As the first stage of the future huge array we have expanded the Akeno air shower array to about 20 km$^2$ by adding 19 scintillation detectors of 2.25 m$^2$ area outside the present 1 km$^2$ Akeno array with a new data collection system. These detectors are spaced about 1 km from each other and connected by two optical fiber cables. This array has been in partial operation from 8th, Sep. 1984 and full operation from 20th, Dec. 1984. 20 m$^2$ muon stations are planned to be set with 2 km separation and one of them is now under construction.

1. Introduction

The origin of the highest energy cosmic rays is an interesting problem. We have a chance to connect their sources with the astronomical objects, because their propagation becomes simpler than that of lower energies and the possible sources may be limited to some kinds of active astronomical objects. The observation of giant air shower (GAS) produced by cosmic rays above 10$^{19}$ eV have been made at Volcano Ranch[1], Haverah Park[2], Nara-brai[3] and Yakutsuk[4]. But there still remain the discrepancies among experiments not only in their energy spectrum but also in their arrival direction distribution.

In order to clarify the present ambiguities on the experiments and to extend the observation to higher energy, a plan of huge surface array of area over 100 km$^2$ is currently under discussion in Japan. In this report we describe about the "Akeno Branch" which is just constructed at Akeno with the intention of being a part of the huge array.

2. Array of "Akeno Branch"

The detector arrangement of the "Akeno Branch" is shown in fig.1. The open circles are the scintillation detectors of 2.25 m$^2$ each, located at about 1 km separation. The closed circles are scintillation counters of 1 m$^2$ area of the
existing "1km² Akeno array"[5]. The four large ones are also connected to
the present new recording system. The open square is a muon detectors of
20m² area under construction and the closed ones will be arranged within a
few years. Each detector is connected to the next one with two optical
fiber cables successively on a string as shown by a solid line. One cable
is used for sending the control commands to each module of the detector
from the center, and the other is for data transmission.

Inside the 1km² array, there are unshielded detectors of total area
of 169m², shielded detectors of 225m² (10GeV for vertical traversing muons)
and 75m² (0.5GeV), and 53 fast timing channels of 10nsec resolution.
These are effective to measure the properties of the large showers at far
from the core.

3. Data acquisition system
In each station there is a module called Detector Control Unit (DCU)
which is designed with one board micro computer(Z-80A). DCU consists of 3
major parts; communication part, data processing part and detector monitor
and control part. Several DCU's are tied to a common string which
consists of two directional optical fibers. One fiber of outgoing
direction from the center is used to send commands, clock pulses for the
timer of DCU and timer frame (clear pulse for the timer). Another one is
used to accept the status information of each detector for the trigger
conditions and to collect shower data and monitor data from DCU's at the
center. The communication data rates on strings are 625kb/s.

Every DCU has a timer which synchronizes to that of the center with
20nsec accuracy. All signals from the detector are digitized and stored
in the ring-image-memory of DCU with the incident time of 20nsec accuracy.
Each DCU sends the information to the center in every 3.2 µsec period
whether the detector is hit by a particle or not. With this status
information, coincidence requirements can be set at the center. 6 folds
coincidence of neighbouring detectors is required for the trigger. When
GAS hits over the array, central unit recognizes coincidence of signals
from many detectors and knows its occurrence time. Then the central unit
issues a command for all DCU's to search for the GAS data in the ring
memory with the time information of coincidence. Each DCU which has
accepted this command, stops data acquisition and searches for the all
corresponding data recorded within 100 µsec before and after the
coincidence. Central unit commands DCU's to send the picked out data one
by one. These data are sent to micro-computer(NEC 16bit PC9801) at Akeno
central laboratory through RS232C line of optical fiber and stored in the
10MB Hard Disk.

With this system not only the air shower data and monitor data are
acquired but also detector conditions can be controlled at the center.
Supplied voltage to the phototube, temperature, counting rate and pulse
height distribution of detectors are monitored periodically. The
discrimination level of the amplifier and the high voltage to the
phototube can be controlled on request from the center. These functions
enable us to maintain the detectors stable for long term and make data
reliable. The details of this system are described in Ohoka and
Teshima[6].

4. Array response
The response of the present array was examined by analyzing the
artificial showers which were simulated by the Monte Carlo method. The
fluctuations of electron density and the shower front structure at core distances between 500m and 3000m of 10^{18}-10^{19}eV EAS observed at 4km^2/20km^2 array[7] were used for the present simulation.

The threshold energy of detectable air shower is found to be about 10^{17.5}eV and the recording efficiency reaches 100% at 10^{18.5}eV as shown in fig.2. The histograms show the response and effective area for the showers hit inside the array. The broken line shows the area for all events including outside the array. The sensitivity for shower size and arrival direction in case of showers hit inside the array are shown in fig.3(a),(b) respectively. We can determine the electron size with 30% accuracy, arrival direction with 3 degree and core position with 80m. However for the showers outside the array, these are 150%, 9 degree and 150m, we need much caution to use the outer showers for the discussion of primary energy spectrum and their arrival directions.

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\text{Fig.2 The detection efficiency of EAS with "Akeno Branch".}
\]

\[
\text{Fig.3 The sensitivity for shower size(a) and arrival direction(b) in the case of showers whose core hit inside of array.}
\]
5. Conclusion and future plan

The observation of ultra high energy cosmic rays has started at Akeno. In order to determine their origin, the expansion of array to 100km$^2$ is under planning. The technical problems for expansion is already solved through the experience under the construction of Akeno Branch.

The schematic diagram of recording system of the future array is shown in fig.4. The whole array is divided into several Branches. Each Branch is managed by BCU (Branch Control Unit) which is connected successively to the next one with two optical fiber cables "String". This structure is exactly the same as that inside Branch. The commands from the center and data from the Branch are put on this "String". The clock pulse is supplied from the central unit SCU (System Control Unit) to each DCU (Detector Control Unit) via BCU (Branch Control Unit). Since the timer of every DCU synchronizes to the central timer, we can manage the GAS hit in the boundary gap between branches, in the same way as ones hit inside a Branch.

![Schematic diagram of recording system of future surface array.](image)

**Fig.4** The data acquisition system of future surface array.

Acknowledgements

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Reference

[7] M.Teshima et al., This conf. HE 4.7-3