Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics B (Proc. Suppl.) 175–176 (2008) 315–317
NUCLEAR PHYSICS B
PROCEEDINGS
SUPPLEMENTS
www.elsevierphysics.com

Future Plans for the GAMMA Array on Mt. Aragats

L.W. Jones[a], Y.A. Gallant[b], A.P. Garyaka[c], R.M. Martirosov[c], S.V. Ter-Antonyan[c], N.M. Nikolskaya[d], J. Procureur[e]

[a]Dept. of Physics, University of Michigan, Ann Arbor MI, U.S.A.

[b]Labo. de Physique Théorique et Astroparticules, Université Montpellier II, France

[c]Yerevan Physics Institute, Yerevan, Armenia

[d]Moscow Lebedev Physics Institute, Moscow, Russia

[e]Centre d'Etudes Nucléaires de Bordeaux-Gradignan, Gradignan, France

The GAMMA collaboration is studying the possibility of instrumenting the 40 × 40 meter hadron calorimeter structure at the center of the GAMMA array. This mechanical structure, built about 25 years ago, has never been instrumented, and if this could be done, it would provide a valuable addition to the GAMMA array for the investigation of the EAS hadron component and for multivariate analysis of the GAMMA data.

1. CALORIMETER HISTORY

From Dr. Martirosov's discussion in the accompanying report, it is clear that the GAMMA array has significant research capabilities in the study of the primary spectrum and composition around the "knee". It is located at an elevation of 3200m on Mt. Aragats and includes an air shower array consisting of 33 surface detector stations, each containing 3 meter-square scintillators spread over an area of 100 m radius. It also includes an underground muon detector with a 5 GeV threshold, consisting of 150 meter-square scintillation counters. However one detector system which could be added and which would significantly enhance the capabilities of this installation would be a hadron calorimeter. The KASCADE colaboration has a large calorimeter at their Karlsruhe installation (near sea level), and has shown its value in their presentations and discussions.

In fact, in the early 1980s, Professor Nikolsky of the Lebedev Institute and Professor Mamijanian of the Yerevan Physics Institute proposed to build such a hadron calorimeter on Mt. Aragats, and the concrete (beton) structure which they initiated remains at the center of the GAMMA array [1]. In the illustration of the GAMMA array in Dr. Martirosov's presentation, this structure is at the center of the array, with 9 airshower detector stations on its top surface. The structure is $40m \times 40m$, and is composed of 6 layers of concrete, each 60 cm in thickness, and spaced by 40 cm. These 40 cm spaces are created by a set of parallel steel supporting I-beams which are spaced by 3 m horizontally. The I-beams go the 40 m length of the structure; in alternate layers they are perpendicular to each other, so that 40 m long detector elements could be utilized and the alternate layers of detector elements would be at right angles to each other. The total concrete thickness of the structure is 3.6 m, or about $900g/cm^2$ of concrete. There is more concrete on the ground, therefore the underground area is shielded by enough concrete so that the muon threshold for counters in this underground area is 5 GeV.

Funding for, and hence work on this "ANI" calorimeter structure stopped in the early 1990s, however the concrete structure has remained, serving as a muon shield and (on its top surface) as a flat site for the 9 air shower detector sta-

0920-5632/$ – see front matter
doi:10.1016/j.nuclphysbps.2007.11.020

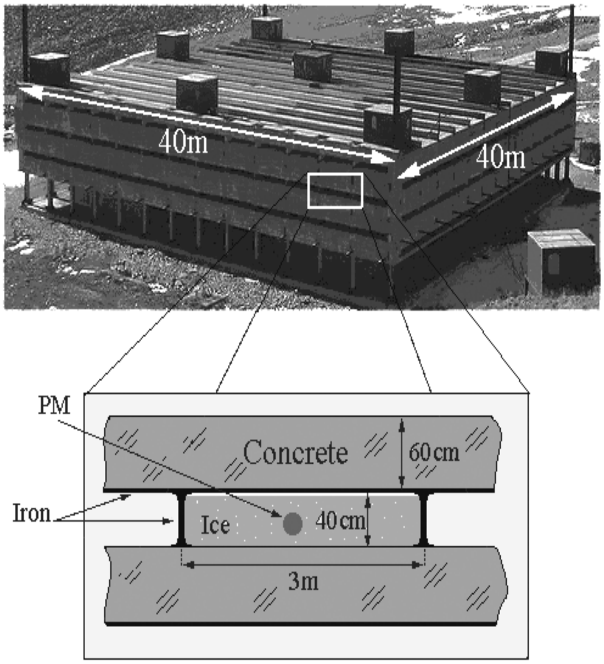

Figure 1. The ANI calorimeter structure, with an expanded drawing of one cell of the ice Cherenkov detector, as discussed in the text.

tions. Recently, within the GAMMA collaboration, there have been discussions on the possibility of installing detectors within this s tructure, and hence realizing Nikolsky's and Mamijanian's original objectives.

