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# A Proposal Dealing With the Simulation Study and Data Acquisition System Development Within the Lone Star (L*) Calorimeter Program

by


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# I. INTRODUCTION

This proposal is not presented as a complete proposal for a major subsystem, but rather is a proposal for support to enable a collaboration of The University of Mississippi, Oak Ridge National Laboratory and the University of Tennessee to play a major role in the design and testing of a protype calorimeter system which is based in a foreign institute.

This proposal is presented as a request for support for international collaboration on a sampling calorimeter development program for the Lone Star (L*) detector system. We propose to perform the simulation studies which will lead to a prototype calorimeter design that is optimum for this detector. In addition, we propose to provide the data acquisition system for this calorimeter which would have the characteristics necessary for use at the SSC.

## I. The Mechanical Design and Construction of this Calorimeter

The major mechanical design and construction of the prototype calorimeter will be done primarily by the Institute for Theoretical and Experimental Physics (ITEP) in Moscow under the direction of Prof. Y. Galaktionov. The ITEP group is presently doing a sampling calorimeter design study including both detector type and mechanical structure. The goal is to choose the detector type, to build a prototype and put it in a test beam. One possible calorimeter structure for L* is presented in Fig. 1. At this time scintillator, TMS and gas based active media calorimeter designs are being investigated. The final design will depend to a great extent in the results of the initial simulation studies. It goes without saying that these studies should begin as soon as possible.

# II. SIMULATION STUDIES

## A. Background

In order to have a strong experimental calorimeter development program, a substantial effort must be involved in calculational analysis of the detector system. This calculational capability must be fundamentally sound and based on previous interchange between theoretical calculations and experimantal test programs. The CALOR89 code system[1] for analyzing calorimeters offers a solid approach for investigating all facets of detector systems and will be used in this work. Due to financial constraints, only a few prototype detectors can be built and tested. However, once the calculated results have been shown to agree with the test program data, a much wider variation of the design can be calculationally investigated. This will be the approach followed so as to maximize effort and minimize cost.

The High Energy Physics group at The University of Mississippi in collaboration with personnel at Oak Ridge National Laboratory is presently working to integrate CALOR89 into the GEANT3 framework. This project is being supported partially through the generic SSC R&D program. Comparisons between CALOR89 and GEANT3 are also being done. See Appendix 1. This project is the initial phrase of a long-term program to develop a major simulation center at The University of Mississippi. Included in this program is a request to the Mississippi legislature for a three year $ 1.8 M appropriation for the establishment of the center.

## B. Design Calculations

It is well known that the SSC presents a severe environment for a calorimeter. Besides the high event rate handling capability the calorimeter must be able to measure the energy of both jets and electrons while allowing a certain level of discrimination between them.

To achieve these characteristics, one needs unit compensation and reasonable energy resoluation as well as a certain level of transverse and longitudinal granularity and hermiticity. To initiate the simulation studies, we shall first address the problem of selecting the most suitable active and passive media. We shall use the integrated CALOR89-GEANT3 code for these studies. Particular interest will be focussed on the compensation and time resolutions of the system. Following this, we shall simulate selected geometric configurations which are suitable in terms of fabrication and mechanical rigidity. These studies will impact the choice of granularity and the level of hermiticity as well as energy resolution. Particular attention will be paid to configurations which will lend themselves to detailed studies in a test beam. Originally the 7 GeV proton beam at ITEP will be used. Later the system will be moved to the CERN test beams. Comparisons between the measured results and predications of the simulation studies will be made. Efforts will be made to understand the source of the discrepancies, if any, and suitable modifications made either in the configurations or the code to correct them.

The goals of the program are:

1. Develop methods for quickly converting the codes to the various detector media and geometry.

2. Study the relative merits of Pb and Uranium calorimetry with active media of TMS, gas, and scintillator. The experience of other groups such as the ZEUS collaboration[2] will be incorporated into this effort.

3. Study compensation characteristics of each style detector.

4. Determine the best particle separation as a function of longitudinal sampling frequency and transverse cell size.

5. Investigate hermiticity based on realistic engineering support structures, and

6. Determine the sources of discrepancies between experimental results and simulation calculations and try to reconcile them.

The program will require at least two years and may extend well into the third year. The first year will involve the determination of the best calorimeter materials and configuration based on our design studies and tests. The second year will concentrate on the hermiticity considerations and on beam test comparisons.

## III. DATA ACQUISITION AND THIRD LEVEL FILTERING

### A.Introduction

A number of new technologies have recently become available which we propose to explore by building a data acquisition system for a prototype SSC calorimeter. The menu of interesting objects include:

1) Fast ADCs with 12 or more bits of precision have become available. Of particular note are a 12-bit ADC from Crystal Semiconductor (Part No. CS5212) with a one microsecond conversion time and a 16-bit ADC from Burr Brown with a four microsecond conversion time.

2) Fast CMOS analog switches now allow one to multiplex a number of channels into a single ADC without changing the charge that is stored. The signal in a calorimeter channel can be compared to a user-selected level and only channels above threshold are digitized. Sparsification is thus done prior to digitization. Double analog buffers are proposed to futher increase the utilization of each ADC and to decrease dead time.

3) The number of ADCs and TDCs which can be purchased per dollar can also be increased by reducing power requirements drastically with CMOS rather than ECL logic chips. This also saves on cooling.

4) Because calorimeter resolution is proportional to 1/SQRT(E) the linear result from the ADC will be compacted by a square root function to compress the data. The speed at which an event moves through a data acquisition system is directly proportional to its size.

5) We propose to abandon the idea of all data passing through a single bus. Event fragments will be built in a system of multiple VME crates(figures 2 & 3). Imagine six ADC crates each attached to six VME crates. After initialization, six events may be built

simultaneously. The VME interface card for this scheme is already working at Fermilab. The theoretical VME speed is 40 MB/s so event building at 200 MB/s seems feasible.

6) The VME crates will be filled with RISC processing boards. The chip of choice right now is the 25 MHz MIPS R3000 which has been benchmarked by Digital Review at 20 MicroVAXII's when running their standard set of FORTRAN programs. These processing boards will provide a third level trigger for finding jets, electrons, photons, and missing energy. VME crate extenders may be used to add even more third level processing power. This becomes even more attractive when one considers that the performance-to-processing price ratio seems to be doubling each year. In addition to MIPS chips, the Intel i860 which integrates the CPU, flotaing point unit, and the caches onto a single chip, promises to be very cost effective if good high level language compilers emerge for it.

