In-medium scaling law and electron scattering from high-spin states in ^{208}Pb

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The effects of the environment modifications in the structure of the low-lying high-spin states of ^{208}Pb are studied by analyzing how the *in-medium* scaling law works on the excitation energies, wave functions, and electron scattering form factors corresponding to these states. It is shown that the consideration of f_π^* in addition to the effective ρ-meson mass does not affect to much most of the states analyzed. However, some of them appear to be extremely sensitive to its inclusion in the residual nucleon-nucleon interaction. As a result, a value of $m_\rho^*/m_\rho \approx f_\pi^*/f_\pi \approx 0.91$ gives a good description of the (e,e') form factors of these particular states without any quenching factor. This value is in agreement with the one found for ^{48}Ca in a similar analysis performed in a previous work.

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I. INTRODUCTION

The modifications that nuclear processes suffer due to changes in the density and/or the temperature of the surroundings of the system have been a focus of interest in nuclear physics in the last years. Thus, the behavior of nuclear matter under extreme conditions of temperature and for high densities should be investigated by means of heavy-ion collision experiments. Also, we could study how hadrons evolve inside the nucleus, where the strong interaction works, by means of electron scattering experiments with high-energy and high-duty cycle. These processes should provide an inestimable aid in understanding the key points of the question.

On the other hand, it seems evident that the implications of these effects on nuclear properties are not at all trivial, even at low energy. However, the complexity of the problem (the variety of effects coming into play, the possibility of having unwanted double counting, etc.) makes it to be of difficult handling in general. Despite this, and in some particular cases where the nuclear problem is reasonably well controlled (e.g., double closed shell nuclei with low-lying excited states of magnetic character, which show relatively simple wave functions), it is possible to obtain additional and rather clean information concerning the question of the medium effects. This has been the philosophy underlining a series of recent works [1–5] in which attention has been paid to study one of the main consequences of the nucleus-medium interaction: the necessary decrease in the strength of the tensor part of the nucleon-nucleon (NN) interaction in the nuclear medium. In these works this reduction has been phenomenologically investigated making use of random-phase approximation type calculations together with an analysis of different experimental results in both medium (^{48}Ca) and heavy (^{208}Pb) nuclei.

Different mechanisms have been proposed to be responsible for this reduction: enhancement of the ρ-exchange tensor interaction [6], core polarization effects [7], screening effects induced by two-particle–two-hole excitations [8], and the *in-medium* scaling law [9]. All of them give rise to the required reduction, but its amount is not fully determined yet.

In heavy nuclei [3] (actually ^{208}Pb), the reduction was estimated by putting into agreement the observed quenching factors for (e,e') and (p,p') excitations of the 14^- (6.75 MeV) and the two 12^- (6.43 MeV and 7.06 MeV) high-spin states. Following the *in-medium* scaling law of Brown and Rho [9], a value of $m_\rho^*/m_\rho \approx 0.79$ was found to work adequately.

For medium nuclei, such as ^{48}Ca, it has been stressed [4] that the tensor piece of the interaction should be reduced somewhat by between 30% and 60% in order to describe reasonably well the empirical information available. However, and contrary to what was found in ^{208}Pb, this could not be accomplished considering the scaling of the ρ-meson mass only [5]. In order to provide the additional reduction needed, the strong pion-nucleon coupling constant was also considered to reduce in the medium and by putting $m_\rho^*/m_\rho \approx f_\pi^*/f_\pi \approx 0.91$ a rather good agreement with the experiment was obtained [5]. It is important to note that the only f_π coupling constant entering in the in-medium scaling law is the pion decay constant. As a consequence, these results seem to indicate that the scaling could be extended to include the strong pion-nucleon coupling constant, which is not unreasonable in the light of the expected in-medium behavior of $\delta\mathcal{L}_\pi$ (see Ref. [6]).

On the other hand, the consideration of the scaling of the strong f_π is supposed to be not too large in the ^{208}Pb region [6] and, in fact, it has been found [5] that its inclusion in the analysis only affects the strength of the quenching for the lower 12^- state (actually this quenching diminishes), leaving the two remaining states (the 14^- and the higher 12^-) practically unchanged.

