Michigan State University

National Superconducting Cyclotron Laboratory

ENHANCED E0 AND E2 TRANSITION RATES IN THE MID-SHELL Xe ISOTOPES

P.F. MANTICA and W.B. WALTERS

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P. F. Mantica

Department of Chemistry and National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824

W. B. Walters

Department of Chemistry and Biochemistry, University of Maryland, College Park, MD 20742

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Abstract

New measurements for lifetimes of excited 0^+ and 2^+ levels in ^{120}Xe following β decay of ^{120}Cs isomers are reported. From these data, $E0$ and $E2$ transition rates are derived which exceed values calculated from models assuming only a limited valence nucleon space. The observed collectivity can be described by the inclusion of additional valence protons associated with particle–hole intruder configurations involving the $\pi g_{9/2}$ orbital.

21.10.Tg, 23.20.Js, 23.20.Nx, 27.60.+j

There exist well documented cases of shape coexistence in even–even nuclei in the region around Z = 50, particularly for the Sn (Z = 50) and Cd (Z = 48) nuclei nearest to the N = 66 mid shell [1]. Even in the Pd isotopes (Z = 4 6), which are four protons removed from the Z = 50 closed shell, inelastic scattering [2] and Coulomb excitation [3] measurements suggest the first excited 0^+ state in $^{110}Pd_{64}$ is the bandhead for an intruding two particle–six hole structure. For the odd-Z nuclei around Z = 50, particle–hole intruders are established for nuclei nearest mid shell from Rh (Z = 45) to Cs (Z = 55). The experimental evidence used to identify these coexisting structures has typically been the appearance of band structures with distinctive energy spacings, and the electromagnetic transition probabilities for both intraband and interband decays [4].

For the even–even nuclei which lie above the Z = 50 closed shell, there has been, to this point, a lack of convincing evidence for shape coexisting structures. In the Te isotopes nearest mid shell, the 0_2^+ state has been identified [5] at low excitation energy (around 1 MeV) in $^{118}Te_{66}$, $^{120}Te_{68}$, and $^{122}Te_{70}$, and in each case this state decays via an electric monopole ($E0$) transition to the ground state. The only strong evidence for band structure built upon these excited 0^+ states occurs in ^{118}Te [1]. For the Xe isotopes, excited 0^+ states were identified below 1 MeV in ^{118}Xe and ^{120}Xe through the observance of $E0$ transitions following β decay of ^{118}Cs and ^{120}Cs, respectively [6]. Subsequently conversion–electron spectroscopy reported by Walters *et al.* [7] identified additional high–energy $E0$ transitions in the even–even Xe isotopes from A = 118 – 124. Similar to the case for the Te isotopes, there is no strong evidence for band structure built upon these states.

This situation is not very different from that in the region around Z = 82. In this region, there are well established shape coexisting structures in the even-even Pt, Hg, and Pb isotopes [1], and in the odd-Z isotopes both below (Au and Tl) and above (Bi and At) the shell [4]. For the Po and Rn nuclei above the shell, which are two– and four– protons removed from the Z = 82 closed shell, strong evidence has only recently been presented suggesting coexisting structures in the Po isotopes [8].

The experiments reported here were undertaken to investigate the role six–particle, two–

hole intruder configurations play in determining the low energy structure of the mid–shell Xe isotopes. To this end, we have completed measurements of transition rates for decays of excited states in ^{120}Xe. The data were compiled using the UNISOR isotope separator facility on–line to the 25 MV folded tandem accelerator at Oak Ridge National Laboratory. Sources of ^{120}Cs were produced in the heavy-ion fusion/evaporation reaction between a 175–MeV ^{32}S beam and a 6 mg/cm^2 ^{92}Mo target. The evaporation products from the heavy–ion reaction were ionized and mass separated, and the desired A = 120 products (including ^{120}Cs) were deposited into a moving tape. The UNISOR picosecond lifetime system was employed [12], where triple coincidence data were collected in order to measure the lifetimes of low energy levels in ^{120}Xe. The counting station consisted of a thin plastic scintillator detector, a 1.3–cm thick conical BaF_2 detector, and two 35% p–type Ge detectors.

Lifetime values were determined for a number of low spin levels in ^{120}Xe from the β–γ–γ data using the centroid shift method and the relative and absolute comparison techniques outlined by Mach *et al.* [14]. For the first excited 2^+ state, it was not possible to determine the level lifetime from the β–γ–γ data due to the fact that, other than the 322–keV transition, individual γ ray transitions could not be resolved in the BaF_2 spectrum. The lifetime for the 2_1^+ state was therefore determined in a β–γ double coincidence measurement, where the centroid shift between the β–322 timing spectrum and a 'prompt' timing spectrum was used to extract the level lifetime [see Fig. 1]. The prompt spectrum was derived by gating the BaF_2 fast γ detector on the background region immediately above the energy gate for the $2_1^+ \rightarrow 0_1^+$ transition. From this new lifetime for the 2_1^+ state of 64±4 ps, we extract a $B(E2; 0_1^+ \rightarrow 2_1^+)$ value of 1.78(11) e^{2}b^2 for ^{120}Xe [13].

