Measurements and calculations of the neutron spectrum in different irradiation channels of the TRIGA Mark II reactor, Slovenia

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2nd Research Coordination Meeting, Vienna, Austria, May 2007

Scope

Neutron spectrum characterisation of irradiation channels of TRIGA Mark II reactor

- Al-Au(0.1%) discs in 33 irradiation channels (6 in the core, 27 in the carousel facility).
- Al, Au, Mn, Mo, Ni, W, Zn, Zr monitors for spectrum determination in 4 channels (CC, FPTS, PT, IC40).
- Full-core model for the MCNP5 Monte Carlo code is used for activation and spectrum calculations (Andrej Trkov).

Proficiency tests

- The efficiency test for calibration of an HPGe detector using: Ba-133, Eu-152, Ra-226 and Co-56 (Zsolt Revay).
- The gamma spectrum analysis test for k0_IAEA program (Menno Blaauw).
- The proficiency test of the SMELS samples Types I, II and III using k0_IAEA program (María Arribére).

Nuclear research reactor
TRIGA Mark II (250 kW)
(reactor core No. 189, 2006)

- Short and long irradiation in the CC:

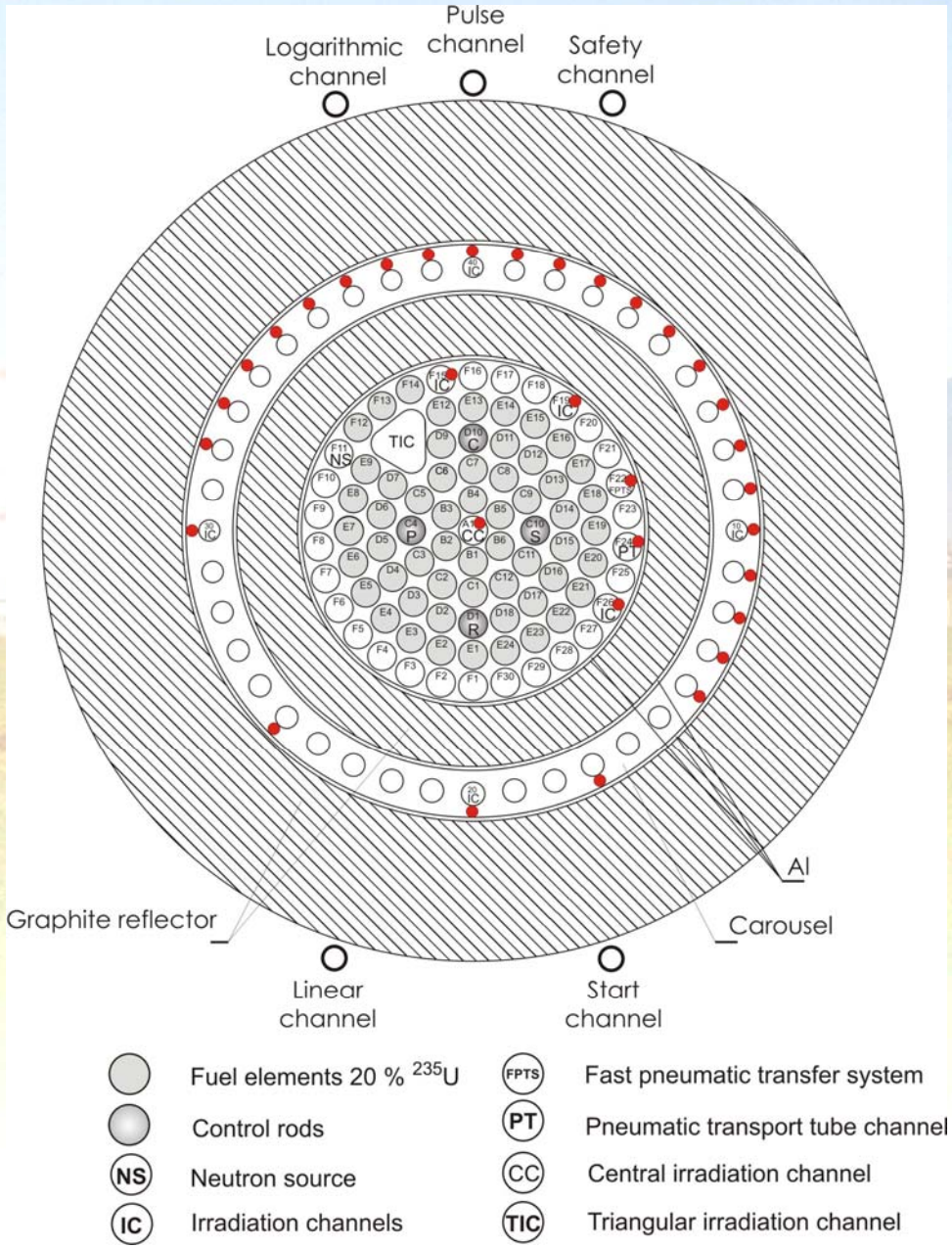
$\varphi_{th} \sim 10 \cdot 10^{12}$ cm^{-2} s^{-1}

