

20 years of a stimulating collaboration

Santiago

Bertrand

and many collaborators for various works

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Topics :

Single and double beta transitions
Parity-non-conservation
Baryon properties
Implementation of relativity in few-body systems

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probably, first time I am meeting Santiago



work on given processes and general aspects (polarizability)

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QUENCHING OF THE GAMOW-TELLER STRENGTH IN THE $^{42}\text{Ca}(p, n)^{42}\text{Sc}$ REACTIONS. NOGUERA¹ and B. DESPLANQUES²*Institut Laue-Langevin, 156X, 38042 Grenoble Cedex, France*

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Contributions to the Gamow-Teller strength in $^{42}\text{Ca}(p, n)^{42}\text{Sc}$ reaction coming from second order configuration mixing effects are calculated. They account for half of the quenching presently unexplained from shell model calculations in the $0\hbar\omega$ space. Other contributions which can provide further quenching are discussed.

The reaction $^{42}\text{Ca}(p, n)^{42}\text{Sc}$ at $E_p = 160$ MeV and $\theta = 0^\circ$ has been used by Goodman et al. [1] to measure the Gamow-Teller (GT) strength function. In the simplest shell model, the total strength, which is defined as $B(\text{GT}) = \sum_f |\langle f | \sum_\mu \sigma_\mu \tau^+ | i \rangle|^2$, is expected to be equal to 6. Experimental results show the existence of a strong peak at $E_x = 0.6$ MeV with strength 2.67 and three other peaks with very weak strengths at higher energy. It thus appears that a large amount of strength is missing.

Recently, Toki and Bertsch [2] have interpreted this quenching as due to the Δ -hole polarization mechanism [3-11]. Their results reproduce well the strength found by Goodman et al. It is known, however, that this mechanism, whose efficiency is presently debated [12-14], is not the only one. Second [15-18] and some third [19] order configuration mixing effects can also provide some quenching of GT transitions.

In this paper we examine contributions to the GT strength in the $^{42}\text{Ca}(p, n)^{42}\text{Sc}$ reaction arising from second order effects. As GT and isovector M1 transitions involve operators which are generators of the SU(4) group (spin-isospin), it is appropriate to discuss corrections in connection with this symmetry.

In the case where SU(4) would be an exact symmetry and the initial state a pure $S = 0, T = 1$ configuration, all the GT strength would be concentrated on one final state. SU(4) symmetry breaking will fragment this strength between several states with $0\hbar\omega$ as well as many $\hbar\omega$ excitation energy. Usual shell model calculations allow to determine the distribution of the strength within the $0\hbar\omega$ space. Some strength is, however, expected to be found at higher energy, and it is what is left in the " $0\hbar\omega$ space" which is considered here. Our study is therefore closer to the ones by Shimizu et al. [15] and Towner and Khanna [16] than to the one by Bertsch and Hamamoto [17]. As the above reduction is essentially due to the SU(4) breaking part of the interaction (spin-orbit, tensor, ...), some emphasis will be put throughout this paper on the corresponding contributions of the force.

Like Toki and Bertsch, our starting point is the G-matrix calculation performed [20] by Kuo and Brown (KB) for the $0f-1p$ shell nuclei. KB included in their calculation the $(g_{9/2})^2$ configuration but not the $(g_{7/2} g_{9/2})$ configuration. This truncation of the basis produces an artificial violation of the GT strength sum rule. To avoid this problem and also to simplify the analysis of the results, we determine the eigenstates of this interaction within the $0\hbar\omega$ space. The $(g_{9/2})^2$ configuration, which is eliminated at present, will be reintroduced through second order configuration mixing. Hereafter, we refer to these new states as KB states. In table 1, we give the strength measured experimental-

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Double beta decay and $SU(4)$ symmetry

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Abstract. The amplitude for $\beta\beta$ decay with 2ν emission is shown to be related to (p, n) and (n, p) reactions on the initial and final states, respectively. The suppression of both $\beta\beta$ and (n, p) reaction is connected, and its origin is discussed by referring to the $SU(4)$ symmetry. From present data on the first ones, we estimate the forward (n, p) strength of relevance for the $\beta\beta$ problem. The interest of the experimental determination of this strength is emphasized. Assuming a perturbative breaking of the $SU(4)$ symmetry, results are given for ^{76}Ge , ^{82}Se , ^{128}Te and ^{130}Te .

