Summary of (non-spin) physics at DIS 2005

Matthew Wing (DESY/UCL)

- **Structure functions**

- **Diffraction**

- **Jets and heavy quarks**

- **Electroweak and exotics**

Structure functions

Structure of the proton

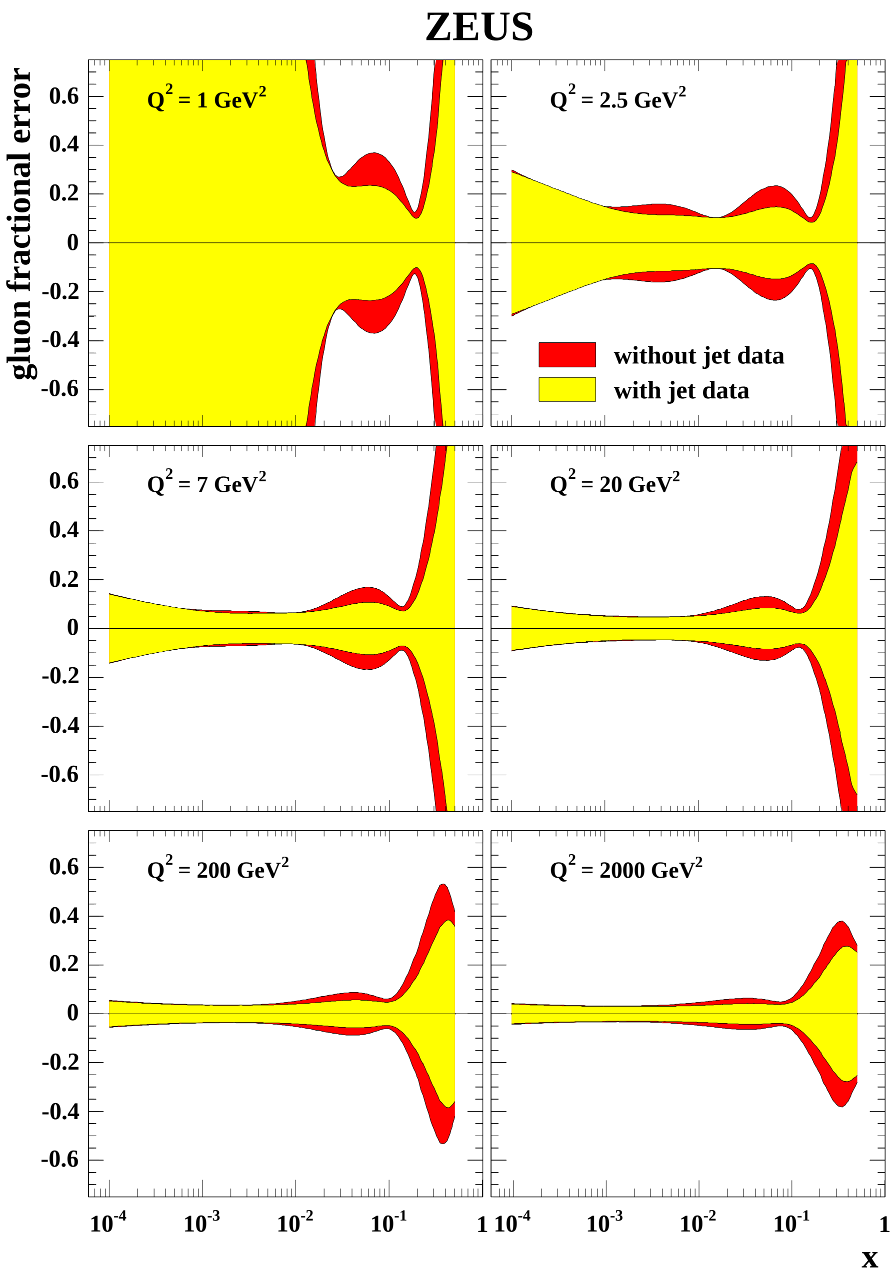
Deepen our understanding of the structure of the proton (and hadrons in general): parton composition, scheme to describe distributions, confinement

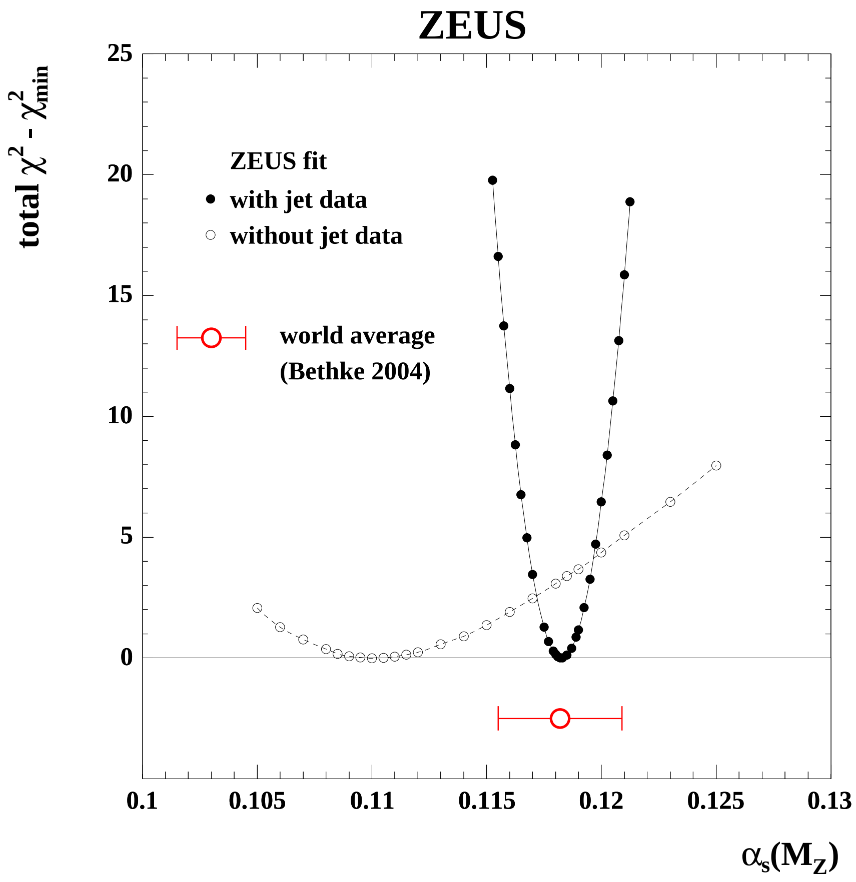
Essential for predictions of measured observables at other hadron colliders, e.g. LHC, with full uncertainties

Review improvements on their determination:

NNLO, inclusion of new data, understanding data, heavy quarks

NLO QCD fits J. Terron (ZEUS)





Extraction of α_s using ZEUS data alone

Jets constrain the gluon and α_s

NLO QCD fits D. Stump, R. Thorne, J. Rojo

Difference of opinion on need for NNLO; MRST think essential, CTEQ less so

However general move to NNLO PDFs. MRST calculated $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ at NNLO

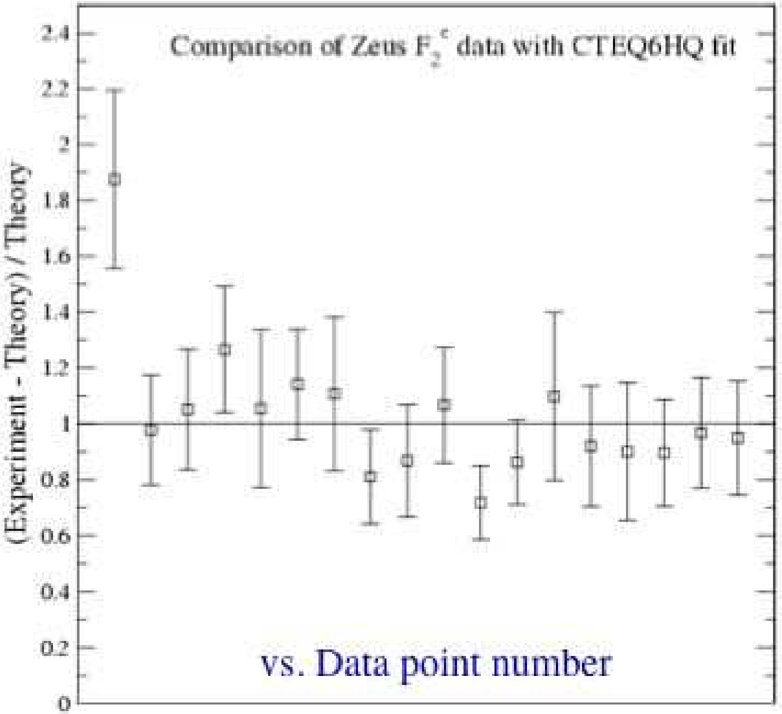
Also new approach using neural networks

- **no bias from assumed functional form**
- **should give a better estimation of PDF uncertainties**
- **structure functions determined; determination of PDFs underway**

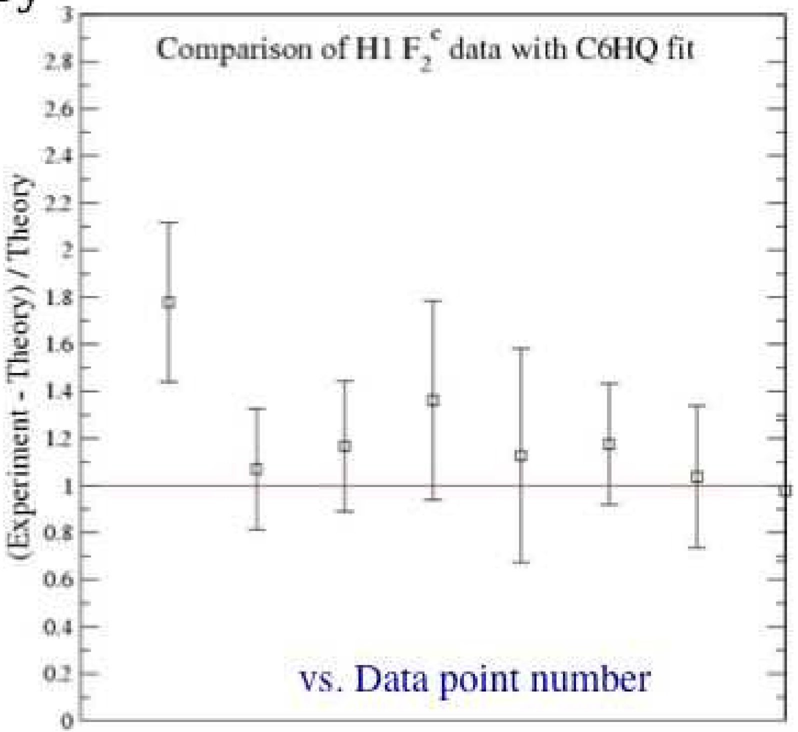
Heavy Quark PDFs
F. Olness (CTEQ)

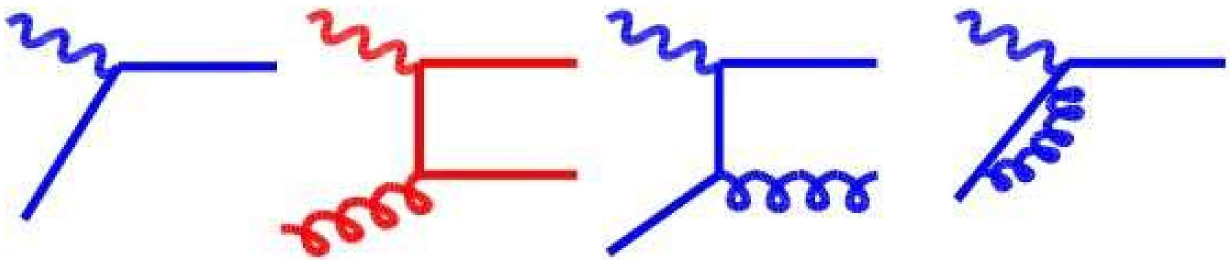
How does it do for the F_2^c data???

$$\frac{\text{Experiment} - \text{Theory}}{\text{Theory}}$$



(Exp -Theory)/Theory



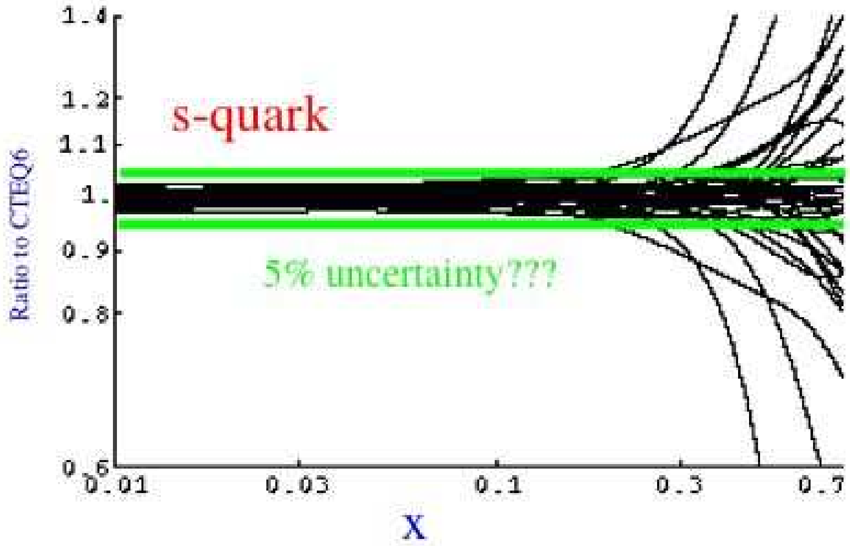


Strange PDF

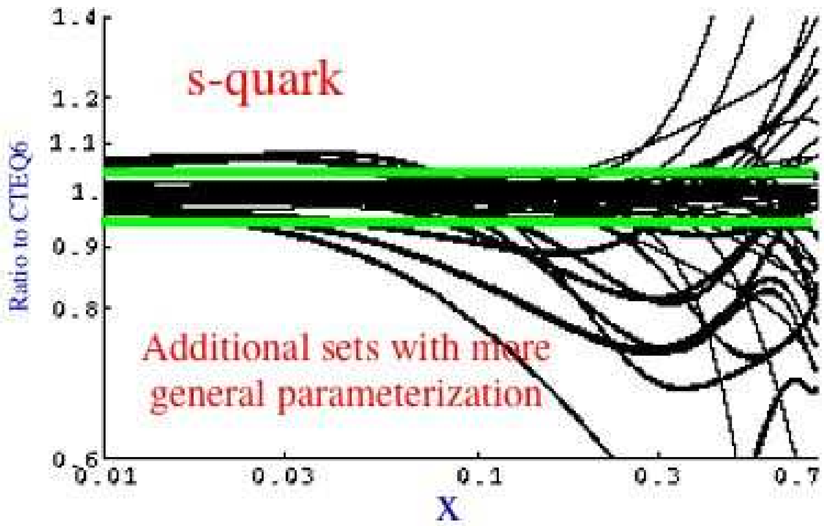
F. Olness (CTEQ)

What is true uncertainty on s-quark PDF???

40 CTEQ6M PDF sets



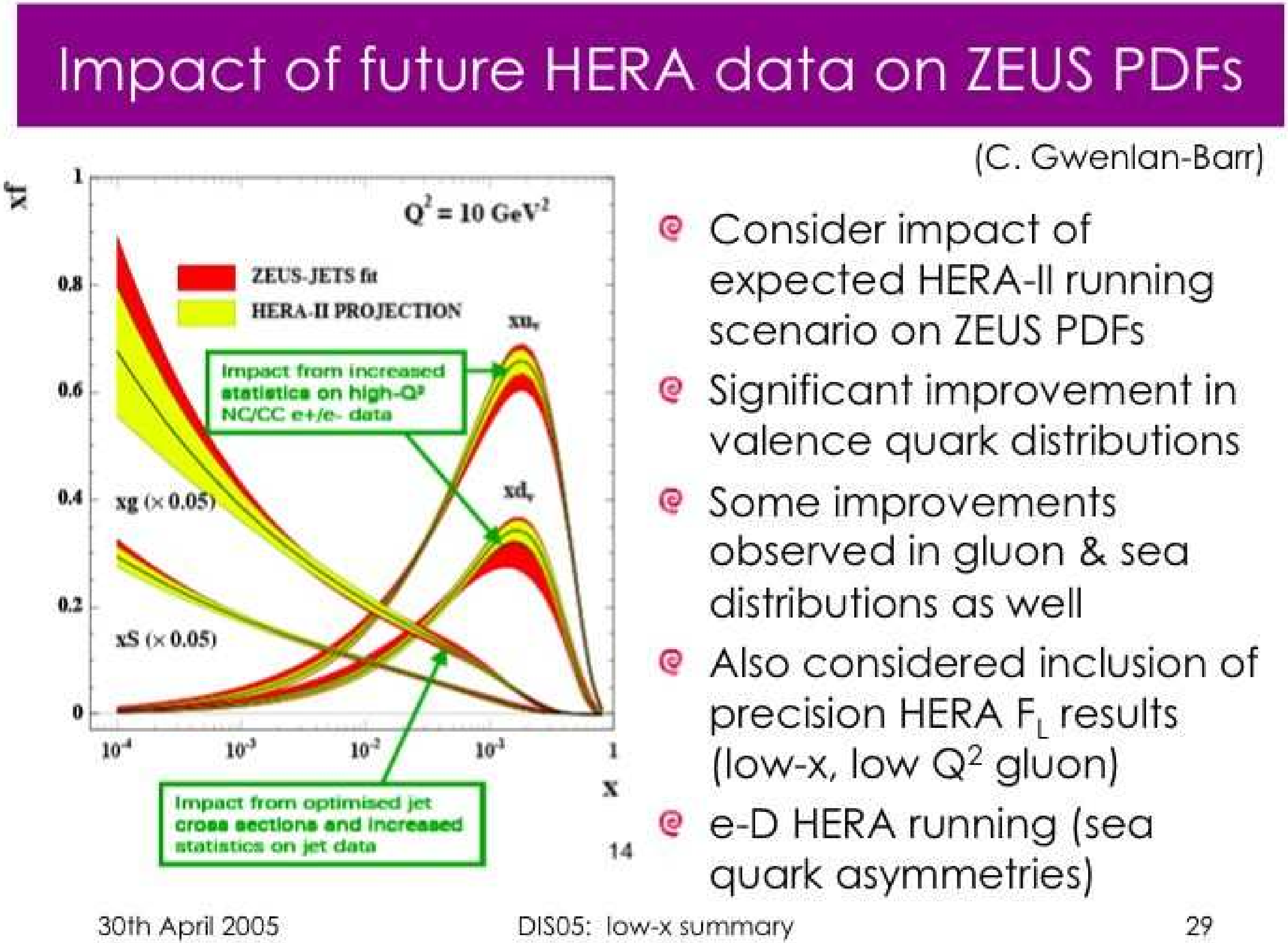
Closer to the true error



Curves shown are examples; this is not an exhaustive set

Warning: The Director General has determined the band of PDF's can greatly underestimate the true uncertainty

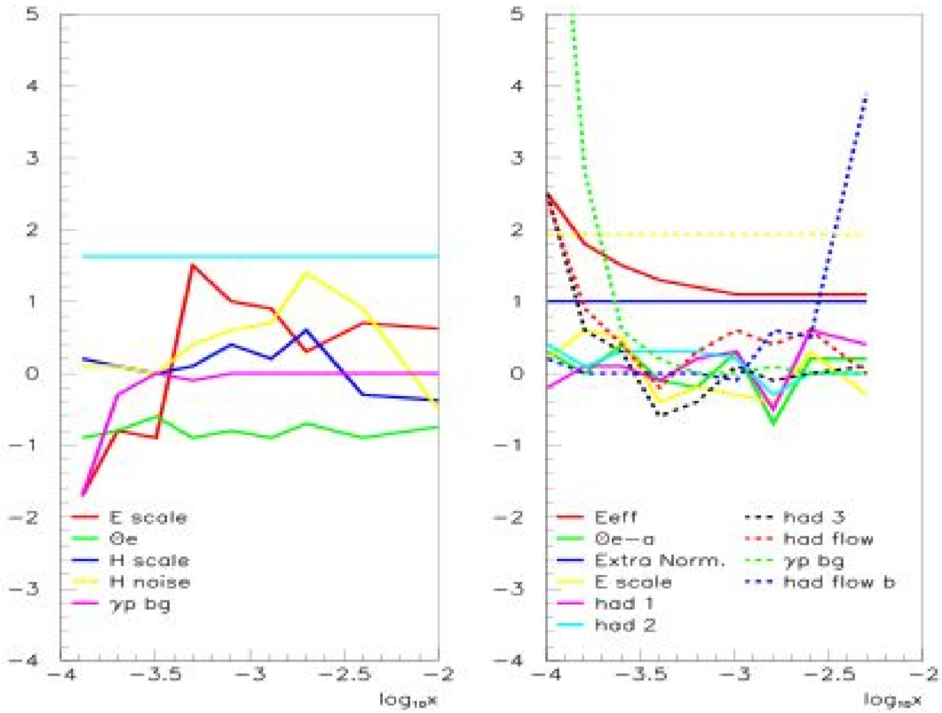
Future PDFs C. Gwenlan



Averaging of H1 and ZEUS F_2 data S. Glazov

Reduction of the systematic errors

H1 and Zeus use different kinematic reconstruction methods – different shape vs x, Q^2.

