

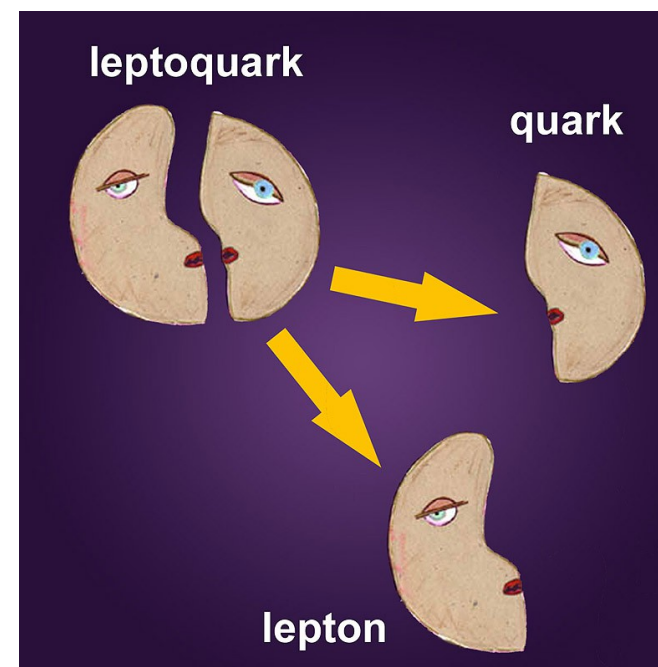


# Search for First-Generation Leptoquarks at HERA

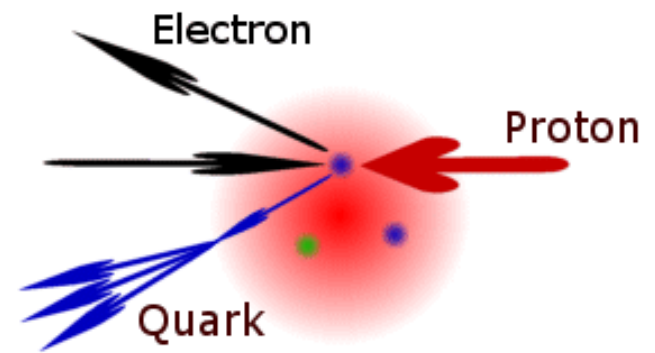
Phys. Rev. D 86, 012005 (2012)

Katarzyna Wichmann on behalf of the ZEUS Collaboration

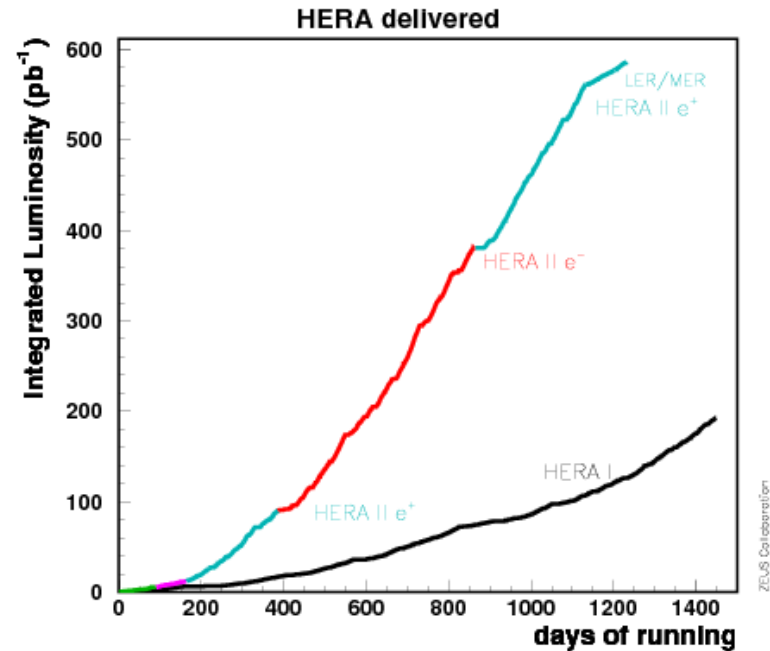
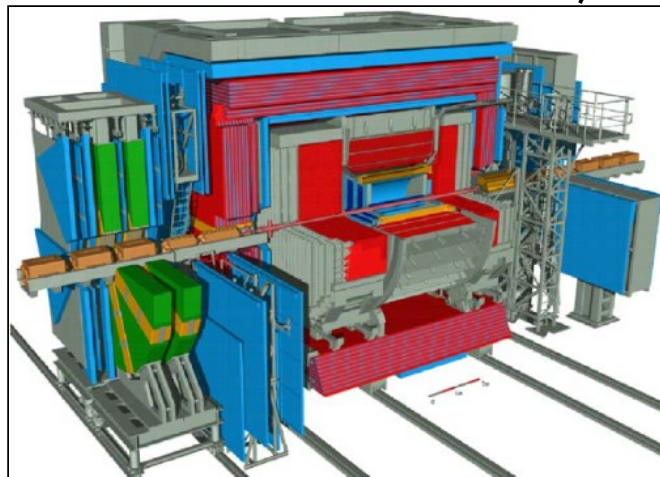
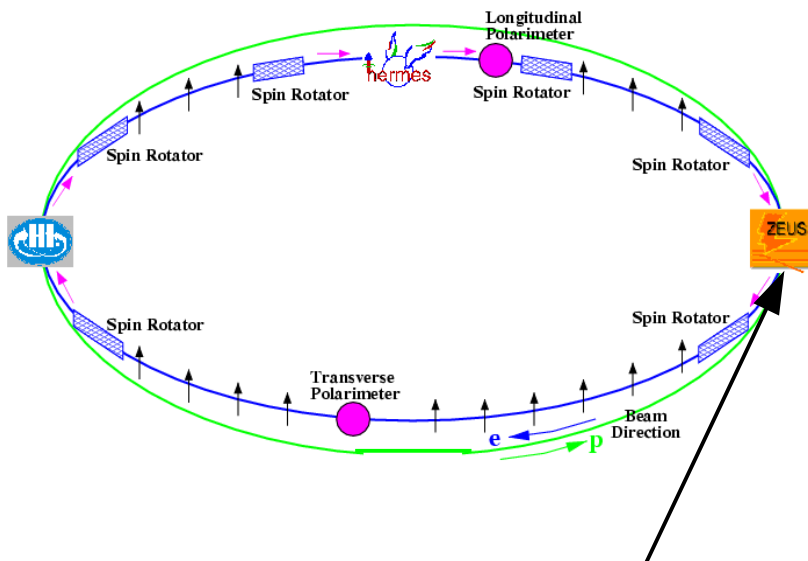
- HERA Accelerator & ZEUS Detector
- Search for leptoquarks at HERA
- Limits on leptoquarks



