Application of Relativistic Mean Field Theory with Pion to Gamow-Teller Transition Strengths in Nuclei

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We develop a mean field model based on the Relativistic Mean Field (RMF) Theory which treats the pion explicitly by breaking the parity symmetry of single-particle states. The application of the model to N=Z nuclei shows that the pion affects the nuclear mean field largely. On this basis it was suggested that an occurrence of surface pion condensations is possible in medium and heavy nuclei [1]. In the present study we examine the physical significance of such effect for nuclear structure observables such as the Gamow-Teller strengths obtained by experiments of (p,n) reactions performed in RCNP [2]. These experiments show that only a half of the strength is carried by 1p-1h excitations, while the rest can be interpreted as carried by 2p-2h excitations due to the coupling to 1p-1h states by the strong tensor force [3, 4].

In order to reproduce the above effect we have utilized the RMF+Pion model formalism for calculation of Gamow-Teller strengths in medium and heavy nuclei. The Gamow-Teller transition matrix elements were derived for the case of RMF and RMF+Pion model wave functions.

We developed a numerical algorithm for Tamm Dankoff (TDA) mixing of the strengths through $\vec{\sigma}\cdot\vec{\sigma}$ and $\vec{\sigma}\cdot\vec{\sigma}\,\delta(\vec{r_1}-\vec{r_2})$ residual interactions providing respective model predictions for the Gamow-Teller strengths. The developed formalism and numerical programs have been applied to calculate the Gamow-Teller transition strengths in ^{56}Ni and ^{90}Zr. We found that the involvement of the pionic degrees of freedom redistributes the Gamow-Teller transition strength to a larger number of states at higher energies as an effect of the parity mixing. This is demonstrated in Fig. 1 for ^{90}Zr comparing (a) the result of a pure RMF wave function with (c) the case where RMF+Pion states are considered.

The TDA mixing due to residual interaction additionally modifies the strengths. This is seen in Fig 1 (a),(b) for RMF wave function and Fig 1 (c),(e) for RMF+Pion wave function, where in both cases the δ- residual interaction is applied [for the case of RMF+Pion the respective log scaled patterns are also shown, Fig 1 (d),(f)].

The analysis of both residual interactions with respect to the RMF+Pion wave function shows that the effect caused by the simple $\vec{\sigma}\cdot\vec{\sigma}$ (contact) term is not enough to reproduce the strength provided by the 2p-2h channel. The respective theoretical patterns for the Gamow-Teller transition strength show a qualitative agreement with experimental data in ^{90}Zr at weak residual interaction, but with the increasing TDA mixing the Gamow-Teller (GT) resonance is shifted to rather higher energy compared to the experiment. That is why we take the more realistic $\vec{\sigma}\cdot\vec{\sigma}\,\delta(\vec{r_1}-\vec{r_2})$ residual interaction which requires the calculation of two-body matrix elements.

So, the RMF+Pion+δ patterns, Fig. 1 (e) and (f) indicate the possibility for redistributing the strength in a way that keeps the resonance structure closer to the experimental shape. This result gives a basis for a further adjustment of model parameters to reproduce the experimental strengths quantitatively.

The results of our model study suggest a considerable role of the pion degrees of freedom

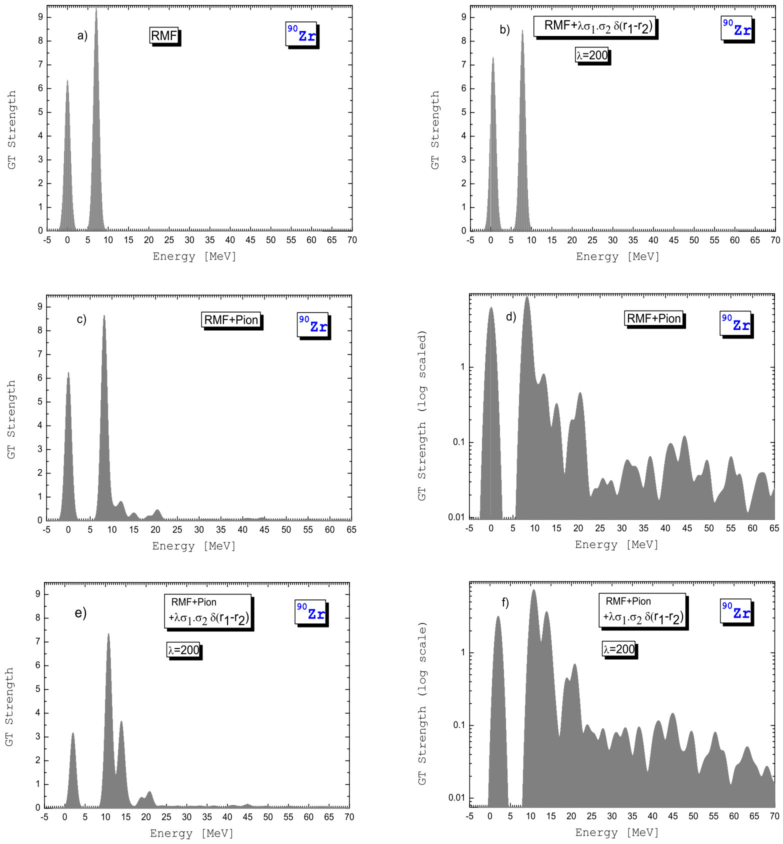

Figure 1: Gamow Teller transition strengths for ^{90}Zr obtained by: (a) pure RMF wave function; (b) RMF+δ- dependent residual interaction; (c) RMF+Pion wave function [(d) log scaled pattern]; (e) RMF+Pion+δ [(f) log scaled].

on these observables. The need of future precise experimental data on Gamow-Teller transition strength as well as further refinement of model formalism is very important to study extensively this role.

References

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