MANCHESTER 1824

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Unified approach to e/ν-N DIS cross sections at all Q^2

Arie Bodek
University of Rochester

Un-Ki Yang
University of Manchester

A model for all Q^2 region?

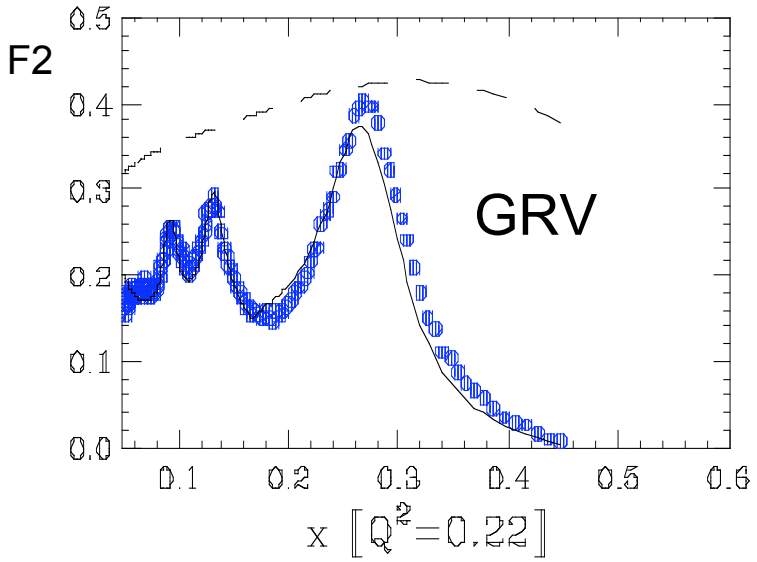
- The high Q^2 region of lepton-nucleon scatterings is well understood in terms of quark-parton model by a series of e/μ/ν DIS experiments

- But the low Q^2 region is relatively poorly understood in neutrino scattering: very important for many neutrino oscillation experiments. Many interesting issues
  - PDFs at high x?
  - Non-perturbative QCD? target mass, higher twist effects
  - Duality works for resonance region?
  - Axial vector contribution?
  - Nuclear effects?

- Can we build up a model for all Q2 region?

Challenges

- A model to describe all Q^2 region from high down to very low energies for charged lepton and neutrino scatterings
  [DIS, resonance, even photo-production(Q^2=0)]
  - Resonance region is overlapped with a DIS contribution
  - Hard to extrapolate DIS contribution to low Q^2 region from high Q^2 data, because of non-pQCD effects



- A model in terms of quark-parton model
  - Understanding of high x PDFs at low Q^2?

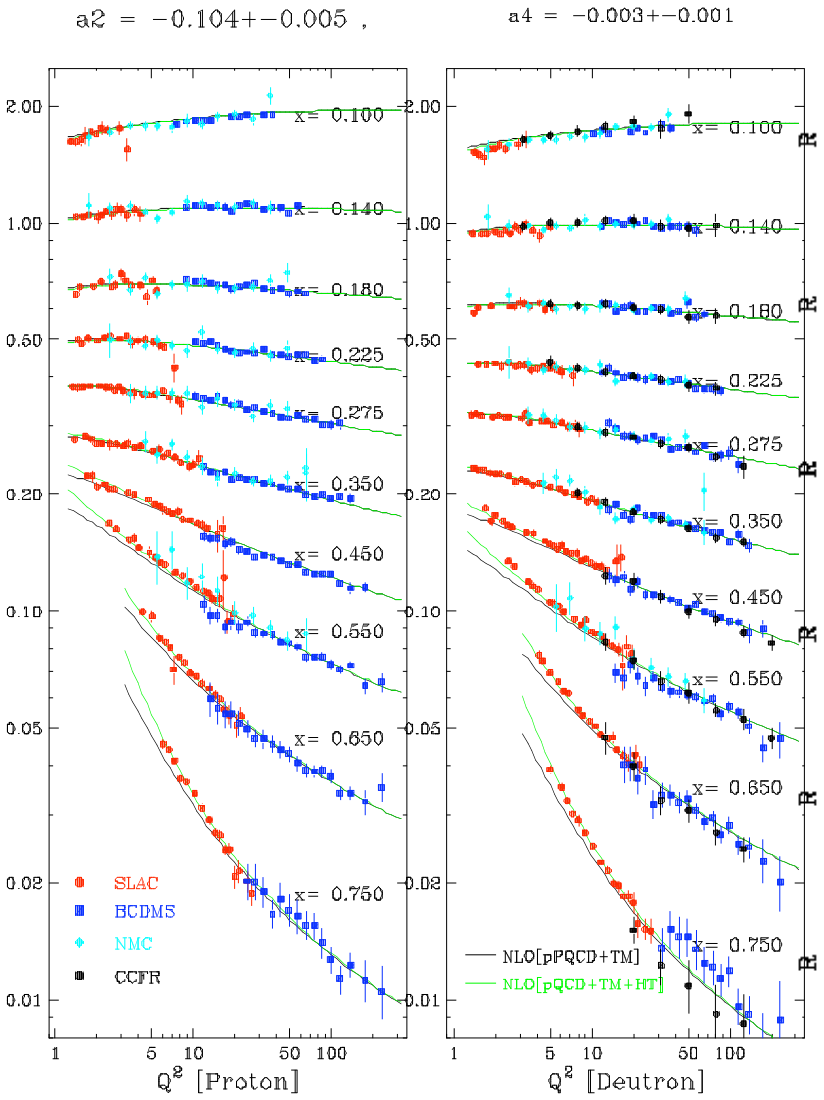
    wealthy SLAC, JLAB data.
  - Understanding of resonance scattering in terms of quark-parton model? (duality works, many studies by JLAB)

