TESTS OF THE DØ CALORIMETER RESPONSE IN 2-150 GEV BEAMS*

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Abstract

At the heart of the DØ detector, which recently started its maiden data run at the Fermilab Tevatron p$\bar{\text{p}}$ collider, is a finely segmented hermetic large angle liquid argon calorimeter. We present here results from the latest test beam studies of the calorimeter in 1991. Modules from the central calorimeter, end calorimeter and the inter-cryostat detector were included in this run. New results on resolution, uniformity and linearity will be presented with electron and pion beams of various energies. Special emphasis will be placed on first results from the innovative technique of using scintillator sampling in the intermediate rapidity region to improve uniformity and hermeticity.

INTRODUCTION

The DØ experiment at the Fermilab Tevatron uses a large angle hermetic detector to study p$\bar{\text{p}}$ collisions at 1.8 TeV. The three major components of the detector include a central tracking detector surrounded by a liquid argon calorimeter, which in turn is enclosed in a magnetic tracking muon detector. A cut-out view of the calorimeter and central detector is shown in Figure 1.

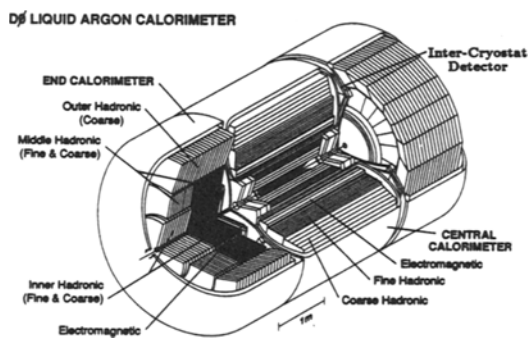

Figure 1. Cut-out view of the DØ calorimeter.

The DØ calorimeter system is designed for high resolution electromagnetic energy mea-

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surement, good resolution jet energy measurement, large angular coverage with fine segmentation, and uniformity of response with very few cracks. The liquid argon calorimeter modules are contained in three separate cryostats. The central calorimeter covers the pseudo-rapidity ($\eta \equiv -\ln\tan(\theta/2)$) range of $-1.2 < \eta < 1.2$. The end calorimeters provide coverage between $0.7 < |\eta| < 4.5$. Previous test beam studies[1-4] of calorimeter modules have demonstrated the excellent resolution and uniformity in the forward region. In this paper we will present results from the 1991 'Load II' test beam run, where modules from the central calorimeter and intermediate η region were studied.

An interesting innovation to preserve hermetic and uniform calorimeter coverage in the region where the central and end calorimeters meet was tested during the Load II run. By adding additional sampling using liquid argon readout gaps and scintillator tiles, the calorimeter energy resolution was significantly enhanced in this difficult intermediate region. Other innovations during the Load II run include the successful use of low energy beams to study calorimeter response, and the use of beams of neutral pions and photons.

DESCRIPTION OF THE DØ CALORIMETER

The DØ calorimeter is built with a psuedo-projective tower geometry pointing to the nominal $p\bar{p}$ collision point. Each cell in the calorimeter has transverse dimensions of 0.1 in η and 0.1 radians in ϕ. Enhanced electron position resolution is achieved through 0.05×0.05 transverse segmentation in the third depth layer at electromagnetic shower maximum. Alternating layers of absorbers and readout gaps sample particle showers as they traverse the projective towers in the calorimeter. The total interaction length ranges between 8-10. The primary absorber material are 3-6 mm uranium plates with some steel and copper absorbers in the outer hadronic sections. Ionization from showering particles is collected in the liquid argon gaps. A single layer of scintillator sampling is also used between the cryostats to augment uniformity of response.

Longitudinally, the calorimeter is divided into electromagnetic, fine hadronic and coarse hadronic sampling sections. The electromagnetic layers provide 21 radiation lengths of finely segmented sampling, with successive readouts of 2,2,7 and 10 radiation lengths in depth. The hadronic layers provide 7-8 interactions lengths of material in 4-6 readout segments.

A slice of the DØ calorimeter extending 0.8 radians in ϕ with modules from the central and end calorimeters was assembled inside the Load II cryostat. Data were collected for secondary and tertiary beams of π, e and μ particles at various energies between 2-150 GeV. Additional detectors were used to provide measurement and identification of the beam particles entering the cryostat. Analysis of the data from the Load II run are underway. We present preliminary results here on calorimeter response and outline the scope of future analysis.

