STUDY OF TWO-BODY PHOTODISINTEGRATION OF ^{3}He AND ^{3}H

A.A.Kotov, L.A.Vaishnene, A.I.Chtchetkovski, G.E.Petrov, M.Karlsson[1], J.-O.Adler[1], K.Hansen[1], M.Lundin[1], B.Schroeder[1],V.Avdeichikov[2], B.L.Berman[3], W.J.Briscoe[3], G.Feldman[3], G.V.O'Rielly[3], I.I.Strakovski[3], J.R.Calarco[4], N.R.Kolb[5]

[1] *Department of Physics, University of Lund, Sweden*
[2] *Division of Cosmic and Subatomic Physics, Department of Physics, University of Lund, Sweden*
[3] *The George Washington University, Washington DC, USA*
[4] *University of New Hampshire, NH, USA*
[5] *Saskatchewan Accelerator Lab, Saskatoon, Saskatchewan, Canada*

1. Introduction

The properties of nuclei and nuclear matter, including the equation of state of the nonideal Fermi gas in the interiors of neutron stars, are based upon nucleon-nucleon potentials. Therefore, both theoretical models and experimental investigations of these potentials are of great importance for nuclear physics and astrophysics. New models for the nucleon-nucleon potentials have recently been developed and applied to calculations of the photodisintegration cross sections of the A = 3 systems ^{3}He and ^{3}H. To test these calculations, measurements of the cross sections are needed in a broad energy range. However, the existing data sets for two-body photodisintegration of ^{3}He and ^{3}H from threshold (5.5 and 6.3 MeV, respectively) up to 50 MeV are rather sparse and generally inconsistent with each other.

There are several measurements on the $\gamma^3\text{He} \rightarrow pd$ reaction. These have been performed using bremsstrahlung photons, electrodisintegration or radiative capture. Unfortunately, the measured cross sections vary by approximately 25% in the energy region below 30 MeV, making careful comparisons with theory difficult. None of these experiments have been done using monoenergetic photons, except for the radiative capture experiments, and these were restricted to $E_\gamma < 17$ MeV.

By contrast, there are significantly fewer measurements of the $\gamma^3\text{H} \rightarrow nd$ reaction. Two of these experiments have used bremsstrahlung photons, and the most recent measurement of this reaction was performed using monoenergetic photons from positron annihilation in flight. Unfortunately, the latter data set has rather large uncertainties, and the former two data sets are clearly inconsistent with each other.

By charge symmetry, the two-body breakup cross sections on ^{3}He and ^{3}H should be identical, except for Coulomb effects. In the neighbouring case of ^{4}He, however, the question of charge symmetry has been controversial for over 20 years. In that case, charge symmetry suggests that the ratio of the (γ, p) and (γ, n) cross sections should be nearly unity, and a recent result from Saskatchewan Accelerator Laboratory (SAL) in which both channels were measured simultaneously gave a ratio consistent with the charge-symmetry predictions. Comparisons of the isospin mirror channels in the A = 3 system have been made, and difference in the two-body breakup channels has been shown to be inconsistent with theoretical predictions. However, since the data sets available at that time were rather sparse and contradictory, it was a rather difficult to make a reliable comparison.

Two significant developments have prompted renewed interest in this fundamental photodisintegration reactions. First, modern high duty-factor accelerator facilities providing tagged photon beams permit a significant improvement in measurements using monoenergetic photons. This enables a reliable and substantially more precise data-set to be obtained using these modern experimental techniques, which renders the earlier data (prior to 1981) largely obsolete. Second, state-of-the-art exact theoretical calculations of the A = 3 systems have recently been realized. The need to match these new calculations with equal high-quality data is clearly indicated. This was the motivation for the experiment performed at SAL, in which the two-body photodisintegration of both ^{3}He and ^{3}H was measured using tagged photons in the energy range E_γ = 18–52 MeV. However, most of the discrepancies in the earlier cross-section measurements occurred in the vicinity of 10–15 MeV, below the lowest tagged photon energy available at SAL, but in an energy range accessible to the photon tagging facility at Lund University. The lower-energy region, which encompasses the peak in the photodisintegration cross section, is also more sensitive to details of the theoretical calculations. Thus, the validity of the current theoretical treatments can be more stringently tested at these energies. These are the primary motivations for extending measurements of the A = 3 systems into this critical lower-energy region at Lund facility. It is important to note that Lund is the only nuclear physics laboratory in the world currently able to provide tagged photons as low in energy as 10 MeV, and so provides a unique facility where such a low-energy photonuclear experiment can be performed.

2. Experimental setup

The lower photon energy range that was used in the Lund experiment (E_γ = 10–30 MeV) is result in correspondingly lower deuteron energies (E_d ~1.5 MeV for E_γ = 10 MeV) in the photodisintegration reaction. Such a low-energy deuteron cannot traverse even thinnest ΔE solid-state detector (about 50 μm) in ΔE–E telescopes used at the SAL, which is required to provide energy-loss information for the purpose of particle identification (separating protons from the deuterons). In order to provide optimal proton-deuteron separation at the lower energies available at Lund, a new large solid angle acceptance installation for registration and identification of the charge and mass of light charged particles from photonuclear reactions was designed and created [1]. The installation consists of three main parts - a detecting system, a target box and a system for pumping and gas filling, which performs also the gas pressure control. The detector system is a further development of a prototype of a Bragg-PPAC ionization detector that has been successfully tested at tagged photon beam of MAXlab with Al-target and which was described in detail in Ref. [1]. The Bragg-PPAC detector is a combination of a Bragg ionization chamber and a parallel plate avalanche counter (PPAC). The principle of operation of the Bragg-PPAC ionization detector is based on measurement of an ionization density distribution produced by the detected particle in the detector volume, i.e. the Bragg curve, which allows to determine the energy, Bragg peak amplitude and the range of the particle stopped within the detector. Different combinations of these quantities can be then used for reliable identification of the type of the registered particle [1].

