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Progress Report
for
The Liquid Argon Calorimeter Subsystem

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ABSTRACT

During the past several months, Tennessee, Mississippi, and the Oak Ridge National Laboratory have been coordinating efforts to benchmark the CALOR89 code system against the DO and HELIOS prototype calorimeter data, and to use the CALOR89 system to generate currently needed data for radiation damage studies, signal collection time, and compensation characteristics of various calorimeter designs. This report describes these results and gives our plans and projected budgets for the following year.

I. Introduction

A strong experimental Superconducting Super Collider (SSC) calorimeter development program must involve a substantial calculational analysis of the proposed detector system. The CALOR89¹ code system offers a solid approach for investigating all facets of calorimeter systems. Due to financial constraints, only a few prototypes can be built and tested. The remainder of the studies must be analytical. Once the calculated results have been shown to agree with the test data, a much wider variation of the design can be investigated. This approach is being followed in our subsystem research.

During these several months, Tennessee, Mississippi, and the Oak Ridge National Laboratory have been coordinating efforts to benchmark the CALOR89 code system against the DO² and HELIOS³ prototype calorimeter data, and to use the CALOR89 system to generate currently needed data for radiation damage studies, signal collection time, and compensation characteristics of various calorimeter designs. Even though the total benchmarking of the DO and HELIOS data has not

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been completed, the current caliber of the code is such that preliminary data generated will certainly be adequate for initial design studies. This report describes current progress and gives our plans and projected budgets for the following year.

II. The CALOR89 Code System

A flow diagram of the CALOR89 code system is given in Fig. 1. The transport codes that comprise this system include HETC88⁴, the high energy hadronic transport code, EGS4⁵, the electron, positron, and gamma ray transport code, MORSE⁶, and MICAP⁷, the low energy ($\leq 20\text{MeV}$) neutron transport codes. Source gamma rays and electrons for EGS4 and neutrons for MORSE are obtained from the data generated in HETC88. The remainder of the codes are for analysis (SPECT and ANALYSIS), cross-section generation (PEGS), and signal reduction due to saturation/recombination effects (LIGHT). The major changes in CALOR and the main reasons for the additional benchmarking are an improved high energy collision model following the methods used in FLUKA87⁴ and a new low energy neutron transport code, MICAP. To prevent too many changes at once, the code will be benchmarked against the new high energy model using the MORSE code and will be followed by additional benchmarking using the MICAP code.

III. DO-Benchmark Calculations

In a recent paper, experimental results were presented on the hadronic and electronic response of a uranium-liquid argon calorimeter module.² The module used was a hadronic section of the DO calorimeter and the quantities measured were the energy resolution, the electromagnetic to hadronic response ratio (e/π) and the longitudinal hadronic shower development. Experimental data was presented for incident particle energies of 25 to 150 GeV. Work is in progress to obtain comparisons between this experimental data and calculated results obtained with the CALOR89 computer code system.

The dimensions of the calorimeter module are given in detail in Ref. 2 and will not be repeated here. The calorimeter module is basically 6mm uranium plates separated by 5.7mm of liquid argon and G10 signal board. At the back of the module, the uranium is replaced by stainless steel. In the calculations, the module was modeled in rather complete detail using the combinatorial geometry routine included in CALOR89.

In Fig. 2, the calculated and measured integrated longitudinal shower containment for 25 GeV incident pions are compared as a function of thickness.² The circles are taken from Ref. 2 and is the prediction of a parameterization of Bock, *et al*.⁸ In the figure, both the calculated and experimental data have been normalized to agree with the parameterization at the largest thickness shown.

In Figs. 3a and 3b, the measured fractional resolution is shown as a function of incident energy for electrons and pions. The solid curves are fits to the experimental data taken from Ref. 2. Calculated values for 25 GeV incident pions and electrons are also shown. The two calculated values for incident pions corresponding to integration times of 50ns and 250ns. The experimental values contain a correction for noise, and this same correction has been added to the calculated values for comparison purposes. The agreement between the calculated and experimental data is quite satisfactory.

Fig. 1. The CALOR89 Code System

Fig. 2 Integrated shower containment for the DO calorimeter

Fig. 3a Electron energy resolution for the DO calorimeter.

Fig. 3b Pion energy resolution for the DO calorimeter.

In Fig. 4, the measured hadronic-to-electromagnetic energy deposition ratio (e/π) is shown as a function of incident particle energy. Also shown are the calculated values for integration times of 50ns and 250ns. There is a noticeable difference between the results for the two integrations times and the longer time gives the better agreement with the experimental data.

Comparison at the higher incident energies are in progress.

IV. HELIOS-Benchmark Calculations

Progress has been made in benchmarking CALOR89 with the HELIOS³ experiment. HELIOS is a Uranium/Liquid Argon calorimeter and was tested with electrons and pions, and protons at energies from 17 GeV to 450 GeV. The geometry for the calorimeter has been generated and the LIGHT program used to generate saturation/recombination curves for liquid argon. The 17 GeV π - and e- cases have been almost completely processed through the CALOR system. Only MORSE output remains to be generated. Five hundred histories 17 GeV π - and 300 for 17 GeV e- are being analyzed. Preliminary analysis of the 45 GeV data has been started.

During the first parts of the benchmarking, HETC crashed consistently due to "out-of-detector" particles. A modification to the JOM9 routine was made which has eliminated the problem while still producing results that are constant with the previous runs.

V. Anticipated Progress for FY91

During FY91, the calculations to aid in the design of the SSC Liquid Argon Calorimeter will be started. Benchmark calculations on DO and HELIOS which were started during FY90 will be completed and the calculated data which can be compared with experimental data will be further analyzed. Differences between experimental and calculated results will be determined and the differences resolved. Additional calculations as needed for the prototype will be started. Improvements in the CALOR system as it relates to liquid argon calorimetry will be continued.

VI. Budgets for FY91 (See overall budget sheet for breakdown)

University of Tennessee	\$30K
University of Mississippi	To be provided by J. J. Reidy
Oak Ridge National Laboratory	\$75K*

*Will be supplemented by Oak Ridge Detector Center funds.

Fig. 4 Compensation characteristics of the DO calorimeter.

VI. References

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