

ISTITUTO NAZIONALE DI FISICA NUCLEARE
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LNF-85/28(R)
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FURTHER MEASUREMENTS OF NEUTRON FLUXES AT THE GRAN SASSO
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With the purpose of defining the background neutron fluxes inside the INFN Laboratories at the Gran Sasso tunnel, in the period May 27-31, 1985 we have performed a series of measurements inside the Laboratory B and outside the tunnel.

1.- THE INSTRUMENTATION

We used as detector a Harshaw BF₃ neutron proportional counter Model B6 24 S. Its characteristics are:

Outside diameter	: 5 cm
Active length	: 61 cm (overall 71.4 cm)
Cathode wall	: 304 Stainless Steel 0.9 mm thick
Active volume	: c.a. 1.2×10^3 cm ³
Fill pressure	: 70 cm Hg
Filling gas	: BF ₃ 96% enriched in ¹⁰ B
Sensitivity	: 100 c/n cm ⁻² for thermal neutrons
Capacity	: tube + connector = 11 pF total (including filter and cable) = 40 pF

The counter was also used inside a cylindrical moderator of polyethylene 12 cm thick for detecting neutrons in the range from about 500 KeV to 10 MeV. The sensitivity of the moderated counter to neutrons from a source of AmB was measured to be 25 c/n cm⁻².

Two of these counters were used in the measurements.

Unfortunately, both counter showed a rather poor resolution. Fig.1 showh a typical 1024 channel spectrum of the pulses from the counter exposed to moderated neutrons :

SPETTRO N. 15

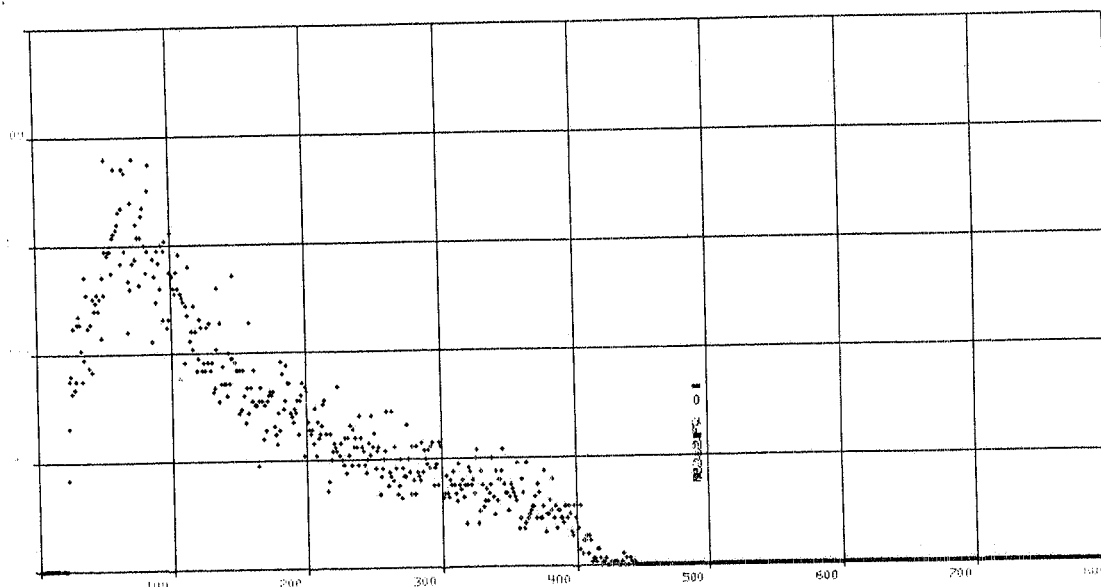


FIG. 1

it is visible the peak of the alphas from the $(n, {}^{10}\text{B})$ reaction, whose resolution is worst than 50%, in accordance with (2).

The counter is connected to a Charge PreAmplifier (FET input) via a HV filter. In order to improve the resolution, we operated the counter at a voltage (between 2.4 and 2.5 KV) lower than that suggested by the firm (3 KV).

Both the Charge PreAmplifier (CPA) and the HV filter were studied and built in our laboratory for particular performances. We wanted to reduce as much as possible the background noise of the CPA, the HV leakage pulses, the connector losses, the humidity and microphonic disturbances, etc. such as to be able to detect very low rates of neutron pulses. The CPA and HV filter are described in another report in press. The total noise background of the electronics (excluded the counter) was less than 10^{-2} count-per-hour in the region of interest of the spectrum.

The pulses from the CPA (sensitivity about 22 mV/MeV Si eq. i.e. 22 mV per $2.8 \times 10^{-5} e^-$ terminated in 50Ω and $z_{out} = 50\Omega$) were fed to the amplifier (gain = 50; shaping time = $5 \mu\text{s}$) and to the 1024 channel ADC of the SILEN Analyzer System BS 27/N.

