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Fermilab

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Directors Office

July 16, 1987

Dr. Frank Sciulli
Nevis Laboratories
P.O. Box 137
Irvington, New York 10533

Dear Frank,

During their June meeting, the PAC considered your letter of intent to calibrate calorimeter modules for the ZEUS detector at Fermilab. They recognized the importance of providing test beams for the development of high energy physics detectors, while simultaneously noting the potential problems with tests that require long-term commitments of a beam line and substantial Fermilab resources. The fact that the testing will result in research at a Brand X laboratory is not relevant; that elementary particle physics advances is what counts. The PAC suggested to me that such tests should be treated the same as any other experimental proposal so that its priority and impact can be judged in the context of the whole laboratory program.

I will heed their advice and invite you to present your proposal at the next PAC meeting, which will occur on December 10-11 at Fermilab. In the meantime, good luck with ZEUS and all of the other gods.

Sincerely,

Leon

Leon M. Lederman

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Columbia University

DEPARTMENT OF PHYSICS

NEVIS LABORATORIES

P.O. Box 137
Irvington, N.Y. 10533
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June 5, 1987

Prof. Leon M Lederman
Director, Fermilab
Batavia, Illinois

Dear Leon:

It was, as always, a pleasure to talk with you last week. I am enclosing, at your suggestion, an outline of what we need to do in the testbeam at Fermilab, with what I feel is a minimum of background information for coherence. If it is desirable, we can elaborate on some or all of the items.

The physicists from the seven U.S. institutions engaged in the Zeus effort are interested in the physics of lepton-nucleon scattering. For many of us, this has been an important focus for years, even decades. We believe that discoveries made in this field, like Bjorken scaling and neutral currents, have been critical in the development of the Standard Model, and that there may well be important and unique physics waiting at the Q^2 of two orders of magnitude higher. The only place where such physics can be done will be at HERA. We have a major responsibility in that program, and we have anticipated the support of our colleagues and our national facilities to help carry it out. Since DESY is a laboratory without fixed target beams, it is essential that all physicists involved in experimentation there have such support.

At the same time, we are designing and constructing a detector which is at the cutting edge of the technology. It has much in common with work being done at Fermilab, and with R&D work which will be necessary for detectors at future machines such as the SSC, so the work should be of common technical benefit. The testbeam that we use for this work should also be of interest to and could be used by other interested physicists as well.

Thank you for your help and support. We look forward to a collaboration of mutual benefit.

Best regards,

Frank Sciulli

Frank Sciulli

U.S. Zeus Spokesperson

June 5, 1987

FNAL Testbeam Needs for U.S. Zeus Collaboration

Argonne National Laboratory

Columbia University

University of Illinois

Ohio State University

Pennsylvania State University

Virginia Polytechnic Institute

University of Wisconsin

spokesperson: F. Sciulli

I. Introduction - Unique Technical Problems at HERA

A. Precise Energy Resolution on Jets

The physics of lepton-nucleon scattering requires accurate measurement of nucleon structure functions. For the Charged Current processes, only the hadronic jet from the struck quark is observable. The measured energy and angle of this jet are used to obtain the relevant parameters, such as x and Q^2. Over essentially the entire kinematic plane, the resolution in these reconstructed quantities is dominated by the resolution in the jet energy measurement.

The Zeus collaboration has adopted precise resolution for jets as a principal goal. For this reason, we have converged on a design incorporating compensated calorimetry. It utilizes depleted Uranium (DU) and scintillator as the inert and active media, respectively. The geometry has been chosen such that the fractional energy resolution on single hadrons will be $.35/\sqrt{E}$. Combining this with an EMC resolution of $.16/\sqrt{E}$ and an equal mean response for photons (electrons) and hadrons ($\pi/e = 1$) will give a jet resolution of about $.32/\sqrt{E}$.

Early calculations predicted that this resolution would be achievable with a DU cell thickness of 3.2 mm and a scintillator thickness of 2.5 mm. Tests carried out at CERN with test calorimeters have verified this calculation. Figure 1 shows a summary of that data. At fixed beam energy, one can determine from a histogram of the summed calorimeter pulse heights, the ratio of the distribution RMS to the mean. The figure shows this ratio multiplied by $\sqrt{E}$, as a function of the beam setting (E). As the figure shows, the desired resolution has been achieved with the geometry described. It should be noted that the data of figure 1 are directly measured resolutions and so incorporate ALL sources of error (including containment). At the same time, the relative mean response of electrons and pions was measured to be equal within a few percent.