1 Introduction

Double beta decay is the process by which a nucleus $^A Z$ in its ground state undergoes a transition to the ground or low lying state of the nucleus $^A(Z+2)$ by a simultaneous change of two neutrons into two protons. A great achievement of experimental science has been the direct observation [1] by Elliott et al. of the decay of ^{82}Se into ^{82}Kr plus two electrons and two antineutrinos with a half-life of $(1.1 \pm_{0.3}^{0.8}) \times 10^{20}$ years, in agreement with the geochemical measurements of Kirsten [2], $(1.30 \pm 0.05) \times 10^{20}$ years, and Manuel [3], $(1.0 \pm 0.4) \times 10^{20}$ years, and the cosmochemical (meteorite) measurements of Martí and Murty [4], $(1.2 \pm 0.3) \times 10^{20}$ years. Furthermore, there are results [5] by means of geochemical techniques on ^{128}Te and ^{130}Te , as well as some positive result [6] in ^{76}Ge , $(1.0 \pm_{0.2}^{0.3}) \times 10^{20}$ years, in which the total energy of the two electrons is measured.

For this two neutrino mode of $\beta\beta$ decay, the phenomenon is treated as a second order effect of the charged current effective hamiltonian of the standard electroweak interaction. Due to the implications for lepton number non conservation, Majorana character of neutrino and, more generally, for theories beyond the standard electroweak model, the other modes of double beta decay, such as the 0ν mode and the 0ν with emission of a Majoron mode, are particularly interesting. However, in order to correctly interpret the results of experiments on double beta decay, one has to reliably extract the various nuclear matrix elements associated with the different decay processes. In this letter, we restrict ourselves to the discussion of the transition to the ground state of the daughter nucleus for the standard 2ν mode.

Many attempts have been made in the literature to calculate the nuclear matrix element involved. In the shell model calculations [7], the results yield significantly larger values than the ones needed to explain the lifetimes measured either in the laboratory experiment on ^{82}Se decay or by means of geochemical techniques on ^{82}Se , ^{128}Te and ^{130}Te . There is a problem, as yet not fully understood, with this two-neutrino matrix element [and some controversy [8] about the existence of the problem for the corresponding neutrinoless nuclear matrix element]. It has been pointed out [9] that the matrix elements for the 2ν , and to some extent also for the $0\nu, \beta\beta$ decay are suppressed when evaluated in the QRPA with the inclusion of particle-hole and particle-particle components of the neutron-proton interaction. Although these calculations based on QRPA usually give matrix elements smaller than the shell model values, the results depend very sensitively on the value of the particle-particle interaction constant, which is not known with high accuracy. One concludes from this approach that the amplitudes can vary between zero and the shell model value for the allowed transition. Confronted with these problems one feels the necessity of both a phenomenological approach, in which the

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$\beta\beta 2\nu$ decay in ^{48}Ca

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A schematic study of the $\beta\beta 2\nu$ decay of ^{48}Ca is made in a shell-model approach. The emphasis is especially put on the role of the spin-orbit potential in relation with the contribution of other terms in the strong interaction. This is discussed with a particular attention to the behavior of these ones under the SU(4) symmetry. Different methods in calculating the transition amplitude are also looked at with the aim to determine their reliability and, eventually, why they do not work. Further aspects relative to the failure of the operator expansion method to reproduce the results of more elaborate calculations are examined.

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I. INTRODUCTION

The importance of the double beta decay process is well recognized. First, the neutrinoless mode, yet unobserved, is of fundamental interest, as it will be a signal for neutrino mass and lepton number nonconservation. Second, the double beta decay with two-neutrino emission ($\beta\beta 2\nu$), allowed in the standard model, is a very rare process which was not experimentally observed until 1987, in the decay of ^{82}Se studied by Elliot *et al.* [1]. Subsequent results in other nuclei were obtained by other groups (see Ref. [2] for a recent review of the experimental situation). Recently Balysh *et al.* [3] have measured the double beta decay half-life of ^{48}Ca . This nucleus is the lightest one for which such a measurement is feasible.

