Exotic nuclei at the nucleon drip lines and beyond constitute a forefront research area in nuclear physics. The physics drivers include: (1) to discover how shell structures evolve into extreme isospin regions; and (2) to extend our knowledge of the strong interactions, especially elusive three-nucleon forces (3NF), under these conditions. In order to help pave a path towards these goals, we present baseline conditions. In order to help pave a path towards these goals, we present baseline conditions. In order to help pave a path towards these goals, we present baseline conditions.

We focus especially on $^{14}$F, with isospin $T=2$, that is expected to lie beyond the proton drip-line and therefore unstable. This proton-rich nucleus will strain the convergence properties of the $ab$ initio methods we adopt here, and also push the limits of state-of-the-art experimental facilities. Indeed, the first experimental results regarding this four proton excess isotope will be available soon from Cyclotron Institute at Texas A&M University [1].

We perform the first $ab$ initio study of $^{14}$F. We use the No-Core Shell Model (NCSM) [2, 3] which employs a many-body harmonic oscillator basis which treats all nucleons as spectroscopically active. The basis space includes all many-body states with excitation quanta less than or equal to $N_{\text{max}}$ that makes it possible to completely remove spurious center-of-mass excitations. We used the code MFDn [4–6] and the realistic $NN$ interaction JISP16 [7] which is known to provide a good description of $p$ shell nuclei [7, 8] without an additional 3NF. The largest calculations were performed in the $N_{\text{max}} = 8$ basis space, which for this nucleus contains 1,990,061,078 basis states with total magnetic projection $M = 0$ and natural parity (negative). The determination of the lowest ten to fifteen eigenstates of the sparse Hamiltonian matrix, for each oscillator parameter $\hbar \Omega$, requires 2 to 3 hours on 7,626 quad-core compute nodes at the Jaguar supercomputer at ORNL.

We show our complete results for the $^{14}$F ground state energy in Fig. 1. The solid curves are our NCSM results with the bare interaction JISP16. These results are strict upper bounds for the ground state energy, and converge monotonically with $N_{\text{max}}$ to the infinite basis space results. The dashed curves in Fig. 1 are obtained in more conventional NCSM calculations with effective $NN$ interactions derived from the initial bare interaction JISP16 by the Lee–Suzuki–Okamoto (LSO) renormalization procedure [9]. The renormalization procedure is truncated at the two-body cluster level — i. e. induced three-body, four-body, etc., contributions are neglected; hence we refer to these calculations as LSO(2) renormalized. Note that these results differ slightly from preliminary approximate results presented at recent conferences [10, 11].

By comparing the bare and LSO(2) renormalized JISP16 results in Fig. 1, we observe that the tendency of the LSO(2) renormalized calculations is misleading. For increasing basis spaces from $N_{\text{max}} = 0$ to 6, the minimum of the $\hbar \Omega$-dependent curves increases, suggesting an approach from below to the infinite basis space result.

PACS numbers: 21.60.De, 27.20.+n, 21.10.Dr
At $N_{\text{max}} = 6$, LSO(2) renormalized JISP16 produces a nearly flat region at approximately the same energy as the minimum obtained with the bare JISP16 interaction. On the other hand, the bare interaction provides a variational upper bound for the ground state energy, which decreases with increasing $N_{\text{max}}$.

Other light nuclei ($^6$He, $^6$Li, $^8$Be, $^{12}$C, $^{16}$O, ...) show a qualitatively similar behavior: the LSO renormalized interactions produce results which are neither an upper bound nor a lower bound, and the approach to the infinite basis space is non-monotonic. Hence the convergence pattern of the LSO renormalized results is difficult to assess. Furthermore, with the patterns displayed in Fig. 1 for JISP16, the minima of the $\hbar \Omega$-dependent ground state energy curves for both the bare and the LSO(2) renormalized interaction may be expected to coincide for $N_{\text{max}} \geq 8$ as in some other nuclei. For these reasons, we did not perform expensive $N_{\text{max}} = 8$ LSO(2) renormalized JISP16 calculations for $^7$Li.

