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Physics Beyond the Standard Model: Experimental

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The search for physics beyond the Standard Model includes Technicolor particles, Higgs Bosons, compositeness, many variations of Supersymmetry, large extra dimensions, model-independent searches for anomalies, and other topics. This article reports a subset of these ongoing searches at the high-energy colliders, Tevatron, HERA and LEP.

1. Introduction

At the time of the DPF 2000 conference in August 2000, the HERA accelerator at DESY and the LEP accelerator at CERN are collecting data at the highest energies and luminosities. In addition, the Tevatron run, which was completed in 1996, continues to produce new physics results. This article gives an overview of the experiments' results in the pursuit of physics beyond the Standard Model.

The most general searches look for any deviations from the Standard Model. These model–independent treatments are a growing methodology for the most inclusive searches. They attempt to scan all the measurable signatures and phase space but are not necessarily maximally efficient for a particular model. The opposite approach, examining a specific proposed model of new physics will be more efficient for finding that model, but loses some efficiency for other, possibly as yet unknown, models. The latter is more common to date but a mixture is more likely to be pursued in the future.

Most of the proposed models of new physics that the accelerators address predict new particles which may be produced in collisions or may manifest themselves as effects in the measurements of Standard Model parameters. This article concentrates on the production of new particles at the colliders; other measurements, such as the W boson mass and B meson mixing, and their relation to physics beyond the Standard Model may be found elsewhere in these proceedings.

Some models are incremental additions to the Standard Model such as fourth generation quarks or additional gauge bosons. Others propose new interactions such as Technicolor. Supersymmetry introduces a new symmetry which implies doubling the particle spectrum. Technicolor and Supersymmetry are examples of theories that explain the hierarchy problem: why the electroweak scale is so much smaller than the Planck scale. This review will briefly address each theory as the relevant results are presented. The major sections of this paper are Tevatron results, HERA results, and LEP results.

2. Tevatron

In the last run of the Tevatron experiments, CDF and DØ, studied 120 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s}$ of 1.8 TeV. The results of the Tevatron searches have been published over the past several years and continue at this time. The next sections report a sampling of more recent results.

2.0.1. *SUSY Higgs Bosons*

Supersymmetry requires two Higgs doublets to cancel anomalies. After electroweak symmetry breaking, there are five physical Higgs bosons: lighter CP-even h, heavier CP-even H, CP-odd A, and the charged $H^{\pm}$. As Higgs bosons, these couple strongly to heavy quarks and, in the SUSY framework, they couple proportional to $\tan\beta$, a SUSY parameter. This allows a large cross section for production as emission from an off-shell b quark produced in a QCD $b\bar{b}$ event. Since the Higgs particles decay to $b\bar{b}$ 90% of the time at large $\tan\beta$, this would lead to the signature of four b quarks and good sensitivity if $\tan\beta$ is large.

CDF has performed this search[1] in events collected with a multi-jet trigger. The requirements are four jets with $E_t > 15$ GeV and three of the jets must be tagged as containing a b quark by using the silicon microstrip detector to find secondary vertices in the jet. The resulting limits are presented in Figure 1.

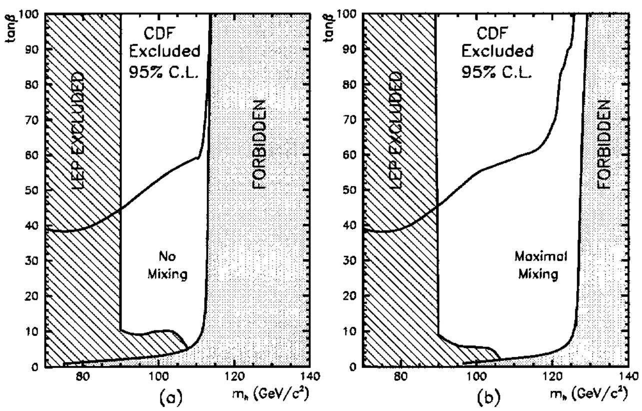

Fig. 1. The limits from the CDF search for SUSY Higgs produced in QCD $b\bar{b}$ events leading to four–b events.

2.0.2. *Technicolor and SUSY with Heavy Flavors*

Technicolor proponents make the case that there is no need for the Higgs boson proposition in order to solve the hierarchy problem.[2] All the functions of the Higgs could also be provided by a new strong QCD-like force called Technicolor. There would also be a new set of fermions with the Technicolor charge, both Techniquarks and Technileptons. The quarks would form new Technimesons such as π_T, which mix with the W to perform electroweak symmetry breaking. Other mesons such as the Technirho, ρ_T, would be produced strongly and decay to Technipions. The π_T^0 decays to $b\bar{b}$ and $\pi_T^{\pm} \to bc$.

