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The DØ Monte Carlo

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THE DØ MONTE CARLO

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Abstract

The DØ detector at the Fermilab Tevatron began its first data taking run in May 1992. For analysis of the expected 25 pb^{-1} data sample, roughly half a million simulated events will be needed. The GEANT-based Monte Carlo program used to generate these events is described, together with comparisons to test beam data. Some novel techniques used to speed up execution and simplify geometrical input are described.

THE DØ DETECTOR

DØ is a large, hermetic detector designed for the accurate reconstruction of leptons, photons and jets. It has recently been completed by an international collaboration of 36 institutions and began data taking with 1.8 TeV proton-antiproton collisions at the Fermilab Tevatron collider in May 1992.

The detector[2] consists of a central tracking volume (including a transition radiation detector) surrounded by a hermetic, compensating, uranium - liquid argon calorimeter. The calorimeter enables electrons, photons and jets to be identified. This in turn is enclosed in a full acceptance magnetized iron toroid system for the measurement of muon momenta.

As is typical of such large and complex detectors, a full simulation of the detector response to physics and background processes is needed to understand systematic effects. The simulation has also played a large part in the design of the detector[3]. Events are generated using a variety of event generator programs (ISAJET, HERWIG, PYTHIA, etc.). These will not be discussed further here as DØ is not yet in a position to choose between them on the grounds of their fidelity to data. The generated particles are then tracked through a detector model in the framework of the CERN program GEANT (version 3.14)[4].

DATA DRIVEN GEOMETRY

As most users of GEANT are probably aware, one of the most error-prone and tedious tasks involved in the creation of a detector simulation is to code the geometrical model through which GEANT tracks the particles. In DØ we have attempted to remove all the complex details of this geometrical model from the Fortran code and instead use a number of ASCII datafiles which are read by the program and contain all the arguments to the GEANT geometry calls. This avoids having any hard-coded constants and permits easier editing and alteration of the geometry. The package makes use of the RCP framework[5] which permits flexible input syntax and machine independence.

The creation of the GEANT geometry is then reduced to a simple loop over four routines: MIXTURES, which defines the GEANT mixtures; SETROT, which sets up the rotation matrices; VOLPOS, which positions volumes, and VOLORD, which orders the volumes. Each is controlled by a set of ASCII data files containing all the actual parameters used.

Ideally one might imagine that this geometrical information could be obtained from some engineering database or CAD/CAE system. Though this is not possible presently, this data-driven system could relatively easily be enhanced in that direction.

GEOMETRICAL MODELS

The complete DØ detector has been modelled in GEANT. If one naively creates a model with complete details such as uranium plates and argon gaps, GEANT will spend an inordinate amount of time in the calorimeter part of the detector, generating and tracking hundreds of secondaries through the calorimeter volumes. It is therefore normally necessary to take some steps to speed up the way in which the calorimeter is handled, as will be described later. For comparison with test beam data, however, it is reasonable to simulate the calorimeter structure in detail because only one incident particle is involved and the detector elements are reduced in number.

Full Simulation

In this case we have attempted to model the calorimeter in complete detail, including uranium absorber plates, G10 signal boards, spacers, steel supports and so forth. We have not found it necessary to model the electric field or saturation of ionization (Birk's constant) in the liquid argon, though this could be added.

Models have been made for the calorimeter test beam setups exposed to beam at Fermilab in 1990[6,7] (End Calorimeter modules) and 1991 (Central and End Calorimeters). GEANT version 3.14 was used with low (10 keV EM, 100 keV hadronic) cutoffs. In all cases the GHEISHA shower generator was used. Typical processing times were of the order of 30 minutes per 50 GeV/c incident particle on a VAXstation 3100 M76.

