LHeC and New Physics at High Scales

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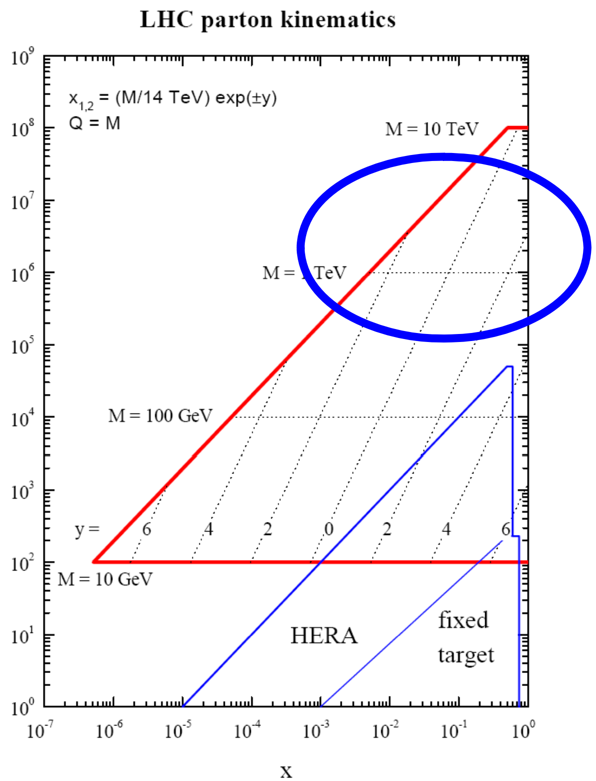
- Sensitivity to new physics in ep collisions at 1.4 (1.9) TeV :
  quark radius, electron-quark resonances, eeqq contact interactions.

- Added value w.r.t. the LHC

- LHeC w.r.t. the interpretation of LHC discoveries :
  are there limitations due to our limited knowledge of high x pdfs ?



Existing studies for new physics at LHeC

- LHeC 2006 paper: JINST 1:P10001,2006 [hep-ex/0603016]
- DIS'07 (EP) and DIS'08 (A. Zarnecki) talks
- ECFA's talk (M. Klein) in November 08 (with updates for Ee = 140 GeV)
- Older studies (THERA (2000), Aachen LEP x LHC) relevant as well.

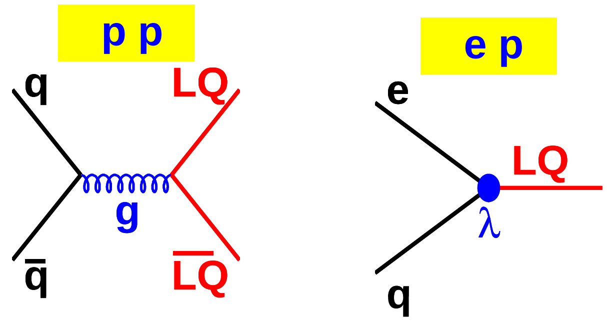
At this workshop:

- "dedicated" session on Beyond the Standard Model
- combined session with SM group, "Higgs and Electroweak at LHeC", later today.