7) The advent of 2.3 Gigabyte Exabyte tape drives is changing the face of high energy physics data storage. One can now store 13 6250bpi nine track tapes or ten IBM 3480 cassettes on a single 8mm catridge costing $6. The data speed per tape drive is 0.25 MB/s. In December, both the data rate and data density are scheduled to double. Four Exabyte tape drives may be run at full speed by a single VME/SCSI controller card. The data rate to tape for 48 0.5 MB/ Exabyte tape drives running in parallel is 24 MB/s. Tapes only have to be changed once every 2.5 hours. If the third level trigger rejects 7/8 of the events then the 200 MB/s event building rate and the 24 MB/s tape writing speed match.

8) Offline computing now costs less than $1000 per MicroVAXII and the price is decreasing rapidly with time. It is reasonable to expect that an off-line farm of microprocessors can handle the generation of 500 4.6 GB 8mm tapes per day. Note the revolution. Instead of writing one 200 kilobyte SSC event per second, one can write over 100 200KB events/second. Instead of trying to process events serially on a single mainframe computer, hundreds of events are processed in parallel on fast RISC microprocessors.

B.Application to an SSC detector

These principles are already being used to construct the fastest data acquisition system in the world for E791 at Fermilab's Tagged Photon Lab. We propose to build on that experience and assemble a prototype SSC detector DA system as part of the L* prototype calorimeter. The SSC will require ADCs and TDCs which are fast, cheap, and consume minimal power. We propose to test what appear to be the best devices by these standards in a DA system which can exploit them. The L* prototype calorimeter seems to be a near ideal detector to use in this regard.

The ADCs(fig.4) and TDCs(fig.5) which look the most promising are being developed by Sten Hansen and others in the Fermilab Physics Department. The ADC multiplexes 64 channels through an analog bus to six 16-bit Burr Brown ADCs with a conversion time of four microseconds. Channels which do not exceed a user specified threshold are not digitized. A double analog buffer is provided to decrease dead time. The sensitivity of the ADC is 50pc/bin. Thirteen of the ADC bits (3 are dropped) are compressed by a square root function into a 10-bit data word which is combined with a 6-bit address. A leading word count is then provided and data is sent to a FASTBUS backplane.

The Fermilab Physics Department TDC board uses two 11-bit Micro Power Systems ADCs with 1/2 microsecond conversion times. Sixty-four channels are provided per board, each with analog double buffering and double hit capability. Only channels with hits are digitized. Ten bits of timing data is then combined with a 6-bit address. A leading word count is then provided and data is sent to a FASTBUS backplane.

We shall build events in parallel in multiple VME crates as we are doing in E791. However, E791 is using CPU boards based on the Motorola 68020 microprocessor. Scheduling does not permit the introduction of the faster Fermilab ACP II (Advanced Computing Program) boards based on the MIPS RISC R3000 processor which is 20 times faster than an ACPI processor with a 68020. This MIPS CPU should provide enough processing power to explore third level triggering algorithms for things like electron identification, jet finding, and missing energy triggers using the calorimeter prototype. The events which remain after filtering would be written on 16 8mm Exabyte tape drives in parallel. Exabyte should soon introduce a double-speed double-density tape drive which we propose to explore. It will run at 0.5 MB/sec and store 4.6 Gigabytes of data on one tape.

The system will assembled and some preliminary testing done at the Tagged Photon Laboratory(TPL) during CY90. The UMiss group is running on E791 at TPL during this period. Most of CY91 will be devoted to test beam measurements using units of the prototype calorimeter. Late CY91 and CY92 will see the system interfaced to the full prototype and complete testing done at count rates approaching SSC values. One faculty man-year per year minimum will be devoted to this project.

C.Summary

The facets of data acquisition which we propose to explore are four-fold:

1) Fast, cheap, low power, ADCs and TDCs.
2) Parallel event building.
3) Third level triggering algorithms using state-of-the art parallel microprocessors.
4) High-density tape drives focusing on 8mm Exabytes.

We propose to develop this system in conjunction with the design and testing of the L* prototype calorimeter thereby providing a high data rate DA system for the detector while benchmarking the DA system using an actual SSC-type front end detector.

## IV. FACILITIES AND PERSONNEL

The U. Miss. HEP group has four faculty ( L. Bolen, L. Cremaldi, J. Reidy and D. Summers), four graduate research assistants, one postdoc position where applicants are being screened, three undergraduate assistants and one quarter time electronics technician. A fifth faculty position has been approved for the HEP group and a search will be initiated this fall. One faculty man-year per year will be devoted initially to this project along with one graduate student. As the data acquisition system development expands the level of personnel support will increase. Support for a post-doctoral research associate and an electronic engineer who will spend full-time on the project , and for a half-time programmer is requested. Support for a detector center has been requested from the State of Mississippi which we envision as a satellite center to the detector center being established at ORNL.

The University of Mississippi mainframe computing facilities include a CDC 860/A, Cyber 205, ETA-10, and an Amdahl 470V/8. The High Energy Physics group has a μVax II, a Silicon Graphics Iris Workstation and has requested a Silicon Graphics unit with eight co-processors in a separate proposal. CALOR89 is running on the Amdahl and is being installed on the ETA-10. It will be installed on the Silicon Graphics Workstation (and the workstation upgraded with the R3000 RISC processor giving a 15 MIP machine) as soon as possible. Computer time on the mainframe (after a base fee of $10,000) is available at no charge to faculty for research.

Oak Ridge National Laboratory has CALOR89 running on an IBM 3033 and a CRAY XMP. However, free time is not available on these systems. Dr. Tony Gabriel of ORNL will spend about 10% of his time on the project. Oak Ridge National Laboratory requests support for one programmer.

The University of Tennessee has CALOR89 running on an IBM 3090 under the direction of Prof. Handler. He and Mr. Joe Hargis, a programmer, will devote 20% of their time to the project.

## V. REFERENCES

1. T. A. Gabriel et al., "CALORS 7: HETC87, MICAP, EGS4, and SPECT, A Code System for Analyzing Detectors for Use in High Energy Physics Experiments," published in the Proceedings of the Workshop on Detector Simulation for the SSC, Argonne National Laboratory, August 24-28, 1987.

   T. A. Gabriel et al., CALOR89: A Monte Carlo program package for design and analysis of calorimeter systems - in preparation - ORNL/TM-11185.

