Leptoquark Searches at H1

Ilias Panagoulias
National Technical University of Athens

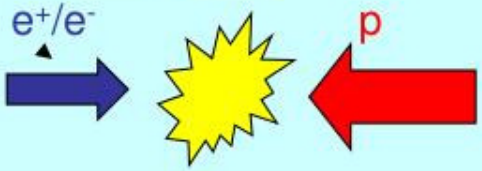
25th Workshop on Recent Developments in High Energy Physics&Cosmology
Athens, 28 March 2007

Outline

- Introduction
- High Q^2 Deep Inelastic Scattering
- Introduction to the Leptoquark Model
- Invariant Mass Spectra
- Limits on Leptoquarks
- Conclusion and Outlook

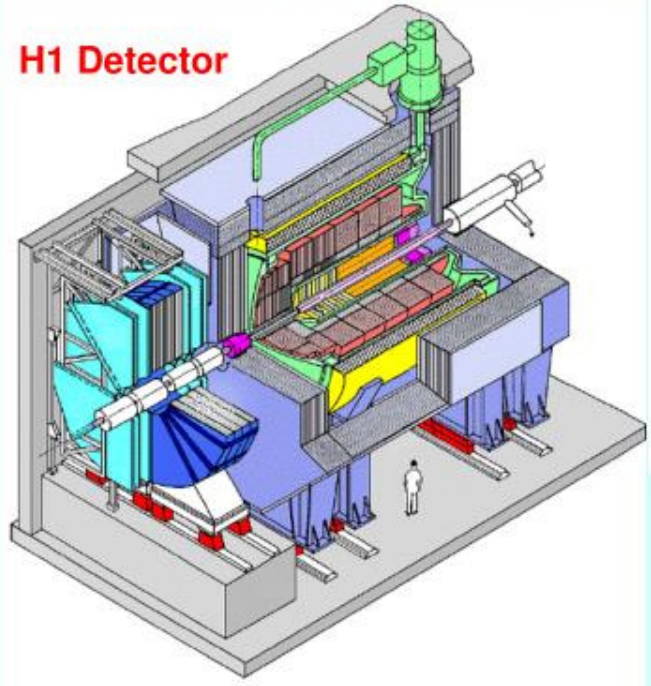
Introduction

HERA data



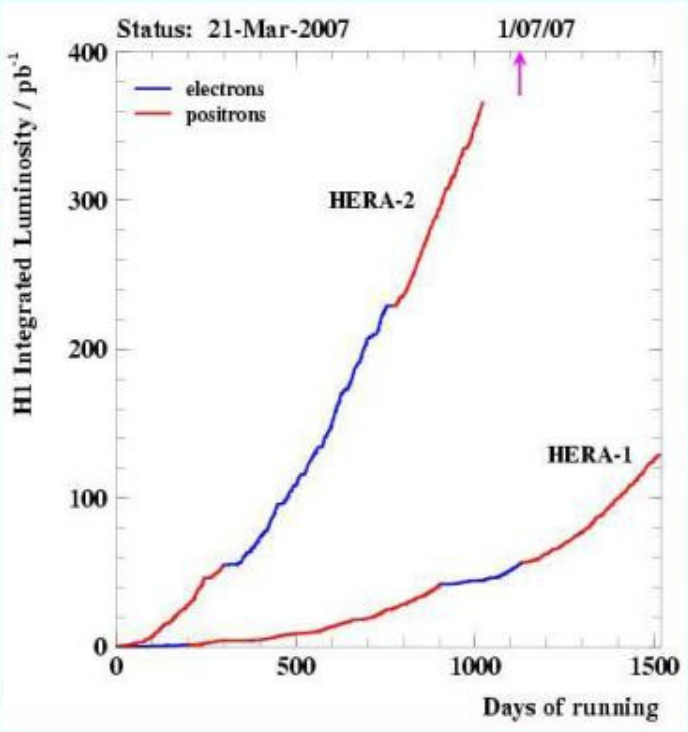
27.5 GeV **820 GeV** 1994-1997

920 GeV 1998-2007



Total H1 luminosity

more than 400 pb^{-1}

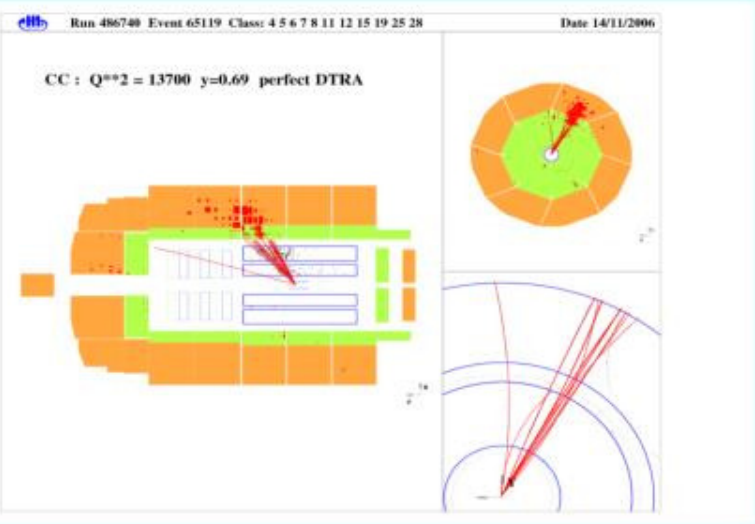


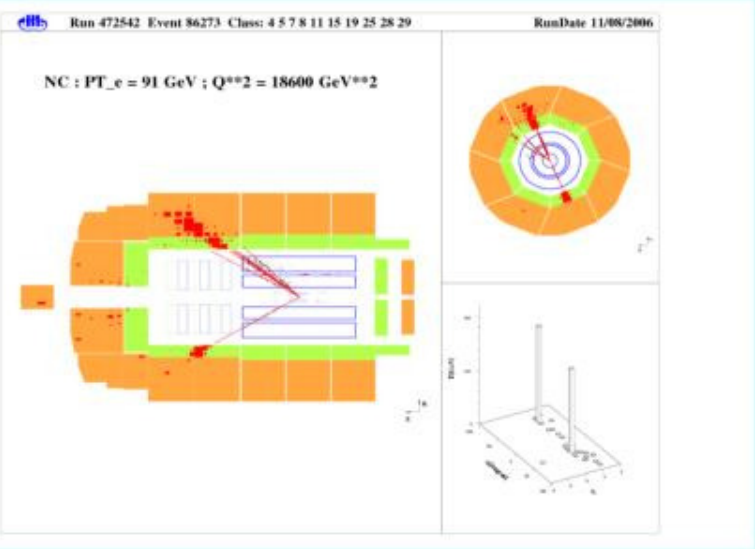
From 2003 longitudinally polarized lepton beam

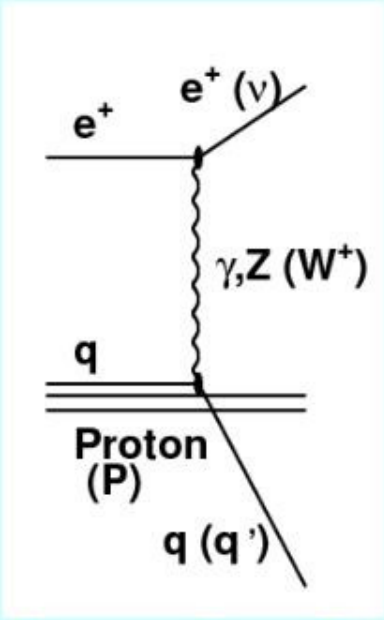
Presented results in this talk

Year	L
1994-97 e^+	37 pb^{-1}
1998-99 e^-	15 pb^{-1}
1999-00 e^+	65 pb^{-1}
2004-05 LH e^-	60 pb^{-1}
2004-05 RH e^-	32 pb^{-1}

High Q^2 DIS







- Q^2 = -(4 momentum of propagator)^2 : the virtuality of the exchanged boson
- x : fractional momentum of proton carried by the struck quark
- y : fractional energy of the incoming lepton transferred to the proton in the proton's rest frame

Introduction to the Leptoquark Model

LEPTOQUARKS

