Contact Interactions and Future Prospects for High Energy Physics

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Outline

- Introduction
- Model
- **Data**
- Results
- **Predictions**
- Summary

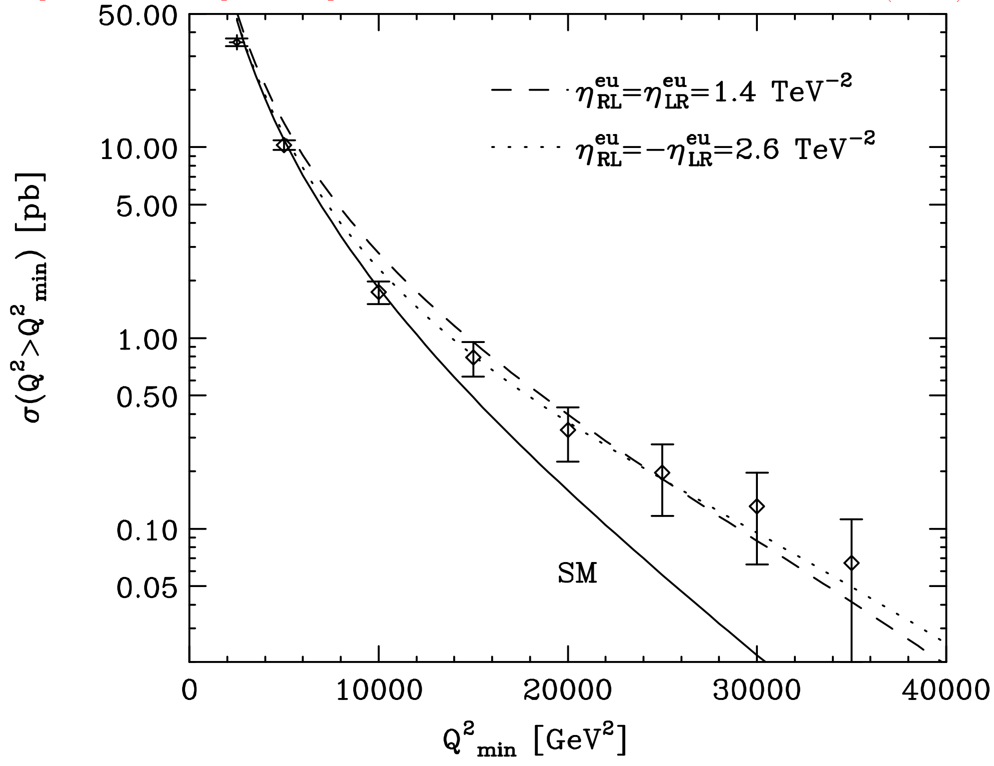
Introduction

HERA High-Q^2 results 1994-96

H1 and ZEUS experiments reported an excess of events in e^+p NC DIS at very high momentum transfer scales Q^2, as compared with the predictions of the Standard Model.

This excess can be described as resulting from new eq (contact) interactions.

V.Barger, K.Cheung, K.Hagiwara, D.Zeppenfeld, Phys. Lett. B404 (1997) 147.



Contact Interactions with mass scales of the order of 2 TeV would be required to describe HERA data.

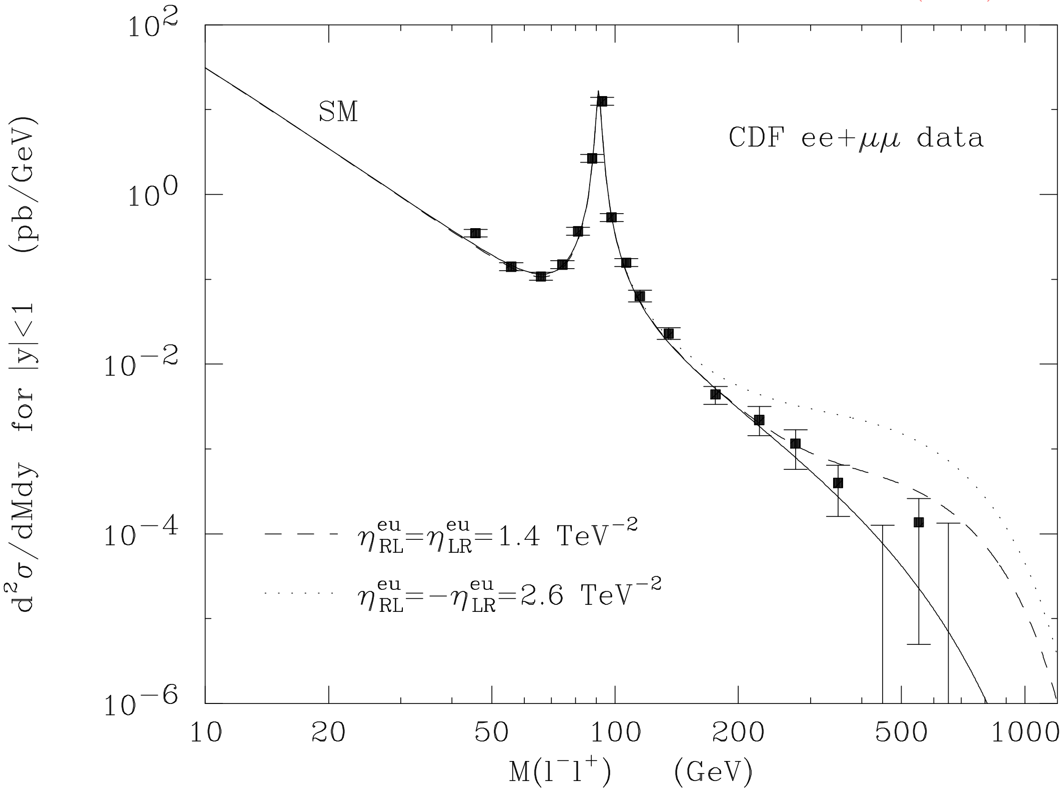
Introduction

Comparison to other experiments

New interactions should also produce visible effects at other experiments.

Drell-Yan lepton-pair production at the Tevatron :

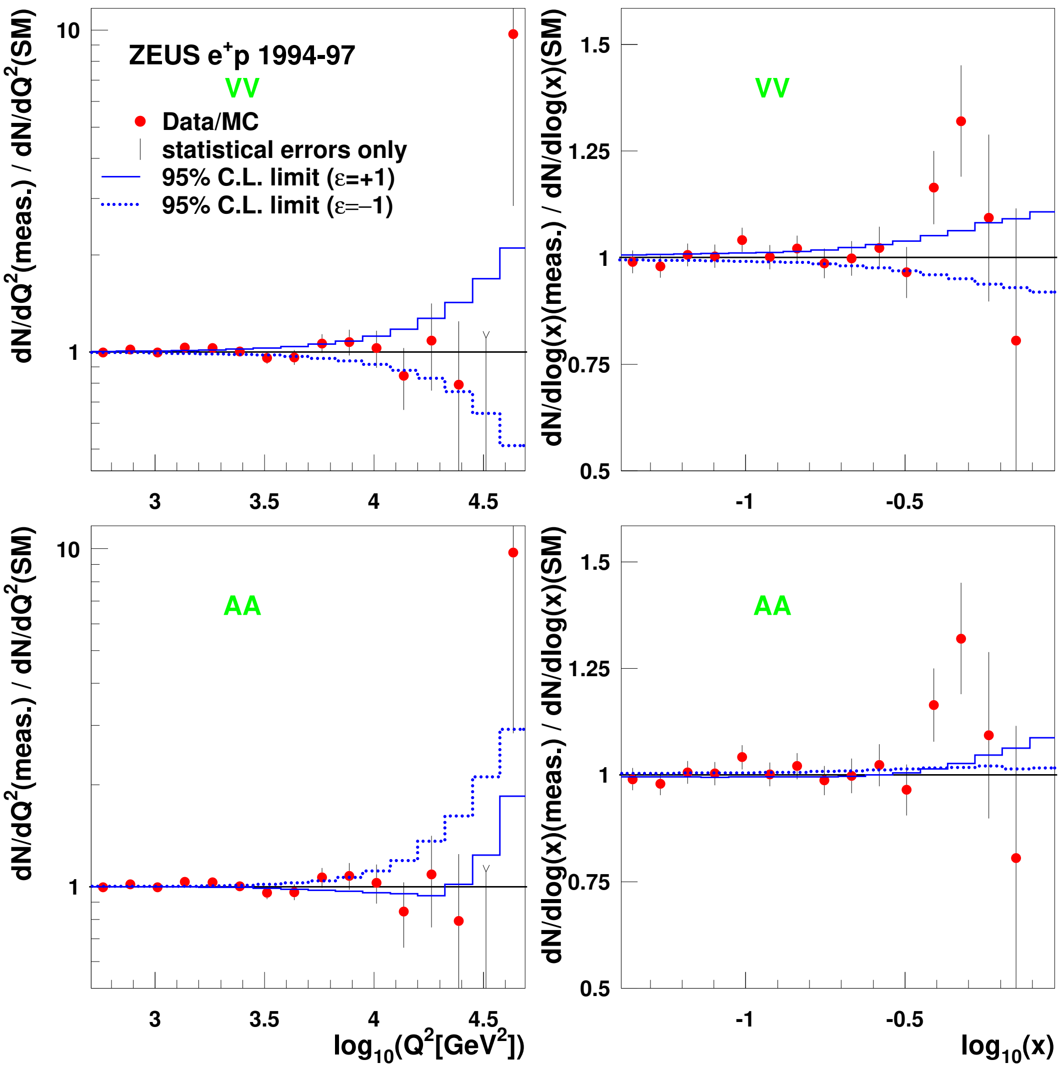
V.Barger, K.Cheung, K.Hagiwara, D.Zeppenfeld, Phys. Lett. B404 (1997) 147.



Data are consistent with the Standard Model predictions.

Introduction

New ZEUS results



Contact Interaction model applied to ZEUS data is able to describe the excess of events still visible in the last Q^2 bin.

On the other hand, the data (fit results for all models) are consistent with the Standard Model on the 95% CL.

Introduction

Is "High-Q^2 effect" real ?...
Or is it just a statistical fluctuation ?...

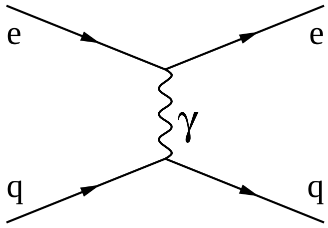
The aim of this analysis

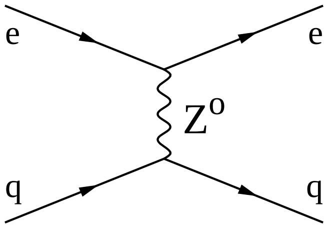
- Use all available experimental data
  HERA, Tevatron, LEP...
- Verify consistency with the Standard Model
- Extract most general constraints on the mass scale
  of the new interactions
- Calculate limits on the possible effects to be observed in future HERA, LEP and Tevatron running.

