# Correcting a few anomalously large Cumulative Fission Yield uncertainties in ENDF/B-VIII.0

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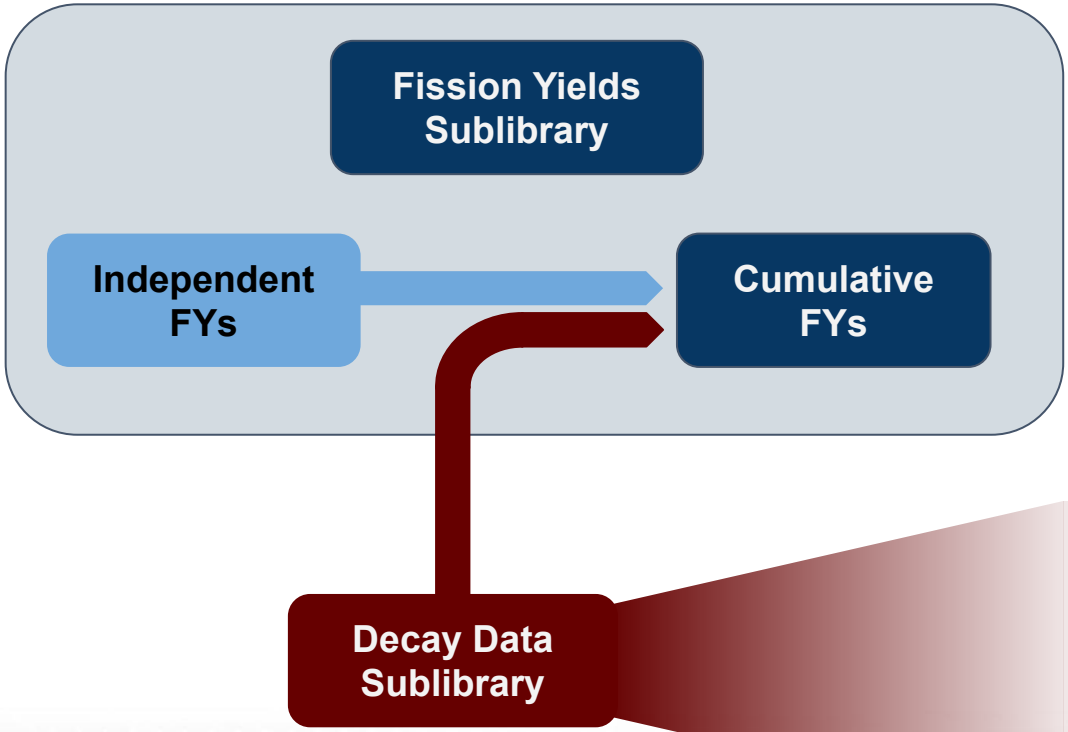
# Background