A schematic view of the detection system together with target box is presented in Fig.1. The detection

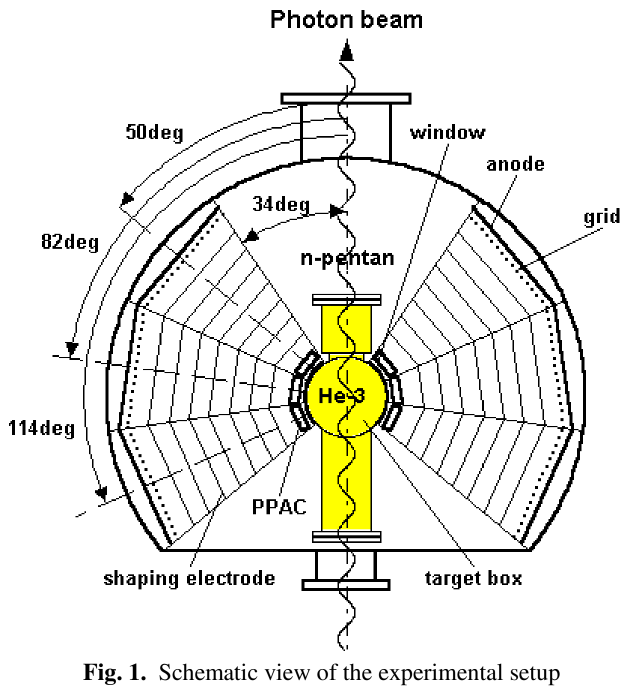

Fig. 1. Schematic view of the experimental setup

system comprises six identical Bragg-PPAC detectors, placed in the chamber ~ 0.6 m diameter filled with working gas (*n*-pentan). To provide a maximum solid angle acceptance the Bragg-PPAC detectors are located at very close distance (~ 5 mm) around the target box in the centre of the chamber. Two thin windows of the target box (2 μm Mylar foil on the thin perforated aluminium support) separate the target box volume from the volume of the Bragg-PPAC detectors. The construction of the target box allows one to employ two types of thin windows which can be used for different pressure direction: inward or outward target box. Any type of the window provides reliable sealing at the pressure difference up to 250 Torr. So the installation may be used in various inclusive and coincidence experiments both with the gas target and the solid one. Each Bragg-PPAC detector consists of PPAC, anode, Frish grid and three shaping electrodes. The PPAC cathode is used as the Bragg chamber cathode as well. The total solid angle of the Bragg-PPAC detector system is approximately 1 sr.

3. Results

The Bragg-PPAC chamber is a newly developed detector that have the ability to separate protons and deuterons at very low energies, thus making it possible to unambiguously determine two-body break up events. In the Bragg chamber, which is a gaseous ionization chamber with a Frish grid, the electron collection is carried out along the direction of the registered particles. The ionization density distribution along the particle track follows the distribution of the energy loss. Thus the charge collected at the anode generates a signal which shape represents the ionization density as a function of position, *i.e.* the Bragg curve. For particles stopped within the chamber this curve has a maximum near the end of the range, the so-called Bragg peak. Thus, if the signal is read out using a Flash ADC we get a complete determination of the ionization density which lets us determine the energy, the Bragg peak and the range of the particle. These quantities are then used to identify the type of particle. For an example the Bragg Peak amplitude *vs* Energy plot of raw data is given in Fig. 2. Data analysis is in progress.

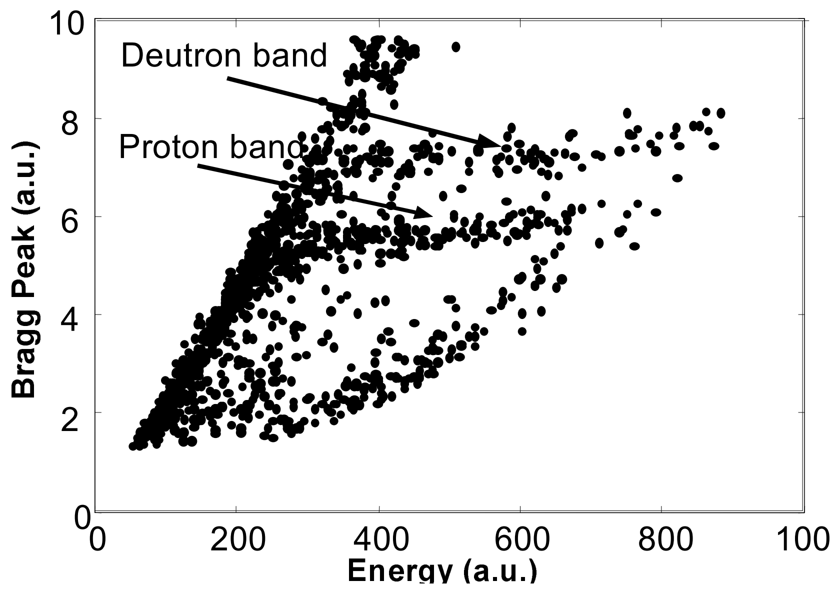

Fig. 2. Bragg Peak *vs* Energy plot for particles from ^{3}He target

References

[1] A.A.Kotov *et al.*, Nucl. Instrum. Meth. **A423**, 376 (1999).