Two Proton Decay in ^{12}O

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Two-proton radioactivity was observed experimentally in the decay of ^{45}Fe [1], ^{54}Zn [2] and ^{48}Ni [3]. From then many theoretical studies of one and two-proton radioactivity have been carried out within the framework of different models including RMF+BCS approach for medium mass region [4]. Towards light mass region proton-proton correlations were observed in two-proton decay of ^{19}Mg and ^{16}Ne by Mukha *et al.* [5]. Recently, different mechanism of two-proton emission from proton-rich nuclei ^{23}Al and ^{22}Mg has been investigated by Ma *et al.* [6] and transition from direct to sequential two-proton decay in sd shell nuclei is observed by Golubkova *et al.* [7]. Encouraged with these recent studies of two proton emission in light mass nuclei, we have applied our RMF+BCS approach [4, 8, 9] for the study of two proton emission in light mass region and in this paper we present our result of two proton emission in ^{12}O.

TABLE I: One proton and two proton separation energy for ^{12}O

^{12}O	S_{2p} [MeV]	S_p [MeV]
RMF(TMA)	-0.1	0.325
Mac-Mic	-1.92	3.261
Expt.	-1.638	-0.32

We have calculated ground state properties of ^{12}O using deformed RMF+BCS calculation with TMA parameter [4] and in Table I, we have mentioned two- and one-proton separation energy (S_{2p} and S_p) which are compared with Macroscopic-microscopic approach (Mac-Mic) with Nilson Strutinsky prescription [10, 11] and experimental data [12]. It is satisfactory to note that our results with both the theories are in reasonable agreement with available experimental data [12] which earmark our prediction. Moreover, it is found that ^{12}O and its daughter nucleus after 2p-emission ^{10}C both are having their spherical ground state configuration with β_{2m}= 0 which allow us to employ the RMF+BCS approach with spherical symmetry [8, 9] for the analysis of results in terms of spherical single particle wave functions and spherical single particle energy levels. In this regard in FIG. 1, we have displayed our results of spherical RMF calculation [8, 9].

In the upper panel, we have displayed sum of scalar and vector potential (right scale) along with sum of potential and centrifugal barrier shown by dot-dashed line. This nucleus ^{12}O acquires long life time against two-proton decay due to the combined barrier provided by the Coulomb and centrifugal effects, even though it has negative two proton separation energy. The combined effect of Coulomb barrier and centrifugal barrier prevents the protons from quickly leaving the proton rich nucleus ^{12}O located beyond the two-proton drip-line as can be seen from upper panel of FIG. 1. The delay associated with the tunneling process allows for the observation of two-proton radioactivity. The wave function for the proton single particle states plotted in up-

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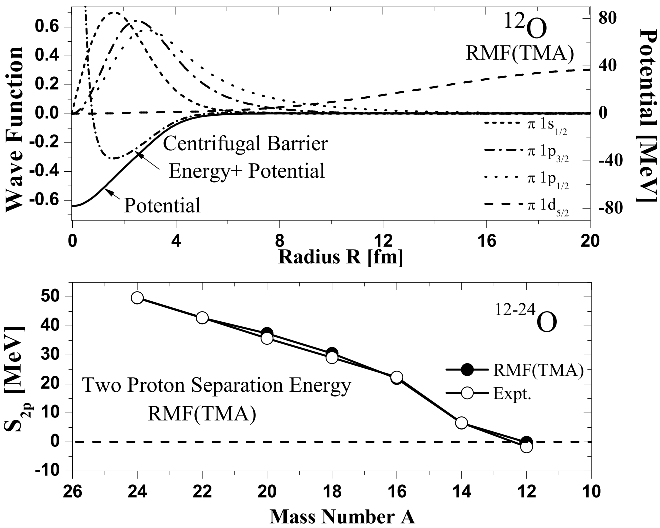

FIG. 1: Lower Panel: Calculated results for two proton separation energy, S_{2p} for the O isotopes obtained within the spherical RMF(TMA) along with available experimental data [12]. Upper Panel: The RMF potential energy (sum of the scalar and vector potentials) is shown as a function of radius along with sum of RMF potential energy and the centrifugal barrier energy for last occupied proton single particle state (right scale). This panel also shows radial wave functions of significant proton single particle states for the nucleus ^{12}O.

per panel of FIG. 1 are clearly seen to be confined within a radial range of about 8 fm and has a decaying component outside this region. In contrast, the main part of the wave function for other positive energy state e.g. $1d_{5/2}$ is seen to be spread over outside the potential region. Hence nucleus ^{12}O remains bound due to centrifugal barrier with wavefunction inside the potential region and possesses a bit long life time to be a potential candidate of two proton emission.

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References

[1] M. Pfutzner et al., Eur. Phys. J A **14** (2002) 279.

[2] P. Ascher et. al., Phys. Rev. Lett. **107** (2011) 102502.

[3] M. Pomorski et. al., Phys. Rev. C **83** (2011) 061303.

[4] D. Singh et al., Int. Jour. Mod. Phys. E **21** (2012) 1250076.

[5] I. Mukha et al., Phys. Rev. C **77** (2008) 061303(R).

[6] Y. G. Ma et al., Phys. Lett. B **743** (2015) 306.

[7] T. A. Golubkova et al., arXiv:1605.01013 (2016).

[8] G. Saxena et al., Physics of Atomic Nuclei **80** (2017) 211.

[9] G. Saxena et al., Int. Jour. Mod. Phys. E **22** (2013) 1350025.

[10] Mamta Aggarwal, Phys. Rev. C **89** (2014) 024325.

[11] Mamta Aggarwal, Phys. Lett. B **693** (2010) 489.

[12] M. Wang et al., Chin. Phys. C **36** (2012) 1603. http://www.nndc.bnl.gov/