A Unified Model for inelastic e-N and neutrino-N cross sections at all Q^2

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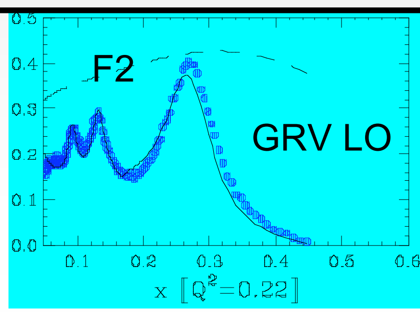
Section III.4: PDFs from Small to Large x II
Parallel Session 2, Monday, October 24, 4:30 - 6:00PM,
Room: Sweeney - Meeting 3 Chair: Abhay Deshpande

Time	Speaker	Title	Links
5:45	Arie Bodek		A Unified Model for inelastic e-N and nu-N cross sections

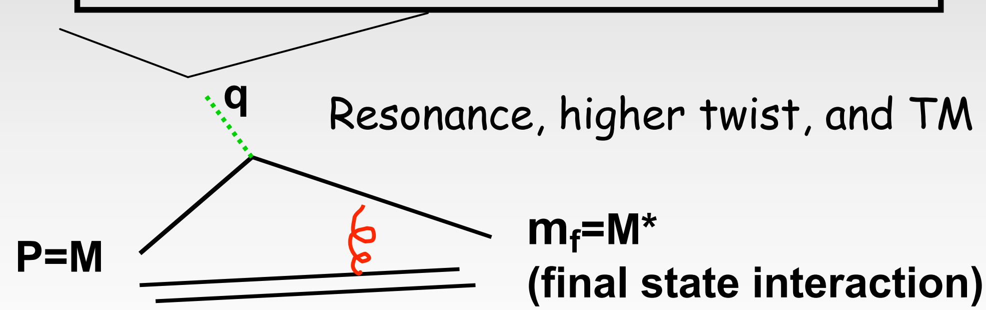
PANIC05 Santa-Fe , October, 2005

Modeling on neutrino cross sections

- Describe DIS, resonance, even photo- production (Q^2=0) in terms of quark-parton model. With PDFS, it is straightforward to convert charged-lepton scattering cross sections into neutrino cross section.
- Challenge:
  - Understanding of high x PDFs at very low Q^2?
  - Understanding of resonance scattering in terms of quark-parton model?



- NNLO QCD+TM approach
  good to explain non-pert. QCD effects at low Q^2
- Effective LO approach (pseu do NNLO: for MC)
  Use effective LO PDFs with a new scaling variable, ξw to absorb target mass, higher t wist, missing higher orders



$$\xi_w = \frac{Q^2+m_f^2+O(m_f^2-m_i^2)+A}{M\nu\,(1+(1+Q^2/\nu^2))^{1/2}+B} \longrightarrow X_{bj}= Q^2/2M\nu$$

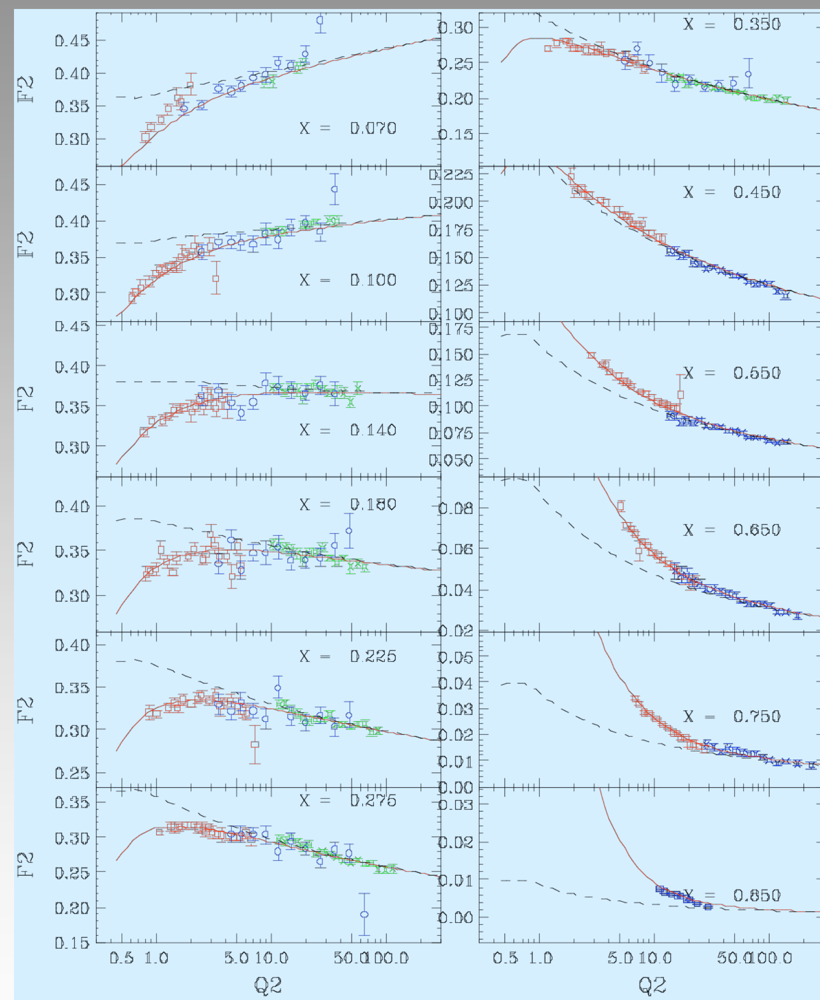
Effective LO model - 2003

F2 e-Proton
Solid- GRB98 PDFs
Dashed -Modified GRB98 PDFs

1. Start with GRV98 LO (Q^2_{min}=0.80 GeV^2)
   - dashed line- describe F2 data at high Q^2
2. Replace the Xbj with a new scaling, ξ_w
3. Multiply all PDFs by **K factors for** photo prod. limit and higher twist
   $[\ \sigma(\gamma) = 4\pi\alpha/Q^2 * F_2(x, Q^2)\ ]$
   $Ksea = Q^2/[Q^2+Csea]$
   $Kval = [1- G_D{}^2 (Q^2)\ ]$
   $*[Q^2+C2V] / [Q^2+C1V]$ motivated by Adler Sum rule
   where $G_D{}^2 (Q^2) = 1/ [\ 1+Q^2 / 0.71\ ]^4$
4. Freeze the evolution at $Q^2 = Q^2_{min}$
   - $F_2(x, Q^2 < 0.8) = K(Q^2) * F_2(Xw, Q^2=0.8)$

➢ Fit to all DIS F2 P/D (with low x HERA data)
A=0.418, B=0.222

Csea = 0.381,C1V = 0.604, C2V= 0.485
χ^2/DOF = 1268 / 1200 Solid Line



A : initial binding/TM effect+ higher order

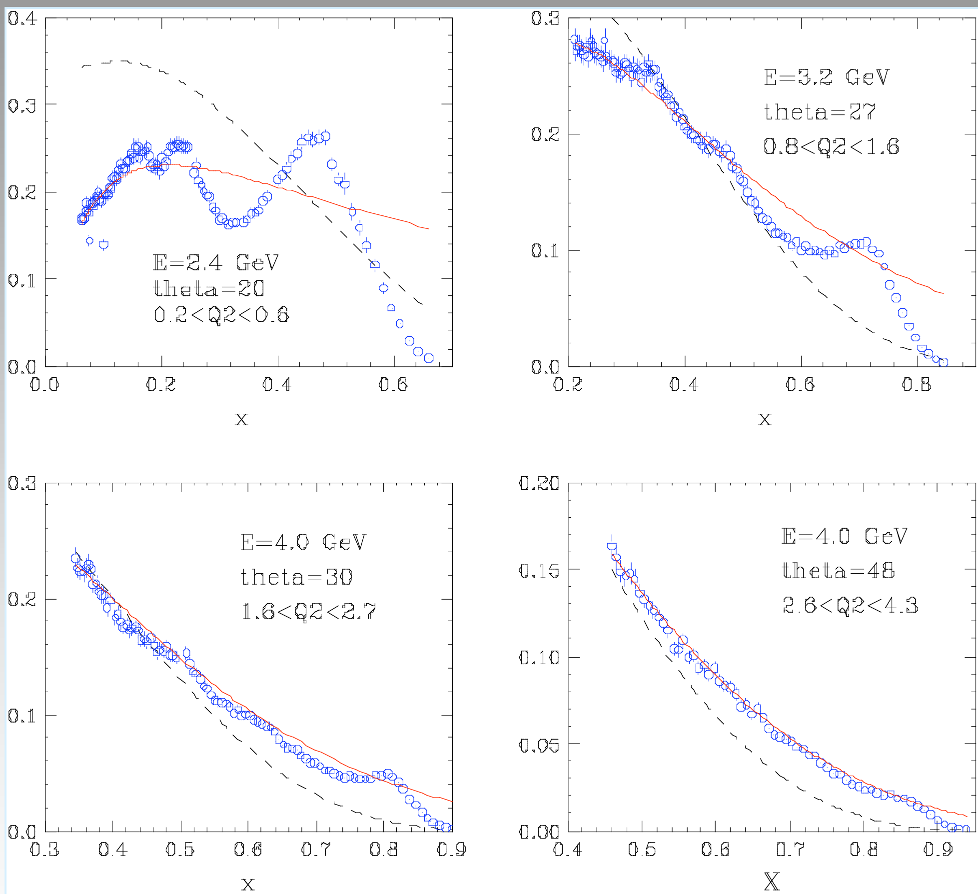
B : final state mass m_f^2, Δm^2,

K Factor: Photo-prod limit (Q^2 =0), Adler sum rule

$$\xi_W = \frac{Q^2+m_f^2+O(m_f^2-m_i^2) + A}{M\nu\ (1+(1+Q^2/\nu^2)\ )^{1/2} + B}$$

$\longrightarrow$ Xbj= Q^2 /2 $M\nu$

Comparison with effective LO model



F$_2$(d) resonance low Q2

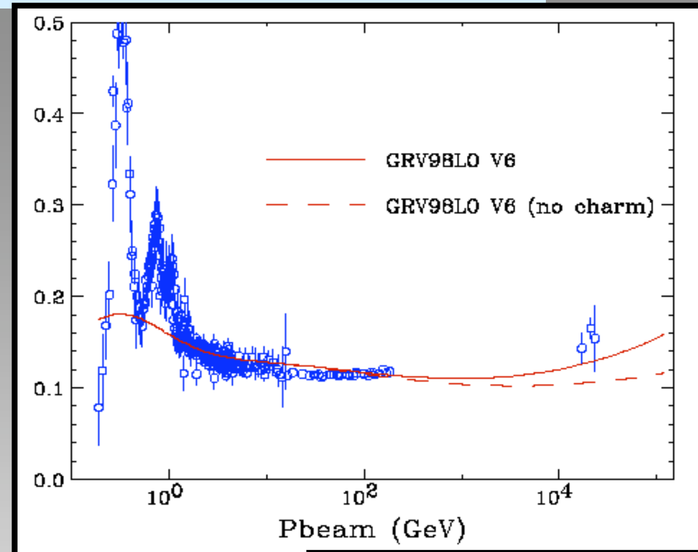


Photo-production (P)

