Second All-Union Seminar on "The Lifetimes of the Excited States of Nuclei" (Leningrad, Physicotechnical Institute of the Academy of Sciences of the USSR, 20–22 December 1988)

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About 50 scientists from Moscow, Leningrad, Kiev, Minsk, Tashkent, Dubna, and Novosibirsk participated in the seminar. Institutes of the USSR Academy of Sciences and the Academies of Sciences of Union republics, other scientific research organizations and universities were represented. A total of 24 reports were given. Special attention was given to current problems in theoretical and experimental studies of the durations of nuclear reactions in the 10^{-21} to 10^{-14} s range and the lifetimes of the excited states of nuclei in the 10^{-15} to 10^{-8} s range.

A great deal of the seminar's work involved analysis of theoretical approaches which make it possible to extract data on the duration and kinetics of nuclear processes proceeding from known data on the cross sections of neutron-nuclear reactions. V. S. Ol'khovskiĭ reported on a study of the kinetics of nuclear processes in an area of well separated resonances interfering with a nonresonant background. A theoretical explanation has been given of the effect of a sharp change in the duration of nuclear reactions in the region of isolated multi-channel resonances greatly distorted by a nonresonant background. This effect is accompanied by the appearance of energy anomalies in the cross sections. The effect of delayed emission of neutrons in (α,n) type reactions has also been established. It follows from the calculations that low energy neutron scattering by various nuclei of light and moderate atomic weight lasts 10^{-18} s and less. The report of A. I. Kal'chenko, G. V. Maksimenko and G. A. Prokopets presented the results of theoretical calculations of the duration (τ_R) of pre-equilibrium processes based on an analysis of experimentally observed fluctuations in the radiation widths of neutron-nuclear resonances. The calculations were made using a quantum-statistical approach which was first proposed by V. G. Nosov. Values of τ_R were calculated for 78 nuclei in the range $20 \leqslant A \leqslant 236$, and were found to be from 10^{-21} to 10^{-17} s. The large difference in τ_R values for neighboring nuclei indicates the dependence of the relaxation process on the structural characteristics of individual nuclei. The report of V. S. Ol'khovskiĭ and Yu. V. Senyuk analyzed the link between the duration of compound processes and the density of forbidden resonances ($\langle\rho\rangle$). This made it possible, using the results of measurements of the lifetimes of compound nuclei, to obtain by means of the shadows method estimates of $\langle\rho\rangle$. It was found that the energy dependence of $\langle\rho\rangle$ obtained in this manner differs from predictions of the Fermi gas model.

The report of V. K. Basenko and G. A. Prokopets presented estimates of the lifetimes of compound states and densities of forbidden resonances in the scattering of fast neutrons. The estimates were obtained on the basis of analysis of measurement data on the dependence of the transmission of neutrons on target thickness.

Discussions which arose in connection with various theoretical approaches to explain the characteristics of temporal distribution of gamma quanta resonantly scattered by nuclei in Mössbauer experiments in the report of V. V. Lomonosov, S. B. Sazonov and P. F. Samarin and in the report of V. S. Ol'khovskiĭ and G. A. Prokopets led to a useful exchange of opinions. An interesting possibility became apparent for a further development of studies consisting of taking into account the effect of a difference in the crystal fields in the source and the scattering material, which was studied by the authors of the former paper, in the framework of a consistent quantum mechanical approach to explain the temporal distribution of resonantly scattered gamma quanta, which was developed by the authors of the latter paper.

At the seminar, a great deal of attention was paid to the techniques of measuring the durations of nuclear processes. A comparative analysis of all known methods of measuring nuclear times shorter than 10^{-15} s was presented in the report of F. S. Akilov and A. I. Muminov, which examined the fundamental physical principles of the various methods, their areas of application, and their potential to explain the mechanisms of essentially nonequilibrium processes.

The report of S. A. Karamyan examined new possibilities to determine the lifetimes of highly excited nuclear states which are formed in reactions with heavy ions where the nucleus is extremely affected by conditions such as high specific excitation energy (per nucleon), great nuclear rotation speed, and a very high intensity of the electromagnetic field. Since the lifetimes of such system states are comparable with the characteristic times of kinetic rearrangements within the system, this leads to the observed effects, which make it possible to estimate lifetimes in the 10^{-21} to 10^{-19} s range. Results obtained in this way, together with known results from traditional methods, make it possible to construct a systemization of the duration of nuclear decay in the 10^{-21} to 10^{-15} s range. In the report it is shown that in general such a systemization corresponds to traditional statistical calculations and makes it possible to refine the specific parameters of the theory. The second report of S. A. Karamyan examined a new experimental possibility for the use of the shadows effect in single-crystal targets to determine the duration of decay of excited reaction products of inelastic collisions of complex nuclei.