A consistent set of $B(E2; 0^+ \rightarrow 2^+)$ values for the mid–shell Xe isotopes has proven elusive. The results of the first lifetime measurements for these nuclei, collected using the recoil distance Doppler shift technique (see compilation of Raman *et al.* [9]), suggested a saturation of $B(E2)$ strength as one approached mid–shell. More recent analysis of recoil distance data by Dewald [10], however, suggested that there is no saturation of $B(E2)$ strength at mid-shell in the Xe isotopes. The result of Dewald for the $B(E2; 0_1^+ \rightarrow 2_1^+)$

value for ^{120}Xe of 1.53(14) e^2b^2 agrees with the result reported here using the technique of delayed coincidences. A remeasurement of this $B(E2; 0_1^+ \rightarrow 2_1^+)$ value using the recoil distance technique by the Notre Dame group [15] has resulted in a value of 1.78(14) e^2b^2, which also agrees with these measurments. Taken together, these new measurements appear to represent a significant reduction in the uncertainty for the $B(E2)$ values for ^{120}Xe and they have been incorporated in the recent compilation by Raman *et al.* [16].

The new $B(E2)$ data for ^{120}Xe certainly do not support the inclusion of Pauli effects [17] into the Hamiltonian of the IBM–2. The $B(E2)$ values are consistent with the results obtained from isotope shift measurements [18] on the light Xe isotopes, and also with the expectation that proton–neutron interactions, and hence, collectivity, would be at a maximum for the Xe isotopes nearest mid shell. Indeed, the results from the 'normal' IBM–2 calculations [19] (without the inclusion of Pauli blocking terms) come close to reproducing the new experimental results. This also is the case for the results from the Total Routhian Surface (TRS) calculations [20]. A summary of the results of the three calculations are presented, along with the experimental $B(E2; 0_1^+ \rightarrow 2_1^+)$ values, in Fig. 2. These new values show that, rather than being anomalously low, the three mid–shell $B(E2; 0_1^+ \rightarrow 2_1^+)$ values are actually larger than the values extrapolated by methods based on valence nucleon number.

Both the relativisitic mean field (RMF) approach and the Woods-Saxon potential as examined by Raman *et al.* [16] do well in reproducing the trends observed in the $B(E2; 0_1^+ \rightarrow 2_1^+)$ values for the Xe isotopes through the neutron mid shell. Both these approaches owe their success to the inclusion of interactions of the $\pi g_{9/2}$ orbital near mid shell. That the $\pi g_{9/2}$ orbital must play a role would appear obvious inasmuch as it has been identified through spin and moment measurements [21,22] as the ground state of ^{119}Cs. In contrast, approaches to calculations of these $B(E2)$ trends that include only the obvious $g_{7/2}$ and $d_{5/2}$ valence protons that lie just above the Z = 50 closed shell are seen to be inadequate.

We concur with Raman *et al.* [16] that it is difficult to substantiate a change in group structure [15,23] within the FDSM to accommodate the $B(E2; 0_1^+ \rightarrow 2_1^+)$ values for the mid–shell Xe isotopes. At first glance, the level structures of the even–even Xe isotopes [Fig. 3] around the N = 66 mid shell appear to have simple collective features that would easily fit a boson or fermion scheme, or an asymmetric vibrator model. In an earlier paper, we showed how well an IBM–2 calculation could describe the observed structures for ^{124,126,128}Xe [24]. However, an extension of those calculations to lighter Xe nuclides reveals considerable divergence from the experimental data [19]. For the mid–shell Te nuclides, Rikovska *et al.* [25] have utilized a mixed configuration calculation within the IBM–2, where a four-particle, two–hole proton configuration is specifically mixed with the simple two–proton particle configuration, to describe the appearence of shape coexisting structures in the mid-shell Te nuclei. This approach can account for the change in proton occupancy within the IBM–2 as is suggested from the Woods–Saxon and RMF calculations. The failure of the various algebraic models (IBM, FDSM) to describe the experimental data in these light Xe isotopes can most probably be attributed to the fact that they assume only a limited valence nucleon space.

The presence of numerous $E0$ transitions in the mid–shell Xe nuclides offers additional insight into the structure of these nuclides. Transitions having either $E0$ multipolarity or a mixture of $E0 + M1/E2$ multipolarity have been observed depopulating lower-energy states from ^{118}Xe to ^{124}Xe [7,11], as is shown in Fig. 3. $E0$ transitions are observed from states lying above 2 MeV in the even–even Xe isotopes from ^{126}Xe to ^{120}Xe, and these states are likely to have large contributions from the $\pi(h_{11/2})^2_0$ configuration [28]. It is clear from Fig. 3 that the electric monopole intensity (that is, the number of transitions showing some $E0$ multipolarity component) reaches a peak at mid shell in ^{120}Xe.

The monopole strength parameter, $\rho^2(E0)$, gives a fundamental measure of the $E0$ strength, and can be determined using the relation $\rho^2(E0) = ln2/T(E0)\Omega$. Here $T(E0)$ is the partial half–life of the level in question and Ω is the electronic factor, values for which are tabulated in Ref. [29]. One of our goals in the determination of lifetimes of excited levels in ^{120}Xe was to extract partial half–life information for the excited 0^+ levels below 2 MeV. Bhagwat *et al.* [30] have attempted such measurements in ^{120}Xe using a β-e slow coincidence technique. They extracted a value for $\rho^2(E0)$ for the two $E0$ decays from the 0^+_3

state in ^{120}Xe. Values for $\rho^2(E0) \times 10^3$ of $0.18^{+0.09}_{-0.05}$ and $1.06^{+0.54}_{-0.28}$ for the 1623– and 714–keV transitions are based on a half–life measured for the 1623–keV state of 602 ± 205 ps.