Recently we introduced the ab initio No-Core Full Configuration (NCFC) approach [8, 12], by extrapolating NCSM results with the bare interaction in successive basis spaces to the infinite basis space limit. This makes it possible to obtain basis space independent results for binding energies and to evaluate their numerical uncertainties. We use two extrapolation methods: a global extrapolation based on the calculations in four successive basis spaces and five $\hbar \Omega$ values in a 10 MeV interval (extrapolation A); and extrapolation B based on the calculations at various fixed $\hbar \Omega$ values in three successive basis spaces and defining the most reliable $\hbar \Omega$ value for the extrapolation. These extrapolations provide consistent results [8]. Combining both extrapolation methods suggests a binding energy of 72 ± 4 MeV for $^{14}$F which agrees well with AME03 nuclear binding energy extrapolations [14], see Table II.\footnote{AME03 extrapolation [14].}

To check the accuracy of our approach, we performed similar calculations for the mirror nucleus $^{14}$B with a known binding energy of 85.423 MeV [13]. This value agrees with our NCFC result of 86 ± 4 MeV. We also performed NCFC calculations of the neighboring nucleus $^{13}$O using basis spaces up to $N_{\text{max}} = 8$. The calculated binding energy of 77 ± 3 MeV also agrees with the experimental value of 75.556 MeV [13].

We note that a good description of both $^{14}$F and $^{13}$O in the same approach is important in order to have a consistent description of the $^{13}$O+$p$ reaction that produces $^{14}$F. In this way, any experimentally observed resonances can be directly compared with the difference of our results for the $^{14}$F and $^{13}$O energies. In this respect it is interesting to note that although the total energies of the extrapolations A and B differ by about 2 MeV, the differences between the ground state energies of these three nuclei are almost independent of the extrapolation method: for $^{14}$F and $^{13}$O the predicted difference is 4.6 MeV, and for $^{14}$F and $^{14}$B it is 13.5 MeV. (The numerical uncertainty in these differences is unclear, but expected to be significantly smaller than the uncertainty in the total energies.)

We also calculated the $^{14}$F excitation spectrum in anticipation of the experimental results. It is unclear how to extrapolate excitation energies obtained in finite basis spaces, but we can extrapolate the total energies of excited states using the same methods as discussed above for the ground state energy. For the lowest state in each $J^+$ channel the convergence pattern should be similar to that of the ground state; for excited states with the same quantum numbers we simply assume the same convergence pattern. We perform independent separate extrapolation fits for all states. The differences between the extrapolated total energies and the ground state energy is our prediction for the excitation energies.

This approach to extrapolating the total eigenenergies is supported by applying it to $^6$Li, see Table II. We have results for $^6$Li in basis spaces up to $N_{\text{max}} = 16$ where a good convergence is achieved and hence the extrapolation uncertainties are small. These results are compared in Table III with the extrapolations based on calculations in basis spaces up to $N_{\text{max}} = 8$, i.e. in the same basis spaces used for the $^{14}$F and $^{14}$B studies.

We see that the excitation energies based on $N_{\text{max}} = 8$ and smaller basis space results are consistent with the results obtained in larger spaces. The level ordering is the same and the difference between the $N_{\text{max}} = 8$ and $N_{\text{max}} = 16$ results is generally much smaller than the estimated uncertainties in the total energies of the $N_{\text{max}} = 8$ extrapolations. This suggests that the numerical uncertainty in the excitation energies is significantly smaller than the uncertainty in the total energies: apparently, the calculated total energies share a significant systematic uncertainty, an overall binding uncertainty, which cancels when results are expressed as excitation energies. Furthermore, we see that both extrapolation methods agree very well with each other (within their error estimates), and that the error estimates decrease as one increases the basis space.

The extrapolation B leads to results for the two lowest excited states that are practically independent of the oscillator parameter $\hbar \Omega$, see Fig. 2. Also the bare and LSO renormalized NCSM results for these two states show very little dependence on $\hbar \Omega$. These states are narrow resonances, and agree very well with experiment.

| Nucleus | Extrapol. A | Extrapol. B | Experiment |
|---------|------------|-------------|------------|
| $^{14}$O | $-75.7(2.2)$ | $-77.6(3.0)$ | $-75.56(0.01)$ |
| $^{14}$B | $-84.4(3.2)$ | $-86.6(3.8)$ | $-85.42(0.02)$ |
| $^{14}$F | $-70.9(3.6)$ | $-73.1(3.7)$ | $-73.3(0.4)^a$ |

\footnote{AME03 extrapolation [14].}

TABLE I: NCFC results obtained with JISP16 for the ground state energies (in MeV) of $^{14}$O, $^{14}$B and $^{14}$F. Experimental data are taken from Ref. [13].
TABLE II: NCFC results for the $^6\text{Li}$ ground state $E_{gs}$ and excitation energies $E_x$ (in MeV) obtained in different basis spaces with JISP16. For extrapolations A and B we include in parentheses an estimate of the accuracy of the total energies; for the LSO(2) renormalized interaction, we present the spread in excitation energy for $\hbar \Omega$ variations from 12.5 to 22.5 MeV. Experimental data are taken from Ref. [15].

