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E2, E4, and E6 statistical decay spectra in ^{208}Pb

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Abstract Statistical decay spectra for the decay of giant resonances in ^{208}Pb by one neutron emission are calculated using the Hauser-Feshbach formalism and the experimental levels of the residual nucleus. The predicted decay spectra are compared with available experimental results. It is shown that the decay spectra are sensitive to multipole admixtures of the excited state and can be used to study such admixtures. The available experimental data for the decay of the **E2** resonances in ^{208}Pb contain spurious peaks that do not belong to the spectrum of ^{207}Pb. The uncertainty of the experimental data make it impossible to decide whether the decay is purely **E2** or a mixture of 80% **E2** plus 20% **E6.**

1. Introduction

We have shown[1-3] that the decay of the giant monopole and dipole resonances in ^{208}Pb are dominantly statistical. This was achieved by comparing a measured neutron decay spectrum with the results of a Hauser-Feshbach calculation in which the experimental energy levels of the residual nucleus are used instead of a level density function. As discussed in ref.1 the use of a level density function is inadequate to explain the structures in the decay spectra due to the low lying states of the residual nucleus. Because level density functions are smooth functions they cannot predict structures in the decay spectra. In previous work[4,5] several alternative mechanisms were suggested to account for the observed structures. Usually

these structures were explained as being a result of direct or semi-direct decay. Since the decay spectrum of the isoscalar E2 resonance has been measured for ^{208}Pb in an $(\alpha, \alpha'.n)$ coinciderice experiment[6], it is interesting to compare the measured decay spectrum with that predicted for a statistical decay, to find out whether the decay of the isoscalar E2 resonance also is dominantly statistical.

In ref.6 a statistical calculation was performed for the relative branching ratios of the decay into the low lying states of ^{207}Pb, for E2, E4 and E6 multipolarities. The authors conclude that the obtained branching ratios are in qualitative agreement with their experimental data for the population of the lowest three states in ^{207}Pb, under the assumption of pure E2 strength. Because a strong population of the $(13/2)^+$ state in ^{207}Pb is observed, they conclude that in the region of the isoscalar E2 resonance there are higher multipolarities as well. Assuming that there are only E6 and E2 multipolarities in this energy region (8.5 - 12.5 MeV excitation energy in ^{208}Pb) they set a lower limit of 20% for E6 admixture.

In this work we calculate the predicted statistical neutron decay spectra for E2, E4 and E6 multipolarities and compare them with the experimental spectrum[6].

2. The statistical calculations

In order to calculate the predicted neutron spectra we use the Hauser-Feshbach formalism[7,8] following the same procedure described in refs.1-3. For this case there is no need to use a nuclear model to assign spins and parities to experimental energy levels of ^{207}Pb, as in ref.2, because all levels that can be populated and their corresponding spins and parities are known from experiment . The transmission coefficients are computed using the global optical potential from Rapaport et al[10]. The influence of different parametrization of the optical potential in the transmission coefficients and their effect on the predicted statistical decay spectra is discussed in ref.2.

3. Results

Figs. 1 to 3 show the predicted statistical neutron decay spectra, for an excitation energy of 10.6 MeV in ^{208}Pb, under the assumption of pure E2, E4 and E6 multipolarities, respectively. In these figures it was assumed that the experimental energy resolution for neutron d'etection is $\Gamma = 300$ keV, by repreçenting each neutron line by a Gaussian with FWHM equal to the energy resolution. These figures show that at this excitation energy, where few levels of the residual nucleus can be populated, the decay spectrum is very sensitive to the multipolarity of the excited state. Consequently, under the assumption of a statistical process, multipolarity admixtures can be inferred from measured decay spectra.

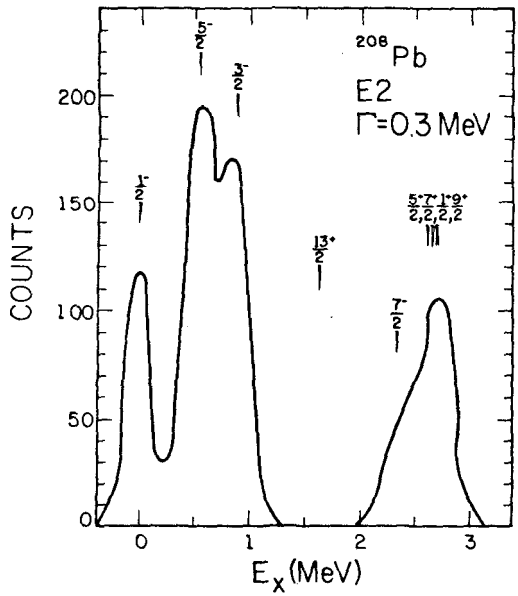

Fig.1 - Predicted statistical decay spectrum for an E2 excitation at 10.6 MeV in ^{208}Pb.