Excellent agreement with the data was obtained without the need for any explicit tuning. As examples, Fig. 1 shows the transverse electromagnetic shower shape; Fig. 2 the response in the vicinity of gaps between sections of uranium absorber plate, and Fig. 3 the modeling of tie-rods passing through the EM calorimeter. Agreement is also good for hadronic showers: Fig. 4 shows the transverse hadronic shower shape and Fig. 5 the energy spectra in two calorimeter layers for incident hadrons. Finally, Fig. 6 shows the response to muons. All are well modelled.

A full detector simulation modelled in this detail is in preparation, though it will obviously be slow to run.

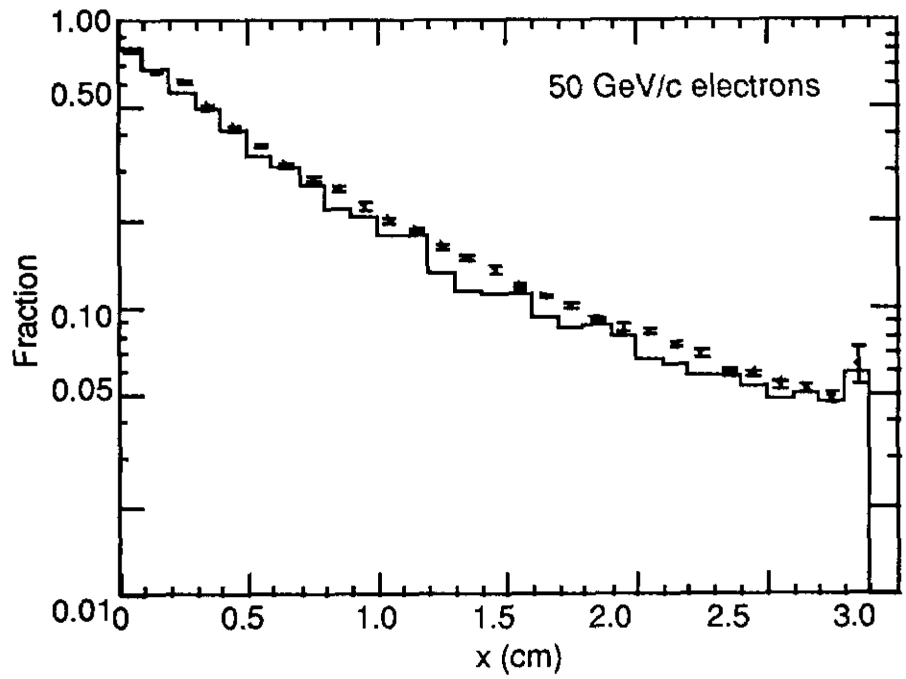

Figure 1. Transverse profile for 50 GeV electron showers in the EM calorimeter. The fraction of energy deposited for all cells a distance > x from the shower impact position is plotted as a function of x, for data (points) and Monte Carlo (histogram).

