Update of neutron studies in EDELWEISS

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R Lemrani and G Gerbier for the EDELWEISS collaboration

DAPNIA-SPP, CEA-Saclay, Gif-Sur-Yvette, France

E-mail: `rachid.lemrani@cea.fr`

Abstract.   The neutron background in the Modane Underground Laboratory is discussed. Neutron-induced nuclear recoils in EDELWEISS-I are simulated with MCNPX in calibration and low background runs conditions.

1. Introduction
EDELWEISS [1] is a direct dark matter search experiment located in the Modane underground laboratory. Germanium bolometers are used to detect nuclear recoils induced by WIMPs, with a strong discrimination of the events produced by electronic recoils. The neutron background, which may produce signal-like nuclear recoils, is strongly suppressed by passive shielding. With a rock overburden equivalent to 4800 m of water, the residual neutron background originates mainly from the radioactivity of the rock. In the first part, we discuss the neutron background in the laboratory. In the second part, MCNPX [2] simulations of EDELWEISS-I neutron calibration runs with a ^{252}Cf source are presented and compared with the data. The expected rates of neutron-induced nuclear recoils in low background runs are also shown.

2. Neutron flux in the Modane underground laboratory (LSM)
### 2.1. LSM neutron flux simulation
The neutron production rates and spectra in the bulk of the Modane rock were calculated with the SOURCES code [3]. The code treats neutrons from (α,n) reactions and fission due to radioactive isotopes present in the rock. Some cross-sections were updated or added to the code library [4] to allow higher alpha energies (more than 6.5 MeV). Ca and Mg cross-sections computed using the EMPIRE code [5] were used. The Modane rock consists of glossy schist with 2.65 g/cm^3 density. The element concentrations were determined by spectroscopy analysis [6] with 0.84 ppm ^{238}U and 2.45 ppm ^{232}Th contaminations. A production rate of 1.3 neutrons/g/year was obtained at a mean energy of 2.2 MeV with a 77% contribution from (α,n) reactions.

Starting from the spectrum determined with SOURCES, the neutrons were propagated with MCNPX. Figure 1 shows the obtained neutron flux in the cavity ($30\times10\times11$ m^3) of the laboratory.

2.2. LSM neutron flux measurement revisited
Using the neutron flux measurement with a ^{6}Li liquid scintillator in [6], we attempted a discrimination between the SOURCES spectrum and the previous calculation performed in [6]. The neutron signature was a neutron-induced nuclear recoil followed by neutron absorption by

