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Diffraction at DØ

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Abstract. We present results from the DØ collaboration on diffractive studies in $p\bar{p}$ collisions at the Fermilab Tevatron. An overview of some interesting results at $\sqrt{s} = 1.8$ TeV is presented focusing on diffractive production of W and Z bosons. We then outline the plan for diffractive studies at 1.96 TeV highlighting the status of the new Forward Proton Detector.

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Diffractive events are inelastic collisions of color-singlet particles where neither color or flavor is exchanged between the particles in the collision. An example of diffraction in proton - anti-proton collisions, is the interaction $p + \bar{p} \to p + X$ where the proton remains intact throughout the process but sufficient momentum is transfered to disassociate the $\bar{p}$ into a multi-particle system. The daughters of the $\bar{p}$ follow the initial $\bar{p}$ direction leading to highly asymmetric events. Since the proton stayed intact, a large solid angle surrounding the proton is essentially free of particles and is known as a rapidity gap. This rapidity gap is the experimental signature for diffractive events. For a more detailed description of diffractive interactions at the Tevetron, see [1].

The DØ detector collected data at $\sqrt{s} = 1.8$ TeV from 1992 − 1996 (Run I). The Run I DØ detector [2] was a multipurpose particle detector consisting of an inner detector for tracking charged particles, a Uranium/liquid-Argon calorimeter for measuring electromagnetic and hadronic showers, and a muon spectrometer consisting of magnetized iron toroids and three layers of drift tubes. The detector also included a Level 0 trigger detector consisting of plastic scintillating paddles in the forward region in front of the calorimeter used to indicate inelastic collisions. The presence of a rapidity gap was determined by studying the multiplicity of cells above a threshold in the calorimeter, n_{CAL}, and the multiplicity of paddles with hits in the Level 0 detector, n_{L0}. The Run II configuration is described below.

One of the most interesting Run I measurements was the study of diffractively produced W and Z bosons [3]. Since the W and Z production mechanism is clearly understood at the quark level, these studies directly probe the active constituents in diffractive interactions. The Run I data set included large, clean samples of W and Z bosons [4]. Thus one only needs to determine the fraction of these events that include rapidity gaps.

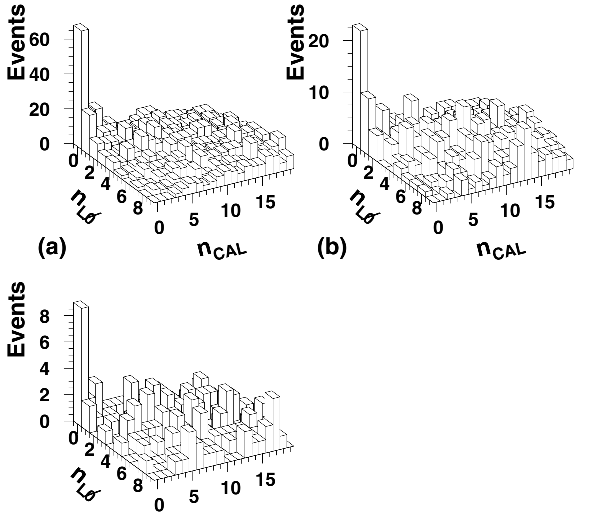

Fig. 1. Level 0 detector multiplicity versus calorimeter multiplicity for central W events **a**, forward W events **b**, and Z events **c**. The large peak at (0,0) indicates the presence of rapidity gaps in all samples

The fraction of events with a rapidity gap is extracted from a two-dimensional fit to the n_{L0} versus n_{cal} distribution shown in Fig. 1. Diffractive events are modeled as a 2-D exponential and non-diffracive events are modeled as a polynomial surface. The gap fractions and significance above background for the W and Z samples are listed in Table 1. We clearly observe diffractive production of W bosons and there is strong evidence for diffractive Z boson production.

