Single W boson production at HERA

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- Introduction & motivation
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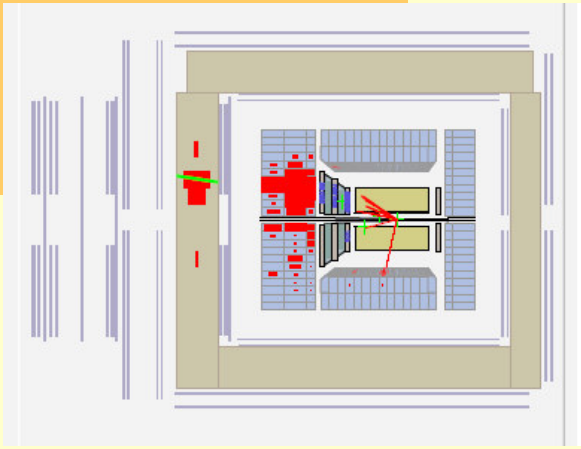
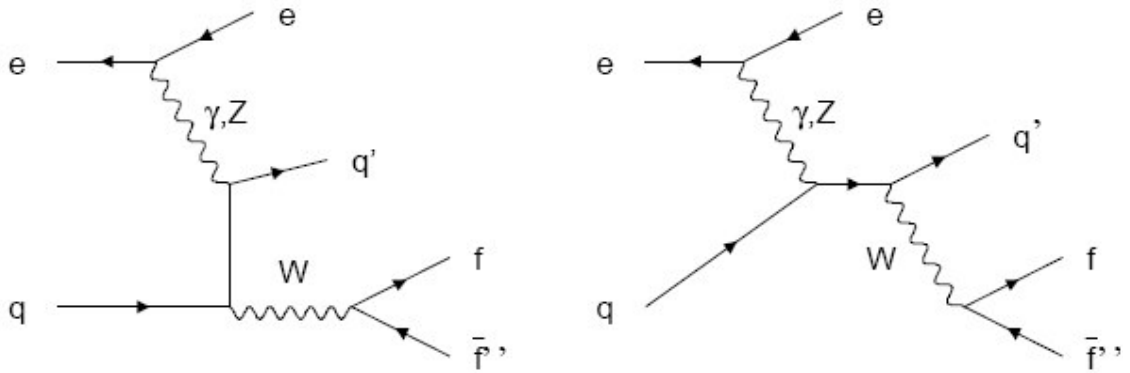
- Results
- Outlook & summary



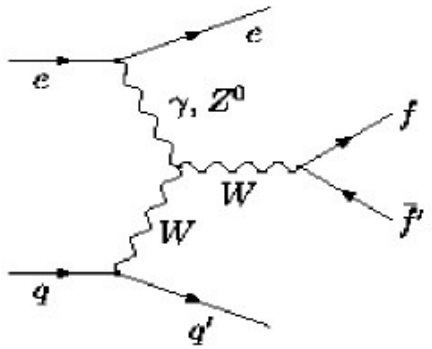
Motivation

- At HERA energies production of single Ws and Zs is possible, but with rather small cross section, $\sigma \approx 1.1$ pb.

- Dominant LO diagrams:



- Diagrams with TGCs also contribute:



Note: Contribution of ep $\rightarrow \nu$WX small

W production becomes background in searches BSM (eg. anomalous single top production)

SM predictions

Large contribution from low Q^2 electron scattering ($\rightarrow$ photoproduction)

Resolved photon contribution is negligible at high p_T of Ws and NLO QCD corrections at about 10% level:

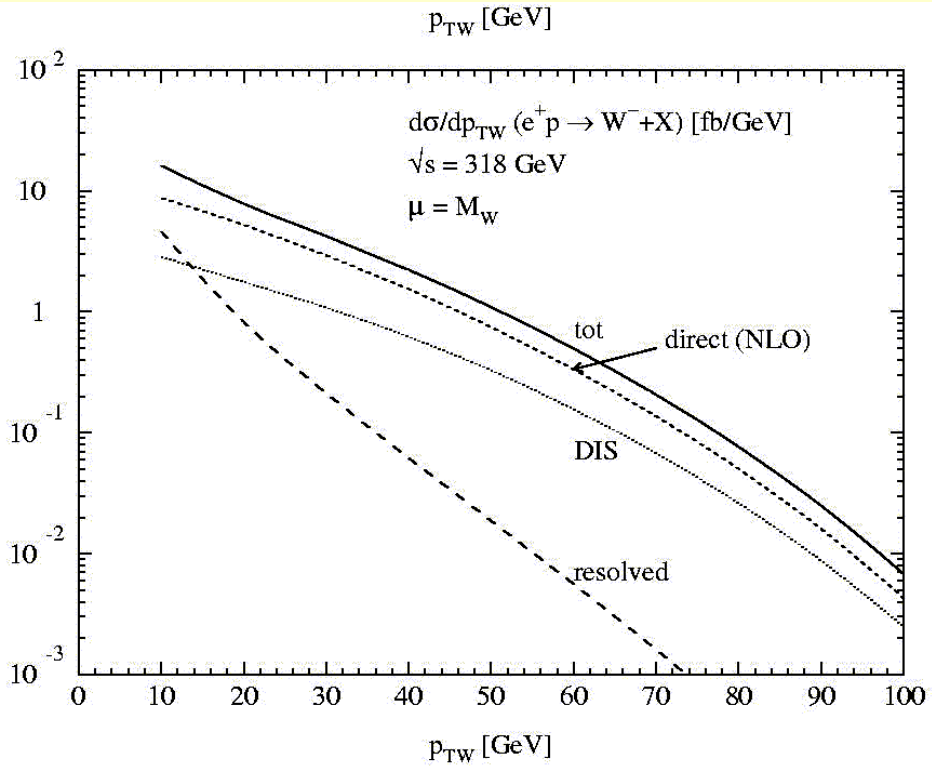


Figure 8: *Transverse momentum distributions of W bosons at HERA. The full curves show the total p_{TW} distributions, while the broken lines exhibit the individual LO DIS, NLO direct and LO resolved contributions.*

Diener et al.(2002)

Previous results

94-97 ZEUS e^+p data at 300 GeV, 47 pb^{-1}:

- estimated cross section (for electronic and muonic W decays): $\sigma = 0.9^{+1.0}_{-0.7} \pm 0.2$ pb;

- published in PLB 471 (2000), also with limit $\sigma < 3.3$ pb;

- cross-section for hadronic W decays estimated from fits to 2/3 jet invariant mass spectra (EPS03):
  $\sigma = 2.97 \pm 2.51\ ^{+1.75}_{-0.53}$ pb; 95% limit: $\sigma < 8.3$ pb

