ZEUS New Results

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on behalf of the ZEUS Collaboration
DIS 2004, Strbské Pleso, Slovakia, April 14, 2004

HERA I:

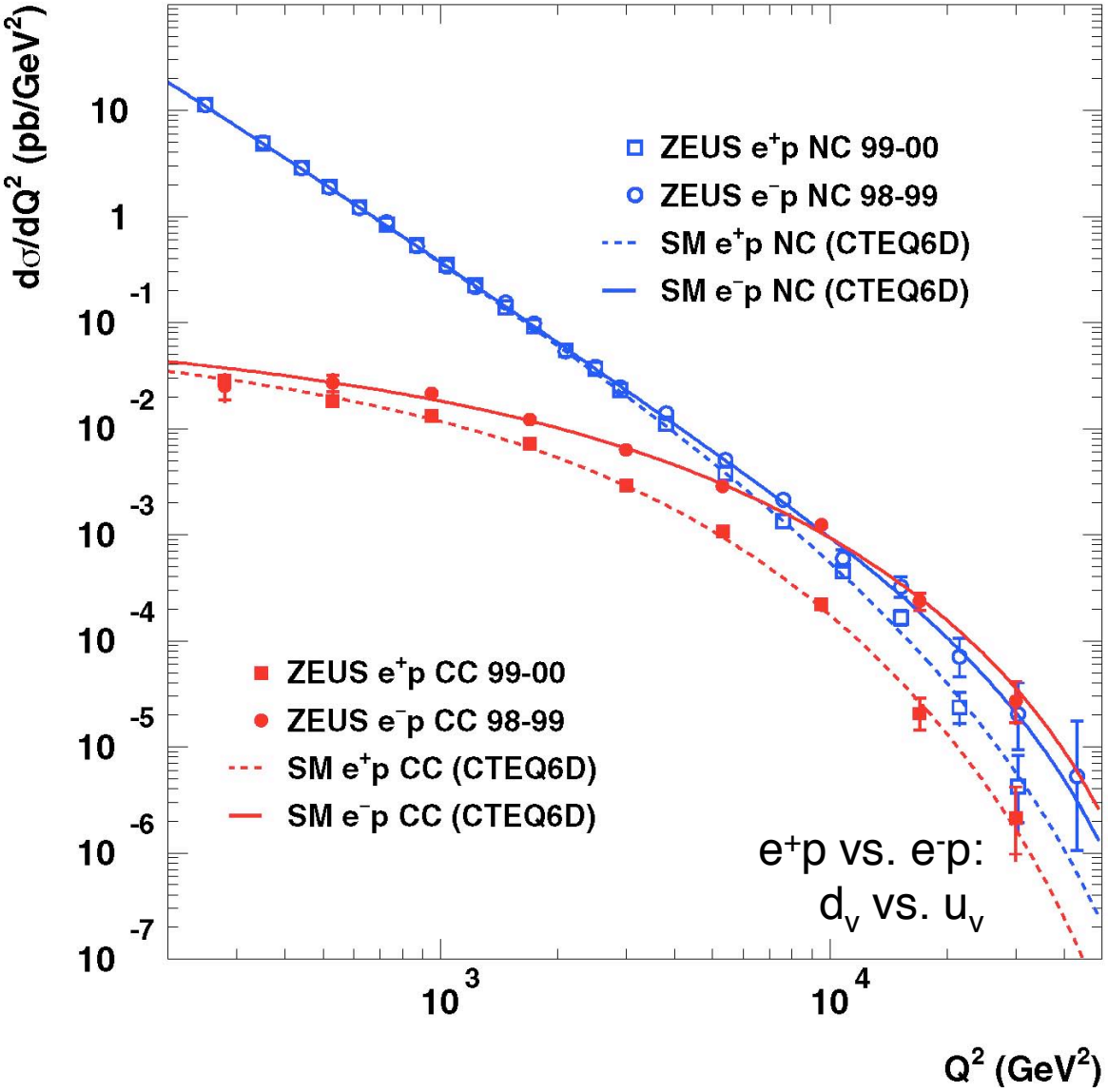
Structure Functions & QCD fits
Hadronic Final States & α_s
Heavy Flavors
Diffraction
Searches

HERA II:

Polarized Charged Currents
Tagged Charm

This talk is available on:
http://www.hep.wisc.edu/wsmith/zeus/wsmith-ZEUS-DIS04.pdf

Electroweak Unification



Charged & Neutral Current σ's

- Protons on electrons and positrons

$Q^2 < 1000\ GeV^2$

- $\sigma^{NC} >> \sigma^{CC}$ due to γ vs. W propagator

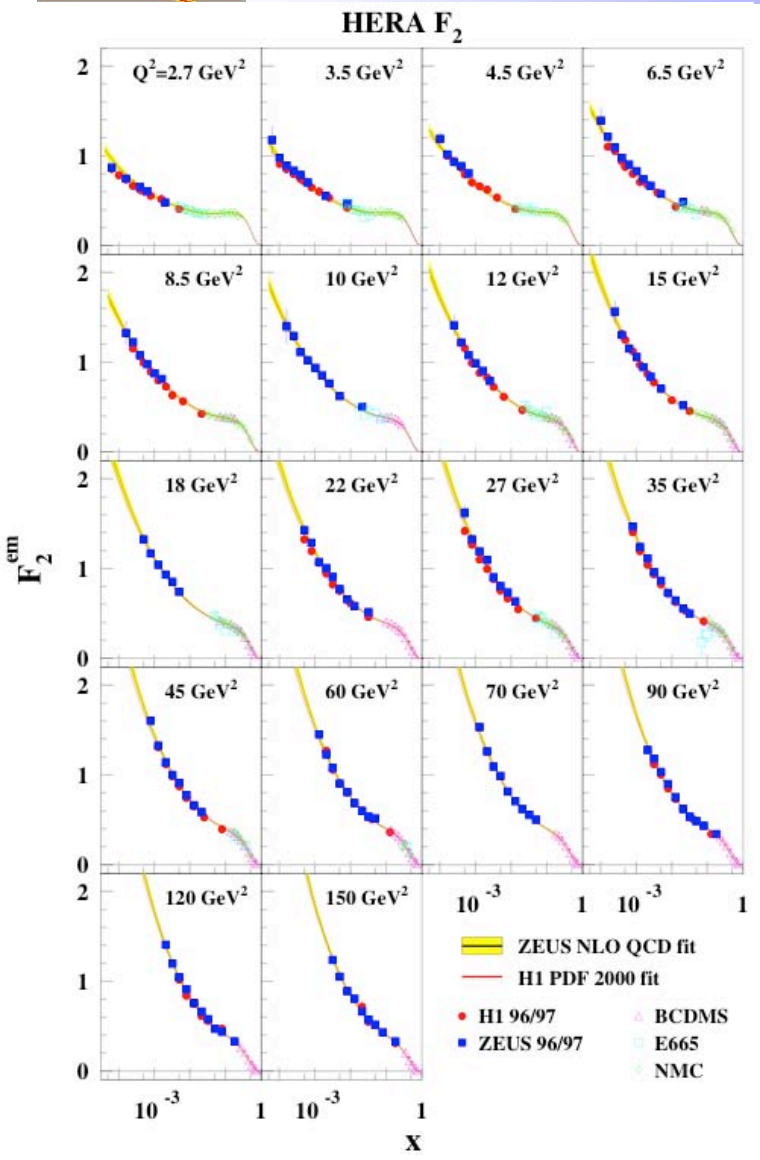
$Q^2 \geq 10000\ GeV^2$

- Unification of weak & EM forces

Standard Model

- Excellent description of data

Structure Functions

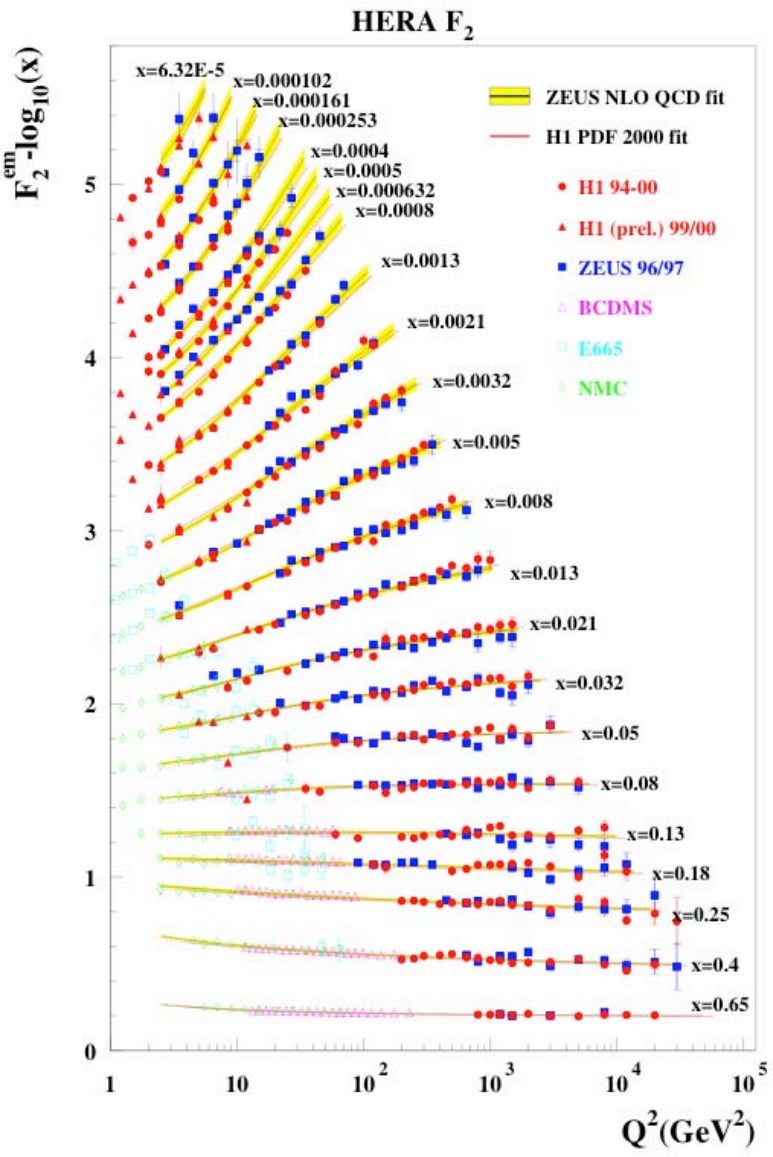


←F_2 vs. x

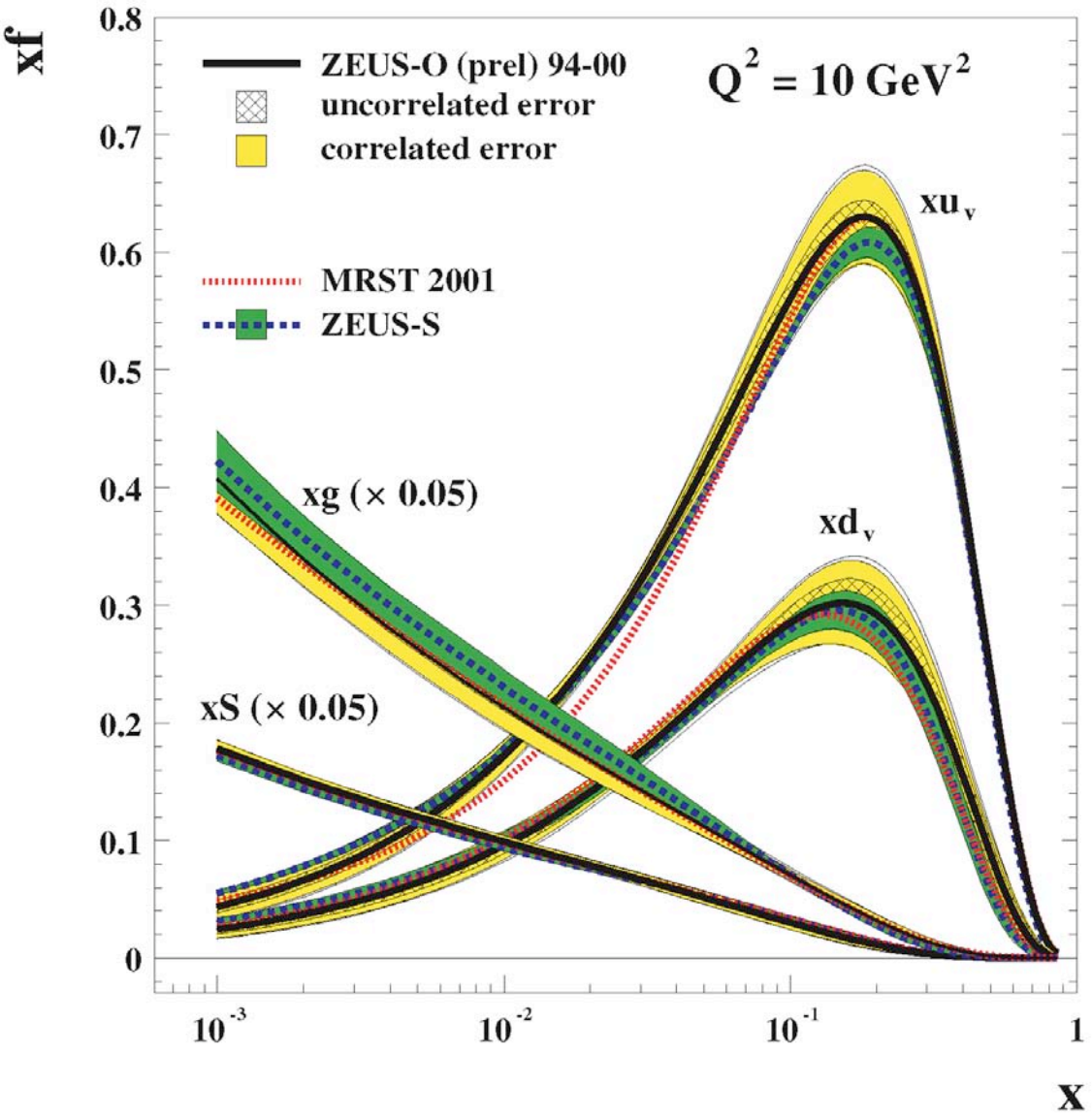
- Rapid rise of F_2 as $x \rightarrow 0$
- No slow down of F_2 rise seen yet

F_2 vs. Q^2→

- Data span 4 decades of Q^2
- +/- scaling violations
- SM gives excellent description



New QCD Fits



New ZEUS-only Structure Function fit uses high-Q^2 data

- $Q^2 < 30{,}000\ GeV^2$
- Less need for FT, sum rules to constrain $x > .05$
- Includes all 94-00 e^+p & e^-p data

