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Precision Physics at LHC

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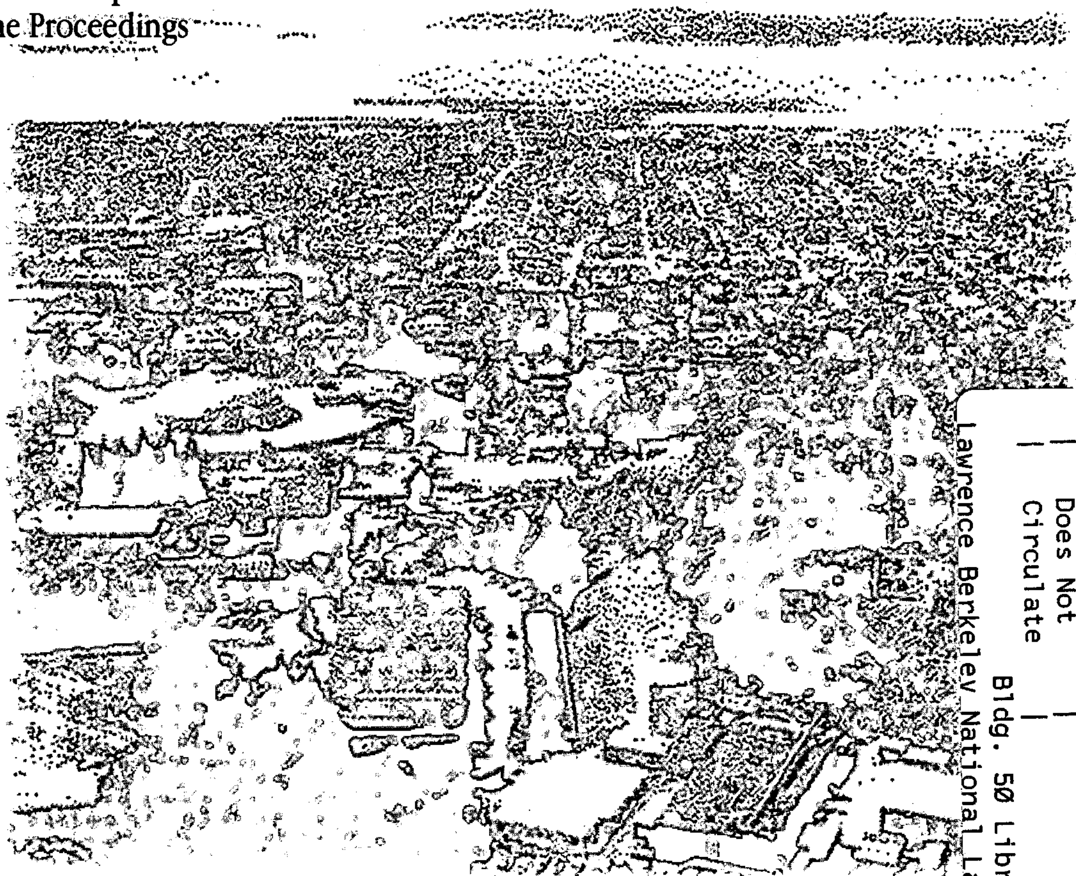

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Precision Physics at LHC[1]

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Abstract. In this talk I give a brief survey of some physics topics that will be addressed by the Large Hadron Collider currently under construction at CERN. Instead of discussing the reach of this machine for new physics, I give examples of the types of precision measurements that might be made if new physics is discovered.

INTRODUCTION

The LHC machine is a proton-proton collider that will be installed in the 26.6 km circumference tunnel currently used by the LEP electron-positron collider at CERN [1]. The 8.4 tesla dipole magnets each 14.2 meters long (magnetic length) are of the "2 in 1" type; the apertures for both beams have common mechanical structure and cryostat. These superconducting magnets operate at 1.9K and have an aperture of 56 mm. They will be placed on the floor in the LEP ring after removal and storage of LEP. The 1104 dipoles and 736 quadruples support beams of 7 TeV energy and a circulating current of 0.54 A.

