ZEUS Status Report

Kunihiro Nagano
on behalf of the ZEUS Collaboration

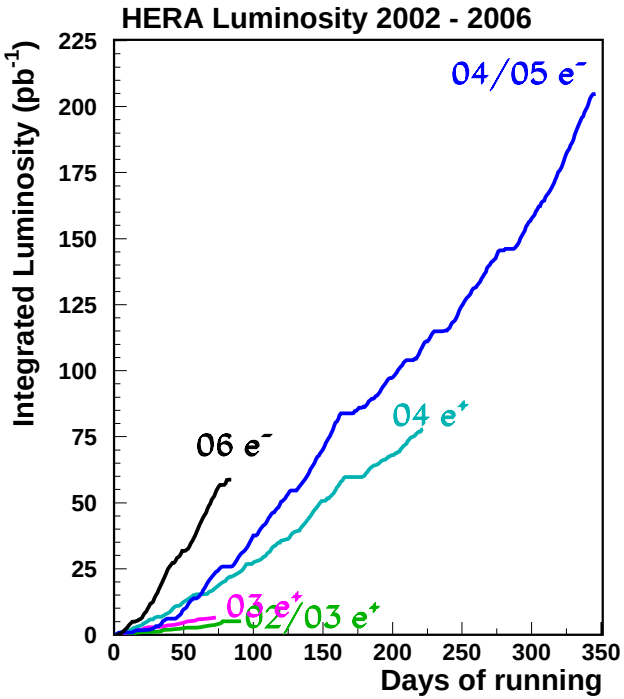
at the 61st Physics Research Committee Meeting, 11/May/2006

Contents

I. Data taking and running

- Recent running conditions
- Improvement in the detector understanding
  -- New MVD alignment

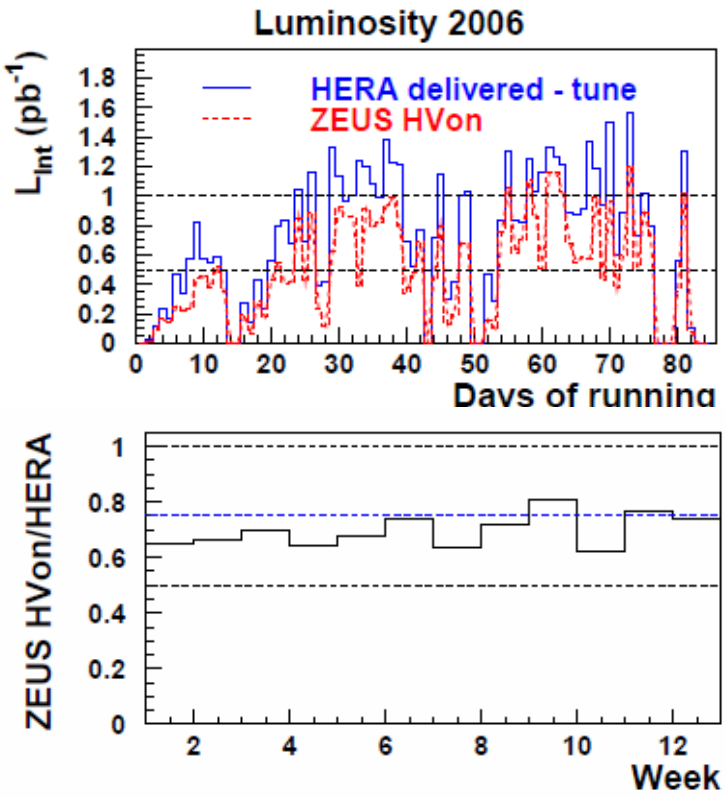
Recent ZEUS runs



► **HERA delivered luminosity as a function of days of running**

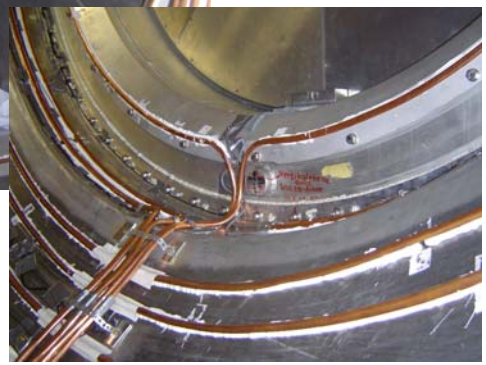
- Thank you for the excellent performance of HERA in 2006

► **ZEUS gated luminosity and efficiency**



- HERA could deliver and ZEUS could collect > 1 pb^{-1} / day
- ZEUS efficiency with HV on ~75%

➔ ZEUS DAQ and detectors are operating well including the Forward Straw Tube Tracker (STT)

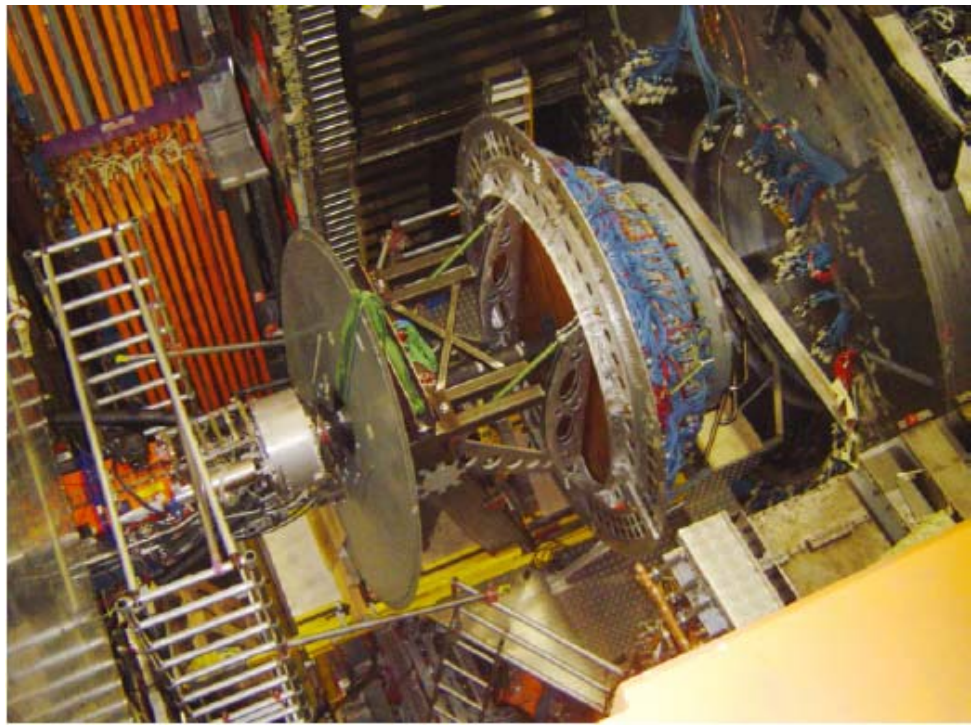


STT cooling upgrade

- **During the shutdown Nov.05 to Jan.06, STT was once removed to upgrade its cooling system, and then was reinstalled**

-- Insufficient STT cooling interfered solenoid operation

-- Thus, STT was off for 04-05 e- runs



- Whole procedure was completed successfully.

→ No interference problem to solenoid operation observed.

→ STT is on for 06 e- runs, and is taking data.

ZEUS operation

- HERA delivered : 58.75 pb^{-1}
  ZEUS gated with HV on : 41.22 pb^{-1}

- ZEUS inefficiency is mostly due to HV trips for CTD.
- Suffering from proton background spikes, some caused by outside construction work (parking lot near H1 hall)

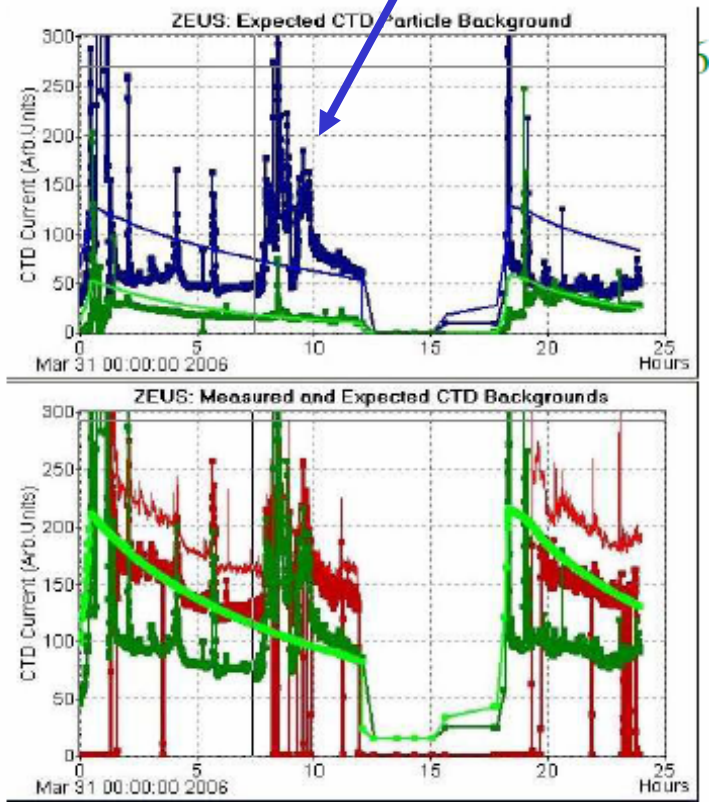
➔ Less spiky proton beam is desirable

- On 2.May, there was a vacuum leak at the absorber 4 (SR11)

→ Luminosity back on last Friday (5/May)

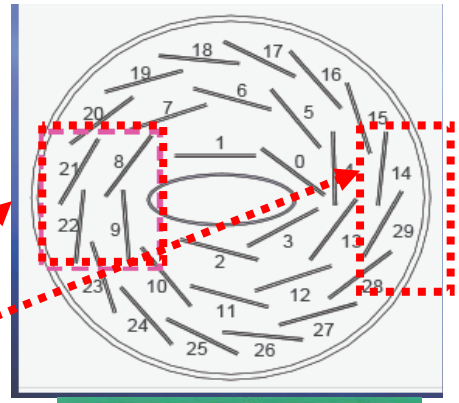
→ Electron beam-gas background condition is very good

