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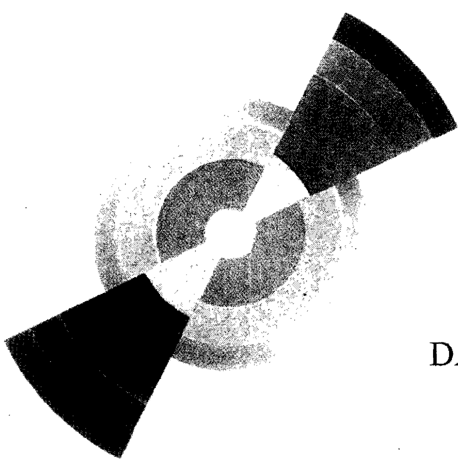

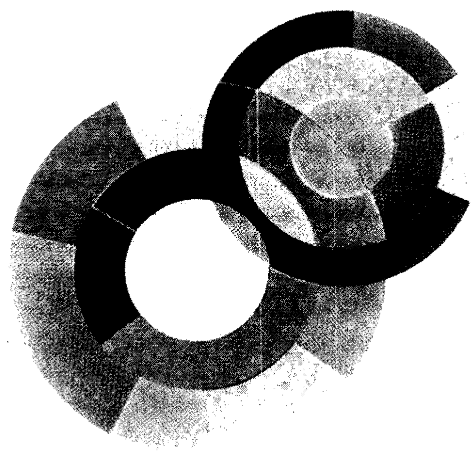

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Status of the Photonuclear Data Library for CINDER'90

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Abstract. In this article we present the development of a new photonuclear activation library for CINDER'90 evolution code (LANL). The IAEA evaluations for 164 isotopes are explicitly included and more than 600 isotopes are added using the HMS-ALICE predictions. GNASH evaluations are used in the case of actinides.

INTRODUCTION

Recently a renewed interest in photonuclear process has appeared. It is motivated by a number of different applications where progress in high-intensity electron accelerators was awaited [1]. Major problems in modeling photonuclear reactions are the lack of photonuclear data on corresponding cross sections despite the huge effort of the IAEA [2], where data are available for 164 isotopes. In addition no material evolution code including photonuclear reactions is available.

For this reason, in close collaboration with the LANL, we have been working on the development of a new photonuclear activation data library to be included into the material evolution code CINDER'90 [3]. The reaction codes HMS-ALICE [4] and GNASH [5] have been used to calculate photonuclear reactions for more than 600 isotopes.

STATUS OF THE DATA LIBRARY FOR PHOTONS

To include photo-reaction capability for CINDER'90, we keep similar structure as for neutrons. For each isotope the library contains:

- The life time of the isotope, the natural decay and the branching ratio for radioactive isotopes
- The energy of the decay particles
- The number of possible reaction products and for each reaction:
  - The reaction product
  - The corresponding group cross section
- The fission fragment distribution if fission can occur

The photon flux is described by a 25 group flux from 0 to 25 MeV in steps of 1 MeV. Contrary to the 63 neutron groups, we choose a constant step because photonuclear cross sections are rather smooth.

IAEA evaluations

In 1996, the IAEA initiated a project on Compilation and Evaluation of Photonuclear Data, as it recognized a lack of concentrated effort on this subject. The objectives were to create an international library of evaluated photonuclear cross sections for transport calculations and to prepare a handbook on photonuclear data-evaluations. The description of this library and its validation can be found in [6]. We include all 164 isotopes in our photactivation library as a starting point.

HMS-ALICE calculations

HMS-ALICE [4] is a multi-particle reaction code to calculate reaction cross sections, for nuclei heavier than ^{9}Be in the energy range from a few keV to the pion mass threshold. The major advantage of this program is that the results can be obtained very quickly for a big number of nuclei. Below we compare the HMS-ALICE predictions for light and heavy nuclei with the IAEA evaluations.

Carbon and aluminum are the most frequently used materials among the light nuclei. Figs. 1 and 2 present our results for ^{12}C and ^{27}Al. In brief, for ^{12}C, (γ,1n) and

$(\gamma,1p)$ cross sections are largely underestimated. Contrary, we found that other reaction channels as (γ,α) are overestimated in the same simulation. For ^{27}Al, the situation is the opposite: the neutron emission is overestimated, while proton production is in a good agreement with the data. The obtained differences are difficult to explain at the moment. However it is clear that HMS-ALICE needs some improvements to predict the photonuclear reactions for light nuclei.

