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March 1, 1989 - February 28, 1990

entitled

HIGH ENERGY ACCELERATOR AND COLLIDING
BEAM USER GROUP

Submitted to

U. S. Department of Energy

September, 1989



UNIVERSITY OF MARYLAND
DEPARTMENT OF PHYSICS AND ASTRONOMY
COLLEGE PARK, MARYLAND

MASTER

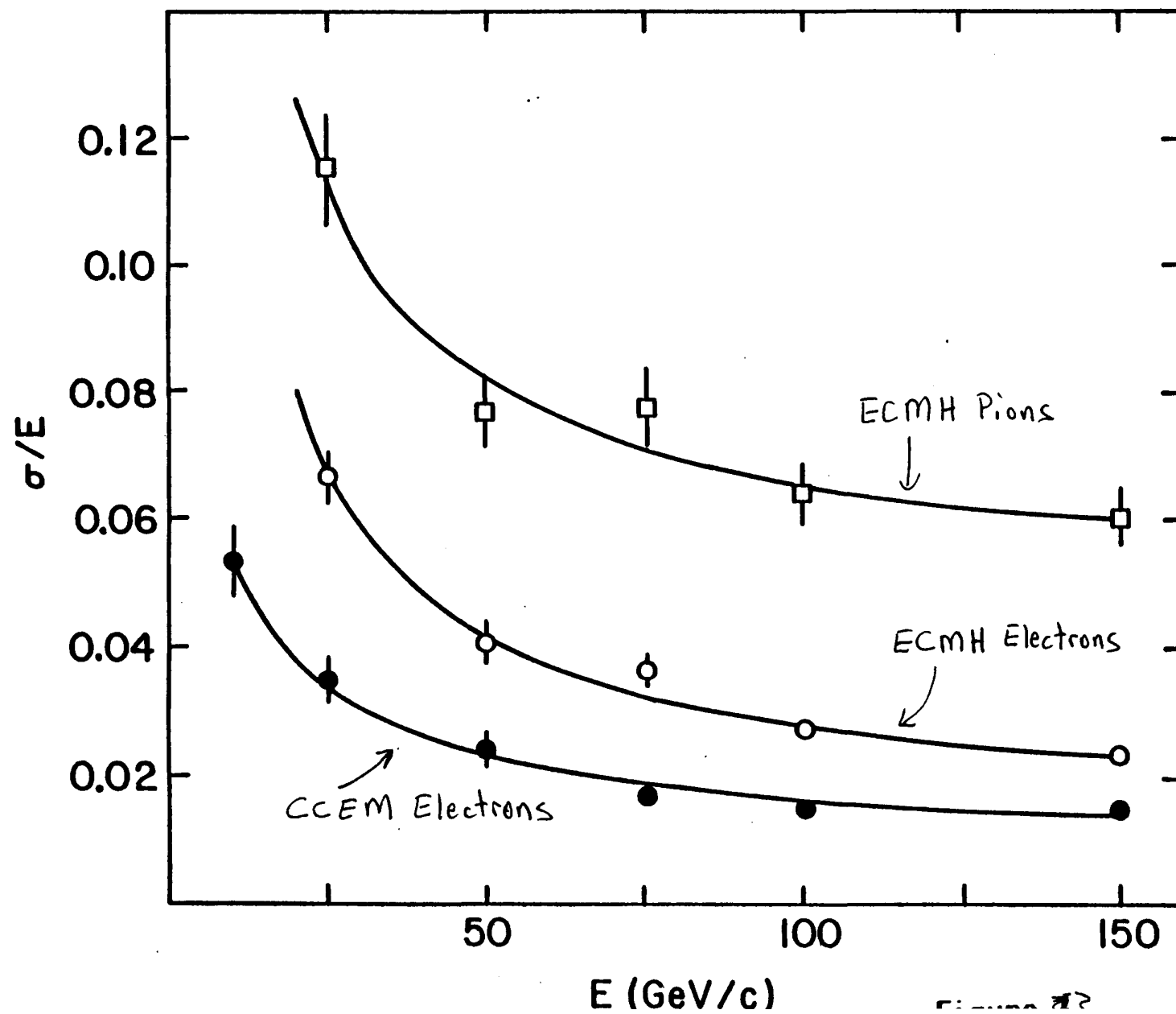
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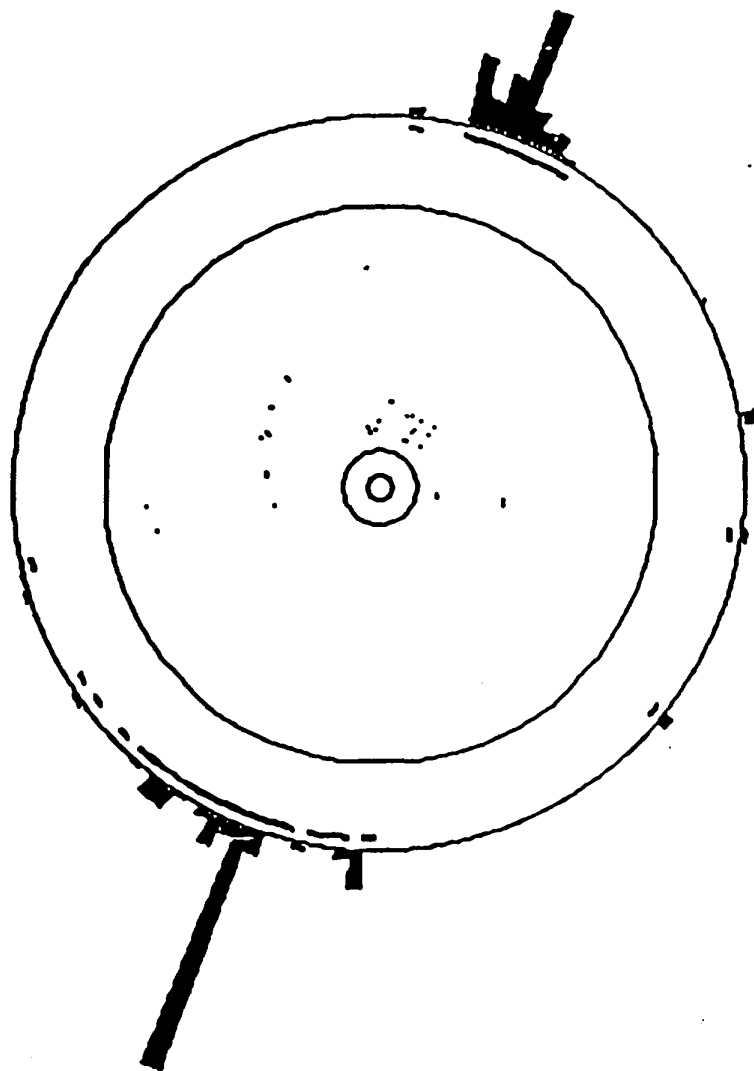


Run 443 Evt 22734 Total E(ZB): 34.0 GeV, in clusters: 31.8 GeV Clusters(ZB): 13 Muon Tks: 0 Filter Type: 1 Trigger Bits

■ 1 GeV (EB)

■ 5 GeV (FD)

TPT02
TOFOR
TOFMANY
EBTOTKI
EBTOTLO
TPTOCL
TPTOI



13-8-89

23:20

The First Z^0 event
detected at LEP.

The jet chamber high
voltage was not yet on.

OPAL
ONLINE

13/08/1989 23:16:46

1.1

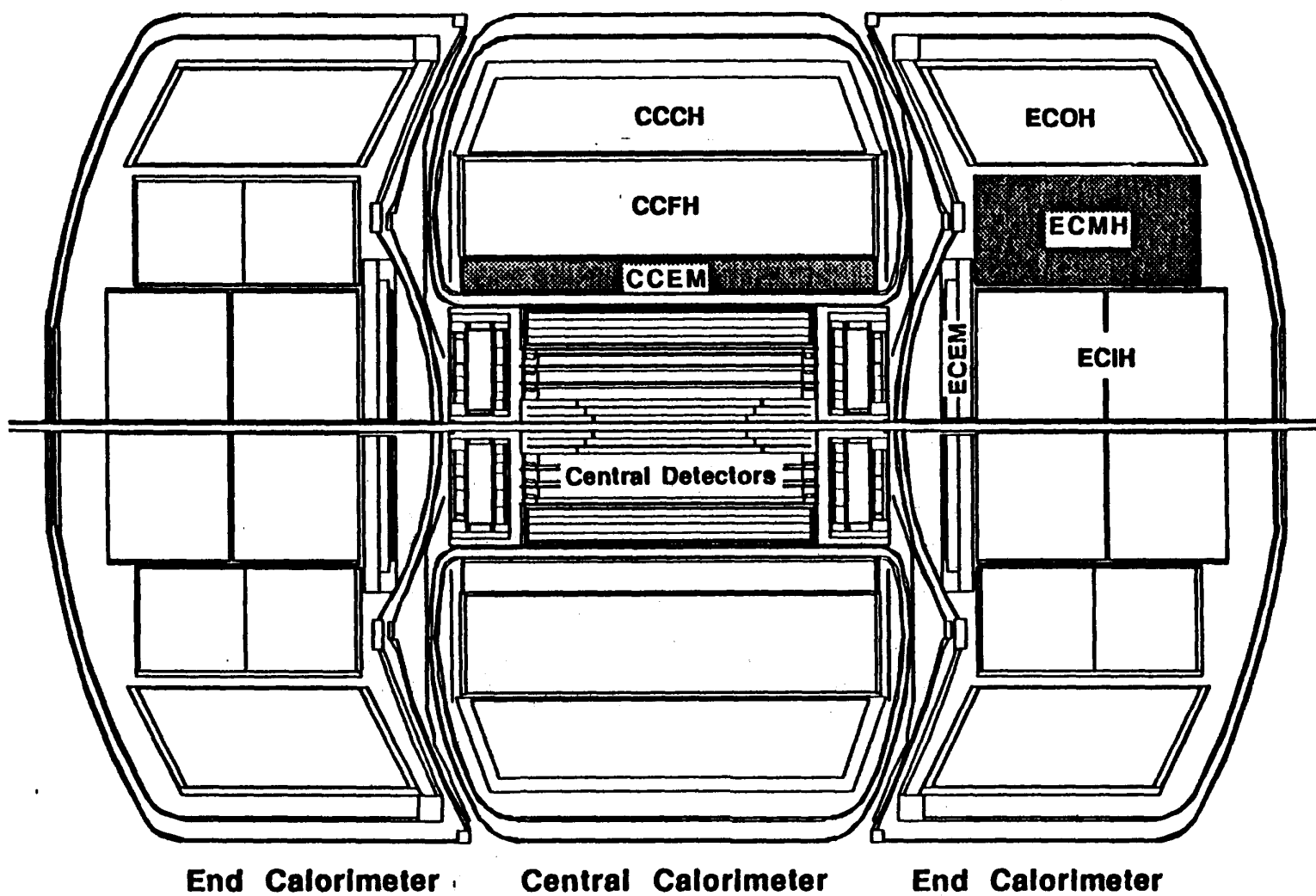


Figure 1

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MASTER

I. PHYSICS PROGRESS REPORT

A. Introduction

As this report is being written, the pilot run of LEP at CERN is at an energy of 91 GeV is being analyzed. OPAL reported the first Z^0 hadronic event at 23:09 on August 13. The pilot run ended on August 17 with about 47 Z^0 events detected by all four detectors. OPAL recorded 21 Z events (18 hadronic and 3 leptonic). The regular run is scheduled to begin on Sept. 11 at a higher luminosity. Each detector at LEP should accumulate ten to twenty thousand Z^0 events by the end of 1989. If the luminosity approaches design, 10^6 Z^0 events can be accumulated in 1990.

The OPAL detector at LEP is in very good condition. The forward detector which measures the luminosity via Bhabha events and which is lead by Dr. Richard Kellogg has been completed, tested and successfully inserted in position in May, 1989. The on line system was exercised and debugged during the LEP tune-up process so that it was ready for data on Day 1.

The hadron calorimeter, under the leadership of Dr. Austin Ball, has progressed extremely well. The installation process for the 64 endcap cans were successfully carried out last summer and fall. During the year cabling, high and low voltage electrical installations were completed. The on-line system was designed, deployed and debugged primarily by our graduate student Wayne Springer. The hadron calorimeter has had a difficult time in getting safety clearance from the CERN authorities for circulating flammable gas. This was finally granted on August 18th, too late for the pilot run, but soon enough to allow it to be ready for the regular run.

The software and physics preparations of the OPAL collaboration have made excellent progress this past year. A final calibration test run of the hadron calorimeter was successfully carried out at CERN and results from this run

have been incorporated into a new version of ROPE, the analysis package of OPAL. Dr. Adrian Buijs has played a crucial role in many software developments for the hadron calorimeter as well as for the detector as a whole. Prof. Chang and Mr. Hou have made important contributions to the luminosity monitor Monte Carlo calculations. Prof. Jawahery has carried out a study of how much can be gained for particle identification in OPAL by adding a silicon vertex detector in front of the current wire chamber vertex detector. Many of the Maryland OPAL physicists have joined OPAL analysis working groups on a variety of physics topics. The current set of programs for OPAL, with provision for regular updating, are installed at College Park on the expanded UMD HEP Computer System. Thirteen Maryland employees have been in residence at CERN this past summer. During the academic year the number will be reduced to seven.

Physics results on deep inelastic muon interactions from E665 are almost ready for release. Data processing of the 1987-88 run has been slower than expected primarily due to difficulties encountered in the efficiency of track reconstruction. New algorithms needed to be devised and debugged. The system is now working smoothly with preliminary physics distributions on structure functions, π^0 production, jet production, particle multiplicities etc. being prepared. Dr. S. Kunori and three Maryland graduate students have been important contributors to this program. Erik Ramberg should complete his Ph.D. on this work in the next month or two and Silhacen Aid should finish his Ph.D. a few months later.

Prof. Nick Hadley has joined our group in January, 1989. He has greatly expanded our efforts on the $D\phi$ experiment at the Tevatron Collider. We have recruited one research associate and two Maryland graduate students who are working on the liquid argon calorimeter for $D\phi$ at Fermilab. Most recently,

after an extensive search, we recruited Dr. Andrew Baden from Harvard U. and the CDF experiment to join this effort. He will be a Research Assistant Scientist during the 89-90 academic year and will receive a regular Assistant Professor appointment beginning July 1, 1990. Dr. Kunori has also contributed to the $D\phi$ program and will continue that effort in the future. A small construction project for $D\phi$ will begin at Maryland in the near future.

Dr. Jawahery and his student, C. Park, have lead the analysis of the CESR 1988 run on the $5S(b\bar{b})$ state. Interesting evidence has been obtained about the production of the B_s meson at this resonance. A large number of other interesting physics results have been produced by the CLEO collaboration.

Prof. C. Y. Chang continues to participate in the CYGNUS experiment at Los Alamos, where he was in residence during the first part of 1989. The extensive air shower array has been expanded but so far no new bursts of the size and interest of last year's burst from Hercules X-1 have been seen.

The final papers on the $\nu_e e^-$ elastic scattering and related physics topics are almost ready for publication. A detailed discussion of this landmark experiment is contained in the Ph.D. thesis of D. Krakauer who was directed by Prof. R. Talaga. Unfortunately Prof. Talaga was not promoted to tenure. He left the U. of Maryland in January, 1989 to work at Argonne National Laboratory on the Zeus experiment at HERA.

Other interesting publications have appeared or will appear on the theory of polarization in electron storage rings by L. Hand and A. Skuja, on e^+e^- and $\gamma\gamma$ interactions at PETRA with JADE, and on a test of the Pauli principle.

Unfortunately after a long illness, Prof. Robert Glasser has taken disability retirement from the University in January, 1989. Since Dr. Adrian Buijs opted to work for CERN after his CERN fellowship ended, rather than return to our group, we have employed a new research associate Alfred Lee,

from Yale U., for OPAL, beginning Sept. 1, 1989. It is essential that the Maryland team at CERN be strengthened in this way in order for us to continue to play a significant role in the OPAL physics program. Dr. D. Fong has completed close to 50% of the scheduled upgrade of the UMDHEP Computer System.

Finally intensive plans and discussions are underway with respect to Maryland's participation in the SSC experimental program and in possible upgrades of the OPAL detector at LEP.

B. OPAL Experiment at LEP. (A. Ball, A. Buijs, C. Y. Chang, D. Fong, S. Hou, A. Jawahery, R. G. Kellogg, J. Lorah, A. Skuja, G. A. Snow, R. W. Springer,, and G. T. Zorn at the U. of Maryland in collaboration with physicists from Birmingham, Bologna, Bonn, California (Riverside), Cambridge, Carlton, CERN, Chicago, Freiburg, Heidelberg, London Birkbeck College, London Brunel Univ., QMC London, Manchester, Montreal, NRC (Canada), Rutherford Lab., Saclay, Technion, Telaviv, Tokyo and Weizmann Inst.).

B.1. General Comments

The OPAL experiment is a collaboration of twenty two institutions from eight countries on three continents. In North America, Canada and the United States are well represented, in Europe, England, France, Italy, Switzerland, and W. Germany are participants and in Asia, Israel and Japan are important members of the collaboration. OPAL has 276 physicists and graduate students and is still the smallest of the four LEP detectors by far. The spokesman for the experiment is Aldo Michelini of CERN. Administration for OPAL has been revised this past year with the appointment of a Physics Coordinator, Albrecht Wagner of Heidelberg and his Deputy Physics Coordinator, G. J. Van Dalen of UC Riverside. Physics Working Groups have been established for numerous topics with R. Kellogg of Maryland leading the Luminosity Group and A. Buijs, formerly of Maryland, leading the $\pi\bar{\pi}$ group. A general spirit of cooperation and goodwill pervades the OPAL collaboration.

The experimental hardware for OPAL is in excellent shape. With the approval obtained on Aug. 18th for circulation of flammable gas in the hadron calorimeter and the endcap muon detectors, all parts of OPAL should be ready for data taking when the official run of LEP begins on September 11th.

Since our last Progress Report, two extensive calibration runs at CERN have been carried out by the Maryland group and collaborators, one on the hadron calorimeter and the second on the luminosity monitor. The results of these final calibration runs have been incorporated into the OPAL analyses

software programs. The luminosity monitor has already been using this new package in the pilot run.

The pilot run of LEP was successfully carried out in the period August 13-18. Fifteen minutes after collisions began OPAL found the first Z^0 event at LEP. This event was displayed in the Aug. 17 Nature Magazine. In all OPAL accumulated 21 Z^0 events (18 hadronic and 3 leptonic) and 31 Bhabha events during an actual running time of 15 hours and 13 minutes distributed over 5 1/2 days. Two examples are shown in Figs. 1 and 2. When LEP resumes running on Sept. 11, the luminosity is expected to be higher by a factor between 3 and 10.

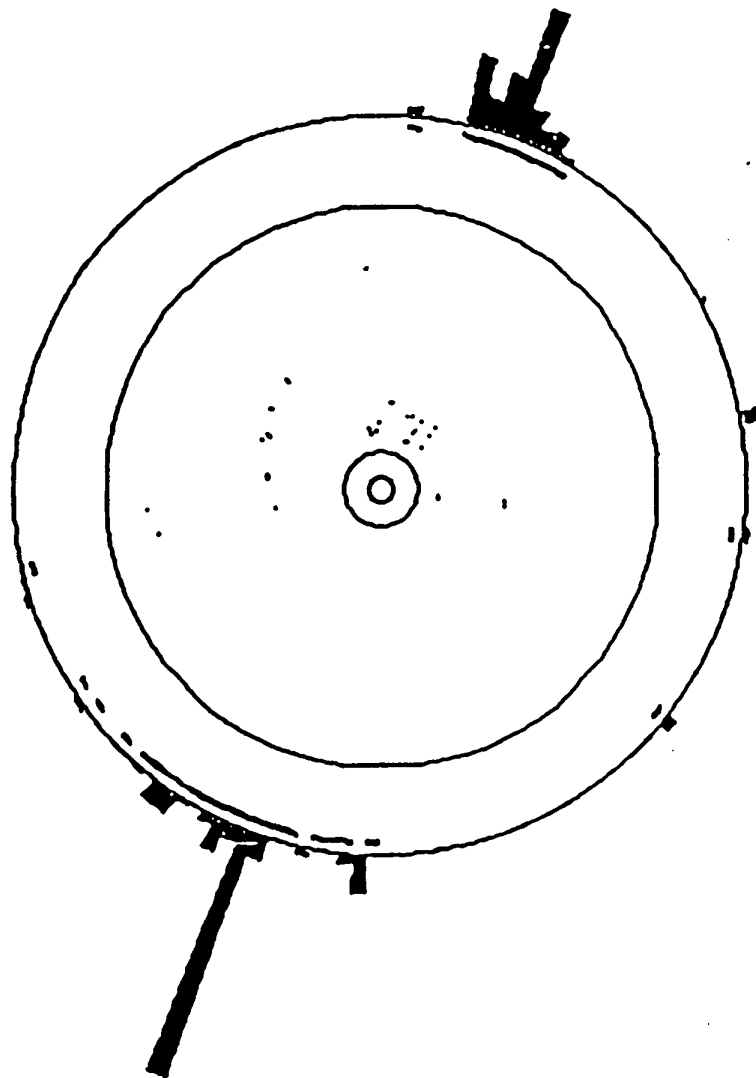
The luminosity monitor built, with the leadership of Richard Kellogg, works beautifully. The background encountered in the pit due to beam gas collisions was somewhat smaller than had been anticipated so that the threshold for Bhabha event energies can be set at or about 15 GeV in each half of the detector.

The commissioning of the hadron calorimeter has proved to be a substantially more massive and more expensive task than had been envisaged seven years ago when we first assumed this responsibility. Nevertheless, under the leadership of Austin Ball, it has been carried to its final stage with no substantial difficulty. The final test can only come after the appropriate circulating gas has come to equilibrium and the high voltage has been turned on, a process that takes 2-3 weeks after the go ahead of August 18th.

The on line systems for the hadron calorimeter and for the luminosity monitor are in good working order. Many improvements in the software chain have been carried out. The emphasis is rapidly shifting to physics analysis as we approach the time of having a reasonable statistic of real Z^0 events, rather than only a large statistic of Monte Carlo Z^0 events.

The strong support of both D.O.E. and the U. of Maryland has been

Run 443 Evt 22734 Total Z(B): 34.0 GeV, in clusters: 31.8 GeV Clusters(ZB): 13 Muon Trks: 0 Filter Type: 1 Trigger Bks
1 GeU (EB) TPT02
5 GeU (FD) TPT0R
TOFMANY
EBTOTNI
EBTOTLO
TPTOCL
TPTOI



13-8-89

23:20

The First Z^0 event
detected at LEP.
The jet chamber high
voltage was not yet on.



13/08/1989 23:16:46

1.1

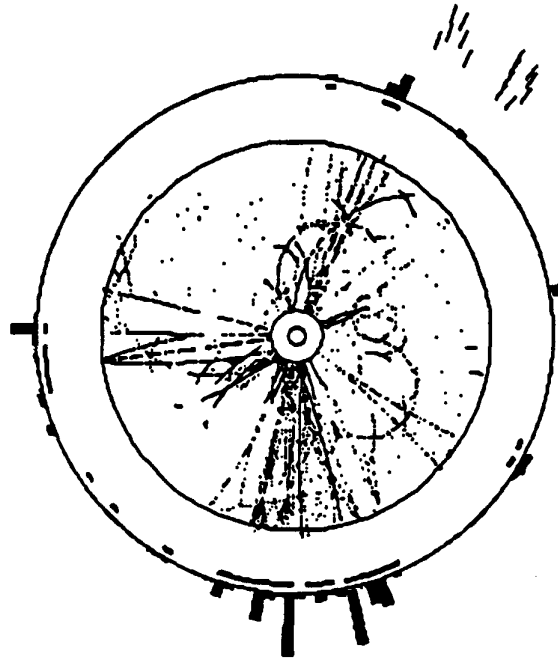
Run 446 Evt 61050 Total $\Sigma(E)$: 21.3 GeV, in clusters: 15.5 GeV Clusters(Σ): 13 Mean Dts: 2 Filter Type: 10 Trigger Dts:

■ 1 GeV (EB)

■ 5 GeV (FD)

CJ
CZ
TB
PB
EB
PE
EE
HP
MB
FD
TR
TT
FI

TH1
TH2
TBM1
TBM2
TDT02
TOFOR
TOFMANY
H3X
ESTOTH1
ESTOTLO
TDT01
TDT01



Beam ON

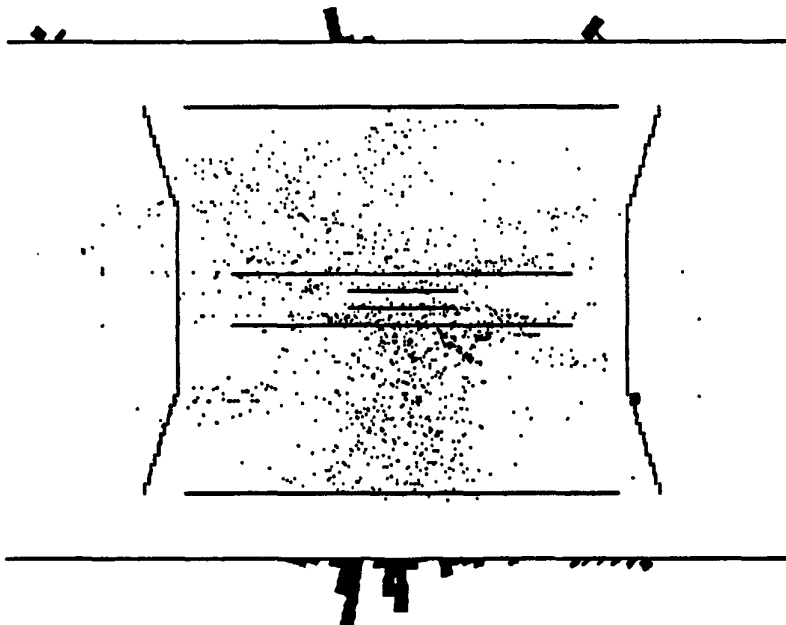
Run 446 Evt 61050 Total $\Sigma(E)$: 21.3 GeV, in clusters: 15.5 GeV Clusters(Σ): 13 Mean Dts: 2 Filter Type: 10 Trigger Dts:

■ 1 GeV (EB/EE)

■ 5 GeV (FD)

CJ
CZ
TB
PB
EB
PE
EE
HP
MB
FD
TR
TT
FI

TH1
TH2
TBM1
TBM2
TDT02
TOFOR
TOFMANY
H3X
ESTOTH1
ESTOTLO
TDT01
TDT01



Beam ON

17/08/1989 20:55:47

A 3-jet event at the Z^0 . The OPAL jet chamber did not yet have its full voltage, hence the Z coordinate was not reconstructed accurately

absolutely essential in allowing us to overcome the many physical and financial difficulties that we encountered along the way. These are not completely behind us as will be spelled out in the Renewal Proposal.

B.2. The OPAL Forward Detector (F. Desrosier, S. Hou, R. Kellogg, W. Miller, D. Norkin, A. Skuja)

The OPAL Forward Detector is being built by a collaboration of the University of Maryland, University College London, Brunel University, and Bologna University. The detector consists of two identical sub-detectors which encircle the beampipe on either side of the main OPAL detector (see Fig. 4). Each sub-detector consists of an electromagnetic calorimeter, a set of proportional tube chambers embedded in the calorimeter, two planes of tracking drift chambers, a set of four precisely located scintillator telescopes, and a ring of "gamma catcher" calorimeters which close the acceptance hole between the main forward detector and the OPAL pole tip. The clear acceptance window of the detector extends from 47 to 120 mrad from the beam. Since the trajectory of particles entering the detector is essentially parallel to the 0.4 T magnetic field of the OPAL central detector, the forward detector is essentially a calorimetric device, able to measure the energy and position of electrons and photons emitted at small angles to the beam direction.