Unified approach

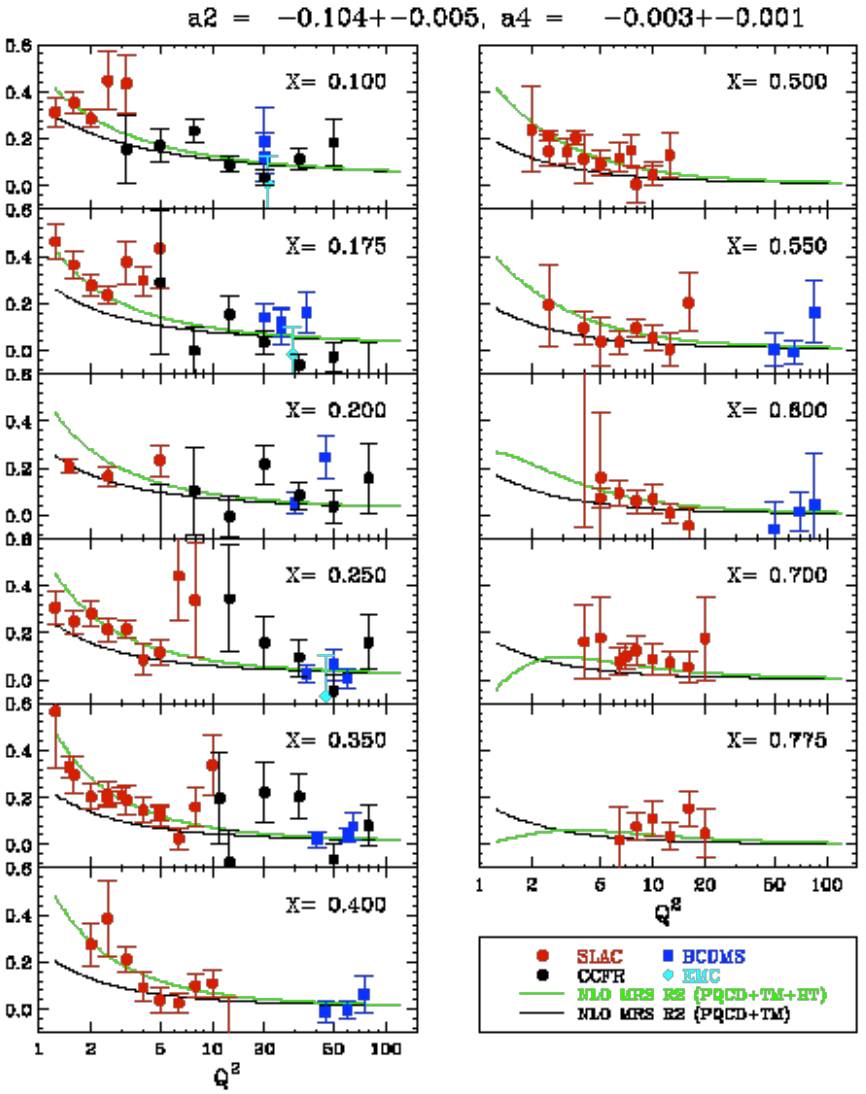
- NNLO pQCD +TM describes the DIS and resonance data very well
  - Theoretically, breaks down at low Q^2
  - Practically, no way for MC
- A phenomenological HT from the NLO analysis is close to the NNLO pQCD term

Comparisons with NLO pQCD+TM+HT

F_2

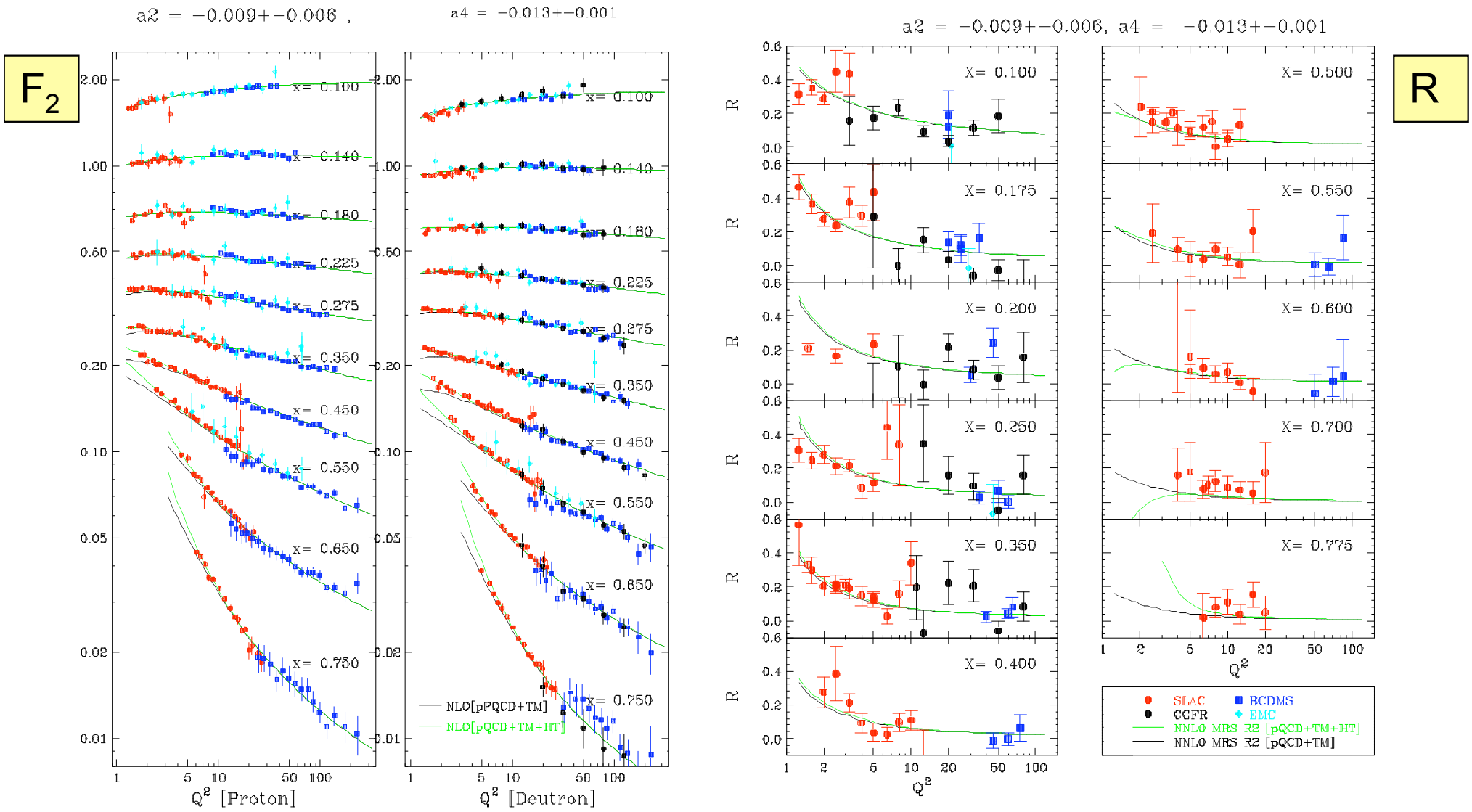


R



PRL 82, 2467 (1999): Bodek & Yang

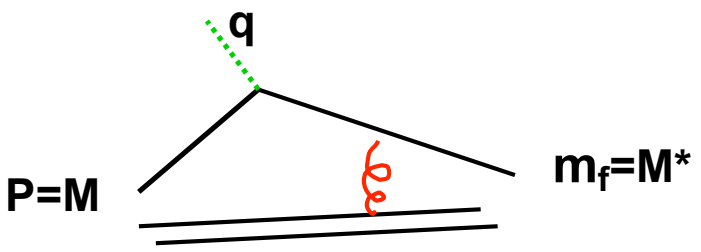
F_2, R comparison with NNLO pQCD+TM



Eur. Phys. C13, 241 (2000) Bodek & Yang

Unified approach

- NNLO pQCD +TM describes the DIS and resonance data very well
  - Theoretically, breaks down at low Q^2
  - Practically, no way for MC
- A phenomenological HT from the NLO analysis is close to the NNLO pQCD term
- Can we use an effective LO PDFs with a modified scaling variable to absorb TM, HT, missing higher orders?



