EW at HERA

and "RELATED" NEW PHYSICS

Photon 2009

International Conference on the Structure and Interactions of the Photon including the 18th International Workshop on Photon Collisions and the International Workshop on High Energy Photon Linear Colliders

11-15 May 2009

DESY, Hamburg

Topics

- Photons in astroparticle physics
- Photon collider technology
- Photon detectors

Luca Stanco – INFN Padova

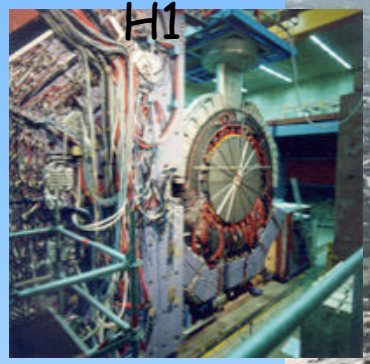
on behalf of ZEUS and H1 collaborations

- HERA: a QCD and EW machine

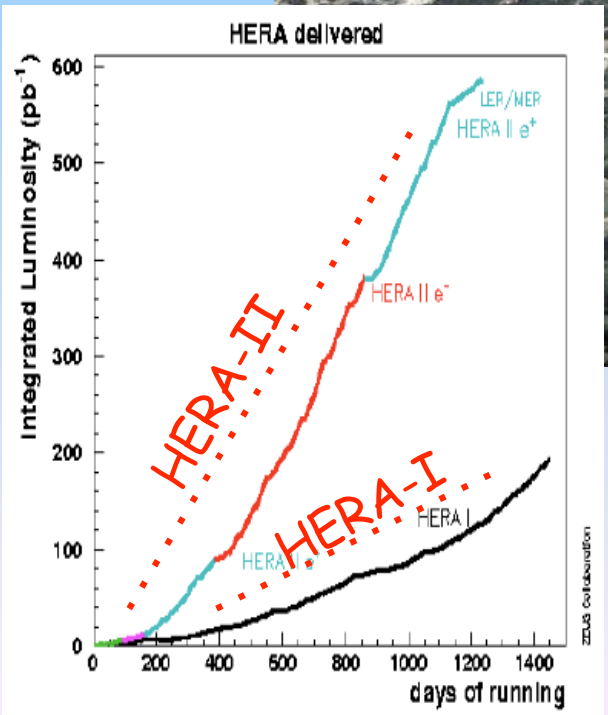
Results on:

- EW constraints
- Isolated Leptons
- Single TOP

HERA: a collider e-p



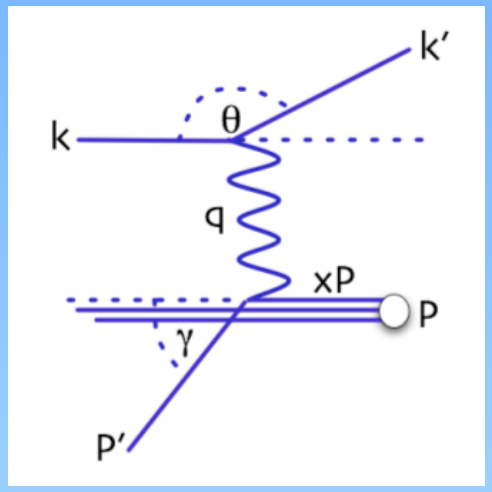
ZEUS



0.5 fb^{-1} per exp.: e^+p, e^-p, LowEnergyRange, MER

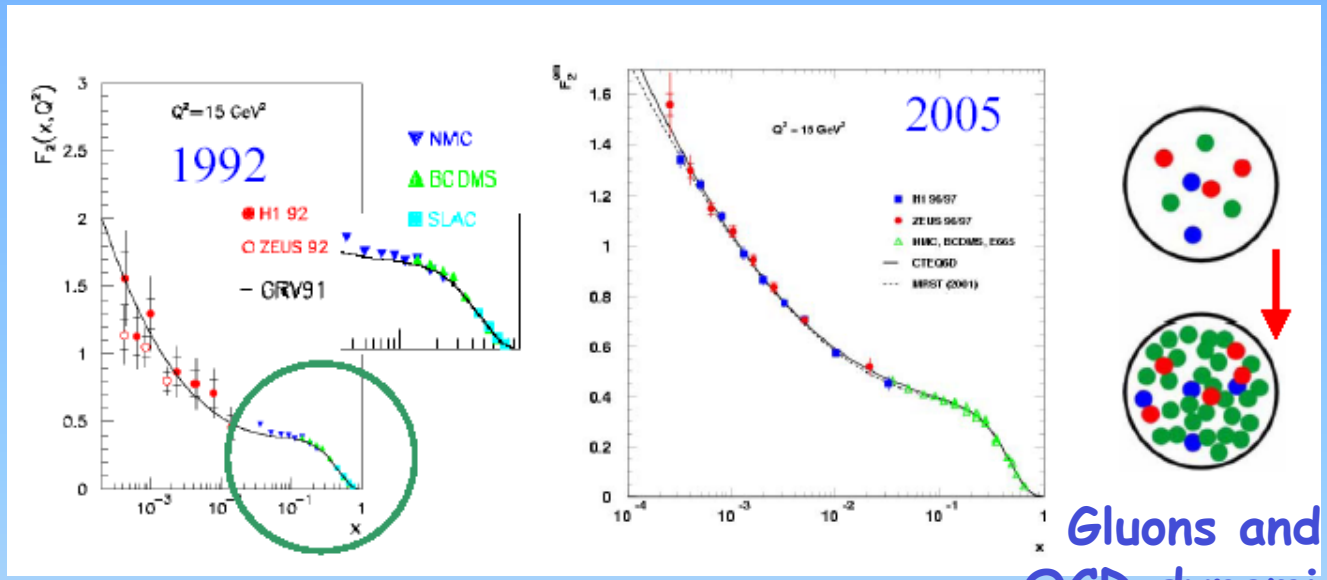
HERA-II feature: longitudinal polarization P_e
routinely achieved $P_e \approx 30\% - 40\%$

HERA: the QCD machine



$$Q^2 = -q^2 = (k - k')^2$$

$$x = \frac{Q^2}{2p \cdot q}$$



Gluons and QCD dynamics

Q^2 ~ $1/\lambda$: the scale of the interaction corresponds to the spatial resolution at which the proton structure is probed

For $Q^2 \approx M^2_Z, M^2_W$ study also EW interactions:

$$\frac{d^2\sigma^{\pm}}{dx\, dQ^2} = (1 \pm P_e)\, \frac{G_F^2}{4\pi x} \left[\frac{M_W^2}{M_W^2 + Q^2}\right]^2 \left(Y_+ F_2 \mp Y_- x F_3 - y^2 F_L\right)$$

