Water activation loop at the JSI TRIGA research reactor

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WATER ACTIVATION CHALLENGES

- High dose rates (~100 Sv/h) around cooling circuit (ITER)
- Large discrepancies and inconsistencies among nuclear data libraries
- Lack of:
  - water activation experiments in fusion relevant conditions
  - experimental facilities featuring high energy γ sources
  - calculation tools/methodologies for dose rate calculations

PROPOSAL

- **Design and installation of water activation loop at JSI TRIGA reactor**
  - γ detector characterization & calibration (6 MeV – 7 MeV)
  - shielding experiments using ITER relevant materials
  - integral cross-section measurements of oxygen isotopes
  - dose rates and γ spectrum measurements along the water loop
  - reference irradiation facility for benchmark experiments

CURRENT LOOP STATUS

- Design and modelling phase
- Optimization of the main parameters
- Equipment procurement process

TIMELINE

- Design complete: September 2022
- Facility commissioned: Early 2023
- Measurements: Second half 2023/ 2024/2025 (experimental campaign?)

Water activation

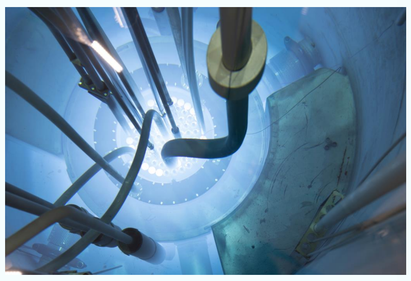
Most relevant water activation reactions and corresponding decay characteristics

Reaction	Natural abundance of oxygen isotope	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 %)	~10 MeV
			γ: 7.12 MeV (5 %)	
$^{17}O(n,p)^{17}N$	0.04 %	4.14 s	n: 0.38 MeV (35 %)	~8 MeV
			n: 1.17 MeV (53 %)	
			γ: 0.87 MeV (3 %)	
$^{18}O(n,\gamma)^{19}O$	0.2 %	26.9 s	γ: 0.20 MeV (96 %)	< 1 eV
			γ: 1.36 MeV (50 %)	

- **0.6 %** of fission neutrons are above 8 MeV (IRDF-II)

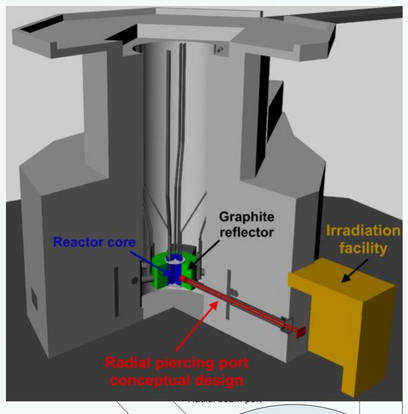
JSI TRIGA Mark II Research Reactor

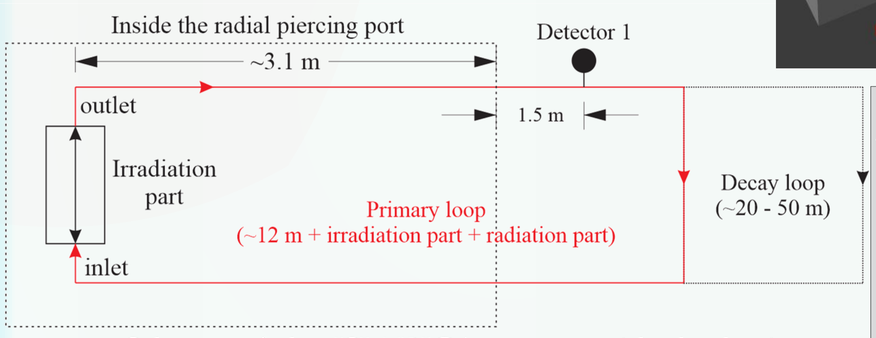
- P_{max}
  - 250 kW (steady state)
  - 1 GW (pulse)
- 1st criticality: 31st May, 1966
- Fuel
  - UZrH (12 wt. % U)
  - Enrichment = 20 %