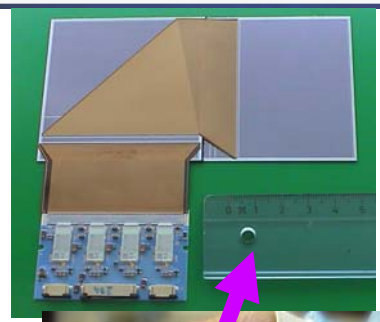
Proton bkgd



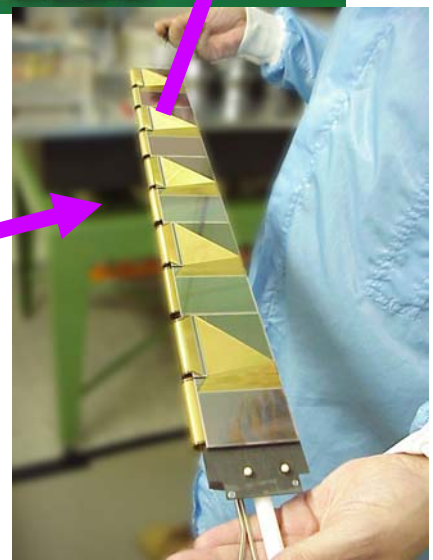
Micro Vertex Detector (MVD) alignment

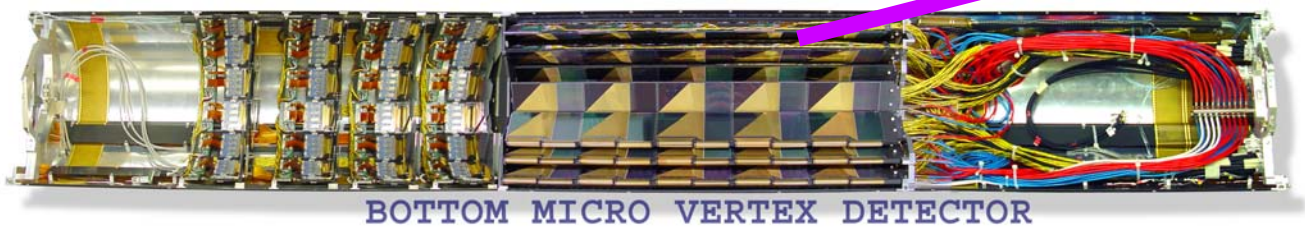
- Had been aligned using cosmic data
- With large statistics of physics data and detailed analysis, getting to know that there is still some room to improve alignment:
  -- MVD hit residuals worse (and data/MC agreement worse) where there is not enough cosmic data



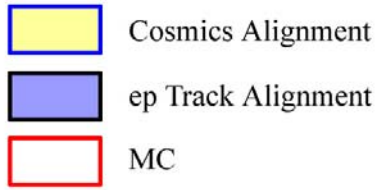


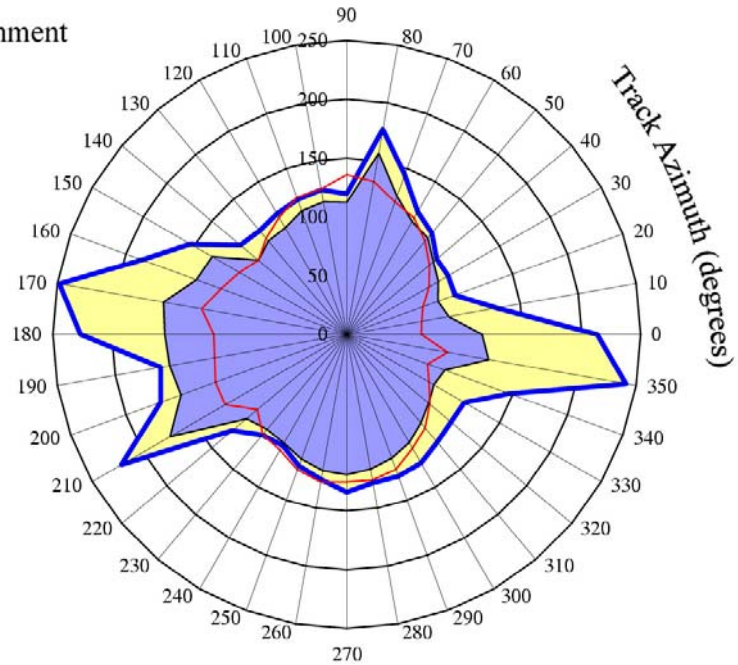
- **Alignment using "Millepede": Linear least square fit with a large number of parameters**
  -- Alignment parameters and tracks are fitted simultaneously
  *** Cosmic → ep data**
  -- Large amount of data available
  *** Ladder by Ladder → Sensor by Sensor**
  -- Was 6 parameters(3pos+3rot.) for each ladder
  -- Now 5 parameters for each sensor





MVD alignment -cont'd-

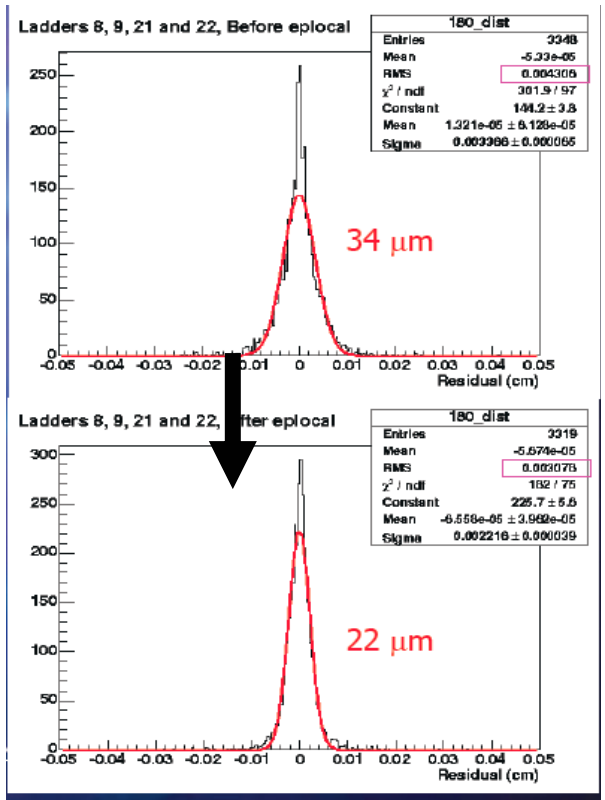




► **Impact parameter to beam spot**

-- Big improvement from cosmic alignment

➔ MC and data agreement greatly improved

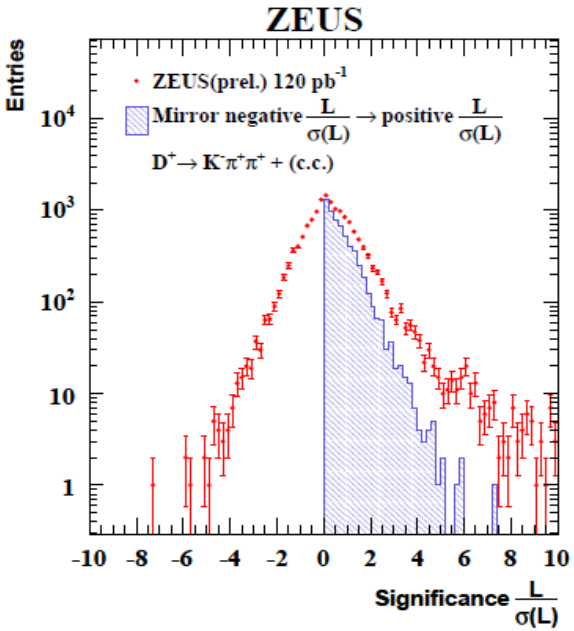


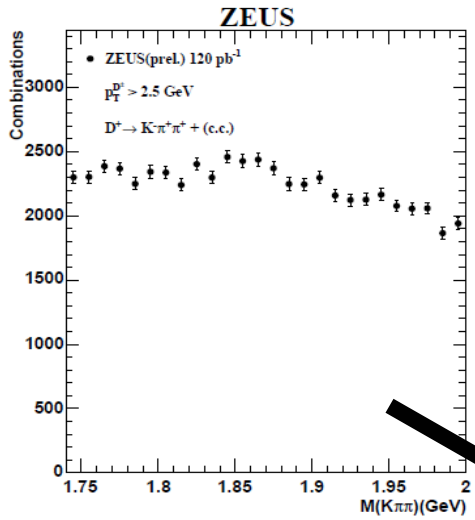
► **MVD hit residuals**

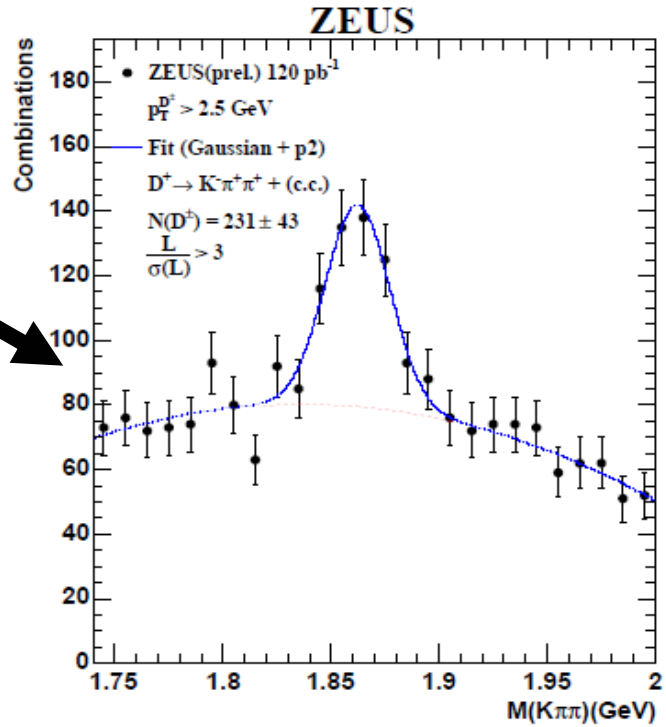
-- Improved at the y~0 "cosmic weak" points

MVD alignment impacts to heavy-flavor tagging

- **Decay length significance: L/σ(L)**
  - ►**Application to $D^+ \rightarrow \pi^+\pi^-K^-$ (+c.c.)**







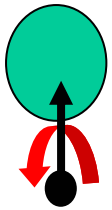
- S/N improved by factor 30 by requiring L/σ(L) > 3

II. Physics Highlights

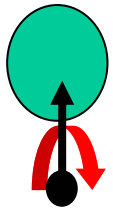
- **HERA-II = With large luminosity of polarized lepton beams, using improved tracking detectors**
  - -- High-Q^2 NC/CC
  - -- EW+QCD fits
  - -- Search for high Pt lepton events with missing Pt

- **HERA-I = With mature detector understanding**
  - -- Di-Jet in DIS and α_s determination
  - -- Multi-jet production in photoproduction
  - -- Light nuclei production in DIS

EW physics with polarized lepton beams



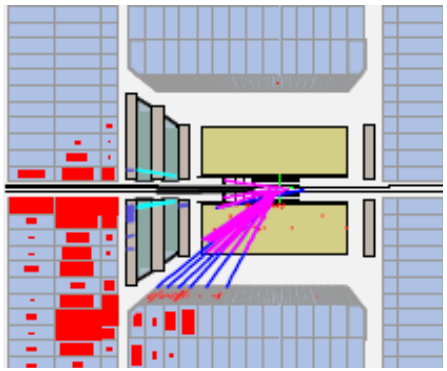
Left-Handed



Right-Handed

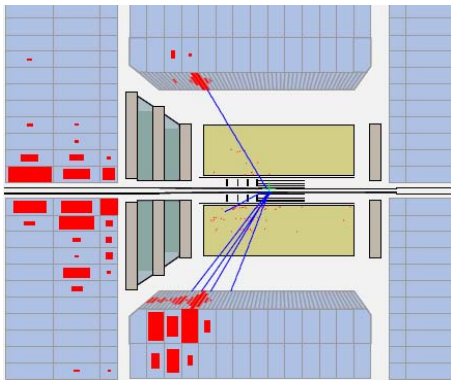
- Polarization = Asymmetry of Helicity states:
  $P = (N_R - N_L) / (N_R + N_L)$
- Helicity = Chirality (if mass is neglected)
  → By means of Pol, chiral structure can be tested.
- RH != LH is: parity violation

