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Hirosaki Air Shower Array II

Setsuo Kawaguchi, Hiroyuki Takada*, Nobusuke Takahashi

Faculty of Science and Technology, Hirosaki University

** Graduate school of Science and Technology, Hirosaki University*

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Abstract

In order to study the arrival time of successive air shower, a new air shower array(Hirosaki Air Shower Array II;AS-Array II) has been constructed on the roof of Building No.1 of the Faculty of Science and Technology, Hirosaki University. This array consists of five fast timing detectors (FT detectors) using GPS antenna. A 2-fold coincidence within 100 ns is used on the triggering condition. The event rate is about 18k events/day. This array is located in south 125 m of the air shower array I(AS-Array I). Two compact AS arrays are operating simultaneously and independently at distant arrays. Most importantly, for the network observations, each station has the GPS receiver as the common clock, so we can compare arrival times of extensive air shower observed at different stations with a high accuracy of 1 μs. By comparing arrival times and arrival directions of two stations, analysis of arrival time of successive air shower within 1 μs is enabled.

1. Introduction

We analyze the arrival time of air shower using Hirosaki AS Array. Some special successive air shower events are recorded in short term among observation data

Recently, N.Ochi et al. [1] and T.Konishi et al. [2] reported that the arrival direction of such the successive air showers tends to concentrate to the Galactic plane. Relating to their reports we analyzed similar problems by following two algorithms. One is with Poisson distribution and the other is with Erlang distribution. Comparing the data analysis by Poisson distribution procedure with that by Erlang distribution procedure, it is concluded that we could get the candidates for successive air shower events without missing them, if we utilize Erlang distribution method [3], [4].

2. Hirosaki AS Array I

The observation of air showers has been started at September 27, 1990 in Hirosaki (Location: 40 ° 35' N, 140 ° 28' E, 63m above sea level). The preliminary results have been already reported in Sci. Rep. Hirosaki Univ. 39, 1-20 (1992) [5]. AS-Array I has been constructed by using GPS, Global Positioning System. This array consists of 20 scintillation detectors of area 0.25m^2 each and 5 fast timing scintillation detectors (FT detectors) of area 0.25m^2 each. 16 detectors are arranged by 5m separation and 4 detectors are distributed around

20〜30m from the center of array. The acceptance area is $25\times25\mathrm{m}^2$. The arrival direction of air shower is determined by the fast timing method.

New data acquisition system of AS-Array I consists of 5 plastic scintillation detectors with NIM/CAMAC modules, especially using the GPS which enables us to record the arrival time of air showers with accuracy of 1 μsec. This has been started at November 11, 1998. The FT detectors are located on each corner and center of a 15m×16m rectangle. A 5-fold coincidence within 140 ns is used on the triggering condition. The event rate is 0.412 ± 0.028 events/min. Results of the analysis are reported by using the observation data (The number of events obtained in the observation of about a year is 202506.) [6].

3. Hirosaki AS Array II

Hirosaki AS Array II is located in south 125 meters of AS-Array I as shown in Photo 1. Counter arrangement, block diagram of the data acquisition, examples of timing charts of 2 fold coincidence, and systematic time delay are reported.

3 − 1. Counter arrangement

The counter arrangement of AS Array II is schematically shown in figure 1. Five scintillation counters equipped for timing and particle density measurement are distributed over $225m^2$. Two-fold coincidence among No. 4, 5 counters within 100 ns are required to be recorded as an air shower. The pulse-height distribution for pulses from photomultipliers is monitored every month and kept constant by adjusting high voltages or thresholds level if necessary.

