Search for Sbottom Production

David Hedin and Vladimir Sirotenko

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This note presents limits on sbottom production using published Run I analyses. We assumed sbottom pair production with each decaying $\tilde{b} \to b+LSP$ where LSP is the lightest supersymmetric particle (usually assumed to be a neutralino). The branching ratio for this decay should be close to 100% even if $M_{\tilde{b}} > M_{\tilde{t}}$. Assuming that the LSP is stable, the final state is therefore 2 b quarks plus missing energy. This is similar to the $\nu\nu bb$ final state used in the third generation leptoquark search, and to the final state assumed in the stop search.

We first review possible stop and sbottom decays. For stop, one can have decays $\tilde{t} \to c + \tilde{\chi}^0$ or $\tilde{t} \to b + \tilde{\chi}^{\pm} \to b + l + \tilde{\chi}^0$. D0 assumes the first channel in its stop searches while LEP experiments look at both channels. If $M_{\tilde{t}} > M_b + M_W + M_{LSP}$ then the decay $\tilde{t} \to t + \tilde{\chi}^0 \to W + b + \tilde{\chi}^0$ will be the dominant stop decay. For sbottom, $\tilde{b} \to b + \tilde{\chi}^0$ dominates, as it directly converts the sbottom to a b-quark. Both couplings and kinematics favor it over other channels. If $M_{\tilde{b}} > M_{\tilde{t}}$, then transitions from sbottom to stop are possible, but they are suppressed. For $\tilde{b} \to \tilde{t} + W$ (with a virtual W), the W would have to have at least one unit of orbital angular momentum. Also, the lowest mass sbottom is typically right handed which reduces the coupling to W. $\tilde{b} \to \tilde{t} + H^{\pm}$ is kinematically suppressed due to the Higgs mass. We therefore assume a 100% branching fraction for $\tilde{b} \to b + \tilde{\chi}^0$[1].

Our stop limits[2] used the channel $\tilde{t} \to c+LSP$, with an assumed branching fraction of 100% when $M_{\tilde{t}} < M_W + m_b + M_{LSP}$. This also assumes that $M_{\tilde{t}} < M_{\tilde{b}}$. The event selection included requiring two or more jets ($E_T > 40$ GeV) and missing transverse energy ($\not\!\!E_T > 40$ GeV). We have run some MC to see if there is any differences in the acceptances between the sbottom and stop final states. 5000 events of each were generated with $M_{\tilde{b},\tilde{t}} = 100$ GeV and $M_{LSP} = 30$ GeV. There were 1934 (c) and 1916 (b) events accepted following requirements on jet E_T and $\not\!\!E_T$. If we assume equal acceptance, then any limits on stop production imply that the same limits would hold for sbottom production. (Note, the stop 3-body upper constraint, $M_{\tilde{t}} < M_W + m_b + M_{LSP}$, does not apply to sbottom decays.) Table 1 (from D. Claes) shows the acceptance for different stop/sbottom and LSP masses. The combined statistical and systematic errors are typically 10-15%. For our published Ia sample of 7.4 ± 0.4 pb^{-1}, 3 events remained in the data consistent with a background estimate of 3.5 ± 1.2 events. (The total luminosity was 13.5 ± 0.7 pb^{-1} but only events with a single interaction were used.) Limits on stop production were placed for masses up to about 100 GeV.

We can also use the data samples and event selection used in the third generation

Table 1: Summary of MC acceptances and cross section limits for jet channel, and the jet and muon channels combined. The muon channel is converted to 7.4 pb^{-1}.

