

Beyond Standard Model Searches at the Tevatron

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1 Introduction

CDF and D0 have been working at the energy frontier at the Tevatron for many years and have gained experience in the detectors responses to all particle types. They can look at a large number of different final states searching for deviations from Standard Model (SM) expectations and interpret them in terms of new models. The results presented here are a selection of recent searches conducted by the two collaborations using up to 6.3 fb^{-1} of data. They are quoted as they were presented at the time of PLHC2011 regardless of any later updates. Further details on physics results can be obtained from the web pages of the two collaborations [1].

2 Same sign dileptons

A wide variety of models for new physics predict events with two like-sign leptons, a signature which has very low backgrounds from SM processes. CDF has studied an inclusive like-sign dilepton sample [2] using 6.1 fb^{-1} of data and interpreted the results in term of :

- Supersymmetry (SUSY)
Analysis has been done in the framework of a practical SUSY model by choosing specific production and decay modes, and including in the model the minimal necessary particle content [3]. The parameters of the model are the masses of the sparticles. The results are expressed as limits on the cross section times branching ratio as a function of the squark and gluino masses.
- Like sign top quark pair production
Flavour-changing neutral processes involving top quarks offer a window to new physics because they are highly suppressed in the SM. CDF has presented the first search for like-sign top pair production [4]. Such pairs can be produced at the Tevatron via the exchange of a heavy s -channel vector boson, or a t -channel one. In the former case the new particle can be a colour-triplet or sextet with charge $4/3$, while in the latter it can be a colour singlet Z' or octet g' , both with zero charge. The analysis is done in the hypothesis of heavy boson masses, so these processes can be described by a gauge-invariant effective four-fermion interaction. Limits can eventually be interpreted in the context of various SM extensions. The effective Lagrangian of the process is expressed in terms of dimensionless constants C_{LL} , C_{RR} , C_{LR} (L and R are the chiralities of the quarks) and Λ , the scale of the new physics. All data distributions are in agreement with the expected background contributions. Limits are obtained on the production cross section times dilepton branching ratio according to the chiralities.
- $H^{++/--}$ search
The CDF collaboration used a generic search for $H^{++/--}$ [5] in which the charged Higgs may be member of a singlet, doublet or triplet [6]. The production process is assumed to be via $q\bar{q} \rightarrow H^{++/--}$ followed by the decay of the doubly charged Higgs to charged leptons: ee , $e\mu$, $\mu\mu$. No excess of events is seen in data compared to what is expected from the background. Limits on the mass of the doubly charged Higgs are obtained (Fig. 1).

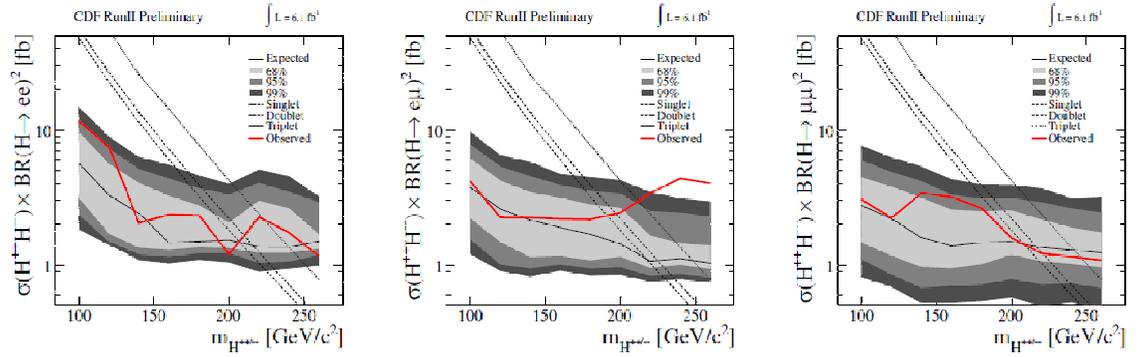


Figure 1: CDF $H^{++/--}$ search : Observed and expected limits compared to the theoretical predictions for ee (right), $e\mu$ (middle) and $\mu\mu$ (right).

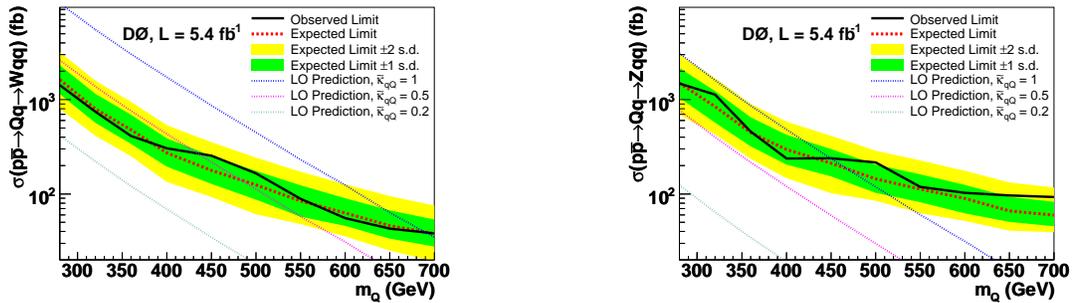


Figure 2: Excluded production cross section for a vector-like quark Q decaying to Wq (left) or to Zq (right) compared to LO predictions for various couplings (see [7] for details).

