Simulation study on the Performance of Synchronized Compact Arrays within 1 km Baseline

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Abstract

The synchronized compact arrays for detecting extensive air shower (EAS) are deployed in Okayama, Japan, as part of the Large Area Air Shower (LAAS) experiments. 4 arrays in Okayama area are independently operated and equipped with the precise GPS system, of which time resolution is 1 μs. The baselines of 4 arrays range from 100m to 1000m. We analyzed time interval distributions of EASs between each array. Event pairs in time interval less than 1 μs were observed, ant the number of them are much more than that expected by chance coincidence. Observing energy ranges were estimated for these events by CORSIKA simutaion codes. By using simultaneous observed EAS at multiple synchronized arrays, we can select higher energy EAS effectively.

1. Introduction

The origin and acceleration mechanism of ultra high energy cosmic rays are still one of fundamental issues in the field of high energy astrophysics. The main difficulty in studying cosmic rays above 10^{14}eV is the extremely low intensity, so that a large collection is are required to observe extensive air shower(EAS) particles using conventional scintillation detector arrays.

The LAAS group[1] has been performing the observation of EAS by using compact arrays deployed in large part of Japan, since 1996. The primary purposes of LAAS project[2] are to study the cosmic ray correlation in the small phase space of arrival time and arrival direction between long baseline arrays. Each array is placed in the small area, of which typical size is 20m×20m, and equipped with the precise GPS system to determine the arrival time of EAS with μs accuracies.

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In 2002, as the part of LAAS group, two new arrays have been installed in the campus of Okayama University of Science.[3] With distance from the array operated since 1996, the 3 arrays are deployed and independently operated within about 100m baseline and another array is located at 1km baseline, in Okayama area. The GPS accuracies provide us to detect simultaneous EAS events by using multiple array timing analysis. The simulation study has been performed to estimate the energy distribution of multiple EAS array with the precise GPS system.

2. EAS arrays in Okayama

The basic requirements of EAS array in LAAS group are to use 50cm $\times$ 50cm $\times$ 5cm plastic scintillation detectors for detecting charged particles with PMT(Hamamatsu H7195), and to acquire both ADC data and TDC data for all detectors. The most important data are EAS arrival time obtained by GPS equipment(Kaizu 3051A, GPS engine:Furuno GT-77N), which provide time stamp in UT for each event with μ second accuracies, and these compact arrays are synchronized within this accuracies. Since 1996, two EAS arrays have been operated in the campus of Okayama University(OU) and Okayama University of Science (OUS1). In 2002, two EAS arrays have also been installed in the latter campus (OUS2 and OUS3). Table 1 gives a summary of these EAS array profiles. The geographic latitude and longitude of OU array are 34 ˚41' and 133 ˚55' respectively. The positions of each array represent each distance from OU array in the table. NOD represents the number of scintillation detectors.

3. Simulations

To study the detection characteristics for each array, the simulated data obtained by use of the CORSIKA(version 6.0.15)-QGSjet EAS simulation package were used in this analysis as well as the simulated one on the basis of Nishimura-Kamata-Grisen (NKG) function.

In this simulation studies, we used three arrays, OU, OUS1 and OUS2a, because OUS2 array was operated by using 5 detectors until the middle of the year

Table 1. The LAAS stations in Okayama area.

Station	X(m)	Y(m)	Alt.(m)	*NOD*	since
OU	0	0	30	8	09/12/1996
OUS1	554	994	63	8	09/02/1996
OUS2	510	902	81	8	04/23/2002
OUS3	637	916	65	5	12/29/2002

2002 and OUS3 was still under construction in 2002. The trigger condition for each arrays were 3-Fold coincidence for OU and OUS2a, and 4-Fold coincidence for OUS1.

In each simulation, zenith angle distribution, primary energy spectrum and starting point fluctuations were included, and fluctuations of the number of particles at each detector was taken in account. In NKG simulations, the primary energy ranges 10^{13}eV to 10^{20}eV, because NKG simulations are not time consumption work. In CORSIKA simulations, Proton-initiated EAS are generated with a zenith angle sampled within 45 $^{\circ}$, because of time consumption. The simulated energy in this case ranges from 10^{13}eV to $10^{17.4}$eV.

