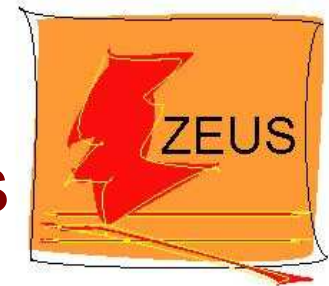


Search for New Physics at HERA



Andrea Parenti (DESY)
for the H1 and ZEUS collaborations



CIPANP 2009

S. Diego, 28/05/2009

Outline

- Introduction to HERA
- Model dependent searches
 - ★ Quark radius
 - ★ Excited fermions
 - ★ Leptoquarks
 - ★ Single top production
- Model independent searches
 - ★ Isolated lepton final states
 - ★ Multi-lepton final states
 - ★ General searches

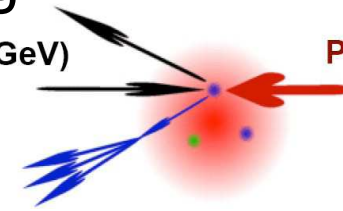
The HERA Collider

- The world only ep collider, in DESY Hamburg

- Center-of-mass energy: up to 320 GeV

e^\pm (27.6 GeV)

P (820/920 GeV)



- Two colliding, general purpose experiments, H1 and ZEUS

- Operations ended in Jun 2007

- Collected luminosity:

- HERA I, 1992-2000:

- ~0.1 $\text{fb}^{-1}/\text{exp}$

- HERA II, 2002-2007:

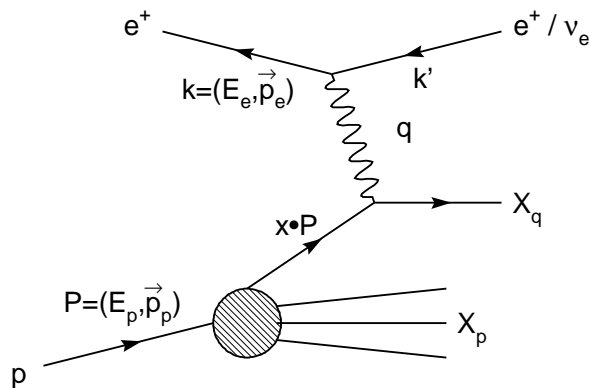
- ~0.4 $\text{fb}^{-1}/\text{exp}$

- (with polarized e^\pm beams)

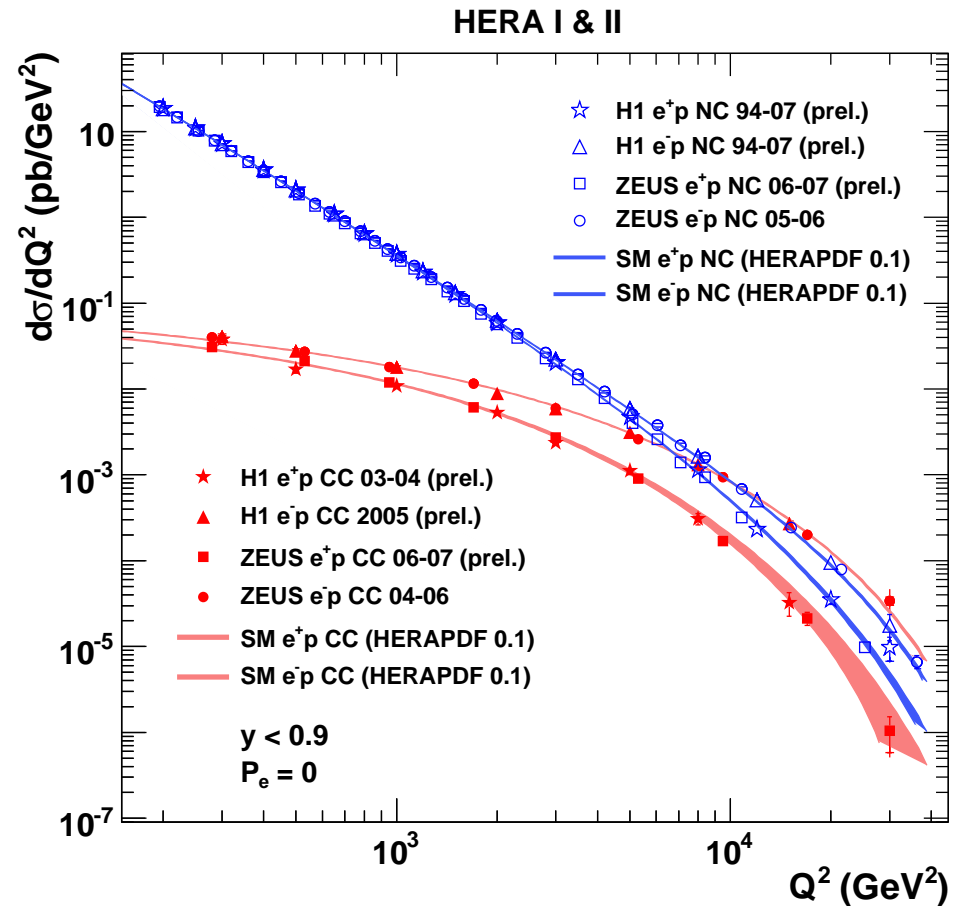


Deep Inelastic Scattering at HERA

- HERA investigates ep collisions



- $Q^2 = -q^2$ gives the resolving power of the EW probe
- New physics would appear at high- Q^2 , ie small distance: at HERA down to 10^{-18}m





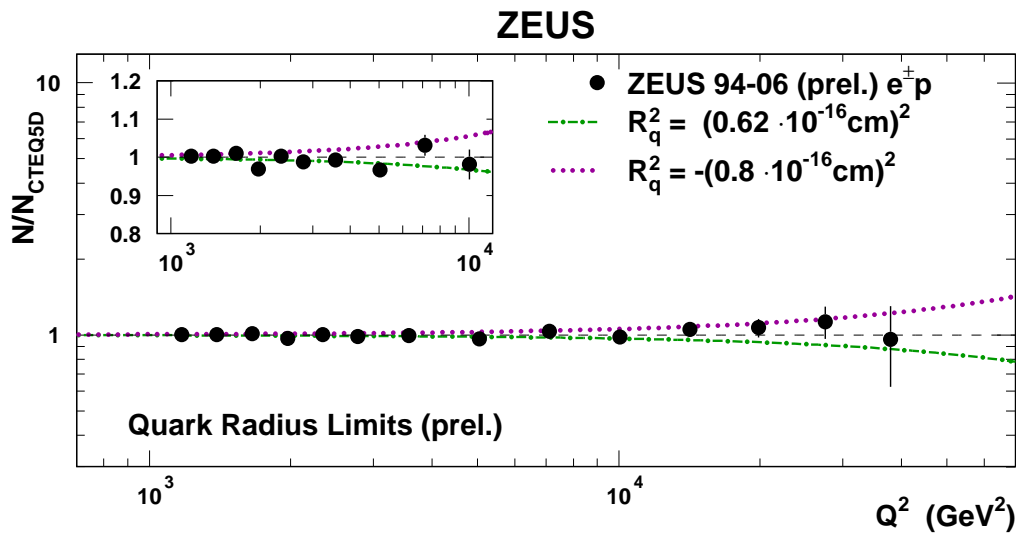
Quark Radius

H1prelim-07-141

ZEUS-prel-07-028

- A decrease in the cross section at high- Q^2 is expected if quarks are not pointlike:

$$\sigma = \sigma_{\text{SM}} \times \left(1 - \frac{\langle R_q \rangle^2 Q^2}{6} \right)^2$$



