Semi-inclusive $D/\bar{D}$ Production

$\nu + \vec{p} \rightarrow l^- + D + X$



$\bar{\nu} + \vec{p} \rightarrow l^+ + \bar{D} + X$



These processes might be observed in the forthcoming neutrino experiments.

⇒ **ν-factory@J-PARC (*If the polarized target can be installed*.)**

Observables

To extract information about the polarized PDFs, we calculated the following observables.

1. Spin Dependent Differential Cross Section

$$\frac{d\Delta\sigma}{dx} \equiv \frac{d\sigma(-) - d\sigma(+)}{dx}$$

x : Bjorken x

$d\sigma(+,-)/dx$: Spin dependent differential cross section with the positive helicity of the target proton or the negative helicity of the target proton

2. Longitudinal Single Spin Asymmetry

$$A^D \equiv \frac{d\sigma(-) - d\sigma(+)/dx}{d\sigma(-) + d\sigma(+)/dx} = \frac{d\Delta\sigma/dx}{d\sigma/dx}$$

Extraction of $\Delta s(x)$

$$\begin{cases} d\sigma = \{U_{cs}^2 s(x) + U_{cd}^2 d(x)\}\, dx \left(\frac{d\hat\sigma}{d\hat t}\right) d\hat t D_c(z) dz \\ d\Delta\sigma = \{U_{cs}^2 \Delta s(x) + U_{cd}^2 \Delta d(x)\}\, dx \left(\frac{d\Delta\hat\sigma}{d\hat t}\right) d\hat t D_c(z) dz \end{cases}$$

$$A^D = \frac{d\Delta\sigma}{d\sigma} \approx \frac{\{U_{cs}^2 \Delta s(x) + U_{cd}^2 \Delta d(x)\}}{\{U_{cs}^2 s(x) + U_{cd}^2 d(x)\}}$$

$$A^{\bar D} \approx -\frac{\{U_{cs}^2 \Delta \bar s(x) + U_{cd}^2 \Delta \bar d(x)\}}{\{U_{cs}^2 \bar s(x) + U_{cd}^2 \bar d(x)\}} = -\frac{\Delta \bar s(x)}{\bar s(x)} \simeq -\frac{\Delta s(x)}{s(x)}$$

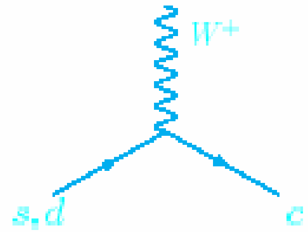
$$\left.\begin{array}{ll} \bar d(x) = \bar s(x),\ \Delta \bar d(x) = \Delta \bar s(x) & \text{Flavor } SU(3)_f \\ \bar d(x) = \lambda \bar s(x),\ \Delta \bar d(x) = \lambda \Delta \bar s(x) & \text{non--}SU(3)_f \end{array}\right\}$$ Above equation is consistent in both cases.

⇨ **We can directly extract the polarized s quark distribution!!**

(The case of $\bar D$ production is more promising.)

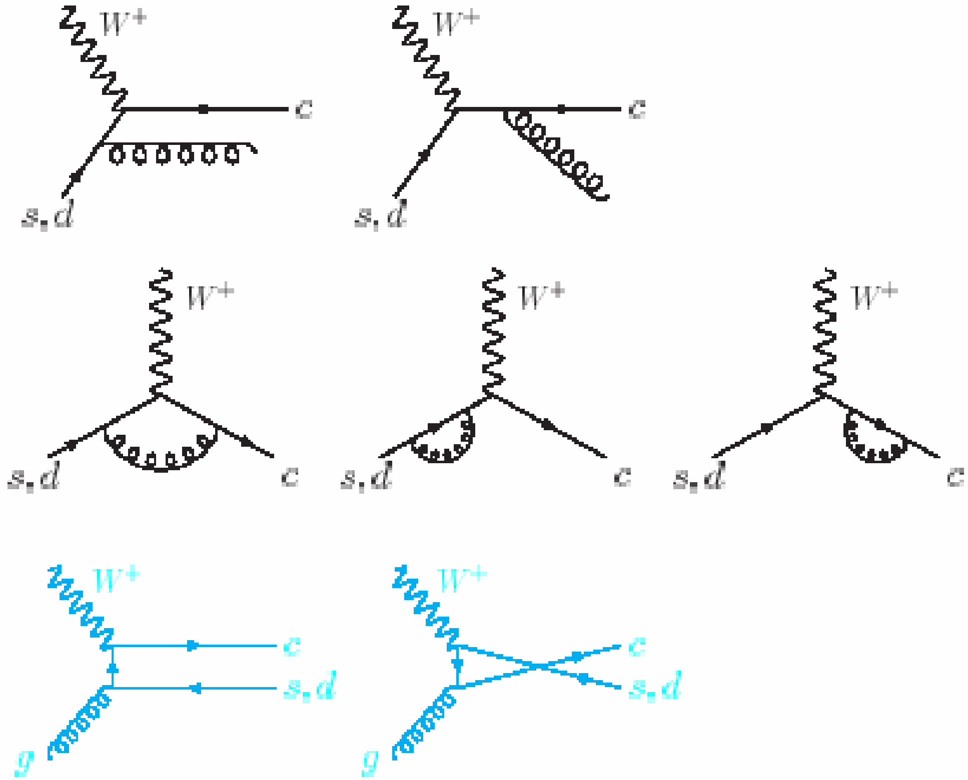
LO and $\mathcal{O}(\alpha_s)$ NLO diagrams of subprocesses

