# Environmental Radiation monitoring at high altitude

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**Abstract**

During 12 days at the end of September 1997 a NaI scintillation counter has been operated at the "Piramide" Laboratory of the CNR at 5050 m. a. s. l. in the Kumbu Valley (Nepal). These observations are the first direct measurements at ground of Environmental Radiation at such an altitude. The data show temperature and pressure effects on low energy secondary cosmic radiation and transport effects on airborne radionuclides related to changes in weather conditions. Together with similar observations at different latitudes and lower altitudes these type of measurements appear as a powerful tool for the study of cosmic ray variations related to solar activity and for the investigation of the atmospheric circulation of radionuclides of natural and artificial origin.

## 1 Introduction:

We identify the *"Environmental Radiation"* (ER) with the $\gamma$ radiation with energy greater than 50 keV, that can be detected by a scintillation counter based on a NaI(Tl) mono-crystal (10 × 20 ∅ cm). Its main components are the low energy secondary cosmic rays and the $\gamma$-rays from airborne natural radio-nuclides transported to the atmosphere from the Earth's surface. Under special conditions and with appropriate operations on the data one can also separate the occasional contribution to radio-nuclides abundance coming from nuclear reactor accidents, nuclear bombs or from other unexpected events (Cecchini et al., 1997).

During the period September 25$^{th}$ - October 6$^{th}$ 1997 one of our standard detectors for ER has been operating at the " Piramide" Laboratory of the CNR in the Kumbu Valley (Nepal) at 5050 m a. s. l.. This laboratory, due to its geographical position, is unique for the possibility of studying the ER characteristics and its variations, namely: a) the intensity of the soft (E > 3 MeV) cosmic radiation, which at this altitude is about 10 times greater than at sea level; b) its rapid variations caused by possible direct emissions from the Sun (e.g. flares, coronal mass ejections), whose activity in this period is very high, besides the modulation effects produced by the solar activity itself; c) variations of the intensity of ER associated with different local meteorological conditions.

## 2 Detector Description :

The detector used is based on a NaI(Tl) mono-crystal having the dimensions (10 cm x 20∅ cm) and shielded by 2 cm of Pb , 0.1 cm of Cu and 0.3 cm of Al shaped around the crystal and the PMT (see figure 1). A ring shaped plastic pipe containing 85g of KOH was placed around the base of the crystal to allow the adjustment of the $^{40}$K photo-peak position in the $\gamma$ spectrum by means of a feedback device,which

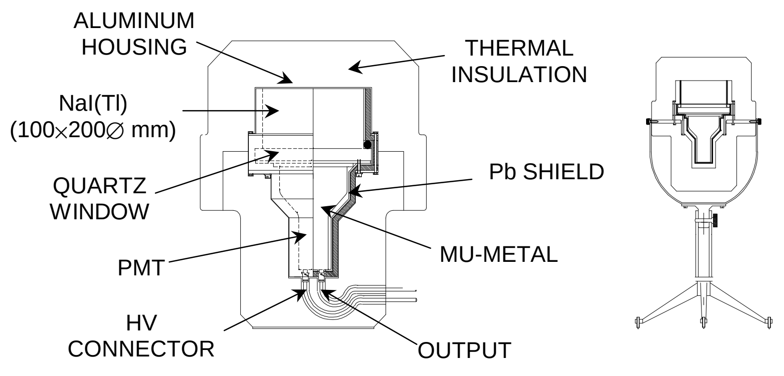


**Figure 1:** Drawing of the detector used at the "Piramide"Laboratory. The detector can be easily disassembled into a few pieces and then mounted in place in a few minutes.

provided an adequate correction to possible deviations of the photo-tube (PMT) High Voltage. The instrument is specially designed to be easily disassembled into a few pieces and easily reassembled so to allow its transportation in places difficult to get to. The computer assisted acquisition electronics is contained in a standard NIM box. Our detector can record the total counts per minute of the $\gamma$–rays in different energy ranges (called rate meters) and can provide their hourly spectra in properly chosen energy bands. The detector can provide 1 to 2 million counts per minute with a good reliability. The working principles have been described in detail elsewhere (Cecchini et al, 1997).

