MODEL DEPENDENT SEARCHES FOR NEW PHYSICS AT HERA

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representing the 

collaborations

Outline:

- Introduction. HERA
- Leptoquarks and LFV
- Excited fermions
- Anomalous top coupling
- Contact Interactions.
- Conclusions

INTRODUCTION. HERA

Asymmetric collider of e^+ (e^-) with p. $E_{CM} \simeq 320$ GeV

Two general purpose experiments, ZEUS and H1.

Two phases

1994-2000 HERA I

2003-2007 HERA II

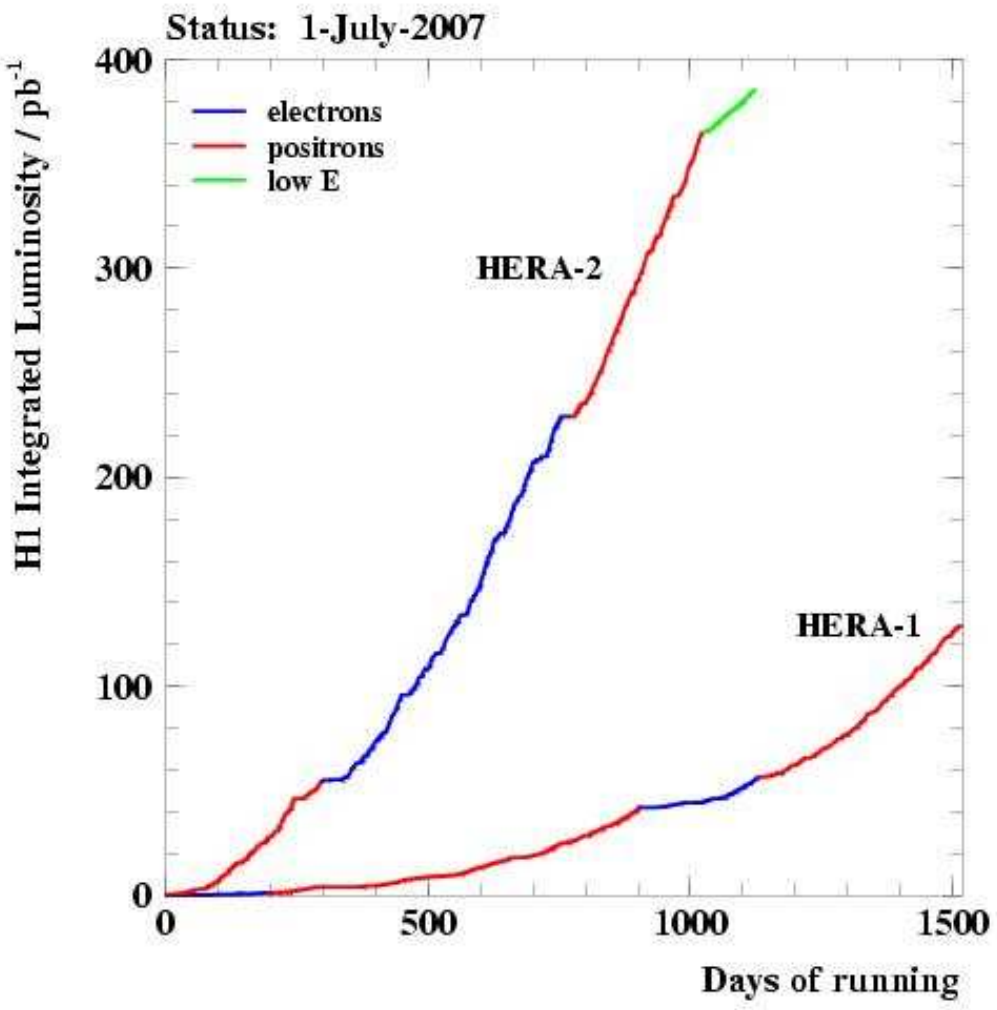
(with longitudinally

polarised $e^{\pm}$ in most of data)

End data taking on June 2007.

Total integrated luminosity

$\simeq 1$ fb^{-1} for the two experiments.



LEPTOQUARKS

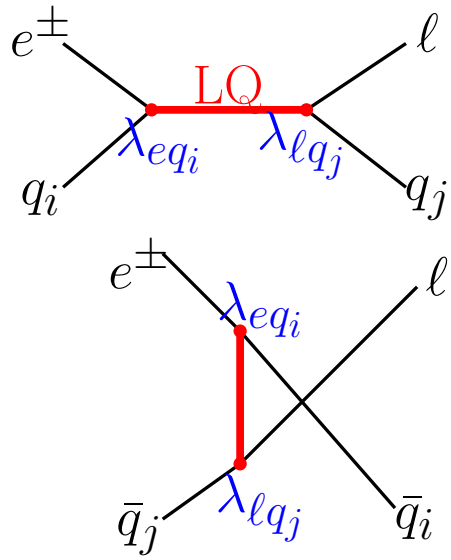
Many extensions of the Standard Model predict Bosons with both Lepton and Baryon numbers.

Phenomenological model of Buchmüller-Rückl-Wyler (BRW):

- invariance under $SU(3)_C \times SU(2)_L \times U(1)_Y$
- L and B conservation
- 7 Scalar and 7 Vector (4 decaying into both eq and νq)
- fermion number $F = 3B + L = 0, 2$
- coupling to either LH or RH leptons, not both
- fixed branching ratio into $e\nu$ 1, 1/2, νq 0, 1/2

$F = 0$ $e^- \bar{q}$ or $e^+ q \Rightarrow$ best sought in $e^+ p$

$F = 2$ $e^- q$ or $e^+ \bar{q} \Rightarrow$ best sought in $e^- p$



Different regimes:

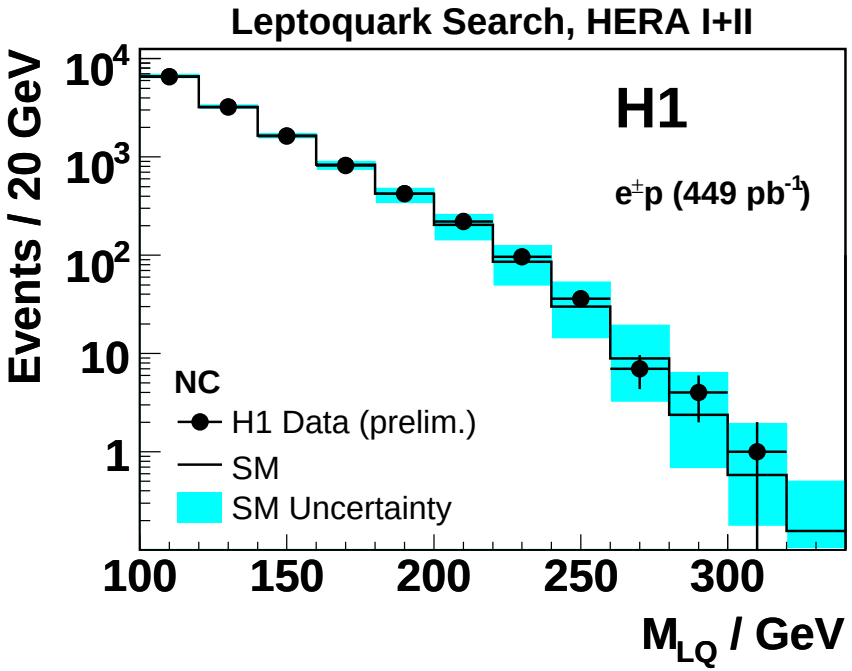
$M_{LQ} << \sqrt{s}$: resonant production, dominated by s-channel

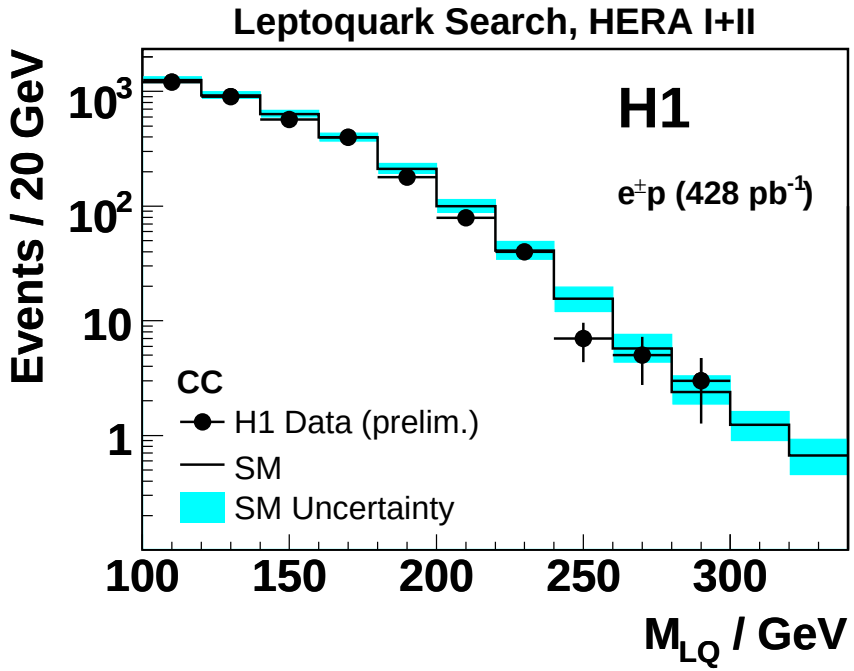
$M_{LQ} >> \sqrt{s}$: both s- and u-channel contribute,
analysis in terms of contact interactions.

