Search for excited fermions at HERA

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on behalf of the H1 and ZEUS collaborations

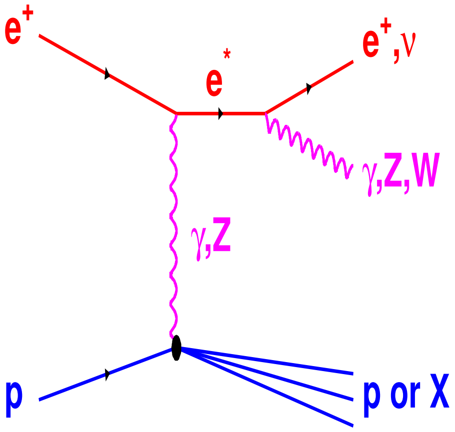
	e^+p (27.5 × 820 GeV)	e^-p (27.5 × 920 GeV)
H1	e^*,ν^*,$q^*$with L=37 pb^{-1}	ν^* with L=15 pb^{-1}
ZEUS	e^* with L=37 pb^{-1}	ν^* with L=16 pb^{-1}

Topics:

- Introduction
- Excited Electrons Searches
- Excited Neutrinos Searches
- Excited Quarks Searches
- Summary

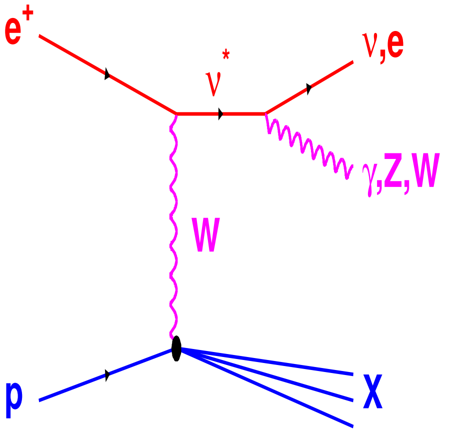
DESY

Description of the channels



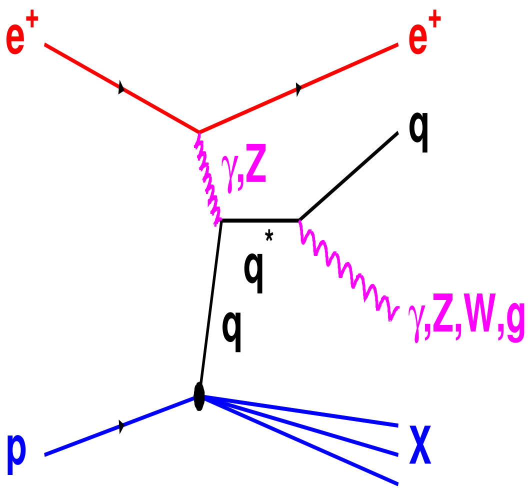
Channels used in the e^* search:

- $e^* \longrightarrow e\gamma$
- $e^* \longrightarrow eZ_{\rightarrow ee,\mu\mu,\nu\nu,q\bar{q}}$
- $e^* \longrightarrow \nu W_{\rightarrow q\bar{q}}$



Channels used in the ν^* search:

- $\nu^* \longrightarrow \nu\gamma$
- $\nu^* \longrightarrow \nu Z_{\rightarrow ee,q\bar{q}}$
- $\nu^* \longrightarrow eW_{\rightarrow e\nu,\mu\nu,q\bar{q}}$



Channels used in the q^* search:

- $q^* \longrightarrow q\gamma$
- $q^* \longrightarrow qZ_{\rightarrow ee,\mu\mu,q\bar{q}}$
- $q^* \longrightarrow eW_{\rightarrow e\nu,\mu\nu,q\bar{q}}$

- Effective Lagrangian

$$\mathcal{L}_{int} = \frac{1}{\Lambda} F_R^* \sigma^{\mu\nu} [g f \frac{\tau^a}{2} W^a_{\mu\nu} + g' f' \frac{Y}{2} B_{\mu\nu} + g_s f_s \frac{\lambda^a}{2} G^a_{\mu\nu}] F_L + h.c$$

where $W^a_{\mu\nu}$, $B_{\mu\nu}$ et $G^a_{\mu\nu}$ are the field-strength tensors of the $SU(2)$, $U(1)$ and $SU(3)_C$ gauge fields, Λ is the compositeness scale and f, f' and f_s are form factors associated to the three gauge groups.

- Coupling constants

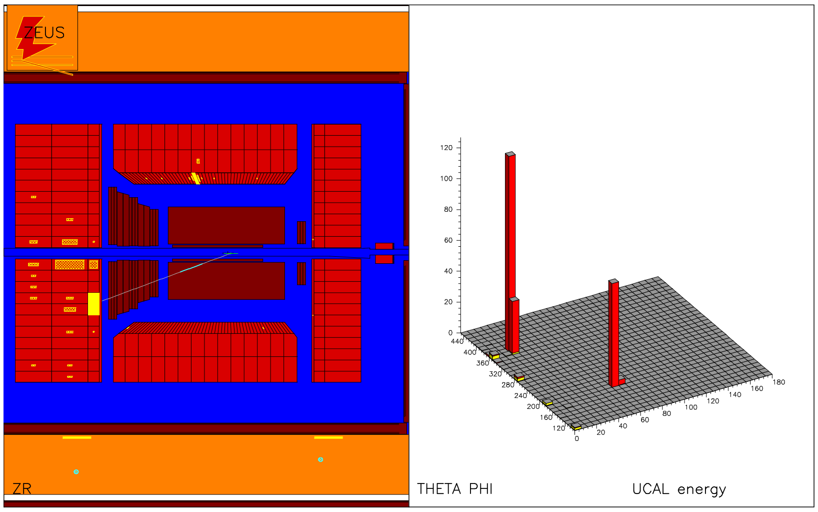
$$\begin{aligned} c_{\gamma F^* F} &= \frac{1}{2}(f I_3 + f' \frac{Y}{2}) \\ c_{Z F^* F} &= \frac{1}{2}(f I_3 \cot\theta_W - f' \frac{Y}{2} \tan\theta_W) \\ c_{W F^* F} &= \frac{f}{2\sqrt{2}\sin\theta_W} \end{aligned}$$