On the theoretical side (see Refs. [4,5] for a recent review) the $\beta\beta 2\nu$ decay which, at the beginning, was a well-defined process in the standard model, has been revealed as a real challenge for nuclear model practitioners. There are two reasons for this situation. On the one hand, the decay mode is highly suppressed and sensitively depends on poorly determined parts of the nuclear interaction. On the other, it is a second order process, which implies a summation on intermediate, and not always well determined, states. Thus, even if it is not a process involving new fundamental physics, the $\beta\beta 2\nu$ decay is related to a new type of nuclear matrix element. This one incorporates information on the wave functions that is not given by other standard observables.

The difficulties in the calculation of the $\beta\beta 2\nu$ decay have been expressed in several different but related ways in the literature.

(i) In QRPA calculations, it has been related to the extreme sensitivity of the transition matrix element to the so-called g_{pp} parameter, which governs the pn excitations [6–8].

(ii) In the SU(4) language, it has been connected to poor determination of the nuclear force in the $L=0$, $S=1$, T

$=0$ ($J=1^+ T=0$) channel [9,8]. At the same time, it was also observed in this scheme that strong truncation of the model basis can produce undesirable contributions to the transition matrix element.

(iii) It has also been connected to the bad description of the β^+ decays, which processes have been used to fit the unknown parts of the nuclear force [7].

In order to avoid some of the previous uncertainties, an alternative approach has been proposed, the operator expansion method (OEM) [10–12]. In the present paper, we will focus our attention on the role of different parts of the nuclear force in the $\beta\beta 2\nu$ decay as well as on different methods used in the literature to describe this process. For that purpose, the simplest nuclear transition to be studied is the $\beta\beta 2\nu$ decay in ^{48}Ca , that offers a double advantage. There exist both a sensitive experimental value $\{T_{1/2}^{2\nu} = (4.3^{+2.4}_{-1.1}[\text{stat}] \pm 1.4[\text{syst}]) \times 10^{19} \text{ y [3]}\}$ and an elaborate shell model calculation [13], which is the natural calculation scheme for this nucleus. While doing these studies, we will have in mind a long standing problem. Different calculations were approximately leading to the same decay rate whereas the intrinsic sign of the transition matrix element was not the same [14], requiring some clarification. With this respect, we will in particular show how higher order effects in the SU(4) symmetry breaking interaction modify previous estimates. On the other hand, a critical study of the OEM approach has been done in Ref. [15]. Based on an analysis of the SU(4) symmetry breaking effects, other features of the OEM have been revealed, which deserve discussion. Our work is therefore concerned more with the role of various approximations than with a realistic calculation of the process. We will use an analytical force to achieve this objective. This allows us to easily compare various methods of calculation and to switch on and off the different parts of the interaction.

The plan of the paper is as follows. We remind the reader in the second section of expressions for the standard transition operator and that one obtained in the OEM approach. In Sec. III, we introduce in the OEM expression the Coulomb splitting effect and make a comparison of the corresponding result with the transition operator derived independently at the first order in the SU(4) symmetry breaking interaction. The effective NN interaction that we will use for our study is

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Parity-non-conservation :

both specific processes and general aspects

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NUCLEAR PHYSICS A

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PNC effects in neutron- ^{232}Th scattering: a window
to class II or new states of nuclei?

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NUCLEAR PHYSICS A

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Is the standard, parity-non-conserving, nucleon–nucleus
interaction a surface one?

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ELSEVIER

The baryonic spectrum in a constituent quark model including a three-body force

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We analyze, within a non-relativistic quark model, the low energy part of the baryonic spectrum in the octet and decuplet flavour representations. The relevance of a strong Coulomb potential is emphasized in order to explain its general features. The addition of a three-body force allows to solve the 'Roper puzzle', giving a consistent explanation to its relative position in the spectrum.