Hypothetical bosons which appear in many SM extensions to explain symmetry between leptons and quarks

- LQs are coupled to both leptons and quarks and carry SU(3) colour, fractional electrical charge, baryon (*B*) and lepton (*L*) numbers
  → Fermion number $F = 3B + L = 0 , 2$

Buchmuller-Ruckl-Wyler Model

- ✓ $SU(3)_C \times SU(2)_L \times U(1)_Y$ invariance
- ✓ Lepton and baryon number conservation
- ✓ Strong bound from rare decays →either left- or right-handed couplings
- ✓ Family diagonal; if not LFV is introduced
- ✓ decay to $l^{\pm}q$ or $\nu_l q'$ with branching ratios $\beta_l, \beta_\nu = 0, 0.5, 1$ depending on the quantum numbers

⇨ 7 scalar and 7 vector LQs

Introduction to the Leptoquark Model

couple to l^-q

couple to l^+q

F	spin	species
2	0	$S_{0,L}; S_{0,R}; \tilde{S}_{0,R}; S_{1,L}$
2	1	$V_{1/2,L}; V_{1/2,R}; \tilde{V}_{1/2,L}$
0	0	$S_{1/2,L}; S_{1/2,R}; \tilde{S}_{1/2,L}$
0	1	$V_{0,L}; V_{0,R}; \tilde{V}_{0,R}; V_{1,L}$

labeled by weak isospin and lepton helicity

Angular distribution

$y=0.5(1-\cos\theta^*)$

θ^* - e scattering angle in eq (vq) rest frame

- Scalar LQs decay isotropicaly
- Vector LQs decay ~ $(1-y)^2$
- NC DIS ~ $1/y^2$

- Resonance width $\Gamma \sim \lambda^2 \cdot M_{LQ}$
- Each LQ characterized by two parameters:
  - LQ mass, M_{LQ}
  - LQ-l-q Yukava coupling, λ

