Finding gamma ray events by the method of obtaining poisson distribution from data collected by an array of Cherenkov detectors

Shima Bayesteh*¶, Mehdi Khakian Qomi†*, Jalal Samimi*§, Hashem Hamedivafa‡, Farzaneh Sheidaei*§ and Mahmoud Bahmanabadi*§

**ALBORZ Observatory of Sharif University of Technology,Tehran,Iran*
†Amirkabir University of Technology, Iran
‡Imam Khomeini International University, Iran
§Sharif University of Technology, Tehran, Iran
¶Zanjan University, Zanjan, Iran

***Abstract*. a small array of Water Cherenkov Detectors (WCDs) has recorded 600000 events related to extensive air showers in Tehran during one year at an altitude of 1200m.**
By employing the method of obtaining count in each time interval distributions we obtained the distribution of extensive air showers.
17 events were found in our data set which are more probable to be related to primary gamma ray photons. For more certainty we did a simulation to compare acquired results from simulation and data to become sure if 17 extensive air showers are electromagnetic or not.

***Keywords*: Water Cherenkov Detectors, gamma ray events, Poisson distribution.**

I. INTRODUCTION

High energy primary cosmic rays or cosmic gamma rays ($> 10^{14}eV$) are responsible for providing Extensive Air Showers (EASs) that are detectable by ground level detector arrays. Our small array of water Cherenkov detectors consists of 4 detectors which have designed in square shape with each side of 608cm. This is a prototype of a larger EAS array that is going to be built at ALBORZ observatory(http://www.astrophysics.sharif.ac.ir). The prototype was installed on the roof of physics department at Sharif University of Technology in Tehran with an altitude of 1200m above sea level. Among logged events that are fractions of charged secondary particles arriving to our ground level array we are seeking for those that are related to electromagnetic showers or in other word primary gamma ray photons that are directed toward Very High Energy (probable TeV) sources. We used EGRET 3rd catalog with 271 gamma ray sources[1] to compare the location of discovered sources and existed sources in the catalog [2].

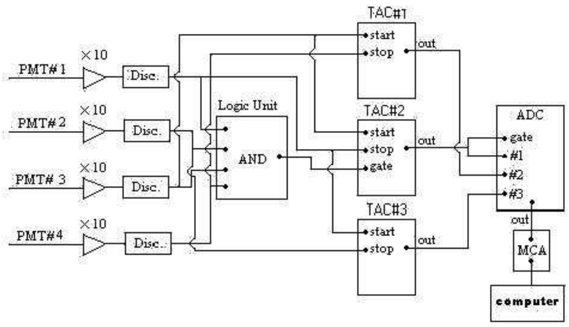

Fig. 1. Schematic diagram of electronic circuit of the Water Cherenkov array.

II. EXPERIMENTAL SET-UP

The Water Cherenkov detectors (WCDs) used in our array consist of a metallic cylindrical tank, with diameter of 64cm in diameter and 130cm height filled up to 120cm with distilled water[3]. Each PMT is located at the top of the water level along the cylinder axis. Figure.1 shows schematic view of Cherenkov detectors electronic circuit. If at least one particle arrives at a Cherenkov detector, the PMT above the detector makes a signal with a pulse height which depends on the direction and the number of secondary particles crossing through it. The output signals from the PMTs are amplified ($\times 10$) with an 8-fold fast amplifier (CAEN N412) and then they reach into 8-fold fast discriminator (CAEN N413A) which its threshold is fixed on 100mV. The next unit is Time to Amplitude Convertor which is set to a full scale of 200ns. As the third Cherenkov is regarded as the reference detector, the output of dist3 is connected to the start input of TAC1, TAC2 and TAC3. The stop inputs of TAC1, TAC2 and TAC3 are fed by orderly dist1, dist2 and dist3. Then the outputs of these three TACs are fed into a multi-parameter Multi Channel Analyzer (MCA) via an Analogue to Digital Convertor (ADC) unit. With this electronic circuit the time lags, T31, T32 and T34 would obtain which lead us to find logged showers directions.

