A Review of Searches for R_P-violating SUSY

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Outline

- Introduction: $\not\!\!R_p$ SUSY
- Pair production of sparticles + $\not\!\!R_p$ decay (LEP, TeVatron)
- $\not\!\!R_p$ single production of sparticles + $\not\!\!R_p$ decay (HERA)
- Summary

$\Rightarrow$ selected topics: analyses where something is new with respect to summer conferences of 2002

R-Parity

discrete multiplicative symmetry in SUSY models:

$$\boxed{R_P = (-1)^{3B+L+2S}}$$

B: baryon number

L: lepton number

B: spin

$R_P = 1$ for SM particles

$R_P = -1$ for SUSY particles

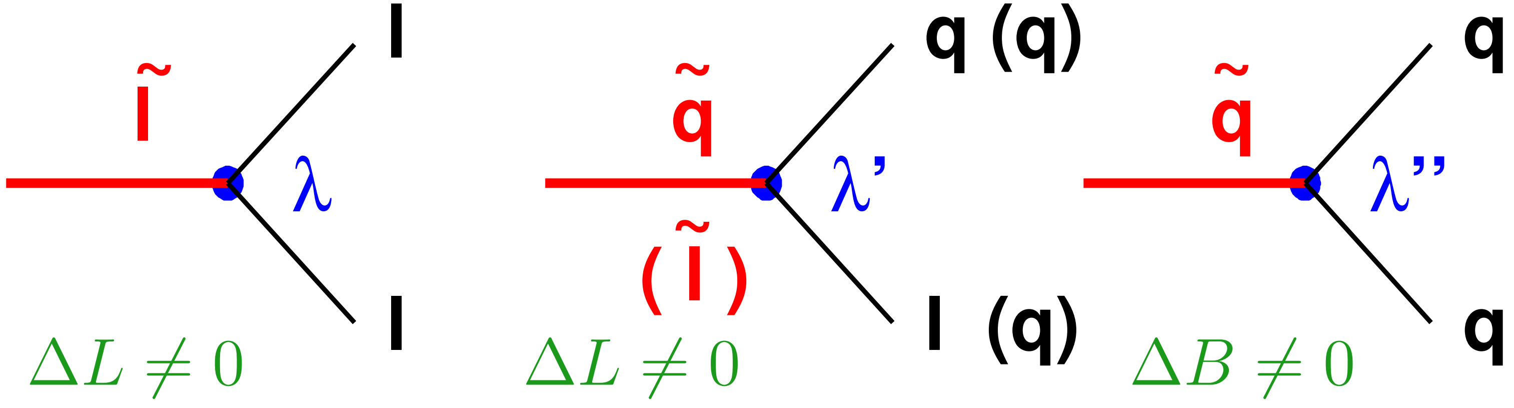
R-Parity conservation:

- SUSY particles produced in pairs
- LSP is stable
- experimental signature of SUSY: E_T^{miss}

R-Parity Violation

- R_P can explicitly be broken by trilinear couplings in superpotential

$$W_{\not R_p} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

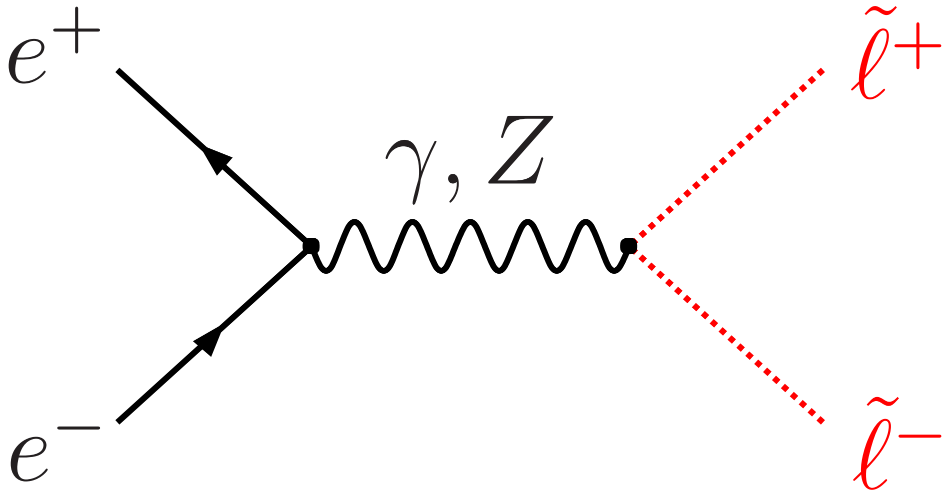


- single sparticle production
- unstable LSP
- final states with large multiplicity

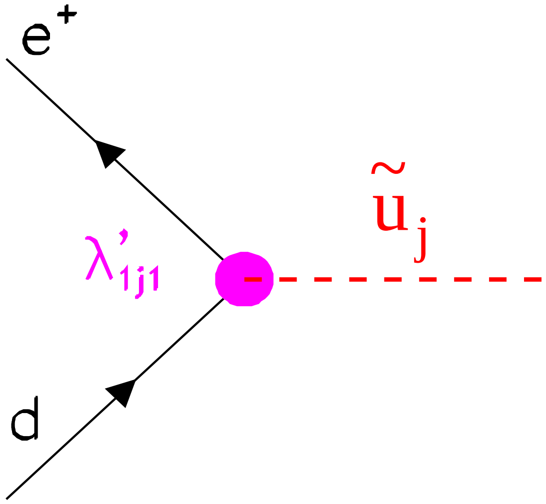
$\Rightarrow$ assume that one $\not R_p$ coupling dominates

Production of SUSY Particles

pair production: R_P-conserving



single production: R_P-violating



$\Rightarrow$ $\not{R}_p$ only in decay

$\Rightarrow$ $\not{R}_p$ coupling may be small

$\Rightarrow$ limits independent of $\not{R}_p$ coupling

$\Rightarrow$ complementary to R_P conservation

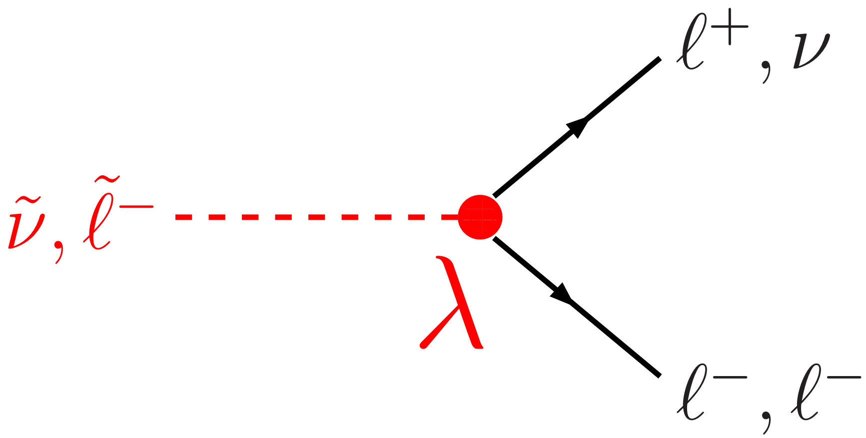
$\Rightarrow$ $\not{R}_p$ both in production and decay