2. B. Anders et al., "Performance of a Uranium-Scintillator Calorimeter", DESY 86-105.

   E. Bernardi et al., "Performance of a Compensating Lead-Scintillator Calorimeter", DESY 87-41.

# VI. BUDGET

## A. Simulation Effort

| | | |
|---|---|---|
| ORNL | Programmer & travel & overhead | $90,000 |
| UTenn | Travel & overhead | $20,000 |
| UMiss | Faculty summer salary-3 mo. | $ 13000 |
| | One postdoc | 30000 |
| | Half-time programmer | 13000 |
| | Fringe benefits | 12320 |
| | Research assistants | 14000 |
| | Travel | 18000 |
| | Computer Fee | 10000 |
| | Communication | 5000 |
| | Supplies | 4000 |
| | **Sub-Total** | $119320 |
| | Overhead(44%) | 52500 |
| | **TOTAL-U. Miss.** | **$171820** |
| | **TOTAL SIMULATION -per year** | **$281820** |

## B. Data Acquisition System Effort

Equipment

| Quantity | Description | Unit Price | Total |
|---|---|---|---|
| 2 | Powered VME Crates | $2000 | $4000 |
| 1 | 19" Rack | 1000 | 1000 |
| 4 | Event Buffer Interface Cards | 250 | 1000 |
| 10 | ACP II MIPS R3000 CPU Boards | 7000 | 70000 |
| 2 | VME Resource Modules | 700 | 1400 |
| 2 | FASTBUS Smart Crate Controllers | 2500 | 5000 |
| 2 | FASTBUS Crates | 3000 | 6000 |

| | | | |
|---|---|---|---|
| 1 | Power Supply for FASTBUS | 2000 | 2000 |
| 10 | 64 Channel ADC Cards, 13-bit, Dynamic range 50 pc/bin, 20 microsecond conversion | 3000 | 30000 |
| 5 | 64 Channel TDC Cards, 10-bit 20 microsecond conversion | 2000 | 10000 |
| 4 | VME/SCSI Tape Controllers | 1200 | 4800 |
| 16 | 2.3 GB 8mm Exabyte Tape Drives | 2500 | 40000 |
| 2 | NIM Crates | 2500 | 5000 |
| 20 | NIM Logic Modules | 2000 | 40000 |
| | **Equipment Total** | | **$220200** |

Non-equipment

| | |
|---|---|
| Electrical Engineer including fringe | $35000 |
| Graduate Student | 15000 |
| Travel | 12000 |
| Supplies | 6000 |
| Communication | 3000 |
| Sub-total | $71000 |
| Overhead(44%) on personnel | 31240 |
| **Non-equipment Total-per year** | **$102240** |

C. Budget Summary

| EFFORT | CY90 | CY91 | CY92 |
|---|---|---|---|
| Simulation | $ 281.8K | $ 309.0K | $ 160.0K |
| DAQ | $ 322.4K | $ 112.2K | $ 124.0K |
| TOTAL | $ 604.2K | $ 421.2K | $ 284.0K |

The figures for CY91 and CY92 are based on the CY90 figure and assuming roughly 10% inflation.

# L* Calorimeter structure ( variation )

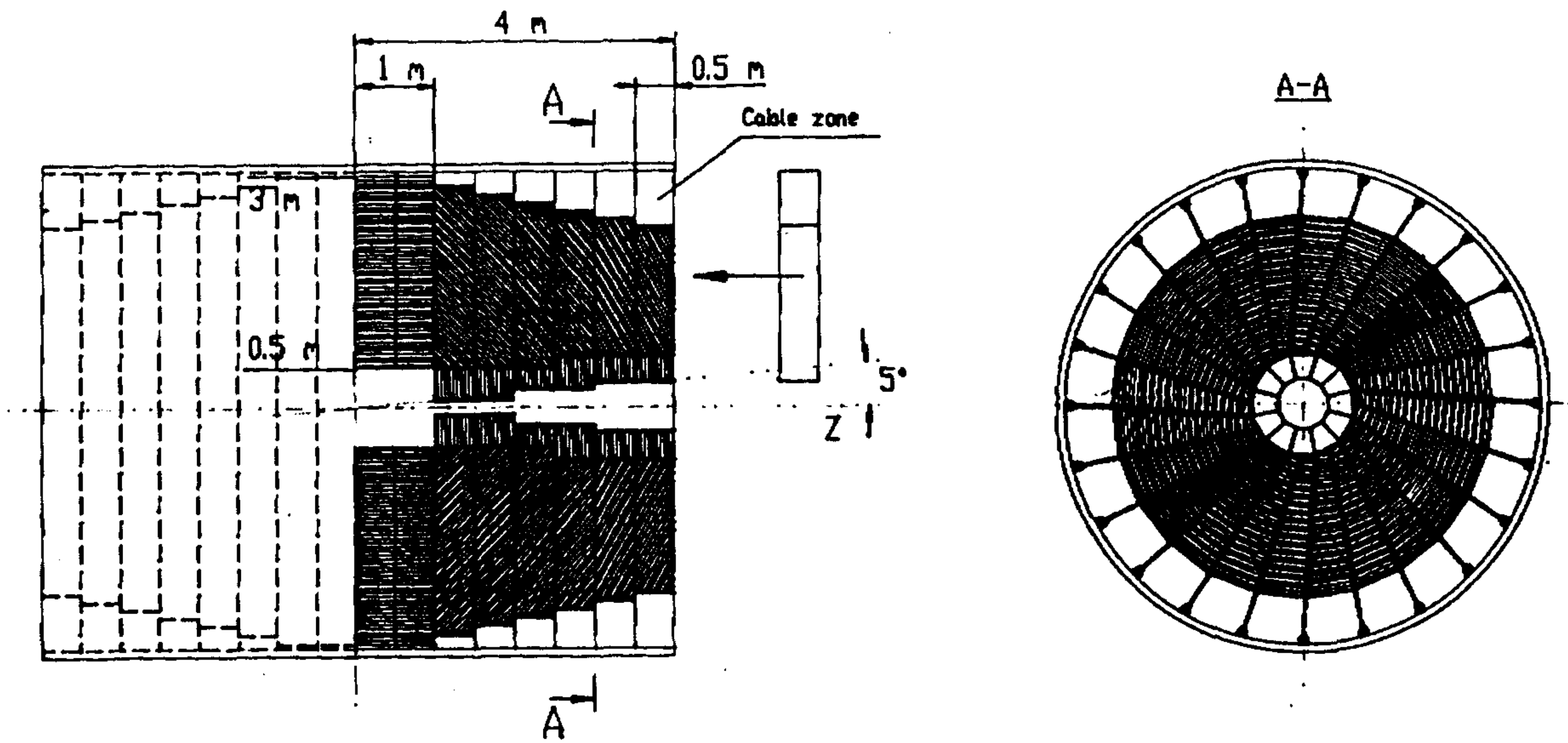



Fig. 1

Total weight 1750 tn
Total number - 384 modules
Ring - 24 modules
Ring weight 110 tn

