Future exotic physics at ZEUS and HERA

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- **Introduction**
- **Inclusive measurements of deep inelastic scattering**
- **Deviations from the Standard Model and search for substructure**
- **Search for leptoquarks**
- **High p_T lepton events from ZEUS**
- **Summary and prospects**

Introduction

Considering exotic, beyond the Standard Model searches for objects at high energy.

Deviations from the Standard Model in inclusive reaction
$\rightarrow$ neutral and charged current deep inelastic scattering, jet production

- **quark substructure, contact interactions**
- **right-handed charge currents**
- **leptoquarks**

Investigation of rare processes independent of model
$\rightarrow$ generic searches, e.g. high p_T leptons

Model dependent search for new particles

- **leptoquarks**
- **R_p-violating supersymmetry**
- **excited fermions**

Should we look for everything?

Where can increased statistics really help?

- **Is a factor of 4 ($\mathcal{L}_{\text{HERA II}} \sim 4 \times \mathcal{L}_{\text{HERA I}}$) enough?**
- **Really want to discover something**
  - **how useful is a new limit?**
  - **already have a limit - is a discovery already ruled out?**
- **Factor of $>$10 in for e^- data can open up some opportunities**
- **Get a factor of 2 from combining experiments**

Priorities, personpower and how it evolves

Inclusive cross section

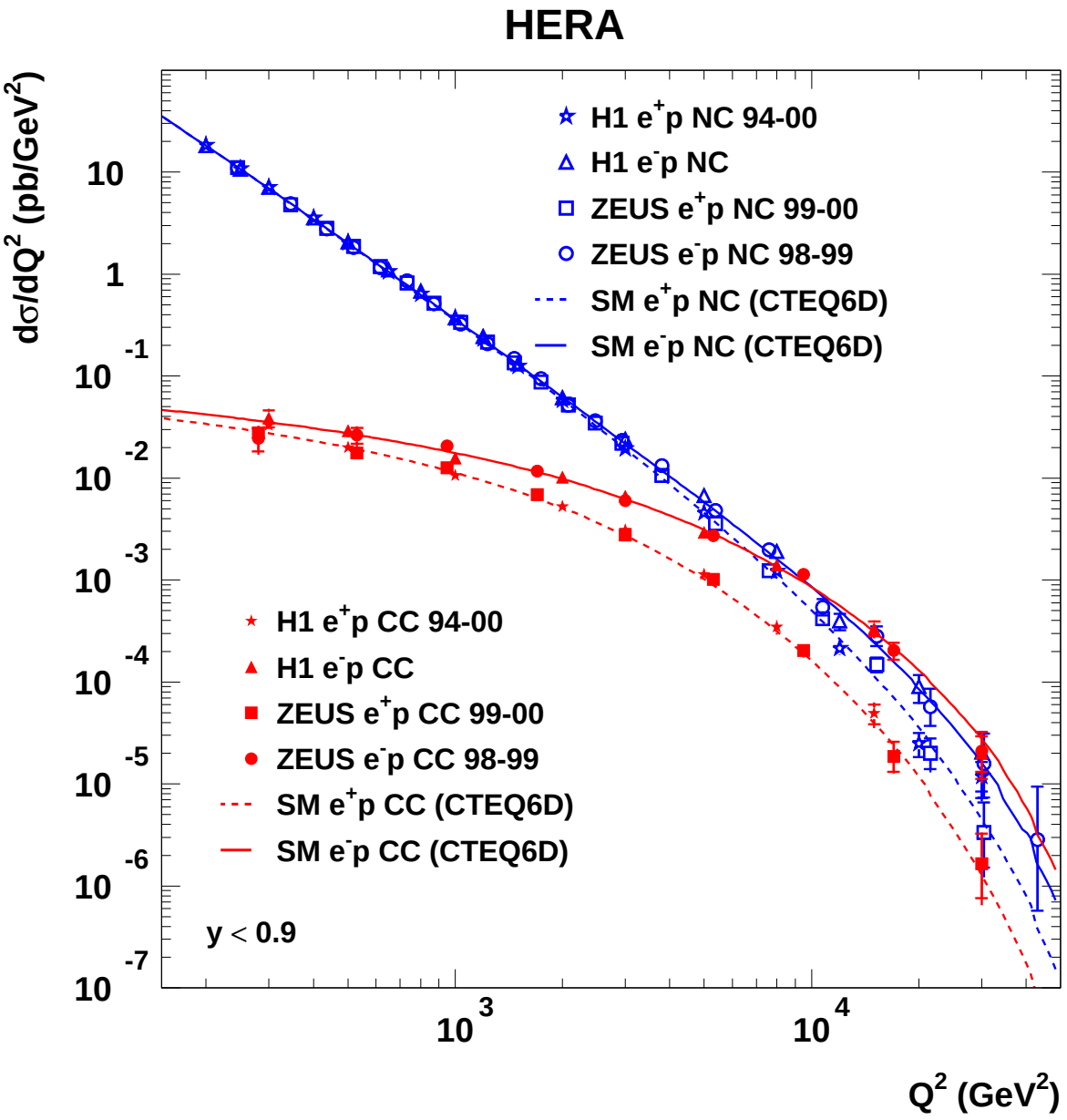
Measurements over 7 orders of magnitude in $d\sigma/dQ^2$

Demonstration of unification of electroweak force

Input to fits to parton density functions

Good description by the SM

- **no new physics**
- **set limits on quark radius, contact interactions, etc.**



First (published) results from HERA II

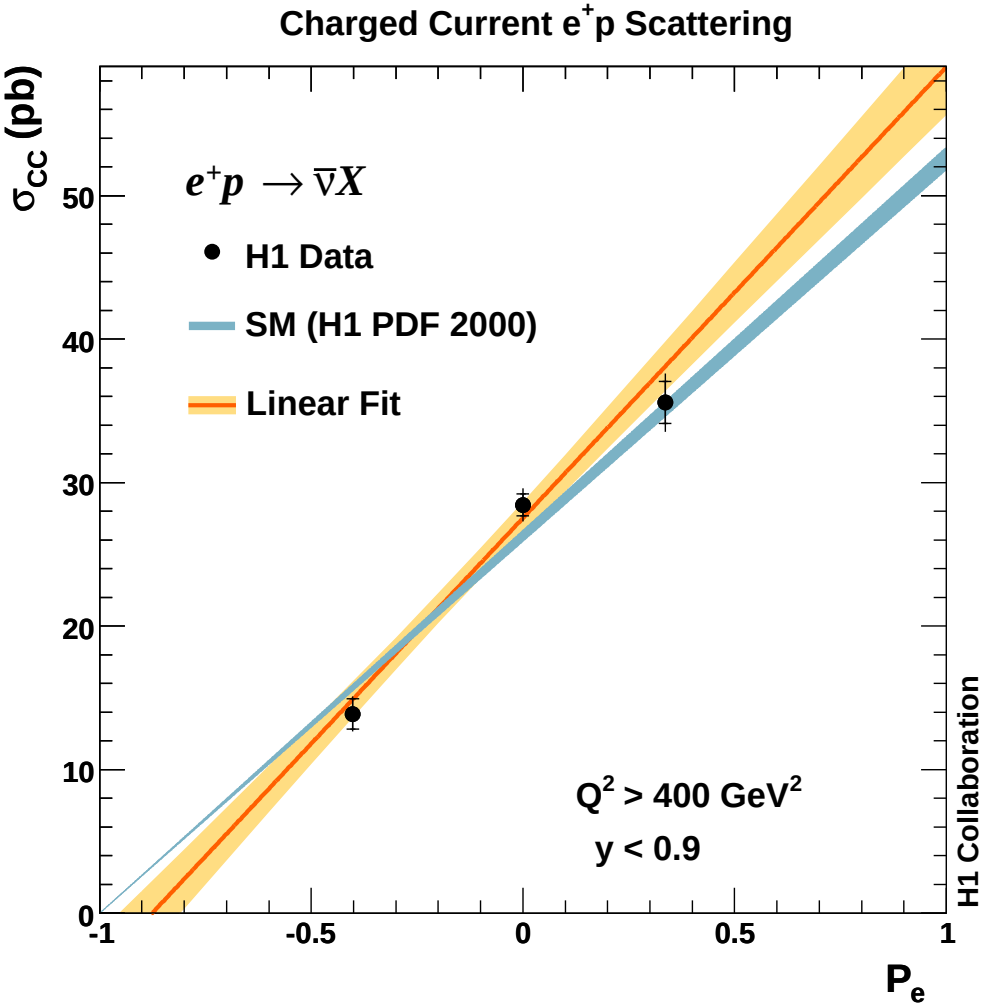
Measurements of charge and neutral current cross sections with polarised positrons
H1: DESY-05-249, ZEUS: with R-D.H.
Preliminary measurements also with electrons.