$\Rightarrow$ $\not{R}_p$ coupling not too small

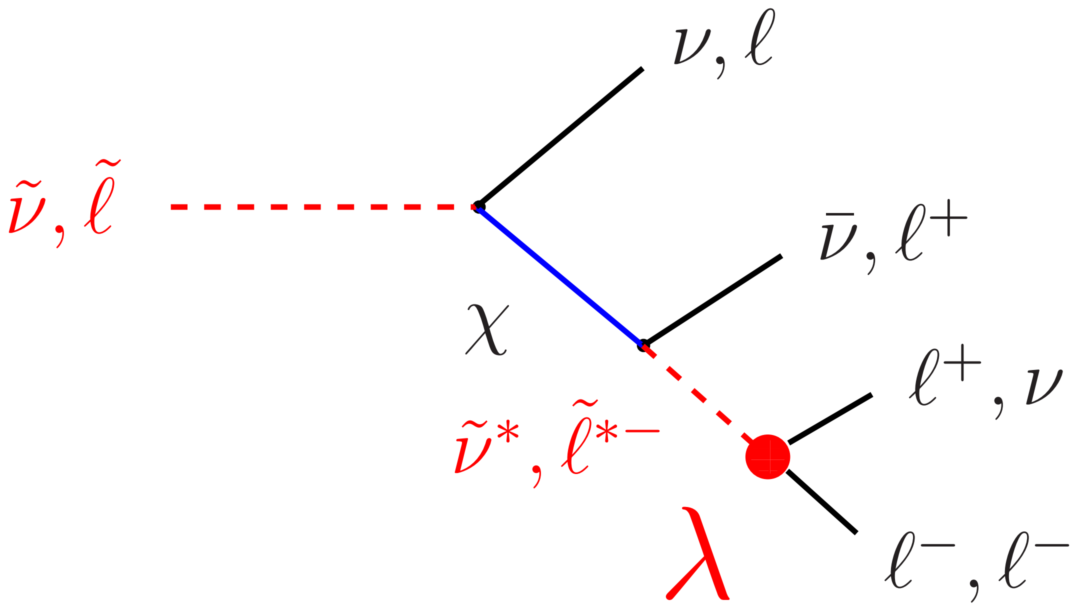
$\Rightarrow$ limits dependent on $\not{R}_p$ coupling

Decay of SUSY Particles

direct



indirect

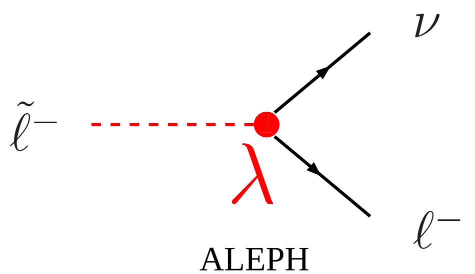


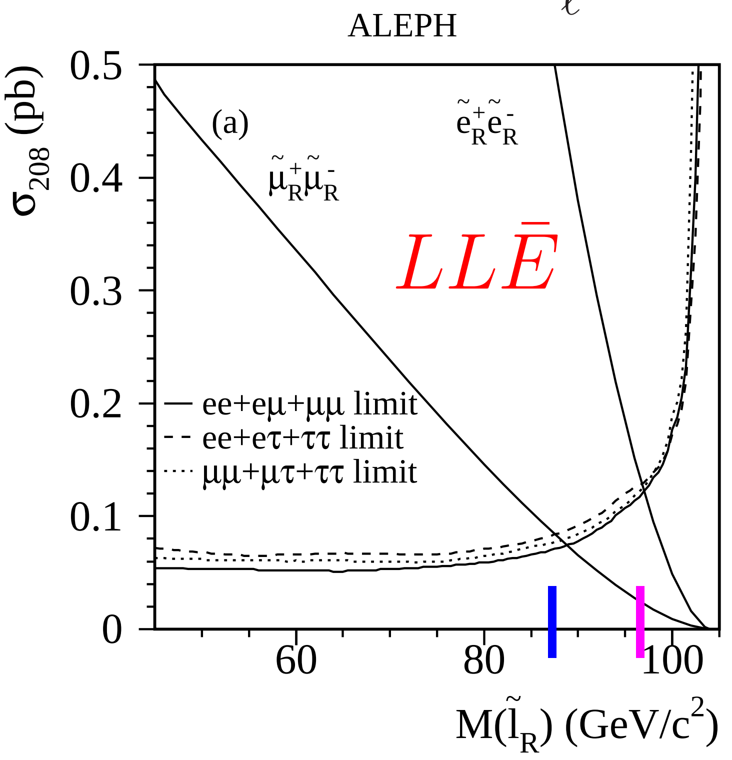
$\Rightarrow$ dominant for larger $R\!\!\!/_p$ couplings

$\Rightarrow$ dominant for smaller $R\!\!\!/_p$ couplings if enough phase space between "mother" and "daughter"

Slepton Pair Production (MSSM)

$e^+e^- \rightarrow \tilde{l}^+\tilde{l}^- \rightarrow 2\ell + \not{E}$

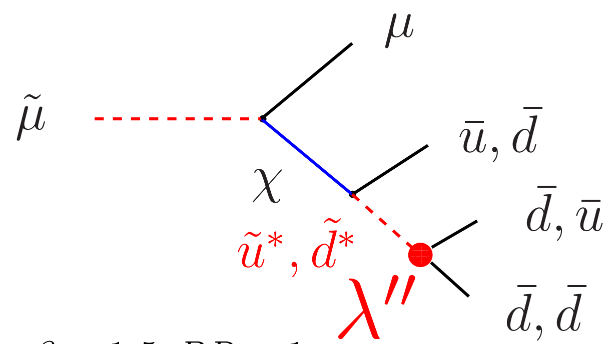




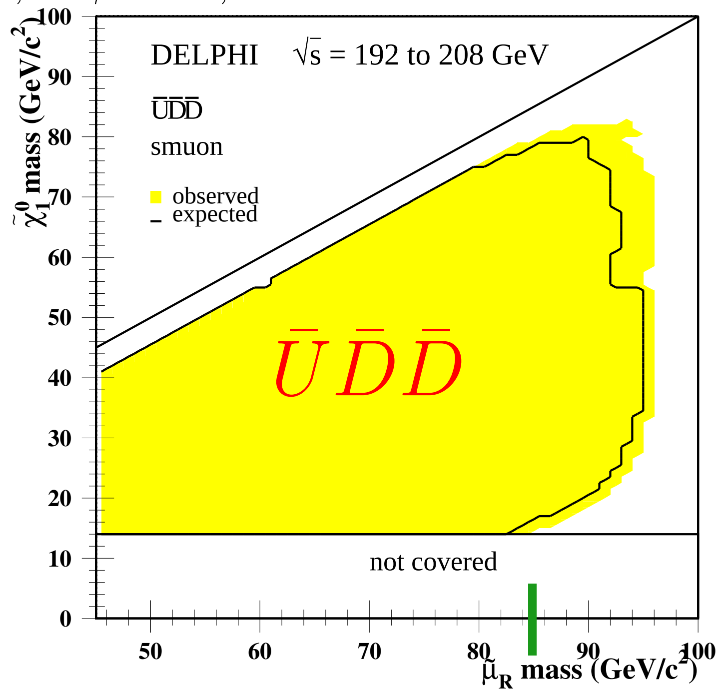
$\Rightarrow m_{\tilde{\mu}_R,\tilde{\tau}_R} > 87$ GeV, $m_{\tilde{e}_R} > 96$ GeV

