Physics Presentations at the March 1998 CMS Week

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Physics presentations at the March CMS week focused on the third generation of fundamental fermions, exploring how top and bottom quarks and tau leptons can be used in CMS.

Tau signatures

At the physics meeting, Michael Dittmar introduced a series of talks on tau signatures. He pointed out that we should explore these final states as a possible way of improving our reach for Standard Model Higgs, and for completeness (especially in comparison with ATLAS). He also made some more general remarks on the Standard Model Higgs search, firstly that we should use NLO cross sections throughout rather than the present mix of LO and NLO (which will improve our performance); and secondly that the use of hard cuts on the p_T of the Z or ZZ system in $H \to ZZ$ searches is dangerous. Such cuts (as used by ATLAS) can be sensitive to event kinematics which differ markedly from the LO to NLO calculation.

Then André Holzner described an analysis aiming to extend the $H \to WW$ search proposed by Dittmar & Dreiner for $m_H \sim 150-170$ GeV through the addition of final states where one W decayed into $\tau\nu$. Hadronic tau decays were reconstructed as one- or three-prong jets contained within a cone of radius $R = 0.1$ and isolated (having $E_T < 5$ GeV or $< 5\%$ of the tau p_T in a larger cone $R = 0.5$). Inclusion of taus would approximately double the signal statistics, but in this case the large additional background coming from $W + jets$ events appears to negate any benefits. This serves to illustrate the problems of a single-tau signal.

Such problems are reduced if tau-pairs are selected, as was the case in the next presentation by Daniel Hug. He described an extension of the "golden" Higgs decay mode $H \to ZZ \to 4\ell$ to include the possibility of one $Z \to \tau^+\tau^-$ decay. This would potentially double the signal rate, which is low (the product of branching ratios is only 0.135%). Taus were selected in the same way, and the result is a $\sim 25\%$ increase in signal statistics (about a 50% efficiency per tau). The 4-momentum of the Z is reconstructed using the τ^+ and τ^- directions and a mass constraint. Mild cuts on p_T^Z and p_T^{ZZ} were applied. The result is a clear Higgs signal in the tau mode for Higgs masses from 200 to 600 GeV which nicely complements that in the e and μ channels.

The fourth presentation on tau signatures was by S. Lehti who described a search for supersymmetric Higgses in the channels $h, H, A \to \tau^+\tau^- \to e\mu + X$. The tau decays of SUSY Higgses are important at large values of $\tan\beta$ where the Higgs-tau coupling is enhanced. Signal selection focused on semileptonic decays of the taus: one electron and one muon were required in the final state. To reduce the dominant Drell-Yan tau pair background it was necessary to require a b-tagged jet — about half of the Higgs events are produced in association with a $b\bar{b}$ pair. This then leaves $t\bar{t}$ events as a background, so events with two jets above 30 GeV or with too large a missing E_T were vetoed. The Higgs mass was reconstructed using the τ^+ and τ^- directions together with the measured missing E_T. Discovery seems possible for large $\tan\beta$; though covering less parameter space than the hadronic tau decays studied earlier, this channel would provide important confirmation of any observation.

b-quarks

Turning now to the physics of the b-quark, Sasha Khanov showed resent progress in b-tagging. Jets from b-quarks were generated at $E_T = 50, 100, 200$ GeV and in three η regions (barrel, transition and forward). Mistagging rates were estimated using corresponding $u\bar{u}$ samples. All were passed through a CMSIM detector model based on the V3 tracker but with the latest pixel design. Tagging efficiencies of about 55%, with a fake rate of 1%, are achievable at 100 GeV in the barrel, but the efficiency falls off both at higher rapidity and for lower and higher jet energies. Most of the mistags seem to be true secondary vertices from interactions in the tracker material. The second-largest source is misreconstructed tracks; conversions and neutral decays are much less.

