Leptoquark Searches at H1

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• H1 at HERA
• The leptoquark model
• Leptoquarks at HERA
• First generation LQs
• LFV LQ decays
• Summary

16th International Workshop on Deep Inelastic Scattering
The H1 experiment at HERA

HERA
An unique ep collider (1992-2007)
Two large collider detectors H1 and ZEUS with asymmetric design

~0.5 fb⁻¹ luminosity balanced in e⁺ & e⁻
HERA II data with longitudinal polarisation (30-40%)

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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
  \[ F = 3B + L = 0, 2 \]

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

Leptoquarks are chiral particles

- Gain in sensitivity for leptoquark search when the lepton beams are longitudinally polarized

<table>
<thead>
<tr>
<th>$F$</th>
<th>spin</th>
<th>species</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0</td>
<td>$S_{0,L}; S_{0,R}; S_{0,R}; S_{1,L}$</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>$V_{1/2,L}; V_{1/2,R}; V_{1/2,L}$</td>
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<tr>
<td>0</td>
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- Resonance width
  \[ \Gamma \sim \lambda^2 M_{LQ} \]
- Each LQ characterized by two free parameters:
  - LQ mass, $M_{LQ}$
  - LQ-l-q Yukawa coupling, $\lambda$
Leptoquarks at HERA

If $LQ \rightarrow eq$, Lepton Flavor Conserving (LFC) decays

If $LQ \rightarrow \mu q/\tau q$, Lepton Flavor Violating (LFV) decays

- resonant production in s-channel
- exchange in u-channel
- signature one jet & one l/ν
- final state indistinguishable from SM NC/CC DIS for 1st generation LQs (LFC)
- clear signal if we assume LFV
Search for first generation LQ at HERA

Neutral Current sample
Signature $ep \rightarrow eX$

Selection
- Isolated $e$, $E_e = 11$ GeV
- $Q^2 > 1000$ GeV
- $0.1 < y_e < 0.9$

Charged Current sample
Signature $ep \rightarrow \nu X$

Selection
- $P_T^{\text{miss}} > 12$ GeV
- $Q^2 > 500$ GeV
- $0.1 < y_h < 0.9$
Search for first generation LQ at HERA

Complete H1 $e^+p/e^-p$ data analysed, $L \sim 0.5$ fb$^{-1}$

Good description of data by SM prediction
Search for first generation LQ at HERA

• Data analysed taking into account the different polarization periods

• No evidence for signal → interpretation in terms of exclusion limits
Search for first generation LQ at HERA

Limits on Yukawa coupling $\lambda$ as a function of $M_{\text{LQ}}$

- $M<300$ GeV resonant production, strong limits
- $M>300$ GeV $u$-channel

For electromagnetic strength $\lambda=0.3$ $M_{\text{LQ}}<291$-330 GeV can be ruled out
Comparison with LEP & Tevatron

**LEP (OPAL, L3)**: indirect constraints from $e^+e^- \rightarrow qq$

**TEVATRON (D0)**: $qq$ annihilation or $gg$ fusion (pair production), limit independent of $\lambda$

**HERA** extends the excluded domain
Search for Lepton Flavor Violation

LFV can be mediated by leptoquarks assuming the outgoing lepton is a muon or a tau (instead of electron).

**Signature** \( ep \rightarrow \mu X \)

**Selection**
- Isolated muon
- \( P_T^{\text{calo}}>20 \text{ GeV} \)
- back to back topology

**Search for Lepton Flavour Violation**

HERA II e-p sample

2 events seen/2.2±0.6 expected
Search for Lepton Flavor Violation

Limits on Yukawa coupling $\lambda$, assuming $\lambda_{eq} = \lambda_{\mu q}$

HERA II $e^+p$ : 10 times more luminosity than HERA I
Summary

• HERA offers a unique possibility to search for resonant production of new particles coupling directly to a lepton and a parton (leptoquarks)

• Results on leptoquark decays are updated by H1 experiment including HERA II (polarised) data
  • LFC LQs: The complete data collected by H1 analysed
  • LFV LQs: New results based on HERA II e-p sample published
    ✓ No significant sign of new physics found with respect of SM prediction
    ✓ Stricter limits are set on all LQs types, comparing to LEP, TEVATRON analysis

• Stricter limits will be obtained soon combining H1 and ZEUS data