Universität Hamburg

BMBF - Förderschwerpunkt
Elementarteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

New Physics Searches at HERA

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on behalf of

H1 and ZEUS

Outline:

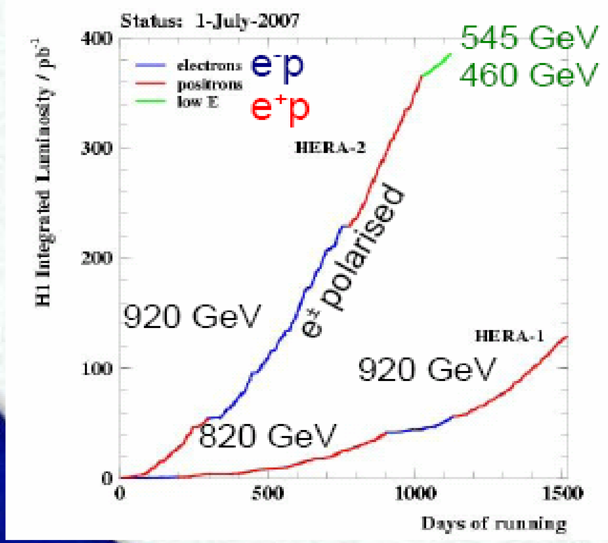
- H1 and ZEUS at HERA
- Searches in inclusive DIS
- Model based searches
- Model independent searches
- Summary

PHENO 2008, Madison, April 28, 2008

HERA ep collider

Ecms:
301 GeV
318 GeV

- ep collision at H1 and ZEUS



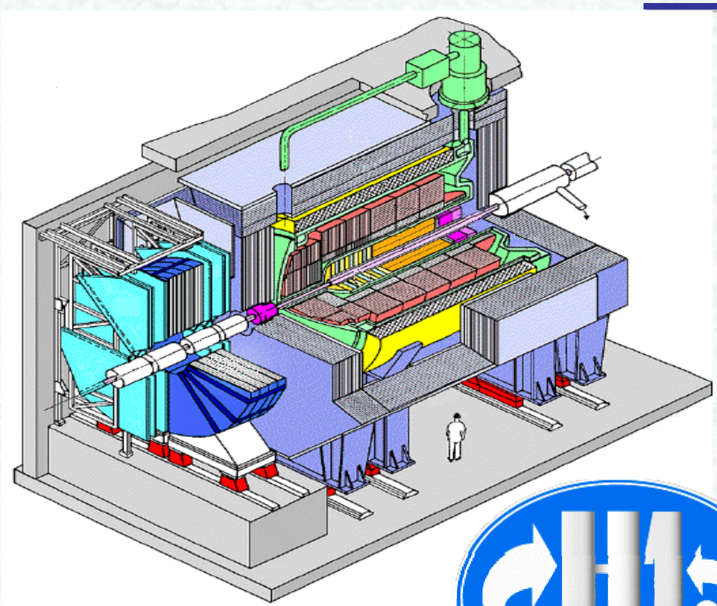
- HERA-I: 1992-2000 L~120 pb^{-1}/exp.
- HERA-II 2002-2007 L~350 pb^{-1}/exp.
  - -Luminosity upgrade:
    ~10x more e-p data than in HERA-I
  - -Longitudinally polarized lepton beam

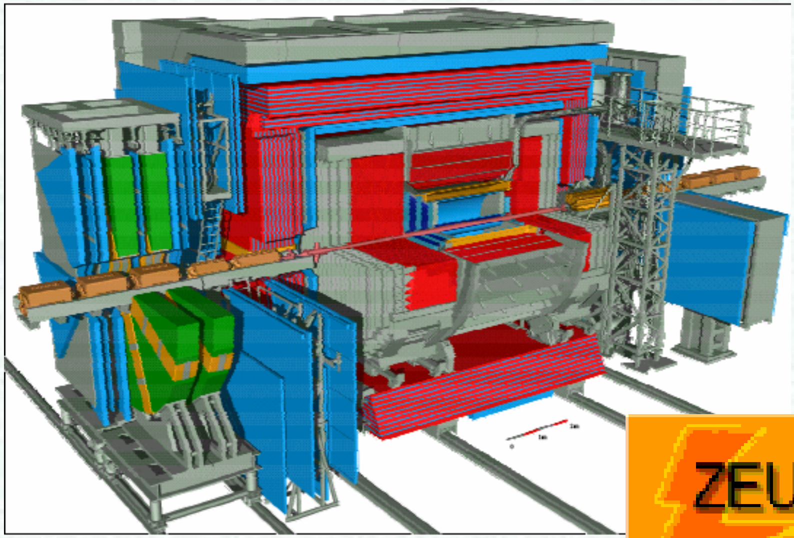
Presented results:

	H1	ZEUS
e+p	294 pb^{-1}	272 pb^{-1}
e-p	184 pb^{-1}	206 pb^{-1}
Total	478 pb^{-1}	479 pb^{-1}

Total luminosity ~ 1fb^{-1}

H1 and ZEUS hermetic multi-purpose detectors





Liquid Argon Calorimeter

optimized for precision measurement
of the scattered lepton

$\sigma_E /E = 12\%/\sqrt{E}$ **(ele)**

$\sigma_E/E = 50\%/\sqrt{E}$ **(had)**

Uranium-scintillator Calorimeter

optimized for precision measurement
of the hadronic final state

$\sigma_E /E = 18\%/\sqrt{E}$ **(ele)**

$\sigma_E/E = 35\%/\sqrt{E}$ **(had)**

Beyond Standard Model searches at HERA

Searches in inclusive DIS

- ✓ NC: Quark Radius, Contact Interaction , Extra Dimensions
- ✓ CC: Polarization dependence

Model based searches

Test models and verify predicted signatures

- ✓ Leptoquarks and LFV
- ✓ Excited Leptons
- ✓ Single Top production
- ✓ Doubly Charged Higgs
- ✓ Supersymmetry

Model-independent searches

Compare data vs SM, reveal anomalies above small SM contribution

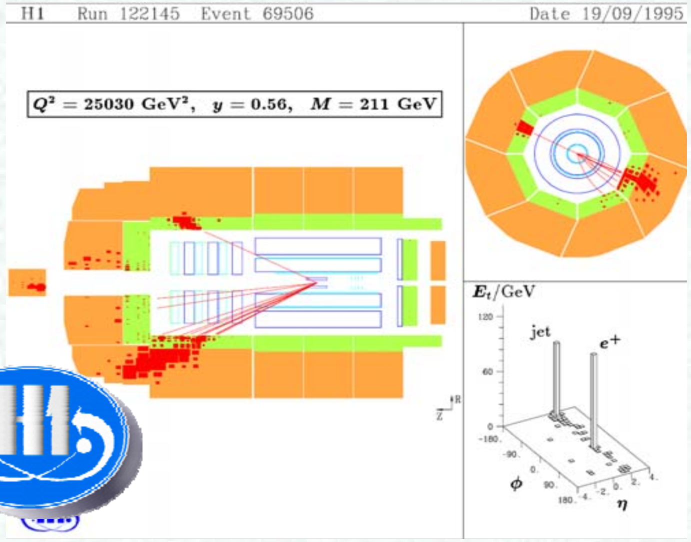
- ✓ Isolated leptons and missing P_T
- ✓ High-P_T multi-leptons
- ✓ General searches
- ✓ Magnetic monopoles

Topics in red covered in this talk

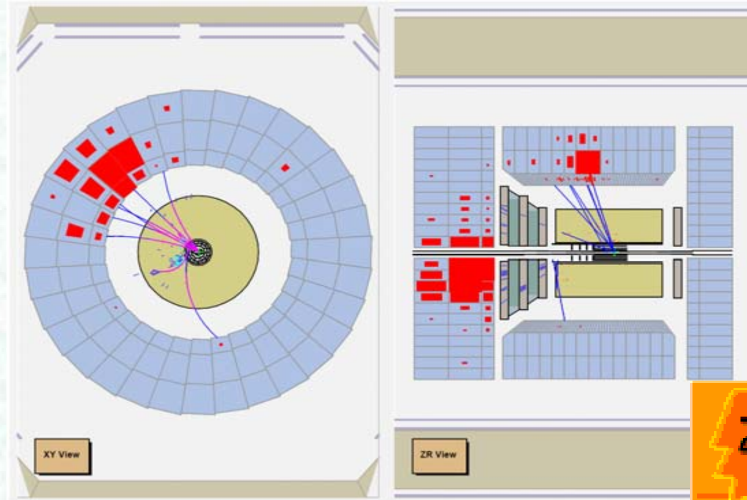
Deep Inelastic e±p Scattering

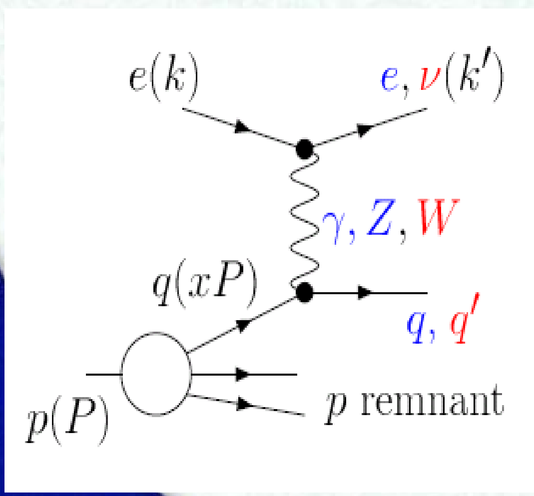
Main processes studied at H1 and ZEUS:

Neutral Current



Charged Current





$$Q^2 = -(k - k')^2$$

$$x = \frac{Q^2}{2P \cdot (k - k')}$$

$$y = \frac{P \cdot (k - k')}{P \cdot k}$$

Q^2 = -(4-momentum of propagator)^2 – the virtuality of the exchanged boson.

x – fractional momentum of proton carried by struck quark q

y – fractional energy of the incoming lepton transferred to the proton in the proton's rest frame

DIS at high-Q^2

Neutral Current and Charge Current cross-sections for e+p and e-p

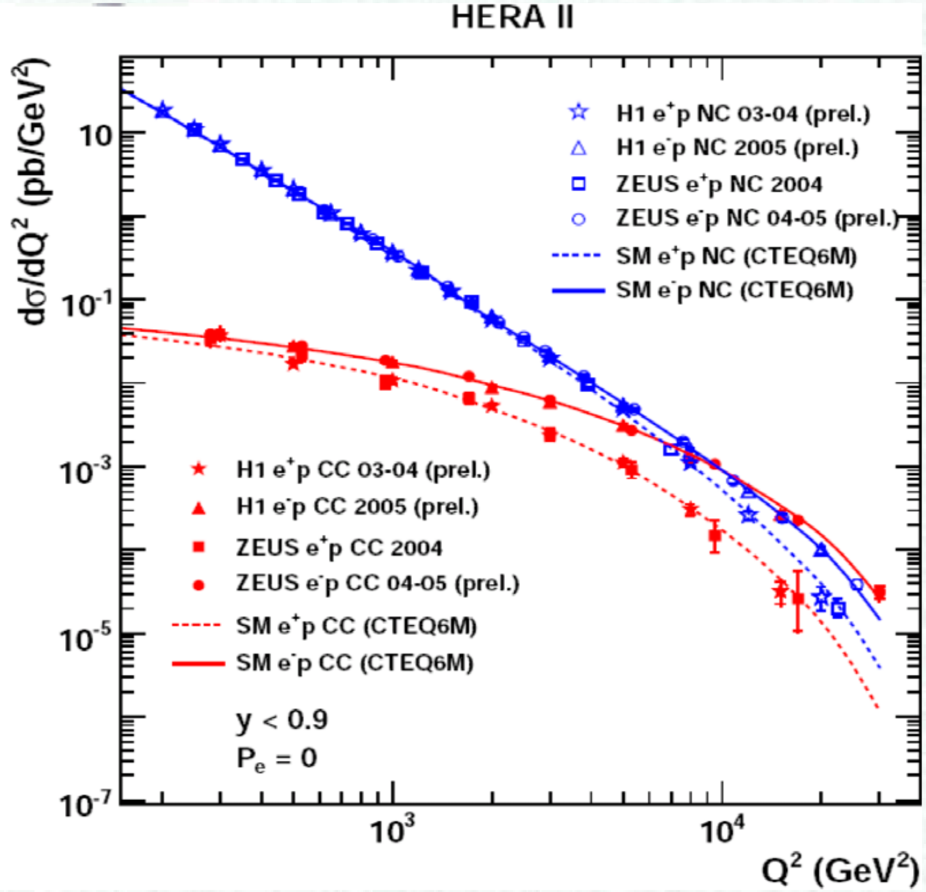
- NC DIS at highest Q^2 =>

  Z^o contribution significant!

- CC DIS: e^-u enhanced

  e^+d suppressed

- Excellent agreement of precise data with Standard Model over many order of magnitude => testing ground for SM and QCD



New Physics would create deviations from SM at high-Q^2!

Quark (sub)structure

Quark radius form factor

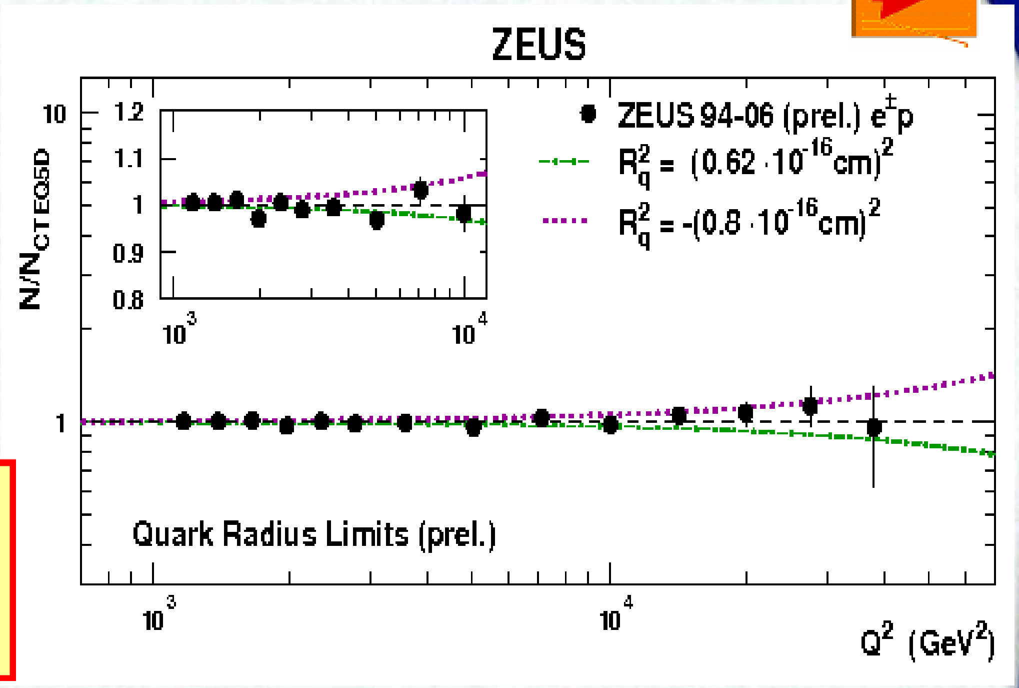
If a quark has finite size =>

SM cross-section decreases

at high momentum transfer:

$$\frac{d\sigma}{dQ^2} = \frac{d\sigma^{SM}}{dQ^2} \cdot \left[1 - \frac{R_q^2}{6} Q^2\right]^2$$

where Rq is the root mean square radius of the electroweak charge distribution in the quark



95% CL limit:

H1: Rq < 0.74 x 10^{-18} m

ZEUS: Rq < 0.62 x 10^{-18} m

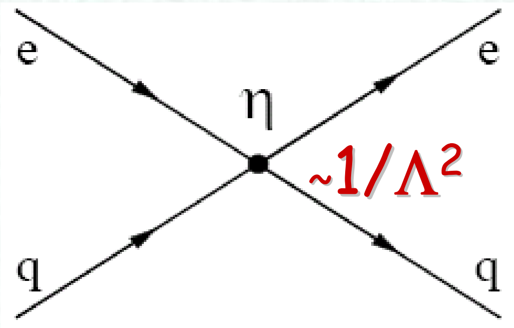
Limit below 1/1000 of the proton radius !