These high-spin states considered in doing this kind of analysis are especially interesting because their wave functions are considerably simple. The main reason for that lies in the fact that the number of one-particle–one-hole (1p1h) configurations contributing to them are

severely restricted by angular momentum selection rules. Recently, Connelly *et al.* [10] have carried out a new high-resolution electron scattering experiment in which the known high-spin states are reanalyzed and several new ones are reported. The main conclusion of this work is the overall consistency of the quenching observed in their analysis of the various excitations. This result supports the fractional occupancy of the shell model orbits [11] as responsible for the lack of strength in single-particle transitions. However, and as the authors pointed out, other effects, such as those due to core polarization and meson-exchange currents, which were not included in their analysis, are expected to bring fluctuations of the measured quenching factors.

In this work we want to concentrate on two main aspects. First, we investigate the information that one can obtain from these new experimental data concerning the modification of the NN interaction in the nuclear medium. Second, we study the effect produced in the quenching factors by the inclusion of meson-exchange current (MEC) contributions in the nuclear current. In Sec. II we briefly describe the calculations we have performed. In Sec. III we present and discuss the results corresponding to the energy excitation spectrum and the form factors for the electroexcitation of the high-spin states previously mentioned. Finally we present our conclusions in Sec. IV.

II. DETAILS OF THE CALCULATIONS

We are interested in analyzing how the consideration of the in-medium scaling of the ρ-meson mass [9] and of the strong pion-nucleon coupling constant [5] in the NN interaction affects the results concerning low-energy properties in ^{208}Pb. More precisely, we want to know the modifications produced by the change of the ratio

$$\frac{m_\rho^*}{m_\rho} \approx \frac{f_\pi^*}{f_\pi} \tag{1}$$

in the excitation energies, in the wave functions, and in the form factors for the electroexcitation of the known high-spin states in ^{208}Pb.

To do that we have carried out a series of calculations in the random-phase approximation (RPA) framework and using two different residual interactions based on the so-called Jülich–Stony Brook interaction [12]. This interaction includes a zero-range part of Landau-Migdal (LM) type, which takes care of the short-range piece of the NN interaction, as well as a long-range component generated by the π- and ρ-exchange potentials (see Ref. [12] for details):

$$V_{\rm res}^{m_\rho^*}(q) = V_{\rm LM} + \frac{f_\pi^2}{m_\pi^2}\mathcal{V}(m_\pi) + \frac{f_\rho^2}{m_\rho^2}\mathcal{V}(m_\rho), \tag{2}$$

where

$$V_{\rm LM} = C_0\,[g_0\,\boldsymbol{\sigma}^1\cdot\boldsymbol{\sigma}^2 + g_0'\,\boldsymbol{\sigma}^1\cdot\boldsymbol{\sigma}^2\boldsymbol{\tau}^1\cdot\boldsymbol{\tau}^2], \tag{3}$$

with $C_0 = 386.04$ MeV fm^3, $f_\pi^2 = 0.08$, and $f_\rho^2 = 4.85$.

In order to include the effective ρ-meson mass, we have considered a first residual interaction given by

$$\begin{aligned} V_{\rm res}^{m_\rho^*} &= V_{\rm LM} + \frac{f_\pi^2}{m_\pi^2}\mathcal{V}(m_\pi) + \frac{f_\rho^2}{m_\rho^{*2}}\mathcal{V}(m_\rho^*) \\ &= V_{\rm LM} + \frac{f_\pi^2}{m_\pi^2}\mathcal{V}(m_\pi) + \varepsilon\,\frac{f_\rho^2}{m_\rho^2}\mathcal{V}(m_\rho/\sqrt{\varepsilon}), \end{aligned} \tag{4}$$

where the parameter ε is defined as

$$\varepsilon = \left(\frac{m_\rho}{m_\rho^*}\right)^2. \tag{5}$$

A second residual interaction

$$\begin{aligned} V_{\rm res}^{m_\rho^*+f_\pi^*} &= V_{\rm LM} + \frac{f_\pi^{*2}}{m_\pi^2}\mathcal{V}(m_\pi) + \frac{f_\rho^2}{m_\rho^{*2}}\mathcal{V}(m_\rho^*) \\ &= V_{\rm LM} + \frac{1}{\varepsilon}\frac{f_\pi^2}{m_\pi^2}\mathcal{V}(m_\pi) + \varepsilon\,\frac{f_\rho^2}{m_\rho^2}\mathcal{V}(m_\rho/\sqrt{\varepsilon}) \end{aligned} \tag{6}$$

has been also used in order to analyze the simultaneous effect of both m_ρ^* and f_π^* consistently with Eq. (1). In this case we take the ε parameter to be

$$\varepsilon = \left(\frac{m_\rho}{m_\rho^*}\right)^2 = \left(\frac{f_\pi}{f_\pi^*}\right)^2. \tag{7}$$

As we have mentioned above, there is some indication [6] that the effective pion coupling constant could not be affected too much in this nucleus. By comparing the results obtained with both interactions we can confirm or not the validity of this assumption.

