International Journal of Modern Physics A

A Search for Doubly Charged Higgs Boson Pair Production in the Muon Channel at DØ

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Several theories predict the existence of light doubly charged Higgs bosons ($H^{\pm\pm}$). A search for the pair production of $H^{\pm\pm}$ using the DØ detector is described, assuming a 100% branching ratio to muons. In the absence of signal, limits at 95% confidence level, of 118.4 GeV and 98.2 GeV are set for left-handed and right-handed doubly charged Higgs bosons respectively.

1. Introduction

Non-standard models can possess several Higgs bosons associated with electroweak symmetry breaking, rather than the standard single, neutral Higgs boson. Some models, such as the Left-Right symmetric model[1] and little Higgs model[2], predict that some of these are doubly charged ($H^{\pm\pm}$). The decay modes of the $H^{\pm\pm}$ are limited; charge conservation forbids decays to quarks and anti-quarks and phenomenological constraints require that the coupling of $H^{\pm\pm}$ to W bosons must be suppressed[3]. In the absence of other decay modes, the $H^{\pm\pm}$ predominantly decay to like sign lepton pairs, if the model allows lepton number violation.

Searches in these channels have been performed at the CERN LEP collider where no signal was observed. The most stringent limit was obtained by the OPAL experiment in the channel where both $H^{\pm\pm}$ decay to muons, assuming that the $H^{\pm\pm}$ decays only to muons [4]. This search excluded, at the 95% confidence level, masses less than 100.5 GeV and 100.1 GeV for left handed and right handed $H^{\pm\pm}$, respectively.

At the Fermilab Tevatron $H^{\pm\pm}$ are pair produced through the Drell-Yan process. This cross section depends only on the electroweak quantum numbers and the mass of the $H^{\pm\pm}$ reducing the model dependence[3]. Described below is the first search for $H^{\pm\pm}$ pair production at the Fermilab Tevatron[5]. The search was made assuming both $H^{\pm\pm}$ decay to muons and uses 113 pb^{-1} of data.

2. Event Selection and Efficiencies

The DØ detector is a multipurpose detector at the Fermilab Tevatron consisting, from the beampipe outwards, of a tracking system, calorimeter and muon system.

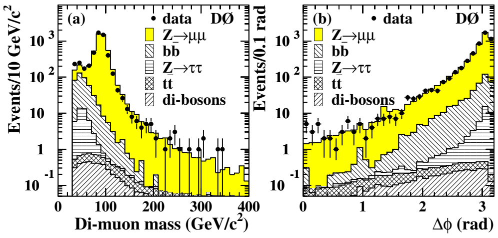

Fig. 1. Measured distribution of di-muon (a) invariant mass and (b) $\Delta\phi$ distributions for events passing the first event selection criterion.The points are the data and the histograms show the contributions from the various background processes.

Muons are identified in the muon system using a combination of drift chambers and scintillators and then required to be matched to a track in the central tracker to utilize the superior momentum resolution of the tracker. The event selection proceeds as follows:

(i) At least two muons were required to be identified, each with momentum transverse to the beam axis greater than 15 GeV.
(ii) At least two muons were required to be 'isolated' from energy deposits in the calorimeter and from tracks to reduce background from $b\bar{b}$ events .
(iii) If there were exactly two muons identified the angular separation in the plane perpendicular to the beam ($\Delta\phi$) was required to be less than 0.8 radians to reduce background from $Z \to \mu^+\mu^-$ and cosmic rays.
(iv) At least two of the muons were required to be have the same charge.

After applying all the selection cuts three candidate events are left.

The efficiency of these selection cuts was evaluated using PYTHIA[6] generated events passed through a GEANT[7] based detector simulation. The tracking, muon identification and triggering efficiencies are corrected using $Z \to \mu^+\mu^-$ data. Figure 1 shows good agreement between kinematic variables in the data and the Monte Carlo simulation for events passing the first of the event selection criteria, where the signal is predicted to be negligible. The efficiency was determined to be $47.5 \pm 2.5\%$ where the uncertainty arises from limited statistics in the Monte Carlo samples and $Z \to \mu^+\mu^-$ data. The value of the efficiency was found to be insensitive to the mass of the $H^{\pm\pm}$.

3. Backgrounds

The contribution of all backgrounds to the signal in the candidate events was evaluated using the same detector simulation as for the efficiencies. The largest background was determined to be from $b\bar{b}$ events contributing 0.8 ± 0.4 events. The Monte Carlo used to estimate this consisted of a sample of inclusive jet events with p_t greater than 30 GeV. Figure 2 shows the distribution of the invariant mass and $\Delta\phi$ for a sample with loosened selection criteria designed to enhance $b\bar{b}$ content.

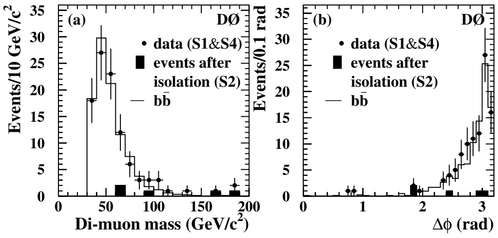

Fig. 2. Measured distribution of di-muon (a) invariant mass and (b) $\Delta\phi$ distributions for events passing the first and fourth event selection criteria.

The cross section of the sample is normalised using a measurement of the inclusive b quark cross section[8]. The uncertainty on the $b\bar{b}$ background is dominated by the uncertainty on this measurement.

A $Z \to \mu^+\mu^-$ event can produce two like sign muons if the charge of one of the muons is incorrectly measured. The number of $Z \to \mu^+\mu^-$ events was estimated to be 0.3 $\pm$ 0.1 events. There are further contributions to the signal events from di-boson and $t\bar{t}$ events. These are predicted to total 0.39 ± 0.03 events. The uncertainty on these estimations is solely due to limited Monte Carlo statistics.

The total background is estimated to be 1.5 $\pm$ 0.4 events.

4. Results and Conclusions

The number of candidate events is consistent with the background prediction. Therefore limits are set, as a function of mass, using the MCLIMIT program[9]. The confidence level for the data to be due to solely background (CL_B) and to be be due to background plus signal (CL_{B+S}) are evaluated separately. The confidence level for signal (CL_S) is defined to be the ratio of CL_{B+S} to CL_S. Accounting for systematic uncertainties for signal and background, a lower mass limit (at 95% confidence level) of 118.4 GeV and 98.2 GeV is set for left-handed and right-handed $H^{\pm\pm}$ respectively, assuming a 100% branching ratio to muons.

References

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