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NEW MEASUREMENT OF ROCK CONTAMINATIONS AND NEUTRON ACTIVITY IN THE GRAN SASSO TUNNEL

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1. INTRODUCTION

Due to the importance of the background of spurious counting in underground experiments, and particularly on those aiming to detect low energy events, like double beta decays or solar neutrino interactions, we have repeated previous measurements of rock radioactivity and neutron background in various positions of the Gran Sasso tunnel[1] with an improved instrumentation. The present measurements confirm with better statistics the results of the previous ones[2,3] on gamma ray contaminants in the rocks, and show for the first time the presence of weak fluxes of thermal and fast neutrons in Laboratory B and in Bypass 12. These fluxes are lower by about an order of magnitude with respect to the upper limits set by our previous measurement[4], and three orders of magnitude lower than those outside the tunnel[4,5].

2. NEUTRON BACKGROUND

These measurements have been carried out with a cylindrical neutron counter of 25 mm diameter and 1000 mm length (active volume) filled with 4 atmosphere ^3He and one atmosphere propane. The typical shape of deposited energy spectrum in the detector due to capture of thermal neutrons is shown in Fig.1; the full energy peak at ~ 765 keV is clearly visible as well the continuum spectrum, which starts at ~ 191 keV, due to the wall effect. The detector efficiency for thermal neutrons is 150 count n^{-1} cm^{-2}.