► Charged-current DIS (ep → ν X)



- "Pure" Weak
  → Chiral structure of weak int. is directly visible as a function of Polarization
- Weak = "100% parity violated" (no RH)
  → Zero cross section @ Pol=1 (-1 for e+)
  → σ (Pol) = (1+Pol) σ (Unpol)

► Neutral-current DIS (ep → eX)

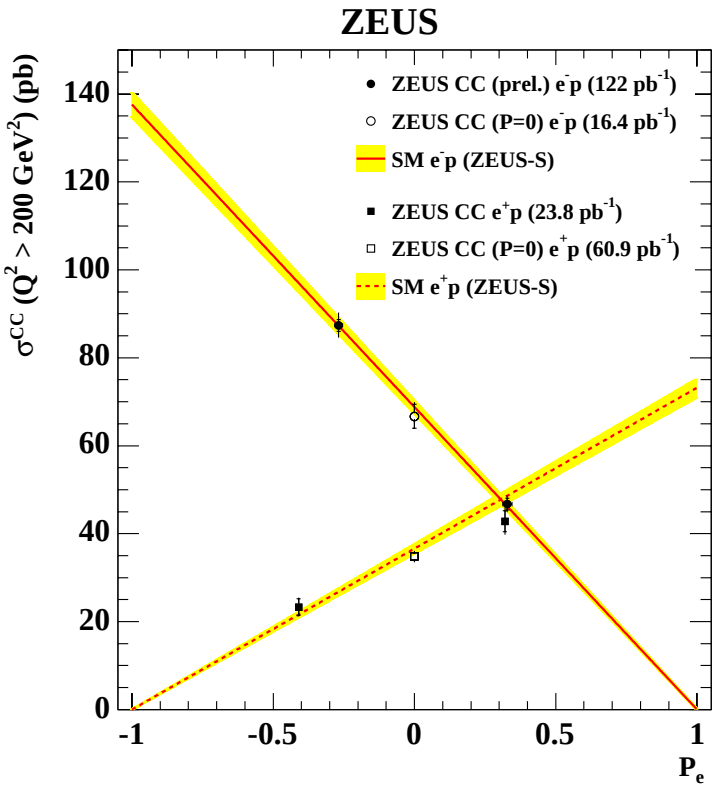


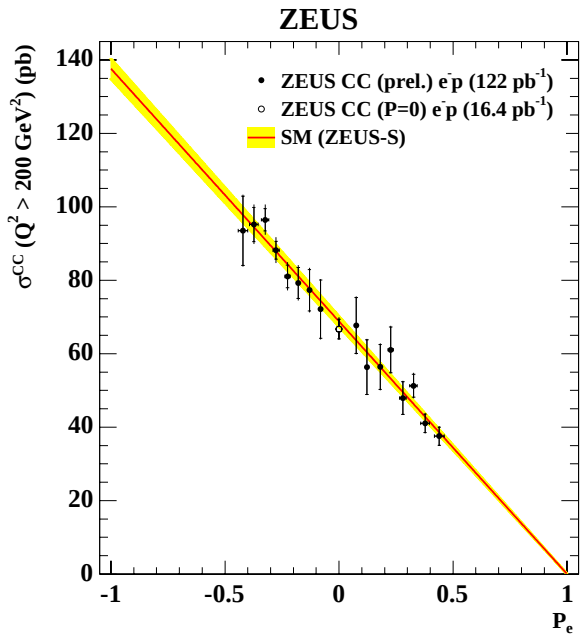
- Weak's parity violating effect through γ-Z interference and pure Z → visible only at large Q^2
- Such γ-Z and Z terms contain EW parameters, i.e. quark couplings to Z, $\sin\theta_W$, M_Z

CC cross section vs. polarization

- **Finalized e^+ 2003-04 analysis → Will be published (Accepted by PLB)**
- **Have analyzed full e^- data taken until 2005** **[New at DIS06]**

→ ~120 pb^{-1} for e- (~8 times more ←→16 pb^{-1} at HERA-I)



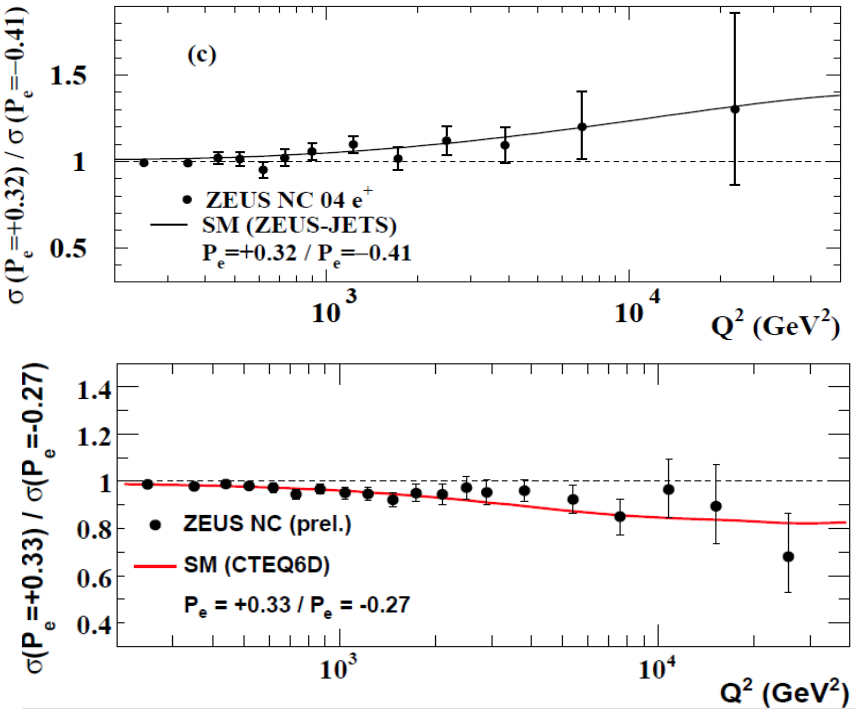


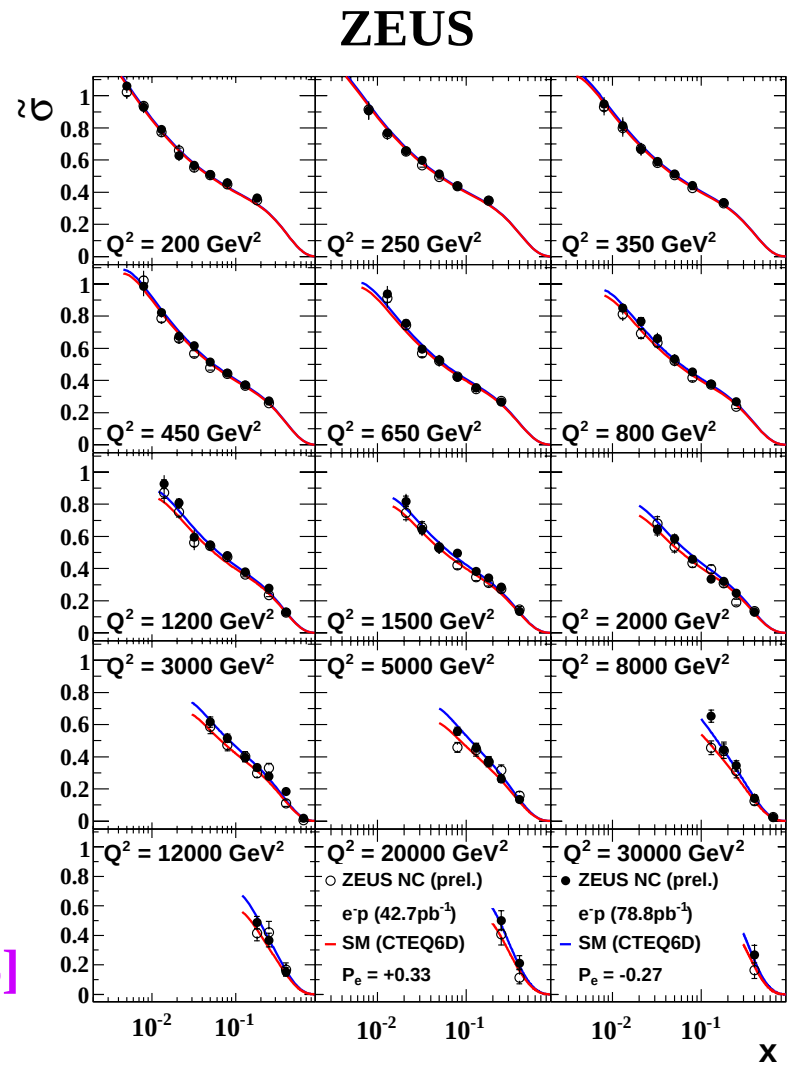
- Clear demonstration of linear dependence on pol. ((1-Pe)/2)
- Consistent with RH=0
- W_{RH} mass limit was derived as 180 GeV (assuming RH/LH CC couplings are same). Error dominated by polarization uncertainty

NC cross section vs. polarization

► **$d\sigma/dQ^2$: weak effects visible at high Q^2**

→ Parity violation in NC first observed at HERA





► **Double differential cross sections**

-- To explore full potential of EW(+QCD) sensitivity ←First HERA-II **[new at DIS06]**

EW+QCD fit

- Reminder: ZEUS-JETS fit = HERA-I F_2 + Unpol. highQ^2 NC+CC + DIS incl.Jet + PhP di-Jets. → The best we could do with HERA-I
- **Now: ZEUS-JETS + Polarized e- NC and CC** **[new at DIS06]**
  - -- First fit using HERA pol data
  - -- Best sensitivity not only to PDFs but also to EW
    - ➔ The best we can do now

NC cross section: $\sigma(e^{\pm}p) = (Y_+F_2^0 \mp Y_-xF_3^0) \mp P(Y_+F_2^P \mp Y_-xF_3^P)$