Model

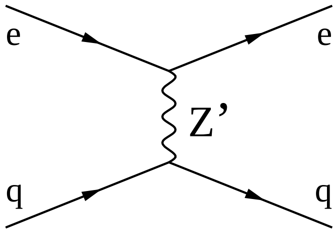
Neutral Current eq Scattering

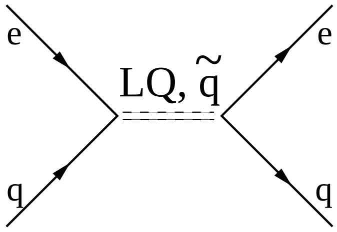
Two processes contribute in the Standard Model :

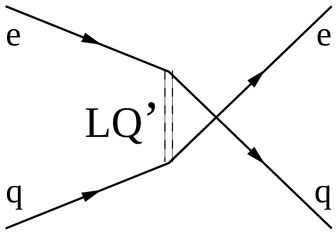


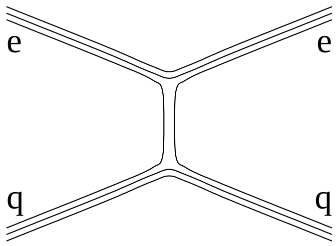


Possible “new physics” processes:

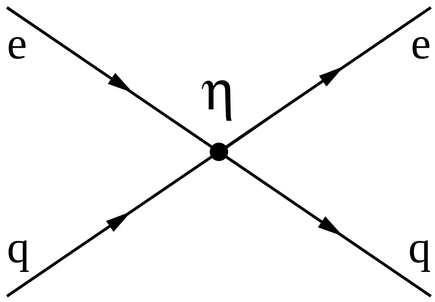








For energies much smaller than their characteristic energy scale Λ these processes can be parameterized as:



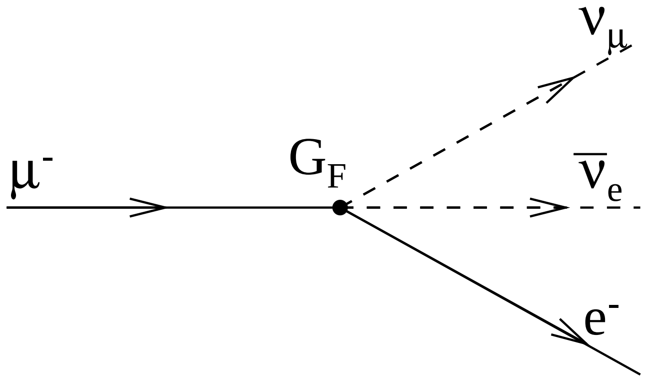
$eeqq$ contact interactions (CI)

Model

Fermi's model

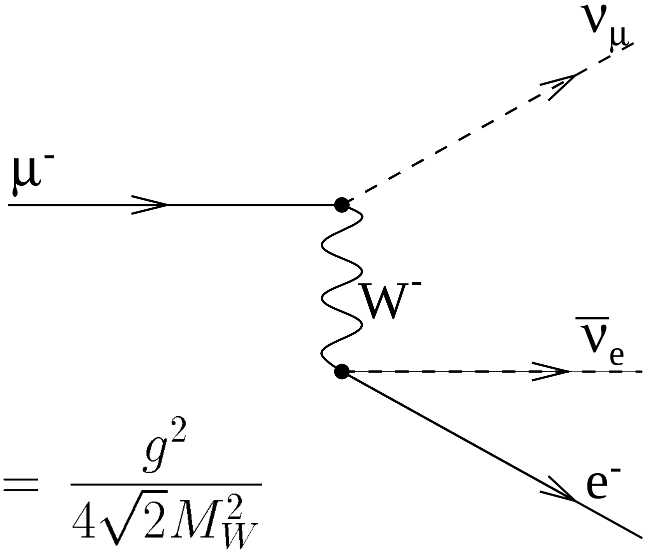
Four-fermion contact interactions are not a new idea. In 1932 Fermi has introduced a very successful model of weak interactions.

μ decay in Fermi's model:



Fermi's model is an effective theory properly describing weak processes at energy scales much smaller than M_W^2.

μ decay in Weinberg-Salam-Glashow model:



$$G_F = \frac{g^2}{4\sqrt{2}M_W^2}$$

Model

Contact Interactions

Effective Lagrangian for vector $eeqq$ contact interactions:

$$\mathcal{L}_{CI} = \sum_{\substack{\alpha,\beta=L,R \\ q}} \eta^{eq}_{\alpha\beta} \cdot (\bar{e}_\alpha \gamma^\mu e_\alpha)(\bar{q}_\beta \gamma_\mu q_\beta)$$

Scalar and tensor terms are constrained beyond sensitivity of collider experiments.

Contact Interactions modify $eq \rightarrow eq$ scattering amplitudes $M^{eq}_{\alpha\beta}$.
At tree level:

$$M^{eq}_{\alpha\beta}(Q^2) = \frac{e^2 e_q}{Q^2} - \frac{e^2}{sin^2\theta_W \cdot cos^2\theta_W} \cdot \frac{g^e_\alpha g^q_\beta}{Q^2 + m^2_Z} + \eta^{eq}_{\alpha\beta}$$

$\eta^{eq}_{\alpha\beta}$ - 4 possible vector CI couplings for every flavour q

New couplings $\eta^{eq}_{\alpha\beta}$ are then related to the energy scale of "new physics" Λ by the formula:

$$\eta = \frac{\varepsilon \cdot g^2_{CI}}{\Lambda^2}$$

where g_{CI} is the coupling strength of new interactions and $\varepsilon = \pm 1$.

By convention we set $g^2_{CI} = 4\pi$.

Model

One parameter models

It is a common practice to consider one-parameter models , which assume different relations between separate couplings:

Model	η^{ed}_{LL}	η^{ed}_{LR}	η^{ed}_{RL}	η^{ed}_{RR}	η^{eu}_{LL}	η^{eu}_{LR}	η^{eu}_{RL}	η^{eu}_{RR}
VV	$+\eta$	$+\eta$	$+\eta$	$+\eta$	$+\eta$	$+\eta$	$+\eta$	$+\eta$
AA	$+\eta$	$-\eta$	$-\eta$	$+\eta$	$+\eta$	$-\eta$	$-\eta$	$+\eta$
VA	$+\eta$	$-\eta$	$+\eta$	$-\eta$	$+\eta$	$-\eta$	$+\eta$	$-\eta$
X1	$+\eta$	$-\eta$			$+\eta$	$-\eta$		
X2	$+\eta$		$+\eta$		$+\eta$		$+\eta$	
X3	$+\eta$			$+\eta$	$+\eta$			$+\eta$
X4		$+\eta$	$+\eta$			$+\eta$	$+\eta$	
X5		$+\eta$		$+\eta$		$+\eta$		$+\eta$
X6			$+\eta$	$-\eta$			$+\eta$	$-\eta$
U1					$+\eta$	$-\eta$		
U2					$+\eta$		$+\eta$	
U3					$+\eta$			$+\eta$
U4						$+\eta$	$+\eta$	
U5						$+\eta$		$+\eta$
U6							$+\eta$	$-\eta$

ZEUS

All models conserve parity:

$$\eta^{eq}_{LL} + \eta^{eq}_{LR} - \eta^{eq}_{RL} - \eta^{eq}_{RR} \;=\; 0$$

Using data from different experiments it is also possible to consider models with many independent parameters .

Model

Contact interactions introduce 4 couplings for every lepton-quark pair.

Three multi-parameter models are considered

General (First-generation) Model

- 8 u-e and d-e couplings can vary independently,
- all other couplings (for s, c, b, t, μ, τ) assumed to vanish.

Model with Family Universality

Assume lepton universality:

$$\eta^{eq}_{ij} = \eta^{\mu q}_{ij} = \eta^{\tau q}_{ij}$$

and quark family universality:

$$\begin{aligned} \eta^{eu}_{ij} &= \eta^{ec}_{ij} = \eta^{et}_{ij} \\ \eta^{ed}_{ij} &= \eta^{es}_{ij} = \eta^{eb}_{ij} \end{aligned}$$

Model with $SU(2)_L \times U(1)_Y$ Universality

Impose $SU(2)_L \times U(1)_Y$ gauge invariance of the Standard Model.
Reduces number of free model parameters from 8 to 7:

$$\eta^{eu}_{RL} = \eta^{ed}_{RL}$$

Relates $eeqq$ and $\nu\nu qq$ couplings:

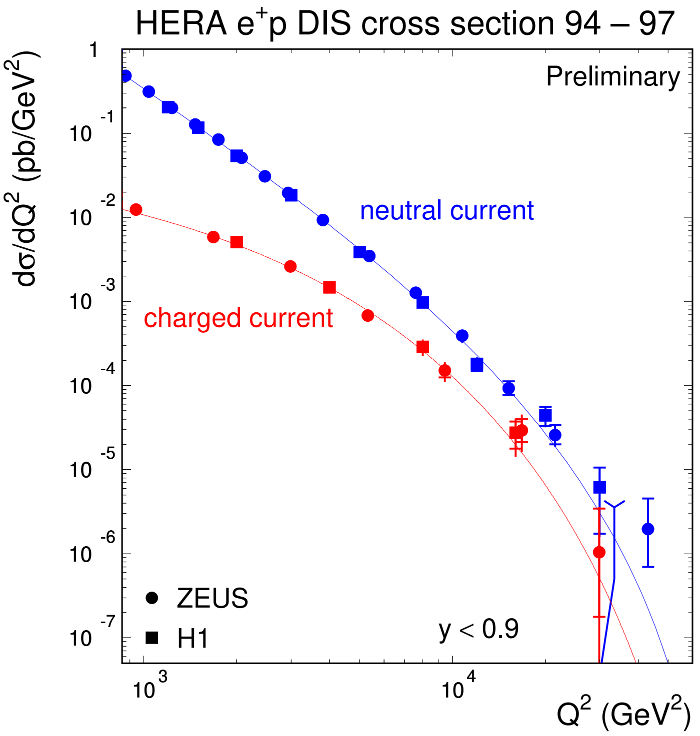
$$\begin{aligned} \eta^{\nu u}_{LL} &= \eta^{ed}_{LL} \\ \eta^{\nu d}_{LL} &= \eta^{eu}_{LL} \\ \eta^{\nu u}_{LR} &= \eta^{eu}_{LR} \\ \eta^{\nu d}_{LR} &= \eta^{ed}_{LR} \end{aligned}$$