In the scenario investigated here,[3] a color–octet ρ_{T8} decays to two Technileptoquarks, particles which carry both lepton and baryon number. These arise when quarks and leptons are included in a single group structure. The leptoquarks carry generation indices and $LQ \to c\nu_\tau$ and $\to b\nu_\tau$, as well as the equivalent charged lepton modes. The signatures are then $c\bar{c}\not{E}_t$ and $b\bar{b}\not{E}_t$, which CDF has searched for in 88 pb^{-1}. In a sample acquired by a $\not{E}_t$ trigger, two jets and $\not{E}_t > 40$ GeV are required. The jets are required to be "tagged", to have tracks displaced from the primary interaction point, consistent with a c (loose cuts) or b (tighter cuts) meson lifetime. The results are consistent with expectations and are presented in Figure 2. The same sample was originally created to search for a SUSY signature[4].

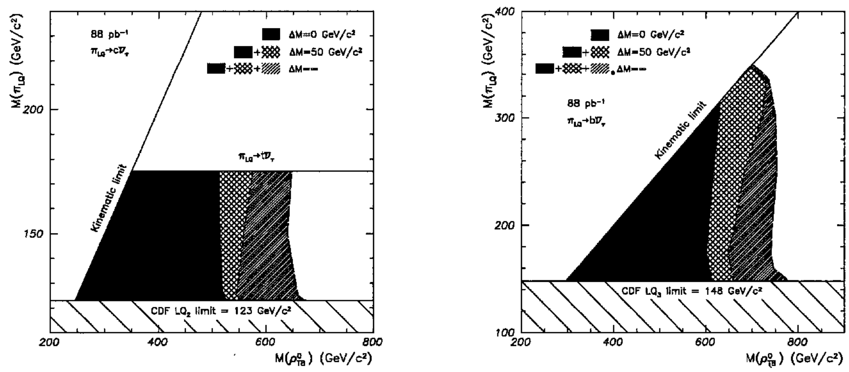

Fig. 2. The limits from the CDF search for a Technicolor color–octet ρ_{T8}, decaying to a pair of leptoquarks which decay to $c\nu_\tau$ or $b\nu_\tau$ giving rise to the signatures $c\bar{c}\not{E}_t$ $b\bar{b}\not{E}_t$.

2.0.3. *R-parity Violating SUSY*

One of the major divisions of SUSY theories arises from whether R–parity is assumed to be conserved or violated (RPV). This parity is given by $(-1)^{L+3B+2S}$ and has the value 1 for Standard Model particles and -1 for SUSY particles. If it is conserved, then the lightest SUSY particle (LSP) must be stable. If the LSP were charged, it would be easily observed, so it also must be neutral which translates to missing E_t in a collider. In addition, SUSY particles must be produced in pairs. If R–parity is not conserved, particles can be singly produced (although pair production often still dominates) and can decay to all Standard Model particles. The decays proceed via one of three allowed couplings: a slepton decaying to two leptons (λ_{ijk}, violating lepton number), a squark decaying to a lepton and quark (λ'_{ijk}, violating lepton number), and a squark decaying to two quarks (λ''_{ijk}, violating baryon number). Many limits on these couplings are provided by rare decays, including proton decay, and other experiments.

In the Tevatron searches for RPV SUSY, pair production of charginos and neutralinos is assumed. These decay to leptons, quarks and the $\tilde{\chi}_1^0$. The $\tilde{\chi}_1^0$ then decays to leptons, via virtual sleptons, for example: $\tilde{\chi}_1^0 \to \nu\tilde{\nu} \to \nu e^{\pm}\mu^{\mp}$. The final state is four leptons and missing E_t. The DØ search[5] re-uses a previous search for three lepton events which requires three identified e's or μ's with $E_t > 5 - 10$ GeV and missing E_t. The CDF search[6] requires four identified leptons, with no isolation requirement. The resulting limits are presented in the $m_0 - m_{1/2}$ minimal SUGRA plane in Figure 3.

