Parton-hadron duality at high Q^2

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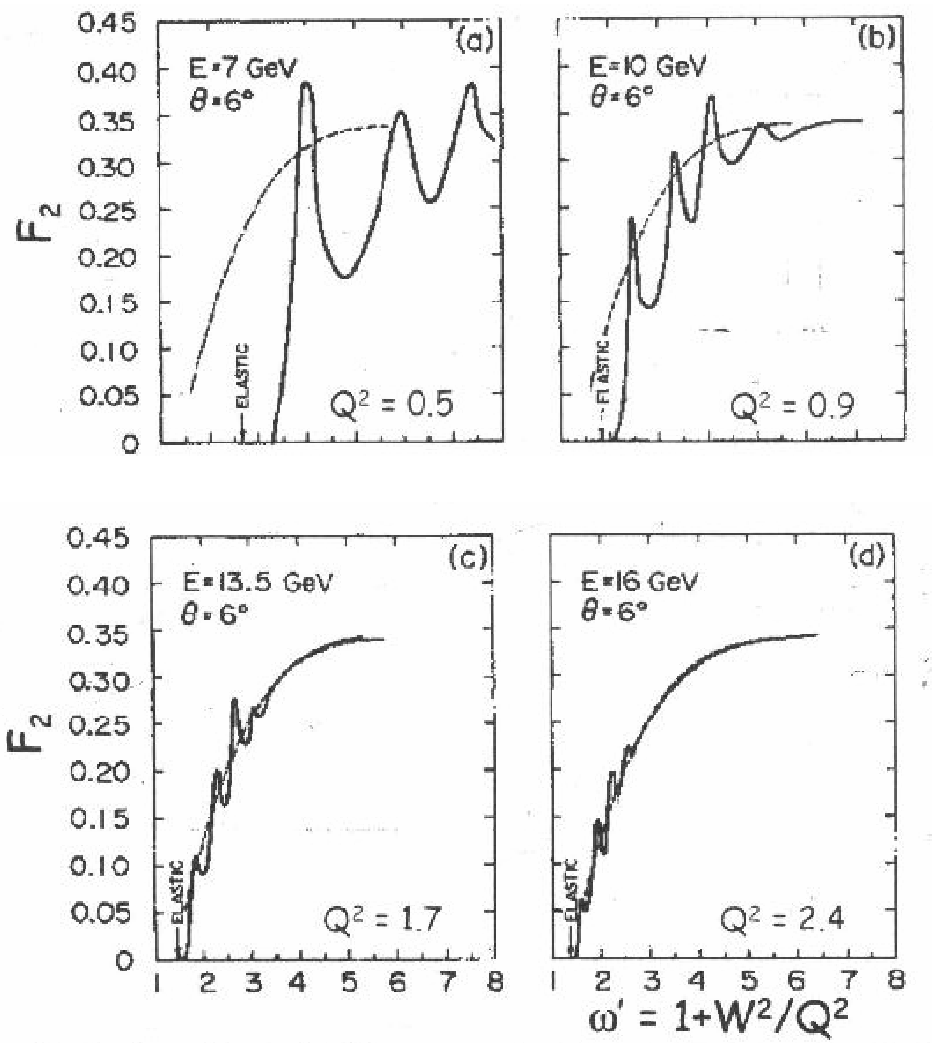
Outline

- **Quark-hadron duality**
- **Physics motivation for E00-116**
- **Analysis status for E00-116**
- **F_2^p and F_2^d at high x from E00-116 data**

Bloom-Gilman duality



'70- Bloom and Gilman observed that the prominent **resonances** in e-p scattering **do not disappear with increasing Q^2** relative to the "background" under them **but follow the DIS scaling limit curve** falling at roughly the same rate as *any "background"*.

Finite energy sum rule:

$$\frac{2M}{Q^2}\int_0^{\upsilon_m} \upsilon W_2\left(\upsilon, Q^2\right) d\upsilon = \int_1^{\left(2M\upsilon_m + m^2\right)/Q^2} \upsilon W_2\left(\omega'\right) d\boxed{\omega'}$$

'76- A QCD based explanation by de Rujula Georgi and Politzer: in the ***resonance regime*** the ***higher twist*** effects are ***small or cancel*** ⇒ **duality**

Duality in the F_2 Structure Function

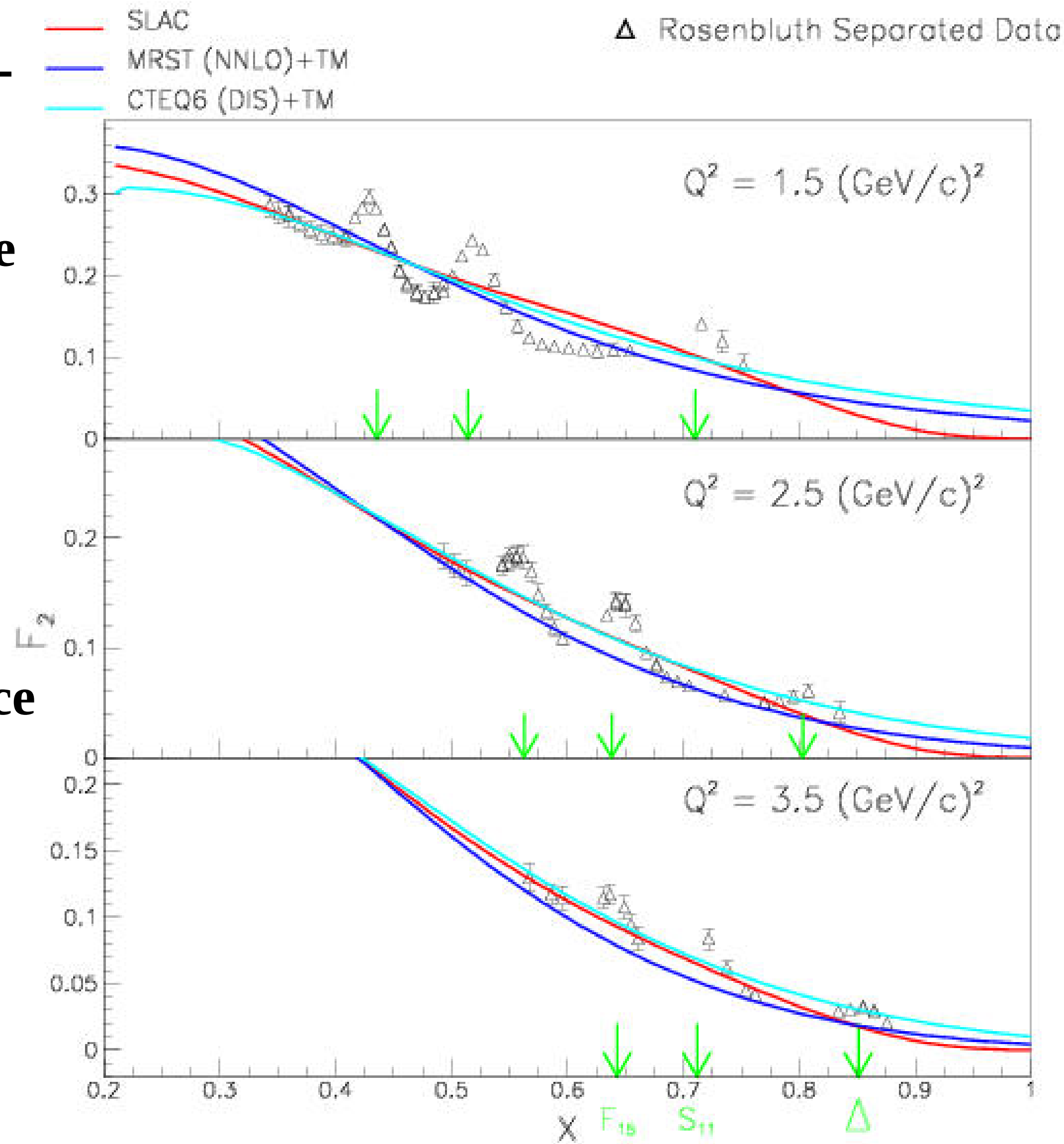
Use Bjorken x instead of Bloom-Gilman's ω'

Empirically, DIS region is where logarithmic scaling is observed: $Q^2 > 5$ GeV^2, $W^2 > 4$ GeV^2

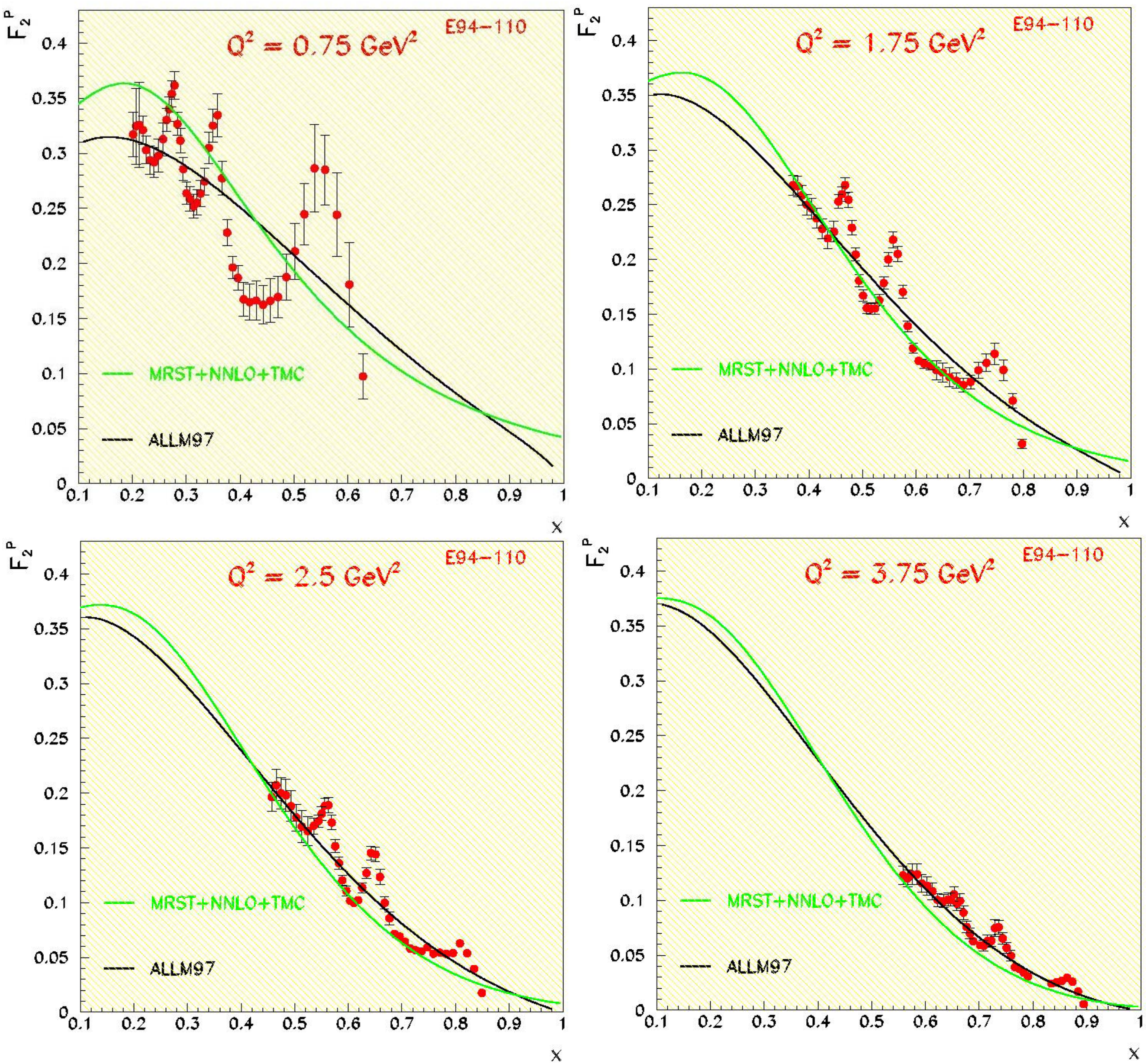
Duality: Averaged over W, logarithmic scaling observed to work also for $Q^2 > 0.5$ GeV^2, $W^2 < 4$ GeV^2, resonance regime

(note: $x = Q^2/(W^2 - M^2 + Q^2)$)

JLab results: Works quantitatively to better than 10% at surprisingly low Q^2



E94-110 Rosenbluth separated data



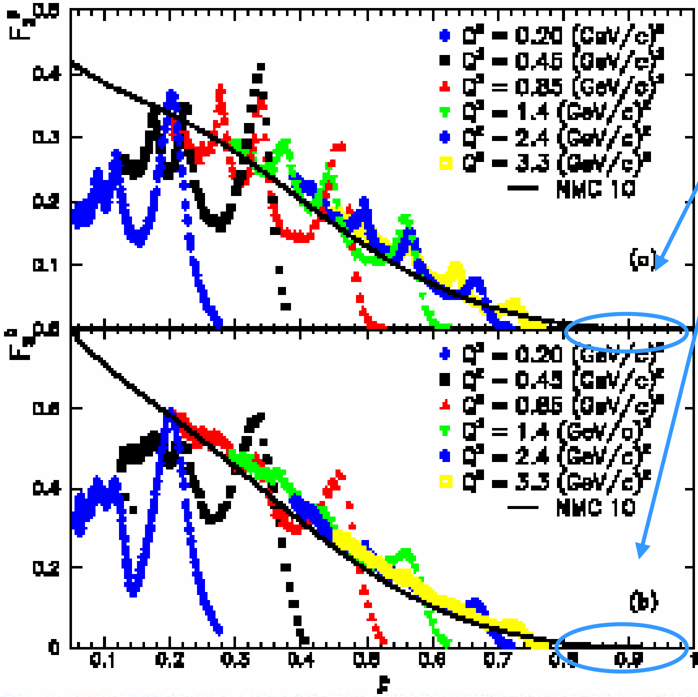
With increasing Q^2 the resonances slide towards higher x on *ALLM97* curve while pdf curve MRST+NNLO+TMC starts undershooting the data.