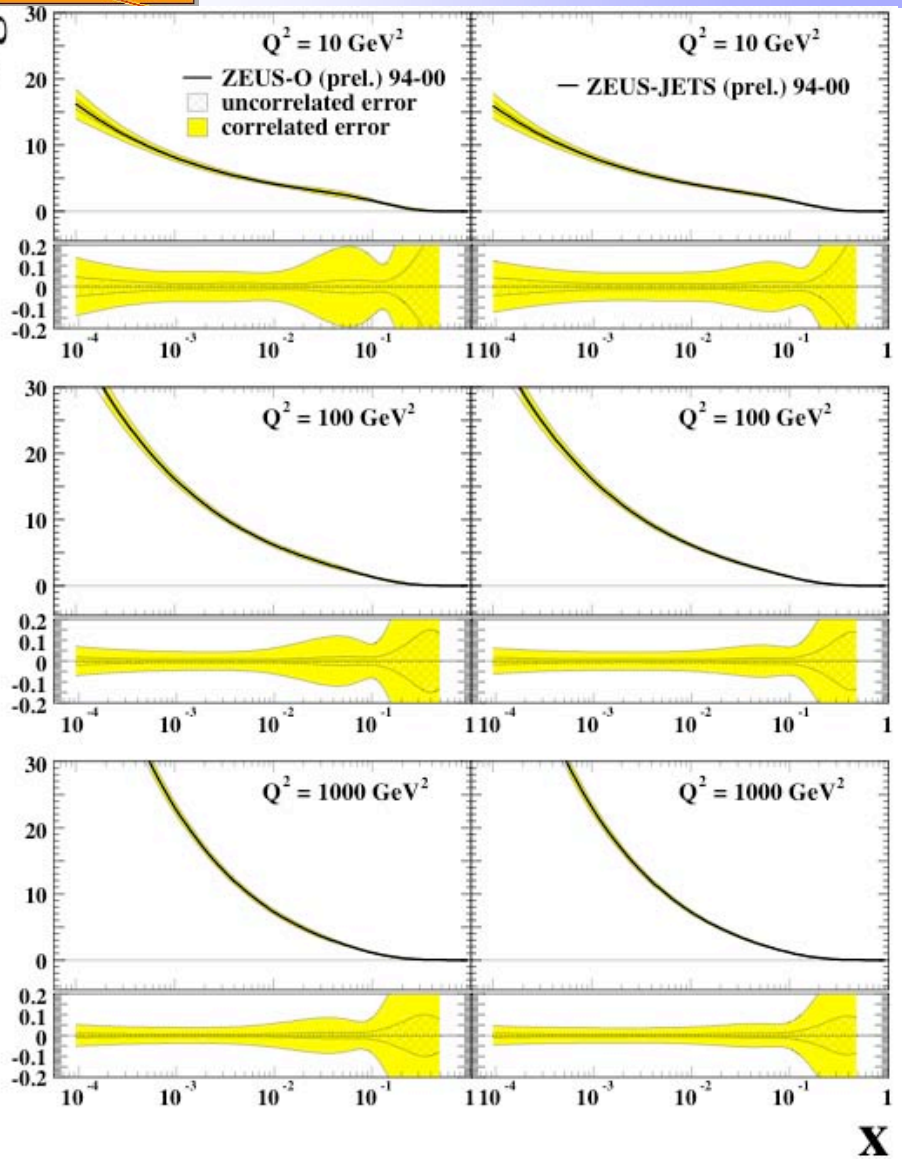
Compare to published ZEUS-S fits

- Use fixed target data
- Use 94-98 ZEUS data

Good Agreement

- ZEUS-only Structure Function fit still needs additional constraint at $x > .1$

Add jets to QCD fits



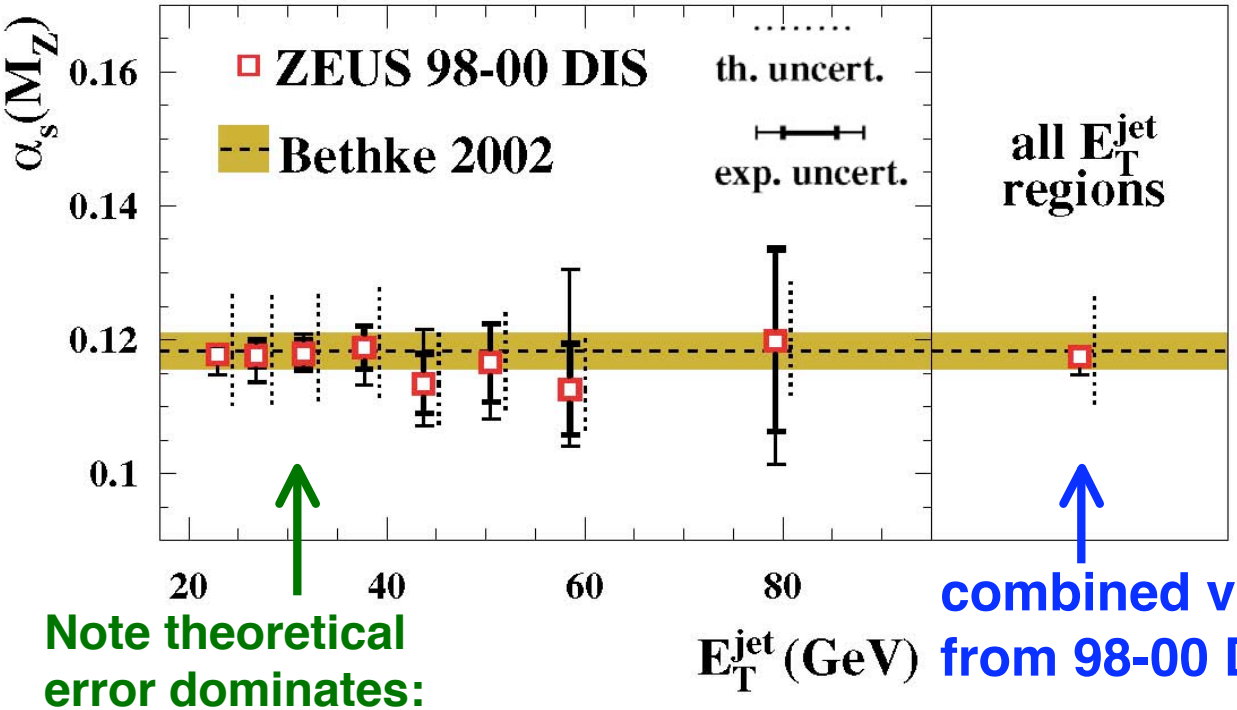
- Include inclusive DIS jet data & high-E_T dijet photoproduction data
- Rigorous & consistent method of treating jets in QCD fits
- Compare ZEUS-only gluon fit with and without jet data included in the fit
- Jets constrain medium x gluon distribution
- Improved precision on the gluon at higher x

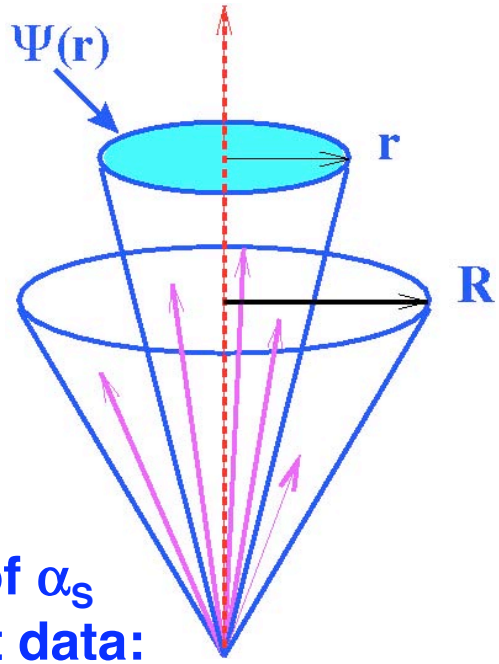
α_s from mean integrated jet shape

$pQCD: \langle 1-\psi(r)\rangle$ = fraction of jet E_T, due to parton emission, in the cone segment btw. r and R=1.

$$\langle 1-\psi(r)\rangle = \frac{\int dE_T \left(E_T / E_T^{jet}\right)\left[d\sigma(ep \to 2\,partons)/dE_T\right]}{\sigma_{jet}\left(E_T^{jet}\right)}$$, where $\sigma_{jet}\left(E_T^{jet}\right)$ for inclusive jet production.

From measured $\langle 1-\psi(r)\rangle$ for $E_T^{jet} > 21$ GeV in each E_T^{jet} region a value of $\alpha_s(M_Z)$ was extracted:



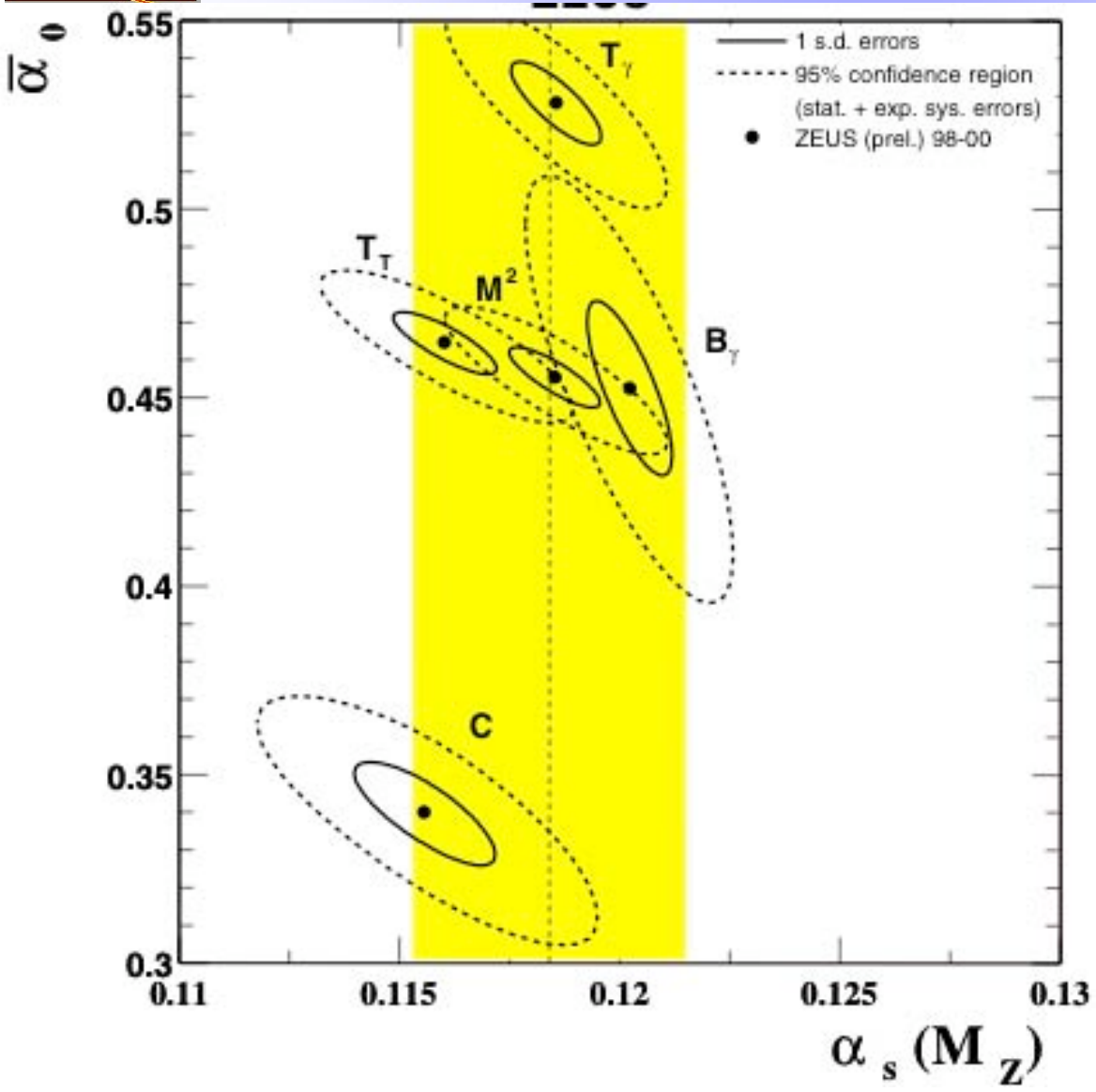


Note theoretical error dominates:

combined value of α_s from 98-00 DIS jet data:

$$\alpha_s = 0.1176 \pm 0.0009(stat)^{+0.0009}_{-0.0026}(sys)^{+0.0091}_{-0.0072}(theo)$$

α_s from DIS event shapes



- **Current region of Breit frame: Thrust (wrt. thrust & γ axes), Broadening, jet Mass, particle pair Correl.**

- **Power Correction: introduce $\overline{\alpha}_0$ to describe non-perturbative effects:**

$$\langle F \rangle = \langle F \rangle_{NLO} + \langle F(\overline{\alpha}_0) \rangle_{POW}$$

- **Fit differential distribut'ns with NLO + PC + NLL resummation (DISRESUM)**

$$\alpha_s \simeq 0.118, \overline{\alpha}_0 \simeq 0.5$$

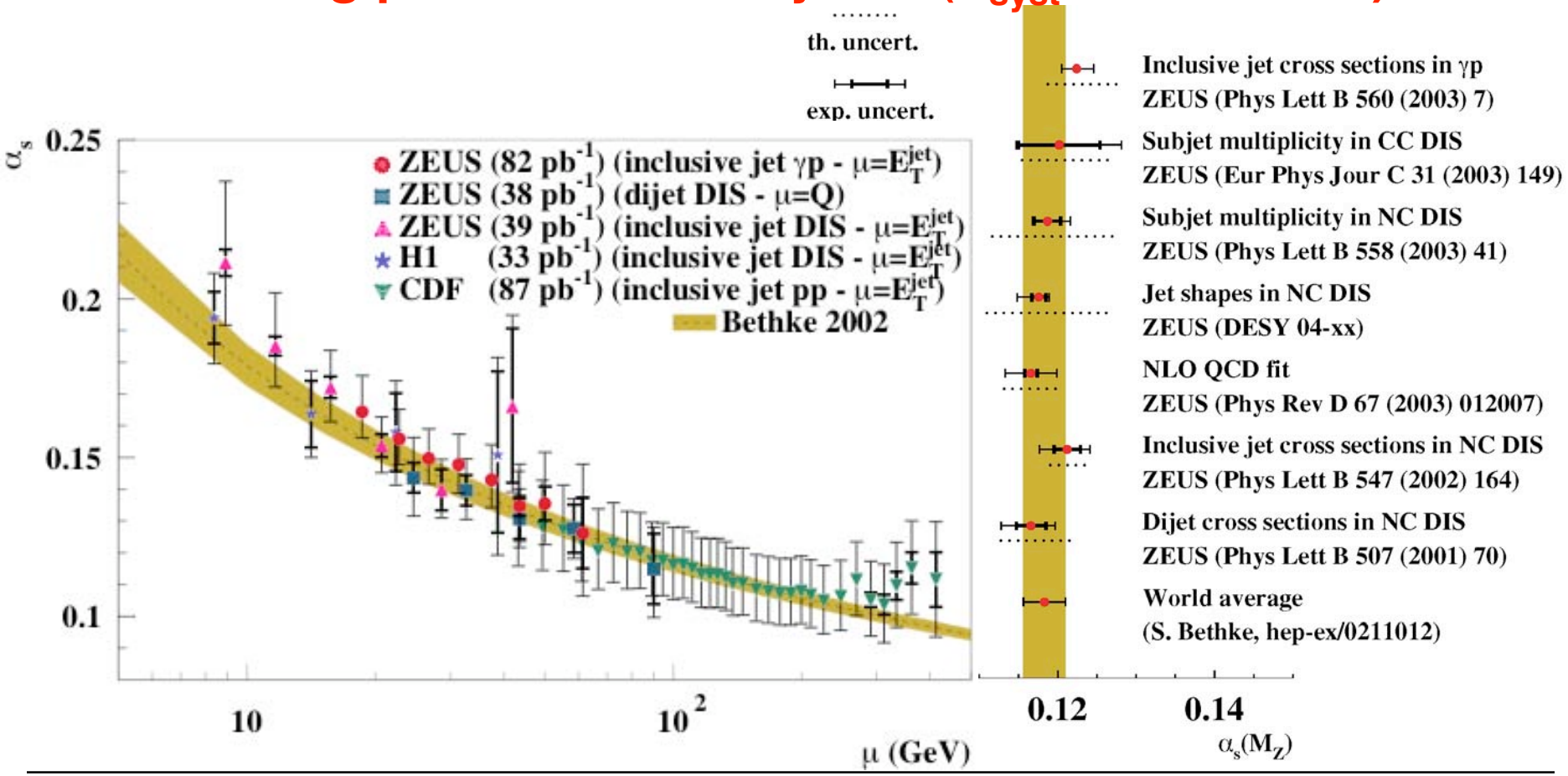
- **Resummation extends fit range and yields consistent α_s, $\overline{\alpha}_0$ for**
- **T_γ, B_γ, M^2, T_T**
  C depends on fit range

α_s Summary

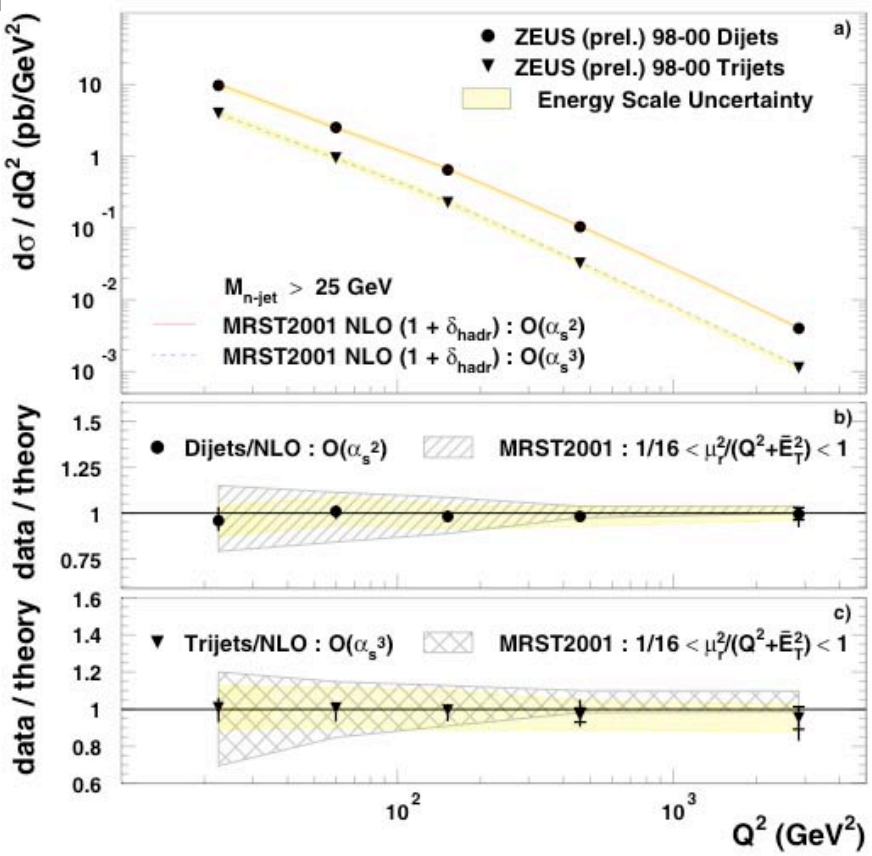
HERA data clearly show running of α_s

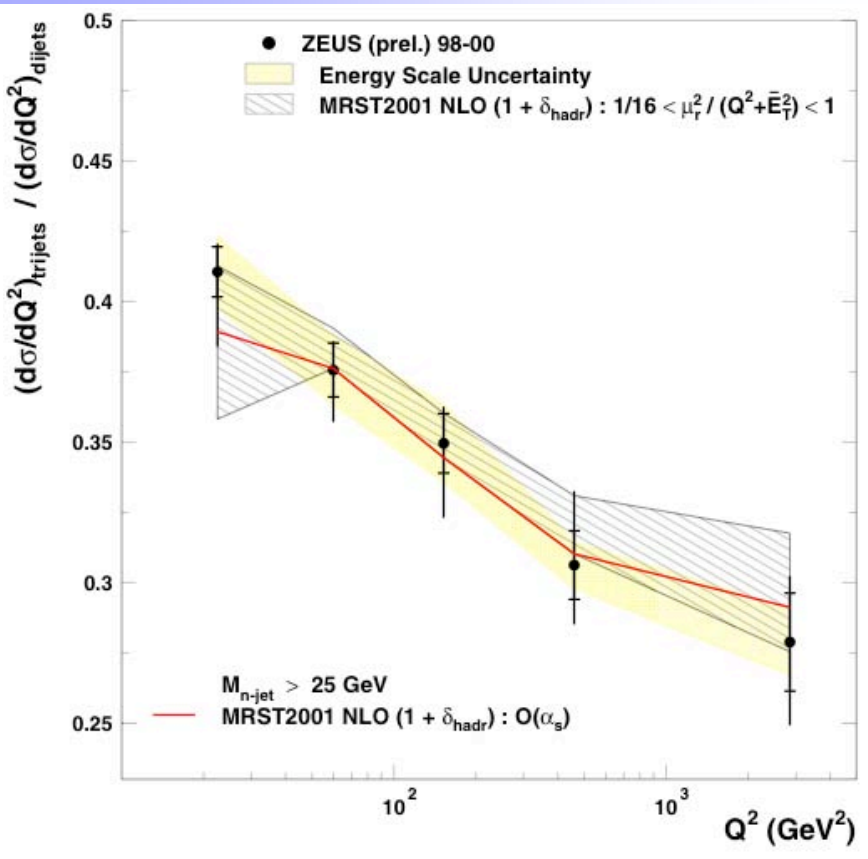
α_s values are as precise as those by other measurements

