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A CASE STUDY FOR EDUCATIONAL COLLABORATIONS BETWEEN HIGH SCHOOLS IN COSMIC RAY PHYSICS

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Abstract

Educational experiments in cosmic ray physics, carried out with small size Geiger counters, suffer of limited statistics. High schools however may share their equipment to use such counters in parallel to increase the statistics and allow for educational measurements of the cosmic ray flux in a reduced time. As a test, a measurement of the barometric coefficient for cosmic rays was carried out by the use of six counters and a specially designed fan-in circuitry.

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1 INTRODUCTION

Educational cosmic ray experiments [1] are quite often carried out at the high-school level - or even at the undergraduated university level – by simple, small sized Geiger counters. The use of such counters is very simple, thus allowing to introduce students to the problem of detecting ionizing particles. Despite their simplicity, Geiger counters still provide a quantitative way of measuring physical quantities of interest in cosmic ray and environmental physics. Commercial Geigers are easily found for educational experiments, and very frequently they are part of the basic tools employed by high-school physics teachers. One of the main drawbacks of such devices is their limited size, which results in a small counting rate for cosmics. With a typical size of 10 cm (length) by 1 cm (diameter), counting rates in the order of 0.3 Hz are usually obtained, thus needing very long collecting times to carry out experiments with enough statistics. One of such examples is the study of the muon flux as a function of the atmospheric pressure, which should allow to extract a rough value of the barometric coefficient, expressing the slight anticorrelation between pressure and muon rate. With one of such small devices, a two-months educational experiment was already performed in the past to measure the value of such coefficient [2]. The experiment has now become part of the suggested activities for several high-school teams collaborating with our group in cosmic ray educational physics [3]. Other inclusive experiments requiring enough statistics collected in a relatively short time may include the study of the variation of the cosmic ray flux with the altitude, or the investigation of the role of an absorber over the detectors. In the framework of existing educational projects involving different schools in the same geographical area, many schools have the possibility to share their equipment for common experiments. We explored such possibility, designing and testing a simple fan-in (OR) circuit which allows to use several small Geiger counters together, thus increasing the statistics. Due to the simplicity of the involved electronics, this Note is intended as a suggestion to other high schools wishing to carry out such experiments. A description of the circuit is reported in Sect.2, while some results obtained by the use of a set of six Geigers, together with a pressure sensor, are shown in Sect.3.

2 EXPERIMENTAL SET-UP

For such study we employed the Geiger sensors provided by PASCO (Mod. SN7928). Such counters are now frequently employed in local high schools, together with one of the available PASCO interfaces for data acquisition and monitoring. They provide TTL-like signals (+5V, 120 μs duration). To connect several counters in parallel and increase the statistics of counting, we designed and used a simple OR circuit, which allows up to eight counters to be used. The circuitry makes use of a 2-sections, 4-inputs NOR gate

(SN7423N) and a 2-inputs NAND gate (SN74F00N), by using De Morgan theorem to build an 8-inputs OR equivalent gate (Fig.1). The connections to these IC's are shown in Fig.2. Despite the presence of pull-down resistors, each input which is not connected to a Geiger needs to be grounded. This solution was implemented by small jack plugs. The output from the OR circuit may be directly connected to one of the digital inputs of a PASCO interface. In our case we used the Mod. 500, which has two digital and three analog inputs. To test the circuit, we devised an experiment where the information from six individual Geiger sensors was collected, together with the analog information from a barometric pressure sensor, to search for the expected anticorrelation between muon flux and atmospheric pressure.

