

# Exploring HERA polarised data

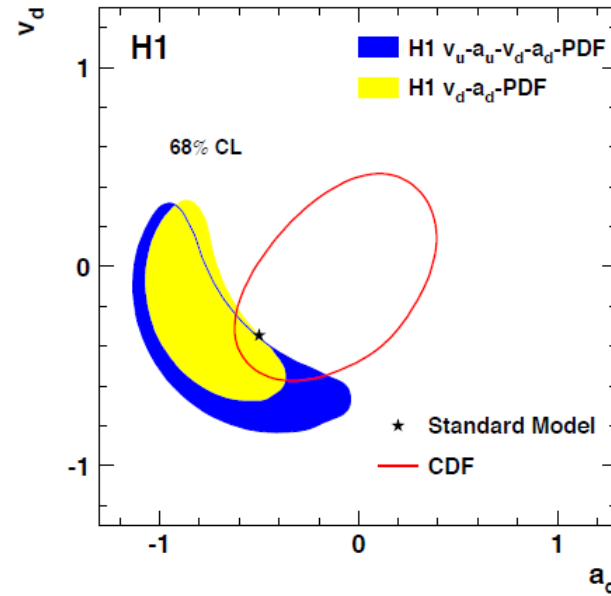
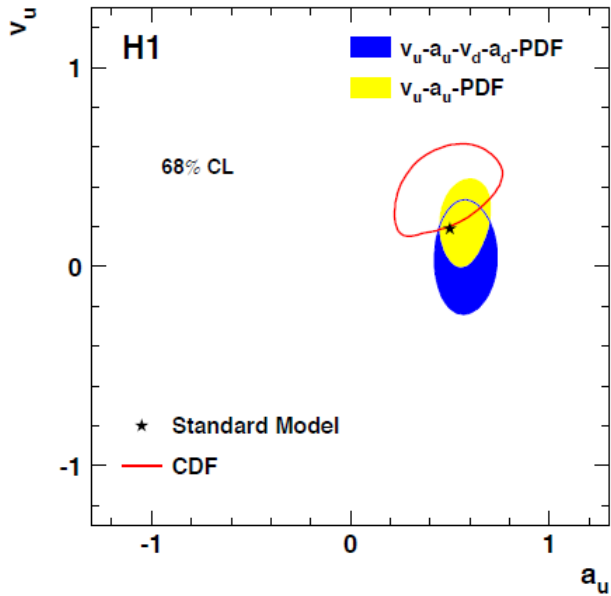
- Electroweak fits
- Polarised data
- Contact Interactions

A. Cooper-Sarkar, V. Myronenko, H. Pirumov, O. Turkot, K. Wichmann, A. F. Zarnecki

# Electroweak fits

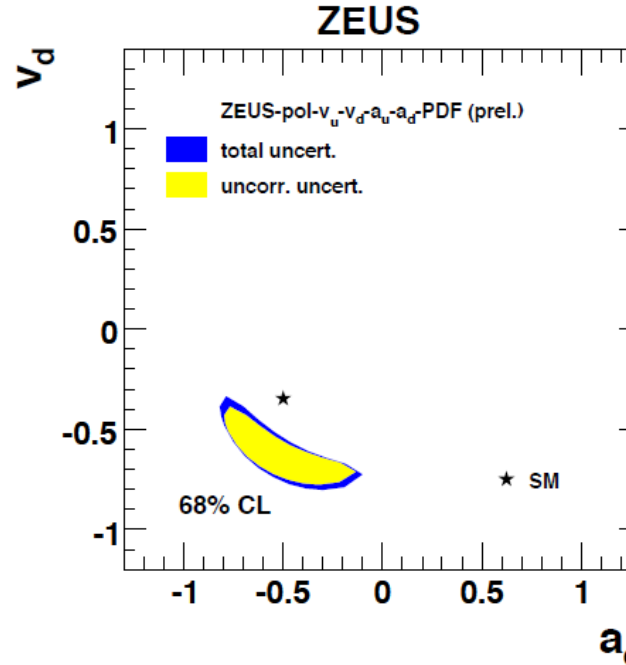
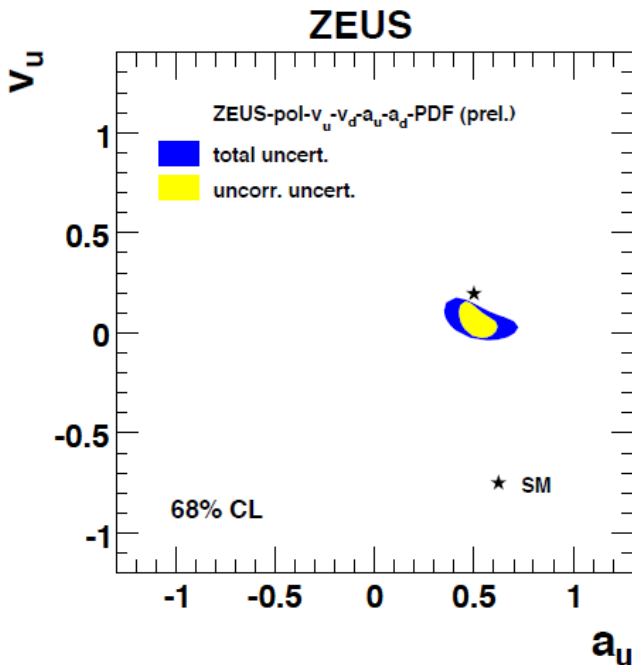
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# Previous measurements



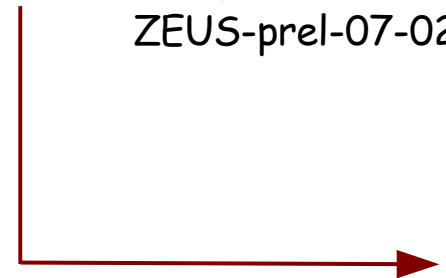
## Determination of EW parameters by H1

- H1 HERA I (unpolarized)  
Phys. Lett. B632, 35, (2006)



## Determination of EW parameters by ZEUS

- ZEUS HERA I + HERA II  
e-p (polarised, partial)  
ZEUS-prel-07-027

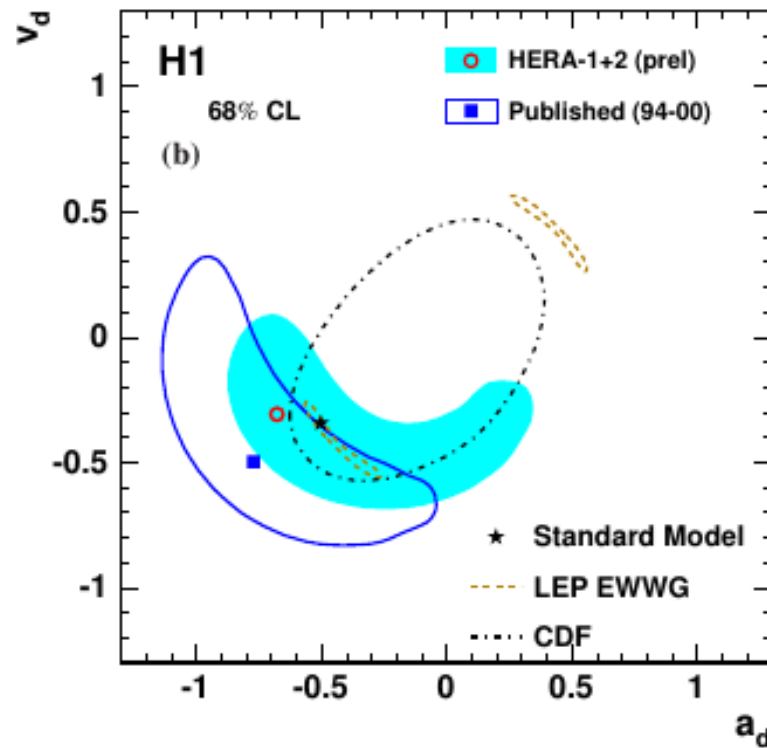
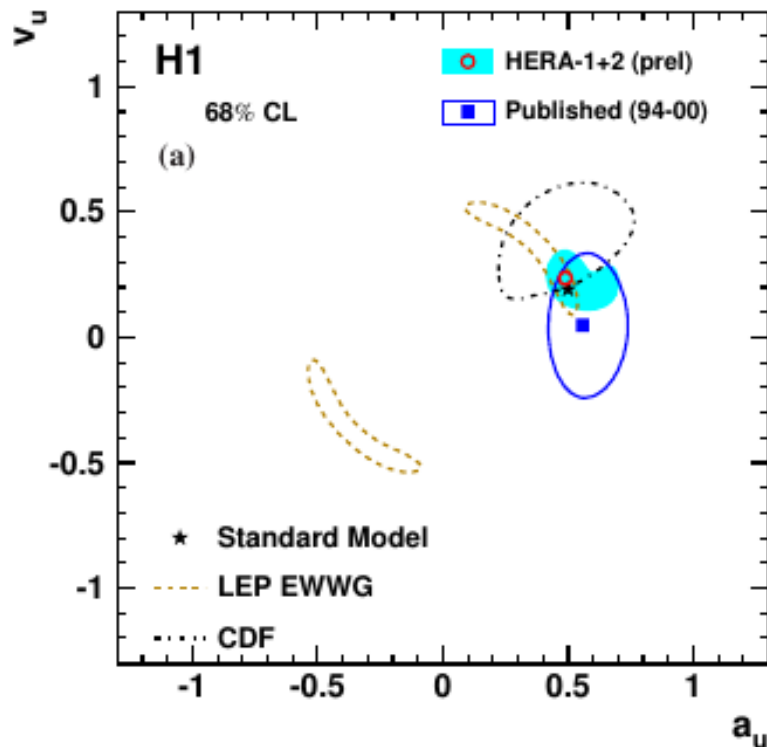


# Polarisation gives access to additional terms in structure functions

$$\tilde{F}_2^\pm = F_2 + k_Z(-v_e \mp Pa_e) \cdot F_2^{\gamma Z} + k_Z^2(v_e^2 + a_e^2 \pm 2Pv_e a_e) \cdot F_2^Z$$

$$xF_3^\pm = k_Z(\pm a_e + Pv_e) \cdot xF_3^{\gamma Z} + k_Z^2(\mp 2v_e a_e - P(v_e^2 + a_e^2)) \cdot xF_3^Z$$

