We propose to continue our participation in the Tile Calorimeter detector of the ATLAS experiment at CERN. The University of Texas at Arlington (UTA) is the lead institution for the construction of the Intermediate Tile Calorimeter (ITC). We also have responsibility for the Extended Barrel module assembly alignment system. In 1997, we built the first two full-scale prototype submodules at UTA. They were assembled into Modules 0A and 0B at Argonne National Laboratory and Barcelona respectively. Subsequently, they were successfully tested at a CERN test Beam during the summer of 1997. During 1998 we plan to complete the design of the ITC and the module assembly alignment system. We will also prepare infrastructure and tooling for full scale ITC production. We request supplemental funding from the Department of Energy to continue our work in ATLAS. This request has been coordinated with US ATLAS management and is part of the overall US ATLAS supplemental funding approved by the DoE.
INTRODUCTION

OVERVIEW

The University of Texas at Arlington (UTA) group is leading the effort to design and build the Intermediate Tile Calorimeter (ITC) to improve hadronic and electro-magnetic calorimeter performance in the intermediate eta regions of the ATLAS experiment. This region between the Barrel and Extended Barrel Tile Calorimeter modules is populated by services, cables and electronics for the Liquid Argon calorimeters and Inner Tracking Detectors. The ITC provides additional calorimetry in this geometrically complex region. Between $0.8 < |\eta| < 1.0$, the ITC adds between 1-2 absorption lengths of steel-scintillator tile calorimetry. In the region $1.0 < |\eta| < 1.6$, the ITC provides a layer of additional scintillator sampling. In the figure below, we show the improvement in measured calorimeter energy as a function of $\eta$, based on a detailed GEANT simulation.

UTA has primary responsibility for the design and production of the ITC. Kaushik De is the level 3 (WBS 1.4.4) manager for this project. Michigan State University (MSU) will play a major role in the design and production of the cryostat scintillators, which are a part of the ITC. The other US Tile Calorimeter (TileCal) institutions -- Argonne National Laboratory (ANL), University of Chicago (UC) and the University of Illinois at Urbana-
Champaign (UI) will participate in various ITC tasks related to their overall responsibilities for ATLAS.

During 1996-97, we completed the preliminary mechanical design of the ITC and built two prototype submodules which were successfully tested with pion and muon beams at CERN. We also designed and built the module assembly base and measured the alignment of Module 0A using a laser system at ANL. This year we will complete the final design of the ITC and start preparations for full scale production to begin in January 1999. We will build a third prototype to check our design changes. Some of the tooling for production and purchase of small supplies will occur in this fiscal year. We will also build the first prototype of the scintillator extension and complete the design of the fiber routing scheme. Finally, we will complete the design and prototype of a new system for checking submodule alignment. We request the Department of Energy to provide funding to support the work at UTA on these critical tasks.

The UTA personnel contributing to the ATLAS Tile Calorimeter project includes three faculty members, Drs. De, Stephens, and White; two postdoctoral fellows, Dr. Elizabeth Gallas and Dr. Mark Sosebee; and our scientific engineer, Dr. Jia Li. Many undergraduate and graduate students at UTA are helping with R&D projects and simulations. Dr. White is the PI for the base program. Dr. De is the TileCal contact person and the PI for this supplemental proposal.

**THE INTERMEDIATE TILE CALORIMETER**

For particles which originate at the nominal interaction point, the ITC extends over approximately $0.8 < |\eta| < 1.6$. The region 0.8-0.9 contains 311 mm thick steel-scintillator
stacks, similar in design to standard Tile Calorimeter submodules. Between 0.9-1.0, the stacks are 96 mm in the z-direction. The combined 0.8-1.0 region of the ITC is called the **plug**. At higher etas, 1.0-1.6, the ITC consists of scintillator only due to space constraints. The scintillators between 1.0-1.2 are called the **scintillator extensions**, while those between 1.2-1.6 are called **cryostat scintillators**.

The plug and scintillator extensions primarily provide hadronic shower sampling, while the cryostat scintillators play an important role in sampling electromagnetic showers. Together, these detectors improve the measurement of total energy in the intermediate region, thereby improving the missing $E_t$ resolution of ATLAS.

There is one ITC submodule per extended barrel module (0.1 in $\phi$) for a total of 128 submodules in ATLAS. Fibers from each 0.1 eta division of the plug are routed to two photomultiplier tubes, one for each side. There are 2 scintillator extension tiles per submodule. The segmentation for each of these tiles is 0.1 x 0.1 in $\eta \times \phi$. For the cryostat scintillators, the segmentation of each tile is 0.2 x 0.2 in $\eta \times \phi$. The shape of these tiles will be trapezoidal, with the scintillator extensions about 345 mm in $\eta \times 280$ mm in $\phi$, while the cryostat tiles will be about 345 mm in $\eta \times 240$ mm in $\phi$. The space constraints limit the maximum thickness of the tile assemblies, including the light-tight covers, to 20 mm for the extension and 8 mm for the cryostat scintillators.

