Clean Fusion and Fission

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Civilization and Energy Problem

Source	Resource (Q)	Pollution	Power Density	Plant Size	Locality	Capital	Reality
Solar Cell	Infinite	Large surface	Weak	Small	Yes	Large	Yes
Wind/ Hydro	Infinite	Large surface	Small	Mod	Yes	Mod	Yes
Oil/Gas	60	CO_2,	Moderate	Mod	Yes	Mod	Yes
Coal	200	SOx NOx				Large	
Fission		LLFP	Large	Large	Mod	Large	
LWR	50	MA					Yes
FBR	300	Accident					?
Fusion	300	LLFP	Large	LL	Mod	LL	?
Cold Fusion	Infinite	Clean	Large	Small	None	Small	?????

Fusion of Hydrogen Isotopes

- $H + H \longrightarrow D + \beta^{+} + \nu$: Weak Interaction, Star
- $H + D \longrightarrow {}^{3}He + \gamma + 5.5\ MeV$ **: Star**
- $D + D \longrightarrow {}^{4}He + \gamma + 23.8MeV$; 10^{-5} %
  $\longrightarrow p + t + 4.02MeV$; 50 %
  $\longrightarrow n + {}^{3}He + 3.25MeV$; 50 %
- $D + T \longrightarrow n + {}^{4}He + 17.6MeV$: hot fusion
- D + Li, P + Li, P + B, etc.

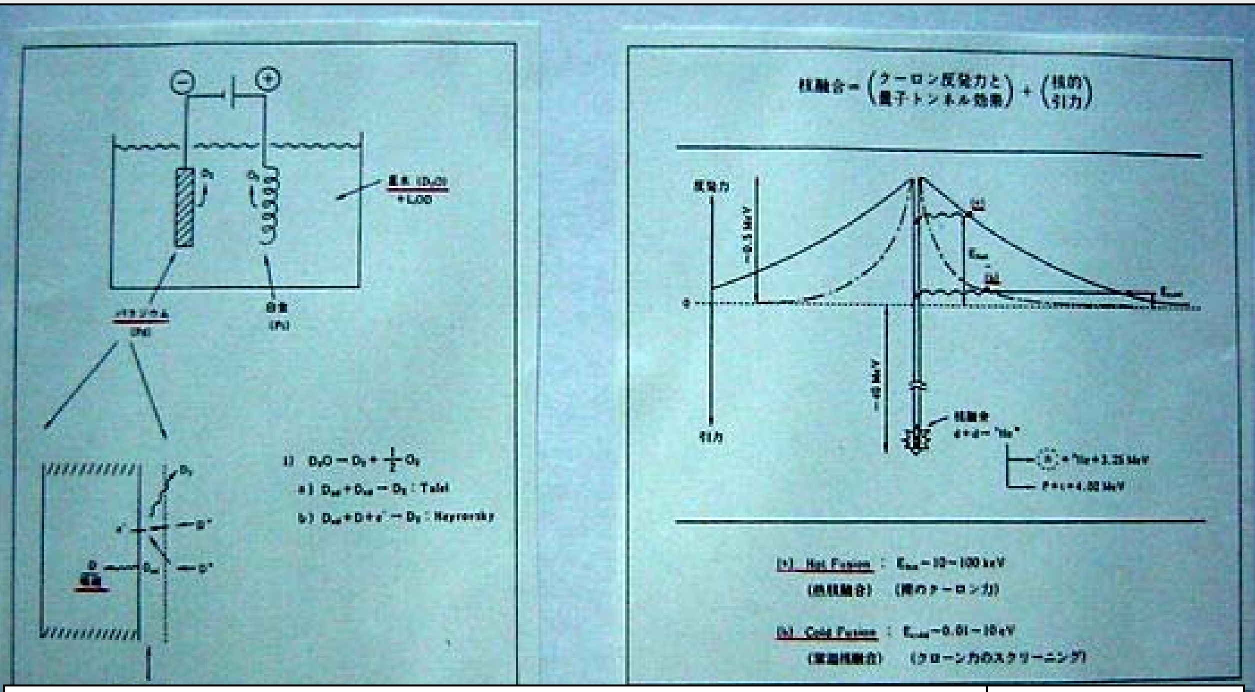
Major Experimental Results of CF Research suggest us

- “COLD FUSION” of known fusion reactions by hydrogen isotopes is NOT the Case.

- We should consider NEW NUCLEAR REACTIONS in Condensed Matter.

Fusion by D_2OElectrolysis ?
Fleischmann-Pons (1989)

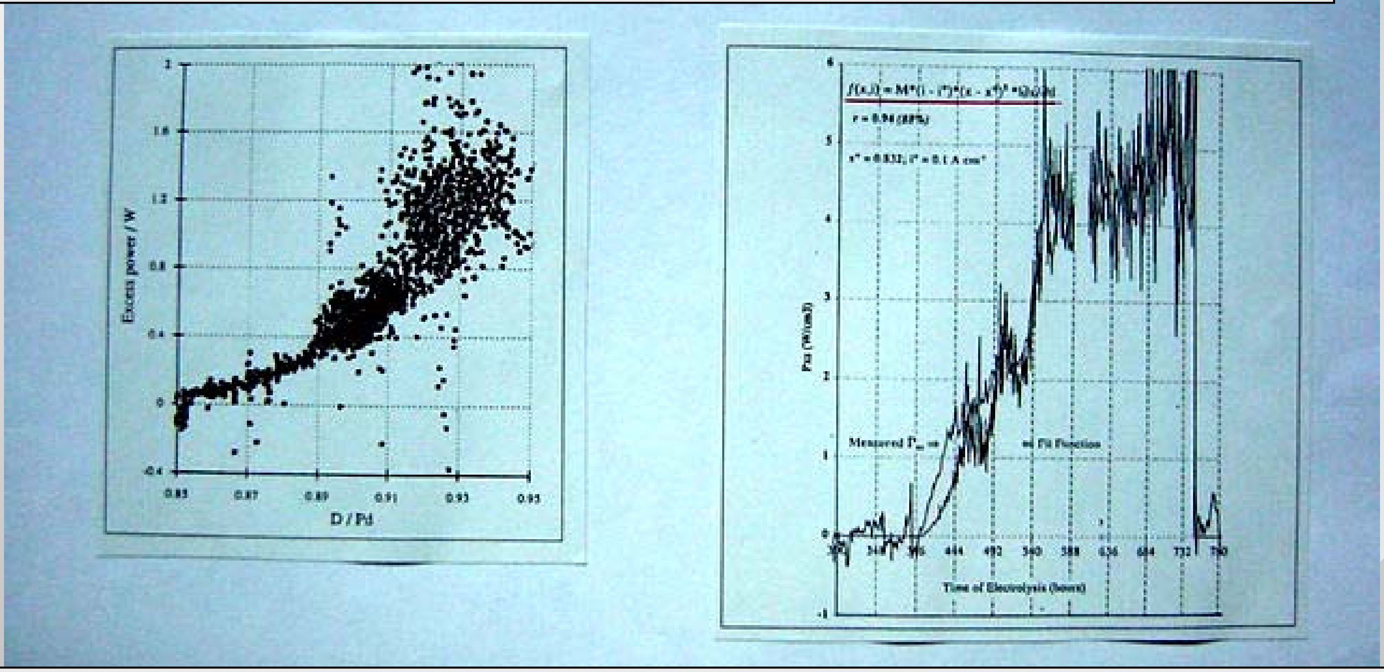
Excess Heat, without neutrons



$D + D \rightarrow n + {}^3He + 3.25$ MeV $D + D \rightarrow p + t + 4.02$ MeV	?

Excess Heat; McKubre, SRI (1992-2003)

100 % reproducible for D/Pd = 1



[Excess Heat] depends on current density , D/Pd ratio and D-flux

Weak Neutron Emission, A.Takahashi, Osaka U.: JNST, 27 (1990)663

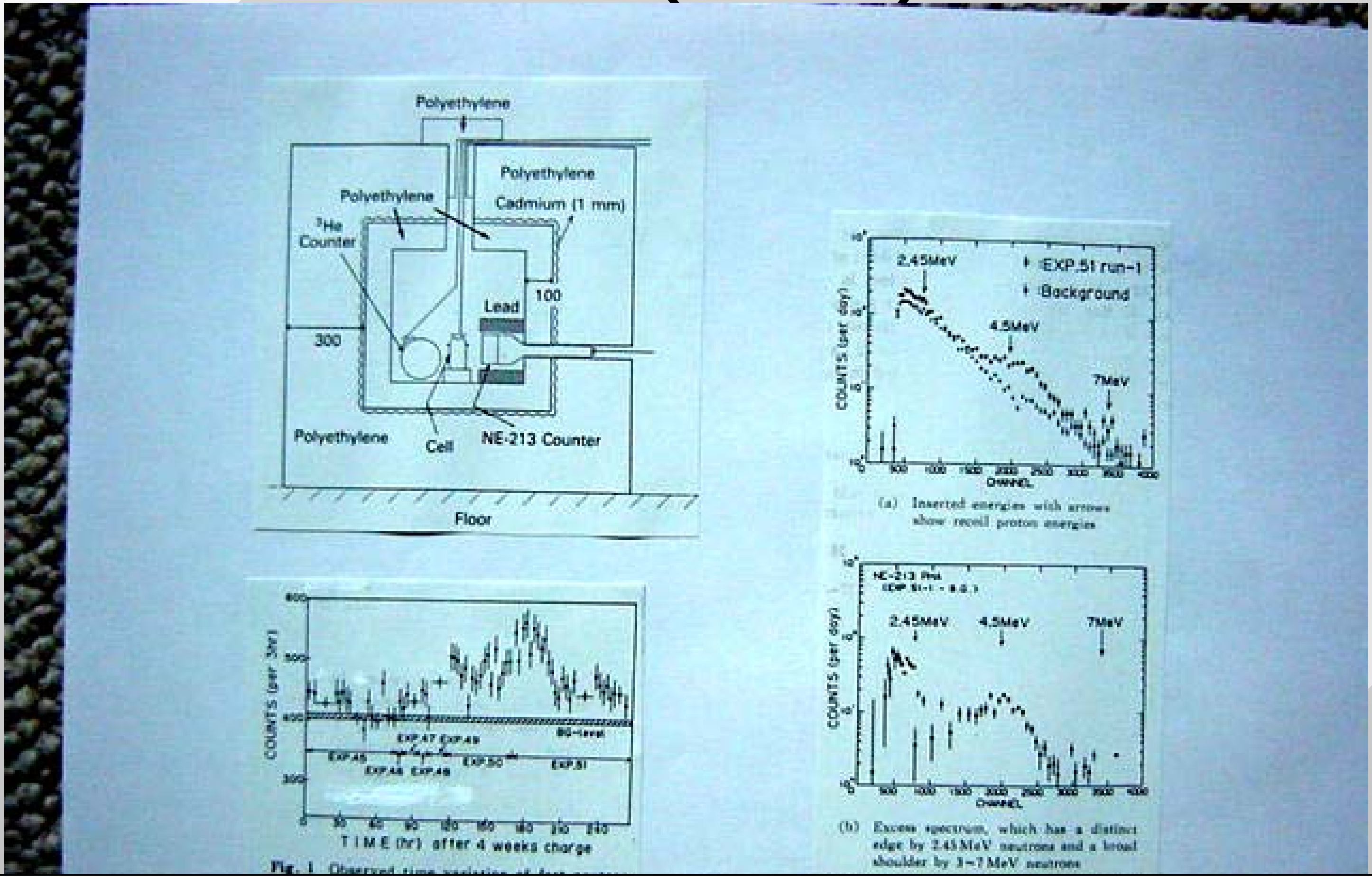


Fig. 1 Observed time variation of fast neutron

(a) Inserted energies with arrows show recoil proton energies

(b) Excess spectrum, which has a distinct edge by 2.45MeV neutrons and a broad shoulder by 3~7MeV neutrons

Recent n-emission data by Jones, and Mizuno (2004)

NEWSWEEK October 15,2001

A believer: *Takahashi says if he doesn't get good results in two years, he'll retire*

SCIENCE

Pining for a Breakthrough

Despite years of ostracism, a small and dwindling army of cold-fusion faithful are ever hopeful

BY GREGORY BEALS

TWELVE YEARS AGO RESEARCHers at the University of Utah claimed to have found a cheap and easy way of producing energy from

that fusion energy can really be harnessed on a tabletop.

The idea of cold fusion is so elegant and appealing that it's difficult for many to resist. Fusion reactions occur when two hydrogen

with chemicals, and you've got fusion without the need for so much as a Bunsen burner.

To many researchers, the upside is so large—limitless, cheap energy—that it may be obscuring their objectivity. "Because of the potentially high payoff, there are certainly people who are willing to cling to their belief in cold fusion even though the evidence is to the contrary," says Al Teich of the American Association for the Advancement of Science. "Once you commit yourself to an idea, it's hard to give it up." Many researchers relish the role of outsider. "You can either work maintaining the edifice of scientific understanding or you can simply ask questions of the universe," says physicist Eiichi Yamaguchi, a fellow at the 21st Century Public Policy Institute in Tokyo. "Researching cold fusion makes me feel a lot like Galileo." And since cold fusionists have claimed only to have produced minute amounts of energy, they can rationalize their ambiguous results by reflecting that many valid experiments also ride on tiny measurements.

Cold fusionists pay a price for this stubbornness. Akito Takahashi, a physicist at Osaka University, has spent more than a decade on cold fusion. Now he has trouble getting research money and attracting graduate students. "Other professors attack me from various sides," he says. "Sometimes they call me directly and tell me to immediately stop my cold-fusion work." Akito Yamaguchi has had funding [illegible]ed down. Japan's Ministry of [illegible]ade [illegible] cold fusion in 1998. Finding peers

After Miles, Arata, McKubre, De Ninno,

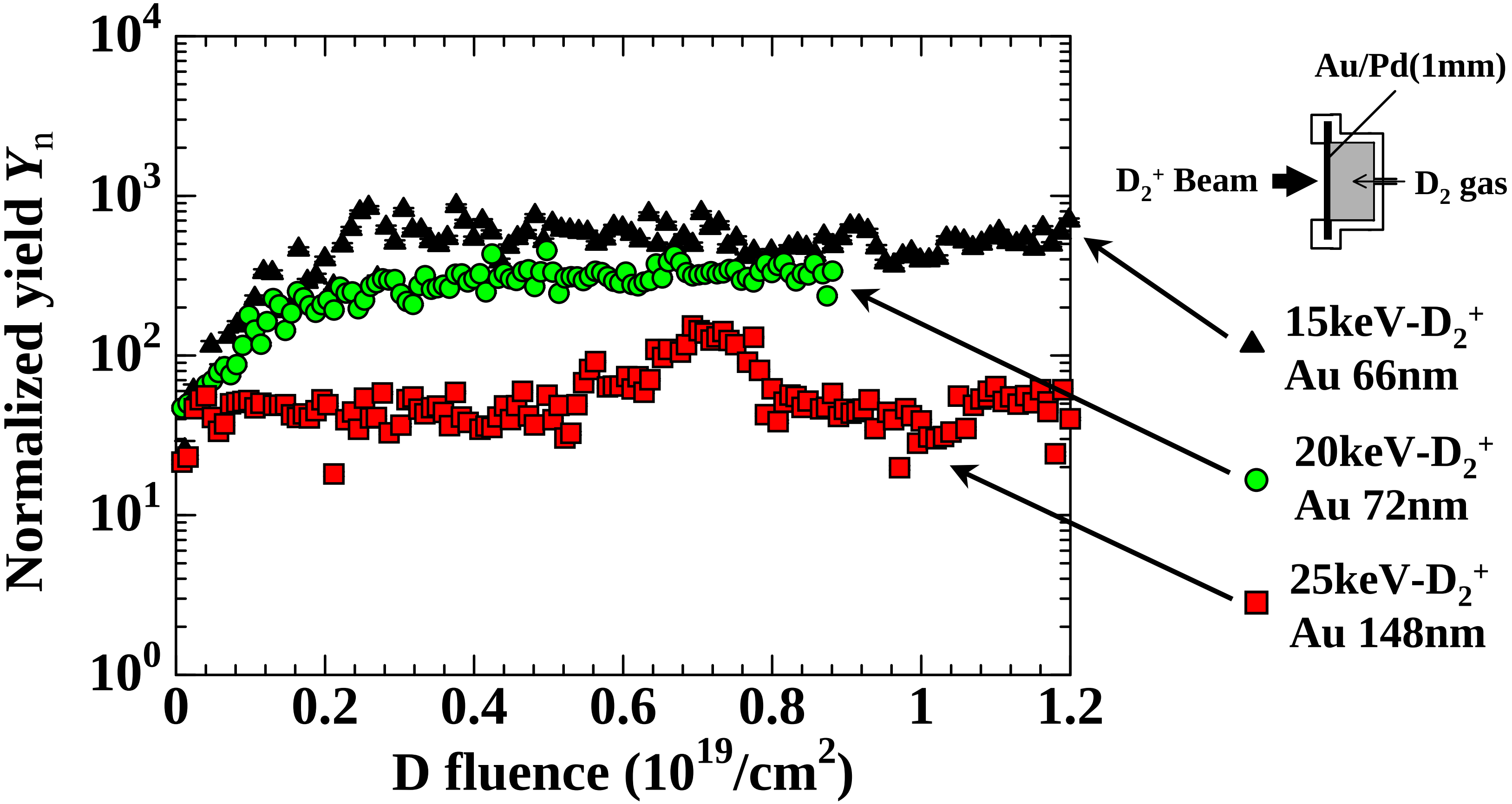
^{4}He was Detected; Isobe, et al.
Osaka U. : JJAP, 41(2002)1546

Cross sectional view of the electrolysis cell

He-4 is Ash !

Au/Pd試料へのD_2^+照射

A Kitamura et al Kobe U



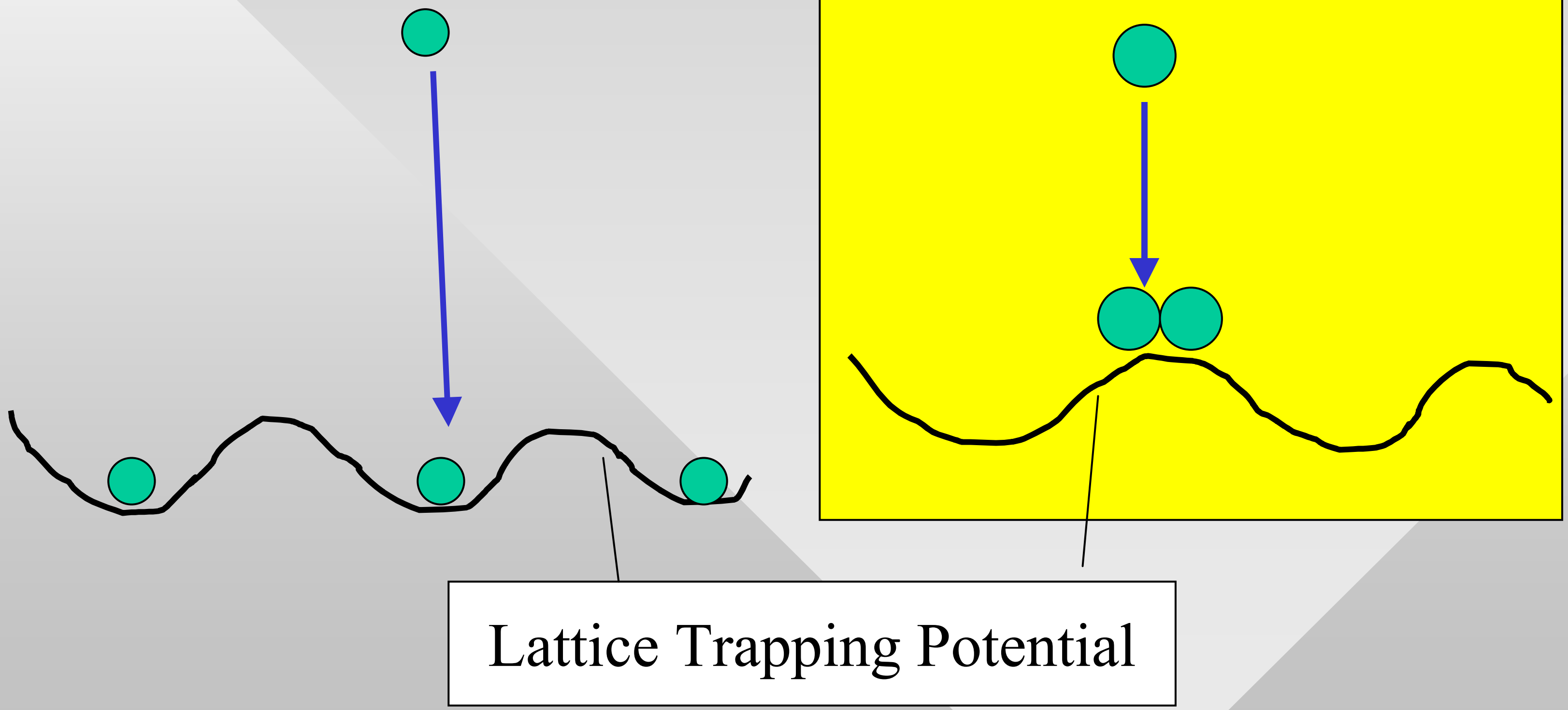
Comparison of Y_n obtained under 15, 20, and 25 keV-D_2^+ irradiation of Au/PdD_x samples.

- More than 500 times enhancement of dd fusion

D-Beam Enhances 3D-Fusion if CF DD Fusion is Stimulated

- Without Stimulation results in 2D fusion

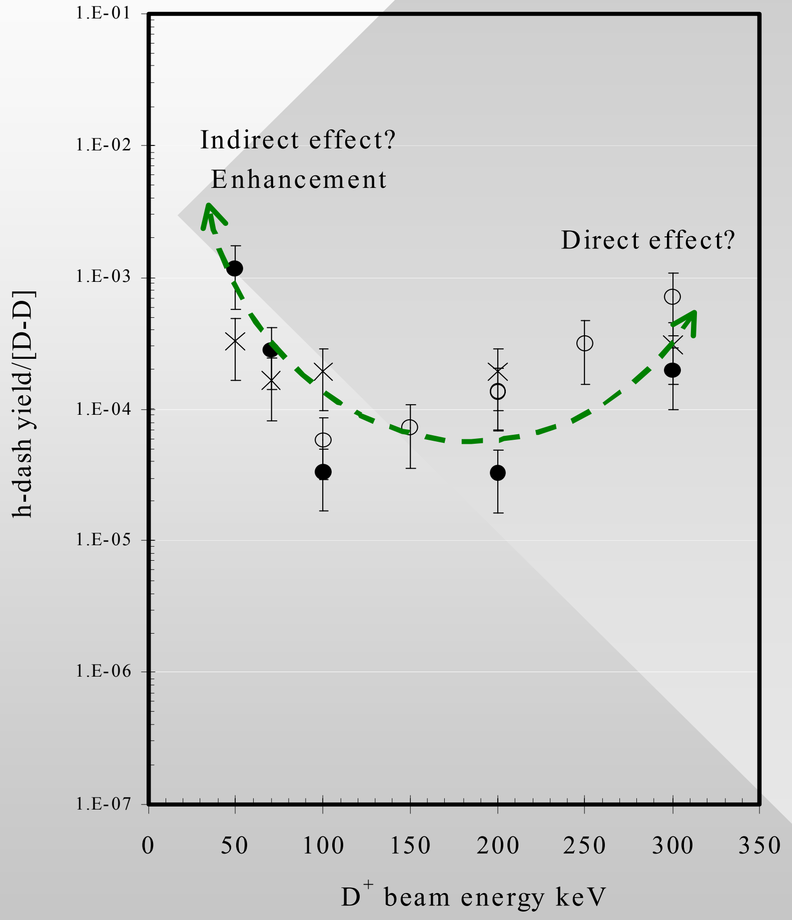
With Stimulation enhances 3D Fusion Rate



Lattice Trapping Potential

A. Takahashi, et al., ICCF10, 2003

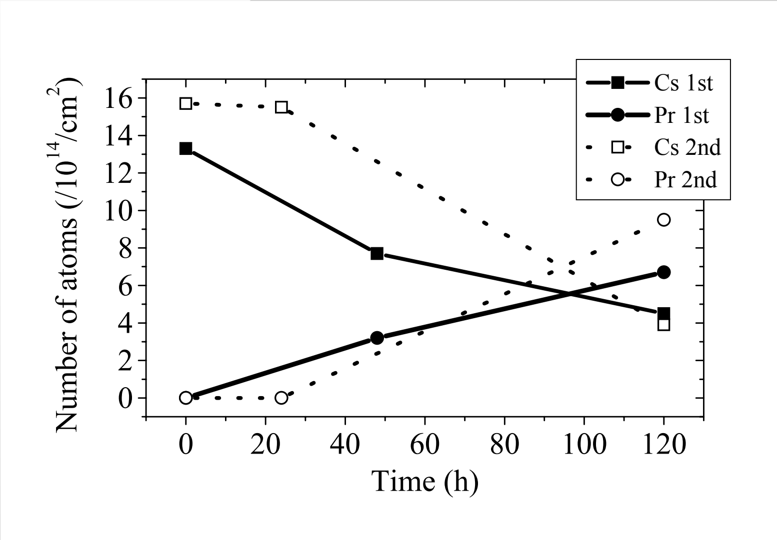
D-Beam Energy Dependence of [3D]/[2D] Ratios

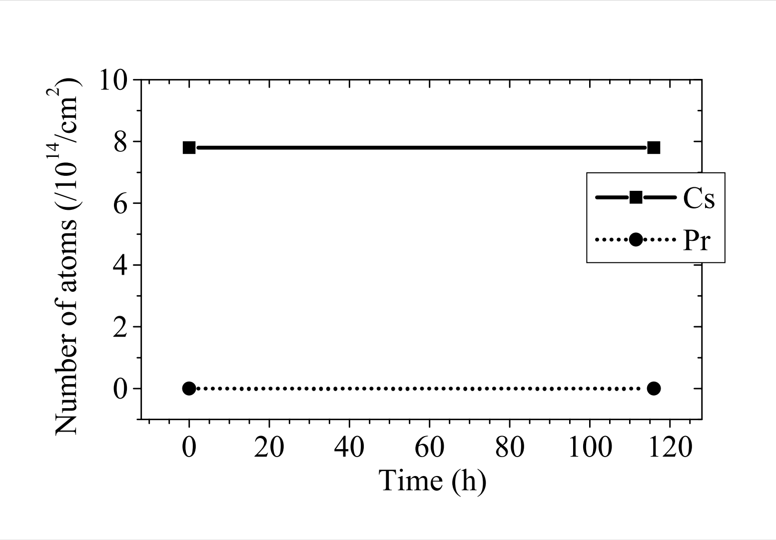


- [3D]/[2D] Yield Ratios by Experiment are in the order of 1E-4 to 1E-3.
- Increasing trend in lower energy region than 100 keV may result in indirect 3D reactions.
- Theoretical values by the conventional Random Nuclear Reaction Theory has given [3D]/[2D] ratio to be in the order of 1E-30
- Experiment shows 1E+26 anomalous enhancement.