$\Rightarrow$ similar bounds as for R_P-conserving SUSY

$e^+e^- \rightarrow \mu^+\mu^-\chi^0_1\chi^0_1 \rightarrow 6\mathrm{j}\mu^+\mu^-$



$\mu = 200\,\mathrm{GeV}, \tan\beta = 1.5, BR = 1$

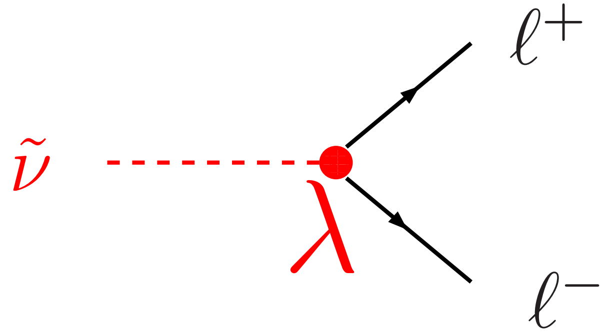


$\Rightarrow m_{\tilde{\mu}_R} > 85$ GeV

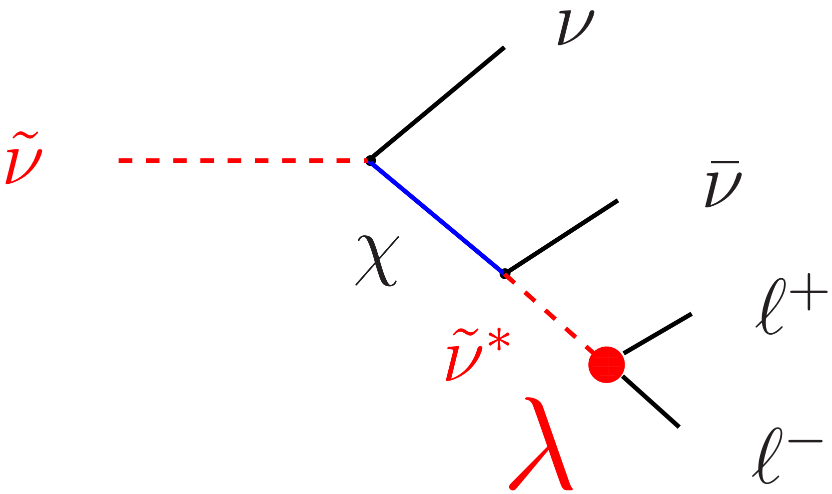
Sneutrino Pair Production in a Constrained MSSM

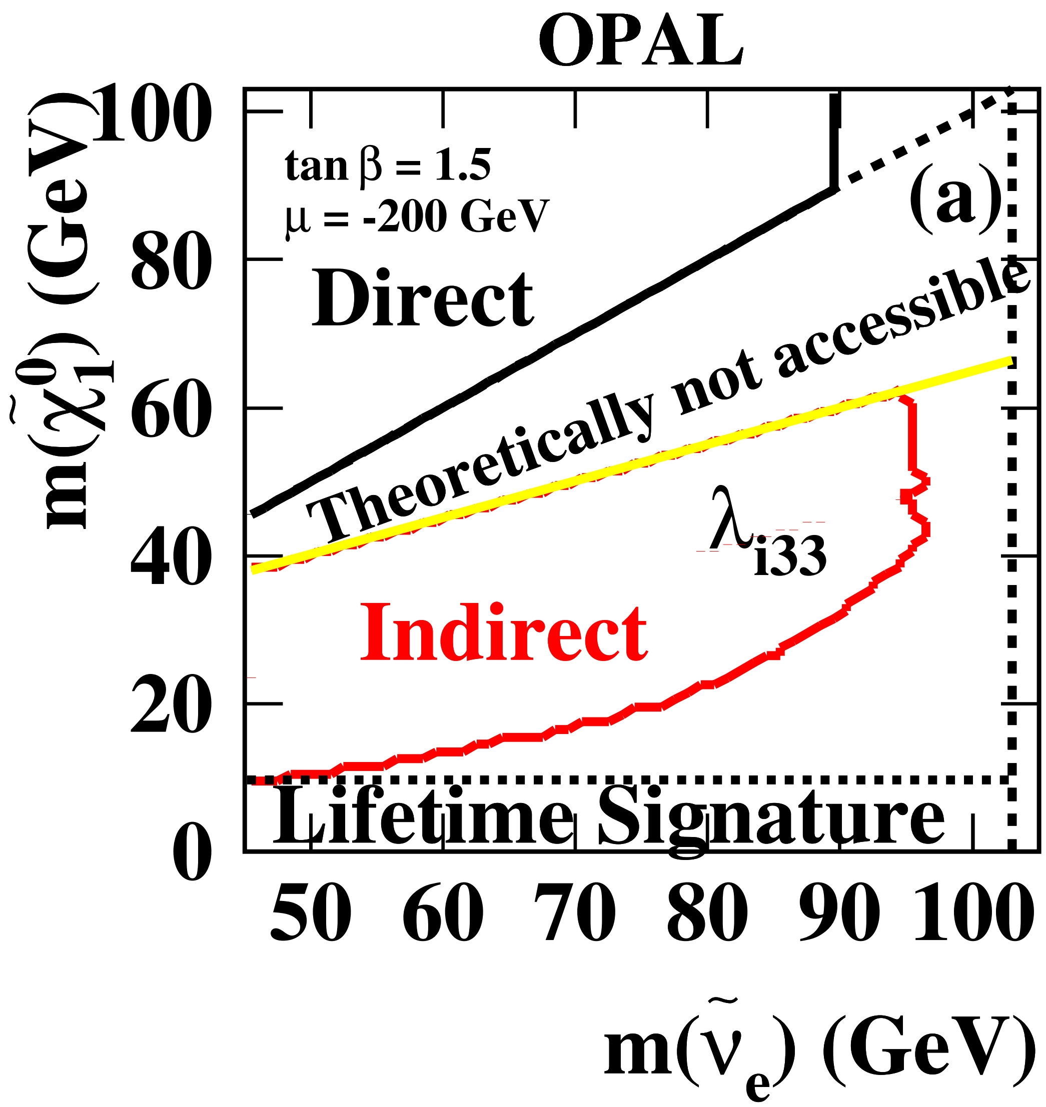
sfermion and gaugino sectors related by RGE