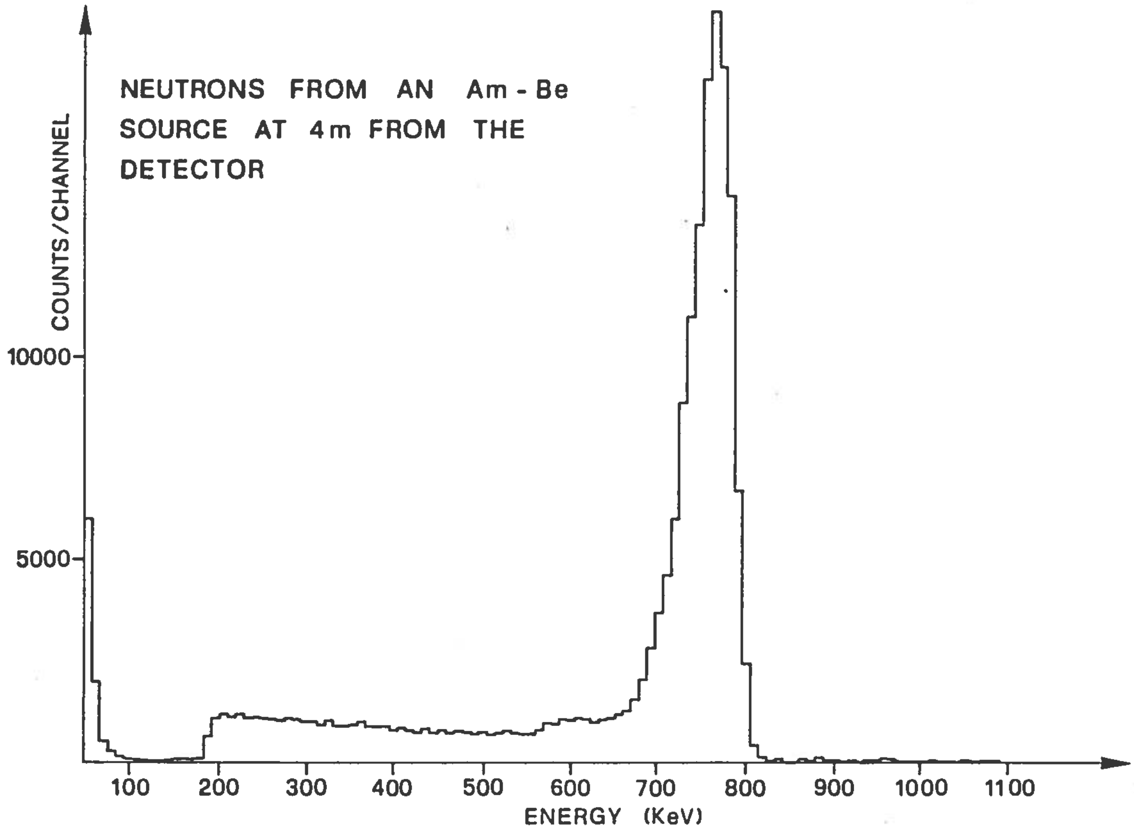
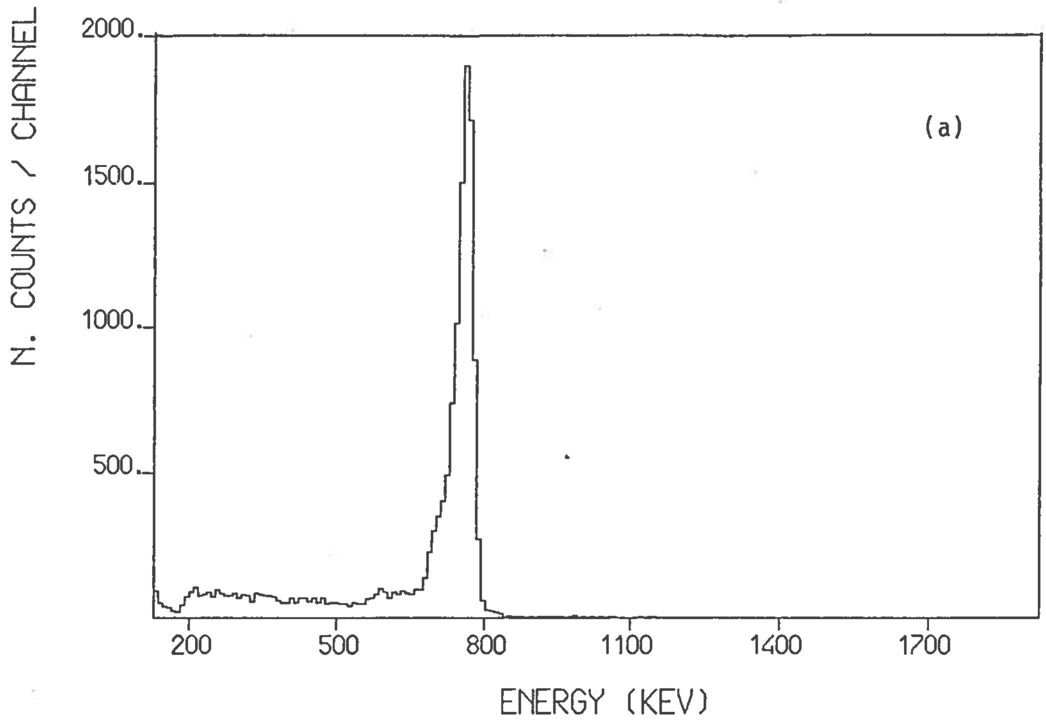


Fig. 1 - Spectrum due to fast neutrons from an Am-Be source in our detector.

Its efficiency to fast neutrons has been obtained in Milano by surrounding it with various layers of paraffin and exposing it to neutrons from a source of Am-Be placed at 4 metre distance from its centre. The counting rates in Milano with and without paraffin shields are reported in Table I for two energy regions, the first one covering the entire energy spectrum (176-870 keV) and the second one the full energy peak region (665-825 keV). It can be seen that the dependence of the counting rate on the thickness of paraffin is similar for background neutrons and for neutrons from the Am-Be source (2÷8 MeV): their energy distribution should not therefore be very different.