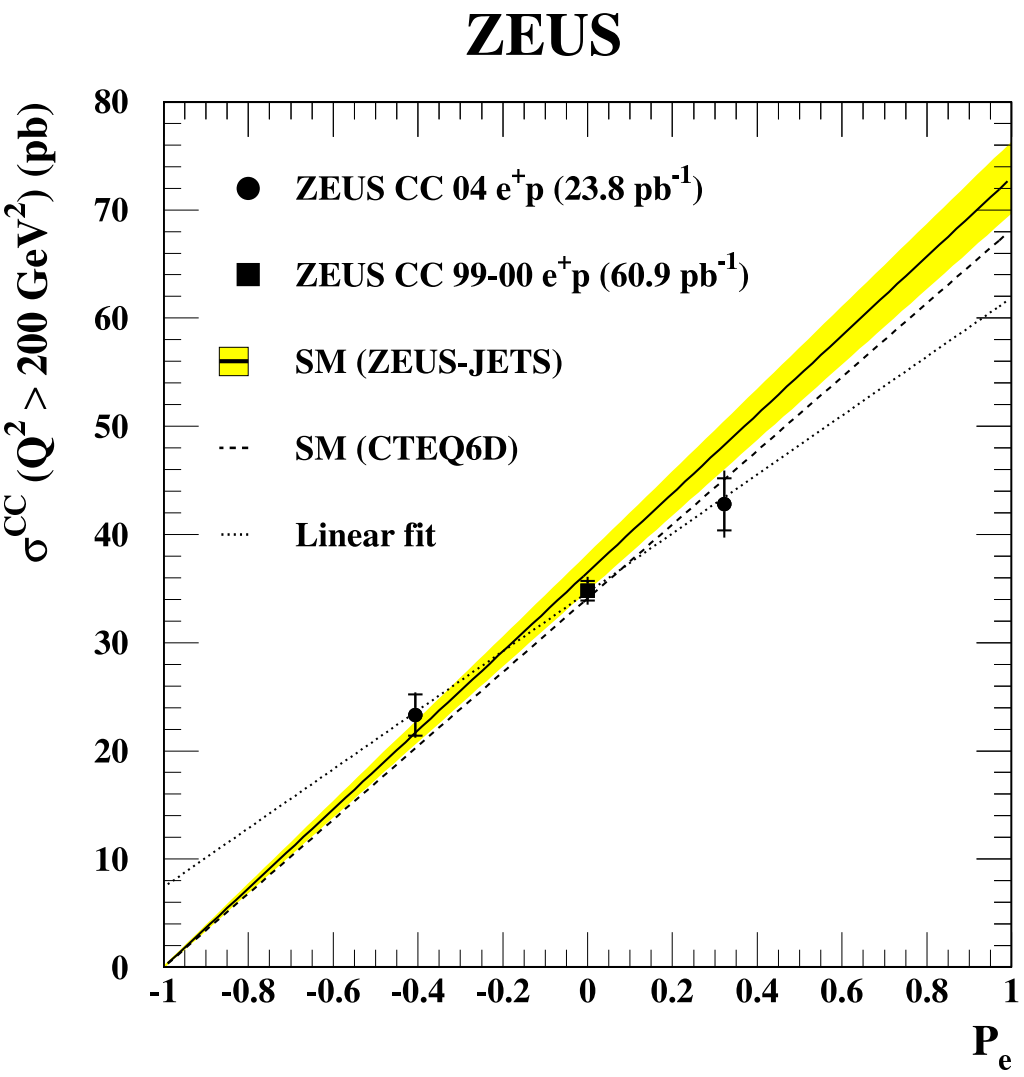
$$\sigma^{\mathsf{CC}}(e^{\pm}p) \sim 1 \pm P_e, \qquad \sigma^{\mathsf{NC}}(e^{\pm}p) \sim H_0^{\pm} - P_e H_{P_e}^{\pm}$$

Sensitivity to right-handed W bosons, W_R.

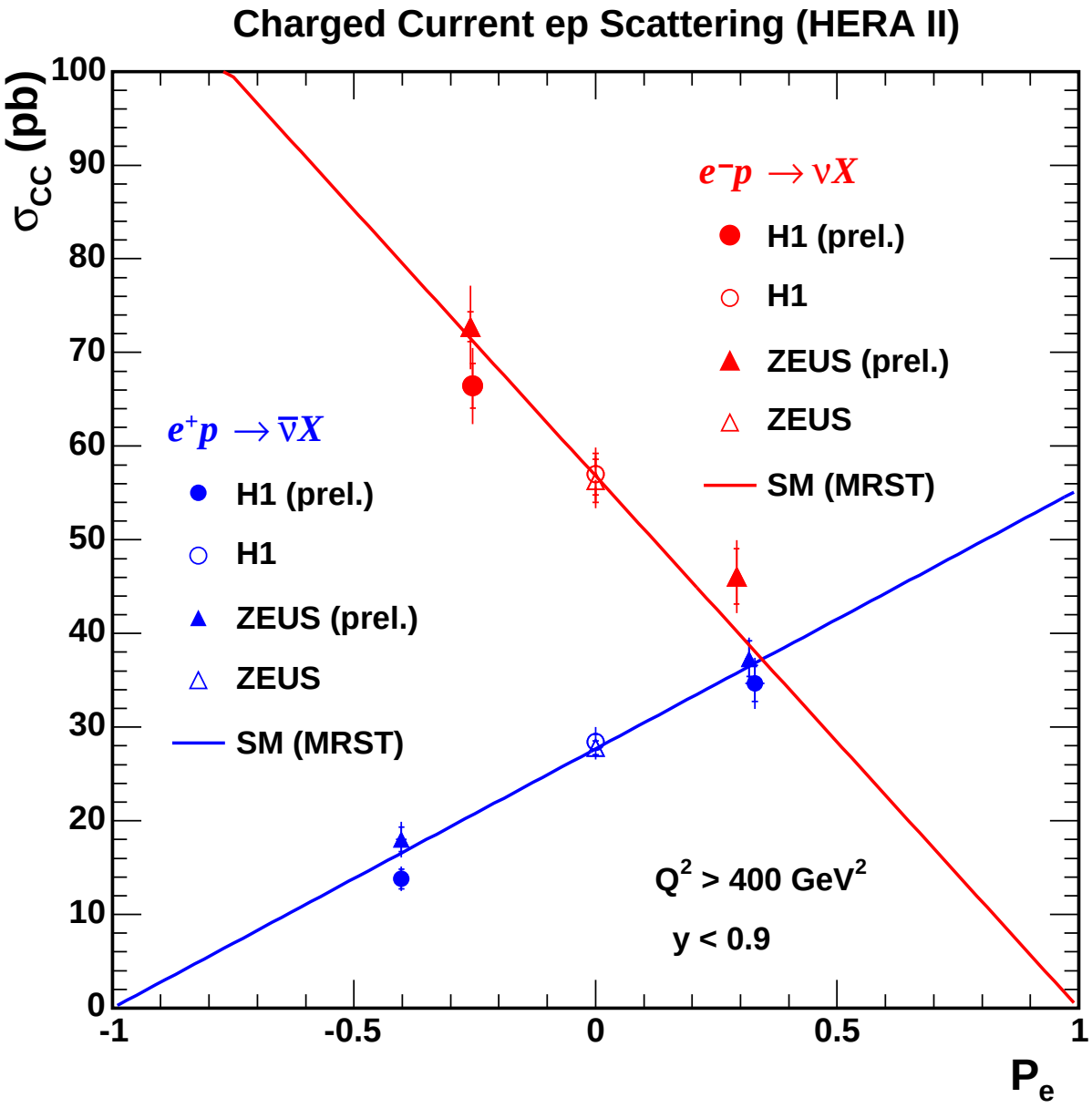
Sensitivity at end of HERA II $\sim$ 400 GeV. (Note Tevatron lower bound is 800 GeV)

