Nuclear Dependence in Weak Structure Functions and the Determination of Weak Mixing Angle

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Outline

Introduction

The present understanding of the nuclear medium effects in DIS is mainly based on charged lepton-nucleus DIS data.

year	set	order	data types used
1998	EKS98	LO	l+A DIS, p+A DY
2001	HKM	LO	l+A DIS
2004	HKN04	LO	l+A DIS, p+A DY
2004	nDS	NLO	l+A DIS, p+A DY
2007	EKPS	LO	l+A DIS, p+A DY
2007	HKN07	NLO	l+A DIS, p+A DY
2008	EPS08	LO	l+A DIS, p+A DY, $h^{\pm}, \pi^0, \pi^{\pm}$ in d+Au
2009	**EPS09**	NLO	l+A DIS, p+A DY, π^0 in d+Au
2009	nCTEQ	NLO	l+A DIS, p+A DY
2010	**nCTEQ**	NLO	l+A and ν+A DIS, p+A DY
2012	**DSSZ**	NLO	l+A and ν+A DIS, p+A DY, $\pi^0, \pi^{\pm}$ in d+Au, computed with nFFs

Paukkunen and Salgado:JHEP2010: “find no apparent disagreement with the nuclear effects in neutrino DIS and those in charged lepton DIS.”

CTEQ-Grenoble-Karlsruhe collaboration: “observed that the nuclear corrections in ν-A DIS are indeed incompatible with the predictions derived from $\ell^{\pm}$-A DIS and DY data”

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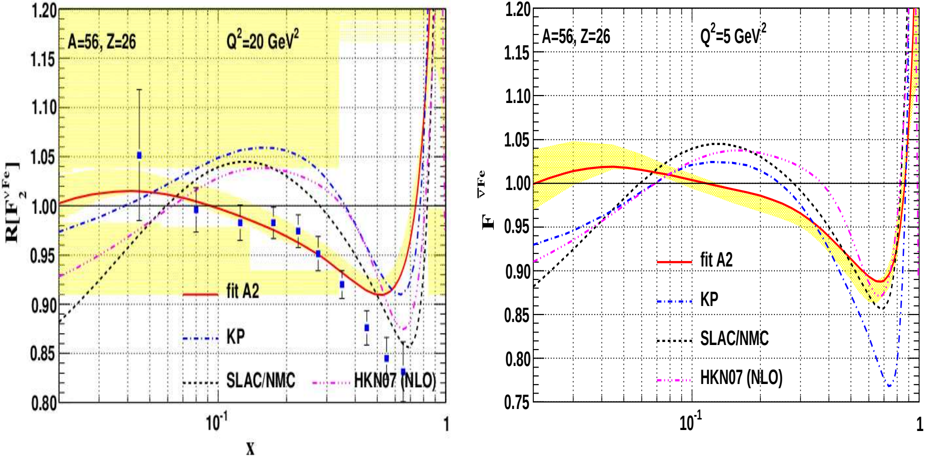


J G Morfin J. of Physics: Conf. Ser. 408 (2013) 012054; Kovarik et al. Phys.Rev.Lett. 106 (2011) 122301

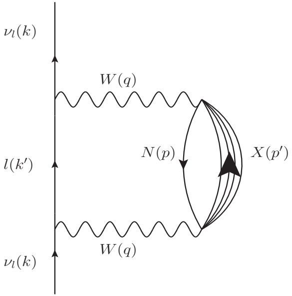
Theoretical Study

On the theoretical side, in the case of deep inelastic scattering process induced by weak interaction, there are very few calculations where the dynamical origin of the nuclear medium effects has been studied.

Kulagin and Petti:PRD 76 094023 2007.

Our group:
PRC 87 035502 (2013)
PRC 85 055201 (2012)
PRC 84 054610 (2011)
NPA 857 29 (2011)
PLB 668 133 (2008)

Neutrino nucleon scattering



$$\nu_l(k) + N(p) \rightarrow l^-(k') + X(p'), \; l = \; e, \; \mu,$$

Anti(neutrino)-nucleon double differential scattering cross section:

ν-*N DCX*

$$\frac{d^2\sigma^N_{\nu,\bar{\nu}}}{d\Omega' dE'} = \frac{G_F{}^2}{(2\pi)^2} \frac{|\vec{k}'|}{|\vec{k}|} \left(\frac{m_W^2}{q^2 - m_W^2}\right)^2 L^{\alpha\beta}_{\nu,\bar{\nu}} \, W^N_{\alpha\beta} \, ,$$

Leptonic Tensor

$$L^{\alpha\beta} = k^{\alpha}k'^{\beta} + k^{\beta}k'^{\alpha} - k.k' g^{\alpha\beta} \pm i\epsilon^{\alpha\beta\rho\sigma}k_{\rho}k'_{\sigma}$$

Hadronic tensor

$$W^{N}_{\alpha\beta} = \left(\frac{q_{\alpha}q_{\beta}}{q^2} - g_{\alpha\beta}\right) W_1^{\nu(\bar{\nu})} + \frac{1}{M^2}\left(p_{\alpha} - \frac{p.q}{q^2}q_{\alpha}\right)\left(p_{\beta} - \frac{p.q}{q^2}q_{\beta}\right) W_2^{\nu(\bar{\nu})} - \frac{i}{2M^2}\epsilon_{\alpha\beta\rho\sigma}p^{\rho}q^{\sigma}W_3^{\nu(\bar{\nu})}$$

The differential cross section:

$$\frac{d^2\sigma^{\nu(\bar{\nu})}}{dx\,dy} = \frac{G_F^2 M E_{\nu}}{\pi(1+Q^2/M_W^2)^2}\left(\left[y^2 x + \frac{m_l^2 y}{2E_{\nu}M}\right]F_1(x,Q^2) + \left[\left(1-\frac{m_l^2}{4E_{\nu}^2}\right) - \left(1+\frac{Mx}{2E_{\nu}}\right)y\right]F_2(x,Q^2) \pm \left[xy\left(1-\frac{y}{2}\right) - \frac{m_l^2 y}{4E_{\nu}M}\right]F_3(x,Q^2)\right)$$

where

$$MW_1^N(\nu,Q^2) = F_1^N(x,Q^2);\;\; \nu W_2^N(\nu,Q^2) = F_2^N(x,Q^2);\;\; \nu W_3^N(\nu,Q^2) = F_3^N(x,Q^2)$$

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Medium effects in ν-A scattering

- Kinematic effect which arises as the struck nucleon is not at rest but is moving with a Fermi momentum in the rest frame of the nucleus.

- Dynamic effect which arises due to the strong interaction of the initial nucleon in the nuclear medium.