The timing spectra obtained by gating on depopulating transitions from the 909– and 1623–keV levels in ^{120}Xe are shown in Fig. 4. The lifetimes were determined using the absolute comparison technique [14], where the difference in centroid position between a timing spectrum derived from the transition of interest and the timing spectrum of a reference cascade reveals the level lifetime. The lifetime of the 1623–keV state, for example, is the difference in the centroid position for the β–322–747 timing spectrum [Fig. 4(a)], which includes the lifetimes of the 322–, 875–, and 1623–keV states, and the β–322–553 timing spectrum [Fig. 4(b)], which accounts for the lifetimes of the 322–keV and 875–keV states. The lifetime for the 909–keV state was determined in a similar fashion using both the β–322–586 and β-322 timing spectra [Fig. 4(c) and (d), respectively]. The fact that the four timing spectra in Fig. 4 are derived from gating the 322–keV transition in the BaF_2 fast timing detector eliminates the need to be concerned with the energy dependence of the centroid position in the timing spectra.

It can be seen from Fig. 4 that we do not observe evidence for a lifetime in excess of 150 ps for decay out of the 0_3^+ level at 1623 keV. One of the clear advantages of the β–γ–γ triple coincidence technique is that the data are 'clean'; that is, through the analysis of a decay sequence there is little ambiguity as to which level sequence is being fed in the β decay. The $\rho^2(E0)$ values we derive for the $E0$ decay from the first and second excited 0^+ states in ^{120}Xe are given in Table I. We have also included in Table I predictions for the $\rho^2(E0)$ values for these transitions in ^{120}Xe from various theoretical treatments.

One of the theoretical treatments included in Table I is the prediction for $E0$ transition strength from the excited 0^+ state in ^{120}Xe attributable to mixed symmetry states in O(6)–like nuclei within the IBM-2 [31]. The general trend of the predicted monopole strength for the even–even Xe isotopes within the O(6) symmetry limit is an increase in $\rho^2(E0)$ with increasing A. Again, it is apparent that the $E0$ activity observed in the these mid shell Xe isotopes arises from a mechanism which is outside the normal IBM–2 model space.

The appearance of a plethora of $E0$ transitions in the decay of ^{120}Xe cannot be completely accounted for merely because of a change in occupation of the N = 4 $\pi g_{9/2}$ orbital. These $E0$ transitions are most likely a product of the change in occupation of the N = 5 $\pi h_{11/2}$ orbital, which will result in a change in $< r^2 >_{N,l}$ [28]. Simply moving a pair of particles from a $\pi g_{9/2}$ orbital into a $g_{7/2}$ or a $d_{5/2}$ orbital that is still in the same N = 4 oscillator shell does not provide a microscopic basis for the observed $E0$ strength. The source of the $E0$ strength lies in the deformation of the intruder band and the admixtures of orbitals coming from pairs of protons in the $h_{11/2}$ orbital, which originates from the N = 5 oscillator shell. The extensive high–spins studies of nuclides in this mass region have succeeded in demonstrating the importance of the prolate and oblate bands built on the $h_{11/2}$ proton orbitals and that these bandheads do lie at low excitation energies [32].

For both the Sn and Cd nuclei nearest mid shell, where evidence for coexisting spherical–deformed structures is generally accepted, the monopole strength parameters for the transitions between the deformed 0^+ bandhead and the 0^+ ground state have been measured. The $\rho^2(E0)$ values for the $E0$ transitions depopulating the first two excited 0^+ states in the $N = 66$ isotones ^{114}Cd [33] and ^{116}Sn [34] are included in Table I. The results obtained here for the $E0$ strength in ^{120}Xe are comparable with those observed in ^{116}Sn. That is, there is significant monopole strength observed between the first and second excited 0^+ states, suggesting a mixing of states having different radii owing to differences in deformation [35]. The increased quadrupole strength in the transition from the 2_1^+ state to the ground state adds additional creedance to the fact that a more deformed shape mixes strongly with the ground state in the even–even nuclei surrounding ^{120}Xe. Although absolute measures of the $E0$ strength have not be made for the neighboring ^{118}Xe and ^{122}Xe, the results in ^{120}Xe suggest that there is a mixing of states having different shapes.

Finally, we note that these new data for ^{120}Xe, the existing data for the Te nuclides, and the data for the adjacent Xe nuclides all suggest that particle–hole intruder configurations play a strong role *only* for the three mid–shell nuclides with N = 64, 66, 68. Indeed, the large $\rho^2(E0)$ value for the $0_2^+ \rightarrow 0_3^+$ transition in ^{120}Xe can be taken as an indication that the intruder strength is depressed only to a position about 1 MeV above the ground state. Examination of the depression of intruder structures in Pt nuclides, as shown by Wood *et al.* [1], reveals that the intruder–dominated structure only crosses the lower seniority structure and becomes the ground state for ^{186}Pt, *i.e.* at a point when the number of neutron holes reaches 18, two more than are ever possible in the Sn region. The structure of ^{188}Pt, which has 16 neutron holes, is indicative of the intruder configuration lying at $\approx$ 1 MeV above the ground state. The mean square charged radii for the ground states of the Hg isotopes also reveal ground state effects of the larger radius associated with the particle–hole structure only for ^{185}Hg and lighter Hg isotopes, which have 19 or more holes in the N = 126 closed shell, numbers not possible in the N = 82 closed shell. For those Pb-region nuclides, as for the Sn-region nuclides, it is the occupancy of the downsloping intruder proton orbitals from the higher oscillator shell (N = 6 for the Z = 82 region) that generates the change in radius that then drives the $E0$ transition strength.