$$\xi_W = \frac{(Q^2 + m_f^2 - m_i^2) + \sqrt{(Q^2 + m_f^2 - m_i^2)^2 + 4Q^2(m_i^2 + P_t^2)}}{2Mv[1 + \sqrt{(1 + Q^2/v^2)}]}$$

$$\xi_W = \frac{Q^2 + B}{\{Mv[1 + \sqrt{(1 + Q^2/v^2)}] + A\}}$$

$$\frac{Q^2}{Q^2 + C} F_2(\xi_w, Q^2)[\mathrm{LO}]$$

Early Fits (2001)

1. Start with GRV94 LO
2. Replace Xbj with a new scaling

$$x_w = [Q^2 + B] / [M\nu + A]$$

3. Multiply all PDFs by a factor of $Q^2/[Q^2+C]$ for photo prod. limit and higher twist

   [$\sigma(\gamma) = 4\pi\alpha/Q^2 * F_2(x, Q^2)$]

4. Freeze the evolution at $Q^2 = 0.25$

5. Do a fit to SLAC/NMC/BCDMS H, D

- $\mathbf{X_w}$: A=1.735, B=0.624, C=0.188 & χ^2/DOF= 1555/958
- $\xi\mathbf{w}$: A=0.700,B=0.327, C=0.197 & χ^2/DOF= 1351/958

(Normalization of each exp. & BCDMS major syst.)

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Fit with ξw

- Use GRV98 LO
- $\xi_w = [Q^2+B] / [M\nu\,(1+(1+Q^2/\nu^2)^{1/2}) + A]$

- Different K factors for valence and sea

  $K_{sea} = Q^2/[Q^2+C_{sea}]$

  $K_{val} = [1- G_D^2(Q^2)] * [Q^2+C2V] / [Q^2+C1V]$,

  $G_D^2(Q^2) = 1/[1+Q^2/0.71]^4$
- Freeze the evolution at $Q^2 = 0.8$

- Very good fits are obtained (with additional low x HERA/NMC F_2)

