



NuTeV Recent Structure Function Results

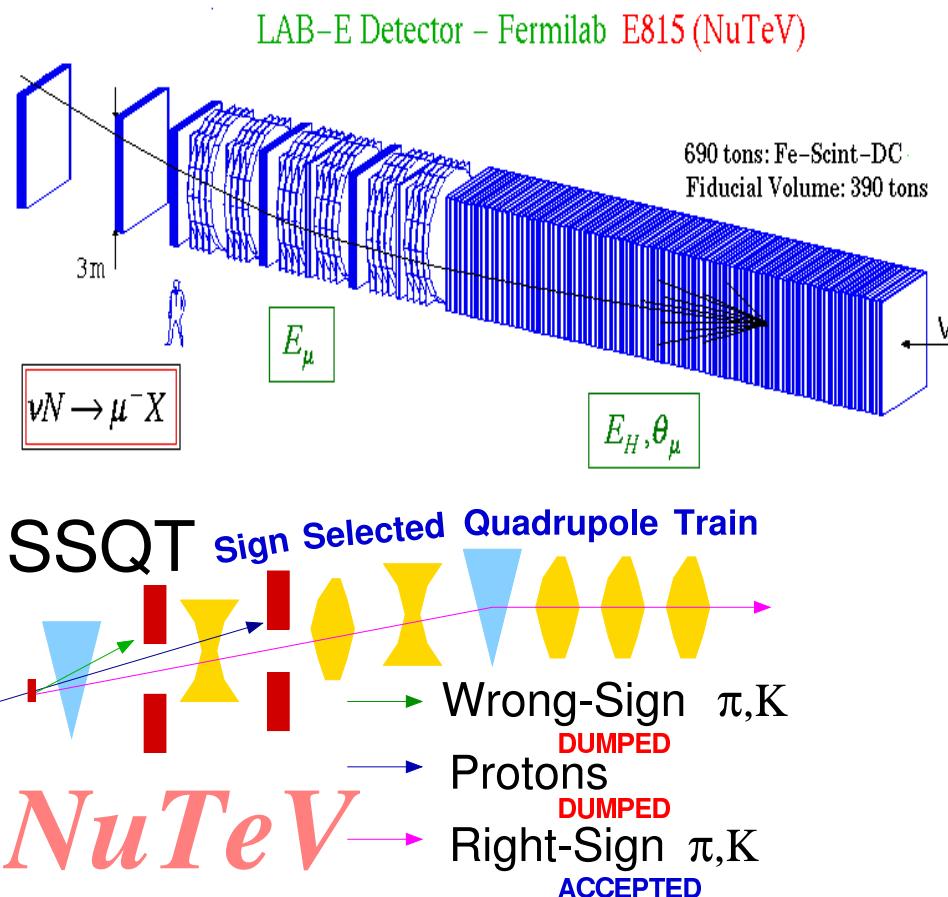
Voica A. Radescu (DESY)
for the NuTeV Collaboration



- NuTeV experiment
- Cross Section Measurements
- Structure Functions and α_S
- Conclusions

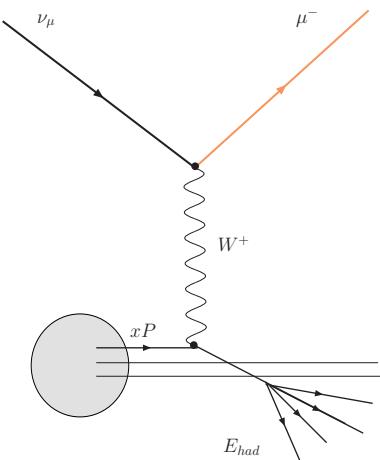
XV International Workshop on Deep-Inelastic Scattering and Related Subjects

NuTeV Experiment:



- a precision $\nu - Fe$ DIS experiment:
Iron Calorimeter + Muon Spectrometer
- Data taking: 1996-97 FNAL fixed target
 $< E_\nu > \sim 120$ GeV, $< Q^2 > \sim 25$ GeV 2
- Sign Selected Beams:
99.9% pure ν_μ , and 99.7% pure $\bar{\nu}_\mu$
- Calibration beam throughout run:
 μ, e^- , hadrons (4.5 - 190 GeV)
 - muons: $\frac{\delta E_\mu}{E_\mu} = 0.70\%$
 - hadrons: $\frac{\delta E_{HAD}}{E_{HAD}} = 0.43\%$
- CC events: $8.6 \times 10^5 \nu$ and $2.3 \times 10^5 \bar{\nu}$

CC Deep Inelastic Neutrino Scattering:



- Lorentz-invariant quantities in terms of measured E_μ , θ_μ , E_{had} :

$$\left\{ \begin{array}{ll} Q^2 = 4(E_\mu + E_{had})E_\mu \sin^2 \frac{\theta_\mu}{2} & \rightarrow \text{negative square 4-momentum transfer} \\ x = \frac{Q^2}{2ME_{had}} & \rightarrow \text{Bjorken scaling variable} \\ y = \frac{E_{had}}{E_\mu + E_{had}} & \rightarrow \text{inelasticity} \\ \nu = E_{had} & \rightarrow \text{energy transferred to hadronic system} \end{array} \right.$$

Neutrino Differential Cross-Section:

$$\frac{d^2\sigma^\nu(\bar{\nu})}{dxdy} = \frac{G_F^2 ME_\nu}{\pi(1 + \frac{Q^2}{M_W^2})^2} \left[\left(1 - y - \frac{Mxy}{2E_\nu} \right) F_2^\nu(\bar{\nu}) + \frac{y^2}{2} 2xF_1^\nu(\bar{\nu}) \pm y(1 - \frac{y}{2}) xF_3^\nu(\bar{\nu}) \right]$$

Neutrino Structure Functions in terms of quark compositions of target:

- $2xF_1^\nu(\bar{\nu})(x, Q^2) = \Sigma [xq^\nu(\bar{\nu}) + \bar{x}q^\nu(\bar{\nu})]$
- $F_2^\nu(\bar{\nu})(x, Q^2) = \Sigma [xq^\nu(\bar{\nu}) + x\bar{q}^\nu(\bar{\nu}) + 2xk^\nu(\bar{\nu})]$
- $xF_3^\nu(\bar{\nu})(x, Q^2) = \Sigma [xq^\nu(\bar{\nu}) - x\bar{q}^\nu(\bar{\nu})]$

Differential Cross Section Measurement

Differential Cross Section in terms of flux and number of events:

$$\frac{d^2\sigma_{ijk}^{\nu(\bar{\nu})}}{dxdy} \propto \frac{1}{\Phi(E_i^\nu)} \frac{\Delta N_{ijk}^{\nu(\bar{\nu})}}{\Delta x_j \Delta y_k}$$

- **Data:**

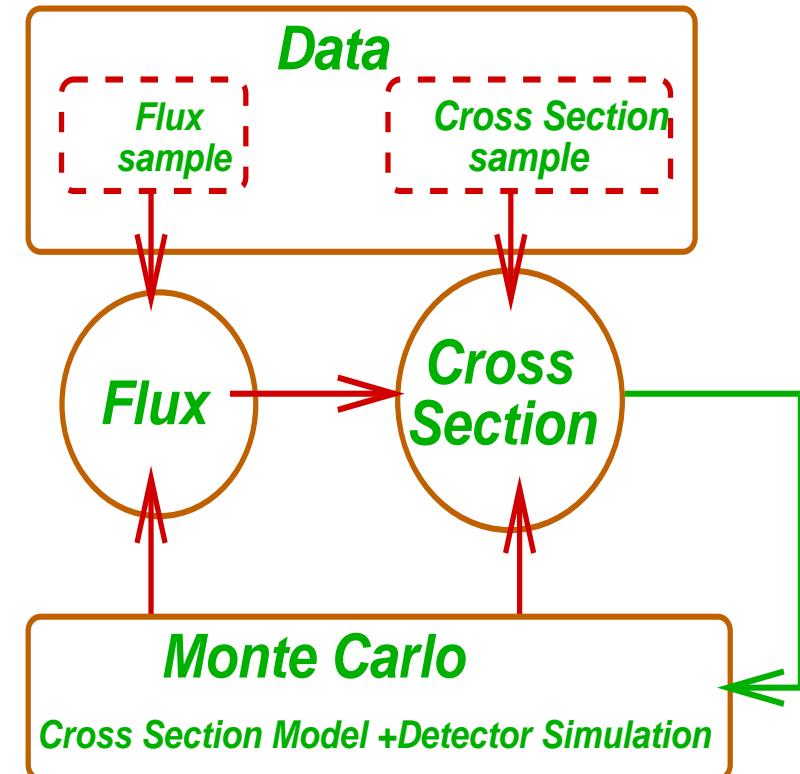
- Flux Sample:
 - nearly independent data set ($E_{had} < 20 \text{ GeV}$)
- Cross Section Sample: toroid analyzed muon
 - containment and good muon track
 - $E_\mu > 15 \text{ GeV}$, $E_{had} > 10 \text{ GeV}$,
 - $E_\nu \in (30, 300) \text{ GeV}$, $Q^2 > 1 \text{ GeV}^2$

- Monte Carlo:

- used only for acceptance and smearing corrections
- Cross-Section Model
 - LO QCD inspired parametrization: **fit to data** :
[A.Buras, K.Gaemers; Nucl.Phys.B132,249(1978)]
 - includes HT parametrization for Q^2 dependence at $x>0.4$ (SLAC,NMC,BCDS).
 - for $Q^2 < 1.35 \text{ GeV}^2$ use GRV Q^2 evolution

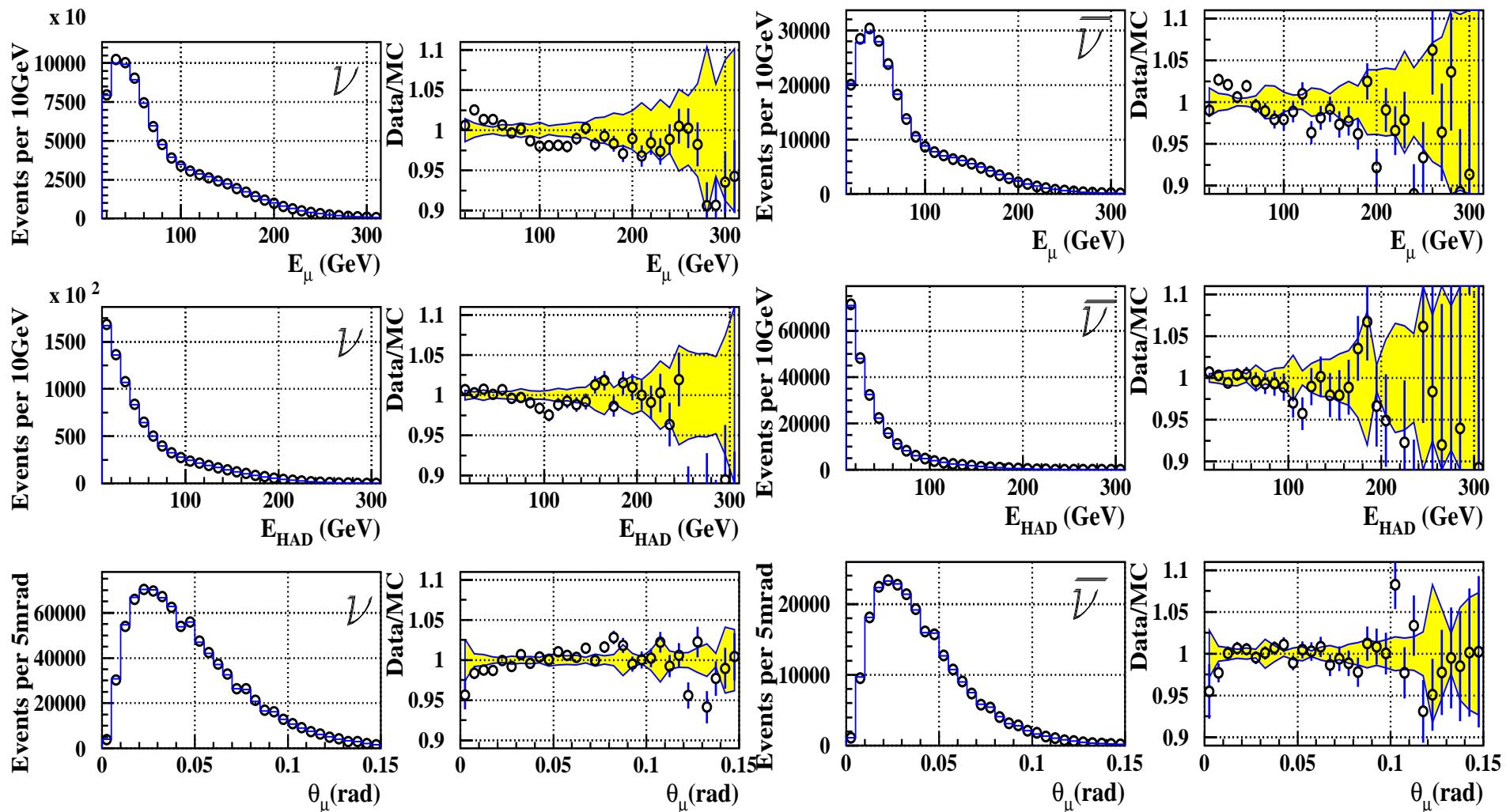
- Detector model:

- E_μ and E_{had} resolution functions parametrized using test beam
- θ_μ parametrized using GEANT hit level MC



- [Phys. Rev. D 74, 012008 (2006)]

Modeling of Data:



- Monte Carlo in good agreement with data over all kinematic region

Cross Section Systematic Uncertainties:

- 7 sources of systematic uncertainties:
 - E_μ and E_{had} scales
 - uncertainties in the smearing models of E_μ and E_{had}
 - uncertainties in relative flux extraction: m_c and $\frac{B}{A}$
 - overall normalization uncertainty 2.1% (flux normalization)
- each systematic error evaluated separately and correlations between them taken into account
- the statistical errors are added in quadrature to the diagonal elements of covariance matrix

NuTeV provides a full point-to-point covariance matrix:

- χ^2 for all systematic uncertainties:

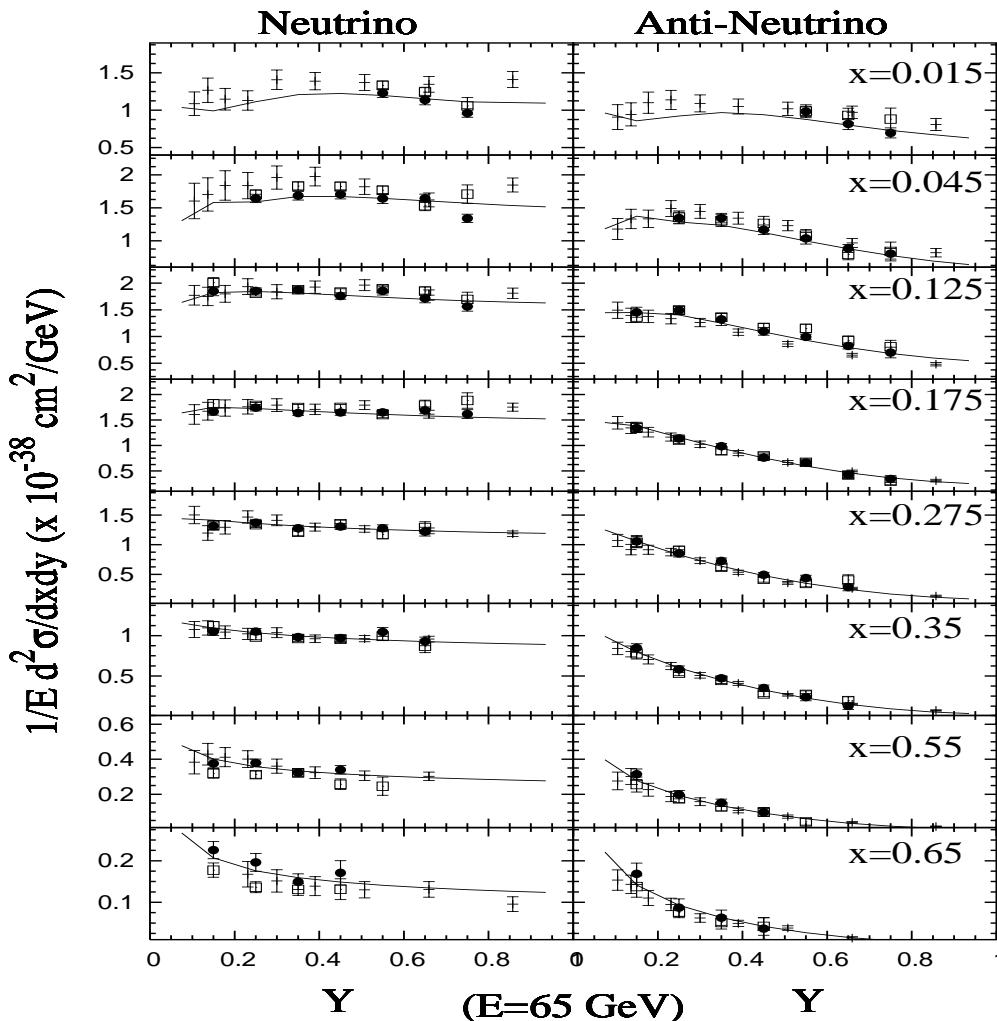
$$\chi^2 = \sum_{\alpha\beta} (D_\alpha - f_\alpha^{theory}) M_{\alpha\beta}^{-1} (D_\beta - f_\beta^{theory})$$

- D_α - measured differential cross section
- f_α^{theory} - the model prediction
- $M_{\alpha\beta}$ is point to point covariance matrix:

$$M_{\alpha\beta} = \sum_i^7 \delta_{i|\alpha} \delta_{i|\beta}$$

- $\delta_{i|\alpha}$ is the 1σ shift in data point α due to systematic uncertainty i .