Contact Interactions

General models:

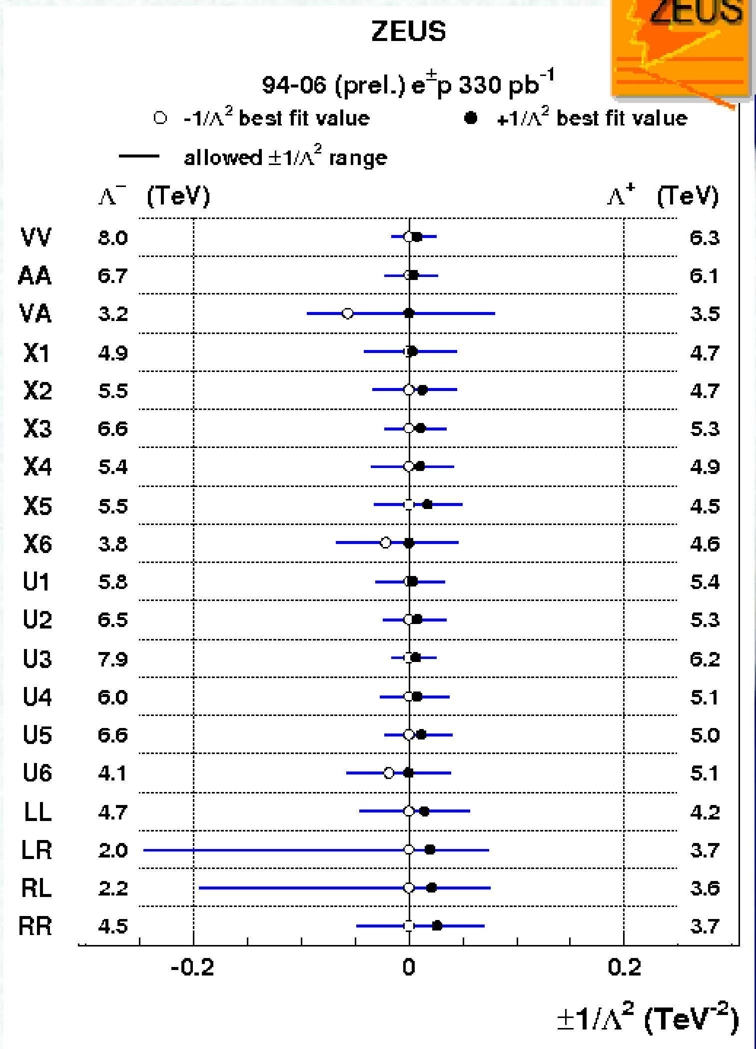
If the scale Λ of new interactions is large:

- Effective **contact interaction** parameterization



Modification of DIS cross-section at high-Q^2

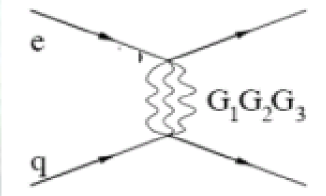
Different models with different helicity structure =>



95% CL limits : Λ > 2.0-8.0 TeV

Sensitive to several TeV range !

Large Extra Dimensions



Arkani-Hamed-Dimopoulos-Dvali Model

If gravity propagates in the 4+δ dimensions

the effective mass scale Ms can be as low as 1TeV

$\Rightarrow$ Gravitational interactions become comparable

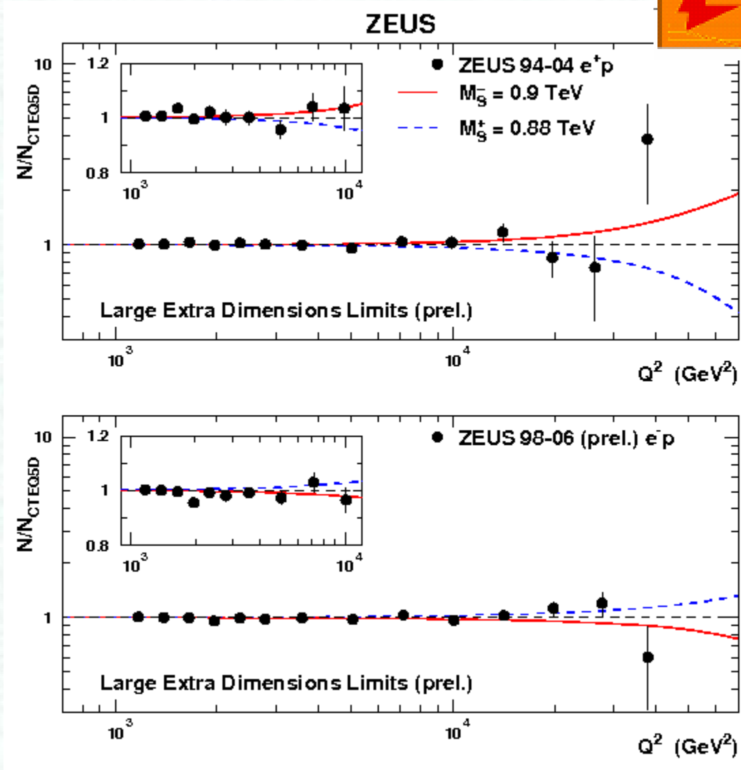
in strength to electroweak interactions

The contribution of graviton exchange to

the ep NCDIS => effective CI type coupling:

$$\eta_G = \pm\lambda \cdot \frac{\varepsilon^2}{M_S^4}$$

where: λ is the coupling strength
and ε is related to the energy scale
of hard interaction ($\sqrt{s}$, Q2)



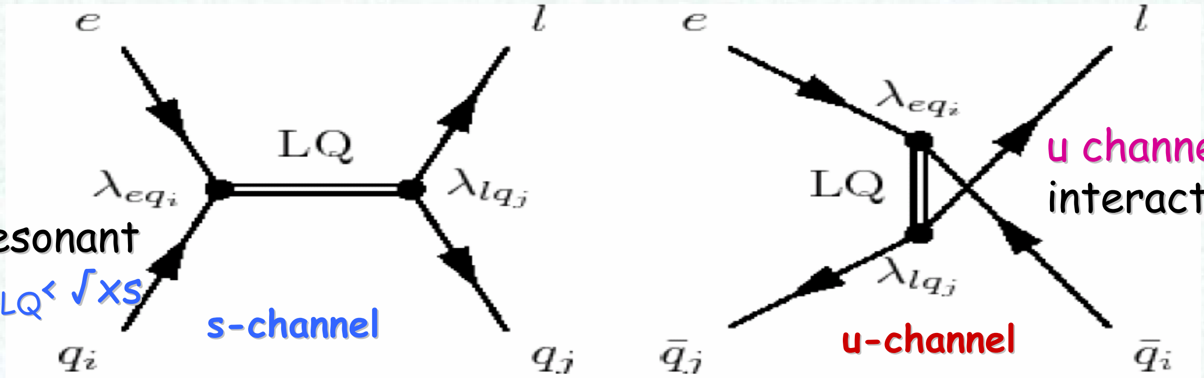
95% CL limits on LED scale Ms:

Ms+ > 0.88 TeV

Ms- > 0.90 TeV

1st generation of Leptoquarks

Scalar or vector color triplet bosons carrying L and B numbers
=> Fermion number F = 3B + L = 0,2



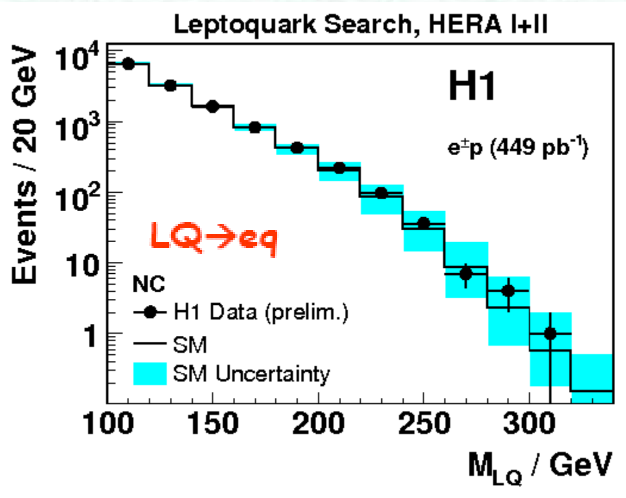
s channel ->resonant production $M_{LQ} < \sqrt{xs}$

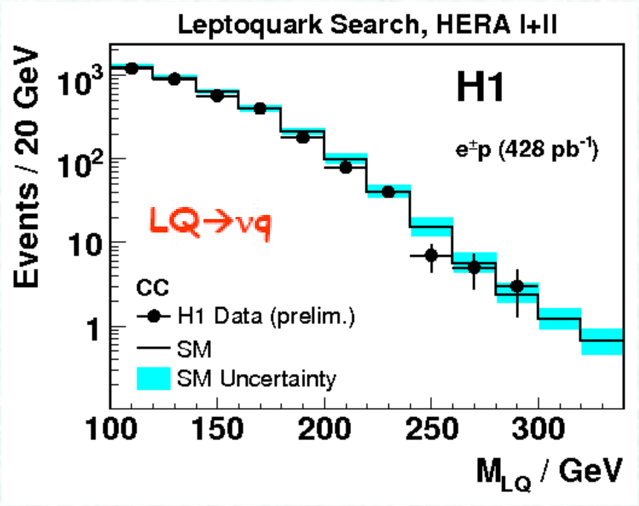
u channel ->contact interaction $M_{LQ} >> \sqrt{xs}$

Buchmuller-Ruckl-Wyler (BRW) model => 7 scalar and 7 vector LQs:

✓ All 14 LQs => LQ->eq'

✓ 2 scalar & 2 vector LQ couple to both eq & νq





1st generation of Leptoquarks

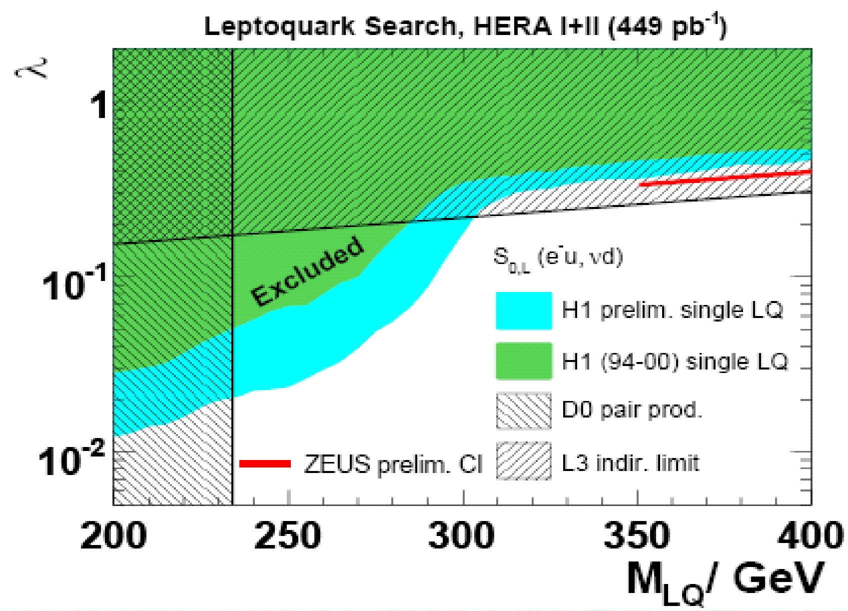
Limit on LQ Yukawa coupling λ as a function of M_{LQ}:

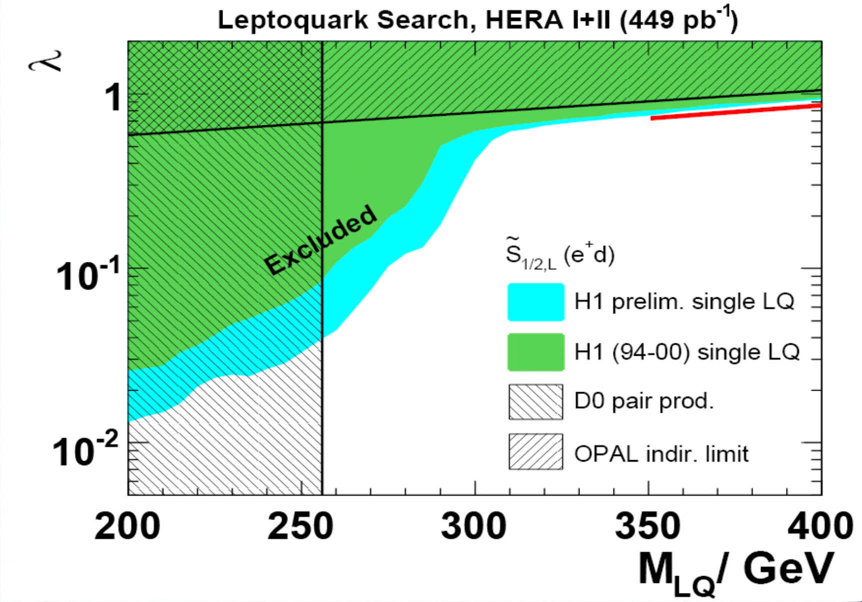
F=2 BRW LQ model

=> e-p data more sensitive than e+p

F=0 BRW LQ model

=> e+p data more sensitive than e-p





For electromagnetic strength λ≈0.3:
M_{LQ}< 291-330 GeV can be ruled out

Limits comparable to those obtained by LEP and Tevatron

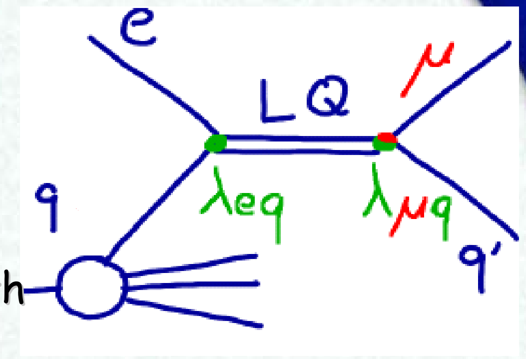
Or..Lepton Flavour Violation

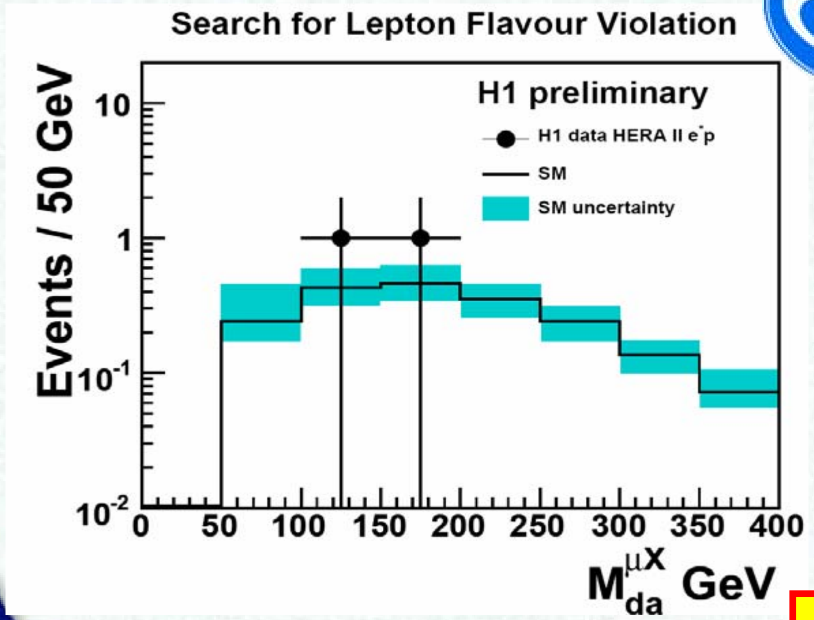
LFV can be mediated by LQ in family non-diagonal models