The major task of the Forward Detector is to measure the beam luminosity by detecting the rate of Bhabha scattered electrons. Additionally we will be able to measure photons emitted at small angles to the beam which arise primarily through initial state radiation in annihilation events, as well as tag the beam electrons arising from gamma-gamma interactions with Q^2 in the range of 5 to 35 GeV^2 . Although the rate of photons from the process $e^+e^- \rightarrow \gamma Z^0$, where Z^0 subsequently decays to two neutrinos is high, we anticipate that the background rate will be too large to employ the forward detector to count the number of neutrino generations by measuring the rate of events which contain a single photon in the forward detector and nothing else in OPAL. The Forward Detector will, however, play an important role in

16 SEGMENTS
 $\Delta\phi = 22.5^\circ$ each

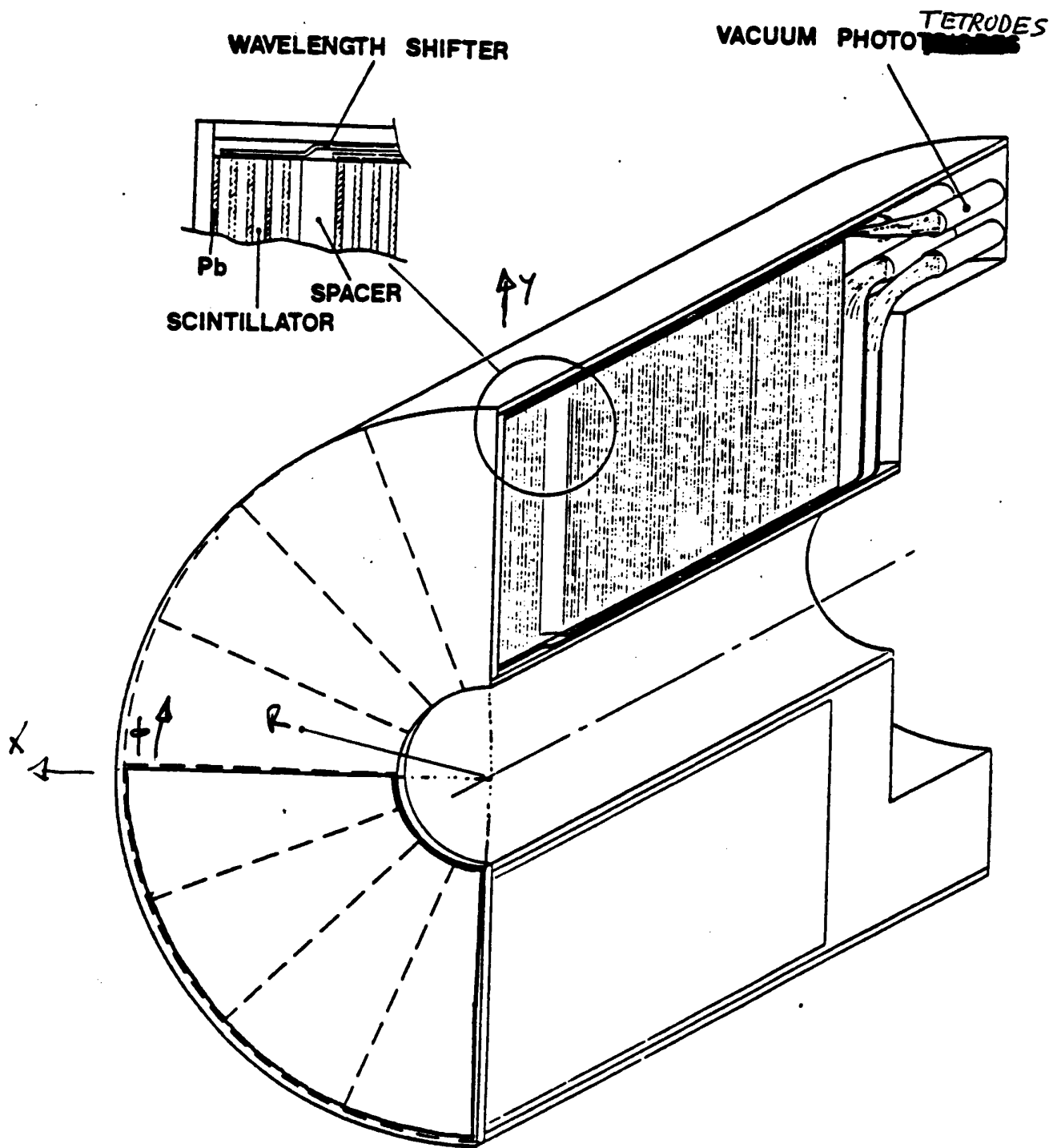


FIG. 4

neutrino counting by extending the OPAL veto coverage to small forward angles.

The calorimeter, built by the University of Maryland, is a cylindrical stack of 34 layers of Pb and pie-shaped scintillator segments (Fig. 4). Each of the 16-22.5 deg. towers of each calorimeter is read out through three wavelength shifters, one on the inside, and one on the outside of the main calorimeter section, behind the tube chambers, and one on the outside of the presampler section in front of the tube chambers. The location of an electron or photon trajectory, even if it showers before entering the detector, can be determined from the ratio of light outputs observed from the inner and outer readouts, and the energy sharing between adjacent azimuthal segments.

Since the forward detector is within the 0.4 T OPAL field, it is not possible to use standard photomultipliers to convert the wavelength-shifted light to electrical signals. The alternative of silicon PIN photodiodes was rejected due to the large signals which they give when traversed by minimum-ionizing particles, which would correspond to the equivalent of about a 20 GeV shower in the calorimeter. We have chosen instead to use Hamamatsu mesh-dynode phototetrodes which exhibit a quantum efficiency of about 20% and an electron gain of up to 70, which is not affected substantially by an axial magnetic field. Since the phototetrode signals are many orders of magnitude smaller than standard photomultiplier pulses, it is necessary to use a low-noise charge preamplifier located close to the phototube before using an integrating ADC to digitize the detector signals. We have chosen the pre-amplifier (FD ref. 2) designed recently by Richard Stevenson of the Rutherford Appelton Laboratory. These amplifiers exhibit a noise figure of only 170 electrons rms referred to their inputs.

The calorimeter was calibrated in a 50 GeV electron test beam in the summer of 1988. After these tests the light pipe system was rebuilt and a

second calibration in a CERN PS test beam was performed in April of 1989. Some calibration results for the determination of the Radius R and the angle ϕ of an electron shower in the calorimeter are shown in the accompanying Figures 1-3. The precision is quite good and can be exploited to yield an on-line luminosity reading. This can be further improved when electron trajectories in wire chambers upstream are added to the system off-line.

The energy resolution of the device is about 18% over the square-root of E (as expected in the original design). A position determining algorithm based on light sharing between different readouts of the calorimeter have achieved a resolution as small as 2 mm at R = 110 mm, growing to 20 mm at R = 280 mm. The ϕ resolution ranges from 0.2° to 1.5° and the R scale is known to ± 2 mm. Only small couplings between the radial and azimuthal functions are found.

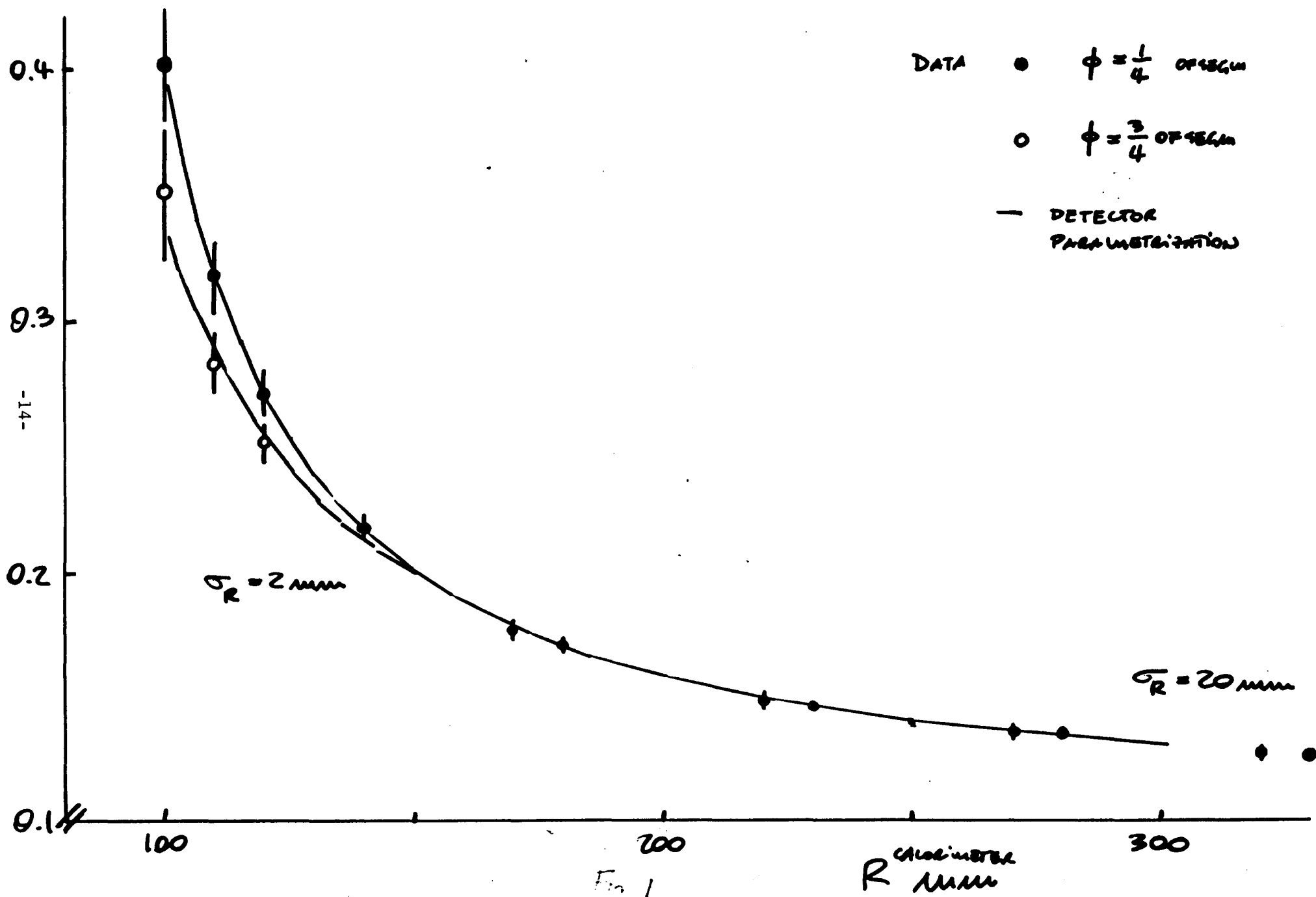
The Forward detector installation was completed at the end of June of 1989, despite extremely difficult working conditions due to the very restricted space available. Extensive on-line software work continued throughout July to ensure the calibration of the calorimeter.

Dr. Richard Kellogg of Maryland also designed the forward detector luminosity trigger for the OPAL detector using the Forward em Calorimeter as the active triggering element. The luminosity trigger can trigger on total energy deposition, back to back Bhabba events, as well as single tags. All these functions were tested during July and worked well during the Pilot Run.

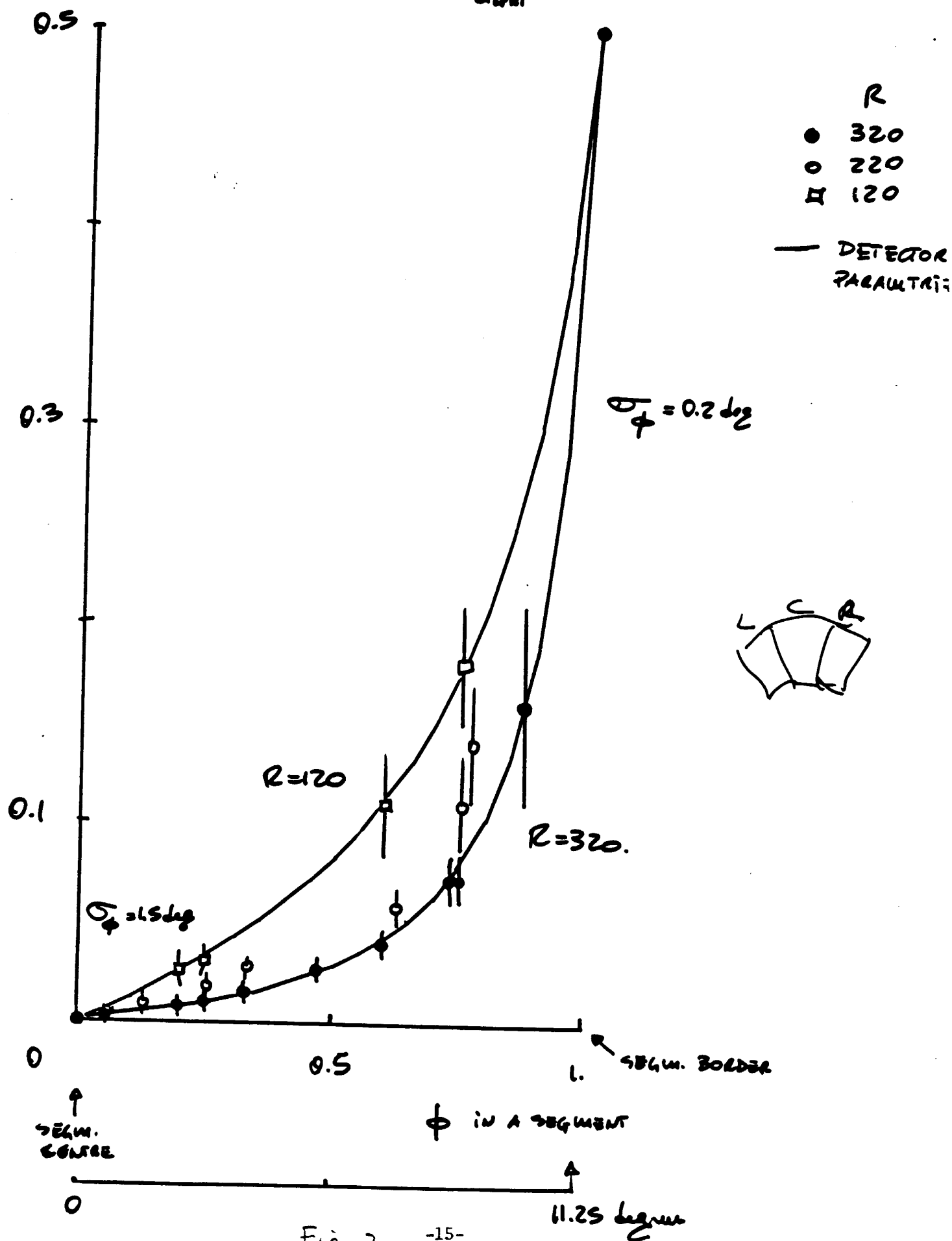
The Maryland group also made considerable contribution to the Monte Carlo software (shower parametrization) as well as on-line and off-line graphics (event displays).

During the pilot run 31 Bhabba events were observed in a kinematic region corresponding to $\sigma_{\text{Bhabba}} = 71$ nb. Fig. 5 shows a typical Bhabba event

$$\eta = \frac{E_{INNER}}{E_{OUTER}}$$



TM CALIBRATION



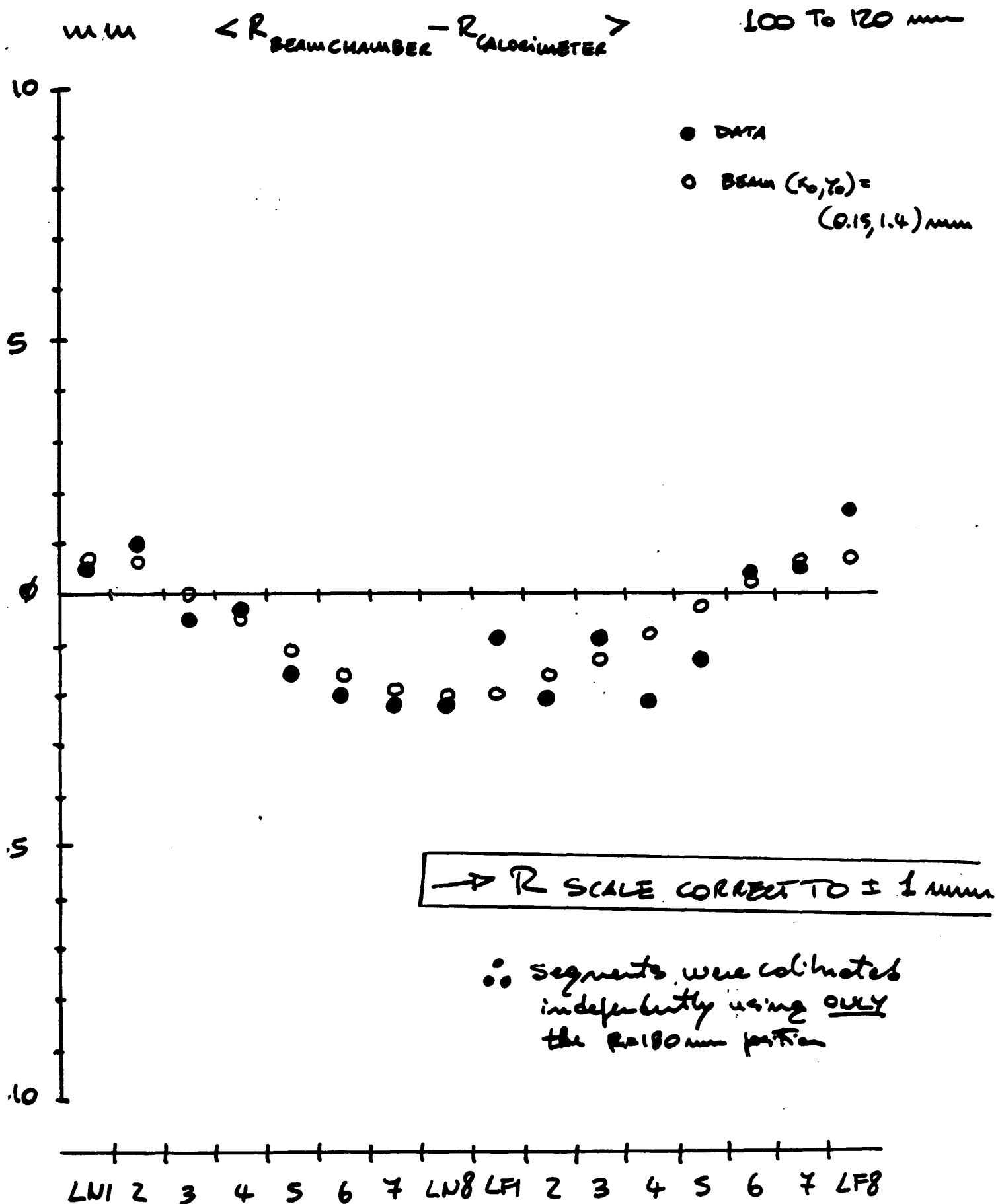


Fig. 3

Fig. 5

FD EVENT DISPLAY

Run:event 443:40663 Date 890814 Time 60631

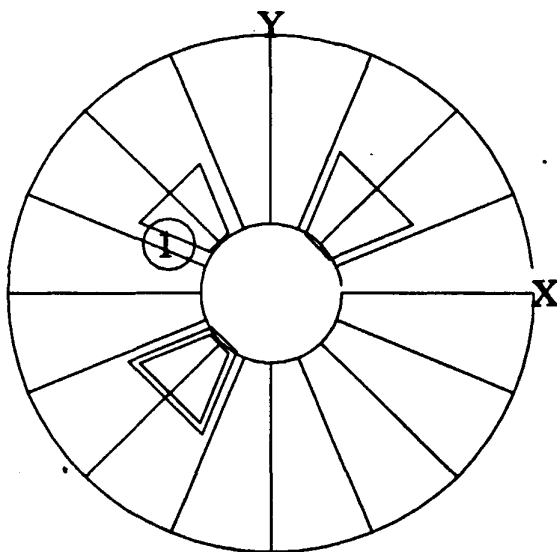
Ebeam 45.500

TRIGGER

SEG REAL
SEG LEFT
FL LEFT
REAL Es*Es

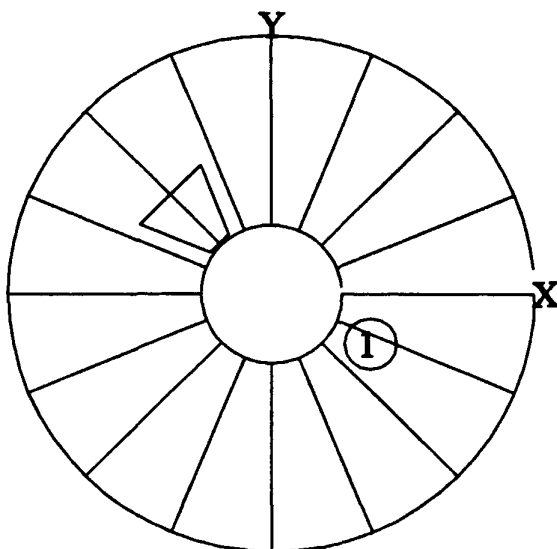
RIGHT

Ecl Eclp
40.8 1.0



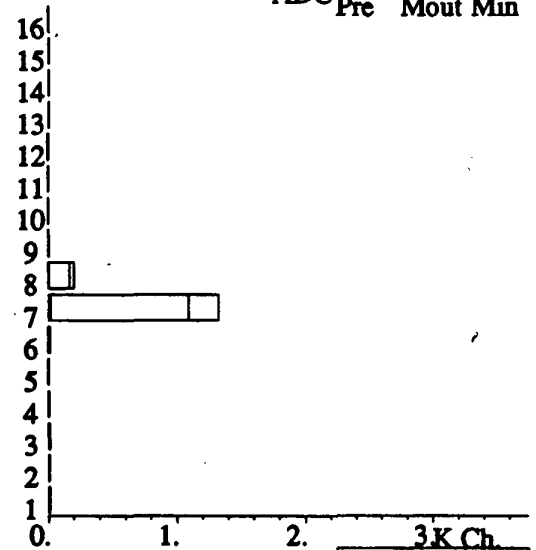
LEFT

Ecl Eclp
43.9 2.1



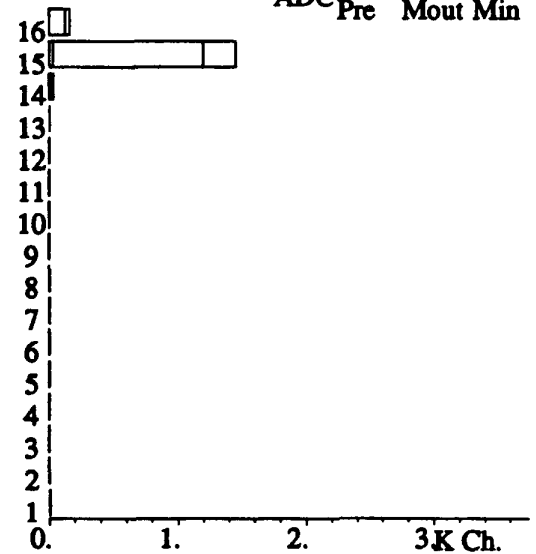
ADC

Pre	Mout	Min
-----	------	-----



ADC

Pre	Mout	Min
-----	------	-----



seen by the forward calorimeter. The black circles indicate the position of the electron positron pair, which the histogram displays the energy deposited in each segment.

We measured a luminosity of $\sim 0.44 \text{ nb}^{-1}$ during the pilot run. The error in this number is completely dominated by the small statistics. This corresponds to a differential luminosity $L \sim 10^{28} \text{ cm}^{-2} \text{ sec}^{-1}$.

B.3. Hadron Calorimeter Hardware & Online System. (A. H. Ball, R. Bard, J. Colmer, D. Fritz, P. Goldey, J. Lorah, L. Shaffer, W. Springer, and J. Subramanyam)

Introduction

The OPAL hardware calorimeter is now ready to operate. Many minor details remain to be finished, but all the systems are sufficiently advanced to allow commissioning to proceed using real data from collisions in LEP. At present, further progress awaits stabilization of the gas mixture following the long-delayed, approval given on August 18 to circulate flammable gas in the detector.

During the last year, remaining components of the low voltage, high voltage, monitoring and readout sub-systems have been designed and built at Maryland. Meanwhile, the strip readout electronics have been completed by our colleagues from the U. of California, Riverside. At CERN, teams from Maryland, Bologna, CERN and Riverside have finished installation of the on-board items (housed locally on the magnet iron). Our 50 Km of umbilical cables have been laid, connected and tested, to carry gas, high voltage, low voltage and signals between the on-board housings and the electronics hut (rucksacks). The gas mixing system and gain monitor have been built and installed in the surface gas building under Maryland supervision and the 256 circuit, underground distribution system has been installed and commissioned. Electronics to provide a hadron calorimeter contribution to the OPAL trigger have been designed and are being built. Online programs have been developed to read-out and monitor data from the calorimeter and to control its high voltage operation. These run in the OS9 environment of the 68010 "FIC" microprocessor - in the hadron calorimeter local systems crate. This allows stand-alone operation or integration with the global detector data

acquisition and control. The integration has been successfully tested.

(i) Cabling

Although the use of CERN-supplied manpower was mandatory for the installation of umbilical cabling between on-board housings and electronics rucksacks and gondolas, very close supervision by Maryland physicists, engineers and technicians proved essential. The planned cut-to-fit approach was very time-consuming and error-prone. Consequently, most cables were prepared in advance, with all connectors pre-fitted, by a team from Bologna and Maryland. To boost available manpower, an outside contractor, Spie-Trindel, was hired to fit high voltage connections, with very satisfactory results. Finally, the flat ribbon signal cables, whose fire-retardant halogen-free insulation is particularly vulnerable, were installed by our own personnel. By testing connections, and replacing bad cables, outside the working hours of the CERN teams, the efficiency of the cabling operation was improved sufficiently to allow its completion by the end of February 1989, more or less on schedule.

(ii) Gas System

The simplified gas mixer designed last year is now installed in the SG6 gas building. It consists of 2 parallel pairs of argon and isobutane supply channels, one pair controlled electronically, the other manually. The manual system is intended for use as a back-up or during purging. After mixing at a controlled pressure, the 75% isobutane, 25% argon mixture is supplied to two underground distributions, one for each side of the experiment. Each can be individually isolated by electrovalves connected to the slow controls system. The total input and output flows are set by manual rotometers, while input and output overpressures are electronically monitored via the oil level in bubblers. Each of the 128 separate gas channels supplied on each side is

equipped with an electronic flow comparator which monitors the ~ 4 liters/hour input and output flows with an accuracy of about 10%. A safety flow of nitrogen is added to the returning gas mixture at a small overpressure to guarantee that no air can be introduced into the detector. A pump in the mine rack returns used gas to the surface, where it can be monitored for oxygen before being vented to the common exhaust.

Each individual gas circuit was tested for integrity using a separate gas supply and return bubbler. One such circuit supplying a layer 5 endcap quadrant, was found to have sustained serious damage during the final stage of magnet assembly and leaks too badly to be operated. The final 75% isobutane mixture is now flowing in all the remaining 255 channels. The overall leak-rate of ~15 liters/hour is considered very satisfactory.

Permission to use flammable gas was delayed for months, for all low pressure gas detectors at LEP, by increasingly stringent safety requirements being imposed, particularly on the surface miner building. Furthermore, since approval was given just before the "pilot" run at Z^0 energies, it was considered imprudent to fill the hadron calorimeter (by far the largest hydrocarbon content) for fear of a lengthy automatic shutdown of power being provoked by a relatively minor gas leak. Nominal operating conditions are, however, expected to have been reached by the time the physics run starts.

A gas-gain monitor operates from a local branch of the miner output. It consists of 3 groups of 4 chambers stacked between a 3-fold scintillator coincidence telescope. The charge registered by each chamber in response to cosmic rays is read into an ADC in the gas control room. Programs running in the gas-control systems crate microprocessor analyze the charge distributions every 15 minutes and transmit this data over ethernet to the hadron tower data acquisition crate. The gas-gain information derived is included in the data

shower for each event. In addition, the local software is capable of notifying the OPAL slow controls system if the gas-gain moves outside an acceptable range. Since this may indicate a bad mixture, the system acts to isolate the miner from the underground distributions by closing the electrovalve in the feed line and stopping the return pump. The resulting rise in return line pressure is sensed by the bubbler in the two underground distributions, tripping the isolating electrovalves of both of them.

(iii) High Voltage

The 7500 streamer chambers, supplied by 1152 separate high voltage channels, have been ramped simultaneously up to 500 V, the maximum acceptable with pure argon. This test revealed 2 new faulty chambers, not significantly affecting the total of 2% of all chambers that had to be disconnected on the basis of unstable performance during previous testing of the barrel and endcap modules before assembly.

The high voltage control software has been adapted to accommodate the anticipated high initial rate of current surges characteristic of large systems of plastic streamer chamber. Overcurrents or undervoltage in one of the 144 power supply outputs now produces an interrupt, initiating a search program which identifies the faulty group of 8 channels. An 8-bit status word describing these channels is zeroed, and the shift operator alerted to manually identify the faulty channel. Once this is removed, the output is reset and the status word modified so that only one bit remains zeroed. The 144 status words are read into each event record so that the exact operational status can be taken into account during analysis.

(iv) Low Voltage

Four 18-channel switches and four master crates were completed and tested at Maryland in early '89. These allow the 72 on-board housings to be

independently powered, and provide separate +5V and -8V fusing for all the electronics cards contained within them. The printed circuit master panels incorporate fault lights to indicate blown fuses or power disconnection at the housings. In addition, voltage sensors send signals to the slow controls system if any of the required voltages is absent.

(v) Readout & Data Acquisition

The tower and layer 1 readout chains are now complete up to the ADC's, although the receiver cards built at Maryland in the past few months were severely delayed by the late delivery of pulse transformers.

Despite the non-availability of operating gas mixture, the wire monitor pulser system (see below) has allowed exhaustive testing of the 976 tower summing amplifiers and 800 layer 1 amplifiers contained in the various on-board housings. At present 99.5% are functioning normally. Most problems were caused by damage to, or bad connection to, the special fire-retardant polyolefin-insulated ribbon cables used for readout of the amplifiers.

A first study of the pedestal widths of the tower ADC channels revealed severe noise picked up by the output tracks of 8 of the 36 transformer networks on each barrel receiver. This may have to be corrected by replacing the tracks with twisted pair cables, or by close shielding of each receiver card.

The long-term nature of the LEP experiments is reflected in the decision to limit their use of electronics pool resources (such as NIM & CAMAC chassis logic modules, etc.) It was therefore essential to purchase the items referred to in our May 1989 supplementary proposal to minimally equip the readout racks. More such items will be necessary to complete the trigger installation. (see below).

A complete suite of programs now exists to read-out and calibrate the

hadron calorimeter tower and layer 1 ADC's and WML 1/4 layer batches. Similar programs have been developed by our Riverside colleagues to read the strip information from the controller memories.

