# STATISTICAL FLUCTUATIONS VERSUS RESONANCES

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It is believed, generally, that at high level density the nuclear reaction cross section is determined by Ericson fluctuations[1]. But careful experimental investigations called in question the fluctuation picture. As early as 1963 Lee and Schiffer[2] found that the assumption of complete randomness, which is basic to the statistical model, is invalid in the strong cross section fluctuations observed in the excitation functions $^{58}$Ni+p. Kanter et al.[3] proved these results by measuring the time evolution of compound elastic scattering by crystal blocking. They found average compound nucleus widths which are substantially smaller than those of the observed structures in the excitation functions. Further, the mean compound nucleus life time is significantly longer at the higher bombarding energy, contrary to expectations of a purely statistical theory. Non-statistical effects have been found also in other experiments. For example, recent careful attempts to find a statistical distribution of decay amplitudes failed.[4]

The basic assumption of the theory of fluctuations[1] in nuclear reaction cross sections is that the scattering amplitude can be written as a sum of contributions from many levels, each given by a Breit Wigner amplitude. It is usual to assume that all the widths are about the same and that the real and imaginary parts of the scattering amplitude have Gaussian distribution with mean zero. The first of these assumptions has not been proved up to now while the second one is experimentally not supported and not disproved fully[4,5]. Thus, it is necessary to prove the basic statistical assumptions by means of numerical calculations in which the nuclear structure is properly taken into account.

Numerical results obtained on the basis of the continuum shell model[7] do not support the statistical assumptions. Neither the widths of the compound nucleus states which are nearly the same at low level density remain so at high level density[8] nor the decay amplitudes of compound nucleus states, even if they are isolated, are uncorrelated[6]. In the first case, the widths of a few resonance states increase at the cost of the remaining ones while the correlation in the latter case is caused by the additional term to the wave function of a state which arises from the coupling to the continuum.

In the standard formulation of nuclear reaction theory, the concept of the doorway state has been worked out for the interplay between short-lived and long-lived resonance states. This concept is, of course, an oversimplification from a spectroscopic point of view. It is justified to use unmixed states as basic states as long as the calculation is performed by means of a complete set of wave functions and no approximations are introduced. But these conditions are not fulfilled in the standard doorway concept.

Analytically, the interplay between the different states is governed by the so-called external mixing of the resonance states via the continuum if the states overlap[9]. The external mixing of the resonance states brings about to fulfill the unitarity condition of the S matrix also in the case a giant resonance mixes with underlying states of the same spin and parity. Deviations from the statistical behaviour occur at the top of giant resonances due to the unitarity of the S matrix the constraint by which correlates the underlying levels in such a manner that the ma-

ximal possible value of the cross section will not be passed over[10]. This non-statistical effect may cause missing spectroscopic strength if it is not taken into account in analysing the giant resonance data. Further, external mixing reduces the spreading of excitation strength in contrast to configurational mixing in the case the excitation strength is concentrated in a giant resonance state[11]. This result comes about because of the comparably short life time of the giant resonance state which effectively reduces the degree of mixing with other resonance states. Thus, standard nuclear structure calculations overestimate the spreading of the excitation strength.

All these non-statistical effects are caused by the interaction of overlapping resonance states via the continuum. The analytical expression of this interaction is known[9] and general trends can be derived. Already at $\Gamma \approx D$, it determines the behaviour of the excitation functions, produces intermediate-like structures[8], fictional doorway and long-lived compound nucleus states[8], determines the interplay of giant resonances with the underlying resonances[9,10,11] etc.

In recent experimental data there is a lot of hints pointing to effects caused by the external mixing of overlapping resonance states. Effects similar to those in proton induced reactions[2,3] are observed in heavy ion scattering. Here, the presence in the excitation functions of both narrow and broad structures indicate that there is an interplay of various interaction times, ranging from the life time of the compound nucleus to the time associated with shape resonances in the ion-ion potentials[12]. At present there is no quantitative formulation of these phenomena in heavy ion scattering in line with the results discussed above for neutron and proton induced reactions. Surely, external mixing of the overlapping resonances determines also here the cross section and will make possible an understanding of the physical origin of the resonance phenomena observed. Besides the numerical formulation, more systematically experimental data are desirable in order to prove the analytical expression for the external mixing in detail.

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