3 RESULTS AND DATA ANALYSIS

Measurements were carried out in our Department, in a lab which is located at the highest floor, leaving only a concrete roof over the counters. Data were collected in 30 minutes steps, in three sets spanning a period of approximately ten days. An overall statistics of about two million events was collected. The average rate during all period was 1.94 Hz, a factor of six with respect to that of each individual counter. Fig.3 shows the variation of the atmospheric pressure for the three sets of data. While the pressure was relatively constant during the first two sets, a large variation was observed during the last set (lasting about 3 days), due to local weather conditions. Since the expected value of the barometric coefficient is very low (smaller than 0.1%/mbar) [2], it is reasonable that the effect will be more clearly seen in the last set of data, where a variation larger than 30 mbar was observed. As an example, fig.4 shows the correlation plot for the first set of data, where no correlation is observed (R^2=0.0002), due to the fact that the pressure was nearly constant during that period. Such anticorrelation is instead observed for the third set of data, shown in fig.5, which has R^2=0.16. From the fit to the data through C = a + b*p, one gets b= - 3.8821 counts/mmHg. Normalizing to the average number of counts, and expressing the pressure in mbar, the value of the barometric coefficient was found to be □ = -0.081 %/mbar, in agreement, within the errors, with a value previously obtained with a single Geiger in a longer run [2]. Including all the data sets in the fit (fig.6), one gets □ = -0.082 %/mbar, with a slight worsening of the correlation (R^2 = 0.13).

4 CONCLUSIONS

The design of a suitable fan-in circuit to connect several small Geiger counters in parallel, to increase the counting rate to an acceptable level, has proven to be effective to carry out an educational measurement of the barometric cosmic ray coefficient in a relatively short time. The anticorrelation between atmospheric pressure and counting rate was clearly seen during a period exhibiting a strong variation of the local pressure due to weather conditions. This effect would hardly be visible with a single Geiger, thus requiring very long collection times, whereas three days were enough in this case to extract a reliable value of the barometric coefficient. The possibility to contribute to the organization of a common experiment by a proper sharing of the equipment needed mirrors what happens for large experiments in professional research. Such possibility was stressed in a series of meeting and on-going contacts with high school teachers and students who are involved in cosmic ray research in the framework of the EEE (Extreme Energy Events) project [4], to which our Institution is actively linked. On a more general basis, high school teams could find other useful examples, where the sharing of their equipment could overcome the limited budget of each individual institution.

5 REFERENCES

[1] For an overall view of the educational activity in cosmic ray physics see for instance the relevant links on the site of Cosmic Ray Educational Observatory in Catania (http://www.ct.infn.it/~rivel/cosmic.html)

[2] B.Famoso, P.La Rocca and F.Riggi, Physics Education 40(2005)461.

[3] M.Finocchiaro et al., Proceedings of the “Workshop Scuola-Università su progetti didattici di fisica”, Catania, 7 Aprile 2006.

[4] http://www.centrofermi.it/eee

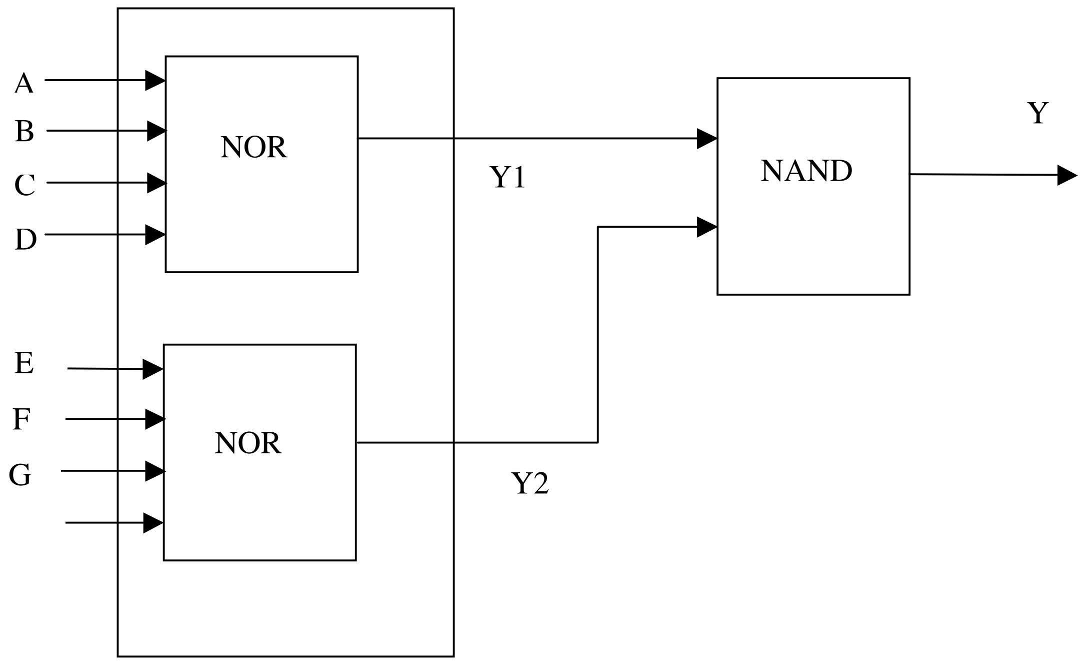


FIG. 1: Schematics of the equivalent OR gate to connect up to 6 Geiger counters (inputs A-H)