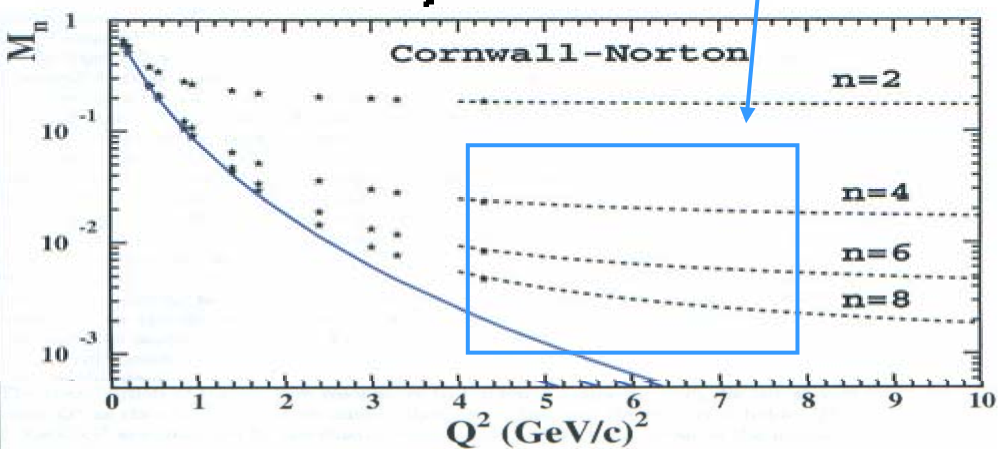
Higher Q^2/x data needed to get more information ...

E00-116 physics motivation

resonance data

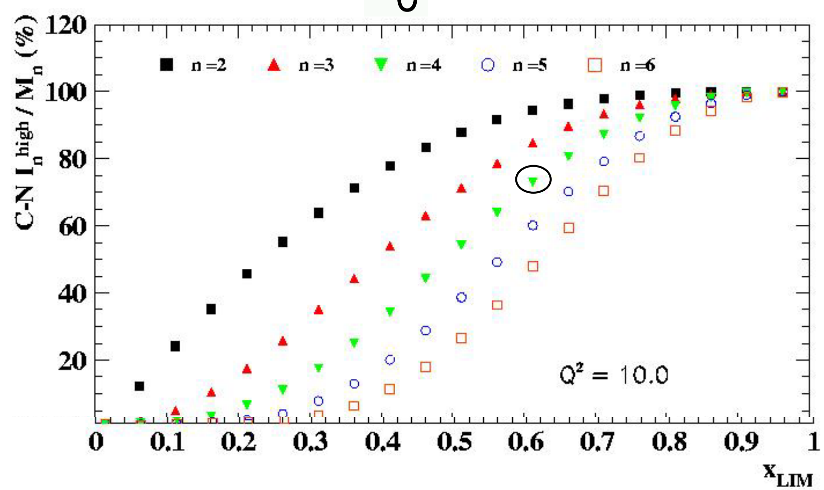
high x



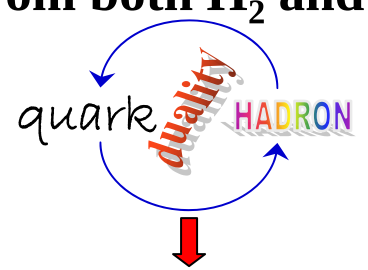


- Constrain higher moments

$$M_n(Q^2) = \int_0^1 dx\ x^{n-2} F(x,Q^2)$$

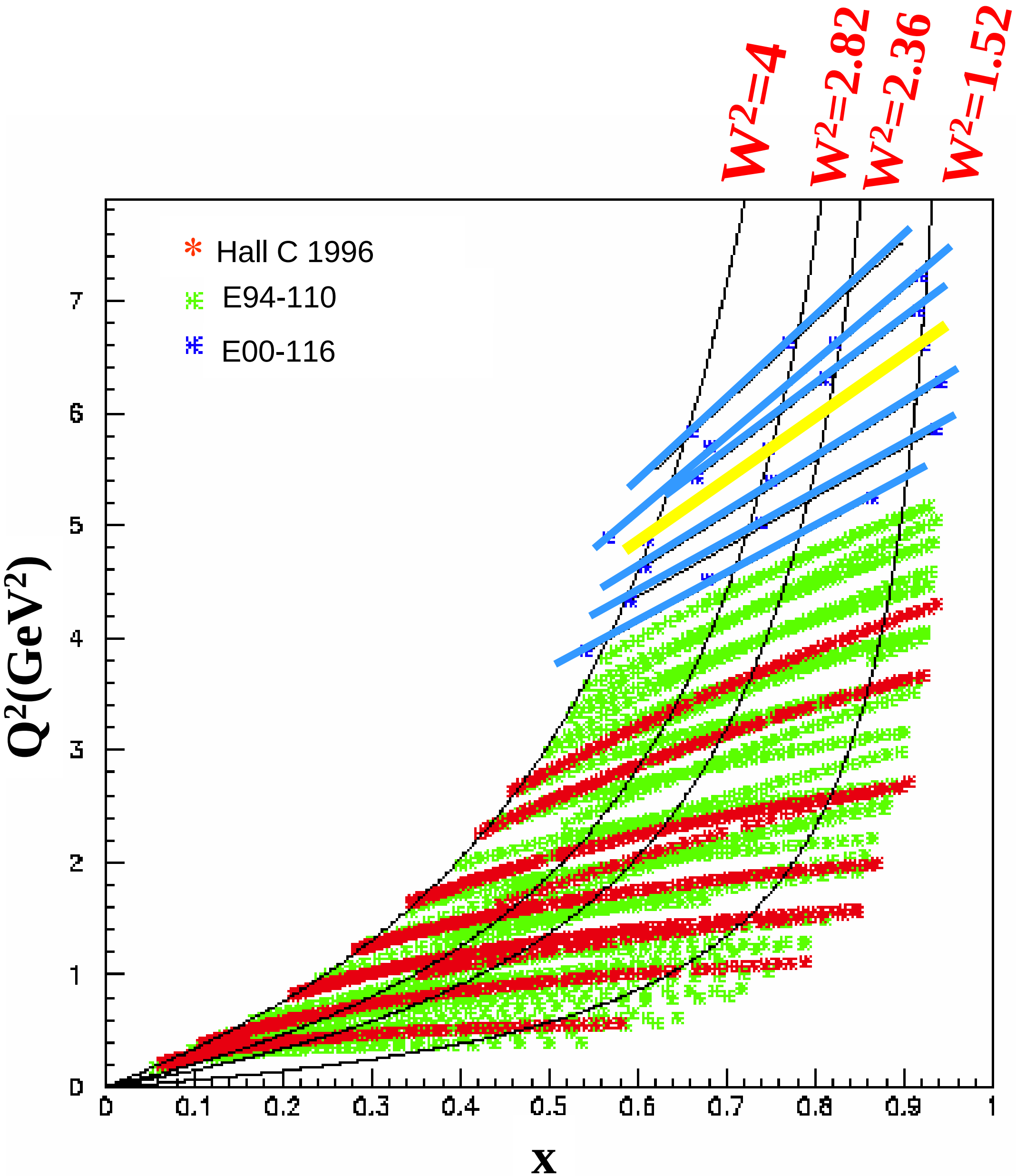


- Higher twist extraction from both H_2 and D_2 data



- High x pdf evolution
- F_2^d / F_2^p ratio at large x

E00-116 kinematics



37.93° { $Q^2 \in (3.88 - 5.25)$, $x \in (0.54 - 0.87)$ }

41° { $Q^2 \in (4.32 - 5.85)$, $x \in (0.59 - 0.94)$ }

45° { $Q^2 \in (4.63 - 6.27)$, $x \in (0.61 - 0.94)$ }

50° { $Q^2 \in (4.88 - 6.59)$, $x \in (0.61 - 0.92)$ }

55° { $Q^2 \in (5.43 - 6.91)$, $x \in (0.67 - 0.92)$ }

60° { $Q^2 \in (4.89 - 7.21)$, $x \in (0.56 - 0.92)$ }

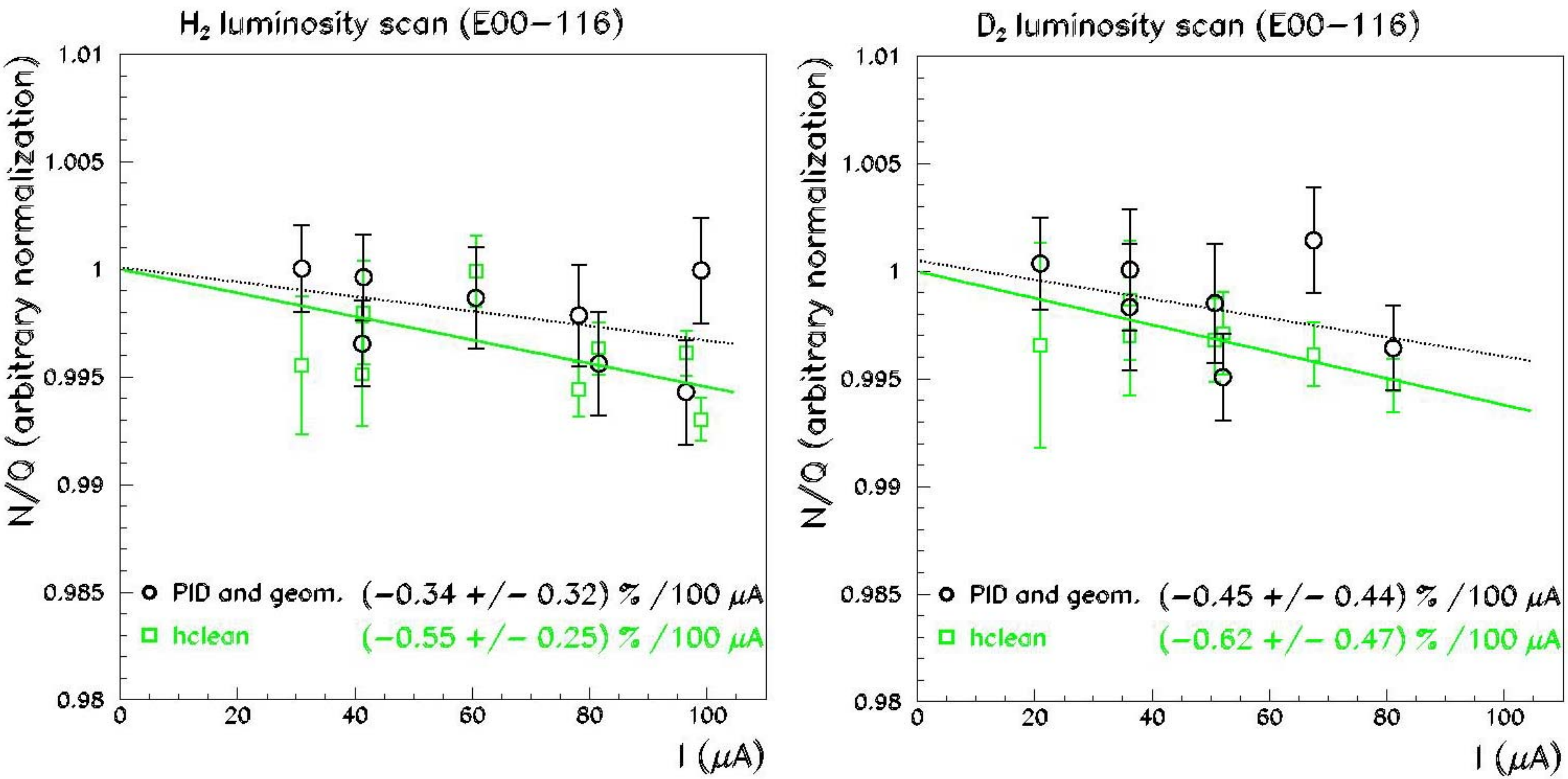
70° { $Q^2 \in (5.83 - 6.62)$, $x \in (0.66 - 0.77)$ }

