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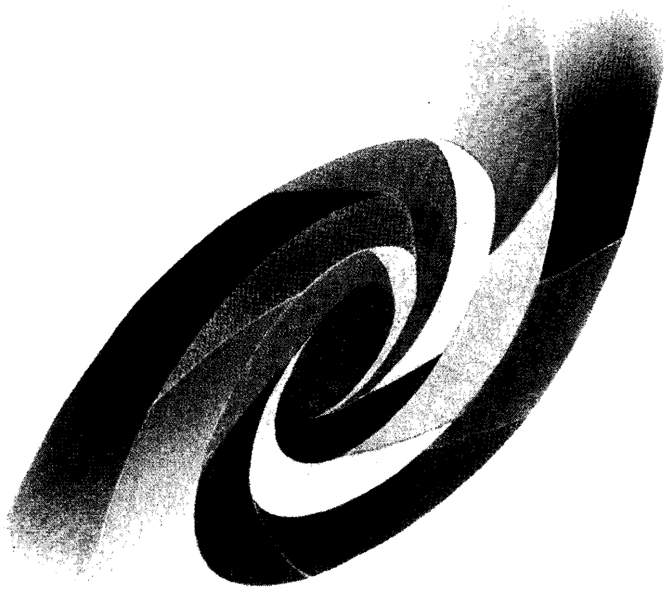

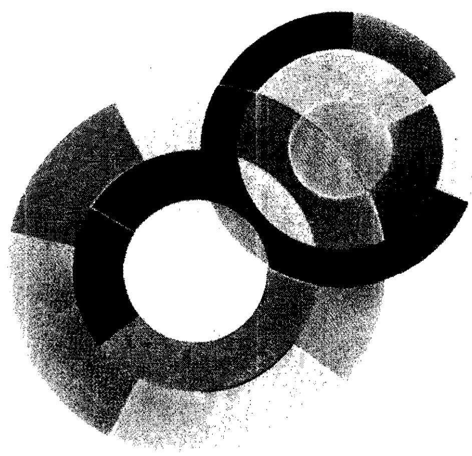

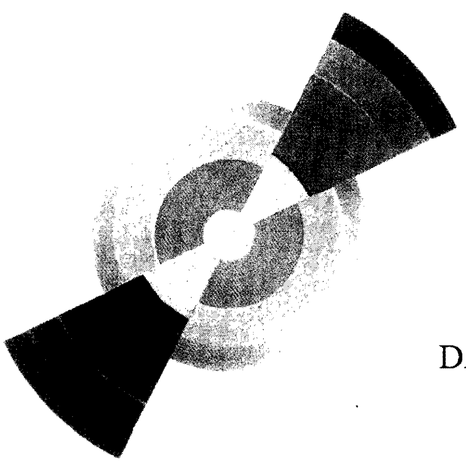

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Fission Fragment Distributions and Delayed Neutron Yields from Photon Induced-Fission

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Abstract. Fission fragment distributions and delayed neutron yields for ^{235}U and ^{238}U are provided by a complete modelization of the photofission process below 25 MeV. The absorption cross section parametrization and the fission fragment distributions are given and compared to experimental data. The delayed neutron yields and the half-lives in terms of six groups are presented and compared to data obtained with a bremsstrahlung spectrum of 15 MeV.

INTRODUCTION

The renewed interest in photonuclear processes is motivated by applications as radioactive ion beam (RIB) production, non-destructive characterization of waste barrels and detection of nuclear materials. These applications require a good knowledge of fission fragment distributions from photon-induced fission which are not well-known at the moment. These fission fragment distributions are also needed for the development of a new photonuclear activation data library for CINDER'90. A companion paper describes in detail this project [1].

Many observables are important to characterize the photofission process. The first one is, of course, the photon absorption cross section (σ_{abs}), the only input channel observable. For the output channel much more observables are available to characterize the reaction. The particle emission cross section ($\sigma(\gamma,xn)$, $\sigma(\gamma,xp)$) and the fission cross section tell us, quantitatively, how the nucleus deexcites. The fission yields give information about the charge and mass distributions of the fission products. Most of these fission products are radioactive, thus during the decay process the delayed neutrons, delayed photons and the activation products are the last observables of the photofission reaction. All these observables depend on the incident γ-energy and on the target nucleus.