In a nuclear medium the expression for the cross section is written as:

$$\frac{d^2\sigma^A_{\nu,\bar{\nu}}}{d\Omega' dE'} = \frac{G_F^2}{(2\pi)^2}\frac{|\mathbf{k}'|}{|\mathbf{k}|}\left(\frac{m_W^2}{q^2 - m_W^2}\right)^2 L^{\alpha\beta}_{\nu,\bar{\nu}}\, W^A_{\alpha\beta},$$

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Nuclear hadronic tensor:

$$
\begin{aligned}
W^A_{\alpha\beta} &= \left(\frac{q_\alpha q_\beta}{q^2} - g_{\alpha\beta}\right) W^A_1 + \frac{1}{M_A^2}\left(p_\alpha - \frac{p.q}{q^2}\,q_\alpha\right)\left(p_\beta - \frac{p.q}{q^2}\,q_\beta\right) W^A_2 \\
&- \frac{i}{2M_A^2}\varepsilon_{\alpha\beta\rho\sigma}p^\rho q^\sigma W^A_3
\end{aligned}
$$

$W^A_i(x, Q^2)$ are redefined as:

$$
\begin{aligned}
M_A W^A_1(\nu, Q^2) &= F^A_1(x, Q^2) \\
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- We use a relativistic nucleon spectral function to describe the momentum distribution of nucleons in nuclei.
- The spectral function has been calculated using Lehmann's representation for the relativistic nucleon propagator.
- Nuclear many body theory is used to calculate it for an interacting Fermi sea in nuclear matter.
- A local density approximation is then applied to translate these results to finite nuclei.

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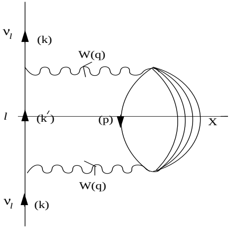
σ for ν-scattering from an element of volume d^3r and surface dS in the nucleus:

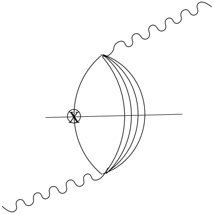
$$d\sigma \quad = \quad \Gamma dt dS = \Gamma \frac{E_\nu(\vec{k})}{|\vec{k}|\; d^3r} = -\frac{2m_\nu}{|\vec{k}|} \,\mathrm{Im}\,\Sigma\, d^3r\,.$$



ν *self energy* $\Sigma(k)$ *following the Feynman rules, is written as:*

$$\Sigma(k) = (-i)\frac{G_F}{\sqrt{2}}\frac{4}{m_\nu}\int \frac{d^4k'}{(2\pi)^4}\frac{1}{k'^2 - m_l^2 + i\epsilon}\left(\frac{m_W}{q^2 - m_W^2}\right)^2 L_{\alpha\beta}\;\Pi^{\alpha\beta}(q)$$

$\Pi^{\alpha\beta}(q)$ is the W self-energy in the nuclear medium:



$$-i\Pi^{\alpha\beta}(q) = \quad (-) \int \frac{d^4p}{(2\pi)^4} iG(p) \sum_X \sum_{s_p, s_i} \prod_{i=1}^{n} \int \frac{d^4p'_i}{(2\pi)^4} \prod_l iG_l(p'_l) \prod_j iD_j(p'_j)$$

$$\left(\frac{-G_F m_W^2}{\sqrt{2}}\right) \langle X|J^\alpha|N\rangle \langle X|J^\beta|N\rangle^* (2\pi)^4 \delta^4(q+p-\Sigma_{i=1}^n p'_i)$$

Relativistic Dirac propagator $G^0(p_0, \vec{p})$ for a free nucleon:

$$G^0(p_0,\vec{p}) = \frac{M}{E(p)} \left\{ \frac{\sum_r u_r(p)\bar{u}_r(p)}{p^0 - E(\vec{p}) + i\epsilon} + \frac{\sum_r v_r(-p)\bar{v}_r(-p)}{p^0 + E(\vec{p}) - i\epsilon} \right\}$$

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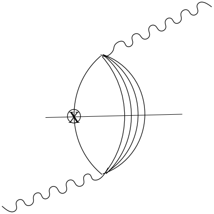

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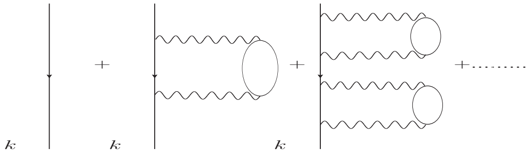
The nucleon propagator in the interacting Fermi sea is obtained by making a perturbative expansion of $G(p^0, p)$ in terms of $G^0(p^0, p)$ by retaining the positive energy contributions only:



$$
\begin{aligned}
G(p_0, p) &= \frac{M}{E(p)} \frac{\sum_r u_r(p)\bar{u}_r(p)}{(p^0 - E(p) + i\varepsilon)} + \\
&\quad \left(\frac{M}{E(p)}\right)^2 \frac{1}{(p^0 - E(p) + i\varepsilon)} \sum \frac{\sum_r u_r(p)\bar{u}_r(p)}{(p^0 - E(p) + i\varepsilon)} + \ldots \\
&= \frac{M}{E(p)} \frac{\sum_r u_r(p)\bar{u}_r(p)}{\left(p^0 - E(p) + i\varepsilon \frac{M}{E(p)} \Sigma\right)}
\end{aligned}
$$

This allows us to write the relativistic nucleon propagator in a nuclear medium in terms of the spectral functions of holes and particles as:

$$G(p^0,\vec{p}) = \frac{M}{E(\vec{p})}\sum_r u_r(\vec{p})\bar{u}_r(\vec{p})\left[\int_{-\infty}^{\mu} d\omega \frac{S_h(\omega,\vec{p})}{p^0-\omega-i\epsilon} + \int_{\mu}^{\infty} d\omega \frac{S_p(\omega,\vec{p})}{p^0-\omega+i\epsilon}\right]$$

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for $p^0 \leq \mu$

$$S_h(p^0,\vec{p}) = \frac{1}{\pi}\frac{\frac{M}{E(\vec{p})}Im\Sigma(p^0,p)}{(p^0-E(p)-\frac{M}{E(\vec{p})}Re\Sigma(p^0,p))^2+(\frac{M}{E(\vec{p})}Im\Sigma(p^0,p))^2}$$

for $p^0 > \mu$

$$S_p(p^0,\vec{p}) = -\frac{1}{\pi}\frac{\frac{M}{E(\vec{p})}Im\Sigma(p^0,p)}{(p^0-E(p)-\frac{M}{E(\vec{p})}Re\Sigma(p^0,p))^2+(\frac{M}{E(\vec{p})}Im\Sigma(p^0,p))^2}$$

P. Fernandez de Cordoba and E. Oset, Phys. Rev. C 46 (1992) 1697

Nuclear hadronic tensor:

In the LDA, the nuclear hadronic tensor can be written as a convolution of nucleonic hadronic tensor with the hole spectral function

$$W^A_{\alpha\beta} = 4\int d^3r \int \frac{d^3p}{(2\pi)^3} \int_{-\infty}^{\mu} dp^0 \frac{M}{E(\vec{p})} S_h(p^0,\vec{p},\rho(r)) W^N_{\alpha\beta}(p,q)$$

Weak nuclear structure functions $F^A_2(x_A,Q^2)$ and $F^A_3(x_A,Q^2)$ with Fermi motion, Pauli blocking, nucleon correlations and binding energy:

$$F^A_2(x_A,Q^2) = 4\int d^3r \int \frac{d^3p}{(2\pi)^3} \frac{M}{E(\vec{p})} \int_{-\infty}^{\mu} dp^0\, S_h(p^0,\mathbf{p},\rho(\mathbf{r})) \frac{x}{x_N} \times \left(1+\frac{2x_N p_x^2}{M\nu_N}\right) F^N_2(x_N,Q^2)$$

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Weak nuclear structure functions $F_2^A(x_A, Q^2)$ and $F_3^A(x_A, Q^2)$ with Fermi motion, Pauli blocking, nucleon correlations and binding energy:

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where

$$\gamma = \frac{q_z}{q^0} = \left(1+\frac{4M^2x^2}{Q^2}\right)^{1/2} \quad \text{and} \quad x_N = \frac{Q^2}{2(p^0q^0 - p_zq_z)}$$

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where

$$\gamma = \frac{q_z}{q^0} = \left(1+\frac{4M^2x^2}{Q^2}\right)^{1/2} \quad \text{and} \quad \mathrm{x_N} = \frac{Q^2}{2(\mathrm{p^0q^0 - p_zq_z})}$$

Weak nuclear structure functions $F_2^A(x_A,Q^2)$ and $F_3^A(x_A,Q^2)$ with Fermi motion, Pauli blocking, nucleon correlations and binding energy:

$$F_2^A(x_A,Q^2) = 4\int d^3r \int \frac{d^3p}{(2\pi)^3}\frac{M}{E(\vec{p})}\int_{-\infty}^{\mu} dp^0\, S_h(p^0,\mathbf{p},\rho(\mathbf{r}))\frac{x}{x_N} \times \left(1+\frac{2x_N p_x^2}{M\nu_N}\right) F_2^N(x_N,Q^2)$$

$$F_3^A(x_A,Q^2) = 4\int d^3r \int \frac{d^3p}{(2\pi)^3}\frac{M}{E(\vec{p})}\int_{-\infty}^{\mu} dp^0 S_h(p^0,\mathbf{p},\rho(\mathbf{r})) \times \frac{p^0\gamma - p_z}{(p^0-p_z\gamma)\gamma} F_3^N(x_N,Q^2)$$

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π *and* ρ *mesons contribution to the nuclear structure function*

The pion and rho meson cloud contributions to the F_2 structure function have been implemented following the many body field theoretical approach.

The pion structure function $F_{2A,\pi}(x)$:

$$F^A_{2,\pi}(x) = -6\int d^3r \int \frac{d^4p}{(2\pi)^4}\,\theta(p^0)\,\delta ImD(p)\frac{x}{x_\pi}\,2M\,F_{2\pi}(x_\pi)\,\theta(x_\pi - x)\,\theta(1-x_\pi)$$

The ρ-meson structure function $F^A_{2,\rho}(x)$:

$$F^A_{2,\rho}(x) = -12\int d^3r \int \frac{d^4p}{(2\pi)^4}\theta(p^0)\delta ImD_\rho(p)\frac{x}{x_\rho}2MF_{2\rho}(x_\rho)\theta(x_\rho - x)\theta(1-x_\rho)$$

We have used CTEQ PDFs for the numerical calculations.

1. The NLO evolution of DIS structure functions are taken from the works of Vermaseren and van Neerven et al.NPB724(2005)3 van Neerven and Vogt NPB568(2000)263.
2. The TMC correction has been taken from the works of Schienbein et al. JPG 35 (2008) 053101.
3. For the shadowing and antishadowing effects, Glauber-Gribov multiple scattering model has been used following the work of Kulagin and Petti. PRD76(2007)094033.

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Deuteron Structure Functions

$$F_2^D(x,Q^2) = \int \frac{d^3p}{(2\pi)^3} |\Psi_D(\mathbf{p})|^2 \frac{\left(1-\gamma\frac{p_z}{M}\right)}{\gamma^2} \left(\gamma'^2 + \frac{6x'^2(\mathbf{p}^2 - p_z^2)}{Q^2}\right) F_2^N(x,Q^2)$$

and

$$F_3^D(x_A,Q^2) \quad = \quad \int \frac{d^3p}{(2\pi)^3} |\Psi_D(\mathbf{p})|^2 \frac{p^0\gamma - p_z}{(p^0 - p_z\gamma)\gamma} F_3^N(x,Q^2)$$

Another treatment: Ciofi degli Atti, Frankfurt .. PRC 76 (2007) 055206

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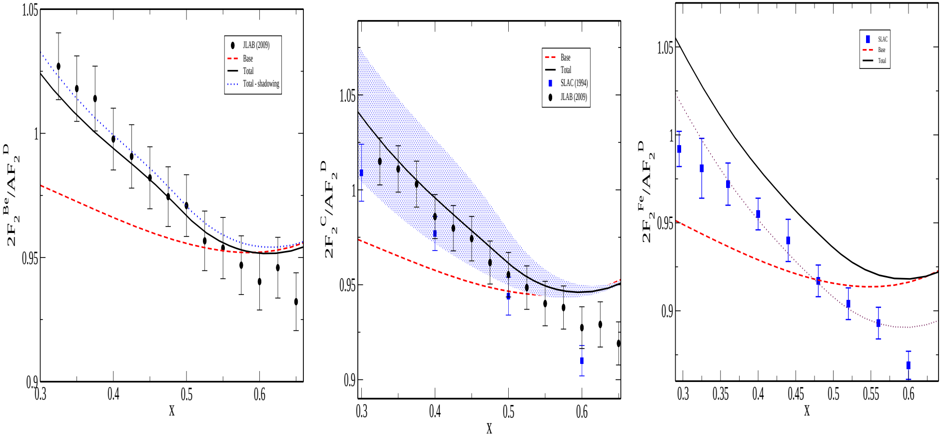
Electromagnetic Structure Function