Analysis status for E00-116

- **Detector calibrations: done**
- **Luminosity studies: done**
- **BCM calibration: done**
- **Detector efficiencies checking: done**
- **Tracking efficiency checking: done**
- **Background estimation:**
  - **pion contamination estimation: done**
  - **charge symmetric background estimation: done**
- **Radiative corrections: need iteration**
- **Cross section extraction: final/iteration**
- **F_2^p and F_2^d extraction: preliminary**

Luminosity studies

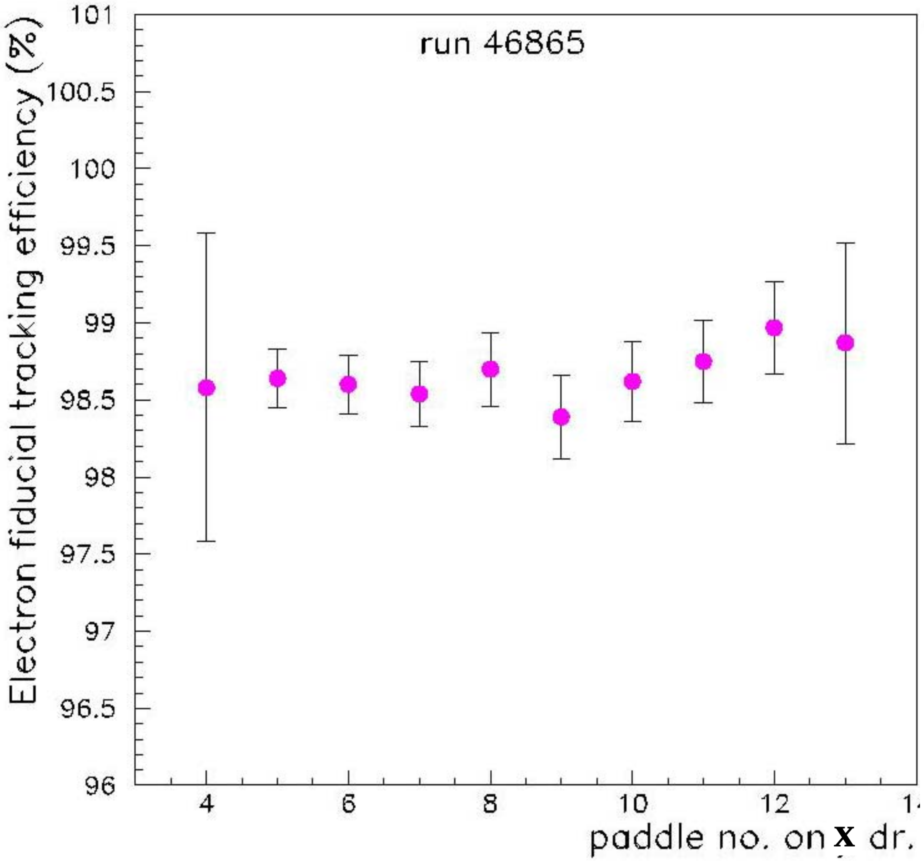
- We quantify the boiling effect in the targets with increasing current.

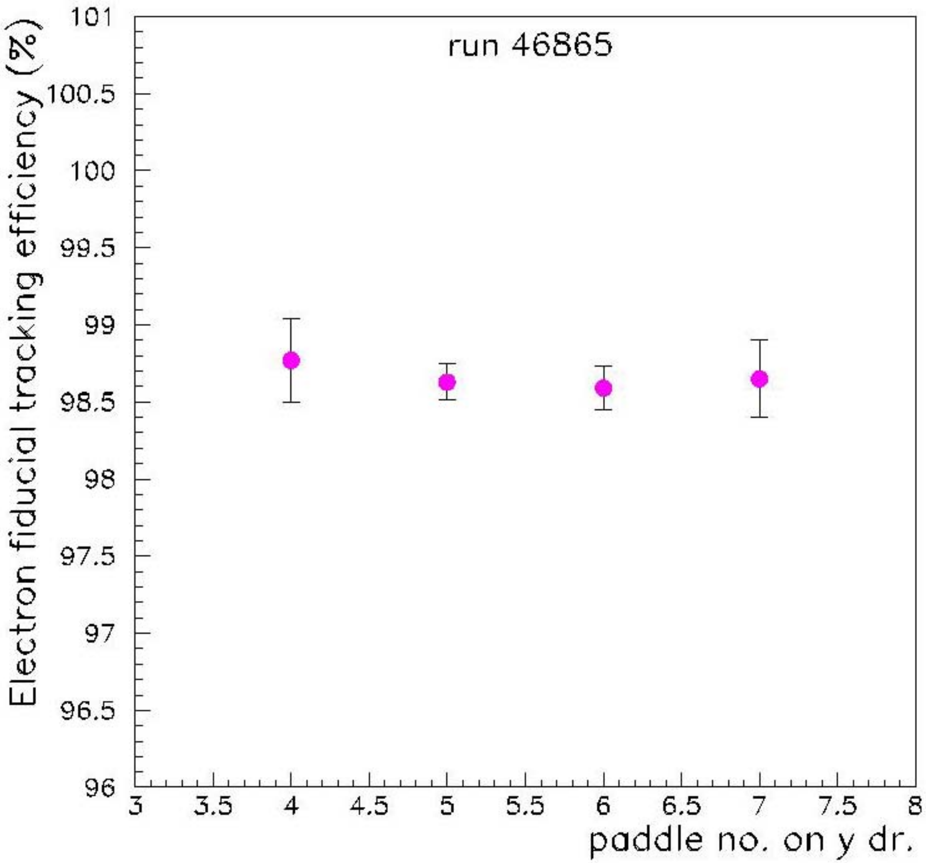


- On average, the scaler and tracking based studies reveal about 0.5 % correction with an error of about 0.3 %.

Tracking efficiency checks

- We are at low rates so we don't worry about the rate dependence of the tracking efficiency.
- But the tracking efficiency could have an angle dependence.





- We don't see any angle dependence in the tracking efficiency.

Background analysis

- ***Pion contamination***:

  We are at large angles so the (e,e^-) cross section is typically low.
  We are at low momentum so we have high π/e ratio.
  The typical PID cuts don't clean up all the pions.

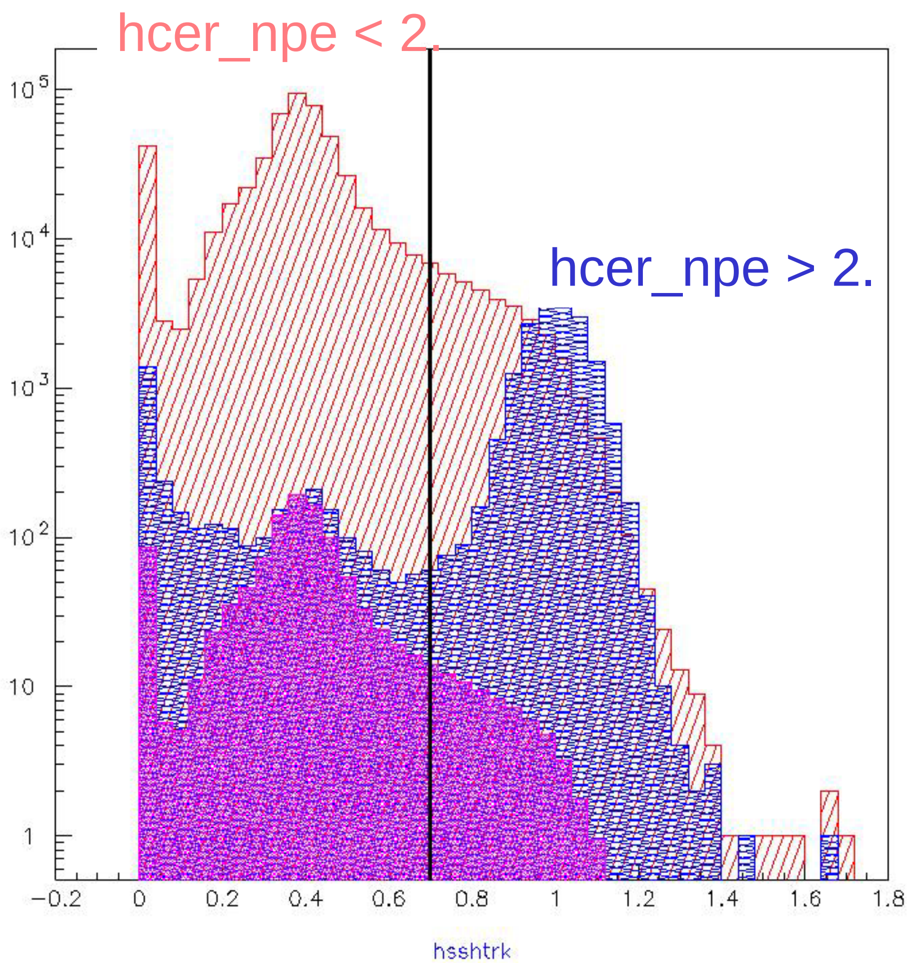
- ***Charge symmetric background:***

  We used SOS for H,D (e, e+) measurement.

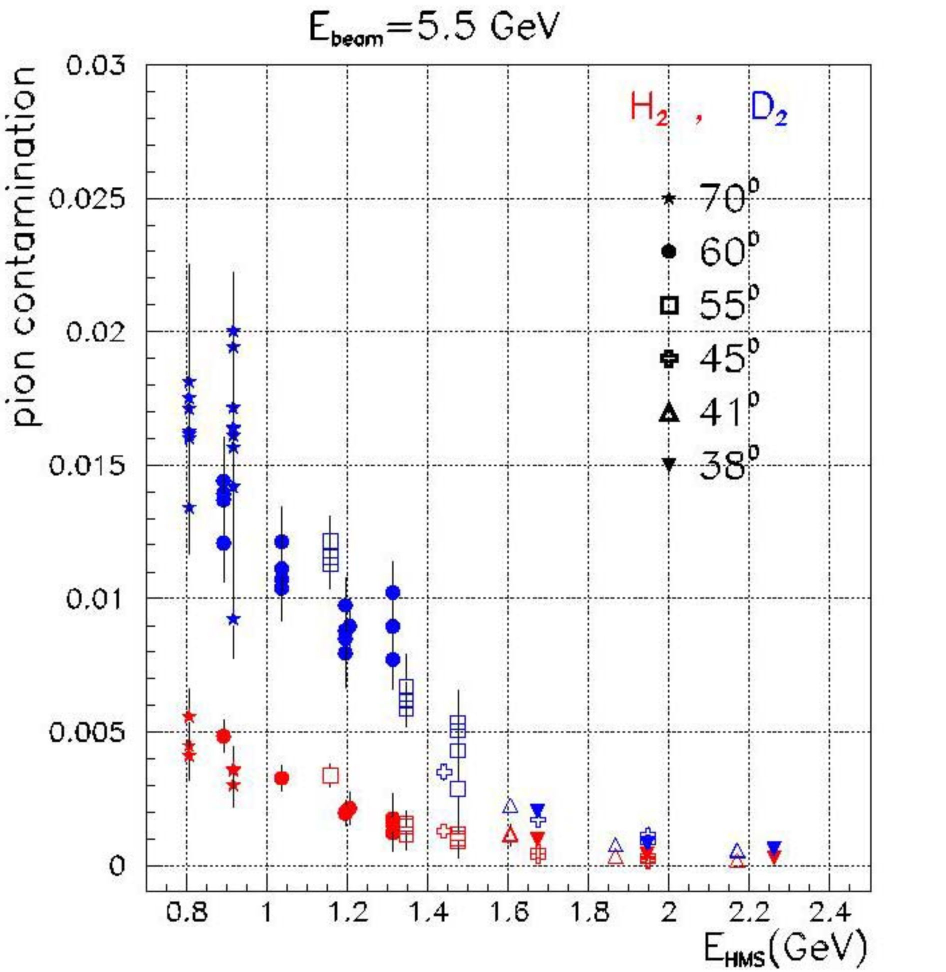
  SOS has a larger acceptance than HMS. (e, e+) cross section is varying strongly as a function of θ and E' . Therefore we need to disentangle θ and E' dependence in order to do the subtraction.