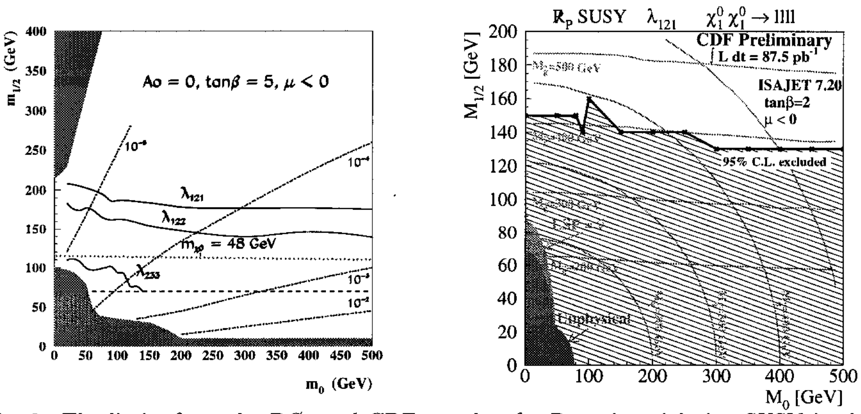

Fig. 3. The limits from the DØ and CDF searches for R-parity-violating SUSY in the multi-lepton signatures. In the DØ analysis, the excluded region is below the solid line indicated for λ_{ijk} and above the dotted line indicating the value of that λ. The CDF limit assumes a large λ_{121}.

2.0.4. *Large Extra Dimensions*

Recently it was realized that if the multiple extra dimensions studied in string theory were not tightly curled, but rather loosely curled up or "large", there would be important, observable consequences.[7] The extra dimensions decrease the effective Planck scale, the scale where gravity becomes strong: $M_S^2 = M_{\text{Planck}}^2/R^n$ where M_S is the effective planck scale, R is the radius of the extra dimensions, and n is the number of extra dimensions. For example, for M_S of about 1 TeV, we could have two extra dimensions of radius 1 mm.

When the extra dimensions are this large, they can distort gravity on the scale of the dimension radius. For $r < R$, the gravitational potential goes as $1/r^{n+1}$ instead of $1/r$. The scale of the current limits in table-top measurements of gravity is on this order. Figure 4 shows the current limit from one such experiment.[8] In this experiment, the response of a mechanical oscillator is observed as a function of the distance to a nearby mass. The current experiment is limited by thermal noise, so a new generation is planned which employs a cryogenic apparatus.

With large extra dimensions, gravitons become phenomenologically important at colliders. Gravitons can travel in the extra dimensions while the other gauge particles are trapped on a surface called a brane, representing our three space and one

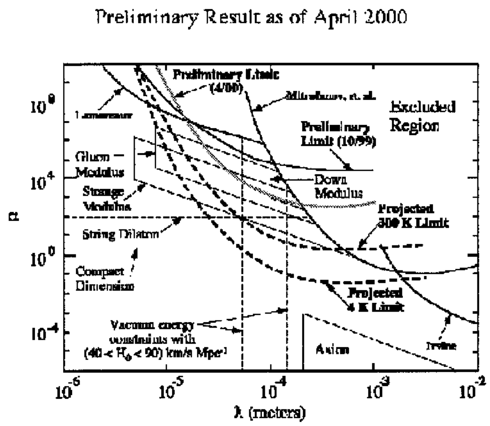

Fig. 4. The current limits on anomalous gravity from the Cavendish–style experiment of J. Price *et al.*[8]

time dimensions. The graviton has many excitations in the extra dimensions, which appear as a Kaluza–Klein tower of graviton states each with slightly different mass. The graviton couples to all familiar particles via their stress–energy tensors. Each graviton state couples with a very weak gravitational strength but the cumulative effect of the tower of states is observable.

DØ has searched[9] for the effect of these extra dimensions. A graviton could be produced in the s channel, which then decays to a particle and anti-particle pair causing a wide bump in the two–particle mass spectrum[7]. In their search, DØ has combined both the e^+e^- and $\gamma\gamma$ searches, where the experiment is most sensitive, into a search using all events with two electromagnetic clusters. The mass spectrum is shown in Figure 5.

A fit to both the mass spectrum and the $\cos\theta^*$ spectrum (which would also be distorted), yields limits shown in Figure 5. The cross section is particularly simple: $\sigma = \sigma^{\mathrm{SM}} + (F/M_S^4)\sigma^{\mathrm{int}} + (F/M_S^4)^2\sigma^{\mathrm{KK}}$. The three terms are the Standard Model Drell–Yan, an interference term and an LED term; M_S is the redefined Planck scale, also called the string scale. F is a parameter of order ± 1 which depends on the details of the theory calculations.[10,11]

2.0.5. *DØ Model-independent Search*

The search for new physics has become more complex over the years as more and more phenomenology has been developed. While most theories have significant numbers and ranges of parameters, SUSY is particularly difficult, with hundreds of parameters with an almost unlimited spectrum of potentially observable models. Due to this effect, the collaborations are developing plans to make generalized searches for anomalous events, without regard to the model that might give rise to the events. These searches would be wide-ranging, encompassing as many topologies as possible.

