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О ПРИРОДЕ РЕЗОНАНСА 72I,6 эВ В УРАНЕ-238

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А н н о т а ц и я

На времяпролетном спектрометре ГНЕИС в Гатчине измерены спектры γ-лучей радиационного захвата нейтронов в отдельных резонансах ^{238}U в диапазоне энергий нейтронов от 400 эВ до I300эВ.

Из полученных данных сделан вывод о том, что резонанс при энергии 72I,6 эВ по своей природе является преимущественно состоянием класса-II, тогда как резонанс I2II,4 эВ, по-видимому, есть обычное состояние класса-I.

Abstract

The neutron capture γ-ray spectra of isolated resonances of ^{238}U have been measured in the energy range from 400 eV to 1300 eV using TOF-facility GNEIS in Gatchina. From the data obtained it was concluded that the 721.6 eV resonance is predominantly class-II by nature, whereas the 1211.4 eV resonance seems to be a class-I state.

1. Introduction

The two lowest-energy resonance clusters in the subthreshold fission cross section of ^{238}U are dominated by the 721.6 eV and 1211.4 eV resonances. Anomalously small capture width ($\sim$4.7 meV [1]) of the 721.6 eV resonance, which is considerably smaller than the average capture width $\overline{\Gamma}_\gamma$ = 23.5 meV of near-by s-wave resonances, is a strong evidence that this resonance is not a normal class-I state. If the 721.6 eV resonance is predominantly class-II in character, then not only its Γ_γ would be smaller, but the γ-ray spectrum of this resonance would be softer than that for class-I resonances, since in the second well the available decay energy is smaller by E_{II} ($\sim$2 MeV for ^{239}U).

It was shown by Difilippo et al.[2] that analysis of the fission cross section of ^{238}U in the vicinity of the 720 eV and 1210 eV clusters is ambiguous and admits two possible interpretations: $T_A > T_B$ and $T_A < T_B$, where T_A, T_B are the transmissions through the inner and outer barriers, respectively. The situation is complicated by the fact that prior to the present measurements, Browne [3] observed a much softer γ-ray spectrum for the 721.6 eV resonance than for neighbouring resonances, whereas Weigmann et al.[4] observed no difference.

We have undertook our measurements in order to resolve this discrepancy.

2. Experiment

The neutron capture γ-ray spectra for isolated resonances of ^{238}U have been measured in the energy range between 400 eV and 1300 eV using the neutron time-of-flight spectrometer GNEIS [5] in Gatchina. The main parameters of the LNPI 1-GeV synchrocyclotron utilized as a pulsed neutron source are as follows:

- proton beam energy...................... 1 GeV
- average proton beam current.......... 2.3 μA
- pulse width.............................. 10 ns
- average neutron production rate... $3 \cdot 10^{14}$ n/s
- repetition rate........................ 50 Hz

A high purity (^{238}U isotopic enrichment 99.996 %) metal sample of uranium, 40 mm diameter and $6.4 \cdot 10^{-3}$ at/barn of thickness was placed at 45-m flight path. The γ-rays from resonance neutron capture were detected by a single-crystal NaI(Tl) scintillator detector. In order to reduce the background due to the neutrons scattered in the sample, a 30-mm layer of ^{6}Li was placed between sample and detector.

Since neutron binding energy B_n in ^{239}U is equal to 4.8 MeV, only capture events with pulse-heights smaller than ~5.2 MeV were stored. Two-dimensional spectra (neutron TOF x pulse-height, 1024 x 64) were accumulated during the measurements. Four experimental runs of 75-125 hours duration have been performed. The results of the first measurement are presented and discussed in this report.

3. Results and discussion

The data treatment have been done after the manner of Weigmann et al.[4]. Their idea is to detect a γ-decay branch within the second well using two different γ-ray energy bias values: lower B1 and upper B2. Then for B2 > B_n - 2 MeV the ratio of resonance areas A_γ

$$R = \frac{A_\gamma \text{ (bias B2)}}{A_\gamma \text{ (bias B1)}}$$

should be smaller for a resonance with a major class-II fraction than for normal class-I resonances.

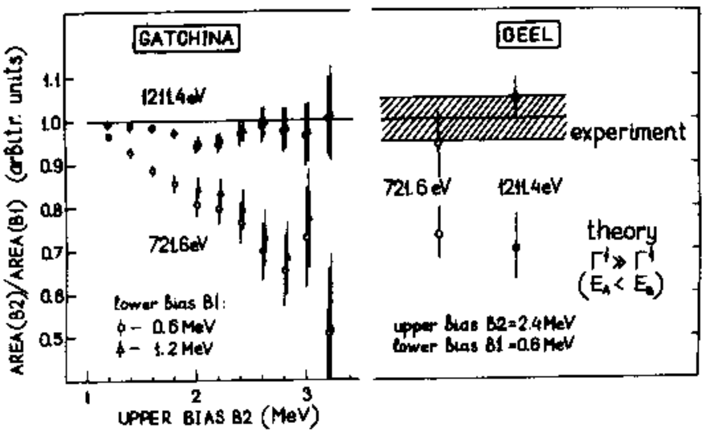

Fig.1. Results of the capture γ-ray measurements for the 721.6 eV and 1211.4 eV resonances of ^{238}U.

The results obtained in the present work (Gatchina) are displayed in Fig.1, where the ratio R is plotted as a function of upper bias B2. Also shown are the results of Weigmann et al. [4] (Geel). For every given value of B2 the average R-value obtained over resonances in the explored neutron energy range from 400 eV to 1300 eV was taken equal to unity.

