FERMILAB-Conf-03/192-E January 2004

SEARCH FOR NEW PHENOMENA IN CDF

Luca Scodellaro (for the CDF collaboration)
Padova University & INFN, Italy

Abstract

We present the most recent results and perspectives of the searches for new phenomena at the CDF experiment of the Tevatron collider.

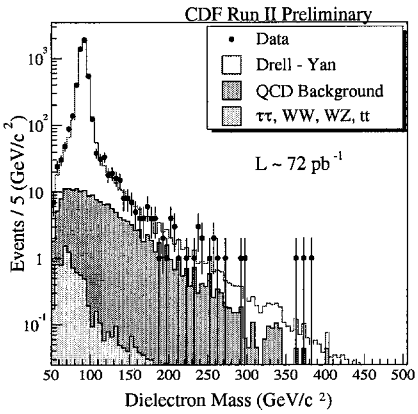

Figure 1: *Dielectrum mass spetrum.*

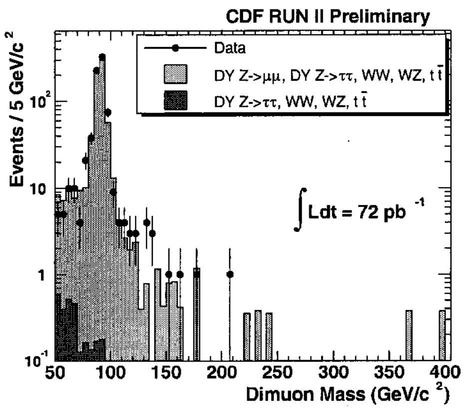

Figure 2: *Dimuon mass spetrum.*

1 Introduction

The Run II of the Tevatron collider began in spring 2001. The accelerator provides $p\bar{p}$ collisions at a center-of-mass energy $\sqrt{s}$ of 1.96 GeV. The CDF detector has undergone substantial upgrades since the end of Run I. A detailed description of the new devices can be found in reference [1].

2 Drell-Yan Dilepton Production

High mass dileptons allow to search for new particle production. In particular, the CDF collaboration has recently looked for new neutral gauge boson Z' and Randall-Sundrum gravitons in approximately 72 pb^{-1} of Run II data.

2.1 Search for New Neutral Gauge Boson Z' in Dielectron Channel

High P_T electron data have been used to search for Z' boson decaying into an electron pair $q\bar{q} \rightarrow Z' \rightarrow e^+e^-$. The event selection is based on the detection of a good central electron with $E_T > 25\ GeV$ and a second good electron with $E_T > 25\ GeV$ either in the central or in the plug calorimeter. A cut on the missing transverse energy significance, $\not{E}_T/\sqrt{\Sigma E_T} < 2.5$, is also applied to remove $W{+}jets$ background. The observed dielectron mass spectrum agrees with background expectation (fig.1). 95% CL upper limit on the production cross section times branching ratio into electrons is set as a function of Z' mass. When Standard Model couplings are assumed, a 95% CL lower limit on the Z' mass is established at 650 GeV/c^2.

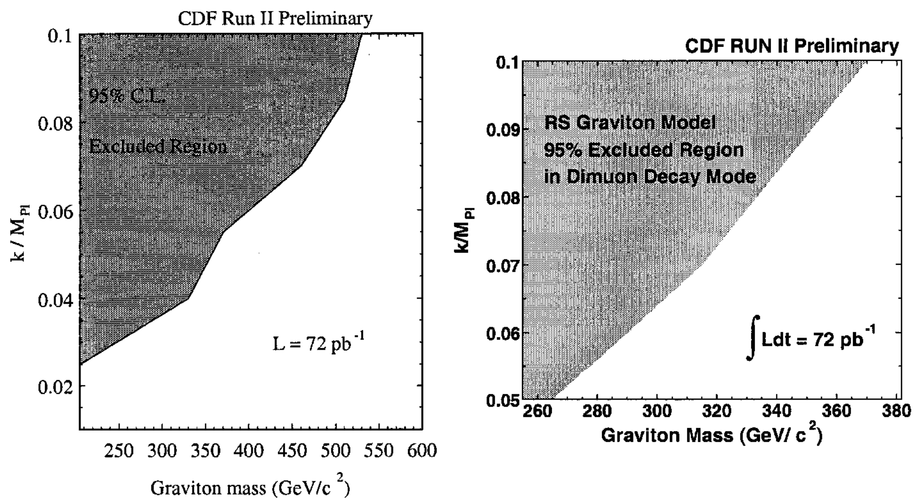

Figure 3: 95% *CL excluded regions in the mass-coupling parameter plan for Randall-Sundrum gravitons in the dielectron (left) and dimuon (right) channels.*