		jet channel		both channels	
$M_{\tilde{b}}$	M_{Lsp}	acceptance	σ limit (pb)	acceptance	σ limit (pb)
40 GeV	0 GeV	0.00238			
40	10	0.00094			
45	40	0.00099			
55	0	0.01052			
55	20	0.00574			
55	30	0.00148			
55	40	0.00190			
55	50	0.00047			
70	10	0.03018			
70	30	0.01834	50	0.0292	32.1
70	50	0.00388		0.0063	245
85	0	0.03099			
85	20	0.03467			
85	40	0.02870	29	0.0480	18.8
85	60	0.01071		0.0152	84
100	10	0.04306			
100	20	0.04310	18.4	0.0958	9.3
100	30	0.03757			
100	40	(0.034)	23.3	0.0701	12.6
100	50	0.02979		0.0606	14.7
115	20	0.04474			
115	40	0.05081	15.3	0.1088	8.0
115	60	0.03382			

leptoquark analysis [3]. This required two jets, with at least one tagged as coming from a b by the presence of an associated muons, plus clean missing transverse energy. Two events remained with a background from top, W and Z channels of 2.5 ± 0.6 events. Luminosities of 19.5, 92.4 and 60.1 pb^{-1} were collected with a low p_T muon plus jet, a high p_T muon plus jet, and a dimuon trigger respectively. We utilize ISAJET events to calculate the acceptance for di-sbottom decay as a function of $M_{\tilde{b}}$ and M_{LSP}. The amount of missing transverse evenrgy ($\not\!\!E_T$) decreases for smaller $M_{\tilde{b}}$ and for small $M_{\tilde{b}}$-M_{LSP} mass differences. We see this in Fig. 1. A cut of $\not\!\!E_T > 35$ GeV was used. Table 2 summarizes acceptances and approximate 95% C.L. limits if we combine the muon channels for various $M_{\tilde{b}}$ and M_{LSP}. We use the relative luminosity to obtain a combined acceptance, which is then given for 19.5 pb^{-1}.

Combining the samples, we observe 5 events in the data with a background of 6.0 ± 1.3 events. The combined acceptance, normalized to 7.4 pb^{-1}, is given in Table 1 [4]. (Note that the muon samples add less than half this acceptance gain to the stop limits). We assumed that the systematic errors were completely correlated between the two analyses. Assuming no correlation does not make a large change in the results; with $(M_{\tilde{b}}, M_{LSP})$ of (100,40) we obtain a limit of 12.6 pb using correlated errors and 12.4 pb using uncorrelated. Combining the two analyses allows us to lower the 95% C.L. on the cross section by about a factor of 2 for higher values of $M_{\tilde{b}}$ compared to just the stop analysis.

Mass limits are obtained by comparing the measured cross section limits to that expected for $\tilde{b}\bar{\tilde{b}}$ production. Table 3 gives the production cross section as a function of $M_{\tilde{b}}$. The "old" column is from H. Baer (via D. Claes) and was used for the published D0 stop limit. The "new" column is from PROSPINO, and is a NLO calculation using CTEQ4M pdfs [5]. The production cross section for the lightest sbottom/stop ($\tilde{b}_1$) particles are the same for a given mass. The cross sections depending very slightly (a percent or so) on the assumed mass for the heavier sbottom/stop $\tilde{b}_2$ and values of 150 and 300 GeV/c^2 were used. The mixing angle between the two sbottom masses was also varied with values of -1., .39 and 1.0 used for sinθ_T. The average value is shown in the Table. The calculations were performed at masses of 50, 70, 90, 110 and 130 GeV with geometric means used for the other masses.

We assume a 100% branching fraction for $\tilde{b} \to b + LSP$. Comparing Tables 1 and 3, and using the combined results, we obtain the best limits on $M_{\tilde{b}}$. Figure 2 plots the limts on the $(M_{\tilde{b}}, M_{LSP})$ plane. We place a lower limit on the sbottom mass of $M_{\tilde{b}} > 115$ GeV/c^2, which is valid for $M_{LSP} < 20$ GeV/c^2.