Bunches of protons separated by 25 ns and with an RMS length of 75 mm intersect at four points where experiments are placed. Two of these are high luminosity regions and house the ATLAS [2] and CMS [3] detectors. Two other regions house the ALICE detector [4], to be used for the study of heavy ion collisions, and LHC-B [7], a detector optimized for the study of B-mesons and B-Baryons. The beams cross at an angle of 200μrad resulting in peak luminosity of 10^{34} cm^{-2} sec^{-1} which has a lifetime of 10 hours. At the peak luminosity there are an average of $\sim 20pp$ interactions per bunch crossing. Ultimately, the peak luminosity may increase to 2×10^{34} cm^{-2} sec^{-1}. The machine will also be able to accelerate heavy ions resulting in the possibility of Pb-Pb collisions at 1150 TeV in the center of mass and luminosity up to 10^{27} cm^{-2} sec^{-1}.

The rest of this talk will concentrate on the physics of the ATLAS and CMS detectors which are designed to exploit the high luminosity pp mode of the LHC and to perform measurements that will lead to an understanding of the mechanisms behind electroweak symmetry breaking. The great success of recent experiments in hadron and electron colliders has confirmed the validity of the standard model to a very high degree of precision and have brought into sharper focus the need to perform experiments that can provide insight into the sector of the model that is responsible for the generation of the W and Z masses. There are

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many possible options for this mechanism and while some, such as super-symmetry, might be favored by a majority of theorists, there is little experimental guidance at present.

Most discussions of this physics in the context of LHC experiments focus on the huge energy range opened up by this facility and the consequent opportunity to discover particles over a very large mass range. In this talk, I will have a rather different emphasis and will give examples of the types of detailed measurements that can be done once new physics is discovered. I will first discuss the measurements that might be made to determine the properties of Higgs bosons and will then discuss and example of a scenario in which super-symmetric particles are produced. In his talk at this meeting, Frank Paige, will give another, more detailed, example of the latter.

HIGGS PHYSICS

The standard model Higgs boson could be observed in several channels at LHC depending upon its mass. For a very detailed discussion of Higgs physics at LHC see ref [6]. The following decay channels have been discussed

- $pp \to H \to \gamma\gamma$
- $pp \to H \to \ell^+\ell^-\ell^+\ell^-$
- $pp \to H(\to ZZ(\to \ell^+\ell^-\nu\overline{\nu}))X$ at large mass
- $pp \to H(\to W(\to jet + jet)W(\to \ell^+\nu))$ at large mass
- $H \to b\overline{b}$ for a Higgs boson produced in association with a W or $t\overline{t}$ pair.

The first of these is useful for masses immediately above those that can be probed at LEP. The signal to background ratio is poor. Excellent photon energy resolution is required to observe this signal, and this process is one that drives the very high quality electromagnetic calorimetry of both experiments. A simulation from the atlas collaboration is shown in Figure 1 [8] This mode can discover the Higgs if its mass is too high to be detected at LEP and below about 140 GeV. At larger masses the branching ratio becomes too small for a signal to be extracted. If the Higgs is produced in association with a W or $t\overline{t}$, the cross section is substantially reduced, but the presence of additional particles proportionally larger reduction in the background. Observation in this channel will provide important information regarding the Higgs boson couplings.

The search for the Standard Model Higgs relies on the four-lepton channel over a broad mass range from $m_H \sim 130\,\mathrm{GeV}$ to $m_H \sim 800\,\mathrm{GeV}$. Below $2m_Z$, the event rate is small and the background reduction more difficult, as one or both of the Z-bosons are off-shell. In this mass region the Higgs width is small ($\lesssim 1\,\mathrm{GeV}$) and so lepton energy or momentum resolution is of great importance in determining the significance of a signal [9].

