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SEARCHES FOR NEW PARTICLES

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Abstract

Searches at HERA, LEP and the Tevatron for effects beyond the Standard Model are discussed. Special emphasis is given to experiments aiming at finding compositenes, scalar particles and signatures of supersymmetry. The status of recently observed indications for new effects is summarised.

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1 Introduction

The experimental results that emerged during the two years since the last ICHEP conference exhibited two general trends. Most of those relating to QCD, the Z^0 lineshape, its leptonic couplings and the W mass were in stunning agreement with the Standard Model . However, a few measurements suggested it may have to be extended. Such indications were found for excessive beauty production in Z^0 decays [1], an excess of two jet production at transverse energies of 400 GeV [2], and an enhancement of four - jet events with a sum of two-jet masses of $\sim$ 105 GeV [3]. Although none of these observations was unambiguous or significant enough to claim a failure of the Standard Model, they received a lot of attention and inspired many follow-up experimental and theoretical analyses.

The main challenge of the Standard Model during this period came from the big parton colliders. Results from the Tevatron $p\bar{p}$ collider are by now based on $\sim$100 pb^{-1}, HERA collected some 12 pb^{-1} of ep luminosity. These four-to five fold larger data samples allow for a higher sensitivity to new effects with suppressed couplings and enlarge the explored mass range. The LEP e^+e^- collider has doubled its luminosity at the Z^0 and, more important for new particle searches, has almost doubled its c.m. energy. Each LEP experiment has collected some 5-6 pb^{-1} at c.m. energies of 130 and 136 GeV, and by now about 10 pb^{-1} at the W-pair threshold of 161 GeV [1].

As simple as the basic structure of the Standard Model is, consisting of fermions as matter fields, gauge bosons as carriers of interactions and one scalar giving masses to fermions and gauge bosons, it has rather unaesthetical properties. Completely obscure is the apparent waste of fundamental particles - why so many almost identical fermion generations, and why so many interactions which are based on the same principle of local gauge invariance? A traditional solution would be if boson and fermions were composite. Several analyses submitted to this conference looked for signs of compositeness of fermions or gauge bosons, or searched for fermions outside the SU(3)$_c\times$SU(2)$_L\times$U(1)$_R$ structure and for new kinds of bosons.

An additional open issue of the Standard Model is the Higgs boson, the only remaining particle of the Standard Model for which at most feeble evidence exists. Several analyses considered also possible non-standard realisations of the scalar sector. Finally, there is the question, if fermions and gauge bosons are really disjunct or if they are just realisations of Supersymmetry [8]. According to the large fraction of papers on SUSY, submitted to this conference, it is *the* extension which most physicists believe in.

In the following I will discuss the search for new effects based on cross section measurements of apparently Standard Model processes and will then briefly summarise the topological search for new fermions and bosons. In somewhat more detail I will address in Section 4 searches in the Higgs sector, in Section 5 the status on the mass peak in 4-jet

[1] By the time of the conference first results based on $\sim$2 pb^{-1} per LEP experiment were presented. Here the outcome from the complete run at 161 GeV will be given. The data were presented at a CERN seminar on Oct, 8 [4, 5, 6, 7]. The results of ALEPH, DELPHI and L3 are all preliminary, those from OPAL partly final.

events at LEP, and finally in Section 6 review SUSY searches.

2 Contact Interactions

Once the mass threshold for the production of a new particle is crossed, it may be identified by event topologies which are forbidden in Standard Model processes. Alternatively, new particles may show up indirectly through deviations of the cross sections of apparent Standard Model processes. These may allow a glimpse of new physics (NP) occuring at a much higher energy scale Λ_{NP} than the one of $\sqrt{s}$ directly probed.

If, for example, the scattering fermions consist of preons at some high energy scale $\Lambda_{NP}^2 \gg s$, a remnant preon interaction may still be detectable at the interaction energy. Such deviations are conveniently parametrised in the framework of contact interactions. Schematically the matrix element of the observed interaction consists of the Standard Model part S and the part of new physics P which is suppressed by $g^2 \cdot s/\Lambda_{NP}^2$. The cross section is then given as

$$\sigma \propto \frac{1}{s}\left[|S|^2 + \frac{s}{\Lambda_{NP}^2}|SP| + \frac{s^2}{\Lambda_{NP}^4}|P|^2\right]$$

By convention $g^2/4\pi$=1. For $s \ll \Lambda_{NP}^2$, the preon interaction mainly becomes manifest through its interference with the Standard Model contribution and is more prominent, the closer Λ_{NP} is.

Two classes of assumptions about the dynamics of P lead to variants of Λ_{NP}.

- The interference may be constructive or destructive (Λ_{NP}^+, Λ_{NP}^-).
- The interactions may have a certain chirality and the scale is denoted as Λ_{LL}, Λ_{LR} etc., or in terms of axial of vector scales.

No additional assumptions about the source of the deviation enters the formalism. It therefore provides some parametrisation not only of compositeness, but of any (slow) deviation from the Standard Model . Still, for simplicity, we will refer to Λ_{NP} as composite scale. In general, composite models are disfavoured by theoretical arguments. However, the interest in contact interactions was recently renewed by the CDF claim of an excess of the two-jet rate in $p\bar{p}$ collisions at high E_T. The slowly and continuously growing deviation from the Standard Model expectation as published in [2] is exactly what can be expected from compositeness effects in $q\bar{q} \to q\bar{q}$ scattering. Further analyses showed, this is not the only explanation, but an alternative choice of parton distribution functions can accomodate all relevant data, including the high E_T ones [9].

Compositeness would be even more attractive if all kinds of fermions consist of the same preons. Then deviations would not only appear in $q\bar{q}$ scattering, but in any reaction involving fundamental fermions. As such, eq scattering probes if electrons and quarks, and accordingly e-lepton scattering if electrons or any of the other leptons have a common

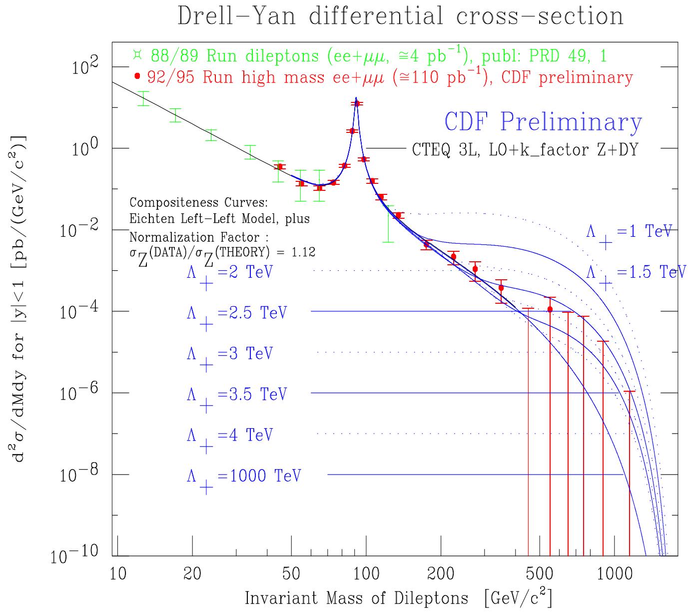

Figure 1: Search for compositeness scale using the Drell Yan process $q\bar{q} \to (e^+e^-), (\mu^+\mu^-)$ [14]

substructure. If the excess in the 2-jet rate would really indicate compositeness, deviations from the Standard Model may also appear in other rections, though this is not mandatory.

A comprehensive list of searches for contact interactions has been submitted to this conference. Both H1 [10] and ZEUS [11] at HERA studied eq scattering, OPAL at LEP used their data around 135 and 161 GeV to analyse eq and $e(e,\mu,\tau)$ interactions [12]. CDF, besides their $q\bar{q}$ study, used the Drell-Yan process $q\bar{q} \to e^+e^-, \mu^+\mu^-$ to search for a common $q(e,\mu)$ structure [14]. Neither of these experiments finds a significant deviation in any of these channels. The 95%CL lower limits for Λ_{LL}^+ and Λ_{LL}^- are shown for some channels in Table 1.

Table 1: Lower limits on composite scales $\Lambda_{LL}^{+,-}$ in TeV from various fermion interactions. For HERA the stronger of the respective H1 and ZEUS limits are given. The CDF $q\bar{q}$ limit is based on the dijet angular distribution [15].

fermions	intf.	CDF	H1,ZEUS	OPAL
e e	+			2.0
	-			1.3
e q	+	2.4	1.7	2.5
	-	3.4	2.3	2.1
q q	+	1.8		
	-	1.6		

The different interactions show consistently that composite scales must be larger than $\mathcal{O}(2\,TeV)$. All experiments contribute to the eq limit with CDF currently setting the most stringent limit. Their measurement is shown in Fig 1. The results show no support of the interpretation of CDF's high E_T excess as a signal of compositeness. If anything is going on in the quark channel, it is unique to quarks and seems not to apply to leptons. The data can also be interpreted in terms of other non Standard Model effects. For example, the H1 collaboration sets indirect limits on vector or scalar leptoquarks [10].

3 Searches for New Fermions and Bosons

Most convincing and least ambiguous signals of new physics are event topologies that cannot be explained by the Standard Model . The potentially clearest experimental signatures are high energetic photons, W's or Z^0's (mostly identified via their decays into electrons or muons), or missing energy. More complicated are signatures that are based on quarks and gluons alone. Since Standard Model processes are rather unambiguously defined, some experiments perform topological searches for new particles without reference to a specific model. An example is given in [16]. Most of the searches, however, are directed towards finding evidence for a definite model.

In general, at least two parameters are required for interpreting some search $X \leftrightarrow AB$, X being a new particle. One is its mass m_X, the other one the XAB coupling. If gauge couplings are involved, theory gives, in general, definite predictions. Yukawa couplings or those involving a mixture of standard and non-standard fermions are uncertain. In general there are also no constraints on the mass scale where these extensions become relevant. Notable exceptions are SUSY and the Higgs sector.