Structure functions:

$$F_2^{0,P} = \sum_i A_i^{0,P}(Q^2)[xq_i(x,Q^2) + x\bar{q}_i(x,Q^2)]$$

$$xF_3^{0,p} = \sum_i B_i^{0,P}(Q^2)[xq_i(x,Q^2) - x\bar{q}_i(x,Q^2)]$$

unpolarized coefficients

$$A_i^0(Q^2) = e_i^2 - 2e_i v_i v_e P_Z + (v_e^2 + a_e^2)(v_i^2 + a_i^2)P_Z^2$$

$$B_i^0(Q^2) = -2e_i a_i a_e P_Z + 4a_i a_e v_i v_e P_Z^2$$

polarized coefficients

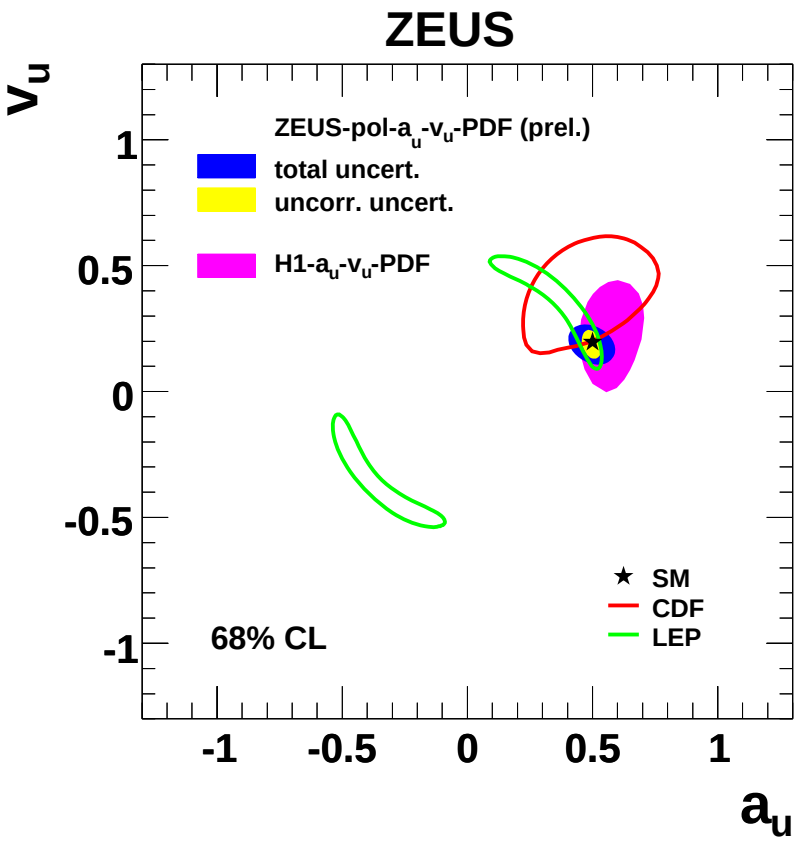
$$A_i^P(Q^2) = 2e_i v_i a_e P_Z - 2v_e a_e (v_i^2 + a_i^2)P_Z^2$$

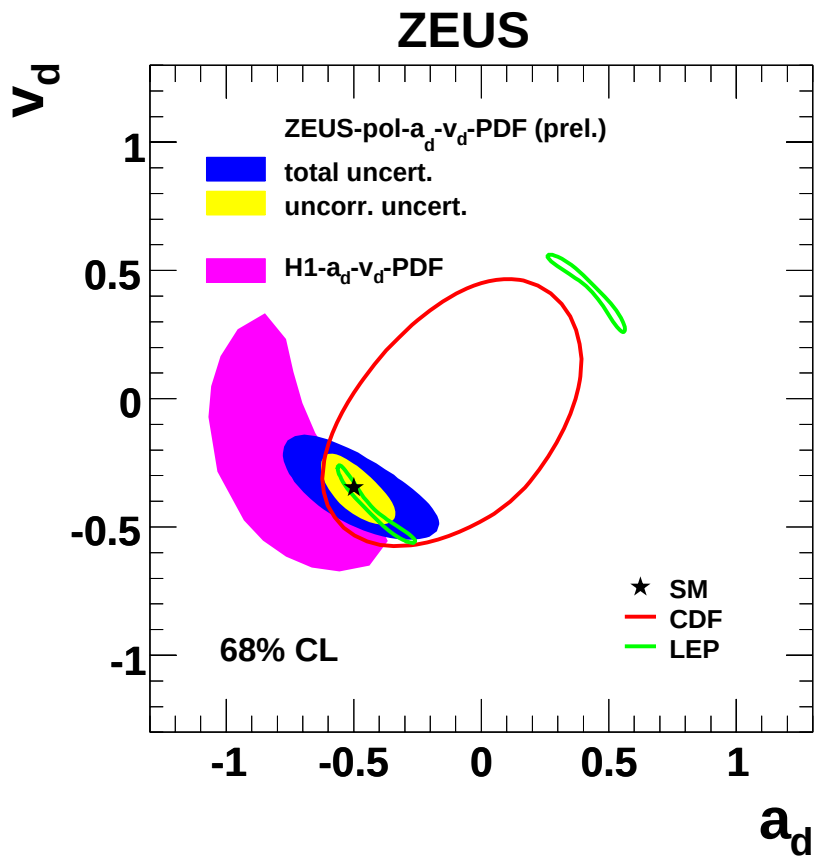
$$B_i^P(Q^2) = 2e_i a_i v_e P_Z - 2v_i a_i (v_e^2 + a_e^2)P_Z^2$$

v_e is very small (~0.04).
$P_Z >> P_Z^2$ (~middle Q^2) → unpolarized xF_3 → a_i, polarized F_2 → v_i

Light quark couplings to Z

- V_u, V_d, A_u, A_d ➔ 4 fits in which 2 of them are free to be determined





- High precision, competitive to other experiments
- Big improvement in v determination (compared to HERA-I unpolarized)
  → Polarized data sensitivity

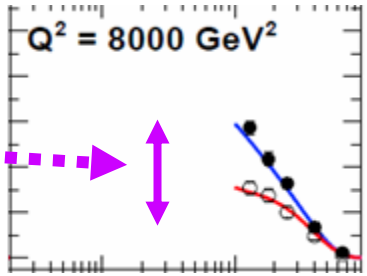
PDFs / xF_3

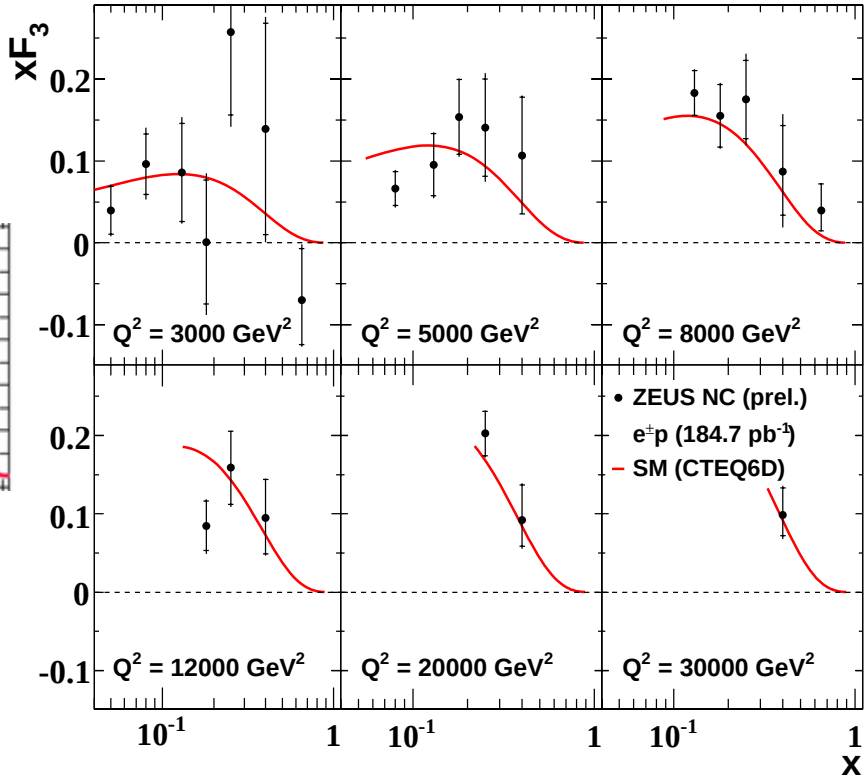
ZEUS

► **xF_3^{Unpol} = Valence quark**

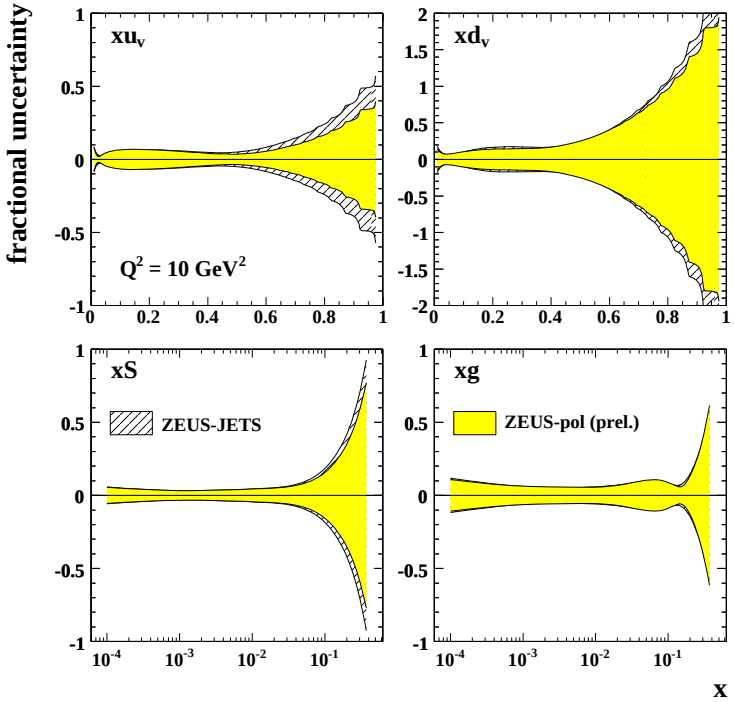
-- Combined RH and LH samples to obtain 'pseudo-unpolarized' big luminosity sample

$$xF_3^{Unpol} \propto \sigma^{Unpol}(e^-) - \sigma^{Unpol}(e^+)$$





ZEUS

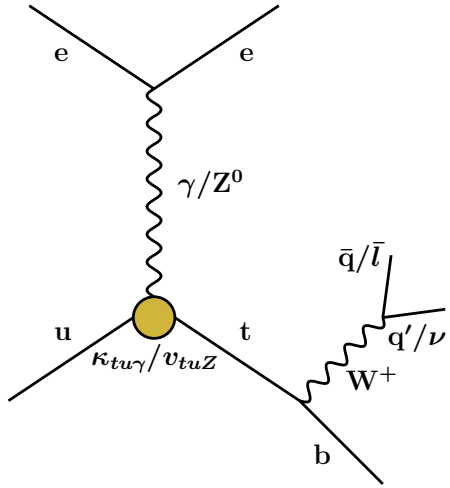


► **Precision of u-quark PDF determination by the EW+QCD fit**

-- Improved in particular at large x as expected, i.e. $\sigma(NC) \propto 4u + d$

$\sigma(CC) \propto u$

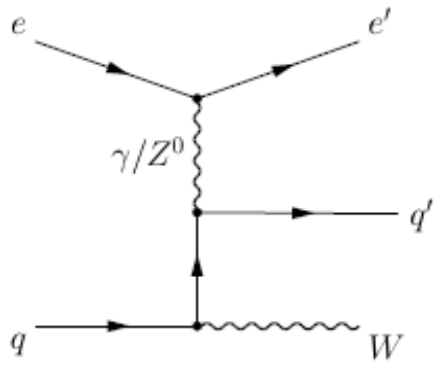
Search for isolated lepton with missing Pt



- Reminder: ZEUS completed search for isolated lepton with missing Pt in the context of single top production for HERA-I

	HERA I (130 pb^{-1})
e	$2/2.90^{+0.59}_{-0.32}(45\%)$
μ	$5/2.75 \pm 0.21(50\%)$
τ	$2/0.20 \pm 0.04(50\%)$

- Now extending the analysis with emphasis moved to:
  -- Selection optimal for W production search, closer to H1 analysis as H1 observes excess in data in particular at large P_T^X (P_T of hadron system)