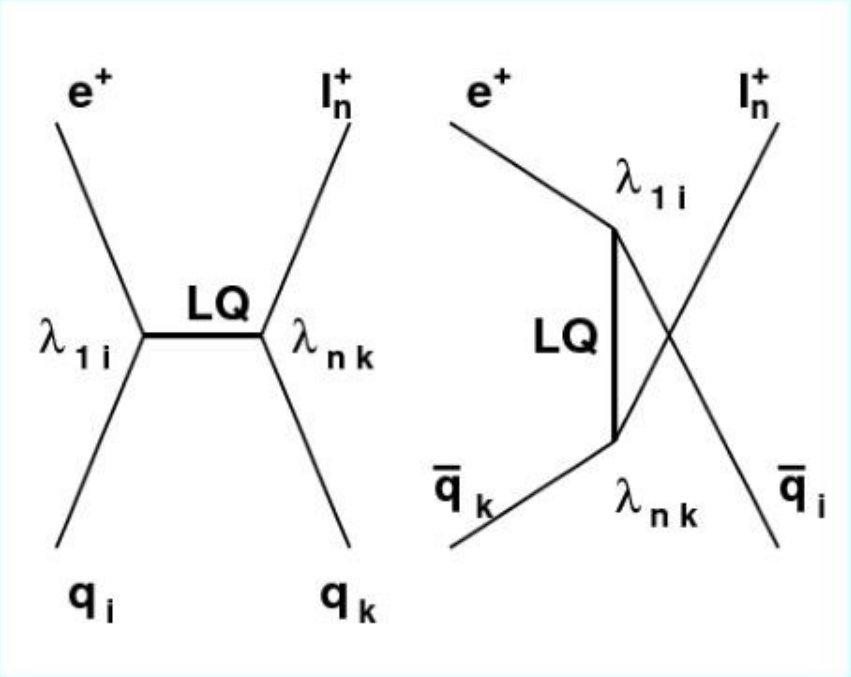
Leptoquarks at HERA

Single production

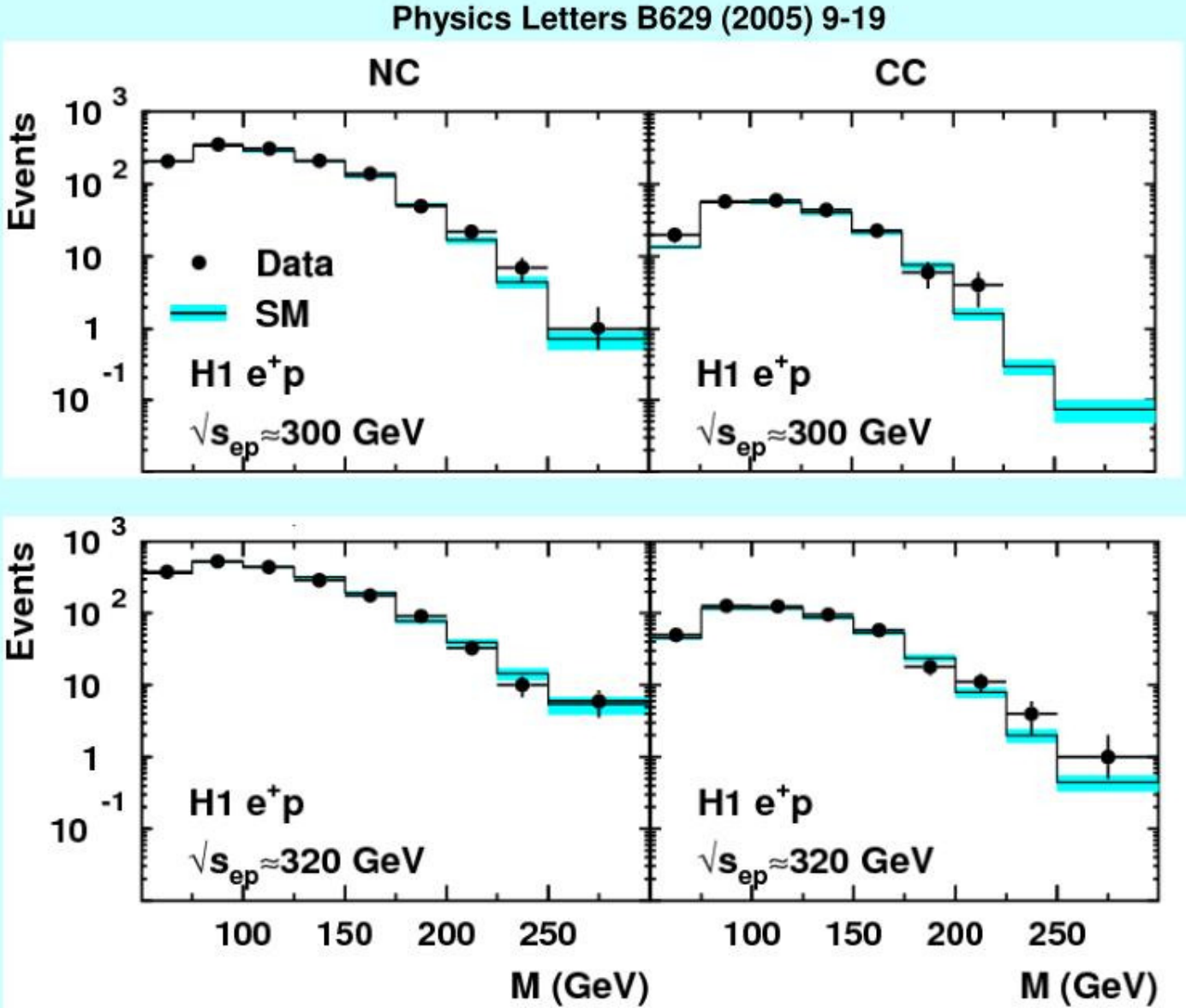
- LQ resonantly produced in the s-channel
- LQ exchanged in the u-channel