No deviation from SM \Rightarrow
 limits are set on R_q (95% CL):

- ★ ZEUS: $R_q < 0.62 \cdot 10^{-3} \text{ fm}$
- ★ H1: $R_q < 0.74 \cdot 10^{-3} \text{ fm}$

- With a similar fit we can also look for contact interactions (\rightarrow backup slides)



Excited Fermions (1)

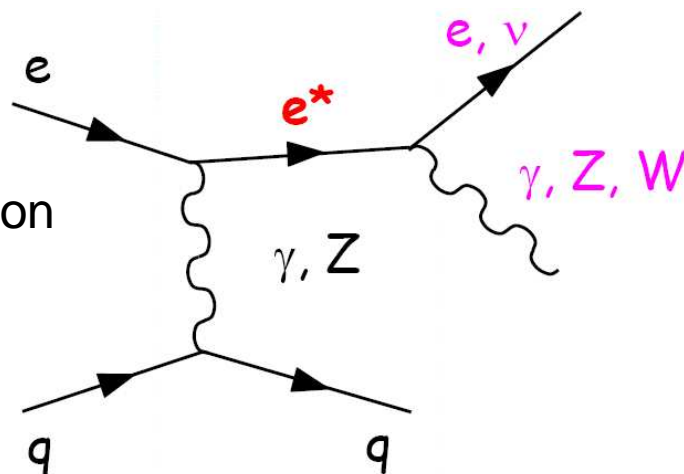
arXiv:0904.3392
Phys.Lett.B666:131
Phys.Lett.B663:382

- Excited fermions would be signature of compositeness
- Compositeness could explain 3 families and mass hierarchy
- Excitation/de-excitation described by effective Lagrangian:

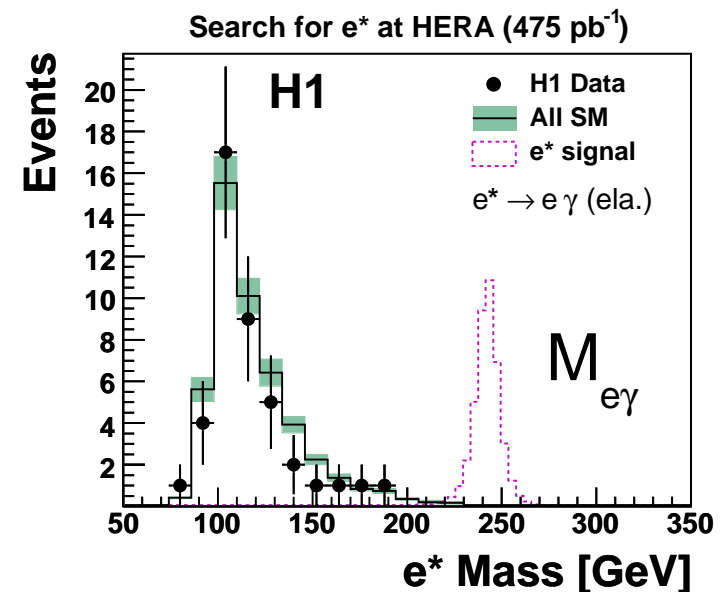
$$\mathcal{L}_{\text{GM}} = \frac{1}{2\Lambda} \bar{F}_R^* \sigma^{\mu\nu} \left[g f \frac{\tau^a}{2} W_{\mu\nu}^a + g' f' \frac{Y}{2} B_{\mu\nu} + g_s f_s \frac{\lambda^a}{2} G_{\mu\nu}^a \right] F_L$$

[f, f' and f_s are the couplings to the SM gauge groups]

Example: production and decay of e*

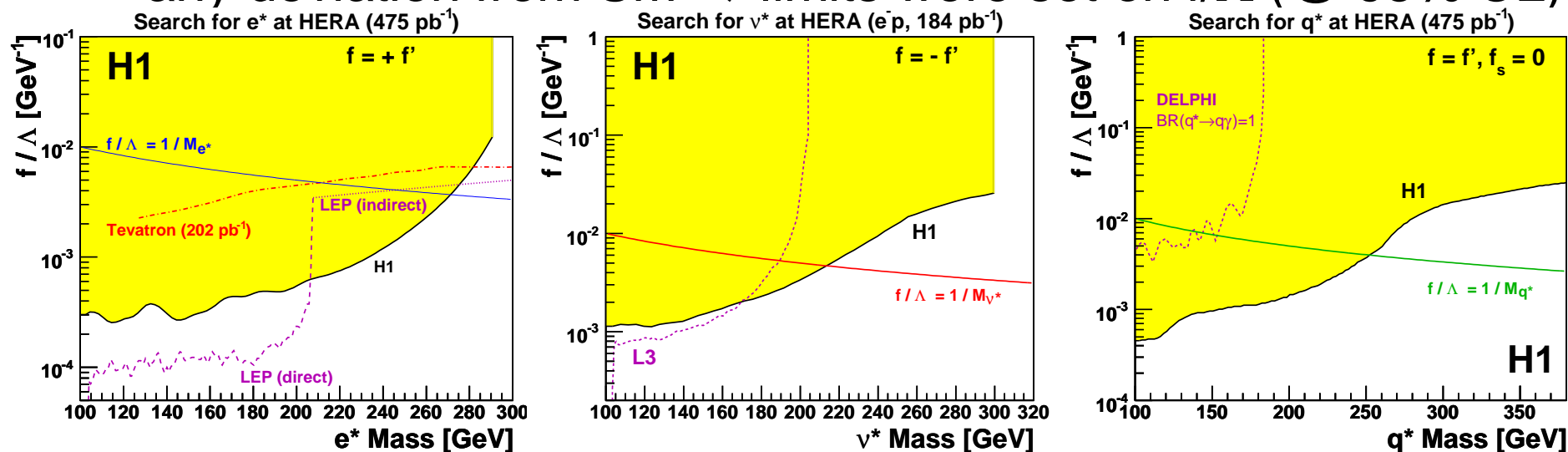


CIPANP09



Excited Fermions (2)

- H1 looked for all possible decay channels and did not find any deviation from SM \Rightarrow limits were set on f/Λ (@ 95% CL)



