

# LAAS Network Observation of Air Showers

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## Abstract

A network observation of air showers started in Japan. The network as Large Area Air Shower (LAAS) group consists of eleven air shower arrays (stations) enclosing an area of 130,000 square kilometers. Nine stations out of eleven are in operation, the remainder is under construction. The observation aims at finding out time correlations in primary cosmic rays. Each station is equipped with the Global Positioning System as a common clock, so the arrival times of air showers can be recorded with an accuracy of one microsecond. Profiles of stations and current status of the network are reported here.

## 1 Introduction:

Time correlations in primary cosmic rays have been disregarded except for some cases of bursts from the specific objects in space. Since cosmic rays are under influence of the Galactic magnetic field throughout their journey from their source to an earth-based detector, time correlations should have been destroyed even if they existed at an earlier stage. As a result, most people do not expect any correlations in them. For gamma rays, which are not affected by the Galactic magnetic field, the small steady flux is usually below the detectable level and again, people do not expect any observations of correlations.

However, time correlations have been discovered as chaotic structure in air shower arrival time intervals by the Kinki University and Osaka City University groups (Katayose et al., 1995; Ohara et al., 1995; Kitamura et al., 1997). This discovery contains the large area correlation (over 460 km) as well as the time correlation (over 30 hours). If this is confirmed by further extensive analyses, it is expected to provide some insight into modeling of the formation and acceleration of cosmic rays. This was the primary motivation to establish the Large Area Air Shower (LAAS) group. Eleven air shower arrays form a network with an unprecedented enclosed area of 130,000 km<sup>2</sup>. Among them, nine stations are in operation, and the remainder is under construction, as described in the following section.

## 2 Experiment:

The LAAS group consists of eleven air shower arrays (stations). Each station is equipped with the Global Positioning System (GPS) as a common clock, so the arrival times of air showers can be recorded with an accuracy of a microsecond. The elevations of all stations are almost at sea level. Most of stations use the detector with a 50cm\*50cm\*5cm plastic scintillator and a fast timing photomultiplier.

The following subsections are alphabetical descriptions of all stations. Their coordinates and some profiles are summarized in Table 1. Their locations are indicated on the map of Japan as Figure 1. Mutual distances are tabulated in Table 2. The following descriptions are as of May 1999.

**2.1 Ashikaga Institute of Technology (AIT):** This station starts observation around October 1999. The construction is now in progress at Ashikaga in Tochigi Prefecture, about 400 km northeast of Osaka stations. The array will consist of seven scintillation counters, located at the apexes and the center of an equilateral hexagon.

**2.2 Hirosaki University (HU):** This station has been operating since November 13, 1998 without long interruptions. It is situated in Aomori Prefecture in the northeastern part of Japan, about 800 km (and the most) far away from Osaka stations. Five scintillation counters sit on the corners and the center of a 15m-by-16m rectangle. The trigger condition is 5-fold coincidence within 150 ns., yielding a trigger rate of 0.422 events/min.

**2.3 Kinki University (KU1, KU2):** In Osaka Prefecture, Kinki University has two independent stations. The distance between them is 110 m, the shortest among the LAAS group.

The first station (KU1) started observation on May 14, 1993. Since then it has been taking air shower data continuously except for three long (10-30 days) interruptions. Situated on the rooftop of the No.31 building of Kinki University, the array has five scintillation counters forming a 19m-by-19m square (and its center). The trigger condition is 5-fold coincidence within 60 ns, resulting in a trigger rate of 0.27 events/min. The angular resolutions are estimated to be  $2.8^\circ$  for the zenith angle and  $10.3^\circ$  for the azimuthal angle.

The second station (KU2) has been operating since July 1998. It is on the rooftop of the No.15 building of the University. A scintillation counter is located at each apex of two concentric equilateral triangles with side lengths of 10.3 m and 20.6 m. Including the central counter, there are seven counters in all. The trigger condition is 7-fold coincidence within 50 ns. The trigger rate is 0.220 events/min.

**2.4 Kochi University (KCU):** Using eight scintillation counters, the Kochi array started running on March 11, 1999. It is situated in Kochi Prefecture as the most southwest station, about 200 km far from Osaka stations. Adjustment works are under way.

**2.5 Nara University of Industry (NUI):** This station has been working since July 10, 1996. However, it was stopped for four months in 1997. The site is in Nara Prefecture, about 10 km east of Osaka stations. Seven scintillation counters are located at the apexes and the center of a hexagon with about 9 m sides. The trigger condition is 7-fold coincidence, and the trigger rate is 0.20 events/min.

**2.6 Okayama University (OU):** This station began operation on September 12, 1996 and has been operating almost continuously. However, about three weeks' data was lost owing to an electronic accident. It is located in Okayama Prefecture, about 150 km west of Osaka stations. Five scintillation counters for triggering are arranged at the corners and the center of a 10m-by-10m square. Three non-trigger counters are situated at 10-20 m from the center. The time window for triggering is 45 ns. The trigger rate is 0.41 events/min. The total number of air showers detected by the end of January 1999 is about  $5.0 \times 10^5$ . Each shower angle is calculated by fitting the shower front to a plane, and the errors in the fitting procedure are assigned to the zenith and azimuthal errors. The resulting angular resolutions are estimated to be  $4.4^\circ$  for the zenith angle and to be  $12.9^\circ$  for the azimuthal angle. This array will be moved by tens of meters and rearranged into a new layout in April 2000.

