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Study of the Dijet Invariant Mass in W + 2 jet events

PoS(EPS-HEP2011)216

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The DØ Collaboration presents a study of the dijet invariant mass spectrum, M_{jj}, in events with two jets produced in association with a $W \to \ell\nu$ boson. The goal is to verify a claim from the CDF Collaboration about the possible existance of an anomalous dijet resonance at $M_{jj} \approx 145$ GeV. Thus, we investigate the 110 GeV $< M_{jj} <$ 170 GeV mass range and report our results.

The 2011 Europhysics Conference on High Energy Physics, EPS-HEP 2011,
July 21-27, 2011
Grenoble, Rhône-Alpes, France

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1. Introduction

Recently, the CDF Collaboration reported an excess of events in the dijet invariant mass spectrum M_{jj}, corresponding to 3.2 standard deviations (s.d.) [1], while studying the $WW+WZ$ production in which the W boson decays leptonically ($W \rightarrow \ell\nu$, $\ell = e, \mu$) and the associated W or Z boson decays hadronically ($W/Z \rightarrow jj$). With an updated data set from 4.3 fb^{-1} to 7.3 fb^{-1} of integrated luminosity collected with the CDF detector the significance of an excess increased to 4.1 s.d [2]. Assuming that the excess arrises from a hypothetical particle X with $\mathrm{BR}(X \rightarrow jj) = 1$, the resulting signal can be modeled as a Gaussian dijet resonance with a width $\sigma_{jj} = \sigma_{W\rightarrow jj} \cdot \sqrt{M_{jj}/M_{W\rightarrow jj}}$. The selection efficiency for the hypothetical WX signal is modeled with WH Monte Carlo (MC), where a Higgs boson is generated with a mass of 150 GeV. Based on these assumptions, the CDF Collaboration reports an estimated production cross section of $\sigma(p\bar{p} \rightarrow WX) \approx 4$ pb. To verify their claim we analyze 4.3 fb^{-1} of integrated luminosity collected with the DØ detector and emulate the CDF event selection as closely as possible. Finally, we report our results obtained from a fit to the DØ data.

2. Event Selection and Fits to DØ data

To select $W(\rightarrow \ell\nu) + jj$ events, we require a single electron or muon with $p_T > 20$ GeV and $|\eta_{e,\mu}| < 1.0$, $\not{E}_T > 25$ GeV, two jets with $p_T > 30$ GeV and $|\eta_j| < 2.5$ (we veto events with additional jets with $p_T > 30$ GeV), $|\Delta\eta(j_1, j_2)| < 2.5$, $\Delta\phi(j_1, \not{E}_T) > 0.4$, $p_T(j_1, j_2) > 40$ GeV and $M_T^{\ell\nu} > 30$ GeV (and $M_T^{\mu\nu} < 200$ GeV in the muon channel). The diboson processes WW, WZ and ZZ, are modeled with PYTHIA, W+jets, Z+jets, and $t\bar{t}$ processes are modeled with ALPGEN, and single top-quark production is modeled with COMPHEP. Both ALPGEN and COMPHEP generators, are interfaced to PYTHIA for parton showering and hadronization, following a GEANT-based detector simulation. All MC samples except the W+jets, are normalized to next-to-leading order (NLO) or next-to-NLO predictions for SM cross sections. The multijet background in both the electon and muon channels, is determined from data and corrected for contributions from processes modeled by MC. The multijet normalizations are determined from fits to the $M_T^{\ell\nu}$ distributions in which the multijet and W+jets relative normalizations are allowed to float. The expected yields of multijet background are determined from this fit. Here, we would like to point out that we do not apply any additional corrections such as those to ΔR_{jj} or η_j distributions to improve the MC modeling of the W+jets and Z+jets production.