The other experimental searches and theoretical analyses submitted to this conference can be split into four categories,

- new bosons similar to the W and the Z^0, or leptoquarks,
- new fermions like new generations, representations of a new group structure, or excited fermions,
- rare decays of Z^0's and W's,
- entirely new particles like monopoles or tachyons [17].

No evidence is found for any of them. A summary is given in Table 2. Quite few experiments consider excited electrons and leptoquarks. Those will be briefly discussed below.

Excited electrons naturally occur in models of composite fermions. A higher state e^* is assumed to decay into the ground state e or ν_e via emission of a photon or, if massive enough, via a Z^0 or W. Excited electrons may be pair produced $e^+e^- \rightarrow e^{*+}e^{*-}$. Its cross section is rather unambiguosly given by the gauge couplings $(\gamma, Z^0)e^*e^*$, masses $m_{e^*} < E_{cm}/2$ can be probed. Possible is also single production in association with a standard electron $e^+e^- \rightarrow e^+e^{*-}$, $e^+q \rightarrow qe^{*+}$ The cross sections of these reactions depend on the magnetic transition between excited and normal electrons, but have a

Table 2: Overview over some other than SUSY and Higgs searches submitted to this conference. The experiments are denoted by A=ALEPH, C=CDF, D=DELPHI, D0=D0, H=H1, L=L3, O=OPAL, Z=ZEUS. The interpretation of the GALLEX search for neutrinoless double β decays are denoted by G. The limits quoted are given in GeV and are typical ones. In most cases they depend on additional parameters, partly addressed in the fifth column. In searches for rare W and Z^0 decays, the typical maximum branching ratio is given.

particle	decay mode	experiments	mass limit	comment
Fermions				
b'	$b\gamma$	D0 [18]	95	
Neutrino N	lX	A [19], D, L [20], O [21]	72	Dirac N
Chgd. Lepton L	NW	A [19], L [20], O [21]	74	if $m_N < 56$
Excited quark q^*	$q\gamma$	C [13], H [22], Z [23]	several 100	
	qg, qW	C [13], D0 [24]	200-700	
Excited electron e^*	$e\gamma$ eZ^0, νW	A [25], D [26], H [22], L [27], O [28], Z [23]	76 - 200	see discussion
Excited μ, τ	$(\mu,\tau)\gamma$	A [25], D [26], L [27], O [28]	similar	
Excited ν	$\nu\gamma$, eW, νZ^0	A [25], D [26], H [22], L [27], O [28], Z [23]	80-200	
Bosons				
Z'	e^+e^-, $\mu^+\mu^-$	C [13], D0 [24]	690	SM couplings
	indirect	L [29]		Z^0 lineshape
W'	WZ^0	C [13], D0 [24]	500	W, W' mixing
W_R	$q\bar{q}$	Z [30]		$m_{\nu_R} > m_{W_R}$
	eN	G [31]		
X	$\gamma\gamma$	D [32], O [33],		
	$\nu\bar{\nu}$	D [32]		
Leptoquark LQ_1	$e(u,d)$	C [13], D0 [35], H [36], Z [37] G [31]	143	(see discussion)
		C [13]	12000-20000	Pati-Salam LQ
LQ_2	$\mu(c,s)$	C [13]	180	(see discussion)
LQ_3	τb	C [13]	94	(see discussion)
W,Z decays			BRatio	
Z^0	ggg	D [38]	10^{-2}	
	$e\mu$, $e\tau$ $\tau\mu$	D [39], L [40]	10^{-5}-10^{-6}	
W	various	D0 [41]		

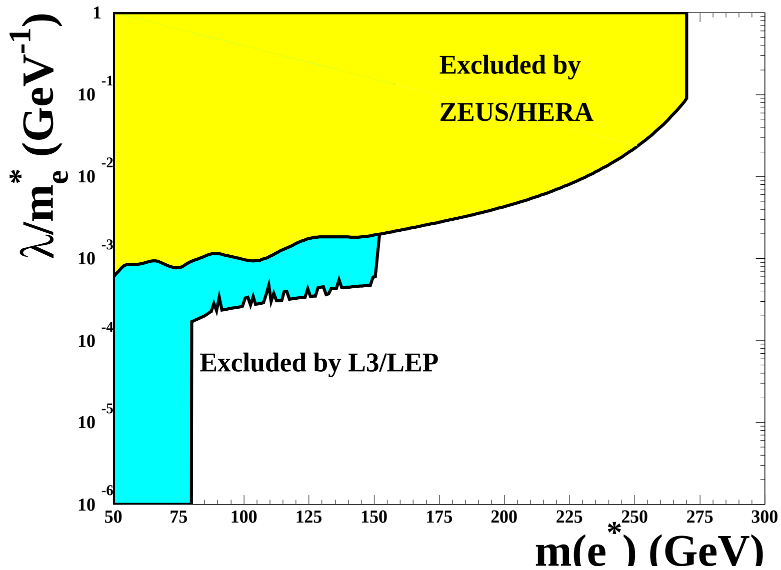

Figure 2: Preliminary limits on excited electron e^* in the $e^* \to e\gamma$ decay mode as a function of the $e^*e\gamma$ coupling obtained at HERA [23] (light shaded) and LEP [27] (dark shaded).

higher mass reach of $m_{e^*} < E_{cm}$. The effective coupling is frequently parametrised as $\lambda/m_{e^*} = f/\sqrt{2}\Lambda$, although in general it could be more complicated.

Searches for the e^* have been performed at LEP [25, 26, 27, 28] and HERA [22, 23] using the three potential decay modes. In the case of $e^* \to e\gamma$ decays, the experiments look for a mass peak in the $e\gamma$ system. No significant signal is observed and the result is interpreted in terms of limits on mass and coupling strength as shown in Fig. 2. An absolute bound of $m_{e^*} >$79.7 GeV is set by LEP. HERA reaches e^* masses of more than $\sim$ 250 GeV, its limits, however, depend on the $\gamma e^* e$ coupling.

Another hypothetical particle of common interest at the various colliders is the leptoquark, a fundamental boson that has lepton and baryon number and relates the otherwise disjunct lepton and quark sectors. Leptoquarks LQ occur in many extensions of the Standard Model like compositeness and GUTs. The direct experimental signature is an excess of events with a high energy, isolated lepton in conjunction with quark production, possibly a mass peak in the lepton-quark system. To avoid FCNC the Yukawa couplings should be generation diagonal, i.e. each LQ couples to members of only one generation, yielding leptoquarks $(LQ)_i$, i=1,2,3 denoting the respective generation. Searches for scalar LQ have been performed at LEP, the Tevatron and HERA. The cross section in e^+e^- and $q\bar{q}$ collisions are given by the gauge couplings of leptoquarks to (γ, Z^0) or gluon, those at HERA on their Yukawa couplings.

Analyses at HERA [36, 37] are based on searches for mass peaks in the eq or νq system. If generation diagonality is assumed, only first generation leptoquarks can be probed. Limits can be set on LQ masses of more than 200 GeV. At the Tevatron the process $g \to (LQ)\overline{(LQ)}$ leads to two isolated leptons in association with quarks. Limits on LQ's of all three generations exist. CDF uses only charged leptons [13], while D0 [35] also included

νq decays. The limits depend on the branching ratio $\beta = B(LQ \rightarrow l^+ q)/B(LQ \rightarrow \text{all})$ and have been published for $\beta \geq 0.2$. The limits are shown in Fig. 3.

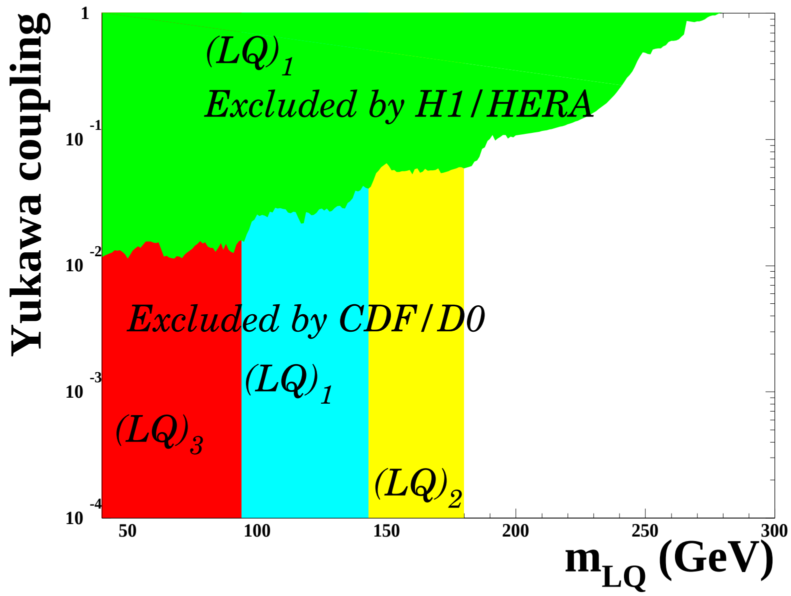

Figure 3: Preliminary limits on scalar leptoquarks $(LQ)_i$ of generation i=1,2,3 as a function of its Yukawa coupling as excluded at HERA [36] and the Tevatron. The limits for second and third generation leptoquarks are taken from CDF [13], the limit for first generation leptoquarks from D0 [35]. For the Tevatron limits β=0.5 was assumed.

4 Studies on the Scalar Sector

Essentially the first stringent limits on the masses of the Standard Model Higgs have been obtained with the on-set of LEP. By now almost the entire LEP1 data sample of 20 millon Z^0 decays has been analysed by the four LEP experiments [42, 43, 44, 45]. No evidence has been found which translates into a combined lower limit of the Standard Model Higgs mass of 66 GeV. From the Standard Model fits to electroweak results from LEP, SLD, the Tevatron and ν scattering experiments, on the other hand, an upper limit of $M_H \leq$ 520 GeV can be set [46].