FIRST GENERATION LEPTOQUARKS-1

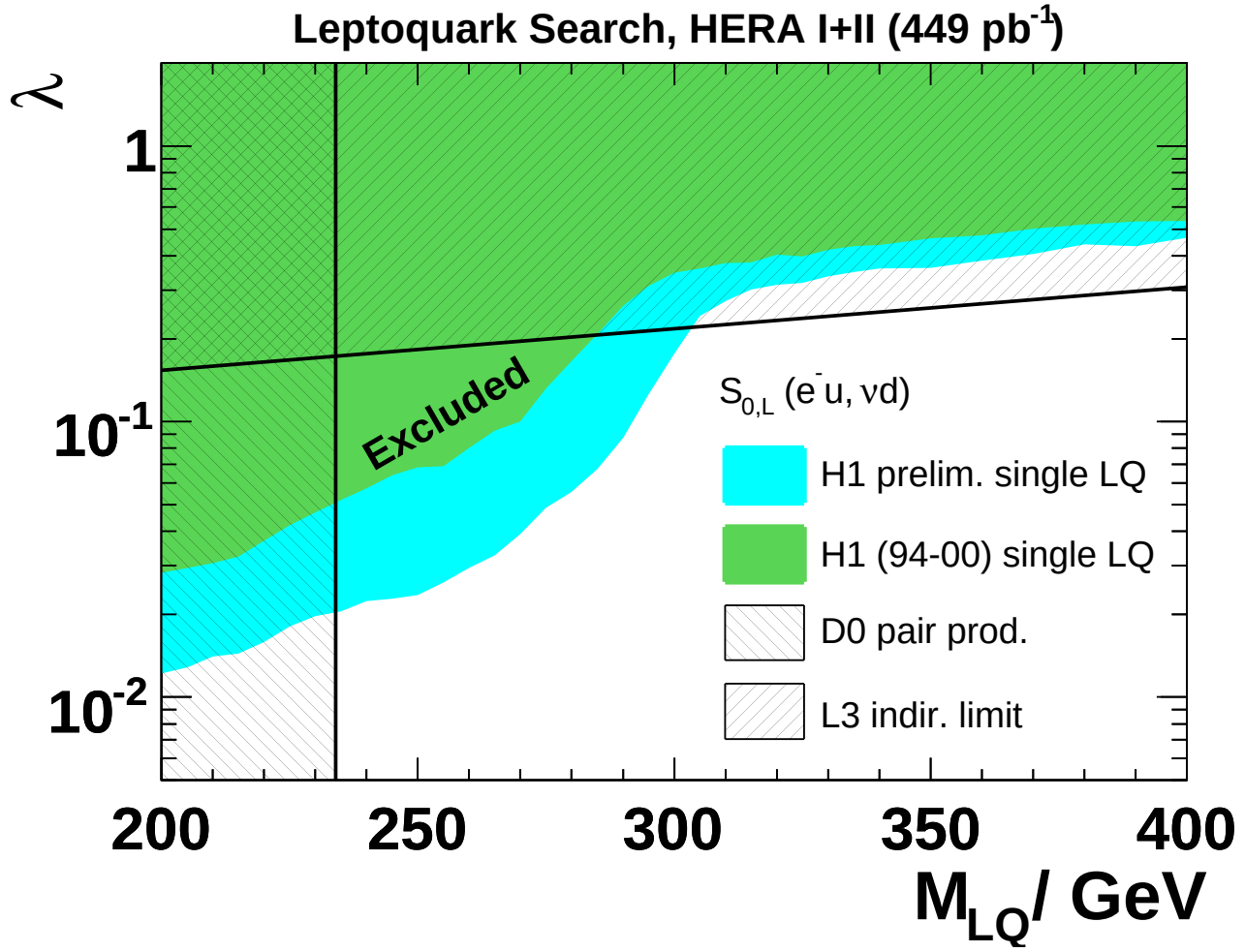
No excess seen in mass spectra (e-jet, ν-jet).

The use of polarization of both signs within the HERA II sample enhances the sensitivity to individual LQ species.





FIRST GENERATION LEPTOQUARKS-2



LEPTON FLAVOUR VIOLATION

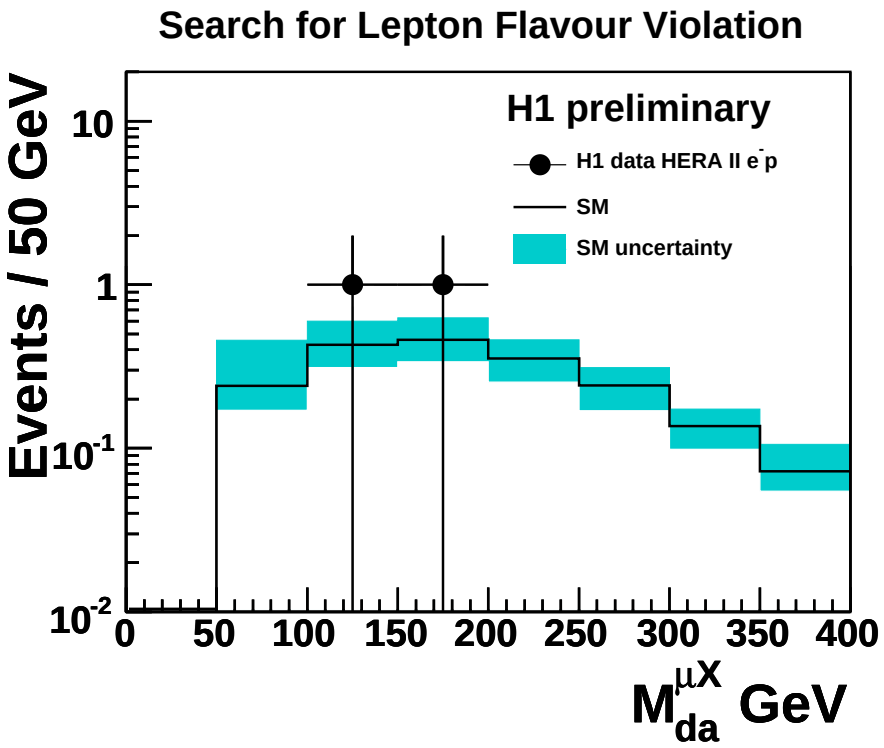
Mediated by LQs in family non-diagonal models.

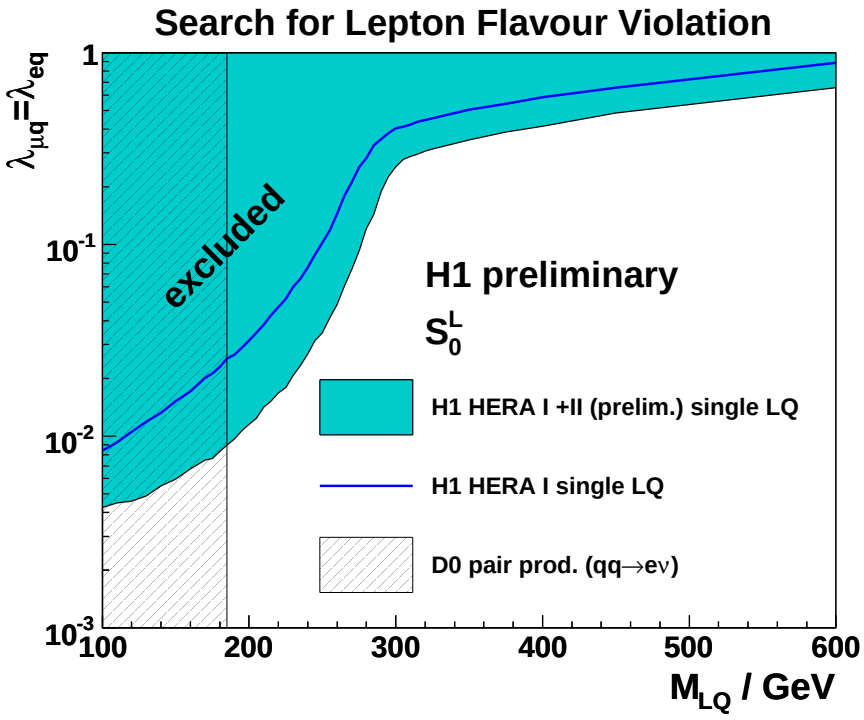
$e^{\pm}$ replaced by a μ or a τ in the final state.