Incoming e --> μ or τ in the final state

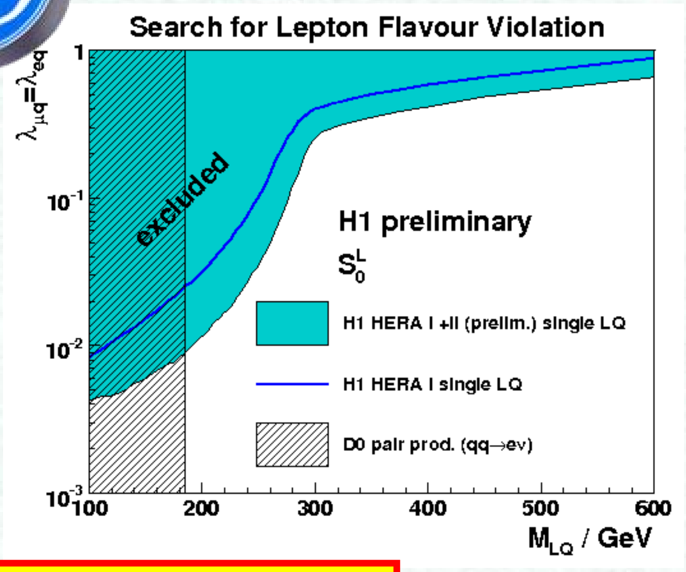
Process: $e^-p \to \mu^- X$ mediated by F=2 LQ in e-p data

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





Assumption: $\lambda eq = \lambda \mu q$



For a coupling of $\lambda \approx 0.3$:
F=2 LQs with M_{LQ} up to 433 GeV can be ruled out

Excited Leptons

Gauge mediated model for compositeness of fermions (Hagiwara et al.):

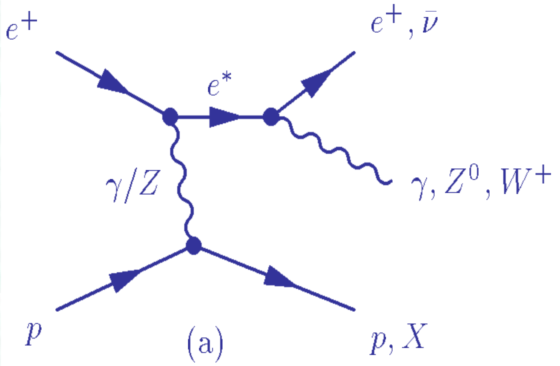
Excited leptons: spin ½, isospin ½ and the same currents as SM leptons

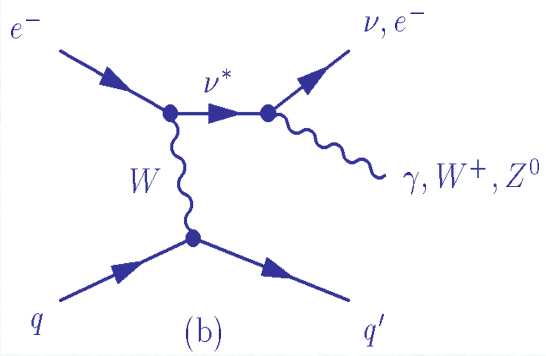
Effective Lagrangian to parameterize compositeness

$$L_{F^*F} = \frac{1}{2\Lambda}\overline{F^*_R}\sigma^{\mu\nu}\left[gf\frac{\tau}{2}\partial_\mu W_\nu + g'f'\frac{Y}{2}\partial_\mu B_\nu\right]F_L + h.c.$$

Λ compositeness scale

f, f' weight factors of the gauge groups (U(1), SU(2))





Investigated channels:

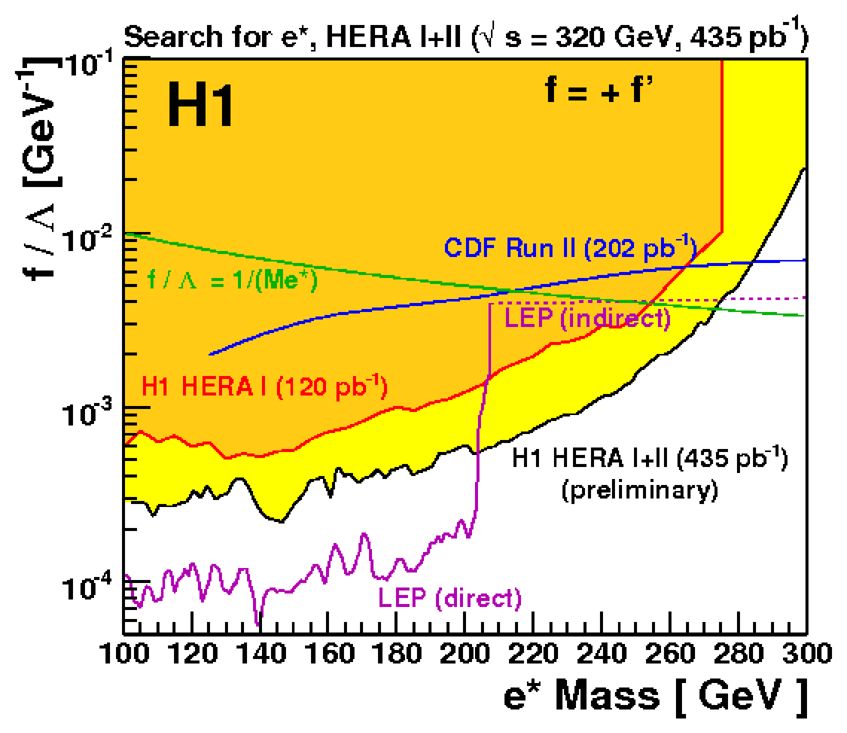
- **e*->eγ**
- **e* -> eZ with Z->qq**
- **e* -> νW with W -> qq'**

Investigated channels:

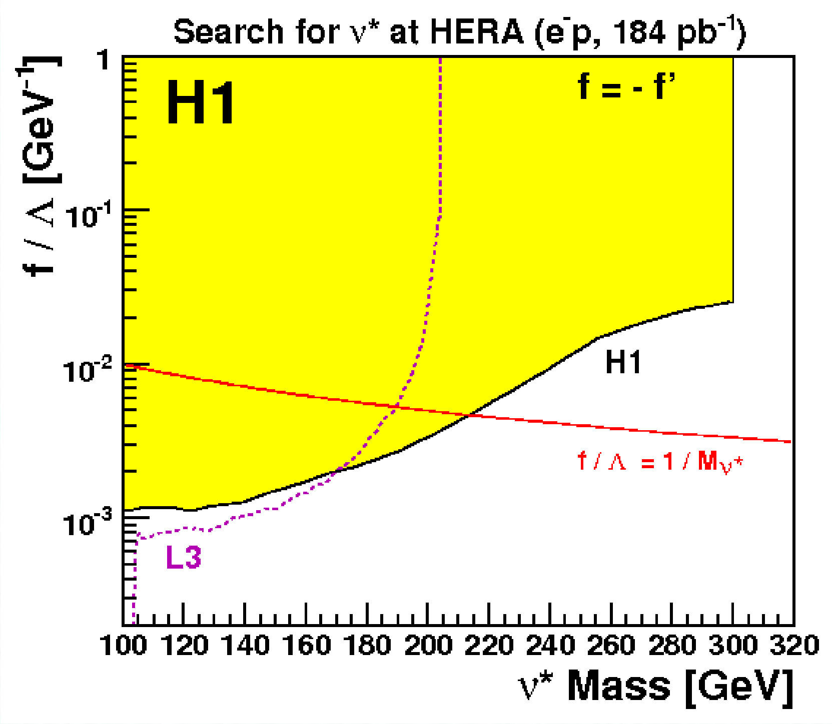
- **ν*->νγ**
- **ν* -> νZ with Z->qq**
- **ν* -> eW with W -> qq'**

Excited Leptons

Excited electrons



Excited neutrinos

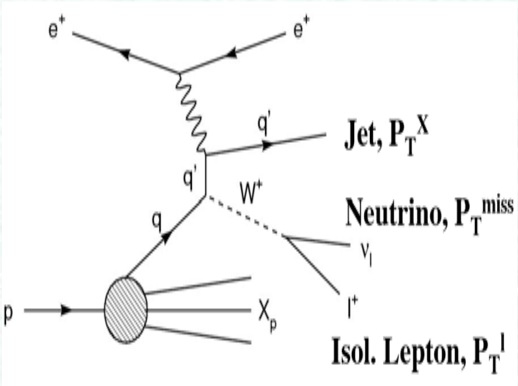


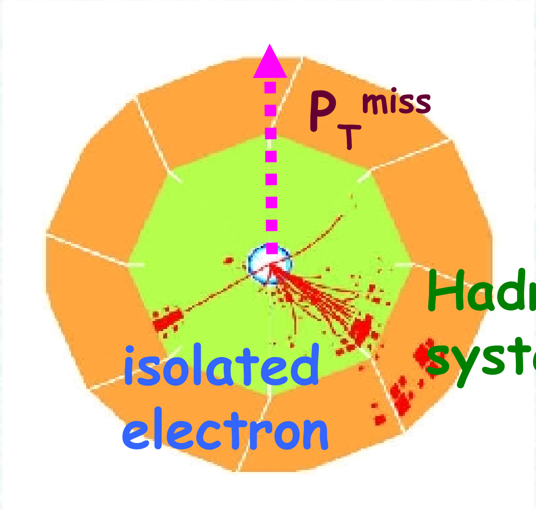
for ν*, e⁻p much more sensitive than e⁺p

For $f/\Lambda=1/M_{F^*}$, 95% upper limits:
- e* 273 (f=+f'), GeV
- ν* 196 (f=f'), 213 (f=-f') GeV

High-Pt leptons with missing Pt

In the SM, isolated leptons are produced by single W production (σ~1pb)



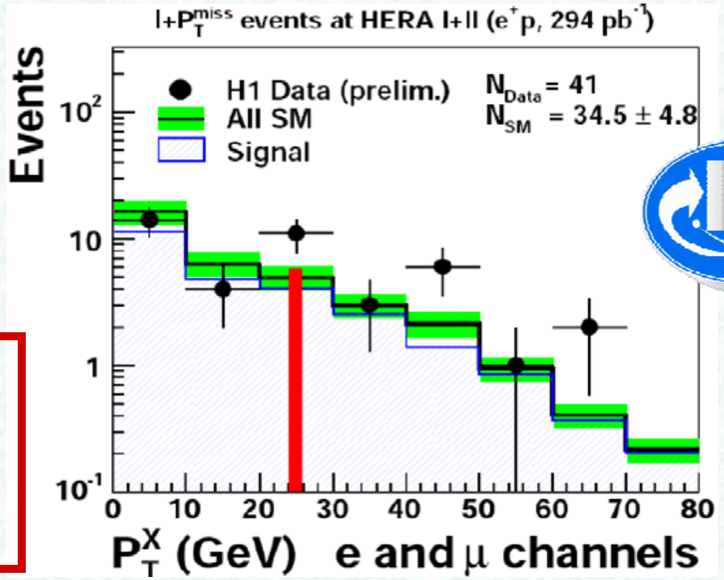


Signature:

Jet hadronic system with large transverse momentum

Isolated lepton

Large missing transverse momentum



e+p data: P_t^X > 25 GeV

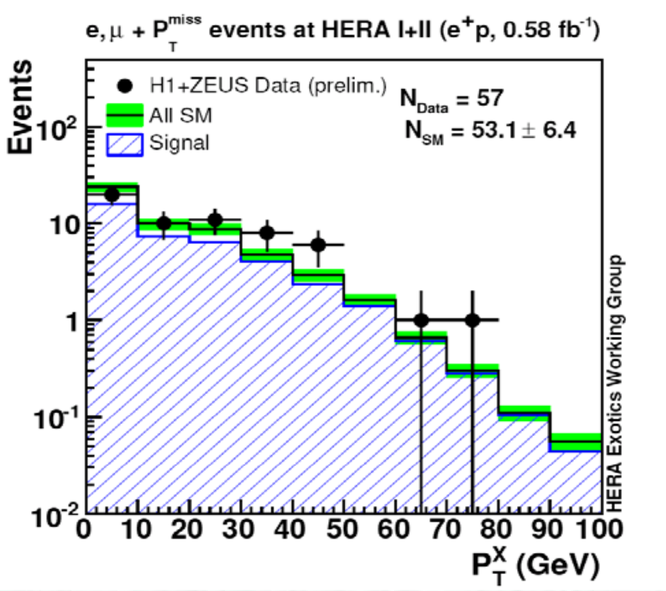
H1: 21 events for 9 ± 1.5 expected (~3σ)

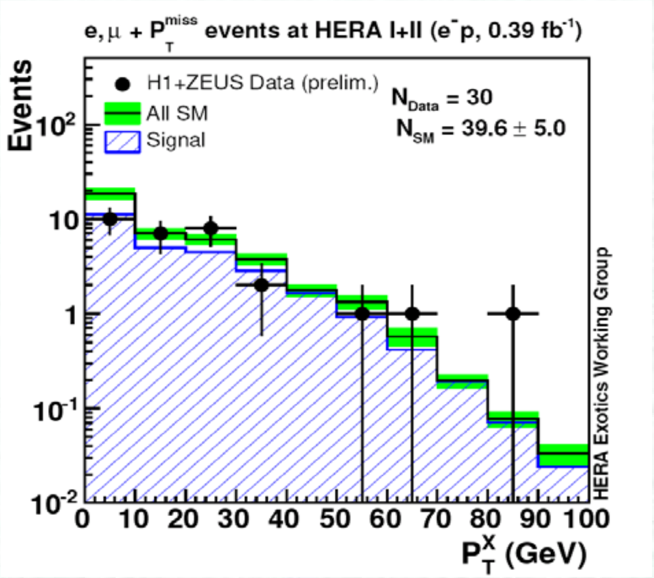
ZEUS: no events in excess of SM

High-Pt leptons with missing Pt

H1 and ZEUS results combined in common phase-space

Total luminosity L = 0.97 fb^{-1}



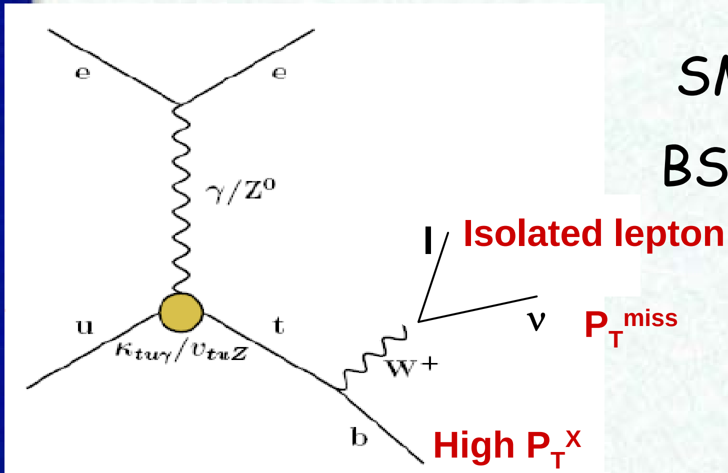


Good agreement with the SM

Excess observed in H1 e+p P_T^X > 25 GeV sample is reduced (~1.8 σ)