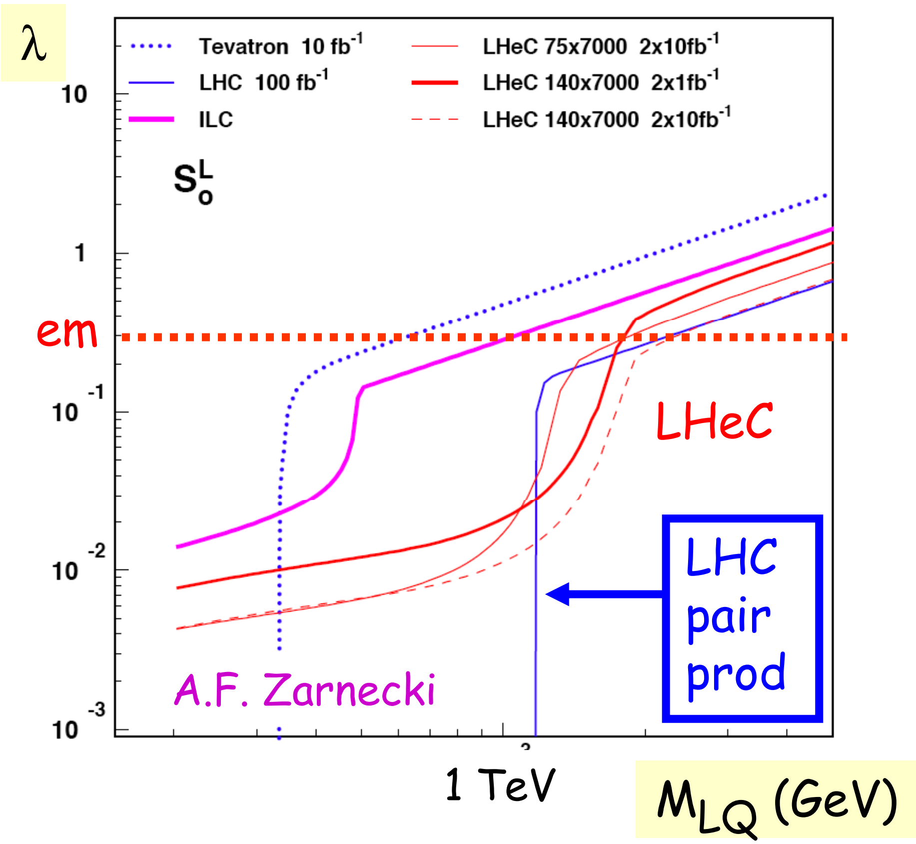
Electron-quark resonances

Apparent symmetry between the lepton & quark sectors ?
Exact cancellation of QED triangular anomaly ?

- “Leptoquarks” (LQs) appear in many extensions of SM
- Scalar or Vector color triplet bosons
- Carry both L and B, frac. em. charge



λ (unknown) coupling l-q-LQ



LQ decays into (lq) or (νq) :

- ep : resonant peak, ang. distr.
- pp : high E_T lljj events

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.

ep : golden machine to study LQ properties

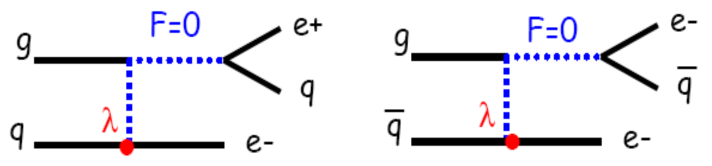
F = 0 or 2 ?	Compare rates in e^-p and e^+p
Spin ?	Angular distributions
Chiral couplings ?	Play with polarisation of lepton beam
Couples to ν ?	Easy to see since good S/B in νj channel

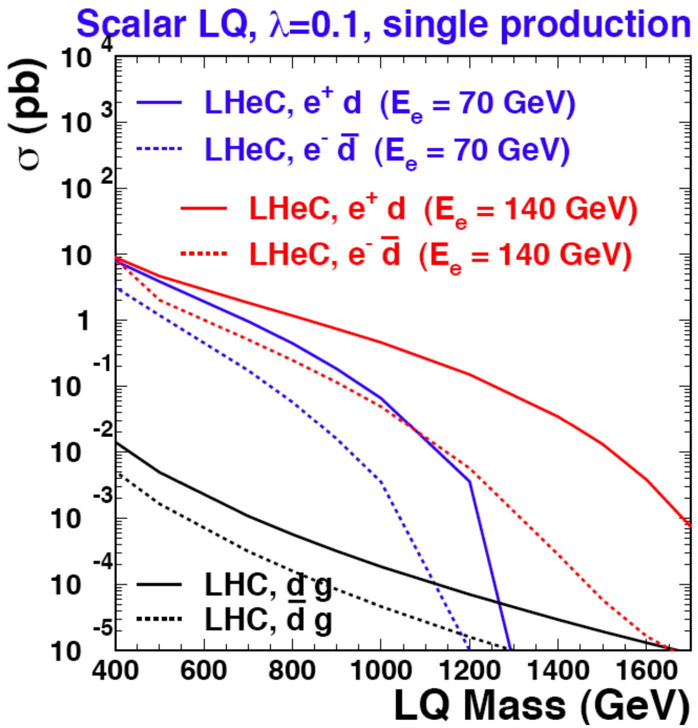
Classification in the table below relies on minimal assumptions.
ep observables would allow to disentangle most of the possibilities (having a polarised p beam would complete the picture).