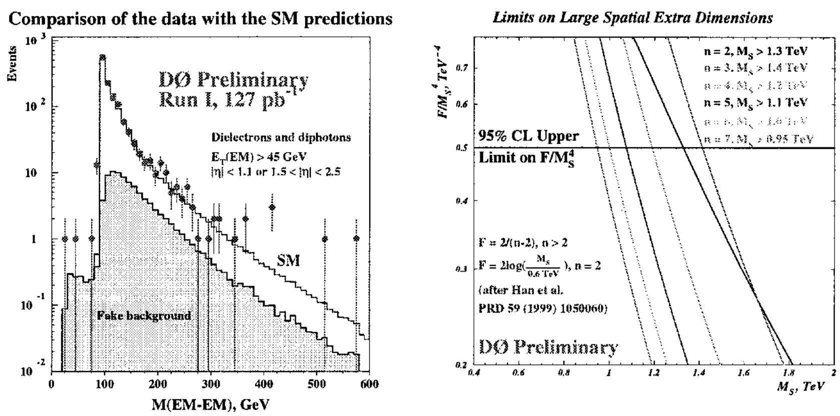

Fig. 5. The two-cluster mass from the DØ search for large extra dimensions in two electromagnetic clusters and the limits from the search. The limit for $n = 5$ corresponds to the convention with $\lambda = 1^{10}$.

By making a general search, the fluid nature of model building is recognized, as opposed to the permanent nature of the observations. This promotes general experimental limits which will be more suitable to apply to future models as they appear. Hopefully, by looking at as many signatures as possible, this approach will be more likely to hit upon the particular excess that nature might provide. On the other hand, a model-focused search has greater sensitivity for the one particular model. A very–well motivated or simple model, such as the search for the Standard Model Higgs, would still be investigated as a model-driven search.

Sleuth is a worked example of a general model–independent search, performed by DØ.[12] In this example, the data sample is events with both a high-P_t e and μ and $\not{E}_t$ – many models of new physics could produce this signature. Sleuth defines an exact prescription for sorting the events into signatures, for example, by counting the number of jets, and selects variables (such as lepton P_t) which should reflect evidence of a new high–mass particle. The distributions of these variables are searched for excesses, also by a fixed prescription. All excesses are summarized as a series of probabilities that the observations are consistent with Standard Model backgrounds. The benefit of the fixed prescriptions is that any anomalous event or events can be categorized and selected *a priori*, which is critical to computing the significance of the excess.

In the application of this method to the $e\mu$ sample, there are two significant physics backgrounds: WW production in the zero-jet bin and $t\bar{t}$ in the two–jet bin. These backgrounds are first ignored, as a check, showing the method "discovers" the excess, then they are included for the actual search. The results are summarized in Table 1.

3. HERA

The two collider experiments at HERA, H1 and ZEUS, have been collecting e^+p

Table 1. Probabilities that exclusive signatures are consistent with backgrounds in the DØ $e\mu$ sample. The first probability ignores the background contribution from $t\bar{t}$ and WW.

Signature	Obs	Exp	prob$_{\text{no } t\bar{t},WW}$	prob
$e\mu\not{E}_t$	39	48.5 ± 7.6	0.008	0.14
$e\mu\not{E}_t j$	13	13.2 ± 1.5	0.034	0.45
$e\mu\not{E}_t jj$	5	5.2 ± 0.8	0.01	0.31
$e\mu\not{E}_t jjj$	1	1.3 ± 0.3	0.38	0.71
$e\mu\not{E}_t$ all				0.72

and e^-p data since 1992. The experiments' primary focus is proton structure, but they have comparable or better sensitivity in several searches for new physics, compared to other collider data available. Up to 1999 they have collected approximately 40 pb^{-1} e^+p at $\sqrt{s} = 300$ GeV, 15 pb^{-1} e^-p at $\sqrt{s} = 318$ GeV, and 20 pb^{-1} e^+p at $\sqrt{s} = 318$ GeV, per experiment.

Single leptons produced with missing E_t are the signature of single W production which occurs at a low rate at HERA. This signature is also consistent with new physics, for example, an R-parity-violating squark. Table 2 shows the results of H1[13] and ZEUS[14] searches for this signature. Figure 6 shows the H1 muon data and the ZEUS lepton data. There exists a possible excess in the H1 data, slightly larger at high P_T^X, but not confirmed in the ZEUS data.

Table 2. Summary of the HERA searches for events with a high-p_t lepton and missing E_t. P_T^X is the vector sum of all transverse energy except the lepton.

