CERN-INTC-2013-024, INTC-P-384, Beta-delayed neutrons from oriented nuclei 137,139 I and 87,89 Br

Robert Grzywacz (University of Tennessee)
for VANDLE and NICOLE collaborations

The Committee welcomes the repair of the NICOLE dilution refrigerator and hopes that the full system will be soon operational at ISOLDE. The aim of the proposal is to investigate beta-delayed neutron and gamma radiation from oriented 137,139I and 87,89Br nuclei. Spin and parity of excited states will be determined through the angular distribution of neutrons and gammas. Such information is required for providing nuclear physics inputs to the network calculations which simulate the astrophysical processes and for the reference database. The committee finds the proposal of high interest since the method proposed is innovative and of high relevance for the study of exotic nuclei where particle emission is a relevant mechanism of decay. It is important to validate the sensitivity of the proposed method on one case, e.g. Br. A question was also raised concerning the possible background due to neutrons scattered from the large NICOLE setup. The committee thus asks for a clarification letter concerning the background, before the 17 shifts for studies on Br isotopes can be scheduled ***. The shifts for the iodine studies can be requested once the Br experiment takes place and a status report is submitted.*** *Therefore, the committee recommended for the approval of the Research Board 17 shifts, under the condition that a clarification letter is received concerning the neutron background.*

Neutron background

We would like to address the committee's concern regarding the scattered neutron background from NICOLE setup, (Fig 1, left) on VANDLE data. We have analyzed this problem using GEANT4 simulation code. The influence of the bulk of NICOLE setup would be somewhat similar to the one encountered at HRIBF which included large frames and clover type germaniums placed in close geometry, see Fig.1 (right). In order to address this request we have performed GEANT 4 simulations using a simplified NICOLE model, see Figure 2. In this model we have included the vacuum chambers and magnets around the implantation point, the support structure, the cryostat, and liquid helium and nitrogen. We used reasonable estimates about dimensions and liquid gases distribution based on the available information and drawings. While this is not an exact model of NICOLE, we consider is close enough to be used to estimate the contribution of the scattering of neutrons. With used this simplified NICOLE model to perform Monte Carlo simulations for three neutron energies 0.3 MeV, 1 MeV and 5 MeV. We found the time of flight response to the mono-energetic neutrons, see Figure 3, for VANDLE placed at 75cm from the NICOLE implantation spot. The mono-energetic simulation was used to construct a response function for arbitrary energy, using the prescription developed for VANDLE, which was also employed previously by Miyatake et al. [1]. This new response function was used to simulate an expected neutron time of flight spectrum for the case of ^{137}I using data extracted from [2], see Figure 4. In order to emphasize the role of the scattering from NICOLE materials, we are also presenting the spectrum obtained using similar method but without intervening structure of NICOLE setup. It is clear, that the effects of background are significant. However, the majority of the structures will be resolved using proper background subtraction techniques. Figure 5 shows a possible contribution of scattered neutrons. The yellow histogram represents uniformly scattered neutrons from the source and red and blue histograms are spectra taken at 90 and 0 degree assuming L=2 distribution. In the presence of the background, one needs to accumulate sufficient amount of the statistics at 0 degrees in order to be able to clearly identify peaks above background. For the factor of 10 suppression between 90 and 0 degree VANDLE bars, the statistics of 10^5 neutrons per day and per bar gives a 3σ limit for the observation of the peaks in TOF spectrum. This is already sufficient to discern between L=2 and L=4 neutrons for the strongest peaks. The assumption of uniform background distribution is obviously simplistic and requires more advanced simulation and will be performed prior to the experiment. This setup has still significantly less scattering than the setup used by Miyatake et al.[1].

Status of NICOLE

The first step in installation of the NICOLE fridge was performed during the campaign May 14 - 24, 2014, see Fig 6. Professor Taka Ohtsubo of Niigata University, with a significant help of the ISOLDE in-house group and the NICOLE members for Orsay, France (Stephanie Roccia and Asenath Etile) achieved unpacking of the fridge parts, which were sent to ICE Oxford for repair, and finding other necessary pieces left at ISOLDE and assembled the the fridge in the position in the iSOLDE experimental hall. The assembled fridge was tested for vacuum leaks at room temperature and no leaks were found. After this successful first stage the fridge the following procedures will have to be conducted before NICOLE is ready for an on-line experiment:

1. Leak test at LN2 temperature.
2. Installation cooling water lines.
3. Cleaning circulation line by booster pump with LN2 trap.
4. Fixing the bend of the circulation line trap before condenser.
5. Circulation test (testing the fridge at mK temperatures).
6. Install some wire connection.
7. Alignment to the beam line.
8. Connect to the beam line.

