Search for R_p-violating SUSY and excited fermions at HERA

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International Europhysics Conference on High Energy Physics
July 12-18, 2001, Budapest, HUNGARY

on behalf of the

and

Collaborations

What are we searching at HERA?

in this talk:

2 topics of searches beyond SM

HERA experiments H1 and ZEUS have collected

e^+p scattering: $\sim 110\ \mathrm{pb}^{-1}$

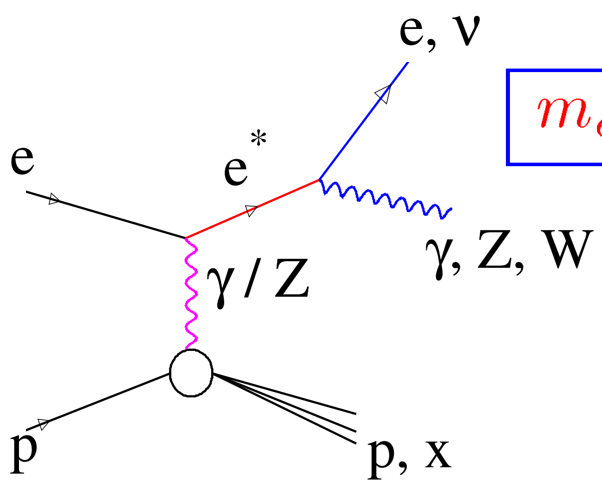
e^-p scattering: $\sim\ \ 15\ \mathrm{pb}^{-1}$

per experiment.

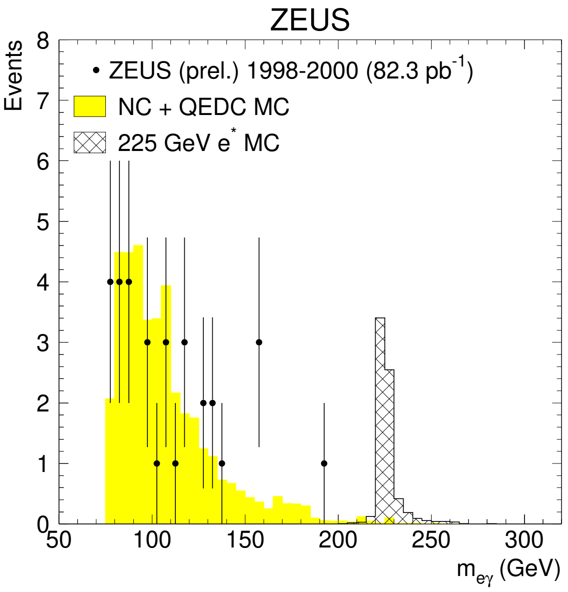
	SIGNAL	THEORY
1.	Excitations of Fermions f^*	Compositeness
2.	e-q Resonances: Production of New Particles	Squarks in R-parity Violating Supersymmetry (SUSY) (Leptoquarks)