N. V. Eremin discussed the essence of methods for measuring the duration of nuclear reactions in the 10^{-22} to 10^{-19} s range based on interference phenomena in X-ray and bremsstrahlung spectra which accompany the reaction. The

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report presented the data available in the literature obtained with these methods to study the evolution of nuclear systems. A comparison was made of the results of measuring resonance parameters of isolated levels with the results of phase analysis, and the potential for a real reduction in the ambiguity of phase analysis using temporal measurements was established. Theoretical aspects of extracting data on the durations of nuclear reactions from measurements of interference effects in the analysis of bremsstrahlung spectra were examined in the report of V. A. Plyuĭko.

The report of Yu. V. Melikov, S. Yu. Platonov, A. F. Tulinov, O. V. Fotina, and O. A. Yuminov presented results of a cycle of studies on the duration of induced fission of actinide nuclei using the shadows method. In these studies, a new physical phenomenon was experimentally detected, the temporal delay of the decay duration along the fission channel of excited isotopes of ^{235,236,238,239}Np formed in the reactions of ^{235,238}U(d,xnf) and ^{235,238}U(p,xnf) in comparison to the duration of decay along any other channel. Analysis of the temporal characteristics of the decay within a model of a two-peaked fission barrier, which was developed by V. M. Strutinskiĭ, made it possible to obtain information on the density of states in the second potential well and on the parameters of the two-peaked barrier. Based on an analysis of the energy dependence of the behavior of level density in the second potential well, a conclusion was made on the asymmetry of the shape of Np isotopes in deformations corresponding to the second well. The report of M. V. Aprelev, Yu. V. Kangropol', and Yu. G. Kudryavtsev gave results of measurements using the K-vacancy method for the lifetime of the compound ^{117}Sb nucleus with an excitation energy of 26 MeV formed in the reaction ^{113}In(α, p)^{116}Sn. The method uses as a time standard the lifetime of $K\alpha$-vacancies, and is based on the measurement of the ratio of intensities of the $K\alpha$-lines of the final ^{116}Sn nucleus and the compound ^{117}Sb nucleus. A great deal of the seminar's work was devoted to the lifetimes of the excited states of nuclei, experimental techniques, measurement results, and their physical interpretation.

The report of D. V. Bugaev, V. I. Kogan, V. Z. Maĭdikov, V. P. Pikul', N. K. Skobelev, and N. T. Surovitskaya analyzed the possibility of measuring the lifetimes of nuclear isomeric states based on a study of delayed auto-ionization of recoil atoms which arises as a result of internal conversion after the atoms escape into the vacuum.

The paper of P. P. Kabina, I. A. Kondurov, Yu. E. Loginov, V. V. Martynov, S. L. Sakharov, V. A. Sushkov, and E. I. Fedorova reported the results of measurements made using the method of delayed $\gamma\gamma$-coincidences for several dozen values of decay half-lives of the excited states of odd-odd nuclei of ^{104}Rh, ^{108,110}Ag, ^{116}In, ^{112,124}Sb, ^{128,130}I, and ^{134}Cs. The characteristic values of the delay factors for the probability of transitions are 10^2 to 10^3 for M1 transitions and 10^4 to 10^7 for E1 transitions.

A. Ya. Zobov, I. Kh. Lemberg, and A. A. Pasternak presented the results of comprehensive studies of the structure of transition nuclei with $A = 70$–110. These studies were done in collaboration of the cyclotron laboratory of the A. F. Ioffe Physicotechnical Institute of the USSR Academy of Sciences and groups of experimentalists and theoreticians from the following institutes: The GDR Academy of Sciences Central Institute for Nuclear Research, the Czech Academy of Sciences Institute for Nuclear Physics, the Ukrainian SSR Academy of Sciences Institute for Nuclear Research, the Siberian Division of the USSR Academy of Sciences Institute for Nuclear Physics, and the Uzbek SSR Academy of Sciences Institute for Nuclear Physics. These studies included determination of the energies of excited states, their quantum characteristics and lifetimes, as well as an interpretation of the acquired results. In the course of systematic studies based on a significantly advanced method using the Doppler effects of the energy shifts of γ rays to measure τ, several hundred values were obtained for the lifetimes of the excited states of nuclei in the 10^{-14} to 10^{-8} s range. A comprehensive systemization of the data on the energies of excited states with positive parity in even-even nuclei and on their lifetimes obtained in these studies made it possible to extend conclusions of the model of interacting bosons to the collective states of even-even nuclei with $A < 110$. New experimental data on high-spin states of ^{74}Se made it possible to compare in detail the potential of the model of interacting bosons and the recently formulated alternative model of nonlinear oscillations, developed by O. K. Vorov and V. G. Zelevinskiĭ.

