ISINN-25

FRANK LABORATORY
OF NEUTRON PHYSICS

Method for investigation of the superfluidity of excited nucleus

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Contents

Introduction

- The method was created, developed and tested in FLNP, JINR.
- Taking advantage of experimental intensities of two-step cascade gamma-decay following capture neutron reaction.
- The experiment on recording this cascade gamma-transition was carried out in Dubna (Russia), Riga (Latvia), Rez (Czech Republic) and Dalat (Vietnam).

Nuclear superfluidity

- The nuclear superfluidity was caused by pairing of nucleons and was presented by N. N. Bogolubov in 1958.
- This effect is revealed because of the existence of energy gap between superfluid and normal states.
- To understand dynamic of changing phase of nuclear matter, it is necessary to determine simultaneously the level density and the partial widths at all excitation energies.

How do we do?

- Step 1: Extract the cascade intensity distribution of primary transition $I\gamma\gamma(E1)$ from the spectrum of experimental cascade intensity $I\gamma\gamma(E1, E2)$.
- Step 2: Parameterize level density ρ and partial width Γ $((\rho=\varphi(p1,p2...); \Gamma= \psi(q1,q2))$.
- Step 3: Fit $I\gamma\gamma(E1)$ to their experimental values.

Model's Foundation

1. The model of density of n-quasi-particle states, which is presented by V. M Strutinsky for describing the level density of fermion type.
2. A phenomenological relation between changing a density of quasi-particle levels and nuclear entropy for describing the collective enhancement of level density.
3. The model of S. G. Kadmenskij, V. P Markushev and W. I Furman (KMF) with adding some peaks (from 2 to 4) have shape of the asymmetrical Lorentzian curve to describe a distribution of widths of E1 and M1-tranmissions.

Dubna practical model

The cascade intensity distribution that depends on energy of primary transition is presented:

$$I_{\gamma\gamma}(E_1) = \sum_{\lambda,f}\sum_{i}\frac{\Gamma_{\lambda i}}{\Gamma_{\lambda}}\frac{\Gamma_{if}}{\Gamma_{i}} = \sum_{\lambda,i}\frac{\Gamma_{\lambda i}}{\langle\Gamma_{\lambda i}\rangle m_{\lambda i}} n_{\lambda i}\frac{\Gamma_{if}}{\langle\Gamma_{if}\rangle m_{if}} \qquad (1)$$

- $m_{\lambda i}$: number of excited levels in intervals from the compound state λ to the intermediate level i.
- m_{if} : number of excited levels in intervals from the intermediate level i to the final level f.
- $n_{\lambda i}$: number of intermediate cascade levels in small interval ΔE of energy of primary transitions.

Fitting Process

➢ Using the maximum likelihood fitting method we obtain parameters:

- The breaking thresholds of Cooper nucleon pairs U_l;
- A common parameter E_u for all Cooper nucleon pairs;
- The independent parameters A_l of the density of vibrational levels above the break up threshold U_l;

➢ Uncertainty of experimental distribution Iγγ(E1) $\leq$ 10-20% in any energy interval, we obtain the most accurate parameters.

Results

- Recently, we have been using the Dubna method to study for compound nucleus ^{172}Yb.
- Experiment of this study was performed at DDNR reactor, in Dalat, Vietnam.

