LHeC and New Physics at High Scales: Towards the CDR…

Emmanuelle Perez (CERN),
Georg Weiglein (IPPP Durham)
Georges Azuelos (Montreal)

LHeC convenor's meeting, December 09, CERN

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5 New Physics at Large Scales

5.1 Physics beyond the Standard Model in ep

➔ New physics in high Q2 DIS

Some general introduction regarding possible contributions from New Physics in high Q2 DIS:

A deviation from the SM at high Q2 could be due to:

- production of new a particle
  - e.g. resonance electron-quark
- exchange of a new boson - e.g. Z' :
  - sensitivity up to ~ 1 TeV
- eeqq contact interaction
  - -sensitivity up to 20-40 TeV depending on models
- exchange of a tower of KK gravitons in ADD model of extra-dim
  - sensitivity on the Ms scale up to xx TeV
- manifestation of quark substructure
  - sensitivity on the quark radius down to ~ 8 10^{-20} m

5.2 New Particles or Interactions

5.2.1 Electron-Quark Resonances

- leptoquarks
- could be squarks in Rp violating SUSY

LHC could discover eq resonances with a mass of up to 1.5 – 2 TeV via pair production.

Quantum numbers ? Might be difficult to determine in this mode.

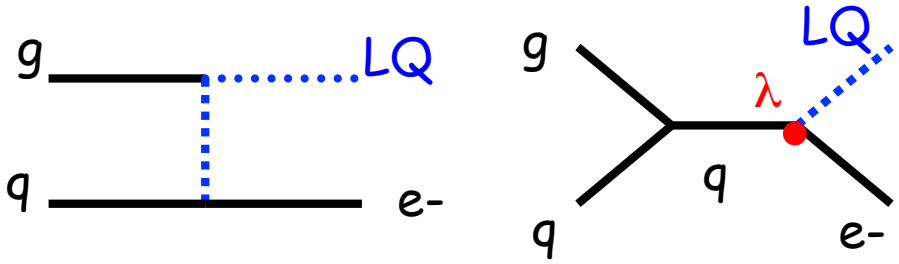
Single LQ production can be better suited for LQ "spectroscopy".

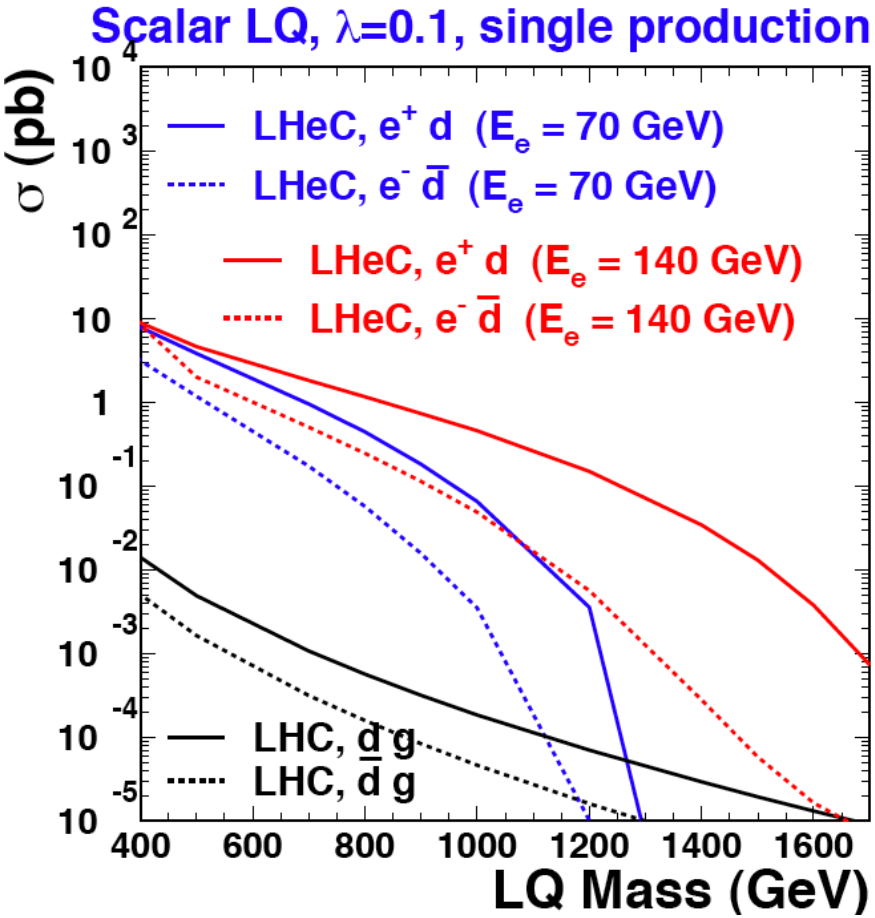
-> Show examples of measurements which could not be done at LHC but which could be done in ep at LHeC.
Not forgetting that single LQ production is also possible at LHC – though not much studied so far, experimentally.

