DØ RESULTS IN DIFFRACTION

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Abstract. The first search for diffractively produced Z bosons in the muon decay channel is presented, using a data set collected by the DØ detector at the Fermilab Tevatron at $\sqrt{s} = 1.96$ TeV between April and September 2003, corresponding to an integrated luminosity of approximately 110 pb^{-1}. The current status of the FPD commissioning is also presented.

INTRODUCTION

QCD models single diffractive scattering of hadrons as proceeding via the exchange of a colour singlet object. In single diffraction, where one proton[1] remains intact with a small momentum loss and the other dissociates, there may be an area devoid of activity (rapidity gap) in the region of the outgoing intact proton. We present here the first ever search for diffractively produced Z bosons in the muon decay channel at the Fermilab Tevatron.

DIFFRACTIVE Z BOSON PRODUCTION

Event selection and data analysis

Z bosons produced via single diffraction are identified by demanding a rapidity gap near the beampipe in either the outgoing proton or antiproton direction. The data set was collected between April and September 2003 by the DØ detector at the Fermilab Tevatron, corresponding to an integrated luminosity of approximately 110 pb^{-1}. The DØ detector is described in detail elsewhere [1]. The Z boson is selected via its decay into two oppositely charged muons each with $p_T > 15$ GeV. At least one muon must be isolated in the central tracking detector and the calorimeter: Σp_T of tracks within a cone of radius 0.5 around the muon is required to be less than 3.5 GeV, and in the calorimeter (ΣE_T in a cone of radius of 0.5 around the muon) - (ΣE_T in a cone of radius of 0.1 around the muon) is required to be less than 2.5 GeV, where the cone radius is defined in pseudorapidity η and azimuthal angle ϕ as $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$. Cosmic ray muon events

[1] Here the term 'proton' is used to refer to both protons and antiprotons.

are vetoed by requiring that the distance of closest approach of muon tracks to the beam position is less than 0.02 cm for tracks with hits in both the Silicon Micro-vertex Tracker (SMT) and Central Fiber Tracker (CFT), or less than 0.2 cm for tracks with hits only in the CFT. In addition, the muon tracks are required to fulfil $|\Delta\phi_{\mu\mu} + \Delta\theta_{\mu\mu} - 2\pi| > 0.05$ radians, where θ is polar angle.

The rapidity gap search makes use of two detectors, the Luminosity Monitor (LM) and the end calorimeter. The LM comprises two scintillating detectors, one on each side of the interaction region, which cover the pseudorapidity range $2.7 < |\eta| < 4.4$. The total output charge is discriminated to give an on/off signal for each detector. The end calorimeter is divided into three regions: (1) four electromagnetic layers closest to the beam, (2) four fine hadronic layers and (3) one coarse hadronic layer furthest from the beam. Each layer is divided into cells in the $\eta - \phi$ plane. For this analysis, the energy is summed separately on each side (outgoing proton and antiproton) in the range $2.6 < |\eta| < 5.3$, using electromagnetic cells with $E_{\mathrm{cell}} > 100$ MeV and fine hadronic cells with $E_{\mathrm{cell}} > 200$ MeV.

The log of the energy sum on the outgoing antiproton side is plotted in Figure 1 for bunch crossings in which there are no visible interactions. These are selected from a randomly triggered sample with the requirements that both LM detectors are off and there is no vertex with greater than two associated tracks. These events are used to approximate rapidity gap events, in which there is no activity in the outgoing antiproton direction. The log of the energy sum on the outgoing antiproton side is also shown for a sample of minimum bias events in the figure. These are selected requiring hits in both detectors of the LM within a small time window. A third (25 GeV jet) sample is selected by requiring a vertex with at least three tracks, and at least one jet with $p_T > 25$ GeV that passes jet quality cuts. Jet events in which the highest p_T jet lies in the region $|\eta| > 2.4$ are excluded. The minimum bias and jet samples are dominated by events in which both protons dissociate.

Events with no interaction and events with antiproton dissociation are separated by applying a cut at an energy sum of 10 GeV. This is also the case in the outgoing proton direction. To select single diffractive candidates in the Z boson sample the LM detector is required to be off and the energy sum less than 10 GeV on one side, and the LM detector is required to be on and the energy sum greater than 10 GeV on the other side.