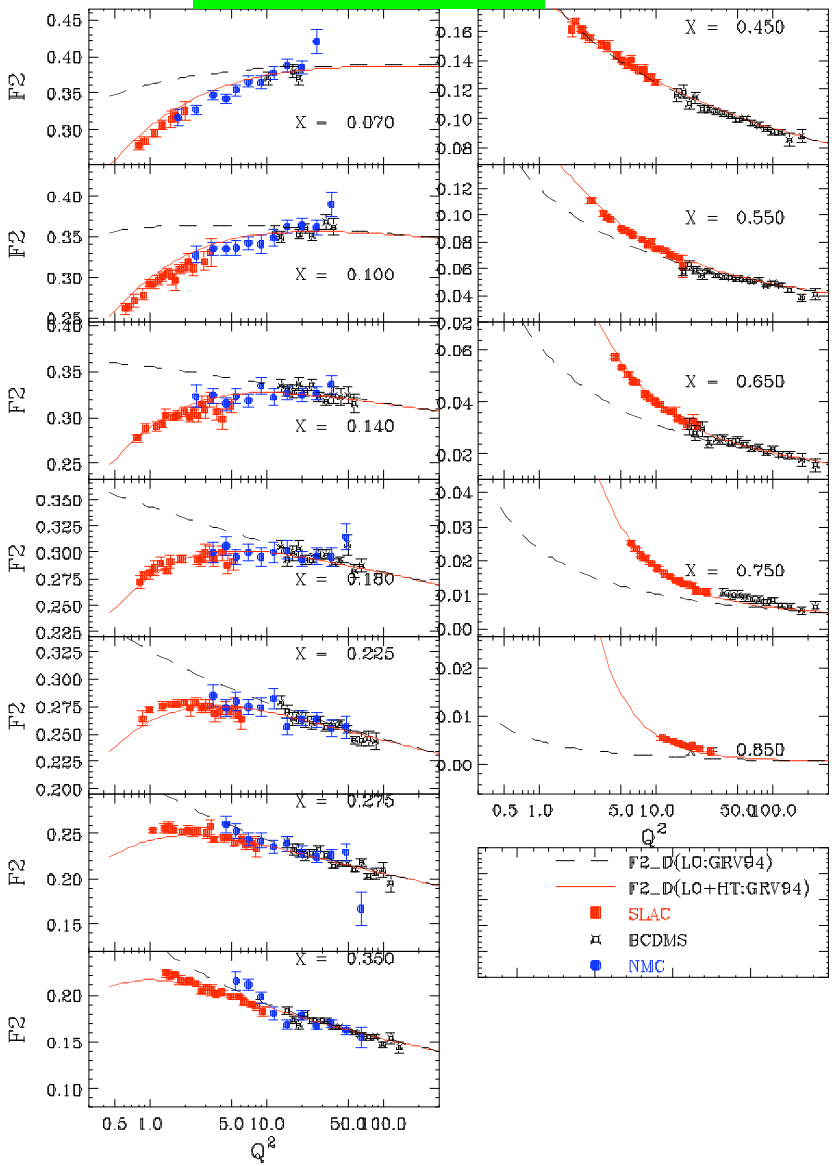
  A=0.418, B=0.222, Csea = 0.381

  C1V = 0.604, C2V= 0.485

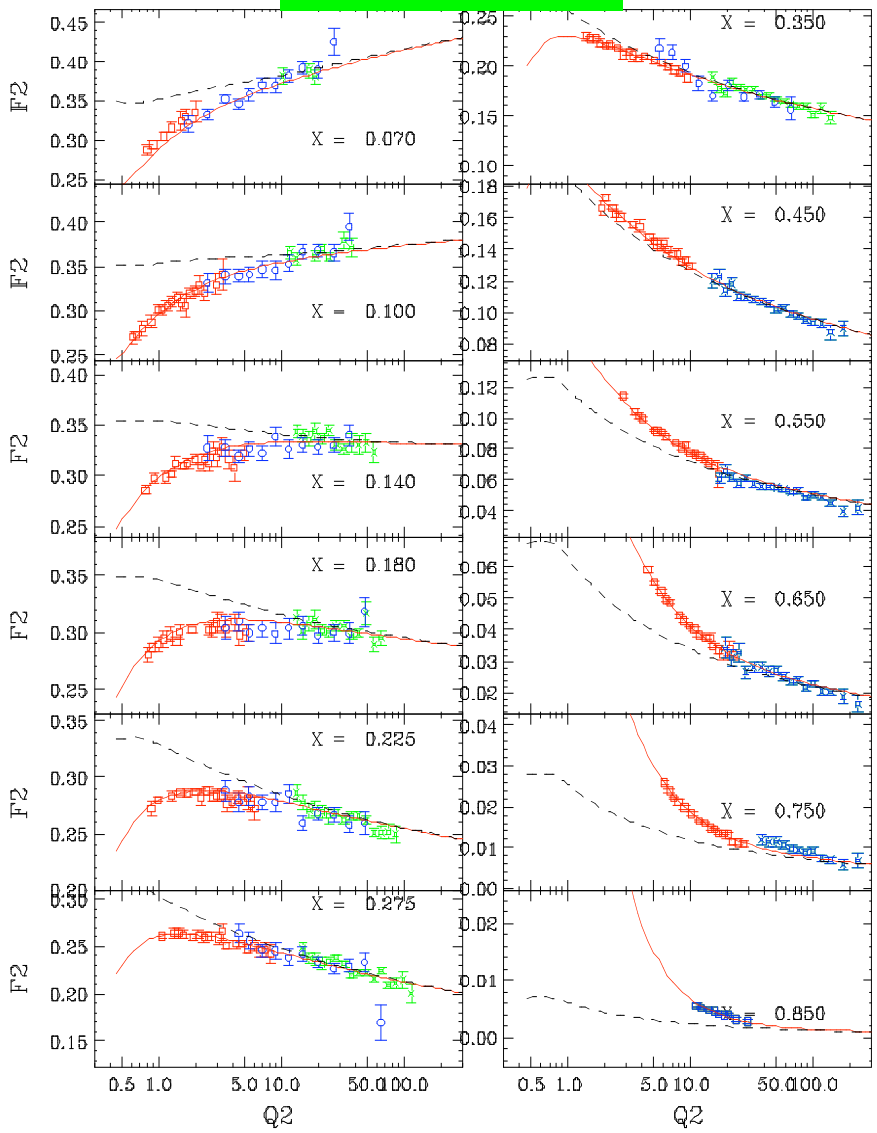
  χ^2/DOF= 1268 / 1200

Fit Results on DIS $F_2(d)$ data

Fit using Xw

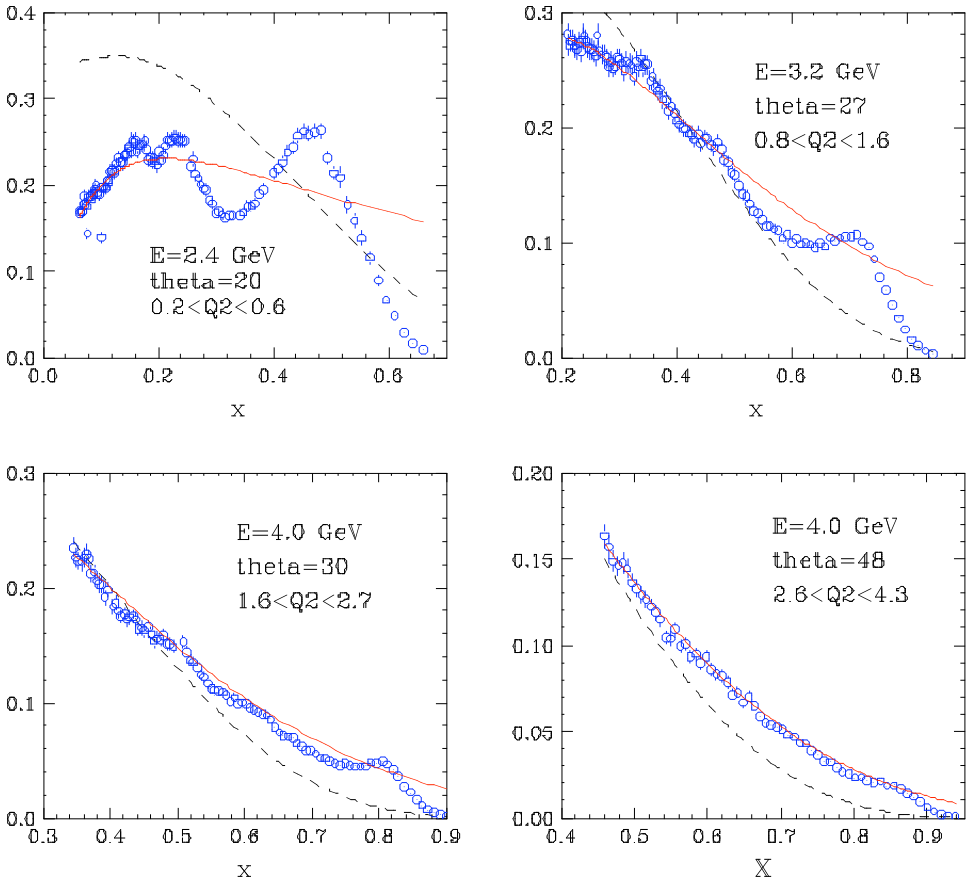


Fit using ξw



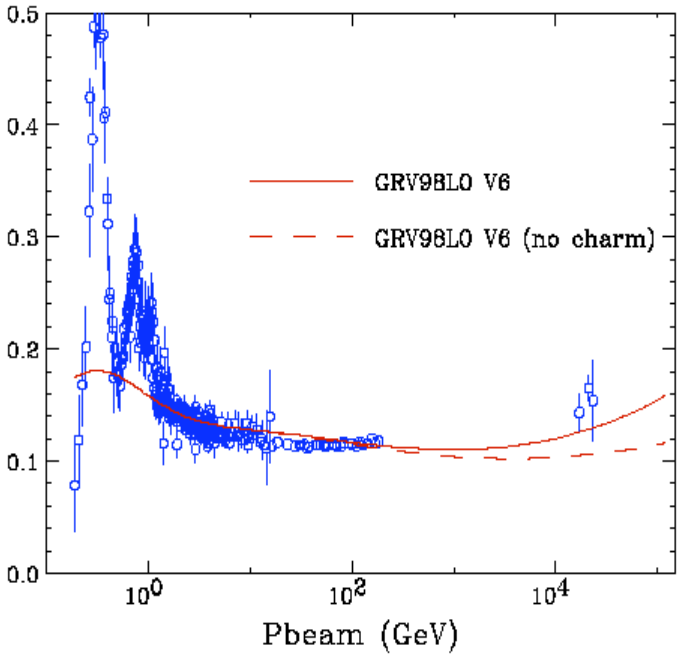
Comparisons with resonance and photo-production data

F_2(d) resonance



Not included in the fit

Photo-production (p)



