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GAMOW-TELLER β^+-DECAY OF DEFORMED NUCLEI NEAR PROTON DRIP-LINE

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ABSTRACT : Using a quasiparticle Tamm-Dancoff approximation (TDA) based on deformed Hartree-Fock (HF) calculations with Skyrme interactions, the distribution of the Gamow-Teller (GT) β^+-decay strength is estimated for the HF local minima of even-even deformed nuclei near the proton drip-line in the region of $28 < Z < 66$. The distribution often depends sensitively on the nuclear shape (namely, oblate or prolate). In the region of $Z < 50$ the possibility of observing the β-delayed proton emission depends sensitively on the excess of Z over $Z = N$. In the region of $Z > 50$ the almost entire GT strength estimated is found to lie below the ground state of even-even mother nuclei, and the observation of the total GT strength by β-delayed charged-particle(s) emission will be of essential importance.

1 Introduction

In β-stable nuclei the GT giant resonance (GR) lies above the ground state, so that it can be populated by charge exchange reactions such as (p,n) or $({}^3He,t)$. In contrast, the almost entire GT strength of medium-heavy nuclei near proton-drip-line is expected to lie below the ground state of mother nuclei and, thus, may be populated in principle by β^+-decay [1]. If the β-decay can detect the GT strength up till the giant resonance region, a reduction factor of the GT strength can be experimentally obtained, since the amount of the GT strength extracted from charge-exchange reactions has always suffered from the problem of how to subtract the background in the reactions [2]. The knowledge of GT β^+-decays of nuclei with $Z < 40$ near proton-drip-line is also of essential importance for the rapid-proton capture process, socalled rp-process, in astrophysics [3]. The deformed proton-drip-line nuclei, of which the GT strength distribution is estimated in our present work, have a good chance to be studied in the near future by the experimental facilities of radioactive ion beams, which are currently being constructed or planned [4].

In order to obtain the distribution of the total GT strength in proton-drip-line nuclei, it is essential not only to perform the β-γ spectroscopy but also to measure the processes of β-delayed charged-particle emission [3], since in the traditional β-γ spectroscopy the GT β-decay to very low-lying states in daughter nuclei, for which the available decay energy is larger, is so much favoured in comparison with that to higher-lying states. In ref.[5] we have studied the distribution of the GT β^+ decay strength of three $N{=}Z$ deformed nuclei, ${}^{72}_{36}Kr_{36}$, ${}^{76}_{38}Sr_{38}$ and ${}^{80}_{40}Zr_{40}$, having been stimulated by learning [6] the possibility of measuring the process of the β-delayed proton emission in respective daughter nuclei. Those three $N{=}Z$ nuclei lie just on the borderline of the nuclear chart in which the major part of GT GR is going to be populated by GT β^+-decay [1]. Namely, the result obtained in ref.[5] shows that in those nuclei about a half of the total GT strength lies below the ground state of mother nuclei. In the proton-drip-line nuclei with $Z > 50$ it is expected that the peak of the GT GR will lie well below the ground state of mother nuclei. Thus, in this paper we study the GT β^+-decay strength distribution in deformed (in our HF calculation) nuclei in the region of $28 < Z < 66$ near proton-drip-line. We concentrate here on deformed nuclei, since for spherical nuclei a better estimate can be made in spherical shell-model calculations [7]. The deformed shape of the nuclei presently investigated was predicted more than 10 years ago [8].

When we find a deformed solution in HF calculations with Skyrme interactions, which has either the lowest energy or the energy very close to that of the lowest minimum with spherical shape, we estimate the distribution of the GT strength based on the HF local minima. We do so, partly because which of energetically close-lying minima becomes lowest depends sometimes on Skyrme interactions used and partly because all energetically close-lying shapes are interesting since in the phenomena such as rp-process nuclei have anyway a finite temperature.

In sect.2 our model is described, while in sect.3 the result of numerical calculations is presented and discussed. In sect.4 a conclusion is given.

2 Description of our model

The model used in the present work is, in essence, the same as the one employed in ref.[5] and is briefly summarized in the present section. First, we perform deformed HF calculations [9] with Skyrme interactions, using the BCS approximation with a given pairing-gap parameter, which is assumed to be independent of deformation. We have found that the HF local minimum, which in the nuclei presently studied is often obtained for both a prolate and an oblate deformation, appears at nearly the same value of quadrupole moment even if we vary the value of the constant pairing gap from 1.2 MeV to, say, 0.8 MeV. Since in the ground state of a real nucleus, which is approximated by a HF local minimum, the value of gap parameters is supposed to be around 1 MeV, the present approximate way of treating the pair correlation may be acceptable. We do not solve BCS equations for a given coupling constant literally including many one-particle levels, since we want to avoid to use the calculated one-particle levels lying higher up in the continuum noting that the proton Fermi level in the present nuclei is close to the continuum. At the obtained HF minimum we estimate GT excitation modes with TDA, using a schematic separable spin-isospin interaction [10],

$$V_{12} = X_{\sigma\tau}\, \vec{\sigma_1} \cdot \vec{\sigma_2}\, \vec{\tau_1} \cdot \vec{\tau_2} \tag{1}$$

A logically more reasonable model would be to solve TDA or random phase approximation (RPA) with the same Skyrme interaction as the one used in the HF calculation. To the best of our knowledge there is no publication in which such calculations are performed for deformed nuclei. In our present work we will be satisfied with using the interaction (1). We have indeed found that the result of ref.[1], in which the same Skyrme interaction as the one used in the spherical HF calculation is employed in spherical TDA calculations, can be well reproduced by using the separable interaction (1) with $X_{\sigma\tau} = 20/A$ MeV. Some discussion of the strength of the interaction (1) can be found in ref.[11], in which β-strength functions of many nuclei are evaluated using somewhat different models with different intention.

The β-decay Q-value is a crucial quantity if one is interested in the partial half-life. In many nuclei studied in the present work (especially those in the $50 < Z < 66$ region) the experimental Q-value is not known. We show the calculated Q-value of the present β^+-decay, which is defined as

$$Q_{calc} = \lambda_p(Z) - \lambda_n(N+1) - E_p - E_n - 0.78 \tag{2}$$

in MeV, where Z (N) denotes the proton(neutron) number of mother nuclei and E_p (E_n) represents the lowest quasiproton (quasineutron) energy, while λ denotes the Fermi energy and 0.78 MeV comes from $(m_n - m_p - m_e)\, c^2$.

3 Result of numerical calculations and discussions

The GT strength shown in all figures (figs.1-5) in the present paper is estimated using the bare GT operator. Since the total GT strength observed in charge-exchange reactions populating GT GR in β-stable nuclei was only about a half of the sum rule almost independently of the mass number [2], the GT strength expected to be observed should presumably be obtained by reducing the strength plotted in figs.1-5 by a factor of about 2.

In the deformed HF calculation we use the SIII interaction as a standard Skyrme interaction, though in several nuclei we have actually compared the result obtained from the SG2 or the SkM$\star$ interaction with that of the SIII interaction. As the strength of the interaction (1) we use $X_{\sigma\tau} = 20/A$ MeV. Pairing gap parameters, $\Delta_p = \Delta_n = 1$ MeV, are used for all nuclei irrespective of deformations.

We perform TDA calculations using two-quasiparticle (one proton-quasiparticle and one neutron-quasiparticle) states, in which all one-proton states with one-particle energies less than +3 MeV and all one-neutron states with negative one-particle energies are included. Since in the present nuclei there is a sufficiently high Coulomb barrier, calculated one-proton states with positive energies but less than +3 MeV may be safely used. Restricting the space of the one-particle levels included in TDA in this way, we miss less than 10 percent of the total GT strength. A major part of the missing strength is related to the difference between the proton and the neutron wave functions with the same quantum-numbers and, thus, to the isospin mixture [12]. We have checked that when we solve the TDA equation literally including all two-quasiparticle states obtained from our deformed HF code, the resulting change of the strength plotted in figs.1-5 is not really visible, though some small strength appears in a higher energy region.

3.1 Deformed nuclei near proton-drip-line in the $28 < Z < 50$ region

In fig.1 we show the estimated GT strength of $N = Z$ nuclei, ${}^{64}_{32}Ge_{32}$, ${}^{68}_{34}Se_{34}$, ${}^{72}_{36}Kr_{36}$, ${}^{76}_{38}Sr_{38}$, ${}^{80}_{40}Zr_{40}$ and ${}^{84}_{42}Mo_{42}$, for the shape of the HF local minima using the SIII interaction. For completeness we have included the nuclei ${}^{72}Kr$, ${}^{76}Sr$ and ${}^{80}Zr$, which are studied in ref.[5]. Though the nucleus ${}^{60}_{30}Zn_{30}$ is calculated to be slightly deformed, the result is qualitatively similar to that for ${}^{64}_{32}Ge_{32}$ and, thus, is not shown in fig.1. The lowest minimum has an oblate shape for ${}^{68}Se$, ${}^{72}Kr$ and ${}^{84}Mo$, a spherical shape for ${}^{80}Zr$, and a prolate shape for ${}^{60}Zn$, ${}^{64}Ge$ and ${}^{76}Sr$. However, the difference between the HF total energies of those local HF minima shown in fig.1 for a given nucleus is at most 1.5 MeV in the present numerical calculation. Especially for ${}^{80}Zr$ and ${}^{84}Mo$ the HF total energies for the spherical and the oblate minima are nearly the same. In the case that the energy difference between the HF minima is less than 1 MeV, the shape of the lowest HF minimum may be sometimes interchanged when other Skyrme interactions are used. We have checked that even if the interchange happens, the estimated distribution of the GT strength for a given shape in fig.1 remains almost unchanged. In the case of ^{80}Zr and ^{84}Mo the observed small excitation energy of the first excited 2^+ state, 290 and 443 KeV in ^{80}Zr and ^{84}Mo , respectively [14,15], already indicates that these nuclei are deformed.