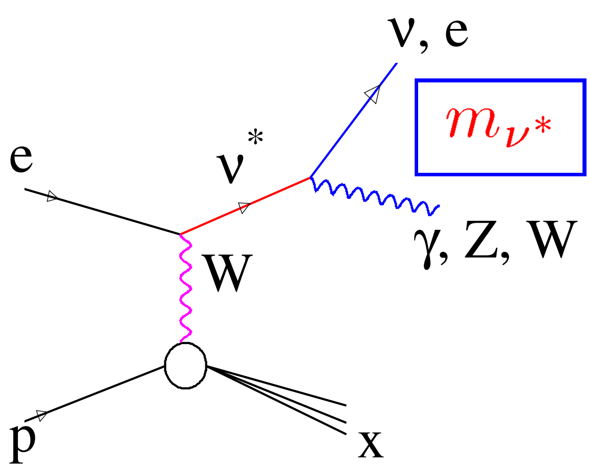
3. Conclusions and Future Prospects

1. fermionic substructure ⇒ excited fermions

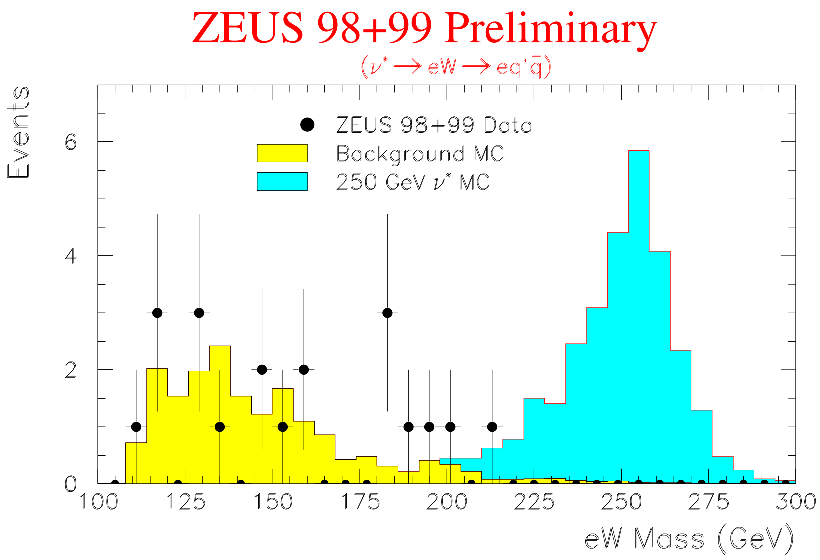


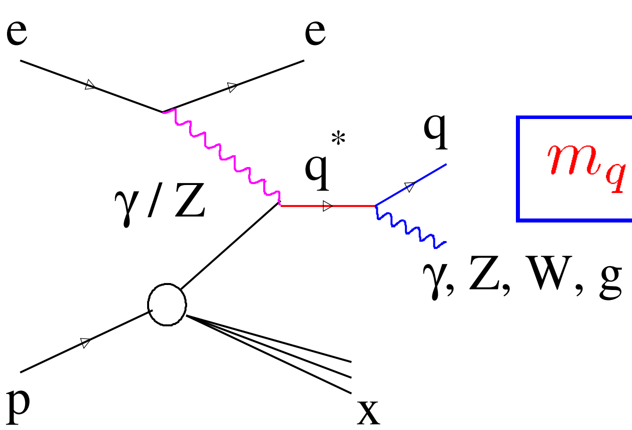
m_{e^*}



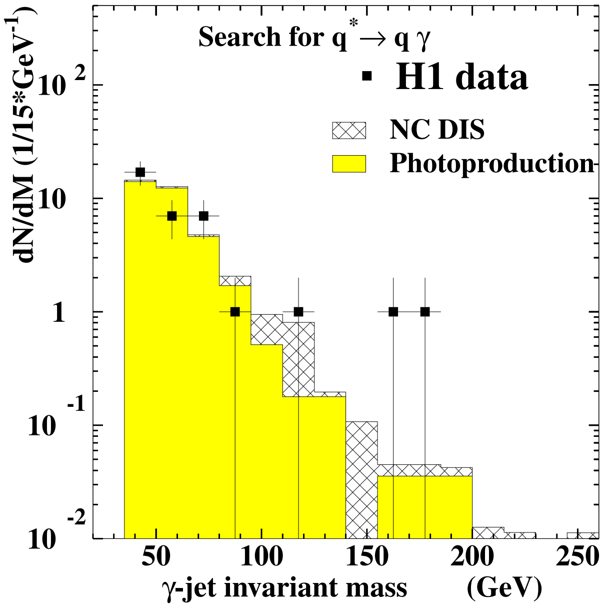


m_{ν^*}





m_{q^*}



⇒ no evidence for excited fermion production

Phenomenological Framework

Hagiwara, Komamiya, Zeppenfeld: Z. Phys. **C 29** (1985) 115

excited fermion f^* is composite of a scalar and a spin $\frac{1}{2}$ constituent

- in our case: f^* has spin $\frac{1}{2}$, isospin $\frac{1}{2}$

- effective Lagrangian:

SM couplings

new couplings

$$\mathcal{L}_{eff} = \frac{1}{2\Lambda} \bar{F}_R^* \sigma^{\mu\nu} \left(g \; f \; \frac{\tau^a}{2} W^a_{\mu\nu} \leftarrow \mathrm{SU(2)} \right.$$

