Cross-sections of the $^{127}I(n, {}^2n)^{126}I$ nuclear reaction

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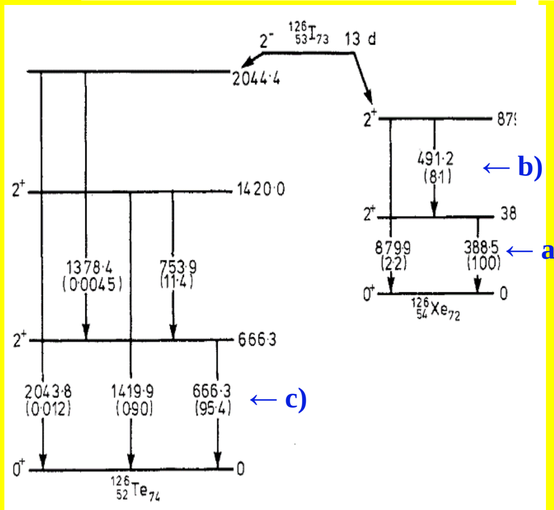
Abstract

- The formation of bound dineutron states in nuclear reactions was observed, following Migdal's theoretical prediction that such states may be formed in the potential well but outside of the volume of some of heavy nuclei.
- Our previous experiments predominantly used ^{159}Tb, ^{175}Lu and ^{197}Au as target nuclei, while now we focused on ^{127}I, a medium-weight nucleus, which was considered as less favorable due to its low ranking against selection criteria.
- Potassium iodine (KI) samples were irradiated with neutron flux from deuteron-deuteron reaction.
- Neutron energy ranges used were $7.20^{+0.13}_{-0.11}$ MeV and 8.78 ± 0.09 MeV, with respective flux rates of 1.12E+06 n/(cm^2·s) and 1.38E+06 n/(cm^2·s). Irradiations were performed for approximately 36,000 s per sample.
- After irradiation, several instrumental spectra were acquired on HPGe spectrometer in order to observe full absorption gamma-peaks with 388 keV, 491 keV and 666 keV energies, stemming from the decay of ^{126}I.
- The only possibility to observe ^{126}I as a reaction product under these irradiation conditions is due to the formation of a bound dineutron state.
- The estimated cross-section for this reaction is 0.25 ± 0.08 mb for 7.8 MeV neutrons and 0.24 ± 0.07 mb for 8.78 MeV neutrons.
- This study paves the way to medium-mass nuclei to produce the dineutron.

Discussion

- It was expected to find the signs of $^{127}I(n, {}^2n)^{126}I$ nuclear reaction with its threshold E_{th} = 9.217 MeV against of 8.87 MeV maximum neutron beam energy $E_{n,max}$.
- Gamma-peaks due to the ^{126}I decay were observed in each instrumental spectrum.
- Our findings resulted in statistically significant gamma-peaks observations: the only explanation is the dineutron in a bound state must be formed.
- Using experimental data on peak areas, gamma-rays detection efficiencies and spectra timings, the cross-sections of this reaction were estimated with the expression below:

$$\sigma_{exp} = \frac{N_{counts} \times \lambda \times A}{\left(1-\exp\left(-\lambda t_{irr}\right)\right) \times \exp\left(-\lambda t_{cool}\right) \times \left(1-\exp\left(-\lambda t_{meas}\right)\right) \times \xi \times I_\gamma \times \phi \times N_A \times m \times p}$$



- σ = 0.25 ± 0.08 mb (E_n = 7.28 MeV)
- σ = 0.24 ± 0.07 mb (E_n = 8.78 MeV)

Gamma-energy, keV	Detection efficiency
388.6	1.3596E-02
491.2	1.0797E-02
666.3	8.2731E-03

