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An inclusive search for new physics in like-sign dilepton events at CDF with 6.1 fb^{-1}

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We present a search for new physics in events with two high p_T leptons of the same electric charge using data with an integrated luminosity of 6.1 fb^{-1}. The observed data are consistent with standard model predictions.

I. INTRODUCTION

A wide variety of models of new physics predict events with two like-sign leptons, a signature which has very low backgrounds from the standard model. Examples include supersymmetry [1], heavy neutrinos [2], same-sign top quark production [3] and fourth-generation quarks [4].

CDF examined the like-sign dilepton data in RunI [5] and in RunII in 1 fb^{-1} [6].

In this note, we present a study of the inclusive like-sign dilepton sample, comparing it to the standard model prediction and assessing the statistical consistency. Companion notes interpret the sample in terms of supersymmetry [7] and same-sign top quarks [8].

II. DATASET AND SELECTION

Events were recorded by CDF II [9, 10], a general purpose detector designed to study collisions at the Fermilab Tevatron $p\overline{p}$ collider at $\sqrt{s} = 1.96$ TeV. A charged-particle tracking system immersed in a 1.4 T magnetic field consists of a silicon microstrip tracker and a drift chamber. Electromagnetic and hadronic calorimeters surround the tracking system and measure particle energies. Drift chambers located outside the calorimeters detect muons. We examine data taken between August 2002 and September 2010, with integrated luminosity of 6.1 fb^{-1}.

The data acquisition system is triggered by e or μ candidates [11] with transverse momentum (p_T[10]) greater than 18 GeV/c. Electrons and muons are reconstructed offline and selected if they have a pseudorapidity (η[10]) magnitude less than 1.1, $p_T \geq 20$ GeV/c and satisfy the standard CDF identification and isolation requirements [11]. Jets are reconstructed in the calorimeter using the JETCLU [12] algorithm with a clustering radius of 0.4 in azimuth-pseudorapidity space and corrected using the standard techniques [15]. Jets are selected if they have $p_T \geq 15$ GeV/c and $|\eta| < 2.4$. Missing transverse momentum [14] is reconstructed using fully corrected calorimeter and muon information [11].

We select events with

- A pair of isolated leptons of the same electric charge.
- The leading lepton must have $p_T > 20$ GeV/c, $|\eta| < 1.1$.
- The sub-leading must have $p_T > 10$ GeV/c, $|\eta| < 1.1$.
- The two leptons must come from the same primary vertex
- The dilepton invariant mass $m_{\ell\ell}$ must be at least 25 GeV/c^2.
- We reject events which have two OS leptons in the Z window, $m_{\ell\ell} \in [86, 96]$.
- We reject events which have two SS electrons in the Z window, $m_{\ell\ell} \in [86, 96]$.

In each event, we calculate the H_T, the scalar sum of the lepton p_T, the jet E_T andthe missing transverse energy.

III. BACKGROUNDS

Backgrounds to the like-sign dilepton signature with real like-sign leptons are rare in the SM; they are largely from WZ and ZZ production.

The dominant background comes from events in which the second lepton is due to the semi-leptonic decay of a b- or c-quark meson, largely from W+jets production or $t\bar{t}$ production with semi-leptonic decays. This ("fake") background is described using a lepton misidentification model from inclusive jet data applied to W+jet events.

The second largest source of background comes from processes which produce electron-positron pairs; either the electron or positron emits a hard photon leading to an asymmetric conversion (e.g. $e^-_{hard} \to e^-_{soft}\gamma \to e^-_{soft}e^-_{soft}e^+_{hard}$) and the reconstruction of an same-charge pair. The major contributions via this mechanism are from Z/γ^*+jets and $t\bar{t}$ production with fully leptonic decays.

Estimates of the backgrounds from Z/γ^*+jets processes are made with PYTHIA normalized to data in opposite-sign events. The detector response for both Z+jets and $t\bar{t}$ processes is evaluated using CDFSIM, where, to avoid double-counting, the same-charge leptons are required to originate from the W or Z decays rather than from misidentified jets.

The dominant systematic uncertainty is due to uncertainty in the lepton misidentification model. Additional uncertainties are due to the jet energy scale [15], contributions from additional interactions, and descriptions of initial and final state radiation [16] and uncertainties in the parton distribution functions [17, 18].

IV. OBSERVED DATA

A. Event Yield

Table I shows the observed and predicted event yields.

B. Event Kinematics

Figures 1-4 show kinematic distributions of observed and predicted same-sign lepton events.

We calculate the maximum Kolmogorov-Smirnov (KS) distance for the $m_{\ell\ell}$, MET, and N_{jets} variables, lepton p_T and H_T. In each case, the p-value does not indicate significant deviation from the background-only hypothesis, see Table II.