$$+ \; g' \; f' \; \frac{Y}{2} B_{\mu\nu} \leftarrow \mathrm{U(1)}$$

$$+ \; g_s \; f_s \; \frac{\lambda_a}{2} G^a_{\mu\nu} \leftarrow SU(3)_C$$

$$\left. \right) F_L + h.c.$$

compositeness scale

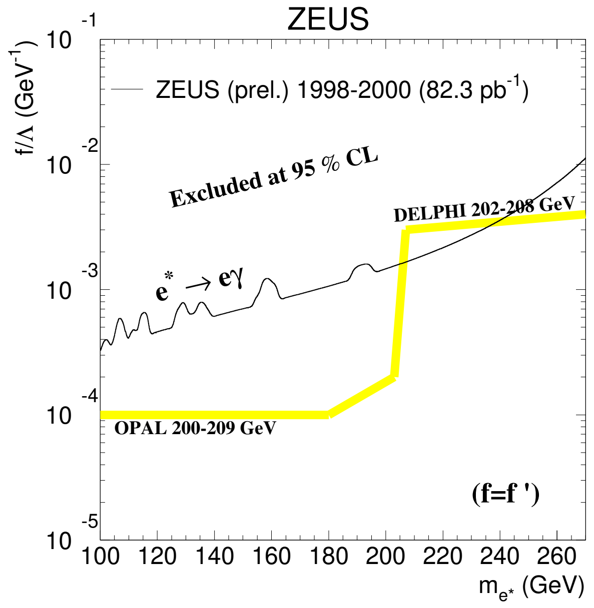
weak isodoublets:
F_R^*, F_L^*

- coupling constant:

$$c_{\gamma f^* f} = \frac{1}{2} \left(f \; I_3 + f' \frac{Y}{2}\right)$$

$\Rightarrow$ limits for f (or f / Λ)

Limits obtained on f ($f = \pm f'$) on 95% CL

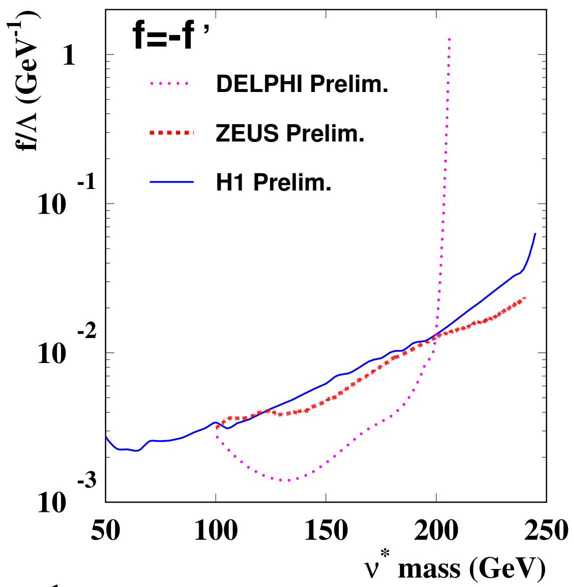


NEW

$\Rightarrow$ improvement by factor 2-3

$\Rightarrow$ comparable limits for larger m_{e^*} with LEP

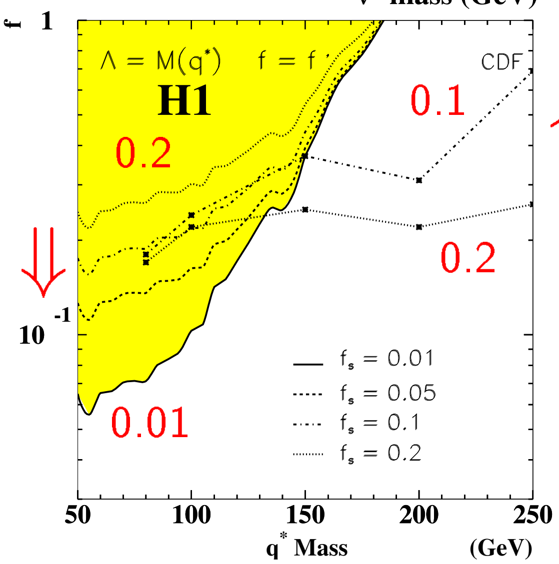
$\boxed{m_{e^*}}$



$\Rightarrow$ unique sensitivity beyond LEP $\sqrt{s}$ (q^* is similar)

$\Rightarrow$ new $\underline{e^- p}$ luminostiy: more sensitve than LEP even for smaller ν^* masses: (u quark density in proton larger, in e^+p helicity suppression due to W exchange)

