Neutrino-^{12}C Interactions within the PQRPA

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In neutrino oscillation experiments with liquid scintillators, the charge-exchange reactions $^{12}C(\nu_e, e^-)^{12}N$ and $^{12}C(\nu_\mu, \mu^-)^{12}N$, both *exclusive* (to the 1^+ ground state) and *inclusive* (to all final states), are just tools. As such, and to be useful, the corresponding cross sections σ_ν^{exc} and σ_ν^{inc} must be accurately accounted for by nuclear structure models. From recent works [1-4] we have learned, however, that neither RPA nor QRPA are able to explain the weak processes (β-decays, μ-capture, and neutrino induced reactions) among the ground states of the triad $\{^{12}B, ^{12}C, ^{12}N\}$: (i) in the plain RPA a rescaling factor of order of 4 is needed to bring the calculations and data in agreement [1], (ii) a subsequent *ad hoc* inclusion of partial occupancy of the $p_{1/2}$ subshell reduces this factor to less than 2 [1-2], and (iii) when the RPA is supplemented with the pairing correlations selfconsistently through the QRPA, the exclusive cross sections turn out to be again overestimated by a factor of $\cong 4$ [4]. Moreover attention was called to difficulties in choosing the ground state of ^{12}N when the QRPA is used [4]. We explain the origin of the difficulties that appear in a straightforward application of the BCS approximation in a light nucleus such as ^{12}C, and we demonstrate that the problem is circumvented by the employment of the particle number projected BCS (PBCS). We simultaneously show that the proton-neutron QRPA is not a recommended approach, and that the aforementioned RPA-QRPA puzzle is solved within the projected QRPA (PQRPA) for the charge-exchange excitations [5]. The later approach furnishes satisfactory results not only for the weak processes among of the triad $\{^{12}B, ^{12}C, ^{12}N\}$, but also for the inclusive ones. We sketch as well a new formalism for the nuclear weak observables that furnishes very simple final formulae for the muon capture rate and neutrino-nucleus cross section.

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