CC double diff. cross-section

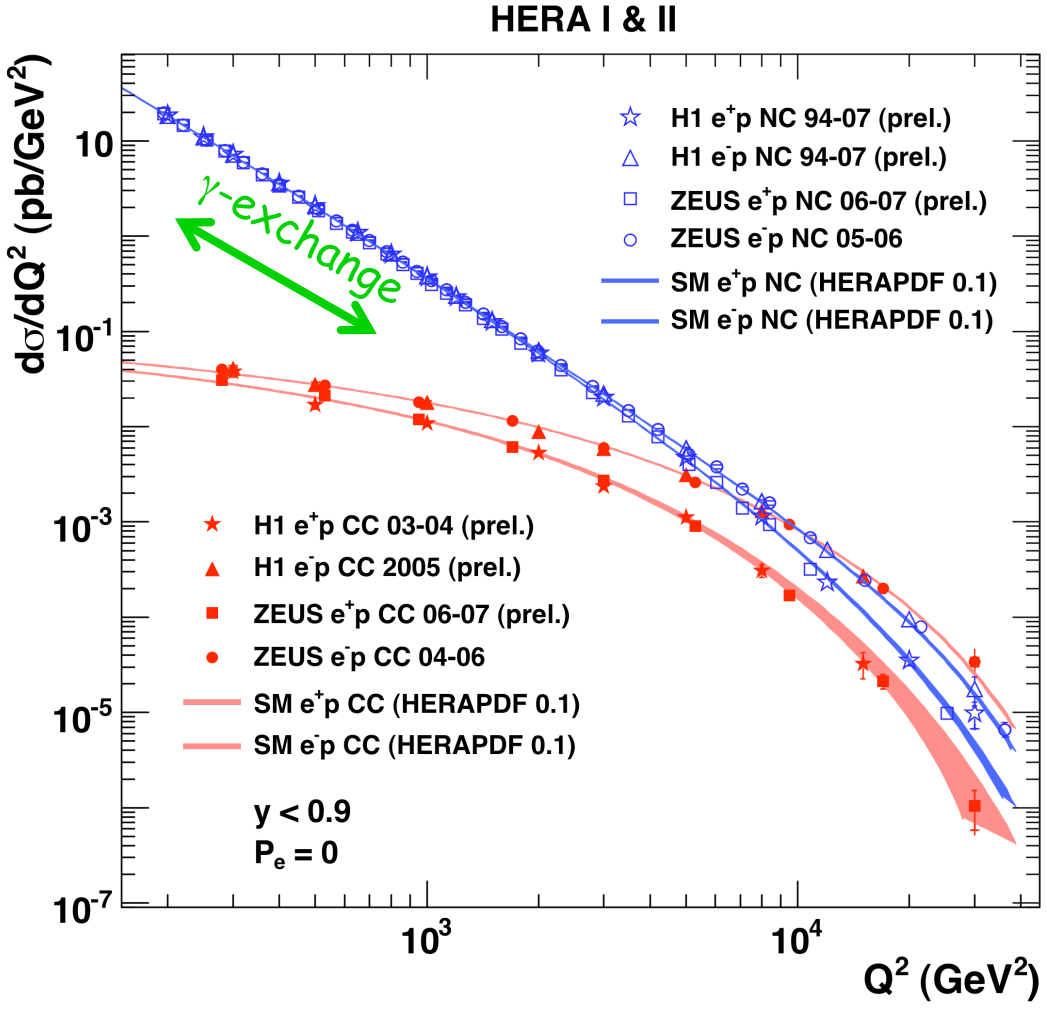
Beam Polarization

QPM Structure Functions

ElectroWeak unification: status-of-the-art

Neutral Current e-p (ZEUS publ., H1 prel.)
e+p (ZEUS prel., H1 prel.)

Charged Current e-p (ZEUS publ., H1 prel.)
e+p (ZEUS prel., H1 prel.)



$$\text{NC}: \quad \frac{d\sigma}{dQ^2} \sim \frac{1}{Q^4}$$

$$\text{CC}: \quad \frac{d\sigma}{dQ^2} \sim \frac{1}{(Q^2 + M_W^2)^2}$$

Z and W dominate exhanges

(corrected for the Polarization effects)

NC and Structure Functions: Parity Violation test

NC cross section written with structure function

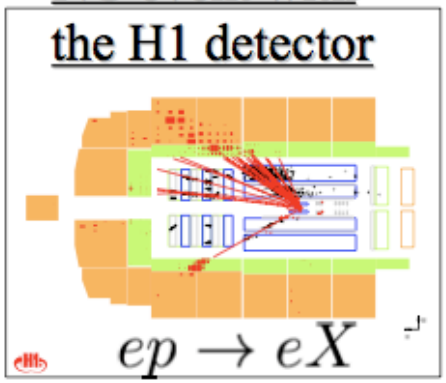
$$\frac{d^2\sigma(e^{\pm}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2(x,Q^2) \mp Y_- xF_3(x,Q^2)\right]$$

Parity violating structure function

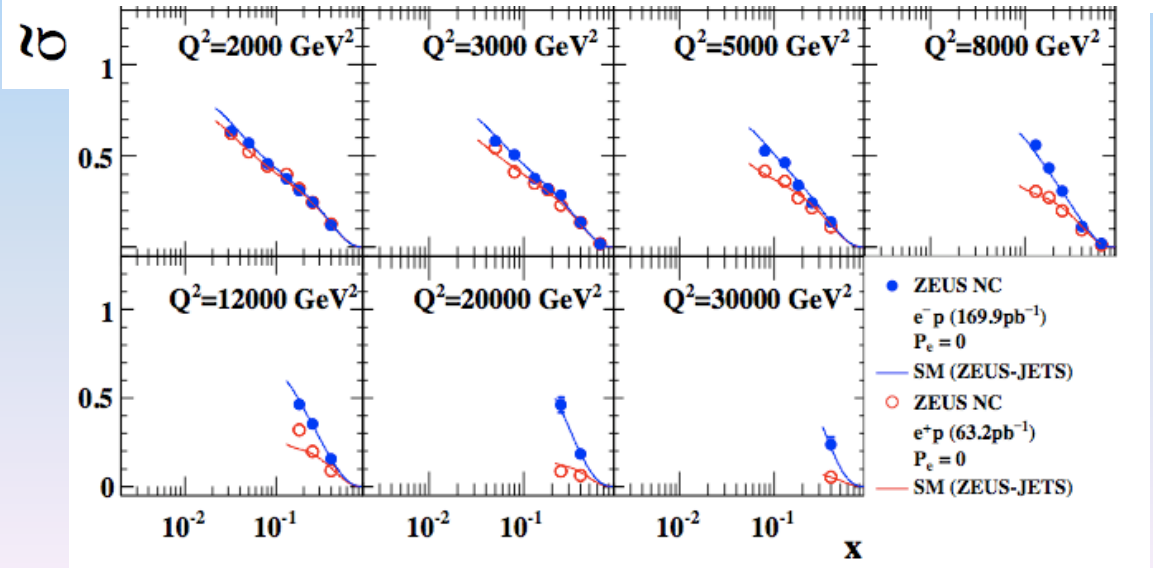
$$, Y_{\pm} = 1 \pm (1-y)^2$$

$$\tilde{\sigma}(e^{\pm}p) = \frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+}\frac{d^2\sigma(e^{\pm}p)}{dxdQ^2}$$