Experimental as well as theoretical (see eq.(2)) Q-values of the β^+-decays are indicated in fig.1 by arrows. Going from N=Z=32 to N=Z=42 in fig.1, it is seen that the portion of the total GT strength, which lies below the arrows and, thus, can be energetically populated by β^+-decay, is visibly increasing. Moreover, in heavier N=Z nuclei the possibility for detecting the β-delayed proton emission increases appreciably, as is seen from the fact that the dotted line, which indicates the proton separation energy measured (or obtained from a systematics of experimental data) for daughter nuclei, lies well below the arrows. From fig.1 it is also seen that the shape of the GT strength distribution is noticeably different for the oblate and the prolate minimum, especially for the nuclei, ^{68}Se , ^{72}Kr , ^{76}Sr , ^{80}Zr and ^{84}Mo .

In fig.2 the GT strength estimated for N=$Z+2$ nuclei, $^{66}_{32}Ge_{34}$, $^{70}_{34}Se_{36}$, $^{74}_{36}Kr_{38}$, $^{78}_{38}Sr_{40}$, $^{82}_{40}Zr_{42}$ and $^{86}_{42}Mo_{44}$, is shown at the HF local minima. The lowest HF minimum has an oblate shape for $^{66}_{32}Ge_{34}$ and $^{70}_{34}Se_{36}$, a spherical shape for $^{82}_{40}Zr_{42}$ and $^{86}_{42}Mo_{44}$, and a prolate shape for $^{74}_{36}Kr_{38}$, $^{78}_{38}Sr_{40}$. In ^{82}Zr and ^{86}Mo the difference of estimated HF total energies for the spherical and the oblate shape is 0.6 MeV.

Going from the N=Z to the N=$Z+2$ nuclei in the neighbourhood of the proton-drip-line it is seen that a considerable part of the GT strength disappears from the β^+-decay window and, moreover, the observation of β-delayed proton emission becomes impossible or nearly impossible.

In fig.3 the GT strength estimated for N=$Z-2$ nuclei, $^{62}_{32}Ge_{30}$, $^{66}_{34}Se_{32}$, $^{70}_{36}Kr_{34}$, $^{74}_{38}Sr_{36}$, $^{78}_{40}Zr_{38}$ and $^{82}_{42}Mo_{40}$, is shown at the HF local minima. The lowest HF minimum has an oblate shape for $^{66}_{34}Se_{32}$ and $^{70}_{36}Kr_{34}$, a spherical shape for $^{82}_{42}Mo_{40}$, and a prolate shape for $^{62}_{32}Ge_{30}$, $^{74}_{38}Sr_{36}$ and $^{78}_{40}Zr_{38}$. The difference of the estimated total HF energies of the spherical and the oblate shape in ^{82}Mo is 0.4 MeV. In all N=$Z-2$ nuclei examined here not only the β-delayed proton emission can occur, but also the β-delayed two-proton emission is possible in higher-lying states with an appreciable amount of the GT strength.

In the case of $N=Z-2$ nuclei the final states in daughter nuclei which can be populated by the GT β^+-decay have either $T=0$ or 1 or 2 . The population ratio coming from the isospin Clebsch-Gordan coefficients is 1/3 , 1/2 and 1/6 , respectively. However, it is difficult to guess the energy difference between the lowest-lying $T=0$, 1 and 2 states in those $N=Z$ odd-odd proton-drip-line nuclei. If we examine the odd-odd nuclei near the β-stability line, for example, it is known that the lowest-lying $T=1$ state of $^{14}_{7}N_7$ is found at an excitation energy of 2.3 MeV, while the ground states of all $N=Z$ odd-odd nuclei in the $f_{7/2}$ shell have $J=0$, that means $T=1$. Therefore, in the present work we have not tried to decompose the GT strength estimated for the β^+-decay of those $N = Z - 2$ nuclei into the isospin components of daughter nuclei.

Furthermore, for the β^+-decay of those $N = Z - 2$ nuclei the Fermi β^+-decay is possible to the $T = 1$ state (namely, the isobaric analogue state) of daughter nuclei. To what extent this Fermi decay is dominat over the GT decay calculated above depends sensitively again on the excitation energy of the isobaric analogue state in daughter nuclei.

3.2 Deformed nuclei near proton-drip-line in the $50 < Z < 66$ region

Restricting ourselves to the nuclei in which a local minimum with a reasonably low energy is obtained for a deformed shape in our HF calculation, in figs.4 and 5 (for the $N = Z + 4$ and the $N = Z + 6$ nuclei, respectively) we present the calculated distribution of the GT strength for the nuclei near the proton-drip-line with $56 \leq Z \leq 64$. We have chosen nuclei in this region of the nuclear chart, since there is a possibility of making those compound nuclei in the planned (or being constructed) facilities of radioactive ion beam (see, for example, ref.[4]). In those nuclei not only the β-delayed proton or two-proton emission but also the β-delayed α emission will be energetically possible. However, the probability of the α emission depends sensitively on the formation probability of α paricles inside the daughter nuclei, namely on the nuclear shell structure. Thus, it is not trivial whether the α-particle emission will strongly compete with the proton or the two-proton emission or not.

In fig.4 the GT strength of N=Z+4 nuclei, ${}^{116}_{56}Ba_{60}$, ${}^{120}_{58}Ce_{62}$, ${}^{124}_{60}Nd_{64}$ and ${}^{128}_{62}Sm_{66}$, estimated for the lowest HF minimum, which has a prolate shape, is shown. Using the SIII interaction the nucleus ${}^{128}Sm$ lies already slightly outside of the proton drip line. Neither Q-values of β^+-decay nor Q-values of charged particle(s) emission are experimentally known for those nuclei. It is seen that the almost entire strength of GT GR lies inside the β^+-decay window. In these nuclei an oblate HF local minimum exists above the lowest prolate minimum. The difference of the calculated HF total energy for the oblate minimum from that for the prolate minimum is 1.6 , 3.0 , 3.7 and 3.7 MeV for ${}^{116}Ba$, ${}^{120}Ce$, ${}^{124}Nd$ and ${}^{128}Sm$, respectively. The distribution of the GT strength for the oblate shape shows typically the presence of two gross peaks and is qualitatively similar to that of ${}^{80}Zr$ in fig.1.

In the HF calculation we have tried Skyrme interactions other than the SIII interaction. For example, both for the prolate and the oblate HF minima in the nucleus ${}^{120}Ce$ the distribution of the GT strength calculated with the SG2 interaction is very similar to that with the SIII interaction, while the HF solution with the SkM$\star$ interaction lies outside of the proton drip line. The energy difference between the prolate and the oblate HF local minima is in most nuclei slightly smaller if we use the SG2 interaction.

In fig.5 the calculated result of N=Z+6 nuclei, ${}^{122}_{58}Ce_{64}$, ${}^{126}_{60}Nd_{66}$, ${}^{130}_{62}Sm_{68}$ and ${}^{134}_{64}Gd_{70}$, estimated for the prolate HF minimum is shown. As is seen from the comparison between fig.4 and fig.5, going from N=Z+4 to N=Z+6 for a given isotope, the calculated Q-value of β^+-decay decreases by more than 1 MeV. However, we observe that the almost entire strength of GT GR lies anyway below the Q-value and the shape of the distribution of the GT strength remains relatively unchanged. Neither Q-values of β^+-decay nor Q-values of charged particle(s) emission are experimentally known for these nuclei. An oblate HF local minimum is obtained also in these nuclei and lies above the lowest prolate HF minimum by 3.0 , 3.5 , 3.0 and 2.4 MeV for ^{122}Ce , ^{126}Nd ^{130}Sm and ^{134}Gd , respectively.

4 Conclusion and discussions

We have studied the distribution of the Gamow-Teller β^+-decay strength of even-even deformed nuclei near proton drip line in the region of $28 < Z < 66$. In the deformed drip-line nuclei with $28 < Z < 50$ we often obtain the HF local minimum both at a prolate and an oblate shape, of which the estimated HF total energies are very close to each other. Which of the two deformed shapes is lower depends sensitively on the proton or the neutron number and sometimes on the Skyrme interactions. However, the GT strength distribution estimated for a given shape is nearly independent of Skyrme interactions employed and, moreover, it often depends sensitively on the nuclear shape (oblate or prolate). Changing the neutron number by -2 (+2) from N=Z , we have obtained the result that the major part of the GT GR strength appears in (disappears from) the β^+-decay window. Correspondingly, the observation of β-delayed proton emission becomes very easy (nearly impossible).