Because of the absence of any experimental evidence on the Higgs sector one should be open also to possible non - Standard Model production of scalars. Alternative models propose anomalous couplings of the Higgs to fermions and gauge bosons, an enlarged Higgs sector with more than one fundamental scalar, or a composite Higgs as assumed in technicolour models.

The D0 collaboration has searched for Higgs production in conjunction with a W [47]. The experimental study consists of two main steps. Firstly a W is identified by its $(e, \mu)\nu$ decay. Secondly two energetic jets are required to accompany the W and their invariant mass is reconstructed. After appropriate cuts D0 retains 27 events in agreement with 25.5 background events expected from QCD and top production. The two-jet mass spectrum together with the background expectation is shown in Fig. 4. No peak is observed and the measurement is interpreted in terms of a 95% upper limit on the production of a heavy particle X produced in association with a W. The lower limit $\sigma_{WWX} \cdot BR(X \rightarrow jj)$ is between 40-20 pb for m_X between 80 and 120 GeV. Such a limit is some two orders of magnitude above the Standard Model expectation for a Higgs, but is interesting in view of models suggesting exotic production of scalars. For example, according to [48] this channel could be due to technipions with a cross section of several picobarns.

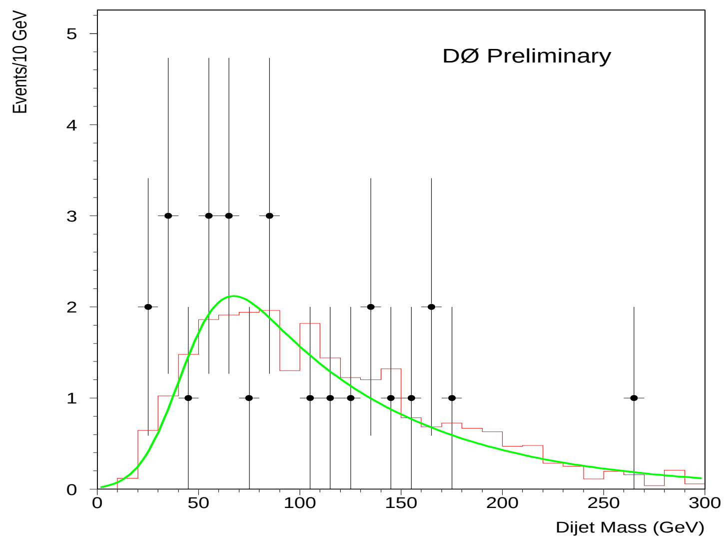

Figure 4: Mass spectrum of dijets produced in association with a W [47].

Non Standard Model Higgs production is also considered in the framework of anomalous gauge boson - Higgs couplings. One possible effect is an enhanced Z^0 decay into $H\gamma$. Such a Higgs production mechanism has been searched for at LEP [33, 49] in hadronic events with an isolated photon. The Standard Model hadron background is due to $q\bar{q}$ production with photons from either the incoming electron or the outgoing quarks. A Higgs would appear as a mass peak in the recoil spectrum against the photon. At least for a massive Higgs the good photon energy resolution leads to an excellent mass resolution of the hadronic system of ~ 1 GeV. No signal has been observed and, for masses of less than 70 GeV, the excluded cross section is some one to two orders of magnitude above the Standard Model expectation (Fig 5).

Another alternative to the Standard Model is a larger Higgs sector by, for example, introducing a second doublet (2HDM). Assuming CP conservation, such enlarged sector implies five fundamental scalars, two CP even H_1, H_2 which mix with an angle α into two mass eigenstates h, H (convention $m_h \leq m_H$), a CP odd state A and charged Higgses H^+, H^-. In the general 2HDM the Higgs masses and couplings are defined, if the masses of H_1, H_2, α, and the ratio of the vacuum expectation values $\tan\beta$ are given. Since the two doublets are related to up type and down type quarks, respectively, $\tan\beta$ should be larger than one, reflecting $m_t \gg m_b$ while being smaller than $\mathcal{O}(50)$. The most restrictive searches on two Higgs doublet models have been performed in Z^0 decays at LEP. The basic production processes are displayed in Fig. 6. If the 2HDM is embedded in the framework of the Minimal Supersymmetric Model (MSSM) constraints apply leading to additional relations between m_h, m_A and m_Z. In this case it is sufficient to analyse the

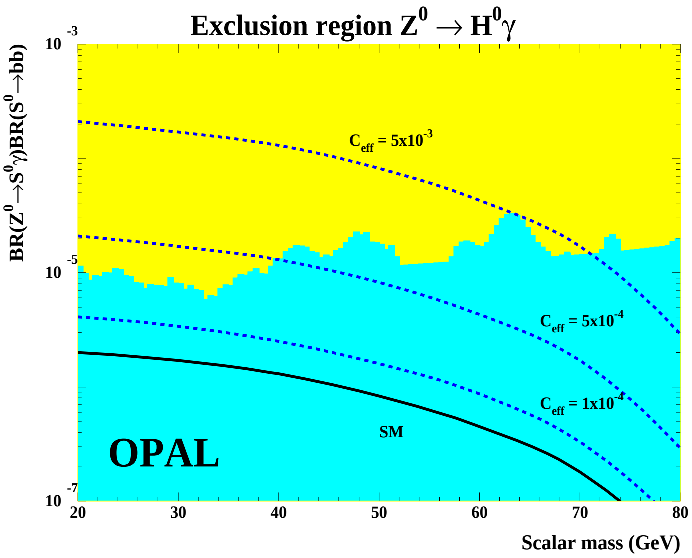

Figure 5: Upper limit the branching fraction $Z^0 \rightarrow H^0\gamma$ as a function of m_H [33]. The excluded region is light shaded. Indicated are also the expectations of the Standard Model and in case of some anomalous couplings.

data for contributions a and b.

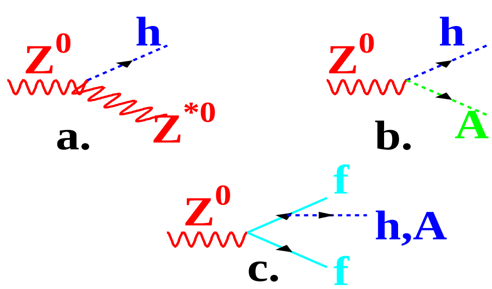

Figure 6: Generic diagrams for Higgs production in Z^0 decays

In the general 2HDM the analysis and limits are identical to MSSM if $m_A + m_h < M_Z$ which will be discussed below. However, if $m_A < M_Z$, but $m_h > M_Z$ (and vice versa), the MSSM limits invoke theoretical relations that are not valid for the general 2HDM. Instead complementary constraints can be obtained through the Higgs Yukawa radiation (Fig 6c) [50]. Experimentally this process has been studied by the ALEPH collaboration using events with four, preferentially heavy, fermions [51]. The highest sensitivity is reached with two leptons and two other leptons or jets. Events with four beauty particles, which should have the largest cross section, are of only limited use because of the large QCD background. This search covers Higgs masses down to $m_H \sim 2m_e$. No signal was observed, the corresponding exclusion range for the CP-odd A is shown in the plane of $\tan\beta$ vs. m_A in Fig. 7. The L3 collaboration [44] has interpreted their search for a Standard Model Higgs in terms of limits on h and obtains limits on $\sin^2(\beta - \alpha) \sim 10^{-1} - 10^{-2}$ for $m_h \leq 45$ GeV. Since this implies $\alpha \sim \beta$, exclusion regions for m_h vs $\tan\beta$ are similar to those in

Fig. 7. It is interesting to note that even for this simple extension of the Higgs sector, no absolute limits on the Higgs mass can be set, with only modest restrictions in the $\tan\beta$ range.

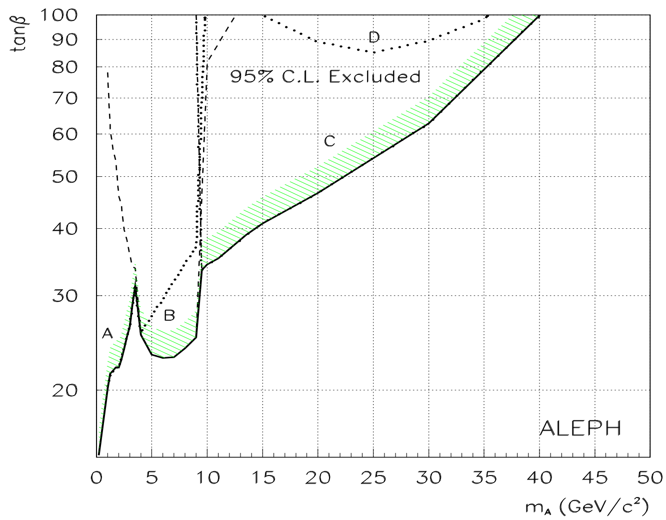

Figure 7: Limit on the pseudoscalar A as a function of mass and $\tan\beta$ [51]

The superpotential requires at least two Higgs doublets to give masses to both up and down type quarks and leptons, which implies five spin 1/2 Higgsinos and five spin 0 Higgses. The MSSM implies a relation between m_h, m_A and the masses of the electroweak bosons. As a result, at the tree level, the only free parameters that determine the mass spectrum are m_A and $\tan\beta$. These simple relations are modified through radiative corrections, particularly those involving the top mass m_t and the masses of SUSY particles m_S, and may lead to important mass shifts. On the other hand they are at most such that the lightest Higgs particle must be lighter 120 - 135 GeV for top masses between 169 and 181 GeV [53] representing an experimentis crucis for the MSSM.

Experimental searches are based on processes a, b of Fig. 6. The signature for a. is identical to the one for the Standard Model Higgs. For the $Z^0 \to hA$ channel mass peaks in events of the type $b\bar{b}b\bar{b}$, $q\bar{q}\tau^+\tau^-$ or $\tau^+\tau^-\tau^+\tau^-$ are searched for. Also in this channel no signal has been observed. Its absence can be translated into exclusion regions in the MSSM parameter space. The result of the DELPHI collaboration is shown in Fig. 8 for m_A vs. $\tan\beta$ [52]. Here it was assumed that m_S=1 TeV, no squark mixing (A_{ij}=0) and m_t=175 GeV. For $\tan\beta \geq 1$ this choice implies m_A >45.2 GeV and m_h >45.4 GeV. However, taking into account the possible freedom of SUSY parameter leads to weaker limits. For a top mass of 185 GeV and, particularly, large squark mixing m_A >23.8 GeV and m_h >44.3 GeV [45].