Fig.4 shows the experimental neutron decay spectrum (histogram) from ref.6, which also has an energy resolution of 300 keV. The curve is the predicted decay spectrum assuming that the excited states around 10.6 MeV in ^{208}Pb are pure 2^+

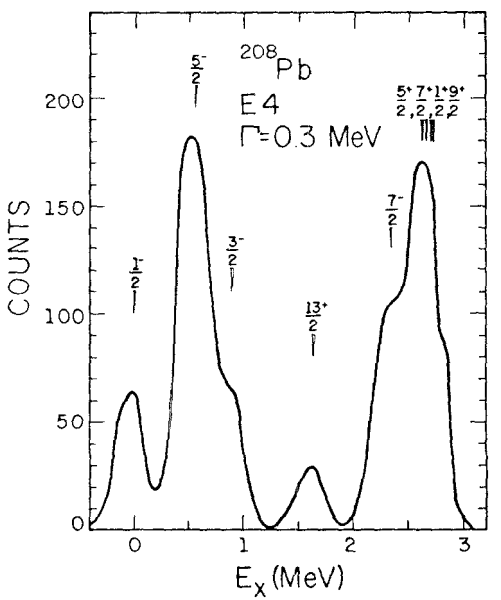

Fig.2 – Predicted statistical decay spectrum for an E4 excitation at 10.6 MeV in ^{208}Pb.

states. In the experimental spectrum peaks A and B do not belong to the decay of ^{208}Pb, since they do not correspond to decay into any low-lying state of ^{207}Pb. Since peaks A and B are spurious, it is difficult to assess if the peak at the energy corresponding to decay into the $(13/2)^+$ state in ^{207}Pb is real. If this peak is also spurious, one would conclude that there is a reasonable agreement between the measured spectrum and that predicted for a pure **E2** statistical decay. The agreement is good for the first three low-lying states, but it is poor in the region of the group of states: $5/2^+, 7/2^+, 1/2^-, 9/2^-$. However, assuming that the peak in the region of the $(13/2)^+$ state is real, then from figs. 1 to 3, it is evident that this peak implies E4 and/or E6 admixtures.

Fig.5 shows the same experimental data as fig.4, but the curve is the predicted decay spectrum assuming **80%** E2 and **20%** E6. Now the decay into the $(13/2)^+$ state is well accounted for, but the agreement between measured and calculated spectrum becomes worse for the other peaks, relative to the spectrum for pure

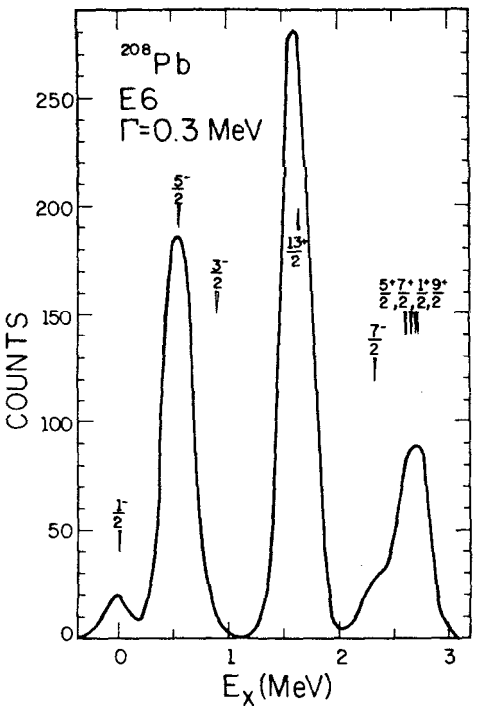

Fig.3 – Predicted statistical decay spectrum for an E6 excitation at 10.6 MeV in ^{208}Pb.

E2 (fig.4). This, along with the existence of spurious peaks A and B casts doubts about the E6 admixture. We have tried to explain the experimental spectrum with a higher admixture of E6, with admixtures of E2, E4 and E6 and also with E4 and E2 admixture. All these trials yields spectra incompatible with the experimental results.