| $E(J^+,T)$ | Extrap. A | Extrap. B | LSO(2) | Extrap. A | Extrap. B | LSO(2) | Experiment |
|------------|-----------|-----------|---------|-----------|-----------|---------|------------|
| $E_{gs}(1^+,0)_1$ | $-30.9(0.6)$ | $-31.1(0.3)$ | $-31.47(0.09)$ | $-31.48(0.03)$ | | | $-31.994$ Stable |
| $E_x(3^+,0)$ | $2.6(0.5)$ | $2.5(1.2)$ | $2.2-2.7$ | $2.56(0.04)$ | $2.55(0.07)$ | $2.53-2.55$ | $2.186 \pm 2.4 \cdot 10^{-6}$ |
| $E_x(0^+,1)$ | $3.6(0.6)$ | $3.5(1.2)$ | $3.3-3.7$ | $3.65(0.06)$ | $3.65(0.06)$ | $3.6-3.8$ | $3.563 \cdot 8.2 \cdot 10^{-6}$ |
| $E_x(2^+,0)$ | $5.3(0.9)$ | $5.5(1.8)$ | $4.8-5.8$ | $4.5(0.1)$ | $4.5(0.2)$ | $4.8-5.0$ | $4.312 \pm 1.30$ |
| $E_x(2^+,1)$ | $6.3(0.7)$ | $6.1(1.6)$ | $6.2-6.5$ | $5.9(0.1)$ | $5.9(0.1)$ | $6.0-6.4$ | $5.366 \pm 0.54$ |
| $E_x(1^+,0)_2$ | $6.1(1.7)$ | $6.6(0.3)$ | $7.1-8.5$ | $5.4(0.3)$ | $5.4(0.2)$ | $6.1-6.6$ | $5.65 \pm 1.5$ |

We noted earlier that the LSO renormalized interaction does not provide a monotonic approach to the infinite basis space for the binding energies and this prevents simple extrapolation. On the other hand, the excitation energies with the LSO renormalized interaction are often quite stable with $N_{max}$. However, it is important to realize that this does not necessarily mean that these excitation energies are numerically converged: they do depend on $\hbar \Omega$. The dependence of the excitation energies on $\hbar \Omega$ decreases slowly with increasing $N_{max}$, as seen in Table II. In fact, the excitation energies obtained with LSO(2) renormalized JISP16 are nearly the same as those obtained with the bare interaction, except at small values of $\hbar \Omega$, as illustrated in Fig. 2. For most states, the NCFC provides better results for the excitation energies, with less basis space dependence than the LSO(2) NCSM calculations in finite basis spaces. Nevertheless, we can employ the LSO procedure to obtain estimates of the binding and excitation energies in small basis spaces where there are no NCFC results. We summarize our results for the spectra of $^{14}\text{F}$ and $^{14}\text{B}$ in Table III. The excitation energies are obtained as a difference between the extrapolated total energies of the excited state and that of the ground state (see Table I). The spectra are rather dense and the spacing between energy levels is smaller than the quoted numerical uncertainty, which is that of the extrapolated total energies of the excited states. However, as discussed above, we expect that for narrow resonances the actual numerical error in the excitation energy is (significantly) smaller than the error in the total energy.

![Graph showing the spectrum of $^6\text{Li}$](image)

FIG. 2: (Color online) NCSM results for the spectrum of $^6\text{Li}$ with LSO(2) renormalized (dashed) and bare (dotted) JISP16 at $N_{max} = 14$, compared to NCFC extrapolations to infinite basis space (solid). Experimental data are from Ref. [15].

On the other hand, the three higher excited states have a much larger width, see Table III. Our calculations for these broad resonances show a significant dependence on both $\hbar \Omega$ and $N_{max}$, in particular for the excited $(1^+,0)_2$ state which has the largest width. The extrapolation to infinite model space reduces but does not eliminate the $\hbar \Omega$ dependence. We further note that the $\hbar \Omega$-dependence of these excitation energies is typical for wide resonances as observed in comparisons of NCSM results with inverse scattering analysis of $\alpha$-nucleon scattering states [10], and that the slope of the $\hbar \Omega$ dependence increases with the width of the resonance. This is consistent with the results presented in Fig. 2: the width of the $(1^+,0)_2$ state is larger than the width of the $(2^+,0)_2$ state; the latter is larger than the $(2^+,1)_2$ state width. Thus, there appears to be a significant correlation between the resonance width and the $\hbar \Omega$ dependence. The validity of the extrapolation to infinite model space is not entirely clear for these states.