CC cross sections for polarised positrons



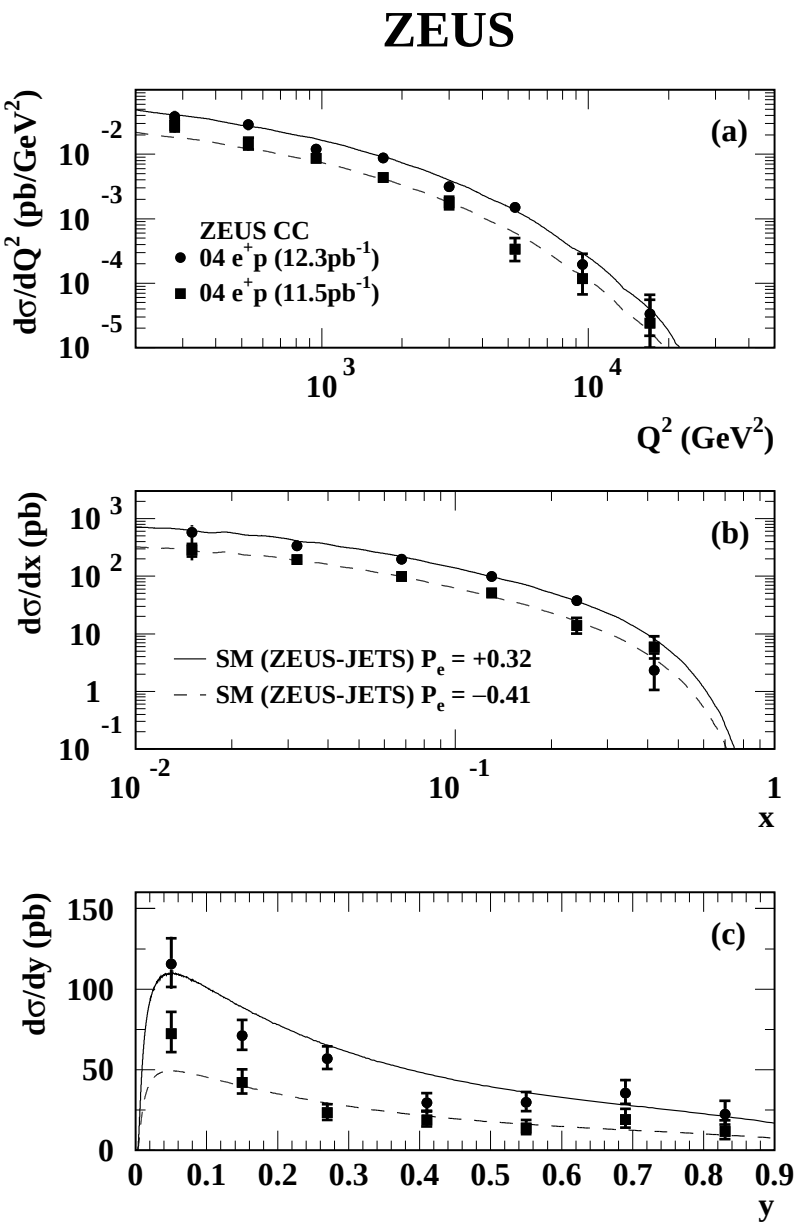


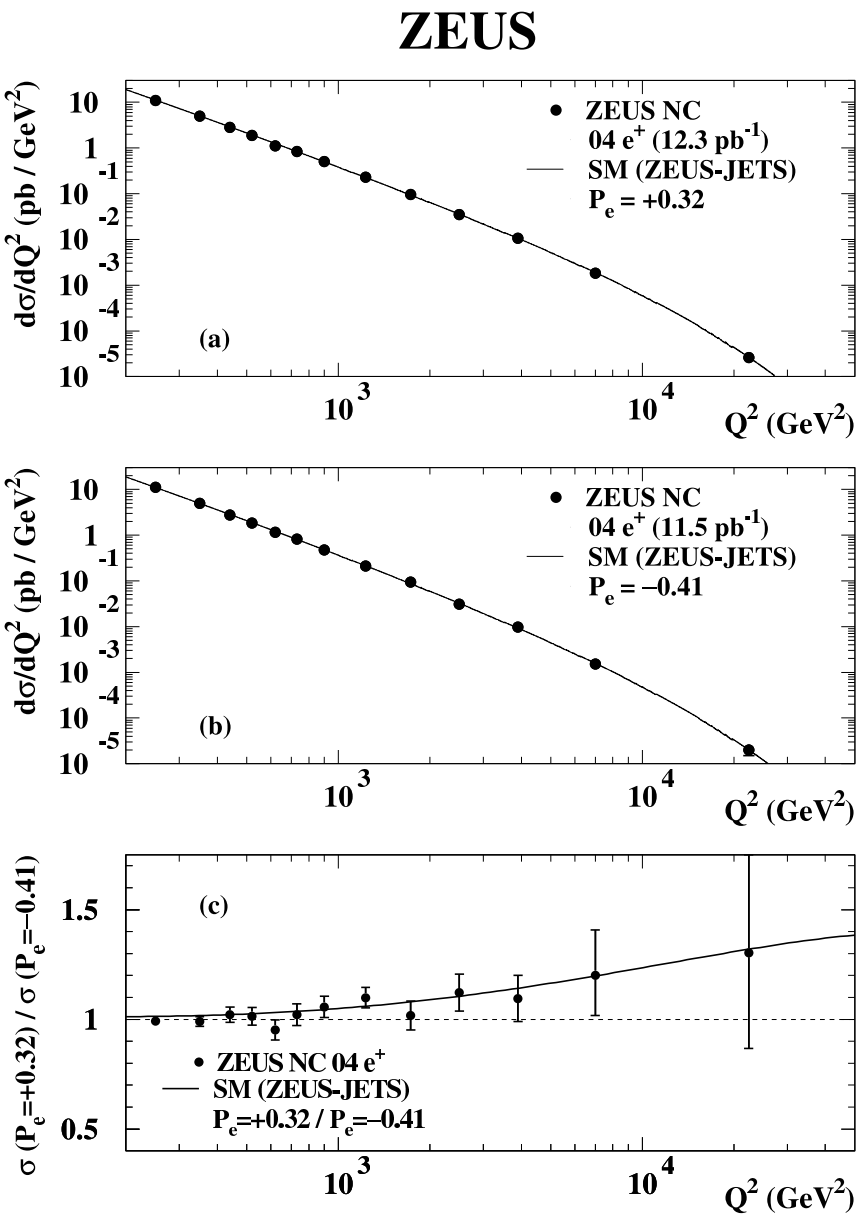
CC cross sections for polarised leptons



Consistency with the SM - no right-handed charge currents

CC/NC cross sections for polarised leptons





SM agrees well with data - more data needed for (small) effects or deviations

Contact interactions I

H1: DESY-03-052, ZEUS: DESY-03-218

Extra dimensions

Coupling strength,

$$\eta_G = \frac{\lambda}{M_S^4}$$

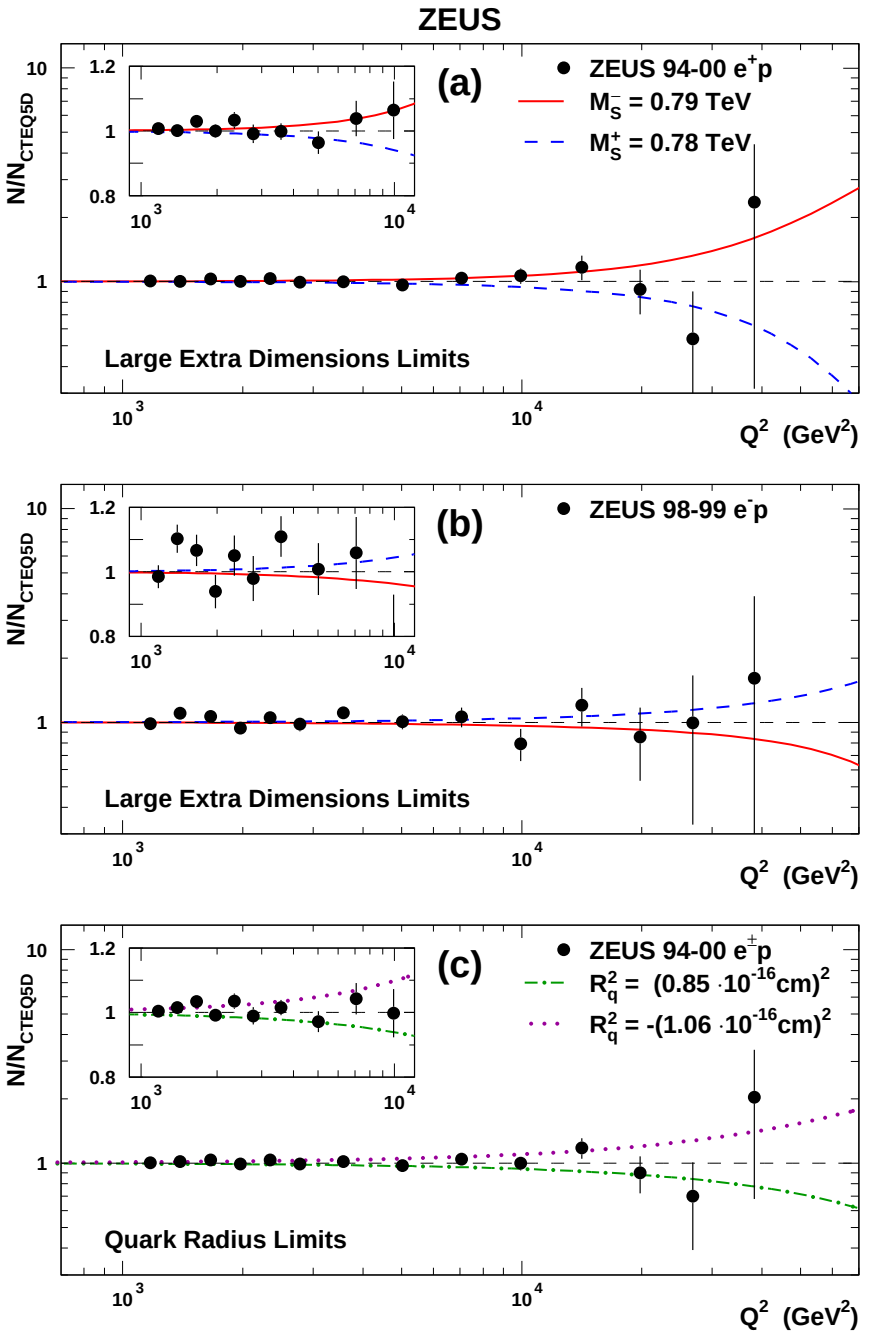
Mass scale, $M_S > 0.8$ **TeV**

Quark size

Probing Q^2 **up to 40,000 GeV**^{2}