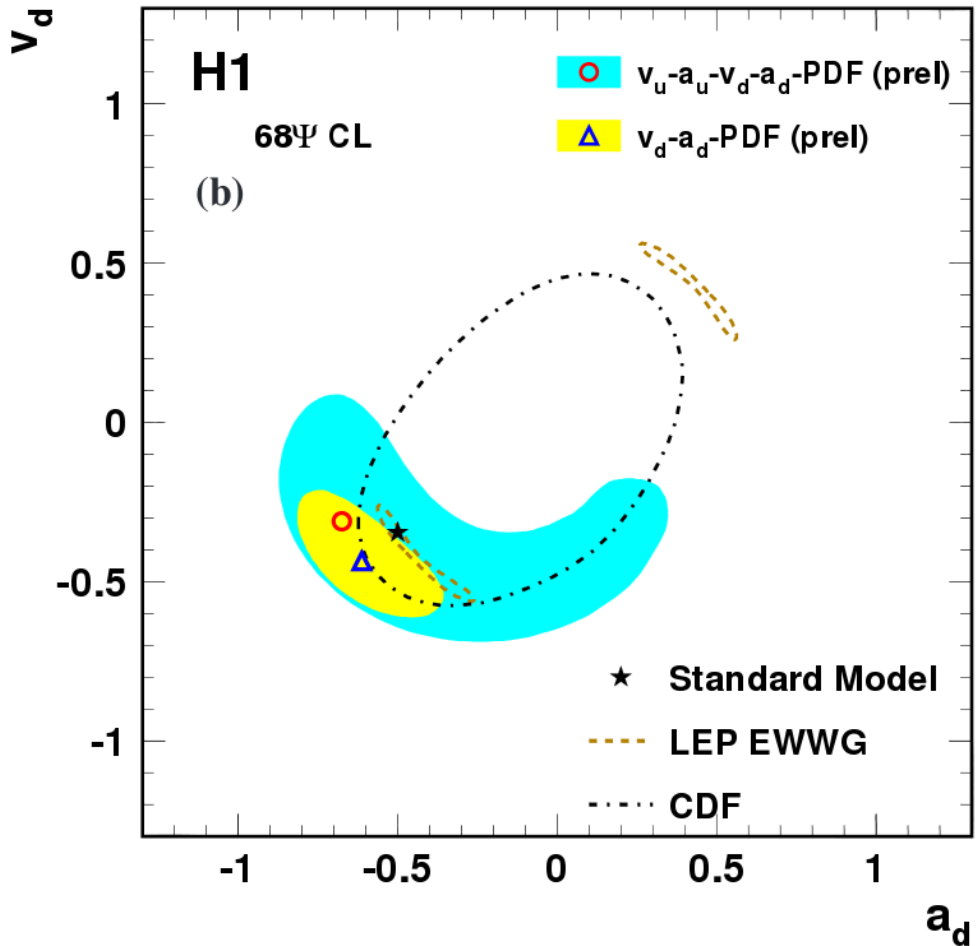
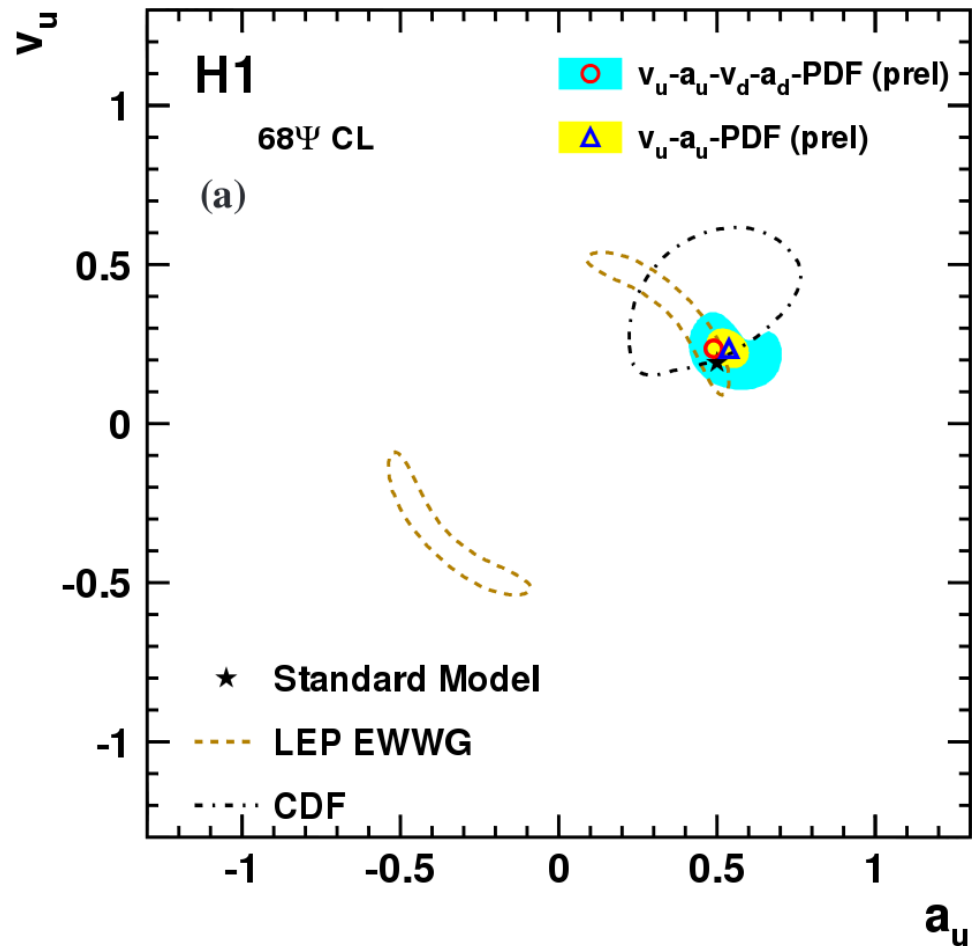
$$(F_2, F_2^{\gamma Z}, F_2^Z) = x \sum (e_q^2, 2e_q v_q, v_q^2 + a_q^2)(q + \bar{q}) \quad (xF_3^{\gamma Z}, xF_3^Z) = 2x \sum (e_q a_q, v_q a_q)(q - \bar{q})$$



- Precision improved with respect to results based on unpolarized HERA data
- in particular for vector couplings

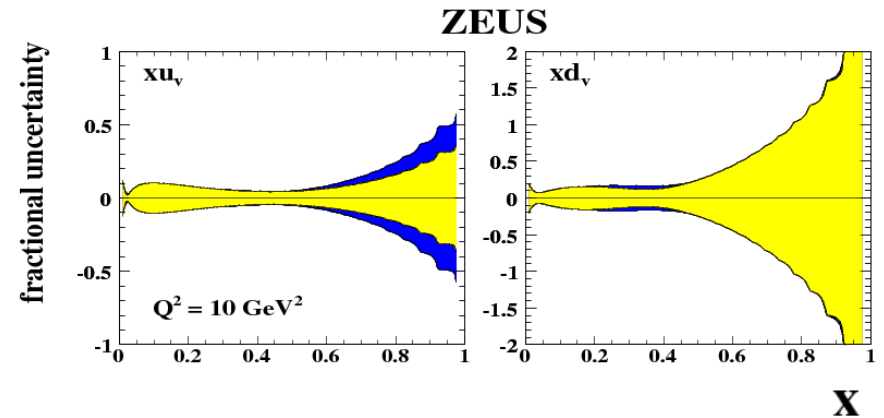
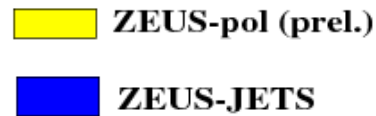
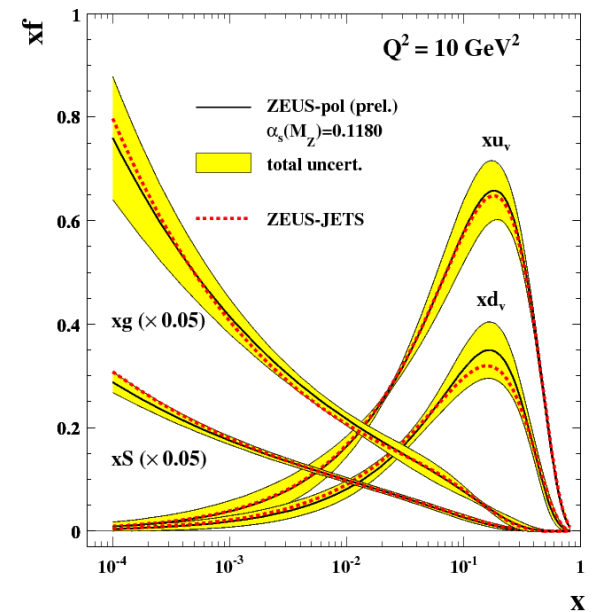
# "Restricted" fits

