The BSUIN project – overview and same results.

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Abstract. The Baltic Sea Underground Innovation Network (BSUIN)\textsuperscript{[1]} project aims to make the underground laboratories in the Baltic Sea region more accessible for innovation, business development and science by improving the information about the underground laboratories, the operation, user experiences and safety. BSUIN is EU funded by Interreg Baltic Sea\textsuperscript{[2]} funding cooperation. The BSUIN consortium has 14 members from eight Baltic Sea countries. Six underground labs are looking for new collaboration in the project. One of the goals of the BSUIN project is to propose standard methods for the characterization of underground laboratories, including natural radiation background characterisation. We have proposed scheme for thermal neutron flux measurement: simple and low-cost but still very reliable. A pilot measurements were made in mines in Freiberg (Germany) Data analysis is in progress

1. Introduction
The purpose of the BSUIN project is to develop a service offering of Baltic Sea Region’s (BSR) underground laboratories (UL) in order to develop their capability to offer technology transfer utilizing the facilities and research infrastructures of the ULs for business development. Currently the Baltic Sea ULs operate separately and their capacity to offer services to businesses is limited mostly to regional or national level. The project aims to develop the capabilities of ULs in order to improve their service offering as a capacity for innovation and to create a network of the Baltic Sea Regions Uls As a main outcome the BSUIN consortium will create a sustainable network organization, which will disseminate the technical, marketing, operational quality, training and other information about the BSR ULs created during the project.

2. BSUIN partners
Fourteen BSUIN partners from nine countries around the Baltic Sea are members of the BSUIN consortium. There are two partners from Finland, Sweden, Germany and Russia, three partners from Poland and a partner from Estonia, Latvia and Lithuania in the BSUIN consortium. There are also seventeen associated partners, who support BSUIN.

List of BSUIN partners:

(i) University of Oulu, Kerttu Saalasti Institute (Finland)
(ii) Oulu University of Applied Sciences (Finland)
(iii) University of Silesia in Katowice (Poland)
There are six, existing or potential, underground laboratories involved in the BSUIN project. They are located in five countries, the exact location is shown in figure 1.

Figure 1. The map of underground laboratories involved in the BSUIN project. Underground laboratories are marked with circles. The INTERREG Baltic Sea [2] support area is also marked.

3. Work packages
Work at BSUIN is organized in five Work Packages: WP1 – ”Project management and administration”, WP2 – ”Characterization of underground facilities”, WP3 – ”Service design, market design and branding of ULS as a capacity for innovation”, WP4 – ”Underground environment improvement”, and WP5 – ”Networking of BSR ULS and their users”.
Tasks implemented in Work Package 2 are related to measurements of physical values. WP2 the package is divided into 4 activities:

- WP2.1 Geophysical characterization
- WP2.2 Natural radioactive background characterization
- WP2.3 Structural characterization
- WP2.4 Organizational characterization

The National Centre for Nuclear Research is the leader of activity WP2.2. The goal of this activity is the description of natural radioactivity background (NRB) in BSUIN underground locations. The extremely accurate characterization of NRB is essential in order to enable the utilization of the ULs as low NRB environments for product R&D, such as development of nuclear measurement or production of materials for nuclear industry or applied scientific research.

4. Minimal setup for thermal neutron flux measurements

4.1. The idea
As the first subject, we decided to consider what the simplest setup for thermal flux measurements should be. It is obvious that a setup containing many counters and sophisticated measuring electronics will be gave more reliable results than a smaller and simpler one, but in many cases it will be an overkill: unnecessarily raising the complexity and cost of the measurement. We would like to propose a setup as simple as possible, but still able to measure thermal neutron flux in underground laboratories with sufficient reliability.

In our opinion, the setup should have the following features:

- consist of at least two detectors, so that the measurement uncertainty can be determined by comparing the results
- the method of distinguishing real neutron recording from noise should exist
- the presence of the operator during the measurements should not be necessary, which will make very long-term measurements easier and cheaper

4.2. Our realisation
In our implementation, we used two proportional helium counters type ZDAJ NEM425A50. This type of counter is filled with helium $^3\text{He}$ and efficiently registers thermal neutrons thanks to the significantly high cross section for reaction $^3\text{He}(n,p)^3\text{H}$. Charged reaction products carry the released energy equal to 764 keV. A amplitude spectrum recorded by the counter has a characteristic shape with a peak corresponding to 764 keV energy and a tail of smaller amplitudes for cases when one of the reaction products escaped from the active volume. An example of amplitude spectrum, obtained with a relatively large flux of thermal neutrons is shown in the figure 2.