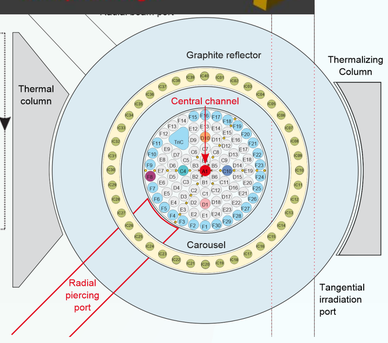


Closed water activation loop

- Utilization of radial piercing port
  - high neutron flux ~10^{12} n/cm^{2}s
- Primary loop: ^{16}O, ^{17}O
- Secondary decay loop: ^{18}O
- Commission in early 2023







Scheme of the JSI TRIGA reactor with the basic conceptual design of the water activation loop

Primary loop

- Irradiation part (Snail #1)
- Radiation part (Snail #2)
- Detector (HPGe, He3)
- Flow meter
- Temperature control
- Pressurizer
- Pump
- Valves

Secondary loop

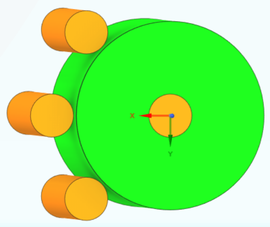
- Radiation part (Snail #2)
- Detector (HPGe)
- Flow meter

Characteristics

- Total water volume: ~7.5 l
  - Irradiation: 37 %
  - Radiation 37 %
  - Transport 26 %
- Flow rate: 0.5 l/s
- Demineralized water
- Pressure drop: ~ 8 bars
- ALU transport pipes
- Gamma detector:
  - 2x HPGe
- Neutron detector:
  - 4x He3

Systems

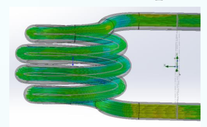
- Regulation system
  - Valves
  - Pump (flow control)
- Cooling system
- Water filling/emptying system
- Shielding (passive)

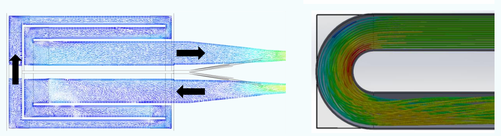


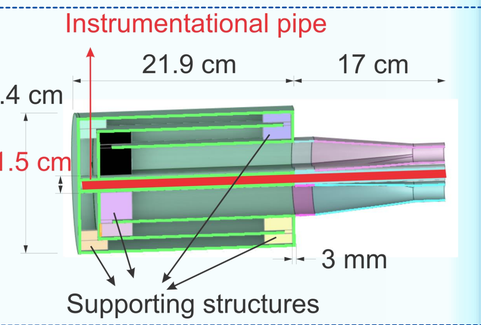
Design optimization

- Optimization of the main parameters
  - irradiation part, pipe dimensions, loop length, water flow, detector's position, etc.
- Goal:
  - **high specific activity**
  - **low experimental uncertainty**
  - **flexible loop**

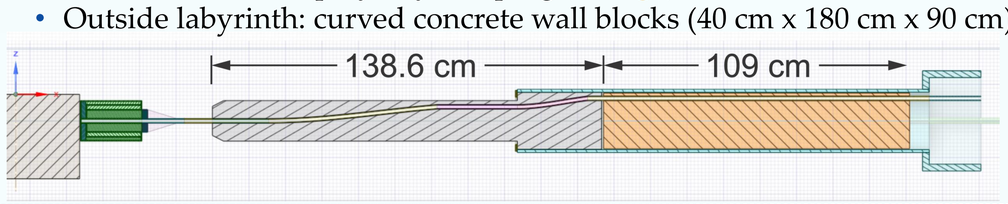
- Different designs of the irradiation part
  - Spiral (V = ~0.5 l)
  - U-turn (V = ~1 l)
  - Snail (V = ~3 l)

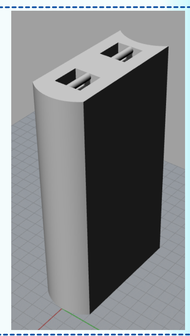






- Passive shielding
  - Gamma: aluminium-concrete plug (grey)
  - Neutrons: Borated polyethylene plug (orange)
  - Outside labyrinth: curved concrete wall blocks (40 cm x 180 cm x 90 cm)





- Specific saturation activity at detector

$$a_{sat}(t) = \frac{R\left(1 - e^{-\lambda t_{irr}}\right)e^{-\lambda t_{trans}}}{1 - e^{-\lambda(T_{loop}+t_{irr})}}$$

- CPS estimation at detector
  - N16: ~100 – 2000
  - N17: ~10 – 100

measurable !!!