FERMILAB-PROPOSAL-0884
884 rec'd 2/1/96
cc: B. Baller 2/2/96

A proposal for a beam test of the ATIC detector

T. Gregory Guzik, Joachim Isbert, John P. Wefel
Lousiana State University, Baton Rouge, LA70803-4001
Eun-Suk Seo, F.B. McDonald, J.Z.Wang
University of Maryland, College Park, MD 20742-2431
Wolfgang K.H. Schmidt
Max-Plank Institute, Lindau, Germany
N. Grigorov, M. Panasyuk, Victor Zatsepin
Moscow State University, Moscow, 119899
James H. Adams, S. E. Inderhees, Jr. R. A. Kroeger
Naval Research Laboratory, Washington, D.C., 20375-5352
Sun Kee Kim*
Seoul National University, Seoul, 151-742
Ali R. Frzely
Southern University, Baton Rouge, LA 70813

Abstract

We request a test beam for the study of the response and calibration of the ATIC (Advanced Thin Ionization Calorimeter) detector. The detector is designed for a balloon flight program to measure high energy primary cosmic ray protons, He, and other heavier elements with energies ranging from 10 GeV to 100 TeV. The detector consists of one interaction length of carbon converters with interleaved scintillators for the charge measurement, followed by 22 radiation length BGO crystal arrays for the measurement of electromagnetic shower energy from the hadronic interactions. A Monte Carlo study has demonstrated that the detector will perform as we expect. A beam test at Fermlab with 800 GeV protons, the highest available beam on earth, will assure the concept of the detector and will provide a basis for the precise calibration of the detector response.

*Contact person
e-mail address dokr01::skkim

1 Introduction

The Advanced Thin Ionization Calorimeter(ATIC) has been designed for the study of ultra high energy cosimc ray hadrons with energy ranging from 10 GeV to 100 TeV. We will measure the energy spectrum of protons, He, and other heavier elements to resolve a fundamental question about the shape of the spectra in this energy range. In high energy astrophysics, these matters are important issues because the energy spectrum in this range would provide important clues about the acceleration and transportation of high energy particles in the universe. A proposal for a five year balloon flight program was submitted to NASA and is close to the approval.

The ATIC detector consists of one interaction length carbon converters followed by an electromagnetic calorimeter based on BGO crystals. The concepts of thin calorimeter need to be tested with the test beam. So far the high energy cosmic ray spectrum has been studied mostly by emulsion type detectors. By adopting the state of the art detector technology in high energy physics, we can make significantly better measurement of this spectrum and this will be a first step for the next generation cosmic ray experiment. This measurement relies heavily on the Monte Carlo(MC) simulations to unfold the energy spectrum from the smeared energy spectrum due to the limited energy resolution. We propose to test a prototype detector using the high energy proton beam at the Tevatron. This test will provide not only a comparison of data to the MC simulation but also an important reference for the final energy calibration of the detector.

Another objective of the beam test is to study the response of the charge detector and the background due to the backscattered particles from the calorimeter into the charge detector. It is very important to understand the background in order to resolve the H/He ratio in the energy range we are interested in.

2 The ATIC detector

The ATIC detector is designed to measure individual elements in ultra high energy cosmic ray spectrum, which consist mostly of protons and He. Protons and He or other heavier ions interact with nuclei in the longitudinaly segmented carbon target of about one interaction length thickness. Scintillation strip counter arrays are interleaved between layers of the carbon target plane to determine the trajectory of the incident particle and to reject backward scattered secondaries. Following the converter, a calorimeter module of 50cm x 50cm x 25cm, consists of 400 of BGO crystals. The dimension of each crystal is 2.5 cm x 2.5 cm x 25 cm. The calorimeter is a total absorption calorimeter that can read out the longitudinal and transverse profile of a shower. This also allow us to measure the position and the direction of the showering particles to extrapolate to the interaction point inside the carbon target. The total radiation length of the calorimeter is 22.3 Xo. The interaction length of BGO calorimeter is approximately one interaction length and additional hadronic interaction may occur in the BGO to increase the total energy deposition. In Figure 1, we showed the overall view of the ATIC detector. The prototype to be used at the beam test will be a box shaped detector with a dimension of 25cm x 25cm x 65cm, which corresponds to a quarter of the whole ATIC detector.