Measurements in the Gran Sasso have been carried out immediately outside the tunnel, in Laboratory B, in Bypass 12 and in the tunnel at 100 metres from the Assergi entrance. The corresponding spectra are shown in Figs. 2 to 5, and the counting rates are listed in Table I. Clear signals of neutrons appear both in Laboratory B and in Bypass 12, with similar intensities, but



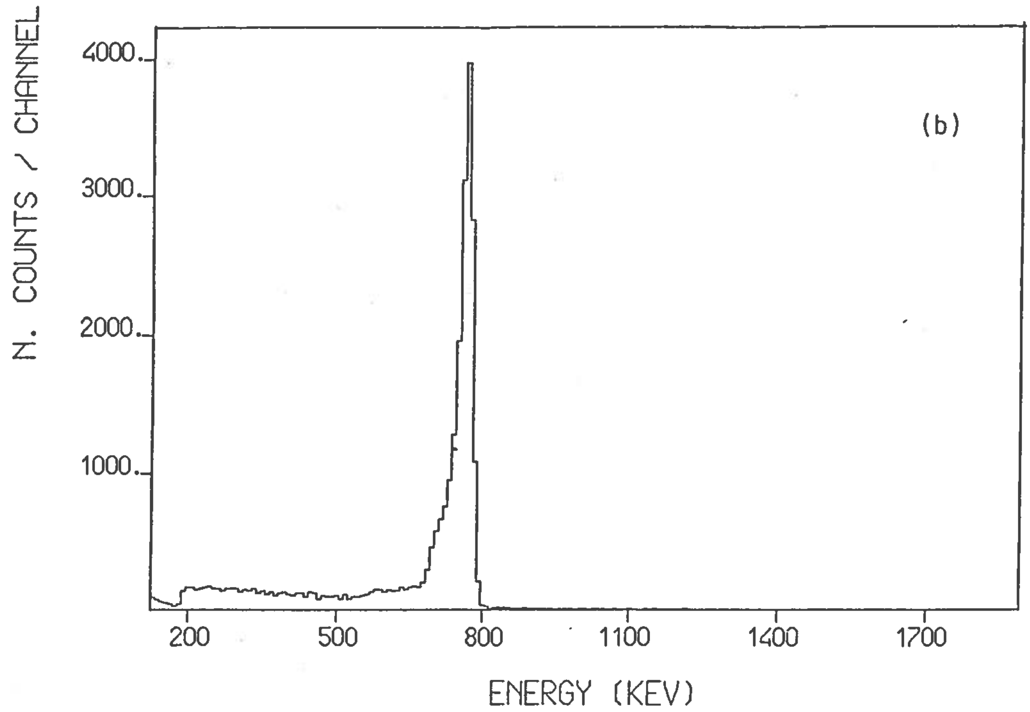


Fig. 2 - Spectrum due to thermal (a) and fast (b) neutrons immediately outside the tunnel.