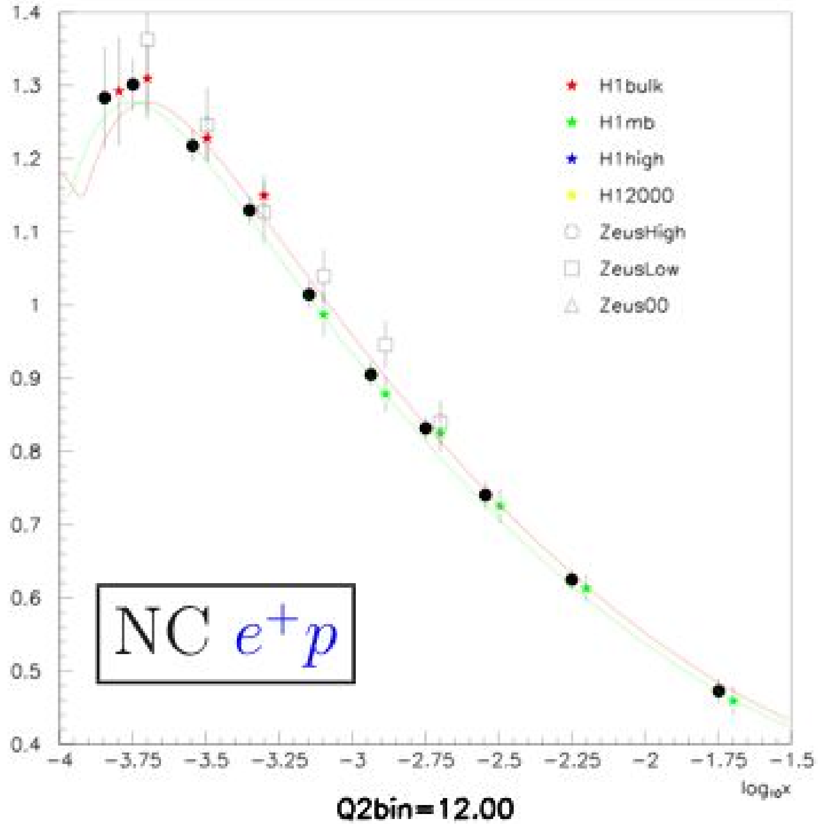


Sensitivity to syst. errors for $Q^2 = 6.5$ GeV^2

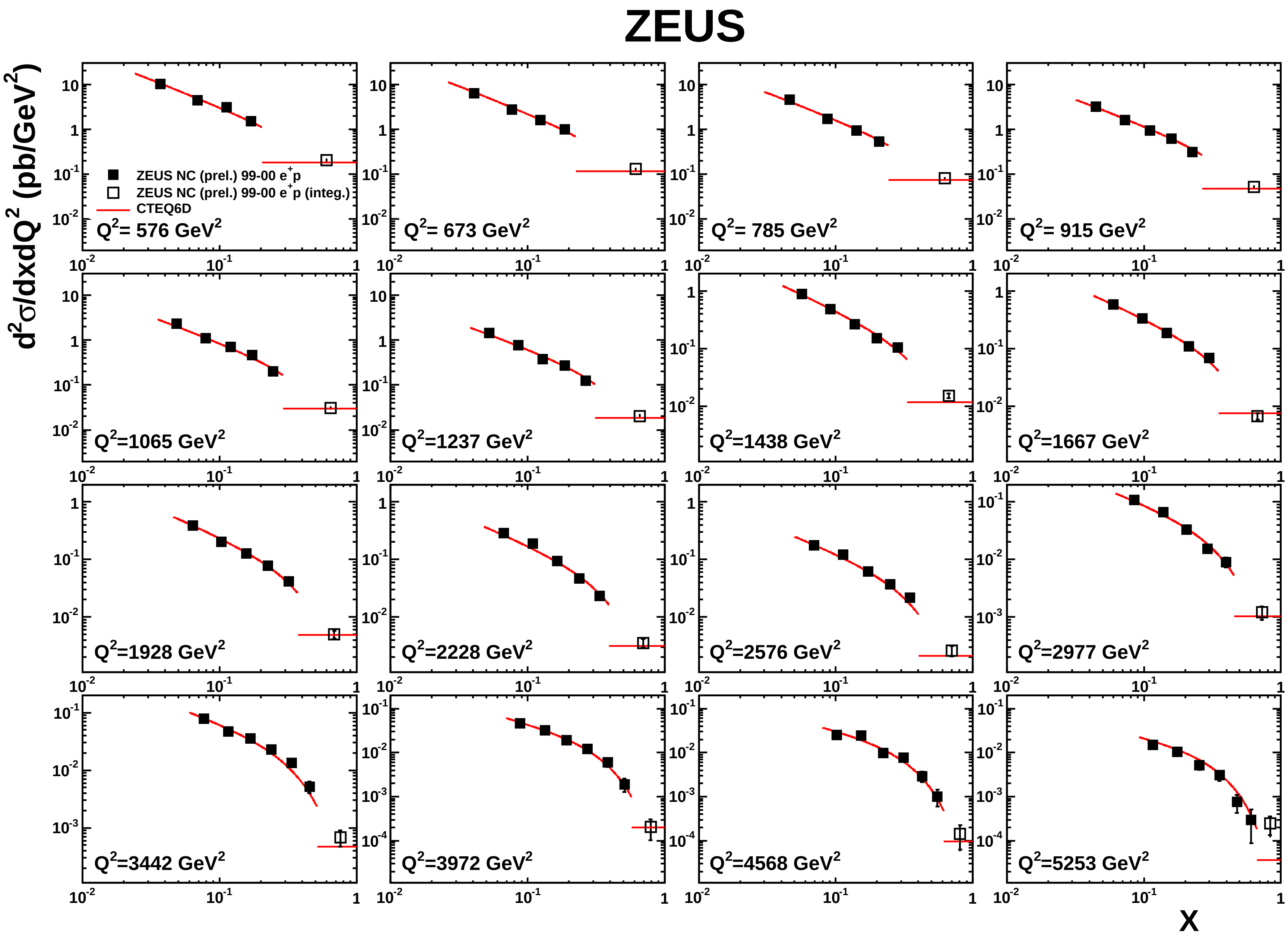
Averaging of H1 and ZEUS F_2 data S. Glazov

Average of all published HERA NC/CC data

16 individual data sets of NC/CC data published by H1 and Zeus collaborations. Examples for some Q^2 bins:



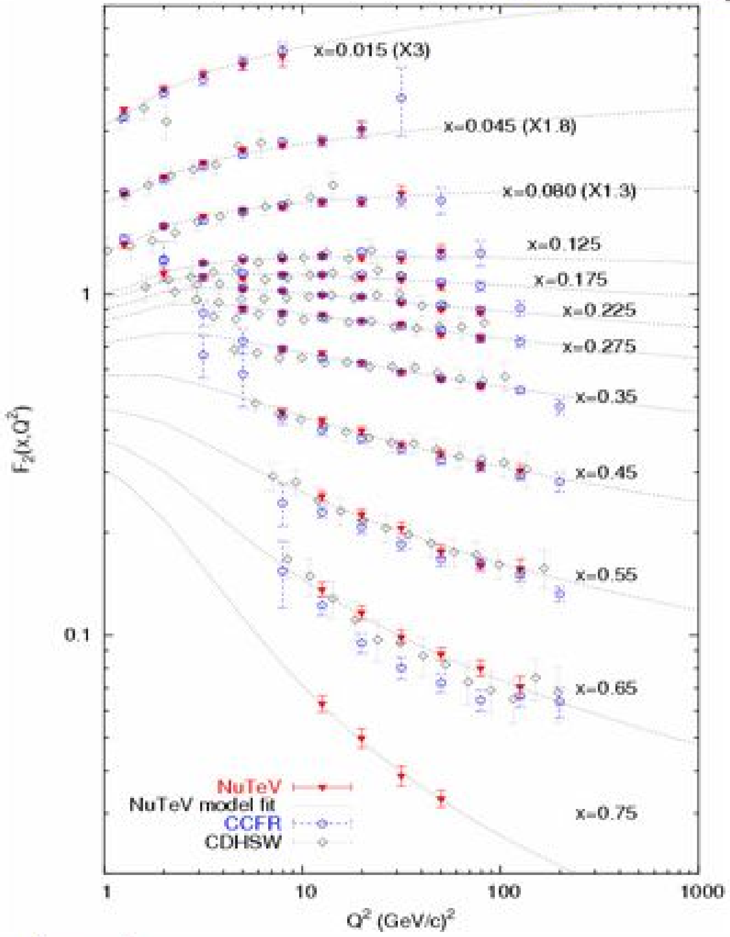
Deep inelastic scattering at high x Y. Ning (ZEUS)



New technique; extending up to $x = 1$; more data; constraints on PDFs?

Deep inelastic scattering at high x M. Tzanov (NuTeV)

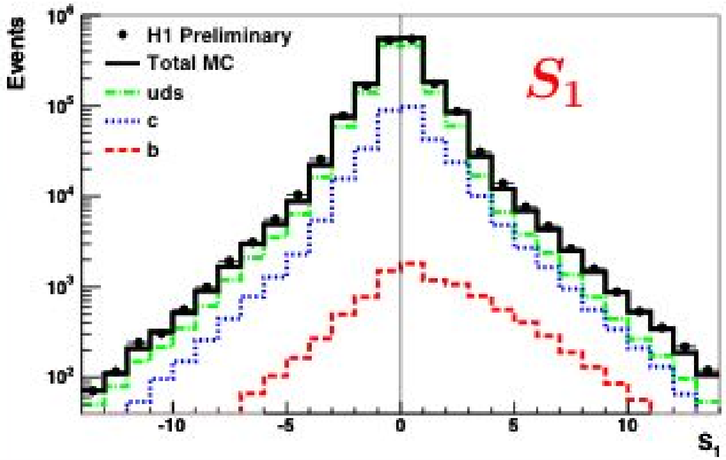
F_2 Measurement

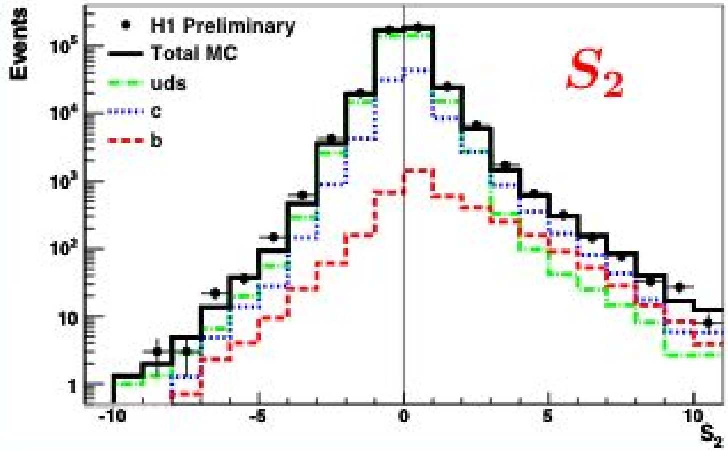


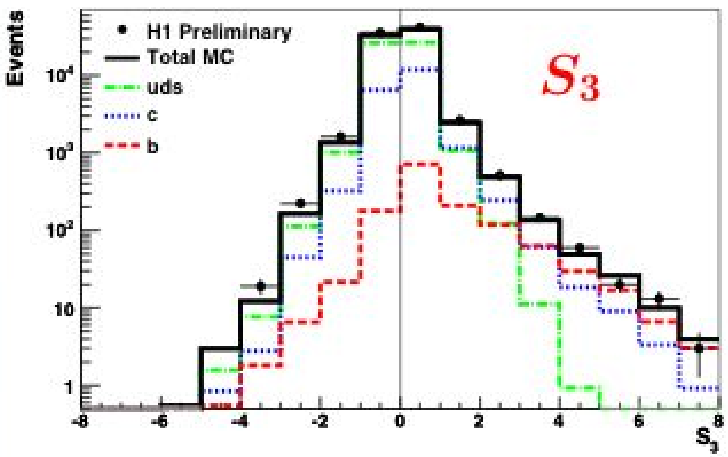
- Isoscalar ν-Fe F_2
- NuTeV F_2 is compared with CCFR and CDHSW results
  - the line is a fit to NuTeV data
- All systematic uncertainties are included
- All data sets agree for $x<0.4$.
- At $x>0.4$ NuTeV agrees with CDHSW
- At $x>0.4$ NuTeV is systematically above CCFR

Heavy flavour tagging T. Klimkovich (H1)

Significance (S_i) at Low Q^2







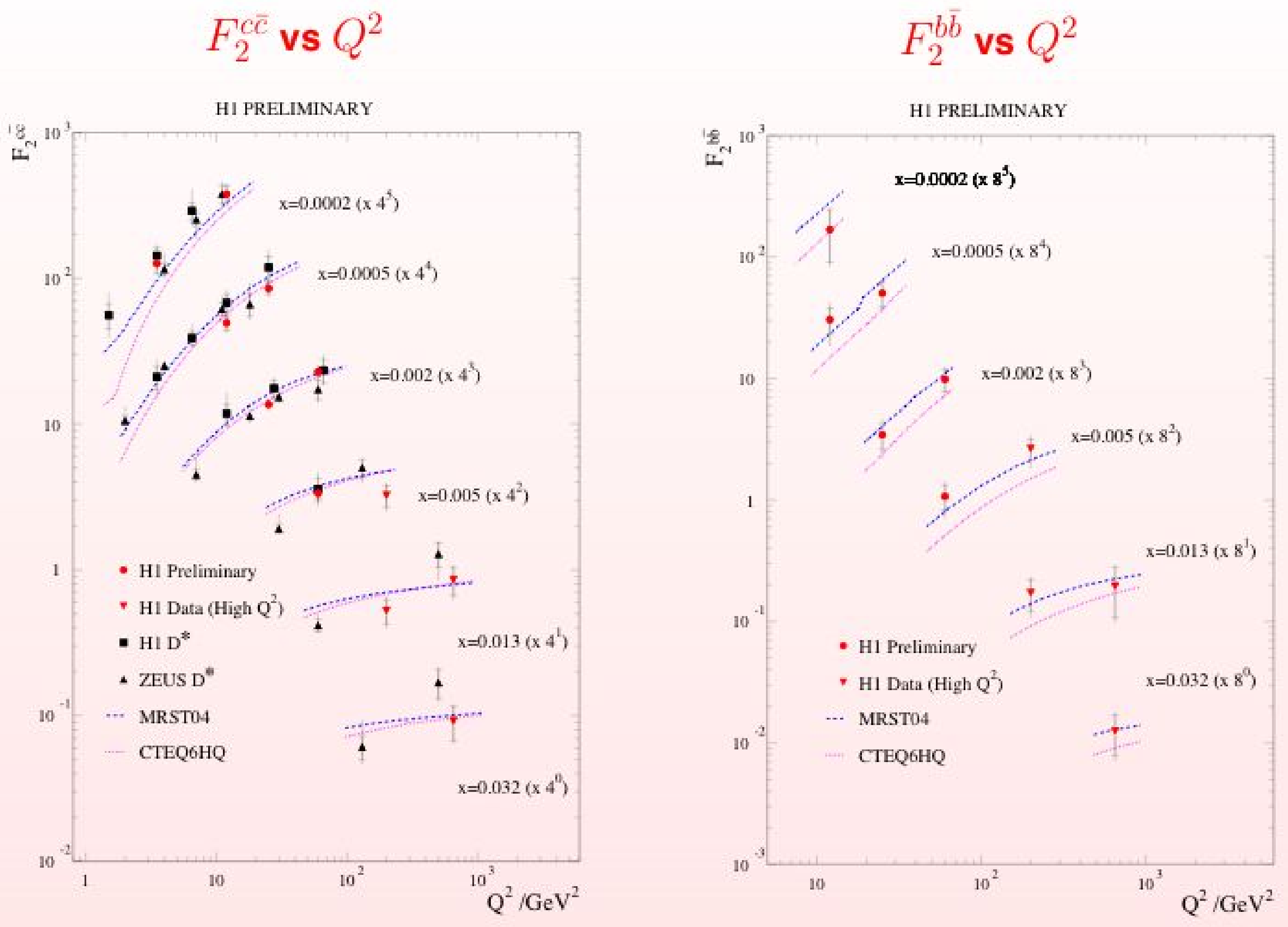
At low Q^2, beauty fraction is smaller. Need to do more to separate b and c

Define three distributions:

- S_1 highest significance track
- S_2 2nd highest significance track with same sign as S_1
- S_3 3rd highest significance track with same sign as S_1 and S_2

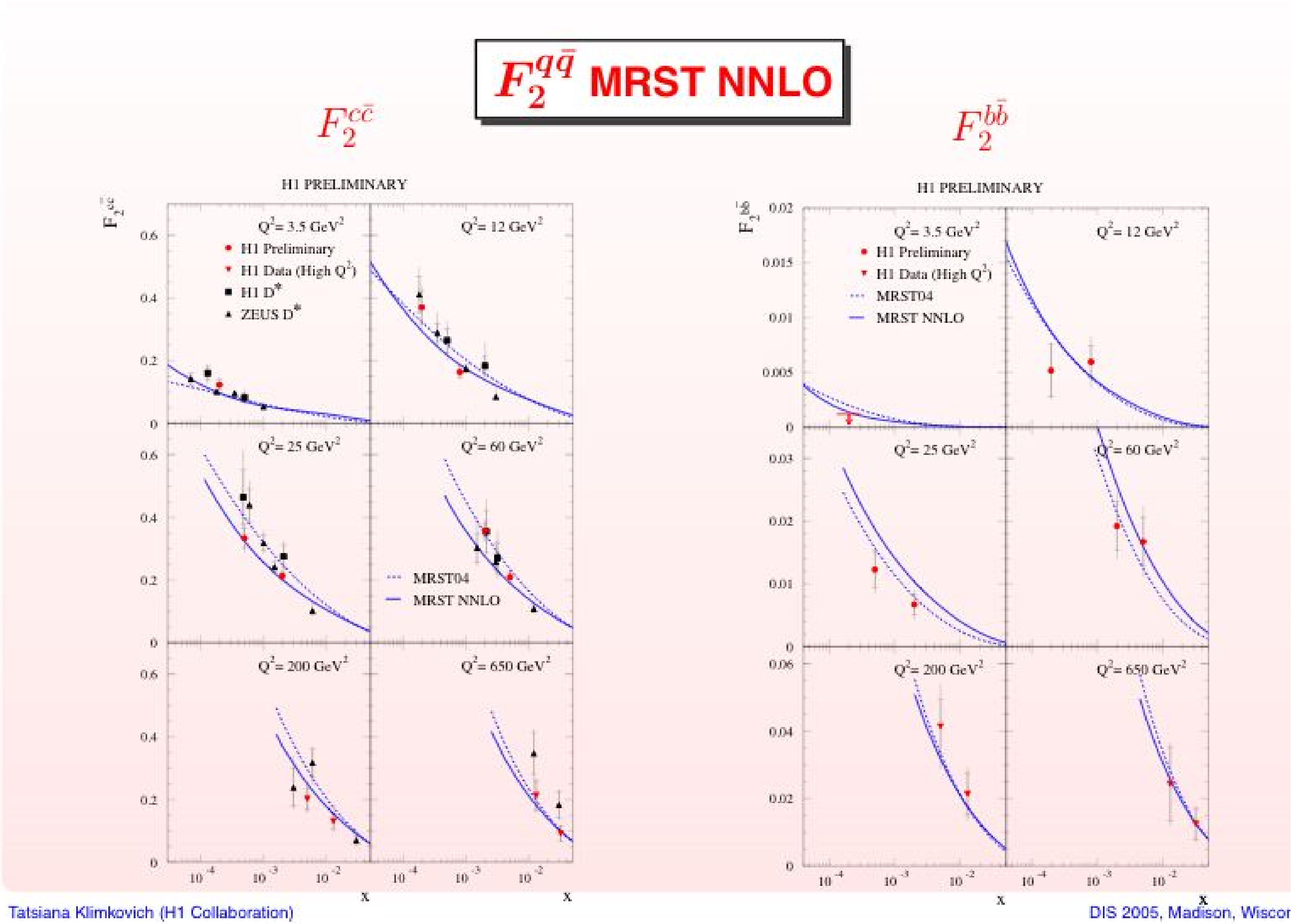
Beauty contribution to the proton structure function