In summary, a consistent picture of the important features of the low–energy nuclear structure of these Xe nuclides now emerges from the combination of our new lifetime data, available in–beam structure data, and the extensive calculations for these nuclides. This successful description includes not only the full N = 50 to N = 82 neutron shell and the $d_{5/2}$ and $g_{7/2}$ proton orbitals, but also particle–hole structures that involve promotions of protons from the upsloping $g_{9/2}$ orbital from below the Z = 50 closed shell to the $h_{11/2}$ downsloping orbital from above the shell, both of which approach the Fermi surface at deformation values of $\beta_2 \approx 0.25$. This description is supported throught the observation of enhanced $B(E2)$ and $B(E0)$ values for the mid shell Xe nucleus, ^{120}Xe, supporting the notion that intruding six–particle, two–hole configurations influence the low–energy level structures of the even-even Xe nuclides nearest the N = 66 mid shell. The admixtures of the higher seniority states result in only small pertubations in the energy–level positions while at the same time yielding enhanced $E0$ and $E2$ strengths.

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REFERENCES

[1] J. L. Wood, K. Heyde, W. Nazarewicz, M. Huyse, and P. van Duppen, Phys. Rept. **215**, 101 (1992).

[2] R. Hertenberger, D. Hofer, H. Kader, F. J. Eckle, P. Schiemenz, G. Graw, Gh. Cata-Danil, R. de Leo, S. Micheletti, M. Pignanelli, and N. Fujiwara, Nucl. Phys. **A562**, 157 (1993).

[3] L. Hasselgren, J. Srebrny, C. Y. Wu, D. Cline, T. Czosnyka, L. E. Svensson, A. Backlin, C. Fahlandern, L. Westerberg, R. M. Diamond, D. Habs, H. J. Korner, F. S. Stephens, C. Baktash, and G. R. Young, Univ. Rochester report NSRL-338 (1989).

[4] K. Heyde, P. van Isacker, M. Waroquier, J. L. Wood, and R. A. Meyer, Phys. Rep. **102**, 291 (1983).

[5] P. M. Walker, C. J. Ashworth, I. S. Grant, V. R. Green, J. Rikovska, T. L. Shaw, and N. J. Stone, J. Phys. G **13**, L195 (1987).

[6] J. Genevey-Rivier, A. Charvet, G. Marguier, C. Richard–Serre, J. D'Auria, A. Huck, G. Klotz, A. Knipper, G. Walter, and the ISOLDE Collaboration, Nucl. Phys. **A283**, 45 (1977).

[7] W. B. Walters, J. Rikovska, N. J. Stone, T. L. Shaw, P. M. Walker, and I. S. Grant, Hyperfine Int. **43**, 343 (1988).

[8] N. Bijnens, P. Decrock, S. Franchoo, M. Gaelens, M. Huyse, H.–Y. Hwang, I. Reusen, J. Szerypo, J. von Schwartzenberg, J. Wauters, J. G. Correia, A. Jokinen, P. Van Duppen, and The ISOLDE Collaboration, Phys. Rev. Lett. **75**, 4571 (1995).

[9] S. Raman, C. H. Malarkey, W. T. Milner, C. W. Nester, Jr., and P. H. Steltson, At. Data Nucl. Data Tables **36**, 1 (1987).

[10] A. Dewald, Prog. Part. Nucl. Phys. **28**, 409 (1992).

[11] P. F. Mantica, Jr., B. E. Zimmerman, C. E. Ford, W. B. Walters, D. Rupnik, E. F. Zganjar, H. K. Carter, J. Rikovska, and N. J. Stone, *Exotic Nuclear Spectroscopy*, ed. W.C. McHarris (Plenum Press, New York, 1990) 495.

[12] P. K. Joshi, P. F. Mantica, S. J. Robinson, R. L. Gill, and E. F. Zganjar, Nucl. Instr. Methods A**335**, 461 (1993).

[13] P. F. Mantica, P. K. Joshi, S. J. Robinson, E. F. Zganjar, R. L. Gill, W. B. Walters, D. Rupnik, H. K. Carter, J. Kormicki, and C. R. Bingham, *Nuclei Far From Stability/Atomic Masses and Fundamental Constants 1992*, eds. R. Neugart and A. Wöhr (IOP, Bristol, 1993) 667.

[14] H. Mach, R. L. Gill and M. Moszynski, Nucl. Instr. Methods A**280**, 49 (1989).

[15] J. C. Walpe, B. F. Davis, S. Naguleswaran, W. Reviol, U. Garg, and J. X. Saladin, Phys. Rev. C**52**, 1792 (1995).

[16] S. Raman, J. A. Sheikh, and K. H. Bhatt, Phys. Rev. C**52**, 1380 (1995).

[17] T. Otsuka, X.-W. Pan and A. Arima, Phys. Lett. B**247**, 191 (1990).

[18] W. Borchers, E. Arnold, W. Neu, R. Neugart, K. Wendt, G. Ulm, and the ISOLDE Collaboration, Phys. Lett. B**216**, 7 (1989).

[19] P. F. Mantica, W. B. Walters, and J. Rikovska (unpublished).

[20] R. Wyss, A. Granderath, R. Bengtsson, P. von Brentano, A. Dewald, A. Gelberg, A. Gizon, J. Gizon, S. Herissopulos, A. Johnson, W. Lieberz, W. Nazarewicz, J. Nyberg, and K. Schiffer, Nucl. Phys. **A505**, 337 (1989).

[21] H. Fisher, P. Dabkiewicz, P. Freilinger, H. J. Kluge, H. Kremmling, R. Neugart, E. W. Otten, and the ISOLDE Collaboration, Z. Phys. A**284**, 3 (1978).

[22] T. L. Shaw, V. R. Green, C. J. Ashworth, J. Rikovska, N. J. Stone, P. M. Walker, and I. S. Grant, Phys. Rev. C**36**, 413 (1987).