At Los Alamos (LANL) the CINDER'90 [2] activation code was developed to obtain the activation products and associated delayed neutrons, created by neutron-induced fissions. For different applications, the same code will be extended for photon-induced reactions, including photofission. However, the data concerning relevant observables are scarce and the evaluations difficult to make. Data provided by the IAEA database are not sufficient (about 160 nuclei are available and more than 600 nuclei are needed) and do not include the fission yields. The GNASH code [3] could complete the database, but initially it was dedicated to neutron reactions, and it would be very hard and time consuming work to use it for all nuclei in the case of photonuclear reactions. It is finally used for actinides only [1]. Another code, HMS-ALICE [4], is easier to use and is a good candidate to provide the required CINDER'90 inputs [1], even if, up to now, the fission yields are not available. For all the reasons mentioned above, we decided to test the code ABLA [5] from GSI which is known to give good results for high energy fission-spallation process.

MODELIZATION AND COMPARISONS WITH DATA

Our modelization proceeds in two parts: the γ absorption and the deexcitation of the nucleus. The γ excitation of the nucleus is based on the giant dipole resonance principally, but also on the giant quadrupole resonances. The absorption cross section is the sum of these components, each of them determined from empirical systematics [6]. The nucleus deexcitation is performed with the ABLA code based on a statistical model, where fission is in competition with particle emission. In other words, the complete code provides neutron (proton) emission, fission cross sections and also fission yields. Multi-chance fissions are taken into account as well.

To check the validity of the GSI codes we compare our theoretical results to available data. These data are the cross sections (absorption, particle evaporation and fission), the fission yields, and the delayed neutrons. We will focus on Uranium, since they are the nuclei experimentally investigated most of the time. On the other hand, Plutonium and other actinides are being studied as well.

Cross Sections

In figure 1 we compare our predictions with data for the absorption cross section in the case of ^{238}U. The curves *New evaluation* and *GSI* are both based on the giant dipole resonance but the former uses the Peter Möller systematics [7]. This improvement has now been incorporated in the GSI code.

The results, detailed in [8], have good shapes and the right absolute values (here for ^{238}U, but also for ^{235}U and ^{239}Pu, not shown). The same results can be obtained with another parameterization, RIPL2 [1]. The main drawback is the fission/evaporation competition (not presented here). This competition versus the γ-energy could be improved, even if the results are not so bad [8]. Nevertheless this behaviour does not affect the observables discussed hereafter: fission yields and delayed neutrons.

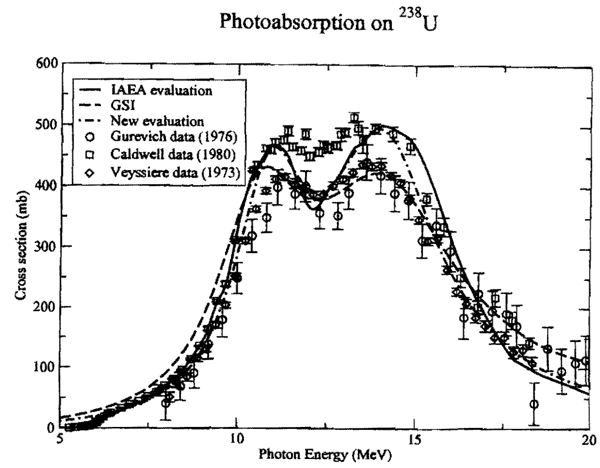

FIGURE 1. PHOTON ABSORPTION CROSS SECTION FOR ^{238}U.

Fission Yields

Figures 2 and 3 show the yields of fission fragments for Uranium 235 and 238. Our predictions are compared to 15 and 25 MeV bremsstrahlung data [9-11] (squares). The widths of the peaks are well reproduced by the calculations (line) while the heights are slightly different. We also observe a better agreement for ^{235}U at 15 MeV than 25 MeV while it is the opposite for ^{238}U. For the next step (delayed neutron yield calculations), it is important to reproduce here the relative yields of the precursors which are more abundant at the peaks of the mass distributions

Delayed neutrons

The isotopic distributions of fission fragments produced by ABLA are injected in CINDER'90 in order to obtain the cumulative yields. Those are classified in six groups (according to their half-lives) and the delayed neutron yields for 100 fissions and the weighted half-lives are calculated.

