Safety Report
Experiment 1056
Precise Determination of the ^{8}Li Valence Neutron ANC: Testing Mirror Symmetry and the ANC Method in Astrophysics

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1 Introduction

Recently, intense interest in asymptotic normalization coefficients (ANCs) has been generated by their connection to radiative capture reactions. In particular, the astrophysical S factor for the important ^{7}Be(p,γ)^{8}B reaction, $S_{17}(0)$ has been derived from measurements of (^{7}Be,^{8}B) transfer reactions. Although much effort has been expended to determine $S_{17}(0)$ both directly by means of radiative capture measurements and indirectly via Coulomb breakup and ANC measurements, the situation is still somewhat confused. The most recent radiative capture measurement by Junghans *et al.* is by far the most precise measurement and therefore dominates weighted averages. However, it is curious that the other low energy radiative capture measurements and the indirect measurements agree quite well and imply a lower value for $S_{17}(0)$.

ANCs are usually determined by analysing transfer reaction data in the framework of the distorted wave Born approximation (DWBA). The DWBA transition amplitude for the transfer reaction contains a remnant term which is not proportional to the ANC. All recent DWBA analyses of transfer reactions have implicitly assumed that the ANC can be inferred from the overall constant by which the theoretical DWBA calculation is scaled to match the experimental cross section. In these experiments, particularly those involving heavy ions, the effect of the remnant term on the inferred ANCs is not clear.

In this experiment the ANC of the valence neutron in ^{8}Li will be measured using the elastic transfer reaction ^{7}Li(^{8}Li,^{7}Li)^{8}Li at three beam energies, 8, 11, and 13 MeV. The interference between elastic scattering and neutron transfer produces characteristic oscillations in the differential cross section as a function of the scattering angle. By analysing the amplitudes of the interference minima and maxima, the ANC for $^8\mathrm{Li}\rightarrow{}^7$Li +n can be determined. It is essential to ascertain the effect of the remnant term in order to precisely infer the ANC and test previous ANC analyses based on the DWBA. This will be accomplish by carrying out the measurement at three beam energies. In conjunction with previous measurements, this experiment will test mirror symmetry in the A = 8, T = 1 system and assess the validity of the ANC method for determining astrophysical S factors. Provided no problem with the method are found, the ANC and charge symmetry will be used to infer the astrophysical S factor, $S_{17}(0)$, for the ^{7}Be(p,γ)^{8}B reaction.

2 Description of the Experiment

The experiment will use an ISAC radioactive ^{8}Li beam with a flux of 2×10^{7} pps. The ^{7}Li target will be housed in the TUDA chamber, and two types of silicon strip detectors will be used to tag the events. One type will be $8\times300\mu$ LEDA sectors at 7.2 cm from the target, and the other will be a S2 detector at 13 cm from the target. The LEDA detector will span lab angles from 36° to 60.5°, and the S2 detector will span lab angles from 4.9° to 15°. The cm angles covered will sample the range from 10.6° to 179° by virtue of the fact that the ^{8}Li ion does not exceed 61° in the lab and the ^{7}Li ion does not exceed 90°. A ^{7}Li event in the S2 detector will be accompanied by a ^{8}Li signal in the LEDA detector. Tagging this correlation will be used for extracting the desired signal. This technique can also be used for some of the LEDA ^{7}Li events as the ^{8}Li can also end up in the LEDA. The cm angles covered for the ^{7}Li events will range from 58.9° to 107.8° for LEDA and 150° to 170.1° for S2. The backward cm angles will manifest the interference between the elastic and the neutron transfer amplitudes.

The target ladder will be the one used in previous TUDA experiments, such as E879 and E928. The target will be a self supported foil of 25 μg/cm^{2} ^{7}LiF with a thin 15 μg/cm^{2} backing of C. The target ladder will also have the usual collimators and a small faraday cup [1] to assist in focussing and tuning the beam.

The backgrounds for this experiment will come from scattering off of carbon and fluorine. The ion energies for these events are different from those of ^{7}Li(^{8}Li,^{7}Li)^{8}Li and they also do not have the coincident correlations. Thus they can be differentiated from the desired signal. There will also be background from ^{8}Li decays. The decay chain ^{8}Li(β^{-})^{8}Be$\rightarrow2\alpha$ gives off a rather energetic electron and two α's. The electron will have a rather low pulse height signal in the detectors and no timing correlation with the RF. These should not be a problem. The two α decay will be quite inconvenient. However TDC-RF correlation, background subtraction, and the ^{7}Li,^{8}Li coincident technique should also reduce this background to a manageable level.