NC event with the H1 detector



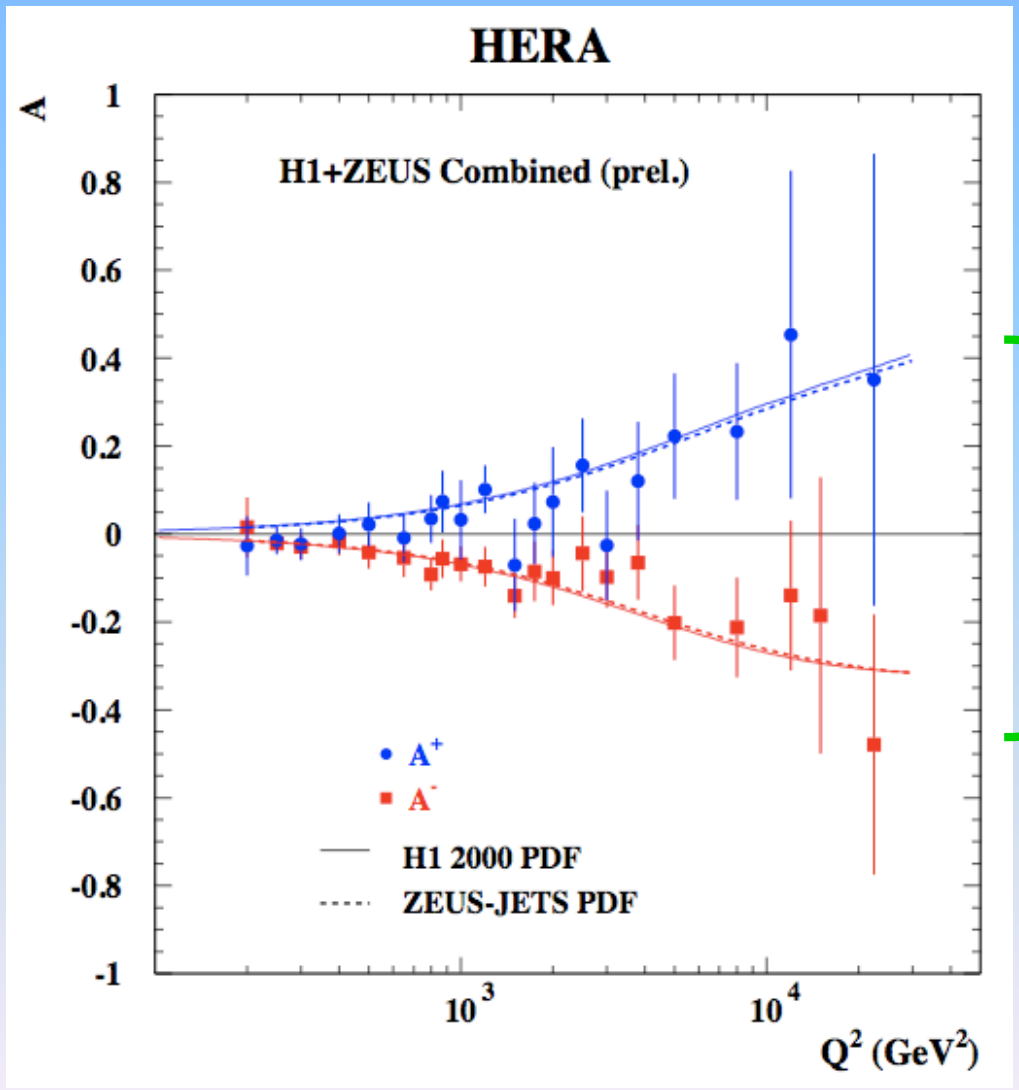
ZEUS *(e- HERA-II plus e+ HERA-I)*

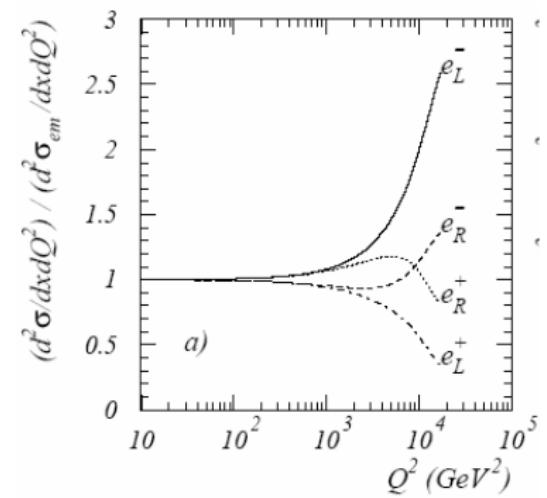


xF_3 term changes its sign pending incident e+ or e- beam

The e-p cross-section is larger than e+p, remarkably in high Q^2 region

Weak Interaction check with **Polarization (NC)**





$$F_2 \sim \sum_i x(q_i + \bar{q}_i) \times (e_i^2 + 2P_e \chi_Z a_e e_i \mathbf{v_i})$$

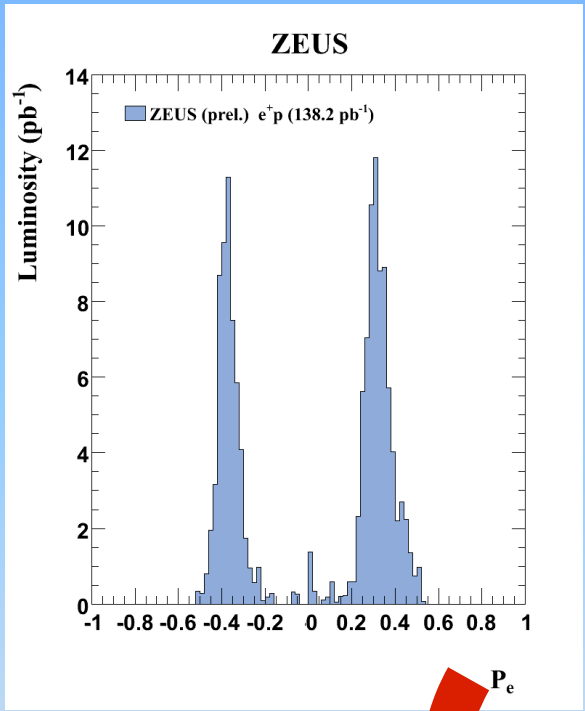
$$A^{\pm} = \frac{2}{P_R - P_L} \cdot \frac{\sigma^{e^{\pm}p}(P_R) - \sigma^{e^{\pm}p}(P_L)}{\sigma^{e^{\pm}p}(P_R) + \sigma^{e^{\pm}p}(P_L)}$$

Asymmetry proportional to vector coupling

Parity Violation size,

demonstrated down to 10^{-18} m

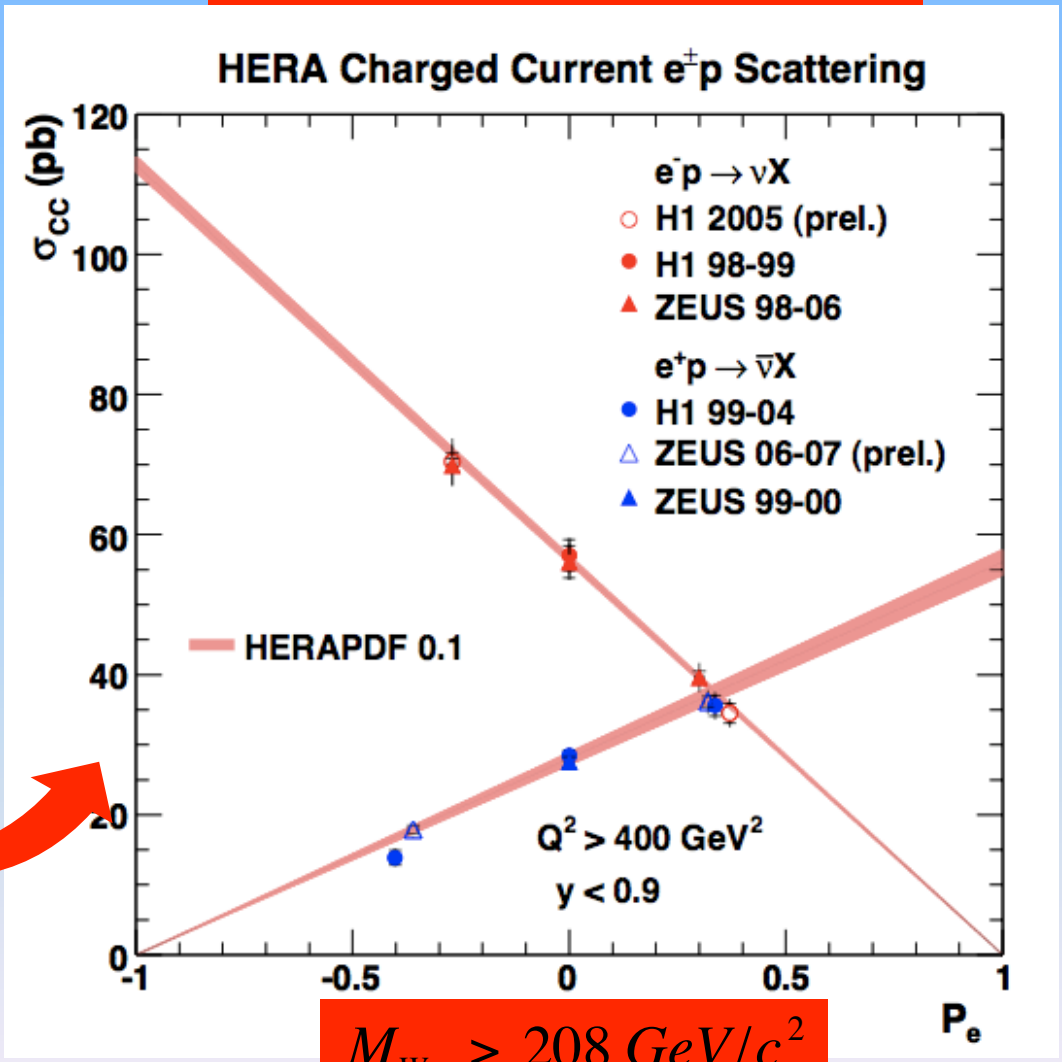
Weak Interaction check with Polarization (CC)



