Core excitation in ^{12}Be

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Motivated by much recent discussion of the $N=8$ neutron shell closure, we review the theoretical description of ^{12}Be within a three-body ($n+n+^{10}\text{Be}$) model with core excitation. Agreement with recently deduced $\langle ^{11}\text{Be} | ^{12}\text{Be} \rangle$ spectroscopic factors requires a smaller deformation of the ^{10}Be core in ^{12}Be than in ^{11}Be , with a reduced role for core excitation. Observables for the ground state and 2^+ , 1^- and 0_2^+ excited states of ^{12}Be are presented. Limitations and improvements of the model are discussed.

1. Introduction

As one explores nuclei far from the beta-stability line, many basic nuclear properties have to be re-assessed. The magic numbers themselves are no exception. Exotic light nuclei are attractive for such studies since they promise a simpler description of the essential phenomena. An example is the insight being gained into the $N=8$ neutron-shell closure from precise measurements on the mass 11 and mass 12 systems. These new data, in turn, require the reassessment of theoretical models. Here we reconsider whether a $n+n+^{10}\text{Be}$ three-body model of ^{12}Be , which includes core excitation [1], can accommodate present empirical knowledge.

Interest in the beryllium isotopes is long standing, going back to the measurement of a strong $^{10}\text{Be}(2_1^+ \rightarrow 0^+, \text{gs})$ E2 transition [2], suggestive of large collectivity. This collectivity in ^{10}Be contributes strongly to the observed parity inversion of the two particle-bound states of ^{11}Be , with energies $E(1/2^+) = -0.5$ MeV and $E(1/2^-) = -0.18$ MeV.

Experimental information on the $^{11}\text{Be}(\text{gs})$ from different sources is now broadly in agreement. An inverse kinematics $^{11}\text{Be}(\text{p}, \text{d})$ experiment at GANIL [3] gives results consistent with an s-wave- $^{10}\text{Be}(0^+)$ component in excess of 70% and a 10–20% d-wave- $^{10}\text{Be}(2^+)$ neutron component in the $^{11}\text{Be}(\text{gs})$. Theoretical predictions, using a $n+^{10}\text{Be}$ two-body model with core excitation [4] and from shell model calculations [5,6], are in agreement with this, and with the findings of the $^9\text{Be}(^{11}\text{Be}, ^{10}\text{Be}\gamma)$ one-neutron removal experiment performed at the NSCL [5]. Since the valence neutron in the $^{11}\text{Be}(\text{gs})$ occupies the sd-shell, a pertinent question is whether one recovers the $p_{1/2}^2$ closed shell configuration in

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^{12}Be upon addition of a neutron. This is of interest not only for the structure of ^{12}Be but also for that of the heavier beryllium isotopes.

Four recent experimental studies of ^{12}Be are of direct relevance. The ($^{12}\text{Be}, ^{11}\text{Be}\gamma$) one-neutron removal measurements at the NSCL [7] allowed a direct estimate of the $\langle ^{11}\text{Be}(j^\pi) | ^{12}\text{Be}(\text{gs}) \rangle$ spectroscopic factors. Supported by this data, a shell model analysis then places the two valence neutrons two-thirds in the sd-shell, and one-third in the p-shell. Proton inelastic scattering from ^{12}Be , performed at RIKEN at 54 MeV/nucleon [8], and analysed within the rotational model, deduces a nuclear deformation length for ^{12}Be of 2.00 ± 0.23 fm. Associated shell model arguments again suggest a large ($\approx 45\%$) sd-shell $^{12}\text{Be}(\text{gs})$ admixture. In addition, a Coulomb excitation experiment, at RIKEN, reports a $^{12}\text{Be}(1^-; 2.73 \text{ MeV})$ excited state [9]. A state at this energy was previously observed and given a 0_2^+ assignment [10]. A recent report, however, shows experimental evidence for an excited 0^+ state at 2.24 MeV [11].

There have also been several theoretical investigations of ^{12}Be . Shell model studies [12,10,6,13] predict, consistently, a significant (sd) 2 component for the valence neutrons. The available shell model calculations treat the p- and sd-shells separately, each with up to $4\hbar\omega$ excitations, but do not include full (psd)-shell configuration mixing. While such calculations are becoming feasible, the determination of a suitable effective interaction in this extended model space is itself a major project. Between the microscopic and macroscopic models, the molecular orbital model was recently applied to the beryllium isotopes [14]. There, ^{12}Be is treated as a 4-neutron plus two α structure. Once again, the breakdown of the N=8 shell closure, and the role of the spin-orbit interaction are important issues.