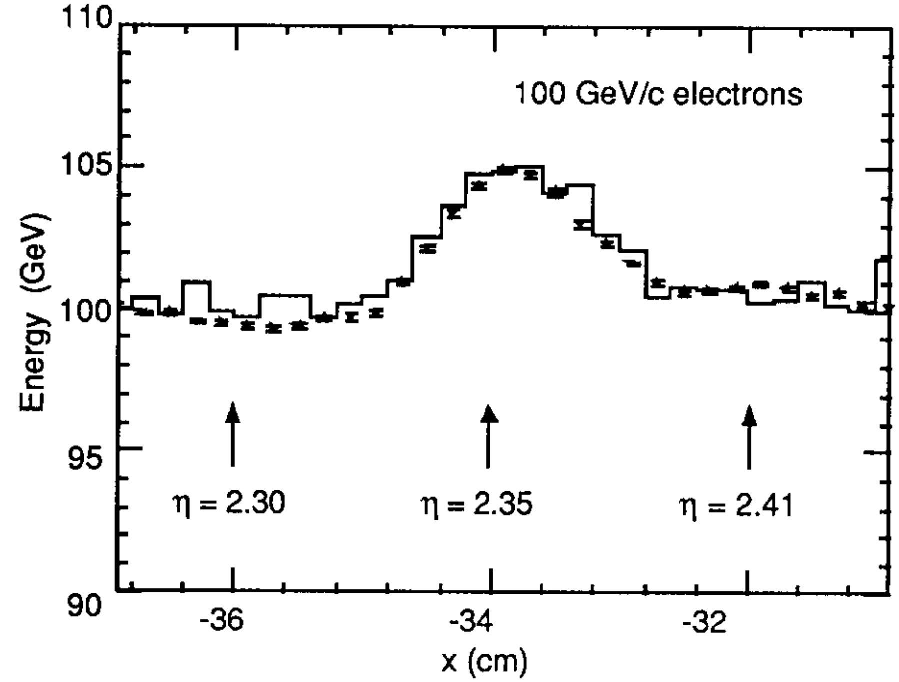

Figure 2. Mean shower energy as a function of position, in the vicinity of the 1 mm gap between uranium absorber plates, for data (points) and Monte Carlo (histogram).

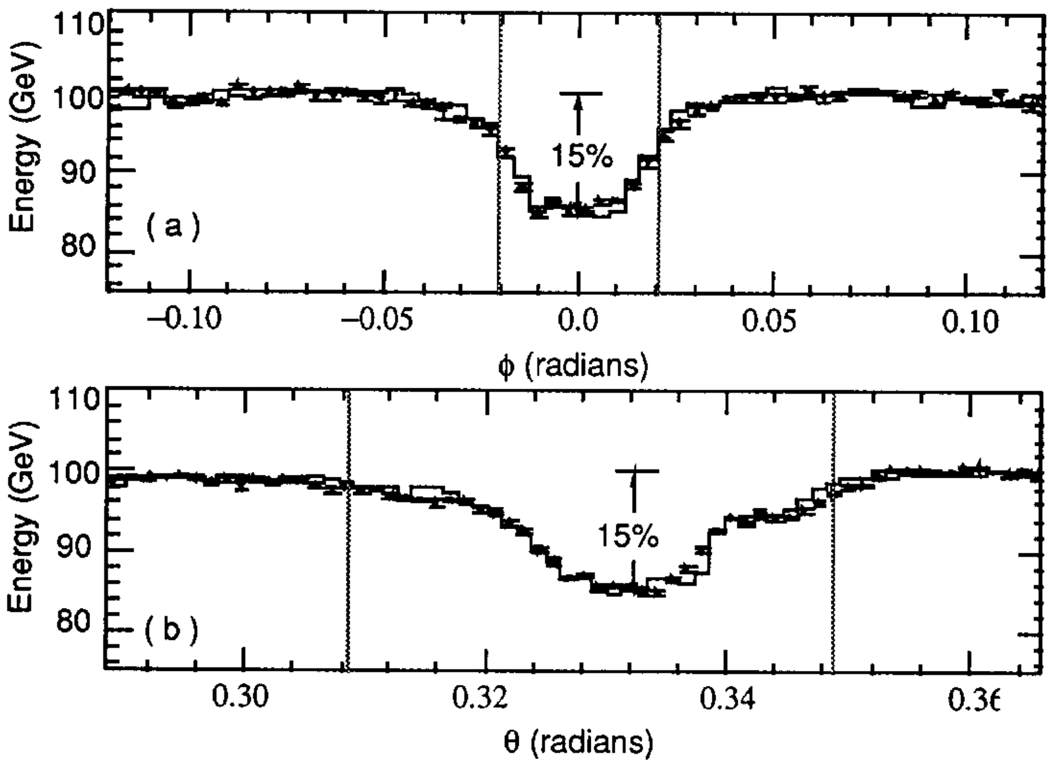

Figure 3 . Mean pulse height as a function of azimuth (a) and polar angle (b), for 100 GeV/c electrons in the vicinity of a tie-rod through the EM calorimeter absorber plates. The dotted lines indicate the region where the HV electrode is cut away. Points are data and the histogram is Monte Carlo.