# 3 Environmental effects on airborne radio-nuclides (wind and precipitation effects):

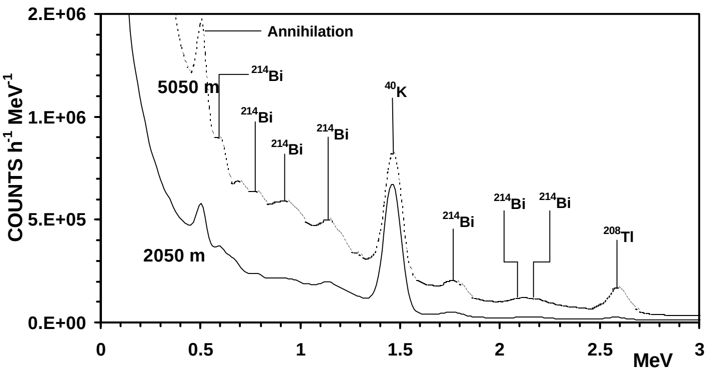


**Figure 2:** Energy spectrum of the gamma radiation detected by our detector in two different locations: EASTOP (Italy) at 2050 m a. s. l. and at "Piramide" Laboratory at 5050 m a. s. l.

Figure 2 shows the differential spectrum in the energy interval 0.1 MeV < $E_\gamma$ < 3.0 MeV measured at two different altitudes. We can notice:

- all photo-peaks corresponding to the $^{214}$Bi and $^{214}$Pb daughter products from the $^{238}$U chain are easily identifiable; the $^{208}$Tl photo-peak (from the Thorium chain) is mainly due to the building material of the "Piramide" Laboratory;
- contributions due to $^{137}$Cs or other man-made isotopes were not observed.

The bi-hourly counting rate corresponding to the energy interval 0.1 – 3.0 MeV has a fairly regular diurnal wave, of amplitude 5 $\div$10 %, with a maximum at 9 $\div$10 a.m. and a minimum at 6 $\div$ 7 p.m., solar local time (figure 3); this is probably due to a combination of atmospheric effects on the Radon daughter concentrations. It is known, indeed, that in the mountain environment the amount of Radon is affected by peculiar factors other than ordinary transport from soil to

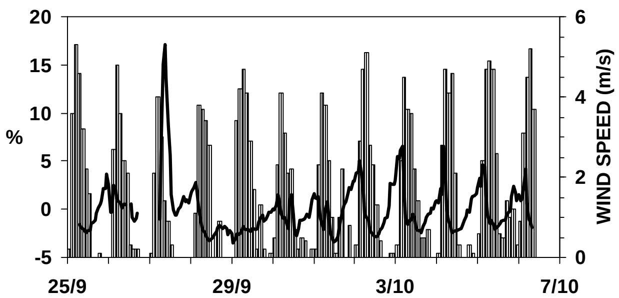


**Figure 3a:** Bi-hourly counting rate in the energy band 0.1-3.0 MeV together with wind speed recorded at "Piramide" Laboratory.

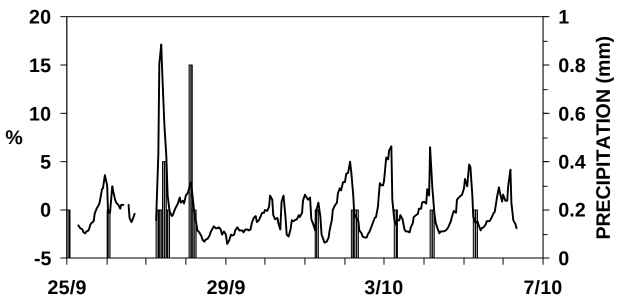


**Figure 3b:** Bi-hourly counting rate in the energy band 0.1-3.0 MeV together with precipitation recorded at "Piramide" Laboratory.

air (Wilkening, 1970): in the early morning, non-uniform heating of the different levels of the mountain slope causes convective transport of Radon rich air from the valley to the top, and this manifests itself in a high concentration of the gas at the top of the mountain, reaching a maximum during the first hours after sunrise. The sudden decrease of the counting rate that follows may be caused by the cleaning action of the wind, as is evident in the figure 3a. Note that this periodical behaviour of the counting rate was surely enhanced by the regularity of the meteorological conditions. During the short period of monitoring of ER we have recorded an increase of the order of 15% in the aforementioned counting rate, associated with snowfall (see figure 3b). This increment may be due to the gamma emission from the radioactive aerosol which is carried to the ground by the snow. The fact that this increase is due to radioactivity is confirmed by the spectrum resulting from the difference between the one in correspondence of the maximum of counting rate and the one corresponding to the minimum, as we can see in figure 4 , were the peaks of the radon daughters are identified.