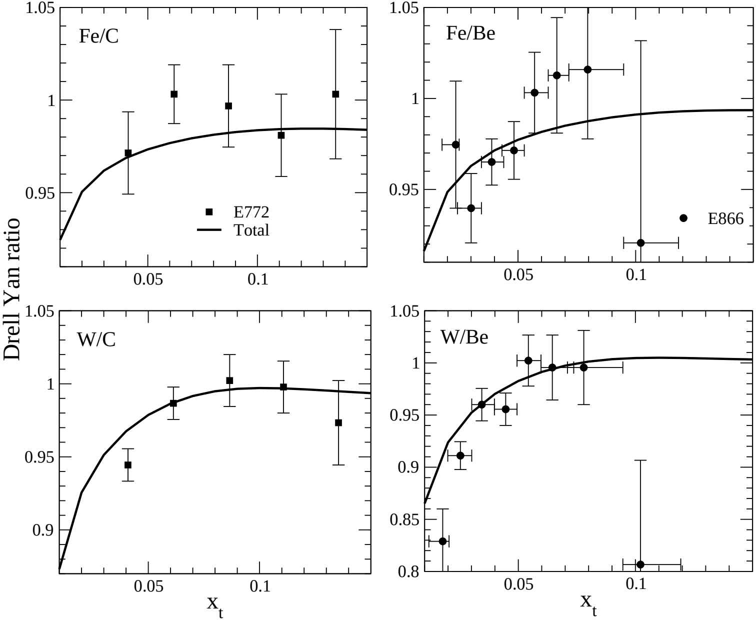
$$F_2^A(x,Q^2) = 4\int d^3r \int \frac{d^3p}{(2\pi)^3} \int_{-\infty}^{\mu} d\omega\, S_h(\omega,\mathbf{p},\rho(\mathbf{r})) \frac{\left(1-\gamma\frac{p_z}{M}\right)}{\gamma^2} \times \left(\gamma^2 + \frac{6x^2(\mathbf{p}^2 - p_z^2)}{Q^2}\right) F_2^N(x,Q^2)$$

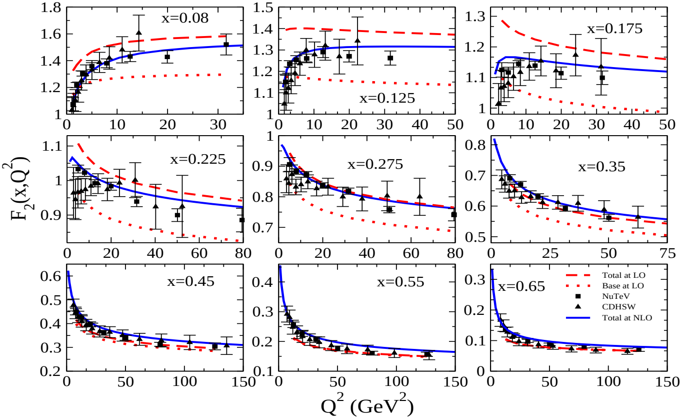
Electromagnetic Nuclear Structure Function

$\frac{2F_2^A}{AF_2^D}(A = Be, C, Fe)$ vs x

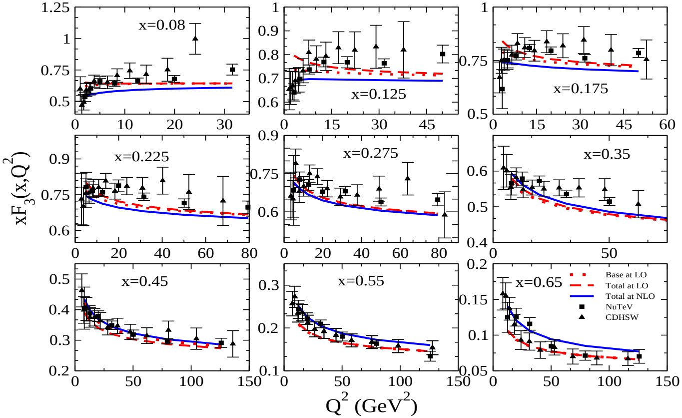


MSA, I Ruiz Simo, M J Vicente Vacas NPA 857 29 (2011)

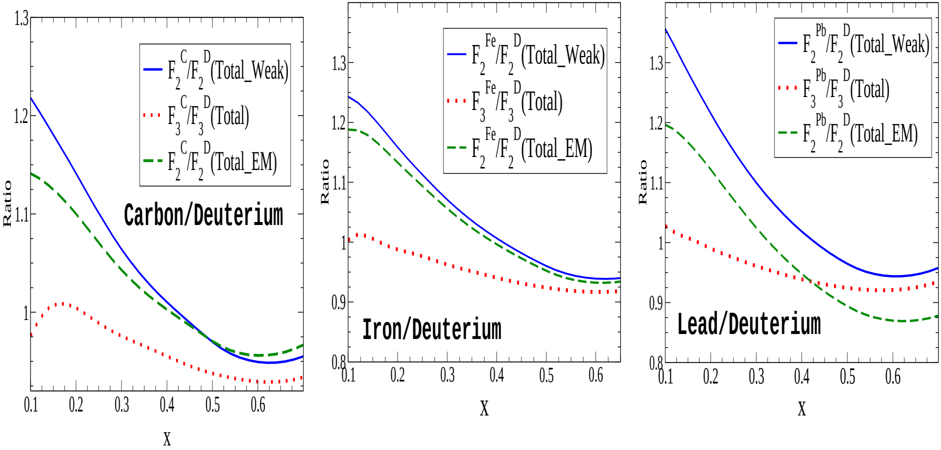

Drell Yan ratio
Fe/C
E772
Total
Fe/Be
E866
W/C
W/Be
x_t
1.05
1
0.95
0.9
0.85
0.8
0.05
0.1



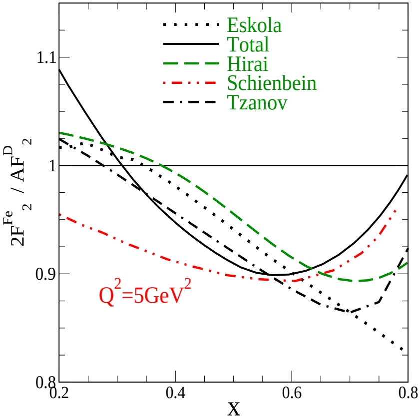
H Haider, I Ruiz Simo, MSA and M J Vicente Vacas PRC 84 054610 (2011)

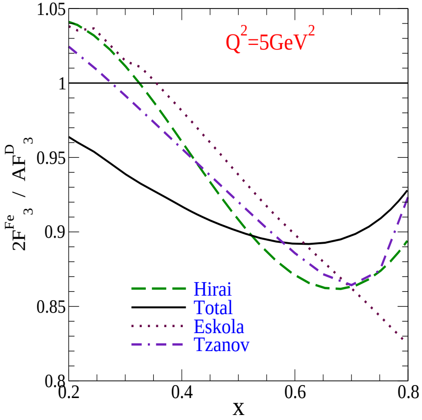


H Haider, I Ruiz Simo, MSA and M J Vicente Vacas PRC 84 054610 (2011)