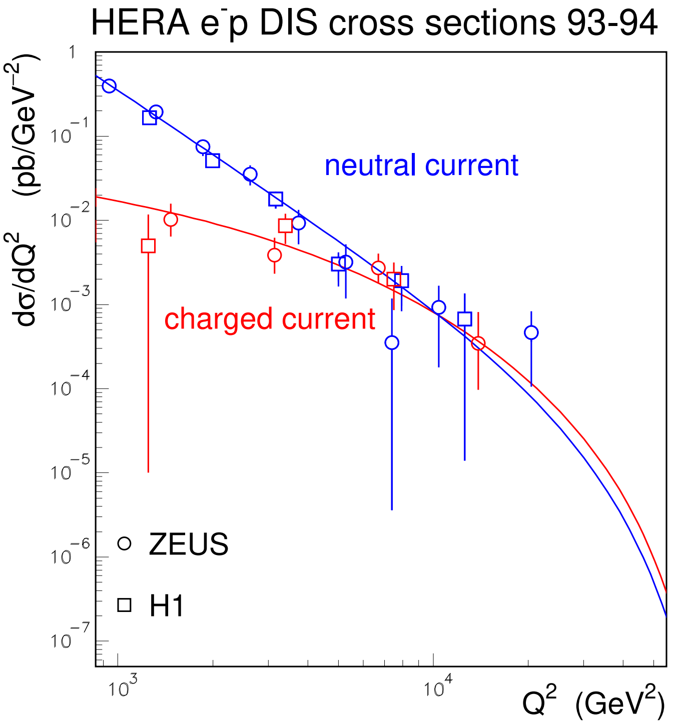
Induces charged-current contact interaction $e\nu qq'$:

$$\eta^{CC} = \eta^{ed}_{LL} - \eta^{eu}_{LL}$$

Data Samples

HERA $e^{\pm}p$ data





Data Samples

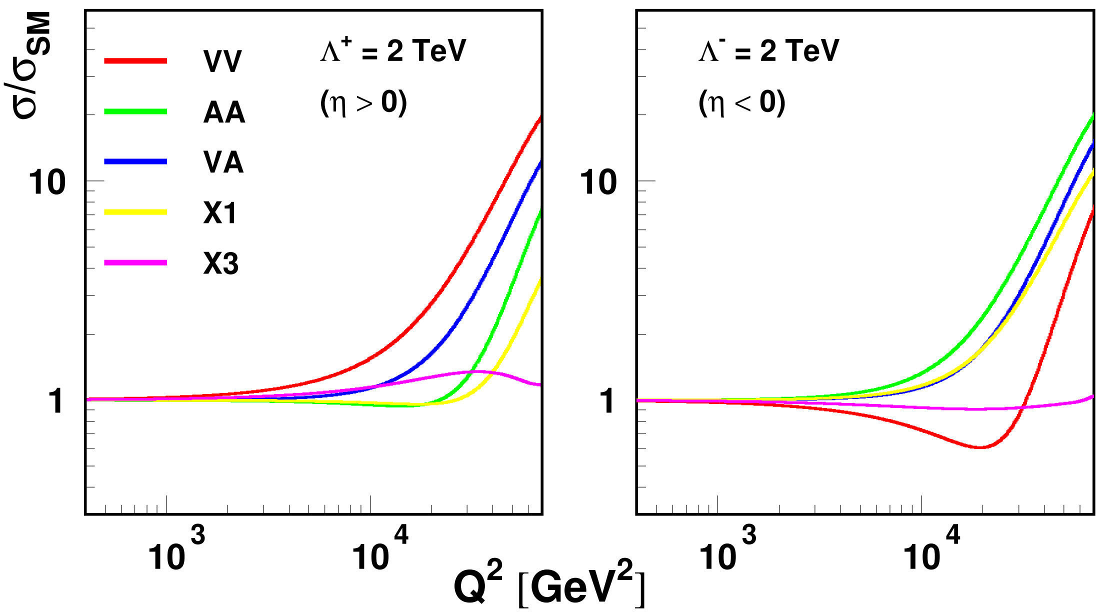
HERA $e^{\pm}p$ data

NC e^+p DIS cross section:

$$\frac{d^2\sigma^{e^+p}}{dxdy} = \frac{sx}{16\pi}\sum_q q(x)\left\{|M^{eq}_{LR}|^2 + |M^{eq}_{RL}|^2 + (1-y)^2\left[|M^{eq}_{LL}|^2 + |M^{eq}_{RR}|^2\right]\right\}$$
$$+ \ \bar{q}(x)\left\{|M^{eq}_{LL}|^2 + |M^{eq}_{RR}|^2 + (1-y)^2\left[|M^{eq}_{LR}|^2 + |M^{eq}_{RL}|^2\right]\right\}$$

We are most sensitive to η^{eq}_{LR} and η^{eq}_{RL} (q=u,d) .

CI modify the Q^2 dependence of the scattering amplitude $M^{eq}_{\alpha\beta}(Q^2)$. This has "direct" influence on the cross-section $\frac{d\sigma}{dQ^2}$:

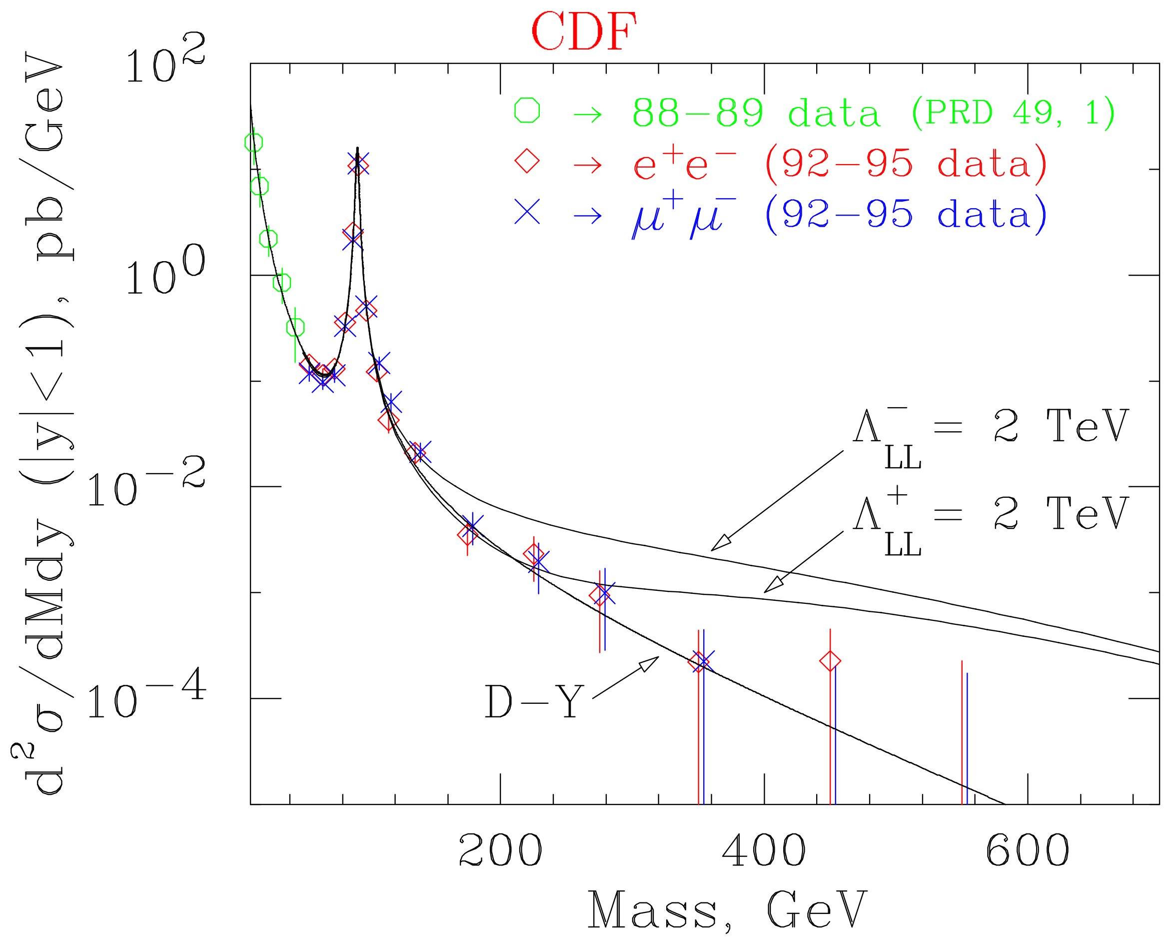


Pure CI term always results in the cross-section increase at high Q^2. Decrease of the cross-section is due to CI-SM interference terms.

Used in the analysis are also data on NC e^-p DIS (1993-94) and CC e^+p DIS (for SU(2) model).

Data Samples

Lepton pair production at the Tevatron



For Drell-Yan cross section:

$$\frac{d^2\sigma^{LO}}{dMdy} = \frac{KM^3}{72\pi s} \sum_q q(x_1)q(x_2) \sum_{\alpha,\beta} |M^{eq}_{\alpha\beta}|^2$$

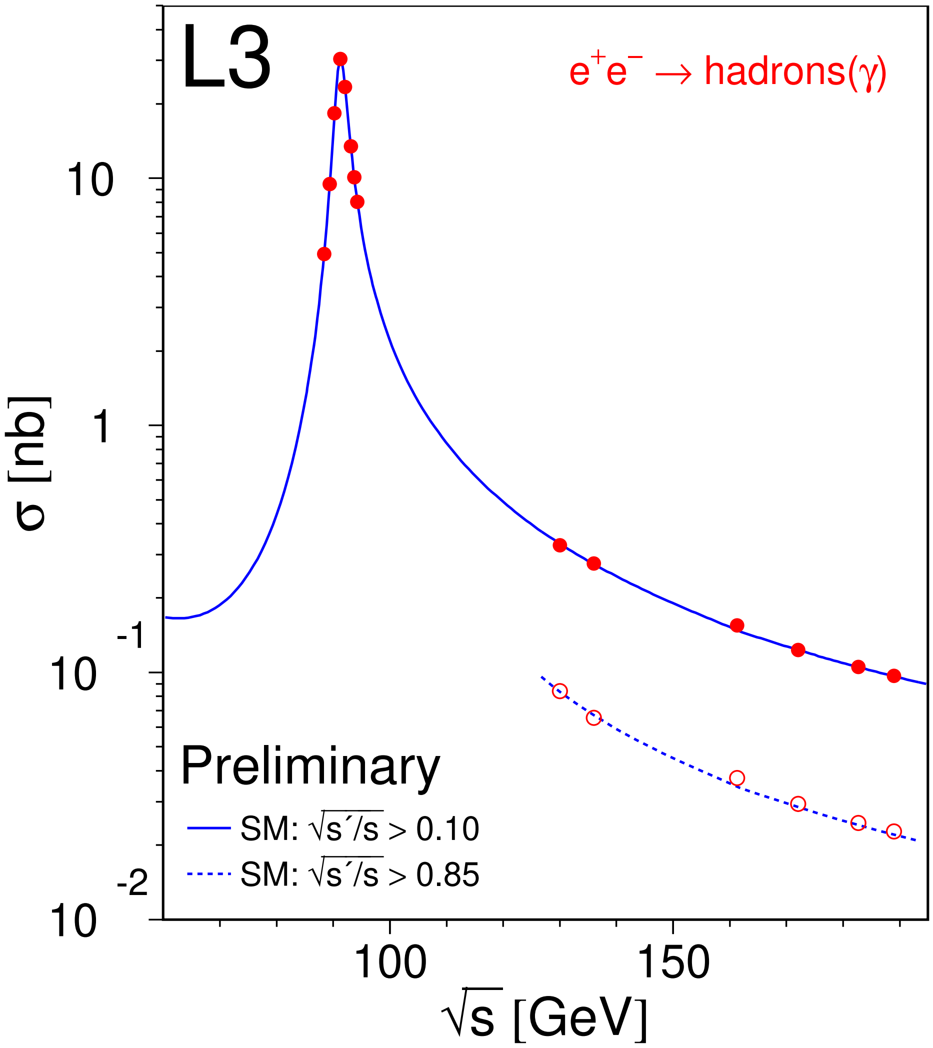
Sensitive to all $\eta^{eq}_{\alpha\beta}$.
However, as for HERA, q=u,d dominate.