2.2 Search for New Neutral Gauge Boson Z' in Dimuon Channel

The search of Z' boson production in the dimuon channel is based on the selection of two good muons with transverse momentum $P_T > 20\ GeV/c$. Cuts on the track impact parameter and isolation are applied to remove cosmic ray and QCD background respectively. No excess over the Standard Model prediction is observed in the dimuon mass distribution (fig.2), and 95% CL upper limit on the production cross section times branching ratio into muons is set as a function of the Z' boson mass. Finally, by assuming Standard Model couplings, a 95% CL lower limit on the Z' mass is set at 455 GeV/c^2.

2.3 Results for Graviton Searches

The Randall-Sundrum model provides a small extra-dimension solution to the hierarchy problem by means of a non-factorizable geometry [2, 3]. Excited gravitons in 5 dimensions are expected to be observable. Results for resonance searches in high mass dileptons have also been used to draw excluded regions in the graviton mass-coupling parameter k/M_{PL} plan (fig.3).

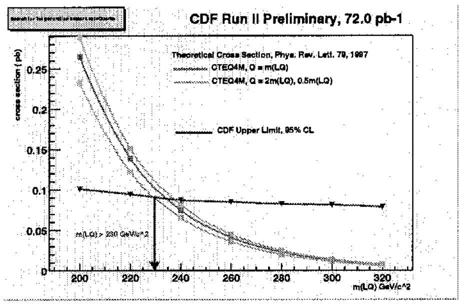

Figure 4: 95% *CL upper limit cross section as a function of the leptoquark mass compared with NLO theoretical expectations.*

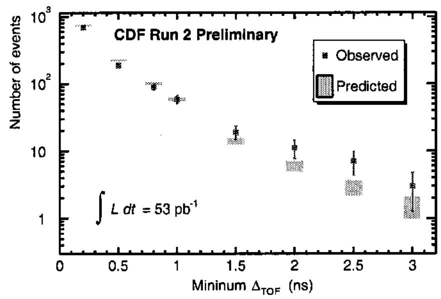

Figure 5: *Event maximum* Δt *distribution compared with background expectation.*

3 Leptoquark Searches in Run II

Leptoquarks are generally pair produced in $p\bar{p}$ collisions [4]. They decay into a lepton-quark pair, with generation mixing suppressed by FCNC constraints [5]. A search for first generation leptoquark has been recently performed in the dielectron+jets channel at CDF. 72 $pb{-}1$ of inclusive electron data have been selected by requiring two central electrons with $E_T > 5\,GeV$ and two jets ($E_T > 30\,GeV$ and 15 GeV respectively). No events are observed after kinematic cuts. 95% CL upper limits on the production cross section as a function of the leptoquark mass are set (fig.4). By assuming $Br(LQ \to lq) = 1$ and using the NLO theoretical estimate, a scalar leptoquark with mass below 230 GeV/c^2 is excluded.

4 CHArged Massive Particles

Physics theories extending the Standard Model usually predicts new conserved quantum numbers leading to stable particles. Long-lived CHArged Massive ParticleS (CHAMPS) escaping CDF detector can be detected by high-P_T muon triggers. Moreover, due to their large mass, these particles are expected to move slowly, leading to long Time-Of-Flight (TOF) through the detector. CHAMP production has been investigated by exploiting the new TOF system, providing sensitivity to higher $\beta\gamma$ values than the dE/dx measurement used in Run I analyses. 52 pb^{-1} of high-P_T muon data have been used. In order to have full tracking efficiency on CHAMPS with mass larger than 100 GeV/c^2, a cut at 40 GeV/c is applied on the transverse momentum of the candidate tracks. The time t_0 at which the interaction is occurred is estimated by averaging

