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POSSIBILITY OF FISSION PRODUCTS BY MULTI-PHOTON EXCITATION PROCESS FOR A>100 NUCLEI

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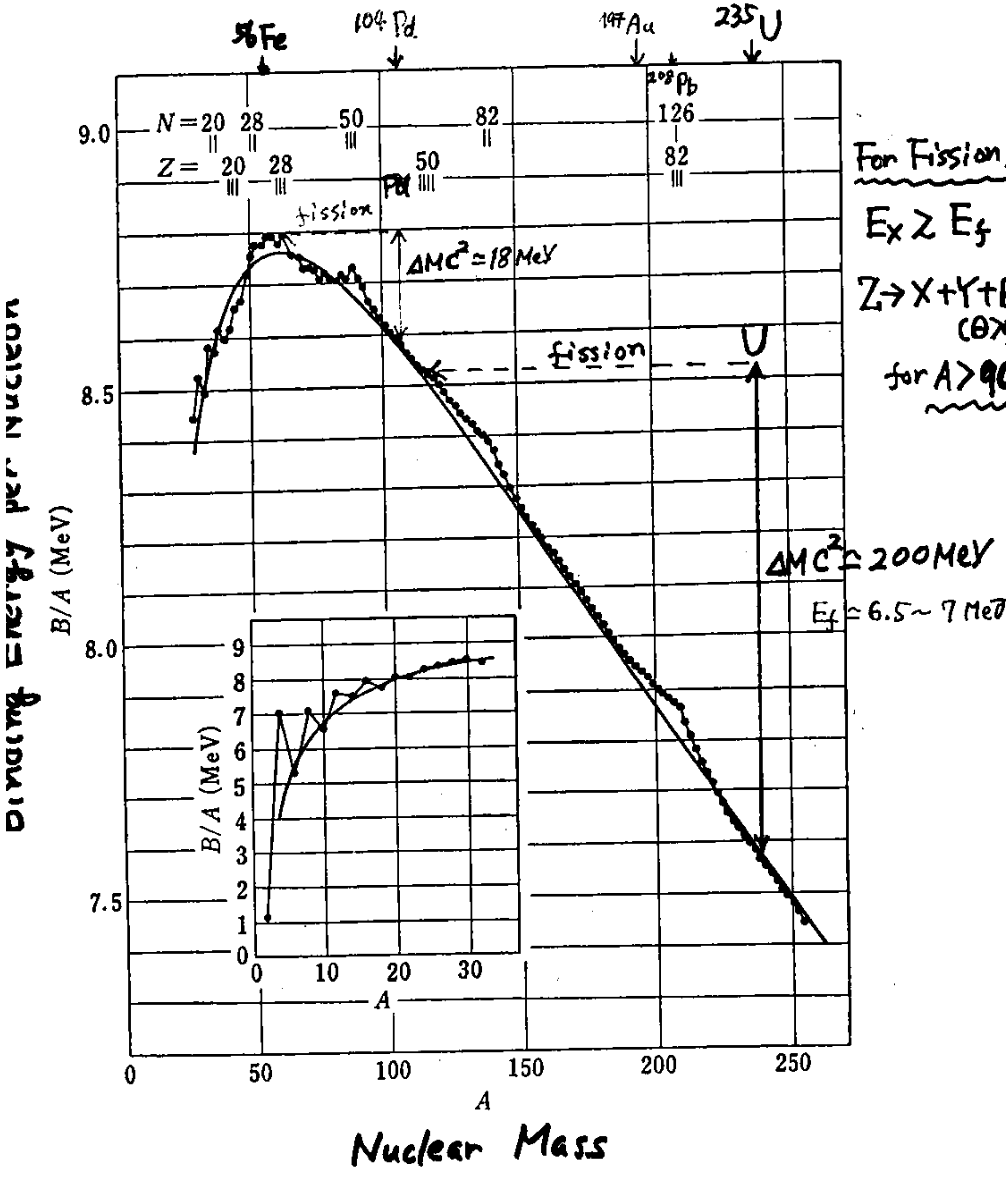

56Fe
104 Pd
197Au
208Pb
235U
N = 20 28 50 82 126
Z = 20 28 50 82
Pd
fission
$\Delta Mc^2 \simeq 18$ MeV
fission
U
$\Delta Mc^2 \simeq 200$ MeV
$E_f \simeq 6.5 \sim 7$ MeV
For Fission
$E_x \geq E_f$
Z → X + Y + E
for A > 90
Binding Energy per Nucleon
B/A (MeV)
9.0
8.5
8.0
7.5
0
50
100
150
200
250
A
Nuclear Mass

"TRANSMUTATION" by Electrolysis and
Discharge Experiments with Pd, W and Au,
claimed by Mizuno, Miley, Ohmori, Iwamura,
Karabut, etc.

Reporting;

Fission-like products, Non-natural Isotopic Ratios
Radiation-less

But;

M(metal) + n, M+p, M+d can ***NOT*** make enough Nuclear Excitation over Fission Barriers (E_f) to induce fission, except for U and TU.

: ASSUMPTION :

Fission by Multi-Photon Excitation
for A>100 Nuclei
($Q > 0$)

1) Multi-Photon Cascade Excitation (Pump-up) Through Low Lying Nuclear Collective States

2) Collective Deformation: E1 to Tandem Oscillation

3) Selective Channel Scissions

Multi-Photon Induced Fission !

MPIF

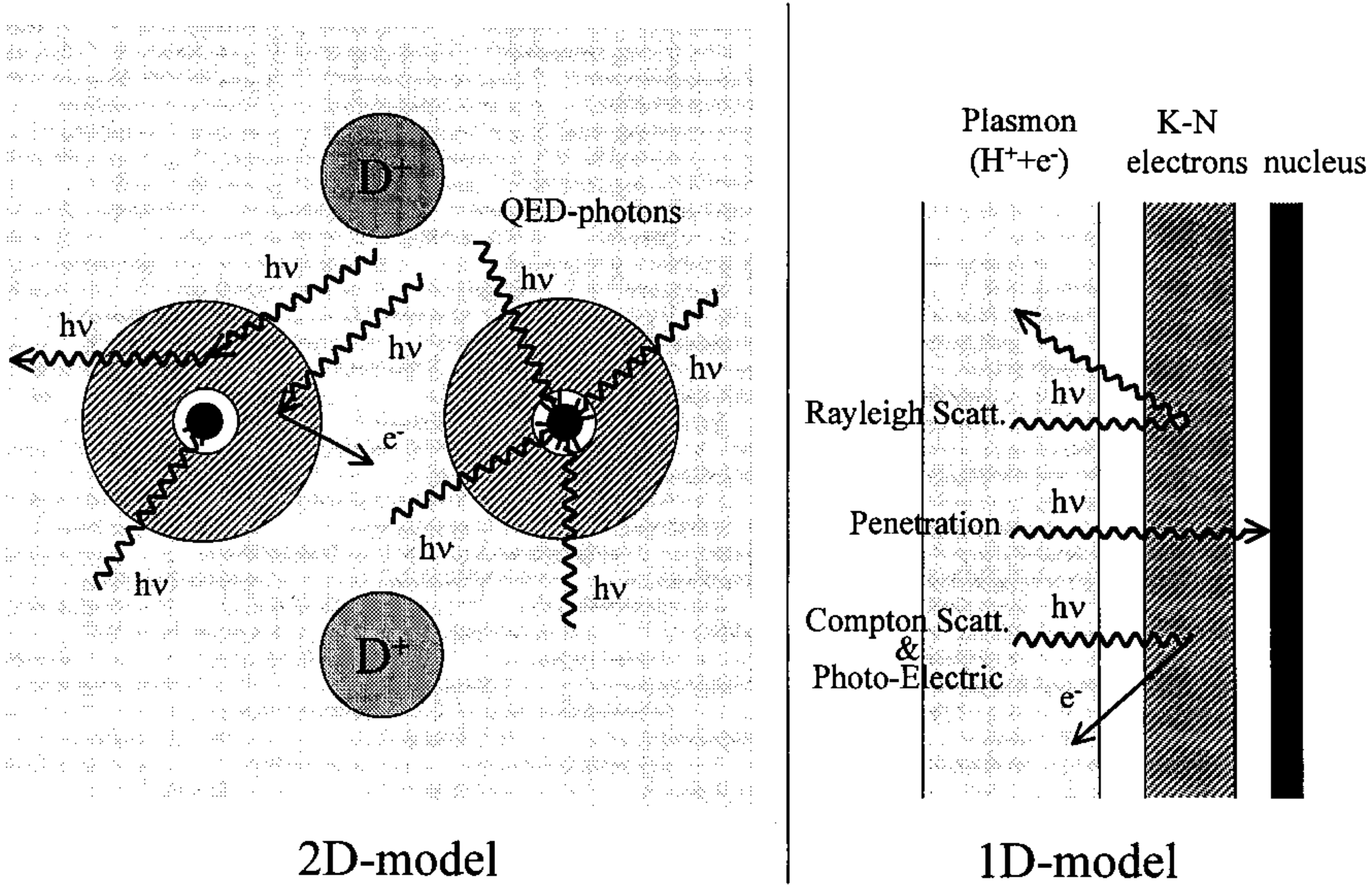

Fig. Multi-Photon Absorption in Pd nucleus by QED Coupling to PdDx Plasma Oscillation