III. Data analysis

We obtained EASs distribution in various time intervals. As we expect, the majority of recorded extensive air showers arrive randomly to our array, so that their distributions are poissonian. the Poisson distribution is a Discrete probability distribution that expresses the probability of number of events occurring in a fixed interval of time, if these events occur with a known average rate and independently of the time since the last event; therefore according to our count rate variation we should choose fixed intervals for which the count rate stays almost steady. Our data set, has been collected in one year. We split this duration into time pieces in two ways, and for each period we consider time windows 10sec, 30sec, 100sec, 300sec, 1000sec and 3000sec.

A. separating one year into six two-months

After finding number of showers distribution in each time window, we fitted them with poisson distribution as shown in figure2. There are few points in the outskirt of the distributions which maybe related to events that are adaptable with random spectrum and they must be investigated as nonrandom events such as electromagnetic showers. If these events are found in other time windows the probability of finding nonrandom events would increase. Table1 shows some of these events have been observed in two or more time windows.

B. dividing into three unequal periods

If we draw count rate variation during the year we find out that between 3rd and 4th two-month we have a great change in slope which can be linked to a systematic problem. Therefore according to change in the count rate up to just 10 percent we have three parts that with a good accuracy we can say that count rate is stable. Figure3 shows count rate change and the rational for second division. Table2 is related to gained results from an analysis similar to the previous one for first current division.

C. A test on the certainty of finding probable gamma ray events

As we get from the previous sections, the events that have been observed in three time windows are more probable to be nonrandom or cosmic gamma ray events. We performed a test to become more certain that these events are the electromagnetic events. We performed this test for all events which have been observed in three time windows but we present only the result of this test for 17 events in 5th two month which have been found in three time windows 300, 1000 and 3000 seconds, because the outcome of this test for these events was desirable; but for other observed events was not. In figure4 we see count in each time window

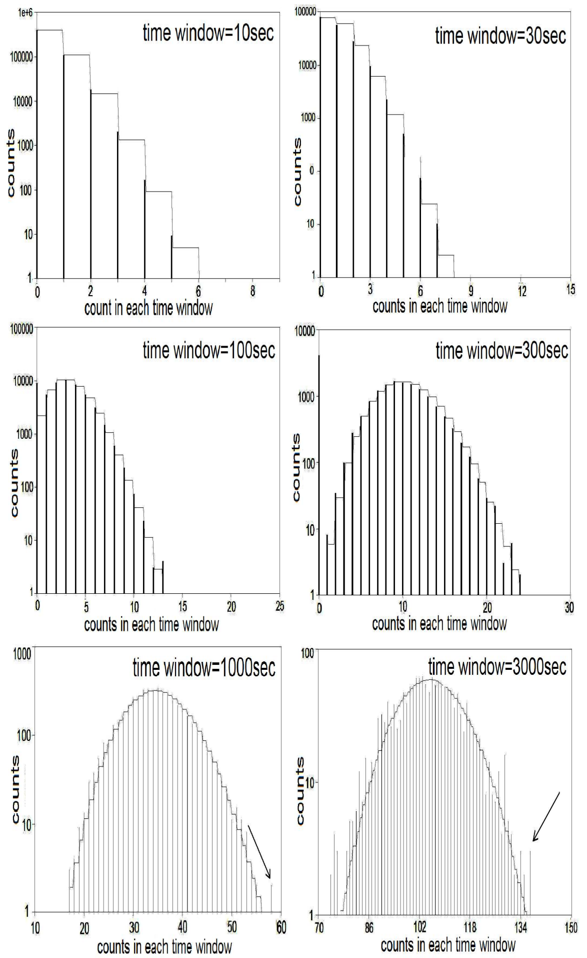

Fig. 2. Count in each time window distributions for the first two-month.