V. CONCLUSIONS

We present a search for new physics in events with two high p_T leptons of the same electric charge using data with an integrated luminosity of 6.1 fb^{-1}. The observed data are consistent with standard model predictions.

TABLE I: Predicted and observed event yields in same-sign lepton events.

CDF RunII Preliminary $\int \mathcal{L}dt = 6.1$ fb^{-1}				
Process	Total $\ell\ell$	$\mu\mu$	ee	$e\mu$
$t\bar{t}$	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.0
$Z \to ee$	15.7 ± 2.7	0.0 ± 0.0	15.7 ± 2.7	0.0 ± 0.0
$Z \to \mu\mu$	8.7 ± 2.0	0.0 ± 0.0	0.0 ± 0.0	8.7 ± 2.0
$Z \to \tau\tau$	2.2 ± 0.9	0.0 ± 0.0	1.3 ± 0.6	1.0 ± 0.6
WZ	24.7 ± 1.3	7.0 ± 0.4	5.1 ± 0.3	12.7 ± 0.7
WW	0.2 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.0
ZZ	3.5 ± 0.2	0.9 ± 0.1	0.8 ± 0.1	1.7 ± 0.1
$W(\to e\nu)\gamma$	7.8 ± 1.7	0.0 ± 0.0	7.8 ± 1.7	0.0 ± 0.0
$W(\to \mu\nu)\gamma$	7.8 ± 1.7	0.0 ± 0.0	0.0 ± 0.0	7.8 ± 1.7
$W(\to \tau\nu)\gamma$	0.6 ± 0.4	0.0 ± 0.0	0.3 ± 0.3	0.3 ± 0.3
Fakes	51.6 ± 24.2	8.2 ± 5.3	22.1 ± 8.9	21.3 ± 10.6
Total	123.0 ± 24.6	16.1 ± 5.4	53.3 ± 9.5	53.6 ± 10.9
Data	145	14	66	65

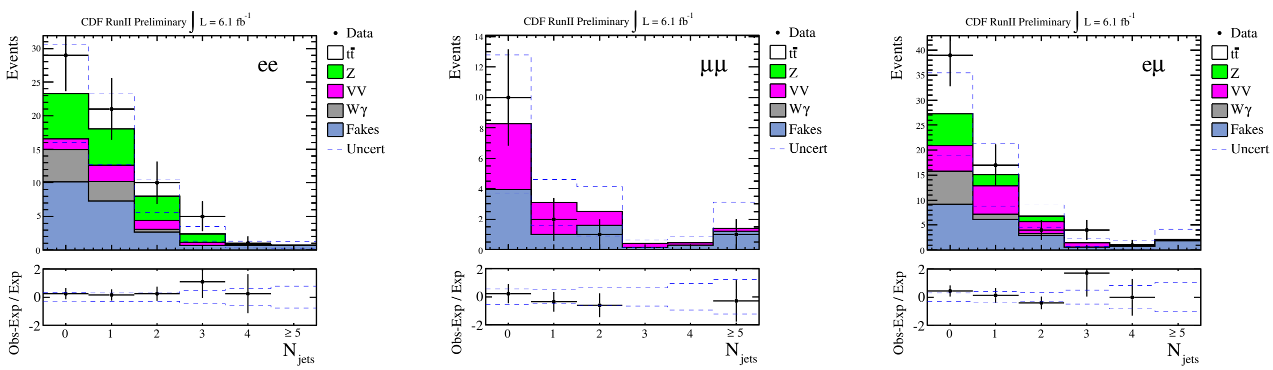

FIG. 1: Distribution of jet multiplicity in observed same-sign dilepton events and expected backgrounds.

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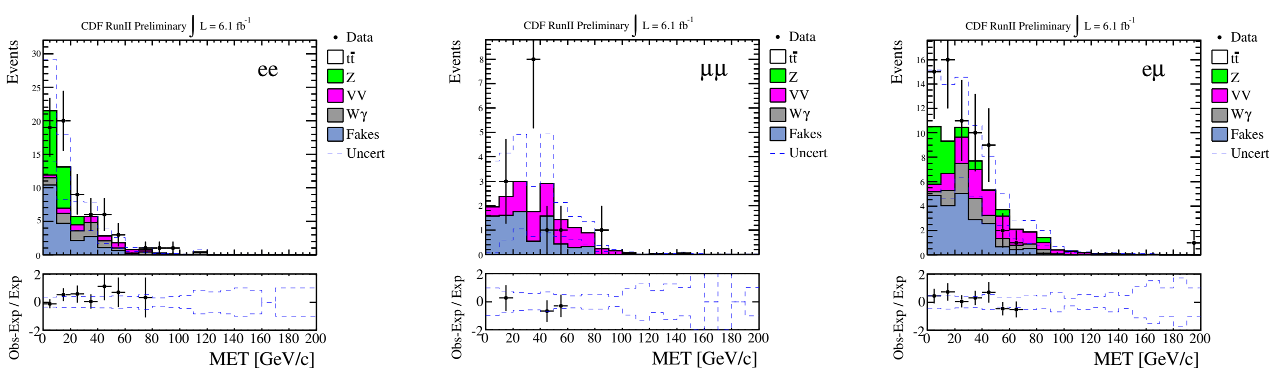

FIG. 2: Distribution of missing transverse energy in observed same-sign dilepton events and expected backgrounds.

