Search for resonant sneutrino production at $\sqrt{s} = 202$ to 208 GeV

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Abstract

Searches for $\tilde{\nu}$ resonant production in e^+e^- collisions under the assumption that R-parity is not conserved and that the dominant R-parity violating coupling is λ_{121} have been updated in the data recorded by DELPHI in 2000 at centre of mass energies of up to 208 GeV. No deviation with respect to the Standard Model predictions was observed, and upper limits were derived on the λ_{121} coupling.

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Introduction

At LEP, the existence of the R-parity violating couplings λ_{121} or λ_{131} would allow resonant sneutrino ($\tilde{\nu}$) production. The indirect decay channels $\tilde{\nu} \to \tilde{\chi}^0 \nu$ and $\tilde{\nu} \to \tilde{\chi}^{\pm} l^{\mp}$ already searched for in 1997, 1998 and 1999 data [1, 2, 3] were looked for in 2000 data; the results are presented in this note and are still preliminary.

With a non zero λ coupling, the neutralinos and charginos can decay into three leptons, charged or neutral (R_p violating decays). Therefore if one takes into account all possible decays (violating R-parity or not), of the neutralinos and charginos, the possible final states for both processes $e^+e^- \to \tilde{\nu} \to \tilde{\chi}^0 \nu$ and $e^+e^- \to \tilde{\nu} \to \tilde{\chi}^{\pm} l^{\mp}$ are of two kinds, either purely leptonic (two acoplanar leptons, four or six-leptons) or semi-leptonic (multi-lepton multi-jet). The predicted production rates of the purely leptonic final states and of the semi-leptonic final states are of the same order, so it is wishable to look for all kinds of topologies.

1 Data samples

Due to the LEP mode of running in 2000, the centre of mass energy has varied almost continuously, nevertheless with an accumulation around three particular values. The data sample was thus splitted into three centre of mass energy bins: $\sqrt{s}$ below 205.5 GeV, between 205.5 and 207.5 GeV and above 207.5 GeV, called respectively "204 GeV", "206 GeV", and "208 GeV". The data taken while the DELPHI TPC was not fully operational were not used; this concerns the highest energy bin, which has therefore a much lower integrated luminosity. The integrated luminosities of the three sub-samples were about 73., 79.5 and 7. pb^{-1} respectively, and their luminosity weighted average energy was respectively 205.0 GeV, 206.7 GeV and 208.2 GeV.

For the Standard Model processes, the simulated centre of mass energies were 204 GeV, 206 GeV and 208 GeV (wherefrom the names of the samples were chosen), and the MC generators used were:

- $\gamma\gamma$ events: `BDK`[4] for $\gamma\gamma \to l^+l^-$ processes, and `TWOGAM`[5] for $\gamma\gamma \to$ hadrons processes;
- no-fermion processes: $e^+e^- \to \gamma\gamma(\gamma)$[6];
- two-fermion processes: `BHWIDE`[7] for Bhabhas, `KORALZ`[8] for $e^+e^- \to \mu^+\mu^-(\gamma)$ and $e^+e^- \to \tau^+\tau^-(\gamma)$ events, and `PYTHIA`[9] for $e^+e^- \to q\bar{q}(\gamma)$ events;
- four-fermion processes: `EXCALIBUR`[10] and `GRC4F` for all types of four fermion processes.

For the signal simulation, we have used the `SUSYGEN 2.20/03` program [11] forcing $M_{\tilde{\nu}} = m_0$, followed by the full DELPHI simulation and reconstruction program. The R-parity violating coupling λ_{121} was set to 0.05, and the centre of mass energy was set to 206.7 GeV. Nine sets of the MSSM parameters m_0, μ and M_2 (with $\tan\beta = 1.5$), where simulated, and a faster simulation (`SGV` [12]) was used to compute the efficiencies for the sets where we did not have full simulation.

2 Data analysis

In order to select the final states defined above, we first apply a preselection:

- at least two charged tracks of standard quality;
- total charged energy E_{ch} greater than $0.1 \times \sqrt{s}$;
- total charged plus neutral energy in the event E_{tot} greater than 20 GeV;
- total transverse momentum p_T greater than 5 GeV;
- absolute value of event charge $|Q_{ev}|$ at most 1 if the number of charged tracks $n_{ch} < 7$;
- at least one charged track in the barrel (polar angle between 40^o and 140^o);
- absolute value of the cosine of the polar angle of the missing momentum $|\cos\theta_{miss}|$ below 0.95 (0.9 if $n_{ch} = 2$);
- at least one isolated (i.e. with no other charged track in a 5^o half-cone) lepton ('loose' selection) with momentum above 5 GeV and with a maximum angle of 170^o with respect to the closest charged track.