$\sigma(\gamma\text{-proton}) = 4\pi\alpha/Q^2 * F_2(x, Q^2)$

where $F_2(x, Q^2)$

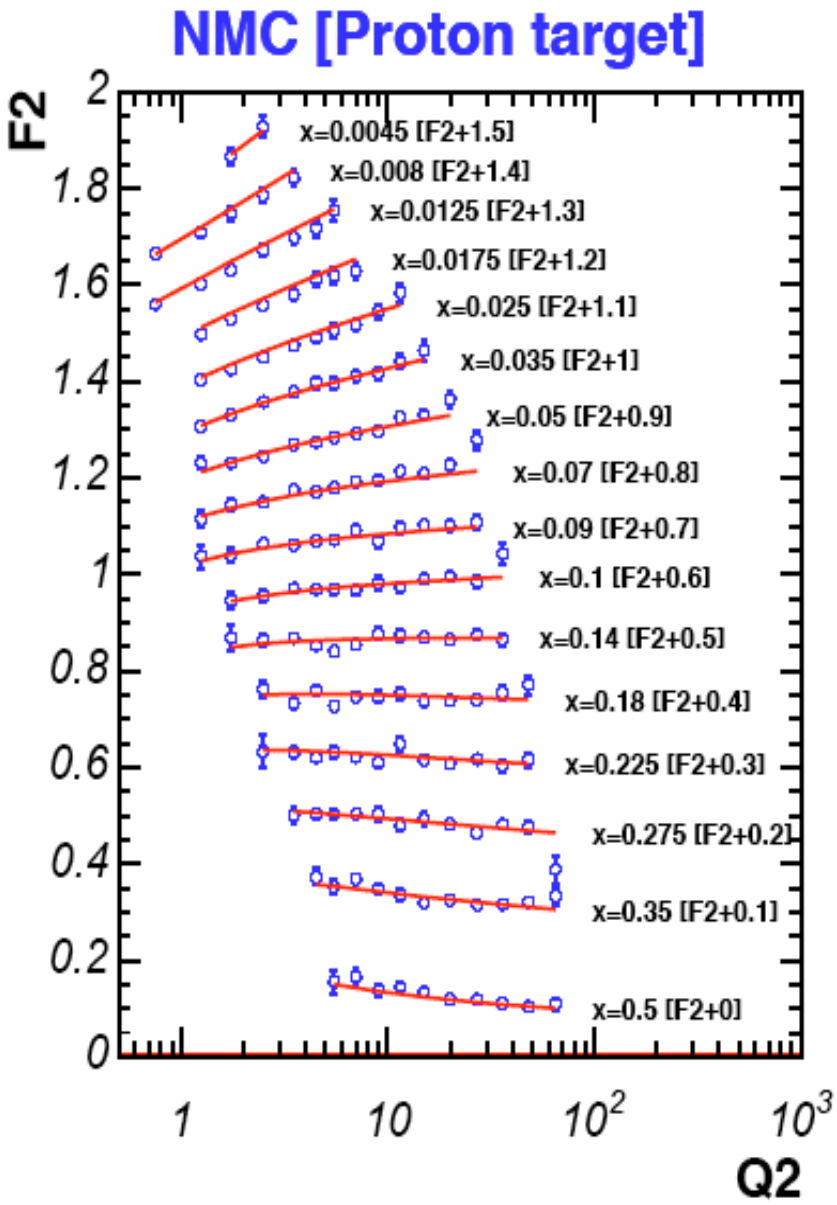
$= Q^2/(Q^2 + C) * F_2(\xi_w)$

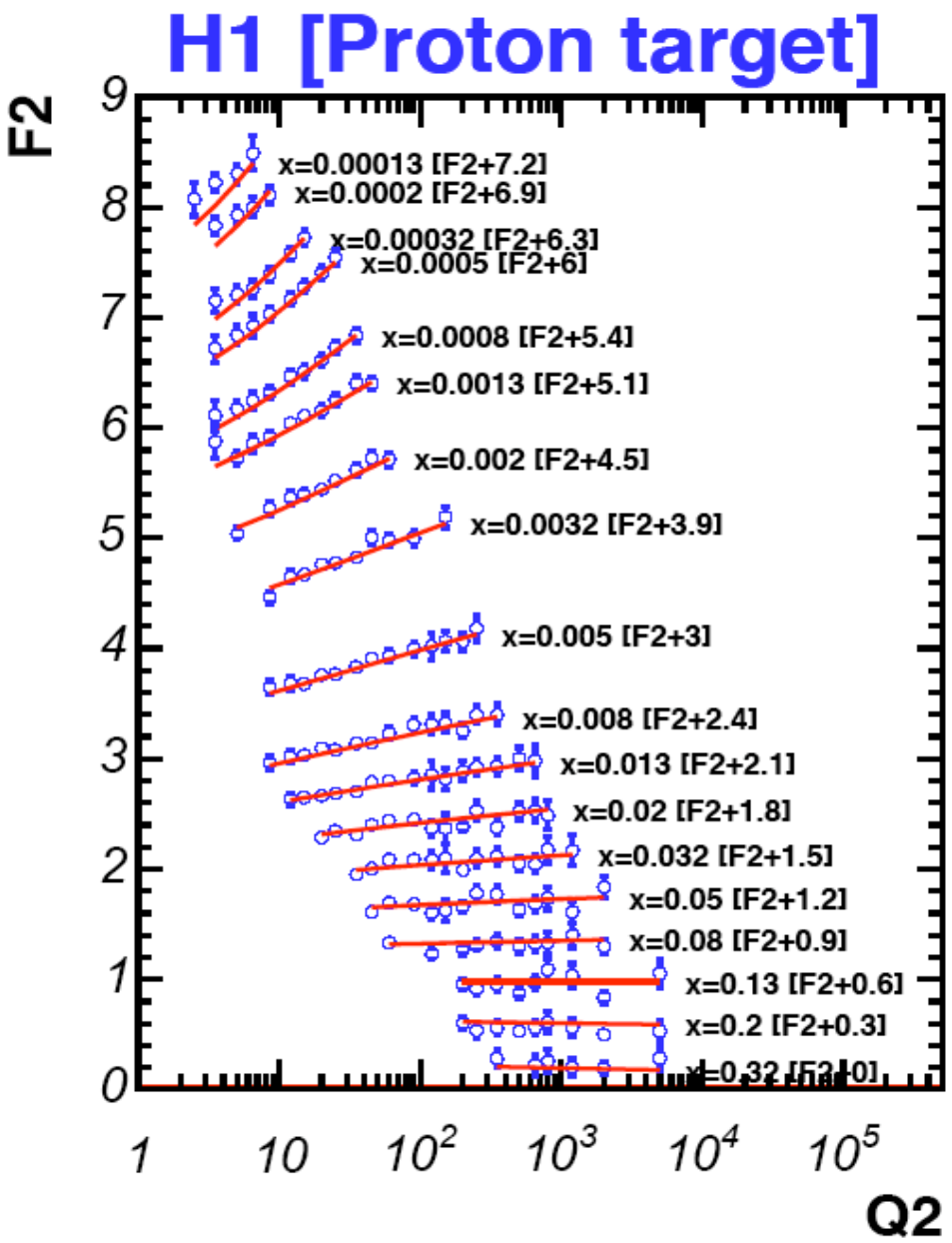
Improved Fits

- Improvements in our model
  - Separate low Q^2 corrections to d and u valence quarks, and sea quarks (mainly for intellectual reason)
  - Include all inelastic F2 proton/deuteron (SLAC/NMC/BCDMC/HERA), photo-production on proton/deuteron in the fits