LO



Main contribution come from blue diagrams.

NLO



Differential Cross Sections with structure functions F_i and g_i

Unpol : $$\frac{d^3\sigma^{\nu p}}{dx\,dy\,dz} = \frac{G_F^2 s}{2\pi(1+Q^2/M_W^2)^2}\left[(1-y)F_2^{W^\mp} + y^2 x F_1^{W^\mp} \pm y(1-\frac{y}{2})xF_3^{W^\mp}\right]$$

Pol : $$\frac{d^3\Delta\sigma^{\nu p}}{dx\,dy\,dz} = \frac{G_F^2 s}{2\pi(1+Q^2/M_W^2)^2}\left[(1-y)g_4^{W^\mp} + y^2 x g_3^{W^\mp} \pm y(1-\frac{y}{2})xg_1^{W^\mp}\right]$$

where

$$x = \frac{Q^2}{2P_p\cdot q}, \quad y = \frac{P_p\cdot q}{P_p\cdot P_\nu}, \quad z = \frac{P_p\cdot P_D}{P_p\cdot q}$$

$P_p,\ P_\nu,\ P_D,\ q$	:	Momentum of proton, neutrino, D meson, $W^\pm$ boson
G_F	:	Fermi coupling
s	:	Center of mass energy squared
M_W	:	$W^\pm$ boson mass
$F_i,\ g_i$	:	Unpolarized, Polarized structure functions

The structure functions F_i and g_i in νp scattering are obtained by the following convolutions.

$$\left\{ \begin{matrix} \mathcal{F}_i^c \\ \mathcal{G}_i^c \end{matrix} (x, z, Q^2) \right\} = \left\{ \begin{matrix} s \\ \Delta s \end{matrix} (\xi, \mu_F^2) \right\} D_c(z)$$

$$+ \frac{\alpha_s(\mu_R^2)}{2\pi} \int_\xi^1 \frac{d\xi'}{\xi'} \int_{\max(z,\zeta_{\min})}^1 \frac{d\zeta}{\zeta} \left[\left\{ \begin{matrix} H_i^q \\ \Delta H_i^q \end{matrix} (\xi', \zeta, \mu_F^2, \lambda) \right\} \left\{ \begin{matrix} s \\ \Delta s \end{matrix} (\frac{\xi}{\xi'}, \mu_F^2) \right\} \right.$$

$$\left. + \left\{ \begin{matrix} H_i^g \\ \Delta H_i^g \end{matrix} (\xi', \zeta, \mu_F^2, \lambda) \right\} \left\{ \begin{matrix} g \\ \Delta g \end{matrix} (\frac{\xi}{\xi'}, \mu_F^2) \right\} \right] D_c(\frac{z}{\zeta}) \quad .$$