Calculations have been performed for ε values ranging from 1 to 2. In the case $\varepsilon = 1$ both interactions coincide and the Jülich–Stony Brook interaction is recovered. For each ε we have adjusted the g_0 and g_0' in order to reproduce the energies and B values of the two 1^+ states in ^{208}Pb, as was done in previous works [2–5]. These two states appear to be especially adequate to do that because of their respective isoscalar and isovector character. On the other hand the resulting residual interactions are the same as those considered in Ref. [5], which allows us to compare the results here obtained with those found for ^{48}Ca in [5]. In this respect it should be pointed out that the only difference between both calculations corresponds to the single-particle configuration space used.

It is important to remark again that, in the ^{48}Ca nucleus, the agreement with the experimental information is possible only if one takes into account both m_ρ^* and f_π^* simultaneously and for $\varepsilon \sim 1.2$ [5]. On the other hand, the value $\varepsilon \sim 1.6$ was found to work correctly for the 14^- and 12^- states in ^{208}Pb, when only the effective ρ-meson mass correction was included in the calculations [3]. Our purpose is to investigate if this conclusion is modified or not when also the effective pion coupling constant is put into the play and when the experimental data of Connelly and co-workers [10] concerning the new high-spin states in lead are considered.

III. RESULTS

A. 1p1h configuration analysis

We start the discussion of the results by comparing the observed quenching factors with those found by Connelly *et al.* [10] who have calculated the (e,e') form factors by assuming simple 1p1h configurations in the wave functions. Table I shows the energy, spin parity, and the 1p1h configuration considered in each case, together with the normalization factors needed to bring theory and experiment into agreement. Therein we have not included the (8^-) state at 6.833 MeV, because the data do not permit a clear assignment of spin and parity. The single-particle wave functions have been generated by means of a Woods-Saxon potential, the parameters of which have been taken from Ref. [13].

In what refers to the 9^+ state at 5.260 MeV, a reasonable agreement with the data can be obtained also if one uses the $\nu(1j_{15/2}, 2f_{5/2}^{-1})$, provided a normalization factor of $Q = 0.78$ is included. On the other hand the wave function we have used to evaluate the Q factor for the 9^+ state at 5.954 MeV is the normalized wave function producing the mixing percentages quoted in [10] with $Q = 0.69$, a value that should be compared with the 0.77 we have found (see footnotes in Table I).

The results show a certain discrepancy with the values given in Ref. [10]. Despite the fact that in the analysis of Connelly and collaborators the fit to the experimental data has been done in a distorted-wave Born approximation, the difference observed in some of the states must be ascribed to the different parameters used for the potential. In [10] some of these parameters are readjusted for each state, while we have considered the same set of them for all the single-particle states. The reason for that lies in the fact that we are interested in knowing if the experimental information can be accounted for by means of RPA calculations based on the modified residual NN interactions we have introduced and if it is possible to fulfill this task for a given value of the ε parameter.

B. Energy spectrum

The second point of interest to us corresponds to the excitation energy spectrum, particularly for the high-spin states we want to study. Figure 1 shows the comparison of the experimental values found by Connelly *et al.* [10] with the values obtained in RPA calculations performed with the interactions $V_{\rm res}^{m_\rho^*}$ (central levels) and $V_{\rm res}^{m_\rho^*+f_\pi^*}$ (right levels) and varying the ε parameter. Some facts deserve a comment. First, some of the energy values (mainly those corresponding to negative parity states) show a strong dependence on ε, while those with positive parity do not (except the first 11^+). Second, the ordering of the levels is correct with the only exception being the inversion between the first 11^+ and the two following 9^+ states. Also, it should be pointed out that the RPA calculations only give one higher 12^- state instead of the two experimentally observed, which are due to more complicated coupling mechanisms. Finally, the energy values are in a reasonable agreement with the experimental ones, specially those with positive parity. For the negative parity states the shift in energy is at most ~ 400 keV in the minima of the different curves.