On receipt of a trigger, latch patterns and (after conversion) tower and layer 1 ADC values are read into the memories of the separate master and slave "FIC's" serving the 2 sides of the calorimeter. On completion of the read, command, pedestals are subtracted to leave only addresses and charge values for channels above threshold. The addresses of latched WML 1/4 layers are similarly stored. A merging and formatting process then combines data from the two sides in the master FIC, using the "VIP" link between the two OS9 crates and arranges the data in ZEBRA format. On demand the ZEBRA banks are transmitted to the event builder. An auxiliary process can also transmit events via ethernet to a local VAX station. A histogramming routine samples the output stream, generating arrays which are formatted at intervals as H-BOOK histograms for display.

ADC pedestal values are read and stored in a dedicated run before each filling of LEP and in shorter runs during pauses in data-taking. An analysis routine calculates average pedestal values and widths for each channel, storing these in a data module for use by the subtraction routine, and for regular transmission to the offline data-base.

(vi) Monitor System

Assembly of the wire monitor latch (WML) cards, which discriminate, then latch or scale the wire signals from each group of 6 chambers, was completed during Spring 1989. By staging shipments to CERN, it was possible to finish our board installation of these while suitable working platforms remained in place. The WML's incorporate a test pulser, which on command will inject, onto the chamber wires, pulses chosen to induce appropriate signals on the

pads and strips for test purposes. Despite some initial problems with the address and data buses, the WML has performed very well, enabling thorough testing of both pad and strip readout chains even though the chambers themselves could not be operated for lack of gas. Programs are being written to automate this test procedure, and to read both the latch and singles rate information.

Monitoring of the detector performance via diagnostic histograms takes place at 2 levels. Since filtering of events occurs before collection by the online VAX, basic histograms for each detector have to be generated in the local "FIC" microprocessor. Consequently the strip diagnostics in the dedicated strip readout FIC are separated from the tower, high voltage, WML, gain and status information. Software to recover all histograms together at the online VAX exists, but the sophistication of the monitoring is limited by the data acquisition duties of the FIC. The VAX itself provides limited possibilities for combined monitoring on a selected sample of events, although at present only a sub-set of those in the FIC are generated. A longer term solution may be provided by local VAX-stations with large disk capacity,, sampling the sub-detector events assembled by the FIC's.

(vii) Safety & Slow Control

At the request of the safety officer, an attempt was made to inert the volumes containing chambers and on-board electronics. To this end, nitrogen purge lines were fitted to each housing, and sniffer lines, attached to a multiplexed analyser, were inserted around the electronics contained in the end of each barrel wedge module. Although a determined effort was made to seal the volumes concerned, the oxygen level could not be markedly reduced for any reasonable nitrogen flow. Considering that these volumes were not engineered to be gas-tight, such a result is perhaps not surprising. The

system has been modified to include isobutane sensors, and by deliberately opening all seals, the purge facility may be utilized with compressed air to disperse any leaks which are detected.

To satisfy the requirement for monitoring DC voltages in many electronics crates of differing design and function, a basic monitoring card was developed at Maryland. Mounted in suitable NIM, CAMAC or VME modules, such cards provide optocoupled signals to the slow controls system to verify power loss. The low voltage, high voltage and gas systems exchange signals with slow controls as previously described. Application software containing rules governing the actions to be taken and warnings to be given remains to be developed.

A major feature of OPAL is its rapid opening into 3 sections for maintenance. Before this can happen safely, many umbilical cables linking the sections have to be disconnected. A simple key interlock system has been installed, using keys attached to vulnerable cable bundles. This warns the operator if they attempt to open the experiment before all necessary disconnections have been made, to allow the keys to reach suitably mounted key-switches.

(viii) Trigger

Following intense pressure on manpower at CERN in Spring 1989, design of the hadron calorimeter component of the OPAL trigger was shifted to Maryland. After reassessment and Monte Carlo studies, the original scheme was substantially simplified.

Suitable attribution of tower signals to channels of the "CIA" ADC's makes the 16-fold sum signals which they generate correspond to the summed charge in 4 x 4 blocks of towers. There are 92 such blocks, which form the basic trigger elements. Each has a separate pedestal, which must be subtracted using a different amplifier and a CAMAC addressable DAC.

The main feature of the modified design is that, after pedestal subtraction, the processing is entirely digital. Three separate thresholds, E_1 , E_2 & E_3 ($E_1 < E_2 < E_3$) are applied to each signal. These thresholds are individually adjustable for each of 18 half-rings composed of typically 6 elements. The 92 " $>E_1$ " signals are mapped onto the 144 elements of the hadron layer of the θ - ϕ matrix which is a key feature demanded within the layers, and with corresponding elements of other layers serving the tracking detectors, lead-glass, time-of-flight counters and outer muon detectors.

The " $>E_3$ " signals are used as a "hadron cluster" trigger, but coincidences with at least one other detector will be necessary to reduce triggers from cosmic rays, which would amount to ~ 5 hz even at a threshold of 15 GeV. To allow for the possible splitting of energy between two or more elements the " $>E_2$ " signals are grouped into all possible 2×2 arrays. Simple programmable array logic then generates a trigger if two or more elements within any array are on.

Monte Carlo simulations of multi-hadron events at Z^0 energies show that for realistic thresholds, this trigger has as good an efficiency as one where the pedestal-subtracted analog signals are added in all possible 3×2 arrays before discrimination.

The "TPMATCH" cards which interface the " $>E$ ", signals to the trigger matrix are now being assembled at Maryland, but the "TRIGCOMP" cards which perform pedestal subtraction, and set thresholds, still need design and modifications. These are mostly concerned with integrating the pole-tip calorimeter signals into the hadron trigger. Most necessary cabling is already in place, and it is hoped to have signals available for the matrix by the time the hadron layer card is ready in November 1989.

(ix) Commissioning & Longer Term Prospects

It is hoped to operate the detector for about a week for final commissioning before the physics run starts. This will give some time for debugging (particularly of high voltage), before access to the on-board distributions is once again lost. The basic online acquisition and monitoring software will be frozen at this stage, with little change from the current status. Work will continue to allow strip and tower data to be combined and monitored at the local VAX stations connected to the local systems crates.

The initial performance should be close to that achieved in the winter 1988 test beam. For example, Fig. 1 shows the tower response as a function of angle for various incident single pion energies. The predictions of a Monte Carlo simulation are shown for comparison. Fig. 2 shows the muon identification efficiency for known muons, compared with the probability of mis-identifying a known hadron as a muon, both as a function of layers in which hits are demanded.

To achieve optimum performance, extensive calibration work will be necessary using both muons and test pulses to measure the response of each tower separately. Similarly, the strip comparator thresholds will have to be tuned to get the best compromise between efficiency for single muons and multiple hits due to cross-talk.

Maintenance promises to prove a serious problem, due to the size of the detector and the expense and logistics involved in returning components to Maryland for repair. To partially relieve this problem, we intend to set up a small lab. equipped with a local systems crate, associated "FIC" microprocessor, a CAMAC crate and high and low voltage supplies. This will provide a diagnostic and test facility for hardware maintenance, and also a much-needed OS9 software development environment de-coupled from the data acquisition system, which will be in continuous use during LEP operations.

Tower response .. Bare HCAL

π^- beam

Real data

MC data

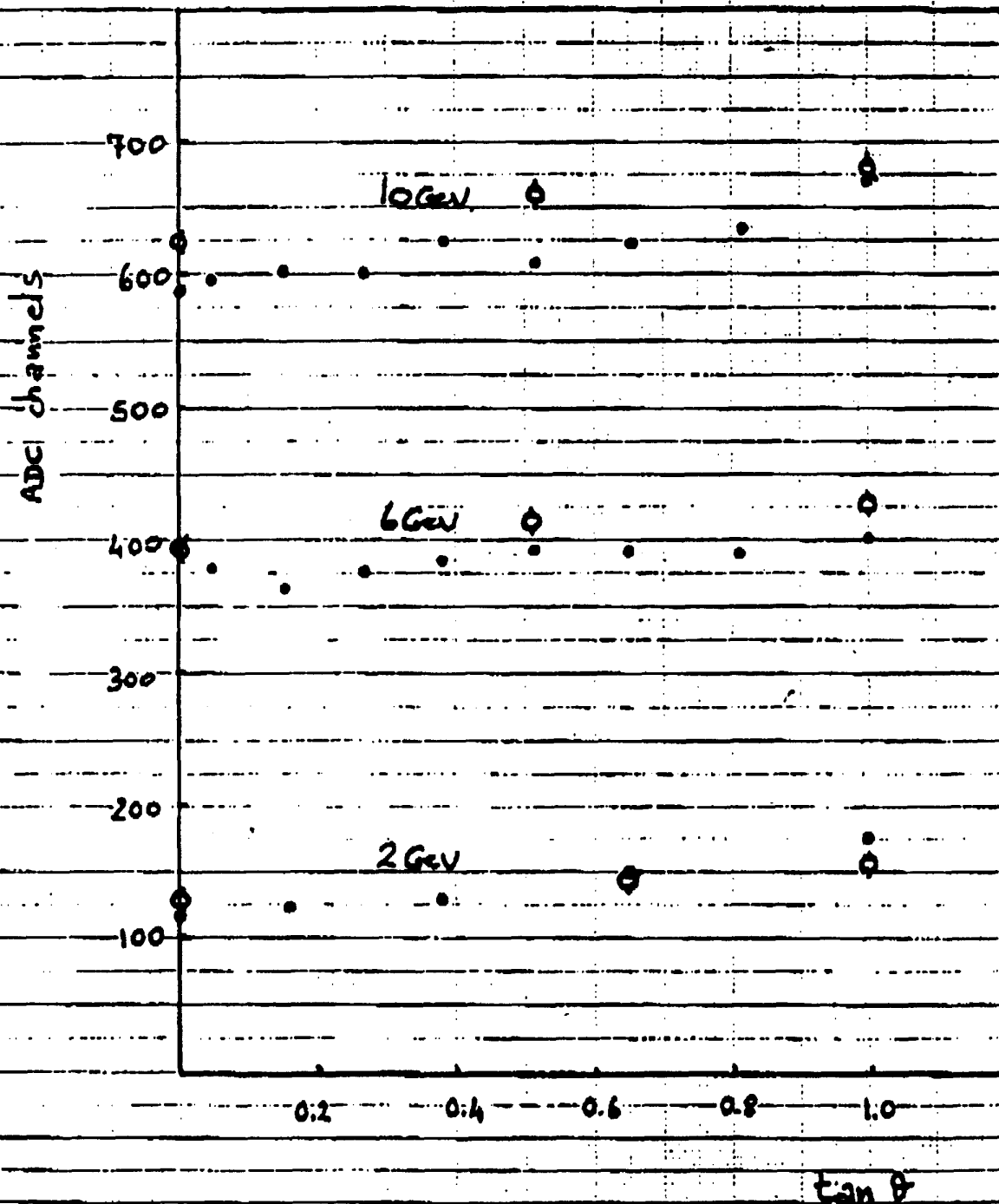


FIG 5.2.3 AVERAGE TOWER RESPONSE TO SINGLE PARTICLE PION BEAMS OF VARIOUS ENERGIES AT VARIOUS ANGLES OF INCIDENCE θ . ALSO SHOWN ARE THE PREDICTIONS OF A MONTE-CARLO SIMULATION

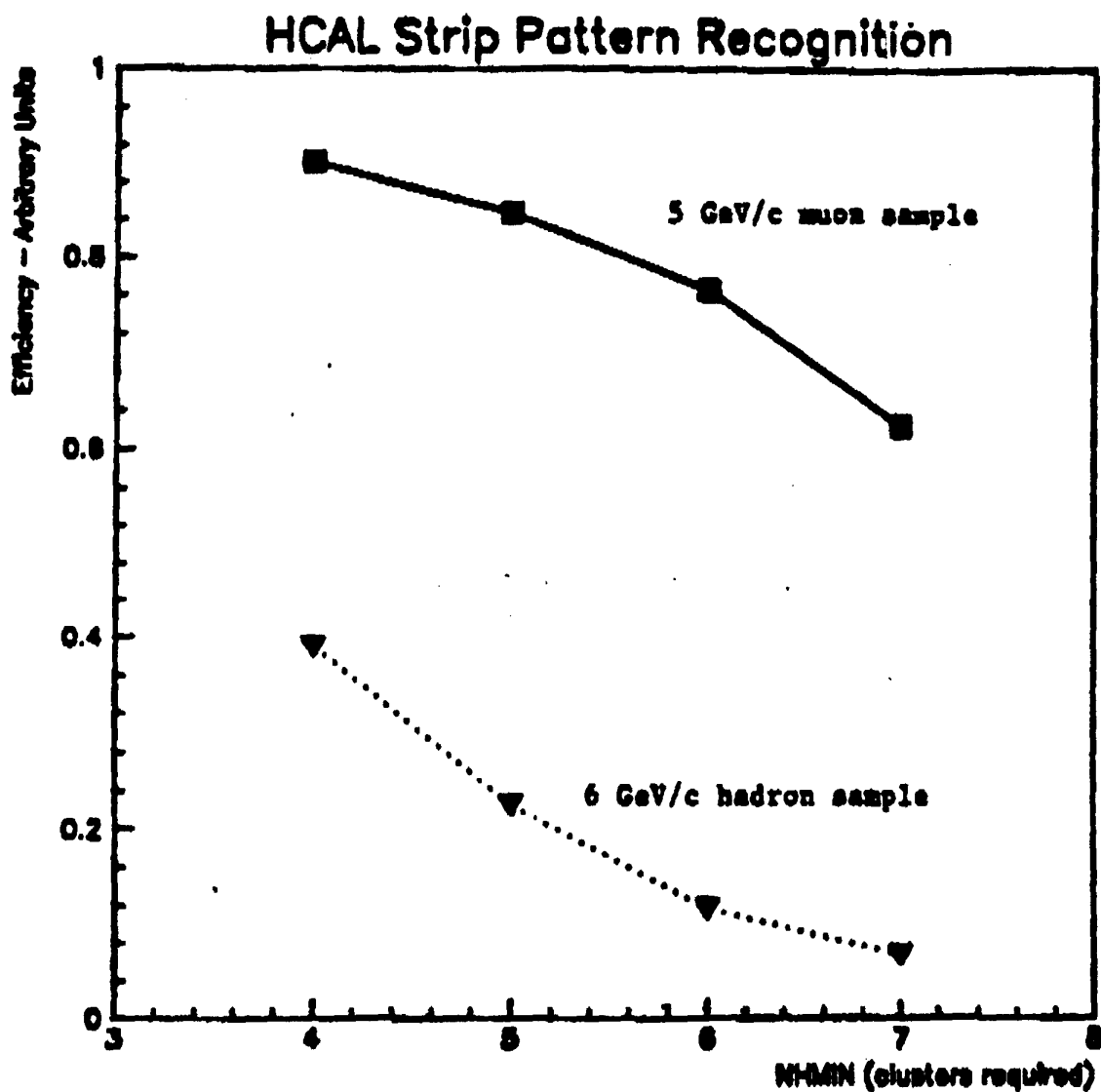


Fig 5.2.4 Muon efficiency vs. number of layers allowed

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B.4. Off-line Software Development for OPAL. (A. Buijs, C. Y. Chang, S. Hou).

1. Introduction

Over the past years, the development of simulation and reconstruction code for the OPAL hadron calorimeter has taken place in parallel with construction and commissioning of the hardware. Up to now, the offline code has been based on two main programs.

- a. GOPAL, the simulation code for OPAL
- b. ROPE, the offline reconstruction code that produces the final Data Summary Tapes, given the raw data as input.

Recently, a third program has been developed, GROPE, an interactive version of ROPE for event viewing and scanning. It is generally felt that scanning of a large data sample will be necessary, especially in the first days of data taking.

In this report, we will discuss the progress on all three programs with respect to the hadron calorimeter.

2. GOPAL

GOPAL is the simulation program for the OPAL detector. It is based on the GEANT package, for tracking generated particles through a realistic description of the OPAL geometry.

GOPAL can be run in one of three modes:

- a. The full mode, in which a detailed description of all detector components is used, and particles are tracked down to low energies.
- b. The smear mode, in which the detector is described in coarse structures with average material densities. Tracking is stopped at higher energies, and parametrizations are used to describe the detector response.
- c. The no detector mode, in which no tracking takes place and the DST is

filled straight from generators.

The full mode generates data in the form expected from the data acquisition chain and is therefore most important for obtaining an understanding of the detector and for developing offline reconstruction code. In this mode, three steps are taken for each detector component, in the form of calls to three routines:

- a. GEOM, the set-up of the detailed description of the device using GEANT,
- b. HITS, in which quantities are stored for each tracked particle that is found to traverse an active component of the detector, and
- c. DIGITS, in which the response to the hits is simulated.

The Geometry and HITS routines for the hadron calorimeter barrel and endcap had been developed some time ago and are thought to describe the calorimeter adequately.

The DIGITS routines, both for the barrel and endcap have been rewritten completely in the past year, mainly for two reasons:

- a. Results from a testbeam module similar to the actual calorimeter have become available.
- b. The exact format of the raw data from the data acquisition system have been established. In the past, the raw data were split between barrel and endcap, whereas the physical layout of the electronics requires a separation in towers and strips.

In the rewriting of the DIGITS code, the following strategy was followed: the free parameters in the simulation were adjusted to fit the results obtained from the testbeam for muons under various conditions. Subsequently, it was checked that the simulation of pions under the same parameters agreed with the test beam results for pions.

The following effects were taken into account in the simulation:

- a. Hits in inefficient areas of the tubes (chamber walls) were removed.
For efficiency reasons, not every Iarocci tube has been coded into the geometry, but instead a whole layer was defined as an active area. Therefore, a small fraction of the tracks has to be removed in the digits stage.
- b. Tracks traversing a layer under a shallow angle are made to give hits in several adjacent cells.
- c. Tracks overlapping along one tube are merged to give a single hit.
- d. The charge deposited by the streamer on the wire is parametrized as a function of the track angle w.r.t. the wire. For the parametrization, a linear combination of a Gaussian and a Landau distribution, both with identical means and widths was used.
- e. Parametrization as a function of charge deposition is used to calculate the number of cross-talk hits induced on neighboring strips.
- f. In the calculation of the charge deposited on the pads, the overlap on adjacent pads of one streamer is taken into account, and a correction is made for a dead area between pads.
- g. The density of the Iarocci tube material has been raised to give the average density of the chamber gas and walls, thus reducing the mean free path of particles traveling parallel to the layers. The energy cut-off of neutrons has been lowered.

The aforementioned effects were coded in a modular way, made easy through the use of the ZEBRA package, which allows the dynamic creation and deletion of data banks. A temporary bank can be created for each hit, and subsequent routines can operate on those, delete them or create additional ones. The use of ZEBRA banks avoids the necessity of large arrays, which are inefficient in memory usage.

3. ROPE

The raw data structures have been defined and are implemented in GOPAL and ROPE. With the use of the improved Monte Carlo simulation and the results of the test beam run, the algorithms have been improved to find energy clusters in both the towers and strips and to find muons traversing the calorimeter. The final results of the clustering algorithms are propagated to the DST.

Code has been developed to store information in the OPAL database and to retrieve it during the analysis. This applies for detector parameters like survey constants, as well as for time-dependent quantities like pedestals and gains.

4. GROPE

In the framework of the interactive version of ROPE, an event viewing program has been written, based on the GKS standard, to display the various components of the OPAL detector. GROPE is installed on VAX, IBM and APOLLO computers and is operational on the VAX cluster in Maryland. A three-dimensional view of the hadron calorimeter is included in this package, showing both the tower signal and the strips. In addition, a 'roll-out' view is being developed that can be superimposed on similar views of the electromagnetic calorimeter.

5. Physics Workshop

As part of the preparation for data taking, a physics workshop was held in the first days of June of this year. To this end, 20,000 multihadronic events were generated and analyzed. In addition, samples of specific event types were generated. Several members of the Maryland group (G. Zorn, S. Hou, G. Snow, and D. Fong) have participated in the mu pair and tau pair working groups. (The latter is lead by A.Buijs). Samples of these event types have

been generated also on the Maryland VAX cluster. Other members have participated in the Luminosity Group (R. Kellogg, C. Y. Chang, S. Hou and A. Skuja) and in the b pair production group (A. Jawahery). As a final exercise of the physics workshop, a mixed sample of events corresponding to the first days of data taking has been generated, with a composition known only to one person in OPAL. When the true content of this 'Pilot run simulation' was revealed, the tau analysis group had correctly identified the tau events, with an efficiency of around 80%. In this exercise, it became clear that the hadron calorimeter will potentially play a significant role in the separation of pions and rho mesons. However, detailed algorithms for this still have to be developed.

6. Calculation of the OPAL Forward Acceptance

Very recently a detailed study of the acceptance of the FDCAL of the OPAL detector has been carried out by C. Y. Chang, and S. Hou, using a Monte Carlo simulation of the calorimeter responses to single electrons and to Bhaba events at LEP energies. To reduce the computation time, electromagnetic showering processes in this analysis are handled with a bootstrap method. A similar analysis without the bootstrap has been carried out by J. E. Conboy and M. Dallavalle of U.C. London.

An overall view of the forward detector layout is shown in Fig. 1. The detector has cylindrical symmetry about the beam axis. The material encountered by electrons or photons from the interaction point of OPAL to FDCAL was carefully mapped out. The non-calorimetrized material is shown in Fig. 2a and 2b. Fig. 2b shows that the support structures make up a few radiation lengths of inert material in the $\theta = 40$ mrad to 49 mrad angular region, and also beyond ($\theta = 120$ mrad). The FDCAL consists of a preradiator with inner edge at $\theta = 44$ mrad and the main calorimeter with inner edge at

Technical drawing of the Forward Detector Layout, showing various components and their dimensions. The drawing is oriented vertically on the page.

Components and Dimensions:

- PH TUBE A**: Located in the upper left section.
- PH TUBE C**: Located below PH TUBE A.
- PRE SAMPLER (16 LAYERS)**: A vertical component in the center.
- MAIN CALORIMETER (129 LAYERS 3.4mm Pb, 0.0mm SCINTILLATOR)**: A large rectangular component on the right.
- FINE LUMINOSSITY MONITOR (16 SENSORS 400 SENSORS AT 45° IN THE VERTICAL)**: A vertical component on the left.
- CATCHER**: A component on the far left.
- TC 1** and **TC 2**: Thermocouples located near the Fine Luminosity Monitor.
- Tube Chamber (16 LAYERS)**: A component near the Pre Sampler.
- Gap for Lead & Gas Lines**: A horizontal gap at the top.
- Stainless Steel**: Labeled on the right side of the Main Calorimeter.
- 10 HRAD** and **47 HRAD**: Radiation levels indicated on the right side.
- Scale Bar**: Located at the bottom, showing 0, 50, and 100 mm.
- Grid**: A coordinate grid with dimensions ranging from 0 to 3000 mm.

Text and Notes:

- FORWARD DETECTOR LAYOUT**: Title at the bottom center.
- DRAWN MARK DRYBURN**: Drawn by Mark Dryburn.
- REF ANDREW CHARALAMBOUS**: Reference to Andrew Charalambous.
- SCALE: FULL SIZE**: Scale of the drawing.
- DATE: 23-2-80**: Date of the drawing.
- NOTES**: A section at the bottom right containing additional information.

DRAWN MARK DRYBURN
REF ANDREW CHARALAMBOUS
SCALE: FULL SIZE
DATE 23-2-00

FORWARD DETECTOR LAYOUT

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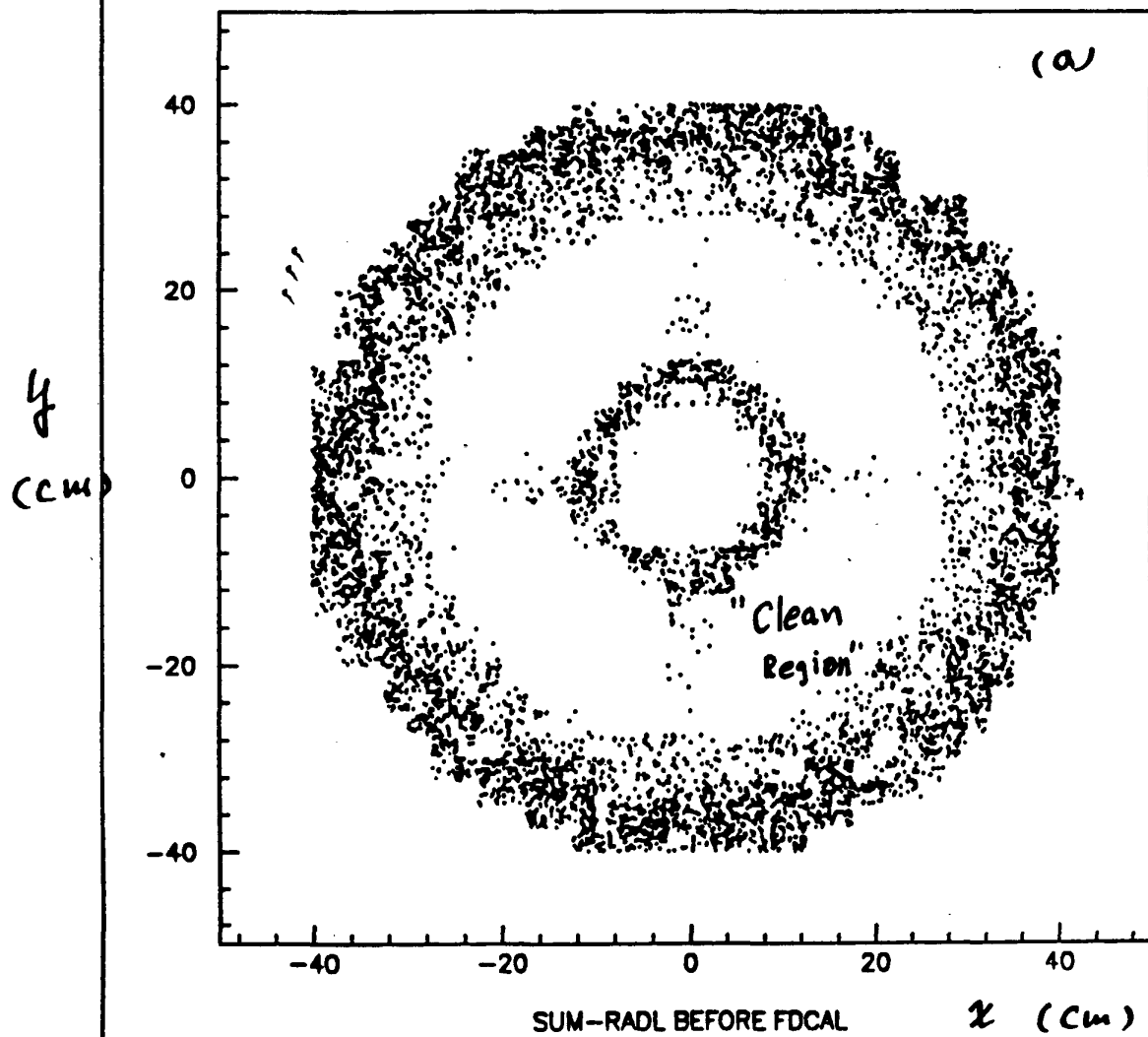


Fig. 2 - a

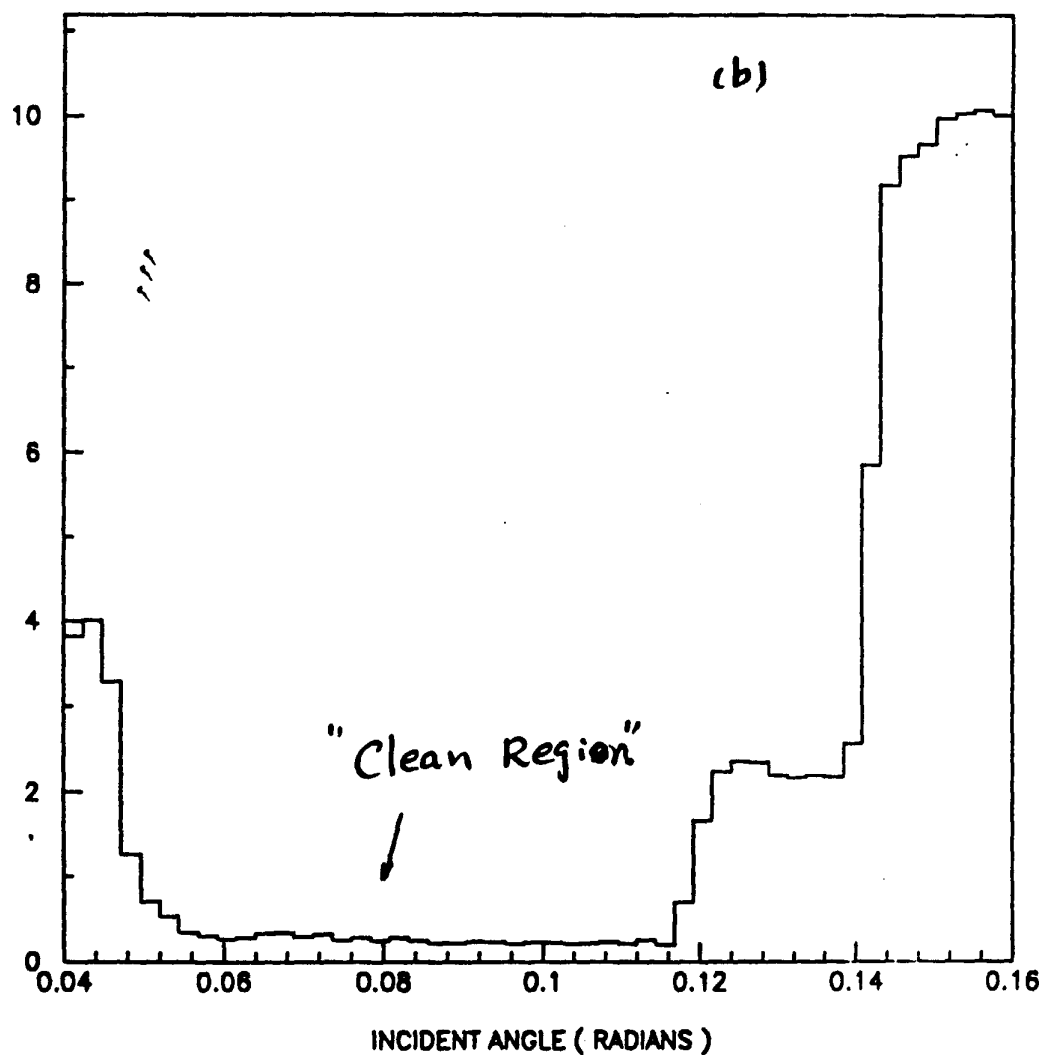


Fig 2 - b

$\theta = 39.9$ mrad. It is crucial to define the inner edge of the acceptance region with great accuracy since the integrated Bhabha luminosity is proportional to $1/\theta^2$. A 1% error in $\theta_{\min}$ (0.4 mrad at 40 mrad, corresponding to a $\Delta r = 1$ mm in calorimeter radius) leads to a 2% error in luminosity.