	ZEUS		H1	
	'94-'99	'94-'99 $P_T^X > 25$ GeV	'94-'00	'94-'00 $P_T^X > 25$ GeV
e observed	7	1	6	3
e expected	6.1 ± 0.9	0.8 ± 0.04	6.1 ± 1.5	1.1 ± 0.3
μ observed	4	0	8	6
μ expected	3.7 ± 0.4	0.8 ± 0.1	2.0 ± 0.5	1.2 ± 0.3

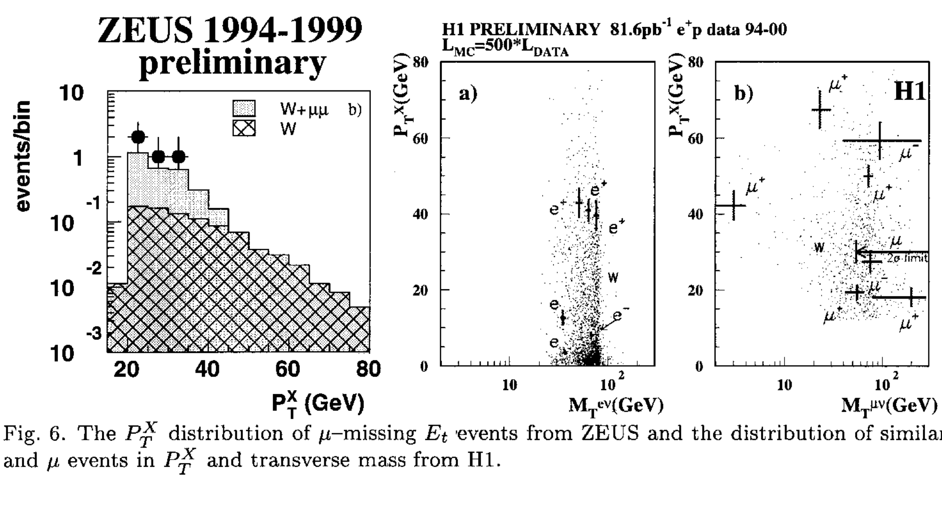

Fig. 6. The P_T^X distribution of μ–missing E_t events from ZEUS and the distribution of similar e and μ events in P_T^X and transverse mass from H1.

The HERA experiments perform several other searches. The neutral current $d\sigma/dQ^2$ spectrum would be altered by the virtual exchange of several particles such as composite quarks, high-mass leptoquarks, and gravitons in large extra dimensions theories. Compositeness searches[15] are summarized in Table 3. Large extra dimensions would reveal themselves as an exchange of Kaluza-Klein gravitons leading to a distortion in the cross section. H1 sets limits on M_S of 0.63 TeV ($\lambda = 1$) and 0.93 TeV ($\lambda = -1$).[15]

Table 3. Summary of the H1 searches for compositeness couplings based on the $d\sigma/dQ^2$ spectrum.[15]

	Compositeness Couplings Limits in TeV								
Coupling	LL	LR	RL	RR	VV	AA	VA	LL+RR	LR+RL
Λ^- (TeV)	1.6	1.8	1.9	1.6	3.0	5.8	4.0	2.0	2.1
Λ^+ (TeV)	4.3	5.4	5.4	4.3	9.2	3.5	3.9	5.9	7.4

Leptoquarks are particles that carry lepton and baryon number. They appear in theories that unite leptons and quarks in a single group structure. They may have charges of 1/3 to 5/3, may have left– or right–handed couplings and may be scalars or vectors. A sample of representative limits[16] from direct and indirect searches are shown in Figure 7.

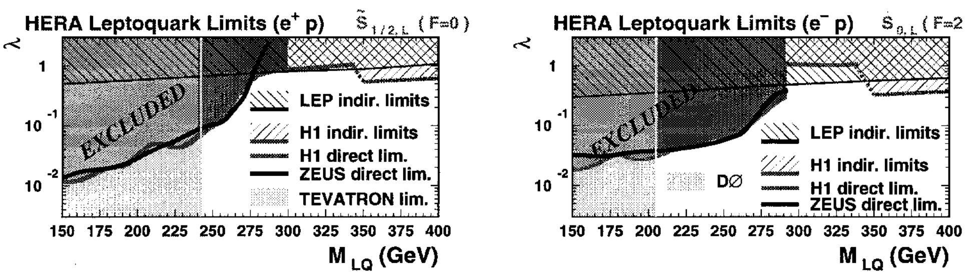

Fig. 7. Two of the leptoquark limits from HERA experiment H1.

4. LEP

The LEP experiments at CERN are continuing to collect e^+e^- data in August 2000 and this final run of LEP will end sometime during the fall. Since data taking is continuing, new developments in searches will occur. The results presented here represent the state of the searches at the LEP Committee meeting on July 20, 2000. The data is approximately 90 pb^{-1} per experiment in 2000. Most data was taken with a center of mass energy of 206 to 207 GeV, with a few percent taken at energies up to 210 GeV.

