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Search for New Physics in Dilepton and Diphoton Final States at CDF

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The CDF detector has accumulated a large data sample of $p\bar{p}$ collisions at $\sqrt{s}$ =1.96 TeV at the Fermilab Tevatron. In this report we present the results of searches for physics beyond the Standard Model using final states of 2 leptons or 2 photons using 190 pb^{-1} to 448 pb^{-1} of data. No deviation from the predictions of Standard Model was observed. The non-observation was used to derive cross section limits on contributions to these final states from possible new physics processes. For many specific new physics models, such as Z', Randall-Sundrum Graviton, Large Extra Dimensions and SUSY, these cross section limits can be used to place strong constraints on their parameters.

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1. Introduction

Although up to date no serious experimental data can contest the validity of the Standard Model (SM) in describing the electromagnetic, weak and strong interactions of fundamental particles, many important questions remain open: What is the origin of electroweak symmetry breaking? How is the hierarchy problem solved? Can electroweak and strong interactions, and even gravity, be unified? Models developed to answer these questions predict naturally much richer physics phenomena than the SM that can be observed on high energy particles colliders.

The CDF experiment, operating on the current highest energy collider, the Tevatron, is carrying out a comprehensive program to search for physics beyond the Standard Model in various final states (channels). One of those is the high mass dilepton, and the other high mass diphoton. The advantage of using these channels is that their productions in $p\bar{p}$ collisions via Standard Model processes are well understood, while experimentally high p_T leptons and photons can be cleanly identified. Many models of physics beyond the SM have well-developed dilepton and diphoton phenomenology, eg. SUSY, extended gauge theories, Extra Spatial Dimensions, Grand Unification Theory. The CDF searches are based on signatures and strive to be independent of specific models. Only when no deviation is found model details are used to calculate acceptance in order to constraint model parameters. Four analyses are presented here: *ee*, $\mu\mu$ search, *ee* search using M_{ee} and $\cos\theta^*$, $\tau\tau$ search and $\gamma\gamma$ search.

2. Search for anomalous resonance with dielectrons and dimuons

A simple and straightforward search is looking for high-mass bumps in the invariant mass spectra of isolated dielectrons and dimuons. CDF has done such an analysis with 200 pb^{-1} of data[1]. The measured mass spectra agree very well with background predicted by the SM and no mass bump has been observed. Instead limits on the production cross section, $\sigma(X_{ll})$, of a new particle X that decays to dielectrons and dimuons are extracted, as shown in Fig. 1. Limits for spin-0, 1 and 2 are presented separately to take into account the dependence of the experimental acceptance on the angular distributions of the lepton pair, which is sensitive to the spin of the decaying particle. The limits combining both dielectron and dimuon channels are approximately 25 fb at 95% CL for $m_{ll} > 600\,\mathrm{GeV/c^2}$ for all spins.

Fig. 1 also shows the prediction from representative models with higher order correction‡. Comparing with the limits on $\sigma(X_{ll})$ lower mass bounds of the new particle X predicted by these models can be set. For example, using the combined $\sigma(X_{ll})$ 95% CL limit for spin 0, lower mass bounds of 730 and 665 GeV/c^2 are obtained for R-parity violating $\tilde{\nu}$ [2] for $(\lambda'^2 \cdot Br) = 0.01$ and 0.005 respectively. For spin-1, masse bound of 825 GeV/c^2 is obtained for SM-like (sequential) Z' boson[3], while bounds of 690, 675, 720 and 615 GeV/c^2 are obtained for Z'_χ, Z'_Ψ, Z'_η and Z'_I from the E6 model[4]. For spin-2 the lower mass bounds are 710, 510 and 170 GeV/c^2 for the first excited states of the RS graviton[7] for the coupling parameter k/M_{PL} = 0.1, 0.05 and 0,01 respectively.

‡ A constant K-factor of 1.3 is used, except in the case of RPV $\tilde{\nu}$ where NLO calculation is used

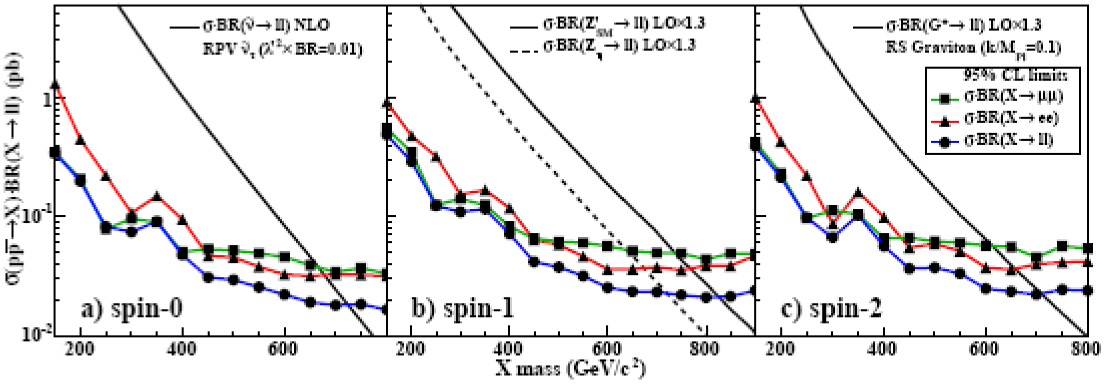

Figure 1. The σ(X_{ll}) limits from ee, μμ and combined[§] channels as a function of m_X for spin-0 (a), spin-1 (b), and spin-2 (c). Also shown are theoretical predictions of representative models.