In the plenary session, Nikita Stepanov described the b-physics potential of CMS, drawing on work done for the recent LHCC B-physics workshop. All these studies used a full GEANT simulation of the tracker. (Pavel Galumian covered much of the same ground in the parallel session, comparing CMS with LHC-B). Nikita first described the rare decay $B \to \mu^+\mu^-$ whose branching ratio is a few $\times 10^{-9}$ in the SM. Requiring a displaced vertex for the muons and exploiting the 30 MeV dimuon mass resolution yields about 13 signal events over a background of 50 in 10^4 pb^{-1} and the SM signal should be measureable at the 5σ level in 10^5 pb^{-1}. Various modes have been proposed to determine the phase angles and magnitudes of the terms in the CKM matrix. The gold-plated mode $B_d^0 \to J/\psi K_S^0$ determines $\sin 2\beta$ and is theoretically well-controlled. CMS could measure this to about 2% (combining lepton and same-side hadronic tags); LHC-B to 1–2%. Using the $B \to \pi^+\pi^-$ mode to determine the angle γ now appears subject to large uncertainties from penguin diagram contributions, which are suggested by recent CLEO data. The signal rate is also believed to be only one third of that assumed in the TP. Galumian suggested that one might try the $B_s \to D_s^{\pm}K^{\mp}$ mode, in which LHC-B showed a 7–10° sensitivity on γ; but in his opinion they had neglected to consider ambiguities in the solution. The decay $B_s^0 \to J/\psi\phi$ can be used to determine the phase ϕ_{ts}. LHC-B present a 1% sensitivity, while that of CMS ranges from 1% at $x_s = 15$ to 2.5% at $x_s = 30$. Sensitivity to this parameter x_s in B_s^0 mixing extends to $x_s \sim 40$ in CMS, through the $B_s \to D_s^{\pm}K^{\mp}$ mode with $D_s \to \phi\pi$ and K^*K. This compares with a reach of $x_s \sim 60$ for LHC-B. Other topics considered by CMS include rare semileptonic FCNC $B_{d,s}^0$ decays, B-baryons, and rare τ decays. Work is still in progress on understanding how to use the second-level trigger for b-physics, in refining the Monte Carlo simulation, and in developing the reconstruction algorithms.

Also in the plenary session, Daniel Denegri posed the rhetorical question "Why do we need b-jets in CMS?" He described many high-p_T physics topics which require identification and measurement of b-jets, in addition to the b-physics menu presented by Nikita. Firstly b-jets are required to identify top quarks; the LHC will provide a huge sample for standard model physics, and also enable us to search for charged SUSY Higgses produced in top decay. The b-jets produced from top are hard ($E_T \sim 80$ GeV) and central. For neutral SUSY Higgses, as described earlier, roughly half the signal is produced in association with a $b\bar{b}$ pair and requiring a b-tagged jet improves the signal to background ratio from $\sim 1:15$ to $1:2$. The jets in these events are softer ($E_T \sim 20-60$ GeV) and more forward, showing the need for forward pixels. Still under study are the use of similar b-tags to enhance the $H \to \mu^+\mu^-$ signal and allow observation of $b\bar{b}H \to 4b$. One advantage of these associated production channels is that they are unaffected by the cancellation which can suppress the normal Higgs production through gluon fusion if there is large stop mixing and a light stop squark. It may even be posisble to discover the lightest SUSY higgs through its decay to $b\bar{b}$. Higgses are copiously produced in squark and gluino cascade decays; a clean sample of such events can be selected with a hard missing E_T cut and the $b\bar{b}$ mass distribution could allow the Higgs to be observed with very low luminosity. The b-jets from Higgs decay are hard and central; the main problem here is optimizing the dijet mass resolution. Daniel also pointed out that b-jets are copiously produced in SUSY (stop and s-bottom are often the lightest squarks and decay to b's). Tagged b-jets can help reconstruct the complicated cascade decays of SUSY.

Other Topics

Lali Rurua presented an update on the analysis of the dilepton mass edge in $\chi_2^0 \to \chi_1^0\ell^+\ell^-$ decays. She explained how the shape of the mass spectrum can be used to distinguish between the three possible sources of such events, and, together with the cross section, be used to fix the mass parameters m_0 and $m_{1/2}$. She presented some new results on the behaviour at large $\tan\beta$, where (once again) τ decays start to become important. It may be possible to estimate $\tan\beta$ from the relative magnitude of the Z peak and the supersymmetric dilepton peak, since the latter is diverted into tau decays at large $\tan\beta$ and the Z is not. Direct tau reconstruction has not yet been investigated here.

John Womersley presented results on the performance of the CMS calorimeter for relatively low-E_T jets. A CMSIM detector simulation was used, and dijet mass resolutions and jet veto efficiency were studied. For the $Z \to jets$ decay, the mass resolution is 11% in the absence of gluon radiation; with radiation turned "on" the resolution degrades to 19%. He showed that this change is expected from PYTHIA. Jet vetoing is an important tool to reject $t\bar{t}$ backgrounds in many analyses. The GEANT simulation found a similar veto factor to generator-level studies for the case of a $H \to WW$ signal, but the signal efficiency was somehwat lower. It appears that the more realistic simulation bears out the basic soundness of the jet veto, but that the signal efficiencies actually achievable may be lower than has been assumed.

John then briefly turned to the third generation as well, outlining the plans of the Fermilab group to investigate top quark physics in CMS for the October LHCC Standard Model Physics workshop.