# HERA Accelerator

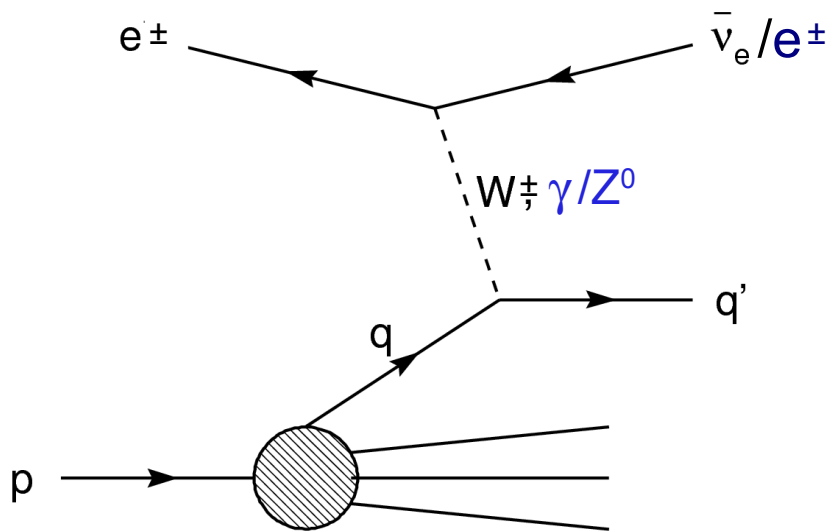


- HERA: ep collider,  $\sqrt{s} = 320 \text{ GeV}$
- From 2003 polarised lepton beam
- 2 colliding beams experiments: H1 & ZEUS
  - collected  $0.5 \text{ fb}^{-1}/\text{exp}$  of luminosity in 1992-2007



ZEUS: multi-purpose detector at HERA

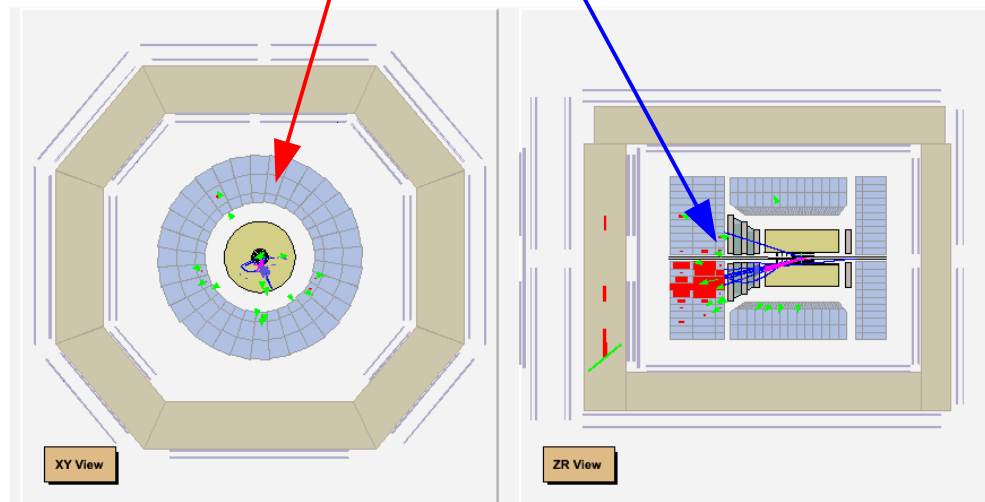
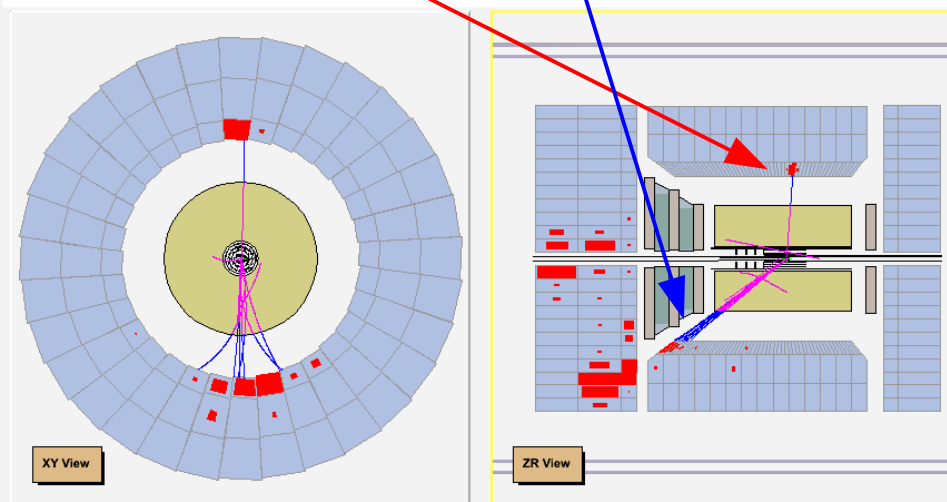
# Physics in ZEUS Detector



