On the Relevance of $\Delta-\Delta$ and $N-\Delta$ Correlations in Nuclear Matter Calculations.

R. Cenni and P. Saracco
Dipartimento di Fisica dell'Università - Genova
INFN, Sezione di Genova - Via Dodecaneso 33, 16146 Genova

Md A. Matin
Department of Physics, Nistarini College - Purulia 723101, India

(ricevuto l'11 Febbraio 1991; approvato il 13 Marzo 1991)

Summary. — The relevance of short range correlations between two $\Delta$’s or a $\Delta$ and a nucleon in evaluating the nuclear binding energy is shown, first by means of a naive model and then within a coupled-channel calculation in which the Hilbert space is enlarged in order to include the $\Delta$ resonance as well. It comes out that direct $\omega$-exchange between $\Delta$’s or a $\Delta$ and a nucleon gives rise, as expected, to a significant repulsion, but the $\pi$-and $\varphi$-exchange in the same conditions can provide, with reasonable parameters, an extra binding whose relevance has not been exhaustively explored yet.

PACS 21.65 – Nuclear matter.

1. – Introduction.

The role of the $\Delta_{33}$-resonance, intended as a true degree of freedom of a nuclear system, has been extensively examined in the recent years [1, 2]. Its relevance has been pointed out not only in intermediate-energy processes, but also in evaluating the properties of the nuclear ground state, where the $\Delta$ comes into plays only as a virtual excitation.

In particular the Bonn group constructed the Bonn potential [3-7] by means of meson exchanges and explicitly including diagrams with intermediate $\Delta$ states, which turned out of great relevance in providing the nuclear binding [3, 8]. As a by-product, calculations provide a large number of $\Delta$’s present in the nuclear ground state [9, 10] (of the order of 7%).

How the $\Delta$ dynamics, in its whole complexity, can influence the nuclear binding energy (BE) is nevertheless a topic which at present has not been fully investigated, and represents the purpose of the present, preliminary paper. First of all let us remark that information about $\Delta$ dynamics, apart from the $\pi N \Delta$ vertex (well known from $\pi N$ scattering), cannot be extracted directly from the experiments, but essen-
tially come from model-dependent analyses. Thus we can desume with good confidence only some qualitative statements.

We know rather well, for instance, the long-range part of the $N\Delta$ exchange interaction (i.e. $N\Delta \rightarrow \Delta N$) or the excitation potentials (i.e. $NN \rightarrow N\Delta$ and similar), which are ascribed to a pion exchange. But when we come to the direct $N\Delta$ or $\Delta\Delta$ long-range interaction, the $\pi\Delta$ vertex is involved, for which, to our knowledge, no reliable phenomenological information is available at present. For the short-range interaction the situation is even worse, and we can only guess that some repulsive short-range correlations (SRC) exist for $N\Delta$ or $\Delta\Delta$ very much in the same way as in the $NN$ case. This seems to be at least likely, either considering meson theory or the various kinds of bag models (but other effects cannot be excluded, as for instance the explanation given by Faessler and coworker to the nuclear hard core in the frame of the bag model [11, 12]). We shall assume in this paper that two baryons cannot live really too near one to another and our purpose is to understand if and how SRC can affect the nuclear binding.

We shall try to reach our goal first by means of a very simplified model embodying $\pi$-exchange plus repulsive SRC (sect. 2). Without examining numerical results, this section will show that quantitatively relevant effects are expected from $N\Delta$ and $\Delta\Delta$ direct interaction.

This seems to go beyond the scheme of the Bonn potential: in that frame (let us oversimplify the situation) one assumes that nucleons can exchange $\pi$, $\rho$, $\omega$, ... mesons and moreover the so-called box diagrams can occur (fig. 1a, b). They are explicitly evaluated and then embodied in the (energy-dependent) potential.

The analysis of sect. 2, even in the presence of repulsive SRC only, suggests a wider scheme, in which $\Delta\Delta$ and $N\Delta$ are also allowed to interact. This can be done in the frame of the so-called «coupled-channel calculations», a procedure

![Fig. 1. The box diagrams. a) and b) the box diagrams (with one or two $\Delta$'s respectively) in $NN$ scattering. c) and d) contribution of the box diagrams to the BE (direct). e) and f) contribution of the box diagrams to the BE (exchange).](image)