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A SEARCH FOR NEUTRAL HIGGS BOSONS AT HIGH $\tan\beta$ WITH THE DØ DETECTOR

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Many models of Electro-Weak symmetry breaking predict two Higgs doublets, and thus five Higgs bosons, three of which are neutral (h, H, A). The Minimal Supersymmetric extension of the Standard Model (MSSM) predicts the coupling of the bottom quark to the CP-odd scalar A to vary as $\tan\beta$. The sum of the production of the CP-even scalars, h and H, is also proportional to $\tan^2\beta$. After searching for neutral Higgs bosons in multi-jet events containing three or more bottom-quark jets collected at the Tevatron by the DØ detector during Run II, we can exclude $\tan\beta > 80 - 120$ for $90\,GeV < m_A < 150\,GeV$.

Keywords: MSSM Higgs search; high tanbeta limit

1. The MSSM Higgs Boson at the Tevatron

The Minimal Supersymmetric extension of the Standard Model (MSSM) introduces two scalar Higgs doublets through symmetry breaking. They have the three neutral eigenstates h, H (with $m_h < m_H$), and A, and two charged eigenstates $H^\pm$. $\tan\beta$ is the ratio of the vacuum expectation values of the two doublets. Even though it is a free parameter, large values are favored by the ratio of the top and bottom masses.

In general, the coupling of the neutral Higgs boson to down-type quarks like the bottom is enhanced by $\tan\beta$ relative to the Standard Model Higgs, following modified Yukawa couplings. The production cross sections are thus proportional to $\tan^2\beta$. The $h, H \to b\bar{b}$ branching ratio is expected to be about 90% in the mass range of our interest. At large $\tan\beta$, one of h or H is nearly degenerate with A[1]. We do not distinguish between h or H, assuming that either one is degenerate with A, effectively doubling the cross section of the visible neutral Higgs boson.

The dominant production process at the Tevatron is $p\bar{p}$ $(\to gb \to bh) \to bb\bar{b}$. The signal over background ratio is increased with a high number of b-jets in the final state; $bb\bar{b}$ is thus an important signature for discovery. We used $131\,pb^{-1}$ of DØ's Run II data.

2. Event Selection

For all events with at least three b-tagged jets, the invariant mass distribution of the two highest E_T jets is compared to the expected background and signal contributions. As the minimum number of jets per event, ${n_j}^{min}$, both three and four were studied. Event selection was done based on a maximum number of allowed jets (${n_j}^{max}$, a minimum jet E_T for the first, second and third leading jet in jet E_T, the allowed η range for these jets ${|\eta_j|_{max}}^{1,2,3}$. The Higgs masses 100, 120 and 150 GeV were studied; for each Higgs mass and ${n_j}^{min}$ an optimized set of event selection criteria was used.

To distinguish b quark jets from light quark jets, a loose b-tag requirement was used: we required b quark jets to have a secondary vertex with a minimum 2D decay length significance, i.e. cutting on the distance significance of the secondary vertex from the primary vertex in the ϕ plane. This yields an efficiency plateau for b quark jets at 50%, while allowing for a light jet tag efficiency ("mis-tag") of about 2% (both values are derived from data).

3. Cross Section Predictions

The cross section of Higgs and b quark jets is a field of active phenomenological research[2]. For the cross section prediction and the invariant mass distribution of the different signal mass regions, we simulated events using PYTHIA's[3] Standard Model Higgs simulation. We adjusted the leading order cross section predictions by next-to-leading order corrections[4,5].

The main background contributions stem from events with four light jets with three or more mis-tagged jets, and events with two b-jets and two light jets, of which at least one was mis-tagged. Other but smaller contributions come from events with four b-jets, almost negligible are events with $Zb\bar{b}$ and $t\bar{t}$. The possible background contributions were simulated by ALPGEN[6] (for $b\bar{b}j$, $b\bar{b}jj$, $b\bar{b}b\bar{b}$) and PYTHIA (for $t\bar{t}$).

The mis-tagged light jet contribution to the b-tagged sample and its invariant mass distribution was predicted from data. We used a sample with four jet events, of which two jets were b-tagged. Applying a third b-tag to these jets, we can extract the fraction of light jet events for each invariant mass bin. From that, we calculate the expected contribution of these events to the invariant mass distributions with three and four jets of which three are b-tagged (see figure 1).

3.1. *Systematic Uncertainties*

The systematic uncertainties for the acceptance have been determined for the different values of m_h, ${n_j}^{min}$, and found to be between 21.8 % and 27.7%. The dominant components are jet energy scale (JES) and resolution, as well as b-tagging efficiency. The background's systematic uncertainty is between 8% and 10%, depending on ${n_j}^{min}$ and m_h; it is mostly b-tagging related.

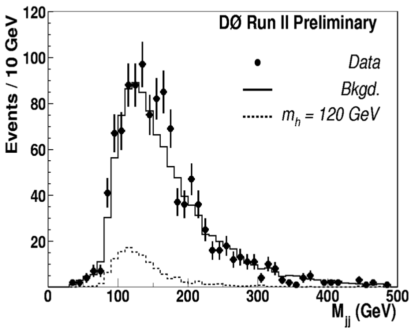

Fig. 1. Invariant mass spectrum for ≥ 3 jet events with ≥ 3 b-tagged jets, showing the expected background and excluded signal at 95% C. L..

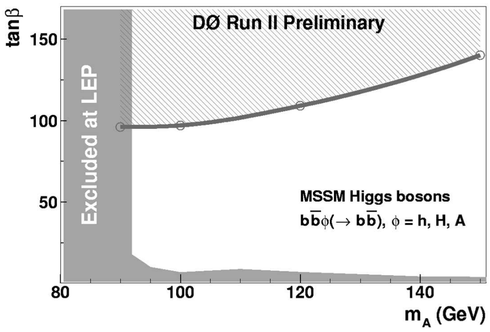

Fig. 2. MSSM parameter space ($\tan\beta$, m_A) excluded by this analysis and LEP.

4. Exclusion Limit, Outlook

The exclusion limits were calculated using a $b/(s+b)$ (b: background, s: signal) likelihood ratio (CL_s method[7]). For a given m_A, a sweep through the $\tan\beta$ space was performed. The resulting limits are shown in figure 2. They are complementary to the limits set by the LEP Higgs working group[8], which are also shown in this figure. With $131\,pb^{-1}$ of DØ's data, we can exclude the values of $\tan\beta > 80-120$, depending on the value of $90\,GeV < m_A < 150\,GeV$.

The limits calculated in this analysis are compatible with previous limits. This will change in the next update of this analysis: already now, we have a data set three times as big, b-tagging with a higher performance, a better jet energy scale correction, triggers with higher signal efficiencies, and improved cuts.

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