- Neutral Current (NC):  
 $\gamma, Z^0$  exchange
- Charged Current (CC):  
 $W^\pm$  exchange

NC: electron + jet

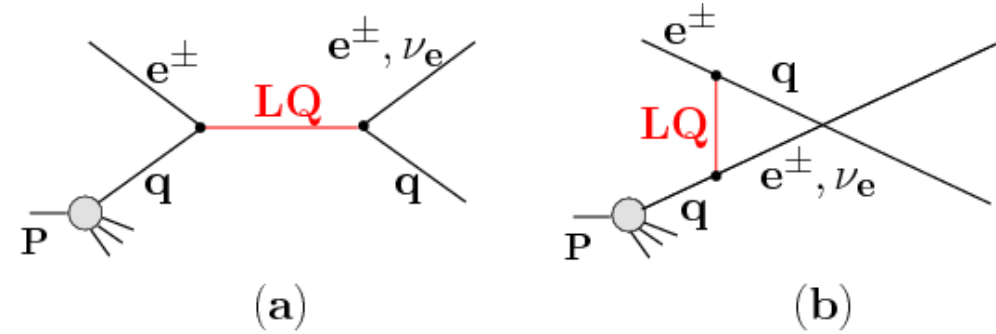
CC: missing  $p_T$  + jet



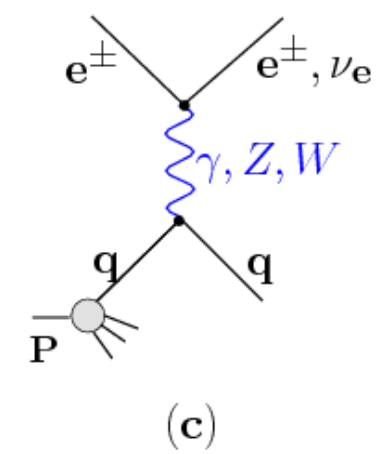
# Leptoquarks @ HERA

- Leptoquarks - scalar or vector colour triplet bosons, carrying both lepton (L) and baryon (B) number
  - HERA is well suited for leptoquark searches
  - Fermion number:  $F=L+3B$ , ( $F=0,2$ )
  - spin: 0, 1

(a) @ HERA leptoquarks can be produced in s-channel for  $M_{LQ} < \sqrt{s}$   
 (b) ...or exchanged in u-channel



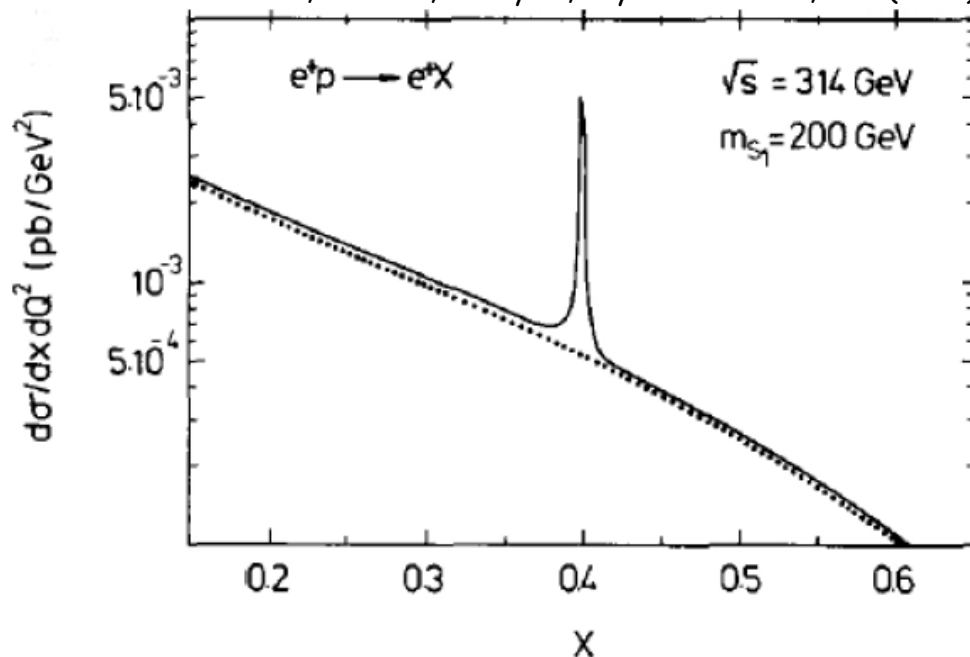
- LQs @ HERA have the same initial and final state as NC/CC DIS
  - **e-jet or  $\nu$ -jet in the final state**
  - interfere with the SM



# Search Strategy @ HERA

- Leptoquark events: **the same signature as NC or CC events**
- LQ contribution in SM: **peak in invariant mass distribution** (for  $M_{LQ} < \sqrt{s}$ )
- LQ cross section has different polarization dependence than NC (or CC) cross section  
 → data samples with different polarization examined separately

