CDF note 8452

Searching for the Anomalous Production of Z-Bosons with High Transverse Momentum in 0.94 fb^{-1} at the Tevatron

The CDF Collaboration
URL http://www-cdf.fnal.gov

(Dated: August 22, 2006)

We present a broad search for signatures containing a high transverse momentum ($\mathrm{p_T}$) Z^0 boson in 0.94 fb^{-1} of CDF-II data. In addition to inclusive production of Z^0 's with large values of $\mathrm{p_T}$, we investigate signatures that have a much smaller Standard Model crossection, and hence are more sensitive to new phenomena, such as right-handed heavy quarks, technicolor particles, gauginos or squarks, or excited states resulting from large extra dimensions. The specific channels in which we search are of the form Z^0 + X + anything and Z^0 + X + Y + anything, where X and Y can be leptons, photons, missing energy, or large total transverse energy (H_T). For each signature we compare the observed $P_T(Z)$ spectra and other distributions with Standard Model expectations. Alas, we do not see anything striking, yet.

Preliminary Results for Autumn 2006 Conferences

I. INTRODUCTION

The Standard Model (SM) is the most successful theory describing the interactions of elementary particles. However, even this theory has some unsolved problems, such as a large number of constants, the existence of the Higgs particle, Grand Unification, Super-symmetry, and flavor and CP violations. Many Standard Model extensions address solving these difficulties. Most of these SM extensions introduce new heavy particles coupled to the electroweak sector, such as right-handed heavy quarks, technicolor particles, gauginos or squarks, or excited states resulting from large extra dimensions. These particles decay producing gauge bosons (W's and Z's, and photons) with large transverse momenta (P_T). This paper presents a signature-based method [1, 2] for searching for new heavy particles based on their weak decays. We consider the inclusive production of Z's with large values of $\mathrm{p_T}$, and then further investigate signatures that have a much smaller Standard Model crossection, and hence are more sensitive to new phenomena. These specific channels in which we search are of the form Z + X + anything and Z + X + Y + anything, where X and Y can be leptons, photons, missing energy, or large total transverse energy (H_T). For each signature we compare the observed $P_T(Z)$ spectra and other distributions with Standard Model expectations.

The CDF II Detector at the Fermilab Tevatron is an azimuthally and forward-backward symmetric spectrometer designed to study $p\overline{p}$ collisions at $\sqrt{s}$ = 1.96 TeV. This is a general purpose solenoidal detector which combines precision tracking for charged particles with fast projective calorimetry and fine-grained muon chambers. Tracking systems are enclosed in a superconducting solenoid which generates a 1.4 T magnetic field parallel to the beam axis. Calorimeters and muon systems are outside the solenoid. The present study employs leptonic decays of Z's using data collected at CDF Run II at the Tevatron from 2001 to February of 2006. Technical details of the detector are described elsewhere [3].

The collisions of protons and anti-protons occur every 396 ns with $\sqrt{s}$ = 1.96 TeV. To select collisions of interest (events) from this enormous flow a sophisticated triggering and data acquisition system is used. In this analysis we observe events triggered with high-P_T leptons (electrons and muons).

Monte Carlo (MC) samples of SM processes are used to predict the observed P_T spectra. We use MC samples of Z + jets, $t\bar{t}$, diboson (WW, WZ, ZZ, and Zγ), and $Z^0 \to \tau^+\tau^-$ in the analysis. Contributions from 'fake' electrons and muons are estimated with data.

II. SEARCH STRATEGY

We present a broad signature-based search for signatures containing high-P_T Z's. Such signatures are characteristic of the decays decays of new, hypothetical, heavy particles such as Z', Q_R, squarks, gauginos, or Kaluza-Klein excitations. The Z^0 bosons are reconstructed in $Z \to ee$ and $Z \to \mu\mu$ decay modes.

The search strategy includes three stages:

- In the first stage we consider inclusive Z^0 -production.
- In the second stage we select events where the Z^0 is produced in association with X: Z^0 +X+anything. The symbol X stands for any reconstructed object such as a lepton (e or μ), a photon, high transverse momenta, or the signature of missing transverse energy.
- In the third stage we study Z^0 +X+Y+anything. In this case X and Y can be any of the above (nonidentical) reconstructed objects (multiple identical objects will show up in the plots in the Z^0 +X search).

In the first stage, inclusive Z^0 production, the observed events are split into three control samples to compare the underlying event structure at different $P_T(Z)$ scales:

- Inclusive Z's,
- Z's with $P_T(Z) > 60$ GeV,
- Z's with $P_T(Z) > 120$ GeV.

The observed distributions in a number of variables are then compared with Standard Model predictions calculated using a tuned CDF version of the PYTHIA Monte-Carlo generator [4]. We also set a limit on the anomalous production of inclusive Z^0 's at 95% CL, assuming the new physics has the same acceptance as Standard Model Z^0 -boson production.