We noted earlier that the LSO renormalized interaction does not provide a monotonic approach to the infinite basis space for the binding energies and this prevents simple extrapolation. On the other hand, the excitation energies with the LSO renormalized interaction are often quite stable with $N_{max}$. However, it is important to realize that this does not necessarily mean that these excitation energies are numerically converged: they do depend on $\hbar \Omega$. The dependence of the excitation energies on $\hbar \Omega$ decreases slowly with increasing $N_{max}$, as seen in Table II. In fact, the excitation energies obtained with LSO(2) renormalized JISP16 are nearly the same as those obtained with the bare interaction, except at small values of $\hbar \Omega$, as illustrated in Fig. 2. For most states, the NCFC provides better results for the excitation energies, with less basis space dependence than the LSO(2) NCSM calculations in finite basis spaces. Nevertheless, we can employ the LSO procedure to obtain estimates of the binding and excitation energies in small basis spaces where there are no NCFC results.

We summarize our results for the spectra of $^{14}\text{F}$ and $^{14}\text{B}$ in Table III. The excitation energies are obtained as a difference between the extrapolated total energies of the excited state and that of the ground state (see Table I). The spectra are rather dense and the spacing between energy levels is smaller than the quoted numerical uncertainty, which is that of the extrapolated total energies of the excited states. However, as discussed above, we expect that for narrow resonances the actual numerical error in the excitation energy is (significantly) smaller than the error in the total energy.

Figure 3 shows that different excited states can have very different convergence behavior. (Although we presented in Fig. 4 the $^{14}\text{B}$ results, the behavior of the $^{14}\text{F}$ states is similar.) At $N_{max} = 8$, there are five low-lying excited states; the excitation energy of these states depends only weakly on the basis space as $N_{max}$ increases from 2 to 8. Then there are numerous higher excited states which depend strongly on the basis space: their excitation energies decrease rapidly with increasing $N_{max}$. Only after extrapolation to the infinite basis space do they appear at excitation energies comparable to the other low-lying excited states. We see a similar phenomenon in NCFC calculations of other nuclei.
TABLE III: NCFC results for the $^{14}$F and $^{14}$B excitation energies $E_x$ (in MeV). For extrapolations A and B we include in parentheses an estimate of the accuracy of the total energies; for the LSO(2) renormalized interaction, we present the spread in excitation energy for $\hbar \Omega$ variations from 12.5 to 22.5 MeV. Experimental data are taken from Ref. [17].

| NCFC and NCSM ab initio calculations with JISP16 | $^{14}$F | $^{14}$B | $^{14}$B |
|-------------------------------------------------|-------|-------|-------|
| $E_x$ ($J^\pi$, $T$) | Extrap. A | Extrap. B | LSO(2), $N_{max} = 6$ | Extrap. A | Extrap. B | LSO(2), $N_{max} = 6$ |
| $E_x$ ($1^-$, 2) | 0.9(3.9) | 1.3(2.5) | 1.4–2.2 | 1.1(3.5) | 1.4(2.8) | 1.4–2.3 |
| $E_x$ ($3^-$, 2) | 1.9(3.3) | 1.5(4.6) | 1.0–1.8 | 1.7(2.9) | 1.4(4.6) | 1.0–2.1 |
| $E_x$ ($2^-$, 2) | 3.2(3.5) | 3.3(3.5) | 3.3–3.7 | 3.3(3.1) | 3.3(3.8) | 3.5–3.8 |
| $E_x$ ($4^-$, 2) | 3.2(3.2) | 2.8(4.8) | 2.0–2.6 | 3.1(2.9) | 2.7(4.8) | 2.0–3.1 |
| $E_x$ ($1^-$, 2) | 5.9(3.5) | 5.4(4.6) | 5.8–6.4 | 5.9(3.1) | 5.5(4.8) | 5.7–6.4 |
| $E_x$ ($0^-$, 2) | 5.1(5.4) | 5.8(1.0) | 5.8–10.5 | 5.5(4.8) | 6.1(1.4) | 4.9–10.4 |
| $E_x$ ($1^-$, 2) | 6.2(4.8) | 6.3(2.8) | 7.2–11.5 | 6.4(4.3) | 6.4(3.1) | 6.1–11.3 |
| $E_x$ ($2^-$, 2) | 6.4(4.6) | 6.3(3.4) | 7.3–10.9 | 6.9(4.1) | 6.7(3.6) | 6.6–10.9 |
| $E_x$ ($3^-$, 2) | 6.9(4.2) | 6.4(4.6) | 7.6–10.6 | 7.0(3.7) | 6.5(4.7) | 6.4–10.5 |
| $E_x$ ($5^-$, 2) | 8.9(3.5) | 7.9(5.9) | 9.2–11.0 | 8.8(3.1) | 7.8(5.9) | 8.5–10.8 |