Fig. 10a shows the reconstructed calorimeter energy in one half of the calorimeter for Bhabha events generated at 90 GeV as a function of θ of the electromagnetic cluster. Comparing this with Fig. 10b that shows the number of radiation lengths of inert material in front of the calorimeter as a function of θ , one sees that the sharp fall off in calorimeter energy vs. θ in the 40-50 mrad region is directly related to the absorption of electromagnetic energy by the inert material. The pilot run has revealed that a threshold of energy in each half of the calorimeter can be set between 15 and 20 GeV. One possibility therefore to define the sharp angular edge of the calorimeter is to use a precisely set energy threshold of the calorimeter as the measure, since Fig. 10a illustrates that the energy threshold defines the angular threshold fairly precisely. Alternative possibilities are also being studied with the new faster Monte Carlo for Bhabha events. The aim is to minimize the systematic error in the luminosity measurement while keeping the maximum event statistics in the OPAL Bhabha sample.

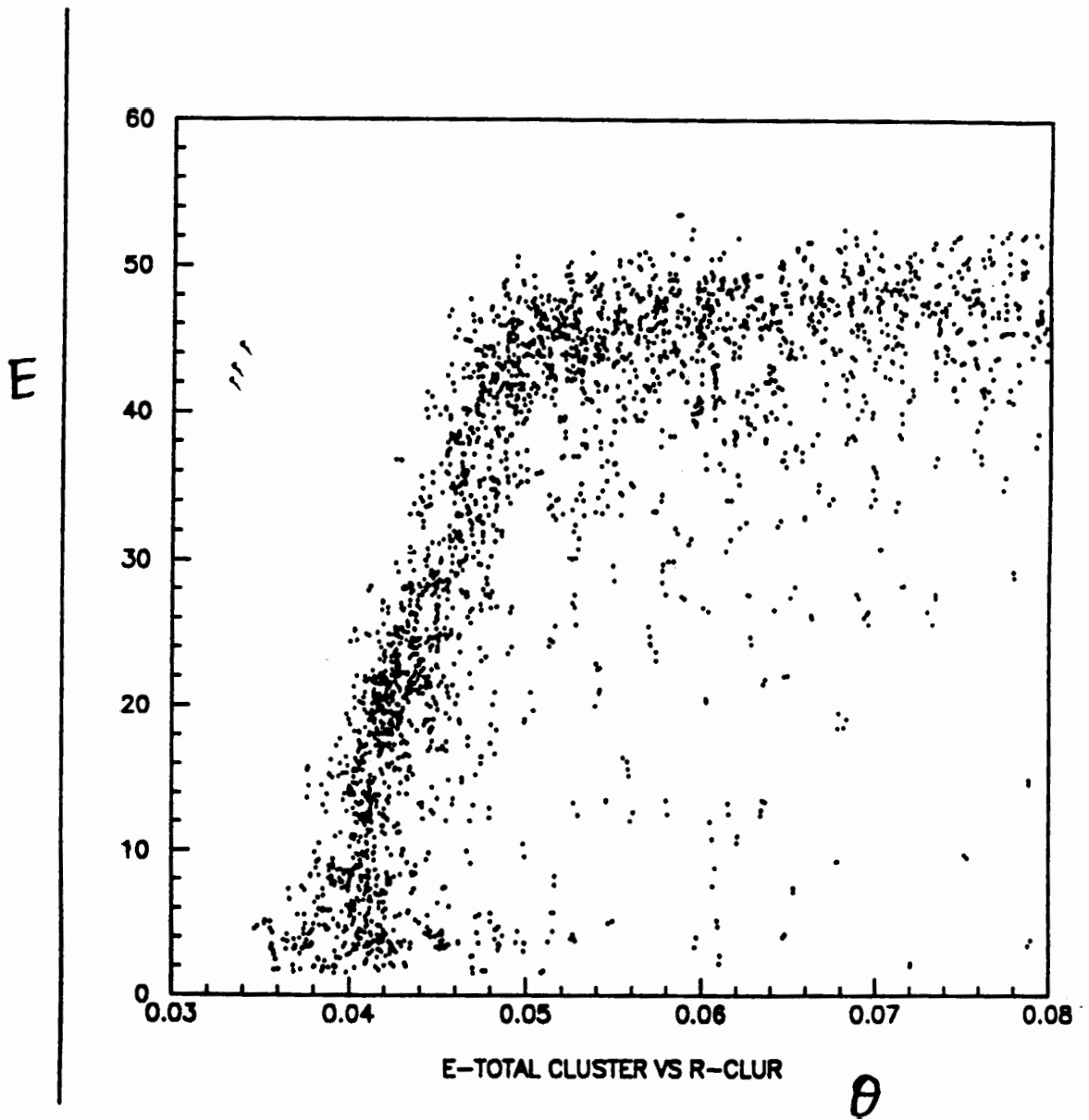


Fig. 10-a

Number of Radiation length

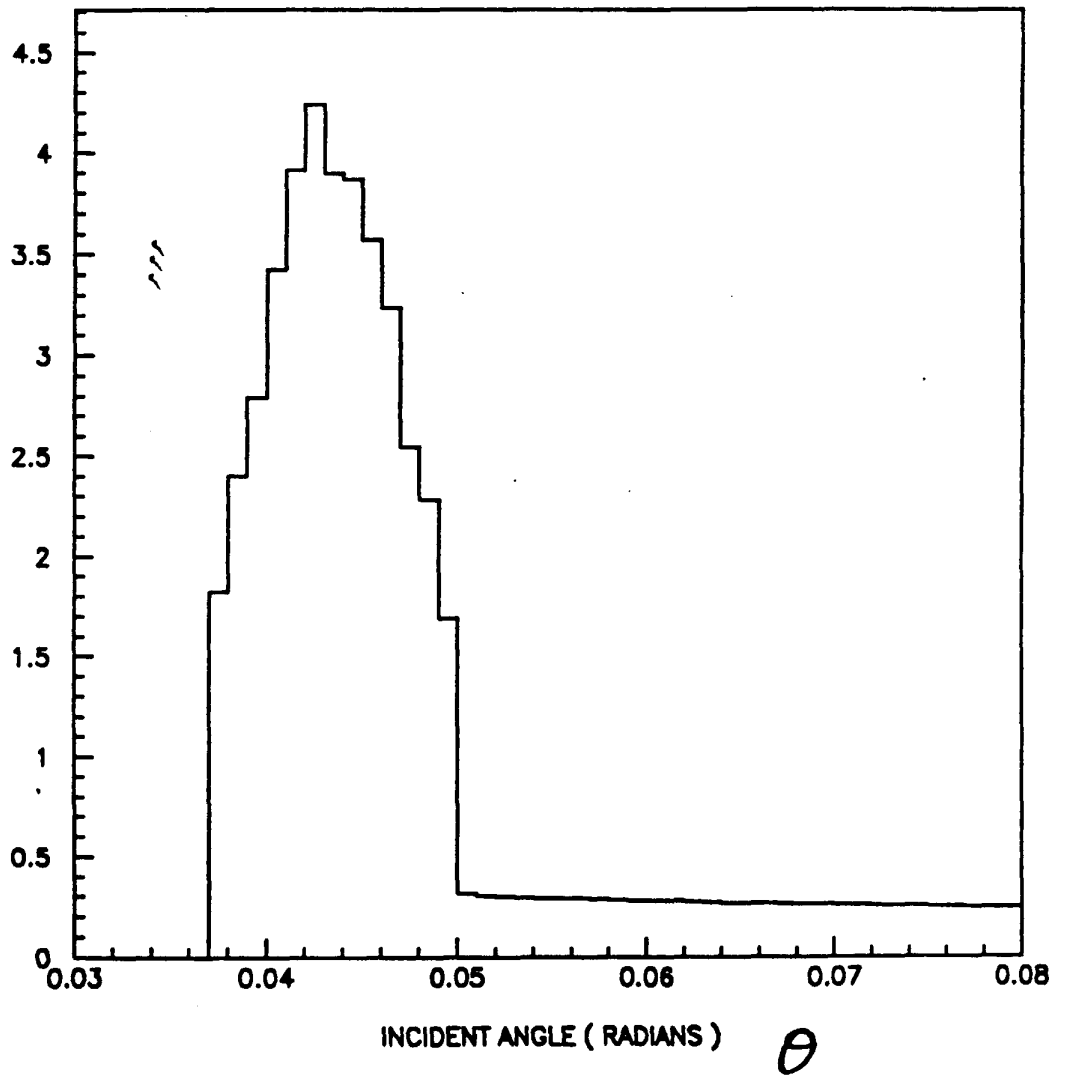


Fig. 10-b

C. Deep Inelastic Muon Scattering (E665 at Fermilab). (S. Aid, S. Kunori, S. O'Day, E. Ramberg, A. Skuja and G. Snow of the University of Maryland in collaboration with physicists from Argonne, California (San Diego), Cracow, Fermilab, Harvard, Illinois (Chicago Circle), Max Planck Institute (Munich), MIT, Washington, Wuppertal and Yale).

The Fermilab experiment E665 finished taking data from its first run in February 1988. In total 36 million triggered events were recorded on 3000 magnetic tapes. About 10% of muon scattering events have been reconstructed by a preliminary version of the reconstruction program after Data Split and Event Filter. The Data Split splits events according to their trigger types and the Event Filter reduces the data sample to one third by rejecting false triggers. Data analyses have been started while efforts to improve the efficiency of the reconstruction program is continuing.

A second run will start in January 1990. Major upgrades for the next run are 1) a new vertex drift chamber system replacing the streamer chamber, 2) a new target configuration and 3) improved triggers. None of these is the direct responsibility of the Maryland group. Our hardware responsibility for the next run is to fix and maintain the electromagnetic calorimeter in collaboration with Harvard University, similar to the last run.

In the following sections, we describe 1) summary of the 1987-88 run, 2) status of data processing, 3) status of analyses and 4) status for next run.

1. Summary of the 1987-88 run.

The E665 apparatus in the last run is shown in Fig. 1. It consists of beam momentum tagging stations (not shown in the figure), vertex system, forward spectrometer and muon system behind 3 meters of iron absorber. This open geometry with three magnets, beam tagging magnet (NMRE), the vertex magnet (CVM) and the forward spectrometer magnet (CCM), provides good

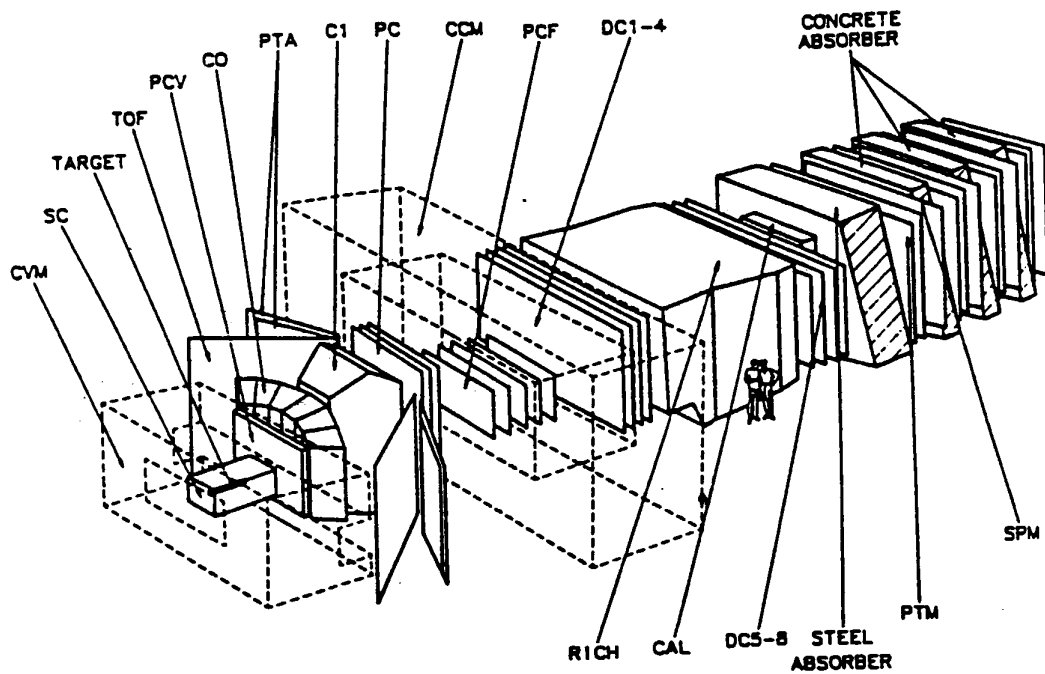
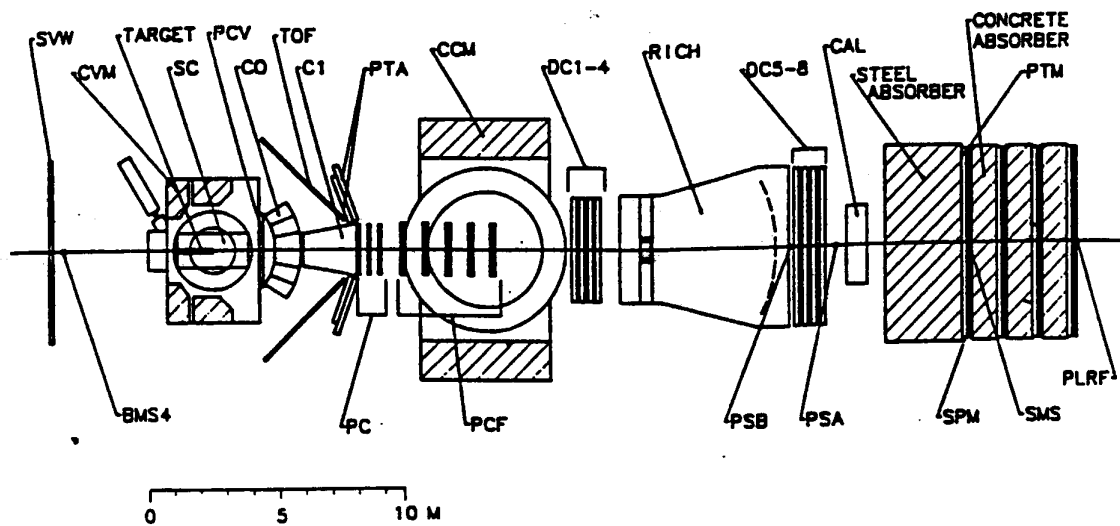


Fig. 1

measurement of beam and scattered muon momenta as well as charged hadron momenta. With the electromagnetic calorimeter we measure photon energies. Two threshold and one ring imaging Cherenkov counters and time of flight counters identify particles from 1 GeV to above 100 GeV.

In the 1987-89 run positive charged muons at 500 GeV were incident on liquid hydrogen, liquid deuterium and pressurized gaseous xenon targets. 100 GeV muons were also incident on the deuterium and xenon targets. We used two major triggers, the Large Angle Trigger (LAT) and the Small Angle Trigger (SAT). The LAT accepted the scattered muon down to 3 milliradians, while the SAT down to 1.0 milliradian, corresponding to a lower limit of Q^2 (roughly 2 GeV^2 and 0.3 GeV^2 respectively). More details have been presented in previous reports.

2. Status of data processing and event reconstruction

The two major triggers, LAT and SAT, account for roughly 70% of the 36 million events on the raw data tapes. The rest of them are for monitoring and beam normalization. Semiautomatic procedures to split the Raw data into ten data streams according to trigger type were developed by S. Kunori. The Data Split job started in October 1988 using a new computer, AMDAHL, at Fermilab. 75% of data were split by the end of 1988. In 1989 we lowered the priority of the job in order to provide more manpower and CPU time to develop other programs. We processed an additional 15% by July 1989. The remaining data will be done by the end of this summer.

The LAT and SAT include interactions in the iron absorber as well as some beam particles not interacting in the target but triggered due to a timing problem of the trigger. The filtering algorithms to remove those events were developed by Dr. S. Kunori and S. O'Day of Maryland and A. Bhatti of the

University of Washington for the LAT and by S. Magille and Dr. M. Adams of the University of Illinois, Chicago for the SAT. The filter rejects more than two thirds of the triggers. The Event Filter job started in May 1989 and processed 20% of the 500 GeV data by the end of July.

Half of the filtered events were processed through the full reconstruction program. The forward track pattern recognition program has been developed by a group lead by Dr. C. Halliwell of the University of Illinois, Chicago and Dr. H. Melanson of Fermilab. Fig. 2 shows the pattern recognition efficiencies for the scattered muons as a function of momentum transferred (Q^2), energy transferred (ν), total hadronic mass (W) and charged multiplicity. Clear loss is seen at higher multiplicities, i.e. high W , high ν and low Q^2 . Since we are interested in hadronic final states at high W as well as in nuclear structure functions, it is important to have high efficiency for high multiplicities. It is the main focus in our current software effort to improve this efficiency.

The track fitting program was initially developed by S. O'Day of Maryland based on a program used by the EMC collaboration. The work was transferred to A. Salvarani of the University of California, San Diego in February 1988. he completed tuning and debugging the program under the guidance of Dr. S. Kunori.

The vertex finding and fitting program has been also well developed. The program finds primary vertices in the target as well as decay vertices from K^0 and lambda particles. Fig. 3 shows primary vertex distributions for events with Q^2 greater than 4 GeV^2 . The 1.5 meter liquid deuterium target is clearly seen centered at -11 meters in the X coordinate. Fig. 4 shows a two dimensional distribution of Q^2 and ν . Fig. 5 shows distributions of the

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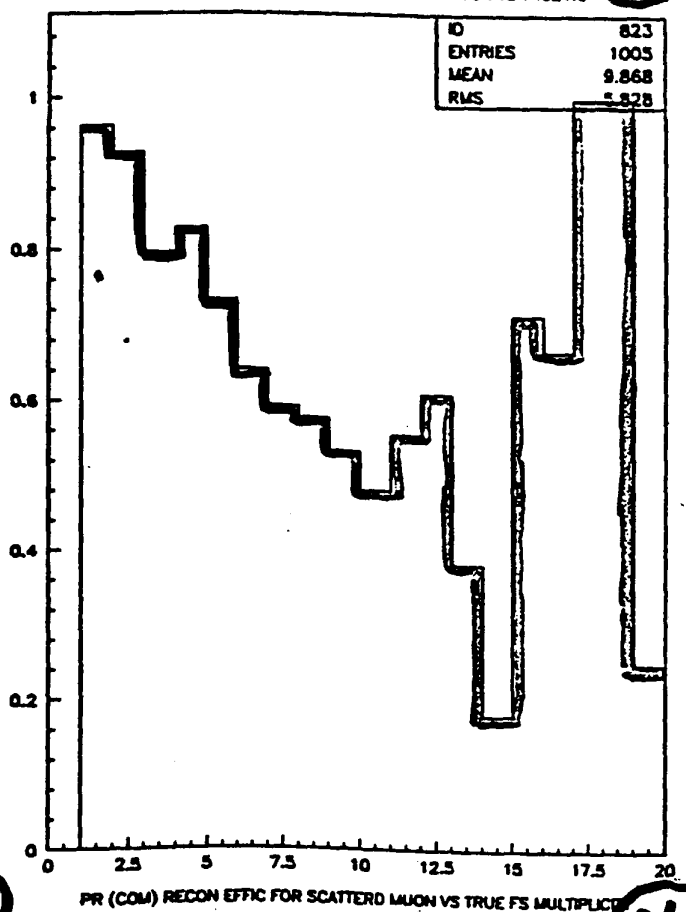
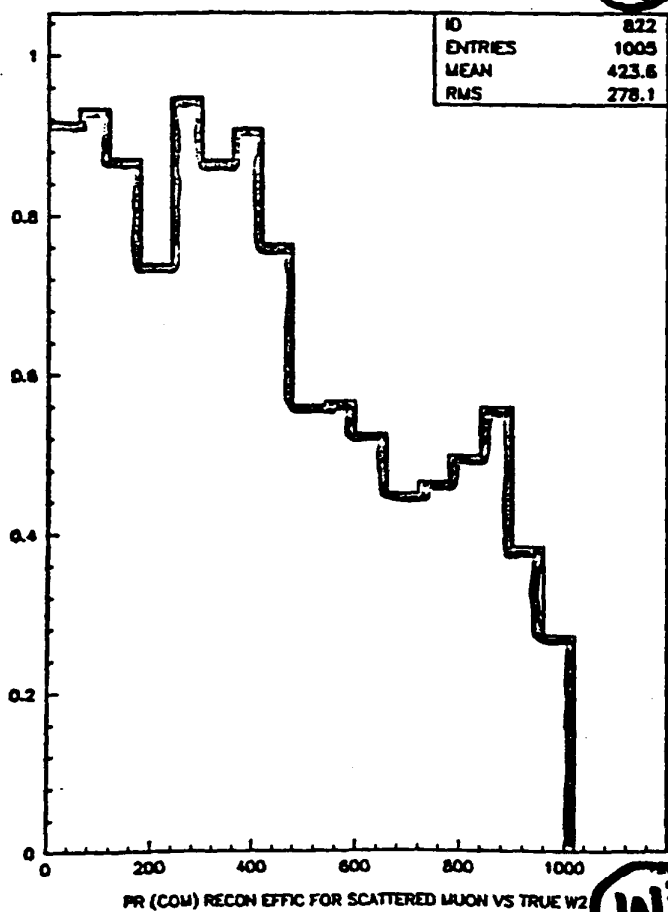
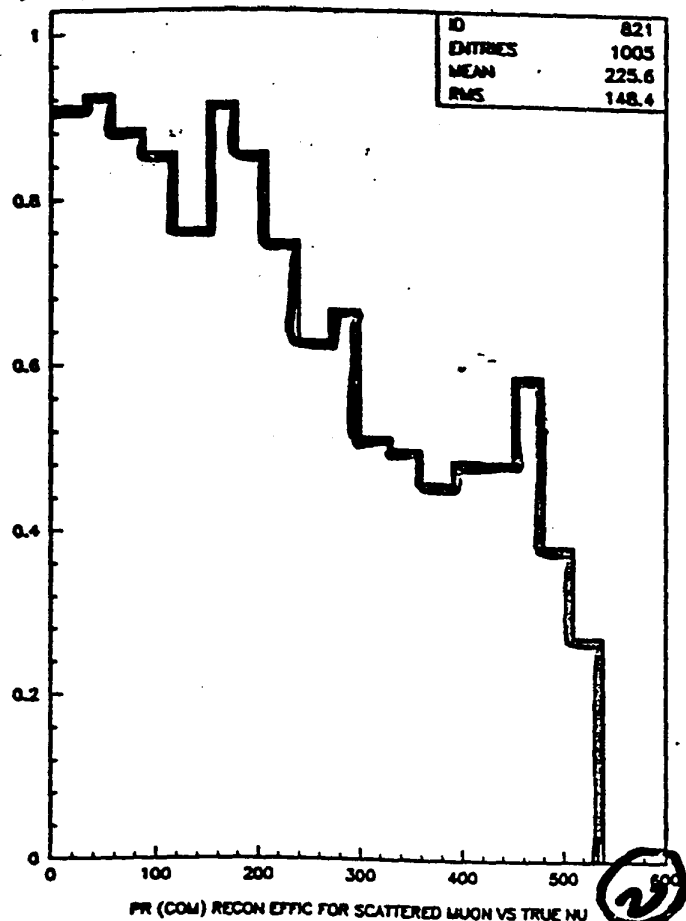
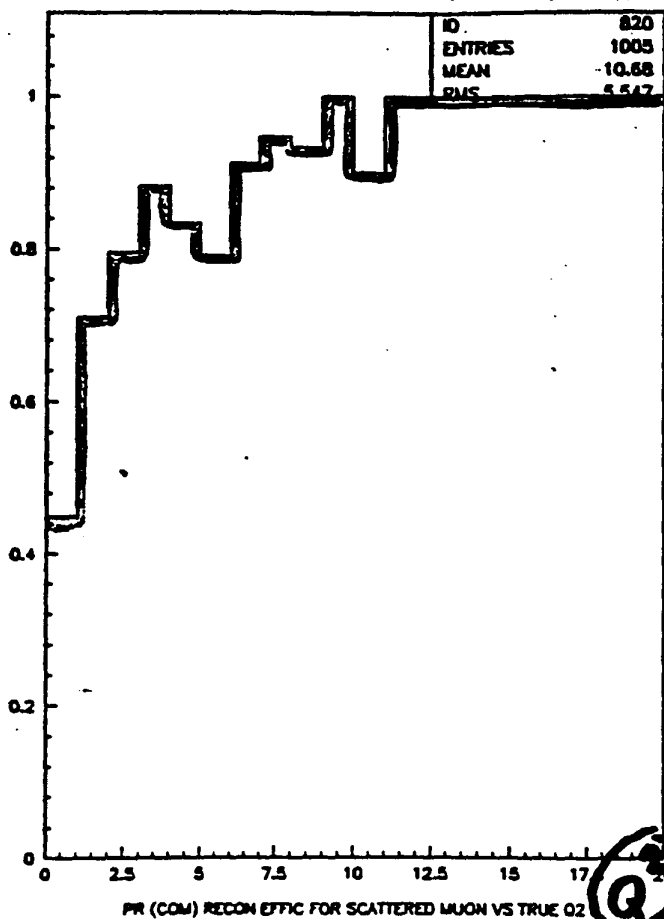