Normalization for the experiment will principally lie with measuring the forward ^{8}Li elastic scattering events. These events should be very close to classic Rutherford scattering, the cross section of which can be calculated and the flux inferred. There will also be a large apperature downstream TUDA faraday cup which will measure the total charge deposited by the beam. However since a significant fraction of electrons

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[1] This cup is for tuning purposes only. This is not the large downstream cup which will monitor beam current during the experiment

from the ^{8}Li(β^{-})^{8}Be decay will escape the cup, the absolute normalization will be lost.

The TUDA acquisition system is VME based and capable of acquiring data from up to 512 electronic channels, which is more than enough for the proposed setup (max. 192). The VME DAQ is also capable of handling up to 20 kHz event rate and again this should be more than sufficient for this experiment. The data will be acquired online event by event allowing cuts and coincidence requirements to be applied offline as necessary. The data being acquired will be monitored online using a Sun workstation to verify beam and target status and detector/electronics stability. The electronics and the data aquisition system that will be used is the fairly standard TUDA setup, and except for some minor modifications and upgrades, has been used for all the previous TUDA experiments. The present electronics setup and DAQ was used as recently as April 2006 for the E1031 ^{12}C fusion experiment.

3 Safety Concerns

The present experiment is a standard TUDA setup and has been run before with no safety issues other than RIB. The only change to be noted as far as personnel safety is concerned is that the HV bias supplied to the current integrators is now supplied via a (beam OK) interlocked current limited power supply. There was some concern previously about receiving a 300V shock from an interlocked battery source. Running ethanol in the preamp chiller was approved for the previous experiment, E1031. There are no real non-radiation safety concerns for this experiment.

This experiment will request a flux of 2×10^{7} pps of ^{8}Li. As mentioned previously the decay chain, ^{8}Li(β^{-})^{8}Be$\rightarrow 2\alpha$, emits a rather energetic electron with a 12.96 MeV maximum energy. A rather crude model of the faraday cup[2] estimates that approximately 49% of these e's will escape the cup assuming that the electron only loses energy through ionization loss. Bremsstrahlung was not considered. This should be an adequate assumption for electron energies less than 10 MeV. An observation that the energy deposited by an electron and the depth it penetrates into organic matter, the E/t ratio, is approximately constant at 189 MeV/m, allows a crude calculation of the radiation field. The calculation gives 86 μSv/hr at 1 m.

This field exceeds the casual occupancy level of 10 μSv/hr and the full time occupancy level of 1 μSv/hr set by TRIUMF. It should be noted that the measured field is expected to be less than the calculated 86 μSv/hr, because the actual faraday cup is a cylinder with a 1/8 inch Fe wall, and the decay electron will have to penetrate Fe thicknesses, on the average, greater than the 1/8 inch as assumed in the model. Based on the 86 μSv/hr figure, the 10 μSv/hr limit will occur at 3m from the faraday cup, and the 1 μSv/hr limit will occur at 9m from the cup. It is proposed to barricade the area where the fields exceed 10 μSv/hr, and post notices where the field exceeds 1 μSv/hr.

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[2] a circular sphere of 1/8 inch Fe with a 2×10^{7} Bq ^{8}Li source at the centre

This will be the safety procedure followed for this experiment. Once the tune of 2×10^7 pps is established, radiation field surveys will be done for:

1. The beamline faraday cup, FC4, intercepting the beam.
2. The target ladder faraday cup intercepting the beam.
3. The beam dump faraday cup intercepting the beam. This survey has 2 cases.
    - (a) for an empty target ladder location in the beam.
    - (b) for the ^{7}LiF target in the beam.

The last case, with the ^{7}LiF target, will be the normal running condition. The barricades and notices will setup according to this case.

Other than what has been discussed, there are no other radiation concerns. The two α's from the decay chain will not get out of the faraday cup or the TUDA chamber. The number of e's from ^{8}Li stopping in the TUDA chamber should be negligible w.r.t those from the faraday cup.