We envisage a second campaign either in August and early September 2014. This time window depends on availability of Taka Ohtsubo, who has heavy teaching duties in June and July at his university. Taka's experience is essential for a successful completion of the second stage of the installation. Despite of the encouraging development, we cannot guarantee that NICOLE would be ready for an on-line experiment at the end of the second campaign. There are rather complicated tasks to be worked on. As the second half of the iSOLDE schedule is likely to be prepared in the summer before we know the results of the second phase of the NICOLE commissioning, we suggest that the scheduling of the on-line NICOLE experiment is postponed to early 2015.

References

[1] H. Miyatake et al., Phys. Rev. C 67, 014306 (2003).
[2].H. Ohm et al., Z.Phys. 296, 23 (1980)

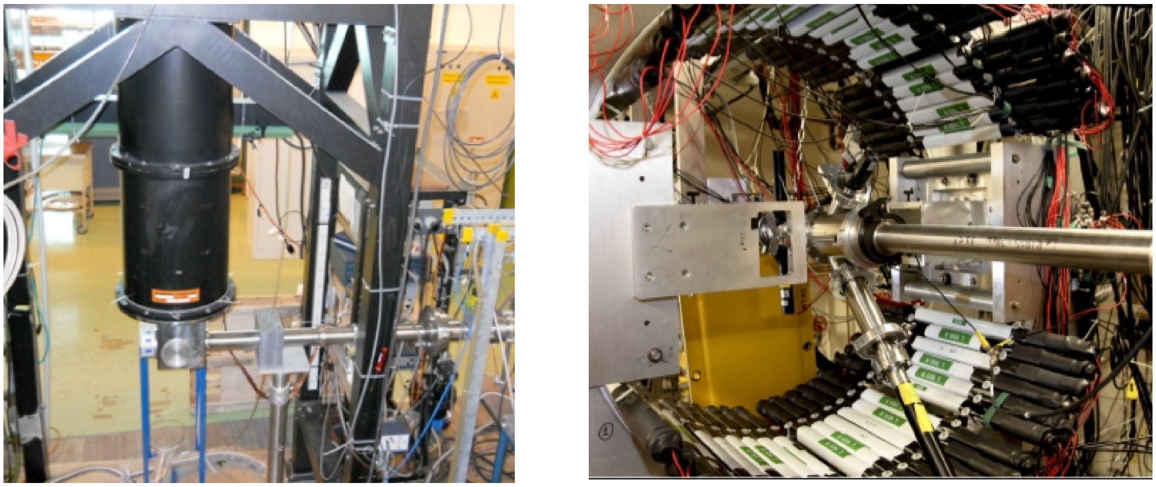

Figure 1. (Left) NICOLE setup with shown significant parts of the system, support pillars and the cryostat. (Right) VANDLE system in the 50 radius ring as implemented at HRIBF.