Single W production is observed at HERA

Anomalous Single Top production

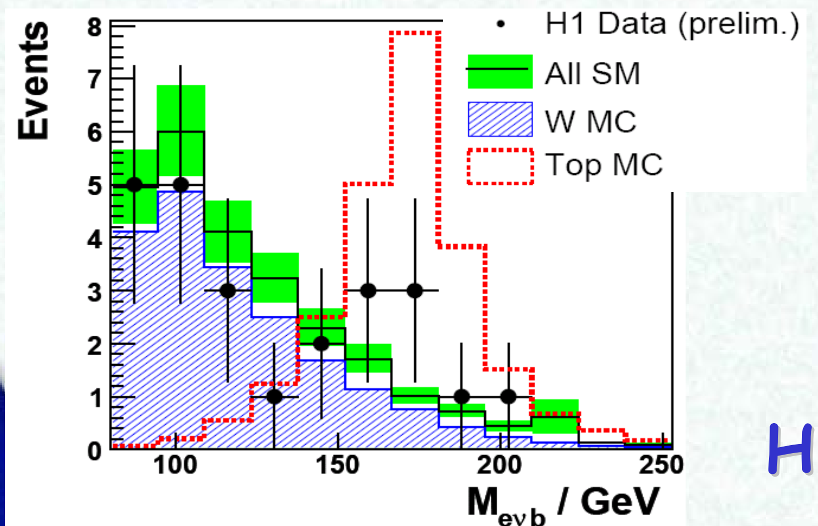


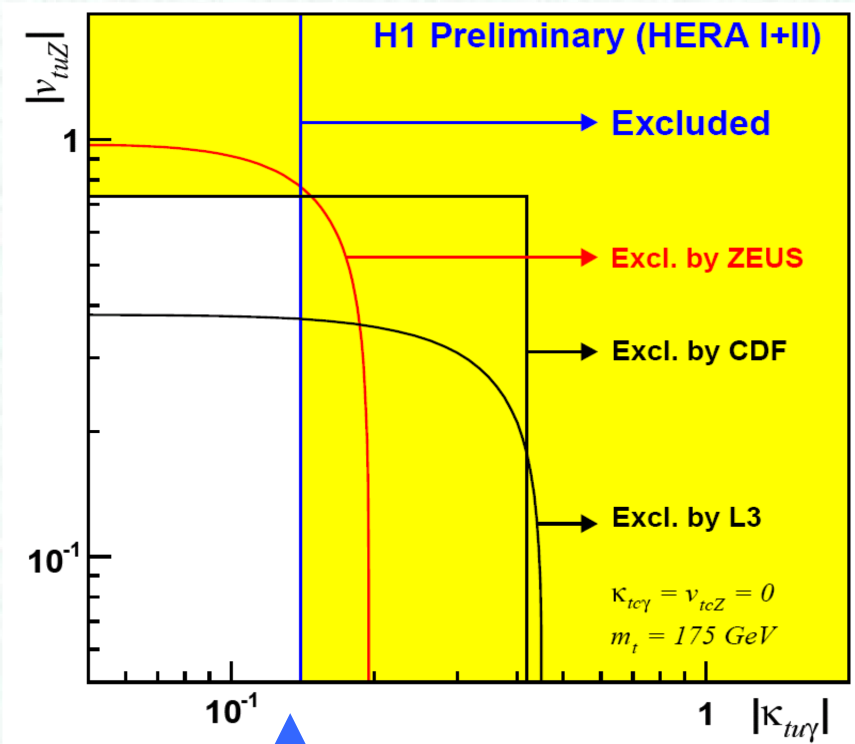
$\kappa_{tu\gamma}$: Anomalous γ magnetic coupling

V_{tuZ} : Anomalous Z vector coupling

SM: single top production σ<1fb

BSM: top production via flavor changing NC





H1: most stringent limit on $k_{tu\gamma}$

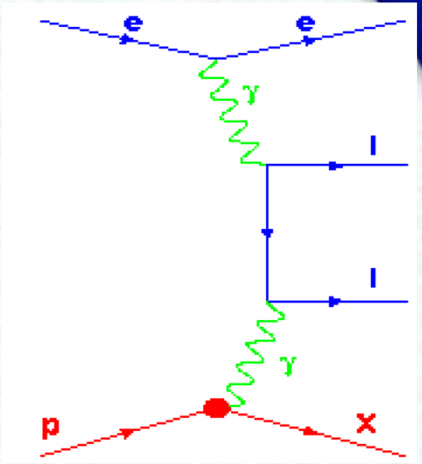
High Pt multi-leptons

Small and very precisely known SM contribution

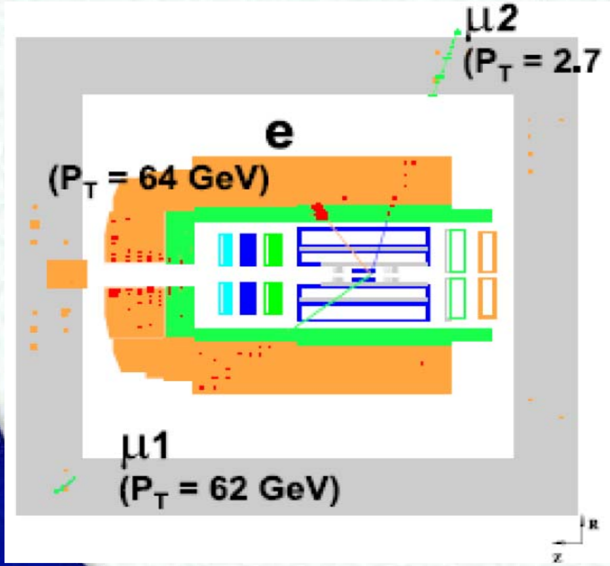
✓ Mainly produced via $\gamma\gamma$ in SM

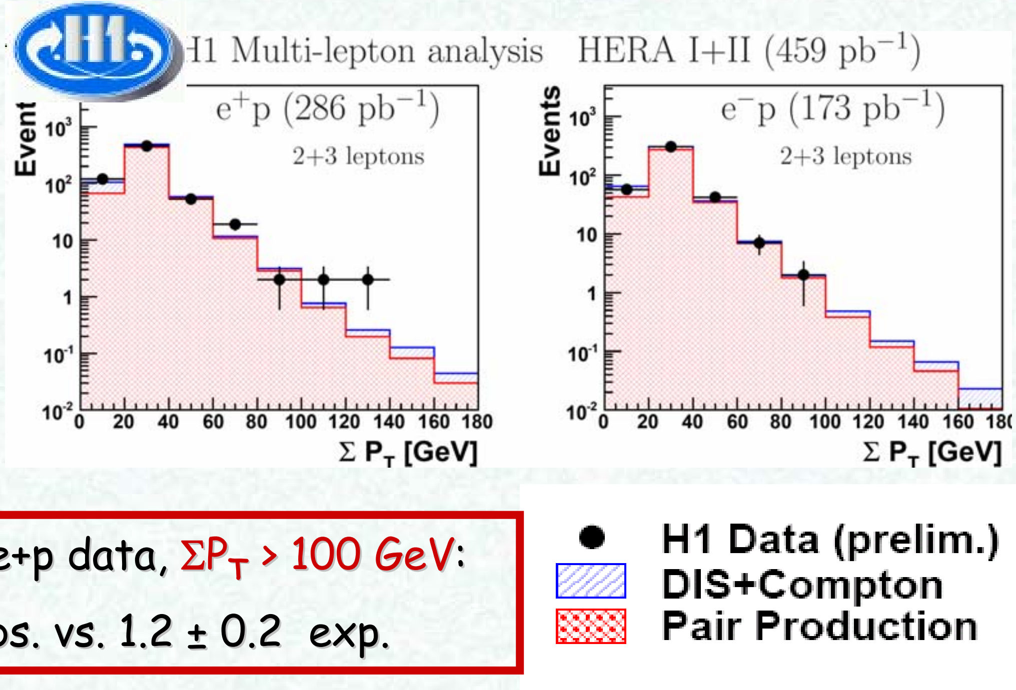
✓ Look for events with at least 2 high-Pt isolated leptons (e or μ)

✓ Topologies: ee, eee, eμ, $\mu\mu$, e$\mu\mu$



Scalar sum of transverse momentum (L~0.5 fb^{-1})





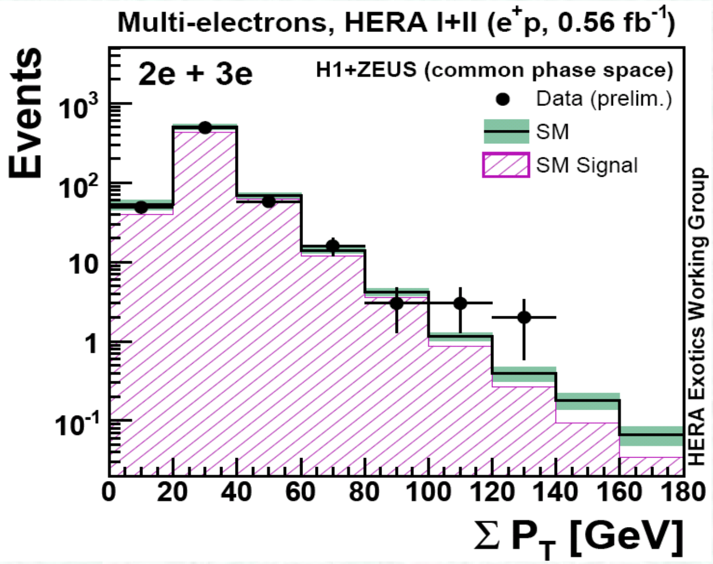
H1 e+p data, $\Sigma P_T > 100$ GeV:

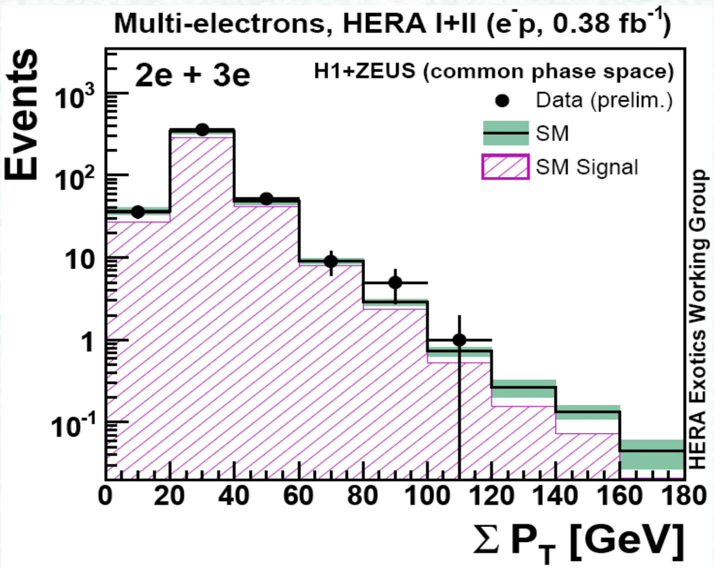
4 obs. vs. 1.2 ± 0.2 exp.

Multi-electrons H1 and ZEUS combined

H1 and ZEUS results combined in common phase-space

Total luminosity $L=0.94\ fb^{-1}$





$\Sigma Pt > 100$ GeV:

Data sample	Data	SM
e^+p (0.56 fb^{-1})	5	1.82 ± 0.21
e^-p (0.38 fb^{-1})	1	1.19 ± 0.14
$e^{\pm}p$ (0.94 fb^{-1})	6	3.00 ± 0.34

High Pt events mainly in e+p data

General searches

A model independent search for deviation from the SM prediction

HERA II data (L=337 pb^{-1})

HERA I (L=117 pb^{-1}) published

[PLB 602(2004)14]

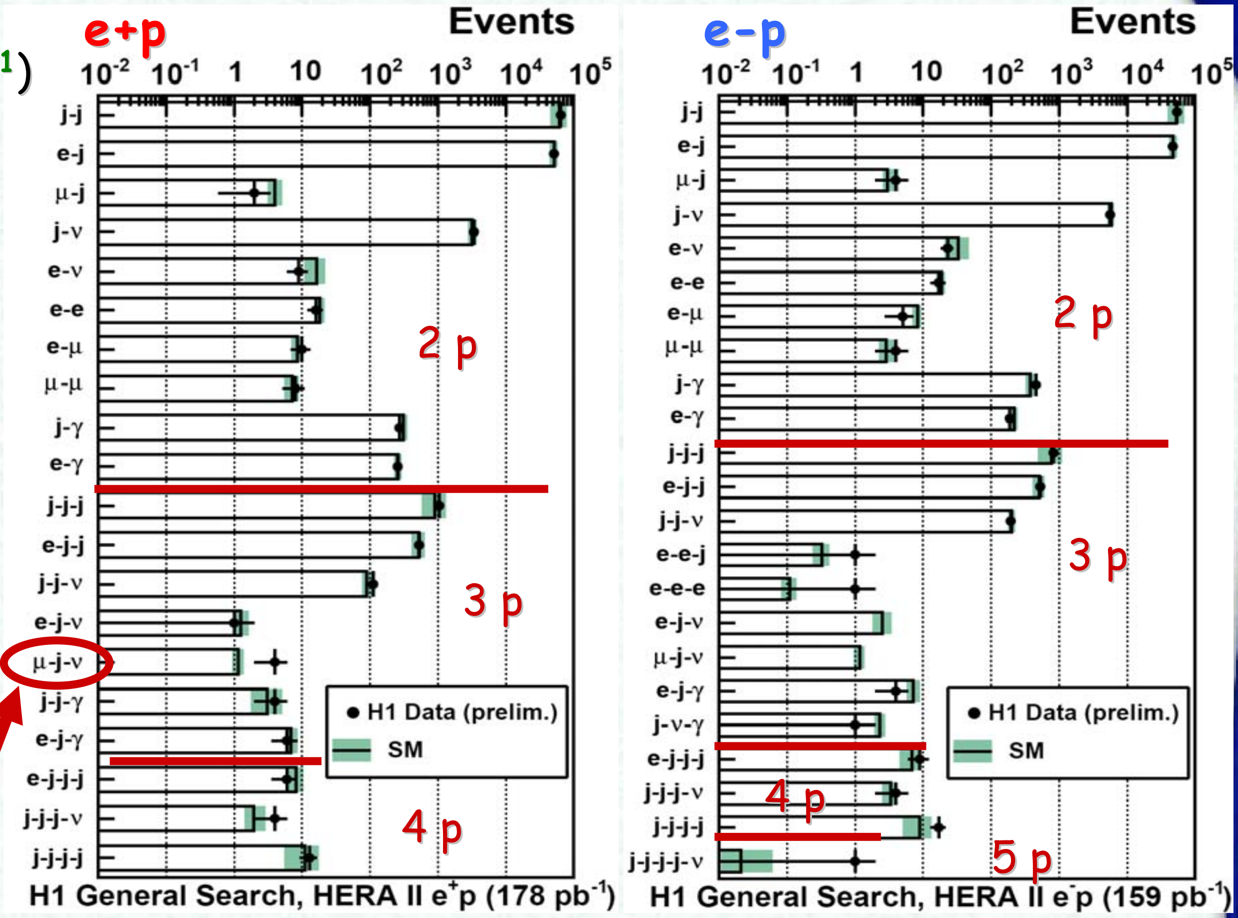
All topologies with >= 2 isolated particle:

e, γ, μ, jet, ν

A common phase space:

P_T > 20 GeV

10 < θ < 140 deg.