Within the MSSM a charged Higgs has, at tree level, a mass of $m_{H^\pm} = \sqrt{m_A^2 + m_W^2}$ and, even taken radiative corrections into account, is likely to be heavier than 80 GeV. Although this range is beyond the current LEP reach, searches for $H^\pm$ have been performed in the mode $e^+e^- \to c\bar{s}\tau\nu$. No mass peak was observed and a lower limit

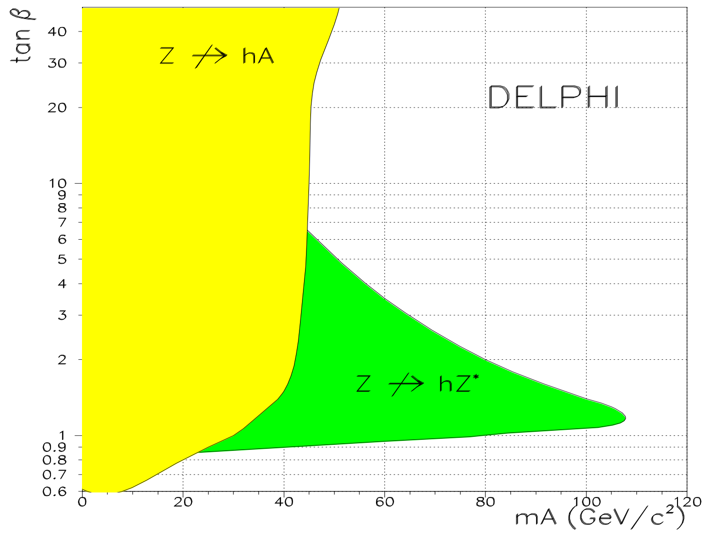

Figure 8: Preliminary exclusion range in the MSSM of the pseudoscalar A as a function of mass and $\tan\beta$ [52].

of 44.1 GeV could be set [54]. Masses of $m_{H^\pm} \leq m_t - m_b$ ~170 GeV are accessible in top decays. In a preliminary analysis CDF has searched for these decays identifying the $H^\pm$ via its decay into $\tau^+\nu_\tau$ [13]. This mode is the dominent one for large $\tan\beta$. No excessive τ production has been observed and limits of $m_{H^\pm} \geq 137$ GeV for $\tan\beta > 200$ could be set. The LEP and CDF limits are shown in Fig. 9.

Further searches on non Standard Model Higgs, which are submitted to this conference consider invisible decays like $H^0 \rightarrow \chi^0\chi^0$. The absence of a mass peak in the $q\bar{q}\not{E}_T$ channel of the Standard Model Higgs search can be interpreted in this case as a lower limit of 66.7 GeV [44].

5 ALEPH excess of 4 jet events

One of the recent deviations from the Standard Model was reported by the ALEPH collaboration at LEP energies of E_{cm}= 135 GeV [3]. In an attempt to find hA production they selected events with four well separated and fairly massive jets. They observed 16 events while expecting 8.6. To reconstruct the h, A bosons, they combined in a second step pairs of two jets and determined their respective masses M_{ij}, M_{kl}. Since the cross section for h, A production is largest if their masses are similar, they selected that one of the three possible combinations that yields the smallest $|M_{ij} - M_{kl}|$. In the corresponding distribution of $M_\Sigma = M_{ij} + M_{kl}$ they observed a prominent peak around M_Σ =105 GeV. In the interval between 101.85 and 108.15 GeV, corresponding to $\pm$ twice their mass resolution, they observe 9 events, while expecting 0.8. The statistical probability for this to happen in any mass interval is $\sim 10^{-4}$.

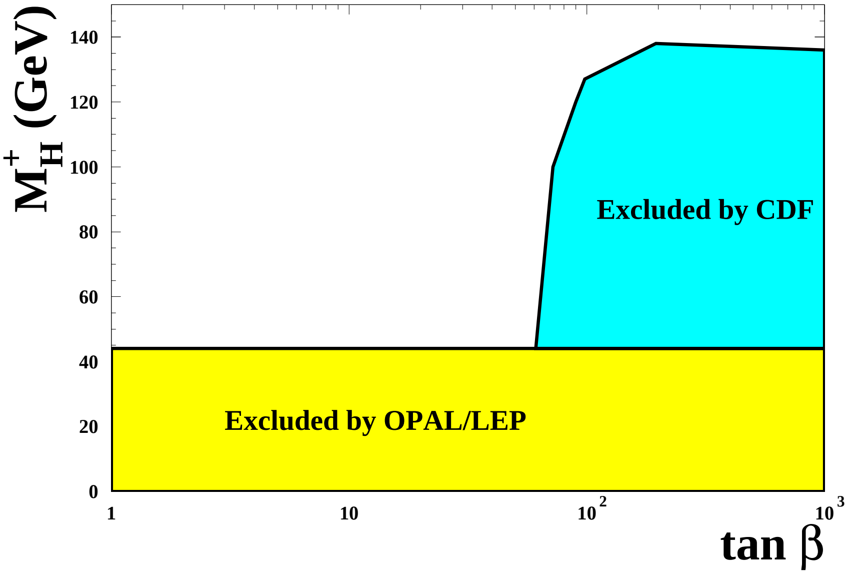

Figure 9: Exclusion range of charged Higgses as a function of mass and $\tan\beta$ [13, 54].

Since the analysis is rather independent of the specifics of the ALEPH detector, the other LEP collaborations analysed their data in a rather similar way. DELPHI, L3, and OPAL [55] observed in total 33 four jet events for an expected 26.4. In the mass range of 102-108 GeV they find 6 events while expecting 2.6 (probability for an upward fluctuation 0.017). The statistical consistency between the ALEPH result and the other collaborations is poor. The combined mass spectrum is shown in Fig. 10a. Interpreting the accumulation around 105 GeV as a signal for a new particle, its cross section would be 1.2$\pm$0.4 pb.

A further test is provided with the recent LEP running at 161 GeV. Apart from the rather remote possibility of the 4 jet excess being due to some s-channel resonance, the signal should also appear at higher energies. The analysis is repeated largely with the same cuts as used for the 135 GeV data. Energy dependent quantities like mass resolution, which increases to 2.5 GeV, are taken into account. Supplementary cuts were invoked to suppress W-pairs that newly appear at 161 GeV. At this stage different procedures are used by the four LEP experiments to treat this background. After all these cuts ALEPH retains seven events in agreement with 7.2 expected from Standard Model processes. Five of the events have a mass consistent with the excess observed at 135 GeV. The other LEP experiments together observe in the mass interval of interest 7 events for a background of 5.9. The combined mass spectrum is shown in Fig 10b [2]. Again, the data from ALEPH and those from DELPHI, L3 and OPAL from the 161 GeV run are in poor statistical agreement. If one combines the 135 and 161 GeV data, ALEPH finds in total 14 events with a background of 1.8, while the average of the other experiments is 3.3$\pm$1.0 with a background of 2.8$\pm$1.0. These two results hardly consistent. The reason for this difference is currently not understood. Small discrepancies between the various analyses exist, but

[2]The DELPHI, L3 and OPAL collaborations provided the exact mass values of their candidates. The masses from ALEPH had to be taken from the binned histogram presented in [5]. Due to binning effects small deviations from their true values may appear.

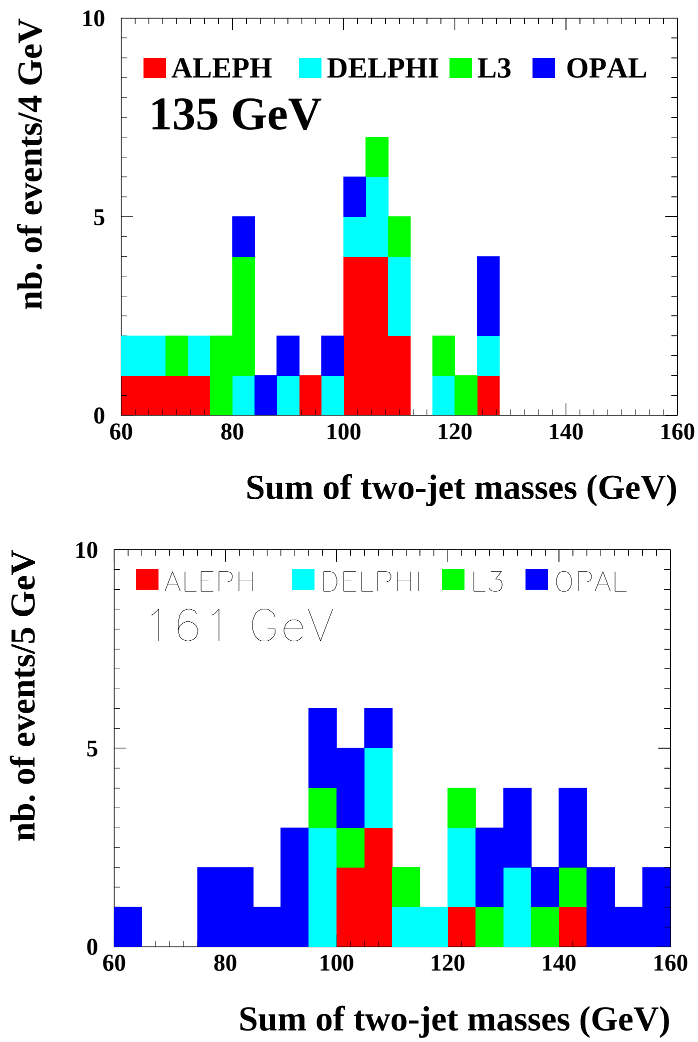

Figure 10: M_Σ spectrum combined from all four LEP experiments at c.m. energies of 135 and 161 GeV.

various studies suggest them to have only a minor effect on the results. Without further detailed information and a thorough comparison of the various analyses, it is impossible at this stage to draw a firm conclusion on the reported excess.