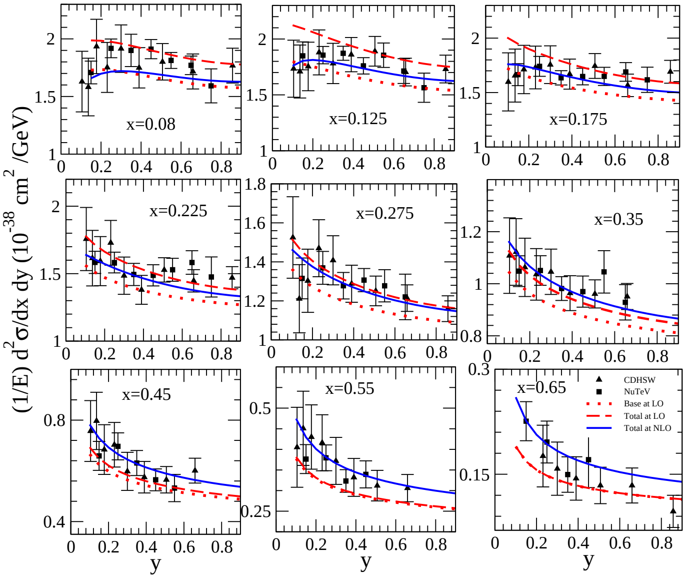

Carbon/Deuterium
F2C/F2D(Total_Weak)
F3C/F3D(Total)
F2C/F2D(Total_EM)
Ratio
X
Iron/Deuterium
F2Fe/F2D(Total_Weak)
F3Fe/F3D(Total)
F2Fe/F2D(Total_EM)
Ratio
X
Lead/Deuterium
F2Pb/F2D(Total_Weak)
F3Pb/F3D(Total)
F2Pb/F2D(Total_EM)
Ratio
X

$\frac{2F_2^{Fe}}{56F_2^D}$ vs x *and* $\frac{2F_3^{Fe}}{56F_3^D}$ vs x

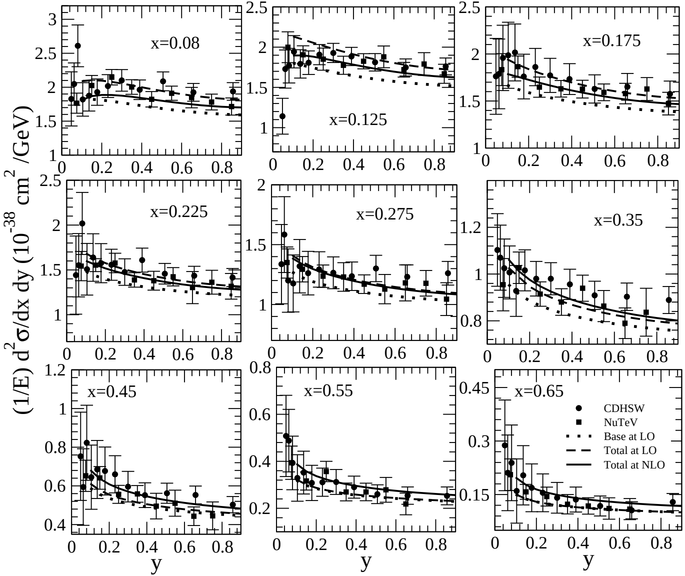




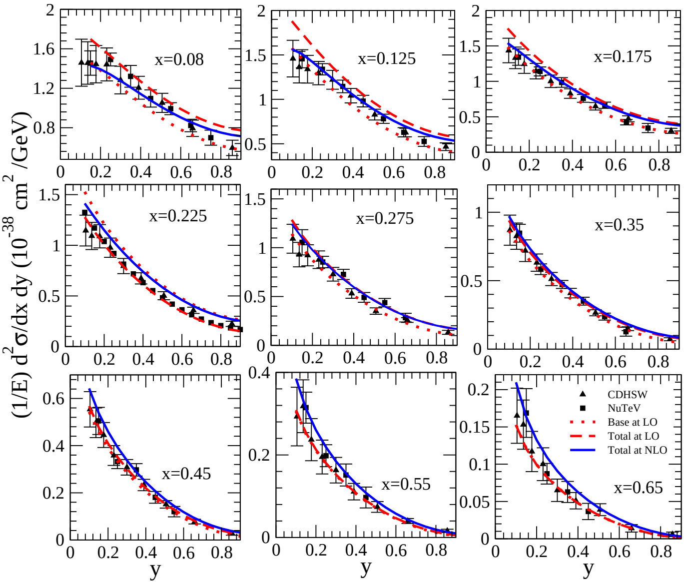
$\frac{1}{E}\frac{d^2\sigma}{dxdy}$ vs E_ν at $E_\nu = 65$ GeV ^{56}Fe



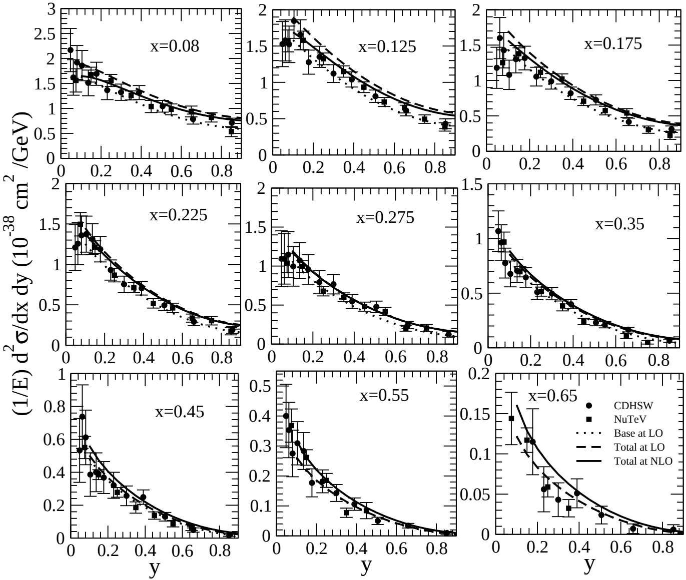
$\frac{1}{E}\frac{d^2\sigma}{dxdy}$ vs E_ν at $E_\nu = 150$ GeV $\quad {}^{56}Fe$



$\frac{1}{E}\frac{d^2\sigma}{dxdy}$ vs $E_{\bar{\nu}}$ at $E_{\bar{\nu}} = 65$ GeV ^{56}Fe