In the deformed drip-line nuclei with $50 < Z < 66$ we have again found the HF local minimum both at a prolate and an oblate shape. However, the estimated total energy of the HF prolate shape is always lower than that of the HF oblate shape. For nuclei with $N \leq Z+6$ the almost entire strength of GT giant resonance is energetically reachable by β^+-decay, and the β-delayed charged-particle emission (proton or two protons or α-particle) would be very important for detecting the β^+-decay.

In the presentation of the estimated GT strength we have used the bare GT operator. Therefore, the GT strength expected to be observed should presumably be obtained by reducing the presented values by a factor of about 2 . This reduction factor has been observed in charge exchange reactions but the very quantitative value could not really been pinned down because of the background subtraction problem in the reaction cross sections. If we can observe the β^+-decays to the GT giant resonance in proton-drip-line nuclei which are investigated in the present work, we may have a good chance to fix the reduction factor of the GT strength in the giant resonance region.

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References

[1] I.Hamamoto and H.Sagawa, Phys.Rev. **C48**, R960 (1993) : I.Hamamoto, Nucl.Phys. **A577**, 19c (1994).

[2] For exampe, see, C.Gaarde, Nucl.Phys. **A396**, 127c (1983) : A.Brockstedt et al, Nucl.Phys. **A530**, 571 (1991) : F.Osterfeld, Rev.Mod.Phys. **64**, 491 (1992), and references quoted therein.

[3] For example, see, C.Detraz and D.J.Vieira, Annu.Rev.Nucl.Part.Sci. **39**, 407 (1989) : A.C.Mueller and B.M.Sherrill, Annu.Rev.Nucl.Part.Sci. **43**, 529 (1993).

[4] For example, see, J.D.Garrett and D.K.Olsen, A proposal for physics with exotic beams at the Holified Heavy Ion Research Facility, Oak Ridge National Laboratory, Feb., 1991.

[5] I.Hamamoto and X.Z.Zhang, submitted to Phys.Lett.B.

[6] Ch.Miehé, private communications.

[7] For example, see, B.A.Brown and K.Rykaczewski, Phys.Rev. **C50**, R2270 (1994) and references quoted therein.

[8] P.Moller and J.R.Nix, Nucl.Phys. **A361**, 117 (1981) ; At.Nucl.Data.Tables **26**, 165 (1981) : S.Aberg, Phys.Scri. **25**, 23 (1982) : I.Ragnarsson and R.K.Sheline, Phys.Scri. **29**, 385 (1984) : P.Bonche, H.Flocard, P.H.Heenen, S.J.Krieger and M.S.Weiss, Nucl.Phys. **A443**, 39 (1985).

[9] D.Vautherin, Phys.Rev. **C7**, 296 (1973).

[10] A.Bohr and B. Mottelson, Nuclear Structure, Vol II, pp 636 ff, Benjamin, New York (1975)

[11] P.Moller and J.Randrup, Nucl.Phys. **A514**, 1 (1990) : M.Hirsch A.Staudt, K.Muto and H.V.Klapdor-Kleingrothaus, At. Data Nucl. Data Tables **53**, 165 (1993).

[12] J.Dobaczewski and I.Hamamoto, Phys.Lett. **B345**, 181 (1995).

[13] G.Audi and A.H.Wapstra, Nucl.Phys. **A565**, 1 (1993).

[14] C.J.Lister, A.A.Chishti, B.J.Varley, W.Gelletly and A.N.James, Nuclear Structure of the Zirconium Region, eds. J.Eberth, R.A.Meyer and K.Sistemich, Springer-Verlag, Berlin (1988) p.298.

[15] W.Gelletly, M.A.Bentley, H.G.Price, J.Simpson, C.J.Gross, J.L.Durell, B.J.Varley, O.Skeppstedt and S.Rastikerdar, Phys.Lett. **B253**, 287 (1991).

Figure captions

Figure 1 : Distribution of GT strength estimated for β^+-decay of $N=Z$ deformed nuclei in the $28<Z<50$ region, ${}^{64}_{32}Ge_{32}$, ${}^{68}_{34}Se_{34}$, ${}^{72}_{36}Kr_{36}$, ${}^{76}_{38}Sr_{38}$, ${}^{80}_{40}Zr_{40}$ and ${}^{84}_{42}Mo_{42}$, as a function of calculated excitation energy of daughter nuclei. Fig.1a shows the result for prolate shape, Fig.1b for oblate shape, and Fig.1c for spherical shape. The bare GT operator is used in the numerical calculation. The estimated quadrupole moment, Q_2 , for the respective local HF minima is written. Using the SIII interaction in the HF calculation in which oscillator bases of $N_{max}=12$ are employed, the lowest HF minimum has an oblate shape for ${}^{68}Se$, ${}^{72}Kr$ and ${}^{84}Mo$, a spherical shape for ${}^{80}Zr$, and a prolate shape for ${}^{60}Zn$, ${}^{64}Ge$ and ${}^{76}Sr$. The summed values per 1 MeV energy bin are plotted as a histogram. The solid line expresses the GT strength populating both $I^\pi = 1^+$ states with $K^\pi = 1^+$ and those with $K^\pi = 0^+$, while the shadowed bins denotes the strength populating $I^\pi = 1^+$ states with $K^\pi = 0^+$. Solid-line arrows indicate the β^+-decay Q-value obtained from either experiments or a systematics based on measured masses [13], while dashed-line arrows denote the Q-value obtained from the present model calculation. Proton separation energies in daughter nuclei from measurements (or from a systematics based on experimental data) are indicated by dotted lines.

Figure 2 : Distribution of GT strength estimated for β^+-decay of $N=Z+2$ deformed nuclei in the $28 < Z < 50$ region, ${}^{66}_{32}Ge_{34}$, ${}^{70}_{34}Se_{36}$, ${}^{74}_{36}Kr_{38}$, ${}^{78}_{38}Sr_{40}$, ${}^{82}_{40}Zr_{42}$ and ${}^{86}_{42}Mo_{44}$, as a function of calculated excitation energy of daughter nuclei. Fig.2a shows the result for prolate shape, Fig.2b for oblate shape, and Fig.2c for spherical shape. Using the SIII interaction in the HF calculation in which oscillator bases of $N_{max}=12$ are employed, the lowest HF minimum has an oblate shape for ${}^{66}Ge$ and ${}^{70}Se$, a spherical shape for ${}^{82}Zr$ and ${}^{86}Mo$, and a prolate shape for ${}^{74}Kr$ and ${}^{78}Sr$. The nuclei, ${}^{82}Zr$ and ${}^{86}Mo$, are included here, since HF calculations with Skyrme interactions other than the SIII interaction may produce the lowest HF minimum at a deformed shape. See caption to fig.1.

Figure 3 : Distribution of GT strength estimated for β^+-decay of $N=Z$-2 deformed nuclei in the $28<Z<50$ region, ${}^{62}_{32}Ge_{30}$, ${}^{66}_{34}Se_{32}$, ${}^{70}_{36}Kr_{34}$, ${}^{74}_{38}Sr_{36}$, ${}^{78}_{40}Zr_{38}$ and ${}^{82}_{42}Mo_{40}$, as a function of calculated excitation energy of daughter nuclei. Fig.3a shows the result for prolate shape, Fig.3b for oblate shape, and Fig.3c for spherical shape. Using the SIII interaction in the HF calculation in which oscillator bases of $N_{max}=12$ are emplyed, the lowest HF minimum has an oblate shape for ${}^{66}Se$ and ${}^{70}Kr$, a spherical shape for ${}^{82}Mo$, and a prolate shape for ${}^{62}Ge$, ${}^{74}Sr$ and ${}^{78}Zr$. The nucleus, ${}^{82}Mo$, is included here, since HF calculations with Skyrme interactions other than the SIII interaction may produce the lowest HF minimum at a deformed shape. See caption to fig.1.

Figure 4 : Distribution of GT strength estimated for β^+-decay of N=Z+4 deformed nuclei in the $50 < Z < 66$ region, as a function of calculated excitation energy of daughter nuclei. Using the SIII interaction in the HF calculation in which oscillator bases of N_{max}=12 are employed, the lowest minimum in these nuclei has prolate shape. The nucleus $^{128}_{62}Sm_{66}$ (and $^{132}_{64}Gd_{68}$) lies slightly outside of the proton drip line. The dashed-line arrows denote the Q-value obtained from our model calculation. The Q-value of the β^+-decay and the proton separation energy, which are obtained from the systematics based on experimental data, are shown by solid-line arrows and dotted lines, respectively, in the case that the values are given in ref.[13]. Since the ambiguity of those values is not negligible in these nuclei, it is indicated by the length of the line parallel to the x-axis. See also caption to fig.1.