Results

Figure 2 shows the di-muon invariant mass distribution for two samples. Fig. 2(left) shows those events that fail the two rapidity gap cuts on both the outgoing proton and antiproton sides. These are strong candidates for non-diffractive production of Z bosons. A resonant peak is observed together with a small background contribution, arising mainly from the $(Z/\gamma)^*$ continuum. Fig. 2(right) shows those events that pass both rapidity gap cuts on one side and fail both on the other. These are candidates for single diffractively produced Z bosons, where one proton is intact and the other dissociates.

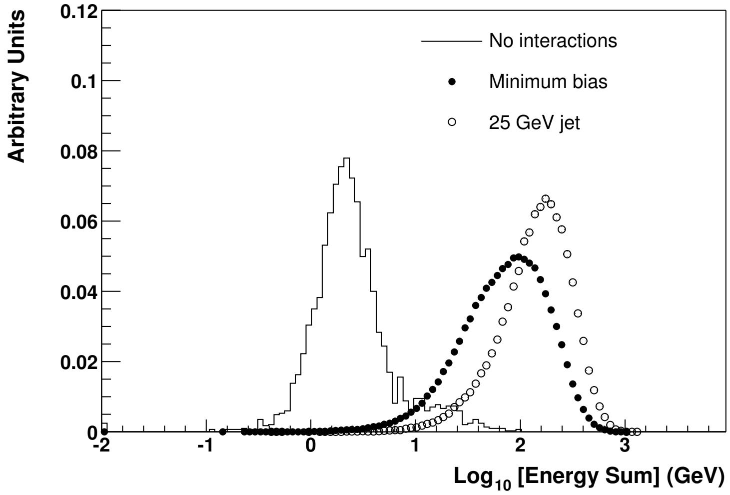

FIGURE 1. Log of energy sum in the outgoing antiproton direction ($-5.3 < \eta < -2.6$), comparing events with no visible interactions with events in which both protons dissociate. Areas are normalised to unity. An energy sum cut is applied at 10 GeV for rapidity gap candidates.

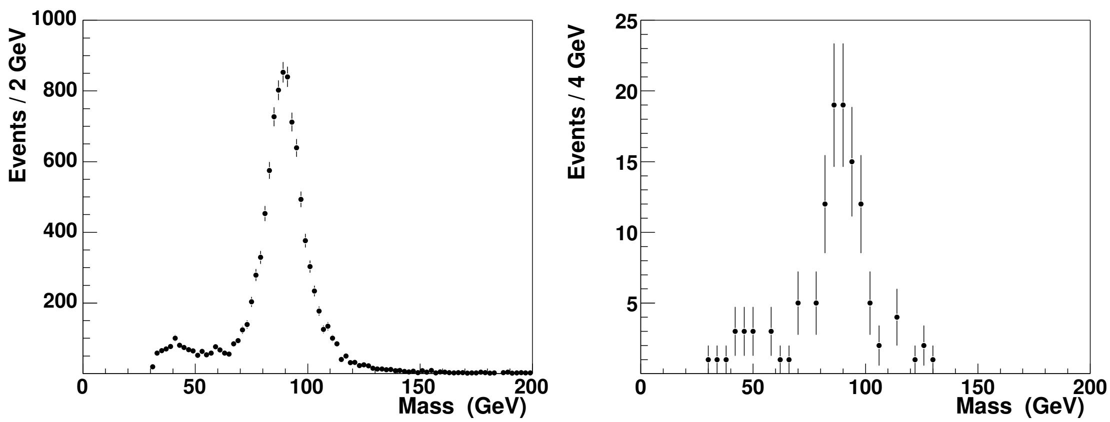

FIGURE 2. The di-muon invariant mass distribution for Z boson candidates with no rapidity gap (left) and a single rapidity gap (right). A rapidity gap is defined as one LM detector off and energy sum less than 10 GeV in the same region (see text for details).