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1. Introduction

The baryon spectroscopy has already been the subject of a large number of theoretical studies and it is generally claimed that a good account of the experimental spectrum is obtained. A closer look at the results however shows that discrepancies of 100 MeV in absolute or relative values are not rare and occur in the lower part of the spectrum. As the comparison of different works shows, such departures are still too large to ascribe unambiguously predicted states to observed ones. More accurate predictions seem to be necessary. In some cases, as in the extensive work of Isgur and Karl [1], discrepancies are quite small (with a few exceptions), but the overall agreement is achieved, in a harmonic oscillator model, by treating on a different footing states belonging to different major shells. In other cases, only the position of some states, such as the Roper resonance, is discussed but often independently of the position of other states [2, 5].

A few more consistent studies have been performed. They rely on an essentially exact treatment of the 3-quark system with quark-quark forces and use either non-relativistic approaches [6], or relativistic ones [7] (Bethe Salpeter equation). These analyses involve large non-perturbative corrections due to a full treatment of short range

potentials such as the Coulomb or spin-spin interaction (appropriately corrected for its zero range). This feature precludes to use them in a finite basis calculation, unless parameters are considered as very effective ones. On the other hand, these approaches involve less freedom than other ones and, as one might expect, are not so good in accounting for the whole experimental spectrum.

Specifically, in non-relativistic pictures the first excited state of the nucleon has a negative parity while it is well known that the experimental one, the Roper resonance, has a positive parity. One may therefore wonder whether this resonance (and the similar states in other sectors: Δ , Σ , Λ , ...) is made of three constituent quarks or not. To this respect, the explanation based on the radial excitation of the bag surface [2, 3] can give the impression that the Roper resonance is some kind of intruder state and implies degrees of freedom quite different from constituent quarks. A similar conclusion may be inferred from works where quarks are assumed to move in some average deformed mean field [8]. Exotic explanations have also been considered for other states. Due to difficulties in reproducing some helicity amplitudes relative to γ -decay, it has been suggested that some low energy states such as the Roper resonance (again) or the states P_{11} at 1710 MeV and P_{13} at 1730 MeV be hybrid states [9]. Such an explanation has also been suggested for the state $\Delta(5/2^-)$ at 1930 MeV which is relatively quite low in energy [10].

While the above exotic explanations may be founded, we believe it is worth while pursuing a program intending to correctly describe the baryon excitations in terms of constituent quarks and, possibly, to see which price has to be paid for that. Models based on constituent quarks are quite appealing for their simplicity and also provide an easy classification of the states. They allow for a complete and consistent treatment of all the states without any restriction, including states of positive as well as negative parities, with and without strangeness. Additionally, they are probably more transparent than other ones as to the relationship of peculiarities in the spectrum to some new physical ingredients. However we do not believe that

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Nucleon Form Factors at High q^2 Within Constituent Quark Models

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Abstract. The nucleon form factors are calculated using a non-relativistic description in terms of constituent quarks. The emphasis is put on present numerical methods used to solve the three-body problem in order to reliably predict the expected asymptotic behaviour of form factors. Nucleon wave functions obtained in the hyperspherical formalism or employing Faddeev equations have been considered. While a q^{-8} behaviour is expected at high q for a quark-quark force behaving like $1/r$ at short distances, it is found that the hypercentral approximation in the hyperspherical formalism ($K = 0$) leads to a q^{-7} behaviour. An infinite set of waves would be required to get the correct behaviour. Solutions of the Faddeev equations lead to the q^{-8} behaviour. The coefficient of the corresponding term, however, depends on the number of partial waves retained in the Faddeev amplitude. The convergence to the asymptotic behaviour has also been studied. Approximate expressions characterizing this one have been derived. From the comparison with the most complete Faddeev calculation, a validity range is inferred for restricted calculations.