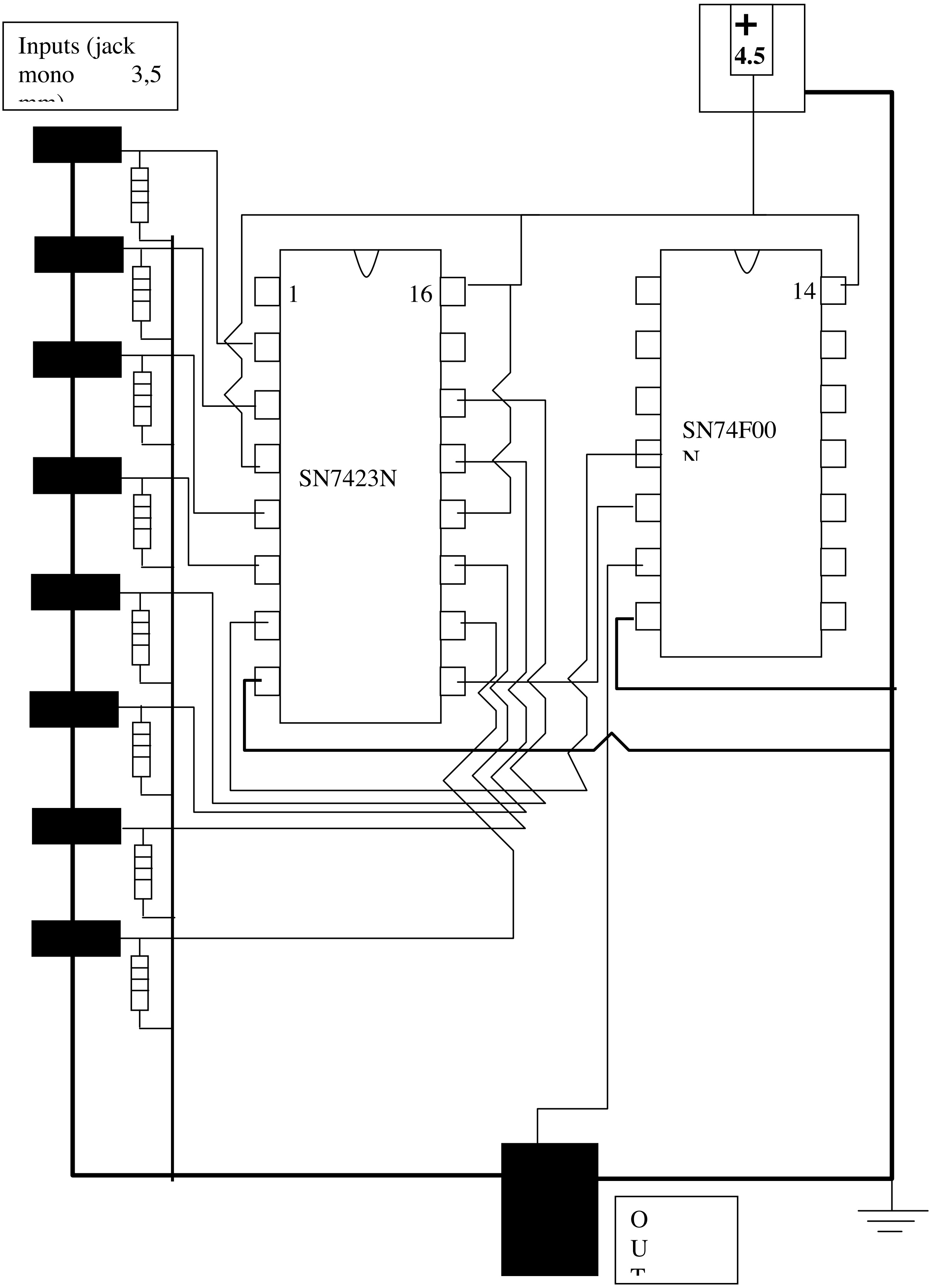


FIG. 2: Connections to the IC's.