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2.1 Transfer of QED Photons

- QED-photons emitted from PdDx (MHx) plasmon, especially by dynamic condition of D or H
  (X-rays data by Iwamura, Karabut, and so on)

- Penetration through orbital electrons
  (K-N shell)-cloud of Pd (M), competing with photo-electric absorption, Compton scattering and Rayleigh (elastic) scattering.
  P (E_q) : Transmission Probability of QED photon

- Some of QED photons can reach at Pd-nucleus (M), to make multiple-E_1 absorption.
  $\Delta E_x = nE_q$: excitation energy of nucleus
  n : multiplicity (> about 100)
  E_q : energy of QED-photon
  (0.1 ~ 10KeV)

$E_x = \sum_{i=1} \Delta_i E_x$: for E_2 , E_1 transitions

in Cascade Pump-up

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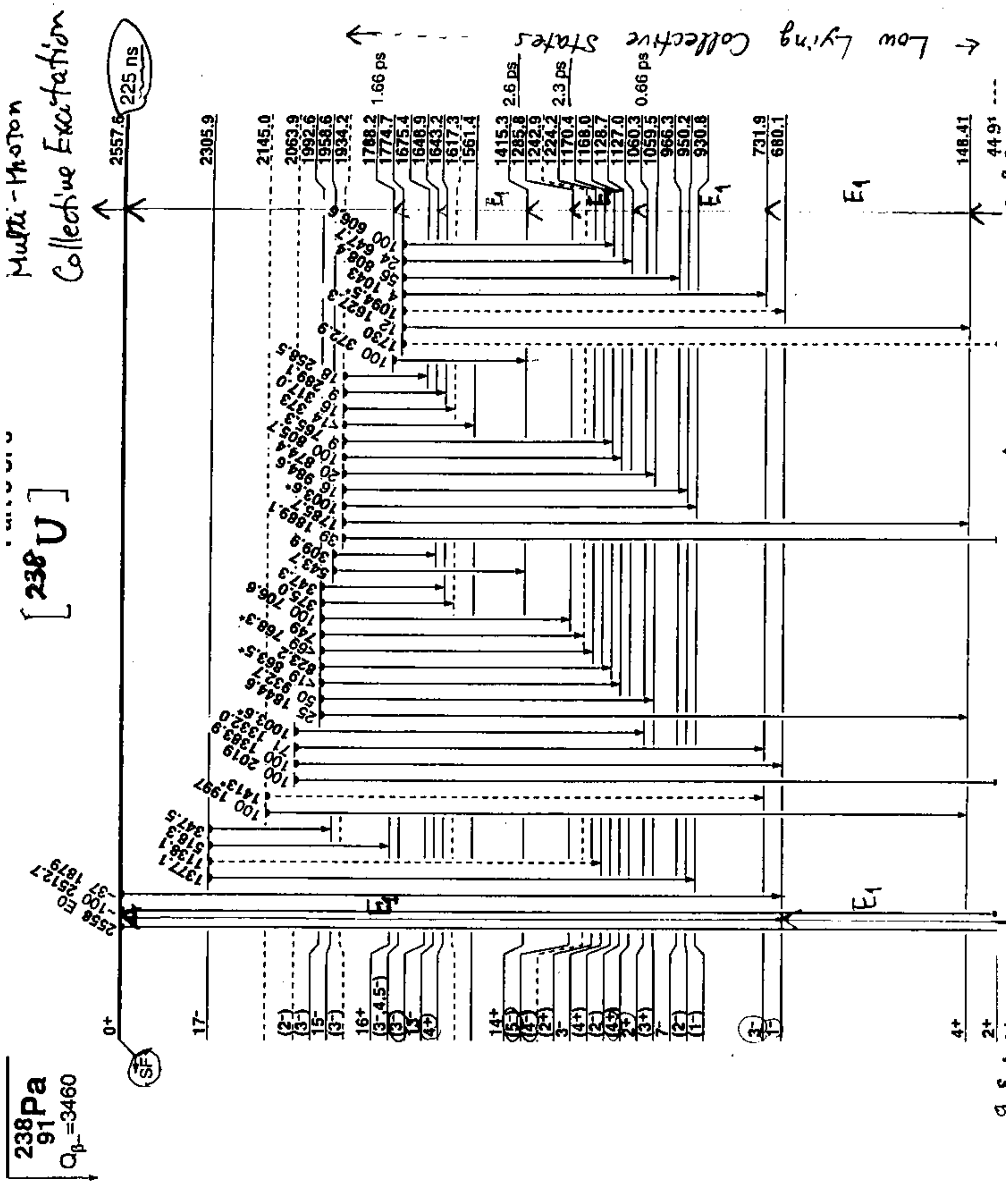
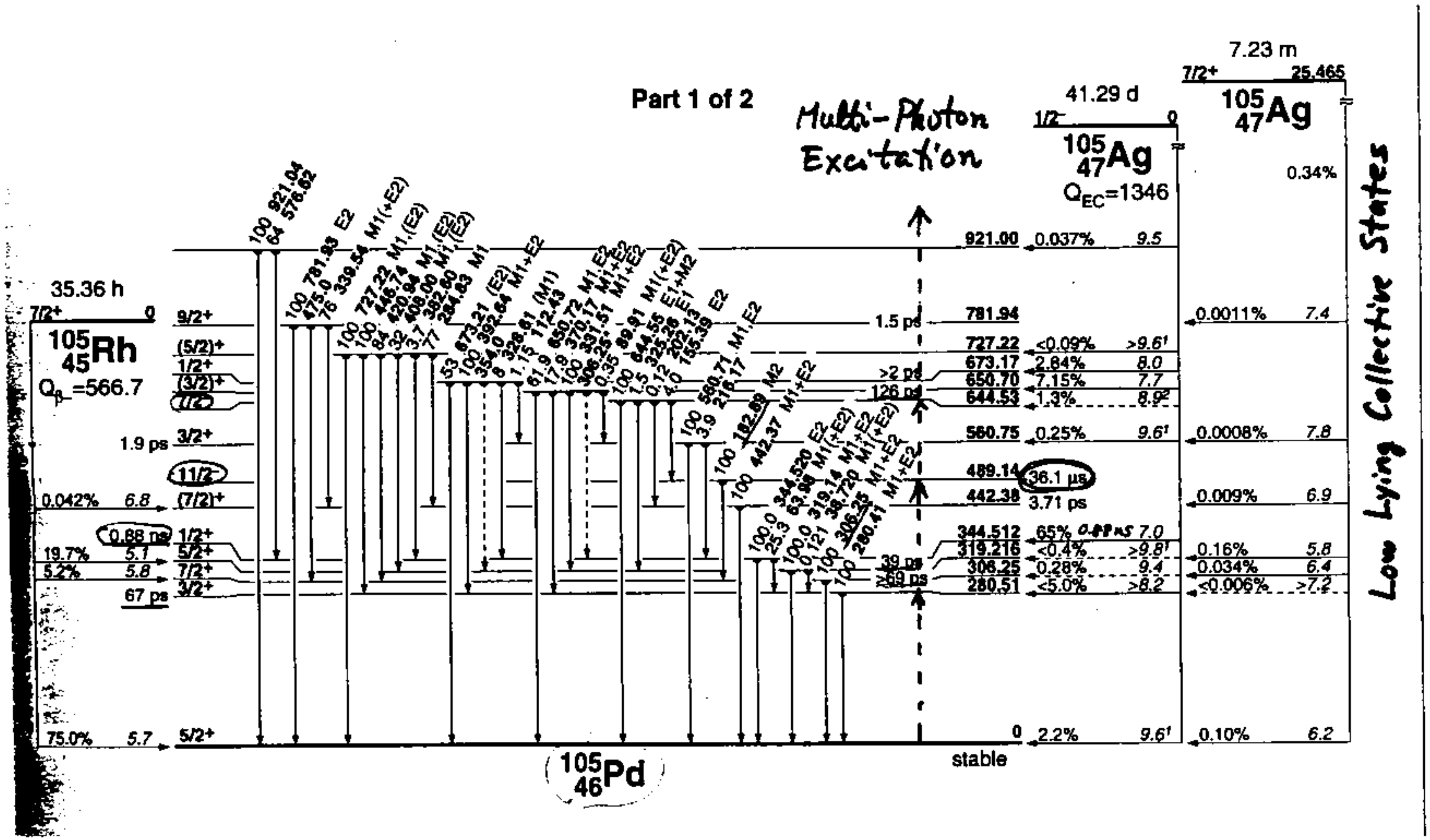
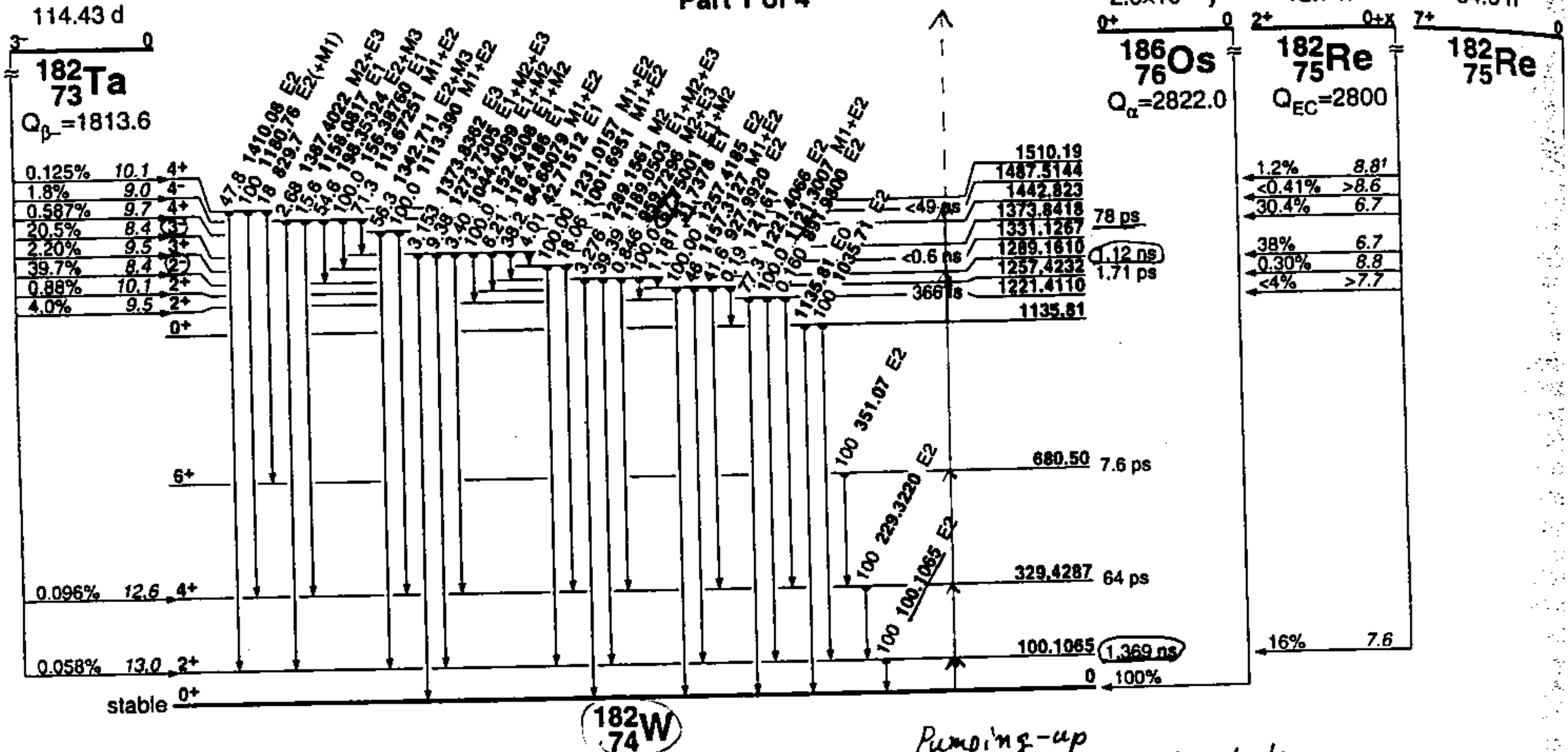

