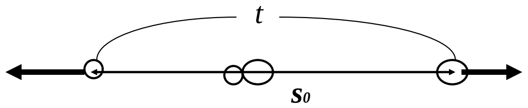
加速途中の中性子放出

●断裂後の時間と分裂片運動エネルギーとの関係
(Eismont)

$$t=\left(\frac{s_0}{v_k}\right)\left[\frac{\sqrt{x}}{1-x}+\frac{1}{2}\ln\frac{1+\sqrt{x}}{1-\sqrt{x}}\right]$$

$x = E/E_k$　E_k=**核分裂片最終運動エネルギー**
s_0 = **荷電中心間距離**
v_k = **最終速度**$=[2\{(M-m)Mm\}\text{‘}1.44(Z-z)z/s_0]^{1/2}$



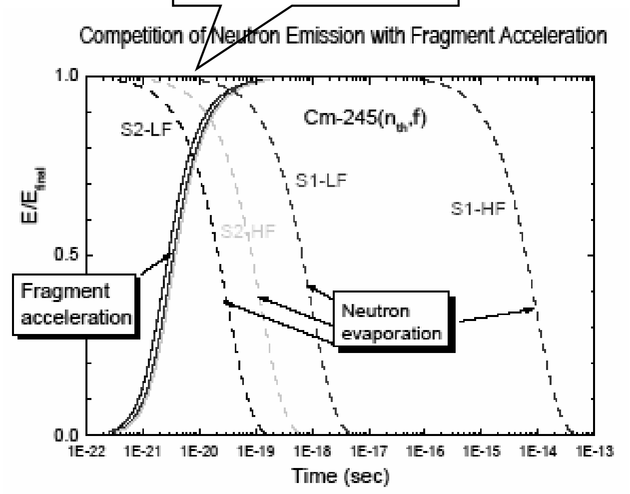
励起分裂片からの中性子放出

●励起エネルギーU, 結合エネルギーB_nの励起核からの中性子放出時間　**(Ericson)**

$$\tau=\frac{2A^{1/3}}{U-B_n}\exp(B_n/T)\cdot 10^{-21}\ (s)$$

$t < \tau$?

Standard-2では加速途中の中性子放出がありうる



2つのパラメータを定義:

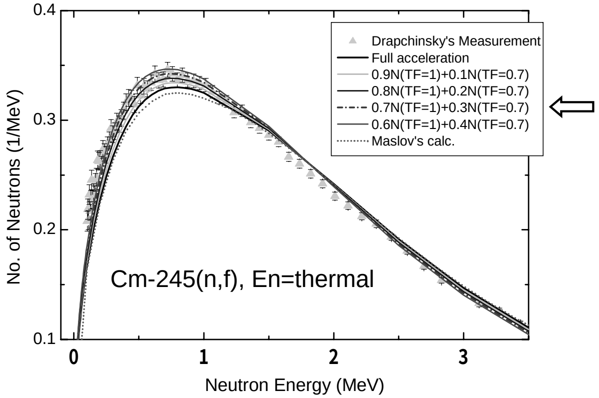
NEDA factor：**加速途中の中性子放出がおこる割合**

TF(Timing Factor)：**核分裂片が最終エネルギーの何%に達した時に中性子放出がおこるかを表す因子**

NEDA＝Neutron Emission During Acceleration

パラメータ・サーチの結果：

実験値を説明するためには、
NEDA=0.3、*TF*=0.7を仮定することが必要



重アクチニドほどNEDAが起こりやすいのは？

1. 重アクチニドほど TXE 大:

$$E_R = 0.2197(Z^2/A^{1/3}) - 114.37$$

$$TKE_{\mathrm{Viola}} = 0.1189(Z^2/A^{1/3}) + 7.3$$

$$TXE = E_R - TKE + B_n + E_n$$
$$= 0.1008(Z^2/A^{1/3}) - 121.67 + B_n + E_n$$

$Z^2/A^{1/3}$ →大 ： *TXE*→大

2. Z^2/A→大で *TKE*の分散大、したがって *TXE*の分散大

⬇

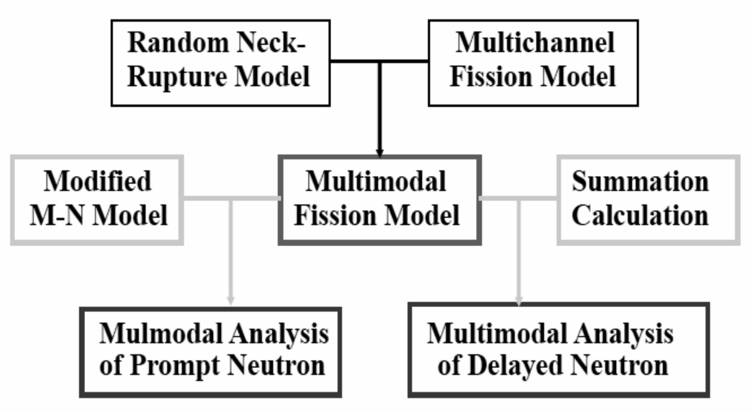
平均励起エネルギーより10MeV以上高い*TXE*をもつFFが10%以上存在する