The missing energy signature ($\not\!\!E_{\mathrm{T}}$-signature) is a combination of cuts:

$$\not\!\!E_{\mathrm{T}} > 25 \text{ GeV and } (H_T < 150 \text{ GeV or } \not\!\!E_{\mathrm{T}}\text{-significance} > 3).$$

We use the following equations to calculate $\not\!\!E_{\mathrm{T}}$-significance:

$$\not\!\!E_{\mathrm{T}} - significance = \frac{\not\!\!E_{\mathrm{T}}}{\sigma(\not\!\!E_{\mathrm{T}})} \tag{1}$$

$$\sigma^2(\not\!\!E_{\mathrm{T}}) = \Sigma\sigma^2_{jet} + \Sigma\sigma^2_{e/\gamma} + \Sigma\sigma^2_{\mu} \tag{2}$$

The sums are calculated for all the reconstructed objects in event.
Jets:

$$\frac{\sigma_{jet}}{E_T(jet)} = \frac{80\%}{\sqrt{E_T(jet)}} \oplus 4\% \tag{3}$$

CEM electrons and photons:

$$\frac{\sigma_{e/\gamma}}{E_T} = \frac{13.5\%}{\sqrt{E_T}} \oplus 2\% \tag{4}$$

PEM electrons and photons:

$$\frac{\sigma_{e/\gamma}}{E_T} = \frac{14.4\%}{\sqrt{E_T}} \oplus 0.7\% \tag{5}$$

Muons:

$$\frac{\sigma_{\mu}}{P_T(\mu)} = 0.091\% * P_T(\mu) \tag{6}$$

Please note that this definition of $\not\!\!E_{\mathrm{T}}$-significance does not use the total energy deposited in the calorimeter and so it is unaffected by additional $p\overline{p}$interactions in the same beam crossing as the collision that produced the Z^0 . Some fraction of this total energy is unclustered and partially comes from these events. (The standard CDF Monte Carlo samples we have used do not include these additional events and this is the reason why we apply the $H_T > 150$ GeV cut in the $\not\!\!E_{\mathrm{T}}$-signature.)

III. DATA SELECTION

We use the following data selection procedure:

Events with inclusive Z^0 -bosons (Z^0 + anything) are selected using high-P_T central ($|\eta| <\sim 1$ electron and muon pairs in the leptonic decay channels $Z \to ee$ and $Z \to \mu\mu$. The reconstructed invariant mass of a leptonic pair is required to be in the mass window from 66 GeV to 116 GeV.

In order to check that the SM modeling represents the data in the broad range of $P_T(z)$ below the very high-P_T region of interest, events with Z's are split into 3 categories:

- Inclusive Z's
- Events with $P_T(Z) > 60$ GeV.
- Events with $P_T(Z) > 120$ GeV.

The numbers of observed $Z \to ee$ and $Z \to \mu\mu$ decays in each category are presented in Table I.

The observed events are triggered on single high-P_T electrons and muons. The electron dataset contains 33,706,930 events and corresponds to an integrated luminosity of 0.94 fb^{-1} . The muon dataset has 15,829,290 events and corresponds to a luminosity of 0.94 fb^{-1} .

Decay mode of the Z-boson	Inclusive	$P_T(Z) > 60$ GeV	$P_T(Z) > 120$ GeV
$Z \to ee$	25079	587	70
$Z \to \mu\mu$	34222	721	74

TABLE I: Numbers of inclusive Z's observed in $Z \to ee$ and $Z \to \mu\mu$ decay modes.

IV. MONTE CARLO PREDICTIONS: STANDARD MODEL

The Standard Model production of inclusive Z^0 's is modeled by means of the leading order (LO) Pythia Monte-Carlo (MC) generator [5]. The following Gen5 MC samples are used in the analysis:

- Z^0 + jets, where the Z^0 decays to e^+e^-, $\mu^+\mu^-$, or $\tau^+\tau^-$
- Diboson: WW, WZ, ZZ, and Zγ (The Zγ process is included in the regular "Z + jets" sample by PYTHIA)
- $t\bar{t}$

The Z^0 + jets datasets are produced using Pythia V6.2 [5] with the requirement that $M(\gamma^*/Z) > 30$ GeV. Tune A and the 'Willis Sakumoto' corrections have been applied [4].

The MC contributions from the various SM processes are combined into inclusive samples using weights proportional to the NLO cross-sections of each contribution. These summed MC-samples are then scaled to the corresponding numbers of the observed events in the $Z \to ee$ and $Z \to \mu\mu$ decay modes separately.

The MC samples are studied with the same analysis routines as are the data and the same selection cuts are applied. The distributions in the dilepton invariant mass, $M_{inv}(\gamma^*/Z)$, predicted with the MC datasets are shown in Figures 1 and 2 for the $Z \to ee$ and $Z \to \mu\mu$ decay modes, respectively. The numbers of events expected in each $P_T(Z)$-category are listed in Table II.

Decay mode of the Z-boson	Inclusive	$P_T(Z) > 60$ GeV	$P_T(Z) > 120$ GeV
$Z \to ee$	25079	500	53.7
$Z \to \mu\mu$	34222	650	61.8

TABLE II: Number of the inclusive Z's expected in $Z \to ee$ and $Z \to \mu\mu$ decay modes.

In addition to the described MC samples we have samples of inclusive $Z \to ee$ and $Z \to \mu\mu$ events in which the Z-bosons are produced with $P_T(Z) > 100$ GeV. These high-P_T samples are used to calculate P_T-dependent distribution of acceptance*efficiency of the Z-bosons.