Single LQ production at LHC

Single LQ production is better suited to study "LQ spectroscopy".

Also possible in pp :



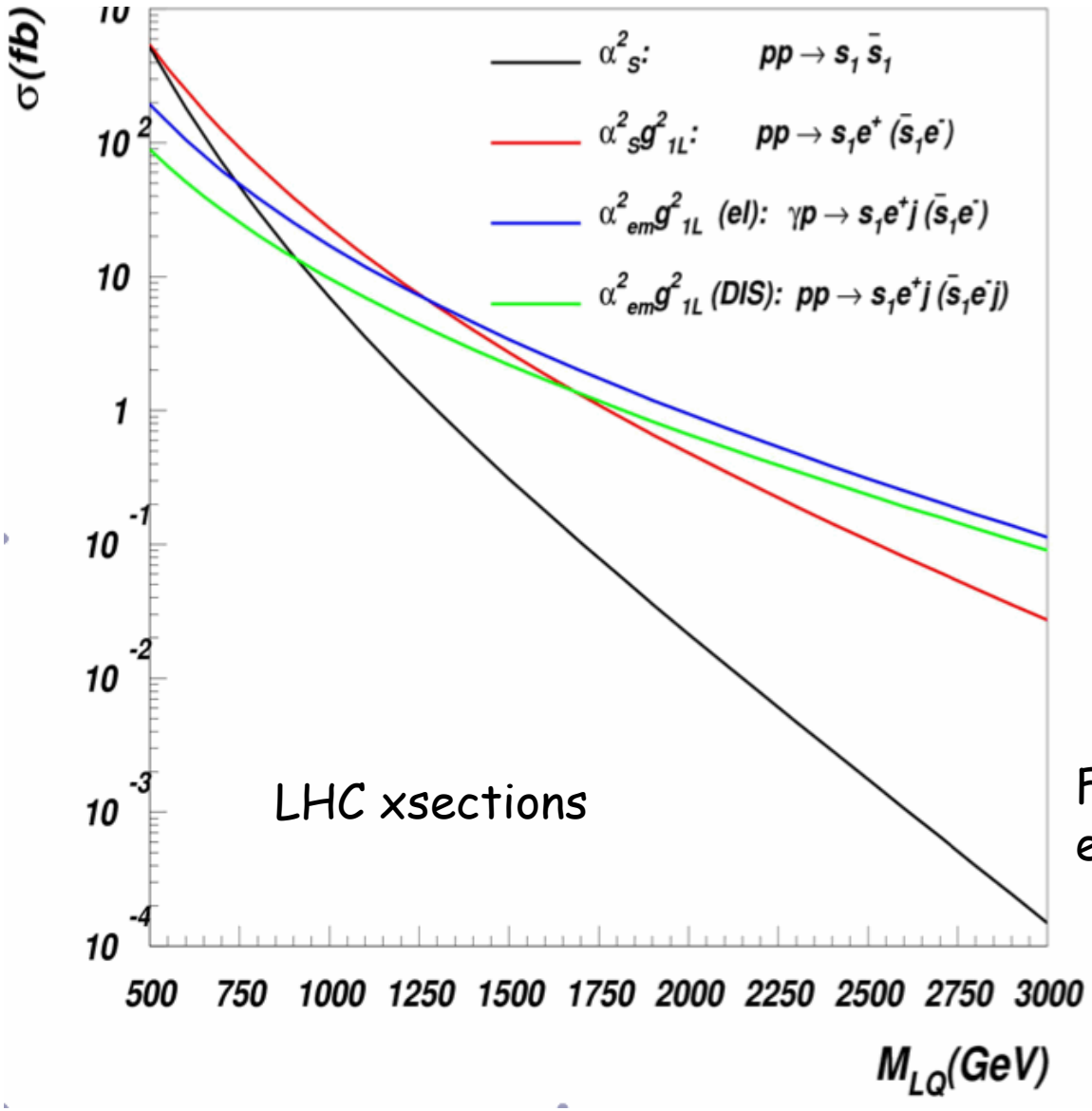


(γ → ee followed by eq → LQ not considered yet.
Work in progress.)

