Eq. (67). That same value for W is expected for a charge–exchange reaction if isospin is conserved while $W = 1$ for strong isospin mixing. It seems that this interesting test has not been used so far.

We have briefly summarized what is known about isospin–symmetry breaking in CN reactions (Harney *et al.*, 1986). The data show that in the Ericson regime, isospin–symmetry breaking is neither so weak as to be altogether negligible nor so strong as to reduce CN scattering to a Hauser–Feshbach situation without any reference to the isospin quantum number. Isospin mixing is expected to become weaker with increasing excitation energy, see (Sokolov and Zelevinsky, 1997) and references therein. As shown in (Harney *et al.*, 1986), data in the Ericson regime can be used to determine the average Coulomb matrix elements $\langle V^2 \rangle^{1/2}$ and spreading widths $\Gamma_1^{\downarrow} = 2\pi z^2 d_2$ or $\Gamma_2^{\downarrow} = 2\pi z^2 d_1$ for isospin violation in nuclei. While the values of the average Coulomb matrix elements vary over many orders of magnitude, the values of the spreading widths are nearly constant versus excitation energy and mass number, see Fig. 15 in (Harney *et al.*, 1986). This fact provides a meaningful consistency check on both theory and data analysis. Similarly to the experiments reviewed in Section VI.A and to the study of symmetry breaking in the regime of isolated resonances (Alt *et al.*, 1998; Dietz *et al.*, 2006), further subtle aspects of the theory in the regime $\Gamma \gg d$ might be tested with the help of experiments on two coupled microwave billiards.

2. Fine Structure of Isobaric Analogue Resonances

If isospin T were a good quantum number, isospin multiplets consisting of degenerate states with fixed T but with different z–quantum number T_z ("isobaric analogue states") would exist in nuclei with the same mass number A but different neutron and proton numbers. The degeneracy is lifted by the isospin–breaking interaction (mainly the Coulomb interaction between protons), and the energies of the members of a multiplet increase with increasing proton number. For proton numbers $Z \approx 20$, the energy difference between neighboring members of a multiplet is of the order of 10 MeV. In a medium–weight nucleus with ground–state isospin T_1, the lowest state with next–higher isospin $T_2 = T_1 + 1$ (an isobaric analogue state of the "parent state", here: the ground state of a nucleus with the same mass number but one proton replaced by a neutron) typically has an excitation energy of several MeV. Higher–lying states with isospin T_2 follow with typical spacings of several 100 keV. These states may be unstable against proton decay. The resulting resonances ("isobaric analogue resonances", IARs) are then observed in elastic proton scattering. The proton channel does not have good isospin and couples to both the IARs and the numerous background states with isospin T_1. The situation is schematically illustrated in Fig. 18. The parent state is the ground state of the nucleus ${}_Z(\mathrm{A}{+}1)_{N+1}$ with isospin T_2. In its ground state the CN nucleus ${}_{Z+1}(\mathrm{A}{+}1)_N$ has isospin T_1. The isobaric analogue state in that nucleus occurs at an excitation energy of several MeV.

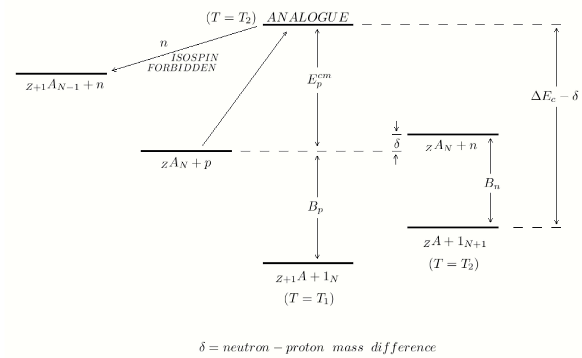

FIG. 18 Level scheme showing the parent nucleus, the isobaric analogue state, and a state of lower isospin (schematic).

Low–lying IARs correspond to simple states of the shell model. Therefore, their elastic widths (typically several keV) are much larger than those of the complicated CN background states. On the other hand, the elastic width of the IAR is typically small compared to the average spacing between IARs which will thus be considered as isolated. The isospin–breaking interaction mixes each IAR with CN background resonances. The mixing strongly enhances the elastic widths of all CN resonances that occur in the vicinity of the IAR. The mechanism is similar to that of a doorway state, see Section I.II.G, except that now all states are resonances, and that the mixing mechanism is rather special. The resulting "fine structure" of an IAR is a topic of special interest. While it is sometimes possible to apply nuclear–structure theory to individual IARs, the background states are too numerous and too highly excited to allow for anything but a random–matrix approach. Thus, the theoretical description uses for the Hamiltonian the matrix (95) with the proviso that the submatrix $H^{(1)}$ is taken from the GOE while the submatrix $H^{(2)}$ has dimension one.

IARs as resonances in the CN were discovered by the Florida State group which partially resolved a proton s–wave IAR in ^{92}Mo(p,p) (Richard *et al.*, 1964). If the CN background resonances overlap only weakly, the excitation curves fluctuate strongly, and the fine structure of an IAR can be completely resolved experimentally. That is possible mainly in the nuclear $1f$–$2p$ shell, see Section I.IV.A. The fine structure is investigated in elastic and inelastic proton scattering and sometimes in the (p, n) reaction. The latter is isospin forbidden and gives direct evidence for symmetry breaking. Depending on the mean level spacing d of the background states, we distinguish three cases: almost all of the original proton strength is retained by the analogue state (weak mixing),