It is this geometry which works; we are committed to a design utilizing it. The U.S. participants are designing and constructing 34 Barrel Sectors, which are modularized into approximately 6000 subtowers. Figure 2 shows a drawing of a typical Barrel Sector, comprising 1/32 of 2π. The design of all calorimeter readout electronics is also being carried out by the U.S. group.

Clearly, the demonstrated intrinsic resolution of this calorimeter must be matched by all other possible sources of error. The mechanical design has had to impose matching constraints on uniformity, while also ensuring reproducibility. Maintaining this uniformity while insuring mechanical stability has been a nontrivial task. This novel design is near completion; we are in the process of ordering components for the first (prototype) Sector Module.

The design of the electronics must assure that the noise in all channels is low enough so this does not become important relative to the good intrinsic resolution. Since very high energy depositions are possible, the signal/noise requirement has been set to a minimum of 20000/1. Because of the high background interaction rate, as well as the requirement to use out-of-time cosmic ray muons for calibration, a time measurement from the counters is also required.

It is important that the first modules be examined carefully in a testbeam as soon as possible after successful assembly and mechanical testing. A measurement showing that the targeted resolution is achieved would indicate that the uniformity issues have been correctly addressed. In the longer term, it is our opinion that small differences in production may give small differences in calibration from tower to tower. Hence, it seems judicious to plan to calibrate each tower of the calorimeter to ensure that this, presently the most precise of all colliding beam calorimeters, is not limited by calibration uncertainty.

B. Beam Current, Vacuum, and Trigger

In order to obtain the necessary luminosity, the HERA machine must circulate a standing current of more than 10^{13} protons. This is about 100 times the typical beam current in hadron colliders. At the same time, the synchrotron radiation from the electron beam limits the vacuum obtainable in the warm straight sections. The result is that the beam gas interaction rate in the straight section upstream of the interaction point is severe by current standards. After some study, we have come to the conclusion that this background can be reduced at the first trigger level to 1000 Hz. However, this requires some sophistication in the trigger at the very first level. It also requires ample time to generate this trigger, about 5 μsec.

For the same reasons to be discussed below for the data acquisition system, the first level calorimetry trigger must also be pipelined. This trigger is also being designed by the U.S. group.

C. Bunch Crossing Rate and Calorimeter Data Acquisition

In order to obtain the requisite luminosity, the HERA machine will contain 200 filled bunches. This implies a beam crossing in the intersection region every 96 nsec. All other bunched colliders presently have at least two orders of magnitude more time between crossings in which to freeze all data channels while a trigger is being formed. (This new problem will also exist for future machines like the SSC.)

Therefore, the readout electronics for the Zeus calorimeter must store information obtained in each beam crossing for 5 μsec, or about 50 buckets, while a decision is made for the first level trigger. All of this must occur while maintaining the necessary dynamic range (ie restoring the channel baseline) and low noise. The electronics readout design for both data acquisition and for first level triggering is highly innovative and largely unprecedented.

The design involves shaping the signal from each photomultiplier and sampling the shaped signal at clocked intervals phased precisely to the beam crossings. Some tolerance to time phasing is incorporated so that cosmic ray muons may be used for maintaining calibrations. However, it is crucial that the calibration be performed with a clock phased to the beam, or alternatively that the calibration be demonstrated to be independent of the clock phase. As discussed below, Fermilab's RF structure makes its fixed target beams quite appropriate to this study.

II. Calibration Needs at Fermilab

The collaboration schedule calls for the first prototype module to be assembled at Argonne this calendar year. After mechanical testing and checkout with cosmic rays, we will begin assembly of the additional modules. By late spring, we expect to have three modules complete. This is the minimum number required to have adequate containment of hadronic showers. We plan to be ready to calibrate these early modules during the fixed target running of 1988. At the same time, we will have the "local" electronics, complete with pulse conditioning and pipeline, assembled on the modules. These tests are crucial for us to verify whether, in production, the necessary mechanical and electronic precision has been achieved.