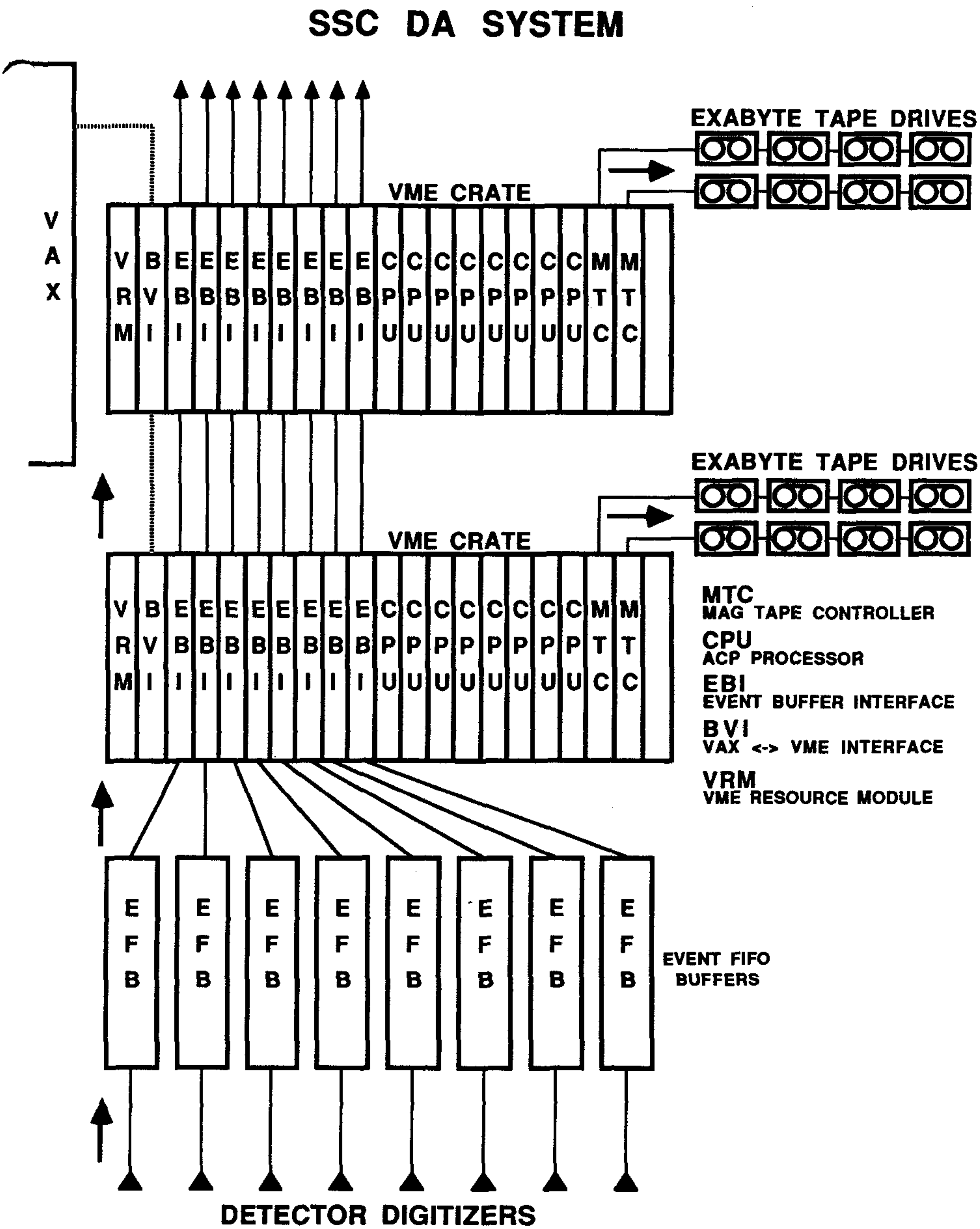

SSC DA SYSTEM
VAX
EXABYTE TAPE DRIVES
VME CRATE
VRM
BVI
EBI
CPU
MTC
EXABYTE TAPE DRIVES
VME CRATE
MTC
MAG TAPE CONTROLLER
CPU
ACP PROCESSOR
EBI
EVENT BUFFER INTERFACE
BVI
VAX <-> VME INTERFACE
VRM
VME RESOURCE MODULE
EFB
EVENT FIFO
BUFFERS
DETECTOR DIGITIZERS