- Precision improved when only two couplings fitted instead of all four



# Proposed analysis

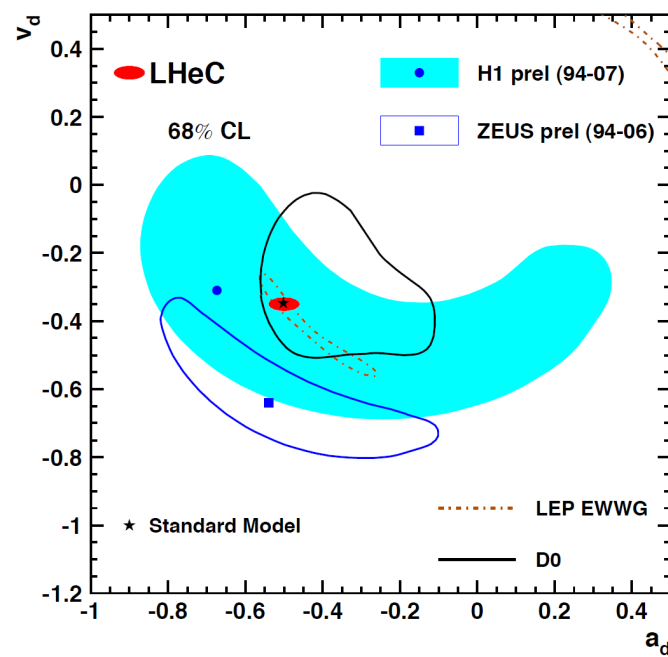
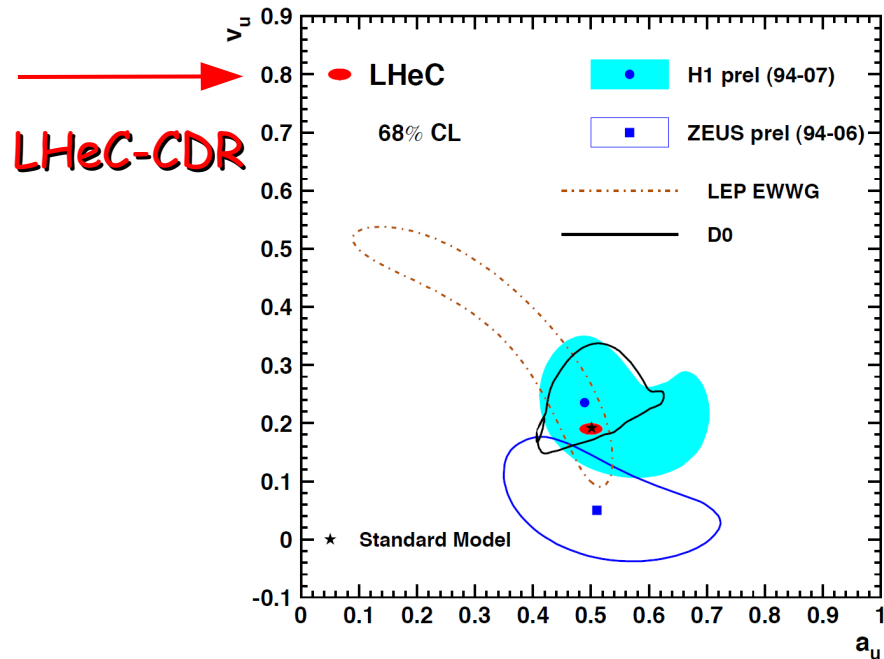
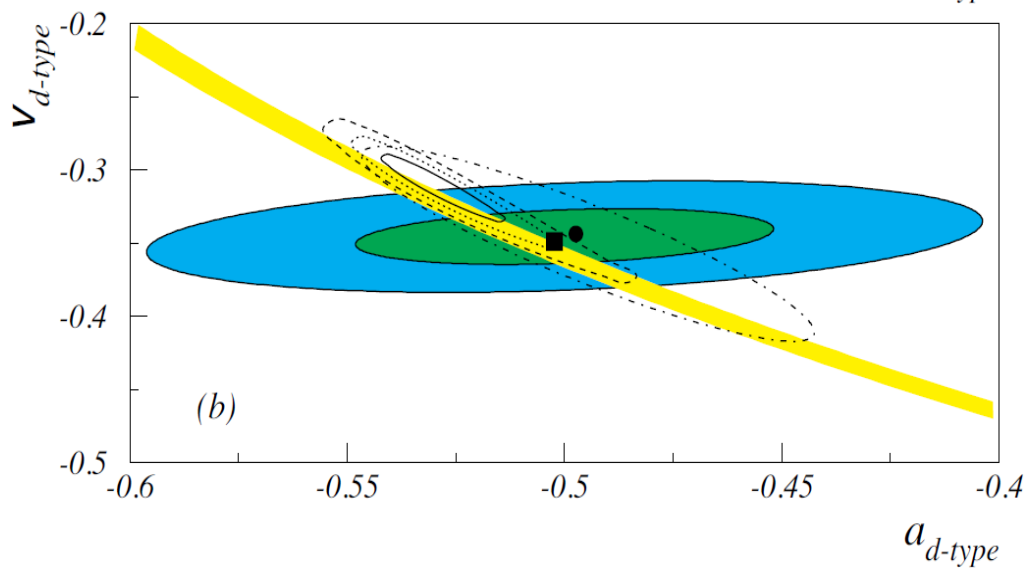
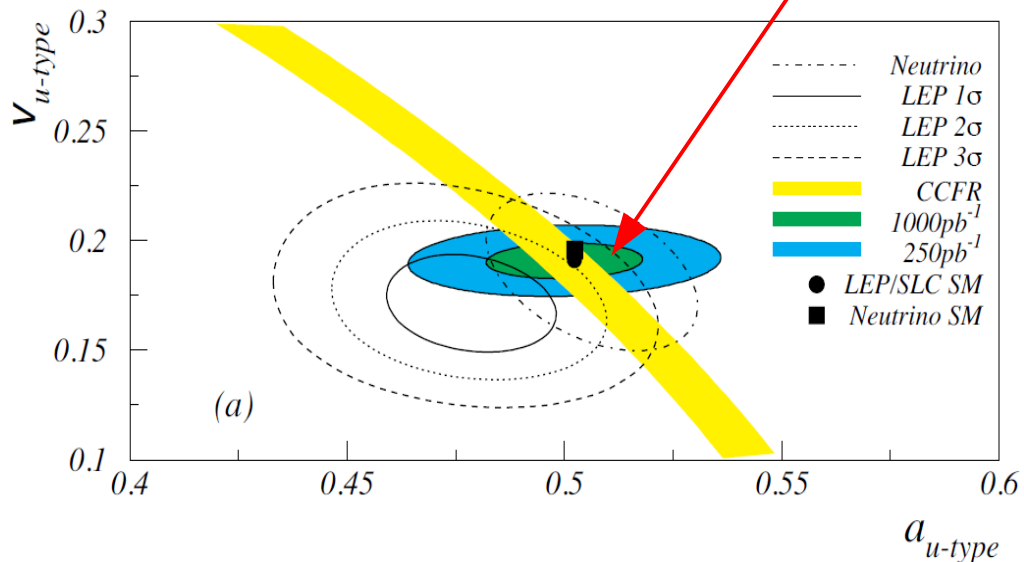
- Improve experimental precision on couplings of light quarks to  $Z^0$ 
  - **Simultaneous fit of PDFs and couplings**
  - Use all existing HERA data



- Provide HERAPDF EW fit using HERA data only
- Try HERA data + additional constrains from previous measurements
  - correlations are usually provided in publications
- Try to improve accuracy on Weinberg angle measurements

# Back to future...

Estimates for HERA from ~1995/96



# Data & Tools

## Input data

- ZEUS data:
  - HERA I full data set
  - HERA II full data set (polarized)
- H1 data:
  - HERA I full data set
  - HERA II full data set (polarised)

## Fitting tool

- Using HERAFitter package for EW parameters determination

[www.herafitter.org](http://www.herafitter.org)



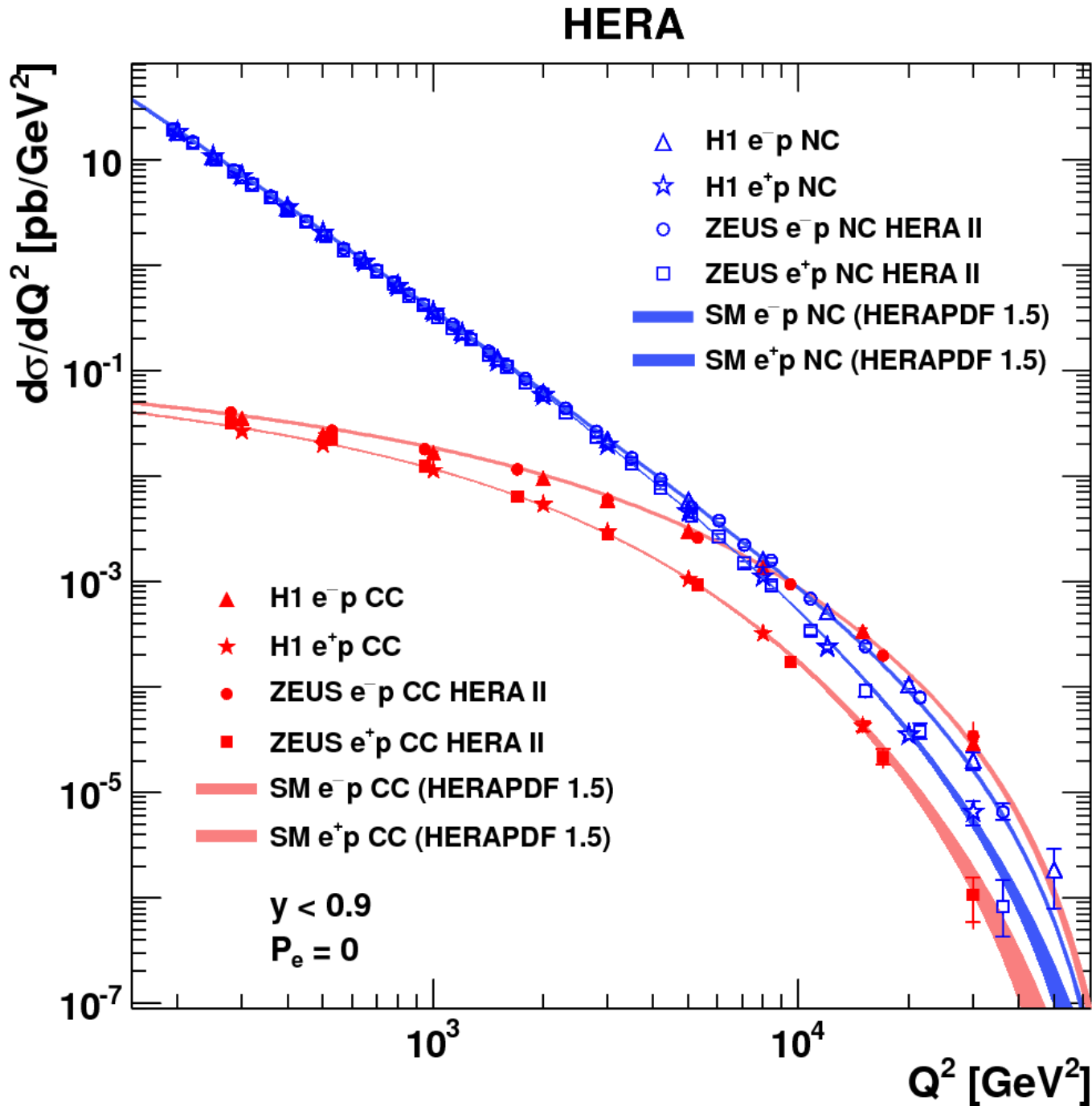
→ lets look at available data



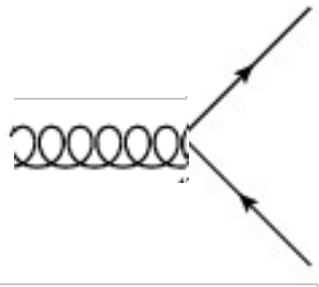
All H1 and ZEUS inclusive UNPOLARISED  
measurements final  
→ we combine them