4.1. *Higgs Searches*

The search for the Standard Model Higgs boson in the Zh channel provides a limit at 113.4 GeV at 95% confidence level.[17] The search for the SUSY Higgs bosons uses the search for the Standard Model boson in the region of phase space where it is efficient, large $\sin(\beta-\alpha)$, where β is the usual SUSY parameter and α is the mixing between the neutral CP-even Higgs. In the region of large $\cos(\beta-\alpha)$ the search for $Z^* \to hA$ is added, which increases the prediction for $(b\bar{b})(b\bar{b})$ and $(\tau\tau)(b\bar{b})$. The exclusion[18] is shown in Figure 8 for two scenarios. For no stop quark mixing (which effects the predicted Higgs mass through renormalization), the limits are $M_h > 90.4$ GeV, $M_A > 90.5$ GeV and $\tan\beta < 0.4$ or > 7.7. For maximal stop mixing, the limits are $M_h > 90.5$ GeV, $M_A > 90.5$ GeV and $\tan\beta < 0.5$ or > 2.3. These limits are general, applying to all MSSM models.

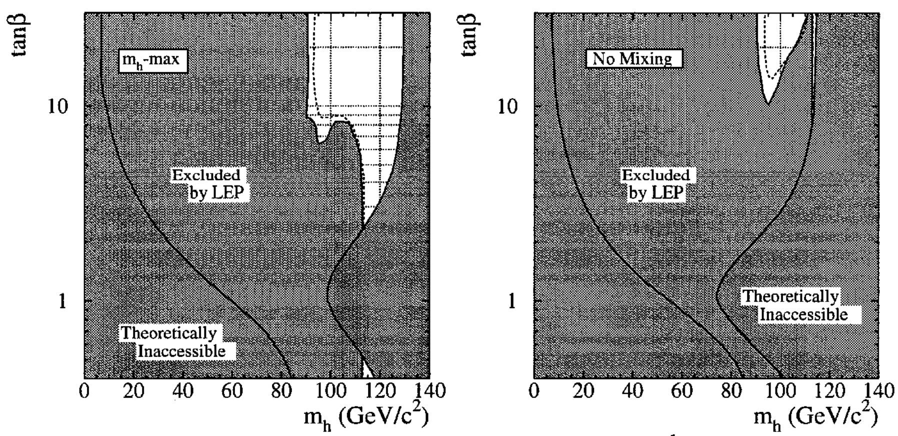

Fig. 8. The combined LEP limits on the SUSY Higgs with 90 pb^{-1} per experiment on July 20, 2000.

The MSSM also predicts a charged Higgs particle, which can be produced directly. The charged Higgs decays to $c\bar{s}$ or $\tau\nu$ so that the signatures are $c\bar{s}\bar{c}s$, $c\bar{s}\tau\nu$ and $\tau^-\bar{\nu}\tau^+\nu$. The current limits[18] are $M(H^\pm) > 77.4$ GeV for all combinations of branching ratios, $M(H^\pm) > 88$ GeV when the $\tau\nu$ branching ratio is one. The mixing of a two Higgs doublet model can be arranged such that the lightest Higgs decays only to bosons. Below the WW threshold, $\gamma\gamma$ dominates. This Higgs is excluded below a mass of 106.4 GeV. If the lightest Higgs were to decay to invisible particles, such as SUSY neutralinos, it could still be observed in Zh production as a Z and missing energy. This Higgs is excluded below 107.7 GeV if it decays invisibly 100% of the time.

4.2. *Extra Dimensions Searches*

The LEP E^+e^- collisions are sensitive to the Kaluza–Klein gravitons in two ways. The first is the s–channel production of a graviton, decaying to a pair of fermions or bosons, all of which have been searched for[19]. The LEP searches find limits on M_S as large as 1.2 TeV for $\lambda = -1$ and 1.3 TeV for $\lambda = +1$.[19] The second sensitive process is the emission of a graviton (causing missing energy) balanced by a photon or Z in the t channel. Limits on M_S are in the range 0.8-1.25 TeV from the γ

search; the Z searches are less sensitive.

4.3. *SUSY Searches*

The SUSY search results from the LEP experiments include a now-standard set of searches for charginos, neutralinos, sleptons and squarks in the most likely MSSM scenarios as well as a growing body of searches covering rare decays, R–Parity violation and other models such as gauge-mediated SUSY (GMSB).