$e^+e^- \to \tilde{\nu}\bar{\tilde{\nu}} \to 4\ell$

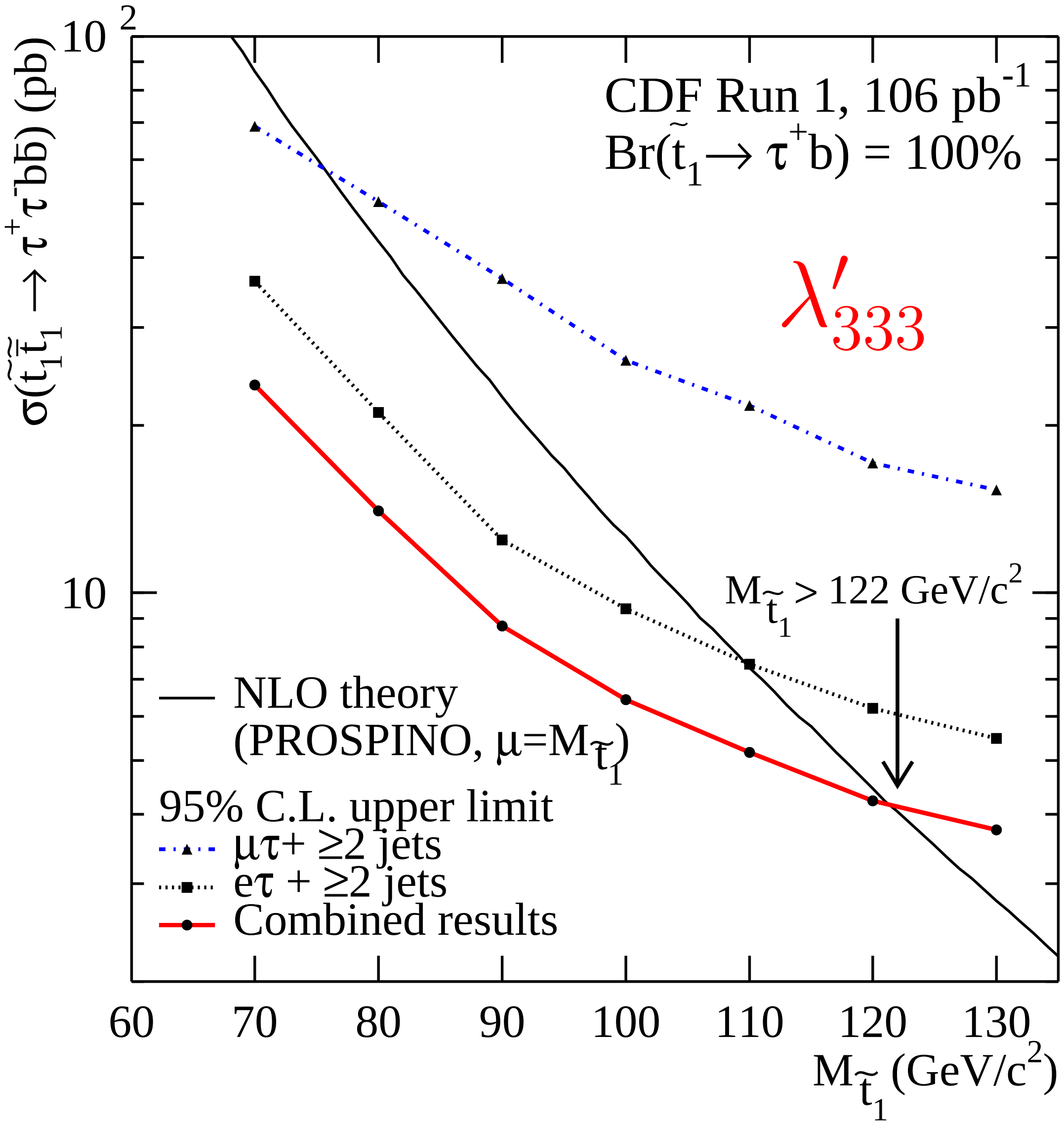


$e^+e^- \to \tilde{\nu}\bar{\tilde{\nu}}\chi_1^0\chi_1^0 \to 4\ell + \not{E}$





Pair Production of Stop Quarks at CDF



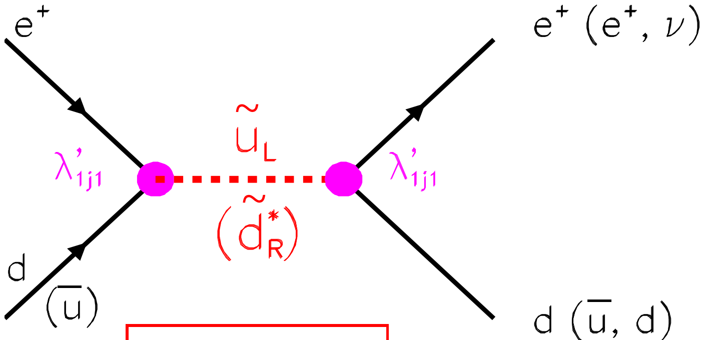
$$p\bar{p} \longrightarrow \tilde{t}_1\bar{\tilde{t}}_1 \longrightarrow \tau^+ b \;\; \tau^- \bar{b}$$

$$\tau^+ \longrightarrow \ell^+\nu_\ell\bar{\nu}_\tau \qquad \tau^- \longrightarrow \text{hadronic}$$

$\Rightarrow$ $m_{\tilde{t}_1} > 122$ GeV for Br =1

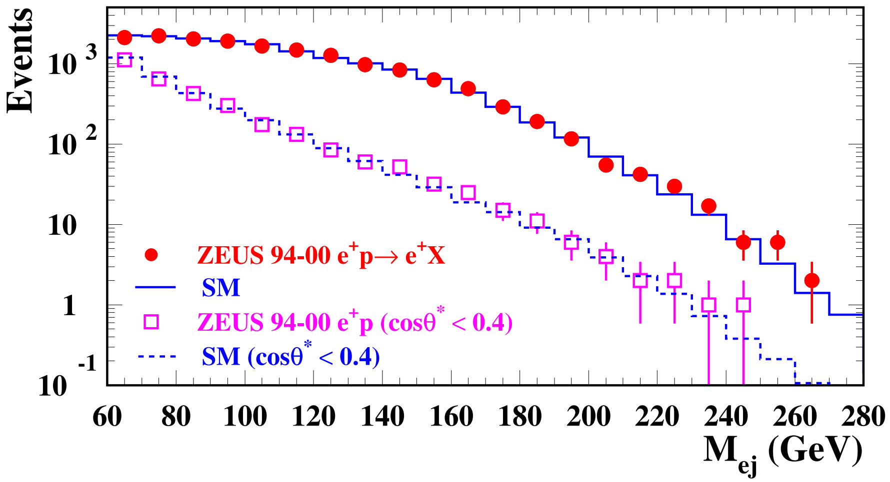
$\Rightarrow$ compare with ALEPH limit of $m_{\tilde{t}_1} > 93$ GeV from $e^+e^- \to \tilde{t}_1\bar{\tilde{t}}_1 \to \tau^+\tau^- jj$