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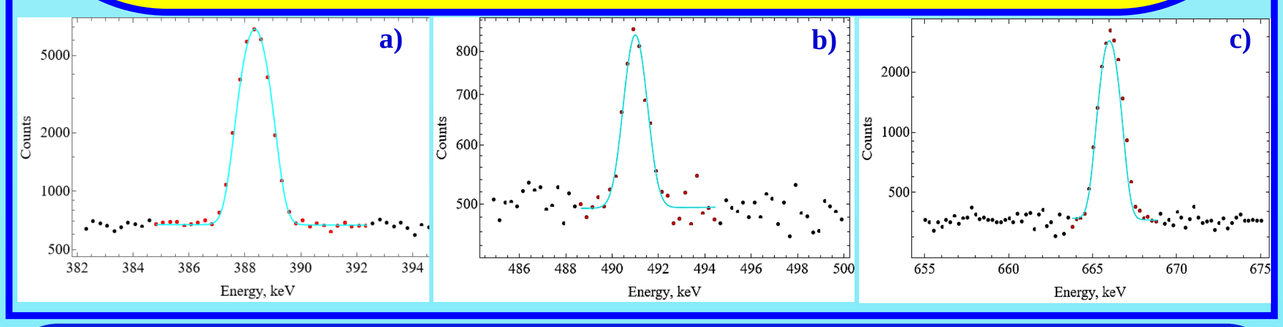
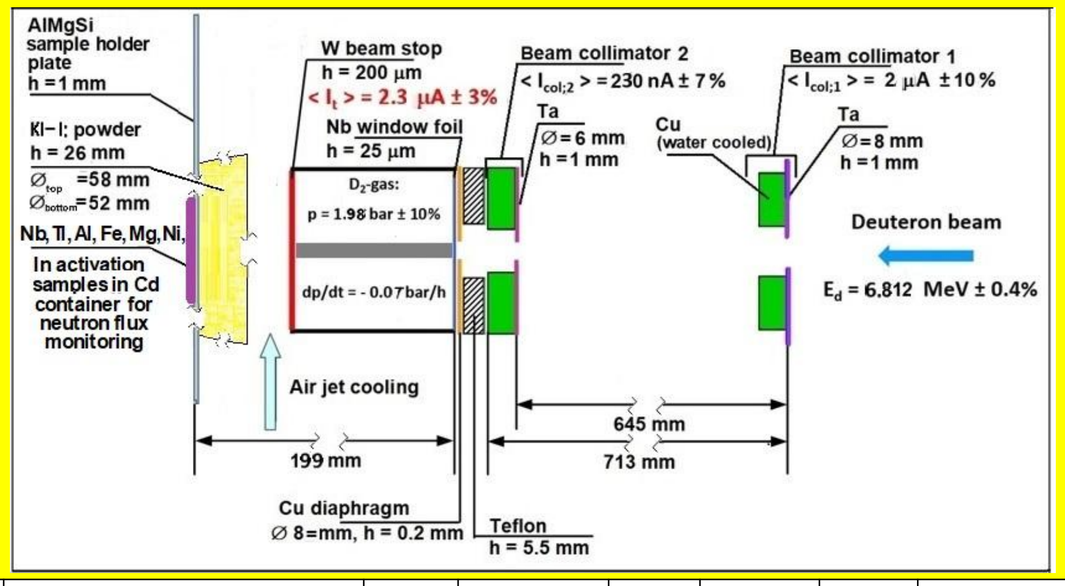