Background

- Events indistinguishable from SM CC and NC DIS respectively (if not LFV)
- Photoproduction ($\gamma p \rightarrow X$)
- Lepton pair production ($ep \rightarrow e l^+ l^- X$)
- W production ($ep \rightarrow eW X$)



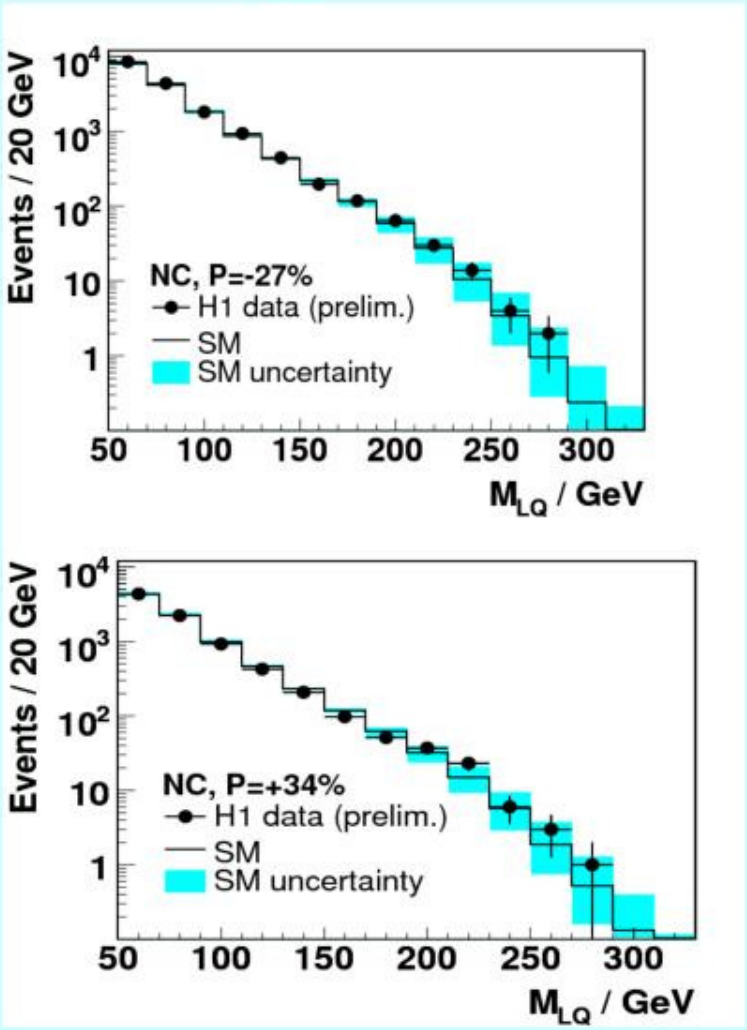
Invariant Mass Spectra from HERA I (e+p)



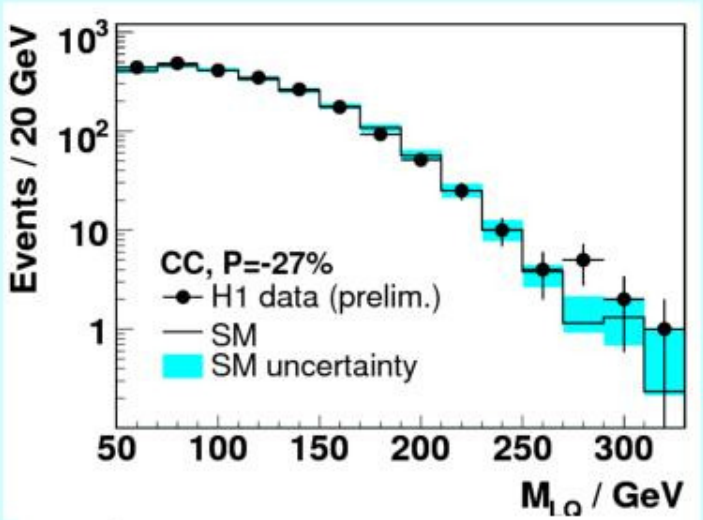
Invariant Mass Spectra from HERA II (e^-p)