Muon pair production included for models with family universality.

Data Samples

LEP hadronic cross-section

All 4 LEP experiments have presented σ_{had} measurements for $\sqrt{s}$ up to 189 GeV.



Quark pair production cross section:

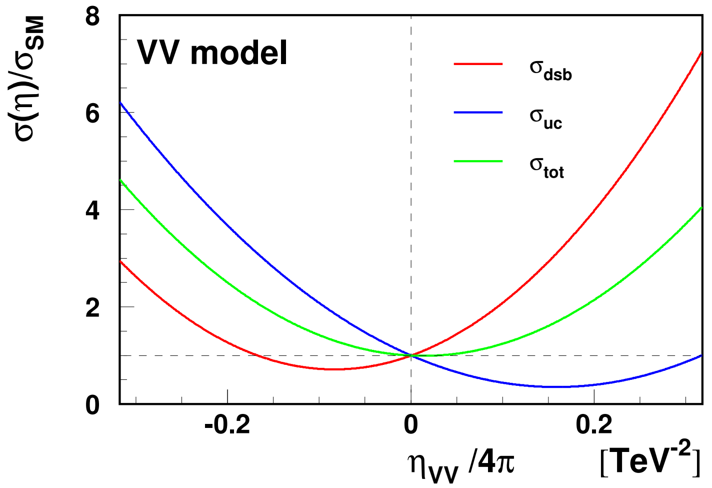
$$\sigma_{had}^{LO}(s) = \frac{K s}{16\pi} \sum_q \sum_{\alpha,\beta} |M_{\alpha\beta}^{eq}|^2$$

Sensitive to all $\eta_{\alpha\beta}^{eq}$.

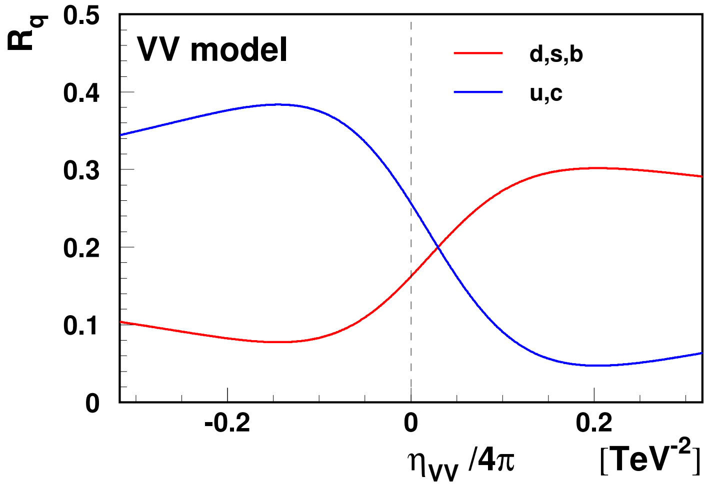
Data Samples

R_b/R_c measurements at LEP

In the total hadronic cross-section σ_{had}, interference term contributions for up- and down-type quarks cancel .



Interference terms "add" in the cross-section ratios for flavour-tagged samples



Included in this analysis are R_b (ALEPH, DELPHI, OPAL) and R_c (DELPHI) measurements for $\sqrt{s}$=133-189 GeV.

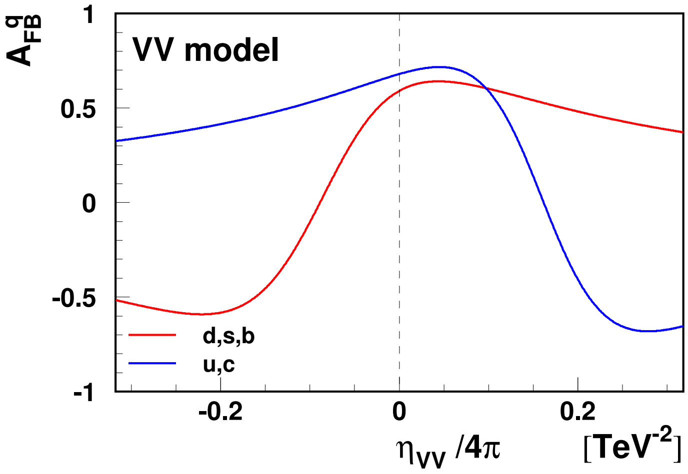
Data Samples

Forward-Backward asymmetry at LEP

On the quark level:

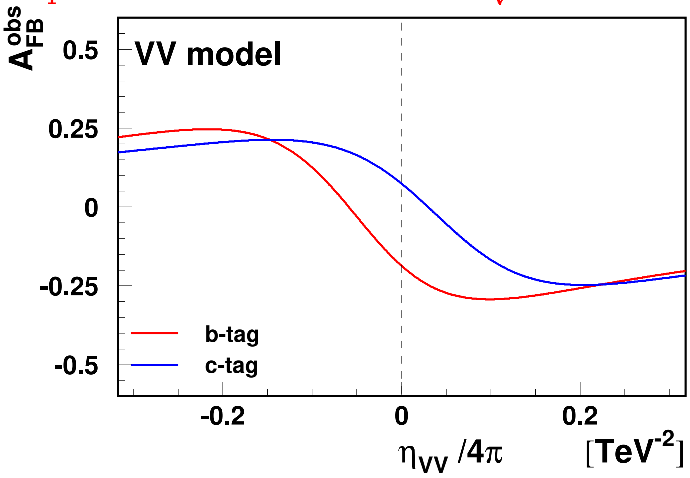
$$A^q_{FB} = \frac{3}{4} \cdot \frac{|M^{eq}_{LL}|^2 - |M^{eq}_{LR}|^2 - |M^{eq}_{RL}|^2 + |M^{eq}_{RR}|^2}{|M^{eq}_{LL}|^2 + |M^{eq}_{LR}|^2 + |M^{eq}_{RL}|^2 + |M^{eq}_{RR}|^2}$$

The dependence on η is not very strong (for $\eta \sim 0$).



However, observed charge asymmetries for flavour tagged samples are modified by (varying) contribution of opposite-sign quarks.

Expectations for DELPHI at $\sqrt{s}$=183 GeV



Included in this analysis are data from ALEPH, DELPHI and OPAL.

Data Samples

Last but not least...

Low Energy experiments

- Atomic Parity Violation experiments

  The Standard Model predicts parity non-conservation in atoms caused (in lowest order) by exchange of the Z° boson between atomic electrons and quarks in the nucleus.

$$\begin{aligned}
\Delta Q_w(Cs) &= 0.71 \pm 0.84 \\
\Delta Q_w(Tl) &= 1.9 \pm 3.6 \\
\Delta Q_w^{CI} &\sim \sum_{\substack{q= \\ u,d}} \sum_{\beta} (\eta^{eq}_{L\beta} - \eta^{eq}_{R\beta})
\end{aligned}$$

- Polarisation Asymmetry in (low energy) scattering

  Polarisation asymmetry directly measures the parity non-conservation resulting from γ-Z° interference.

$$A = \frac{d\sigma_R - d\sigma_L}{d\sigma_R + d\sigma_L}$$

  Used in this analysis:

  - eD results from SLAC
  - eBe results from Mainz
  - eC results from Bates
  - $\mu^\pm C$ results from CERN
    assuming family universality

Data Samples

Low Energy experiments

- neutrino-nucleus scattering

Assuming $\mathrm{SU}(2)_L$ invariance constraints on $\nu\nu qq$ contact interactions can be derived from the precise measurement of

$$R^{\nu} = \frac{\sigma^{\nu N}_{NC}}{\sigma^{\nu N}_{CC}}$$

- Unitarity of the Cabibbo-Kobayashi-Maskawa matrix

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9969 \pm 0.0022$$

whereas the expected contribution from the contact interaction is

$$V^{meas}_{ud} = V^{SM}_{du} \cdot \left(1 - \frac{\eta^{CC}}{4\sqrt{2}G_F}\right)$$

- electron-muon universality

Contact interactions would also lead to effective violation of e-μ universality in charged pion decay.

Current experimental limits on $R = \Gamma(\pi^- \to e\bar{\nu})/\Gamma(\pi^- \to \mu\bar{\nu})$

$$\frac{R_{meas}}{R_{SM}} = 0.9966 \pm 0.030$$

expected contribution from the contact interaction

$$\frac{R_{meas}}{R_{SM}} = \left(1 - \frac{\eta^{CC}}{4\sqrt{2}G_F}\right)^2$$

Procedure

Consider probability function in the coupling space

$$\mathcal{P}(\vec{\eta}) = \prod_i P_i(\vec{\eta})$$

where the product runs over all experimental data i.

For low energy experiments and LEP data Gaussian probability distribution is used.

For HERA high-Q^2 results and Drell-Yan lepton pairs at Tevatron Poisson probability distribution is used for the observed number of events.

"Best" coupling values are found using MINUIT, by minimizing $\mathcal{P}(\vec{\eta})$.

For multi-parameter models, Monte Carlo technique is used to determine probability functions for couplings and resulting limits.

Corrections

Experimental conditions are taken into account:

- detector resolution

  Event migration due to finite Q^2 resolution (for high-Q^2 HERA data) or M_{ll} resolution (for lepton pair production data from Tevatron).

  Flavour mixing and charge "confusion" factors at LEP.

- systematic errors

  For every data set common systematic shift parameter δ is introduced (assume 100% correlation of systematic errors).

  Parameter δ can been treated as an additional free parameter when maximizing the overall model probability $\mathcal{P}(\vec{\eta})$.