Figure 5 : Distribution of GT strength estimated for β^+-decay of N=Z+6 deformed nuclei in the $50 < Z < 66$ region, as a function of calculated excitation energy of daughter nuclei. Using the SIII interaction in the HF calculation in which oscillator bases of N_{max}=12 are employed, the lowest minimum in these nuclei has prolate shape. All nuclei plotted lie inside of the proton drip line. See also captions to figs.1 and 4.

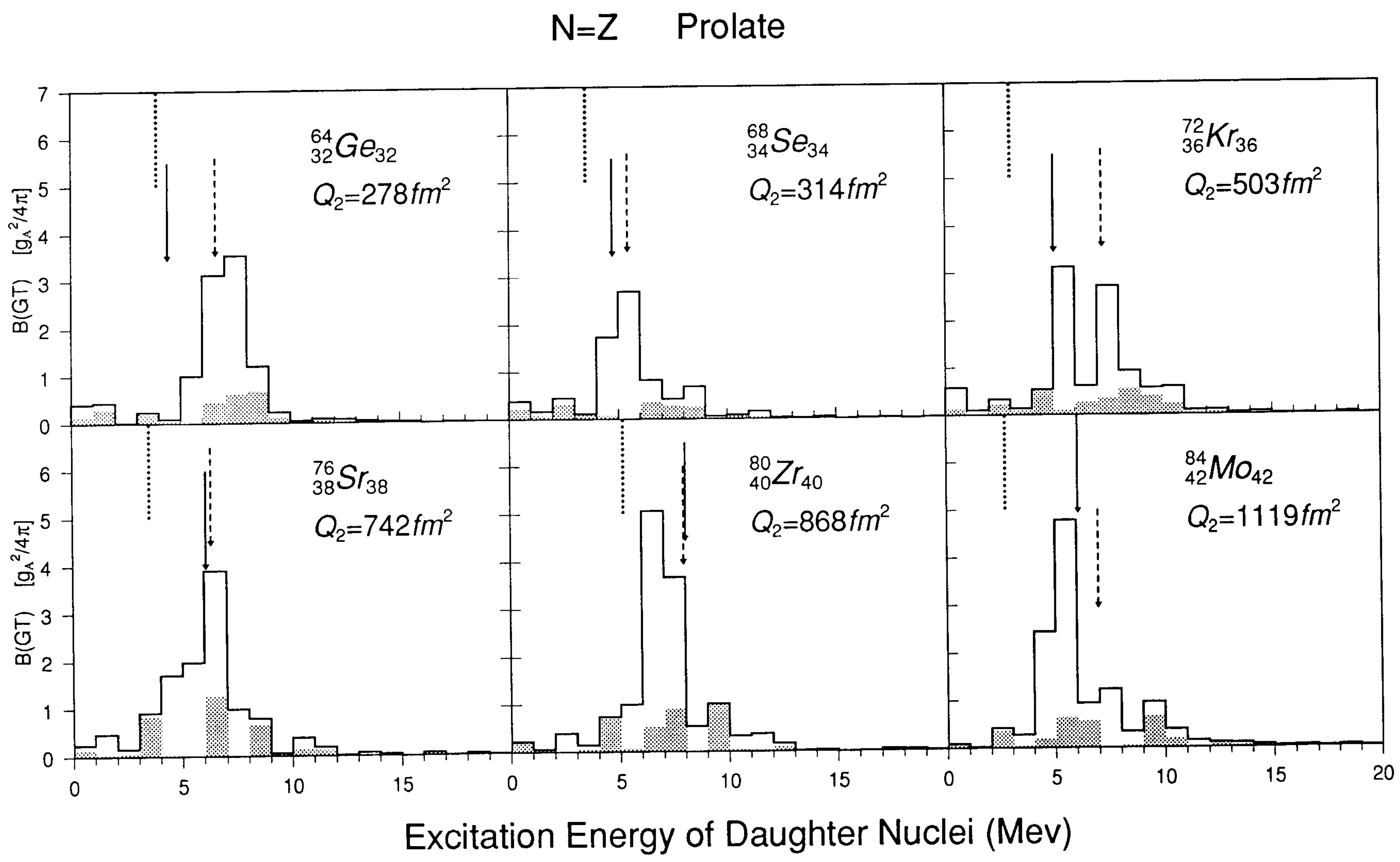
N=Z Prolate
$^{64}_{32}Ge_{32}$
$Q_2=278fm^2$
$^{68}_{34}Se_{34}$
$Q_2=314fm^2$
$^{72}_{36}Kr_{36}$
$Q_2=503fm^2$
$^{76}_{38}Sr_{38}$
$Q_2=742fm^2$
$^{80}_{40}Zr_{40}$
$Q_2=868fm^2$
$^{84}_{42}Mo_{42}$
$Q_2=1119fm^2$
B(GT) $[g_A^2/4\pi]$
0
1
2
3
4
5
6
7
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 1a

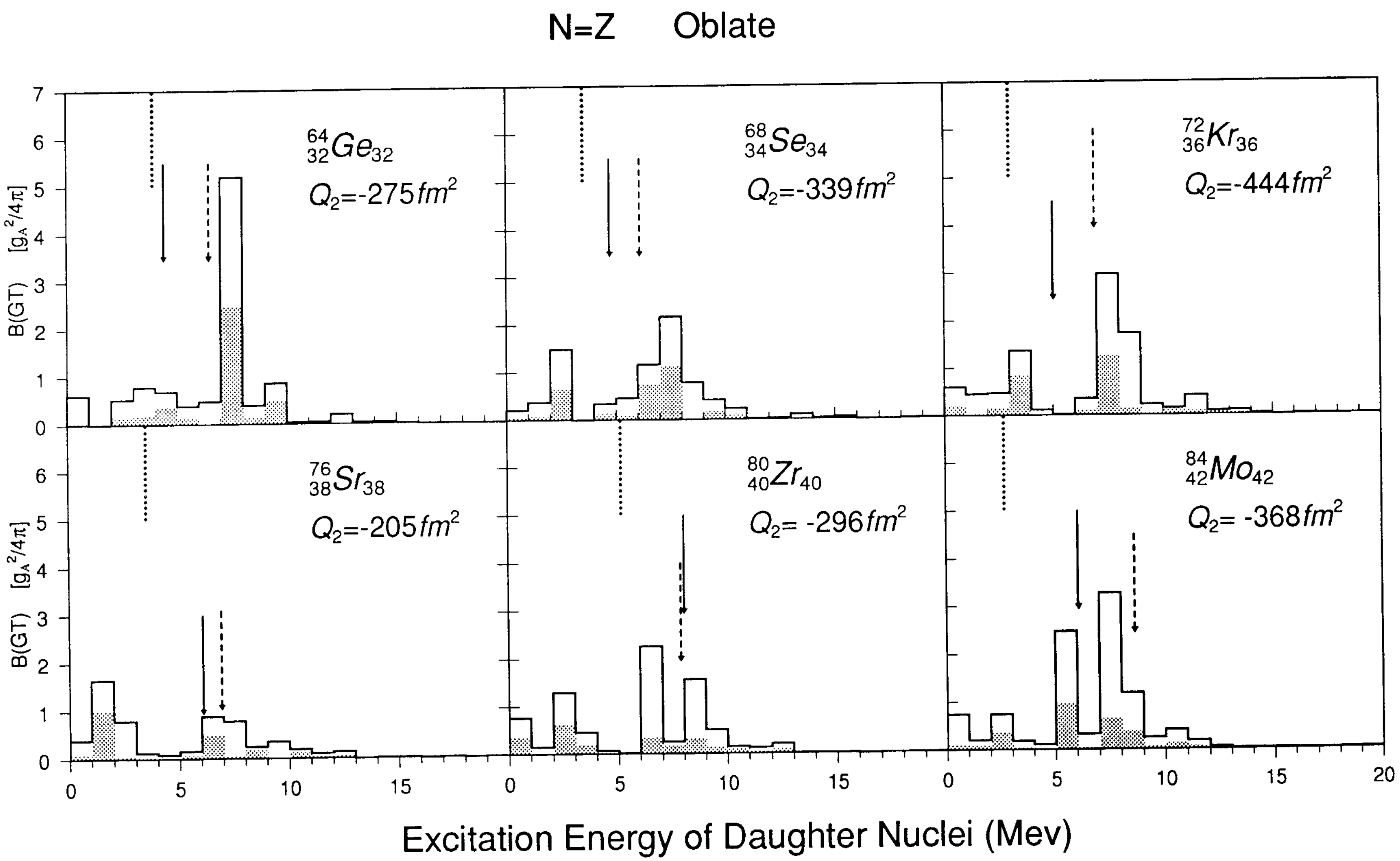
N=Z Oblate
$^{64}_{32}Ge_{32}$
Q_2=-275 fm^2
$^{68}_{34}Se_{34}$
Q_2=-339 fm^2
$^{72}_{36}Kr_{36}$
Q_2=-444 fm^2
$^{76}_{38}Sr_{38}$
Q_2=-205 fm^2
$^{80}_{40}Zr_{40}$
Q_2= -296 fm^2
$^{84}_{42}Mo_{42}$
Q_2= -368 fm^2
B(GT) $[g_A{}^2/4\pi]$
0
1
2
3
4
5
6
7
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 16