For $m_H < 2m_Z$, the main backgrounds arise from $t\overline{t}$, $Zb\overline{b}$ and continuum $Z(Z/\gamma)^*$ production. Of these, the $t\overline{t}$ background can be reduced by lepton isolation and by lepton pair invariant mass cuts. The $Zb\overline{b}$ background cannot be reduced by a lepton pair invariant mass cut but can be suppressed by isolation requirements. The ZZ^* process is an irreducible background. Both CMS and ATLAS studied the process for $m_H = 130$, 150 and 170 GeV.

At larger values of the Higgs boson mass where it decays to two on-shell Z's, the signal to background ratio is excellent and the observability is limited only by the available statistics. One can turn to decay channels that have a larger branching ratio. The first of these is $H \to ZZ \to \ell\ell\nu\overline{\nu}$. Here the signal involves looking for a Z decaying to lepton pairs and a large amount of missing energy. The signal appears as a Jacobian peak in the missing E_T spectrum. There are more potentially important sources of background in this channel than in the 4ℓ final state. In addition to the irreducible background from ZZ final states,

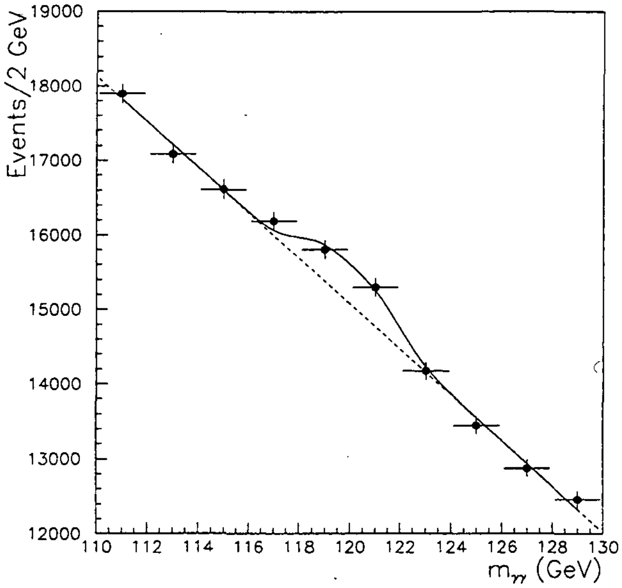

FIGURE 1. A simulation of the possible observation of a Higgs boson via its decay to the $\gamma\gamma$ final state. Shown is the reconstructed $\gamma\gamma$ invariant mass distribution, with a signal showing evidence for a Higgs boson decay. Figure from the ATLAS collaboration.

one has to worry about $Z + jets$ events where the missing E_T arises from neutrinos in the jets or from cracks and other detector effects that cause jet energies to be mismeasured. At high luminosity the background from the pile up of minimum bias events produces a E_T^{miss} spectrum that falls very rapidly and is completely negligible for $E_T^{miss} > 100$ GeV, provided the calorimeter extends to $\mid \eta \mid < 5$ [10].

The CMS analysis of this process [3,11] uses a central jet veto requiring that there be no jets with $E_T > 150$ GeV within $\mid \eta \mid < 2.4$. By requiring a jet in the far forward region (see below), most of the remaining ZZ background can be rejected. A study by CMS requiring a jet with $E > 1TeV$ and $2.4 < \mid \eta \mid < 4.7$, produces an improvement of approximately a factor of three in the signal to background ratio at the cost of some signal.

Substantially larger event samples are available if the decay modes $H \to WW \to \ell\nu + jets$ and $H \to ZZ \to \ell\ell + jets$ can be exploited efficiently. Extraction of a signal is more difficult due to the larger background that arises from $t\bar{t}$, $W + jet$ and $Z + jet$ events. Nevertheless one can expect that these channels could be exploited to confirm a discovery in the purely leptonic final state [3,12,2]

Depending upon its mass, the Higgs boson might be observed in several channels simultaneously. For example, a mass 110 GeV could result in the following measurements, M_h with a precision of order 100 MeV, and the following combinations of cross-sections and branching ratios

- $\sigma(pp \to H + X)BR(H \to \gamma\gamma)$
- $\sigma(pp \to H + W)BR(H \to \gamma\gamma)$
- $\sigma(pp \to H + W)BR(H \to b\bar{b})$

At a mass of order 135 GeV, the following should be measurable

- $\sigma(pp \to H + X) BR(H \to \gamma\gamma)$
- $\sigma(pp \to H + W) BR(H \to ZZ^*)$

If the Discovered particle is a Higgs boson, then the production rates and branching ratios are predicted once the mass is known. These measurements would therefore enable consistency checks to be performed.