The largest deviation from SM in μ-j-ν (e+p)

Good agreement between data and SM predictions

Summary

✓ HERA data taking ended on June 30 2007 after 15 years successful operation:
=>the two experiments combined have collected ~1fb^{-1} data

✓ Many analyses use already full dataset

✓ H1 +ZEUS started to perform common analyses

✓ Results show no significant deviations from the Standard Model

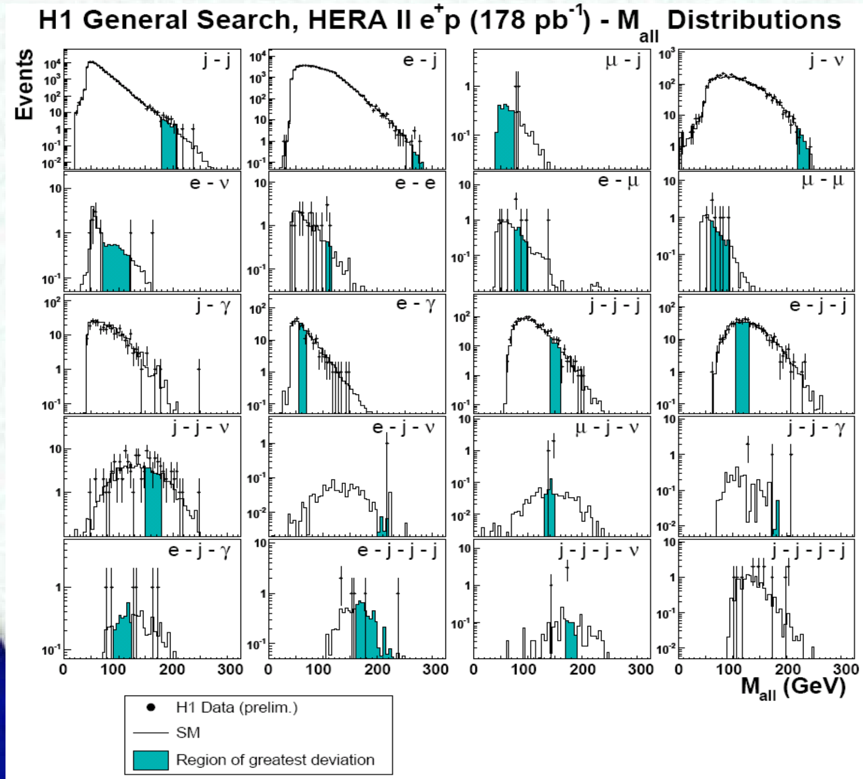
✓ HERA provides strong results in searches beyond SM

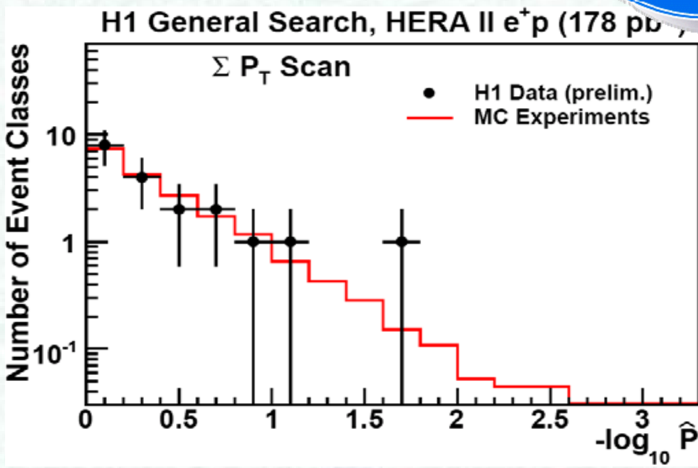
Extra-slides

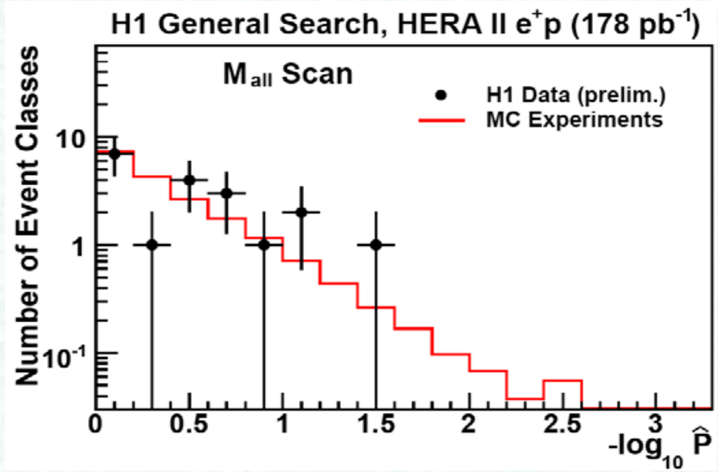
General searches

Agreement to SM quantified by looking for maximum deviation in ΣP_T and M_{all} distributions

=> Statistical analysis to quantify the significance of deviations (P)







Observed fluctuations compatible with the SM prediction

General Models

Coupling structure

Couplings $\eta^{eq}_{\alpha\beta}$ are related to the "new physics" mass scale Λ by the formula:

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

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

$$g^2_{CI} = 4\pi$$

Different models assume different helicity structure of new interactions $\Rightarrow$

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}
LL	$+\eta$				$+\eta$			
LR		$+\eta$				$+\eta$		
RL			$+\eta$				$+\eta$	
RR				$+\eta$				$+\eta$
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							$+\eta$	$-\eta$

Also referred to as compositeness models

(Λ - compositeness scale)

Contact Interactions

Cross-section

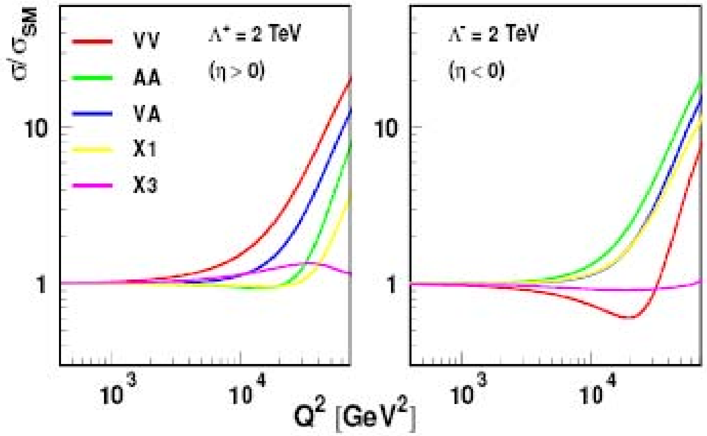
Contact Interactions modify tree level $eq \rightarrow eq$ scattering amplitudes $M^{eq}_{\alpha\beta}$:

$$M^{eq}_{\alpha\beta}(Q^2) = \underbrace{\frac{e^2 e_q}{Q^2}}_{\gamma} - \underbrace{\frac{e^2}{sin^2\theta_W \cdot cos^2\theta_W} \cdot \frac{g^e_\alpha g^q_\beta}{Q^2 + m_Z^2}}_{Z^0} + \underbrace{\eta^{eq}_{\alpha\beta}}_{?}$$

Resulting contribution to the differential NC DIS cross-section:

$$\frac{d\sigma}{dx\,dQ^2}(\eta) = \frac{d\sigma^{SM}}{dx\,dQ^2} \cdot [1 + A(x,Q^2)\,\eta + B(x,Q^2)\,\eta^2]$$

General formula for all CI type models



Models

Leptoquarks

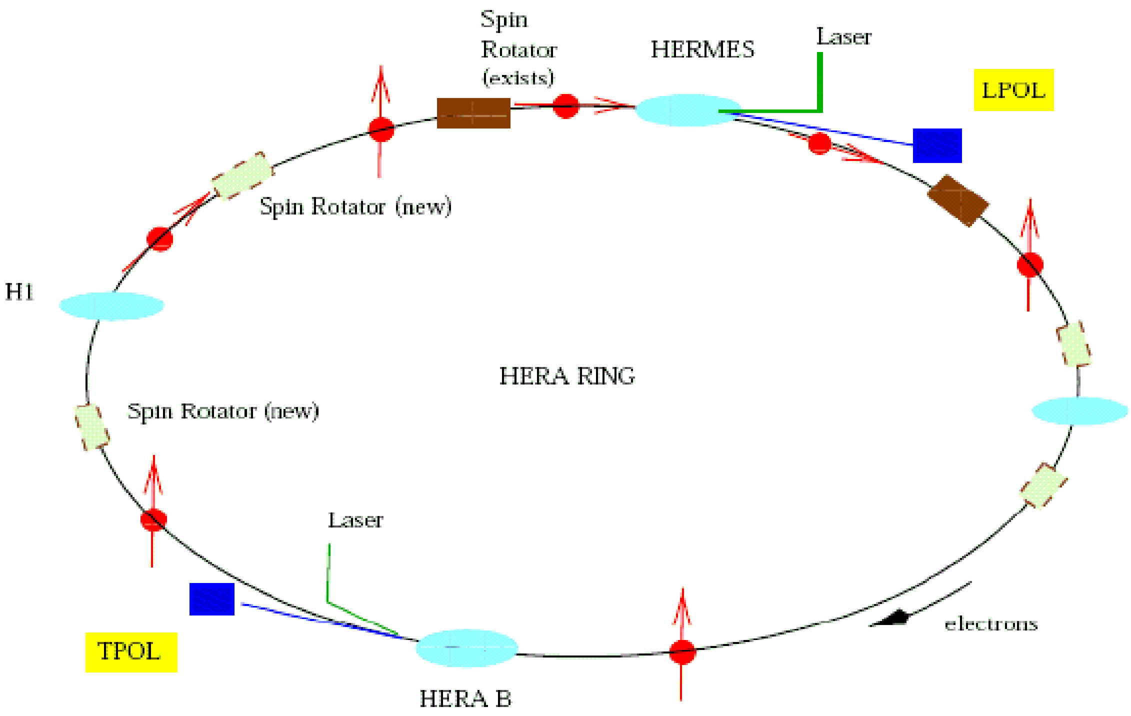
Aachen notation

Model	Fermion number F	Charge Q	$BR(LQ \to e^{\pm}q)$ β	Coupling		Squark type
S_0^L	2	$-1/3$	1/2	$e_L u$	νd	$\tilde{d}_R$
S_0^R	2	$-1/3$	1	$e_R u$		
$\tilde{S}_0$	2	$-4/3$	1	$e_R d$		
$S_{1/2}^L$	0	$-5/3$	1	$e_L \bar{u}$		
		$-2/3$	0		$\nu \bar{u}$	
$S_{1/2}^R$	0	$-5/3$	1	$e_R \bar{u}$		
		$-2/3$	1	$e_R \bar{d}$		
$\tilde{S}_{1/2}$	0	$-2/3$	1	$e_L \bar{d}$		$\overline{\tilde{u}_L}$
		$+1/3$	0		$\nu \bar{d}$	$\overline{\tilde{d}_L}$
S_1	2	$-4/3$	1	$e_L d$		
		$-1/3$	1/2	$e_L u$	νd	
		$+2/3$	0		νu	
V_0^L	0	$-2/3$	1/2	$e_L \bar{d}$	$\nu \bar{u}$	
V_0^R	0	$-2/3$	1	$e_R \bar{d}$		
$\tilde{V}_0$	0	$-5/3$	1	$e_R \bar{u}$		
$V_{1/2}^L$	2	$-4/3$	1	$e_L d$		
		$-1/3$	0		νd	
$V_{1/2}^R$	2	$-4/3$	1	$e_R d$		
		$-1/3$	1	$e_R u$		
$\tilde{V}_{1/2}$	2	$-1/3$	1	$e_L u$		
		$+2/3$	0		νu	
V_1	0	$-5/3$	1	$e_L \bar{u}$		
		$-2/3$	1/2	$e_L \bar{d}$	$\nu \bar{u}$	
		$+1/3$	0		$\nu \bar{d}$	

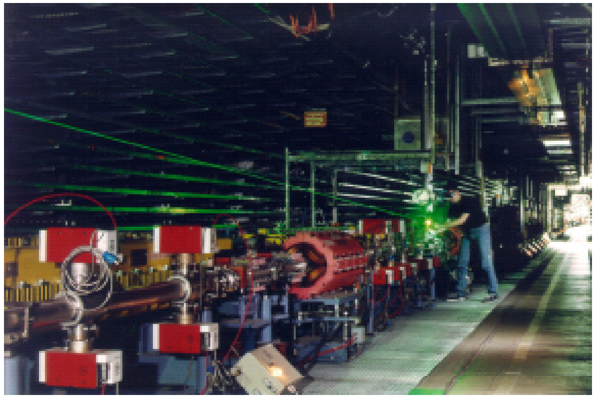
Polarized e$^{\pm}$

e beam acquires transverse polarization by the Sokolov-Ternov effect (magnetic moment couples to the dipole B field, spin flip by synchrotron radiation emission).

Spin rotators provide longitudinal polarization at the experiments (Hermes since 1995, H1 and ZEUS since 2003).



- Polarization typically 30-40%.
- Polarization monitored by Compton backscattering of laser beams.