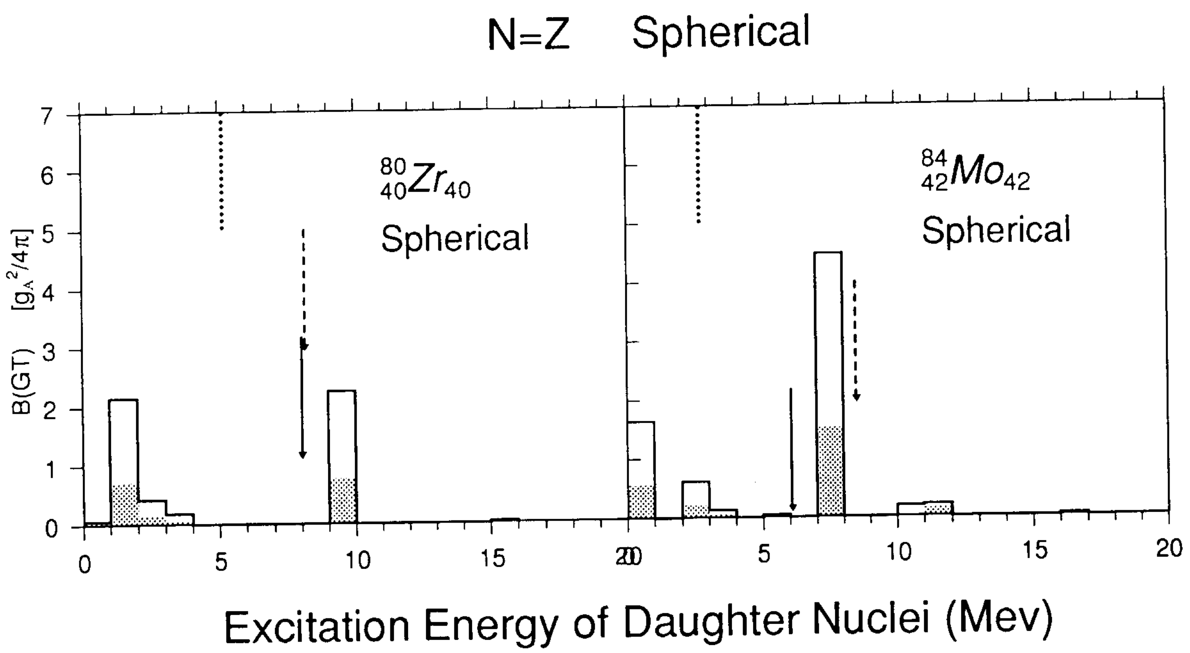
N=Z Spherical
B(GT) [$g_A^2/4\pi$]
0
1
2
3
4
5
6
7
$^{80}_{40}Zr_{40}$
Spherical
$^{84}_{42}Mo_{42}$
Spherical
0
5
10
15
20
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 1c

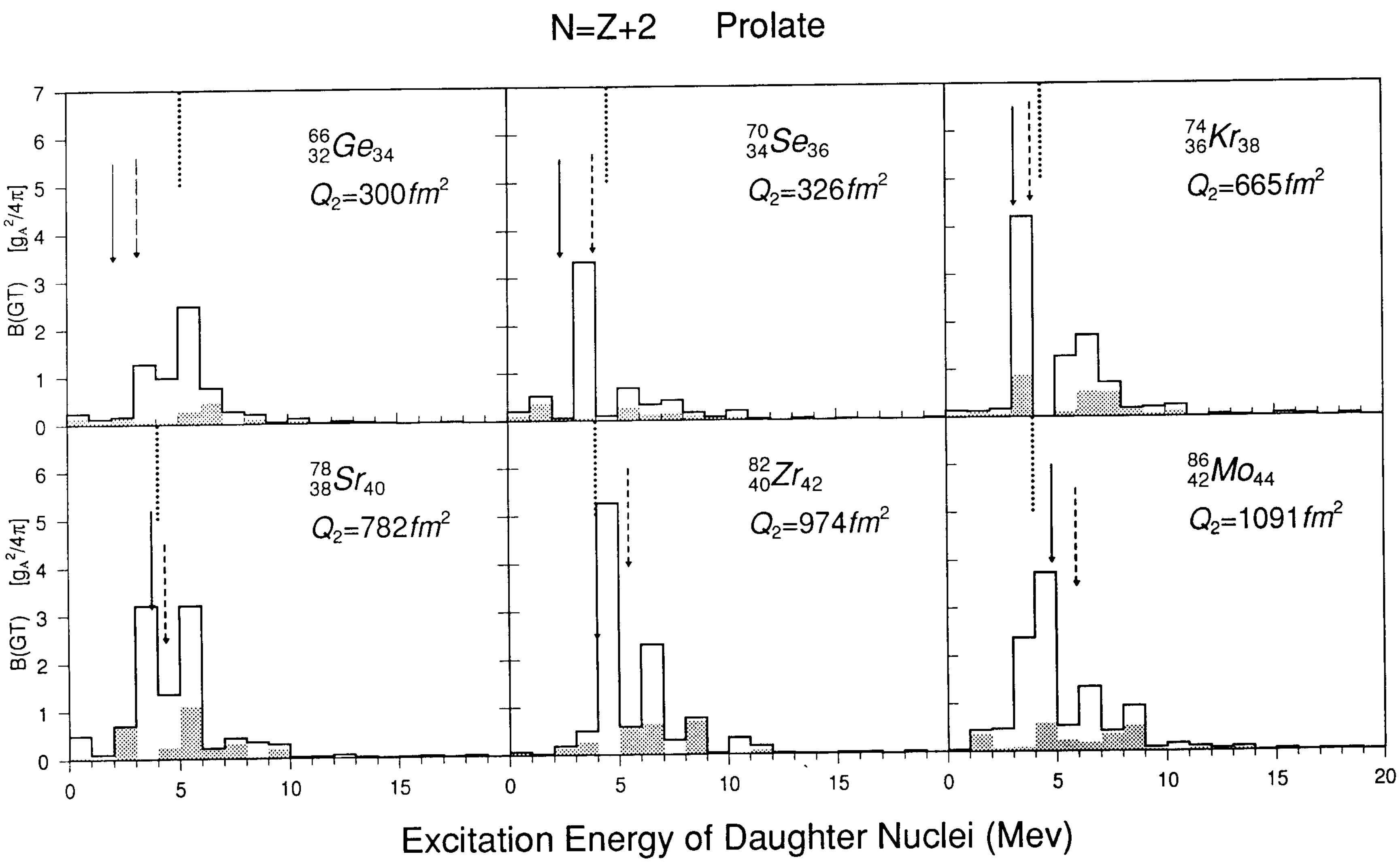
N=Z+2 Prolate
$^{66}_{32}Ge_{34}$
$Q_2=300fm^2$
$^{70}_{34}Se_{36}$
$Q_2=326fm^2$
$^{74}_{36}Kr_{38}$
$Q_2=665fm^2$
$^{78}_{38}Sr_{40}$
$Q_2=782fm^2$
$^{82}_{40}Zr_{42}$
$Q_2=974fm^2$
$^{86}_{42}Mo_{44}$
$Q_2=1091fm^2$
B(GT) $[g_A^2/4\pi]$
0
1
2
3
4
5
6
7
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 2a