Anomalous enhancement of DDD fusion was confirmed

Selective Transmutation by Iwamura et al. (MHI): JJAP, 41(2002)4642





D permeation through Pd complex

^{133}Cs to ^{141}Pr

H permeation through Pd complex

NO CHANGE

- Reproduced at Osaka U., and many times at MHI

Major Claims by Experiments

1) **Excess Heat with ^{4}He Generation**

Miles, Arata, McKubre, Gozzi, Isobe •De Ninno, Celani

2) **Very Weak Neutrons Generation**

Takahashi, Jones, and so on •Mizuno

3) **Anomalous Enhancement of D-Fusion**

Kitamura, Kasagi, Takahashi, •Huke

4) Selective Transmutations

Iwamura, Mizuno, Miley, Ohmori, •Celani

Is Reproducibility Improved?

- **Excess Heat**:

100% by D/Pd ratio GE. 1.0

- **Nuclear Products**:

By nano-scale modification of Pd surface,

nano-particle,

stimulation with Laser, Ultra-Sonic,

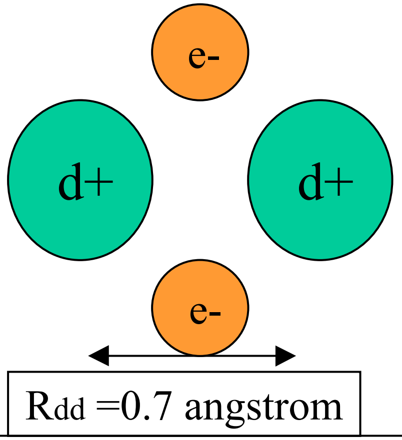
Plasma-Discharge, etc.

Problems in Theorization

- How to construct a Consistent Theory which can explain anomalous results (heat with ^{4}He, scarce neutrons, selective transmutation) systematically.
- New Theory must be compatible to already established physics.

Theoretical Modeling

- **Possible Mechanism to Exceed;**
- **$\lambda_{dd} = 10^{-60}$ f/s/cc**
- **for D_2 Molecule**



- **How is the condition**
- **R_{dd} << 0.7 angstrom possible to enhance λ_{dd} ?**
- **cf: 1 watt = 10^{12} (f/s/cc) for d-d reaction**
- **R_{dd} = 2 angstrom for PdD ground state**

Possibility of Super-Screening of Coulomb Barrier is looked for

- Transient or Dynamic Conditions in PdDx
- Overcome Thomas-Fermi gas limitation for Coulomb screening by electrons
- Transient "Bosonization" (Quasi-Particle State) of electrons to play a role for Super Screening
- Lattice Focal Points; sites, deffects,

D + D → He–4 + lattice energy(23.8MeV) by the QED energy transfer from nuclear excited state (He–4*: 23.8MeV) to lattice phonons.

IS NOT POSSIBLE !

Arata-Fujita-Zhang used 5nm diam. Pd nano-crystals which contained about 8,000 Pd-atoms per a nano-Pd-particle.

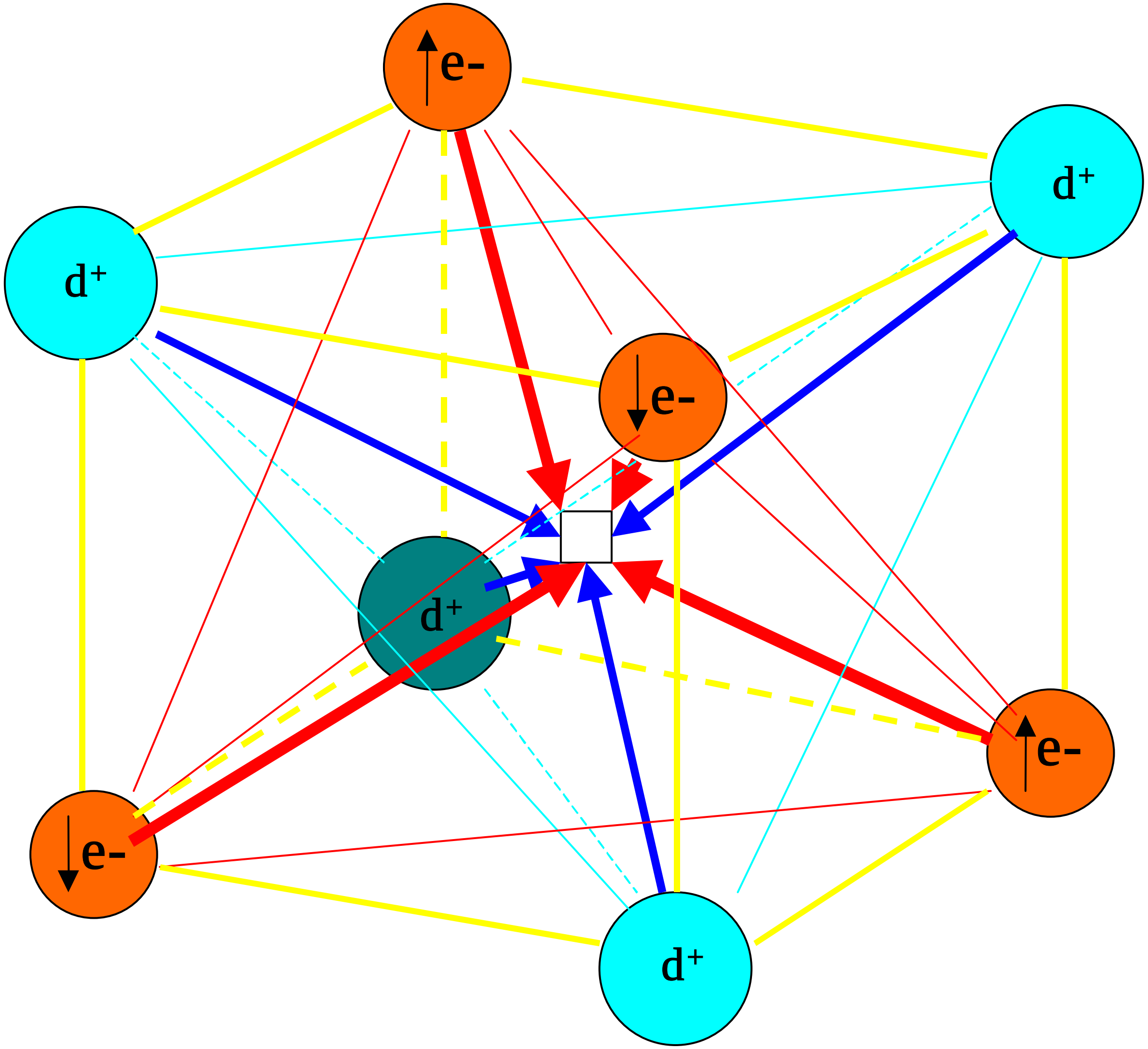
If 23.8MeV nuclear excited energy of He-4* were transferred to share in lattice phonons of a nano-particle, each Pd-atom in a nano-particle of Pd should have had about 3 keV phonon (lattice vibration) energy, which was 100 times greater than Pd-atom-displacement energy(20-40 eV) from lattice.

There are of course no such high energy phonons in lattice vibrations. Over the displacement energy, all lattice atoms are evaporated and solid state-physics does not make sense there. To receive 23.8MeVenergy by lattice phonons of coherent domain, we need more than one-million (1000,000) lattice atoms which make crystal size greater than 30 nm in diameter (or 25x25x25 nm cubic).

This means that the presumed QED energy transfer from nuclear to lattice was impossible in the condition of Arata-Fujita's experiment.

Classical View of Tetrahedral Symmetric Condensation (TSC)

Orthogonal coupling of two D_2 molecules makes miracle !



Transient Combination of Two D2 Molecules (upper and lower)

Squeezing From O-Sites to T-site

3-dimension Frozen State for 4d+s and 4e-s

Quadruplet e* (4,4)

Formation of Electrons around T-site

Basic Mechanism will be:

- **Tetrahedral Symmetric Condensation (TSC):**

  4 deuterons + 4 electrons make a transient

  Bose-type condensation by 3-dimensionaly

  constraint squeezing motion

- **Octahedral Symmetric Condensation (OSC):**

  for 8 deuterons + 8 electrons, also possible

The Place where TSC is born?

1) In Natural Gas-Phase of D_2 (H_2): Very small probability for two D_2(H_2) molecules to make orthogonally coupled state.

→ Possible at very low temperature?

(Bose-Einstein Condensation)

2) In Surface-Lattice conditions: O(T)-Sites, Defect/Void, Fractal-surface(adatom +dimer + corner-hole)

→ (Dynamic Bose Condensation of TSC)

Speculated Mechanism-1:

1) D-Cluster Resonance Fusion in Lattice and Products

- **a) 23.8 MeV ^{4}He-Particles** by 4D Fusion
- **b) 47.6 MeV ^{8}Be-Particles** by 8D fusion

2) Transmutation by Secondary Reactions

2-1) $M(A,Z) + {}^{4}He \longrightarrow M(A+4,Z+2)$, Fission, etc.

2-2) $M(A,Z) + {}^{8}Be \longrightarrow M(A+8,Z+4)$, Fission, etc.

Speculated Mechanism-2 :

a) Selected Channel Fission Model

Model Check by ^{235}U + n Fission
Application to A<200 Nuclei
Pd, W, Au

b) Estimation for Fission Products

Mass Distribution
Element Distribution
Isotopic Ratios
Radioactivity
: Comparison with Claimed Experimental CF Data

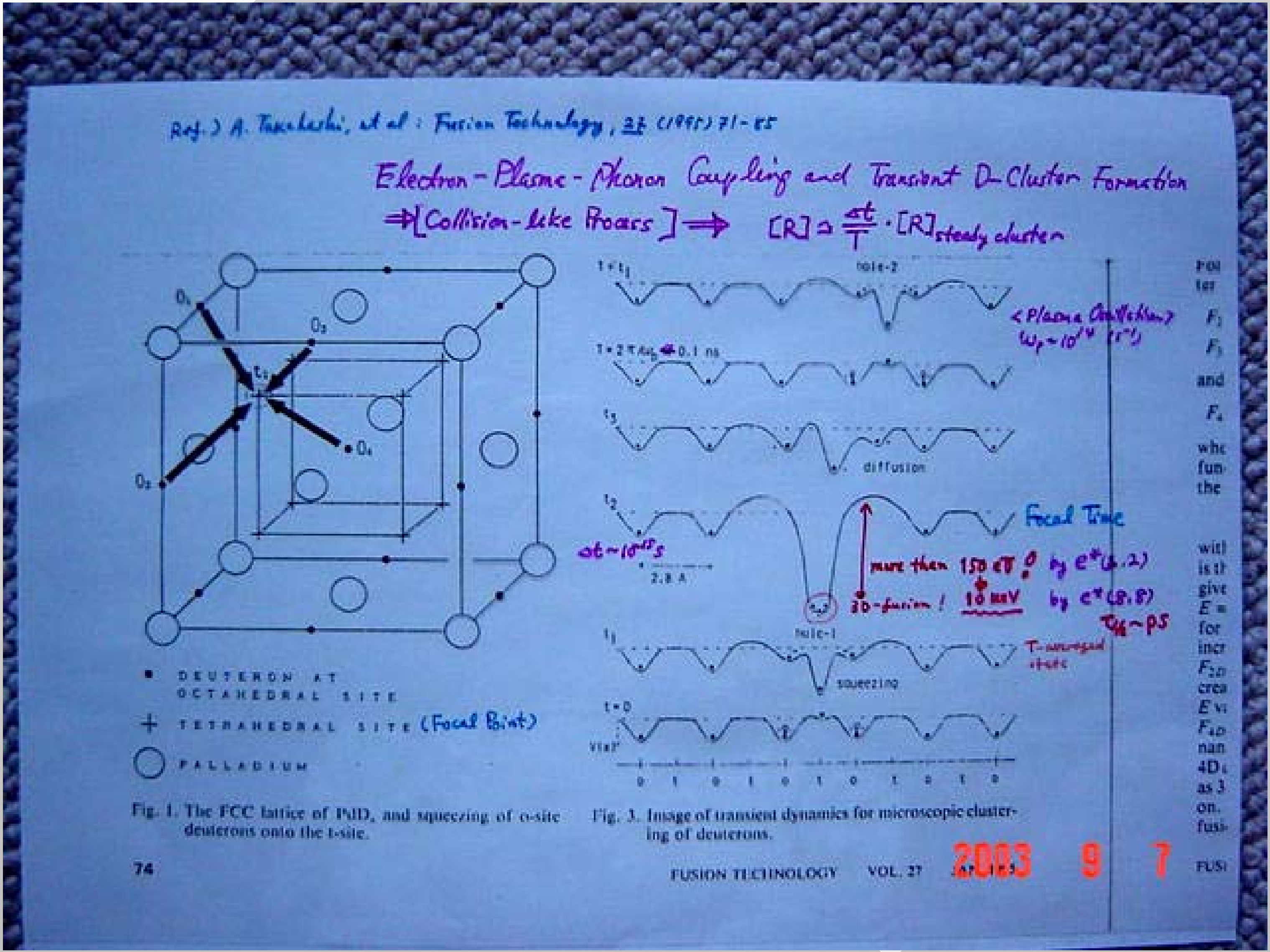
OUTLINE-1 : D-Cluster Fusion

Transient D-Cluster Condensation in PdDx Lattice

Transient Quasi-Particle State of Electrons (e*) and DDe* State Potentials to Realize Super-Screening for Fusion

Resonance Multi-Body Fusion: 3D, 4D, 8D to Produce ^{4}He and Mass-8 & Charge-4 Increased Transmutation

D-Cluster Formation in PdD Transient Dynamics by Phonon Excitation



Ref.) A. Takahashi, et al : Fusion Technology, 27 (1995) 71-85

Electron - Plasma - Phonon Coupling and Transient D-Cluster Formation

⇒[Collision-like Process] ⇒ $[R] \simeq \frac{\Delta t}{T} \cdot [R]_{\text{steady cluster}}$

● DEUTERON AT OCTAHEDRAL SITE

+ TETRAHEDRAL SITE (Focal Point)

○ PALLADIUM

Fig. 1. The FCC lattice of PdD, and squeezing of o-site deuterons onto the t-site.

Fig. 3. Image of transient dynamics for microscopic clustering of deuterons.

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Phonon Excitation by Laser

- Dielectric Response Function of Metal:
- (Classical Drude-Model for free electron gas)
- $\varepsilon(\omega) = 1-(\omega_p \tau)^2/(1+(\omega\tau)^2)$
- $\approx 1-(\omega_p/\omega)^2$
- with $\omega_p = (4\pi Ne^2/m)^{1/2}$: plasma frequency
- which is over UV region (1E+15 (1/s))
- 100 % penetration by $\omega > \omega_p$

•EUV-Laser irradiation can excite phonons inside bulk metal!

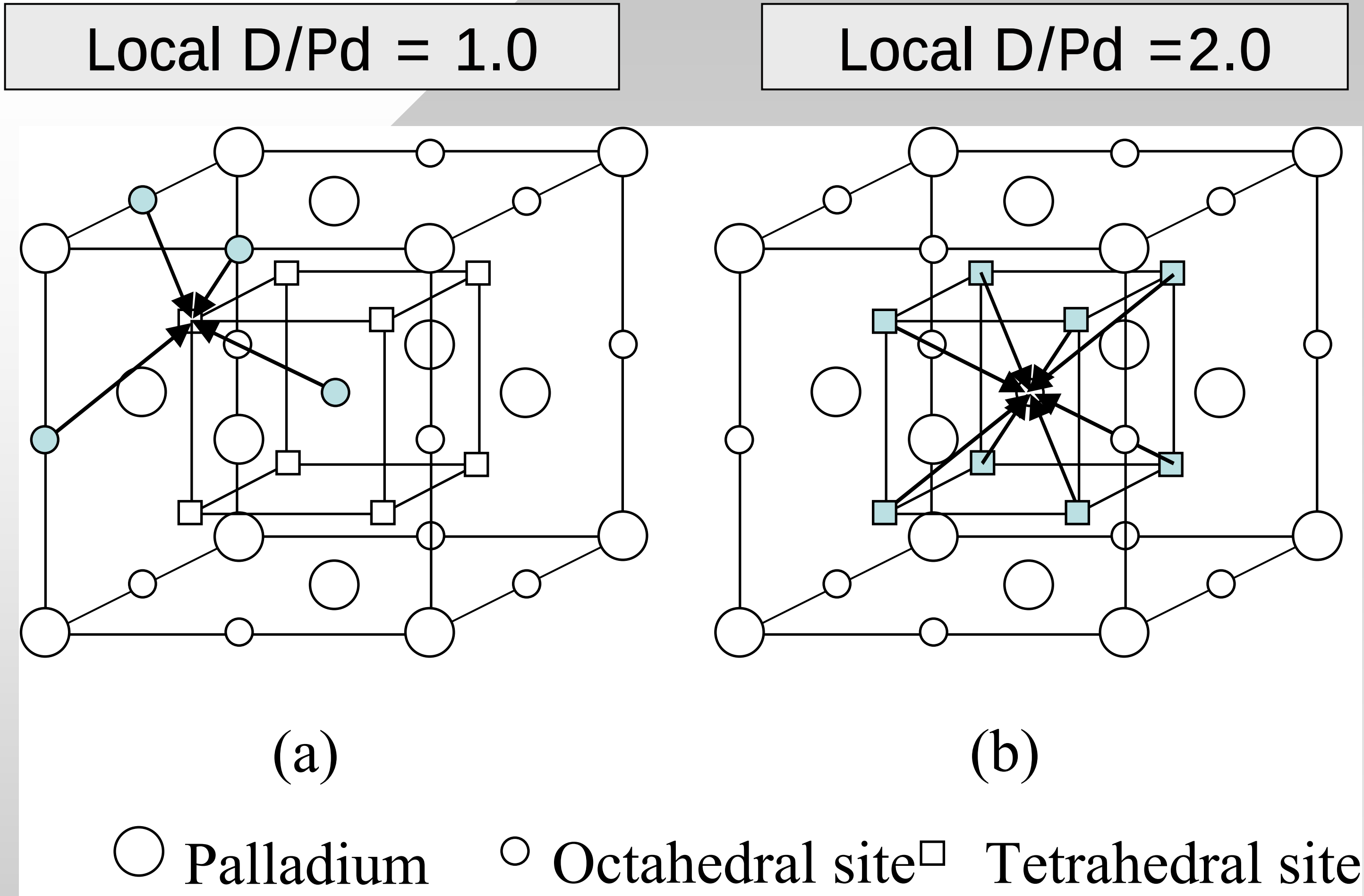
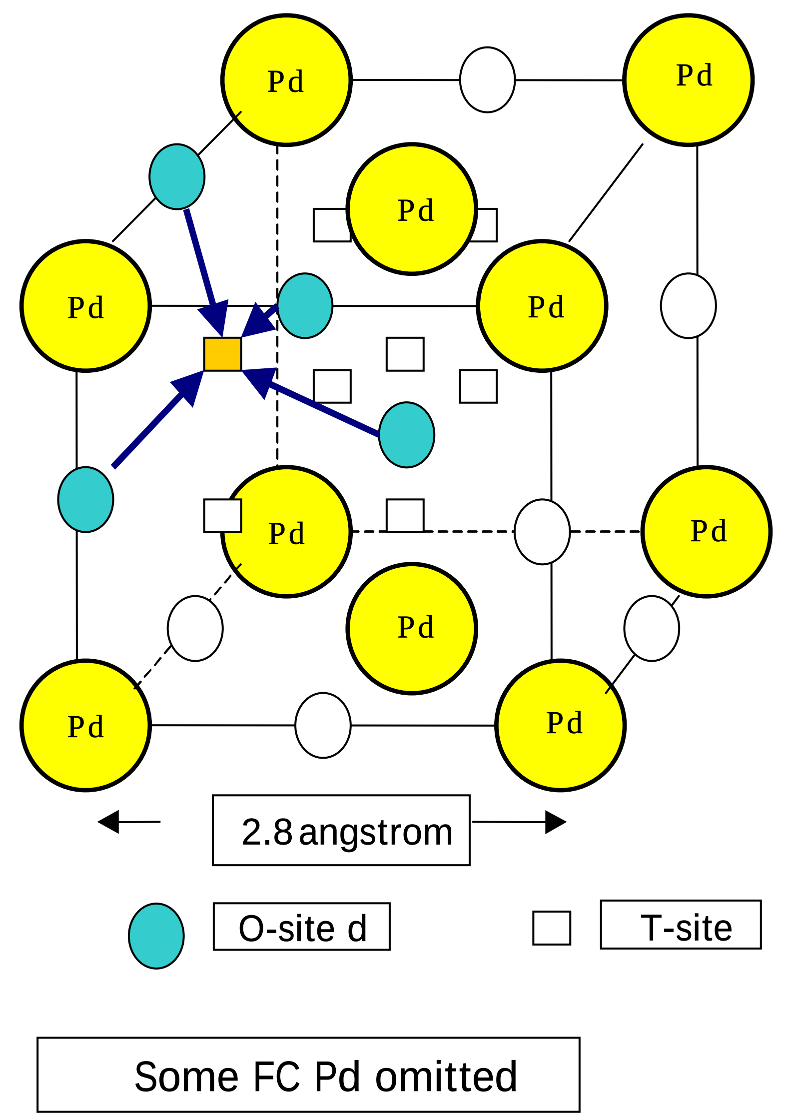