T. Klimkovich (H1)



Beauty contribution to the proton structure function

T. Klimkovich (H1)

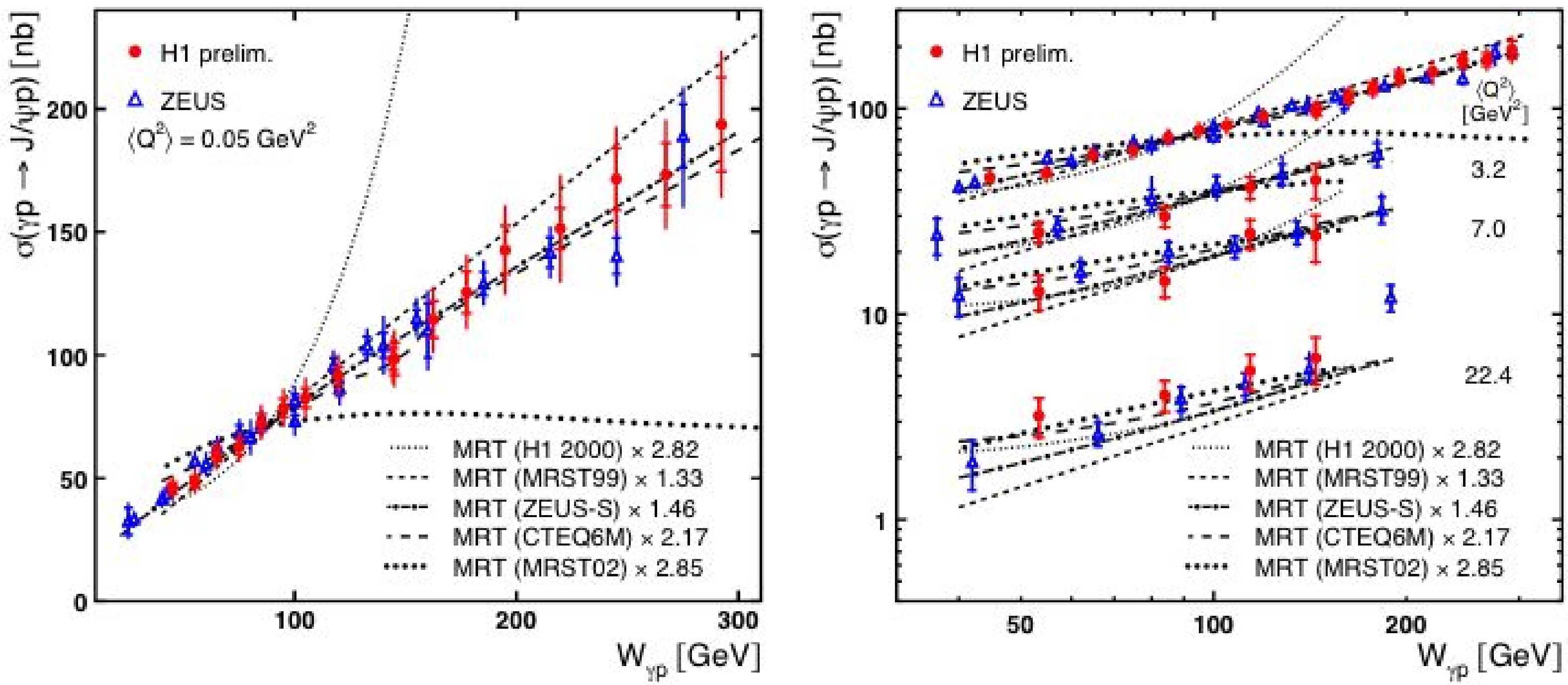


Exclusive VM to constrain the gluon density

T. Teubner, C. Kiesling (H1)

IV. Data vs TH: constraining $f(x, k_T^2)$ via diffr. VM production

Preliminary H1 and ZEUS data compared to MRT predictions:



Plots thanks to Philipp Fleischmann (H1)

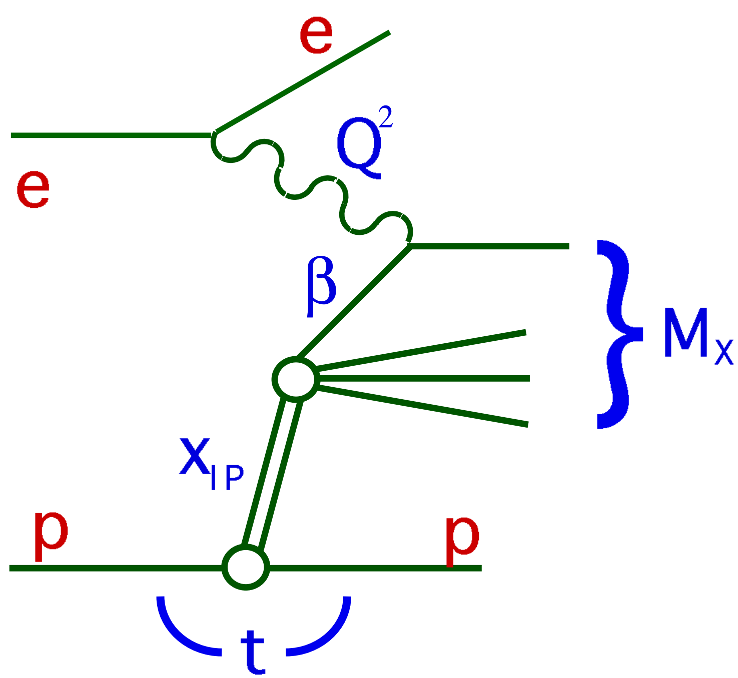
Diffraction

Diffractive scattering

Diffractive processes contribute $\sim 10\%$ to the total DIS cross section.

Colour singlet exchange process

Events have clear experimental signature - large rapidity gap, tagged proton, low hadronic mass



Fractional energy loss of the proton

$x_{I\!P} = \frac{q\cdot(P-p_Y)}{q\cdot P}$

Fraction of P momentum carried by struck quark

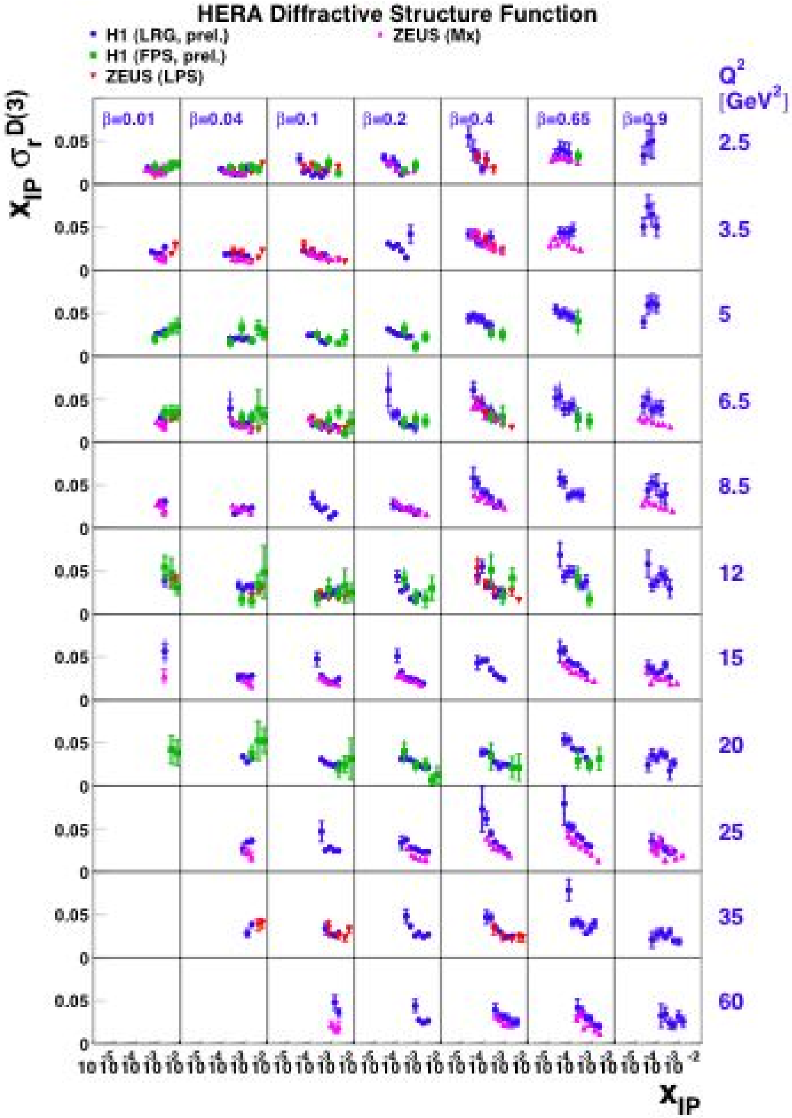
$\beta = x/x_{I\!P}$

Momentum transfer at P vertex

$t = (P - p_Y)^2$

QCD factorisation has been proven (Collins) for these class of events $\Rightarrow$ can measure "diffractive parton distributions".

Inclusive diffractive structure function **P. Laycock, H. Lim**

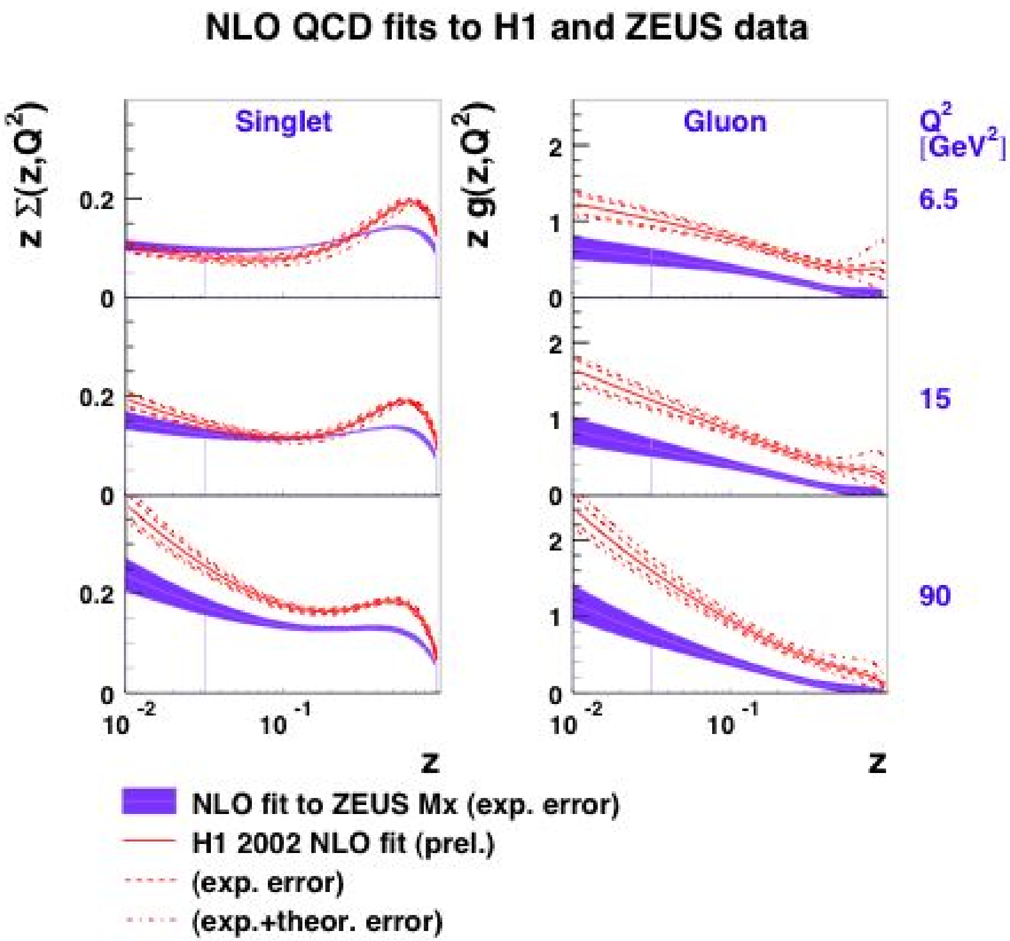


Comparison of all data
$(M_Y < 1.6)$

(only Q^2 bins with at least two datasets shown)

Diffractive parton distributions P. Laycock

NLO fit to ZEUS Mx data



Observations:

- Singlet similar at low Q^2, evolving differenly to higher Q^2
- Gluon factor ~ 2 smaller than H1 gluon

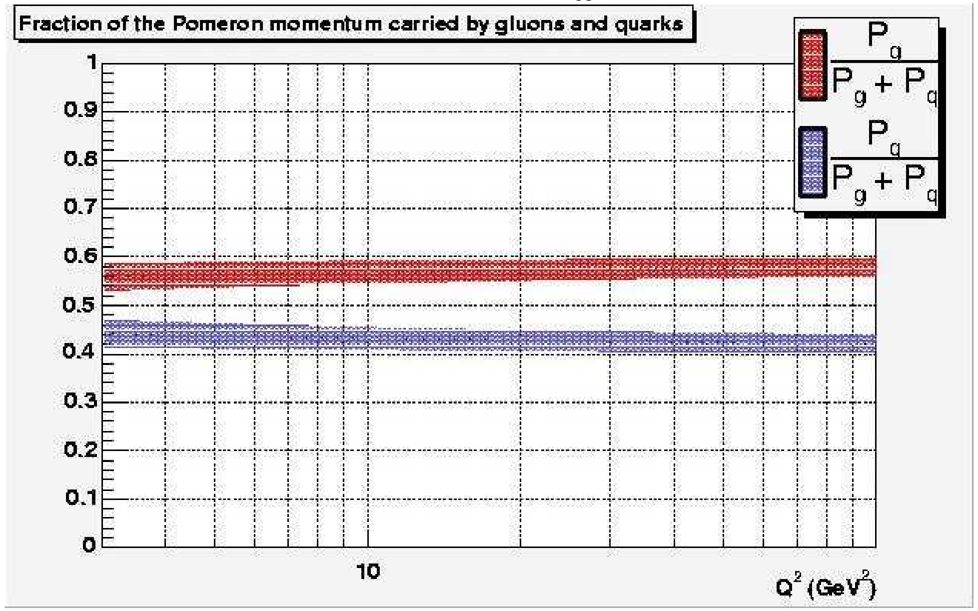
Reminder that data comparisons revealed differences

- at low M_X (high β) Most of those points are not included in the fit
- in the Q^2 dependences Different Q^2 evolution means different gluon

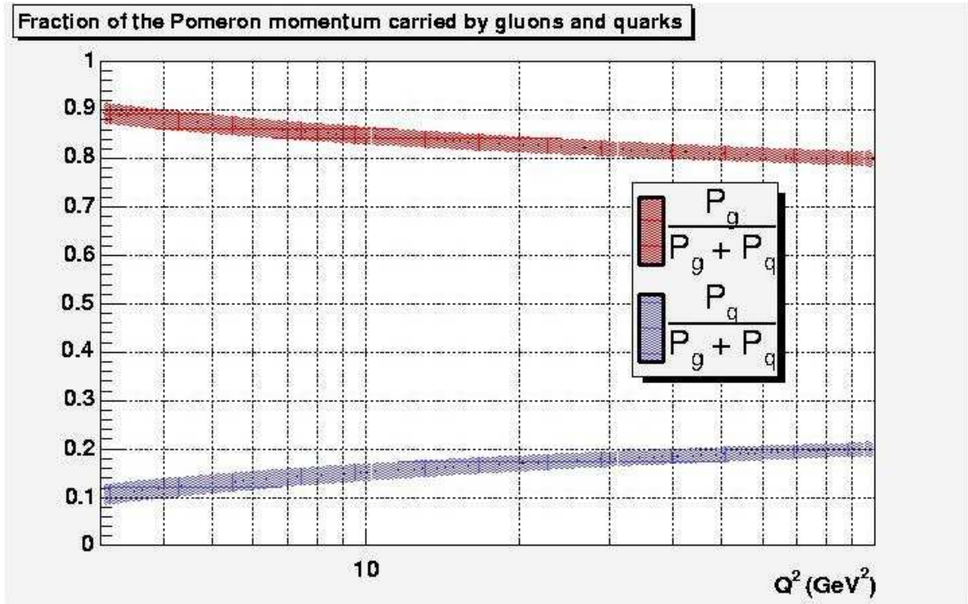
$\rightarrow$ Observed differences in the data explain the differences in the extracted pdfs

