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

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^{17}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}Ne is of importance for nuclear astrophysics

Role of ^{17}Ne in rp-process

rp-process

- rapid proton capture
- waiting points

Resonant radiative capture rate:

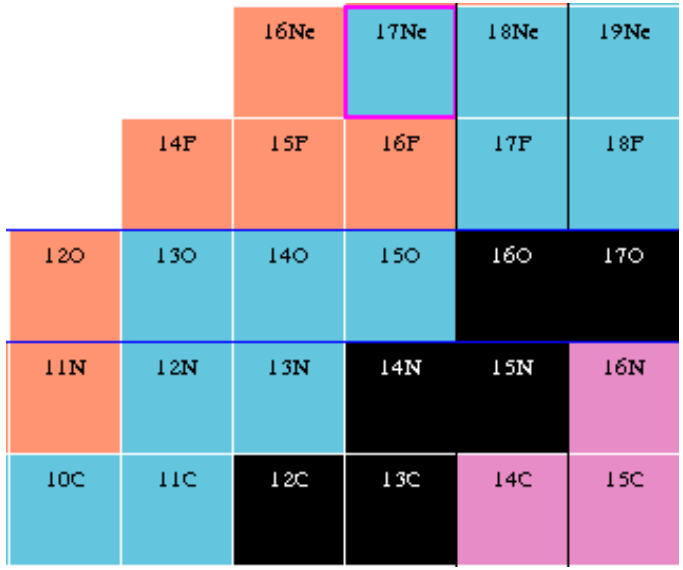
$$\langle \sigma_{\mathrm{part},\gamma} \rangle (T) \sim T^{-\frac{3n}{2}} \, e^{-\frac{E_r}{kT}} \, \frac{\Gamma_\gamma \Gamma_{\mathrm{part}}}{\Gamma_{\mathrm{tot}}}$$

is determined by branching ratio of particle and γ decay channels.

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

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

$T_{1/2}(^{15}\mathrm{O}) = 122$ c!



Problems:

- observation of true $2p$-decay from the ^{17}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

$$\Gamma_{2p}/\Gamma_\gamma = N_{2p}/N_\gamma \approx N_{2p}/N_{\mathrm{tot}}$$

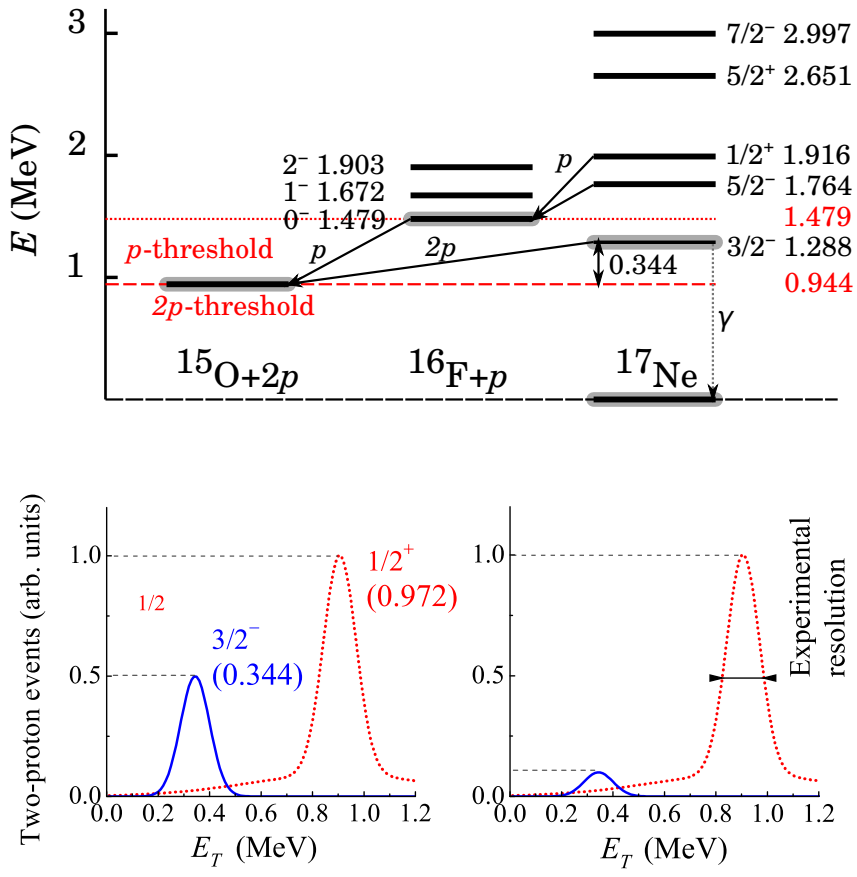
- Low statistic for the state of interest
- Background from the states above $2p$-threshold
- High luminosity
- High energy resolution