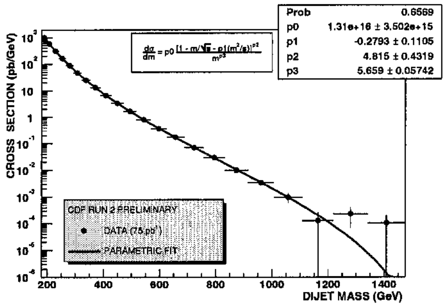

Figure 6: *Dijet mass distribution presented as a differential cross section in* 10% *wide mass bins.*

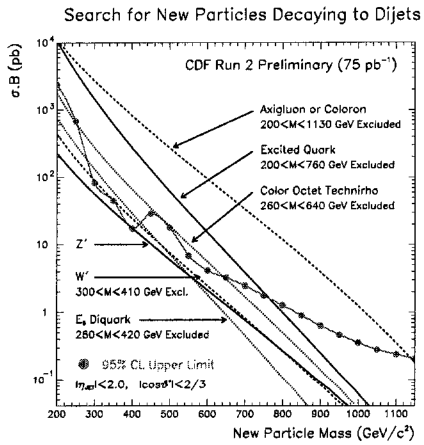

Figure 7: 95% *CL upper limits on the cross section times branching ratio for new particles decaying into dijets.*

the measured time for tracks with $P_T < 20$ GeV/c. Tracks with high time of flight difference Δt with respect to t_0 are looked for. The maximum probability of discovery has been found to be guaranteed by a cut $\Delta t > 2.5$ ns. Tracks with $20 < P_T < 40$ GeV/c are used to predict the background (fig.5): $2.9 \pm 0.7(stat.) \pm 3.1(sys.)$ events are expected, while 7 events are observed. Production cross section upper limits are established for a stable stop model [6]. By assuming NLO predictions, a 95% CL lower limit on the stop mass is set at 107 GeV/c^2.

5 Dijet Mass Bumps

75 pb^{-1} of inclusive jet samples have been used to search for new particles decaying into dijets. The two highest E_T jets in each event are used to compute the dijet invariant mass spectrum (fig.6). QCD production in the t-channel pole is suppressed by requiring the dijet satisfies

$$|tanh(\Delta\eta/2)| < 2/3. \qquad (1)$$

No evidence for new particles is observed, and excluded mass regions for several models are drawn (fig.7).

Table 1: *Missing E_T and photon triggers.*

Missing E_T Triggers	
MET45	$\not{E}_T > 45\ GeV$
MET_L3PS100	$\not{E}_T > 25\ GeV$ & prescale 100
MET35+2JETS	$\not{E}_T > 35\ GeV$ & 2 jets w/ $E_T > 10\ GeV$
MET+BJET	$\not{E}_T > 20\ GeV$ & 2 displaced tracks ($\lvert d_0\rvert > 100\ \mu m$)
Photon Triggers	
INCLUSIVE PHOTON	$E_T^\gamma > 25$ or 50 or $70\ GeV$
DIPHOTON	$E_T^\gamma > 12$ or $18\ GeV$
TRIPHOTON	$E_T^\gamma > 10\ GeV$
PHOTON+BJET	$E_T^\gamma > 10\ GeV$ & 1 displaced track ($\lvert d_0\rvert > 120\ \mu m$)
PHOTON+MUON	$E_T^\gamma > 16\ GeV$ & $P_T^\mu > 4\ GeV/c$
PHOTON+DIJET	$E_T^\gamma > 18\ GeV$ & $E_T^{jet1} > 18\ GeV$, $E_T^{jet2} > 10\ GeV$

Table 2: *Observed and expected number of diphoton events with additional electron or muon.*

	Obs.	Exp. $E_T^\gamma > 13\ GeV$	Exp.
$e\gamma\gamma$	0	$0.27 \pm 0.10 \pm 0.14$	$0.04 \pm 0.03 \pm 0.02$
$\mu\gamma\gamma$	0	$0.04 \pm 0.007 \pm 0.02$	$0.007 \pm 0.005 \pm 0.004$

6 Exclusive Missing E_T + Jets Searches in Run I

Missing transverse energy signature has been recently used to test extra dimension solution to the hierarchy problem [7] with Run I data. Gravitons are expected to be produced in association with an extra parton. Required experimantal signature is large missing E_T ($\not{E}_T > 80\ GeV$) plus an extra jet: 284 events are observed while 271 ± 16 events are expected mainly from $Z \to \nu\bar{\nu}$ background. By assuming a number of 2, 4 or 6 extra dimension, an effective Plank scale below 1.0, 0.77 and 0.71 TeV respectively has been excluded at 95% CL.