1 Introduction

A great interest is currently devoted to the nucleon form factor and, in particular, to its behaviour at high-momentum transfers. Indeed, from QCD in the perturbative regime [1], one expects the nucleon form factor, $G_M(q^2)$ (or $F_1(q^2)$), to scale like

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Participants at the European Conference

on Few-Body Problems in Physics

(Autrans, June 1998, following the one in Peniscola)



Implementation of relativity for properties of few -body systems

(last paper)

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038202

Effective boost and "point-form" approach

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Triangle Feynman diagrams can be considered as describing form factors of states bound by a zero-range interaction. These form factors are calculated for scalar particles and compared to point-form and nonrelativistic results. By examining the expressions of the complete calculation in different frames, we obtain an effective boost transformation, which can be compared to the relativistic kinematical one underlying the present point-form calculations, as well as to the Galilean boost. The analytic expressions obtained in this simple model allow a qualitative check of certain results obtained in similar studies. In particular, a mismatch is pointed out between recent practical applications of the point-form approach and the one originally proposed by Dirac.

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The point-form calculation of form factors in impulse approximation has recently been performed for various systems: the deuteron [1], the nucleon [2] and a bound state of two scalar particles interacting via the exchange of a massless scalar boson [3]. With respect to a nonrelativistic calculation, discrepancies with experimental data are slightly increased in the first case and essentially removed in the second one. For the latter case, there is no experiment but a more complete calculation in ladder approximation can be performed. Indeed, the Bethe-Salpeter equation [4] can then be solved easily, due to a hidden symmetry in the Wick-Cutkosky model [5,6]. Moreover, this model accounts for minimal features of realistic interaction models, such as the field-theory character or explicit relativistic covariance. For this system, the exact and point-form calculations of the form factors strongly differ [3], especially when the zero-mass limit is approached or when large Q^2 are considered, two limits that a relativistic approach should be able to deal with. This test case points to an important contribution from two-body currents. Amazingly, a calculation using the nonrelativistic expressions for the form factors with the point-form wave functions does rather well. The difference resides mainly in the expression of the transformed momenta under a boost. Unfortunately, the complexity of the calculation in the Wick-Cutkosky model prevents one from checking this point directly on the expression of the form factors.

However, there exists a simpler model that allows for a completely analytic solution and which, therefore, is particularly useful to gain insight into the origin of the above-mentioned properties. This model describes a bound state of two scalar particles together with a zero-range interaction, providing another case where the Bethe-Salpeter equation may be solved in closed form. Contrary to the Wick-Cutkosky model, however, the interaction now is of short

range, which allows one to check qualitative features obtained in Ref. [3] with a different interaction model. The fully covariant amplitude for the bound state of total mass $M^2 = P^2$ in this case is given by

$$\Phi(P, p) = \frac{C}{(m^2 - p^2)[m^2 - (P - p)^2]}, \quad (1)$$

where p is the four-momentum of one of the two constituents with equal mass m , and C is a normalization constant.

This solution may be used to calculate form factors of the bound state in closed form. These form factors are represented by the triangle Feynman diagram shown in Fig. 1. Of particular interest in the present context is the expression obtained for the electromagnetic form factor after integrating over the zero component of the spectator particle four-momentum. In the Breit frame it reads

$$F_1(Q^2) = \frac{C^2}{2} \int \frac{d\vec{p}}{(2\pi)^3} \times \frac{(e_i + e_f + 2e_p)}{e_p(e_i + e_p)[E^2 - (e_i + e_p)^2][E^2 - (e_f + e_p)^2]}, \quad (2)$$

with $E = \sqrt{M^2 + (\vec{Q}/2)^2}$, $e_i = \sqrt{m^2 + (\vec{p} + \vec{Q}/2)^2}$, $e_f = \sqrt{m^2 + (\vec{p} - \vec{Q}/2)^2}$, and $e_p = \sqrt{m^2 + p^2}$. In this form it does

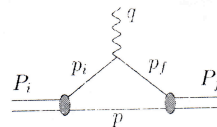


FIG. 1. Representation of a virtual photon absorption on a two-body system with the kinematical definitions.

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The collaboration did not finish with the last paper
but the collaboration continued with discussions
about the ways followed by each of us

SANTI,

Have a happy and nice 60th birthday

Enjoy further nice years in physics

Thanks a lot for everything I learnt from you,

physics of course,

but also about all aspects of life in your country