V. BACKGROUNDS FROM FAKE Z^0 -BOSONS

A. Hadron Jet Backgrounds

This background consists of events in which one or more leptons are "fake", i.e. contain jets misidentified as leptons. We expect that in our samples the two fake leptons, or, less often, one real lepton and one fake lepton, making up the Z in the background events have no charge correlation [14]. This assumption means that the number of same-sign and opposite-sign pairs are about equal. Therefore, we use the number of the same sign lepton pairs to estimate the hadron jet background in the $\gamma^*/Z^0 \to l^+l^-$ sample.

The $Z \to \mu\mu$ sample (66 GeV $< M_{inv}(ll) <$ 116 GeV) contains only 2 events with muons of the same sign, compared to 34222 events with muons of opposite sign.

The number of same-sign electron pairs in the $Z \to ee$ sample is corrected for the number of real e^+e^- pairs mis-reconstructed as e^+e^+ or e^-e^- using the MC predictions for $Z \to ee$ production.

We observe 272 same-sign electron pairs and 25079 e^+e^- pairs. We remove the contribution of real $\gamma^*/Z^0 \to e^+e^-$ events from the number of observed events by subtracting the number of observed e^+e^- events scaled by fraction of same-sign to opposite-sign events in the Monte-Carlo samples for $Z \to ee$. The remaining number of the same-sign electron pairs is used to estimate the hadron jet background in the $Z \to ee$ sample (see Fig. 1).

B. Electroweak Backgrounds

Several electroweak processes mimic $\gamma^*/Z^0 \to l^+l^-$ production. The processes are $Z^0 \to \tau^+\tau^-$, W^+W^-, and $t\bar{t}$ production. Their contributions to γ^*/Z^0 production are estimated from the corresponding MC-simulated samples. The MC simulations are based on the Standard Model predictions.

C. Cosmic Ray Backgrounds

High-energetic cosmic muons traverse the CDF detector at some significant rate and are reconstructed as $\mu^+\mu^-$ pairs. We remove cosmic muons with the cosmic ray tagging algorithm (See Ref. [6]) which basically fits the two tracks of the $\mu^+\mu^-$ pair with a single arc. If the fit is successful, the muon pair is tagged as a cosmic ray and is removed from the $Z \to \mu\mu$ sample [6]. The algorithm is $99.75 \pm 0.05\%$ efficient and the mistag rate is $0.03 \pm 0.02\%$. A powerful discriminant against cosmic rays that combines momentum balance and 'back-to-backness' in a single number is the magnitude of the vector sum of the two muon tracks. The number of cosmic rays in the dimuon sample, estimated from the distribution of $|\vec{P}(Z)|$, is 0 (Cosmic $\mu^+\mu^-$ pairs have a peak at 0 GeV and real $Z \to \mu\mu$ decays have negligibly small phase space at low $|\vec{P}(Z)|$).

VI. CONTROL SAMPLES: Z PRODUCTION; MC AND DATA

The distributions for the variables characterizing the underlying event structure are shown below. The figures contain three histograms for the samples with different cuts on the transverse momentum of the Z^0 boson. The first, in the upper left-hand corner, is for all values of $\mathrm{p_T}$ (inclusive Z^0 's). The expected contributions from Standard Model processes are shown stacked on top of each other, so that the upper edge of the histograms are the SM prediction. The next two plots show the distributions for Z^0 bosons with $\mathrm{p_T} > 60$ GeV and 120 GeV, respectively. Good agreement of data and SM predictions is observed at the three different $P_T(Z)$ scales.

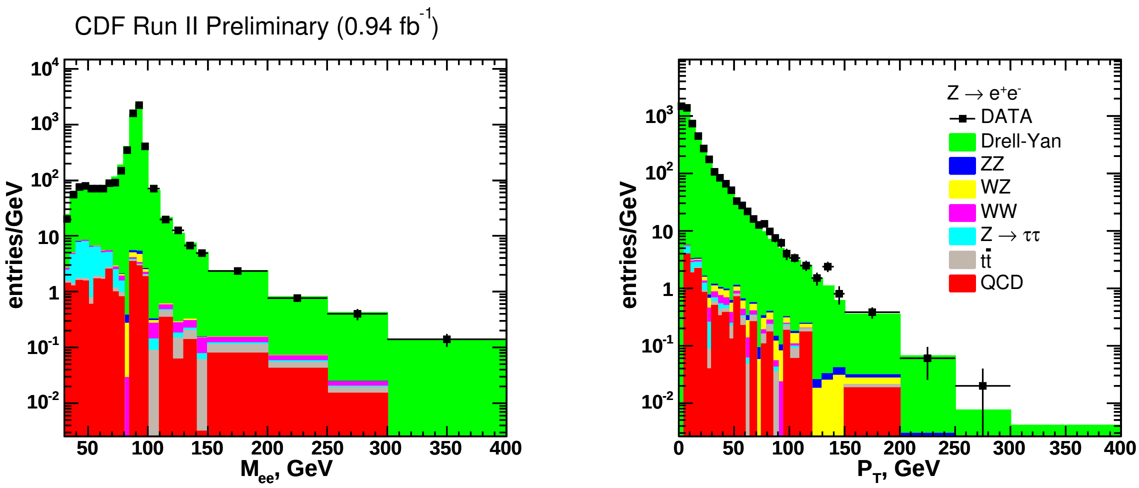

FIG. 1: Invariant mass (left) and transverse momentum (right) for $Z \to ee$. A mass cut of $66 <$ M(ee) < 116 GeV has been applied to the right-hand plot.