3 Single vector-like quarks

Among the theories that have been proposed to describe phenomena at the TeV scale, some of them predict the existence of massive vector-like quarks (VQ). Their left and right components transform the same way in $SU(3) \times SU(2) \times U(1)$. They can be singly produced via the electroweak interaction and may decay into a W or Z boson and a SM quark. DØ [7] has separated the search in two independent channels : lepton, missing transverse energy, and a jet (decay into Wq) and dilepton +jet (decay into Zq). The absence of any statistically significant excess in data above the expected background allows the derivation of cross section limits. They are compared to VQ production in two scenarios : VQ not coupled to down-quarks and decaying exclusively to Wq are excluded for masses below 693 GeV (551 GeV if decaying to Zq) (Fig. 2). In the scenario of no-coupling to up-quarks, the mass limits are 403 GeV (Wq) and 430 GeV (Zq).

4 $W + 2$ jets

Measurements of associated production of a W -boson and jets are fundamental to probe the SM and are an essential starting point for searches for physics beyond the SM. CDF has measured the production cross section of a W in association with either a W or a Z boson from a selection of a

lepton (electron or muon) plus jets in a data sample of 4.3 fb^{-1} [8]. The best fit to the observed dijet mass distribution using all known components of the background shows an excess of data in the 120-160 GeV mass range corresponding to a 3.2 standard deviations (Fig. 3). Recently CDF has analyzed a larger sample (7.3 fb^{-1}), made additional tests and obtained a larger disagreement of 4.1 standard deviations [9]. The D0 collaboration does not confirm such an excess in a data sample of 4.3 fb^{-1} [10].

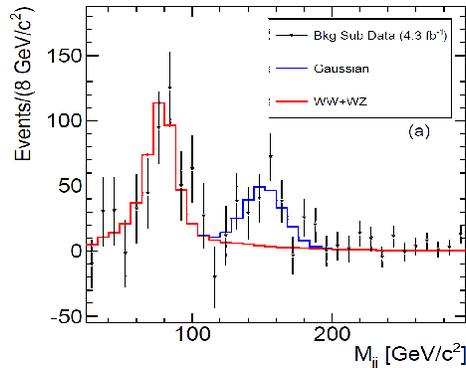


Figure 3: CDF dijet invariant mass distribution for the $W + 2$ jets selection where the W decays leptonically. The distribution is obtained by adding electron and muon selected events. See [8] for details.

5 Charge asymmetry in like sign $\mu\mu$ events

The violation of the CP symmetry is a necessary condition for baryogenesis. However, the present observed level of CP violation in K^0 and B_d^0 and the small expected one from B_s^0 are not sufficient to accommodate this asymmetry, suggesting the presence of additional sources beyond the SM. D0 has measured the like-sign dimuon charge asymmetry in a data sample corresponding to an integrated luminosity of 6.1 fb^{-1} [11]. The periodic reversal of the D0 solenoid and toroid polarities results in a cancellation of most detector-related asymmetries. Two asymmetries are measured. The first one is defined as $A = \frac{N^{++} - N^{--}}{N^{++} + N^{--}}$ where N^{++} and N^{--} represent the number of events in which the two muons of highest transverse P_T have the same positive or negative charges. After kinematic selections and background removal, the residual asymmetry is assumed to arise solely from the mixing of B_q^0 that then decay semileptonically. The corrected asymmetry is defined as A_{sl}^b . The second asymmetry is obtained from the measurement of the charge asymmetry in semileptonic decays of b-hadrons: $a = \frac{n^+ - n^-}{n^+ + n^-}$, where n^+ and n^- correspond to the number of positively and negatively charged muons. The two asymmetries have different contributions from background and detector effects. So a is used to constraint the background contribution to A , thereby achieving a further reduction of the total uncertainty on A_{sl}^b . The final result is $A_{sl}^b = -0.00957 \pm 0.00251(stat) \pm 0.00146(syst)$. It differs from the SM prediction of $A_{sl}^b(SM) = (-2.3 + 05 - 0.6) 10^{-4}$ by 3.2 standard deviations. Figure 4 presents the measurement of A_{sl}^b in the $a_{sl}^d - a_{sl}^s$ plane together with direct measurements of a_{sl}^d from the B factories [12] and an independent D0 measurement of a_{sl}^s in $B_s^0 \rightarrow D_s \mu X$ [13].

6 Conclusions

The CDF and D0 experiments have accumulated more than 10 fb^{-1} of high quality data and have already set limits on BSM physics beyond what one could have expected. While the LHC has surpassed the reach of the Tevatron in certain areas, CDF and D0 still have, and will continue to have, a competitive BSM physics program, particularly when studying complex final states.

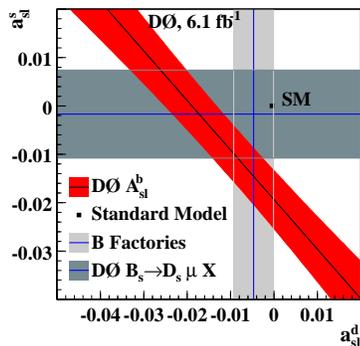


Figure 4: Comparison of A_{sl}^b in data with the SM prediction for a_{sl}^d and a_{sl}^s and other measurements [12] [13]. The bands correspond to $\pm 1\sigma$ uncertainties.

7 Acknowledgments

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