# NON-STATISTICAL EFFECTS IN BETA & GAMMA DECAYS AND BETA-DELAYED FISSION ANALYSIS

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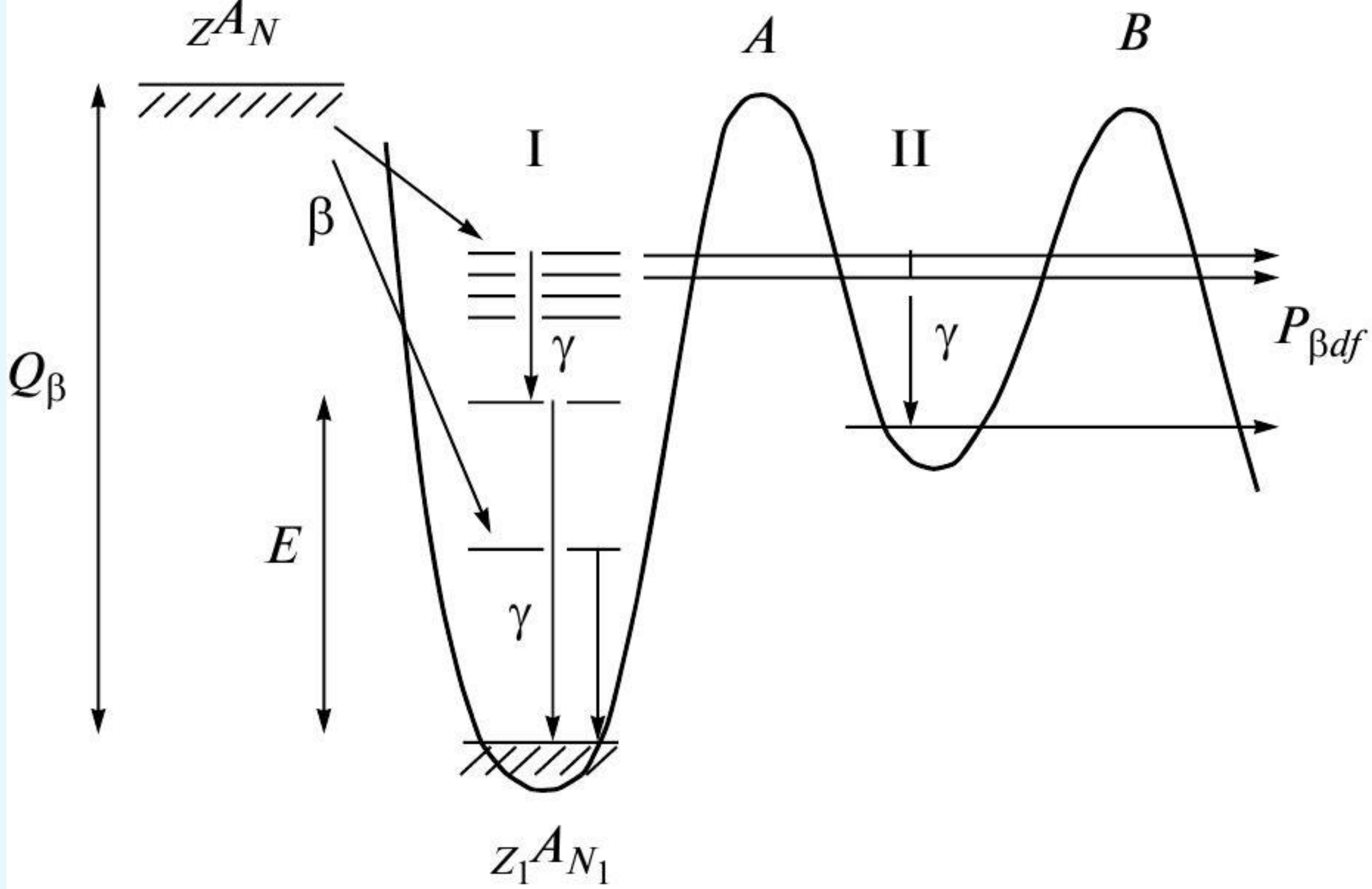


**Fig. 8.** Scheme of the nuclear β-delayed fission (β*df*). Heights of the internal (*A*) and external (*B*) fission barriers for the daughter nucleus are given.