Diffractive parton distributions **A. Levy**

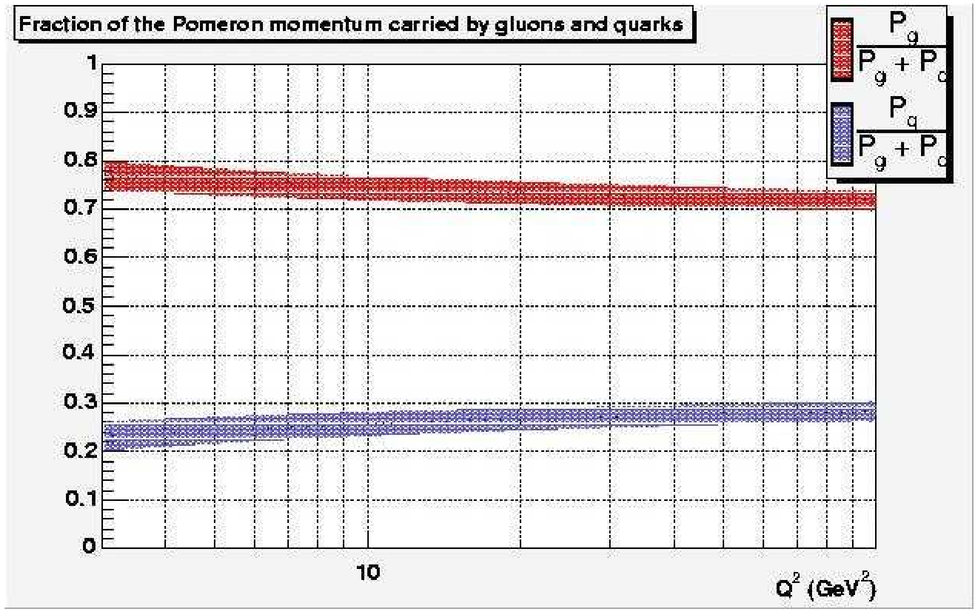
ZEUS M_x



H1



ZEUS LPS



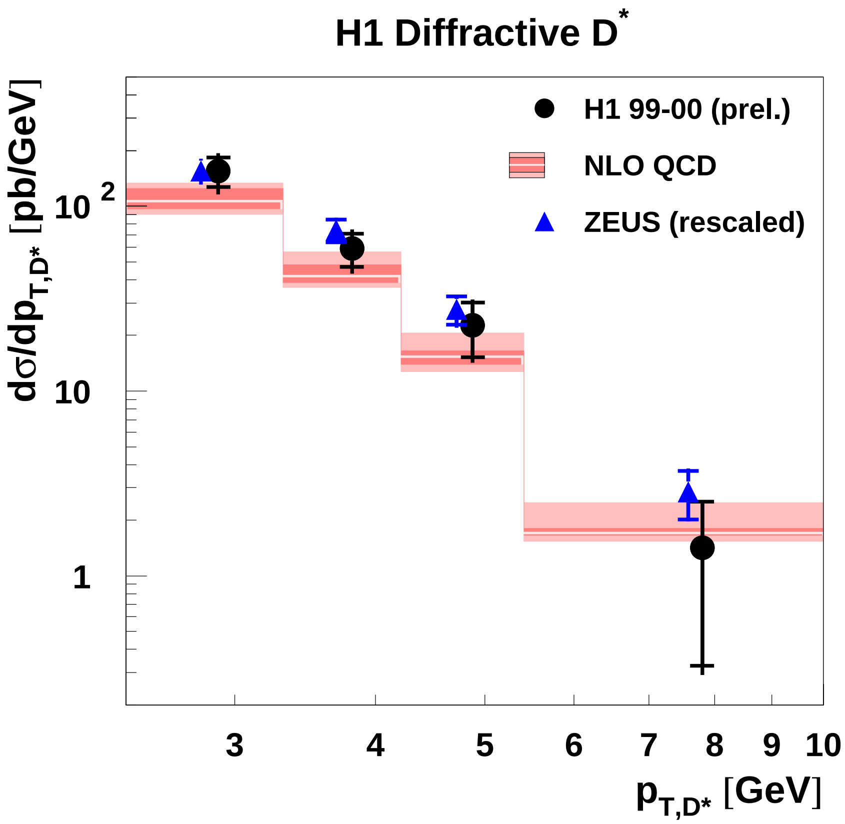
Good fits obtained to each data set

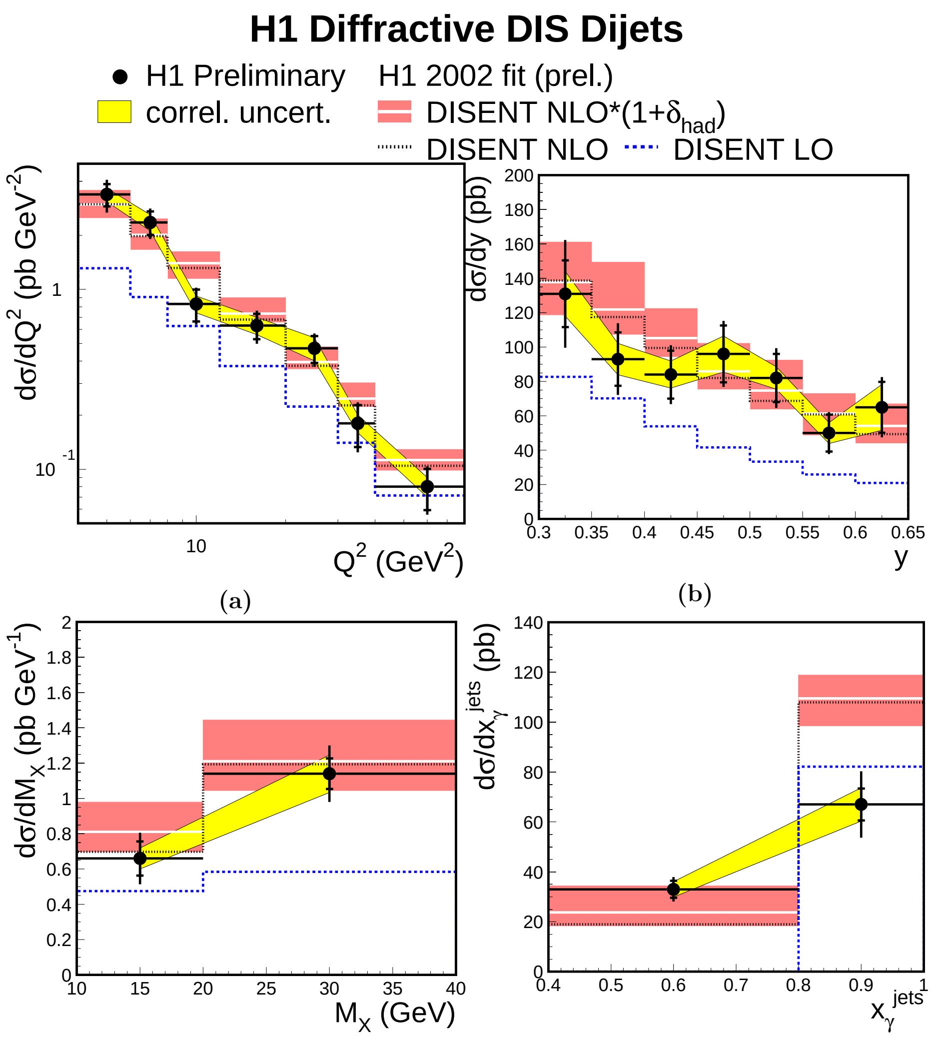
Observed differences come from observed differences in data

Data are incompatible in some regions

Jet and charm production in diffractive DIS processes

M. Beckingham, M. Mozer (H1)





(a)

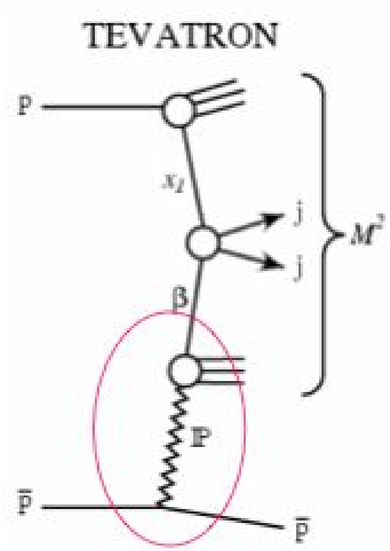
(b)

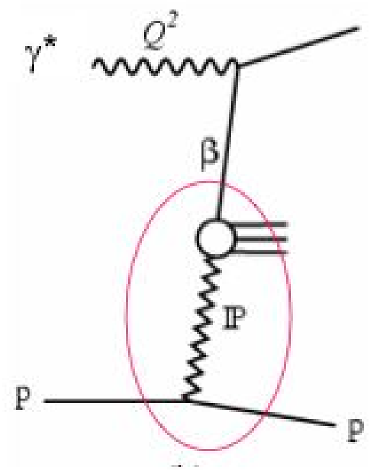
(c)

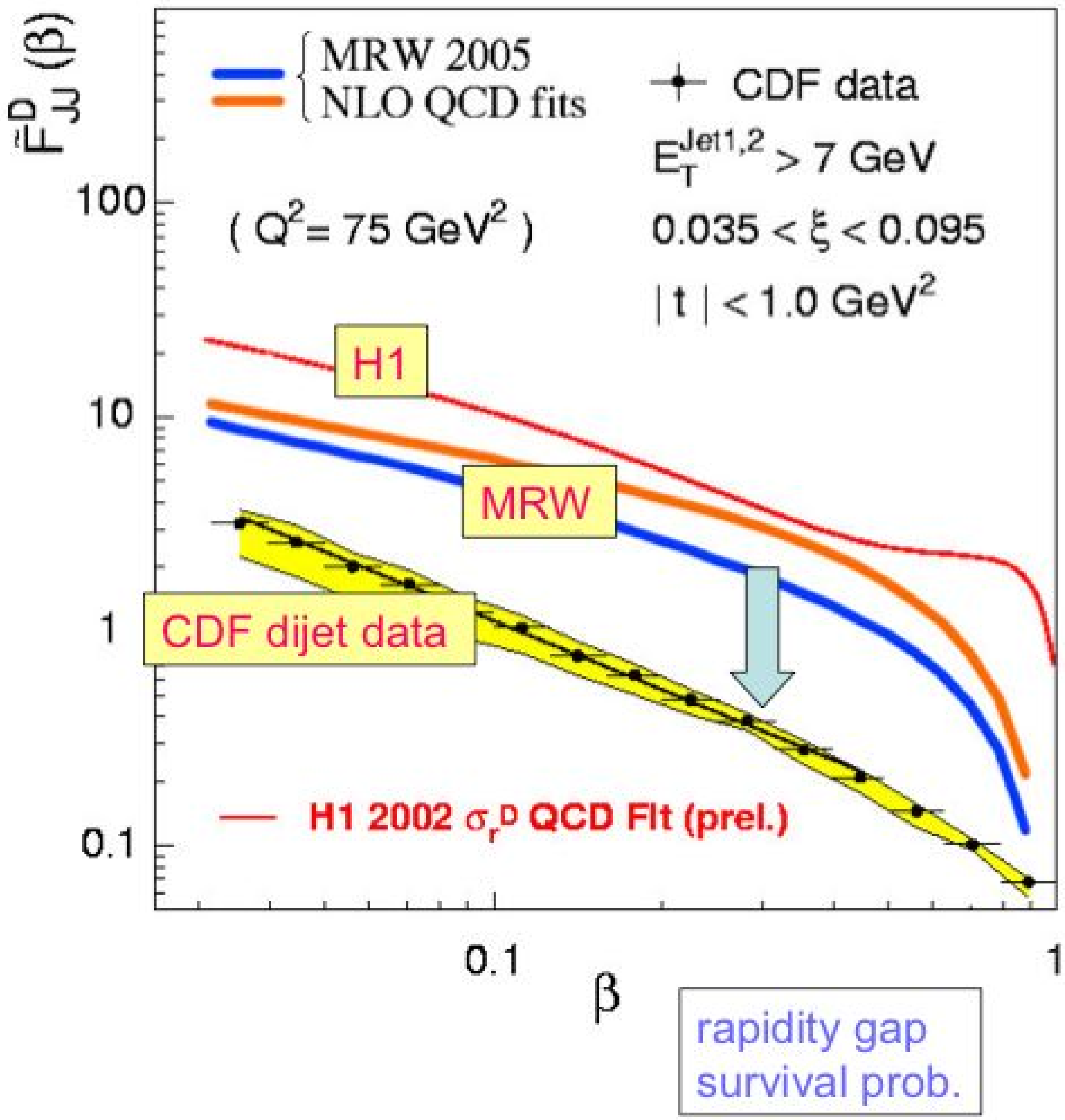
(d)

Factorisation holds

Jet production in diffractive processes **A. Martin**

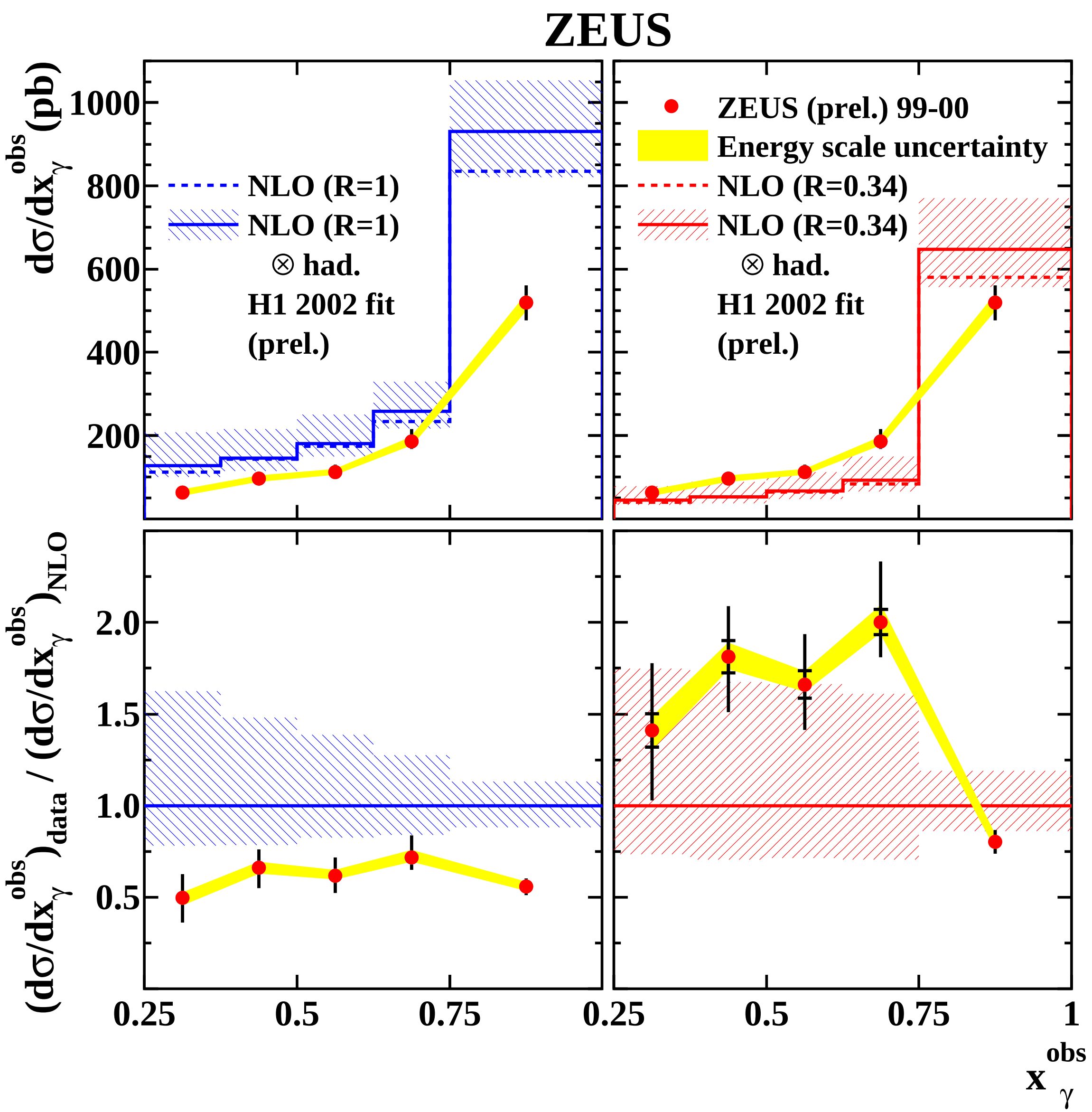






Jet production in diffractive photoproduction processes

M. Mozer (H1), R. Renner (ZEUS)



Factorisation breaking for all x_γ^{obs}

Diffractive summary

Much recent interest with the possibility of studying diffractive processes at the LHC.

Requires well-understood data and extracted parton densities with full uncertainties à la inclusive DIS.

Do data agree? Measure in the same kinematic region, compare methods.

Factorisation holds in DIS, both for charm and jet production, but does not hold for jet photoproduction (both direct and resolved).

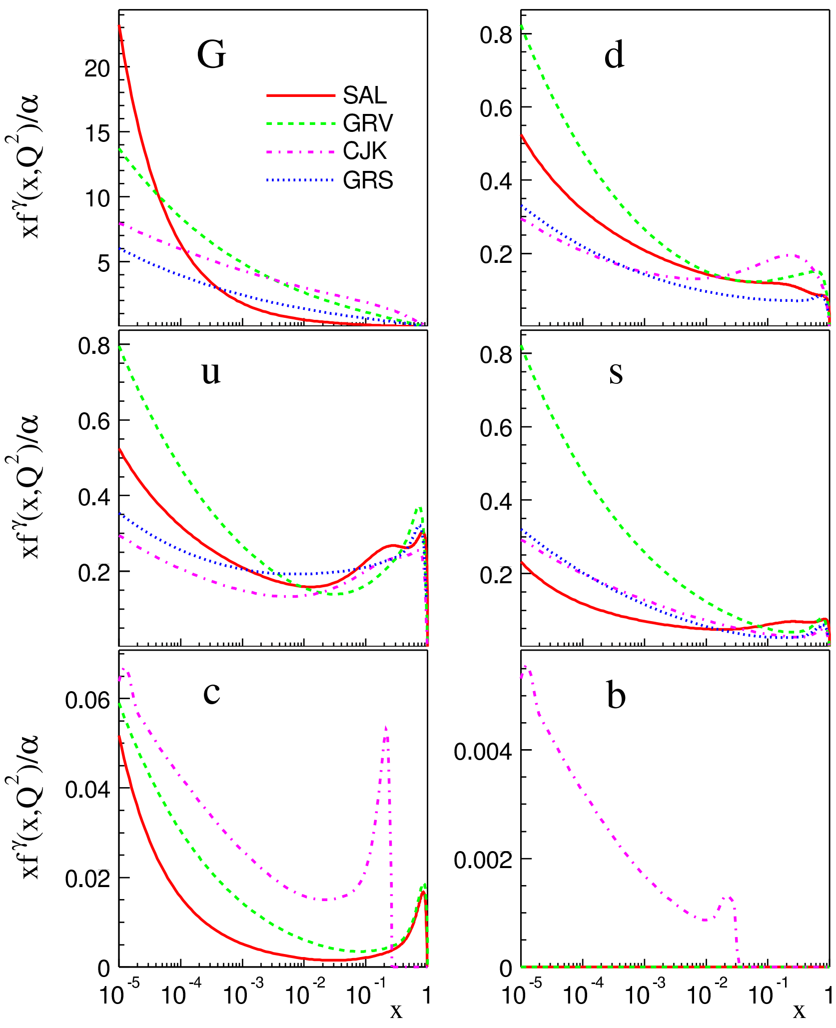
Validity of factorisation tests (and statements thereof) when comparing extracted PDFs+NLO to final state observables?