Fig. 3-1: 4D and 8D Fusions in Pd lattice

Tetrahedral Condensation of D-Cluster



Transient Bose Condensation of Deuterons

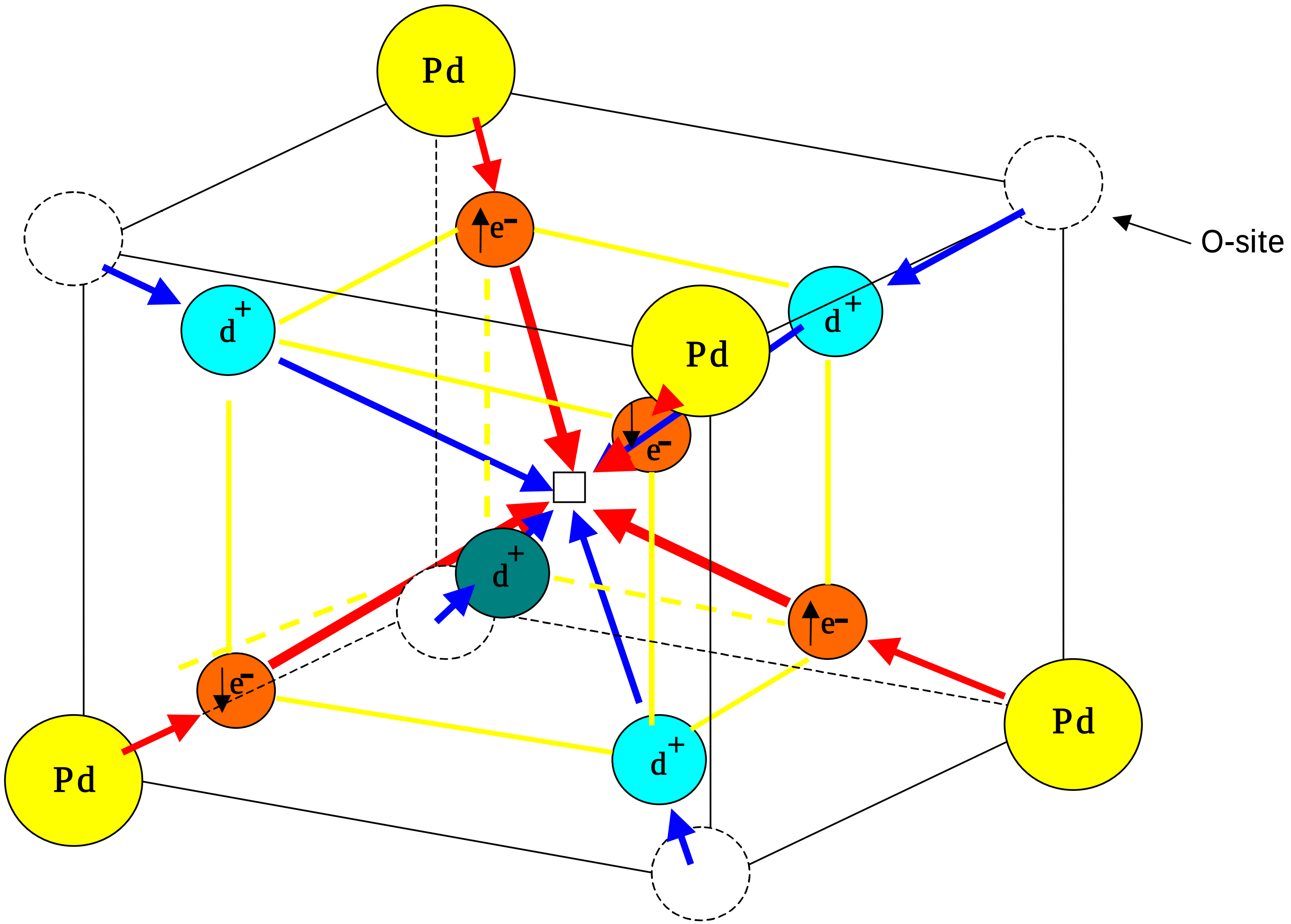
From O-site to T-site

Associating Transient Squeezing (Bosonozation) of 4d-shell Electrons

Generation of Short-Life Quasi-Particle e* like Cooper-pair

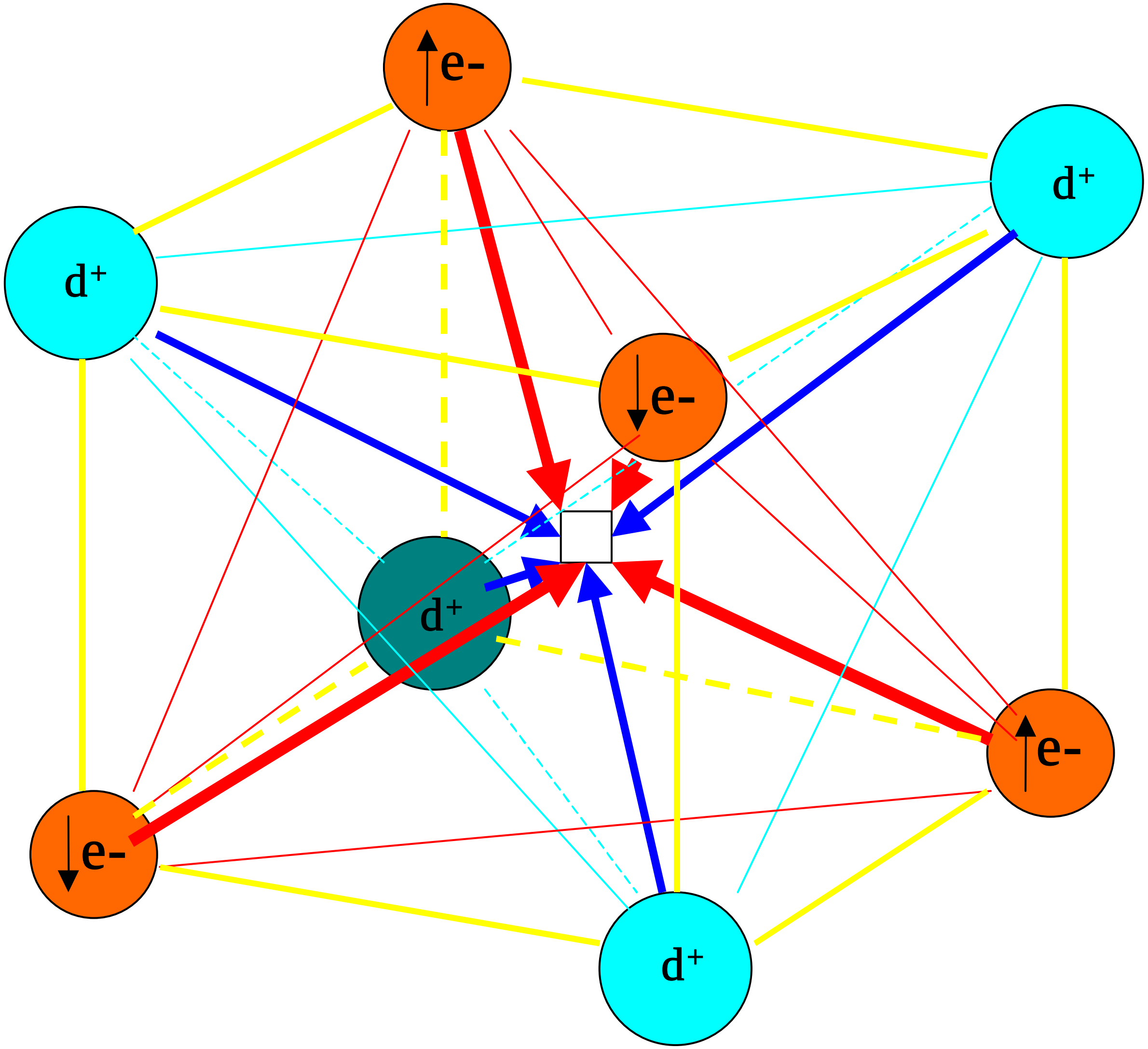
D-Cluster as Mixture of DDe, DDee, DDe*,DDe*e*

Tetrahedral Condensation of Deuterons in PdDx



Classical View of Tetrahedral Condensation

Orthogonal coupling of two D_2 molecules makes miracle !



Transient Combination of Two D2 Molecules (upper and lower)

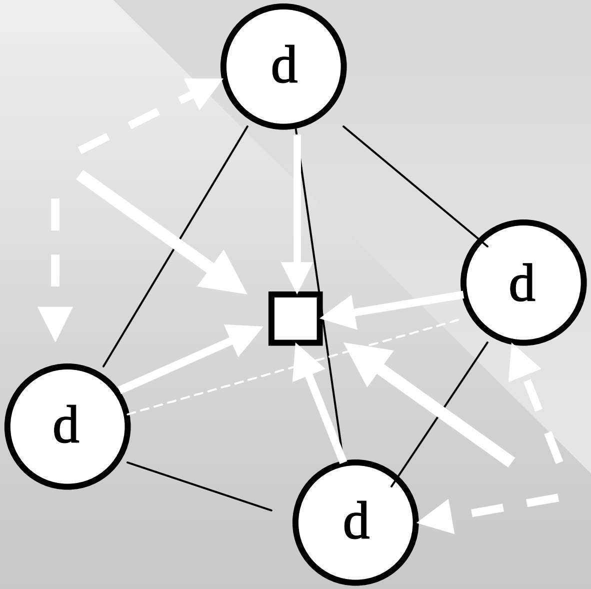
Squeezing From O-Sites to T-site

3-dimension Frozen State for 4d+s and 4e-s

Quadruplet e* (4,4)

Formation of Electrons around T-site

Transform from 3-dim to 2-dim for TCC

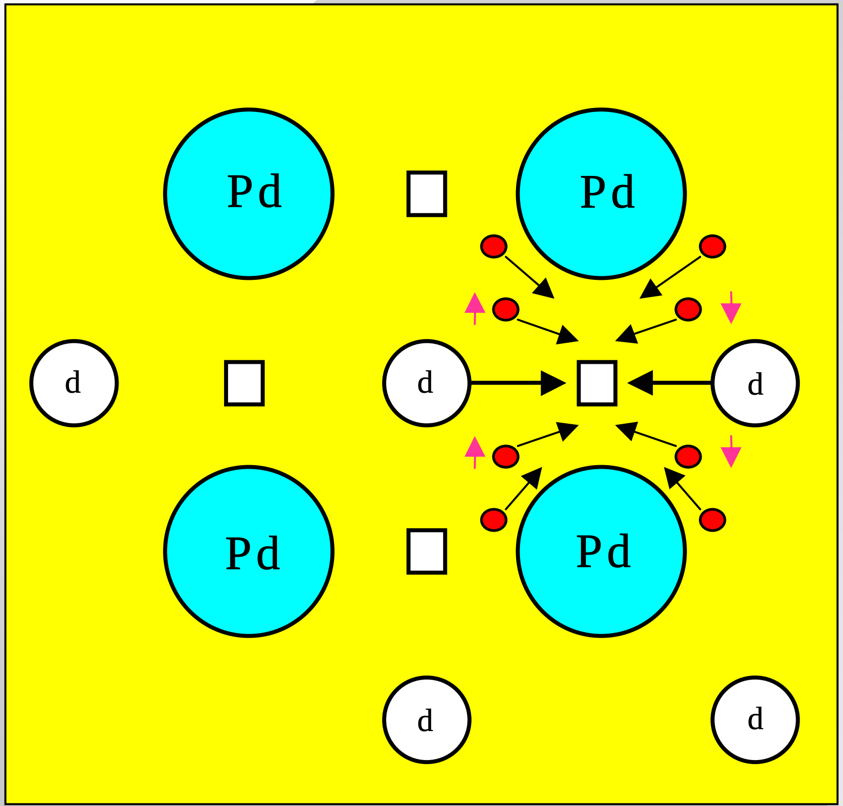


IN Tetrahedral "coherent" Condensation (TCC),

Sum Momentum Vectors (red) for two deuterons become mirror-symmetric in each other on a line,

So that 3-dim TCC is transformed to 2-dim squeezing problem

Two-Dimensional View of Transient D-Condensation



Lattice Phonon + Plasmon ($d^+ + e^-$)

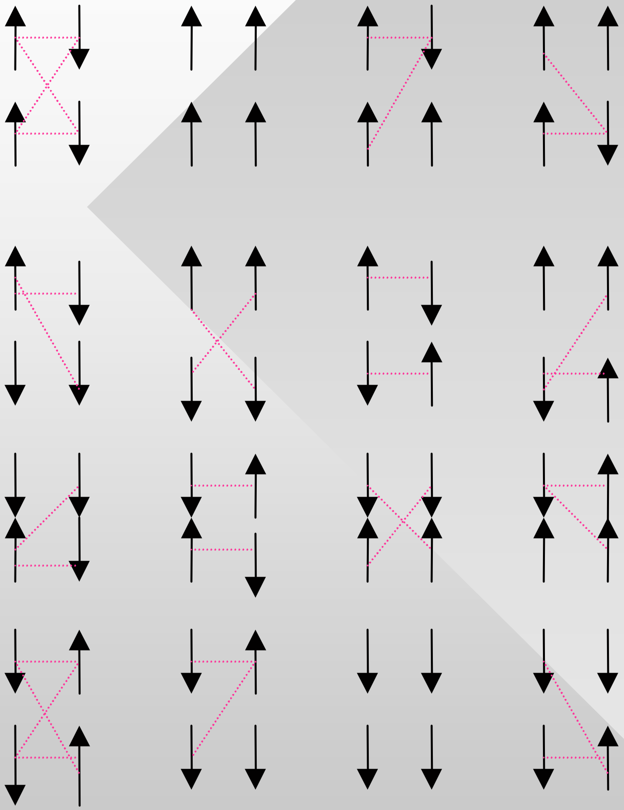
Generation of e* by Transient Pairing of Electrons (k↑, -k↓)

Overcome Femi-Gas Limitation (Pauli exclusion) for d-d screening

Superposition of dde, ddee, dde* and dde*e*

Transient Molecular States

Combination Probability for TEQP Generation



Broken lines show pairing of spin-and-momentum-reversed electrons in Tetrahedral Coherent Condensation

<Cooper Pair>

= 12/16

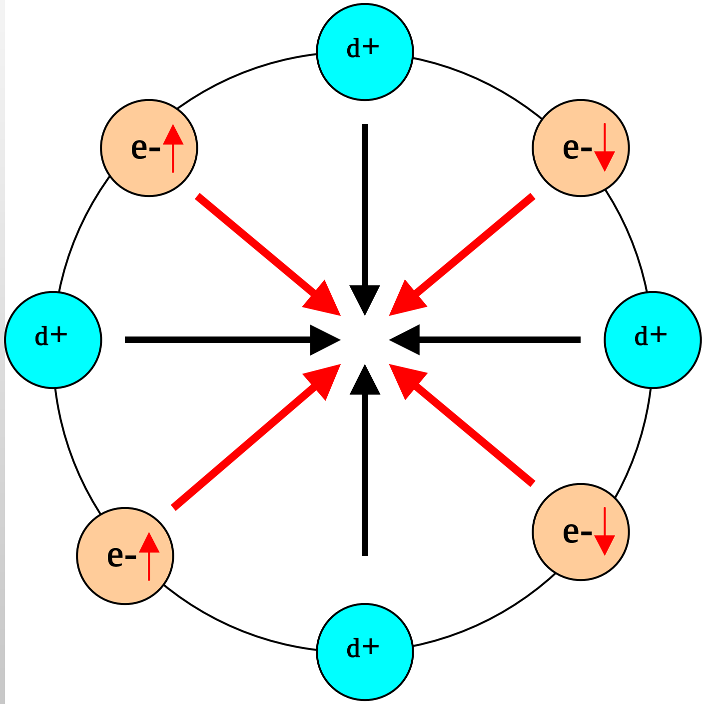
< Quadru Coupling>

= 2/16

<No Pair> = 2/16

2-dimensional View of Tetrahedral Condensation

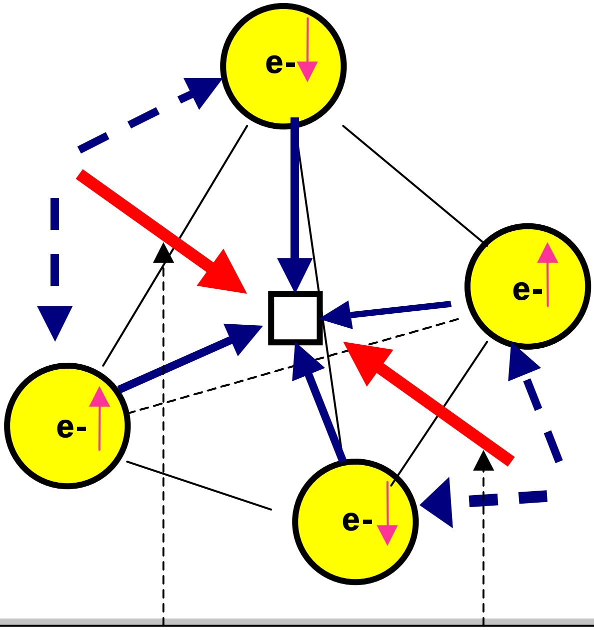
- **Symmetric TCC**



- **Charge Neutral Condensation in Average is possible**
- Quadruplet e*(4,4) is formed as ***Single Particle*** at central focal point (T-site) of **0.01 nm diameter domain**
- **<Life Time of e*(4,4)>**
- > (1.0E-9)cm/Ve
- =1.0E-9/4.3E5 =2.3E-15
- **= 2.3 fs**

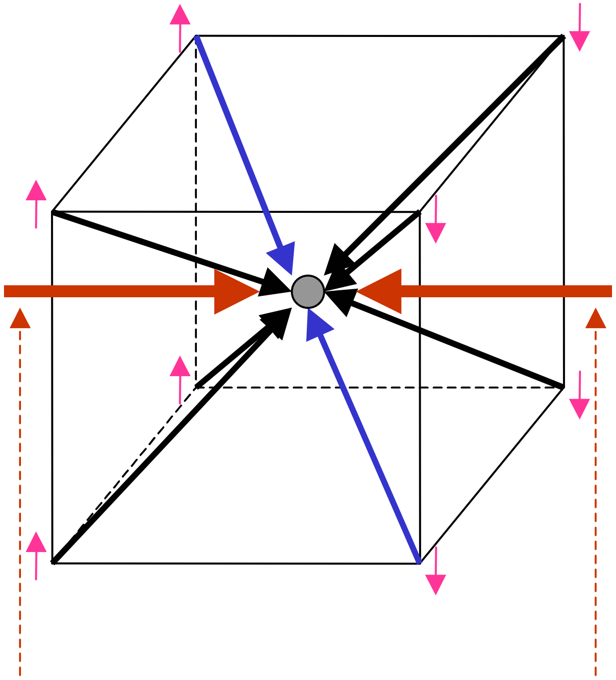
Quadruplet and Octal-Coupling of Electrons

Quadruplet e*(4,4)



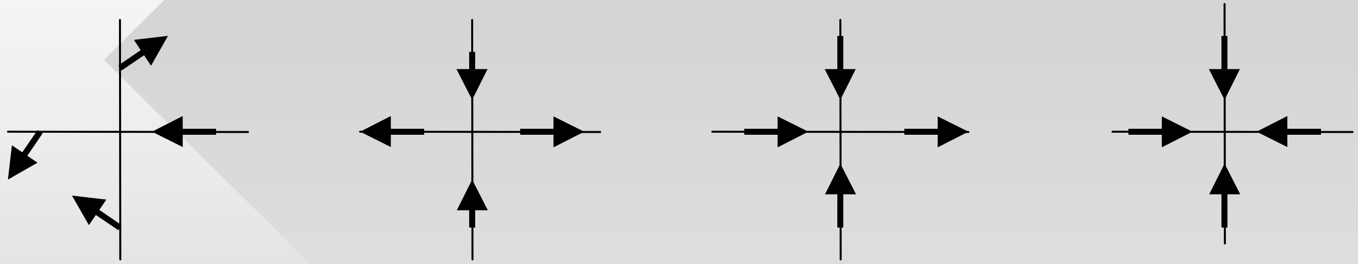
Sum Momentum Vector

Octal-Coupling e*(8,8)



Sum Momentum Vector

Combination Probability of EQPET Molecule by Tetrahedral “Coherent” Condensation (TCC)



(a) incoherent

(b)anti-coherent

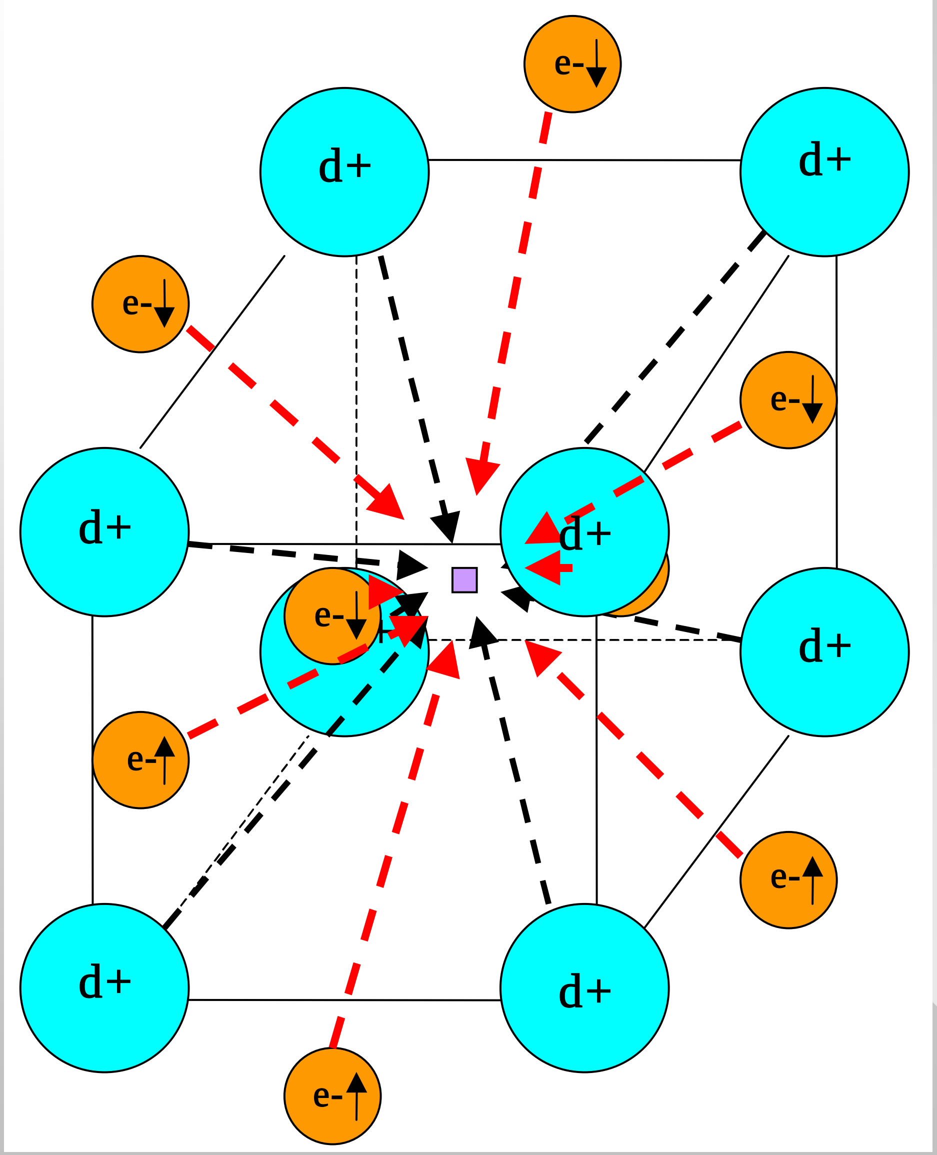
(c) coherent

(d) coherent

TCC

- < dde *(2,2)> = (12/16)x(1/4) = 18.75 %
- < dde *(4,4)> = (2/16)x(1/4) = 3.12 %
- <EQPET Molecule Total> = 21.87 %
- (c.f. 18 % by EODD for Rdd < 0.1 angstrom)

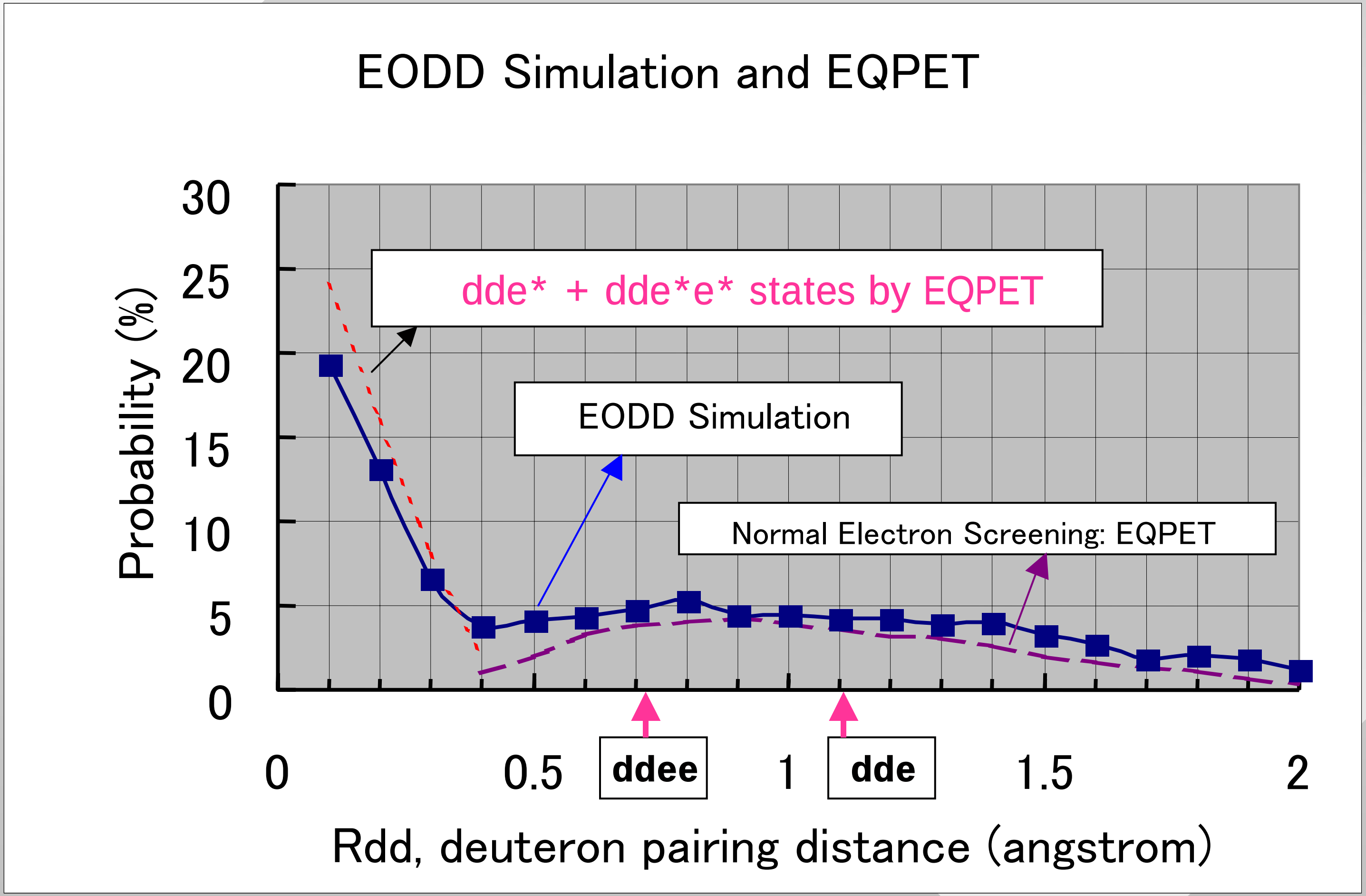
Octahedral Symmetric (Coherent) Condensation