Transfer Reaction

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

Experimental Approach

combined mass method



Combined Mass Method

Missing Mass

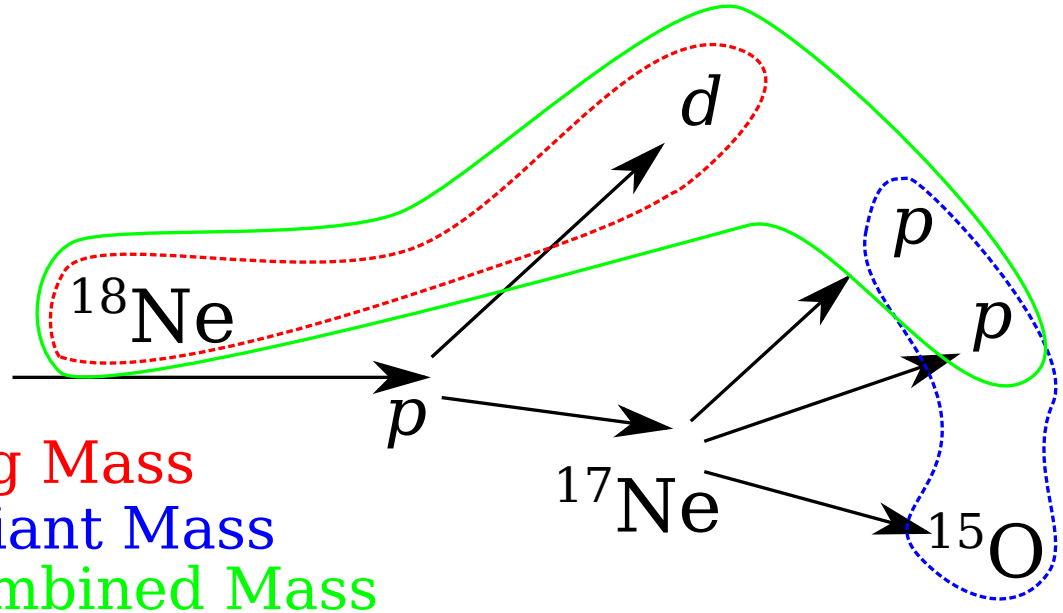
- high beam intensity
- "thin" target
- luminosity restriction

Invariant Mass

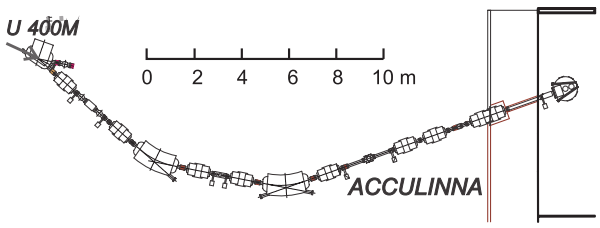
- high resolution on a "thick" target
- high detectors load
- luminosity restriction

Combined Mass

- full kinematics experiment
- acceptable resolution
- no strict luminosity restriction