Fig. 2

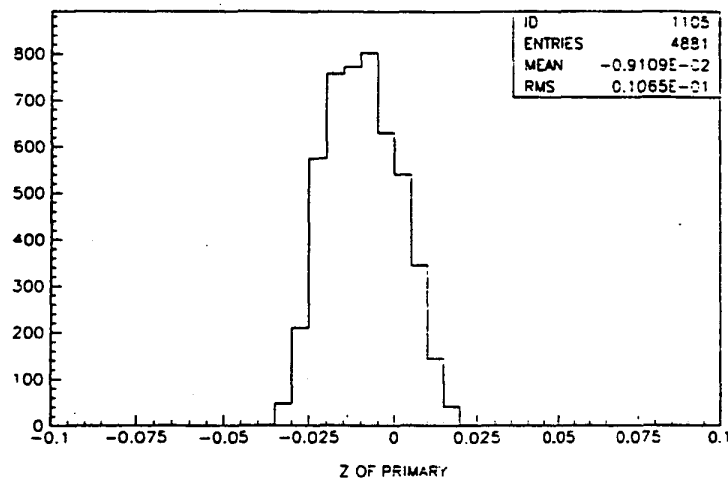
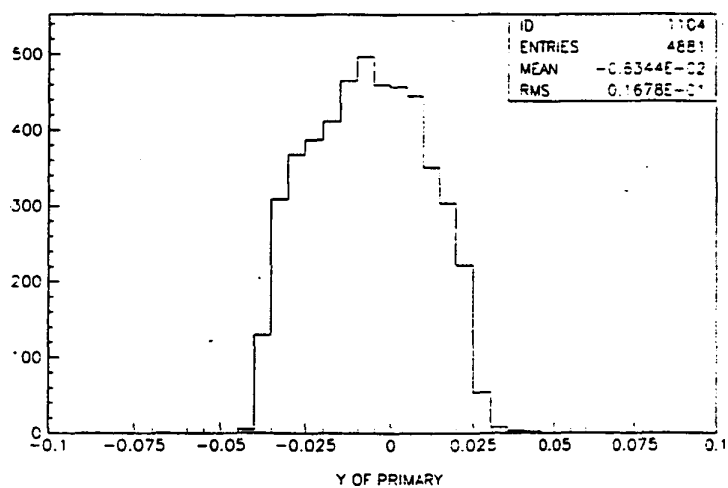
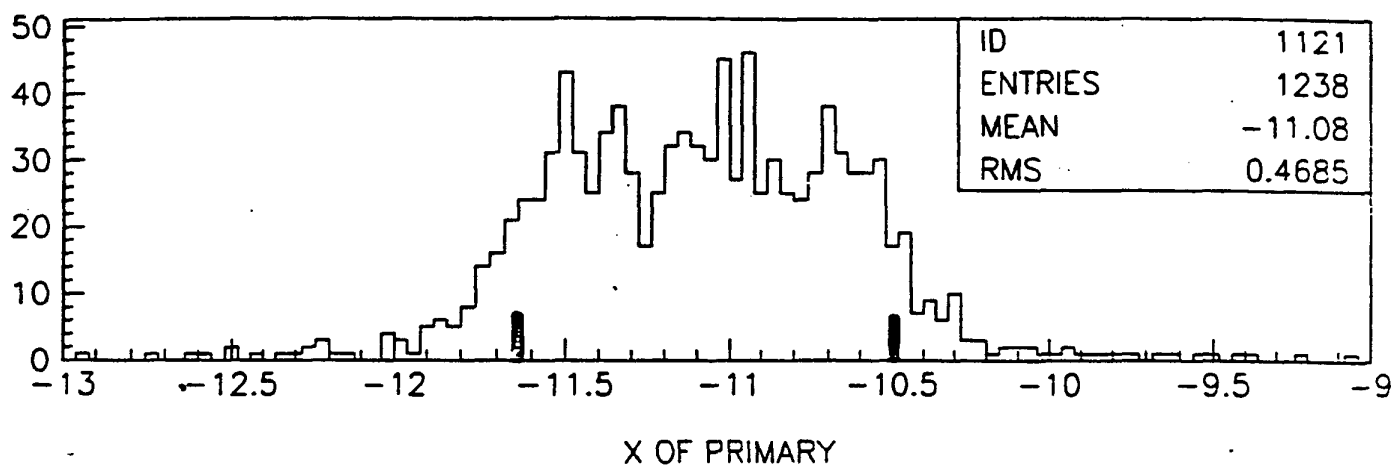
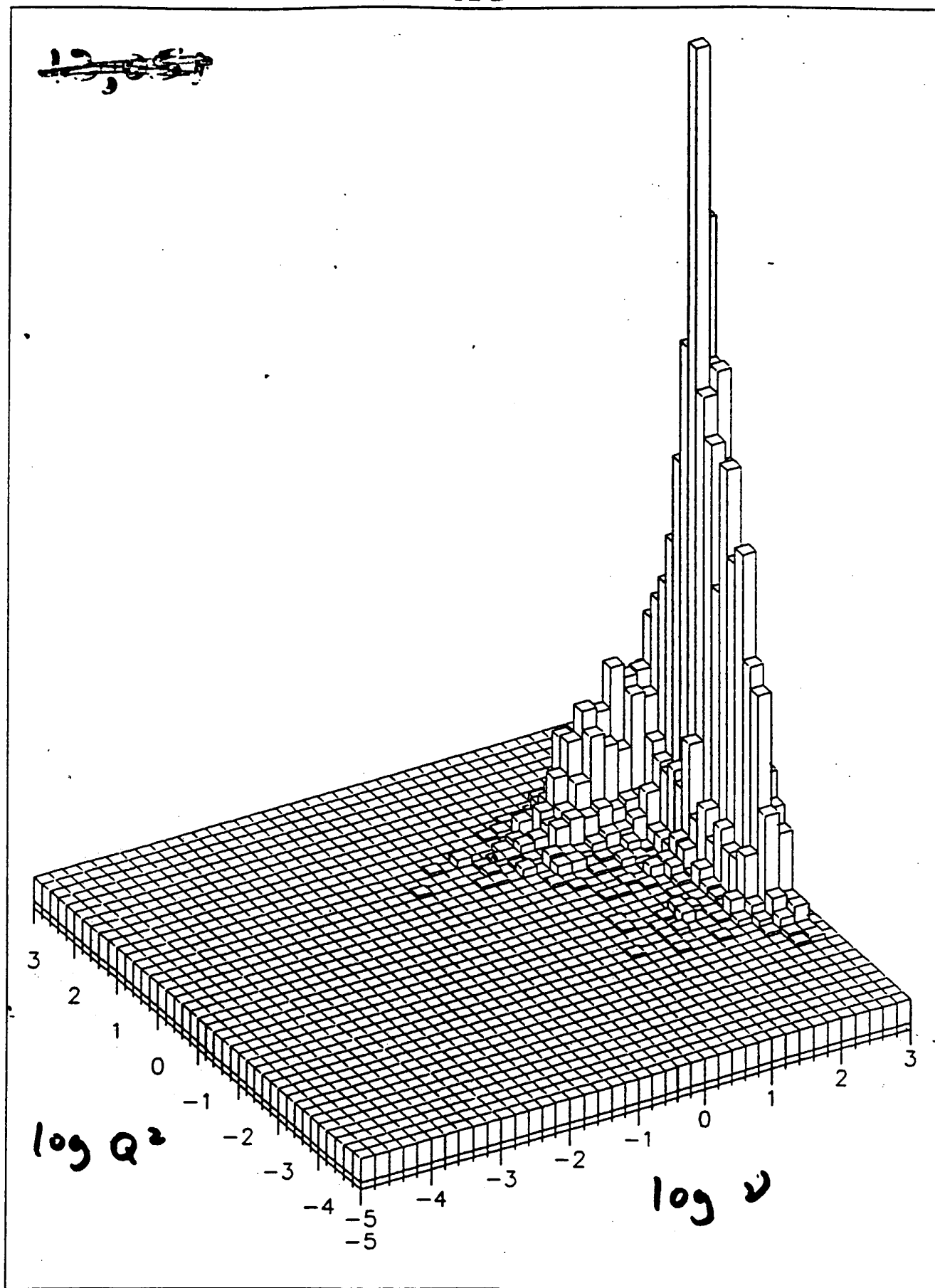


Fig. 3
-49-

500 GeV D2 LAT

$\theta > 0.25 \text{ mrad}$



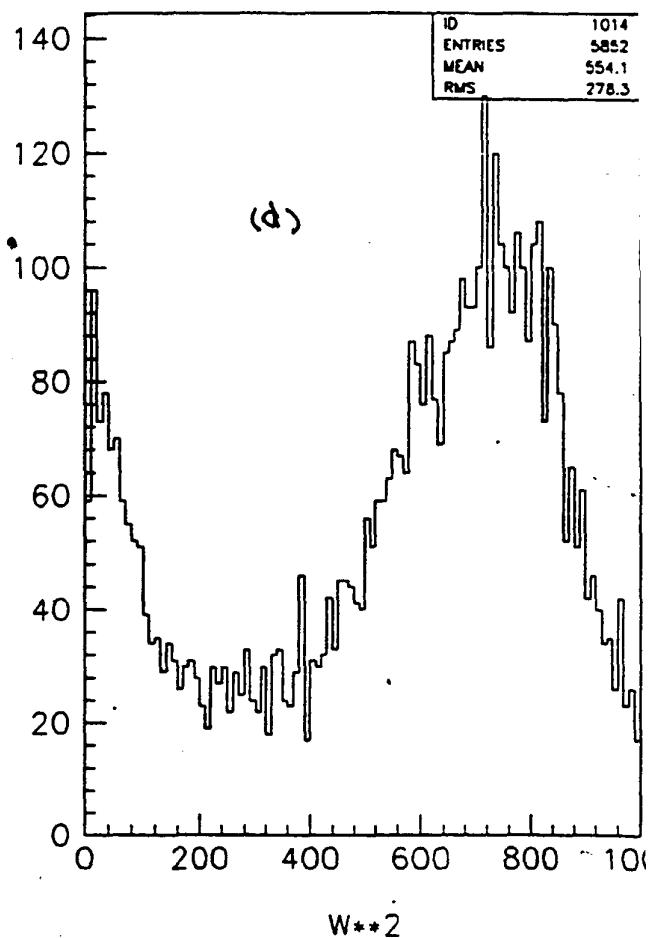
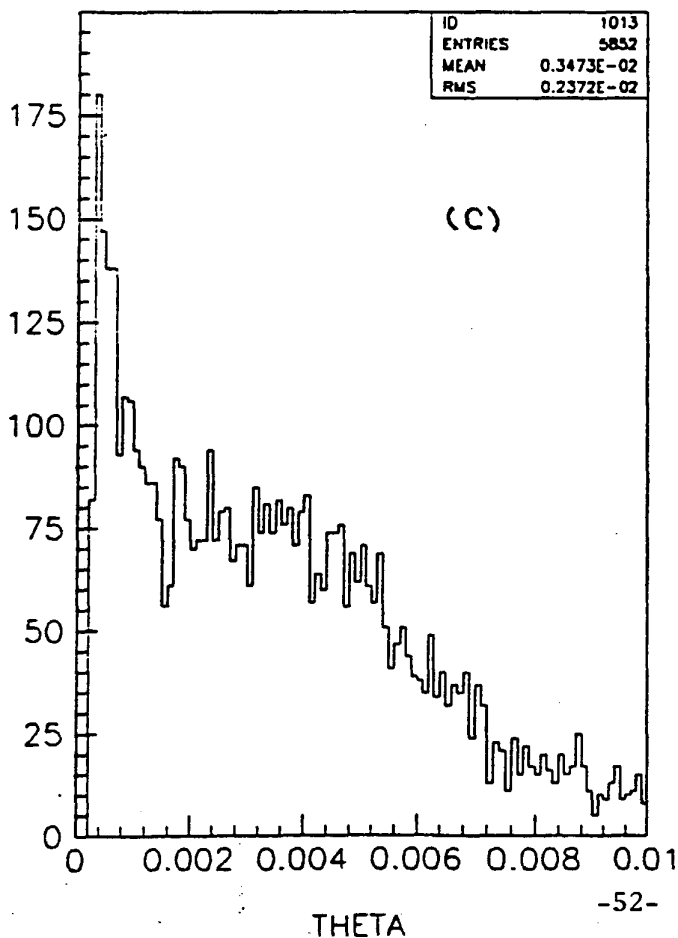
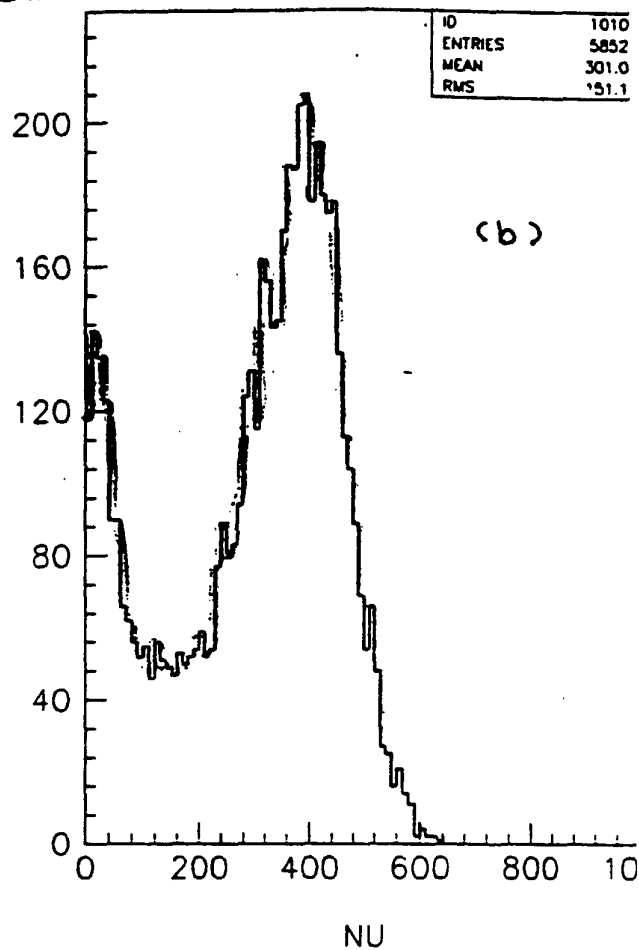
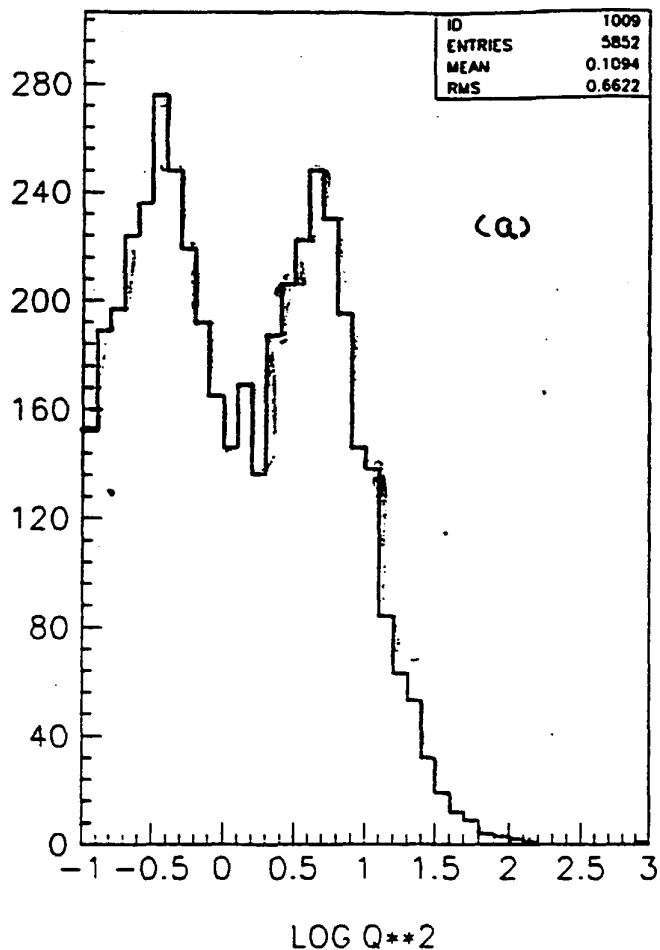
kinematical variables. There are two peaks in the Q^2 , ν and W distributions. Events with small Q^2 , large ν and large W are mainly due to electromagnetic events, muon-electron scattering and muon bremsstrahlung.

In addition to the electronic forward spectrometer data, the experiment took about 600 thousand streamer chamber pictures. 21,000 pictures have been measured at Fermilab, MPI at Munich and Cracow by the end of July 1989 after event selection using Q^2 reconstructions by the forward spectrometer. S. O'Day developed a track matching program between the streamer chamber tracks and the forward spectrometer tracks with the help of S. Soldner-Rembold and Dr. H-J. Trost of MPI. As the first step of his work he determined relative alignment constants of the streamer chamber to the forward spectrometer using the beam trigger. During this work he found relatively big distortions in the reconstructed track momenta after the correction for optical distortion. We concluded that the optical constants were not completely optimized. The work to improve the constants is in progress at MPI and Cracow, while S. O'Day continues to improve the efficiency of the track matching program.

Another major contribution of the Maryland group in the software development is the Monte Carlo program. Dr. S. Kunori and S. Aid developed the Monte Carlo code for the experiment and S. Aid has been maintaining the program for the last few years. The program has been widely used in the collaboration. In the fall of 1988 E. Ramberg and Dr. S. Kunori introduced a new tracking code GEANT, developed by CERN, into the program. GEANT replaces the tracking part of the original Monte Carlo code. Other parts of the code, beam generation, event generation and detector response simulation, are common for both tracking codes. We use the original tracking code for fast simulation, and the GEANT version for detailed study. E. Ramberg has been extensively using the GEANT version of the program for his study on the

$\theta > 0.25$ mrad

500 GEV D2 LAT



electromagnetic and pi-zero production in the deep inelastic interactions.

3. Data analyses.

As described in the previous report the E665 experiment covers a wide range of physics topics. We measure the A dependence of structure functions as well as hadron final states from the deep inelastic muon interactions. Three students of Maryland have started analyzing data for their thesis topics. E. Ramberg on neutral pion, π^0 , production in the deep inelastic interactions. S. Aid is studying the comparison of the structure functions for proton, deuteron and Xe in the Q^2 range greater than a few GeV^2 . S. O'Day is studying the charged multiplicity distribution using the streamer chamber data to cover the backward region in the hadron rest system in addition to the forward region. In the following we briefly describe the status of analyses by E. Ramberg and S. Aid.

a) Analysis on the π^0 production by E. Ramberg

The analysis on the π^0 production is most advanced among analyses going on in the collaboration. His analysis uses extensively the signals from the electromagnetic calorimeter built by the Maryland group in collaboration with Harvard.

Fig. 6 shows a comparison between the GEANT simulation of the calorimeter to muons and the actual data, obtained from 'halo' muons in our apparatus. This not only shows that our simulation works, but also confirms our expectation that the minimum ionizing signal of muons can be seen in the pad towers of the calorimeter.

One important results obtained from the muon signal is a verification of our gas gain monitor data. In Fig. 7 the average halo muon signal is compared to the gas gain we expect from monitoring of the pressure and temperature of

SIGNAL FOR MUONS

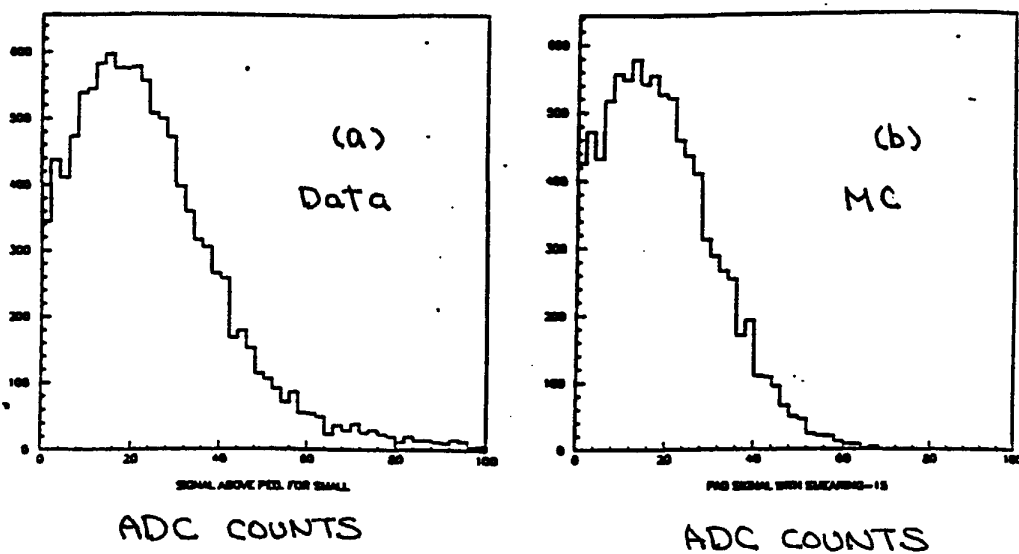


Fig. 6

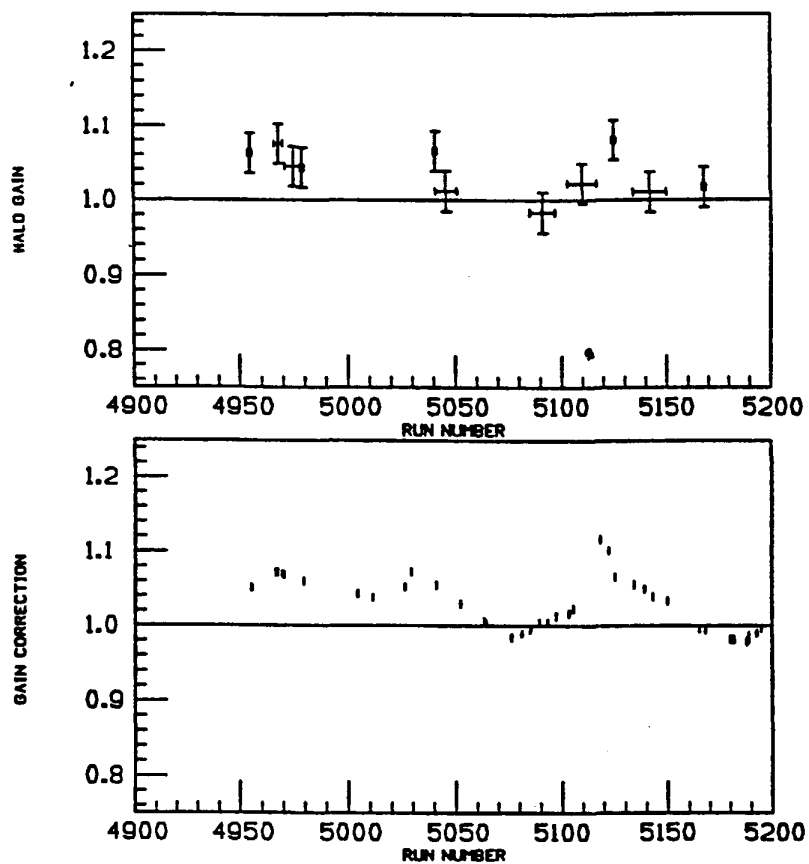


Fig. 7

the gas in the calorimeter. As can be seen, the averages track very well.

Considerable analysis on the electron calibration of the calorimeter has been carried out. Fig. 8 shows the resolution of the calorimeter as a function of energy in the calorimeter. The resolution obeys the expected inverse-square-root behavior, with a resolution currently reported as $44\%/\sqrt{E} + 7\%$. In the comparison to GEANT we see that this resolution curve is different from the expected $50\%/\sqrt{E} + 1\%$ but it is likely that a better simulation of the dead region in the calorimeter will give a better comparison.

Fig. 9 shows the invariant mass spectrum of neutral cluster pairs from the hydrogen target in the SAT data. The π^0 signal is clearly seen, but lies on a background that is equal in size. Ramberg has thoroughly analyzed Monte Carlo events to determine the best way to extract the π^0 signal from data. The analysis shows that his algorithm will extract the true π^0 cluster pairs from background at a ratio of 1.25 to 1. This ratio can be improved by making stringent cuts on data, but this would lead to a more biased sample. He is currently working on determining what the best set of such cuts should be.

With the algorithm he extracted the $z(=E(i)/E(\text{had}))$ and P_t distributions with respect to the virtual photon direction for identified π^0 's. The acceptance corrected distributions are shown in Fig. 10, along with a comparison to Monte Carlo expectations. In Fig. 11 the average number of identified π^0 's is shown rising logarithmically with respect to the available energy squared, W^2 . Mr. Ramberg will soon complete his Ph.D. thesis based on this work.

b) Analysis of Structure Functions by S. Aid.

The kinematical regions covered by two different triggers, LAT and SAT

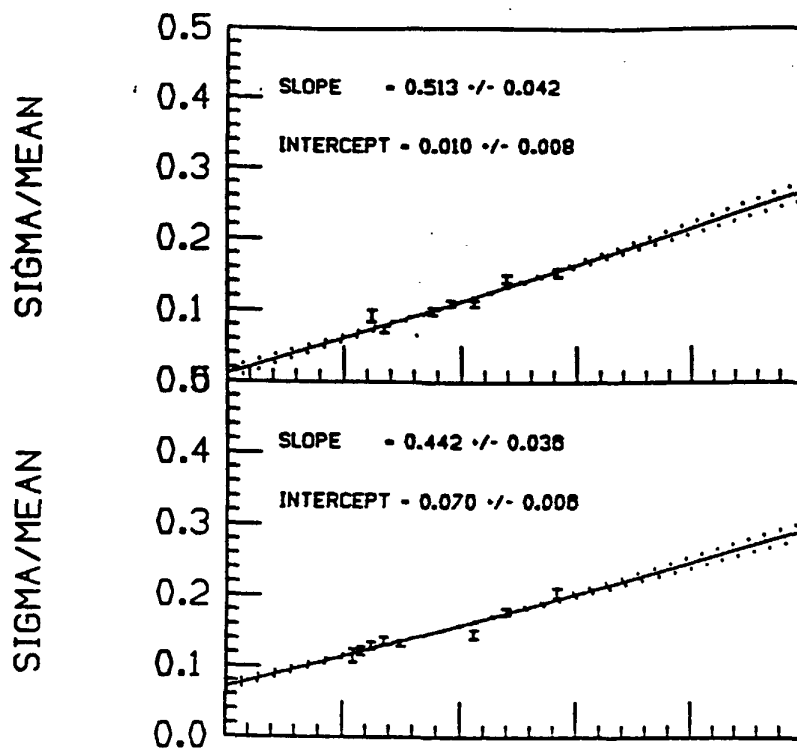


Fig. 8

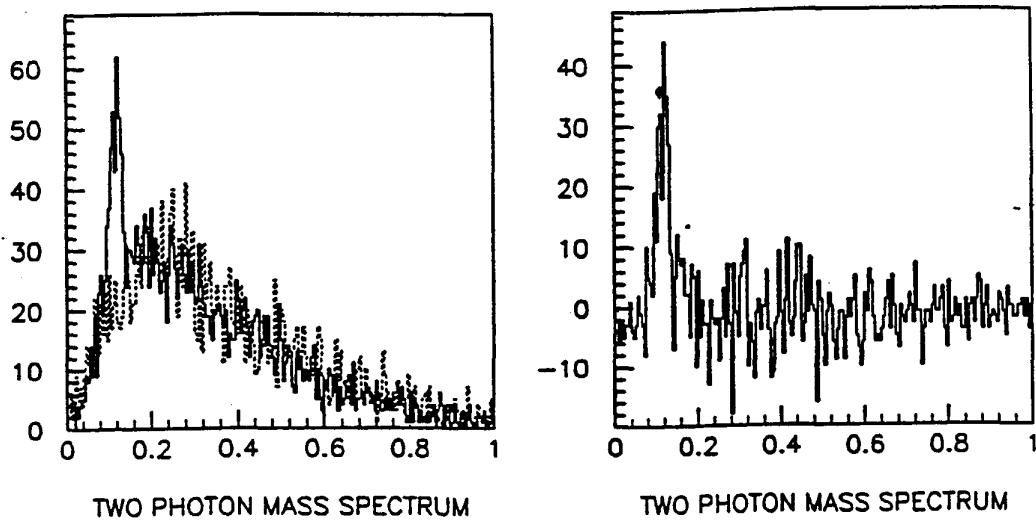


Fig. 9

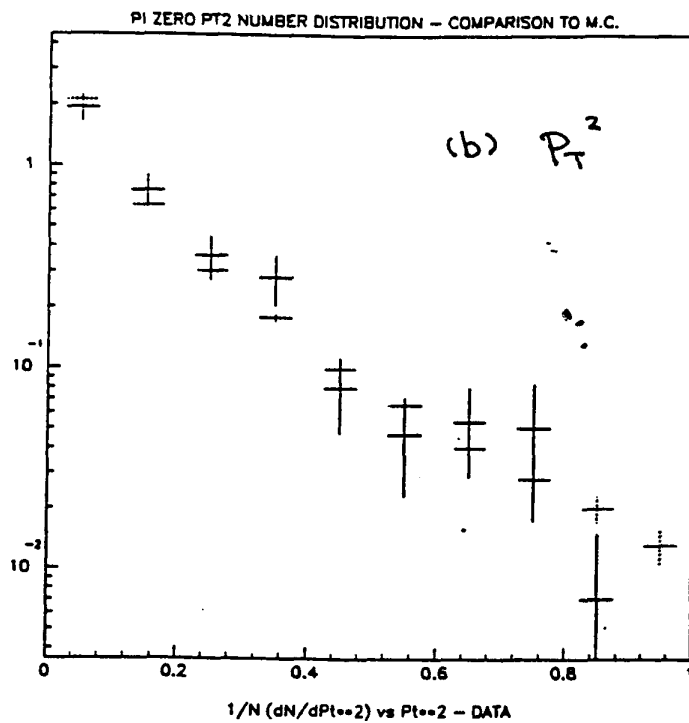
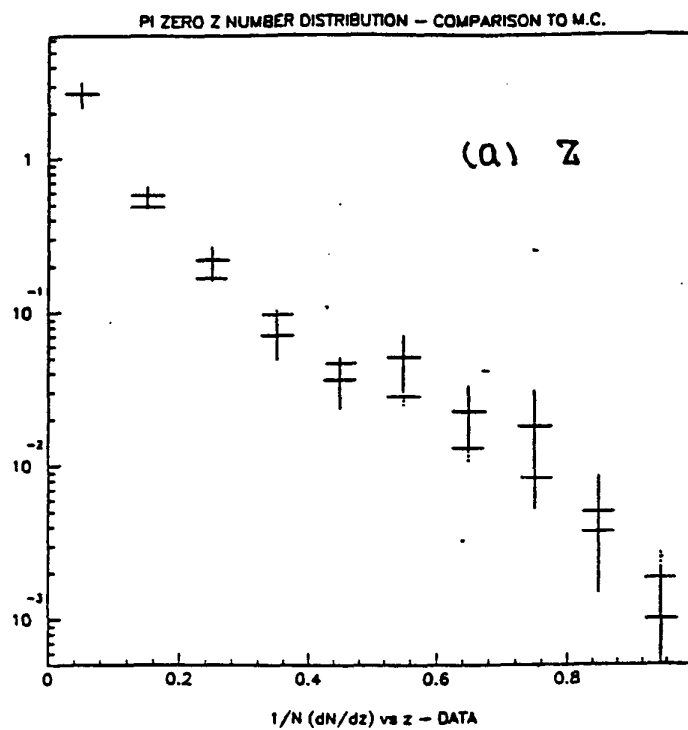


Fig. 10

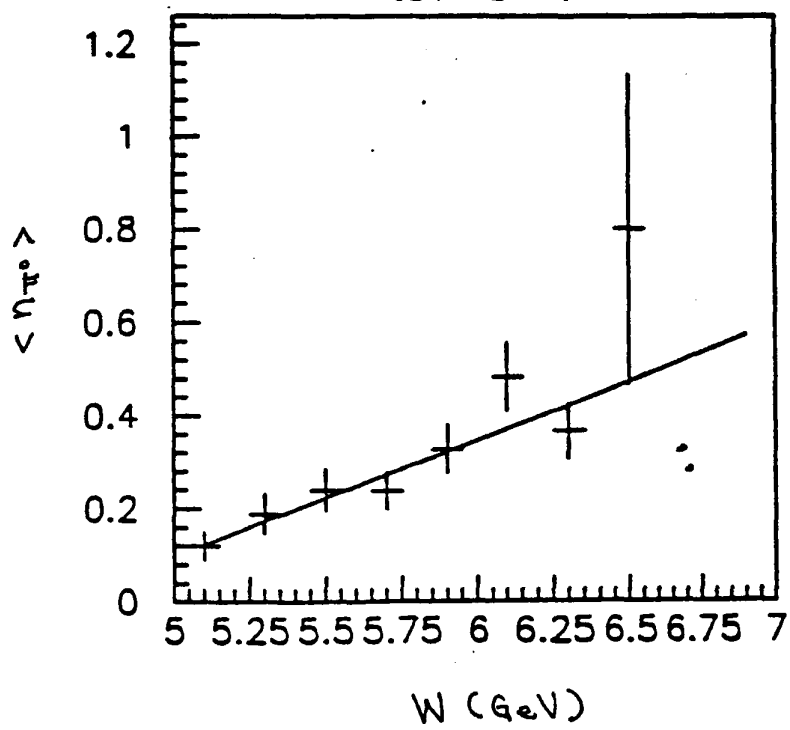


Fig. 11

are shown in Fig. 12. LAT covers the region of $Q^2 > 2 \text{ GeV}^2$ and $X_b > 0.01$, while SAT covers Q^2 down to 0.3 GeV^2 and X_b down to 0.001 . Although the SAT kinematical region includes the entire LAT kinematical region, higher Q^2 and X_b regions in SAT are limited by statistics because the overlap with the LAT events is roughly 12%.