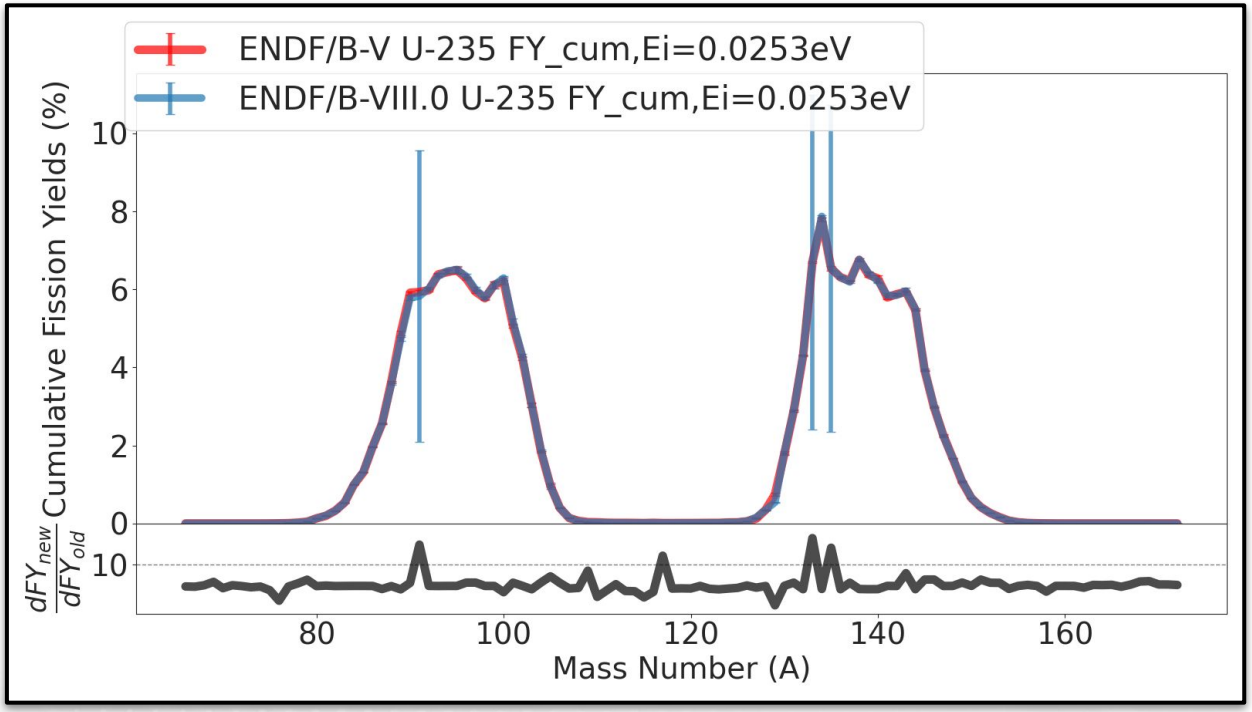



With ENDF/B-VI.8, a new **decay data sublibrary** was introduced

To ensure consistency, the FY sublibrary was updated to include the changes in the decay

The introduction of new isomers in the decay data sublibrary required **Isomeric Yield Ratios to be assigned**, and the **Cumulative Yields** to be **recalculated** based on the new decay schemes

