

REQUEST TO THE DEPARTMENT OF
ENERGY
FOR FUNDING OF THE UNIVERSITY OF
MICHIGAN ATLAS PROJECT

1.0 Overview

The Large Hadron Collider (LHC) being built at the European Organization for Nuclear Research will represent the premier tool in the world for the exploration of the new frontiers in particle physics when it is completed approximately eight years from now. With this facility we expect to be able to address many fundamental topics concerning the origin of particle masses and composition of matter at the sub-quark level.

With the demise of the U.S. commitment to the Super Conducting Super Collider (SSC), the LHC will be the focus of scientific inquiry in particle physics well into the next decade. Researchers interested in the continuing advance of our understanding of nature will be attracted by the research opportunities offered by the LHC, as has been recognized by the U.S. government in its decision to contribute to the funding of the LHC Project.

The high energy program at the University of Michigan has historically been one of the strongest in the nation. Our creation of the concept of the "racetrack synchrotron" -- one that does not have to be perfectly circular as originally thought, has made possible most of the accelerators developed over the past several decades, the bubble chamber was invented here, much of the early spark chamber work was done here, and much of what is known about proton polarization effects is the result of work done by faculty here (including the very discovery of proton spin by Dennison). Against this historical background, our present high energy faculty constituted the largest single university contingent on the only experiment approved for the SSC, are leading contributors to the Fermilab CDF and DZERO experiments that jointly announced the discovery of the top quark, and are now focussing our future research plans on the LHC Atlas experiment.

Seven members of the University of Michigan High Energy Physics program (Bob Ball, Jay Chapman, Myron Campbell, Homer Neal, Jianming Qian, and Greg Tarle') submitted an application for admission to the ATLAS collaboration in May of 1997 and were unanimously voted into the collaboration at its subsequent meeting in September. Since that time Michigan has added two prominent individuals to our staff with interest in ATLAS. Bing Zhou who is already a member of the ATLAS collaboration will be joining us soon with plans to contribute to D0 in addition to ATLAS work and David Gerdes who has expressed the expectation that he will make ATLAS his second major activity to CDF. At Michigan Task C and Task K of the DOE grant have joined forces to participate in the development of ATLAS MDT muon chambers for the forward region. This work is part of the US ATLAS program, in coordination with the Boston Muon Collaboration and with the University of Washington. The Michigan work will focus on two aspects of detector development, the construction of the largest MDT tubes and the development of front-end electronics for these and other MDT tubes of the system. Greg Tarle' is directing the tube construction project and J. Chapman is leading the electronics development aspects of the Michigan project. At this time it is expected that Bing will be active in the detector development and that David Gerdes will focus on electronics. Homer Neal has agreed to chair the US ATLAS committee charged with the development of a plan for US computing.

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For 1998 the US ATLAS collaboration initially designated a modest \$62K of ATLAS detector funds for Michigan. The use of these funds was outlined in the original 1998 supplement from Michigan for ATLAS funds, with \$45K being set for chamber R/D and chamber construction site development, and \$17K directed toward the establishment of a demonstration data-acquisition system for quality assurance testing of the drift tubes. Since that supplement was submitted, the collaboration has encouraged Michigan to adopt a faster ramp for the establishment of the fabrication site in Ann Arbor and to assume an important role in the coordination, integration and certification of the front-end electronics for the muon chambers. This supplemental request is a response to that initiative.

2.0 MDT Chamber Construction

The University of Michigan will be responsible for the R/D, prototyping, construction and testing of the “Monitored Drift Tube (MDT)” chambers in the forward muon spectrometer listed in the table below. In total, there will be of the order of 35,000 individual drift tubes that will have to be constructed for these chambers. Our efforts will include the design, analysis, manufacture, quality assurance and quality control of the drift tubes, their spacers, their alignment, chamber environmental services, their assembly into chambers, and their delivery to CERN for installation.

TABLE 1. MDT Chamber Development Items

WBS Item	Description
1.5.1.3.3	UM MDT Prototype Production
1.5.1.4.1.3	UM Tube Production
1.5.1.4.2.8	MDT Chamber EEL2 Assembly
1.5.1.4.2.15	MDT Chamber EML3 Assembly
1.5.1.4.2.16	MDT Chamber EML4 Assembly
1.5.1.4.2.17	MDT Chamber EML5 Assembly
1.5.1.4.2.20	MDT Chamber EMS5 Assembly

The design of the drift tube assembly stations will incorporate the development of techniques for automatic wire stringing, tensioning and crimping, automated endplug insertion and crimping, and central locator insertion for the longest chambers.

A distinctive feature of these chambers, as compared to the other chambers in the spectrometer, is that for the most part they represent the longest chambers in the spectrometer. Difficulties attendant to the length of the chambers are associated with the accurate positioning of the 50-micron diameter wires that must be centered in the drift tubes for the entire length of the aluminum tubes. Studies indicate that a central locator may indeed be required at the mid-point of the 6 meter chambers, but this feature will surely complicate the construction process. R/D in this and other areas will proceed during the present fiscal

year, with the expectation that a final design will be completed by September, 1998. Our plans for the following fiscal year were originally to be the preparation of a large, high-bay assembly area at the University of Michigan where the chambers will be constructed and tested over the period 1999 - 2003.