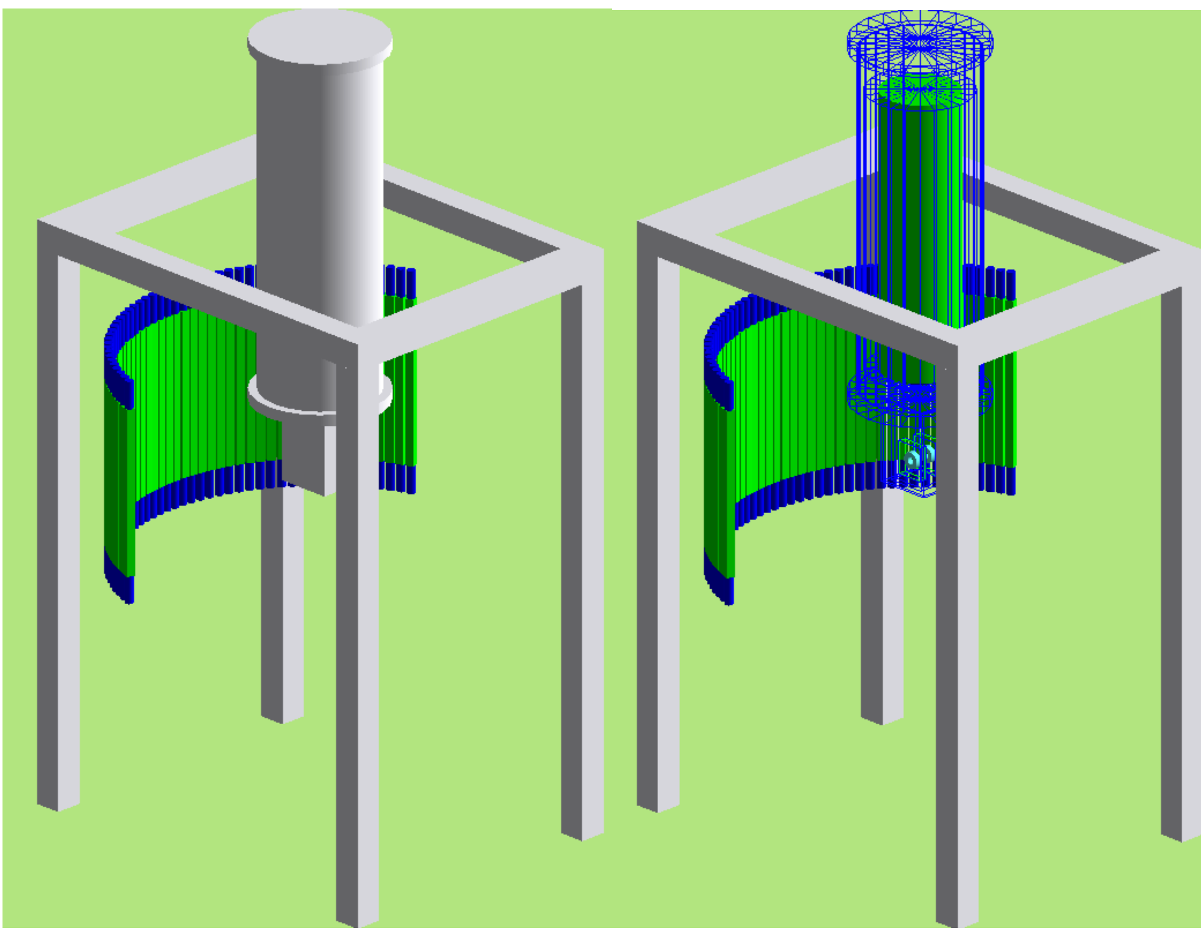

Figure 2 . Simplified NICOLE model used for Geant 4 simulations.

