Search for $2p$ Decay of the First Excited State of $^{17}\text{Ne}$

$^{17}\text{Ne}$ structure

- mixture of $[s^2]/[d^2]$ components of ground state; problem of $2p$-halo.
- true $2p$-decay from first excited state ($J^\pi = 3/2^-$) that only 344 keV above $2p$-threshold

Knowledge about structure of $^{17}\text{Ne}$ is of importance for nuclear astrophysics
Role of $^{17}\text{Ne}$ in rp-process

rp-process

- rapid proton capture
- waiting points

Resonant radiative capture rate:

$$\langle \sigma_{\text{part},\gamma}(T) \rangle \sim T^{-\frac{3n}{2}} e^{-\frac{E_r}{kT}} \frac{\Gamma_\gamma \Gamma_{\text{part}}}{\Gamma_{\text{tot}}}$$

is determined by branching ratio of particle and $\gamma$ decay channels.

$\Gamma_{2p}/\Gamma_\gamma$ branching ratio:

- $\Gamma_{2p}/\Gamma_{\gamma_{\text{exp.}}} \leq 7.7 \times 10^{-3}$ [Chromic, et. al., PRC66 2002]
- $\Gamma_{2p}/\Gamma_{\gamma_{\text{theor.}}} = (0.9 - 2.5) \times 10^{-6}$ [L.V. Grigorenko and M.V. Zhukov, PRC76 2007]

Problems:

- observation of true $2p$-decay from the $^{17}\text{Ne}$ first excited state
- reducing a gap between experimental limit and theoretical prediction for $\Gamma_{2p}/\Gamma_\gamma$
Problem of $\Gamma_{2p}/\Gamma_\gamma$ Ratio Measurement

\[ \frac{\Gamma_{2p}}{\Gamma_\gamma} = \frac{N_{2p}}{N_\gamma} \approx \frac{N_{2p}}{N_{\text{tot}}} \]

- Low statistic for the state of interest
- Background from the states above $2p$-threshold
- High luminosity
- High energy resolution

**Transfer Reaction**

$^1\text{H}(^{18}\text{Ne}, d)^{17}\text{Ne}$

**Experimental Approach**

combined mass method
Combined Mass Method

**Missing Mass**
- high beam intensity
- “thin” target
- luminosity restriction

**Invariant Mass**
- high resolution on a “thick” target
- high detectors load
- luminosity restriction

**Combined Mass**
- full kinematics experiment
- acceptable resolution
- no strict luminosity restriction

Diagram:
- $^{18}\text{Ne}$
- $^d$
- $^{17}\text{Ne}$
- $^{15}\text{O}$
- missing mass
- invariant mass
- combined mass
- high detectors load
- luminosity restriction
- full kinematics experiment
Experimental Setup

H targets
- “Thin”, gaseous. \((4.6 \times 10^{20} \text{ atoms/cm}^2)\)
- “Thick”, liquid. \((8.9 \times 10^{21} \text{ atoms/cm}^2)\)

debuteron telescope
3x 1 mm thickness silicon detectors

proton telescope
- 1.4 mm aluminum filter
- 2x 1mm Si detectors
- 4x4 CsI(Ti) wall
Population of $3/2^-$ State

“Thin” target:
- G.S. peak can be clearly separated from excited state
- DWBA based fit
- Estimates for $1/2^-$ and $3/2^-$ cross sections

“Thick” target:
Total yield of $3/2^-$ is:

$$N_{\text{tot}} = 38(6) \times 10^3$$
There is no event associated only with $2p$-decay of $3/2^-$

New $\Gamma_{2p}/\Gamma_{\gamma}$ limit:

$$\Gamma_{2p}/\Gamma_{\gamma} \leq 1.6(3) \times 10^{-4}$$
Summary

- The experiment for $^{17}$Ne low-energy spectrum studies have been performed at the Flerov Laboratory of Nuclear Reactions of JINR.

- Original method of combined mass has been used in the experiment.

- Due to new method and advanced analysis new branching ratio limit for $\Gamma_{2p}/\Gamma_\gamma \leq 1.6(3) \times 10^{-4}$ has been achieved.

- The results have been published in [PHYSICAL REVIEW C96, 025807 (2017)].