TRIGA Integral Activation of Mn Foils, Li2O and LiF as Potential Tritium Production Monitors for Fusion Applications

I. Kodeli[a], V. Radulović[a], G. Veniger[a], D.Kavšek[a], T. Kuc[b], M. Ciechanowski[b], W. Pohorecki[b]

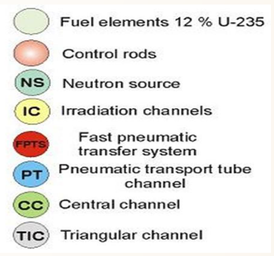
[a] *Jožef Stefan Institute, Ljubljana, Slovenia*
[b] *AGH University of Science and Technology, Krakow, Poland*

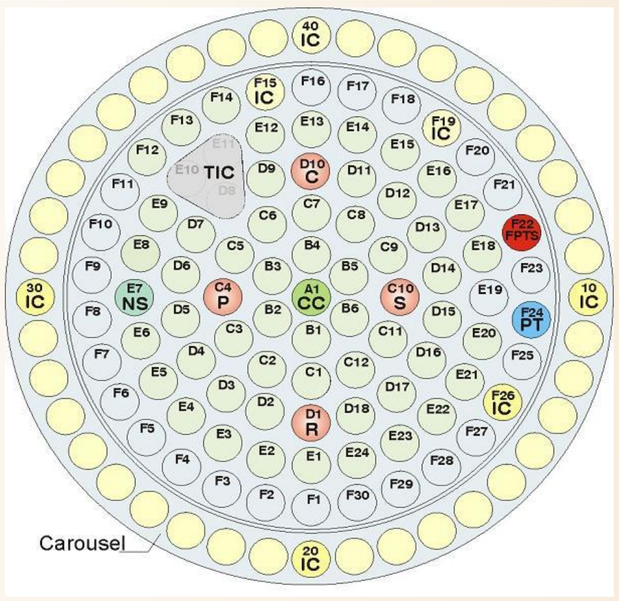
SUMMARY

Two series of measurements were performed in the JSI TRIGA research reactor, in 2014 and 2017, to validate the ^{55}Mn(n,γ)^{56}Mn cross sections and experimentally investigate the relationship between the ^{55}Mn(n,γ) reaction and the tritium production rate through the ^{6}Li(n,t) reaction. Indeed, the previously observed similarities between the sensitivity profiles of the neutron reaction of tritium production - ^{6}Li(n,t) and those of the ^{55}Mn(n,γ)^{56}Mn reaction in the TBMs indicated that the latter reaction could be used as a tritium production monitor, at least for short-term monitoring, the half-life of ^{56}Mn being 2.579 h. However, experimental verification and improvements and validation of the Mn cross-sections are needed in order to meet the required accuracy. Foils of certified reference materials Al-1%Mn and Al-0.1%Au, as well as TLD(LiF) and Li_2O samples were irradiated, both bare, and under cadmium and boron nitride to study the potential use of manganese detectors for monitoring tritium production in fusion devices. In order to obtain complementary information for data validation purposes, the irradiations were performed in irradiation facilities with different neutron spectra in the JSI TRIGA reactor. Bare, Cd-covered and BN-covered irradiations were needed for the subtraction of epi-thermal neutron contribution in the ^{55}Mn(n,γ)^{56}Mn reaction. The transport calculations were performed using the Monte Carlo transport code MCNP6.1 with a detailed model of the TRIGA reactor including the irradiation capsules and covers. The uncertainties involved in the measurements and the calculations were carefully evaluated.

OBJECTIVE: Direct Tritium production monitors by Integral activation experiment of Mn foils.

- Irradiation of Mn foils in a TRIGA thermal reactor to study the energy response of the ^{55}Mn(n,γ)^{56}Mn reaction. The latter reaction can be proposed as a tritium production monitor since its energy distribution of the response was found to be very similar to the sensitivity profile of the tritium production in ^{6}Li.
- In 2014 and 2017 two experimental campaigns were performed at the JSI TRIGA research reactor, consisting of irradiating Mn foils at different positions in the reactor.