# Electroweak unification

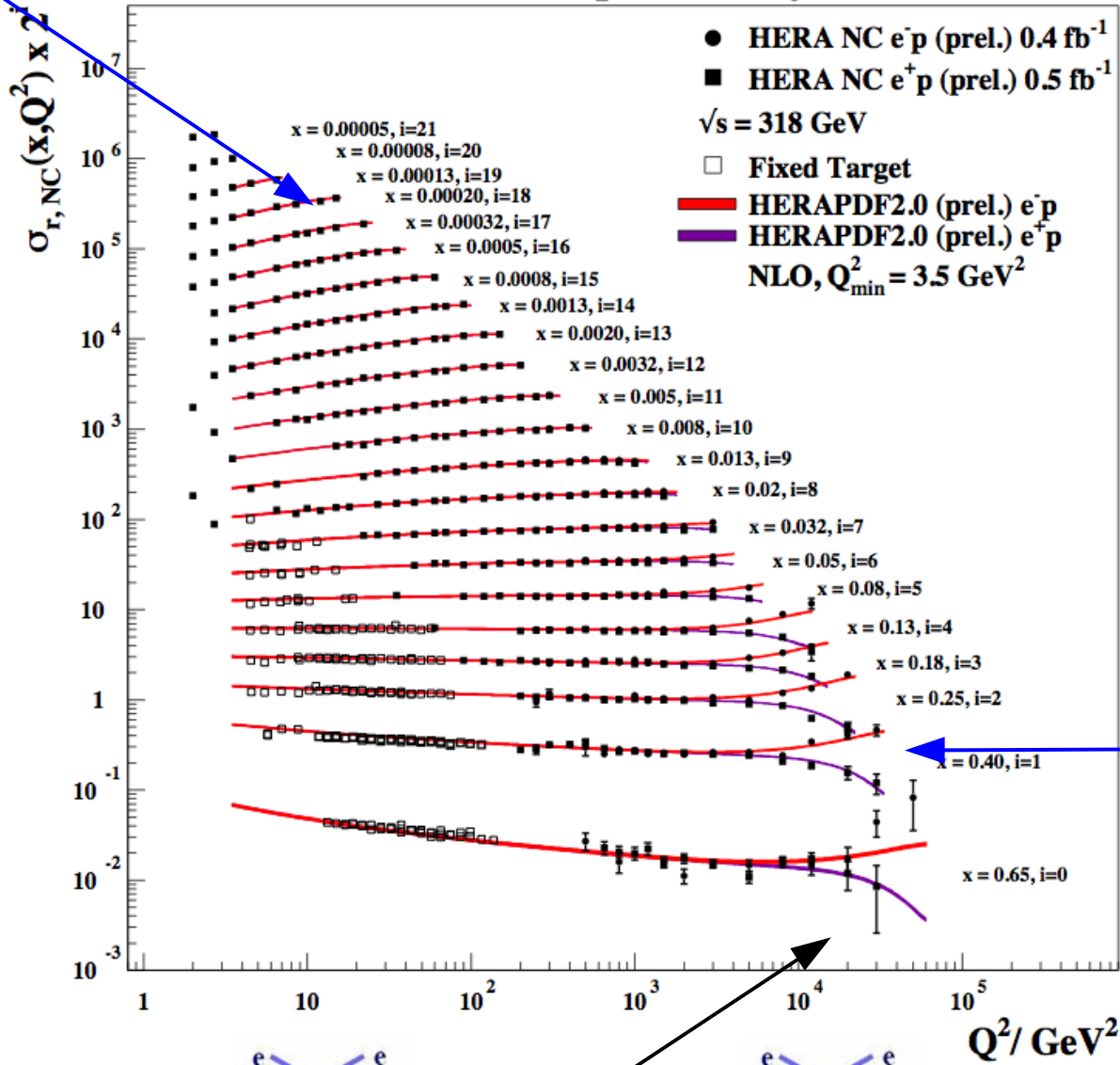


# QCD scaling and EW effects beautifully seen

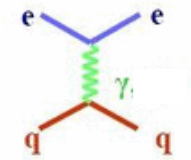
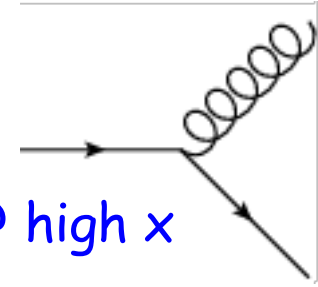