We checked carefully at the beginning and at the end of each measurement the performances, resolution and linearity of the apparatus with a charge terminator (4.7 pF) connected in parallel to the detector. The system was excited with a square wave from a pulser-attenuator circuitry and we got for our operating conditions (nominal C feedback = 1 pF ; R feedback = $100 \text{ M}\Omega$; Ampli gain = 50; shaping time = $5 \mu\text{s}$) a resolution better than 10 KeV Si eq. with detector and HV connected (R polarization = $50 \text{ M}\Omega$).

Without detector and with HV at a voltage 25% larger than tube operating voltage, the resolution was 3 KeV Si eq. The linearity was controlled at 1 and 2 MeV Si eq. The chain was calibrated for 1 MeV Si eq. at about channel 100.

Given the bad resolution of the counter, we decided to count all the pulses over a threshold set at the start of the peak (over channel 20 for the peak centered at about channel 80).

2.- THE MEASUREMENTS

The measuring apparatus was mounted inside a van and supplied with a portable AC generator, located at 50 m from the van for minimizing microphonic noise.

The van was parked inside the Laboratory B, near a wall, rather far from where mines were detonated: we checked that mine detonation did not influence the measurements. Measurements up to 10 hour long were performed for each condition. The ambient conditions were: Temperature 7 °C and Humidity about 99%.

We performed measurements with: i) the BF₃ counter bare; ii) surrounded by a cover of Cd 1.5 mm thick, and iii) inside the polyethylene moderator. Similar measurements were performed in open air, outside the tunnel.

Table I shows the results of the measurements.

TABLE I

Detector	Inside Lab B (in count s ⁻¹)	Outside the tunnel (in counts s ⁻¹)
BF ₃ bare	$(3.10 \pm 0.36) \times 10^{-3}$	$(2.58 \pm 0.16) \times 10^{-1}$
BF ₃ moderated in polyethylene	$(3.49 \pm 0.35) \times 10^{-3}$	$(2.44 \pm 0.04) \times 10^{-1}$
BF ₃ shielded with Cd	$(3.61 \pm 0.32) \times 10^{-3}$	$(2.35 \pm 0.08) \times 10^{-2}$

We interpreted the measurements inside Laboratory B as follows. The difference between the readings of the BF₃ moderated in polyethylene (or the BF₃ bare) and the BF₃ surrounded by Cd, which would have given, through the relative sensitivity, the measured flux of fast neutrons (or of thermal neutrons), is not statistically significant. The counter used is not sensitive enough (because of its intrinsic background) to detect the neutrons fluxes present inside the Laboratory B. From the statistical errors of the recorded count rates one may infer the upper values of the sensitivity of the measurements. These errors are about 0.35×10^{-3} for both the moderated and bare BF₃. This

gives an upper limit of the fast neutron flux of $1.4 \times 10^{-5} \text{ n cm}^{-2} \text{ s}^{-1}$ (or $2 \times 10^{-6} \text{ n cm}^{-2} \text{ s}^{-1} \text{ ster}^{-1}$ assuming that neutrons are distributed over $2\pi \text{ ster}$) and an upper limit of about $3.5 \times 10^{-6} \text{ n cm}^{-2} \text{ s}^{-1}$ for the thermal neutron component.

We noted a rather high variation (up to 60% in some cases) of the count rate from one measurement to another for the same detector configuration, which caused the rather large statistical fluctuations in the measurements. This may be caused by gamma fluxes from the large amounts of excavated rocks stored inside the laboratory close to the van when some of the measurements were performed. Samples of the rocks are being analysed.

The measurements in the open air outside the tunnel (at about 950 m above sea level) showed a flux of about $9 \times 10^{-3} \text{ n cm}^{-2} \text{ s}^{-1}$ fast neutrons (energy between about 500 KeV and 10 MeV) and about $2 \times 10^{-3} \text{ n cm}^{-2} \text{ s}^{-1}$ of thermal neutrons, which are in accordance with the expected values.

3.- CONCLUSIONS

The fast and thermal neutron fluxes inside the Laboratories have been calculated to be of the order of $10^{-7} \text{ n cm}^{-2} \text{ s}^{-1}$ (report in press).

The present measurements improve by a factor of about 3 previous measurements⁽¹⁾. However we need to improve the sensitivity of the detector system still by an order of magnitude or more.

We want to thank M.Lindozzi and A.Pecchi for their skillful help and assistance as well as the ANAS and the COGEFAR for their hospitality and courtesy during our stay at the Gran Sasso facility.

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