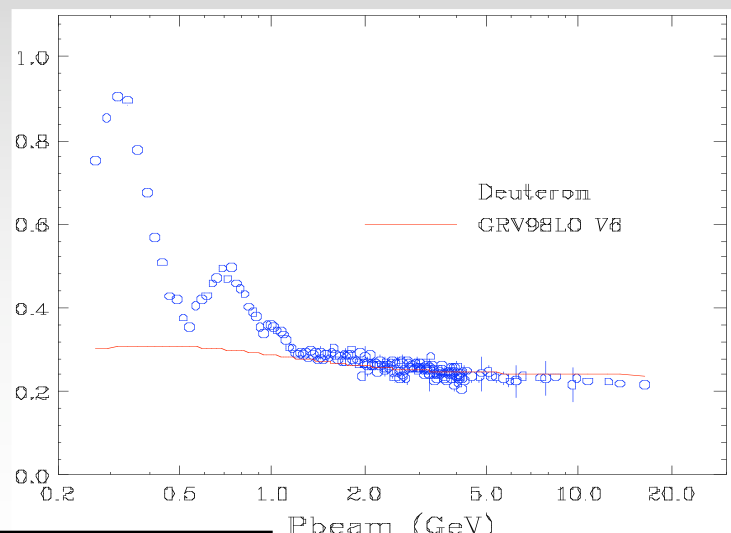


Photo-production (d)

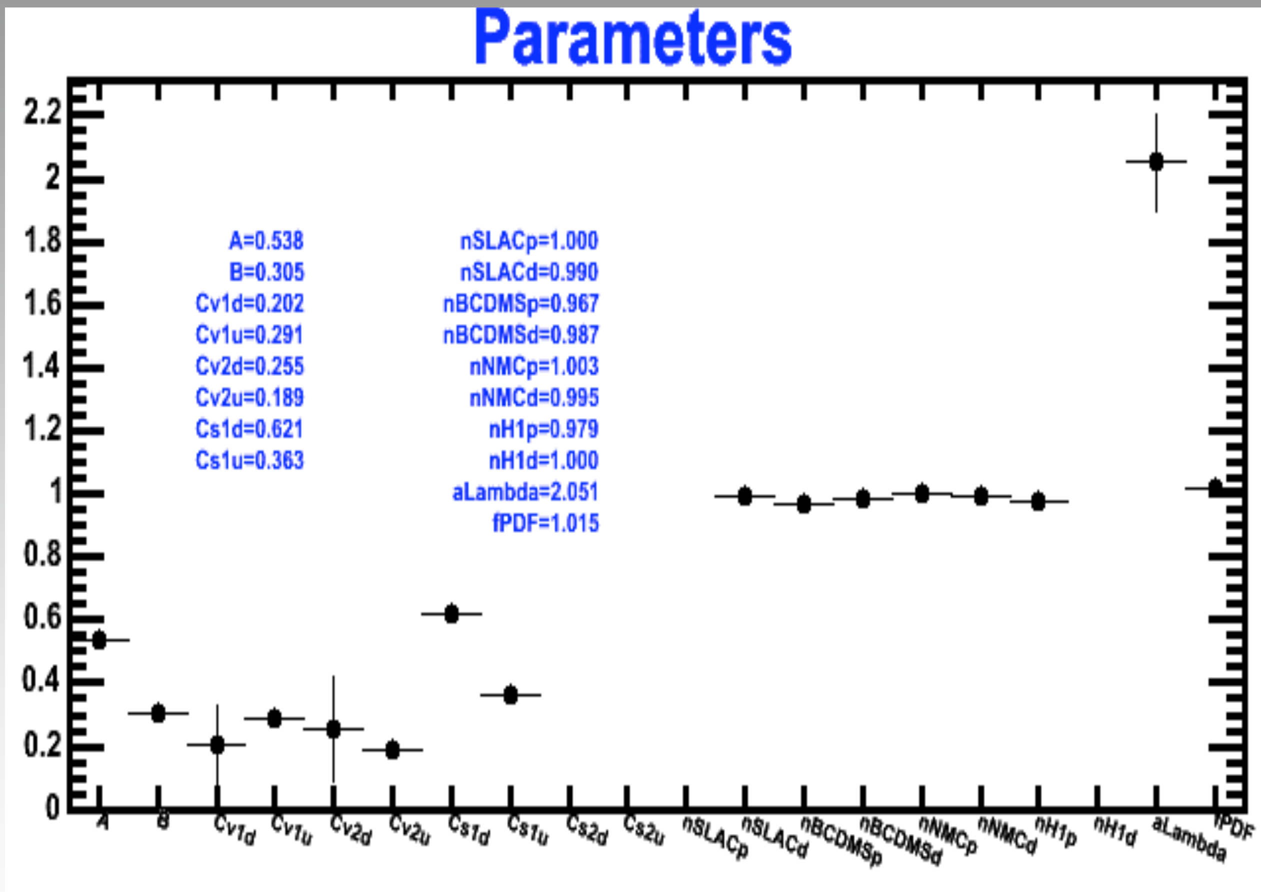
2004 Updates on effective LO model

- Improvements in our model
  - Separate low Q^2 corrections to d and u valence quarks, and sea quarks
  - Include all inelastic F2 proton/deuterium (SLAC/NMC/BCDMC /HERA), photo-production on proton/deuterium in the fits (the c-cbar photon-gluon fusion contribution is included, important at high energy)
- Toward axial PDFs (vector PDFs vs axial PDFs)
  - Compare to neutrino data (assume V=A)

    CCCFR-Fe, CDHS-Fe, CHORUS-Pb differential cross section (without c-cbar boson-fusion in yet - to be added next since it is high energy data)
  - We have a model for axial low Q2 PDFs, but need to compare t o low energy neutrino data to get exact parameters - next.