- Partial widths

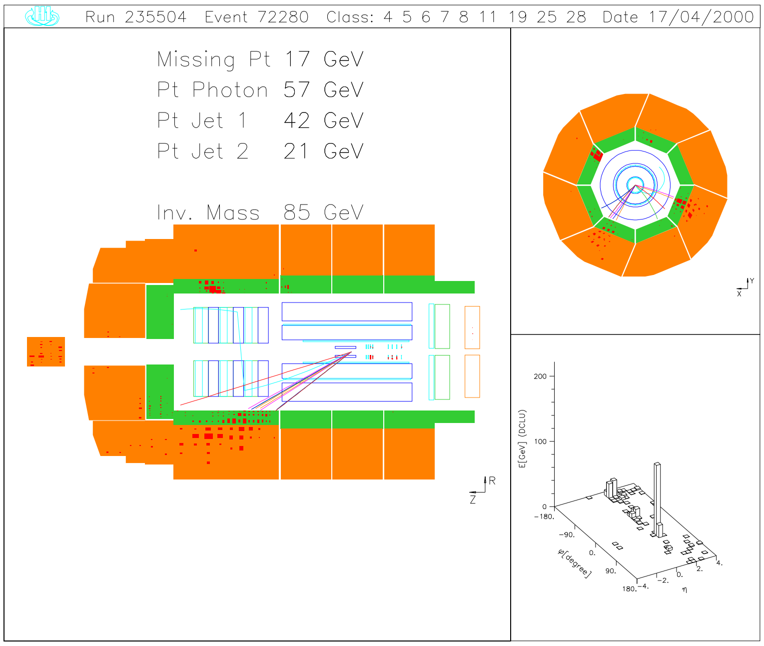
$$\Gamma(F^* \to FV) = \alpha \frac{M^3_{F^*}}{\Lambda^2} c^2_{V F^* F} (1 - \frac{M_V^2}{M^2_{F^*}})^2 (1 + \frac{M_V^2}{2 M^2_{F^*}})$$
$$(V = \gamma, Z, W)$$

$$\Gamma(q^* \to qg) = \frac{1}{3} \alpha_s f_s^2 \frac{M^3_{q^*}}{\Lambda^2}$$

Event displays



- ZEUS: $e^* \rightarrow e\gamma$ candidate

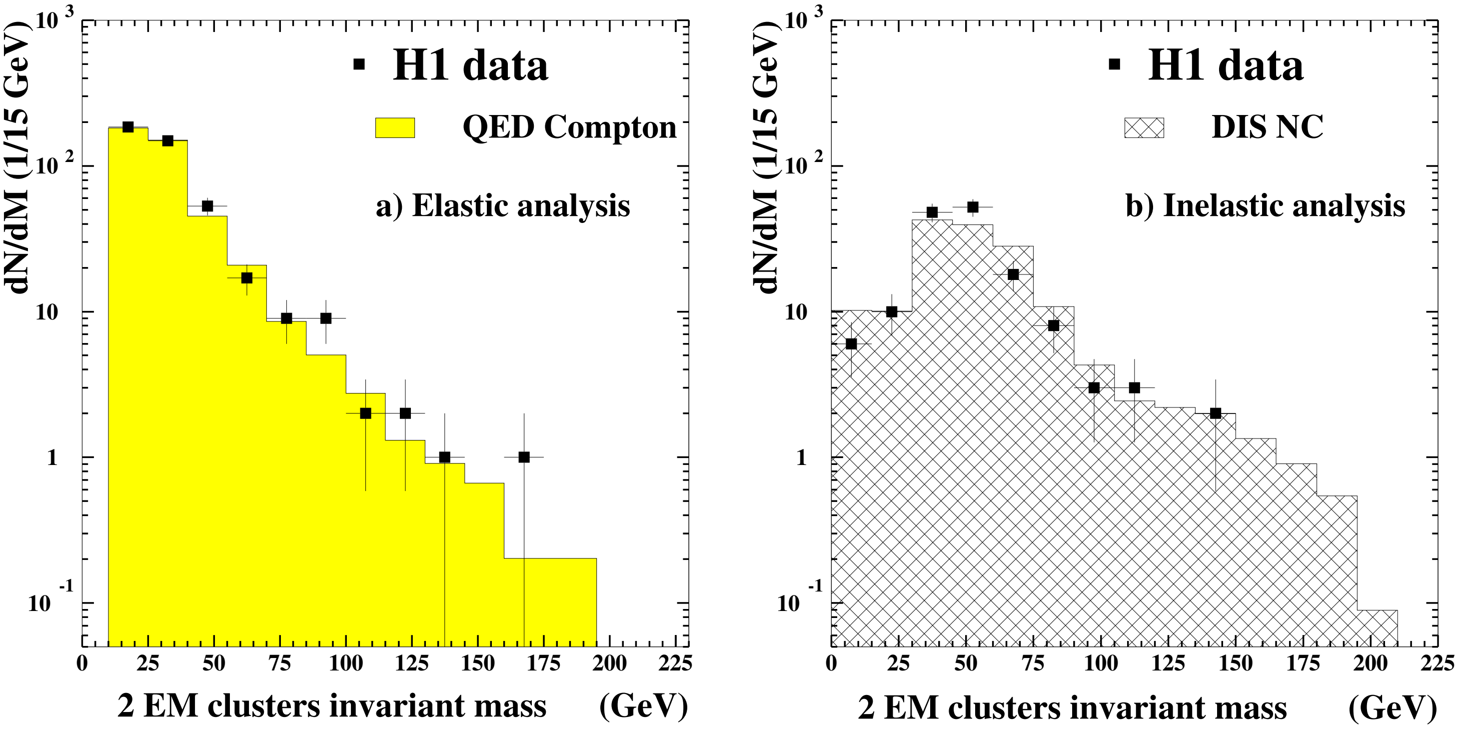


- H1: $\nu^* \rightarrow \nu\gamma$ candidate

H1: Search for $e^* \to e\gamma$

Elastic analysis	Inelastic analysis
2 isolated EM clusters ($E_i \geq 5$ GeV) $E_1 + E_2 \geq 20$ GeV $M_{12} \geq 10$ GeV $E_{tot} - E_1 - E_2 \leq 4$ GeV	2 isolated high E_T EM clusters $E_T(1) \geq 20$ GeV $E_T(2) \geq 10$ GeV $E_{tot} - E_1 - E_2 \geq 4$ GeV
Data = 428 events Bck = 424 ± 15 events	Data = 150 events Bck = 158 ± 8 events

combined efficiency ≥ 80 %

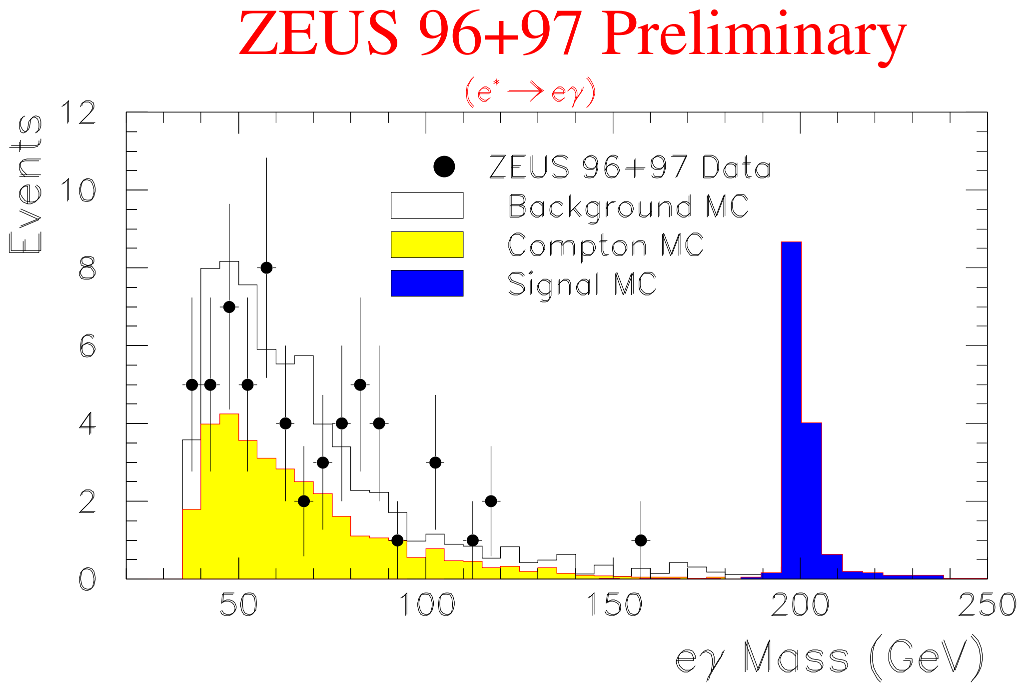


ZEUS: Search for $e^* \to e\gamma$

- 2 isolated EM clusters (one e and one γ)
  if 0.3$\leq \theta(EM_i) \leq$ 2 rd $E_T(EM_i) \geq$ 10 GeV
  if $\theta(EM_i) \leq$0.3 rd $E_T(EM_i) \geq$ 30 GeV
- $M(e\gamma)$ determined with the angles of the e and the γ

