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**Memo CP-D/705**

**Date:** 22 May 2011  
**To:** Distribution  
**From:** N. Otsuka

**Subject: Fission quantity correlated with fragment kinetic energy**

Fission experiments often report correlation observables (e.g. correlation between neutron multiplicity and total kinetic energy). Unfortunately many of them cannot be perfectly expressed perfectly by the current EXFOR REACTION formalism (SF1-SF9). Our current solution is to express them by an existing quantity code with the general quantity modifier MSC. Compilers who wish to define these quantities more strictly would need a new formalism. The “Matrix formalism” proposed by Vladimir Pronyaev is such an example.

However, some complicated quantities should be more strictly defined by a REACTION code if they are frequently used by evaluators. Participants of the IAEA Coordinated Research Project (CRP) “Prompt Fission Neutron Spectra of Actinides” (coordinated by R. Capote) stress importance of some observables for prompt fission neutron of  $^{235}\text{U}(n_{\text{th}},f)$  ( $\langle v_p \rangle \sim 2.4$ ) measured by K. Nishio *et al.* [1], A.S. Vorobyev *et al.* [2] etc.

| <b>Quantity</b>   | <b>Notation<br/>(Example)</b> | <b>EXFOR<br/>22464<br/>[1]</b> | <b>EXFOR<br/>41516<br/>[2]</b> |
|---|-------------------------------|--------------------------------|--------------------------------|
| A: primary (pre-neutron emission) fragment mass   |                               |                                |                                |
| Average neutron energy emitted from a fragment A  | $\langle E(A) \rangle$        | Fig.4<br>(.003)                | (unpub.)                       |
| Average neutron multiplicity from a fragment A  | $\langle v(A) \rangle$        | Fig.5<br>(.004)                | Fig.5<br>(.012)                |
| Correlation between average total neutron multiplicity and total kinetic energy             | $\langle v(TKE) \rangle$      | Fig.7<br>(.006)                | Fig.5<br>(.014)                |
| Correlation between average neutron multiplicity from a fragment A and total kinetic energy | $\langle v(A, TKE) \rangle$   | Fig.8<br>(.007)                |                                |

These quantities must be correctly and strictly defined by the REACTION code.

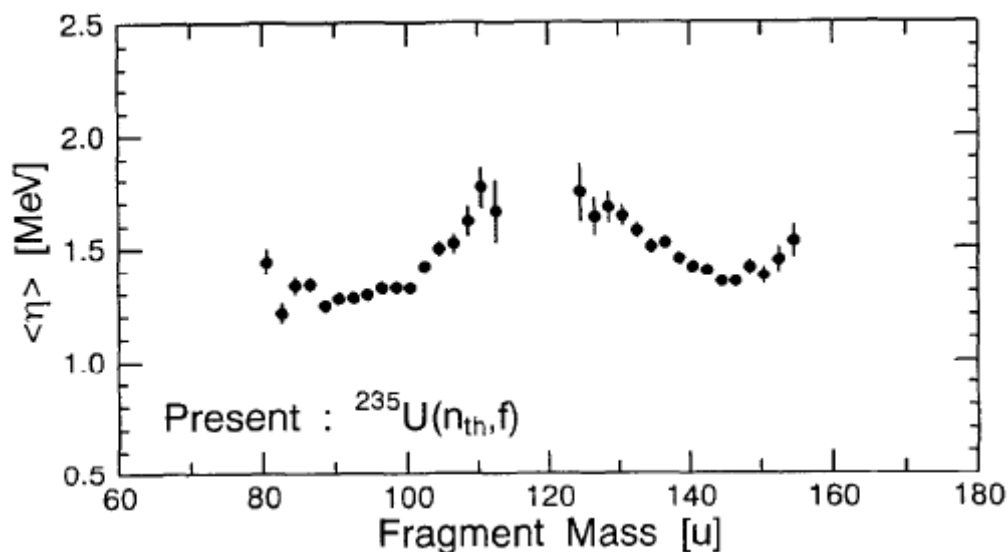
**Proposals:**

- 1) Give PRE in SF5 when the primary fragment mass is coded under MASS.
- 2) Use /TKE in SF6 when correlation with total kinetic energy is given.
- 3) Use a new heading code TKE for total kinetic energies.
- 3) Use LF+HF in SF5 when total neutron multiplicity is coded with MASS in SF4.