Zeus is doing precision Jet Physics (σ_{syst} down to 2%):



Ratio of DIS trijets to dijets



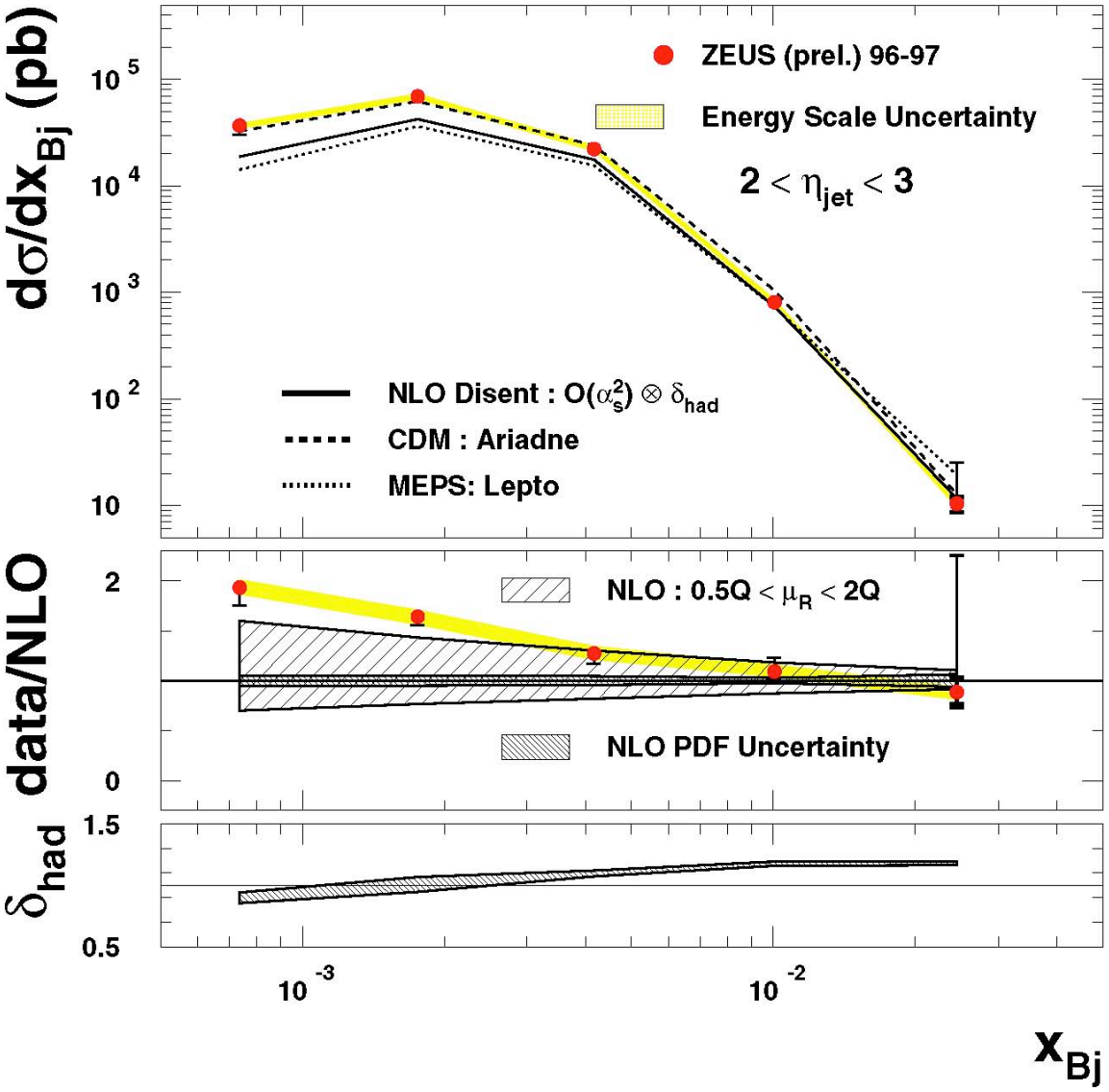


Comparison to NLO gives good description

Large renormalization scale error at low x

New method should yield another α_s measurement

Forward Jets & BFKL



k_T-inclusive jet algorithm

Phase space enhances BFKL dynamics:

$\cos\gamma_h < 0$ - removes single jets

$2 < \eta_{jet} < 3$ - forward jets

$\frac{1}{2} < \frac{E^2_{T,jet}}{Q^2} < 2$ - limit parton evolution

along gluon ladder - enhances BFKL

- **Data slightly above NLO at low x, although well described at high x**
- **Ariadne describes data**
- **Lepto doesn't describe data**
- **Large renormalization uncertainty at low x where calculation shows most difference -- higher orders?**

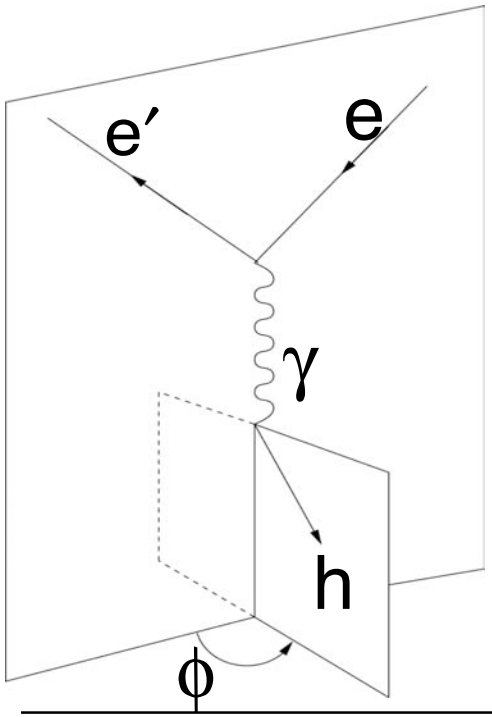
Azimuthal asymmetry

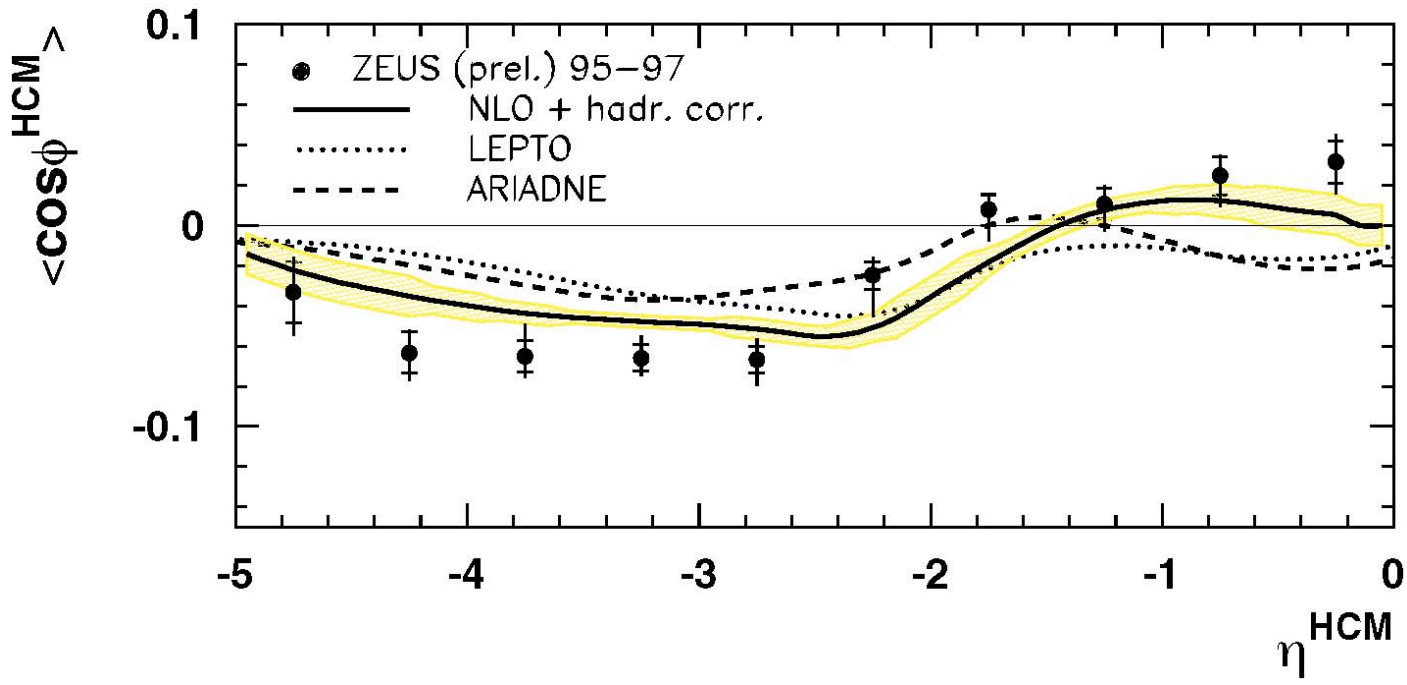
QCD prediction due to longitudinal & transverse photon evolves in η as Boson-Gluon-Fusion takes over from QCD-Compton events

Use energy flow objects in hadronic c.o.m. frame

- **include charged and neutral hadrons (previously just charged tracks)**
- **enhance hard partons by weighting with energy, i.e. energy flow**

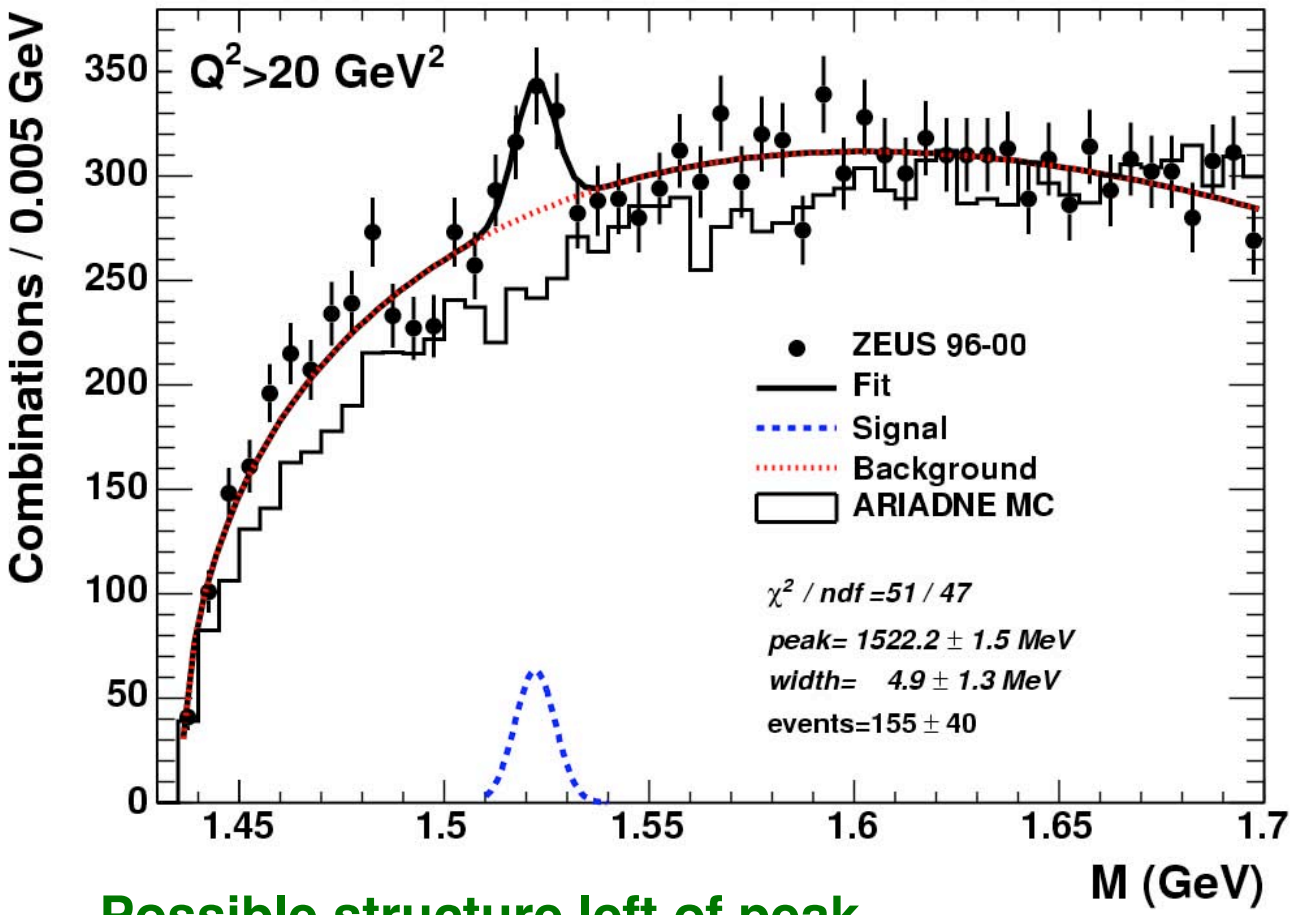
NLO effects are not negligible and provide better agreement with experimental data





Evidence for strange pentaquarks I

- Select $p/\bar{p}$ and K^0_s in inclusive DIS ($Q^2 > 20$ GeV^2)
- Plot $m(pK^0_s) + m(\bar{p}K^0_s)$
- Fit bg + single Gaussian
- Peak at 1522 ± 2 MeV
- Width consistent with resolution
- Statistical significance $\sim 3.9\,\sigma$
- Note that observation is in fragmentation region - no influence of original baryon in the beam