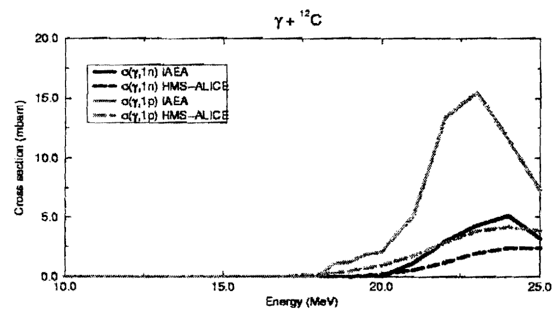

FIGURE 1. Particle production for ^{12}C obtained with HMS-ALICE (dashed lines) in comparison with the IAEA evaluations (solid lines).

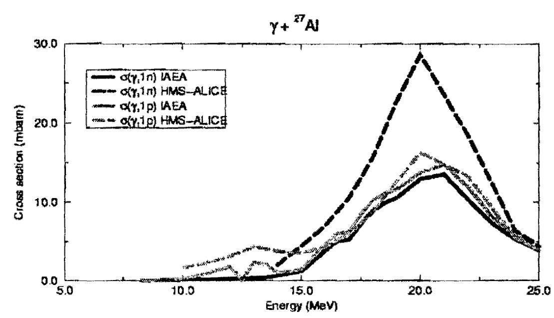

FIGURE 2. Same as Fig. 1 but for ^{27}Al.

In the case of heavy nuclei, we study ^{208}Pb because it is often used in nuclear technology and existing data are of good quality. Our results are presented in Fig. 3. ^{208}Pb cross sections have a very regular shape and are very close to the model predictions in the entire energy range considered. Contrary, in the case of ^{181}Ta, Fig. 4 shows some inconsistency between IAEA evaluations and HMS-ALICE results for the $(\gamma,1n)$.

We found that this discrepancy is directly related to the model for the total absorption cross section. Indeed, the IAEA evaluation gives an absorption cross section with two peaks, whereas the model in HMS-ALICE for absorption cross section is based on a single Lorentzian with a single peak. It is known that, in the case of deformed nuclei, the total absorption cross section should be modeled by the sum of two Lorentzians [7]. As particle-emission cross sections are based on total-absorption cross section, they can not be

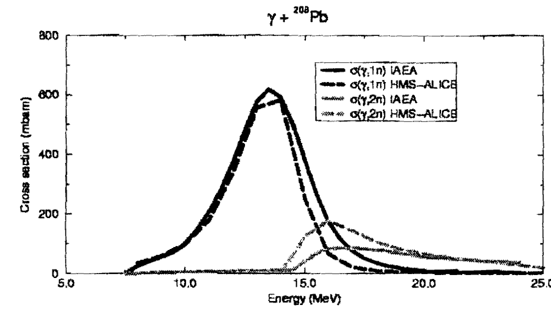

FIGURE 3. Same as Fig. 1 but for ^{208}Pb.

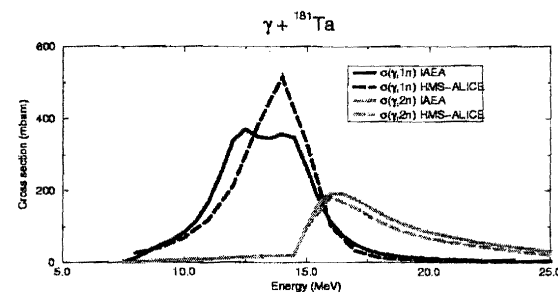

FIGURE 4. Same as Fig. 1 but for ^{181}Ta.

reproduced properly for deformed nuclei with a single lorentzian.

This is particularly true for the actinides as shown in Fig. 5. Here, we clearly confirm that the HMS-ALICE predictions, for the total photo-absorption cross sections, are based on a single Lorentzian. They have only one peak, whereas all IAEA evaluations (based on experimental data) have two peaks.