where

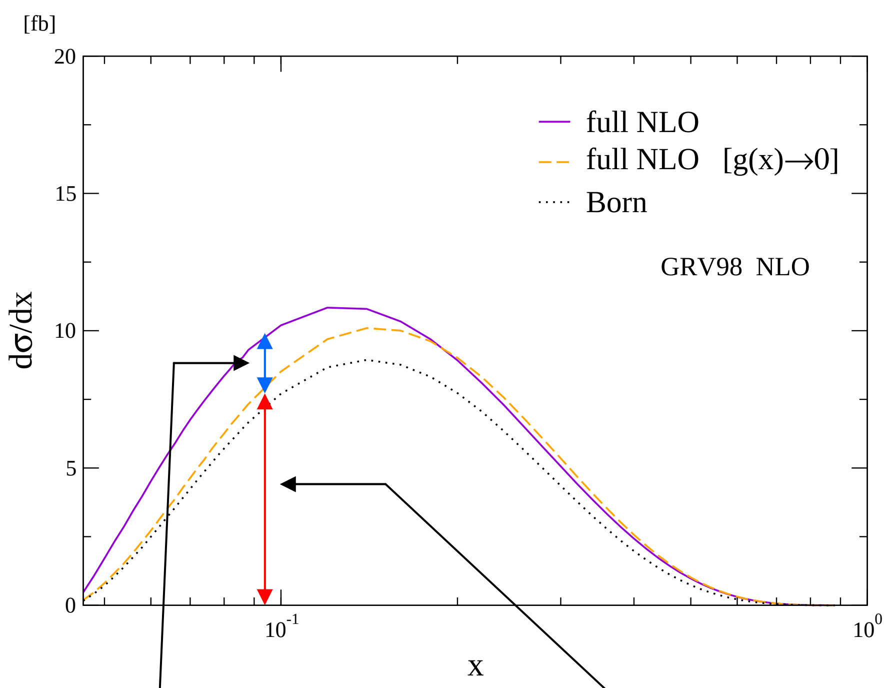
$$s \equiv |V_{cs}|^2 s + |V_{cd}|^2 d$$

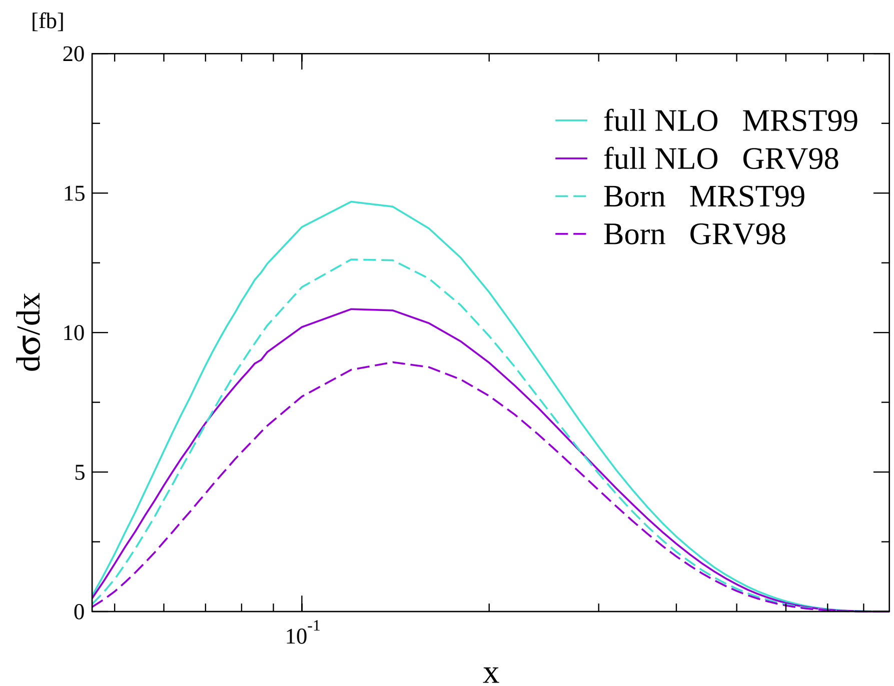
$$\xi = \frac{Q^2}{2P_p \cdot q} \left(1 + \frac{m_c^2}{Q^2} \right), \quad \xi' = \frac{Q^2}{2p_{s,g} \cdot q} \left(1 + \frac{m_c^2}{Q^2} \right), \quad \zeta = \frac{p_{s,g} \cdot p_c}{p_{s,g} \cdot q}$$

$$\left\{ \begin{matrix} \mathcal{F}_1^c \\ \mathcal{G}_3^c \end{matrix} \right\} = \left\{ \begin{matrix} F_1^c \\ -g_3^c \end{matrix} \right\}, \quad \left\{ \begin{matrix} \mathcal{F}_3^c \\ \mathcal{G}_1^c \end{matrix} \right\} = \frac{1}{2} \left\{ \begin{matrix} -F_3^c \\ g_1^c \end{matrix} \right\}, \quad \left\{ \begin{matrix} \mathcal{F}_2^c \\ \mathcal{G}_4^c \end{matrix} \right\} = \frac{1}{2\xi} \left\{ \begin{matrix} F_2^c \\ -g_4^c \end{matrix} \right\}$$