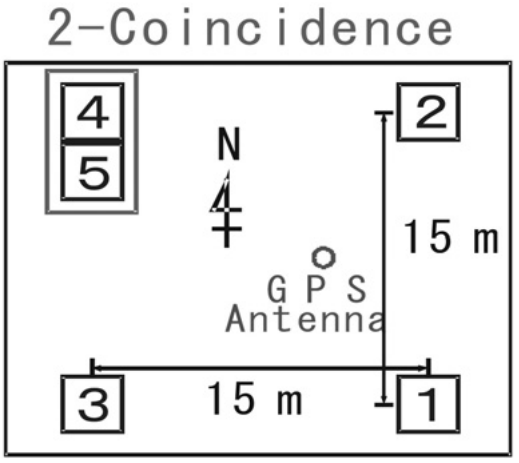

Figure 1. The counter arrangement of Hirosaki AS-Array II. 1 to 5 are fast timing scintillation detectors of area $0.25\mathrm{m}^2$ each. The triggering requirement is two fold coincidences of FT detectors No.4 and No.5.

A GPS timing module provides the arrival time of air showers in universal time with an accuracy of 1 μs. The shower angle of each air showers is reconstructed by fitting a plane shower front to the measured time delays (TDC values; Time to Digital Converter values) between FT1, FT2, FT3 detectors and triggered detectors. From the zenith angle θ and the azimuthal angle ϕ, the arrival direction of the air shower in equatorial coordinates (the right ascension α and the declination δ) is also calculated.

Installations of AS-Array II are following;

Location: 40 ° 35 ′ N, 140 ° 28 ′ E,
66m above sea level in Hirosaki Univ.
Size of plastic scintillator: 50cm×50cm×5cm
Size of FT-detectors array: 15m×15m
Number of FT-detectors: 5
Triggering condition: 2-fold coincidence of No.4 and No.5, within 100 ns
TDC resolution: 100 psec.
Trigger rate : 〜18000 / day
Photo-multiplier tube: Hamamatsu H1161

3 – 2. Block diagram of the data acquisition system

Block diagram of the data acquisition system is shown in figure 2. The signals of 5 FT detectors and GPS signals are gathered by coaxial cables into the laboratory. GPS signals of air shower arrival time, the arrival time differences of shower particles and the pulse height of their detectors are stored in NIM/ CAMAC system. The stored data is recorded on hard disk automatically. A summary of specifications of the NIM/CAMAC modules which are used in this system is following;

Quad CF discriminator (Kaizu 381, NIM)
Output pulse : ∼1.2ns, ∼800ps, 55MHz
8-fold 1-veto coincidence (Kaizu 220, NIM)
Output pulse : ∼1ns, 52MHz
Event timing module (Kaizu 3051, CAMAC)
1 μs/day,
GPS antenna: Furuno GPA-014
TDC (LeCroy 2228A, CAMAC)
No. of channels: 8,
Dynamic Range: 11bits,
Least Count: 50(or 100) ps,
Time Range: 0-100 (or 200) ns,
Conversion Time: 100 μs
ADC (LeCroy 2249W, CAMAC)
No. of channels: 12,
Dynamic Range: 11bits,
Charge sensitive type,
Gain: -0.25 pC/count,
Full Scale Range: ∼-500 pC
(Maximum count=1980),
Conversion Time: 106 μs

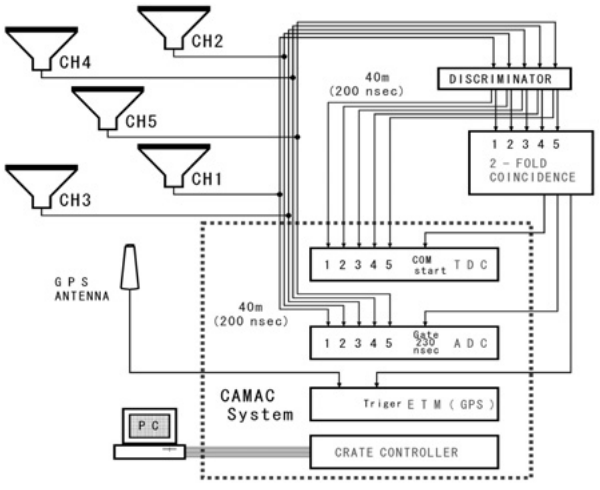

Figure 2. Block diagram of Hirosaki AS-Array II.