NC

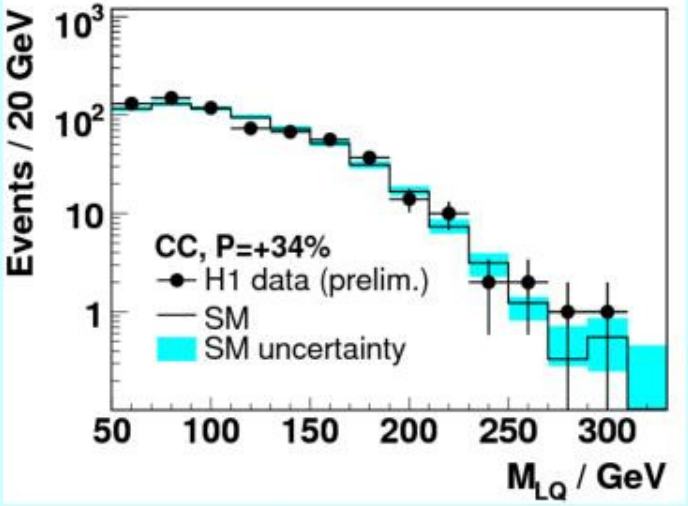
CC



L=60 pb^{-1}



L=32 pb^{-1}



Good overall agreement between data and SM ⇒ no evidence of LQ

Setting constraints on Leptoquarks

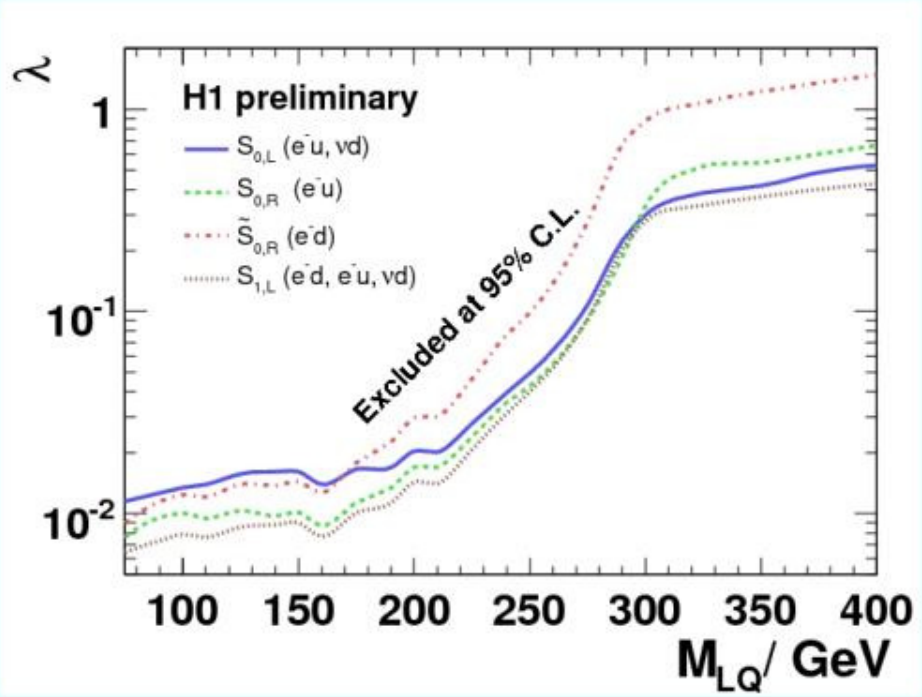
Fractional event counting method

- BRW model : two free parameters M, λ
- Analysis in M-y binned plane (sensitive quantities)
- Apply weight to each bin according to each signal-to-background ratio ($w_i = s_i / (s_i + 2b_i)$)

- Two hypothesis (Monte Carlo)
  - **Background**
  - **Signal + background**
- No generic LQ MC used but reweighted SM MC to LQ cross section
- In weighted bins compare data to both hypotheses

⇨ ***calculate minimal λ(M) to be excluded***

Limits on scalar LQs with F=2 (HERA II)



