Electro- and photodisintegration of deuterium

H. Arenhövel
and
W. Fabian
Institut für Kernphysik
Universität Mainz
D-6500 Mainz

Abstract: Deuteron break-up by inelastic electron scattering or photoabsorption is discussed with emphasis on effects from meson exchange currents and isobar configurations.

1. Introduction

The simplest nuclear system, the two-nucleon system serves as a basis for the determination of the nucleon-nucleon interaction, one of the most important ingredients of nuclear physics. Both the bound state properties and the N-N scattering data as well are used to fix any "realistic" potential model of the N-N force, which may be a phenomenological potential or, more ambitious, constructed from meson theory (OBE-potential and higher order)\textsuperscript{1}.

The internal structure of the two-body system, however, like wave functions, charge density etc. will to some extent depend on the chosen potential model, and it is certainly of great importance to know how well the real internal structure is described by the given potential model. To this end one has to investigate the two-nucleon system by some probe like real or virtual photons, pions, protons etc. in elastic scattering or disintegration processes.

A particularly well suited probe is a real or virtual photon since it has the virtue of being a rather weak probe with a well known interaction, thus allowing a unique interpretation of experimental data. Therefore, the aim of the present talk will be to discuss the disintegration of deuterium by photoabsorption and inelastic electron scattering. In particular we will investigate the question in which region of energy and momentum transfer interaction effects, like meson exchange currents (MEC) and nuclear isobar configurations (IC) play a role and how well they are described by present theoretical models.

2. Formal developments

For electron-deuteron scattering we can rely on the Born approximation, which describes the scattering process by the exchange of a virtual photon. This means we can treat photoabsorption and inelastic electron scattering on the same footing,
i.e., as absorption of a real or virtual photon. The absorption cross section of a (real or virtual) photon of energy \( \omega \) and momentum \( \mathbf{q} \) by an unpolarized deuteron then is given by

\[
\frac{d\sigma}{d\Omega} = \frac{k_{M\alpha}}{12\pi \omega} \sum_{i, f, \lambda, \lambda'} J_{fi, \lambda, \lambda'} J^{*}_{fi, \lambda, \lambda'} \sigma^{(i)}_{\lambda, \lambda} \, d\Omega_{np} \tag{1}
\]

with the transition matrix element

\[
J_{fi, \lambda, \lambda'} (q, \omega) = \tilde{e}_\lambda \cdot <f|\mathbf{J}(q)|i> \tag{2}
\]

of the Fourier component of the nuclear current density. Its longitudinal component \((\lambda = 0)\) is related to the charge density by current conservation. The photon polarization is denoted by \( \tilde{e}_\lambda (\lambda = 0, \pm 1) \) and \( \sigma^{(i)}_{\lambda, \lambda} \) is the density matrix of the incoming photon. For photon absorption it is given by

\[
\sigma^{(i)}_{\lambda, \lambda} = \frac{1}{2} (1 + \mathbf{P} \cdot \mathbf{\sigma})_{\lambda, \lambda} \tag{3}
\]

where \( \mathbf{P} \) denotes the photon polarization. In electron scattering the virtual photon has longitudinal and linear transverse (in the scattering plane) polarization with a density matrix given by \( \sigma^{(i)}_{\lambda, \lambda} \)

\[
\sigma^{(i)}_{\lambda, \lambda} = \frac{\alpha \omega}{2\pi(q^2\omega)^{\frac{3}{2}}} \frac{k_e}{k_{\lambda, \lambda}} \rho_{\lambda, \lambda} \, d\omega \tag{4}
\]

The functions \( \rho_{\lambda, \lambda} \) are determined by the electron kinematics. Explicit expressions are given in refs. \( \text{2,3)} \), e.g., one has

\[
\rho_{00} = V_{\text{long}} (\theta_e) \\
\rho_{11} = V_{\text{trans}} (\theta_e) \tag{5}
\]

where \( V_{\text{long}} \) and \( V_{\text{trans}} \) are defined in ref. \( \text{4)} \). The internal structure of the two-body system determines the charge and current matrix elements which are expanded in terms of multipole moments \( \text{3,5)} \). Expanding the final \( n-p \) scattering state into partial waves one arrives at

\[
\frac{d\sigma}{d\Omega} = \sum_{\lambda, \lambda'} \sigma^{(i)}_{\lambda, \lambda'} \sqrt{(1+\delta_{\lambda,0})(1+\delta_{\lambda',0})} e^{i(\lambda'-\lambda)\phi_{np}} C_{\lambda, \lambda'} (\theta_{np}) \, d\Omega_{np} \tag{6}
\]