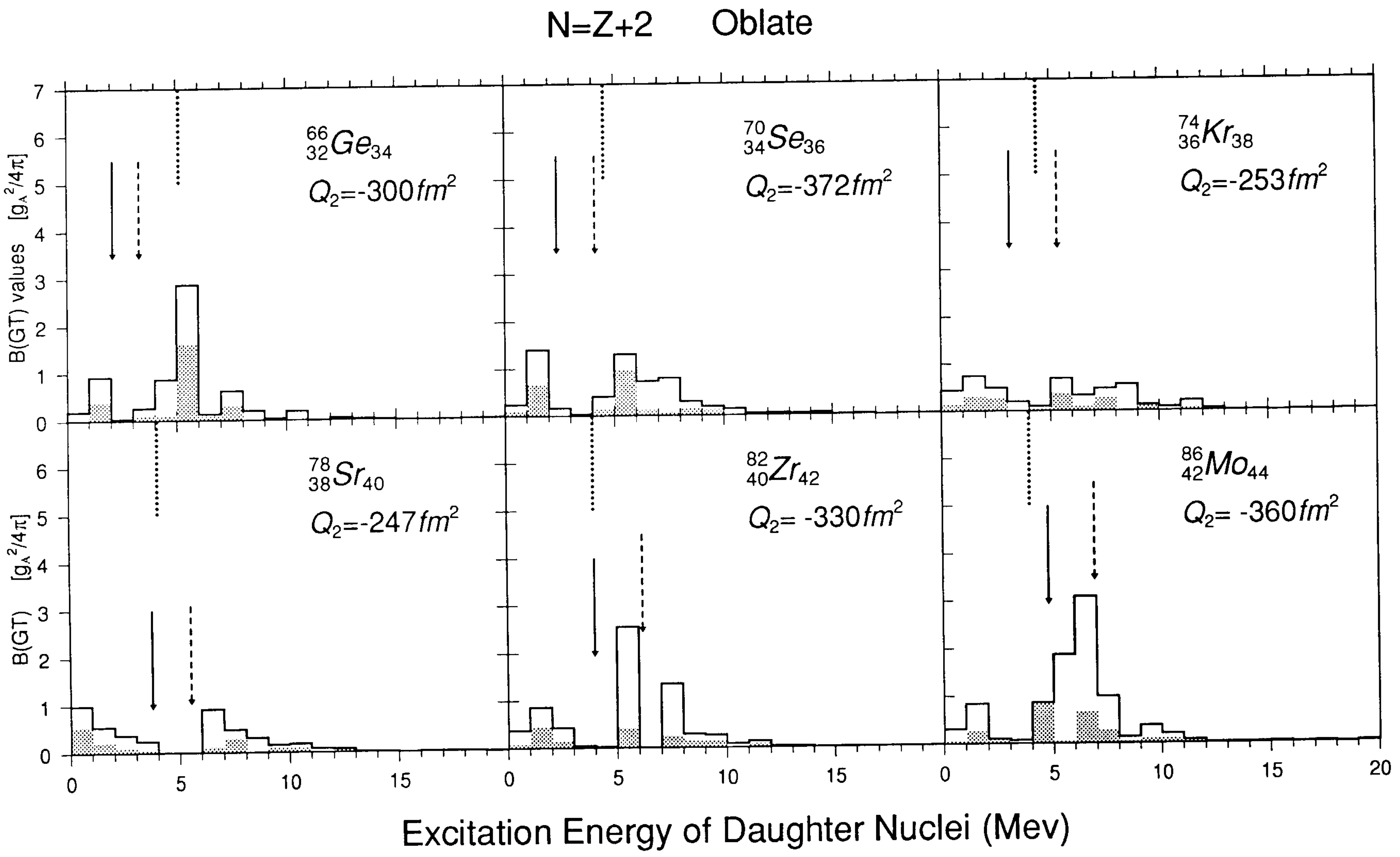
N=Z+2 Oblate
$^{66}_{32}Ge_{34}$
Q_2=-300fm^2
$^{70}_{34}Se_{36}$
Q_2=-372fm^2
$^{74}_{36}Kr_{38}$
Q_2=-253fm^2
$^{78}_{38}Sr_{40}$
Q_2=-247fm^2
$^{82}_{40}Zr_{42}$
Q_2= -330fm^2
$^{86}_{42}Mo_{44}$
Q_2= -360fm^2
B(GT) values [$g_A^2/4\pi$]
B(GT) [$g_A^2/4\pi$]
0
1
2
3
4
5
6
7
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 2b

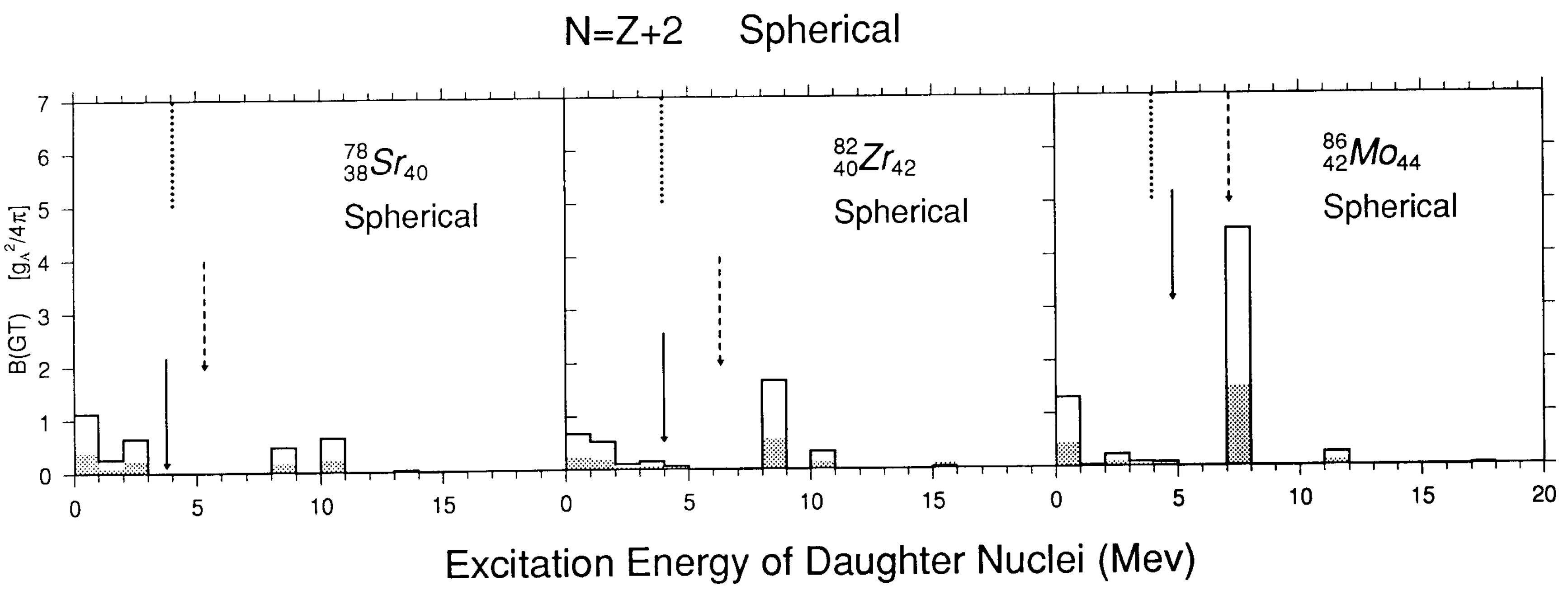
N=Z+2 Spherical

fig. 2c

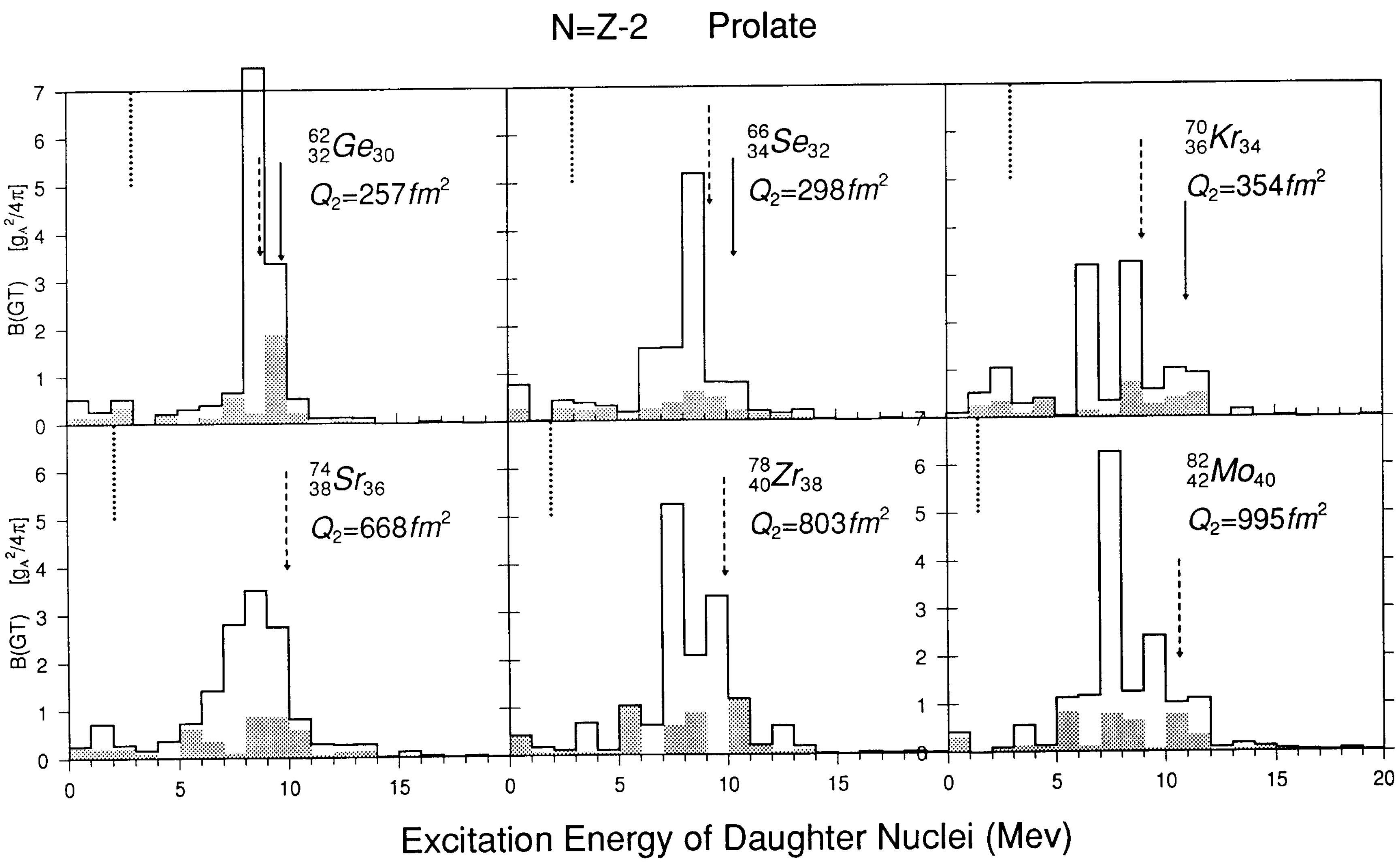
N=Z-2 Prolate
B(GT) [$g_A^2/4\pi$]
0
1
2
3
4
5
6
7
$^{62}_{32}Ge_{30}$
Q_2=257fm^2
$^{66}_{34}Se_{32}$
Q_2=298fm^2
$^{70}_{36}Kr_{34}$
Q_2=354fm^2
$^{74}_{38}Sr_{36}$
Q_2=668fm^2
$^{78}_{40}Zr_{38}$
Q_2=803fm^2
$^{82}_{42}Mo_{40}$
Q_2=995fm^2
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 3a