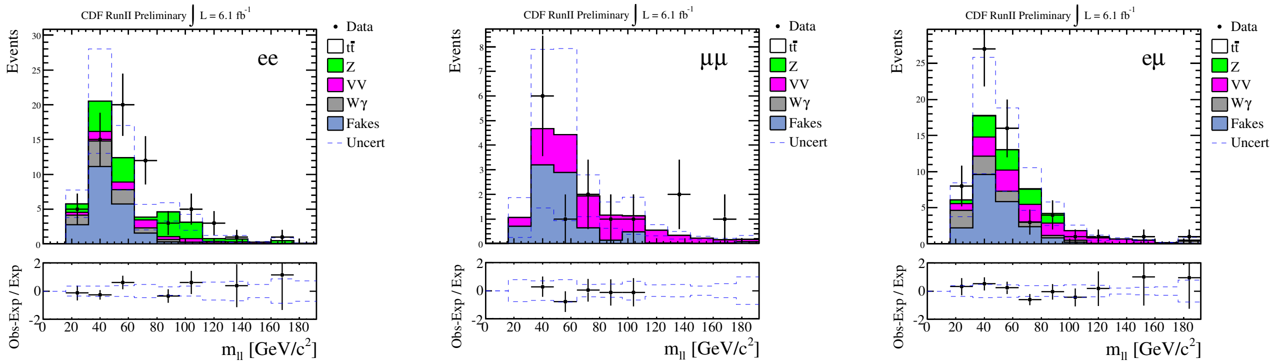

FIG. 3: Distribution of dilepton invariant mass in observed same-sign dilepton events and expected backgrounds.

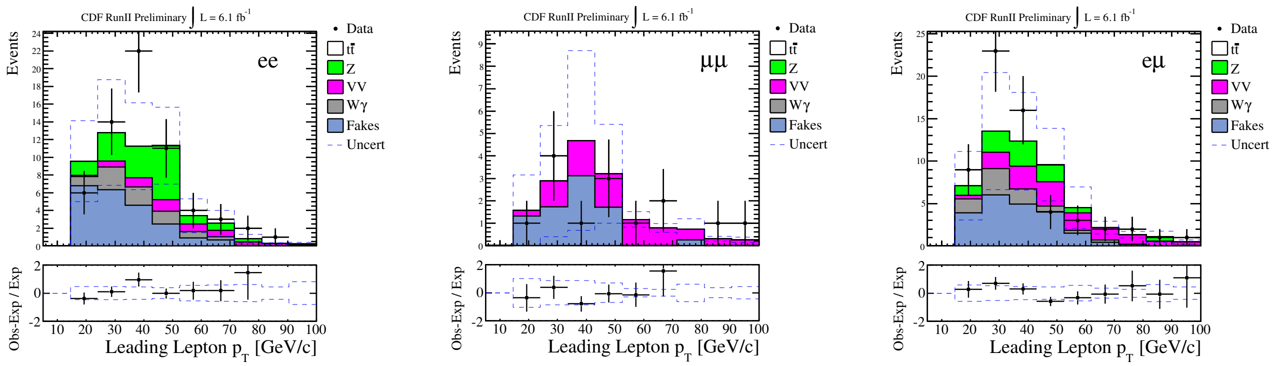

FIG. 4: Distribution of leading lepton p_T in observed same-sign dilepton events and expected backgrounds.

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TABLE II: Results of KS-distance test for Standard Model prediction. The maximum KS distance and corresponding p-value is given for several kinematic distributions presented in this analysis.

CDF RunII Preliminary $\int \mathcal{L}dt = 6.1$ fb^{-1}				
Distribution	Total $\ell\ell$	ee	$\mu\mu$	$e\mu$
$m_{\ell\ell}$	0.11 (79%)	0.22 (47%)	0.23 (46%)	0.30 (59%)
MET	0.19 (34%)	0.23 (27%)	0.24 (32%)	0.21 (69%)
N_{jets}	0.19 (56%)	0.31 (31%)	0.20 (57%)	0.21 (84%)
Lepton 1 p_T	0.16 (49%)	0.18 (47%)	0.25 (30%)	0.26 (60%)
Lepton 2 p_T	0.12 (66%)	0.21 (41%)	0.23 (33%)	0.40 (33%)
H_T	0.15 (45%)	0.22 (34%)	0.22 (32%)	0.24 (58%)

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