There could be Higgs bosons other than the one predicted by the standard model and the LHC will be able to search for these also. Most of the decay modes already discussed can be used in this case, but other modes might become available. The simplest modification to the Higgs sectors is that in the minimal super-symmetric model. Here there are three neutral and one charged Higgs bosons; h, H, A and $H^{\pm}$. If one assumes that the masses of all the other super-symmetric particles are too heavy to influence the properties of these bosons, the masses and decay properties are given by two independent variables which can be taken to be m_A and $\tan\beta$. Possible new observations of these particles include

- H and $A \to \tau^+\tau^-$
- H and $A \to \mu^+\mu^-$
- $A \to Z(\to \ell^+\ell^-)h(\to b\bar{b})$
- $H \to h(\to b\bar{b}h(\to \gamma\gamma)$
- $t \to H^+b$

The first of these is particularly important as it enables the mass of the particle to be measured well and is applicable over a large region of parameter space. A simulation is shown in Figure 2 from the CMS collaboration [13]. Events are selected by requiring that an isolated electron or muon be observed. A further selection requiring that the events contain a jet with a single charged track with $25 < p_t < 40$ GeV and no other track with $p_t > 2.5$ GeV. The dominant background is then from the Drell-Yan production of τ pairs. Using the measurement of $ETmiss$, the momenta of the τ candidates can be reconstructed and the invariant mass of the $\tau\tau$ system formed. This is shown in Figure 2. A signal is clearly visible. A similar conclusion is reached by ATLAS [14].

These many channels can be combined to probe the whole of the parameter space in the model. For a very detailed and exhaustive discussion see [6]. The conclusions can be summarized as follows. The modes are sufficient for either experiment to *exclude* the entire $tan\beta - M_A$ plane at 95% confidence with 10^5 pb^{-1}. Over a significant fraction of the parameter space at least two distinct modes will be visible. For example, if h is observed at LEP II and M_A is small the LHC will see the H^+ in top quark decay, $H \to ZZ^*$, and possibly $H/A \to \tau\tau$.

SUPER SYMMETRY

If super symmetry proves to be accessible at LHC, then it is most likely that the first new particles to be exploited will be the squarks and gluions. Since these have strong couplings, their production rates are much larger than those relevant to direct Higgs boson production. Indeed it is possible that Higgs bosons could be produced in the decays of these super-symmetric particles and that this source of Higgs bosons would be the largest one and the one that leads to their discovery.

The mass spectrum and detailed decay properties of the super symmetric particles are very model dependent making a general study rather difficult. The situation is complicated by the real possibility that the LHC may be a factory for super-symmetric particles; many different ones are produced at the same time. Early studies of super-symmetric signals

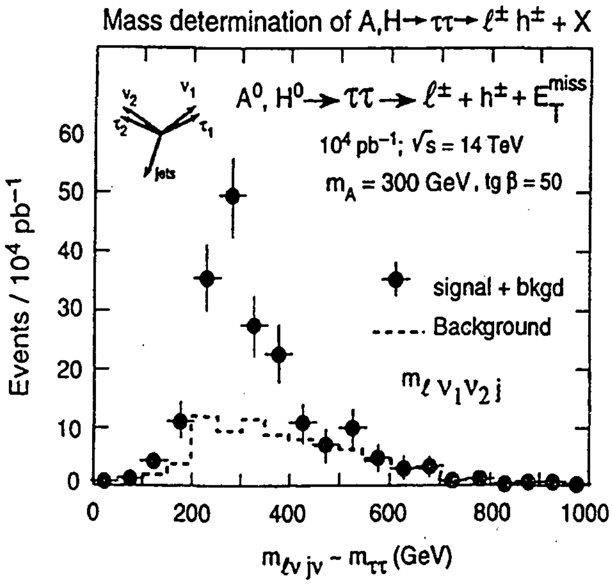

FIGURE 2. A simulation of the possible observation of a Higgs boson via its decay to the $\tau\tau$ final state. Shown is the reconstructed $\tau\tau$ invariant mass distribution, with a signal showing evidence for a Higgs boson decay. Plot from the CMS collaboration