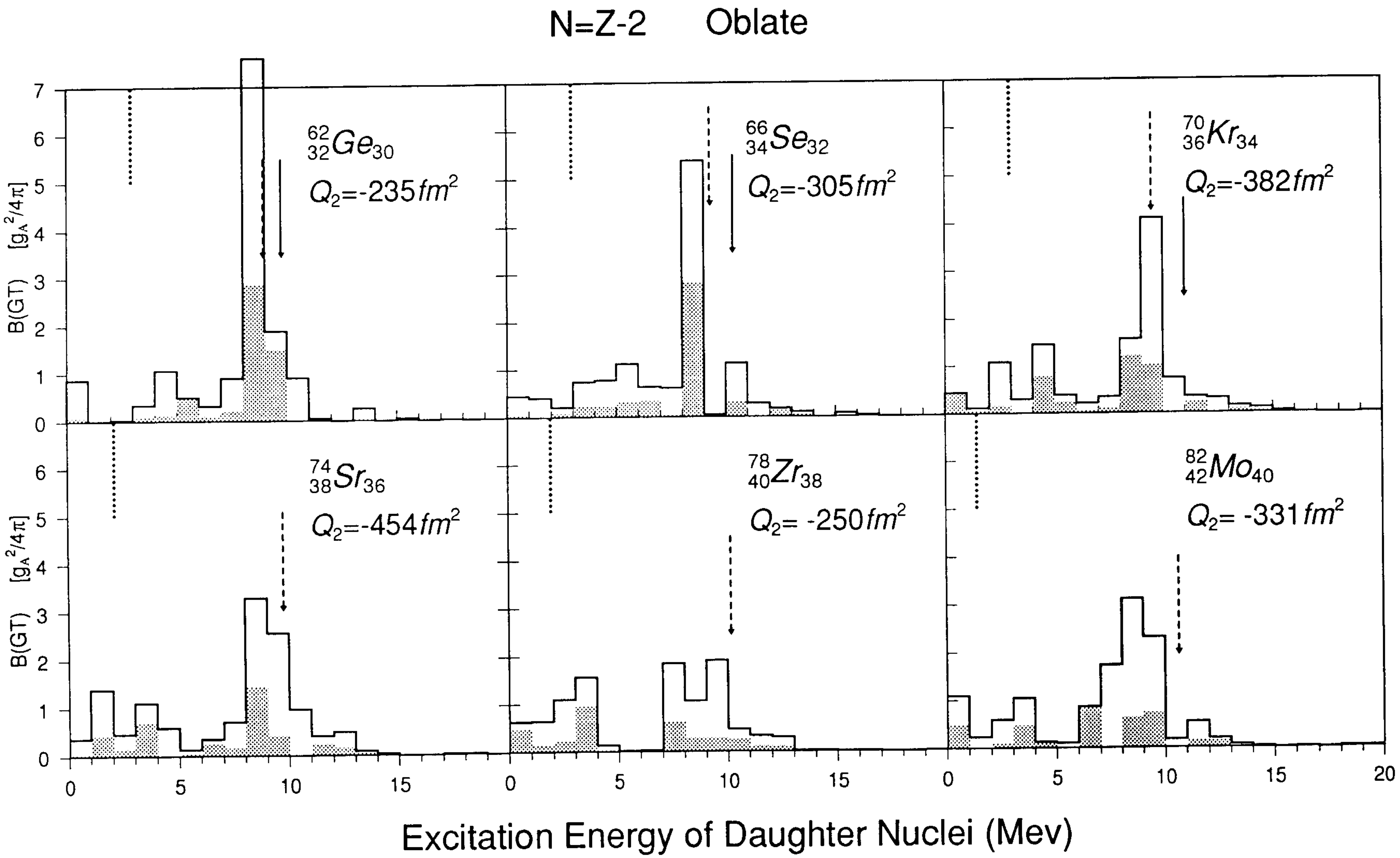
N=Z-2 Oblate
$^{62}_{32}Ge_{30}$
Q_2=-235 fm^2
$^{66}_{34}Se_{32}$
Q_2=-305 fm^2
$^{70}_{36}Kr_{34}$
Q_2=-382 fm^2
$^{74}_{38}Sr_{36}$
Q_2=-454 fm^2
$^{78}_{40}Zr_{38}$
Q_2= -250 fm^2
$^{82}_{42}Mo_{40}$
Q_2= -331 fm^2
B(GT) [$g_A^2/4\pi$]
0
1
2
3
4
5
6
7
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 3-6

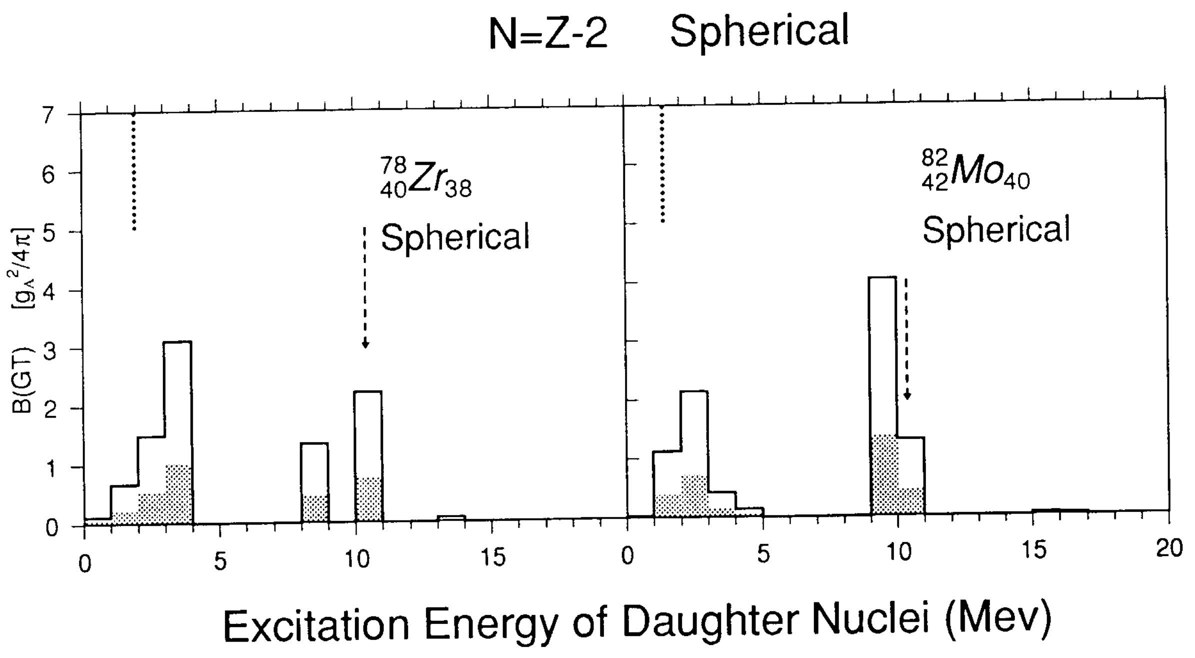
N=Z-2 Spherical
B(GT) [$g_A^2/4\pi$]
0
1
2
3
4
5
6
7
$^{78}_{40}Zr_{38}$
Spherical
$^{82}_{42}Mo_{40}$
Spherical
0
5
10
15
0
5
10
15
20
Excitation Energy of Daughter Nuclei (Mev)