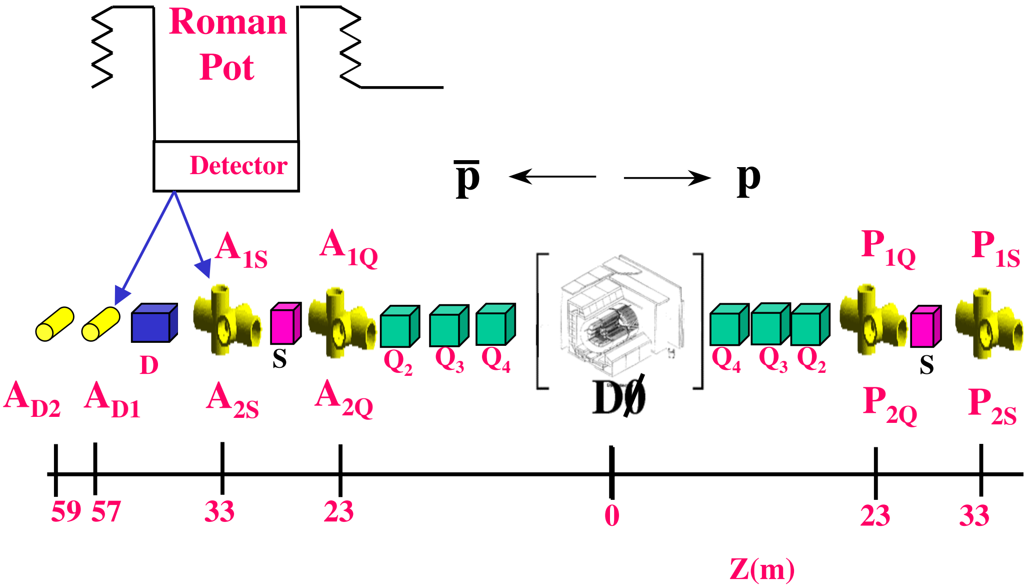

Fig. 2. Layout for the Forward Proton Detector

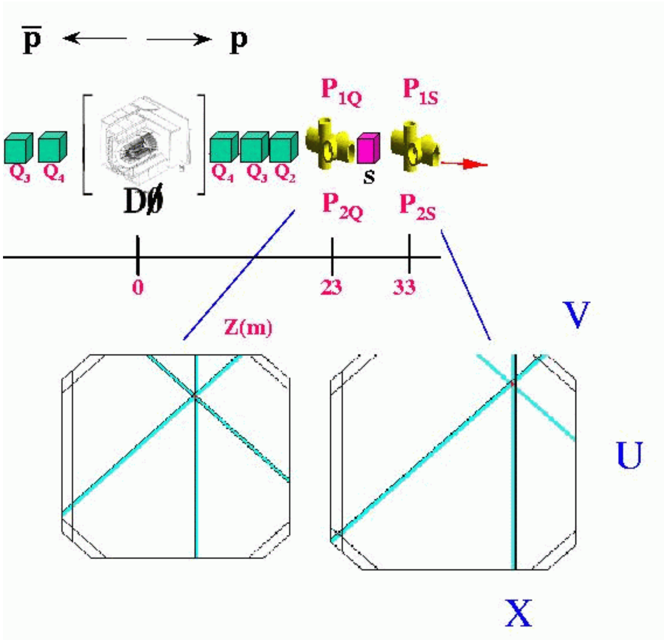

Fig. 3. Event display of an outgoing proton track reconstructed in the FPD. The $\bar{p}$ arm of the FPD is only partially shown in the figure. The intersection of x, u, and v fibers and the coincidence of hits in different spectrometers allows for a measurement of the scattering angle and momentum of the proton

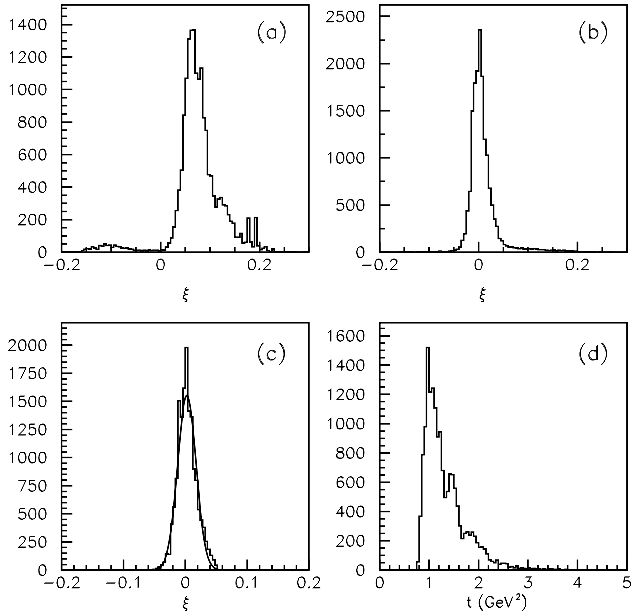

Fig. 4. Distributions for ξ and t in elastic collisions determined by the FPD. The distributions are shown before and after calibration. **a** ξ before calibration, **b** ξ after calibration; **c** t after calibration, **d** t before calibration