-Short irradiation in the PT and in the FPTS (up-to 30 min.)

$\varphi_{th} \sim 3.5 \cdot 10^{12}$ cm^{-2} s^{-1}

- Long irradiation in the IC-40 (typically 20 hours)

$\varphi_{th} \sim 1.1 \cdot 10^{12}$ cm^{-2} s^{-1}



Experimental

Experimental equipment

- 250 kW light-water moderated nuclear research reactor TRIGA Mark II with graphite reflector.
- Semiconductor coaxial HPGe detector (Canberra, 45% relative efficiency) at the O-2.
- Semiconductor coaxial HPGe detector type NIGC 26 (PGT, serial No. DN 124) at the F-8.
- Analytic weight METTLER AE 163 (accuracy ± 0.00001 g)
- Al-Au discs (Al(99.9%)-Au(0.1%)) 5 mm in diameter and 0.2 mm high.
- Polyethylene containers
- Al and polyethylene rabbits.

Sample preparation

- 33 Al-Au discs 5 mm in diameter and 0.2 mm high were prepared from Al-Au wire (Al(99.9%)-Au(0.1%)) 1.0 mm in diameter using hydraulic press (SPECAC, UK).

Experimental

Irradiation

- All 33 samples irradiated at maximum power (250 kW)
- Starting on 13.6.2006 at 10:47:17 and finishing at 12:00:17
- Time and other parameters recorded during irradiation
  - R regulation rod position
  - P_1/P_2 power level on linear/safety channel, respectively
  - T_{f1}/T_{f2} , T_{v1}/T_{v2} fuel and coolant temperature readings
  - Compensating rod at 350 steps withdrawn (range 200 to 900)
  - Safety and shim rods withdrawn.

Time	P_1/P_2 [%P_{max}]	Position R	T_{f1}/T_{f2} [°C]	T_{v1}/T_{v2} [°C]
11:00:00	97/104	384	215/210	16/26
11:15:00	98/105	383	215/210	15/26
11:30:00	98/106	383	215/210	15/26
11:45:00	98/106	382	215/210	15/26

Experimental

Measurement(s)

$^{197}Au(n,\gamma)^{198}Au$,	$T_{1/2}$ = 3880.8 min;	E_γ = 411.8 keV.
$^{27}Al(n,\alpha)^{24}Na$,	$T_{1/2}$ = 897.6 min;	E_γ = 1368.6 keV.

The first measurement(s)