New since Divonne:

Calculation of the x-section for the gamma-q process
(Sasha Belyaev)

S. Belyaev



Single LQ prod xsections are shown for lambda = 0.1.

Gamma-q mode increases considerably the single xsection: dominates at high masses.

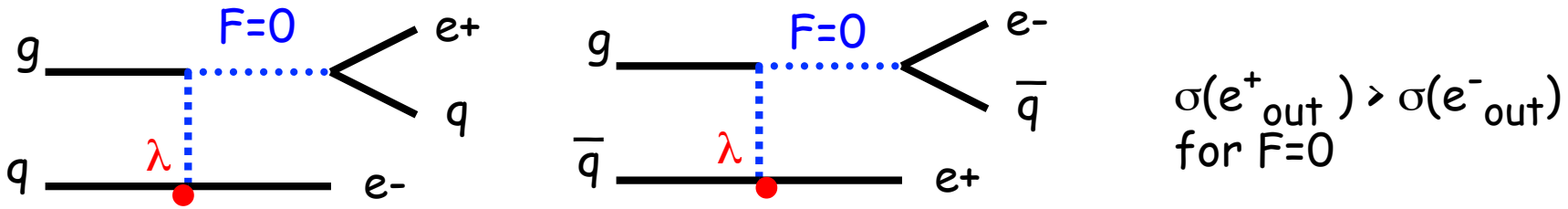
(compare blue versus red)

For masses below ~ 1 TeV, previous estimates are ~ OK.

Determination of LQ properties at LHC versus LHeC

- Example 1 : determination of the fermion number

In pp: look at signal separately when resonance is formed by (e^+ + jet) and (e^- + jet) :



$\sigma(e^+_{out}) > \sigma(e^-_{out})$ for F=0

Sign of the asymmetry gives F, but could be statistically limited at LHC.

Easier in ep ! Just look at the signal with incident e+ and incident e-, build the asymmetry between $\sigma(e^+_{in})$ and $\sigma(e^-_{in})$.

- Example 2 : determination of the spin

This time with a "real" analysis, involving a simulation of the signal and of the dominant backgrounds.

Georges A + post-doc from Victoria (V. Bansal, t.b.c.)
EP & Sasha B.

5.2.2 New Leptons

- Excited fermions: cf E. Sauvan & N. Trinh, Divonne 2008
  ~ done.

- Anomalous interactions of 4th family leptons:
  see Abbas K. Cifti at Divonne 09.

This is *the* example where LHeC could see something that could escape the LHC.

But it would be nice to have :
- Something coming from LHC which may indicate (strongly) that an excited electron may exist in the LHeC range…
- Or work with a "light" new lepton, i.e. under the hypothesis that the LHC has seen it. As for LQs, show examples of measurements which could be done at LHeC only.

Hopefully the Ankara group can help us there.

5.2.3 Mass Measurements in RP conserving SUSY

- R-parity conserved SUSY: if $\Sigma M < \sim 1$ TeV, mass measurements more precise than what can be achieved at LHC ?

Nobody is working on that.

The x-sections are not very large… not very encouraging…
Esp. since this sounds like a non-trivial analysis.

Back-up plan: just mention some typical xsection and a vague statement regarding the possibility of mass measurements in the "introduction" Sub-section.

5.4 Resolving Ambiguities

5.4.1 Discrimination of Z' Models

5.4.2 Ambiguities between eeqq Contact Interactions

5.4.3 New Physics at the LHC and pdf Effects - DY, dijets

Z' : study done by T. Rizzo.

Basically completed. Could be made more "generic" but not in Tom's plans.

This is an example where polarization is really needed.

Note that this is anyway challenging for LHeC :

needs high energy, high lumi, polarization, and after all, limited to Z' masses of about 1.2 TeV…

eeqq contact interactions :