concentrated on a specific particle and a particular decay mode demonstrating that cuts could be made that ensure that the signal from this decay stands out above the standard model background. These studies provide a convincing case that super-symmetry could be discovered at the LHC. The next level of work addresses the question of how the masses and couplings of the particles could be determined and the underlying theory constrained. Here one faces the problem that the dominant background for super-symmetry is super-symmetry itself. I will make a few general remarks about super-symmetry phenomenology at the LAC and will then discuss one case study. Frank Paige will discuss others in his talk [15]

The following features are characteristic of most super-symmetric models

- Squarks are heavier than slept ons
- The stop and possibly bottom squarks are the lightest squarks.
- The gluino is heavier than the charged and neutral "ino"'s that are partners of the electroweak gauge bosons.
- The lightest super symmetric particle (LSP) is stable or sufficiently long lived that it leaves the detector. This particle is almost always electrically neutral.

The following generic signals arising from the production and decay of sparticles are

- E_T^{miss} from the loss of the LSP.
- High Multiplicity of large p_t jets from the decay of heavy objects.
- Many leptons from decays of charged and neutral inos.
- Copious b production from the decays of sbottom and stop squark and Higgs bosons.

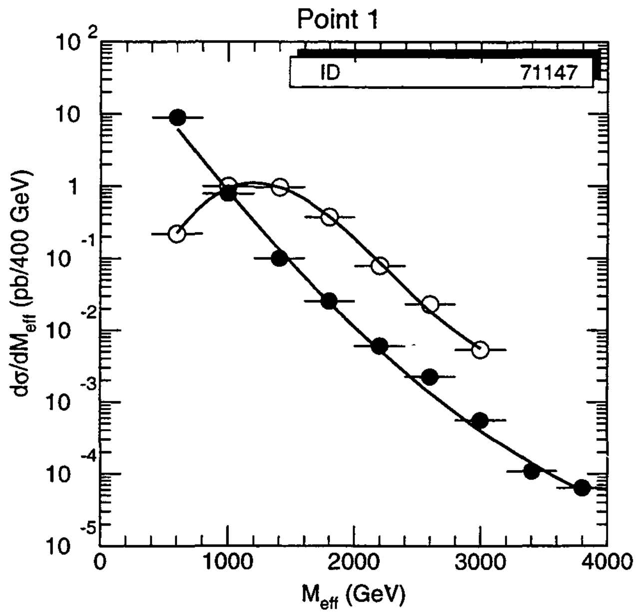

FIGURE 3. Distribution in the variable M_{eff} (see text). The closed circles represent the distribution in the standard model. The open circles show the possible contribution from super-symmetry.

The relative importance of these signals will depend upon the model. The first could be absent in models where the LSP is unstable. Additional signals could also be present. for example in the dynamically broken models [16], the LSP may be unstable and may decay to $\gamma + \tilde{G}$, reducing the missing E_T rate ($\tilde{G}$ exits unobserved) but providing **every** super-symmetry event with an additional pair of isolated photons.