		$S_{0,L}$	$S_{1,L}$	$\tilde{S}_{0,R}$	$S_{0,R}$	$S_{1/2,L}$	$\tilde{S}_{1/2,L}$	$S_{1/2,R}$
F = 2	$S_{0,L}$		β_ν	P_e	P_e			
	$S_{1,L}$	β_ν		P_e	P_e		e^+/e^-	
	$\tilde{S}_{0,R}$	P_e	P_e		P_p			
	$S_{0,R}$	P_e	P_e	P_p				
F = 0	$S_{1/2,L}$						P_p	P_e
	$\tilde{S}_{1/2,L}$			e^+/e^-		P_p		P_e
	$S_{1/2,R}$					P_e	P_e	

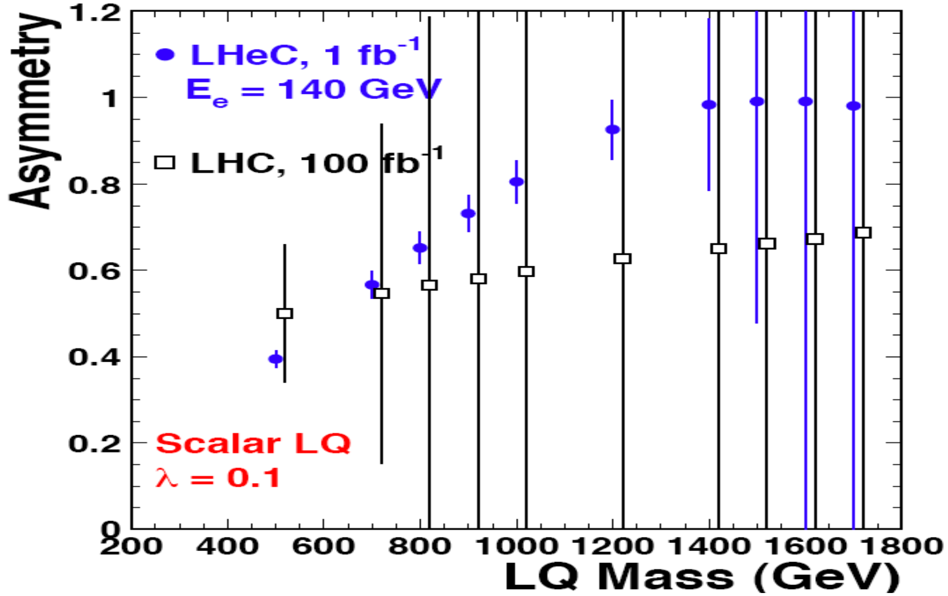
If LHC observes a LQ-like resonance, M below 1 – 1.5 TeV, LHeC could solve the possibly remaining ambiguities (if λ is not too small)

"LQ spectroscopy" : LHeC versus single LQ production at LHC





γ → ee followed by eq -> LQ not considered yet. Sasha Belyaev (Southhampton) proposed to work on this.

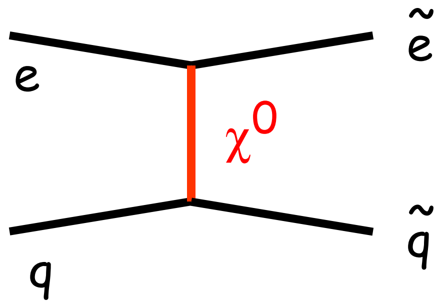


LHC potential for determining the LQ fermion number - crude analysis as done for the JNST paper.

Single LQ at the LHC, with realistic background simulation: see talk by Theodora Papadopoulou (Athens).