The observation lead to several theoretical speculations on the possible nature of such a signal. For example, papers submitted to this conference relate the signal to supersymmetry, either in its $\not{R}_p$ mode or assuming light gluinos [56].

6 SUSY

Supersymmetry is currently considered the strongest contender for extensions of the Standard Model . Apart from its conceptual beauty and its deep implications at the Planck scale, one of the reasons for its popularity is that it provides a solution for the hierarchy problems if it has a low energy, i.e. $\leq$1 TeV realisation. This new symmetry, at least if properly broken, implies a doubling of fundamental particles and, in its general form, a host of free parameters. Several assumptions reduce their numbers considerably, leading to a variety of models, but also, within these models, to rather unambiguous predictions of mass relations and couplings.

- The general superpotential includes terms involving the mixing of the two Higgs fields $\mu H_1 H_2$, Higgs-sfermion couplings like $\lambda_i \tilde{F}_j \tilde{F}_i H_k$, but also sfermion - fermion couplings like $\lambda_{ijk} Q_i L_j D_k$. The latter terms could lead to proton decays and can be suppressed by putting in by hand exact R-parity conservation $R_p = (-1)^{3B+L+2S}$, B, L, S denoting the baryon number, lepton number and spin. R_p conservation is one essential assumption of the MSSM, however an equivalent SUSY model with R_p breaking ($\not{R}_p$) is also viable.

- Some relations between parameters are assumed to, for example, avoid FCNC. Both R_p conserving and violating realisations are possible. If R_p is conserved, this leads to the Minimal Supersymmetric Standard Model (MSSM).

- What is actually often referred to as MSSM includes additional assumptions on the unification at the GUT scale. The assumed equality of the coupling constants and gaugino masses $m_{1/2}$, after evolving them down to the electroweak scale, lead to well defined mass relations, characterised by M_2. Quite often also a common scalar mass m_0 is assumed. A free parameter is also the soft SUSY breaking term A_0, which affects the SUSY realisation in particular through A_t and A_b, which are related to the stop and sbottom masses. In addition the mixing term μ of the superpotenial, and those Higgs parameters discussed in Section 4 are free. Many SUSY analyses at LEP are interpreted in terms of these parameters. Tevatron results are frequently discussed using further assumptions, in particular the radiative breaking of electroweak symmetry, which lead to additional relations. In this case, for example, only the sign of μ is unconstrained. Again, the same relations can be invoked in $\not{R}_p$ SUSY.

How SUSY is realised has considerable impact on the experimental searches. Firstly it affects the experimental signature, most prominently for the alternatives of R_p conservation and violation. In addition, the decay modes and thus the experimental detectability of SUSY particles depend on the unknown parameters. Furthermore, these parametrisations relate results from searches for different SUSY particles and their combination allows indirect limits to be set. As convenient as such a common convention is, one should keep in mind that it is founded on assumptions added to the basic principle of super symmetry.

The existence of several particles with R_p =-1 with the same quantum numbers could lead to a mixing of the spin 1/2 charged and neutral gauginos and higgsinos of the electroweak sector into mass eigenstates called charginos an neutralinos.

$$\begin{pmatrix} \chi_1^\pm \\ \chi_2^\pm \end{pmatrix} = \mathcal{M}(M_2, \mu, \tan\beta) \begin{pmatrix} \tilde{W}^\pm \\ \tilde{H}^\pm \end{pmatrix}$$

$$\begin{pmatrix} \chi_1^0 \\ \chi_2^0 \\ \chi_3^0 \\ \chi_4^0 \end{pmatrix} = \mathcal{M}'(M_2, \mu, \tan\beta) \begin{pmatrix} \tilde{\gamma} \\ \tilde{Z}^0 \\ \tilde{h}_1 \\ \tilde{h}_2 \end{pmatrix}$$

As a result the production and the decay of charginos and neutralinos depend on the relative contributions of the higgsino and gaugino component, i.e. on the mixing parameter.

The search for SUSY particles had received a further motivation from the excess of Z^0 decays into beauty quarks $R_b = \Gamma(Z^0 \to b\bar{b})/\Gamma(Z^0 \to \text{hadrons})$ observed at LEP. Such an excess can occur in SUSY due to processes as those depicted in Fig. 11. Whereas the pre-Warsaw R_b measurement was too high to be accomodated by SUSY models, the current difference [46] $\Delta R_b = R_b^{obs} - R_b^{SM} = 0.0021 \pm 0.0013$ is what is expected if either the stop or the chargino masses are close to the reach of LEP [57]. On the other hand, the measurement is in excellent agreement with the Standard Model and bears no indication of any exotic effect. Note also, that the apparently lower forward - backward asymmetry of beauty quarks [46] which can be interpreted as an additional left handed component, is in disagreement with SUSY expectations. However, its significance is only three standard deviations and it is thus premature to derive any firm conclusions.

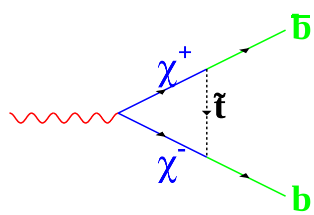

Figure 11: Possible SUSY contribution to R_b

6.1 $\not{R}_p$ SUSY

Allowing R_p violation the superpotential includes terms

$$\lambda_{ijk} L_i L_j \bar{E}_k \; + \; \lambda'_{ijk} L_i Q_j \bar{D}_k \; + \; \lambda''_{ijk} U_i D_j \bar{D}_k$$

where Q, L, denote the quark and lepton doublet superfields and U, D and E the respective singlet superfields. The indices ijk represent their respective generations. The λ, λ' and λ'' are dimensionless Yukawa couplings. The first two terms violate lepton, the third baryon number. If both lepton and baryon number violating terms would be non-zero, the proton decay rate is unacceptably large. This is avoided by demanding only one Yukawa coupling to be non-zero. In general λ'' seems to be tiny and most analyses emphasise λ and λ'. The latter contribution leads to a production and decay of SUSY particles as shown in Fig. 12. Clearly, this is a process which can be probed ideally at HERA. Note also, that the signature is very similar to the one of leptoquarks.

Essentially two kinds of topologies are used for $\not{R}_p$ SUSY searches at HERA. One is a s-channel resonance enhancement in the process $e^+q \to (e^+q), (\nu q')$ at a mass $M_{\tilde{q}} = \sqrt{s \cdot x_l}$,

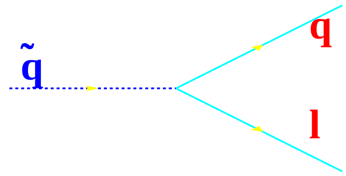

Figure 12: Typical diagram of $R\!\!\!/_p$ squark decay

the other one is an apparent lepton flavour violation, for example $e^+q \rightarrow \tau^+q$. The former one is sensitive to λ'_{1kl} with k,l=1,2,3. For the latter to occur, at least two couplings have to be non-zero, e.g. $\lambda'_{111} \cdot \lambda'_{312} \neq 0$.

A comprehensive search for a resonance production of squarks in the $R\!\!\!/_p$ framework was performed by the H1 collaboration [58]. Based on ~2.8pb^{-1} they studied eight different topologies for either direct decays $\tilde{q} \rightarrow lq$ or cascade decays via charginos or neutralinos $\tilde{q} \rightarrow q\chi \rightarrow lq + X$. As an example, the e^+-jet mass spectrum is shown in Fig. 13. The observed distribution can be well explained by DIS neutral current interactions, no significant mass peak is observed. The results are interpreted in terms of limits on the Yukawa couplings λ'. They depend somewhat on the detailed SUSY parameters because of possible cascade decays of squarks.

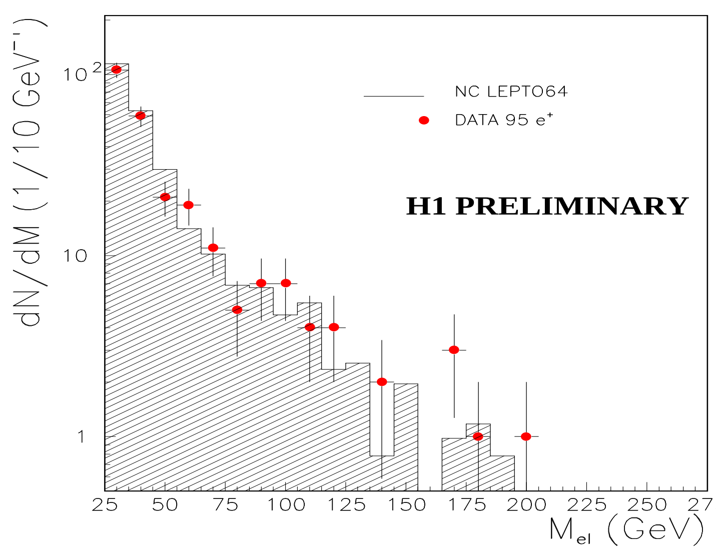

Figure 13: Preliminary e^+-jet mass spectrum in a search for $R\!\!\!/_p$ squark decays [58].

The ZEUS collaboration searched for $e \rightarrow \mu, \tau$ transitions [37]. No signal is observed in a preliminary analysis of data corresponding to 9.6pb^{-1}. Assuming the couplings λ'_{11k} or λ'_{1j1} at the production vertex to be identical to the λ'_{ijk} at the decay vertex, limits on the Yukawa couplings can be derived. Those involving a final state τ are depicted in Fig. 14.