3 – 3. Timing charts of 2 fold coincidence

The curvature of air shower is determined by the arrival time differences of shower particles. Four FT detectors are distributed in a plane at intervals of 15m and one FT detector is placed adjacent to detector No.4 which is installed the northwest corner as shown in figure 1.

Timing charts of 2 fold coincidence is shown in figures 3-1, 3-2 and 3-3 which are incident from right above, incident from northwest and incident from southeast respectively. Pulse width of discriminator output is set 100 ns for detection of delaying particles in a shower.

3 – 4. Systematic time delay

The systematic time delay is examined experimentally by mean of the close arrangement of five FT detectors. The analysis has done for 1478 showers. The time delay distributions are shown in figures 4. In the figures, n-5ch means systematic time delay difference between ch.n(n=1∼4) detector and ch.5 detector. The mean of delay time difference distributions are set less than ±0.5 ns by variable delay modules. The mean values of delay time difference; $\triangle t$ and standard deviations; σ are shown in Table 1. In this Table, FTn(n=1∼5) is TDC value in each FT detectors.

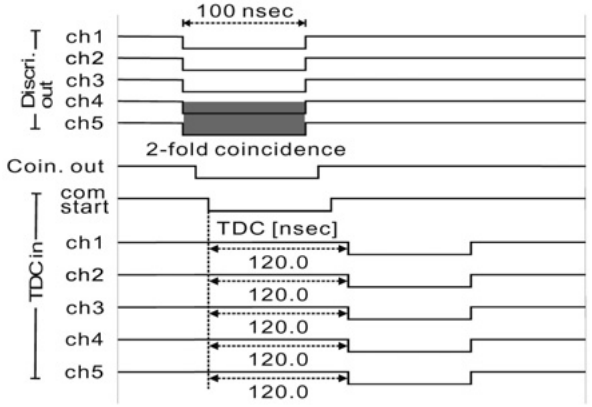

Figure 3 – 1. Timing chart of 2 fold coincidence. In the case of incidence from right above.

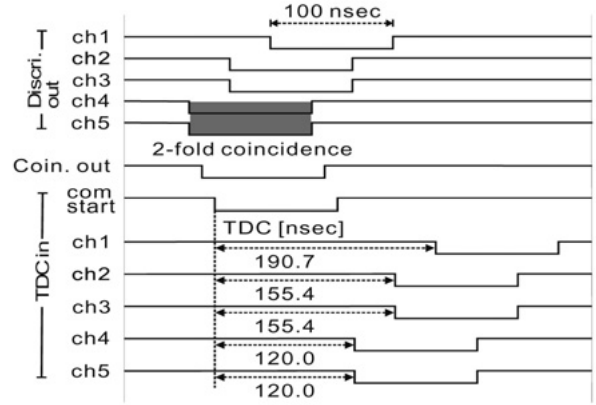

Figure 3 – 2. Timing chart of 2 fold coincidence. In the case of incidence from northwest.

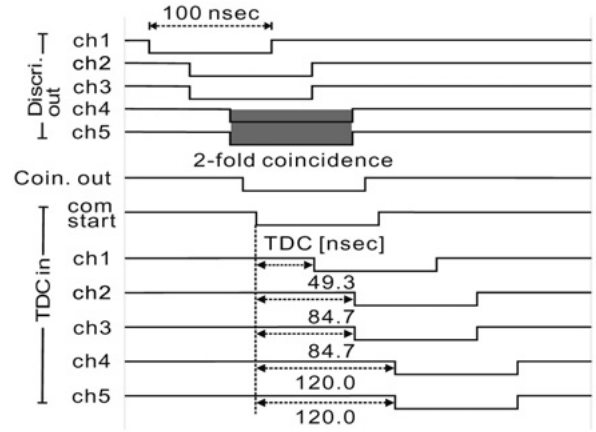

Figure 3 – 3. Timing chart of 2 fold coincidence. In the case of incidence from southeast.

