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Search for new particles at ZEUS

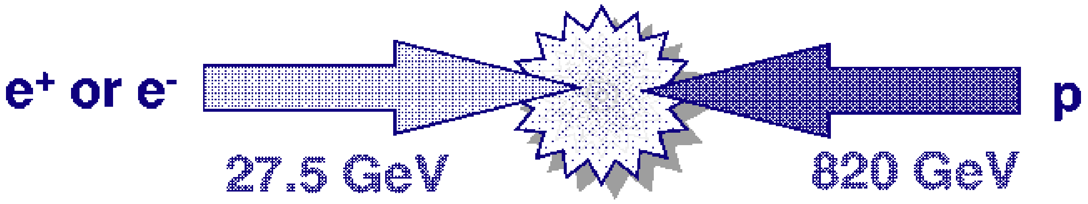
Outline:

- Introduction
- Search for excited fermions
- Search for selectron-squark production
- Summary

International Europhysics Conference on High Energy Physics
Jerusalem, 19–26 August 1997

HERA

Hadron Electron Ring Anlage



$$\sqrt{s} \sim 300\text{GeV}$$

HERA complements searches at LEP and Tevatron due to presence of initial state lepton and quark

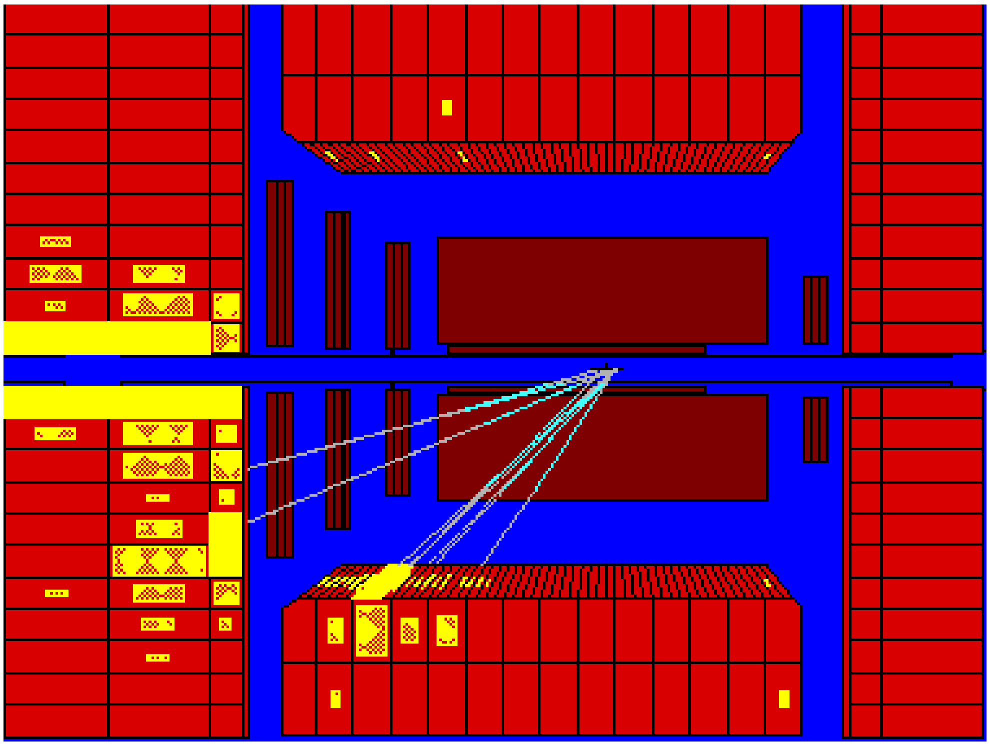
ZEUS luminosity:

e^-p	1993	0.5	pb^{-1}
	1994	0.3	
e^+p	1994	2.9	
	1995	6.5	
	1996	10.6	
	1997	$\sim$ 18.	so far
	1997	$\sim$ 30.	expected

Present results :

$f^\star$	$9.4\ pb^{-1}\ e^+p$ (1994-95)
$\tilde{e}\tilde{q}$	$20.\ pb^{-1}\ e^+p$ (1994-96)

ZEUS Detector



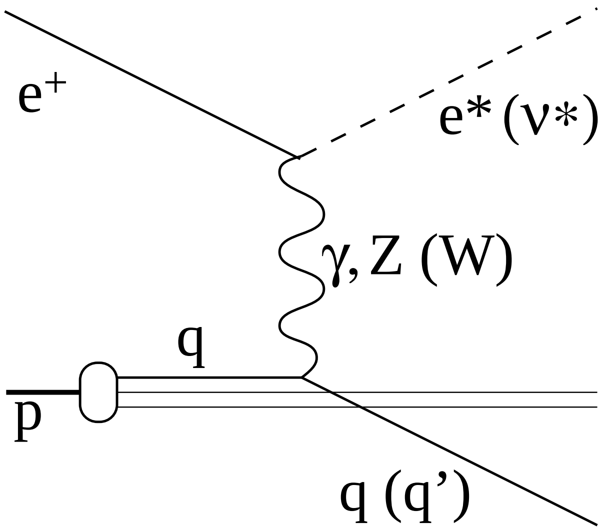
- **Calorimeter (CAL):**
  - Solid angle coverage 99.7%
  - Equal response to electrons and hadrons $\dfrac{e}{h} = 1$
  - Test beam resolution: $\dfrac{\sigma(E)}{E} = \begin{cases} 18\%/\sqrt{E} & \text{em.} \\ 35\%/\sqrt{E} & \text{had.} \end{cases}$
  - Energy scale uncertainty: $\pm 3\%$
- **Central tracking detector (CTD):**
  - Angular acceptance: $15^\circ < \theta < 164^\circ$
  - Resolution: $\dfrac{\sigma(p_t^{\text{track}})}{p_t^{\text{track}}} = [0.005\, p_t^{\text{track}}\,(\text{GeV})] \oplus 0.016$

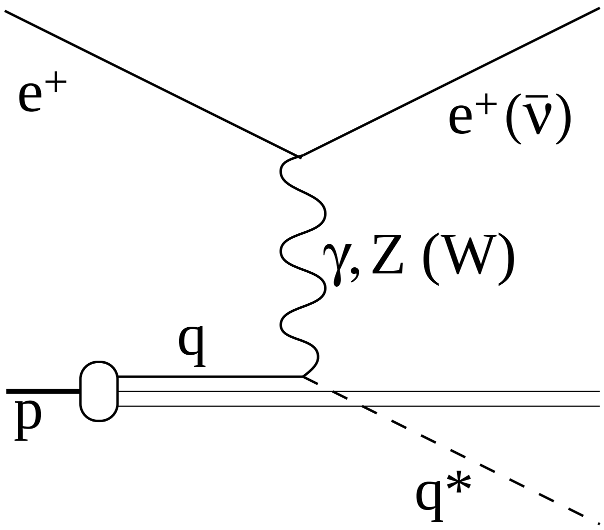
    (for full length tracks)

Excited fermion production at HERA

Signal for compositeness

Excitation of lepton or quark in hard eq scattering:





Excited fermion search

Limits from other experiment:

- LEP 1.5 and LEP 2
  - independent of couplings:
    excited leptons excluded below 80 GeV
  - depending on assumed couplings:
    excited leptons excluded up to about 160 GeV
- Tevatron
  excited quarks excluded below 760 GeV
  assuming strong coupling

Earlier HERA results:

- ZEUS 1993
  M.Derrick *et al*, Z Phys C 65 (1995) 627
- H1 1994
  S.Aid *et al*, Nucl Phys B 483 (1997) 44

Present analysis:

- Consider $f^\star = e^\star, \nu^\star, q^\star$
- Search for resonance decaying to light fermions:

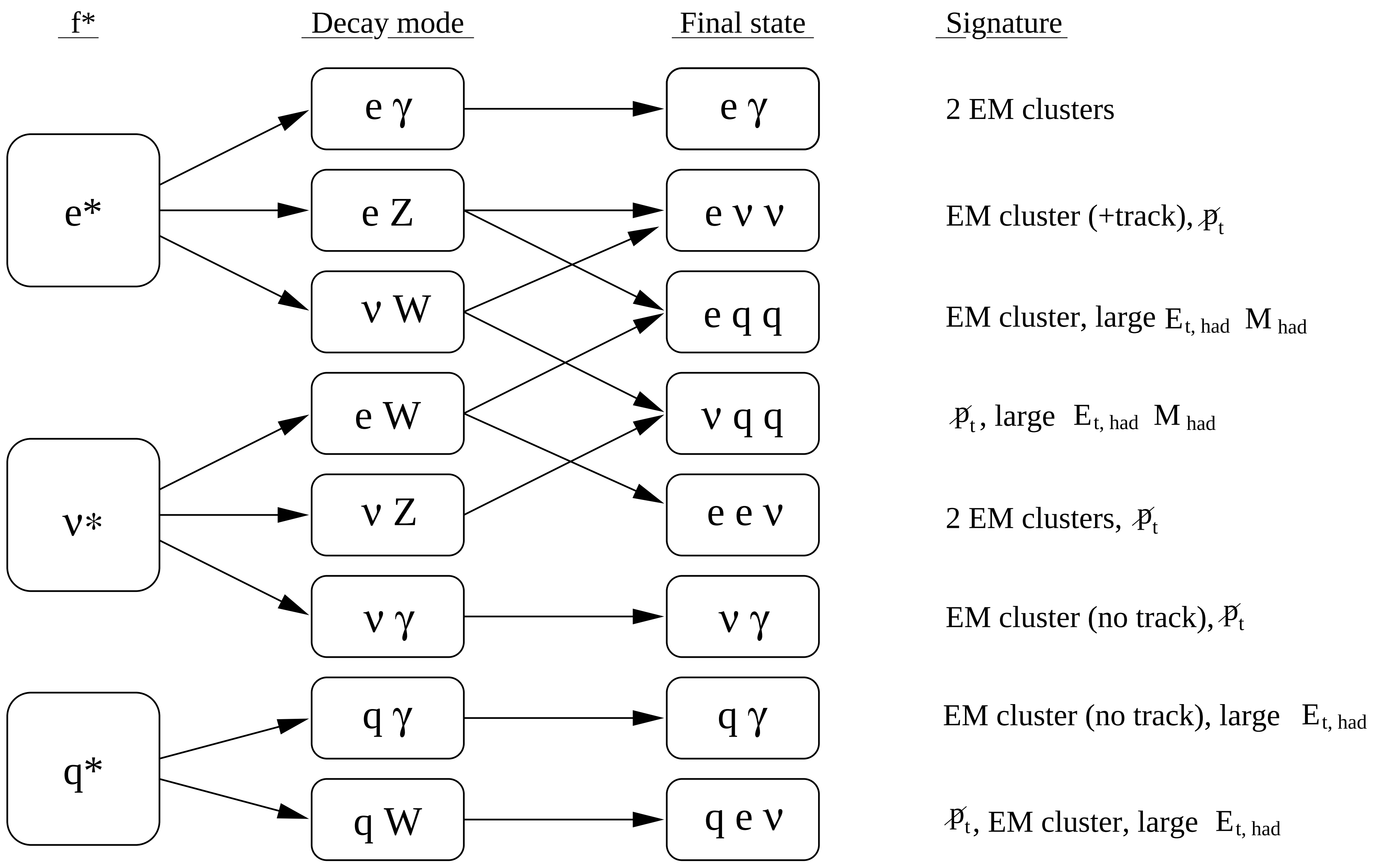
$$f^\star \rightarrow f + \gamma/Z^\circ/W$$

- Include

$$\begin{aligned} Z^\circ &\rightarrow \nu\bar{\nu},\, q\bar{q} \\ W &\rightarrow e\nu,\, q\bar{q}' \end{aligned}$$

$\Rightarrow$ 8 final topologies considered

ZEUS excited fermion search 1994-95



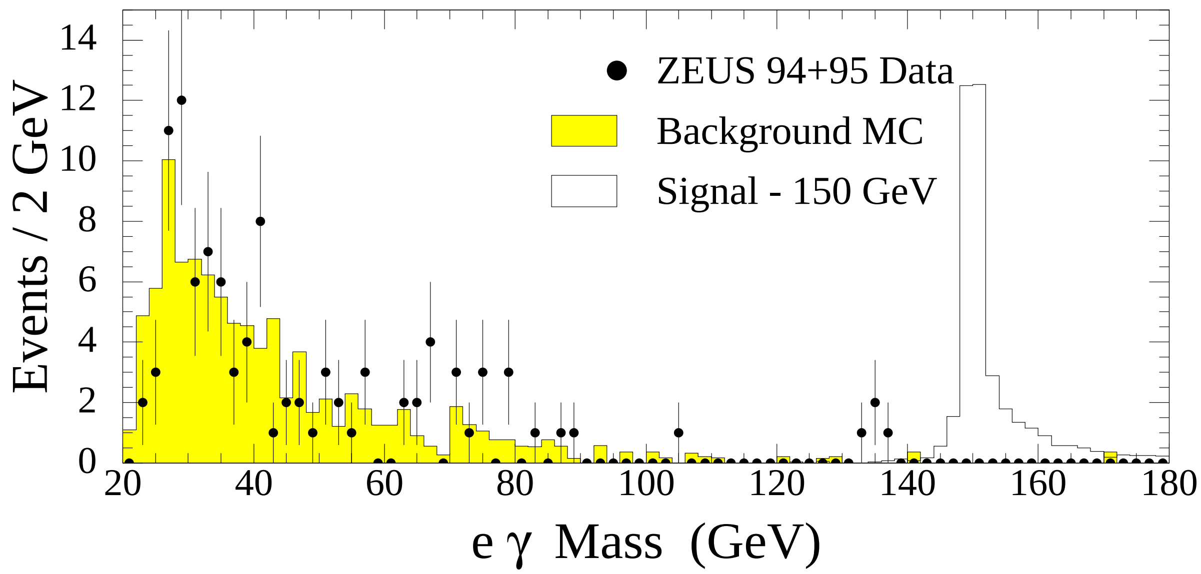
$e^{\star} \rightarrow e\,\gamma$ **search**

Selection requirements:

- two isolated electromagnetic clusters with high E_t,
- $E - p_z \sim 2 \cdot E_{e\_beam}$, as expected for NC DIS,
- Little other activity in the detector.

Acceptance: 40% for $M_{e\gamma} = 30$ GeV,
80% for $M_{e\gamma} > 150$ GeV.

Mass of the $e\,\gamma$ final state reconstructed using e and γ angles:



Expected number of events:

QED-Compton	81.5 ±4.2
NC DIS	16.0 ±2.4

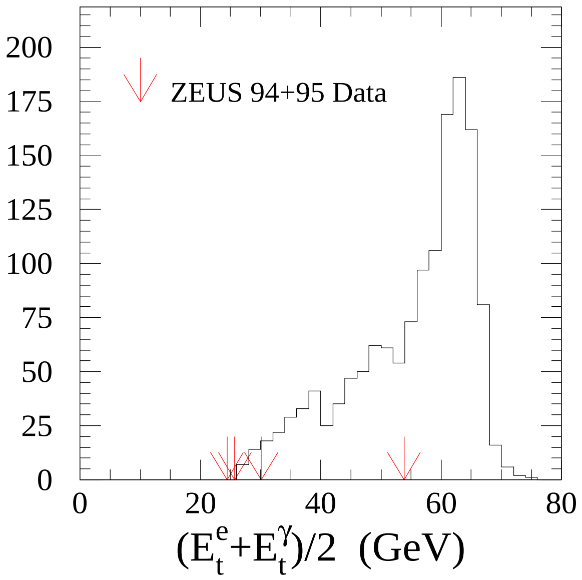
Observed : 103 events.