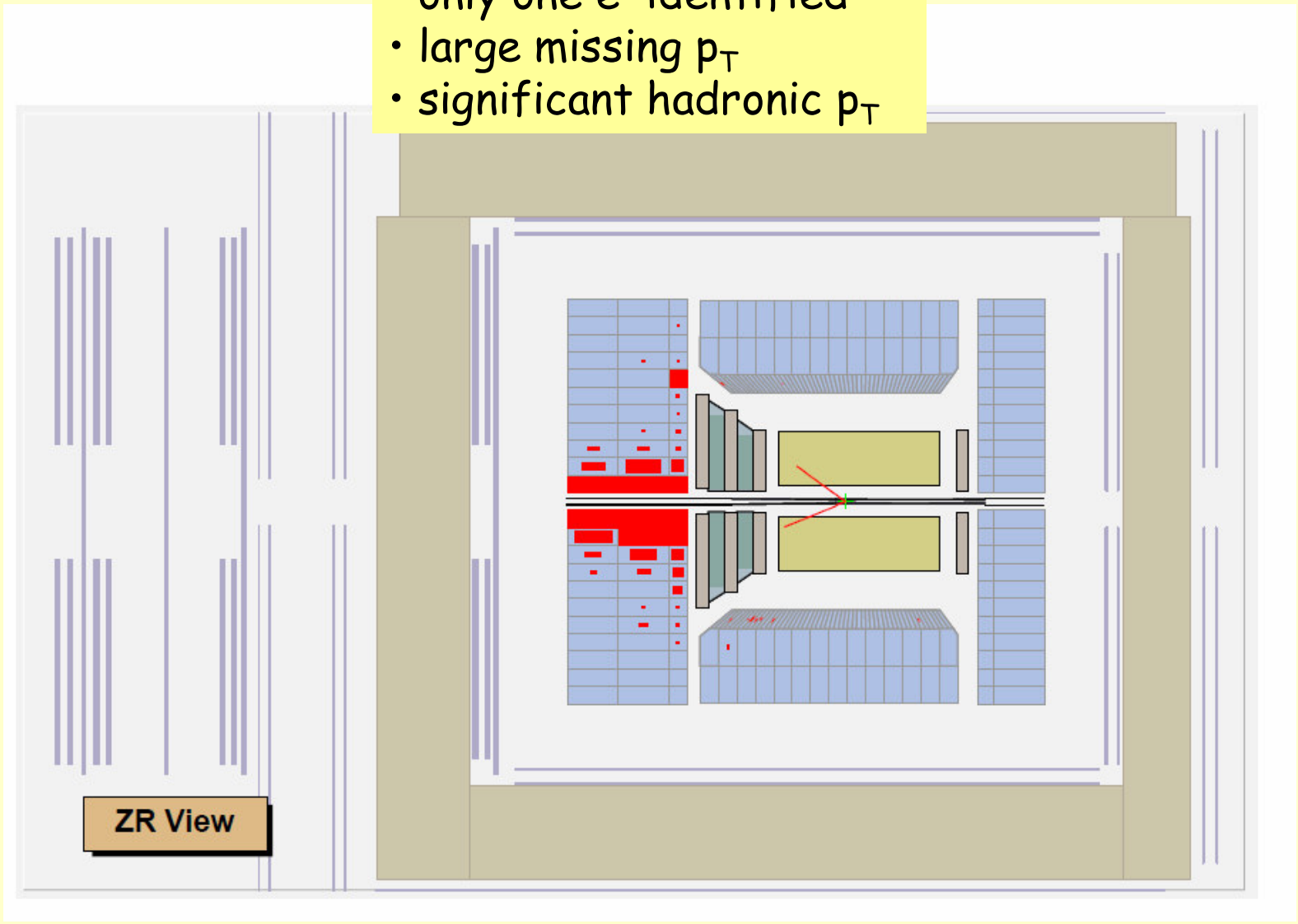
H1 observes excess of isolated high p_T leptons

- excess present both in e and μ channels
- excess visible at high hadronic p_T

ZEUS does not see high p_T excess in e and μ channels, but a slight excess of $W \rightarrow \tau\nu$ events

$W \rightarrow e\ \nu$ candidates

Major features:
- only one e identified
- large missing p_T
- significant hadronic p_T



Data preselection

Use 99-00 e^+ data corresponding to 66.3 pb^{-1} with preselection cuts:

- Calorimeter timing + algorithms based on the pattern of tracks to reject non-ep events

- P_T > 9 GeV and transverse mass > 10 GeV (removes non W events)