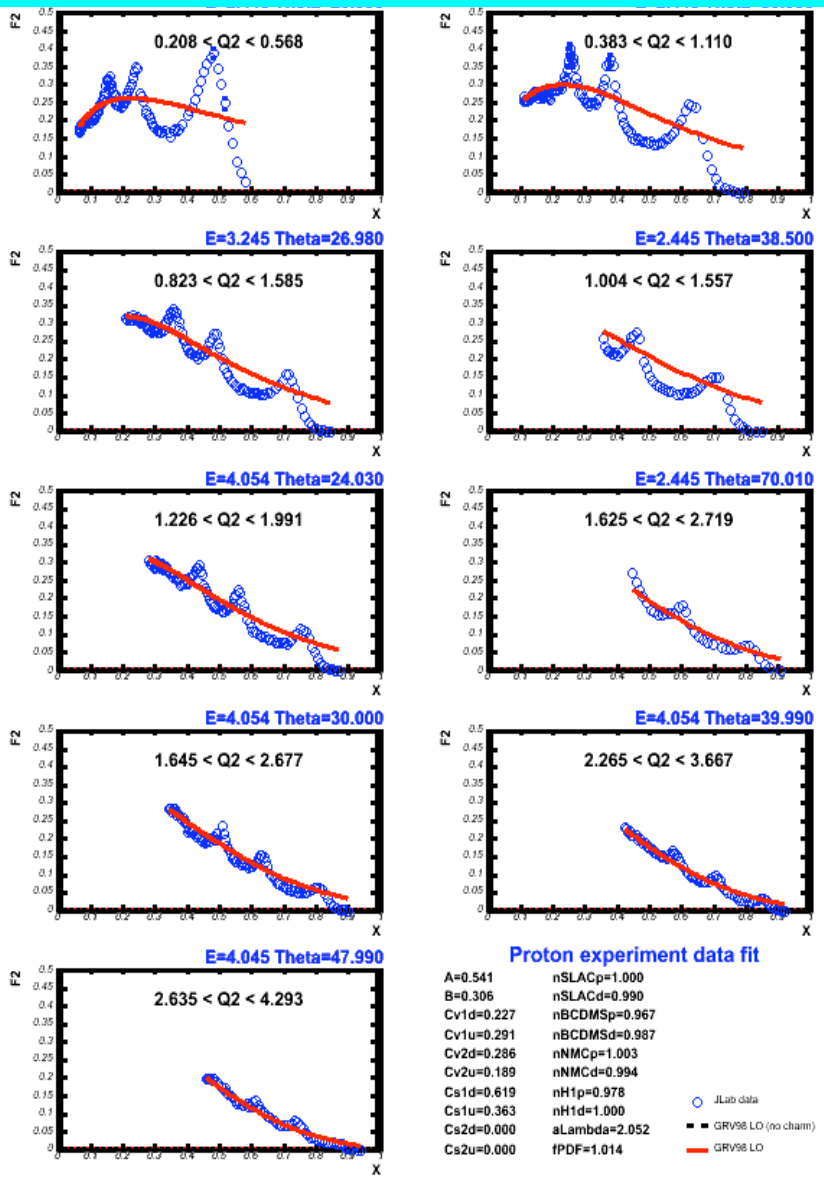
- Toward axial PDFs (vector PDFs vs axial PDFs)
  - Compare to neutrino data (assume V=A) CCFR-Fe, CDHS-Fe, CHORUS-Pb differential cross section
  - Need to compare to low energy neutrino data to get exact parameters (not done)

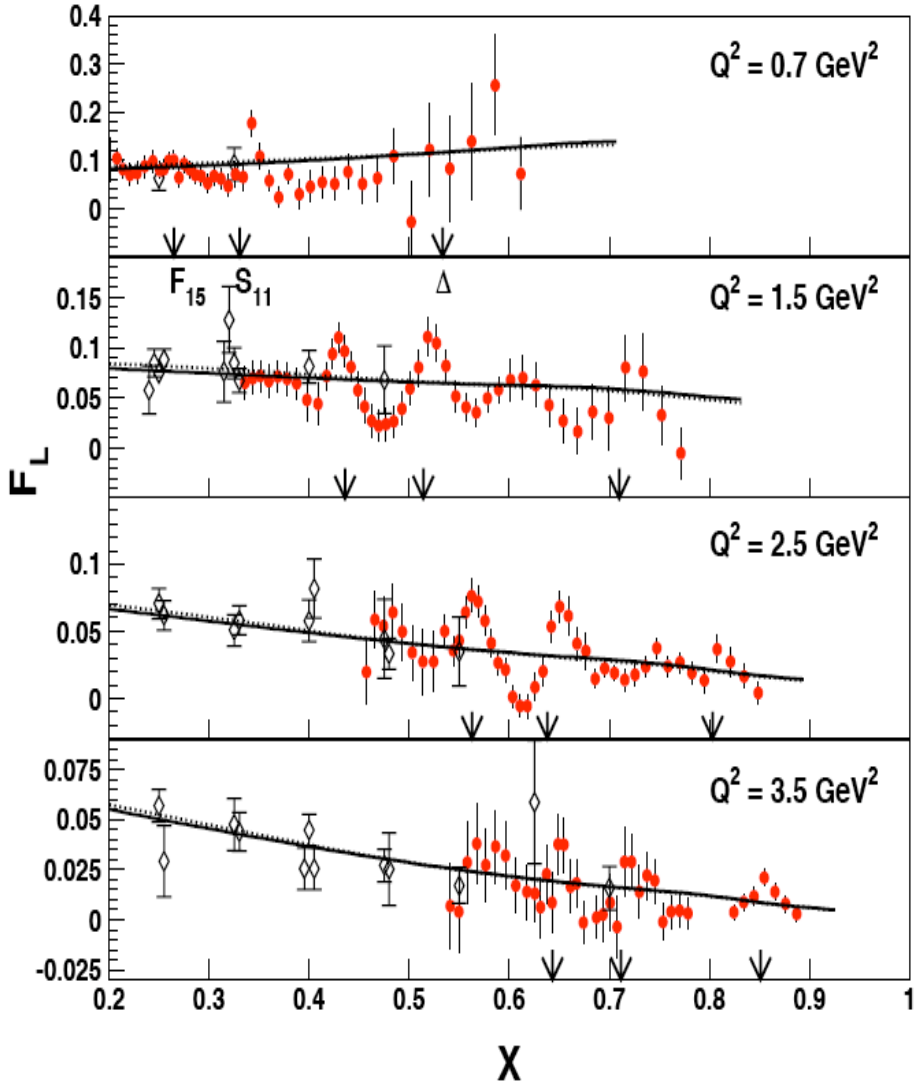
    $Kvector = Q^2/[Q^2+C1]$ -> $Kaxial = [Q^2+C2]/[Q^2+C1]$


