Searches and Expected Signatures at DØ

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1 Introduction

In many cases new physics manifests itself as production of new heavy particles with small cross sections. Therefore, searches for new phenomena typically are limited by statistics and require highest possible luminosity.

The recent upgrades of the Tevatron at Fermilab increased the energy to 1.96 TeV and boosted luminosity of the machine. The Tevatron detectors also underwent extensive upgrades to fully utilize the Tevatron potential. The performance of the collider and detectors during the first year of operation was reviewed in separate talks.

By the time of this conference the datasets recorded by DØ achieved 35 pb^{-1} of integrated luminosity with typically 10 pb^{-1} used for physics analyses.

The DØ results on new phenomena searches presented in this talk establish the first datasets and analyses paths using the RunII data. They pave the way to greatly enforced searches as luminosity increases.

2 Search for Large Extra Dimensions

In some formulations of the Large Extra Dimensions (ED) theory, the standard model (SM) particles are confined to a D3-brane, as expected in the string theory, and SM gauge interactions are therefore restricted to this brane. At the same time, gravity is allowed to propagate in the extra dimensions with size much larger than $(M_{\mathrm{weak}})^{-1}$.

One of the ways to probe large ED at colliders is to look at the effects of virtual gravitons in the fermion or boson pair production.

2.1 Dielectron and Diphoton Channels

For this analysis we combine the dielectron and diphoton channels by looking for pairs of EM objects in the calorimeter. This technique allows to increase the sensitivity to the effects of extra dimensions by eliminating tracking inefficiency, at an expense of a slight increase of the background in the dielectron channel.

The data used for this analysis was selected using all the available data taken between September 2001 and May 2002. The triggers required either one or two EM towers with the threshold between 10 and 20 GeV and are fully efficient for the kinematic cuts used in this analysis.

The EM candidates were required to be either in the central (CC) region of the detector, $|\eta_d| < 1.1$, or in the forward (EC) region, $1.5 < |\eta_d| < 2.5$, where η_d is the pseudorapidity measured with respect to the center of the detector. We required two EM objects with the $E_T > 25$ GeV and veto the events where there are more than two EM objects passing loose isolation (ISO< 0.2) and EM fraction (EMF> 0.9) cuts. Finally, we force objects in the candidate events to be well measured by requiring $\not\!\!E_T < 30$ GeV. The integrated luminosity of the resulting sample determined from the NLO Z-peak cross section was found to be 9.85 ± 0.38 pb^{-1} .

The SM backgrounds for this analysis are Drell-Yan production and direct diphoton production. The instrumental background comes from dijet and direct photon events, where jet(s) are misidentified as EM objects. We measured the instrumental background selecting the events that survive all the cuts above, except that the EM objects are required to pass anti-quality cuts, orthogonal to the cuts used for the candidate sample.

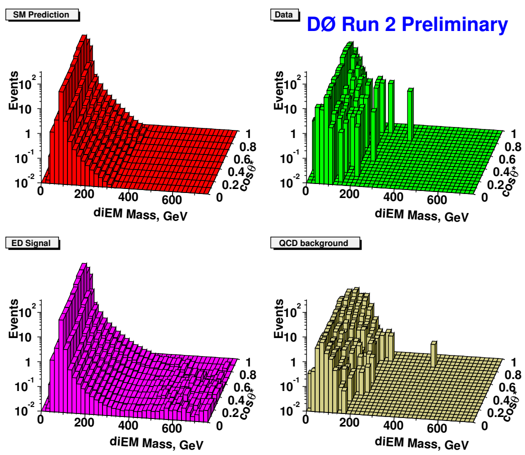


Fig. 1. The di-EM mass vs. $\cos\theta^*$ distribution for the base candidate sample. Top left: SM background from Drell-Yan and direct diphotons; top right: data; bottom left: ED signal plus the SM background for $\eta_G = 2.0$; bottom right: instrumental background.