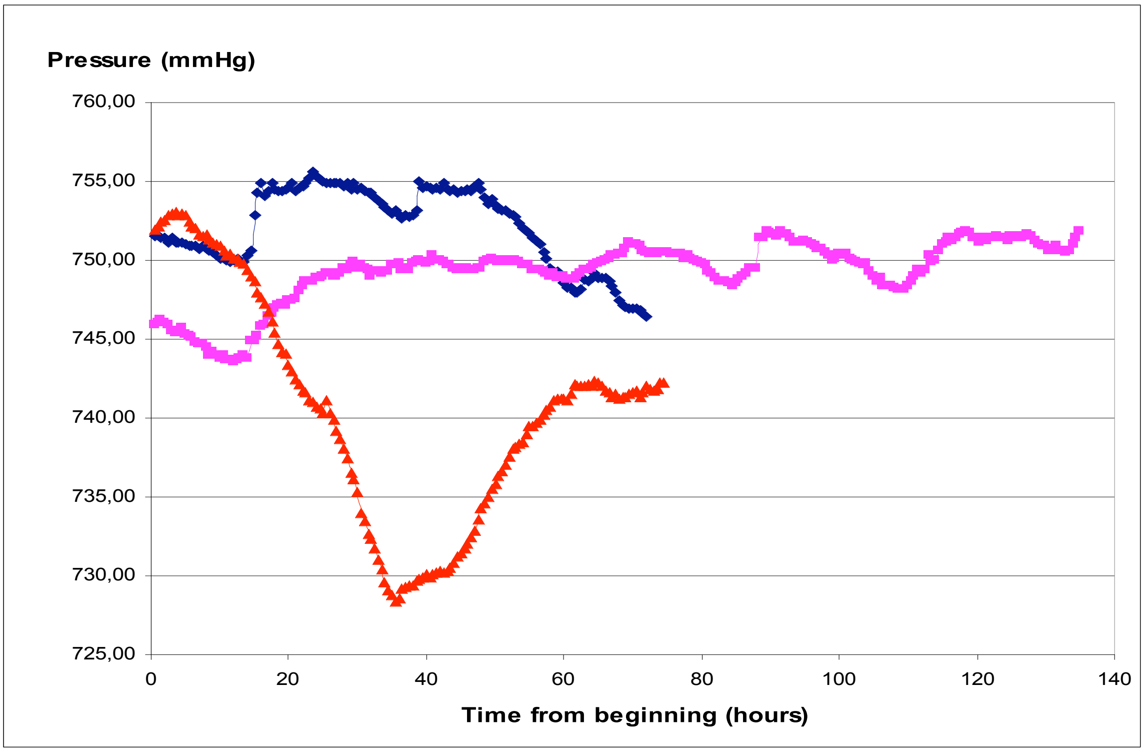


FIG. 3: Variation of the atmospheric pressure for the three sets of data.