$\longrightarrow$ good mass resolution σ=2.6 GeV for $M(e^*)$=250 GeV

- $\frac{E_T(EM_1)+E_T(EM_2)}{M(e\gamma)} \geq 0.4$
- N_{tot}(tracks) $\leq$ 3 select the elastic part of the cross-section
- DATA: 60 events BCK: 68 $\pm$ 2 events
- mean efficiency: $\simeq$ 70 %

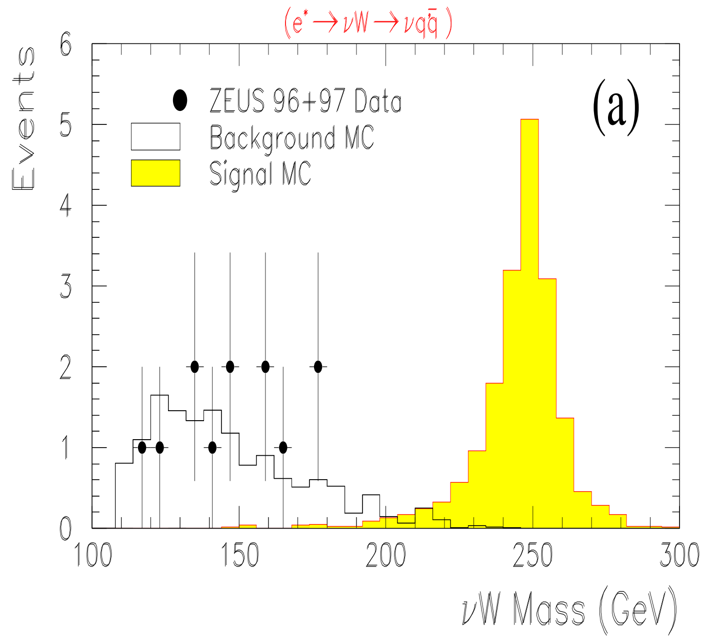


For $M(e\gamma)$ $\geq$100GeV DATA: 7 events BCK: 8.8$\pm$0.7 events

ZEUS: Search for $e^* \to eZ$ and $e^* \to \nu W$

- 2 jets plus an electron   main bck: NC DIS
- 2 jets plus missing P_T main bck: CC DIS

ZEUS 96+97 Preliminary



Specific cuts for $e^* \to \nu W$ search:

- $E_T^{had} \geq 50$ GeV + $M_{had} \geq$60 GeV

  OR

- $E_T^{had} \geq 80$ GeV + $M_{had} \geq$40 GeV
- $P_T^{miss} \geq 25$ GeV
- Data: 12 events
- Bck: 14.3±0.9 events

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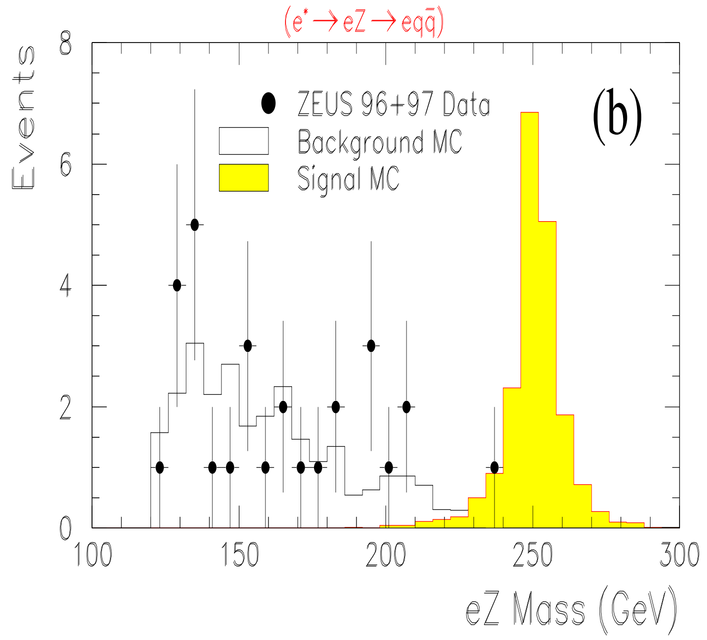


Specific cuts for $e^* \to eZ$ search:

- $E_T^{had} \geq 60$ GeV + $M_{had} \geq$80 GeV

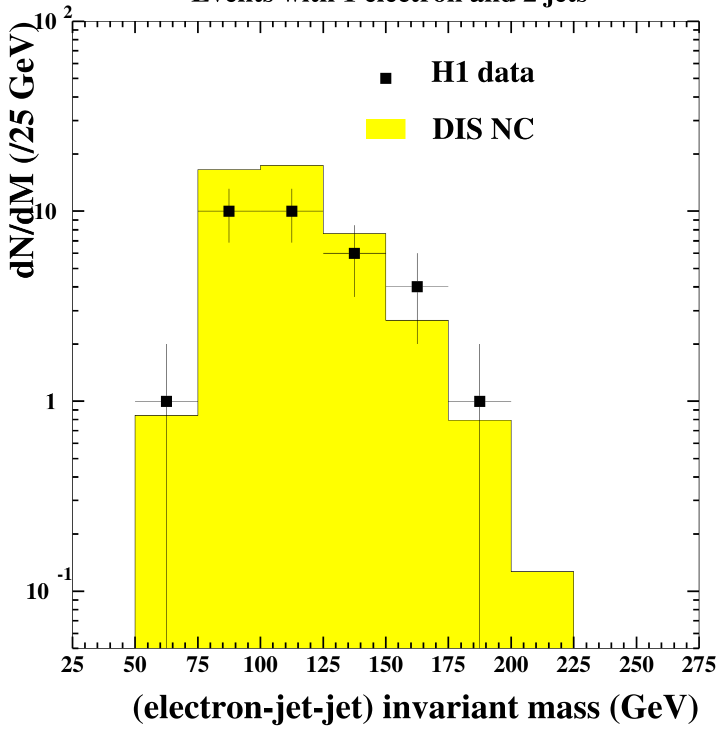
  OR

- $E_T^{had} \geq 80$ GeV + $M_{had} \geq$40 GeV
- $E_T(EM) \geq 25$ GeV

  (≥ 30 GeV if forward)
- $0.8 \leq M_{eq\bar{q}}/M(eZ) \leq 1.2$
- Data: 29 events
- Bck: 26.7±0.9 events