Possible structure left of peak (expected in this region) →

Try different background shape →

Evidence for strange pentaquarks II

- fit bg + two Gaussians

(2nd Gaussian parametrizes potential resonance or empirical shoulder in background shape)

$$m = 1521.5 \pm 1.5\,(stat)\,^{+2.8}_{-1.7}\,(sys)\;MeV$$

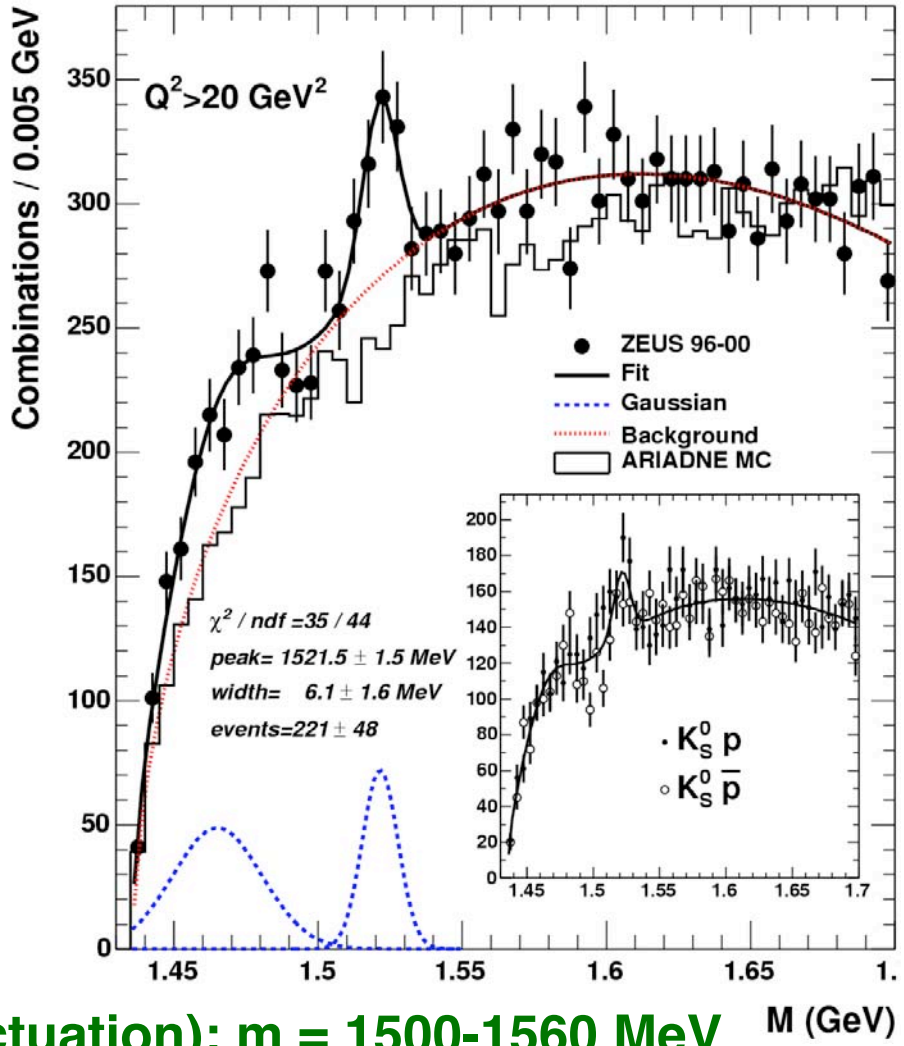
- **Gaussian width 6.1 ± 1.5 MeV still compatible with experimental resolution of ~2 MeV**

(Breit-Wigner fit: $\Gamma = 8 \pm 4$ MeV)

- **significance ~ 4.6 σ**

- signal seen in both charges (inset)

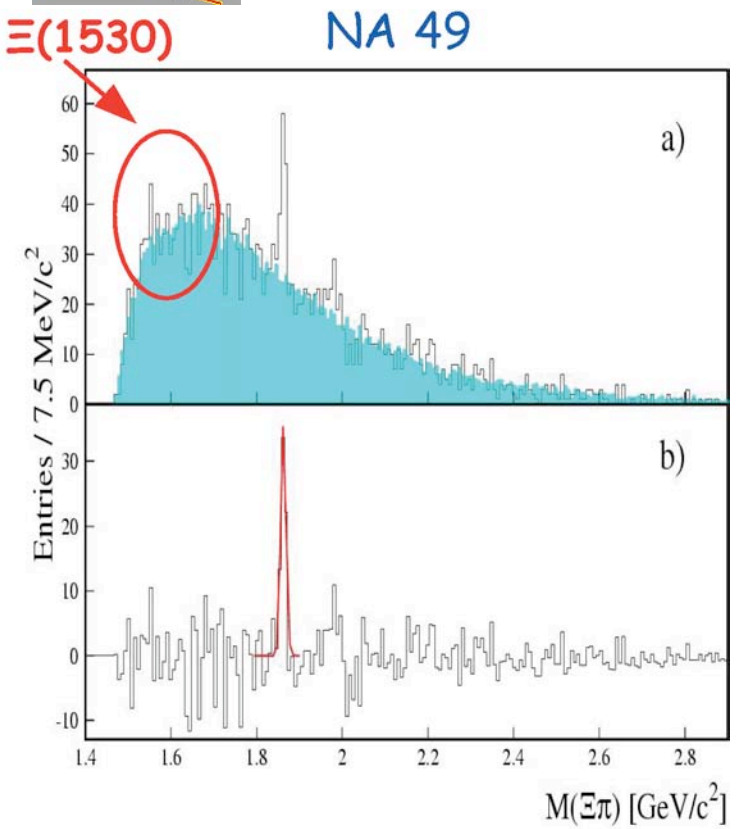
- **if interpreted as $\theta^+ + \theta^-$** antipentaquark!

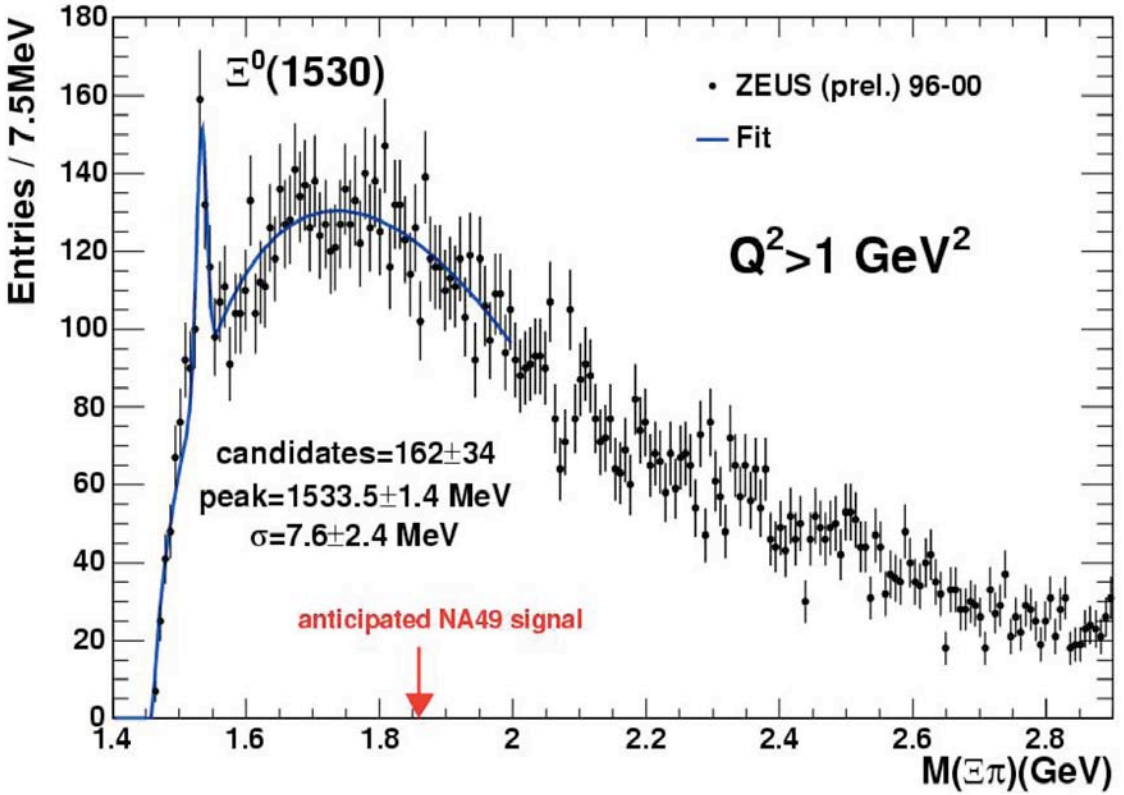


p(fluctuation): m = 1500-1560 MeV

σ = 1.5-12 MeV: 6 x 10^{-5}

NA49 Signal in ZEUS





NA49 signal(pentaquark)/signal(Ξ(1530)) ~ 6-8

Ξ(1530) seen more clearly in ZEUS than in NA49

- **ZEUS has higher statistics & smaller background**

ZEUS should see NA49 signal but does not

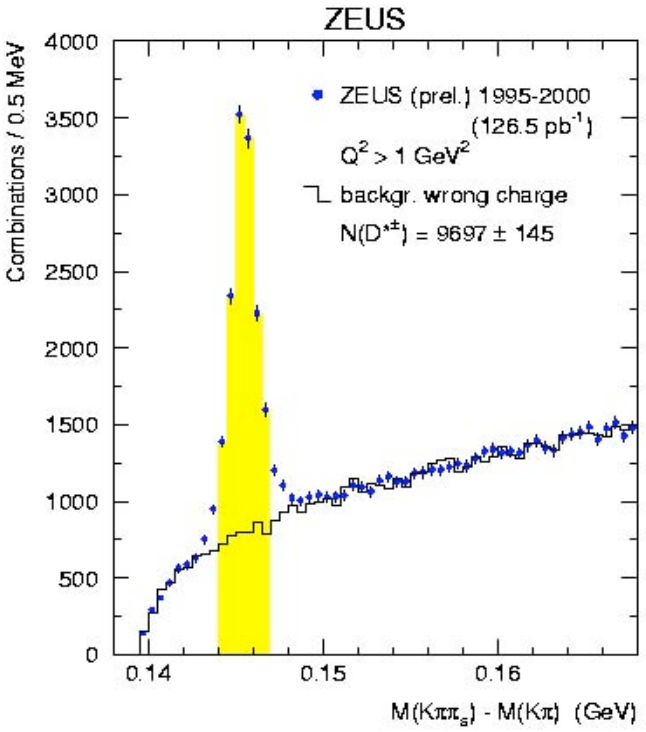
Search for charmed pentaquark I

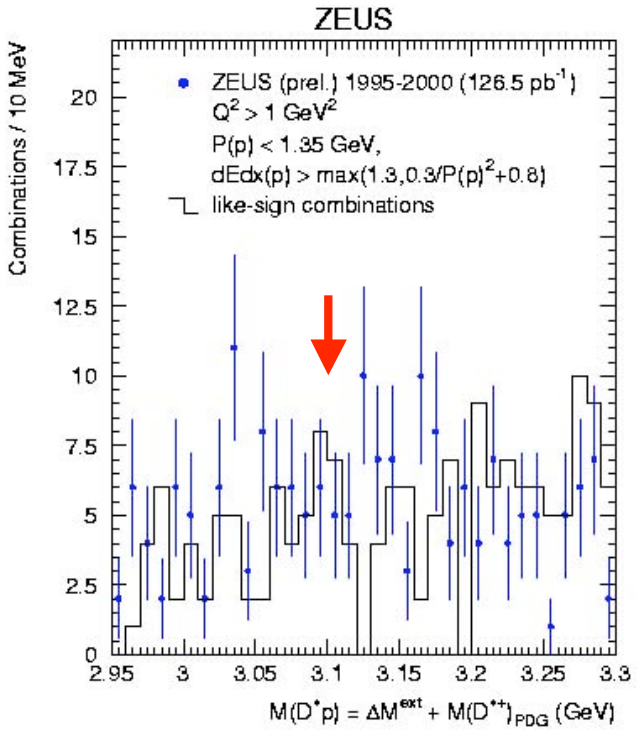
DIS D* sample 1995-2000, Q^2>1 GeV^2: ~9700 D*

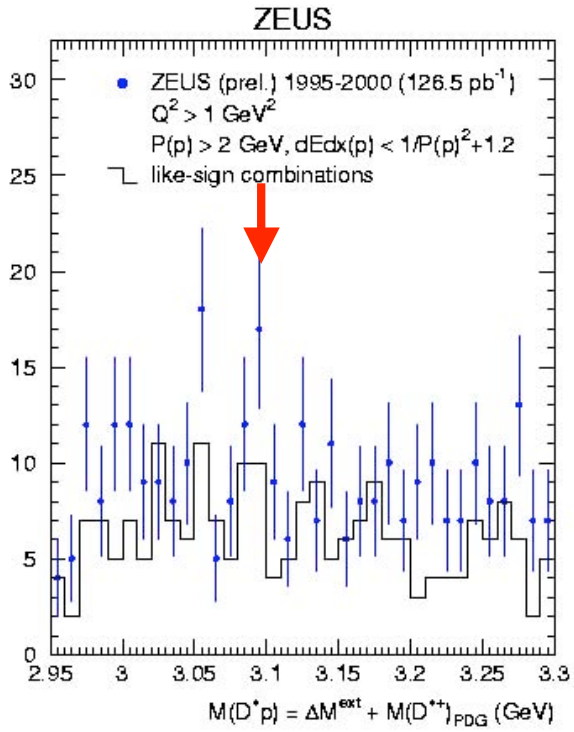
$p_T(D^*) > 1.35$ GeV, $|\eta(D^*)| < 1.6$, p (dE/dx) and D*p cuts similar to H1