[23] D. H. Feng, C. L. Wu, M. W. Guidry, and Z. P. Li, Phys. Lett. B**205** 156 (1988).

[24] P. F. Mantica, Jr., B. E. Zimmerman, W. B. Walters, J. Rikovska, and N. J. Stone, Phys. Rev. C**45** 1586 (1992).

[25] J. Rikovska, N. J. Stone, P. M. Walker, and W. B. Walters, Nucl. Phys. **A505**, 145 (1989).

[26] K. Kitao, Nucl. Data Sheets **75**, 99 (1995).

[27] T. Tamura, Nucl. Data Sheets **71**, 461 (1994).

[28] P. F. Mantica, Jr., B. E. Zimmerman, W. B. Walters, and K. Heyde, Phys. Rev. C**43**, 1696 (1991).

[29] D. A. Bell, C. E. Aveledo, M. G. Davidson, and J. P. Davidson, Can. J. Phys. **48**, 2542 (1970).

[30] A. Bhagwat, S. S. Al-Ghamdi, P. M. Walker, B. D. D. Singleton, C. G. Barham, and I. S. Grant, J. Phys. G**18**, 977 (1992).

[31] B. R. Barrett and T. Otsuka, Phys. Rev. C**46**, 1735 (1992).

[32] See, for example, Y. Liang, D. B. Fossan, J. R. Hughes, D. R. LaFosse, T. Lauritsen, R. Ma, E. S. Paul, P. Vaska, M. P. Waring, and N. Xu, Phys. Rev, C**45**, 1041 (1992).

[33] R. Julin, J. Kantele, M. Luontama, A. Passoja, T. Poikolainen, A. Bäcklin, and N.-G. Jonsson, Z. Phys. A**296**, 315 (1980).

[34] J. Kantele, R. Julin, M. Luontama, A. Passoja, T. Poikolainen, A. Bäcklin, and N.-G. Jonsson, Z. Phys. **289**, 157 (1979).

[35] K. Heyde and R. A. Meyer, Phys. Rev. C**37**, 2170 (1988).

FIGURES

FIG. 1. Delayed and prompt TAC spectra for the measurement of the centroid shift for the 2_1^+ to 0_1^+ transition in ^{120}Xe.

FIG. 2. Experimental $B(E2; 0_1^+ \rightarrow 2_1^+)$ values for the even–even Xe isotopes near mid shell.

FIG. 3. Systematics of the even-even Xe nuclei from A = 118 to A = 126. Lines between levels indicate transitions having some component of $E0$ multipolarity. The structures are taken from the following: ^{118}Xe [26], ^{120}Xe [11], ^{122}Xe [27], ^{124}Xe [7], ^{126}Xe [24].

FIG. 4. Timing spectra for the transitions depopulating the first and second excited 0^+ states in ^{120}Xe: (a) includes sum of 1623, 553, and 322 keV level lifetimes, (b) includes sum of only 553 and 322 keV level lifetimes, (c) includes sum of the 909 and 322 keV level lifetimes and (d) includes only the lifetime of the 322 keV state. The centroid shift between spectra (a) and (b) and between spectra (c) and (d) represent the lifetimes for the 1623– and 909–keV states, respectively. The time calibration for each spectrum is 6.65 ps/channel.

TABLES

TABLE I. $T(E0)$ and $\rho^2(E0)$ values for the decay of the first two excited 0^+ states in ^{120}Xe.