S. Aid has already started analyzing data to get structure functions of xenon, deuterium and hydrogen in the LAT data sample. Fig. 13(a) shows X_b distributions for the D_2 data sample with $Q^2 > 4 \text{ GeV}^2$ and $0.1 < y < 0.6$. This cut removes most of pure electromagnetic events. Fig. 13(b) is a ratio of the measured X_b distribution to the Monte Carlo calculation including normalization for beam luminosity. The ratio is fairly constant around 0.6 except in the highest bin, indicating that the overall efficiency of our event reconstruction program is roughly 0.6. While other people in the collaboration are trying to improve the event reconstruction efficiency, S. Aid has started detailed studies on normalization and systematic errors, leading to a comparison of structure functions for the three different targets.

4. Status for the next run.

The Maryland group has responsibility for the electromagnetic calorimeter in collaboration with Harvard. In 1987-88 run there were a few dead chambers and some oscillations in the front-end electronics in the calorimeter. Those problems have been fixed. Because some chambers were dead due to problems of gas flow in the chamber, we decided to add gas flow meters in the exhaust line of each plane. This will be done this fall.

For the next run we will also improve the fast calorimeter trigger (SAT) using integration modules built by Maryland. With these modules we form a

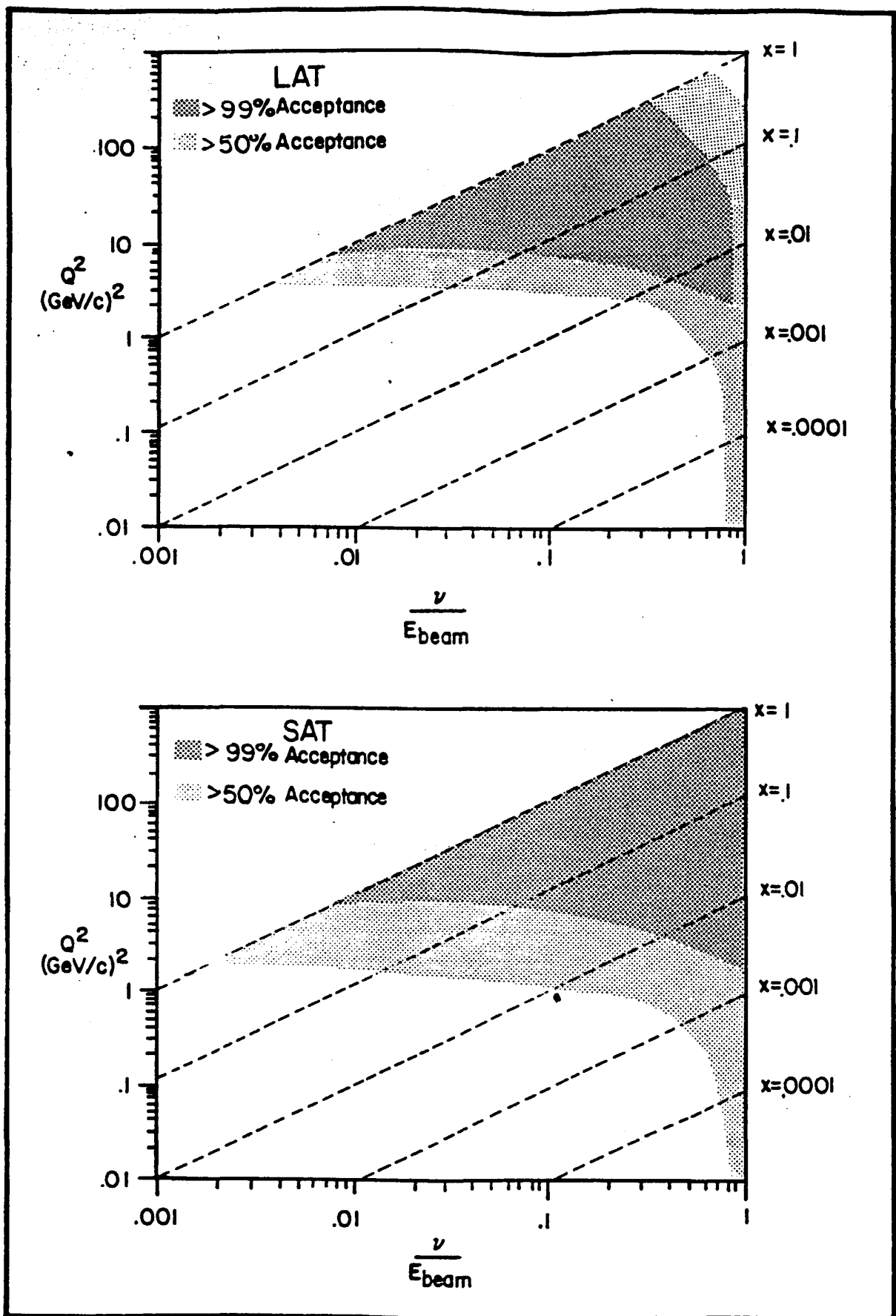


Figure 12

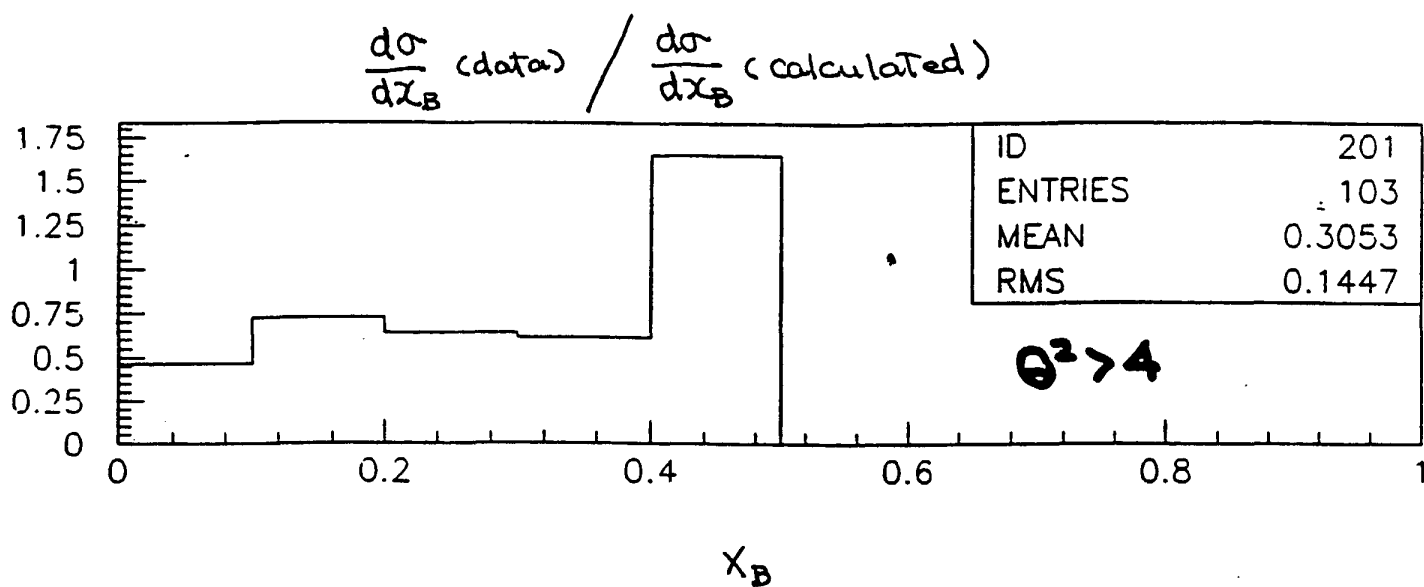
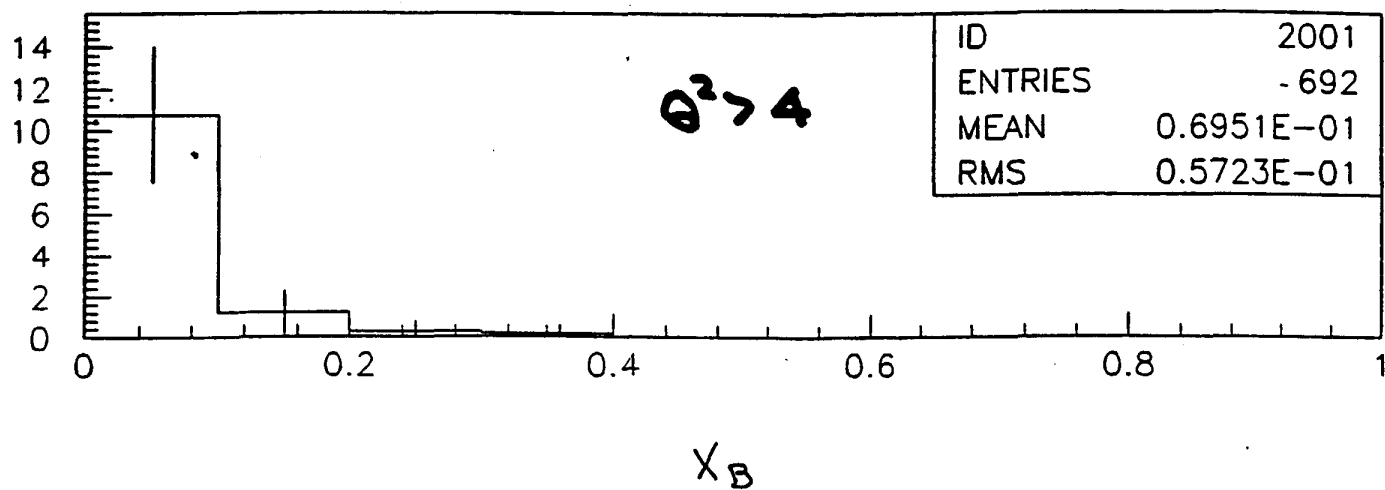


Fig. 13

first level trigger by setting a threshold at the rising edge of the pulse from the calorimeter and a second level trigger by setting another threshold on the integrated signal. Those modules require earlier arrival of the pulse from the calorimeter anode wires. Dr. A. Skuja and S. O'Day rearranged the signal lines to get enough time to form the level 1 trigger.

D. D ϕ Experiment at TeV 1. (A. Baden, N. J. Hadley, S. Kunori, K. Streets, T. Gu, D. Norman at the University of Maryland in collaboration with the University of Arizona, Brookhaven National Laboratory, Brown University, University of California at Riverside, Columbia University, Fermilab, Florida State University, University of Florida, University of Hawaii, Indiana University, Lawrence Berkeley Laboratory, University of Michigan, Michigan State University, New York University, Northern Illinois University, University of Rochester, CEN Saclay, Serpukhov, SUNY Stony Brook, Yale University).

1. Introduction

The D ϕ experiment, which is being built by a collaboration of more than 100 physicists from 22 institutions, is a large 4 π detector facility designed to study proton-antiproton collisions at 2 TeV center of mass energy. Since D ϕ has no magnetic field, it is able to have compact, highly segmented nearly hermetic calorimetry with excellent energy resolutions. It has excellent lepton identification for both electrons and muons. We hope to use the strengths of D ϕ to search for phenomena that are predicted by the standard model, but have not been observed, such as the top quark and Higgs boson, as well as to search for phenomena that lie beyond the standard model, such as supersymmetry and technicolor.

The D ϕ experiment has been under construction during 1989 and large parts of the apparatus have been installed at Fermilab. In addition, the analysis of the 1987-1988 test beam data is now complete and preparations for continued study of the detector in the FNAL test beam during the 1990 fixed target run are well under way. The goal of all of these efforts is to be ready to take data during the next Fermilab collider run which is now scheduled for early 1991.

The University of Maryland group has expanded during 1989 as planned, from two Ph.D.'s (Prof. Hadley and Dr. Kunori) to four Ph.D.'s and two graduate students. Dr. Katherine Streets joined the group in June as a

Research Associate and Dr. A. Baden will join as a Research Assistant Professor in September and will assume teaching duties as an Assistant Professor in July 1990. Ms. T. Gu and Mr. D. Norman joined the group in January 1989 and will obtain their Ph.D.'s from $D\phi$ data.

The Maryland group has responsibilities both in hardware, for construction of $D\phi$ high voltage fanouts and current monitoring system, and in software, for development of muon analysis programs and for jet reconstruction algorithms. We are also involved with the test beam effort and with the installation of the central calorimeter modules.

2. High Voltage Fanouts

The Maryland group is responsible for building most of the $D\phi$ high voltage fanouts as well as the current monitoring system for the $D\phi$ calorimeters. We are building about 1800 channels of HV fanout without current monitoring and 2700 channels of HV fanout with current monitoring.

The HV fanouts without current monitoring were designed at Fermilab and are required to have less than 2 nanoamps of leakage current at 10,000 volts. The fanouts will be built and tested at Maryland by our electronics engineer and technicians, using the services of the Maryland Physics Department machine shop. At present, sample parts are being ordered for the fanouts and the machine shop is getting ready to make prototype units. The schedule for the construction of the fanouts is tight. Maryland did not get involved in the project until June and most of the units have to be finished by December 1989.

The high voltage fanouts with current monitoring are currently under design at Maryland. The difficult part of the job will be to provide 2688 channels with computer controlled current monitoring that has a dynamic range

of 100 nA to 30 μ A at 4000 volts at a reasonable cost per channel. The fanouts themselves will be similar to those designed for use without the current monitoring.

3. Calorimeter Test Beam Data Analysis

Since D ϕ does not have a magnetic field; it must rely on calorimetry for measurement of electrons and jets. From the 1987-1988 test beam data, we have verified the predicted resolutions of the D ϕ uranium liquid argon calorimeters as a function of incident particle energy. We have also studied the relative response of the detector to electrons and pions. For the offline analysis Maryland was responsible for studying the resolution of the central calorimeter electromagnetic modules (CCEM) as well as for track finding and beam momentum reconstruction. The response of an end calorimeter middle hadronic module (ECMH) to electrons and pions was also studied. (See Fig. 1.)

We note here that the ratio of the calorimeter's response to electrons and hadrons was found to average 1.03 from 10 GeV to 150 GeV with all points falling between 1.003 and 1.082. See Fig. 2. In order to characterize the resolution of the calorimeter modules, we assumed the following energy response for the fractional resolution (σ/μ)

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

here E is the beam energy in GeV, C is a constant term reflecting such effects as upstream energy loss and shower leakage and non-equal response to electromagnetic and hadronic energy, S is due to statistical errors in the sampling, and N is due to energy independent effects such as electronic and uranium noise. The results obtained are: for electrons in the CCEM, $S = 0.162 \pm$

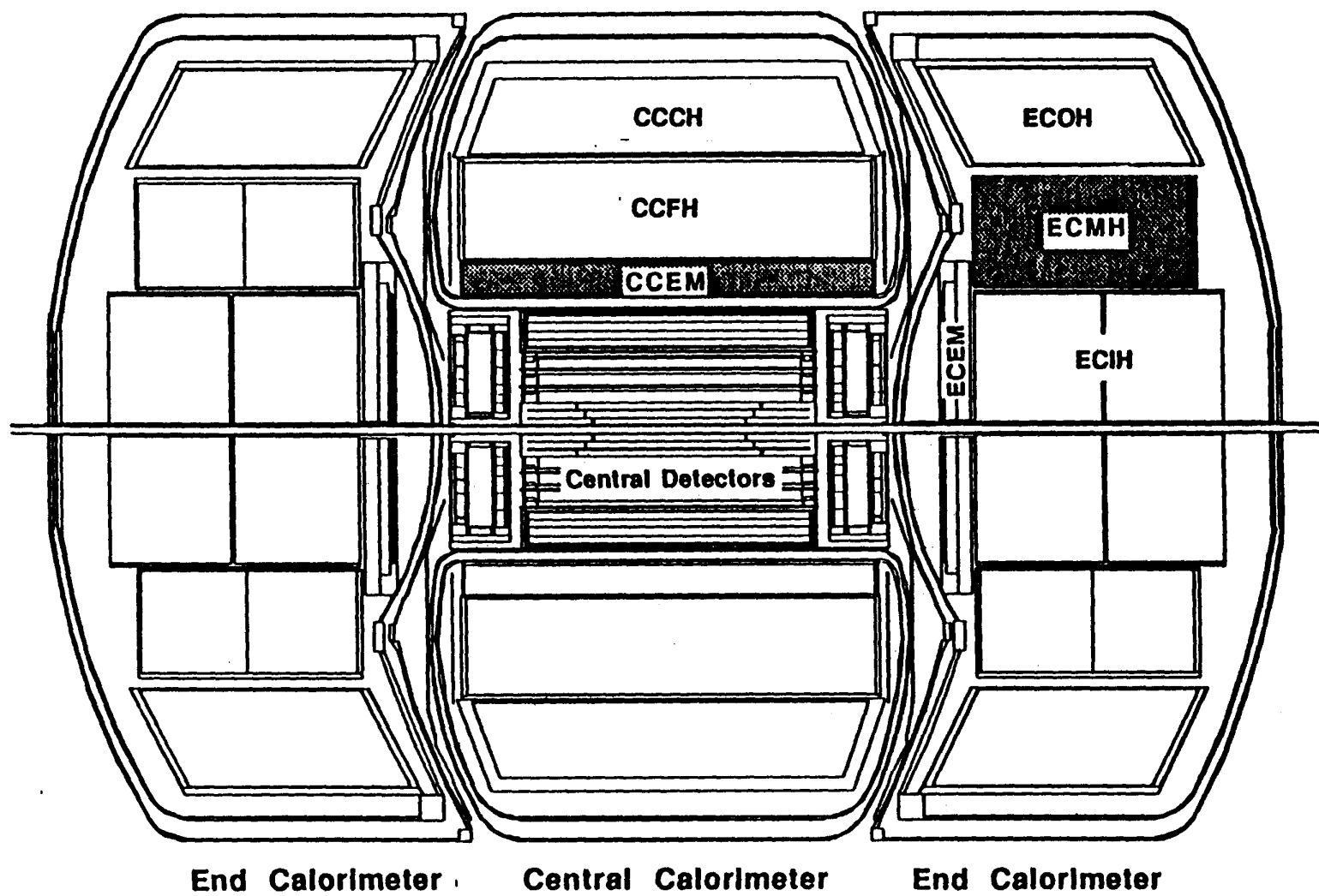


Figure 1

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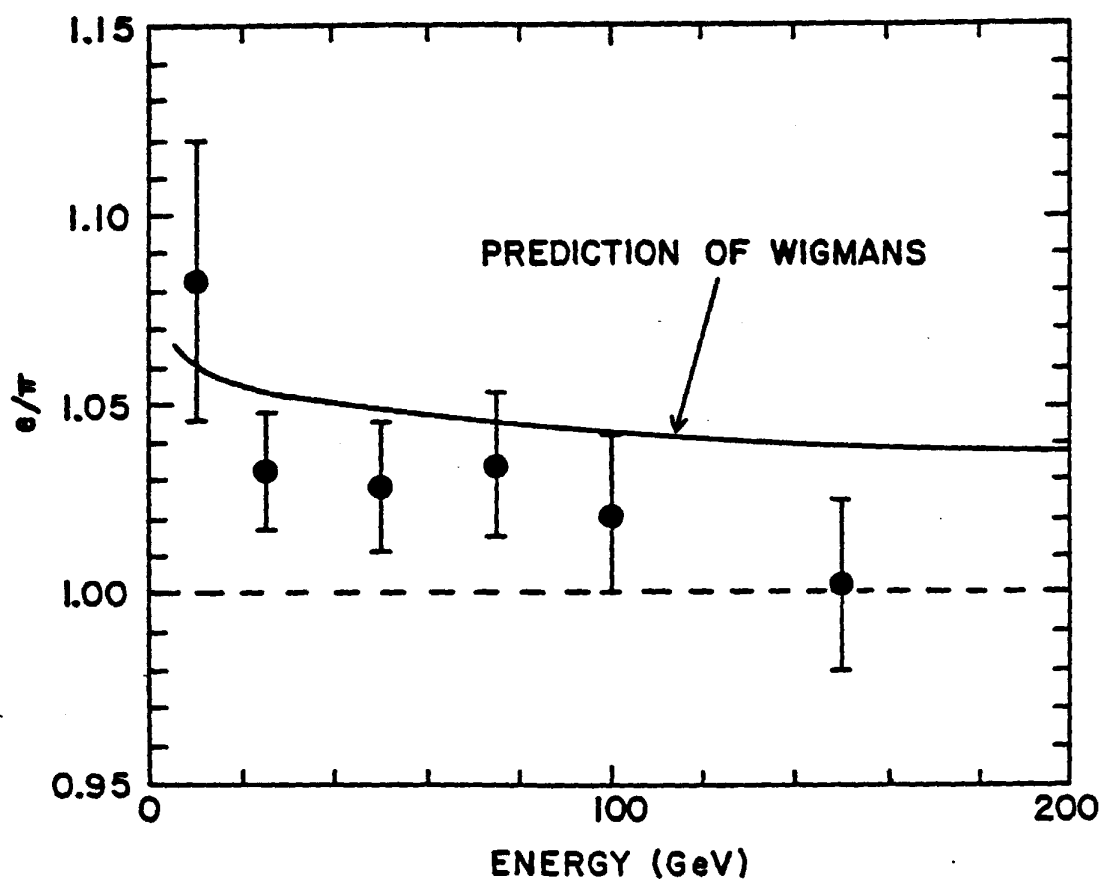


Figure 2

0.011, $C = 0.003 \pm 0.004$ and $N = 0.140$; for pions in the ECMH, $S = 0.439 \pm 0.042$, $C = 0.047 \pm 0.005$, and $N = 1.28$. The values of the noise terms, N , were obtained by analyzing pedestal runs. Fig. 3 gives plots of (σ/μ) as a function of beam energy. For the ECMH hadronic resolution, the constant term C was dominated by the effects of shower leakage. This will not be the case in the real $D\phi$ detector where there will be more than one ECMH module and the full shower will be contained. Correcting the shower leakage and the spread in preamplifier gains, we estimate the intrinsic resolution of the ECMH calorimeters to be $S = 0.49 \pm 0.04$ and $C = 0.02 \pm 0.01$. We note that in the $D\phi$ proposal the electromagnetic sampling term was predicted to be $15\%/\sqrt{E}$ and the hadronic sampling term to be $50\%/\sqrt{E}$ in agreement with the above results. The individual modules as built are, therefore, performing at the expected level. A detailed description of these results has been accepted for publication in Nuclear Instruments and Methods.[1].

[1] M. Abolins et al., "Hadron and Electron Response of Uranium/Liquid Argon Calorimeter Modules for the $D\phi$ Detector", to be published in Nuclear Instruments and Methods.

4. 1990 Calorimeter Test Beam Preparations

$D\phi$ plans a major effort in the FNAL test beam during the next fixed target run at Fermilab. During this run, we hope not only to test individual calorimeter modules, but groups of modules and the cracks between them. Since $D\phi$ does not have a magnetic field, the test beam is the best place to obtain a thorough understanding of the detector. This test beam work is a large effort

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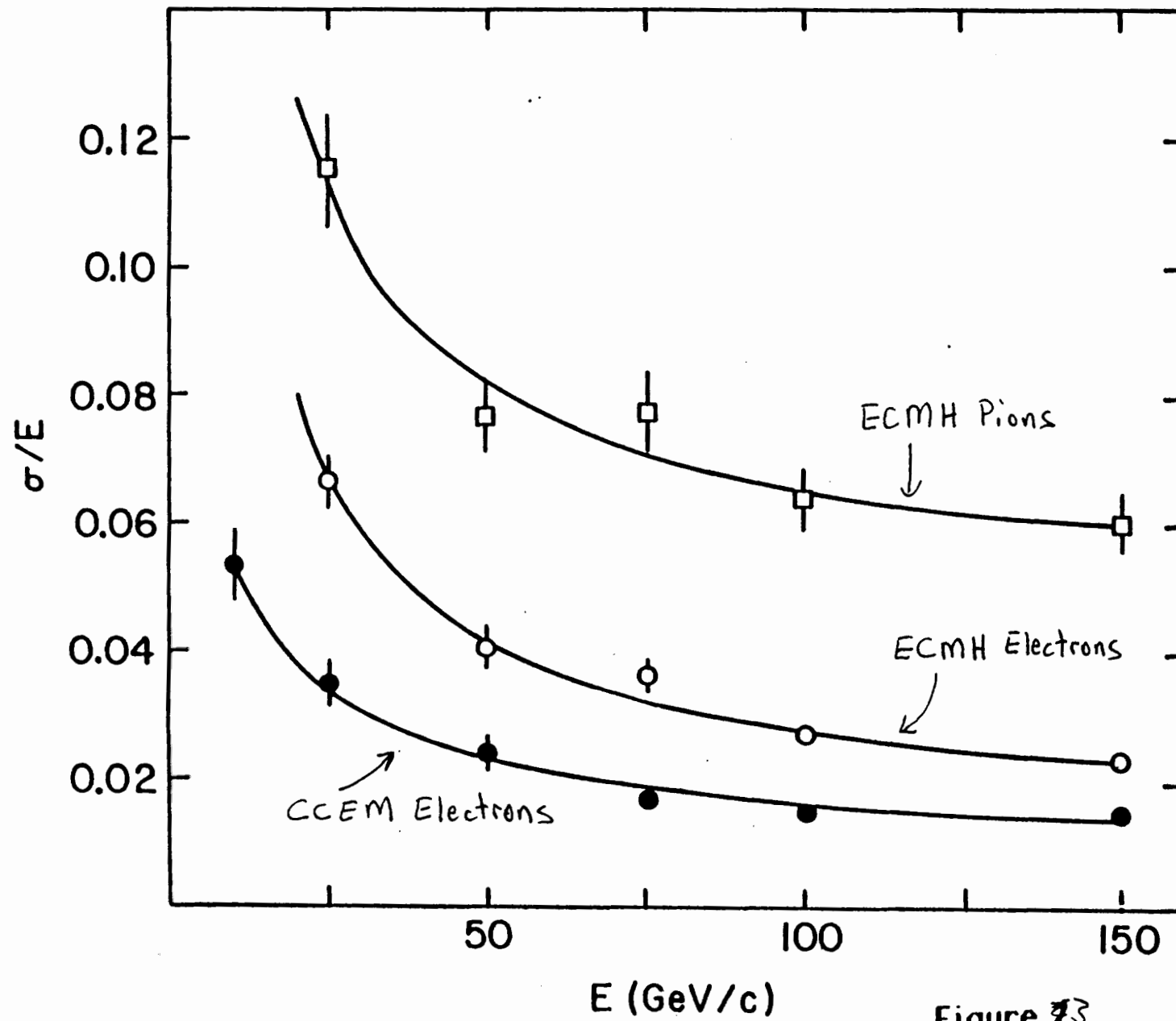


Figure 73

and involves most of the member institutions in the $D\phi$ collaboration. The Maryland group is working on electronics debugging and testing for the test beam as well as a variety of tasks such as cabling and the optimization of the selection of instrumented channels to ensure that the relevant regions of the calorimeter modules will be live. (There are not enough feedthroughs in the test beam cryostat to instrument all of the channels of the modules that can fit in the cryostat.)

We have also studied the feasibility of calibrating the calorimeters in the $D\phi$ cryostat with cosmic rays which will be the first data taken with the modules in the $D\phi$ apparatus. With one weeks running, it should be possible to calibrate most of the central calorimeter at the 5% level using cosmic muons. This calibration will in turn be compared with the results from the test beam.

5. Muon and Jet Software

With considerable help from K. Hammoutene at BNL and Doug Fong at Maryland, the $D\phi$ software was established on the Maryland HEP VAX cluster in January 1989.