@ low x

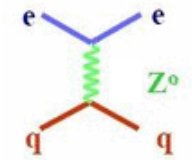
H1 and ZEUS preliminary



@ high x

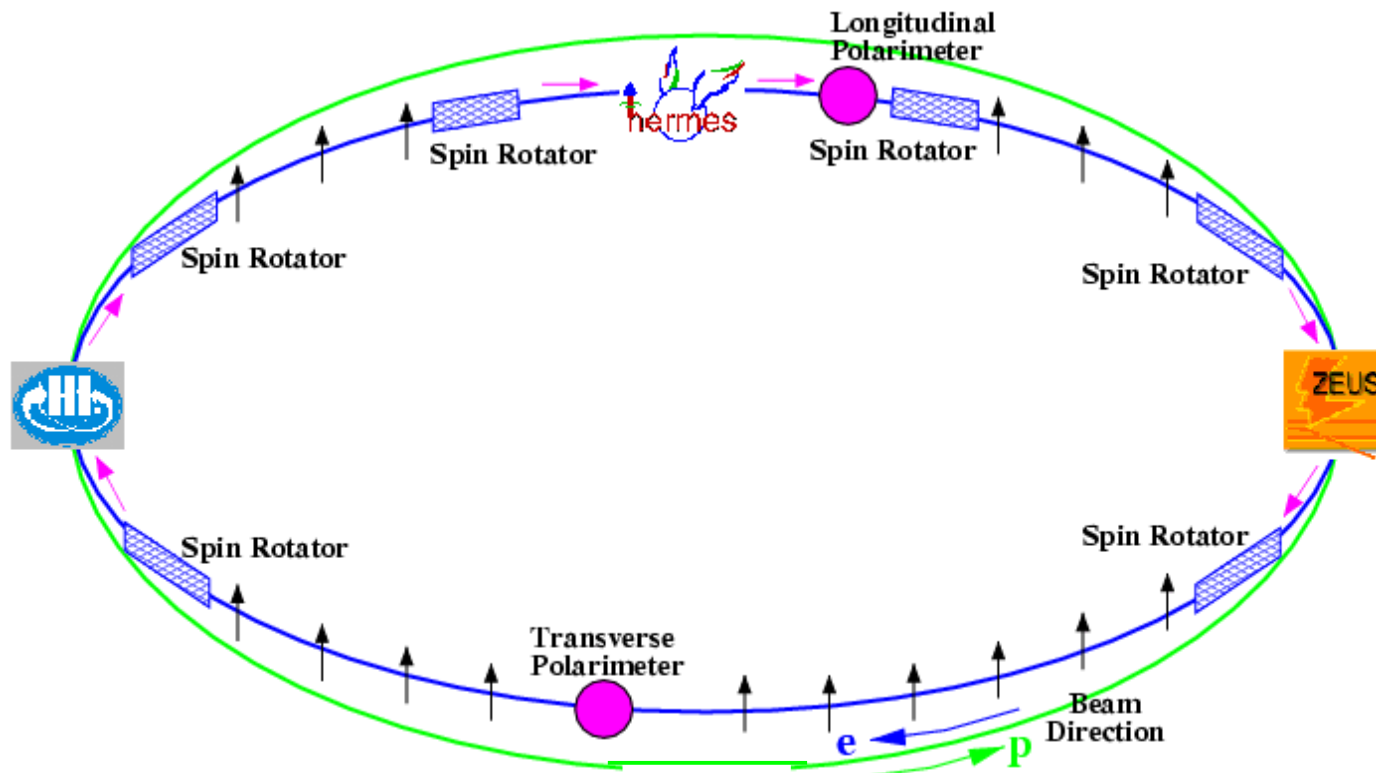


@ high Q^2

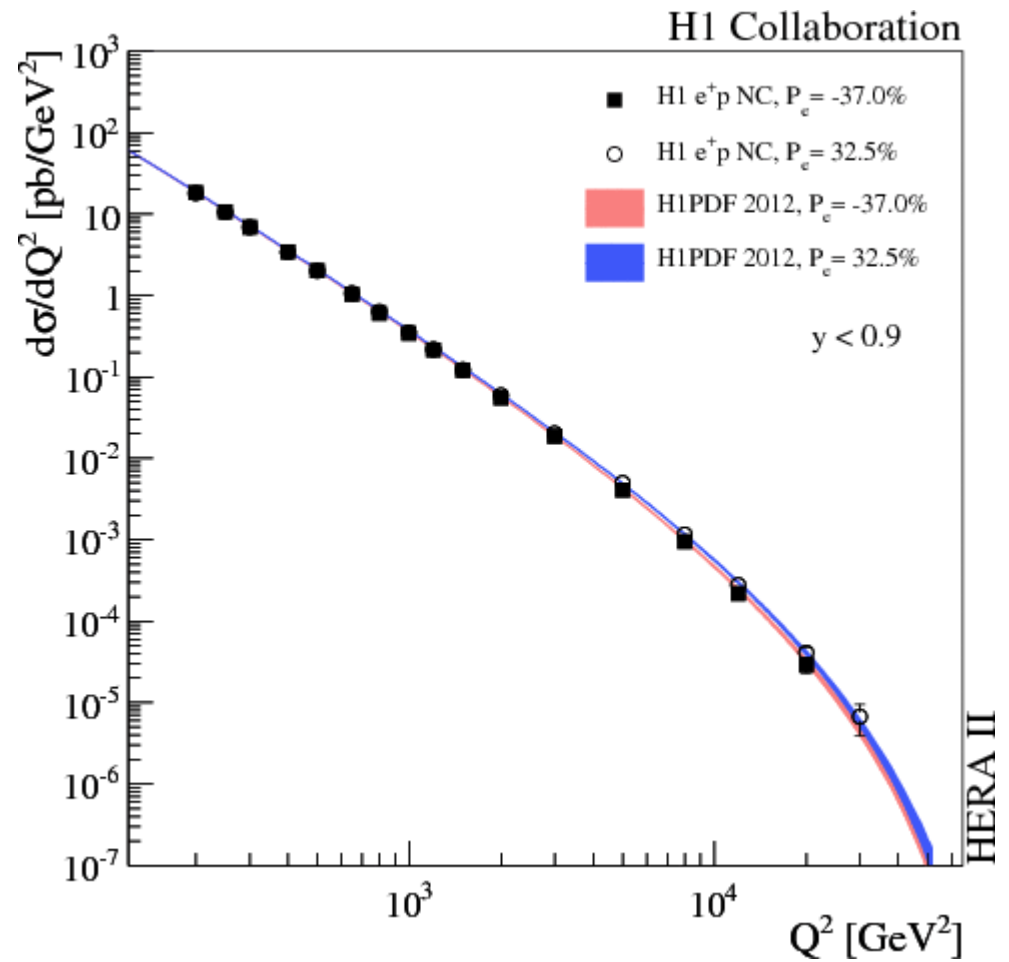
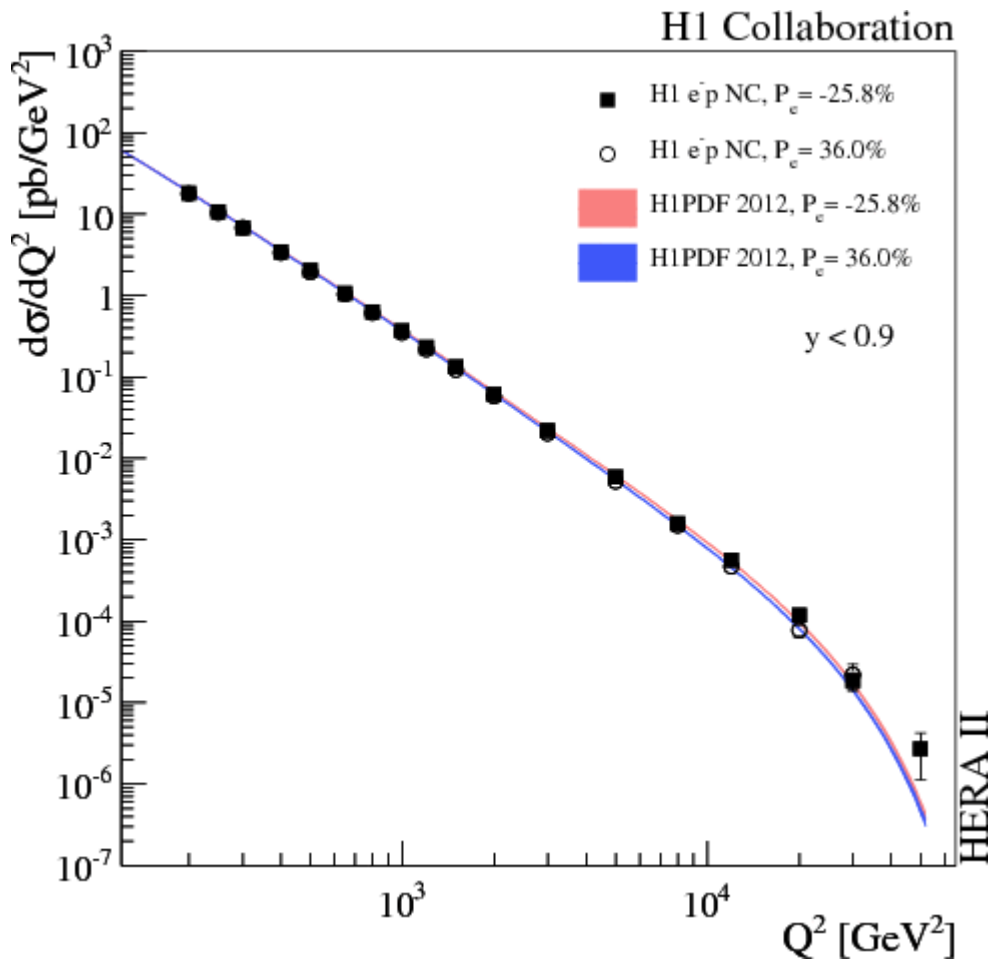


# Polarization @ HERA

- From 2003 polarized lepton beam
  - Spin rotators flipping transverse polarization to longitudinal and vice versa
- Positive and negative helicities possible
- Polarization of  $\sim 30\text{-}55\%$  achieved

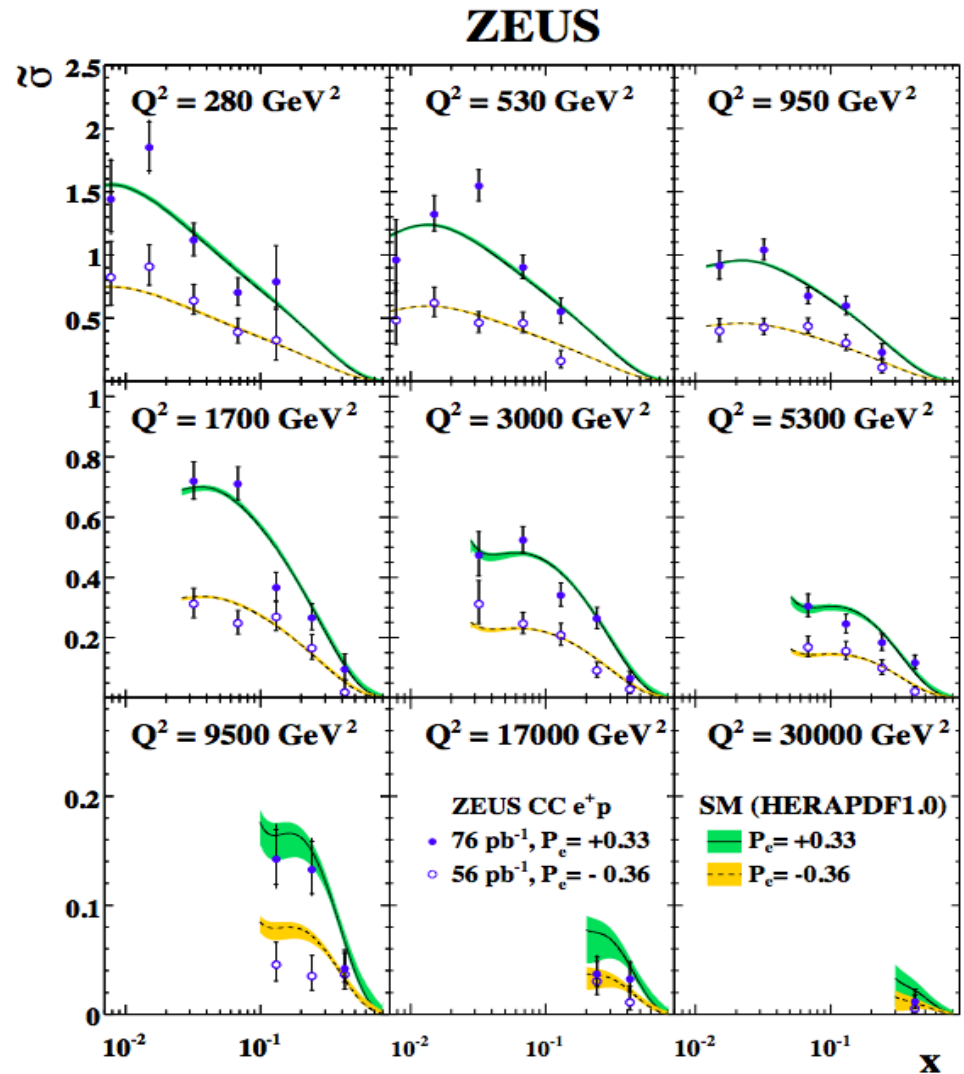
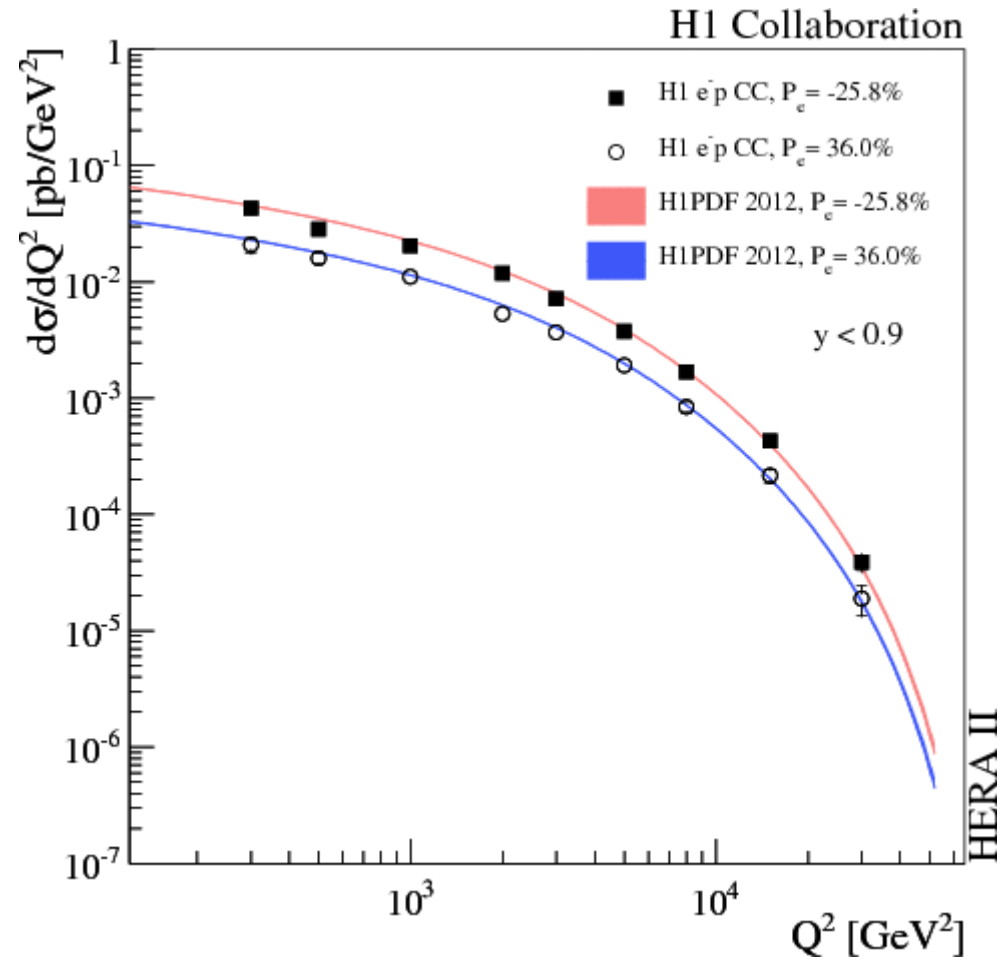