(ZEUS preliminary 2007)

$$\sigma^{CC}_{e^{\pm}p}(P_e) = (1 \pm P_e)\,\underbrace{\sigma^{CC}_{e^{\pm}p}(P_e = 0)}$$

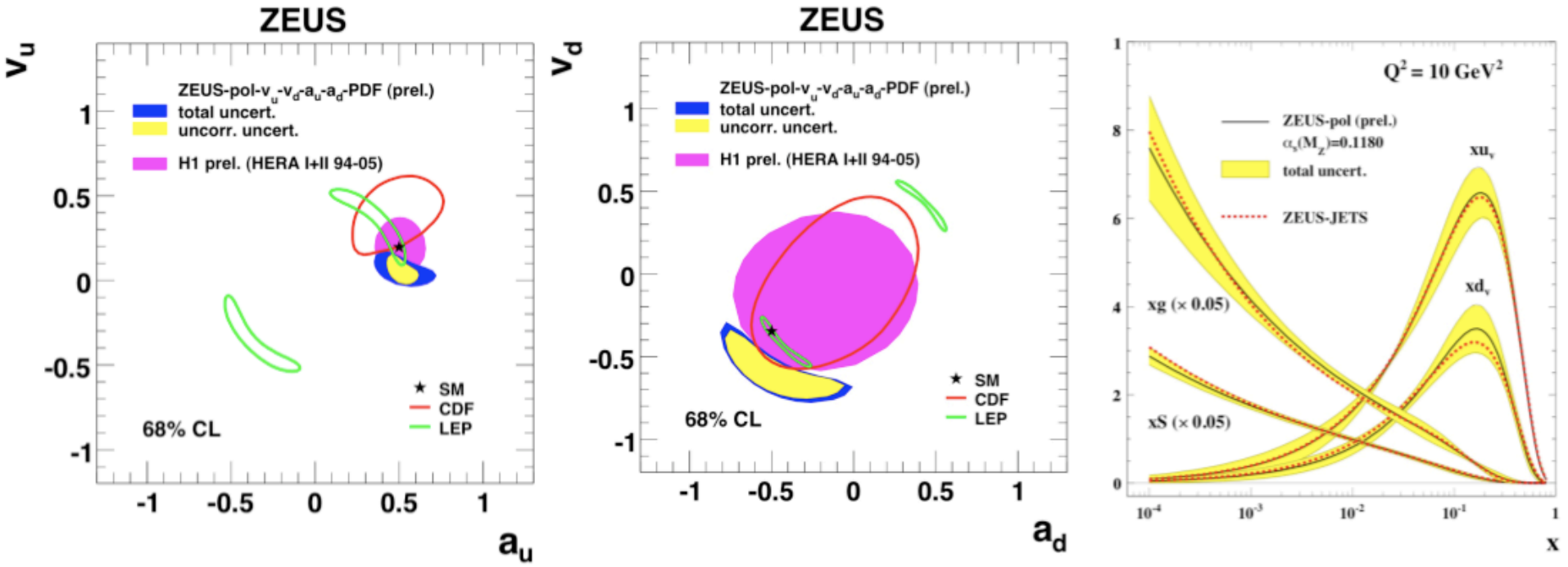
V-A chiral structure



$M_{W_R} > 208\ GeV/c^2$

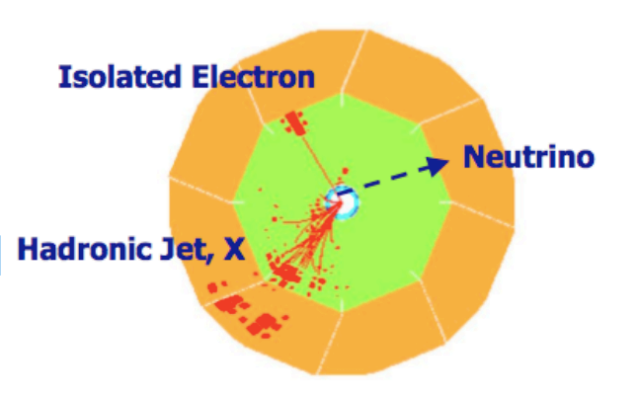
(H1 collaboration, Phys.Lett B634 173,2006)

DGLAP fits for QCD-EW: PDFs' and **uv-quarks** couplings

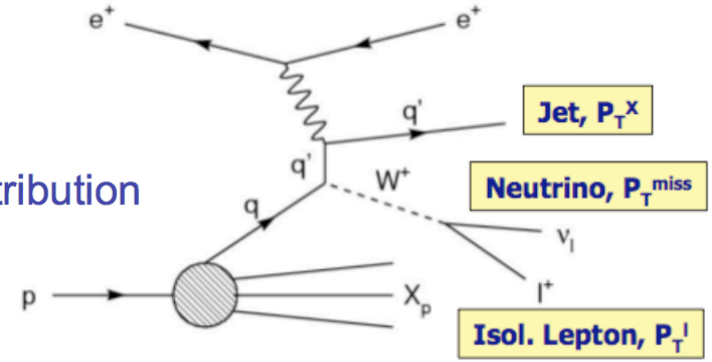


- Simultaneous test of the **EW** and **Strong** sectors of SM
- Best determination of **u**-coupling to **Z**
- Competitive with *Tevatron* and *LEP* results

Isolated high-p_T leptons: status-of-the-art



W production:
dominant SM contribution

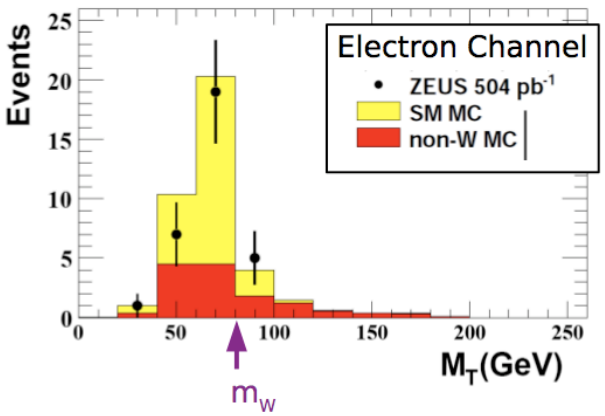


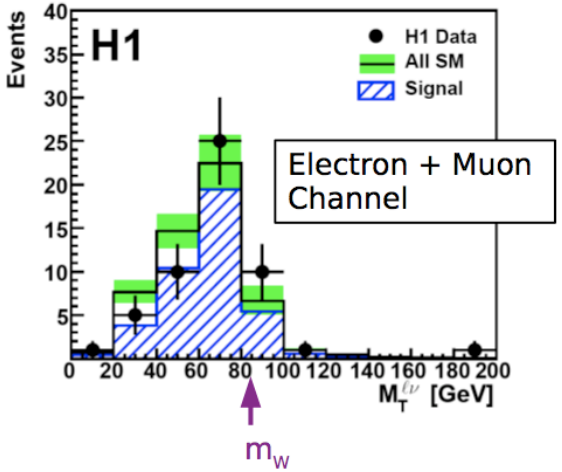
Final analysis from H1 and ZEUS on Electron and Muon leptons
H1 looked also at the Tau leptons: challenging, large background

ZEUS

$$M_T^{\ell\nu} = \sqrt{(P_T^{\text{miss}} + P_T^{\ell})^2 - (\vec{P}_T^{\text{miss}} + \vec{P}_T^{\ell})^2}$$