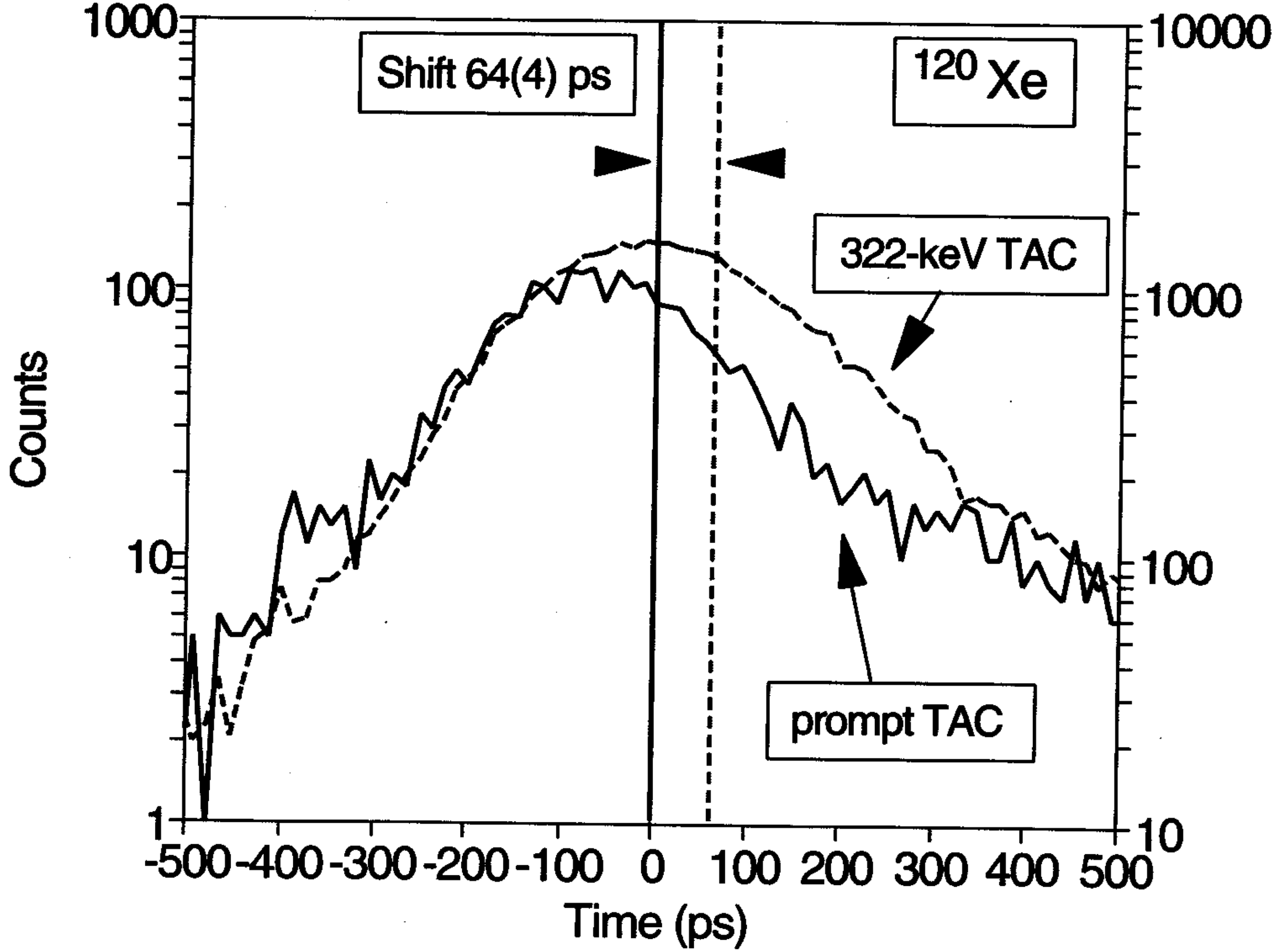
Transition	$0_2^+ \rightarrow 0_1^+$	$0_3^+ \rightarrow 0_2^+$	$0_3^+ \rightarrow 0_1^+$
Energy(keV)	909	714	1623
	$T(E0)$ $(10^9 s)$		
^{120}Xe[a]	< 4	7(2)	24(8)
	$\rho^2(E0)$ (10^3)		
^{120}Xe	> 18.6	13(4)	1.5(5)
single particle	360	360	360
SPU[b]	20	20	20
vibrational[c]	180	0	0
rotational	1.72	3.44	finite
IBM–2 O(6)[d]	0	0	11.2
^{116}Sn	4.3(13)	100(20)	0.9(2)
^{114}Cd	30(8)	0.41(9)	1.7(2)

[a] Based on τ of < 9 ps and 120(40) ps for the 909– and 1623–keV states, respectively.

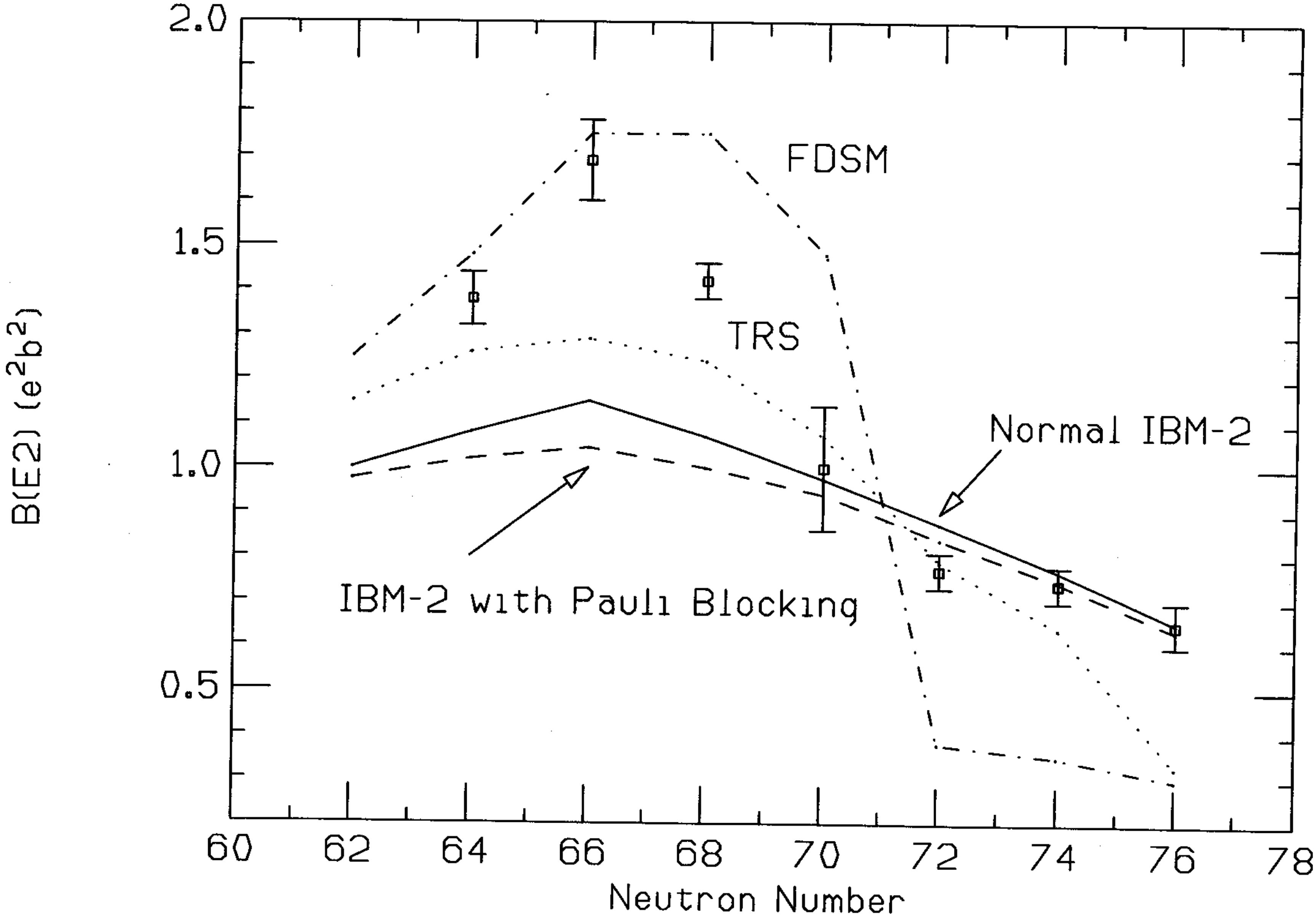
[b] $\rho^2(E0)$ in single particle units as taken from Ref. [35]

