Comparison of Experimental Data and Calculation Results for Kwinta Experiment of E&T RAW Collaboration (December, 2011)

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(for collaboration "Energy & Transmutation of Radioactive Wastes")

Introduction

It is well known that nuclear power meets the condition of sustainable development being at the same time economically competitive, not consuming oxygen and so not creating greenhouse gases, and, as a consequence, not disturbing the ecosystem balance of our planet. In many research institutes all over the world are actively studied aspects of electronuclear energy production in the subcritical reactors. Feasibility of application of natural/depleted uranium or thorium without the use of $U-235$, as well as utilization of spent of fuel elements of atomic power plants is demonstrated based on analysis of results of known experiments, numerical and theoretical works[1,2] The investigations described in this paper were performed within the framework of the scientific programme called "Investigations of physical aspect of electronuclear energy generation and atomic reactors radioactive waste transmutation using high energy beams of synchrophasotron/nuclotron JINR (Dubna)"- project "Energy & Transmutation of Radioactive Wastes". The scientific description of the project, including main ideas, history, former experiments, description and results, uranium fission calorimeter description, experimental methodology used for neutron and proton field properties investigation (activation and Solid State Nuclear Track Detectors (SSNTD), nuclear emulsions, $He-3$ detectors etc.), can be found in publications of the "Energy plus Transmutation" collaboration [3-5]. The main aim of this work is comparison experimental data of $U-238(n,f)$ and U-238(n,g) with calculation results for experiment made in December 2011.

Geometry and materials of assembly; beam parameters

The calculation model of 'Kwinta' assembly is based on the work [6]. The simulation of experiments are made by MCNPX 2.7 code[7] based on Monte Carlo method. In Table 1.1 are presented base average parameter of deuteron beam for two value of beam energy it is 1 and $4GeV$.

Calculation method

To calculate number of $238(n,f)$ reaction N_f the following definition was used

$$N_f = \int_0^\infty \phi(E)\sigma(E)\rho\, d\, E \qquad (1)$$

where: $\phi(E)$ - density of neutron flux calculated by MCNPX 2.7 based on ENDF (Evaluated Nuclear Data File); $\sigma(E)$ - cross section from JENDL (Japanese Evaluated Nuclear Data Library); ρ - density of $U-238$.

To calculate neutron flux $\phi(E)$ we used geometry and materials presented in work [6] and deuteron beam parameters from Table 1.

In this calculation method was used :

1. Beam profile parameters from [8]
2. MCNPX 2.7 code [7]
   a. ENDF - Evalueted Nuclear Data File
   b. Bertini[9,10]+ FLUKA[11]+Abla model[7]
3. Formula 1 and the $U-238(n,f)$ cross section from JENDL Data Library was used for fission of $U-238$ (see Fig. 1).
4. The $U-238(n,f)$ cross section from TENDL[12] and JENDL[13] Data Library (see Fig. 2). In the energy ranges $(1e-8, 2.3e-2)$ and $(2.3e-2, 200)$ MeV the cross section from JENDL and TENDL Data Library respectively was used for calculation of $Pu-239$ production. Additively in the range $(2.0e-6, 2.3e-2)$ MeV the cross section is approximative average cross section (see Fig. 2).

Table 1: Beam parameters. The [$*$] means experimental data made by group of physics from Belarus using the SSNT method.In the work [8] are presented experimental data based on the activation method.

Total beam energy	Total number of deuterons	Beam shift in X [cm]	Beam shift in Y [cm]	FWHM in X [cm]	FWHM in Y [cm]
$1GeV$	1.53*1013	1.8 [8] 1.290.18 [*]	-0.3 [8] 0.190.06 [*]	3.8 [8] 2.60.3 [*]	4.7 [8] 3.50.3 [*]
$4GeV$	1.93*1013	1.5 [8] 1.370.014 [*]	0.3 [8] 0.190.016 [*]	2.4 [8] 1.520.04 [*]	2.8 [8] 1.440.04 [*]

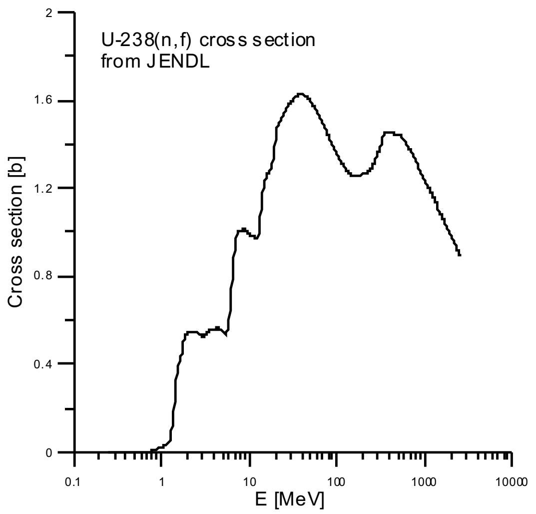

Figure 1: The $U-238(n,f)$ cross section from JENDL Data Library.

