Search for R–Parity Violating Decays of SUSY Particles in the L3 Experiment.

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- Some words about Supersymmetry and R–Parity.
- Searches performed in L3
  - ☞ λ coupling analyses $\longrightarrow$ $\sqrt{s}$ = 189 GeV
  - ☞ λ' coupling analyses $\longrightarrow$ $\sqrt{s}$ = 189 GeV
  - ☞ λ'' coupling analyses $\longrightarrow$ $\sqrt{s}$ = 202 GeV
- Results and Conclusions

Supersymmetry and R–Parity

Supersymmetry: Symmetry between bosons and fermions.

$$|B> \stackrel{Q}{\rightarrow} |F>$$
$$|F> \rightarrow |B>$$

SUSY particles differ from their SM counterpart by one half–unit of Spin only.

R–Parity:

$$R_p = -1^{3\mathcal{B}+\mathcal{L}+2\mathcal{S}}$$

$\mathcal{B}$**: Baryon number,** $\mathcal{L}$**: Lepton Number,** $\mathcal{S}$**: Spin.**

$$\hookrightarrow R_p = \begin{cases} -1: & \textbf{SUSY particles} \\ +1: & \textbf{S.M particles} \end{cases}$$

SUSY with R–Parity violation

- The LSP ($\tilde{\chi}_1^0$) is no longer stable and can decay in the detector into SM particles.
- New SUSY decay modes, alternative to the canonical $\not{E} + X$ SUSY signatures.

$$\mathcal{W}_{\not{R}} = \underbrace{\lambda_{ijk} L_i L_j \bar{E}_k}_{\not{L}} + \underbrace{\lambda'_{ijk} L_i Q_j \bar{D}_k}_{\not{L}} + \underbrace{\lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k}_{\not{B}}$$

Analysis assumptions:

☞ SUSY particles are pair–produced in $e^+ e^-$ collisions.
($e^+ e^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0,\ \tilde{\chi}_i^0 \tilde{\chi}_j^0,\ \tilde{\chi}_1^+ \tilde{\chi}_1^-,\ \tilde{\ell}_R \tilde{\ell}_R$, $\sigma \sim$ 0.1–1 pb)

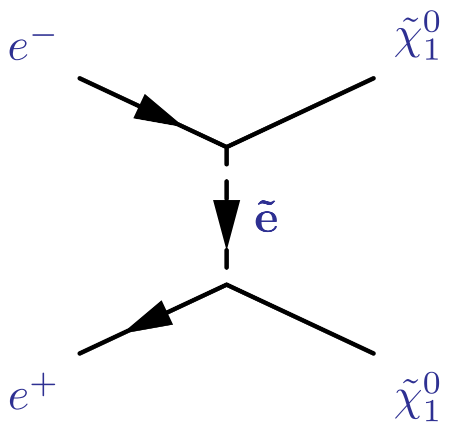
☞ They decay at IP: $\delta < 1$ cm $\Longrightarrow \lambda, \lambda', \lambda'' \sim 0.1$.

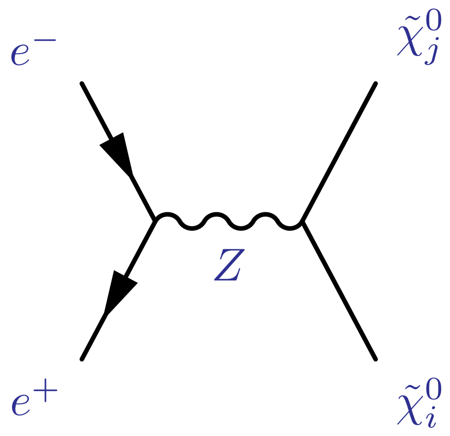
☞ Only one non–zero coupling at a time.

☞ λ', λ'': no quark flavour identification.