low momentum p

high momentum p







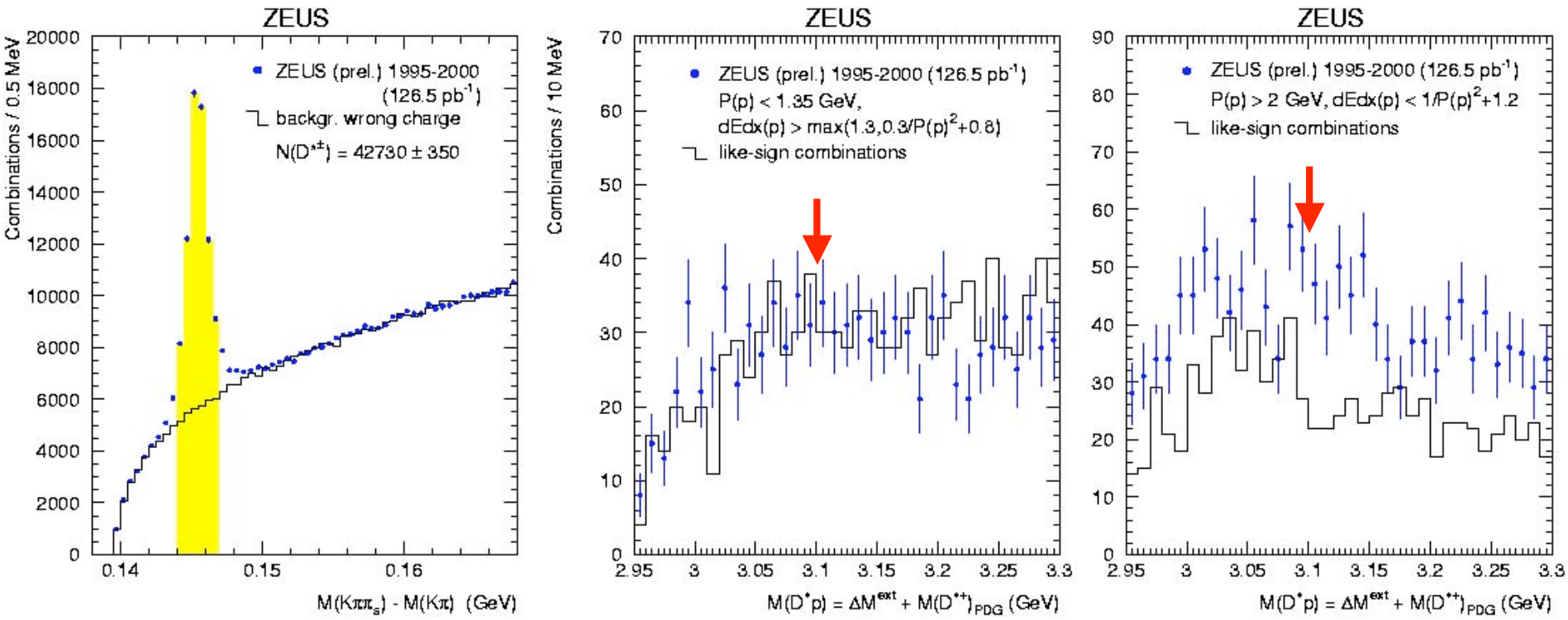
no evidence for signal at 3.1 GeV

Search for charmed pentaquark II

ZEUS inclusive (γp & DIS) D* sample 1995-2000: ~43000 D*

same D*, p and D*p cuts as for DIS selection

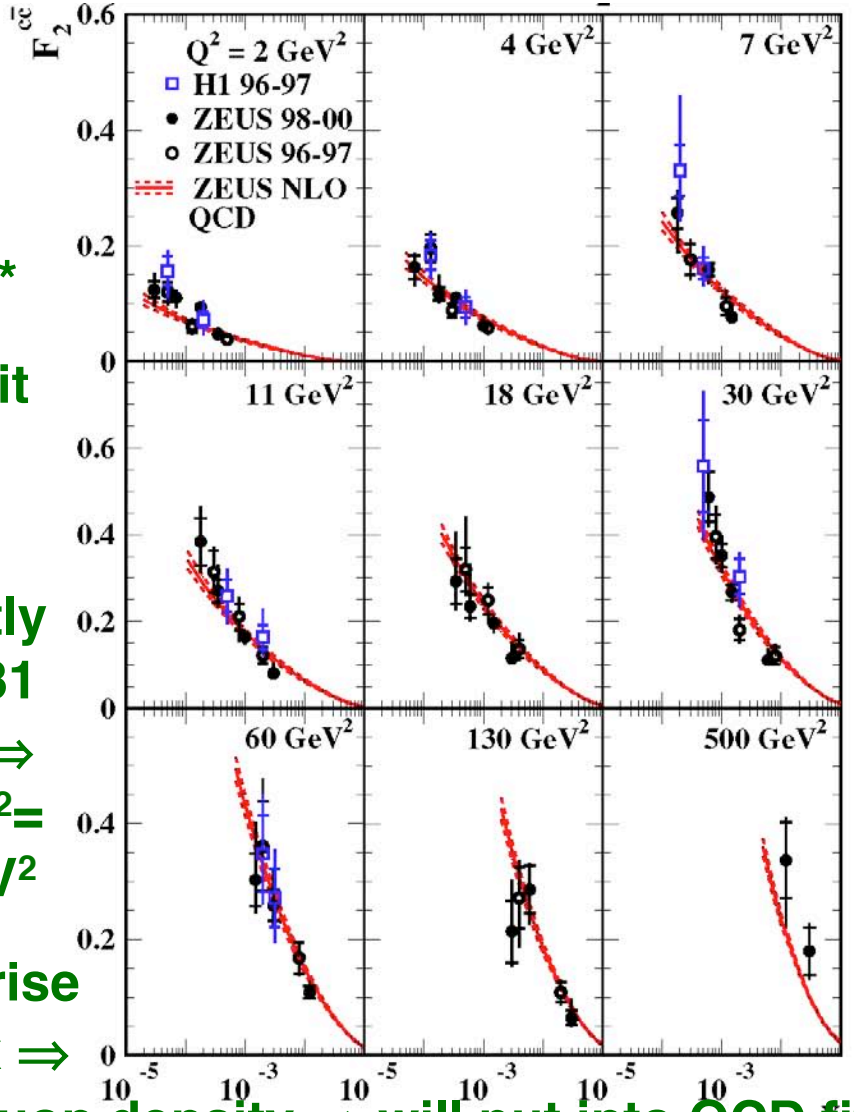
low momentum p **high momentum p**

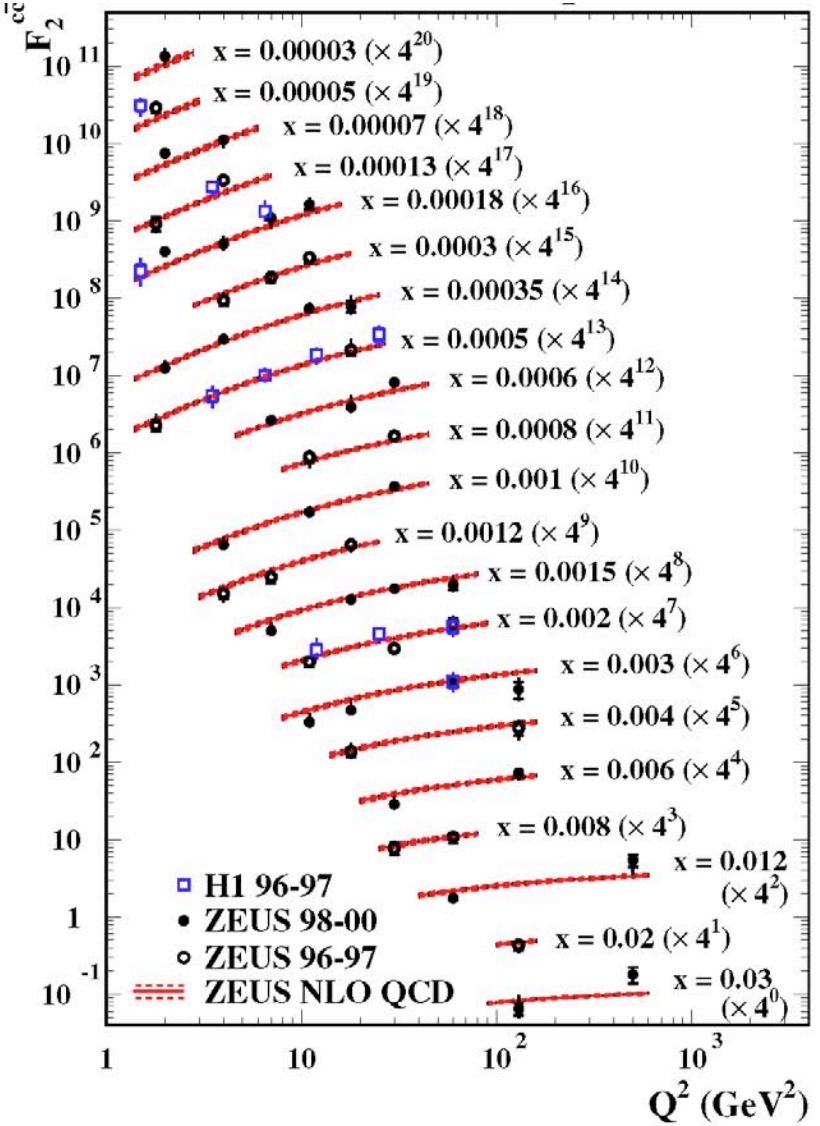


no evidence for signal at 3.1 GeV

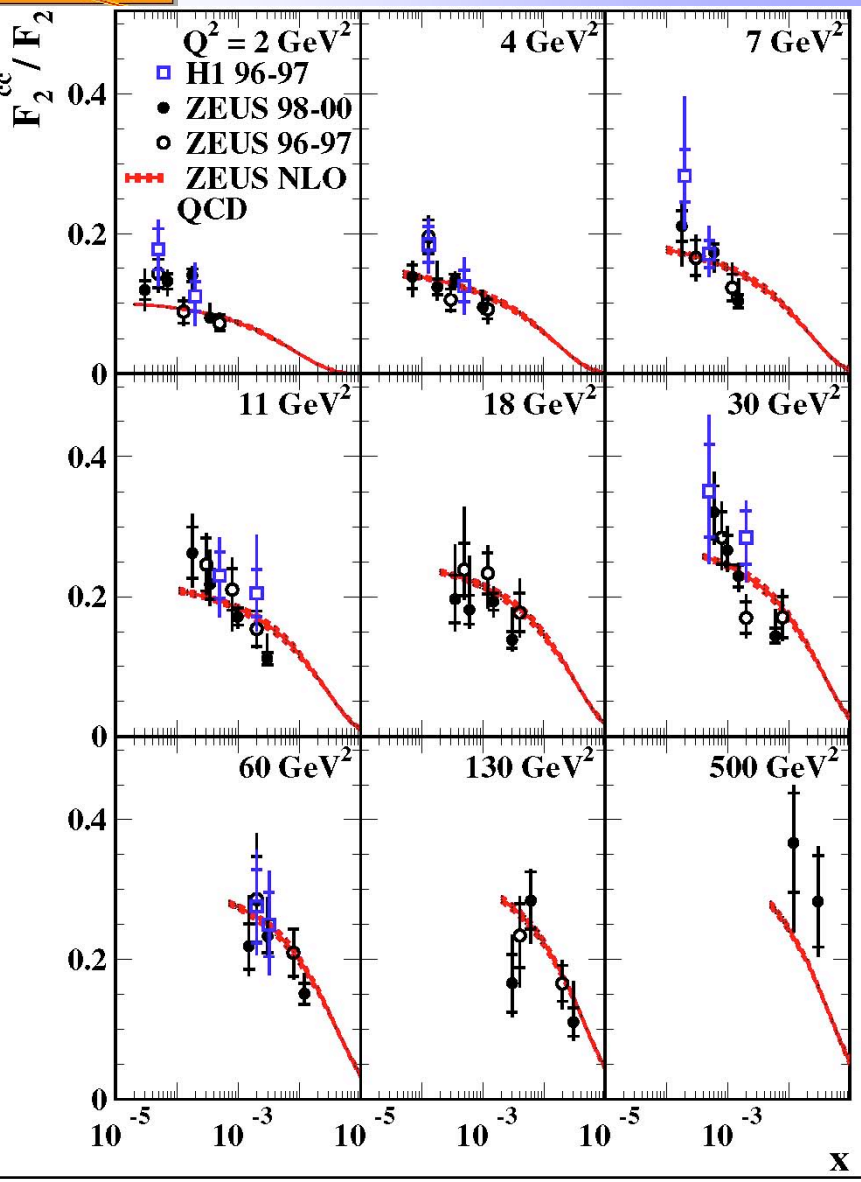
Charm in DIS: $F_2^{c\bar{c}}$ from D*

- Final HERA I result
- 5500 D*
- Good fit by NLO QCD
- Recently added 31 points ⇒ up to Q^2= 500 GeV^2
- Steep rise at low x ⇒ large gluon density ⇒ will put into QCD fit





Charm in DIS: $F_2^{c\bar{c}}/F_2$



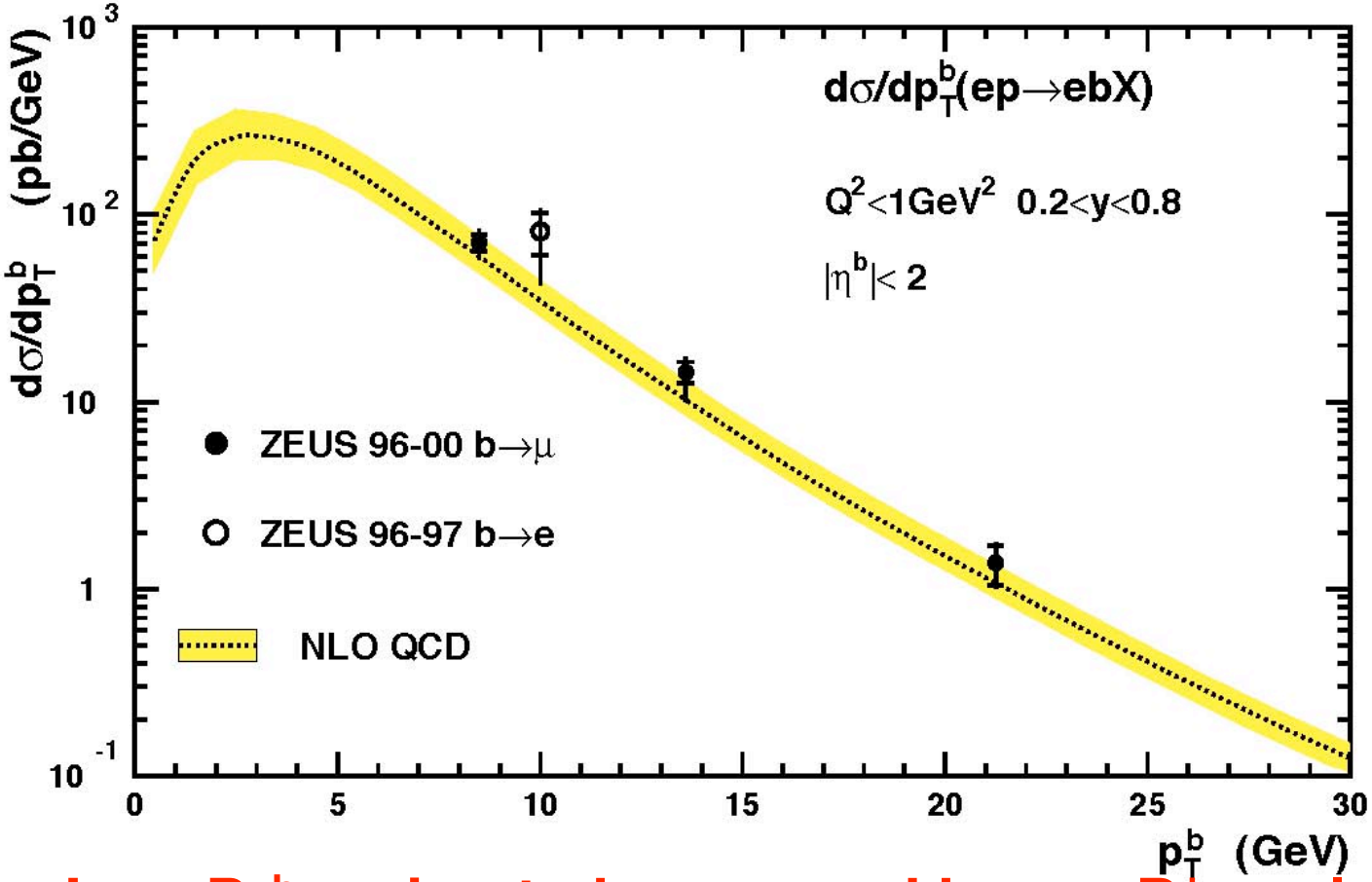
Precise measurements of charm in DIS

Good description of the data by NLO QCD using a modern PDF

Double differential cross sections can be used to further constrain the gluon in the proton

- **At lowest Q^2, data and theory uncertainty comparable**

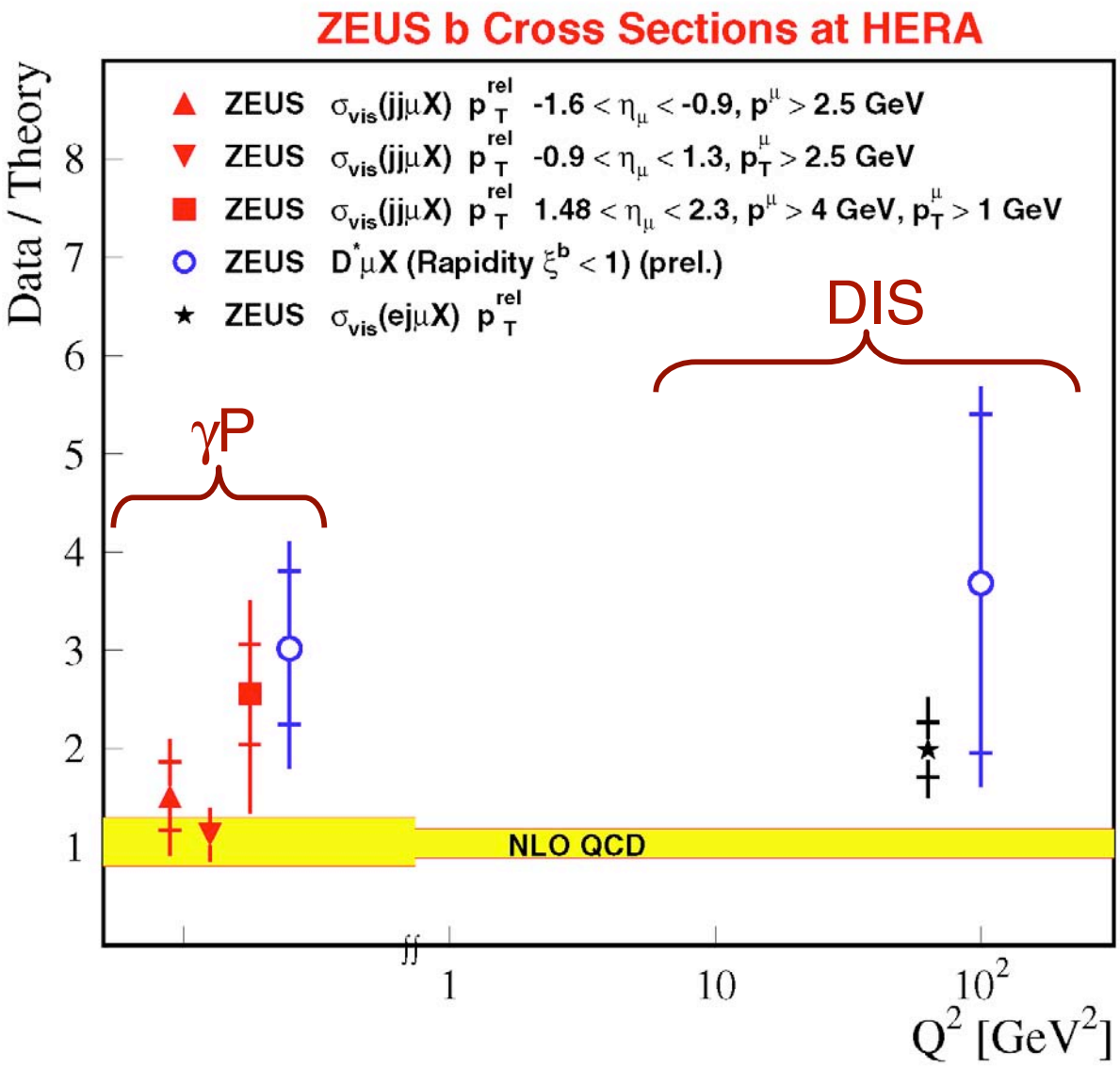
Beauty Photoproduction



Cross section for b-quark extrapolated using NLO calculations

- Low P_T^b region to be covered by μ + D* analysis
- Good agreement with NLO QCD predictions
- Good agreement with previous ZEUS publications

