ON THE DOORWAY-MECHANISM IN DEEP-INELASTIC HEAVY-ION REACTIONS

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In recent years, two somewhat diametrically opposed approaches have been pursued to describe dissipative phenomena in heavy-ion reactions. On the one hand, statistical models have been used to treat the excitation of complicated internal configurations /1,2,3/. On the other hand collective modes, like the giant resonances, were made responsible for this reaction-type /4/. Both these aspects are expected to be important. We therefore try to unify these pictures by assuming that the reaction is initiated through a population of collective doorway-states which are strongly coupled to the ground-state. These states subsequently decay into complicated configurations which are treated statistically.

To distinguish these two classes of states we divide the total Hilbert-space into two subspaces by projection-operators P and Q. P projects on the doorway-states and Q on the complicated configurations. Applying these projectors to the total T-matrix of the system one arrives at a set of coupled equations for the projected T-matrices PTP and QTP (the ground-state belongs to P-space). The cross-section of the deep-inelastic component is obtained as

$$\frac{d\sigma_{o\to f}}{dE_f\, d\Omega_f} = \frac{v_f}{v_i}\left(\frac{\mu_f}{2\pi\hbar^2}\right)^2 \left|\langle f|QTP|o\rangle\right|^2 \rho(E-E_f) \qquad (1)$$

where $|f\rangle$ is a complicated state of the Q-space and $|o\rangle$ is the ground-state. The quantities v,μ are velocities and reduced masses respectively. Solving the equation for QTP by iteration one finds that it separates into two factors

$$\langle f | QTP | o \rangle = \sum_i \mathcal{T}_{fi}\, t_{io} \qquad (2)$$

where the states labeled by i are a complete set in the Q-space. The operator t is to comprise all the graphs whose last interaction on the left side is V_{PQ} =PVQ (V = total interaction) while $\mathcal{T}$ is to represent all graphs containing the interaction V_{QQ} = QVQ only.

In the further calculation, we apply the random-matrix model of Weidenmüller and coworkers /1/ to the residual interaction V_{QQ}. Interpreting like in /1/ energy-averages as ensemble-averages over random-matrices V_{QQ}, the averaged cross-section for deep-inelastic processes is proportional to the quantity:

$$\alpha := \overline{\sum_{ij} \mathcal{T}_{fi}\, t_{io}\, t_{oj}\, \mathcal{T}_{jf}} \qquad (3)$$

Decomposing the following quantities into averaged and fluctuating parts

$$\mathcal{T}_{fi}\mathcal{T}_{jf} = \overline{\mathcal{T}_{fi}\mathcal{T}_{jf}} + (\mathcal{T}_{fi}\mathcal{T}_{jf})^{fl} \qquad (4)$$

$$t_{io}\, t_{oj} = \overline{t_{io}\, t_{oj}} + (t_{io}\, t_{oj})^{fl} \qquad (5)$$

$$t_{io} = \overline{t_{io}} + t_{io}^{fl} \qquad (6)$$

and assuming the fluctuations of $(\mathcal{T}\mathcal{T})$ and $(t\,t)$ to be statistically independent one obtains

$$\alpha = \overline{\mathcal{T}_{fi}\mathcal{T}_{if}} \left\{ \overline{t_{io}}\,\overline{t_{oi}} + \overline{t_{io}^{fl}\, t_{oi}^{fl}} \right\} \qquad (7)$$

(i=j is a result of the averaging). The term $\overline{\mathcal{T}\mathcal{T}}$ corresponds exactly to the cross-section calculated by Weidenmüller et al./1/, while the second factor {....} is not in their theory. This extra-term describes how the doorway-states feed probability into the space of complicated configurations.

As for the first term in (7)

$$\beta = \overline{\mathcal{T}_{fi}\mathcal{T}_{if}}\; \overline{t_{io}}\; \overline{t_{oi}} \qquad (8)$$

we note that the calculation of $\overline{t}$ requires a coupled-channel calculation in P-space, where the optical potential is determined by the parameters of the random-matrix model. Similar to ref. /1/ this calculation yields an ensemble-averaged density operator in Q-space

$$\bar{\rho} = G_{opt}^{(+)} V_{QP} |\Psi_P\rangle\langle\Psi_P| V_{PQ} G_{opt}^{(-)} + \\ + G_{opt}^{(+)} \overline{V_{QQ} \bar{\rho} V_{QQ}} G_{opt}^{(-)} \qquad (9)$$

where the Green's function $G_{opt}^{(+)}$ is defined as in ref. /1/; and $|\Psi_P\rangle$ is the solution of the coupled-channel equations in P-space. These equations must be solved with the ordinary boundary-conditions of a reaction problem.

The quantity β turns out to be given by

$$\beta = \langle f | \bar{\rho} | f \rangle \qquad (10)$$

The physical picture underlying (9) is very simple: first doorway-states are excited by a direct mechanism which subsequently decay into the complicated Q-states due to the interaction V_{QP}. The dynamics in Q-space is treated by the random-matrix model. The second term $\overline{t^{\mu\epsilon} t^{\mu\epsilon}}$ related to the initial stage in (7) is negligible if t varies slowly in the energy-averaging interval. It possibly may be treated with the methods of the Hauser-Feshbach theory.

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High Density Nuclear Mach Shock Waves in Relativistic Nucleus Nucleus Collisions by H.Stöcker, W. Scheid and W. Greiner

High Density Nuclear Mach Shock Waves (HDNMSW) occurring in central heavy ion collisions of high energy are up to now the only tool to produce and investigate bulks of highly excited and strongly compressed nuclear matter. Due to strong meson (π-,σ-) condensates phase transitions of dense nuclear matter into density isomeric states (superdense nuclei) can be expected. We discuss the occurrence of pion condensation in - and the influence of phase transitions on - relativistic nucleus nucleus collisions. We calculate the propagation of HDNMSW in a relativistic dynamical model. The comparison of the calculated angular - and energy distributions for the emission of matter with recent experimental data seems to indicate a phase transition in nuclear matter at densities of about $3\rho_o$.