Charginos would be pair-produced and would likely decay to $W\tilde{\chi}_1^0$ with the W decaying to $\ell\nu$ or $q\bar{q}$. These lead to limits on the chargino mass of 103.1 GeV if $M(\tilde{\nu}) > 300$ GeV (so it doesn't spoil the cross section) and $M(\tilde{\chi}_1^\pm) - M(\tilde{\chi}_1^0) >$ 10 GeV. [20,21] When these conditions are not met, the limits decrease to order 90 GeV. Limits on neutralinos are more complex, coming from the chargino limits using the chargino–neutralino mass matrix and the assumption of the unification of parameters M_1 and M_2, as well as less sensitive direct searches for decays via a virtual Z. With the assumptions of M_1, M_2 unification and large m_0, the limits from charginos and neutralinos imply a limit on the LSP of $M > 38.2$ GeV (for $\tan\beta = 1$, the worst case). If $\tan\beta > 2$, as implied by the SUSY Higgs search, $M > 49$ GeV.[22]

In the GMSB scenario, the Gravitino is very light and becomes the LSP. If the $\tilde{\chi}_1^0$ is the next–to–lightest SUSY particle, it can decay to $\gamma\tilde{G}$, yielding the signature $\gamma\gamma$ and missing energy. In this scenario, the $\tilde{\chi}_1^0$ is limited to be more massive than approximately 90 GeV.[20,23]

Standard searches[20] for pair-produced light squarks include the SUSY top quark (stop) in its decay modes of $c\tilde{\chi}_1^0$ (two acoplanar jets) and $b\ell\tilde{\nu}$ (two acoplanar b's with leptons). The sbottom would similarly decay via $b\tilde{\chi}_1^0$ yielding two acoplanar b jets. These limits, which are near the kinematic limit, are show in Figure 9.

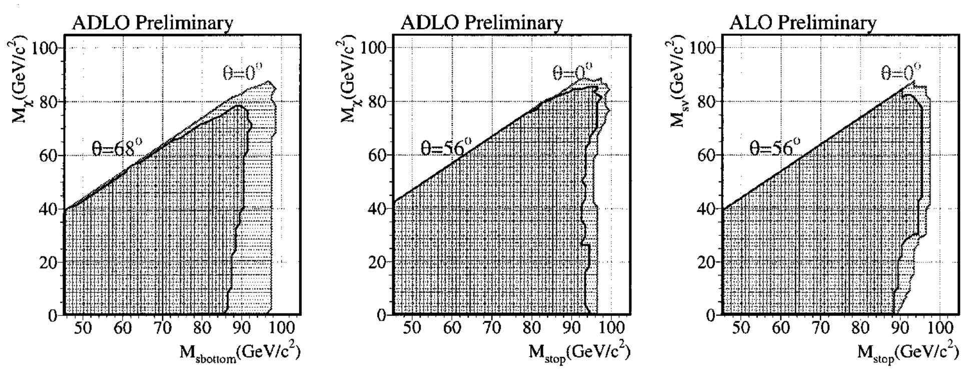

Fig. 9. The LEP combined limits on SUSY top and bottom squarks.

Searches for SUSY leptons[20,24] start with the decay modes $\tilde{\ell} \to \ell\tilde{\chi}_1^0$, giving the signature of two acoplanar leptons and missing energy. For electrons and muons, the limits are in the range 94-98 GeV, near the kinematic limit and close to the expectation. Previously, all four LEP experiments reported an excess of τ events consistent with the production of a SUSY τ. Summing the observation of the experiments for data collected last year, 268 events were observed with 222 expected, at a 202 GeV center of mass. The data this year has been consistent with expectations so the excess appears to have been an fluctuation, the current limits are shown in Figure 10.

Also in Figure 10 is the Aleph[25] limits on a stau in the GMSB scenario. In this case the decay $\tilde{\tau} \to \tau\tilde{G}$ could occur on a short time scale, yielding the signature of two prompt τ's, or in an intermediate range, yielding kinked tracks or on a long time scale, yielding a signature of a slow, massive particle with large dE/dx.

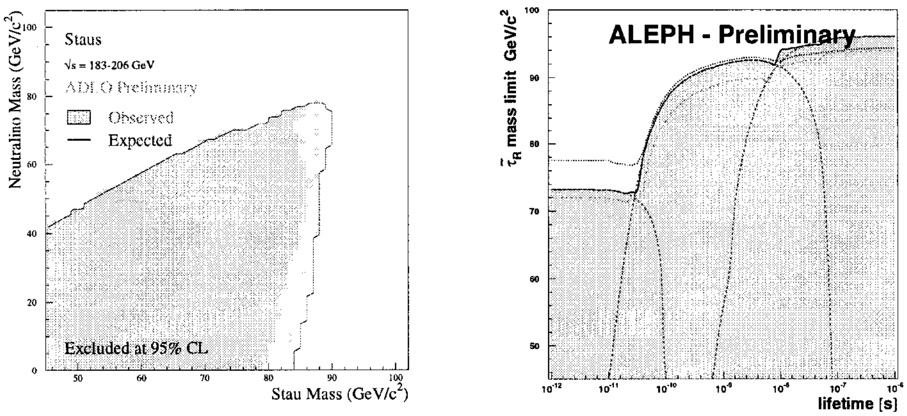

Fig. 10. The LEP combined limit on the SUSY tau and the Aleph limit on the GMSB tau on the signatures of two prompt tau's, kinked tracks, and long-lived massive particles.