$$f(Q^2) = 1 - \frac{R_q^2}{6} Q^2$$

Quark radius, $R_q < 10^{-18}$ **m**



Contact interactions II

General contact interactions

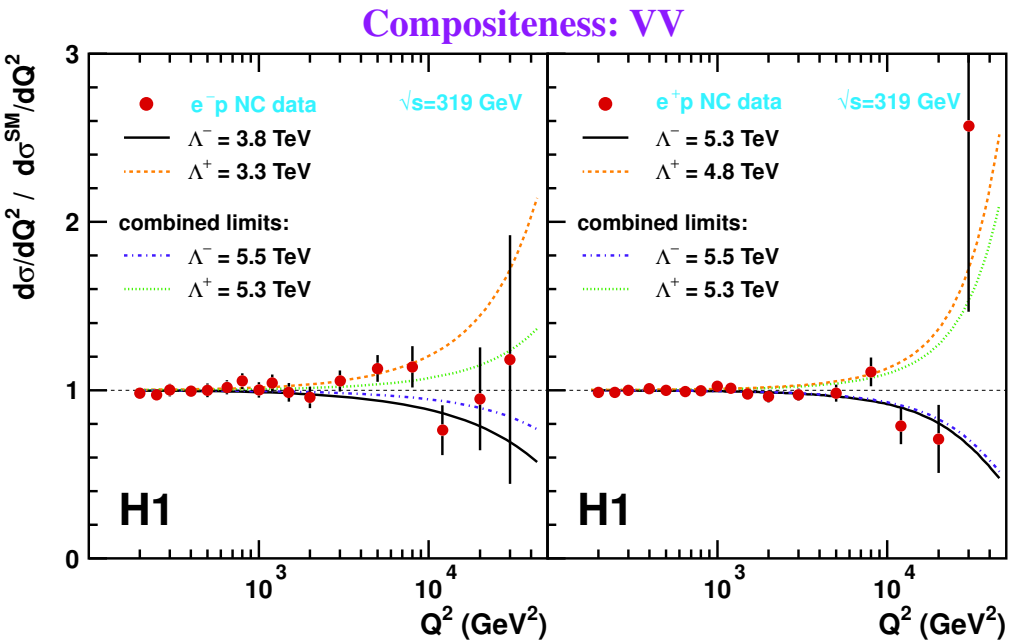
Four-fermion interaction:

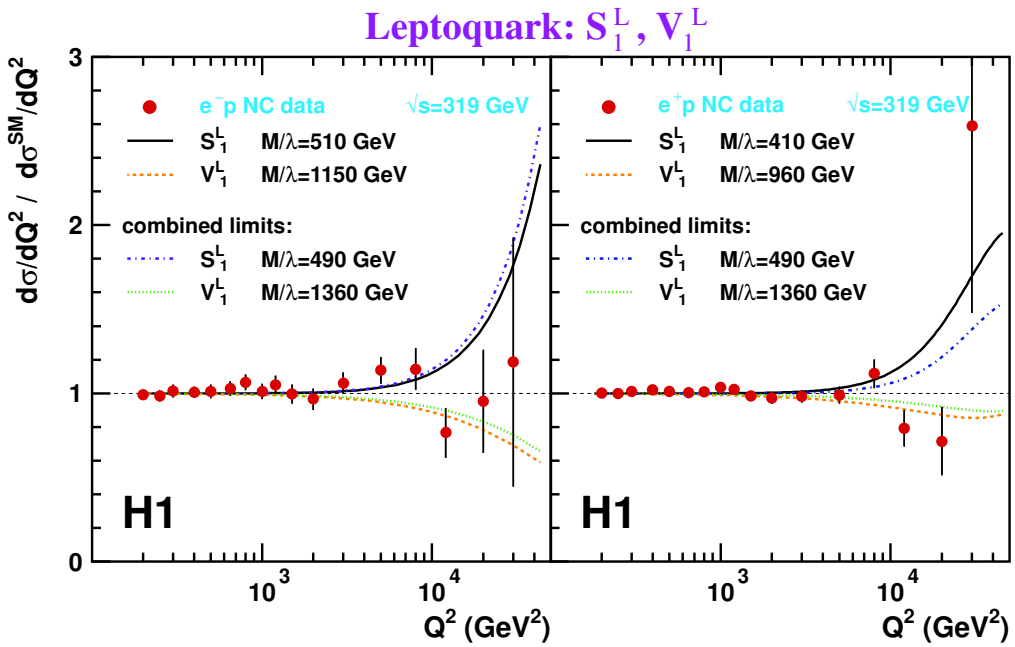
$$\mathcal{L} = \sum_{q} \sum_{i,j=L,R} \eta_{ij}^{eq} \left(\bar{e}_i \gamma^\mu e_i\right) \left(\bar{q}_j \gamma_\mu q_j\right)$$

$$\eta_{ij}^{eq} = \epsilon_{ab} (g/\Lambda_{ab}^{q})^2$$

Describe effects of leptoquarks, heavy weak bosons, electron or quark compositeness.

Sometimes higher sensitivity for $e^- p$ than $e^+ p$ data.