H1





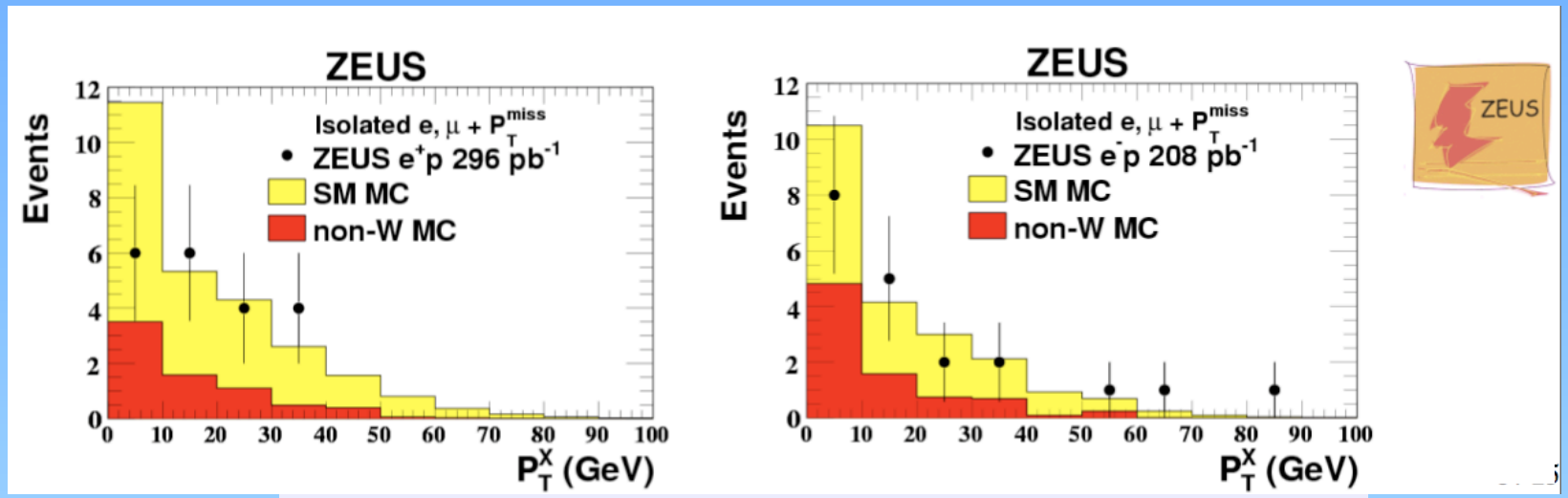
ZEUS $0.89^{+0.25}_{-0.22}(stat.) \pm 0.10(syst.)\ pb$

H1 $\sigma_W = 1.14 \pm 0.25(stat.) \pm 0.14(syst.)\ pb$

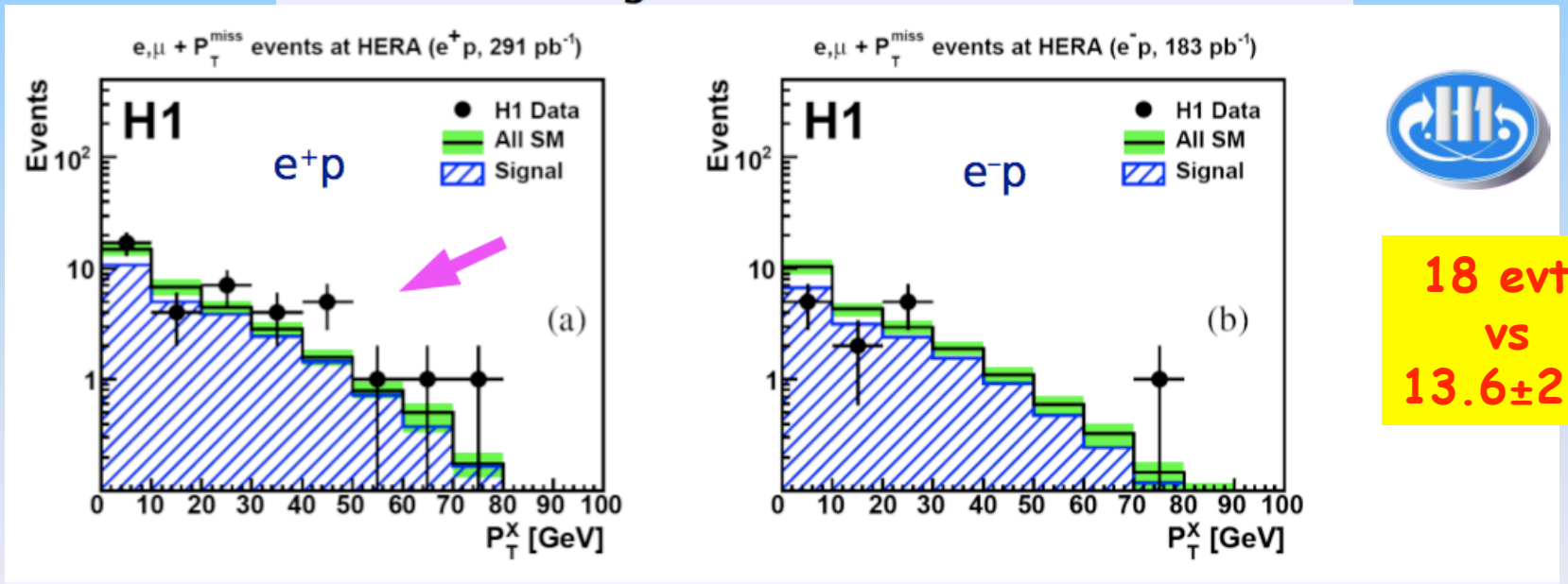
EPVEC $1.27 \pm 0.19\ pb$

(combined in progress)

nice Jacobian peaks,
however at higth p_T...



Good overall agreement with Standard Model



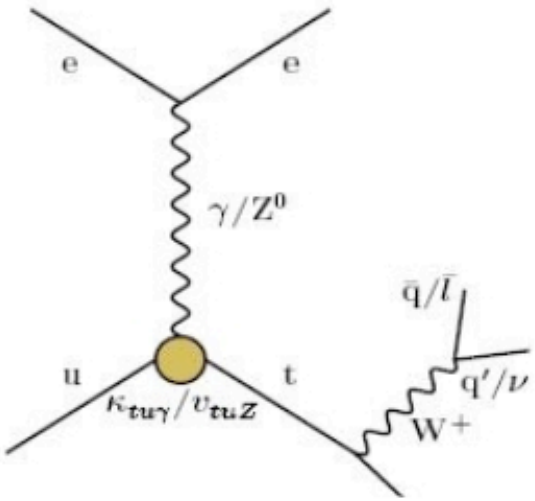
18 evts vs 13.6±2.2

Interesting events at high hadronic $P_T^X > 25$ GeV observed in e^+p by H1

H1: $\sigma_{\ell+P_T^{\rm miss}} = 0.23 \pm 0.05\,({\rm stat.}) \pm 0.04\,({\rm sys.})\ {\rm pb}.$

Anomalous **Single TOP** production at HERA

Final results from H1 (HERAII: 474 pb^{-1}), **HERAI+II in DESY-09-50**
ZEUS preliminary: 277 pb^{-1} (HERAII), **combined with HERAI** (120 pb^{-1})

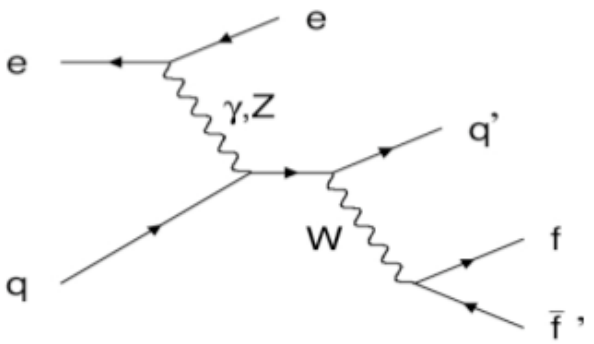


Anomalous single top production (BSM) proceeds via FCNC with a coupling $\kappa_{tu\gamma}$.

$$\mathcal{L} = \frac{ee_u}{\Lambda}\bar{t}\sigma_{\mu\nu}q^{\nu}\kappa_{\gamma}uA^{\mu}$$

Neglect **c** and Z couplings.