In recent years there have been a number of attempts [15–17] to start from a state-independent effective nucleon-nucleon interaction (such as the Volkov or the Minnesota potential), and *deduce* the existence of s-wave intruder states and N=8 shell melting in nuclei such as $^{10,11}\text{Li}$ and ^{11}Be . All these attempts give p-shell states at energies below those of sd-shell states, and therefore fail to describe the inversions seen experimentally. There is thus still a need for few-body models which use phenomenological neutron-core interactions fitted to measured resonances and virtual states. The applicability of the conceptually simple few-body models, as a guide to our understanding of these and similar light systems, is thus an important question.

The first study [18] of ^{12}Be assumed a $n+n+^{10}\text{Be}$ three-body model with an inert core and showed that the n-core interaction had to be modified to reproduce the empirical two-neutron separation energy S_{2n} . Then, both $p_{1/2}^2$ and $s_{1/2}^2$ valence neutron configurations were equally possible. Subsequently, core excitation effects were included [1], allowing the then known properties of ^{12}Be to be reproduced. Significantly, that model yielded a very small $p_{1/2}^2-^{10}\text{Be}(0^+)$ and a very large $^{10}\text{Be}(2^+)$ excited core component. It is necessary, therefore, to assess whether a three-body excited core model can accommodate the new experimental results for ^{12}Be .

2. Model Space and antisymmetrisation

In the present ^{12}Be calculations, the $0^+(\text{gs})$ and $2^+(3.368 \text{ MeV})$ states of the ^{10}Be core are included. The intrinsic Hamiltonian of the core is assumed to be rotational. We assume

local interactions between the bodies, using the GPT effective interaction [19] between the neutrons. The neutron-core interactions are discussed below. The three-body problem is written in hyperspherical coordinates, and the set of coupled hyperradial equations solved using a Gauss-Laguerre basis. The maximum hypermoment is K_{max} , which also truncates the maximum angular momentum between the core and the neutrons, called ℓ_{max} . Most calculations use $K_{max}=20$, but for excited states calculations, typically $K_{max}=12$. The maximum number of Jacobi polynomials included in the hyperangular expansion was 30, and the number of Gauss-Laguerre basis states used was also 30. The hyperradial grid extended to $\rho_{max}=20$ fm.

Within this three-body model, n-core antisymmetrisation is restricted to the application of the Pauli principle that the valence neutrons do not overlap occupied core states, which are assumed to be fully occupied. We apply the Feshbach-Pauli-projection method [21,20]. The lowest states of the n-core subsystem, which overlap the occupied $s_{1/2}$ and $p_{3/2}$ core states, are then projected out prior to diagonalising the three-body Hamiltonian. Details can be found in [1], but the procedure consists principally of two parts. First, 3-body forbidden states are constructed as spline expansions of the forbidden n-core wavefunctions, and then Gramm-Schmidt orthogonalisation is used. In these steps the radial ranges of the splines and the 2-body bound states must cover the values allowed by ρ_{max} . The number and the spacing of the spline-functions must also be consistent with the hyperradial grid and step [1]. We use bound states and 20 spline functions which extend to 20 fm in their respective coordinates. In the Gramm-Schmidt orthogonalisation, to avoid numerical instabilities, orthogonalised forbidden states are omitted if their norm falls below a parameter we call $\mathcal{O}_{min}$. Orthogonalised norms can become low, especially when dealing with three-body states J^π that can be formed from products of two distinct forbidden states. Here, therefore, $[s_{1/2}p_{3/2}]_{J^\pi}$ two-neutron configurations with $J^\pi = 1^-$ or 2^- are sensitive to this parameter, which should be made as small as possible, subject to the calculations yielding stable results. We use $\mathcal{O}_{min} = 0.1$. Results for this value have converged.