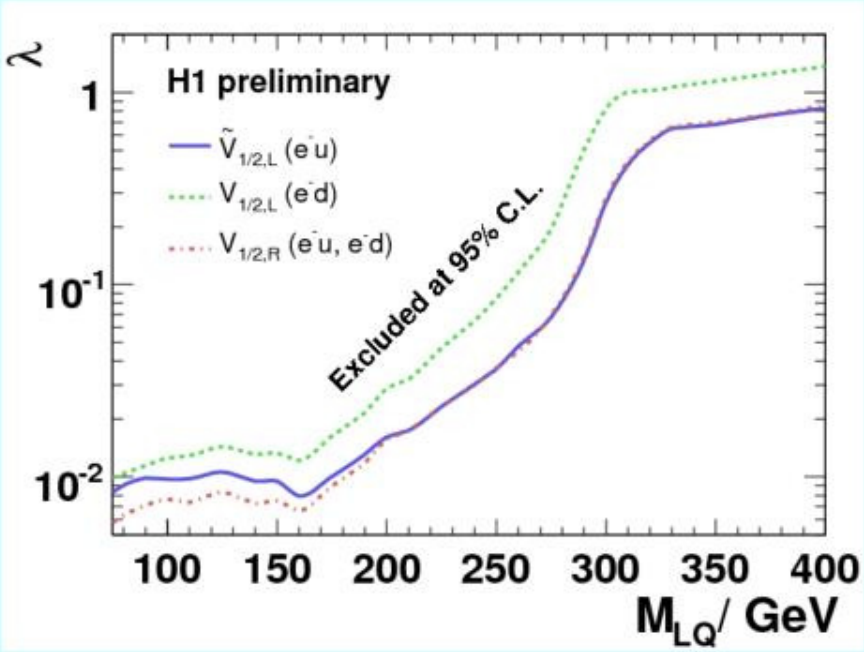
F=2 BRW LQ models

⇨ e^-p data more sensitive than e^+p

Combining NC&CC data for $S_{0,L}$, $S_{1,L}$ increases sensitivity

At $\lambda = (4\pi\alpha)^{1/2} \approx 0.3$ lower limits on $M_{LQ} > 276 - 304$ GeV

Limits on vector LQs with F=2 (HERA II)

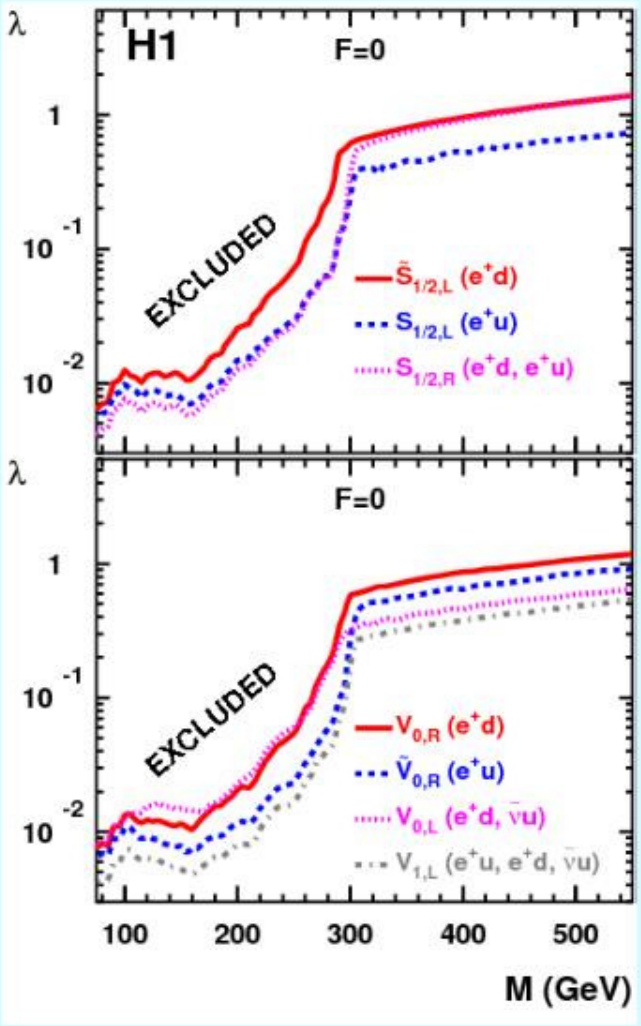


F=2 BRW LQ models
⇒ e^-p data more sensitive than e^+p

F=2 vector BRW LQ model
⇒ eq channel only

At $\lambda = (4\pi\alpha)^{1/2} \approx 0.3$ lower limits on $M_{LQ} > 280 - 303$ GeV

Limits on LQs with F=0 (HERA I)