3. Search with dielectrons using M_{ee} and $\cos\theta^*$

In addition to the invariant mass spectrum, the angular distribution of the two leptons can be used to detect physics beyond SM because new resonance could interfere with the Drell-Yan process thus alter the angular distribution[6]. With 448 pb^{-1} of dielectron data CDF has measured the invariant mass spectra and the scattering angle distributions in the high mass region (see Fig. 2). Both distributions agree well with the SM predictions. Using information from both distributions, lower masse bounds of 845, 720, 690, 715 and 625 GeV/c^2 are obtained for Z'_{SM} Z'_χ, Z'_Ψ, Z'_η and Z'_I respectively.

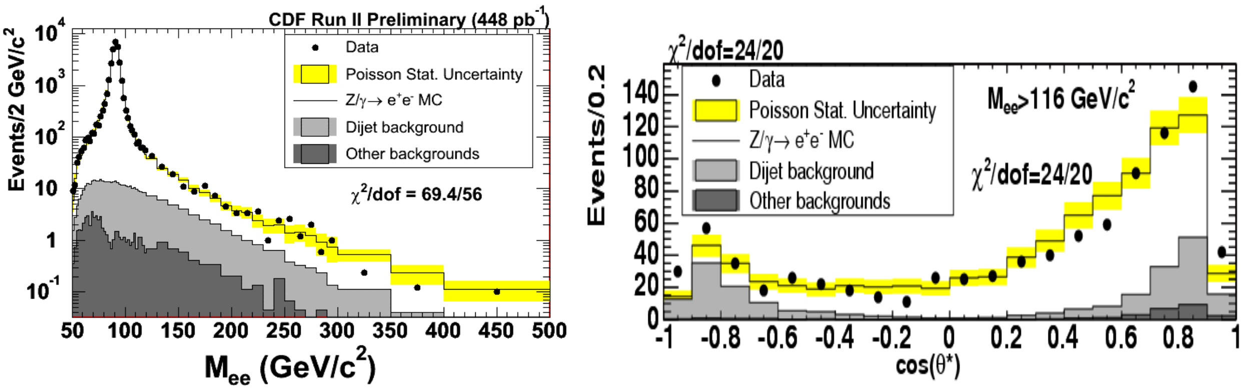

Figure 2. The M_{ee} distribution (left) and the cosθ* distribution for M_{ee} >116 GeV/c^2(right).

4. Search for anomalous resonance with ditaus

The search for mass-bump in the ditau channel[7] is similar to those with dielectrons or dimuons. Since tau can decay leptonically or hadronically, three distinct final states are used: $e\tau_h$, $\mu\tau_h$ and $\tau_h\tau_h$ where τ_h denotes an identified hadronic tau decay. Due to the presence of neutrinos in the tau decays, the invariant mass $M_{\tau\tau}$ cannot be directly measured. Instead the visible mass $M_{vis} = m(l, \tau_h, E_T^{miss})$ is used. In an analysis using a data sample of 195 pb^{-1}, no

[§] BR($X \rightarrow ee$) = BR($X \rightarrow \mu\mu$) is assumed deviation from SM prediction is observed and limits on new particle decaying to tau pairs are set. For example the 95%CL mass limit of for a Z'_{SM} is 399 GeV/c^2.

5. Search for anomalous resonance with diphotons

High mass diphoton is another interesting hunting ground for new physics. For example in the Randall-Sandrum (RS) model with a warped extra spatial dimension, diphoton resonances can be produced via the graviton in the extra dimension[5].

CDF has searched for diphoton mass resonance with a data sample of 345 pb^{-1}. The measured diphoton mass spectrum, shown in Fig. 3, is in good agreement of SM prediction. Also shown in Fig. 3 is the derived resonance production cross-section limit, compared to predictions from the RS model. The lower mass bounds obtained for the first excited states of the RS graviton are 690 and 220 GeV/c^2 for k/M_{PL} = 0.1 and 0,01 respectively.

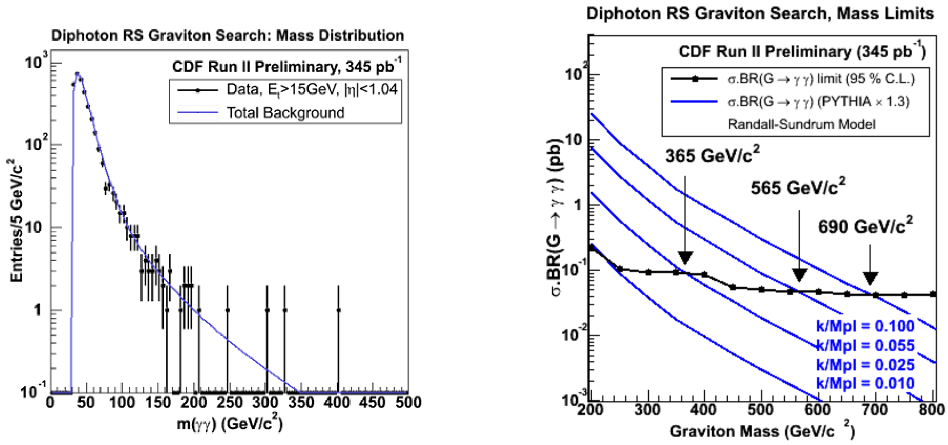

Figure 3. Left: Observed diphoton mass distribution compared to SM prediction; Right) Measured cross section limit compared to predictions from the RS model.

6. Conclusions

Recent results of searches for physics beyond the Standard Model using final states of 2 leptons or 2 photons from the CDF experiment show no deviation from the predictions of Standard Model. Production cross-section limits are obtained, and for many specific new physics models, such as Z', Randall-Sundrum Graviton, Large Extra Dimensions and SUSY, these cross section limits are used to place strong constraints on their parameters.

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