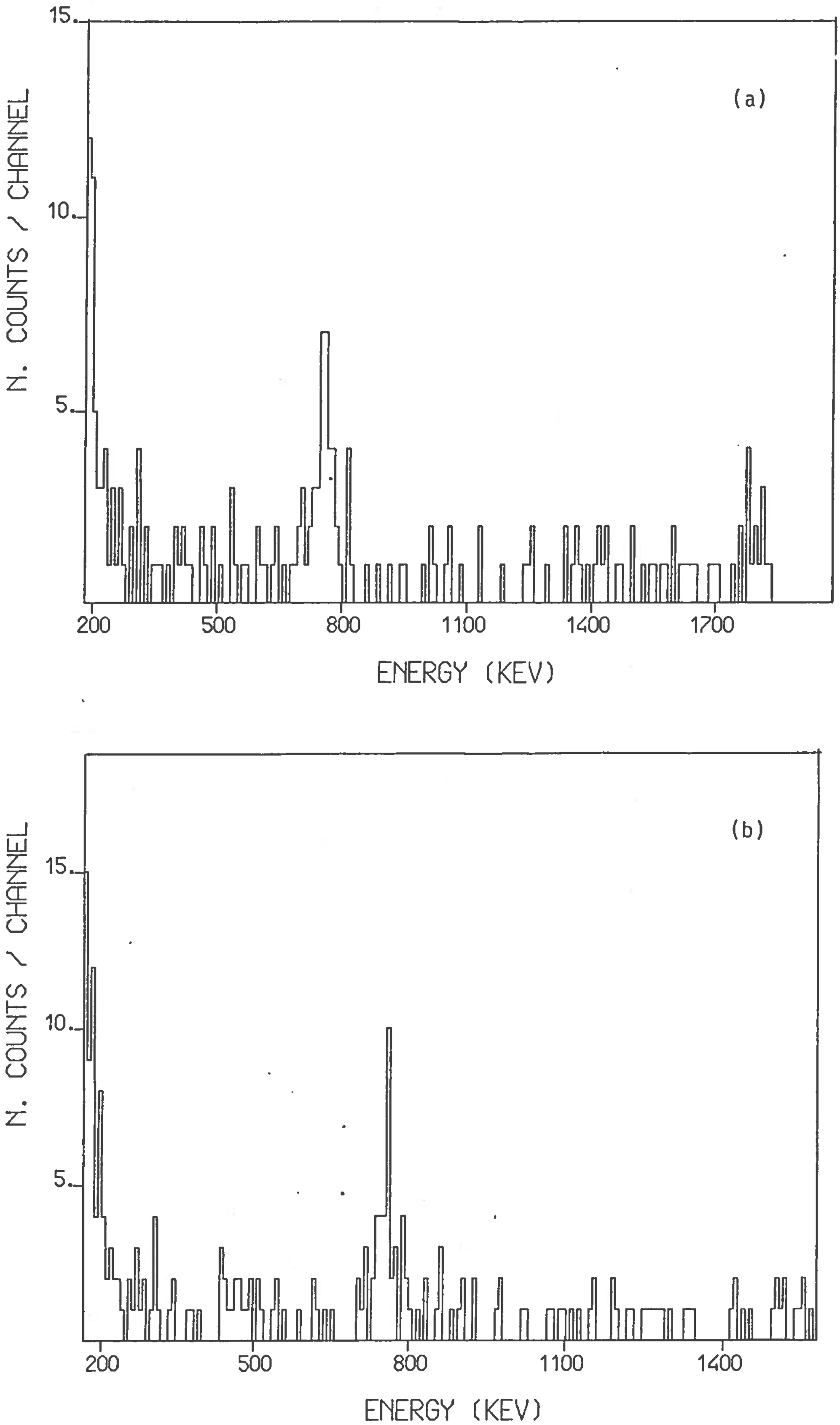


Fig. 3 - Spectrum of thermal (a) and fast (b) neutrons in Lab. B.