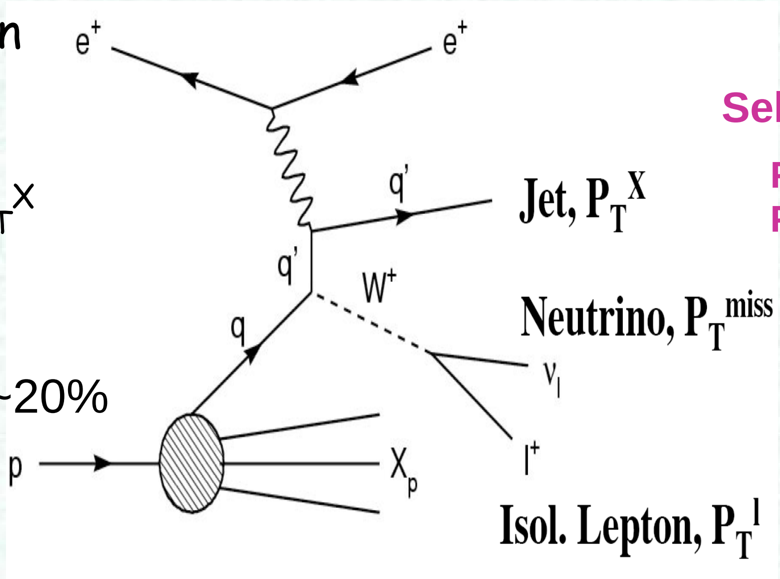


Standard Model prediction

Real W production in photoproduction
with W decay into leptons
main process for this event topology
Hadronic system with typically low p_T^X

$\sigma_W \sim 1.3\ pb^{-1}$
W decay branching ratio into e or μ ~20%

Other signal processes:
CC W production ~7%
Cabbibo-Parisi Z0 production ~3% (only e channel)



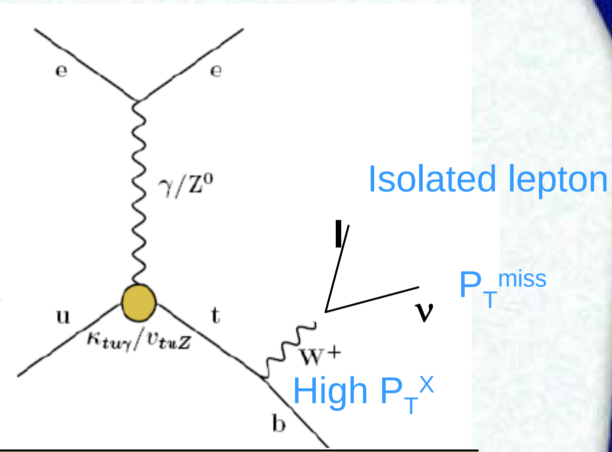
Selection cuts
For μ only: P_T^X>12GeV
>12GeV
>10GeV

Modeled using EPVEC generator with NLO QCD correction:
Modifies cross section by ~10%, reduces theoretical uncertainty to ~15%

Anomalous single top production

SM single top production s<1fb-1

Top production via flavor changing NC in BSM
Candidate process for excess
But: same rate for e^+ and e^-

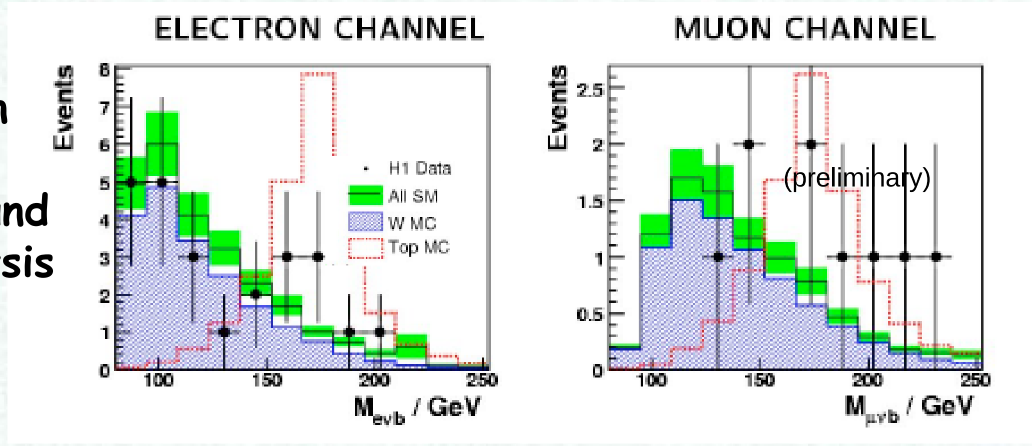


$\kappa_{tu\gamma}$: Anomalous γ magnetic coupling
V_{tuZ} : Anomalous Z vector coupling

Search for FCNC based on isolated lepton events of HERAI+I
additional good top quark reconstruction and positive lepto
charge requirement (if possible)

24 events selected,
26 events SM prediction

No significant signal found
using multi variant analysis



Single top results

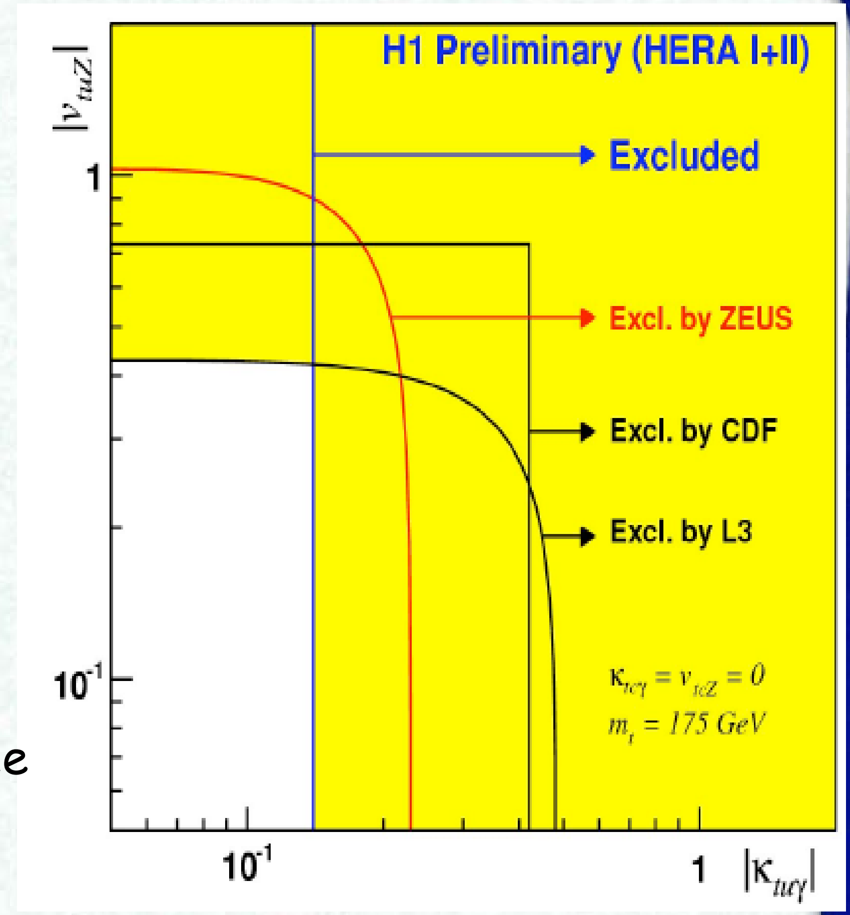
Limits on FCNC cross section derived using maximum likelihood:

σ(ep->etX) < 0.16 (95% CL)

HERA 1 results:
H1: σ(ep->etx) < 0.55 pb
Zeus: σ(ep->etX)<0.23 pb

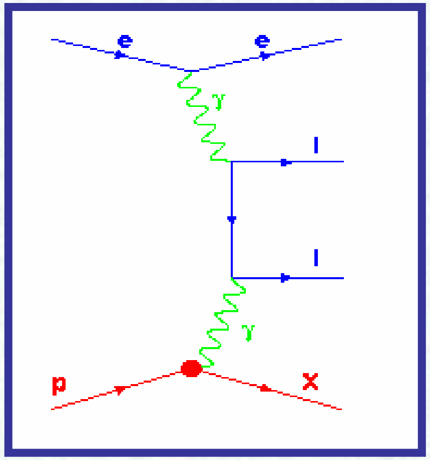
Upper bound on the anomalous coupling:
$k_{\tau\upsilon\gamma}$ < 0.14

New limit extends into region of phase space uncovered by other colliders

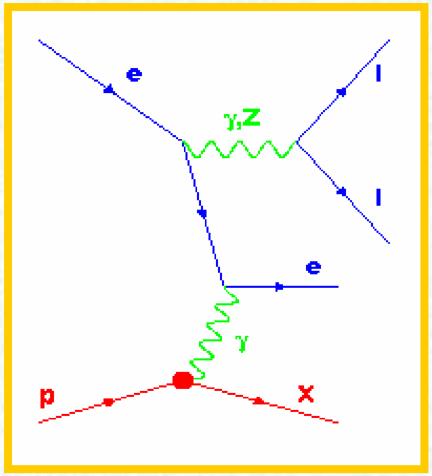


Multi-lepton events at HERA

How are lepton pairs produced ?



γγ process dominant



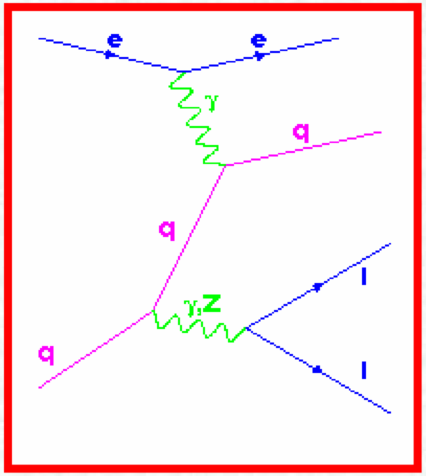
Cabbibo-Parisi

- ee -> ee

annihilation & Scattering

- ee -> μμ

annihilation



Drell-Yan negligible

Multi-lepton production is a QED process

-very well understood in the Standard Model

Any excess over SM prediction <u>at high mass region</u> is sensitive to new phenomena (e.g. $H^{\pm\pm}$)

Multi-lepton events at high mass

Selection:

- Look for events with at least 2 high Pt leptons:
- $P_t^{l1} > 10$ and $P_t^{l2} > 5$ GeV and $20^\circ < \theta_l < 150^\circ$
- Additional lepton: Ee>5 GeV or $P_t^{\mu} > 2$GeV ($5^\circ < \theta_l < 175^\circ$)
- Covered topologies:

* H1: ee, eμ, μμ and eee, eμμ   * ZEUS: ee, eee

Dominant background:

- NC DIS: DIS e + fake electron
- QED Compton: γ misidentified as e

Invariant mass M_{ll}:

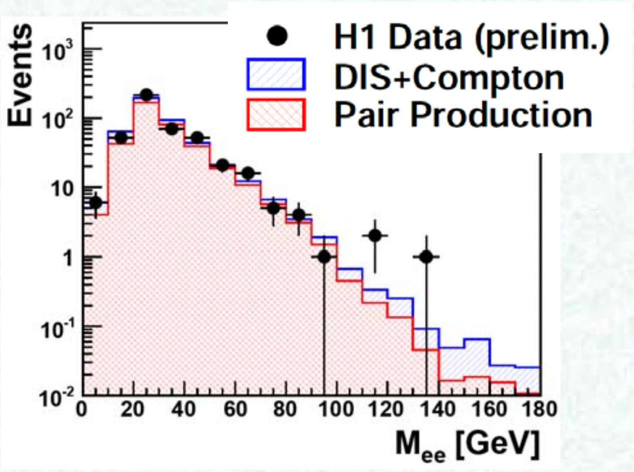
- Reconstructed using 2 highest Pt leptons

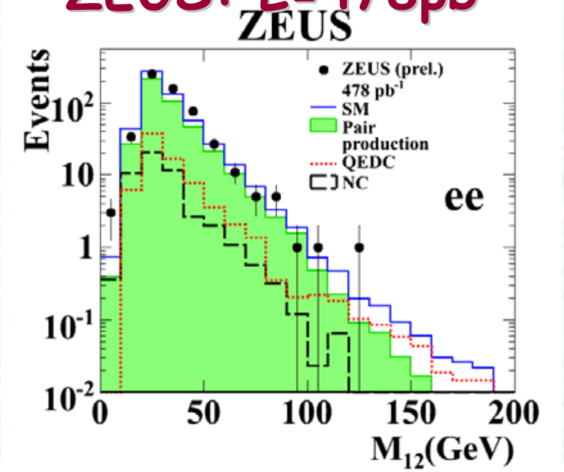
Multi-electron mass

H1: L= 459 pb^{-1}

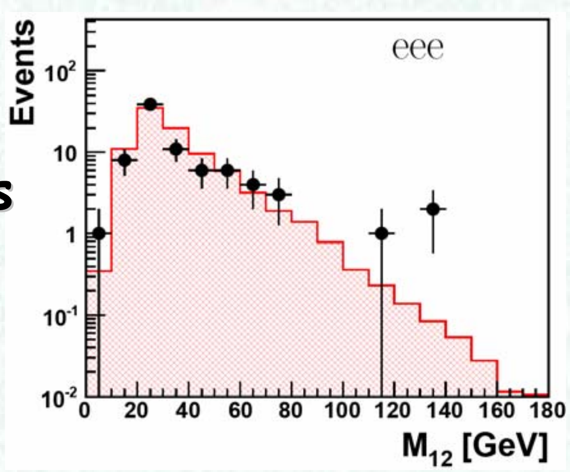
ZEUS: L=478pb^{-1}

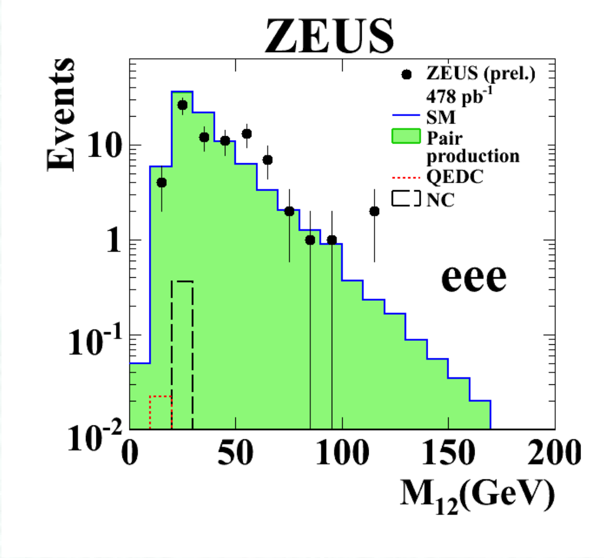
ee events





eee events

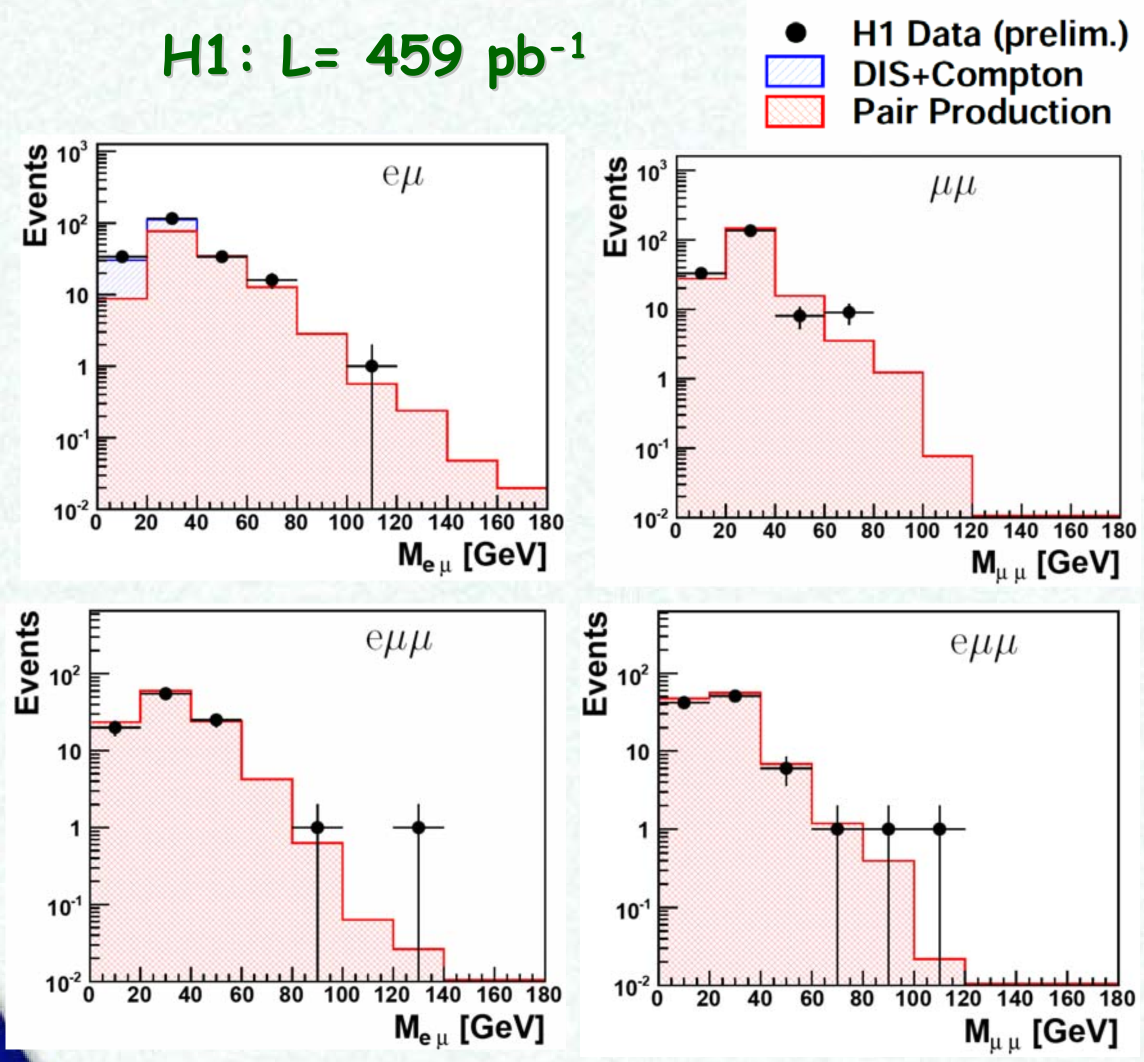




Overall good agreement with the Standard Model

Topologies with μ(s)

