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Model-independent search for new physics at D0 experiment

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Abstract. Finding the evidence of new physics beyond the Standard Model is one of the primary goals of RunII of the Tevatron. Many dedicated searches for new physics are ongoing at the Tevatron but in order to broaden the scope and maximize the chances of finding the new physics, we also search in a model-independent way. The results of such searches for indications of new physics at the electroweak scale are presented using data collected using the D0 detector from $p\bar{p}$-interactions at $\sqrt{s} = 1.96$ TeV.

Keywords. Standard Model; $p\bar{p}$ collisions; D0 experiment.

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1. Introduction

Particle physics is at a stage where there is no unique way forward. The Standard Model (SM) of particle physics has been remarkably successful: all particles predicted by this model have been discovered, with the notable exception of the Higgs boson. Despite its success, there are strong motivations from the theory to expect new physics at energies at or just above the electroweak scale. Assuming that Beyond Standard Model (BSM) physics exists, we do not know how it appears, rendering its search difficult.

Motivated by uncertainty and expectations of physics beyond the SM, we examined data from many channels in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV at the Tevatron Collider at Fermilab, collected by the D0 experiment, for deviations from the SM. Similar approaches have been applied to data from the D0 Collaboration [1–3], the H1 Collaboration at the HERA *ep* collider at DESY [4], and the CDF Collaboration at the Tevatron [5,6].

2. Search strategy

The search technique we have chosen trades some sensitivity for breadth of search: we do not make data selections specific to a particular model. But we do look systematically at many channels in a coordinated fashion, applying knowledge of the SM and a consistent model of detector effects.

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We apply standard corrections (efficiencies, k factors, re-weighting, mistag rates, etc.) used by collaboration to compare data and Monte Carlo (MC). However, in such a broad analysis, one cannot hide from the fact that MC samples do not describe all SM backgrounds without *ad hoc* corrections. The way we have chosen to determine further empirical correction factors is to single out specific inclusive channels which are dominated by a single SM background process. In this way, a well-understood correction factor can be fit to the ratio of data and MC in that channel. We typically derive one such factor per inclusive final state by fitting to the distributions, listed below, with high-p_{T} tails (potential signal regions) excluded.

The inclusive channels we select are dominated by W and Z boson production. This is because there exist MC generators based on the SM that are expected to be able to reproduce the $p\bar{p}$ interactions producing such final states in great detail. We divide the data into seven inclusive channels:

(a) $\ell^+\ell^- + X$ ($\ell = e$ or μ)
(b) $\ell + \text{jet} + X$ ($\ell = e$ or μ, and no additional leptons)
(c) $\ell + \tau + X$ ($\ell = e$ or μ).

For each of these channels, a set of histograms were fit to determine the scale factors and another set were used as checks on the quality of the fit.

Once the final weights are determined from the inclusive channel distributions, the events are passed on to the experiment-independent programmes which divide the events based on exclusive final states.

In order to look for discrepancies between data and the SM prediction in a large number of final states, we use tools called Vista and Sleuth. Vista mainly concentrates on discrepancies that affect the bulk of distributions rather than narrow regions of phase-space because it looks at the raw numbers of events and MC/data agreement across full distributions. Sleuth is an attempt to systematically search for new physics as an excess in the tails of Σp_{T} distributions. This variable adds the absolute values of the p_{T} of each object in the event to the $\not\!\!E_{\mathrm{T}}$.

3. Methodology testing

To check the sensitivity of a search with SLEUTH, we examine whether a top quark (produced in $t\bar{t}$ pairs) which contributes objects with high p_{T} would have been discovered in the current data sample. For this test, we used all the background samples, except for the $t\bar{t}$ MC. The main concern is whether other final states would compensate for the missing $t\bar{t}$ events, and thus SLEUTH would not be sensitive to $t\bar{t}$ production in data.

We examine the $\ell jjb\bar{b}\not\!\!E_{\mathrm{T}}$ final state, which we expect to be dominated by $t\bar{t}$ events. Figure 1 shows that the presence or absence of a $t\bar{t}$ signal has a great impact. With a threshold of 0.001, the SLEUTH test, including the $t\bar{t}$ MC, yields a statistical probability of compatibility of 0.98 after correcting for the number of trials. However, without the $t\bar{t}$ contribution, this probability is $<1.1 \times 10^{-5}$.

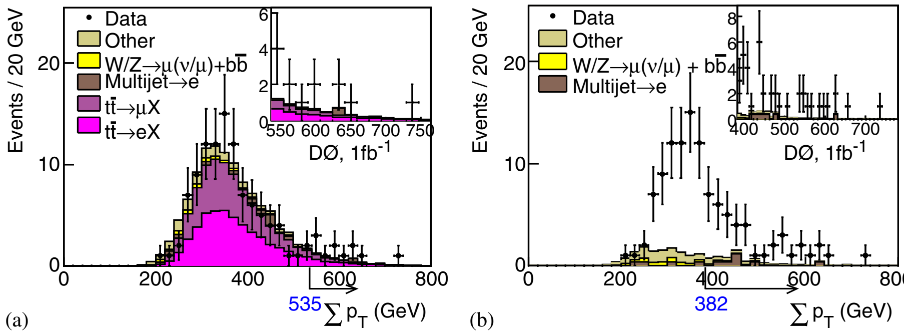

Figure 1. Sensitivity to new physics test using the $t\bar{t}$ final state. (**a**) The $t\bar{t}$ MC is included. (**b**) The results of the entire analysis without the $t\bar{t}$ MC.

4. Results

Using 1.07 fb^{-1} RunIIa dataset, Vista finds 117 exclusive final states with 5543 kinematic shape distributions. Two final states are found to have more than 3σ discrepancy. These are the final states μ + 2 jets + $\not{E}_{\rm T}$, with a probability corresponding to a 4.5σ discrepancy, and $\mu^+\mu^-$ + $\not{E}_{\rm T}$ with a discrepancy of 6.7σ. Out of 5543 distributions, 16 were found to be a 3 or more σ discrepancy, after correcting for the trials. The majority of these are related to spatial distributions involving jets. All these discrepancies are related to known simplifications in our modelling assumptions, e.g., no systematic uncertainties are taken into account, aside from the adjustments made by the normalization factors.

All Vista final states are input to Sleuth algorithm. Sleuth finds a total of 31 final states after folding. The two discrepant Vista final states are found again in Sleuth, as expected. No additional final state is found to be discrepant by Sleuth.

5. Conclusions

In conclusion, we have performed a broad search for new physics using our full RunIIa dataset (1.07 fb^{-1}). A total of 117 exclusive data final states and 5543 relevant kinematic distributions were compared to the complete Standard Model background predictions using Vista. Only two out of the 117 exclusive final state show a statistically significant discrepancy. Given the known modelling difficulties in both the final states, we refrain from attributing the observed discrepancies to new physics. No additional final state was found to be discrepant by Sleuth.

The full analysis detail can be found in [7]. We also have a factor of 10 more data already recorded by the D0 experiment and the same amount of data by CDF Collaboration. So we hope to have much more sensitive searches for possible new physics in the near future. We are also involved in a similar analysis performed at the CMS experiment. The preliminary results of the CMS analysis was also shown at the Lepton–Photon 2011 Conference. The improved analysis with a lot more CMS data is underway.

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