Pion contamination estimation

- **We assume that for hcer_npe < 2 we have only pions and for hcer_npe > 2 still some pion contamination → we "scale" the pion spectrum to subtract pions.**

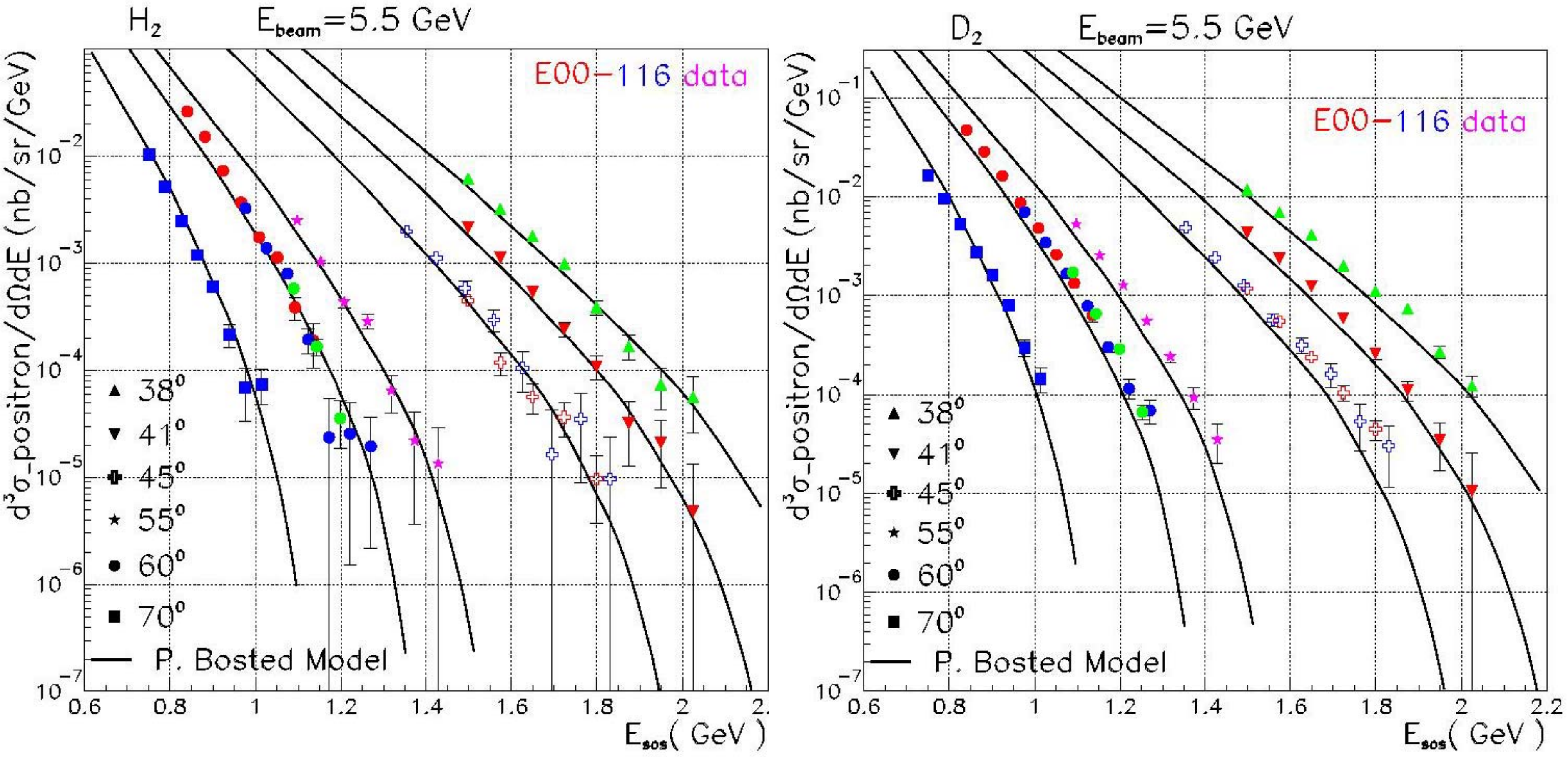


- **The pion contamination is parameterized as a function of momentum and the fit is used for subtraction.**



Charge symmetric background estimation

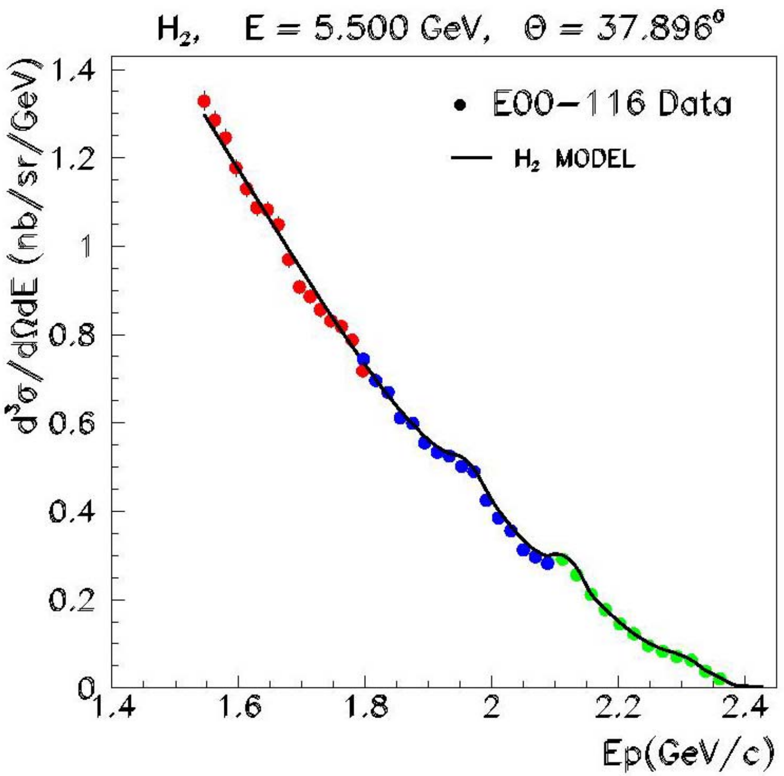
- For **positron cross section calculation**, spectrometer **acceptance corrections** were applied and **P. Bosted model(based on Wiser π^+,π^- production data)** was used for **bin centering correction**.

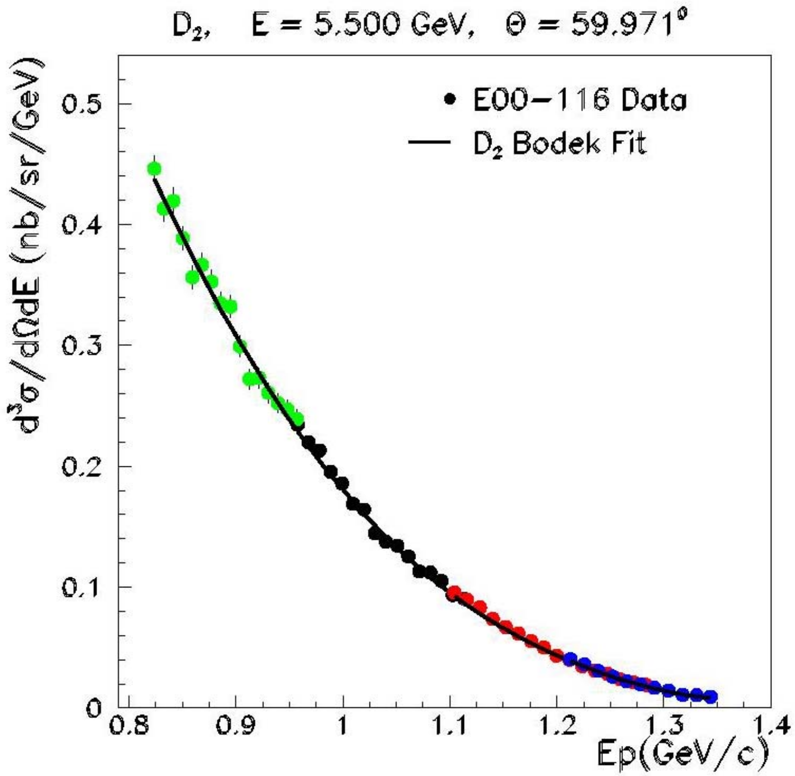


- The background was subtracted on a theta/momentum grid.

Cross sections extraction

- **For H_2 target all corrections are final and two iterations were performed.**



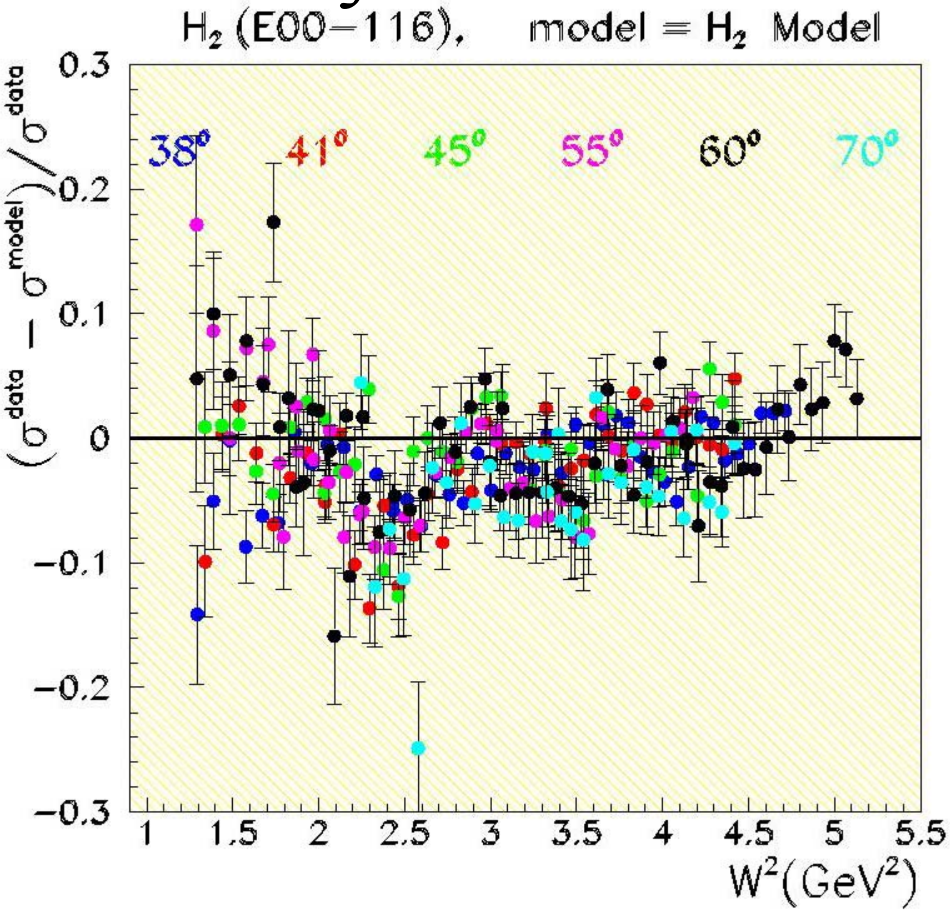


- **For D_2 target, the born inelastic cross section was obtained by subtracting the radiated elastic and quasielastic contributions and correcting for the radiative effects.**

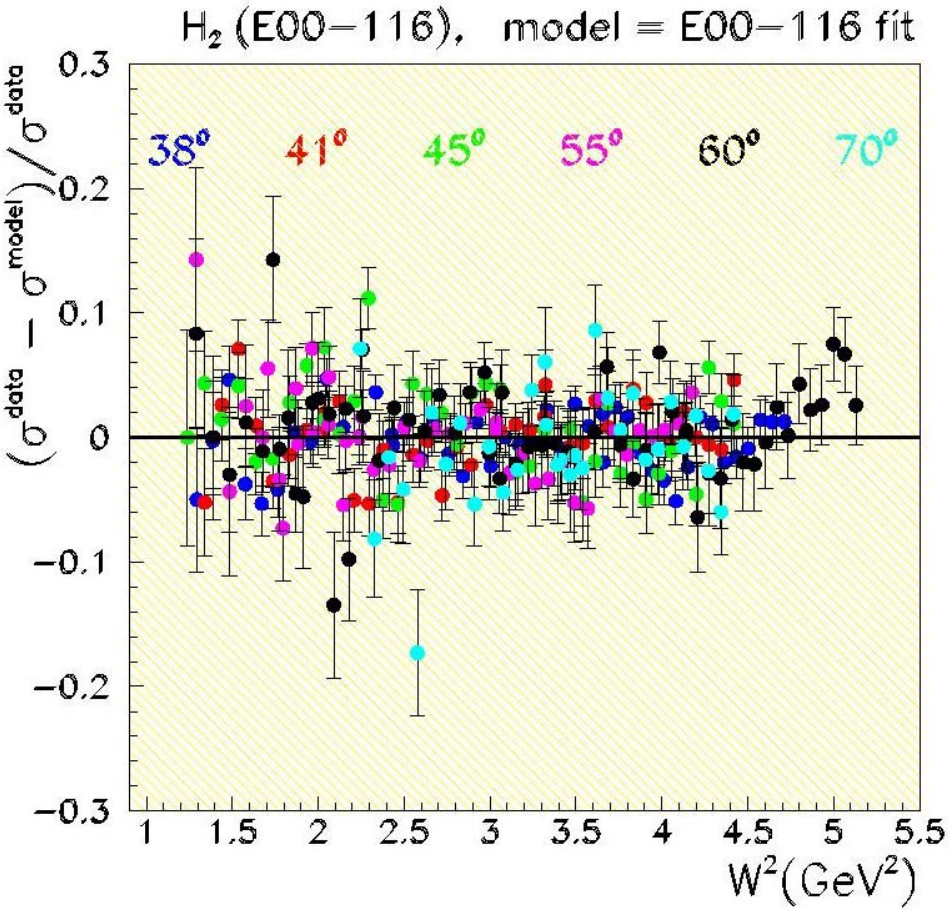
H_2 cross sections

- We still need to iterate the radiative corrections.