The efficiency of these requirements is on average at $\sqrt{s} \simeq 206$ GeV of 72%, 90% and 87% respectively on the two-lepton, four or six-lepton and semi-leptonic signals.

Then we designed three more series of requirements, in order to select the three kinds of topologies that we search for.

- Two acoplanar leptons final states:
  - we required the charged track multiplicity to be two,
  - at least one well identified ('tight' selection) lepton, and not two muons identified,
  - the acoplanarity below 140^o,
  - the acolinearity above 50^o,
  - the invariant mass of the two leptons[1], M_{ll}, lower than $0.25 \times \sqrt{s}$,
  - the angle α_{ll} between the two charged tracks lower than 100^o.
- Four or six-leptons final states:
  - we asked for $4 \leq N_{ch} \leq 6$,
  - at least two well identified leptons (electrons or muons),
  - the y_{cut} Durham 'distance' (scaled invariant mass) for which the event flips from four to three jets y_{34} greater than 10^{-4}.
- Semi-leptonic final states:
  - there must be at least 7 charged tracks and at most 25,
  - there must be at least two well identified leptons (electrons or muons),
  - the p_T of the second lepton $p_T(l_2)$ had to be above $0.05 \times \sqrt{s}$,
  - y_{34} had to be greater than 10^{-3},
  - when the number of jets was forced to 4, the number of jets with a maximum total multiplicity of 4 was required to be at least 2.

[1] when the second lepton was not identified, it was assumed to be an electron.

$2-l$ sel.: criterion	204 GeV data	204 GeV SM MC	206 GeV data	206 GeV SM MC	208 GeV data	208 GeV SM MC
Preselection	1214	1128.4	1181	1217.	110	107.9
n_{ch}	497	481.5	497	516.5	57	45.7
Nb of id. lept.	332	375.8	350	402.8	36	35.7
Acoplanarity	45	46.1	47	48.8	5	4.4
Acolinearity	29	29.9	33	31.4	3	2.9
M_{ll}	17	16.4	18	16.	1	1.6
α_{ll}	**12**	**10.6 ± 0.7**	**12**	**10. ± 0.8**	**0**	**1.1 ± 0.08**

4 or $6-l$ sel.: criterion	204 GeV data	204 GeV SM MC	206 GeV data	206 GeV SM MC	208 GeV data	208 GeV SM MC
Preselection	1214	1128.4	1181	1217.	110	107.9
n_{ch}	62	43.8	61	48.2	4	4.2
Nb of id. lept.	10	7.3	10	8.	1	0.7
y_{34}	**3**	**2.3 ± 0.4**	**0**	**2.7 ± 0.4**	**0**	**0.2 ± 0.04**

Semi-lept. sel.: criterion	204 GeV data	204 GeV SM MC	206 GeV data	206 GeV SM MC	208 GeV data	208 GeV SM MC
Preselection	1214	1128.4	1181	1217.	110	107.9
n_{ch}	461	448.1	433	484.6	37	43.1
Nb of id. lept.	35	43.4	43	47.5	3	4.4
$p_T(l_2)$	7	8.1	8	8.6	0	0.8
y_{34}	5	5.7	6	6.	0	0.6
N_{jet}(low mul.)	**4**	**3.5 ± 0.3**	**4**	**3.9 ± 0.4**	**0**	**0.4 ± 0.04**

Table 1: Data/Monte Carlo comparison at each step of the event selection.

The average efficiency of these selections, including the preselection, is at $\sqrt{s} \simeq 206$ GeV 41%, 66% and 45% respectively on two-lepton, four or six-lepton and semi-leptonic signals assuming $\tan\beta = 1.5$.

The step by step comparison of the number of data and of SM Monte Carlo events after these selections is shown in Table 1. There is clearly no excess of data in any of the three channels.

Some important variable distributions are also shown in Figure 1. The background composition in each channel is displayed in Table 2.