- Vertex cut: -50 < z < 50 cm

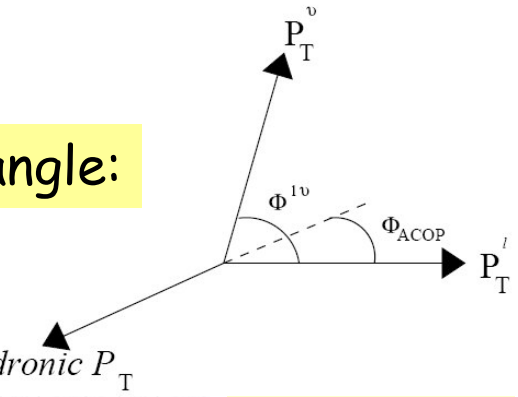
- One electron found (neural net algorithm):
  - measured Calorimeter energy of electron is corrected using information from tracking
  - E_{cor} > 8 GeV
  - θ^e < 2.0 and P_T^e > 5 GeV
  - E_{ncone} < 4 GeV for the cone radius of 0.8
  - e track isolated by 0.5 in (η,ϕ) from other primary vertex tracks, and within 10 cm of cluster

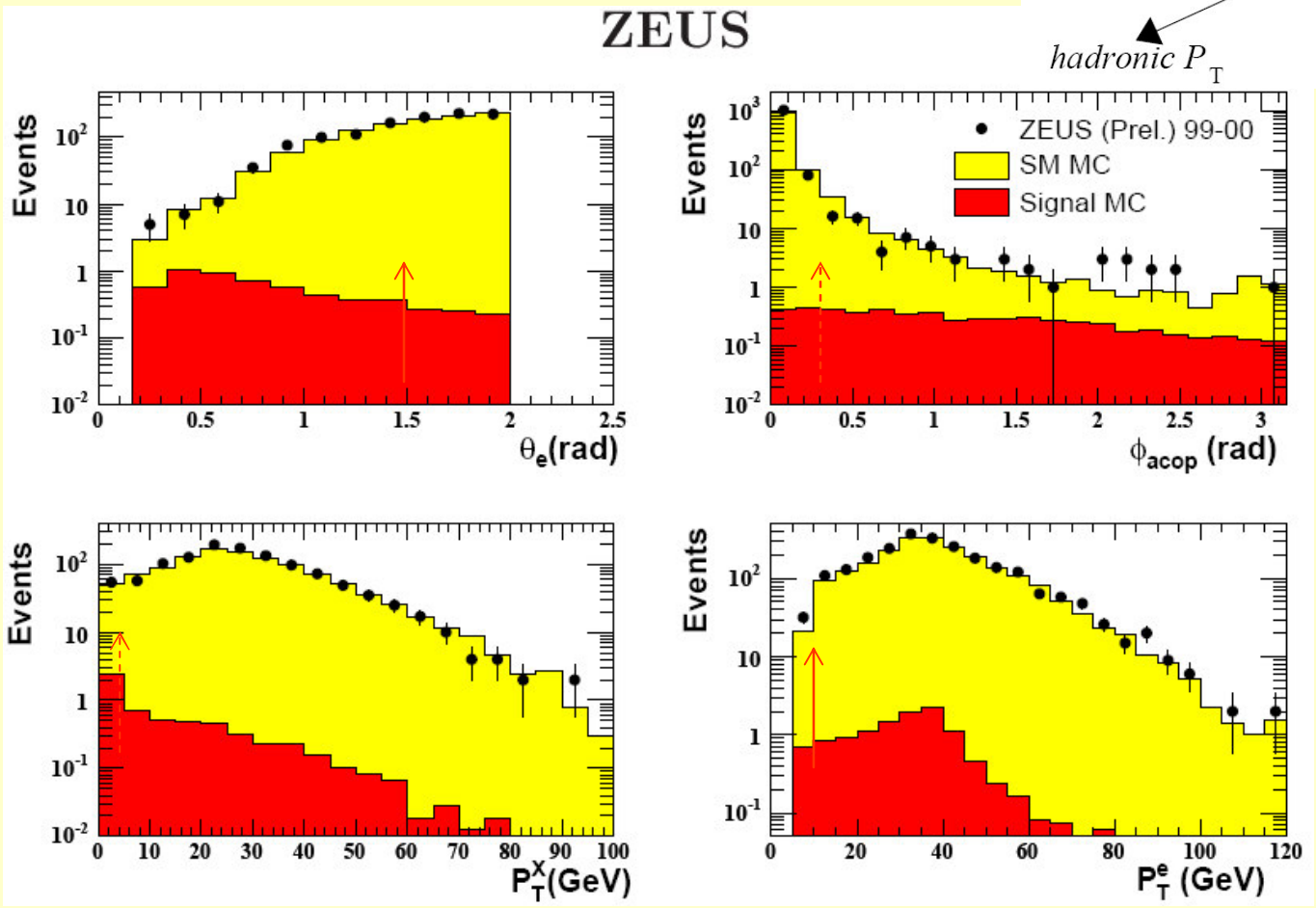
MC samples

- EPVEC single W events: 40×data luminosity
- Herwig 6.1 direct and resolved photoproduction: 2-5×data lumi
- Grape dielectron, dimuon and ditau events
- Django6 (Ariadne) NC DIS, $Q^2 > 400$ (100) GeV^2: 10 (4)×data lumi
- Django6 (Ariadne) CC DIS, $Q^2 > 10$ GeV^2: 2-20×data lumi

MC description

Key signature – large acoplanarity angle:

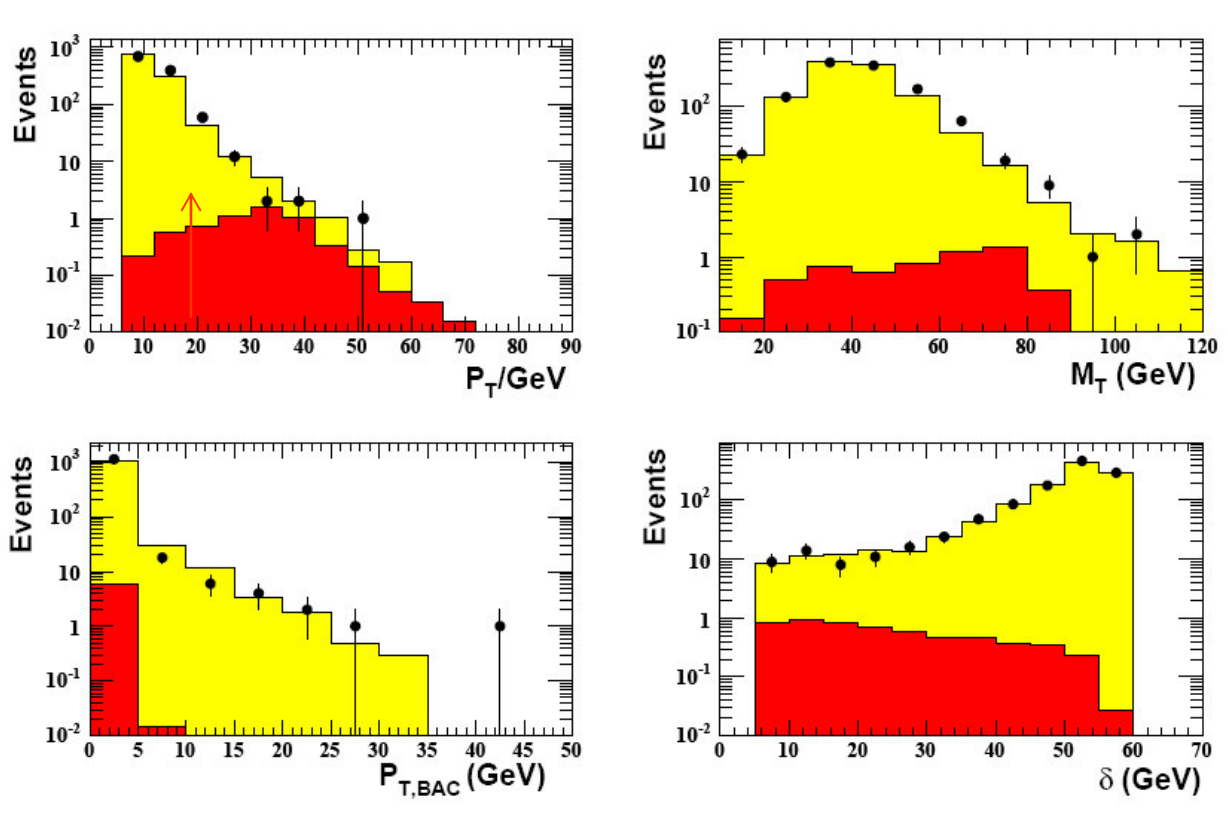




MC vs data II

$$P_T = \sqrt{(\sum_i p_{X,i})^2 + (\sum_i p_{Y,i})^2}$$

$$M_T = \sqrt{2P_T^l P_T^\nu (1 - \cos\Phi^{l\nu})}$$



Good description by MC; NC is dominating background

Final selection

- $P_T > 20$ GeV
- $\theta_{\rm acop} > 0.3$ (if $P_T^X > 4$ GeV)
- $P_T^e > 10$ and $\theta_e < 1.5$
- P_T (track) > 5 GeV

To suppress fake electrons

5 candidates:

Candidate	1	2	3	4	5
electron polar angle (rad)	1.33	1.02	1.33	0.38	0.58
P_T^e (GeV)	20.3	33.5	52.8	28.0	30.6
hadronic P_T^X (GeV)	9.3	17.0	35.2	2.82	29.4
missing P_T (GeV)	25.2	20.0	25.1	29.2	48.4
transverse mass (GeV)	44.9	50.4	69.0	57.2	73.5

Results

5 events found, and
EPVEC LO MC predicts $3.2 \pm 0.1^{+1.1}_{-1.0}$ W events (with efficiency of 39%); other SM processes give $3.5 \pm 0.6^{+1.7}_{-1.6}$ events (mostly NC)

95% CL limit is $\sigma < 2.8$ pb

Systematics for signal mostly due to e ID; and for backgrounds due to hadronization modeling (Ariadne vs MEPS)

Note: One (two) event(s) with $p_T^X > 30(25)$ GeV

Summary & outlook

New ZEUS analysis of the W production (with electronic decays) in 99-00 data shows good agreement with SM predictions

