EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Clarification letter to the ISOLDE and Neutron Time-of-Flight Committee

Spin assignments of nuclear levels above the neutron binding energy in ^{88}Sr

October 5, 2011.

F. Gunsing[2], F. Bečvář[3], B. Baramsai[5,8], F. Belloni[2], E. Berthoumieux[2], E. Chiaveri[1], K. Fraval[2], C. Guerrero[1] M. Krtička[3], G. Mitchell[5,6], G. Rusev[6,7], I. Tomandl[4], A. P. Tonchev[6,7], V. Vlachoudis[5]

and the n_TOF Collaboration

[1] *CERN, Geneva, Switzerland*
[2] *CEA-Saclay, Irfu, F-91191 Gif-sur-Yvette France*
[3] *Charles University, CZ-18000 Prague, Czech Republic*
[4] *Research Centrum, CZ-25068 Řež, Czech Republic*
[5] *North Carolina State University, USA*
[6] *Triangle Universities Nuclear Laboratory (TUNL), USA*
[7] *Duke University, USA*
[8] *Los Alamos National Laboratory, USA*

CERN-INTC-2011-043 / INTC-CLL-008
05/10/2011

Spokespersons: Frank Gunsing, František Bečvář
<frank.gunsing@cea.fr>, <becvar@mbox.troja.mff.cuni.cz>
Technical coordinator: Eric Berthoumieux <eric.berthoumieux@cern.ch>

Requested protons: 4×10^{18} protons on target (split into 2 runs)

In document INTC-2011-030, INTC-P-304 presented to the INTC in July 2011 we described our proposal to measure the reaction ^{87}Sr + n at n_TOF in two different and independent experiments: one cross section measurement over a large energy range with C_6D_6 detectors, similar to many other n_TOF measurements, and one new type of measurement at n_TOF with the 4π BaF_2 total absorption calorimeter (TAC) having the purpose of spin assignments of resolved resonance states. In its minutes, the INTC acted positively on the scientific interest but would like to receive complementary information, in particular on two points stated here below. For the cross section measurements with C_6D_6 detectors, the advantages of using n_TOF with its high resolution and large energy range covered in a single measurement are obvious, and have been set ahead in many previous n_TOF proposals. But the present proposal on spin assignment measurements are a new type of experiments at n_TOF and needs clarification on two items as pointed out by the INTC.

- The INTC would like to have more details on the added value of the present experiment compared to the ongoing studies at Los Alamos, using the same sample.

At the LANSCE facility in Los Alamos, a similar spin assignment experiment is ongoing. Since we are aware of this experiment, we felt obliged to inform the INTC, in the proposal as well as in the presentation. However it is important to stress that there are important differences between the facilities which justify an experiment at CERN of which the results are expected to be complementary since they will overlap only partly with those of Los Alamos. The DANCE detector at Los Alamos is a device similar to the TAC at n_TOF. DANCE has a granularity of 160 crystals, compared to 40 crystals of the TAC. As explained in the second point, the difference in granularity is irrelevant for this particular measurement.

The main difference originates from the time-of-flight resolution which is better at n_TOF as compared to LANSCE. The time-of-flight pulse of n_TOF has a rms width of 6 ns while while the LANSCE moderated neutron beams have a rms of 1 μs. The distance at n_TOF is 185 m while DANCE is operating at 20 m resulting in a much higher gamma flash in the DANCE array and significantly reducing the exploitable upper energy limit. At these distances the instantaneous flux is equivalent at both facilities. The repetition rate at n_TOF is below 1 Hz but 20 Hz at LANSCE. The lower repetition rate of n_TOF results of course in a lower average flux, which means that more beam time is needed to obtain the same counting statistics. On the other hand the low repetition rate leads to reduction of time-independent background and prevents overlap of slow, thermalized neutrons from the previous TOF cycle, reducing therefore considerably the thermal neutron induced background, and allowing to measure down to thermal neutron energies.

The much higher resolution of n_TOF in combination with the lower impact of the gamma flash allows to observe resolved resonances to a higher energy. In this way multiplicity spectra and spin assignments for more resonances can be obtained. The spin assignments for the resonances observed both at LANSCE and n_TOF will therefore serve as a welcome validation of the data processing and spin assignment methods.

In addition to the TAC experiment and unlike the experiment at DANCE, the n_TOF proposal includes measurements with the C_6D_6 detectors, which cover a much larger energy range and which will make it possible to extract information on weak neutron resonances of the ^{87}Sr+n system. Moreover, from the obtained cross section one can calculate the Maxwellian averaged cross sections to clarify the s-process path in the Kr-Rb-Sr region. Finally, cross section measurements in a large energy region is a powerful constraint for optical model-based cross section calculations.

- The INTC would like to know how the challenge of extracting the spectroscopic information will be overcome.

The spectroscopic information consists of multiplicity gamma-ray spectra for each multiplicity and each resolved resonance. The gamma-decay path of each resonance gives rise to a gamma-ray multiplicity, which forms a distribution when taken over many events. This decay of the compound nucleus is statistical and the spin difference between the initial state, the resonance, and the final state, the ground state, is small.

For most medium and heavy mass nuclei the average multiplicity is in the order of 3 to 4. Multiplicities larger than about 8 have a very low probability, which has been verified by statistical decay Monte Carlo calculations. In a TOF window corresponding to the width of a resonance, the number of coincidences are determined by counting the number of coincident detector hits. This is the detected multiplicity. Due to Compton scattering, adjacent detectors may be triggered by the same gamma-ray from the decay cascade. Therefore we determine also the cluster multiplicity, taking into account this effect. For the n_TOF TAC with 42 crystals, the detected and cluster multiplicity are very close, and the granularity is sufficient to match the expected multiplicities. In comparison, the DANCE detector at Los Alamos has a higher granularity of 160 crystals, which will not form an advantage in this case.

An additional motivation concerns photon strength function studies. Having the gamma-ray spectra for the individual multiplicities and two values of s-wave capturing state spin, a combined trial-and-error DICEBOX and GEANT4 analysis is expected to yield new information on behaviour of $E1$ and $M1$ photon strength functions in a so far not well explored mass region. This information in combination with results of ongoing analysis of the ^{88}Sr(γ,γ') reaction data from Forschungszentrum Dresden may shed light on a persisting problem of the disagreement between NRF and (n,γ) regarding the shape of the low-energy tail of the GDR. An attemt to solve this problem will be facilitated by our access to recent Prague data on two-step gamma cascades following the capture of thermal neutrons in ^{87}Sr.

Summary of requested protons: 2×10^{18} protons on target for spin determinations of ^{87}Sr +n resonances with the TAC and 2×10^{18} protons for cross section measurements with the C_6D_6 setup.