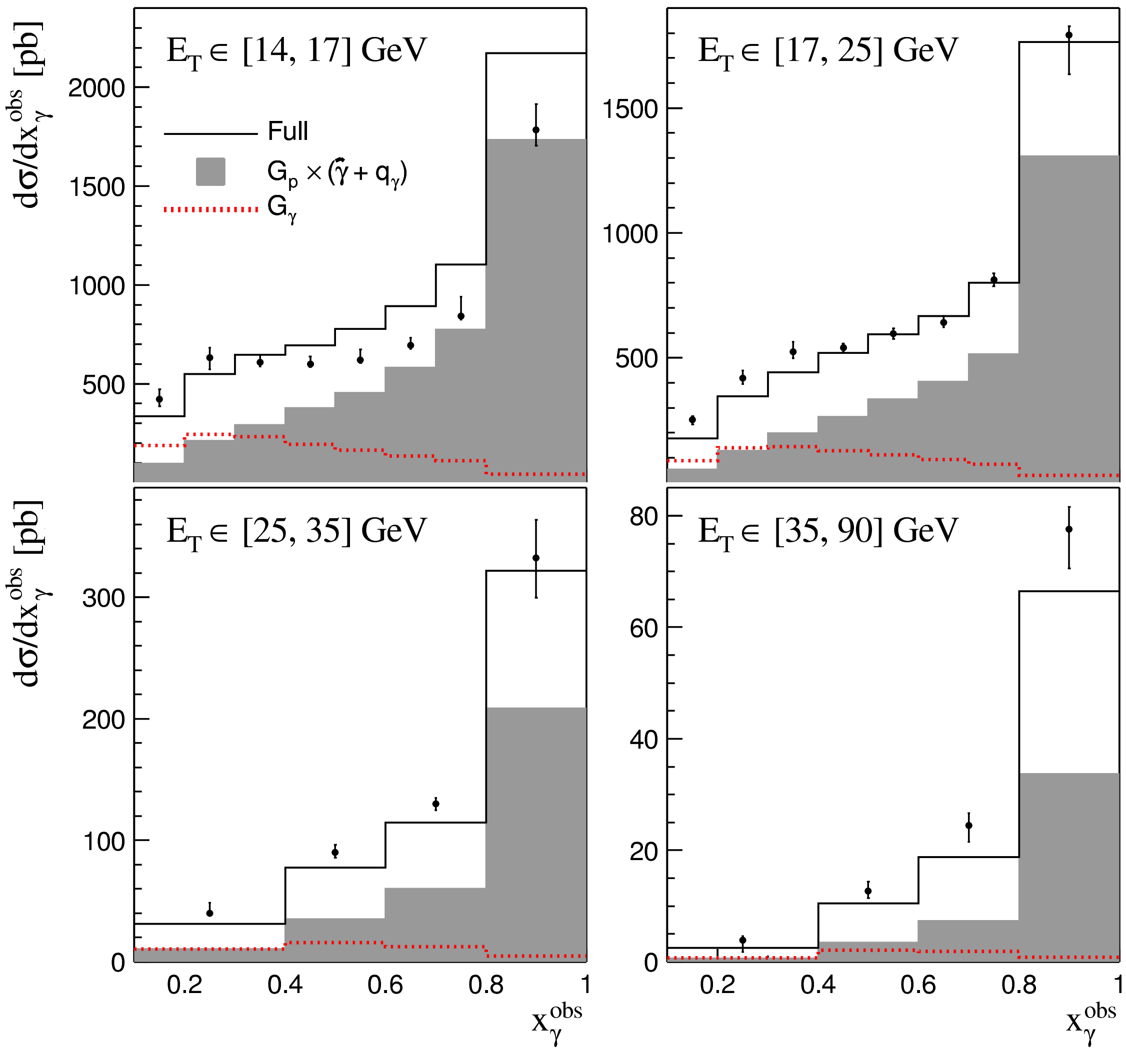
Jets, heavy flavour and QCD

Jet production

- **Constraints on the parton densities in the proton (and photon)**
- **Extraction of the strong coupling constant**
- **Understanding QCD calculations, underlying event, etc.**
- **Sensitivity to differences in BFKL and DGLAP schemes**
- **Search for new physics**
- **Study heavy quarks with less dependency on hadronisation**

Photon PDF - A. Levy

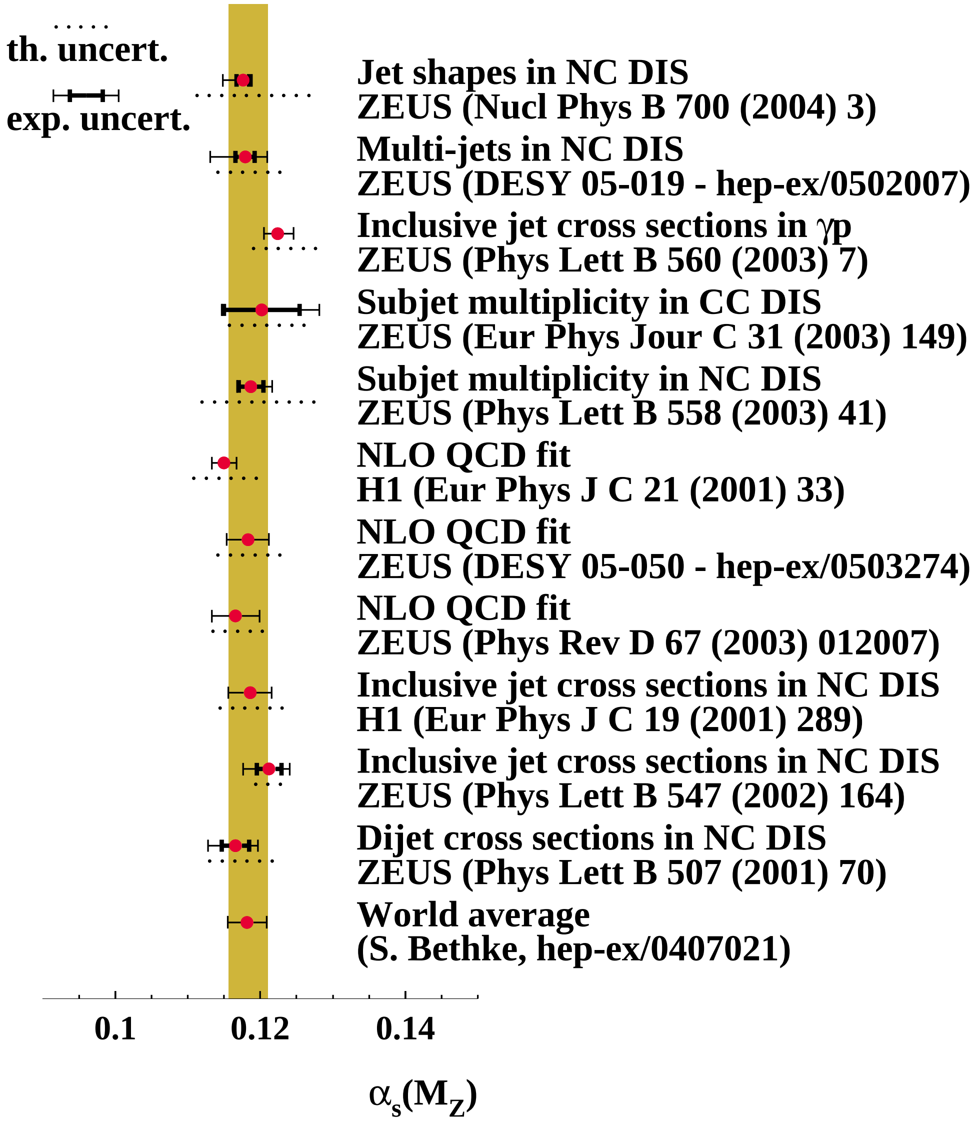


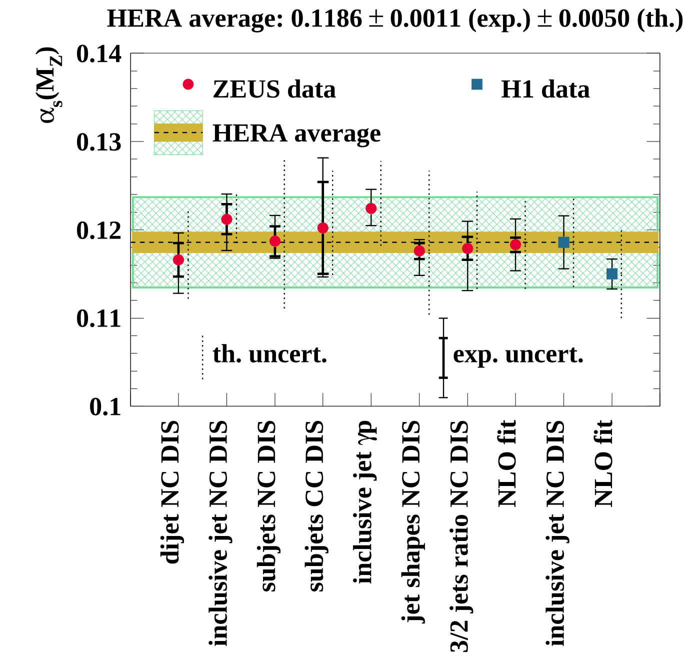


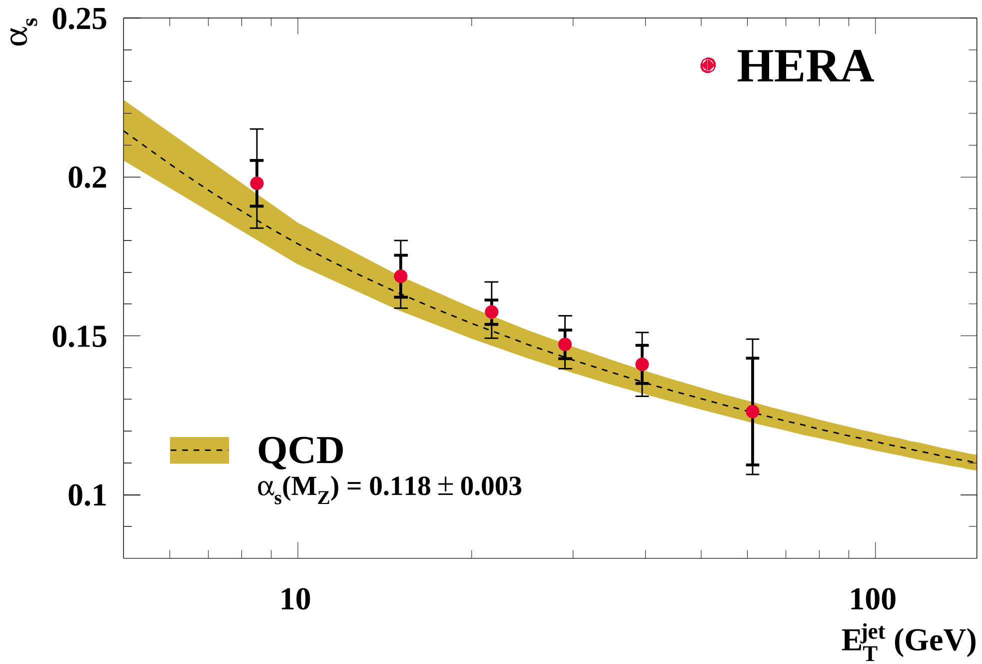
Uses F_2^p data at low x to constrain the gluon

New photon PDF available with propagated experimental uncertainties

Strong coupling constant - C. Glasman

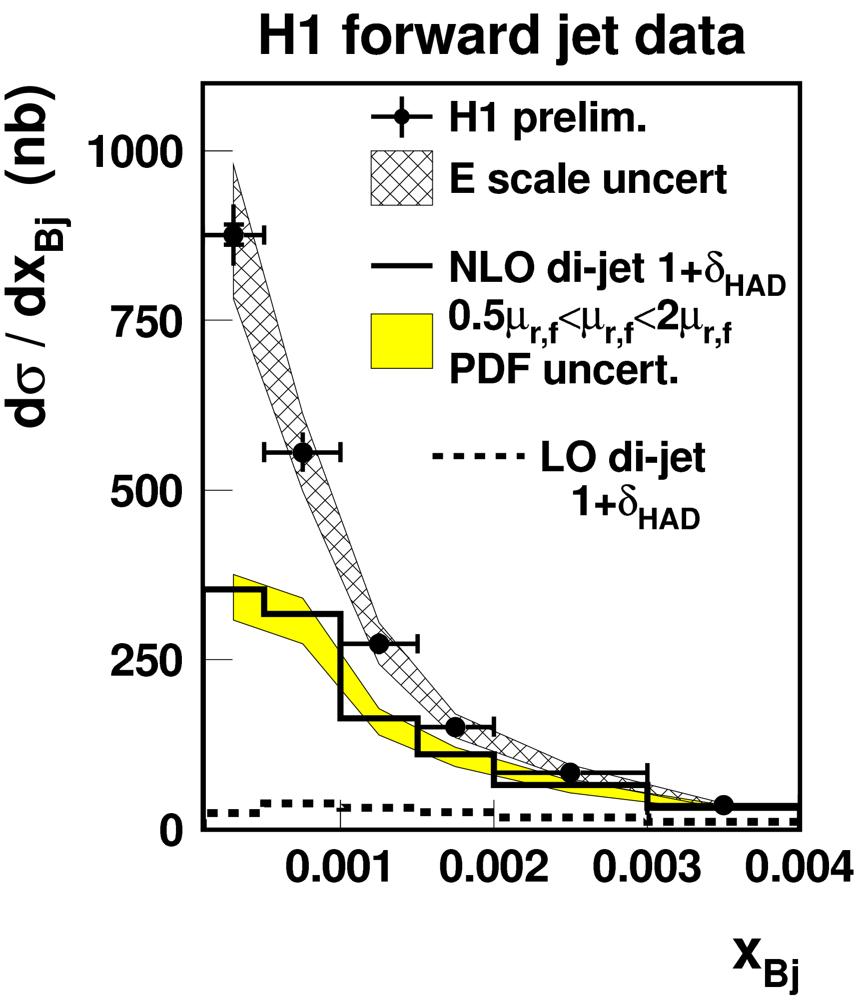


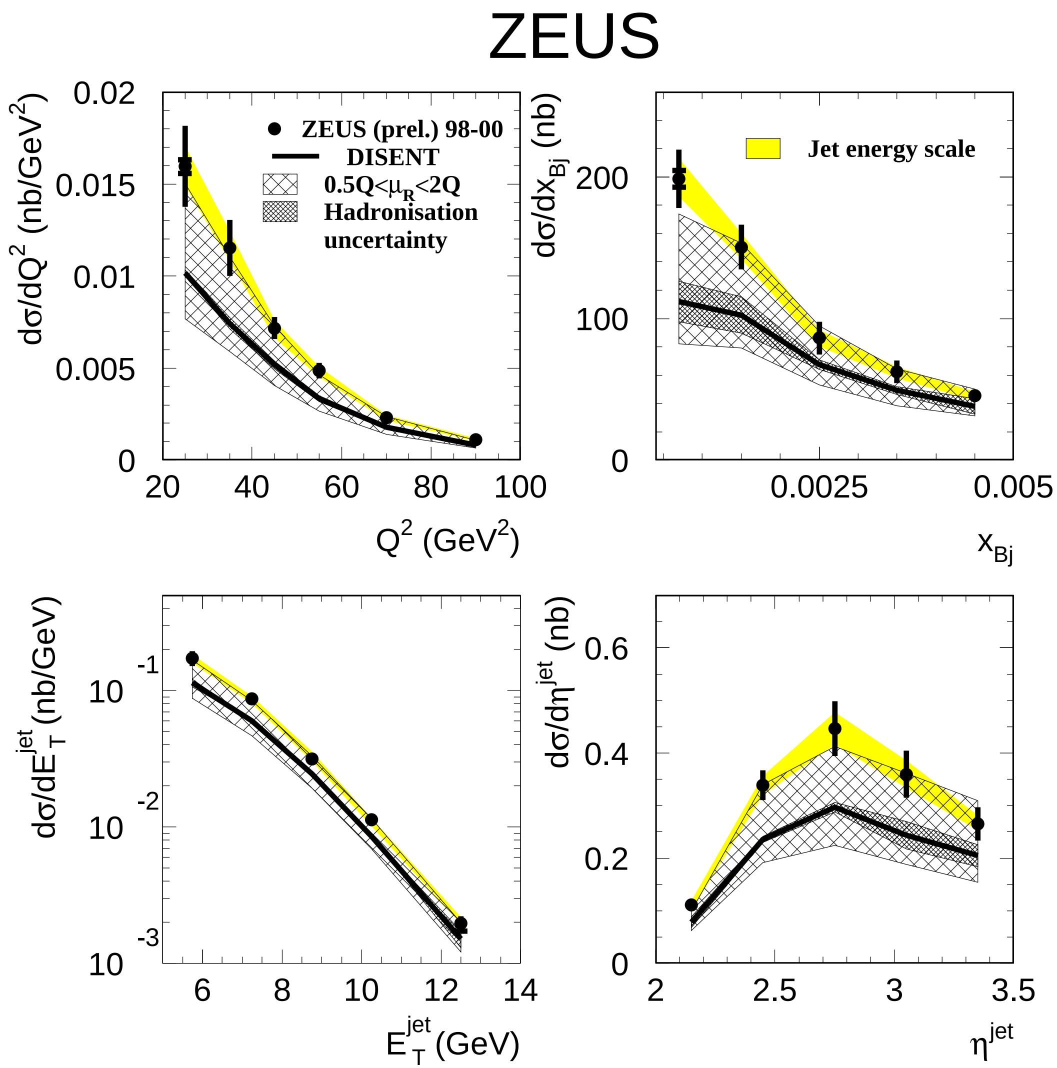




NNLO calculations needed

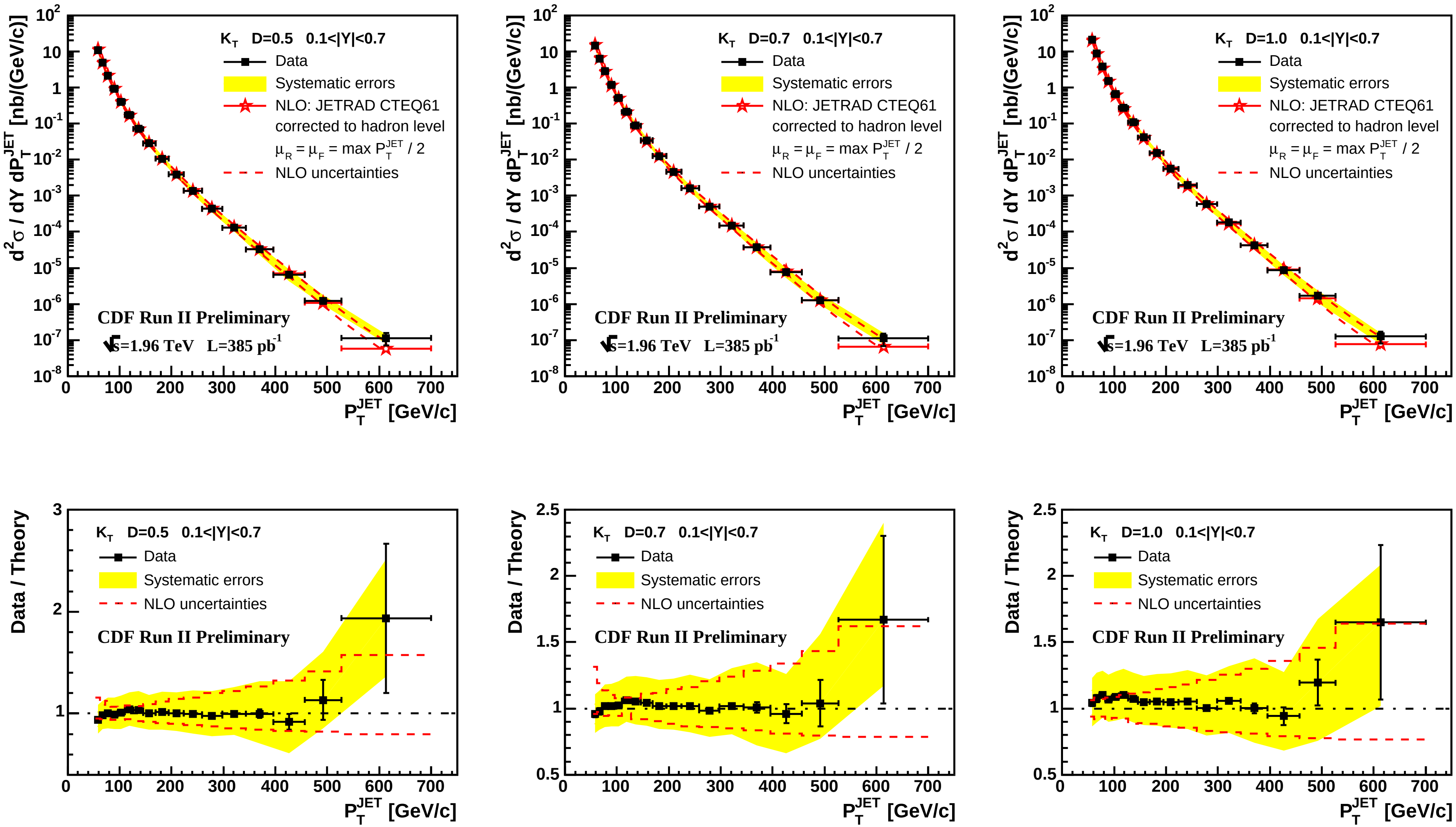
Forward jet production at HERA - A. Knutsson (H1), N. Vlasov (ZEUS)





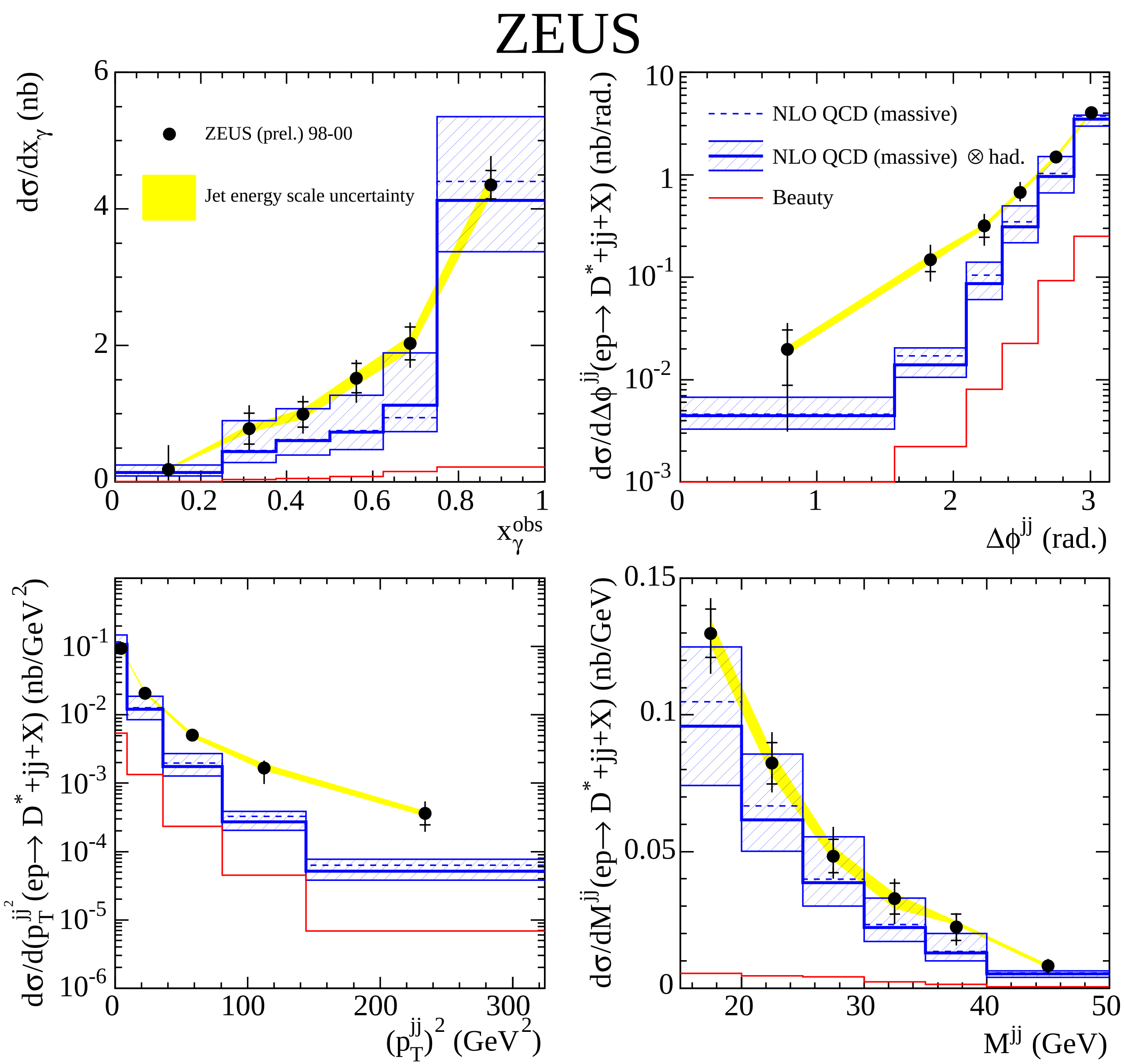
Difference in results... Scale and variation?