4. Results and Conclusions

Fig.1 and Fig. 2 display the simulated energy distribution for 2 arrays and several combinations of simultaneous trigger events. The primary energy distribution of observed EAS by OUS2 is similar to that of OUS1, because OUS1 array and OUS2 array which are the typical arrays used in LAAS group, have the essentially same profiles for EAS events, such as angular acceptances and detector spacings. The mean primary energy of EAS observed in a single array, is about $10^{14.6}$eV. In Fig. 1, the primary energy distribution of simultaneous trigger events in both OUS1 and OUS2 are also shown. The definition of simultaneous events is experimentally that the time difference between the EAS arrival time stamps acquired by GPS signals at each array is less than 3 μs, which corresponds to the resolution of GPS. This result demonstrates the potential of energy separation of EAS events by using OUS1-OUS2 simultaneous trigger conditions, from those by single site trigger conditions. Including OU array of which baseline is about 1000m from OUS site, highest energy EAS events can be selected among EAS events observed at OUS1 or OUS2.

Consequently, by using multiple synchronized LAAS arrays in Okayama area, the potential to determine energy spectrum has been addressed. The further advantages of this multiple array techniques will be reported in this conference.

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5. References

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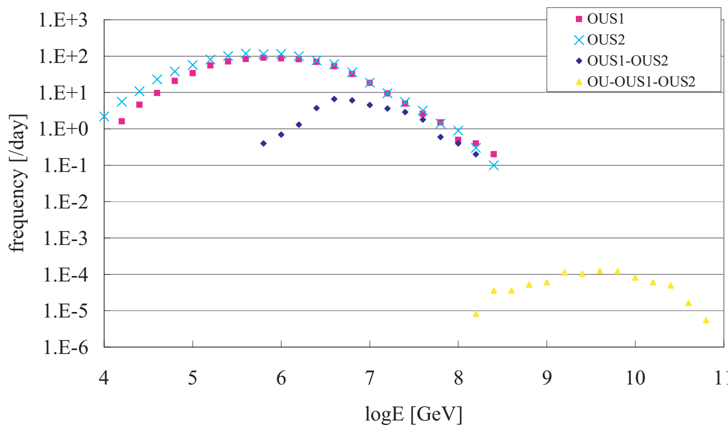

Fig. 1. Observing energy region simulated by NKG simulations.

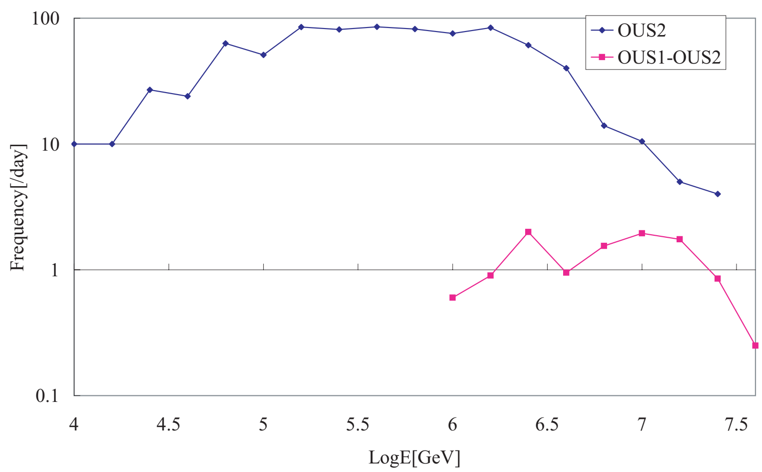

Fig. 2. Observing energy region simulated by CORSIKA simulations.

Table 2. Comparison of observed trigger rates and simulated ones under the single/multiple array(s) trigger conditions. Ē represents the most probable observed energies.

Station	Observed	NKG		CORSIKA	
	rate[/day]	rate[/day]	Ē	rate[/day]	Ē
OUS2a	1522±39	974±31	$10^{14.6}$eV	813±22	$10^{14.6}$eV
OUS1	730±27	730±30	$10^{14.8}$eV	-	-
OUS1-OUS2a	23±5	33±5	$10^{15.6}$eV	10	$10^{15.8}$eV
OU-OUS1-OUS2a	-	-	$10^{18.4}$eV	-	-