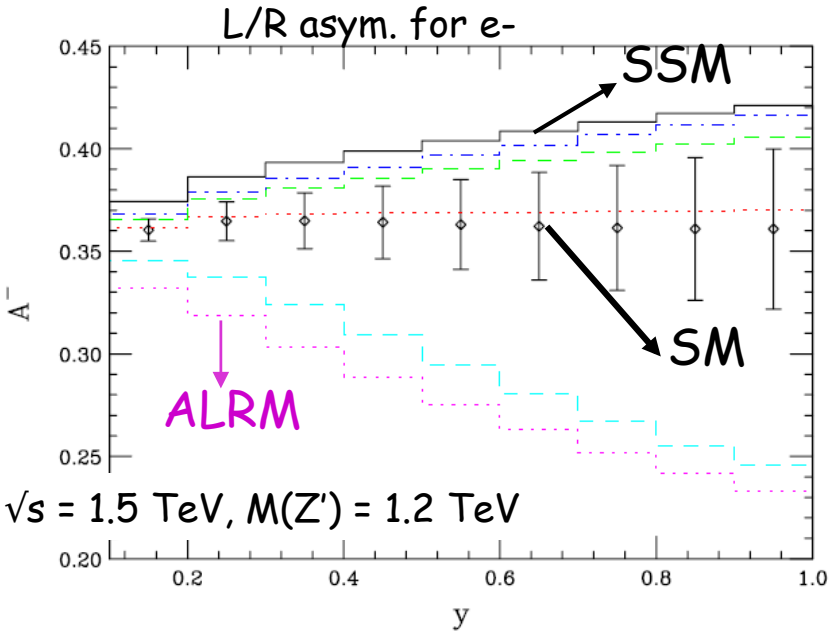
We have one example of LHeC "added value" (EP). Would be nice to have a more generic study butunlikely that I will have time. Could chase Zarnecki for the 10th time…

Examples of new physics in eeqq amplitudes

- new Z' boson: pp measurements alone do not allow for a model-independent determination of all of the Z' couplings ($g_{L,R}^{e}$, $g_{L,R}^{u,d}$)

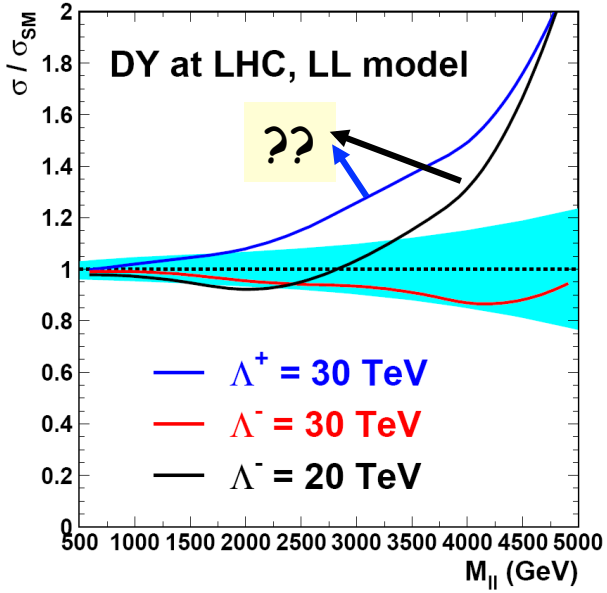
LHeC data may bring the necessary complementary information, before a LC.

T. Rizzo, PRD77 (2008) 115016

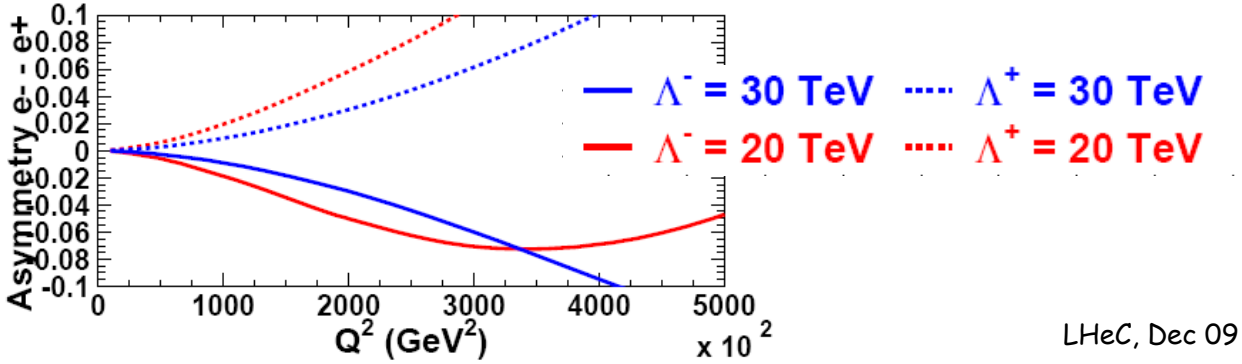


- Contact Interactions:

$$\mathcal{L}_{CI} = \sum_{i,j=L,R} \varepsilon_{ij}^{eq} \frac{4\pi}{\Lambda^2} (\bar{e}_i \gamma^\mu e_i)(\bar{q}_j \gamma_\mu q_j)$$



At LHeC, sign of the interference can be determined by looking at the asym. between σ/SM in e^- and e^+.