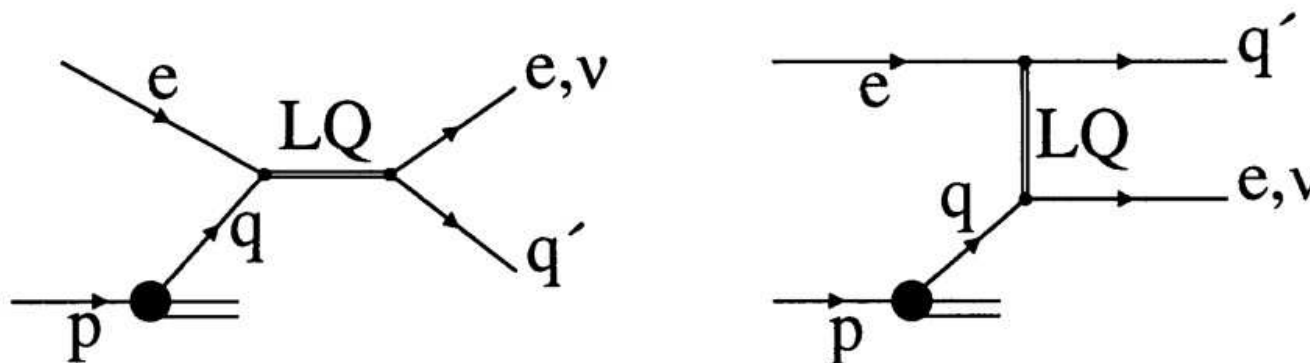
- f/Λ limits can be translated into mass limits assuming $f/\Lambda = 1/M_{f^*}$

- $M_{e^*} > 272 \text{ GeV}$
- $M_{\nu^*} > 213 \text{ GeV}$ [assuming $f=-f'$]
- $M_{q^*} > 252 \text{ GeV}$ [assuming $f_s=0$]

Leptoquarks (1)

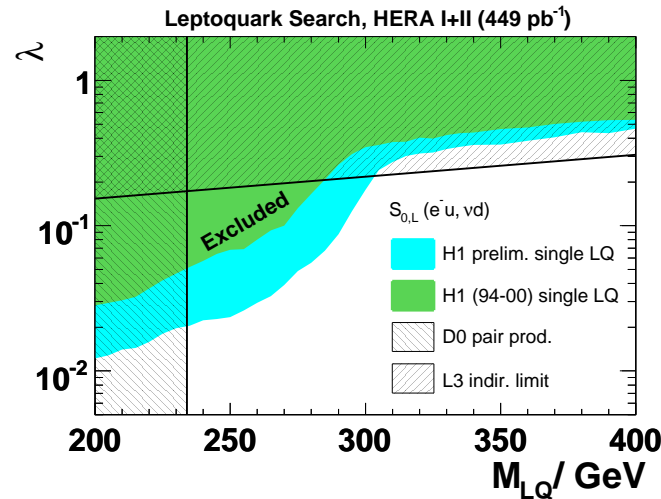
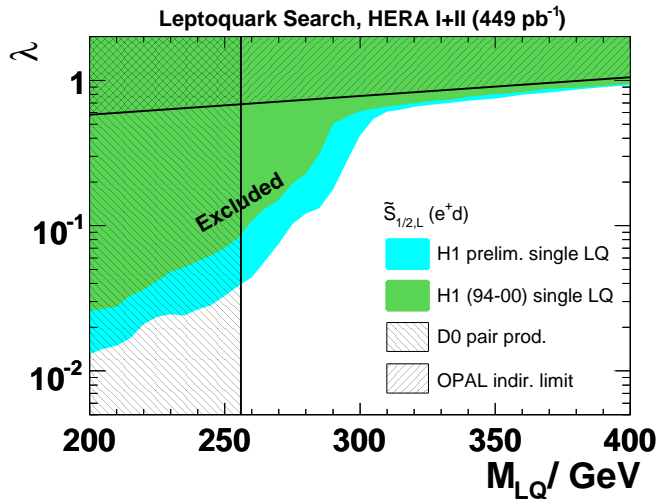
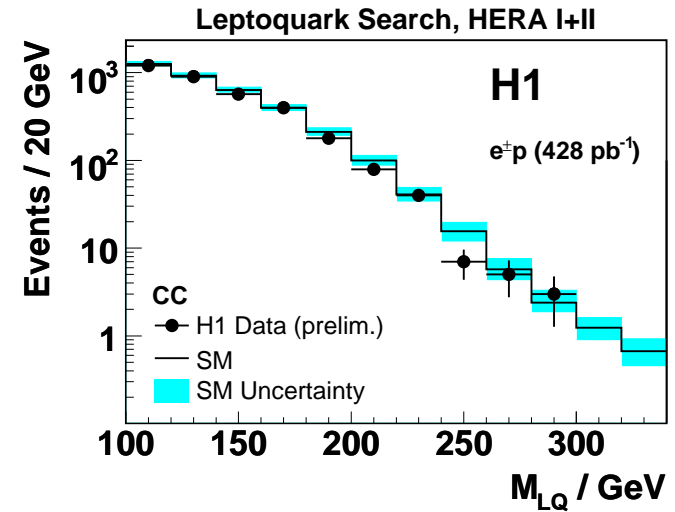
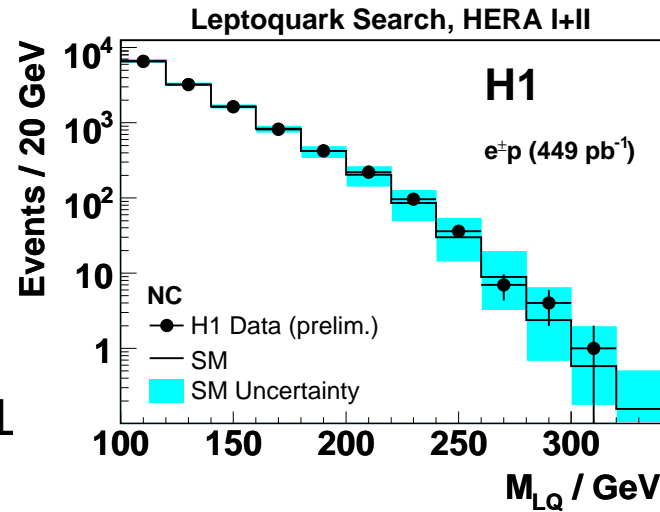
H1prelim-07-164

- LQs appear in many SM extensions
- Couple to both electrons and quarks and carry SU(3) color, fractional electric charge, baryon (B) and lepton (L) number
 - Fermion number: $F = 3B + L = 0, 2$
- LQs model are explored in Buchmüller-Rückl-Wyler (BRW) framework (14 different LQ types)
- We search for LQ decaying into e-jet or ν -jet:



Leptoquarks (2)

- Full statistics analyzed by H1 (prel. results)
- No deviation from SM, so limits on coupling are derived @ 95% CL