$\boxed{m_{\nu^*}}$



$\Rightarrow$ more sensitive for small f_s than TeVatron

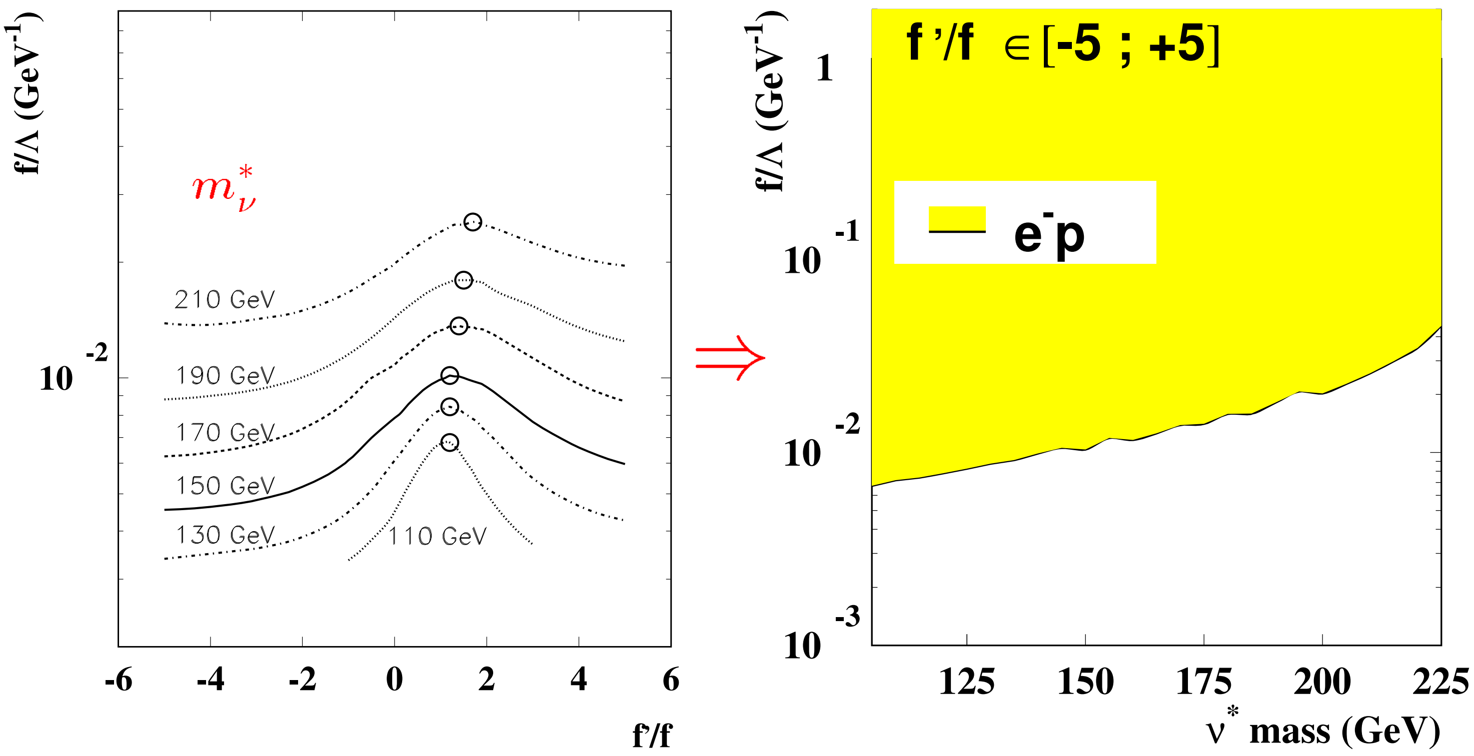
$\boxed{m_{q^*}}$

$\Rightarrow$ sensitive to f, f'; complementary to TeVatron

$\Rightarrow$ limits will further go down with higher luminosity

Less Model-dependent Limits for $f\ /\ \Lambda$ (H1)

consider arbitrary ratios: $f'\ /\ f$



$\Rightarrow$ NEW limits are extension beyond LEP mass reach

- alternative method to study possible fermion substructures: form factors

  $\Rightarrow$ previous talk (X. Liu)

  assign finite size of radius R to electroweak charges of leptons and/or quarks (γ, Z still pointlike)

  $\Rightarrow$ e pointlike: $R_q < 1.6 \cdot 10^{-16}$ cm (H1)
  $R_q < 0.73 \cdot 10^{-16}$ cm (ZEUS)

  CDF: $R_q < 1 \cdot 10^{-16}$ cm

2. Squarks in R-Parity Violating SUSY

Minimal Supersymmetric Standard Model (MSSM):