H1 looked for $ep \to \mu X$ mediated by $F = 2$ LQ in $e^{-}p$ data.

Signature: isolated muon and jet, back to back in events with high missing Pt.

SM background: lepton pair production, real W, photoproduction, DIS.





EXCITED FERMIONS

Gauge mediated model for compositeness of fermions (Hagiwara et al.):
excited fermions with spin and isospin 1/2 with both left-handed, F_L^*, and right-handed components, F_R^*,in weak isodoublets.
Transitions between known fermions, F_L, and excited states F^*, magnetic de-excitation.
Λ compositeness scale. Parameters f, f' and f_s weight factors of the three gauge groups (U(1), SU(2), SU(3)). At least one of f, f' and f_s must be non-zero.
Relations between f, f' and f_s, fix branching ratios of excited-fermion decays; cross section then depends only on f/Λ.

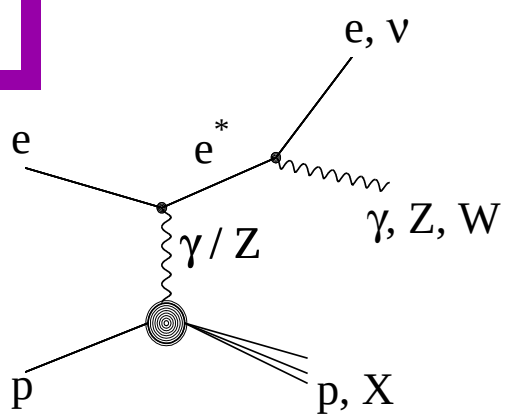
EXCITED ELECTRONS

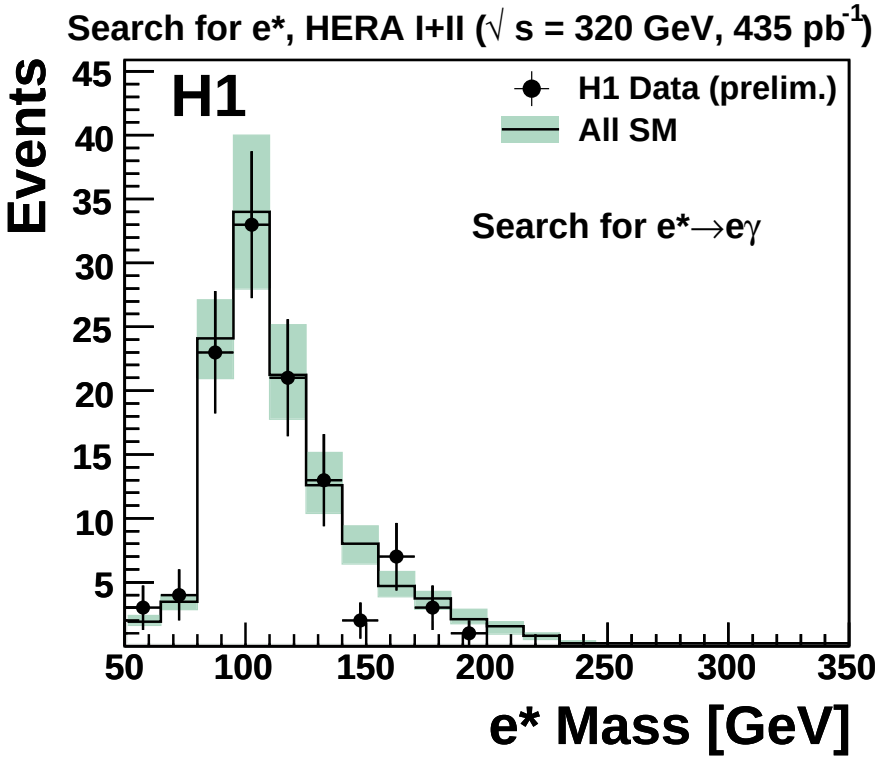
Looked for $e^* \to e\gamma$

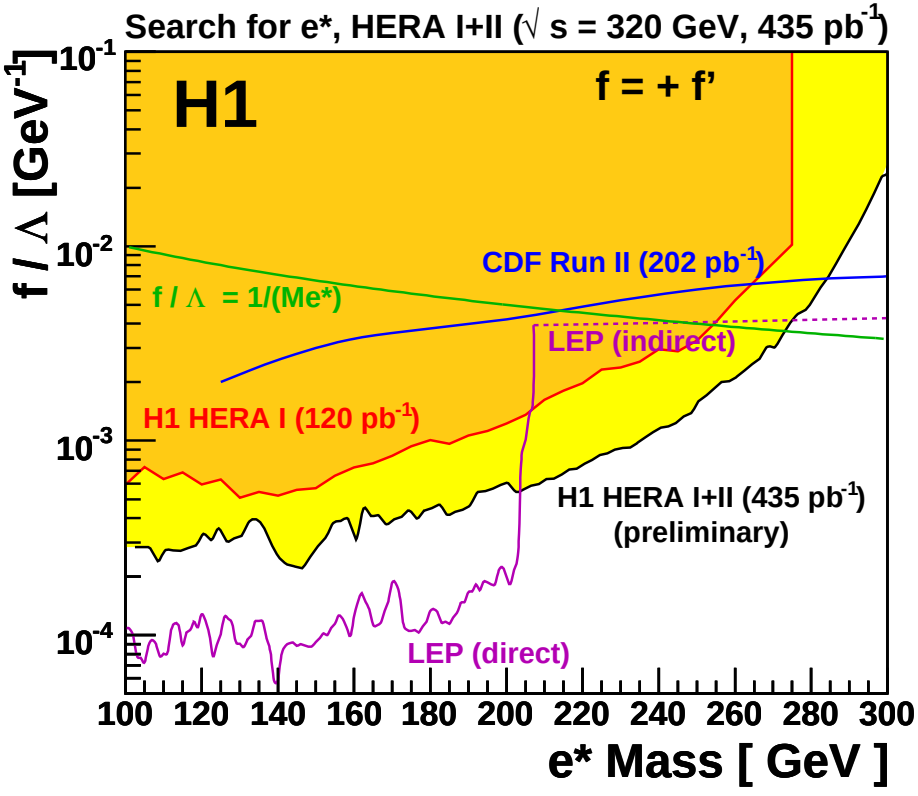
$e^* \to eZ$ with $Z \to q\bar{q}$

and $e^* \to \nu W$ with $W \to qq'$.

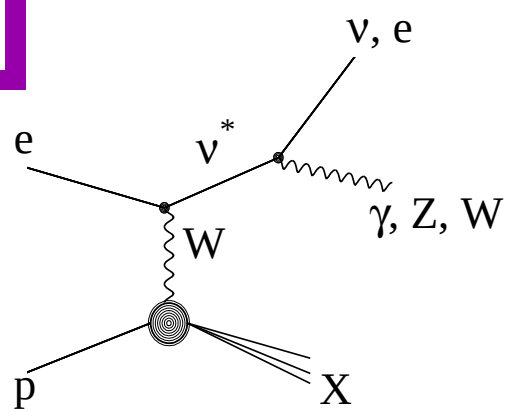
No evidence. Improved limits using HERA II.