► **Electron channel**

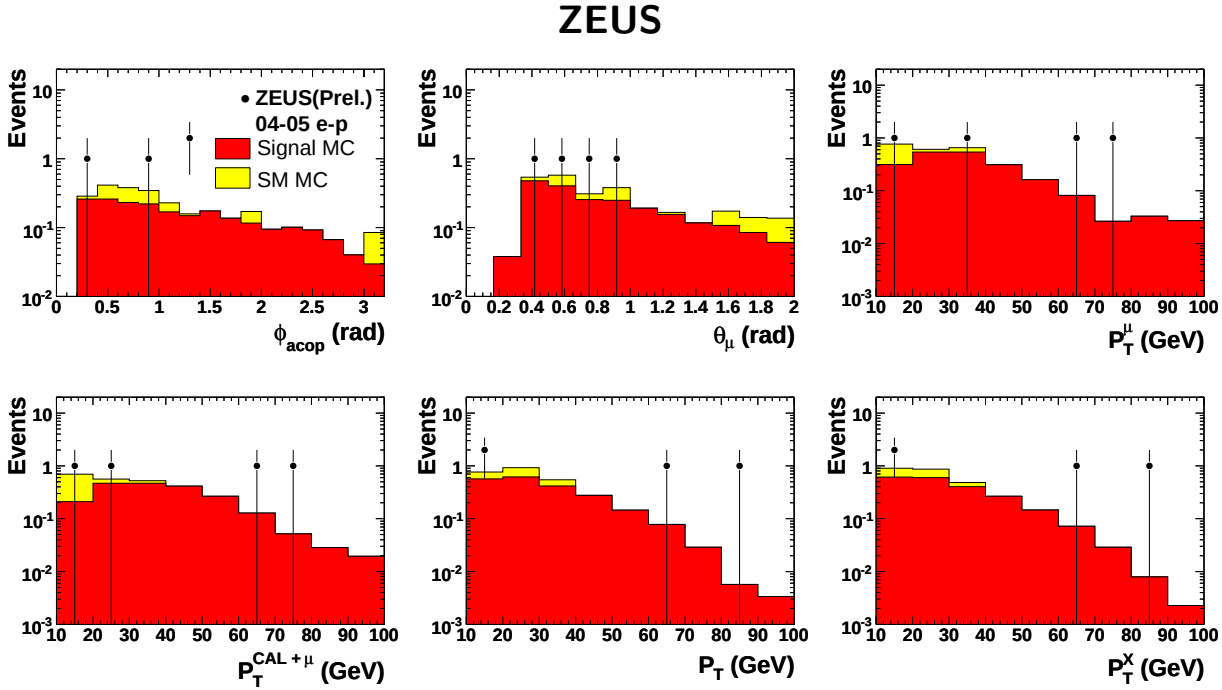
- 98-05 250 pb^{-1} were analyzed **[New at DIS06]**

e-channel			$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
98−05	e^-p	143 pb^{-1}	4 / 1.98 ± 0.36 (58 %)	3 / 2.86 ± 0.46 (43 %)
99−04	e^+p	106 pb^{-1}	1 / 1.50 ± 0.15 (59 %)	1 / $1.50^{+0.12}_{-0.13}$ (78 %)

Muon channel

- **Analyzed 04-05 e^- 126 pb^{-1}**
  [New at this PRC]
- Analysis details:
  - -- CAL MIP was used for muon ID
  - -- Sample: inclusive missPt (CC) trigger
  - -- ϕ_{acop}>0.2 rad
  - -- $P_T^X > 12$ GeV
  - -- $P_T^{miss} > 12$ GeV

➔ 4 events observed, while 2.8 events expected

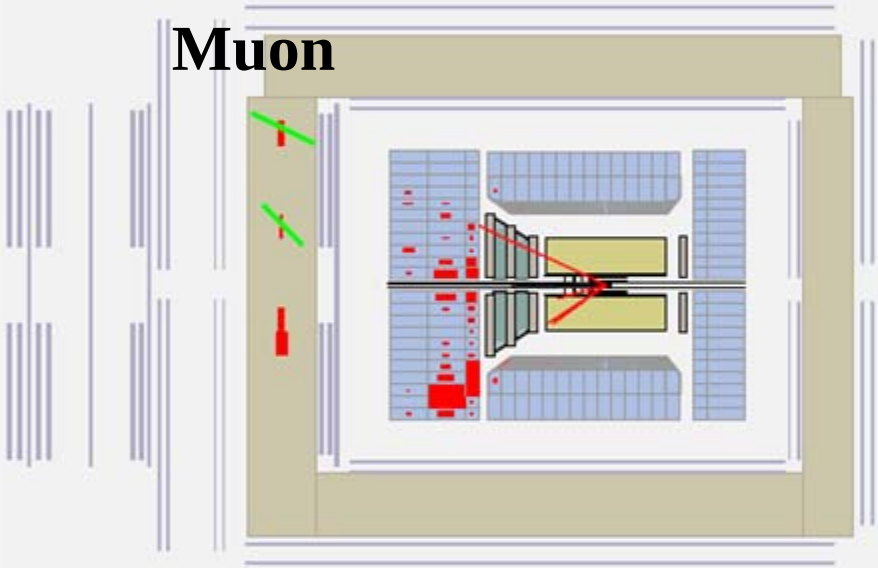


μ-channel	$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
$04-05 \quad e^-p \quad 126\ \mathrm{pb}^{-1}$	$2 \quad / \quad 1.4 \pm 0.2 \quad (68\ \%)$	$2 \quad / \quad 1.4 \pm 0.2 \quad (86\ \%)$

Muon candidates

- P_T^X = 66 GeV
- P_T^{miss} = 20 GeV

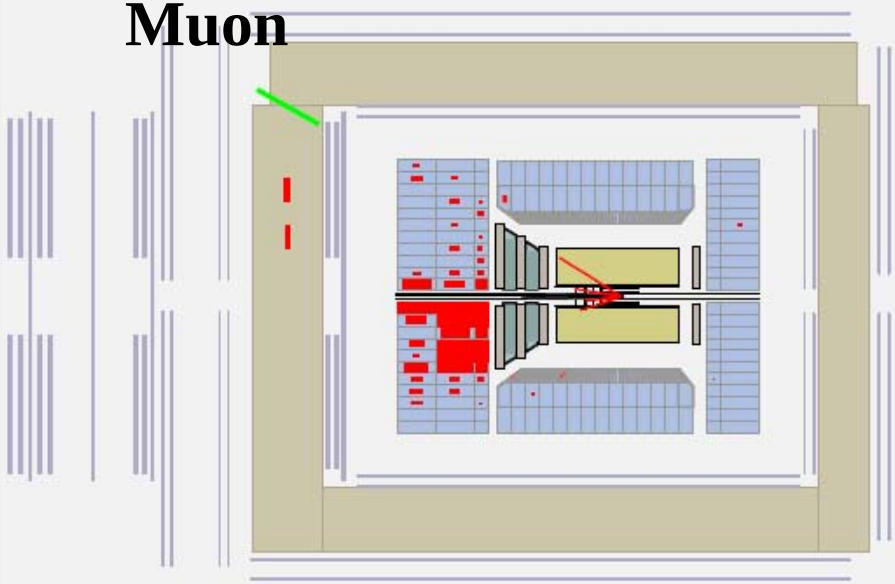
Muon



ZR View

- P_T^X = 82 GeV
- P_T^{miss} = 77 GeV

Muon



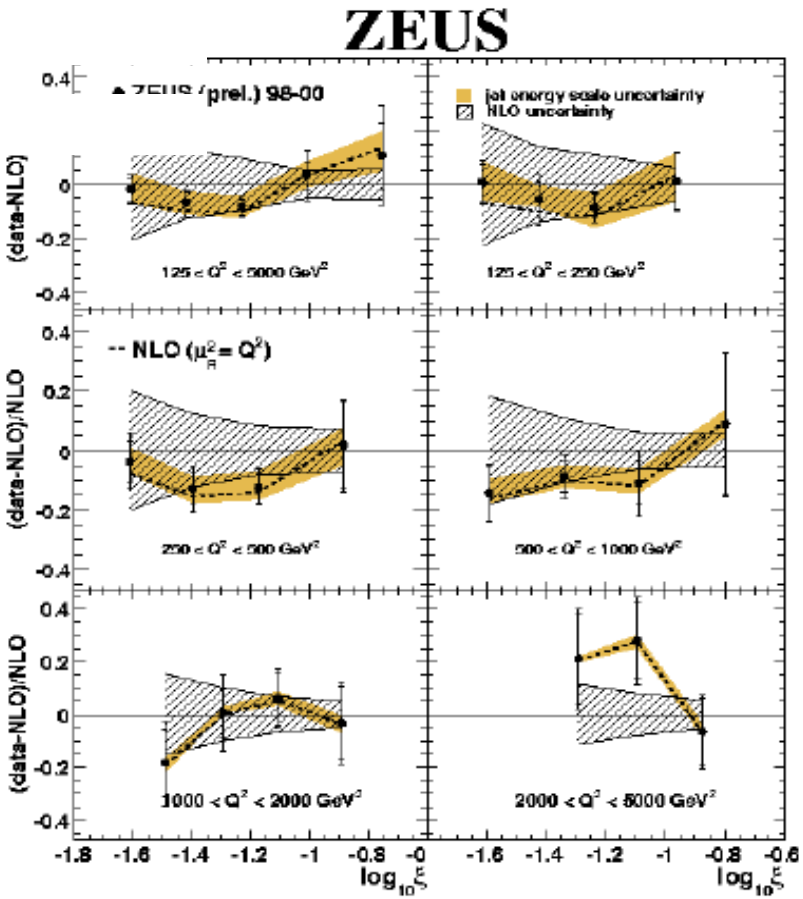
ZR View

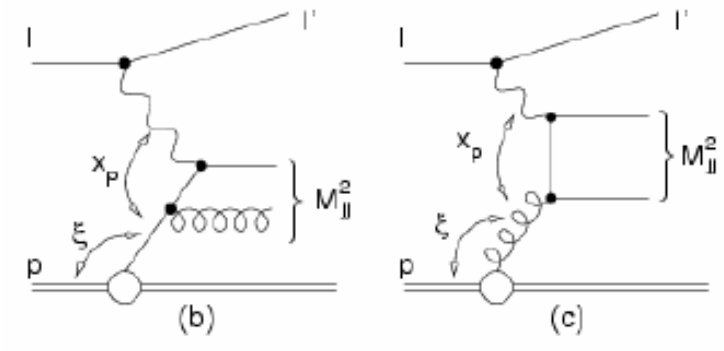
Di-Jet cross sections in DIS

● Given that HERA jets were shown to be important ingredients for determination of PDFs (in particular gluon) and α_s :

→ Double differential cross sections with large luminosity (82 pb^{-1})