  Normal probability distribution for parameter δ is included in $\mathcal{P}(\vec{\eta})$.

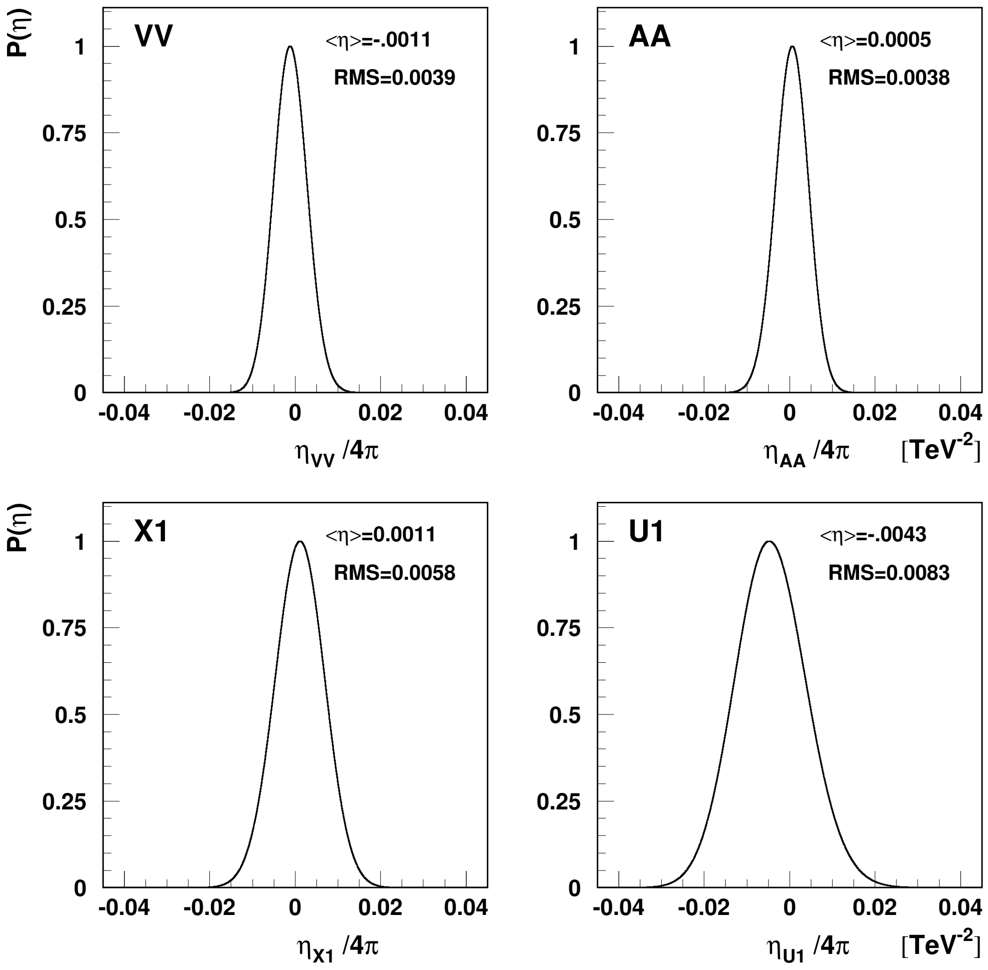
- radiative corrections

  Relevant for LEP σ_{had} measurement only. Otherwise radiative corrections are assumed to be the same as for the Standard Model.

Results

One parameter models

Probability functions for chosen models with family universality:

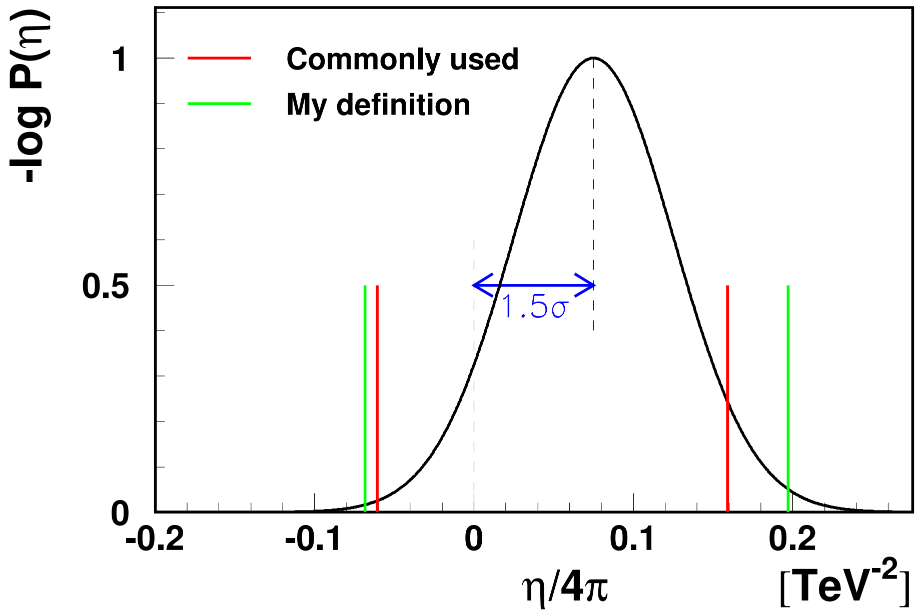


Results for all one-parameter contact interaction models are consistent with the Standard Model.

Worst agreement (SM probability ∼6-7%) observed for U1 and U3 models with $SU(2) \times U(1)$ universality, mainly due to low energy CC constraints.

Results

Limit setting procedure



Commonly used in literature:

$$\int_{-\infty}^{\eta^-} d\eta\ p(\eta) \ = \ 0.05 \cdot \int_{-\infty}^{0} d\eta\ p(\eta)$$
$$\int_{\eta^+}^{+\infty} d\eta\ p(\eta) \ = \ 0.05 \cdot \int_{0}^{+\infty} d\eta\ p(\eta)$$

Limits depend on variable choice...

My limit definition:

$$\mathcal{P}(\eta^-) \ = \ 0.05 \cdot \max_{\eta<0} \mathcal{P}(\eta)$$
$$\mathcal{P}(\eta^+) \ = \ 0.05 \cdot \max_{\eta>0} \mathcal{P}(\eta)$$

Does not depend on variable choice.
Resulting mass scale limits usually 10-15% smaller.

Results

Mass scale limits

For one-parameter models with family universality

Model	Mass scale limits [TeV]			
	No SU(2)		With SU(2)	
	Λ^-	Λ^+	Λ^-	Λ^+
VV	9.8	10.7	9.6	11.4
AA	10.5	10.1	9.9	11.1
VA	6.6	6.2	6.3	8.0
X1	8.7	8.1	8.1	9.5
X2	8.2	8.4	7.8	9.6
X3	9.9	10.2	9.5	11.1
X4	5.7	5.2	6.0	5.4
X5	5.9	6.4	6.2	6.4
X6	6.2	5.8	6.2	5.8
U1	6.4	7.7	7.9	17.0
U2	6.9	9.1		
U3	8.5	11.7	8.6	18.2
U4	5.1	5.5		
U5	6.4	8.8	7.1	8.8
U6	7.0	5.6		

U2, U4 and U6 models violate $SU(2) \times U(1)$ invariance.

Mass scale limits range from 5.1 to 18.2 TeV.

Significant improvement as compared to single experiments.

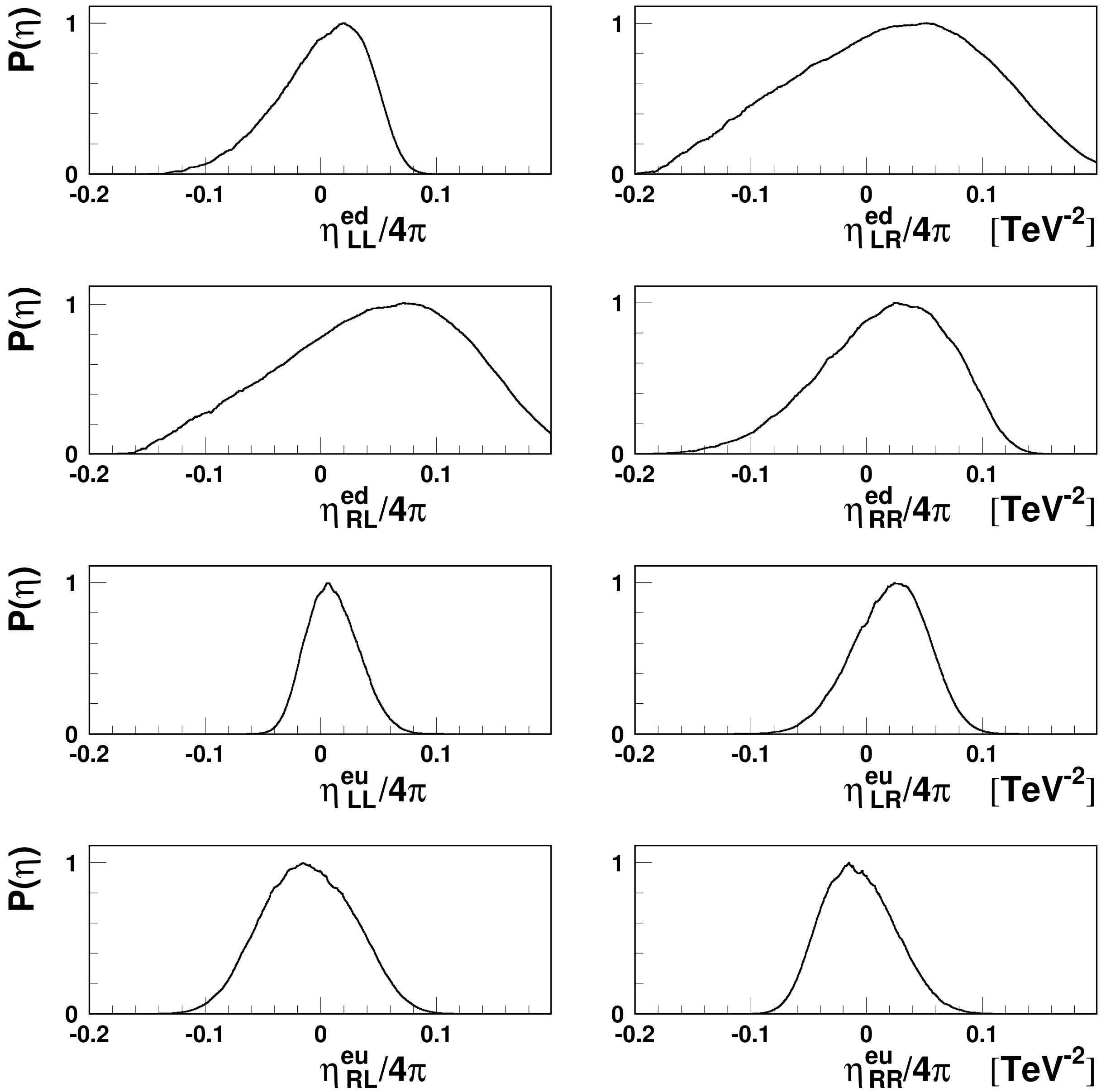
One-parameter models test only specific combinations of couplings !