The double-differential distribution in diEM mass and $\cos\theta^*$ is shown in Fig. 1. The data are well fitted by the sum of Drell-Yan/$\gamma\gamma$ and instrumental background sources with gravity contribution consistent with zero. Based on this we determine the fundamental Plank scale to be larger than 920 GeV in the Giudice-Rattazzi-Wells (GRW) formulation of large extra dimensions.

2.2 Dimuon Channel

We extended the above technique to the dimuon channel, which has not been analyzed at hadron colliders in the past. For this analysis events are required to have been taken by a dimuon trigger. The luminosity for this sample is $4.5pb^{-1} \pm 0.55$.

All muons must pass the certified tight quality criteria including the muon scintillator timing requirement of $\Delta t < 12ns$ which mitigates cosmic ray muons faking dimuons. In order to reject muons from jets, a muon isolation cut is applied, this requires $\Delta R(\mu, jet) > 0.5$.

Shown in Fig. 2 are the $|cos(\theta^*)|$ and invariant mass distributions for data (dots) and background.

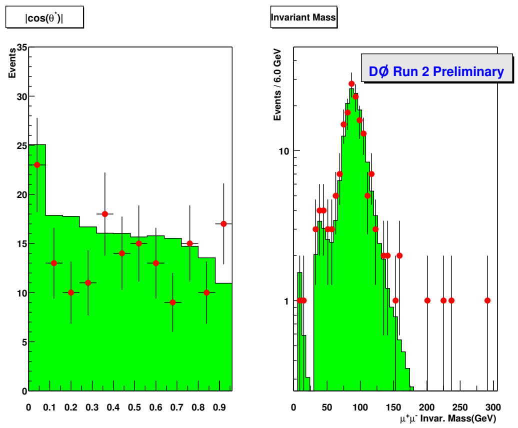


Fig. 2. Distributions in $|cos(\theta^*)|$ and invariant mass for data (dots) and background.

The limit in the dimuon channel was established in a similar fashion as the diEM channel discussed in the previous section. The lower 95% CL limit on the fundamental Planck scale was found to be 500 GeV in the GRW convention. While this is not the world's most stringent limit, this does represent the first such result obtained from a hadron collider in the dimuon channel.

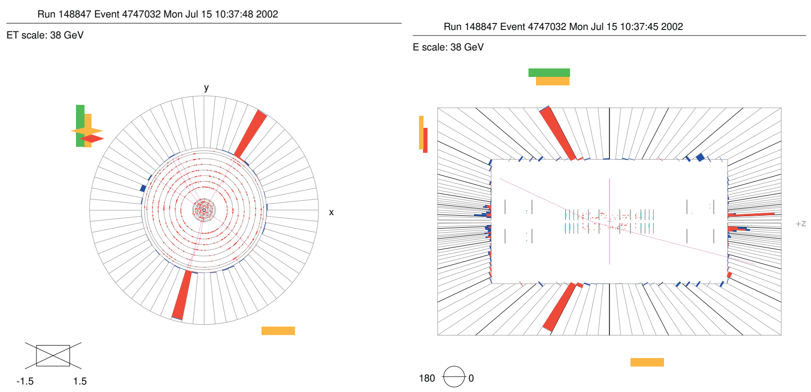
3 Search for RPV SUSY in Trilepton Channels

We searched for multi-lepton events in the processes with R-parity violation via leptonic λ Yukawa couplings. Together with the standard SUSY charginoneutralino production this process gives a strong motivation for the tri-lepton search.

The sample used for the final tri-lepton selection corresponds to a recorded luminosity of 5.2 ± 0.8 for the events with electrons only and 4.6 ± 0.7 pb^{-1} if the presence of a muon is required. The following cuts on the leptons were used:

- at least one EM-candidate satisfying the EM trigger: p_T(EM-candidate) $>$ 30 GeV/c and $|\eta$(EM-candidate)$| < 0.8$;
- p_T(EM-candidate) $>$ 15 GeV/c and $\Delta R > 0.7$ between any pair of leptons;
- p_T(μ-candidates) $>$ 5 GeV/c, where p_T is the local track transverse momentum measured in the muon detector and $\Delta R > 0.7$ between the muon and any jet.