$e^\star \to e\,\gamma$ search

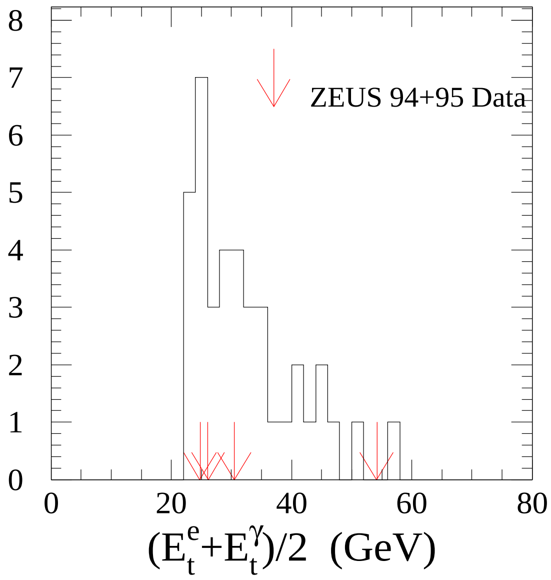
4 candidate events at $M_{e\gamma} \sim 135$ GeV

- Transverse energy distribution:

$e^\star$ signal for $M_{e^\star} = 135$ GeV

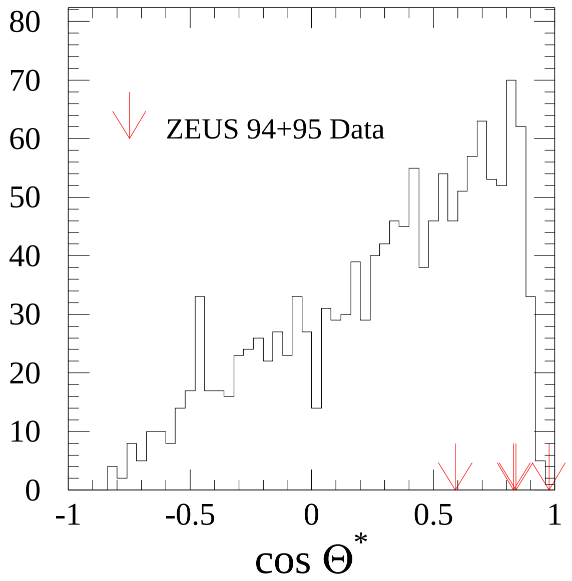


NC DIS with $M_{e\gamma} > 100$ GeV

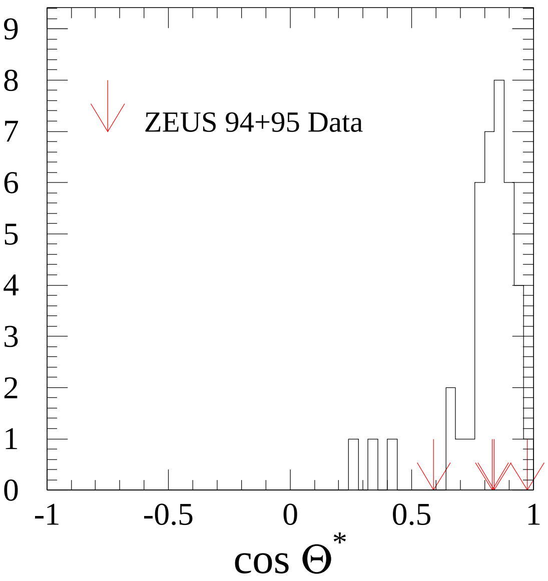


- γ scattering angle (in $e\gamma$ rest frame)

$e^\star$ signal for $M_{e^\star} = 135$ GeV



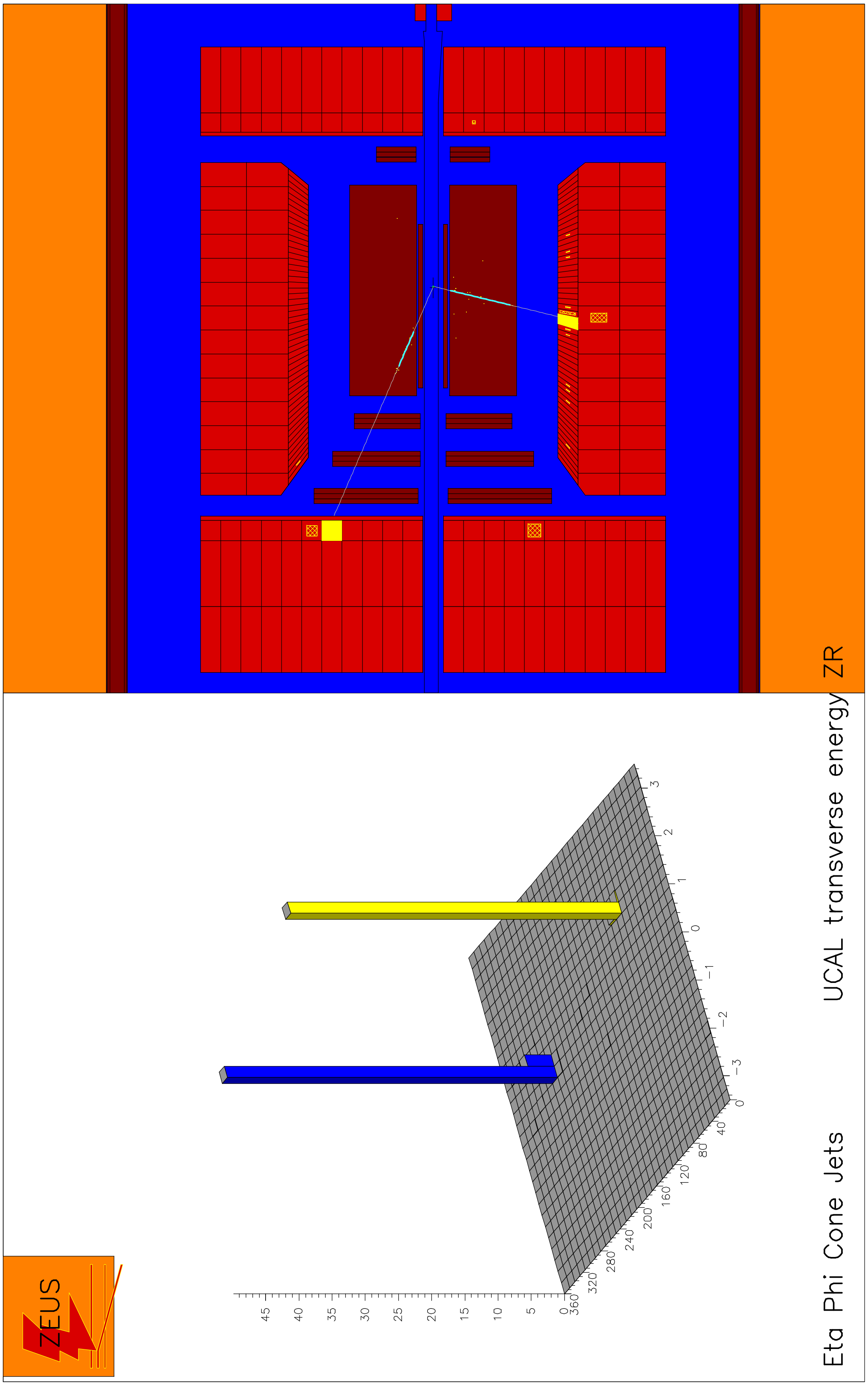
NC DIS with $M_{e\gamma} > 100$ GeV



Data are consistent with background expectations.