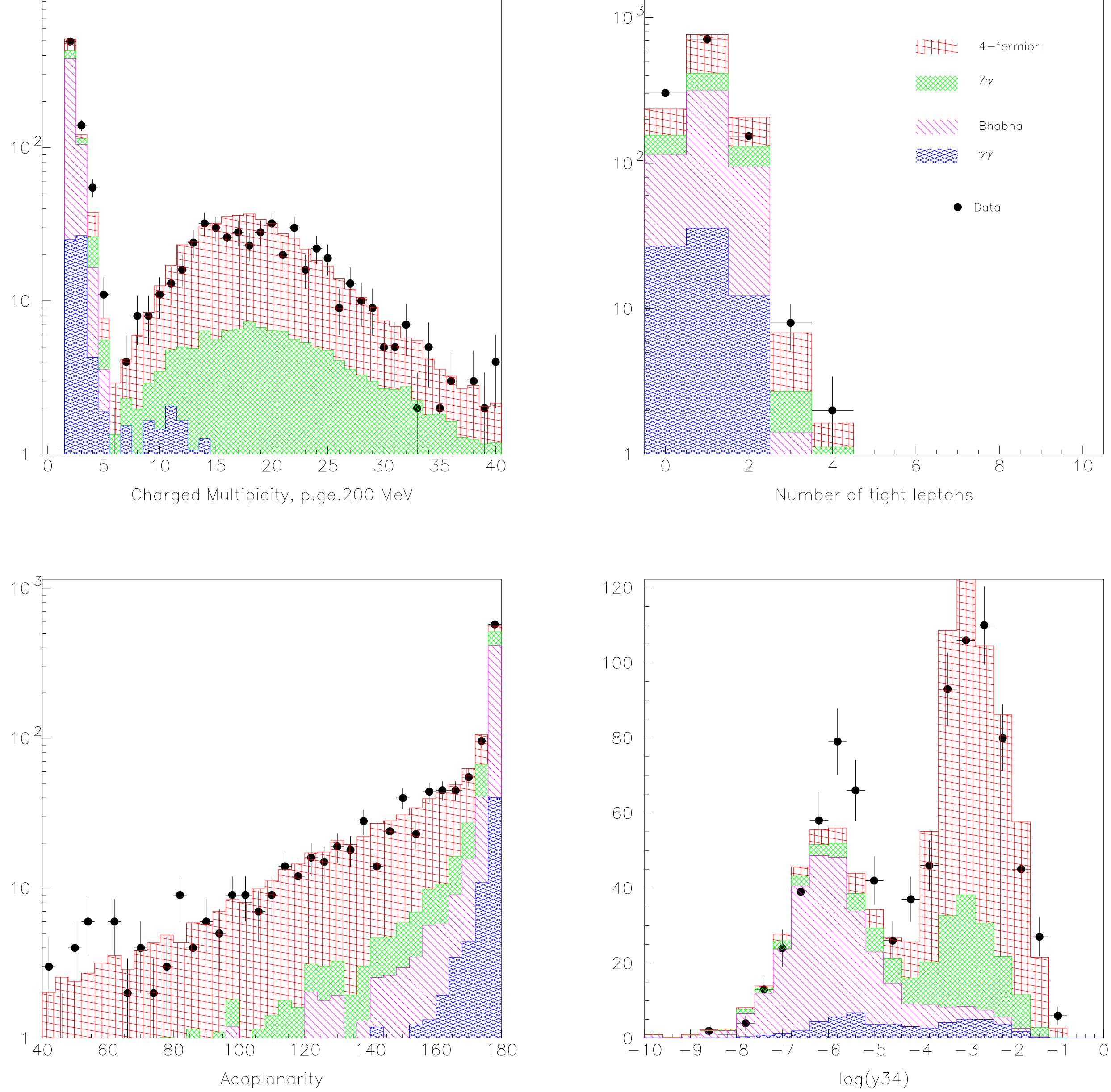

Figure 1: Data/Monte-Carlo comparison at the preselection level for $\sqrt{s} \simeq 206$ GeV.

3 Results

We have used again the `SUSYGEN 2.20/03` program to scan a wide portion of the MSSM parameter space[2] (127,000 points for each $\tan\beta$) and compute all the cross sections of the processes studied here. The parameter ranges were the same as before [2], i.e.