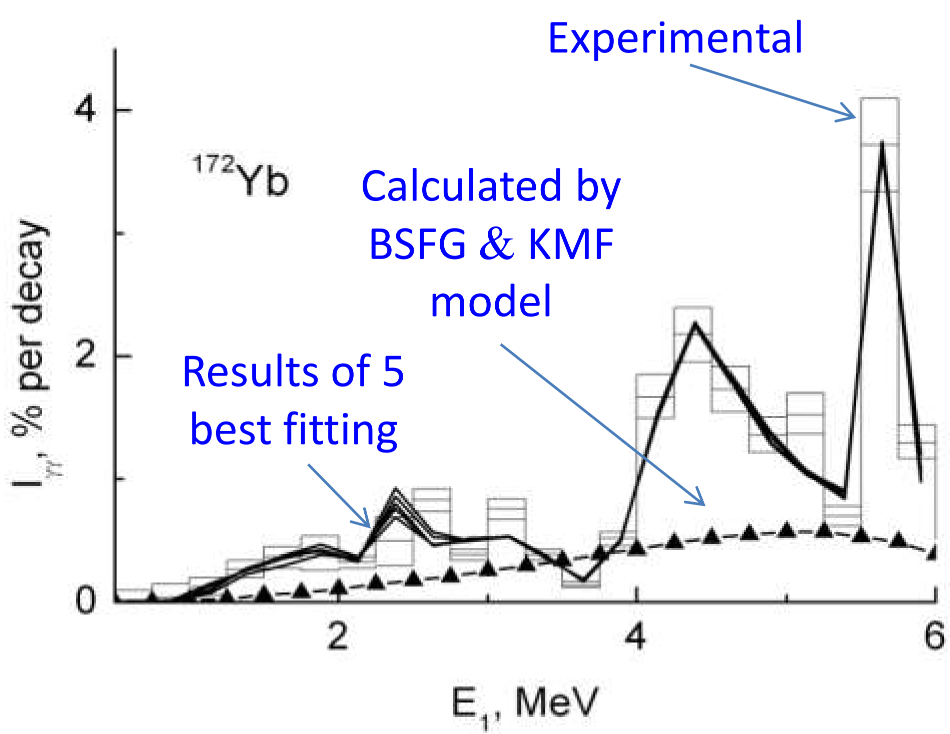


Fig. 1. the cascade intensity distribution of primary transition.

Results

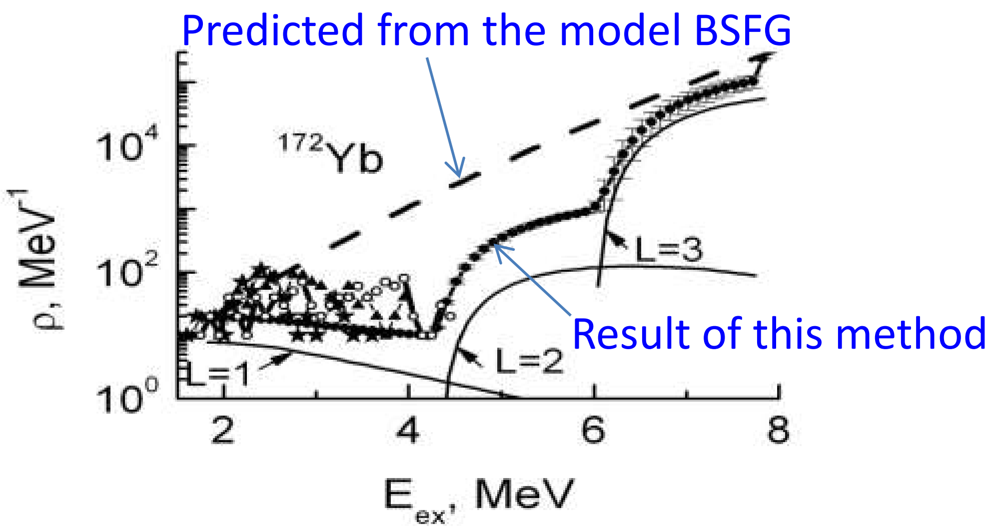


Fig. 2. The level density of ^{172}Yb nucleus.