Before iteration

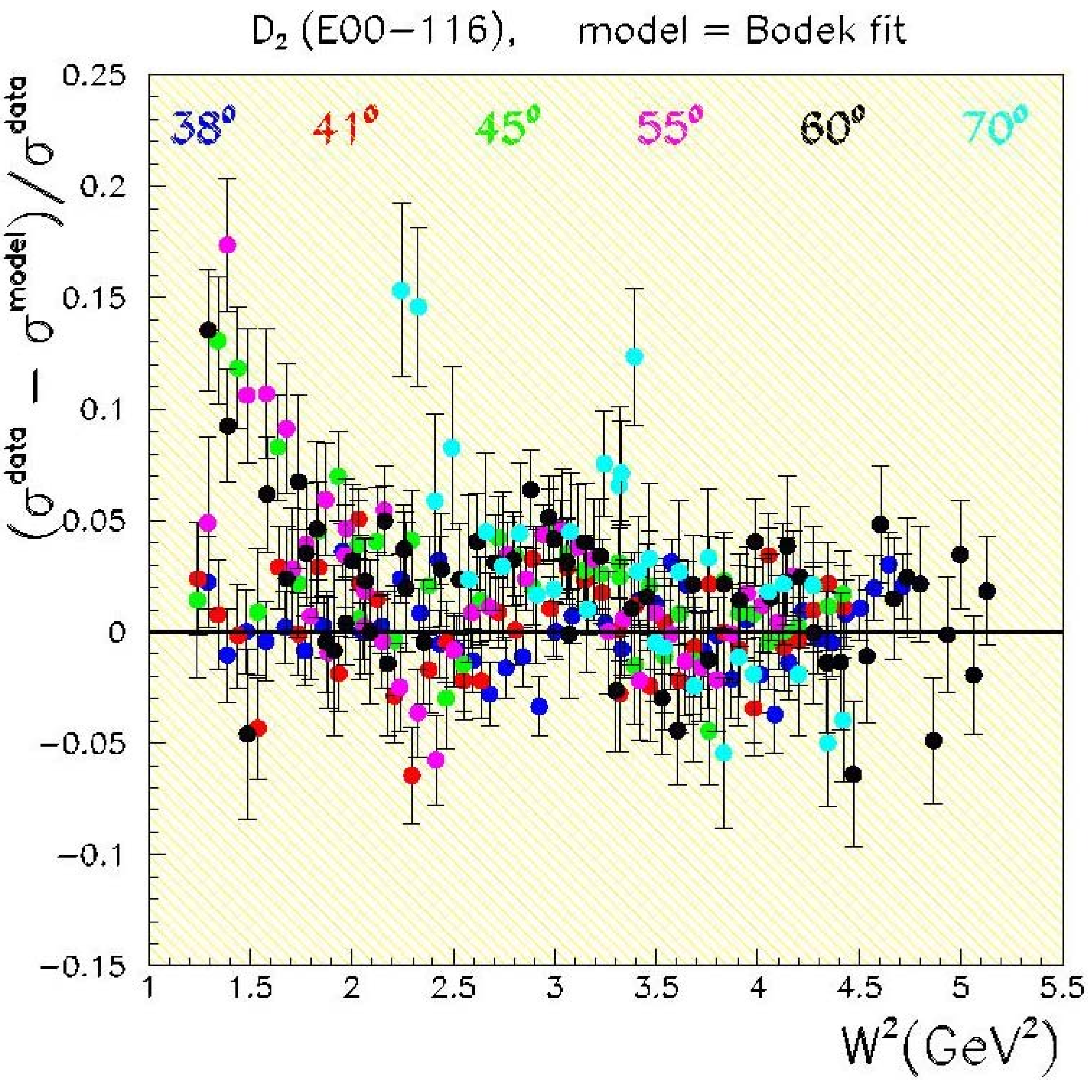


After two iterations



- The new fit will be used for bin centering and to get radiative corrections.

D_2 cross sections

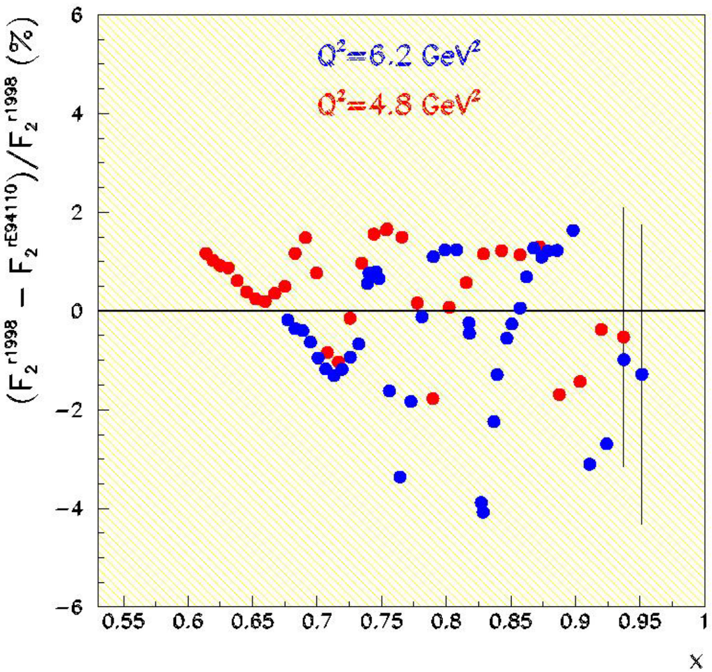


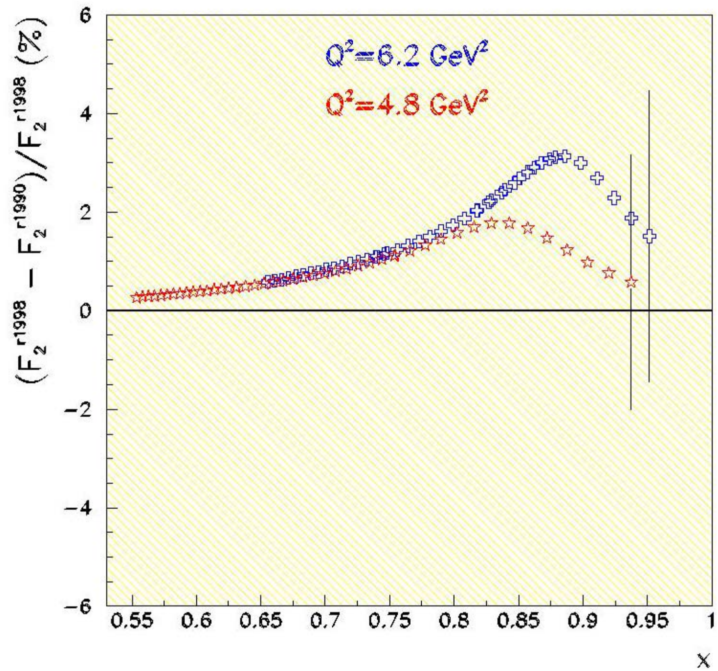
- Up to now no iteration was performed on D_2 data.
- There seem to be small systematic fluctuations so we will try get a better fit.

F_2 extraction

$$F_2 = \frac{d^3\sigma}{d\Omega dE'} \boxed{\frac{1+R}{1+R\varepsilon}} \frac{K\upsilon}{4\pi^2\alpha} \frac{1}{\Gamma} \frac{1}{1+\upsilon^2/Q^2}$$

- **E00-116 measures**
  We wish to construct F_2 but have not measured R.
- **For F_2 extraction R1998 was used.**

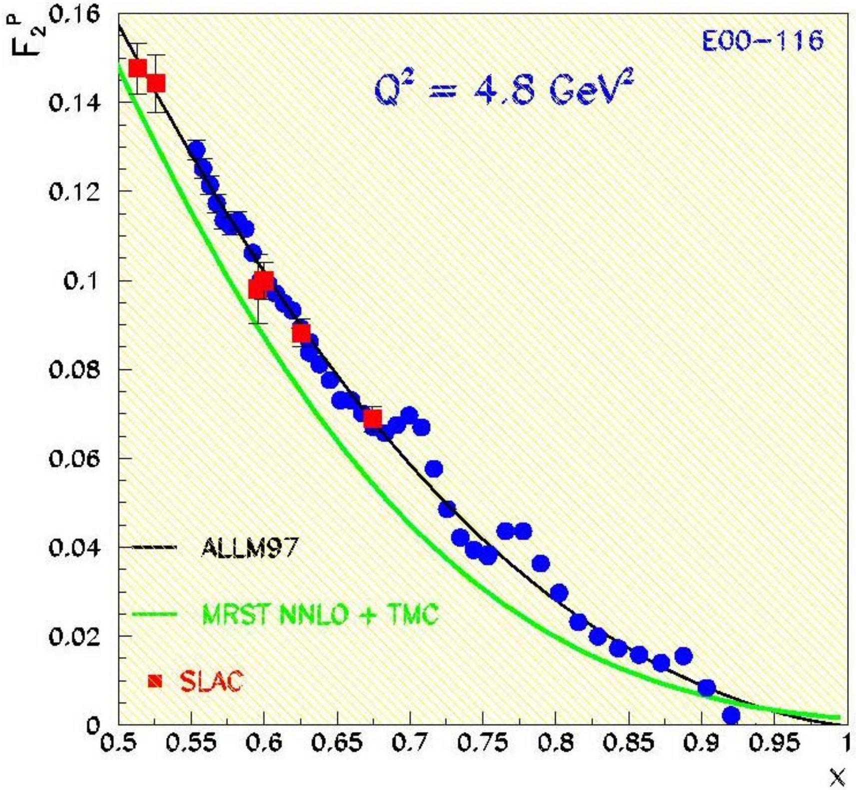


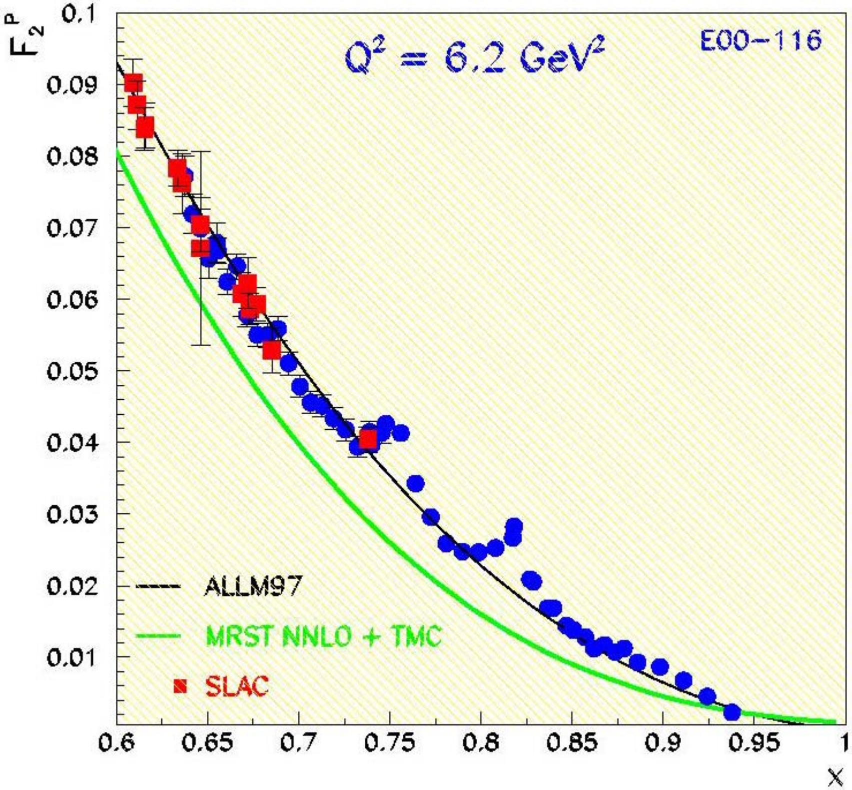


- **Estimated uncertainty on F_2 originating from the R parameterization used is about 2%.**

