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Operation of the DØ Uranium Liquid-Argon Calorimeter System

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THE DØ COLLABORATION

ABSTRACT

The DØ calorimeter consists of three separate cryostats containing uranium modules in liquid argon. This calorimeter has transverse segmentation of 0.1 x 0.1 in η x ϕ and consists of eight or nine longitudinal readout segments. The coverage in η extends to 4. As a result of the large coverage and fine segmentation there are 50,000 channels of electronics. After a brief description of the electronics, stability and noise aspects will be investigated. Results of the liquid-argon purity studies will be discussed. The backgrounds in the calorimeter due to the Fermilab main ring will also be examined.

The DØ calorimeter is a major part of the DØ detector located at the $p\bar{p}$ Tevatron collider at FNAL. The DØ detector is a 4π, hermetic, general purpose detector with no central magnetic field. The design was optimised for good electron and muon identification and measurement. The calorimeter is an important element in the electron identification. The DØ calorimeter has been described in detail elsewhere.[1]

1. The Calorimeter

The DØ calorimeter is a sampling calorimeter using uranium as the absorbing material and liquid argon as the sampling medium. The calorimeter is composed of three separate cryostats. Longitudinally the calorimeter consists of three sections: an electromagnetic section and two hadronic sections, one fine and one coarse. The absorber for the electromagnetic section is 3.0mm or 4.0mm depleted uranium plates for the central or end regions, respectively. The fine hadronic sections are made of 6.0mm depleted uranium plates doped with 1.7% niobium. The coarse sections have 46.5mm copper or stainless steel plates in the central region or the end regions. The cell structure consists of a 2.3mm gap on both sides of a 1mm charge collection board sandwiched between two absorber plates, which act as ground planes.

Since the DØ calorimeter is composed of three cryostats, there are cracks between the cryostats. To improve the energy response in this region, there are massless gaps inside each cryostat and scintillators between the cryostats. The massless gaps

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*Presented at The Third International Conference on Calorimetry in High Energy Physics, Sept 29 - Oct 2, 1992 at Corpus Christi, TX are the same structure as the other calorimeter modules with no absorber material. Details of this section of the calorimeter are discussed elsewhere in these preceedings.[2]

The calorimeter is highly segmented for good resolution. The longitudinal segmentation is 8 or 9 depths. The electromagnetic section is divided into 4 depth segments of 2, 2, 7, and 10 radiation lengths, respectively. The fine hadronic section has 3 or 4 depth segments of 1 interaction length each; whereas, the coarse hadronic or leakage section has 1 depth segment of 2–3 interaction lengths except in the area between cryostats where there are 3 segments. The transverse segmentation is generally 0.1 x 0.1 in η x ϕ. In the third electromagnetic depth segment, where shower maximum occurs, the segmentation is increased to 0.05 x 0.05 for better position resolution. Because of the small pad size close to the beam pipe, the segmentation is reduced for $\eta > 3.2$. This fine segmentation and large coverage, down to η of 4, leads to 47,808 readout cells. These cells are arranged in semi-projective towers.

2. Electronics

The readout electronics for the DØ calorimeter has been described in detail elsewhere.[3] There are three basic sections to the readout electronics: the preamps, the BLS's and the ADC's. The preamplifiers are located just outside the cryostat and inside the muon iron. They were designed for low noise and are charge sensitive devices. Two types of preamps are used. The difference is just the feedback capacitor, which is either 5pF or 10pF. The 10pF preamps are used in the electromagnetic section at shower maximum.

The BLS's or base-line subtractors are located under the detector, and this is where the signal shaping is done. The bunch crossing time at the Fermilab Tevatron is 3.5μs. The preamp signal is sampled just before beam crossing and again 2.2μs after beam crossing. The first sample measures the baseline and the second sample measures the peak of the signal. The difference signal is then multiplexed to the ADC's. The BLS contains an analog buffer to hold an extra event, which helps to reduce deadtime in a high luminosity environment.