The Maryland group, principally S. Kunori has continued its efforts on the muon system software for $D\phi$ this year. The data format from the $D\phi$ GEANT program was modified to match to the raw data from online. The alignment constants of the muon PDT's in the data base were updated. Installation of parametrization of the hadron punchthrough process is underway, as are efforts to design the interface between the calorimeter reconstruction program and the muon reconstruction program.

N. Hadley and S. Aronson from BNL have responsibility for leading the $D\phi$

jet algorithm group. A jet finding algorithm based on adding all the energy in a fixed cone in $\Delta\eta$ $\Delta\phi$ space was coded and tested on $D\phi$ Monte Carlo events. This algorithm is similar to that used by UA1 and CDF. A number of other jet finding algorithms, including a nearest neighbor algorithm similar to that used by UA2, are in progress.

6. Calorimeter Installation

T. Gu and D. Norman are now at Fermilab working on the installation of the central calorimeter (CC) modules into the cryostat. This is a large effort that includes physicists from most of the groups in collaboration. At this date (August 4) 13 modules of a total 64 have been installed. The CC installation is scheduled to be completed this fall.

E. Physics with the CLEO Detector at CESR. (A. Jawahery and C. Park, U. of Md., plus Carnegie Mellon U., Cornell U., Ithaca College, U. of Florida, Harvard U., U. of Kansas, U. of Minnesota, Ohio State U., Purdue U., U. of Rochester, SUNY at Albany, Syracuse U., and Vanderbilt U.)

The past year has been devoted to analysis of the very successful 1987-88 run of CESR at the $4S$ and $5S$ $b\bar{b}$ resonances. Since the last Progress Report ten papers have been or soon will be published in refereed journals from the CLEO collaboration. Seven new reports have been submitted to the SLAC Electroweak Conference in August 1989 and many more results are on the way. Mr. Park was in residence at Ithaca this past year. He will return to College Park to write his Ph.D. thesis on the $\Upsilon(5S)$ analysis and to complete his required course work.

Prof. Jawahery and Mr. Park have been leading the effort on the analysis of the $\Upsilon(5S)$ data. The purpose of this study is to search for evidence of B_S and B_S^* resonance production. Only B_u and B_d meson states can be produced at the $\Upsilon(4S)$ so the $\Upsilon(5S)$ study has the possibility of opening a new chapter in B physics with the CLEO detector. To search for indications of B_S production a measurement of particle yields at the $\Upsilon(5S)$ is underway and almost complete. The data sample consists of 212 pb^{-1} at the $\Upsilon(4S)$, 116 pb^{-1} at the $\Upsilon(5S)$ and 101 pb^{-1} at the continuum energy below the $B\bar{B}$ threshold. The $\Upsilon(4S)$ and $\Upsilon(5S)$ data contain 239,000 and 35,000 $B\bar{B}$ events respectively.

Since the spectator quark in $B_S(\bar{B}_S)$ is an $\bar{s}(s)$ one expects that particles containing a strange quark such as D_S , ϕ , $K^\pm$, K_S mesons or Λ hyperon should be enhanced relative to their production via B_u or B_d mesons. Similarly the production of non-strange charmed mesons should be lower from B_S than from B_u or B_d mesons. So far the production rates of D_S , ϕ , K_0 , Λ , D^{*+} , D^0 and D^+ have been determined by similar techniques at the $\Upsilon(5S)$ and the $\Upsilon(4S)$. These integrated yields are shown in Table I. In this analysis the new drift

Table 1.

particles	Number of Events		Particle Fractions	
	$\Upsilon(4S)$	$\Upsilon(5S)$	$\Upsilon(4S)$	$\Upsilon(5S)$
D_s	192 ± 27	47 ± 17	0.0032 ± 0.0004	0.0058 ± 0.0017
ϕ	2979 ± 303	510 ± 170	0.034 ± 0.003	0.0453 ± 0.011
$K^\pm$				
K^0	43979 ± 722	6832 ± 400	0.617 ± 0.026	0.668 ± 0.046
Λ	1592 ± 186	421 ± 106	0.019 ± 0.002	0.024 ± 0.007
D^{*+}	881 ± 51	100 ± 24	0.0072 ± 0.0004	0.0042 ± 0.0014
D^0	5259 ± 215	797 ± 117	0.022 ± 0.001	0.024 ± 0.003
D^+	3822 ± 442	536 ± 237	0.0256 ± 0.0031	0.0253 ± 0.011

chamber system for CLEO has played an important role with its improved momentum and dE/dX resolution. In each case continuum contributions have been subtracted off.

Comparing the measurements at the $\Upsilon(4S)$ and $\Upsilon(5S)$, one finds clear enhancements in the yields of D_S , and ϕ mesons and a deficit in the production rate of D^{*+} mesons at $\Upsilon(5S)$. The combined statistical significance of the enhancements observed in D_S , ϕ and the deficit in D^{*+} represent a three standard deviation effect in favor of the production of B_S mesons at the $\Upsilon(5S)$ resonance. The substantial uncertainties in the data and in the needed branching ratio make it difficult to derive an accurate value for the branching ratio $B(\Upsilon(5S) \rightarrow B_S \bar{B}_S X)$. The most likely values are in the 10-30% range.

A search for several possible exclusive decays such as $B_S \rightarrow D_S^+ \pi^-$, $B_S \rightarrow D_S^+ \pi^- \pi^+ \pi^-$ was carried out in the $\Upsilon(5S)$ data sample. No significant peak was seen in the mass range 5.30 to 5.40 GeV which is the expected mass region for the B_S meson.

A second project in which Prof. Jawahery has played an important role is the search for the decay $D^0 \rightarrow K^0 \bar{K}^0$. This work has recently been completed and submitted to PRL. To understand D decays theoretically it is important to distinguish between simple spectator diagrams, weak annihilation diagrams and more complicated diagrams in which final state interactions play an important role. The decay mode $D^0 \rightarrow K^0 \bar{K}^0$ may shed light on this matter. In the absence of SU(3) flavor breaking the two W-exchange diagrams which contribute to this decay cancel, leaving final state interactions as the most probable mechanism for this mode. Evidence for the existence of this mode was first presented by the E400 collaboration. The new CLEO collaboration confirms this result and finds $B(D^0 \rightarrow K^0 \bar{K}^0) = 0.11^{+.06}_{-.04} \pm .02\%$.

The data sample used consists of 312 pb^{-1} in the vicinity of the $\Upsilon(4S)$

resonance and 117 pb^{-1} on the $\gamma(5S)$. The decay mode $K_S^0 \bar{K}^0$ is searched for by looking for a D^0 mass peak in the $K_S^0 K_S^0$ sample and insisting that this D^0 come from the decay of a $D^{*+} \rightarrow D^0 \pi^+$, with its characteristic low momentum pion.

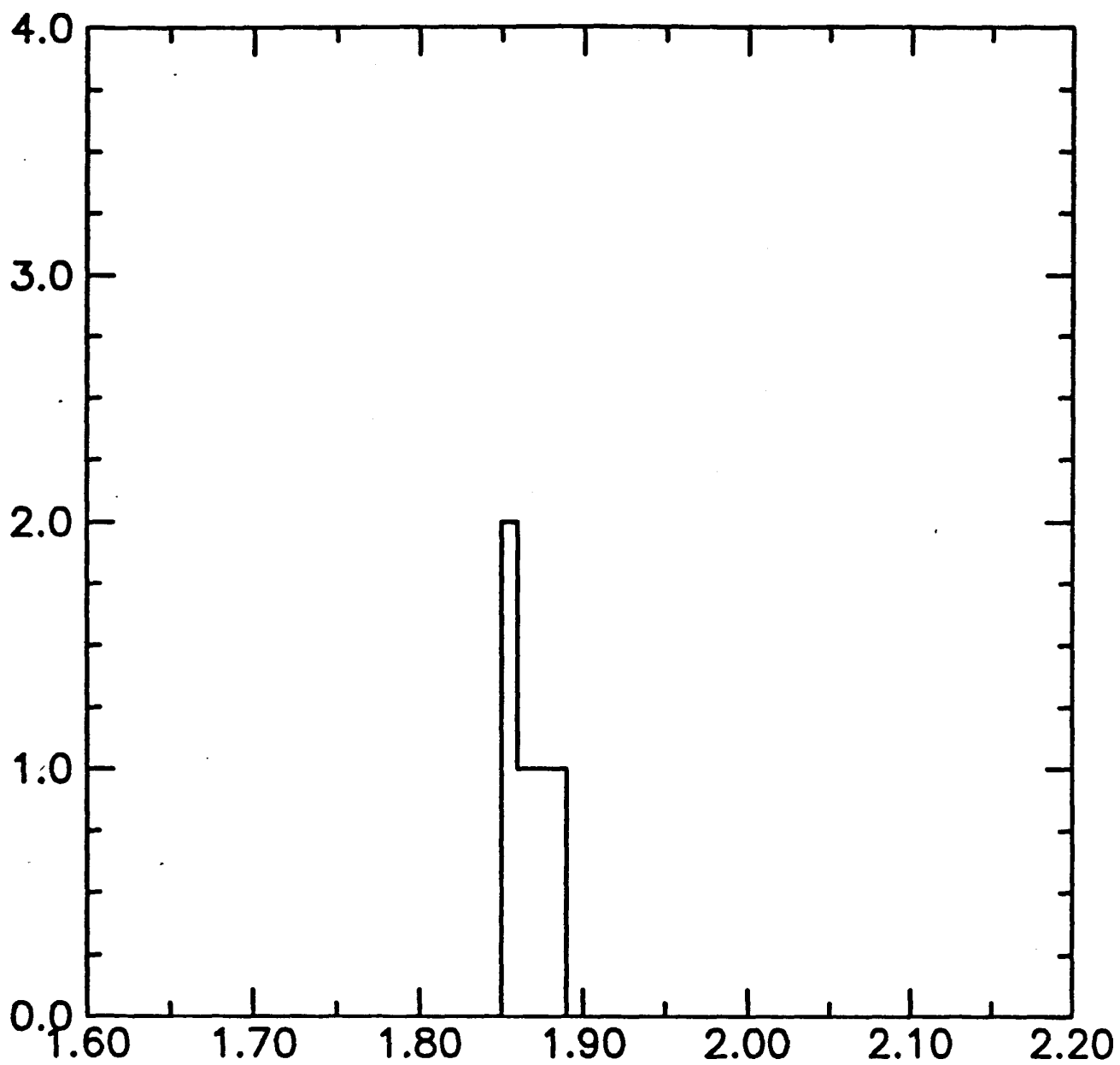
The $K_S^0 K_S^0$ invariant mass spectrum satisfying this criterion is shown in Fig.

3. 5 events are seen all clustering at the D^0 mass. The estimated background is 0.1 event. A signal of 125 ± 5 events is also seen in the more inclusive sample of $K_S^0 K_S^0$ in which the $D^{*+} \rightarrow D^0 \pi^+$ condition is removed. The experimental result is in agreement with the theoretical calculation of X. Y. Pham (P. L. 193B, 331, 1987) based on final state rescattering effects in $D^0 \rightarrow K\bar{K}$ decays, but disagrees with two other theoretical estimates. It appears that final state interactions do provide a suitable explanation for the rate of the decay $D^0 \rightarrow K^0 \bar{K}^0$, signaling its importance to the theory of charm decays.

A third CLEO project to which Prof. Jawahery contributed significantly is the Measurement of the D_S Decay Modes, to be published in Phys. Letters B. In this work a comparison is carried out among the decay modes (a) $D_S^+ \rightarrow \phi \pi^+$, (b) $\bar{K}^{*0} K^+$, (c) $K^{*+} \bar{K}^0$ and (d) $\bar{K}^0 K^+$. The D_S^+ mesons are produced in non-resonant electron positron annihilations. The data arises from an extensive run of 429 pb^{-1} in the $\sqrt{S} = 10.5$ energy region at CESR.

Fig. 1 shows the quality of the resonant peak data obtained. Table I lists the branching ratios and the comparisons between them. The branching

Table I				
Summary of D_S^+ branching ratios				
Mode	# of Events	Efficiency %	$B \cdot \sigma(\text{pb}), x_1 \geq 0.5$	$B/B(D_S^+ \rightarrow \phi \pi^+)$
$D_S^+ \rightarrow \phi \pi^+$	405 ± 27	14.3 ± 0.3	$6.5 \pm 0.5 \pm 0.3$	1.0
$D_S^+ \rightarrow \bar{K}^{*0} K^+$	149 ± 25	5.1 ± 0.4	$6.8 \pm 1.1 \pm 0.7$	$1.05 \pm 0.17 \pm 0.12$
$D_S^+ \rightarrow K^{*+} \bar{K}^0$	40 ± 7	1.2 ± 0.1	$7.8 \pm 1.4 \pm 0.8$	$1.20 \pm 0.21 \pm 0.13$
$D_S^+ \rightarrow \bar{K}^0 K^+$	110 ± 19	4.0 ± 0.3	$6.4 \pm 1.1 \pm 0.6$	$0.99 \pm 0.17 \pm 0.10$



$K_s^0 K_s^0$ Invariant Mass (GeV/c²)
Figure 3

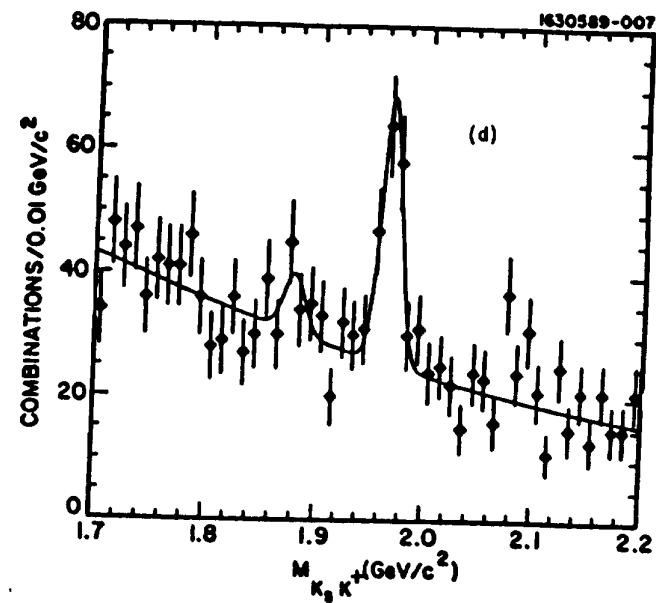
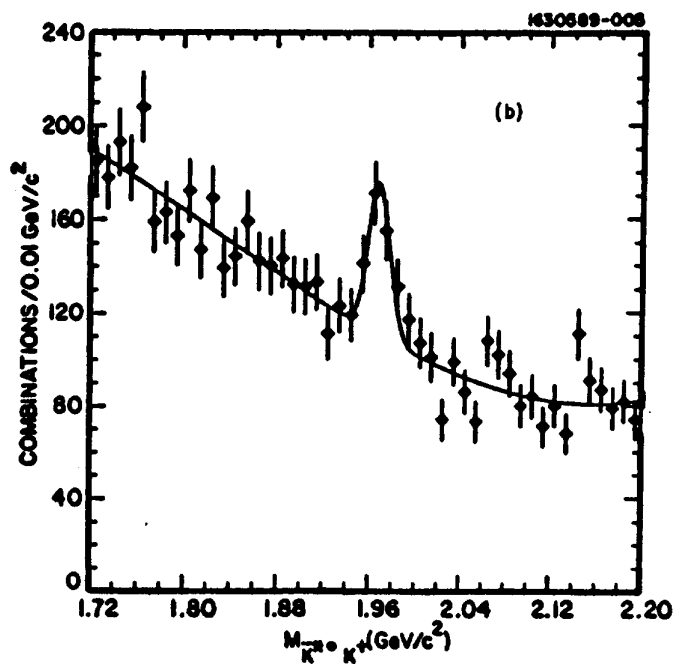
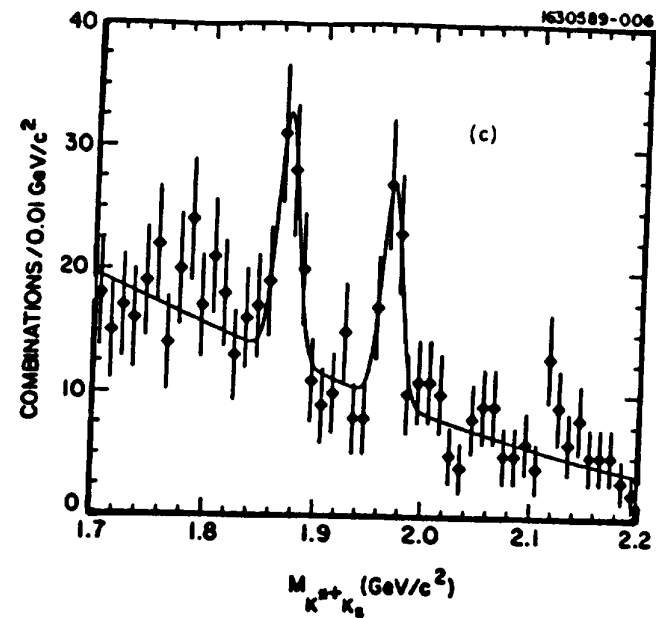
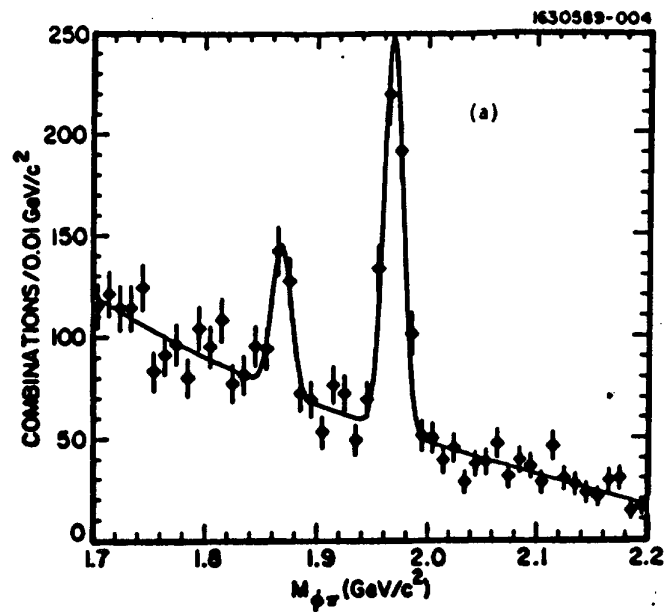


Figure 1

Figure 1

ratio of $D_S^+ \rightarrow \phi\pi^+$ is estimated to be $2 \pm 1\%$. The ratios of branching ratios as listed in Table 1 can be given with much more precision and are close to 1. In Table II these experimental branching ratios are compared to theoretical calculations. The theoretical models as yet do not give a

Table II				
Comparison of Relative D_S^+ branching fractions				
Decay Mode	Experiment	Theoretical Prediction		
		Stech <i>et al.</i>	Block <i>et al.</i>	Kamal <i>et al.</i>
$\frac{D_S^+ \rightarrow K^{*0} K^+}{D_S^+ \rightarrow \phi\pi^+}$	1.05 ± 0.17^a 0.84 ± 0.26^b 0.87 ± 0.13^c 1.44 ± 0.37^d	0.5	0.77	0.68-82
$\frac{D_S^+ \rightarrow K^{*+} K^0}{D_S^+ \rightarrow \phi\pi^+}$	1.20 ± 0.21^a	0.25	-	0.1 - 0.2
$\frac{D_S^+ \rightarrow K^0 K^+}{D_S^+ \rightarrow \phi\pi^+}$	0.99 ± 0.17^a 0.92 ± 0.28^d	0.5	0.43	-

^aThis Experiment.

^bReference 5, Anjos *et al.*

^cReference 4, Adler *et al.*

^dReference 4, Albrecht *et al.*

satisfactory description of all the data. Finally the mass difference $M_{(D_S^+)} - M_{(D^+)}$ is measured to be 98.5 ± 1.5 meV, consistent with Anjos *et al.* (P.R.L. 60, 897 (1988)).

Other interesting CLEO results published or reported recently include

(i) "A Search for $b \rightarrow u$ Transitions in Exclusive Hadronic B Mesons Decays," with negative results.

(ii) "A Search for a Neutral Higgs Boson in B meson Decay", again with negative results. The significance of this result depends on the theoretical probability of the decay $B \rightarrow H^0 X$. Since this probability is proportional to m_{top}^4 , as the mass of the top is forced higher by collider experiments, the significance of the negative search becomes higher. In fact it is reasonable

to conclude from this search that a minimal neutral Higgs of mass between 0.2 and 3.6 GeV is excluded. Once the Higgs meson can decay to $c\bar{c}$ and/or $\tau\bar{\tau}$, the sensitivity to the presence of a Higgs meson is lost.

(iii) "On Semileptonic Branching Ratios of B^0 and B^- Mesons and $B\bar{B}$ Mixing".

In this work new measurements of the semileptonic branching ratio of neutral B mesons and the ratio of the semileptonic branching ratios for charged and neutral B mesons are combined with other measurements to yield best-fit values of these quantities. This results in a substantial reduction of the systematic error in the measurement of the $B^0\bar{B}^0$ mixing parameter, r . The value of r obtained by including both CLEO and ARGUS data in the fit is $r = 0.17 \pm 0.05$.

(iv) "P-Wave Charmed Mesons in e^+e^- Annihilations," in which evidence for $L = 1$ charmed mesons has been obtained.

(v) "Study of Rare D^0 Decays", in which the first observations of $D^0 \rightarrow K^- \pi^+ \pi^- \pi^+ \pi^0$, $D^0 \rightarrow \phi \pi^+ \pi^-$ and $D^0 \rightarrow \bar{K}^{*0} \eta$ decay modes have been made. The ratio $BR(D^0 \rightarrow K^+ K^-)/BR(D^0 \rightarrow \pi^+ \pi^-) = 2.22 \pm 0.36 \pm .30$ is a substantial improvement over previous results.

(vi) "A Measurement of the B^0 Semileptonic Branching Ratio", in which the first measurement of the $\bar{B}^0$ semileptonic branching ratio has been made:

$$B(\bar{B}^0 \rightarrow \ell \nu X) = 10.6 \pm 2.8 \pm 1.1\%.$$

F. Experiments at Los Alamos

F1. CYGNUS Experiment - Search for Point Sources of Ultra High Energy Neutral Cosmic Rays. (C. Y. Chang, D. A. Krakauer (graduated), R. L. Talaga (now at A.N.L.), U. of Maryland in collaboration with the Cosmic Ray Group at U. of Md., George Mason U., Los Alamos National Laboratory and U. of California, Irvine).

The CYGNUS experiment consists of an air shower array and a detector to sample the muon content of these showers. It is located at the end station of the LAMPF accelerator at Los Alamos National Laboratory (107.6°W and 35.9°N) at an altitude of 2134 m., corresponding to an atmospheric depth of 800 gm/cm². The air shower array (CYGI) covers an area of $> 10^4 \text{ m}^2$ with 108 scintillation counters (0.83 m² x 0.10 m) surrounding the neutrino detector of experiment E225. Ninety six additional counters (CYGII), spaced on a wider grid as shown in last year's Progress Report have just been added on the east side of the existing array. The active, multiwire proportional counter shield for the now completed E225 experiment is used as an associated muon detector with an effective area for muon detection of $\sim 44 \text{ m}^2$ for typical showers.

The trigger requirement of 20 counters with pulse height greater than that due to 0.1 minimum ionizing particle, one counter greater than 7 particles and a total particle sum greater than 20 particles, allows primaries of energy greater than 100 TeV to be detected with good efficiency. The trigger rate for CYGI is about 4 Hz which is reduced by online cuts to 1 Hz written to tape. The CYGI array has operated with over 90% on-time. CYGII is about to be added to the system now that the physical installation of all CYGII counters has been completed. Recently thin lead sheets have been placed on the CYGI counters to improve the signal and timing response of the counters. A new satellite clock has been added to the array which gives absolute timing accuracy of $< \pm 1 \text{ } \mu\text{sec}$.

The angular resolution of the array from time measurements of the shower front was determined to be $\sim 1^\circ$ for small showers and $\sim 0.5^\circ$ for large showers. The systematic angular error has been found to be $\leq 0.2^\circ$. In summary, the CYGNUS array, which is the first array specifically designed to look for UHE radiation from point sources, has a threshold below 100 TeV and an angular resolution better than 1° for showers, thus making it a most powerful detector for such a search.

The most interesting results from the CYGNUS experiment to date has been the observation of bursts of events from the source Her X-1. The data were reported in considerable detail in last year's Progress Report and have since been published (B. L. Dingus et. al., PRL 61, 1906 (1988)). The data presented two unusual results:

- Showers in the bursts have significantly more muons than are expected from traditional gamma ray showers
- The periodicity of 1.23568 sec. exhibited by these events differs from the X-ray period of Her X-1 by 1.6%.

Statistically the number of bursts seen is 17 in two periods (7 in 30 minutes, 10 in 15 min.). The confidence level that these observations are not merely a statistical fluctuation is found to be 2×10^{-5} . The observed period for these bursts are the same as those found in lower energy showers (VHE) by Haleakala and Whipple observatories a month or two earlier. The shift of this period from the X-ray period of 1.23777 sec. may indicate a possible difference in production sites of the different types of radiation.

The average number of muons found in these burst events was at least as large as typical cosmic ray background events from the same zenith angle. No evidence is seen for a reduction in the number of muons as had been expected for UHE γ ray events. The events behave as if the primaries had hadronic

interaction properties but the period synchronization requires that these events be produced by a neutral particle of mass < 60 MeV. Could the interactions of γ rays with hadrons at CM energies in the 100 GeV to 1 TeV range produce more pions and hence muons as has been suggested by F. Halzen and M. Drees, or is something even more mysterious going on?

The search for steady emissions over background from the CYG X-3 and Her X-1 binary system has lead only to upper limits for radiation in the UHE region. (PRL 60, 1785 (1988)).

It is clear that a great deal more data must be accumulated to clarify the situation. The CASA-MUMA array of the Chicago and Michigan groups is coming on line this year at a similar longitude making simultaneous observations of sources possible by both arrays. This will provide the second independent observer needed to truly confirm the episodic behavior of these sources. In this connection it is interesting to note the following recommendation made by the HEPAP Sub-Panel High Energy Gamma Ray and Neutrino Astronomy in July 1988: "The Los Alamos CYGNUS detector is an operating facility with significant potential. It should be continued. Two experiments with overlapping fields of view are advantageous when studying sporadic sources".

Prof. C. Y. Chang spent part of the 1989 Spring Semester at Los Alamos and U. of California, Irvine, working on the CYGNUS experiment. He has prepared some Iarocci chambers for prototype tests for a much expanded muon detection system that the collaboration may try to construct in the future. The U. of Maryland HEP Computer System has played a major role in the analysis of data from the CYGNUS system, and will continue to do so.

F.2. Electron Neutrino - Electron Elastic Scattering Experiment (E-225)
(D. A. Krakauer and R. L. Talaga, U. of Maryland, in collaboration with U. of California-Irvine and the Los Alamos National Laboratory).

The Los Alamos experiment completed data analysis during the past year and is preparing publications of the final results. Daniel Krakauer completed his thesis, titled "Measurement of Neutrino-Electron Scattering and Inverse Beta-Decay of Carbon Using Neutrinos from Stopped Muon Decay". Results from that work are given below, followed by a summary of later improvements.

Neutrino-Electron Scattering

The data sample contained 262 ± 46 electron-neutrino electron elastic scattering events. The measured total cross-section for electron-neutrino electron scattering is

$$\frac{\sigma(\nu_e e)}{E_\nu} = (9.75 \pm 1.70 \text{ (stat)} \pm 1.23 \text{ (syst)}) \times 10^{-45} \text{ cm}^2/\text{MeV}$$

Subtracting the contributions from the purely charged-current and purely neutral-current amplitudes results in a model-independent measurement of the W/Z interference contribution

$$I(W/Z) = -(9.24 \pm 1.61 \pm 1.17) \times 10^{-45} \text{ cm}^2/\text{MeV}$$

demonstrating unambiguously the destructive nature of the interference. The measured interference is $(0.97 \pm 0.18 \pm 0.13)$ of the strength predicted by the WSG model with $\sin^2 \theta_W = 0.23$. Besides providing additional constraints on the possible values of the weak-neutral current coupling constants (g_V, g_A) , the agreement with WSG allows the first limits to be placed on neutrino flavor changing neutral currents (FCNC). Experimentally, the observed interference

requires (90% cl) that the coupling to FCNC be less than 0.36 times the total neutral current coupling strength. These results were among those featured in the Rapporteur talk on neutrino-electron scattering by J. Panman at the Stanford Lepton-Photon Conference in August, 1989.

Furthermore, the agreement of observed elastic scattering rates with the WSG predictions allows new stringent limits on the magnetic moment of the electron and muon neutrinos; namely

$$\mu(\nu_e)^2 + 2.1 \mu(\nu_\mu)^2 < 1.64 \times 10^{-18} (\mu_{\text{Bohr}})^2 \quad (90\% \text{ cl})$$

This leads to the separate limits:

$$\mu(\nu_e) < 12.8 \times 10^{-10} \mu_{\text{Bohr}}, \quad \mu(\nu_\mu) < 8.8 \times 10^{-10} \mu_{\text{Bohr}}$$

Neutrino-Nucleus Scattering

As reported in the last Progress Report, the observation of 181 ± 17 events with ^{12}N beta decay lead to the first measurement of a neutrino induced exclusive nuclear transition. The measured cross-section of $(1.03 \pm 0.10 \pm 0.10) \times 10^{-41} \text{ cm}^2$ is in excellent agreement with recent theoretical calculations. This is the only experimental data available to help verify the correctness of neutrino-nuclear cross-section calculations in the energy range of interest for solar and astrophysical neutrino observations.