Three events - two eee and one $ee\mu$ - satisfy those criteria in agreement with SM expectations. The only $ee\mu$ candidate is shown in Figure 3. The di-electron invariant mass is compatible with production of a Z boson.



e_1	e_2	μ
p_T(cal) = 46.5 GeV/c $\eta = -0.36$ $\varphi = 1.02$ no track match	p_T(cal) = 43.5 GeV/c $\eta = -0.33$ $\varphi = 4.47$ no track match	p_T = 12.9 GeV/c $\eta = -0.92$ $\varphi = 2.59$ charge = -1
$m_{e_1 e_2}$ = 88.9 GeV/c^2	ME$_T$ = 11.9 GeV	

Fig. 3. $x - y$, $r - \varphi$ views and properties of an example $e + e + \mu$ candidate.

4 GMSB SUSY in Di-Photon Events

The phenomenology of the Gauge Mediated Symmetry Breaking (GMSB) models is strikingly different from gravity mediated SUSY. We used a GMSB framework assuming neutralino LSP with lifetime short enough so that it decays before the calorimeter into a photon and a gravitino. All standard SUSY signatures in this scenario are complemented by a pair of photons.

All SM sources of events with two photons and large missing transverse energy (MET) can be divided into ones where MET is due to mis-measurement (mostly QCD with direct photons or jets misidentifies as photons) and with true MET, dominantly $W\gamma \longrightarrow e\nu\gamma$. All SM backgrounds with true missing E_T involve electrons and not photons, so they are reduced by the matching track veto. The yield of these backgrounds was measured in data by requiring a track pointing to one of the EM clusters.

The following selections were used for the final data sample :

- two CC photons with $E_T > 20$ GeV
- $E_T(\gamma_1) > 25$ and $|\eta_{det}(\gamma_1)| < 0.8$ or $|\eta_{det}(\gamma_1)| < 0.8$ and $|\eta_{det}(\gamma_2)| < 0.8$
- $m_{\gamma\gamma} < 80$ or $m\gamma\gamma > 102$
- $0.5 < \Delta\phi(j_1, MET) < \pi - 0.5$
- Missing $E_T > 35$ GeV

Shown in Fig. 4 is the MET spectrum of the $\gamma\gamma$ sample.

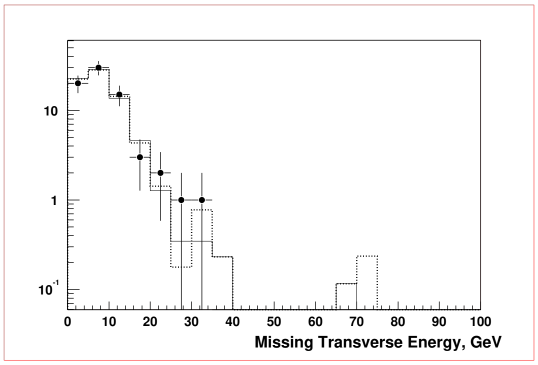


Fig. 4. MET for $\gamma\gamma$. Points with errors are data, solid histogram is the sum of QCD and Drell-Yan backgrounds as determined from data, dashed histogram is sum of all backgrounds as obtained from data (QCD, Drell-Yan and $e \longrightarrow \gamma$).

As we find that the number of observed events agree with expectations we set a "model-independent" limit on events with two photons (with invariant mass not within 80-102 GeV) and missing E_T (which is not collinear to the leading jet) to be

$$\sigma \; < \; 0.9 \; pb \; @95\% CL.$$

5 Search for Leptoquarks in the Dielectron Channel

Leptoquarks(LQ) are hypothesized particles that carry color, electric charge, lepton number and appear in theories of extended gauge sectors and composite models. Leptoquarks are assumed to be produced in pairs and to decay into an electron and a quark with a branching ratio β.