Sensitive to **u** (valence) and anomalous **γ** exchange



Search for signal in **muon**, **electron**, **hadron** channels

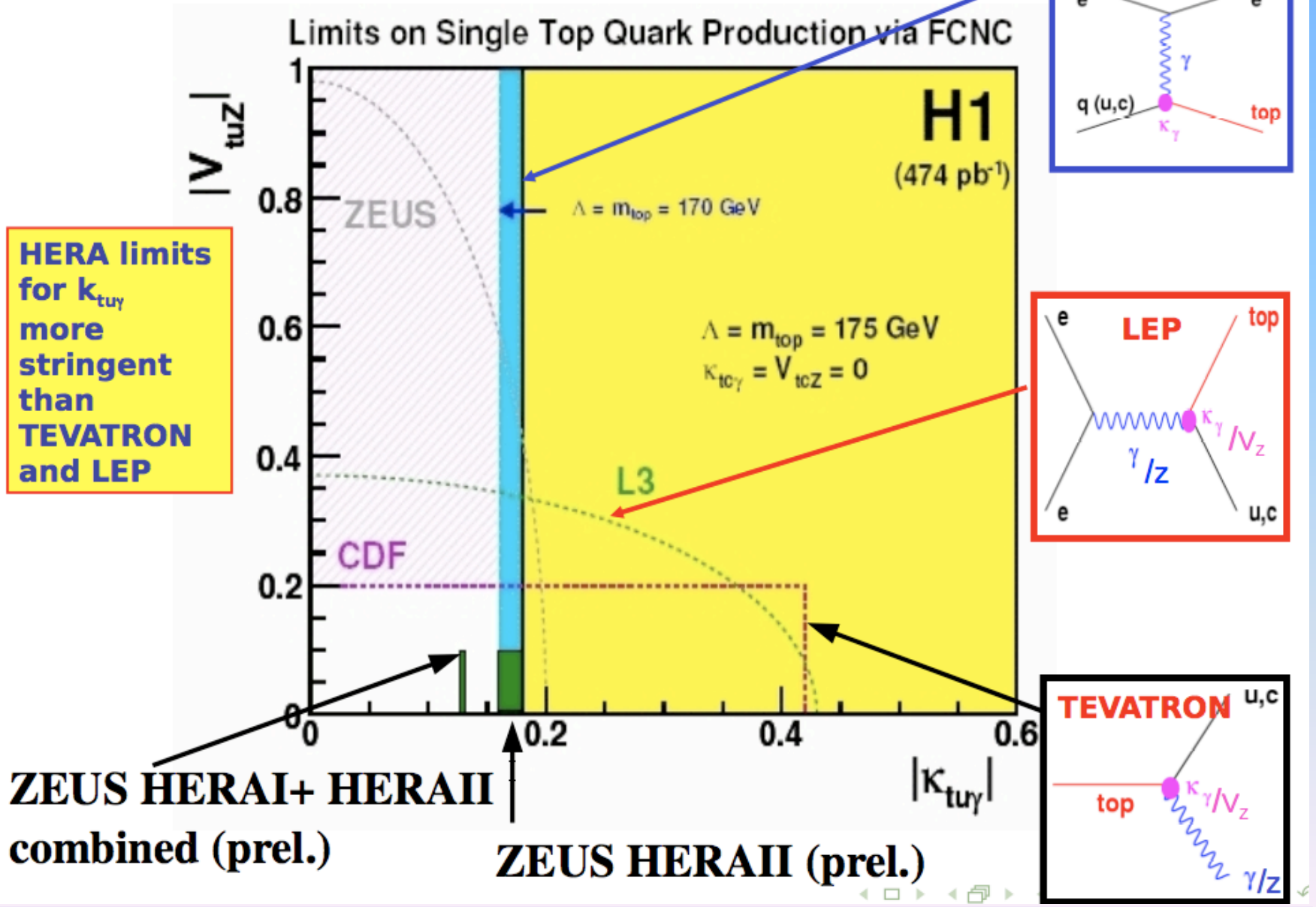
Intrinsic background from SM production of W *(lepton decay)*

(think also to previous "signal"...)

No excess ➔ limits, H1: $\sigma < 0.25$ pb, $k_{tu\gamma} < 0.18$, ZEUS: $\sigma < 0.13$, $k_{tu\gamma} < 0.13$

(slight excess)

Stefano Antonelli at DIS09



Conclusions

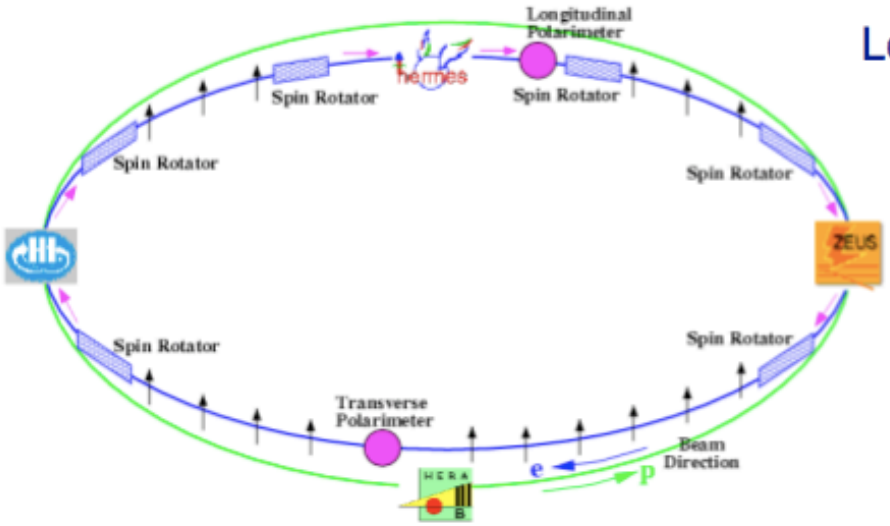
- H1 and ZEUS exploit most of HERA DATA for EW studies
- Unique HERA results done and undergoing

- Many EW checks, Universality, Chiral Structure, Parity Violation
- Single W production, measured, intriguing signal left at hight p_T
- Anomalous Single TOP production, SM checked (Colliders complementarity)

BIG thanks to HERA !!

Backup Slides

HERA-II feature: Polarization



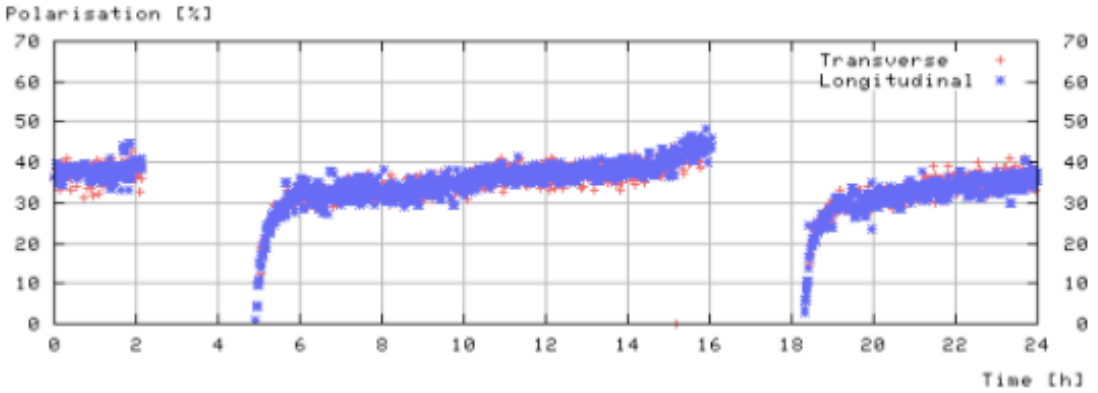
Longitudinal polarisation of the lepton beam

- Transverse polarization builds up naturally (Sokolov-Ternov effect, rise time ~30 min)
- Spin rotators before/after H1 and ZEUS
- Polarisation = Asymmetry of helicity states:

$$P_e = \frac{N_R - N_L}{N_R + N_L}$$

Polarisation build-up
P_e ~ 30-40% routinely achieved

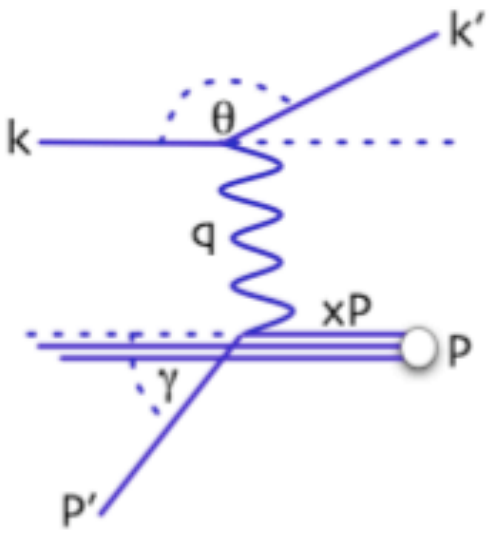
Measured by two independent Compton polarimeters.