NuTeV Differential Cross Section:



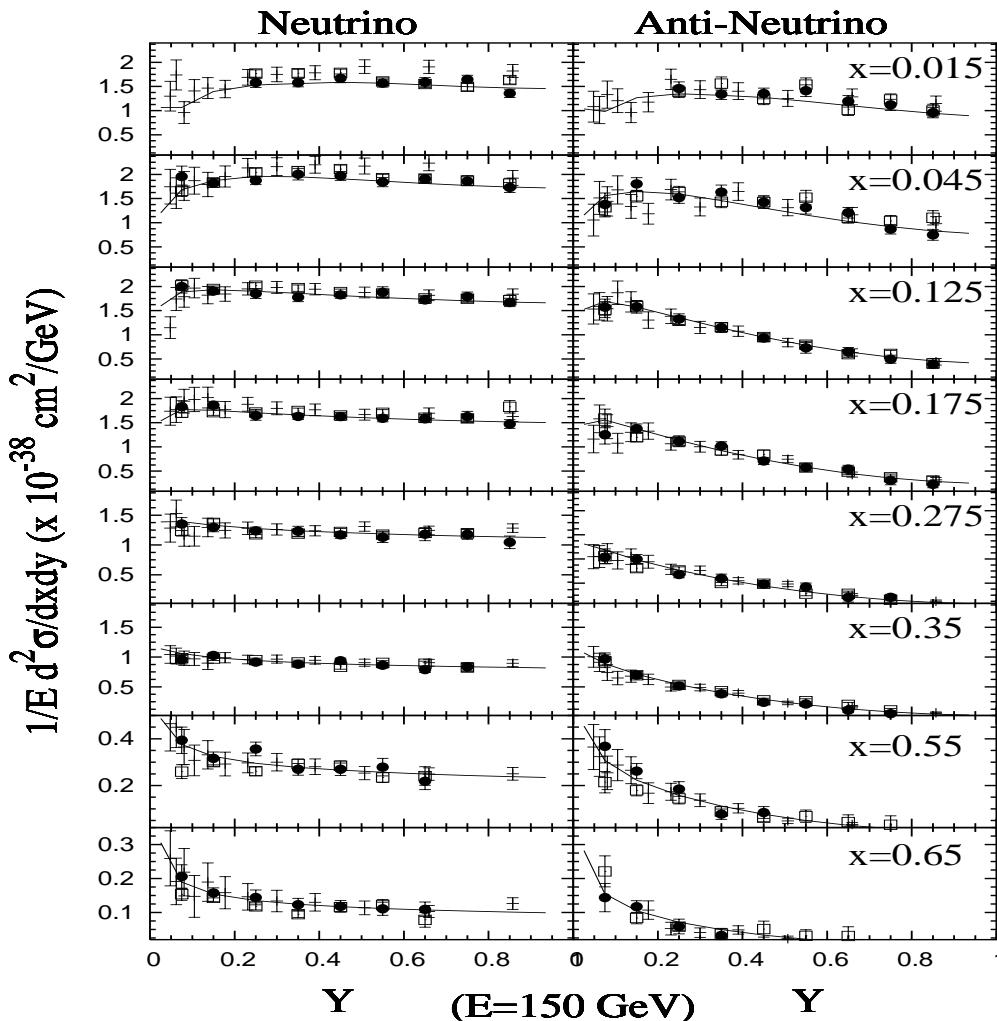
LABEL:

filled circles - NuTeV :: open squares - CCFR ::
 crosses - CDHSW :: line - NuTeV model

- plots show extracted $\nu(\bar{\nu}) - Fe$ Cross-Sections as function of y for different x bins at $E_\nu = 65 \text{ GeV}$ and 150 GeV
- NuTeV has comparable statistics to other ν experiments:
 - CDHSW [Z. Phys C49 187, 1991] - crosses
 - CCFR [U. K. Yang PhD. Thesis] - open squares
- Better control of largest systematic uncertainties:

data	E_μ scale	E_{had}	range
CDHSW	2%	2.5%	20-200 GeV
CCFR	1%	1%	30-300 GeV
NuTeV	0.7%	0.43%	30-350 GeV

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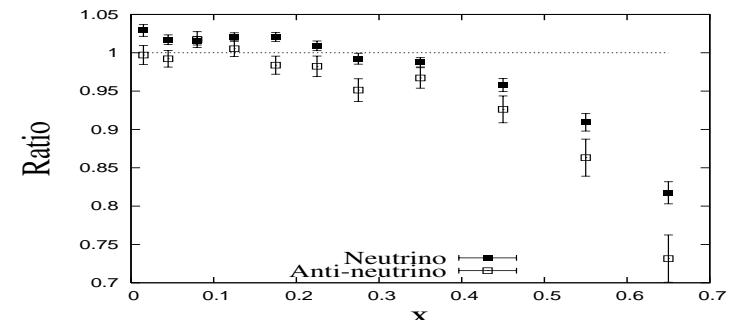
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Neutrino Data Comparison:

- NuTeV compared to other $\nu - Fe$ experiments (CCFR and CDHSW):

- good agreement at moderate x with CCFR over the full E_ν and y range (level and shape), and with CDHSW (level)
 - at $x > 0.4$ CCFR is consistently below NuTeV:



- CCFR and NuTeV similar in design and analysis method;
 - largest single contribution is due to miscalibration of the magnetic field map of the toroid in CCFR:
accounts for $\sim +6\%$ of the 18% difference at $x = 0.65$.
 - model difference (fit to NuTeV data):
accounts for $\sim +3\%$ difference at $x = 0.65$.
 - improved muon and hadron energy smearing models:
accounts for $\sim +2\%$ difference at $x = 0.65$.
 - Other differences between CCFR and NuTeV experiments:
 - NuTeV had separate neutrino and antineutrino runs (SSB):
 - NuTeV always set to focus the “right-sign” muon: better acceptance
 - CCFR had simultaneous neutrino and antineutrino runs
 - CCFR had toroid polarity $\sim 50\%$ set to focus on μ^+ and $\sim 50\%$ set on μ^-

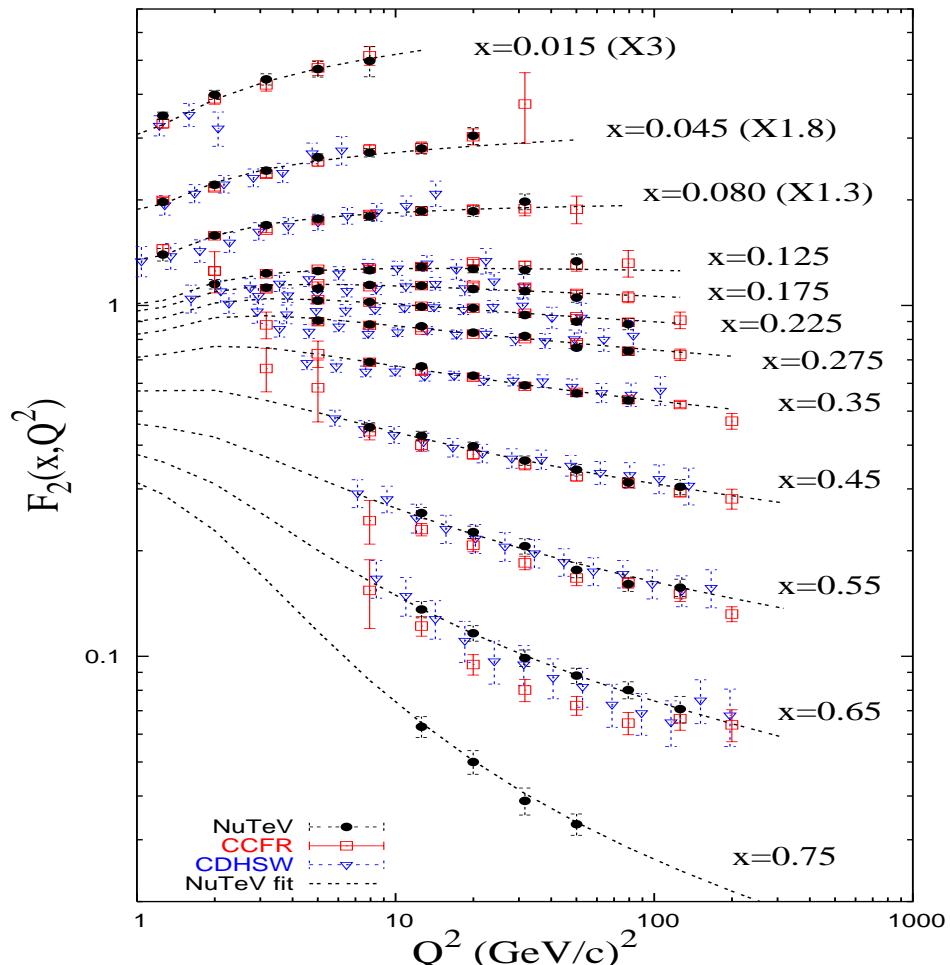
Extraction of Structure Functions: 1p fit

- One parameter fit:

$$\begin{aligned} \left[\frac{d^2 \sigma^\nu}{dx dy} + \frac{d^2 \sigma^{\bar{\nu}}}{dx dy} \right] \frac{\pi}{2M G^2 E_\nu} &= \left(1 - y - \frac{M x y}{2E} + \frac{1 + \left(\frac{2M x}{Q} \right)^2}{1 + R_L} \frac{y^2}{2} \right) F_2^{avg} + y \left(1 - \frac{y}{2} \right) \Delta x F_3 \\ \left[\frac{d^2 \sigma^\nu}{dx dy} - \frac{d^2 \sigma^{\bar{\nu}}}{dx dy} \right] \frac{\pi}{2M G^2 E_\nu} &= \Delta F_2 \left(1 - y - \frac{M x y}{2E} + \frac{1 + \left(\frac{2M x}{Q} \right)^2}{1 + R_L} \frac{y^2}{2} \right) + \left(y - \frac{y^2}{2} \right) x F_3^{avg} \approx \left(y - \frac{y^2}{2} \right) x F_3^{avg} \end{aligned}$$

$$\begin{aligned} x F_3^{avg}(x, Q^2) &= \frac{1}{2} (x F_3^\nu(x, Q^2) + x F_3^{\bar{\nu}}(x, Q^2)) \\ F_2^{avg}(x, Q^2) &= \frac{1}{2} (F_2^\nu(x, Q^2) + F_2^{\bar{\nu}}(x, Q^2)) \end{aligned}$$