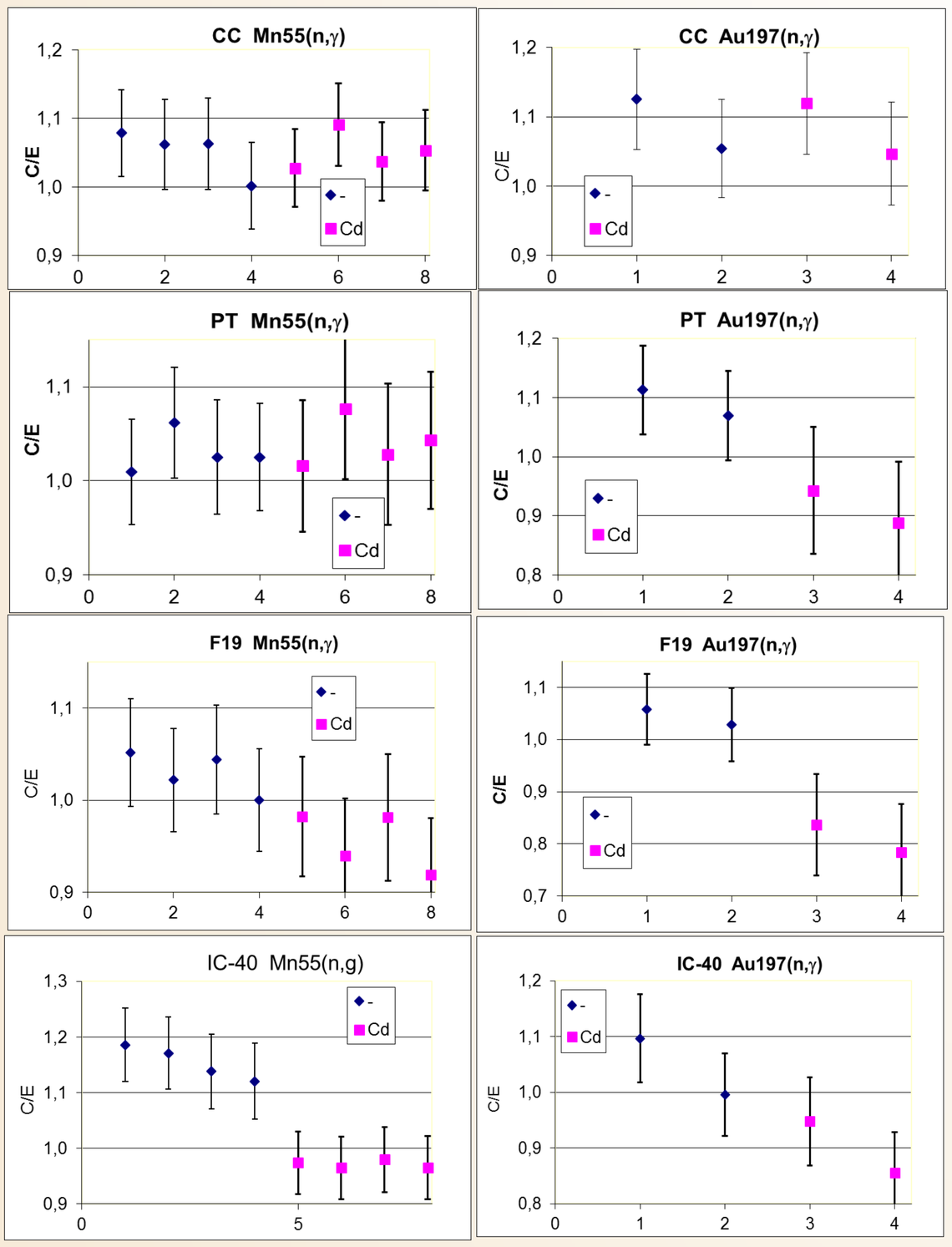
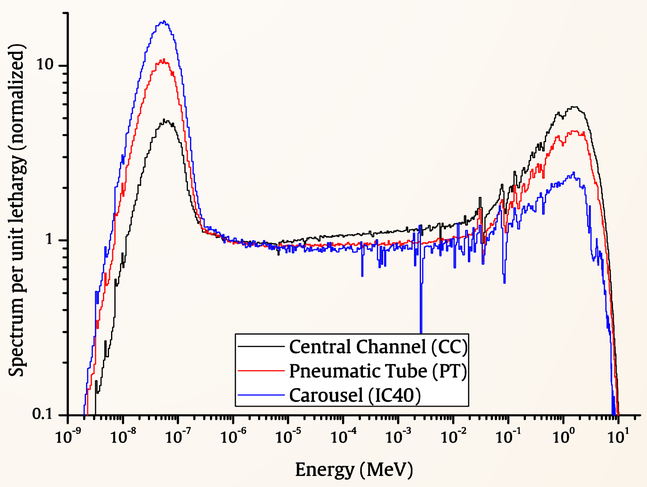


FIGURE: C/E comparison for the capture reaction measurements in different TRIGA reactor positions.