Deep Inelastic Scattering at HERA

Two processes:

Neutral Current (NC) - exchange γ and Z^0 ($e^{\pm} p \to e^{\pm} X$)
Charged Current (CC) - exchange of $W^{\pm}$ ($e^{\pm} p \to \nu X$)



$$Q^2 = -q^2 = (k - k')^2$$ Virtuality of exchanged boson

$$x = \frac{Q^2}{2p \cdot q}$$ Bjorken scaling variable

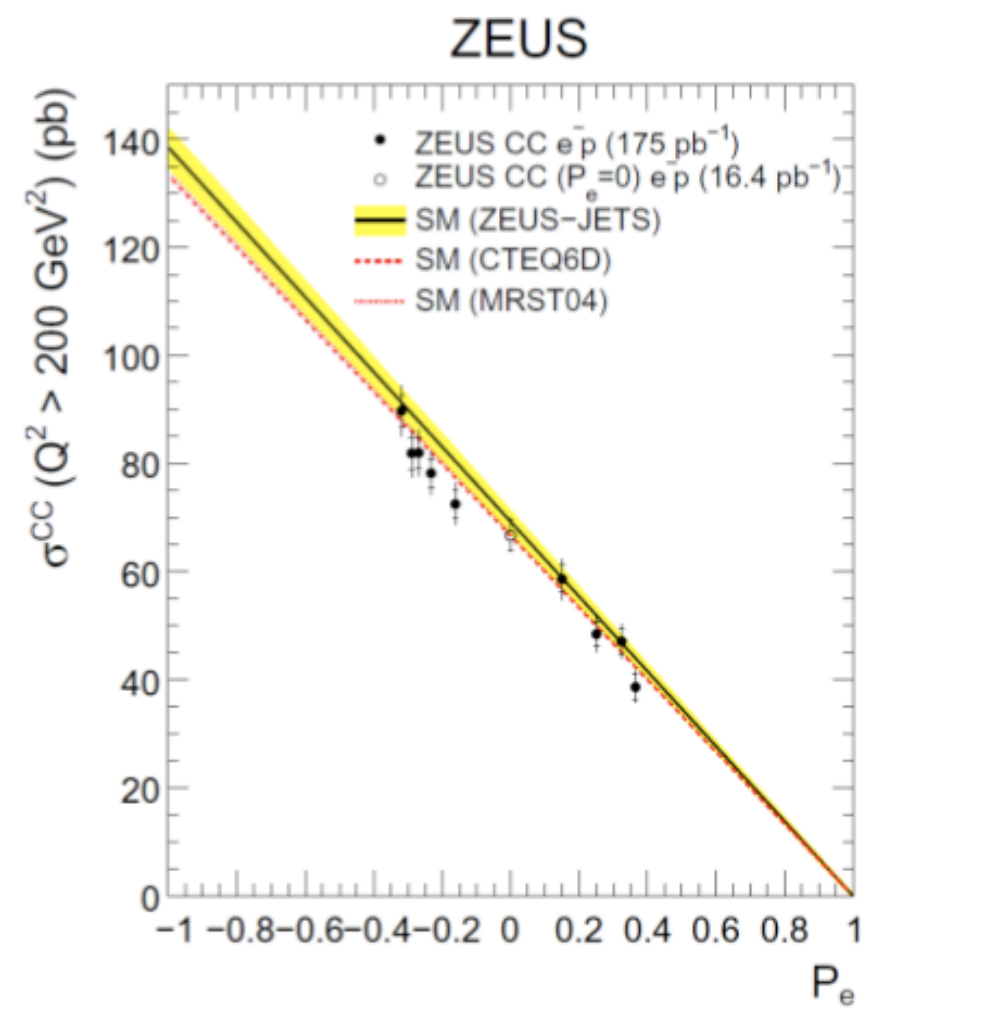
$$y = \frac{p \cdot q}{p \cdot k}$$ Inelasticity

$$Q^2 = sxy$$

$Q^2 \sim 1/\lambda$: the scale of the interaction corresponds to the spatial resolution at which the proton structure is probed

Main observables of interest: double differential cross sections $d^2\sigma/dxdQ^2$

Chiral Structure of CC, by ZEUS



DESY-08-177

Total cross-section
vs Electron Polarization
provides striking evidence

Isolated Lepton yield

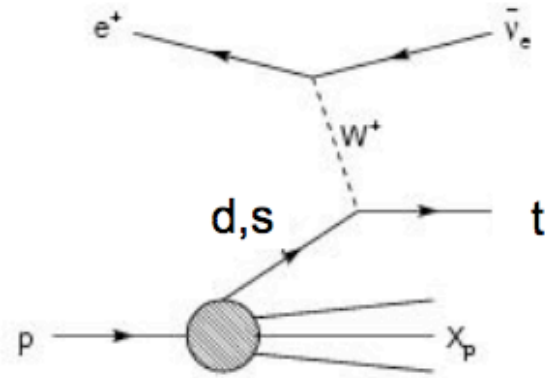
- H1: Good overall agreement of data and SM prediction, 18 / 13±2 at high P_T^X
- ZEUS: Good overall agreement of data and SM prediction, also at high $P_T X$

H1 1994-2007 $e^{\pm}p$ 474 pb^{-1}		Data	SM Expectation	SM Signal	Other SM Processes
Electron	Total	39	43.1 ± 6.0	30.3 ± 4.8	12.9 ± 3.4
	$P_T^X > 25$ GeV	10	7.5 ± 1.3	5.79 ± 0.99	1.71 ± 0.71
Muon	Total	14	11.0 ± 1.8	10.1 ± 1.7	0.88 ± 0.29
	$P_T^X > 25$ GeV	8	6.1 ± 1.0	5.64 ± 0.99	0.47 ± 0.15
Combined	Total	53	54.1 ± 7.4	40.4 ± 6.3	13.7 ± 3.5
	$P_T^X > 25$ GeV	18	13.6 ± 2.2	11.4 ± 1.9	2.18 ± 0.80

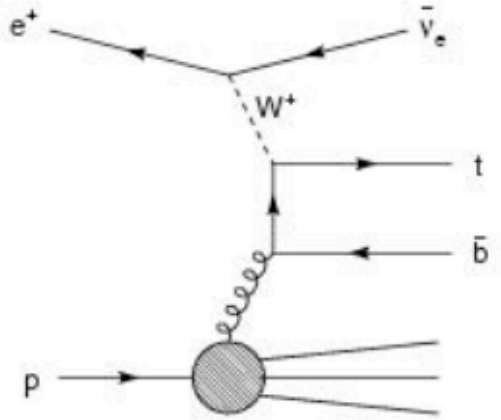
- What are those high-P_T^X events?
- Does H1 control their background?
- Study the main background contributions to the channels →

ZEUS Isolated Lepton Candidates	$P_T^X < 12$ GeV	$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
e^-p 208 pb^{-1}	9/11.3 ± 1.5 (54%)	6/5.1 ± 0.7 (67%)	5/5.5 ± 0.8 (75%)
e^+p 296 pb^{-1}	7/12.6 ± 1.7 (68%)	7/6.2 ± 0.9 (75%)	6/7.4 ± 1.0 (79%)
$e^{\pm}p$ 504 pb^{-1}	16/23.9 ± 3.1 (61%)	13/11.2 ± 1.5 (71%)	11/12.9 ± 1.7 (77%)

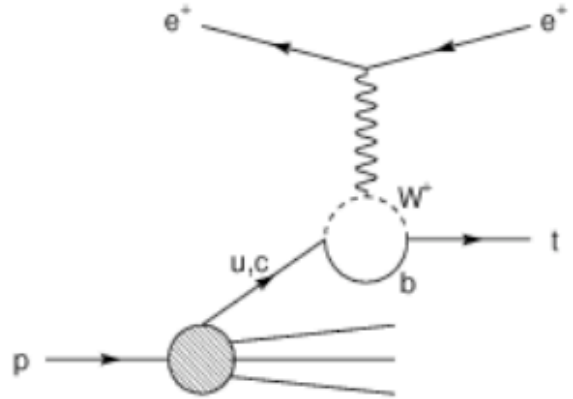
Single TOP production at HERA in the **SM**