W. Buchmüller, R. Rückl, D. Wyler, Phys. Lett. B 191, 442 (1987)

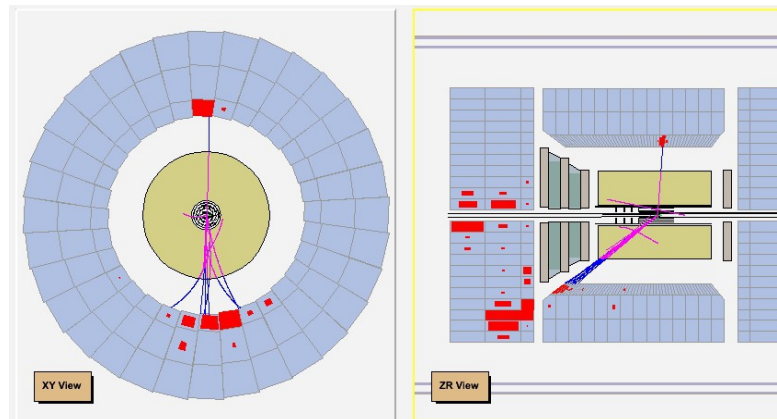


- Lepton scattering angle  $\theta^*$  in the lepton-jets scattering frame can be used to reduce DIS background
  - resonance has different distribution than NC DIS

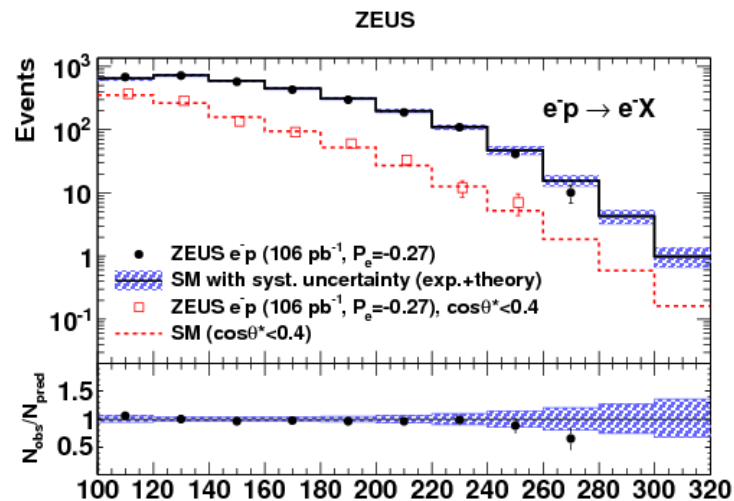
Look for LQ-deviations from SM in NC & CC distributions

# Leptoquarks in ZEUS Detector

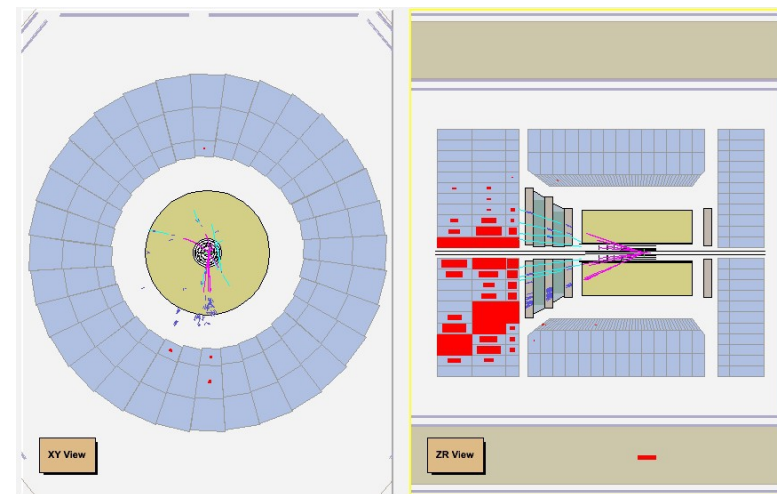
Integrated luminosity of 366 pb<sup>-1</sup> (2003-2007)



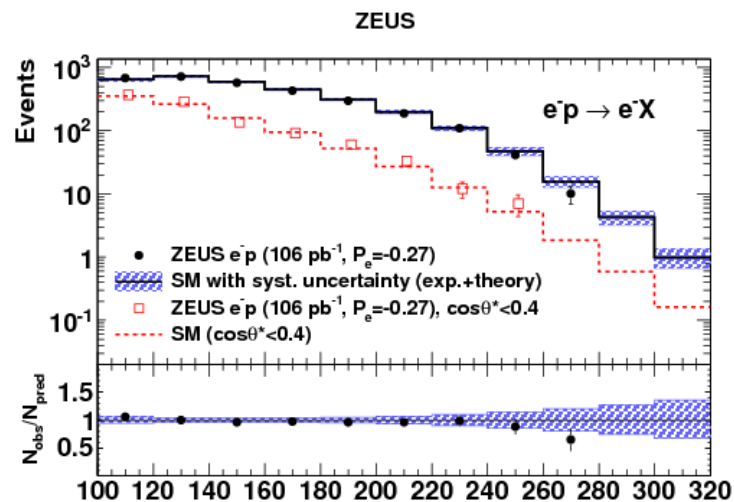
$M_{e\text{-jet}}$   
 e+jet final state



$M_{ejs}$  (GeV)



