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Searches for heavy exotic states at the Tevatron

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for the CDF and DØ collaborations

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31310: Searches for heavy exotic states at the Tevatron

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Abstract. We present the results of searches for Standard Model Higgs, charged stable massive particles, dijet mass resonances, and heavy neutral gauge bosons in Tevatron $p\overline{p}$ collisions at $\sqrt{s} = 1.8$ TeV using the CDF and DØ detectors.

While the Standard Model has enjoyed many phenomenological successes, the mechanism of electroweak symmetry breaking remains at large. This suggests that the Higgs boson may be heavy enough to remain elusive, or, perhaps, there is additional physics beyond the Standard Model. Until the LHC comes online, the Tevatron will remain at the energy frontier and thus plays a unique role in the search for Higgs and non-Standard Model physics. Here we report on the results of searches within the Tevatron's exclusive energy reach.

1 Standard Model Higgs

The CDF collaboration has searched for the Standard Model Higgs decay signature WH^0 with $W \rightarrow \ell\nu$ and $H^0 \rightarrow b\overline{b}$ [1]. Events with an isolated high p_T lepton ($p_T > 20$ GeV/c) and large missing energy ($\not{E}_T > 20$ GeV) are selected if they are not consistent with a Z^0 or a top dilepton decay. The events are additionally required to have at least one jet associated with a b hadron decay using reconstructed secondary vertices from CDF's silicon vertex detector. The event is considered double tagged if an additional b-jet is tagged by the same algorithm or an algorithm that searches for soft leptons consistent with a semileptonic b decay. The events are classified by jet multiplicity with the signal assumed to be in the W + 2 jet bin. The other bins are compared to the simulated background from QCD + top.

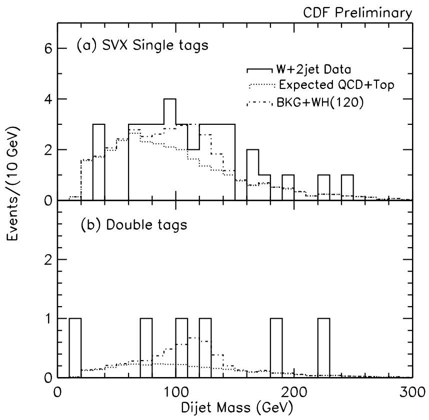

Fig. 1. $b\overline{b}$ dijet mass spectrum for (a) single tags, and (b) double tags.

An excess of double tagged events is observed in the W + 2 jet bin, however, the $b\overline{b}$ mass spectrum is consistent with expected background as shown in Figure 1.

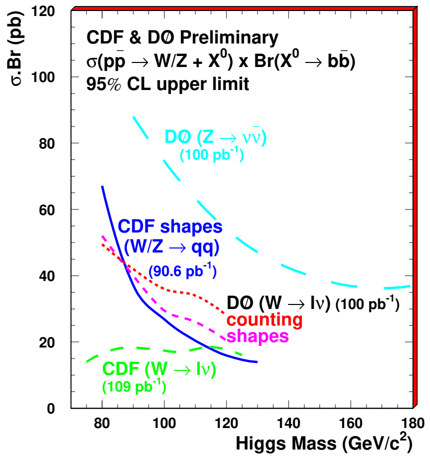

Fig. 2. Summary of limits on Standard Model Higgs from the Tevatron.

The DØ collaboration has also searched for heavy neutral scalars[2]. They use the decay signature $Z^0 X$ with $Z \to \nu\nu$ and $X \to b\bar{b}$ where the b jets are identified by their decays to soft muons. The muon is required to have $p_T > 3.5$ GeV$/c$ and to be central in pseudorapidity, $|\eta| < 1.0$. Events consistent with $W \to \ell\nu$ decays are removed. To identify the presence of neutrinos, a cut on missing transverse energy of $\not{E}_T \geq 35$ GeV is chosen because it is efficient for a simulated 90 GeV Higgs signal. After all cuts are applied, there are 2 events left which is consistent the expected background from top, W, and Z^0 of 2.6±0.7 events.

Figure 2 summarizes the limits on the Higgs cross section based on these and other analyses at the Tevatron.

2 Charged stable massive particles

CDF has exploited it's central tracking system in a search for strongly produced, stable, charged objects at high mass. Because such objects are massive, they will have a low velocity and therefore will suffer large ionization losses in the tracking chambers: $\frac{dE}{dx} \approx \frac{1}{\beta^2}$. At low values of $\beta\gamma$ ($\beta\gamma < 0.85$) the mass can be uniquely determined from dE/dx when combined with a momentum measurement as illustrated in Figure 3. If these objects are stable ($\gamma\tau > 10^{-8}s$), they will penetrate the detector and trigger as high p_T muons.

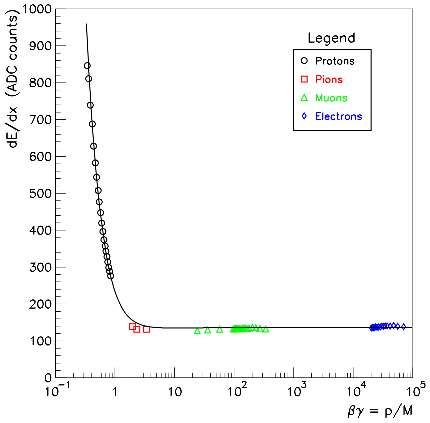

Fig. 3. dE/dx in CDF's silicon vertex detector.