CENTRAL CALORIMETER RESPONSE

We parametrize the energy response of the calorimeter as:

$$\left(\frac{\sigma}{\mathrm{E}}\right)^2 = \mathrm{C}^2 + \frac{\mathrm{S}^2}{p} + \frac{\mathrm{N}^2}{p^2}$$

where E and σ are the mean and sigma from a gaussian fit to the measured calorimeter energy distribution in GeV at a beam momentum of p GeV. The parameters C and S are fitted[5] over a range of particle energies as shown in Figure 2. The noise term N is determined from the width of the pedestal distributions for the same cells used in measuring

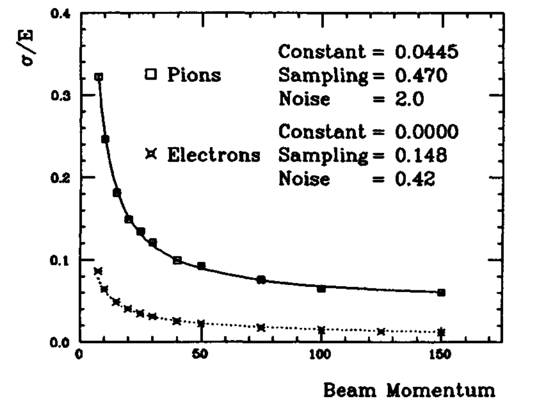

Figure 2. Calorimeter response for electrons and pions.

the calorimeter energy. From the fit, we find that the constant term for electrons is negligible, while for pions it is very small, $C = 0.045$ GeV. The sampling term, S, which represents the intrinsic resolution of the DØ calorimeter, is 14.8% for electrons and 47.0% for pions. All measurements were made in the central calorimeter at $\eta = 0.05$. Cuts using information from detectors outside the calorimeter were applied to clean up the sample of beam particles.

The DØ calorimeter system has an excellent dynamic range with very little noise. In

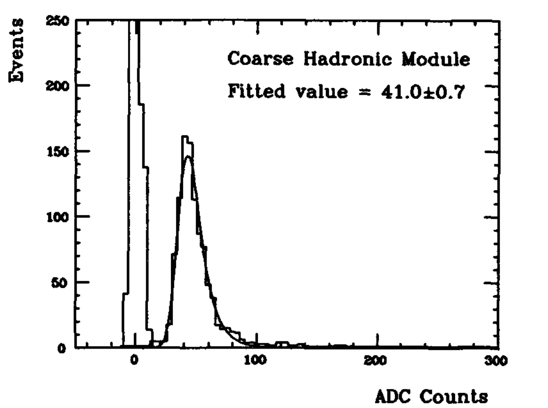

Figure 3. Calorimeter response to 15.9 GeV muons compared to pedestal distribution.

Figure 3 we show the response[6] from 15.9 GeV muons in one layer of the coarse hadronic modules along with the response to random pedestal events. The minimum ionizing muon peak is clearly separated from the random noise, with a most probable value of 41.0 ± 0.7 ADC counts from a Landau fit. The full range of the digitizing system is greater than 32,000 ADC counts.

LOW ENERGY BEAMS

It is important to study the calorimeter response to low energy particles since a large fraction of the energy of jets created at the collider come from low energy particles. For the Load II run, a special tertiary low energy beam was created. Preliminary results[7] from the study of the calorimeter response in low energy electron and pion beams show excellent linearity and resolution with particle energies down to 2 GeV. The low energy response as a function of energy is shown in Figure 4. The

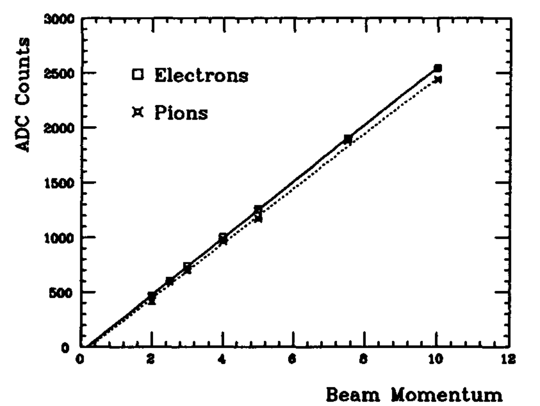

Figure 4. Linearity of calorimeter response with low energy beam.

deviation of the measured energy from a linear fit is less than 2% and is shown in Figure 5.

THE INTER-CRYOSTAT REGION

At intermediate angles, $0.8 <\mid \eta \mid< 1.4$, showers propagate through both the central

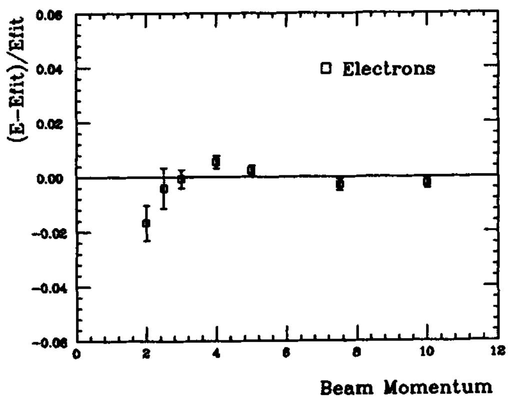

Figure 5. Deviation from linearity.

and end calorimeters. Energy resolution in this region is degraded by the presence of support walls, end plates of calorimeter modules and cryostat walls, comprising 1-3 interaction lengths. In order to improve energy measurement, three additional layers of sampling are interspersed among the 'dead' material to sample shower development. Two of the sampling layers are inside the cryostats and are called 'massless gaps.' The third layer, attached to the wall of the end calorimeters, use scintillator modules, and is known as the inter-cryostat detector[8] (ICD). These additional layers are treated as standard sampling layers in DØ with the support plates and cryostat walls acting as absorber plates.