In what refers to this minimum value of the energies of these states, it is worth noting here the strong effect produced by the inclusion of f_π^*. As one can see, while the consideration of m_ρ^* only gives rise to this minima for high values of the ε parameter, $\varepsilon \sim 1.6$–1.8, when f_π^* enters into play these minima are moved towards smaller ε (around 1.2–1.4). Of course this is due to the additional reduction in the tensor piece of the interaction produced by the effective pion coupling constant, and the impor-

TABLE I. High spin states considered in this work, 1p1h configurations used to describe them and the normalization factors Q quoted in Ref. [10] and obtained from our calculations (not including MEC).

			Q	
Energy (MeV)	J^π	1p1h configuration	Ref. [10]	This work
5.010	9^+	$\nu(2g_{9/2}, 1i_{13/2}^{-1})$	0.54 ± 0.01	0.64
5.260	9^+	$\pi(1h_{9/2}, 1h_{11/2}^{-1})$	0.53 ± 0.04	0.55
5.291	11^+	$\nu(2g_{9/2}, 1i_{13/2}^{-1})$	0.38 ± 0.03	0.28
5.860	11^+	$\nu(1i_{11/2}, 1i_{13/2}^{-1})$	0.61 ± 0.05	0.75
5.954	9^+	$\nu(1i_{11/2}, 1i_{13/2}^{-1})$, $\pi(2f_{7/2}, 1h_{11/2}^{-1})$	$0.50 \pm 0.05, 0.19 \pm 0.03$[a]	0.77[b]
6.283	10^-	$\nu(1j_{15/2}, 1i_{13/2}^{-1})$	0.64 ± 0.07	0.25
6.437	12^-	$\nu(1j_{15/2}, 1i_{13/2}^{-1})$	0.46 ± 0.07	0.66
6.745	14^-	$\nu(1j_{15/2}, 1i_{13/2}^{-1})$	0.53 ± 0.04	0.55
6.884	10^-	$\pi(1i_{13/2}, 1h_{11/2}^{-1})$	0.32 ± 0.09	0.29
7.064	12^-	$\pi(1i_{13/2}, 1h_{11/2}^{-1})$	0.32 ± 0.05	0.26
7.086	12^-	$\pi(1i_{13/2}, 1h_{11/2}^{-1})$	0.18 ± 0.02	0.16

[a] Mixing percentages corresponding to the two 1p1h configurations and fitting the data.

[b] Value obtained using the normalized wave function
$0.851257\,\nu(1i_{11/2}, 1i_{13/2}^{-1}) - 0.524750\,\pi(2f_{7/2}, 1h_{11/2}^{-1})$.

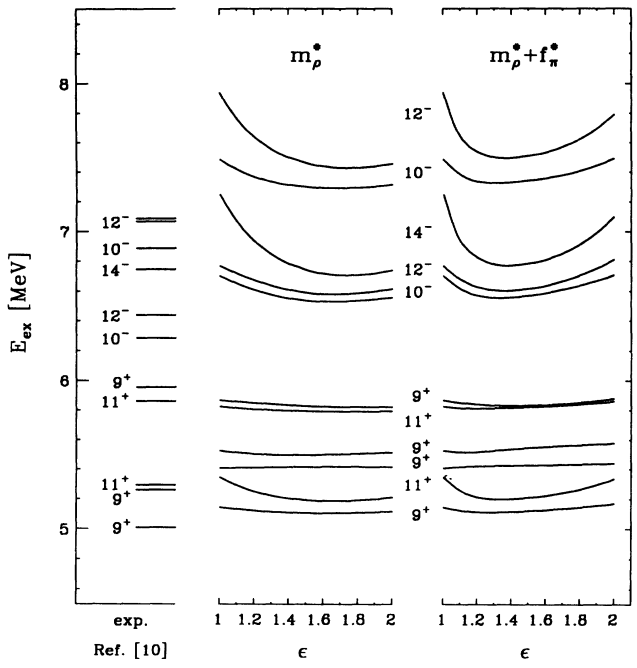

FIG. 1. Excitation energies for the high-spin states of interest. The experimental values (left plot) are from Ref. [10]. The calculated values have been obtained for ε ranging from 1.0 to 2.0 and including the effect of m_ρ^* (central plot) only and also that of f_π^* (right plot).

tant point is that small values of ε were required to obtain a good agreement betwee theory and experiment in the case of the ^{48}Ca nucleus for the calculation with the interaction $V_{\rm res}^{m_\rho^*+f_\pi^*}$ (see Ref. [5]). This result could indicate that the consideration of in-medium scaling in both the ρ-meson mass and the strong pion-nucleon coupling constant makes the necessary reduction of the tensor piece of the residual interaction almost independent of the nucleus considered.

