From Experiment to Data: Measurement of the $^{17}O(n,p)^{17}N$ Integral Cross Section at the KATANA Facility

J. Peric[a,b], D. Kotnik[a], D. Govekar[a,b], L. Snoj[a,b], V. Radulović[a,b]

[a]*Reactor Physics Department, Jožef Stefan Institute, Ljubljana, Slovenia*
[b]*Faculty of mathematics and physics, University of Ljubljana, Ljubljana, Slovenia*

julijan.peric@ijs.si

CHALLENGE

- **$^{17}O(n,p)^{17}N$** reaction research
- ^{17}N neutrons will be a moving neutron source in ITER.

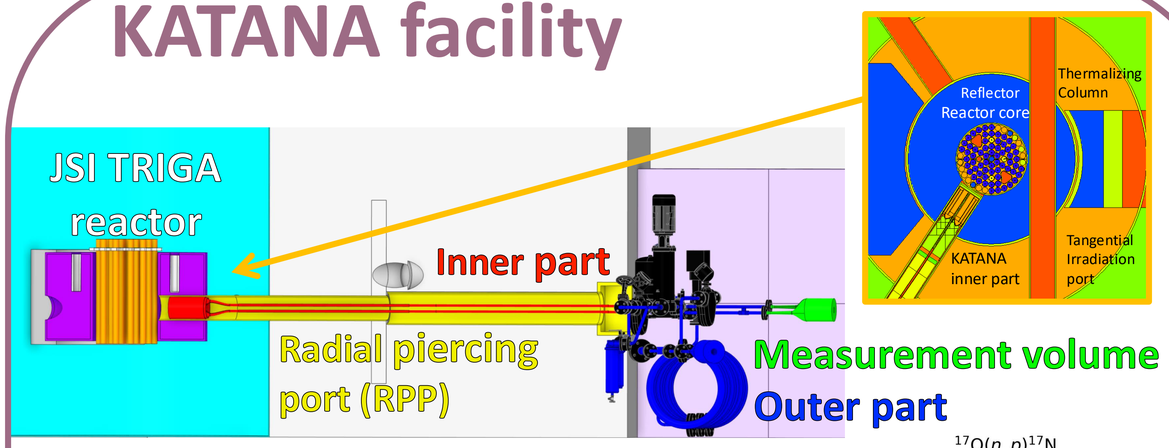
METHOD

- Calibrated ^{3}He and BF_3 detectors measure ^{17}N neutrons in a closed water loop (KATANA – JSI TRIGA).

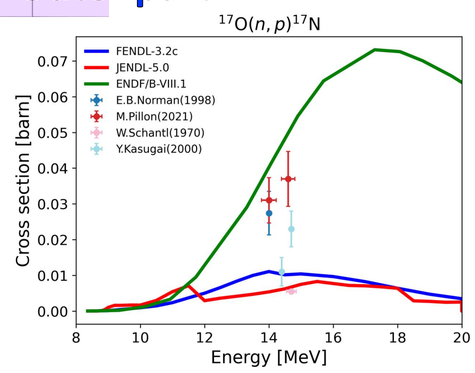
CONCLUSION

- **σ_{int}= 3.98 mb (BF_3, ±4.4 %)**
- No evaluated library reproduces the experiment within uncertainty.

KATANA facility



Reaction	$t_{1/2}$	Major decay products	Threshold energy	Natural abundance
$^{16}O(n,p)^{16}N$	7.13 s	γ: 6.13 MeV (67%) γ: 7.12 MeV (5%)	≈ 10 MeV	99.76%
$^{17}O(n,p)^{17}N$	**4.17 s**	**n: 0.38 MeV (35%) n: 1.17 MeV (53%) n: 1.70 MeV (7%)**	**≈ 9 MeV**	**0.04%**
$^{18}O(n,\gamma)^{19}O$	26.9 s	γ: 0.20 MeV (96%) γ: 1.36 MeV (50%)	< 1 eV	0.2%

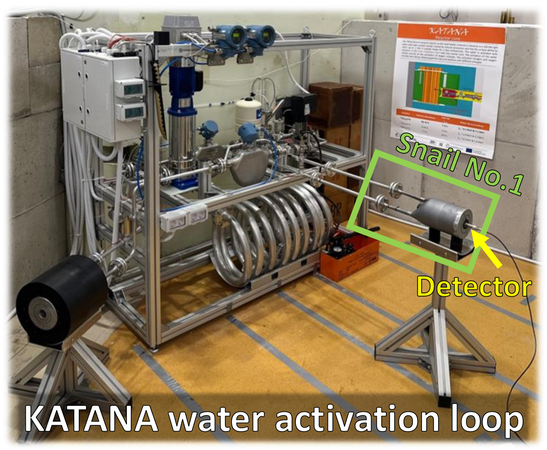


Water circulates through the inner irradiation Snail in the Radial Piercing Port, where ^{16}O, ^{17}O and ^{18}O are activated. It then flows to the outer measurement Snail, where short-lived ^{16}N, ^{17}N and ^{19}O are measured under controlled, repeatable conditions.

Experiments

^{3}He and BF_3 calibration
At the CMI thermal neutron fluence-rate field, neutron signals were recorded at multiple positions using ^{3}He and BF_3 detectors to determine the detector response at absolute fluence rate. These measurements were used to normalise the Snail No. 1 MCNP model.

KATANA neutron emission measurement
The experiment was conducted during the stable irradiation scenario of KATANA, with a flow rate of 0.66 l/s, using the JSI TRIGA reactor at 250 kW steady state. The neutron signal was measured inside Snail No. 1 with ^{3}He and BF_3 detectors.