# Background

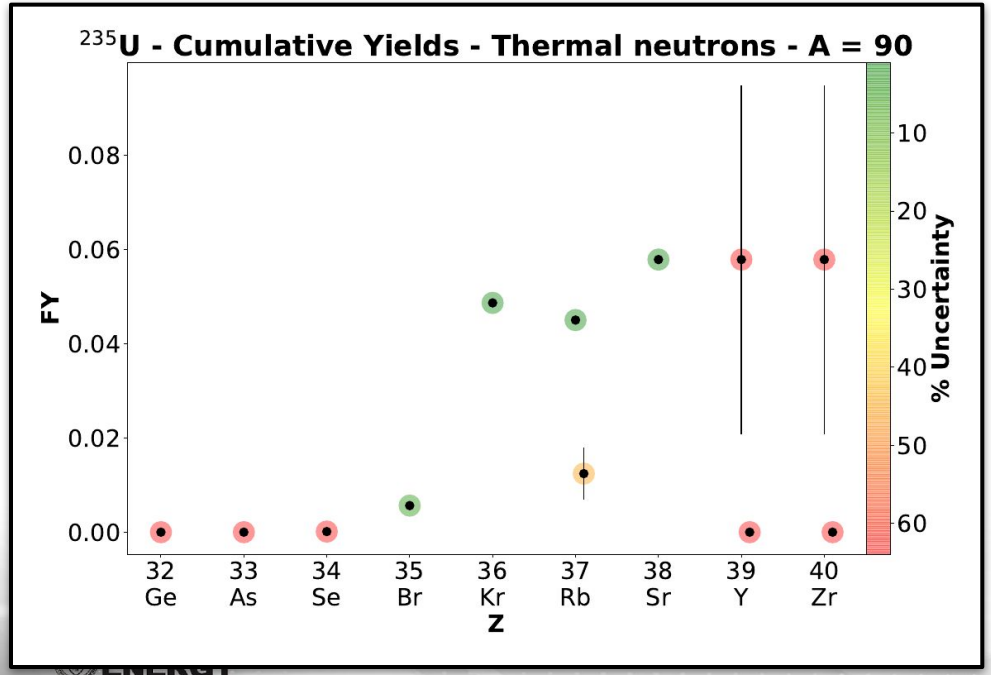


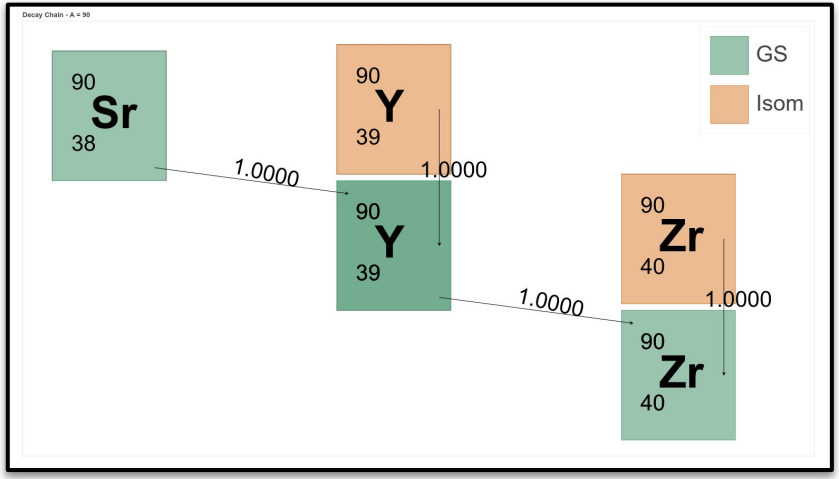

The update caused the uncertainties for some end-of-chain CYs to increase dramatically
(up to 180 times the value in the older version of the library)

End-of-chain (**nearly stable**) CYs are generally **experimentally well determined** and their uncertainty is comparable or better than the shorter-lived nuclides in the chain

# Correction of CYs

We identified 8 mass chains where the uncertainty was anomalously large, and re-calculated it for 15 fission products