Beyond LQs… Other model-driven analyses :

→ SUSY with R-parity conservation



Pair production via t-channel exchange of a neutralino.

Cross-section sizeable when ΣM below ~ 1 TeV.

e.g. for best fit in J. Ellis et al [JHEP 0708:083,2007], $\tan\beta = 10$, $\sigma \sim 15$ fb.

Added value w.r.t. LHC to be studied :

- could extend a bit over the LHC slepton sensitivity
- precise mass measurements
- relevant information on χ^0 sector

Interest from Massimo Corradi (INFN), Gudrid Mortgaat-Pick (IPPP)

→ Single production of excited fermions

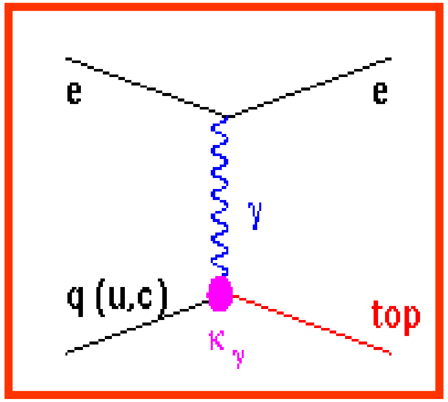
See talk by Nguyet Trinh (CPPM)

→ Further models …

Esp. models which predict new effects
- "easy" to see in ep because of low, well-understood backgrounds
- more difficult to establish in pp because of large bckgs

Example from HERA experience:
Anomalous top production via BSM coupling tuγ.

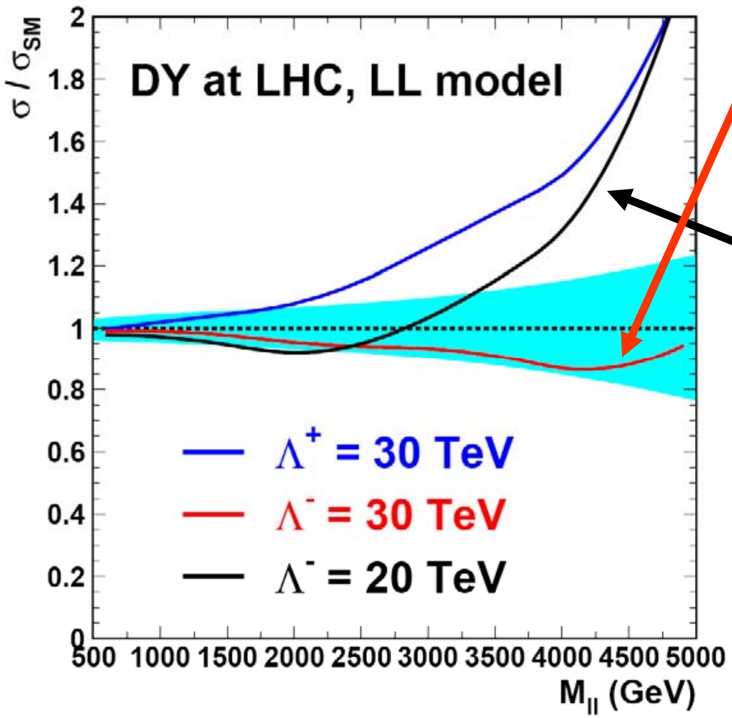
Tevatron : best sensitivity from tt pair production, followed by one top → qγ.
(single top analysis difficult because of large W + jets bckgd).