- Cross-Sections corrected to :
 - isoscalar target
(5.67% excess of n over p in Fe target)
 - QED radiative effects
[D.Y.Bardin and Dokuchaeva,JINR-E2-86-260(1986)]
- Fit for $F_2^{avg}(x, Q^2)$ input model for
 - $R_L(x, Q^2)$ [L.W.Whitlow *et.al.* Phys.Lett. B250(1990)]
 - $\Delta x F_3(x, Q^2)$ [R.Thorne and R.Roberts, Phys.Lett. B 421 (1998)]
- Fit for $x F_3^{avg}(x, Q^2)$ no inputs required



Extraction of Structure Functions: 1p fit

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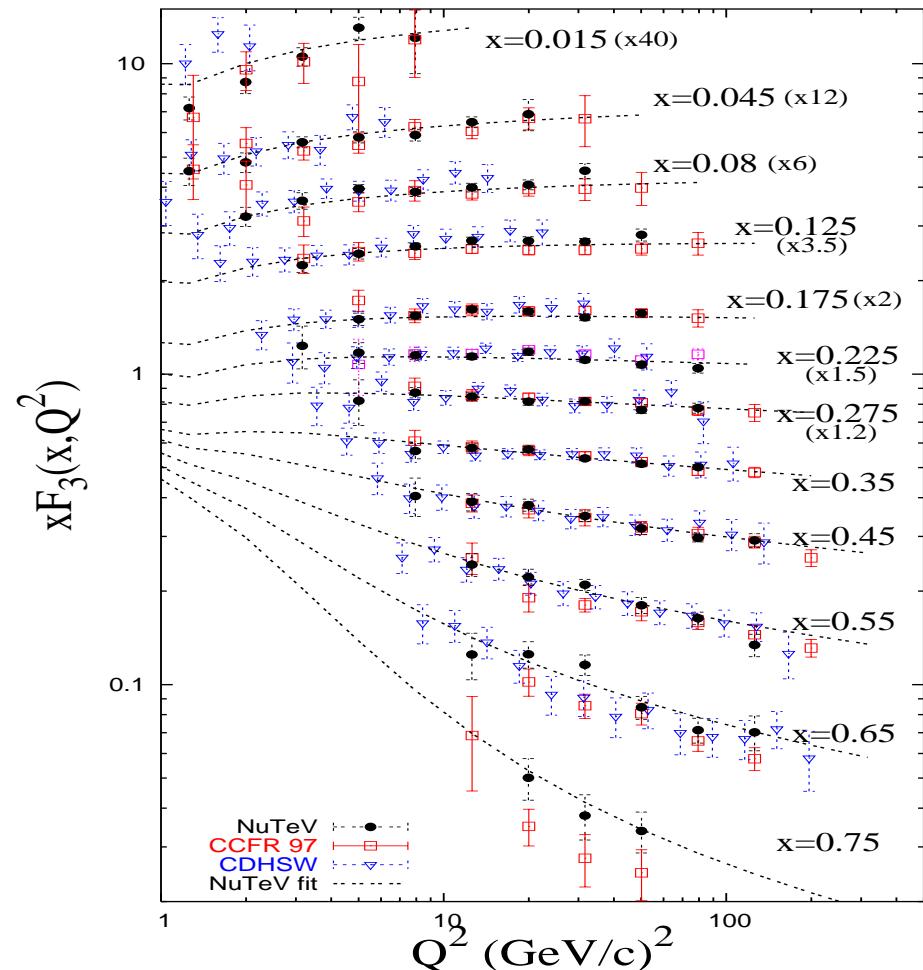
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Extraction of Structure Functions: 2p fit

- Two parameter fit: to obtain correlation between F_2 and xF_3

$$\frac{d^2 \sigma^\nu}{dxdy} = \frac{2MG^2 E_\nu}{\pi} \left[\left(1 - y - \frac{Mxy}{2E} + \frac{1+4M^2x^2}{1+R_L} \frac{y^2}{2} \right) \left(F_2^{avg} + \frac{\Delta F_2}{2} \right) + y \left(1 - \frac{y}{2} \right) \left(xF_3^{avg} + \frac{\Delta xF_3}{2} \right) \right]$$

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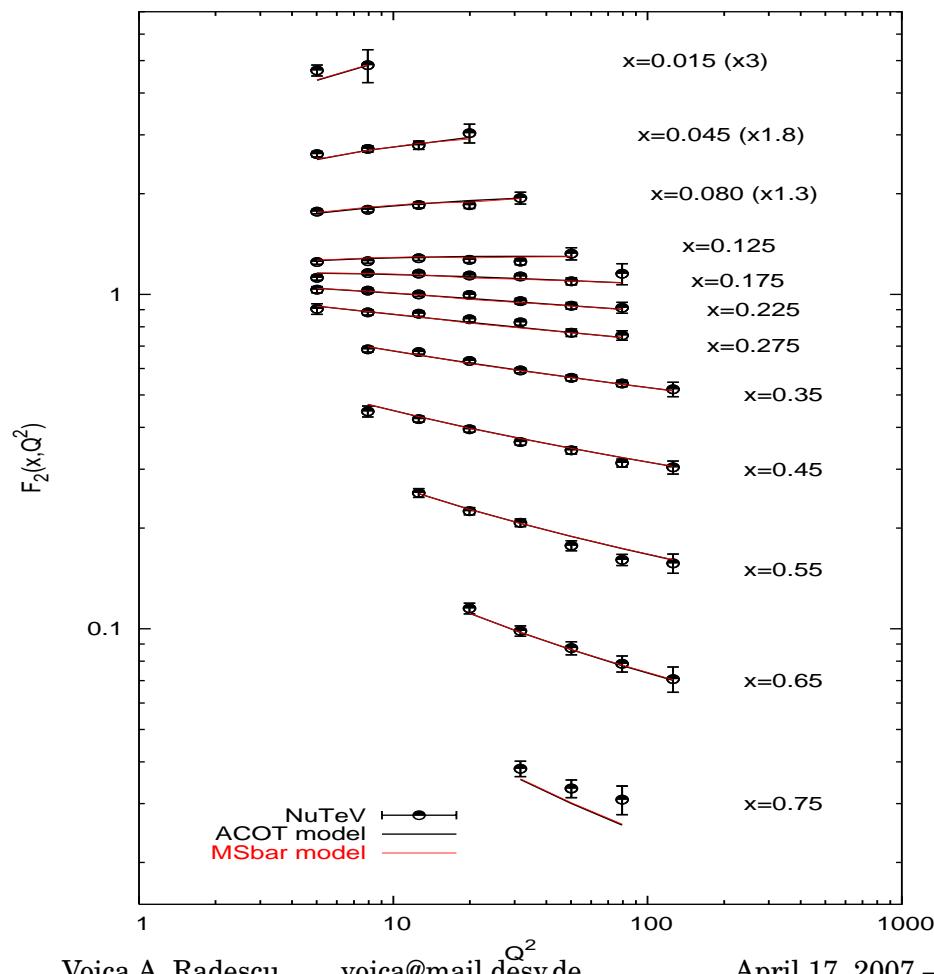
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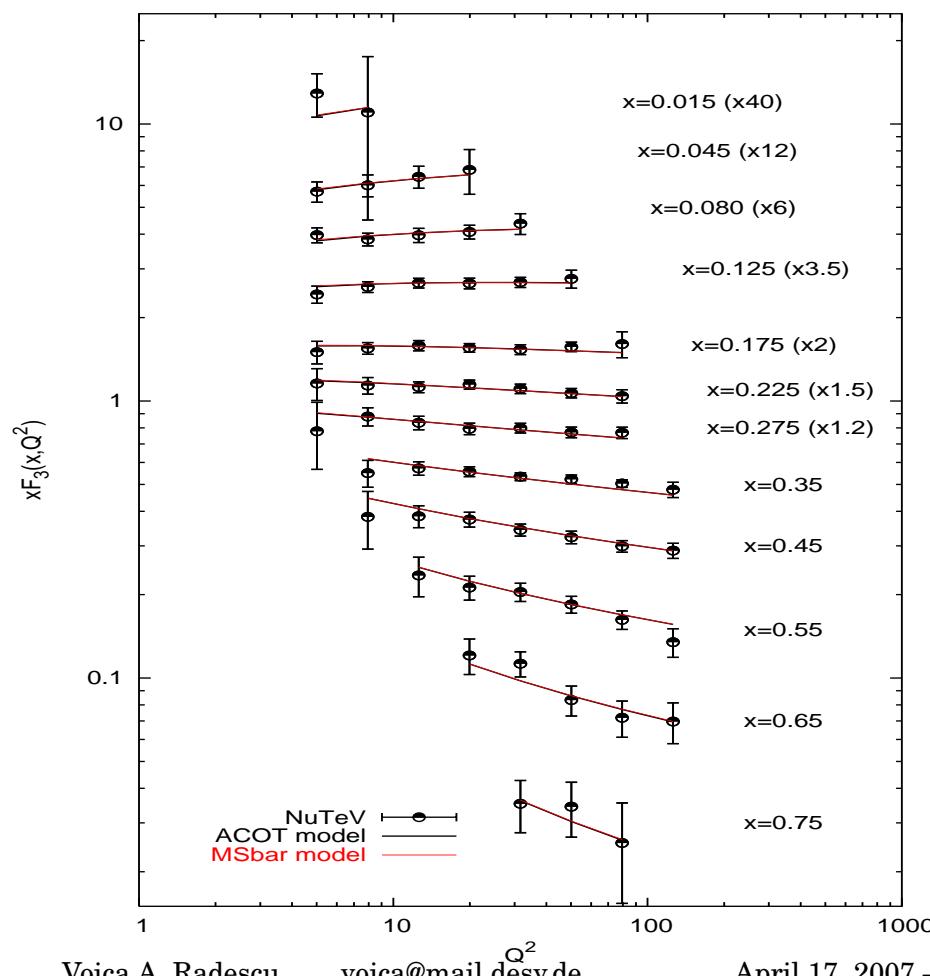
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- Use cross section error matrix