When 4 e- down-spins are arranged on upper half with 4 e- up-spins on lower half, Averaged charge-neutral condensation is Possible to form central e*(8,8) Transient Quasi-Particle State at O-site

Transient Molecular States by EQPET

- **EQPET: Electronic Quasi-Particle Expansion Theory**
- **EODD: Electron Orbit Deformation Dynamics simulation (Kirkinskii-Novikov)**



Fusion Rate of D-Cluster

① : **D-Cluster Formation Process:**

$F_{nD} = <\Psi 1^2><\Psi 2^2><\Psi 3^2>***<\Psi n^2>$

② : **Barrier Penetration Process:**

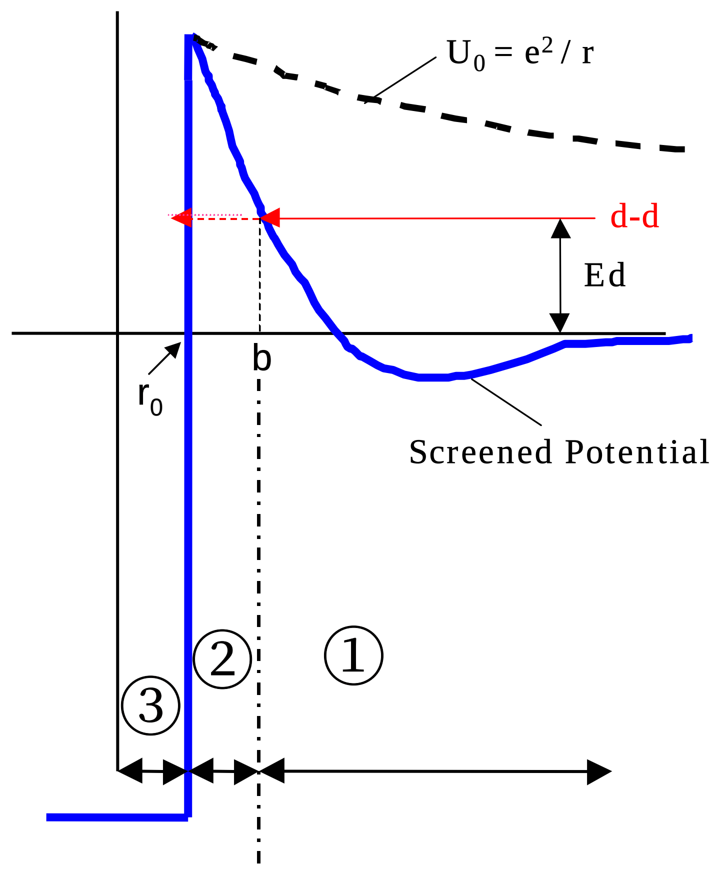
$P_B = \exp(-n\Gamma_n)$

③ : **Nuclear Fusion Process**

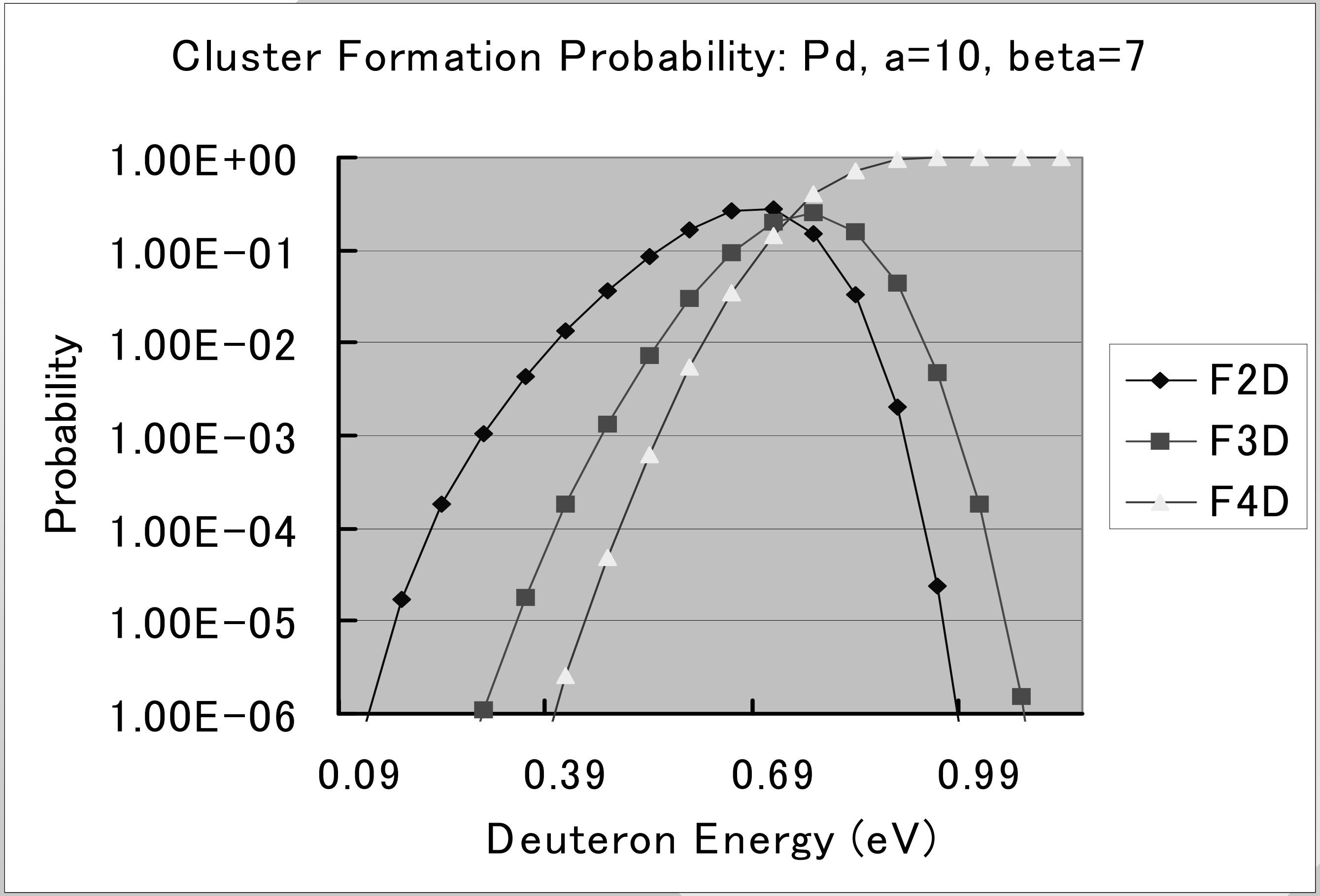
$\sigma = S_{nD} / E_d$

< Fusion Rate > = $\sigma v * P_B * F_{nD}$

D+(D+(D+D))⇒ 4D



Cluster Formation Probability in Atomic Level



- Calculation by Excitation Screening Model

Barrier Factor for Screened Potential

Gamow Integral over b to r0

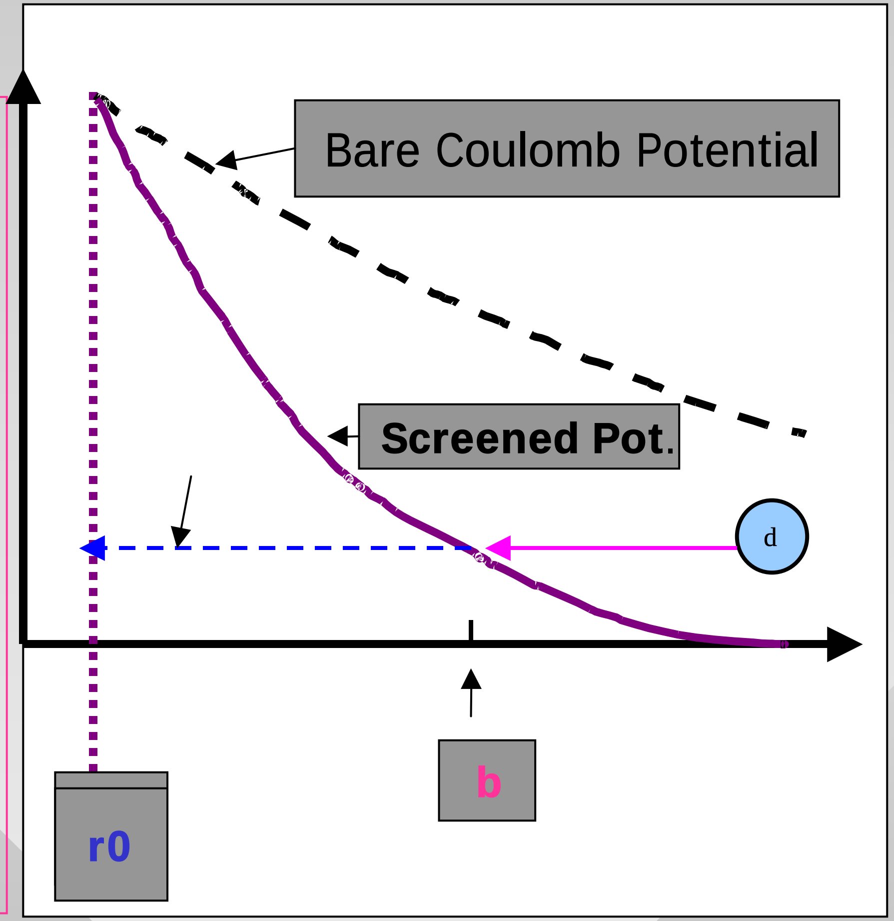
$$\Gamma_n = (2\mu)^{1/2}/h \int (V_s(r) - E_d)^{1/2} dr$$

$V_s(r)$: Screened Potential for a d-d pair in a TRF or ORF cluster of n deuterons

b is important parameter to be estimated

b should be far less than 70 pm

r0 is about 5 fm for contact surface reaction of strong interaction



EQPET: Electronic Quasi-Particle Expansion Theory

- Wave functions of TSC or OSC cluster can be approximated by linear combination of partial wave functions for normal and quasi-molecular states, dde, ddee, dde* and dde*e*.
- 4D and 8D clusters are composed of dde, ddee, dde*, dde*e*,...molecules.

EQPET: continued-1

"Bosonized" electron wave function Ψ_N for N-electrons system in MDx lattice will be approximated by a linear combination of normal electron wave function $\Psi_{(1,1)G}$ and quasi-particle wave functions $\Psi_{(2,2)G}$ $\Psi_{(4,4)G}$ and $\Psi_{(8,8)G}$ as;

$$|\Psi_N> = a_1 | \Psi_{(1,1)G}> + a_2 | \Psi_{(2,2)G}> + a_4 | \Psi_{(4,4)G}> + a_8 | \Psi_{(8,8)G}> \quad (3)$$

For the time-window of potential deep hole [1,2], effective (time-averaged) screening potential, for a d-d pair in a transient D-cluster of 4-8 deuterons for TRF and ORF condition [2], can be defined by a screened potential of quasi-particle complex;

$$V_s(R) = b_1 V_{s(1,1)}(R) + b_2 V_{s(2,2)}(R) + b_4 V_{s(4,4)}(R) + b_8 V_{s(8,8)}(R) \quad (9)$$

EQPET: continued-2

For a dde* or dde*e* molecule,

wave function of a d-d pair (2D) is given by the solution of the following Schroedinger equation:

$$(-h^2/(8\pi\mu))\nabla^2 X(R) + (V_n(R) + V_s(R))X(R) = E X(R) \qquad (11)$$

By Born-Oppenheimer approximation, we assume as,

$$X(R) = X_n(R) X_s(R) \qquad (12)$$

Overlapping rate of $X(R)$ at R = r0 gives estimation of d-d fusion rate λ_{2d} as:

$$\lambda_{2d} = G \, | X(R) |^2_{R=r0}$$
$$= G \, | X_n(R) |^2_{R=r0} \, | X_s(R) |^2_{R=r0} \qquad (13)$$

EQPET: continues-3

Using WKB approximation for the barrier ($V_s(R)$) penetration probability,

$$|X_s(R)|^2_{R=r0} = \exp(-2\Gamma_n(E_d)) \qquad (14)$$

;Barrier Factor (BF)

where E_d is the relative deuteron energy and Γ_n is Gamow integral for a d-d pair in D-cluster (n-deuterons with electrons) that is defined as:

$$\Gamma_n(E_d) = (2\mu)^{1/2}/(h/\pi) \int_{r0}^{b}(V_s(R)-E_d)^{1/2}dR \qquad (15)$$

Using astrophysical S-factor for strong interaction,

$$G|X_n(R)|^2_{R=r0} = vS_{2d}(E_d)/E_d \qquad (16)$$

Consequently we can approximately define fusion rate as:

$$\lambda_{2d} = (vS_{2d}(E_d)/E_d)\exp(-2\Gamma_n(E_d)) \qquad (17)$$

Screened Potential of EQPET Molecule

Using the Single Particle Approximation, for e*, screened potential is given by applying solutions in Pauling's book:

For dde*,

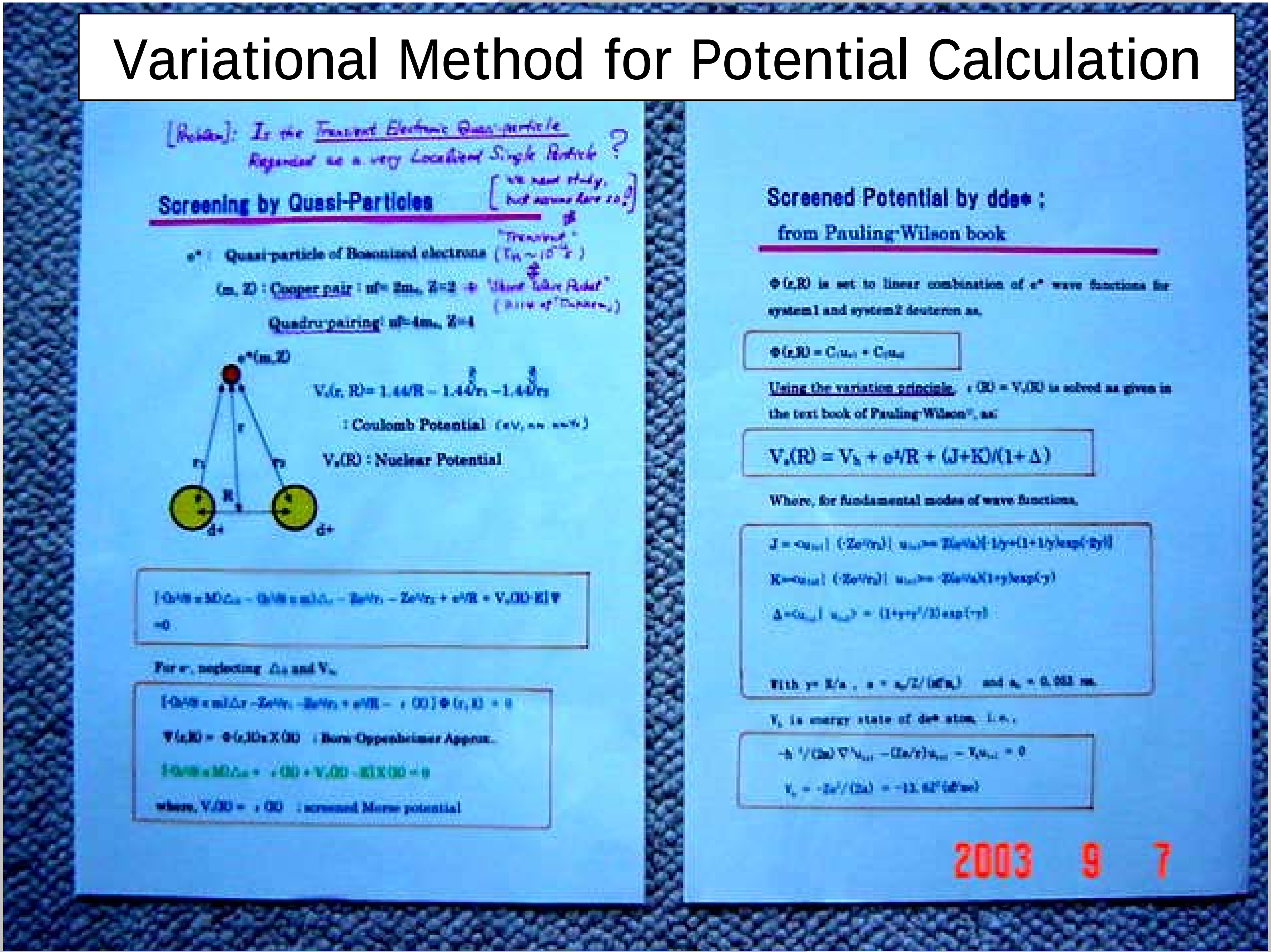
$$Vs(R) = Vh + e^2/R + (J + K)/(1 + \Delta)$$

For dde*e*,

$$Vs(R) = 2Vh + e^2/R + (2J + J' + 2\Delta K + K')/(1 + \Delta^2)$$

For de*, $Vh = -13.6(e^*/e)^2(m^*/me)$

Variational Method for Potential Calculation



[Problem]: Is the Transient Electronic Quasi-particle Regarded as a very Localized Single Particle ?

Screening by Quasi-Particles

[We need study, but assume here so.]

"Transient"

e^* : Quasi-particle of Bosonized electrons

(m, Z) : Cooper pair : $m^* = 2m_e$, Z=2

Quadru-pairing: $m^* = 4m_e$, Z=4

$V_c(r, R) = 1.44/R - 1.44/r_1 - 1.44/r_2$

: Coulomb Potential

$V_n(R)$: Nuclear Potential

For e^*, neglecting Δ_R and V_n,

$\Psi(r,R) = \Phi(r,R) \cdot X(R)$: Born-Oppenheimer Approx.

where, $V_s(R) = \varepsilon(R)$: screened Morse potential

Screened Potential by dde* ;

from Pauling-Wilson book

$\Phi(r,R)$ is set to linear combination of e^* wave functions for system1 and system2 deuteron as,

$$\Phi(r,R) = C_1 u_{a1} + C_2 u_{b2}$$

Using the variation principle, $\varepsilon(R) = V_s(R)$ is solved as given in the text book of Pauling-Wilson, as:

$$V_s(R) = V_b + e^2/R + (J+K)/(1+\Delta)$$

Where, for fundamental modes of wave functions,

$J = \langle u_{a1} | (-Ze^2/r_b) | u_{a1} \rangle = (Ze^2/a)[-1/y + (1+1/y)\exp(-2y)]$

$K = \langle u_{a1} | (-Ze^2/r_a) | u_{b2} \rangle = -(Ze^2/a)(1+y)\exp(-y)$

$\Delta = \langle u_{a1} | u_{b2} \rangle = (1+y+y^2/3)\exp(-y)$

With $y = R/a$, $a = a_0/Z/(m^*/m_e)$ and $a_0 = 0.053$ nm.

V_b is energy state of de^* atom, i.e.,

$-\hbar^2/(2m)\nabla^2 u_{100} - (Ze^2/r)u_{100} - V_b u_{100} = 0$

$V_b = -Ze^2/(2a) = -13.6Z^2(m^*/m_e)$

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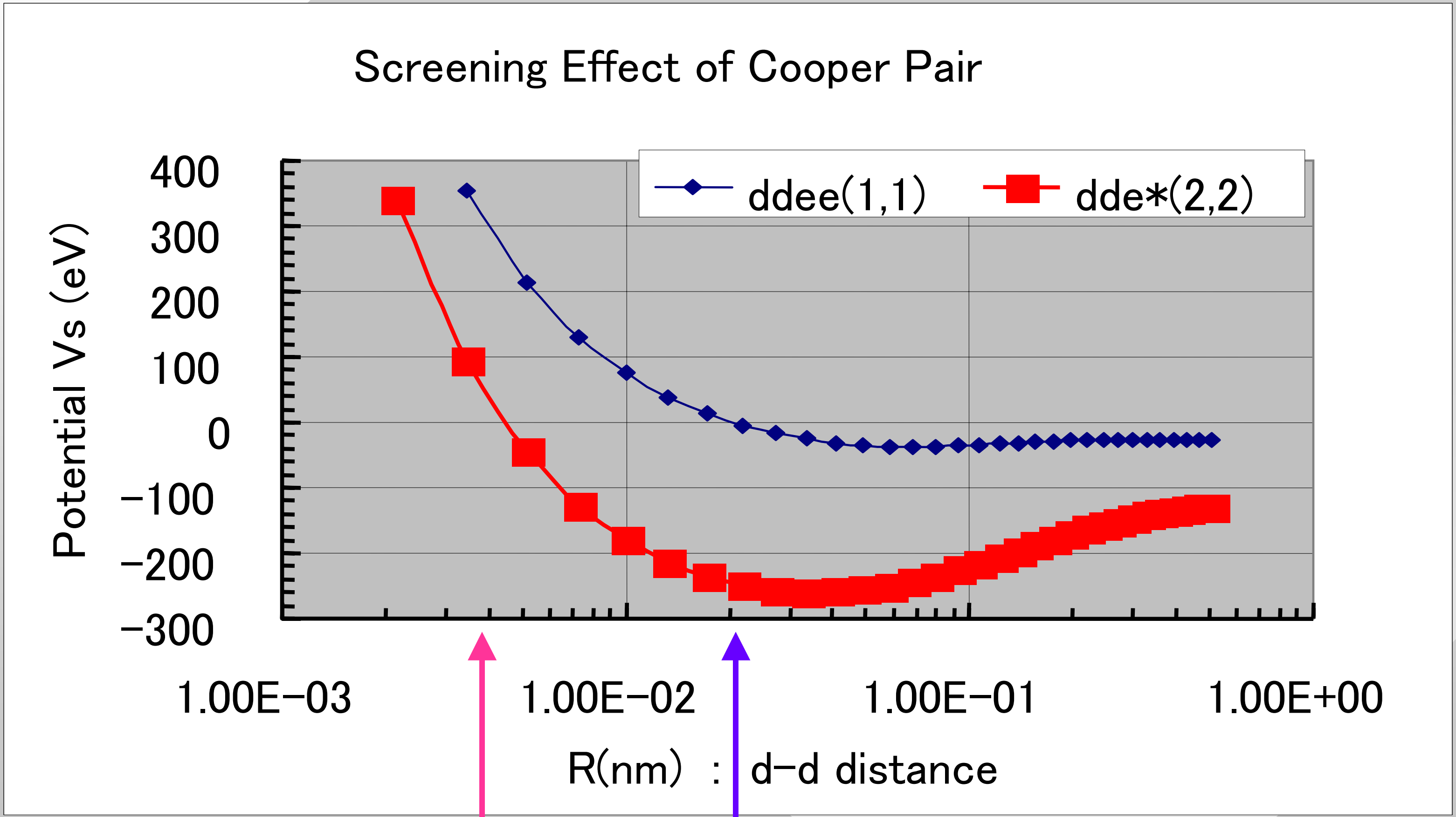
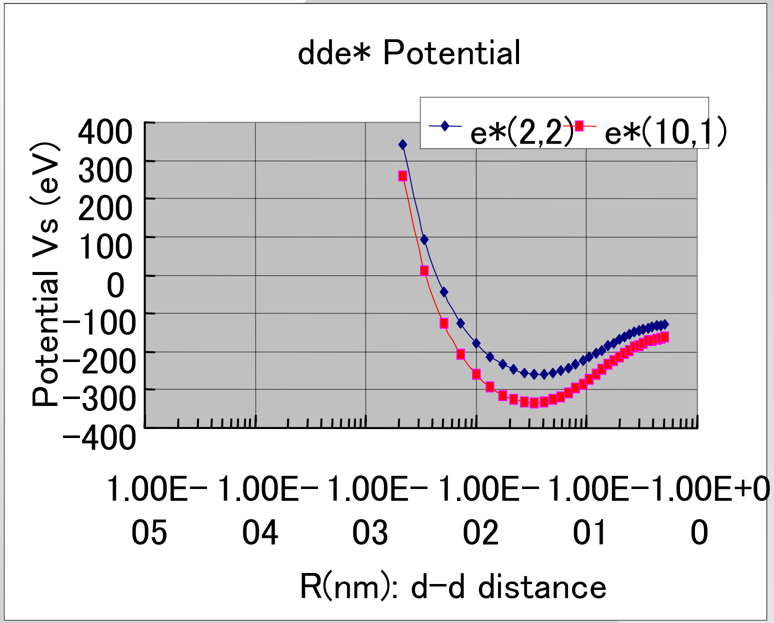
Screening Effect by EQPET Molecules