fig. 3c

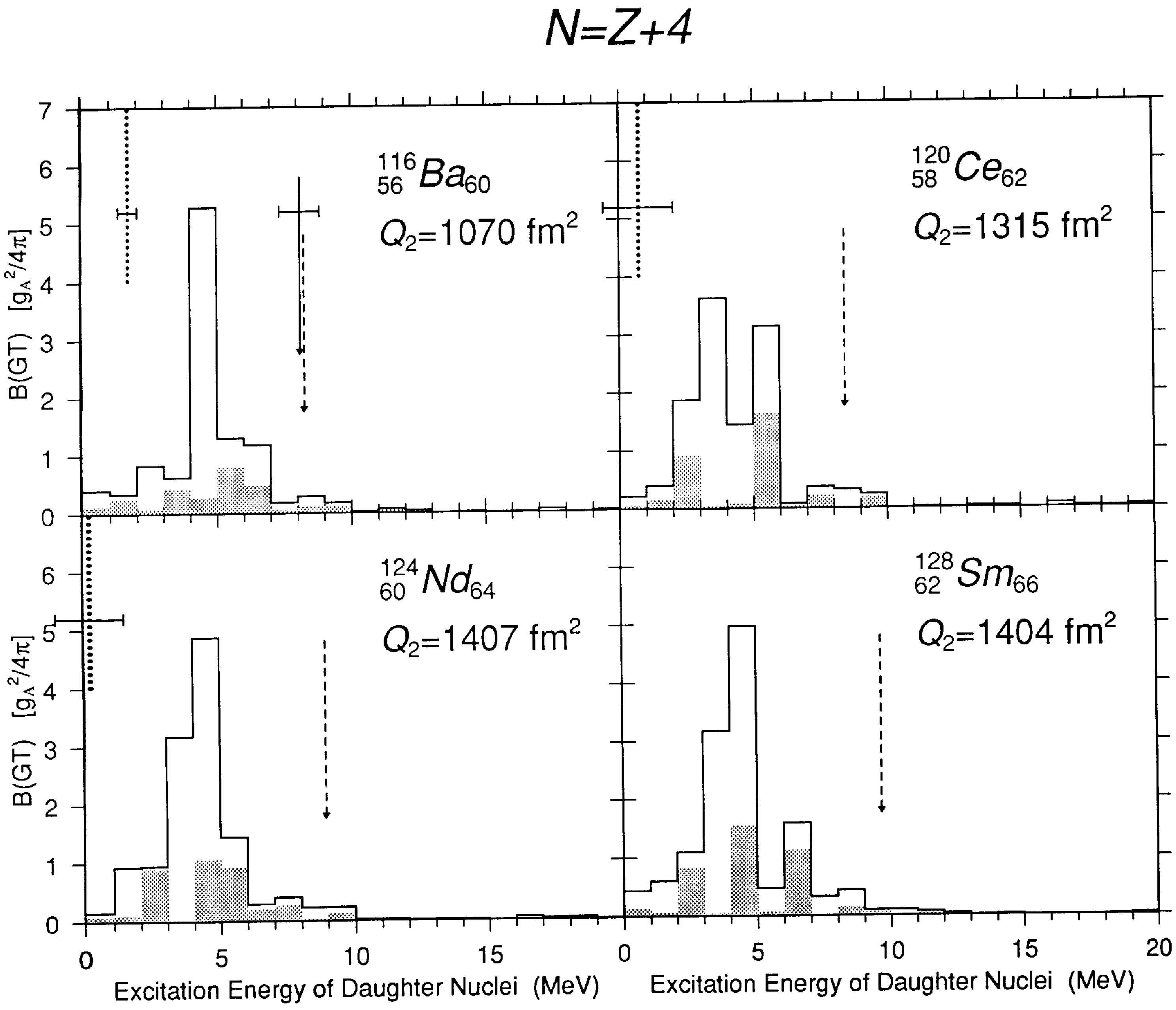
N=Z+4
$^{116}_{56}Ba_{60}$
Q_2=1070 fm^2
$^{120}_{58}Ce_{62}$
Q_2=1315 fm^2
$^{124}_{60}Nd_{64}$
Q_2=1407 fm^2
$^{128}_{62}Sm_{66}$
Q_2=1404 fm^2
B(GT) [$g_A{}^2/4\pi$]
B(GT) [$g_A{}^2/4\pi$]
0
1
2
3
4
5
6
7
0
1
2
3
4
5
6
0
5
10
15
0
5
10
15
20
Excitation Energy of Daughter Nuclei (MeV)
Excitation Energy of Daughter Nuclei (MeV)

fig. 4

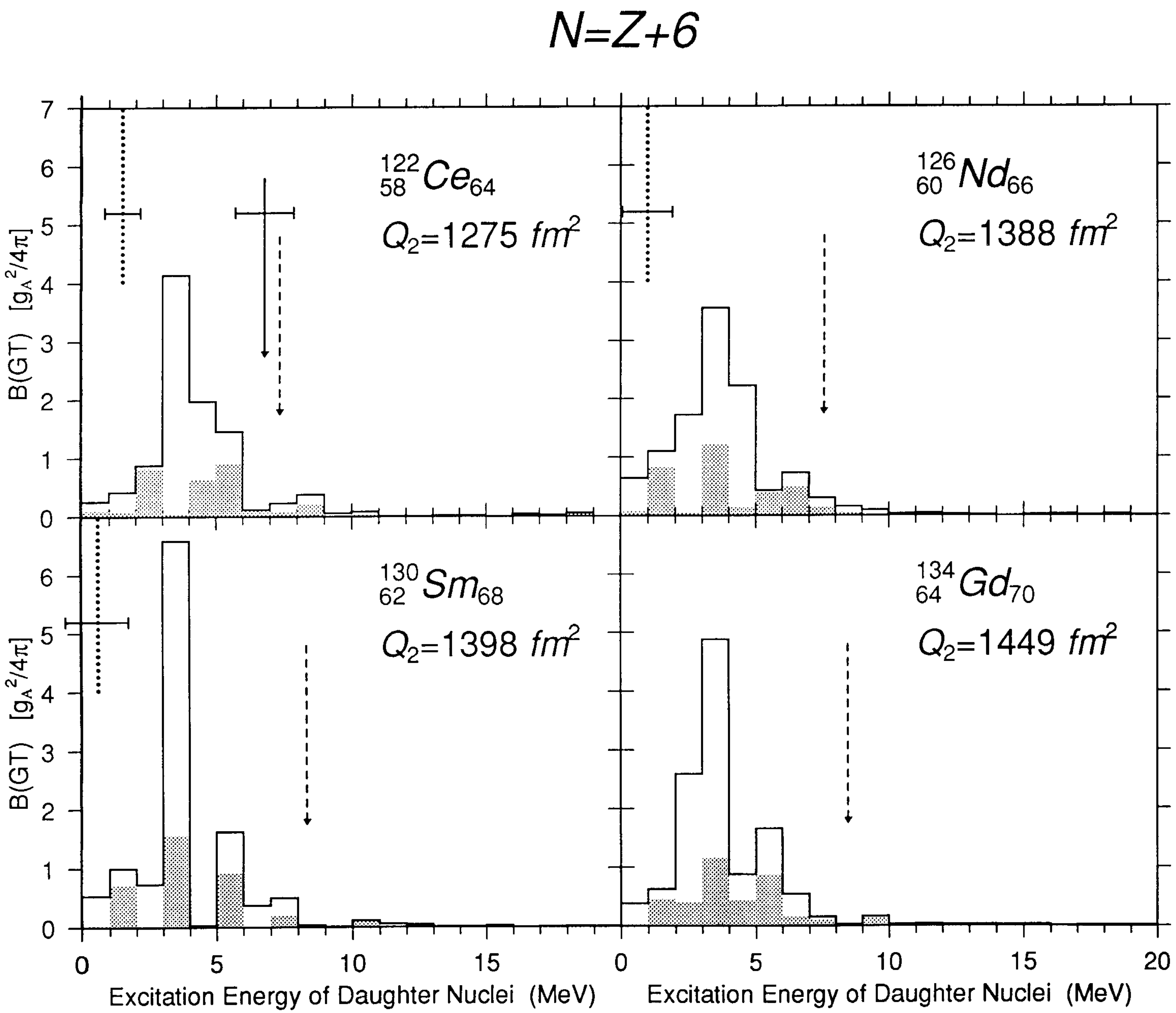
N=Z+6
$^{122}_{58}Ce_{64}$
Q_2=1275 fm^2
$^{126}_{60}Nd_{66}$
Q_2=1388 fm^2
$^{130}_{62}Sm_{68}$
Q_2=1398 fm^2
$^{134}_{64}Gd_{70}$
Q_2=1449 fm^2
B(GT) $[g_A{}^2/4\pi]$
B(GT) $[g_A{}^2/4\pi]$
0
1
2
3
4
5
6
7
0
5
10
15
20
Excitation Energy of Daughter Nuclei (MeV)
Excitation Energy of Daughter Nuclei (MeV)

fig.5