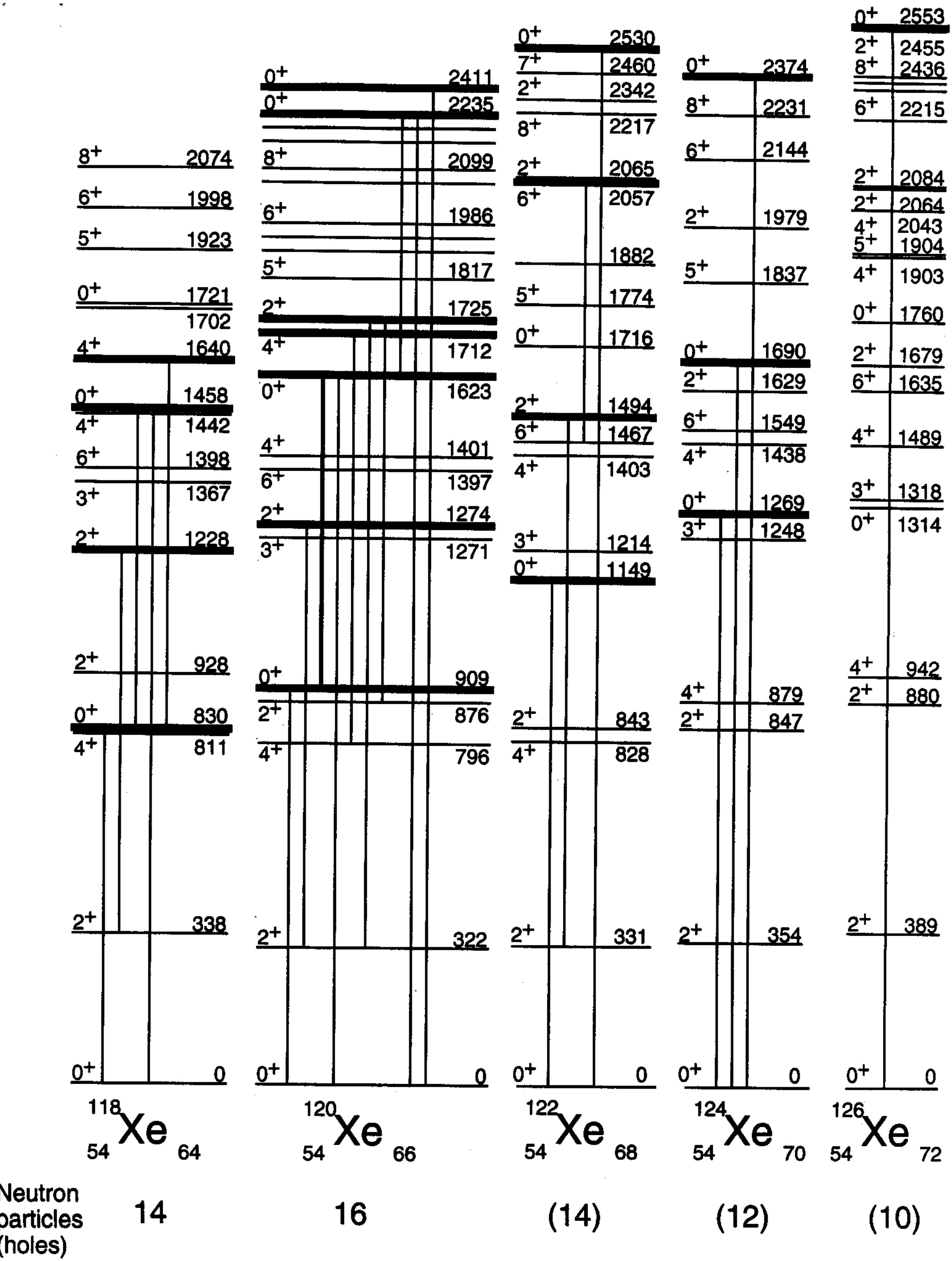
[c] determined as in Ref. [35]

[d] from Barrett and Otsuka [31]