- HERA limits are complementary to LEP and Tevatron

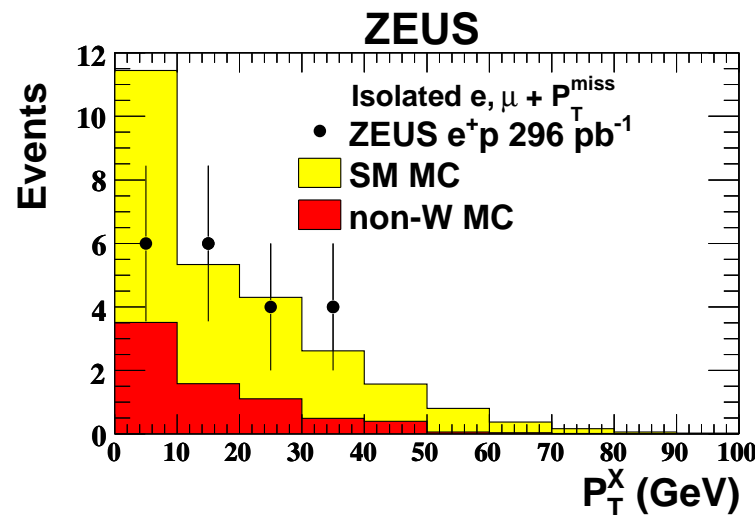
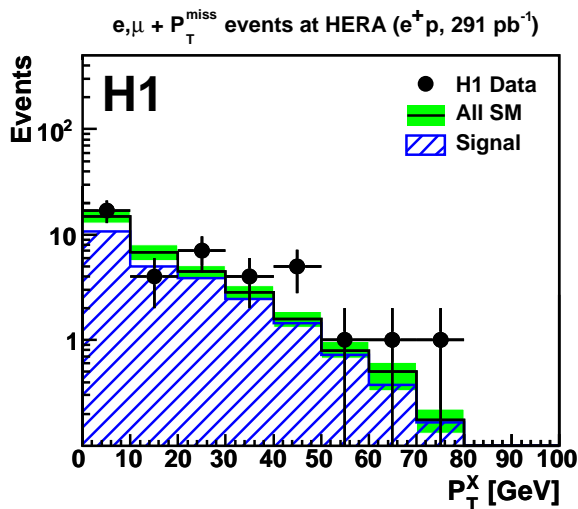
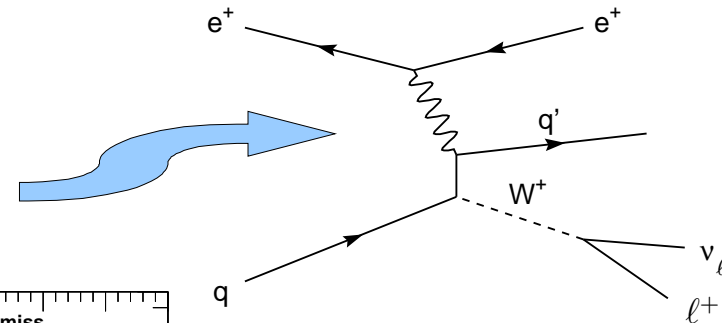


Isolated Leptons

arXiv:0901.0488

Phys.Lett.B672:106

- Look for events with isolated, high- P_T lepton (e, μ), missing P_T and hadronic system (P_T^X)
- SM production: $ep \rightarrow eW^\pm X$ ($\sigma \sim 1.3 \text{ pb}$)



★ In H1 e^+p data, $P_T^X > 25 \text{ GeV}$: 17 obs / $8.0 \pm 1.3 \text{ exp}$ (2.4σ excess)

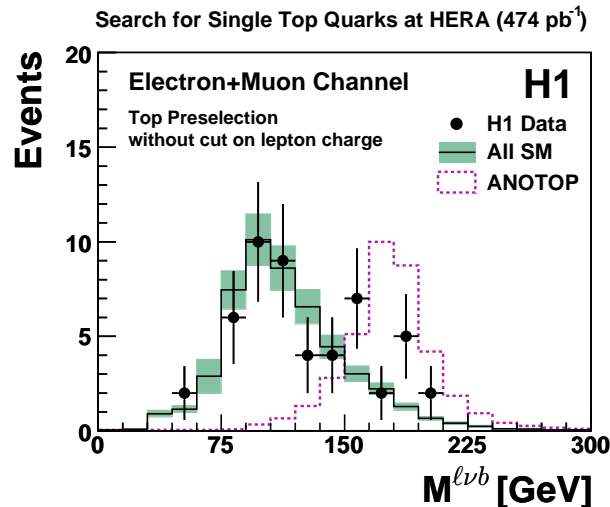
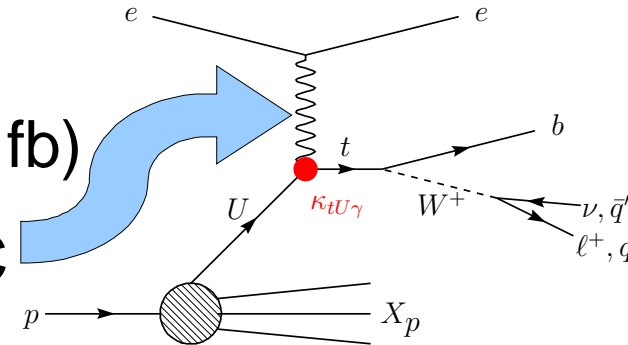
★ No excess seen in e^-p , also no excess observed by ZEUS



Single Top production

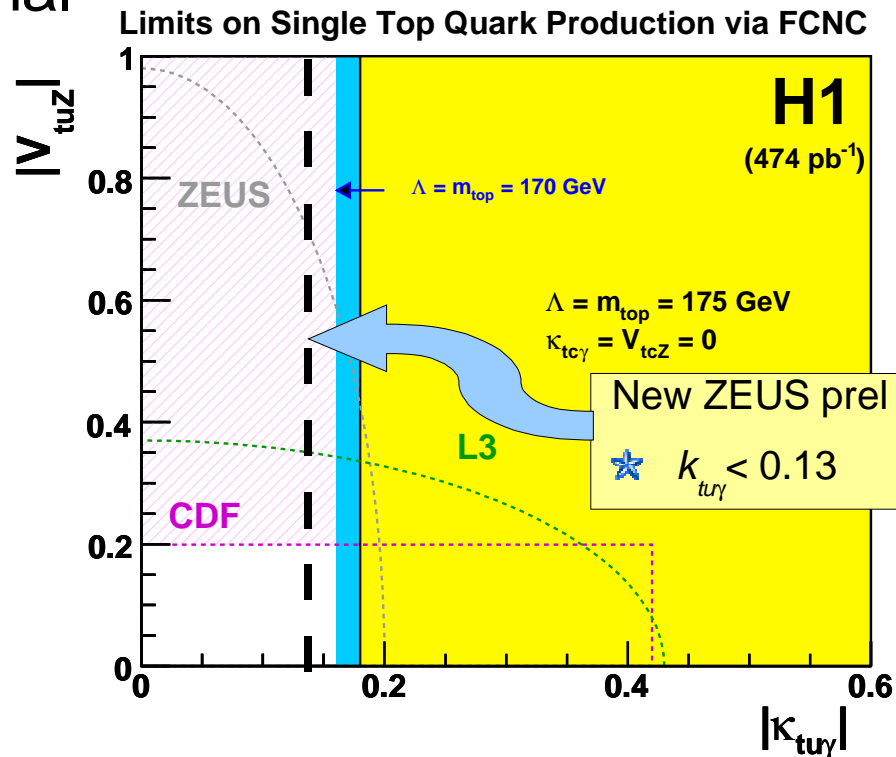
arXiv:0904.3876
ZEUS-prel-09-009

- Produced in SM via CC interaction
 $ep \rightarrow \nu tb X \dots$ but tiny cross section $\sigma = O(1\text{fb})$
- BSM: production via Flavor Changing NC
- No significant excess in the signal region, limits are set on anomalous coupling $k_{t\gamma}$