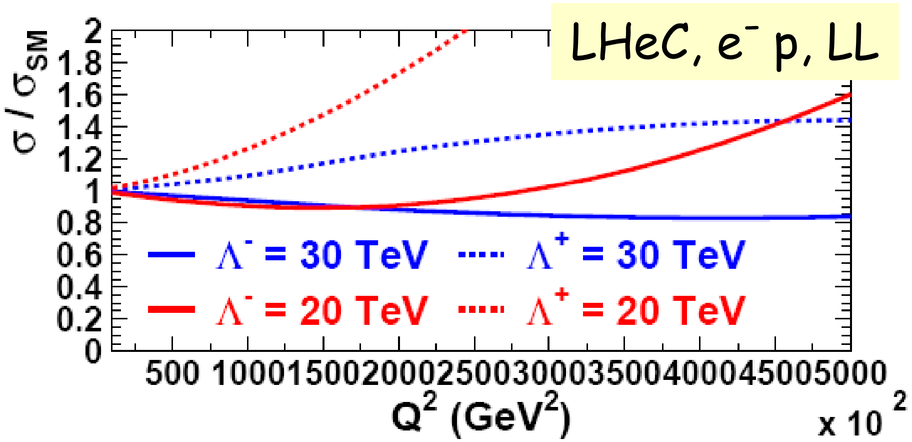
See talk by Gerhard Brandt (DESY).

eeqq contact interactions : added value of LHeC w.r.t. LHC

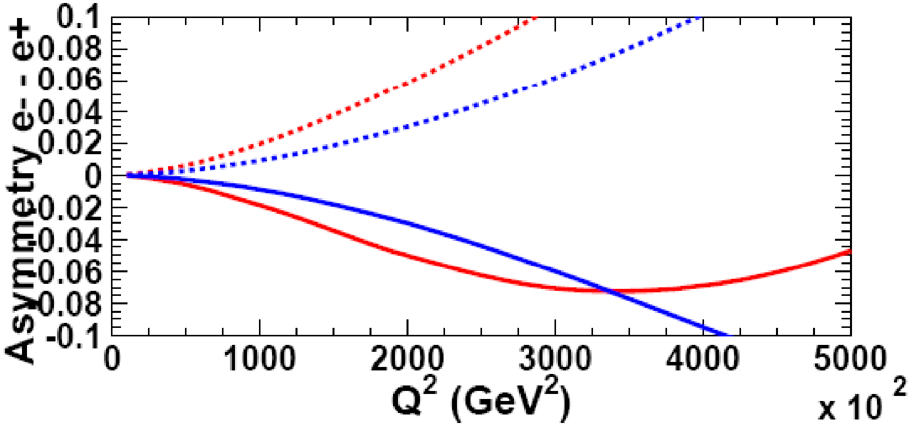
(DIS'07)



- LL model, Λ = 30 TeV, sign = -1 : effect in DY can be "absorbed" in pdf unc.
- In some cases, may be difficult to determine the sign of the interference of the new amplitude with SM.



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

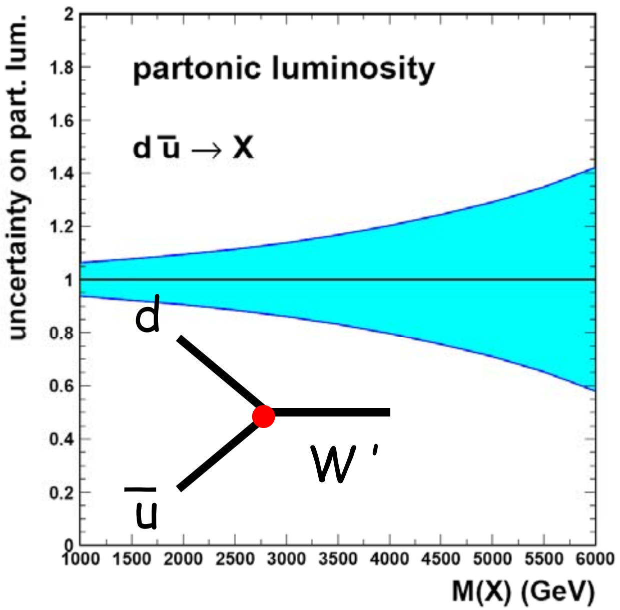


E. Perez

p structure & interpretation of LHC discoveries

- We may need more precise pdf's :

Example: new W ', resonant slepton production in RpV SUSY



(DIS'07)

40% uncertainty on part. lum. for a 6 TeV W '. Translates into an uncertainty on the coupling of the W'.

