Underground Low Flux Neutron Background Measurements in LSM Using a Large Volume (1m³) Spherical Proportional Counter

I Savvidis¹, I Giomataris², E Bougamont², I Irastorza⁴, S Aune², M Chapelier², Ph Charvin², P Colas³, J Derre², E Ferrer³, G Gerbier², M Gros³, P Mangier³, XF Navick³, P Salin⁵, J D Vergados⁶ and M Zampalo³

¹ : Aristotle University of Thessaloniki, Greece
² : IRFU, Centre d'études de Saclay, 91191 Gif sur Yvette CEDEX, France
³. LSM, Laboratoire Souterrain de Modane, France
⁴: University of Saragoza, Spain
⁵ : LSBB, France
⁶: University of Ioannina, Greece
E-mail: savvidis@physics.auth.gr

Abstract: A large volume (1m³) spherical proportional counter has been developed at CEA/Saclay, for low flux neutron measurements. The high voltage is applied to a small sphere 15mm in diameter, located in the center of the counter and the wall of the counter is grounded. Neutrons can be measured successfully, with high sensitivity, using ³He gas in the detector. The proton and tritium energy deposition in the drift gaseous volume, from the reaction ³He(n,p)³H, can provide the neutron spectra from thermal neutrons up to several MeV.

The detector has been installed in the underground laboratory in Modane (LSM) to measure the neutron background. The sphere has been filled with gas mixture of Ar + 2% CH₄ +3gr He-3, at 275 mbar. The thermal neutron peak is well separated from the cosmic ray and gamma background, permitting of neutron flux calculation. Other potential applications requiring large volume of about 10 m in radius are described in detail in reference 1.

1. Introduction

The investigation on the large volume spherical proportional counter resulted in the development of a new neutron detector, based on the ³He(n,p)³H reaction[1]. The low background of the detector and the possibility to separate the γ ray pulses from the protons and alpha particle pulses increases the sensitivity on the neutron detection. The detector can successfully measure very low neutron fluxes (10⁻⁶n/cm²/s, for thermal neutrons), providing the neutron energy spectrum from thermal up to several MeV at ground and underground level.

The large spherical geometry drift (1m³), the good energy resolution (<2% FWHM with alpha particles at 5.5 MeV) and the simple read out (one channel reading) are some of the advantages of the detector. Other potential applications of this device requiring large volume are described in detail in reference [2,3,4,5,6,7].

2. The detector

The detector consist of a copper sphere, 1.3 m in diameter and 6mm thick (figure 1). The spherical vessel is well pumped (up to 10⁻⁹ mbar) and then is filled with a gas mixture at a pressure from several hundreds of mbars up to 5 bars. Out gassing in the order of 10⁻⁹ mbar/s is necessary for the amplification stability, because the present of the O₂ in the drift volume changes the detector characteristics.
A small stainless ball of 14 centimeter in diameter fixed in the center of the spherical vessel by a stainless steel rod, acts as an electrode with positive high voltage and as a proportional amplification counter. The detector was operated with positive bias applied to the anode (inner sphere) while the cathode (external sphere) remained at ground potential. A high voltage capacitor was decoupling the high voltage cable to protect the sensitive preamplifier.

3. The energy resolution

The energy resolution of the detector has been tested using $^{222}$Rn gas and detecting the alpha particles from $^{222}$Rn and $^{222}$Rn daughters. Since the $^{222}$Rn gas cover homogenously all the drift volume of the detector, we have alpha emission in every direction and in all the positions of the detector. The gas mixture consist of Ar (98%) and CH₄(2%) at pressures, from 150 mbars up to 1 bar. The high voltage vary from 1.5 kV up to 5 kV depending on the gas pressure.

Figure 1. A photograph of the spherical vessel

Figure 2. The peaks observed from a $^{222}$Rn radioactive source. From left to right we observe the $^{222}$Rn peak at 5.5 MeV, the $^{218}$Po and $^{214}$Po at 6.0 MeV and 7.7 MeV respectively.
In the figure 2 is shown the peaks observed from a $^{222}$Rn radioactive source. From left to right we observe the $^{222}$Rn peak at 5.5 MeV, the $^{218}$Po and $^{214}$Po at 6.0 MeV and 7.7 MeV respectively. The energy resolution was 2% FWHM at 200 mbar gas pressure and 2.8 kV High Voltage.

5. The thermal neutron flux in the LSM

In the present work we have been used the $^3$He gas as converter for thermal and fast neutron detection up to several MeV. Neutrons interact with $^3$He as follows, $n^3$He→$^1$p+$^1$H+765 keV. The signal is the sum of the p and $^3$H energy deposition in the drift volume and depends on the neutron energy. In the case of thermal neutrons we measure one peak 765 keV and for the fast neutrons the energy peak is $E_n + 765$ keV, were $E_n$ is the fast neutron energy.

The detector has been installed in the LSM, to measure the underground neutron flux. The gas mixture was Ar +2% CH4 at p=280 mbar with 3 gr of He-3. Thermal neutron capture rate was 0.0048 evts/s = 417 evts/d and the thermal neutron flux was $\Phi_{th} = 1.9 \times 10^{-6}$ n/cm²/s. In the figure 3 is shown the thermal neutron peak after rise time cut.

![Image](image.png)

**Figure 3.** The thermal neutron peak after rise time cut.

6. Conclusions

The spherical proportional counter is a high sensitivity neutron detector. The sensor is stable for long time measurements and the decrease in gain is small ($\approx 0.2\%$ per day). The detector can measure low fluxes of the underground thermal neutrons and the seasonal variation of the flux.

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