VII. HIGH PT SIGNAL REGION: COMPARISON OF THE SM MC AND DATA

The distributions of $P_T(Z)$ for $Z \to ee$ and $Z \to \mu\mu$ are in a good agreement with SM predictions (from a custom-tuned PYTHIA [4] (see figures 1 and 2). The sources of the systematic uncertainty are discussed below in the next section.

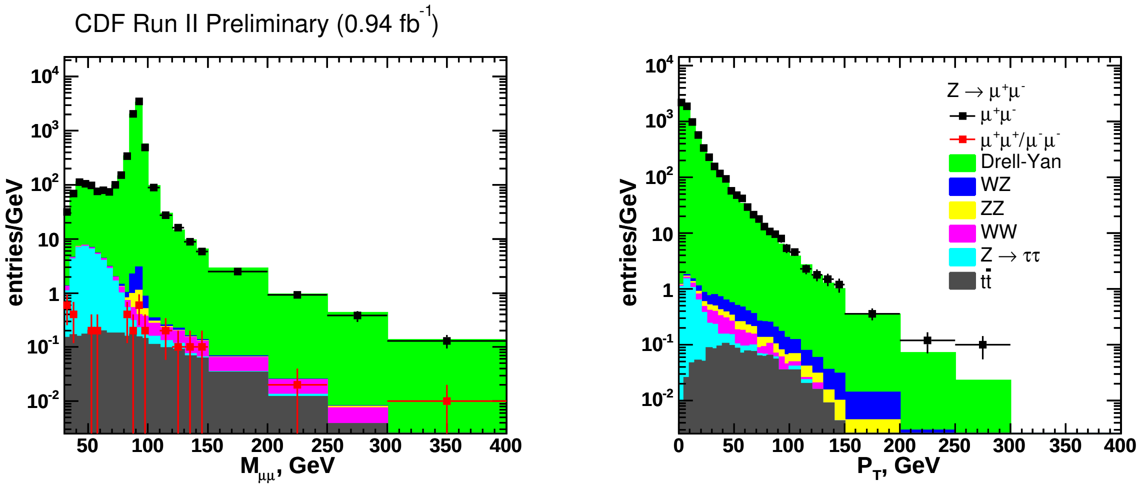

FIG. 2: Invariant mass (left) and transverse momentum (right) for $Z \to \mu\mu$. A mass cut of 66 < M($\mu\mu$) < 116 GeV has been applied to the right-hand plot.

VIII. SYSTEMATIC UNCERTAINTIES

A. Theoretical uncertainties on the shape of $P_T(Z)$ distribution

There are four sources of theoretical uncertainty:

- the choice of renormalization scale that minimizes higher-order corrections,
- the value of Λ_{QCD},
- the parametrization of the structure functions,
- resummation at low P_T.

The error of 10% is taken for the entire range of $P_T(Z)$ (See [7] for more details). The predictions of the PYTHIA MC have been compared with those from NNLO ResBos (CTEQ4M) in [8] and found in a good agreement.

B. Uncertainties on acceptance and reconstruction efficiency

The systematic uncertainties on efficiency and acceptance are studied in [9], where the same selection criteria were used.

The error on the luminosity is taken to be the usual Tevatron 6%.

IX. ACCEPTANCE AND EFFICIENCY.

The acceptance and efficiency ratios are taken from the MC predictions. The numbers of Z^0 's are counted before applying any cuts and after reconstruction. The ratio is P_T -dependent and calculated for the same bins as the distribution of $P_T(Z)$.

X. STATISTICAL AGREEMENT IN HIGH-P_T REGION

While the inclusive spectrum is the least sensitive of our signatures to new physics, as it is dominated by Z^0 +jet production, it is a useful pedagogical exercise to set a limit on anomalous production of inclusive Z's. We use a Bayesian approach to calculate an upper limit on a cross section in the presence of uncertainties on background level and acceptance. The limit calculation software is implemented in a package (see [10]) presented by the CDF Statistics Committee (see [11]). The more complete description of the approach can be found in [12].

Summarizing briefly the situation, we observe N events, which includes both signal and background. The observed events are used to set an upper limit σ_u on the cross section σ at confidence level β (we take $\beta = 0.95$). The upper limit includes the expected background $b \pm \sigma(b)$ and efficiency $\epsilon \pm \sigma(\epsilon)$, which includes reconstruction efficiency and acceptance. The n observed events are considered to be a deviation from a Poisson distribution having a mean of $(\sigma * L * \epsilon + b)$, where L is the observed luminosity.

$$\int_0^{\sigma_u} p(\sigma|N)d\sigma = \beta \tag{7}$$

The prior p.d.f. for σ is chosen to be $\sigma^{\alpha-1}d\sigma$, where α =0.5 (normally $0.5 \geq \alpha \geq 1$).