Conclusions

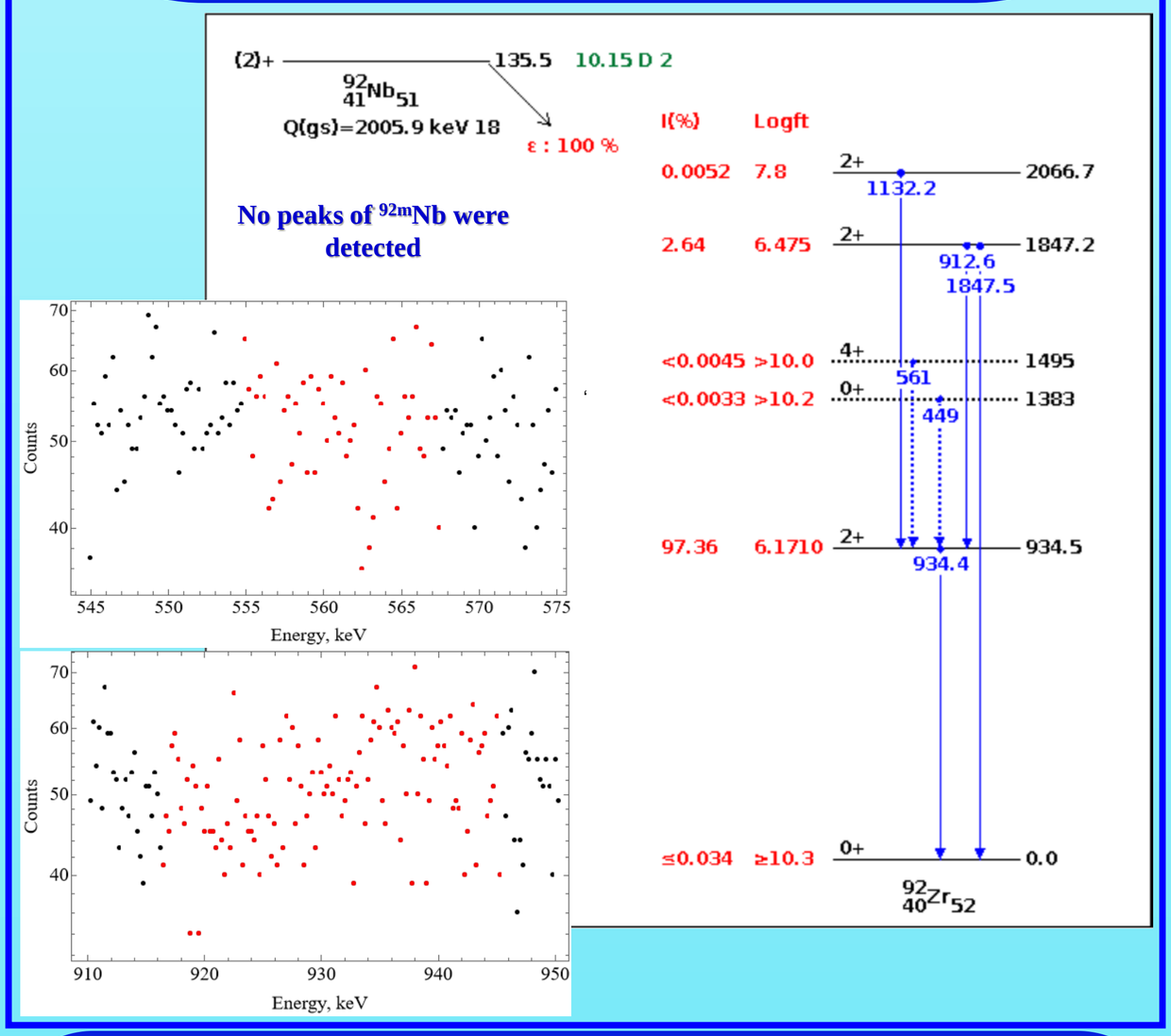
- In this study, the dineutron in a bound state was indirectly observed with a statistical significance > 5σ as a reaction product of the $^{127}I(n, {}^2n)^{126}I$ nuclear reaction with corresponding cross-section estimates.
- The list of "likely to dineutron forming" nuclei is now expanded from heavier to medium masses.

Experimental setup



No.	Experiment	$t_{irr.\ tot}$, s	E_d, MeV	$E_{n,\ min}$, MeV	$E_{n,\ average}$, MeV	$E_{n,\ max}$, MeV	$< \phi_n >$, n/(cm^2·s)
1	$d + D_2$-gas p_{gas} = 1.93 bar ± 10% Sample KI-I (m = 90.6898 g), Nb-1	36,140	5.429±0.4%	7.09	7.20	7.33	$1.12E+06^{+18\%}_{-27\%}$
2	$d + D_2$-gas p_{gas} = 1.93 bar ± 10% Sample KI-III (m = 62.9366 g)	18,000	5.429±0.4%	7.09	7.20	7.33	$1.12E+06^{+18\%}_{-27\%}$
3	$d + D_2$-gas p_{gas} = 1.91 bar ± 10% Sample KI-II (m = 91.2413 g), Nb-2	36,540	6.669±0.4%	8.44	8.63	8.73	$1.33E+06^{+18\%}_{-29\%}$

- Niobium foils Nb-1 and Nb-2 were used to detect all neutrons with E_n > 8.927 MeV.
- $E_{threshold}(^{93}Nb(n, 2n)^{92}Nb)$ = 8.927 MeV.



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