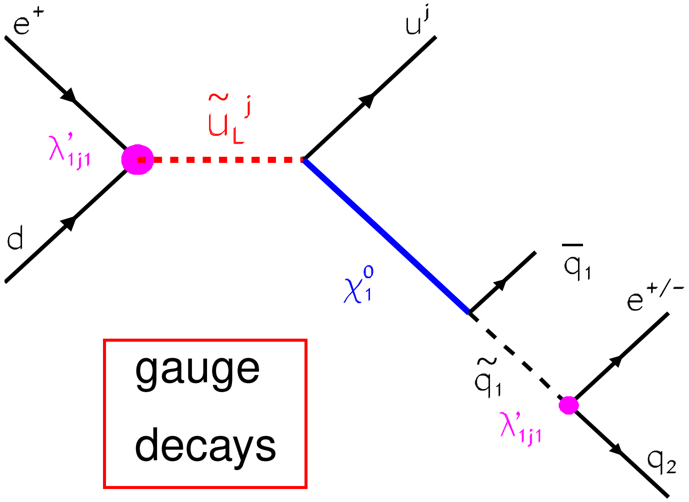
$R\!\!\!/_p$ Squark Production at HERA: e^+p & e^-p



$R\!\!\!/_p$ decays

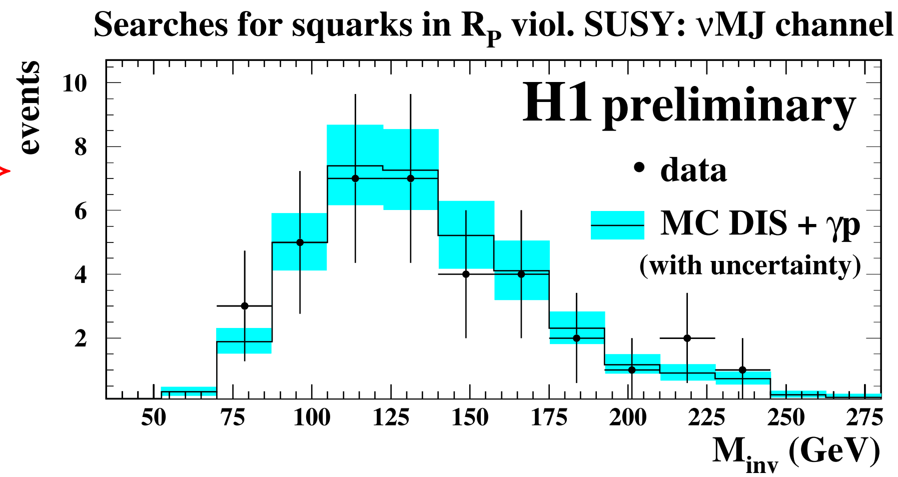
- e^+ + jet $\Rightarrow$
- ν + jet





gauge decays

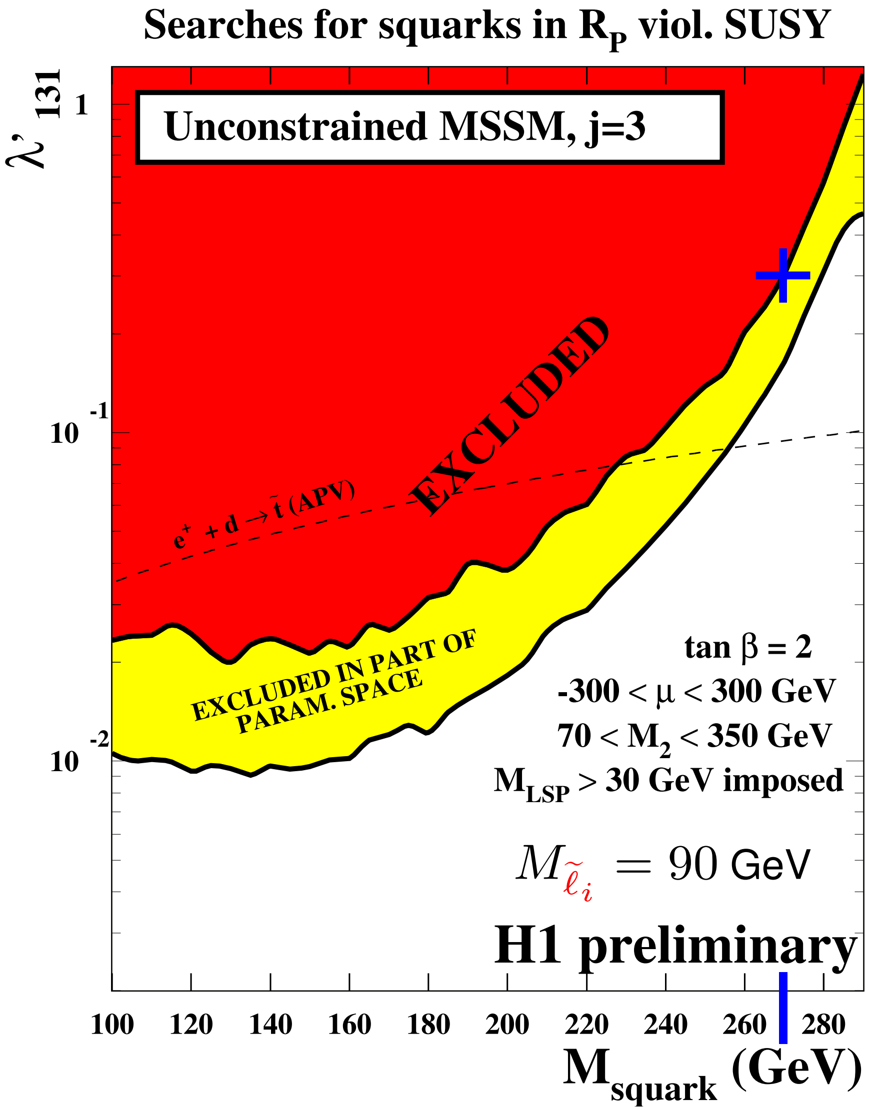
- e^+ + multi-jets
- e^- + multi-jets
- ν + multi-jets $\Rightarrow$
- $e + l$ + multi-jets
- $\nu + l$ + multi-jets



$\approx 100\%$ of squark decays covered: similar sensitivity in all channels

$\Rightarrow$ no evidence for squark production

$\tilde{t}$ production at HERA: Unconstrained MSSM



- sfermion masses are free

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

M_2: soft SUSY breaking mass term
μ: mixing mass term for 2 Higgs doublets
$\tan\beta$: ratio of the vev's of the 2 neutral scalar Higgs fields

