Two and Three-body Photodisintegration of the Triton at energies below 30 MeV







By: Calvin R. Howell, Duke University

Collaborative research project

Duke University/TUNL and University of Rochester/Laboratory for Laser Energetics

Grant Proposal to

The Department of Energy, Office of Science Nuclear Data Interagency Working Group (NDIAWG) Research Program: DE-FOA-0002440

Project Period: July 1, 2022 – June 30, 2025

Duke University and TUNL PI: Calvin R. Howell

Univ. of Rochester and LLE

Co-PI: Chad Forrest Co-PI: Walter Shmayda

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US 2015 Nuclear Science LRP: Organizing Themes

- May the strong force be with you: Emergence of the nuclear strong force from QCD
- Theory of nuclei: to explain, predict and use: ab-initio calculations (few-nucleon systems and light nuclei), nuclear density functional theory for heavy nuclei

Hierarchy of theoretical treatments of nuclear systems

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O Reanalyzed by Tornow, Witala and Braun, FBS 21 (1996)97.

TUNL 99

Bonn 00

LAMPF 98

-6 ²H(n,nnp) ²H(n,p)nn πd a_= -16.9±0.3 fm a__= -18.7±0.2 fm -8 capture -15.4±0.3 fm a__= -10 -18.4 -12 ±0.4 fm -14 φ -16 a_{nn}(fm) -18 -20 -22 -24 -26 -28 -30

Reactions used to determine a_{nn}

- (1) $\pi^{-} + d \rightarrow n + n + \gamma$
- (2) $n + d \rightarrow n + n + p$

Proposed Reactions to determine a_{nn}

- (3) $\gamma + {}^{3}H \rightarrow n + n + p$
- (4) $\mu^- + d \rightarrow n + n + \nu_{\mu}$

Figure made from table in C.R. Howell, arXiv:0805.1177 [nucl-ex]

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World data on ³H photodisintegration

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D.D. Faul *et al.*, Phys. Rev. C 24, 849 (1981): LLNL; e+ annihilation beam; $E_{\gamma} < 25$ MeV; moderated BF₃ neutron detectors; 200 kCi gas target D.M. Skopik *et al.*, Phys. Rev. C 24, 1791 (1981): U. Saskatchewan; ³H(γ , d) at $E_{\gamma} = 15 - 36$ MeV (bremsstrahlung); TiT (2 Ci) foil R. Kosiek *et al.*, Phys. Lett. 21, 199 (1966): U. Heidelberg; ³H(γ ,d) at $E_{\gamma} = 17 - 31$ MeV (bremsstrahlung); 191 Ci gas target

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4



³H Photodisintegration: Science Impact

 $\gamma + {}^{3}H \rightarrow n + n + p$ (3-body photodisintegration) $\gamma + {}^{3}H \rightarrow n + d$ (2-body photodisintegration)

• First double differential cross-section measurements of 3-body photodisintegration of ³H

- evaluate theory treatment of nucleon interactions and meson exchange currents in 3-nucleon system w/o complication of the Coulomb force
- □ First determination of the ¹S₀ neutron-proton scattering length with this reaction (probe long-range 3-nucleon interactions)
- \square First determination of the ${}^{1}S_{0}$ neutron-neutron scattering length with this reaction
- First angle differential cross-section measurements of 2-bodv photodisintegration of ³H



Tritium gas cell





Target cell active volume: Diameter = 30 mm Length = 40 mm Pressure = 13.6 atm Activity = 990 Ci

Target cells will be:

- Engineered at TUNL
- Fabricated and assembled at TUNL
- Pressure tested at TUNL (to 400 psi = 14.2 atm)
- Pressure certified by an independent ASME approved engineering firm
- Filled at the UR/LLE



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3-body Photodisintegration of ³H : nn FSI

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Technical Capabilities Outcomes:

- The radiation safety infrastructure at TUNL will provide the capabilities for safe handling of encapsulated gas tritium sources.
- TUNL will have the scientific and technical expertise for managing a gas tritium inventory in accordance with NRC regulations.
- Cross-section measurements of photodisintegration of tritium will be demonstrated using the quasimonoenergetic photon beam at HIGS with two neutron detector configurations.
- Researchers on this project will gain experience with optimizing the signal-to-background ratio in the neutron time-of-flight spectrum from photon-induced reactions on a tritium gas target.
- The TUNL-LLE collaboration will be positioned to make ³H photodisintegration measurements at more photon beam energies.

Project Physics Deliverables: phase-1 measurements

- First kinetically complete cross-section data for 3-body photodisintegration of ³H. Data for several neutronneutron coincidence angle pairs will be measured at two photon beam energies: $E_{\gamma} = 23$ and 30 MeV
- Angular distribution cross-section data for 2-body photodisintegration of ³H at E_{γ} = 23 and 30 MeV
- First determination of the ${}^{1}S_{0}$ np scattering length using ${}^{3}H$ photodisintegration
- First determination of the ${}^{1}S_{0}$ nn scattering length using ${}^{3}H$ photodisintegration

Phase-2 Measurements: the next three years



Setup-2: nn FSI, np FSI, Collinear point ٠

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Thank you





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