2. DETECTOR POSSIBILITIES

Nikolsky's original proposed detectors were ionization chambers. Samvel Ter-Antonyan of the GAMMA collaboration has suggested a different, very inexpensive detector option [2]. He has suggested filling the detector gaps ($3m \times 0.4m \times 40m$) with ice, and reading out the Cherenkov radiation from this ice with photomultipliers on each end of each 40 m ice block.

At the 3200 m elevation of Mt. Aragats, such an ice detector is practical most of the year as the ambient temperature is usually below freezing. The channels would be filled with water, which would then freeze; of course windows would be located on either end to contain the water until it freezes. There are several negatives to this inexpensive idea, of course. The channels would require a highly reflective coating, as the ice would be in optical contact with the walls, and hence total-internal-reflection cannot be assumed. Cherenkov counters also have the problem that they are sensitive to the vertical angle of the incident particles; particles inclined toward the phototubes would produce a larger signal than vertical particles. Also, the 3 m width of each element is quite large, and a smaller segmentation would be preferable in order for better spatial resolution. Of course this could be achieved with the ice Cherenkov counters by dividing the 3m horizontal spaces with vertical polished, reflecting metal sheets, and having separate phototubes at the ends of each smaller element. As with any Cherenkov detector, having a smaller cross section detector increases the number of surface reflections between the source and the detector, and with imperfect reflecting surfaces, this would correspondingly reduce the efficiency of the detectors, and make the signal more dependent on the distance between the detector and the source.

Another Cherenkov detector medium might be mineral oil, which would have a higher index of refraction. Scintillation counters, either solid plastic or fluid, might also be used. Although certainly more expensive than Cherenkov detectors, they would have greater light output, and - with plastic - the light piping via total internal reflection would be much simpler than for ice or other liquid Cherenkov counters. The light output would also be independent of the incident angle of the radiating particles.

Gas ionization chambers, Nikolsky's originally proposed detectors, would have many advantages. They could be of smaller diameter, e.g. 10 - 20 cm, which would significantly improve the lateral resolution. A larger signal could be achieved by operating them as gas proportional counters, using a smaller diameter anode wire and an appropriate gas mixture. Using a resistive wire anode would enable the longitudinal position of the ionization signal source to also be determined, by comparing the signal from the two ends of this anode. This concept was used successfully with 3.6 m proportional counters in a Fermilab experiment. One problem at Mt. Aragats is the availability of argon gas, which is not readily available in Armenia (as it is in Western Europe and America). Nikolsky, in fact, proposed using nitrogen as an ion chamber gas. For an ion chamber or proportional counter, the essential concern is that oxygen, water vapor, and other gases which capture electrons to form negative ions be removed from the gas in the chambers. One interesting possibility would be to acquire a small liquid air facility and to produce the needed argon on site.

Of course higher cost, finer spatial resolution, faster modern detector techniques are also of interest; e.g. resistive-plate chambers and solid state detectors. And, besides the cost and construction of the detectors themselves, the required electronics are a significant consideration. A complete calorimeter, consisting of 6 layers, each of 1600 square meters, and with 10 cm lateral resolution (hence 400 units per layer) and readouts at both ends (e.g. ion chamber or proportional chamber anodes or scintillator rods) would require 4800 readout channels.

3. FIRST STEPS

A first step in this program should be small-scale, careful tests of these various options, which would stimulate specific designs and serious cost estimates. With a selected detector option, it would be sensible to first build a small area calorimeter, e.g. 5×5 meters, in one corner of the existing ANI structure, as a prototype. This would exercise the technology and the participating staff in the problems and properties of the technology. Tests of detector prototypes could be made at CERN or Fermilab. Funding is certainly a major hurdle. The collaboration will look forward to instructive interactions with their cosmic ray and accelerator colleagues.

REFERENCES

1. T.V. Danulova, et al., Izvestia Akademii Nauk Armyanskoy SSR PHYSICA Tom 17 (1982) 129-282 (in Russian).
2. Samvel Ter-Antonyan "Ice Cherenkov detector for high energy EAS hadrons at mountain level" GAMMA collaboration internal report (2006).