Model predictions of the fission-product yields for $^{238}\text{U}$
Part II: First-chance fission

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Abstract: The results of model calculations on nuclide yields produced by first-chance fission of excited $^{238}\text{U}$ nuclei are presented. The calculations show the washing out of structural effects (even-odd structure and fission channels), the broadening of the mass distribution and the reduction of the neutron excess with increasing excitation energy. The calculations are relevant for the design of future secondary-beam facilities.

The present work is the second of a series of reports on predicted fission-product yields for $^{238}\text{U}$. In the first part, we describe the details of the semi-empirical fission model used for the calculations. The model is a more advanced version of the statistical saddle-scission model described in ref. [1]. In the second part, we present the predictions for the nuclide production by first-chance fission of $^{238}\text{U}$ at different excitation energies. In the third part, we calculate the complete nuclide production obtained from fission, when $^{238}\text{U}$ is excited to different excitation energies. This calculation includes multi-chance fission. The forth part presents predictions on nuclide production by fission reactions, using $^{238}\text{U}$ as a target or projectile nucleus, under a few selected experimental conditions. In these cases, many fissioning nuclei in a large excitation-energy range may contribute to the fission yields. Finally, in the fifth part we compare the model predictions with available data.

The nucleus $^{238}\text{U}$ is of prime importance for technical applications due to its high abundance. Further, it is the most neutron-rich fissile nucleus found in nature and, therefore, it seems to be well suited for the production of neutron-rich nuclides by fission in secondary-beam facilities.

Data on the production of nuclides, fully identified in Z and A, by nuclear fission are scares. In most experiments mass distributions are obtained [2], in a recent experiment with secondary beams a large number of element distributions has been determined [3]. Only a few experiments performed at ILL, Grenoble, on thermal-neutron-induced fission have given a rather comprehensive overview on the nuclide production in the light fission-fragment group for a few systems [4]. Since $^{235}\text{U}$ does not fission after capture of thermal neutrons, no data of that kind are available for this nucleus. Data of excellent quality on nuclide production from higher excitation energies only exist for fission induced by relativistic $^{238}\text{U}$ projectiles in various targets, e.g. [5,6,7]. The experimental conditions of these experiments, however, are rather complex, since the fission fragments originate from many systems, fissioning at a wide range of excitation energy. For the understanding of the basic features which govern the nu-
clide production by fission, it is very helpful to know the nuclide yields emerging from one fissioning nucleus at a well-defined excitation energy. This is the first-chance fission, occurring before any particle decay of the excited nucleus. Please note that these yields are usually not observable, except at low energies, because they cannot be isolated from the fission emerging from other nuclei formed after evaporation of predominantly neutrons.

The nuclide production by first-chance fission, which is the subject of the present work, nicely illustrates the variations of the nuclide yields with excitation energy of the fissioning nucleus. The following three effects are observed when the excitation energy increases:

- The influence of pairing correlations and shell effects decreases.
- The fluctuations in mass and in neutron excess increase.
- The fission fragments become more neutron deficient on the average due to neutron evaporation.

The figures give an overview on calculated nuclide production in first-chance fission of $^{238}$U on the chart of the nuclides as well as mass and nuclear-charge distributions. Predictions are given for a series of excitation energies. In the first two cases (1 and 5 MeV), only first-chance fission occurs.
Fig. 1: Nuclide yields from the fission of $^{238}\text{U}$ at an excitation energy of 1 MeV above the fission barrier. The yields are normalised to 200%. Primordial nuclei are marked by open squares. The limits of the known nuclides are indicated by full lines.

Fig. 2: Mass distribution and nuclear-charge distribution from the fission of $^{238}\text{U}$ at an excitation energy of 1 MeV above the fission barrier. The yields are normalised to 200%.
Fig. 3: Nuclide yields from the fission of $^{238}$U at an excitation energy of 5 MeV above the fission barrier. The yields are normalised to 200%.

Fig. 4: Mass distribution and nuclear-charge distribution from the fission of $^{238}$U at an excitation energy of 5 MeV above the fission barrier. The yields are normalised to 200%.
Fig. 5: Nuclide yields from first-chance fission of $^{238}$U at an excitation energy of 10 MeV above the fission barrier. The yields are normalised to 200%.

Fig. 6: Mass distribution and nuclear-charge distribution from first-chance fission of $^{238}$U at an excitation energy of 10 MeV above the fission barrier. The yields are normalised to 200%.
Fig. 7: Nuclide yields from first-chance fission of $^{238}$U at an excitation energy of 20 MeV above the fission barrier. The yields are normalised to 200%.

Fig. 8: Mass distribution and nuclear-charge distribution from first-chance fission of $^{238}$U at an excitation energy of 20 MeV above the fission barrier. The yields are normalised to 200%.
Fig. 9: Nuclide yields from first-chance fission of $^{238}\text{U}$ at an excitation energy of 50 MeV above the fission barrier. The yields are normalised to 200%.

Fig. 10: Mass distribution and nuclear-charge distribution from first-chance fission of $^{238}\text{U}$ at an excitation energy of 50 MeV above the fission barrier. The yields are normalised to 200%.
Fig. 11: Nuclide yields from first-chance fission of $^{238}$U at an excitation energy of 100 MeV above the fission barrier. The yields are normalised to 200%.

Fig. 12: Mass distribution and nuclear-charge distribution from first-chance fission of $^{238}$U at an excitation energy of 100 MeV above the fission barrier. The yields are normalised to 200%.