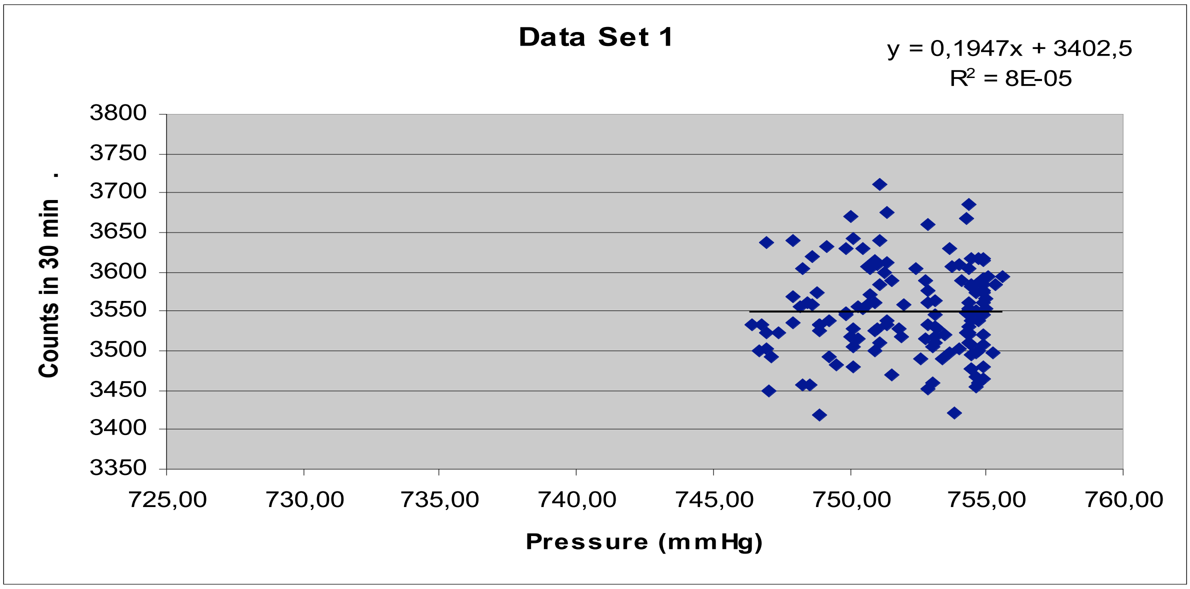


FIG. 4: Correlation plot for the first set of data, where the atmospheric pressure was nearly constant. No anticorrelation is seen.

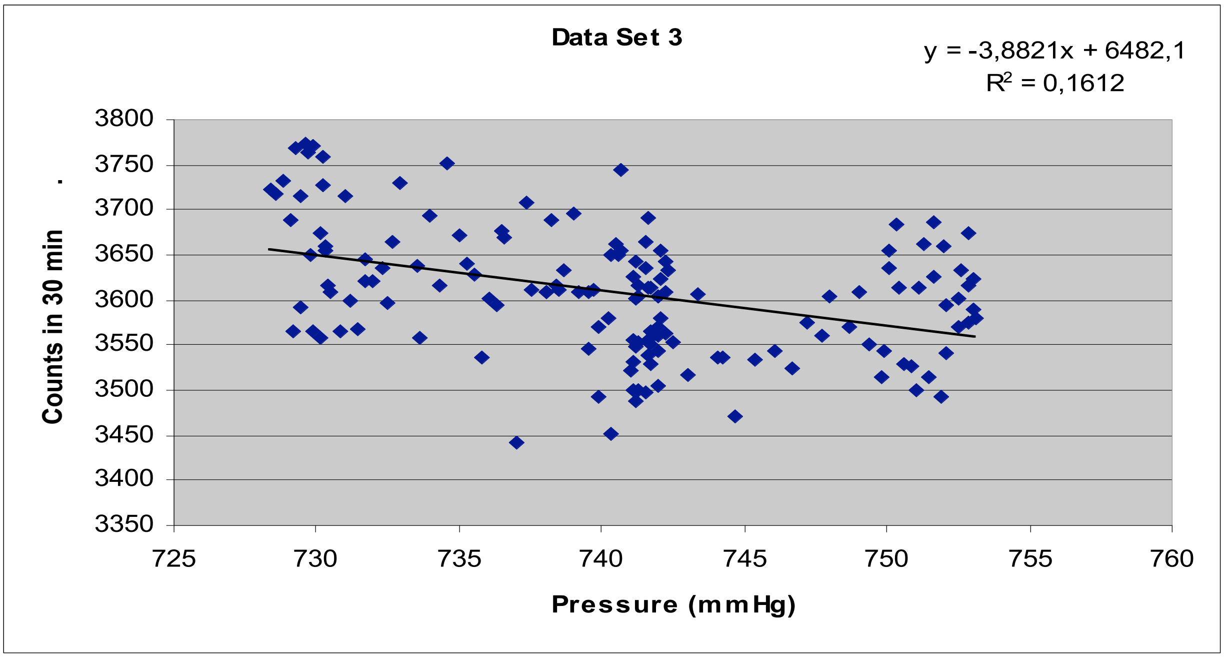


Fig.5: Same as fig.4, for the third set of data.