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]


H1 [Proton target]
F2
Q2
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]

Comparisons with resonance data



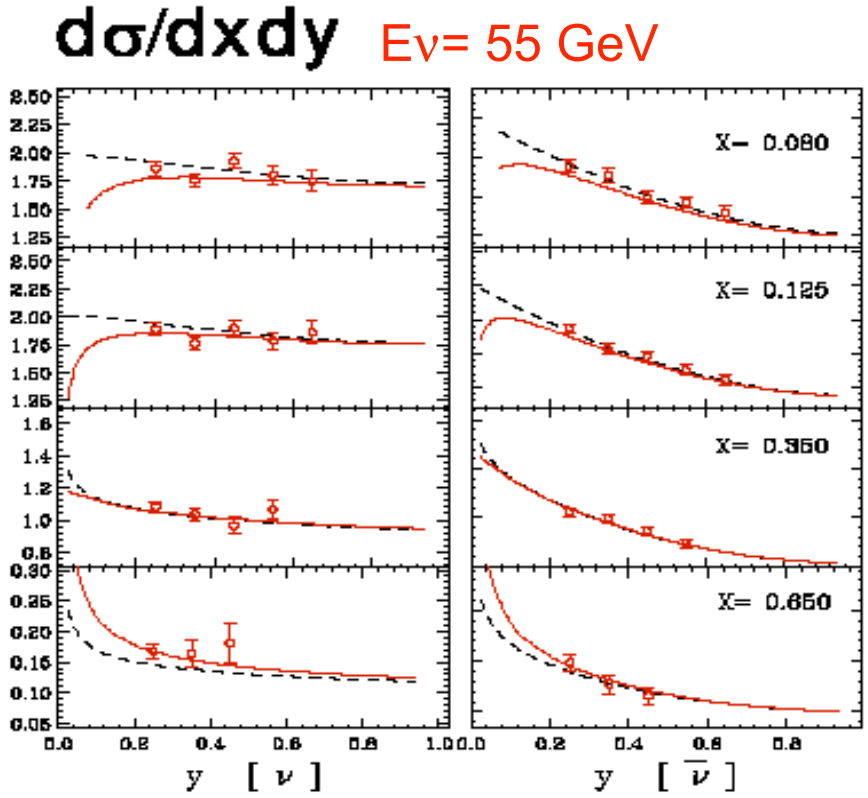


Proton

Not included in the fit!!!

Using F2(fit)+R1990

Comparison with neutrino data (assume V=A)



––ξw PDFs GRV98 modified

---- GRV98 (x,Q²) unmodified

Left: (neutrino), right anti-neu

- Apply nuclear corrections using e/μ scattering data.
- Use R=Rworld fit
- But contribution with charm-scattering is not included
- More careful treatment on xF_3 is under investigation

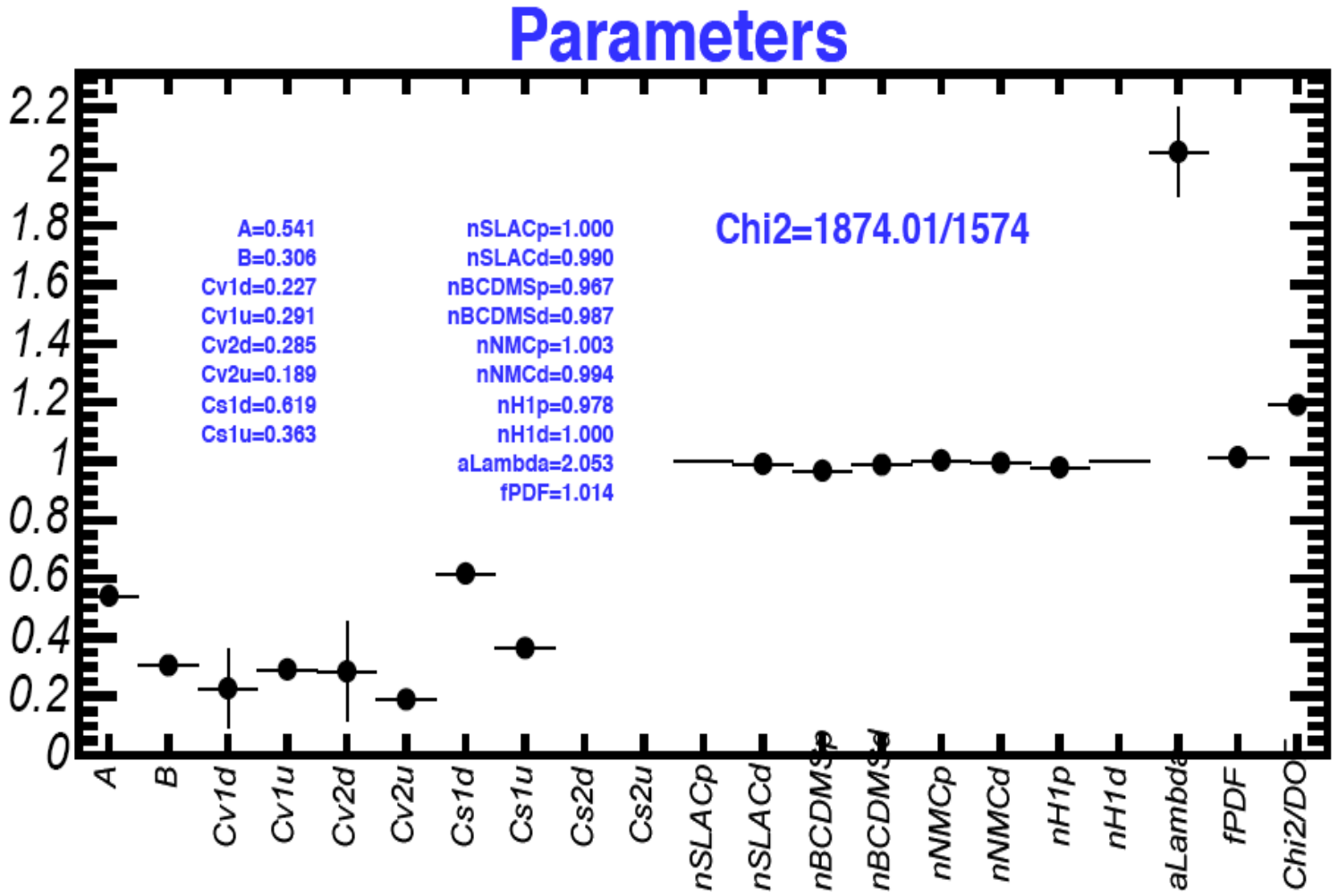
Summary

- Our modified GRV98 LO PDFs with a scaling variable xw describe all SLAC/BCDMS/NMC/HERA DIS data as well as photo-production data
- Our predictions in good agreement with resonance data, and with high-energy neutrino data
- This model should also describe a low energy neutrino cross sections reasonably well, except the region where axial vector contribution is significant ($Q^2<1$): used for MINOS, MiniBooNE, K2K etc