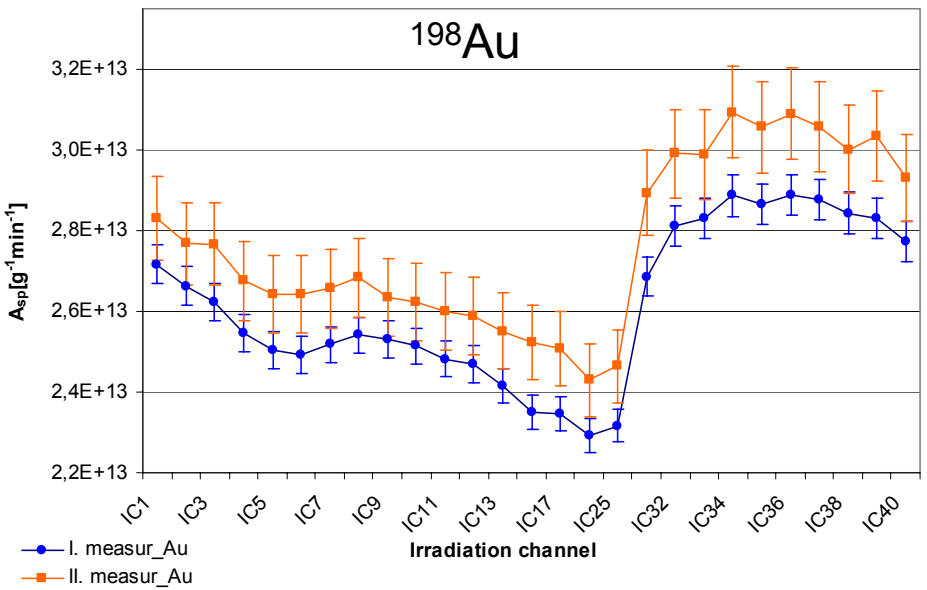
- were done at the O-2 starting 21 hours after the end of irradiation and finished within 12 hours. Measuring time (real time) for all samples was 20 min. Both nuclear reactions were detected with reasonable counting statistics. For the measurement absolutely calibrated coaxial type of an HPGe detector (Canberra, 45% relative efficiency), connected to an ORTEC® DSPEC^{PLUS} high-rate multichannel analyzer, was used. For net peak area evaluation, the HyperLab program was used. For effective solid angle, true-coincidence and specific activity calculations the KayWin program was applied.

The second measurement(s)

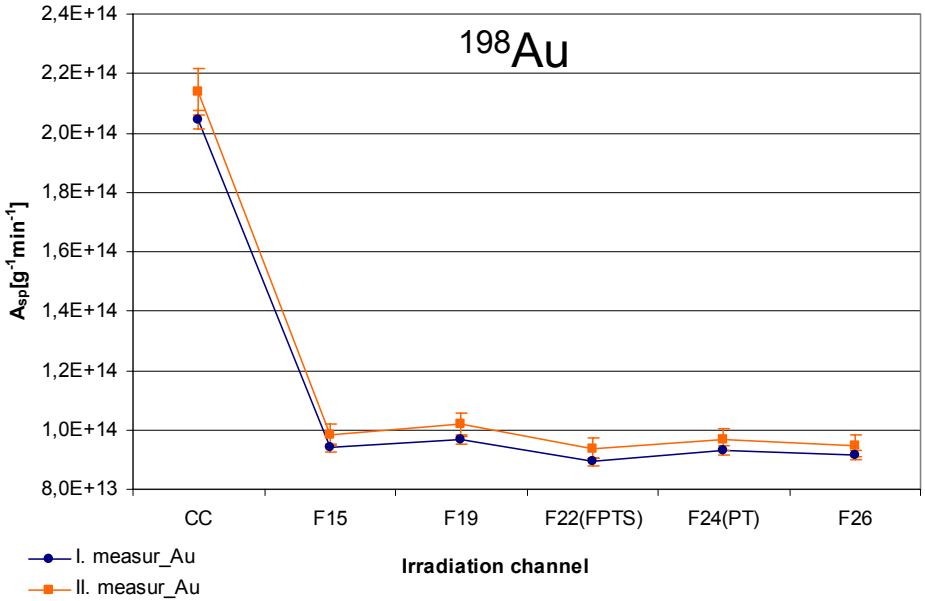
- were done at the F-8. The measurements started after three days of cooling time, so the measurement of threshold reaction (n,α) was not suitable for all samples and results obtained are not reported. Measuring time (real time) for samples varied from 5 to 80 min. All the measurements were completed within 17 days of cooling time. For the measurements a PGT (Princeton Gamma Tech) type NIGC 26 coaxial HPGe detector, connected to a NUCLEUS multichannel analyzer, was used.