These general features will be used to determine that something new physics is seen at LHC. In order to be more concrete, I will proceed with a specific example in the context of the SUGRA model [17] This model has the advantage that rather few parameters specify it completely. The model is assumed to unify at some high scale where a common gaugino mass $m_{1/2}$ is defined. All scalar particles are assumed to have a common mass m_0 at this scale. Three other parameters then fully specify the model: $\tan\beta$, a variable A with dimension of mass that affects mainly the splitting between the partners of the left and right handed top quark, and the sign of μ. For example, events are selected which have at least 4 jets one of which has $E_t > 100$ GeV and the others have $E_T > 50$. An additional requirement of $E_T^{miss} > 100$ GeV and sphericity $S > 2$ is made, and the event rate is plotted against M_eff defined as the scalar sum of the E_T of the four jets and E_T^{miss}. The distribution in this variable is shown in figure 3 From this figure one can see that at low values of M_{eff} the standard model contributions will dominate. At larger values the contribution from super-symmetric particles of large mass will begin to dominate. There is a strong correlation between the mass scale of super-symmetry and the position of the peak in this distribution. This can be used to determine the scale, defined as the lesser of the squark and gluino masses, to about 10/

Once super-symmetry has been discovered and its mass scale established approximately. More detailed studies will be carried out in order to constrain the underlying super-symmetric model. There is a large rate of production for the second lightest neutralino from the decays of heavier super-symmetric particles. This is occurs because this particle

(χ_2) has a component that is the partner of the W gauge boson and is therefore produced with substantial rates in the decays of super-symmetric particles that are too light to decay by strong interactions. This particle will then decay to the LSP. If kinematic-ally allowed, the decay $\chi_2 \to LSP + h$ is dominant. This results in a production of Higgs bosons that is much larger than that expected in the standard model. In this case the h will likely be discovered from its dominant decay to $b\bar{b}$ in super-symmetry events! If this channel is closed then the dominant decay $\chi_2 \to \ell^+\ell^- LSP$ will be substantial. Events will have two isolated leptons of opposite charge. This characteristic signature can be used the measure the mass difference of χ_2 and LSP and can be used as a hook to work up the decay chain to discover other super symmetric particles.

I will illustrate this last comment by a specific example. For this purpose a particular point in the parameter space was selected for simulation [23]. The mass spectrum is as follows: Gluino $m_{\tilde{g}} = 298$ GeV $m_{\tilde{q}_r} = 312$ GeV, $m_{\tilde{q}_l} = 317$ GeV $m_{\tilde{t}_1} = 263$ GeV, $m_{\tilde{t}_2} = 329$ GeV
$m_{\tilde{b}_1} = 278$ GeV, $m_{\tilde{b}_2} = 314$ GeV Sleptons $m_{\tilde{e}_l} = 215$ GeV, $m_{\tilde{e}_r} = 206$ GeV, Neutralinos $m_{\chi_1} = 44$ GeV, $m_{\chi_2} = 98$ GeV, $m_{\chi_3} = 257$ GeV, $m_{\chi_4} = 273$ GeV Charginos $m_{\chi_1^\mp} = 96$ GeV, $m_{\chi_2^\mp} = 272$ GeV Higgs $m_h = 68$ GeV, $m_H = 378$ GeV, $m_A = 371$ GeV, $m_{H^+} = 378$ GeV.

At this point the total production rate for gluino pairs is very large, and many other supersymmetric particles are produced in the decay of gluinos. Of particular significance is χ_2 which decays to $\chi_1 e^+ e^-$ and $\chi_1 \mu^+ \mu^-$ with a combined branching ratio of 32%. The position of the end point of this spectrum determines the mass difference $m_{\chi_2} - m_{\chi_1}$ [18]. Backgrounds are negligible if the events are required to have two such dilepton pairs, which can arise from the pair production of gluinos with each decaying to $b\bar{b}(\to \chi_2(\to \chi_1 \ell^+\ell^-))$ which has a combined branching ratio of 24%. The event rate is so large that the statistical error in the determination of the mass difference is very small and the total error will be dominated by systematic effects. The enormous number of $Z \to \ell^+\ell^-$ decays can be used to calibrate, and an error of better than 50 MeV on $m_{\chi_2} - m_{\chi_1}$ is achievable[3]. In the context of the model, this measurement constrains $M_{1/2}$ with an error of order 0.1%.