$^a$Updated from Ref. [18].

$^b$The existence of this state is uncertain (see Ref. [17]).

The dependence on $\hbar \Omega$ varies considerably over the excited states as seen in Fig. 4. The lowest five excited states have a weak dependence on $\hbar \Omega$, whereas the higher excited states depend strongly on it. We expect our results for these higher excited states to have a larger numerical error than our results for the lower excited states with the weaker $\hbar \Omega$ dependence. Furthermore, in analogy to the excited states in $^6$Li discussed above, we expect these higher states to be broad resonances. Interestingly, the high-lying $J^\pi = 5^-$ state has a relatively weak $\hbar \Omega$ dependence (compared to states with similar excitation energy); it is also less dependent on $N_{max}$, and may correspond to a narrower resonance.

Note, the conventional wisdom suggests leading configurations for the ground and 5 lowest-lying levels of $^{14}$F ($^{14}$B) to be formed by the $p_{3/2}$ neutron (proton) and $s_{1/2}$ or $d_{5/2}$ proton (neutron). Other low-lying states, with the exception of our low-lying $5^-$ state, involve $p_{1/2}$ and/or $d_{3/2}$ single-particle states.

In Fig. 4 we can also see that the excitation energies obtained with LSO(2) renormalized JISP16 are nearly

FIG. 3: (Color online) Negative parity $^{14}$B spectrum obtained with JISP16 at fixed $\hbar \Omega = 25$ MeV in successive basis spaces, and extrapolated to infinite basis space using Extrapolation B. Experimental data are taken from Ref. [13].

FIG. 4: (Color online) NCSM results for the negative parity spectrum of $^{14}$B with LSO(2) renormalized (dashed) and bare (dotted) JISP16 at $N_{max} = 6$, compared to NCFC extrapolations to infinite basis space (solid) from $N_{max} = 4$–8. The most reliable $\hbar \Omega$ value for this extrapolation method is at $\hbar \Omega = 25$ MeV for all states depicted. Experimental data are taken from Ref. [13].
the same as those obtained with the bare interaction, at least at $N_{\text{max}} = 6$. Note that the NCFC results differ significantly from the bare and LSO(2) results, in particular for the higher excited states with a strong $N_{\text{max}}$ dependence; these extrapolated results also tend to have a somewhat weaker dependence on $\hbar \Omega$ than the results in finite basis spaces, and are expected to be more accurate.

Some of the excited states in $^{14}$B were observed experimentally. Unfortunately, the spin of most of these states is doubtful or unknown. Overall, the calculated excitation energies appear to be too large when compared with the experimental data; in particular our result for the excited $2^-$ state, the only excited state with a firm spin assignment, is about 1.5 MeV above the experimental value. However, the spin of the lowest five states agrees with experiment, except for the $2^-$ and $4^-$ being interchanged, assuming that the tentative experimental spin assignments are correct. We do not see additional states between 2 and 3 MeV, but this could be related to the fact that all our excitation energies appear to be too large. Also, given the strong dependence on $N_{\text{max}}$ of the higher excited states, it is not unlikely that these states will come down further with increasing basis space.

We performed the first theoretical ab initio study of the exotic proton-rich nucleus $^{14}$F which has yet to be observed experimentally. Using the $NN$ interaction JISP16, we presented a prediction for the $^{14}$F binding energy that is supported by comparing our NCFC results with experimental data for the binding energies of the mirror nucleus $^{14}$B and the neighboring nucleus $^{13}$O obtained within the same approach in the same basis spaces.