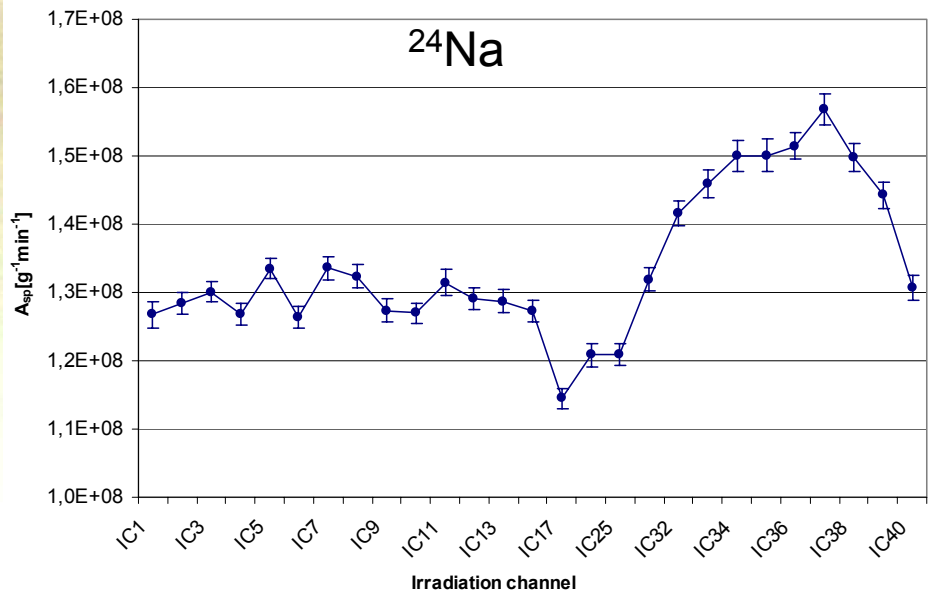
Results and discussion

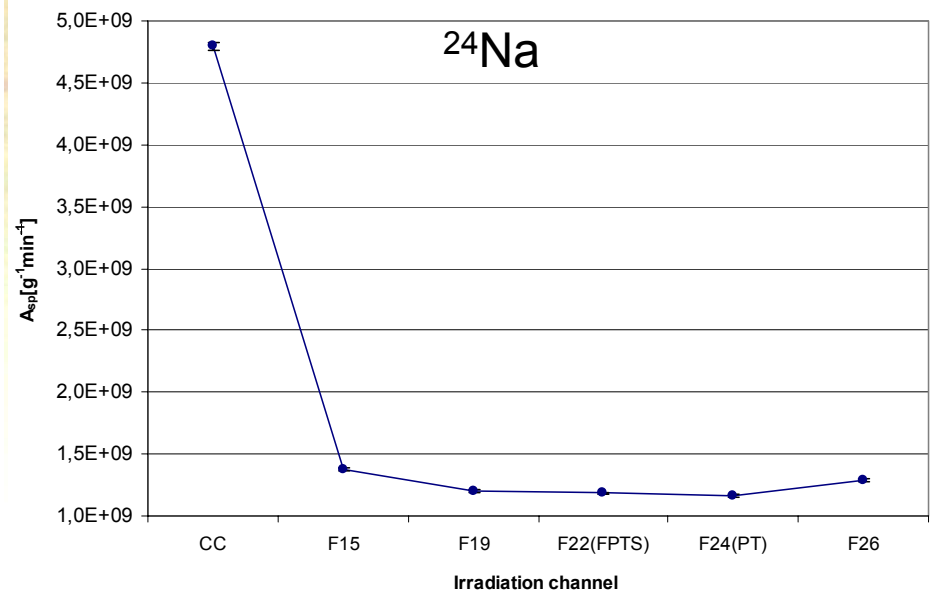
Carousel



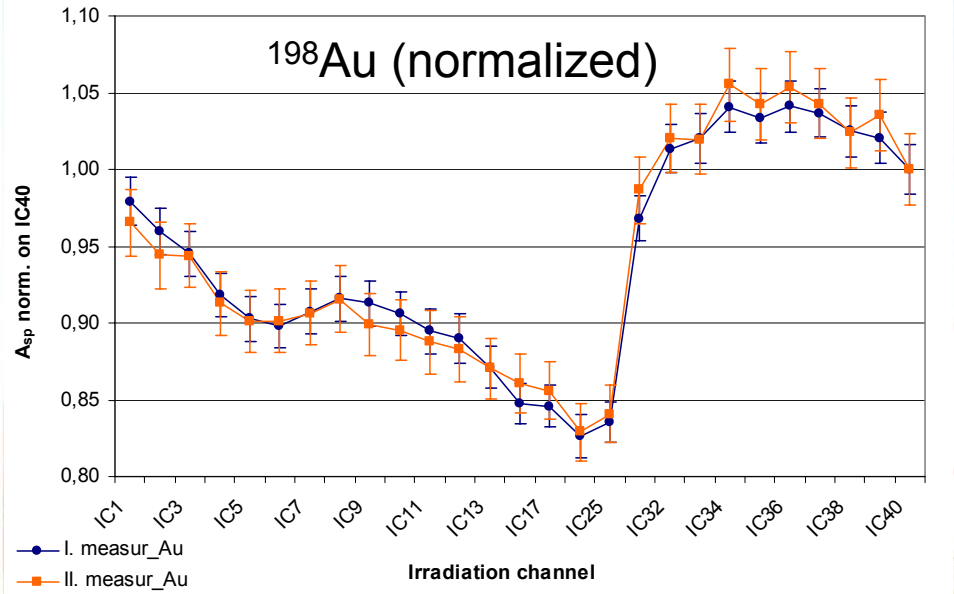