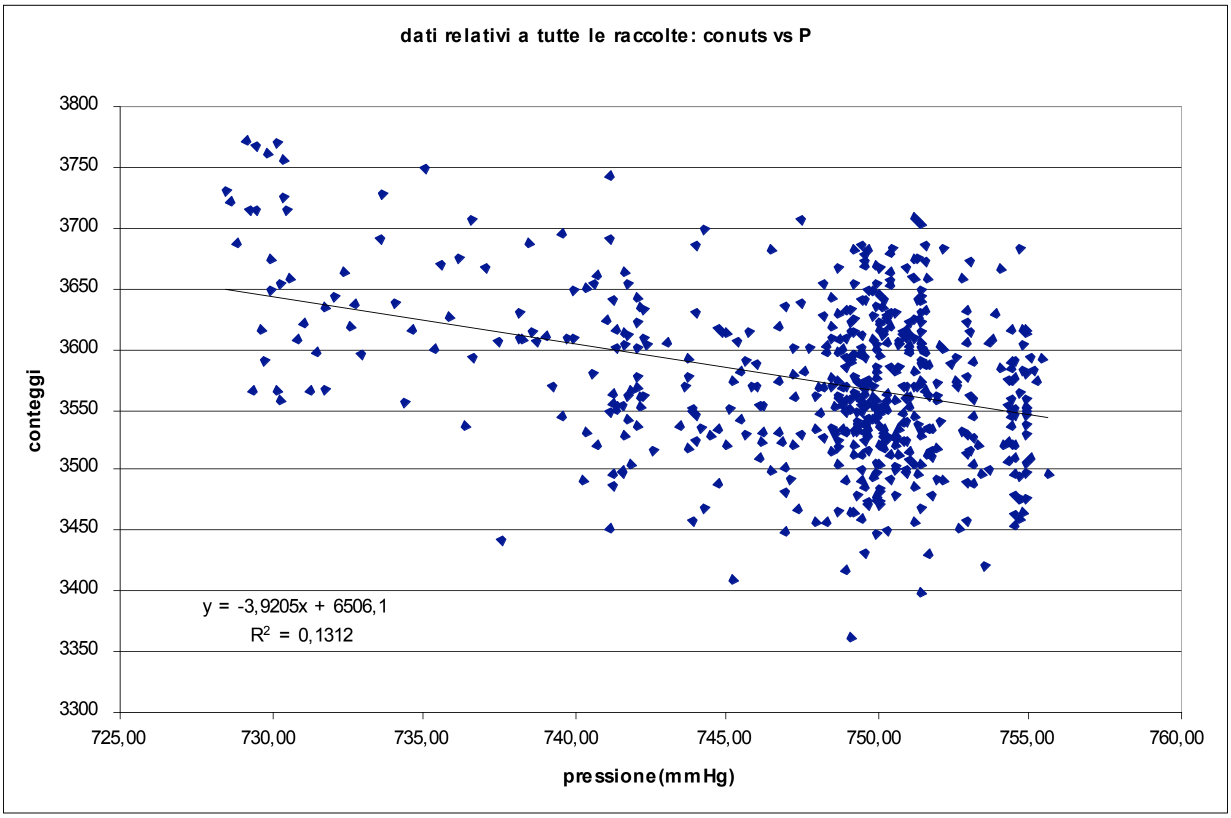
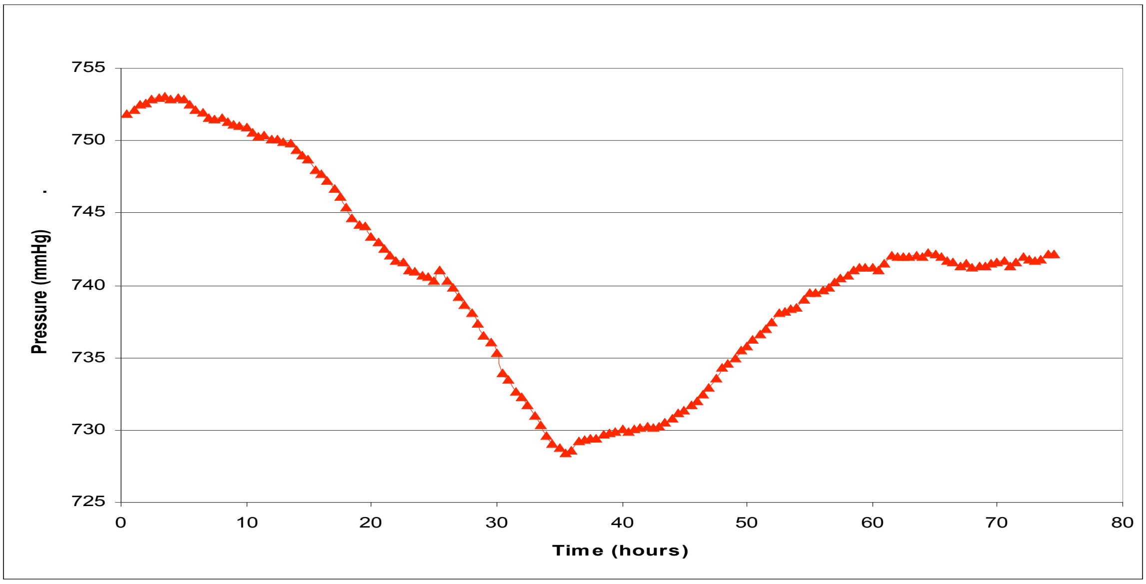