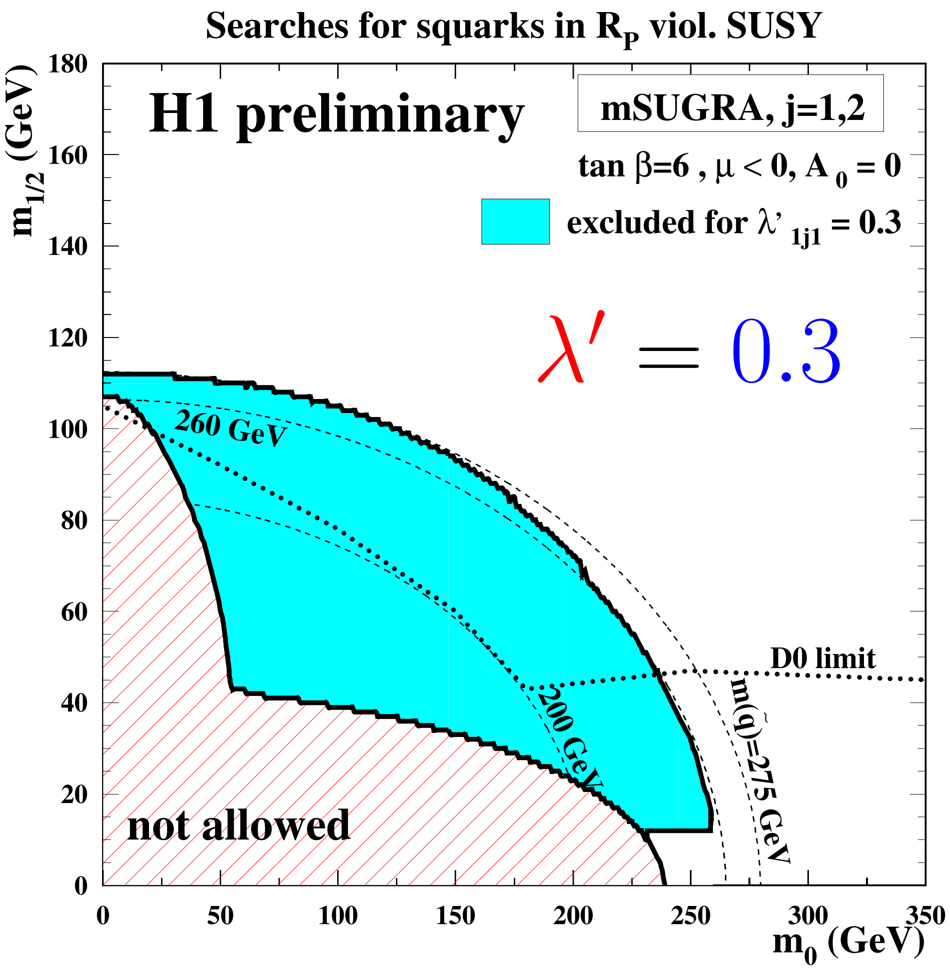
$\Rightarrow$ limits widely parameter independent

$\Rightarrow$ masses up to 270 GeV ruled out for $\lambda' = 0.3$

$\Rightarrow$ LEP rules out up to ≈ 100 GeV

$\tilde{u}$, $\tilde{c}$ production at HERA: Minimal SUperGRAvity

electroweak symmetry breaking driven by radiative corrections



⇒ only 5 parameters:

$\tan\beta$, sign of μ

m_0: common scalar mass

$m_{1/2}$: common gaugino mass

A_0: common trilinear coupling

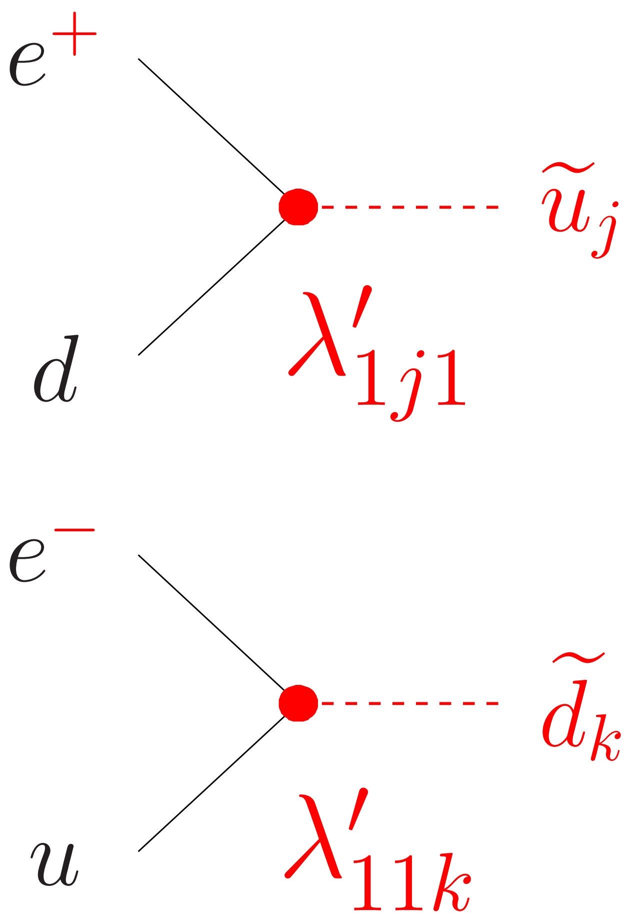
at GUT scale

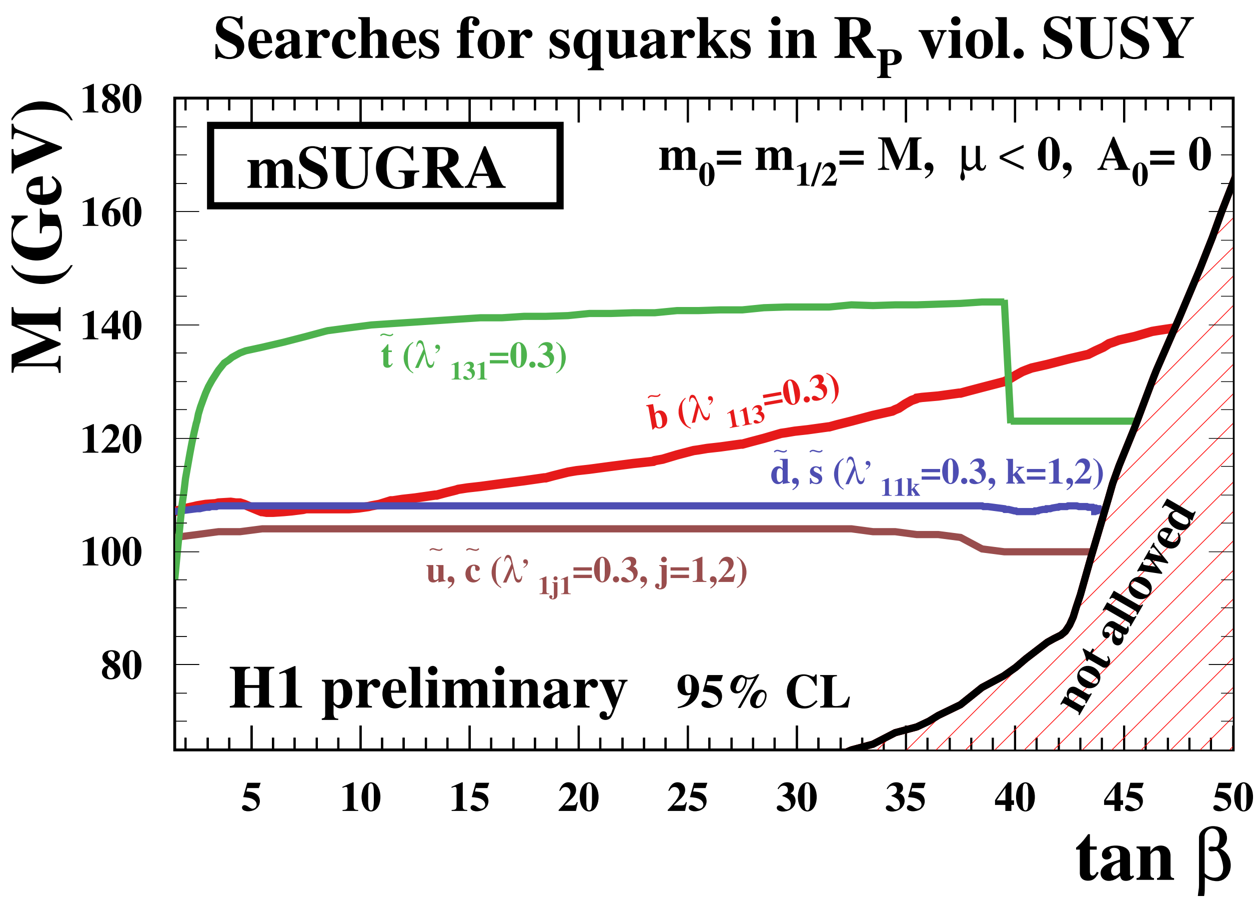
⇒ HERA sensitivity follows squark mass isocurve

