

FIRST DATA FROM DØ IN RUN 2

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Run 2 of the Tevatron collider at Fermilab has begun in the spring of 2001. During its first year of operation the Tevatron has delivered an integrated luminosity of approximately 30 pb^{-1} to the DØ experiment. These data have been used to commission the detector. The progress in understanding the detector performance and the prospects for an exciting physics program to be carried out in the next years are the subject of this review.

1 Physics goals for Run 2 at the Tevatron

The Tevatron collider at Fermilab is the world's highest energy accelerator, colliding protons and antiprotons at a centre of mass energy of $\sim 2 \text{ TeV}$. Since the end of Run 1 the accelerator complex has been upgraded to raise the collision energy and to deliver larger integrated luminosities (2 fb^{-1} before 2005, and 15 fb^{-1} before the startup of the LHC), extending the physics reach of the experiments. The DØ detector has also been upgraded¹ to cope with the reduced time between bunch crossings, the increase in luminosity and backgrounds, and to extend the physics capabilities of the experiment.

The physics goals of Run 2 include the investigation of the electroweak symmetry breaking mechanism and searches for physics beyond the Standard Model. The luminosity gain will also yield large statistics for precise measurements at lower mass scales, such as b -physics and QCD.

The large increase in luminosity means that the reach for discoveries at the highest mass scales will be increased, while formerly rare processes, like the production of weak bosons and of the top quark, become the object of precision measurements. With 15 fb^{-1} at the end of Run 2, the Tevatron experiments will be able to search for the Higgs boson in much of the phase space currently allowed by Standard Model fits^{2,3}. Meanwhile this allowed range can be reduced with improved precise measurements of the masses of the top quark and of the W boson, reducing

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the uncertainty in their determination respectively to 1–2 GeV and 20 MeV at the end of Run 2⁴.

With 2 fb^{-1} the mass reach in the search for supersymmetric particles will extend to 400 GeV for squark and gluinos, 200 GeV for stop and sbottom quarks and 180 GeV for charginos in the trilepton final state⁵. Other models (TeV-scale gravity and extra dimensions, technicolour, leptoquarks) will also be used to guide searches for new phenomena. In addition to these optimised searches, model independent searches for new physics will also be performed, following the approach pioneered by DØ in Run 1⁶.

2 Upgrade of the DØ detector

The Run 2 upgrade builds on the strengths of the Run 1 DØ detector, its state of the art hermetic calorimeter system and its lepton identification capabilities over a large rapidity range. To achieve the Run 2 physics goals the detector has undergone a series of large changes, highlighted in the cross sectional view of the DØ detector shown in Fig. 1.

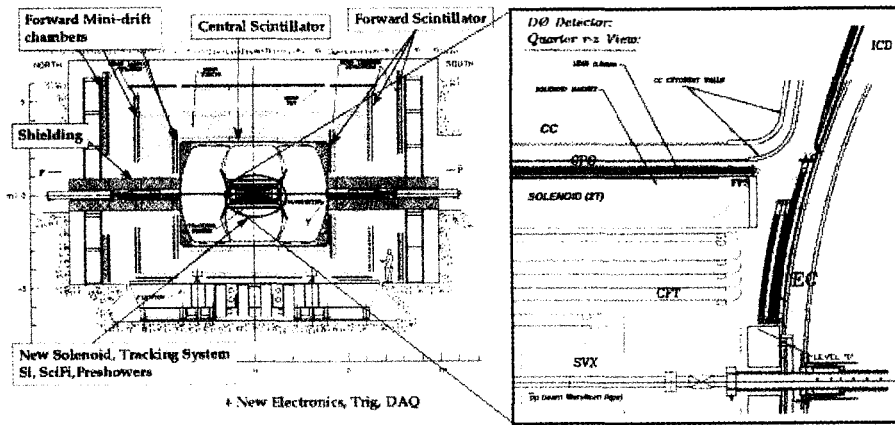


Figure 1: Transverse view of the DØ detector, highlighting the parts of the detector which have been upgraded in view of Run 2.