$M_{\nu\text{-jet}}$   
 nu+jet final state

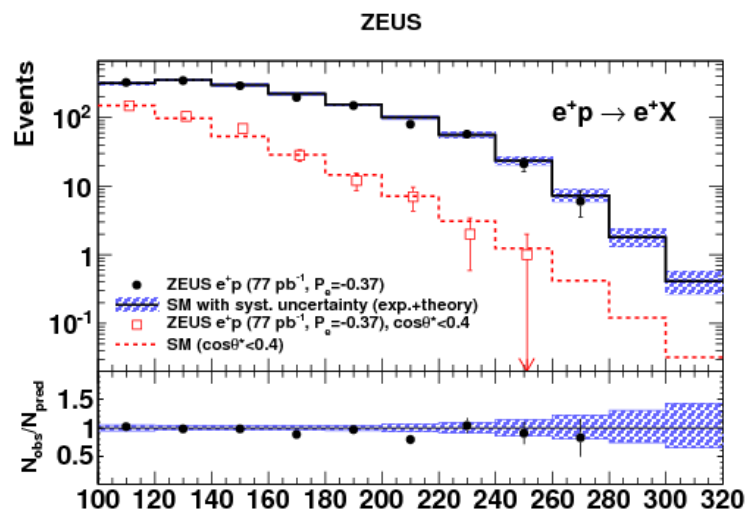
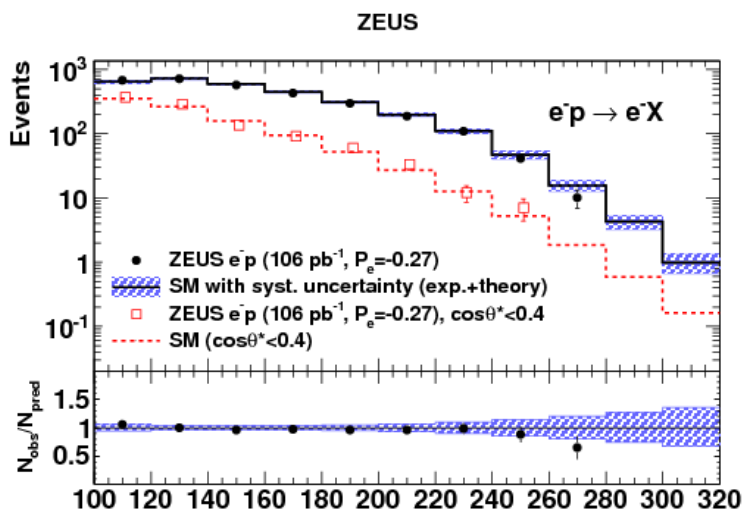


$M_{\nu js}$  (GeV)

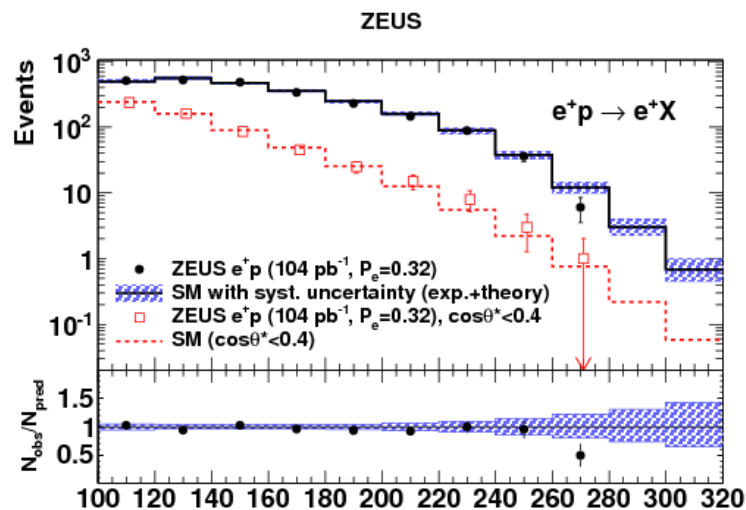
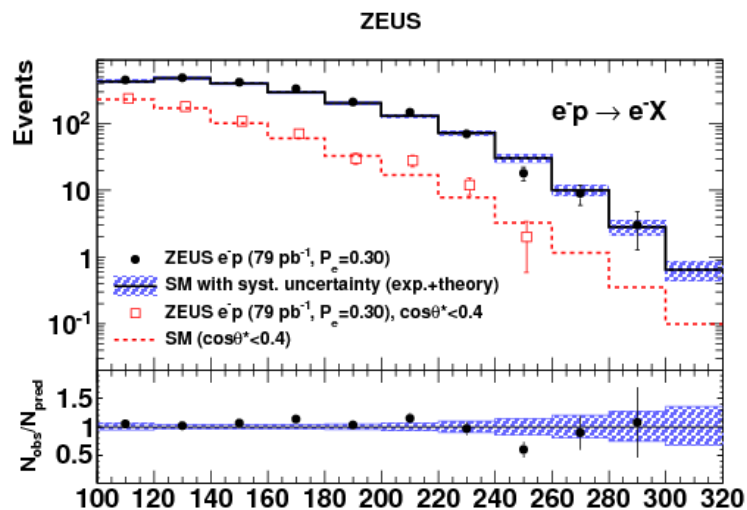
# NC Invariant Mass Distribution