Results

General model

Probability functions for single couplings

All coupling allowed to very simultaneously.



All couplings consistent with the Standard Model.

Results

Mass scale limits

Mass scale limits for single couplings
assuming no constraints on other couplings.

Coupling	Mass scale limits [TeV]					
	General model (1st. generation)		Model with family universality		SU(2) model with family univ.	
	Λ^-	Λ^+	Λ^-	Λ^+	Λ^-	Λ^+
η^{ed}_{LL}	3.1	3.6	4.3	5.4	7.5	6.1
η^{ed}_{LR}	2.4	2.2	2.8	3.2	3.6	3.7
η^{ed}_{RL}	2.6	2.1	3.9	2.8	4.5	3.9
η^{ed}_{RR}	2.8	2.8	3.3	3.5	3.5	5.1
η^{eu}_{LL}	5.1	3.9	5.3	4.1	6.5	7.8
η^{eu}_{LR}	4.1	3.3	3.7	3.5	4.9	4.7
η^{eu}_{RL}	3.1	3.5	3.1	3.5	4.5	3.9
η^{eu}_{RR}	3.7	3.7	3.8	4.2	4.8	4.4

Least constrained coupling combination:

η_1	2.1	2.7	3.1

For general model:

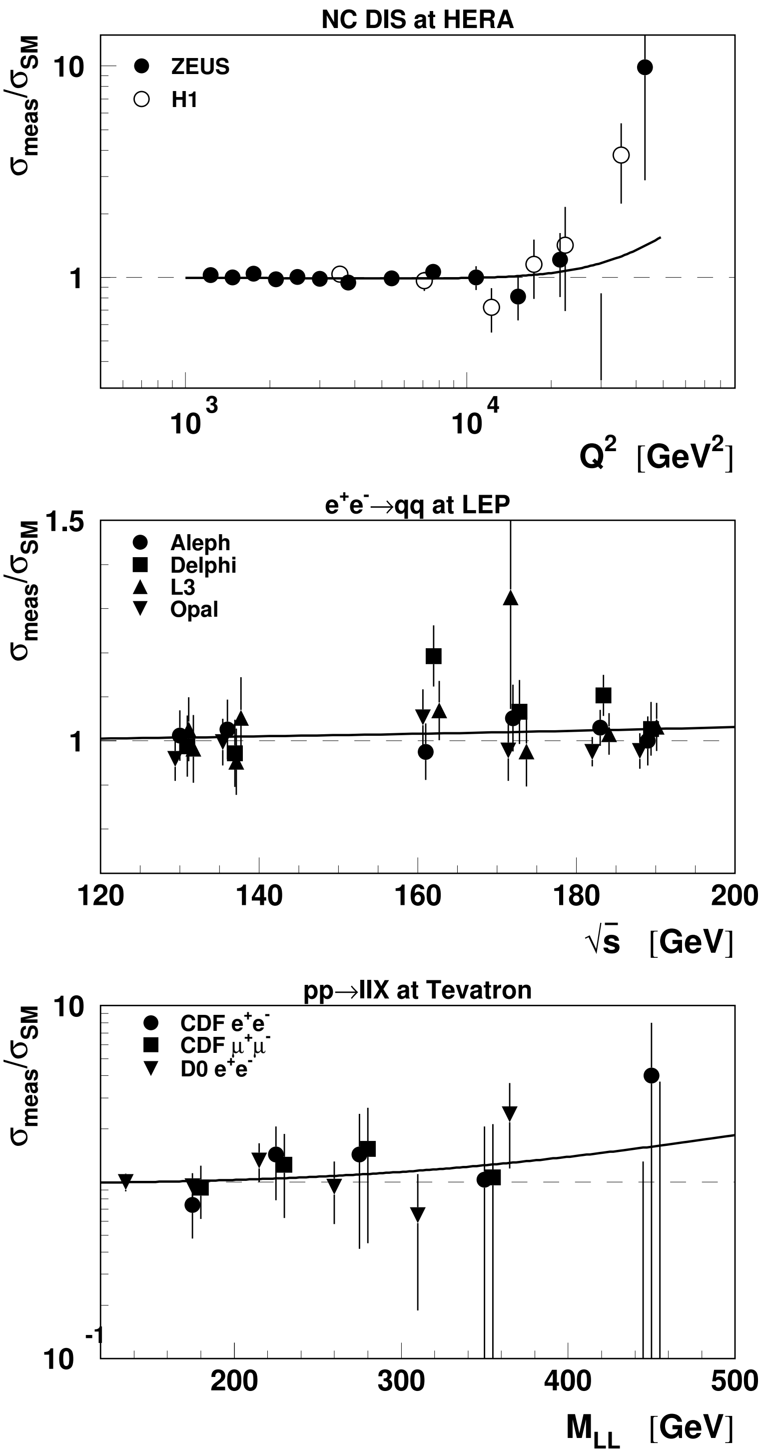
$$\eta_1 \equiv -0.26\eta^{ed}_{LL} + 0.84\eta^{ed}_{LR} + 0.15\eta^{ed}_{RL} + 0.33\eta^{ed}_{RR} - 0.06\eta^{eu}_{LL} + 0.11\eta^{eu}_{LR} - 0.10\eta^{eu}_{RL} + 0.27\eta^{eu}_{RR}$$

$\boxed{\text{Excluded are all models with } \Lambda < 2.1 \text{ TeV .}}$

on 95% CL

Predictions

General model fit results compared to high energy data



In order to verify how significant these "predictions" are one has to consider their statistical uncertainty .

Predictions

Probability function

Having defined $\mathcal{P}(\vec{\eta})$ we should be able to calculate the probability for any other variable, which can be expressed in terms of $\vec{\eta}$.

For example, we can try to find out what is the probability of observing deviations from Standard Model predictions for e^+p NC DIS at high Q^2.

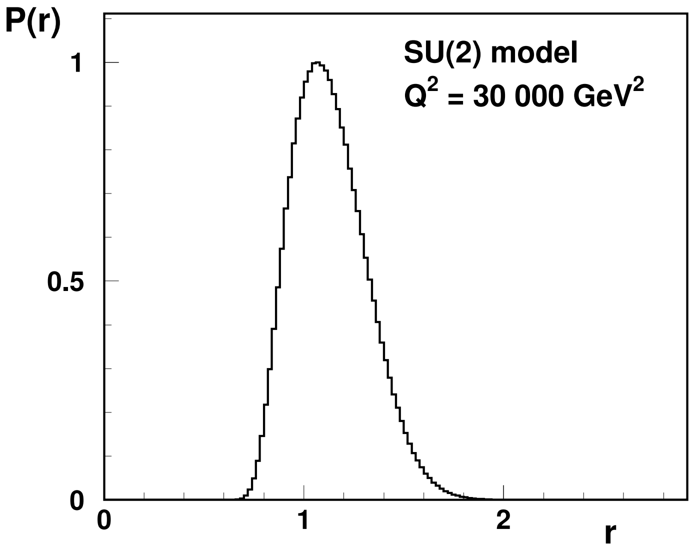
Consider cross-section ratio:

$$r \;=\; R(\vec{\eta}) \;=\; \frac{\frac{d\sigma}{dQ^2}(\vec{\eta})}{\frac{d\sigma^{SM}}{dQ^2}}$$

Probability function $P_r(r)$:
probability that our data come from the model with $R(\vec{\eta}) \;=\; r$.

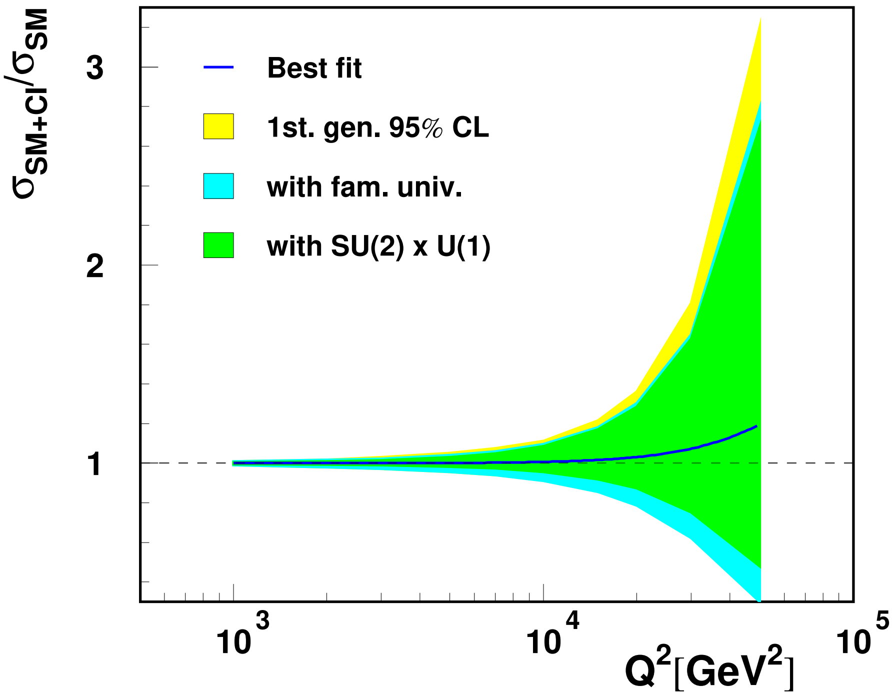
$$\boxed{P_r(r) = \langle \mathcal{P}(\vec{\eta}) \rangle_{R(\vec{\eta})=r}}$$

Averaging is based on the assumption that $\vec{\eta}$ has flat underlying (prior) distribution (all $\vec{\eta}$ values are equally probably).