Constraints on the Yukawa couplings can also be obtained from decays of D-mesons, the τ lepton and the Z^0 [59], the most stringent limit of $\lambda'_{111} \leq 3.9 \cdot 10^{-4}\sqrt{m_{\tilde{g}}/100}$ is due to the non-observation of neutrinoless double β-decay [31]. Apart from detailed SUSY parameters the limits depend of course on the squark masses. For example, the H1 limits scale approximately like $\lambda'_{1jk} \propto \exp[bm_{\tilde{q}}]$ for squark masses between 50 and 275 GeV. Assuming $m_{\tilde{q}}$=100 GeV, and in turn just one λ'_{ijk} to be non-zero, most limits range between 0.01 and 0.5. No limits exist for λ_{32k}.

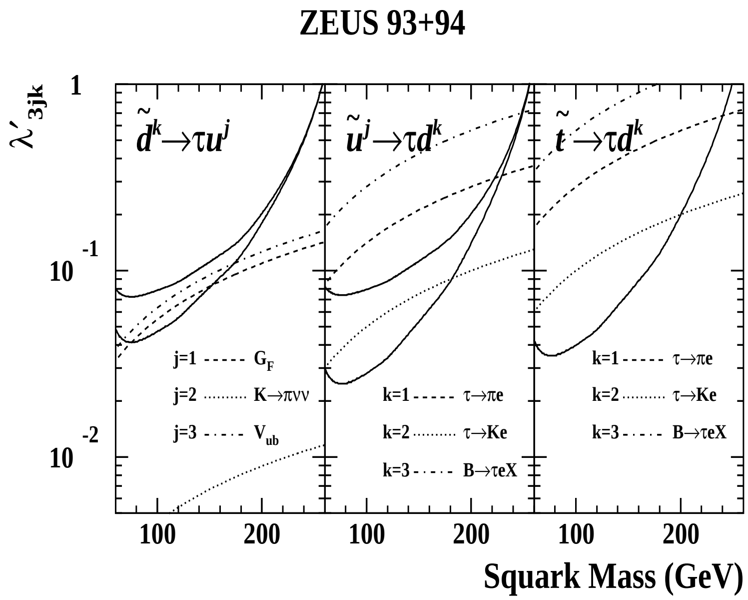

Figure 14: Preliminary upper limits on $\not{R}_p$Yukawa couplings from the absence of $e \to \tau$ transitions [37]. The full lines represent different assumptions on the decay mode. Also shown are limits from other processes.

$\not{R}_p$ supersymmetric particles can also be pair produced in e^+e^- collisions or the Tevatron. The ALEPH collaboration has searched for chargino and neutralino production assuming the lightest SUSY particle χ_1^0 to decay into $l^+l^-\nu$, which would involve a coupling of the type λ_{ijk}. No signal is found either in Z^0 decays or in the high energy data at 135 and 161 GeV [60]. This result is translated into exclusion regions in the SUSY parameter space. No experimental study on $\not{R}_p$ SUSY at the Tevatron has been published.

6.2 'Standard' SUSY

The standard SUSY assumes R_p conservation with important implications for experiments.

- Lepton flavour and baryon number are always conserved.
- SUSY particles appear in pairs.
- A light stable SUSY particle exists (LSP). From cosmological assumptions, it should be electrically neutral and weakly interacting and thus corresponds to χ_1^0. This gives rise to the spectactular signature of apparently missing energy and acoplanarity.

6.2.1 Charginos

The most stringent searches for charginos have been performed at the Tevatron and particularly at LEP exploiting the pair production

$$q\bar{q} \to W^{\pm} \to \chi^{\pm}\chi^{0} \qquad e^{+}e^{-} \to Z^{0} \to \chi^{+}\chi^{-}$$

(note that MSSM parameters relate masses and properties of $\chi^{\pm}$ and χ^{0}). The chargino is mostly assumed to decay into

$$\chi^{\pm} \to \chi_1^0 W^{\pm} \to \chi_1^0 f\bar{f}$$

where χ_1^0 is the 'invisible' LSP. The experimental signature in e^+e^- collisions are therefore

- hadronic acitivity in four jets and $\not\!\!E_T$,
- two jets, a charged lepton and $\not\!\!E_T$,
- two oppositely charged leptons, possibly of different flavour, and $\not\!\!E_T$.

At LEP the decays into all fermions are utilised, whereas at the Tevatron only the decay into electrons and muons stand out significantly enough from the QCD background. In both reactions the experimental sensitivity depends critically on the mass difference $\Delta M_{\chi} = M_{\chi^{\pm}} - M_{\chi_1^0}$. Low ΔM_{χ} make it more difficult to disentangle the SUSY processes from background.

A bound on the chargino mass which is independent of decay properties and even ΔM_{χ}, can be directly inferred from the Z^0 width yielding $m_{\chi^{\pm}}$ <45.2 GeV. Above the Z^0 searches are founded on the missing energy signature.

No significant signal is observed and the result is translated into the minimal excluded cross section for some $\chi^{\pm}$ mass. An example from the LEP 161 GeV run for two values of ΔM_{χ} as a function of M_{χ} is given in Fig. 15 [61]. Similar results are also obtained by the other LEP experiments [62, 63, 64]. A corresponding result from the Tevatron gives the limit in the cross section of three lepton production [65, 66]. These presentations are largely free of MSSM assumptions. The strongest limits come from the LEP running at 161 GeV. A combination of the mostly preliminary results from all LEP experiments yields 7 candidates while Standard Model processes, particularly W-pair production, lead to an expected 8.6 events.

The interpretation of these measurements in terms of mass limits on $\chi^{\pm}$ depends on the SUSY parameters. One important dependence is due to the $\tilde{\nu}_e$ mass which contributes to $\chi^+\chi^-$ production via t-channel exchange and interferes negatively with the s-channel γ, Z^0 exchange. Bounds on $\tilde{\nu}_e$ of 42.8 GeV are derived from the invisible Z^0 width [3]. A scan in the allowed MSSM parameter space translates the measured cross section limits into $m_{\chi^{\pm}} > 62.7$ GeV for ΔM_{χ} >5 GeV as shown in Fig. 16 [63]. This limit is independent of the $\tilde{\nu}$ mass or any other SUSY parameter. Similar results are obtained by the other LEP experiments [62, 61, 64].

[3]The results on Γ_{inv} were taken from [46]. I am grateful to P.Clarke for discussions on the uncertainties of this measurement.

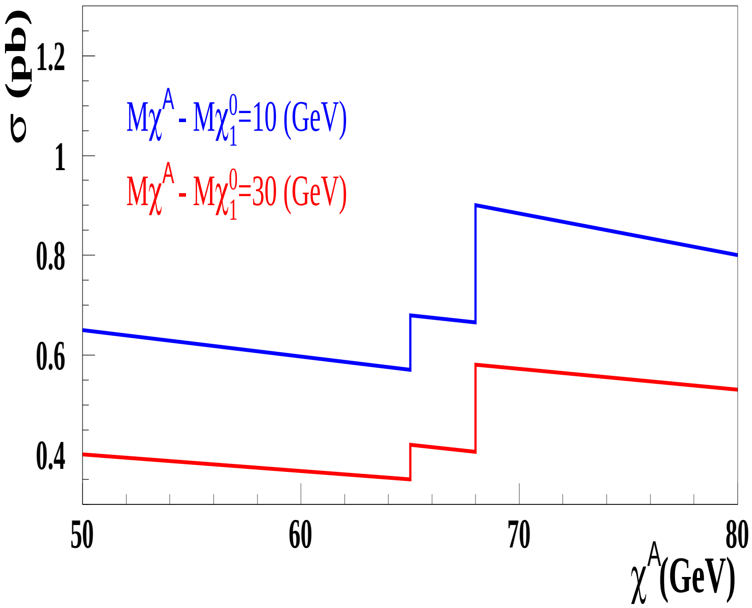

Figure 15: Upper limit on the cross section for chargino production at 161 GeV e^+e^- c.m. energy [61](prel.). The limit is given for two values of ΔM_χ as a function of $M_{\chi^\pm}$.

6.2.2 Neutralinos

Constraints on the lightest neutralino χ^0 are less general. The Z^0 widths provide information to the extent in which a neutralino couples to the Z^0, i.e. only if it has a reasonable higgsino component. Additional, more model dependent, limits are due to searches for χ^0_2 in the reaction $e^+e^- \to \chi^0_1\chi^0_2$ or $\chi^0_2\chi^0_2$ at the Z^0 or at higher energies. With a grain of salt one can say that a 'higgsino like' χ^0_1 must be heavier than $\sim$ 45 GeV [67, 68, 69, 70].

A neutralino with a dominant gaugino character could be produced in association with sfermions in t-channel reactions like $e^+e^- \to \tilde{\gamma}\tilde{\gamma}$ or $eq \to \tilde{e}\tilde{q}$. Limits from the non-observation of these processes depend on sfermion masses. The H1 collaboration, for example, excludes such a neutralino of mass less than 30 GeV, if $(m_{\tilde{e}} + m_{\tilde{q}})/2 \leq$63 GeV [71].

The various results can be combined in a stringent way in terms of the MSSM parameters. The excluded region for a low and high $\tan\beta$ value in the μ vs. M_2 plane is shown in Fig. 17 [64]. Similar results are are also presented in [72, 73, 61]. Chargino searches exclude in general a larger range in the parameter space. Since chargino and neutralino masses are related by the MSSM parameters, indirect constraints on neutralino masses can be obtained that are stronger than those from direct searches. ALEPH, for example, finds $m_{\chi^0} >$20.4 GeV for any $\tan\beta$ if $m_{\tilde{\nu}} > 200$ GeV [72]. By the same token even stronger limits can be derived using relations between sfermion and -ino masses as suggested in SUGRA models [74]. The H1 measurement [71] excludes the region $\mu <$-50 GeV and $M_2 \leq$60 GeV for small $\tan\beta$ if sfermions are light.