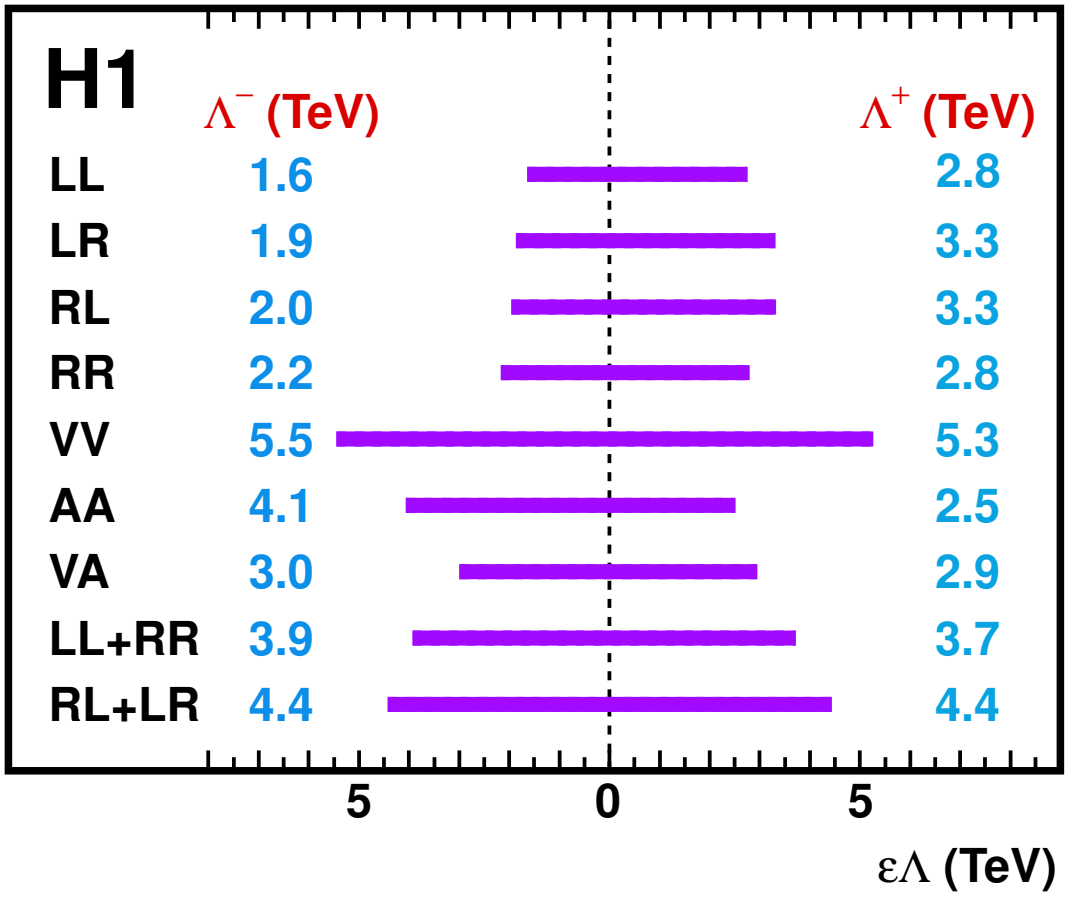
Contact interactions III

Lower limits $\Lambda \sim 1.5 - 6$ TeV

Comparable to other experiments: Tevatron, LEP

HERA sets some new limits

Lower limits $M_{LQ}/\lambda_{LQ} \sim 0.3 - 1.4$ TeV



Contact interactions - future

$\Delta_{\text{stat}}^{\text{HERA I}} \sim$ **3% at** $Q^2 \sim$ **1000 GeV**^{2} **and 10% at** $Q^2 \sim$ **10000 GeV**^{2}

HERA I measurement of NC cross section: $\mathcal{L} \sim$ **100 pb**$^{-1}$**.**

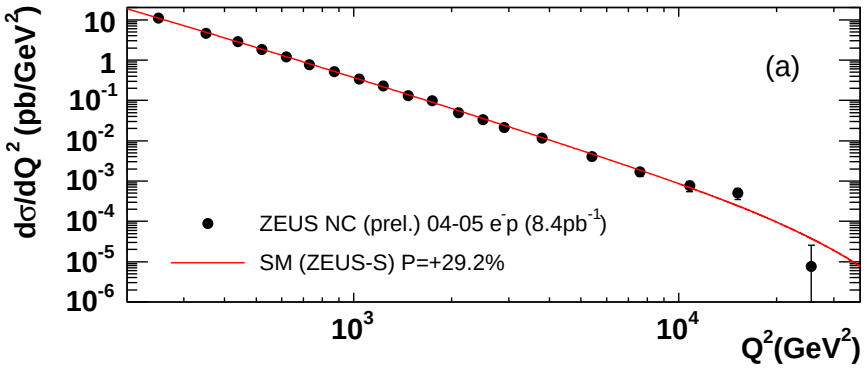
Most precise HERA II measurement of NC cross section: $\mathcal{L} \sim$ **50 pb**$^{-1}$**.**

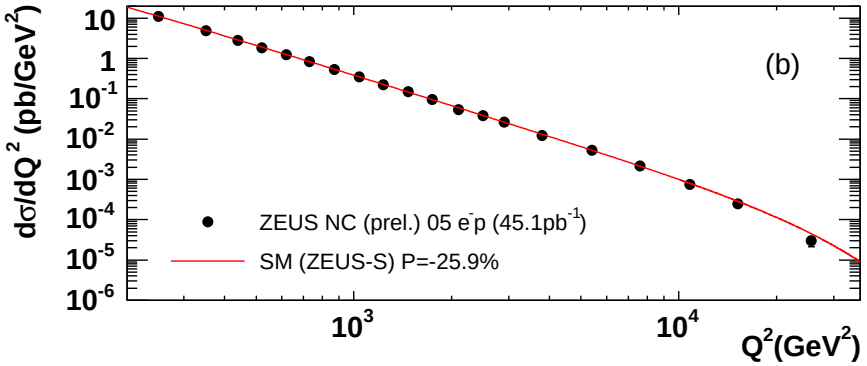
HERA II data on tape: $\mathcal{L} \sim$ **200 pb**$^{-1}$**.**

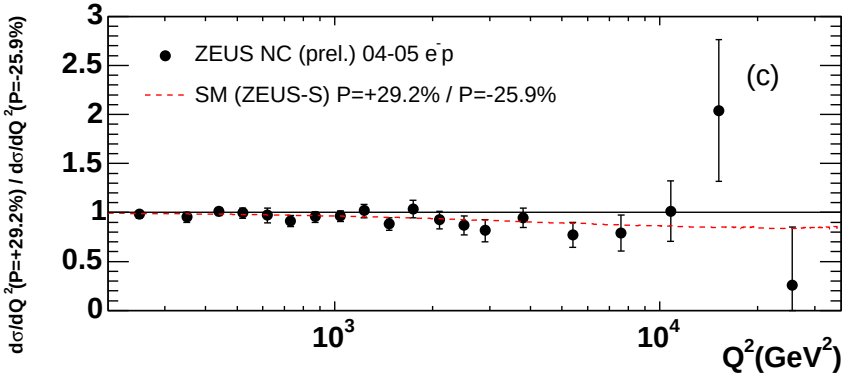
HERA II data to come: $\mathcal{L} >$ **300 pb**$^{-1}$**.**

Analysis (by-product) of final high-Q^2 **cross sections, and combining results.**

ZEUS







Leptoquarks - introduction

Connecting lepton and quark sectors

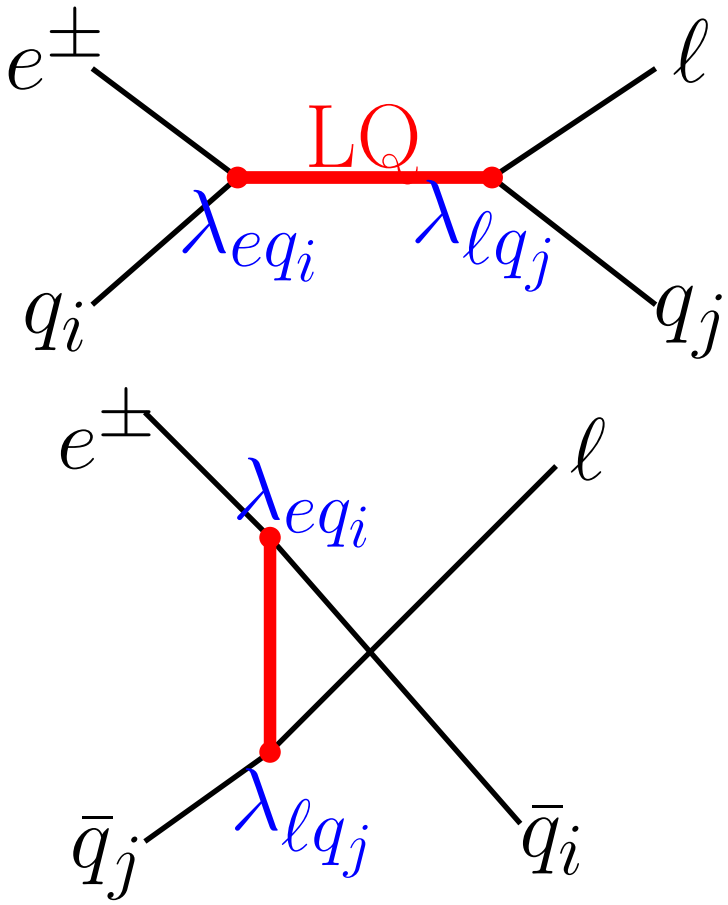
Objects have lepton and baryon numbers and fractional electric charge.