EXCITED NEUTRINOS



Looked for $\nu^* \to \nu\gamma$

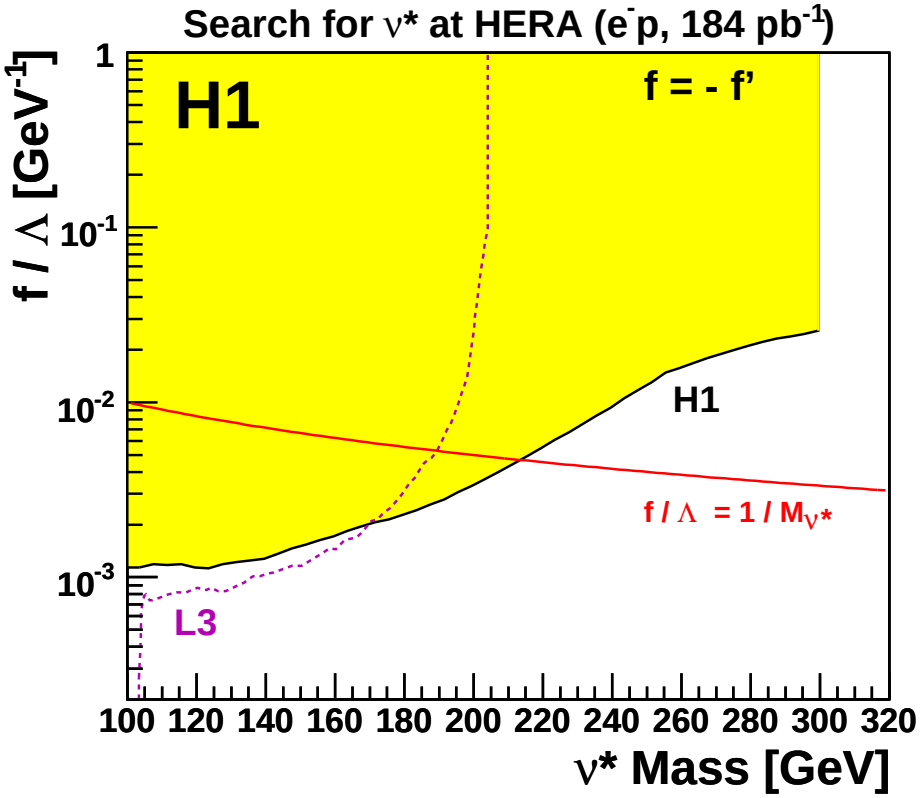
$\nu^* \to \nu Z$ with $Z \to q\bar{q}$

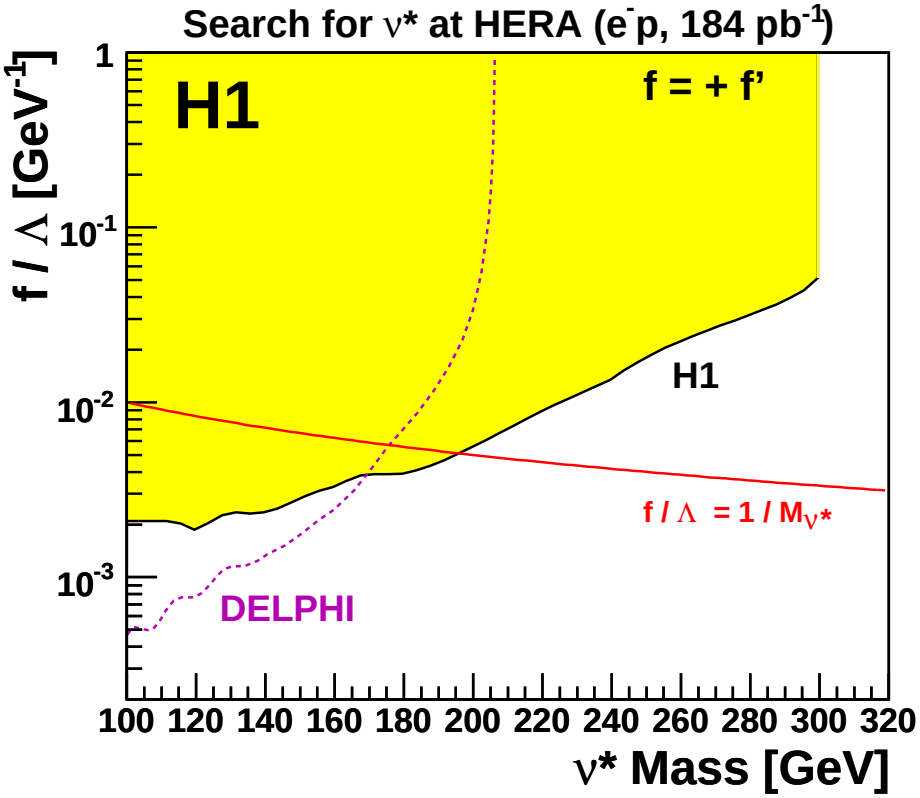
and $\nu^* \to eW$ with $W \to qq'$.

No evidence. Improved limits using HERA II.

$e^- p$ data have the advantage of enhancing the CC cross section.

H1 paper arxiv:0802.1858





ANOMALOUS TOP COUPLING

At HERA top quarks can only be singly produced. SM, single-top production proceeds due to (CC) reaction $ep \to \nu t\bar{b}\mathrm{X}$.

SM cross section at HERA is less than 1 fb $\Rightarrow$ any observed single-top event must come from physics beyond the SM.

FCNC reaction: incoming lepton exchanges a γ or Z with an up-type quark in the proton, yielding a top quark in the final state most sensitive to a coupling of the type $tq\gamma$.
u-quark dominant at large x $\Rightarrow$ production of single top quarks is most sensitive to a coupling of the type $tu\gamma$.

Deviations in terms of couplings of the type tuV (with $V = \gamma, Z_0$).

Effective Lagrangian contains magnetic coupling k_g and vector coupling v_z assumed to be real and positive. k_g and v_z zero at tree level and extremely small at the one-loop level in SM.

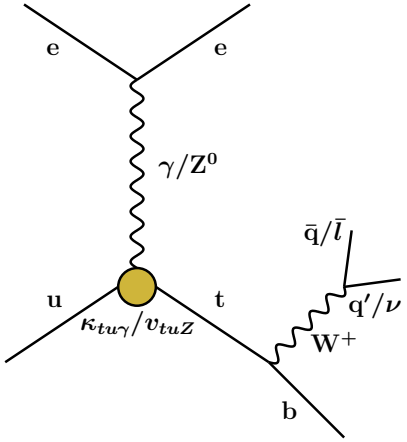
RESULTS

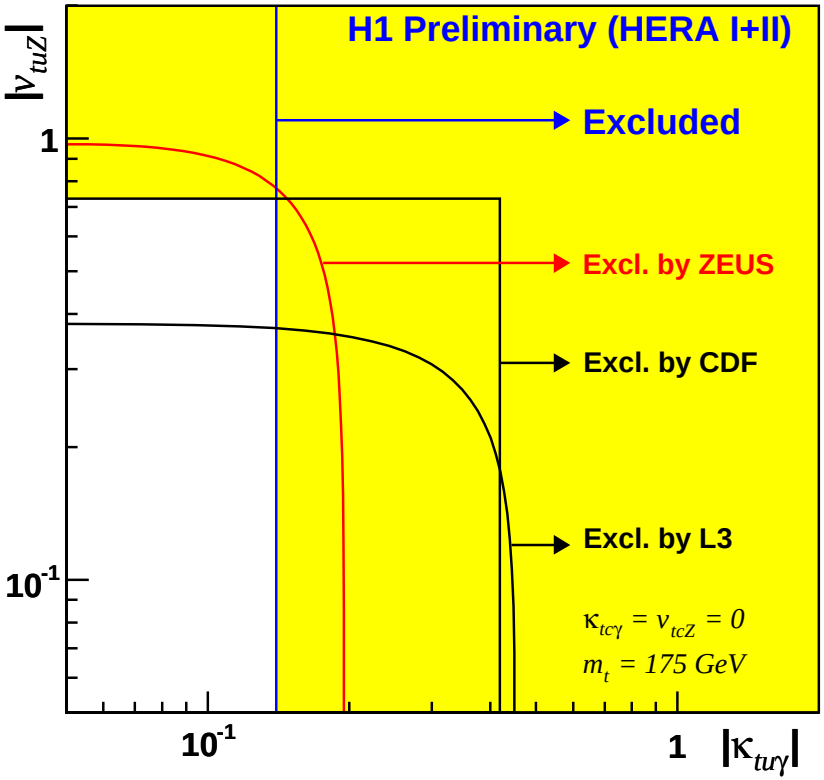
H1 searched for single top: $t \rightarrow bW$

$W \rightarrow e\, P_{Tmiss}$ jet $W \rightarrow \mu\, P_{Tmiss}$ jet

in a multivariate analysis

Background from SM : mainly real W production.