# Polarized NC DIS



- No significant dependence on polarization in NC DIS
- In agreement with the Standard Model using H1PDF2012

# Polarized CC DIS

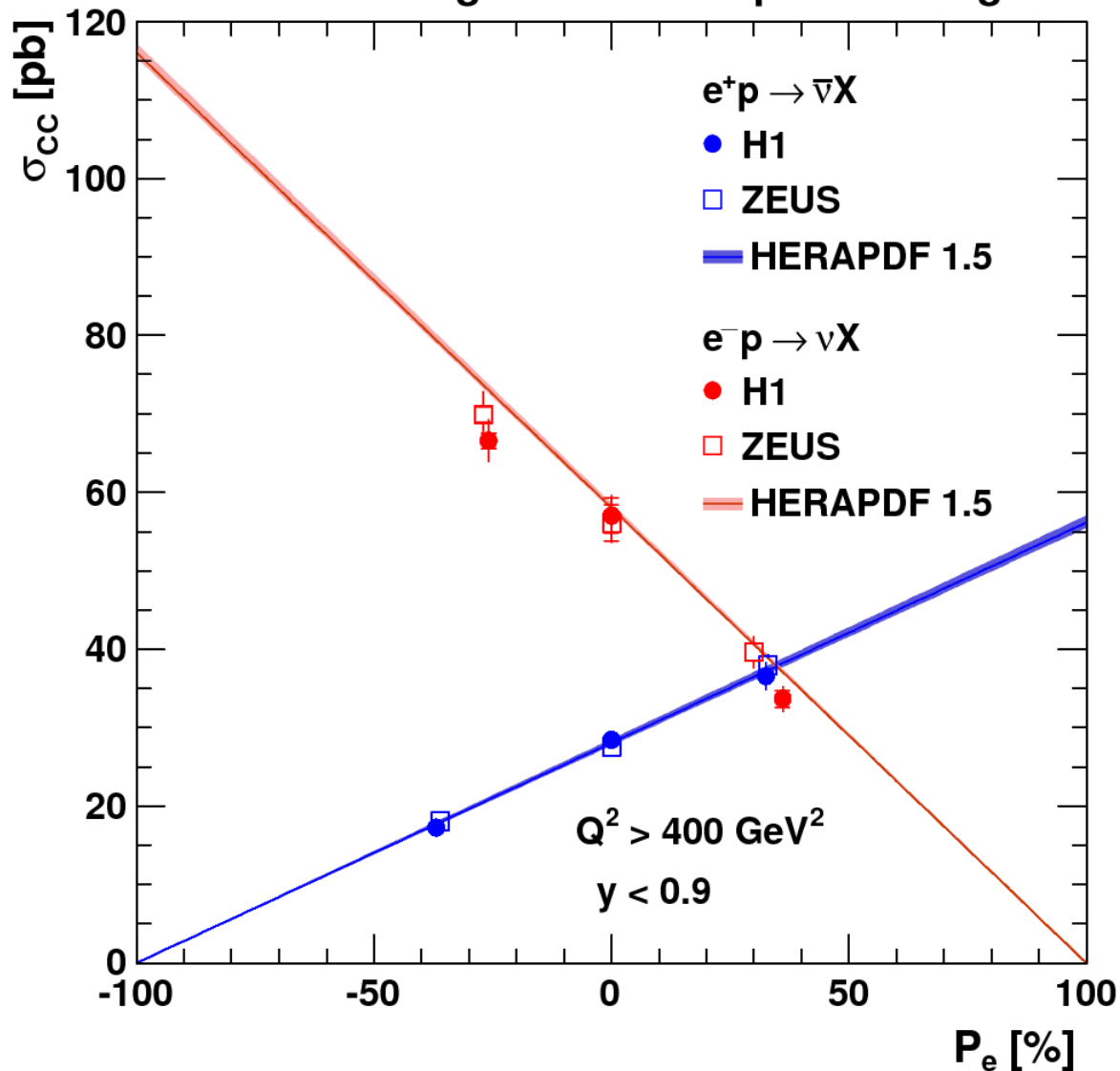


- Very clear dependence on polarization in CC DIS
- In agreement with Standard Model

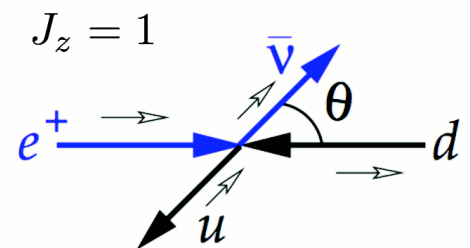
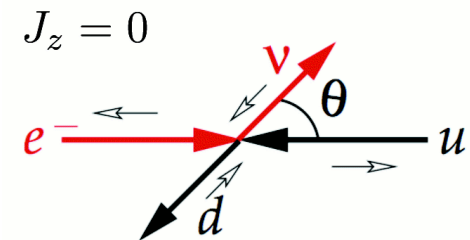
# CC polarization dependence in SM

$$\frac{d^2\sigma_{CC}^{\pm}(P_e)}{dx dQ^2} = (1 \pm P_e) \frac{d^2\sigma_{CC}^{\pm}}{dx dQ^2}$$

HERA Charged Current  $e^{\pm}p$  Scattering



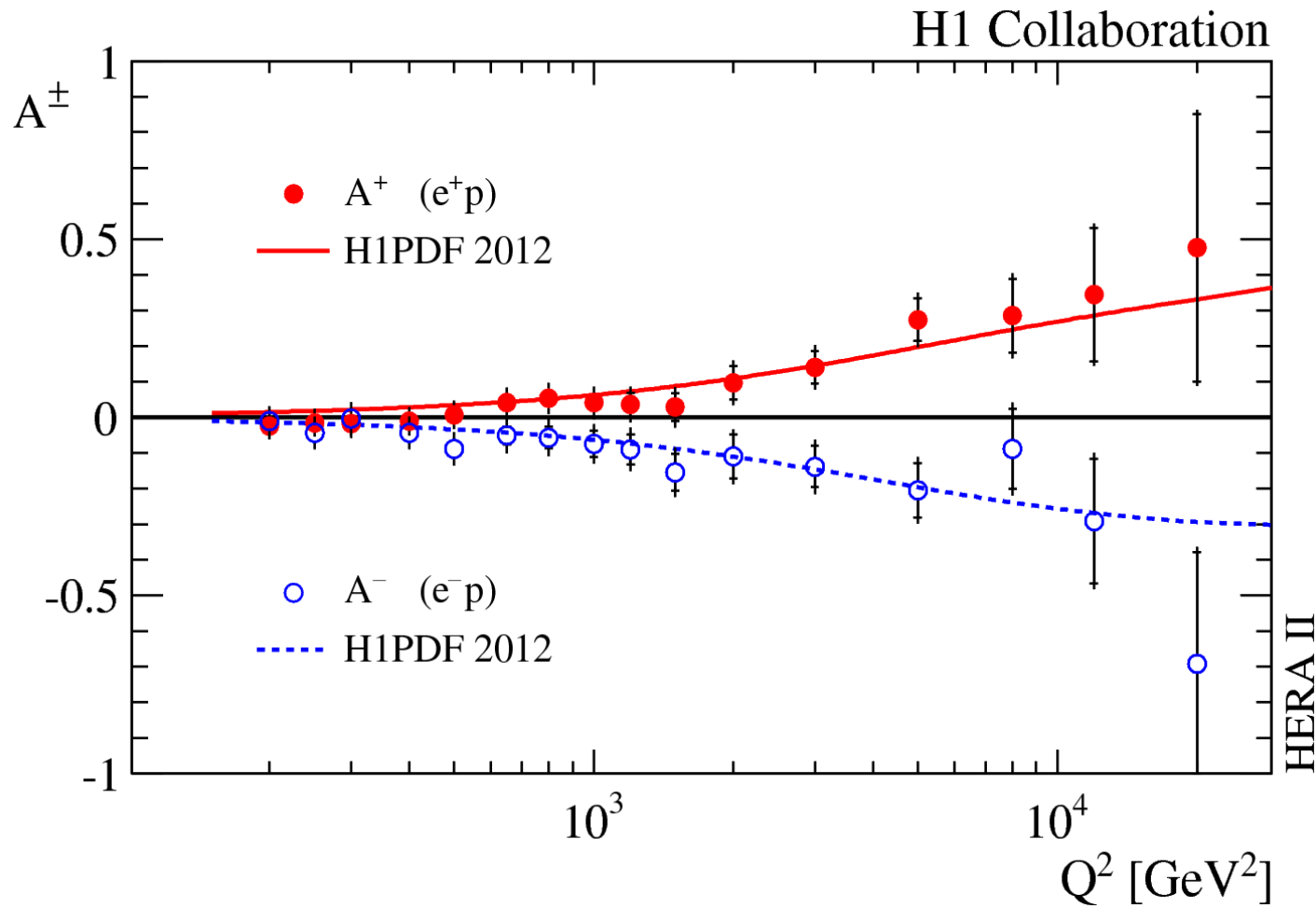
- Chiral structure of EW interactions probed
- No sign for right-handed currents