$e^{\star} \rightarrow e\,\gamma$ **search**

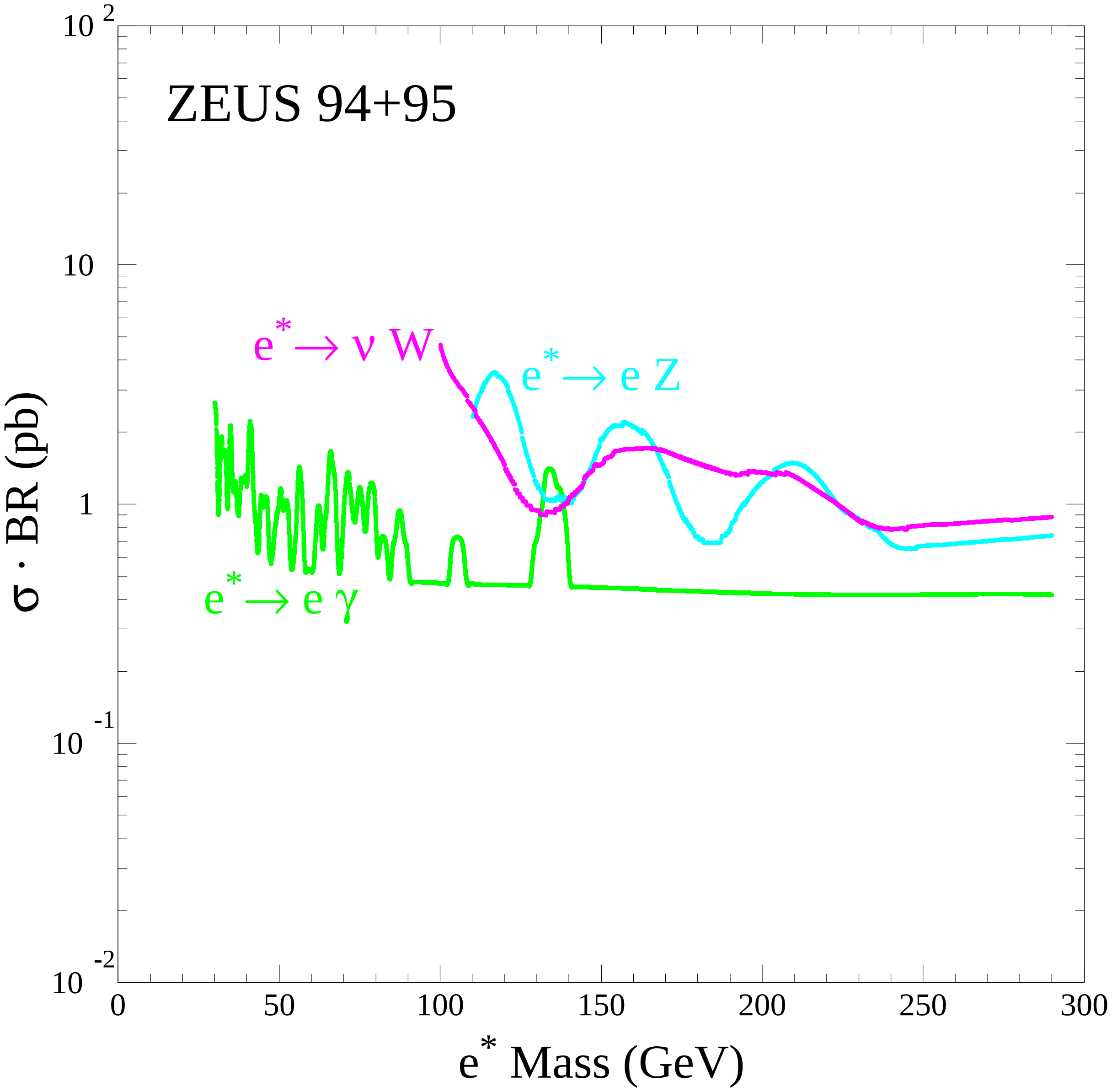
High E_t candidate event



Search for $e^\star$ production

No evidence for $e^\star$ resonance

$\rightarrow$ upper limits on $\sigma\cdot$ BR:



Independent of phenomenological model.

Excited fermion production

$f^\star$ production depends on $f^\star f\,V$ coupling ($V = \gamma, Z^\circ, W^\pm, g$)

Phenomenological model

(Hagiwara, Komamiya, Zeppenfeld)

- spin $\frac{1}{2}$ excited fermions
- L,R weak isodublets
- transition Lagrangian:

$$\mathcal{L}_{ff^*} = \frac{1}{\Lambda}\,\overline{f}^*_{\mathrm{R}}\,[f \cdot SU(2)_L + f' \cdot U(1)_Y + f_s \cdot SU(3)_c]\, f_{\mathrm{L}}$$

where:

– $f,\ f',\ f_s$ are couplings associated with the gauge groups

– Λ is the compositeness scale

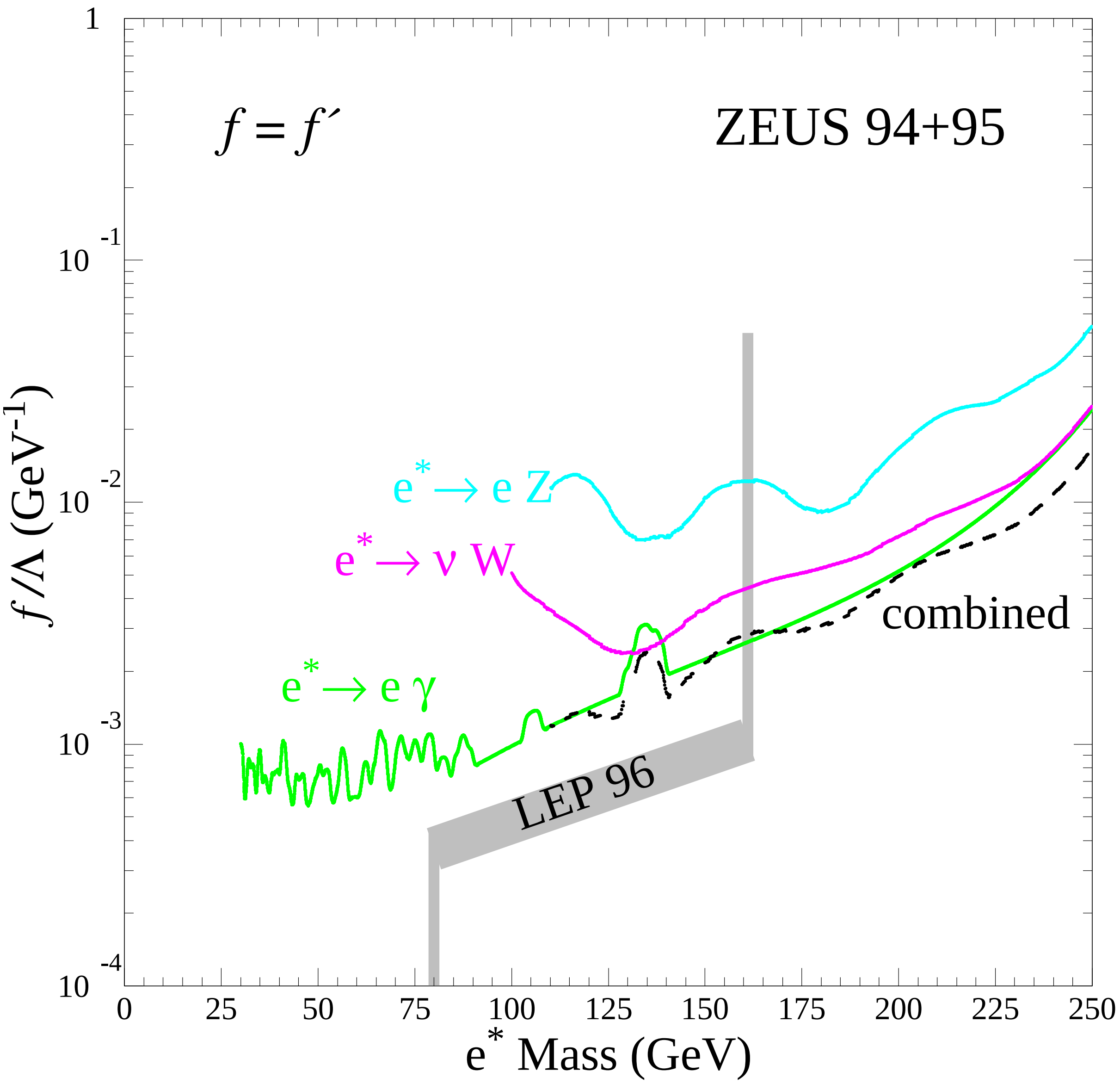
- Limits are presented assuming:

  ◦ $f = f'$ for $e^\star$ production/decay

  ◦ $f = -f'$ for $\nu^\star$ production/decay (to allow for $\nu^\star \to \nu\gamma$)

  ◦ $f_s = 0$ for $q^\star$ production/decay (only electroweak couplings considered)