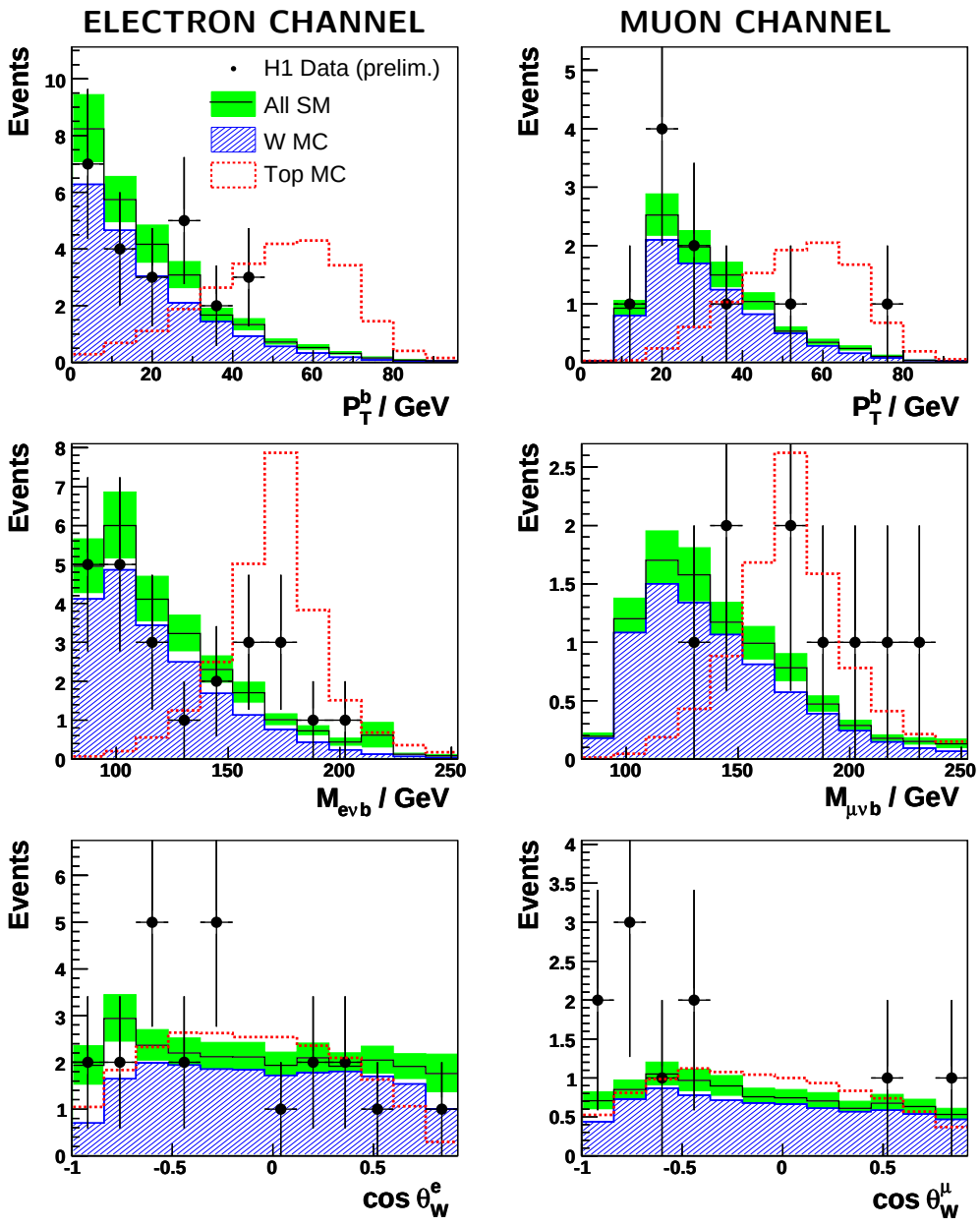




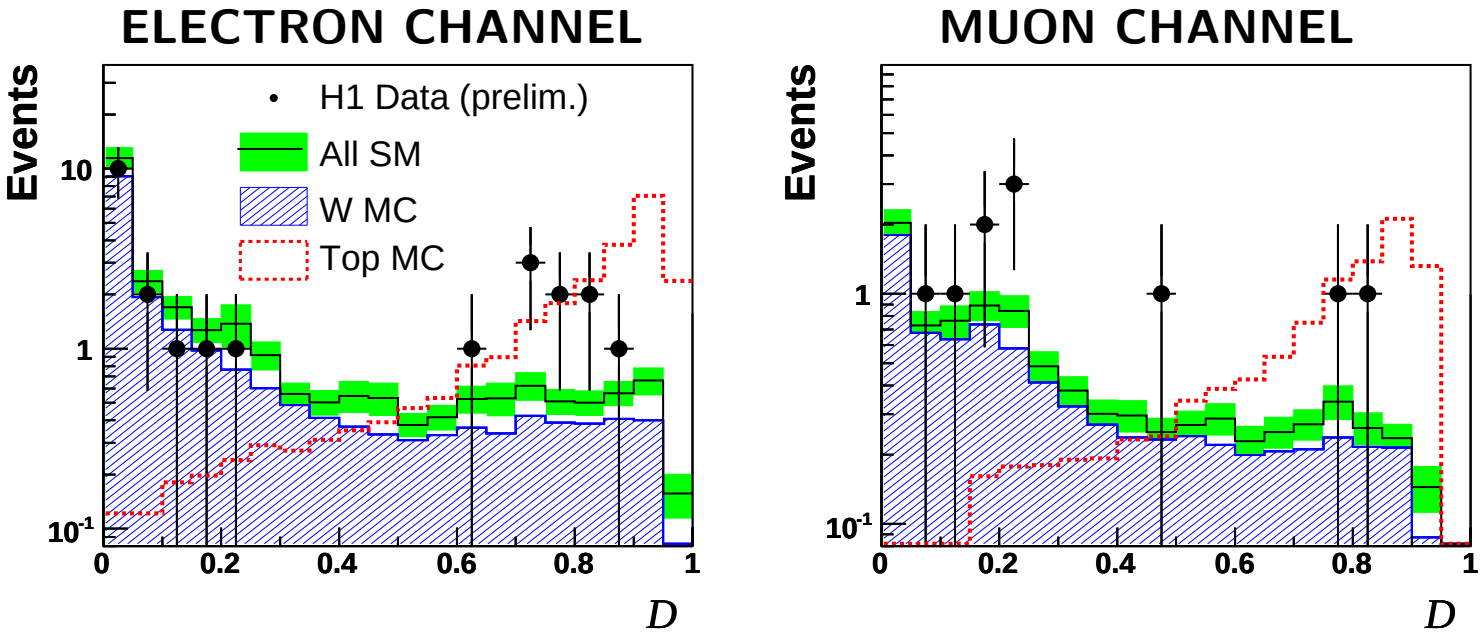
$\sigma_{ep \rightarrow etX} < 0.16$ pb

Most stringent limit to date: $k_{tu\gamma} < 0.14$

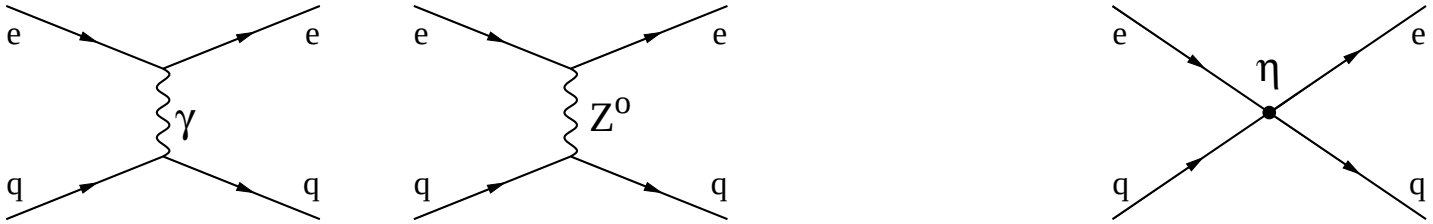
VARIABLES


ELECTRON CHANNEL
MUON CHANNEL
H1 Data (prelim.)
All SM
W MC
Top MC
Events
P_T^b / GeV
M_{evb} / GeV
$M_{\mu\nu b}$ / GeV
cos θ_W^e
cos θ_W^μ

DISCRIMINANT



CONTACT INTERACTIONS



4-fermion contact interactions (CI) describe effects from processes at much higher scales, which could alter the SM distributions at high Q^2 and interfere with the predictions at intermediate Q^2.

Vector terms (scalar and tensor are already costrained):

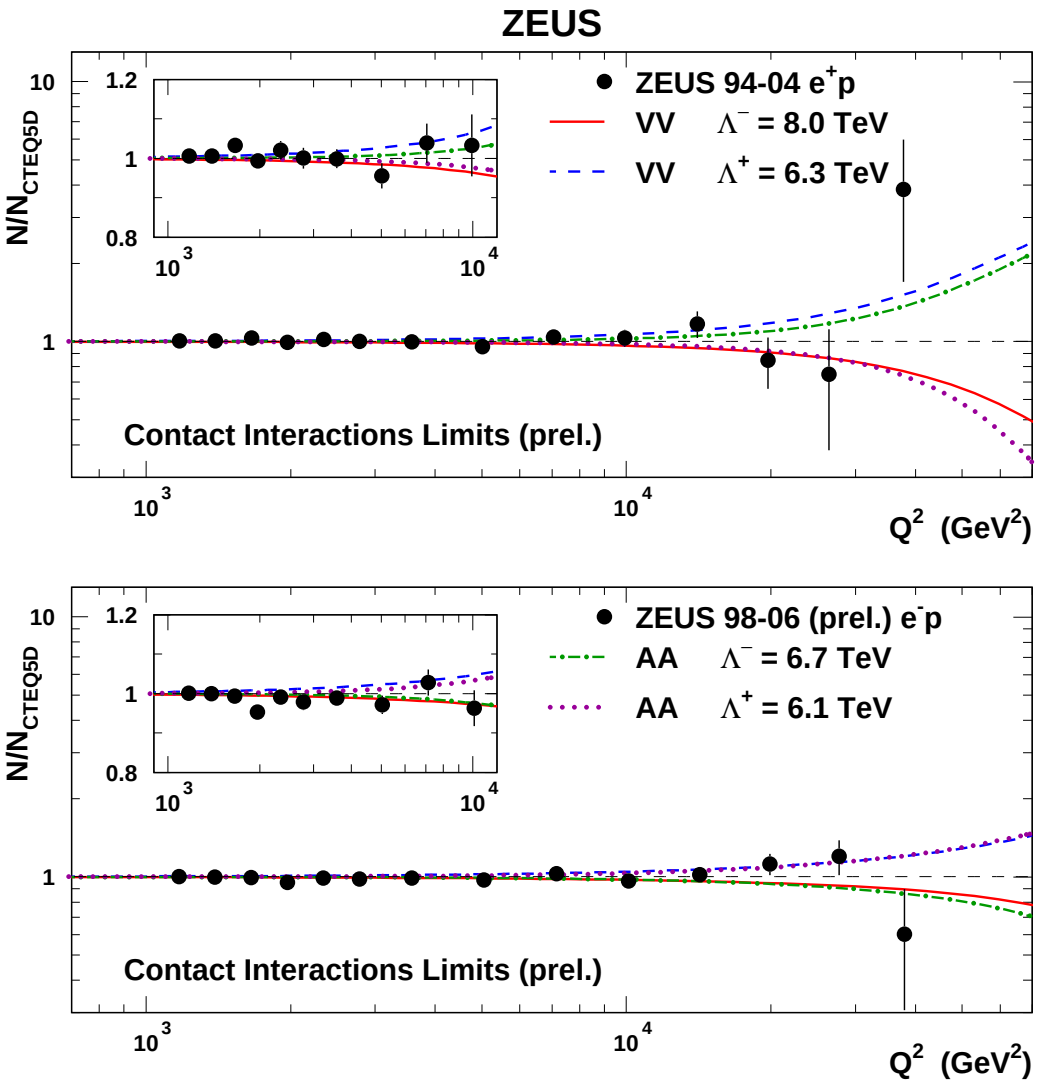
$$L_{CI} = \sum_{\alpha,\beta=L,R}^{q=u,d} \eta^q_{\alpha\beta}(\bar{e}_\alpha \gamma^\mu e_\alpha)(\bar{q}_\beta \gamma_\mu q_\beta)$$