As a case study, discussion on 22464.003-004 and 006-007 are appended.

## Appendix: Coding of K. Nishio et al. [1] (EXFOR 22464)

### 1) Average neutron energy $\langle E(A) \rangle$ (Fig.4 of [1], EXFOR 22464.003)



#### Current coding

REACTION: (92-U-235(N,F)MASS,PR,KE,N,MXW)

Primary fragment mass under the heading MASS

#### Proposed coding

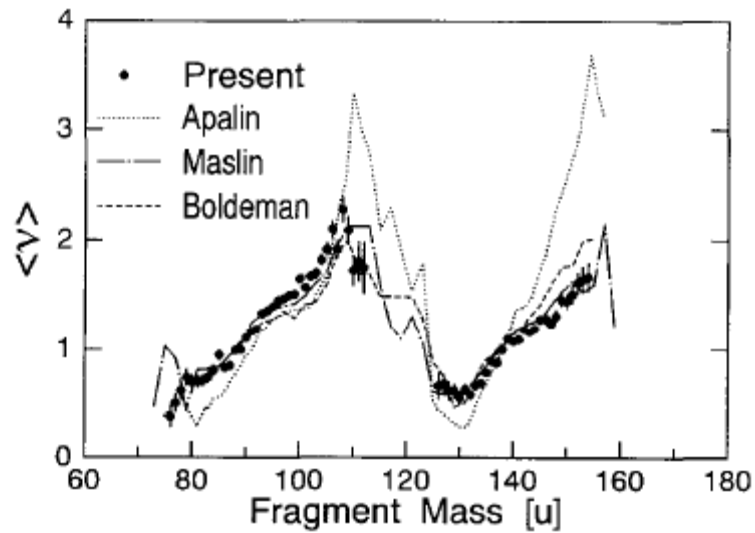
REACTION: (92-U-235(N,F)MASS,PRE/PR,KE,N,MXW)

#### Comments

**1.1** This quantity is for “prompt fission neutron” (PR) from “primary fragment mass” (PRE). Indication of PRE is essential to explain masses coded under MASS, because that indicates authors corrected measured secondary (post-neutron emission) mass for prompt emission neutrons. PR (prompt) is less important.

**1.2** We should keep the following rule: **When a quantity for prompt neutron is coded with MASS, the quantity is regarded for a prompt neutron emitted from the fragment mass given under MASS.** (Sometimes *total* prompt fission neutron multiplicity is coded as a function of the fragment mass. See the next page.).

2) Average neutron multiplicity  $\langle \nu(A) \rangle$  (Fig.5 of [1], EXFOR 22464.004)



**Current coding:**

REACTION: (92-U-235(N,F)MASS,PR,NU,FF,MXW)

Primary fragment mass under the heading MASS

**Proposal:**

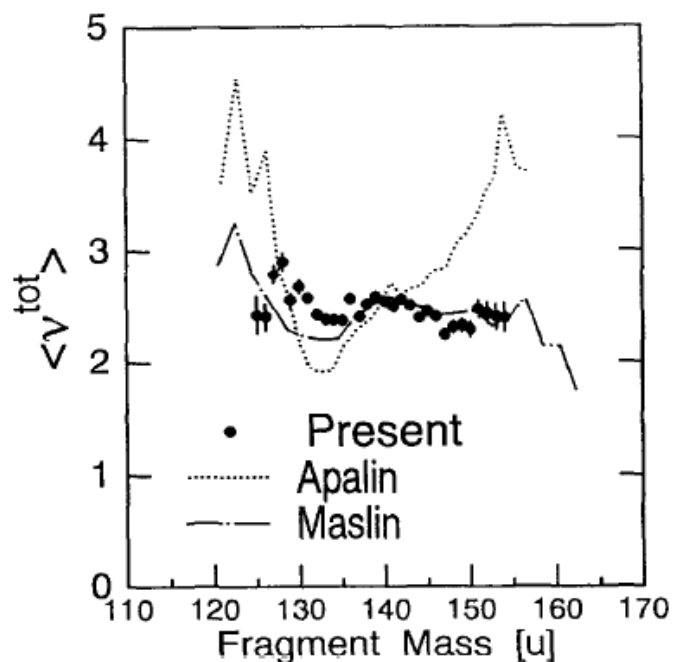
REACTION: (92-U-235(N,F)MASS,PRE/PR,NU,,MXW)