$\frac{1}{E}\frac{d^2\sigma}{dxdy}$ vs $E_{\bar{\nu}}$ at $E_{\bar{\nu}} = 150$ GeV $\quad ^{56}Fe$



Asymmetric Nucleus

The expressions for $F_2^A(x)$ and $F_3^A(x)$ are obtained as:

$$F_2^A(x_A,Q^2) = 2\int d^3r \int \frac{d^3p}{(2\pi)^3}\frac{M}{E(\mathbf{p})}\left[\int_{-\infty}^{\mu_p} dp^0\; S_h^p(p^0,\mathbf{p},k_{F,p})F_2^p(x_N,Q^2) + \int_{-\infty}^{\mu_n} dp^0\; S_h^n(p^0,\mathbf{p},k_{F,n})F_2^n(x_N,Q^2)\right]\frac{x}{x_N}\left(1+\frac{2x_N p_x^2}{M\nu_N}\right)$$

$$F_3^A(x_A,Q^2) = 2\int d^3r \int \frac{d^3p}{(2\pi)^3}\frac{M}{E(\mathbf{p})}\left[\int_{-\infty}^{\mu_p} dp^0\; S_h^p(p^0,\mathbf{p},k_{F,p})F_3^p(x_N,Q^2) + \int_{-\infty}^{\mu_n} dp^0\; S_h^n(p^0,\mathbf{p},k_{F,n})F_3^n(x_N,Q^2)\right]\frac{p^0\gamma-p_z}{(p^0-p_z\gamma)\gamma}$$

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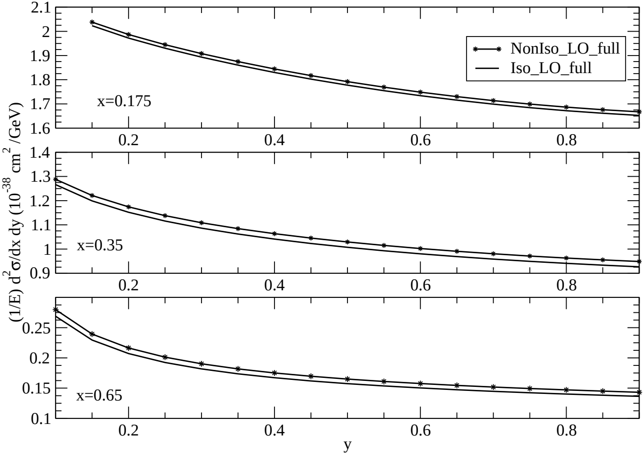
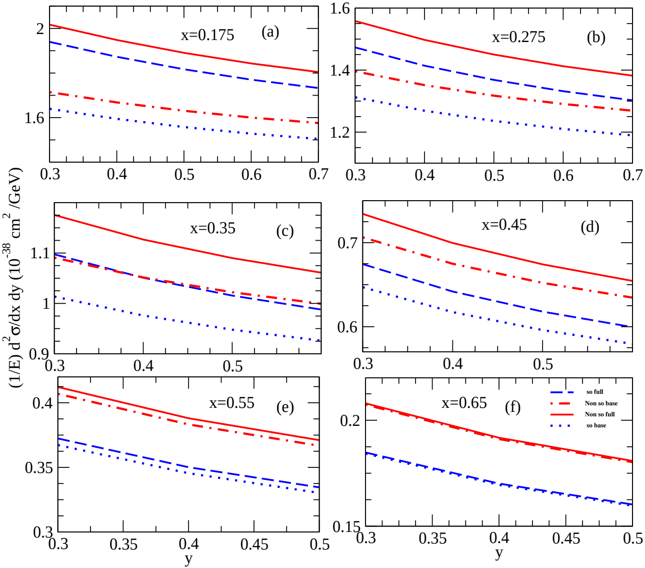
where $k_{F,p} = (3\pi^2\rho_p)^{1/3}$ and $k_{F,n} = (3\pi^2\rho_n)^{1/3}$

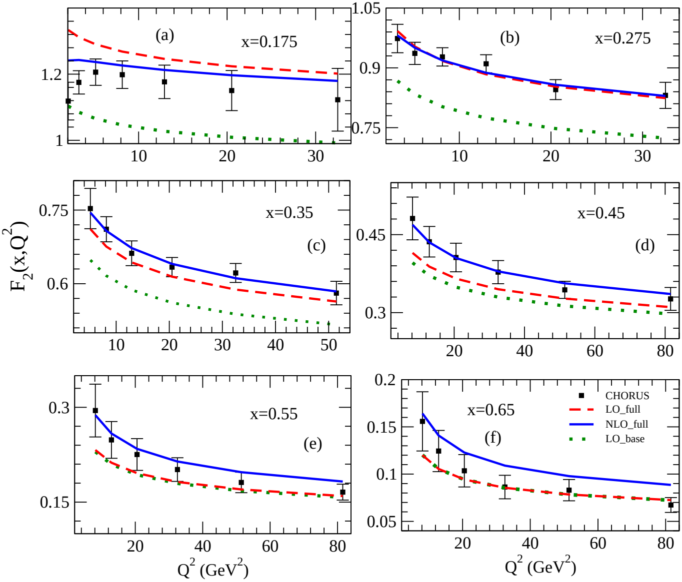
Comparison of Isocalar and Non-Isoscalar Target ^{56}Fe