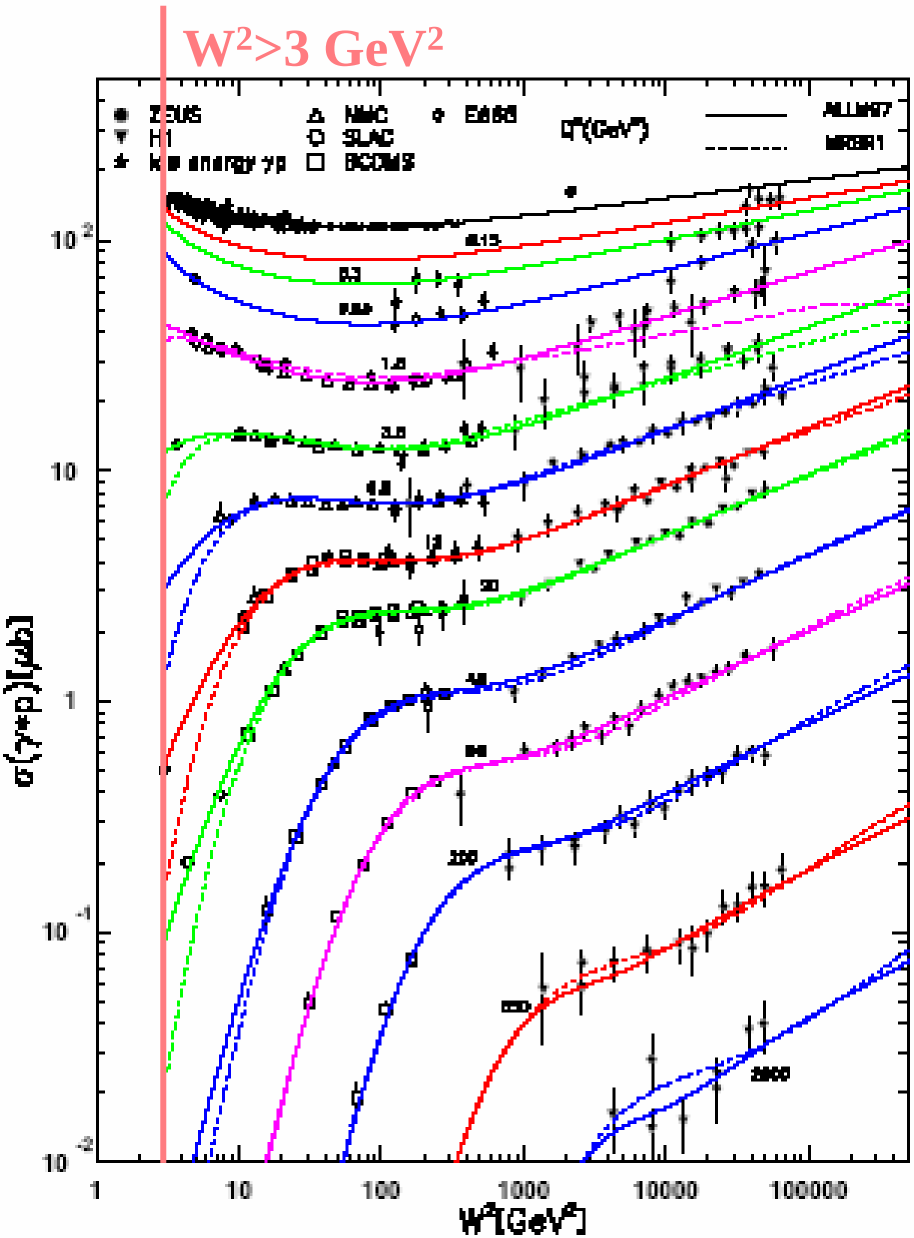
F_2^p from E00-116 data

- As observed from E94-110 , MRST pdf evolution curve undershoots the data at intermediate Q^2, high x.
- ALLM97 fit behaves as a “scaling curve” for the resonance data.





What is ALLM97 ?



ALLM97 (Abramowicz,Levin,Levy,Maor) is a fit to a wide range of γ^*p scattering data(all existing data by 1997) with $W^2>3$ GeV^2 including also photoproduction data (γp).

The fit form assumed for F_2 is the product of:

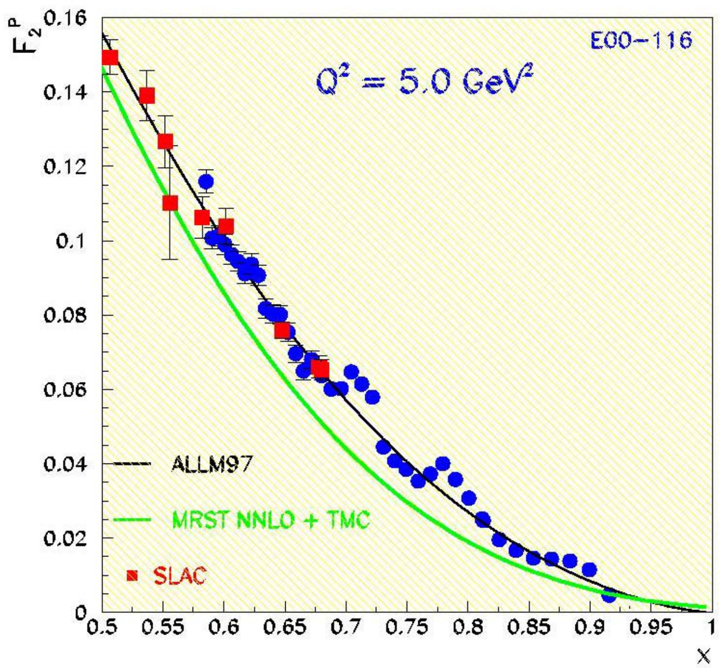
➡ $Q^2/(Q^2+m_0^2)$

➡ $c_{P,R}(t) * x_{P,R}^{a_{P,R}(t)} * (1-x)^{b_{P,R}(t)}$

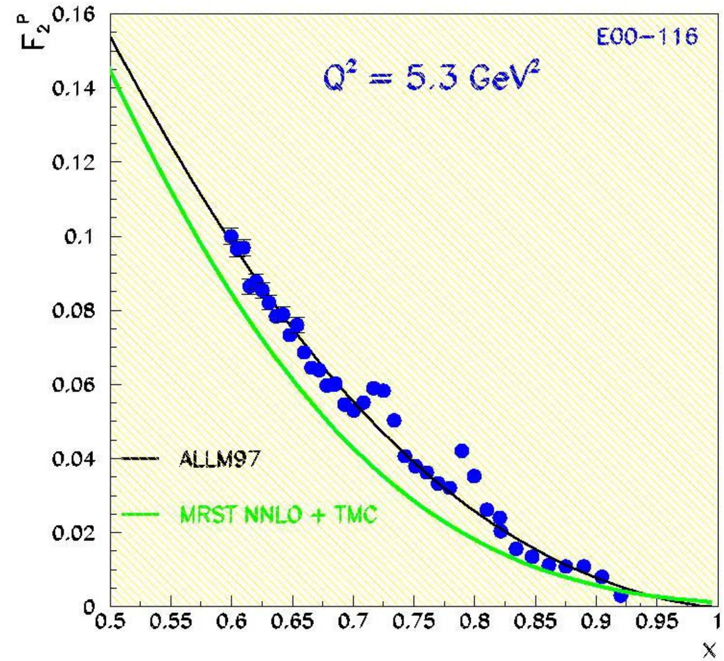
where $t = \ln\left\{\dfrac{\ln[(Q^2+Q_0^2)/\Lambda^2]}{\ln(Q_0^2/\Lambda^2)}\right\}$