R-parity: $R_p = (-1)^{3B+L+2S}$

B: baryon number
L: lepton number
S: spin

- particle: $R_p = \ \ 1$
- sparticle: $R_p = -1$

$\Rightarrow$ R_p conservation: associated $\tilde{e}\,\tilde{q}$ production

R parity-violating $\not{R}_p$ SUSY:

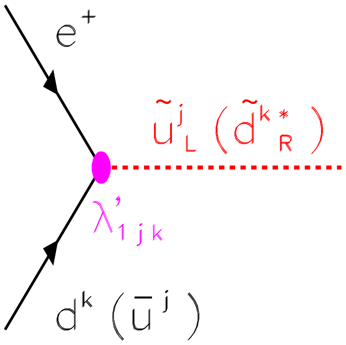
introduce Yukawa couplings between squark and lepton-quark

Butterworth, Dreiner: Nucl. Phys. **C 397** (1993) 3

$$\mathcal{L}_{eff} = \lambda'_{ijk} \left(\ldots \ - e^i_L \tilde{u}^j_L \bar{d}^k_R - \ \ldots \right) + \text{ c.c.}$$

i, j, k: generation indices

$\Downarrow$



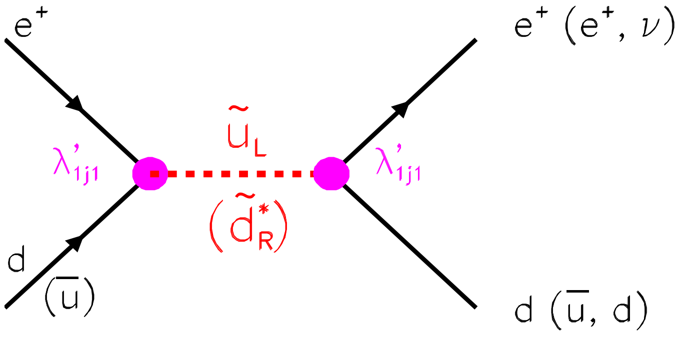
$\Rightarrow$ resonant production of single squarks possible

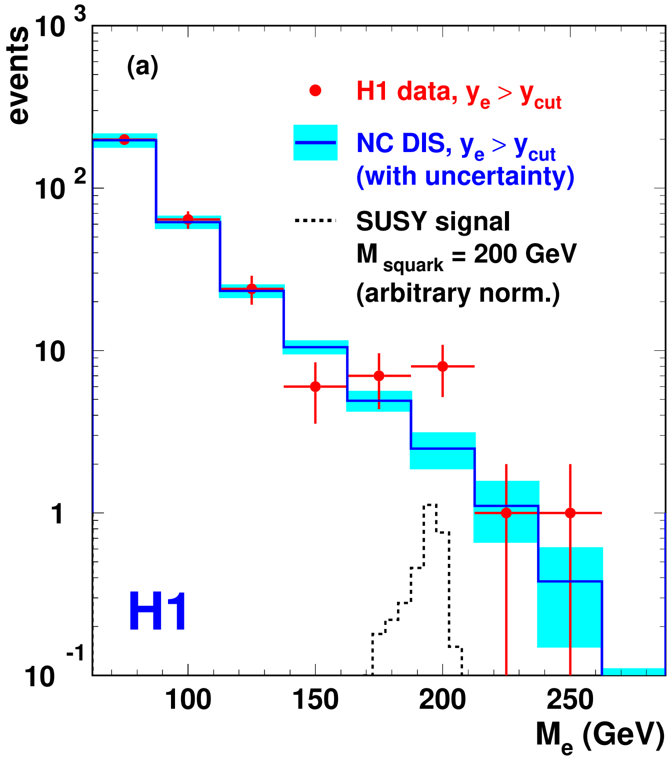
e^+ beam $\Rightarrow$ mainly probing λ'_{1j1} couplings

Different $\not{R}_p$ Squark Decay Modes

e^+p data: 1994–97 ($\sqrt{s} = 300$ GeV)