In near future: muon analysis will be added and combined to provide the final combined HERA I results;

- first preliminary results for leptonic signals at HERA II are also expected (already with comparable luminosity) where sensitivity to beam charge (e^+/e^-), and longitudinal polarization will be tested

Shouldn't we test/measure also neglected so far CC signal:

$$ep \to \nu WX$$

eg. using $W \to$ jets

Outlook II

Looking forward to new data and new analyses to clarify the puzzling pattern of events with isolated leptons at HERA

		ZEUS	H1	H1 (HERAII)
p_T,hadr > 25 GeV		130.1 pb-1	118.4 pb-1 (τ: 108 pb-1)	53 pb-1
e	exp. (SM)	$2.90^{+0.59}_{-0.32}$	$1.49^{+0.18}_{-0.18}$	$0.84^{+0.19}_{-0.19}$
	exp. (W)	45%	$1.27^{+0.17}_{-0.17}$	$0.58^{+0.09}_{-0.09}$
	obs.	2	5	5
μ	exp. (SM)	$2.75^{+0.21}_{-0.21}$	$1.44^{+0.18}_{-0.18}$	$0.85^{+0.13}_{-0.13}$
	exp. (W)	50%	$1.28^{+0.18}_{-0.18}$	$0.63^{+0.10}_{-0.10}$
	obs.	5	6	0
τ	exp. (SM)	$0.20^{+0.03}_{-0.03}$	$0.53^{+1.36}_{-1.36}$	---
	exp. (W)	$0.10^{+0.01}_{-0.01}$	$0.87^{+0.15}_{-0.15}$	---
	obs.	2	0	---

- ZEUS: *Phys.Lett.**B559**,153-170(2003), Phys.Lett.**B583**,41-58(2004)*
- H1: *Phys.Lett.**B561**,241(2003), H1prelim-04-061, H1prelim-04-163 (incl. update)*