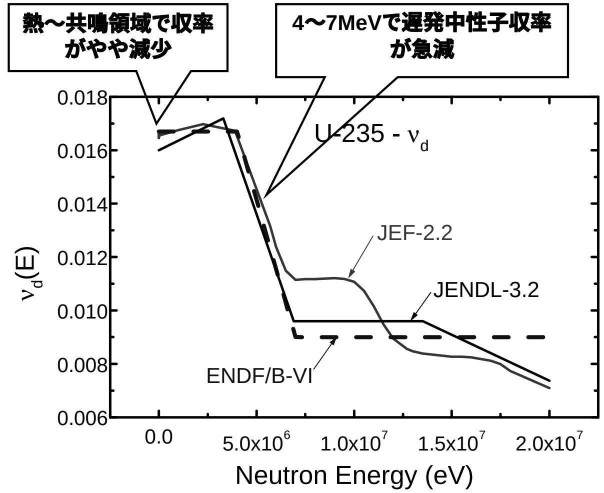
⬇

Z^2/A →大： t→小

マルチモード核分裂モデルの応用（2）

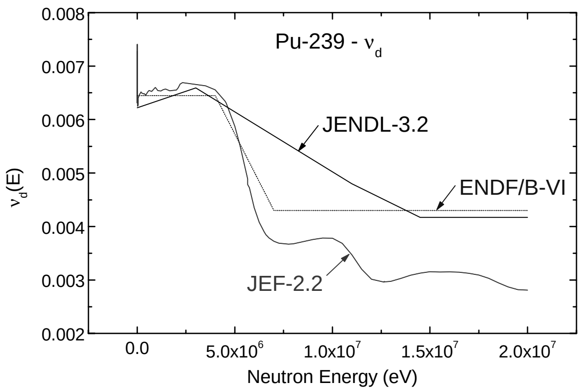
遅発中性子収率データの理論評価



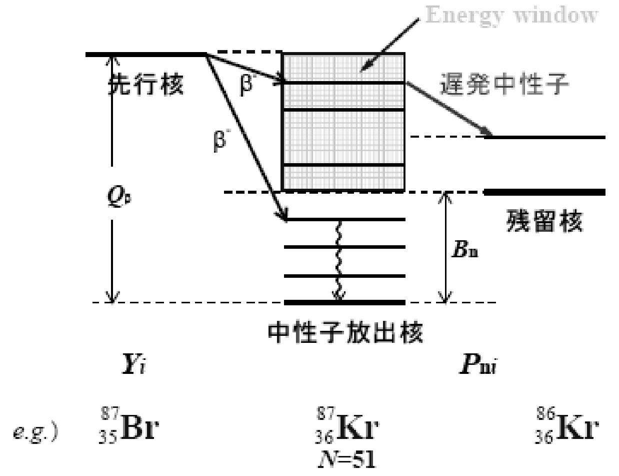

熱～共鳴領域で収率がやや減少

4～7MeVで遅発中性子収率が急減

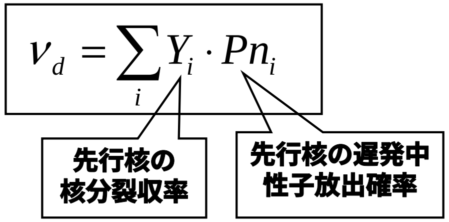
Pu-239の遅発中性子収率の評価値



先行核からの遅発中性子放出



総和法による遅発中性子収率の計算



$$\nu_d = \sum_i Y_i \cdot Pn_i$$

先行核の核分裂収率

先行核の遅発中性子放出確率

- **Five-Gaussian公式**
  1次FF→2次FP収率
- **荷電分布**
- **偶奇効果**

- **P_nデータセット**
  - **A.C.Wahl (271核種)**
  - **Kratz-Herrmann**
- **アイソマ生成比**

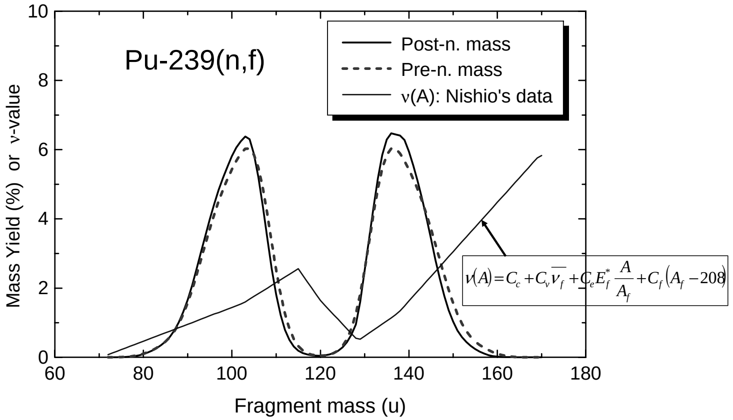
中性子放出前収率から放出後収率への変換

$$\sum_0^{A_0} M(A) = \sum_0^{A_0+\nu\left(A_0+\nu+1/2\right)} FY(A) + (dFY/dA)\frac{\left\langle \sigma^2(\nu_f;A)\right\rangle}{2} + \cdots$$

$$\nu^*(A) = \nu(A+\nu+1/2)$$

$$M(A) = (1+\nu_0^* - \nu_{-1}^*)\ FY\ (A - \frac{\nu_0^*}{2} + \frac{\nu_{-1}^*}{2} - \frac{1}{2}) + \left[\left(\frac{dFY}{dA}\right)_0 - \left(\frac{dFY}{dA}\right)_{-1}\right]\frac{\left\langle \sigma^2(\nu_f;A)\right\rangle}{2} + \cdots$$

中性子放出前収率と放出後収率の比較



$$\nu(A) = C_c + C_v\overline{\nu_f} + C_e E_f^* \frac{A}{A_f} + C_f\left(A_f - 208\right)$$