Table 1. Time difference of delay cable.

FTn - FT5	⊿t	σ
FT1 - FT5	− 0.41 ns	5.87 ns
FT2 - FT5	− 0.22 ns	5.75 ns
FT3 - FT5	− 0.39 ns	5.27 ns
FT4 - FT5	+ 0.03 ns	5.57 ns

4. Preliminary results of data analysis

Results of preliminary analysis; counting ratio, distribution of arrival time difference, and arrival direction, are reported in following. Total events number is 607k during 33 days

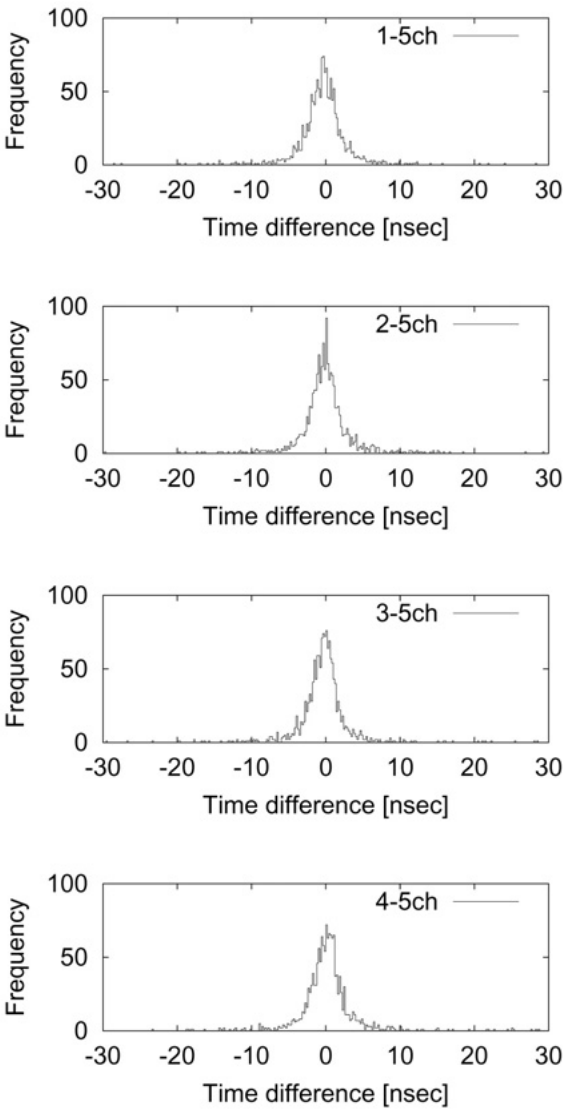

Figure 4. Distributions of time delay.

4 – 1. Trigger rates

Trigger rates per day in the cases of 3〜5 fold coincidence are given by analysis of 2 fold coincidence data. Triggering rates and its time variations are shown in table 2 and figures 5 respectively. In these figures, 2〜5-coin means 2 〜5-coincidence with 100 ns.

Table 2. Trigger rate in 2〜5 fold coincidence

n-coincidence	Trigger rate per day
2-coin	18400
3-coin	1923
4-coin	1026
5-coin	459

4 – 2. Difference of arrival time

Arrival time difference and its deviations are shown in table 3 and figures 6 respectively.

Table 3. Arrival time difference

n-coincidence	Time difference(sec)
2-coin	4.7
3-coin	45.4
4-coin	85.0
5-coin	190.1

4 – 3. Distribution of arrival direction

The zenith angle θ and the azimuthal angle ϕ of each air shower is reconstructed by fitting a plane shower front to the measured time delays between triggered counters. The arrival direction of the air shower in equatorial coordinates (the right ascension α and the declination δ) is also calculated. Distributions of the arrival direction are shown in figure 7.