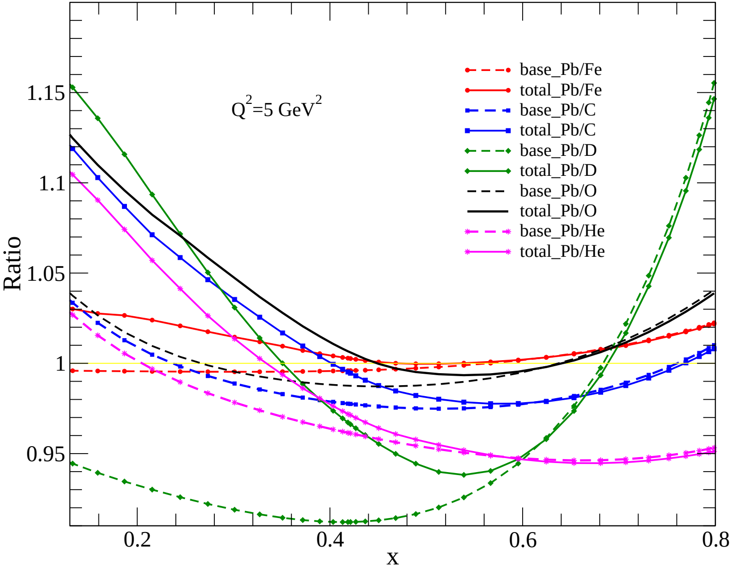


x	% difference
0.175	4-5%
0.65	10-12%

F_2 vs Q^2 $\quad ^{208}Pb$



$\frac{AF_2^{Pb}}{208F_2^A}(A = D, He, O, C, Fe)$ vs x



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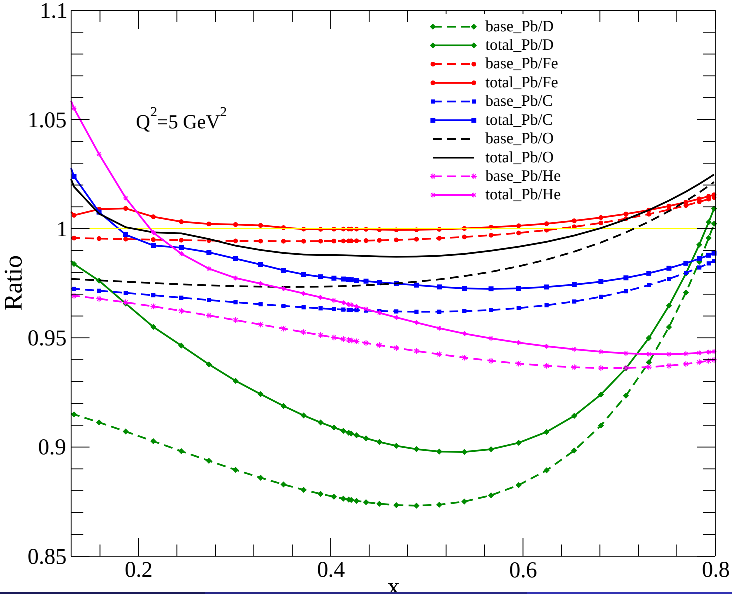
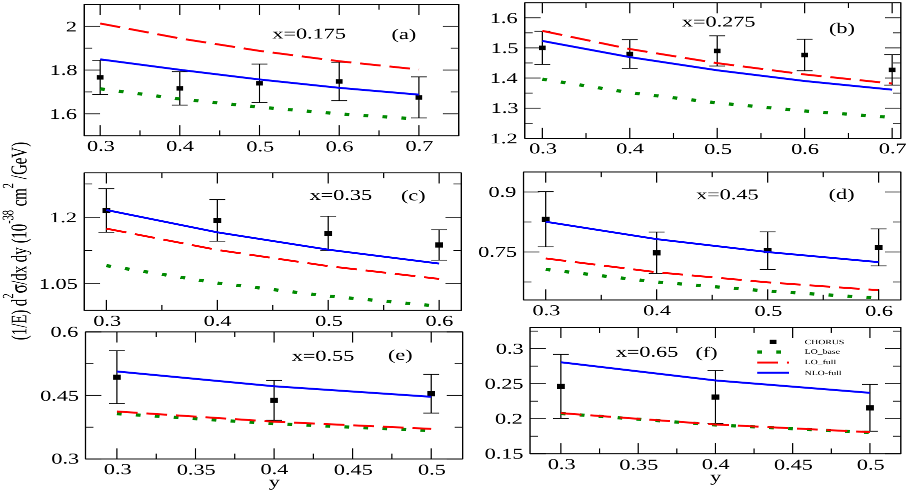


$\frac{1}{E}\frac{d^2\sigma}{dxdy}$ vs E_ν at $E_\nu = 25$ GeV $\quad {}^{208}Pb$



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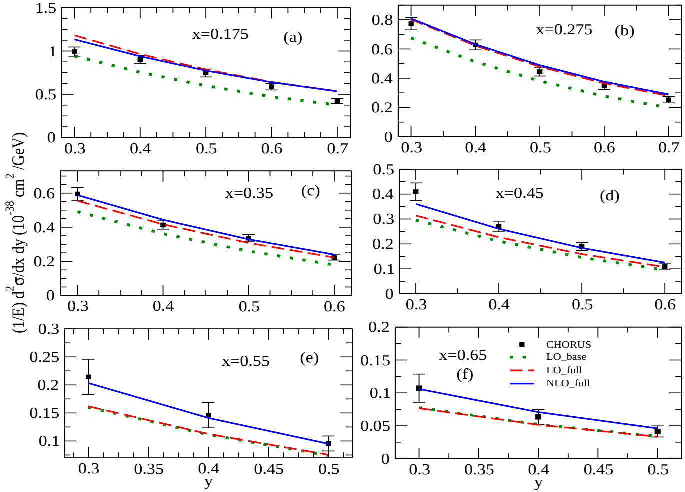
$\frac{1}{E}\frac{d^2\sigma}{dxdy}$ vs $E_{\bar{\nu}}$ at $E_{\bar{\nu}} = 25$ GeV ^{208}Pb



H Haider, I Ruiz Simo and MSA PRC 85 055201 (2012)

Determination of weak mixing angle using PW relation

Paschos and Wolfenstein(PW) relation for the nucleon target:

$$R_{PW} = \frac{\sigma(\nu_\mu\, N \to \nu_\mu\, X)\; - \;\sigma(\bar{\nu}_\mu\, N \to \bar{\nu}_\mu\, X)}{\sigma(\nu_\mu\, N \to \mu^-\, X)\; - \;\sigma(\bar{\nu}_\mu\, N \to \mu^+\, X)} = \frac{1}{2}\; - \;\sin^2\theta_W$$

For the isoscalar nuclear target:

$$R_{PW} = \frac{\sigma(\nu_\mu\, A \to \nu_\mu\, X)\; - \;\sigma(\bar{\nu}_\mu\, A \to \bar{\nu}_\mu\, X)}{\sigma(\nu_\mu\, A \to \mu^-\, X)\; - \;\sigma(\bar{\nu}_\mu\, A \to \mu^+\, X)}$$

PW relation may be written as:

$$R_{PW} \;=\; \frac{\frac{\sigma(\nu_\mu A\to\nu_\mu X)}{\sigma(\nu_\mu A\to\mu^- X)} - \frac{\sigma(\bar{\nu}_\mu A\to\bar{\nu}_\mu X)}{\sigma(\bar{\nu}_\mu A\to\mu^+ X)}\frac{\sigma(\bar{\nu}_\mu A\to\mu^+ X)}{\sigma(\nu_\mu A\to\mu^- X)}}{1-\frac{\sigma(\bar{\nu}_\mu A\to\mu^+ X)}{\sigma(\nu_\mu A\to\mu^- X)}}$$

$$= \frac{R^{\nu}\; - \;r\,R^{\bar{\nu}}}{1-r}$$

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$$= \frac{R^\nu - r R^{\bar{\nu}}}{1 - r}$$