Inclusive jet cross section at the Tevatron



NLO describes data very well up to highest p_T^{jet}

Charm jet cross section at HERA - T. Kohno (ZEUS)



Perfect distributions to test MC@NLO implementation for HERA

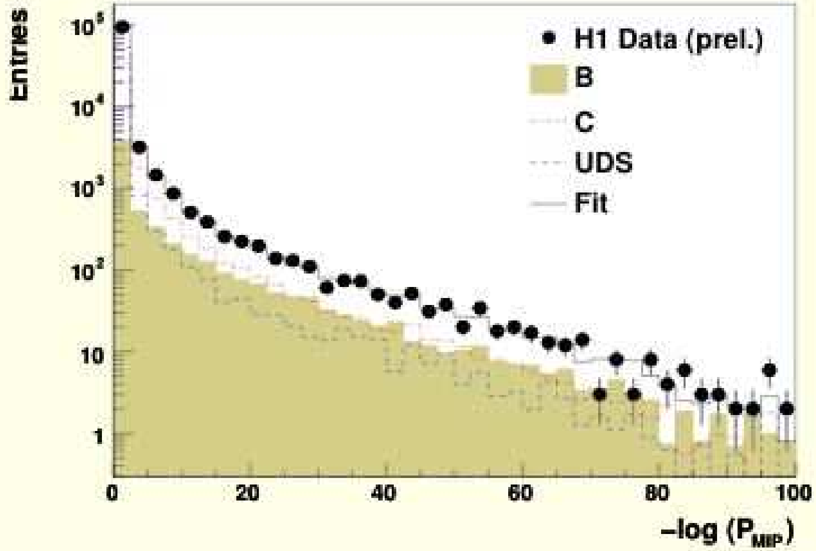
Heavy flavour tagging L. Finke (H1)

Lifetime Observables II

Alternative lifetime tag

Jet Probability*:

- ▷ Use **all selected tracks** within the two leading jets.
- ▷ Construct a probability P_{MIP} (from the significances) that the jets are compatible with the primary vertex.
- ▷ Low (i.e. large negative logarithm) probabilities indicate **secondary vertex**.
- ▷ Fit fractions of beauty, charm and light quarks.



Resulting cross sections are found to agree with the results obtained with S_1 and S_2.

(*follows ALEPH paper Phys. Lett. B **313** (1993) 535)

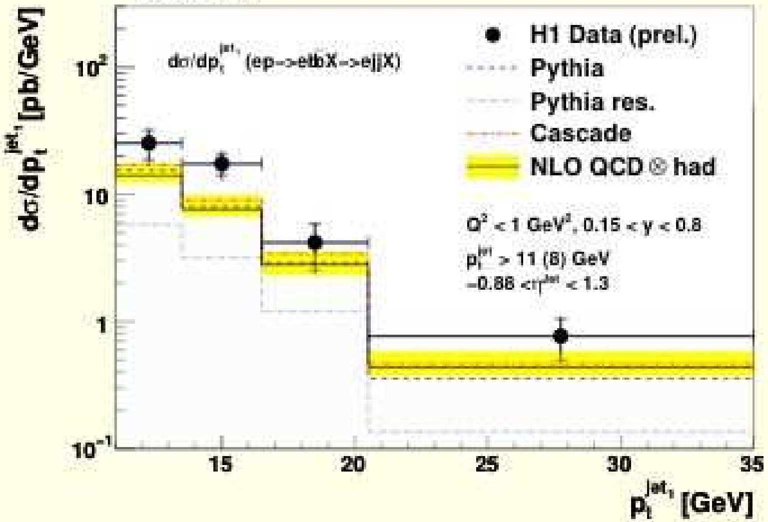
Heavy quark jet cross section at HERA - L. Finke (H1)

Beauty & Charm in Photoproduction

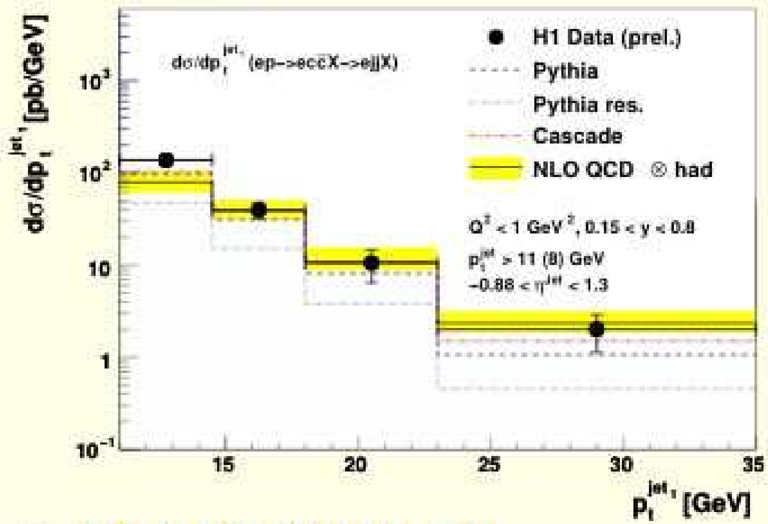
$$d\sigma/dp_t^{jet_1}(ep->ecc(bb)X->ejjX)$$

H1 99/00 e^+ data: $Q^2 \sim 0,\ 0.15 < y < 0.8$ || $p_t^{jet} > 11(8)$ GeV, $-0.88 < \eta^{jet} < 1.3$

BEAUTY



CHARM



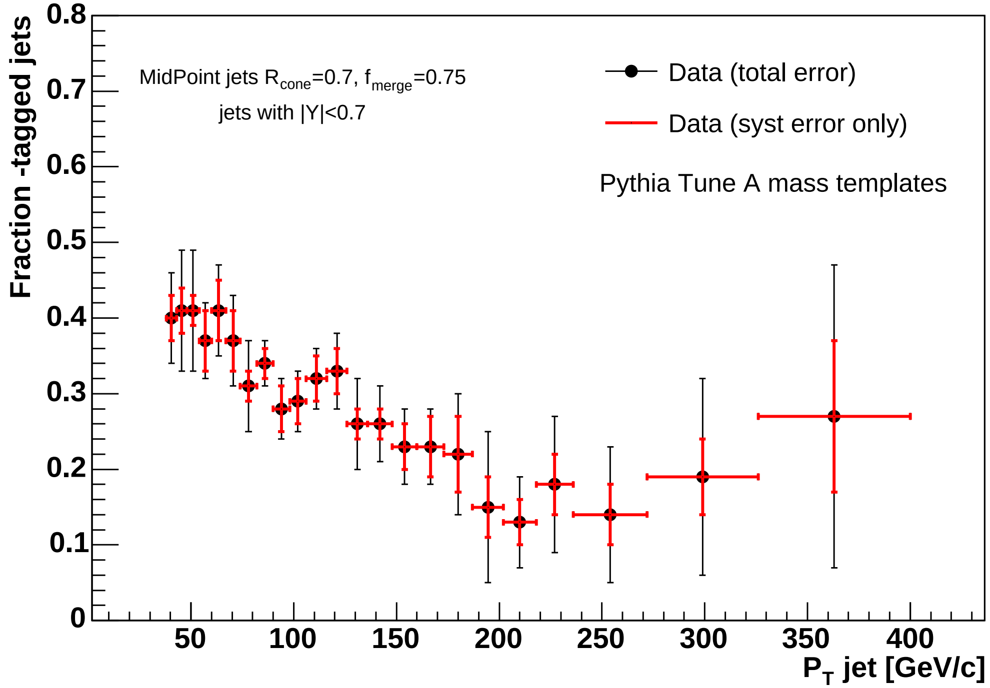
▷ **LO + PS QCD Models:**
Good description of shape.

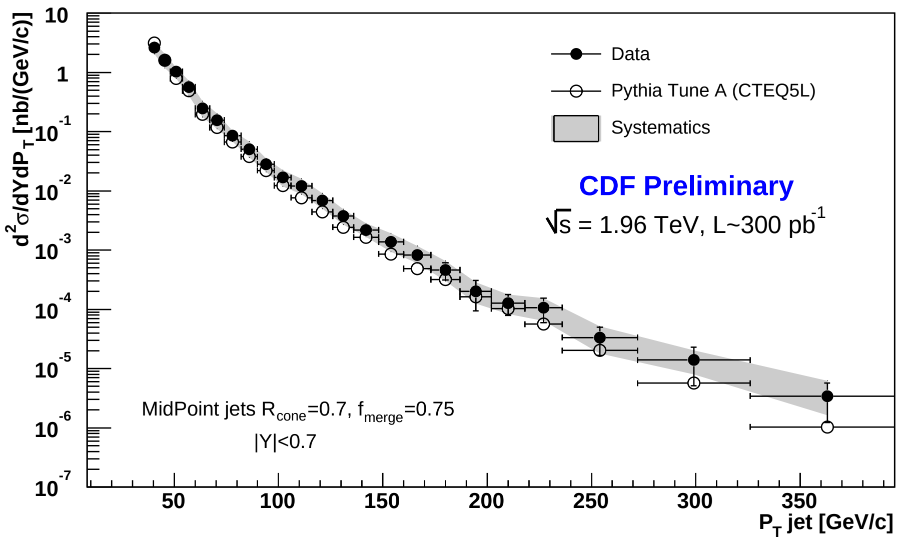
▷ **NLO QCD (FMNR):**
Slightly higher (at low p_t).

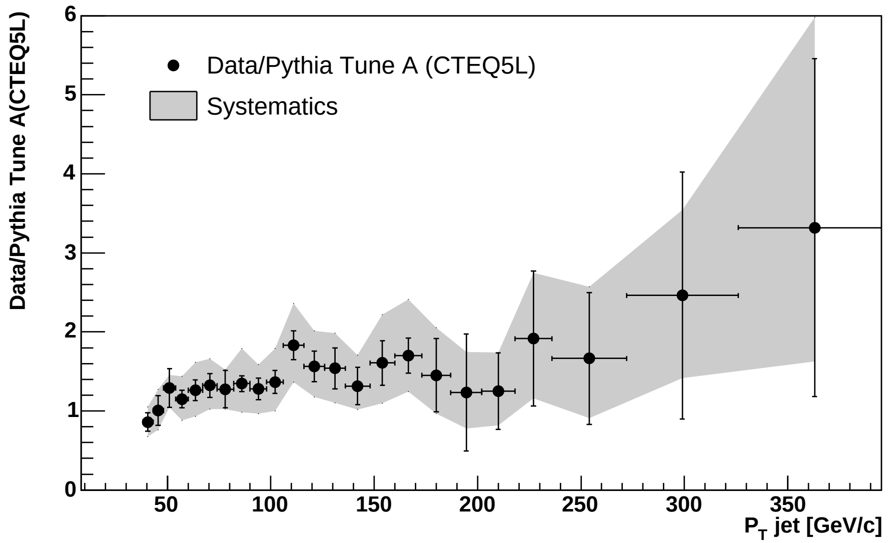
▷ **LO + PS QCD Models:**
Good description of shape and norm.

▷ **NLO QCD (FMNR):**
Fits within uncertainties.

Beauty jet cross section at the Tevatron







Description by PYTHIA is good.

Comparison with MC@NLO to come soon.

Improved Monte Carlo programmes - S. Frixione, P. Skands

<u>**Matrix Element Corrections**</u>

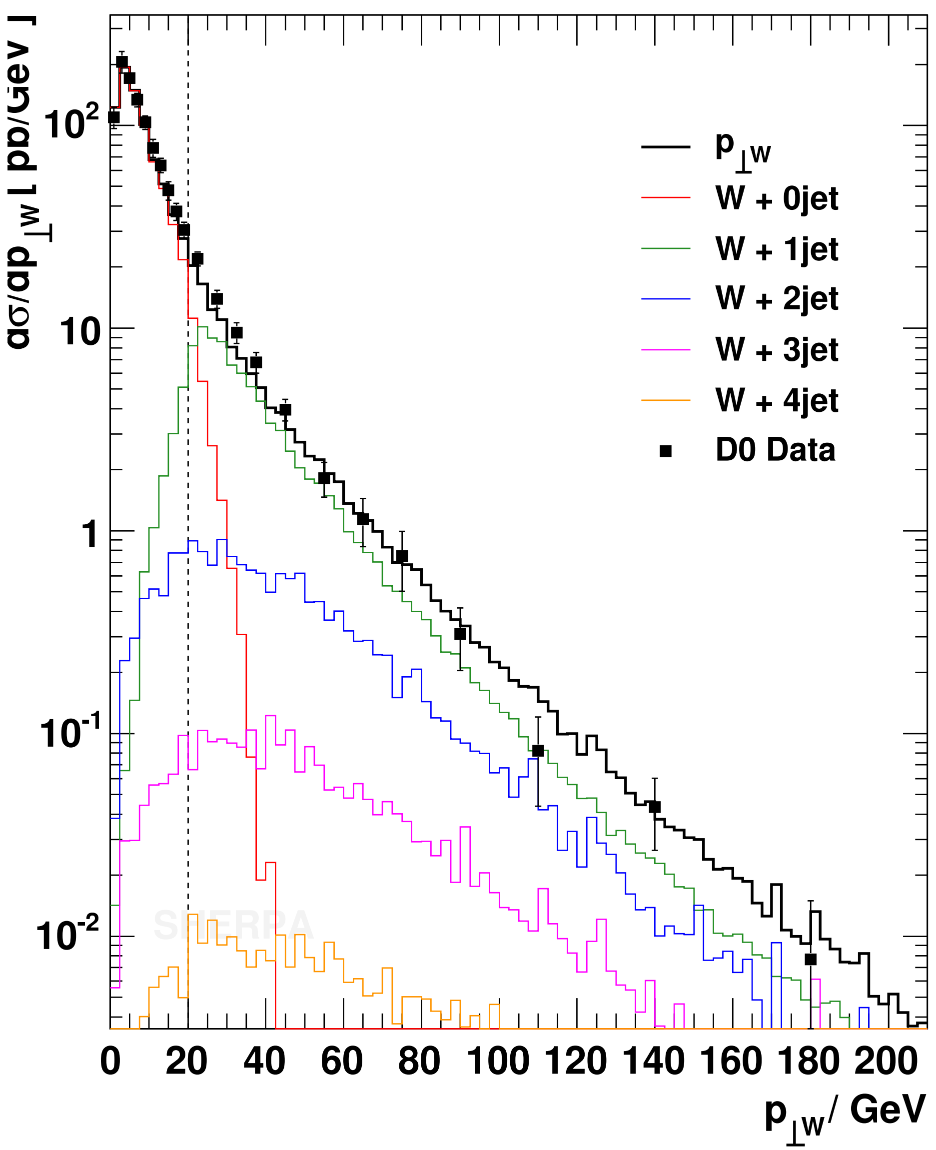
Calculate more real emission diagrams before starting the shower.

Problem: Double counting due to the shower generating the same diagrams and the diagrams are divergent.

Solution: Use an arbitrary parameter, δ_{sep}, to cut off the divergences.

Effect needs to be studied for each observable considered.

SHERPA →

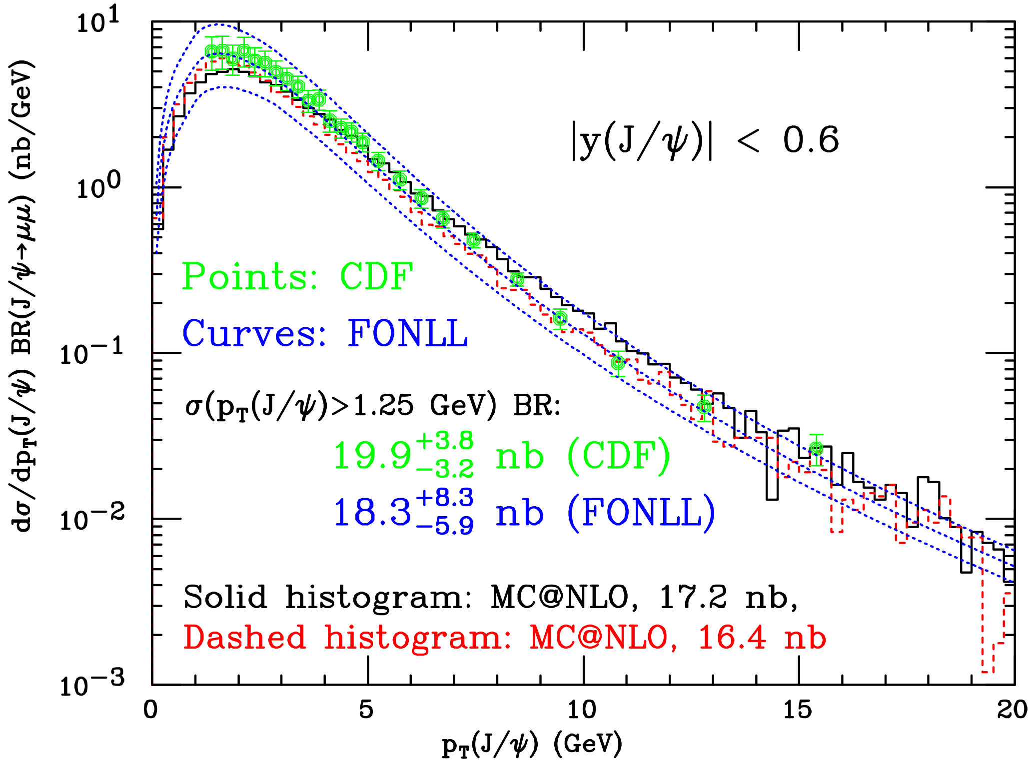


Improved Monte Carlo programmes - S. Frixione, P. Skands

<u>**NLO with parton showers**</u>

Advantages: Reliable cross section prediction and no δ_{sep} parameter.