Beauty γp & DIS cross sections

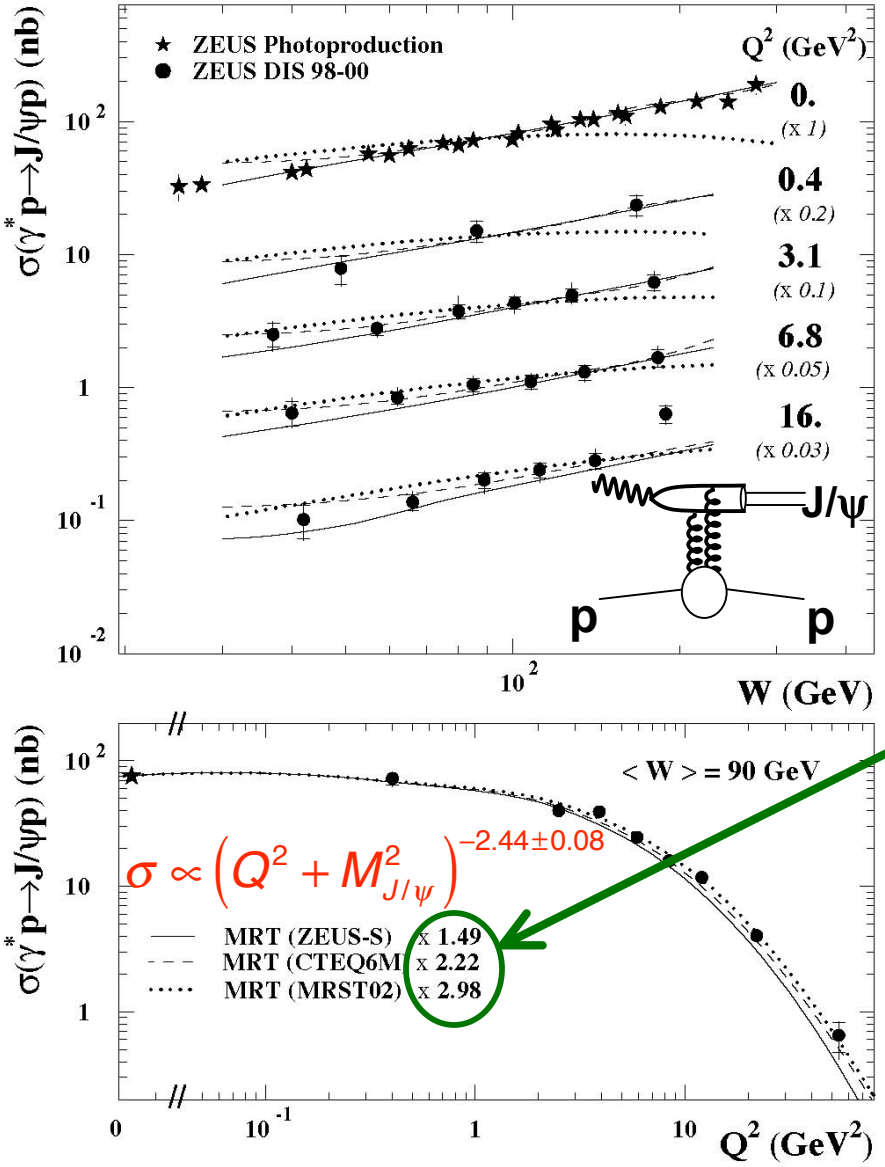


Various measurements in different kinematic regions

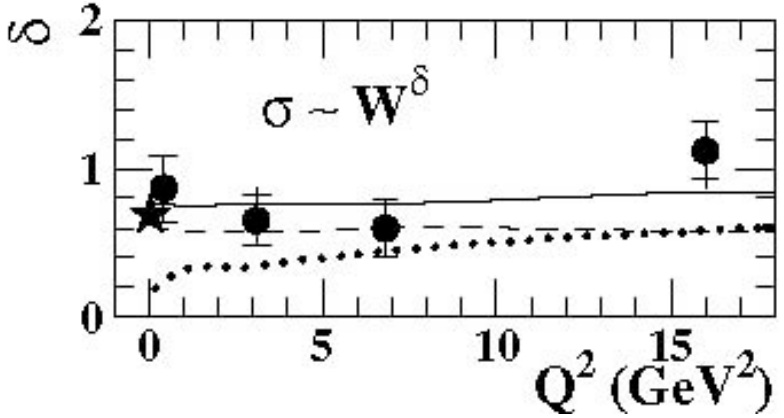
NLO QCD in general agreement with some small discrepancies:

- **γp: NLO QCD good for all regions, while LO+PS low for high η & p_T**
- **DIS:NLO QCD low for high E_{tjet} & η, low Q^2 & p_T, same for LO+PS**

Diffractive J/ψ production



- No change of W dependence with Q^2
- Mass of J/ψ sets the scale already in photoproduction
- Consistent with pQCD expectation over Q^2 range
- Sensitive to gluon^2 in proton
  - Same as extracted from F_2
- Need NLO corrections



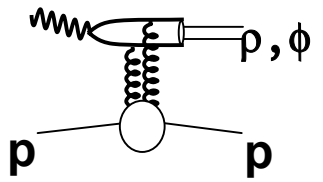
Diffractive ϕ production

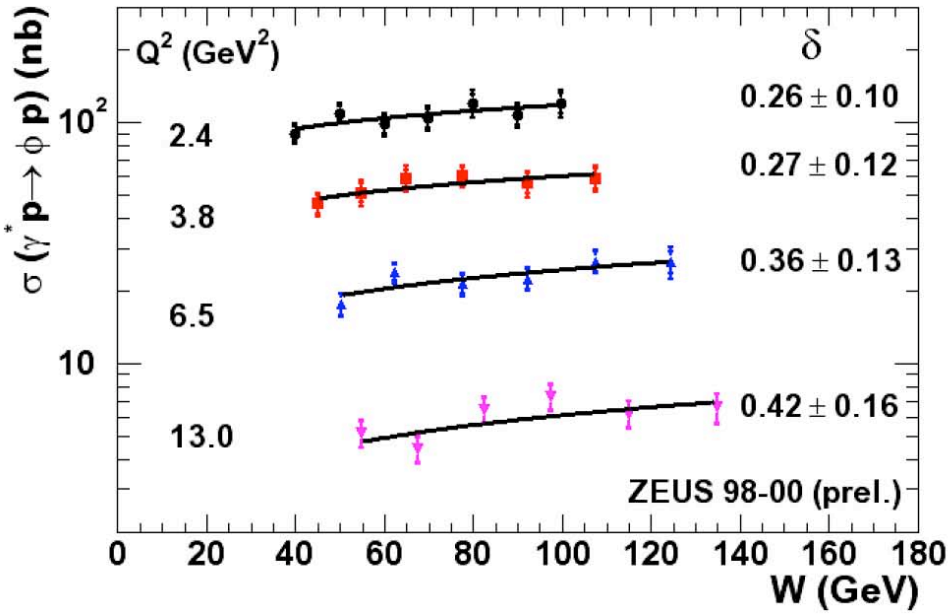
Fit to $\sigma \sim W^{\delta}$ - δ is a function of Q^2 - consistent with QCD

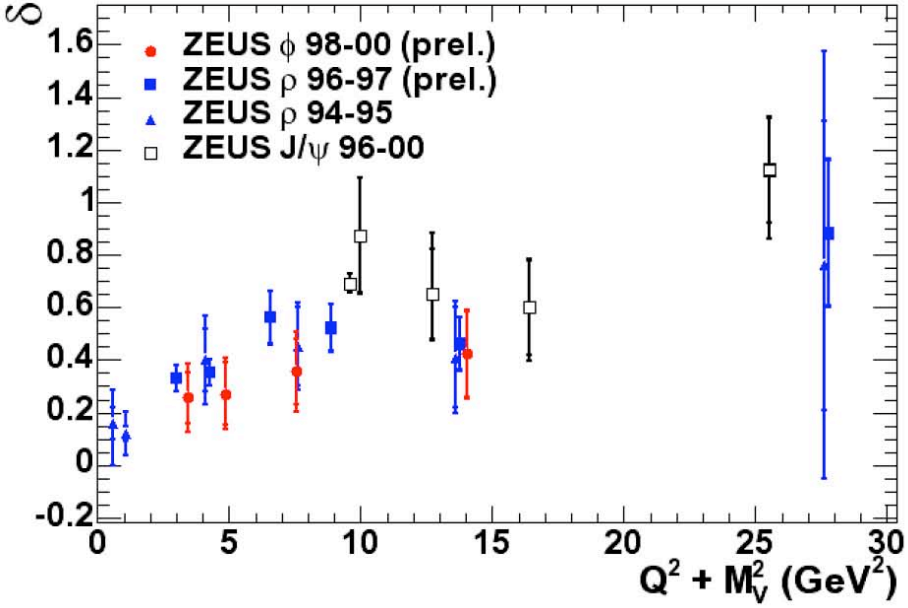
Data agree well with results from other Vector Mesons

Rise of δ with $Q^2+M_V^2$ observed in global VM picture

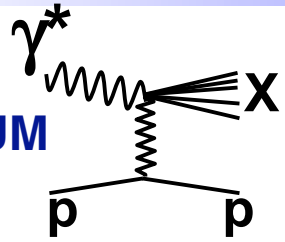
- **ρ , ϕ : transition from soft to hard regime**
- **J/ψ : hard already in photo-production**



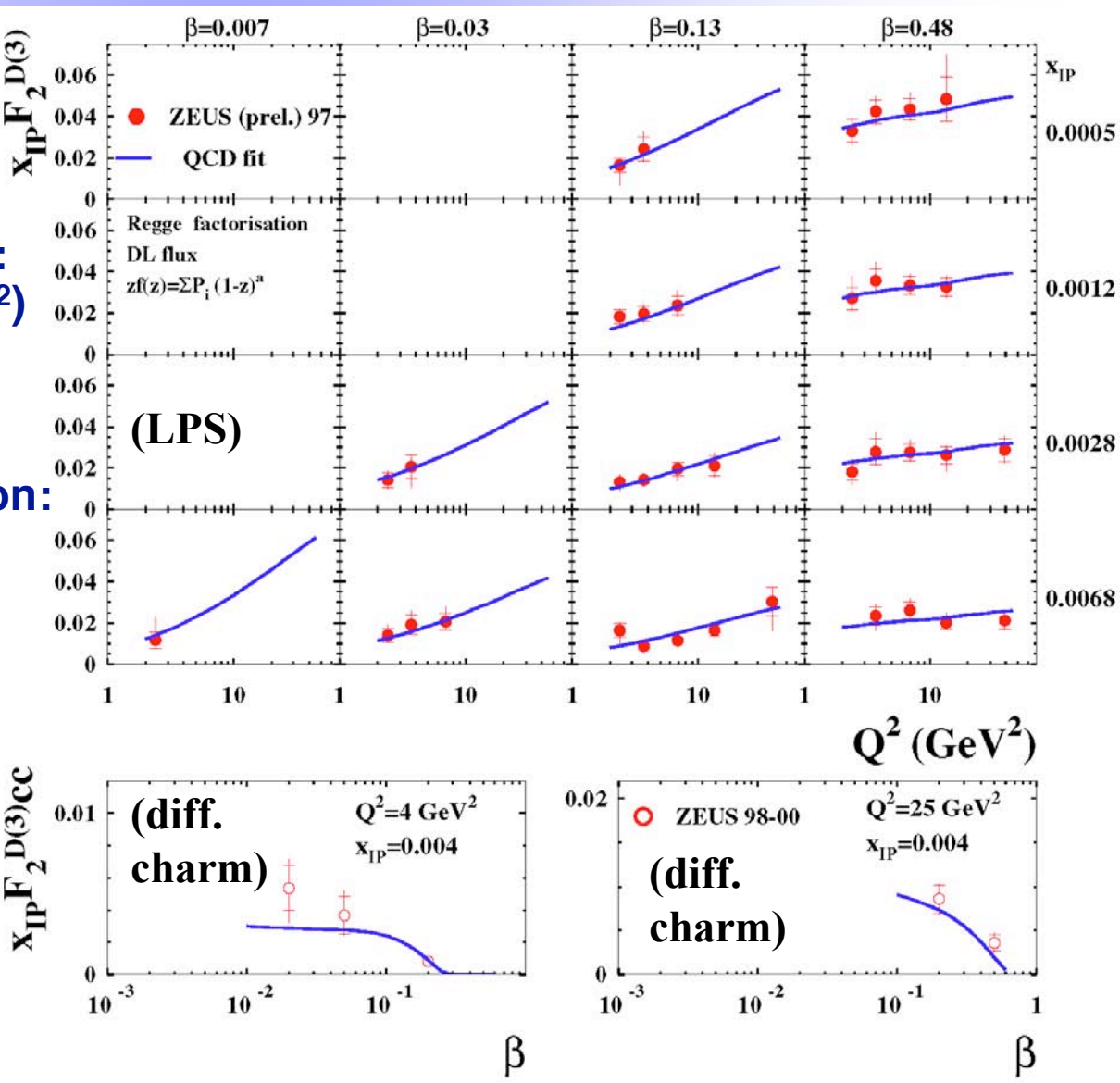




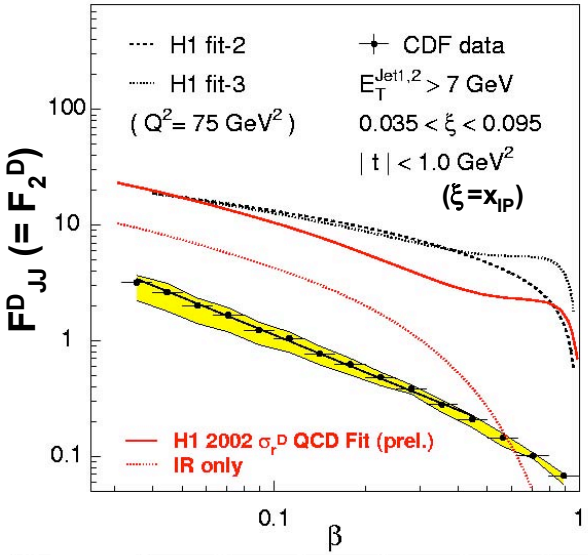
NLO QCD fit to $F_2^{D(3)}$ + diff. charm



- NLO fit, QCDNUM
- x_{IP} <0.01
- Regge factorization assumed: $F_2^{D(3)}(x_{IP},ß,Q^2) = f_{IP}(x_{IP})F_2^{IP}(ß,Q^2)$
- DL flux used
- Initial scale Q^2=2 GeV^2
- Diffractive PDF parametrization:
  - $zf(z) = (a_1+a_2z+a_3z^2)(1-z)^{a4}$
- Thorne-Robert variable flavor number scheme
- QCD fit describes data
  - χ^2 = 37.9/36 DOF
- Fractional gluon momentum is (82±8(stat) ±9(syst))%
- Implies diffractive hard scattering factorization



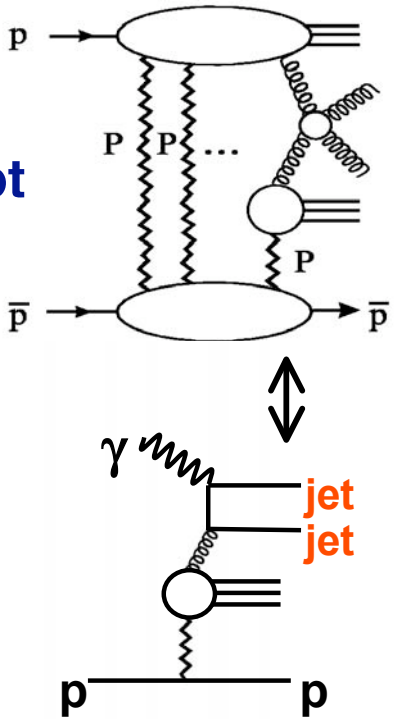
Hard Diffractive Factorization

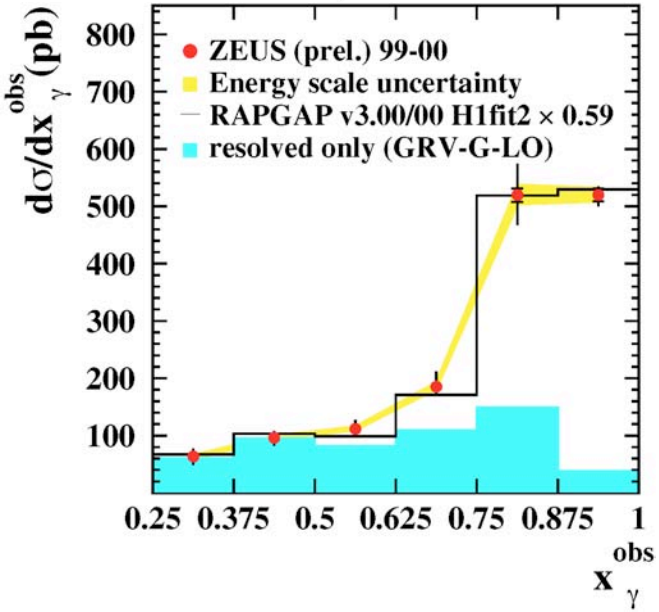


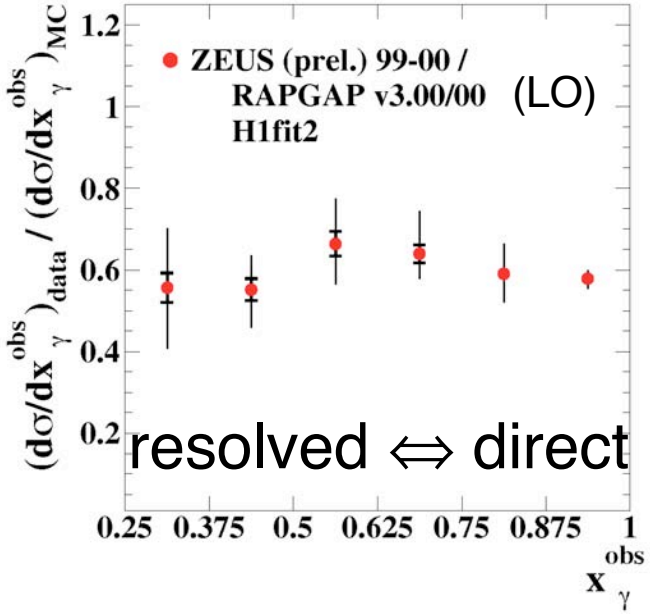
Extraction of F_2^D from CDF dijet data is x10 lower than extrapolation from HERA data