Discussions

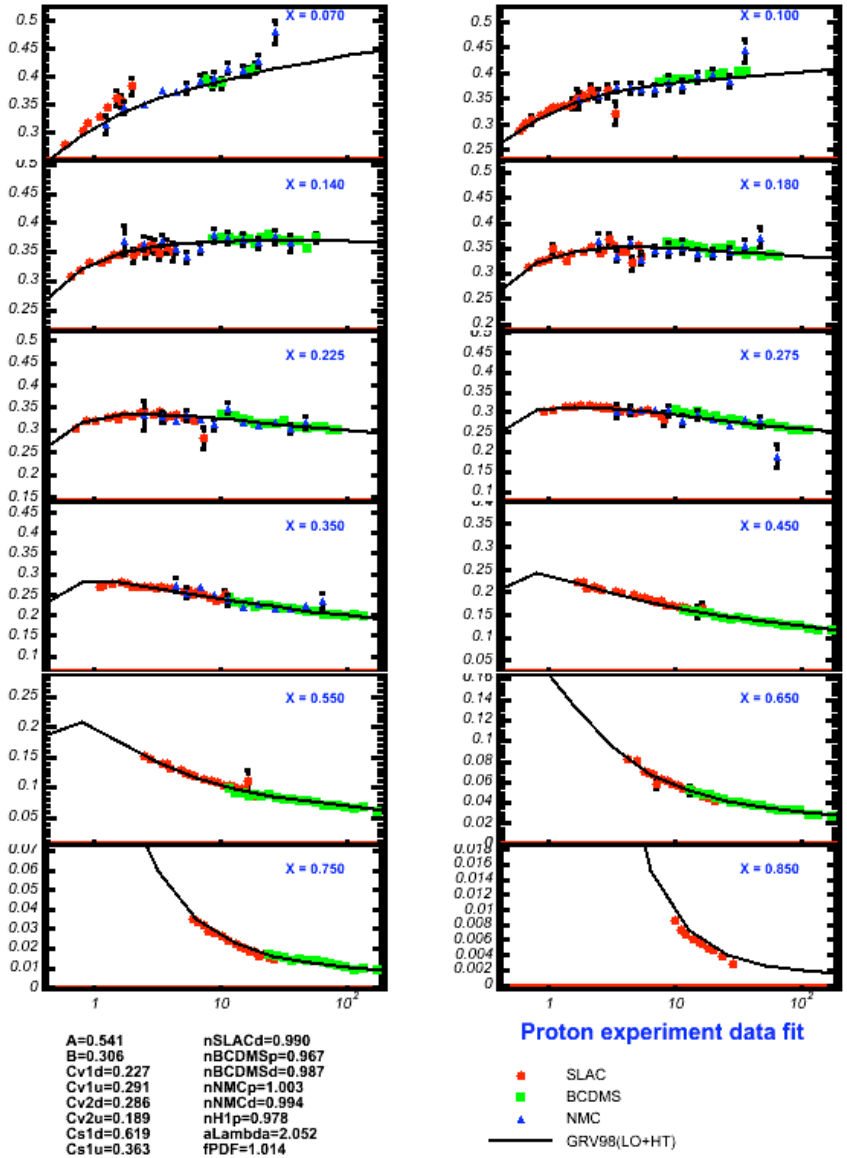
- Things needed to be measured or better understood
  - Measurements for different nuclei targets for charged lepton (from JUPITER at JLAB) and neutrino scattering (like MINERvA exp).
  - Understanding of nuclear effects in neutrino scattering requires a precise knowledge of valence quarks at high x (from charged lepton data): SLAC and Jlab F2 proton will be very powerful.
  - Different nuclear corrections to sea and valence quarks?
    - xF_3(valence), and F_2-xF_3(sea) data vs models?
  - Measurements for axial vector contributions.

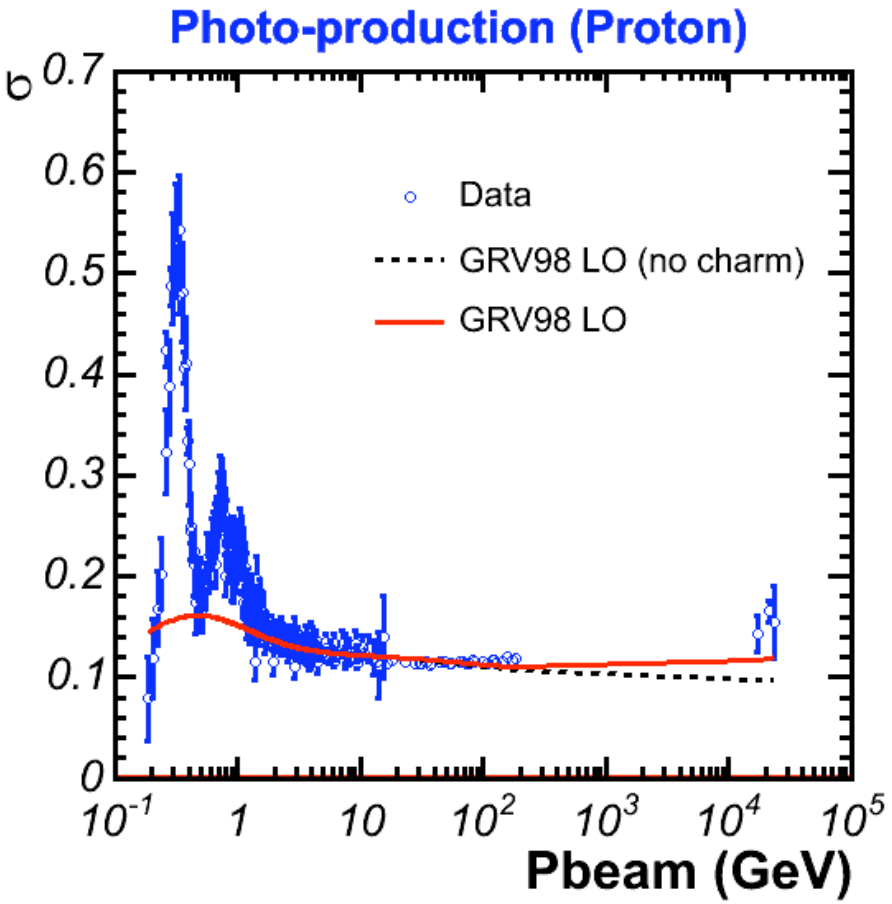
Fit Results



8 model parameters + 7 exp. Norm + 1 PDFs

Fit results to $F_2(p)$ and $F_2(d)$





Proton