The probability $P_{\beta d}$ of β-delayed process is :

$$P_{\beta d} = \frac{\int_0^{Q_\beta} S_\beta(E) f(Q_\beta - E) \Gamma_d(E)/\Gamma_{tot}(E)\, dE}{\int_0^{Q_\beta} S_\beta(E) f(Q_\beta - E)\, dE}$$

where $\Gamma_d(E)$ – delayed process width, $\Gamma_{tot}(E)$ – total width.

$$\Gamma_{tot} = \Gamma_d + \Gamma_\gamma$$

Below $Q_\beta$ there are local maxima in $S_\beta(E)$ both for *GT* and *FF* *β*-transitions. The fine structures of these maxima both in $\beta^-$ and in $\beta^+$/EC $S_\beta(E)$ are important for delayed process analysis.

The previously dominant statistical model assumed that there were no resonances in $S_\beta(E)$ in $Q_\beta$-window and the relations $S_\beta(E)$ = Const or $S_\beta(E) \sim \rho(E)$, where $\rho(E)$ is the level density of the daughter nucleus, were considered to be a good approximations for medium and heavy nuclei for excitation energies $E$ > 2–3 MeV.

In delayed fission analysis the γ-decay widths $\Gamma_\gamma$ **calculated using the statistical model**, which, in general, can only be an **approximation**.

In β-decay the simple (non-statistical) configurations are populated and as a consequence the **non-statistical effects were experimentally observed** both for $\boldsymbol{S_\beta(E)}$ (resonance structure) and **γ-decay** : (M1-E2 correlations in (*p*,γ) nuclear reactions)

For correct calculations of the beta-delayed fission probabilities $P_{\beta df}$ it is necessary to have **experimental information and systematic** on $S_\beta(E)$ peaks width and fine structure for delyed fission nuclei.

Because the information about γ-decay is very important for delayed fission analysis, it is necessary to consider the influence of **non-statistical effects on delayed fission** probability not only for β-decay, but also **for γ-decay**.

# NON-STATISTICAL EFFECTS IN BETA & GAMMA DECAYS AND BETA-DELAYED FISSION ANALYSIS

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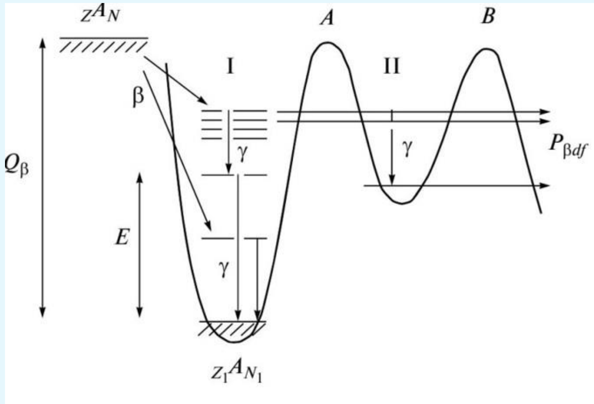
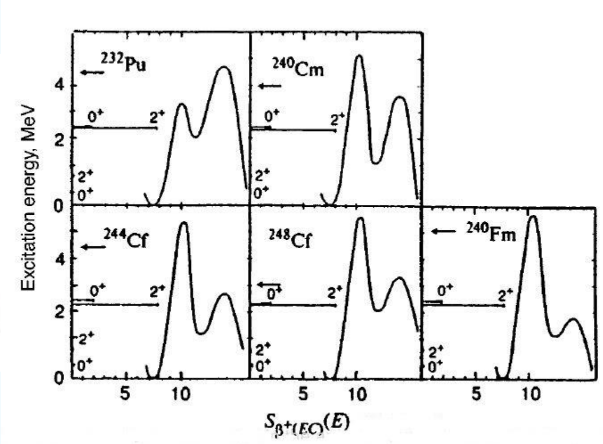
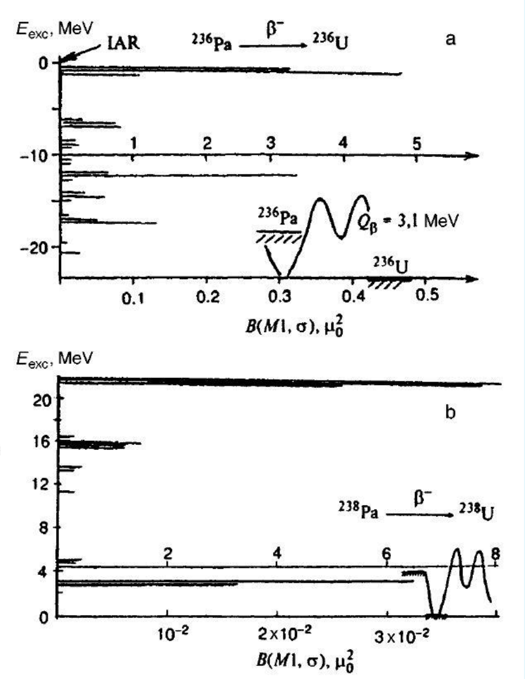