In practice, antisymmetrisation effects are also partially included in the n-core interaction, since the parity inversion in ^{11}Be is not the result only of couplings to excited core configurations. Since the deformation of the intrinsic state of the ^{10}Be core necessarily requires neutrons in the $p_{1/2}$ as well as in the $p_{3/2}$ sub-shell, the negative parity $p_{1/2}$ states in ^{11}Be are strongly affected by correlations with the other p-shell neutrons from the core. We take this into account through an effective ℓ -dependence in this n-core interaction. The validity of this treatment of the p-wave potential has been tested for ^{11}Be [4], but needs to be further examined within ^{12}Be models.

3. The n- ^{10}Be subsystem

We begin our consideration of the n-core interaction from the earlier be12-b model of reference [1], now denoted EXC1. Its main features are a strong nuclear quadrupole deformation $\beta_2 = 0.67$ and a weak parity-dependence in the potential depths. These V_ℓ were chosen to reproduce the ^{11}Be bound states and d-wave resonance energies. The p-wave strength, $\approx 10\%$ less than that in the s- and d-waves, is argued as an additional Pauli principle repulsion in p-waves. A consequence is the small calculated $p_{1/2}^2$ component in

Table 1

Model interactions for the n- ^{10}Be system. In all cases the Woods-Saxon potential radius is 2.4833 fm, with diffuseness 0.65 fm.

	$V_s(\text{MeV})$	$V_p(\text{MeV})$	$V_d(\text{MeV})$	$V_{so}(\text{MeV})$	β_2
EXC1	54.239	49.672	54.239	8.5	0.67
EXC2	61.650	51.202	58.000	13.0	0.30
EXC3	54.545	48.256	54.545	6.0	0.67
EXC4	52.100	49.356	49.356	6.0	0.85
EXC5	58.200	52.141	54.000	13.0	0.50

the $^{12}\text{Be}(\text{gs})$. This is at variance with the recent nucleon-removal reaction measurements [7] discussed earlier.

One must remember that the presence of both $p_{1/2}$ and $d_{5/2}$ -waves means that the spin-orbit potential plays a significant role, see also [14]. That is, the three-body calculations contain a combination of spin-orbit, ℓ -dependent, and core deformation effects, and models which reproduce a given set of physical ^{11}Be observables may produce quite different results for ^{12}Be . This investigation attempts to clarify how each of these effects contributes to the description of ^{12}Be .

Table 2

Calculated ^{11}Be bound states for the model n- ^{10}Be interactions shown (energies in MeV, radii in fm and B(E1) in $e^2 \text{ fm}$). The measured rms radius is from [22] and the B(E1) from [23].

	$E(1/2^+)$	$P(s_{1/2} \otimes 0^+)$	$\langle r^2 \rangle^{1/2}$	$E(1/2^-)$	$P(p_{1/2} \otimes 0^+)$	$B(E1)_{1/2^- \rightarrow 1/2^+}$
EXC1	-0.502	0.846	2.88	-0.185	0.784	0.13
EXC2	-0.497	0.938	2.92	-0.185	0.948	0.20
EXC3	-0.501	0.865	2.89	-0.181	0.708	0.12
EXC4	-0.499	0.864	2.90	-0.181	0.696	0.12
EXC5	-0.501	0.884	2.89	-0.181	0.903	0.17
exp	-0.50		2.9	-0.18	> 0.9	0.115
			± 0.05			± 0.010

If we allow parameter variation, and freedom also in V_ℓ , then we can produce the set of representative n-core potentials of Table 1. All potentials fit the two ^{11}Be bound state energies. Here, EXC2 has a lower deformation, compensated by a stronger ℓ -dependence and V_{so} . Case EXC3 has a lower V_{so} , preserving the original deformation and ℓ -dependence. Case EXC4 also has a lower V_{so} , but a stronger deformation and weak ℓ -dependence. Case EXC5 has a strong V_{so} , and deformation intermediate to EXC1 and EXC2. In all cases, the shape of the spin-orbit potential agrees with the definition in [1]. All potentials produce $\langle ^{10}\text{Be} | ^{11}\text{Be} \rangle$ spectroscopic factors within experimental limits, and also the predicted $^{11}\text{Be}(\text{gs})$ rms matter radius [22]. Models EXC2 and EXC5, predict a larger $p_{1/2}$ component for the ^{11}Be excited state, and $B(E1, 1/2^- \rightarrow 1/2^+)$ values slightly above

Table 3

Calculated two-neutron configuration probabilities for $^{12}\text{Be}(\text{gs})$, with $K_{\text{max}}=20$ and $\ell_{\text{max}}=12$. Energies are given in MeV, radii in fm, and the width of the calculated ^{10}Be fragment momentum distribution, denoted FWHM, is in MeV/c. The two-neutron separation energy is from [24], the matter rms radius from [25] and FWHM from [26].