Via $s-$channel production and $u-$channel exchange

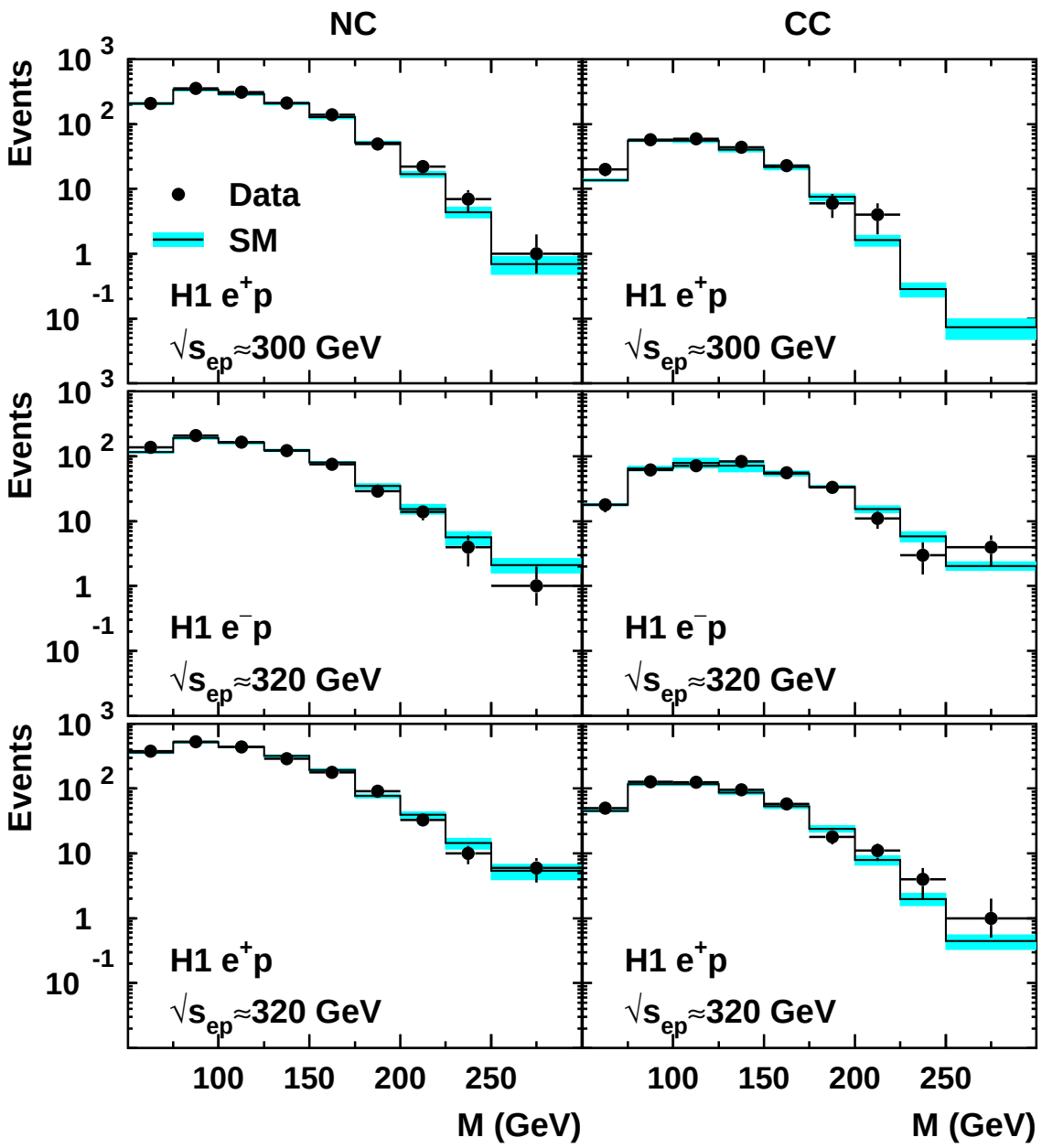
Search for resonant state, M_{lj}

Dedicated search within Buchmüller, Rückl and Wyler (BRW) models

Background DIS has similar topology although different lepton scattering angle



Leptoquarks - base plots



No narrow resonance seen (by either collaboration)

Leptoquarks - generic

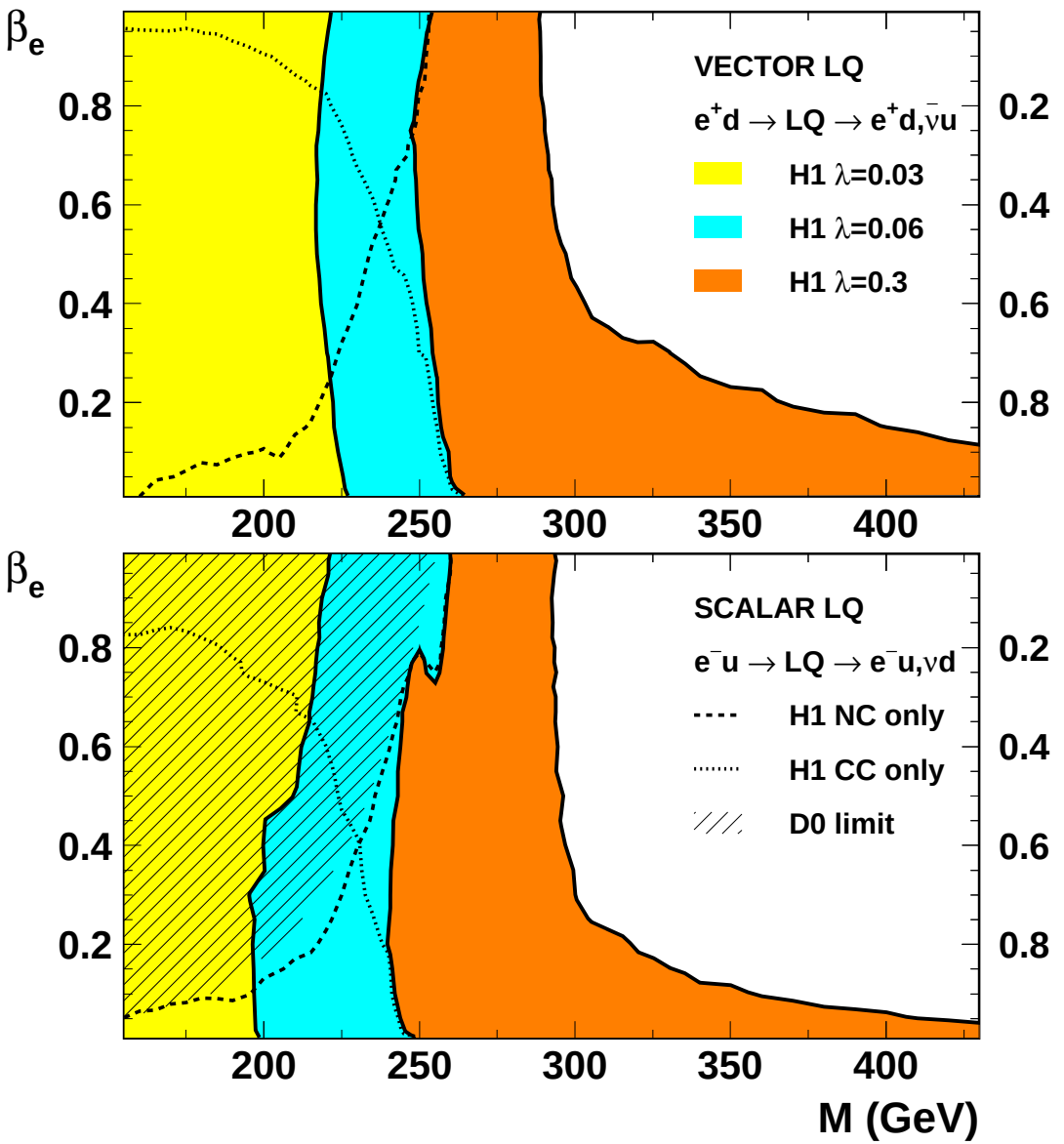
Both collaborations set strong limits

Extend considerably beyond D0 limit

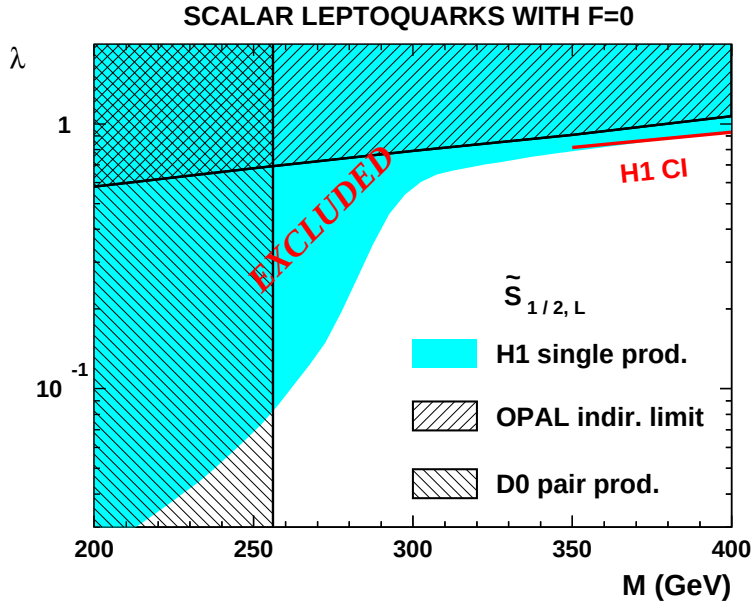
Further improvements from Tevatron at high β