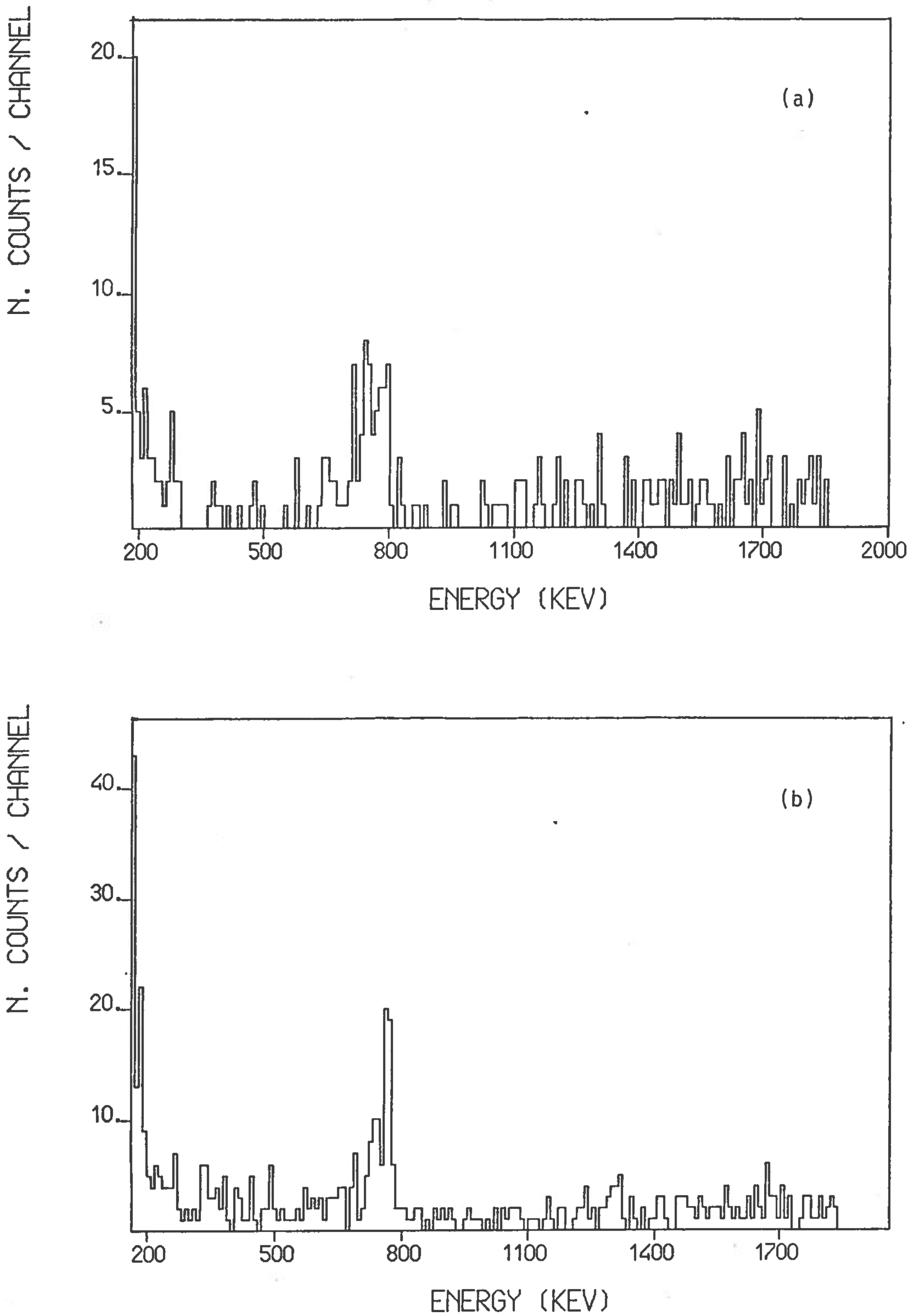


Fig. 4 - Spectrum of thermal (a) and fast (b) neutrons in Bypass 12.