There has been a considerable upgrade of the DØ detector for Run II which began in 2001 with an increased Tevatron energy of $\sqrt{s} = 1.96$ TeV. The major upgrade for the DØ diffractive physics program is the introduction of the Forward Proton Detector (FPD) [5]. The FPD, shown in Fig. 2, consists of two magnetic spectrometer arms that use the Tevatron quadrapole and dipole magnets as analyzers. The trajectories of the outgoing protons or anti-protons are measured by scintillating fiber detectors placed in Roman Pots allowing the measurement of both the scattering angle and the momentum transfer in the diffractive collision. Figure 3 is an event display of a proton tagged event where the outgoing proton track is reconstructed using the coincidence of fiber hits in two spectrometers. During stable beam conditions, the detectors can be inserted into the beam pipe to within approximately 6 mm of the beam.

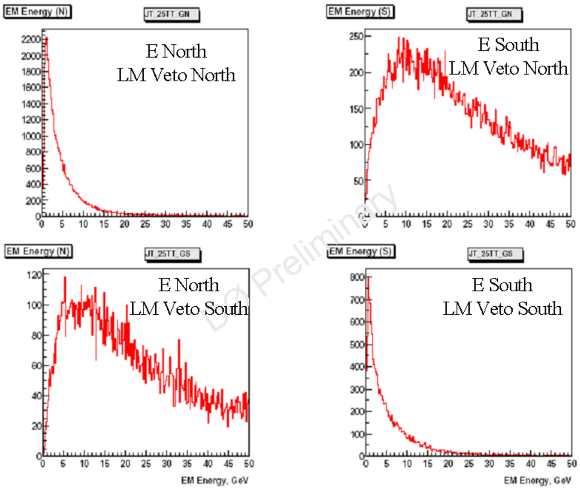

Fig. 5. Energy in the calorimeter behind the luminosity monitors. *Upper left* is the energy in the region the North luminosity monitor indicated was a rapidity gap. *Upper right* is the energy opposite the gap. *Lower right* and *left* are the corresponding figures for the South luminosity monitor

Construction and commissioning of the FPD is still in progress. With alignment, tracking, and background rejection studies well underway. In particular, the test stand electronics have been configured to trigger on elastic collisions. The $\xi = \Delta p/p$ and t distributions for these events are shown in Fig. 4. Funds have recently been obtained through an NSF MRI grant to complete the detector by Fall 2003.

Other forward DØ upgrades include the replacement of the Level 0 detector with improved scintillators now referred to as the luminosity monitor and additional scintillators along the beam line for veto counters. The absence of hits in the luminosity monitors is currently used as a rapidity gap trigger. Figure 5 shows the energy in the calorimeter behind the luminosity monitors on the gap side and the side opposite of the gap.

Table 1. Fraction of W and Z events in the DØ Run I data set with a rapidity gap along with the significance above background

Sample	Gap fraction (%)	significance
Central W	$1.08^{+0.19}_{-0.17}$	7.7σ
Forward W	$0.64^{+0.18}_{-0.16}$	5.3σ
Total W	$0.89^{+0.19}_{-0.17}$	7.5σ
Total Z	$1.44^{+0.61}_{-0.52}$	4.4σ

All forward detectors will be incorporated into the DØ trigger and readout. This allows for specific diffractive triggers to be implemented using either rapidity gaps or (anti-)proton tags as triggers. Also, gap and FPD information will be available in hard scattering events triggered by the calorimeter or muon system.

In conclusion, we recall that some of the most interesting studies from the Tevatron Run I focused on diffractive processes. With the new abilities at DØ to tag outgoing protons and anti-protons with the FPD, improved detectors for measuring rapidity gaps, and the ability to form diffractive specific triggers, Run II is guaranteed to produce exciting diffractive results.

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