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Design of an Experiment to Measure a_{nn} Using $^3H(\gamma, pn)n$ at HIγS*

F.Q.L. Friesen[1,a], M.W. Ahmed[2], B.J. Crowe[2], A.S. Crowell[1], L.C. Cumberbatch[1], B. Fallin[1], Z. Han[1], C.R. Howell[1], R.M. Malone[1], D. Markoff[2], W. Tornow[1], and H. Witała[3]

[1] *Department of Physics, Duke University and Triangle Universities Nuclear Laboratory, Durham, NC, USA*
[2] *Department of Mathematics and Physics, North Carolina Central University and Triangle Universities Nuclear Laboratory, Durham, NC, USA*
[3] *M. Smoluchowski Institute of Physics, Jagiellonian University, Cracow, Poland*

Abstract. We provide an update on the development of an experiment at TUNL for determining the $^1S_0$ neutron-neutron (nn) scattering length (a_{nn}) from differential cross-section measurements of three-body photodisintegration of the triton. The experiment will be conducted using a linearly polarized gamma-ray beam at the High Intensity Gamma-ray Source (HIγS) and tritium gas contained in thin-walled cells. The main components of the planned experiment are a 230 Ci gas target system, a set of wire chambers and silicon strip detectors on each side of the beam axis, and an array of neutron detectors on each side beyond the silicon detectors. The protons emitted in the reaction are tracked in the wire chambers and their energy and position are measured in silicon strip detectors. The first iteration of the experiment will be simplified, making use of a collimator system, and silicon detectors to interrogate the main region of interest near 90° in the polar angle. Monte-Carlo simulations based on rigorous 3N calculations have been conducted to validate the sensitivity of the experimental setup to a_{nn}.

1 Introduction

The goal of the experiment is to determine a_{nn} to an uncertainty less than ±1 fm. This will be the first determination of this quantity using a photodisintegration reaction. The initial measurements will be carried out with a 15-MeV gamma-ray beam where the total cross section is at its maximum [1]. The measurements will be performed with sufficient accuracy to resolve discrepancies in existing three-body photodisintegration cross-section data. Witała and Glöckle showed that increasing the strength of the nn S-wave force in the CD-Bonn potential by about 10% could resolve the standing discrepancy observed in nn quasi-free scattering in nd breakup [2]. Our data for the $^3H(\gamma, pn)$ reaction will provide another determination of the strength of the nn S-wave interaction. Also, data for the $^3H(\gamma, p)$, $^3H(\gamma, pn)$, $^3He(\gamma, p)$, and $^3He(\gamma, pp)$ reactions provide assessments of ab initio 3N calculations, including tests for long-range 3N force effects.

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[a] e-mail: fqf@tunl.duke.edu

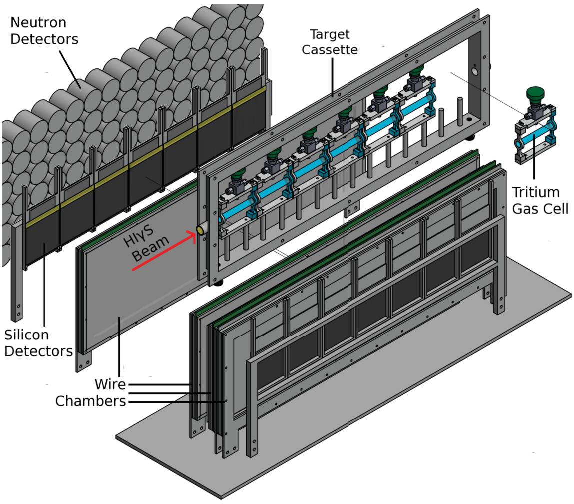

Figure 1. Diagram of the experimental setup for tracking-based measurements of ^{3}H and ^{3}He photodisintegration differential cross-sections. The gas targets are mounted to a central open-sided structure (target cassette) that lies along the beam axis. Two planes of wire chambers followed by a plane of large-area silicon strip detectors are on each side of the targets. The setup is about 80 cm long x 20 cm tall x 30 cm wide. A leak-tight stainless steel box will enclose the entire apparatus and provide additional containment of the tritium gas, as well as electrical and optical shielding for the detectors. A ^{3}H scrubbing system (not shown) will connect to the internal volume of the target cassette through the bottom plate.

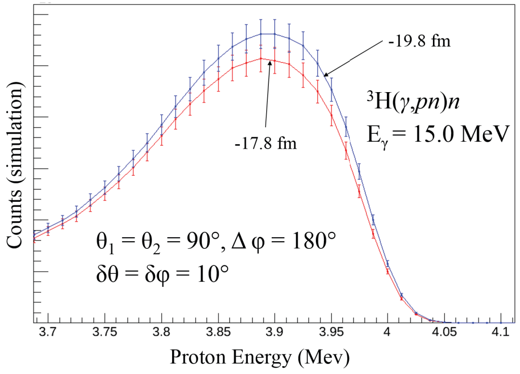

Figure 2. The predicted scattering length sensitivity for coincident detection of a proton and a neutron assuming a single gamma energy. The difference in azimuthal angle between the particles has been constrained to 175° ± 5°. The polar (θ) angles have been constrained to 90° ± 5°. This figure includes propagation of particles through the tracking apparatus. Error bars are 3% for reference.

2 Experimental Setup

The collimator system to be used in the first iteration of the experiment will constrain the trajectories of the emitted charged particles. Neutrons detected in coincidence will be used to identify 2-body events kinematically. Cross sections measured with the tracking system will be determined with uncertainties better than ±5% in the angle range from 45° to 135° relative to the beam axis and for an azimuthal angular acceptance of approximately ±60°.

The main kinematic configuration of interest for a_{nn} measurements is the nn final state interaction, in which the proton and unbound pair of neutrons are emitted colinearly in opposite directions, such that the proton energy is maximal. This configuration will be isolated using measured charged particle energy, time differences between detection of particles, and relative locations of detected particles.

References

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