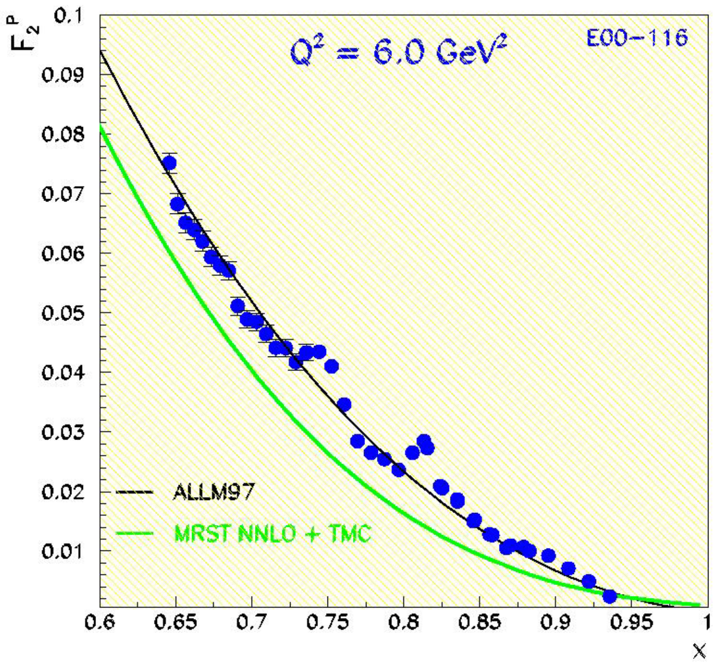
$x_{P,R}$=modified Bjorken x

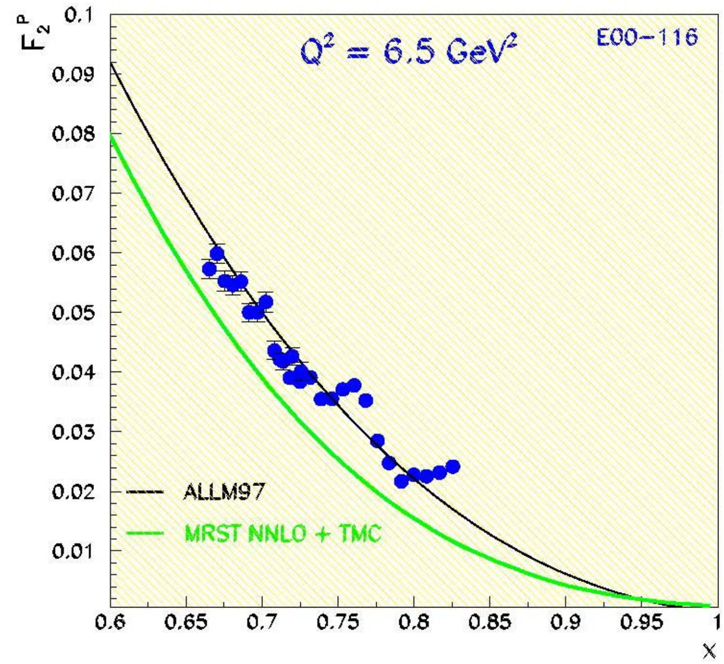
$1/x_{P,R}=1+(W^2-M^2)/(Q^2+m^2_{P,R})$



Remaining spectra of F_2^p

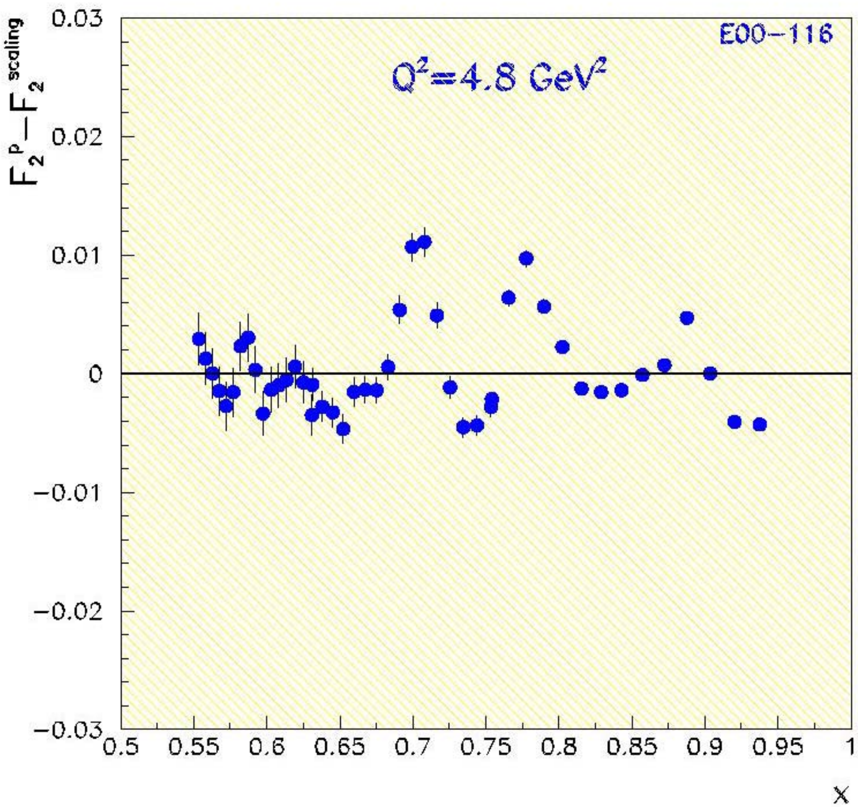


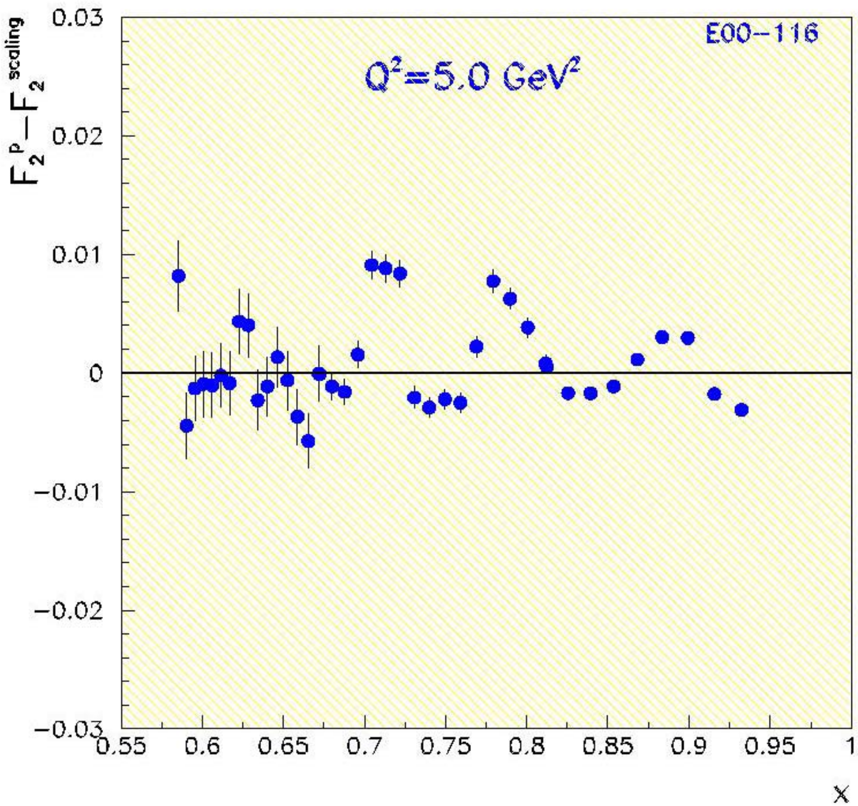




How well ALLM97 describes the H_2 data ?

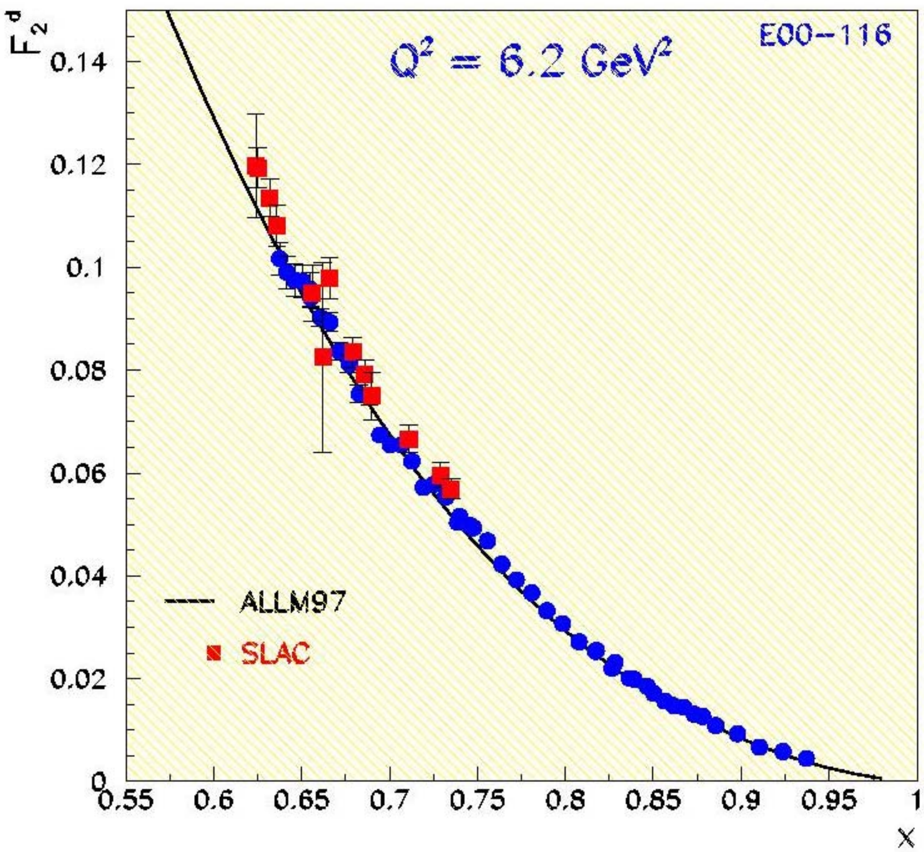
- **Global duality studies revealed that when integrating over the entire spectrum - resonance + DIS region – with ALLM97 as scaling curve, duality holds up to 2% .**

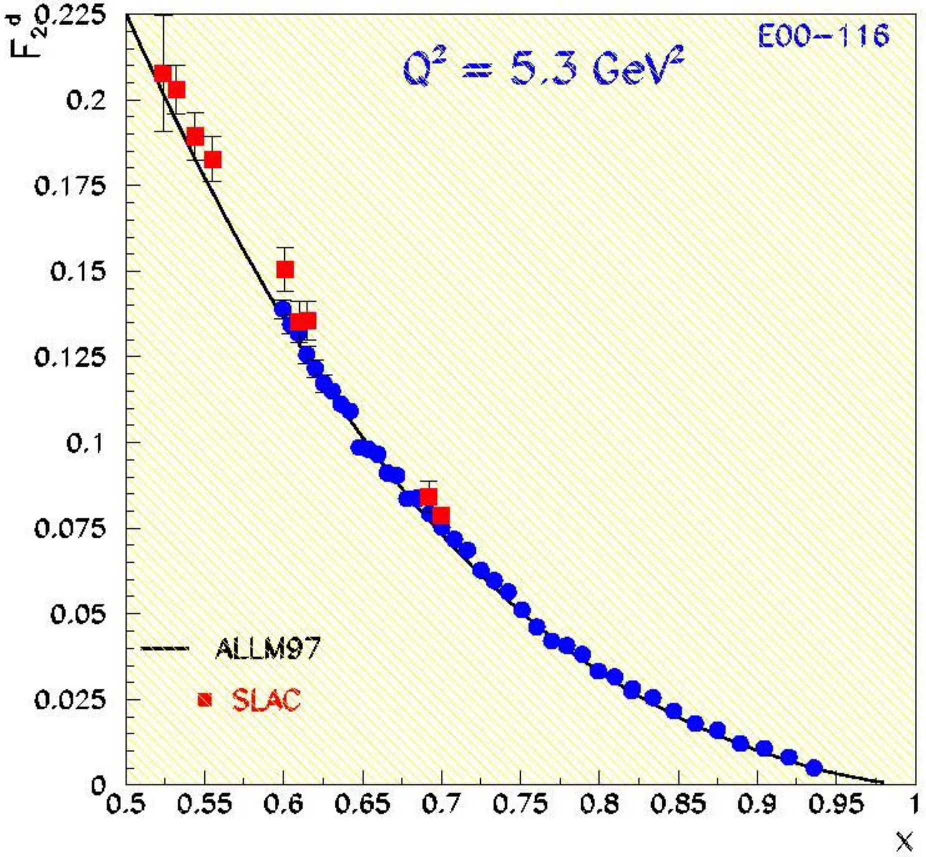


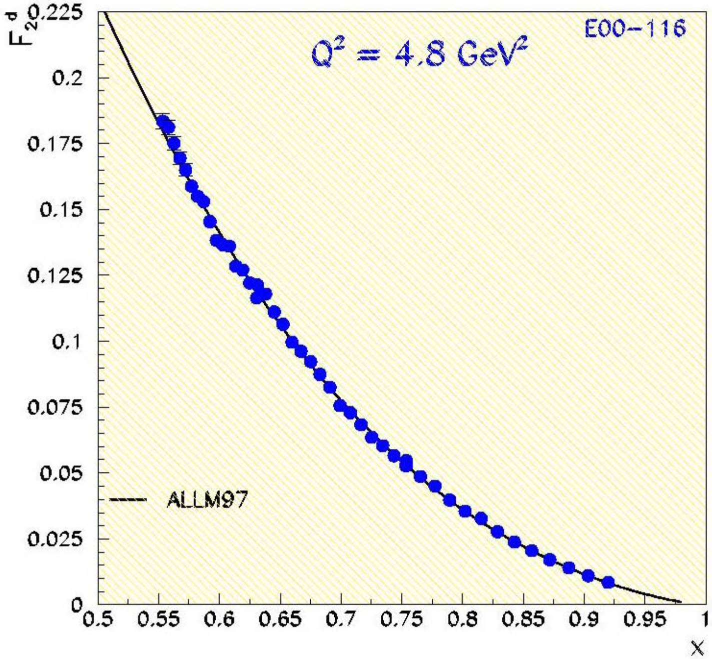


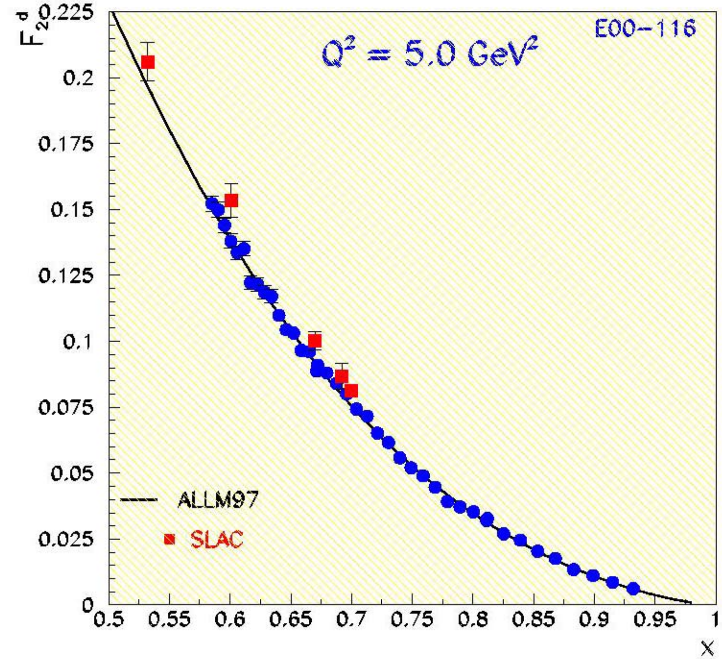
F_2^d from E00-116 data

- ALLM97 for D_2 is:(the fit to world dis F_2^p) X (parameterization of F_2^d/F_2^p as a function of x from world data)