Search for $e^\star$ production



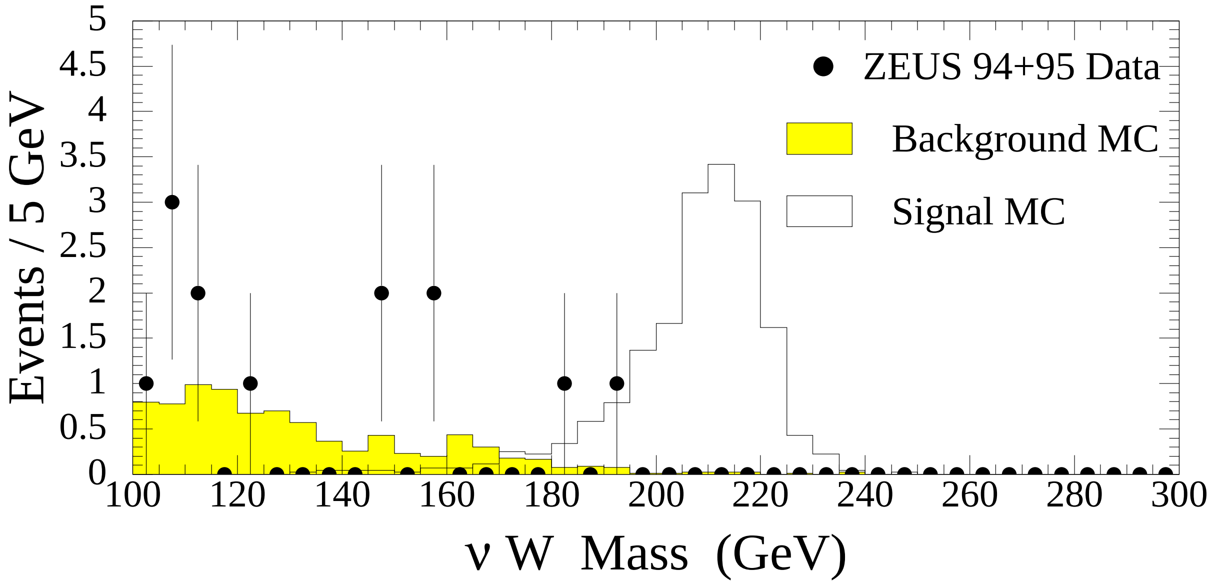
Assuming that

$$\frac{f}{\Lambda} = \frac{1}{M_{e^\star}}$$

excited electrons are ruled out for:

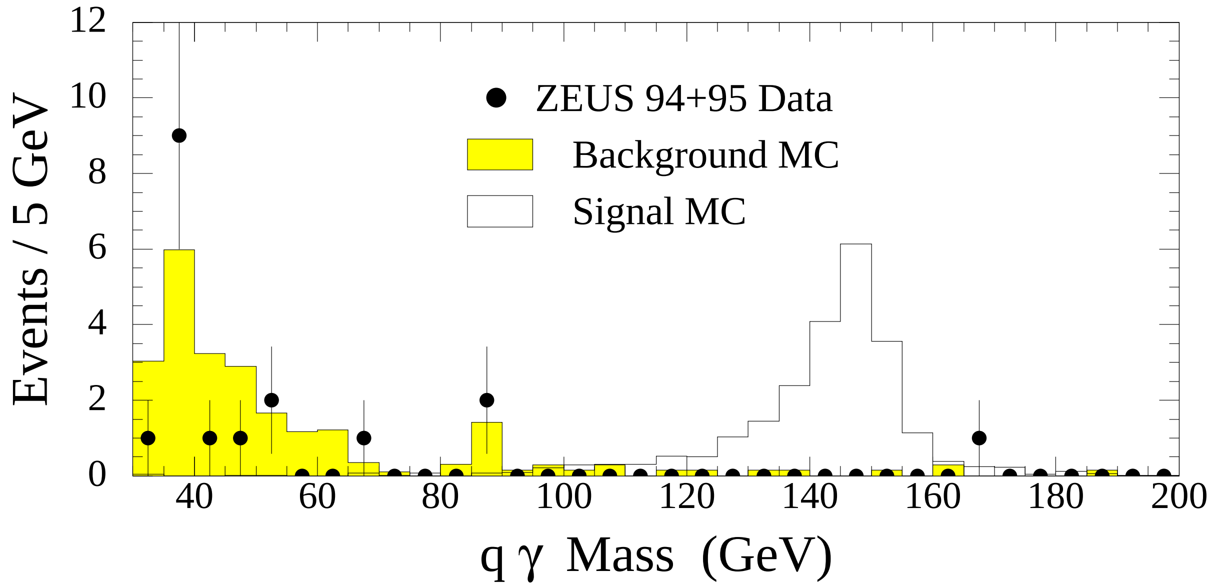
$$30\,\mathrm{GeV} < M_{e^\star} < 200\,\mathrm{GeV} \quad (95\% CL)$$

Search for $e^\star \to \nu W \to \nu q \bar{q}$ / $\nu^\star \to \nu Z^\circ \to \nu q \bar{q}$



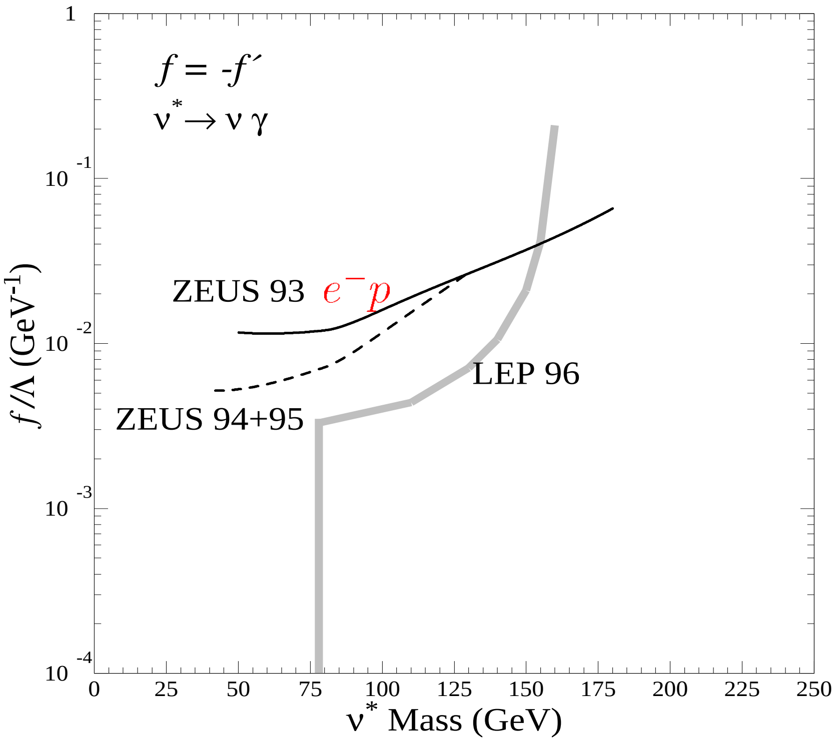
Expected SM background: 8.4 ±1.5 events (mainly CC DIS)
Observed : 13 events

Search for $q^\star \to q\gamma$



Expected SM background: 23.5 ±2.5 events (mainly prompt γ)
Observed : 18 events

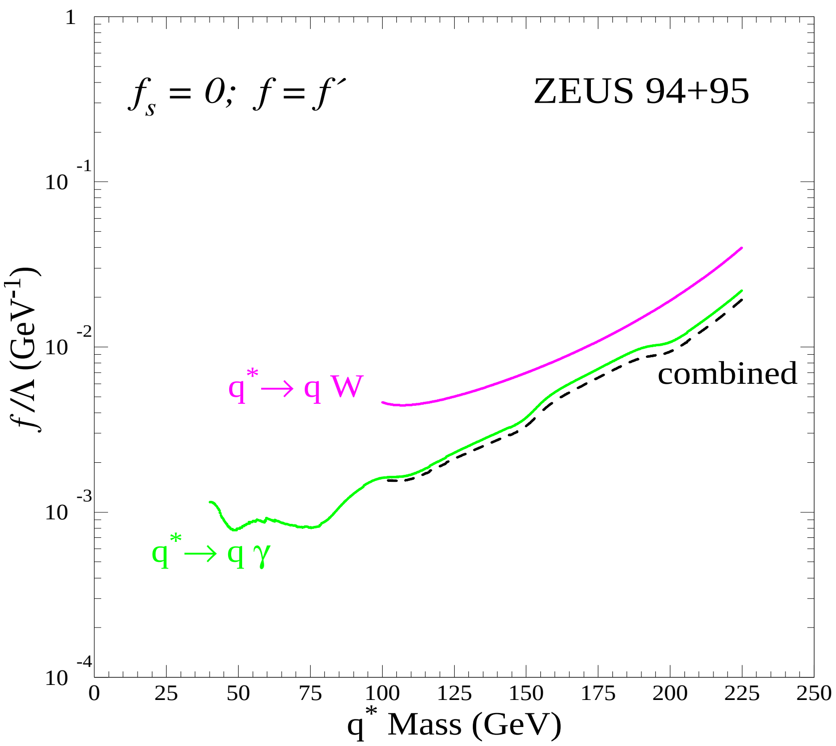
Limits on $\nu^\star$ production



Excluded $\nu^\star$ mass range:

$40 < M_{\nu^\star} < 96$ GeV

Limits on $q^\star$ production

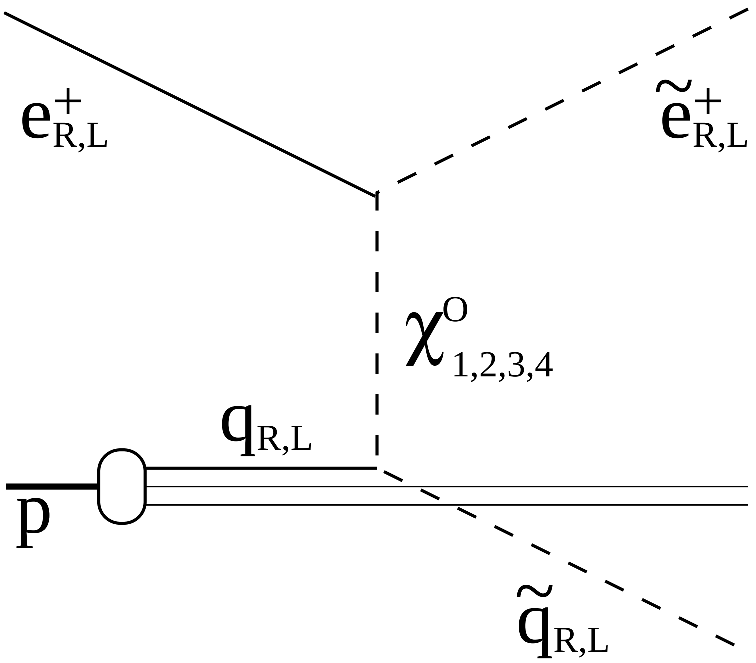


Excluded $q^\star$ mass range:

$40 < M_{q^\star} < 169$ GeV

$\tilde{e}\,\tilde{q}$ production at HERA

Lowest order R-parity conserving SUSY process in ep:



Only decays to the lightest neutralino are considered:

$$\tilde{e} \rightarrow \chi_1^\circ\, e \qquad\qquad \tilde{q} \rightarrow \chi_1^\circ\, q$$

Assuming that R-parity is conserved and χ_1° is LSP

$\rightarrow \chi_1^\circ$ is stable and escapes detection.

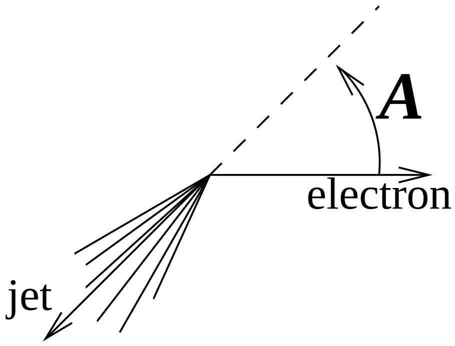
Signature for $\tilde{e}\,\tilde{q}$ production:

- Electron and hadronic jet in the final state,
- Missing p_t, low $E - p_z$ and acoplanarity.

Search for $\tilde{e}\,\tilde{q}$ production

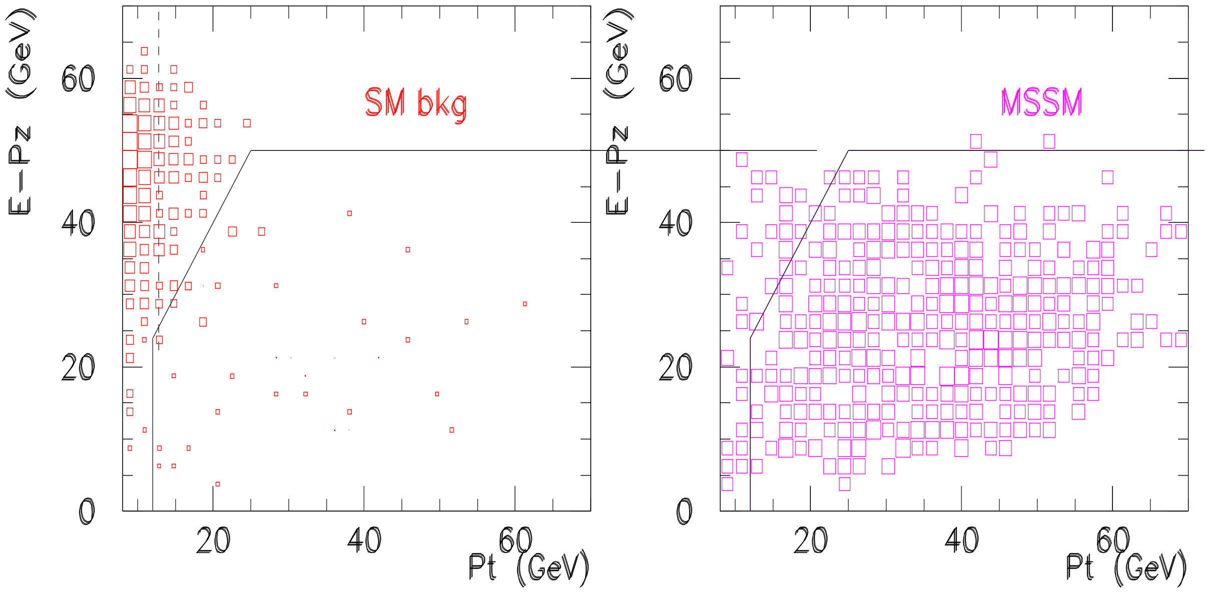
Selection requirements:

- Reconstructed vertex within ±50 cm from nominal IP,
- Scattered electron with $p_t > 4$ GeV and $\theta_e < 2.5$ rad,
- Hadronic system with $p_t > 4$ GeV,
- Acoplanarity $A > 0.25$ rad,



- Final selection in $E - p_z$ vs $\not{p}_t$ plane.

For NC DIS background we expect: $\not{p}_t \sim 0$, $E - p_z \sim 2 \cdot E_{e\_beam}$

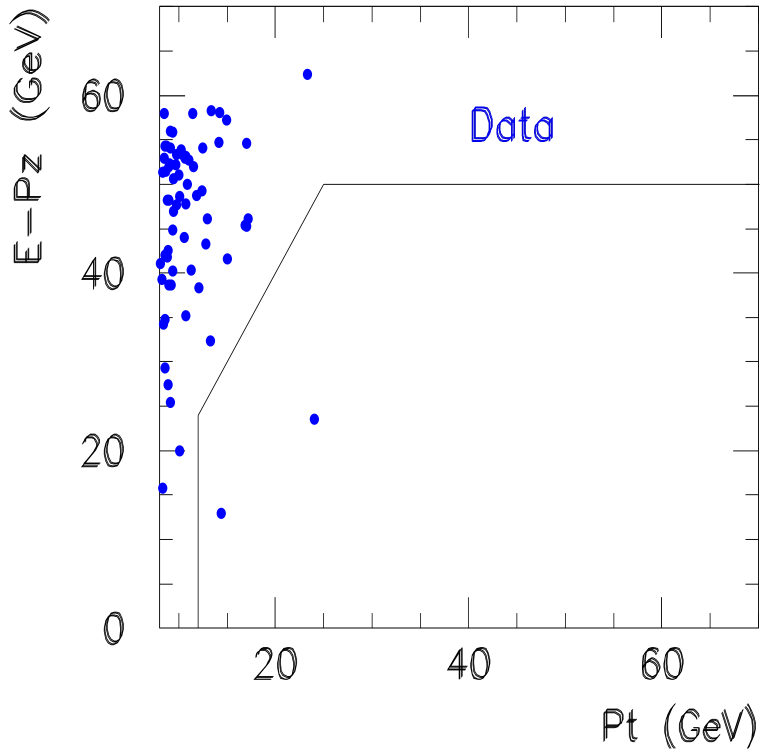


We select events with $\not{p}_t > 12$ GeV and $E - p_z < 50$ GeV and $2\not{p}_t > E - p_z$.