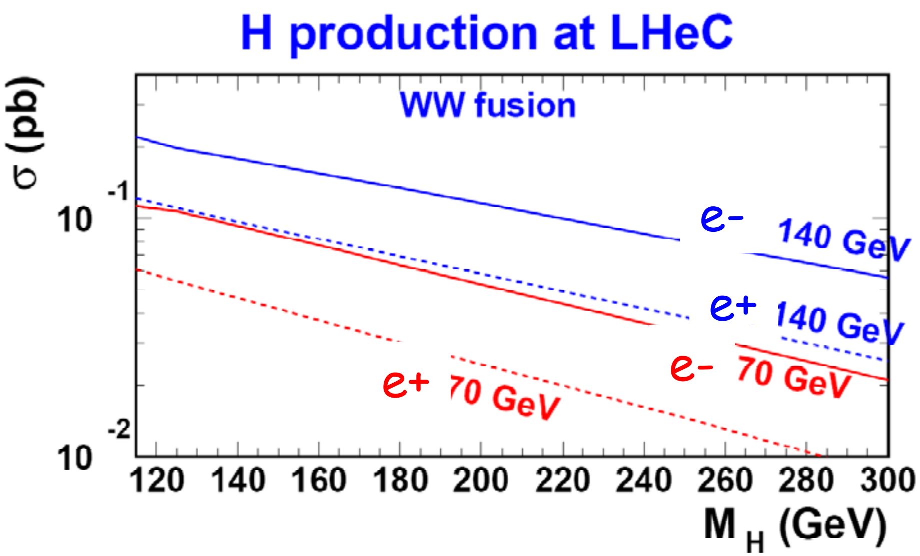
Idem for the couplings of a new Z' close to the kinematic limit.

- We may need ep in addition to pp data in order to establish that DGLAP and modified pdf's could not fake the LHC signal - see talk by EP.

LHeC and the Higgs boson ?

LHC will (hopefully) discover a Higgs boson.
If the Higgs is ~ 120 GeV, it may be difficult to get information on the Hbb coupling from LHC data.
See talk by Sue Ann Koay (UCSB).

Production cross-section for a 120 GeV Higgs at LHeC (Ee = 140 GeV) is sizeable.



Plot shows LO x-sections from CompHep.
Further x-section calculations:
See talk by Uta Klein (Liverpool).
Higher order corrections seem sizeable.

Could LHeC bring information on the Hbb coupling ?
See talk my Masahiro Kuze (Tokyo).

Conclusions

For “new physics” phenomena “coupling” directly electrons and quarks (e.g. leptoquarks, eeqq contact interactions) : LHeC has a sensitivity similar to that of LHC.

The further study, in ep, of such phenomena could bring important insights : leptoquark quantum numbers, structure of the “eeqq” new interaction. These studies may be difficult, if possible at all, in pp.

LHC sensitivity to new (directly produced) particles not much limited by our pdf knowledge. “Contact-interactions” deviations may be more demanding.

However, the interpretation of discoveries at LHC may require a better knowledge of the high x pdfs : e.g. determination of the couplings of a W ' or Z ' if “at the edge” .

Work ahead … (not an exhaustive list)

- Determination of LQ quantum numbers at LHC : real MC analysis with realistic simulation & backgrounds.

- Contact interactions : systematic analysis of
    - how pp data could discriminate between various models.
    - the complementarity between pp, ep, ee (cf A. Zarnecki, Tevatron/LEP/Hera)

- Assess the limitations due to our poor knowledge of high-x gluon in searches with jets.

- Further study of the LHeC potential in dedicated models (SUSY, excited fermions, anomalous couplings, …).
  e.g. If slepton + squark accessible at LHeC, what additional information do we learn compared to LHC ?

- Higgs and Hbb coupling : requirements on the detector performance ?