FORWARD PROTON DETECTOR

The Forward Proton Detector was designed to study diffractive events produced at the DØ interaction point at Tevatron. It is an ensemble of 9 momentum spectrometers comprised of 18 Roman Pots, inside which a detector based on scintillating fibers can be brought as close to the beam as 6 mm, allowing the reconstruction of the trajectories of the scattered protons. This approach provides a way to measure the scattering angle and momentum fraction lost with a much better resolution than using the rapidity gap method alone. For a full description of the FPD, see [2].

The first 10 Roman pots were installed between 2001 and 2002 and since January

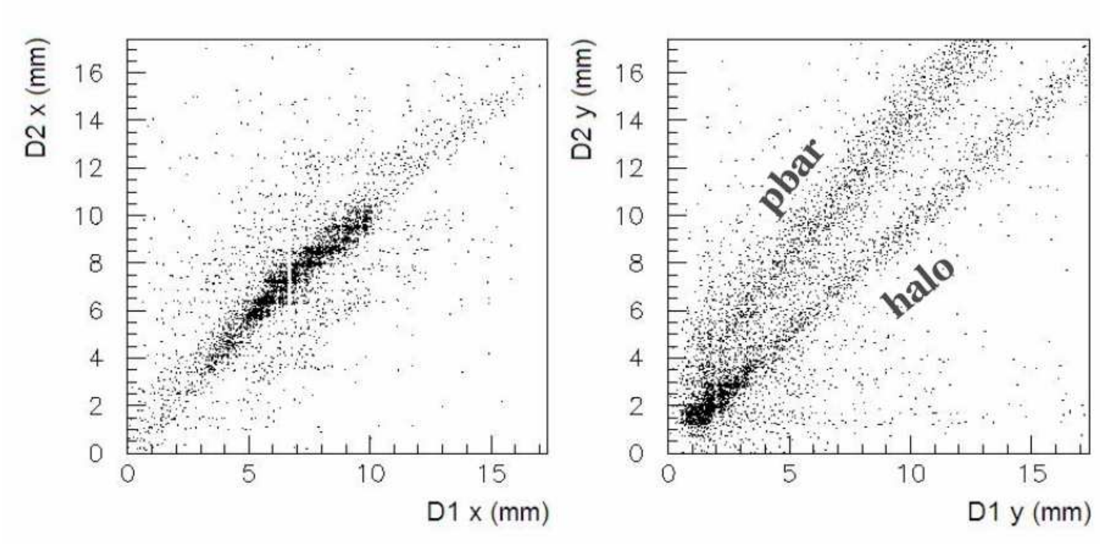

FIGURE 3. Hit correlation for the dipole spectrometer. On the left, the x coordinate of a hit on the first detector is plotted against the one on the second detector; on the right, the same correlation is plotted for the Y coordinate

of 2004, all of them are taking data integrated with the DØ detector and functioning as designed.

Each one of the 18 detectors has a sensitive area of about 17.5x17.5 mm^2, 6 layers of fibers in 3 planes (u,x and v) and a trigger scintillator. The 3 planes can measure the hit of a proton passing through it without ambiguity. Combining the hit measured in two detectors of a spectrometer (see [2]), it is possible to track the particle from the interaction point.

The hit correlation on both detectors of a spectrometer can be used to separate the scattered proton from the halo particles. Since the halo particles have basically the same energy as the beam ones, they are affected the same way by the electromagnetic fields along the path between both detectors, however, the scattered proton, after loosing energy has its path more affected by the fields along its way from the first detector to the second one. Thus, the scattered proton has its path deviated towards the center of the ring (increasing Y coordinate), making them to be off diagonal in the correlation plot.

This effect can be seen in figure 3, where it is shown the X (left) and the Y (right) coordinate correlations for the dipole spectrometer. On these plots, it has been used a simple selection criteria where only events with only one hit per detector were selected.

SUMMARY

A search for diffractively produced Z bosons in the muon channel has been presented. The sample is large enough to allow a study of the kinematic properties of the Z bosons for the first time. It has also been shown that the Forward Proton Detector is under commissioning and working as expected. Future diffractive studies at DØ will be done using both the FPD signals and the rapidity gap technique.

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