Diproton Correlation and Two-Proton Emission from Proton-Rich Nuclei

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博士論文

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（陽子過剰な原子核の陽子対相関と二陽子放出崩壊）

大石　知広

平成２５年

Contents

Abstract

In this thesis, we investigate the two-proton emission in proton-rich nuclei. The aim of this study is to discuss the relation between the observables in the emission and the diproton correlation, which is a characteristic phenomenon due to the nuclear pairing correlation.

The pairing correlation between two nucleons plays an essential role in nuclear structure. Especially, two nucleons near the Fermi surface in nuclei have been predicted to make the "diproton" and "dineutron" correlations. These correlations mean the spatial localization of two nucleons, associated with the dominance of the spin-singlet configuration. This is a characteristic prediction of the modern theory of nuclear structures, and to investigate this property is expected to enhance the predictive powers of that theory. Especially, the dineutron correlation has been actively studied recently with a strong connection to the exotic features of neutron-rich nuclei. These nuclei far from the beta-stability line have attracted novel interests in nuclear physics, and their basic information have been extensively investigated for the past few decades.

On the other hand, the diproton correlation in proton-rich nuclei has been less studied [1]. Given the situation, in the former half of this thesis, we discuss the universality of the diproton and dineutron correlations, with a theoretical study of the ^{17,18}Ne and ^{18}O nuclei. Our study is based on a three-body model, which provides a semi-microscopic description for the two nucleons inside nuclei. We show that a diproton correlation exists in the ground state of ^{17,18}Ne, similarly to a dineutron correlation in ^{18}O. It is also shown that the Coulomb repulsive force between the two protons does not affect significantly this correlation. Consequently, the nuclear pairing interaction plays an important role to occur the dinucleon correlations inside nuclei.

In the later half of this thesis, we focus on the relation between the diproton correlation and the two-proton emission. Even with theoretical predictions, for the dinucleon correlations, there have been no direct experimental evidences, because of a difficulty to access the intrinsic structures of nuclei. Recently, on the other hand, "two-proton emission" has been focused as a direct probe into the diproton correlation: through this process, a pair of protons is emitted directly from the parent nuclei. The emitted two protons are expected to carry information about the nuclear pairing correlation, possibly including the diproton correlation. In order to extract information on the diproton correlation, one has to treat both the quantum meta-stability and the many-body properties in an unified framework. For this purpose, we develop a time-dependent three-body model [2]. By applying this model to the ^{6}Be nucleus, which is the lightest two-proton emitter, we investigate several novel properties about the role of pairing correlations in the meta-stable state. We find that, by considering the diproton correlation in the initial state of the two protons, (i) the experimental decay width of ^{6}Be is well reproduced (see Fig.1), and (ii) the two protons are expected to be emitted mainly as a diproton-like cluster with the spin-singlet configuration, in the early stage of the emission. These results strongly suggest the dependence of the two-proton emission on the diproton correlation. Namely, the two-proton emission can be an efficient tool to access the diproton correlation.

Despite these important theoretical findings, in order to extract the information on the diproton correlation from the experimental data, there still remain several points to be improved. The most important one is to take the final-state interactions into account sufficiently. For the two-proton emission from the ^{6}Be nucleus, our result for the early stage of the emission predicts a dominant diproton-like configuration. On the other hand, there is only little signal of such a configuration in the experimental data of the energy-angular correlation pattern, which correspond to the late stage of the emission. This discrepancy is due to a strong disruption of the diproton

correlation in the late stage, caused by the final-state interactions among all the particles. In order to establish the agreement between the calculated result and the experimental data, we need to expand our model-space so that a longer time-evolution can be carried out. After this improvement, we will be able to discuss in detail the relation between the diproton correlation and the two-proton emission.

As a summary of this thesis, the first step to investigate the diproton correlation by means of the two-proton emission has been established. The time-dependent method based on the three-body model has provided an intuitive way to describe the quantum dynamics with a great advantage to understand the role of pairing correlations. We expect that the improved time-dependent method will be a powerful tool for two-proton emissions, and also for other quantum meta-stable processes. After further investigations, the obtained knowledge of the pairing correlations and the meta-stable processes will be an important result not only for nuclear physics but also for atomic, molecular, condensed matter and quantum informative physics.

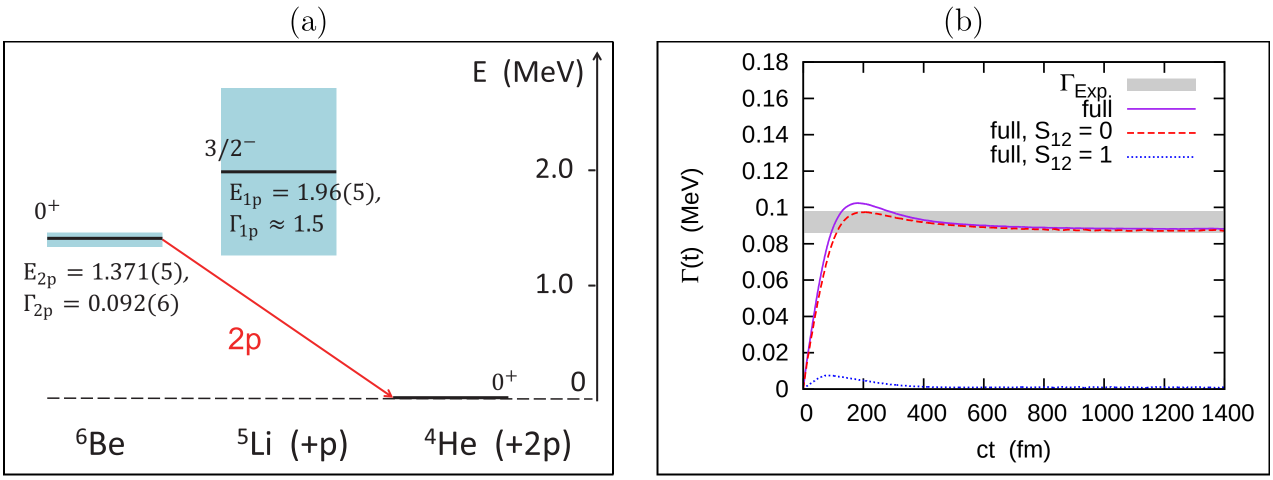

Figure 1: (a): The decay scheme of the ^{6}Be nucleus, which is the lightest two-proton emitter. (b): The decay width of ^{6}Be, calculated with our time-dependent three-body model. The pairing correlations between the emitted two protons are fully taken into account. The total width is plotted as "full", whereas the partial decay widths due to the spin-singlet and triplet configurations of the two protons are plotted as "full, $S_{12} = 0$" and "full, $S_{12} = 1$", respectively. The experimental decay width is also indicated by the shaded area.

References

[1] T. Oishi, K. Hagino and H. Sagawa, Phys. Rev. C **82**, 024315 (2010).

[2] T. Maruyama, T. Oishi, K. Hagino and H. Sagawa, Phys. Rev. C **86**, 044301 (2012).