XI. RESULTS: LIMITS ON ANOMALOUS PRODUCTION OF THE INCLUSIVE Z-BOSONS

The Bayesian approach (see Sect. X) is applied bin-by-bin to the distribution of $P_T(Z)$ for $Z \to ee$ and $Z \to \mu\mu$ separately. The cross section limits obtained are presented in Figures 3 and **??** for $Z \to ee$ and $Z \to \mu\mu$ respectively. The corresponding cumulative (integral) Bayesian limits are shown in Fig. **??**. We assume that the production mechanism is the same as for the Standard Model.

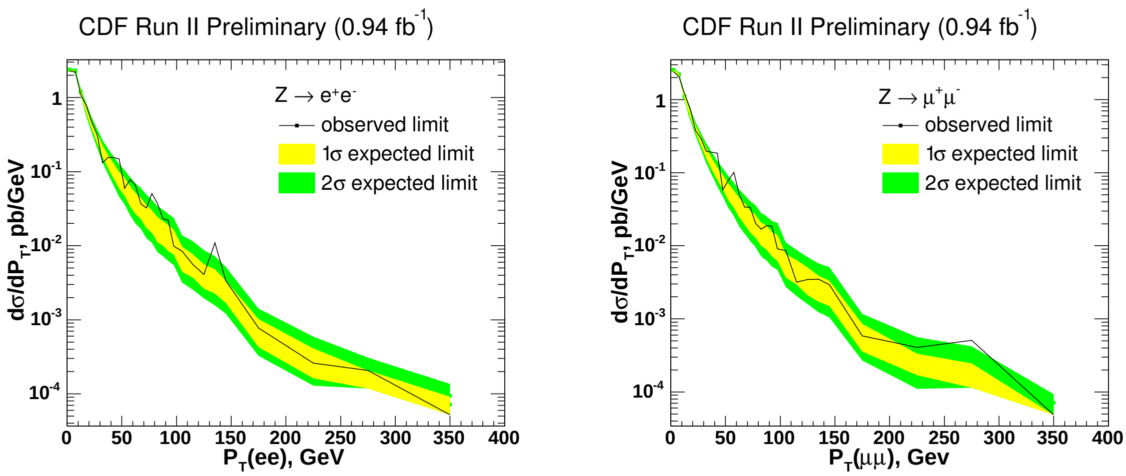

FIG. 3: The Bayesian limits on the differential cross section for anomalous $Z \to ee$ (left) and $Z \to \mu\mu$ (right) production at 95% CL. The yellow band represents the expected limit for 1σ fluctuations of the observed events in each bin, the green band - 2σ.

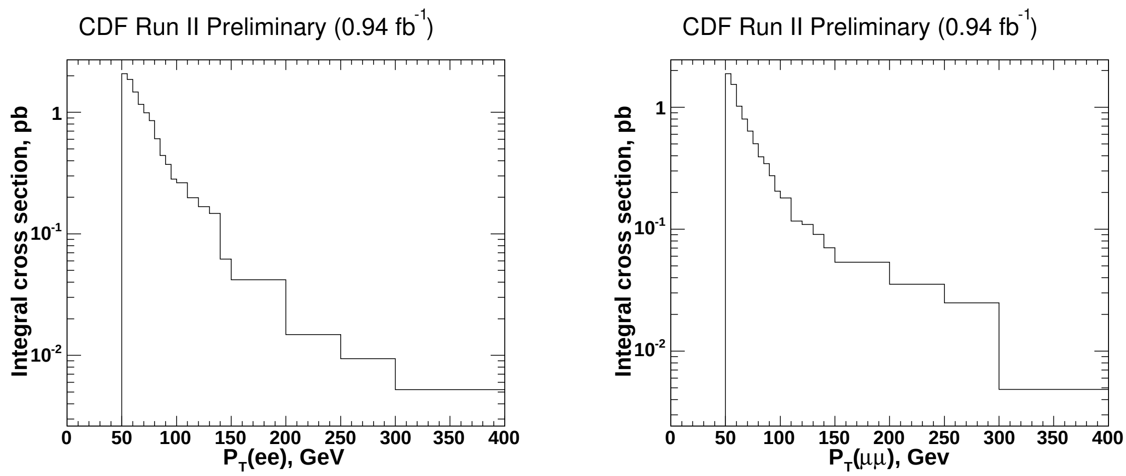

FIG. 4: Bayesian limits on the integral cross sections of anomalous production in $Z \to ee$ (left) and $Z \to \mu\mu$ (right) modes. The limits are set at 95% CL.

XII. SUMMARY TABLES OF THE Z+X AND Z+X+Y SIGNATURES.

The new physics we are looking for in events with high-Pt Z^0 bosons would involve the decays of one or a pair of new heavy objects. It is therefore expected that there would be multiple additional objects beyond the high-Pt Z^0 in such events. For example, in the model of Bjorken, Pakvasa, and Tuan [13], heavy right-handed new quarks would be produced with strong cross-sections, and each would decay to a light quark plus a heavy boson (W, Z, or H), giving several signatures with a high-Pt Z plus multiple objects. The SM background to high-Pt Z^0 's is largely QCD production of Z^0 + jets. Thus a search for high-Pt Z^0 + one or more additional objects, where the additional objects can be leptons, photons, missing Et or high Ht, could be sensitive to smaller cross-sections. In this section we consider a high-Pt Z^0 plus one, 'X', and two additional objects, 'X' and 'Y', where X or Y can be additional leptons, photons, signature of missing transverse energy ($\not{E}_T$), or large transverse energy (H_T).