Because we presently cannot rely on complete production uniformity, we feel it is necessary to plan on calibrating each tower, with local electronics, of each module as it is assembled. This will involve use of the test beam through 1990. The requirements on the test beam are as follows:

1) Normal running at approximately 50 GeV with a maximum of 10^5 particles per machine cycle.

2) Reasonable admixtures of electrons, muons, and hadrons with particle identification and momentum tagging.

3) Ability to raise the beam energy to about 150 GeV and to lower it to about 5 GeV at some time is desirable. The exact upper and lower limits, and when this would be done, are negotiable.

4) Adequate floor space, offloading capability into Lab E, etc for the Barrel Sector Modules:

Volume	3.3 m x 0.4 m x 2.0 m
Weight	~ 11 tons

An important property of Fermilab beam operation is the inherent RF structure of 18.6 nsec between bunches. This means that the period between 5 successive bunches is 93 nsec, which is very close to the 96 nsec period of the HERA bunch structure. The tests using the bunch structure at FNAL will be meaningful in extrapolating the response of the calorimeter and associated electronics to the HERA environment.

After discussions last fall with Roger Dixon and others at the Lab, we looked into several possibilities, including the NW hall, and the NT beam into Lab F and Lab E. The location that appears both to satisfy the needs and to be available for the 1988 running period is in Lab E. Several of us have worked with Fermilab in setting up and upgrading the NT testbeam (as part of this year's completion of the neutrino program in Lab E) so that there now exists a well-instrumented tagging system with Cerenkov counters. We believe that we will be able to use the existing overhead crane for off-loading, even though the modules are slightly above the crane limit. Recent discussions between N Hill (Argonne) and R Sherr, the FNAL safety representative for Lab E, indicate that 11 ton modules could probably be accommodated. Once off-loaded, we can supply the necessary jigs for rotating and transporting the modules inside Lab E.

The above four requirements on the beam can be met in the NT beamline using substantially less than 10^{11} extracted protons. The beam is optimized for energies above 35 GeV, but can be operated at lower energies and, with the tagging system, should be adequate for our needs.

The present data acquisition system in Lab E contains the capability to record the beamline information, particularly the Nevis-built TDC system to record information on particle position. (The drift chambers in this beamline were also supplied by us for use in tagging particles near the dipoles in Lab F.) This system reads into a PDP-11; the software exists to record data on magnetic tape and supply it to the VAX-780 for online analysis. There is a small amount of PREP electronics used to create a trigger; this will require only small changes. We would like to maintain this system for at least the first year, possibly upgrading the TDC system to permit more particles to be recorded. The remaining electronics hardware will be supplied by us, since it is an important part of the tests we need to make.

The Lab E neutrino collaboration has agreed that this year's E770 run will complete the data sample for the foreseeable future. Should some new collaboration request the use of the existing equipment, we believe that this could be accommodated if and when the need arises in years subsequent to 1988. The neutrino carts are located on wheels so that they can be moved. Although our preferred use of the testbeam would require some transverse movement of neutrino components, we anticipate that, in the longer term, simultaneous use of the slow beam in NT and the fast or slow beam in NC is feasible. It may require some relocation of the Sector test area in either Lab E or Lab F.

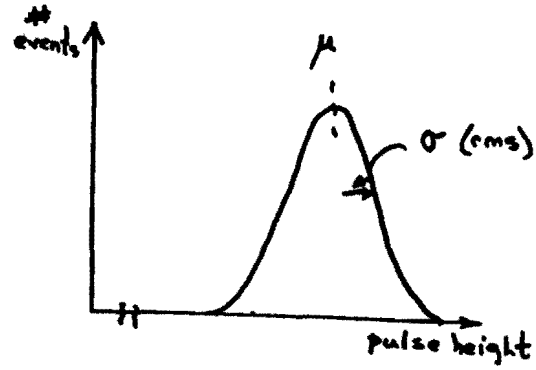
We also mention that it is our intention to maintain a well-instrumented test beamline during the period of use. We do not anticipate requiring 100% of the time in this beam, so that other less frequent uses will be available to other Laboratory users. In addition, users with small amounts of material in the beam could locate upstream and operate parasitically.