**2.7 Okayama University of Science (OUS):** This is in Okayama Prefecture, and about 1.1 km north of OU. This station started operation on July 31, 1995. Since then, two major alterations were made to the array. We describe the three stages of the array separately.

First, from July 31, 1995 to November 14, 1997, the array (OUS-a) had four scintillation counters forming an 8.9m-by-8.9m square. During this period, the observation was stopped twice for a month each.

The trigger condition was 4-fold coincidence, resulting in a trigger rate of 0.53 events/min. The GPS was installed on September 2, 1996. Between this date and the end of this stage, a total of  $2.8 \cdot 10^5$  air showers was collected. The angular resolutions are estimated to be  $4.1^\circ$  for the zenith angle and to be  $12.1^\circ$  for the azimuthal angle, by the same procedure with OU.

On November 14, 1997, four identical counters were added to the array, so that the enclosed area was doubled. During this stage (OUS-b) there was no major interruption. The trigger condition was 8-fold coincidence. The trigger rate was 0.22 events/min., and the number of showers recorded is  $1.3 \cdot 10^5$ . The angular resolutions are  $2.7^\circ$  for the zenith angle and  $8.4^\circ$  for the azimuthal angle.

On January 4, 1999, the trigger condition was relaxed to 4-fold coincidence (but not the same trigger counters with OUS-a), regaining the trigger rate of 0.53 events/min. Currently, the array (OUS-c) is in operation under this condition.

**2.8 Osaka City University (OCU1, OCU2):** Osaka City University is operating two stations, one in Mitsuishi, Okayama Prefecture, and the other in Sugimoto, Osaka.

The Mitsuishi array (OCU1), the largest among the LAAS group, consists of 22 scintillation counters, arranged over a 40m-by-60m area with a typical interval of 10 m. It has been operating since 1961 in Okayama Prefecture, about 120 km west of Osaka stations. The trigger condition is any 4-fold coincidence of the central six trigger counters, resulting in a trigger rate of 1.2 events/min. The Mitsuishi array is the only array among the LAAS group that is accompanied by a muon detector. The muon detector consists of four layers of proportional counters, and its acceptance is  $19.2 \text{ m}^2\text{sr}$ . It is buried beneath 30 m.w.e. of soil, corresponding to a muon threshold energy of approximately 6 GeV.

The Sugimoto array (OCU2) has 10 scintillation counters. The four counters out of 10 are located on the rooftop of a building, and the remainder is situated in the courtyard. It has been working since June 1997. The trigger condition is any 3-fold coincidence from the courtyard counters. The trigger rate is 2.8 events/min.

**2.9 Polytechnic University (PU):** As the newest member of the LAAS group, this array is in preparation. The location will be Sagamihara in Kanagawa Prefecture, about 360 km east of Osaka stations.

### 3 Analyses:

The enormous number of data acquired by these stations is processed and stored in the Kinki University archives via Internet. The standard format of data contains the shower arrival time, the shower direction in equatorial coordinates, the shower direction in horizontal coordinates, the errors of the direction, the deviation from the fitted plane, the average of ADC values, and the estimated shower size. Until now, the shower sizes are not calculated yet. These data are available to all members of the group.

The LAAS group aims at finding out time correlations in primary cosmic rays. Not only the chaotic analysis mentioned above, but a variety of analyses are performed by members of the group. An analysis using the coincidental air showers can be found in Ochi et al. (1999).

## References

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**Table 1:** The coordinates and some profiles of stations (\* ; not available)

Station	HU	AIT	PU	NUI	KU1	KU2	OCU2	OCU1	OUS	OU	KCU
Lati. (N)	40°35'	36°21'	35°35'	34°35'	34°39'	34°39'	34°35'	34°48'	34°42'	34°41'	33°33'
Longi. (E)	140°29'	139°24'	139°20'	135°41'	135°36'	135°36'	135°31'	134°17'	133°56'	133°55'	133°29'
# of counter	5	7	*	7	5	7	10	22	8	8	8
Rate (/min)	0.42	*	*	0.20	0.27	0.22	2.8	1.2	0.53	0.41	*
Work since	11/13,98	10,99	*	7/10,96	5/14,93	7,98	6,97	61	7/31,95	9/12,96	3/11,99

**Table 2:** Mutual distances between stations (km)

	HU										
AIT	478.2	AIT									
PU	563.8	86.0	PU								
NUI	787.9	390.3	350.2	NUI							
KU	786.8	394.2	356.1	10.6	KU						
OCU2	796.4	404.0	365.3	15.9	10.0	OCU2					
OCU1	842.3	495.0	467.6	130.2	120.9	114.6	OCU1				
OUS	871.6	529.3	501.7	161.1	152.3	145.2	34.3	OUS			
OU	872.7	530.2	502.4	161.6	152.8	145.7	35.2	1.1	OU		
KCU	997.2	623.6	581.6	233.4	229.4	219.5	157.1	133.9	132.8	KCU	



**Figure 1:** The locations of eleven stations of the LAAS group. There are two stations in Kinki University. This map covers all of Japan except small islands.