Multi-Photon Collective Excitation
[238U]
238 91 Pa
Qβ-=3460
SF
225 ns
Low Lying Collective States
2557.6
2305.9
2145.0
2063.9
1992.6
1958.6
1934.2
1788.2
1774.7
1675.4
1648.9
1643.2
1617.3
1561.4
1415.3
1285.8
1242.9
1224.2
1170.4
1168.0
1128.7
1127.0
1060.3
1059.5
966.3
950.2
930.8
731.9
680.1
148.41
44.91
1.66 ps
2.6 ps
2.3 ps
0.66 ps
E1
0+
17-
16+
14+
4+
2+

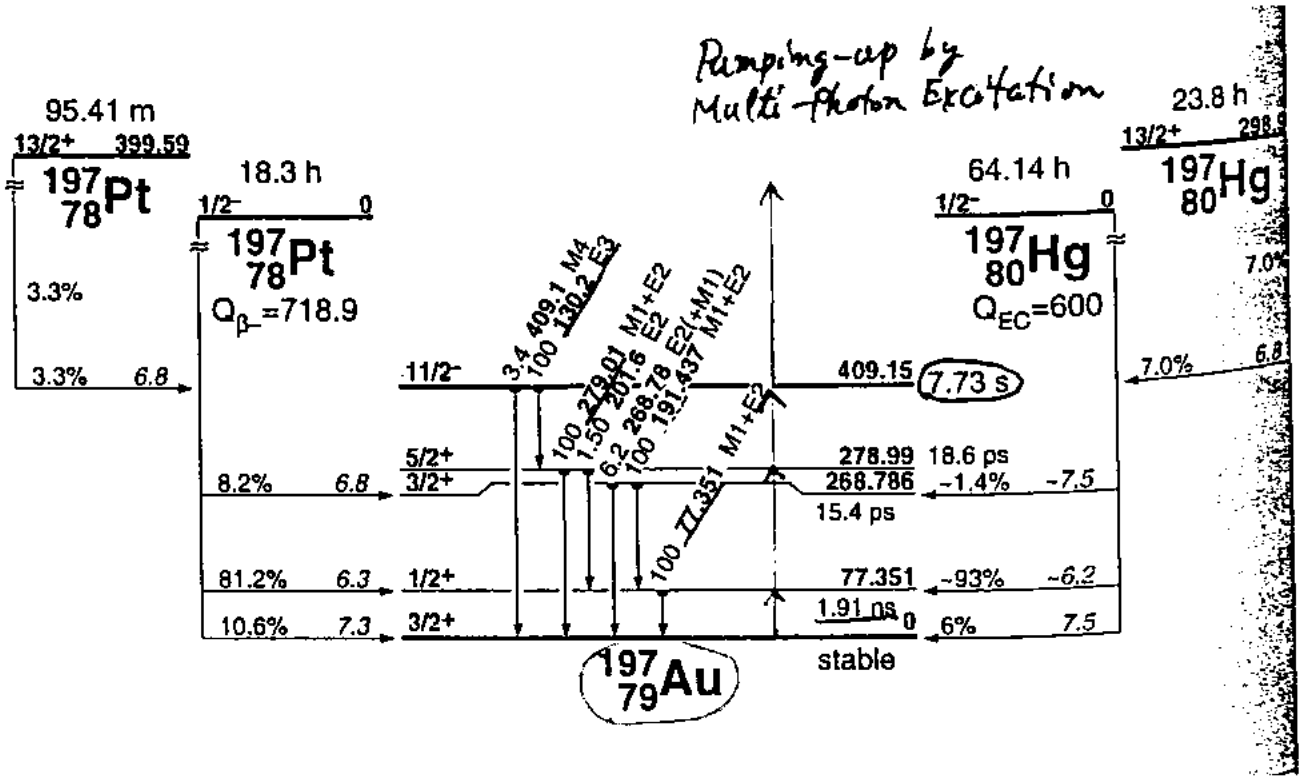
V.S. Shirley ed.:
R.B. Firestone, "Table of Isotopes, 18th Ed., 1996



Part 1 of 4



Pumping-up
by Multi-Photon Excitation


Pumping-up by
Multi-Photon Excitation
95.41 m
13/2+ 399.59
197 78 Pt
3.3%
3.3% 6.8
18.3 h
1/2− 0
197 78 Pt
Qβ−=718.9
8.2% 6.8
81.2% 6.3
10.6% 7.3
11/2−
5/2+
3/2+
1/2+
3/2+
3.4 409.1 M4
100 130.2 E3
100 279.01 M1+E2
1.50 201.6 E2
6.2 268.78 E2(+M1)
100 191.437 M1+E2
100 77.351 M1+E2
409.15 7.73 s
278.99 18.6 ps
268.786
15.4 ps
77.351
1.91 ns 0
stable
197 79 Au
64.14 h
1/2− 0
197 80 Hg
QEC=600
−1.4% ~7.5
~93% ~6.2
6% 7.5
23.8 h
13/2+ 298.9
197 80 Hg
7.0%
7.0% 6.8

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2.2 Low-E Photo-Fission of Pd (W, Au, U)

- Nuclear excitation (E_x) of {M (A>100) / Pd-isotope} by the Giant Dipole Resonarce (E1, or P-wave, $l = 1$)

- Leads to the Dumbbell-type deformation which can go to scission (fission) with Breit-Wigner cross section (for Photon Absorption).

$$\sigma_p^{(l)}(E_x) = \sigma_r \left(\frac{E_x}{E_r}\right)^{l-1/2} \cdot \frac{\Gamma_t^2/4}{\Gamma^2/4 + (E_x - E_r)^2} \qquad (2\text{-}1)$$

E_r = resonance energy (~ 15-20 MeV)
Γ = energy width
σ_r = cross section at E_r

$$\boxed{\sigma_f(E) \propto \sigma_p(E_x) \sum_i p_i(E_x)} \qquad ;\ \text{Fission} \qquad (2\text{-}1)'$$

$P_i (E_x)$ = Channel (i)-dependent Tunnel Fission Probability

- Supposing $E_r \sim 15$MeV , $\Gamma \sim \Gamma_f \sim 4$MeV ,
$E_x < 1$MeV ,
$(\sigma_p (E_x) / \sigma_r) \sim 10^{-3} \sim 10^{-4}$ (2-2)

(needs "Pump-up" to $E_x \sim E_r$, by the { E_1- / E_2- / E_3- } transition from lower level to higher level !)