The improvement in energy measurement and resolution vary as a function of η in the inter-cryostat region due to the changing profile of absorber material. Significant improvements are observed around $\eta = 1.2$ as one approaches the edge of the central electromagnetic modules. In Figure 6, we show the improvement in the energy measured in the calorimeter modules with the addition of the massless gaps and the ICD at $\eta = 1.15$ for a 100 GeV π beam. Without the additional sampling, almost 50% of the pion energy is not measured for a majority of the events. The

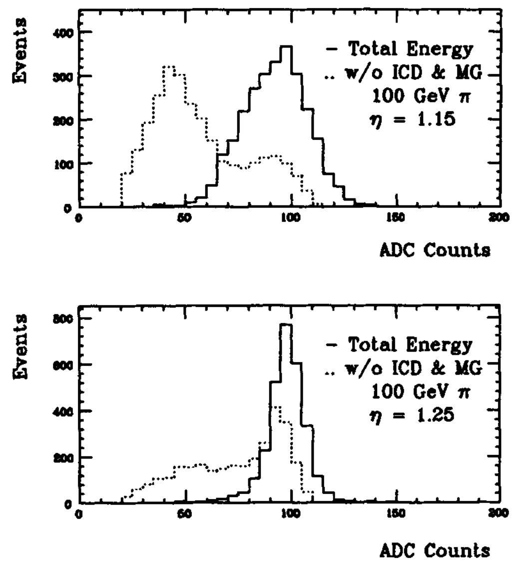

Figure 6. Improvement in measured calorimeter energy with the addition of the ICD and massless gaps.

resulting energy distribution is not gaussian and can result in non-uniform calorimeter response. With the energy from the ICD and the massless gaps added in, the average measured energy is Gaussian and the energy resolution is dramatically improved. Improvement in energy resolution at $\eta = 1.25$ is also shown in Figure 6. We show in Figure 7 the overall im-

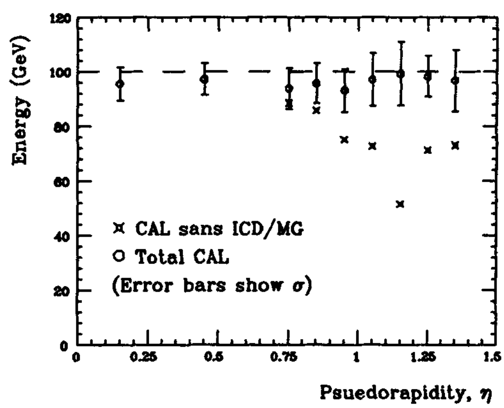

Figure 7. Calorimeter energy measurement versus the pseudo-rapidity of the incident pion.

provement in pion energy measurement across a wide range of η's. As seen from these figures, the use of the ICD and the massless gaps represent a significant innovation in uniform and hermetic liquid argon calorimetry.

NEUTRAL BEAMS

Tertiary beams of photons and neutral pions were created during the Load II run using thin layers of converters. In Figure 8, we show the energy distribution of tertiary photon beams compared to secondary electrons. The beam profiles are fairly well matched. Detailed analysis of the neutral beam data is underway.[9]

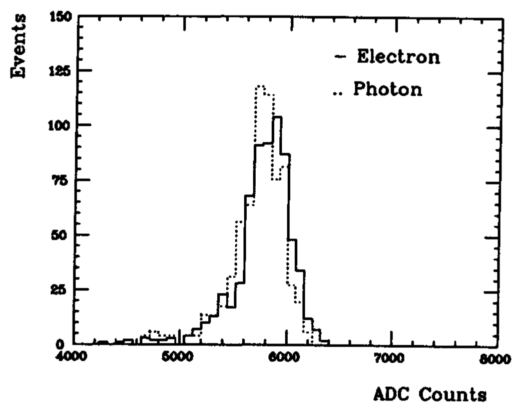

Figure 8. Comparison of photon and electron beams at 25 GeV.

CONCLUSION

The DØ calorimeter shows excellent resolution and uniformity from test beam studies performed over a wide range of energies for a variety of particles. Good linearity was observed extending to low energy beams. The innovative implementation of the ICD and the massless gaps was shown to preserve hermetic and uniform coverage in the intermediate region between the cryostats which contain the liquid argon calorimeter modules. Further studies are in progress, including the energy response to neutral beams.

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