    $K_{vec} = Q^2/[Q^2+C1] \to K_{ax} = /[Q^2+C2]/[Q^2+C1]$

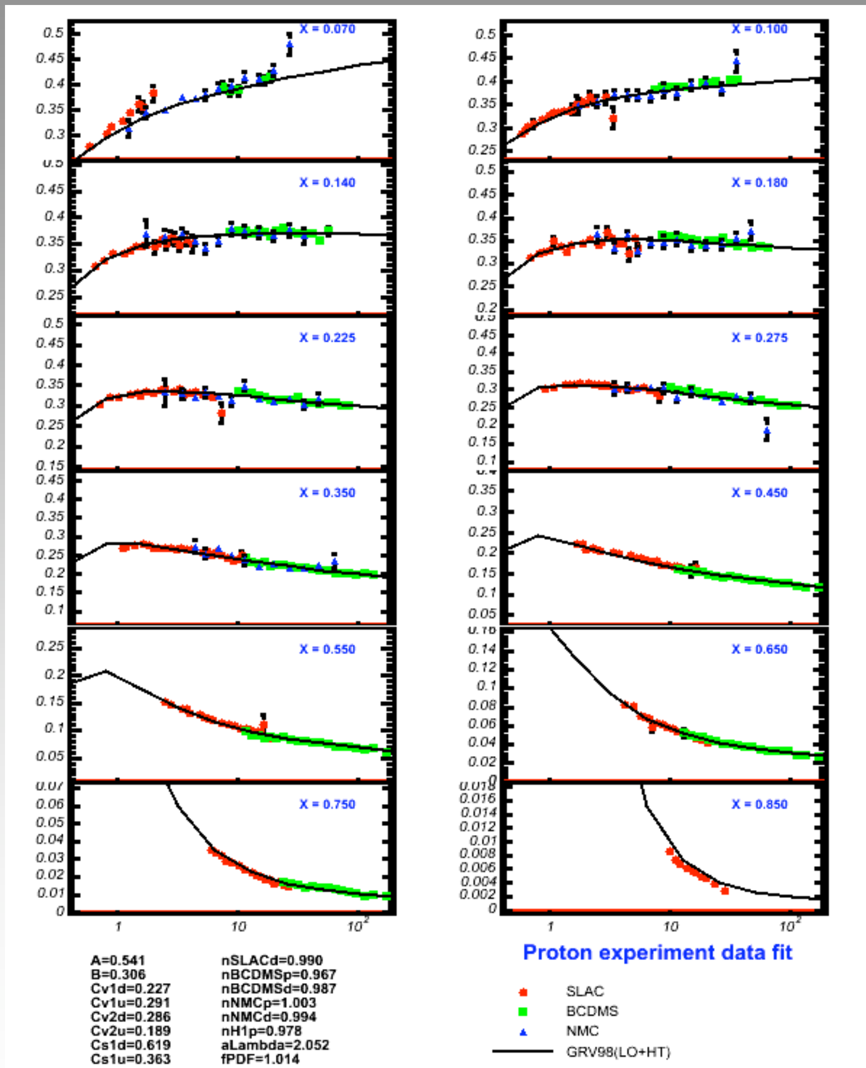
Fit results using the updated model



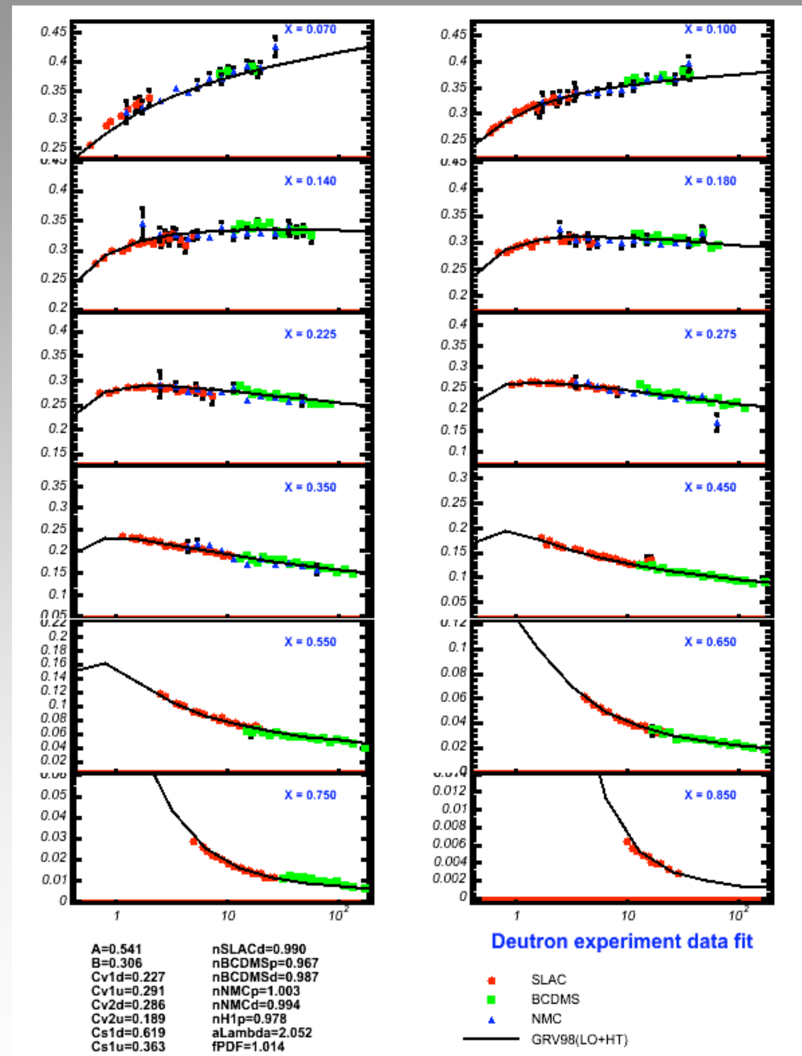
Separate K factors for uv, dv,us,ds

http://web.pas.rochester.edu/~icpark/MINERvA/

Fit results



F2 proton



F2 deuterium

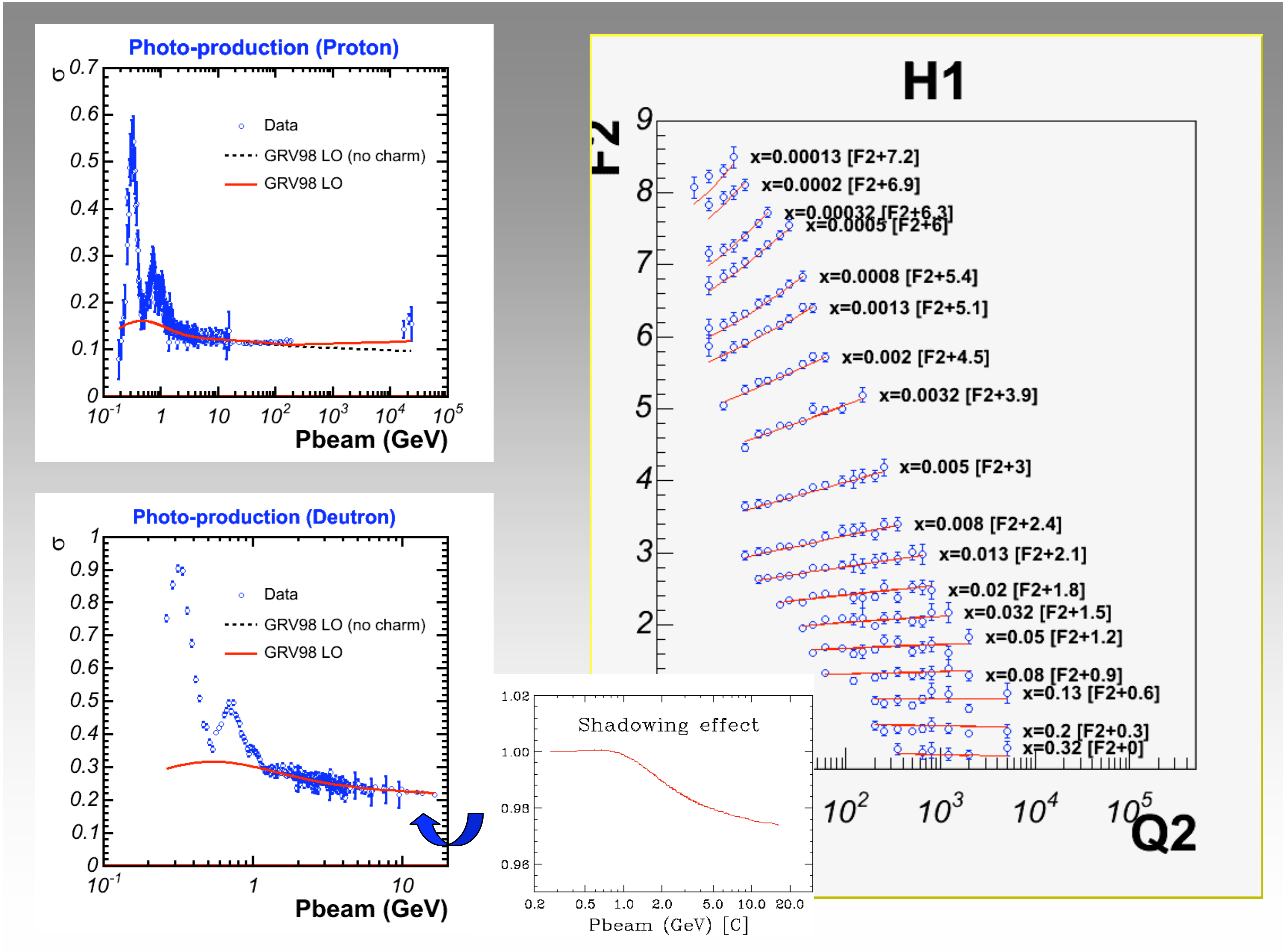
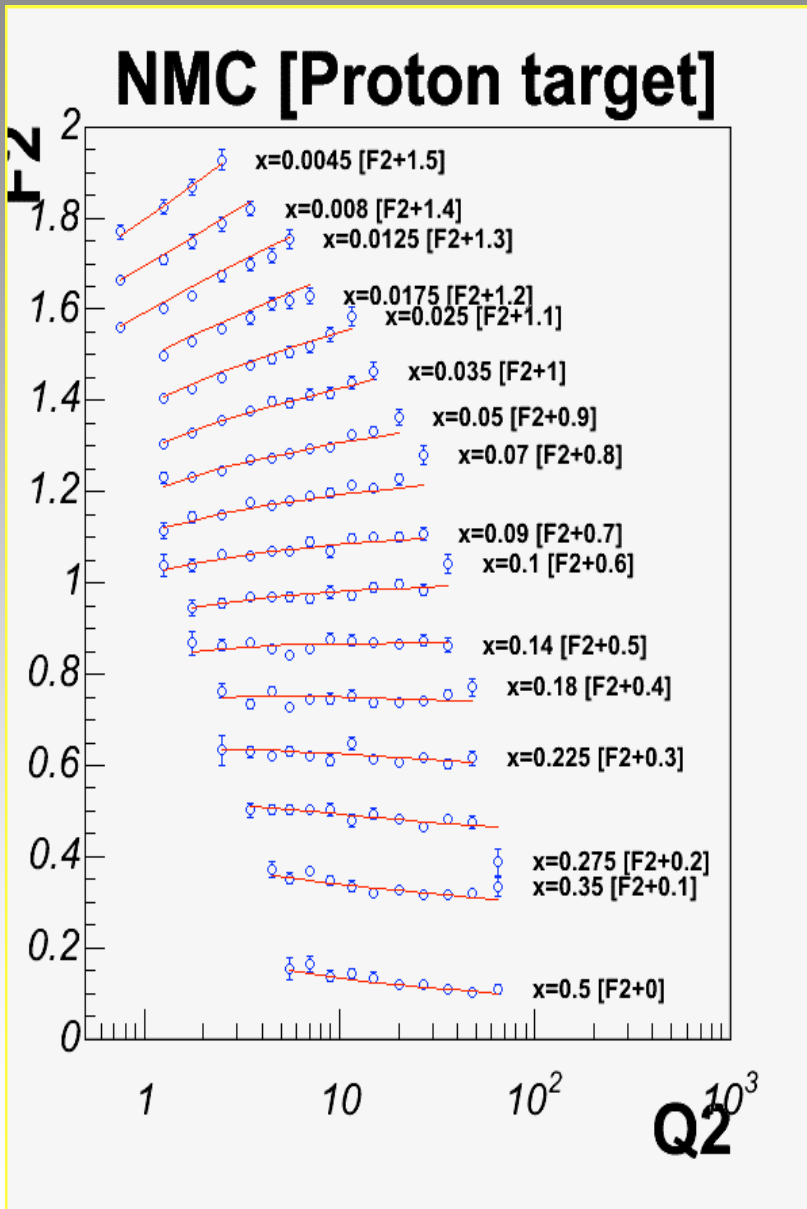
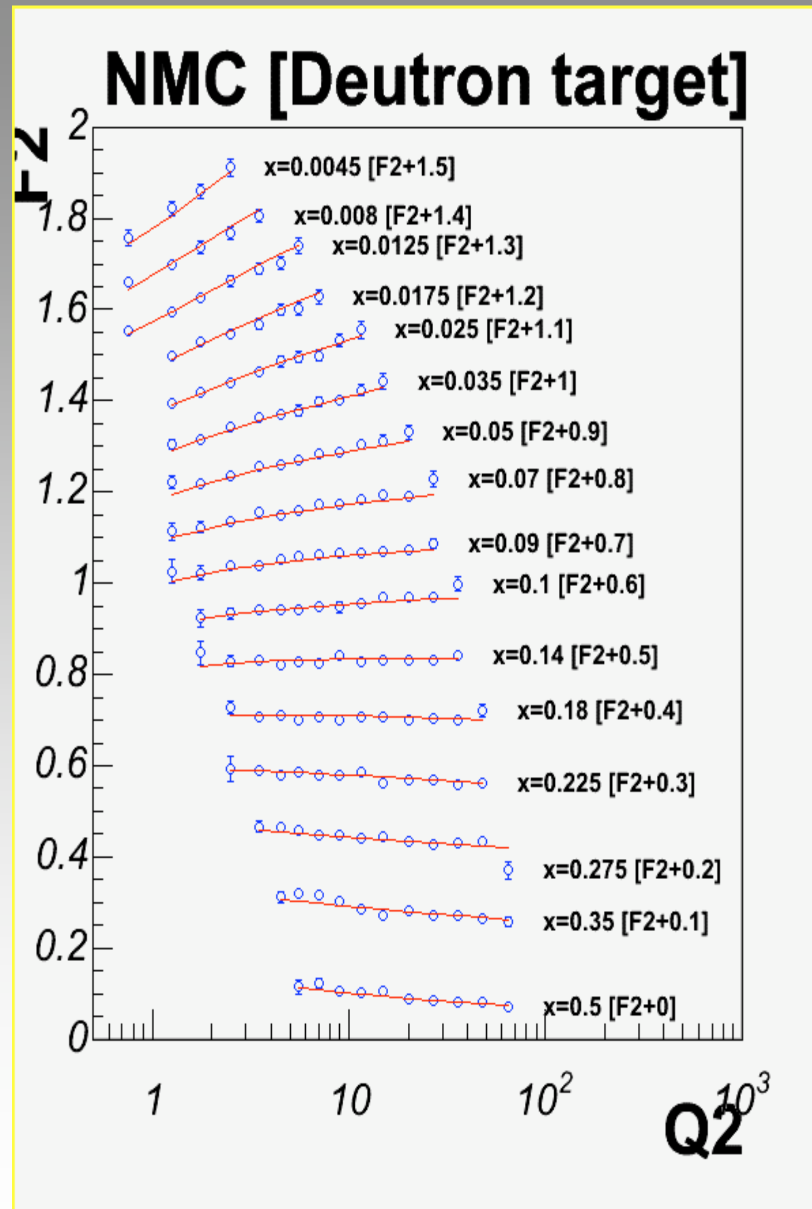


