THE DØ DETECTOR FOR THE FERMILAB COLLIDER

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Abstract

Some of the main features of a new detector for the 2 TeV Fermilab proton-antiproton collider are presented. The "DØ detector" is the first example of a detector relying entirely on calorimetry and hermeticity to achieve excellent energy resolution. Only muon momenta are magnetically measured in a very thick magnetized iron absorber.

INTRODUCTION

By late '86 the Fermilab superconducting ring is expected to be operating as a proton-antiproton collider, sometimes known as TEV-I, at a c.m. energy $\sqrt{s} = 2$ TeV, with a luminosity of 10^{30} $cm^{-1}s^{-1}$. In a departure from tradition, the Fermilab Program Advisory Committee decided, in mid 83, to call for a new general purpose detector for the Fermilab collider, to be located at the DØ interaction area. The new detector is supposed to be complementary to the CDF detector, now nearing completion, with emphasis on calorimetry and lepton identification. The basic design goals were set forward by the newly formed DØ collaboration [1] in a Design Report submitted in December 1983. Following approval by the Fermilab PAC, by technical committees and by the US DOE administration, the DØ detector is now beginning to become reality. A revised design report was prepared in November 1984 [2].

THE DØ DETECTOR

At the new energies and luminosities available at the Fermilab collider it will become feasible to study properties of the weak interactions at an unprecedented level of accuracy as well as to uncover possible new phenomena [2]. The experience of the UA1 and UA2 detectors at CERN has clearly shown the importance of very good hadronic and electromagnetic energy resolution, with 4π coverage and fine segmentation.

At $\sqrt{s}$ = 2 TeV "particles" to be detected are: electrons, photons, jets, neutrinos (photinos? etc.) and muons. With the exception of muons all of the above are best detected by calorimetry. In the case of neutrinos, as well as other more exotic objects such as photinos etc., calorimetry must be hermetic. Thus insensitive regions between detector elements can severely limit the "detectability" of non interacting particles and, of course coverage down to extremely small angles is essential. The DØ detector has no central magnetic field, allowing for construction of a compact and thicker calorimeter which is of paramount importance in detecting the above "particles".

The importance of complete coverage of the full solid angle is schematically illustrated in figure 1. Figure 1a shows the frequency of measuring a missing transverse momentum p_t^M, in events where none is missing, with an ideal detector for which measurements errors are normal-distributed. If small angles are not covered and the detector has dead regions (cracks) or regions of different response, the rms error on p_t^M might hardly be affected but tails appear in the frequency distribution which might completely obscure signals of interest, as indicated in figure 1b. See also M. Barnet's talk at this Rencontre.

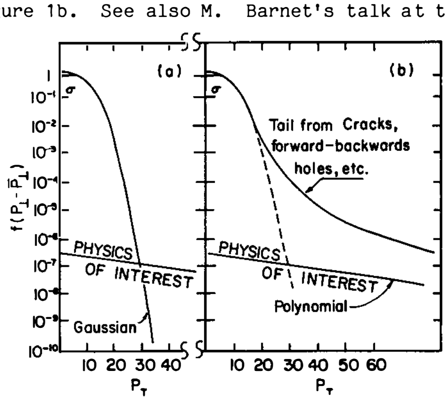

Figure 1. The distribution of the observed missing p_t.

Uranium-Liquid-Argon calorimetry [4] offers at present the best energy resolution and the most reliable calibration. The core of the DØ detector is a uranium-liquid-argon calorimeter surrounding the interaction region to within 1° of the two beams. Since e.m. showers develop more rapidly than hadronic ones and have considerably smaller transverse dimensions the calorimeter is subdived longitudinally into 4 e.m. compartments for a total of ≈20 radiation lengths (X_0) followed by 4 hadronic compartments with total thickness from 7 nuclear absorption lengths (λ_0) at 90° to 9 λ_0 at small angles. The calorimeter is subdivided into ~ 5000 e.m. 'towers' and ~ 1000 hadronic towers pointing to the interaction region, covering constant intervals in rapidity and azimuth. Table I gives some parameters of the DØ and CDF calorimeters in the central region.

TABLE I

Parameter	DØ Detector	CDF Detector
Coverage	$45-135^{\circ}$	$50-135^{\circ}$
Thickness (90°)	7 λ_0	5.6 λ_0
Resolution e.m.	$11\%/\sqrt{E}$ + 0.5%	$14\%/\sqrt{E}$ + 1.5%
Hadr.	$37\%/\sqrt{e}$ + 0.5%	$62\%/\sqrt{E}$ + 5.5%
Segmentation e.m.	3360 twrs, 4 smpls	480 twrs, 1 smpl
Hadr.	576 twrs, 4 smpls	384 twrs, 1 smpl

Tracking around the interaction region is provided by a vertex chamber and a cylindrical shell drift chamber. Small angles are covered by more drift chambers. Figure 2 is a sketch of the DØ detector in the interaction hall.