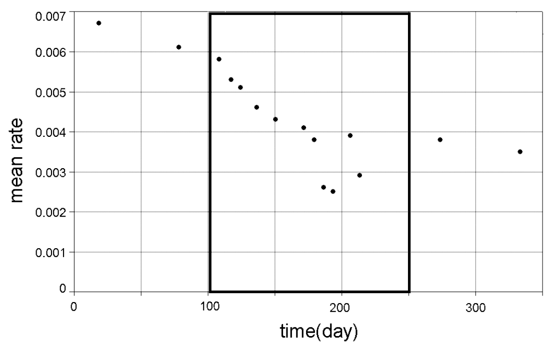

Fig. 3. Mean count rate of showers during one year.

distributions for the 17 events. For each diagram it has been shown two regions, one in the end of each one where 17 events have been observed, and the other one on the distribution peak. We obtained the ratio of found events in three time windows to total events at the end of the distribution and then compared it with the ratio of common events in the peaks of three time windows to total events existed there. For 300sec and 1000sec time windows comparison of these ratios shows that 17 events in these windows can be counted nonrandom,

TABLE I
RESULTS AND SIMILAR EVENTS FROM THE FIRST SEPARATION.

	1st two-month	2nd two-month	3rd two-month	4th two-month	5th two-month	6th two-month
mean count rate	0.00673	0.00617	0.00544	0.00405	0.00385	0.00351
similar events in two time windows	12	12	0	0	55	41
time windows related to row 2	30,300,1000	100,300	—	—	30,100,300,1000,3000	10,30,300,1000
similar events in three time windows	0	0	0	0	24	0
time windows related to row 4	—	—	—	—	30,100,300,1000,3000	—

TABLE II
RESULTS FROM THE SECOND SEPARATION ACCORDING TO STABLE COUNT RATE IN EACH PART.

	1st part	2nd part	3rd part
mean count rate	0.00617	0.00570	0.00370
similar events in two time windows	59	85	84
time windows related to row 2	1000,3000	300,1000,3000	30,100,300,1000
similar events in three time windows	0	17	7
time windows related to row 4	—	300,1000,3000	100,300,1000
time interval of each part	06/11/19-07/02/14	07/02/10-07/04/16	07/05/19-07/11/20

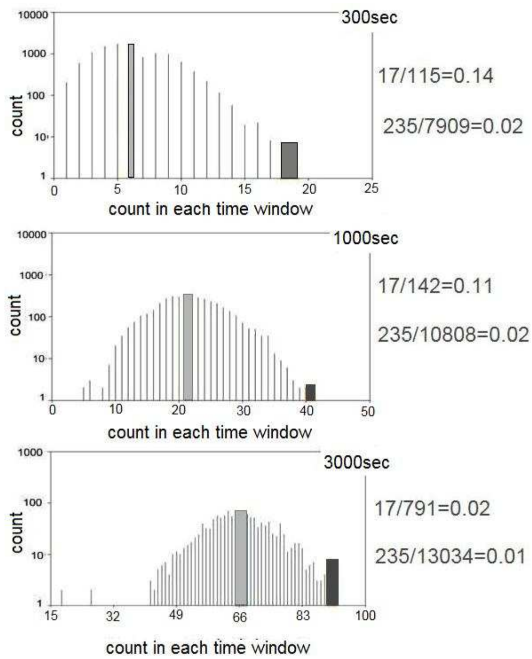

Fig. 4. . Count in each time window for 5th two-month and the result of the test described in text

but in 3000sec time windows there is not any evidence to confirm the previous state. we can deduce that maybe 3000sec time window is not compatible with mean count rate or in other words it is too long for our analysis.