**Comment:**

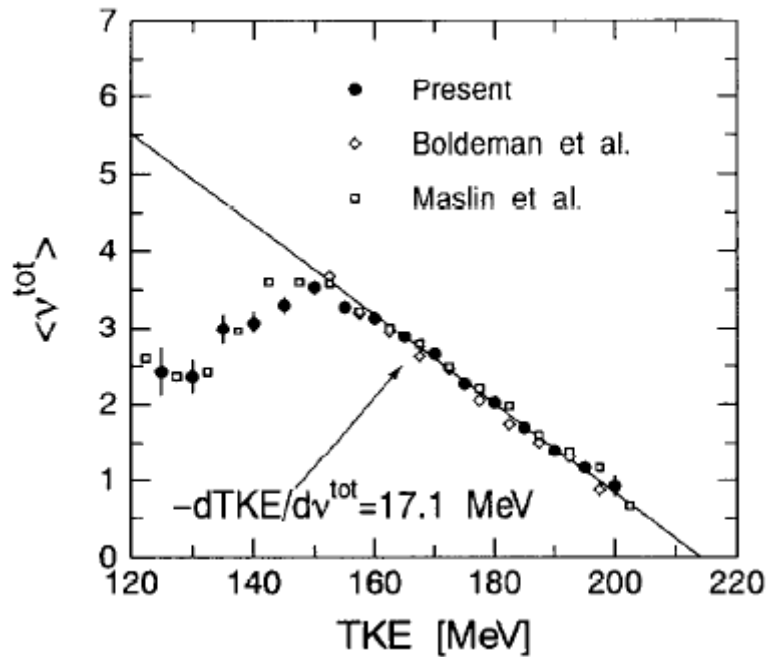
2.1. PRE must be in SF5 (See comment. 1.1).

2.2. This REACTION satisfies the rule mentioned in the comment 1.2.

2.3. How we compile the below figure (Fig.6 of [1])? Use of LF+HF in SF7 to express "total" neutron multiplicity? (92-U-235(N,F)MASS,PRE/PR,NU,LF+HF,MXW)



**3) Correlation between average total neutron multiplicity and total kinetic energy  $\langle \nu(TKE) \rangle$  (Fig. 7 of [1], EXFOR 22464.006)**



**Current coding:**

(92-U-235(N,F),PR,NU/DE,HF,FCT/MXW) +

(92-U-235(N,F),PR,NU/DE,LF,FCT/MXW)

Total kinetic energy under the heading E

**Proposed coding:**

(92-U-235(N,F),PR,NU/TKE,,MXW)

Total kinetic energy under the heading TKE

**Comments:**

3.1 The compiler applied FCT because this is a quantity “as a *function* of heavy fragment's mass” This is obviously a mistake and must be deleted.

3.2 Because MASS is not given in SF4, we do not need the REACTION sum.

c.f. We use (92-U-235(N,F),PR,NU) for *total* prompt neutron multiplicity).

3.3 This quantity is not differential with respect to the total kinetic energy, and DE is misleading. Note that use of PAR in SF5 for elimination of the ZCHEX message must be avoided, because the data is not partial for total kinetic energy.

3.4 Why not we introduce a specific code for total kinetic energy (say, TKE)?

4) Correlation between average neutron multiplicity emitted from a given mass and total kinetic energy  $\langle \nu(A, TKE) \rangle$  (Fig. 8 of [1], EXFOR 22464.007)