Predictions for HERA

Limits for e^+p NC DIS



95% CL limits on integrated cross-section:

$$\frac{\sigma(Q^2 > 15,000\ GeV^2)}{\sigma_{SM}} < 1.40 \quad \text{1st. gen. model}$$

$$< 1.30 \quad \text{SU(2) model}$$

Possible effect can be measured only with

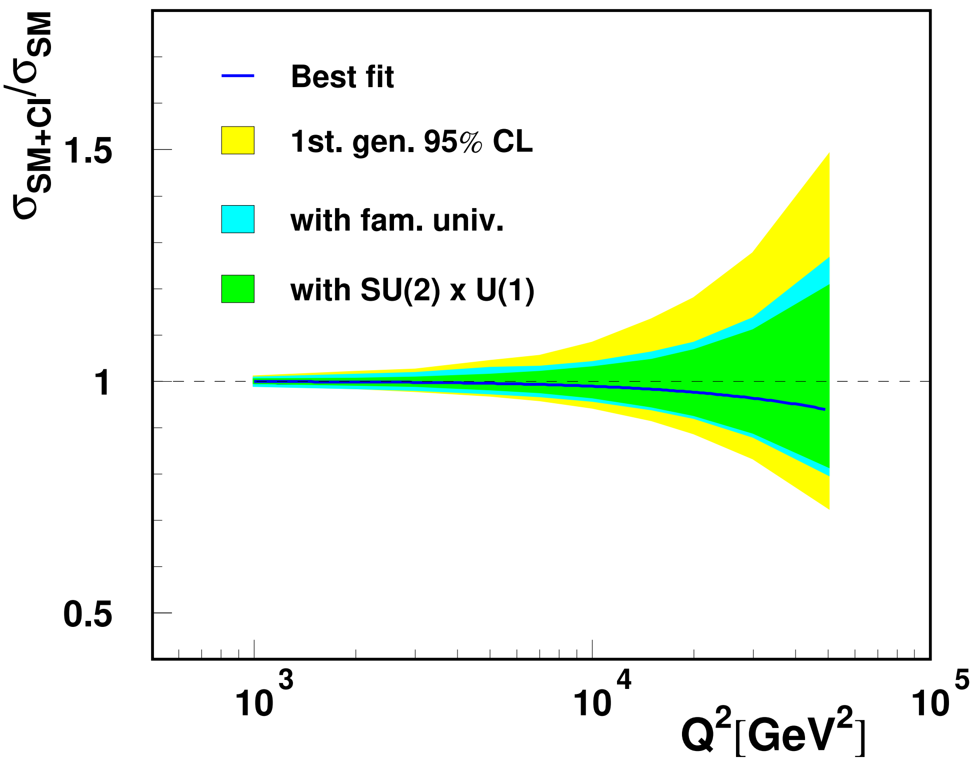
$$\boxed{\mathcal{L} \sim 100 - 200\ \text{pb}^{-1}}$$

depending on the model

required to observe "3 σ" effect for $Q^2 > 15,000\ GeV^2$

Predictions for HERA

Limits for $e^- p$ NC DIS



95% CL limits on integrated cross-section:

$$\frac{\sigma(Q^2 > 15,000\ GeV^2)}{\sigma_{\rm SM}} \quad < \ 1.19 \qquad \text{1st. gen. model}$$

$$< \ 1.07 \qquad \text{SU(2) model}$$

Possible effect can be measured only with

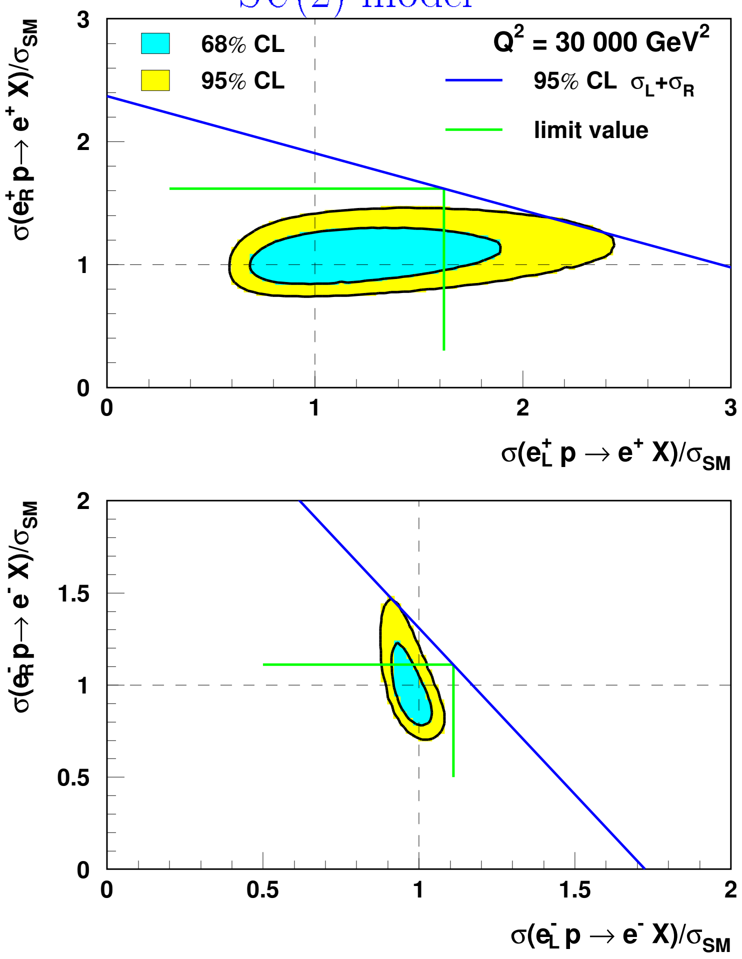
$$\boxed{\mathcal{L} \ \geq \ 400 \text{ pb}^{-1}}$$

Predictions for HERA

HERA "discovery window" can be enlarged for

Scattering of polarised $e^{\pm}$

SU(2) model



Limits from existing data significantly weaker for e_L^+ and e_R^- .
Running with 60% e_R^- polarisation :

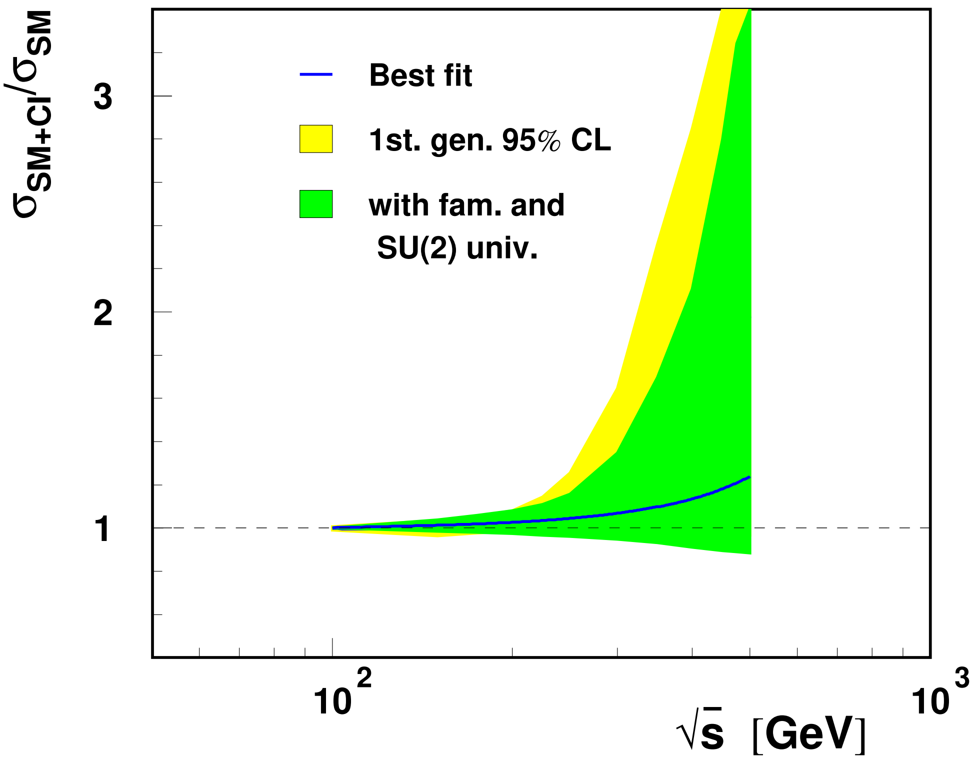
$$\frac{\sigma(Q^2 > 15,000\ GeV^2)}{\sigma_{\rm SM}} \begin{array}{ll} < \ 1.28 & \text{1st. gen. model} \\ < \ 1.19 & \text{SU(2) model} \end{array}$$

$$\boxed{\mathcal{L} \sim 120 - 500 \text{ pb}^{-1}}$$

depending on the model

Predictions for LEP

Limits on $\sigma(e^+e^- \to q\bar{q})$



95% CL limits on $\sigma(e^+e^- \to q\bar{q})$ at $\sqrt{s} = 200$ GeV:

$$\frac{\Delta\sigma}{\sigma_{\rm SM}} < 8\%$$

Very little space left for possible discovery at LEP.

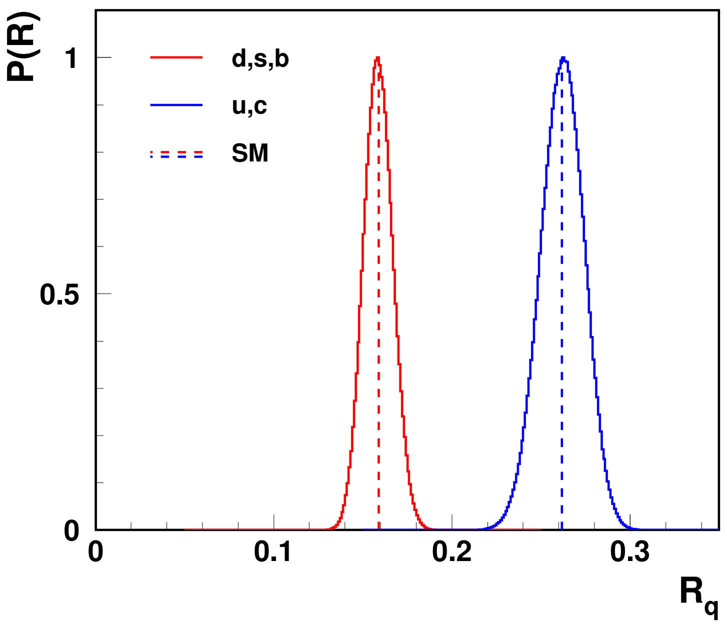
Significant effects possible in the Next-Linear-Collider...