Since the size of the detector is limited in a balloon flight experiment, our goal is to measure the electromagnetic fraction of the first interaction of hadrons, which are mostly from neutral pions and estimate the energy of the primary incident particles. This is possible due to the fact that the inelasticity of hadronic interaction is nearly independent of the incident energy. Our simulation study shows that roughly 40% of the primary particle energy is deposited in the BGO calorimeter, almost independent of incident particle energy. The resolution, limited by the leakage of the hadronic shower, is abot 40% for 1 TeV protons. Figure 2 shows our simulation result for proton, He, and Fe with incident energy of 1 TeV/n. As shown in Figure 3, the energy response is linear up to 10 TeV/n independent of particle species. Although this detector can measure energy of each individual particle, due to the limited energy resolution, we need to deconvolute the measured energy spectrum to obtain the original one. We have carried out the deconvolution study with MC simulations and the result is shown in Figure 4. One can see that we can recover the spectrum very close to the input spectrum.

3 Beam requirement

We need to test the detector with proton beam at the highest available energy. Since we are primarily interested in single proton, we do not need to have high flux beam. Rather, we prefer lower rate beam in order to have low trigger rate. The trigger condition will be the total energy sum in the BGO calorimeter in coincidence with scintillators in front of the BGO modules. We plan to take data at several beam energies and positions as well as several incidence angles. Assuming three energies, three incidence points, and three incidence angle settings, we will need 27 different setups. Approximately 10,000 events per each setup will be good enough for the precision we aiming at. We estimate that 30 hours of beam time is enough for this purpose. Adding an hour for the preparation of each setup roughly 60 hours will suffice. According to our schedule, the best time for the beam test is at the end of 1996 and beginning of 1997. This schedule well matches with Fermilab running schedule.

According to a discussion with a beam line physicist of Fermilab, exsiting test beam area may provide protons up to 300 GeV. To access the primary protons it may be necessary to arrange a test beam inside the beam enclosure. Further study on the feasibility of using the primary beam is on the way.

4 Data acquisition system and computing

We will employ front end electronics specially designed for the ATIC detector. For the digitizers, we request the Fermilab electronics pool to allow us to use their FASTBUS system including Rack, ADC modules and crate controllers as well as NIM modules for the trigger and other setups. Although we will bring our own electronics as much as possible, it would be necessary for us to utilize existing instruments and facilities at Fermilab. We will also bring our own data acquisition system based on a PC. Our PC needs to be connected to Fermilab network for an efficient data taking and monitoring. Data analysis can be carried out at each participating institution using their own computing facilities. For the maximal use of different computing platforms, we are thinking to write the data in the ASCII format, the most portable data format.

5 Financial arrangement

Travel expenses and supplies necessary for the beam test will be fully covered by NASA fund for the ATIC project, of which the Principal Investigator is Prof. J.Wefel of Lousiana State University. Parts of travel expense related with foreign collaborators will be arranged by collaborating US institutions and/or foreign institutions.