核分裂片の荷電分布

$$Y_C = C_0 \exp[-(Z - Z_p)^2 / \sigma_Z{}^2]$$

最確電荷

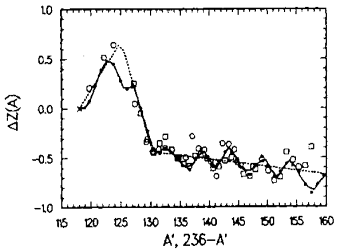
$$\sigma_Z = 0.56$$

$$Z_p = Z_{UCD} \pm \delta Z$$

$$(+\ for\ LF,\ -\ for\ HF)$$

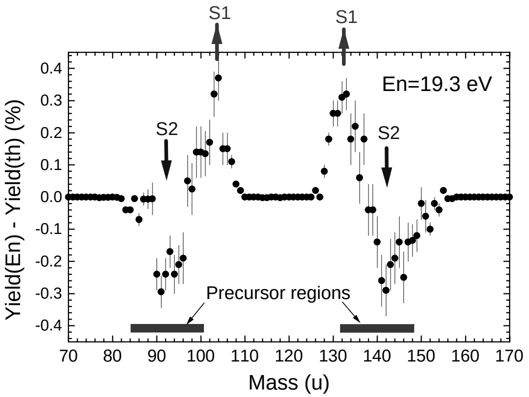
UCD=Unchanged Charge Distribution

$$\frac{Z_C}{A_C} = \frac{Z_L}{A_L} = \frac{Z_H}{A_H}$$

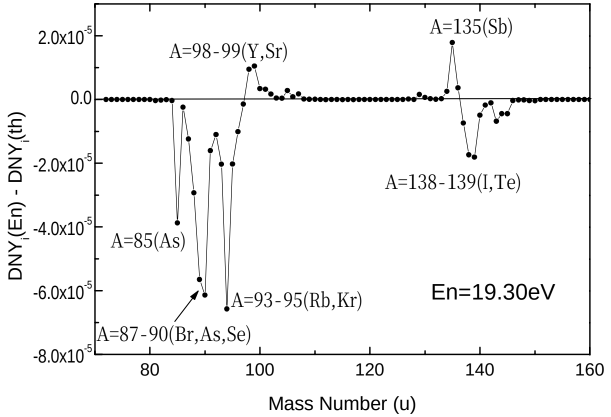


共鳴領域における核分裂収率の揺らぎ

U-235の共鳴

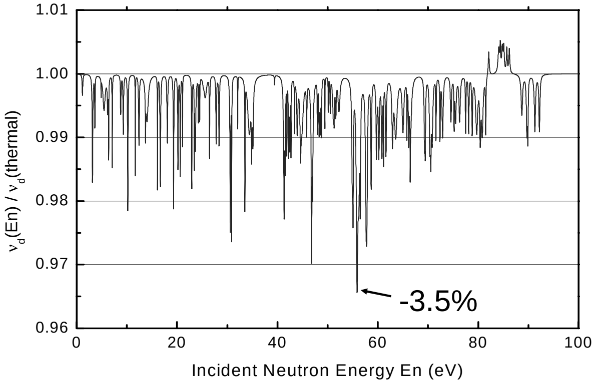


U-235の共鳴における遅発中性子収率の揺らぎ



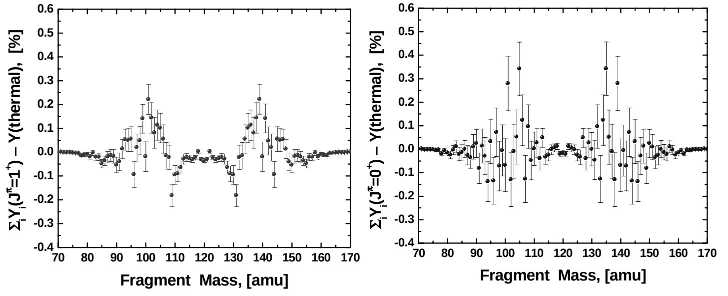
U-235の共鳴領域における
核分裂収率の揺らぎ