CIPANP09

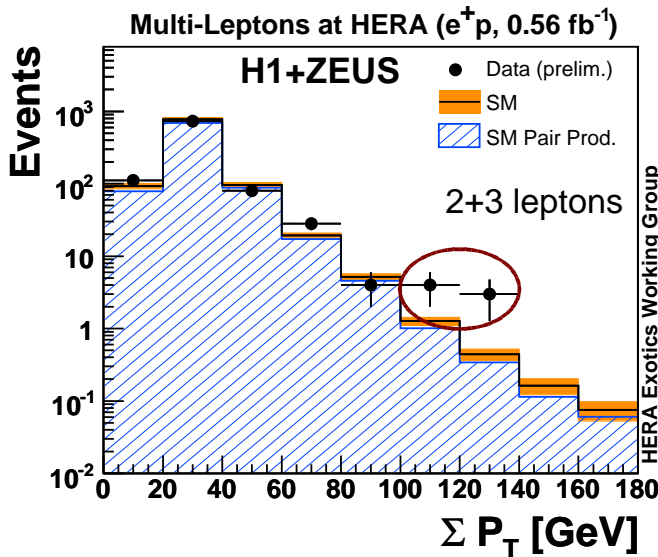
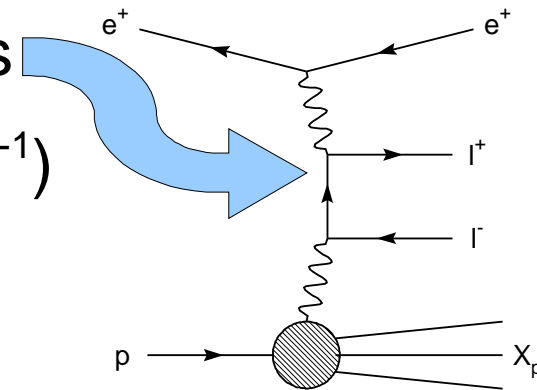
A. Parenti



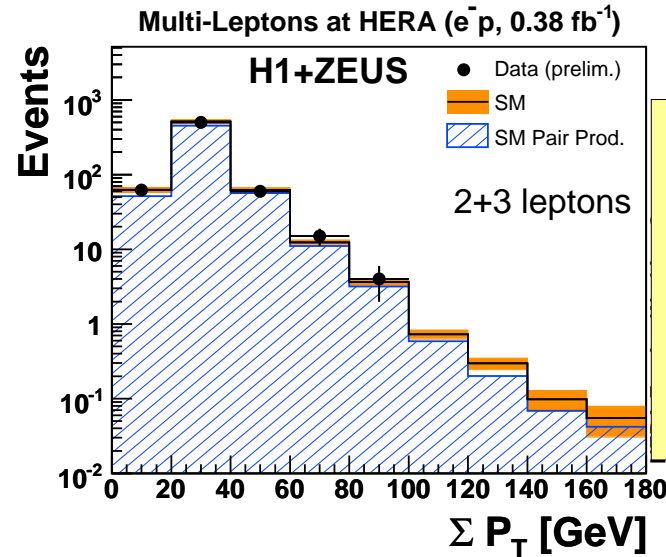
Multi-Leptons

H1prelim-09-064
ZEUS-prel-09-008

- Look for events with 2 or more isolated high- P_T leptons (e, μ)
- SM production via Bethe-Heitler process
- H1 and ZEUS combined results (0.94 fb^{-1})



CIPANP09



A. Parenti

★ In e^+p data, $\Sigma P_T > 100 \text{ GeV}$:
7 obs/ $1.94 \pm 0.17 \text{ exp}$
(excess of 2.6σ)

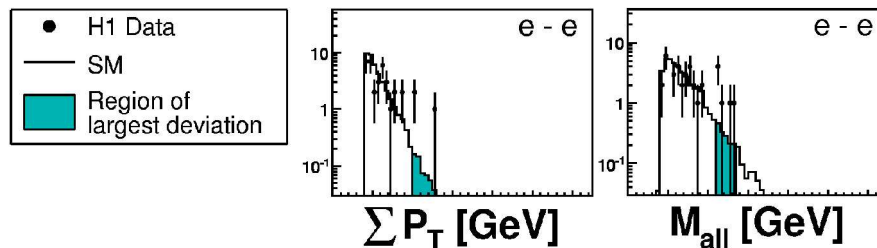
★ In e^-p data, $\Sigma P_T > 100 \text{ GeV}$:
0 obs/ $1.19 \pm 0.12 \text{ exp}$



General Searches

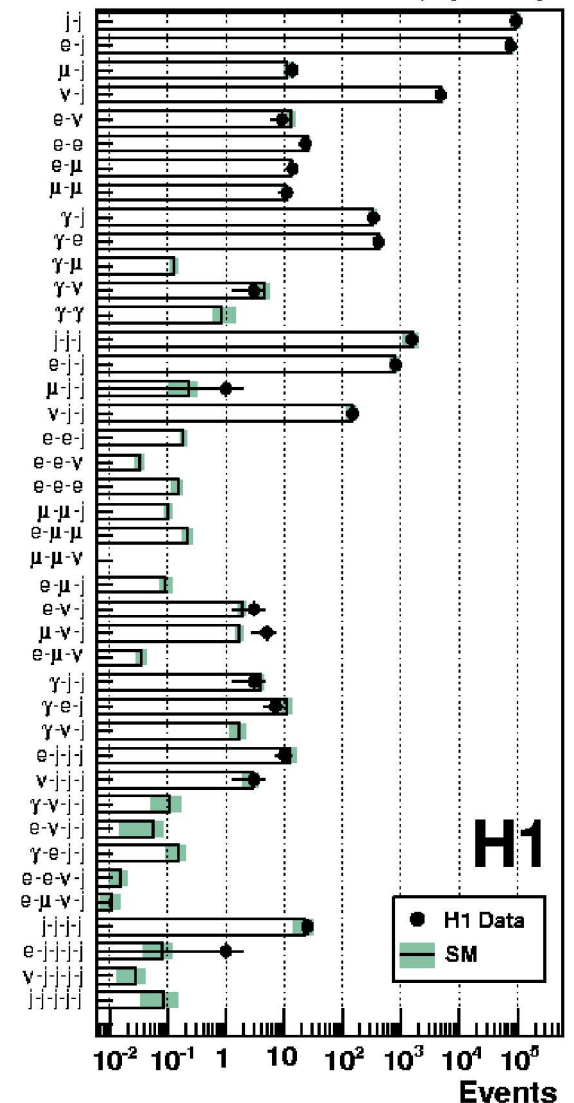
Phys.Lett.B674:257

- Look for events with isolated e, γ, μ, ν , jets having $P_T > 20$ GeV
- Events are classified depending on the number and type of high- P_T objects
 - at least one event in 27 topologies
- In general good agreement with SM
- Deviation from SM is searched for in distributions of ΣP_T and M_{all} with a statistical algorithm