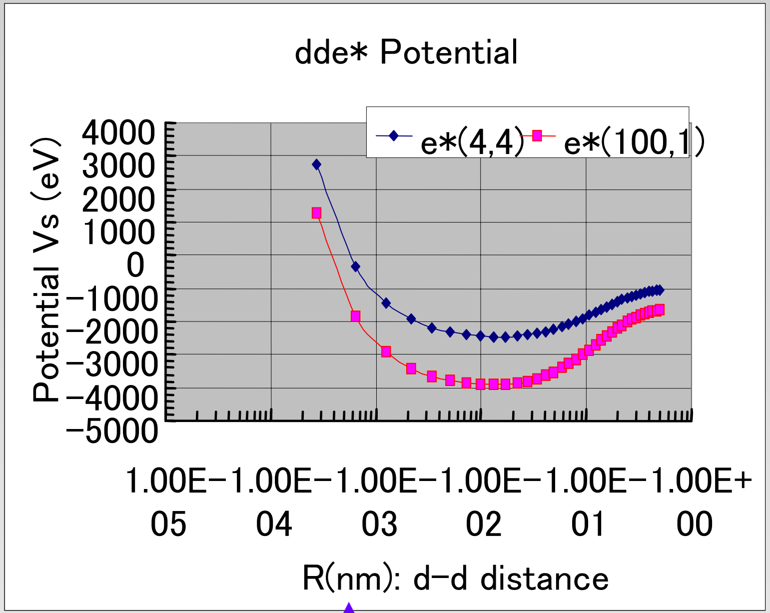


b(2,2) = 4 pm

b(1,1) = 20 pm

Screening Effect: EQPET Molecule vs. Heavy Fermion





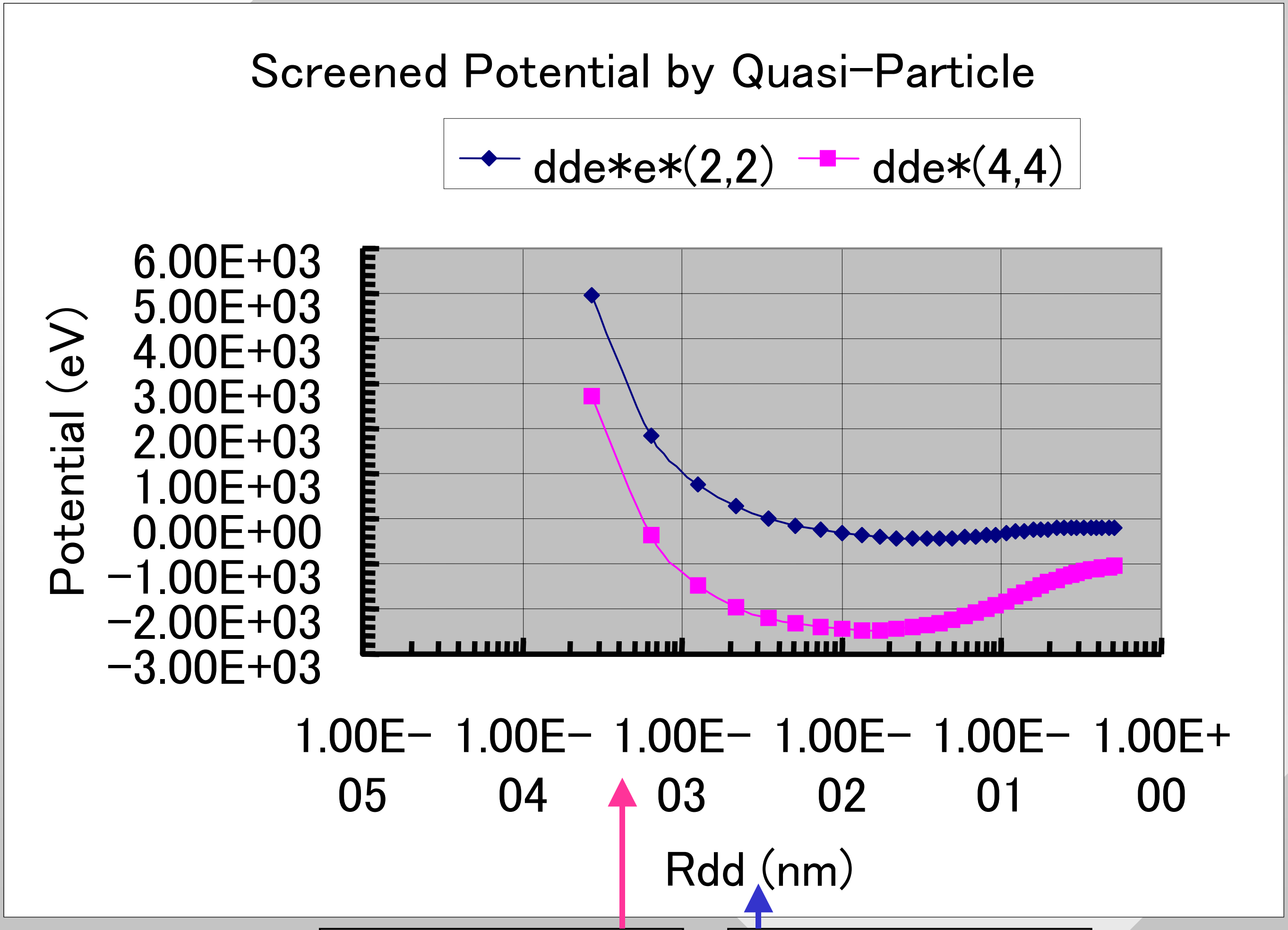
b(4,4) = 450 fm

Cooper pair (single particle) works as strong as mass 10 fermion

Pairing of e*(2,2)s works as strong as mass 100 fermion

e*(4,4)< μ (208,1)<e*(8,8)

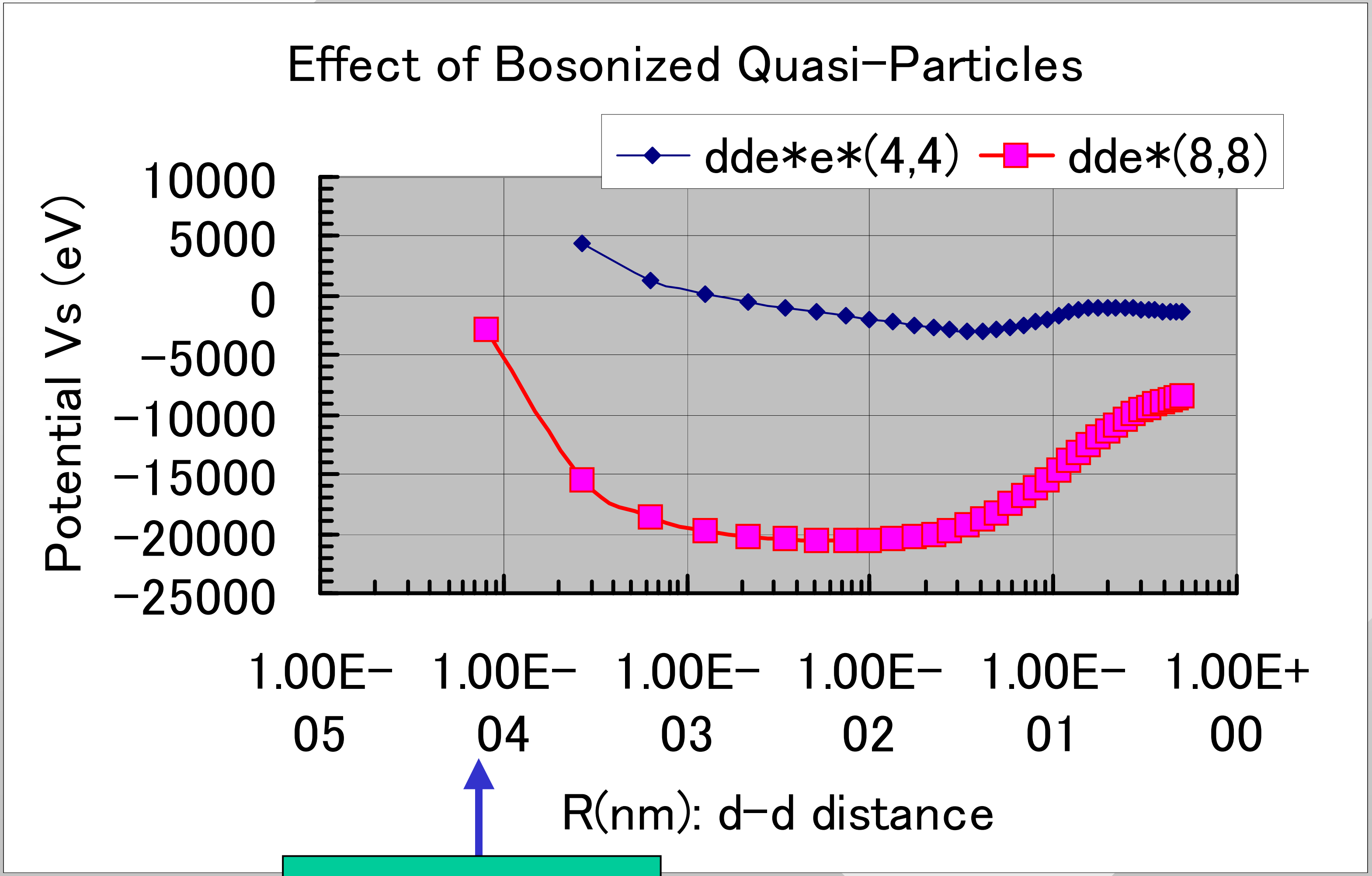
Screening Effect by Quasi-Particle



b(4,4)=0.45 pm

b(2,2)2= 3 pm

Screening Potential for dde*(8,8) Molecule



b = 60 fm

Parameters for Deep Potential Hole : by EQPET

• (m^*/m_e: Z) • for e*	depth of trapping potential (**DTP**)	
	dde*	dde*e*
• (1,1)	- 14.87 eV	- 30.98 eV
• **(2,2)**	**- 260 eV**	**- 446 eV**
• **(4,4)**	**- 2,460 eV**	**- 2,950 eV**
• (8,8)	- 21.0 keV	- 10.2 keV

- DTP values approximately correspond to Screening Energy

Scaling of PEF (Pion Exchange Force) for Nuclear Fusion

Two Body Interaction: PEF = 1

$n + \pi^{+} \rightarrow p$

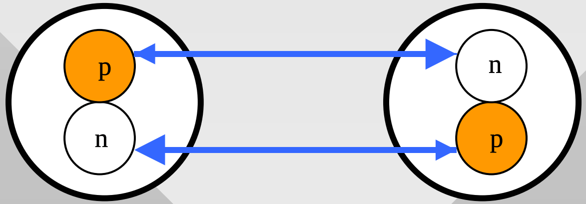
(udd) (ud*) (uud) : u ; up quark

$p + \pi^{-} \rightarrow n$: d ; down quark

(uud) (u*d) (udd) : u* ; anti-up quark

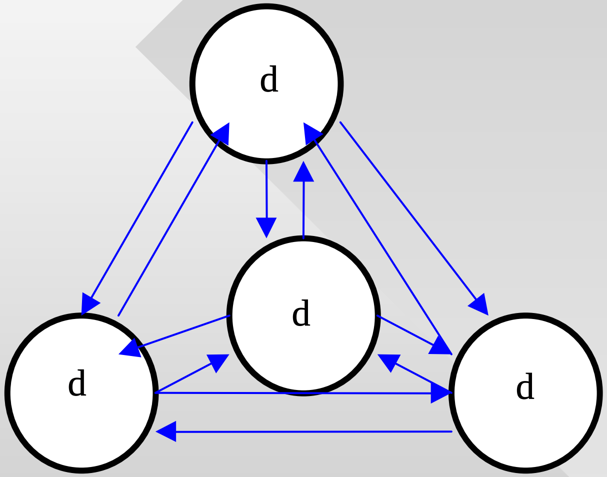
: d* ; anti-down quark

For D + D Fusion; PEF = 2

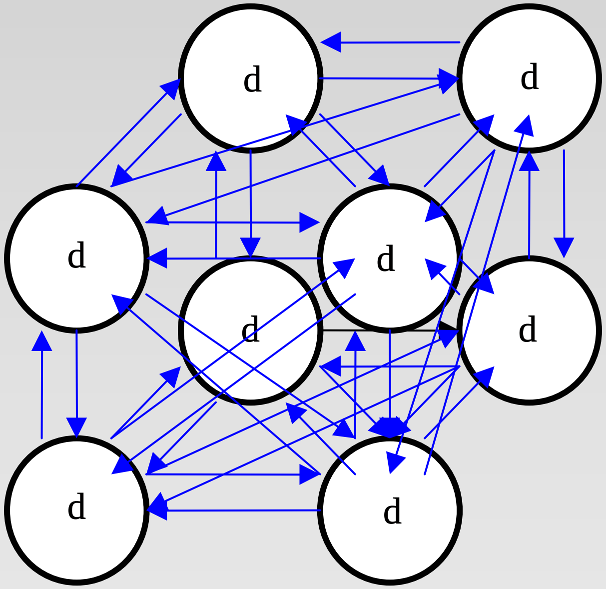


PEF Scaling for Multi-Body Fusion

4D Fusion; PEF = 12



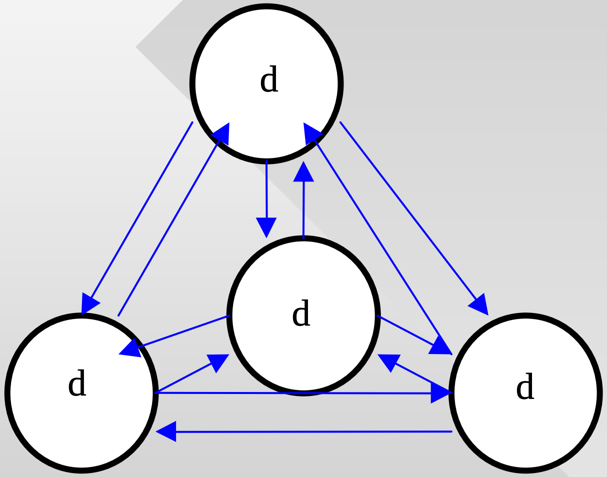
8D Fusion; PEF = 56



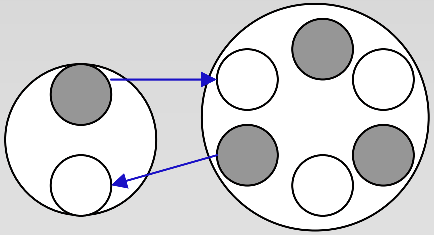
Ideally Symmetric PEF enhances Contact Surface of Nuclear Fusion with short range (few fm) charged-pion exchange

4D →^{8}Be* vs. D+^{6}Li → ^{8}Be* ; for strong interaction

4D Fusion; PEF = 12



D + ^{6}Li Fusion: PEF = 2+ α



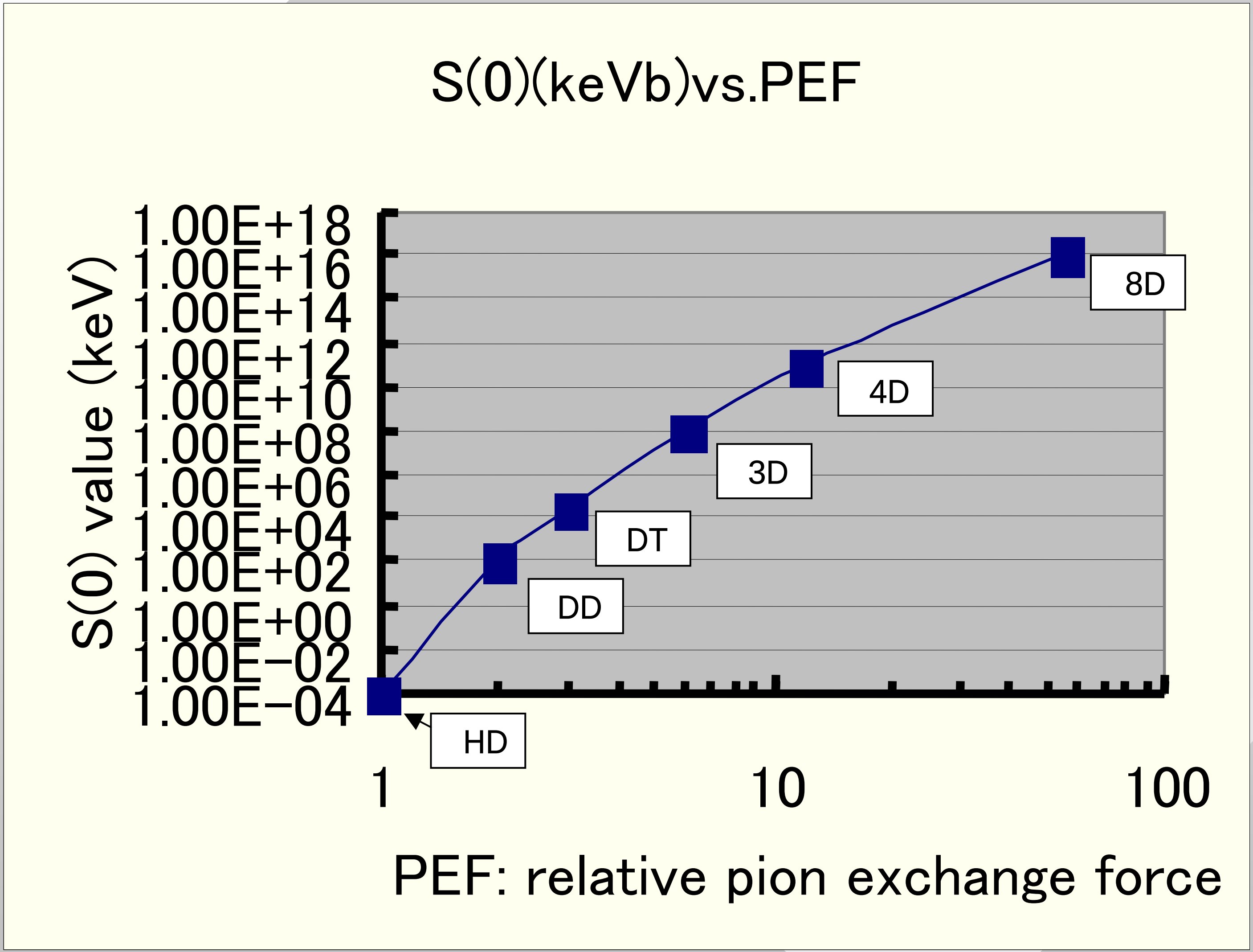
4D Fusion has much larger Contact Surface of PEF than D+^{6}Li with short range (few fm) charged-pion exchange

How does the short range force work?

- There are two lumps of paste.
- 1) Put one lump on a large paper.
- 2) Using another lump, paste uniformly another paper with same size.
- Which can stick much more tightly to a wooden plate, 1) or 2)?
- The answer is of course 2)!

Because 2) has much larger Contact Surface!

Effective S(0)-values for Multi-Body D-Fusion



Barrier Factors (BF) and Fusion Rates (FR)

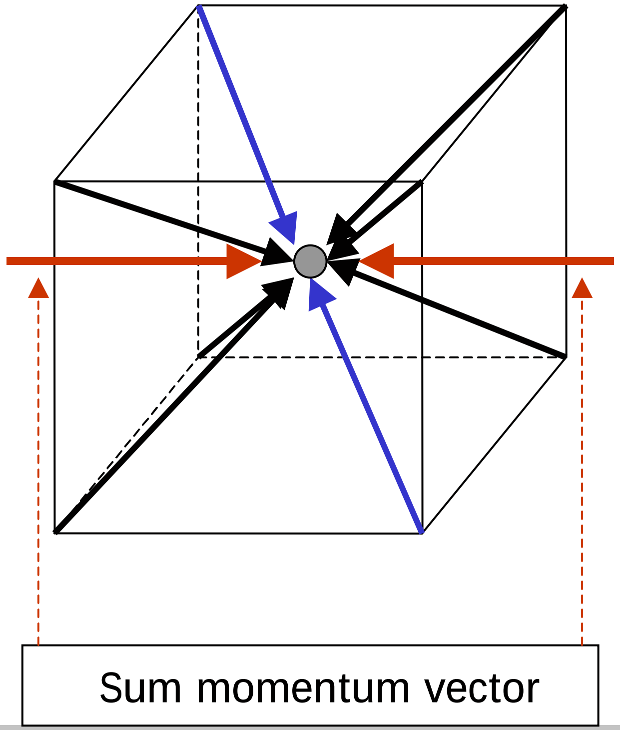
Ed = 0.22eV

(m*, e*)	Barrier Factor				Fusion Rate (f/s/cl)			
	2D	3D	4D	8D	2D	3D	4D	8D
(0,0)	E-1685				E-1697			
(1,1)	E-125	E-187	E-250	E-500	E-137	E-193	E-252	E-499
(2,1)	E-53	E-80	E-106	E-212	E-65	E-86	E-108	E-211
(2,2)	E-7	E-11	E-15	E-30	E-20	E-17	E-17	E-29
(4,4)	(3E-4)	E-5	E-7	E-14	(E-16)	E-11	E-9	E-13
(8,8)	(4E-1)	(2E-1)	(1E-1)	2E-2	(E-13)	(E-7)	(E-3)	E-1

( ) is virtual rate

Modal Fusion Rates for Octahedral Condensation

Octahedral Condensation



- <octal coupling> = (2/256)x(1/8) = 0.0078 = $a_8{}^2$
- <quadru coupling> = (144/256)x(1/8) = 0.0703 = $a_4{}^2$
- <Cooper pair> = ((108/256) + (2/4)x(1/7))x(1/8) = 0.0792 = $a_2{}^2$
- <Normal e> = 0.8427 = $a_1{}^2$

- λ_{2d} = 7.9E-22 (f/s/cl)
- λ_{3d} = 3.5E-13 (f/s/cl)
- λ_{4d} = 7.0E-11 (f/s/cl)
- λ_{8d} = 7.8E-4 (f/s/cl)

•Modal Fusion Rates

- Modal Fusion Rates are
- defined as:

- $\lambda_{2d} = a_1^2 \lambda_{2d\ (1,1)} + a_2^2 \lambda_{2d\ (2,2)}$
- $\lambda_{3d} = a_1^2 \lambda_{3d\ (1,1)} + a_2^2 \lambda_{3d\ (2,2)} + c_4 a_4^2 \lambda_{3d\ (4,4)}$
- $\lambda_{4d} = a_1^2 \lambda_{4d\ (1,1)} + a_2^2 \lambda_{4d\ (2,2)} + a_4^2 \lambda_{4d(4,4)}$
- $\lambda_{8d} = a_1^2 \lambda_{8d\ (1,1)} + a_2^2 \lambda_{8d\ (2,2)} + a_4^2 \lambda_{8d\ (4,4)} + a_8^2 \lambda_{8d\ (8,8)}$

•Modal Fusion Rates for
•Tetrahedral Symmetric
•Condensation

- $a_1^2 = 0.781$, $a_2^2 = 0.187$, $a_4^2 = 0.0312$, $a_8^2 = 0.0$

- **λ_{2d} = 1.87E-21 • (•f/s/cl •)**
- **λ_{3d} = 1.55E-13 • (•f/s/cl •)**
- **λ_{4d} = 3.12E-11 • (•f/s/cl •)**

Power Level by TSC and OSC Fusion

D-Cluster Fusion by TSC

- Assume 1E22 TSC-clusters/cc at Ed=0.22eV
- 4D Fusion Rate = (3.1E-11)x(1E22) = 3E11 f/s/cc =

  3 watts/cc
- 2D Fusion Rate = (1.9E-21)x(1E22) = 19 f/s/cc (10 n/s/cc)

D-Cluster Fusion by OSC

- Assume 1E16 OSC-clusters/cc at Ed=0.22 eV (1ppm PdD2)
- 8D Fusion Rate = (7.8E-4)x(1E16) = 7.8E12 f/s/cc =