NLO QCD fits

- Λ_{QCD} determined from NLO QCD fits to
 - $xF_3(x, Q^2)$ only
 - its evolution independent of gluon distribution
 - $F_2(x, Q^2)$ and $xF_3(x, Q^2)$
 - improved statistical precision for Λ_{QCD}
 - Data fitted for: $Q^2 > 5 \text{ GeV}^2$, $W^2 > 10 \text{ GeV}^2$, $x < 0.8$
 - Evolution starts at $Q_0^2 = 5 \text{ GeV}^2$
 - Λ_{QCD} enters as a free parameter via DGLAP evolution equations
 - Neutrino Scattering sensitive to heavy quark production:
 - Previous experiments used a LO model to correct data
 - Aivazis-Collins-Olness-Tung (ACOT) scheme:
 - fully accounts for quark masses [F. Olness, S. Kretzer]
 - belongs to VFN factorization schemes
-
- $m_c = 1.4 \text{ GeV} \sim Q$
-

QCD Fit results

Parametrization of the PDFs at a reference scale $Q_0^2 = 5$

$$xq^{NS} = \sum_i (q_i - \bar{q}_i) = xu_v + xd_v = (A0_{uv} + A0_{dv})x^{A1_{uv}}(1-x)^{A2_{uv}}$$

$$xq^S = \sum_i (q_i + \bar{q}_i) = \underbrace{xu_v + xd_v}_{xq^{NS}} + 2A0_{ud}(1-x)^{A2_{ud}}$$

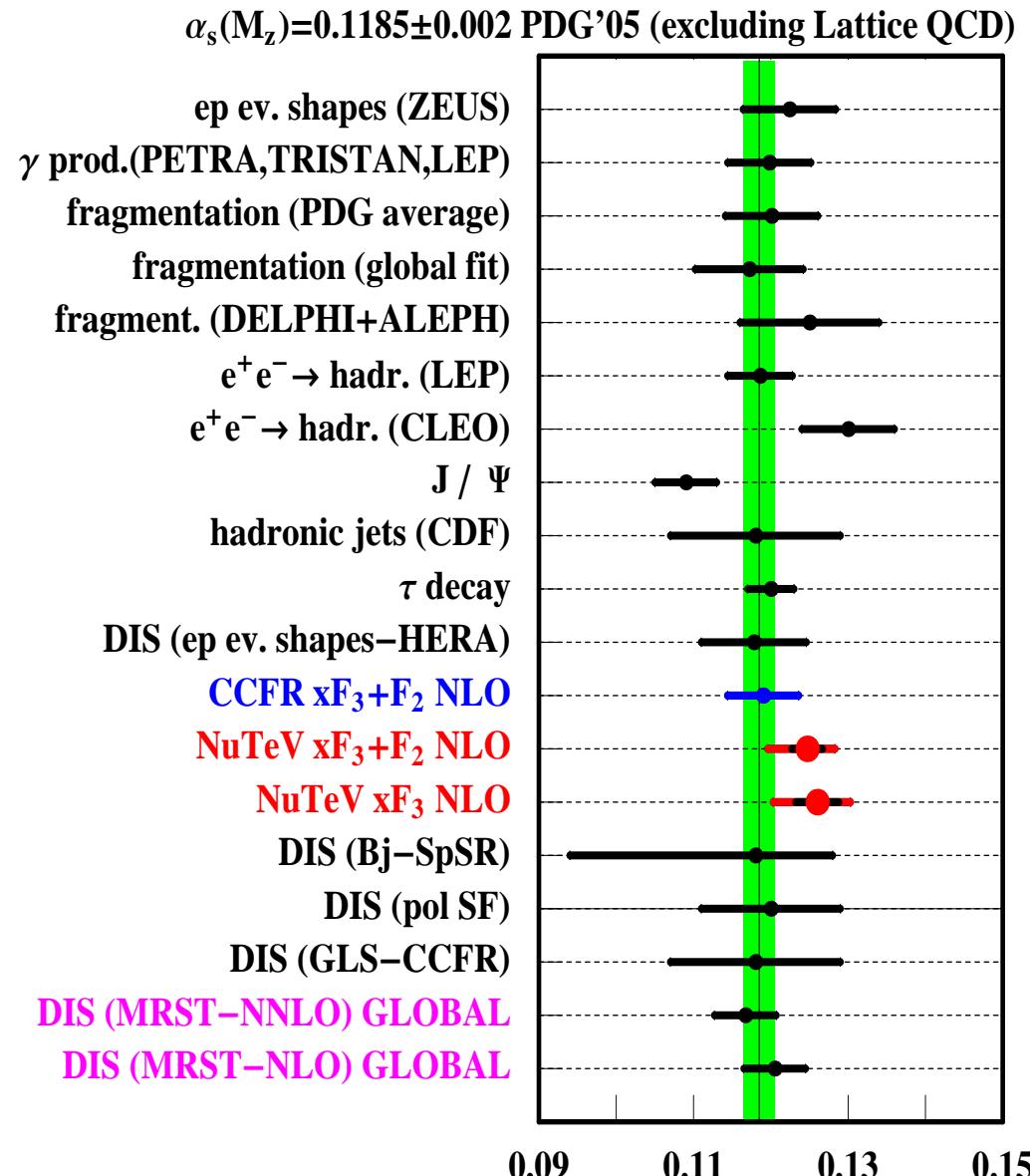
$$xG = A0_g(1-x)^{A2_g}$$

- **Experimental uncertainties**
 - E_μ, E_{had} energy scales
 - energy smearing models
 - flux uncertainties: $\frac{B}{A}, m_c$
 - many are at the level of statistical fluctuations
- full covariance error matrix is constructed
- **Theoretical Uncertainties:**
 - mass quarks: negligible
 - input models: $\Delta xF_3, R_L$
 - **Scale dependence:** μ_R and μ_F
 $\mu_F^2 = C_i Q^2, C_i = 1/2, 1, 2$

Param	xF_3 only	$F_2 + xF_3$
$\Lambda^{(n_f=4)}$ (MeV)	488 ± 59	458 ± 41
$A1_{uv}$	0.73 ± 0.01	0.72 ± 0.02
$A2_{uv}$	3.47 ± 0.06	3.49 ± 0.05
$A0_{uv} + A0_{dv}$	$4.73+2.36$	$4.50+2.25$
$A0_{ud}$		0.67 ± 0.03
$A2_{ud}$		6.83 ± 0.21
$A0_g$		2.21
$A2_g$		4.30 ± 0.41
χ^2/dof	$77/59$	$76/125$
$\alpha_S(M_{Z^0})$	0.1260 ± 0.0028	0.1247 ± 0.0020

NuTeV in World Context

- First measurement of $\Lambda_{QCD}^{nf=4}$ from $\nu - N$ DIS which includes a full NLO treatment for charm production:
 - xF_3 Fit Result:
 $\alpha_s(M_Z) = 0.1260 \pm 0.0028 (exp)^{+0.0034}_{-0.0050} (th)$
 - $F_2 + xF_3$ Fit Result:
 $\alpha_s(M_Z) = 0.1247 \pm 0.0020 (exp)^{+0.0030}_{-0.0047} (th)$
- WEIGHTED WORLD AVERAGE:
 $\alpha_s(M_Z) = 0.1185 \pm 0.0020$ [PDG 2005]
- NuTeV result is:
 - higher than world average, but consistent within errors
 - one of the most precise measurement to date



Conclusions:



- NuTeV has extracted the most precise $\nu - Fe$ differential cross section in the energy range $E_\nu > 30$ GeV to date:
 - [Phys. Rev. D 74, 012008 (2006)]
 - has an improved understanding of the systematic uncertainties:
 - $\frac{\delta E_\mu}{E_\mu} = 0.7\%$
 - $\frac{\delta E_{had}}{E_{had}} = 0.43\%$
 - NuTeV provides a precise data set including a full covariance matrix
- Structure functions from one and two parameter fits have been presented
- First determination of $\Lambda_{QCD}^{n_f=4}$ from $\nu - N$ DIS which includes a full NLO treatment for heavy quarks has been presented:
 - V. Radescu, Ph.D. thesis (2006) [paper in preparation].
 - systematic uncertainties evaluated by constructing a full covariance error matrix
 - one of the most precise determination of α_S to date.