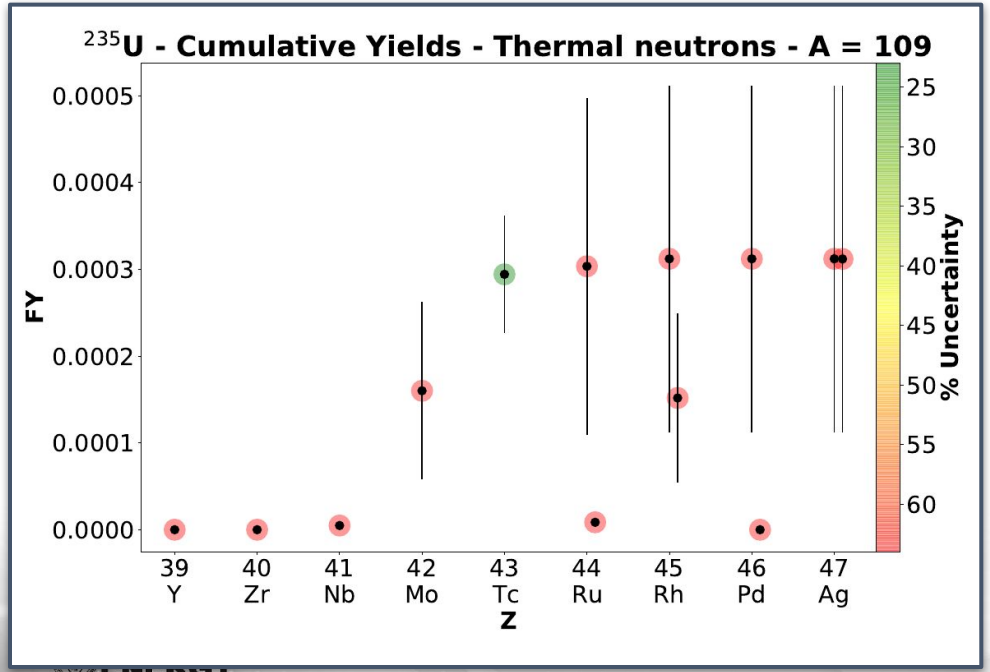


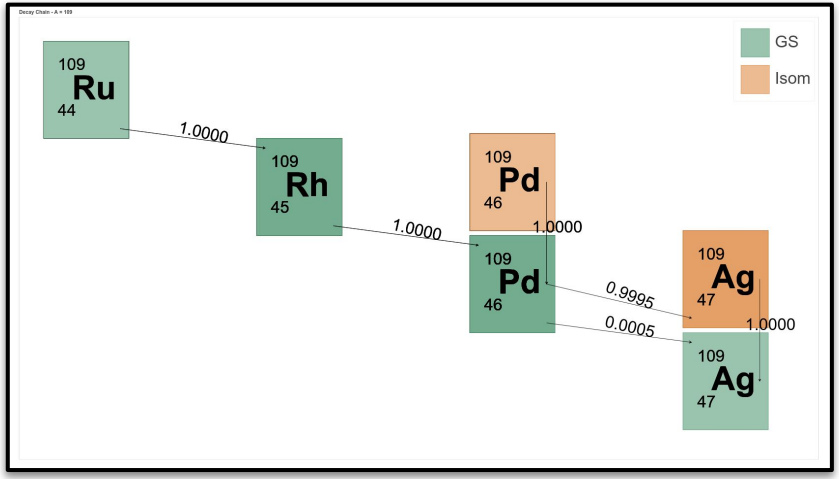




The dCY in ENDF/B-VIII.0 reflects the uncertainty on the IYR (50%), but the dCYs of $^{90}Y_{GS}$ and $^{90}Zr_{GS}$ do not depend on their isomeric yield ratios (the IS decay by IT to the GS), and the largest contribution is from decay of precursors

# Correction of CYs and IYs

In A = 109, we also removed isomers for $^{109}$Ru and $^{109}$Rh, that were added in ENDF/B-VI.0, but not confirmed in measurements since




The IY of $^{109m}$Ru and $^{109m}$Rh was reassigned to the GS, and the uncertainties of the nuclides along the decay chain were re-calculated accordingly.

# Validation

The total energy released in fission, including beta-delayed terms, is given by

$$E = M_t - (\overline{\nu}_t - 1)M_n - \sum CFY_k M_k \qquad (21)$$

where sum is performed over the most neutron rich stable nuclides for each A value.
$M_t$: Target mass excess,
$\overline{\nu}_t$: Total nu-bar,
$M_n$: Neutron mass excess,
$CFY_k$: Cumulative fission yield (chain yield),
$M_k$: mass excess.

Of particular interest is the term given by

$$Y = \sum CFY_k M_k \qquad (22)$$

whose uncertainty will be calculated using the scheme developed by Kopeikin.

V. Kopeikin, L. Mikaelyan, and V. Sinev, Phys. At. Nucl. **67**, 1892 (2004).

| Library | $^{235}$U | $^{238}$U | $^{239}$Pu | $^{241}$Pu |
|---|---|---|---|---|
| JEFF-3.3 | -173.155 ± 0.076 | -173.047 ± 0.298 | -173.585 ± 0.115 | -173.523 ± 0.240 |
| ENDF/B-VIII.0 | -173.125 ± 0.943 | -173.225 ± 0.585 | -173 .676 ± 0.417 | -173.552 ± 0.410 |
| ENDF/B-VIII.0 Mod. | -173.137 ± 0.039 | -173.218 ± 0.081 | -173.694 ± 0.073 | -173.547 ± 0.092 |
| Kopeikin (England & Rider) | -173.43 ± 0.05 | -173.39 ± 0.10 | -173.87 ± 0.07 | -173.82 ± 0.10 |

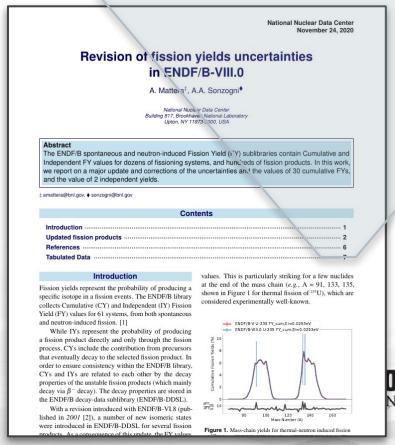
TABLE X. $Y$ and $\Delta Y$ values.