7 Inclusive Missing E_T and Photon Searches in Run II

Several triggers have been implemented to study weakly interacting particle production and new phenomena leading to photons in the final states (tab.1). Large samples are being collected and tested. In particular, the diphoton sample has been deeply studied: 1365 events have been selected by requiring two

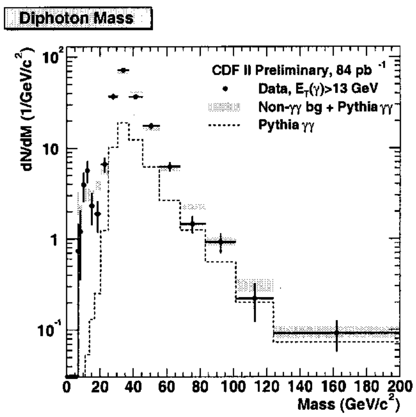

Figure 8: *Observed diphoton mass spetrum.*

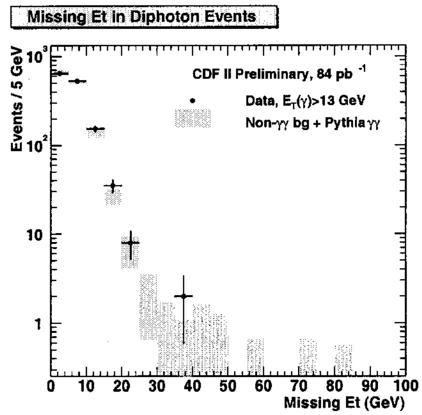

Figure 9: *Missing E_T distribution in diphoton events.*

central photons with $E_T > 13$ GeV (95 events with $E_T > 25$ GeV). Diphoton mass spectrum and missing transverse energy have been investigated (fig.8 and 9). The number of events with additional electron or muon has also been studied (tab.2). Background expectation agrees with data. These samples provide an important testing bench for new physics beyond the Standard Model.

8 Tau Lepton Based Searches

Tau leptons provide an other crucial experimental signature for new phenomena searches. In particular, large cross sections into final states with τ are expected for supersymmetric Higgs production at large β values. Tau detection has been largely improved in Run II and specific $\tau + \not{E}_T$ and ditau triggers have been implemented. Improved tau reconstruction also offers interesting perspectives for supersymmetric searches like for example R-parity violating stop decays

$$p\bar{p} \to \tilde{t}\bar{\tilde{t}} + X \to (b\tau^+)(\bar{b}\tau^-) + X \tag{2}$$

and Chargino-Neutralino production

$$p\bar{p} \to W^\pm \to \tilde{\chi}_1^\pm \tilde{\chi}_2^0 \to (\tau^\pm \nu \tilde{\chi}_1^0)(\tau^\pm \tau^\mp \tilde{\chi}_1^0). \tag{3}$$

9 R-Parity Violating Decaying Particles

The CDF collaboration has recently performed two searches for new particles decaying via R-parity violating interactions with Run I data.

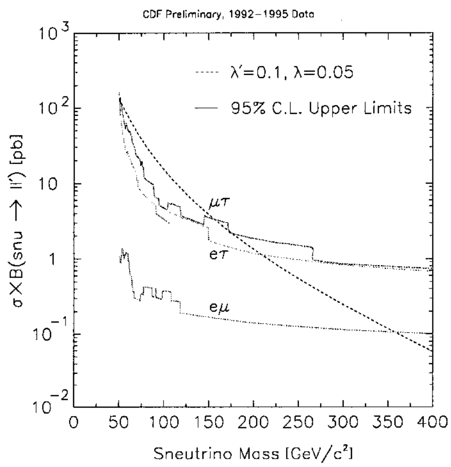

Figure 10: 95% *CL upper limits on cross section times branching ratio as a function of sneutrino mass, together with NLO cross section for the referenced parameters.*