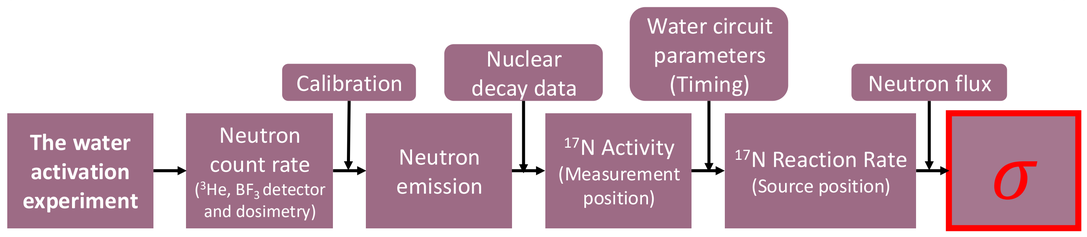


Neutron detector LND 202 (BF_3) LND 25371 (^{3}He) | Preamplifier CAEN A1422 | Digital MCA CAEN V1782 | *Data acquisition CAEN COMPASS* | HV supply CAEN V6533

Experimental setup

Results

Integral cross-section determination
The measured neutron count rate is converted to an absolute ^{17}N neutron emission rate through the CMI calibration. An analytical model of activation, transport decay and recirculation then reconstructs the reaction rate in the irradiation Snail. Finally, the reaction rate is normalised to the ^{17}O density and the irradiation flux.

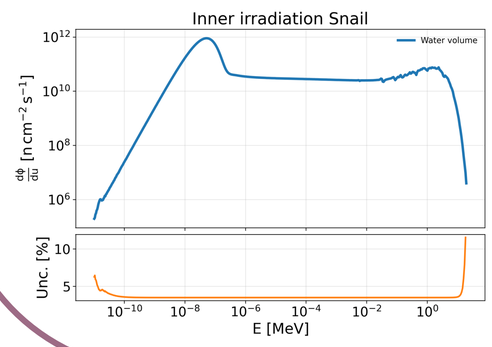


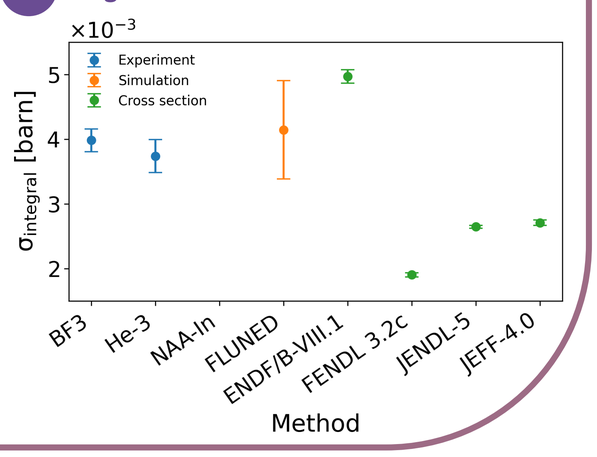
$$\sigma_{\mathrm{int}} = \underbrace{\frac{CR_{\mathrm{KATANA}}}{CR_{\mathrm{CMI}}}\, N_{\mathrm{SS}}^{\mathrm{CMI}}\, \frac{\int F4_{\mathrm{CMI}}(E)\,\sigma_{\mathrm{det}}(E)\,\mathrm{d}E}{\int F4_{\mathrm{KATANA}}(E)\,\sigma_{\mathrm{det}}(E)\,\mathrm{d}E}}_{\mathrm{I}}\ \underbrace{\frac{1}{P_n}}_{\mathrm{II}}$$

$$\times \underbrace{\frac{1-e^{-\lambda T_{\mathrm{tot}}}}{(1-e^{-\lambda t_{\mathrm{irr}}})\,e^{-\lambda t_{\mathrm{trans}}}}}_{\mathrm{III}}\ \underbrace{\frac{\lambda}{FLW\,(1-e^{-\lambda t_{\mathrm{res}}})}}_{\mathrm{IV}}$$

$$\times \underbrace{\left[n_{^{17}\mathrm{O}}\,k_{\mathrm{corr}}\,X_{\mathrm{calib}}\int_{9\,\mathrm{MeV}}^{20\,\mathrm{MeV}} F4_{\mathrm{TRIGA}}(E)\,\mathrm{d}E\right]^{-1}}_{\mathrm{V}}$$

I **Calibrated delayed-neutron source**
II **Neutron emission probability**
III **Activation, transit decay, recirculation**
IV **Flow and residence in measuring volume**
V **Target nuclei and irradiation flux**





Conclusions

- **An analytical reconstruction of activation, transport and recirculation links the measured activity to the reaction rate without full CFD calculations.**
- **The $^{17}O(n,p)^{17}N$ integral cross section in the KATANA spectrum was determined as 3.98·(1 ± 0.04) mb with BF_3 and 3.74·(1 ± 0.07) mb with ^{3}He.**
- **The evaluated libraries span 1.9–5.0 mb: FENDL-3.2c lowest, ENDF/B-VIII.1 highest. JENDL-5 and JEFF-4.0 are closest to the experiment, but none matches it within uncertainty.**
- **KATANA is now a characterised benchmark facility for water activation nuclear data and ITER-relevant detector testing.**

Acknowledgement

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 - EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

EUROfusion

Contact info:



The Abdus Salam International Centre for Theoretical Physics

IAEA