The probability $P_{\beta d}$ of β-delayed process is :

$$P_{\beta d} = \frac{\int_0^{Q_\beta} S_\beta(E) f(Q_\beta - E)\Gamma_d(E)/\Gamma_{tot}(E)\, dE}{\int_0^{Q_\beta} S_\beta(E) f(Q_\beta - E)\, dE}$$

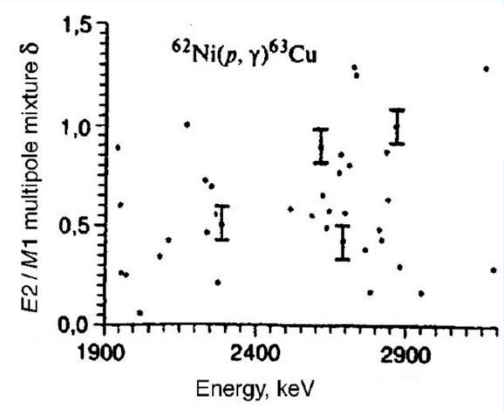
where $\Gamma_d(E)$ – delayed process width, $\Gamma_{tot}(E)$ – total width.




The β–transition probability is proportional to the product of the lepton part described by the Fermi function $f(Q_\beta - E)$ and the nucleon part described by the β-decay strength function $S_\beta(E)$, $\Gamma_{tot} = \Gamma_d + \Gamma_\gamma$ and $\Gamma_d = \Gamma_f$ for delayed fission. The delayed fission probability $P_{df}$ substantially depends on the resonance structure of the $S_\beta(E)$ both for $\beta^-$ and $\beta^+$/EC decays. The analysis of the experimental data on delayed fission demonstrated that the $P_{df}$ can be correctly described only by using the **non-statistical $S_\beta(E)$**, reflecting nuclear-structure effects (I.N. Izosimov, Yu.V. Naumov, *Bulletin of the Academy of Science USSR, Physical Series*, **42,** 25 (1978). https://www.researchgate.net/publication/322539669 )

In β-decay the simple (non-statistical) configurations are populated and as a consequence the non-statistical effects may be observed in γ-decay of such configurations. In delayed fission analysis the **γ-decay** widths **$\Gamma_\gamma$ calculated using the statistical model**, which, in general, can only be an **approximation** (I.N. Izosimov, *Physics of Particles and Nuclei*, **30**, 131 (1999). DOI: 10.1134/1.953101 )




Dependence of the multipole mixture $\delta$ on the incident-proton energy for nonanalog resonances with $I^\pi = \frac{3}{2}^-$ in $^{63}$Cu. The excitation energies of resonances in $^{63}$Cu ranged from 8040 to 9250 keV. The average value of $\delta$ is $\langle\delta\rangle = (0.6 \pm 0.1)$, while the statistical model gives $\langle\delta\rangle = 0$.

Non-statistical effects in $(p,\gamma)$ nuclear reactions in the excitation and decay of the non-analog resonances, for which simple configurations play an important role, were analyzed. The strong non-statistical effects were observed both for $M1$ and $E2$ γ-transitions.

## CONCLUSION

1. For correct calculations of the beta-delayed processes probabilities $P_{\beta d}$ it is necessary to have experimental information and systematic both on $S_\beta(E)$ structure and $\Gamma_\gamma$ values. Only after proper consideration of non-statistical effects both for β-decay and γ-decay it is possible to make a **quantitative** conclusion about fission barriers.
2. For non-statistical effects study in delayed fission both for β-decay and γ-decay it is necessary to measure first of all the $S_\beta(E)$ structure for delayed fission nuclei. We are interesting in collaboration for such experiments.