5. Summary

Hirosaki AS Array II is located in south 125 meters of AS-Array I as shown in Photo 1.

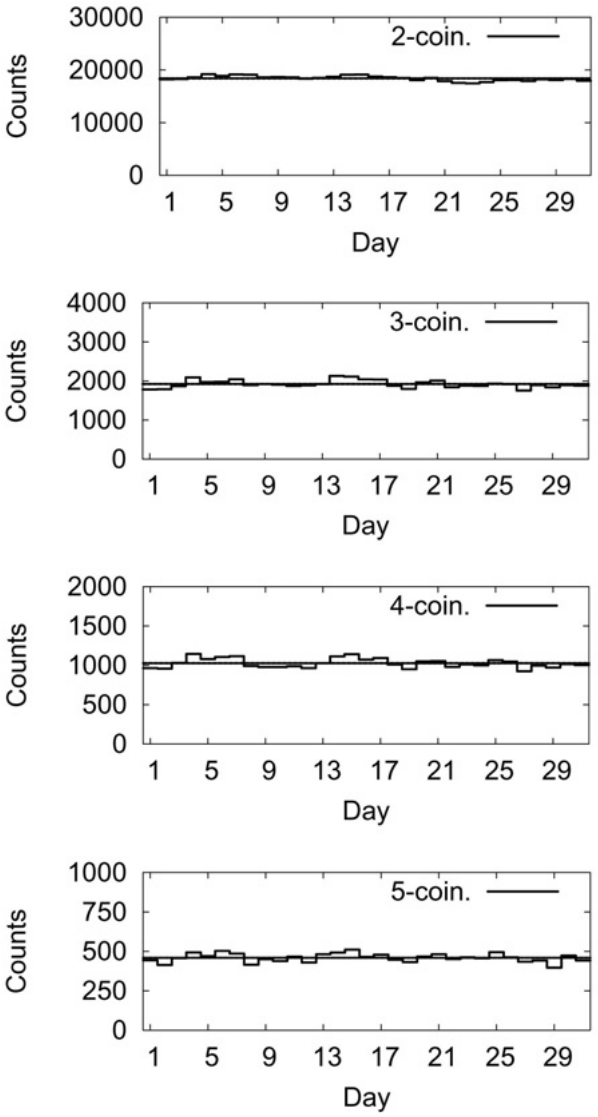

Figure 5. Trigger rate per day in the cases of 2 〜5 fold coincidence during 33 days.

Hirosaki AS-Array II has been operated well from October 6, 2003. Preliminary analysis is almost consistent with AS-Array I data. More detailed analysis is in progress and will be reported in next paper.

By comparing arrival times and arrival directions of two stations, analysis of arrival time of successive air shower within 1 μs is enabled.

6. Acknowledgements

We wish to thanks Prof. A.Iyono and Dr.