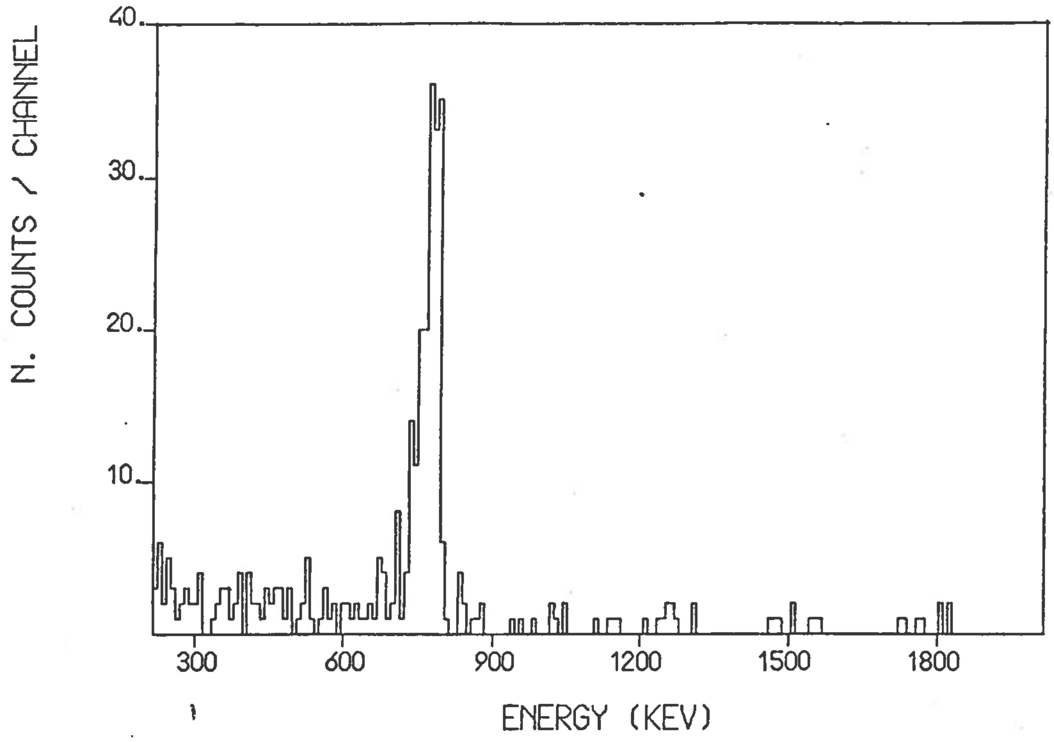


Fig. 5 - Spectrum of thermal neutrons at 100 metres from the Assergi entrance of the tunnel.

TABLE I - Neutron counting rates (counts per hours).

Location	Thickness of Paraffin (mm)	Energy region (keV) 176-870	665-825
Milano (no source)	0	920±20	673±18
" " "	35	1630±40	1188±25
" " "	40	1770±40	1250±25
" " "	80	1460±35	1025±20
" " "	110	1120±30	778±18
Milano (Am-Be source)	0	168500	122600
" " "	35	721000	515500
" " "	80	722900	522800
" " "	110	539500	390100
Gran Sasso (outside tunnel)	0	2735±23	1981±20
" " " "	35	4225±32	3056±26
Gran Sasso (Laboratory B)	0	7.1±.6	2.3±.4
" " " "	35	4.7±.4	1.4±.2
Gran Sasso (Bypass 12)	0	5.8±.4	2.3±.2
" " " "	35	4.7±.3	1.7±.15
" " " "	80	5.8±.6	1.6±.25
Gran Sasso (100 m from the entrance)	0	30.0±1.3	16.9±1.2

unlike what happens outside the tunnel, the signal due to thermal neutrons is larger. Due to the weakness of the signal, the background of spurious counting due to other particles and electronic noise cannot be ignored: it has been determined by a run with the detector surrounded by Cadmium and 35 mm of paraffin in Laboratory B: no peak due to neutron capture appears in this measurement.

By subtracting the background and taking all errors into account we conclude that the neutron background in Laboratory B is:

$(5.3\pm0.9)\cdot10^{-6}$ thermal n/cm^{2}s and $(3.0\pm0.8)\cdot10^{-6}$ fast n/cm^{2}s (1)

while in Bypass 12 is:

$(5.4\pm0.8)\cdot10^{-6}$ thermal n/cm^{2}s and $(2.7\pm0.5)\cdot10^{-6}$ fast n/cm^{2}s (2)

We would like to note that determination of the efficiency, while straightforward for thermal neutrons, is more complicated for fast neutrons which are crossing different thickness of paraffin if coming from an Am-Be source or isotropically from the walls of the underground laboratory. We found out the the average thickness crossed by underground neutrons in our 35 mm layer is roughly equivalent to 85 mm. We have determined therefore the efficiency using the counting rate obtained with the Am-Be source and 80 mm of paraffin. In the counting rates attributed to fast neutrons, there is a contribution from thermal neutrons which escape radiative capture in the paraffin: we have therefore carried out a measurement in Bypass 12 placing the Cd sheet <u>outside</u> the 35 mm layer of paraffin. We obtain a flux of $(3.5\pm0.7)\cdot10^{-6}$ fast n/cm^{2}s indicating that the thermal neutron contribution is neglegible. Further experimental work is in progress in Milano on this point.