- **Diffractive PDFs from HERA not usable at Tevatron?**

An Idea: violation of factorization understood as (soft) rescattering corrections of spectator partons (Kaidalov, Khoze, Martin, Ryskin)



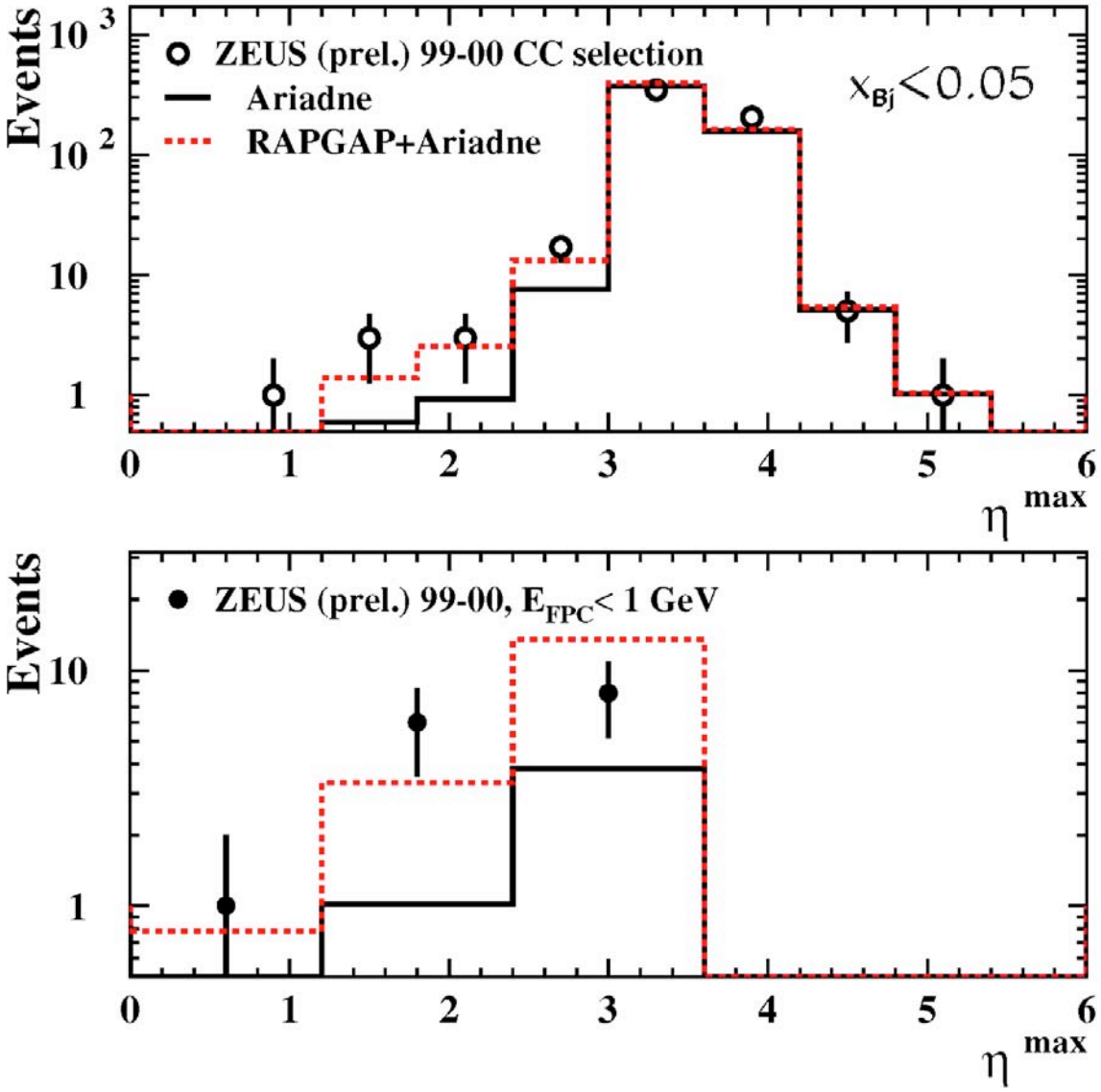




Since resolved photon ~ hadron ⇒ expect same suppression in resolved vs. direct γp

Not seen. **NLO?**

High-Q^2 CC w/Large Rapidity Gap



Need to add Rapgap to describe η_{max} for $x < 0.05$ & $E(\text{Fwd Plug Cal: } 4<\eta<5) < 1$ GeV

Cuts: $E_{FPC} < 1$ GeV, $\eta_{max} < 2.9$, $x_{pom} < 0.05$,

- **9 events remain**

Rapgap: 5.6 ± 0.7 events

MEPS-SCI: 3.9 -1.0 + 0.7 evts

Non-Diff bkgd (Ariadne + GRAPE): 2.1 ± 0.4 events

$\sigma_{ccdiff}(Q^2>200\ \text{GeV}^2, x_{pom}<0.05)$ $=0.49 \pm 0.20(\text{stat}) \pm 0.13(\text{syst})$ pb

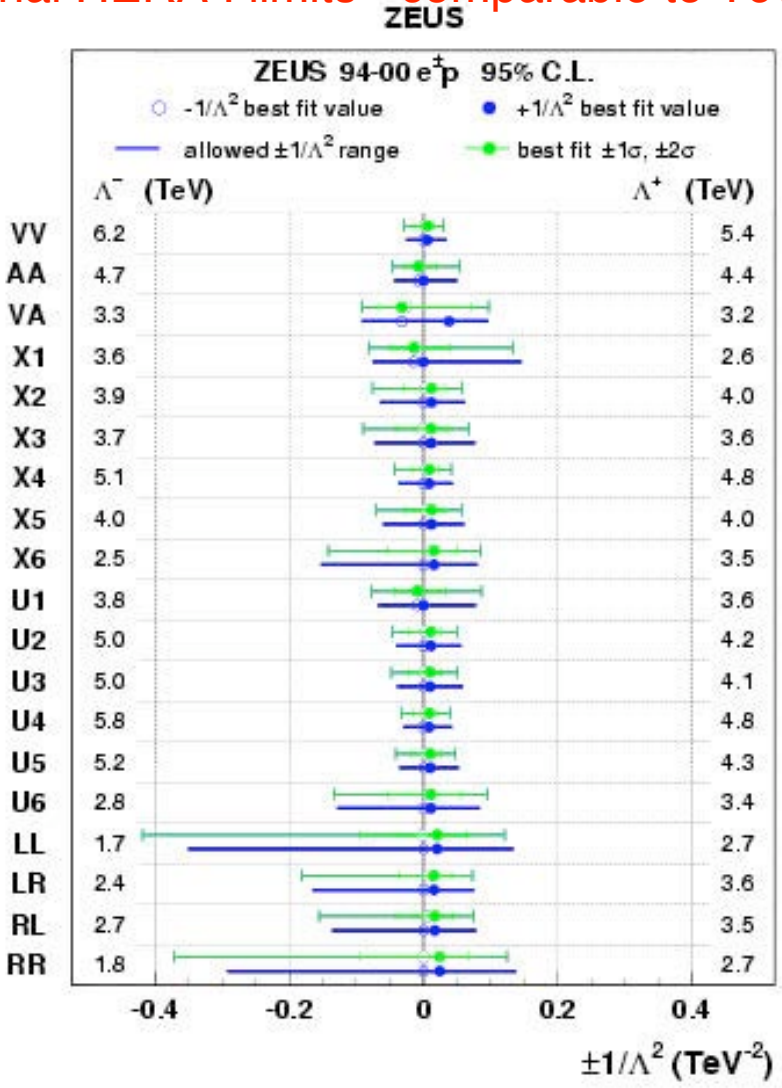
Rapgap prediction: 0.4 pb

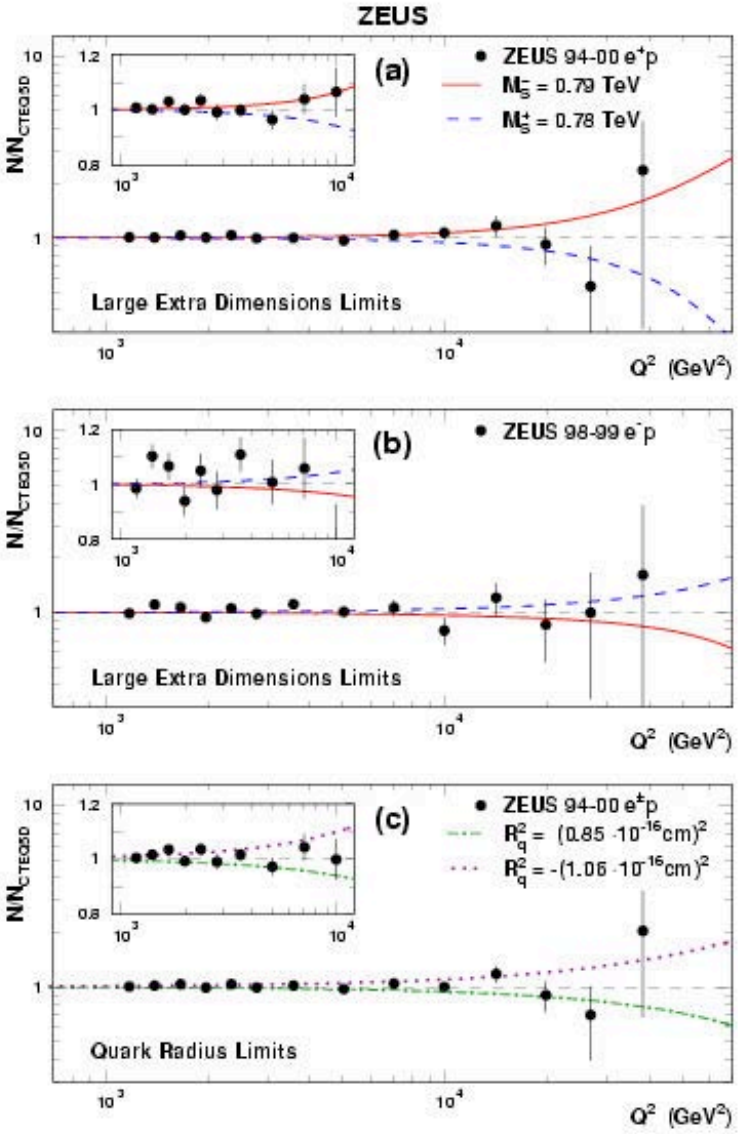
$$\sigma^{CC\ DIFF}_{(Q^2>200GeV^2, x_{pom}<0.05)} \Big/ \sigma^{CC\ TOT}_{(Q^2>200GeV^2, x_{Bj}<0.05)} = \left(2.9 \pm 1.2(stat) \pm 0.8(syst)\right)\%$$

Not conclusive - need HERA II

Contact int., extra-dimensions

Final HERA I limits - comparable to Tevatron

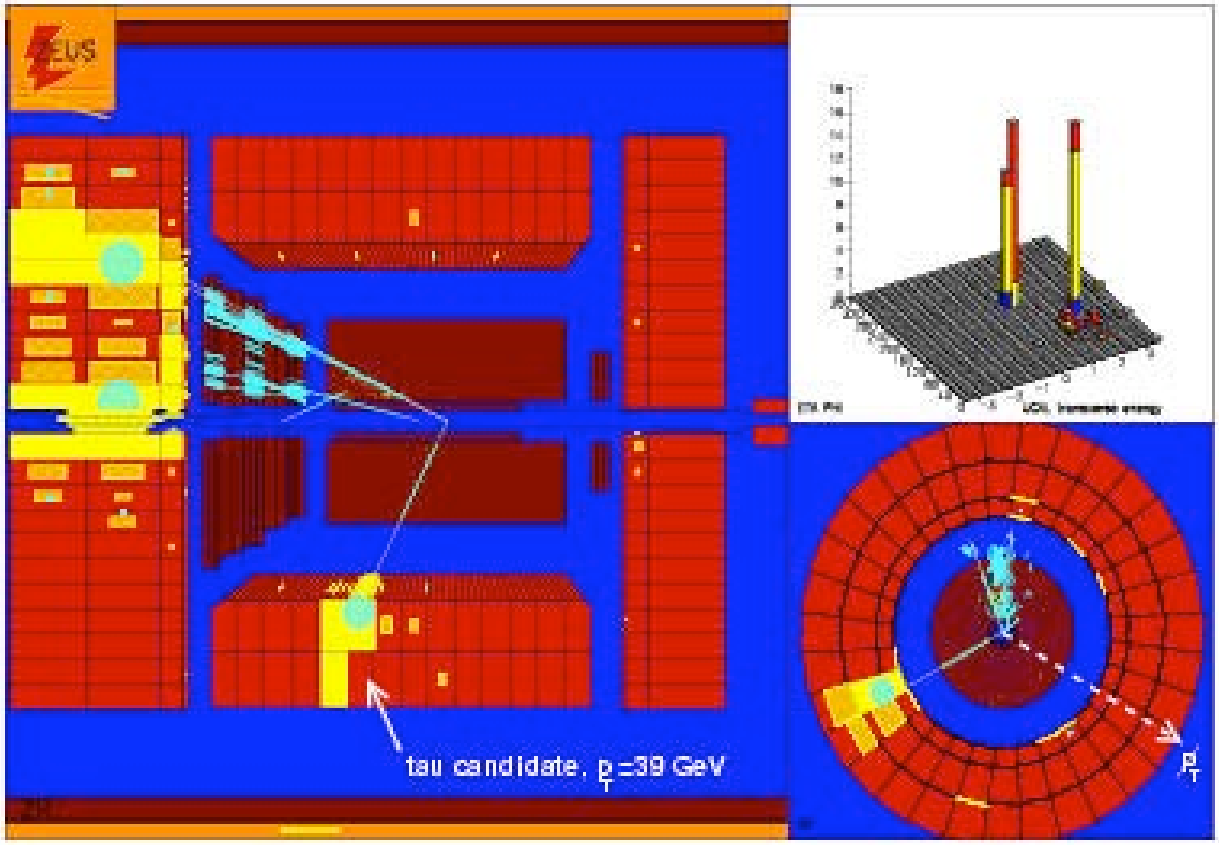


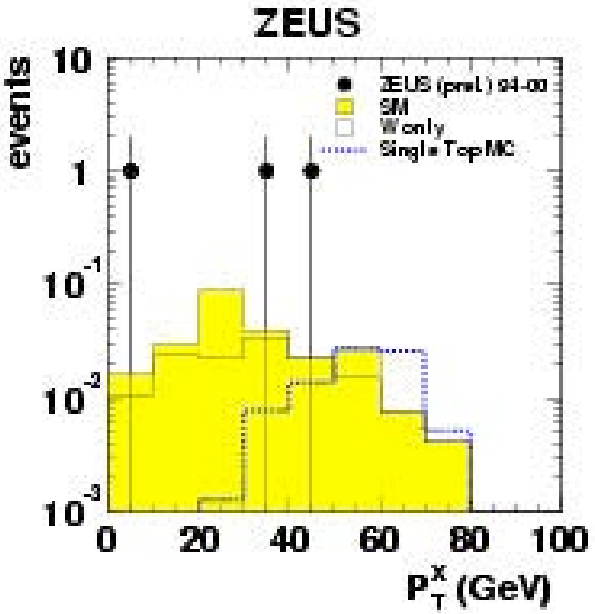


Other Searches for Physics Beyond Standard Model

HERA-I Isolated τ's & missing P_T - tantalizing (only!)