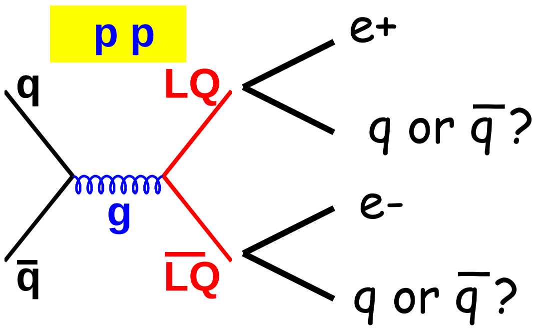
Backups

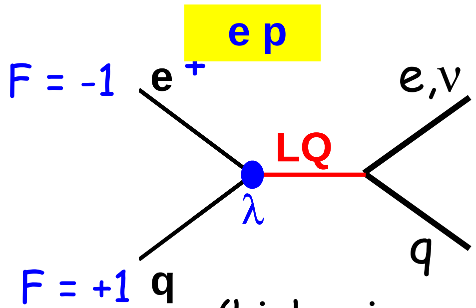
Determination of LQ properties

pp, pair production

ep, resonant production

- Fermion number



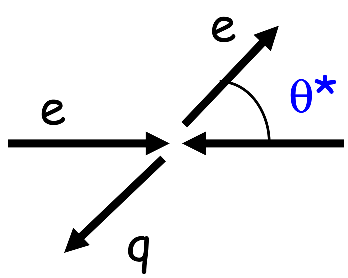


F=0 LQs : $\sigma(e^+)$ higher
F=2 LQs : $\sigma(e^-)$ higher

(high x i.e. mostly q in initial state)

- Scalar or Vector

$q\bar{q} \to g \to LQ\ \overline{LQ}$:
angular distributions depend on the structure of g-LQ-LQ. If coupling similar to γWW, vector LQs would be produced unpolarised...



cos(θ*) distribution gives the LQ spin.

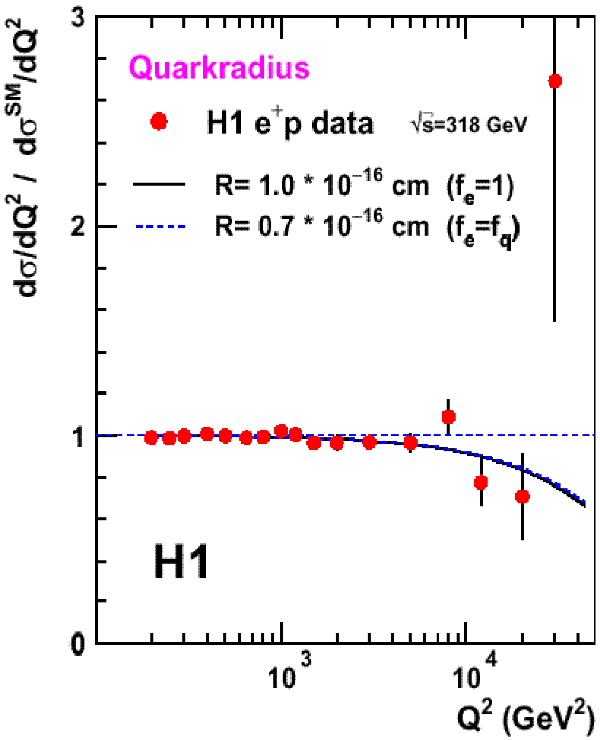
- Chiral couplings

?

Play with lepton beam polarisation.

DIS at highest Q^2 : towards quark substructure ?

LHeC promises to reach 10^{-19} m, i.e
1/10000 (1000) of proton (quark) radius



Assign a finite size < r > to the EW charge distributions :

$$d\sigma/dQ^2 = SM_{value} \times f(Q^2)$$

$$f(Q^2) = 1 - \frac{<r^2>}{6} Q^2$$

Global fit of PDFs and < r > using $d\sigma/dxdQ^2$ from LHeC simulation, 10 fb^{-1} per charge, Q^2 up to 500000 GeV^2 :

$< r_q > < 8. 10^{-20}$ m

One order of mag. better than current bounds.

At LHC : quark substructure may be seen as a deviation in the dijet spectrum.
Such effects could also be due to e.g. a very heavy resonance.
Could we establish quark substructure with pp data only ?