The background of thermal neutrons at about 100 metres from the entrance of the tunnel is about ten times larger that in Laboratory B and Bypass 12.

It is interesting to compare the results in Laboratory B and Bypass 12 with those obtained in Laboratory 27 of the Mont Blanc tunnel, namely

$(2.2\pm.08)\cdot10^{-5}$ thermal n/cm^{-2}s and $(2.9\pm.08)\cdot10^{-5}$ fast n/cm^{-2}s (3).

It seems therefore that, while fast neutrons are more than thermal ones on surface in Gran Sasso and Milano, they are equivalent underground in Mont Blanc. In Laboratory B and Bypass 12 of Gran Sasso, the thermal flux seems definetely larger than the fast neutron one.

3. ACTIVITY OF THE ROCKS AND OF OTHER MATERIALS

Samples of various materials were taken from the three Laboratories, from Bypass 12 and from the cavity situated behind the road in front of Laboratories A and B, and crushed in powder with grains not exceeding one millimeter diameter at the Mineralogy Department of the University of Milano. Their gamma activity has then been measured by means of a 138 cm^3 Ge(Li) shielded with a minimum of 5 cm Oxigen Free High Conductivity Copper and of 20 cm of low activity Lead. The various activities are reported in Table II.

TABLE II - Activity of various materials in the Gran Sasso tunnel (in Bq/Kg).

Material	Activity or 95 c.l. limit			
	^{232}Th	^{238}U	^{40}K	^{214}Bi
Rock Lab.A, pos.a (infiltration)	8.8±.3	84.7±8.4	224±6	41.9±.6
" Lab.A, pos.b (infiltration)	7.7±.4	66.8±7.1	256±13	41.7±.9
" Lab.A, pos.c (infiltration)	9.5±.4	122±13	264±13	56.6±1.4
" Lab.A, pos.d (normal)	<0.5	<8	<5	1.0±.2
Rock Lab.B	.25±.08	5.2±1.3	5.1±1.3	4.2±.3
Water Lab. B	<0.5	<2.4	<4.8	<.4
Concrete Lab. B	5.1±.2	20.±3.2	30±3	6.7±.3
Rock Lab. C	.27±.10	8.2±1.7	2.9±1.4	5.1±.2
Rock Bypass 12 (pos.a)	<.28	4.9±1.9	11.8±1.9	3.5±.2
" " " (pos.b)	<.5	<7	64±2	4.3±.2
Concrete Bypass 12	3.1±.2	13.4±2.3	58±4	5.5±.3
Asphalt Bypass 12	.64±.14	7.2±2.4	7	4.9±.2
Rock cavity 1, pos.a	1.7±.5	2.2±.4	17±2	2.0±.2
" " " " b	1.4±14	4.2±1.1	59±3	2.3±.13
" " " " c	.72±.12	<3	28±1.5	.8±.1

It can be seen that the normal rock has a very low activity (lower e.g. by an order of magnitude than for the rocks of the Mont Blanc Tunnel). There are however, especially in Laboratory A, infiltrations of black marnatic rock which present a much larger radioactivity: they cover less than one percent of the wall surface, and their contribution to the overall background can be neglected. The special concrete used in Laboratory B and in the Bypass 12 shows a radioactivity lower than usual concrete, but not as low as for the bare rock, while the Asphalt activity is similar than the one of the rock itself. Water is excellent as far as contamination is concerned and can therefore safely used for neutron shield.

4. CONCLUSIONS

We conclude that there is in Gran Sasso Tunnel evidence for a weak neutron (thermal and fast) activity, similar in Laboratory B and in Bypass 12, and lower by three orders of magnitude than outside the tunnel. The contamination by radiactive elements in the rocks and water of the tunnel is remarkably low.

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