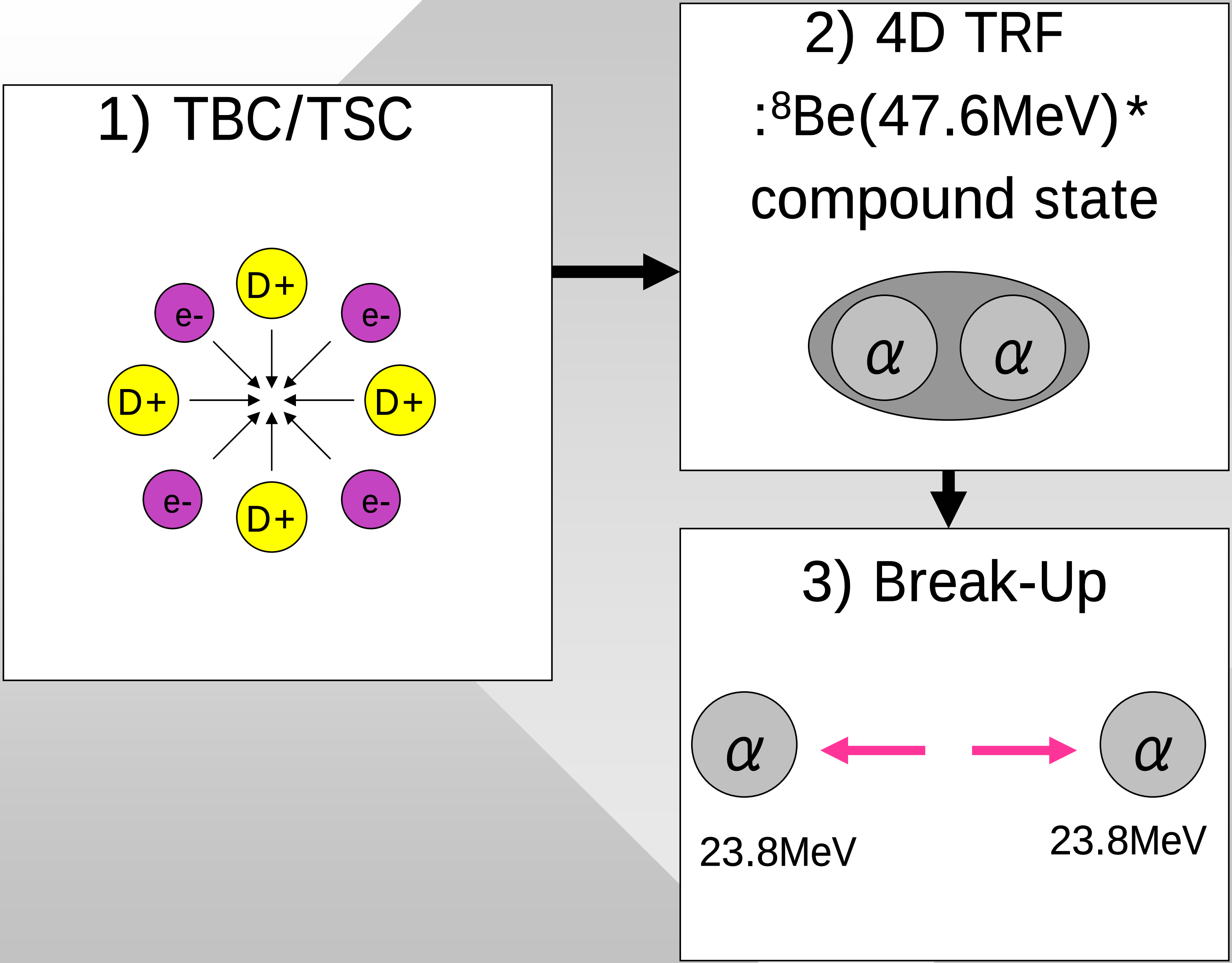
  78 watts/cc
- 4D Fusion Rate = (7E-11)x(1E16) = 7E5 f/s/cc

Major Products of D-Cluster Fusion

- 1) 3D → Li-6* → d + He-4 + 23.8 MeV,
-                       t-3 + He-3 + 9.5 MeV
- 2) 4D → Be-8* → 2xHe-4 + 47.6 MeV
- 3) 5D → B-10* (53.7 MeV)
- 4) 6D → C-12* (75.73 MeV)
- 5) 7D → N-14* (89.08 MeV)
- 6) 8D → O-16* (109.84 MeV) → 2xBe-8 + 95.2 MeV

•4D and 8D Fusion can be selective because of resonant pion exchange

•5D, 6D and 7D processes partially attain 4D resonance.



1) TBC/TSC

2) 4D TRF

:^{8}Be(47.6MeV)*

compound state

3) Break-Up

Decay-Channel of ^{8}Be

4D $\longrightarrow$ ^{8}Be + 47.6 MeV :

^{8}Be $\longrightarrow$ ^{4}He + ^{4}He + 91.86 keV: Major Ch.

$\longrightarrow$ ^{3}He + ^{5}He(n+^{4}He) – 11.13 MeV

$\longrightarrow$ t + ^{5}Li(p+^{4}He) - 21.68MeV

$\longrightarrow$ d + ^{6}Li - 22.28 MeV

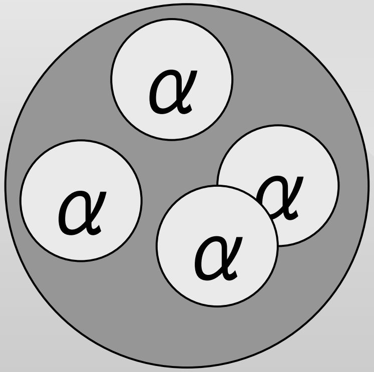
$\longrightarrow$ p + ^{7}Li - 17.26 MeV

$\longrightarrow$ n + ^{7}Be – 18.90 MeV

^{8}Be Excited State may open to threshold reactions

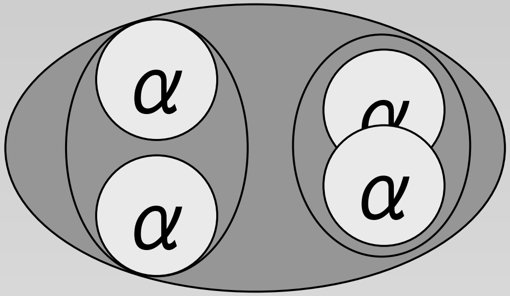
- Alpha-Cluster

$^{16}O(g.s.)$

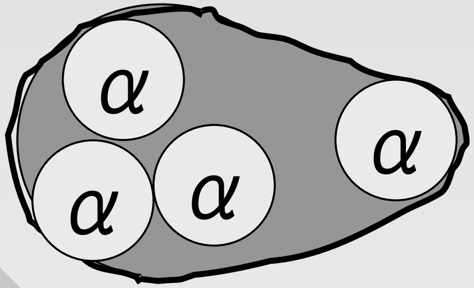


- Ground State

$^{8}Be + ^{8}Be$



$^{12}C + ^{4}He$



- Excited States of $^{16}O^*$

$8D \longrightarrow {}^{8}Be + {}^{8}Be + 95.2$ MeV

$${}^{8}Be \longrightarrow {}^{4}He + {}^{4}He + 47.7 \text{ MeV}$$

(g.s)

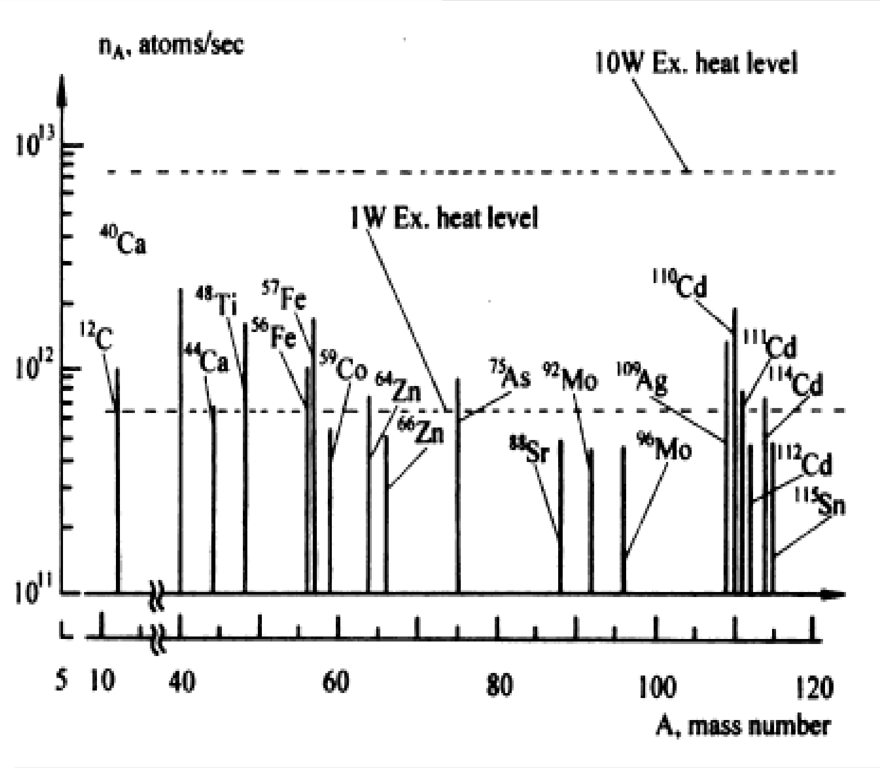
$$8D \longrightarrow {}^{4}He + {}^{12}C + 50.12 \text{ MeV}$$

- ${}^{12}C$ excited state is possible to decay to three ${}^{4}He$ particles.

^{4}He is Major Product: CLEAN FUSION

- Emission of Two 23.8 MeV (Max) ^{4}He-Particles into 180 degree Opposite Directions by 4D Fusion of TSC/TRF, slowing down with soft X-rays and E-deposit to lattice vibration (phonons).
- Emission of Two 47.6 MeV ^{8}Be-Particles into 180 degree Opposite Directions by 8D Fusion of OSC/ORF, following ^{8}Be to two 23.8MeV ^{4}He-Particles decay in 6.7E-17 s.

Karabut Data and Pd + ^{4}He Reactions

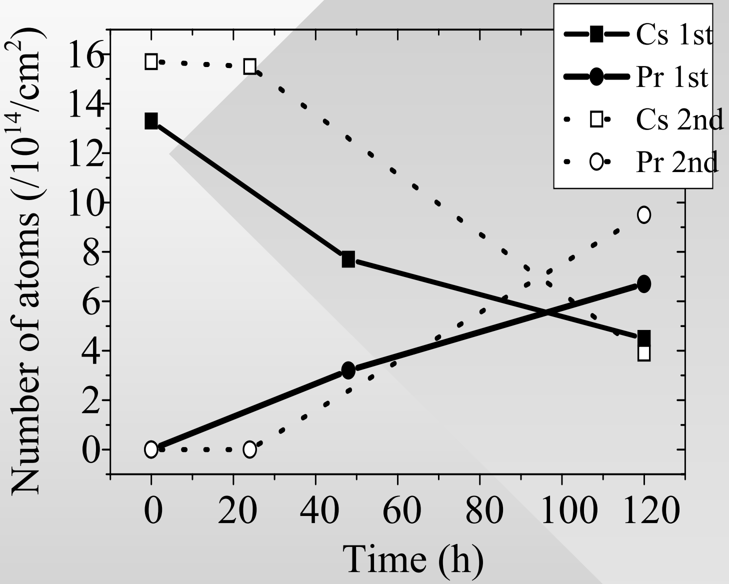


Impurity production rates in Pd cathode of D2 glow-discharge plus SIMS, by Karabut, Proc. ICCF9, 2002

- Secondary Reactions by 23.8MeV ^{4}He of 4D TRF
- $^{105}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{109}\text{Cd}^{*}(1.27\text{y})$
- $^{106}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{110}\text{Cd}$
- $^{108}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{112}\text{Cd}$
- $^{110}\text{Pd} + {}^{4}\text{He} \rightarrow {}^{114}\text{Cd}$
- $^{107}\text{Pd}^{*}(6.5\text{x}10^{6}\ \text{y}) + {}^{4}\text{He} \rightarrow {}^{111}\text{Cd}$

^{109}Ag might be ^{109}Cd ?

A-8 and Z-4 Increased Transmutation by MHI



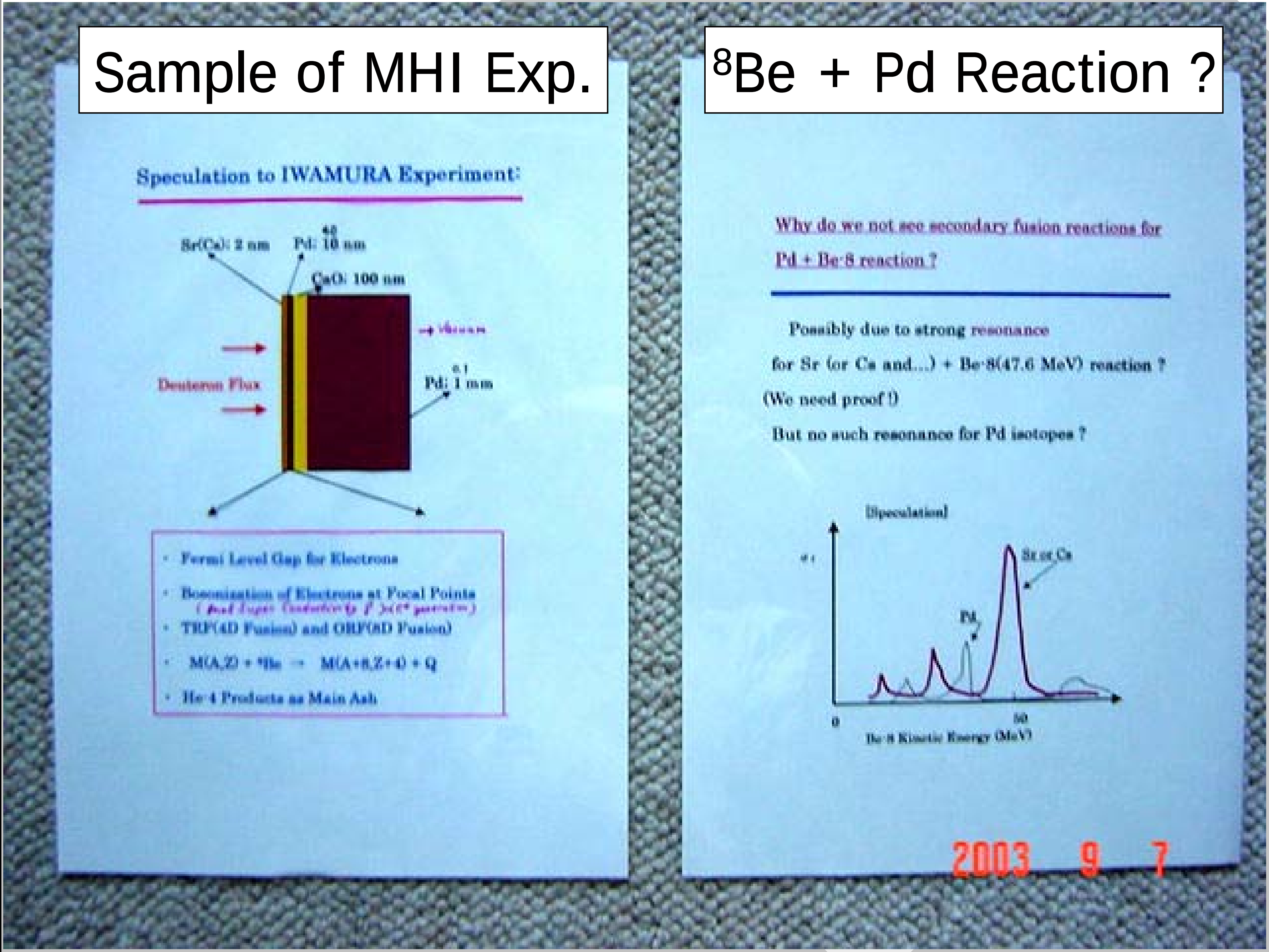
MHI D-permeation experiment with Pd comlplexes, Iwamura et al., Proc. ICCF9

- Cs(A=133, Z=55) to Pr(A=141, Z=59)
- Sr(A=88, Z=38) to Mo(A=96, Z=42)

- M(A,Z) + ^{8}Be(47.6MeV) by 8D ORF

Sample of MHI Exp.

^{8}Be + Pd Reaction ?



Speculation to IWAMURA Experiment:

- Fermi Level Gap for Electrons
- Bosonization of Electrons at Focal Points
  ([illegible])
- TRF(4D Fusion) and ORF(8D Fusion)
- $M(A,Z) + {}^8Be \rightarrow M(A+8,Z+4) + Q$
- He-4 Products as Main Ash

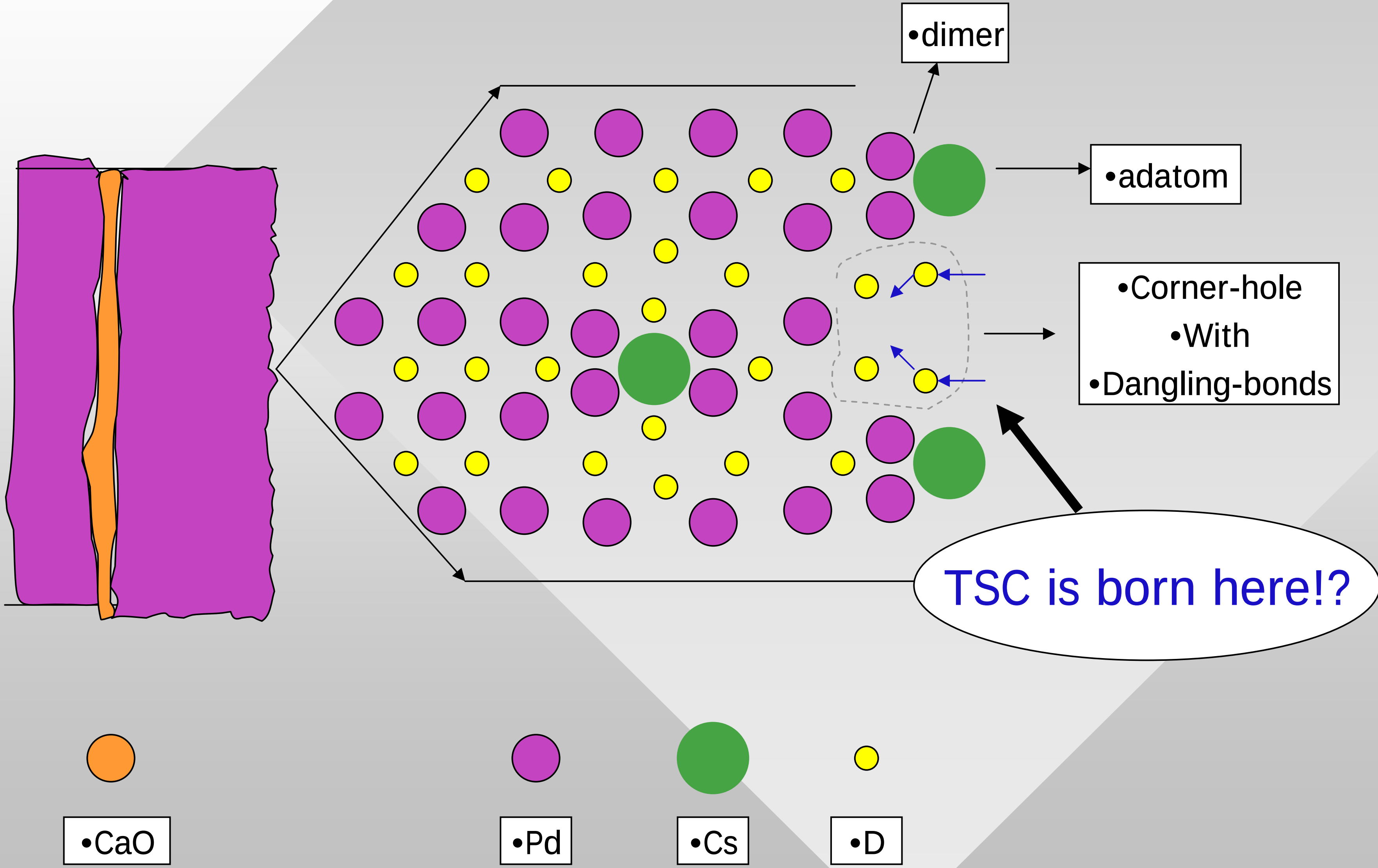
Why do we not see secondary fusion reactions for Pd + Be-8 reaction ?

Possibly due to strong resonance for Sr (or Cs and...) + Be-8(47.6 MeV) reaction ?

(We need proof !)

But no such resonance for Pd isotopes ?

•Image of Surface

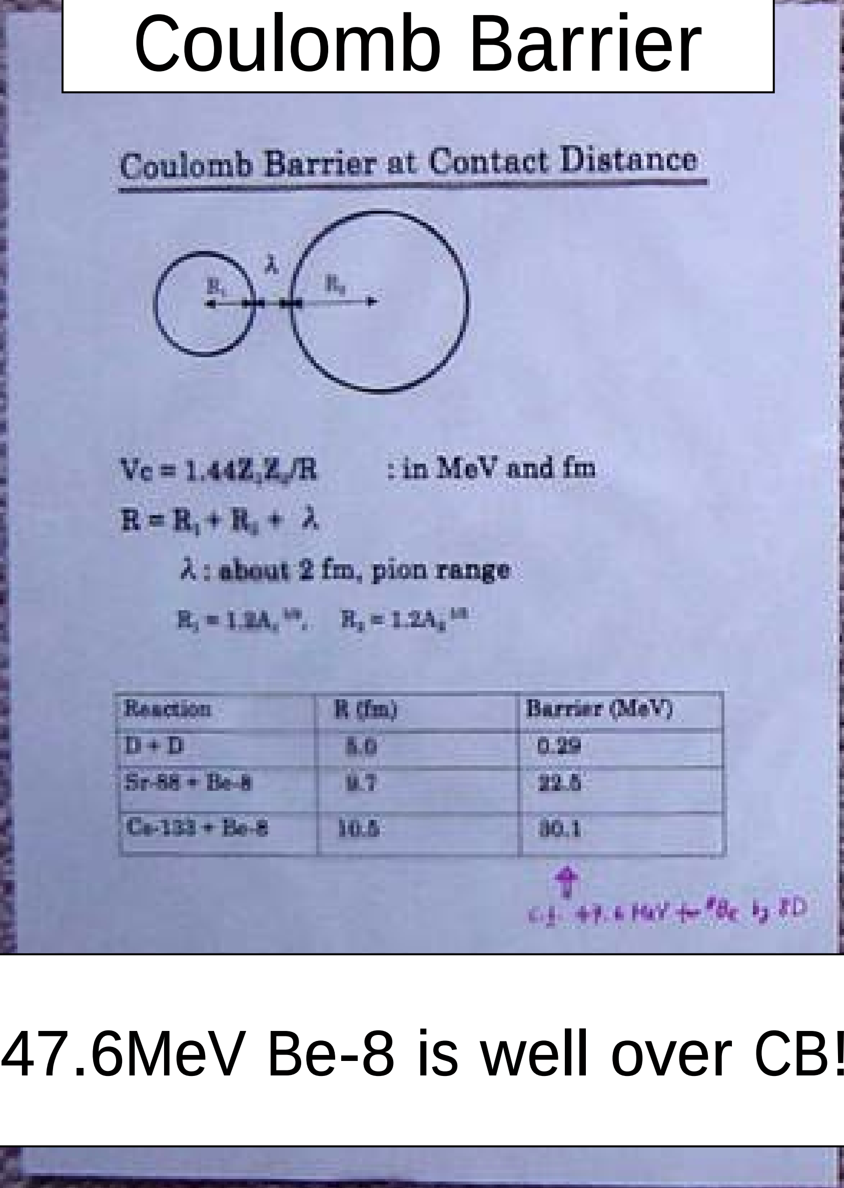


- dimer
- adatom
- Corner-hole
- With
- Dangling-bonds

TSC is born here!?