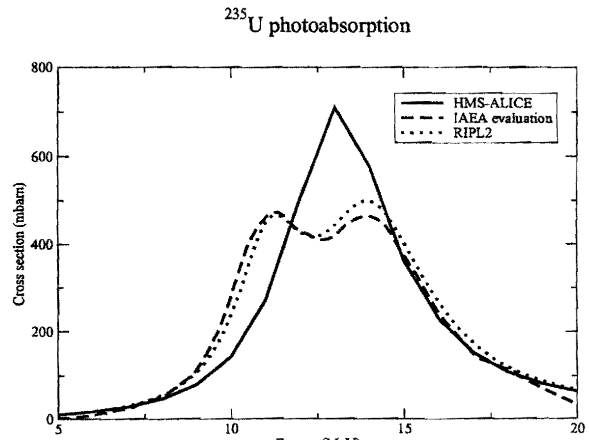

FIGURE 5. Comparison of the HMS-ALICE model for photo-absorption with the IAEA evaluations (in dash line) and the calculation using RIPL 2 parameters (in dotted line).

Calculation of the total absorption cross section can be parametrized as a sum of two Lorentzians, for which we choose the parameters from the RIPL 2 library [8]. Our results presented in Fig. 5 are in good agreement with the IAEA evaluation. This photo-absorption cross section will be soon implemented in HMS-ALICE. After that, the data library will be completed for all actinides. At the moment, some calculations for the more interesting actinides have been done with GNASH.

GNASH calculations

The use of GNASH to evaluate photonuclear cross sections was recommended by Oblozinsky in [6]. More detailed description of this type of calculations can be found in [9].

In Figs. 6 and 7 we present GNASH evaluations for ^{235}U and ^{239}Pu. The total photo-absorption cross section from IAEA was taken as input for ^{235}U and the Berman fit [10] for ^{239}Pu. For partial neutron-production channels, including photo-fission, the experimental data are well reproduced. These results validate the computational procedure employed with GNASH.

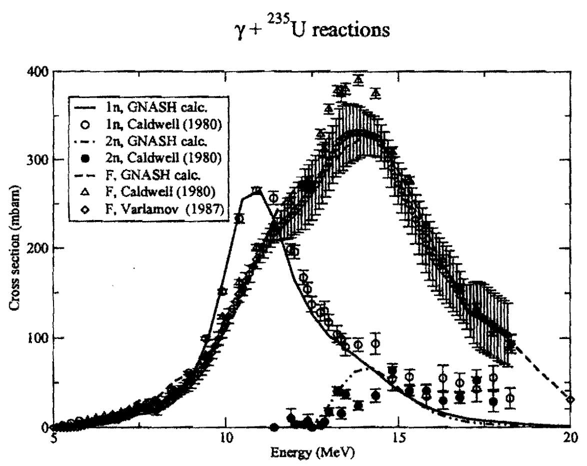

FIGURE 6. Comparison between GNASH evaluations and experimental data for (γ,n), (γ,fiss) and (γ,2n) in the case of ^{235}U.

We performed similar evaluations for ^{237}Np, for which no IAEA evaluations were made. Two independent monoenergetic measurements of total absorption cross section of ^{237}Np do exist [10], however the data are inconsistent as shown in Fig. 8. The black curve in Fig. 8 is the total absorption cross section we used in the GNASH input. This photo-absorption cross section is calculated with the theoretical parameters from the RIPL-2 library [8].

As shown in Fig. 9, we have a rather good agreement between GNASH evalution and the experimental data for photo-neutron production. In Fig. 10, cross sections

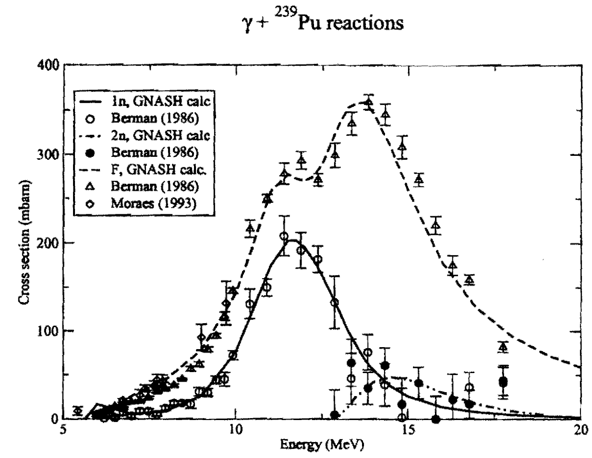

FIGURE 7. Same as Fig. 6 but for ^{239}Pu.