SUSY particle pair–production

- $e^+ \, e^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0$, $e^+ \, e^- \to \tilde{\chi}_i^0 \tilde{\chi}_j^0, i \neq j \neq 1$





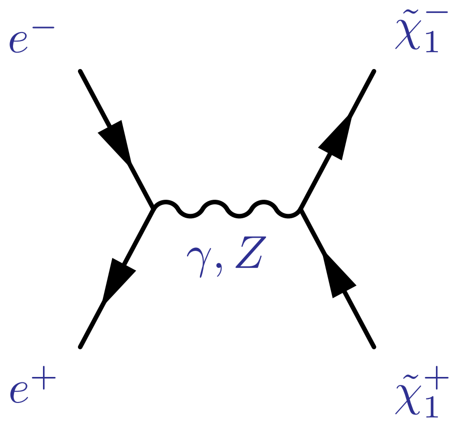
1) $N_{exp.} \sim 78$ **for** $\sqrt{s}$ **= 189 GeV,** $\mathcal{L} = 180$ **pb**$^{-1}$**,** ϵ **= 30 %,**

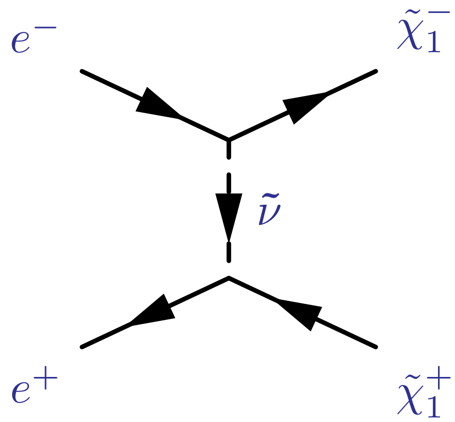
$M_{\tilde{\chi}_1^0}$ **= 40 GeV and** $M_{\tilde{e}}$ **= 70 GeV.**

2)$N_{exp.} \sim 27$ **for** $\sqrt{s}$ **= 189 GeV,** $\mathcal{L} = 180$ **pb**$^{-1}$, ϵ **= 30 %,**

$M_{\tilde{\chi}_i^0} + M_{\tilde{\chi}_j^0} = \sqrt{s}$ **-10 GeV**

- $e^+ \, e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$





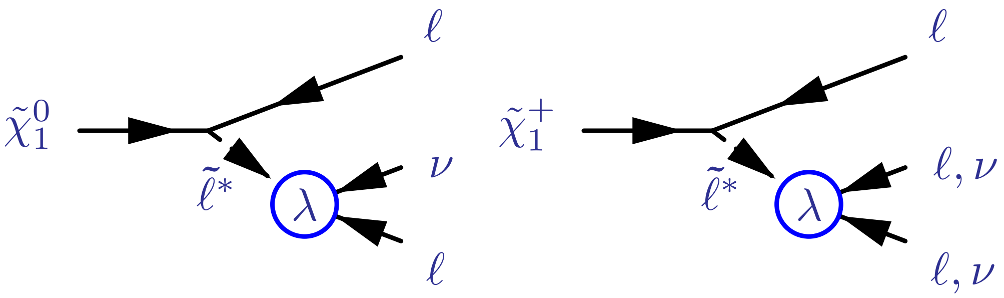
$N_{exp.} \sim 63$ **for** $\sqrt{s}$ **= 189 GeV,** $\mathcal{L} = 180$ **pb**$^{-1}$**,** ϵ **= 50 %,**

$M_{\tilde{\chi}_1^+} =$ **93.5 GeV and** $M_{\tilde{\nu}}$ **= 500 GeV.**

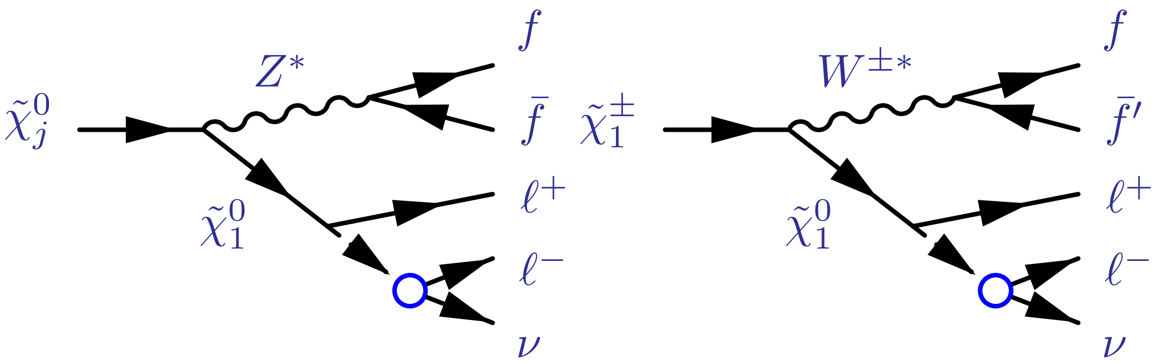
λ couplings

Neutralino and chargino decays studied:

- **Direct decays:**

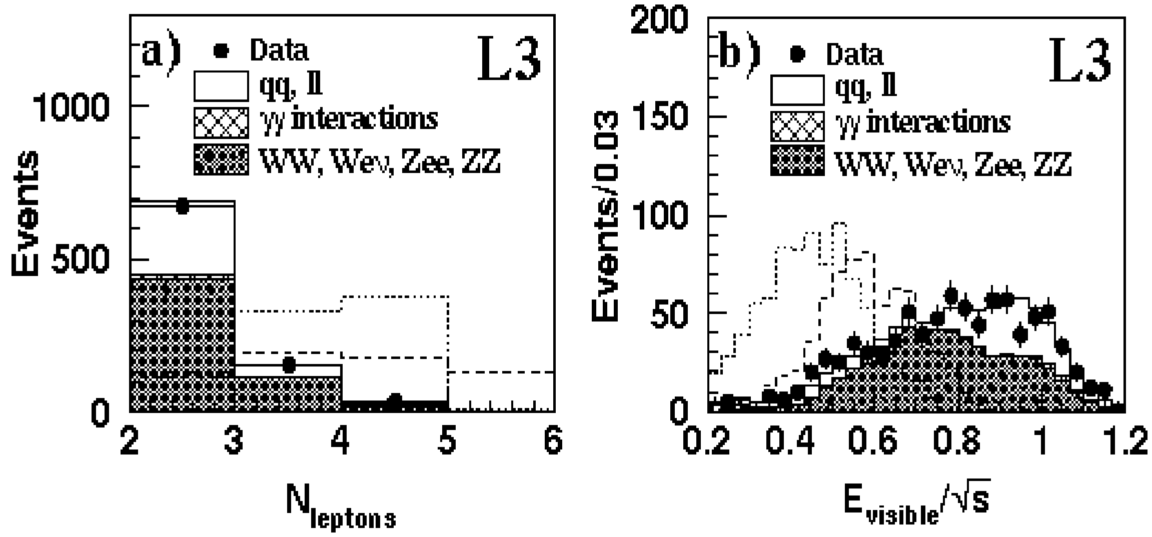


- **Indirect decays:**



$\Longrightarrow$ **Many leptons (+ eventually some jets) in final states.**

λ couplings Analyses



Results ($\sqrt{s}$ = 189 GeV, $\mathcal{L} = 176.8$ pb^{-1})

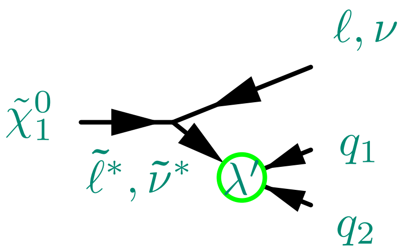
Signal	DATA	S.M. Exp.	Eff. range(%)	Excluded σ (pb)
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ Direct	3	2.0 ± 0.2	4–51	0.85–0.07
$\tilde{\chi}_1^+\tilde{\chi}_1^-$ Direct	21	20 ± 1	9–46	0.80–0.15
$\tilde{\chi}_1^0\,\tilde{\chi}_j^0$ Indirect	5	5.8 ± 0.4	47–60	0.07–0.06
$\tilde{\chi}_1^+\tilde{\chi}_1^-$ Indirect	2	3.8 ± 0.3	14–59	0.17–0.04

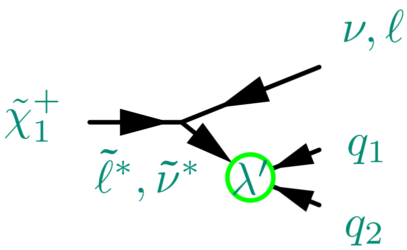
λ' couplings

- 27 couplings covering all leptons and quark flavours accessible at LEP.