Search for $\tilde{e}\,\tilde{q}$ production

ZEUS 1994-96 Preliminary

$\mathcal{L} = 20pb^{-1}$

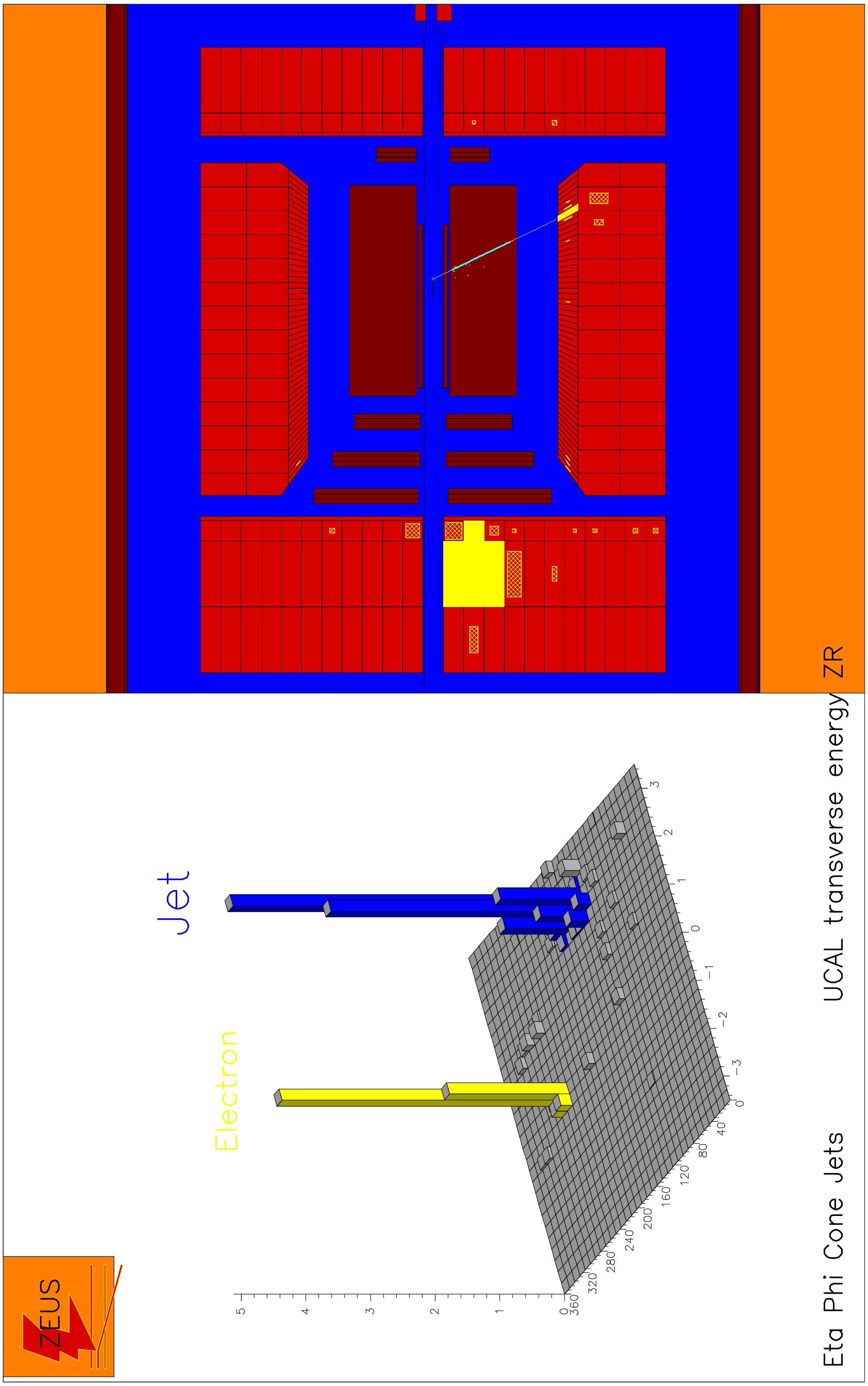


- Events left in data: 2
- Expected SM backgrounds:

Process	Generator	Events	± stat.	± theo.
$ep \to eX$	DJANGO6.2	0.55	±0.28	±0.03
$ep \to \nu X$	DJANGO6.2	0.94	±0.18	±0.05
$ep \to eWX$	EPVEC	0.94	±0.04	±0.09
$ep \to Q\bar{Q}X$	PYTHIA5.7	0.31	±0.31	±0.03
$\gamma\gamma \to e^+e^-X$	LPAIR	0.00	$^{+0.05}$	
Total SM		2.74	±0.46	±0.11

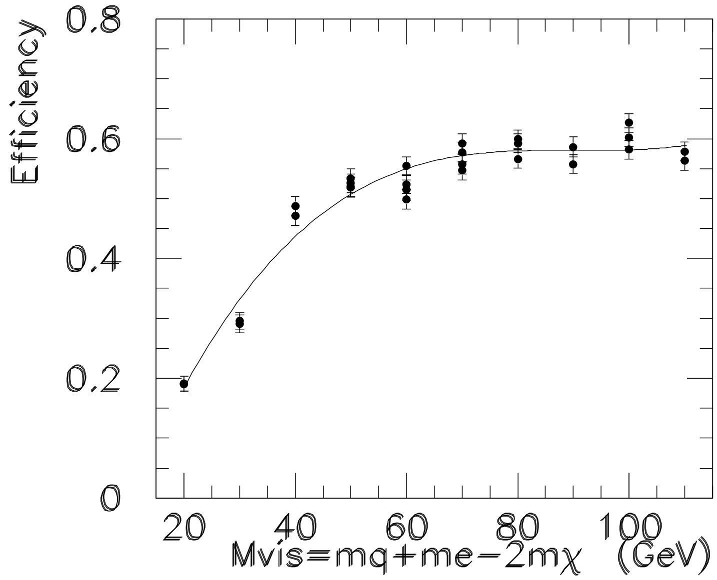
Search for $\tilde{e}\,\tilde{q}$ production

Candidate event

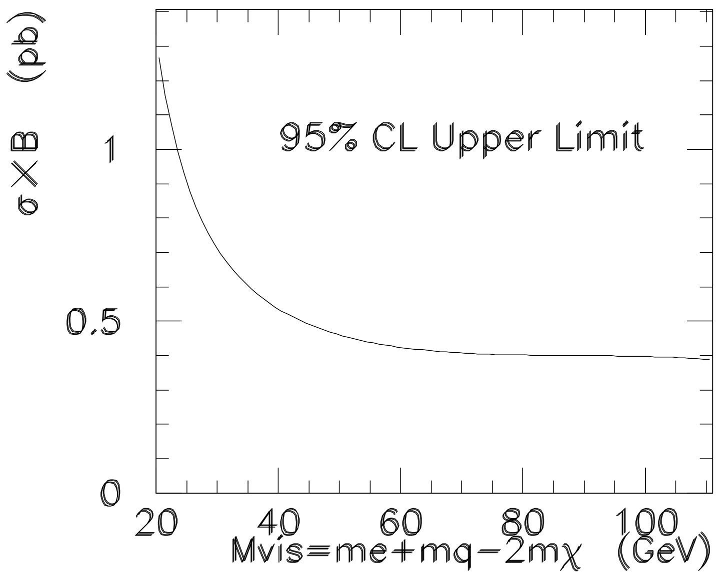


Search for $\tilde{e}\,\tilde{q}$ production

- Efficiency for tagging $\tilde{e}\,\tilde{q}$ events:



- Cross section limit:



Minimal Supersymetric Standard Model

The sross section depends on many model parameters:

$$M_1, M_2, \mu, \tan\beta, m_{\tilde{e}_L}, m_{\tilde{e}_R}, m_{\tilde{q}^i_{L,R}} \qquad i = u, d, s, c, b$$

Limits are presented using simplifying assumptions:

- $m_{\tilde{e}_R} = m_{\tilde{e}_L} \equiv m_{\tilde{e}}$
- $m_{\tilde{q}^f_R} = m_{\tilde{q}^f_L} \equiv m_{\tilde{q}}$ for all the flavour f
- no mixing between L-R scalar fermions
- $M_1 = \frac{5}{3} \tan^2\theta_W M_2$

The branching ratios are evaluated with ISASUSY.