Photo-production (Proton)
σ
Data
GRV98 LO (no charm)
GRV98 LO
Pbeam (GeV)
Photo-production (Deutron)
σ
Data
GRV98 LO (no charm)
GRV98 LO
Pbeam (GeV)
Shadowing effect
Pbeam (GeV) [C]
H1
F2
x=0.00013 [F2+7.2]
x=0.0002 [F2+6.9]
x=0.00032 [F2+6.3]
x=0.0005 [F2+6]
x=0.0008 [F2+5.4]
x=0.0013 [F2+5.1]
x=0.002 [F2+4.5]
x=0.0032 [F2+3.9]
x=0.005 [F2+3]
x=0.008 [F2+2.4]
x=0.013 [F2+2.1]
x=0.02 [F2+1.8]
x=0.032 [F2+1.5]
x=0.05 [F2+1.2]
x=0.08 [F2+0.9]
x=0.13 [F2+0.6]
x=0.2 [F2+0.3]
x=0.32 [F2+0]
Q2

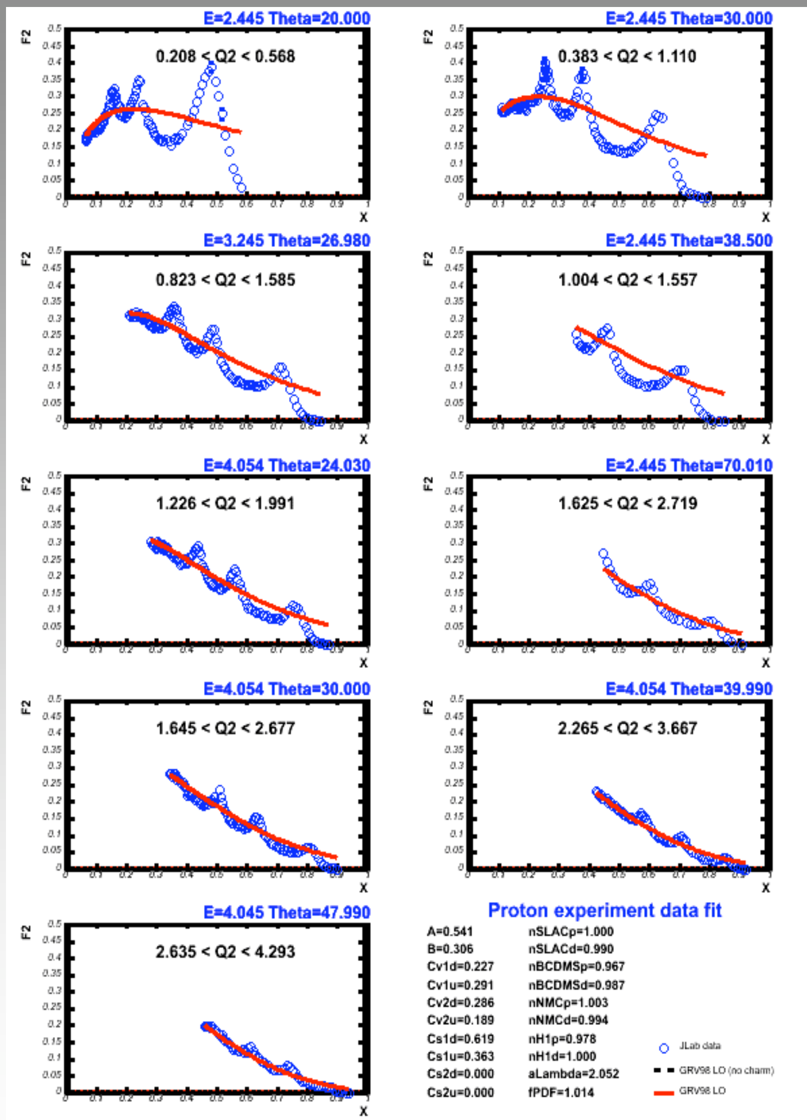


NMC [Proton target]
F2
Q2
x=0.0045 [F2+1.5]
x=0.008 [F2+1.4]
x=0.0125 [F2+1.3]
x=0.0175 [F2+1.2]
x=0.025 [F2+1.1]
x=0.035 [F2+1]
x=0.05 [F2+0.9]
x=0.07 [F2+0.8]
x=0.09 [F2+0.7]
x=0.1 [F2+0.6]
x=0.14 [F2+0.5]
x=0.18 [F2+0.4]
x=0.225 [F2+0.3]
x=0.275 [F2+0.2]
x=0.35 [F2+0.1]
x=0.5 [F2+0]

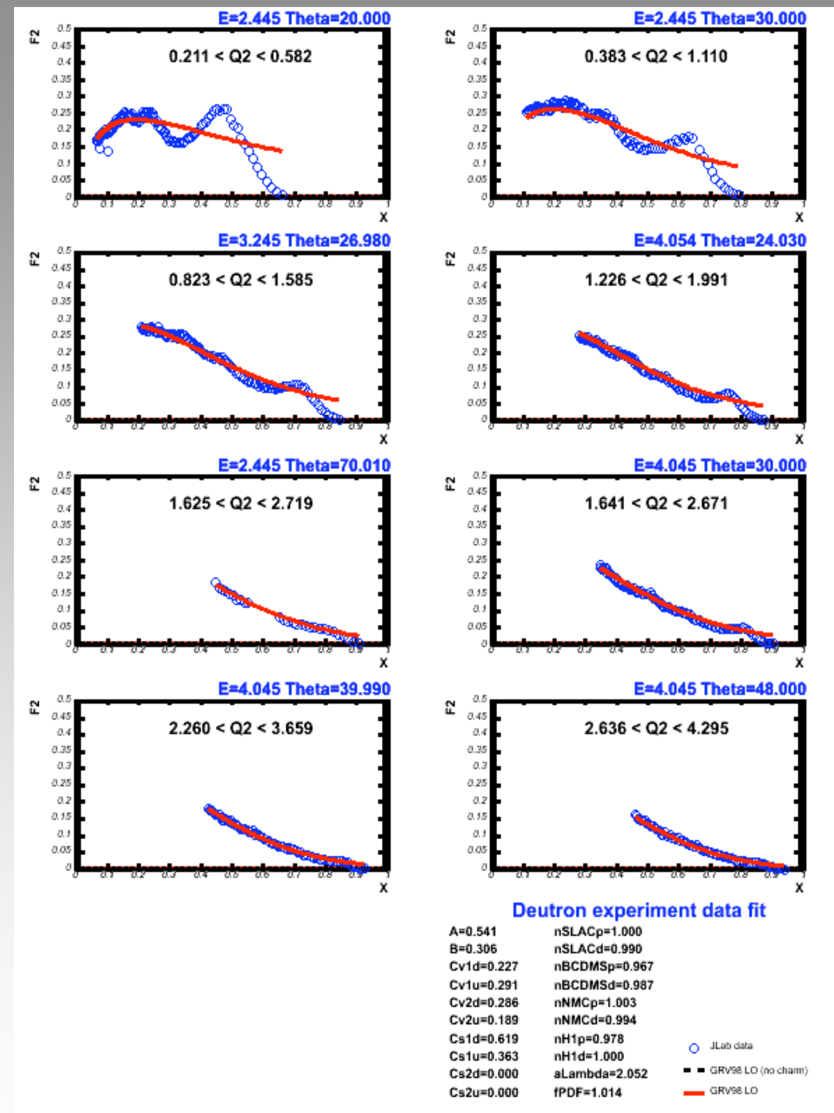


NMC [Deutron target]
F2
Q2
x=0.0045 [F2+1.5]
x=0.008 [F2+1.4]
x=0.0125 [F2+1.3]
x=0.0175 [F2+1.2]
x=0.025 [F2+1.1]
x=0.035 [F2+1]
x=0.05 [F2+0.9]
x=0.07 [F2+0.8]
x=0.09 [F2+0.7]
x=0.1 [F2+0.6]
x=0.14 [F2+0.5]
x=0.18 [F2+0.4]
x=0.225 [F2+0.3]
x=0.275 [F2+0.2]
x=0.35 [F2+0.1]
x=0.5 [F2+0]

Resonance F2 proton

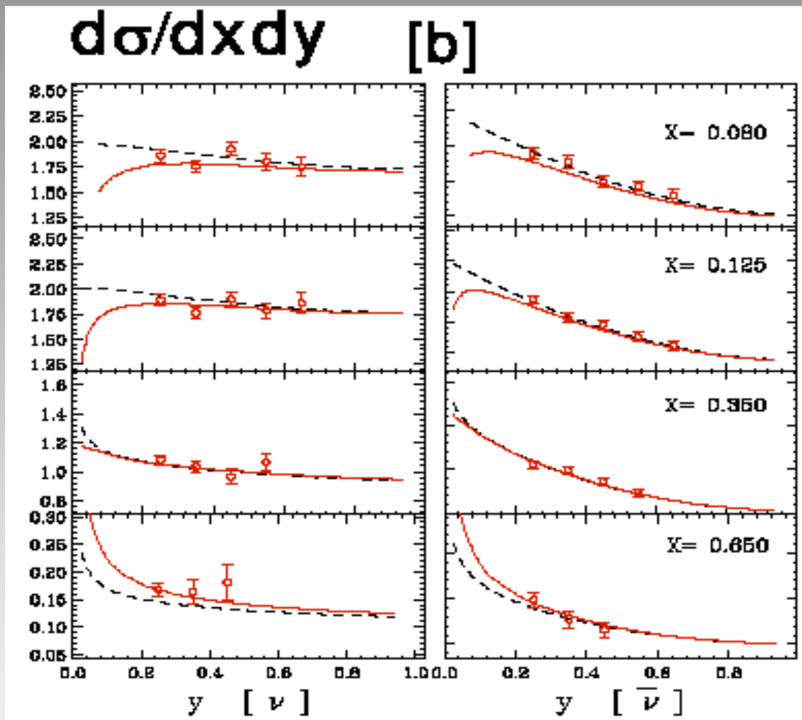


Resonance F2 deuterium



Resonance data are not included in the fit!!!