We summarize the Z^0 +X and Z^0 +X+Y search by presenting two tables of events observed in each category of X and Y. We do this separately for the $Z \to ee$ and $Z \to \mu\mu$ processes. The tables can be found below. The quoted uncertainties on the expected numbers of events include the systematic and statistical (from MC statistics) components. The systematical uncertainties due to jet energy corrections are taken into account.

X	Observed	Expected
Leptons	3	1.6 ± 0.3
Photons	14	12.4 ± 1.5
H_T-signature	45	$36.4\ ^{+4.9}_{-5.8}$
$\not{E}_T$-signature	97	85.4 ± 12.3

TABLE III: Numbers of observed and expected events are listed for each category of Z^0 +X, $Z \to ee$.

X + Y	Observed	Expected
Leptons + Photons	0	0.01 ± 0.01
Leptons + H_T-signature	0	0.16 ± 0.04
Leptons + $\not{E}_T$-signature	1	0.72 ± 0.11(WZ)
Photons + H_T-signature	1	$0.80\ ^{+0.34}_{-0.23}$
Photons + $\not{E}_T$-signature	1	0.24 ± 0.20
H_T + $\not{E}_T$-signature	6	6.6 ± 1.0

TABLE IV: Numbers of observed and expected events are listed for each category of Z^0 +X+Y, $Z \to ee$.

X	Observed	Expected
Leptons	2	2.4 ± 0.4
Photons	14	15.0 ± 1.8
H_T-signature	53	$41.3\ ^{+5.0}_{-5.2}$
$\not{E}_T$-signature	74	$55.9\ ^{+9.7}_{-5.8}$

TABLE V: Numbers of observed and expected events are listed for each category of Z^0 +X, $Z \to \mu\mu$.

XIII. CONCLUSIONS

We have performed a broad search for signatures containing a high transverse momentum (p_T) Z^0 boson in 0.94 fb^{-1} of CDF-II data. In addition to inclusive production of Z^0 's with large values of p_T, we have investigated signatures that have a much smaller Standard Model crossection, and hence are more sensitive to new phenomena, such as right-handed heavy quarks, technicolor particles, gauginos or squarks, or excited states resulting from large extra dimensions. The specific channels in which we have searched are of the form Z^0 + X + anything and Z^0 + X + Y + anything, where X and Y can be leptons, photons, missing energy, or large total transverse energy (H_T). For each signature we compare the observed $P_T(Z)$ spectra and other distributions with Standard Model expectations.

The idea of using signatures is to get to regions where the SM Z-production is small and the new physical processes could be observed more easily. For example, we do observe events consistent with WZ production in the 'Z + Leptons + Missing Energy' category.

X + Y	Observed	Expected
Leptons + Photons	0	0.01 ± 0.01
Leptons + H_T-signature	0	$0.14\ ^{+0.05}_{-0.04}$
Leptons + $\not{E}_{\mathrm{T}}$-signature	0	0.8 ± 0.1
Photons + H_T-signature	0	$0.28\ ^{+0.14}_{-0.13}$
Photons + $\not{E}_{\mathrm{T}}$-signature	0	$0.19\ ^{+0.21}_{-0.10}$
H_T + $\not{E}_{\mathrm{T}}$-signature	6	3.5 ± 0.5

TABLE VI: Numbers of observed and expected events are listed for each category of Z^0 +X+Y, $Z \to \mu\mu$.

These X and Y can be the signatures of extra leptons, photons, missing energy, or high transverse energy. Therefore we have 10 categories:

1. Z + Leptons
2. Z + Photons
3. Z + Missing Energy
4. Z + High Transverse Energy
5. Z + Leptons + Missing Energy
6. Z + Leptons + Photons
7. Z + Leptons + High Transverse Energy
8. Z + Photons + Missing Energy
9. Z + Photons + High Transverse Energy
10. Z + Missing Energy + High Transverse Energy

The number of events in each category was compared to the SM predictions and they agree within uncertainties. Distributions of transverse momenta of the Z-bosons are in agreement with the predictions too.

Acknowledgments

We thank John Campbell and Steve Mrenna for help and wisdom on the Standard Model predictions. We thank the Fermilab staff and the technical staffs of the participating institutions for their contributions essential to this work. This work was supported by the U.S. Department of Energy and National Science Foundation; the Italian Istituto Nazionale di Fisica Nucleare; the Ministry of Education, Culture, Sports, Science and Technology of Japan; the Natural Sciences and Engineering Research Council of Canada; the National Science Council of the Republic of China; the Swiss National Science Foundation; the A.P. Sloan Foundation; the Bundesministerium fuer Bildung und Forschung, Germany; the Korean Science and Engineering Foundation and the Korean Research Foundation; the Particle Physics and Astronomy Research Council and the Royal Society, UK; the Russian Foundation for Basic Research; the Comision Interministerial de Ciencia y Tecnologia, Spain; and by the European Community's Human Potential Programme under contract HPRN-CT-20002, Probe for New Physics.