PW relation in differential scattering form:

$$R^{-} = \frac{\frac{d\sigma_{NC}^{\nu A}}{dx\,dy} - \frac{d\sigma_{NC}^{\bar{\nu} A}}{dx\,dy}}{\frac{d\sigma_{CC}^{\nu A}}{dx\,dy} - \frac{d\sigma_{CC}^{\bar{\nu} A}}{dx\,dy}}$$

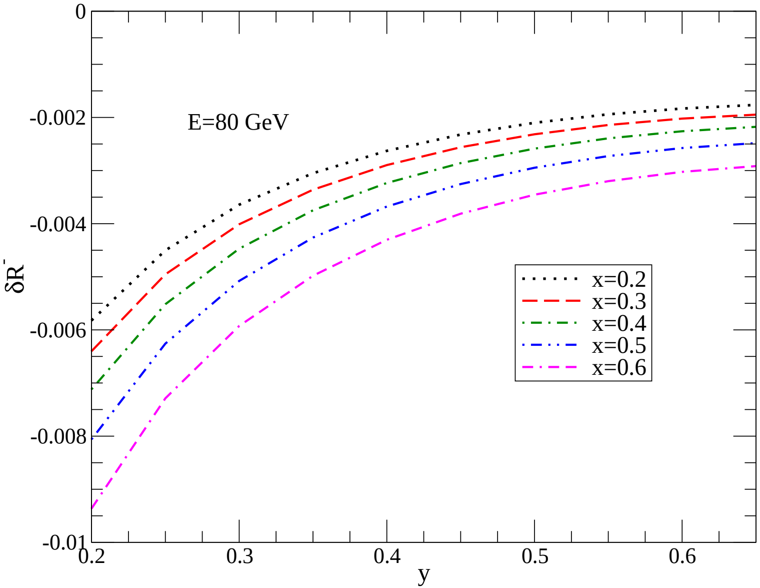
PW relation in differential scattering form:

$$R^{-} = \frac{\frac{d\sigma_{NC}^{\nu A}}{dx\,dy} - \frac{d\sigma_{NC}^{\bar{\nu} A}}{dx\,dy}}{\frac{d\sigma_{CC}^{\nu A}}{dx\,dy} - \frac{d\sigma_{CC}^{\bar{\nu} A}}{dx\,dy}}$$

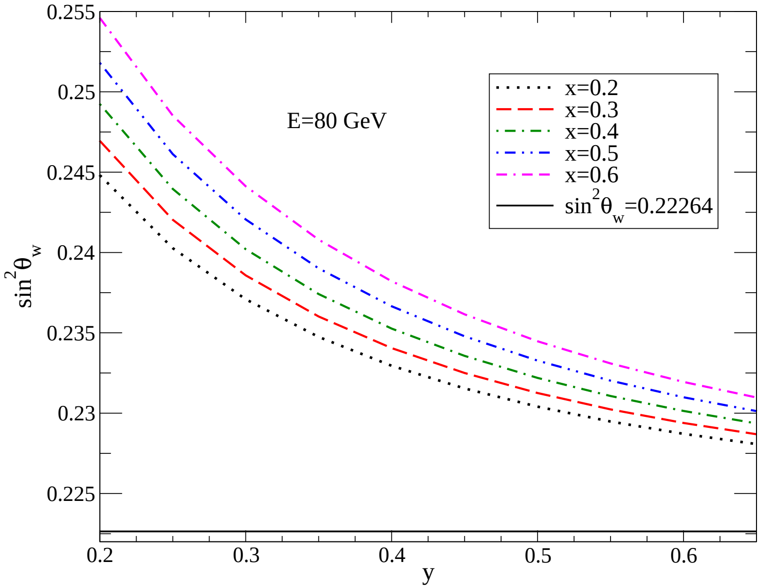
Difference between charged current antineutrino-nucleus cross section and the charged current neutrino-nucleus cross section:

$$\frac{d^2\sigma_{CC}^{\nu A}}{dx_A\,dy_A} - \frac{d^2\sigma_{CC}^{\bar{\nu} A}}{dx_A\,dy_A} = \frac{G_F^2 M_A E_\nu}{\pi}\left[y_A^2 x_A \left(F_1^{\nu A} - F_1^{\bar{\nu} A}\right) + \left\{1 - y_A - \frac{M_A x_A y_A}{2E_\nu}\right\}\left(F_2^{\nu A} - F_2^{\bar{\nu} A}\right) + x_A y_A \left(1 - \frac{y_A}{2}\right)\left(F_3^{\nu A} + F_3^{\bar{\nu} A}\right)\right]$$

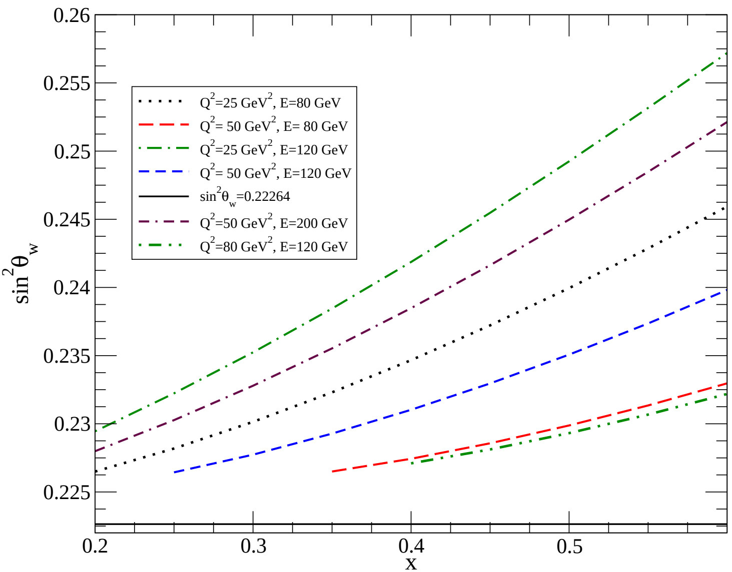
δR^-(Nonisocalarity correction) vs y ^{56}Fe



$Sin^2\theta_W$ vs y $\quad R^- = \frac{1}{2} - \sin^2\theta_W + \delta R^- \quad {}^{56}Fe$



$Sin^2\theta_W$ vs x $\quad$ ^{56}Fe



Conclusions

1. We find that the effect of nuclear medium is also quite important even for DIS.
2. The ratios of structure functions $\frac{F_i^A}{F_i^{A'}}$(i=2,3) are different in nature.
3. The effect of nonisoscalarity in iron is about 2-3% while in lead it is about 10-12%.

Paschos-Wolfenstein ratio

4. There is a strong dependence on nuclear medium effect as well as non-isoscalarity correction in the different regions of x and Q^2.
5. Extraction of $sin^2\theta_W$ also depends upon the ν-energies when evaluated for a given x and Q^2.

Thank You