The small mass difference between the gluino and the sbottom can also be exploited to reconstruct a the masses of these particles [19]. Here a partial reconstruction technique is used. Events are selected where the dilepton invariant mass is close to its maximum value. In the rest frame of χ_2, χ_1 is then forced to be at rest. The momentum of χ_2 in the laboratory frame is then related to the momentum of the $\ell^+\ell^-$ pair by $p_{\chi_2} = (1 + m_{\chi_1}/m_{\ell^+\ell^-})p_{\ell^+\ell^-}$. χ_2 can then be combined with an additional $b - jet$ to reconstruct the $tildeb$ mass. An additional b_jet can then be added to reconstruct the $\tilde{g}$ mass. Figure 4 shows the scatterplot on these two invariant masses together with a projection onto $m_{\tilde{b}}$ and $\delta m = m_{tildeg} - m_{\tilde{b}}$. Peaks can clearly be seen above the combinatoric background. This method can be used to determine $m_{\tilde{g}}$ and $m_{\tilde{b}}$. The values depend on the assumed value of m_{χ_1}: $m_{\tilde{b}} = m_{\tilde{b}}^{true} + 1.5(m_{\chi_1}^{assumed} - m_{\chi_1}^{true}) \pm 3$GeV and $m_{\tilde{g}} - m_{\tilde{b}} = m_{\tilde{g}}^{true} - m_{\tilde{b}}^{true} \pm 0.5$ GeV. Note that the event rates in this example are enormous; there are approximately 2.3 Million events in 10 fb^{-1} that have two isolated leptons four b-jets and missing energy!

Once several quantities have been measured, one will attempt to constrain the parameters of the SUSY model by performing a global fit much as the standard model is tested at LEP [21]. To get and indication of how well this might work, many choices of parameters within the SUGRA model were made and those that resulted in masses within the expected error were retained [22]. Measurements of m_h, $m_{\chi_2} - m_{\chi_1}$ and $m_{\tilde{g}} - m_{\tilde{b}}$ with errors of ± 5 GeV, ± 0.50GeV(10σ) and ± 3 GeV (1.5σ) respectively result in the constraints $\delta m_{1/2} = 1.5$ GeV, $\delta m_0 = 15$ GeV and $\delta \tan\beta = 0.1$. It is clear from this example that precise measurements of

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[3] Recall that the current error on M_W from CDF/D0 [20] comes from an analysis involving E_T^{miss} has far fewer events and has an error of order 150 MeV

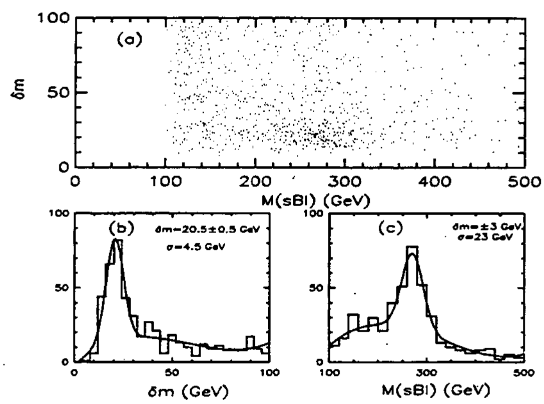

FIGURE 4. The reconstruction of gluino and sbottom decays from the decay chain $\tilde{g} \to \chi_2(\to \chi_1 \ell^+ \ell^-)\tilde{b}$. Events are selected near the end point of the $\ell^- \ell^+$ mass distribution and the momentum of χ_2 reconstructed. Two b−jets are then required and the mass of $b + \chi_2$ ($= m_{\tilde{b}}$ and the mass difference $\delta m = m_{bb\chi_2} - m_{b\chi_2}$ are computed. The scatterplot in these two variables and the projections are shown.

SUSY parameters will be made at LHC if supersymmetric particles exist. For more details and other examples of the types of measurements that might be done at LHC, see ref [23].

CONCLUSIONS

In this talk, I have not tried to give an overview of the new physics that the LHC expermients might see. The reader can refer to other documents for more details [2,3,24]Instead I have tried to give a sense of some of the measurements of the new physics that might be performed once the new physics is seen. Emphasis is often given to searches for the Higgs boson. There are good reasons for this; it is the one missing particle in the standard model, but, more importantly, its properties are fully predicted once its mass is given. Very detailed simulations of signals and backgrounds can be performed therefore. However this emphaisis on the Higgs boson may be misleading. Production rates are very small and consquently experiments need the full luminosity of the LHC.