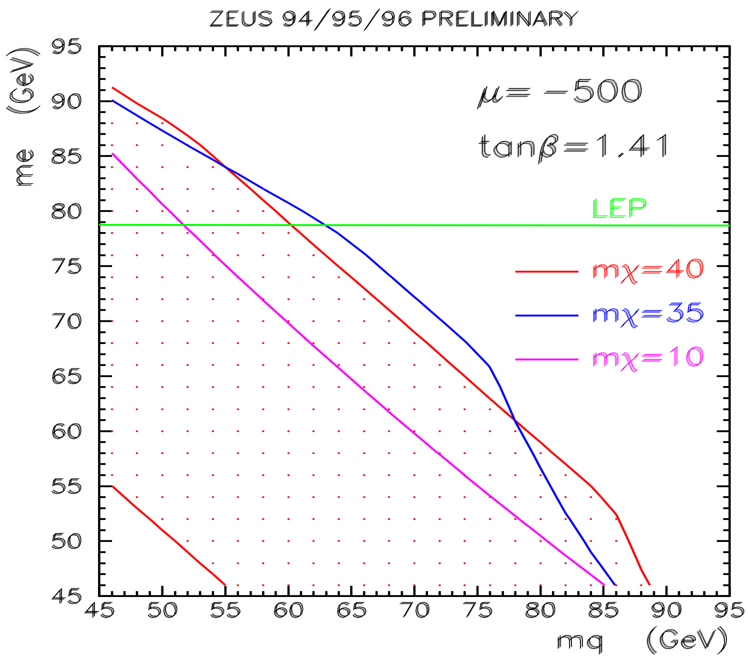
Limits from other experiment:

- LEP
  - Mass $\tilde{e} \geq 80$ GeV $\qquad \sqrt{s} = 161 GeV$
  - Mass $\tilde{q} \geq 45$ GeV $\qquad$ LEP 1
- Tevatron
  depend on gluino mass

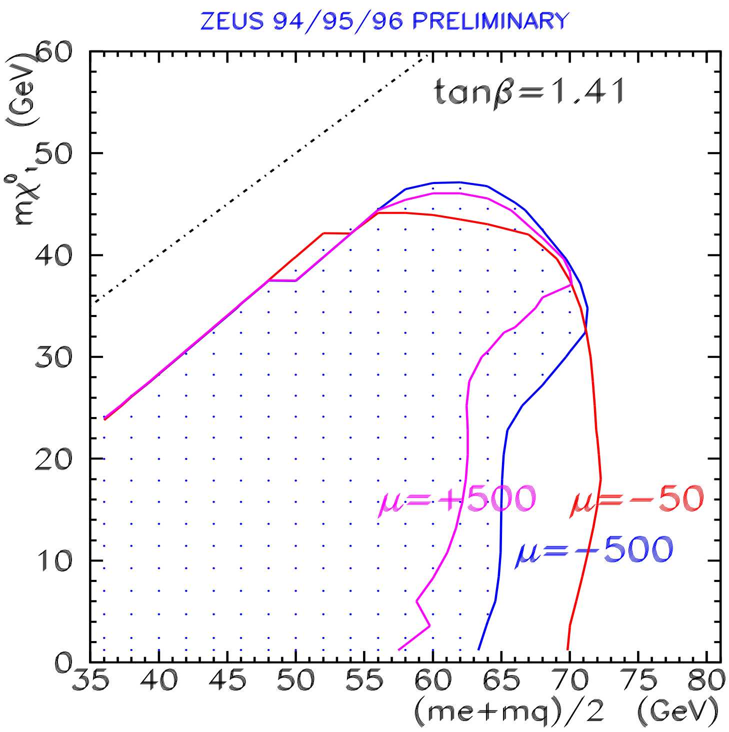
Earlier HERA results:

- H1 1994-95
  S.Aid *et al*, Phys Lett B 380 (1996) 461

Limits on MSSM parameters

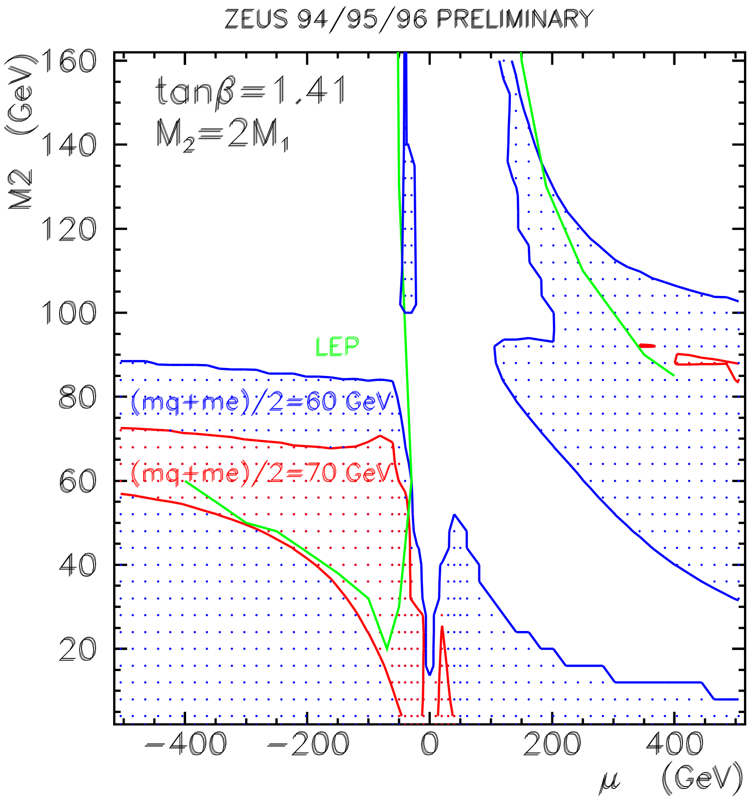


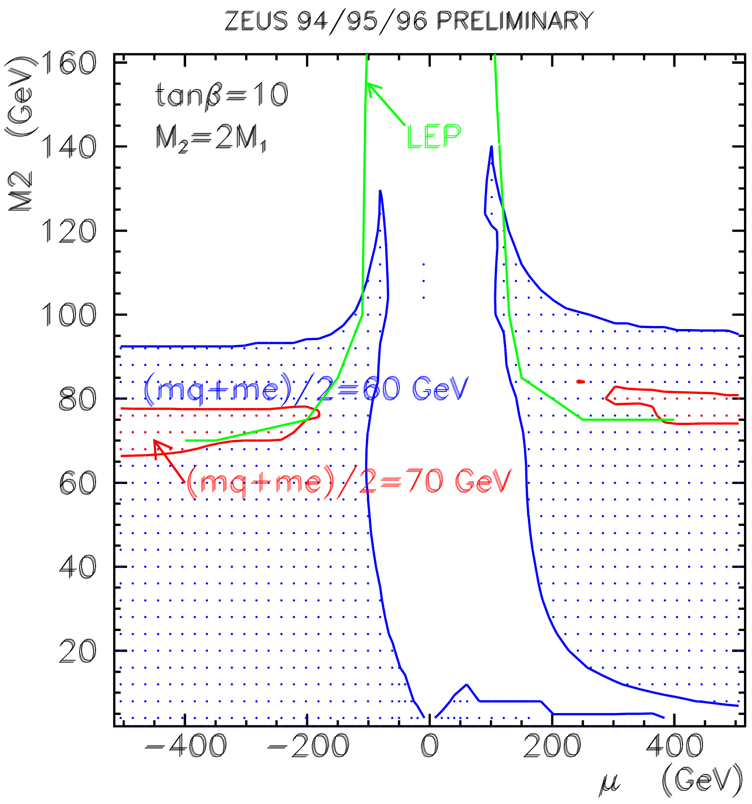
HERA is sensitive mostly to $m_{\tilde{e}} + m_{\tilde{q}}$



$m_{\tilde{e}}$ and $m_{\tilde{q}}$ can be excluded up to about 70 GeV.

Limits on MSSM parameters





Summary

- Excited fermions

  Taking $\frac{f}{\Lambda} = \frac{1}{M_{f^\star}}$, exclude (95% CL)

  - $e^\star$ between 30-200 GeV
  - $\nu^\star$ between 40-96 GeV
  - $q^\star$ between 40-169 GeV
    (electroweak couplings)

- MSSM (preliminary)

  For $\tan\beta = 1.41$, exclude

  - χ_1^0 mass below 47 GeV
  - mass $(\tilde{e} + \tilde{q})/2$ below 72 GeV

- Future prospects
  - $\sim 30\,pb^{-1}$ e^+p in 1997
    (giving $\sim 50\,pb^{-1}$ e^+p 1994-97)
  - $\sim 50\,pb^{-1}$ e^-p in 1998-99
    improved sensitivity for $\nu^\star$,...
  - $\sim 1000\,pb^{-1}$ beyond 2000
    after HERA upgrade

$\Rightarrow$ HERA will continue to deliver new results