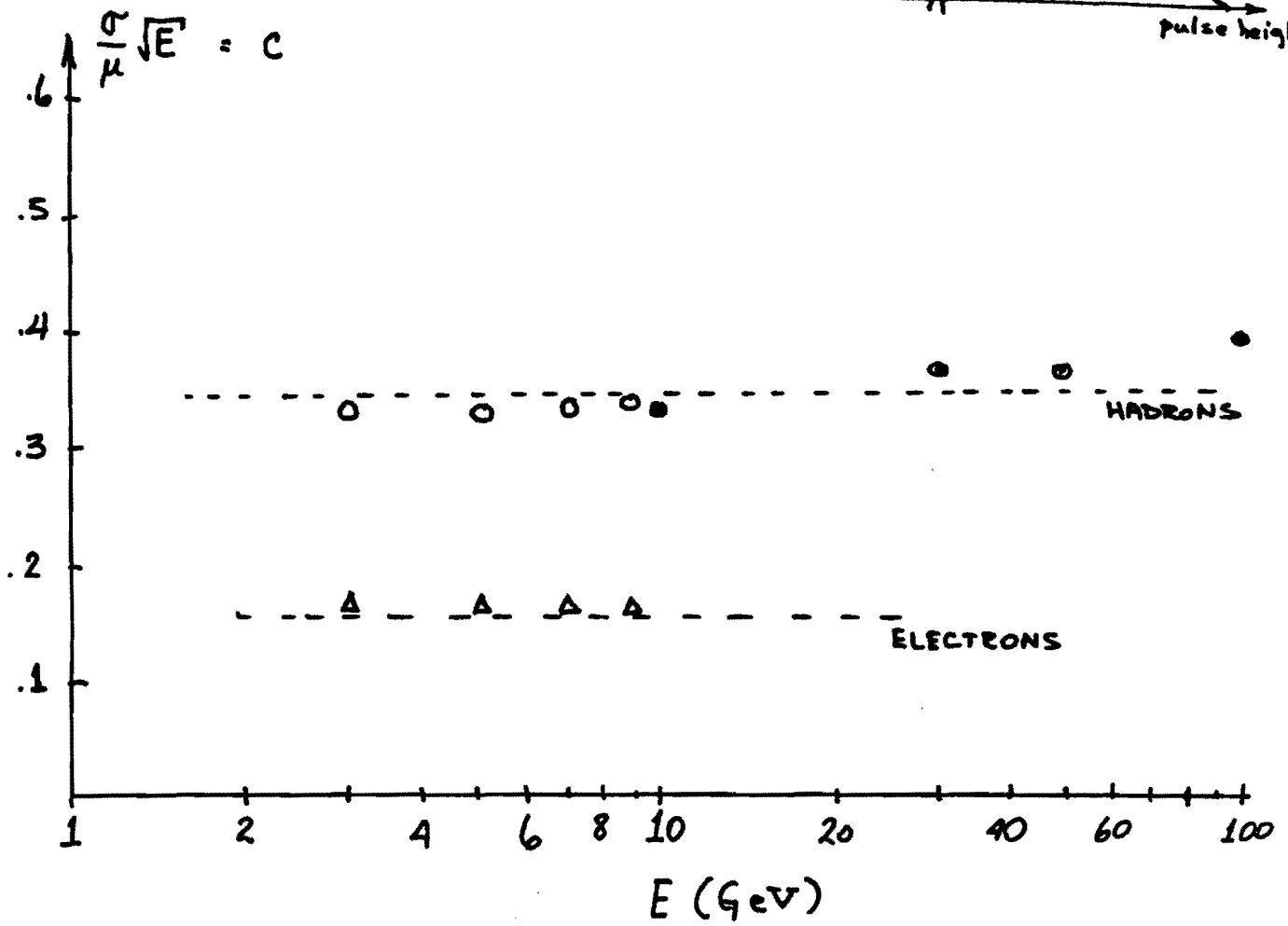
Fermilab, as you can see, is important to the successful design and construction of the Zeus calorimeter and associated electronics. This project is the only major involvement in lepton-nucleon scattering at extremely high momentum transfers by the U.S. community. In addition, the effort involves novel instrumentation for calorimetry which is important to the wider HEP community. Fermilab is presently involved with similar innovative and creative efforts for their own in-house detector facilities. We have learned much from our own interactions with the CDF and D^0 physicists. We anticipate that the interaction, and even friendly competition, during testbeam operation, will be of benefit to us all.