# 4 Low energy secondary cosmic $\gamma$-rays (3 MeV < $E_\gamma$ < 10 MeV):

**4.1 Barometric effect:** In figure 5 we show a comparison between the two-hour means of the gamma ray counting rate in the energy range 3 - 10 MeV and the ground measured atmospheric pressure (the latter is plotted in an inverted scale). First of all, we see a semidiurnal oscillation in the curve corresponding to the pressure, with an amplitude of 1÷2 mbar that can be attributed to the well known atmospheric tide, which is much more evident at or near the tropical latitudes than elsewhere, and which is clearly reflected in the intensity of the cosmic radiation.

This is perfectly consistent with the usual notion of a strong anti-correlation between pressure and secondary cosmic radiation (an increase of 1 mbar in atmospheric pressure corresponds approximately to an increase of 1 gm/cm$^2$ in the air mass above detector to be traversed by the particles), but it is the first time that the effect is so clearly observable in the intensity of so a degraded component of the radiation itself. We attribute this to the fact that the pressure coefficient, which measure the effect of a variation in the atmospheric pressure on the intensity of the secondary cosmic radiation, increases with altitude, as we shall presently show.

We have calculated the barometric coefficient (cfr. Dorman, 1957) and it resulted to be $\beta_P$ = - (5.3 ± 0.8) ‰ mbar$^{-1}$. This is remarkably greater than the one we found at sea level, whose value is $\beta_P$ = (3.70 ± 0.05) ‰ mbar$^{-1}$(Galli et al, 1997); the reason for this difference is to be found in the fact, that the slope of the vertical fluxes of the secondary components of cosmic rays is more pronounced at 5000 m a.s.l. than at sea level; this means that, for the same variation in pressure value, the correspondent variation in the intensity of cosmic rays is more dramatic at higher altitudes.

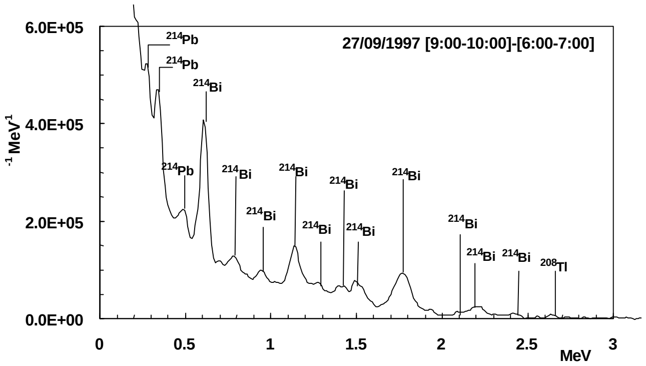


**Figure 4:** Spectrum obtained by the difference between the hourly spectrum during the 15% increase of counting rate in the range 0.1-3.0 MeV and the one of the previous hour.

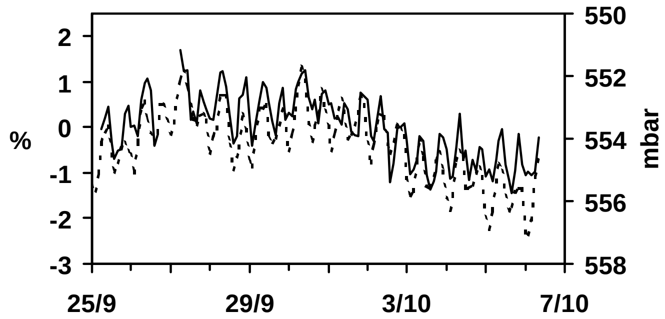


**Figure 5:** Comparison between the bi-hourly counting rate of cosmic rays (energy band 3-10MeV) and the atmospheric pressure (plotted in inverted scale, dotted line) recorded at “Piramide” Laboratory.