We extended our NCFC extrapolation techniques to evaluate excited states, and validated this method by applying it to excited states in $^6$Li. The obtained spectrum for $^{14}$F agrees qualitatively with the limited data, and we made predictions for the spectrum of $^{14}$F. More definite information about the excited states in $^{14}$B would be helpful. It would also be very interesting to compare our predictions for the $^{14}$F binding energy and spectrum with the experimental data that are anticipated soon. Significant differences between our predictions and the experimental results would indicate deficiencies in the $NN$ interaction, JISP16, and/or the role of neglected 3NF’s. This would inform future research efforts and, with the inclusion of additional unstable nuclei in the analysis, aid in the eventual determination of the underlying shell structure evolution.

Although NCSM calculations with LSO(2) renormalized interactions generally give reasonable results for the binding energies and spectra in small basis spaces, they do not improve systematically with increasing basis space. In particular for JISP16 we find that the results for the bare and the LSO(2) renormalized interaction basically coincide for $N_{\text{max}} \geq 8$, both for total energies and for excitation energies. It would be worthwhile, although it is a major undertaking, to evaluate the effects of the induced three- and four-body interactions, which should improve the accuracy of the LSO renormalized calculations. Without a thorough study of those effects however, we prefer the NCFC approach, based on extrapolations of NCSM results with the bare interaction, at least for JISP16.

We thank V. Z. Goldberg (Texas A&M University) for very valuable discussions. We also thank Esmond Ng, Chao Yang and Philip Sternberg of LBNL and Masha Sosonkina of Ames Laboratory for fruitful discussions on computational science and applied mathematics issues underlying code developments. This work was supported by the US DOE Grants DE-FC02-09ER41582 and DE-FG02-87ER40371 and the Russian Federal Agency of Education Contract P521. Computational resources were provided by DOE through the National Energy Research Supercomputer Center (NERSC) and through an INCITE award (David Dean, PI); the $^6$Li runs where performed on the Franklin supercomputer at NERSC and the $^{14}$F and $^{14}$B runs on Jaguar at ORNL.

[1] V. Z. Goldberg, private communication (2009).
[2] D. C. Zheng, J. P. Vary, and B. R. Barrett, Phys. Rev. C 50, 2841 (1994); D. C. Zheng et al., Phys. Rev. C 52, 2488 (1995).
[3] P. Navrátíl, J. P. Vary, and B. R. Barrett, Phys. Rev. Lett. 84, 5728 (2000); Phys. Rev. C 62, 054311 (2000).
[4] J. P. Vary, “The Many-Fermion-Dynamics Shell-Model Code,” Iowa State University, 1992 (unpublished); J. P. Vary and D. C. Zheng, ibid 1994 (unpublished); demonstration runs can be performed through http://nuclear.physics.iastate.edu/mfd.php
[5] P. Sternberg et al., Proc. of the 2008 ACM/IEEE Conf. on Supercomputing (Austin, TX, November 15-21, 2008), IEEE Press, Piscataway, NJ, 1-12.
[6] J. P. Vary et al., J. Phys.: Conf. Ser. 180, 012083 (2009).
[7] A. M. Shirokov, J. P. Vary, A. I. Mazur, and T. A. Weber, Phys. Lett. B 644, 33 (2007).
[8] P. Maris, J. P. Vary, and A. M. Shirokov, Phys. Rev. C 79, 014308 (2009).
[9] K. Suzuki and S. Y. Lee, Progr. Theor. Phys. 64, 2091 (1980); K. Suzuki, ibid 68, 246 (1982); 68, 1999 (1982); K. Suzuki and R. Okamoto, ibid 92, 1045 (1994).
[10] J. P. Vary, A. M. Shirokov, and P. Maris, arXiv:0804.0830 [nucl-th].
[11] A. M. Shirokov, J. P. Vary, and P. Maris, In: Proc. 27th Int. Workshop on Nucl. Theory, Rila Mountains, Bulgaria, 23-28 June, 2008 (Ed. S. Dimitrova), Bulgarian Acad. Sci., 2008, p. 205. arXiv:0810.1014 [nucl-th].
[12] S. K. Bogner et al., Nucl. Phys. A 801, 21 (2008).
[13] F. Ajiengen-Selove, Nucl. Phys. A 523, 1 (1991).
[14] G. Audi, A. H. Wapstra, and C. Thibault, Nucl. Phys. A 729, 337 (2003).
[15] D. R. Tilley et al., Nucl. Phys. A 708, 3 (2002).
[16] A. M. Shirokov, A. I. Mazur, J. P. Vary, and E. A. Mazur,
Phys. Rev. C 79, 014610 (2009).
[17] G. C. Ball et al., Phys. Rev. Lett. 31, 395 (1973).
[18] R. Kanungo et al., Phys. Lett. B 608, 206 (2005).