mean efficiency $\simeq 50$ %

H1: Search for e^*

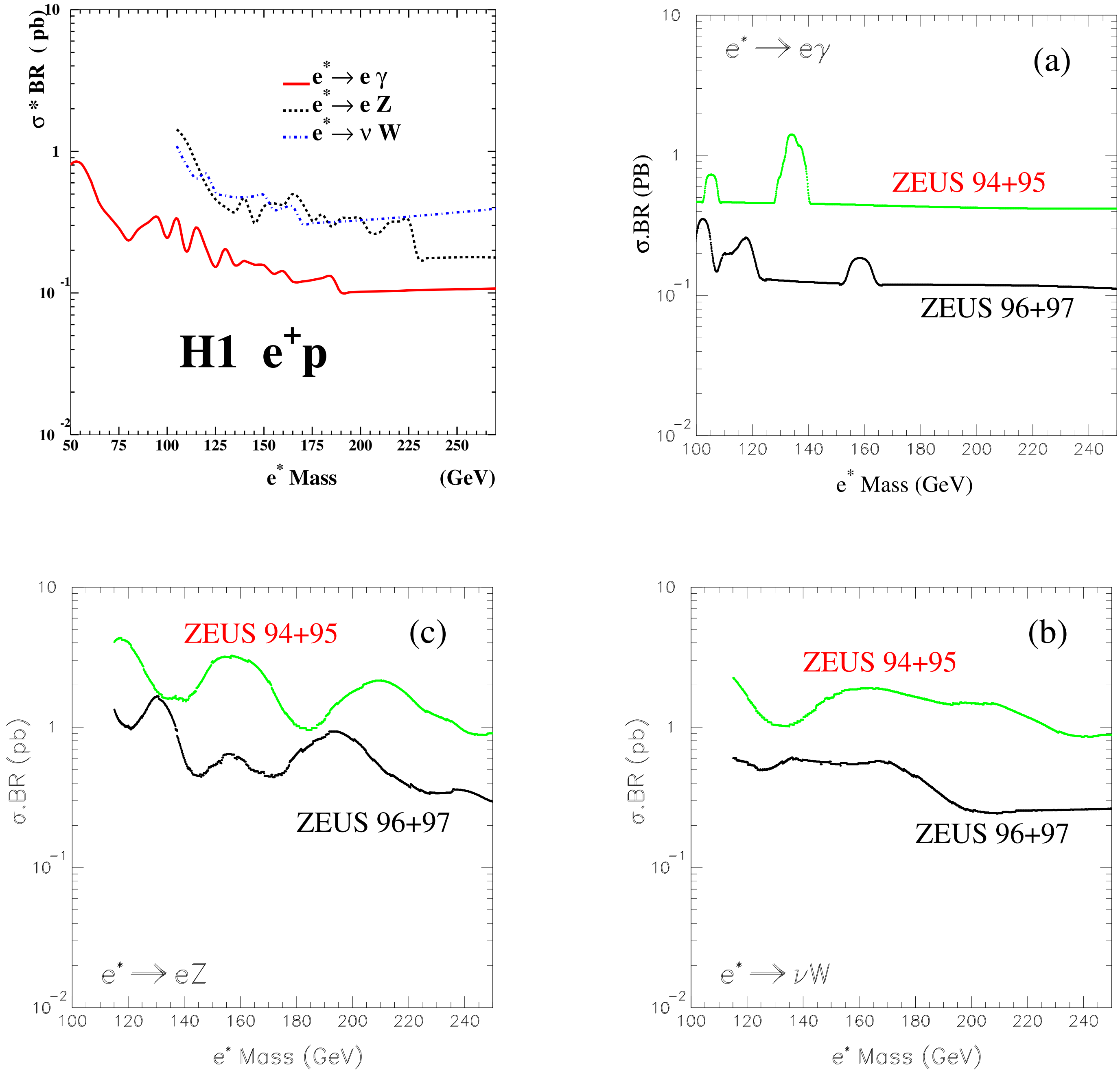


Specific cuts for $e^* \to eZ$ search:

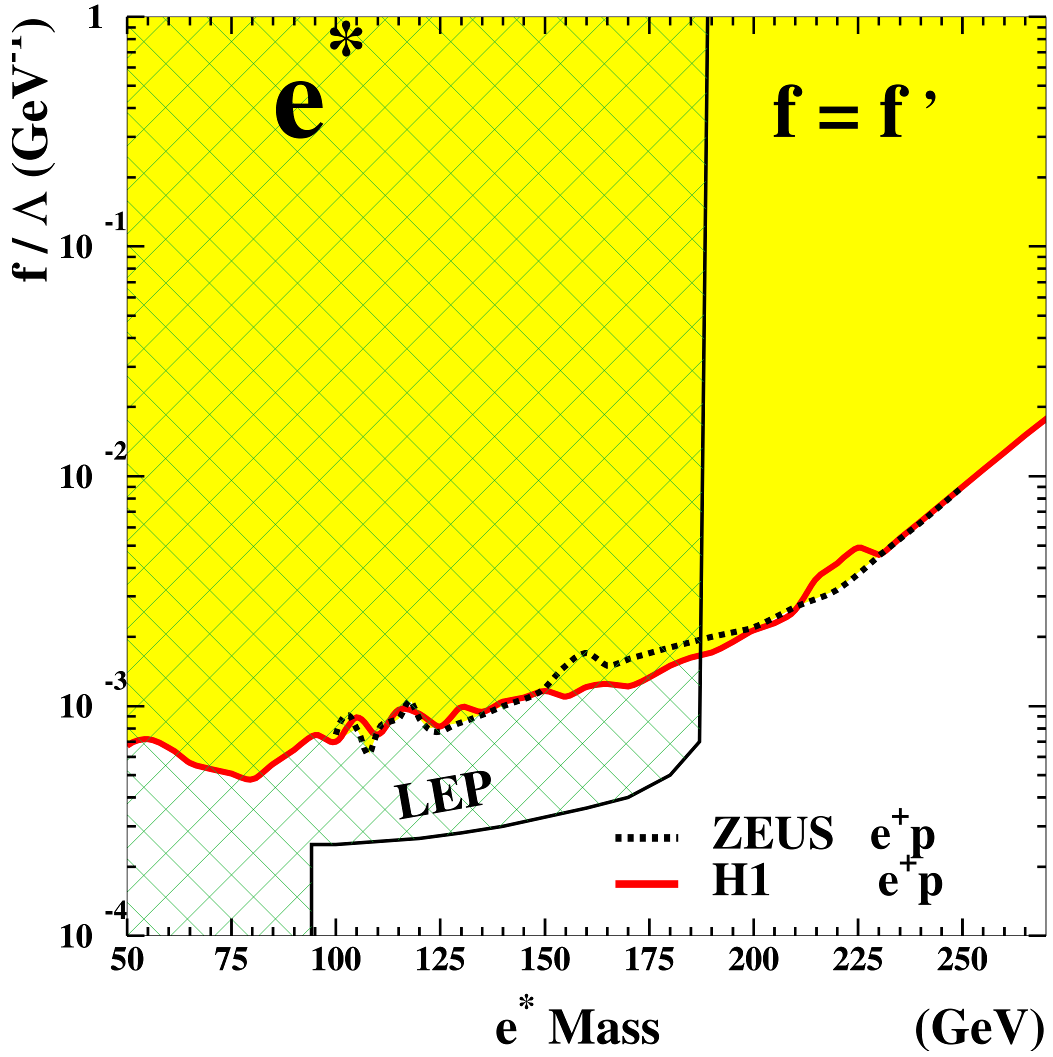
- 2jets with $E_T \geq 20$ GeV and $\theta \geq 10^0$
- one electron with $P_T \geq 15$ GeV and $10^0 \leq \theta \leq 90^0$
- $70 \leq M_{jj} \leq 110$ GeV
- mean efficiency 42 %
- Data: 14 events
- Bck: 12.3±5.4 events