	S_{2n}	$\langle r^2 \rangle^{1/2}$	FWHM	$P(s^2 \otimes 0^+)$	$P(p^2 \otimes 0^+)$	$P(d^2 \otimes 0^+)$	$P(\text{core}=2^+)$
EXC1	3.53	2.61	157.	0.27	0.09	0.19	0.42
EXC2	3.49	2.58	145.	0.24	0.20	0.31	0.22
EXC3	3.18	2.64	156.	0.34	0.09	0.15	0.42
EXC4	3.33	2.66	162.	0.40	0.06	0.11	0.42
EXC5	3.76	2.59	160.	0.26	0.14	0.24	0.35
exp	3.67	2.59					
	± 0.015	± 0.06					

the data [23], whereas EXC1,3,4 are in fair agreement. The calculated ^{11}Be observables are shown in Table 2. A drawback of models EXC2 and EXC5 is that the energy of the $^{11}\text{Be}(5/2^+, 1.28 \text{ MeV})$ resonance is not precisely reproduced. The correction needed in the central potential depth to restore this is of order 4-5 %.

4. Results for ^{12}Be

4.1. The ^{12}Be ground state

The calculated structures of the $^{12}\text{Be}(\text{gs})$ are shown in Table 3. As expected, the weak deformation EXC2 case produces the smallest excited core contribution, but S_{2n} is very close to the experimental value. The lower V_{so} models, EXC3 and EXC4, have more problems binding the two neutrons correctly. Case EXC5 is the most successful in binding the two neutrons. Only those models, EXC2,5, with lower deformation increase the $p_{1/2}^2$ component of the wavefunction, also predicting the largest $d_{5/2}^2$ occupations. Model EXC2 has the neutrons two-thirds in the (sd)-shell, in agreement with experiment [7].

The predicted rms radii are consistent with the value derived from the total reaction cross section [25,22]. The ^{10}Be fragment momentum distributions, calculated from the $^{12}\text{Be}(\text{gs})$ wave functions, cannot be discriminated, currently, given the limited accuracy of the available data [26].

4.2. The $\langle ^{11}\text{Be}(j^\pi) | ^{12}\text{Be}(\text{gs}) \rangle$ overlaps

We now re-express the calculated valence neutron shell occupancies in the $^{12}\text{Be}(\text{gs})$ models in terms of the one-neutron-removal spectroscopic factors to the two $^{11}\text{Be}(j^\pi)$ bound states. The spectroscopic factors $\mathcal{S}(j^\pi)$ are computed from the (numerically obtained) radial overlap functions $\mathcal{R}_{\ell j}(r)$ between the $^{12}\text{Be}(\text{gs})$ and $^{11}\text{Be}(j^\pi)$ bound states as

$$\mathcal{S}(j^\pi) = 2 \int r^2 dr |\mathcal{R}_{\ell j}(r)|^2, \quad (1)$$

where the factor of 2 accounts for the two active neutrons.

In [7], the deduced spectroscopic factors $\mathcal{S}(1/2^+)$ and $\mathcal{S}(1/2^-)$ were approximately equal. The spectroscopic factor to the unbound $^{11}\text{Be}(5/2^+)$ configuration could not be

Table 4

One-neutron-removal spectroscopic factors from $^{12}\text{Be}(\text{gs})$. The experimental values are taken from [7].

	$\mathcal{S}(1/2^+)$	$\mathcal{S}(1/2^-)$	$\mathcal{S}(5/2^+)$	$\mathcal{S}(1/2^+)/\mathcal{S}(1/2^-)$
EXC1	0.54	0.20	0.46	2.70
EXC2	0.44	0.38	0.58	1.16
EXC3	0.68	0.18	0.34	3.78
EXC4	0.82	0.10	0.28	8.20
EXC5	0.52	0.24	0.52	2.17
exp	0.42 ± 0.1	0.37 ± 0.1		≈ 1

measured in that experiment. Our calculated $\mathcal{S}(j^\pi)$ are shown in Table 4.