- CaO
- Pd
- Cs
- D

Coulomb Barrier



Coulomb Barrier at Contact Distance

$V_c = 1.44Z_1Z_2/R$: in MeV and fm

$R = R_1 + R_2 + \lambda$

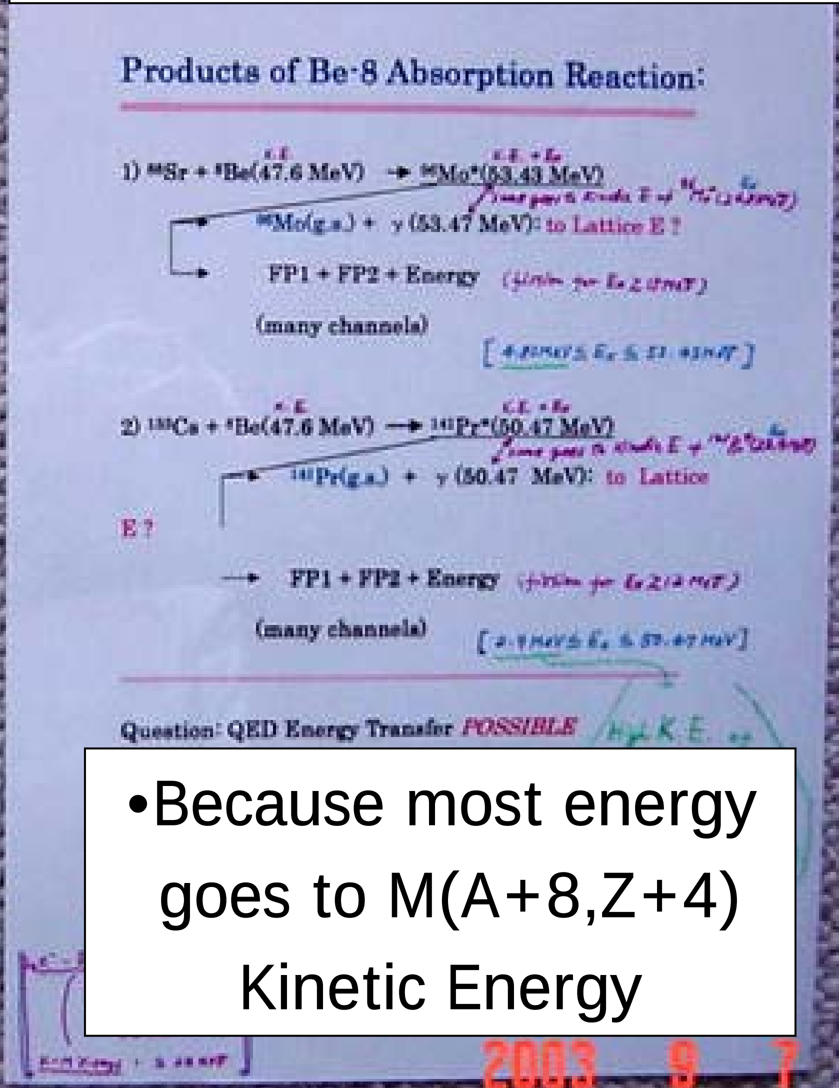
λ : about 2 fm, pion range

$R_1 = 1.2A_1^{1/3}$, $R_2 = 1.2A_2^{1/3}$

Reaction	R (fm)	Barrier (MeV)
D + D	5.0	0.29
Sr-88 + Be-8	9.7	22.5
Cs-133 + Be-8	10.5	30.1

- 47.6MeV Be-8 is well over CB!

Why no hard radiation ?



Products of Be-8 Absorption Reaction:

1) $^{88}Sr + {}^{8}Be(47.6\ MeV) \rightarrow {}^{96}Mo^{*}(53.43\ MeV)$

$^{96}Mo(g.s.) + \gamma\ (53.47\ MeV)$: to Lattice E ?

FP1 + FP2 + Energy

(many channels)

2) $^{133}Cs + {}^{8}Be(47.6\ MeV) \rightarrow {}^{141}Pr^{*}(50.47\ MeV)$

$^{141}Pr(g.s.) + \gamma\ (50.47\ MeV)$: to Lattice E ?

FP1 + FP2 + Energy

(many channels)

Question: QED Energy Transfer *POSSIBLE*

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- Because most energy goes to M(A+8,Z+4) Kinetic Energy

Gamma-Ray Emission ?

- $^{133}\text{Cs} + {}^{8}\text{Be} \longrightarrow {}^{141}\text{Pr} + Q(2.89\text{MeV})$

  For Pr excited state, Eg = 0.145, 0.981

  1.126,.....MeV

- Kinetic Energy of ^{8}Be(47.6 MeV):

  goes to KE of ^{141}Pr

5.95 MeV/nucleon is smaller than n-separation

Energy: particle emission cross section will be small.

If it were so:

$^{133}\mathrm{Cs} + 4\mathrm{D} \longrightarrow {}^{141}\mathrm{Pr}^{*}(Q=50.493\ \mathrm{MeV})$

$\quad \longrightarrow$ Fission !

- But Coulomb barrier ca. 10 MeV is too high to realize in condensed matter.
- This is as difficult as impossible to make $^{141}\mathrm{Pr}$.

•However, 4D-TSC can penetrate through CB !

Minimum Size of TSC is far less than 1 pm!

- 4d + 4e of TSC squeezes into a very small charge-neutral pseudo-particle.
- When 4d reach at the interaction range (several fm) of strong force, ^{8}Be* is formed by QM-penetration through EQPET shielded potential.
- As ^{8}Be* is formed, 4e are left at outer domain, which size is approximated by e*(4,4)Be atom size of 0.8 pm.

V_s Potential for e*(4,4) α α molecule

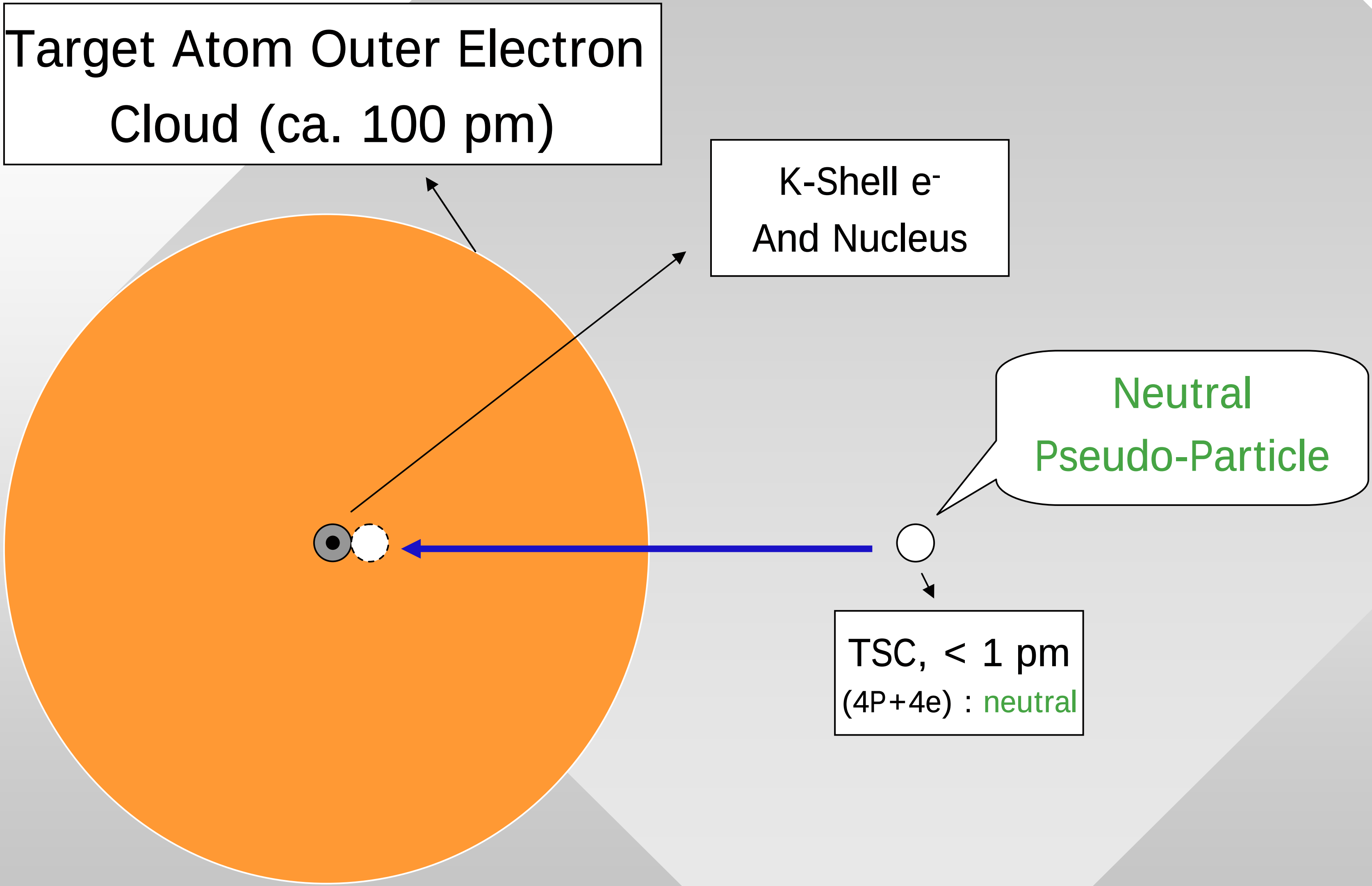
- V_{min} = -9.83 keV
- R_{dd}(GS) = 13 pm
- b-parameter = 0.6 pm (radius, TSC transient)
- Radius of e*(4,4)Be = 53/4/4/4 = 0.8 pm

V_s Potential for e*(8,8)^{8}Be^{8}Be molecule

V_{min} = -32.9 keV

R_{dd}(GS) = 5 pm

b-parameter = 60 fm (radius, OSC transient)



Target Atom Outer Electron Cloud (ca. 100 pm)

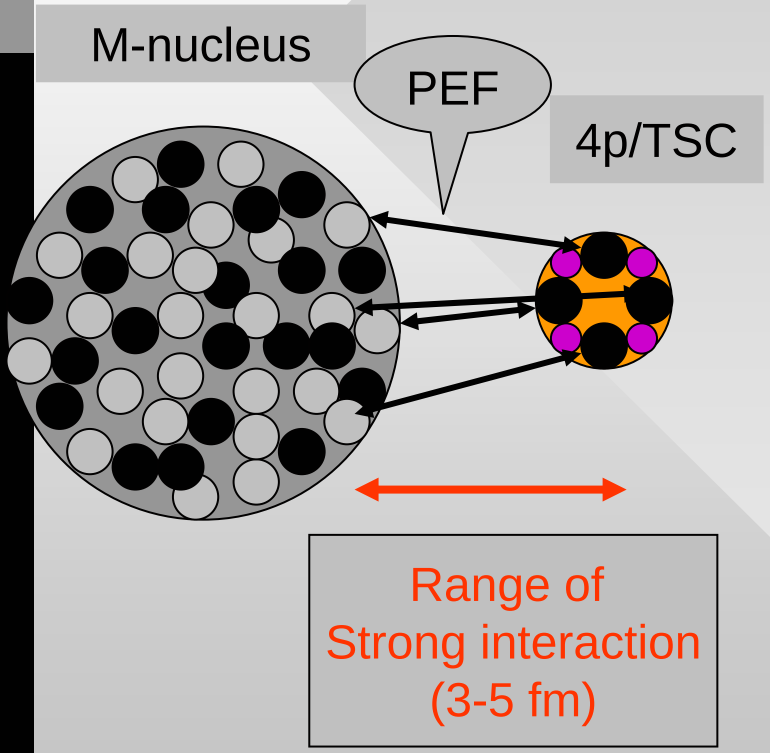
K-Shell e^-
And Nucleus

Neutral
Pseudo-Particle

TSC, < 1 pm
(4P+4e) : neutral

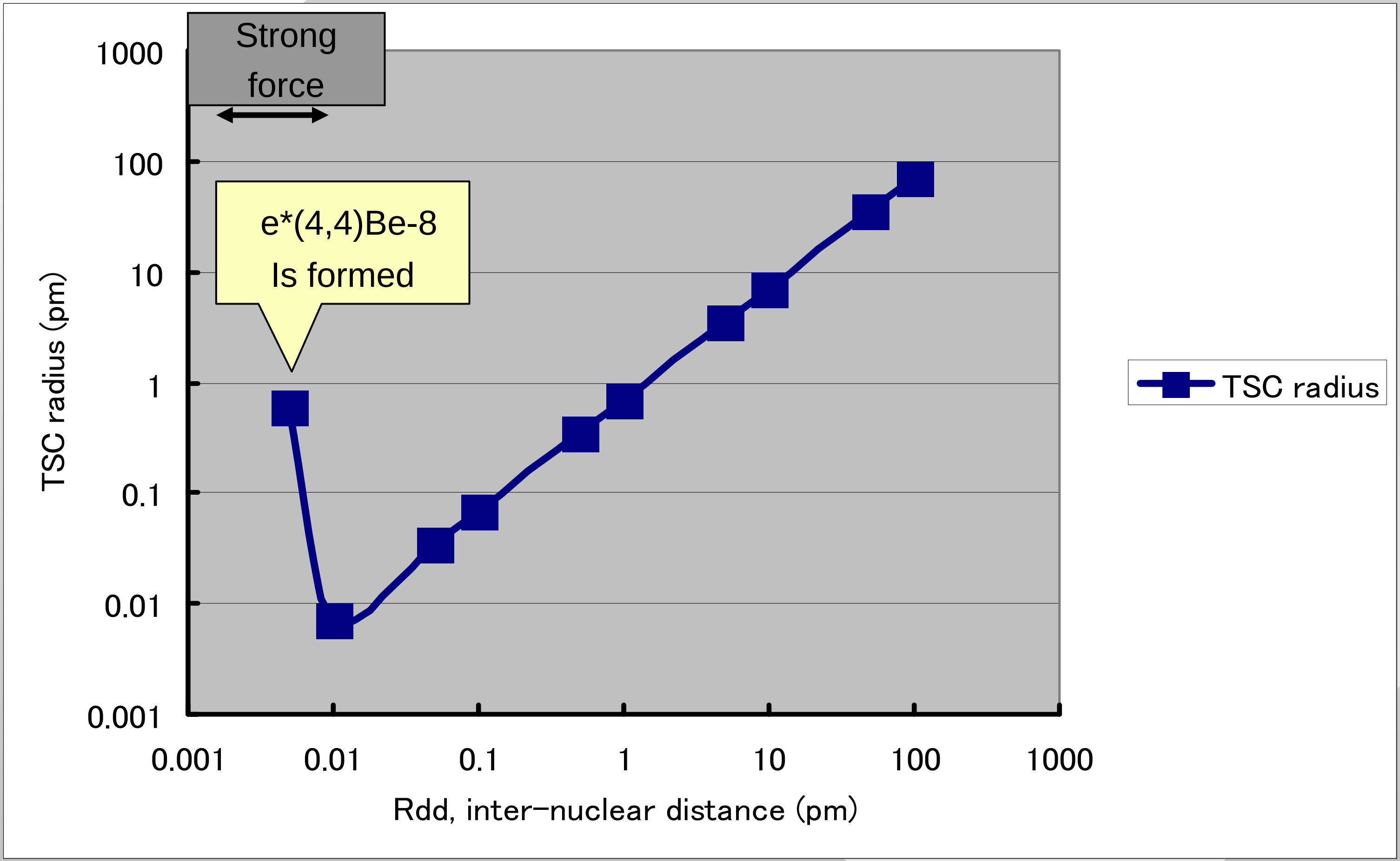
- How deep can TSC penetrate through e-cloud?

M + TSC
Nuclear Interaction Mechanism



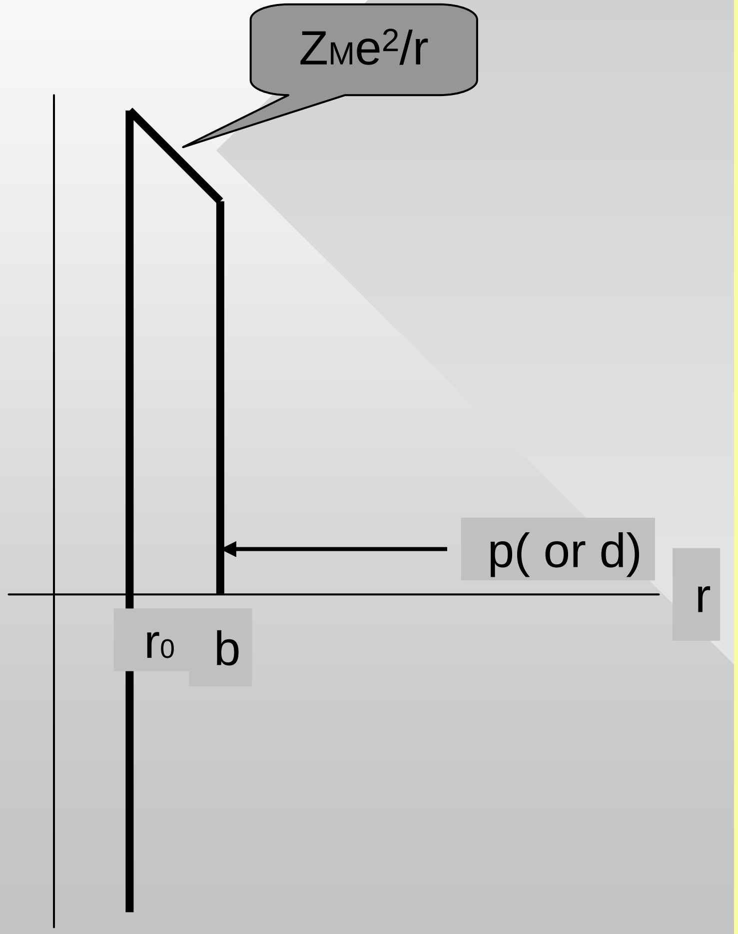
- Topological condition for Pion-Exchange (PEF)
- Selection of pick-up number of protons (+ neutrons for 4d/TSC) from 4p/TSC
- M + (1-4)p(or d) capture reaction

TSC Size by Dynamic Condensation



Sudden Tall Thin Barrier Approx.

When p (or d) gets into the strong force range, electrons separate and p (or d) feel Coulomb repulsion to the M-nucleus charge



- $r_0 = 1.2A^{1/3}$
- $b = r_0 + \lambda_\pi(=2.2\text{ fm})$
- $P_M(E) = \exp(-G)$
- $G = 0.436(\mu V(R_{1/2}))^{1/2}(b - r_0)$
- $R_{1/2} = r_0 + (b - r_0)/2$
- Reaction rate:

$$\lambda = S_{Mp}(E)vP_M(E)P_n/E$$

- $P_n =$

$$\exp(-0.218n(\mu V_{pp})^{1/2}R_{pp})$$

: Plural p (or d) existence probability in λ_π range

for n > 1. $P_n = 1$, for n = 1.

Results by STTBA calculation; M = Ni

- $P_{Mp}(E) = 9.2E\text{-}2$
- $P_{Md}(E) = 3.5E\text{-}2$

Reaction Rates:

- $\lambda_{Mp} = 3.7E\text{-}8$ (f/s/pair)
- $\lambda_{Md} = 2.1E\text{-}7$ (f/s/pair)
- $\lambda_{M4p} = 1.0E\text{-}8$ (f/s/pair)
- $\lambda_{M4d} = 3.4E\text{-}9$ (f/s/pair)
- <Macroscopic Reaction Rate> = $\lambda x N_{TSC}$
- With N_{tsc} = 1.0E+16 in 10nm area, Rate = 1E+8 f/s/cm2 and Y = 1E+14 in 1E+6 sec.

V_{pp} = 1.44/6 = 0.24 MeV
P_{2p} = 0.527
P_{2d} = 0.404

$S_{Mp}(0)$ = 1.0E+8 kevb
$S_{Md}(0)$ = 1.0E+9 keVb

$\lambda_{4d} = 4.9E\text{-}5$

When b-parameter of Ni + TSC potential becomes 0.1 pm, barrier factor is on the order of 1E-22 , which makes ca. 1E+9 reactions/s/cc for the flux of TSC = 1E+14 p/s/cm^2.

- ^{58}Ni+p→ ^{59}Cu*(3.42MeV)^{59}Ni* (7E4 y)
- ^{60}Ni + p → ^{61}Cu*(4.80 MeV)^{61}Ni
- ^{62}Ni + p → ^{63}Cu(6.12MeV);E_g=669keV
- ^{63}Ni + p → ^{65}Cu(7.45MeV)
- ^{104}Pd +p → ^{105}Ag*(4.97MeV)^{105}Pd
- ^{106}Pd + p → ^{107}Ag(5.43MeV)
- ^{108}Pd +p → ^{109}Ag(6.49MeV)
- Prompt Gamma-Rays emit.

  Ni-H gas system exp. By Piantelli (ASTI5)

  ; 660 keV peak by NaI detector

- ^{58}Ni + 4p → ^{62}Ge(11MeV) →FP?
- ^{58}Ni + 4d → ^{66}Ge(54MeV) →FP
- ^{105}Pd + 4p → ^{109}Sn(23MeV) →?
- ^{105}Pd +4d →^{113}Sn(52MeV) →FP
- ^{104}Pd+4d →^{112}Sn(52MeV) →FP
- Fission can be induced by TSC capture!
- Many foreign elements were detected by

  Piantelli, Karabut, Yamada, Ohmori,

  Mizuno, Miley, etc.

Ni + H reactions may be explained!

- When b-parameter of Ni + TSC potential becomes 0.1 pm,
- barrier factor is on the order of 1E-22 ,
- which makes ca. 1E+9 reactions/s/cc for the flux of TSC = 1E+14 p/s/cm^2.

Products by Ni + p reactions

- ^{58}Ni+p→

^{59}Cu*(1.36m, EC)^{59}Ni*(7E4 y)

- ^{60}Ni + p →

^{61}Cu*(3.3h, EC)^{61}Ni

- ^{61}Ni + p →

^{62}Cu*(9.7m, EC)^{62}Ni

- ^{62}Ni + p → ^{63}Cu(6.12MeV);Eg=669keV
- ^{64}Ni + p → ^{65}Cu(7.45MeV)

- Prompt Gamma-Rays emit.

- Ni-H gas system exp. By Piantelli (ASTI5)

; 660 keV peak by NaI detector

- 660 MJ Excess Energy

Fission by M + TSC is possible!

- $^{58}Ni + 4p \rightarrow$

  $^{62}Ge(11MeV) \rightarrow FP$
- $^{58}Ni + 4d \rightarrow$

  $^{66}Ge(54MeV) \rightarrow FP$
- $^{105}Pd + 4p \rightarrow$

  $^{109}Sn(23MeV) \rightarrow ?$
- $^{105}Pd + 4d \rightarrow$

  $^{113}Sn(52MeV) \rightarrow FP$
- $^{104}Pd + 4d \rightarrow$

  $^{112}Sn(52MeV) \rightarrow FP$

- Many foreign elements were detected by

  Piantelli, Karabut, Yamada, Ohmori,

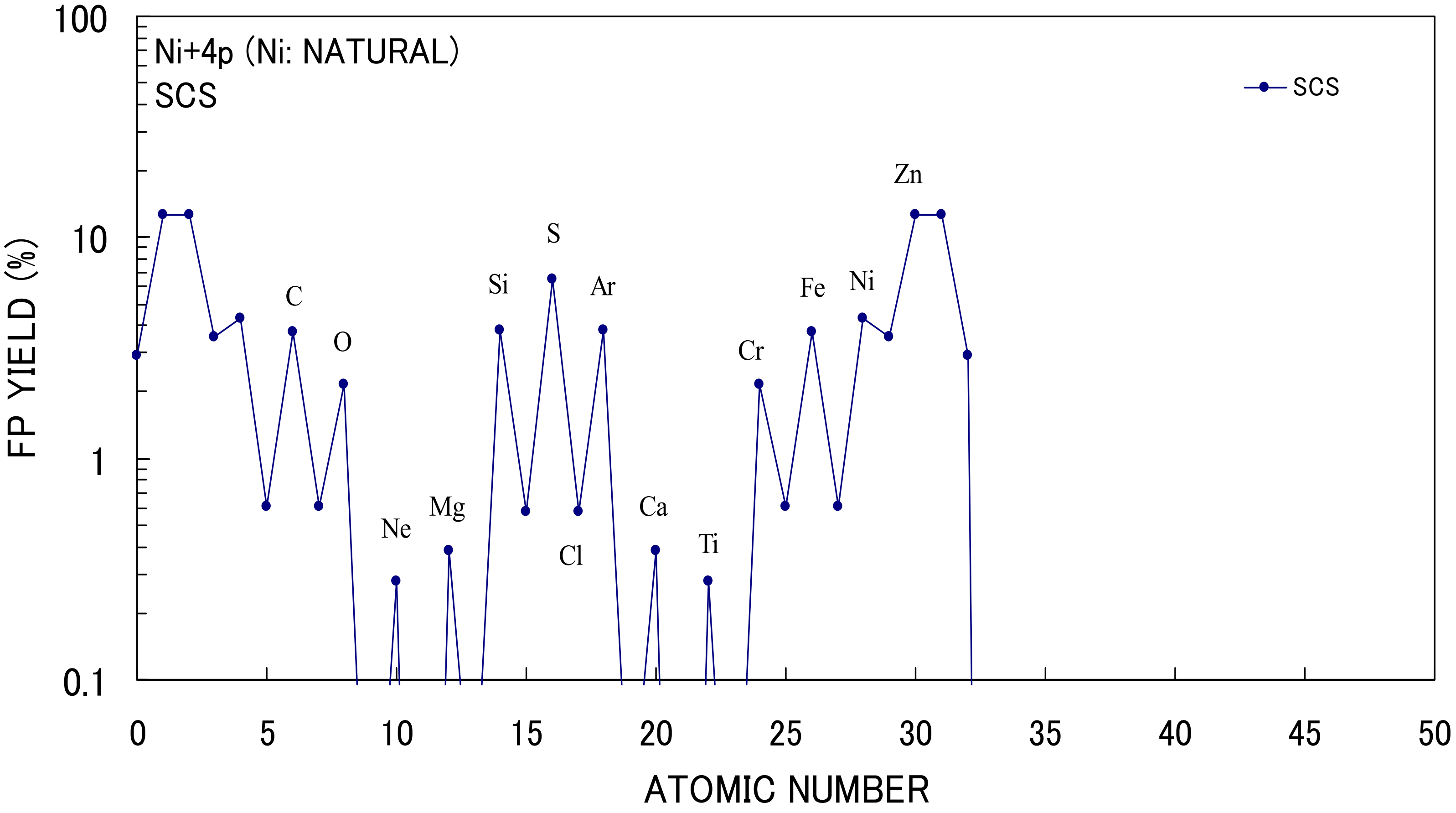
  Mizuno, Miley, etc.