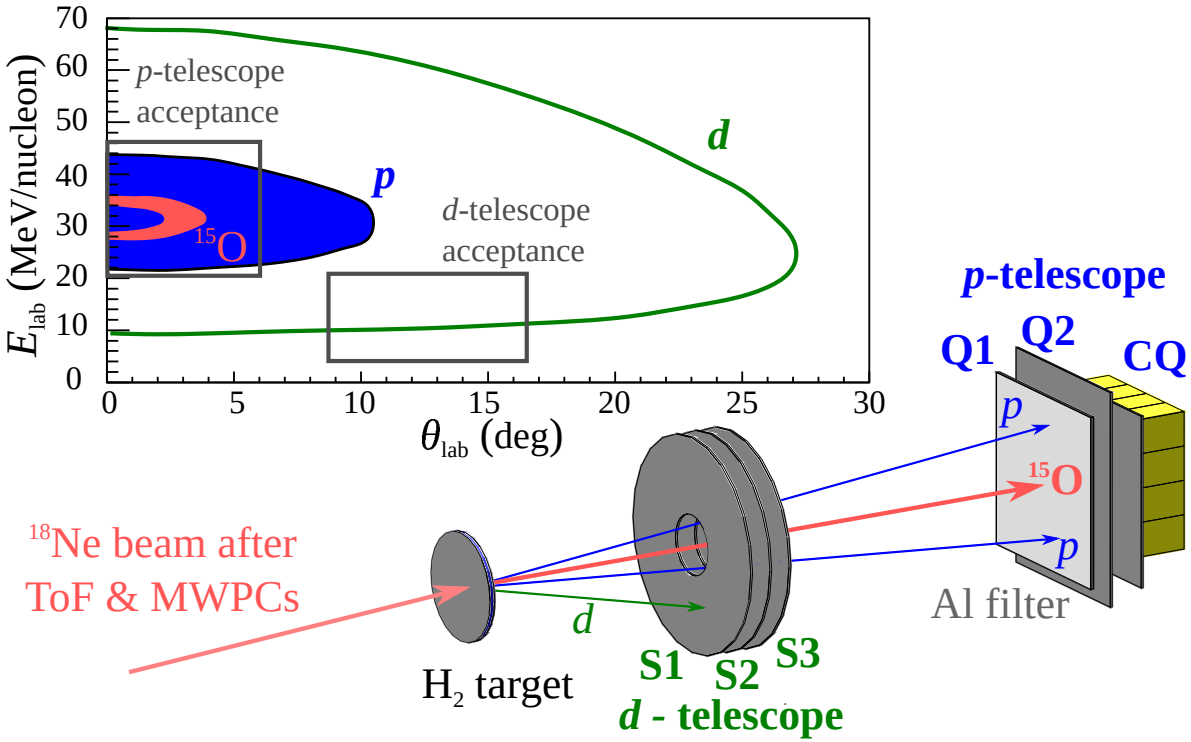


Experimental Setup



H targets

- "Thin", gaseous. $(4.6 \times 10^{20}$ atoms/cm$^2)$
- "Thick",liquid. $(8.9 \times 10^{21}$ atoms/cm$^2)$



deuteron 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

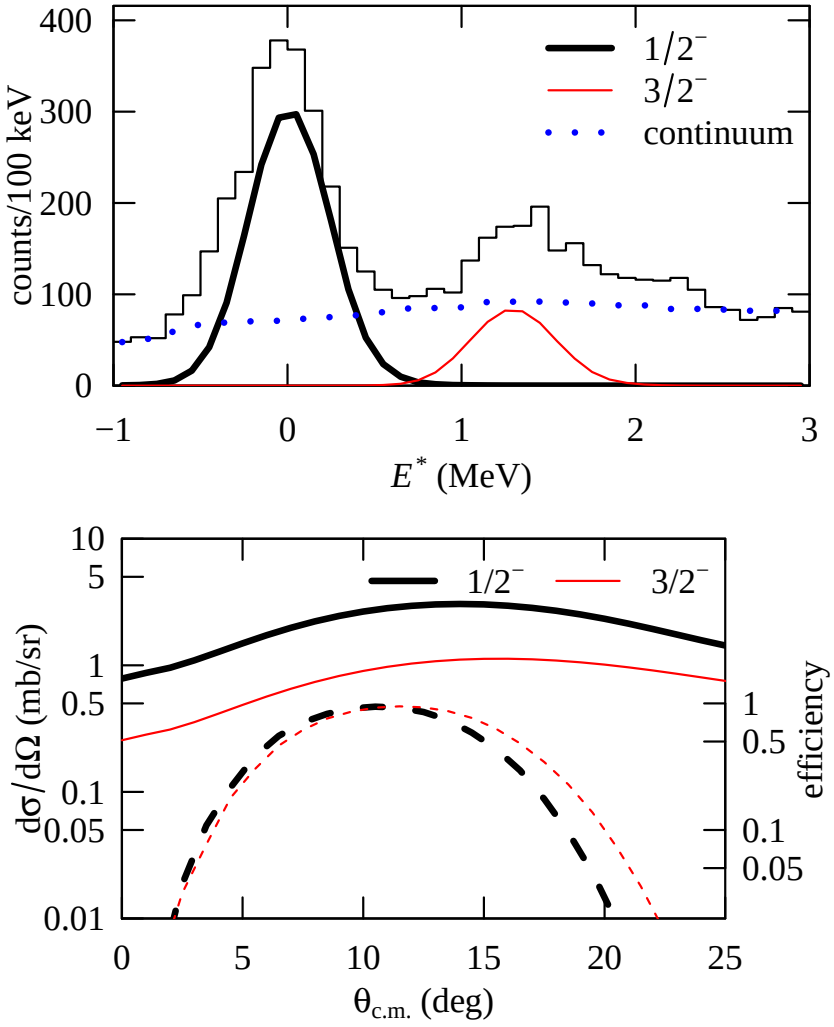
"Thin" target:

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

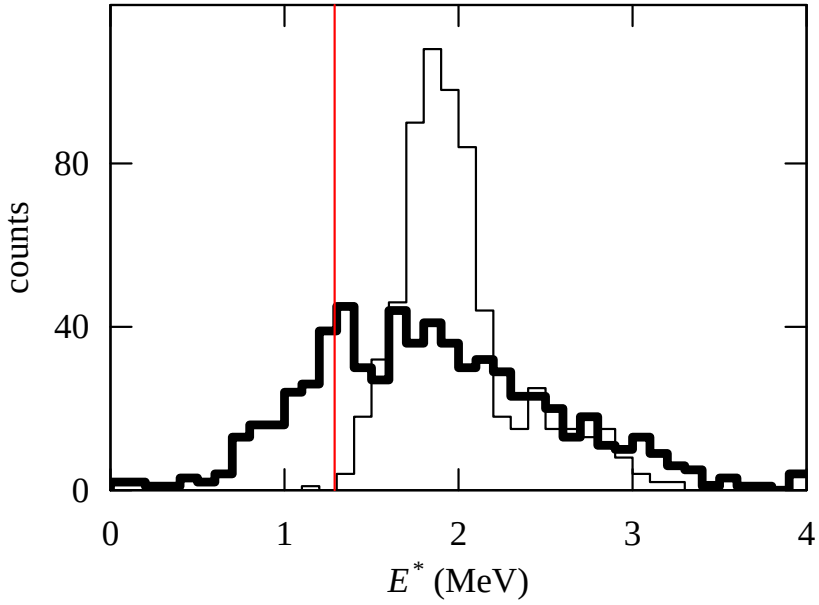
"Thick" target:

Total yield of $3/2^-$ is:

$$N_{\text{tot}} = 38(6) \times 10^3$$



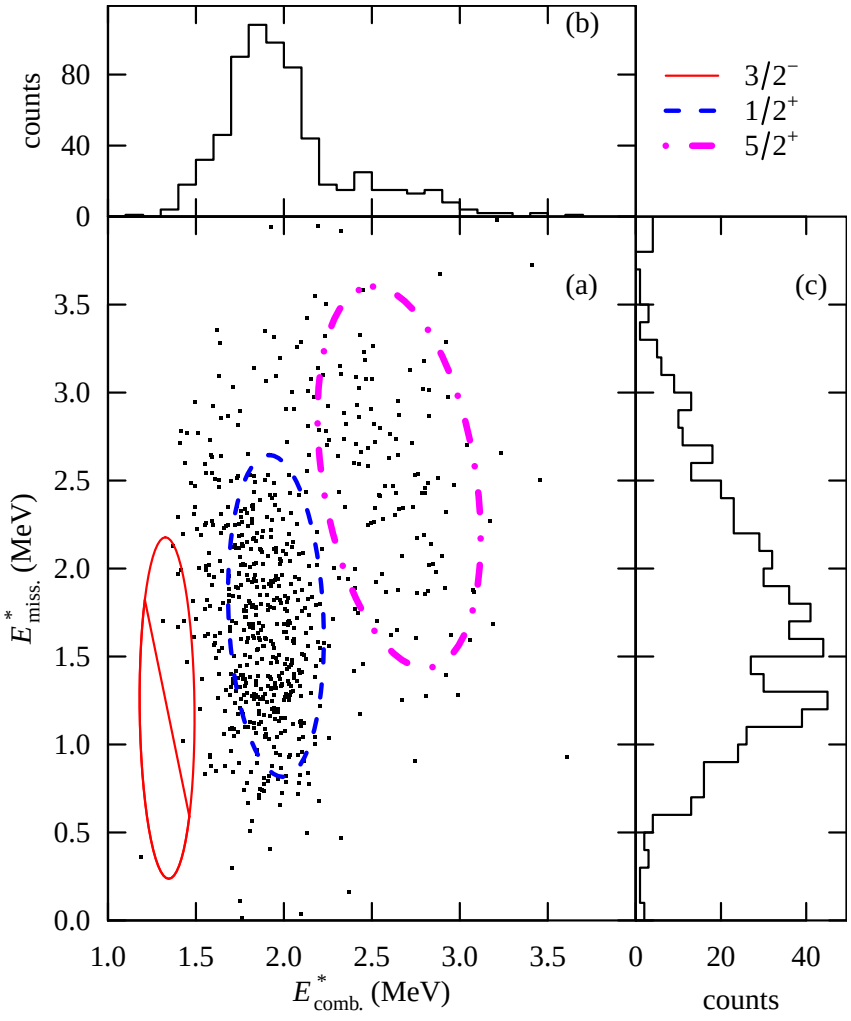
$2p$-coincidence spectra



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)].