Unpolarized Cross Section

$$\nu + \vec{p} \to l^- + D + X \qquad E_\nu = 50\,\mathrm{GeV}$$





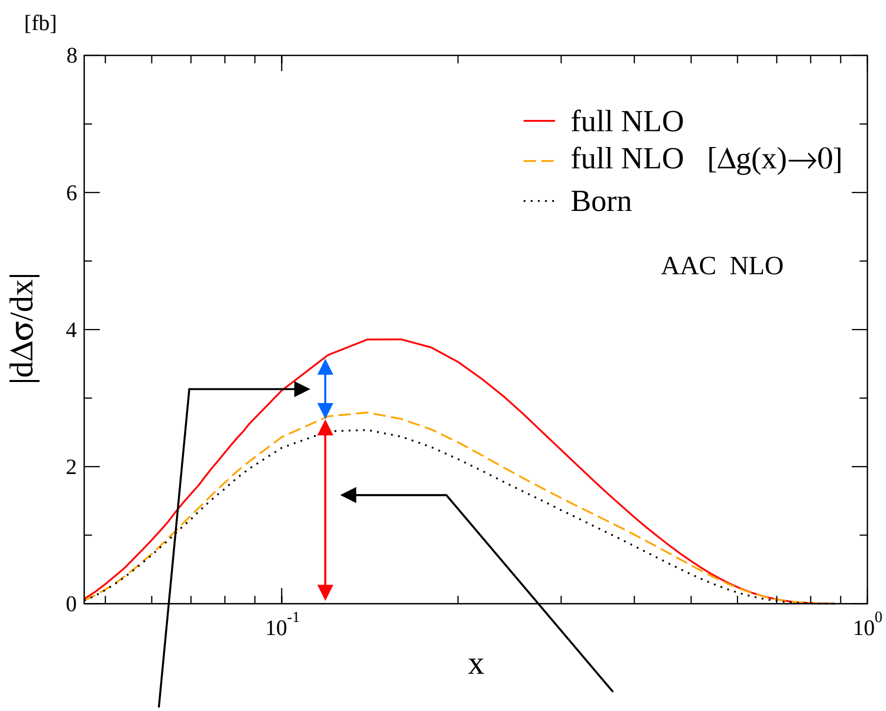
***g* contribution**

(*s*+*d*) contribution

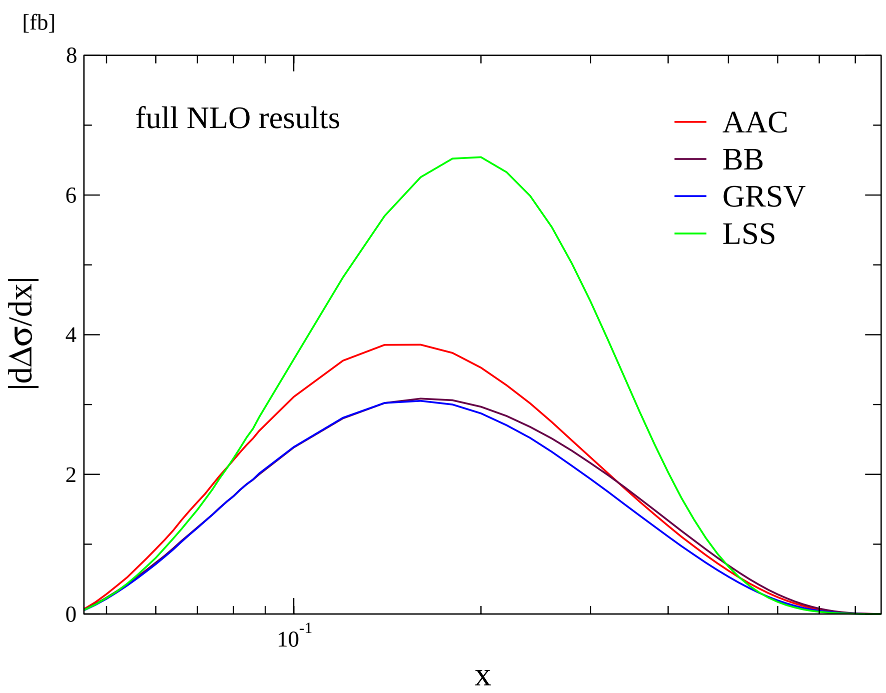
Polarized Cross Section

$$\nu + \vec{p} \rightarrow l^- + D + X \qquad E_\nu = 50\,\mathrm{GeV}$$

Polarized Cross Sections



PDFs Model Dependence



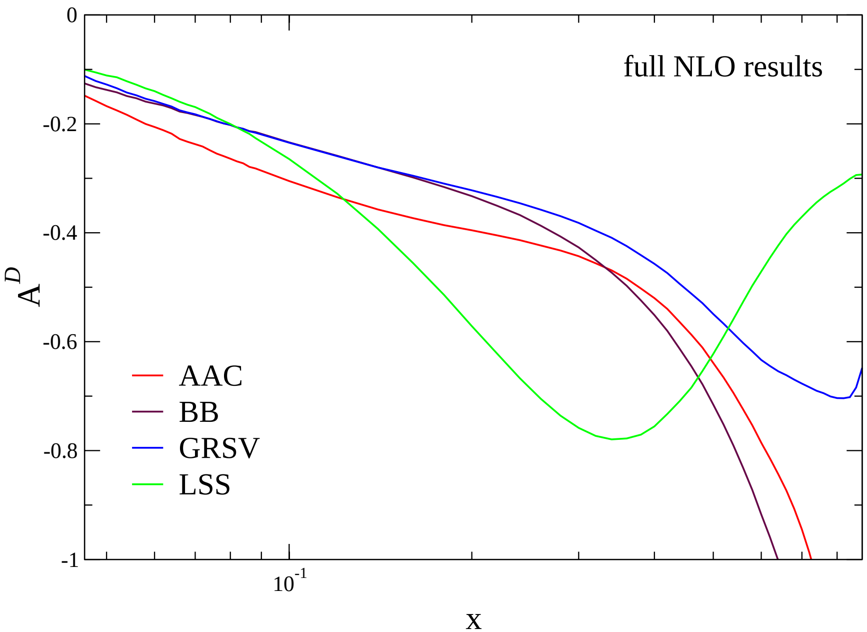
Δg contribution **$(\Delta s+\Delta d)$ contribution**

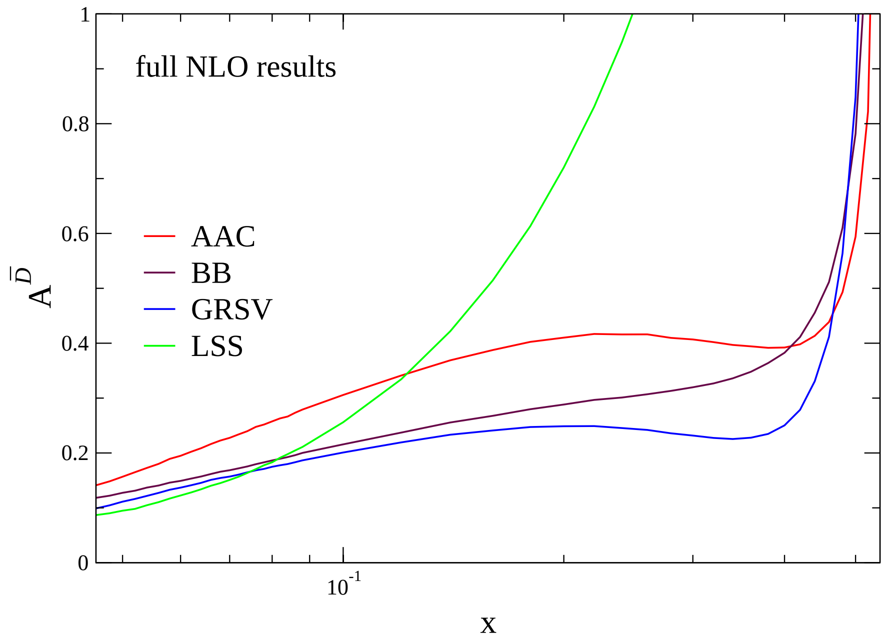
Spin Asymmetry A^D and $A^{\bar{D}}$

- **PDFs Model Dependence** $E_\nu = 50\,\text{GeV}$
  - **Big difference among parametrizations can be seen.**
  - **A^D at large x region dominated by Δd_v.**
  - **$A^{\bar{D}}$ might be promising for extraction of Δs.**

$$\nu + \vec{p} \rightarrow l^- + D + X$$

$$\bar{\nu} + \vec{p} \rightarrow l^+ + \bar{D} + X$$





V. Conclusion

- $D/\bar{D}$ production in neutrino-induced CC DIS is studied including $O(\alpha_s)$ NLO corrections.
  - The cross sections are dominated by Born and NLO boson-gluon fusion process.
  - The parametrization model dependence on the asymmetry is quite large, and the behavior for the LSS are especially different among other parametrizations.

- $\bar{D}$ production is promising to extract the strange quark density, since the valence Δd_v quark contribution is large in D production.

⇨ If $\Delta g(x, Q^2)$ is determined by RHIC experiment with high accuracy, we can directly extract the strange sea $\Delta s(x, Q^2)$.