Core







Carousel



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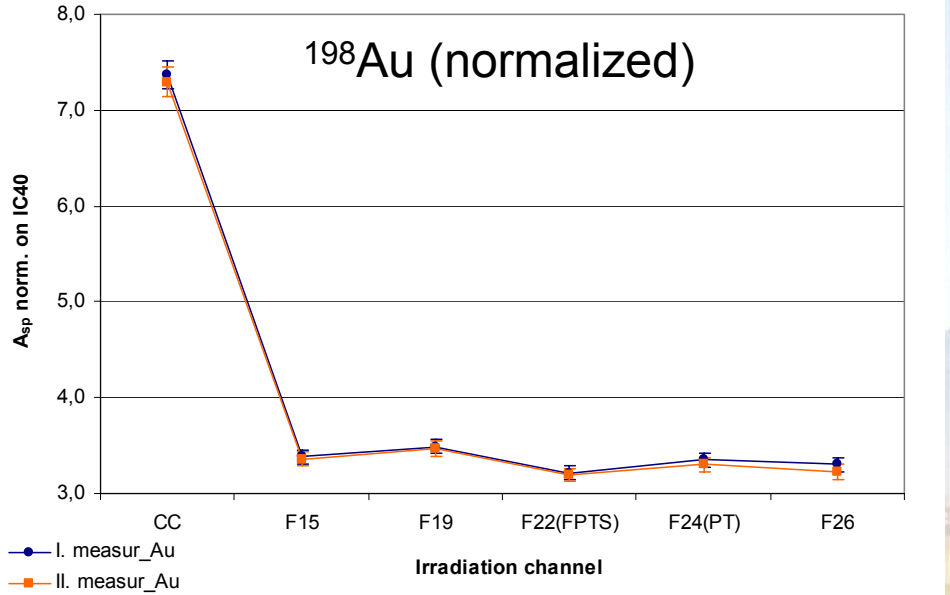