Most theorists would be very dissapointed if the LHC discovered a standard model Higgs boson of mass 400 GeV. Varients of the standard model offer are larger opportunity to understand the origins of mass generation and reason for the size of the elextroweak scale. At present, supersymmetry is the most popular option. In this case the Higgs sector is richer and SSC experiments will probe it. Again event rates for the **direct** production of Higgs bosons are small and the experiments are challenging. If superysmmetry is relavent, the first observations at LHC will come, not from the Higgs sector, but rather from the decays of squarks and gluinos which have vastly larger production rates. I have given an example of some of the detailed measurements that will await LHC experimenters if supersymetry is seen. Indeed a theorist /citeellis jested that the LHC might be more approporaitly called the "bevatrino".

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REFERENCES

1. P. Lefevre, *et al.*, CERN/AC/95-05.
2. Atlas Technical proposal, CERN/LHCC/94-43.
3. CMS Technical proposal, CERN/LHCC/94-38.
4. ALICE Technical Proposal, CERN/LHCC/95-71.
5. LHC-B Technical Proposal, CERN/LHCC/95-XX.
6. E. Richer-Was, *et al.*, ATLAS Note PHYS-NO-074 (1996).
7. LHC-B Technical Proposal, CERN/LHCC/95-XX.
8. D. Froidevaux. F. Gianotti and E. Richter Was, ATLAS Note PHYS-NO-064 (1995),
9. J.-C. Chollet, *et al.*, ATLAS internal note PHYS-NO-17 (1992), L. Poggioli, ATLAS Note PHYS-NO-066 (1995).
10. M. Bosman and M. Nessi, ATLAS Note PHYS-NO-050 (1994).
11. N.Stepanov, CMS-TN/93-87 (1993); S. Abdullin and N. Stepanov, CMS-TN/94-179 (1994).
12. S. Abdullin and N. Stepanov, CMS-TN/94-178 (1994).
13. R. Kinnunen, J. Tuominiemi, and D. Denegri, CMS-TN/93-98 (1993) and CMS-TN/93-103; C. Seez, CMS-TN/93-84.
14. D. Cavalli, *et al.*, ATLAS Note PHYS-NO-025 (1993).
15. F. Paige, these proceedings.
16. M. Dine, A. Nelson and Y. Shirman, *Phys. Rev.* **D51**, 1362 (1995).
17. L. Alvarez-Gaume, J. Polchinski and M.B. Wise, Nucl. Phys. **B221**, 495 (1983);
    L. Ibañez, Phys. Lett. **118B**, 73 (1982);
    J.Ellis, D.V. Nanopolous and K. Tamvakis, Phys. Lett. **121B**, 123 (1983);
    K. Inoue *et al.* Prog. Theor. Phys. **68**, 927 (1982);
    A.H. Chamseddine, R. Arnowitt, and P. Nath, Phys. Rev. Lett., **49**, 970 (1982).
18. J. Soderqvist, To appear in Proceedings of 1996 DPF Summer study Snowmass CO
19. W-M Yao, To appear in Proceedings of 1996 DPF Summer study.
20. F. Abe, *et al.*, *Phys. Rev. Lett.* **75**, 11 (1995), S. Abachi, *et al.*FERMILAB-PUB-96-177-E.
21. LEP Electroweak working group.
22. A. Bartl, *et al.*, To appear in Proceedings of 1996 DPF Summer study;
23. I. Hinchliffe *et al.*, hep-ph/9610544, Phys Rev D (to appear).
24. I Hinchliffe and J Womersley (eds) hep-ex/9612006,Presented at 1996 DPF / DPB Summer Study on New Directions for High-Energy Physics (Snowmass 96), Snowmass, CO, 25 Jun - 12 Jul 1996.
25. J. Ellis, private communication.

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