A 2 T superconducting solenoid has been installed in front of the calorimeter cryostat, surrounding a new tracking system comprising silicon microstrip and scintillating fibres detectors. Preshower detectors have been installed between the solenoid and the calorimeter in the central part of the detector, and in front of the forward calorimeter to compensate for the energy loss of electrons and photons in the solenoid and to improve the angular resolution for photons. The forward muon system has been completely rebuilt, separating the triggering function (using scintillator tiles), from the precision tracking (using mini-drift tubes). The forward muon detector benefits from the new shielding of the beam line, resulting in a large reduction of backgrounds compared to Run 1. In the central region of the detector additional layers of scintillators have been added to the muon system, allowing a more extensive reduction of out of time backgrounds. The readout electronics, the trigger and DAQ systems have all been rebuilt to cope with the reduced time between crossings and the increase in luminosity.

3 Detector performance

3.1 Calorimeter

The DØ calorimeter is a 55k channels U/LAr calorimeter with fine longitudinal and transverse segmentation, uniform response and good energy resolution. New readout electronics with analog pipelines has been installed for Run 2. The calorimeter has been fully operational since the beginning of the run with less than 0.1% bad channels. The commissioning of the preshower detectors and of the new inter-cryostats detectors (scintillator tiles installed in the gaps between the barrel and endcap calorimeters to improve the resolution on the missing transverse momentum) was still ongoing at the time of the conference. A preliminary calibration of the calorimeter has been obtained investigating the invariant mass spectrum of dielectron events originating from the decay of Z^0 bosons, shown in Fig. 2. The knowledge of the absolute calorimeter calibration is currently limited by the available statistics in the Z^0 sample.

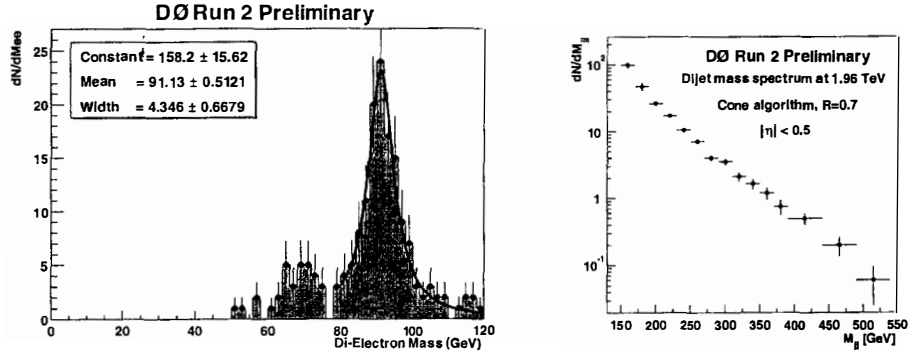


Figure 2: Invariant mass distribution for events with two high p_T electrons (left) and for two jet events (right).

The energy scale for jets was then determined using γ +jets events. Also shown in Fig. 2 is a preliminary dijet invariant mass spectrum, which does not include correction for trigger threshold effects. Due to the increased centre of mass energy of the Tevatron collider, DØ has already observed events at invariant masses in excess of 500 GeV in a sample corresponding to an integrated luminosity of only about 1 pb^{-1} .

While the resolution on the missing transverse momentum will improve with a better understanding of the calibration of the calorimeter, the Monte Carlo already provides a good description of the significance of the measurement of the missing transverse momentum, provided the error on this quantity is taken from data. This permits the use of the missing transverse momentum for analyses, one of the most important tools in the searches for physics beyond the Standard Model.

3.2 Muon detector

In DØ the trajectories of muons penetrating the iron toroid surrounding the calorimeters are measured by drift tubes. Trigger signals are obtained from scintillator counters, which provide a timing signal used to reject background from cosmic rays. In the central region the Run 1 drift tubes are used, with a faster gas mixture and new readout electronics, and new scintillator counters have been installed. The forward system has been completely rebuilt for Run 2: it includes 3 layers of mini drift tubes and scintillator pixel counters. The muon system has been

fully operational since the beginning of Run 2 and thanks to the new shielding close to the beam line the detectors can easily discriminate muons from the low rate of out of time backgrounds.