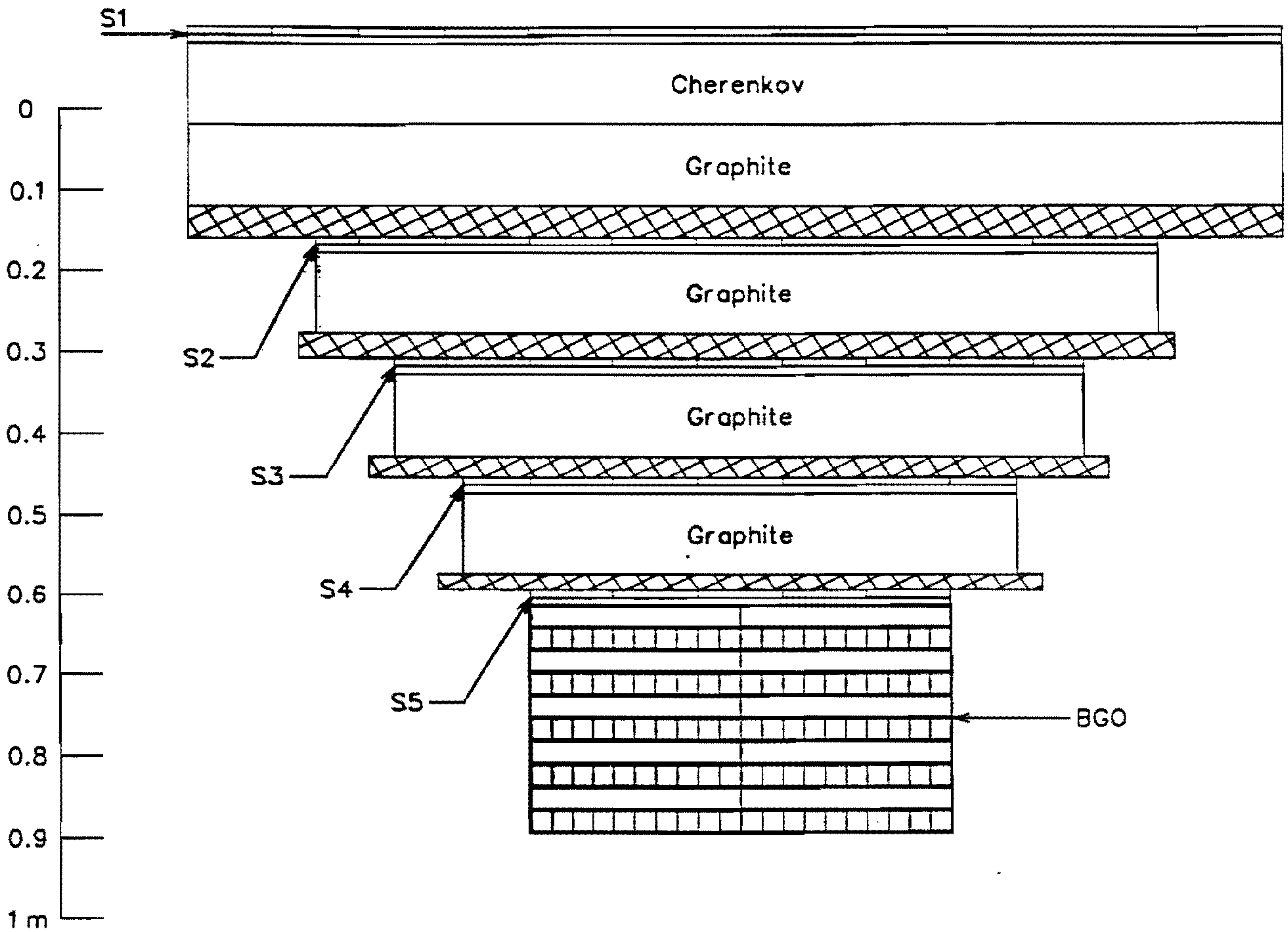
S1
Cherenkov
Graphite
Graphite
Graphite
Graphite
S2
S3
S4
S5
BGO
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1 m

Figure 1

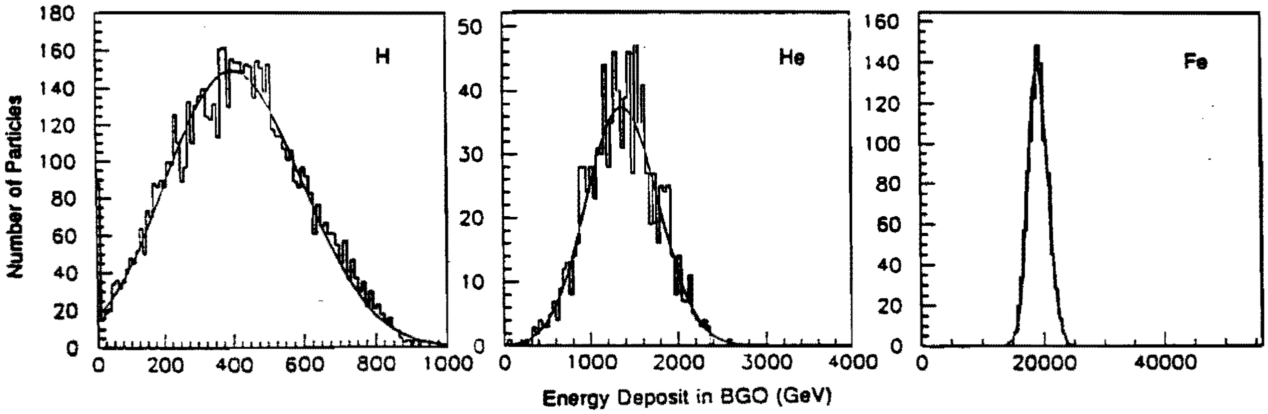

Figure 2: Energy deposition for (a) H, (b) He and (c) Fe at 1 TeV/nucleon.