# Summary

- The FY uncertainty values for 18 Fission Products and all spontaneous fission (SFY) and neutron-induced (NFY) materials was corrected
- We pushed changes to the git repository of ENDF/B-VIII at the end of September 2020.
- The procedure and all the updated values have been documented in a BNL technical report
- Validation with energy released in fission shows consistent results

235-U Energy=2.53E-2

| Nuclide | Quantity | Current Value | Updated Value | Ratio (new/old) |
|---|---|---|---|---|
| $^{90}$Y GS | Δ CFY | 3.7004E-2 | 5.7819E-4 | 6.4000E1 |
| $^{90}$Zr GS | Δ CFY | 3.7004E-2 | 5.7819E-4 | 6.4000E1 |
| $^{91}$Y GS | Δ CFY | 3.7298E-2 | 5.8275E-4 | 6.4003E1 |
| $^{91}$Y M | Δ CFY | 2.1633E-2 | 1.3275E-3 | 1.6296E1 |
| $^{93}$Y GS | Δ CFY | 4.0615E-2 | 7.9430E-4 | 5.1134E1 |
| $^{93}$Y M | Δ CFY | 1.4160E-2 | 1.3719E-3 | 1.0321E1 |
| $^{109}$Ru GS | IFY | 8.5644E-6 | 1.7129E-5 | 5.0000E-1 |
| $^{109}$Ru GS | Δ IFY | 5.4812E-6 | 1.0962E-5 | 5.0000E-1 |
| $^{109}$Ru GS | CFY | 3.0359E-4 | 3.1146E-4 | 9.7475E-1 |
| $^{109}$Ru GS | Δ CFY | 1.9430E-4 | 6.8578E-5 | 2.8333E0 |
| $^{109}$Rh GS | IFY | 2.0599E-8 | 4.1197E-8 | 5.0000E-1 |
| $^{109}$Rh GS | Δ IFY | 1.3183E-8 | 2.6366E-8 | 5.0000E-1 |
| $^{109}$Rh GS | CFY | 3.1220E-4 | 3.1150E-4 | 1.0022E0 |
| $^{109}$Rh GS | Δ CFY | 1.9981E-4 | 6.8578E-5 | 2.9136E0 |
| $^{109}$Pd GS | Δ CFY | 1.9981E-4 | 6.8578E-5 | 2.9136E0 |
| $^{109}$Ag GS | Δ CFY | 1.9981E-4 | 6.8578E-5 | 2.9137E0 |
| $^{109}$Ag M | Δ CFY | 1.9971E-4 | 6.8543E-5 | 2.9137E0 |
| $^{132}$I GS | Δ CFY | 2.7596E-2 | 6.0619E-4 | 4.5523E1 |
| $^{133}$I GS | Δ CFY | 4.2858E-2 | 1.5940E-3 | 2.6888E1 |
| $^{133}$Xe GS | Δ CFY | 4.2874E-2 | 1.5940E-3 | 2.6897E1 |
| $^{135}$Cs GS | Δ CFY | 4.1849E-2 | 7.5736E-4 | 5.5257E1 |
| $^{148}$Pr GS | Δ CFY | 1.0456E-2 | 1.2999E-3 | 1.3805E1 |



National Nuclear Data Center
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**Revision of fission yields uncertainties in ENDF/B-VIII.0**

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**Abstract**
The ENDF/B spontaneous and neutron-induced Fission Yield (FY) sublibraries contain Cumulative and Independent FY values for dozens of fissioning systems, and hundreds of fission products. In this work, we report on a major update and corrections of the uncertainties and the values of 30 cumulative FYs, and the value of 2 independent yields.

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Contents

Introduction ..... 1
Updated fission products ..... 2
References ..... 6
Tabulated Data ..... 7

## Introduction

Fission yields represent the probability of producing a specific isotope in a fission events. The ENDF/B library collects Cumulative (CY) and Independent (IY) Fission Yield (FY) values for 61 systems, from both spontaneous and neutron-induced fission. [1]

While IYs represent the probability of producing a fission product directly and only through the fission process, CYs include the contribution from precursors that eventually decay to the selected fission product. In order to ensure consistency within the ENDF/B library, CYs and IYs are related to each other by the decay properties of the unstable fission products (which mainly decay via $\beta^-$ decay). The decay properties are stored in the ENDF/B decay-data sublibrary (ENDF/B-DDSL).