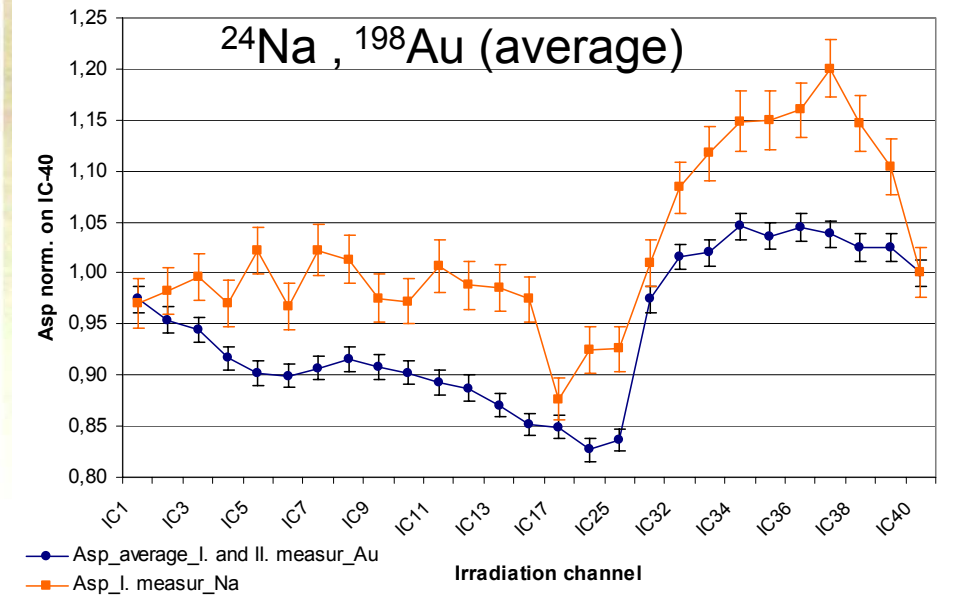

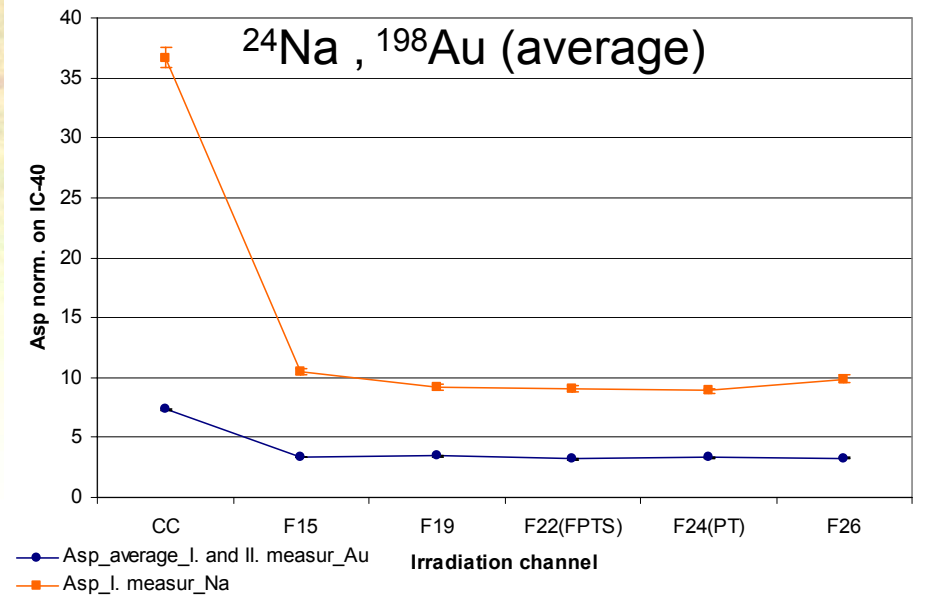

Conclusions

- Measured monitor activities in 33 irradiation channels of the TRIGA reactor (core No. 189).
- Thermal neutron flux on the core periphery drops by a factor of three compared to the central channel; fast neutron flux drops by a factor of ten.
- Measured data sets agree to within about 2% (after normalization).
- Variations of the thermal neutron flux around the core in the carousel facility relative to the position IC40 range from 0.83 to 1.05 (relative values) and for fast neutron flux from 0.88 to 1.20 (relative values).
- Further measurements to validate the neutron spectra in selected irradiation channels are in progress.