**Current coding:**

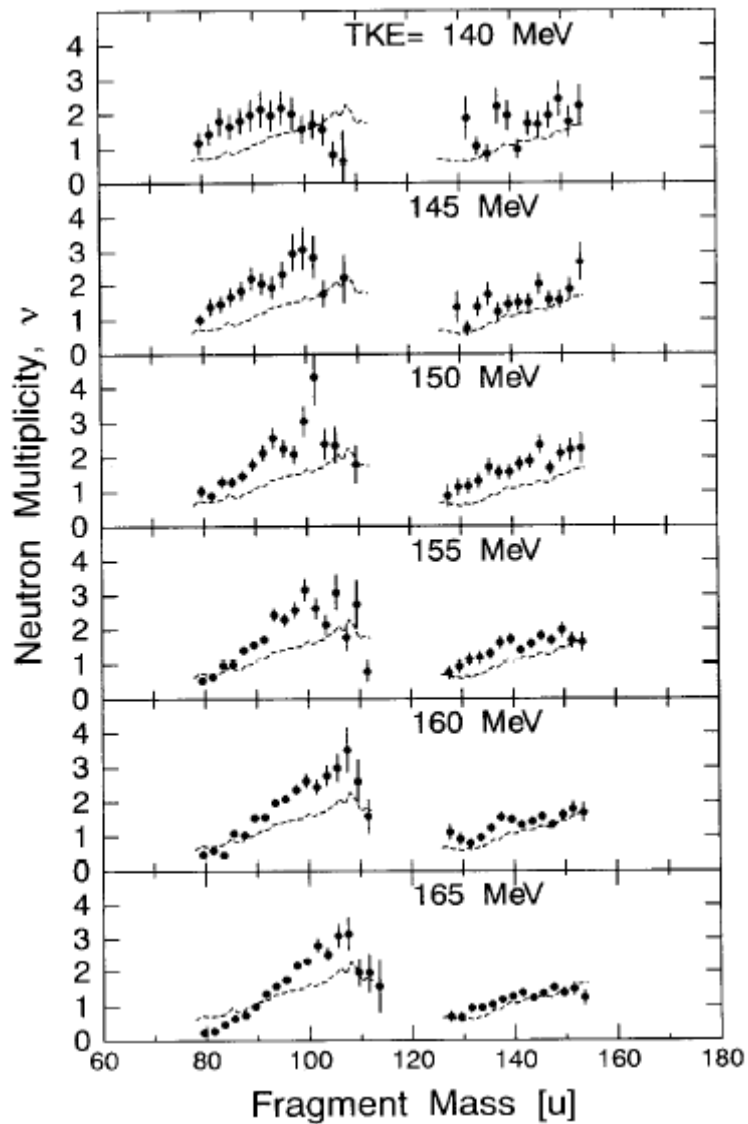
(92-U-235(N,F)MASS,PR,NU/DE,FF,FCT/MXW)

Total kinetic energy under the heading E

**Proposed coding:**

(92-U-235(N,F)MASS,PRE/PR,NU/TKE,,MXW)

Total kinetic energy under the heading TKE



## Similar quantities given by Vorobyev et al. [2]

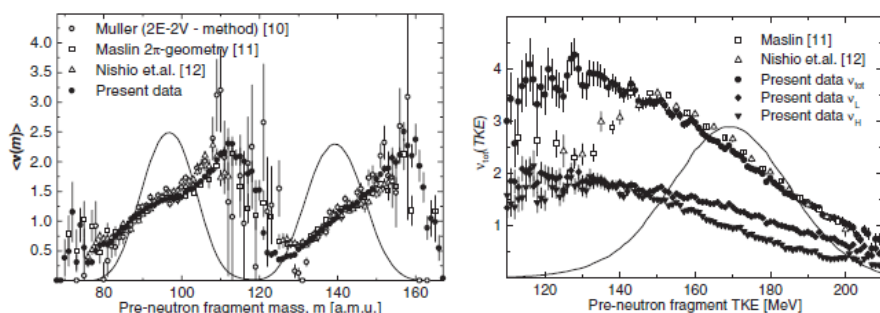


Fig. 5. The neutron yield as a function of pre-neutron fragment mass and TKE together with pre-neutron fission fragment mass and TKE distribution obtained by these measurements (for  $^{235}\text{U}(n_{th}, f)$ ).

## References

- [1] K. Nishio et al., Nucl. Phys. **A632**(1998)540 (EXFOR 22464)  
[2] A.S. Borobyev et al., EPJ Web Conf. **8**(2919)03004 (EXFOR 41516)

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