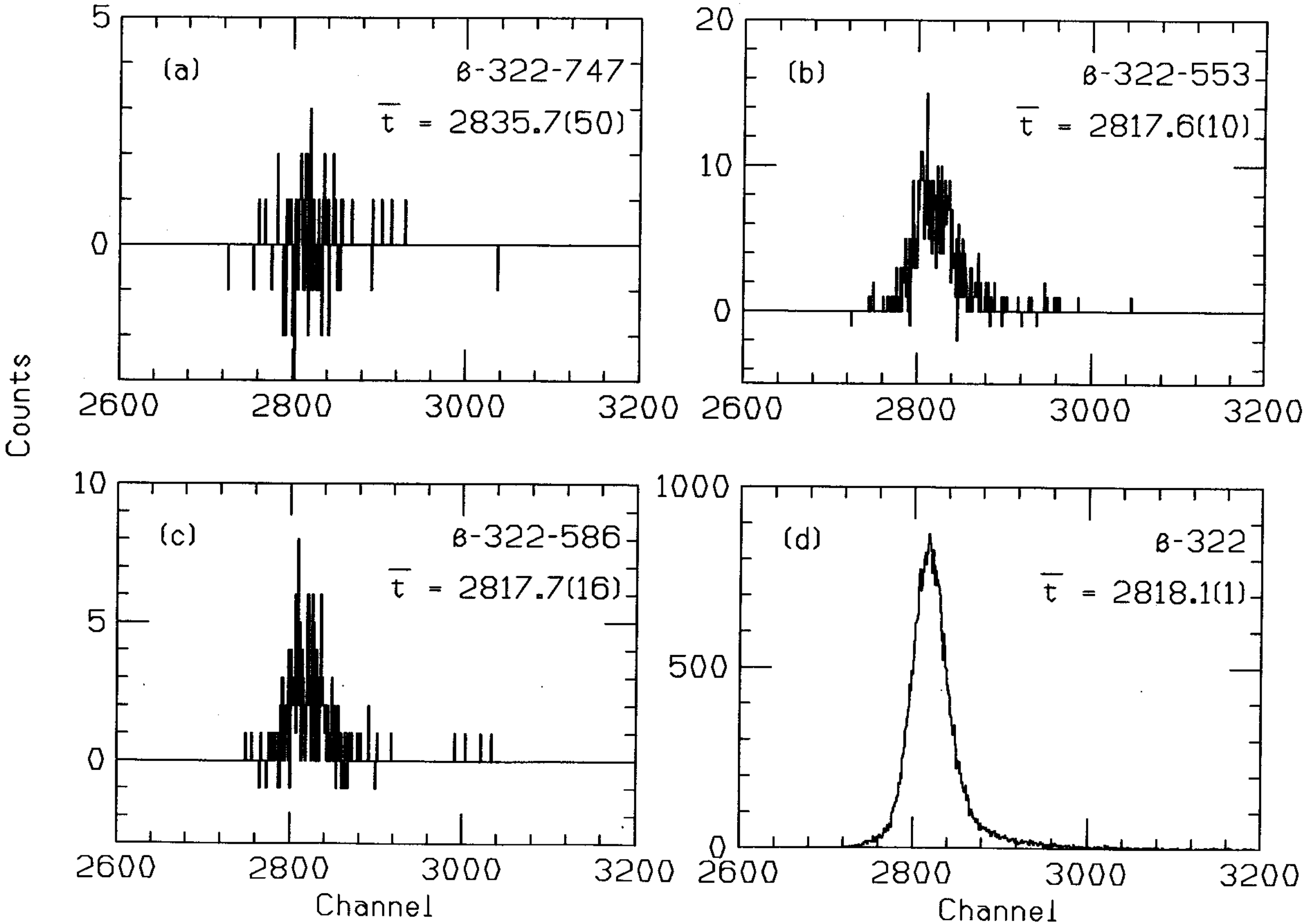


Shift 64(4) ps
^{120}Xe
322-keV TAC
prompt TAC
Counts
Time (ps)
1000
100
10
1
10000
1000
100
10
-500
-400
-300
-200
-100
0
100
200
300
400
500


FDSM
TRS
Normal IBM-2
IBM-2 with Pauli Blocking
B(E2) (e2b2)
Neutron Number



0+ 2074 8+
6+ 1998
5+ 1923
0+ 1721
1702
4+ 1640
0+ 1458
4+ 1442
6+ 1398
3+ 1367
2+ 1228
2+ 928
0+ 830
4+ 811
2+ 338
0+ 0
0+ 2411
0+ 2235
8+ 2099
6+ 1986
5+ 1817
2+ 1725
4+ 1712
0+ 1623
4+ 1401
6+ 1397
2+ 1274
3+ 1271
0+ 909
2+ 876
4+ 796
2+ 322
0+ 0
0+ 2530
7+ 2460
2+ 2342
8+ 2217
2+ 2065
6+ 2057
1882
5+ 1774
0+ 1716
2+ 1494
6+ 1467
4+ 1403
3+ 1214
0+ 1149
2+ 843
4+ 828
2+ 331
0+ 0
0+ 2374
8+ 2231
6+ 2144
2+ 1979
5+ 1837
0+ 1690
2+ 1629
6+ 1549
4+ 1438
0+ 1269
3+ 1248
4+ 879
2+ 847
2+ 354
0+ 0
0+ 2553
2+ 2455
8+ 2436
6+ 2215
2+ 2084
2+ 2064
4+ 2043
5+ 1904
4+ 1903
0+ 1760
2+ 1679
6+ 1635
4+ 1489
3+ 1318
0+ 1314
4+ 942
2+ 880
2+ 389
0+ 0
118 54 Xe 64
120 54 Xe 66
122 54 Xe 68
124 54 Xe 70
126 54 Xe 72
Neutron particles (holes)
14
16
(14)
(12)
(10)


(a)
β-322-747
t̄ = 2835.7(50)
(b)
β-322-553
t̄ = 2817.6(10)
(c)
β-322-586
t̄ = 2817.7(16)
(d)
β-322
t̄ = 2818.1(1)
Counts
Channel
Channel
5
0
20
10
0
10
5
0
1000
500
0
2600
2800
3000
3200