4. Conclusions

We have shown that the shapes of statistical decay spectra are sensitive to the multipolarity of the excited state when the decay is calculated using the actual levels of the residual nucleus with their corresponding spins and parities. Since total angular momentum is conserved and the transmission coefficients depend on the orbital angular momentum, the intensity of the decay into the available levels of the residual nucleus changes with the multipolarity of the excited state,

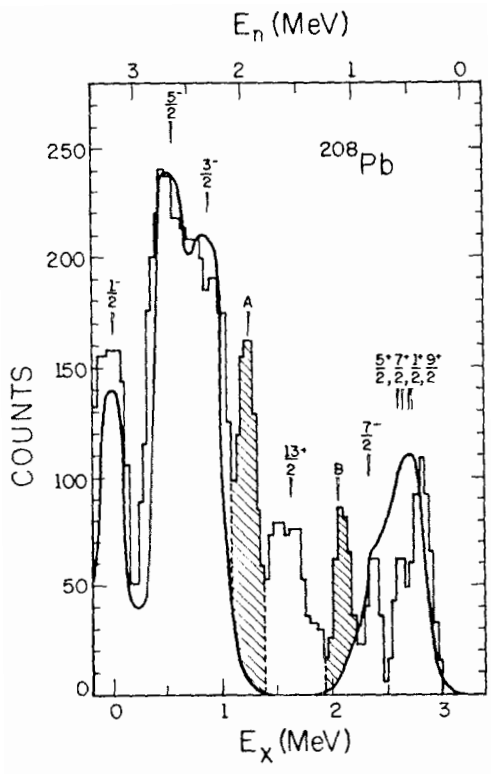

Fig.4 – The histogram is the experimental neutron decay spectrum from ref.6. The curve shows the calculated statistical decay spectrum for an E2 excitation at 10.6 MeV in ^{208}Pb. Peaks A and B in the experimental spectrum do not belong to the decay of ^{208}Pb.

changing the structure of the decay spectra. This opens the possibility of studying multipolarity admixtures from measured decay spectra, comparing the measured spectra with those predicted by a Hauser Feshbach calculation using the actual levels of the residual nucleus.

In the case studied here, which refers to the decay of the isoscalar E2 resonance, located at 10.6 MeV in ^{208}Pb, it was not possible to determine the multipolarity admixture because of the existence of spurious peaks in the experimental spectrum in the vicinity of the $(13/2)^+$ peak. The assumption of E6 admixture

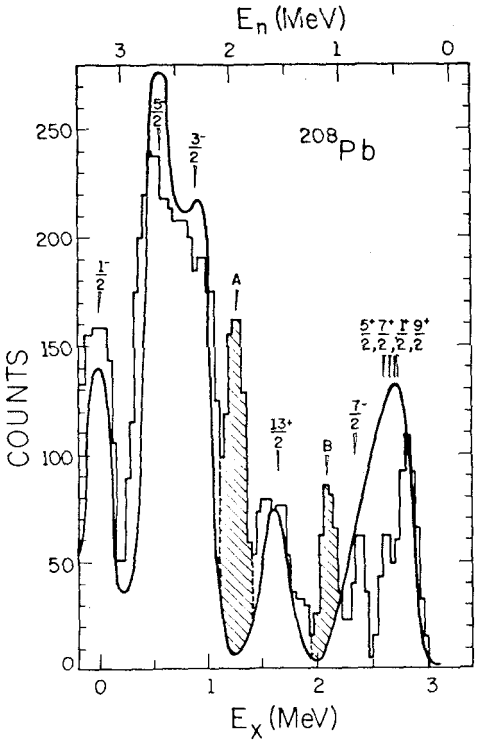

Fig.5 – The histogram shows the same experimental data of fig.4. The calculated spectrum assumes that the excited state around 10.6 MeV in ^{208}Pb has an admixture of 80% E2 plus 20% E6.

accounts for the existence of the $(13/2)^+$ peak but does not improve the agreement between the other observed peaks and the predicted spectrum. If the peak located at the energy position corresponding to decay into the $(13/2)^+$ level of ^{207}Pb is assumed to be a spurious peak, as certainly are the other two at immediately lower and higher energies, then there is a reasonable agreement between measured and calculated spectrum, assuming a statistical process for the decay of the isoscalar **E2** resonance.

We have shown that the experimental data of Steuer et al[6] contain at leat two peaks that do not belong to the sprectrum of ^{207}Pb. New experimental data of better reliability is needed to yield a better understanding of the decay of the **E2** isoscalar giant resonance in ^{208}Pb.

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Resumo

O espectro de neutrons provenientes do decaimento de ressonâncias gigantes multipolares no ^{208}Pb é calculado utilizando o formalismo de Hauser-Feshbach e os níveis experimentais do nucleo residual. Os espectros de neutrons previstos são comparados com os resultados experimentais disponíveis. Mostra-se que os espectros previstos são sensíveis as misturas multipolares do estado excitado podendo desta forma serem utilizados para o estudo de tais misturas. Os dados experimentais disponíveis para o decaimento das ressonâncias E2 no ^{208}Pb contêm picos espurious que não pertencem ao espectro do ^{207}Pb. A incerteza nestes dados experimentais impossibilita concluir se o decaimento é puramente E2 ou uma mistura de 80% E2 mais 20% E6.