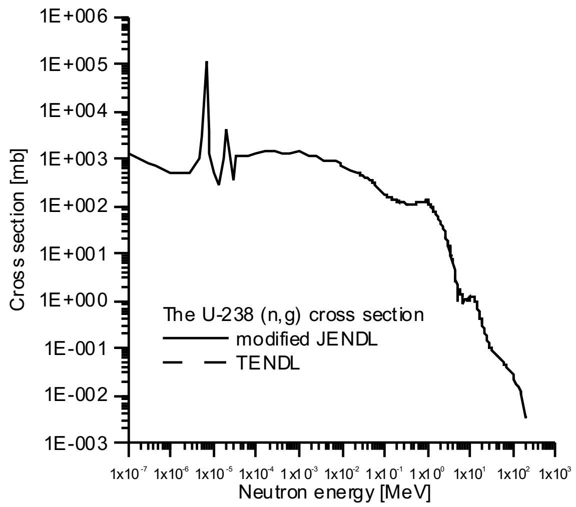

Figure 2: The $U-238(n,g)$ cross section from TENDL and JENDL Data Library. In the range $(2.0e-6, 2.3e-2)$ MeV is approximative average cross section.

Comparison of calculation results and experimental data

The experimental data are from experiment made by E+T RAW collaboration at December 2011. The $U-238(n,f)$ reaction was measured by SSNT and activation detectors. The $Pu-239$ production was measured using activation detector and the 277,6 keV γ -line from $239Np$ from following reaction: $238U(n,\gamma)239U(23.54\,min)\beta- \rightarrow 239Np(2,36\,days)\beta- \rightarrow 239Pu$.

We assume that number of $U-238(n,f)$ reaction is equal to number of $Np-239$ (2,36 days) $\beta-$ reaction.

The likely comparison of $U-238(n,f)$ and $U-238(n,f)$ is presented in the work [14] for experiment made by E+T RAW collaboration at March 2011. However agreement of experimental data and calculation results presented in the Fig.3.1 is better than in experiment made at March 2011 (compare [14]). The experimental errors of activation method does not include the error of cross section of $Al-27(d,x)Na-24$ reaction. This reaction is used for measuring of beam parameter by activation method.

Please not that average relative differences between base beam parameters measured by activation and SSNT method, it is shift and FWHM (see Tab.1) achieved 30-50%. The calculation results are made using only experimental data of beam parameters from [8]. These differences can have essentially influence on calculation results for detectors placed on the $R=0$.

The experimental result of activation detector placed at $z = 240$ mm and $R = 4$ cm is failing and we can ignore it in final conclusion.

Conclusion and remarks

- In case of $U-238(n,f)$ and $U-238(n,g)$ reaction and $z=0$ the calculation results are significantly greater than experimental data (Figs. 3A, 3B). Probably on the first plane falls other neutron flux except from fission and spallation reaction inside of assembly.