→ Di-Jet which has direct sensitivity to α_s and gluon **[New at DIS06]**





► **Cross sections in ξ and Q^2**

$$\xi = x_{Bj}\left(1 + M_{jj}^2 / Q^2\right)$$

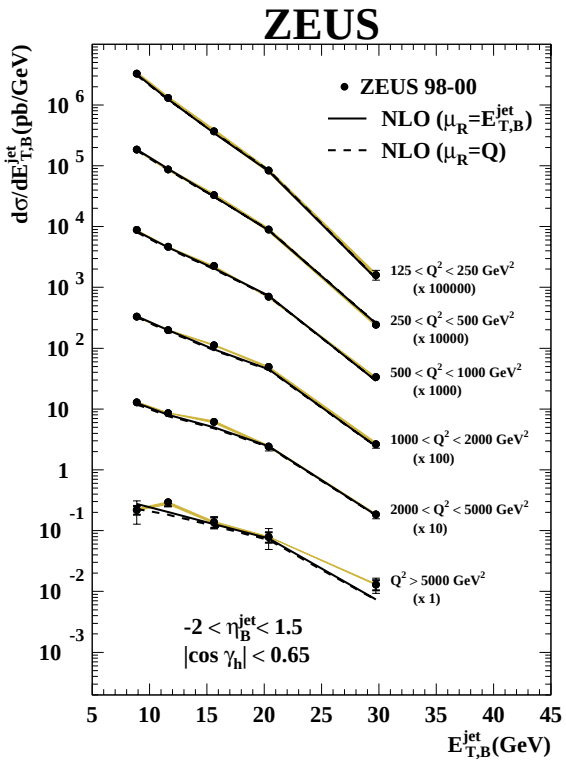
→ Very promising to deliver better constraint on PDFs

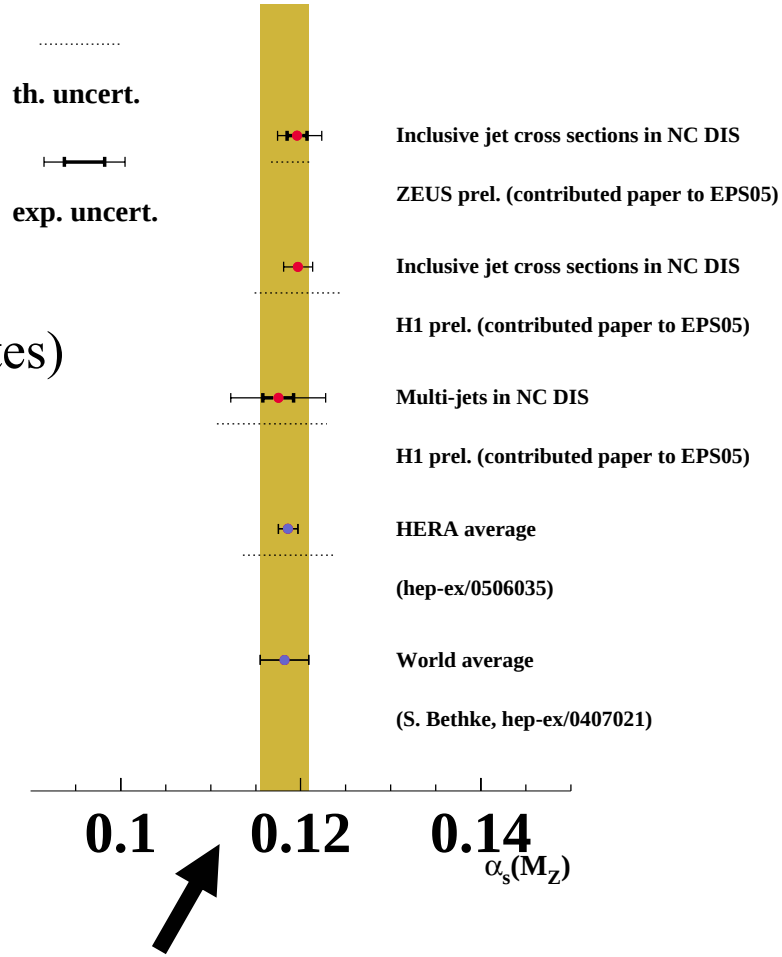
Inclusive Jet in DIS and α_s determination

► **DIS inclusive jet cross section was measured with large luminosity (81.7 pb^{-1})**
► **$d\sigma/dEt$, $d\sigma/dQ^2$ in inclusive jet were used to extract α_s**

- HERA gives one of the most precise measurements (Theo. uncertainty dominates)

► **Double differential cross sections (in E_T, Q^2) were also measured**





World average does not include HERA
HERA average does not include new measurements

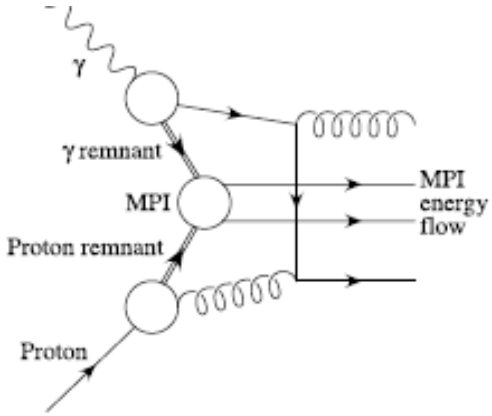
Three- or Four-Jet in photoproduction (PHP)

- **With 121 pb^{-1}: 3-Jet and 4-Jet PHP cross sections were measured**
  → 4-Jet is the first measurement at HERA [New at DIS06]

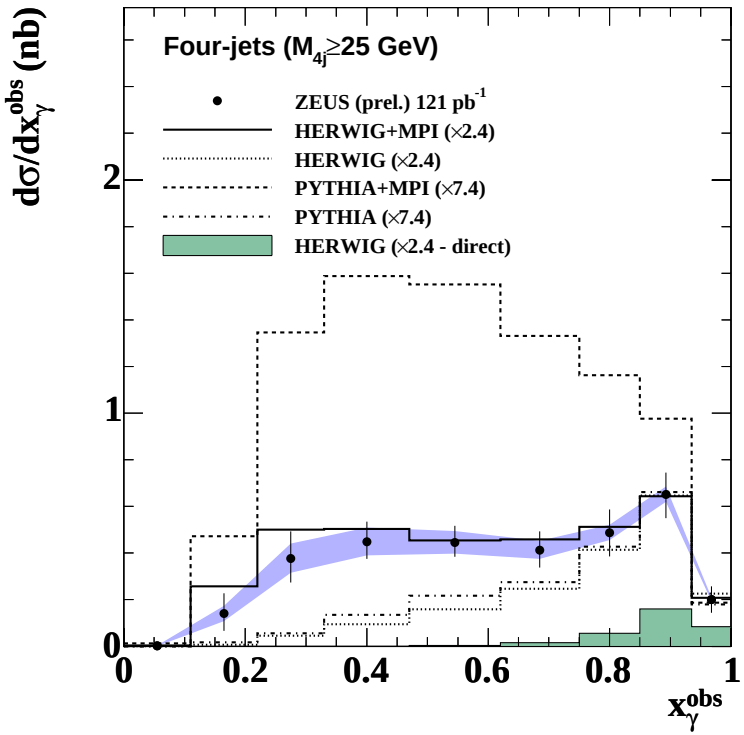
  -- Test of LO ME +PS MCs (Matrix Element + Parton Shower, LLA)

  -- Test of Multi-Parton Interaction (MPI) models

  ➔ Vital inputs to the LHC



► **4-Jet cross sections as a function of x_γ^{obs}**

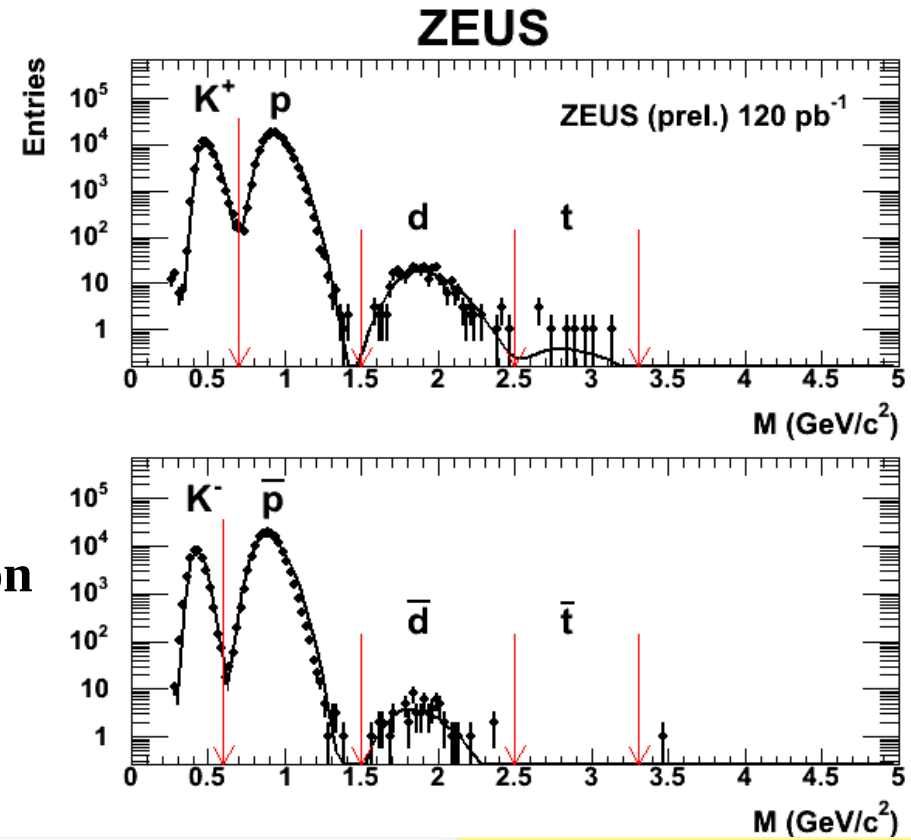


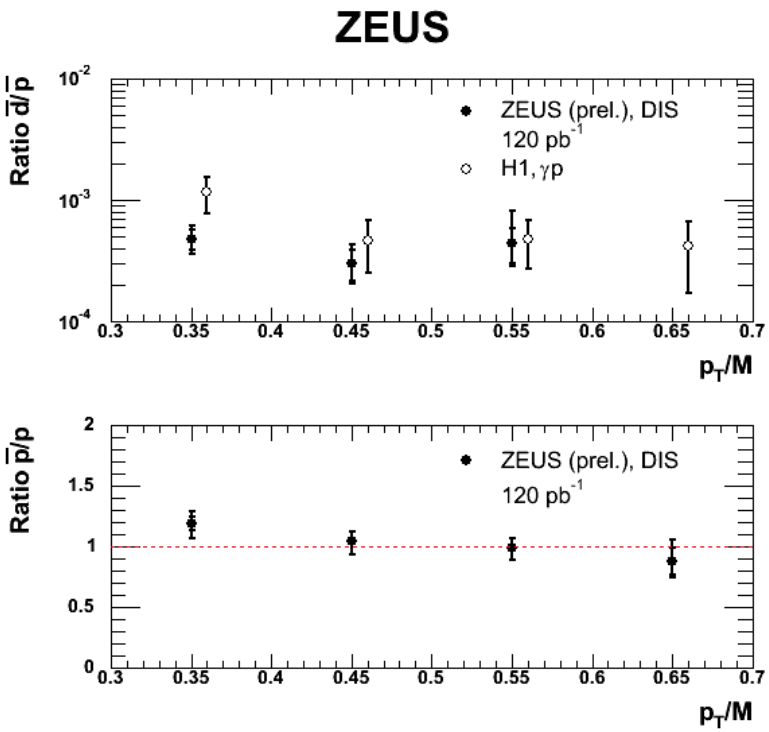
- x_γ^{obs} : > 0.75 ➔ photon direct
  < 0.75 ➔ photon resolved
- LO ME+PS failed at low x_γ^{obs}
- HERWIG + MPI described data