$\eta_{\alpha\beta} = \epsilon \frac{g^2_{CI}}{\Lambda^2}$ define the structure of the model. $g_{CI} = 4\pi$ $\epsilon = \pm 1$

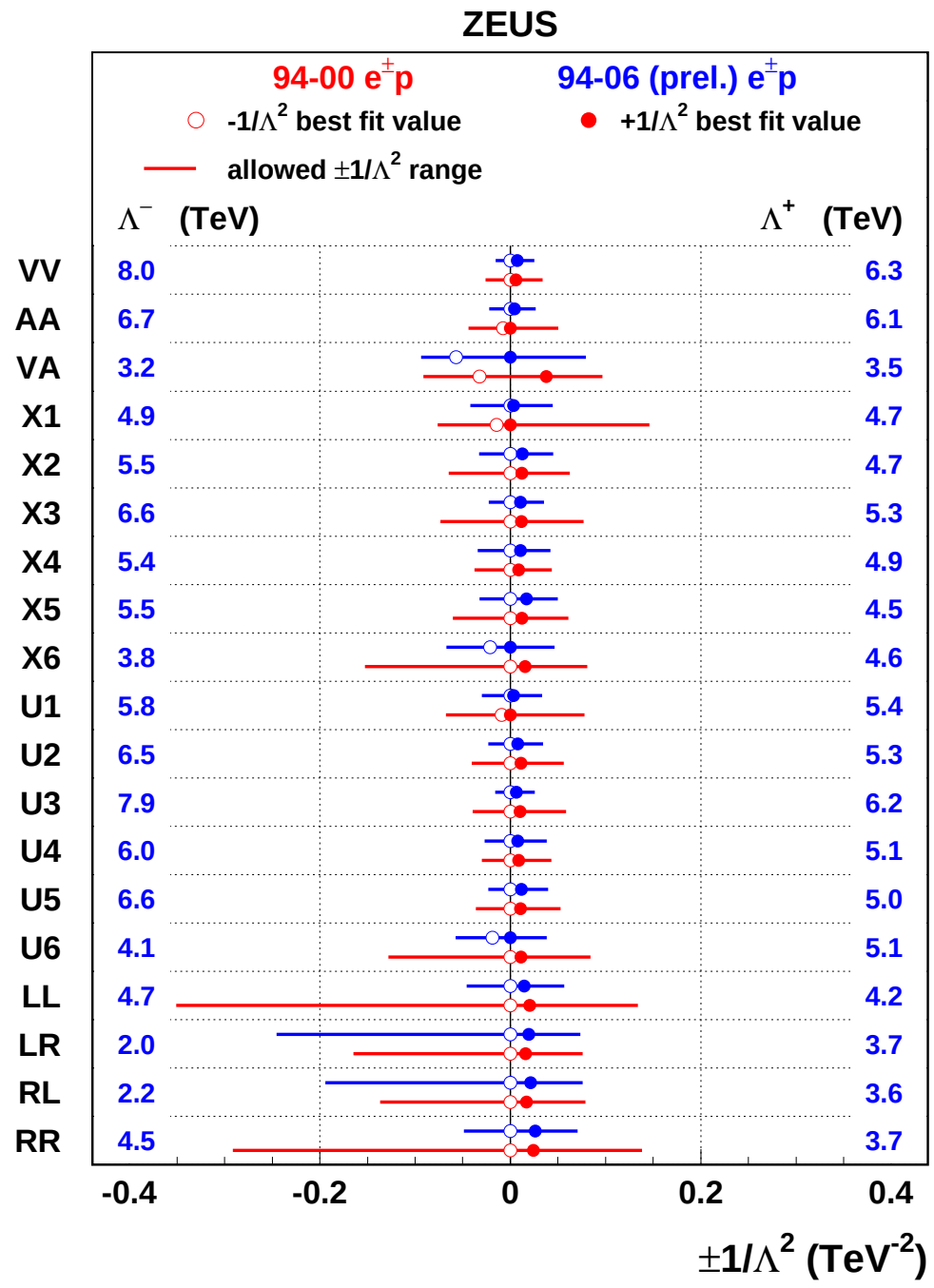
Contact interaction effects could come from the exchange of extra gauge bosons (Z'), production or exchange of leptoquarks or squarks, compositeness, gravitational effects or finite quark radius.