After selection we perform a fit of all SM contributions to data in the M_{jj} distribution. The fit minimizes a Poisson χ^2 function [3] with respect to variations in the rates of individual backgrounds and systematic uncertainties that may modify the predicted M_{jj} distribution. In this fit the cross sections for dibosons and W+jets are floated with no constraint. The M_{jj} distributions of data and the SM predictions after the simultaneous fit of the electron and muon channels are shown in Fig. 1. We also subtract all SM contributions, except dibosons, from data and compare it to the SM prediction for WW+WZ+ZZ as shown in Fig. 2. Figures 1 and 2 clearly show that the DØ data are consistent with the SM prediction.

To probe for an excess of events at $M_{jj} \approx 145$ GeV, in the DØ data, we model a hypothetical signal by a Gaussian with an expected width of $\sigma_{jj} = 15.7$ GeV at $M_{jj} = 145$ GeV. The acceptance

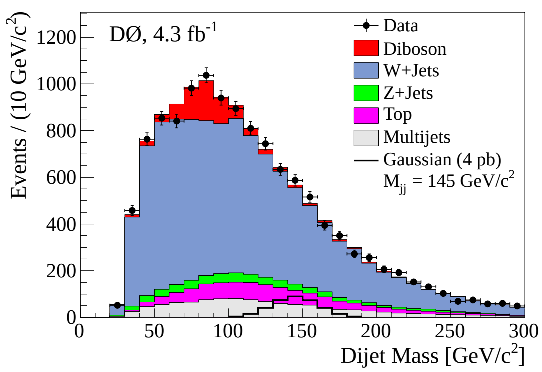

Figure 1: Dijet invariant mass for electron+muon channel after the fit of SM processes to data.

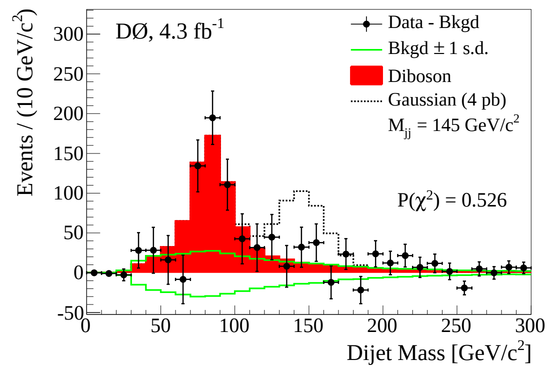

Figure 2: The SM contribution (except dibosons) subtracted data compared to diboson SM prediction.

for $WX \to \ell\nu jj$ process is then estimated using $WH \to \ell\nu b\bar{b}$ MC generated with $M_H = 150$ GeV. For other values of M_{jj}, we use the acceptance estimated from $WH \to \ell\nu b\bar{b}$ MC events with $M_H = M_{jj} + 5$ GeV. We repeat the fit with W+jets and WX cross sections being unconstrained. We also assign systematic uncertainties to Gaussian model which affect both its normalization and shape such as due to a jet energy scale, jet resolution, luminosity, lepton and jet identification. The best fit value for a Gaussian template yields the cross section consistent with zero i.e., $\sigma(p\bar{p} \to WX) = 0.42^{+0.76}_{-0.42}$ (syst+stat) pb.

Further we derive upper 95% C.L. limits on the cross section for a possible dijet resonance as a function of M_{jj} using the CL_s method with a negative log-likelihood ratio (LLR) test statistic [4]. The limits are derived in steps of 5 GeV, allowing the cross sections for W+jets production to float with no constraint, and presented in Fig. 3. For $M_{jj} = 145$ GeV we set a 95% C.L. upper limit of 1.9 pb on the cross section for WX production.