However, it is obvious that such a conclusion needs to be confirmed by analyzing the form factors corresponding to the excitation of these levels. In what follows we discuss the results obtained in this direction.

C. Quenching factors

First of all we have calculated the quenching factors Q needed to bring theory and experiment into agreement, for each ε value and with the two interactions considered. The values of Q have been evaluated in order to obtain the same degree of the description of the data as Connelly *et al.* [10] found with their 1p1h wave function analysis. The results of this study are shown in Fig. 2 for the levels we are interested in. We have not included the third 12^- at 7.086 MeV because it does not add any important aspect to the investigation. In the case of the 9^+ state at 5.260 MeV, we have used the wave functions of the second 9^+ state obtained in our calculations, instead of that of the third one, which is the most similar to the 1p1h wave function considered in Ref. [10], to describe the data. In this way a better agreement with the experiment can be achieved.

As one can see in Fig. 2, the Q factors obtained from the results found with the interaction $V_{\rm res}^{m_\rho^*}$ (solid lines) do not match the value 1.0 for any value of ε with the exception of the two lowest-lying 9^+ states. However, there is an inconsistency in these cases because for the first one ε should be of the order of 1.1–1.2, while a considerably larger value, $\sim$ 1.5–1.6, is required for the second 9^+ level.

When the interaction $V_{\rm res}^{m_\rho^*+f_\pi^*}$ is used (dashed lines), Q reaches unity for two additional states, the 9^+ at 5.954 MeV and the 12^- at 6.437 MeV. The important point is that now an ε value of $\sim$ 1.1–1.3 permits the simultaneous description of the form factors for these four states, without any quenching. This confirms the conclusion we pointed out above for the excitation energies and we can state that it is possible to describe, with a unique interaction [that is, the one given by Eq. (6) with $\varepsilon \sim 1.2$], the (e,e') form factors for different kinds of excited states in different nuclei.

The fact that no apparent differences, apart from those found in the excitation energies, are observed between the calculations performed with the two interactions for most of the states considered is in agreement with the assumption of Brown and Rho [6] concerning the small effect that f_π^* should produce in the ^{208}Pb region. Even more, in those cases with a special sensitivity to f_π^*, the right value of ε (that is, $\sim$ 1.2) makes $m_\rho^*/m_\rho \approx f_\pi^*/f_\pi \approx$ 0.91, a value which is slightly, but not much, less than unity as expected in Ref. [6].

In order to go deeper into this point we have analyzed the wave functions of these states looking at the mixing of the different 1p1h configurations. In this respect it is important to note that the protonic 1p1h components give bigger contributions to the (e,e') form factors than neutronic ones. This is so because of the fact that the nuclear current includes the convection and the spin-magnetization pieces. The first one is mainly due to protons, while in the second protons and neutrons contribute with their magnetic moment, which is bigger (in absolute value) in the case of the proton.

In our calculations we have found only two states, the wave function of which is dominated by a protonic 1p1h configuration, the second 10^- and the second 12^-, in which the main component is the $\pi(1i_{13/2}, 1h_{11/2}^{-1})$, in agreement with the assumption of Connelly *et al.* [10] (see Table I). In these two cases, the modification of ε only produces small changes in the amplitudes corresponding to other neutronic 1p1h configurations, which give rise to small variations in the strength of the form factor and, as a consequence, a Q factor which is practically constant.

The other cases in which the same situation occurs, the two 11^+ and the 14^-, show RPA wave functions which are dominated by neutronic 1p1h configurations, which coincide with those quoted in Table I. No additional components of protonic type contribute and then the small variations observed in the Q factor are due to the modification in the admixture of other neutronic components

which show amplitudes much smaller than that of the dominant configuration.