Mixture Monte Carlo

In this case, extra speed is obtained by modelling the calorimeter as homogeneous blocks of a uranium-G10-argon mixture. This greatly reduces the number of volumes and hence speeds up tracking. However, one needs to put in, "by hand," the sampling fluctuations and attenuation of electromagnetic energy to obtain the correct resolution and e/π response ratio. Figure 7 shows how a single, energy-independent parameter suppressing the EM response is able to model the observed e/π rather well. The full simulation is also shown for comparison.

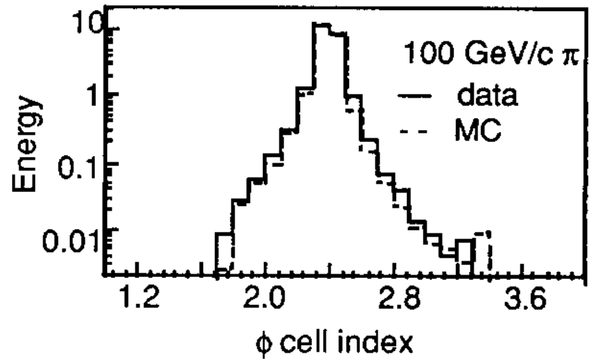

Figure 4. Transverse hadronic shower shape as measured in end-cap IH calorimeter module, for data and detailed GEANT simulation.

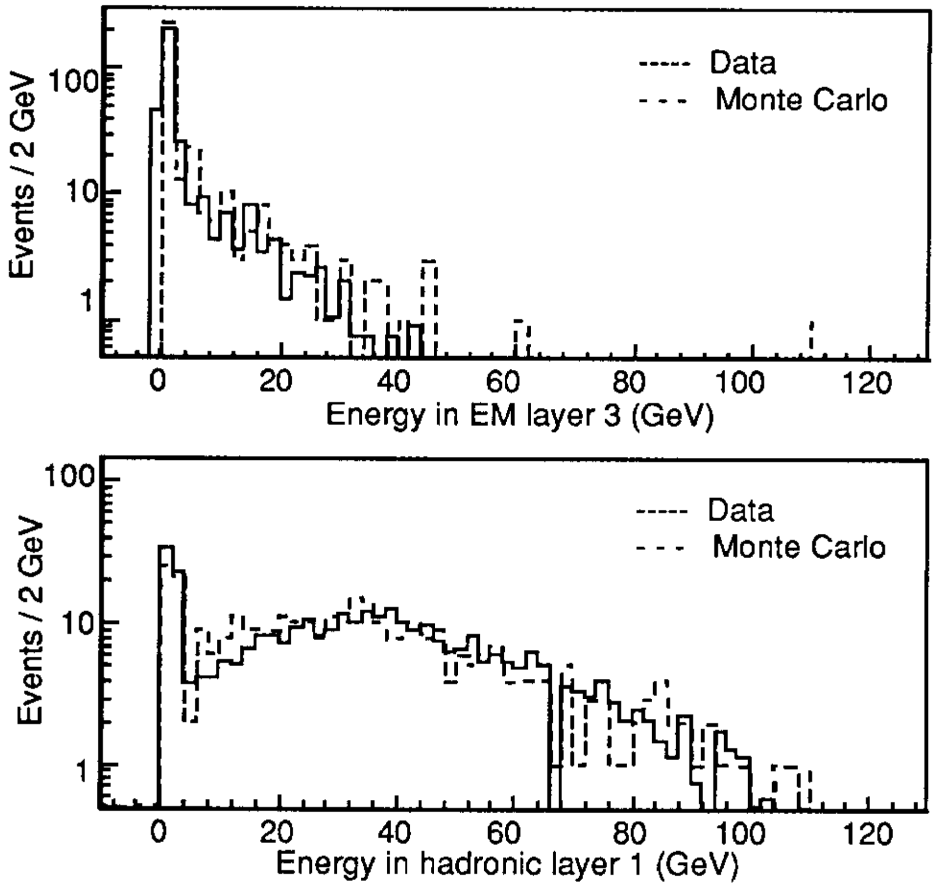

Figure 5. Distributions of energy in two calorimeter layers, for 100 GeV/c incident hadrons; data and GEANT/GHEISHA Monte Carlo.