⇒ masses up to 275 GeV ruled out for $\lambda' = 0.3$

⇒ LEP very sensitive (indirect via χ and $\tilde{\ell}$ searches): HERA competitive for intermediate values of m_0

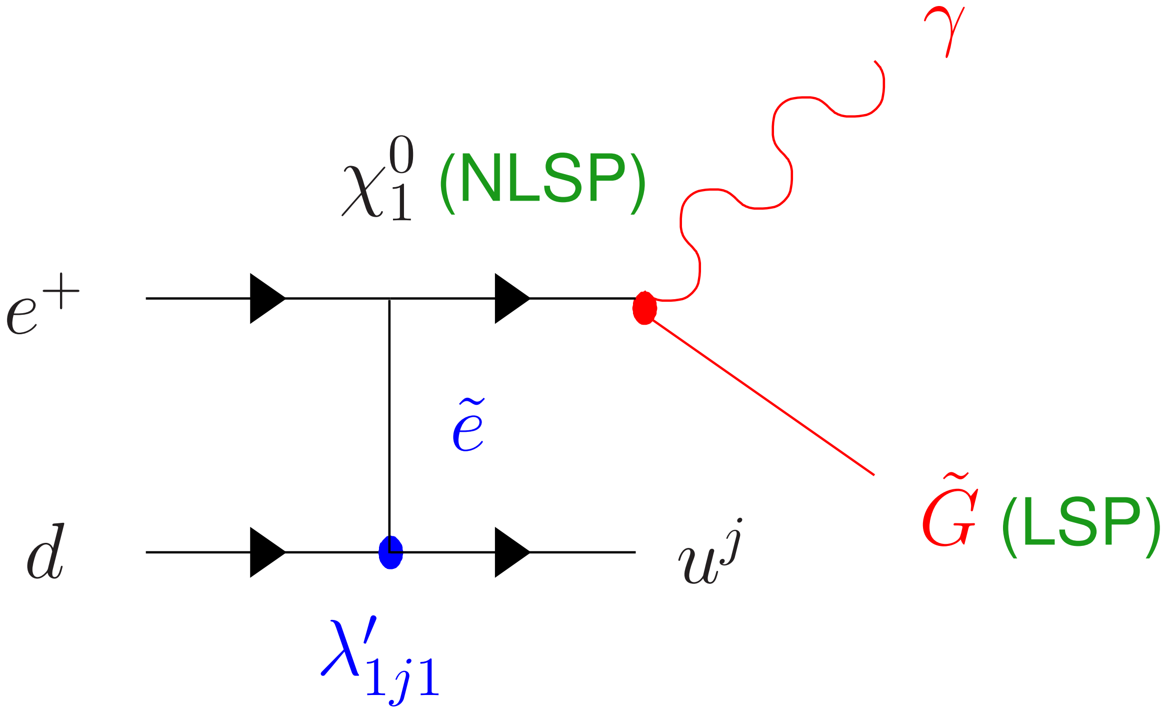
$R\!\!\!/_p$ Minimal SUperGRAvity





$\Rightarrow$ all 6 squark flavors analyzed in e^+p & e^-p scattering

Neutralino Production via t Channel Selectron Exchange at HERA

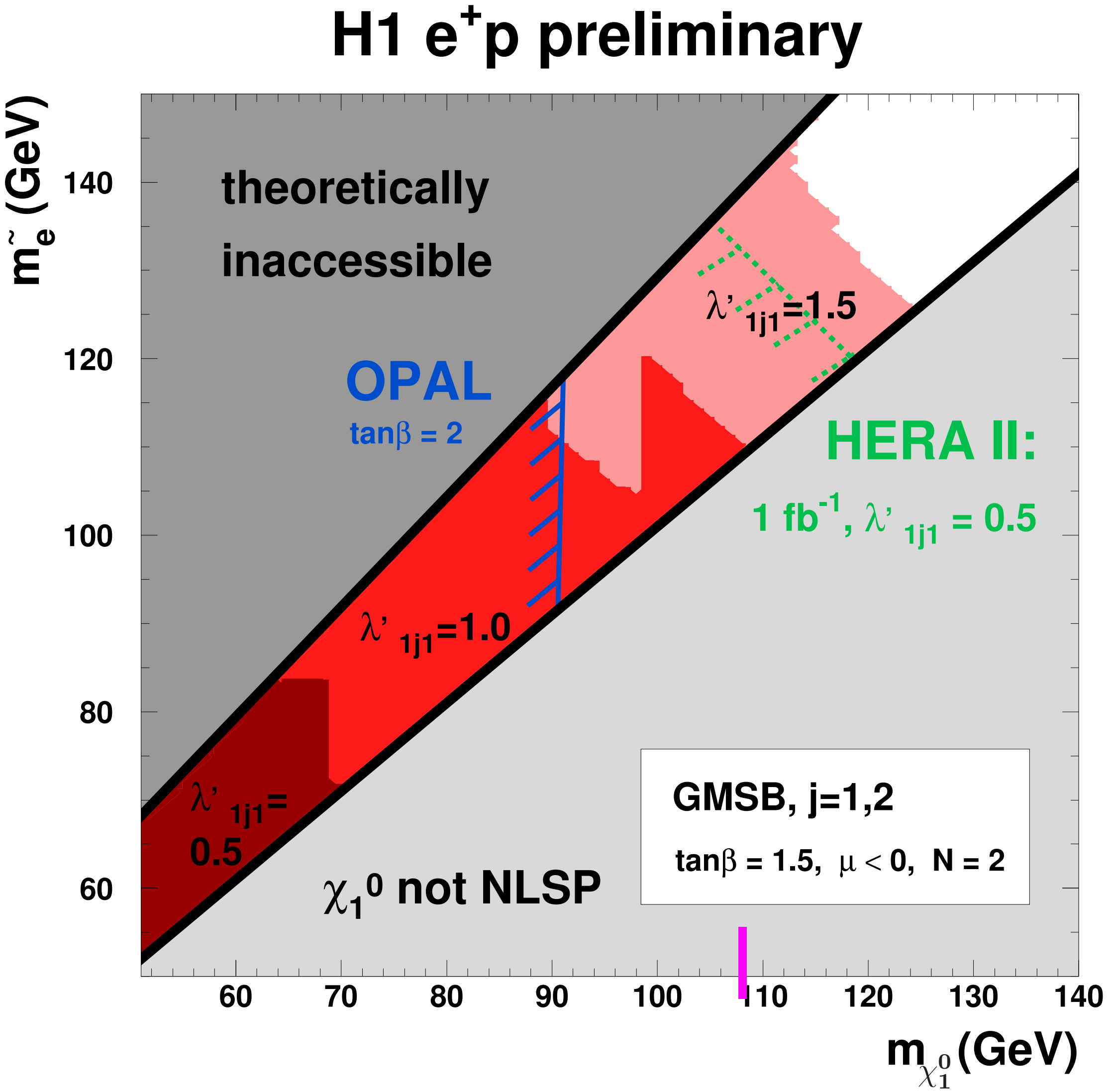


$\Rightarrow$ study of $\not{R}_p$ SUSY independent of squark mass, dependent on $m_{\tilde{e}}$, m_{χ_0}