[1] D. Toback. *Searches for New Physics in Diphoton Events in $\bar{p}p$ Collisions at $\sqrt{s}$ =1.8 TeV.* PhD thesis, University of Chicago, December 1997.
[2] J. Berryhill. *Searches for New Physics in Photon-Lepton Events in $\bar{p}p$ Collisions at $\sqrt{s}$ =1.8 TeV.* PhD thesis, University of Chicago, December 2000.
[3] The CDF II Collaboration. The CDF II detector. Technical Design Report. FERMILAB-Pub- 96/390-E, Nov. 1996.
[4] D. Acosta et al. First measurements of inclusive w and z cross sections from run ii of the tevatron collider. *Phys. Rev. Lett.*, 94:091803, 2005.
[5] Torbjorn Sjostrand, Leif Lonnblad, and Stephen Mrenna. Pythia 6.2: Physics and manual. 2001.
[6] Heather K Gerberich, Ashutosh V. Kotwal and Chris Hays. Cosmic Ray Tagging using COT Hit Timing. CDF Note 6089, 2002.
[7] Peter B. Arnold and M. Hall Reno. The complete computation of high-p_t W and Z production in second-order QCD. *Nuclear Physics B*, (319):31–71, 1989.
[8] C. Balazs, J. Huston and I.Puljak. Higgs boson production: A comparison of parton showers and resummation. *Phys. Rev. D*, 63(014021), 2000.

[9] (The CDF Collaboration. First Measurement of Inclusive W and Z Cross Sections from Run II of the Tevatron Collider. *Phys. Rev. Lett.*, 94(091803), 2005. PRD numbers are not known yet.
[10] Joel Heinrich. User guide to bayesian-liimt software package. CDF Note 7232, 2004.
[11] See http://www-cdf.fnal.gov/physics/statistics/statistics_home.html.
[12] Joel Heinrich, Craig Blocker, John Conway, Luc Demortier, Louis Lyons, Giovani Punzi, Pekka K. Sinervo. Interval estimation on the presence of nuisance parameters. 1.Bayesian approach. *CDF Note*, (7117), 2004. http://xxx.lanl.gov/physics/0409129.
[13] J.D. Bjorken, S. Pakvasa, and S.F. Tuan. Yet Another Extension of the Standard Model: Oases in the Desert? *Phys. Rev. D*, 66(053008), 2002. http://xxx.lanl.gov/abs/hep-ph/0206116.
[14] There is a charge correlation in W+1jet with the jet faking a lepton- this background is small here.

XIV. APPENDICES

Here we present event displays of two interesting events.