Channel	selection criteria	events	background
$e^* \to e\gamma$	2 EM clusters only	428	424 ± 15
$e^* \to e\gamma$	2 high E_T EM clusters	150	158 ± 8
$e^* \to eZ_{\hookrightarrow ee}$	3 EM clusters	1	0.9 ± 0.4
$e^* \to eZ_{\hookrightarrow \mu\mu}$	2 muons + 1 electron	0	0.10 ± 0.03
$e^* \to eZ_{\hookrightarrow \nu\bar{\nu}}$	1 electron + P_t^{miss}	1	2.7 ± 0.4
$e^* \to eZ_{\hookrightarrow q\bar{q}}$	2jets + 1 electron	14	12.3 ± 3.4
$e^* \to \nu W_{\hookrightarrow q\bar{q}}$	2jets + P_t^{miss}	3	3.3 ± 0.6

$\sigma \times BR$ limits at 95 % CL for excited electrons



f/Λ limits at 95 % CL for excited electrons



- Values of $\frac{f}{\Lambda}$ above 7×10^{-4} to 9×10^{-3} GeV^{-1} for e^* masses between 50 and 250 GeV are excluded.

- Assuming $\frac{f}{\Lambda} = \frac{1}{M(e^*)}$ excited electrons with masses between 50 GeV and 229 GeV are excluded at 95% CL.

Comparison of the ν^* cross-section in e^+p and e^-p

The ν^* production cross section in e^-p is higher than in e^+p.

Why? Not interacting with the same quark

+ different chirality factors

Thus e^-p data: better limits even with lower luminosity !

(example: with f=1 and Λ = 1000 GeV)

ν^* mass (in GeV)	50	150	250
$\sigma(e^+p$ at 820 GeV) pb	$3. \times 10^{-2}$	$9. \times 10^{-4}$	$9. \times 10^{-8}$
$\sigma(e^-p$ at 920 GeV) pb	$1. \times 10^{-1}$	$2. \times 10^{-2}$	$3. \times 10^{-4}$

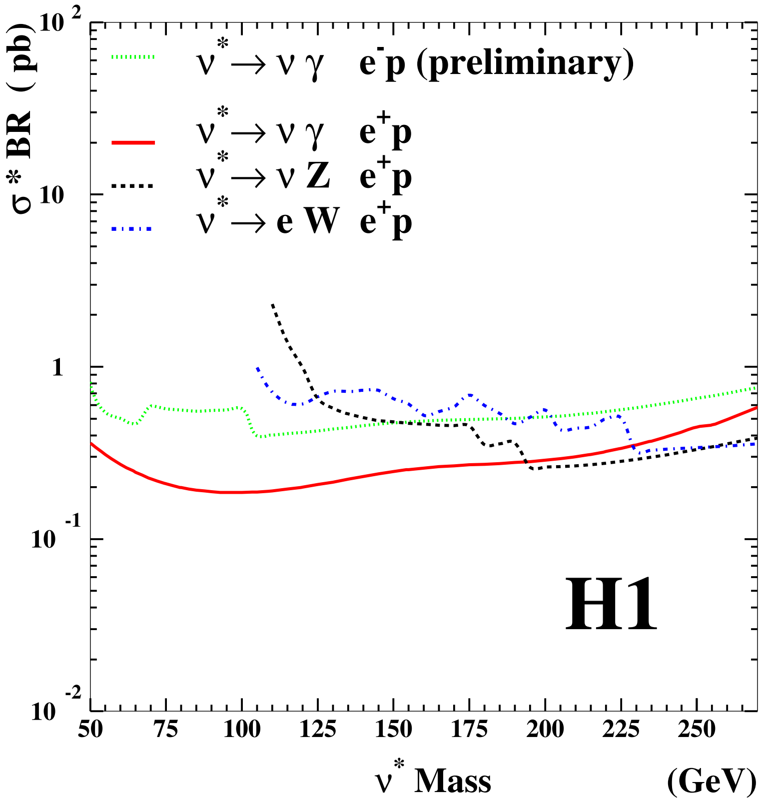
Search for $\nu^* \to \nu\gamma$ in e^-p data

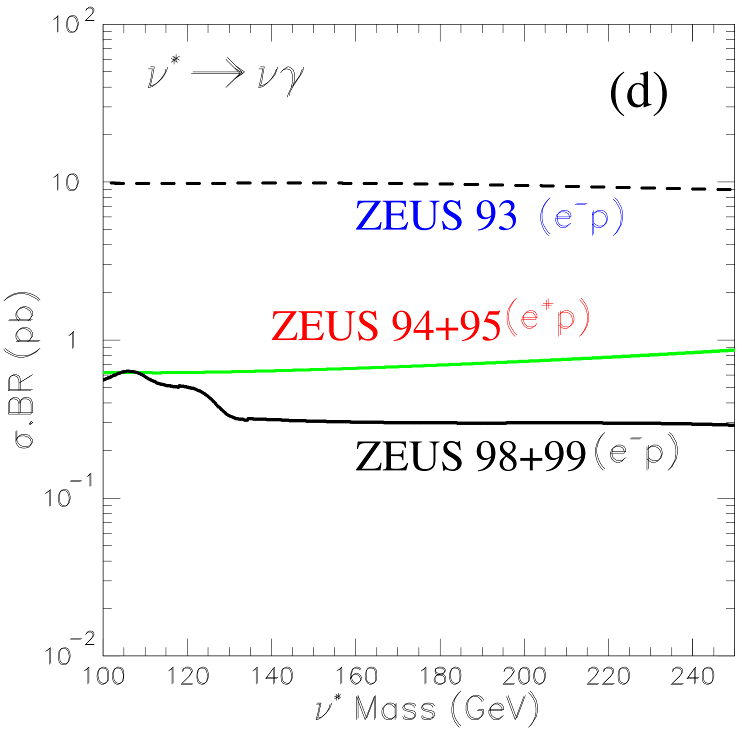
- ZEUS results
  - one isolated EM cluster with $E_T \geq 20$ GeV and $\theta \leq 2$ rd
  - no track pointing to it
  - $P_T^{miss} \geq 25$ GeV
  - $E_T(tot) \geq 50$ GeV
  - Data: 2 events   Bck: 1.8±0.2
  - Good efficiency which varies between 56 to 68% for ν^* masses between 100 and 250 GeV
- H1 results
  - one isolated EM cluster with $E_T \geq 16$ GeV
  - $P_T^{miss} \geq 16$ GeV
  - no track pointing to it if $1 \leq \theta \leq 1.8$ rd
  - no condition on track if forward but then $P_T^{miss} \geq 30$ GeV
  - Data: 2 events   Bck: 2.6±1.2
  - efficiency which varies between 57 to 35% for ν^* masses between 100 and 250 GeV