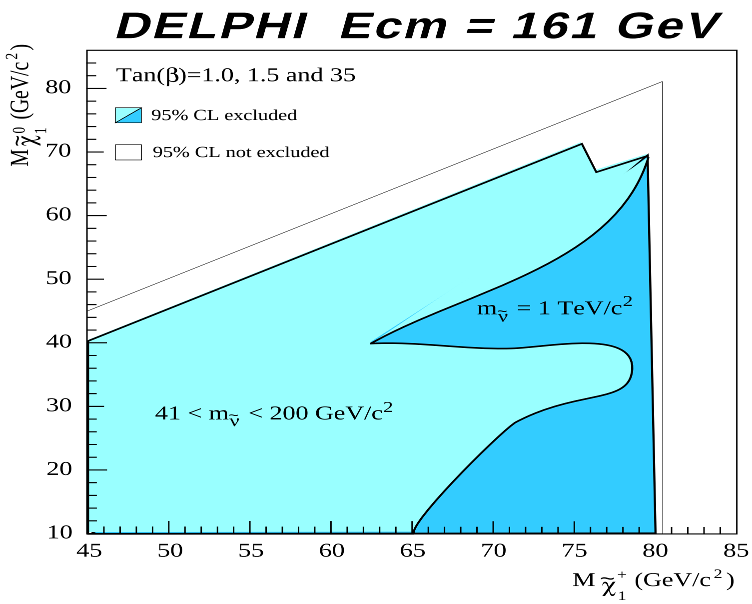

Figure 16: Preliminary limits on the chargino mass as a function of the neutralino mass [63]. Also visible is the dependence on the $\tilde{\nu}$ mass.

6.2.3 Sfermions

The strongest limits on squarks and gluino masses are set by D0 and CDF. Similarly to what has been discussed for the chargino signature, the experimental sensitivity depends on how squarks and gluinos decay and on the mass of the LSP. Squark and gluino searches are traditionally based on a multijet plus missing E_T signature [65, 75]. Recently CDF [76] and D0 [77] have extended their analysis to cascade decays like $\tilde{q} \to q\chi^{\pm} \to ql^{\pm}\nu\chi_1^0$ and similarly for the gluino. The main experimental issue for the missing E_T channel is to be safe from tails of the experimental resolution. This limits the analyses to $\Delta M_{\tilde{q}} >$ 15-30 GeV, depending on the squark and gluino masses. Isolated leptons from chargino decays are a rather clean signature, but suffer from the low branching ratios. Such an analysis could therefore only be performed on the basis of the recently collected large luminosity, but will be of growing importance in the next collider runs.

No signal is observed. This non-observation can be translated into limits on squark and gluino masses using supergravity models. They imply that, with the exception of the stop quark, all other squarks have essentially the same mass, and yield relations between masses of sfermions and gauginos. The exclusion range is shown in Fig. 18. The part $m_{\tilde{q}} < m_{\tilde{g}}$ is obtained by fixing the slepton mass $m_{\tilde{l}}$ to 350 GeV and thus allowing $m_{\tilde{q}} < m_{\tilde{l}}$, a condition, which is unphysical in SUGRA models. With the important exception of very light gluinos of a few GeV, gluinos must be heavier than 180 GeV. Assuming $m_{\tilde{q}} = m_{\tilde{g}}$ they must be heavier than ~230 GeV.

Whereas the $\tilde{u}$, $\tilde{d}$, $\tilde{s}$, $\tilde{c}$, and possibly the $\tilde{b}$ are expected to be degenerate in mass, the stop squark is special. The large top Yukawa coupling leads to large radiative corrections which may render the stop squark light. The left and right $\tilde{t}$ mix to give a mass eigenstate

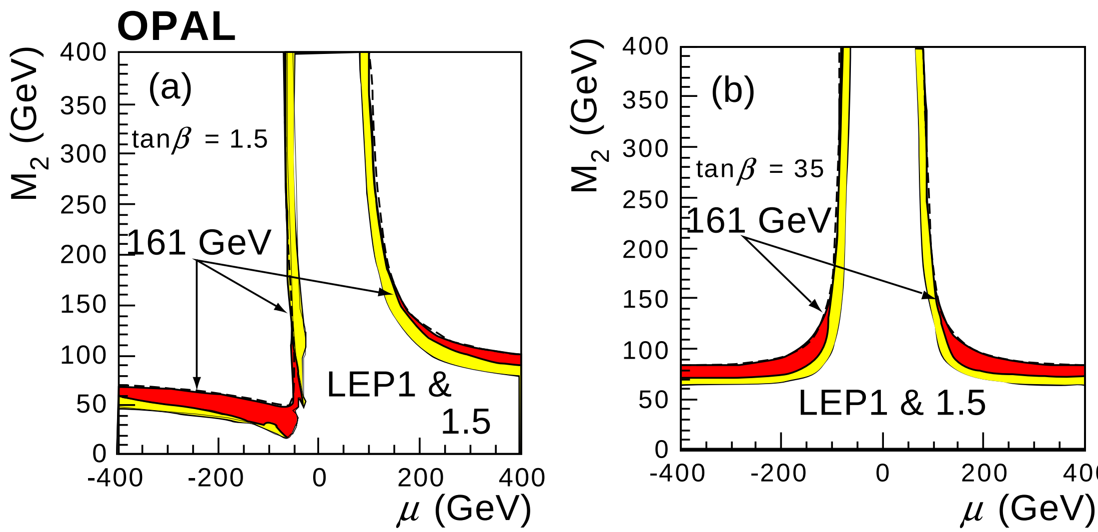

Figure 17: Excluded MSSM parameter space from chargino and neutralino searches at LEP [64]. The shaded areas show the gain from the 161 GeV data. The light shaded area shows the case of minimum m_0, the dark area the case for m_0= 1 TeV.

of the lighter stop $\tilde{t}_1$

$$\tilde{t}_1 = \cos\theta_{\tilde{t}}\tilde{t}_L + \sin\theta_{\tilde{t}}\tilde{t}_R.$$

Stops are of special interest because they could be the lightest charged SUSY particle. The interest is currently further enhanced because, as mentioned above, a light stop could increase beauty production in Z^0 decays. Given that $m_{\chi^\pm}$ is larger than 60 GeV, the dominant decay modes in the relevant mass ranges are $\tilde{t}_1 \to c\chi^0_1$. $\tilde{t}_1 \to bl\tilde{\nu}$.

Searches for stop squarks have been performed at LEP and the Tevatron. Because the $Z^0\tilde{t}_1\tilde{t}_1$ coupling is helicity dependent, it varies with $\theta_{\tilde{t}}$ and the cross section has a minimum for $\theta_{\tilde{t}} \sim 0.98$. This leads to a $\theta_{\tilde{t}}$ dependent sensitivity for the LEP experiments. No significant signal has been observed. Depending on $\theta_{\tilde{t}}$ this translates into limits on the stop mass from DELPHI and D0 as shown in Fig. 19 [73, 75]. The DELPHI limits are similar to those obtained by the other LEP collaborations [62, 61, 78]. The D0 collaboration excludes even heavier stops up to $m_{\tilde{t}_1}$ =90 GeV provided that $\Delta M_{\tilde{t}}$ >30 GeV [75]. Not included in the analysis are possible decays $\tilde{t}_1 \to b + W + \chi^0_1$ which become relevant for $m_{\tilde{t}} > 85$ GeV.

The most stringent limits on sleptons come from LEP. In Z^0 decays selectrons, smuons and staus could be excluded up to masses of 45 GeV. The data taken above the Z^0 allow higher limits to be set for $\tilde{e}$ and $\tilde{\mu}$. The excluded region for selectrons as obtained by the ALEPH collaboration is shown in Fig. 20 [62]. One candidate is found in agreement with the expected Standard Model background and for $\Delta M_{\tilde{e}} = M_{\tilde{e}} - M_{\chi^0_1}$ >2.5 GeV, selectron masses of less than 60 GeV can be excluded. Similar results have been obtained by the other LEP experiments [62, 79, 80]. The H1 analysis on associated selectron squark production mentioned above [71] can also be translated into selectron limits of $m_{\tilde{e}}$ >82 GeV, if the squark mass is 45 GeV and $m_{\chi^0_1}$ <35 GeV.

Up to now only negative searches could be reported. Actually, some people suggest,

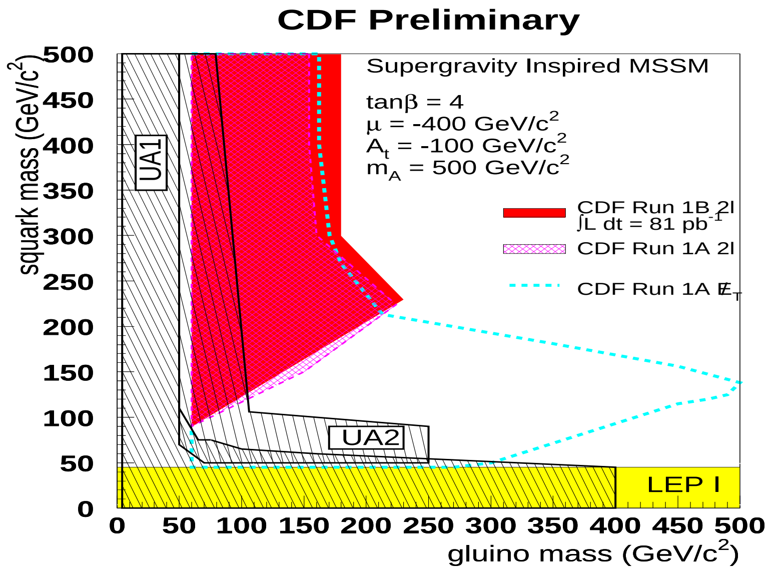

Figure 18: Excluded squark and gluino masses within SUGRA models assuming the parameters listed [65]. The dark shaded region is obtained from dilepton searches, the dotted line indicates limits from the missing E_T search.