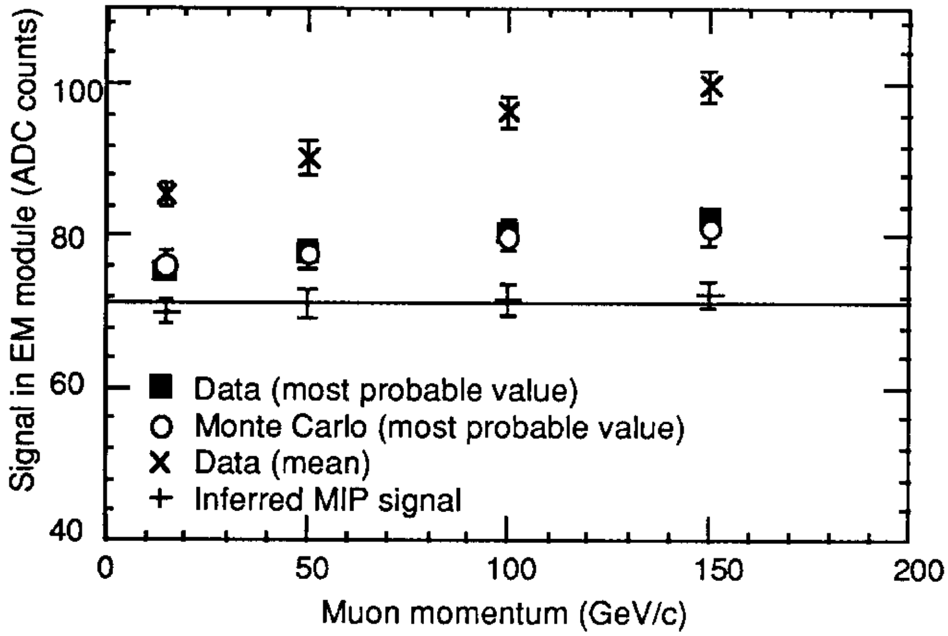

Figure 6. Energy deposited by muons in the EM calorimeter as a function of momentum. Data and GEANT/GHEISHA Monte Carlo are shown together with the calculated energy deposit of a minimum ionizing particle.

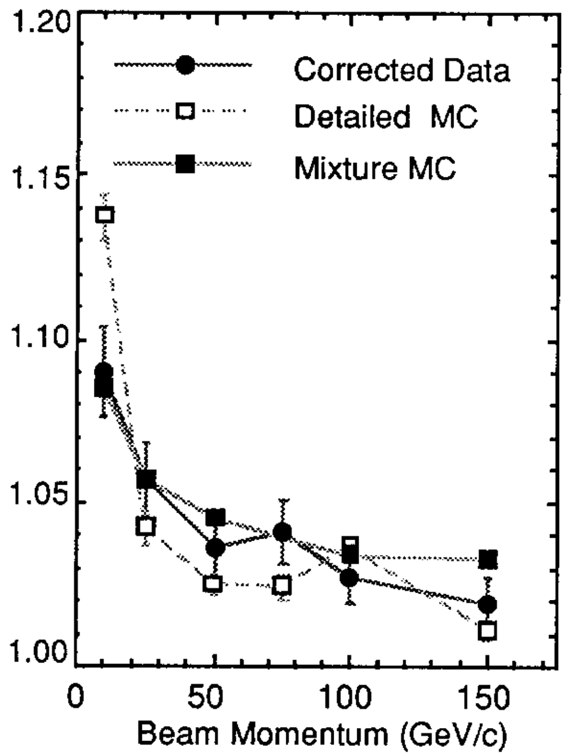

Figure 7. The e/π response ratio, plotted as a function of beam momentum, for data, fully detailed Monte Carlo simulation, and mixture Monte Carlo simulation.