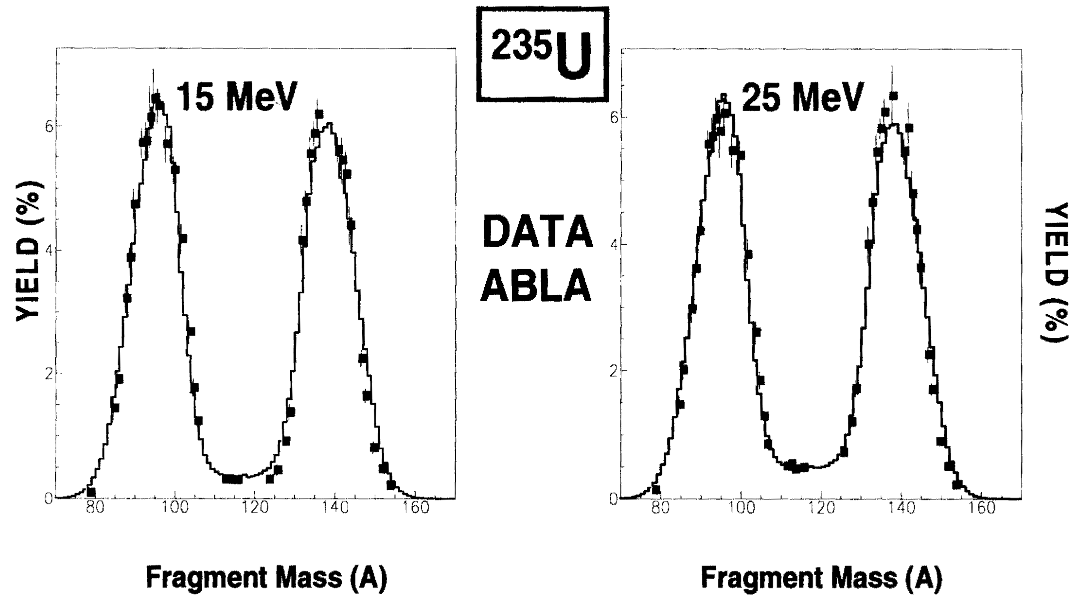

FIGURE 2. FISSION FRAGMENT MASS DISTRIBUTIONS FOR ^{235}U AT 15 (LEFT) AND 25 (RIGHT) MEV. COMPARISIONS BETWEEN DATA (POINTS) AND CALCULATIONS (LINES).

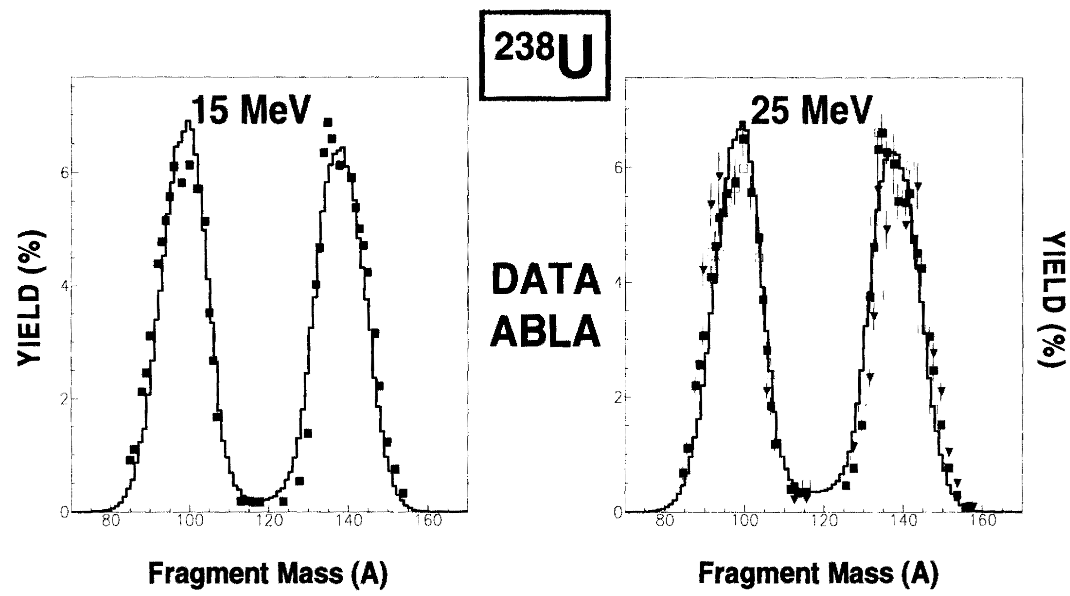

FIGURE 2. FISSION FRAGMENT MASS DISTRIBUTIONS FOR ^{238}U AT 15 (LEFT) AND 25 (RIGHT) MEV. COMPARISIONS BETWEEN DATA (POINTS) AND CALCULATIONS (LINES).