Many Thanks to:



Jeff Owens, Fred Olness, and The NuTeV Collaboration:

T. Adams⁴, A. Alton⁴, S. Avvakumov⁸, L. de Barbaro⁵, P. de Barbaro⁸, R. H. Bernstein³, A. Bodek⁸,
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B. T. Fleming², R. Frey⁶, J.A. Formaggio², J. Goldman⁴, M. Goncharov⁴, D. A. Harris⁸,
R. A. Johnson¹, J. H. Kim², S. Koutsoliotas², M. J. Lamm³, W. Marsh³, D. Mason⁶, J. McDonald⁷,
K. S. McFarland^{8,3}, C. McNulty², D. Naples⁷, P. Nienaber³, V. Radescu⁷, A. Romosan²,
W. K. Sakumoto⁸, H. Schellman⁵, M. H. Shaevitz², P. Spentzouris², E. G. Stern², N. Suwonjandee¹,
M. Tzanov⁷, M. Vakili¹, A. Vaitaitis², U. K. Yang⁸, J. Yu³, G. P. Zeller⁵ and E. D. Zimmerman²

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⁸University of Rochester, Rochester, NY 14627

Uncertainties in NuTeV $\sin^2 \theta_W$ measurements

NuTeV measures $R^- = \frac{\sigma_{NC}^\nu - \sigma_{NC}^{n\bar{u}}}{\sigma_{CC}^\nu - \sigma_{CC}^{n\bar{u}}} \longrightarrow \sin^2 \theta_W$:

$$0.22773 \pm 0.00135(stat) \pm 0.00093(sys)$$

[G.Zeller et al: PRL 88 (2002) 091802]

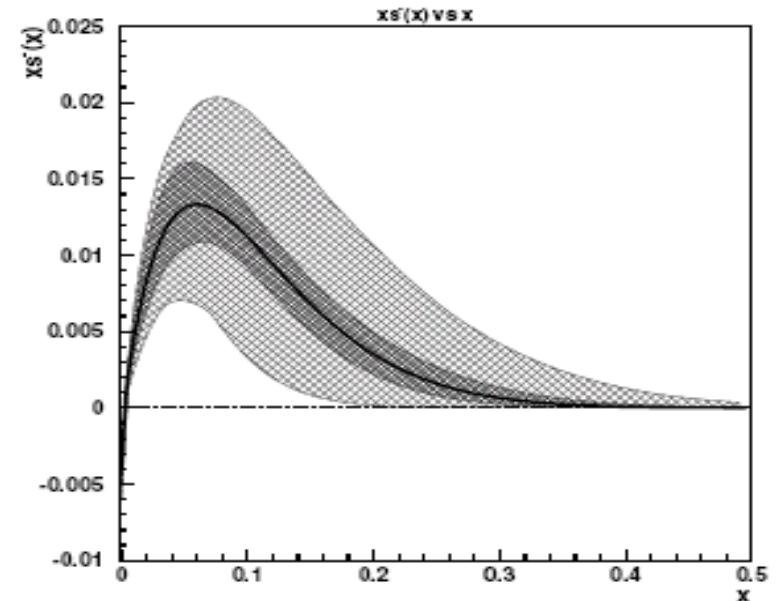
SOURCE OF UNCERTAINTY	$\delta \sin^2 \theta_W$
Data Statistics	0.00135
Monte Carlo Statistics	0.00010
TOTAL STATISTICS	0.00135
$\nu_e, \bar{\nu}_e$ Flux	0.00039
Interaction Vertex	0.00030
Shower Length Model	0.00027
Counter Efficiency, Noise, Size	0.00023
Energy Measurement	0.00018
TOTAL EXPERIMENTAL	0.00063
Charm Production, $s(x)$	0.00047
R_L	0.00032
σ^ν/σ^ν	0.00022
Higher Twist	0.00014
Radiative Corrections	0.00011
Charm Sea	0.00010
Non-Isoscalar Target	0.00005
TOTAL MODEL	0.00064
TOTAL UNCERTAINTY	0.00162

Strange Asymmetry and NuTeV $\sin^2 \theta_W$

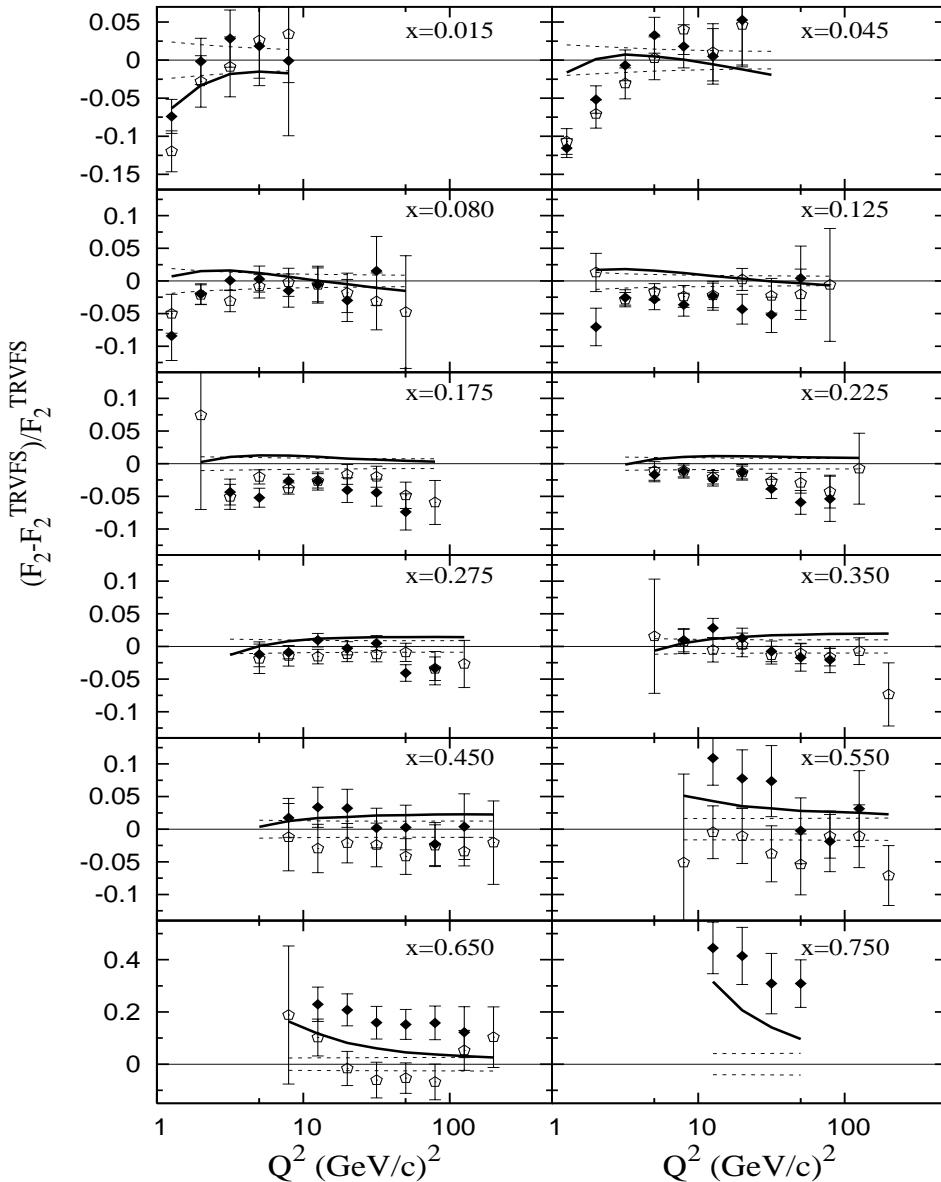
- NuTeV measures $R^- = \frac{\sigma_{NC}^\nu - \sigma_{NC}^{\bar{n}u}}{\sigma_{CC}^\nu - \sigma_{CC}^{\bar{n}u}} \longrightarrow \sin^2 \theta_W$:
 - $0.22773 \pm 0.00135(stat) \pm 0.00093(sys)$ [G.Zeller et al: PRL 88 (2002) 091802]
 - R^- is insensitive to sea quarks uncertainties
 - But assumes symmetric strange sea
- QCD requires $\int (s - \bar{s}) dx = 0$, but no restriction on $S^- dx$
- For agreement with SM $S^- \sim 0.0068$ is required!