Energy-dependence of DNY in the resonance region of U-235



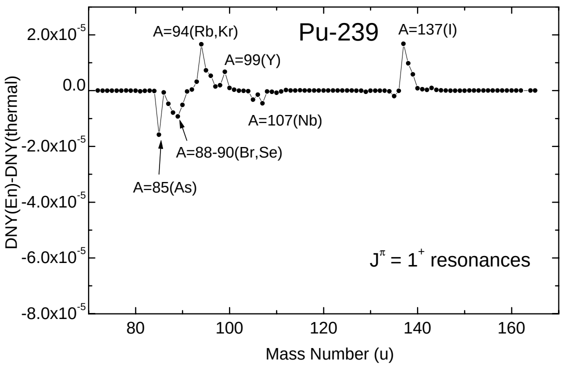
Pu-239の共鳴領域における
核分裂収率の揺らぎ

J=1+ **J=０+**

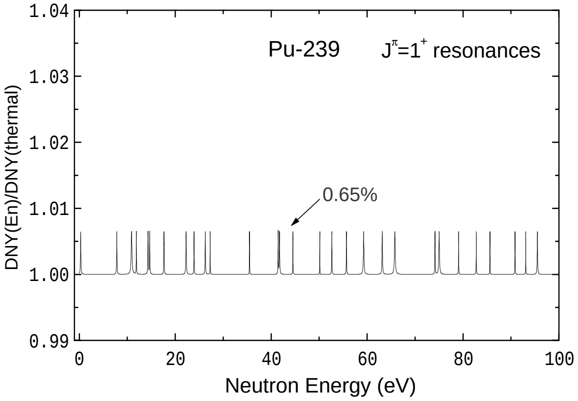


構造あり **有意の構造なし**

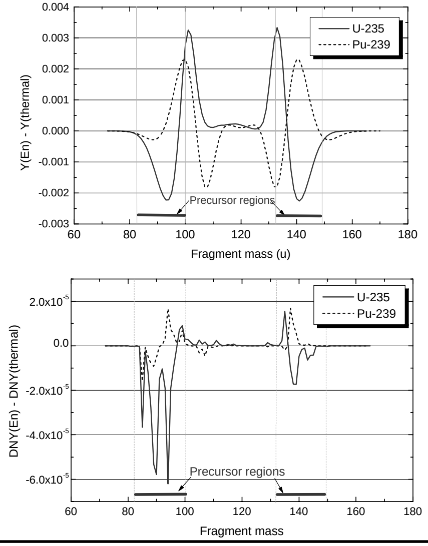
共鳴領域における遅発中性子収率の揺らぎ



共鳴領域における遅発中性子収率の揺らぎ

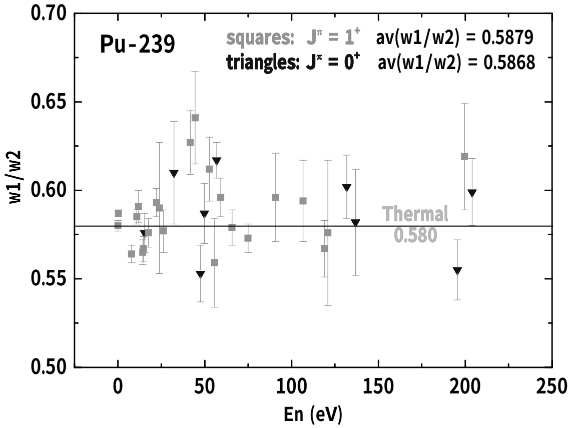


U-235と Pu-239の 比較

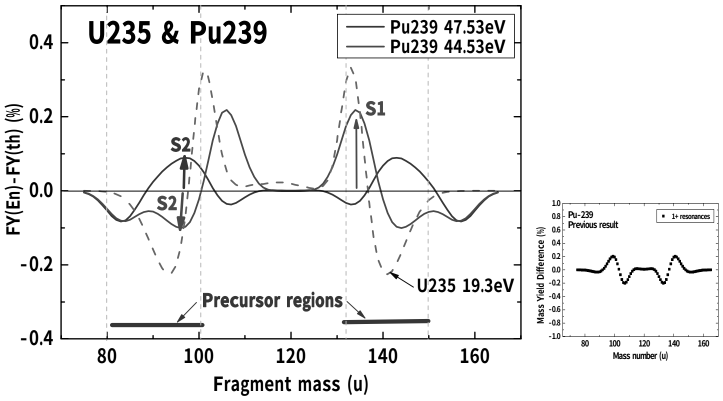


Fluctuation of w_1/w_2 in the resolved resonance region of Pu-239

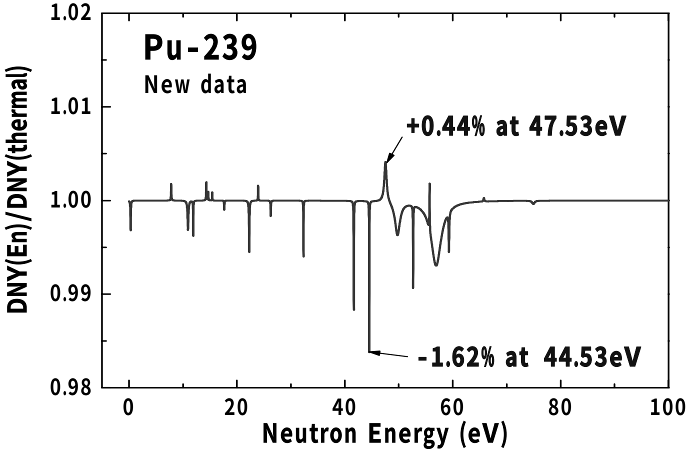
(New data, EC-JRC-IRMM)