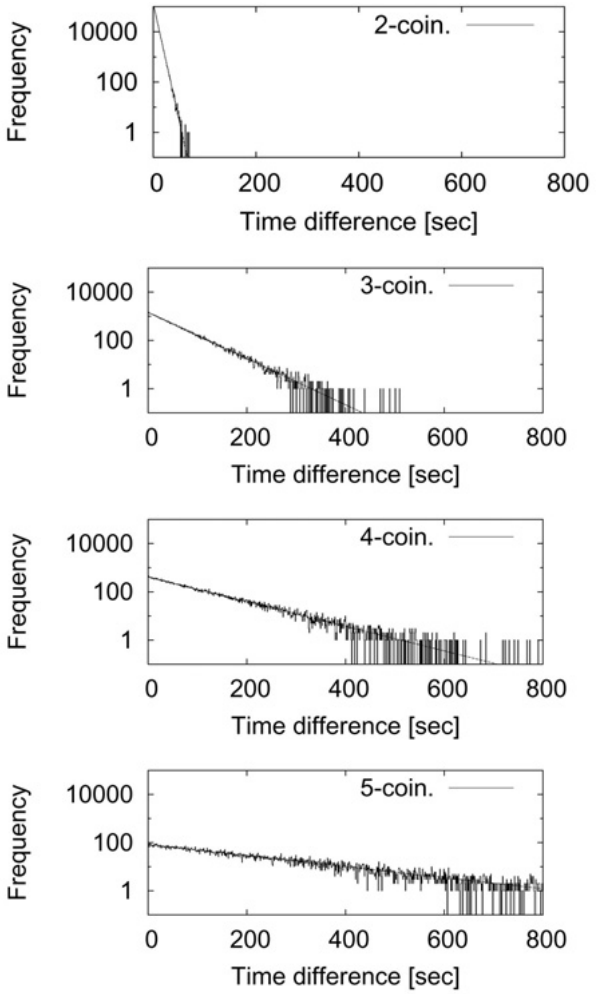

Figure 6. Arrival time difference in the cases of 2∼5 fold coincidence during 33 days.

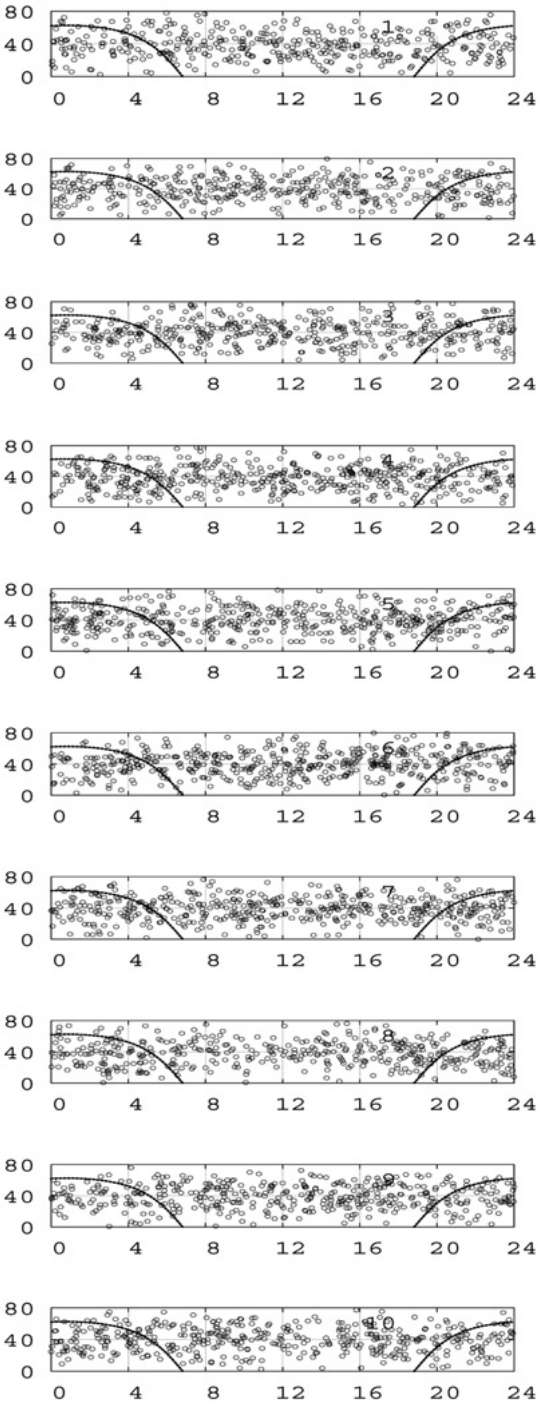

Figure 7. Arrival directions of air showers during 10 days in the case of 5 fold coincidence.

N. Ochi for discussion about two fold coincidences. The calculation of air shower data was made at the computer center of Hirosaki University and computer system of department of electronic and information system engineering. We wish to thanks those staffs for their skillful advice.

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Photo 1. A bird's-eye view of Hirosaki AS Array I and AS Array II.

7. References

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