- $\tan\beta = 1.5$ or 30.,
- $m_0 = 70$ to 230 GeV in steps of 10 GeV ($m_0 = 185$ to 220 GeV in steps of 1 GeV),
- $M_2 = 5$ to 405 GeV in steps of 10 GeV,
- $\mu = -305$ to 305 GeV in steps of 10 GeV.

The scans were performed for $\sqrt{s} = 206.7$ GeV and then rescaled for each of the other two average energies.

[2]We do not consider parameter sets that have already been excluded by LEP1 precision studies.

$2-l$	$l\nu l\nu$	Bhabha	$\gamma\gamma \to ee$	$\mu\mu(\gamma)$, $\tau\tau(\gamma)$	All
204 GeV	9.9	0.4	0.15	0.1	10.6 ± 0.7
206 GeV	9.3	0.2	0.2	0.25	$10. \pm 0.8$
208 GeV	1.	0.02	0.01	0.02	1.05 ± 0.1
all $\sqrt{s}$	20.2	0.6	0.35	0.35	21.65
relative contribution	0.93	0.03	0.015	0.015	1.

4 or $6-l$	$llll$	$\mu\mu(\gamma)$, $\tau\tau(\gamma)$	Bhabha	WW-like	$\gamma\gamma \to \mu\mu$	All
204 GeV	1.4	0.25	0.2	0.15	0.15	2.3 ± 0.4
206 GeV	1.8	0.3	0.2	0.2	0.15	2.75 ± 0.4
208 GeV	0.15	0.02	0.02	0.05	0.01	0.25 ± 0.4
all $\sqrt{s}$	3.35	0.55	0.4	0.4	0.3	5.3
relative contribution	0.63	0.1	0.075	0.075	0.06	1.

Semi-leptonic	$llq\bar{q}$	WW-like	All
204 GeV	3.	0.4	3.5 ± 0.3
206 GeV	3.3	0.5	3.85 ± 0.4
208 GeV	0.2	0.05	0.35 ± 0.04
all $\sqrt{s}$	6.5	0.95	7.7
relative contribution	0.84	0.12	1.

Table 2: Expected background composition at the end of each channel analysis.

All	204 GeV			206 GeV			208 GeV		
multiplicities	data	SM MC	N_{95}	data	SM MC	N_{95}	data	SM MC	N_{95}
	19	16.4	12.1	16	16.6	9.35	0	1.65	3.

Table 3: Data/Monte Carlo comparison at the end of the event selection for all channels summed.

We used the same method as with previous data [2, 3] to derive the limits on the λ coupling. The three channels being totally independant thanks to the charged multiplicity criterion, they were summed (see Table 3). An upper limit at 95% C.L. on the number of signal events (N_{95}) was then calculated for each energy sample. On the other hand, the $(M_{\tilde{\nu}}, \Gamma_{\tilde{\nu}})$ plane was divided into two dimensional bins, of size $\delta M_{\tilde{\nu}} = 1$ GeV and $\delta\Gamma_{\tilde{\nu}} = 100$ MeV. For each parameter set entering a given bin, we used first the `SUSYGEN` scan to get the total cross-section expected for $e^+e^- \rightarrow$ all final states, and second a `SGV` scan on the same parameters to obtain the global efficiency of our analysis, combining the three separate channel efficiencies according to the branching ratios predicted by `SUSYGEN`. A calculation of the limit on λ was performed using N_{95} and these two ingredients for each set, and then the most conservative limit obtained for this bin was retained. This was done separately for each centre of mass energy, and the three samples were then simply combined by keeping the best limit in each bin.

The resulting exclusion plots are shown in Figures 2 and 3 in the $\tan\beta = 1.5$ and $\tan\beta = 30$. cases: for each sneutrino mass and width bin, an upper limit on λ_{121} is given at 95% C.L. One can also derive an upper limit on λ_{121} as a function of $M_{\tilde{\nu}}$ only, assuming a not too small sneutrino width, e.g. $\Gamma_{\tilde{\nu}} \geq 0.1$ GeV; this is shown in the same Figures.

At the best point, namely $M_{\tilde{\nu}} \simeq 206$ GeV where the integrated luminosity is highest, the upper limit at 95% C.L. on λ_{121} is 0.0025.