- All deviations are compatible with statistical fluctuations

H1 General Search at HERA (e^+p , 285 pb^{-1})

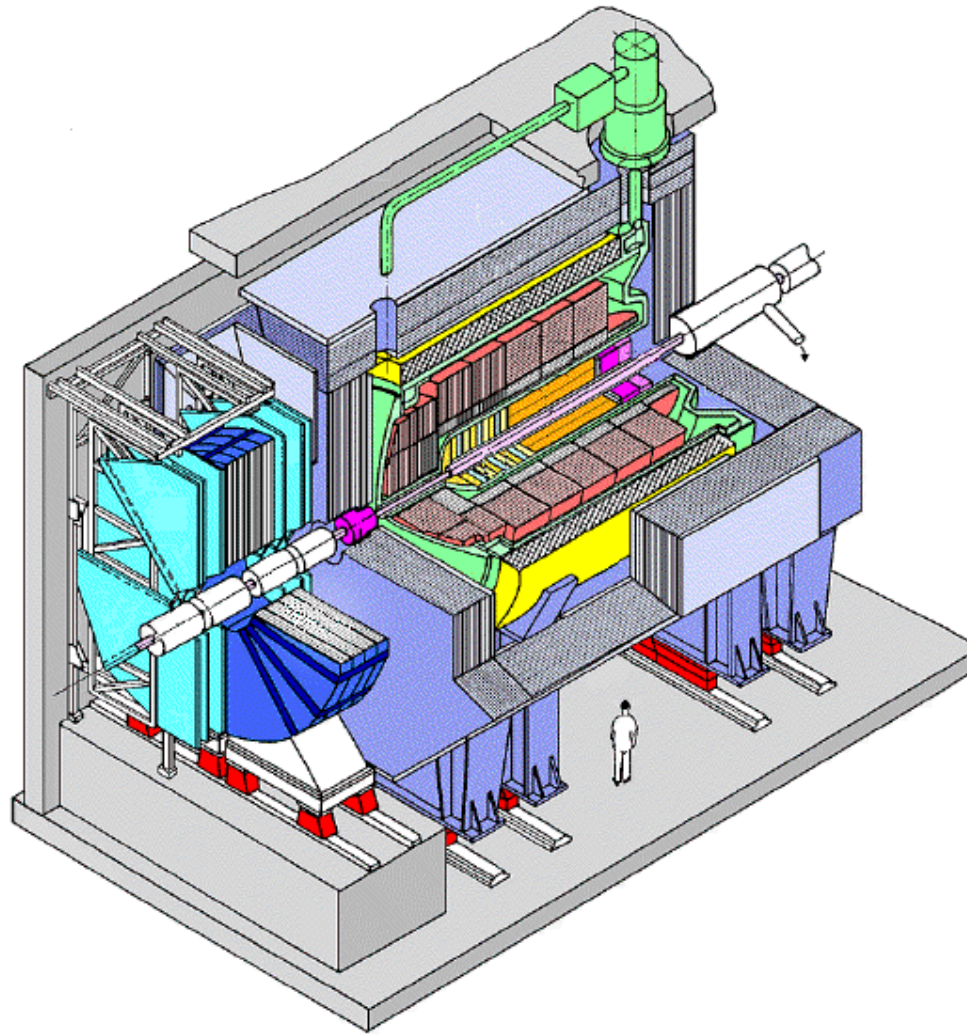


Summary

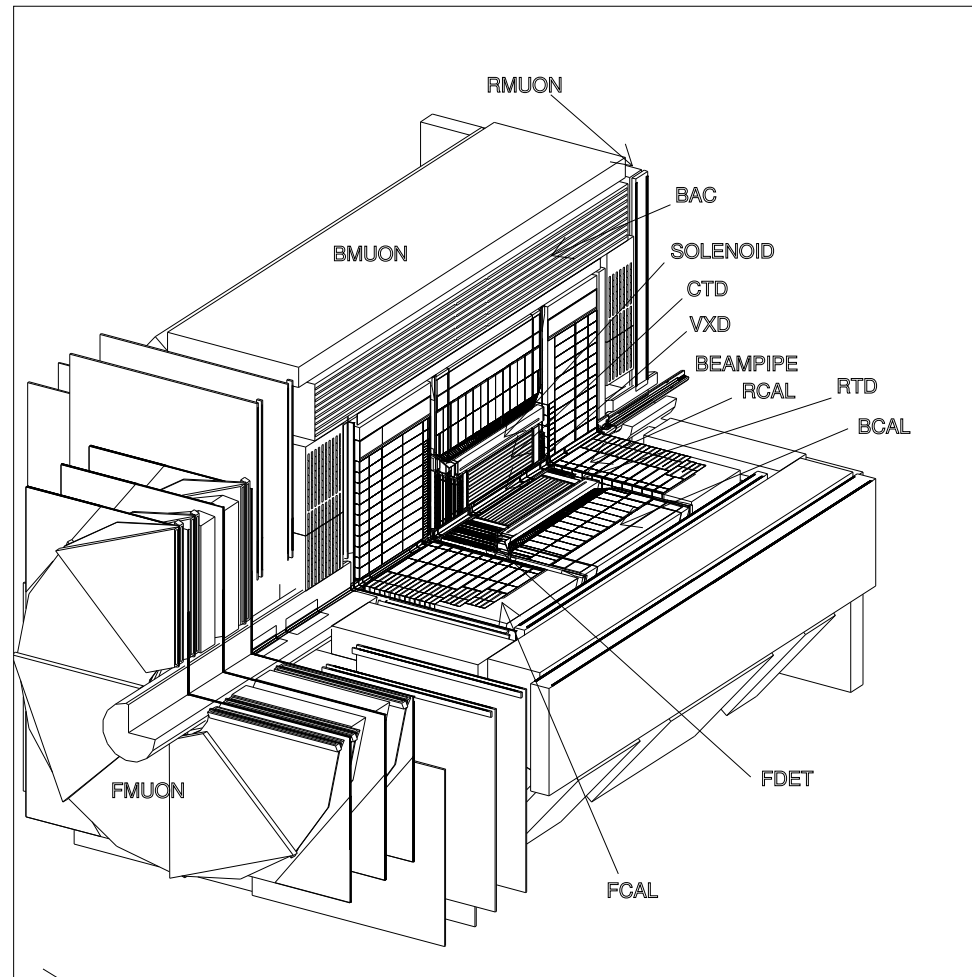
- HERA collected $\sim 0.5\text{fb}^{-1}$ per experiment
- Most analyses make use of the full statistics
- Overall good agreement with the SM:
 - Exclusion limits are set, competitive to LEP and TEVATRON
 - World's best limits on excited fermions, anomalous productions
- To reach the best sensitivity, H1 and ZEUS started combination