[6]Li. The detector ($8.5 \times 8.5 \times 85$ cm^3 NE320 scintillator) and its shielding (5 cm Cu and 12 cm Pb) was simulated with the MCNPX code. The detection efficiency is about 10% for incident neutrons above an energy threshold of 2 MeV. The following treatments were applied: light yield efficiency based on Birks' law fitted to proton data, 10% energy resolution, 43% event selection efficiency. Figure 2 shows the comparison of the simulation to the data using the input spectrum of figure 1. The SOURCES spectrum agrees better in shape with the data than the spectrum determined in [6]. Note however that all simulations are normalised to data. A normalisation factor of about 2 is needed in the simulation, which could be explained by the inhomogeneities in the rock composition and radioactive contaminations. A flux of 1.1 ± 0.1(stat) 10^{-6} n/cm^2/s above 1 MeV is obtained assuming the energy shape of figure 1 and normalising to data (a previous less accurate determination was $1.6 \ 10^{-6}$ n/cm^2/s [7]).
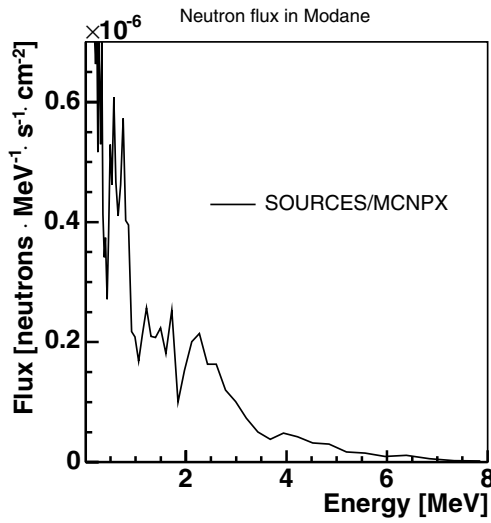
Figure 1. Neutron energy spectrum in the LSM. The neutron production from [238]U and [232]Th traces in the rock is simulated with SOURCES and propagated with MCNPX.
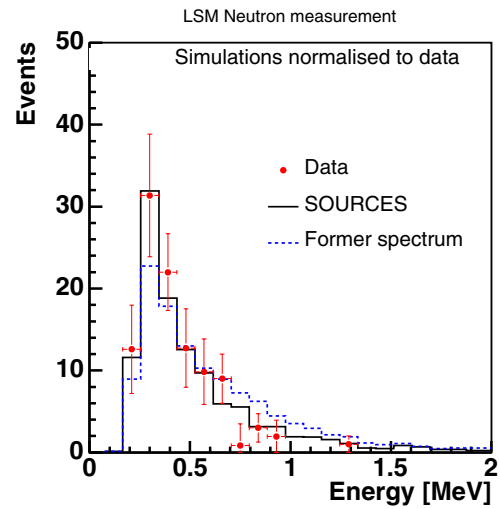
Figure 2. Experimental electron equivalent energy spectrum. Simulated spectrum from rock radioactivity using SOURCES (full line) and spectrum from [6] (dashed line).
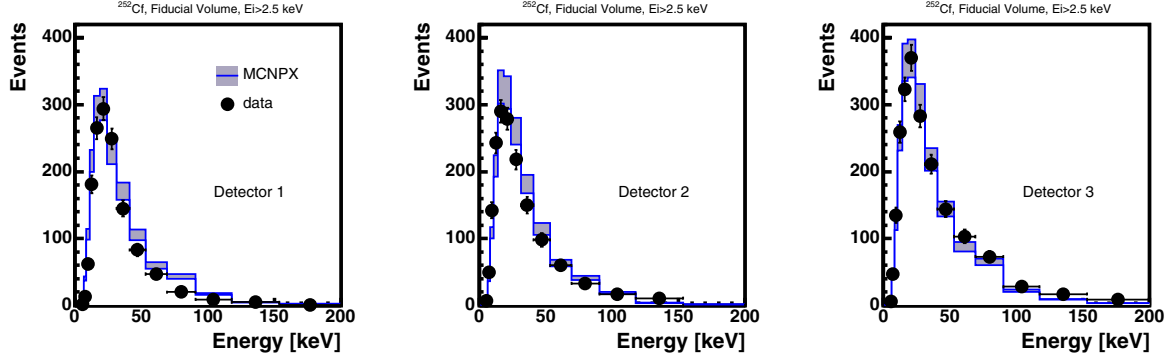
3. Neutrons in EDELWEISS-I

3.1. Neutron calibration

A simulation of the calibration runs using a [252]Cf source was performed with MCNPX. Recoil energies were first converted to ionisation yield (quenching factor) and heat (Luke effect) with experimental resolutions and then reconstructed back (see for instance [1]). The data are fairly well described by the simulation in normalisation and shape for the 3 bolometers.

3.2. Neutrons in low-background runs

The rate of nuclear recoils above 10 keV in low-background runs was derived using MCNPX. EDELWEISS-I shielding consists of a 10 cm Cu and 15 cm Pb γ-shielding and a 30 cm paraffin neutron shielding. We expect about 0.026 neutrons/kg/day from ambient radioactivity (see part 1), 0.002 neutrons/kg/day from the 0.25 ppb [238]U contamination of Copper and less than 0.001 neutrons/kg/day from the upper 0.1 ppb limit on [238]U contamination in lead. This translates into about 2 nuclear recoils expected in EDELWEISS-I data (62 kg·day). Careful comparison to data will be part of a future paper.

Figure 3. Energy spectra of the nuclear recoils in EDELWEISS-I calibration runs with a ^{252}Cf neutron source. The MCNPX simulation is also shown (full line) with a band giving the uncertainty on the activity of the source.

4. Conclusion

The neutron flux in Modane Underground Laboratory was simulated using SOURCES and MCNPX codes. The shape of the obtained spectrum is consistent with the measurement but a normalisation factor of 2 is needed. A neutron flux of 1.1 $\pm$0.1(stat) 10^{-6} n/cm^2/s above 1 MeV is extracted. The simulation of the EDELWEISS-I neutron calibration run was performed and reproduce fairly well the data. In low-background runs we expect about 2 neutron-induced nuclear recoils in 62 kg·day.

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