The ADC is a 12-bit analog-to-digital, successive approximation converter. The 12 bit range is expanded to a 15 bit dynamic range by amplifying the small analog signals by a factor of 8 at the BLS or multiplying the large digital signals by 8 at the ADC. One ADC crate contains 4608 channels. These channels are digitized in approximately 25μs and readout in approximately 1.1ms. This readout time was measured with no zero suppression. The speed can be increased by a factor of 10 with a 2σ zero suppression cut. This is a symmetric cut around the mean of the pedestal, where a channel with a value less than 2σ from the mean is suppressed. The pedestals and sigmas are determined in a separate run from the data collection. In the normal mode of operation, the ADC's perform pedestal subtraction and zero

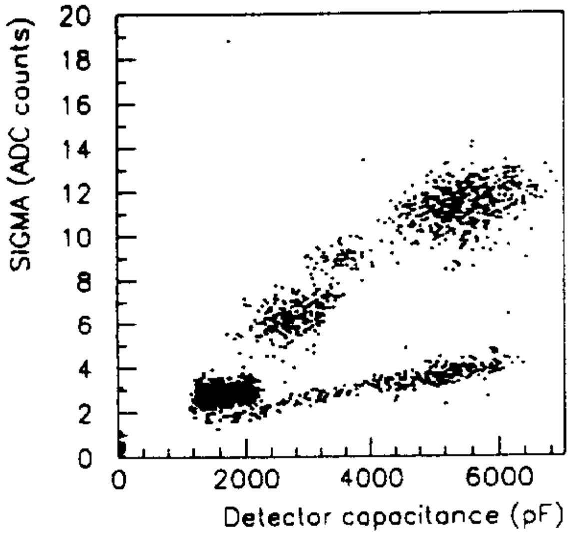

Figure 1: Pedestal sigmas vs detector capacitance for approximately 5000 channels of the detector. This shows the dominance of uranium noise.

suppression before being read out.

3. Electronics Performance

A major factor in the performance of the calorimeter system is noise. The largest source of random noise in this uranium liquid-argon calorimeter is due to the natural radioactive decay of the uranium. Because of the AC coupling of the preamps and the base-line subtraction, the uranium noise only widens the pedestal but does not impact the central value. This can be seen in Figure 1, which shows how the pedestal sigmas are dependent upon the detector capacitance. The upper set of points shows the effect of uranium noise, and the lower set shows the non-uranium channels. This figure demonstrates how the uranium noise dominates the electronics noise for the uranium channels and that there is very little noise due to sources other than uranium.

Another type of noise which affects large calorimeter systems is coherent noise. This becomes important when adding up hundreds of channels as for a jet or for determining missing transverse energy. One quantity which characterizes the amount of coherent noise is the number of channels in whose sum coherent noise equals the random noise.[4] This number is approximately 10,000. Note that for a typical event, approximately 5000 channels are read out for the entire calorimeter when a 2σ zero suppression cut is applied. This shows that the effect of coherent noise is negligible.

Important to the performance of the electronics is its stability. As Figure 2a

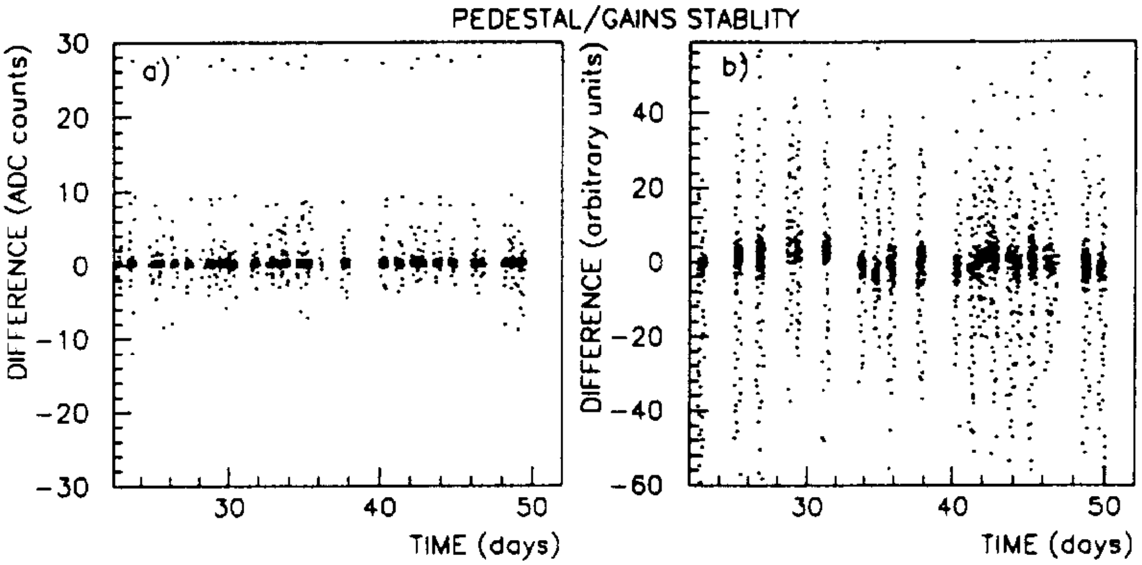

Figure 2: Stability of the electronics vs time is shown for a) pedestals and b) gains.