Calculation results (in red) for ^{235}U and ^{238}U at 15 MeV are presented in Table 1 and compared to data [12]. As expected, results for the $T_{1/2}$ are closer to data than the yields are. The calculated total number of delayed neutrons is in good agreement with data, especially for ^{238}U. For both isotopes, the groups 2 and 4 are overestimated while the 5 and 6 are underestimated. It is clear that the relative contributions of the different isotopes inside each group have to be investigated in detail.

	^{235}U (E_e=15 MeV)				^{238}U (E_e=15 MeV)			
GROUP	Yield		$T_{1/2}$ (s)		Yield		$T_{1/2}$ (s)	
	Data	Calc.	Data	Calc.	Data	Calc.	Data	Calc.
1	0.052±0.010	0.061	54.7±2.5	55.60	0.061±0.010	0.030	56.2±0.8	55.60
2	0.193±0.040	0.424	20.3±1.0	19.10	0.489±0.070	0.638	21.3±0.3	20.33
3	0.146±0.030	0.243	5.45±0.60	5.21	0.545±0.070	0.470	5.50±0.20	5.46
4	0.354±0.070	0.381	2.01±0.25	2.13	0.970±0.150	1.332	2.15±0.10	1.92
5	0.134±0.030	0.074	0.50±0.10	0.47	0.552±0.080	0.413	0.70±0.06	0.47
6	0.083±0.25	0.01	0.19±0.04	0.17	0.502±0.020	0.075	0.19±0.02	0.17
TOTAL	0.962	1.193			3.119±0.4	2.958		

TABLE 1. TOTAL AND PARTIAL DELAYED NEUTRON YIELDS AND HALF-LIVES FOR PHOTOFISSION OF ^{235}U AND ^{238}U.

CONCLUSIONS

All the steps of the photofission have been modelled in order to obtain the fission fragment distributions and the delayed neutron yields. First, the photon-induced absorption cross sections are quite well reproduced by the GSI code based on the giant dipole and quadrupole resonances. The fission yields obtained with ABLA are rather good. This is the strong point of this code for low energies. The delayed neutron yields, obtained after calculations with CINDER'90, are quite well reproduced. Then, we would like to stress that the GSI model for photofission seems to be very encouraging even if the evaporation/fission competition has to be improved. We could also expect a better agreement concerning delayed neutrons after the improvement of the fission fragment distributions.

Finally we would like to mention that an experimental program is also undertaken in order to enlarge the available data on photofission delayed neutron yields and time spectra to validate the model predictions.

ACKNOWLEDGEMENTS

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REFERENCES

1. M.-L. Giacri-Mauborgne *et al,* (this conference)
2. W. B. Wilson *et al,* CINDER'90 – GLOBAL'95 International Conference, Versailles, France, Sept. 11-14; W.B. Wilson, T.R. England and K.A. Van Riper, "Status of CINDER'90 Codes and Data", Los Alamos National Laboratory, preprint LA-UR-99-361 (1999)
3. P. Young *et al,* GNASH, *Nuclear Reaction Data and Nuclear Reactor – Physics Design and Safety, Vol.1* – International Center for Physics – Trieste, Italy, (1996) 227
4. M. Blann *et al, Phys. Rev.* C **54** (1996) 1341
5. A. R. Junghans *et al, Nucl. Phys.* A **629** (1998) 635; J. Benlliure *et al, Nucl. Phys.* A **628** (1997) 458
6. K.H. Schmidt *et al, Nucl. Phys.* A **665** (2000) 221
7. P. Möller, *Atomic Data and Nuclear Data Tables*, **59** (1995) 185
8. J.-C. David *et al,* XVI International Workshop of Physics of Nuclear Fission, Obninsk, Russia, Oct. 2003, *http://nucleus.ru/fission2003/schedule.htm*
9. E. Jacobs *et al, Phys. Rev.* C,**21** (1980) 237
10. H. Thierens *et al, Phys. Rev.* C, **14** (1976) 1058
11. E. Jacobs *et al, Phys. Rev.* C **19** (1979) 422
12. O.P. Nikotin *et al, Atom. Energ.*, Vol 20, No. 3 (1966) 268