H1: Search for ν^* in e^+p data

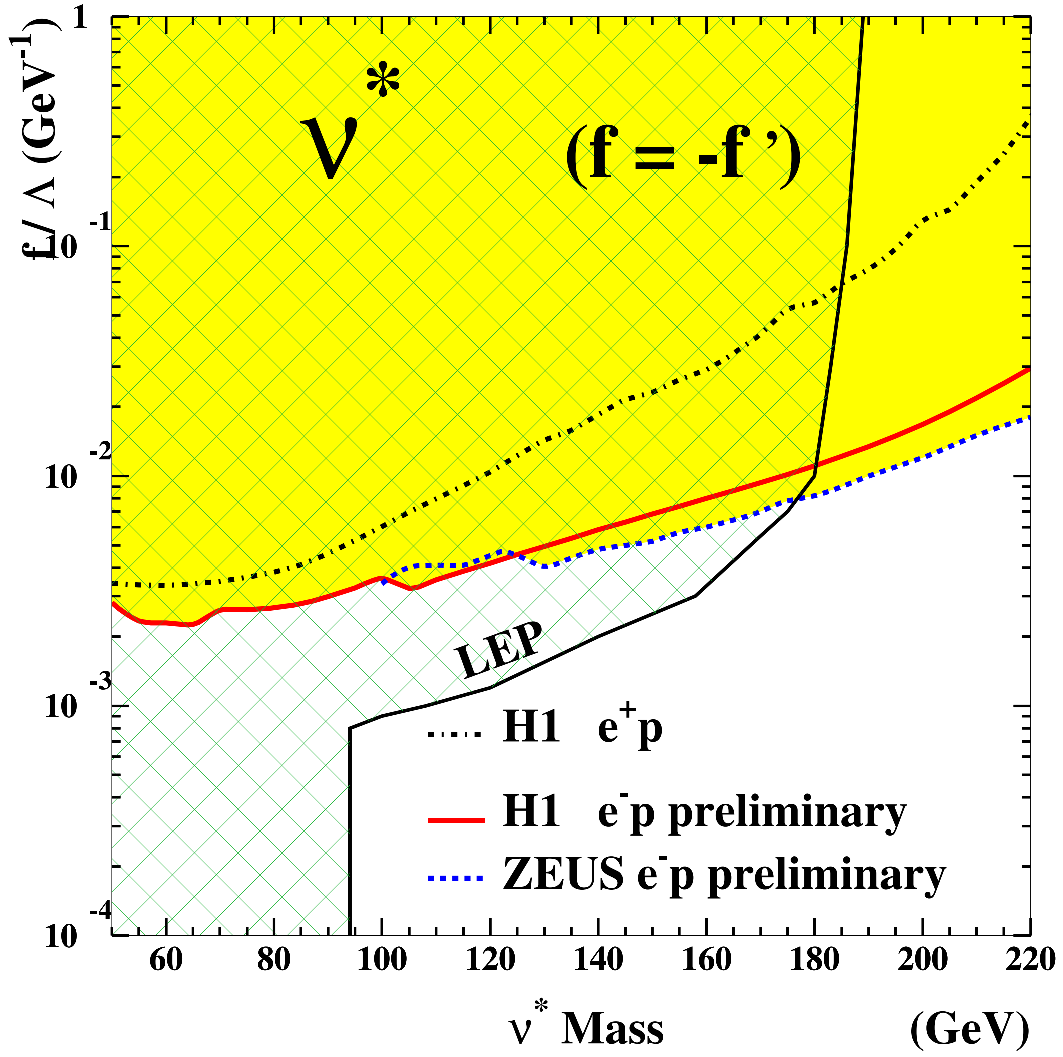
Channel	selection criteria	events	background
$\nu^* \longrightarrow \nu\gamma$	1photon + P_t^{miss}	0	1.0 ± 0.7
$\nu^* \longrightarrow \nu Z_{\hookrightarrow ee}$	2 EM clusters + P_t^{miss}	0	0.020 ± 0.005
$\nu^* \longrightarrow \nu Z_{\hookrightarrow q\bar{q}}$	2 jets + P_t^{miss}	3	2.1 ± 0.8
$\nu^* \longrightarrow eW_{\hookrightarrow e\nu}$	2 EM clusters + P_t^{miss}	0	0.25 ± 0.11
$\nu^* \longrightarrow eW_{\hookrightarrow \mu\nu}$	1 muon + 1 electron	0	0.31 ± 0.05
$\nu^* \longrightarrow eW_{\hookrightarrow q\bar{q}}$	2 jets + 1 electron	18	17.2 ± 4.8

$\sigma \times BR$ limits at 95 % CL for excited neutrinos





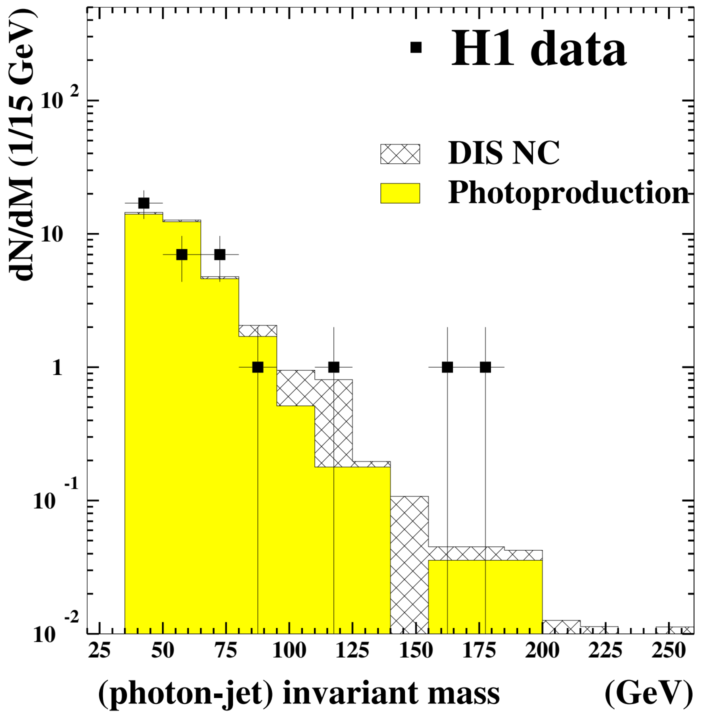
f/Λ limits at 95 % CL for excited neutrinos



- Values of $\frac{f}{\Lambda}$ above 3.5×10^{-3} to 1.9×10^{-2} GeV^{-1} for e^* masses between 50 and 220 GeV are excluded.