- Final Strange Assymetry Results from NuTeV: D. Mason PhD thesis (2006)

- First complete NLO analysis
 - measured a positive strange asymmetry:
 $S^- = +0.00196 \pm \underbrace{0.00046}_{stat} \pm \underbrace{0.00045}_{sys} \pm \underbrace{0.00128}_{external}$



Comparisons to NLO theory models



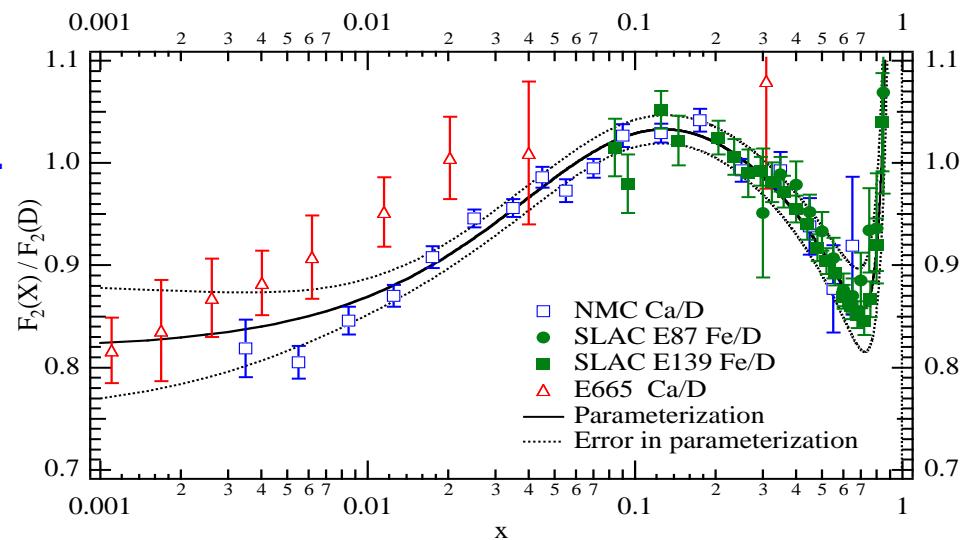
- plots show NuTeV (solid) and CCFR (open) F_2 data ratios to TR-VFS (MRST2001E pdf) curve in all x bins
- Other Models shown:
 - ACOT CTEQ5HQ1 (solid line)
- At low x and Q^2 shape difference with models
- At high x , NuTeV result is above theory curves from 5 to 15%
- BUT ... theory corrected for:
 - Target Mass

[H.Georgi & H.D.Politzer, Phys.Rev D14 1829]
- Nuclear Effects(next)

Nuclear Correction

- correction measured in charged-lepton experiments from nuclear targets
- standard way: apply the same correct. to neutrino scattering
- we used a parametrization fit to data, independent of Q^2
(dominated at $x > 0.4$ by SLAC)

Parametrization as function of x



Comparison with Charged Lepton Data:

apply corrections to charged lepton data:

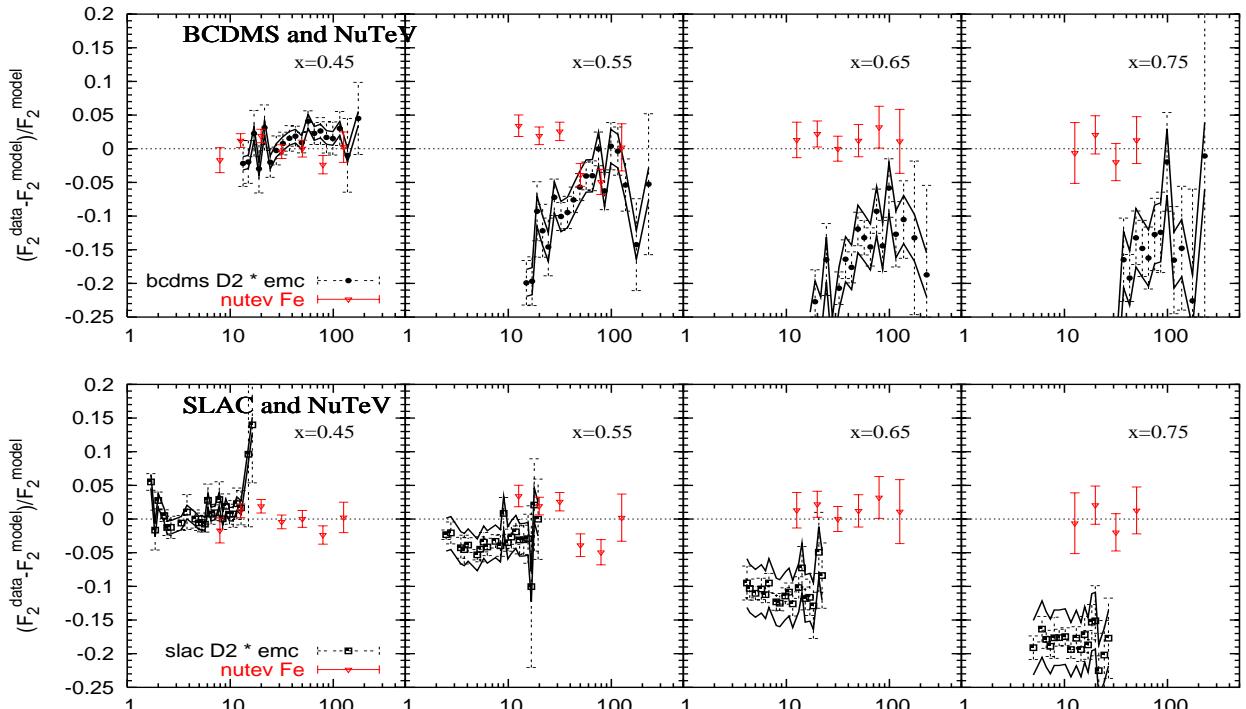
- F_2^l/F_2^ν correction (CTEQ4D pdf):

$$F_2 = \sum_i e_i^2 q_i; \begin{cases} e_i = 1, \text{weak} \\ e_i = \frac{2}{3} \left(-\frac{1}{3}\right), \text{em} \end{cases}$$

$$\frac{F_2^l}{F_2^\nu} = \frac{5}{18} \left(1 - \frac{3}{5} \frac{s + \bar{s} - c - \bar{c}}{q + \bar{q}}\right)$$

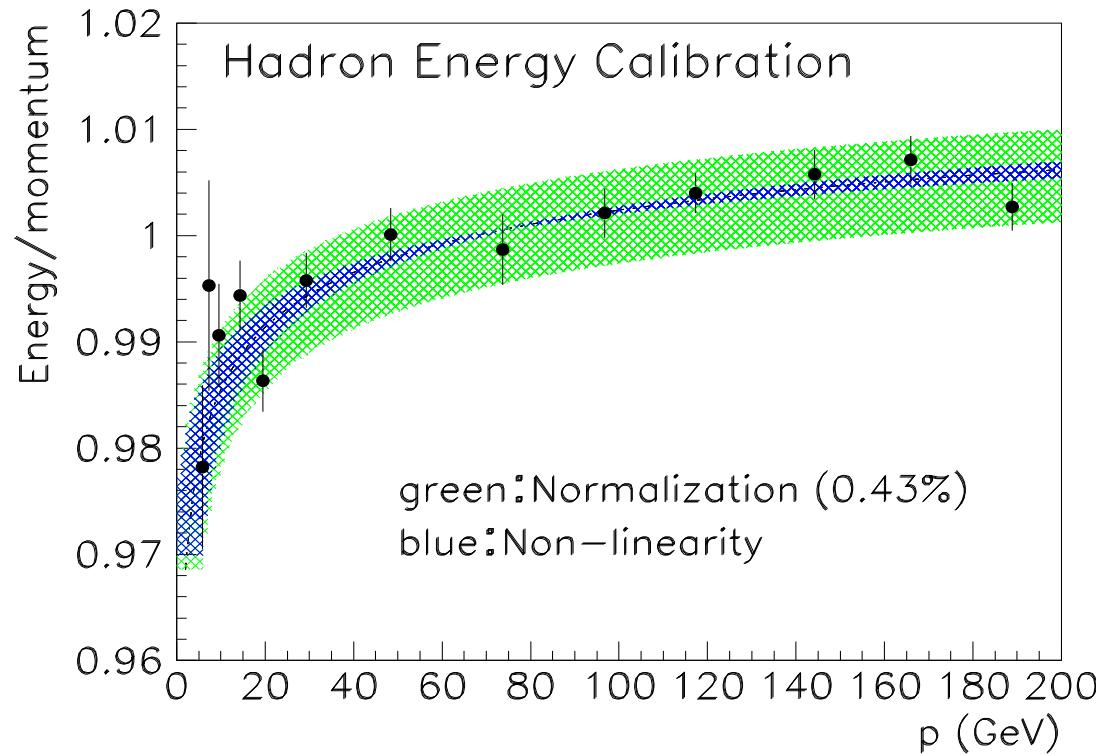
- nuclear correction

- plots show $\frac{F_2^{data} - F_{2model}^\nu}{F_{2BG}^\nu}$; data: NuTeV(Fe), BCDMS(D_2), SLAC(D_2)
- NuTeV above BCDMS(D_2) by $\approx 7\%$ at $x = 0.55$; $\approx 12\%$ at $x = 0.65$; $\approx 15\%$ at $x = 0.75$;
- NuTeV above SLAC(D_2) by $\approx 4\%$ at $x = 0.55$; $\approx 10\%$ at $x = 0.65$; $\approx 17\%$ at $x = 0.75$;