5. Conclusions

An overview of searches for new physics from the Tevatron, HERA, and LEP collider experiments was presented. Highlights include limits on large extra dimensions from all three colliders, in the range M_S greater than approximately 1.1 TeV. Significant exclusions in SUSY Higgs parameter space come from the Tevatron and LEP, applying to all MSSM models. The LEP combined results exclude a range of $\tan\beta$ from 0.5-2.3. Using LEP data as of July 20, 2000 (90 pb^{-1} per experiment in 2000), the mass limit on the Standard Model Higgs is 113.3 GeV, the SUSY Higgs 90.5 GeV, the chargino 103.1 GeV and the lightest neutralino 38.2 GeV. This report can only touch on a fraction of the available search results, or even the results presented elsewhere in these proceedings.

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References

1. T. Affolder *et al.*, submitted to *Phys. Rev. Lett.*, hep-ex/0010052.
2. See, for example, K. Lane, *Phys. Rev.* **D60** (1999) 075007.
3. T. Affolder *et al.*, *Phys. Rev. Lett.* **85** (2000) 2056; R. Haas, these Proceedings.
4. T. Affolder *et al.*, *Phys. Rev. Lett.* **84** (2000) 5704; R. Haas, these Proceedings.
5. B. Abbott *et al.*, *Phys. Rev. Rapid Comm.* **D62** (2000) 071701.
6. M. Gold, these proceedings.
7. Arkani-Hamed, Dimopoulos, and Dvali, *Phys. Lett.* **B429** (1998) 263.
8. Joshua C. Long, Hilton W. Chan, John C. Price *Nucl.Phys.* **B539** (999) 23.
9. B. Abbott *et al.* Submitted to Phys. Rev. Lett., hep-ex/0008065; B. Knuteson, these Proceedings.
10. J. Hewitt, *Phys. Rev. Lett.* **82**, (1999) 4765.
11. Tao Han, Joseph D. Lykken, and Ren-Jie Zhang, *Phys. Rev.* **D59**, (1999) 105006; Gian F. Giudice, Riccardo Rattazzi, James D. Wells, *Nucl. Phys.* **B544**, (1999) 544.
12. B. Abbott *et al.*, submitted to *Phys. Rev.* **D**, hep-ex/0006011.
13. H1 Collaboration, paper 327, submitted to ICHEP 2000, Osaka, Japan.
14. ZEUS Collaboration, paper 455, submitted to ICHEP 2000, Osaka, Japan.
15. H1 Collaboration, abstract 951, submitted to ICHEP 2000, Osaka, Japan.
16. H1 Collaboration, paper 322, submitted to ICHEP 2000, Osaka, Japan; J. Breitweg *et al.*, ZEUS Collaboration, *Eur. Phys. J.* **C16** (2000) 253; ZEUS Collaboration, paper 552 submitted to EPS-HEP99, Tampere, Finland.
17. N. Konstantinidis, these Proceedings.
18. LEP Higgs Working Group, "Searches for higgs Bosons: Preliminary Combined Results using LEP Data Collected at Energies Up to 209 GeV", submitted to ICHEP 2000, Osaka, Japan.
19. ALEPH-CONF 2000-047; CERN EP 2000-094 (DELPHI), submitted to *Phys. Lett.* **B**, abstract 651, submitted to ICHEP 2000, Osaka, Japan, P. Abreau et al., EP 2000-095, (Accepted by *Phys.Lett.* **B**; L3 Collaboration, abstract 497, submitted to ICHEP 2000, Osaka, Japan; M. Acciarri *et al.*, (L3 Collaboration) *Phys. Let.* **B470** (1999) 281; Opal Collaboration, Physics Note 440; G. Abbiendi *et al.*, OPAL Collaboration, *Eur. Phys J.* **C13** (2000) 553; G. Abbiendi *et al.*, OPAL Collaboration, *Phys. Lett.* **B465** (1999) 303;
20. A. De Min for the LEP SUSY Working Group, report to the LEP Committee, July 20, 2000.
21. T. Alderweireld and I. Trigger, these Proceedings.
22. W. Murray for the DELPHI Collaboration, report to the LEP Committee, July 20, 2000.
23. P. Krieger, these Proceedings.
24. G. J. Hughes and I. Trigger, these Proceedings.
25. G. Taylor for the ALEPH Collaboration, report to the LEP Committee, July 20, 2000.