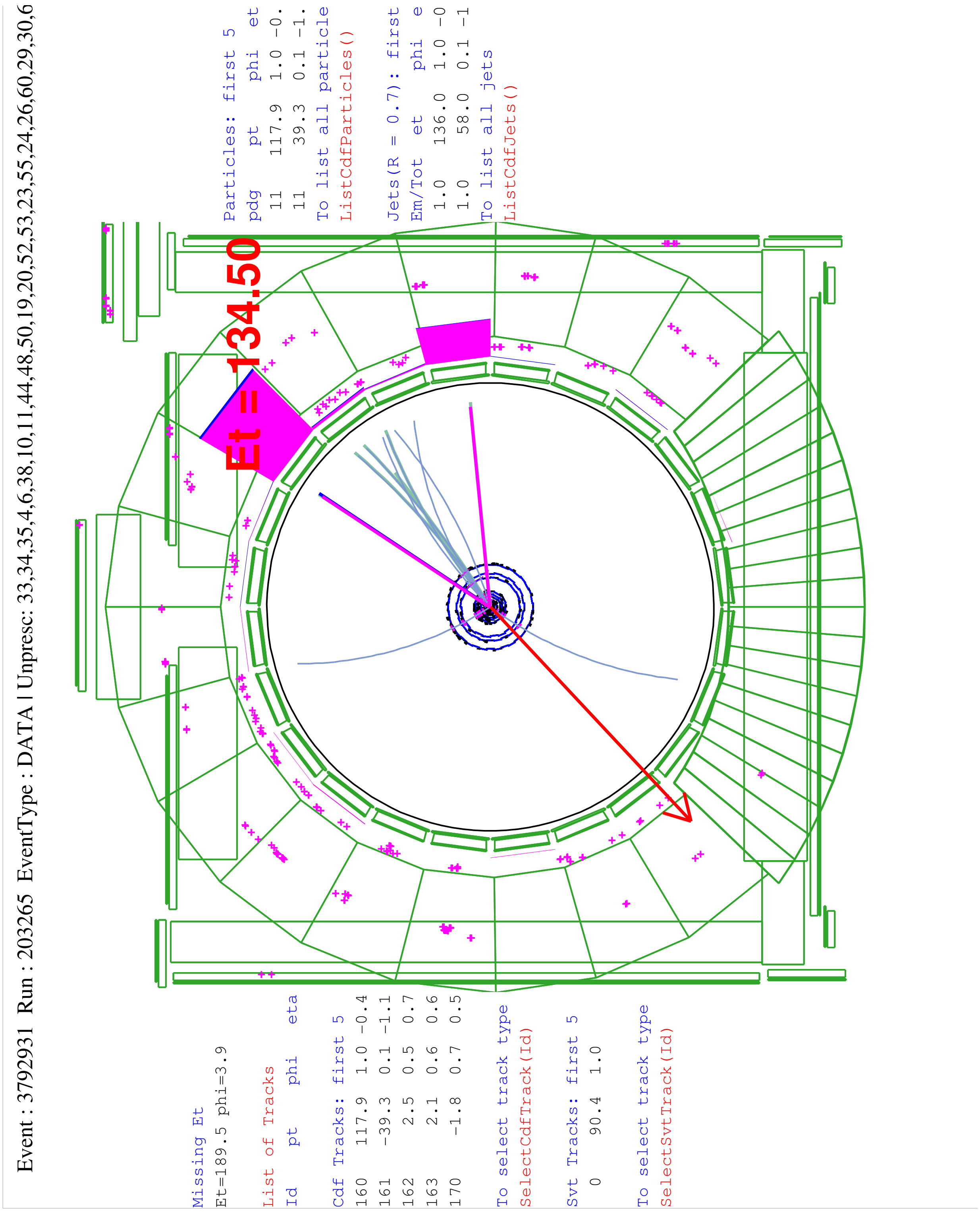

FIG. 5: This is a $Z \to ee$ event with hight missing energy.

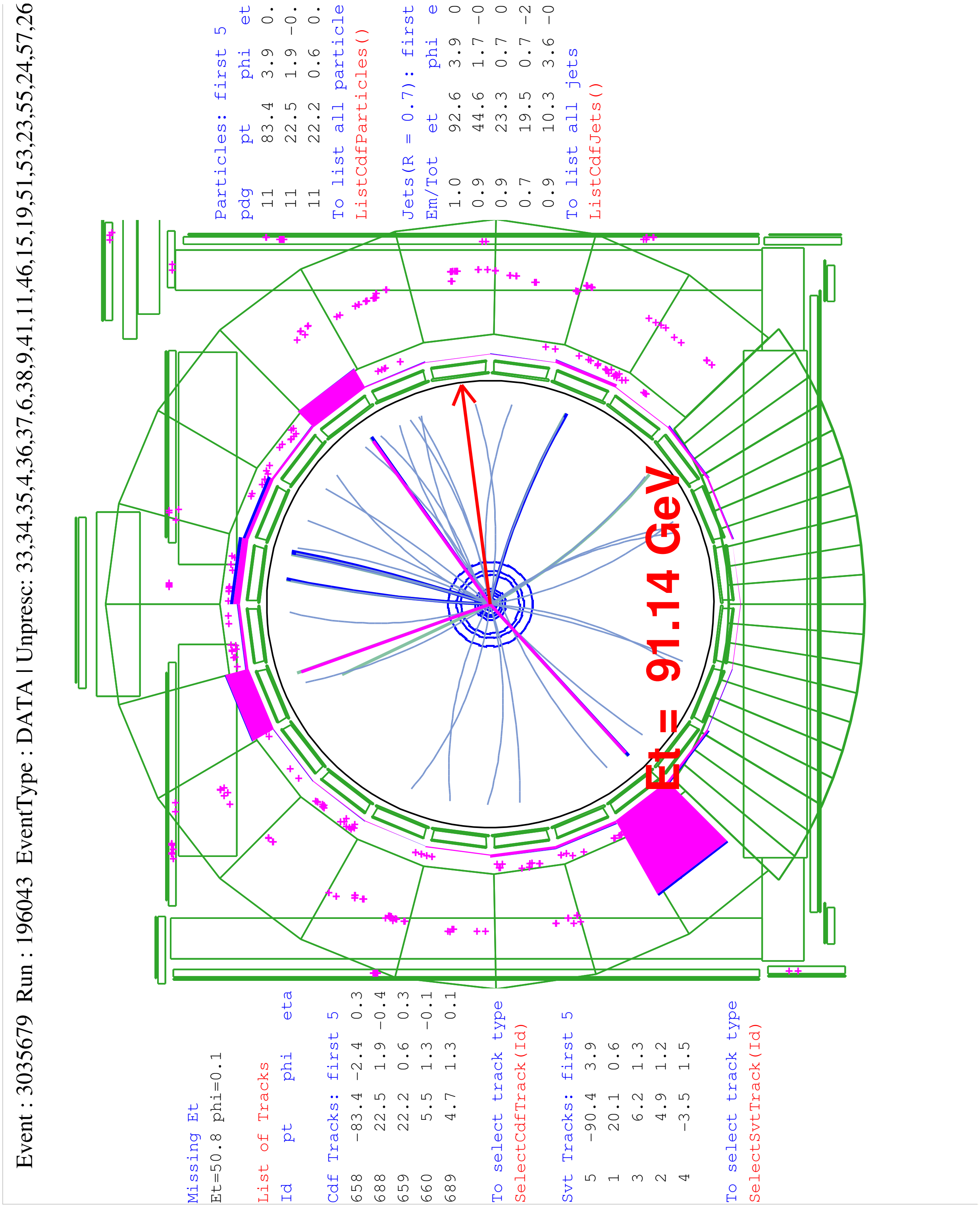

FIG. 6: This is a $Z \to ee$ + Lepton + Missing energy event.