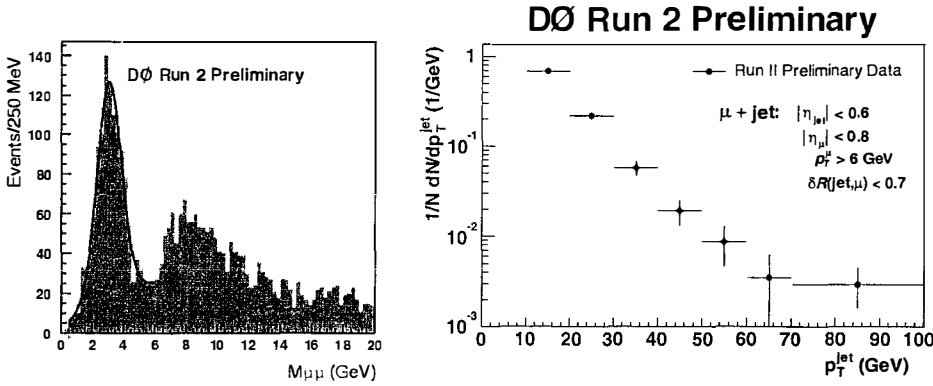


Figure 3: Invariant mass distribution for dimuon events, using only the muon momentum measurement in the iron toroid (left). Transverse momentum spectrum for jets with a soft muon b -tag (right).

Two examples of the measurements performed so far to study the performance of the muon detector are shown in Fig. 3. The left plot shows the invariant mass distribution for muons having $p_T > 3$ GeV. The signal from the J/ψ resonance is clearly visible above the background. Its width is consistent with expectations for the muon system only, where the momentum resolution is dominated by the multiple scattering in the iron toroid. The muon momentum resolution improves with the use of the information obtained from the central tracking system (see Sec. 3.3). The right plot shows the spectrum of jets having a soft-muon b -tag. Muons having a transverse momentum relative to the jet axis in excess of 1 GeV most likely come from the decay of a b quark. Both the transverse momentum distribution of muons relative to the jet and the transverse momentum distribution of these jets agree with expectations, based on the Run 1 data.

3.3 Tracker

The DØ tracking system is entirely new: it is based on a silicon microstrip tracker (SMT) and a central fibre tracker (CFT) installed inside a 2 T solenoid. The SMT consists of 4 barrel layers of single and double-sided silicon microstrip detectors, interspread with disks arranged perpendicular to the beam direction. These, together with additional disks in the forward directions, allow efficient track reconstruction in the SMT up to $|\eta| = 2.5$ independently from the position of the primary vertex, which has a gaussian distribution along the beam axis with a RMS of 30 cm. Altogether the SMT comprises $\sim 800k$ readout channels. It has been in continuous operation since the beginning of Run 2. Fig. 4 shows the K_s^0 peak obtained from the invariant mass of unlike sign tracks reconstructed in the SMT system alone.

At larger radii (between 20 and 51 cm) tracking is performed in 8 double layers of $840 \mu\text{m}$ diameter scintillating fibres. Each layer has two axial and two 2° stereo fibres, read out through visible light photon counters operating at 9 K, with 85% quantum efficiency and good signal to noise ratio. The readout electronics for the fibre tracker (and the preshower detectors) has been completely installed in the spring of 2002. Fig. 4 shows the hits and the reconstructed tracks in the DØ tracker for a typical two jet event. Track information is already being used in analyses, improving the resolution of the muon measurement, and providing a useful tool for the

calibration of the electromagnetic calorimeter. Work is underway to improve the understanding of the vertexing algorithms and to develop impact parameter and vertex based b quark tags, which are crucial in the search for the Higgs boson and for reducing the background in top analyses.