ν -scattering favors perhaps smaller nuclear effects at high x

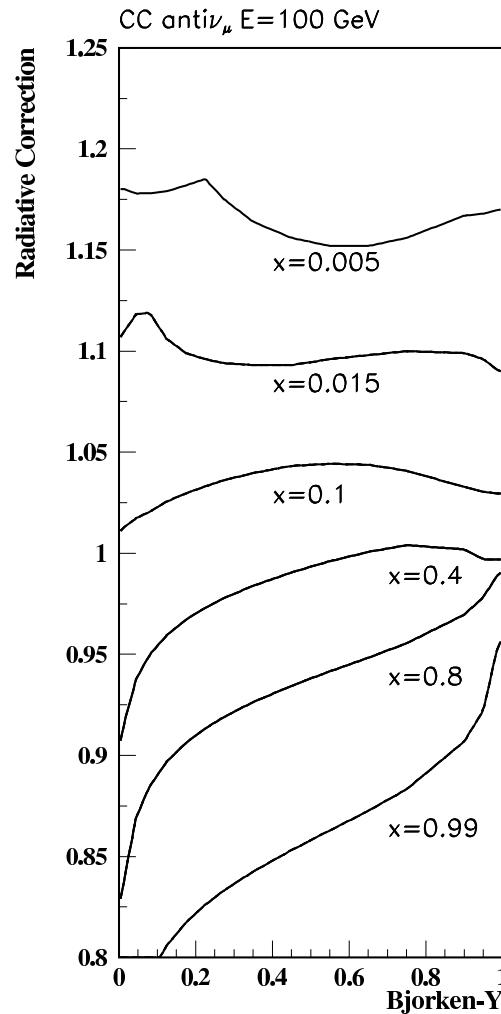
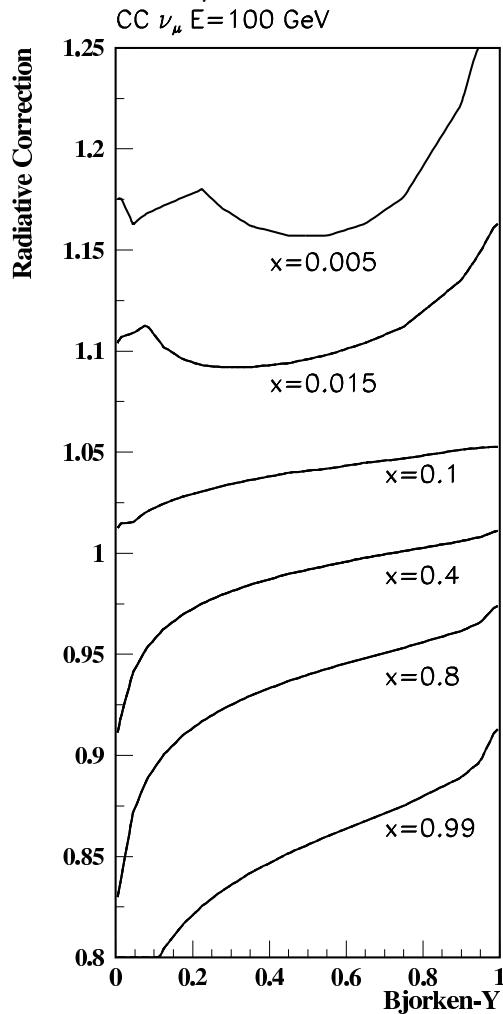
Hadron Energy scale and nonlinearity



- Hadron Energy scale 0.43% (CCFR 1%):
figure shows the ratio of hadron energy response over the test beam momentum and the comparison with the fit for the non-linearity (the blue line) of the calorimeter between 4.5 -190 GeV ($\sim 3\%$).
[ref: "Precis. Calib. of NuTeV Calorim.", D. Harris, et al., NIM A447, 377(2000)]

Radiative corrections

Total size of the QED radiative corrections for 100 GeV of ν_μ (left) and $\bar{\nu}_\mu$ (right) CC scattering as function of y :



- emission of real or virtual γ by a fermion:

$$\frac{d^2\sigma}{dxdy} = \left[\frac{\left(\frac{d^2\sigma}{dxdy} \right)_{1-loop}}{\left(\frac{d^2\sigma}{dxdy} \right)_{0-loop}} \right] \left(\frac{d^2\sigma}{dxdy} \right)_{Born}$$

Bardin

Bardin, D. Y. and Dokuchaeva, JINR-E2-86-260 (1986)

Cross-Section Model



- Buras-Gaemers parametrization of the valence:

$$x^{E_1}(1-x)^{E_2} + AV_2 x^{E_3}(1-x)^{E_4} + AV_3 x^{E_5}(1-x)^{E_6}$$

- Buras-Gaemers parametrization of the sea:

$$AS_1(1-x)^{ES_1} + AS_2(1-x)^{ES_2}$$

- Exponents (E_i and ES_i) and normalization terms (AV_i and AS_i) are fitted to NuTeV differential cross-section data every loop of iteration.

- for Q^2 assume GRV evolution

- assume $m_c = 1.4 GeV$, the standard W-mass and $R_L = R_{WORLD}$

- Higher-Twist parametrization:

- $x' = x \frac{Q^2 + B}{Q^2 + Ax}$

Extracting Relative Flux:

“Fixed ν_0 method”: Integrate data at low ν

- derived from the general form of cross section, integrated over x with fixed $y = \frac{\nu}{E_\nu}$:

$$\frac{dN}{d\nu} = \Phi(E_\nu) A \left(1 + \frac{B}{A} \frac{\nu}{E_\nu} - \frac{C}{A} \frac{\nu^2}{2E_\nu^2} \right) \xrightarrow{\nu \rightarrow 0} \Phi(E_\nu) A$$

$$\begin{cases} A = \frac{G_F^2 M}{\pi} \int F_2(x, Q^2) dx \\ B = -\frac{G_F^2 M}{\pi} \int [F_2(x, Q^2) \mp x F_3(x, Q^2)] dx \\ C = B - \frac{G_F^2 M}{\pi} \int F_2(x, Q^2) \left(\frac{1 + \frac{2Mx}{\nu}}{1 + R(x, Q^2)} - \frac{Mx}{\nu} - 1 \right) dx \end{cases}$$

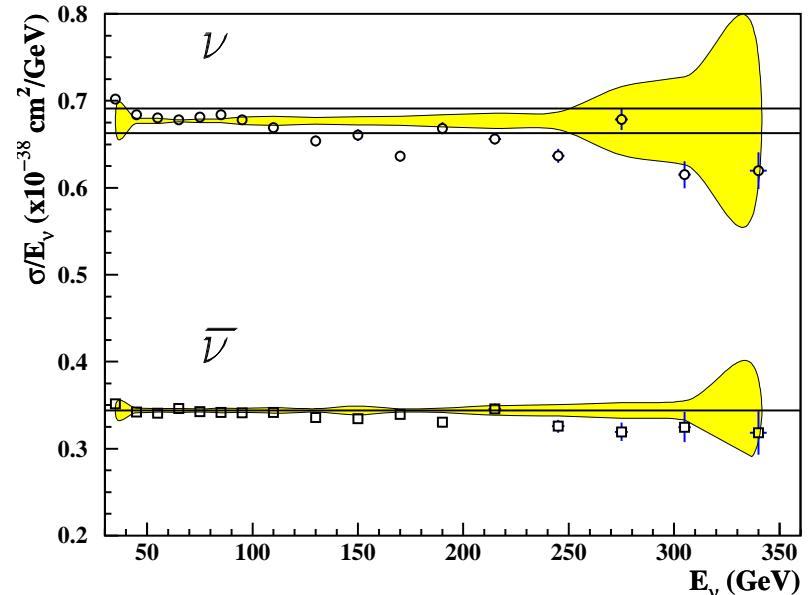
$$\Phi(E_\nu) = \int_0^{\nu_0} \frac{\frac{dN}{d\nu}}{1 + \underbrace{\frac{B}{A} \frac{\nu}{E_\nu}}_{small} - \underbrace{\frac{C}{A} \frac{\nu^2}{2E_\nu^2}}_{small}} d\nu$$

$\frac{B}{A}, \frac{C}{A}$ determined from the fit to $\frac{dN}{d\nu}$ data

- Absolute flux obtained by normalizing our cross-section to the world average value:

$$\frac{\sigma^\nu_{WORLD}}{E_\nu} = 0.677 \pm 0.014 \times 10^{-38} \frac{\text{cm}^2}{\text{GeV}}$$

- Test of Flux extraction:



- $\frac{\sigma^\nu}{E_\nu}$ is flat as function of E_ν within $\pm 2.1\%$
- $\frac{\sigma^\nu}{\sigma^{\bar{\nu}}}$ agrees with world average

Contributing Systematics

- Experimental uncertainties:
 - E_μ, E_{had} energy scales
 - energy smearing models
 - flux uncertainties: $\frac{B}{A}, m_c$
 - many are at level of statistical fluctuations
- Theoretical Uncertainties:
 - mass quarks: negligible
 - input models: $\Delta xF_3, R_L$
 - Scale dependence: μ_R and μ_F
 $\mu_F^2 = C_i Q^2, C_i = 1/2, 1, 2$

C_i	xF_3	$xF_3 + F_2$
2	+74 MeV	+61 MeV
0.5	-113 MeV	-87 MeV

Effects of systematic due to $\pm 1\sigma$ shifts on Λ_{QCD}

MeV Shifts/SF	F_2 and xF_3		xF_3	
Statistical	± 23		± 57	
Systematic	$+1\sigma$	-1σ	$+1\sigma$	-1σ
E_μ scale	+15	-33	+76	-38
E_{had} scale	-19	+13	-10	+65
E_μ smear model	-23		-28	
E_{had} smear model	-16	+12	+3	0
m_c	+1	-15	+1	0
$\frac{B}{A}$	+14	-16	-6	+4
R_L	+12	-12	-	-
ΔxF_3 model	$+25$		$-$	