Comparison with CCFR neutrino data (Fe) (assume V=A)



- Apply nuclear corrections using e/m scattering data.
- Calculate F_2 and xF_3 from the modified PDFs with ξw
- Use R=Rworld fit to get $2xF_1$ from F_2
- Implement charm mass effect through ξw slow rescaling algorithm, for F_2 $2xF_1$, and XF_3

--ξw PDFs GRV98 modified

---- GRV98 (x,Q^2) unmodified

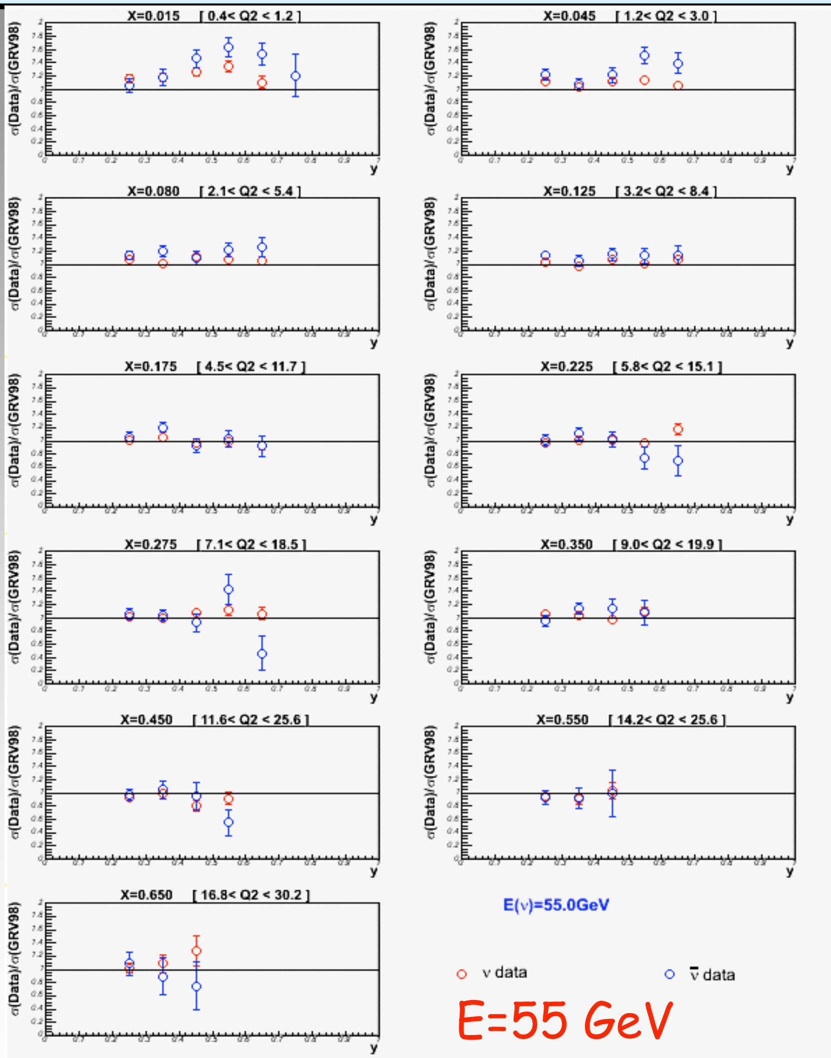
Left: CCFR neutrino data -55 Gev

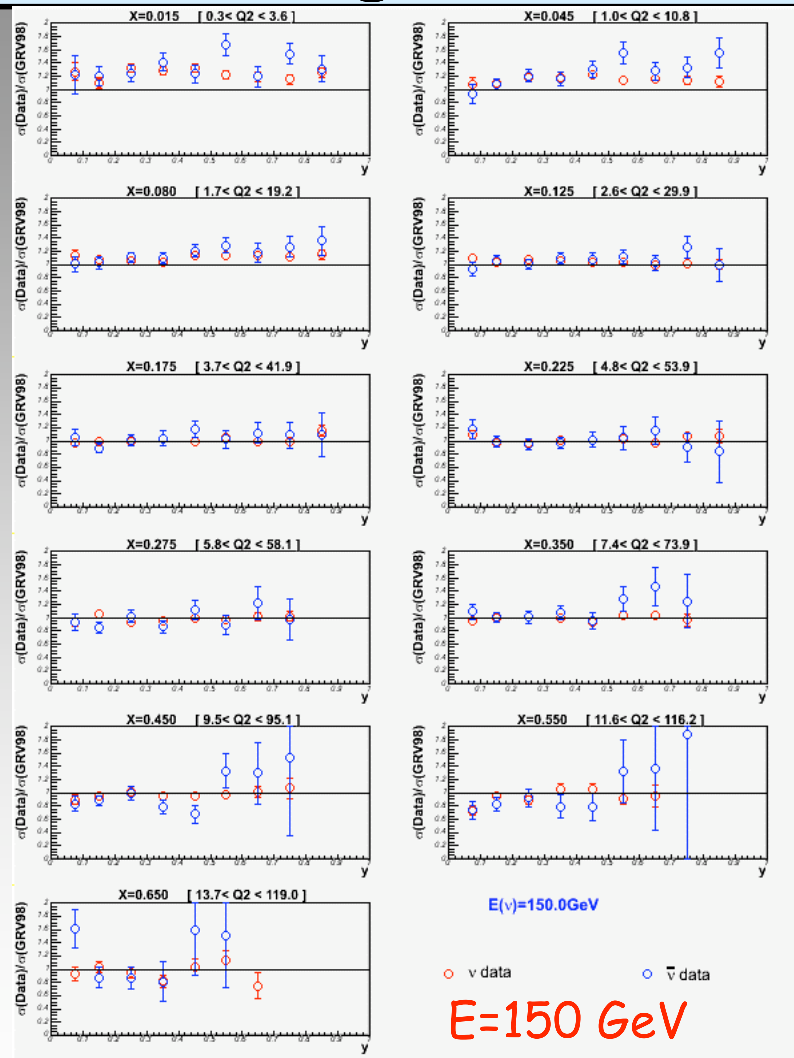
Right : CCFR anti-neutrino data ,-55 GeV

(NuFact03 version)

Our model describes **CCFR** diff. cross sect. (Eν=30–300 GeV) well (except at the lowest x)

Comparison with updated model (assume V=A) CCFR Fe data/ (Bodek-Yang Model)

