Photodisintegration of the Deuteron [D]

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Experimental investigations of the deuteron-photodisintegration [1] have mainly been performed at energies near and above 100 MeV, where inelastic channels like nucleon resonances and meson production open up and where many partial waves contribute. At photon energies below 10 MeV the situation seems much simpler with only two channels (photon scattering and $d\gamma \rightarrow pn$) and only $l=0$ and $l=1$ beeing of importance. Nevertheless an exact knowledge of the cross section near the disintegration threshold is of great importance in the field of nuclear astrophysics, as it - together with the inverse reaction $pn \rightarrow d\gamma$, related to it by detailed balance - determines [2, 3] the reaction rate of the first step in the big bang nucleosynthesis (BBN).

A detailed quantitative understanding of BBN allows to calculate the primordial abundance ratio of the lightest elements and their isotopes as a function of the photon-to-baryon ratio. From now available observations of abundances in distant and thus young stars a big bang photon-to-baryon ratio can be determined to be compared to the value obtained for the later photon decoupling phase of the universe. This value was determined with high accuracy from the inhomogenity of the cosmic microwave background radiation (CMB) [4].

Most previous photodisintegration experiments at near threshold energies were performed with monochromatic photons, delivered either by radioactive decay or by Compton backscattering of a laser beam. In both cases the low photon intensity and systematic errors in determining it accurately have limited the quality of the results. Especially in the region below the maximum cross-section data have been published which are inconsistent within their error bars. One experiment has been reported from a conventional bremsstrahlung facility [5]; there the actual center-of-momentum (CM) energy was determined by a measurement of the outgoing proton energy within the range of 7 -20 MeV.

As already pointed out in early theoretical work by Bethe et al. [6], the $l=0$ (M1) disintegration predominant at energies below 100 keV above threshold can be predicted from the nucleon magnetic moments by an extrapolation from the thermal n-capture on H, which was rather well determined at 295 K. Similarly, the $l=1$ (E1) disintegration, determinin the cross section above 500 keV, can be connected to the processes thoroughly investigated in the multi MeV range. Proton-neutron potentials (of type Argonne-Urbana, Bonn etc.) [7] as well as effective field theories [8] have made different predictions for the energy range around 100 keV. This range has been shown to be of special importance for the nucleosynthesis at 10^9 K. Here the cross section is governed by the competition between M1 and E1 [1].

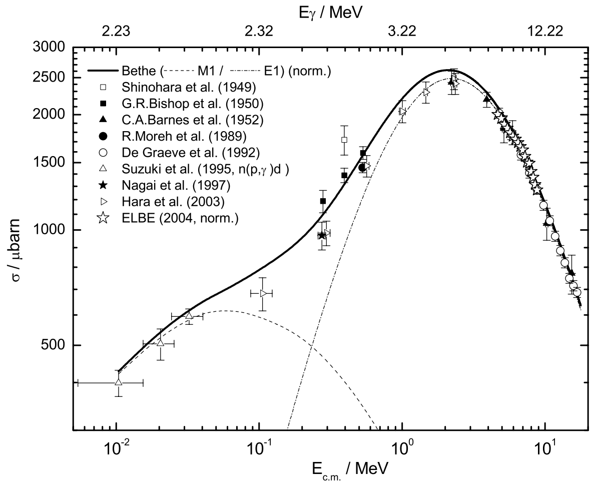

Fig. 1 *Cross section for the Photodisintegration of the deuteron vs. photon energy (top scale) resp. c. m. energy above threshold (bottom scale).*

First studies have been undertaken at the IKH to find out if the electron beam parameters at ELBE - repetition rate in the MHz range and sub-nanosecond pulse width - allow us to improve the data base and thus the comparison to the CMB results. For an extraction of the CM-energy from the nucleon velocities the good time resolution allows a rather short flight path and consequently large solid angle. In an preparative experiment we could show that the low emittance of the electron beam together with the complex photon collimation system allows a proton energy measurement over an extended range (cf. Fig. 1). The energy dependence of these data from ELBE agrees very well to an extended study of the same process at the Ghent linac [5]; obviously the determination of the c. m. energy via the measurement of only one dissociation product delivers consistent results. In future runs at ELBE a normalization to the energy dependent-photon flux can be attained by a simultaneous measurement of photon scattering from added target nuclei with previously determined resonance widths. This method was already successfully applied for the nuclear resonance fluorescence experiments at ELBE.

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