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Update on W+2jet at CDF using 7.3 fb^{-1}

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We report a study of the invariant mass distribution of jet pairs produced in association with a W boson using data collected with the CDF detector which correspond to an integrated luminosity of 7.3 fb^{-1}. The observed distribution showed an excess in the 120-160 GeV/c^2 mass range. Further studies and comparisons with D0 are presented.

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1. Introduction

Measurements of associated production of a W boson and jets are fundamental probes of the electroweak sector of the standard model (SM) and searches for new phenomena. The CDF collaboration at the Fermilab Tevatron collider recently measured the cross section of WW/WZ diboson production from a lepton plus jets final state [1] and observed a discrepancy in the dijet mass spectrum [2]. Multiple studies have been performed since then and the result has been updated with more luminosity [3].

2. Analysis selection

The analysis starts from the reconstruction of a W in its leptonic decay. An high p_T electron or muon candidate is selected with E_T (p_T) > 20 GeV (GeV/c) and $|\eta| < 1.0$ plus missing transverse energy $\not{E}_T > 25$ GeV. To further ensure the presence of a real W, the transverse mass $M_T(W)$ of the lepton $+\not{E}_T$ system is required to be greater than 30 GeV/c^2. Jets are clustered using a fixed-cone algorithm (JETCLU) with radius $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.4$, and their energies are corrected for detector effects that are of the order of 25% for jet $E_T = 30$ GeV. We require events to have exactly two jets each with $E_T > 30$ GeV and $|\eta| < 2.4$, and the dijet system to have $p_T > 40$ GeV/c.

3. Modeling and backgrounds

The resulting sample is dominated by events W+jets events with contributions from WW+WZ, $t\bar{t}$, Z+jets, single top production and multijet QCD sources. The diboson, $t\bar{t}$, and single top components are simulated using the PYTHIA event generator, while W+jets and Z+jets processes are simulated using ALPGEN with an interface to PYTHIA. Multijet QCD events, where one jet is misidentified as a lepton, are modeled using data sidebands.

We perform a combined binned χ^2 fit, for electron and muon events, to the dijet invariant mass (M_{jj}) spectrum using predictions for the multijet QCD, WW, WZ, Z+jets, W+jets, $t\bar{t}$, and single top processes. The final W+jets normalization is determined by minimizing this χ^2 and all other contributions are constrained to be within the variance of their expected normalization.

A fit the dijet mass distribution shows good agreement between the background model and the data within uncertainties, except in the mass region $\sim$ 120-160 GeV/c^2, where an excess over the simulation is seen [3].

We choose to model the excess with an additional Gaussian contribution and perform a $\Delta\chi^2$ test of this hypothesis. The width of the Gaussian is fixed to the expected dijet mass resolution.

In the combined fit, the normalization of the Gaussian is free to vary independently for the electron and muon samples, while the mean is constrained to be the same. The result of this fit is shown in Figs. 1 (c) and (d). The values of parameters returned by the combined fit are shown in Table 1.

The expected distribution of $\Delta\chi^2$ is computed numerically from simulated background-only experiments and used to derive the p-value corresponding to the $\Delta\chi^2$ actually observed.

In deriving the p-value we account for systematic uncertainties that affect the background shapes and the normalization of constrained components. For W+jets we consider, as an alternative,