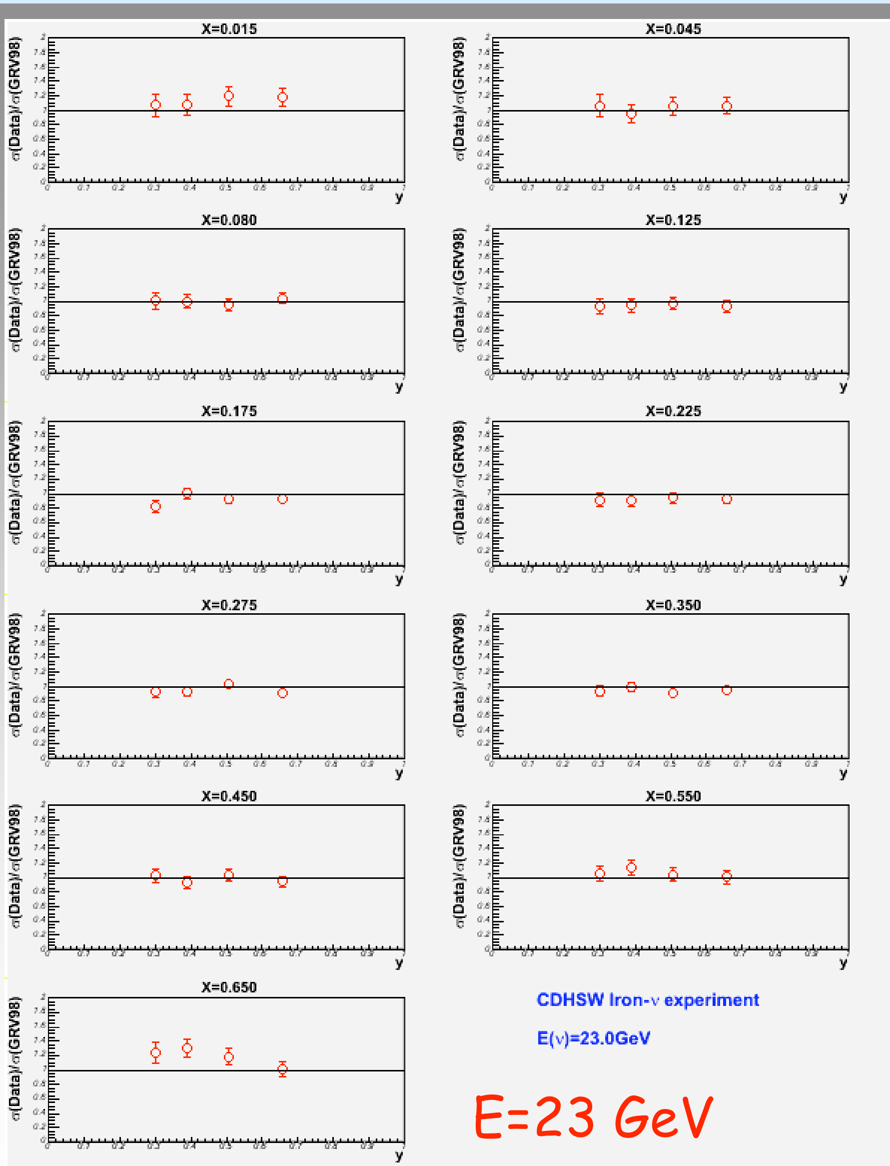


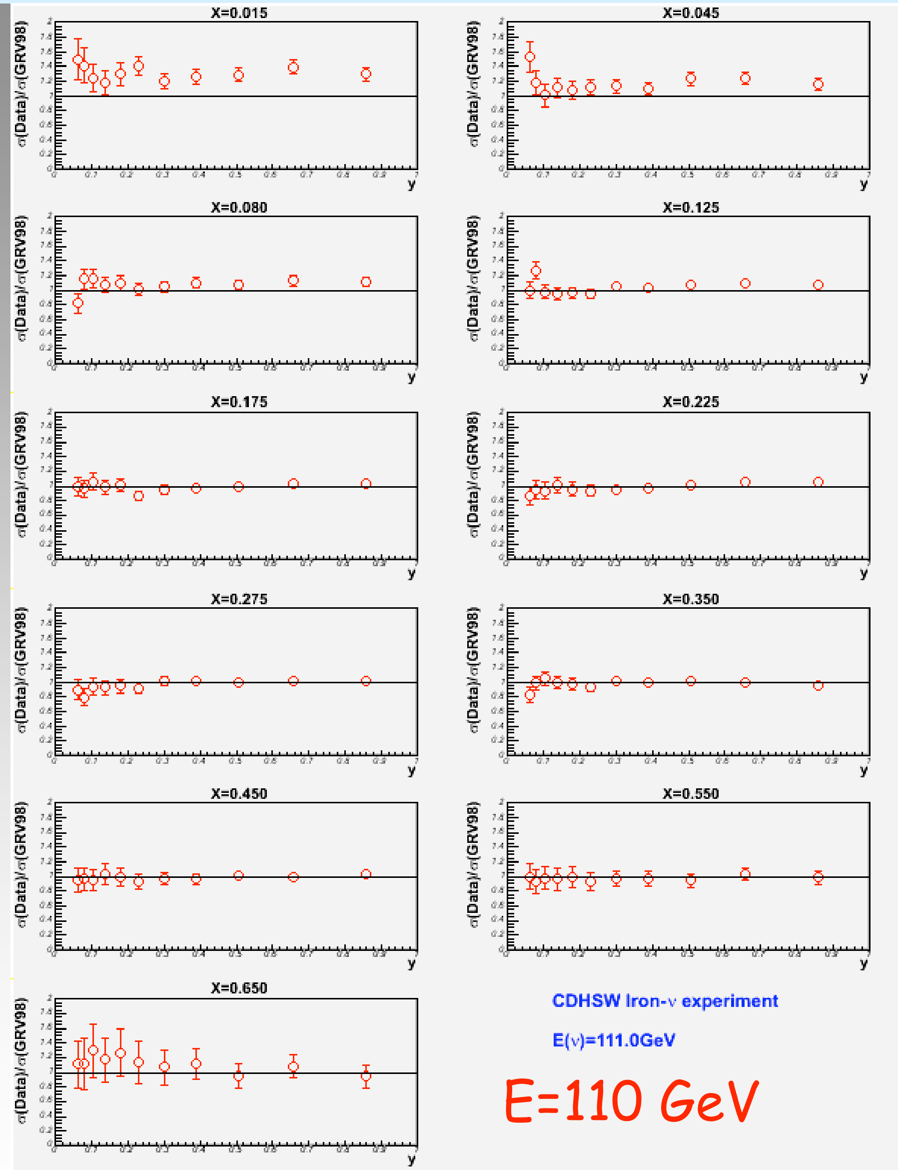


Plots for all energy regions: CCFR diff. cross section data

http://web.pas.rochester.edu/~icpark/MINERvA/

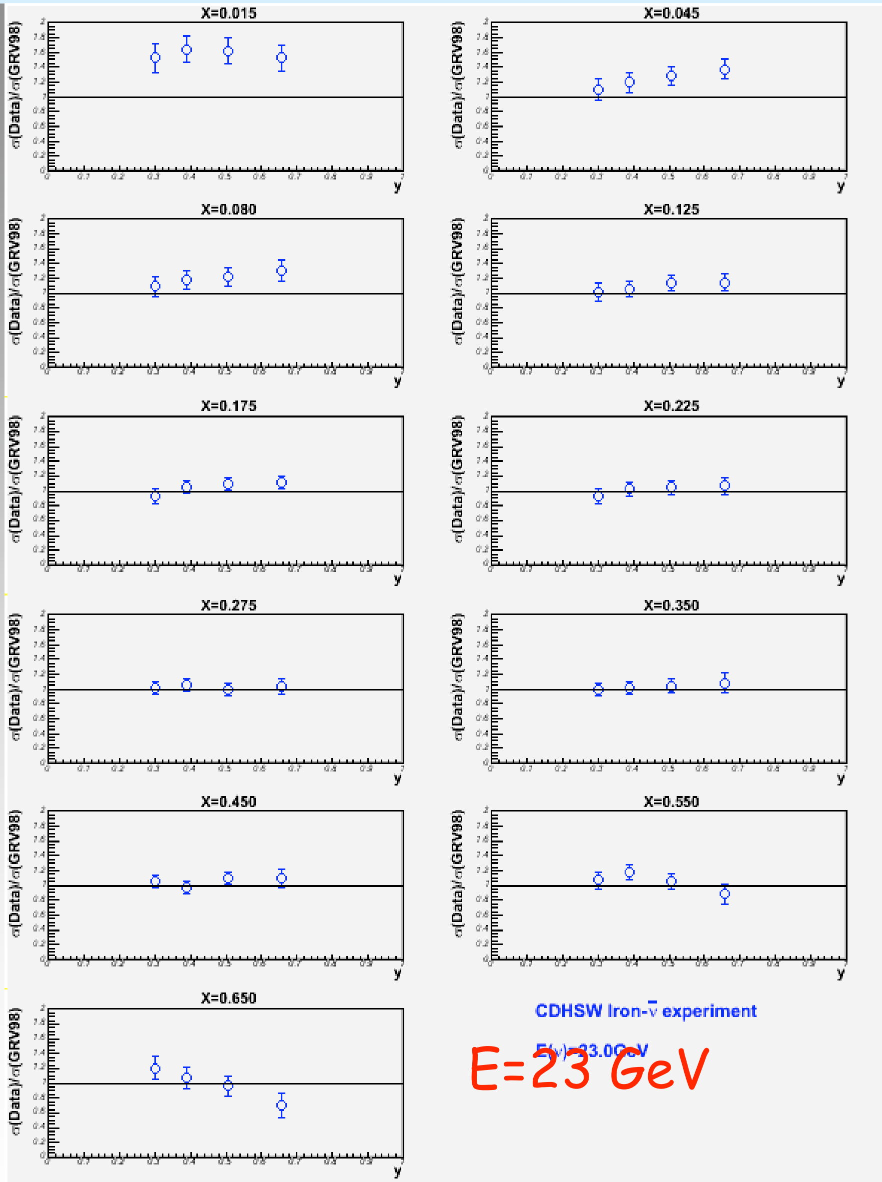
Comparison with CDHSW neutrino data (Fe)

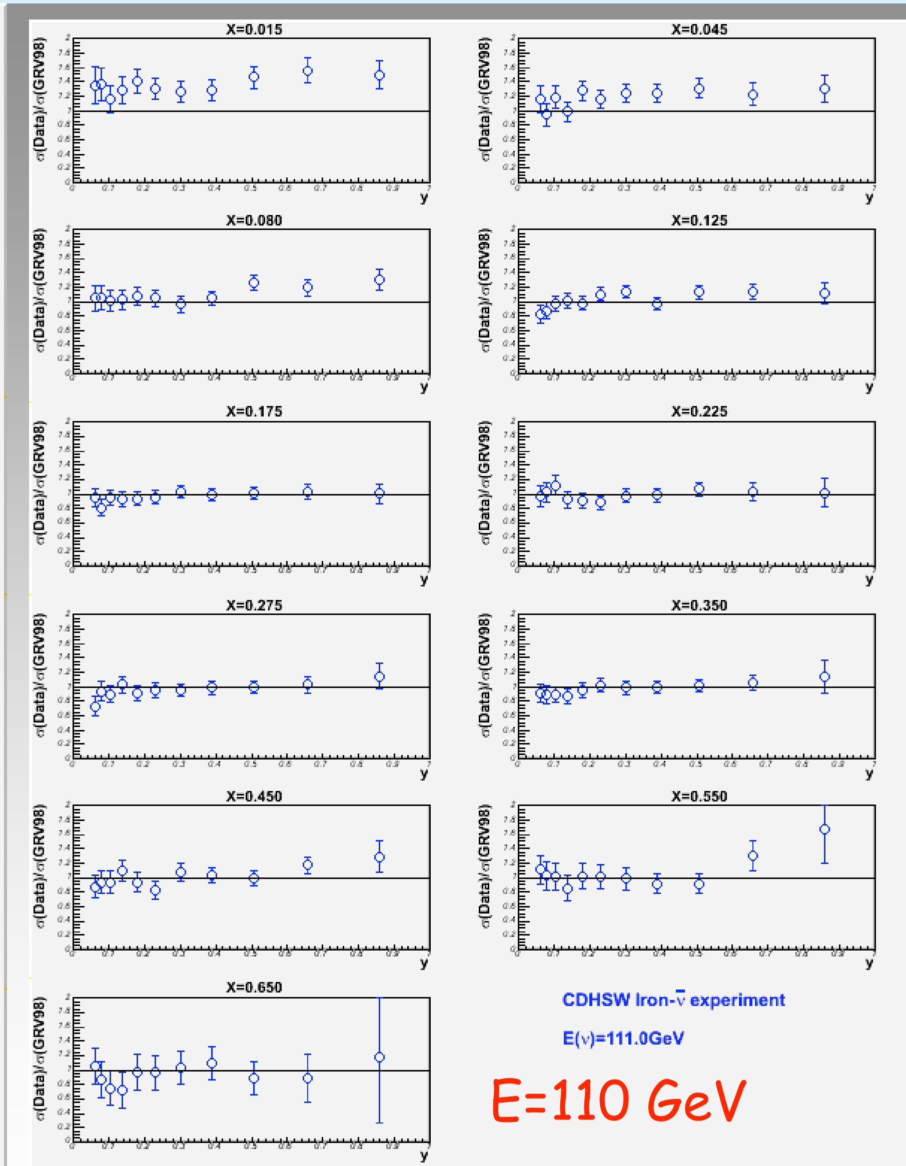




Add radiative correction, ccbar contribution at low x to model - CDHS data/ (Bodek-Yang Model)

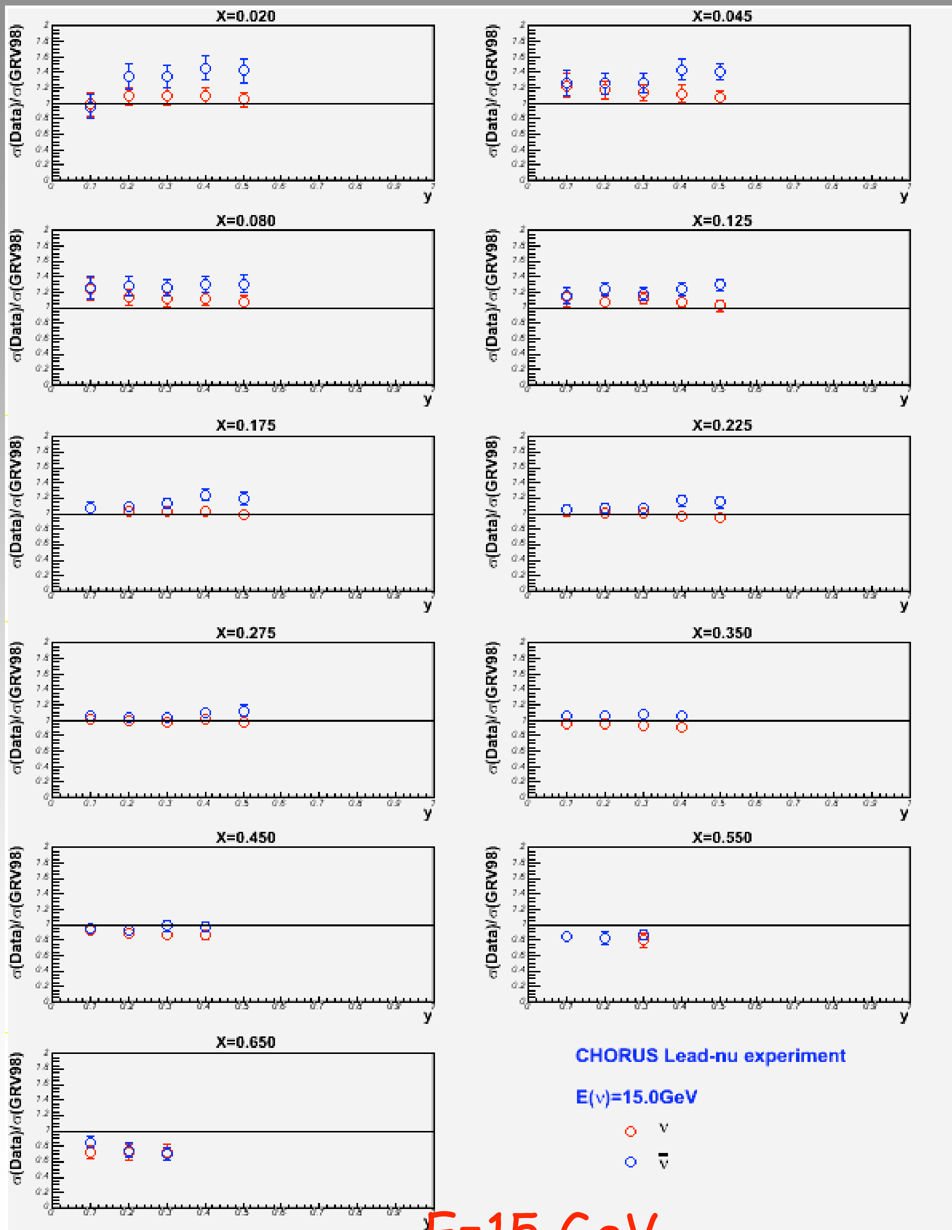
Comparison with CDHSW anti-neutrino data (Fe)