Neutralinos and charginos decays studied:

- Direct decays:





- Indirect decays:
  - $\tilde{\chi}_1^+ \rightarrow W^* \tilde{\chi}_1^0$

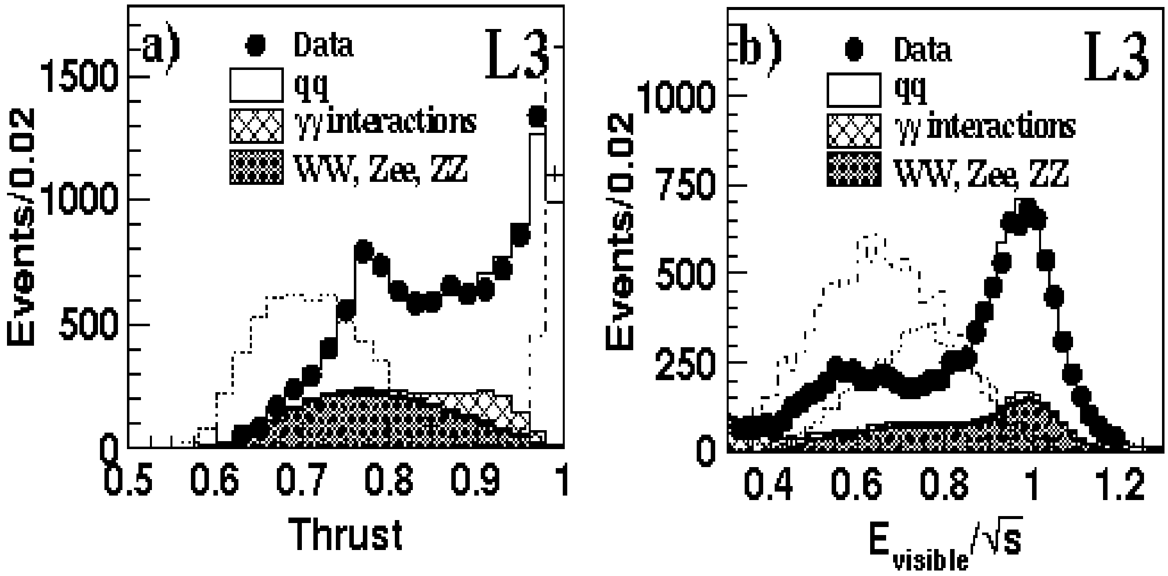
$$\Longrightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow W^* W^* \tilde{\chi}_1^0 \tilde{\chi}_1^0$$

$$\hookrightarrow \begin{cases} qqqq \\ qq\ell\nu \\ \ell\nu\ell\nu \end{cases} \quad 4\,jets\; + \begin{cases} 2\ell \\ 1\ell + \not{E} \\ \not{E} \end{cases}$$

$\Longrightarrow$ **Mixed states of leptons and jets.**

λ' couplings Analyses

Many couplings, many channels:



Results: ($\sqrt{s}$ = 189 GeV, $\mathcal{L} = 176.8$ pb^{-1})

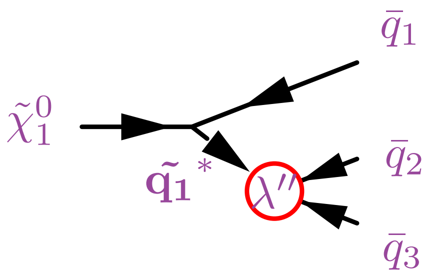
Signal	DATA	S.M.Exp.	Eff.(%)	Excl. σ (pb)
$\tilde{\chi}_1^0\tilde{\chi}_1^0$	41	44 ± 1	11–23	0.65–0.31
$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_i^0\tilde{\chi}_j^0$	257	262 ± 12	31–70	0.55–0.24

($\tilde{\chi}_i^0\tilde{\chi}_j^0$: i,j$\neq$1.)

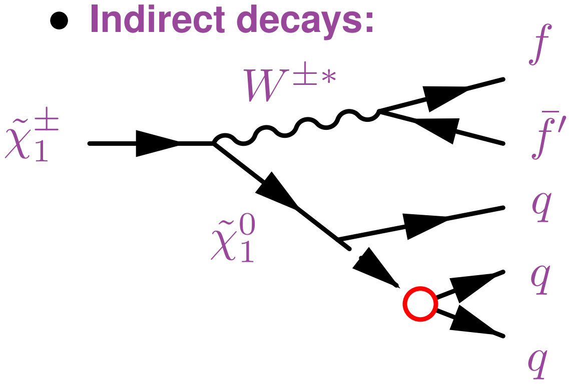
λ'' couplings

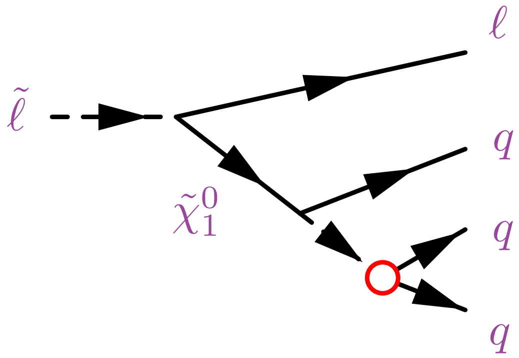
Neutralinos, Charginos and Sleptons searched for:

- **Direct Decays:**



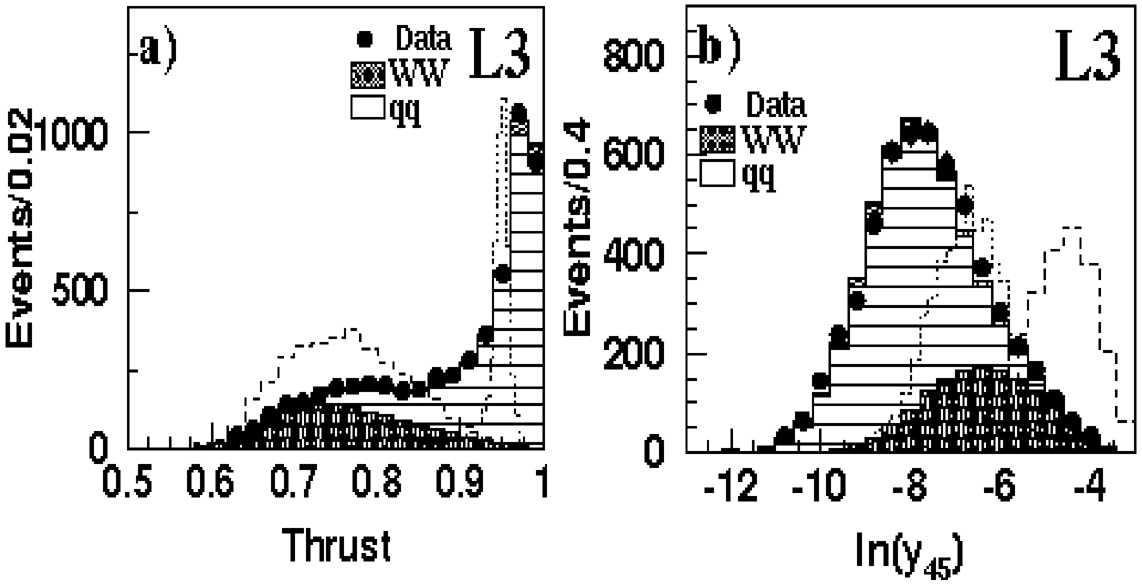
- **Indirect decays:**





$\Longrightarrow$ **Multijet final states (up to 10)**

λ'' couplings Analyses



Results: ($\sqrt{s}$ = 202 GeV, $\mathcal{L} = 37.0$ pb^{-1})

Neutralinos,Charginos:

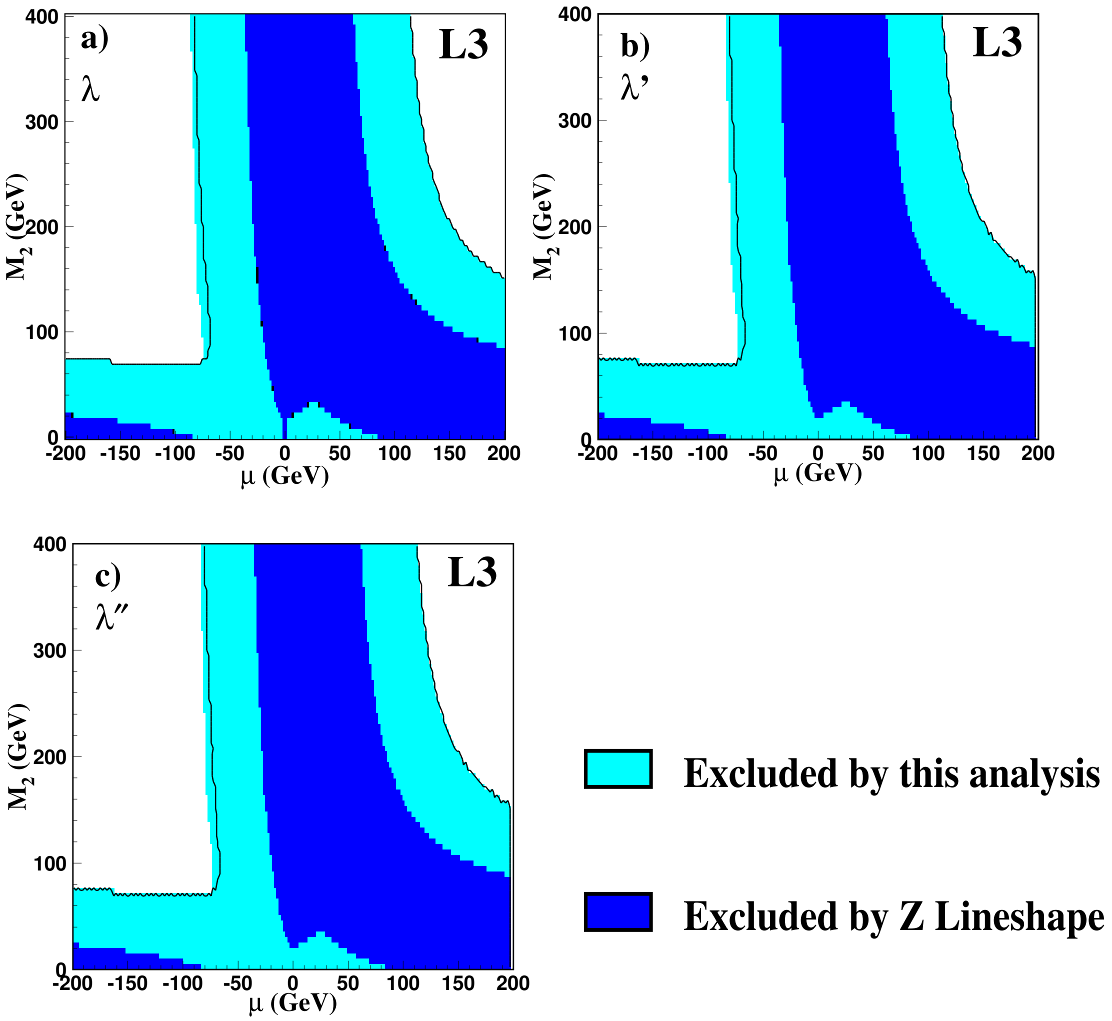
Signal	DATA	S.M. Exp.	Eff. (%)	Excl. σ (pb)
$\tilde{\chi}^0_1\tilde{\chi}^0_1$	50	56 ± 1	29–54	1.17–0.63
$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^0_i\tilde{\chi}^0_j$	23	25.4 ± 0.8	38–72	0.71–0.37

- **Slepton searches: $\tilde{\chi}^0_1\tilde{\chi}^0_1$ selections + lepton identification (e, μ).**

$\tilde{e}^+_R\tilde{e}^-_R, \tilde{\mu}^+_R\tilde{\mu}^-_R$	3	2.6 ± 0.9	29–69	0.52–0.22
$\tilde{\tau}^+_R\tilde{\tau}^-_R$	30	34.0 ± 0.8	39–66	0.70–0.41

Interpretation and limits

Neutralinos,charginos: (m_0 = 500 GeV, $\tan\beta$ =1.41)



Complete scan over M_2 , μ, $\tan\beta$, m_0 $\rightarrow$ limits on masses:

SUSY particle	λ	λ'	λ''
$\tilde{\chi}^0_1$	M$>$30.5 GeV	M$>$32.4 GeV	M$>$37.5 GeV
$\tilde{\chi}^0_2$	M$>$ 50.5 GeV	M$>$67.6 GeV	M$>$73.0 GeV
$\tilde{\chi}^+_1$	M$>$94.3 GeV	M$>$94.0 GeV	M$>$99.8 GeV

Summary and conclusions

- ☞ We have searched for $\tilde{\chi}^0_1$, $\tilde{\chi}^0_2$, $\tilde{\chi}^+_1$ $\not{R}_p$ decays for each of the 3 trilinear couplings, with an extension to $\tilde{\ell}$ decays in the λ'' case.

- ☞ No evidence for SUSY with R–parity violation at $\sqrt{s}$ = 189 GeV nor at higher energies (up to $\sqrt{s}$ = 202 GeV).

