# ITER relevant conditions of the closed-water activation loop at the JSI TRIGA


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## MOTIVATION

- High dose rates (~100 Sv/h) expected around ITER cooling circuit due to activated water
- Experiments essential for code validation
- Current devices have limited availability & are expensive (FNG, FNS, JET, etc.)

## JSI WATER ACTIVATION LOOP

- Stable and high energy n & $\gamma$ source
- Benchmark & shielding experiments
- Calibration of detectors
- Integral cross-section measurements
- Validation of calculation methods in ITER-relevant conditions

## CONCLUSIONS

- Fission type reactors can tackle fusion relevant problems
- Easily accessible irradiation facility
- Cheaper & easy acess compared to JET, TCV, ITER, etc.
- ITER relevant FW irradiation head
- **Commissioning: Dec. 2023**
- **Experiments: 2024, 2025 +**

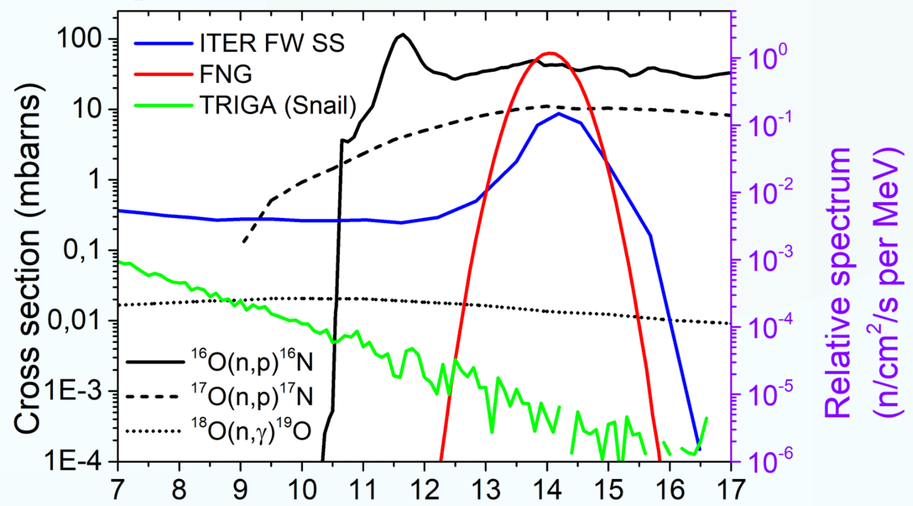
| Parameter | | ITER [1] | FNG [2] | JSI TRIGA [3] |
|---|---|---|---|---|
| Type | | 500 MW fusion reactor | DT generator | 250 kW fission reactor |
| Radiation parameters | Total n flux [n cm$^{-2}$s$^{-1}$] | $5.45 \cdot 10^{13}$ | $5 \cdot 10^{9}$ | $4 \cdot 10^{12}$ (normal)<br>$4 \cdot 10^{16}$ (pulse mode) |
| | Flux above 10.5 MeV | $< 1.5 \cdot 10^{13}$ | $< 5 \cdot 10^{9}$ | $5 \cdot 10^{8}$ |
| | Power variation | YES | NO | YES |
| | Irradiation mode | **Pulse** (several minutes) | **Pulse** (1 – 6 min) | **Continuous** (days)<br>**Pulse** (milliseconds) |
| | Specific activity [Bq/l] | $10^{13}$ ($^{16}N$) | $10^{7}$ ($^{16}N$)<br>$4 \cdot 10^{3}$ ($^{17}N$) | $8 \cdot 10^{7}$ ($^{16}N$)<br>$6 \cdot 10^{3}$ ($^{17}N$)<br>$5 \cdot 10^{6}$ ($^{19}O$) |
| | Dose rates | several Sv/h | ~μSv/h | ~mSv/h |
| | Background | No data | Clean | Clean |
| Water flow parameters | Flow type (Reynolds #) | Turbulent ($4 \cdot 10^{5} - 2 \cdot 10^{7}$) | Turbulent ($2 \cdot 10^{5}$) | Turbulent ($9 \cdot 10^{4}$) |
| | Flow rate | 5 l/s | 0.18 – 1 l/s | <1 l/s (target 0.5 l/s) |
| | Irradiation time (irradiation volume) | 6 – 10 s (30 – 50 l) | 0.14 – 1.8 s (0.14 – 0.32 l) | 6 s (Snail head: 3 l) |
| | Travel time | ~10 s | 2 – 10.7 s | 2.7 s |
| | Recirculation | Once through (delay tank) | Once through (delay tank: 109 l) | Cont. or once through (primary + secondary loop) |
| | Flow branching | YES | NO | OPTIONAL |
| | Temperature | 15 – 150°C | Room temp. | Warm (<60°C) |
| | Pressure | 14 bar (up to 50 bars) | 10 bar | <8 bar |
| | Pipe dimension | 50 – 400 mm | 11 – 25 mm | 12 – 44 mm |
| | Water speed | <10 m/s | <10 m/s | <9.5 m/s |
| Reference | | M. De Pietri, Fus. Eng. Des., 2023 | M. Pillon, Nucl. Instr. Meth. in Phys. Res., 2021 | D. Kotnik, Fus. Eng. Des., 2023 |