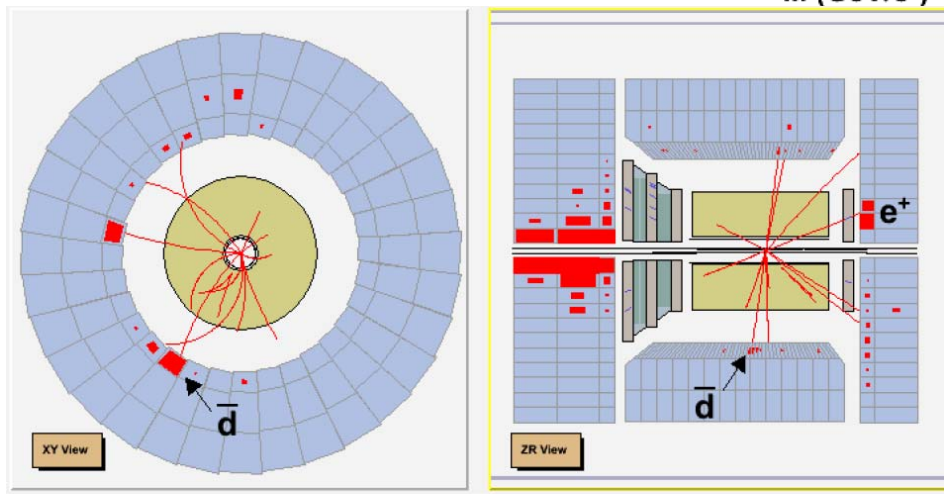
- This trend seen clearer at low Mjjj
- Also observed in 3-Jet events

Light nuclei production in DIS

- **Light nuclei was looked for in DIS events' final state [New at DIS06]**
  - ► **Mass (from dE/dx and mom.)**
    -- First observation of anti-deuteron, triton produced in DIS
  - ► **Prod. Ratio anti-deuteron/anti-proton**
    -- Consistent with H1 (PHP)







Q^2 = 45.5 GeV^2, E_e = 14.2 GeV
antideuteron; P = 1.1 GeV/c, dE/dx(mips) = 2.7, E_{CAL} = 3.2 GeV

III. Low-energy running

- **F_L measurement**

  -- Amongst various use-cases, for example, vector mesons at low W, F_2 measurement at higher x etc., here we considered our feasibility of measuring F_L

F_L

- F_L is a fundamental observable

$$F_2 = \frac{Q^2}{4\pi\alpha^2}(\sigma_L + \sigma_R)$$

$$F_L = \frac{Q^2}{4\pi\alpha^2}\sigma_L$$

← Proton structure as probed by longt. Polarized γ^*

- F_L=0 at QPM, i.e. static model

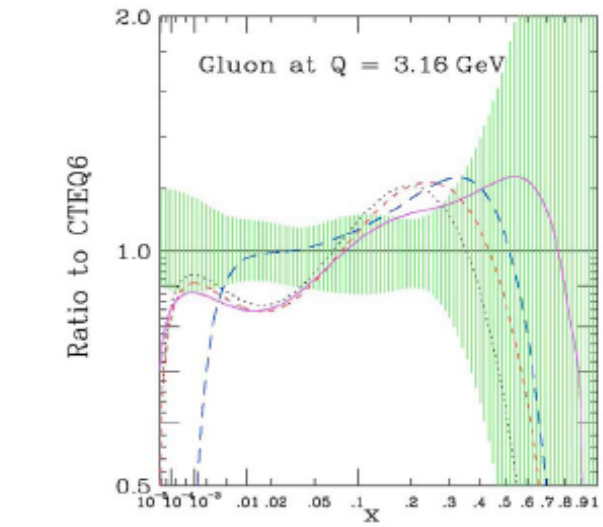
→ Hence, non-zero F_L value can be directly related to parton dynamics inside proton

- F_L @ low-x is particularly interesting as it is a very good test of low-x parton dynamics which is not yet understood

→ Theo. uncertainty is large

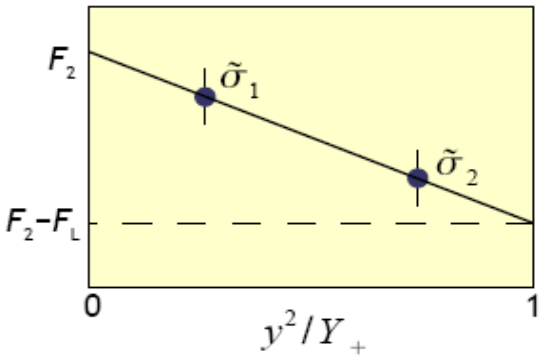
- And HERA is the only place where F_L can be measured at low-x
- No "model independent" extraction of F_L yet

From Pumplin, DIS05



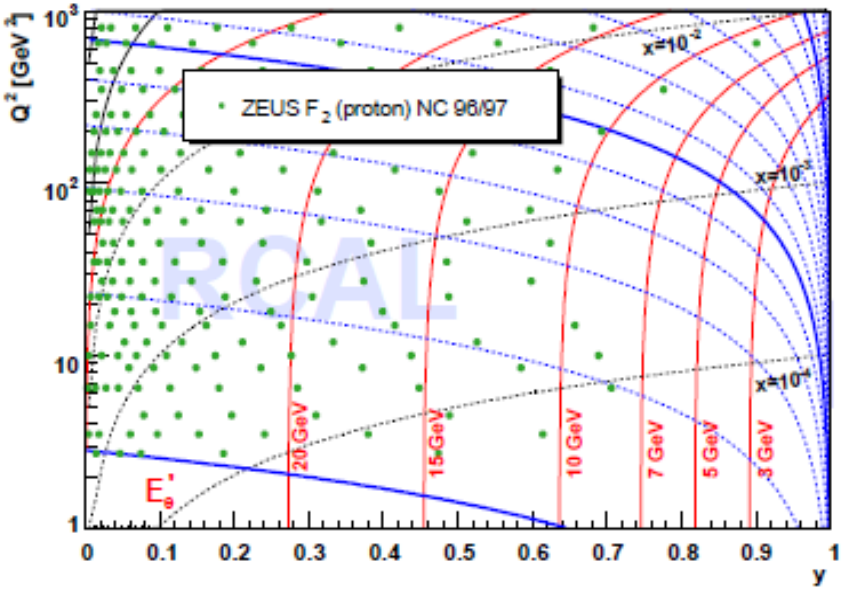
Technical challenges

● Cross sections is a composite of F_2 and F_L → To separate F_L out, >=2 cross sections with different y are needed for each (x,Q^2)



$$\frac{d^2\sigma}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4} Y_+ \{F_2 - \frac{y^2}{Y_+} F_L\}$$

➔ To obtain F_L with high accuracy:
-- larger y difference
-- more points are preferable



● High-y is experimentally challenging as:
-- Hadrons come closer to scattered e
→ Becomes difficult to identify e
→ Event topology comes closer to PHP, giving much larger backgrounds
-- High-y ←→ Low energy electron
→ Efficiency for detecting such low-energy electrons, and also purity against PHP becomes even more difficult issues

Ideas to control PHP backgrounds

- **6m tagger**

  -- Tags 0-degree scattered electron. (Acceptance check of Luminosity photon calorimeter, ep→e γ p)

  -- Provides direct measurement of PHP backgrounds

  -- Acceptance for PHP events: larger for e+ (~25%)

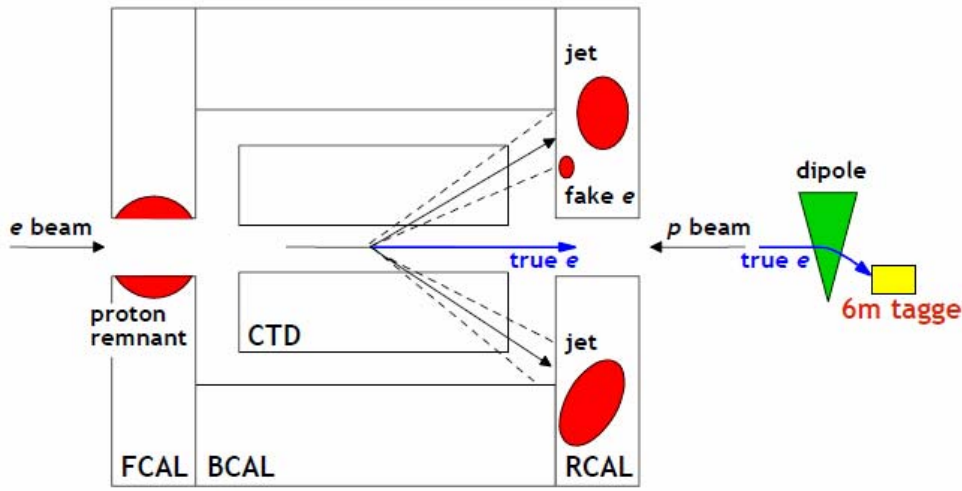
  ➔ Control of PHP backgrounds, giving correct normalization of MCs

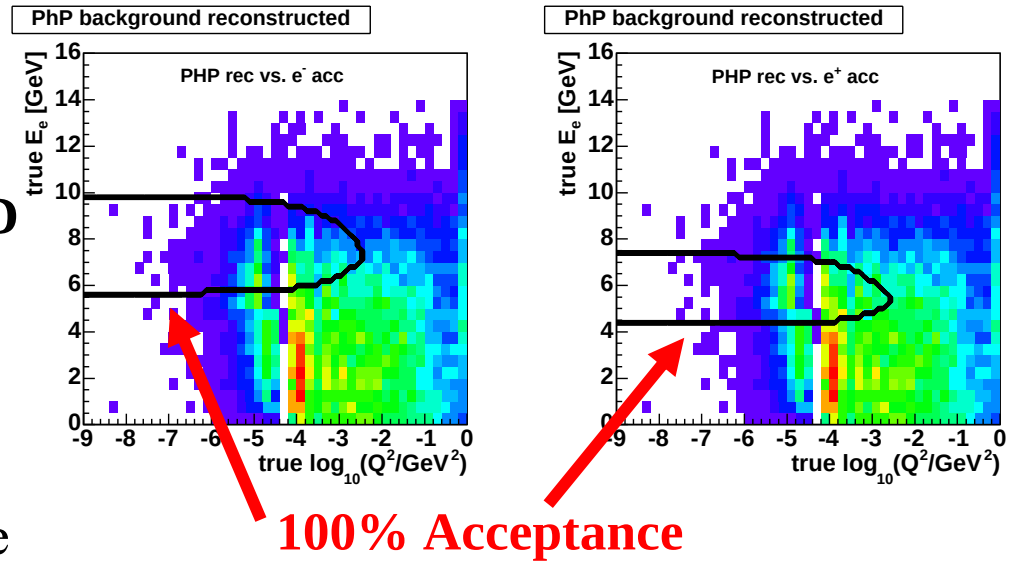
- **Using CTD tracks for Electron ID**

  -- Reduces PHP backgrounds

  -- But at the same time, signal acceptance is limited

→ Feasibility to extend to lower angle using HES/Presamper (under study)