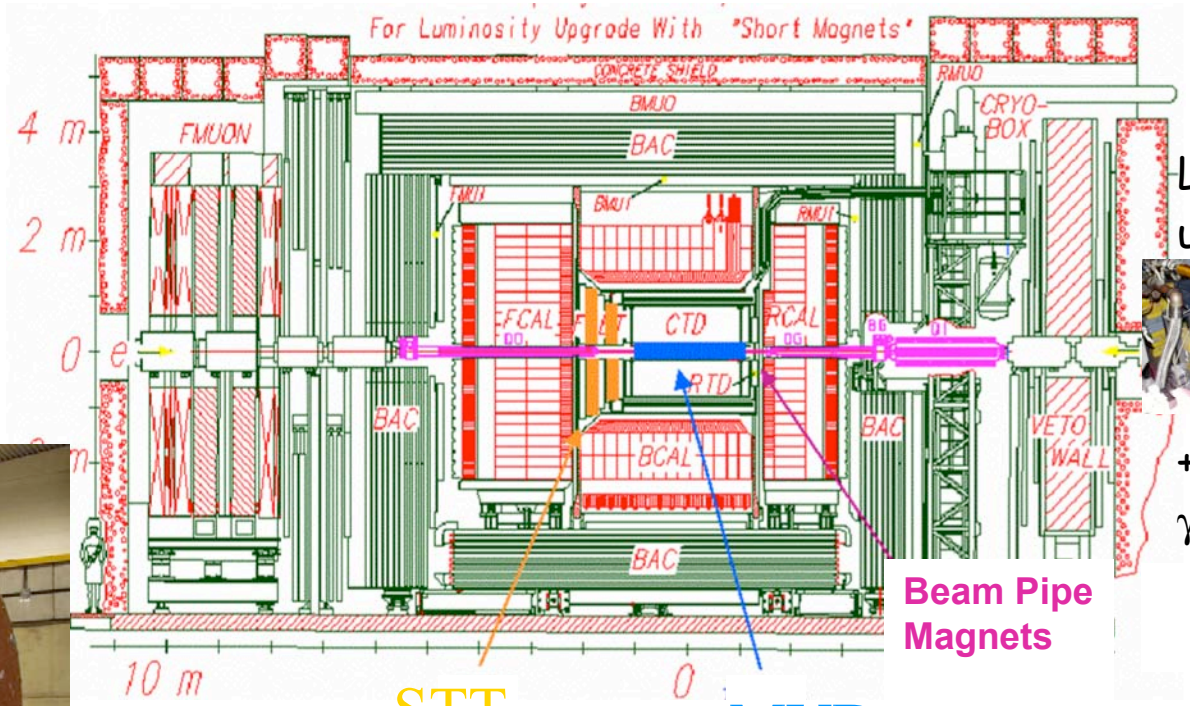
- Excess > SM expectation -- resolve with HERA - II



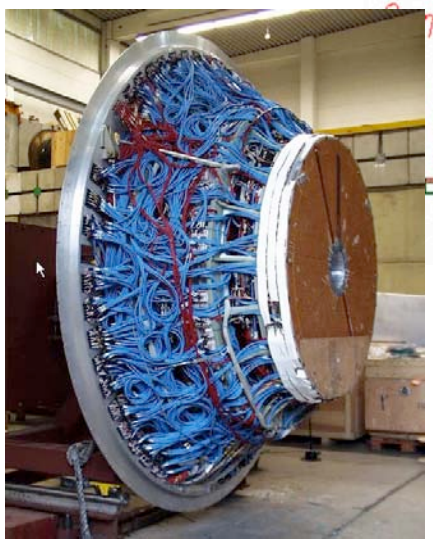


P_t^X cut	observed	expected
none	3	0.23 ± 0.06
25 GeV	2	0.12 ± 0.02
40 GeV	1	0.06 ± 0.01

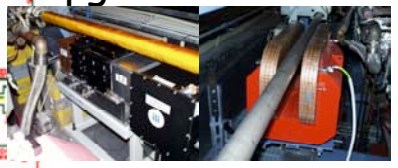
ZEUS HERA-II Upgrades



Straw Tube Forward Tracker



Lumi detector upgrades



+ beam counters, γ tagger

Beam Pipe Magnets

Micro Vertex Detector

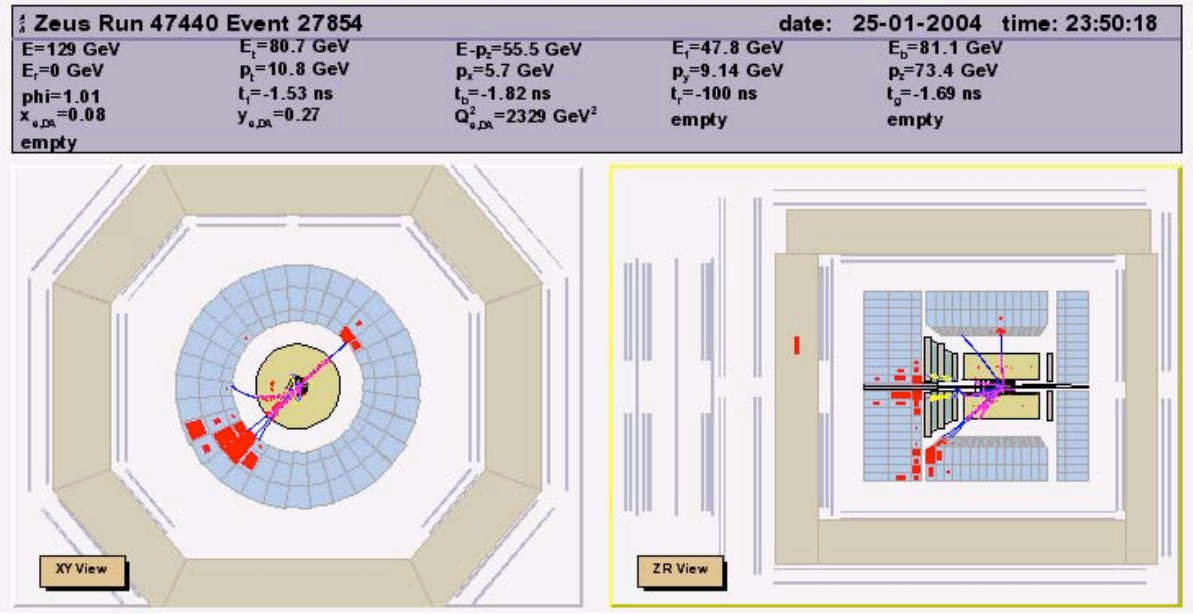
HERA - II Events

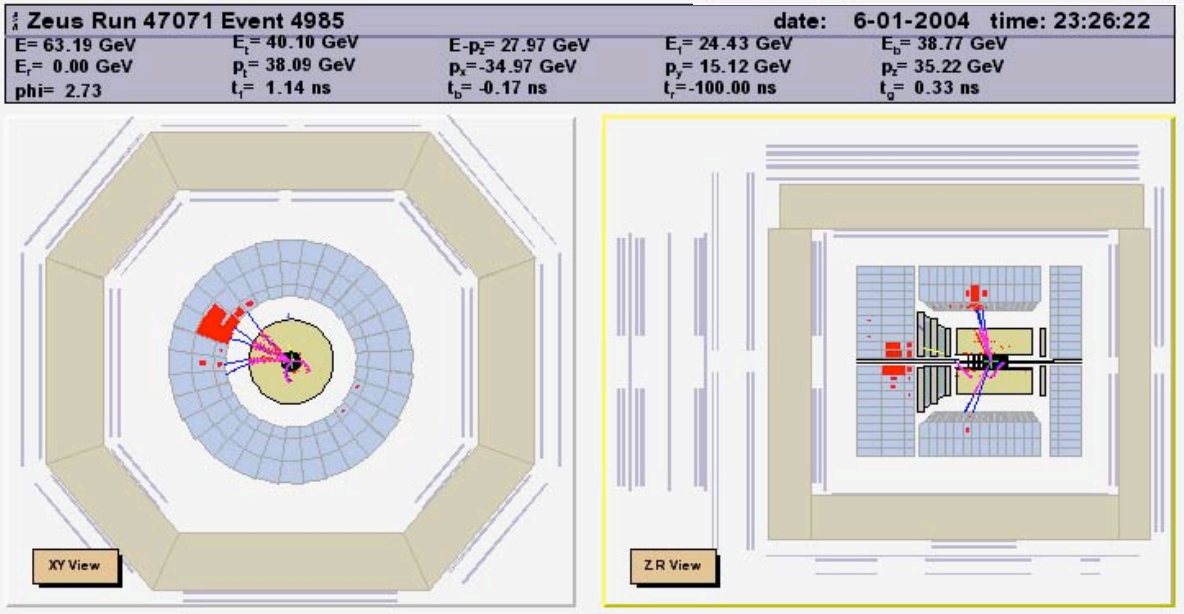
Neutral Current DIS

$e^{\pm} p \rightarrow e^{\pm} X$ (γ,Z^0 exchange)

$Q^2 = 2325$ GeV^2

$x = 0.08$





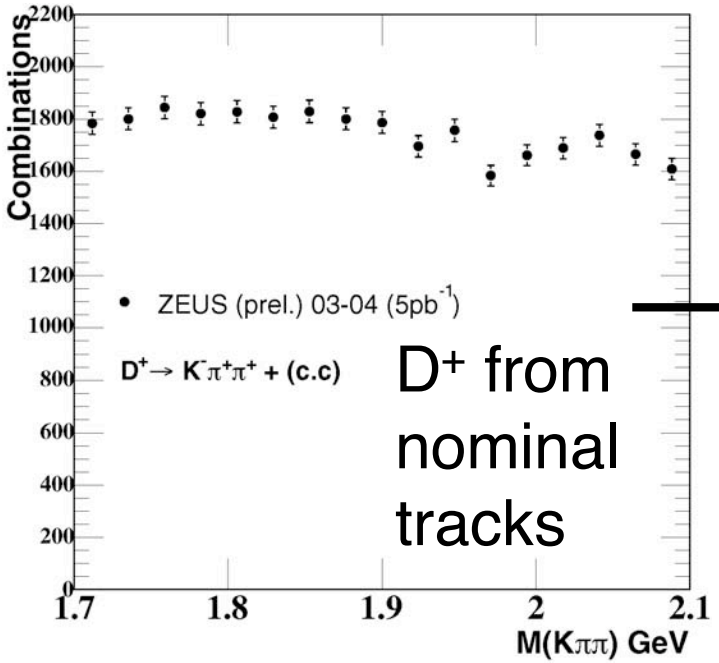
Charged Current DIS

$e^{\pm} p \rightarrow \nu X$ ($W^{\pm}$ exchange)

$Q^2 = 2800$ GeV^2

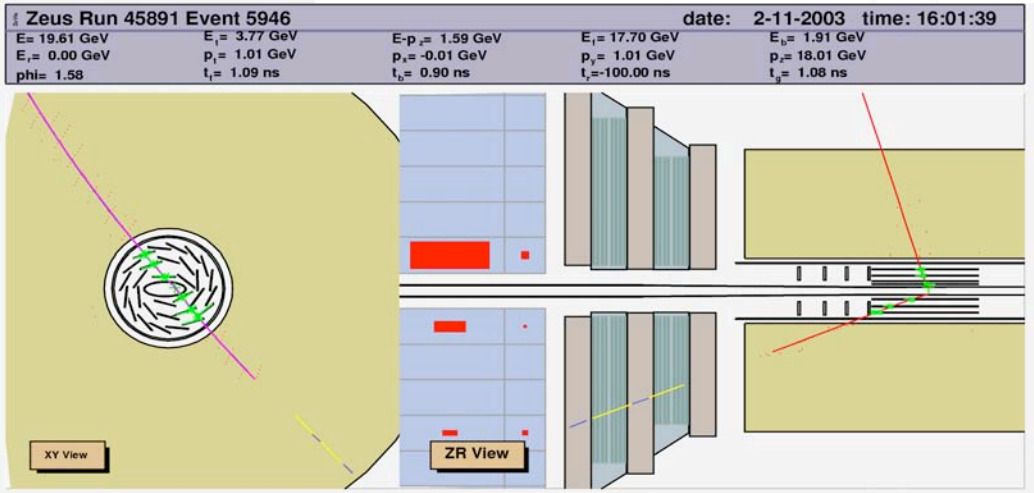
$p_T = 38$

New Zeus Tracking for HERA - II



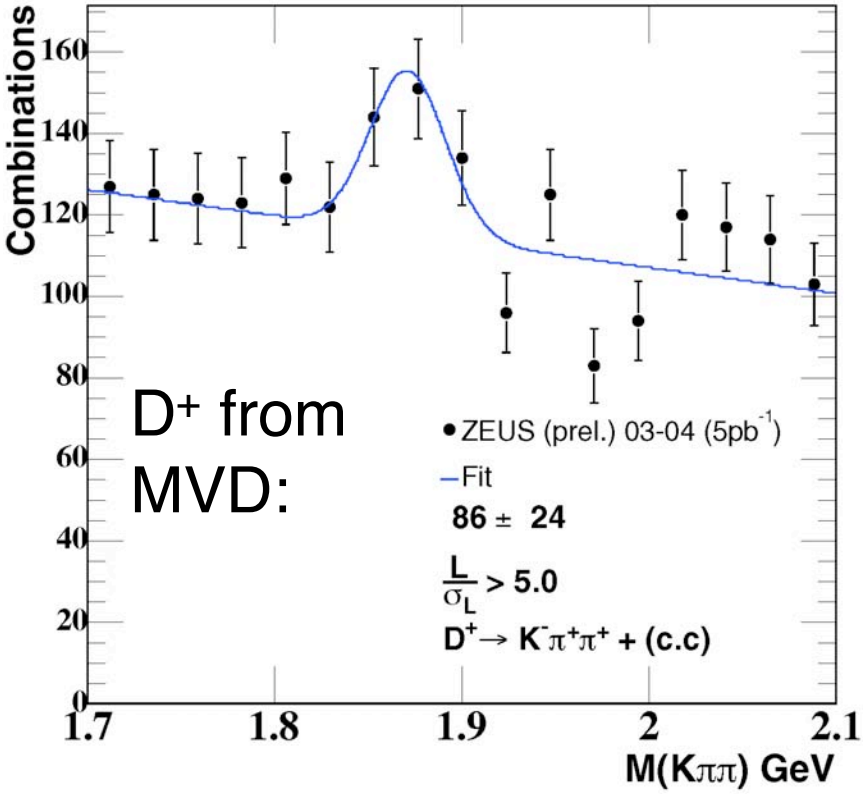
D+ from nominal tracks

MVD & STT:



Zeus Microvertex detector has been used to extract D+ mesons from the 2003-4 data

- **Apply significance cut:**



D+ from MVD:

HERA II CC polarized cross section

Luminosity = 6.6 pb^{-1}

(~ 170 events)

Polarization = 33%

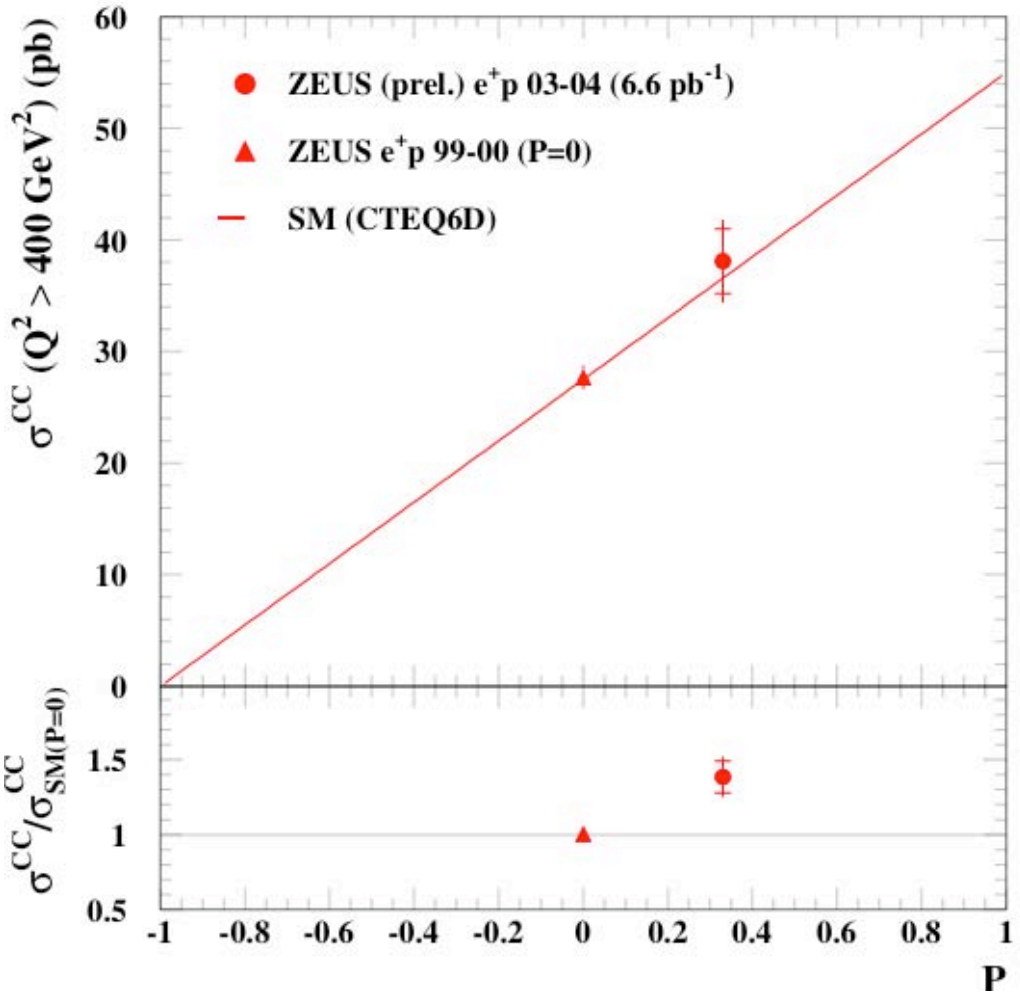
$Q^2 > 400\ GeV^2$

Systematics ~ 2%

- Cal. Energy Scale
- Selection, PDF &Trigger uncertainty

HERA II e^+ point is 2.8 σ above unpolarized HERA I point

Consistent with SM



$\sigma_{CC} = 38.1 \pm 2.9\ (stat.) \pm 0.8\ (sys.) \pm 2.0\ (lumi.) \pm 0.8\ (pol)\ pb$

ZEUS Conclusions & Outlook

New results completing the picture from HERA I:

- Full complement of structure function & cross section measurements
- Precise jet measurements determine α_s within 2% and constrain the structure function QCD fits
- A new era in spectroscopy has begun with the pentaquark
- Charm physics providing new constraints on the gluon
- γp & DIS b cross-sections are now in general agreement with NLO QCD calculations
- Understand diffraction in terms of QCD & diffr. PDFs

First results from HERA II show great promise

- New charm data with Zeus microvertex detector
- Polarized Charge Currents