Charged Current
W coupling to light
down-type quark



Charged Current
involving *b*-quark



Neutral Current
FCNC at loop level
("penguin")

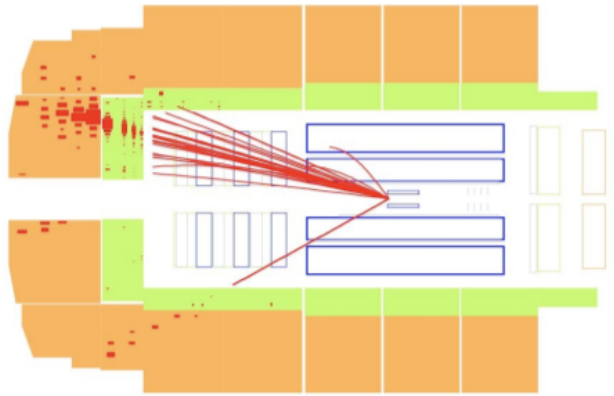
- $\sqrt{s}$ at HERA sufficient for single *top* production
- Production in SM possible but strongly suppressed
- Cross section ~1 fb
  (About 1 *top* event was produced at HERA in the SM)

Not observable

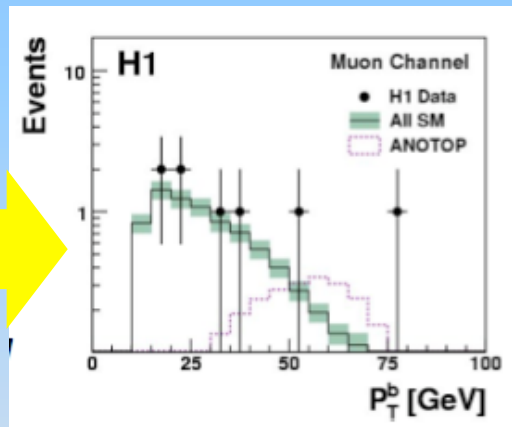
Single TOP results from H1

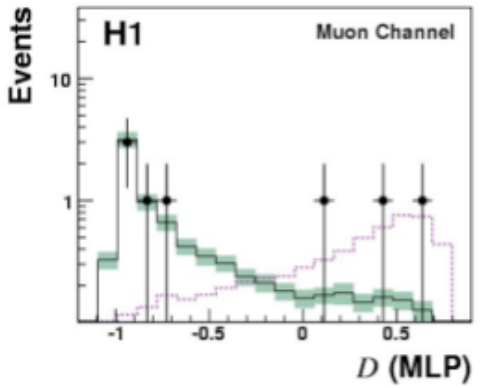
Result published:
DESY-09-050

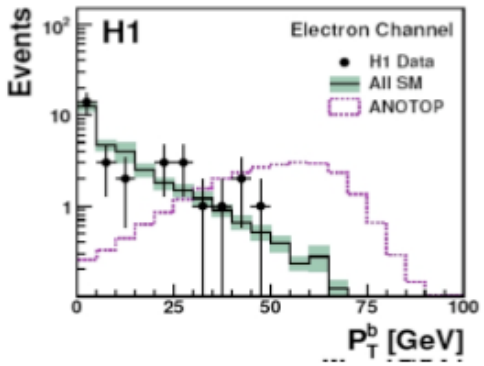
Full data sample collected by H1 at HERA: integrated luminosity $474 pb^{-1}$

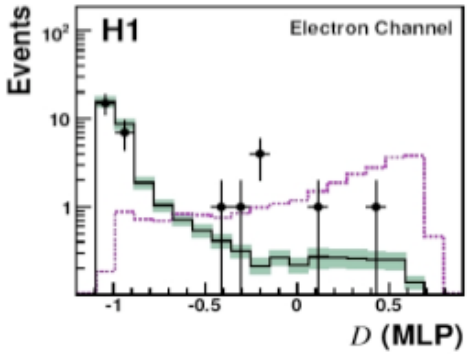


Slight excess in the muon and electron channels

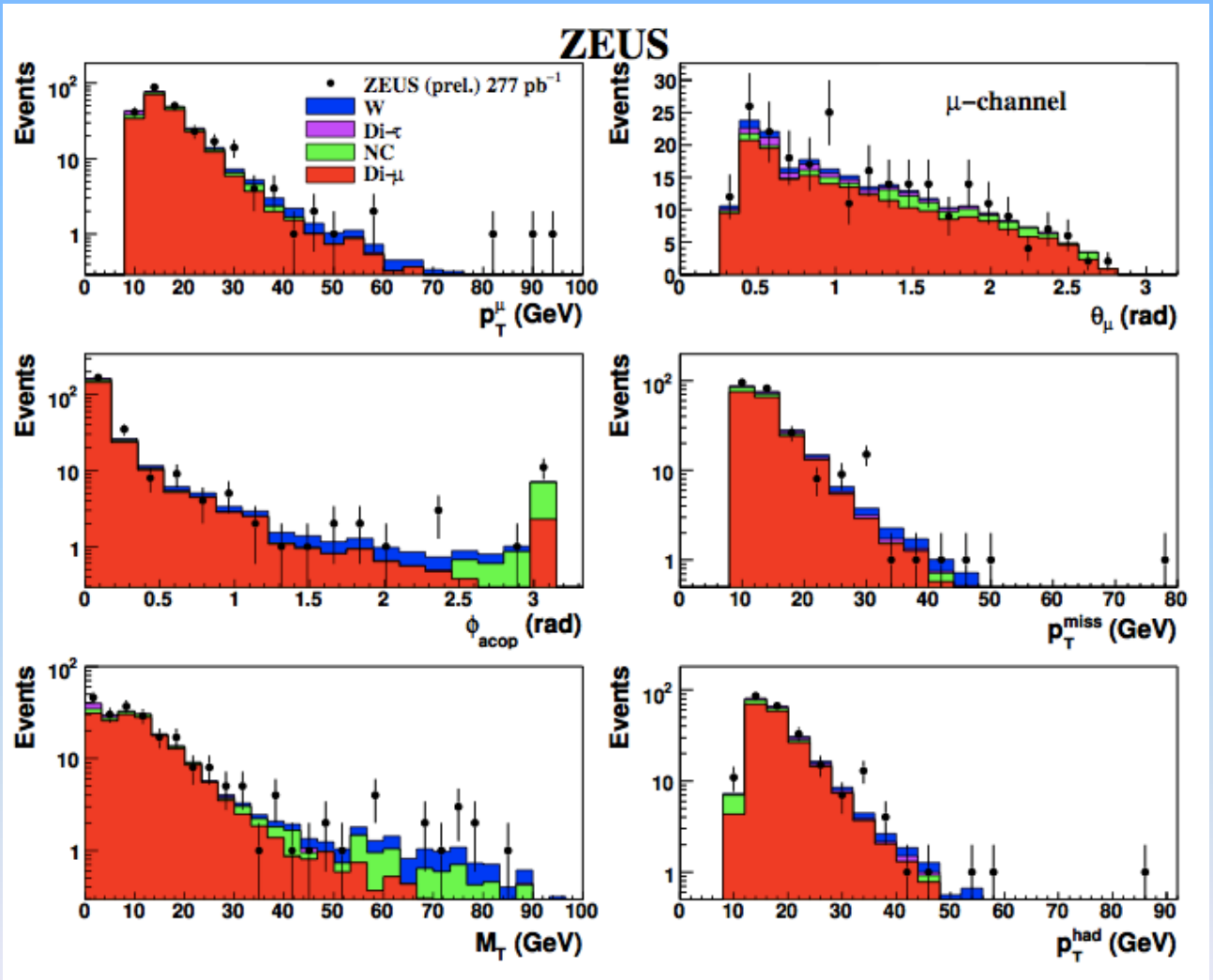








Single TOP results from ZEUS



Muon channel

Main background: di-muon production.

W contribution visible at high transverse mass M_T.