Figure 2

# PARALLEL EVENT BUILDING

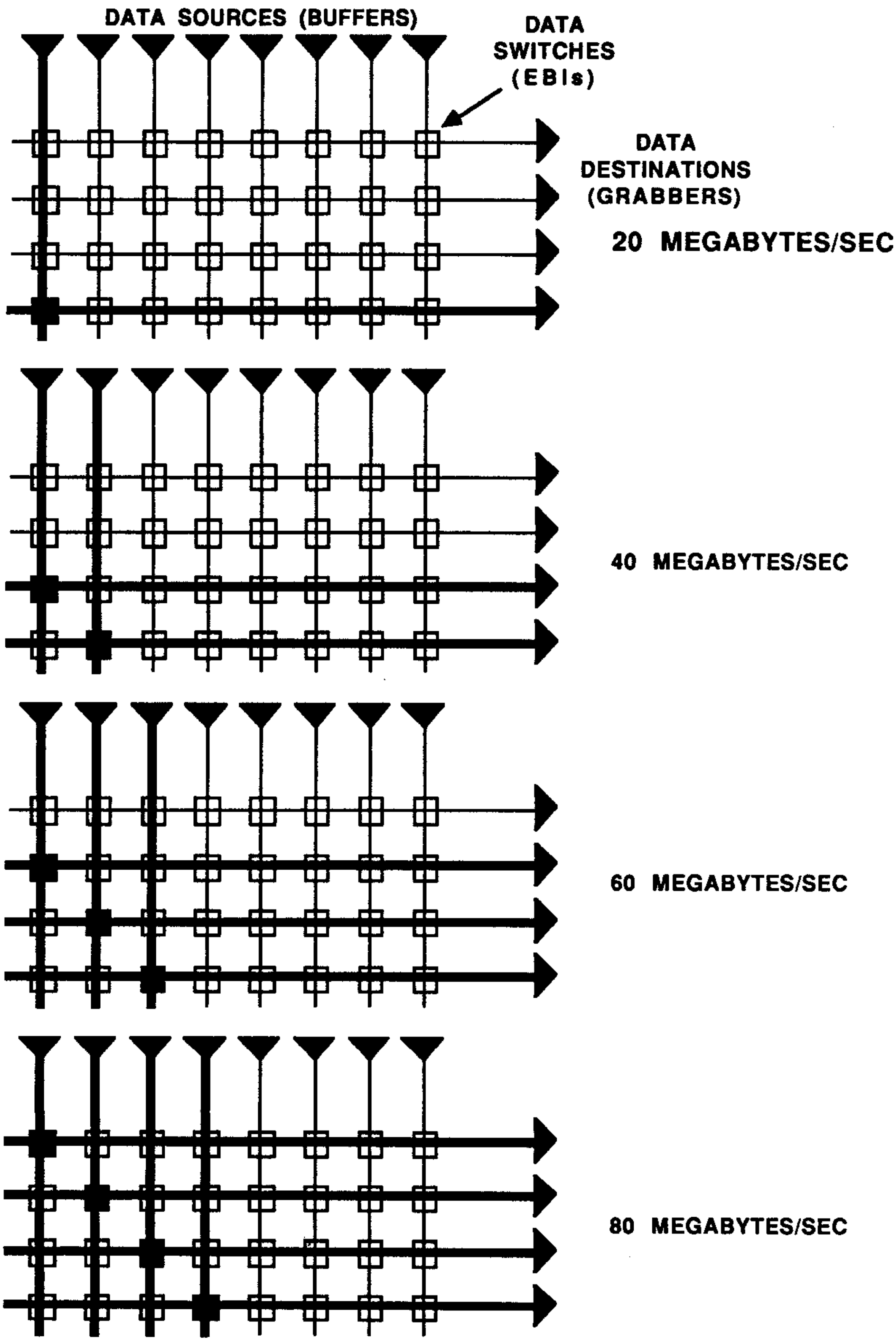



Figure 3.

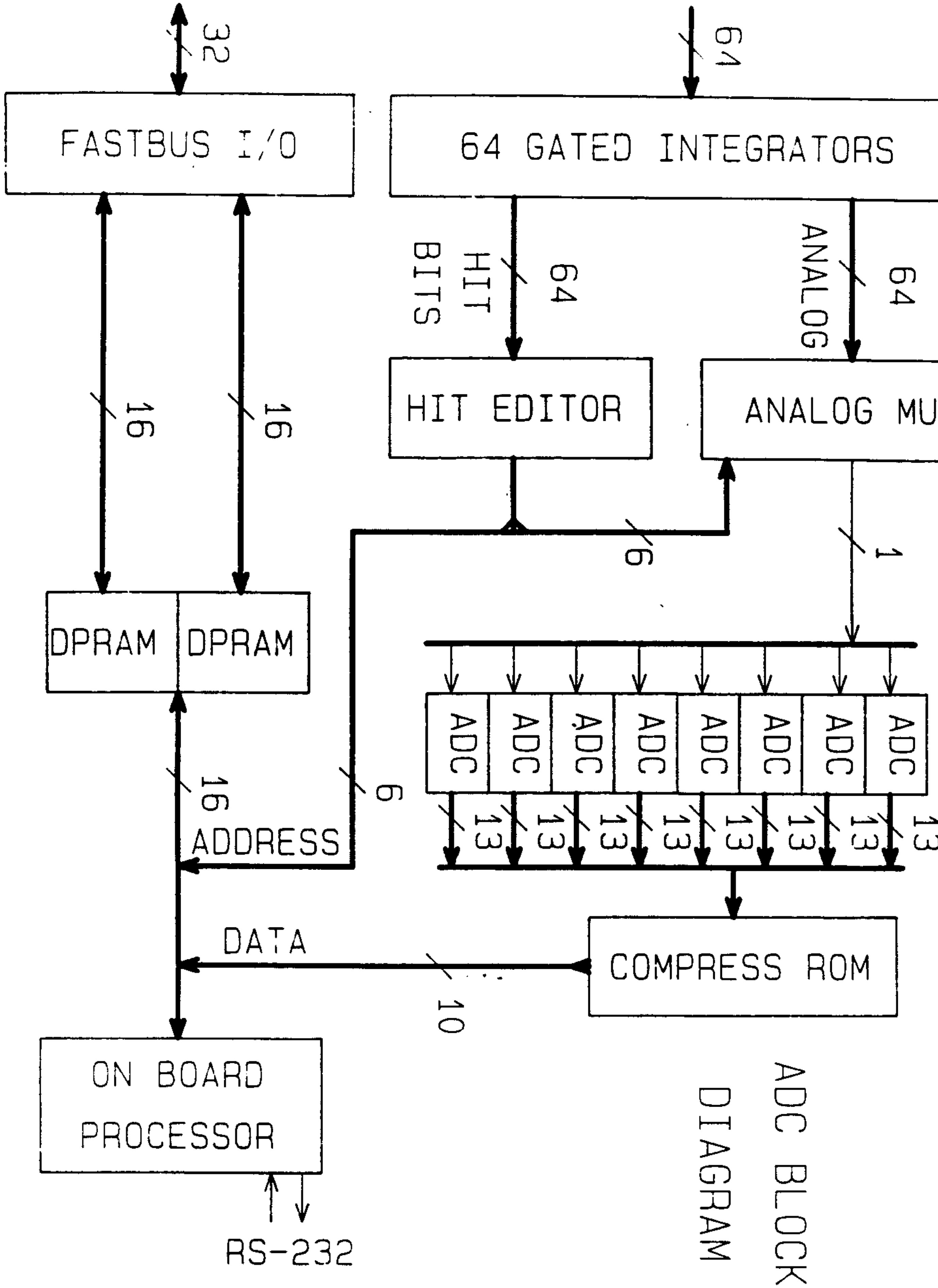
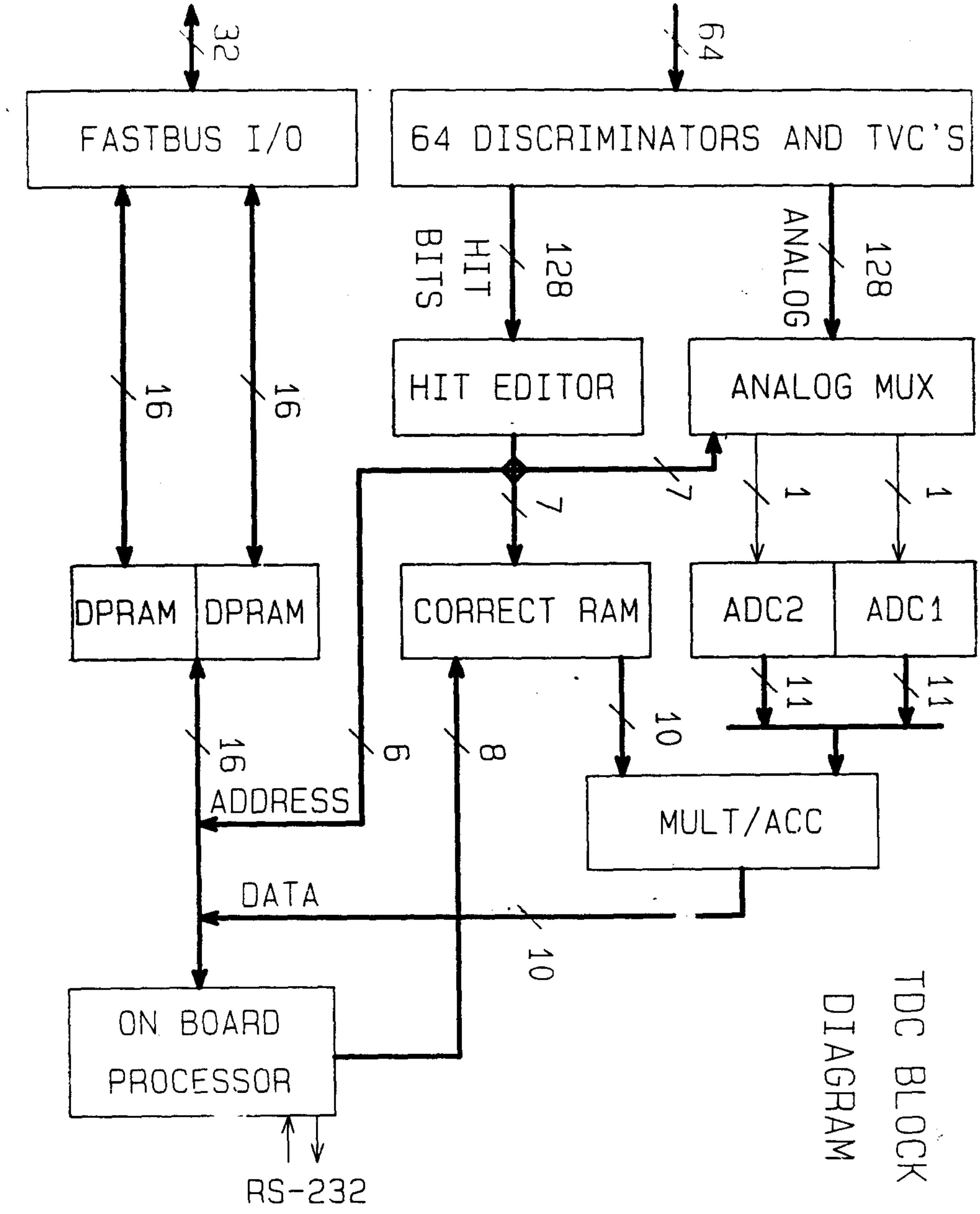