- ☞ Limits on masses obtained in MSSM framework similar to limits from canonical searches (R_p conserved).

- ☞ Similar results are obtained by the 3 others LEP experiments.

$\lambda\, LL\bar{E}$	ALEPH	DELPHI	L3	OPAL
M (GeV), $\tilde{\chi}^0_1$	–	35.5	30	–
$\tilde{\chi}^0_2$	–	50	50	–
$\tilde{\chi}^+_1$	100	99	94	–
$\tilde{e}_R$, **direct**	91	–	–	89
$\tilde{e}_R$, **indirect**	93	87	–	90
$\tilde{\mu}_R$, **direct**	76	–	–	76
$\tilde{\mu}_R$, **indirect**	92	87	–	84
$\tilde{\tau}_R$, **direct**	76	–	–	75
$\tilde{\tau}_R$, **indirect**	91	87	–	85
$\tilde{\nu}_e$, **direct**	–	96	–	89
$\tilde{\nu}_e$, **indirect**	94	83	–	89
$\tilde{\nu}_\mu$, **direct**	86	84	–	74
$\tilde{\nu}_\mu$, **indirect**	82	83	–	70
$\tilde{\nu}_\tau$, **direct**	–	86	–	74
$\tilde{\nu}_\tau$, **indirect**	82	83	–	70
$\tilde{t}$, **indirect**	$\tilde{t}_1,\ (\phi_{mix}=0)$, 89	–	–	–
$\tilde{b}$, **indirect**	$\tilde{b}_1,\ (\phi_{mix}=0)$, 88	–	–	–

$\lambda' \, LQ\bar{D}$	ALEPH	DELPHI	L3	OPAL
M (GeV), $\tilde{\chi}_1^0$	–	30	32	–
$\tilde{\chi}_2^0$	–	–	67	–
$\tilde{\chi}_1^+$	100	89	94	–
$\tilde{e}_R$, indirect	93	–	–	85
$\tilde{\mu}_R$, indirect	86	78	–	72
$\tilde{\tau}_R$, indirect	70	–	–	–
$\tilde{\mu}_L$, direct	77	–	–	–
$\tilde{\mu}_L$, indirect	–	79	–	–
$\tilde{\nu}_\mu$, direct	72	–	–	–
$\tilde{\nu}_\mu$, indirect	63	–	–	–
$\tilde{\nu}_\tau$, indirect	63	–	–	–
$\tilde{t}$, indirect	$\tilde{t}_L$, 83	–	–	–
$\tilde{t}$, direct	89	–	–	84
$\tilde{b}$, indirect	$\tilde{b}_L$, 69	–	–	–

$\lambda'' \bar{U}\bar{D}\bar{D}$	ALEPH	DELPHI	L3	OPAL
M (GeV), $\tilde{\chi}_1^0$	–	36	37.5	29
$\tilde{\chi}_2^0$	–	–	73	–
$\tilde{\chi}_1^+$	100	99	99.8	–
$\tilde{e}_R$	88	70 (*)	81	–
$\tilde{\mu}_R$	80	68 (*)	81	–
$\tilde{\tau}_R$	–	–	81	–
$\tilde{e}_L$	–	53	–	–
$\tilde{\mu}_L$	–	69	–	–
$\tilde{\nu}_e$	84	–	–	–
$\tilde{t}$, indirect	$\tilde{t}_L$, 71	$\tilde{t}_1$, 72	–	–
$\tilde{t}$, direct	$\tilde{t}_R$, 75	–	–	$\tilde{t}_1$, 79
$\tilde{b}$, indirect	$\tilde{b}_L$, 69	$\tilde{b}_L$, 71	–	–
$\tilde{b}_R, \tilde{s}_R, \tilde{d}_R$, direct	65	–	–	–
$\tilde{c}_R, \tilde{u}_R$, direct	75	–	–	–

$\lambda'' \bar{U}\bar{D}\bar{D}$	ALEPH	DELPHI	L3	OPAL
M (GeV), $\tilde{\chi}_1^0$	–	36	37.5	29
$\tilde{\chi}_2^0$	–	–	73	–
$\tilde{\chi}_1^+$	100	99	99.8	76 (*) (94)
$\tilde{e}_R$	88	70 (*)	81	–
$\tilde{\mu}_R$	80	68 (*)	81	–
$\tilde{\tau}_R$	–	–	81	–

(*) 183 GeV Data. Not updated yet.