# Parity Violation in NC DIS

NC polarization asymmetry

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



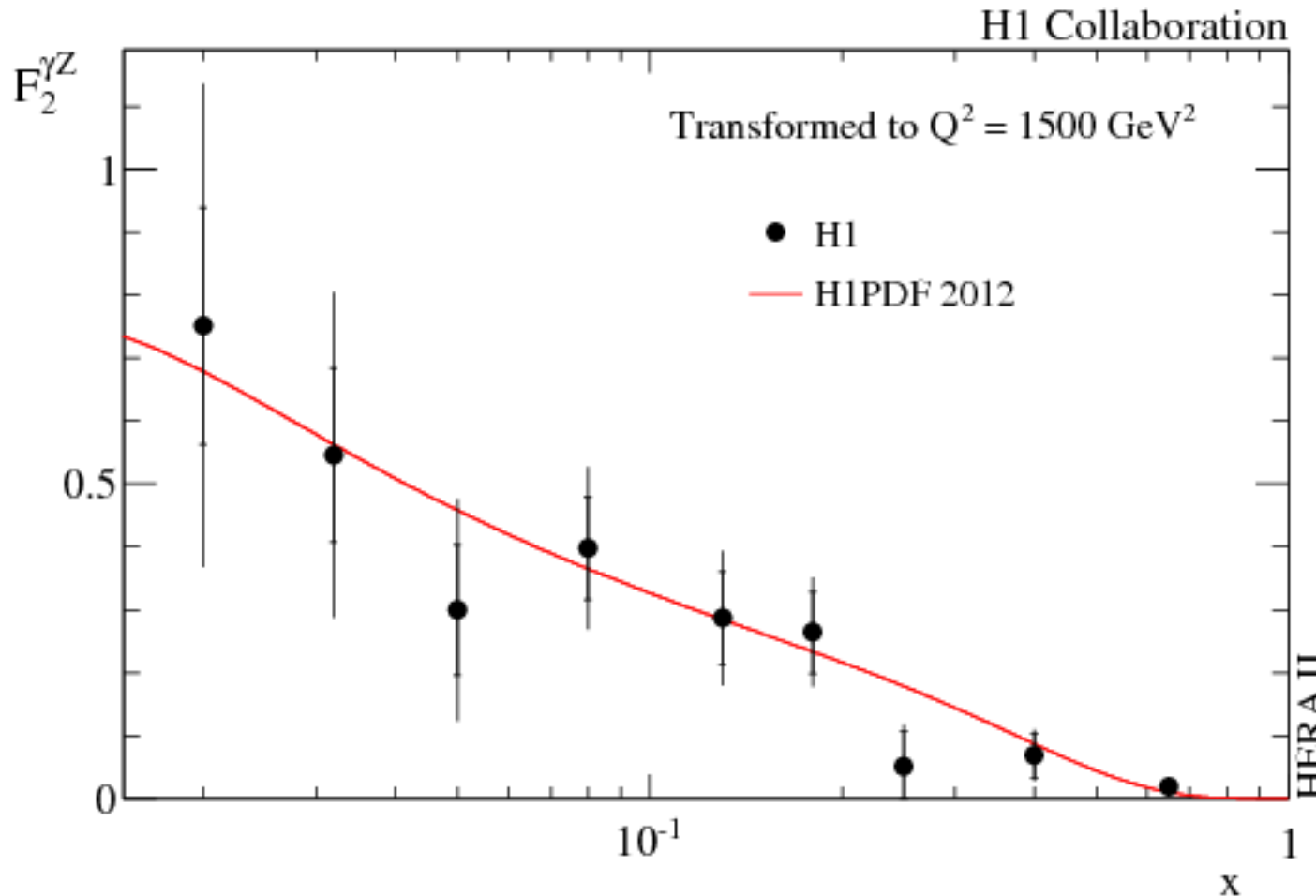
Direct measure of parity violation effect in NC DIS



# Quark-Antiquark Distribution

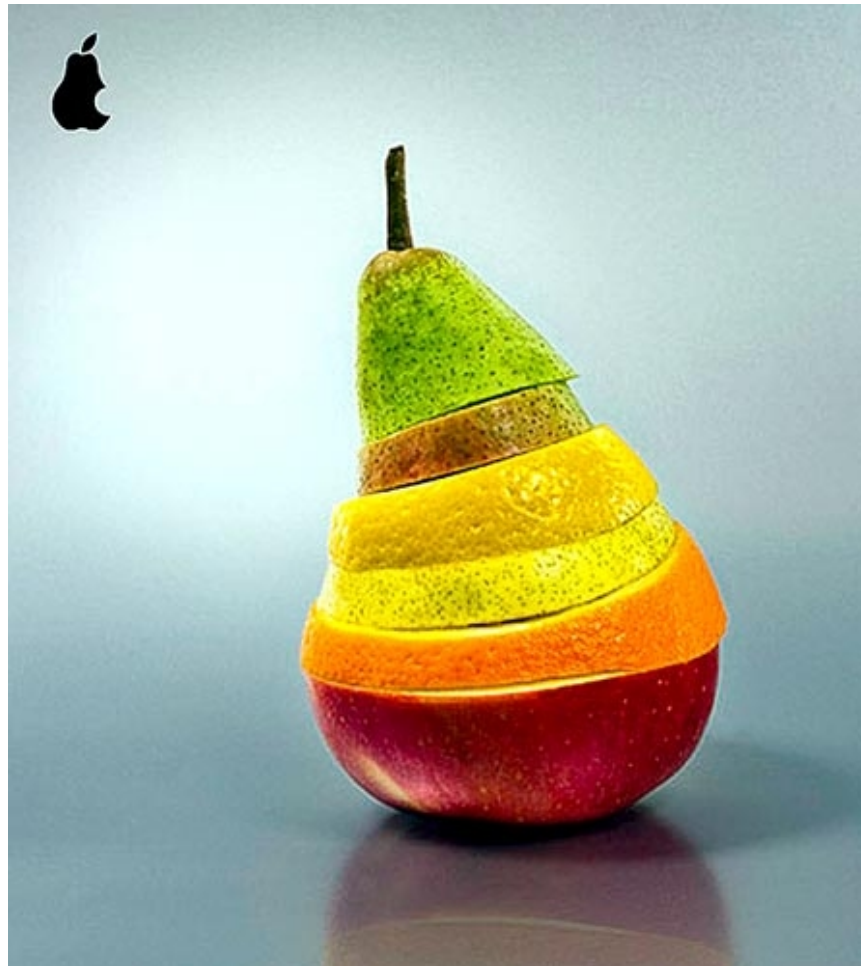
- Parity violating structure function  $F_2^{\gamma Z}$  from polarized NC cross sections
- First and only measurement of  $F_2^{\gamma Z}$

$$\frac{\sigma^+(P_L^\pm) - \sigma^+(P_R^\pm)}{P_L^\pm - P_R^\pm} = \frac{\kappa Q^2}{Q^2 + M_Z^2} \left[ \mp a_e F_2^{\gamma Z} - \frac{Y_-}{Y_+} v_e x F_3^{\gamma Z} - \frac{Y_-}{Y_+} \frac{\kappa Q^2}{Q^2 + M_Z^2} (v_e^2 + a_e^2) x F_3^Z \right]$$



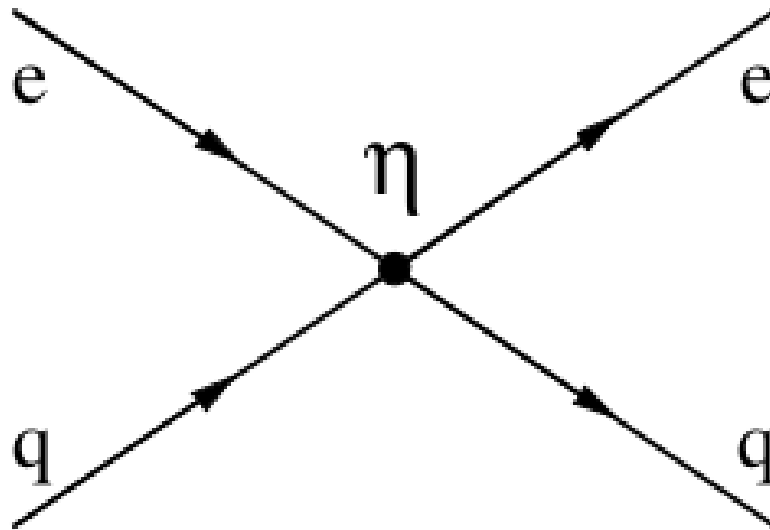
$F_2^{\gamma Z} \sim q + q\text{bar}$

All H1 and ZEUS inclusive POLARISED  
measurements final as well  
→ lets combine them, too!



# Four-fermion $eeqq$ Contact Interactions

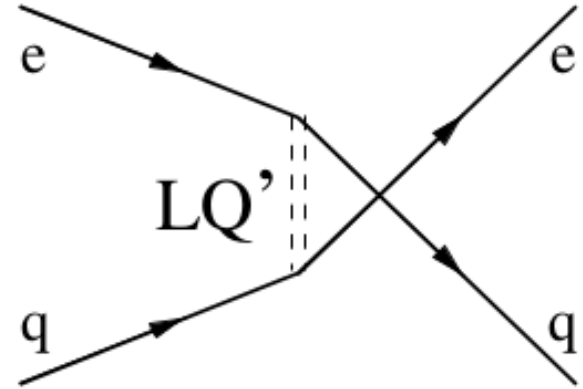
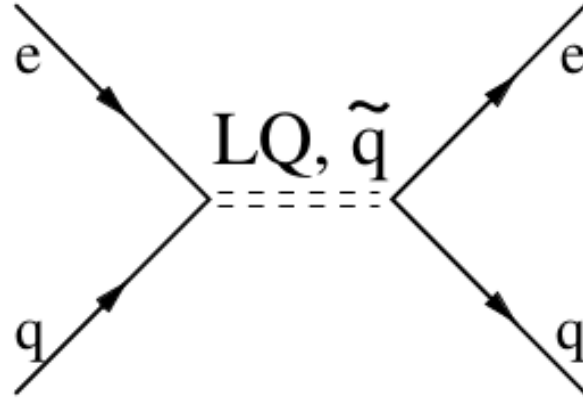
H. Pirumov, O. Turkot, A. F. Zarnecki, K. Wichmann



- An investigation of possible effects due to the virtual exchange allows to search for evidence of new particles with mass much higher than center of mass energy

# CI - convenient method to search for:

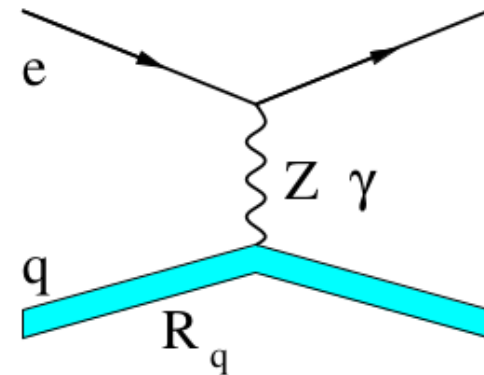
- Leptoquarks



! These models most sensitive to leptons beam polarization

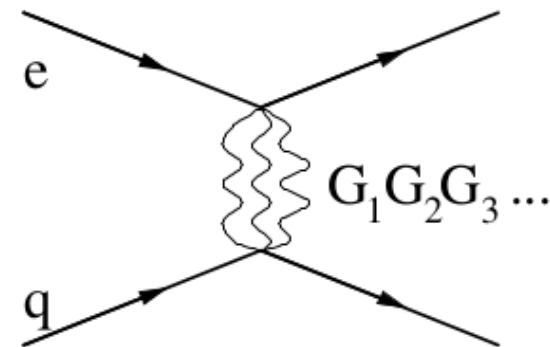
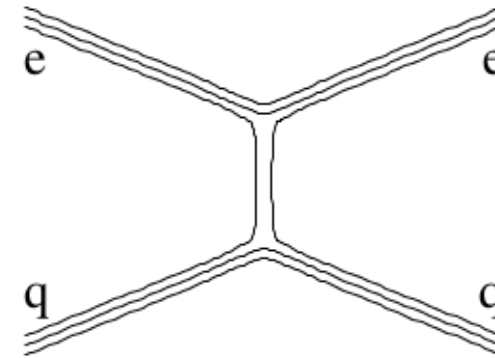
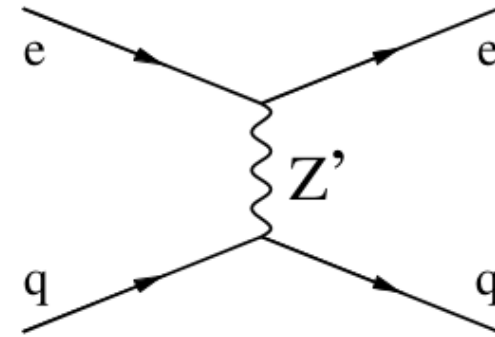
- Quark form factor (quark radius  $R_q$ )