The fission widths of the 721.6 eV and 1211.4 eV resonances are equal to 1.57 meV and 0.36 meV [2], respectively. So far as fission γ-rays are inevitably detected by NaI(Tl), there is a need to evaluate fission contribution into the effect observed. In Fig.1 the results are given for two values of lower bias B1: 0.6 MeV and 1.2 MeV. Provided that B1 = 1.2 MeV, the pulse-heights of more than 70 % of fission γ-ray pulses are below this bias. The data of Fig.1 display the scale of the effects observed and that of the corresponding corrections for fission γ-rays.

As is seen from the data of present measurements, the capture γ-ray spectrum of the 721.6 eV resonance is much softer

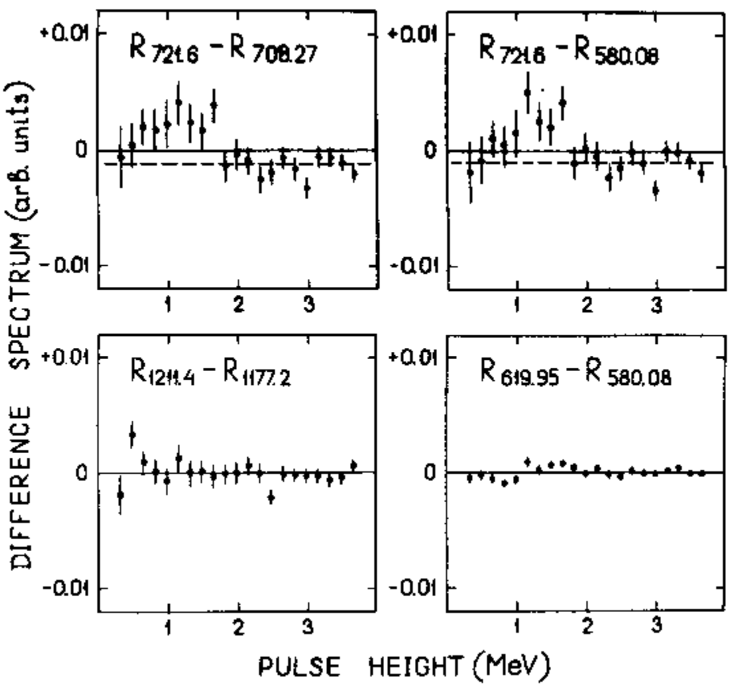

Fig.2. Difference of the pulse-height spectra of capture γ-rays for some resonances of ^{238}U:

$R_{1211.4\ eV}$: Γ_γ = 6.6 ÷ 17 meV ;
$R_{721.6\ eV}$: Γ_γ = 4.7 meV ;
$R_{1177.2\ eV}$: Γ_γ = 22.0 ± 2.0 meV ;
$R_{708.27\ eV}$: Γ_γ = 23.1 ± 1.2 meV ;
$R_{619.95\ eV}$: Γ_γ = 23.2 ± 0.8 meV ;
$R_{580.08\ eV}$: Γ_γ = 24.8 ± 0.8 meV .

than that of neighbouring s-wave resonances, in a good accordance with theoretical predictions for the case $\Gamma^{\downarrow} >> \Gamma^{\uparrow}$($E_A < E_B$). Together with a small value of the capture width for this resonance, our data enable us to make a conclusion that the 721.6 eV resonance is predominantly class-II state by nature. This result is in agreement with the Browne's data [3], whereas it contradicts to the results of Weigmann et al. [4].

So far as the effect observed in the R(B2) - dependence could be caused both by a variation of the γ-ray spectrum shape and by the multiplicity variations, it is interesting to compare directly the capture γ-ray spectra of the resonances under study. Fig.2 shows the difference of pulse-height γ-ray spectra for the 721.6 eV and 1211.4 eV resonances and those for some usual s-wave resonances of ^{238}U. In calculating the difference, the area of every spectrum was previously normalized to unity. A comparison shows that the shape of γ-ray spectrum for the 721.6 eV resonance essentially differs from that of the 1211.4 eV resonance and usual s-resonances. A presence of the enhanced yield of γ-rays with energies E_γ < 2 MeV observed for the 721.6 eV resonance confirms the conclusion about the nature of this resonance.

In a case of the 1211.6 eV resonance the situation is more complicated. Both our data and the results of Weigmann et al.[4] show that there are no solid arguments to consider this resonance as a class-II state. This conclusion is supported by the large value of ~17 meV for its capture width obtained by Muradyan et al.[6]. The last result, however, is in contradiction with the value of ~6.6 meV obtained by Auchampaugh et al.[1]. Apparently, the 1211.6 eV resonance is a pure class-I state. We agree with Weigmann's assumption [7] that the true class-II resonance within the 1210 eV cluster is still undetected.

Quite recently, Muradyan [8] advanced a hypothesis about the existence of the wide class of unusual excited states which could be discovered experimentally due to the unstatistical behaviour of neutron resonances. In particular, the 721.6 eV resonance studied in the present work could be considered within the framework of his hypothesis as an example of such a state -

the highly excited low-spin isomeric state. Unfortunately, nowadays a volume of the available experimental data is not sufficiently large to confirm or to refute this hypothesis. As far as a nature of the excited states in the second well of fission barrier is concerned, the experimental data on these states are described perfectly well by the theoretical mechanism developed by Lynn [9] and Weigmann [10].

4. Conclusion

The data of our measurements on the capture γ-ray spectra of ^{238}U in the neutron energy range between 400 eV and 1300 eV shows that the 721.6 eV resonance is predominantly class-II state by nature, whereas the 1211.4 eV resonance possesses the properties of usual s-wave resonance - class-I state. Apparently, the true class-II resonance within the 1210 eV cluster is still undetected.

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