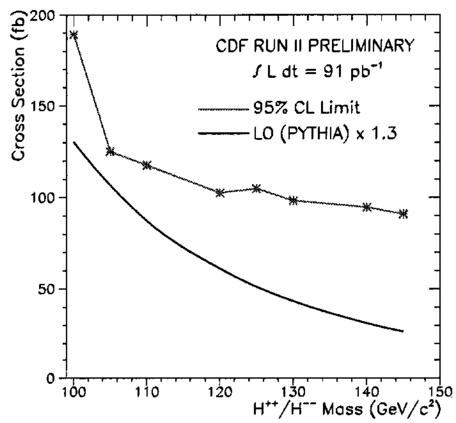

Figure 11: 95% *CL upper limits on cross section times branching ratio into electrons as a function of doubly-charged Higgs mass, compared with theoretical expectation.*

In the first analysis, stop pair production has been considered, with both the stop quarks decaying into τb [8]. A tau is required to decay leptonically, while the second tau is required to decay hadronically: the searched signature is an opposite sign lepton-tau pair plus two jets. After kinematic cuts, no events are observed, while $3.2^{\pm 1.4}_{\pm 0.3}$ events are predicted by Standard Model processes. by assuming $Br(\tilde{t} \rightarrow b\tau) = 1$ and NLO cross sections, a 95% CL lower limit on the stop mass is set at 122 GeV/c^2.
In the second search, $\not{R}_P$-production of a scalar neutrino $\tilde{\nu}$ is considered. Flavour-violating $\tilde{\nu}$ decays into opposite sign leptons are looked for. Events are selected by requiring an opposite sign muon-electron pair, back to back in the azimuthal direction. No excess over the background expectation is observed, and 95% CL upper limits on the production cross section times the branching ratio are derived (fig.10).

10 Search for Doubly-Charged Higgs

The observed lack of symmetry between left- and right-handed weak interactions suggests a more fundamental left-right symmetric lagrangian spontaneously broken at higher energies [9, 10, 11]. The see-saw mechanism, designed

in the context of the left-right symmetric model, successfully predicts light neutrino mass [12], providing a powerful motive to that model. Finally, supersymmetric extensions [13, 14] suggest low mass doubly-charged Higgs, whose same-sign lepton decay mode provides a strong experimental signature.
95 pb^{-1} of inclusive electron data have been recently used at CDF to search for doubly-charged Higgs production via same-sign central electron pair observation. No events are observed in a search reagion of $\pm 10\%$ of the Higgs mass around each Higgs mass considered, and 95% CL upper limits on the production cross section are established (fig.11). We remark that this experimental search is sensitive to the production of any new doubly-charged particle decaying to dielectrons.

11 Conclusions

CDF detector is collecting data from March 2001. Run II searches for new phenomena have already started. First limits using dileptons and dijet mass spectra have been set for various phenomena and specific theories beyond the Standard Model have been tested. Moreover, the new Time-Of-Flight system has been exploited to search for CHAMPS. Results are already improving Run I ones. Larger samples are being collected and tested for searches based on tau lepton, missing transverse energy and photon signature. High integrated luminosity will provide the best opportunity for new physics discovery until LHC starts to run.

References

1. R. Blair *et al* [CDF-II collaboration], FERMILAB-PUB-96-390-E (1996).
2. L. Randall *et al*, Phys. Rev. Lett. **83**, 3370 (1999).
3. L. Randall *et al*, Phys. Rev. Lett. **83**, 4690 (1999).
4. M. Kramer *et al*, Phys. Rev. Lett. **79**, 341 (1997).
5. W. Buchmuller *et al*, Phys. Lett. B **177**, 337 (1986).
6. R. Barbieri *et al*, Phys. Rev. D **63**, 105007 (2001).
7. N. Arkani-Hamed *et al*, Phys. Lett. B **429**, 263 (1998).
8. D. Acosta *et al*, FERMILAB-PUB-03-070-E (2003).
9. R.N. Mohapatra *et al*, Phys. Rev. D **11**, 566 (1975).
10. R.N. Mohapatra *et al*, Phys. Rev. D **12**, 1502 (1975).

11. R.N. Mohapatra *et al*, Phys. Rev. D **23**, 165 (1981).

12. R.N. Mohapatra *et al*, Phys. Rev. Lett. **44**, 912 (1980).

13. C.S. Aulakh *et al*, Phys. Rev. D **57**, 4174 (1998).

14. Z. Chacko *et al*, Phys. Rev. D **58**, 015003 (1998).