$\not{R}_p$: SUSY particles can decay into SM particles

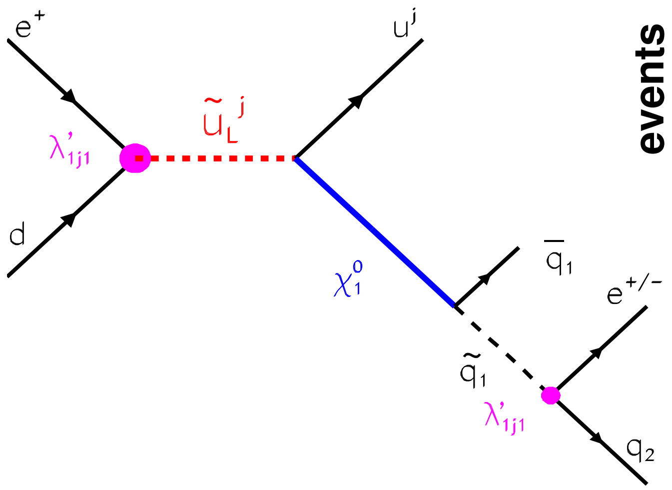


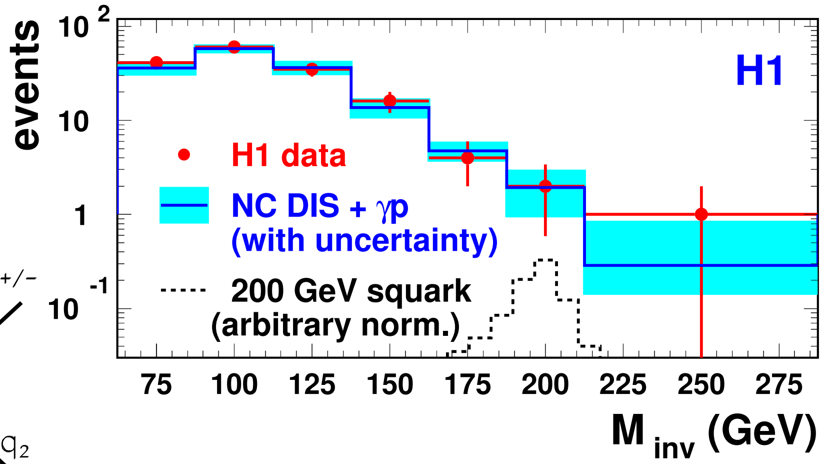


$\not{R}_p$ decays

- e^+ + jet
- ν + jet

$\Rightarrow$





gauge decays

- e^+ + multi-jets $\Uparrow$
- e^- + multi-jets
- ν + multi-jets
- $e + l$ + multi-jets
- $\nu + l$ + multi-jets