- Radiation transport eq. is linear → **source strength does not affect the solution**

## Water activation reactions

| Reaction | Natural abundance | Half-life $t_{1/2}$ | Major decay products | Threshold energy |
|---|---|---|---|---|
| **$^{16}$O(n,p)$^{16}$N** | **99.76 %** | **7.13 s** | **γ: 6.13 MeV (67 %)**<br>**γ: 7.12 MeV (5 %)** | **~10 MeV** |
| $^{17}$O(n,p)$^{17}$N | 0.04 % | 4.17 s | n: 0.38 MeV (35 %)<br>n: 1.17 MeV (53 %) | ~8 MeV |
| $^{18}$O(n,γ)$^{19}$O | 0.2 % | 26.9 s | γ: 0.20 MeV (96 %)<br>γ: 1.36 MeV (50 %) | < 1 eV |

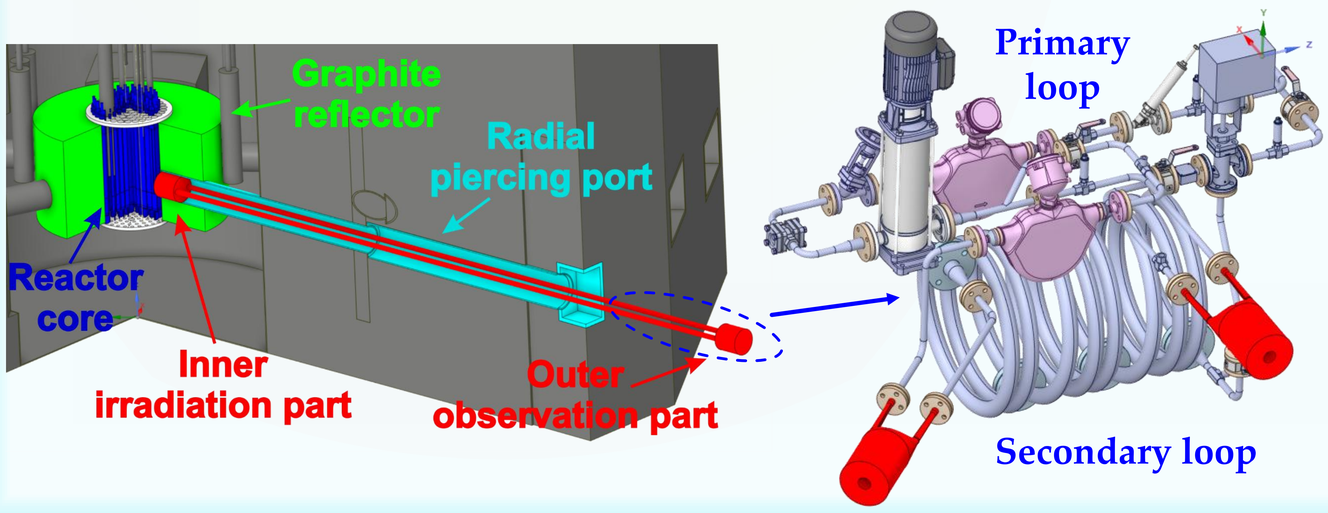
- Fast neutron spectrum, normalized to the total flux, at irradiation locations [4]




| Fraction of neutrons above | ITER First Wall SS | FNG (DT generator) | TRIGA (Snail head) |
|---|---|---|---|
| 8 MeV | 18.1 % | ~100 % | 0.07 % |
| 10.5 MeV | 17.1 % | ~100 % | 0.01 % |

[4]: LG: neill, AD: IDM_F4E, AD: F4EN-A90, AD: IDM IE-TS-AN-00 Analysis and Codes, GG: IAC, project administrator, RO (v. 2YNULU / 1.1)

## Closed-water activation loop at JSI TRIGA




## Outlook: ITER FW relevant irradiation head

Premise of conceptual design is to preserve:

- **Hydraulic features**: pipework, water boxes, fingers
- **Residence time**: adjusted flow rate (same regime, i.e. Reynolds #)
- **Orientation of neutron flux gradients**

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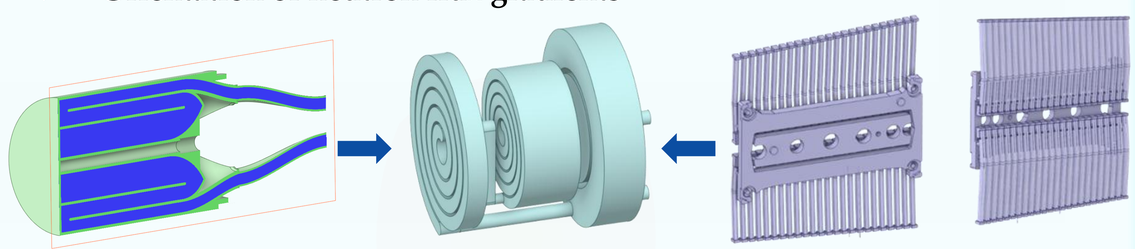

Snail head — Spiral disk design — ITER FW cooling channel