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2.2.2 Reaction Rate

$$R(E_q) = N\sigma_f(E_x) \cdot \Phi_q(E_q) \cdot P(E_q) \qquad (2\text{-}3)$$

where

N : number density of Pd-isotope

Φ_q : photon-flux from QED-plasma

We need; (very large , $10^{20} \sim 10^{21}$ photons / cm^2 / s , c.f.usual photon beam)

If

$P(E_q) \sim 10^{-4}$, $\Phi_q \sim 10^{+16\sim17}$, $N \sim 10^{+22}$ and $\lesssim E_q < 0.1$MeV , $E_x \lesssim E_f$ (LB) :

$R(E_q) \sim \sigma_f(E_x)\ 10^{24} \cdot 10^{15}$:
comparable to high-E (E_x>10MeV) photo-fission ?

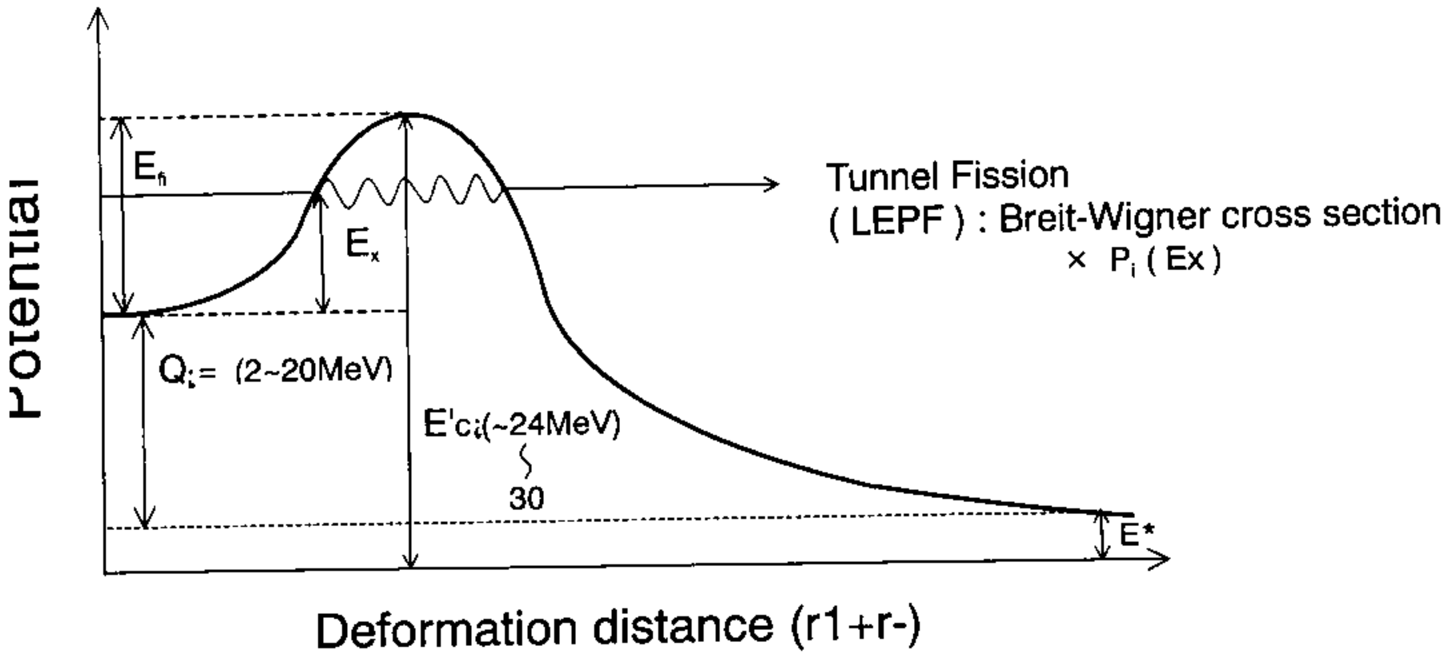
$$\left(\begin{array}{l} \text{If} \quad \sigma_f \simeq 0.1 \sim 10 \sim 100\mu b = 10^{\,7\sim5\sim4} \times 10^{-24} \\ R(E_q) \simeq 10^{\,8\sim10\sim11} (f/s/cc) \sim 10^{11} \end{array}\right) \quad {}_f\sigma_r \fallingdotseq 1b \sim 10b$$

$\downarrow$

~ 1mW / cc ~ 0.1W/cc ~ 1W / cc

Fission Barrier-2

< Channel - Dependent E_f >



<u>For stable FP isotopes.</u> ; $E^*=0$

$\therefore\ E'_c = E_f + Q \quad \rightarrow E_{fi} = E'_{ci} - Q_i$

where Q-values are 2～20MeV for stable FPs of Pd-LEPF.

$E'c_i$ is approximately given as ,

$$E'_{ci} \fallingdotseq 0.5 \left(\frac{r_0}{r}\right) Z_1 Z_2 \qquad \text{(MeV)} \qquad (E=0.6,\ \alpha=3.0)$$

where , $r_0 \sim 1$fm.

for $r = r_1 + r_2 \sim 10$fm , $E'_c \fallingdotseq 24$MeV (for Pd)

Therefore

E_{fi} = 11～22MeV (for Pd)

:depending on scission channel.

Especially ,

E_{fi} = 11～15MeV for most of stable FP channels for Pd-LEPF. <u>(Lowest Band)</u>

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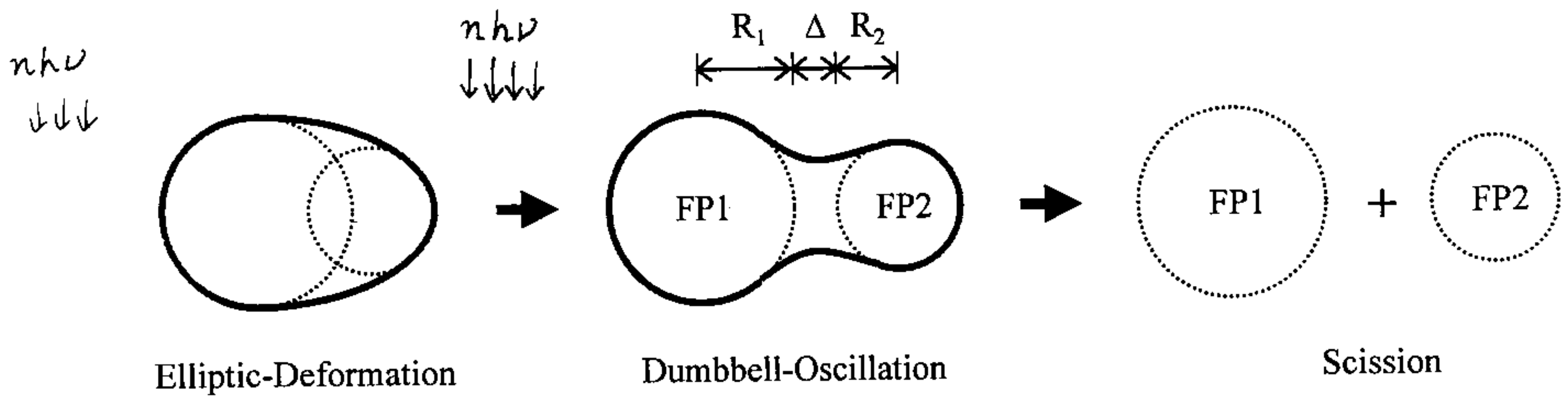
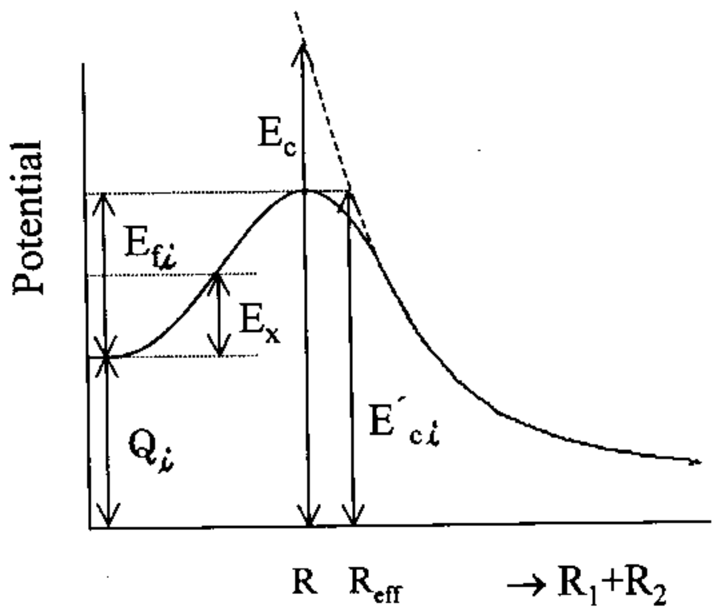