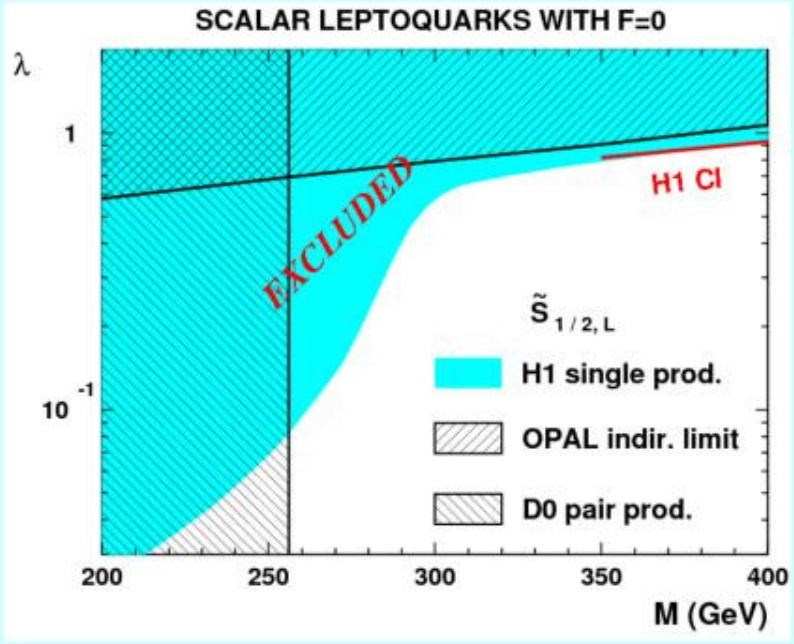
F=0 scalar BRW LQ model

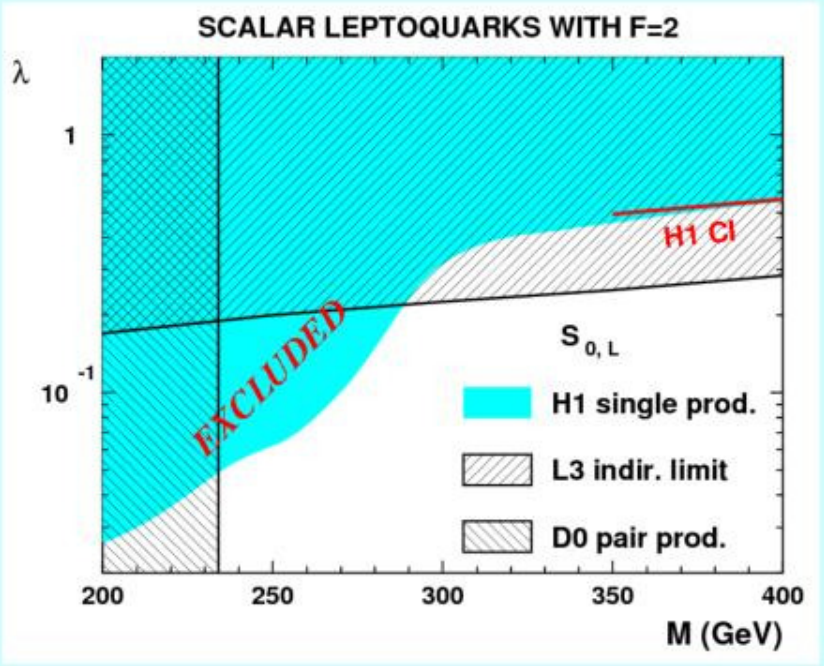
couples to eq only

F=0 vector BRW LQ model
couples to eq and vq
⇒ combining channels

At $\lambda \approx 0.3$ lower limits on MLQ > 275 – 325 GeV

Comparison with other experiments





Tevatron

LQ pair production, λ independent

$qq \rightarrow l^+l^-qq$

LEP

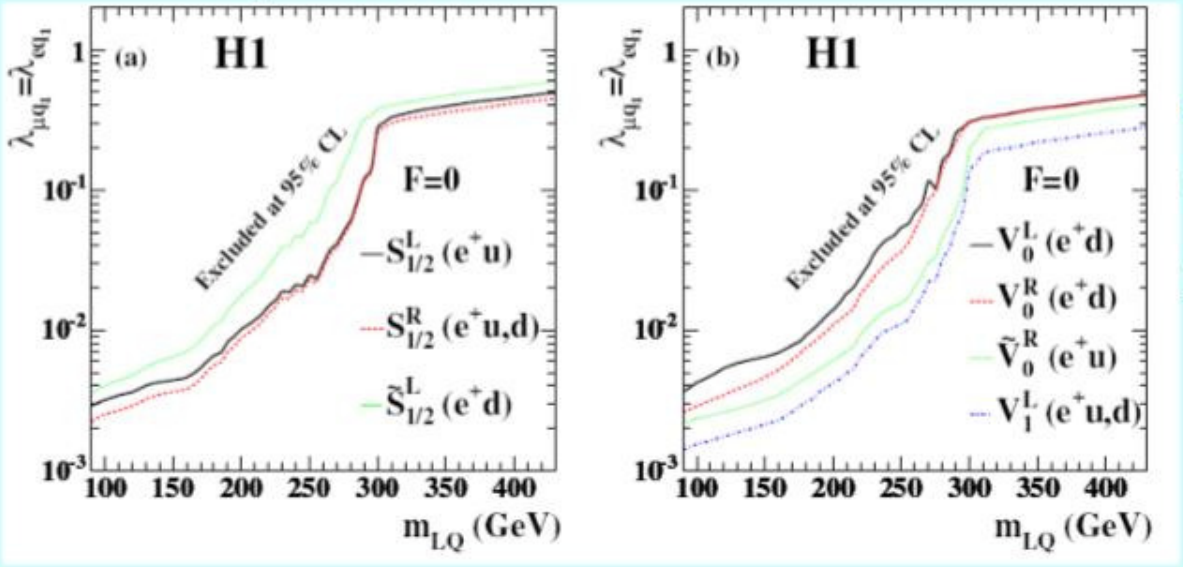
Indirect search in qq pair production

$e^+e^- \rightarrow qq$

For coupling of em strength ($\lambda \approx 0.3$) mass exclusion ≈ 300 GeV

Limits on LFV Leptoquarks

hep-ex/0703004

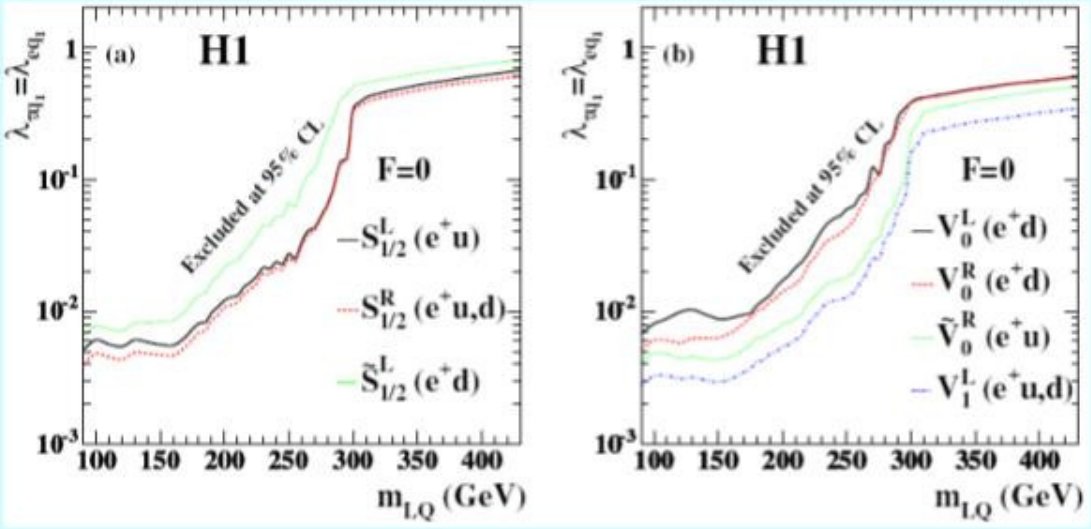


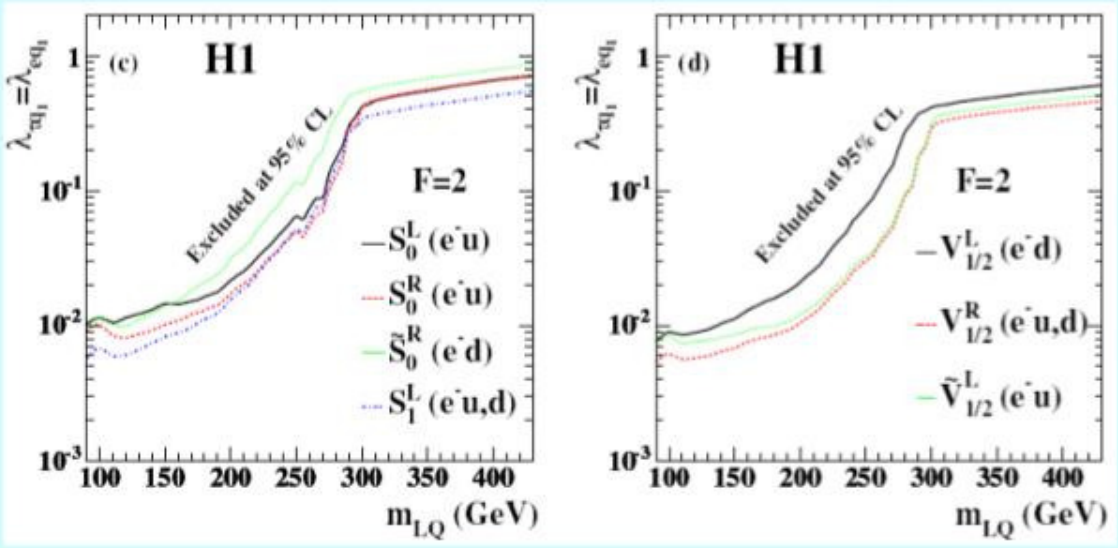
$ep \rightarrow \mu X$

1998-00 data

$L=80\ pb^{-1}$

Limits on LFV Leptoquarks





$ep \rightarrow \tau X$
1998-00 data
L=80 pb-1

Limits on LFV Leptoquarks

H1 lower exclusion limits on m_{LQ} (GeV) at 95% CL							
$F = 0$	$S^L_{1/2}$	$S^R_{1/2}$	$\tilde{S}^L_{1/2}$	V^L_0	V^R_0	$\tilde{V}^R_0$	V^L_1
$eq \to \mu q$	302	309	288	299	298	333	459
$eq \to \tau q$	298	298	285	290	293	307	379
$F = 2$	S^L_0	S^R_0	$\tilde{S}^R_0$	S^L_1	$V^L_{1/2}$	$V^R_{1/2}$	$\tilde{V}^L_{1/2}$
$eq \to \mu q$	294	294	278	306	299	374	336
$eq \to \tau q$	293	294	276	295	282	302	297

$\lambda_{\mu q}=\lambda_{\tau q}=\lambda_{eq}=0.3$

In general these exclusion limits are less stricter than the ones from non LFV LQs.

The combination of two can improve more the constraints.

Conclusion&Outlook

- Search for leptoquarks (including LFV LQs) using all HERA I data collected by H1 and first generation LQs using HERA II e^- data performed
- No signal observed
- Limits on different LQ types have been set
- Limits extend beyond results by other analyses
- $M < 275\text{-}325$ GeV can be ruled out for $\lambda=0.3$

- Analysis of all HERA II data is ongoing
- HERA II e^+p dataset will improve limits with $F=0$
- All data HERA I & II and possible H1 and ZEUS combination (~700 pb^{-1})
  ⟹ more improvements are expected

High energy run in HERA has ended but many interesting events are waiting to be analysed!