Final Data Analysis

Following the completion of Krakauer's thesis, the E225 collaboration carried out a more thorough evaluation of the neutron-induced backgrounds observed in the data. The improved analysis did not significantly change any

of the above conclusions. A Letter describing the measurement of the Charged-Current/Neutral Current Interference has been drafted, and should be submitted by October, 1989. A full review paper, to include the limits of neutrino magnetic moments, neutrino charge-radii, FCNC etc... will follow shortly thereafter.

A secondary analysis of the elastic scattering data has also provided a new lower limit on the radiative lifetime of the muon-neutrino. This should be published as a rapid communication following the initial PRL on the elastic scattering cross-section.

The improved description of beam-associated backgrounds did allow for more certain measurements of the inclusive neutrino-nuclei rates. Therefore, in addition to a Letter (now drafted, to be submitted within a few weeks) on the exclusive reaction $^{12}\text{C}(\nu_e, e^-) ^{12}\text{N}(\text{gs})$, we intend to write a full review article describing the measured inclusive neutrino-carbon cross-section.

The beam-stop calibration experimental results have been accepted for publication in NIM.

G. Further Results from the JADE Collaboration. (P. H. Hill, J.A.J. Skard, and G. T. Zorn, U. of Maryland, with DESY, U. of Hamburg, Heidelberg U., U. of Lancaster, U. of Manchester, Rutherford Lab, and U. of Tokyo).

A number of physics studies on e^+e^- annihilation and two photon interactions described in last year's Progress Report have been published. One work that is almost ready to be submitted for publication by JADE is "A Measurement of the Weak Axial Couplings of the b- and c- Quark" by E. Elsen et al. The first statistically significant measurement of the electroweak asymmetry in the reaction $e^+e^- \rightarrow b\bar{b}$ was made by the JADE collaboration in 1984 (W. Bartel et al., Phys. Lett. 146B, 437 1984). This measurement provided a strong indirect argument for the existence of the top quark since the observed asymmetry was consistent with the isotopic spin assignment, $I_3 = -1/2$, for the b-quark in the Standard Model.

The new work makes use of the entire multihadronic data sample of the JADE experiment with $\sqrt{S} \geq 30$ GeV with a detected electron or muon and encompasses the events used in the earlier analysis of the b-asymmetry. The leptons serve both as a tag of the heavy quark b and c and as an indicator of the charge of the primary parton.

The sample of multihadronic events that satisfy the standard JADE criteria (W. Bartel, et al., Phys. Lett. 129B, 145 (1983)) are as follows

Time Period	$\sqrt{S}$ (GeV)	Hadronic events	Leptons	
			e	μ
1982	34.9	26058	931	1724
1986	35.0	28868	808	2002
1985	43.7	9113	368	862

Standard JADE methods are used to identify the electron and muon tracks. A

maximum likelihood analysis is used in the fits. Quark flavors (b and c) are separated on a statistical basis using the following three variables

$p_{\perp}$: The lepton transverse momentum with respect to the event axis

$m_{\perp}$: The transverse mass

($\cos\theta$): where θ = polar angle of the event axis.

The first two variables are good indicators of the large decay mass of the B hadrons. The variable ($\cos\theta$) must be added to the set of discriminating variables for experimental reasons. The electrons are only selected in the barrel, and there is a loss of hadrons down the beam pipe, so that there are small systematic biases in $p_{\perp}$ as a function of ($\cos\theta$).

Usually a large $p_{\perp}$ negative lepton arises from a b or $\bar{c}$. This is not always true, since a b can decay into a c + $\bar{q}q$ followed by the c decay into a l^+ . More important from the experimental point of view is the contribution of "fake" - leptons, i.e. misidentified π , K or p, which are not strongly correlated with the charge of the primary quark. The probabilities for all of these possibilities are evaluated from experimental data and Monte Carlo calculations and are included in the Maximum Likelihood analysis.

Since the c-quark asymmetry has been measured to be in reasonable agreement with the Standard Model, one can fix the asymmetry of the c-events to -14% at $\sqrt{S} = 35$ GeV (and -23% for $\sqrt{S} = 44$ GeV), and deduce the asymmetries for the b-quark. Combining the results from the e and μ samples one finds

$$A_b = -11.6 \pm 4.8\% \text{ at } 35 \text{ GeV and}$$

$$A_b = -23.2 \pm 14.6\% \text{ at } 44 \text{ GeV.}$$

The acceptance corrected angular distribution for b-quarks are shown in Fig. 7 together with the fitted curve.

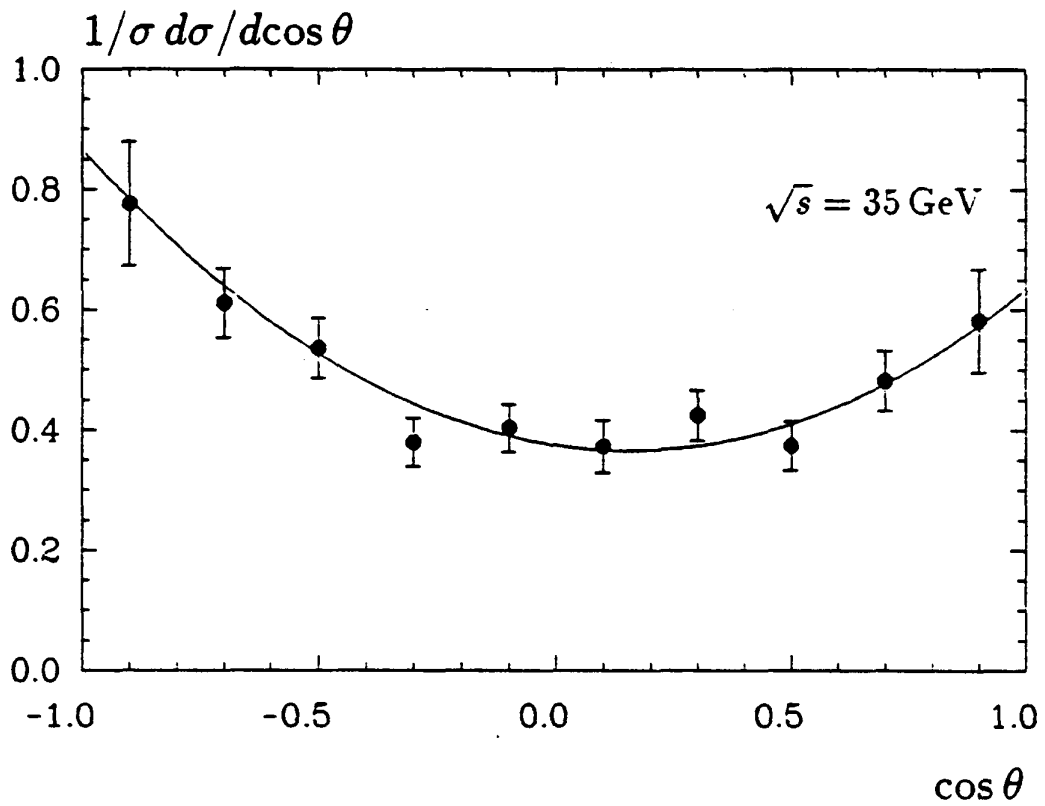


Figure 7: Angular distribution for leptons $b \rightarrow l$ after acceptance correction together with the fit result $A_b = -11.6 \pm 4.8\%$. The errors shown are the poisson errors of the number of lepton events in the corresponding $\cos\theta$ -bin.

Reversing the procedure and fixing A_b yields for A_c

$$A_c = -12.3 \pm 3.6\% \text{ at } 35 \text{ GeV}$$

$$A_c = -9.1 \pm 11.3\% \text{ at } 44 \text{ GeV.}$$

In order to convert this experimental asymmetry measurement into a determination of the weak axial coupling constant A_b , one needs to correct for $b\bar{b}$ mixing, for errors due to the lepton selection process, and for uncertainties in the lepton branching ratios and the charm asymmetry. Assuming an effective mixing parameter $\chi = 0.14$ and including all statistical and systematic errors yields the results

$$a_b = -0.73 \pm 0.34 \text{ with } a_c = 1, \text{ and}$$

$$a_c = 0.80 \pm 0.40 \text{ with } a_b = 1.$$

The JADE result are compared with all other attempts to measure a_b in Fig. 10 before the correction for $b\bar{b}$ mixing. Combining all measurements using their statistical errors only, yields the results $\langle a_b \rangle = -0.72 \pm .22$ (stat.) assuming $\chi = 0.14$ and $a_c = 1$. Combining all a_c measurements assuming $a_b = -1$ yields $\langle a_c \rangle = 1.07 \pm 0.17$ (stat.) in good agreement with the standard model.

Another important JADE result that has been published since our last Progress Report is an "Experimental Investigation of the Energy Dependence of the Strong Coupling Strength" S. Bethke et al., PL 213, 235 (1988). One of the most fundamental properties of the QCD theory is that the coupling strength falls as the energy increases. In this letter the energy dependence of the strong coupling constant α_s is determined from a study of multihadronic

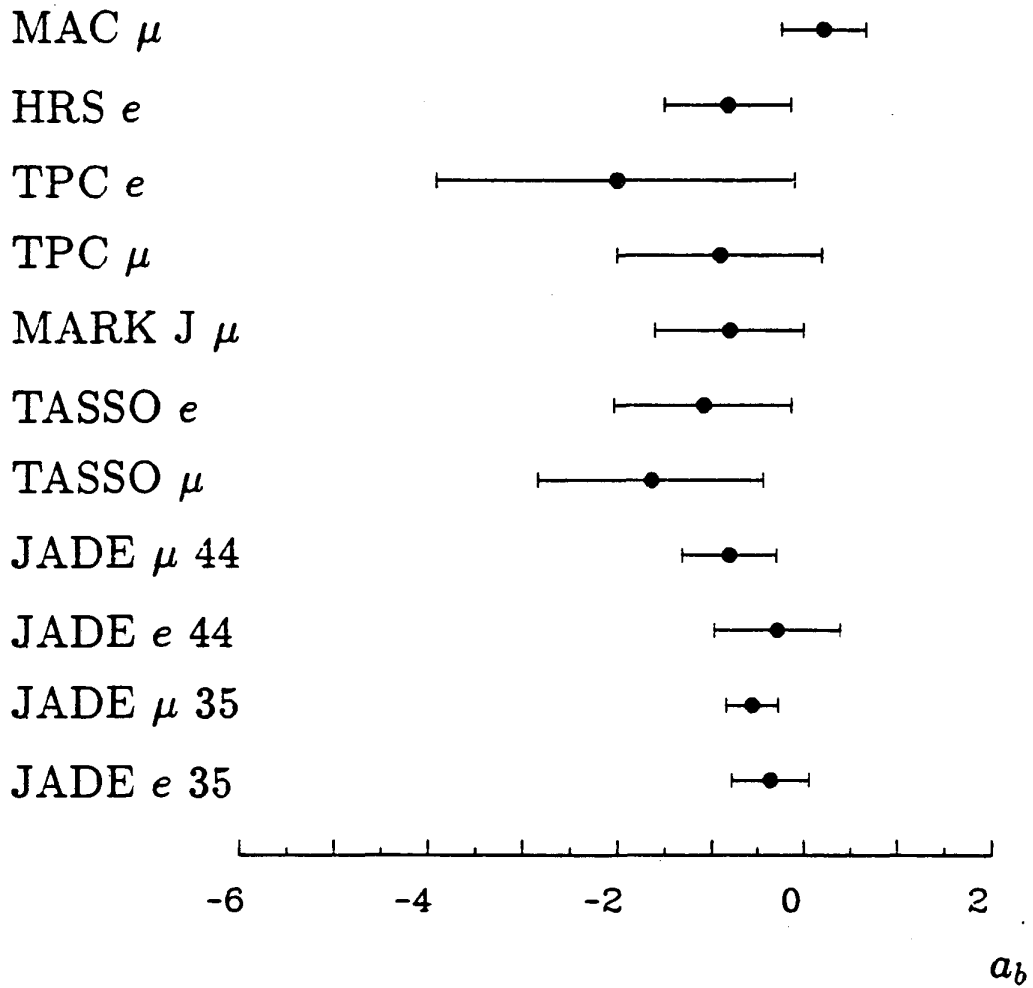


Figure 10: Published values for a_b without correction for $B\bar{B}$ mixing. We assume $a_e = -1$.

events taken with the JADE detector at the PETRA e^+e^- storage ring in the center of mass energy range, 22 GeV to 46.7 GeV. In second order perturbation theory, the energy dependence of α_s is calculated to be

$$\alpha_s(Q^2) = 12\pi [b_0 \ln(Q^2/\Lambda_{\overline{MS}}^2) + (b_1/b_0) \ln \ln(Q^2/\Lambda_{\overline{MS}}^2)]^{-1}$$

where $b_0 = 33 - 2N_f$, $b_1 = 918 - 114N_f$ and N_f = number of quarks produced. In e^+e^- annihilation $Q^2 = E_{CM}^2$, and $\Lambda_{\overline{MS}}$ is the QCD scale parameter which has to be determined by experiment.

Phenomenological models that are used to describe the nonperturbative hadronization process introduce an intrinsic uncertainty in the extraction of α_s from experimental observables. To avoid this systematic error, an observable that is related to α_s and that is closely related to theoretical calculations is studied as a function of energy. The variable is

$R_3 = \sigma_{3\text{-jet}}/\sigma_{\text{total}}$, which in second order QCD can be written,

$R_3 = c_1\alpha_s + c_2\alpha_s^2$. The coefficients C_1 and C_2 depend on the particular invariant mass cutoff (y_{cut}) used to define the jets but they are independent of energy in the region studied. R_3 has been measured by JADE at five energies 22, 30, 34.6, 38 and 44 GeV and the results are shown in graphical

form in Fig. 2 for various y_{cut} 's. R_3 clearly falls with energy whereas a constant α_s would yield a constant value of R_3 .

Another way to study the same effect is to measure $r = R_3(E_{CM})/R_3(E'_{CM})$, the ratio of R_3 at two different energies. From QCD this ratio is expected to be roughly proportional to $\alpha_s(E_{CM})/\alpha_s(E'_{CM})$, which should be less than unity for $E_{CM} > E'_{CM}$, and to be independent of

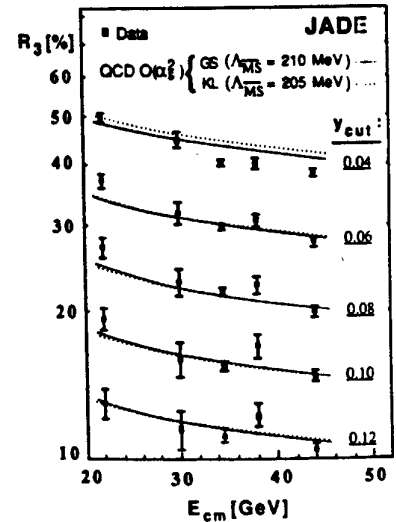


Fig. 2. Three-jet event rates at different centre of mass energies for various values of y_{cut} , together with the direct predictions of the complete second-order perturbative QCD calculations of Gottschalk and Shatz (GS) and of Kramer and Lampe (KL).

y_{cut} . The ratio r of the data $E_{\text{CM}} = 44 \text{ GeV}$ and $E'_{\text{CM}} = 34.6 \text{ GeV}$ is shown in Fig. 3 for various values of y_{cut} . The experimental results agree with QCD predictions of Kramer and Lampe shown for three values of $\Lambda_{\overline{\text{MS}}}$. The mean value of r , $\langle r \rangle = 0.935 \pm 0.023$ is four standard deviations away from $r = 1.0$. The fact that $\alpha_s(Q^2)$ falls with increasing Q^2 seems clearly established by this experimental data.

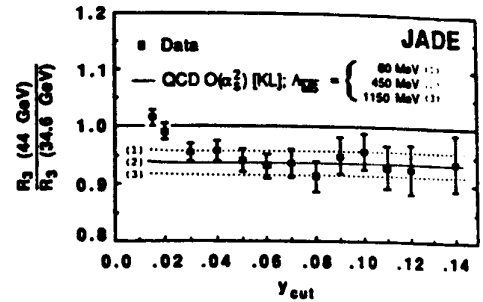


Fig. 3. The ratio of three-jet event rates observed at $E_{\text{CM}} = 44 \text{ GeV}$ and 34.6 GeV .

Other JADE publications since last year's Progress Report include: "A Measurement of the τ lepton lifetime", C. Kleinwort et al., Z. Phys. C42, 7 (1989) in which the τ lifetime is found to be $(301 \pm 29) \text{ fs.}$; and "Observation of Spin 1 Resonance Formation in the Final State $\text{KK}\pi$ Produced in Tagged Two-Photon Collisions," P. Hill et al., Z. Phys. C42, 355 (1989) in which $J = 1$ resonant state of a mass $\sim 1.4 \text{ GeV}/c^2$ is found. This state is probably the $f_1(1420)$. The product of the branching fraction and the two photon width has been determined to be

$$B(f_1(1420) \rightarrow \text{KK}\pi) \cdot \Gamma_{f_1(1420)} = 2.3^{+1.0}_{-0.9} \pm 0.8 \text{ keV.}$$

H. Calculation of Radiative Polarization Effects in Electron Storage Rings
(A. Skuja of the University of Maryland with L. N. Hand of Cornell University).

During 1989 Prof. A. Skuja and Prof. L. N. Hand finished their analytic calculation of non-linear depolarization effects in electron storage rings. This work was published in Physics Letters A in Aug. (Phys. L. A139, 291 (1989)).

Synchrotron radiation from electrons in storage rings leads to the radiative polarization of electrons under ideal conditions. Both of the large colliding beam facilities in Europe (HERA and LEP) plan to exploit this phenomena to facilitate the study of polarized electron interactions at high energies. Experimentally it is observed that strong depolarization effects occur when the spin precession frequency (spin tune) is equal to any linear combination of betatron and synchrotron frequencies with integer coefficients. The depolarization resulting from the spin tune resonating with a single trajectory oscillation frequency is now well understood, and a number of analytic methods of calculating these uncoupled (linear) depolarization resonances have existed for several years.

Hand and Skuja have extended their previous calculation of the polarization in an electron storage ring to include emission of an arbitrary number of photons. Coupled depolarization resonances of all orders result because of the modification to spin motion caused by the emission of these photons. They have produced an explicit calculation of the strengths of both coupled and uncoupled spin-orbit resonances in the approximation of a single spin-flip photon. A formula for transition amplitudes involving any number of spin flips in the presence of all synchrotron photons has also been obtained. Practically, they predict that it will be possible to minimize, or even eliminate, coupled depolarization resonances if appropriate "spin

transparency" conditions are met during electron storage ring design.

A computer calculation of numerical results appropriate to various storage rings will be carried out during 1989-1990.

I. Rare Kaon Decay Experiments at the Brookhaven National Lab. (N. Hadley, the University of Maryland in collaboration with Brookhaven National Lab., the Paul Scherrer Institute (formerly SIN), the University of Washington, and Yale University).

Experiment 851 designed to study the decay $K^+ \rightarrow \pi^+ e^+ e^-$ at the Brookhaven AGS finished taking data this spring. This experiment was a continuation of Brookhaven experiment 777 which searched for decay $K^+ \rightarrow \pi^+ \mu^+ e^-$ as well as studying the decay $K^+ \rightarrow \pi^+ e^+ e^-$. The data from experiment 777 published in October of 1988 [1] set a limit of 1.1×10^{-9} for the decay $K^+ \rightarrow \pi^+ \mu^+ e^-$ an improvement of a factor of 4 from the previous limit.[2] Since the decay is lepton number violating, if it was found, it would be evidence for beyond the standard model physics. The search was motivated by a number of theories in which lepton number violation is allowed (e.g. technicolor). These theories attempt to explain some of the shortcomings of the standard model. With all the data collected to date, we will set a limit in the range 2 to 3×10^{-10} for this decay mode. The current status of the data analysis is that we see no $K^+ \rightarrow \pi^+ \mu^+ e^-$ events, see Fig. 1 and should have a final normalization by the end of the summer. Translating this number into a limit on new physics is, of course, model dependent. However, as an example of the sensitivity of the decay to new physics, we note that in the model of Cahn and Harari [3] where the decay is mediated by new horizontal gauge bosons, the above limit would imply that the mass of these new bosons be greater than 38 TeV, a mass limit equivalent to the direct reach of the SSC.

[1] C. Campagnari et al., Phys. Rev. Lett. 61, 2062 (1988). [2] A. M. Diamant-Berger et al., Phys. Lett. 62B, 485 (1976). [3] R. Cahn and H. Harari, Nucl. Phys. B176, 135 (1980).

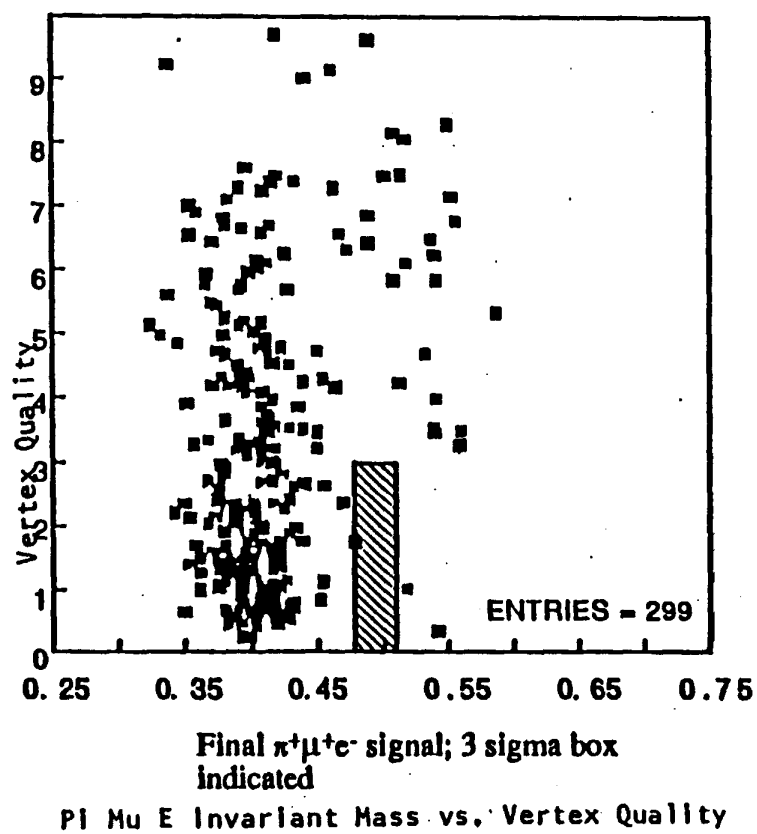
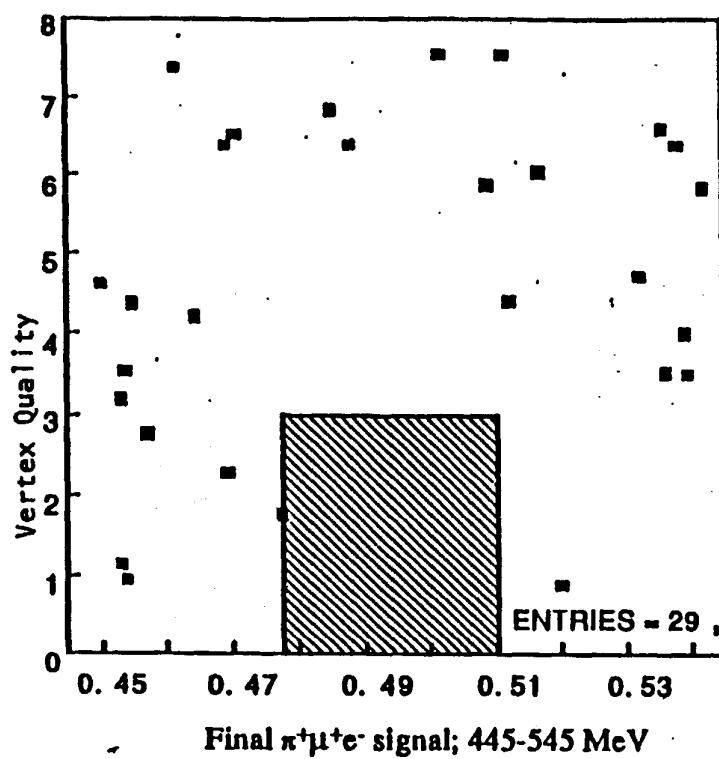


Figure 1.

J. Other Activities

J1. SSC Participation

A great deal of discussion has been ongoing by the younger members of the Maryland HEP group as to how best to participate in the development of detectors for the SSC in a concrete way. The group of A. Baden, D. Fong, N. Hadley and A. Skuja have recently joined a collaboration that is proposing to study the performance of a liquid argon calorimeter for the SSC. This proposal will be submitted to the SSC Physics Research Division under the SSC Major Subsystem R.&D. program. The proposal is to test three modules using different absorbers to try to develop a viable design for use at the SSC. These tests will also be used to study preamplifiers with short 50-100 nS shaping times that are needed to come close to the 16 nS bunch crossing time of the SSC. The Maryland group will provide the Data Acquisition System for the test beam work and to participate in the study of the front end electronics and the trigger.

A second effort is being studied by A. Ball, A. Jawahery and G. T. Zorn centered around silicon vertex detectors. This work is targeted in the near future for a possible upgrade of the OPAL detector but it could at the same time be of use in the design of vertex detector elements for an SSC detector. As in the past members of the group continue to participate in SSC workshops and summer studies, although the immediate pressures of OPAL at LEP and $D\phi$ at Fermilab preclude large scale commitments in the near future.

J2. HEP Computer Developments (D. Fong)

The UMD HEP computer system is in the middle of a substantial upgrade. Five Digital VAX station 3200's have been added to the Local Area Vax Cluster using the VAX 11/780 as the bootnode. This provides dedicated computing power to individual physicists but also greatly increases the total batch computing power of our facility.

We are currently engaged in installing four more VAX stations into the cluster. The disk storage has just been upgraded by about 3.5 Gbytes. We have on order two 8 mm Exabyte cartridge drives so that we can obtain large volumes of data from CERN and Fermilab. The final part of our computer upgrade calls for the upgrade of our bootnode VAX11-780 to a VAX 6000 class computer with HSC I/O server. This will greatly improve the total input/output capacity, preserve our tape drive capacity and open up further paths for future upgrades.

A 14400 baud leased line has been connected between the VAX 11/780 and Fermilab making UMDHEP a part of HEPnet. It is now practical to copy computer files to and from CERN, FERMILAB, CESR, etc. Using the HEPnet link, automatic procedures have been introduced to update the OPAL and D ϕ libraries.

The CERN and OPAL libraries have been continuously updated and checked out. Currently we have installed Geant 313, PAW, HBOOK and the GTS GRAL GKS graphics software. For OPAL the libraries are GOPAL 120, Rope 307 and GROPE 107. The last package enables us to display OPAL event reconstructions on the VAX stations, using 3 dimensional GKS. The pictures can be spooled onto a disk in metafiles and then printed into hard copies on a newly installed DIGITAL Postscript printer.

J.3. Electronics Support Group (Robert Bard and John Colmer).

Most of the effort this past year has gone into producing the hardware needed for the completion of OPAL. We were lucky to keep Laura Shaffer and to hire Cai Qing full time to help with the enormous production.

The multitask Wire monitor Latch was prototyped and parts were procured for 80 boards to be built. Programmable Array Logic, "PALs", were used to make the trigger section of the WML "flexible". This entailed the procuring and set up of appropriate software and hardware on a PC AT computer. Special testers were built to test the many aspects of these boards. Hundreds of special cables were designed, built and tested to enable the hook up of the wire monitor latches. A MWL driver was designed and three devices built and tested.

Sixty four low voltage supply cards were designed, built and tested. These supply power to the electronics boxes. Over 180 low voltage supply ribbon cables were built and tested at Maryland.

About 30 switch yard cards were designed, built and tested at Maryland. These cards "sort" signals from the summing Amplifiers. Four low voltage supply controllers were designed, built and tested. The design of these boards entailed high current bus bars and other high current techniques.

The OPAL slow control monitor circuits required our designing, building and testing various NIM, CAMAC and special purpose monitoring systems.

Just to keep the procurement of parts running smoothly so as to insure that our production facility has been able to move ahead has been a monumental task.

We have also brought on line two AT computer systems and a new fax machine to help keep OPAL's paper work system running smoothly.

We are presently involved with the design of an OPAL trigger system.

As usual, some effort has been made to help support the VAX computer. Many terminals have been repaired, Ethernet hook ups made, and other new installations made.

J.4. Summer Course on Hadron Spectroscopy. (D. C. Peaslee, Guest at U. of Maryland).

A summer course, organized by Dr. Peaslee, on Hadron Spectroscopy was held at the UMCP Physics Department from August 14th through August 18th. The lecturers were Dr. Mark Burchell of SLAC, Prof. Eberhard Klempt of U. of Mainz and Prof. Sadao Oneda of the U. of Maryland. Each lecturer spoke for 60-90 minutes each day. In addition Prof. Nussinov of Telaviv U. gave a guest lecture. The experimental information and analyses presented on meson resonances from the Mark III and Asterix experiments proved to be particularly interesting and stimulating.

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3. INCLUSIVE K^0 PRODUCTION IN e^+e^- ANNIHILATION FOR $9.3 < \sqrt{s} < 31.6$ GeV, Ch. Berger, et al. (PLUTO Collaboration), Phys. Lett. 104B, 79 (1981).
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