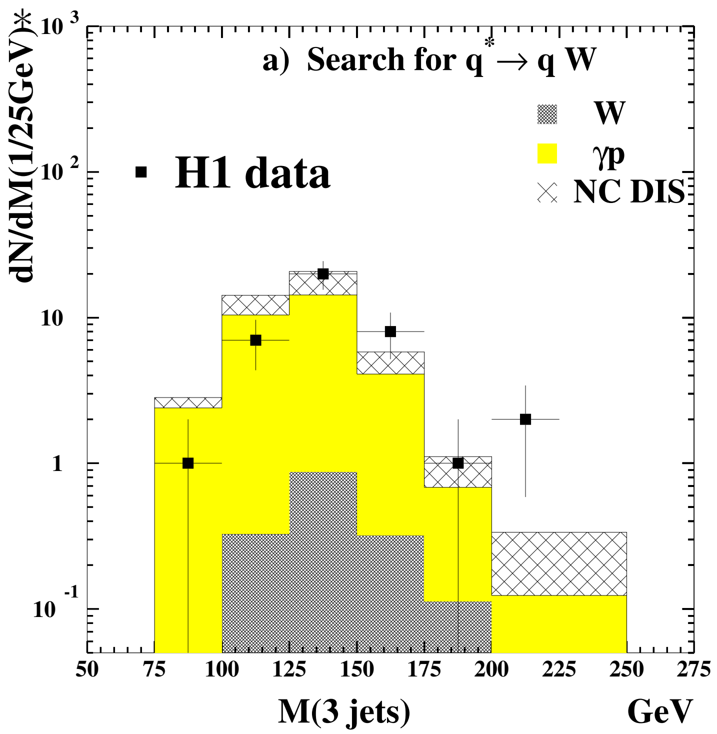
- Assuming $\frac{f}{\Lambda} = \frac{1}{M(\nu^*)}$ excited neutrinos with masses between 50 GeV and 161 GeV are excluded at 95% CL.

H1: Search for $q^* \to q\gamma$ and $q^* \to qW$



Specific cuts for $q^* \to q\gamma$ search:

- $P_\gamma > 20$ GeV
- $10^o \leq \theta_\gamma \leq 90^o$
- a jet: $E_T \geq 15$ GeV and $\theta \geq 10^o$
- Data: 35 events
- Bck: 36±5 events

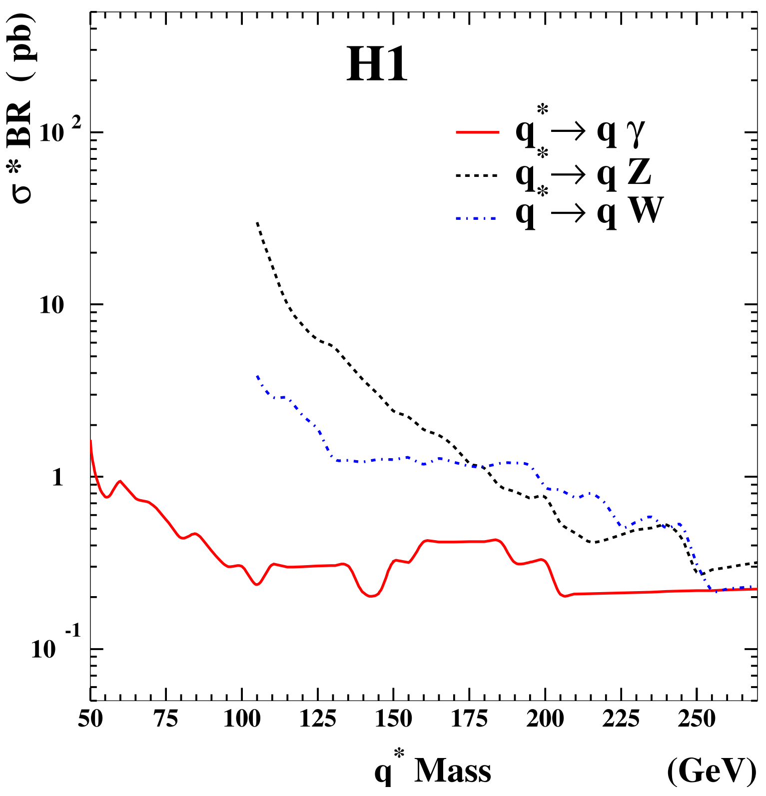


Specific cuts for $q^* \to qW_{\to q\bar{q}}$ search:

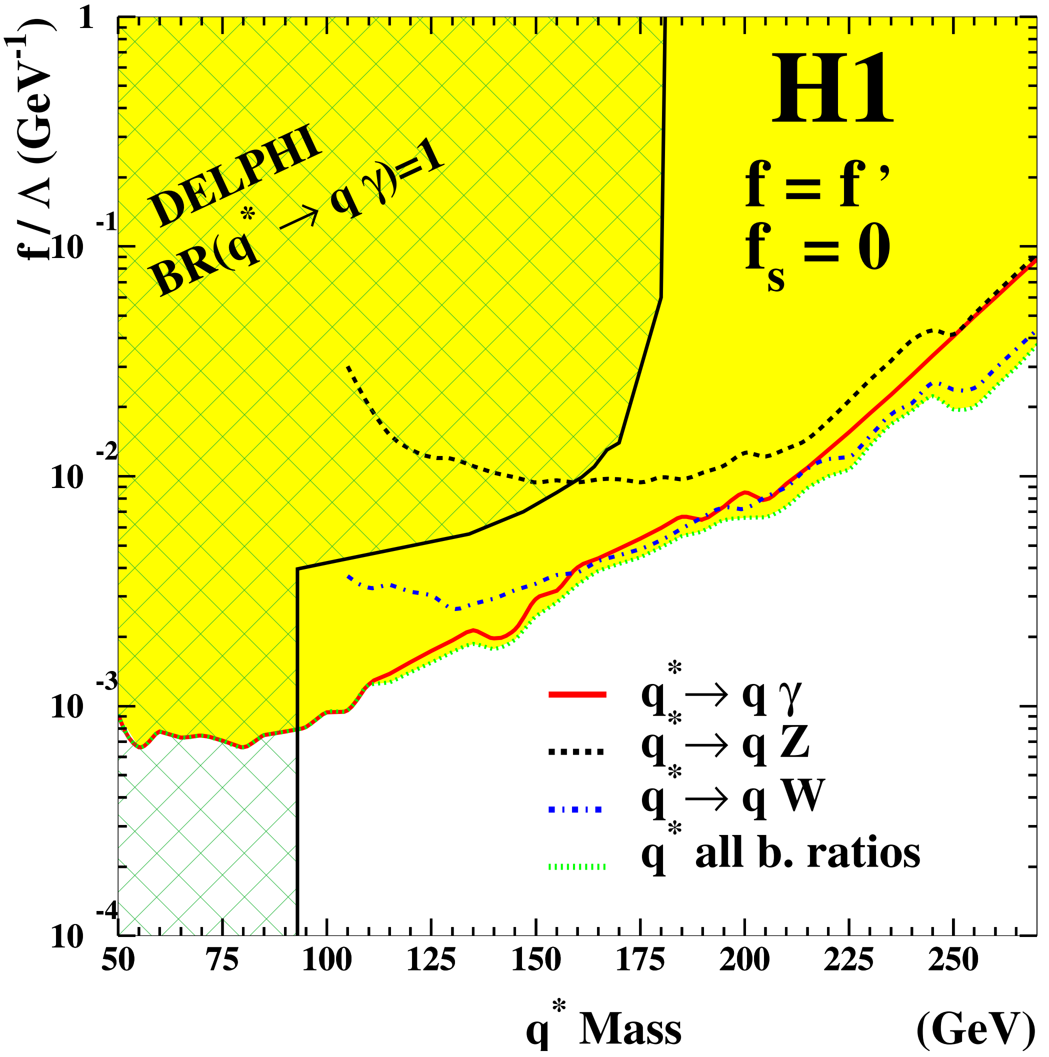
- 3 jets: $E_T \geq 30, 25,$ and 15 GeV
- $60 \leq M(jj) \leq 100$ GeV
- Data: 39 events
- Bck: 45.3±17.3 events