LEP experiments also perform sbottom searches. Fig. 2 also shows preliminary results from ALEPH for the complete $\sqrt{s} = 189$ GeV data[6]. $M_{\tilde{b}}$ limits are obtained provided $M_{\tilde{b}} - M_{LSP} > 10 - 20$ GeV (depending on what experiment). LEP results depend on the mixing between $\tilde{b}_1$ and $\tilde{b}_2$. Excluded regions are shown for the values of the mixing angle which give the maximal and minimal production cross sections. For the most favorable mixing angle, they exclude the region with $M_{\tilde{b}} < 90$ GeV/c^2.

References

[1] S.P. Martin, private communication.

Table 2: Summary of MC acceptances and cross section limits for muon channels. The combined acceptance is given for 19.5 pb^{-1} and includes efficiencies not in the Monte Carlo.

$M_{\tilde{b}}$	M_{Lsp}	no. gen.	No. acc:1mu	1muh	2mu	overall acc.	σ limit
50	20	247000	169	22	7	.00087	292 pb
50	30	100000	34	3	1	.00037	570 pb
60	25	219000	329	41	12	.00186	139 pb
70	30	155000	496	64	27	.0041	63 pb
70	50	200000	159	17	5	.00092	280 pb
80	0	20000	124	27	7	.0101	25.0 pb
80	20	114800	846	114	30	.0094	26.4 pb
85	40	136000	767	104	36	.0073	34 pb
85	60	171900	254	26	10	.0017	145 pb
100	0	20000	295	44	10	.0195	13.0 pb
100	10	50000	721	128	24	.021	12.4 pb
100	20	100000	1369	243	67	.020	13.0 pb
100	30	50000	567	110	29	.017	15.3 pb
100	40	60000	604	96	22	.0137	18.4 pb
100	50	50000	423	66	20	.012	21.3 pb
115	40	50000	791	127	36	.022	11.8 pb
120	0	20000	356	67	27	.0279	9.1 pb

Table 3: Production cross section for Sbottom pairs.

$\tilde{b}$ Mass (GeV/c^2)	50	60	70	80	90	100	110	120	130
σ (pb)(old)	283	133	69	38	21.9	13.0	8.1	5.1	3.3
σ (pb)(new)	482	(204)	86	(43.9)	22.4	(12.8)	7.3	(4.5)	2.8