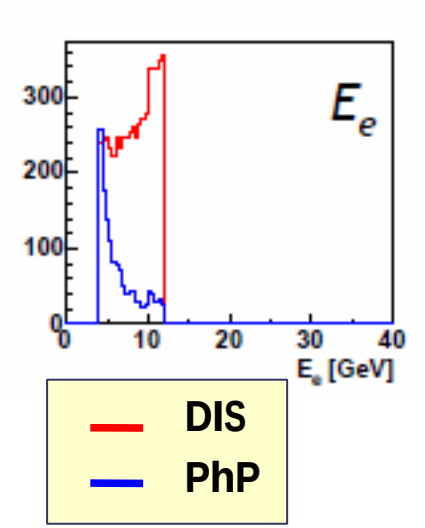




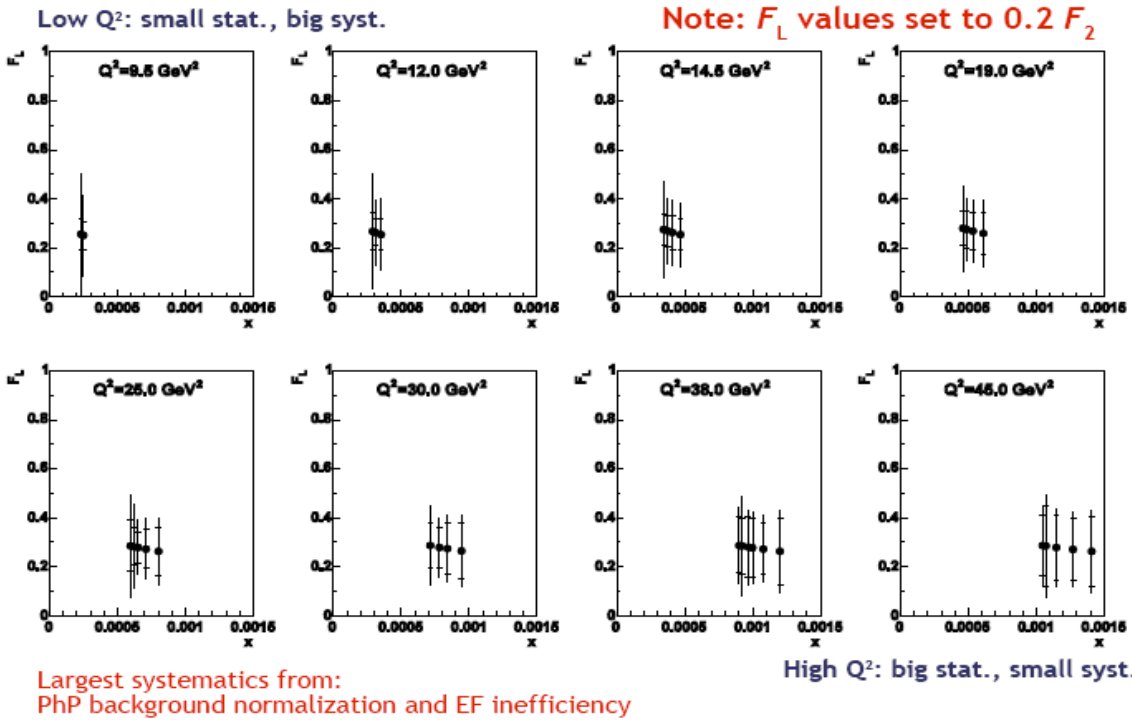
ZEUS feasibility of extracting F_L

- **Beam energies and lumi**
  10 pb^{-1} @ Ep=460 GeV
  30 pb^{-1} @ Ep=920 GeV

► Control plots at low energy run



► Expected precision of extracted F_L



- At low Q^2, systematic error (due to PHP) dominates while at high Q^2, stat error dominates.
- **Although the precision is moderate, the measurement of F_L is of fundamental importance and ZEUS expresses an interest in measuring F_L in a low energy run.**

Summary

- ZEUS in 2006: detector and DAQ are operating fine. CTD trips if proton background is bad, which is the main reason of data-taking inefficiency.
- HERA-II detector understanding progressing well. New MVD alignment brought a significant improvement.
- HERA-II Physics analysis progressing nicely, producing timely results.
- Finalizing HERA-I analyses, still producing world's best or first measurements
- ZEUS expresses interests in low energy running, although the F_L measurement will be experimentally challenging.

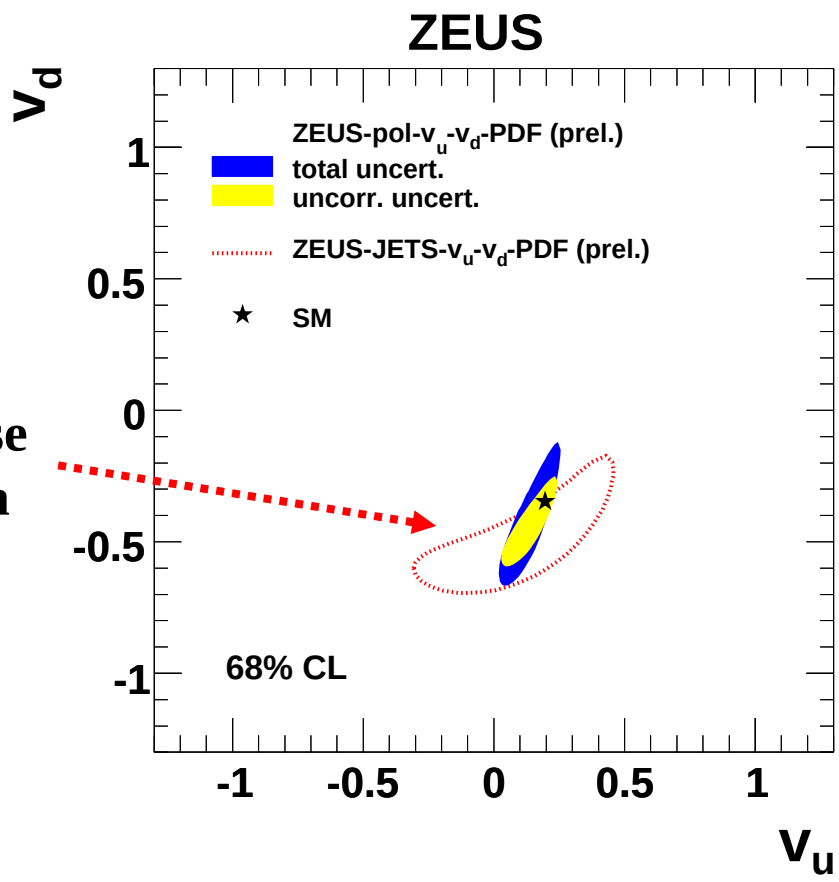
Backup Slides

Light quark couplings to Z -cont'd-

- **Vu, Vd fit**

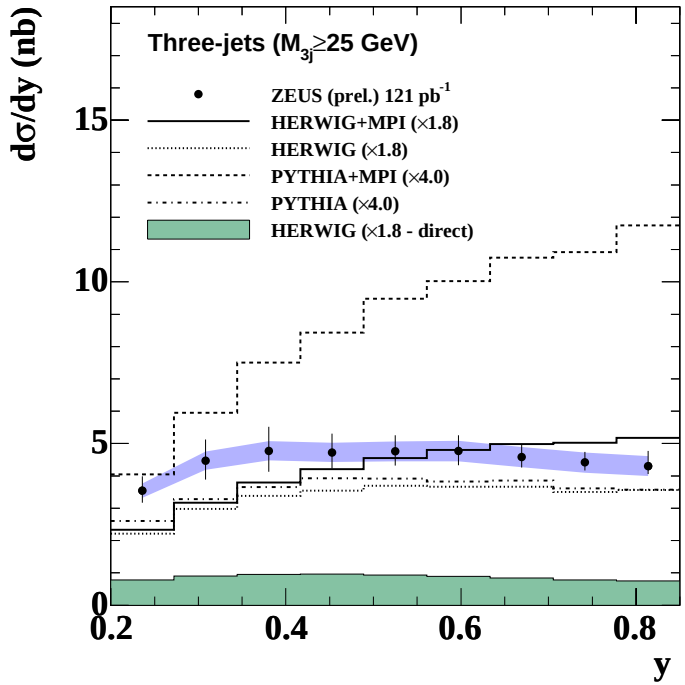
-- Clearly demonstrates the polarized data's sensitivity to v couplings

If we do not use polarized data

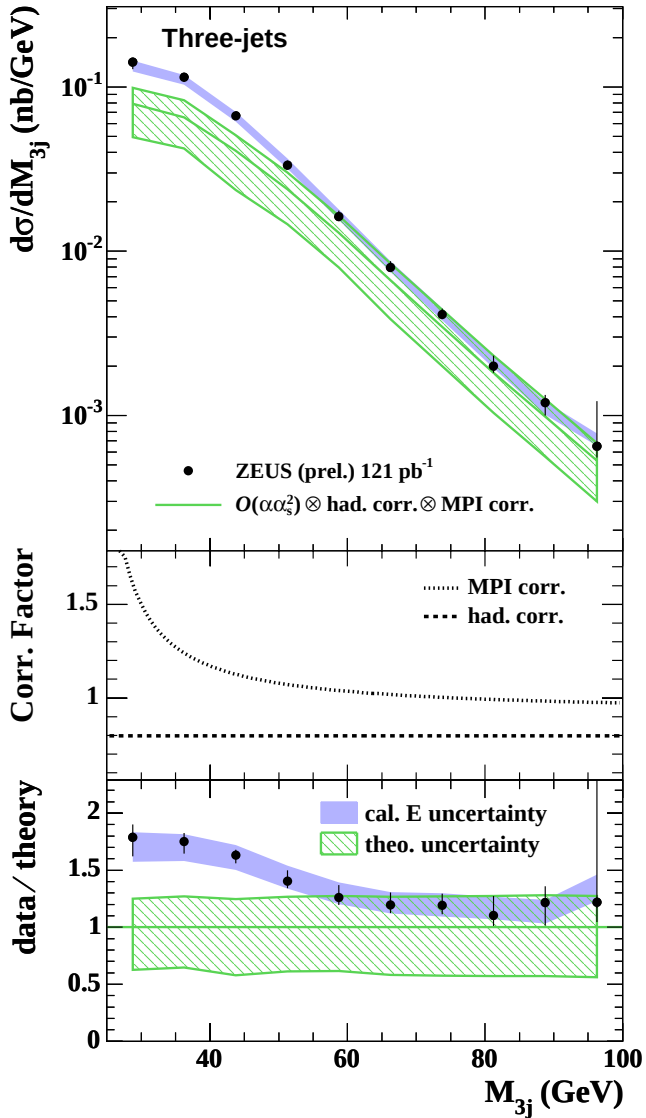


Multi-Jet in PHP -cont'd-

► **Cross section in y**



► **Mjjj vs pOCD**



- HERWIG+MPI describes data well for x_γ^{obs}, Mjjj etc. but makes y description worse
- The pQCD describes data at high mass