Disadvantages: Fewer hard legs and negative weights



We would like such *new* Monte Carlo programmes for HERA.

Improved Monte Carlo programmes - S. Frixione, P. Skands

Other improvements

- HERWIG++ has been improved in its C++ re-write; showering, hadronisation - available for HERA?
- SHERPA has recently added the underlying event - implementation of HERA physics?
- PYTHIA 6.3 contains a re-written parton shower: order in p_T of branchings (rather than Q^2). Compared to some e^+e^- and $p\bar{p}$ data.
- PYTHIA 8 will be the re-write in C++ - priority is for LHC.

NNLO calculations - L. Dixon, M. Klasen

Progress on NNLO calculations

Has been done for structure functions - use in full NNLO QCD fit

For jet production, work ongoing to calculate all diagrams - when will we have a first Monte Carlo type programme?

Use of twistor space where momentum space described using spinors, not Lorentz vectors

Tree-level established; loop-level looks promising

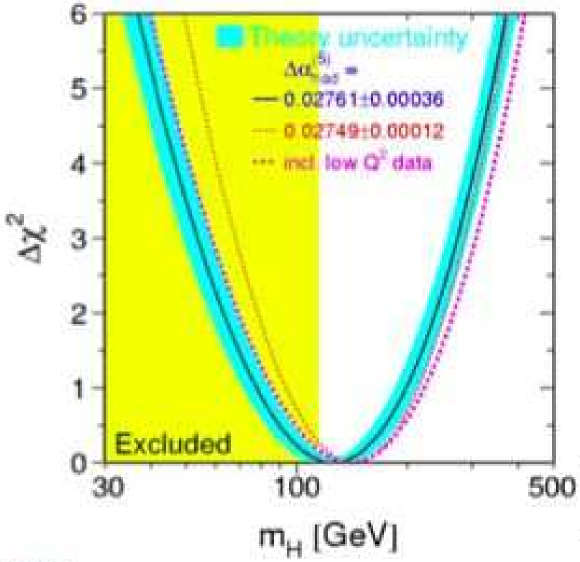
Electroweak and searches

Global EW fits **P. Renton**

P. Renton

Fits to electroweak precision data

THE BLUE BAND PLOT



Global electroweak fit – high Q^2 data

$m_t = 178.4 \pm 3.9$ GeV

$\alpha_S(M_Z) = 0.1188 \pm 0.0027$

$\Delta\alpha^{(5)}_{had}(M_Z) = 0.02770 \pm 0.00035$

$m_H = 126^{+73}_{-48}$ GeV

$\chi^2 = 18.3/13$ df (prob = 15 %)

$m_H < 280$ GeV (95% cl)

for $\Delta\alpha^{(5)}_{had}(M_Z) = 0.02749 \pm 0.00012$ $m_H \Rightarrow 143$ GeV

2004 'blueband' from uncertainties of 2 (& leading 3) loops for M_W & $\sin^2\vartheta_{eff}$ (main effect for m_H)

Awramik,Czakon,Freitas,Weiglein hep-ph/0311148,0407317 &refs therein
Faisst,Kuhn,Seidensticker,Veretin N Phys B665,649(2003) + many more!

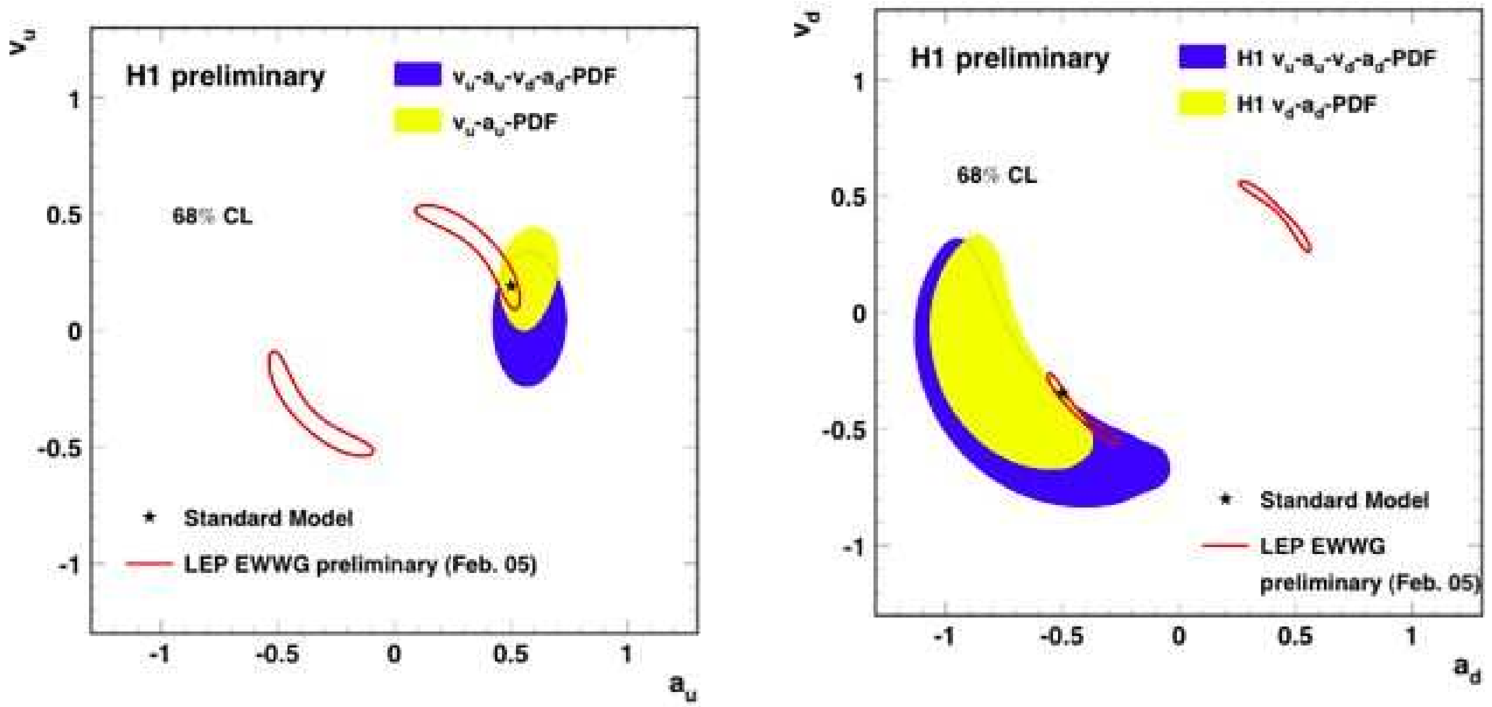
since Summer 2003 (Aachen EPS)

- new top mass increases m_H by ~20 GeV
- new 2-loop terms etc increase m_H by ~6 GeV
- updated heavy flav. res. increases m_H by ~12 GeV

H1 EW fits B. Portheault (H1)

B. Portheault

Determination of electroweak parameters at HERA with the H1 experiment



Precision will improve with HERA II high luminosity data

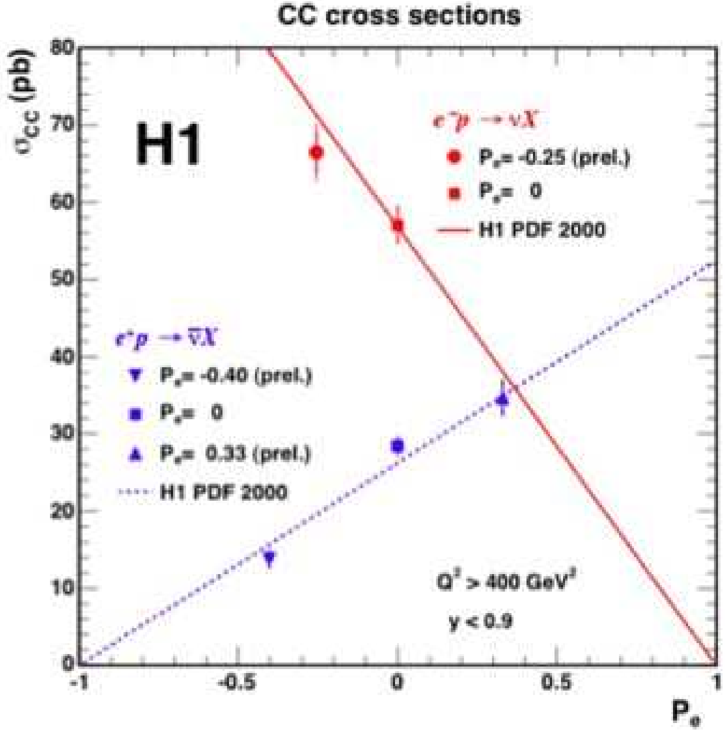
Precision in vector couplings will also improve with long. polarised data

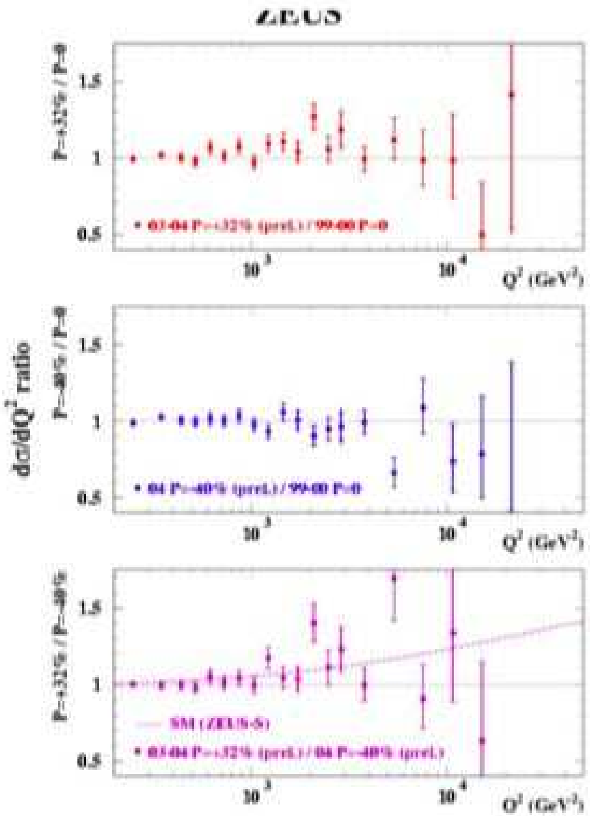
DIS cross section with polarised beams

A. Nikiforov (H1), A. Tapper (ZEUS)

A. Nikiforov & A. Tapper

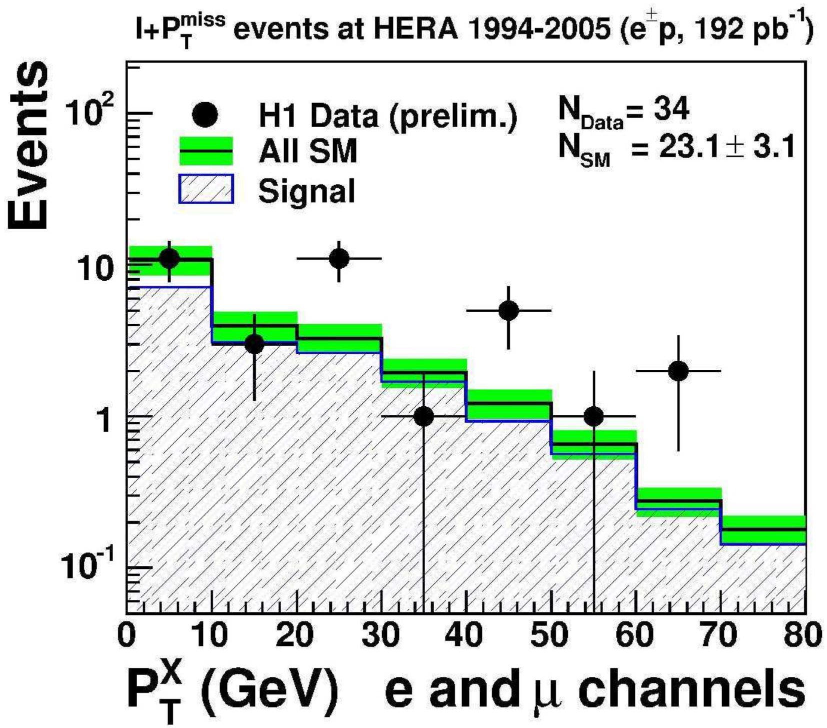
High Q² CC and NC DIS with polarised leptons





Isolated leptons with high missing transverse momentum

C. Veelken (H1), K. Piotrzkowski (ZEUS)



H1	electron obs./exp .	muon obs./exp.	tau obs./exp.
All P_T^X	25/18.3 $\pm$ 2.5	9/4.8 $\pm$ 0.8	5/5.8 $\pm$ 1.4
$P_T^X > 25$ GeV	11/3.0 $\pm$ 0.6	6/3.0 $\pm$ 0.6	0/0.5 $\pm$ 0.1

(Tau for 108 pb^{-1})

Isolated leptons with high missing transverse momentum

C. Veelken (H1), K. Piotrzkowski (ZEUS)

H1	electron obs./exp .	muon obs./exp.	tau obs./exp.
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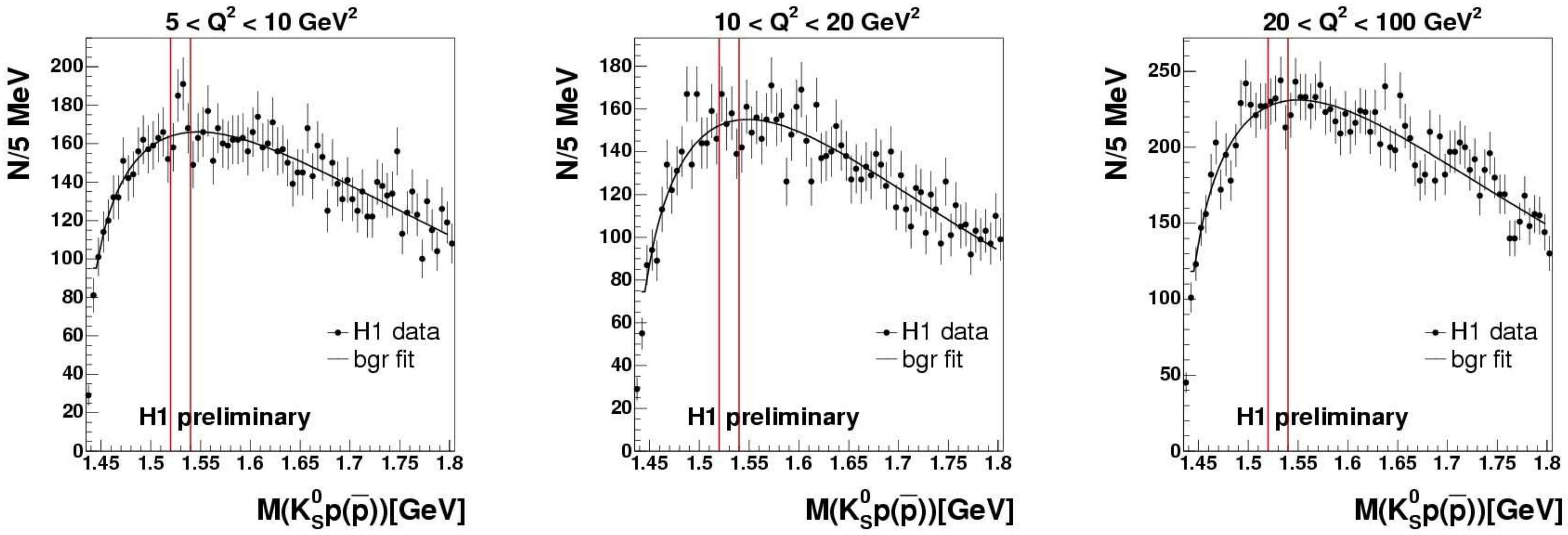
ZEUS	electron obs./exp .	muon obs./exp.	tau obs./exp.
All P_T^X	24/20.6 $^{+1.7}_{-4.6}$	12/11.9 $^{+0.6}_{-0.7}$	3/0.40 $\pm$ 0.12
$P_T^X >$ 25 GeV	2/2.9 $\pm$ 0.6	5/2.75 $\pm$ 0.21	2/0.20 $\pm$ 0.05

Potentially new physics; need to analyse more data quickly

Searches for single top, gravitinos, squarks, sleptons, etc. performed - none found, limits set

Search for Θ^+ - C. Risler (H1)