The ^{11}Be wavefunctions used to compute the overlaps are those produced by the most realistic ^{11}Be model (EXC1). Of the core excited models, only the weak deformation case (EXC2) is in agreement with the results of the knock-out reaction. The indication is that, adding the second neutron to ^{10}Be , the polarization of the core is diminished. This does not of course imply that the deformation of ^{12}Be itself is small.

Table 4 shows that the EXC2 model produces the largest overlap with the $^{11}\text{Be}(5/2^+)$ state. In fact, in this model the ^{12}Be ground state overlaps more with the $5/2^+$ state than the bound states in ^{11}Be , directly reflecting the strong d-wave component. It would be a powerful constraint of models to have an experimental verification of this strength.

4.3. Excited states of ^{12}Be

The first observed excited state of ^{12}Be , located at $E_x = 2.11$ MeV [27], has an unambiguous 2^+ spin assignment. The three-body excited core models predict a 2^+ state with mainly sd-admixture, and a 50% core excited component. We have verified that even though the 2^+ energies relative to threshold may shift considerably, the corresponding excitation energies are rather stable, tending to increase slightly with K_{max} . Calculations for $K_{max}=12$ (the computational limit) produce excitation energies $E_x \approx 2$ MeV in agreement with the experimental value (Table 5). Parameter sensitivity suggests that a theoretical error of 0.3 MeV should be added to these energies, due mainly to the Pauli projection process.

In the recent work by Iwasaki *et al.* [8], a nuclear deformation length was extracted from proton inelastic scattering. Even though no electromagnetic experimental value is quoted, shell model calculations performed therein, suggest the data is consistent with $\delta_{e.m.} = 2.79$ fm. This corresponds to $B(E2, 0^+ \rightarrow 2^+) = [\frac{3ZR\delta_{e.m.}}{4\pi}]^2 \approx 50 e^2 \text{ fm}^4$. The value predicted by our models for the B(E2) are also displayed in Table 5 and have been calculated assuming a quadrupole moment for the core of $7.2 e^2 \text{ fm}^2$ [2]. The models predict E2 transition strengths which are close to the value indicated by [8], the lower values associated with the models having less core excitation. The experiment [8] actually measured nuclear rather than electric deformation, and these will be different if the two valence neutrons contribute significantly to the quadrupole transition densities. We found the $LSJ = 200$ transition densities $\rho_{LSJ}(r)$ for our three-body models, and calculated approximate deformation lengths by matching $\rho_{LSJ}(r) \sim \delta_{LSJ} \rho'(r)$ in the surface region,

Table 5

Results for the excitation energies of ^{12}Be for the set of ^{10}Be -n interactions defined above (energies in MeV , B(E1) in $e^2 \text{ fm}^2$ and B(E2) in $e^2 \text{ fm}^4$).

	$E_x(0_2^+)$	$E_x(2^+)$	B(E2)	$E_x(1^-)$	B(E1)
EXC1	1.9	2.0	20.	2.8	0.05
EXC2	2.0	2.0	4.	2.3	0.05
EXC3	1.4	1.9	21.	2.7	0.05
EXC4	1.7	2.1	38.	2.7	0.06
EXC5	2.2	2.1	12.	2.6	0.06

where $\rho(r)$ is the monopole density. All our three-body models, however, give valence neutron contributions to δ_{200} of the order 0.07~0.16 fm, to be added to the core transition contributions. The only model in agreement with the knock-out reaction data (EXC2), therefore, predicts a quadrupole strength which is much lower than the value suggested by the inelastic data. Ideally one would make a direct comparison with the inelastic data. One should realise that this implies a three-body incoming wave with core excitation. In principle the problem could be solved within a Multiple Scattering formalism yet the theory for including core excitation within MST has never been developed and is certainly not within the scope of this work.

An observed excited state at $E_x = 2.73$ MeV was earlier identified as having $J = 0^+$ [10]. More recently a RIKEN Coulomb excitation experiment [9] finds a 1^- state at this energy. Excitation energies for the 1^- states calculated in this work are presented in Table 5, which predict a $J = 1^-$ state at around $E_x = 2.7$ MeV in agreement with [9]. These values use $K_{max}=12$. For the 1^- state we find that excitation energies are sensitive to K_{max} , and thus these numbers may change, perhaps by up to 500 KeV, when larger calculations become possible. In [9], the $B(E1) = 0.051(13) e^2 \text{ fm}^2$ value is extracted. Though $E_x(1^-)$ may change, B(E1) values already show stability for $K_{max} = 8$. The calculated $B(E1)$ values, shown in Table 5, are in agreement with [9].