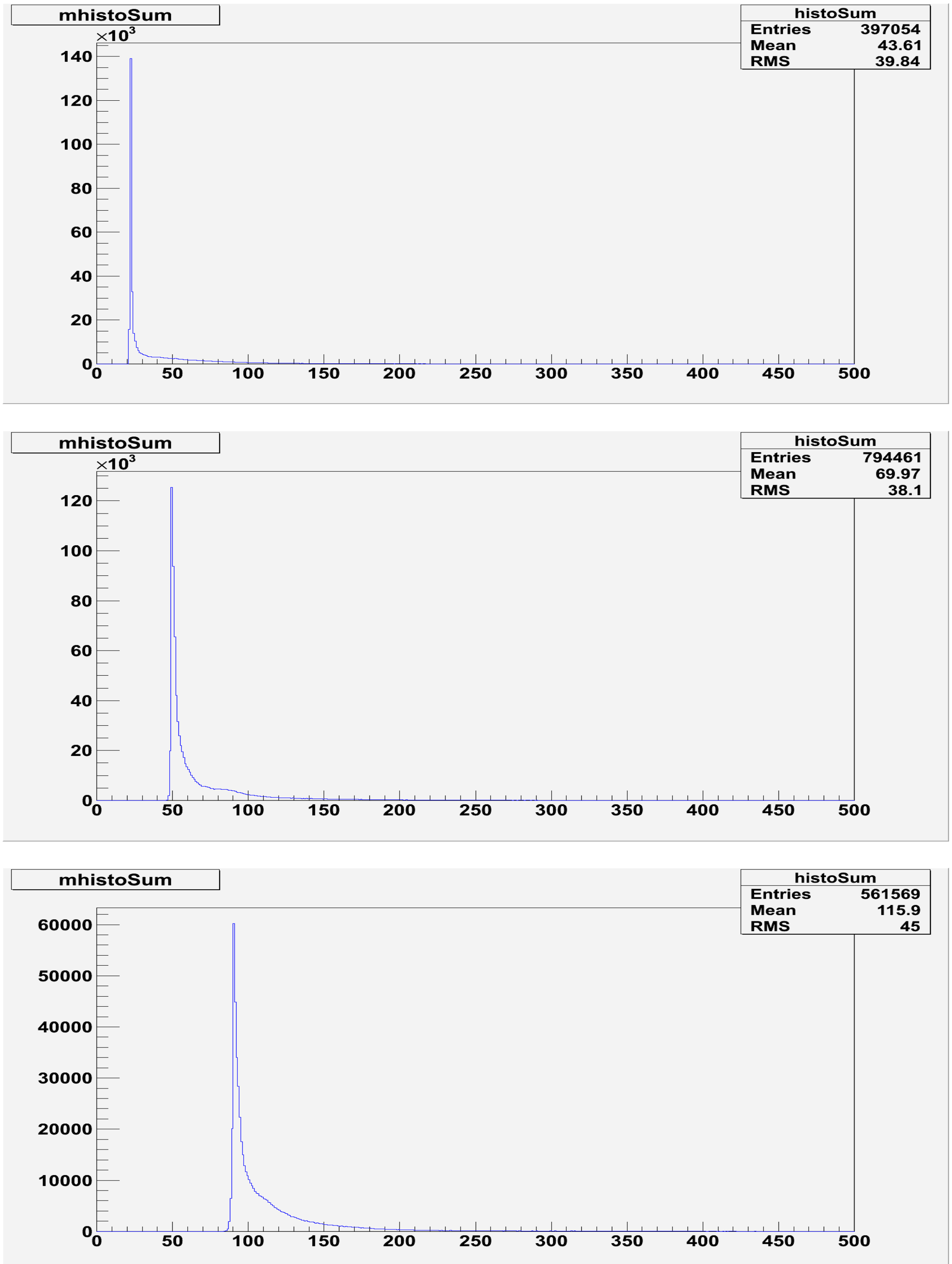

Figure 3. The response of VANDLE to mono-energetic neutrons: 5 MeV (top), 1 MeV (middle) and 0.3 MeV (bottom). The simulation was performed for $5x10^5$ events in each case.