Fig.6: Correlation plot for all the data sets.



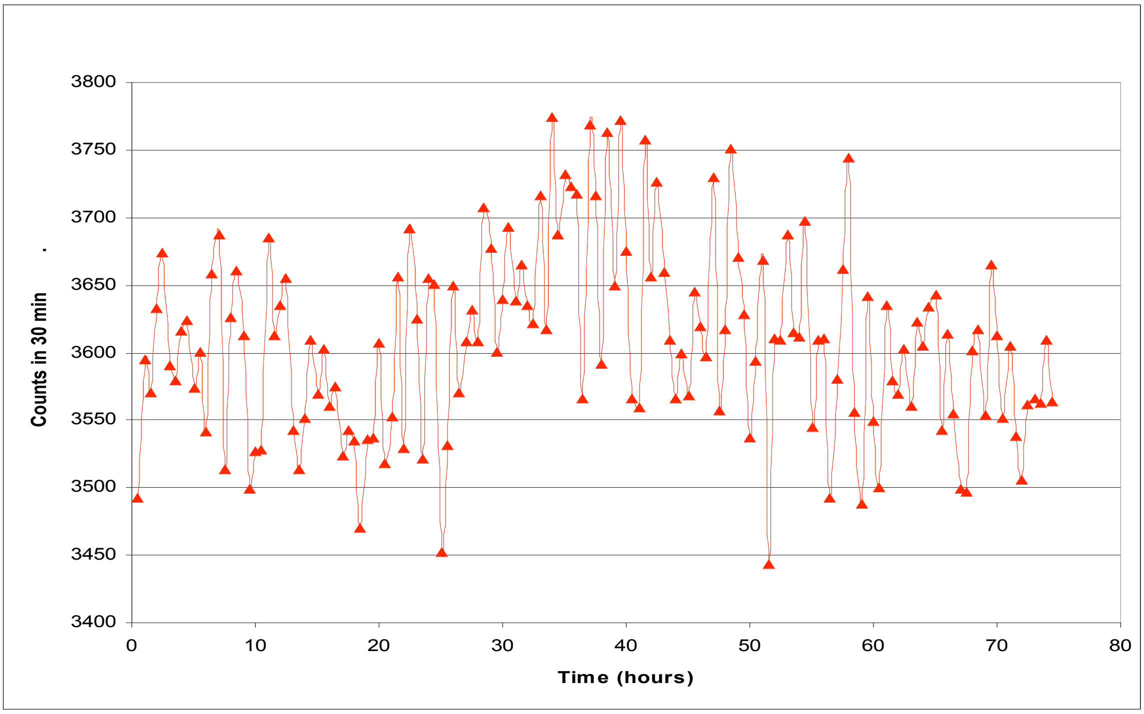


Fig.7: Time variation of the pressure (upper) and counting rate from the six Geigers (lower) during the third data set.