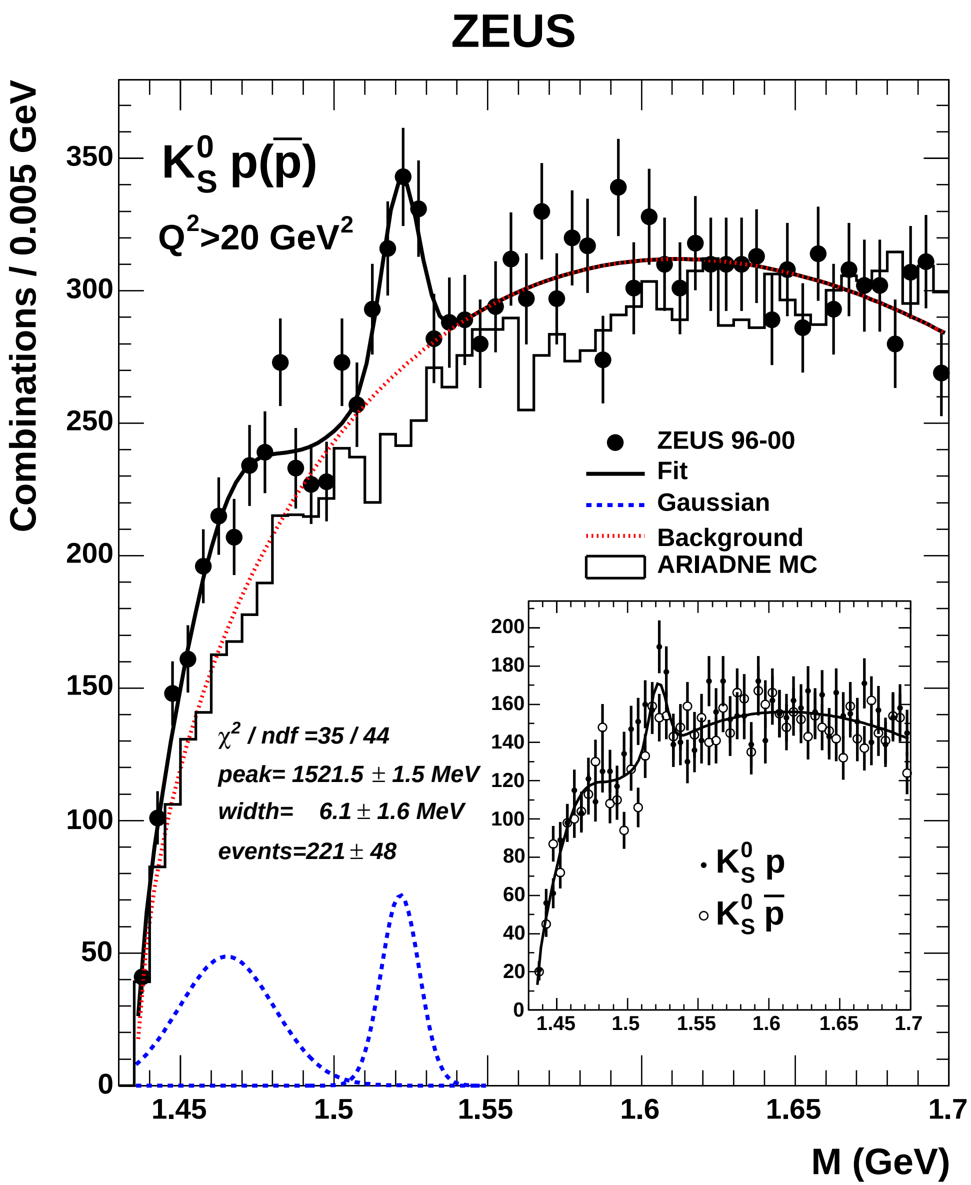


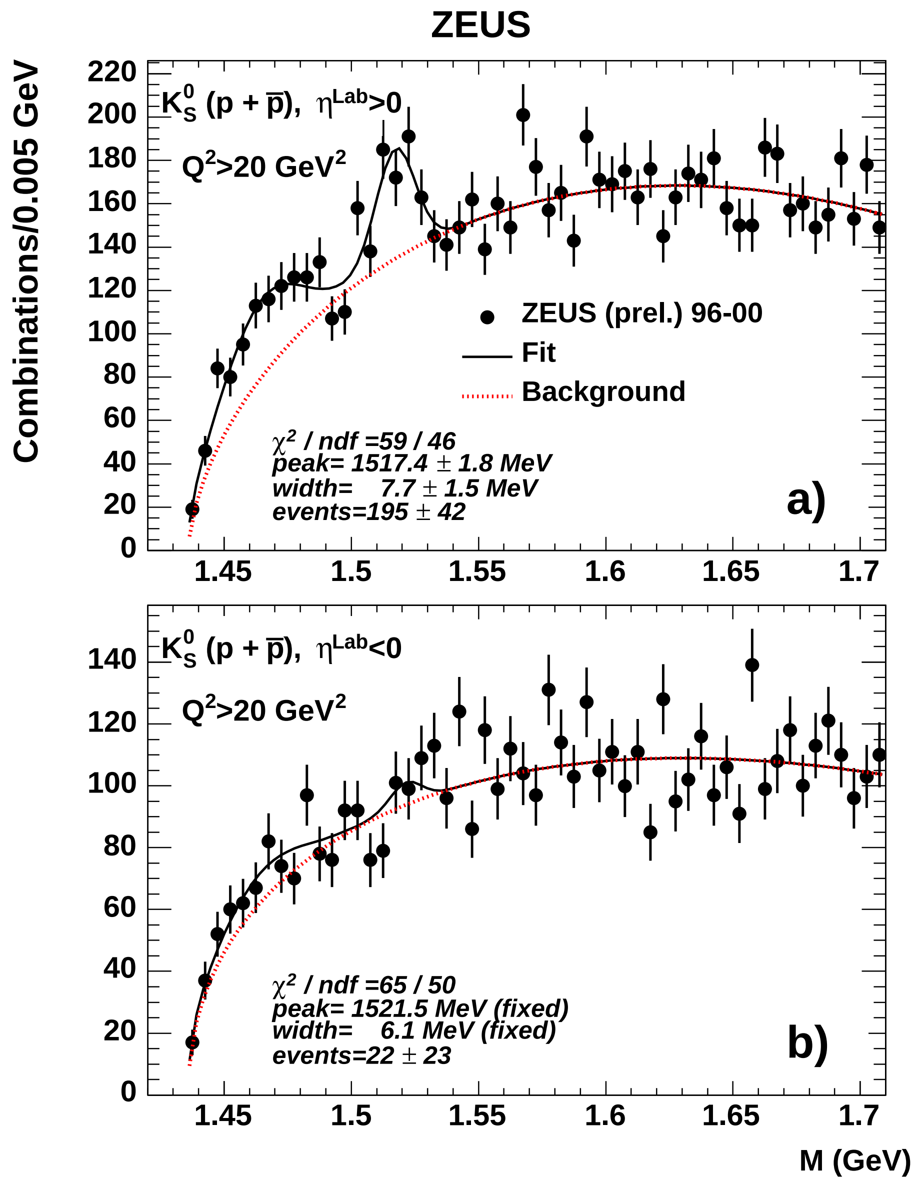
No significant signal seen

$\sigma_{\text{U.L.}} \sim$ **100 pb (20** $< Q^2 <$ **100 GeV^2, 0.1** $< y <$ **0.6)**

cf. ZEUS result: $\sigma(ep \to e\Theta^+ X \to eK^0 pX) \sim$ **125** $\pm$ **27** $^{+36}_{-28}$ **pb**
($Q^2 >$ **20 GeV^2, 0.04** $< y <$ **0.95)**

Search for Θ^+ - Z. Ren (ZEUS)

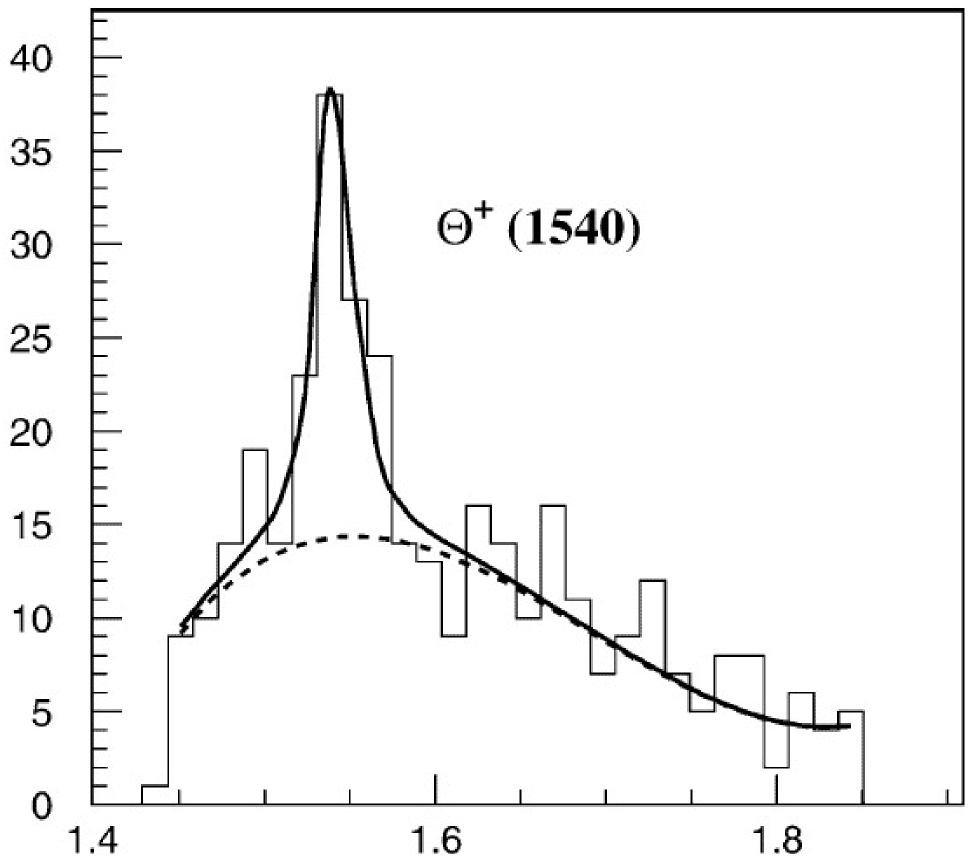




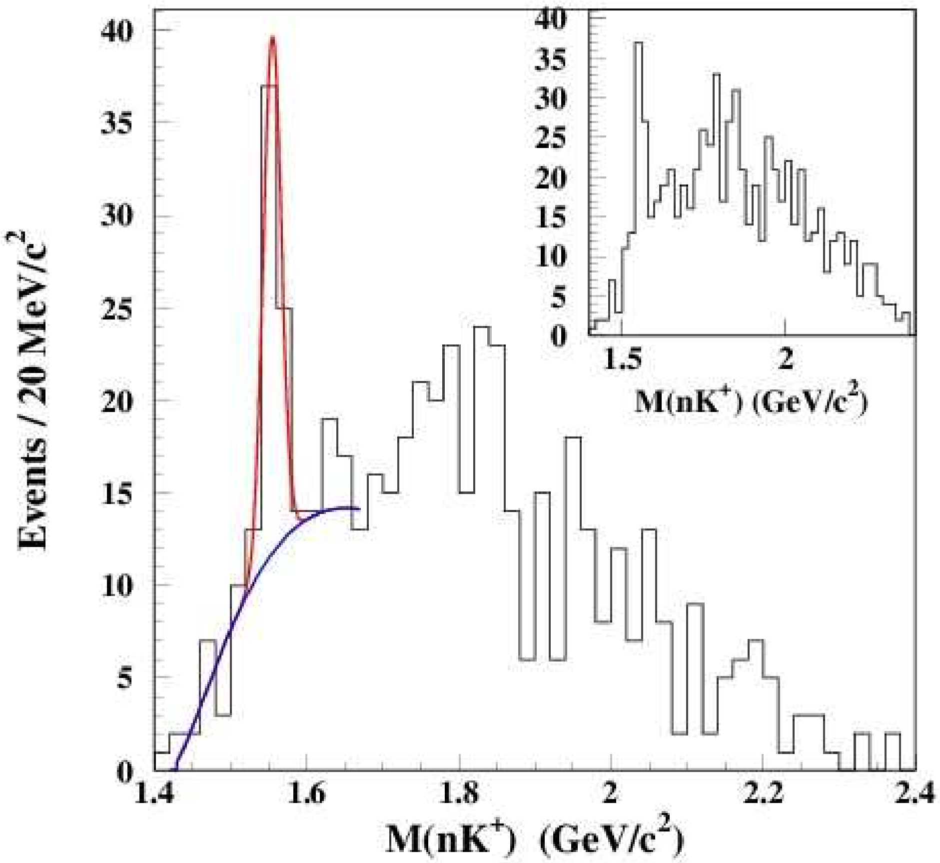
Difference at 3σ level for forward/backward production

Search for Θ^+ - M. Battaglieri (CLAS)

SAPHIR



CLAS



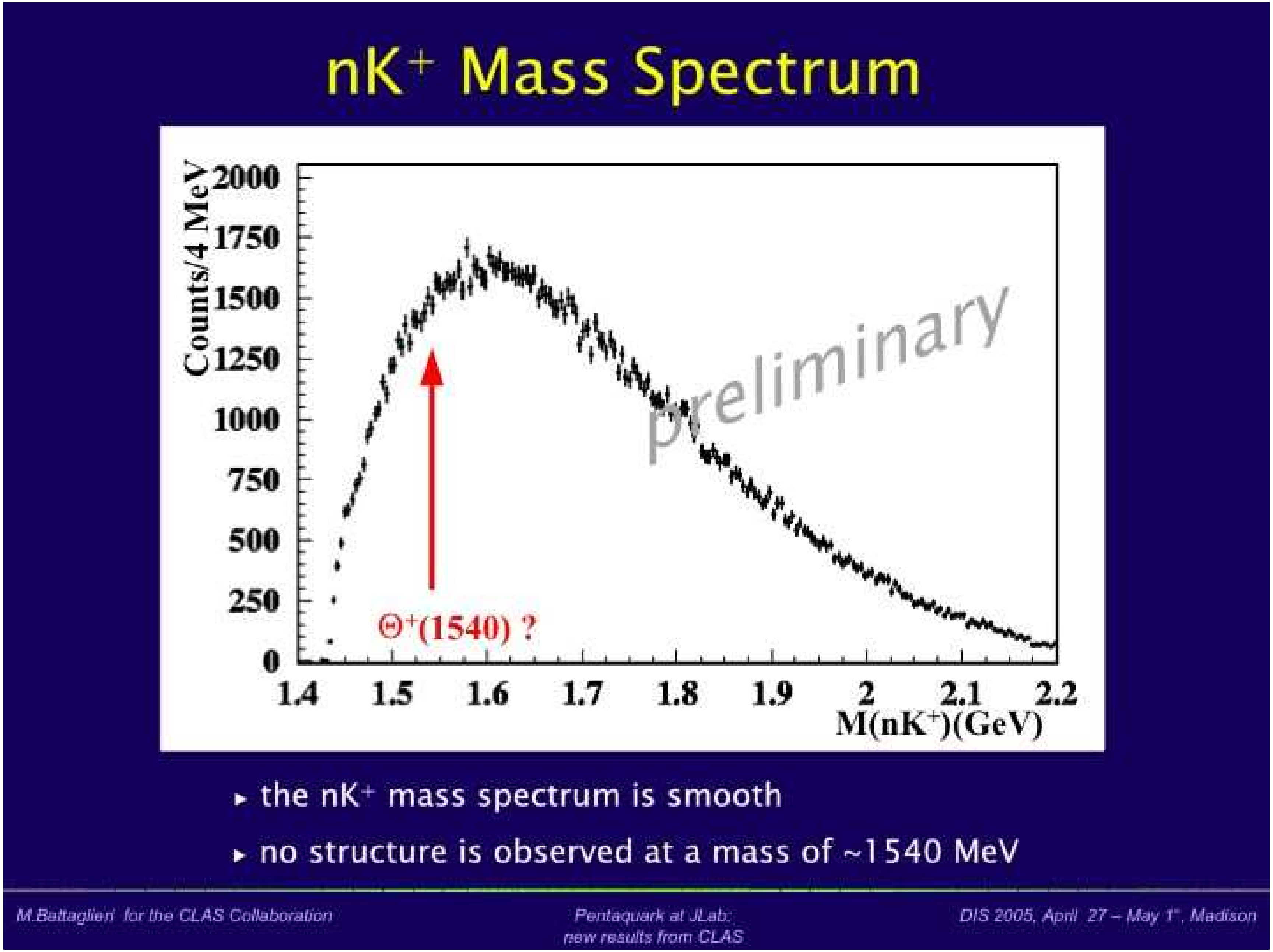
$\gamma p \rightarrow \Theta^+ \bar{K}^0, \quad E_\gamma - 1.6 - 2.6$ **GeV**

Investigated by CLAS here

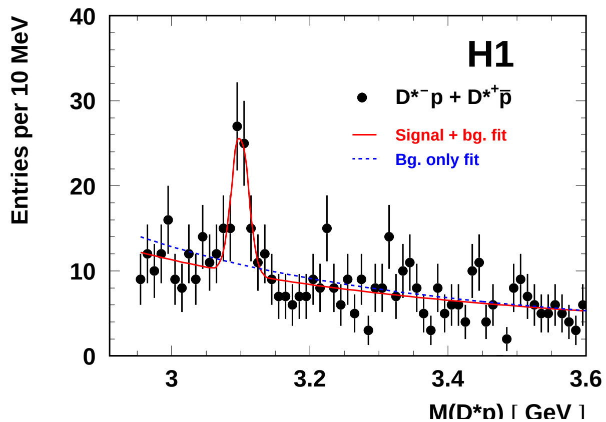
$\gamma p \rightarrow \Theta^+ K^- \pi^+$

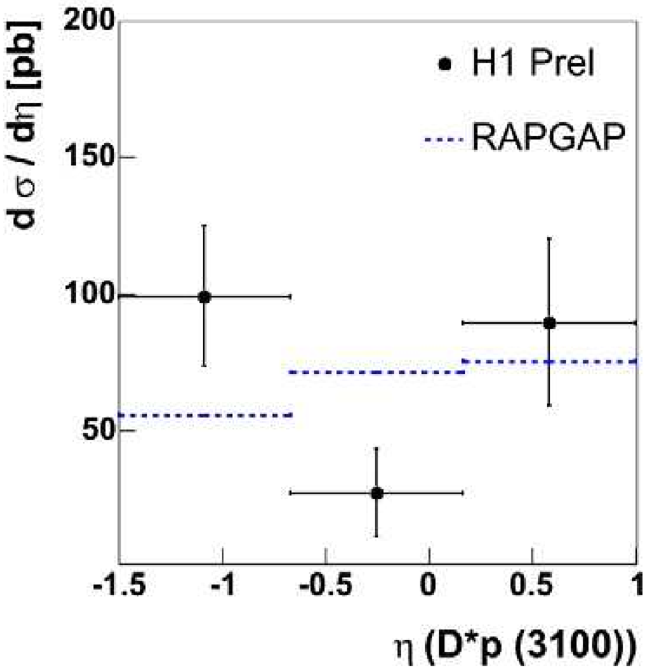
Dedicated experiment in 2006

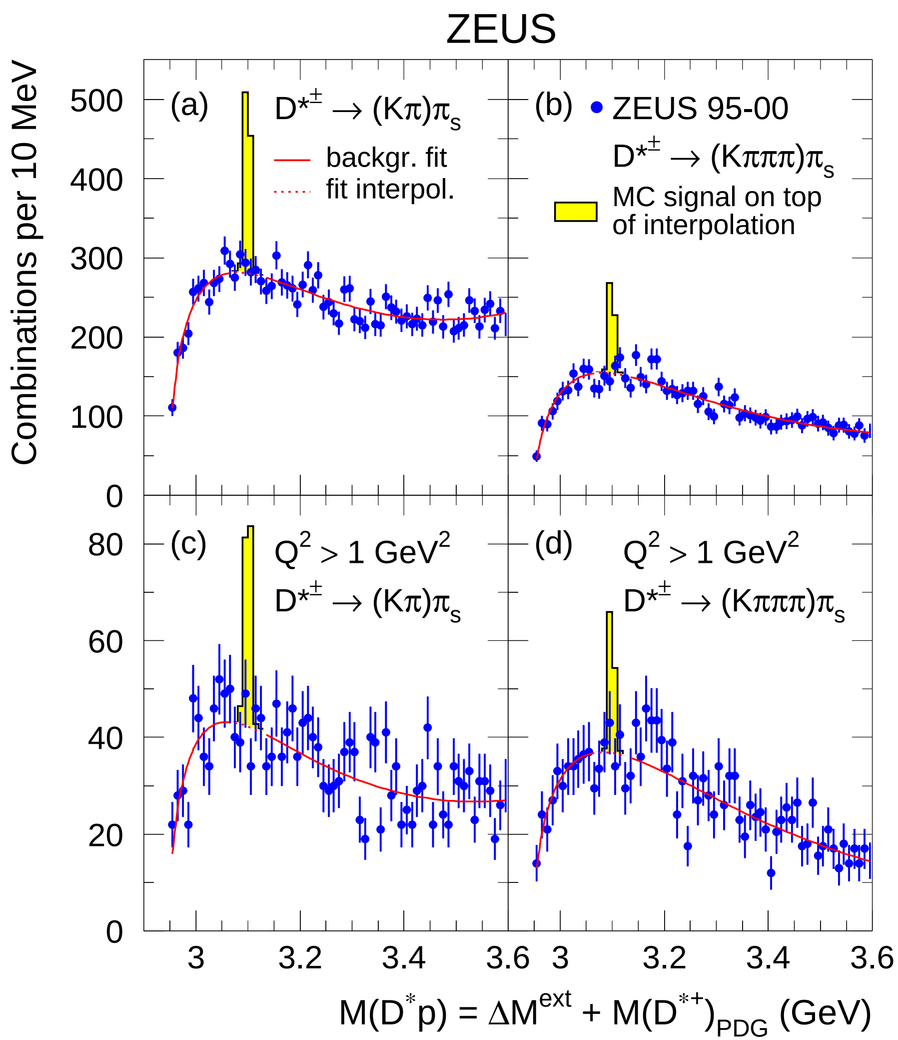
Search for Θ^+ - M. Battaglieri (CLAS)



Search for Θ_c - K. Daum (H1)/Y. Eisenberg (ZEUS)







$$R(D^*p(3100)/D^*) = 1.59 \pm 0.33^{+0.33}_{-0.45}\%$$

$$R(D^*p(3100)/D^*) < 0.35\%$$

Pentaquarks summary

Existence (or not) of pentaquarks in unclear:

- **Many positive and negative results for** Θ^+
- **One positive and many negative results for** $\Phi(1860)(\Xi_5(1860))$
- **One positive and many negative results for** Θ_c

Study of kinematics/properties of "observed" particles can help

The best way forward is to have more data, cf. new CLAS results

Summary

Understanding of structure of the proton (at high Q^2) has deepened - new theoretical and experimental techniques

Jet and heavy-quark production provides many insights but needs more accurate theory for further improvements, cf measurement of α_s

Theorists and Monte Carlo authors should calculate ep processes as a matter of urgency

Looking for exotic physics; high p_T leptons, pentaquarks - more data needs to be analysed

What is the future of DIS - few years of HERA and analysis of data and then: eRHIC, HERA III, eLHC?