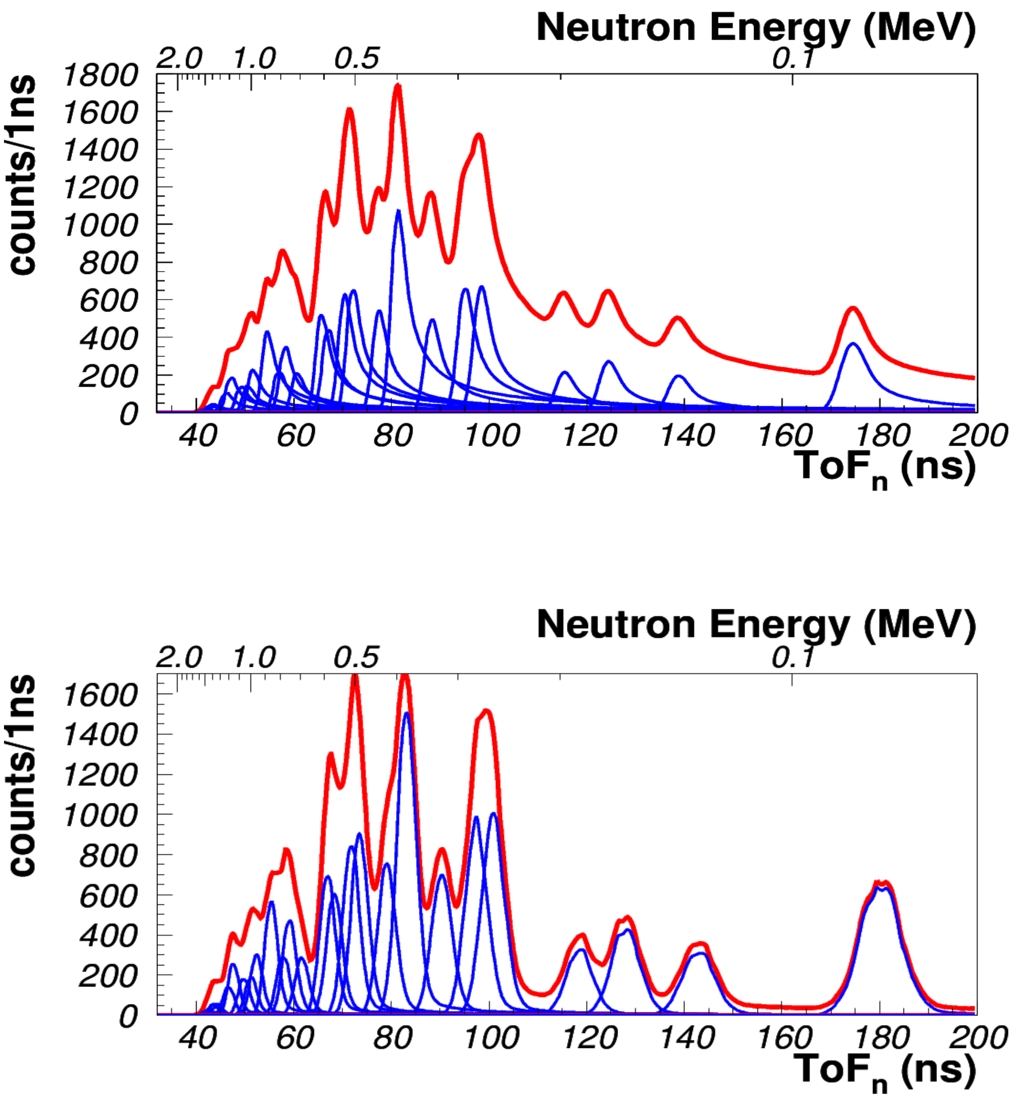

Figure 4. (TOP) simulated response spectrum for VANDLE at NICOLE at 75 cm time of flight with ^{137}I. (BOTTOM) the same simulation but without materials close to the implantation. Plotted in blue are individual peaks from ^{137}I [2] and in red is the integrated spectrum.

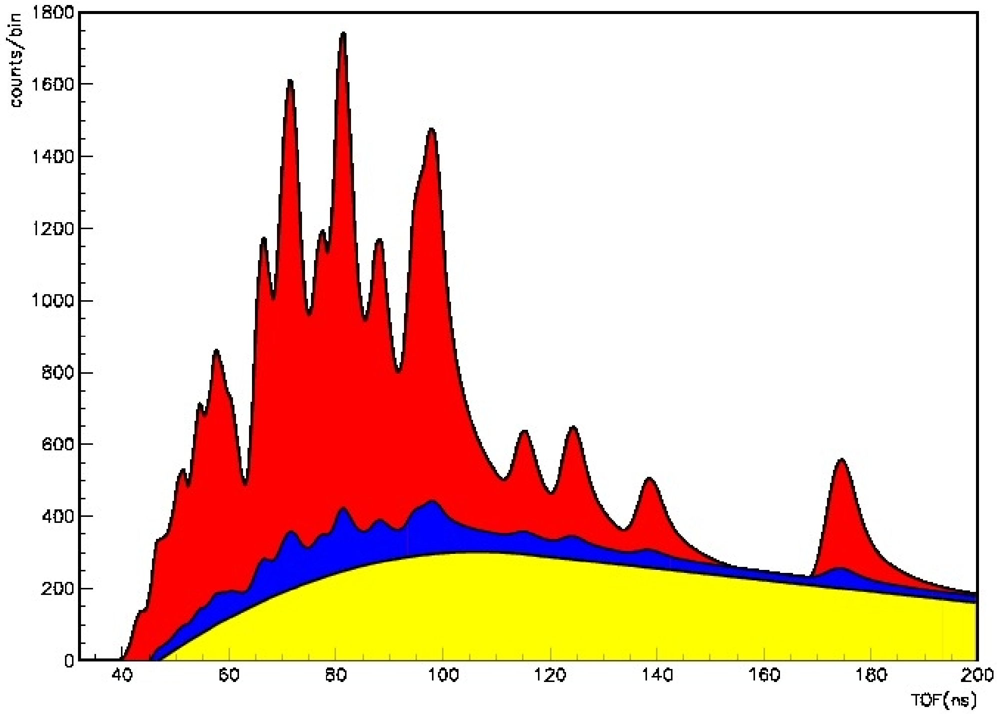

Figure 5. Possible background conditions at NICOLE. The red histogram represent "cold" 90 degree spectrum and blue is "cold" 0 degree spectrum with added isotropic background. Yellow histogram shows an estimated isotropic background from scattered neutrons. The statistics of 10^5 neutrons in red histogram corresponds to roughly 24 h (3 shifts) of data measured with one VANDLE bar.

Figure 6. Photographs showing present assembly of NICOLE at ISOLDE.