This mixture geometry is the DØ standard for full detector simulations. GEANT version 3.14 is used with default cutoffs and the GHEISHA generator. Over 100,000 events have been generated so far.

In addition we have implemented the option of parametrizing the tails of EM showers (below a cutoff, usually a few hundred MeV). This gains a factor 2—5 in speed of execution, with the loss of some detail in the tails of the showers.

Shower Library

The fastest option available is to perform no tracking at all in the calorimeter (except for muons). Hadronic particles, and low-energy electrons and photons are stopped on entry, and a matching shower is obtained from a library on a direct-access file. The shower is scaled in energy, rotated to match the incoming track, and the hits are copied into the readout cells[8]. This results in a speed increase of about 400 for the calorimeter part of the simulation. High energy (above a few GeV) electrons and photons are simulated normally. This gives a more faithful representation of the electron and photon shower shape.

The shower library technique has not been extensively used so far, largely because faster cpu's have become available in the time since it was conceived thus reducing the need. However, with very large MC event samples needed for analysis, it is planned to use the shower library and we are in process of generating events to populate the library. We are also investigating the creation of a library based on showers taken from real data (test beam and collider).

MONTE CARLO GENERATION

The 1992-93 collider run is planned to accumulate 25 pb^{-1} of data. For the analysis of this sample, DØ will need approximately 500,000 simulated events covering trigger simulations, top quark production, W and Z physics, supersymmetry, QCD, direct photons and b physics. Extensive simulations are also needed for the upgrades of the DØ detector planned for the later 1990's.

Generation of this sample is currently underway, using Silicon Graphics and IBM RS-6000 farms at Fermilab. Together these provide approximately 750 MVUPs of processing power and can produce about 1000 events per day. Generation is also being pursued at a number of DØ collaborating institutions which have significant resources, including LBL, Stony Brook (SUNY) and Florida State. Our newest collaboration members, from the SSC Laboratory, also aim to generate events on the PDSF facility at the SSC.

Events are then run through the standard reconstruction programs and made available to users through the FATMEN tape management system on the DØ file server node at Fermilab.

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REFERENCES

[1]Universidad de los Andes (Colombia), University of Arizona, Brookhaven National Laboratory, Brown University, University of California at Riverside, CBPF (Brazil), CINVESTAV (Mexico), Columbia University, Delhi University (India), Fermilab, Florida State University, University of Hawaii, University of Illinois at Chicago, Indiana University, Iowa State University, Lawrence Berkeley Laboratory, University of Maryland, University of Michigan, Michigan State University, Moscow State University (Russia), New York University, Northeastern University, Northern Illinois University, Northwestern University, University of Notre Dame, Panjab University (India), IHEP-Protvino (Russia), Purdue University, Rice University, University of Rochester, CEN-Saclay (France), SUNY at Stony Brook, Superconducting Supercollider Laboratory, Tata Institute of Fundamental Research (India), University of Texas at Arlington, Texas A & M University.

[2] The construction and operation of the detector is described in more detail elsewhere in these proceedings. See the contributions of K. De, B. Gibbard, B. Gobbi, D. Hedin, H. Prosper and H. Weerts.

[3] A.M. Jonckheere, in Proc. of Workshop on Detector and Event Simulation for the SSC, Argonne Nat. Lab., 1987

[4] R. Brun et al., GEANT program manual, CERN.

[5] H. Prosper, in Proc. of Int. Conf. on Calorimetry in HEP, Fermilab, 1990;
H. Prosper and R. Raja, D0 note 793 (unpublished).

[6] S. Abachi et al.,Fermilab-PUB-92/162, to be published in Nuc. Inst. & Meth A.

[7] H. Aihara et al., LBL-31378, to be published in Nuc. Inst. & Meth. A.

[8] N. A. Graf, in Proc. of Int. Conf. on Calorimetry in HEP, Fermilab, 1990.