ZDAJ NEM425A50 helium counter is made of a 50 cm long steel tube with a diameter of 2.5 cm. It is filled with helium under pressure $^3\text{He}$ at 4 atm. and natural krypton under pressure 0.5 atm. Signals from individual counters were measured by independent measurement systems. These were simple devices consisting of an amplifier, ADC and a microcontroller, controlled and powered from a PC via a USB connector. Nevertheless, for every event a 50 samples long waveform was collected (sampling rate 1.4 MHz = one sample per 700 ns). An example waveform for a neutron is shown in the figure 2. This way of events registering allow us to distinguish the neutron from the electronics noises by analysing the shape of the waveform.

Our setup was remotely controlled via the Internet.
5. Data analysis method

The method of data analysis is based on the fact that the signals for real neutron have a longer rise time than the signals from electronic noise. In our case, instead of the rise time, it is more convenient to use the maximum time of the signal (step number of the time in which the maximum occurred). This is the same with the rise time because the position of the trigger is fix. On the two-dimensional histogram of the maximum signal position versus the maximum amplitude, real cases and noise are clearly separated into two "bands". Neutrons can be chosen thanks to the condition that the maximum position is greater than the 29th time step. After this cut, the spectrum of amplitudes will have the shape characteristic of the helium counter spectrum. The two-dimensional histogram the position of the maximum signal versus the maximum amplitude, and the spectrum of amplitudes before and after the cut is shown in the figure 3.

Figure 3. Data analysis method. On the two-dimensional histogram of the maximum signal position versus the maximum amplitude (left panel) real cases and the noise separates clearly into two "bands". Histogram of amplitudes after cutting the position maximum > 29 step of time (right panel) shows the shape characteristic for the spectrum from the helium counter. Data obtained in Freiberg, phase I of measurements.
6. Freiberg pilot program
We carried out pilot measurements of our method at the Freiberg mine (Germany). The measurements were carried out on the main level of the mine, at a depth of 250 m, near the Reiche-Zeche shaft. Measurements took place from March to June 2018 and consisted of two phases:

I: from March 6 to May 15 2018., life time 45.5 days, bare counters
II: from May 15 to June 27 2018r., life time 30.1 days, counters in the borax well

Setup in both phases is shown in the figure 4.

Figure 4. Configuration used for measurement in Freiberg. Left panel: Phase I, bare counters, panel Right: Phase II, counters inside the borax well.

The goal of Phase I was to measure of thermal neutron flux, while phase II was a test of our method. By surrounding the setup of phase I through about 100 kg of borax placed in plastic bottles, the flux of thermal neutrons reaching the counters was reduced. We expected that the rate of neutron counts will decrease, but counts from the internal alpha background will remain at the same level. Exactly this phenomenon was observed, as shown in figure 5.

By comparing the rate of counts obtained in phase I with the predictions of Monte Carlo simulation thermal neutron flux can be determined. It is equal to:

- for counter No. 0 \((2.73 \pm 0.20) \times 10^{-6} \text{ cm}^{-2}\text{s}^{-1}\)
- for counter No.1 \((3.07 \pm 0.27) \times 10^{-6} \text{ cm}^{-2}\text{s}^{-1}\)

The distribution of results is consistent with the statistical uncertainty.

7. Summary
The BSUIN project, funded by the EU, links 14 institutions from 9 countries around the Baltic Sea. One of the tasks is the characterization of underground laboratories in terms of the natural radioactive background. In this context we have proposed a method for
Figure 5. Comparison of the amplitude spectra registered in phase I and II. Spectra normalized on time.

measuring the thermal neutron flux. This method can become the standard used to characterize underground laboratories. We carried out pilot measurements at the Reiche-Zeche mine in Freiberg (Germany). Work will continue.

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References
[1] Baltic sea underground innovation network URL http://bsuin.eu/
[2] Interreg baltic sea URL http://www.interreg-baltic.eu