The current budget request is for \$176K to accelerate the development of the chamber assembly site beyond that possible with the \$45K of R&D funds already provided for chamber design work. With these additional funds Michigan would build a complete MDT assembly station, MDT rooms, module assembly area, and testing hardware. One clean room is needed for wiring individual tubes. This room needs tools for constructing (e.g. pneumatic tube crimpers) and for testing separate tubes (such as a setup for x-ray tomography with CCD readout via VME and PCs). The second room is required for gluing tubes into modules and is considerably more elaborate. This room requires a large (9'x22') granite surface plate, lapped to $\pm 10\mu\text{m}$ to ensure exact tube positioning in the assembly of MDT modules. Such granite plates require several months for delivery so it is imperative we order one as soon as possible if we are to have our assembly station ready by early 1999, as the current schedule demands. Shipping and installation charges are also included. Several pieces of precision hardware are needed for module assembly such as combs (for positioning tubes within a layer), "trophy stands" (which position tubes layers), a "strongback" (temporary frame for tube) layers. This request also includes funds for a PC-based data acquisition system for testing of completed modules.

3.0 MDT Electronics

The MDT chambers are fitted with cards, HedgeHog Cards, that provide the chamber connections and accept daughter cards, Mezzanine Cards, that contain Amplifier-Shaper-Discriminator, ASD, circuits and Time Digitizer circuits, TDCs. Originally the design had a single remaining element in the front-end electronics chain, the ReadOut Driver module, ROD, which transmitted data to the ReadOut Buffer modules located in the data acquisition system. These ReadOut Drivers, called NIMRODs, have recently been moved more than 100m away in the USA cavern. They can no longer connect to Mezzanine cards via twisted-pairs. At the recent acquisition and trigger review, J. Chapman suggested that the need to provide some concentration of data from the mezzanine cards prior to transmission to the NIMRODs, also provides an opportunity to design a concentrator card that can service entire chamber modules/assemblies. This scheme leads to a single fiber connection for complete chamber assemblies with all internal wiring attached to a single concentrator card per chamber. The muon community present at the meeting embraced this concept.

The final system is based on custom integrated circuits and will incorporate very high density electronics for cost efficiency. Current work on the final system has two immediate goals, one is to provide the chamber fabrication sites with chamber certification circuits and a second is to operate the final electronics in as large a scale as is necessary to be assured that it functions as required. These two goals are not entirely compatible. The chamber certification requires a working system by early 1999. Evaluation of the final electronics would best be done later since electronics design options change rapidly with time. A compromise solution has been adopted. The early version of the Mezzanine cards

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will provide a header for extraction of the discriminated ASD output. This output can be cabled to existing TDCs available at each chamber fabrication site for initial testing. The channel count of this minimal system will be small. To provide the next stage of testing, ~10K channels will be fabricated in an early version of the ATLAS system using a near complete version of the Boston University ASD, the CERN designed TDC (or a minimal modification of that design), and a NIMROD that features most of the final design but with VME readout rather than S-Link output to Read Out Buffers. This test will use a near final version of the Mezzanine card as well. It is intended to provide design certification for the full electronics prior to the final production of the ASD/TDCs. Michigan has proposed a demonstration system composed of commercial VME hardware and PC based software package that bypasses the TDC and ROD driver design for the first level test. This system was the subject of the first proposal from Michigan to ATLAS for electronics development and the subject of the \$17K DoE request already funded.

Discussions following Michigan's initial proposal have led to an expanded role for Michigan in the front-end electronics development. The ATLAS muon collaboration has assessed the current situation with respect to the production of 10K test channels of the muon front-end electronics. Delivery of these channels in a timely manner both for certification of the chamber design and for test of the full electronics design is critical for the delivery schedule of the final system. A conclusion of the recent review is that the project is seriously behind schedule. To press this work ahead so that a set of chips and modules are available in early 2000, Michigan has agreed to contribute to the development and testing of the front-end circuits. J. Chapman plans to be at CERN with 3 Michigan students for ~2 months this summer. This team will do all possible to understand and assume responsibility for the ATLAS TDC design. The goal of this effort will be the production of 10K channels of the design and incorporation of that design along with the Boston University ASD (amplifier-shaper-discriminator) and the NIKHEF readout driver into a working front-end system. The work at CERN this summer is critical to understand the scale of the problem. The attached budget assumes that the responsibility for the TDC development moves to Michigan and that a test fixture for the full ASD, TDC, NIMROD, and readout is established here.

3.1 Concluding Remarks

The University of Michigan High Energy program has assumed a significant role in the CERN ATLAS experiment. Tasks which we have been asked to take on in the development of the forward muon chambers are well within the capabilities of our faculty and staff and our departmental support infrastructure. We also expect to contribute to other aspects of ATLAS, including design of the delay-lock loop of the TRT front-end chip, object oriented database development, and various topics associated with U.S computing resource development, the use of the LHC as a testbed for the development of improved tools for collaboratory communication, and the development of a program in Geneva that would facilitate the participation of U.S. undergraduates in projects at CERN.