This figure shows the first prototype of the plug built at UTA in the foreground, while the second prototype is being assembled in the background. The design of the plug has almost been completed. Further prototype and design work is needed for the scintillator sections. These sections of the ITC have to be optimized for the highest light yield using the fewest number of fibers, all in a very compact profile. The minimum light yield required for the scintillator extension and cryostat tiles is around 5 photoelectrons/MIP. This requirement comes from the need to calibrate these tiles with good precision using muons. This value should be attainable based on our experiences with D0, CDF, and the mid-sampler in the April 1996 test-beam run. Furthermore, the uniformity of response across the tile surface should be better than 5%.
ITC PROTOTYPES

Our primary task during the past year has been construction of two ITC prototypes for testing at the CERN test beam as part of Modules 0A and 0B. Each module is a complete slice (0.1 in $\phi$) of the Tile Calorimeter Extended Barrel. Module 0A was assembled at ANL; Module 0B was assembled at IFAE (Barcelona). We supplied ITC submodules to both assembly sites. Both modules were completed on time and successfully tested at CERN. Construction of these submodules was an important test of the production capabilities at UTA. We show below the ITC after it was assembled as part of Module 0A at ANL.

We have set up over 10,000 sq. ft. of space at our Swift Center Detector construction facility for ITC production. An overhead crane covering approximately half the laboratory space is used to manipulate the half-ton ITC submodules as well as to manipulate the compression plates used during stacking. Another one-ton crane on a moveable frame is also available. The Swift Center is certified for welding and equipped with a small machine shop. We have arranged adequate space for the storage of steel plates and completed submodules.

The unusual stepped shape of the ITC submodules requires special stacking and manipulation tools. A stacking tool which can be used for the assembly of both standard and ITC submodules was designed and manufactured at UTA. This stacking tool was used to build the first two ITC prototypes. During prototype construction, we determined that each ITC submodule will require four days for assembly. Therefore we have
scheduled three years of submodule construction starting in January 1999 to build the 128 ITC submodules at the rate of one per week.

ITC submodule production involves the following operations:

1. On day 1, we glue the short stack and let it remain overnight under compression.

2. On day 2, we glue the middle stack (using a precision spacer block) and compress it overnight.

3. On day 3, we glue the end plate and compress.

4. On day 4, we weld, measure and pack the finished ITC submodule.

5. Day 5 is reserved for unanticipated occasional delays in production and may be used to prepare materials for the next submodule.

In this picture, the ITC prototype for Barcelona Module 0B is being compressed for the final time on day 3 of the procedure described above. The stack is complete. After curing the glue overnight, the ITC submodule will be welded using weld bars at the corners of the stack. We have designed and built special manipulation tools to rotate the half-ton submodule, move it to the welding area, dip it in a preservative, and to finally pack it for shipment.

We have assembled at UTA various equipment necessary during the prototype stacking process. A washing tub, drying box and gluing templates are some examples. Much of this equipment will be upgraded for final production. We will convert the washing tub into a preservative dipping tub. Thicker gluing templates are being made, and better gluing system is being developed.

**MODULE ASSEMBLY & ALIGNMENT SYSTEM**

UTA has additional responsibility in support of module assembly at ANL. We have designed and built the base structure on which the girder is placed and the submodules are
assembled. Including the ITC, 10 submodules are needed for a single Extended Barrel Tile module. These submodules must be aligned to a precision of 200 µm in azimuth over the two meters length of the module. The base also has to be straight over a length of two meters along the beam direction to the same precision. Below we show the base built by UTA with the girder placed on it.

We have also developed a design for a new submodule alignment and module envelope checking system. This system will use a precise mechanical gauge that will move on a linear roller guide parallel to the assembly base. A laser light source and the ALMY silicon-strip detectors developed for the alignment of the ATLAS muon system will be used to calibrate and check the position of the base. We plan to build a prototype to test the accuracy of this system in 1998.
PLAN OF WORK

We have made a number of design changes based on the experience of building the two prototype ITC submodules for the test beam. Primarily, these changes involve the weld bars which connect the steel plates at the inner radius. The dimensions of the scintillator tiles and spacer plates have also been changed globally for the Tile Calorimeter. Some tolerances have been relaxed to reduce production cost. We plan to build a third prototype in the next few months to verify these changes. This prototype will not be sent to CERN, but instead will be tested at UTA using cosmic rays.

During the next six months, we plan to continue setting up the infrastructure for submodule production at the Swift Center. We will evaluate and optimize our choice of welding procedure. Various additional templates and measuring tools will be set up. The gluing machine used for prototype submodules requires pre-mixing of the epoxy. This is unacceptable for submodule production, as the epoxy begins to harden before an entire stack has been assembled. Instead, we will modify this machine so that the glue is mixed as it is dispensed. Commercial dispensing-mixer machines are not available for the very small shot sizes used for the Tile Calorimeter.

We are enhancing the module assembly system so that it can be used to check the module envelope during production. The stability of the laser and the alignment system over the entire three year period of construction is of particular concern.
BUDGET JUSTIFICATION

PROFESSIONAL PERSONNEL

We request 9 months of infrastructure support for an engineering associate (Jia Li) to complete design work on the ITC, to design and assemble production tools and to design the assembly system. Jia has already played a crucial role in the early design work for the ITC during the past few years.

Support for a mechanical technician (Victor Reece) is requested for 9 months to complete the design of the gluing system and some small tools, to set up the laboratory infrastructure for ITC construction, to supervise the building of ITC prototypes and to build some of the tools needed for ITC construction. Victor will play a central role in ITC detector construction and testing during the three year production phase of the project starting in early 1999.

UNDERGRADUATE STUDENTS

We successfully used undergraduate students in prototype construction and R&D projects for the ITC during the past year. We will need many well trained students for ITC production during the next 3 years. We request a modest undergraduate salary support of $4000 this year.

PERMANENT EQUIPMENT

Our primary goal for 1997-98 is to build the third full-scale ITC prototype submodule and prepare for full scale submodule production in 1999. We need to complete the ITC stacking fixture, build tools and purchase some small items for production. We request $14,835 for equipment.