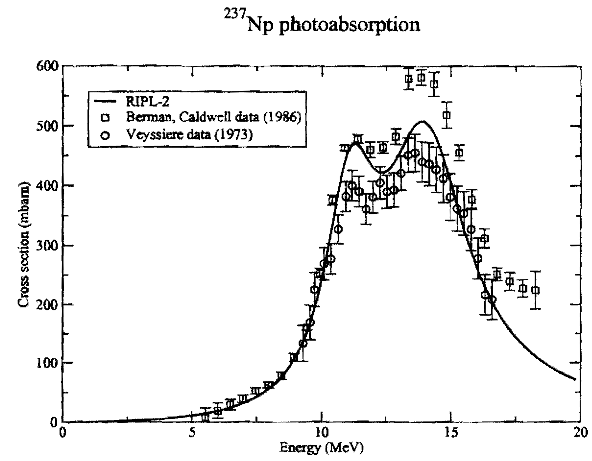

FIGURE 8. Data of ^{237}Np photo-absorption cross section in comparison with GNASH.

are measured with monoenergetic flux (triangles) and Bremsstrahlung flux (circle). Our evaluation for photo-fission cross section of ^{237}Np is in good agreement with data from Soldatov [11] and remains between the two experimental data sets from Berman and Veyssière [10], what is again coherent with our approach for photo-absorption.

In his article [12], Kase measures transmutation yield of ^{237}Np and compares his results with a calculated transmutation yield using photo-fission cross sections from Caldwell and Veyssière [10]. His experimental results are between two model calculations based on the two sets of photo-fission cross sections. Our evaluation on photo-fission cross section is coherent with the result of Kase. These new cross sections are included in the photonuclear activation data library for CINDER'90.

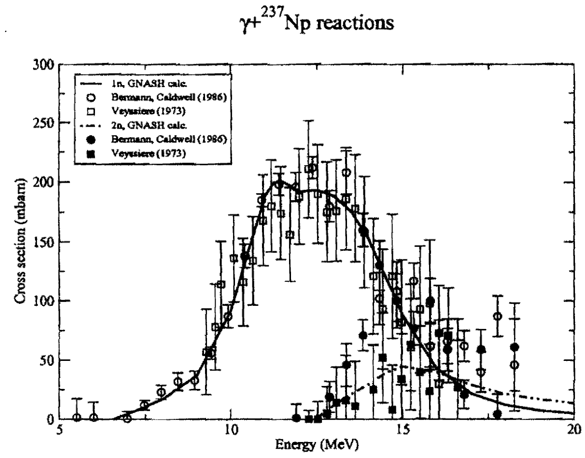

FIGURE 9. ^{237}Np photo-neutron production cross sections from different experiment and predictions by GNASH.

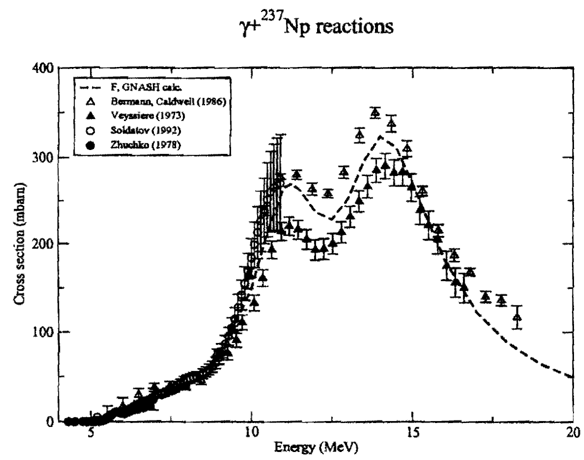

FIGURE 10. Same as Fig. 9 but for photo-fission.

CONCLUSION

In this work we reported on the present status of the photonuclear activation data library for CINDER'90, which by now includes more than 600 isotopes. IAEA evaluation, HMS-ALICE and GNASH predictions were used to construct the library.

Photonuclear cross sections for a number of actinides are still needed, except for ^{232}Th, ^{233,234,235,236,238}U, ^{237}Np, ^{238,239,241}Pu. Photo-fission fragment distributions are not included yet in this library, but work is in progress, (see J.-C. David *et al.* of this conference). An extension of the present library to 150 MeV is planned in the future.

Finally we note that, CINDER'90 was already successfully used to calculate material activation in neutron and photon fluxes in the case of the decommisionning of the LURE electron accelerator in Orsay (France).

ACKNOWLEDGMENTS

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