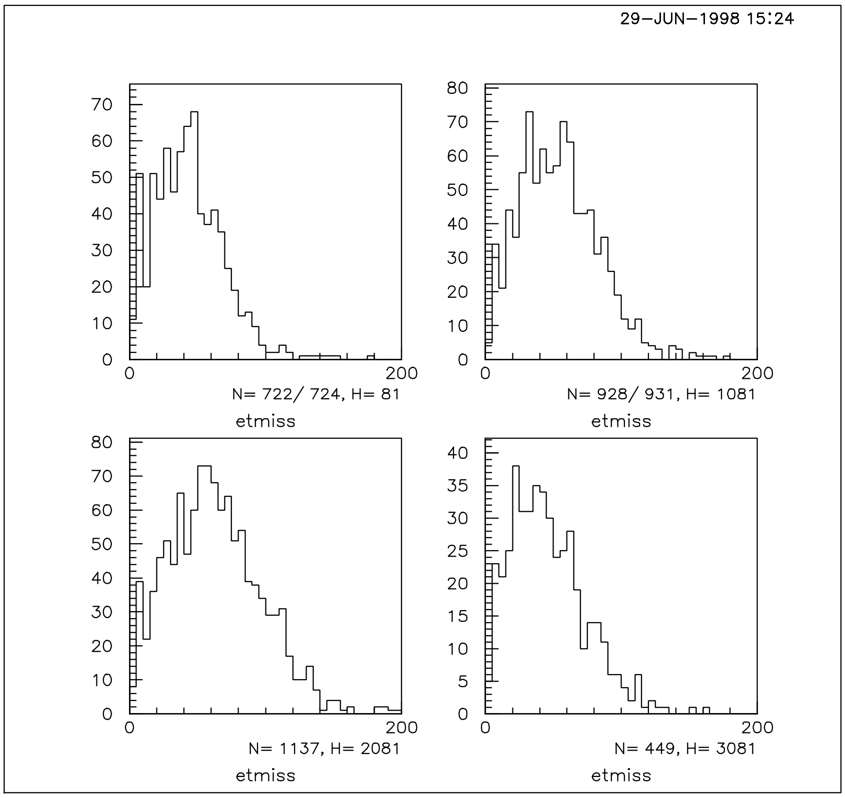

Figure 1: $\not\!\!E_T$ for $\tilde{b}\bar{\tilde{b}}$ production with $(M_{\tilde{b}}, M_{LSP})$ of (a) (80,0), (b) (100,0), (c) (120,0), and (d) (100,40) (masses in GeV/c^2).

[2] S. Abachi et al., PRL **76**, 2222 (1996).

[3] B. Abbott et al., PRL **81**, 38 (1998); Limits on the Production of Pair Produced Third Generation Leptoquarks and ZX Events, D. Hedin and V. Sirotenko, D0 Note 3175, January, 1998 (final version).

[4] The cross section limits were obtained using the combined acceptance. T. Yasuda recalculated limits using separate acceptances, number of data events, and background events. The results were identical (8.09 pb doing separate and 8.07 pb combined for the (115,40) mass point).

[5] W. Beenakker, M. Kramer, T. Plehn, M. Spira and P.M. Zerwas, Nucl. Phys. B515, 3 (1998). Plus private communication with M. Spira.

[6] ALEPH Collaboration, presented at DPF99, UCLA, January, 1999.

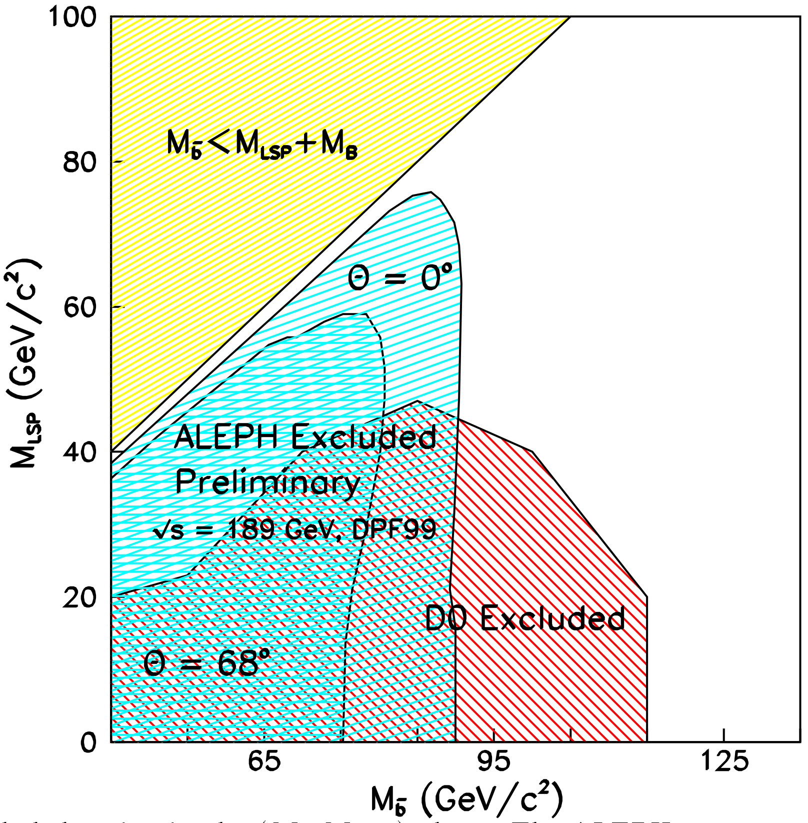

Figure 2: Excluded region in the $(M_{\tilde{b}}, M_{LSP})$ plane. The ALEPH contours correspond to $\theta = 68^o$ and $\theta = 0^o$.