Contact Interaction scale

$$\eta_{\alpha\beta} = \pm\frac{1}{\Lambda^2}$$

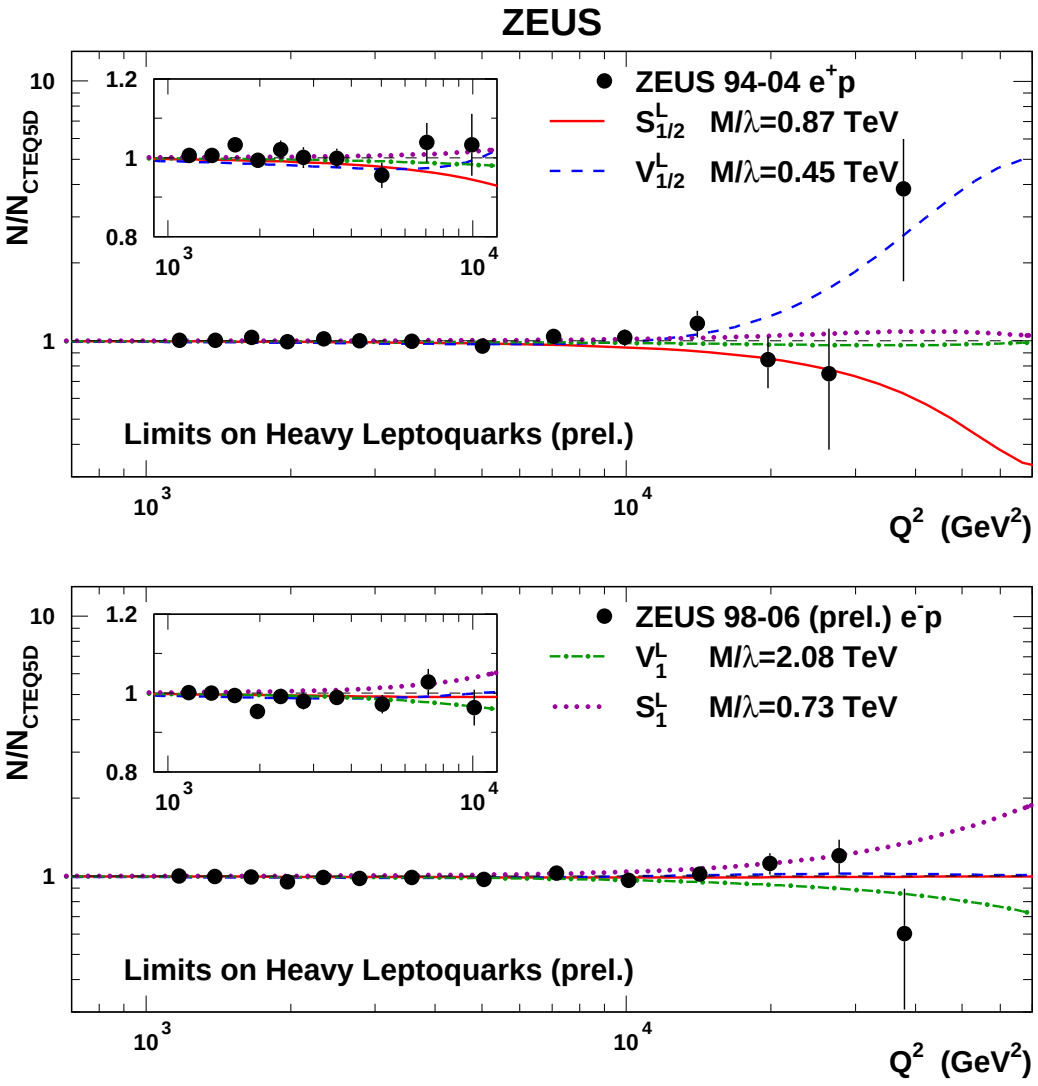


Limits for effective mass scale : Λ_{eeqq} 2.2-8.0 TeV



Heavy Leptoquarks

Limits on M_{LQ}/λ: 0.45-2.08 TeV



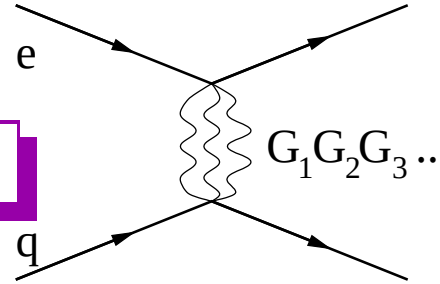
Large Extra Dimensions

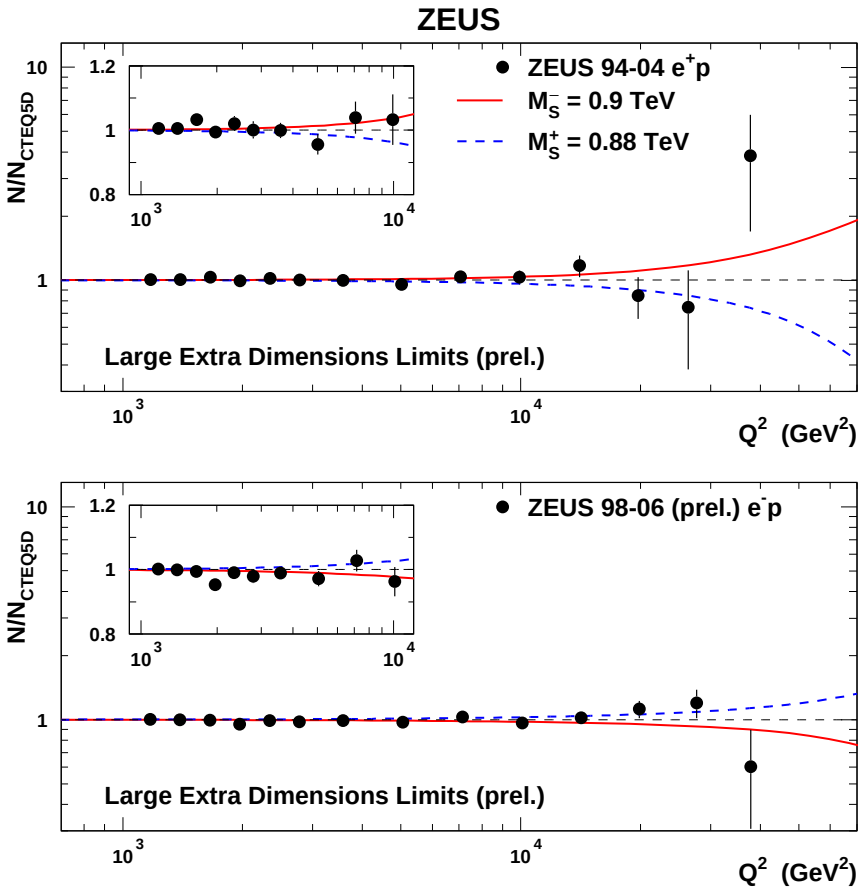
In some $4+n$ dimensional string theories (Arkani-Hamed-Dimopoulos-Dvali model) compactified extra dimensions have size $R \simeq 1$ mm. Effective Planck scale M_S related to $M_P \simeq 10^{19}$ GeV :

$$M_P^2 = M_S^{2+n} R^n$$

Graviton can propagate into the extra dimension, visible in the ordinary 4 dimensions as a Kaluza-Klein tower of excited states with spacing $\Delta m = \frac{1}{R}$. Such states can be summed up to M_S, give sizeable effects, equivalent to a contact interaction term $\eta^G = \frac{\lambda}{M_S^4}$ where $\lambda \simeq 1$ (Giudice, Rattazzi, Wells).
Interfence with Standard Model can be constructive or destructive.

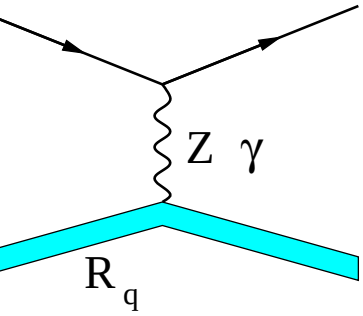
Limits on Mass Scale of Extra Dimensions





Limits on M_S

λ =-1	$M_S > 0.9$ TeV
λ =+1	$M_S > 0.88$ TeV
LEP, Tevatron	
limits	$\simeq 1$ TeV



Quark Radius-1

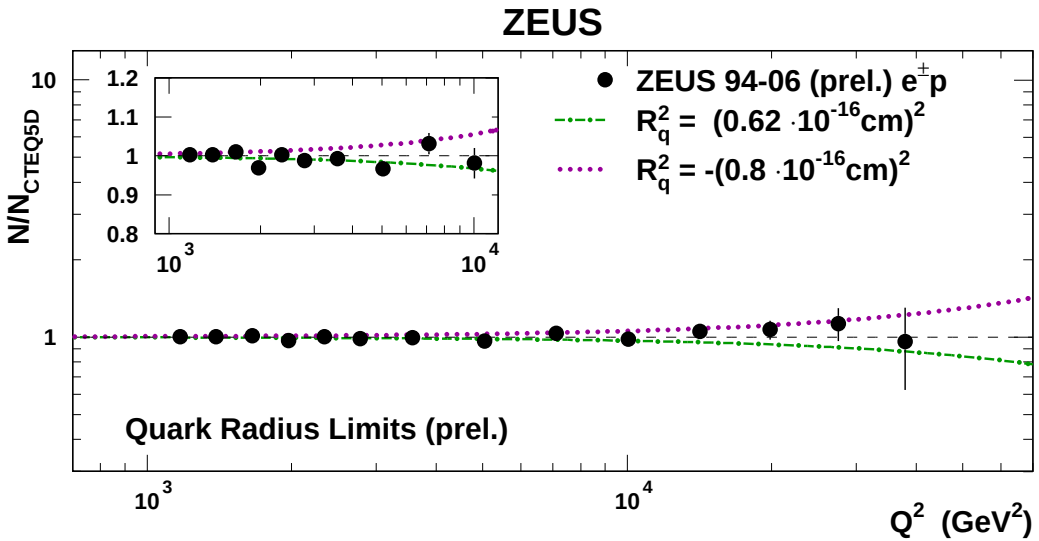
Classical approach to the search for quark substructure.

Charge distribution of radius R_q in the quark can be described using a form factor:

$$\frac{d\sigma}{dQ^2} = \frac{d\sigma^{SM}}{dQ^2} \cdot (1 - \frac{R_q^2}{6} \cdot Q^2)^2)$$