in red: with cut on  $\cos\theta^* < 0.4$

left-handed lepton



right-handed lepton



$M_{ejs} \text{ (GeV)}$

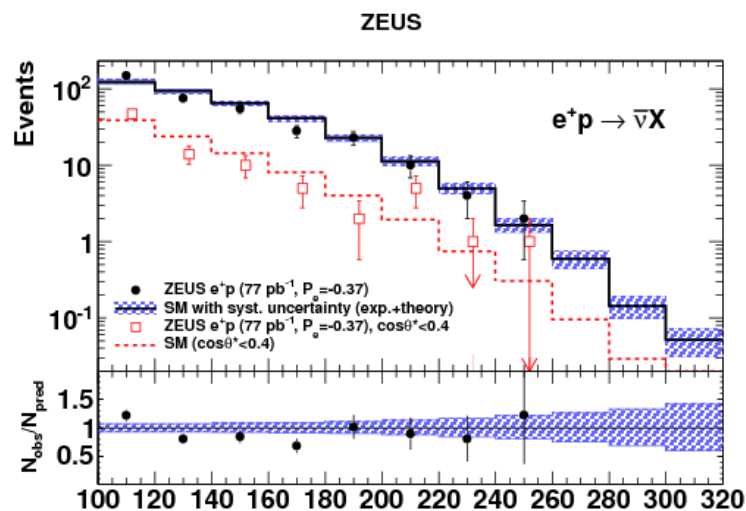
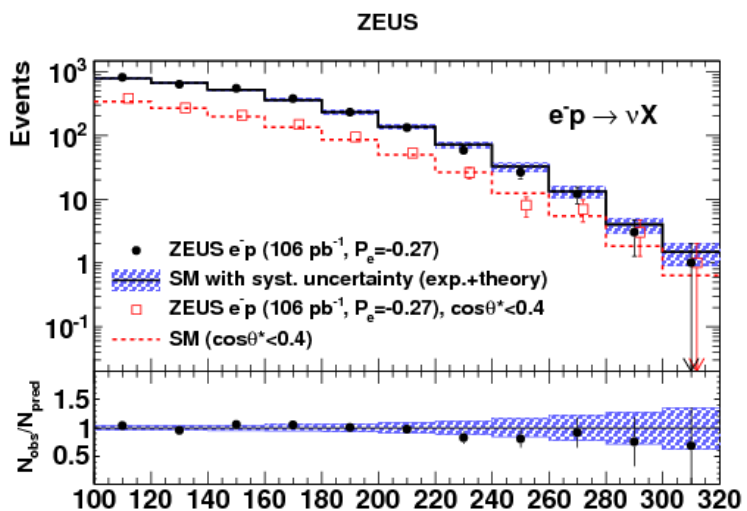
$M_{ejs} \text{ (GeV)}$

Good agreement between data and MC  $\rightarrow$  no evidence for LQs

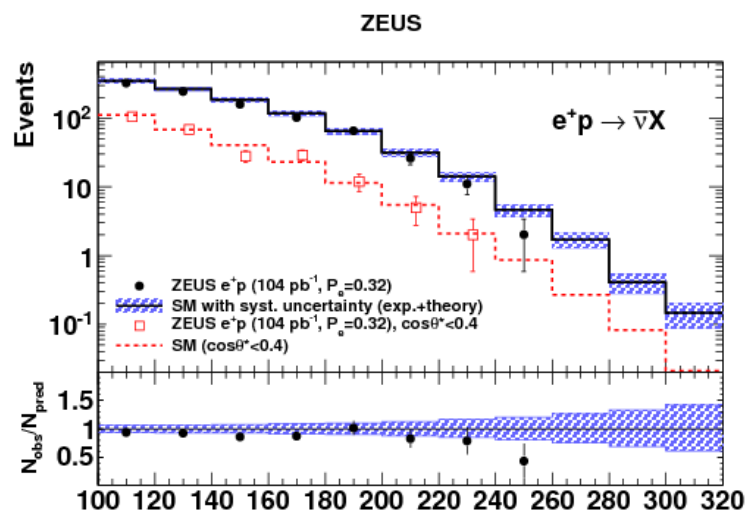
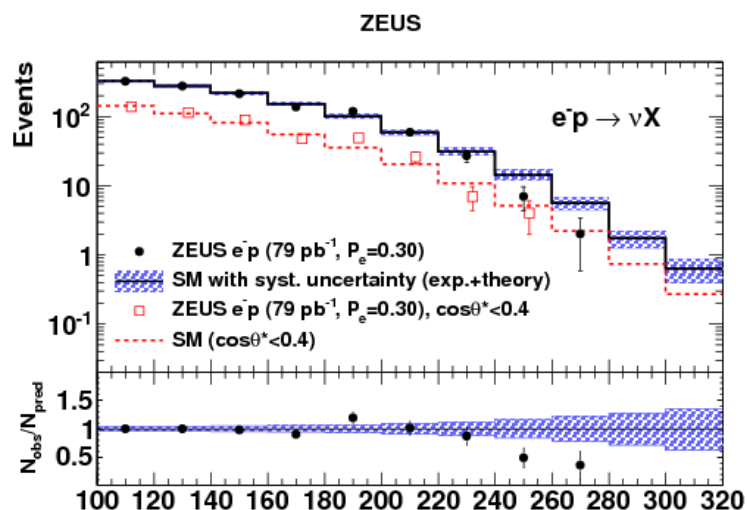
# CC Invariant Mass Distribution