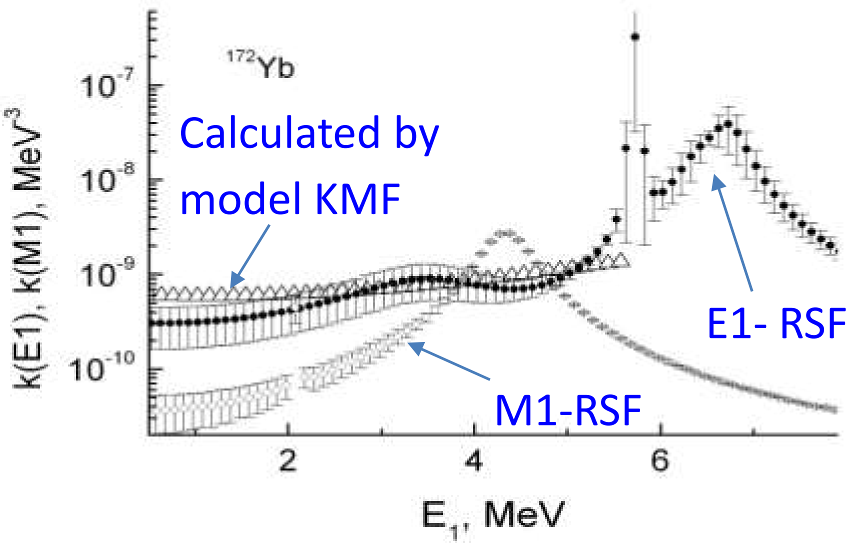
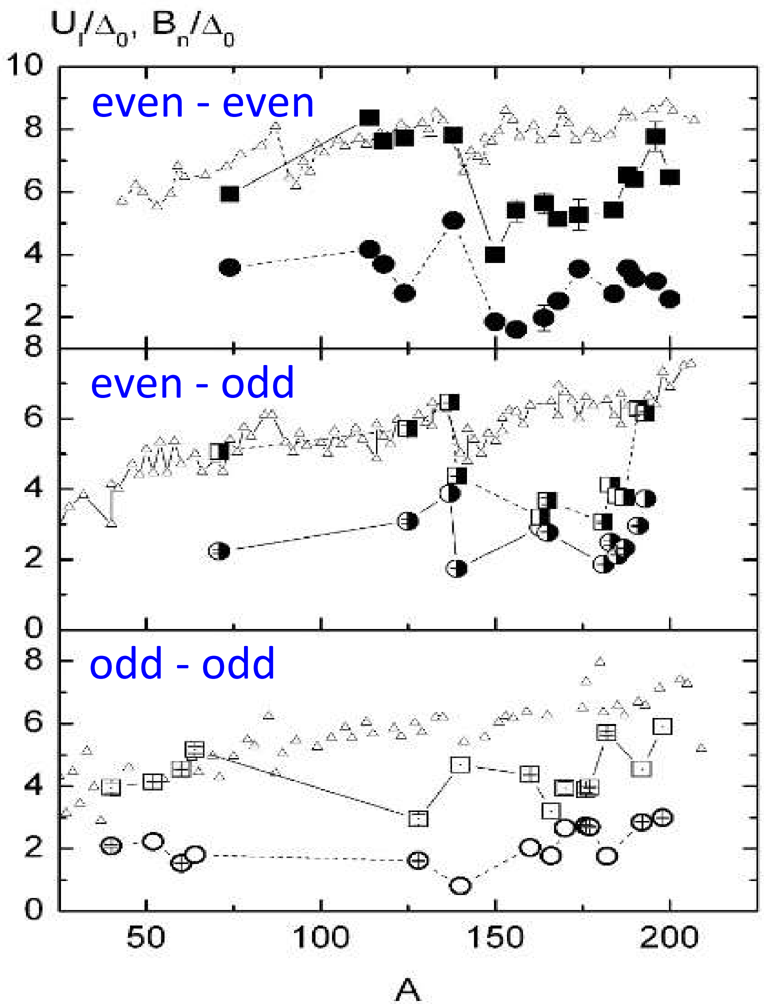


Fig. 3. E1- and M1-radiative strength function

Result



- Up to now **44** excited nuclei with different parities have studied by the Dubna method.
- For spherical nuclei (A<150) $U_3 \approx B_n$, for deformed nuclei (150<A<190) this value is twice less.

Fig.4. Dependence of the breaking thresholds of Cooper pairs on the nuclear mass A.

Conclusion

- We can make a statement that the Cooper pairs breaking thresholds for spherical nuclei are higher than for deformed nuclei.
- Both a number of breaking Cooper nucleon pairs and a shape of excited nucleus have an influence on the dynamics of superfluid phase of nuclear matter.
- The Dubna practical model is an unique model that has possibility to reproduce the experimental cascade intensity distribution with high accuracy.

Thank you for your attention!