shows, the pedestals for most of the 50,000 channels are stable to within 1/2 ADC count, where 1 ADC count is equivalent to 5–6 MeV for most regions of the calorimeter depending upon sampling fraction. This figure shows the time variation of each of the 50,000 channels from its mean over a one month period. Figure 2b similarly shows that the gains, which are determined from a pulser, are stable to within 1/4%. Full scale in Figure 2b is ±1%. Another interesting quantity, determined from the pulser, is the variation among the electronics channels. Figure 3 shows that after compensating for the various detector capacitances and the different preamp feedback capacitors, the r.m.s. of the channel to channel variations of the gains is approximately 3%. Thus the relative gain correction factors for the electronics are small.

4. Liquid Argon Status

The charge collected by the preamp is dependent upon the purity of the liquid argon. Electro-negative contaminants, i.e. oxygen and nitrogen, present in the argon combine with the electrons traversing the gap thus decreasing the charge collected at the preamp. To measure this effect three test cells were placed into each of the three cryostats.[5] Each test cell contains two radioactive sources, one alpha and one beta. The alpha cell consists of a high voltage plane and a ground plane, containing the alpha source, separated by a 2.3mm gap. The results of the alpha test cells are that the purity measured by the different test cells agree to better than 2% and the response of each cryostat has changed by less than 0.2% over the last six months.

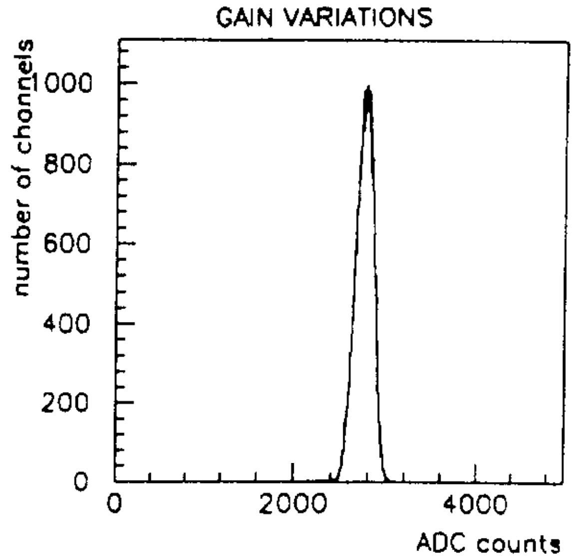

Figure 3: Electronics gain variations between all channels.

The overall oxygen-equivalent contamination level is less than 0.7 ppm.

5. Main-Ring Backgrounds

One major source of concern in the DØ calorimeter is the Fermilab main-ring accelerator, which passes through the coarse hadronic section of the calorimeter. When there are protons in the main ring, there can be extra energy deposited in the calorimeter due to beam-gas and beam-wall interactions. This extra energy is mainly in the coarse hadronic cells which are near the main ring. There can be up to 10 GeV deposited in a single cell. The fine hadronic cells are less susceptible to the main-ring beam; there is less than 1 GeV deposited in a cell, and very few cells are affected. To reduce the effects of the main-ring beam, events are vetoed when the main-ring bunch passes through the detector. This leads to deadtime of 30–35%, and it substantially reduces the backgrounds in the calorimeter. There is very little main-ring energy deposited in the fine hadronic section, no energy deposited in the electromagnetic section, and since the calorimeter trigger is only sensitive to the electromagnetic and fine hadronic sections, there is a very small effect on the trigger due to the main-ring beam.

6. Conclusions

The DØ calorimeter is performing very well. The electronics system is performing reliably; there is a low failure rate with a small number of noisy channels

($\ll$0.1%) and a small number of permanently dead channels ($\sim$0.1%). The electronics is extremely stable with very little noise. The argon is clean and the contamination level is not changing. The backgrounds in the calorimeter due to the main ring are manageable.

Acknowledgements

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References

1. The DØ Collaboration, "DØ Design Report", (1983, revised 1984) unpublished; J. Christenson, These Proceedings.
2. K. Streets, These Proceedings.
3. R.D. Schamberger, *Nuclear Physics B* **23A**, 191 (1991).
4. M. Demarteau, "DØ Calorimeter Electronics Performance", *Proceedings of the First International Conference on Calorimetry*, FNAL, October 29 - November 1, 1990.
5. G. Blazey, "DØ Calorimeter Electronics Performance", *Proceedings of the First International Conference on Calorimetry*, FNAL, October 29 - November 1, 1990.