Test Measurement of the Photodisintegration of the Deuteron

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The photodisintegration of the deuteron, d(γ,n)p, or its inverse reaction n(p,γ)d is one key reaction in the network of the Big Bang nucleosynthesis [1]. It is the first step in the buildup of complex nuclei. There are several theoretical investigations dealing with this reaction and a wealth of experimental data exists, see Fig. 1.

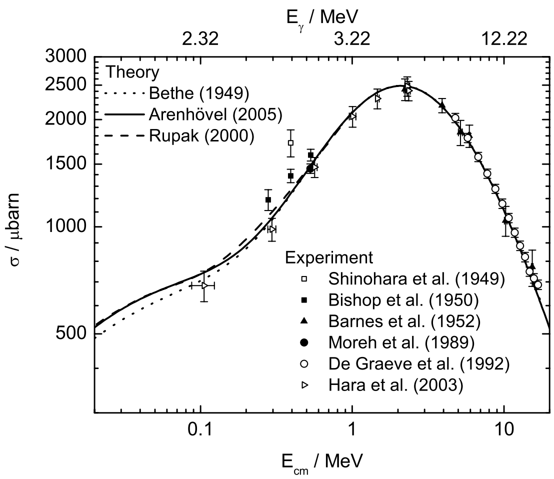

Fig. 1 *Theoretical and experimental data on the d(γ,n)p cross section. All references can be found in [2].*

In the astrophysically relevant energy range from 30 to 130 keV [1], the theoretical calculations as well as the experimental data differ significantly. Especially in this energy region there exists only one experimental data point showing a need of more and precise measurements at this energies. Development of adequate neutron detectors is in progress [3] and test measurements have been done at the bremsstrahlung facility at the ELBE accelerator [4].

Targets of 5 g deuterated polyethylene (CD_2) and of 5 g polyethylene (CH_2) were irradiated by bremsstrahlung photons about 6 hours each. At the same time a target of 5 g ^{11}B was irradiated to determine the photon flux.

The electron beam of 5.5 MeV kinetic energy was employed to reduce the beam-induced neutron background, by staying below the neutron separation energy of every surrounding material. The reduction of the pulse repetition rate to 1.6 MHz caused a reduction of the average beam current to 90 μA but prevented overlapping time-of-flight spectra from adjacent beam pulses.

To determine the photon flux, the scattered photons from ^{11}B were measured with a HPGe detector. From the count rate in the ^{11}B transitions in the photon-energy spectrum one can calculate the incoming photon flux Φ_γ using

$$\Phi_\gamma(E_\gamma) = \frac{A_{Peak}}{\varepsilon_\gamma \cdot T_{live} \cdot I_S \cdot N_B \cdot W} . \qquad (1)$$

Here A_{Peak} is the number of counts in the ^{11}B transition, ε_γ is the efficiency of the HPGe detector, T_{live} is the dead-time-corrected measurement time, I_S is the integrated cross section, N_B the number of ^{11}B nuclei, and W is the angular correlation coefficient. The CH_2 time-of-flight spectrum was normalized to the CD_2 spectrum, using the respective photon fluxes, and subtracted as background from the CD_2 spectrum. From the resulting spectrum one can determine the differential d(γ,n)p cross section $\frac{d\sigma}{d\Omega}$ via

$$\frac{d\sigma}{d\Omega}(E_{cm}) = \frac{\dot{N}_n(E_{cm})}{\Phi_\gamma(E_{cm}) \cdot \varepsilon_n \cdot N_D \cdot \Omega} . \qquad (2)$$

Here $\dot{N}_n(E_{cm})$ is the neutron count rate, $\Phi_\gamma(E_{cm})$ is the incoming bremsstrahlung spectrum, ε_n is the neutron detection efficiency, N_D is the number of target nuclei and Ω is the solid angle of the detector.

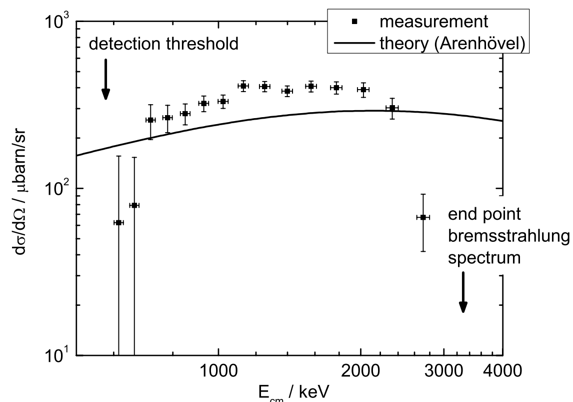

Fig. 2 *Differential cross section of d(γ,n)p (symbols).*

The result is shown in Fig. 2, where the error bars represent the statistic uncertainties only. The systematic uncertainty is in the order of 100 % and is mainly caused by the bad signal-to-background ratio, the uncertainty of the absolute normalization of the photon flux, the uncertainty in the end point energy of the bremsstrahlung spectrum, and the uncertainty of the neutron detectors efficiencies. Investigations to minimize these uncertainties are in progress.

[1] S. Burles, K.M. Nollet, Phys. Rev. Lett. 82 (1999) 4176
[2] R. Beyer, Diplomarbeit (2005)
[3] R. Beyer et al., this report, p. 40
[4] R. Schwengner, R. Beyer et al., NIM A 555 (2005) 211

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