Table 5 also shows the excitation energy of the second 0^+ state, obtained using the hyperspherical truncation of $K_{max} = 12$. Very recent experiments [11] appear to have seen such an excited 0^+ state in ^{12}Be as a delayed 0.14 MeV photon in coincidence with the 2^+ to $0^+(\text{gs})$ transition. This puts a second 0^+ state at 2.24 MeV, within the range covered by our models.

5. Discussion

It is crucial to understand the limits of validity of a model in order to make progress. In this work, the new data available for ^{12}Be have served as severe tests of the three body model with core excitation. In stretching the model to accommodate these new data, and in identifying the difficulties, one can expect to obtain some insight on the relative importance of missing ingredients and refine the ideas concerning possible improvements to the existing model.

To reproduce the spectroscopy deduced from the single-neutron knock-out reaction, the p-wave component of the $^{12}\text{Be}(\text{g.s.})$ wavefunction needs to be increased significantly. This

can be achieved, within the three-body model, only through a reduced core deformation, and hence a reduced core excitation.

Our results imply that adding an extra neutron to the ^{11}Be system depolarises the core to reduce the deformation of the effective field it creates. This increasing sphericity of the ^{10}Be core leads to an enhanced probability for the core being in its ground state, increased mixing of the valence neutron states between the p- and sd-shell, and to melting of the $N=8$ neutron shell closure, in agreement with recent discoveries.

The difficulty in reproducing a large p-shell component in the three body g.s. wavefunction, under the constraint of the known properties of the subsystem ^{11}Be , is connected with the simplified core structure (assumed to consist of purely $0s_{1/2}$ and $0p_{3/2}$ occupied states) and the consequent artificial treatment of the Pauli principle as blocking with respect to these states. We do not include the detailed antisymmetrised pairing interactions between core and valence neutrons when both, for example, are in $0p_{1/2}$ states. This implies, as has been pointed out in [28], that few-body models for beryllium and lithium isotopes are expected to be more accurate when the additional neutrons are within the sd-shell only, as then the Pauli principle and pairing is simpler. Only by constructing a three body model using a full shell model core wave function, as in the GCM calculations of [17,15], can one simultaneously have a realistic core wave function, and a more physical definition of the states that are being projected out of the three body Hamiltonian. Developments of few body models along these lines will necessarily constitute a long-term project.

A further severe test of the three-body models is the excited state spectrum. It is reassuring that all three-body models built under reasonable ^{11}Be constraints are able to predict excitation energies for the 2^+ , 1^- and 0_2^+ excited states rather close to experiment. This is a natural advantage of these model as compared to Shell Model. Even though it is possible to find a range of n-core interactions that produce electromagnetic strengths between excited states and the gs in agreement with recent experimental findings, it appears that within this three body picture it is not possible to simultaneously corroborate the interpretations of the nucleon knockout [7] and proton inelastic scattering data [8].

Coincidentally, the three body model that underpredicts the $B(E2)$ in ^{12}Be , also produces a larger $B(E1)$ in ^{11}Be . A similar problem has consistently been encountered in microscopic calculations. A shell model calculation that does not include in some way the giant quadrupole resonance typically produces much lower values for the $B(E2)$ strength connecting low lying states. On the other hand, $B(E1)$ values resulting from shell model calculations that do not include the giant dipole resonance, tend to be overestimated as the GDR pulls out strength from the lower transitions, without changing the energy spectrum [29].

In the few body model, the n-core interaction is adjusted to the low lying states, and therefore contains no structure information for the giant resonances energy region. One may then also expect that, even if the few body model is able to predict the correct excitation energies for the low lying spectrum, the $B(E1)$ values will tend to be larger and the $B(E2)$ values tend to be smaller than is realistic. It may be interesting to explore the consequences of including either the GDR or GQR in few body models.

Finally, the results obtained for ^{12}Be have implications for the heavier beryllium isotopes [18,30,31]. Our results show that care must be taken when considering the shell structure

of the supporting core, ^{12}Be , in such cases.

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