The remaining cases correspond to situations in which the dominant component is of neutronic type, but small contributions of protonic 1p1h configurations appear. Small variations in the amplitude of these last (as those produce by varying ϵ) produce appreciable changes in the form factors, as is apparent from the Q factors shown in Fig. 2.

The wave function of the fourth 9^+ state obtained in our calculations (that is, the one we have used to describe the data of the 9^+ state at 5.954 MeV) is only basically different to that of the remaining levels. As pointed out in Table I, the agreement between theory and experiment is obtained in this case by assuming a wave function with two 1p1h configurations, the $\nu(1i_{11/2}, 1i^{-1}_{13/2})$, which is the dominant, and the $\pi(2f_{7/2}, 1h^{-1}_{11/2})$. Our RPA results show that also the $\nu(1j_{15/2}, 3p^{-1}_{3/2})$ component contributes and with an amplitude comparable to that of the $\nu(1i_{11/2}, 1i^{-1}_{13/2})$ configuration. It is the variation in the different amplitudes when ϵ is changed which

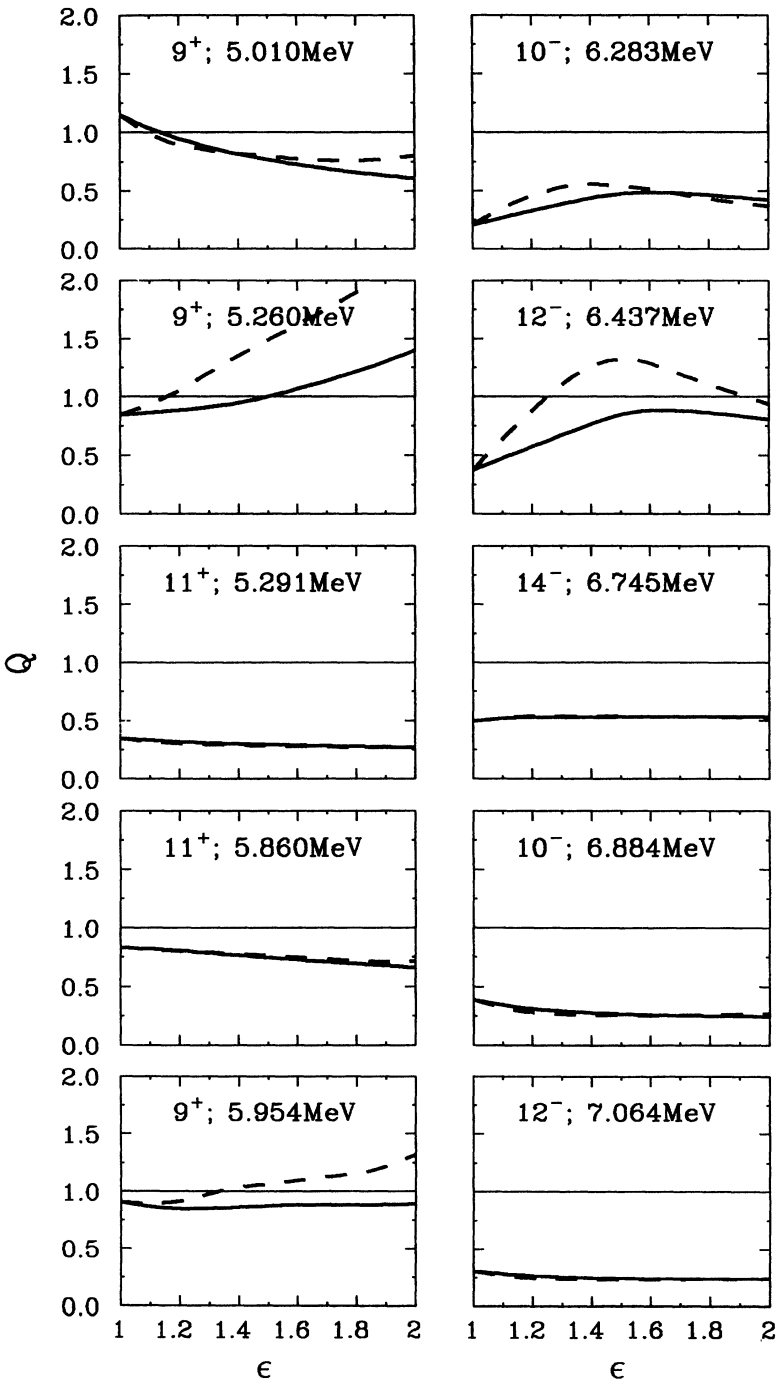

FIG. 2. Quenching factors as a function of the ϵ parameter, caculated for the high-spin states considered in this work. Solid lines include the effect of m^*_ρ only, while dashed lines also take into account the contribution of f^*_π.