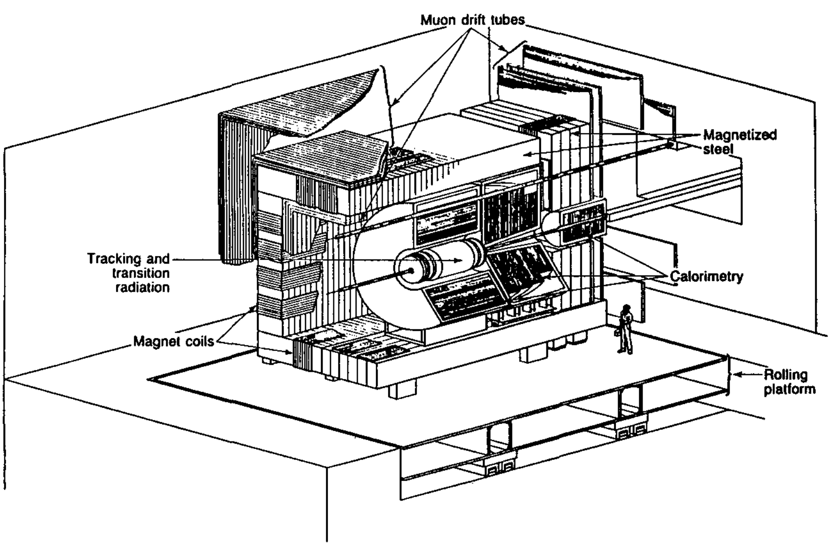

Figure 2. The DØ Detector.

The chambers provide good track pairs resolution and specific ionization measurements for rejection of electron pairs from converted photons. Stacks of transition radiation detectors (TRD) in the central region and at small angles provide electron identification. The four sampling of the e.m. shower, together with the TRD's, give superior electron-hadron separation. For isolated electrons the information from the depth segmented e.m. calorimeter and the TRD detectors results in a pion/electron confusion of less than 4×10^{-5} and, for electrons close to a jet, of less than 10^{-2}. In addition the e.m. calorimeter can distinguish γ from π^0 and other neutral particles decaying into two or more photons, both by shower shape and conversion depth, thus allowing measurements of direct photon production.

Muons are identified as particles which cross without interaction the entire calorimeter and additional magnetized iron which allows momentum analysis with an accuracy of 17% up to transverse momenta of 300 GeV. The total thickness of material that a muon must cross varies from 13 λ_0 at 90^0 to $18\lambda_0$ at 10^0. The incident energy of a single pion, which results in average in one leakage particle is 600 GeV at 90^0 and 6000 GeV at 10^0. Muons can therefore be identified with negligible background, even in the core of a shower over the whole energy range. The muon detector system covers 99% of 4π.

PERFORMANCE OF THE DØ DETECTOR.

Figure 3 shows the expected performance of the DØ detector in terms of its ability to correctly measure transverse missing momentum in $p\bar{p}$ collisions at 2 TeV. The calculation has been performed using events generated with the Isajet Monte Carlo program of F. Paige. [5]. The effect of the 1^0 hole is shown alone and combined with the resolution of the detector, determined from energy and angular resolutions. Both curves correspond to events in which heavy quarks decay non leptonically and there is no W or Z production. Semileptonic decays of quarks give an additional signal, as shown by the dashed line. This contribution can overwhelm other signals, as from the production of gluinos, followed by decay into a photino, which escapes the detector. Events with neutrinos from quark decays can however be removed if

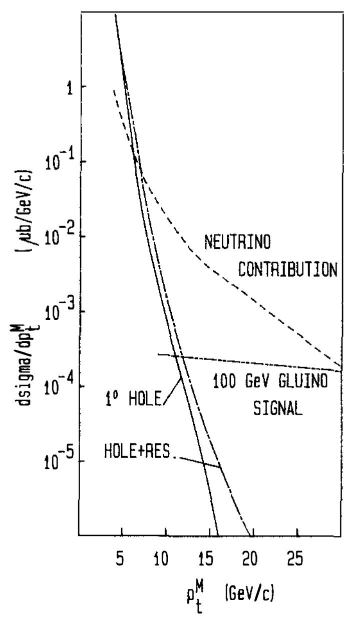

Figure 3. The DØ p_t^M response.

the associated lepton can be recognized with high efficiency. Calculations show that the contribution to the p_t^M spectrum from quark decays can be reduced by at least a factor ten, thus allowing observation of a possible signal due to production of 100 GeV gluinos [6] as indicated in figure 3. The "gluino signal" in figure 3 should be understood as just an example of how a new class of phenomena might be detected in the future. The point we want to stress is the importance of lepton identification over the full solid angle, with high efficiency, in conjunction with superior calorimetry.

PHYSICS WITH THE DØ DETECTOR

The following is a list of some of the Physics for which the DØ detector is best suited.

1. The accurate simultaneous measurement of the $W^{\pm}$ and Z^{o} masses.
2. Measurement of W and Z width to 200 MeV accuracy.
3. Measurement of $p\bar{p} \rightarrow W\gamma X$, to directly observe the electroweak gauge coupling.
4. Measurements of γ/π^{o}, γ+2jets vs. 3 jets to measure the strong coupling constant α_s.
5. Observe $W \rightarrow q\bar{q}$ from dijet invariant mass.
6. Searches for exotic new objects, resulting in leptons, jets or missing p_T, such as : heavy leptons, SUSY particles, heavy quarks, leptoquarks etc.

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REFERENCES

†For the DØ Collaboration.

1. The DØ collaboration consists of physicists from Brookhaven National Laboratory, Brown University, Columbia University, Fermilab, Florida State University, Berkeley Lawrence Laboratory, University of Maryland, Michigan State University, Northwestern University, University of Pennsylvania, University of Rochester, CEN Saclay, State University of New York at Stony Brook and Virginia Polytechnic Institute.
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