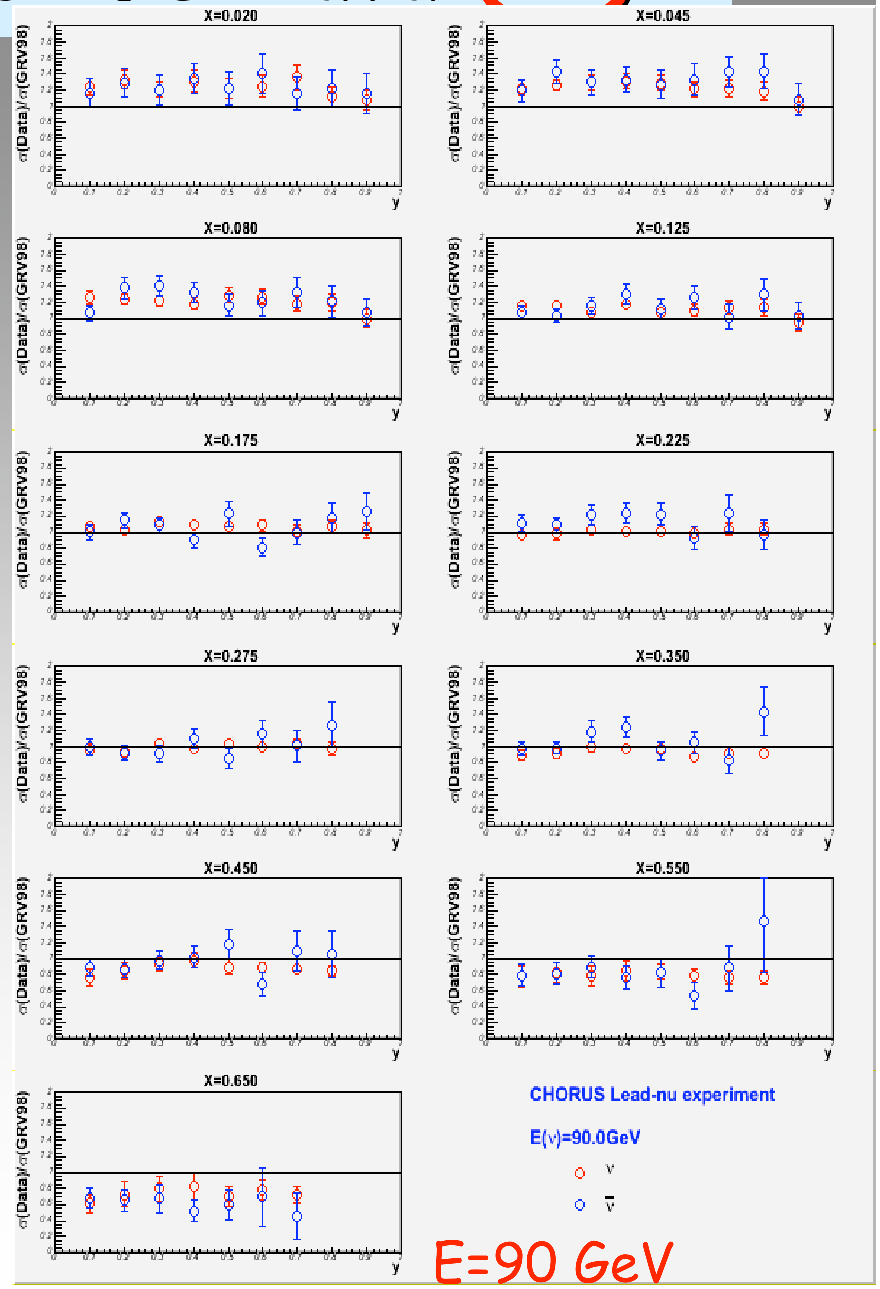


Radiative correction, ccbar contribution at low x

Comparison with CHORUS data (Pb)



E=15 GeV



E=90 GeV

Correct for Nuclear Effects measured in e/muon expt.

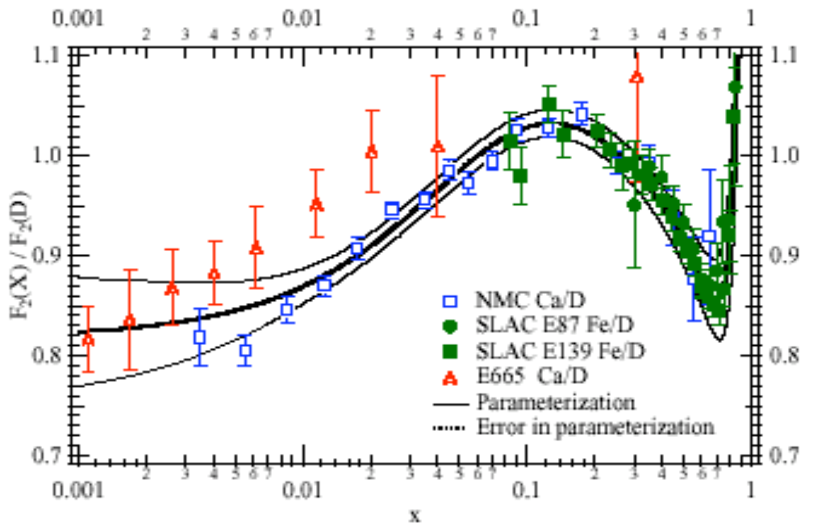
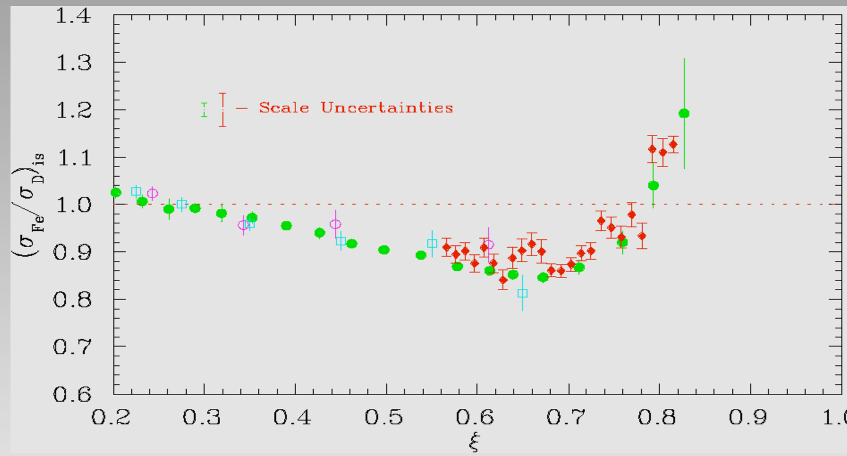


Figure 5. The ratio of F_2 data for heavy nuclear targets and deuterium as measured in charged lepton scattering experiments(SLAC,NMC, E665). The band show the uncertainty of the parametrized curve from the statistical and systematic errors in the experimental data [16].



Comparison of Fe/D F2 data

In resonance region (JLAB)

Versus DIS SLAC/NMC data

In $_{TM}$ (C. Keppel 2002).

Summary of Unified LO Approach works from Q2=0 to high Q2

For applications to Neutrino Oscillations at Low Energy (down to Q2=0) the best approach is to use a LO PDF analysis (including a more sophisticated target mass analysis) and modify to include the missing QCD higher order terms via Empirical Higher Twist Corrections.

Reason:

For Q2>5 both Current Algebra exact sum rules (e.g. Adler sum rule) and QCD sum rules (e.g. momentum sum rule) are satisfied. This is why duality works in the resonance region. For Q2>5 we can also use either NNLO QCD analysis or **a modified leading order analysis which uses duality + Adler to constrain elastic vector and axial form factors** (**Bodek-Yang**)

For Q2<1, **QCD corrections diverge**, and all QCD sum rules (e.g momentum sum rule) break down, and duality breaks down in the resonance region. In contrast, Current Algebra Sum rules e,g, Adler sum rule which is related to the Number of (U minus D) Valence quarks) are valid.

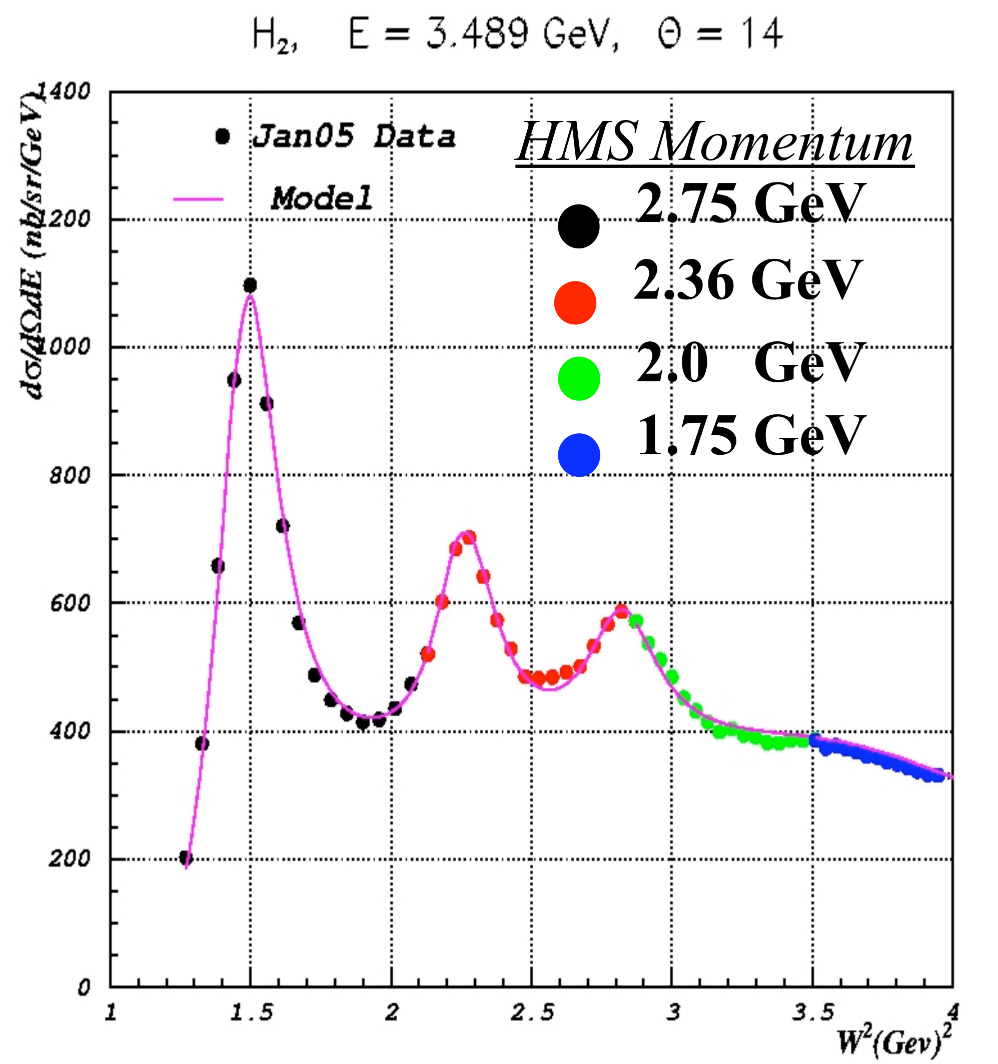
Our unified approach works for both Q2>1 and for Q2<1,

Summary and Plans

- Our effective LO model describe all F2 DIS, resonance, and photo-production data well.
- This model provide a good description on the neutrino cross section data (except axial vector contribution).
- Now working on the axial structure functions and next plan to work on resonance fits.
- JUPITER at Jlab (Bodek, Keppel) taken January 05 - will provided electron-Carbon (also e-H and e-D and other nuclei such as e-Fe) in resonance region

  JUPITER (preliminary data shown in next three slides)
- Future: MINERvA at FNAL (McFarland, Morfin) will provide Neutrino-Carbon data at low energies.