H1: L= 459 pb^{-1}



Di-lepton topology

Tri-lepton topology

Overall good agreement with the Standard Model

Event yields at high M_{ll} > 100 GeV

H1 Preliminary: L= 459 pb^{-1}

	Selection	Data	SM	Pair Production	NC-DIS + Compton
	e^+p collisions (286 pb^{-1})				
e^+p	ee M_{12} >100 GeV	3	1.0 ± 0.2	0.6 ± 0.2	0.4 ± 0.1
	$\mu\mu$ $M_{\mu\mu}$ >100 GeV	0	0.06 ± 0.03	0.06 ± 0.03	—
	$e\mu$ $M_{e\mu}$ >100 GeV	1	0.53 ± 0.05	0.53 ± 0.05	—
	eee M_{12} >100 GeV	3	0.6 ± 0.1	0.6 ± 0.1	—
	$e\mu\mu$ $M_{e\mu}$ >100 GeV	1	0.04 ± 0.02	0.04 ± 0.02	—
	$e\mu\mu$ $M_{\mu\mu}$ >100 GeV	1	0.007 ± 0.005	0.007 ± 0.005	—
	e^-p collisions (173 pb^{-1})				
e^-p	ee M_{12} >100 GeV	0	0.55 ± 0.1	0.3 ± 0.1	0.25 ± 0.07
	$\mu\mu$ $M_{\mu\mu}$ >100 GeV	0	0.03 ± 0.02	0.03 ± 0.02	—
	$e\mu$ $M_{e\mu}$ >100 GeV	0	0.3 ± 0.05	0.3 ± 0.05	—
	eee M_{12} >100 GeV	0	0.32 ± 0.06	0.32 ± 0.06	—
	$e\mu\mu$ $M_{e\mu}$ >100 GeV	0	0.04 ± 0.01	0.04 ± 0.01	—
	$e\mu\mu$ $M_{\mu\mu}$ >100 GeV	0	0.006 ± 0.004	0.006 ± 0.004	—

All high mass events M_{ll} > 100 GeV from e+p data

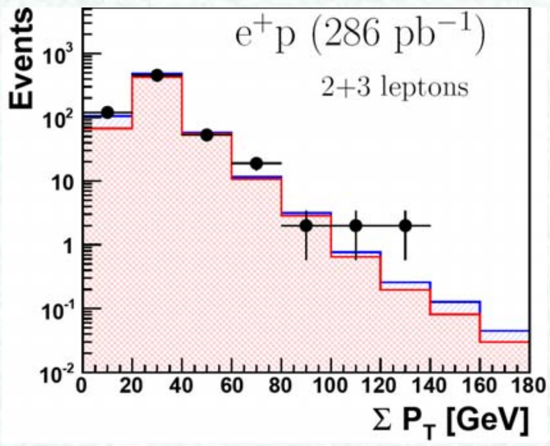
ZEUS Preliminary: L=478pb^{-1}

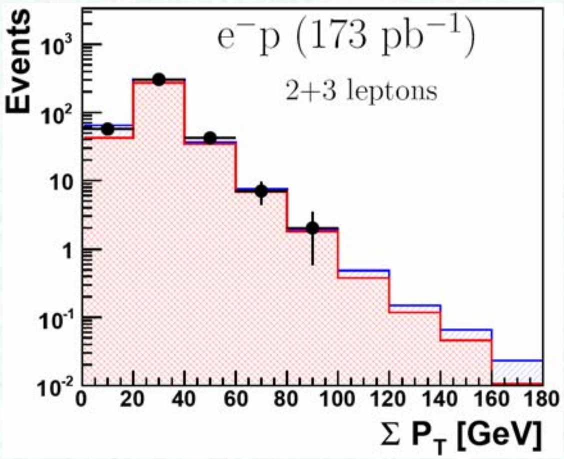
e+p (L=272pb^{-1}) e+p (L=206pb^{-1})

	Data sample	Data	SM	Pair Production	Compton	NC DIS
e+p	ee	1	0.9 ± 0.1	0.5 ± 0.07	0.4 ± 0.12	0.07 ± 0.03
	eee	2	$0.6^{+0.5}_{-0.07}$	0.6 ± 0.07	<0.01	< 0.5
e-p	ee	1	0.8 ± 0.08	0.4 ± 0.04	0.4 ± 0.1	0.04 ± 0.01
	eee	0	$0.4^{+0.5}_{-0.05}$	0.4 ± 0.05	<0.01	< 0.5

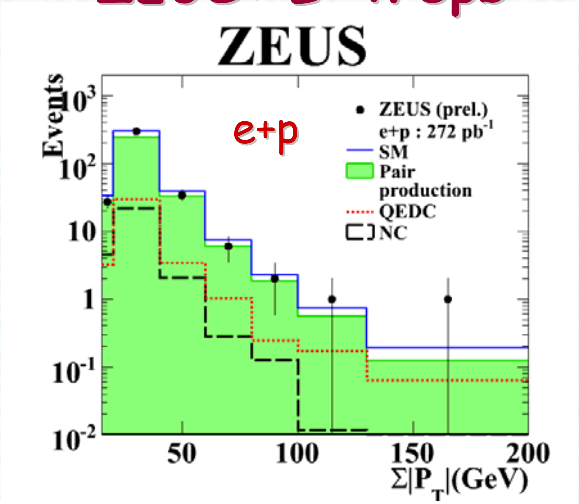
Multi-leptons: scalar ΣPt distribution

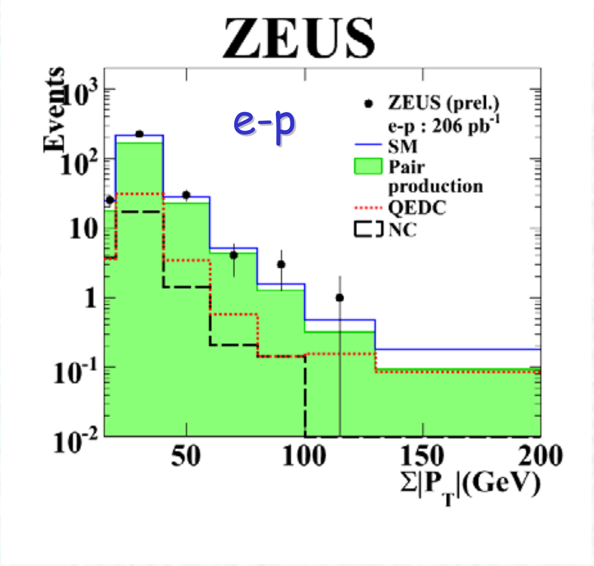
H1: L= 459 pb^{-1}





ZEUS: L=478pb^{-1}





Good agreement with SM

Event yields at scalar ΣP_t > 100 GeV

H1 Preliminary: L= 459 pb^{-1}

Multileptons: electrons and muons

Data sample	Data	SM	Pair Production	NCDIS + Compton
e+p L=286pb	4	1.2 ± 0.2	1.0 ± 0.2	0.2 ± 0.1
e-p L=173pb	0	0.8 ± 0.2	0.6 ± 0.2	0.2 ± 0.1
All L=459pb	4	1.9 ± 0.4	1.5 ± 0.3	0.4 ± 0.1

H1: All events at high ΣPt come from e+p data

ZEUS Preliminary: L=478pb^{-1}

Multileptons: electrons only

Data sample	Data	SM	Pair Production	Compton	NC DIS
e+p L=272pb	2	$0.95^{+0.10}_{-0.09}$	0.67 ± 0.07	$0.26^{+0.07}_{-0.06}$	0.02 ± 0.01
e-p L=206pb	1	$0.68^{+0.08}_{-0.07}$	0.41 ± 0.04	$0.27^{+0.07}_{-0.06}$	0.01 ± 0.01
All L=478pb	3	$1.63^{+0.16}_{-0.12}$	1.08 ± 0.11	$0.53^{+0.15}_{-0.11}$	0.03 ± 0.01

Search for doubly charged Higgs

In extension to SM:

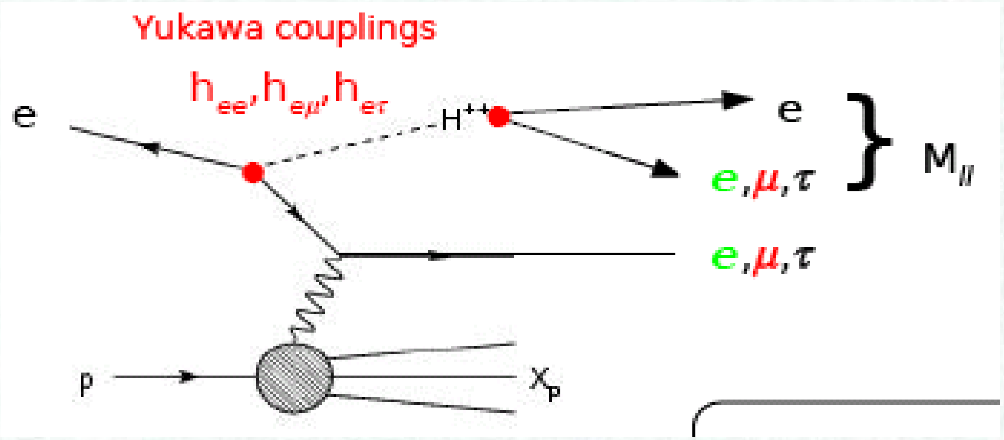
- $H^{\pm\pm}$ appears in Higgs triplet(s) of non-zero hypercharge
- Left-right symmetries: $SU(2)_R \times SU(2)_L \times U(1)_{B-L}$
- provides mass to Majorana neutrinos
- Couplings to leptons $h_{ll}^{R,L}$ unknown

  Democratic scenario: $h_{ee}=h_{e\mu}=h_{e\tau}$

  One dominant coupling $h_{el}>>0$, others ~0

HERA: $e^{\pm}p \rightarrow l^{\pm} H^{\pm\pm} X$

where $H^{\pm\pm} \rightarrow e^{\pm} l^{\pm}$



Double charged Higgs

Selection:

✓Data: HERA-I L=118 pb-1

✓ee, eμ: based on multi-lepton analysis

✓eτ with τ->e,μ and hadrons

✓ 2 high-Pt leptons with the same charge as a beam lepton

✓Reconstruct inv. mass Higgs candidates - M_{ll}

Results:

M_{ll}>65 GeV

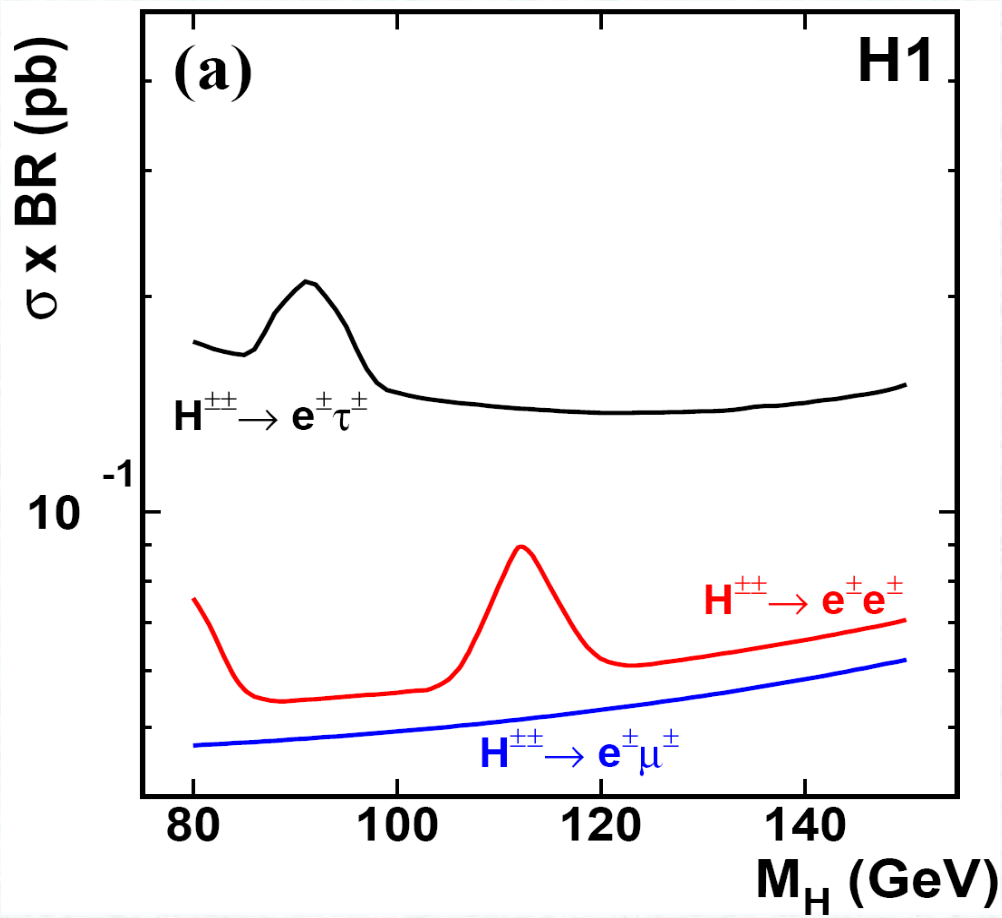
	Obs	SM exp.
ee	3	2.45 ±0.11
eμ	1	4.17± 0.44
eτ	1	2.1 ± 0.5

M_{ll}>100 GeV

Only one ee event satisfies the final selection createria

No evidence for $H^{\pm\pm}$ => set limits

Double charged Higgs: results



Upper limits for $H^{\pm\pm}$ production at 95%C.L. derived by modified frequentist method