FIGURE 1

JULY 1986

DATA RESULTS FROM ZEUS TESTS "35" and "60 x 60"





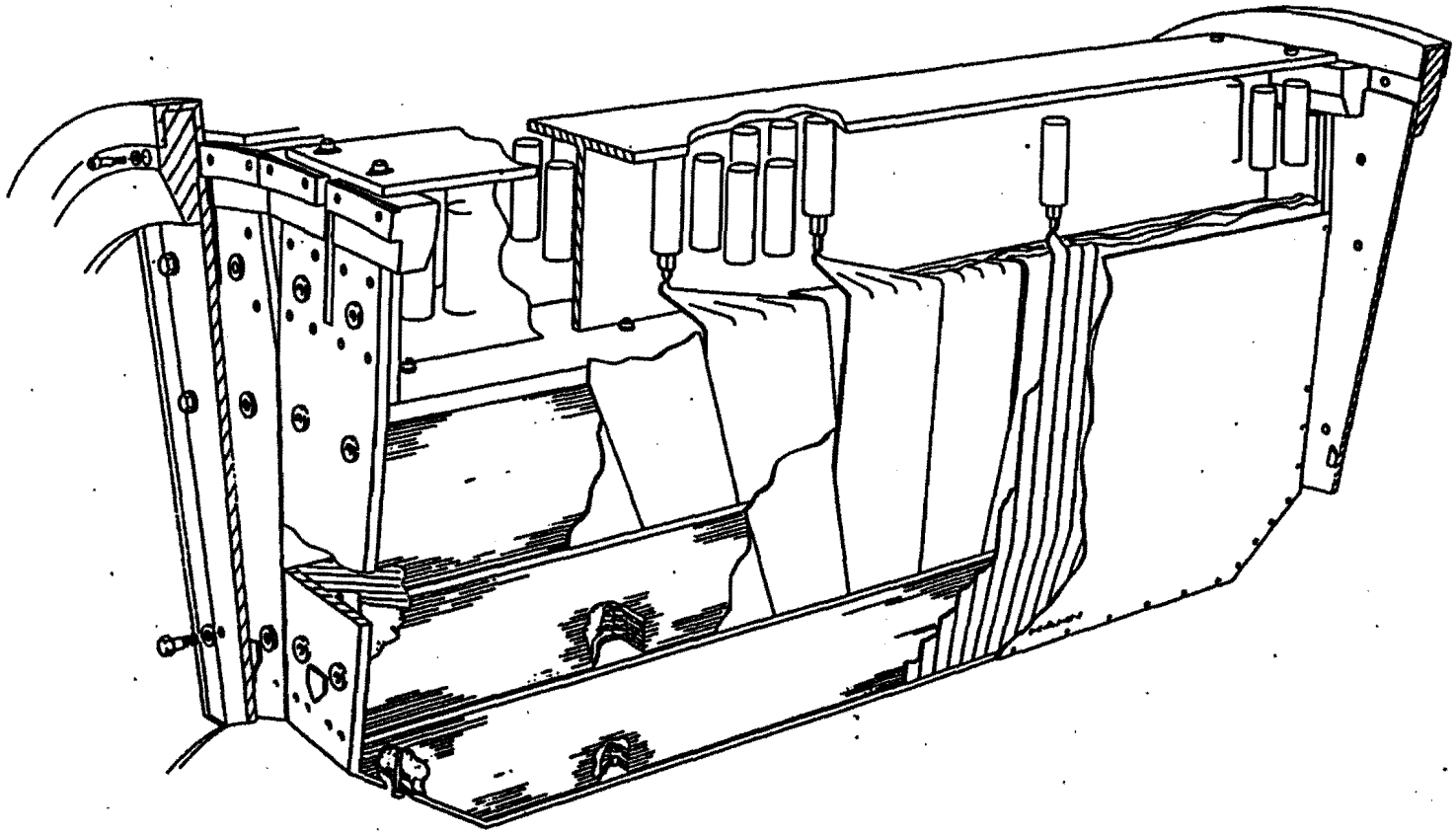


Fig. 2 Cut-away isometric view of a barrel calorimeter module(sector).