$\Rightarrow$ analysis covers $\sim 100\%$ of the $\tilde{q}$ decays

$\Rightarrow$ no evidence for squark production

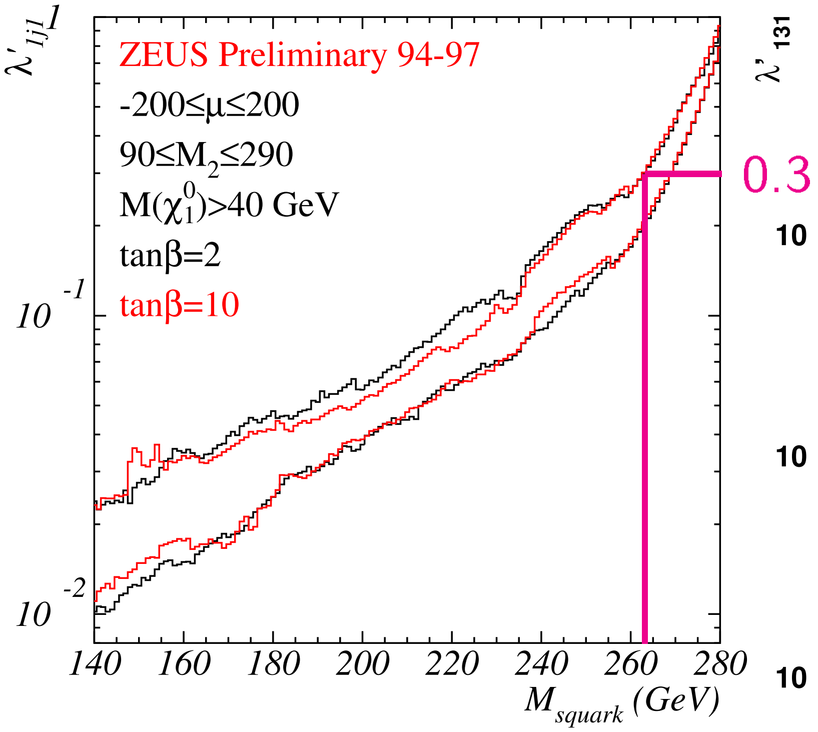
Unconstrained MSSM

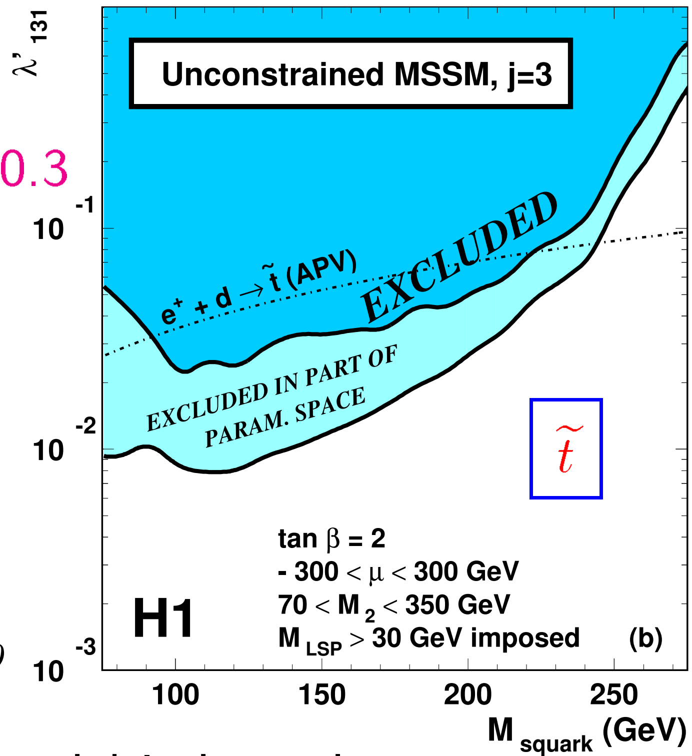
assume: sfermion and gaugino sector not related

$\Rightarrow$ sfermion masses are free parameters

$\Rightarrow$ scan in SUSY parameter space: $(M_2,\ \mu)$, $\tan\beta$

$$\begin{aligned} M_2 &= \text{soft SUSY breaking mass term} \\ \mu &= \text{mixing mass term for 2 Higgs doublets} \\ \tan\beta &= \text{ratio of the vev's of the 2 neutral scalar Higgs fields} \end{aligned}$$





$\Rightarrow$ limits are widely model independent

$\Downarrow$

$\lambda'_{1j1} = 0.3$ (of em strength):

$M_{\tilde{q}} > 260$ GeV

$\Downarrow$

for $\tilde{t}$ (and $\tilde{c}$) production: limits better than indirect bounds from Atomic Parity Violation