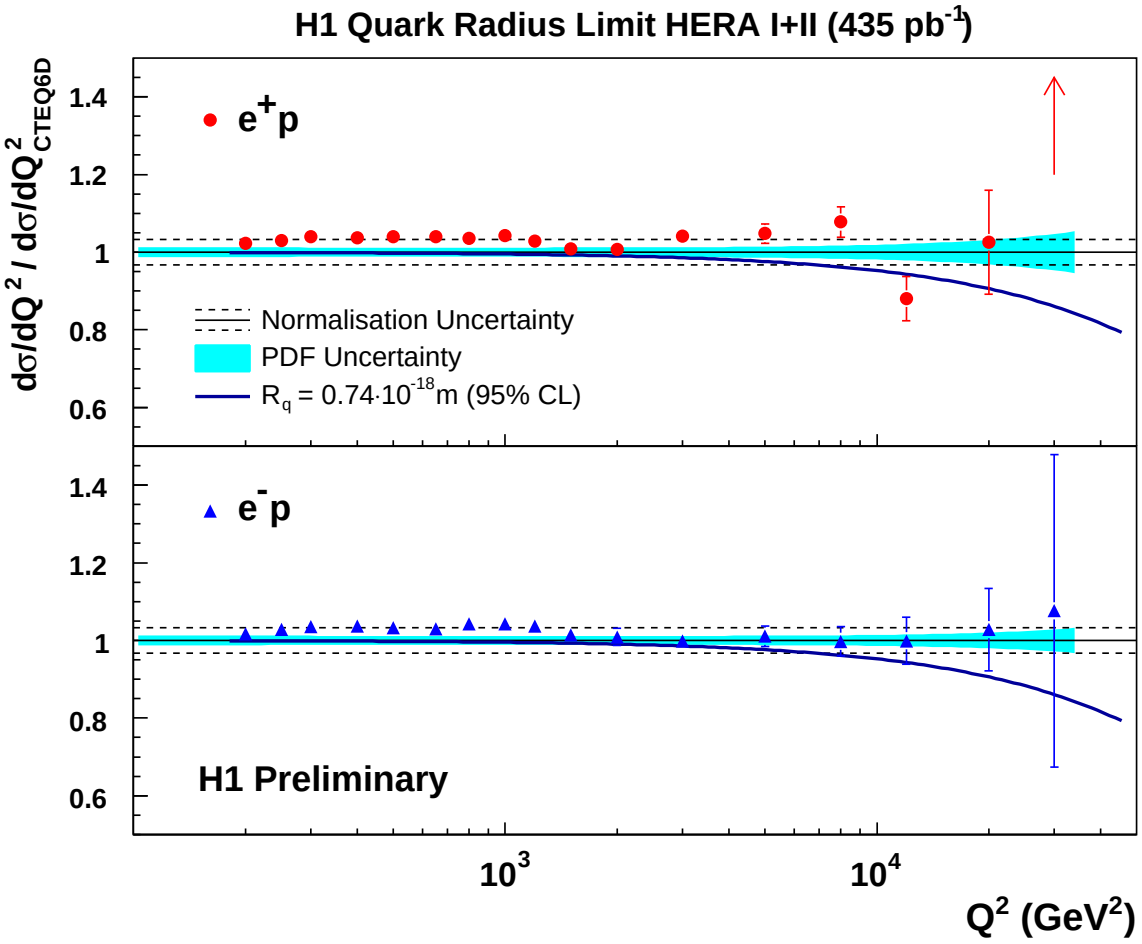
(assuming the electron to be pointlike)

This leads to a decrease of cross sections at high Q^2.



ZEUS $R_q < 0.62 \cdot 10^{-16}$ cm

Quark Radius-2



H1 $R_q < 0.74 \cdot 10^{-16}$ cm

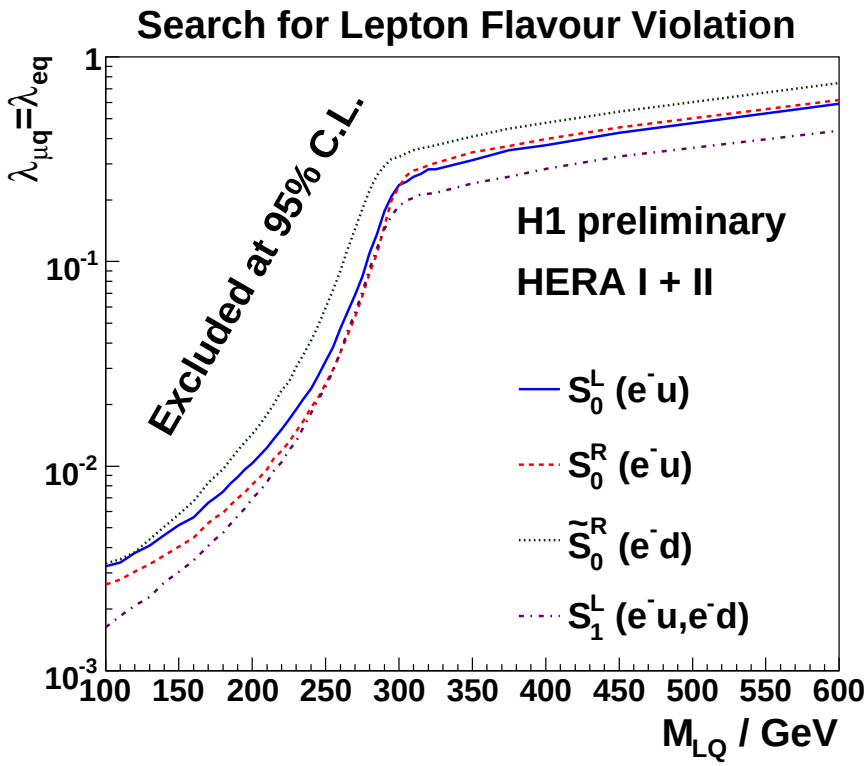
CONCLUSIONS

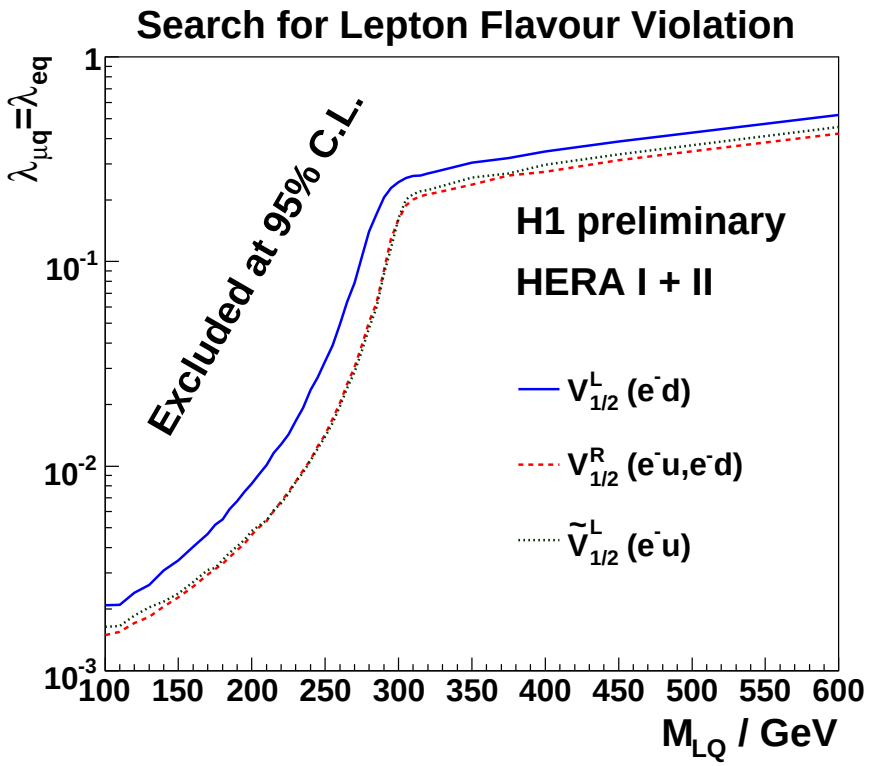
- Complete statistics of 15 years of HERA data taking can be exploited to improve the sensitivity of the searches for new physics in a unique environment.
- H1 and ZEUS at HERA have performed a number of model dependent searches finding no evidence for Leptoquarks or Lepton Flavor Violation, for excited electrons or excited neutrinos. New limits on the anomalous top coupling were set studying the production of single top. And limits on the contact interaction scales and quark radius were updated fitting the DIS differential cross sections at high Q^2.
- Further improvements expected from using the whole HERA II luminosity
- Combination of H1 and ZEUS data for some of these searches is underway.

BACKUP SLIDES

LEPTON FLAVOUR VIOLATION-2

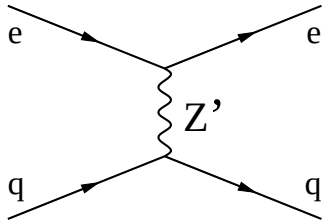
Limits on coupling vs mass for scalar and vector LQs mediating LFV.

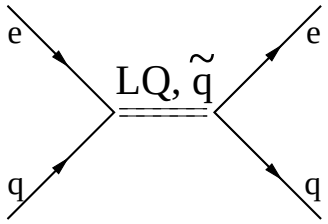




Contact Interaction sources

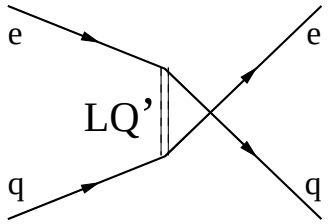
Exchange of extra gauge bosons

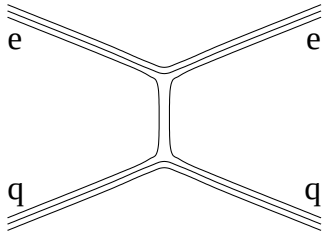




Production of LQ, squark

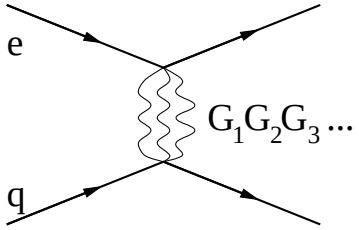
Exchange of LQ

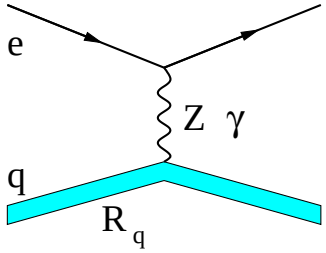




Compositeness

Gravitational effects





Quark radius