$E_c \propto Z_1 Z_2/(R_1+R_2)$
:Coulomb repulsion

$R \propto A^{1/3}$

E'_c: Effective Coulomb Energy

E_x: Excitation Energy

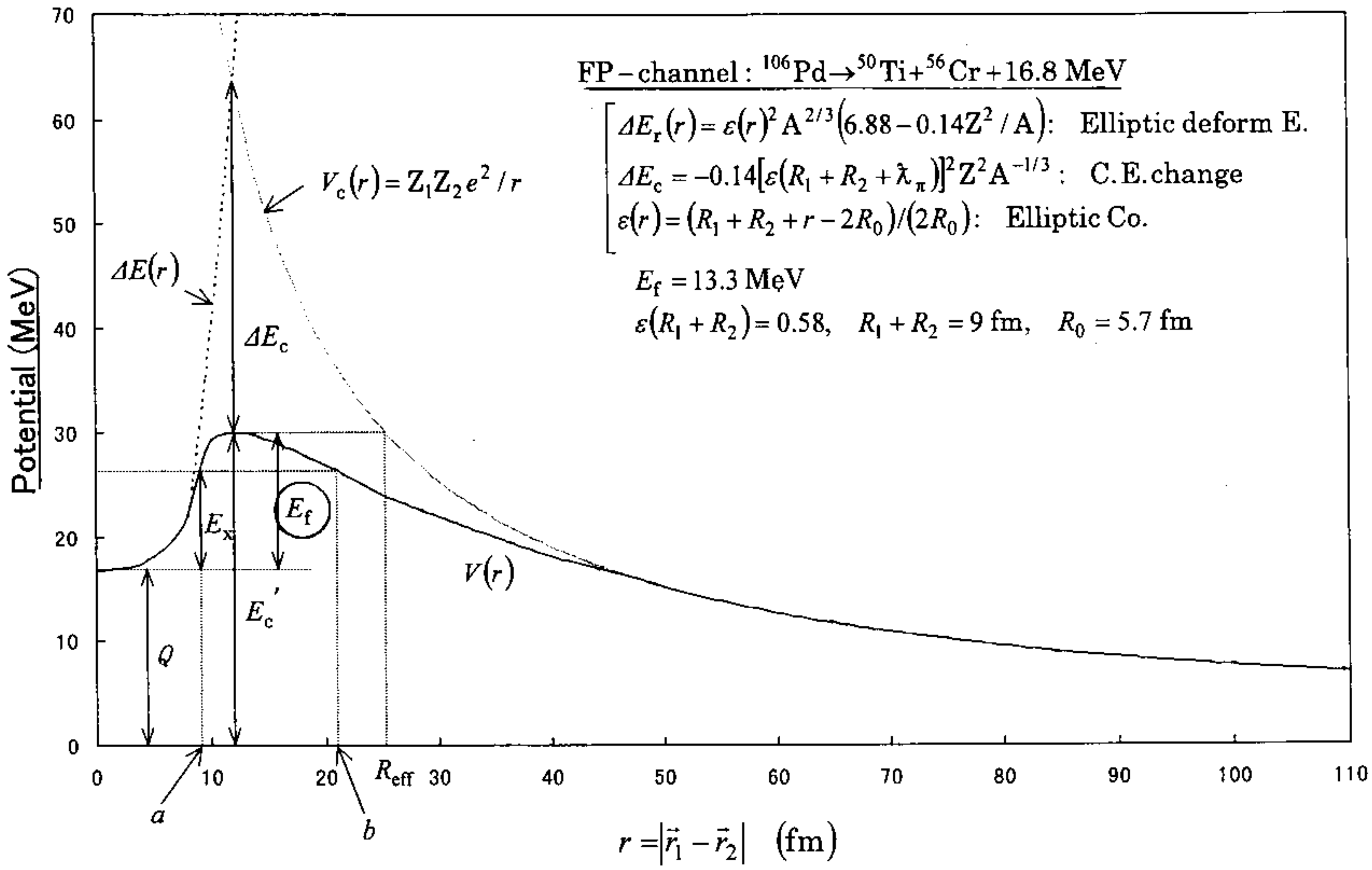
E_f: Fission Barrier

$R_{eff} = R_1+R_2+\Delta$

Δ: Scission Distance ; to be estimated !
($\Delta(A) = \alpha(A)\varepsilon(A)R_{eff}$, shown later)

$E_{fi} = E'_{ci} - Q_i$; channel-dependent fission-barrier

Fig.3 : Tandem (dumbbell dipole) oscillation and scission process


FP – channel : ^{106}Pd → ^{50}Ti + ^{56}Cr + 16.8 MeV
$\Delta E_r(r) = \varepsilon(r)^2 A^{2/3}(6.88 - 0.14 Z^2/A)$: Elliptic deform E.
$\Delta E_c = -0.14[\varepsilon(R_1 + R_2 + \lambda_\pi)]^2 Z^2 A^{-1/3}$: C.E. change
$\varepsilon(r) = (R_1 + R_2 + r - 2R_0)/(2R_0)$: Elliptic Co.
$E_f = 13.3$ MeV
$\varepsilon(R_1 + R_2) = 0.58$, $R_1 + R_2 = 9$ fm, $R_0 = 5.7$ fm
$V_c(r) = Z_1 Z_2 e^2 / r$
$\Delta E(r)$
ΔE_c
E_x
E_f
E_c'
Q
$V(r)$
a
b
R_{eff}
Potential (MeV)
$r = |\vec{r}_1 - \vec{r}_2|$ (fm)
0
10
20
30
40
50
60
70
80
90
100
110

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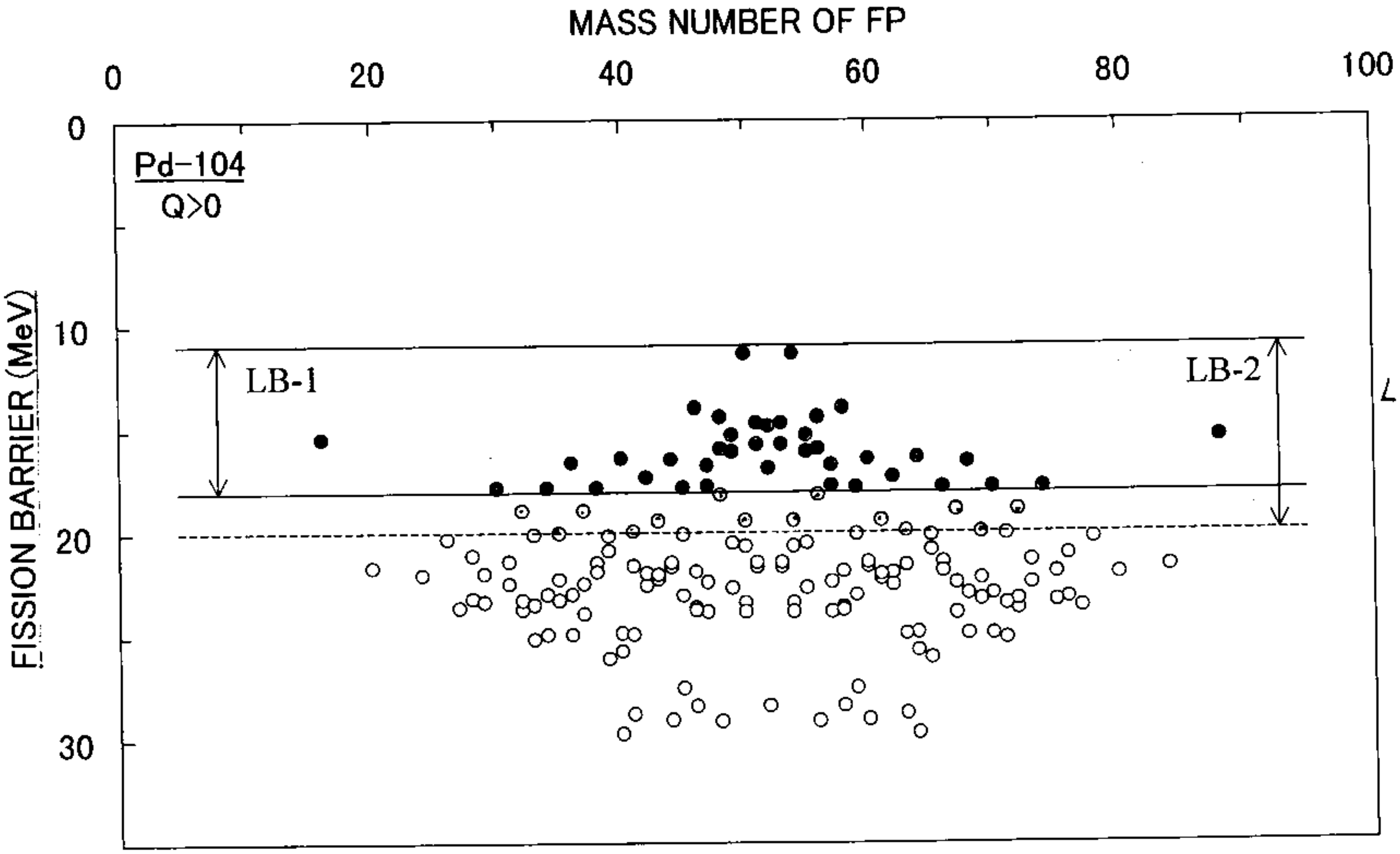