32
64
FASTBUS I/O
64 GATED INTEGRATORS
HIT BITS
64
ANALOG
64
16
16
HIT EDITOR
ANALOG MUX
6
1
DPRAM
DPRAM
ADC
ADC
ADC
ADC
ADC
ADC
ADC
ADC
16
6
13
13
13
13
13
13
13
13
ADDRESS
DATA
COMPRESS ROM
10
ON BOARD
PROCESSOR
RS-232
ADC BLOCK
DIAGRAM

Figure 4



32
64
FASTBUS I/O
64 DISCRIMINATORS AND TVC'S
HIT BITS
128
ANALOG
128
16
16
HIT EDITOR
ANALOG MUX
7
7
1
1
DPRAM
DPRAM
CORRECT RAM
ADC2
ADC1
11
11
16
6
8
10
ADDRESS
MULT/ACC
DATA
10
ON BOARD PROCESSOR
RS-232
TDC BLOCK DIAGRAM


Figure 5

APPENDIX 1

# A PROPOSAL TO INCORPORATE THE *CALOR* PROGRAMS INTO THE GEOMETRY AND DATA MANAGEMENT SYSTEM OF *GEANT*

by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University of Mississippi

and

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# A PROPOSAL TO INCORPORATE THE *CALOR* PROGRAMS INTO THE GEOMETRY AND DATA MANAGEMENT SYSTEM OF *GEANT*

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Abstract

A recommendation from the Workshop on Detector Simulation for the SSC held at ANL in August, 1988 suggested that work to interface CALOR with GEANT be supported. We are proposing to incorporate CALOR into the GEANT framework. This will require three basic steps. First, the latest versions of GEANT and CALOR will be made operable on the University of Mississippi Cyber 205. Second, the interfaces for coupling the codes will be identified and the software developed to implement the union. Finally, testing will be carried out to insure the integrity of the final program. Some calculations will be performed to determine the compatibility and similarity of various modules in the CALOR and GHEISHA codes. The major part of this work will be performed by a post-doctoral associate in the University of Mississippi. This individual will maintain close contact with Dr. Saul Youssef at the Supercomputer Computational Research Institute at Florida State University and Dr. Tony Gabriel at ORNL. Support in the amount of $68,895 is requested from DOE for support of the post-doctoral associate and partial support of the programmer. The University of Mississippi is contributing $4000 toward travel and $58,000 in-kind cost sharing which includes a minimum of 100 hours of free time on the University of Mississippi's Cyber 205.

A PROPOSAL TO INCORPORATE THE *CALOR* PROGRAMS INTO THE GEOMETRY AND DATA MANAGEMENT SYSTEM OF *GEANT*

James J. Reidy and Tony A. Gabriel

The ability to design calorimeter systems and the associated software for on-line analysis are strongly tied to the availability and accuracy of computer simulation programs such as CALOR[1] and GHEISHA.[2] Both the CALOR and GHEISHA programs have special strong points and at times it would be advantageous to use parts of CALOR with parts of GHEISHA so as to maximize the strengths of both. It has been recommended at the Workshop on Detector Simulation for the SSC held at ANL on August 24–28, 1987 that

"1. There is a need for both detailed Monte Carlo codes and fast, simplified codes in the applications to calorimeter tests studies, system designs, and studies of radiation protection.

2. The proper treatment of neutron processes is clearly crucial. Also, two codes being maintained leads to better understanding and confidence. On these considerations, we recommend the adoption of CALOR (the Oak Ridge code employing HETC, MORSE and EGS) and GHEISHA as the standards.

3. As GEANT[4] is becoming a standard for experimental detector description, it becomes important to provide both of these standards within the GEANT framework. This has already happened for GHEISHA and we suggest that the work to interface CALOR with GEANT be supported.

4. While these interfaced versions of the program are very useful, they do not replace the need for stand-alone versions of the hadron cascade codes. We recommend that both CALOR and GHEISHA be maintained in stand-alone versions.

5. It is recognized that the low energy description of CALOR is more accurate than GHEISHA due to the use of the MORSE code for neutron description. It would be useful to set up GHEISHA to use the low energy description of CALOR. (Alternatively, it could be valuable to have the low energy description of GHEISHA available to be used with

the CALOR code."[3]

With reference to recommendation 3 given above, we are proposing to incorporate CALOR into the GEANT[4] framework.