in red: with cut on  $\cos\theta^* < 0.4$

left-handed lepton



right-handed lepton



$M_{ejs} \text{ (GeV)}$

$M_{ejs} \text{ (GeV)}$

Good agreement between data and MC  $\rightarrow$  no evidence for LQs



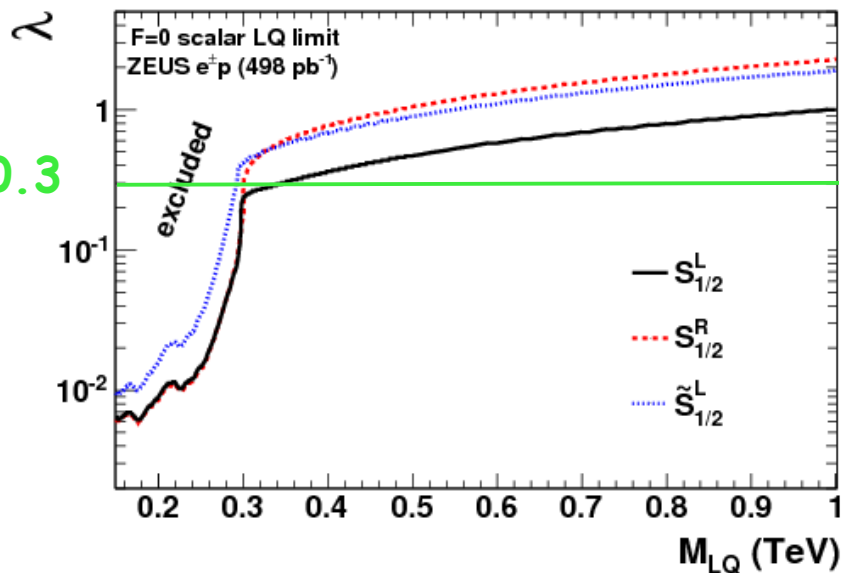
# Leptoquark Limits

- No evidence for LQs observed  $\rightarrow$  limits set within BRW model
- The Buchmüller-Rückl-Wyler model:
  - Standard Model symmetry conserved
  - Lepton and baryon number conserved
  - LQ resonance production
  - LQs couple either to right-handed or to left-handed leptons
  - No flavour-violating couplings
    - $\rightarrow$  7 scalar and 7 vector 1st generation leptoquarks
  - All 14 LQs couple to  $e q$ , 2 scalar and 2 vector LQs also to  $\nu q$
- Limits are set on Yukawa coupling  $\lambda$  ( $e$ - $q$ -LQ coupling) using Bayesian approach

Full HERA statistics of **0.5 fb<sup>-1</sup>** used for limit setting

# Limits for Leptoquarks with $F=0$

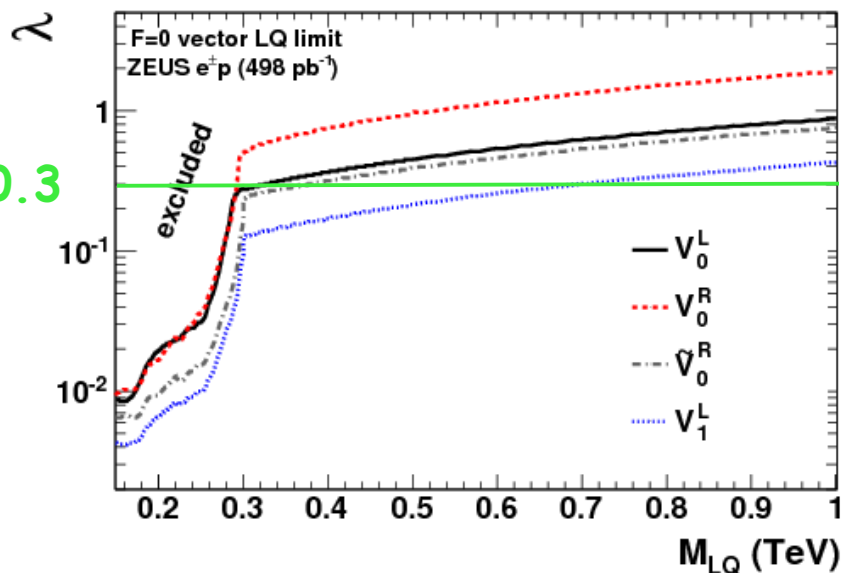
ZEUS



## Scalar LQs:

- Lower limit on  $M_{LQ}$  assuming  $\lambda=0.3$   
 $292 \text{ GeV} - 345 \text{ GeV}$

ZEUS

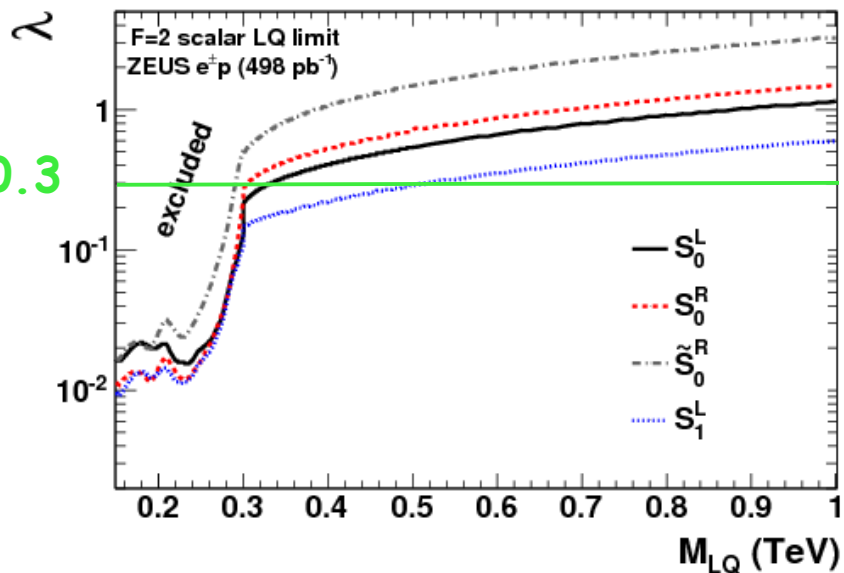


## Vector LQs:

- Lower limit on  $M_{LQ}$  assuming  $\lambda=0.3$   
 $292 \text{ GeV} - 699 \text{ GeV}$