LB1 : 21 chan

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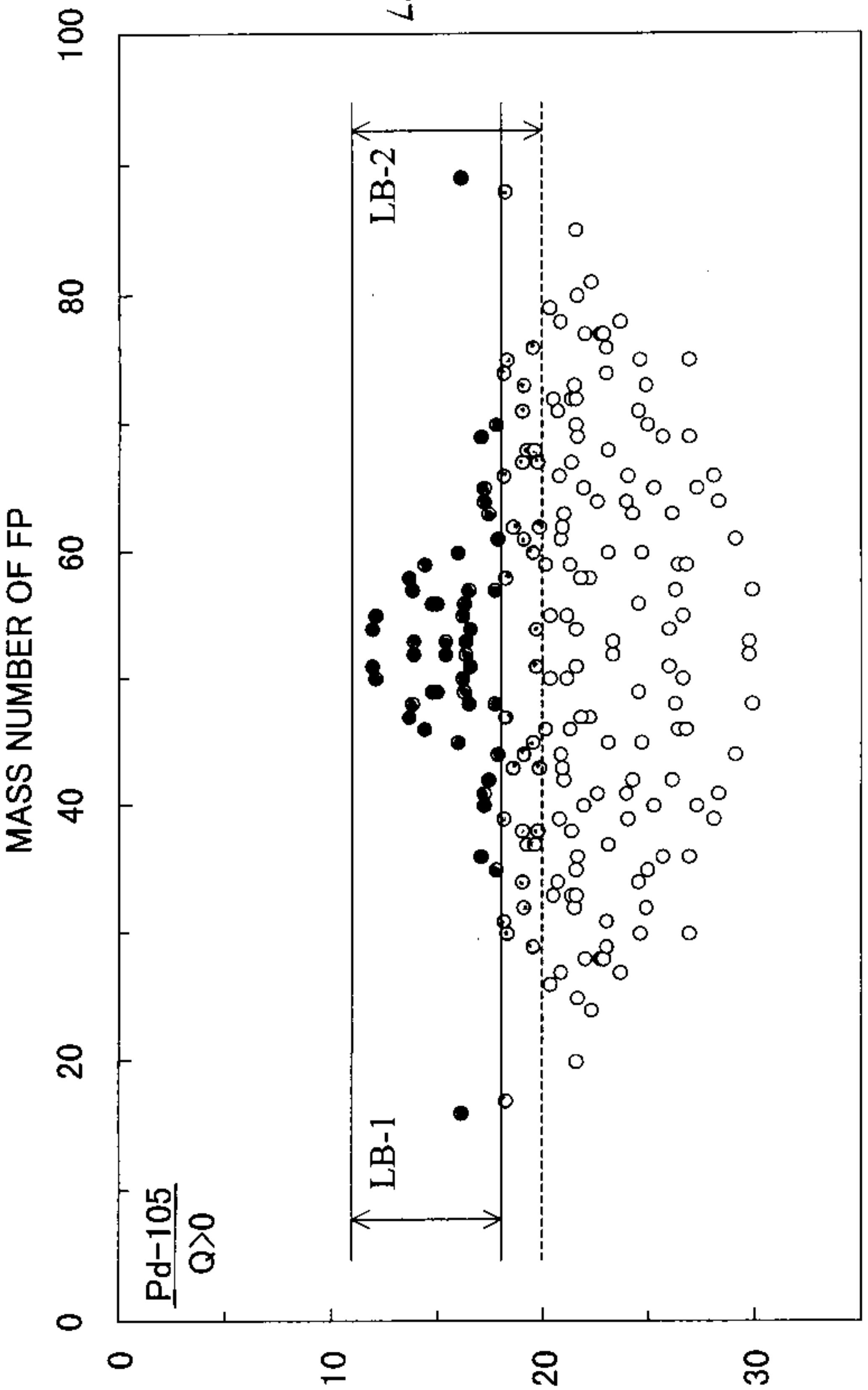
LB1 : 23 chan



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2.3 Fission Products (Q>0)

Pu LEPF → Total = 527 channels

2.3.1 Stable-Isotope Pairs — 32 channels ($E_f \geq LB2$)

2.3.2 Stable-Isotope Pairs after pure β^- - decay — 120 channels ($E_f \geq LB2$)

93 (LB1)

2.3.3 γ - emitters (Short Lives) by β^- - decay

With Fission Cross Section of ;

$$\boxed{\sigma_f (E_x) \propto \sigma_p (E_x) \sum_{E_x \geq E_{fi}} Pi(E_x)}$$

For $E_x > E_{fi}$, $Pi (E_x) = 1.0$

For $E_x < E_{fi}$, $Pi (E_x) \fallingdotseq \exp (-0.218|a-b|(\mu \Delta V_i)^{1/2})$, Tunnel Fission

$$\Delta V_i = E_{fi} - E_x$$

LEPF ⟹ Selective-Channel-Fission

(c.f. "Standard Model" ; 3 fission modes (Standard-1 , Standard-2 , Super Long))

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Top Ten Channels

Table : Top Ten Channels Opening First

Q Fission Barrier

(1) $^{104}Pd \rightarrow {}^{50}Ti + {}^{54}Cr$ +18.96MeV(E_f=11.36MeV)

(2) $^{102}Pd \rightarrow {}^{50}Ti + {}^{52}Cr$ +18.91MeV(E_f=11.60MeV)

(3) $^{105}Pd \rightarrow {}^{51}Ti(5.8m){}^{51}V + {}^{54}Cr$ +18.24MeV(E_f=11.98MeV)

(4) $^{105}Pd \rightarrow {}^{50}Ti + {}^{55}Cr(3.5m){}^{55}Mn$
+18.12MeV(E_f=12.11MeV)

< Gap!

(5) $^{102}Pd \rightarrow {}^{48}Ti + {}^{54}Cr$ +17.49MeV(E_f=13.03MeV)

(6) $^{106}Pd \rightarrow {}^{48}Ca + {}^{58}Fe$ +16.46MeV(E_f=13.23MeV)

(7) $^{106}Pd \rightarrow {}^{50}Ti + {}^{56}Cr(6m){}^{56}Mn(2.6h){}^{56}Fe$
+16.81MeV(E_f=13.32MeV)

(8) $^{108}Pd \rightarrow {}^{48}Ca + {}^{60}Fe(1.6x10^6y)$
+16.10MeV(E_f=13.42MeV)

(9) $^{106}Pd \rightarrow {}^{52}Ti(1.7m){}^{52}V(3.7m){}^{52}Cr + {}^{54}Cr$
+16.49MeV(E_f=13.63MeV)

(10) $^{105}Pd \rightarrow {}^{48}Ca + {}^{57}Fe$ +15.98MeV(E_f=13.81MeV)

Tier-2 Channels: for Pd LEPF

(11) $^{105}\mathrm{Pd} \rightarrow {}^{47}\mathrm{Ca}(4.5\mathrm{d}){}^{47}\mathrm{Sc}(3.3\mathrm{d})\underline{{}^{47}\mathrm{Ti}} + \underline{{}^{58}\mathrm{Fe}}$
$+ 16.07\mathrm{MeV}(E_f{=}13.72\mathrm{MeV})$

(12) $^{105}\mathrm{Pd} \rightarrow {}^{52}\mathrm{Ti}(1.7\mathrm{m}){}^{52}\mathrm{V}(3.7\mathrm{m})\underline{{}^{52}\mathrm{Cr}} + \underline{{}^{53}\mathrm{Cr}}$
$+ 16.33\mathrm{MeV}(E_f{=}13.89\mathrm{MeV})$

(13) $^{104}\mathrm{Pd} \rightarrow \underline{{}^{46}\mathrm{Ca}} + \underline{{}^{58}\mathrm{Fe}} + 15.89\mathrm{MeV}(E_f{=}14.01\mathrm{MeV})$

(14) $^{102}\mathrm{Pd} \rightarrow \underline{{}^{51}\mathrm{V}} + \underline{{}^{51}\mathrm{V}} + 16.47\mathrm{MeV}(E_f{=}14.10\mathrm{MeV})$