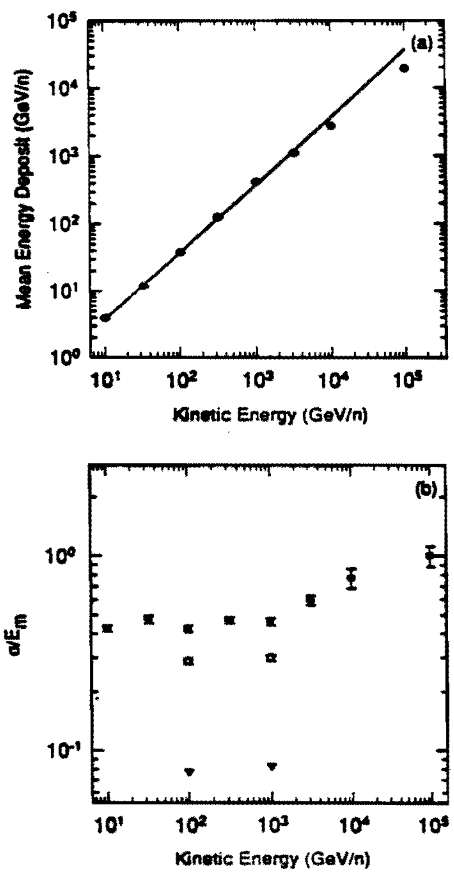

Figure 3: Energy dependence of the mean energy deposit (top) and the energy resolution (bottom) for protons (filled circles), helium (open circles) and iron (filled triangles).

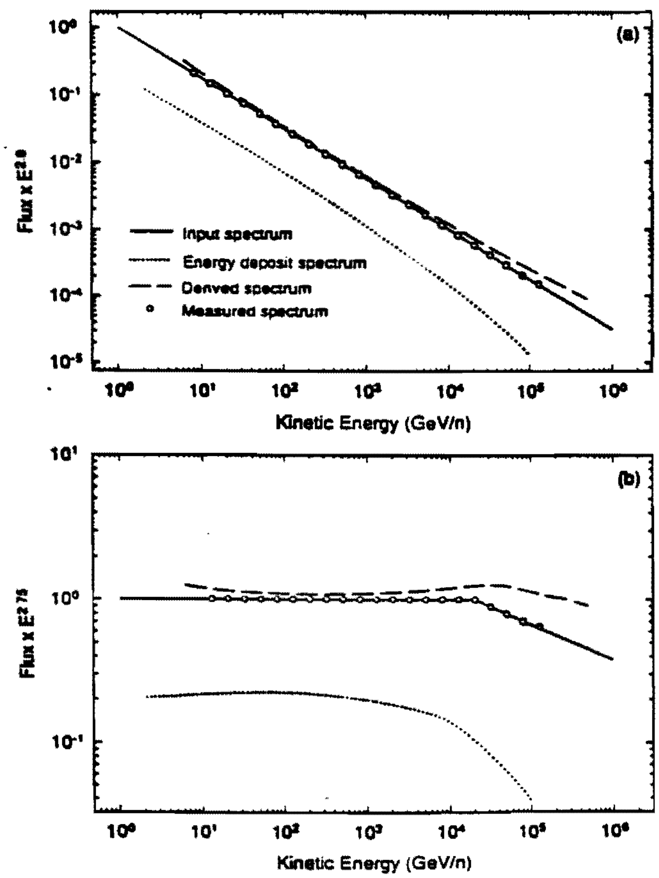

Figure 4: Effect of the energy resolution on the spectral measurement for an input proton spectrum of (a) a single power law, and (b) double power law.