5.5 New Particles or Interactions in γp Collisions

e.g. diquarks or 4th generation quarks, excited quarks.

Done by the Ankara group, cf Divonne 09.

Nice studies and potentially a strong physics case.
Need to better work out the LHC potential, e.g. what can the LHC tell regarding the electric charge of a diquark ??

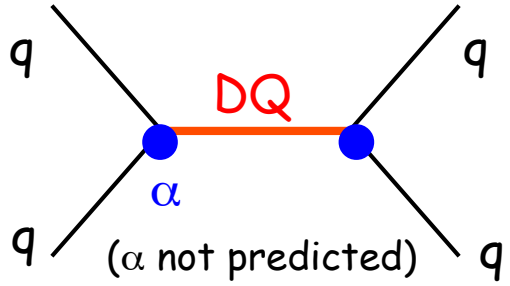
Diquarks (DQs)

Orhan Cakir

Predicted in some superstring models. Scalar or Vector, can carry fractional electric charge.

	$SU(3)_C$	$SU(2)_W$	$U(1)_Y$	Q	Couplings
Scalar diquarks					
DQ_1	3^*	1	2/3	1/3	$u_L d_L(g_{1L}),\ u_R d_R(g_{1R})$
$\widetilde{DQ}_1$	3^*	1	−4/3	2/3	$d_R d_R(\tilde{g}_{1R})$
$\widetilde{DQ}'_1$	3^*	1	8/3	4/3	$u_R u_R(\tilde{g}'_{1R})$
DQ_3	3^*	3	2/3	$\begin{pmatrix} 4/3 \\ 1/3 \\ -2/3 \end{pmatrix}$	$\begin{pmatrix} u_L u_L(\sqrt{2}g_{3L}) \\ u_L d_L(-g_{3L}) \\ d_L d_L(-\sqrt{2}g_{3L}) \end{pmatrix}$
Vector diquarks					
$DQ_{2\mu}$	3^*	2	−1/3	$\begin{pmatrix} 1/3 \\ -2/3 \end{pmatrix}$	$\begin{pmatrix} d_R u_L(g_2) \\ d_R d_L(-g_2) \end{pmatrix}$
$\widetilde{DQ}_{2\mu}$	3^*	2	5/3	$\begin{pmatrix} 4/3 \\ 1/3 \end{pmatrix}$	$\begin{pmatrix} u_R u_L(\tilde{g}_2) \\ u_R d_L(-\tilde{g}_2) \end{pmatrix}$

Had. Collisions:



Existing constraints :
M(DQ) > ~ 650 GeV (CDF)
α < ~ 0.1

LHC could discover DQs up to large masses and measure the mass, spin, width. But what about e.g. the electric charge ??

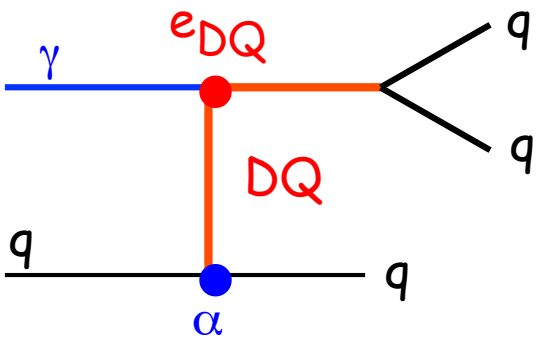
Charge measurement of DQ

Orhan Cakir

Single DQ production in γp collisions:

$\sigma = f(M, \alpha, e_{DQ})$

LHC → e_{DQ}



This diagram exist at LHC and in ep collisions. But much larger cross-section in γp collisions because of the much harder Eγ spectrum.

$W_{\gamma p}$ at LHeC >> $W_{\gamma p}$ at LHC

Hence can have larger cross-sections at LHeC !

γp collisions σ(fb)	LHeC(γp) Ee(GeV)		LHC(γp) (10TeV)	LHC(γp) (14TeV)
M_{DQ} (GeV)	70	140	5+5	7+7
700	36.56 (2.53)	189.37 (18.57)	8.29 (1.13)	12.23 (2.04)
1000	0.53 (0.03)	19.84 (1.39)	2.62 (0.30)	4.58 (0.64)

For α ~ 0.1, DQ can be studied up to ~ 1 TeV at LHeC.