(15) $^{102}\mathrm{Pd} \rightarrow \underline{{}^{46}\mathrm{Ca}} + \underline{{}^{56}\mathrm{Fe}} + 15.81\mathrm{MeV}(E_f{=}14.27\mathrm{MeV})$

(16) $^{102}\mathrm{Pd} \rightarrow \underline{{}^{44}\mathrm{Ca}} + \underline{{}^{58}\mathrm{Fe}} + 15.69\mathrm{MeV}(E_f{=}14.42\mathrm{MeV})$

(17) $^{105}\mathrm{Pd} \rightarrow \underline{{}^{46}\mathrm{Ca}} + {}^{59}\mathrm{Fe}(44\mathrm{d})\underline{{}^{59}\mathrm{Co}} + 15.38\mathrm{MeV}(E_f{=}14.43\mathrm{MeV})$

(18) $^{104}\mathrm{Pd} \rightarrow \underline{{}^{48}\mathrm{Ca}} + \underline{{}^{56}\mathrm{Fe}} + 15.42\mathrm{MeV}(E_f{=}14.45\mathrm{MeV})$

(19) $^{110}\mathrm{Pd} \rightarrow \underline{{}^{48}\mathrm{Ca}} + {}^{62}\mathrm{Fe}(1.1\mathrm{m}){}^{62}\mathrm{Co}(14\mathrm{m})\underline{{}^{62}\mathrm{Ni}}$
$+ 14.76\mathrm{MeV}(E_f{=}14.59\mathrm{MeV})$

(20) $^{102}\mathrm{Pd} \rightarrow \underline{{}^{49}\mathrm{Ti}} + \underline{{}^{53}\mathrm{Cr}} + 15.91\mathrm{MeV}(E_f{=}14.60\mathrm{MeV})$

(21) $^{104}\mathrm{Pd} \rightarrow {}^{51}\mathrm{Ti}(5.8\mathrm{m})\underline{{}^{51}\mathrm{V}} + \underline{{}^{53}\mathrm{Cr}} + 15.62\mathrm{MeV}(E_f{=}14.70\mathrm{MeV})$

(22) $^{108}\mathrm{Pd} \rightarrow {}^{52}\mathrm{Ti}(1.7\mathrm{m}){}^{52}\mathrm{V}(3.7\mathrm{m})\underline{{}^{52}\mathrm{Cr}} + {}^{56}\mathrm{Cr}(6\mathrm{m}){}^{56}\mathrm{Mn}(2.6\mathrm{h})\underline{{}^{56}\mathrm{Fe}}$
$+ 15.23\mathrm{MeV}(E_f{=}14.71\mathrm{MeV})$

(23) $^{105}\mathrm{Pd} \rightarrow \underline{{}^{49}\mathrm{Ti}} + {}^{56}\mathrm{Cr}(6\mathrm{m}){}^{56}\mathrm{Mn}(2.6\mathrm{h})\underline{{}^{56}\mathrm{Fe}}$
$+ 15.43\mathrm{MeV}(E_f{=}14.80\mathrm{MeV})$

(24) $^{104}\mathrm{Pd} \rightarrow {}^{52}\mathrm{Ti}(1.7\mathrm{m})\underline{{}^{52}\mathrm{Cr}} + \underline{{}^{52}\mathrm{Cr}} + 15.49\mathrm{MeV}(E_f{=}14.83\mathrm{MeV})$

(25) $^{105}\mathrm{Pd} \rightarrow {}^{49}\mathrm{Sc}(57\mathrm{m})\underline{{}^{49}\mathrm{Ti}} + {}^{56}\mathrm{Mn}(2.6\mathrm{h})\underline{{}^{56}\mathrm{Fe}}$
$+ 15.04\mathrm{MeV}(E_f{=}15.02\mathrm{MeV})$

$\langle Gain \rangle = (Q+E_x)/E_x \approx (Q+E_f)/E_f \rightarrow 2.0$

(26) $^{106}\mathrm{Pd} \rightarrow \underline{{}^{46}\mathrm{Ca}} + \underline{{}^{60}\mathrm{Fe}(1.5\mathrm{x}10^{6}\mathrm{y})} + 14.64\mathrm{MeV}(E_f{=}15.09\mathrm{MeV})$

(27) $^{106}\mathrm{Pd} \rightarrow {}^{51}\mathrm{Ti}(5.8\mathrm{m})\underline{{}^{51}\mathrm{V}} + {}^{55}\mathrm{Cr}(3.5\mathrm{m})\underline{{}^{55}\mathrm{Mn}}$
$+ 14.93\mathrm{MeV}(E_f{=}15.20\mathrm{MeV})$

(28) $^{104}\mathrm{Pd} \rightarrow {}^{49}\mathrm{Sc}(57\mathrm{m})\underline{{}^{49}\mathrm{Ti}} + \underline{{}^{55}\mathrm{Mn}} + 14.87\mathrm{MeV}(E_f{=}15.29\mathrm{MeV})$

(29) $^{105}\mathrm{Pd} \rightarrow {}^{52}\mathrm{V}(3.7\mathrm{m})\underline{{}^{52}\mathrm{Cr}} + {}^{53}\mathrm{V}(1.6\mathrm{m})\underline{{}^{53}\mathrm{Cr}} + 14.87\mathrm{MeV}$

(30) $^{102}\mathrm{Pd} \rightarrow \underline{{}^{40}\mathrm{Ar}} + \underline{{}^{62}\mathrm{Ni}} + 13.86\mathrm{MeV}(E_f{=}15.42\mathrm{MeV})$

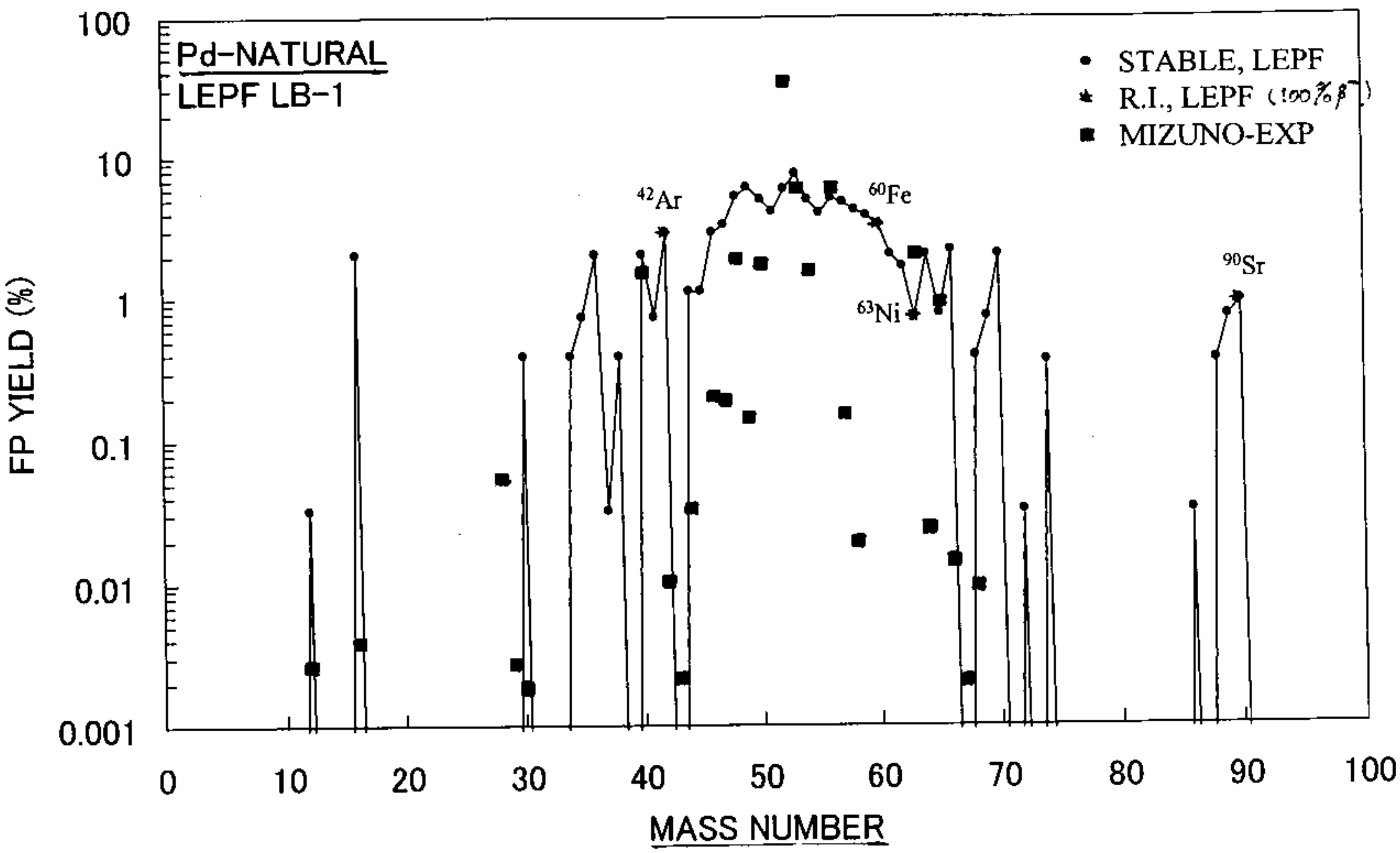

Fig.8 : FP mass-distribution by LEPF / LB1 model for Pd, compared with experiment by Mizuno.