The following cuts are imposed on the data sample based on 8 pb^{-1} :

- two EM objects with $E_T > 25$ GeV in the CC or EC fiducial regions with at least one of them in the trigger region
- at least two jets with $E_T > 20$ GeV within $-2.5 < \eta < 2.5$
- jets are separated from EM objects by a distance $\delta R_{ej} > 0.7$
- Z-veto: invariant mass of the two EM objects should be outside of the Z-mass window i.e. (82 GeV $< M_{ee} <$ 100 GeV)

Figure 5 shows the distribution of S_T for data, signal and background after final cuts. S_T is the scalar sum of the transverse energies of the two electrons and the two leading jets. With more statistics this variable will provide further discrimination for the signal.

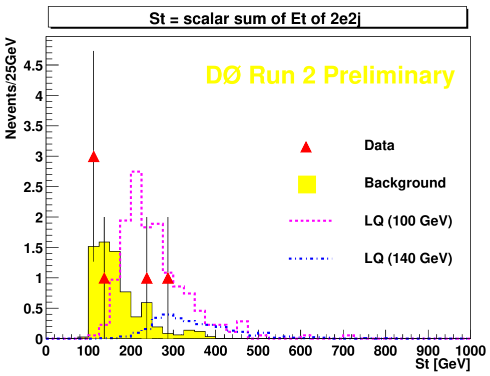


Fig. 5. S_T distribution of eejj events from data compared to background.

The data are consistent with Standard Model background and no evidence for leptoquark production is observed. Comparing the experimental limit with the NLO theoretical calculations for the scalar LQ pair production cross section we place a lower limit on the first generation scalar LQ mass of 113 GeV/c^2 assuming a LQ decay branching ratio (β) of 1.

6 Search for Squarks and Gluinos in Jets $+\not{E}_T$ events

The standard topology for squark and gluino searches is that of multijets and missing transverse energy. This topology was selected in ~ 6 pb^{-1} of data in which the detector, most importantly the calorimeter, was fully operational. The analysis uses events in which three trigger towers recorded an energy in excess of 7 GeV. This multijet trigger is almost fully efficient for events with at least two central jets such that $H_T > 200\,\mathrm{GeV}$, where H_T is the sum of the transverse energies of central jets with $|\eta_{jet}| < 0.8$.

The distribution of the missing transverse energy E_T^{miss} is shown in Fig. 6 together with a typical two-jet event with large E_T^{miss}. The E_T^{miss} distribution is adequately fit over several orders of magnitude using a functional form determined from the Monte Carlo simulation. The event with the highest measured missing E_T of 400 GeV is due to a hardware problem with two readout crates.

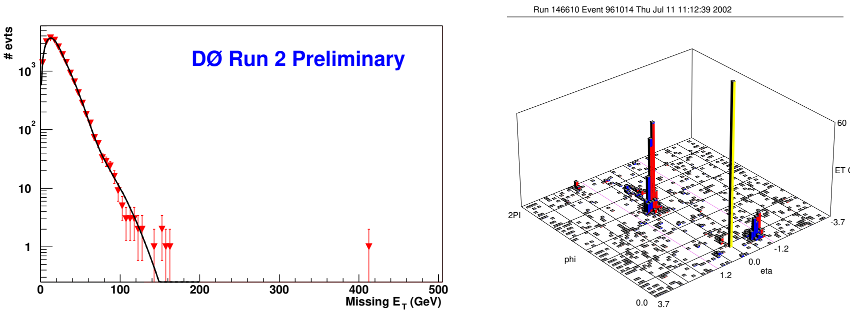


Fig. 6. Missing transverse energy distribution (left) and $\eta - \varphi$ view of the event with the next-to-largest $\not{E}_T$ (right).

In the event shown above, the missing E_T is aligned, in the transverse plane, with the lower energy jet. The angular variables have shown in the past to be powerful tools to discriminate squark or gluino production from QCD processes and will be investigated further.

7 Conclusions

We presented several results on searches for new phenomena with DØ using approximately 10 pb^{-1} of data. All presented limits are statistically limited and will be improved with more luminosity and further calibrations of the detector.