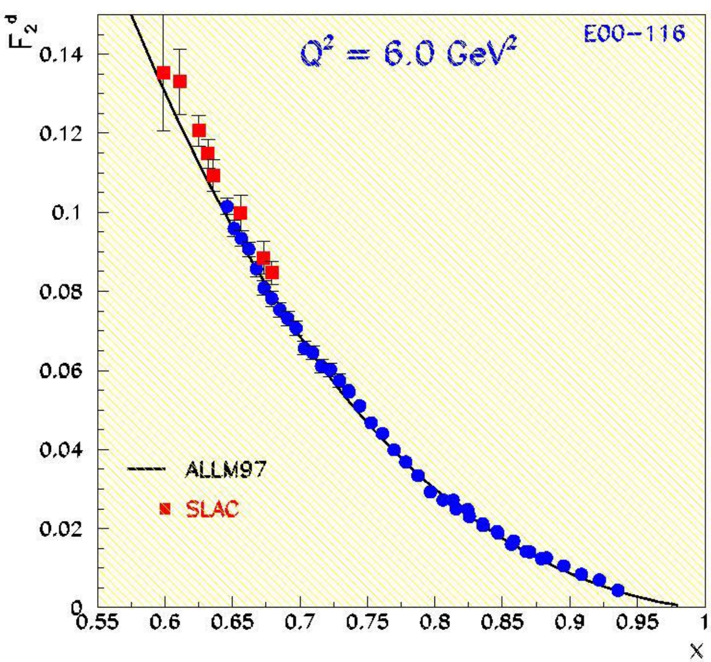


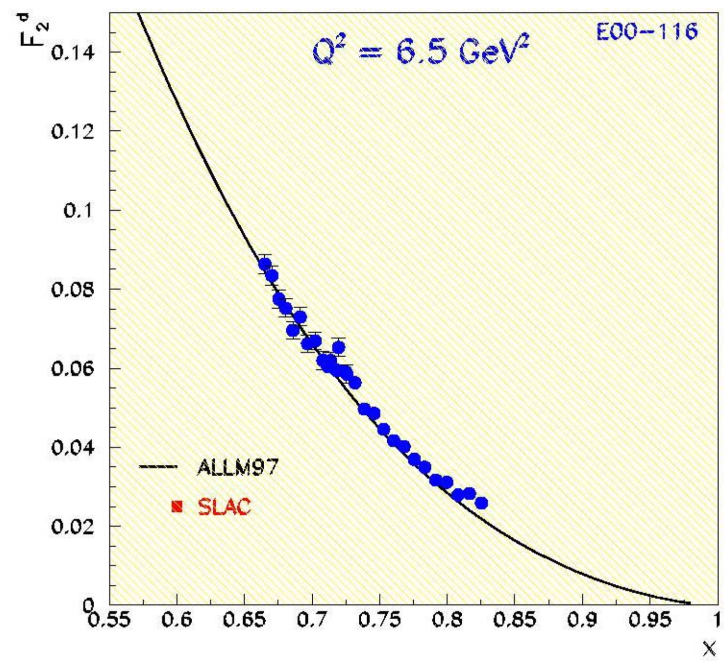






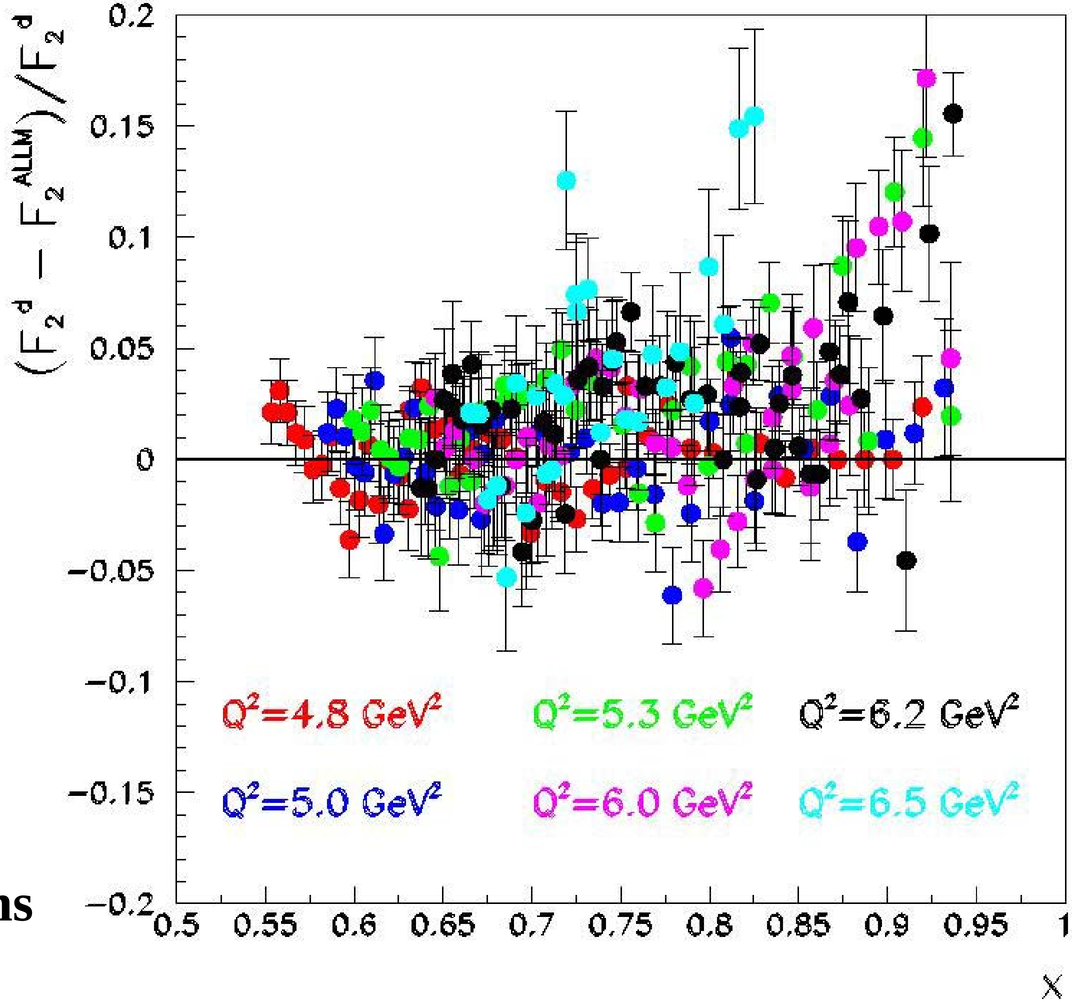
Remaining spectra of F_2^d





How well ALLM97 describes the D_2 data ?

- **Overall, ALLM97 D_2 is about 1.5 % lower than E00-116 data , the discrepancy getting bigger at high x.**
- **E00-116 data seem few percent lower than SLAC data.**

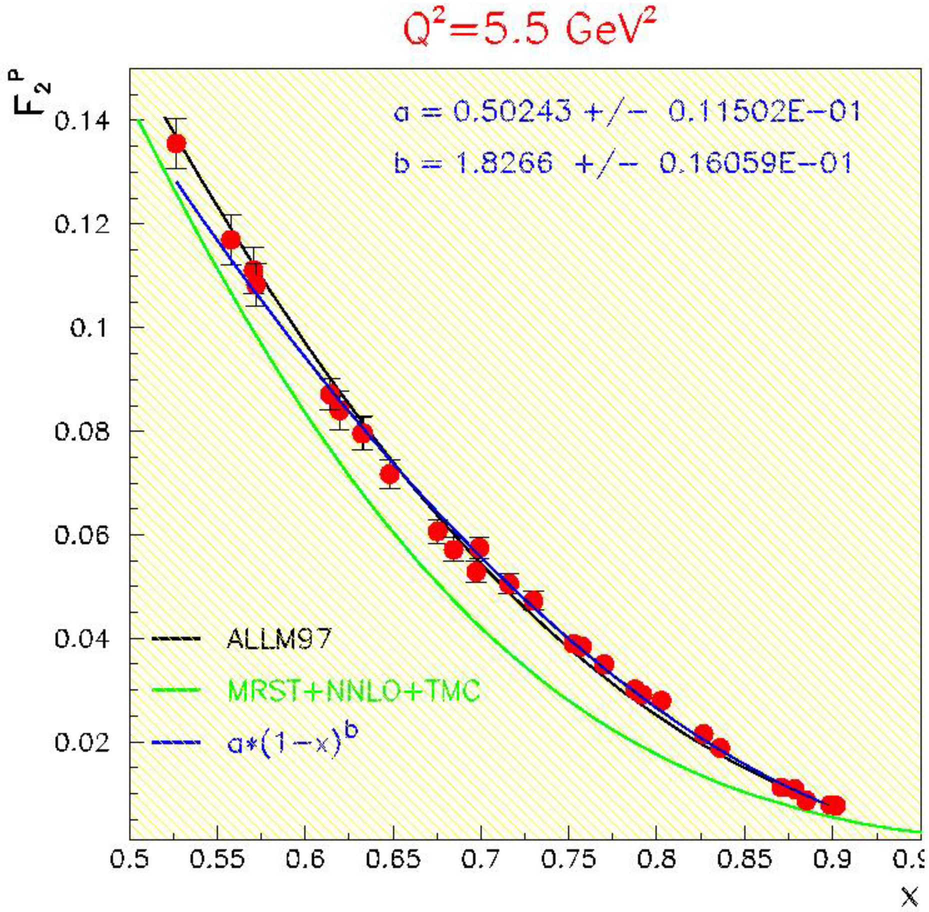


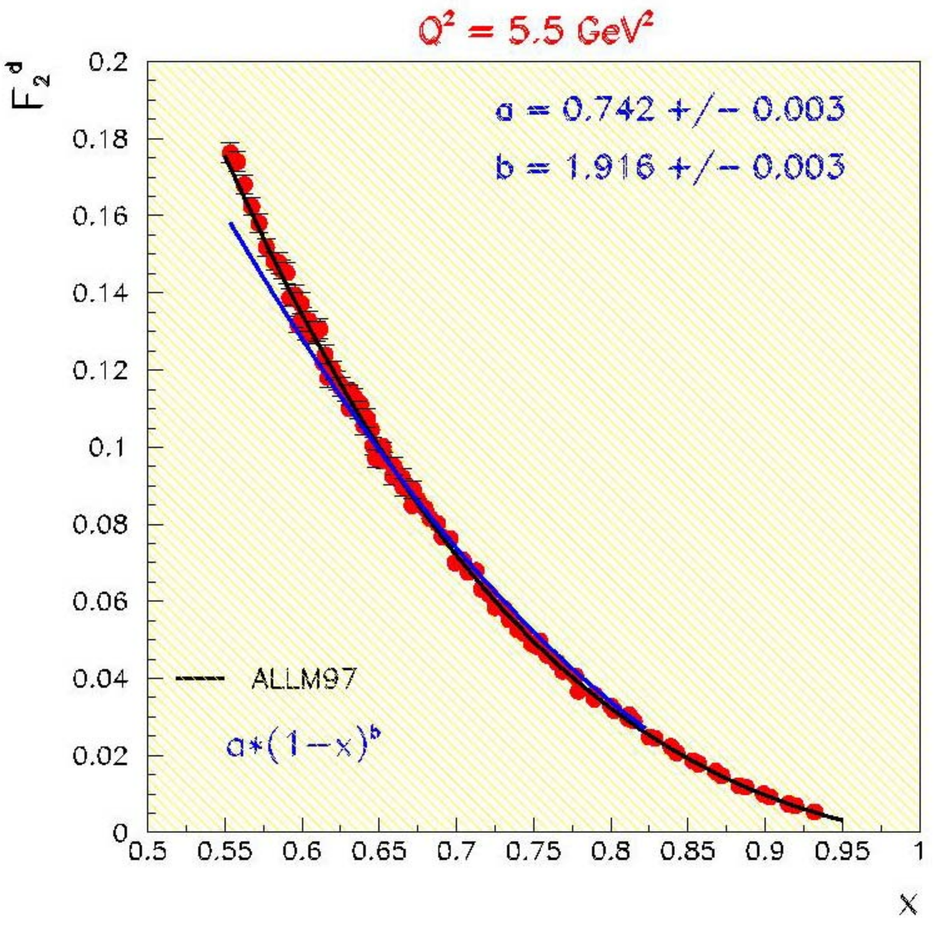
…but D_2 data still need iteration(for both cross sections and radiative corrections)…

$F_2(x)|_{Q^2=const.} \sim(1-x)^b$

- **For a fixed Q^2, the F_2 dependence of x goes like $(1-x)^b$.**

- **E00-116 F_2^p and F_2^d "points" were centered at a fixed $Q^2 = 5.5$ GeV^2 and the x dependence of F_2^p was fitted.**





Summary

- F_2^p extracted from E00-116 resonance data were shown. With increasing Q^2/x they slide on ALLM97 curve but are becoming systematically higher than MRST+NNLO+TMC curve.

- F_2^p dependence of Q^2/x for E00-116 data were checked against world data, ALLM97 fit and MRST+NNLO+TMC. E00-116 data follow the Q^2 / x behavior of ALLM97 fit.

- Preliminary F_2^d were shown against "ALLM97" fit and available SLAC data but D_2 data still need iteration.