Predictions for LEP

Other limits

There are also other observables at LEP sensitive to contact interactions

SU(2) model

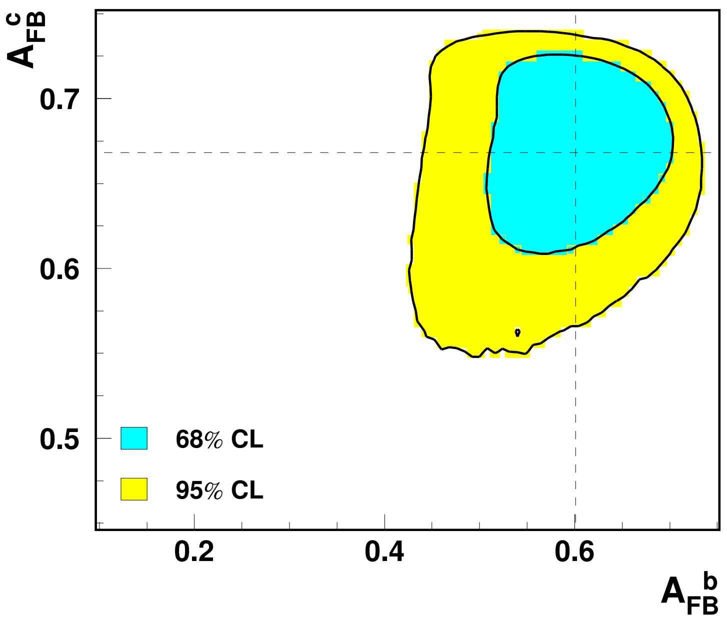


Quark production ratios:

$$0.139 < R_b < 0.179$$
$$0.232 < R_c < 0.291$$

95% CL at $\sqrt{s} = 200$ GeV:

SU(2) model



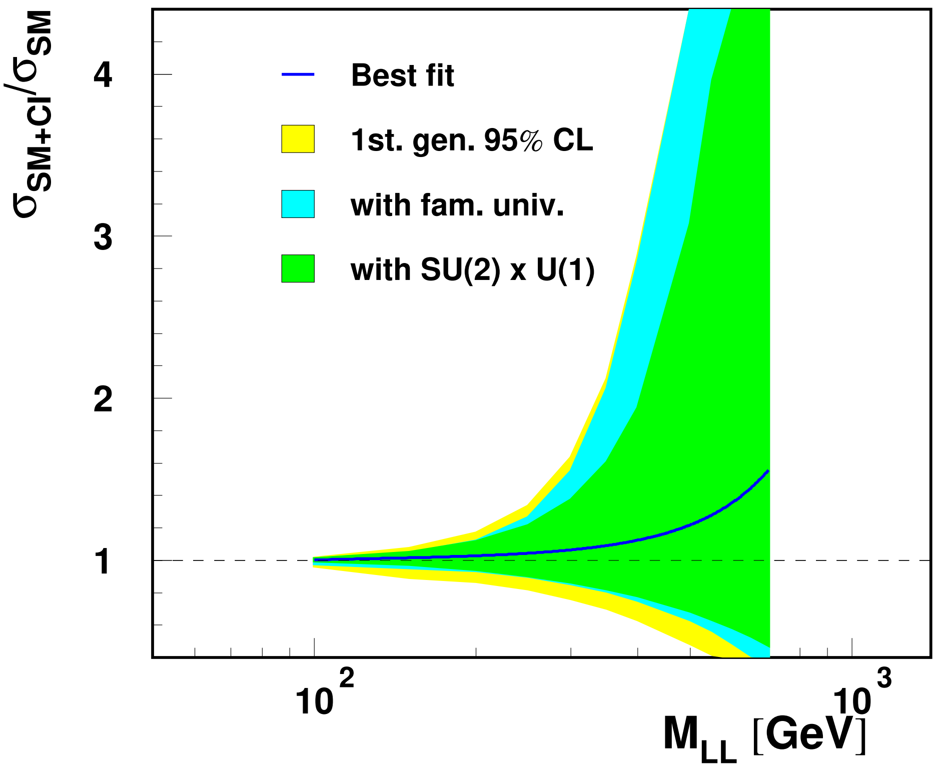
Quark asymmetries:

$$0.431 < A^b_{FB} < 0.732$$
$$0.551 < A^c_{FB} < 0.738$$

95% CL at $\sqrt{s} = 200$ GeV:

Predictions for Tevatron

Limits on $\sigma(q\bar{q} \rightarrow l^+l^-)$



95% CL limits on $\sigma(q\bar{q} \rightarrow l^+l^-)$ at $\sqrt{s} = 1800$ GeV:

$$\frac{\sigma(M_{ll} > 500 GeV)}{\sigma_{\mathrm{SM}}} \begin{array}{lll} < & 10. & \text{general model} \\ < & 5. & \text{SU(2) model} \end{array}$$

Large effects still possible !

Can be measured with

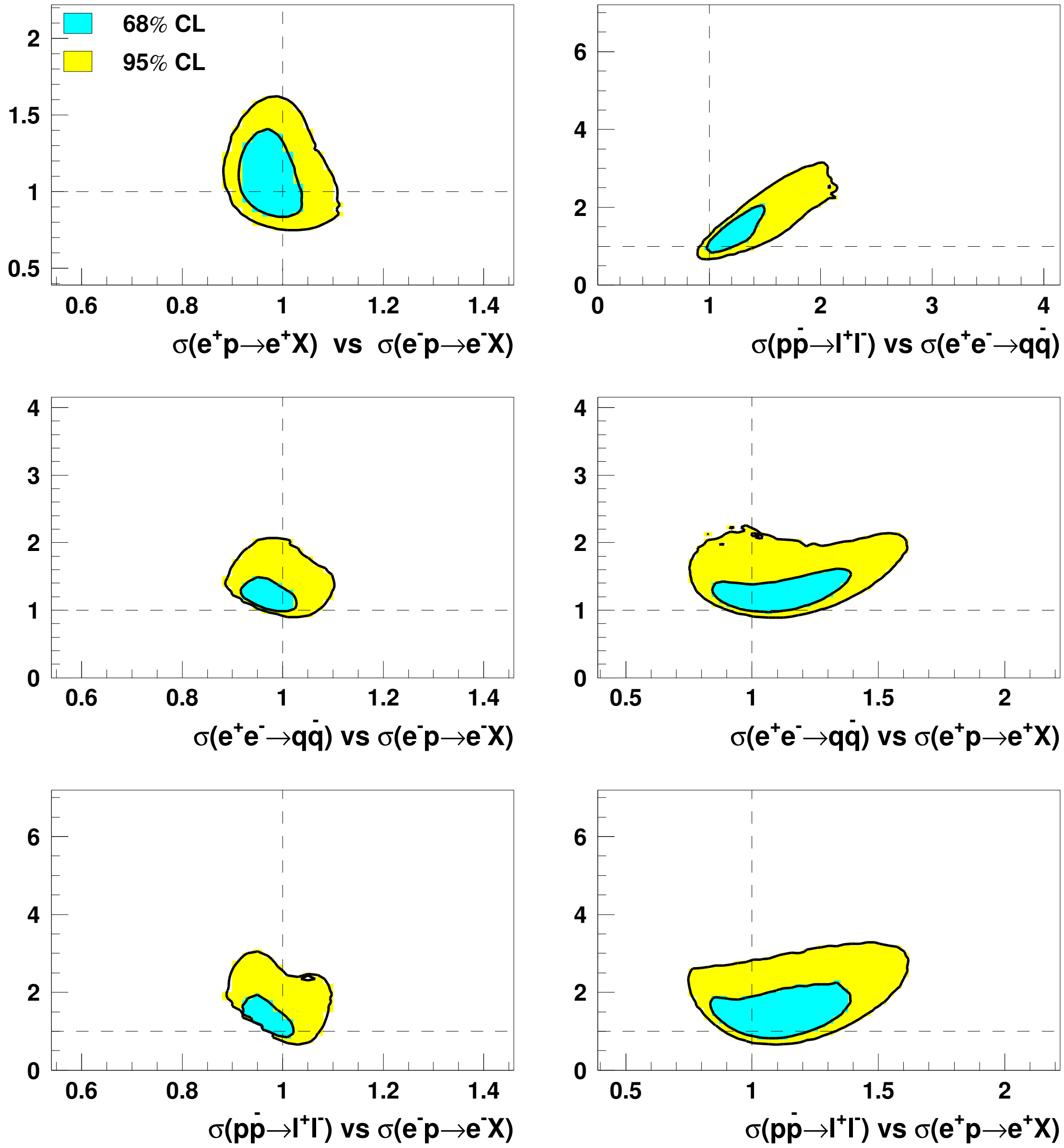
$$\boxed{\mathcal{L} \sim 0.3 - 1 \text{ fb}^{-1}}$$

Best place to look for possible contact interactions in the nearest future.

Predictions

Comparison of experiments

Model with $SU(2) \times U(1)$ universality



$Q^2 = 30\ 000\ GeV^2$ $\sqrt{s} = 400\ GeV$ $M_{ll} = 500\ GeV$

Different experiments are, to large extent, independent.

Significant correlation between LEP (σ_{had}) and Tevatron (Drell-Yan).

The least correlated measurements are e^+p and e^-p NC DIS c-s.

Predictions

Summary of limits

95% CL limits, resulting from existing data, on possible cross-section deviations in future experiments

Reaction	Energy scale	Limits on $\Delta\sigma/\sigma_{SM}$ [%]		
		General m. (1st. gen.)	Model with family univ.	SU(2) model w. fam. univ.
e^+p NC DIS $\sqrt{s}$ =318 GeV	Q^2=10000 GeV^2	11	10	9
	Q^2=20000 GeV^2	36	30	28
	Q^2=30000 GeV^2	81	65	63
	Q^2=50000 GeV^2	220	180	170
e^-p NC DIS $\sqrt{s}$ =318 GeV	Q^2=10000 GeV^2	8	4	3
	Q^2=20000 GeV^2	18	8	7
	Q^2=30000 GeV^2	28	13	11
	Q^2=50000 GeV^2	49	26	21
$e^-e^+ \rightarrow q\bar{q}$	$\sqrt{s}$=175 GeV	5	5	6
	$\sqrt{s}$=200 GeV	8	8	8
	$\sqrt{s}$=225 GeV	14	13	11
	$\sqrt{s}$=250 GeV	26	24	16
	$\sqrt{s}$=300 GeV	65	61	35
	$\sqrt{s}$=400 GeV	185	185	110
$p\bar{p} \rightarrow l^+l^-X$ $\sqrt{s}$ = 1800 GeV	M_{ll}=200 GeV	17	12	12
	M_{ll}=300 GeV	64	55	38
	M_{ll}=400 GeV	190	185	95
	M_{ll}=500 GeV	440	450	210

Summary

- Data from HERA, LEP, Tevatron and low energy experiments were combined to constrain electron-quark contact interactions.
- The mass scale limits obtained for different one-parameter models range from 5.1 TeV to about 18 TeV .
- Model independent limits on single CI couplings correspond to Λ limits from 2.1 to 7.8 TeV .
- Excluded are all models with $\Lambda <$ 2.1 TeV (3.1 TeV for SU(2) model).

- Limits on possible effects to be observed in future HERA, LEP and Tevatron running are estimated.
- Current data exclude any sizable cross-section deviations from the Standard-Model for e^-p scattering at HERA.
- Possible cross-section deviations for LEP and e^+p scattering at HERA are also strongly limited by existing data.
- However, experimental sensitivity can be improved :
  $\Rightarrow$ additional observables at LEP,
  $\Rightarrow$ polarised beams at HERA.
- The best "discovery potential" seems to come from future Tevatron running.

More details of the analysis can be found in hep-ph/9904334

submitted to Euro. Phys. J. **C**