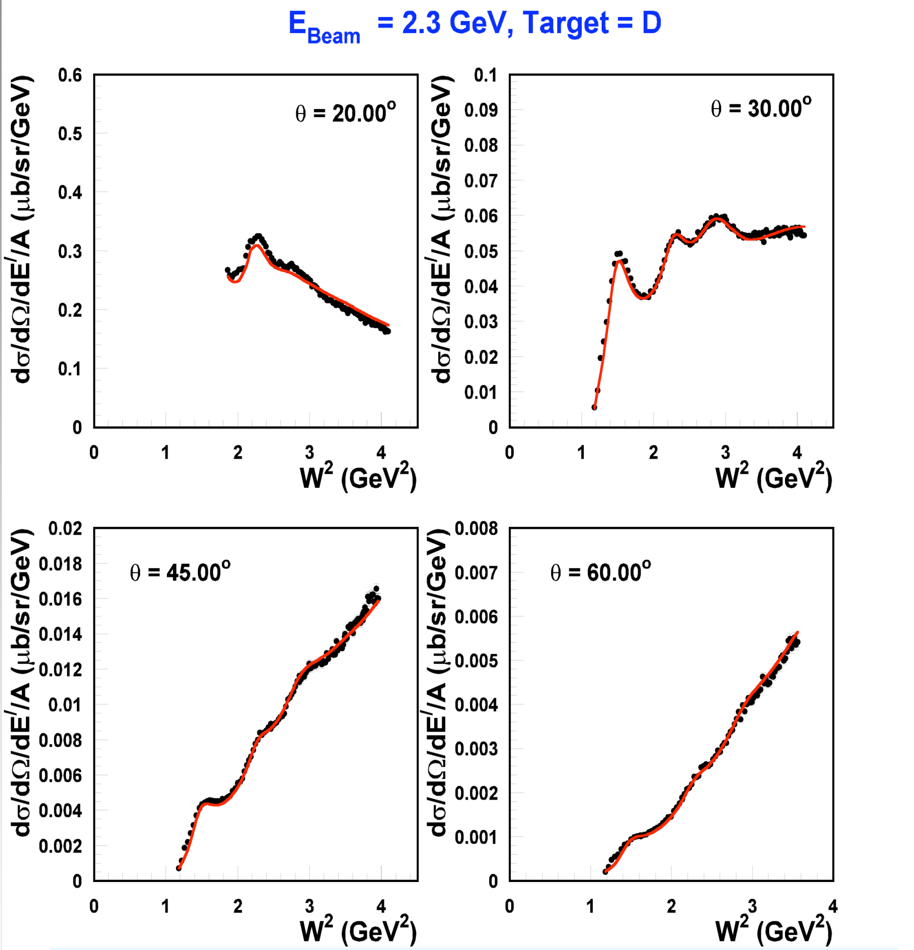
JUPITER Jlab DATA e-p January 2005 data

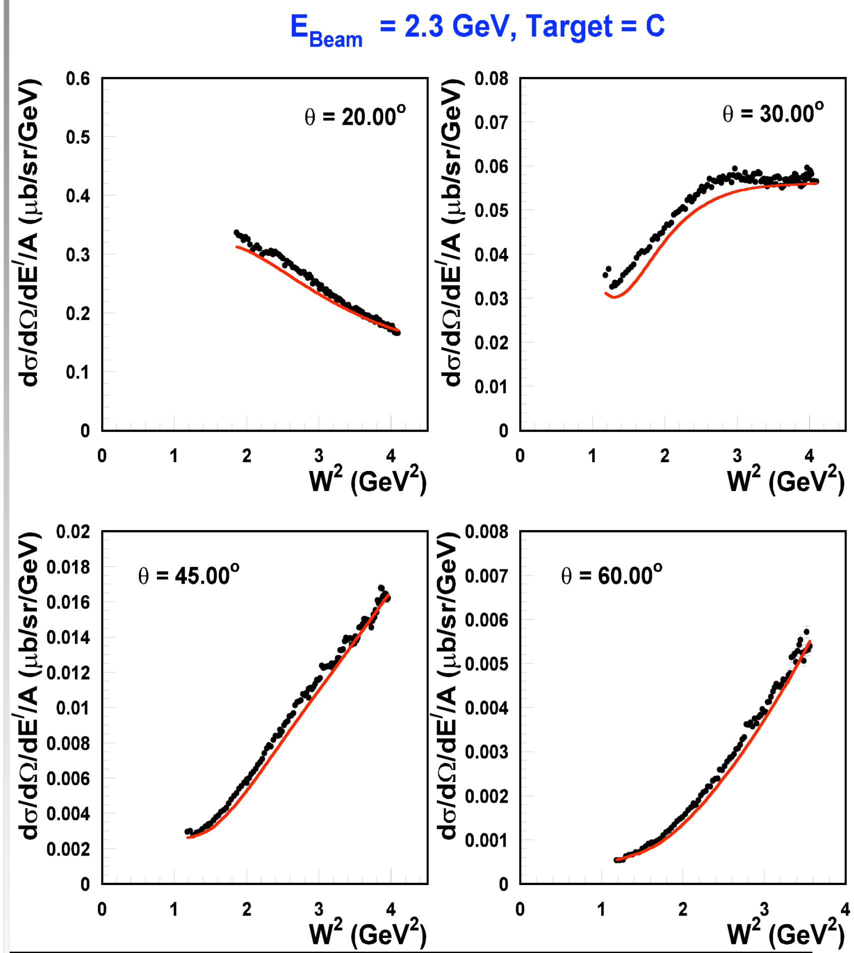


For most recent updated data

see PANIC 2005 Talk by Cynthia Keppel - This Session

Preliminary Deuterium and Carbon Cross Sections - JUPITER Jefferson Lab Jan. 2005 data





- Error bars are statistical only.
- Only inelastic data shown.

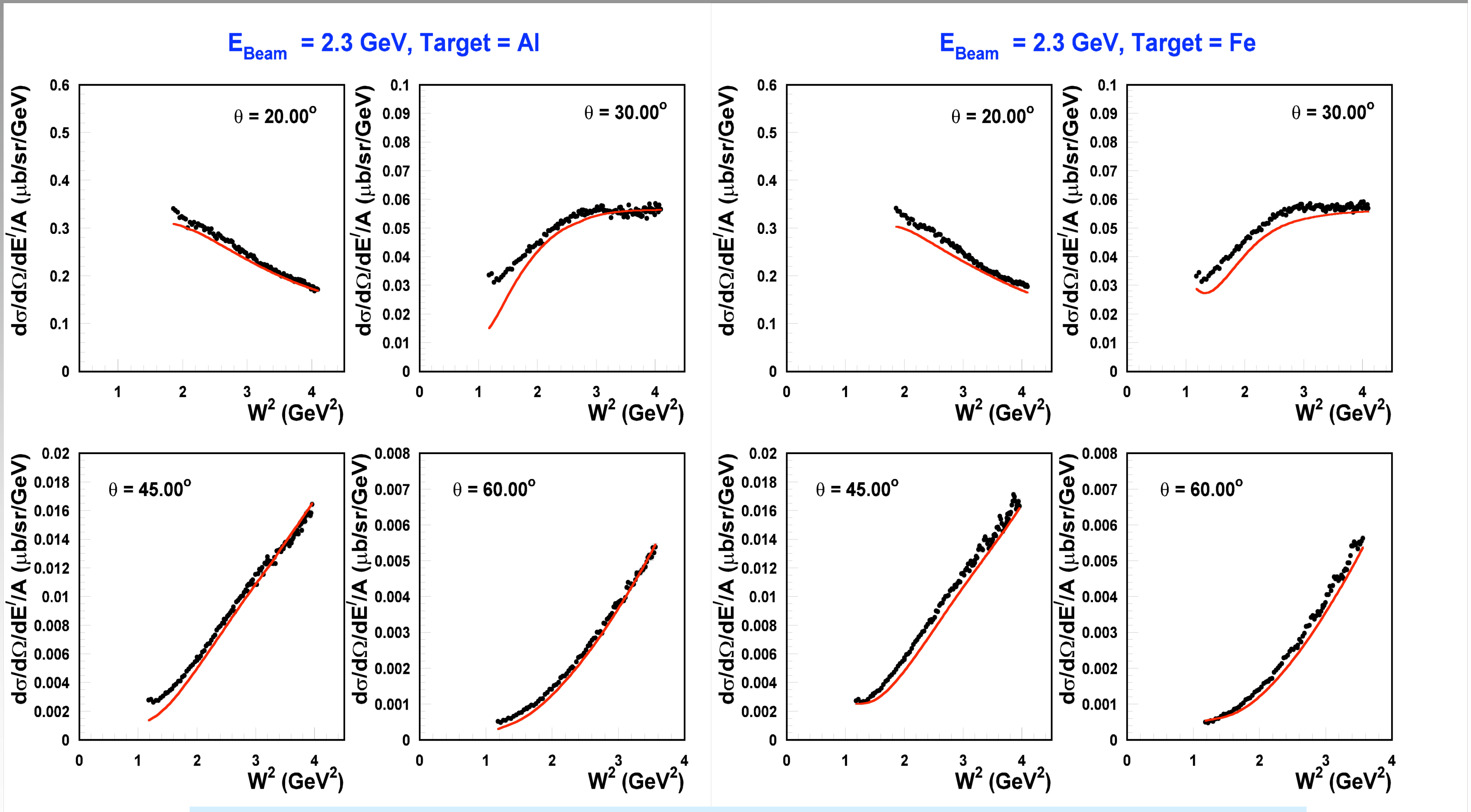
----- Input models for RCs, etc.

For most recent updated data see PANIC 2005 Talk by Cynthia Keppel - This Session

Deuterium: Fits to previous JLab & SLAC resonance region data.

Heavy targets: fits to DIS data (F_2 & R) + y-scaling QE model.

JUPITER e-Al and e-Fe preliminary Cross Sections Jan 2005 data



For most recent updated data

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