The structure of the odd nuclei ^{79}Kr, ^{83}Rb, ^{85}Sr, and ^{99}Ru was systematically studied. To describe the excited states of positive parity of these nuclei, the results of calculations carried out in the framework of the new version of the model of interacting bosons and fermions were used.

In a number of odd nuclei (isotopes of Kr, Rb, Sr, and In) the phenomenon of anomalous intensification of M1 transitions in quasirotational bands, which are formed in three-quasiparticle excitations, was studied and an interpretation was given.

The paper of A. E. Zobov presented the results of experimental studies on the structure of near magic ^{84}Kr and ^{85}Kr nuclei. It was shown that some high-spin states of ^{84}Kr are pure quasiparticle states. This follows from the g factors of these states and the isomeric character of transitions from these states. For the first time for nuclei with $A < 100$ a four-quasiparticle state was identified in the ^{84}Kr nucleus.

The second report of A. E. Zobov discussed the issues of the development of the technique of γ-spectroscopic studies of high-spin states which are excited in reactions with heavy ions based on the use of multi-detector installations. The new technique substantially increases the efficiency and selectivity of recording cascade γ quanta and provides optimal conditions for measuring their energies and the lifetimes of their excited states. When the excited states decay, these γ quanta are emitted. In addition to the installations already in operation (HERA, TESSA, NORDBALL, etc.), the paper also discussed the potential of installations which will go into operation by the year 2000 (GAMMASPHERA, EUROBALL, etc.). The use of these installations will make it possible to carry out γ-spectroscopic studies of discrete transitions in no less than five-fold coincidences.

A number of reports at the seminar were devoted to theoretical interpretation of the results of experimental studies of the structure of nuclei, including the probabilities of electromagnetic transitions extracted from measurements of the lifetimes of excited states.

The report of O. K. Vorov and V. G. Zelevinskiĭ discussed the initial premises and possibilities for describing the collective states of transition nuclei in the framework of a model of nonlinear oscillations proposed by the authors. This model, which is an alternative to the model of interacting bosons, is not inferior to it in describing the experimental data and in a number of cases uses a smaller number of parameters.

The report of K. I. Erokhina, A. E. Zobov, A. I. Isakov, I. Kh. Lemberg, and A. S. Mishin was devoted to the results of a calculation of the structure of excited states in near magic ^{84,85}Kr nuclei in the framework of the multi-particle theory of shells. The theory reproduces well the reduced probability of E2 transitions between excited states of ^{85}Kr, the energy of the states of ^{84}Kr, the values of the gyromagnetic factors of the two- and four-quasiparticle states of ^{84}Kr, and their isomeric character. The report of D. N. Doĭnikov, K. I. Erokhina, A. D. Efimov, and V. M. Mikhailov presented the results of experimental studies of the states of negative parity even isotopes of Se and Kr compared with the data from calculations carried out in the framework of the new microscopic version of the model of interacting bosons and fermions. The report of A. D. Efimov and V. M. Mikhaĭlov presented the results of a calculation of the parameters of the model of interacting bosons based on the microscopic theory. For the first time a joint description was obtained for the basic parameters of the Hamiltonian and the parameter of effective charge, which determines the probability of an electric quadrupole transition.

The seminar materials bear witness to the successful development and improvement of the techniques for measuring the duration of nuclear reactions in the 10^{-21} to 10^{-16} s range. This is very important for a better understanding of the mechanisms of direct reactions, deep inelastic processes, processes which form highly excited nuclear states in the extreme conditions of very high specific excitation energies (per nucleon), the speeds of rotation of the nucleus as a whole and the strengths of the electromagnetic field, and in several cases, the pre-equilibrium processes of the decay of compound systems. Direct confirmation of the theoretically predicted effect of the appearance of a resonant maximum duration of single-channel scattering, corresponding to a minimum (antiresonance) cross section in experimental measurements of the duration of scattering of protons by ^{12}C nuclei near an energy of 1.686 MeV using the bremsstrahlung method, made it possible to develop plans for the collaboration of theoretical and experimental groups in future research.

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