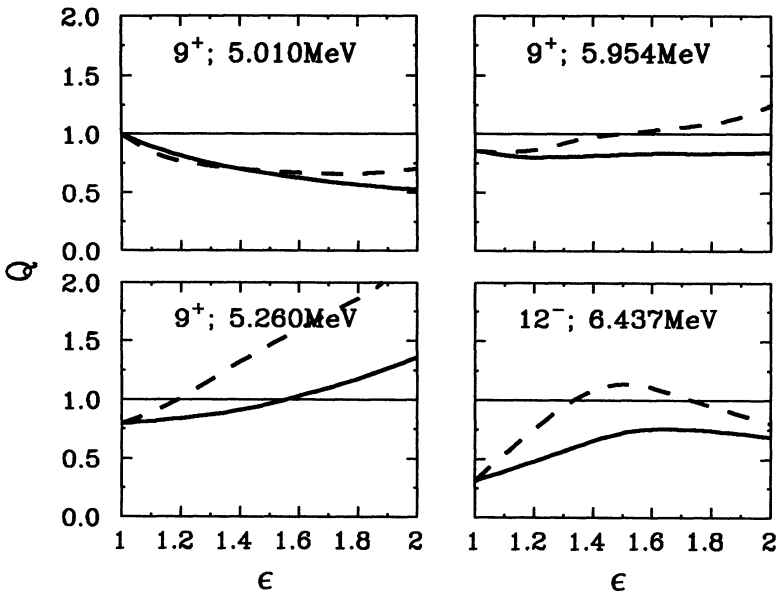

FIG. 3. Same as Fig. 2, but including the MEC effect. Only the four levels in which $Q = 1$ for some of the RPA calculations performed are shown.

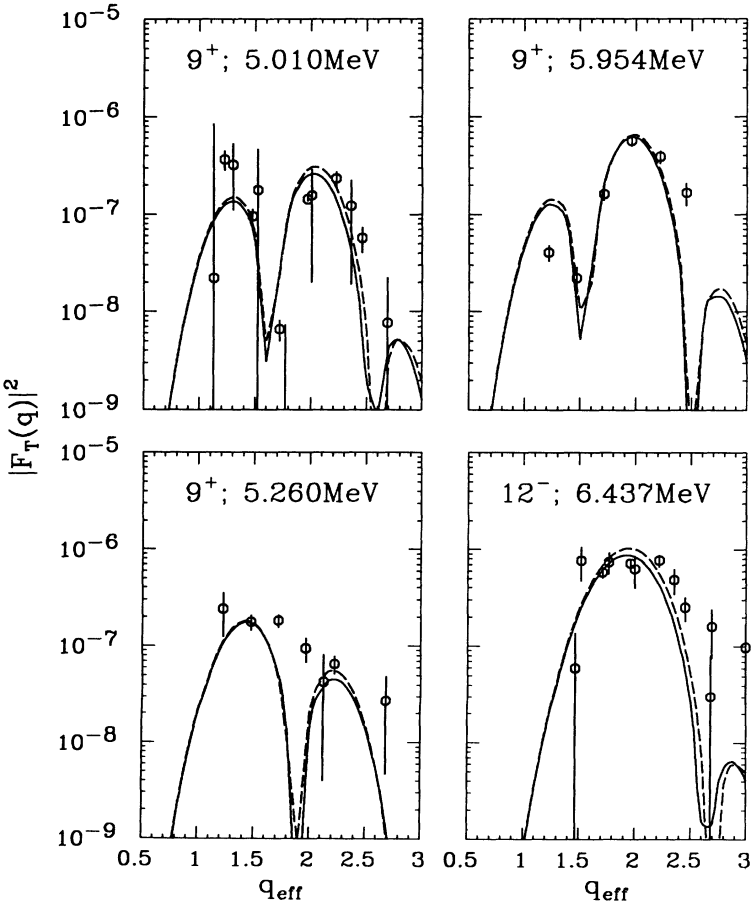

FIG. 4. Form factors for the electroexcitation of the four states discussed in the text. Experimental data are from Ref. [10]. Dashed (solid) lines have been obtained with (without) the consideration of the MEC in the nuclear current.

makes the Q factor practically constant for calculations with the interaction $V_{\rm res}^{m_\rho^*}$ and appreciably variable for the interaction $V_{\rm res}^{m_\rho^*+f_\pi^*}$.