- In case of $U-238(n,f)$ reaction the calculation

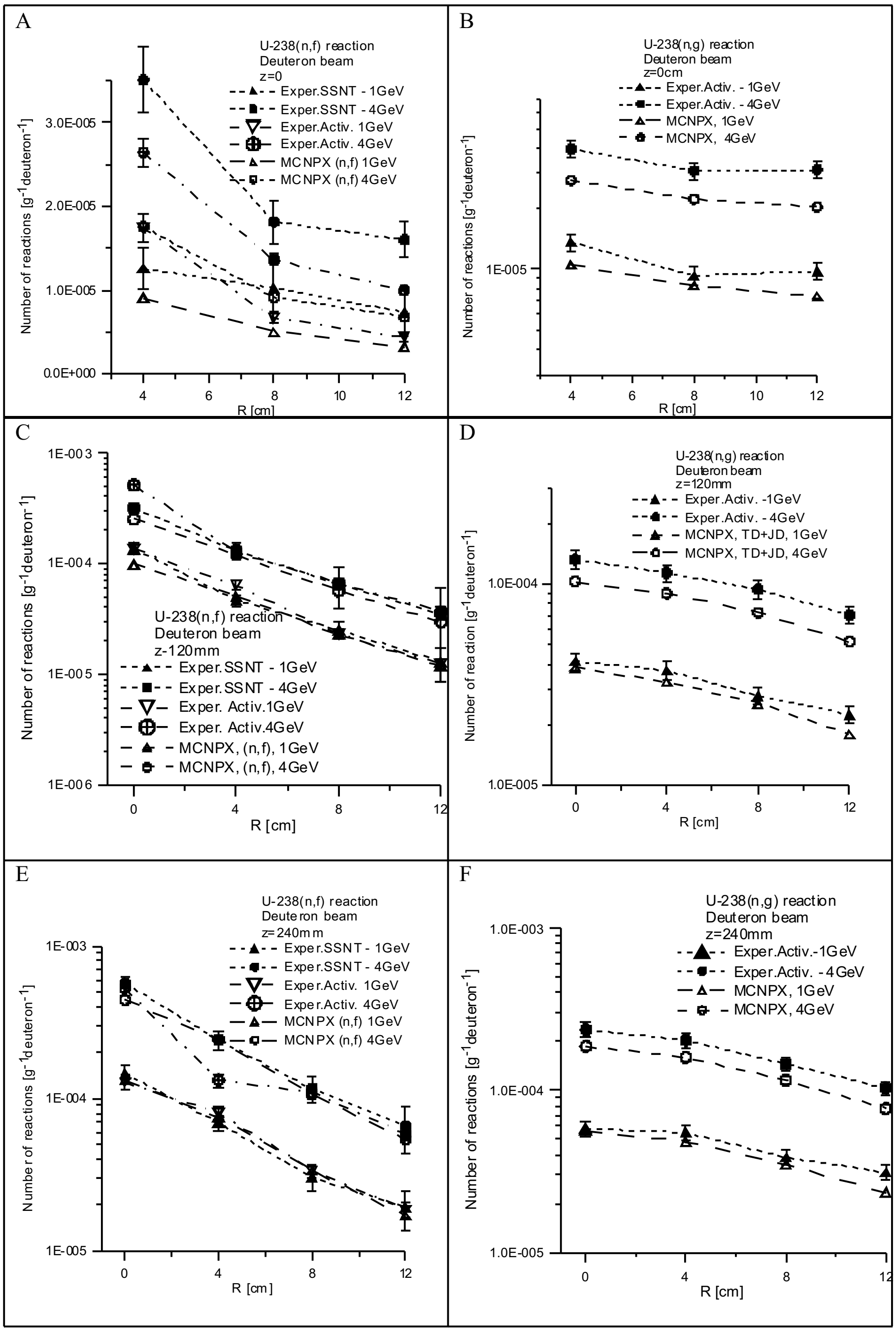

Figure 3: Number of reaction $U-238(n,f)$ (left) and $U-238(n,g)$ (right)per one initial particles per mass unit of U-nat. per energy unit. Measurement plane is placed at $Z=0$, 125 and 245mm. Exper.SSNT and Exper.Activ. mean experimental data from SSNT and Activation detectors.

results are in the range of experimental errors for R greater than 0. (Figs. 3C, 3E). Calculation results for detectors placed on the $R=0$ is less then experimental data. The reasons of disagreement is that these detectors are directly in the beam of deuterons. In these detectors are $U-238(d,f)$ reaction additively. The making of reliable calculation of $U-238(d,f)$ reaction is impossible because is only one point of $U-238(d,f)$ cross section for deuterons energy greater then 100 MeV it is for energy equal to 4 GeV and 2.1 GeV [15, 16]. To overcome this problem it is necessary to measure the cross section of $U-238(d,f)$ reaction in the range of energy (0.5, 6.0) GeV.

- In case of $U-238(n,g)$ reaction the differences between calculation results and experimental data are a little greater experimental errors for R greater than 0 (Figs. 3D, 3F). In my opinion the effective cross section for the $U-238(n,g)$ reaction may be estimate with too low precision for the resonance region. (See Fig. 2). The calculation results does include differences between base parameter of deuteron beam [see Table.1]

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