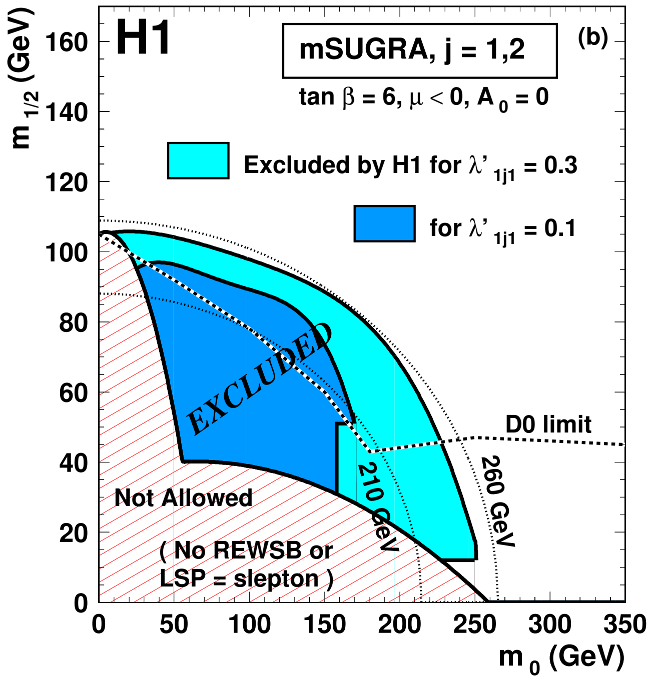
Constrained MSSM

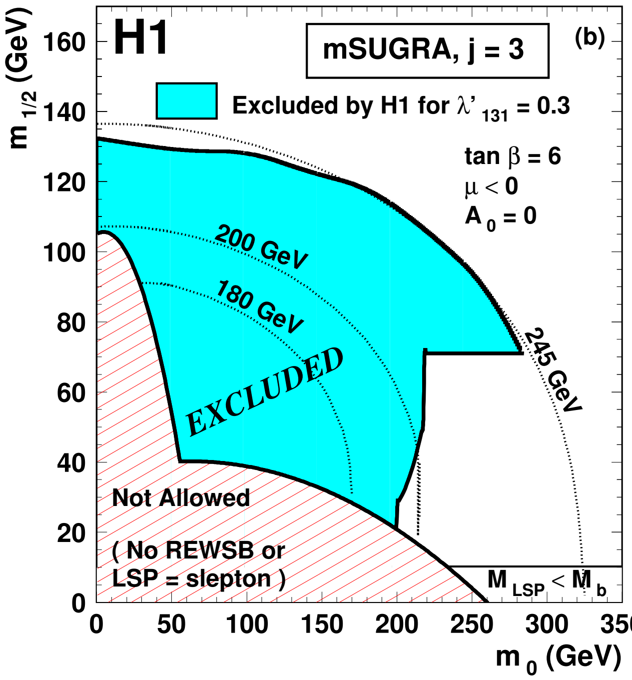
- H1 also sets limits in constrained models:
  sfermion and gaugino sector related by RGE

- limits in mSUGRA:
  assume in addition that electroweak symmetry breaking driven by radiative corrections
  $\Rightarrow$ only 5 parameters: $\tan\beta$, sign of μ

$$m_0 = \text{common scalar mass}$$
$$m_{1/2} = \text{common gaugino mass}$$
$$A_0 = \text{common trilinear coupling at GUT scale}$$

$\boxed{\tilde{u},\tilde{c}}$ $\boxed{\tilde{t}}$





$\Downarrow$

$\lambda'_{1j1} = 0.3$: $M_{\tilde{q}} > 260$ GeV

H1 probes domain not ruled out by D0
LEP has highest sensitivity

$\Downarrow$

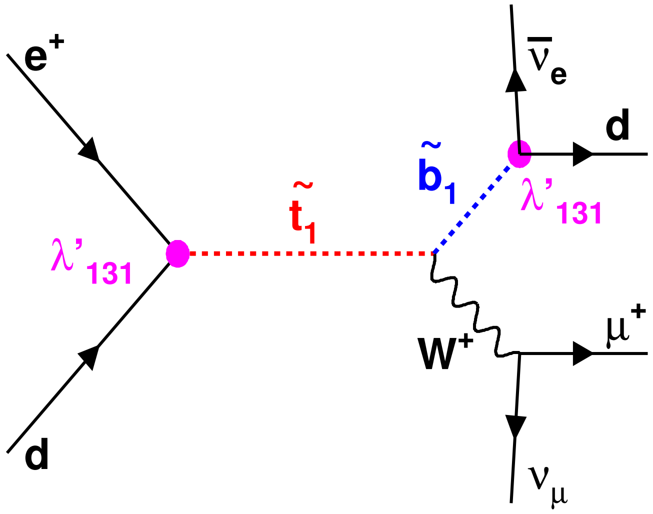
$\lambda'_{131} = 0.3$: $M_{\tilde{t}_1} > 245$ GeV

for intermediate m_0:
sensitivity comparable with LEP
$\Rightarrow$ discovery potential $\sqrt{s}\uparrow$

Thrilling Stop Production ?

$\Rightarrow$ search for $\tilde{t}$ in different decay modes

- so far only $\tilde{t} \rightarrow$ fermions considered
  BUT: bosonic $\tilde{t}$ decays can contribute



$\Rightarrow l$ + jet + p_T^{miss}

(tomorrow: *W production...*, C. Vallee)

$\Rightarrow$ dedicated stop analysis under way !

3. Summary and Future Prospects

- HERA 1: e^+p: $\sim$ 110 pb^{-1}, e^-p: $\sim$ 15 pb^{-1}

  $\Rightarrow$ no evidence for new physics

  $\Rightarrow$ new contstraints on:

  - squarks in $\not{R}_p$-SUSY
  - excited electrons, neutrinos, quarks

- limits are comparable/complementary to LEP and TeVatron searches

- shutdown since fall 2000:
  luminosity and detector upgrade

- first lumi runs: November 2001:
  "HERA 2" will give 1 fb^{-1} in $\sim$ 5 years

- polarized $e^\pm$ beams
  $\Rightarrow$ increased squark production cross section and sensitivity

$\Rightarrow$ we can look forward to new exciting results

for next "post-LEP", "pre-LHC" era !