$\sigma \times BR$ limits at 95 % CL for excited quarks

Channel	selection criteria	events	background
$q^* \rightarrow q\gamma$	1 photon + 1 jet	35	36 ± 5
$q^* \rightarrow qZ_{\hookrightarrow ee}$	2 EM clusters + 1 jet	0	0.65 ± 0.53
$q^* \rightarrow qZ_{\hookrightarrow \mu\mu}$	2 muons + 1 jet	0	0.10 ± 0.03
$q^* \rightarrow qZ_{\hookrightarrow q\bar{q}}$	3 jets	32	25.3 ± 9.1
$q^* \rightarrow qW_{\hookrightarrow e\nu}$	1 electron + 1 jet + P_t^{miss}	1	1.10 ± 0.35
$q^* \rightarrow qW_{\hookrightarrow \mu\nu}$	1 muon + 1 jet	3	0.41 ± 0.03
$q^* \rightarrow qW_{\hookrightarrow q\bar{q}}$	3 jets	39	45.3 ± 17.3



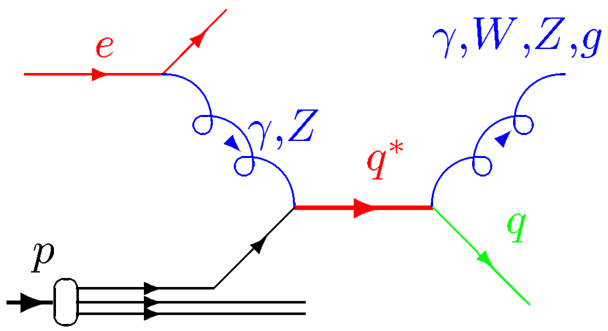
f/Λ limits at 95 % CL for excited quarks

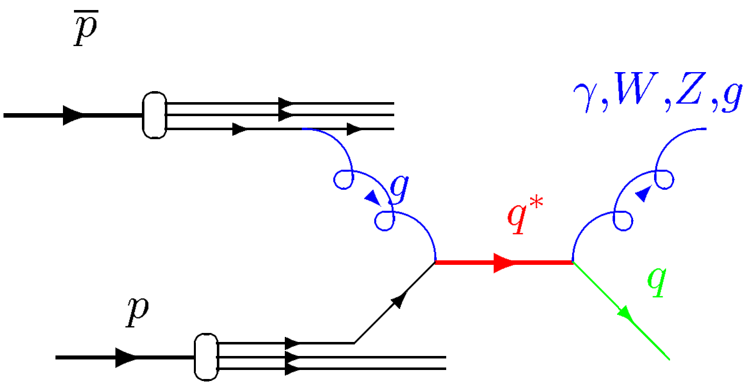


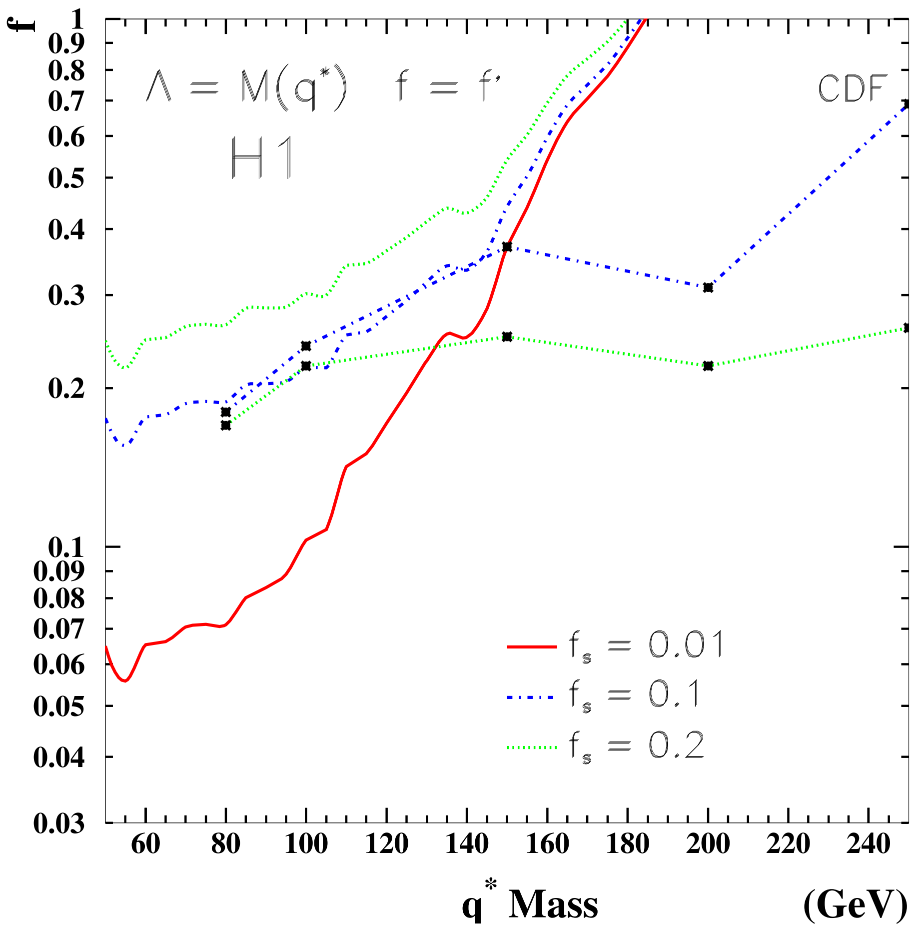
- Assuming $f_s = 0$, values of $\frac{f}{\Lambda}$ above 9×10^{-4} to 2×10^{-2} GeV^{-1} for q^* masses between 50 and 250 GeV are excluded.

- Assuming $\frac{f}{\Lambda} = \frac{1}{M(q^*)}$ and $f_s = 0$, excited quarks with masses between 50 GeV and 188 GeV are excluded at 95% CL.

f/Λ limits at 95 % CL for excited quarks







Summary

• Searches for excited fermions have been performed by the H1 and ZEUS collaborations using 37 pb^{-1} of e^+p data and about 16 pb^{-1} of e^-p data.

• No evidence for excited fermions production is found.

• Mass dependent exlusion limits on cross-sections and on the ratio of coupling constants to the compositeness energy scale are derived.

• Assuming $f/\Lambda = 1/M(f^*)$, excited electrons between the masses 50 GeV and 229 GeV are excluded at 95 % confidence level. In the same way excited neutrinos between the masses 50 GeV and 161 GeV are excluded and the excited quarks for masses between 50 and 188 GeV.

• HERA extends limits beyond the reach of other colliders.

• The results obtained on q^* production are complementary to those given by the Tevatron experiments.