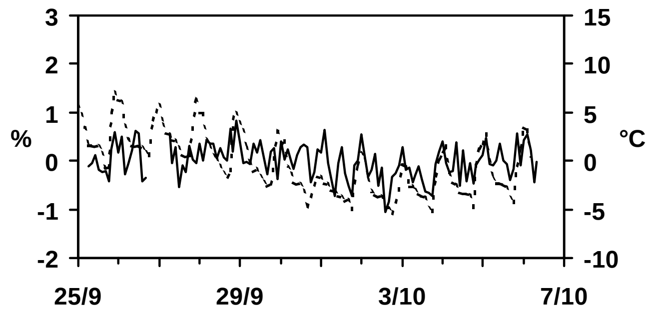


**Figure 6:** Comparison between the bi-hourly pressure corrected counting rate of cosmic rays (energy band 3-10MeV) and the atmospheric temperature, recorded at the altitude of “Piramide” Laboratory, shifted back in time by 4 hours.

**4.2 Temperature effect:** A comparison between the pressure-corrected cosmic $\gamma$-rays and the temperatures registered at the observation level shows (figure 6) a clear correlation between the first at a given hour and the second four hours later; the delay is probably due to the time difference between the variation of the temperature at observation level and the corresponding temperature variation in the upper atmospheric layers, where the $\mu$–particles (which generates, through their decay and propagation in the atmosphere, the gamma component we measure) are produced (Dorman, 1957). This corresponds to a positive effect on the intensity of the cosmic $\gamma$-rays, with a thermal coefficient that we find to be $\alpha_T = (0.61 \pm 0.03)$ ‰ $°C^{-1}$.

**4.3 Altitude effect:** We have compared (figure 7) the cosmic $\gamma$-ray flux, in the 3-10 MeV energy range, measured at the "Piramide" Laboratory at the height of 5050 m, with the ones measured in Italy at 2050 m, at 970 m and at sea level.

We have obtained, for the total intensity in the same energy range, an exponential law with an attenuation length $\lambda=(210\pm20)$ g/cm$^2$, consistent with $\lambda= (188\pm12)$ g/cm$^2$ obtained by Ryan et al. (1979) for the same component of cosmic rays and in the same energy range.

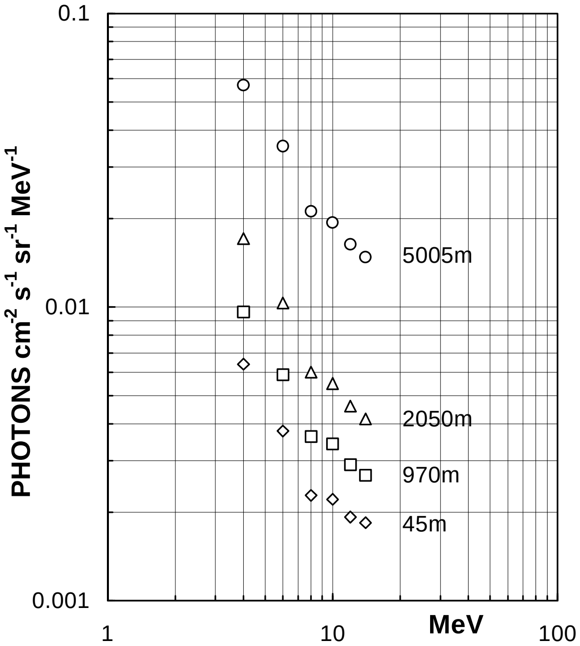


**Figure 7:** Comparison of differential energy spectra recorded at different altitudes: circle – "Piramide" (5050 m a. s. l.), triangle – EASTOP (2050 m a. s. l.), square – LNGS (970 m a. s. l.), diamond – Univ. of Bologna (45 m a. s. l.). The data have been corrected for different geomagnetic latitudes.

## 5 Conclusions:

During the above mentioned monitoring period at the "Piramide" Laboratory, we have for the first time directly measured the transport effects on $\gamma$-emitting airborne radio-nuclides and the effects of altitude, temperature and pressure on low energy secondary cosmic rays.

The monitoring of the ER at different locations on the Earth looks very promising for collecting information in real time on variations and particular events, both of terrestrial (e.g. release of radionuclides by nuclear power plants and aerial transport of artificial and natural radionuclides over large distances) and of extra-terrestrial origin, connected to solar activity and geomagnetic storms. Due to the reasonable cost, reliability and easy transportability of our detector it is possible to foresee the establishment of a permanent network of ER stations for this purpose.

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