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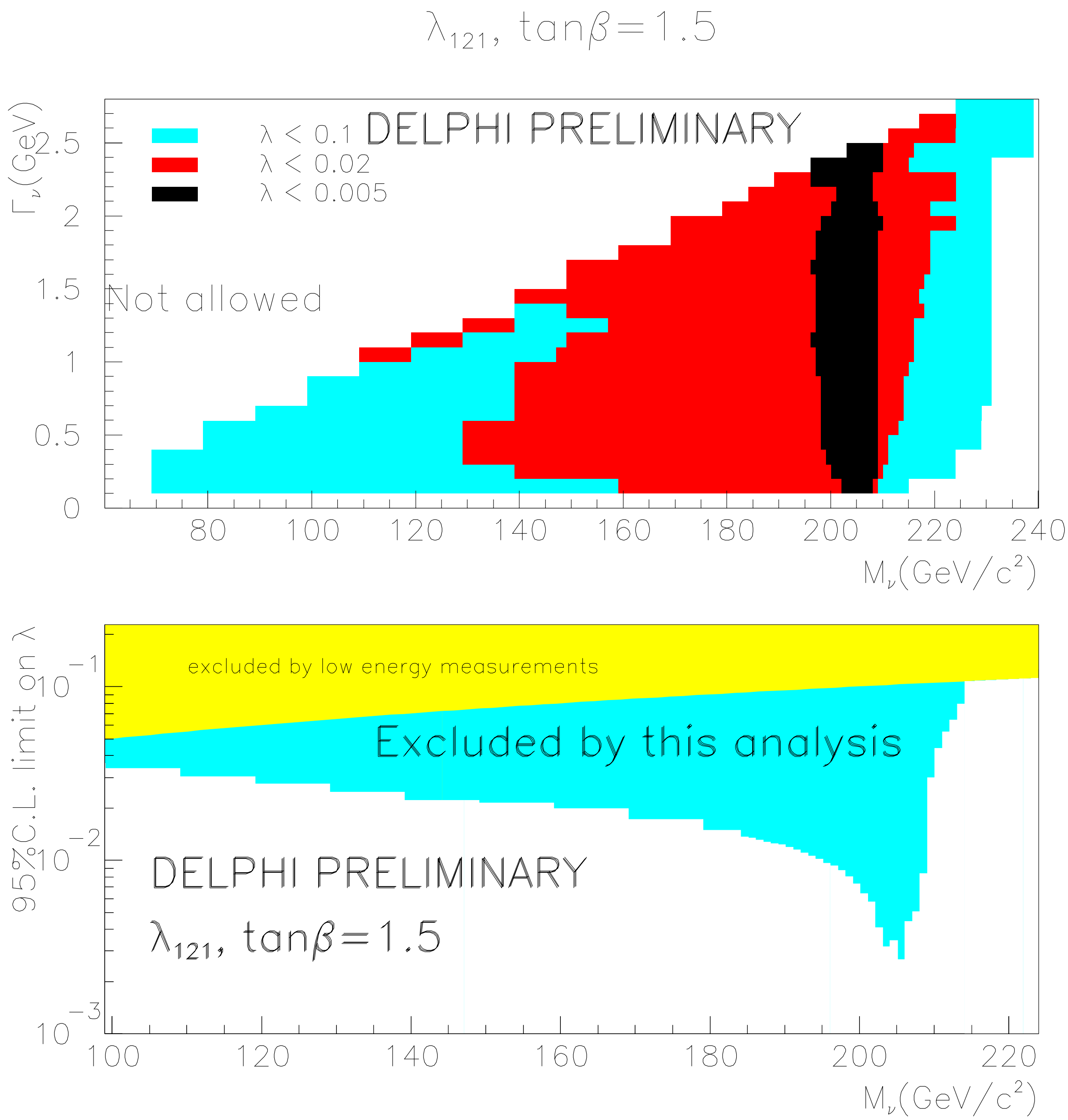

Figure 2: For $\tan\beta = 1.5$, upper limit on λ_{121} as a function of $M_{\tilde{\nu}}$ and $\Gamma_{\tilde{\nu}}$ (top) and as a function of $M_{\tilde{\nu}}$, assuming $\Gamma_{\tilde{\nu}} > 0.1$ GeV (bottom). The indirect limit coming from low energy measurements is given assuming $M_{\tilde{\nu}} = M_{\tilde{e}_R}$.