D. MEC effects

Up to now all the quoted results correspond to calculations performed without including the effects of the MEC's in the nuclear current. In what follows we analyze such effects by evaluating the (e,e') form factors in the framework of a model which considers, additionally to the one-body (convection and spin-magnetization) currents, the two-body currents arising from the exchange of one pion and giving the most important contribution in the excitation energy and momentum transfer ranges in which we are interested in this work; these are the so-called seagull and pionic currents (see Refs. [14,15] for further details concerning these MEC's). In the calculations described below, MEC contributions have been evaluated consistently with the scaling of the strong pion-nucleon coupling constant, by using f_π^* instead of f_π in the second residual interaction.

In the cases we are discussing here, the MEC's give rise to a modification in the strength of the form factor maxima as well as a shift of their positions and that of the scattering minima. In order to estimate the contribution of the MEC we have calculated the relative increment of the corresponding form factors at the peak positions.

We have found only one case, the second 11^+ state, in which the MEC's produce a reduction in the strength the form factor. However, this reduction is small, $\sim 6\%$, and cannot make the corresponding Q factor reach the value 1. In the remaining cases the MEC's enhance the (e,e') form factors and, as a consequence, the quenching factors diminish. In the momentum transfer region of interest to us, the effect of the inclusion of the two-body currents is at most 20%, which does not modify too much the findings of the previous section concerning the levels for which Q was below 1.

More interesting is the effect of the MEC's in those cases in which a good description of the data can be obtained without consideration of any quenching factor. In Fig. 3 we show, for these states, the Q factors calculated for the two NN residual interactions after including the MEC's. The enhancement of the form factor at the peak position (where the Q is evaluated) due to the contribution of the MEC breaks to some extent the consistency found for the calculations performed with the interaction $V_{\rm res}^{m_\rho^*+f_\pi^*}$ when only one-body currents were considered. In any case it seems that still low values of ε (~ 1.2–1.4) for this interaction could provide a reasonable description of the data. This should not be possible using the interaction $V_{\rm res}^{m_\rho^*}$.

To finish the discussion of the results we show in Fig. 4 the form factors for these four states in the case $\varepsilon = 1.2$ for the interaction $V_{\rm res}^{m_\rho^*+f_\pi^*}$ and both with (dashed lines) and without (solid lines) the effect of the MEC's. As we can see an overall agreement with the data is obtained, without the addition of any quenching factor.

IV. CONCLUSIONS

In this work we have analyzed the validity of the in-medium scaling law as a mechanism that, reducing the tensor piece of the NN interaction, permits the description of the experimental data in the region of ^{208}Pb. In particular we have investigated the role of the consideration of f_π^* additionally to the effective ρ-meson mass by studying the recent experimental data of Connelly and co-workers [10] concerning the (e,e') cross section of low-lying high-spin states in this nucleus.

As expected by Brown and Rho [6] the consideration of the effective pion coupling constant does not produce any modification in the form factors of most of the states analyzed. However, some of them are very sensitive to its inclusion in the NN residual interaction. In these cases, the wave function is dominated by a neutronic 1p1h configuration with admixtures of protonic ones which are responsible for the variations observed. For these states, and from the results obtained by calculating the quenching factors needed to put theory and experiment into agreement, it appears that a value of $m_\rho^*/m_\rho \approx f_\pi^*/f_\pi \approx 0.91$ (which corresponds to $\varepsilon \sim 1.2$) can provide such agreement, without any normalization, for four states (one of them the lower 12^- state).

This value is of the same order of that found in ^{48}Ca [5] with a similar analysis and, as a consequence, removes the strong dependence of the scaling with the nucleus considered quoted in previous works [4,5]. The results found support the possibility of including the strong pion-nucleon coupling constant in the in-medium scaling law in a way similar to that shown by the weak pion decay constant.

MEC effects are relatively small in the momentum transfer region we have studied and do not change too much the conclusions drawn when only one-body pieces are taken into account in the nuclear current.

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