Events with good track quality are selected for this analysis from high p_T muon samples which do not have a minimum ionizing requirement. The events are further required to have $|\mathbf{p}| > 35$ GeV, and the dE/dx cut is tightened at lower momentum to reduce background. After all kinematic cuts are applied, no events remain above 100 GeV. Using color triplet quarks as a reference model, lower mass limits of 195 GeV and 220 GeV are obtained at the 95% confidence level for a charge 1/3 and a charge 2/3 quark respectively.

3 Dijet mass resonances

Using the dijet mass spectrum at CDF and DØ to search for resonances, many particles may be sought with a single spectrum. The large background in such a search is compensated by large cross sections for dijet production. B-tagging may be added for background suppression or to detect particles decaying preferentially to the third generation, such as those predicted in Topcolor models.

The CDF dijet mass spectrum is fit to a smooth parameterization of the form:

$$\frac{d\sigma}{dm} = \frac{A(1 - m/\sqrt{s} - cm^2)^N}{m^p} \quad (1)$$

as shown in Figure 4. Limits are set by fitting the spectrum to the above parameterization plus a signal resonance and minimizing the likelihood.

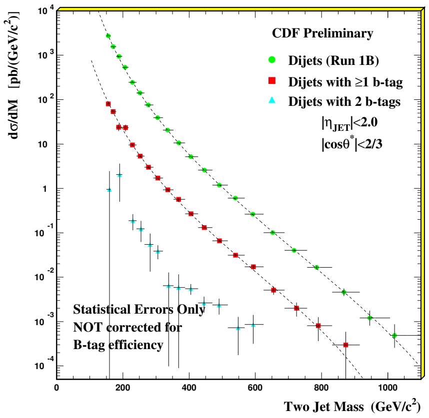

Fig. 4. The untagged, b-tagged, and double tagged dijet mass mass spectra from CDF.

Axigluons and colorons are excluded between 200 and 980 GeV, excited quarks between 80 and 570 GeV and 580 and 760 GeV, color octet technirhos between 260 and 480 GeV, W' between 300 and 420 GeV, and E_6 diquarks are excluded between 290 and 420 GeV. A 2.6 σ fluctuation in the 550 GeV bin weakens some limits [3].

For the DØ dijet mass search, the data is normalized to a detector smeared JETRAD simulation of the QCD background. The simulated background, along with a comparison of the data to the normalization are shown in Figure 5. Minimizing the background plus a signal, they exclude excited quarks below 725 GeV, Z' between 365 GeV and 615 GeV, and W' between 340 and 680 GeV [4].

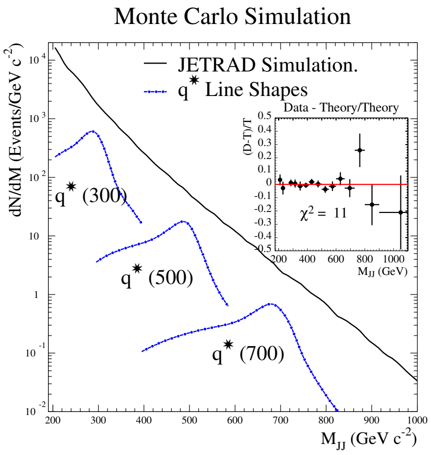

Fig. 5. Simulations of the DØ dijet spectrum and excited quark shapes after detector smearing.

4 Heavy neutral gauge bosons

Many extensions of the Standard Model require the existence of additional neutral gauge bosons. CDF has searched for both ee and $\mu\mu$ decays of such particles by fitting the ee and $\mu\mu$ mass spectra to the expected backgrounds. After lepton identification cuts, a sample of 7234 ee candidates and 2566 $\mu\mu$ candidates remain. The expected background in the $Z' \to \mu\mu$ channel comes from Z^0 and Drell-Yan production. The $\mu\mu$ spectrum is fit to the predicted background distributions normalized to the height of the Z^0 peak, and is found to be consistent with Standard Model processes. Misidentified dijet events contribute an additional background in the $Z' \to ee$ channel. Rather than subtract these events, they are fit to the parametric form in Equation 1 and included the background. A comparison of the ee mass spectrum to the predicted background is shown in Figure 6, with the raw data shown in the inset. Combining these two analyses using a binned maximum likelihood method, a lower mass limit of 690 GeV is found for a Z' with Standard Model couplings [5].

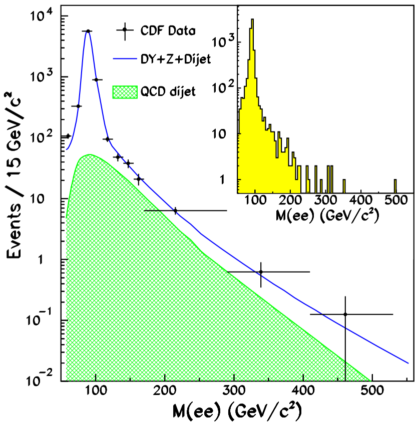

Fig. 6. CDF ee mass spectrum fit to the Drell-Yan + Z + dijet continuum.

DØ has searched for $Z' \to ee$ by counting the number of observed events with a mass window of $M_{Z'} \pm 4\Gamma_{Z'}$ for each Z' value tested, and comparing to the expected number of events from Z^0 and Drell Yan in that window. Above a dielectron mass of 300 GeV, 6 events are observed with 5.8 expected. Above 500 GeV, 1 event is observed with 0.3 expected. This yields a mass limit of 660 GeV assuming Standard Model couplings [6].

With a factor of 20 increase in luminosity and upgrades of both detectors, the mass discovery reach for the particles presented here will be greatly extended during the next run of the Tevatron.

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