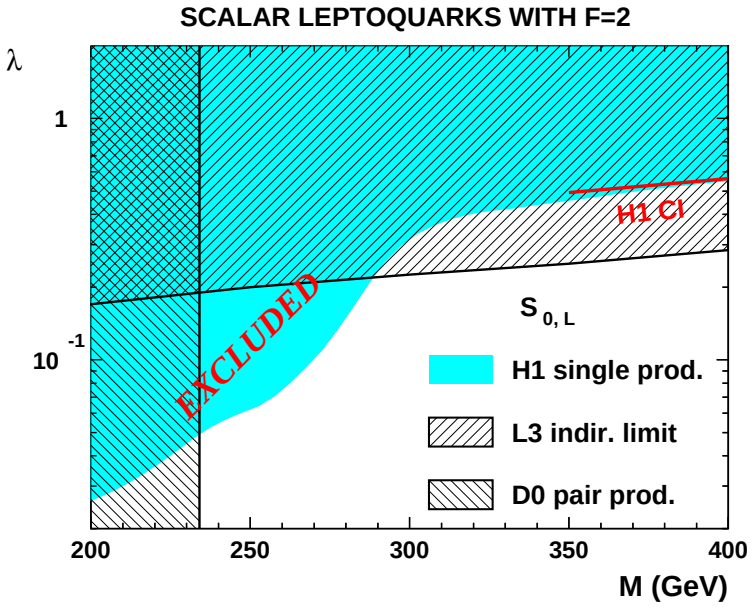
Different colliders will continue to complement each other

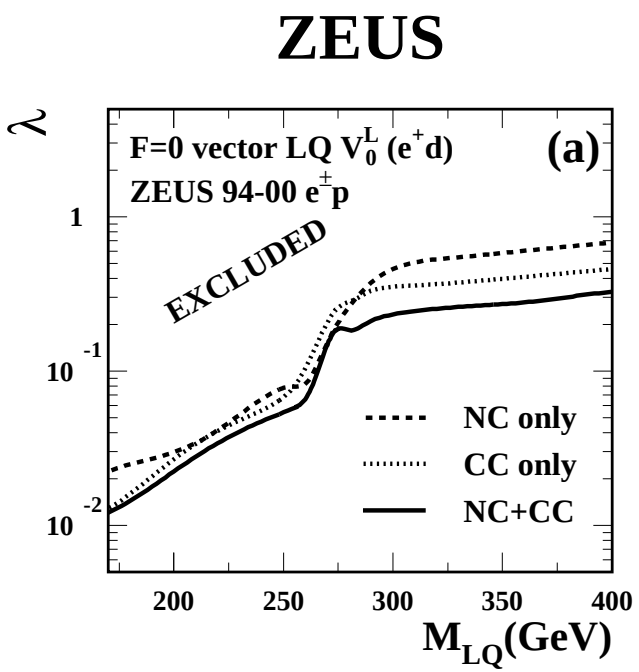
- **Different beam charge: e^+p and e^-p**
- **Coupling by changing polarisation**
- **Cleaner background in νj channel**

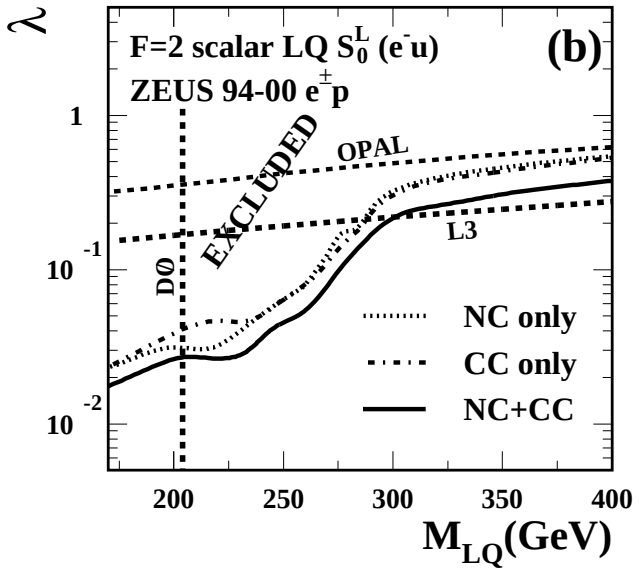


Leptoquarks - BRW model









Leptoquarks prospects*

Already have bounds on their production rate (100 pb^{-1}). What can be done with HERA II data?

Have seen that HERA II inclusive NC DIS is well described by SM, but only fraction of potential data.

E.g. for $F = 0$ LQ, manifesting itself as a resonance below 280 GeV:

Luminosity	$\sigma =$ limit	$\sigma =$ 0.5*limit
350 pb^{-1}	$\sim 4\sigma$	$\sim 2.5\sigma$
700 pb^{-1}	$> 5\sigma$	$\sim 3.5\sigma$

Rough estimates. However, rate cannot be far away from our limits if we want to discover something.

High luminosity comes from combining experiments. Might be essential.

Larger discovery potential for $F = 2$ ($e^- p$ data).

*Thanks to E. Perez

Isolated leptons - history

H1: DESY-02-224, DESY-03-132

ZEUS: DESY-03-012, DESY-03-182, DESY-03-188

HERA I

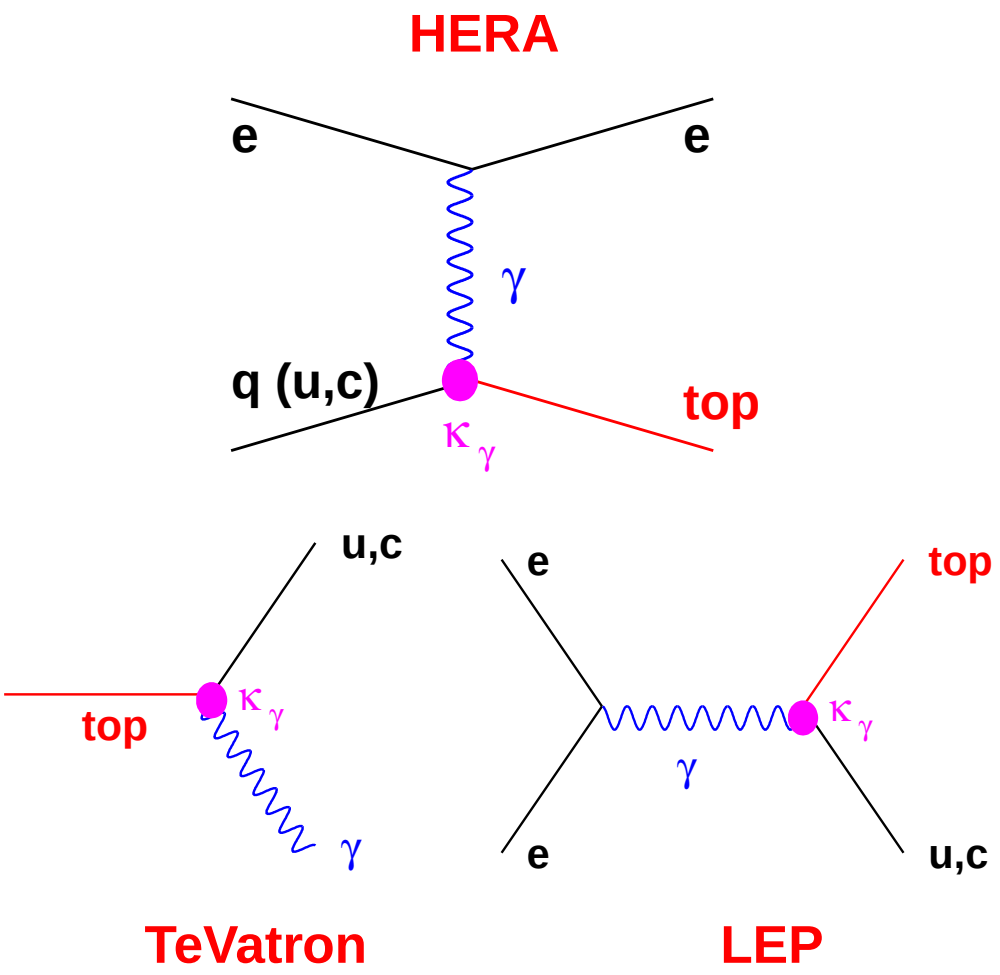
H1	electron obs./exp.	muon obs./exp.	tau obs./exp.
$P_T^X > 25$ GeV	5/1.8	6/1.7	0/0.5