First studies started with this model



# CI - convenient method to search for:

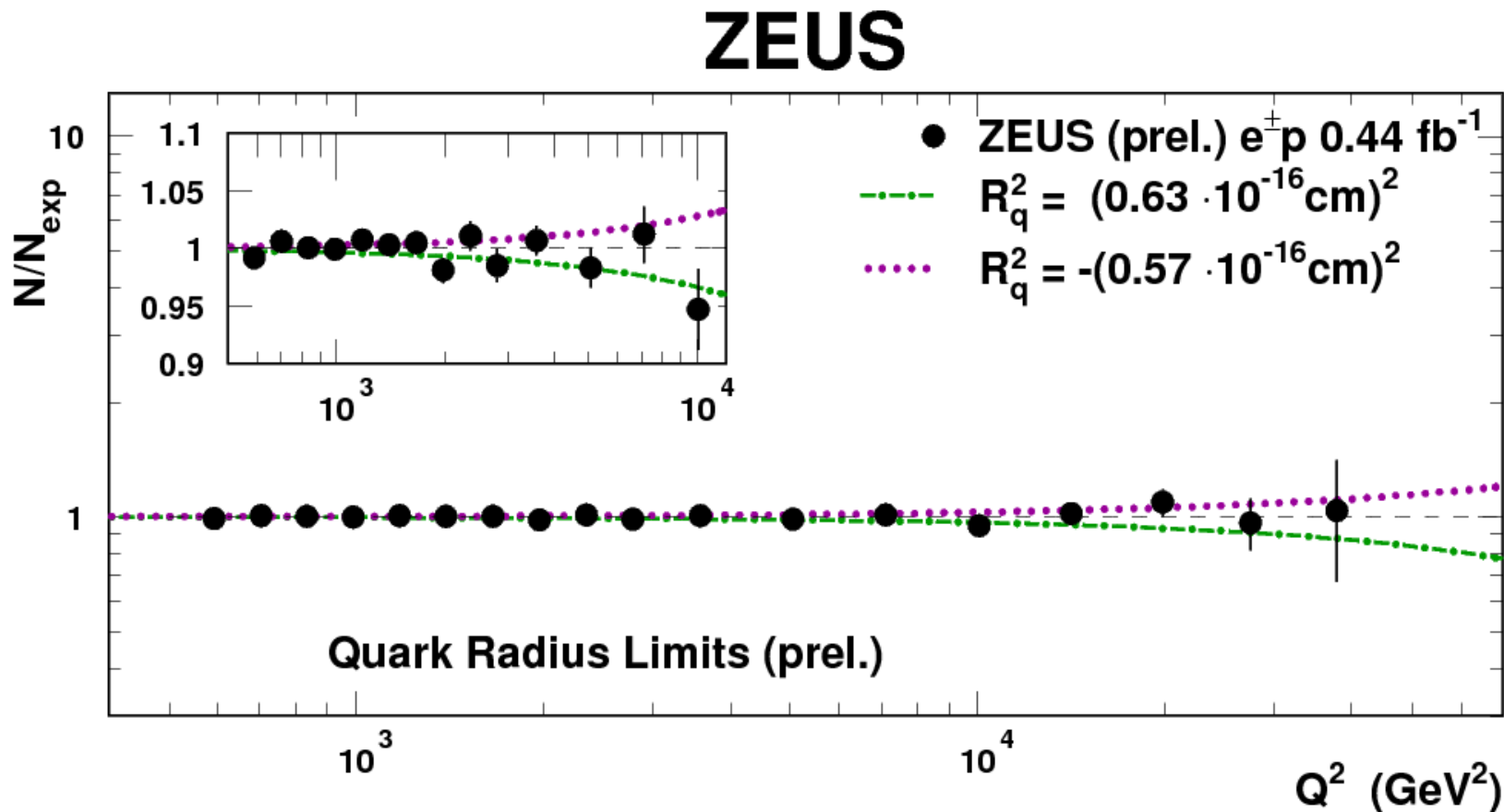
- Possible new interactions
- Compositeness of quarks and leptons
- Large extra dimensions



Test sensitivity of these models to leptons beam polarization

# Search for Contact Interactions @ ZEUS

- At ZEUS searches for CI were done in Neutral Current on event distribution basis
- No deviations from SM observed - limits were set for various CI models (ZEUS-prel-09-013)



# PDF uncertainties in CI analysis

- ZEUS searches for CI done on event distribution basis using NC
- Treatment of PDF uncertainties very **simplified**, although PDF uncertainty was **dominant** source of systematics
- **CTEQ5D** used for nominal SM expectations evaluation
- Fitted data already used in PDF determination (HERA high- $Q^2$ )
  - **Possible influence of CI signal on PDF fit was not considered**
- Resulting PDFs would be biased
  - SM predictions obtained from fit could include some BSM contribution "hidden" in the PDFs
  - one could obtain good agreement of data with (biased) SM predictions and limits could be artificially overestimated
- Particularly important in CI analysis
- Not limited to HERA experiments

see ZEUS note by A. F. Žarnecki  
 "CI analysis with proper treatment of PDF uncertainties"

# Proposed method

- We propose to modify limit setting procedure
- Use HERAFitter for generating MC replicas of inclusive data sets
- Perform COMBINED analysis:
  - Include possible contribution from the BSM processes in QCD fit
  - Calculate Monte Carlo predictions with PDFs fitted **including CI model**, instead of **Standart Model PDFs**
  - For each MC generated set of cross section estimate CI parameter **simultaneously** with PDFs

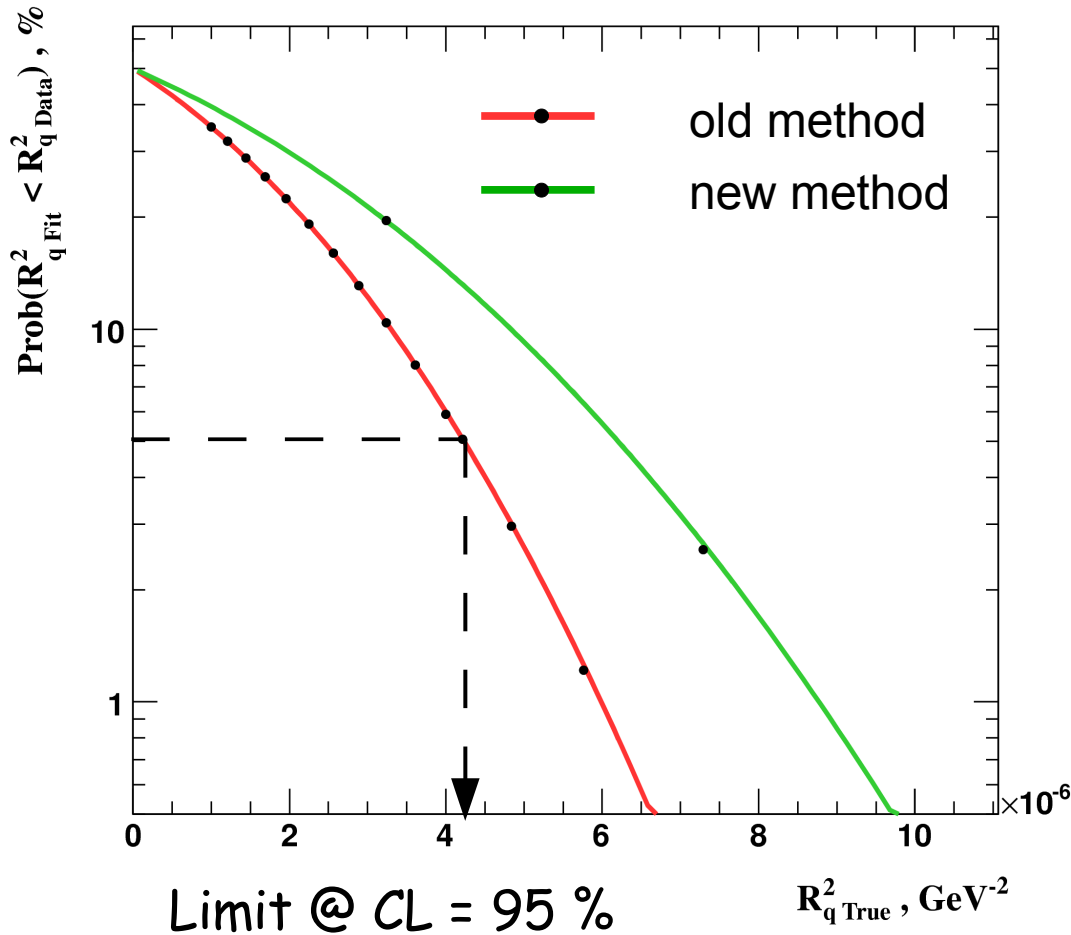


# Difference in old and new methods

resulting limits on model

parameters a bit weaker BUT →

- The only proper procedure to set limits on BSM model parameters using data used to calculate PDFs:
  - perform combined analysis, including possible contribution from BSM processes in QCD fit to data
- This approach we try to develop
- Despite resulting limits on model parameters possibly being not competitive with expected LHC limits



these would be first limits set in strictly correct way

# Summary

- HERA polarised data offer many possibilities to explore
  - Textbook plots, asymmetries, structure functions
  - Electroweak fits
  - Some of the contact interaction models

→ we should combine HERA polarised data

- New method is proposed for contact interaction measurement
  - Including QCD fit in limit setting provides the only strictly correct way to do it