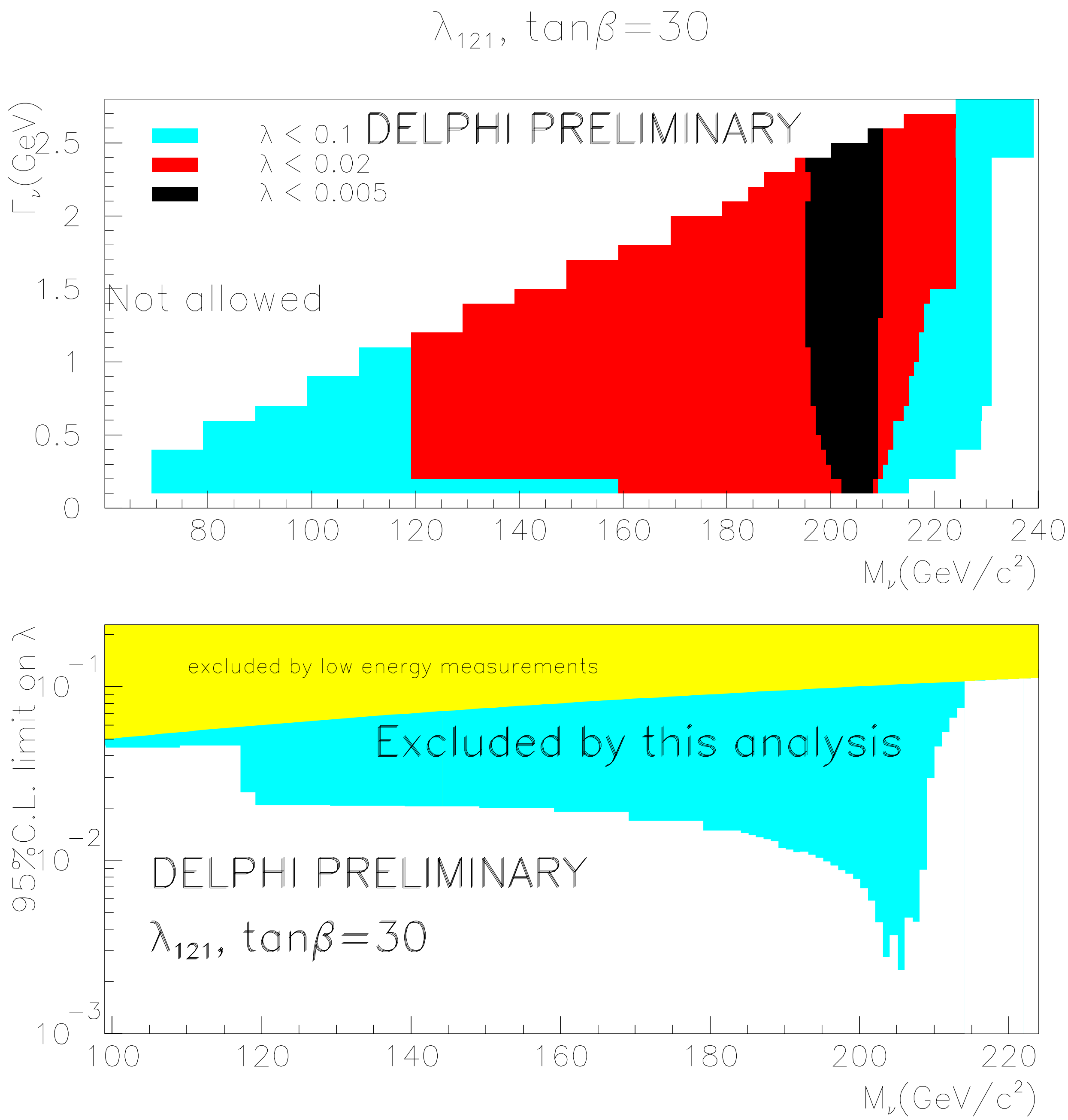

Figure 3: For $\tan\beta = 30.$, upper limit on λ_{121} as a function of $M_{\tilde{\nu}}$ and $\Gamma_{\tilde{\nu}}$ (top) and as a function of $M_{\tilde{\nu}}$, assuming $\Gamma_{\tilde{\nu}} > 0.1$ GeV (bottom). The indirect limit coming from low energy measurements is given assuming $M_{\tilde{\nu}} = M_{\tilde{e}_R}$.