The CALOR computer code system, which has prime application in hadronic and electromagnetic cascade simulation as required for calorimeter design, has been in development since the early 1970's. Many important discoveries have originated from the utilization of this system. Some of these[5] include

1. the importance of hydrogen in the active medium to couple low energy neutrons to the output signal;
2. the significant role of "electromagnetic sampling inefficiencies" in reducing the average ratio of electron to hadron response at the same energy;
3. the importance of saturation effects on the effective signal; and
4. uranium, liquid argon calorimeters are not fully compensating by the mechanisms as was initially explained.

A flow diagram of the codes in CALOR is given in Figure 1. The three-dimensional, multimedia, high-energy nucleon-meson transport code (HETC)[6] is used, with modifications, to obtain a detailed description of the nucleon-meson cascade produced in the devices considered in this paper. This Monte Carlo code takes into account the slowing down of charged particles via the continuous slowing-down approximation, the decay of charged pions and muons, inelastic nucleon-nucleus and charge-pion-nucleus (excluding hydrogen) collisions through the use of the intermediate-energy intranuculear-cascade-evaporation (MECC) model ($E < 3$ GeV) and scaling model ($E > 3$ GeV),* and inelastic nucleon-hydrogen and charged-pion-

* It is anticipated that the new high energy collsion model will be available shortly and that this model will be substituted for the scaling model.

hydrogen collisions via the isobar model (E < 3 GeV) and phenomenological fits to experimental data (E > 3 GeV). Also accounted for are elastic neutron-nucleus (E < 100 MeV) collisions, and elastic nucleon and charged-pion collisions with hydrogen.

The intranuclear-cascade-evaporation models as implemented by Bertini is the heart of the HETC code.[7] This model has been used for a variety of calculations and has been shown to agree quite well with many experimental results. The underlying assumption of this model is that particle-nuclear interactions can be treated as a series of two-body collisions within the nucleus and that the location of the collision and resulting particles from the collision are governed by experimental and/or theoretical particle-particle total and differential cross-section data. The types of particle collisions included in the calculations are elastic, nonelastic and charge exchange. This model incorporates the diffuseness of the nuclear edge, the Fermi motion of the bound nucleons, the exclusion-principle, and a local potential for nucleons and pions. The density of the neutrons and protons within the nucleus (which is used with the total cross sections to determine interaction locations) are determined from the experimental data of Hofstadter.[7] Nuclear potentials are determined from these density profiles by using a zero-temperature Fermi distribution. The total well depth is then defined as the Fermi energy plus 7 MeV. Following the cascade part of the interaction, excitation energy remains in the nucleus. This energy is treated by using an evaporation model which allows for the emission of protons, neutrons, d, $^3$He, $\alpha$, and T. Fission, induced by high-energy particles, is accounted for during this phase of the calculation by allowing it to compete with evaporation. Whether or not a detained fission model is included has very little effect on the total number of secondary neutrons produced.

The source distribution for the electromagnetic cascade calculation is provided by HETC; it consists of photons from neutral pion decay, electrons and positrons from muon decay (although this is usually not of interest in calorimeter calculations because of the long muon lifetime), de-excitation gamma rays from nonelastic nuclear collisions and fission gamma rays. Since the discrete decay energies of the de-excitation gammas are not provided by HETC and only the total energy is known, individual gamma energies are obtained by uniformly sampling from the available energy until it is completely depleted. The transport of the electrons, positrons, and gammas from the above sources is carried out using the EGS system.[8]

Neutrons which are produced with energies below 20 MeV are transported using the MORSE[9,10] Monte Carlo transport code. The neutron cross sections used by MORSE were obtained from ENDFB/IV. Gamma rays (including those from capture, fission, etc.) produced during this phase of the calculations are stored for transport by the EGS code. The MORSE code was developed for reactor application and can treat fissioning systems in detail. This ability is very important since a majority of the fissions results from neutrons with energies less than 20 MeV. Time dependence is included in MORSE, but since neither HETC nor EGS has a timing scheme incorporated, it has been assumed that no time passes for this phase of the particle cascade. Therefore, all neutrons below 20 MeV are produced at $t = 0$. General time cuts used in the MORSE code are 50 ns for scintillator and 100 ns for TMS although studies were also performed with times as long as 400 ns.

The nonlinearity of the light pulse, L, in the scintillator due to saturation effects is taken into account by the use of Birk's law[11]

$$\frac{dL}{dx} \propto \frac{dE/dx}{1 + k_B dE/dx},$$

where $k_B$ is the saturation constant. For the plastic scintillator $k_B = 0.01$ g cm$^2$ MeV$^{-1}$. A similar law is assumed to apply to the charge collected in ionization detectors. This takes into account the loss of signal resulting from recombination effects in the ionization column.[15] A variety of $k_B$ values have been considered in this study of TMS since, at present, this media has not been well investigated. For electrons at all energies, it is assumed that $k_B = 0$.

The principal applications of GEANT include: the tracking of particles through an experimental setup for acceptance studies or simulation of detector response and the graphical representation of the setup and of the particle trajectories. In view of these applications, the GEANT system allows for a description of an experimental setup in a rather efficient and simple way by utilizing geometrical volumes, for generated simulated events from standard Monte Carlo generators, for the transport of particles through various regions (including areas with magnetic fields) taking into account all of the physical effects due to the nature of the particles themselves, for the recording of the elements of the particle trajectories and the response of the sensitive detector elements and for the visualization of the detectors and the particle trajectories therein. At present, particle collisions are accounted for in GEANT by the models incorporated in GHEISHA. By incorporating CALOR into GEANT, these collision models can be used and direct comparisons can be made between CALOR and GHEISHA.

## Proposed Work

To incorporate CALOR into GEANT will require three basic steps. First, the latest versions of GEANT and CALOR will be made operable on the University of Mississippi Cyber 205. Second, the interfaces for coupling the codes will be identified and the software developed to implement the union. Finally, testing will be carried out to insure the integrity of the final program. Some calculations will be performed to determine the compatibility and similarity of various modules in the CALOR and GHEISHA codes. Discussions with Dr. Saul Youssef, who is directing work on GEANT at the Supercomputer Computational Research Institute at Florida State University, has resulted in the following timetable:

| | | |
|---|---|---|
| a) | 1 - 1 1/2 months: | installation and check-out of GEANT on the University of Mississippi Cyber 205 |
| b) | 1 month: | installation and check-out of CALOR on the University of Mississippi Cyber 205 |
| c) | 3 months: | coupling areas located in both coes; software development started to allow coupling |
| d) | 3 months: | debugging and checking of code |
| e) | 4 months: | comparison of CALOR cell models and GHEISHA cell models contained in GEANT. |

Experience dictates that this is a reasonable, albeit optimistic, timetable. The work will be carried out by a post doctoral associate, Dr. Michael Nicholas, who has had extensive experience with the University and Physics Department computer systems as well as the systems at Los Alamos National Laboratory. He will spend about two weeks with Dr. Youssef at Florida State

University to become familiar with GEANT and a week at Oak Ridge National Laboratory to familiarize himself with CALOR. If it appears helpful, a visit to CERN and some time with Dr. Detlef Filges at Julich, who has coupled HETC to HERMES, will be arranged. In the software development of part (c) particular attention will be paid to simplifying the user interface. Pull-down menus will be incorporated where possible.