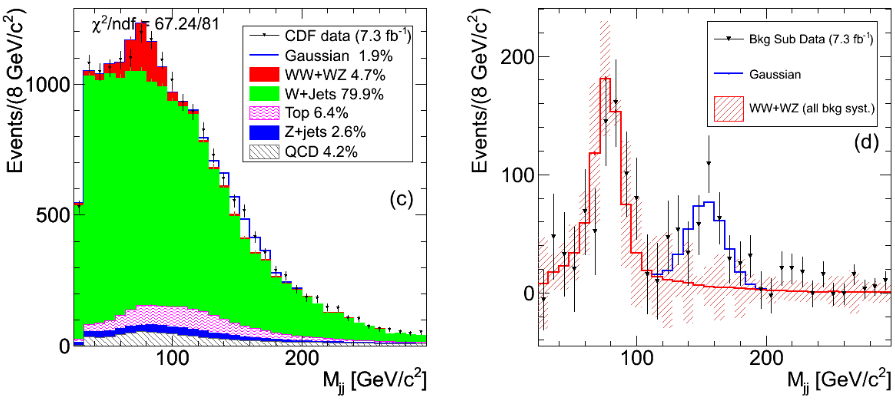

Figure 1: Result of the fit to the invariant mass distribution including the gaussian contribution. The best fit out of the systematics uncertainties on the shape considered is shown.The distributions are shown with a 8 GeV/c^2 binning while the actual fit is performed using a 4 GeV/c^2 bin size.

the M_{jj} distributions obtained by halving or doubling the renormalization scale (Q^2) in ALPGEN. For multijet QCD, we change our model using different lepton isolation ranges. The systematic uncertainty due to uncertainties in the jet energy scale ($\pm 3\%$) affects all components. For each systematic effect we consider the two extreme cases and perform separate fits. For each of the possible combinations of systematic effects we calculate a different $\Delta\chi^2$ distribution and take the conservative approach of using the distribution that returns the highest p-value. The trial factor is also included. Assuming only background contributions the probability to observe an excess larger than in the data is 1.9×10^{-5} corresponding to a significance of 4.1 standard deviations for a Gaussian distribution.

Multiple studies have been performed in order to understand the nature of the excess and are documented in [3]. In particular the requirement of strictly two jets has been removed, in order to exclude mismodeling due to the jet veto. Different NLO MC generators have been used for top and single top, whose contributions are also doubled and still do not account for the excess. W+jets is a main background, therefore we tried another generator SHERPA that uses a different matching between matrix element and parton shower. The overall agreement, as seen in [3], improves both in the low mass and high mass tail. The excess decreases but it is found to be still significant. Further tests are on going to probe also NLO generators.

	Electrons	Muons
Excess events	240 ± 55	158 ± 46
Excess events / expected diboson	0.57 ± 0.15	0.45 ± 0.14
Mean of the Gaussian component	147 ± 5 GeV/c^2	

Table 1: Results of the combined fit. The ratios of the number of events in the excess to the number of expected diboson events in the electron and muon samples are statistically compatible with each other.

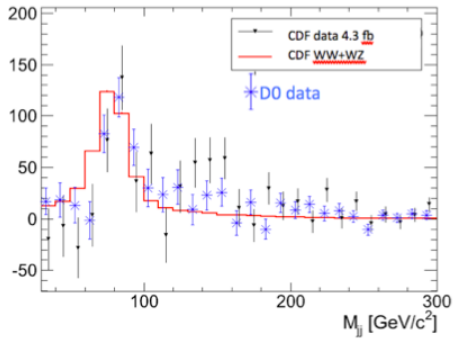

Figure 2: CDF data rescaled to D0 published data to the same diboson yield.

4. Comparison with D0

The D0 Collaboration analyzed in detail the dijet mass distribution of W+jets events observing good agreement between data and MC with $4.3 fb^{-1}$ [4]. These results have not been updated yet with more luminosity.

While some differences are present between the two analysis and the treatment of systematic uncertainties, we can compare the cross section of an hypothetical new resonance assuming the acceptance from a MC sample of WH with m_H= 150 GeV of mass. The cross sections are 0.4$\pm$ 0.8 and 3.1 $\pm$ 0.8 pb , respectively for D0 and CDF leading to a difference between the two experiments of 2.3σ using gaussian approximation for the errors. Rescaling the CDF data to D0 published data to the same diboson yield and using the same bin size we obtain the plot shown in Fig. 2. While CDF data show a bigger discrepancy in the excess region, the overall trend seems to be same.

5. Conclusion

A detailed study of the dijet mass distribution of events produced in association with a W has been presented with a total luminosity of 7.3 fb^{-1}. The best fit to the observed dijet mass distribution using known components, and modeling the dominant W+jets background using ALPGEN+PYTHIA Monte Carlo, shows a statistically significant disagreement. Studies are still underway to understand the origin of this excess.

References

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