$H^{\pm\pm} \longrightarrow e^{\pm}\tau^{\pm}$

$H^{\pm\pm} \longrightarrow e^{\pm}e^{\pm}$

$H^{\pm\pm} \longrightarrow e^{\pm}\mu^{\pm}$

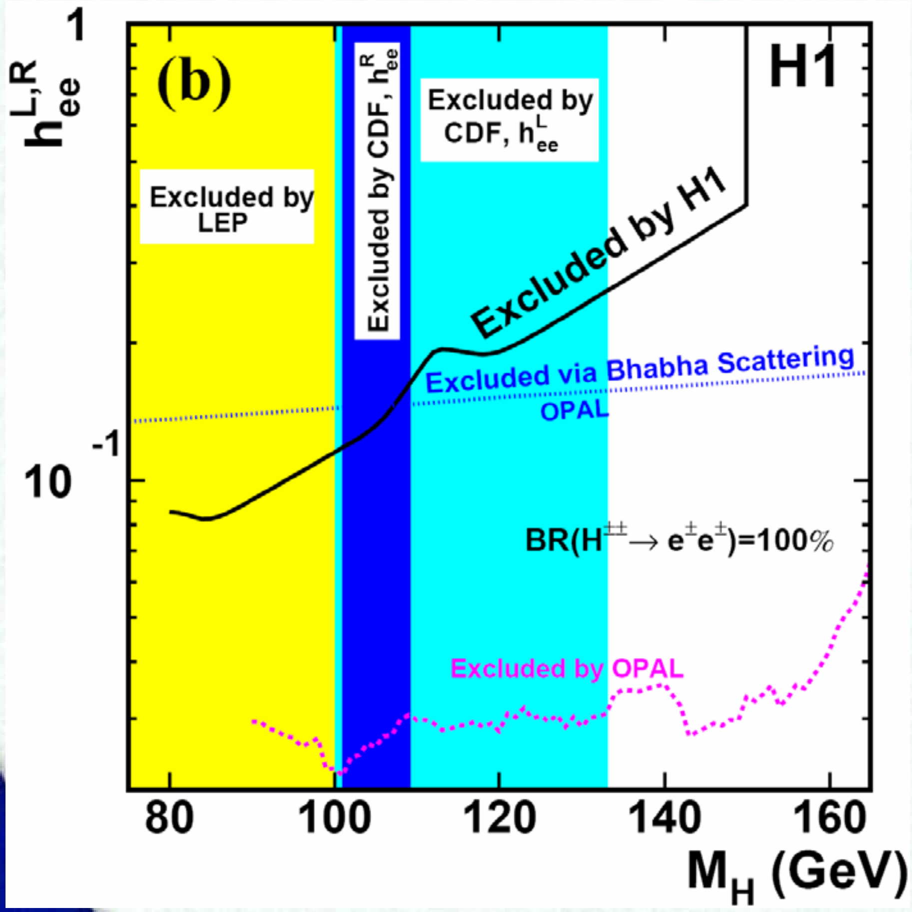
Best sensitivity:

$\sigma x Br(h_{e\mu}) < 0.05$ pb

Double charged Higgs: upper limits on h_{ee}

$H^{\pm\pm}$ boson couples to electron-electron pair only

Topologies: ee and eee (excess was observed in HERA I data)



LEP, TeVatron:

-$H^{\pm\pm}$ Pair Production: h_{el} independent

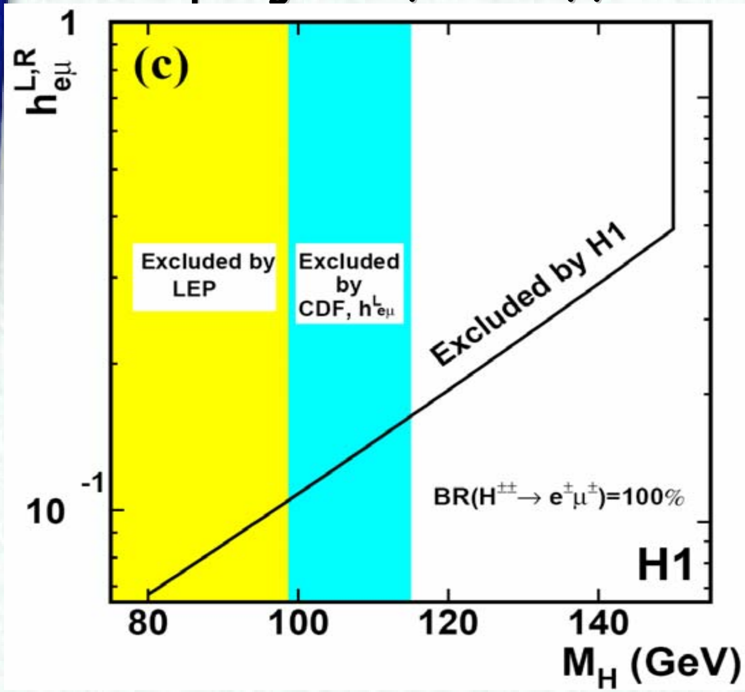
OPAL:

-$H^{\pm\pm}$ single production

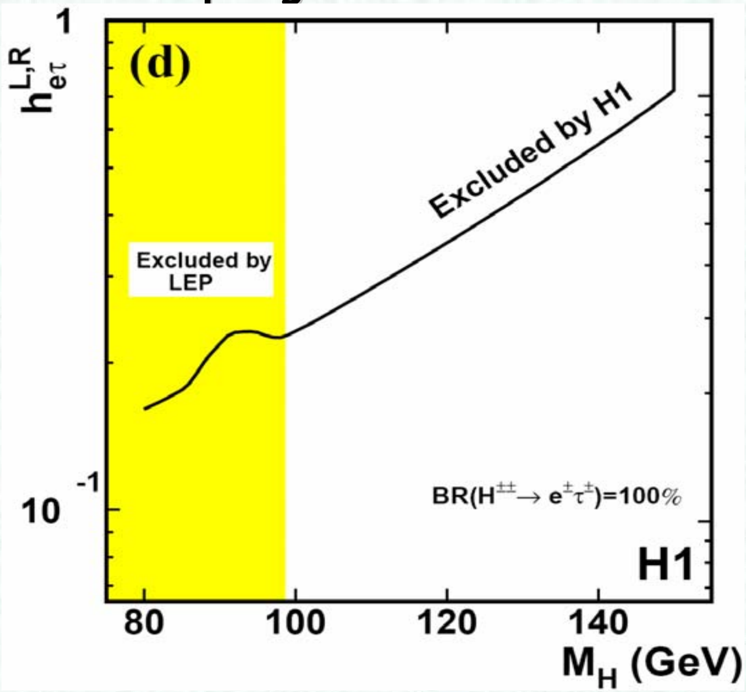
Limits are set for left- and right-handed h_{ee} couplings

Doubly charged Higgs: upper limits on $h_{e\mu}$ and $h_{e\tau}$

- $H^{\pm\pm}$ boson couples to **electron-muon pair** only
- Topologies: $e\mu$ and $e\mu\mu$



- $H^{\pm\pm}$ boson couples to **electron-tau pair** only
- Topologies: $e\tau$ and $e\tau\tau$

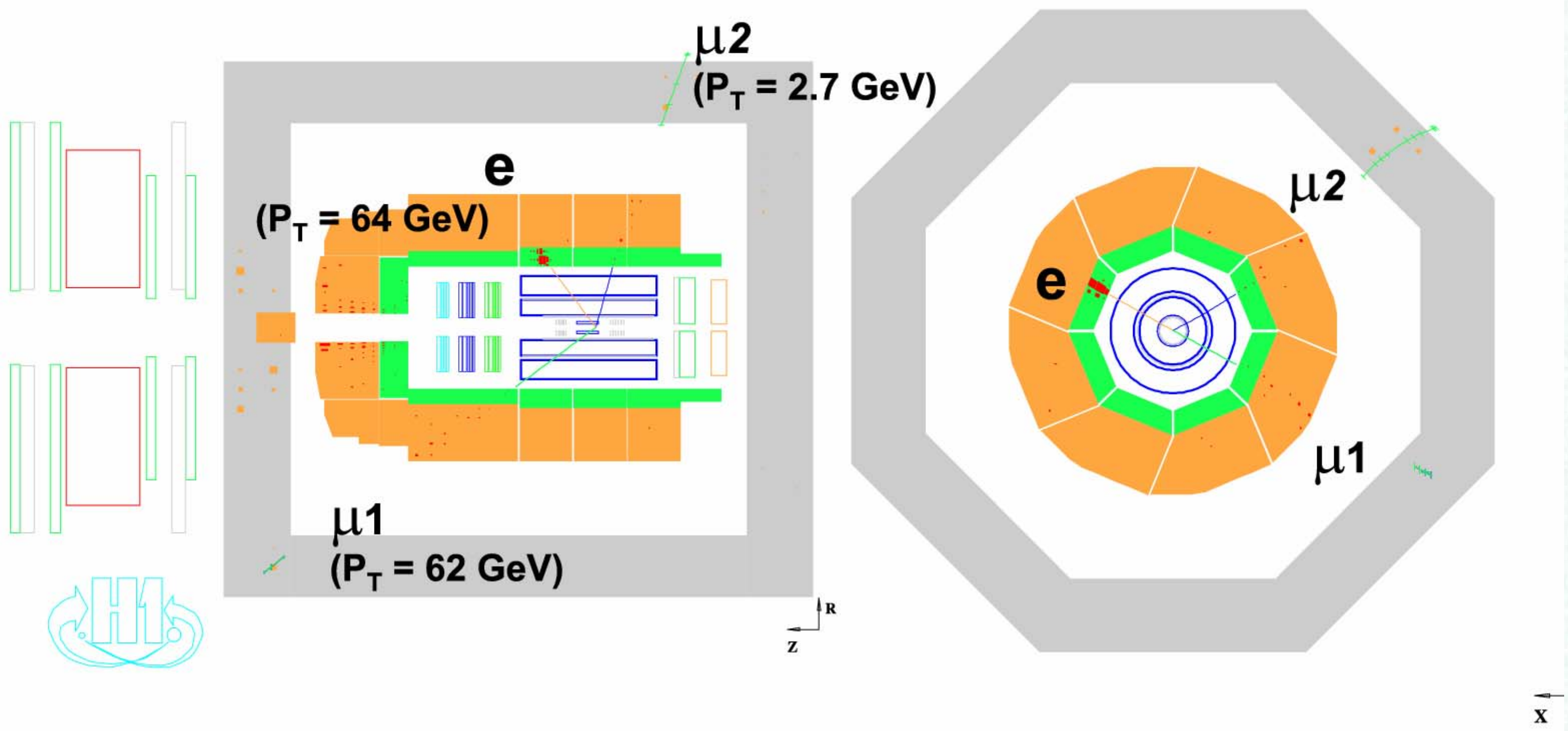


For couplings of em. strength $h_{e\mu}$~0.3: mass exclusion $M_{H^{\pm\pm}}$ > 141 GeV

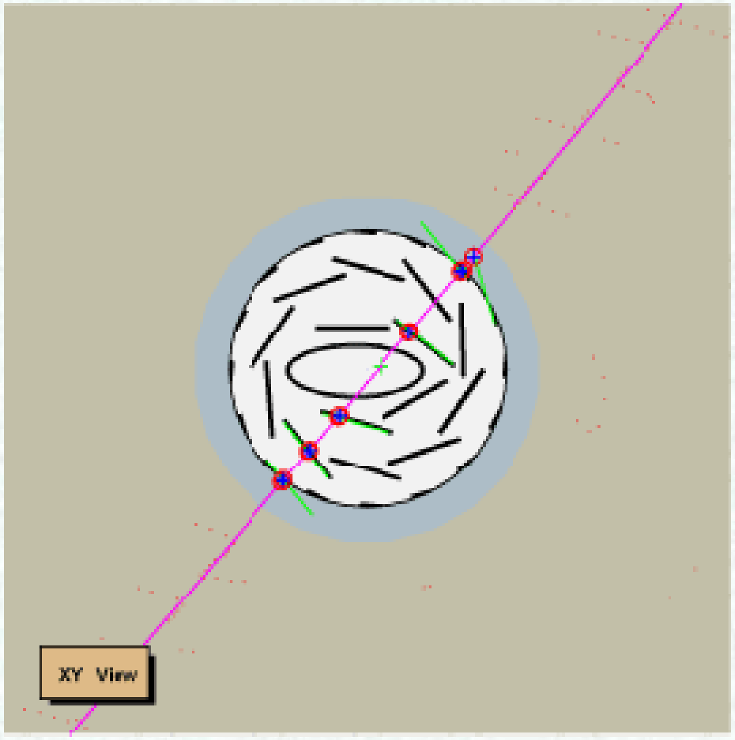
$h_{e\tau}$~0.3: mass exclusion $M_{H^{\pm\pm}}$ > 112 GeV

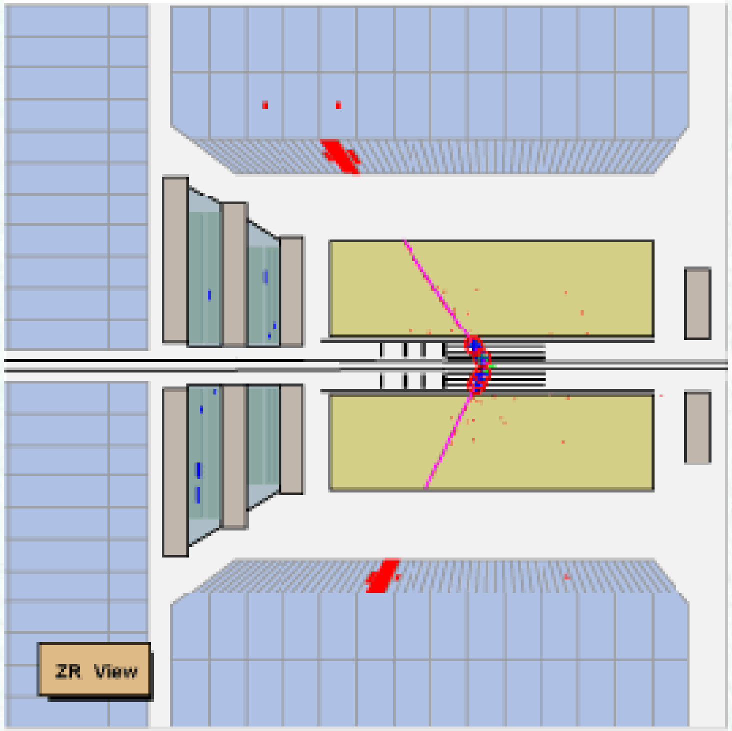
HERA limits extend beyond LEP, TeVatron reach

High mass events H1



High mass events ZEUS





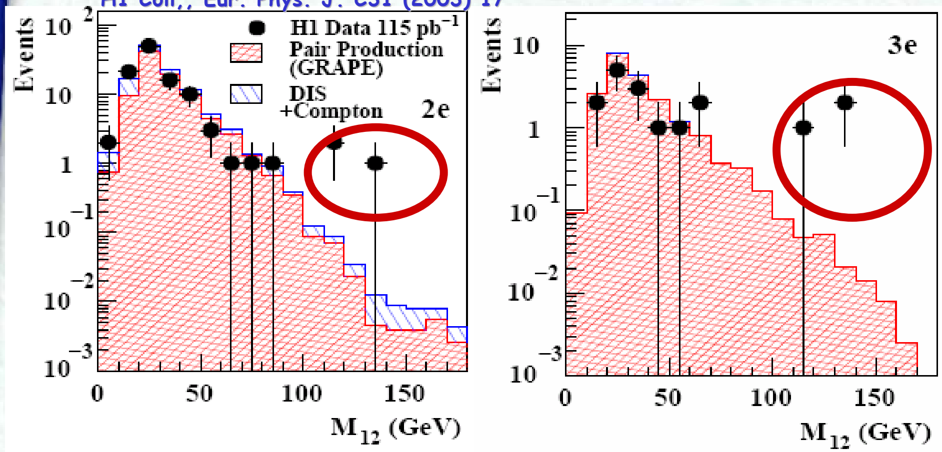
Mass = 100.8 GeV, Pt^{e1} = 50.4 GeV, Pt^{e2} = 50.0 GeV, θ_{e1} = 1.12(rad), θ_{e2} = 0.97(rad).

Motivation

- H1 results for ee and eee channels (HERA-I data)

Distribution of inv. Mass of 2 highest Pt electrons

H1 Coll,, Eur. Phys. J. C31 (2003) 17



- General good agreement with SM
- Interesting events at Mee >100 GeV

Selection	Data	SM	Pair Production (GRAPE)	DIS + Compton
"2e" $M_{12} > 100$ GeV	3	0.30 ± 0.04	0.21 ± 0.03	0.09 ± 0.02
"3e" $M_{12} > 100$ GeV	3	0.23 ± 0.04	0.23 ± 0.03	< 0.02 (95% C.L.)

$H^{\pm\pm}$ production?