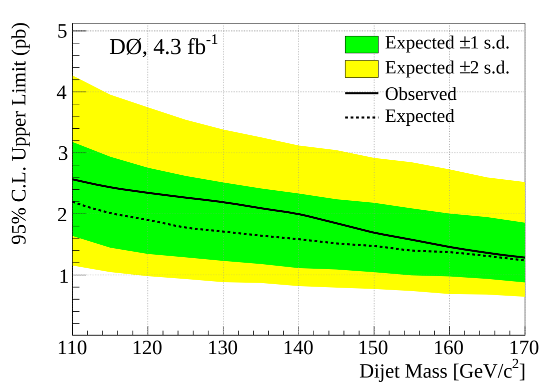

Figure 3: Expected and observed upper 95% C.L limits on the cross section (in pb) for a Gaussian signal as a function of the dijet invariant mass, and the regions corresponding to a 1 s.d. and 2 s.d. fluctuation of the backgrounds.

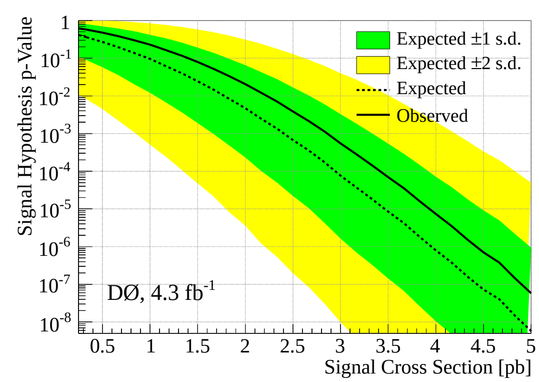

Figure 4: p-values for the signal+background hypothesis with a Gaussian signal at $M_{jj} = 145$ GeV as a function of $\sigma(p\bar{p} \to WX)$. The p-values for the background-only hypothesis, with regions corresponding to a 1 s.d. and 2 s.d. fluctuation of the backgrounds, and the data.

The p-value obtained by integrating the LLR distribution generated from the signal+background hypothesis above the observed LLR, assuming a Gaussian signal with $M_{jj} = 145$ GeV modeled as described, as a function of cross section is also presented in Fig. 4. The p-value for a Gaussian signal with cross section of 4 pb is 8.0×10^{-6}, which corresponds to a rejection of this signal cross section at the 4.3 s.d. level.

In order to test the sensitivity of the DØ data to an existence of reported excess, we repeat the statistical analysis after injecting a Gaussian signal modeled at $M_{jj} = 145$ GeV and normalized to 4 pb, into the DØ data. The size and shape of the injected signal are shown in Fig. 1 and Fig. 2 as a black solid line. Then we compare the LLR distributions for different hypotheses as shown in Fig. 5. They clearly show a different behavior indicating the sensitivity of the DØ data to the excess reported by the CFD Collaboration.

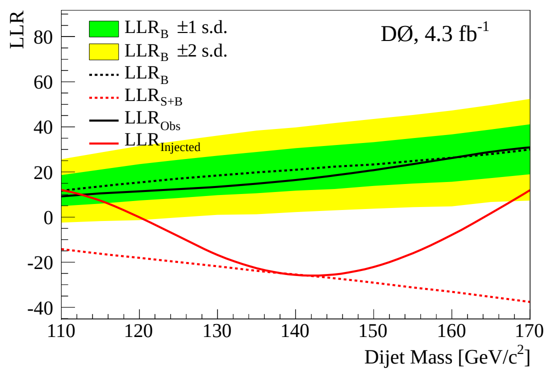

Figure 5: The LLR distribution as a function of M_{jj} for the background-only hypothesis, signal+background hypothesis, observed data, and for test-data injected with a Gaussian signal.

3. Summary

We analyzed 4.3 fb^{-1} of integrated DØ luminosity to study the M_{jj} distribution from $W \to \ell\nu$ + jets events. After applying a similar event selection as the CDF Collaboration we find that the DØ data are consistent with the SM prediction. Thus, we set the upper 95% C.L. limit of 1.9 pb on $\sigma(p\bar{p} \to WX)$ and we reject the hypothesis of $\sigma(p\bar{p} \to WX) = 4$ pb at the level of 4.3 s.d [5].

References

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