SUSY has already been observed! The CDF collaboration reported a spectacular event with two high energy electrons, two high energy photons and substantial missing energy, Fig. 21 [81]. As suggested in [82] one explanation could be the production of a pair of selectrons which decay via

$$\tilde{e}^+\tilde{e}^- \rightarrow e^+\chi_2^0 e^-\chi_2^0 \rightarrow e^+\gamma e^-\gamma \not{E}_T$$

Other non - Standard Model explanations for this event have been put forward. Many imply the existence of similar types of events. However, no such event has been reported yet by either CDF or D0. Analyses at LEP also find no support of these models [5]. A Standard Model explanation could be a double radiative W pair. As we have seen at this conference, one should be cautious of processes with seemingly low probability. Before jumping on any firm conclusion, more events should be found. Up to then there is a lot of room for speculations.

7 Conclusions - the next two Years

What remains of last years' excitement of beyond the Standard Model candidates is not very much:

- The beauty excess in Z^0 decays has shrunk and the LEP average agrees nicely with the Standard Model expectation.
- The four -jet peak at $M_\Sigma \sim 105$ is only observed by one of four experiments.

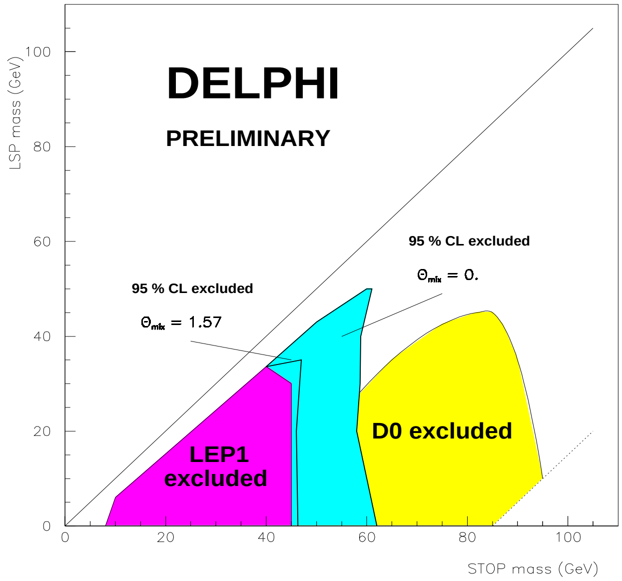

Figure 19: Excluded region of stop masses as a function of $m_{\chi_1^0}$. A mixing angle of $\theta_{\tilde{t}}$=0 was assumed for the LEP result [73, 75].

- The excessive 2-jet production at high E_T at the Tevatron can be explained by modified structure functions.

In conclusion, the Standard Model has survived another two years and it seems more healthy than a few months ago. It is not the first time that experimental indications of new effects disappeared, while the Standard Model persisted. This may be one of the most convincing argument in favour of the strength of the Standard Model at least in the $\leq$ 100 GeV range. It is strong enough to not be disturbed by any of the meanwhile highly precise and comprehensive measurements. However, as mentioned above, it has unaesthetical features and there is a strong belief that at higher masses it has to be extended.

What are the chances for the final challenge until the next Rochester conference? The Tevatron will take a three years' break before having another go, then with the substantial 10-20 fold increase of luminosity. Of course, a deeper analysis of the recently accumulated data may reveal new insights. HERA hopes during the next couple of years for an increase of luminosity by some factor four. The LEP energy will be gradually increased to 192 GeV, and it is fair to say that most of the burden to defeat the Standard Model will be on its shoulders. Actually, while writing this summary, data are taken at an e^+e^- energy of 172 GeV. They imply an increase in the sensitivity of about 10 GeV.

The prospects to discover new particles are not bad: a Standard Model Higgs can be discovered if its mass is less than $\sim$ 95 GeV, some 30 GeV above the present limit and approaching the upper limit allowed in MSSM. As can be seen from Fig. 22, LEP is sensitive to a large region of the MSSM parameter space. If no Higgs is found, for example, for the first time an absolute limit of $\tan\beta$ >2.5 can be set. Charginos or sfermions can be observed if their masses are lower than 90 GeV.

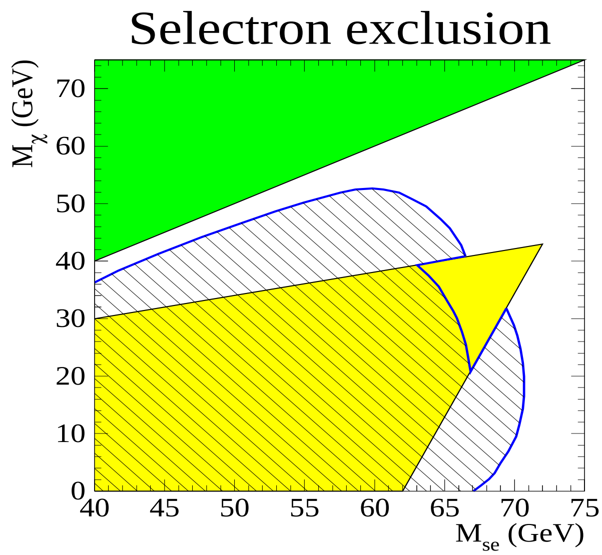

Figure 20: Excluded region (hatched) of selectron masses as a function of $m_{\chi_1^0}$ [62] (prel.). The grey shaded region indictes the kinematically allowed range of the candidate event. The dark grey area is kinematically forbidden.

But note, these points are only the 'expected' new effects. There are many other, though currently less favoured possibilities for a break-down of the Standard Model . It is important to keep an open eye for all of those.

Acknowledgements

In preparing the talk I profited from discussion with numerous experimental and theoretical colleagues. In particular I am grateful to P.Zerwas for his advice. I also would like to thank him and J.Kalinowski for carefully reading the manuscript and clarifying remarks.

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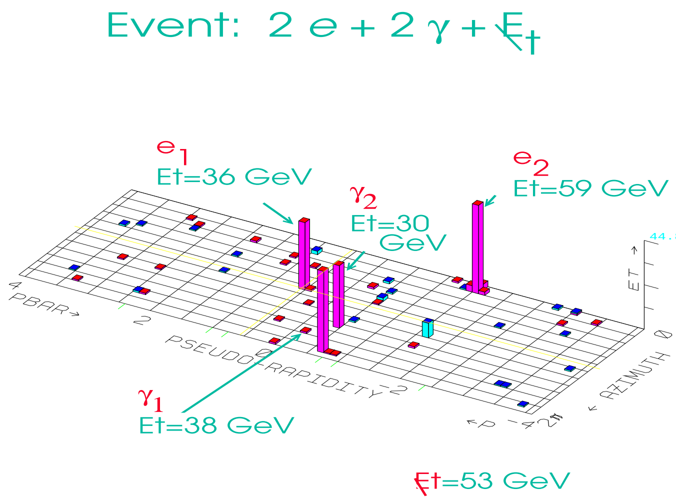

Figure 21: CDF event with two high energy electrons and photons and missing E_T [81].

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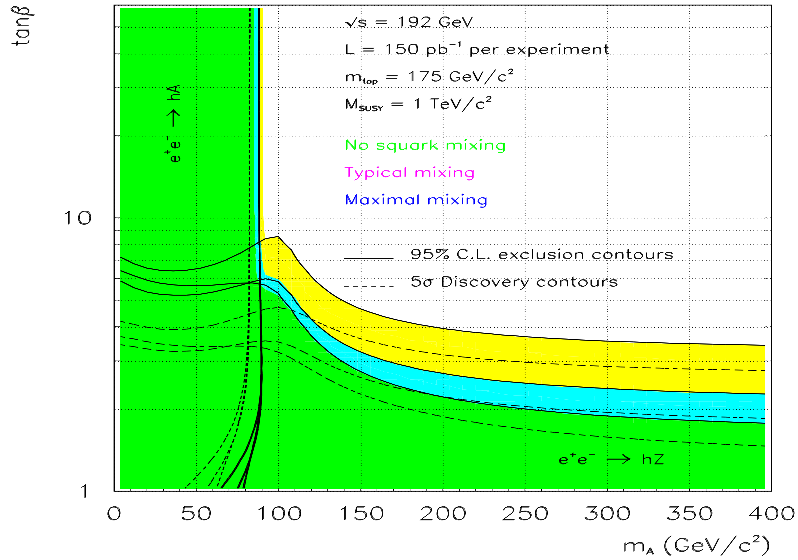

Figure 22: Sensitivity range at LEP2 to MSSM parameters [83].

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Questions

G.Wilson, DESY,Hamburg:

Regarding the Standard Model Higgs search at LEP1: I do not see how the 66 GeV lower mass limit can be valid, given that there is evidence that far fewer candidate events have been selected by the four LEP experiments combined compared to the number of expected background events (21.5 expected, 10 observed).

P.Mättig:

For each individual experiment and also for the combined numbers, expectations and observations differ by at most three standard deviations. This cannot be claimed a significant disagreement. In addition the limit would also only be strongly affected if more candidates are closely be low the 66 GeV limit. However, at least the published candidate events are spread over a large mass window. On the other hand, looking at various analyses, one might get the impression, that there is a trend towards having less events than expected from background studies. It may point to a rather conservative attitude by my experimental colleagues.

K.Lane, Boston:

For the ALEPH 4-jet events, can you explain why the dijet mass difference $(M_{ij} - M_{kl})$ is much broader than the mass sum $(M_{ij} + M_{kl})$.

J.Lefrancois, Orsay:

Answer: the larger resolution on the difference is purely a kinematical effect after you impose a 4C fit.

G.Farrar, Rutgers:

Comment: the stop, chargino and neutralino mass limits are invalid if gluinos are light so they do not decay to LSP and instead have hadronic final states.

P.Mättig:

This is correct. In general, one should be aware that all SUSY analyses and their interpretations invoke several assumptions. In particular these may vary among the different experiments. It is important that these are clearly stated.

M.Macri, Genova:

Is there any analysis of CDF or D0 data in the mass region of the events reported by ALEPH in the LEP 1.5 run?

P.Mättig:

Nothing has been submitted to or reported at the conference. One should note that, because of the large QCD background, Tevatron experiments may have difficulties in extracting purely hadronically decaying narrow resonances.