Backup Slides

The H1 Detector



The ZEUS Detector





Contact Interactions (1)

Phys.Lett.B568:35
ZEUS-prel-07-028

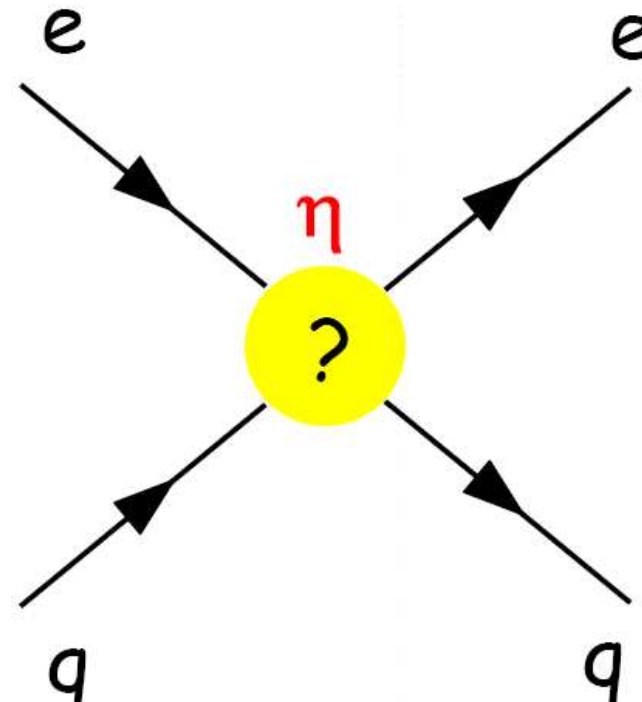
- Any interaction appearing at much higher energy than center-of-mass can be represented by an effective Lagrangian

$$\mathcal{L}_{\text{CI}} = \sum_{a,b=L,R}^{q=u,d} \eta_{ab}^q (\bar{e}_a \gamma_\mu e_a) (\bar{q}_b \gamma^\mu q_b)$$

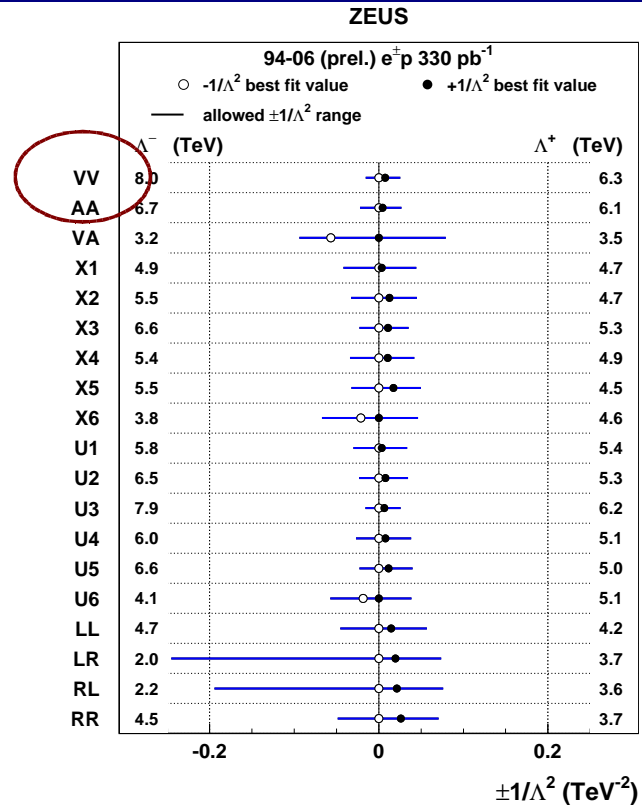
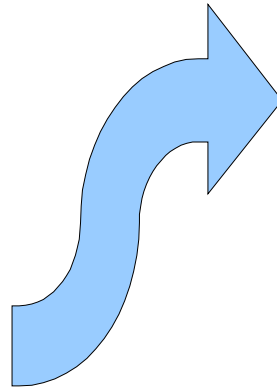
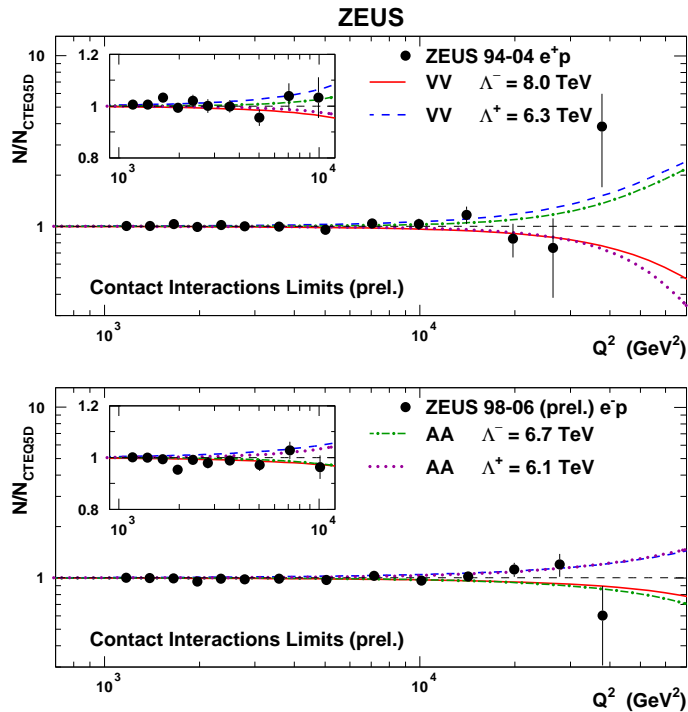
where

$$\eta_{ab}^q = \pm 4\pi / \Lambda^2$$

- Λ is the new physics scale
- Many models are possible, depending on the chiral structure assumed



Contact Interactions (2)



- No deviations from the SM. Limits are set on the scale Λ for each model:

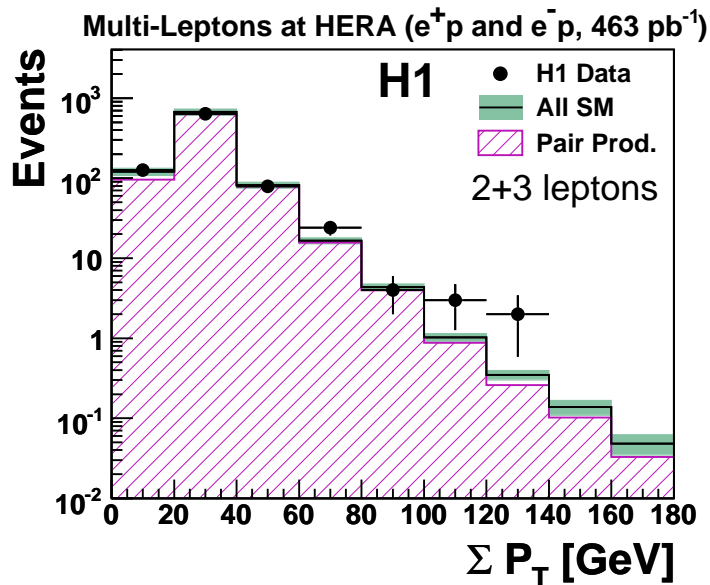
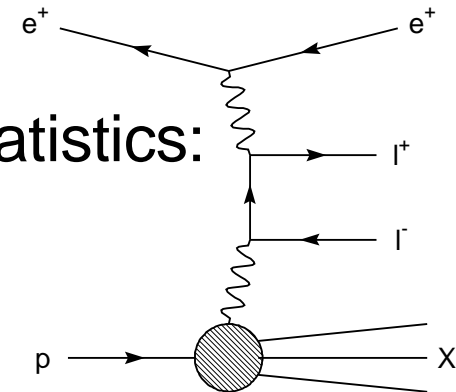
- ★ ZEUS (94-96): $\Lambda > 2.0-8.0$ TeV
- ★ H1 (HERA I): $\Lambda > 1.6-5.5$ TeV



Multi-Leptons

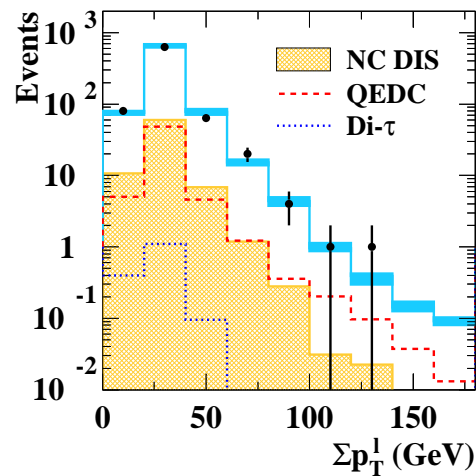
Phys.Lett.B668:268

- Look for events with 2 or more isolated high- P_T leptons (e, μ)
- SM production via Bethe-Heitler process
- Both H1 and ZEUS have results with full statistics:



CIPANP09

ZEUS



A. Parenti

- ★ In H1 e^+p data, $\Sigma P_T > 100$ GeV: 5 obs/ 0.96 ± 0.12 exp
- ★ No excess in e^-p data
- ★ No excess seen by ZEUS

20

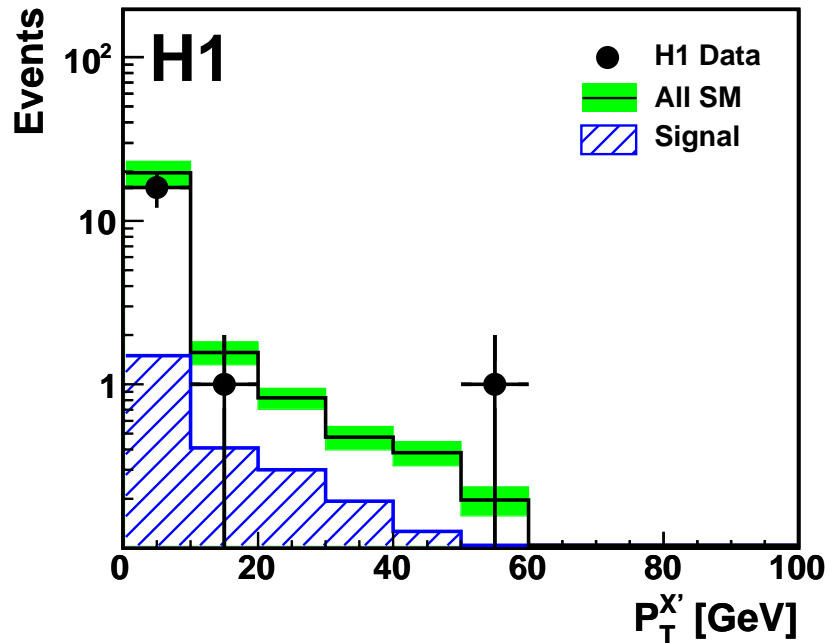


Search for τ production

arXiv:0901.0488

Eur.Phys.J.C48:699
ZEUS-prel-08-009

- Events with an isolated, high- P_T τ , missing P_{ν} , hadronic system

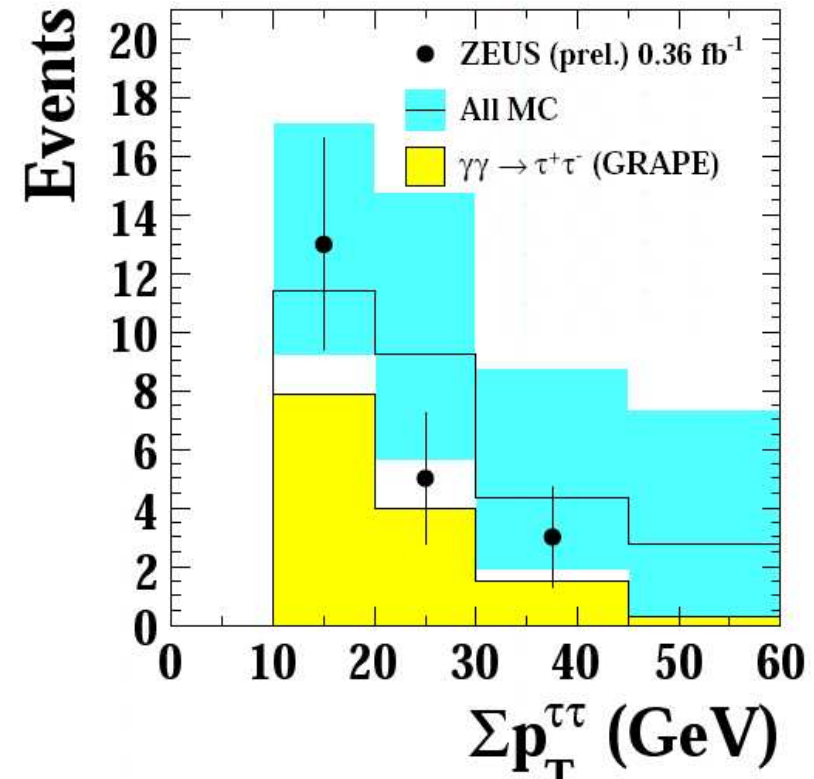


★ H1 analysis, $P_T^X > 25$ GeV:
1 obs / 1.5 ± 0.2 exp

CIPANP09

A. Parenti

- di- τ events



★ ZEUS prelim (HERA II):
21 obs / $27.2^{+7.1}_{-6.3}$ exp

★ H1 (HERA I data):
30 obs / 27.1 ± 4.1 exp