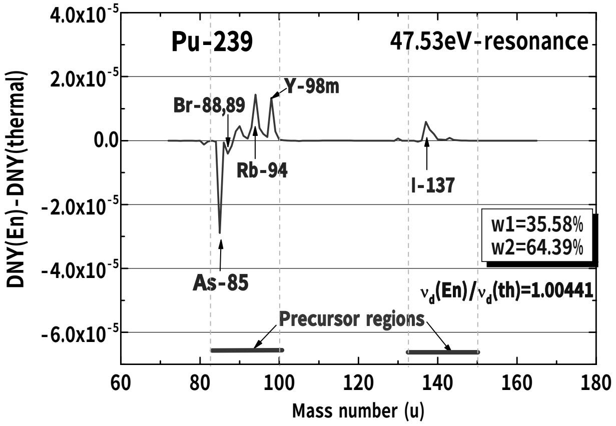
Fluctuation in the FY in the resonance region of Pu-239 & U-235



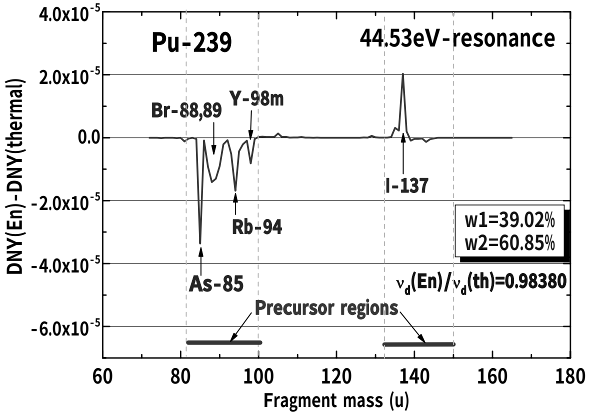
Fluctuation in the DNY in the resonance region of Pu-239



Fluctuation in the DNY as a function of precursor mass



Fluctuation in the DNY as a function of precursor mass



Conclusion

1. Calculation of the DNY in the resolved resonance region below 200eV on the basis of mode branching ratios at individual resonances obtained at IRMM revealed that
   --- *peaks* appear at resonances with
   $w_2 > w_{2\ \mathrm{thermal}}$, the largest peak amounting to +0.44%,
   while
   --- *dips* appear at resonances with
   $w_2 < w_{2\ \mathrm{thermal}}$, the deepest dip to -1.62%.

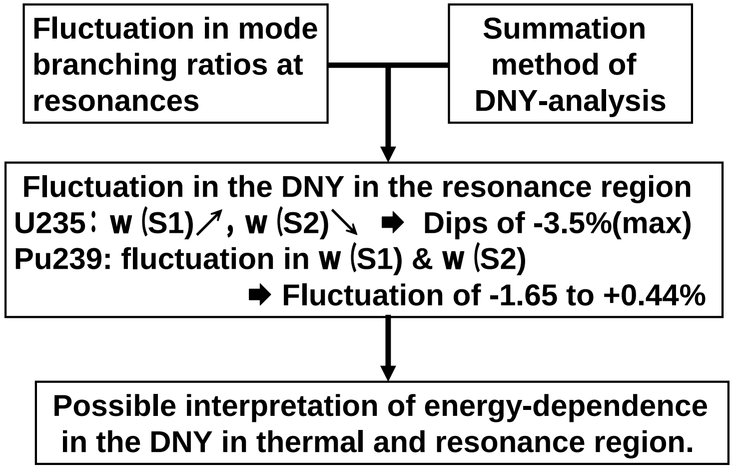
---

2. The absolute value of the DNY at 0.0253eV :
   - the present calculation : $\nu_d = 5.84\times10^{-3}$
     (using A.C.Wahl’s data for P_{n_i})
   - the evaluated value : $\nu_d = 6.22\times10^{-3}$
     (JENDL-3.3)

   The discrepancy of 6% is due to ambiguities
   - in the fission yield (Y_i), and
   - in the DN-emission probabilities (P_{n_i})

   for the precursors.

CONCLUSION



Fluctuation in mode branching ratios at resonances

Summation method of DNY-analysis

Fluctuation in the DNY in the resonance region
U235： w (S1)↗, w (S2)↘ ➨ Dips of -3.5%(max)
Pu239: fluctuation in w (S1) & w (S2)
➨ Fluctuation of -1.65 to +0.44%

Possible interpretation of energy-dependence in the DNY in thermal and resonance region.