Status of the Belgrade CR laboratory and some preliminary results

I.V. Aničin, J. Puzović*, A. Dragić, V. Udovičić, R. Banjanac, D. Joković, N. Veselinović, M. Savić*
Institute of Physics, Pregrevica 118, Belgrade, Serbia
**Faculty of Physics, Belgrade University, Studentski trg 16, Belgrade, Serbia*

dragic@ipb.ac.rs

Abstract

The Belgrade CR Laboratory, http:\\ www.ipb.ac.rs\~cosmic, (44°51′ N, 20°23′ E: vertical rigidity cut-off: 5.3 GV, altitude 78 m a.s.l.) is described. The existing equipment is presented. Current activities and some preliminary results are reported. The plans for future and scientific potential of the laboratory is discussed.

Laboratory description

- The CR laboratory of the Institute of Physics, Belgrade consists of two separate, corridor connected laboratory spaces, about 25 m apart. One laboratory is located on the ground level (GLL), while the other one is a shallow (25 mwe) underground laboratory (UL). Both laboratories are equipped with identical instrumentation.
- Each of the setups consists of a single bigger 100x100x5 cm plastic scintillator detector furnished with four PMTs directly coupled to the corners bevelled at 45°, and an independent single smaller 50x25x5 cm plastic scintillator detector with a single PMT looking at its longest side via a Perspex light guide tapering to the diameter of a PMT. The analyzers are the two fast ADC units with four independent inputs each, made by CAEN, of the type N1728B. These are sophisticated instruments capable of working in the energy histogram mode, when they perform like digital spectrometers, or/and in the oscillogram mode, when they perform like digital storage oscilloscopes. In both modes they sample at 10 ns intervals, into 2^{14} channels. Every analyzed event is fully recorded in the same PC which controls their workings. This enables to off-line coincide the events at all four inputs, prompt as well as arbitrarily delayed, with the time resolution of 10 ns, as well as to analyze the time series not only of all single inputs, but also of arbitrary coincidences, with any sample period from 10 ns up. The two N1728 units are externally synchronized, what makes possible to coincide/correlate the events recorded in the two laboratories. The flexible software that performs all these off-line analyses is entirely homemade. The preamplifier outputs of the PMTs of bigger detectors are paired diagonally, the whole detector thus engaging the two inputs of the FADC. The output of the PMT of the smaller detector is fed into the third input. It serves as a control of regularity of operation of bigger detector, but also for investigations of development of local EM showers and decoherence measurements. The fourth input remains free, and is put to different use in the two laboratories. In GLL a (3x3) NaI detector is at present used to scan the response of the bigger detector as a function of the position of the interaction point, while in the UL a 35% efficiency radiopure HPGe detector is positioned right below the center of the bigger detector in order to study in detail the effects of cosmic rays on the background spectra in low-level high-resolution gamma-ray spectroscopy.

- The UL is kept in a radiopure environment. Laboratory walls are sealed with 1mm tick aluminium and lab space is 2-3 mb overpressured to prevent intrusion of radon. Radon concentration is typically at $\sim 10Bq/m^3$ level.

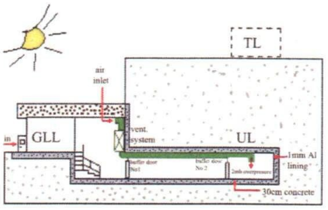

Fig. 1 *Cross sectional view of the laboratory*

Preliminary results

Muon flux and its variations

- Muon flux is measured with smaller plastic scintillators during entire year 2002 at both GL and UL. Muon flux and vertical intensity are:

-at ground level:

$$J_{1G} = (1.37 \pm 0.03) \cdot 10^{-2} s^{-1} cm^{-2}$$

$$I_{vG} = (8.4 \pm 0.2) \cdot 10^{-3} s^{-1} cm^{-2} sr^{-1}$$

-underground:

$$J_{1U} = (4.5 \pm 0.2) \cdot 10^{-3} s^{-1} cm^{-2}$$

$$I_{vU} = (2.5 \pm 0.2) \cdot 10^{-3} s^{-1} cm^{-2} sr^{-1}$$

.

- At cosmic-ray energies relevant for our experiment (primaries with several tens of GeV), cosmic radiation is strongly subjected to solar modulation. In the list of periodicities identified in muon time series in the period 2002-2007 (based also on the measurements with smaller detectors), majority coincides with the established periodicities of solar activity parameters:

- at ground level:

T	5.3	8.4	13.6	20.5	22	27	34.6	37	57	90	194	240	350
ΔT	$5 \cdot 10^{-4}$	0.03	0.1	0.2	0.2	0.3	1	0.6	2.5	3.5	16	24	53

- underground

T	1	8.7	13.6	20.5	25.4	26.5	34.5	37	77	90	162	194	240	350
ΔT_u	$5 \cdot 10^{-4}$	0.03	0.1	0.2	0.3	0.3	1	0.6	2.5	3.5	11.5	16	24	53

- If we concentrate on diurnal variation, and organize data in local solar time, with the raw data amplitude of diurnal variation in the ground detector data is $1.96(7) \times 10^{-3}$ and semi-diurnal $7.4(7) \times 10^{-4}$. At the same time amplitude of diurnal variation in the underground detector data is $9(1) \times 10^{-4}$ and semi-diurnal $6(1) \times 10^{-4}$

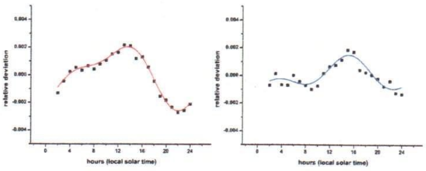

Fig. 2 *Diurnal + semidiurnal variations of muon flux at ground level (left) and underground (right).*

CR induced events in low-level gamma spectroscopy

- To illustrate capabilities of present setup we present spectra of triple coincidences between two PMT pairs at plastic scintillator corners and HPGe detector. An event registered by both PMT pairs is most likely to be a muon (low energy background is effectively suppressed) and a consequent coincidence with HPGe detector represent a muon induced event.

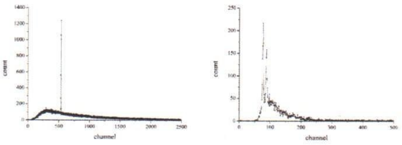

Fig. 3 *Coincident spectra between plastic scintillator and HPGe: prompt (left panel) and delayed (right panel).*

- Dominant feature in the prompt coincident spectrum is annihilation line at 511 KeV, and X-rays from the lead shield surrounding HPGe detector in the spectrum of delayed coincidences.
- Neutrons generated from muons are especially interesting. They represent inconvenient source of background in deep underground experiments. With present day setup in UL, the rate of those events is rather small and can be studied only in a long term program. To test the response of our detectors to neutron events, we triggered a HPGe detector, placed in GLL, with neutrons from a neutron source (*Cf-252*). A portion of the coincident spectrum is shown in Figure 4, with the structure around 692KeV originating from the inelastic neutron scattering on *Ge-72*. Peculiar triangular shape of the line is a result of summing of the transition energy and the recoil energy of the emitting nucleus. From the distribution of time intervals between trigger detector and HPGe, the lifetime of the excited 692KeV state in *Ge-72* is easily determined. It is our intention to use this line shape to determine neutron energy spectrum.

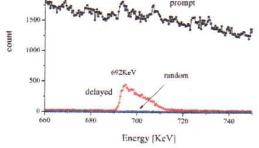

Fig. 4 *The effect of inelastic neutron scattering on Ge-72 seen in delayed coincident spectrum.*