$\Rightarrow$ Gauge Mediated SUSY Breaking: slepton masses lower than squark masses

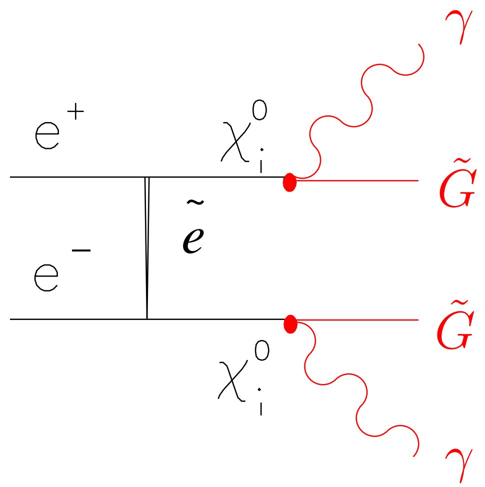
$\Rightarrow$ analyse gravitino ($= p_t^{\mathrm{miss}}$) + photon decay of neutralino

Limits in $\not{R}_p$ GMSB



$\Rightarrow m_{\chi_1^0} < 108$ GeV for $\lambda'_{1j1} \approx 1$

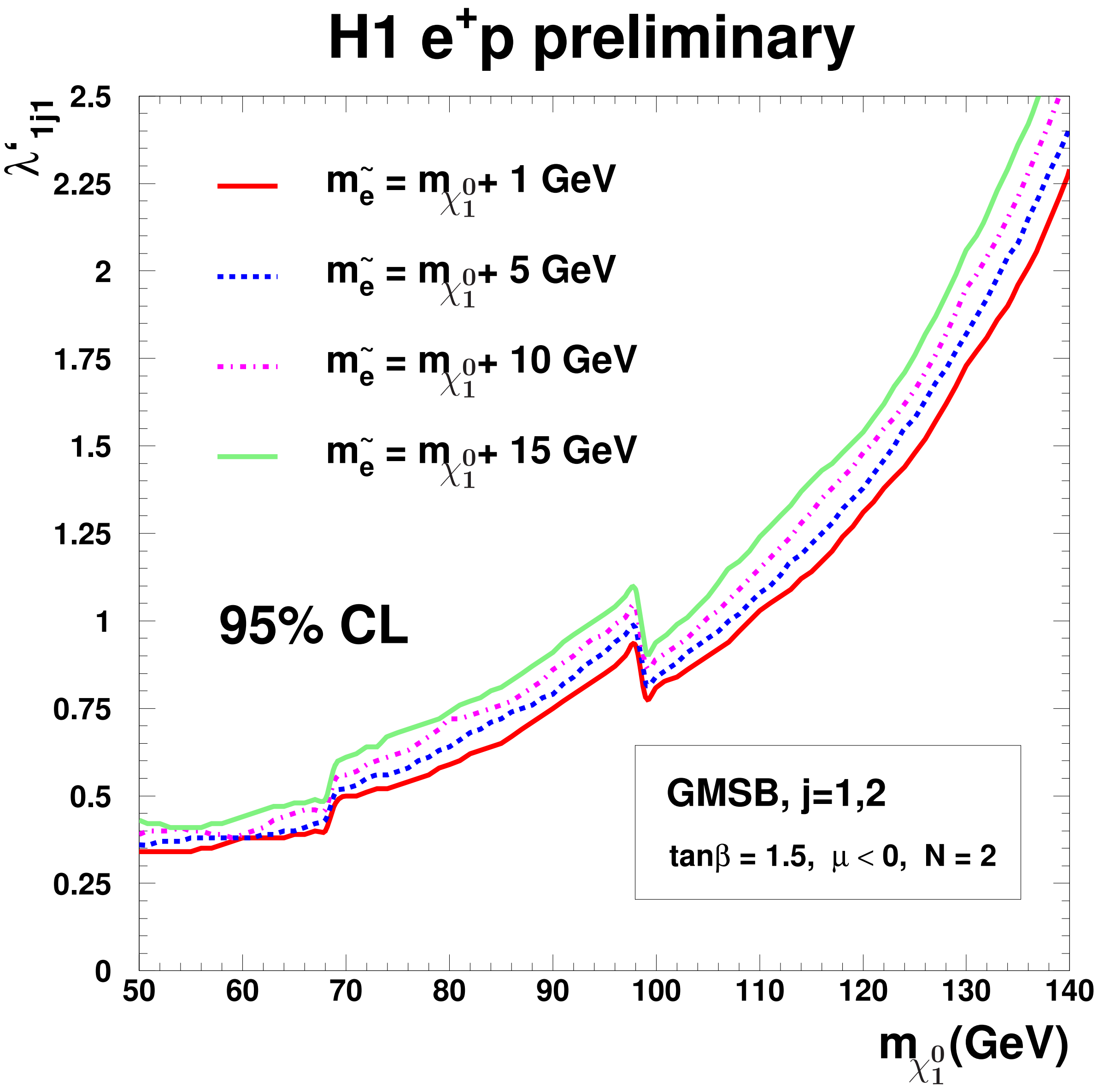
LEP: R_P conserving SUSY



$\Rightarrow$ HERA is competitive with LEP for $\lambda'_{1j1} \approx 1$

$\Rightarrow$ for HERA II large improvement in sensitivity expected

Limits on $\not{R}_p$ Couplings



$\Rightarrow$ first limits on λ'_{121} independent of squark masses

Conclusions

- many different channels for single or pair production of SUSY particles in an $\not{R}_p$ scenario have been investigated:
  LEP $\&$ HERA: all channels; TeVatron: some channels more difficult
- $\not{R}_p$ has inspired new interesting scenarios for SUSY searches and is complementary to R_P conserving searches
- no deviation from SM has been observed at LEP, TeVatron and HERA
- limits from $\not{R}_p$ searches are comparable with the R_P conserving limits
- $\not{R}_p$ searches deliver important contributions to constraints on SUSY models

$\Rightarrow$ interesting results at TeVatron II, HERA II and future colliders

$\Rightarrow$ e.g. light $\widetilde{t}$: HERA II sensitive up to ≈ 300 GeV, TeVatron II up to $\approx 200 - 250$ GeV