D. *considering another time windows*

The next step to test certainty of these 17 events as nonrandom events, is to regard another time windows such as 180sec, 600sec and 800sec. in 180sec time window we observed 12 of those 17 events but in other both windows we did not. All 17 events are shown in Figure.5 and 12 observed events in the other time window are demonstrated with black points. Around each event a region has been defined. The radius of these

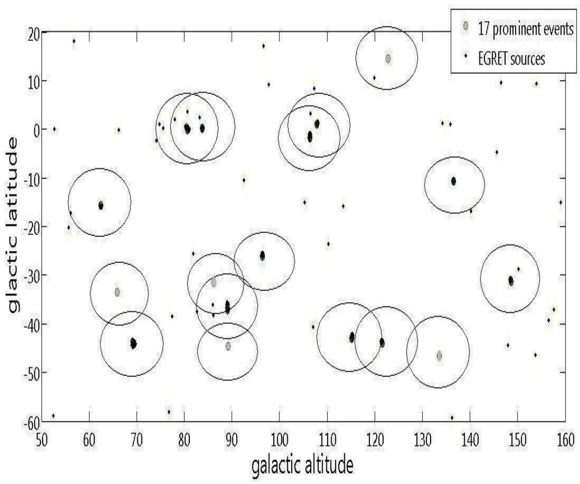

Fig. 5. 17 events location on galactic map near EGRET sources.

regions is equal to angular resolution $\Delta l \sim \Delta b \cong 13\circ$.

IV. ARRANGING A SIMULATION

At the end of our analysis we began to do a simulation. We produced the similar events as we had in 5th two-month, and we repeated all steps operated for the data of this time for random produced events. We acquired count in each time window distributions for three time windows 300sec, 1000sec and 3000sec. As we expected, the distributions are more compatible with Poisson distribution, figure6. Therefore although we know that there are not any nonrandom events among this set, but we obtained those ratios we mentioned in III.C. Now we expect each couple ratio to be in the same order. In spite of producing random events ten times of data events we had in 5th two-month, we did not find any similar events among three time windows in the outskirt of obtained distributions. So to reach into a final result in this part it is needed to create more events.

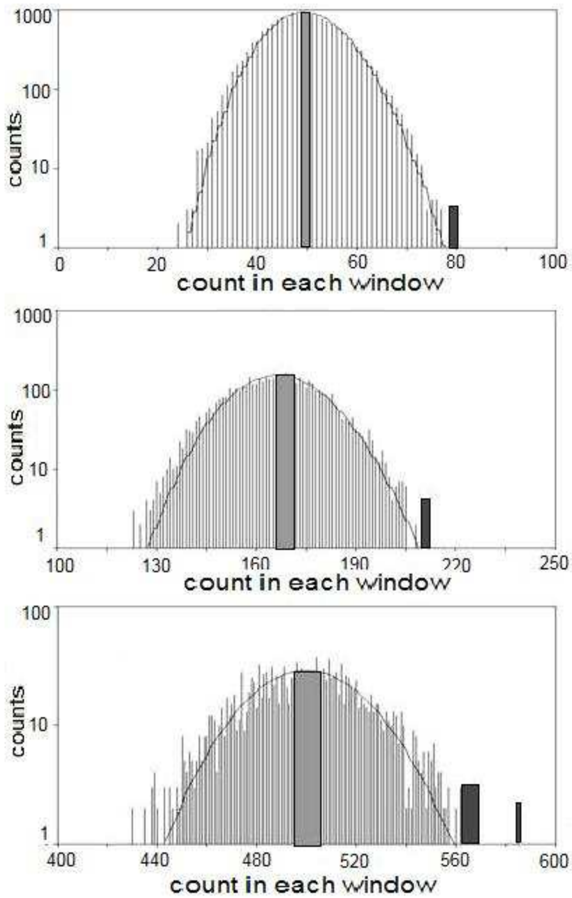

Fig. 6. Obtained distributions from simulated data.

V. Concluding remarks

Finally we can come into conclusion that with this small amount of data and poor angular resolution we cannot claim that any specified sources have been detected with high certainty with our array, in spite of correct method we have employed. So we need to optimize the angular resolution of our detectors to achieve better results.

VI. acknowledgement

The authors acknowledge a research grant from the office of vice-president for research and technology of Sharif University of Technology.

References

[1] Hartman, R. C., Bertsch, D. L., Catelli, J. R., et al. 1997, ApJS, 123, 79
[2] Khakian, M. et al.:2005 A&A 434: 459-467
[3] Sheidaei, F: 2007: 30th ICRC proceeding