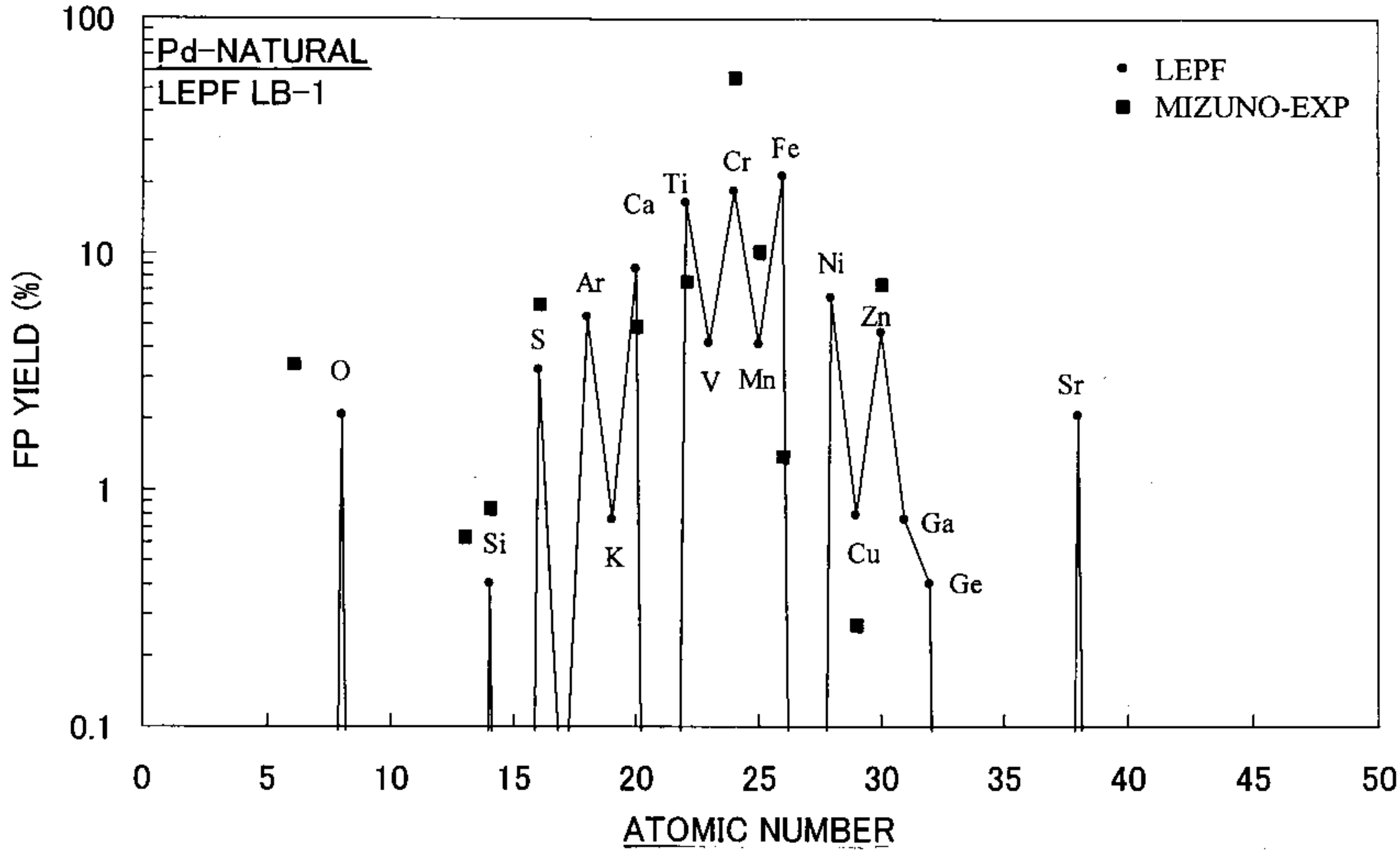

Fig.10 : Z-distribution by LEPF / LB1 model for Pd, compared with experimental data by Mizuno.

Table-7: Comparison of isotopic ratios between natural, Pd-LEPF / LB1 and experiments, for even-Z elements

Isotope		Natural (%)	LEPF / LB1 (%)	Exp (%)	(Mizuno)
Ca	-40	96.94	0.0	(45)	
	-42	0.647	0.0	0.6	
	-43	0.135	0.0	1.7	
	-44	2.086	17.6	41.1	
	-45*		17.6		
	-46	0.004	29.4	35	
	-48	0.187	35.3	25	
Ti	-46	8.25	0.0	15	
	-47	7.44	20.7	9	
	-48	73.72	13.8	10	
	-49	5.41	37.9	4	
	-50	5.18	27.6	62	
Cr	-50	4.345	0.0	3	
	-51*		3.1		
	-52	83.789	37.5	68	
	-53	9.501	34.4	16	
	-54	2.365	25.0	13	
Fe	-54	5.845	2.8 (3.3)*	13	
	-56	91.754	25.0 (30.0)*	64	45+
	-57	2.119	22.2 (26.7)*	16	41+
	-58	0.282	19.4 (23.3)*	7	14+
	-59*		13.9 (16.7)*		
Ni	-58	68.077	0.0		
	-60	26.223	0.0		
	-61	1.140	25.0		
	-62	3.634	33.3		
	-63*		8.3		
	-64	0.926	33.3		
Zn	-64	48.6	0.0	38	
	-66	27.9	44.4	18	
	-67	4.1	0.0	0	
	-68	18.8	22.2	12	
	-70	0.6	33.3	33	
Ge	-70	21.23	0.0		
	-72	27.66	50.0		
	-73	7.73	0.0		
	-74	35.94	50.0		
	-76	7.44	0.0		

*RI ≤ 0.02%   * exclude Fe-60   + Iwamura[4)]

*RI ~ 2%

Pd-natural

Fig.   : RI Products and their Decays by LEPF/SCF-LB2

(152 SCS chanels) = 304 FPs

c.f.

RI Product	Decay and Final Stable Isotope
Si-32	(100% β^-; 172y) ^{32}P
P-33	(100% β^-; 25.34d) ^{33}S
S-35	(100% β^-; 87.51d) ^{35}Cl
Ar-39	(100% β^-; 269y) ^{39}K
Ar-42	(100% β^-; 32.9y) ^{42}K
Ca-45	(100% β^-; 163.8d) ^{45}Sc
Sc-46	(99.9964% β^-; 83.7d)^{46}Ti(Ex=2009.8keV;1.6ps)^{46}Ti
V-49	(100% EC; 330d) ^{49}Ti
V-50	(83% EC; 1.4x10^{17}y) ^{50}Ti
Cr-51	(90.1% EC; 27.7d) ^{51}V, (9.9%EC)^{51}V(Ex=320keV)^{51}V
Mn-53	(100% EC; 3.7x10^{6}y) ^{53}Cr
Mn-54	(100% EC; 312.3d)^{54}Cr(Ex=834,8keV;7.9ps) ^{54}Cr
Fe-55	(100% EC; 2.73y) ^{55}Mn
Fe-59	(53.1% β^-; 44.5d)^{59}Co(Ex=1099.26keV;3.1ps) ^{59}Co, (45% β^-; 44.5d)^{59}Co(Ex=1291keV;551ps) ^{59}Co
Fe-60	(100% β^-; 1.5x10^{6}y)^{60}Co(RI)
Ni-63	(100% β^-; 100.1y) ^{63}Cu
Sr-89	(99.99% β^-; 50.53d) ^{89}Y
Sr-90	(100% β^-; 28.78y)^{90}Y(99.99% β^-;64.1h) ^{90}Zr

18 RIs

In LB2, 152 SCS-channels ⇒ 304 FPs

(Radio Active FPs 18 → 5 γ-emitters
Stable Isotopes 286) small yields

CONCLUSIONS

1) Multi-Photon Induced Fission (MPIF) for A>100 Nuclei was proposed.

2) Selective Channel Scission Model was proposed to Predict Fission Products Distributions

3) Model Analyses were done for U, Au, W and Pd.

4) Major Stable FP Elements were Obtained for Pd Isotopes. Calculated Mass- and Z-Distributions and Non-Natural Isotopic Data showed Qualitative Agreement with Electrolysis Experiments by Mizuno, Miley, and Iwamura.

5) The Model Calculation for U-235 + n Fission showed Reasonable Agreement with existing FP data with two mass peaks.

6) MPIF may be studied by;
   a) X-ray laser, b) Plasma Electrolysis

7) MPIF can be an idea for Clean Fission Energy and Transmutation of HLW.

8) Further Elaboration of Model is NEEDED.
   (Photon Sources & Excitation Process)