# Limits for Leptoquarks with F=2

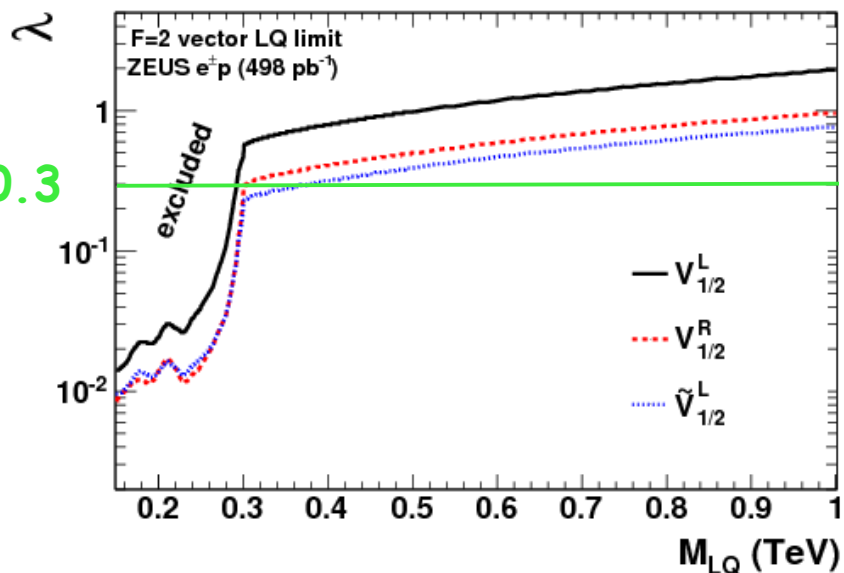
ZEUS



## Scalar LQs:

- Lower limit on  $M_{LQ}$  assuming  $\lambda=0.3$   
290 GeV - 506 GeV

ZEUS

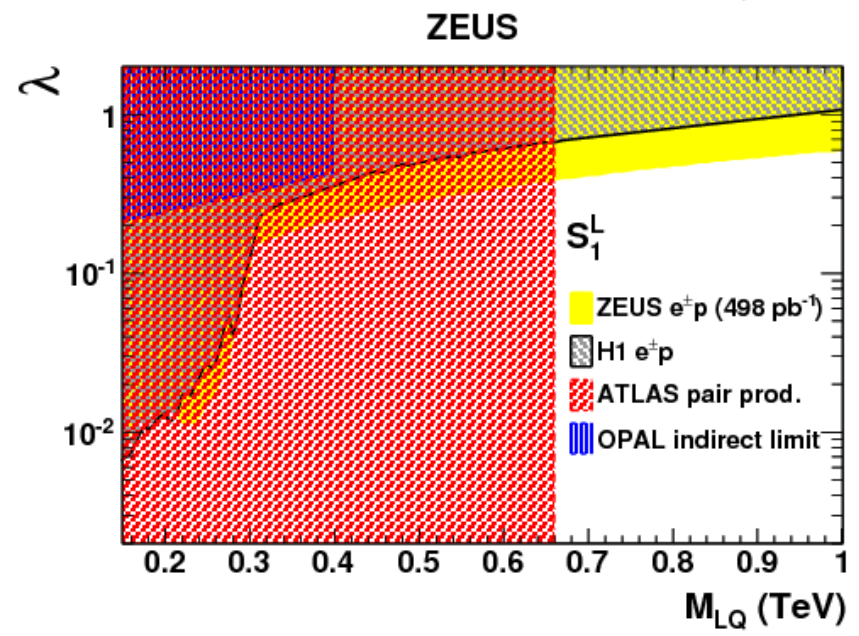
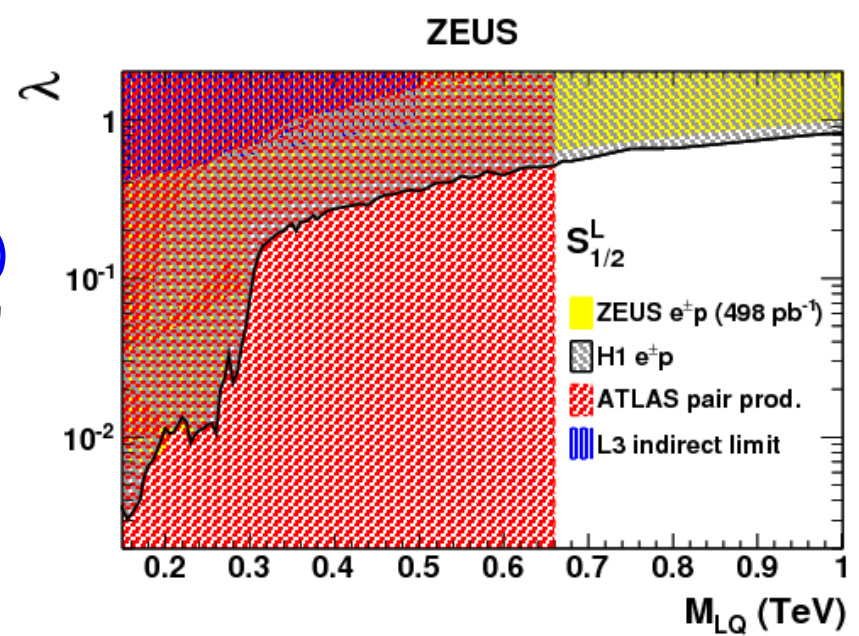


## Vector LQs:

- Lower limit on  $M_{LQ}$  assuming  $\lambda=0.3$   
292 GeV - 376 GeV

# Summary

- New results using full HERA luminosity of  $0.5 \text{ fb}^{-1}$  on LQs  
Phys. Rev. D 86, 012005 (2012)
- No evidence of leptoquarks observed  
 → Coupling limits set as function of LQ mass
- Limits for some LQs compared to results from other experiments
  - HERA limits similar
  - In some cases most stringiest limits from ZEUS
- ZEUS results competitive and complementary to other experiments



HERA limits are the best to date at high masses