JSI TRIGA Mark II Irradiation channel spectra calculated with MCNP 5



Locations used:

- **CC -** central channel
- **IC40 -** in graphite reflector
- **F19**
- **PT -** pneumatic tube in outer “F” ring

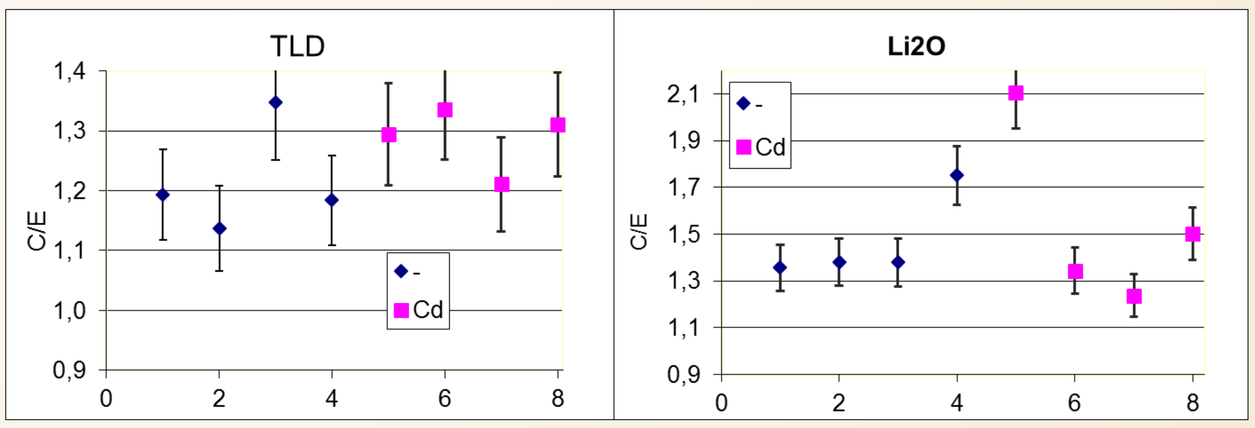


FIGURE: C/E comparison for the Tritium activity measurements using TLD and Li_2O in different TRIGA reactor positions.

ACKNOWLEDGEMENTS

The work leading to this publication has been funded partially by Fusion for Energy under the Specific Grant Agreement F4E-FPA-395-01. This publication reflects the views only of the author, and Fusion for Energy cannot be held responsible for any use which may be made of the information contained therein.

CONCLUSIONS

In order to study the potential use of the ^{55}Mn(n,γ)^{56}Mn reaction as tritium production monitor, a second series of foils of certified reference materials Al-1%Mn and Al-0.1%Au, as well as TLD(LiF) and Li_2O samples were irradiated in different irradiation channels in the JSI TRIGA research reactor, both bare, under Cd and under boron nitride. The irradiations were performed in different neutron spectra, i.e. in the central channel - CC, the pneumatic tube – PT in position F24 in the outer “F” ring of the reactor core, in position F19 and in the IC-40 irradiation channel in the graphite reflector. A detailed MCNP6.1 computation model was prepared including the realistic description of the TRIGA reactor with the irradiated capsules.

Measured results and the uncertainties involved in the measurements and the calculations were studied. Good consistency between the calculated and measured values were observed for the Mn and Au measurements, within 10 % for the CC and PT locations and around 20% for the IC40 irradiations.

For the TLD and Li_2O measurements, the calculations overestimate the measurements by roughly 20 and 50%, respectively, with some irregular trends. Interpretation of the measured TPR in LiPb needs careful approach to take into account different effects:

— Shielding effect of the LiF pellet placed in between two other pellets, reaching up to 8%;

— inhomogeneity of the sample material i.e. not the same mass of Li in 1 g of the sample, i.e. lower ^{6}Li abundance than expected in natural lithium;

— incomplete recovery of irradiated lithium oxide sample while removing to further preparation due to the difficulties with washing out of Li_2O;

— effect of self-absorption.

Although not originally planned, Mn foil irradiations can therefore serve for the verification and validation of other direct tritium production measurements.