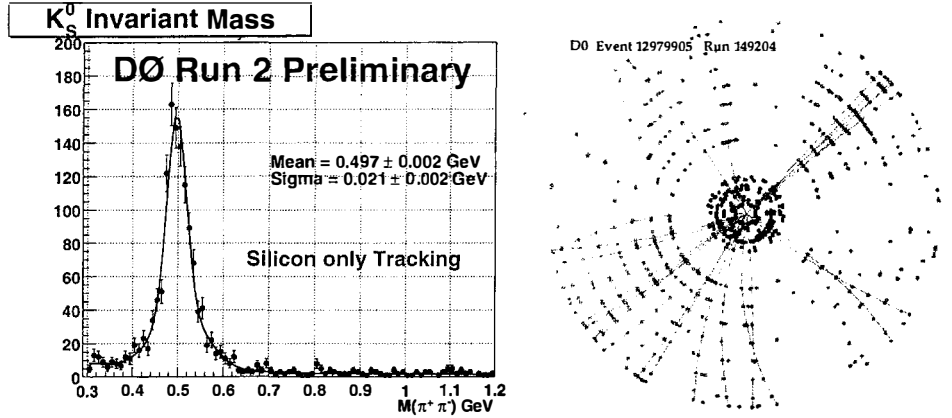


Figure 4: Invariant mass distribution for pairs of unlike sign tracks, using tracks reconstructed only in the silicon detector (left). Cross sectional view of one event in the tracking system (scintillating fibres and silicon microstrip detector): only tracks with $p_T > 500$ MeV are reconstructed (right).

3.4 DAQ and trigger

The trigger and DAQ systems have been almost completely rebuilt for Run 2. High p_T triggers have been running without prescales during the first year of Run 2 operations despite limitations in the DØ data taking capabilities due to delays in the delivery of L2 CPUs and of L3 components. Most of the L2 triggers and a new Ethernet based DAQ system are being commissioned: DØ will be capable of handling design trigger rates before the beginning of the summer. The L1 central tracking trigger (CTT), which uses the track measurements in the CFT, is being commissioned. Its use will result in sharper turn-on curves for muon triggers. The L2 silicon track trigger, an important addition for Higgs physics, will be installed and commissioned later in the fall.

4 First physics results

In addition to the physics signals already discussed in the previous section, a relatively clean sample of $W \rightarrow e\nu$ candidates was obtained by selecting events with a high p_T electromagnetic cluster matched to a track and large missing transverse energy (see Fig. 5). The background has been estimated from data and consists mainly of QCD events with fake electrons. Also shown in Fig. 5 is the E/p ratio for the candidate electrons. Those W candidates with additional jets will constitute the main background for top and Higgs analyses.

Other preliminary results include the first candidates (most likely from background sources) in searches for trileptons and leptoquarks. More extensive results using higher quality data and larger luminosities are expected for the summer.

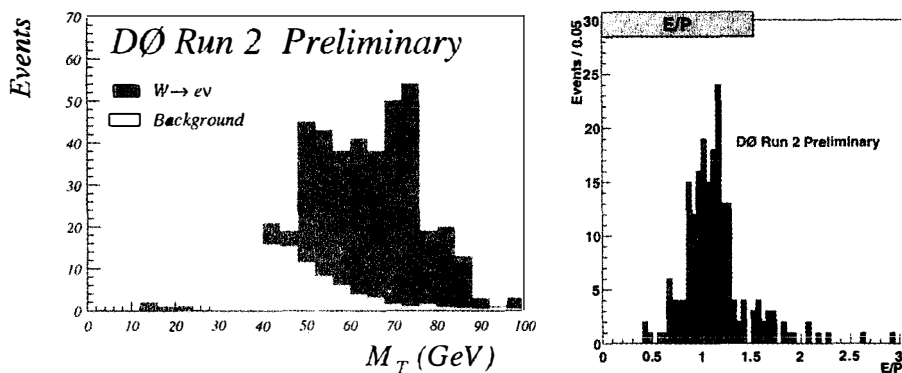


Figure 5: Transverse mass distribution for a sample of $W \rightarrow e\nu$ candidate events (left) and distribution of E/p for candidate electrons, using preliminary alignment and calibration constants (right).

5 Conclusions

The luminosity delivered by the Tevatron in the first year of Run 2 has been used by the DØ experiment mainly for detector commissioning purposes, allowing enormous progress in the understanding of the detector performance. Preliminary analyses have been performed using a subset of the delivered luminosity, indicating that the DØ collaboration will be able to fully exploit the physics opportunities presented by Run 2.

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