## Facilities

The University of Mississippi has extensive and diverse computing resources. A CDC Cyber 205 has been online since January 1, 1988. The 205, one of fewer than 20 true supercomputers in university environments, is capable of an impressive 400 million floating point operations per second. With 4 million 64-bit words of central memory, the operating system can access up to two trillion words of data. It is front-ended by a 10 MIPS, 64-bit CDC Cyber 860 Mainframe. The consultant staff is augmented by personnel from the Supercomputer Computational Research Institute (SCRI) at Florida State University who visit the University of Mississippi facility weekly. Users have 24-hour-a-day, year round access to terminal rooms that contain 60 CMS terminals to the Amdahl 470V/8 and 30 terminals to the Cyber 860. More than 1,000 terminals, personal computers, and work stations located in the various physics laboratories also have access to the computing systems. In addition, the University has an MS-DOS Microlaboratory and a Microcomputer and Graphics Laboratory. Current plans call for the installation of an ETA-10 Supercomputer in December, 1988. This will be about a factor of ten faster than the Cyber 205.

The Nuclear and Particle Physics group, directed by Professor Reidy, has a MicroVAX II/GPX which has direct connection to the Cyber computers via a 19.2 Kb line driver. This MicroVAX II/GPX has a 16 Mb memory, 700 Mb disk storage, and an 800/1600/6250 Kennedy tape drive. An additional DEC 240, Macintosh II, DEC 2000, and Tektronix 4014 are connectd to the MicroVAX via a terminal server. The MicroVAX and the Cybers can also be accessed directly via 2400 baud modems.

Networking of the University of Mississippi computing center to other strategic locations such as Florida State University (FSU) and the Oak Ridge National Laboratory (ORNL) are in progress. Currently, ORNL and FSU are connected through ESNET and the University of Mississippi is completing connection to FSU via SURANET. This will allow remote logins as well as file transfers at 56 Kb. Networking through FSU also gives access to FNAL, SLAC and BNL as well as other major centers (see DOE/ER-0372).

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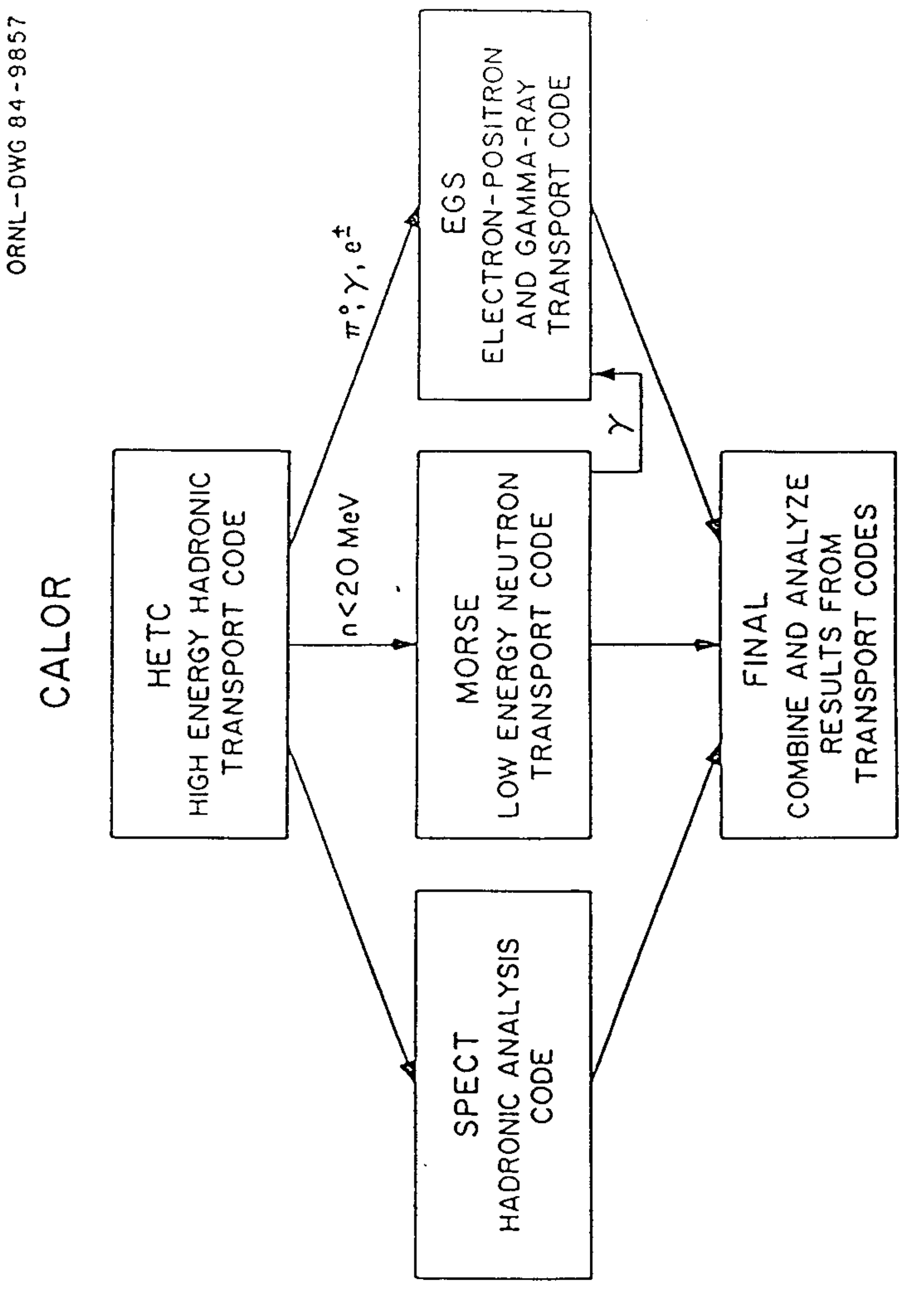

ORNL-DWG 84-9857
CALOR
HETC
HIGH ENERGY HADRONIC
TRANSPORT CODE
$\pi^{\circ}, \gamma, e^{\pm}$
n<20 MeV
EGS
ELECTRON-POSITRON
AND GAMMA-RAY
TRANSPORT CODE
$\gamma$
MORSE
LOW ENERGY NEUTRON
TRANSPORT CODE
SPECT
HADRONIC ANALYSIS
CODE
FINAL
COMBINE AND ANALYZE
RESULTS FROM
TRANSPORT CODES