With a revision introduced with ENDF/B-VI.8 (published in 2001 [2]), a number of new isomeric states were introduced in ENDF/B-DDSL for several fission products. A consistency of the whole IY values

values. This is particularly striking for a few nuclides at the end of the mass chain (e.g., A = 91, 133, 135, shown in Figure 1 for thermal fission of $^{235}$U), which are considered experimentally well-known.



Figure 1. Mass-chain yields for thermal-neutron induced fission

# BACKUP SLIDES

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where sum is performed over the most neutron rich stable nuclides for each A value.
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TABLE X. $Y$ and $\Delta Y$ values.

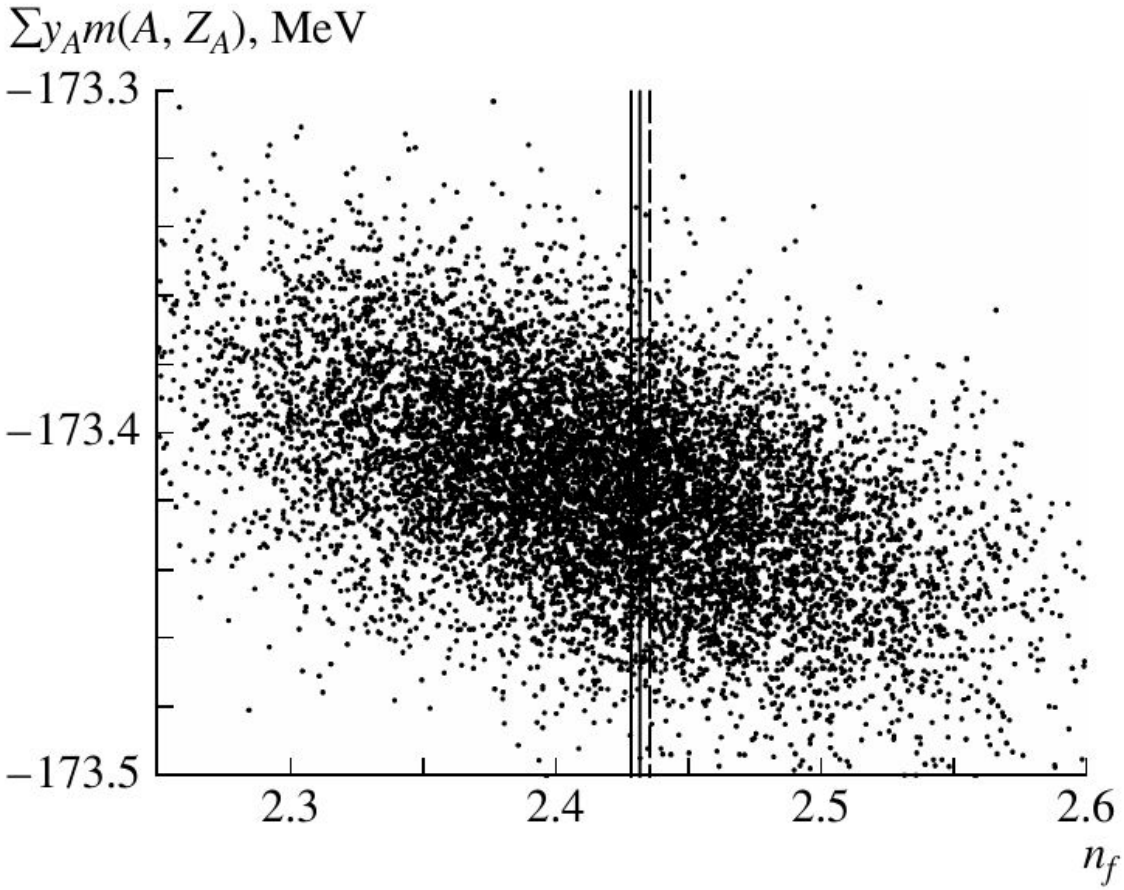


**Fig. 2.** Effect of the errors in the yield of products originating from $^{235}$U fission on the mass defect $\sum y_A m(A, Z_A)$ (see main body of the text). The vertical band corresponds to the experimental value of the number $n_f$ of neutrons.

V. Kopeikin, L. Mikaelyan, and V. Sinev, Phys. At. Nucl. **67**, 1892 (2004).