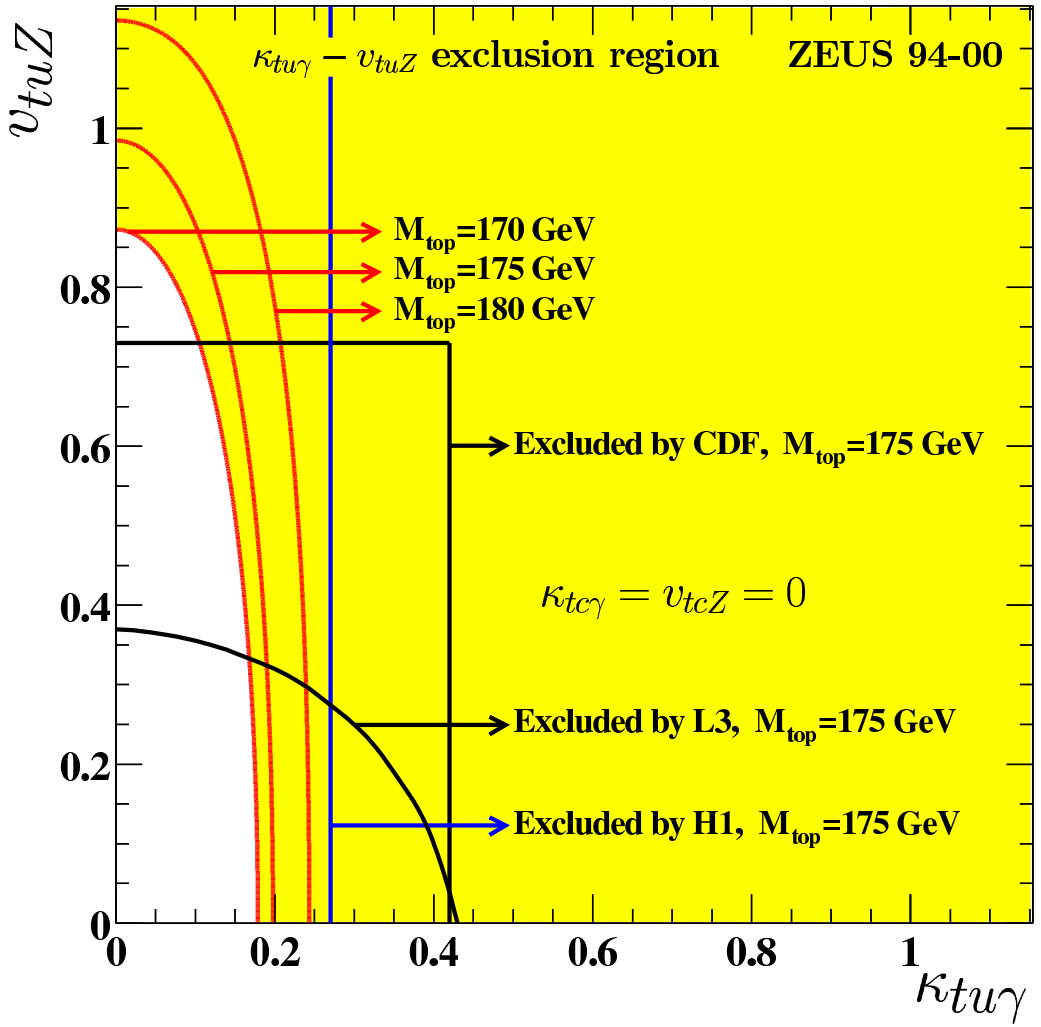
ZEUS	electron obs./exp.	muon obs./exp.	tau obs./exp.
$P_T^X > 25$ GeV	2/2.9	5/2.75	2/0.20

Note, H1 analysis is a 'W-like' analysis and ZEUS single top

H1 observes excess over the SM, ZEUS is consistent

Extraction of single top limits





Strong limits from HERA experiments

W production from ZEUS

H1 continues to see excess of such anomalous events in HERA II data.

W production main source of isolated leptons with missing p_T

Small, but measurable cross section, $\sim$ 1 pb

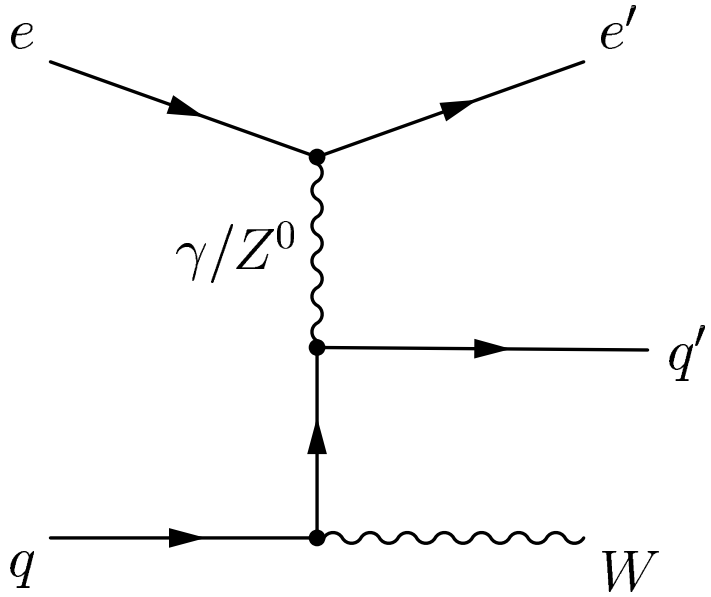
Background mainly from poorly reconstructed NC/CC events and di-leptons

Reanalysing data for W cross-section measurement

Extending isolated lepton search to HERA II data

- $\theta^e <$ **90°,** $p_T^e >$ **10 GeV**
- **Isolation,** $D^{\text{track}} >$ **0.5**
- $p_T^{\text{miss}} >$ **12 GeV,** $\phi^{\text{acop}} >$ **17°**

Comparison with H1 results



Isolated electrons from ZEUS

	12 < P_T^X < 25 GeV obs./exp.	P_T^X > 25 GeV obs./exp.
ZEUS (prel.) 99-00 e^+p	1/1.0 (57%)	1/0.9 (79%)
ZEUS (prel.) 03-04 e^+p	0/0.5 (64%)	0/0.6 (76%)

- Purity and expectations for ZEUS similar to H1 analysis
- 1/1.5 events at $P_T^X > 25$ GeV (106 pb^{-1}) - good agreement with SM
- ZEUS is consistent with the SM
  - independent of final state lepton
  - independent of initial state lepton
  - independent of selection strategy

Future isolated leptons from ZEUS and HERA

	observed	SM	σ	$\mathcal{L}$ (pb^{-1})
H1 e^+p	15	4.6	3.4	158
HERA e^+p	20	9.7	2.3	291
HERA e^-p	4	5.5	-	137
HERA all	24	15.2	1.5	428

Taking all data together, no substantial difference between data and SM.

If new physics produced at the combined rate, will be difficult to observe.

However, will continue this search area in the hope of finding something.

Summary and prospects

Results at HERA are (so far) consistent with the Standard Model

Lots of physics can be done with inclusive cross sections

Analysis of HERA I data is generally finished

H1 see an excess of events with isolated high-p_T leptons - ZEUS does not.

Analysis of HERA II data started. What shall we look for?

Summary and prospects

Will measure high-Q^2 NC cross sections - any deviations will show up or we can set limits for contact interactions, etc.

Will measure high-Q^2 CC cross sections and set limit on W_R.

Continue to analyse events with isolated high-p_T leptons.

Generic search (à la H1) has not been done by ZEUS but could provide something new and provides useful information of semi-inclusive measurements.

Channels with increased sensitivity due larger amount of e^- data.