- Fission can be induced by TSC capture!

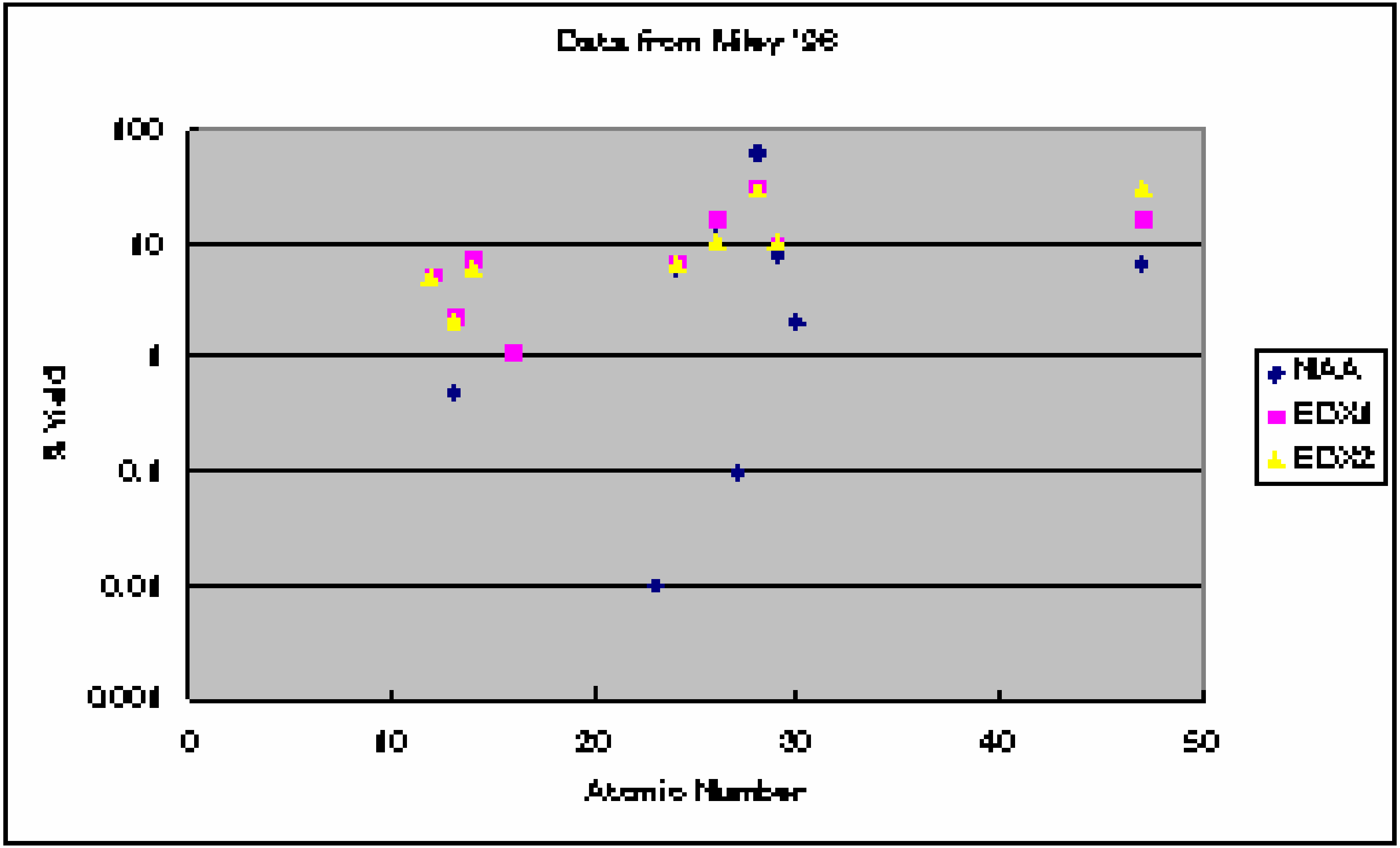
Table : Natural abundance of Ni isotopes and

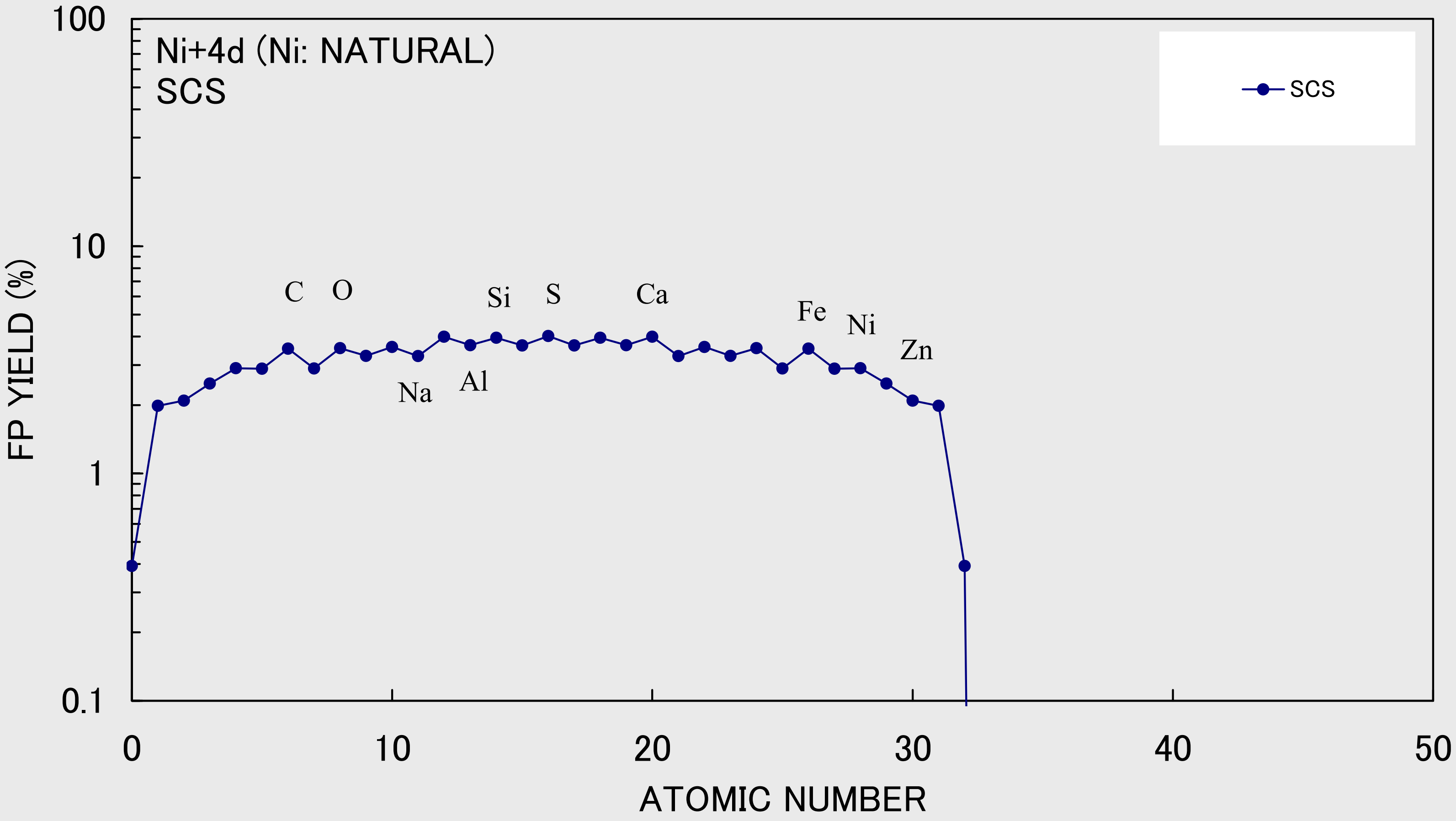
the excitation energies of compound nucleus by + 4p and + 4d reactions

Nuclides	Natural abundance (%)	+ 4p	Excitation energy (MeV)	+ 4d	Excitation energy (MeV)
^{58}Ni	68.077	^{62}Ge*	11.2	^{66}Ge*	53.9
^{60}Ni	26.223	^{64}Ge*	19.1	^{68}Ge*	55.1
^{61}Ni	1.140	^{65}Ge*	21.3	^{69}Ge*	55.4
^{62}Ni	3.634	^{66}Ge*	24.0	^{70}Ge*	56.4
^{64}Ni	0.926	^{68}Ge*	29.0	^{72}Ge*	58.0


Ni+4p (Ni: NATURAL)
SCS
SCS
FP YIELD (%)
ATOMIC NUMBER
100
10
1
0.1
0
5
10
15
20
25
30
35
40
45
50
C
O
Ne
Mg
Si
S
Cl
Ar
Ca
Ti
Cr
Fe
Ni
Zn

Ni-H Exp. By G. Miley and J. Patterson, J. New Energy, 1996, 1(3)p.5




Ni+4d (Ni: NATURAL)
SCS
SCS
100
10
1
0.1
FP YIELD (%)
0
10
20
30
40
50
ATOMIC NUMBER
C
O
Na
Al
Si
S
Ca
Fe
Ni
Zn

^{133}Cs + TSC Reactions

- ^{133}Cs + d → ^{135}Ba(Ex=12.91MeV) → ^{135}Ba(stable) + gammas(12.91MeV)
- ^{133}Cs + 2d → ^{137}La(Ex=25.32MeV) → FPs

  or ^{137}La(6E+4 y) + gammas
- ^{133}Cs + 3d → ^{139}Ce(Ex=38.29MeV) → FPs

  or ^{139}La(stable) + gammas
- **^{133}Cs + 4d → ^{141}Pr(Ex=50.49MeV) → FPs**

  or ^{141}Pr(stable) + gammas

Note: (1) + 2d is equivalent to ^{4}He + 23.8MeV.

(2) We need to detect 50.49 MeV gamma?

M+4d/TSC is much easier than M+4p/TSC

- Because fusion strong force (PEF values) for M+4d is about twice of M+4p
- (c.f.) $S_{dd}/S_{pd} = 10^6$

  with PEF = 2 for dd

  and PEF = 1 for pd

- Because we need to multiply probability of anti-parallel spin arrangement for protons in 4p-TSC.

- $^{133}Cs+p \rightarrow {}^{134}Ba(8.17MeV)$

  $\rightarrow {}^{134}Ba(stable)$
- $^{133}Cs+2p \rightarrow {}^{135}La(13.16MeV)$

  $\rightarrow {}^{135}Ba(stable)$
- $^{133}Cs+3p \rightarrow {}^{136}Ce(20.28MeV)$

  $\rightarrow {}^{136}Ce(stable)$

  or FPs
- $^{133}Cs+4p \rightarrow$

  $^{137}Pr(24.28MeV,1.28d)$

  $\rightarrow {}^{137}Ce(1.43d){}^{137}La$

  or FPs

If it were so:

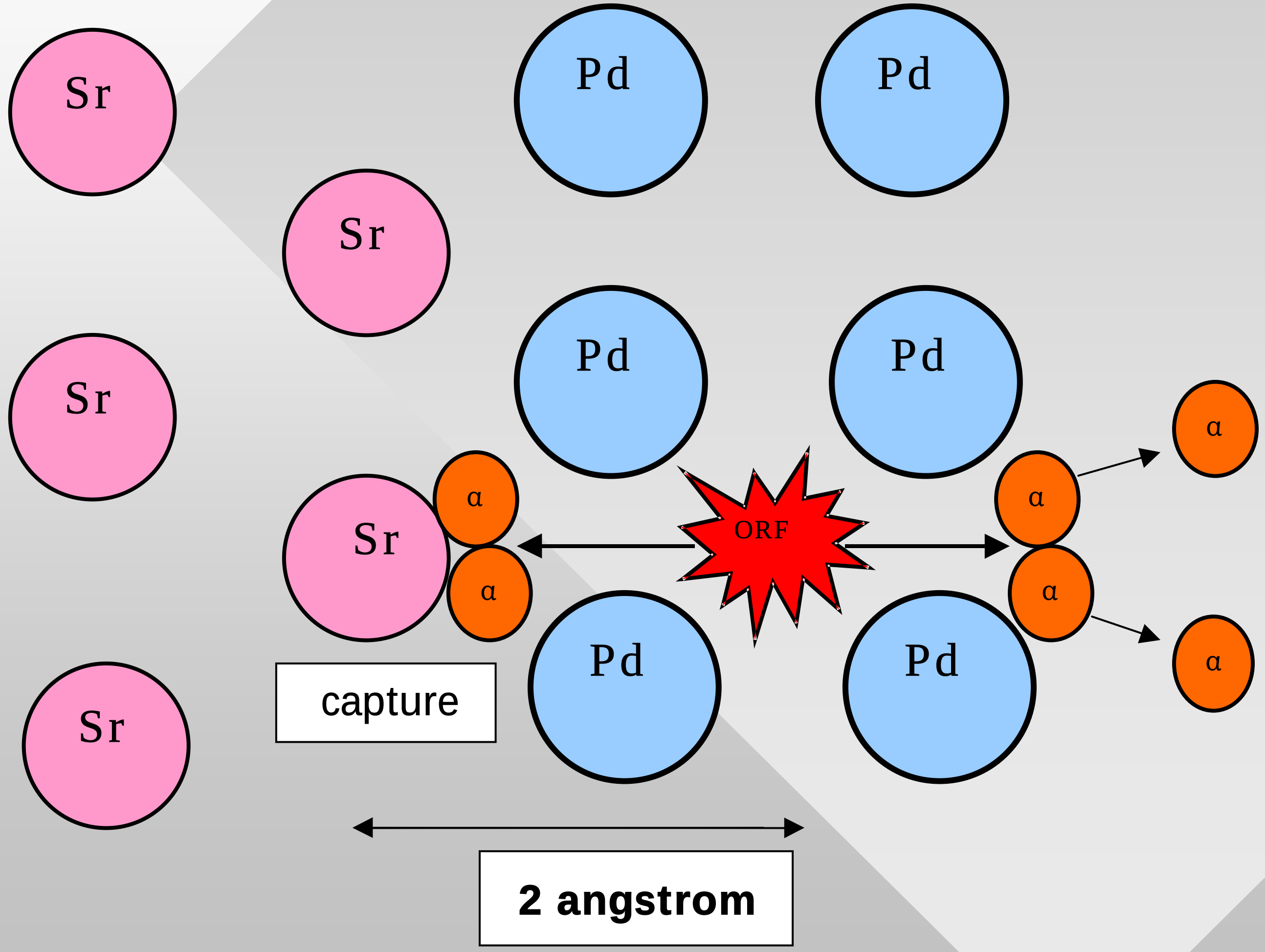
^{133}Cs + 8n (cluster-n, if existing) $\longrightarrow$

^{141}Cs(Q=-5.53 MeV) $\longrightarrow$ ^{141}Ba(18.3m) $\longrightarrow$

^{141}La(3.92h) $\longrightarrow$ ^{141}Ce(32.5d) $\longrightarrow$ ^{141}Pr

- ^{141}La and ^{141}Ce should be found in experiments: No Observations !
- Threshold reaction: E_{8n} should be GT 5.6 MeV.
- So, this is not possible in condensed matter.

Transmutation by 8D fusion of ORF Condensation



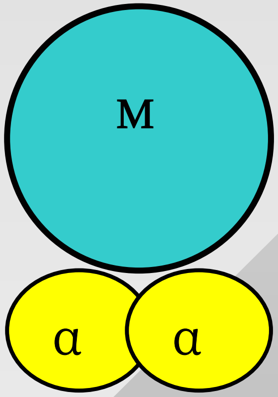
capture

2 angstrom

^{8}Be Absorption Reaction for Transmutation

- $8D \rightarrow \quad 2\times{}^{8}Be + 95.2\ MeV$
- **$M(A,Z) + {}^{8}Be(47.6\ MeV) \rightarrow M(A+8, Z+4) + Q$**
- $^{88}Sr + {}^{8}Be(47.6\ MeV) \rightarrow \quad {}^{96}Mo + Q$
- $^{133}Cs + {}^{8}Be(47.6\ MeV) \rightarrow \quad {}^{141}Pr + Q$

Deformed cloud of ^{8}Be makes large contact surface of pion-exchange for capture (fusion) reaction.



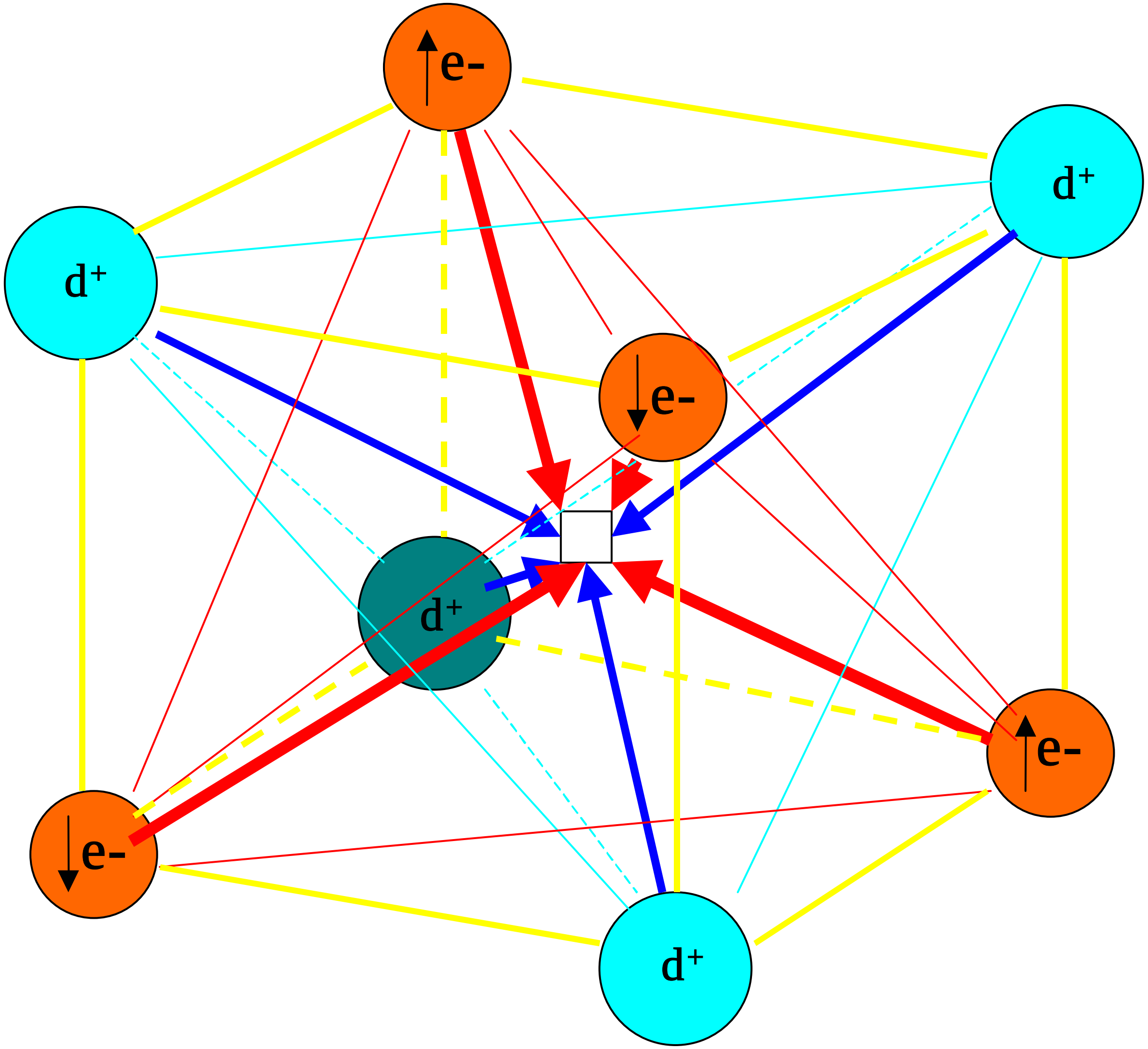
$^{3}He/^{4}He$ Production Ratio by Tetrahedral Symmetric Condensation

AIMS

- Some works report ^{3}He generation, in addition to ^{4}He: Arata-Zhang, McKubre et al., and so on
- Based on EQPET model to treat 4-body resonance fusion of mixed H/D state under tetrahedral symmetric condensation, calculation is made to estimate variation of ^{3}He/^{4}He production ratio as a function of H/D mixing rate.
- EQPET: Electronic Quasi-Particle Expansion Theory

Classical View of Tetrahedral Condensation

Orthogonal Coupling of Two D_2 Molecule makes Miracle !



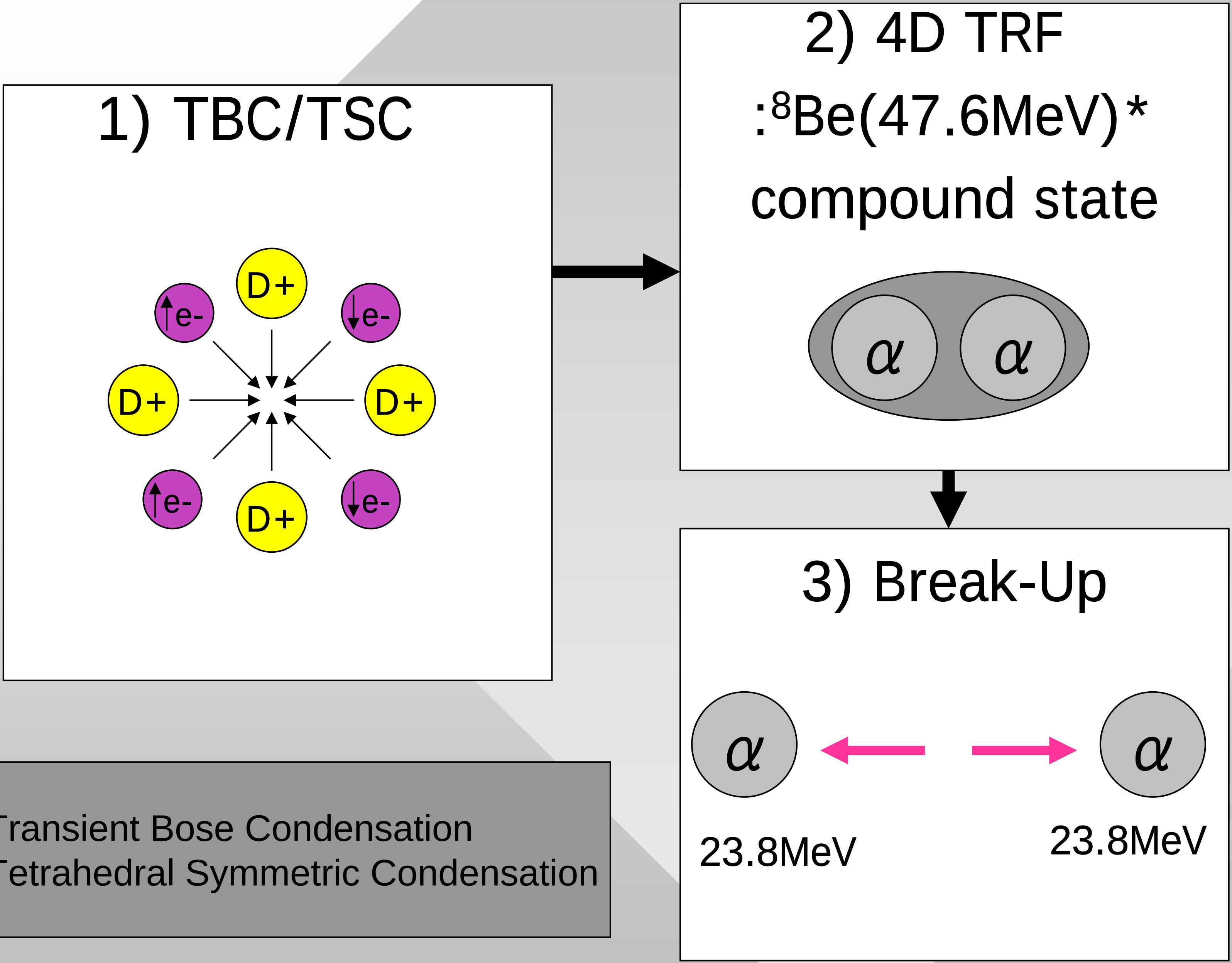
Transient Combination of Two D2 Molecules (upper and lower)

Squeezing only from O-Sites to T-site

3-dimension Frozen State for 4d+s and 4e-s

Quadruplet e* (4,4)

Formation of Electrons around T-site



1) TBC/TSC

2) 4D TRF

:^{8}Be(47.6MeV)*

compound state

3) Break-Up

TBC: Transient Bose Condensation
TSC: Tetrahedral Symmetric Condensation

Assumptions

- By replacing one or two deuterons in 4D TSC with one or two protons
- And assuming same velocities for d and p due to keeping charge-neutrality and energy-minimum in dynamic motion
- We can apply the model to H/D mixed systems

Basic 4-body Fusion by TSC

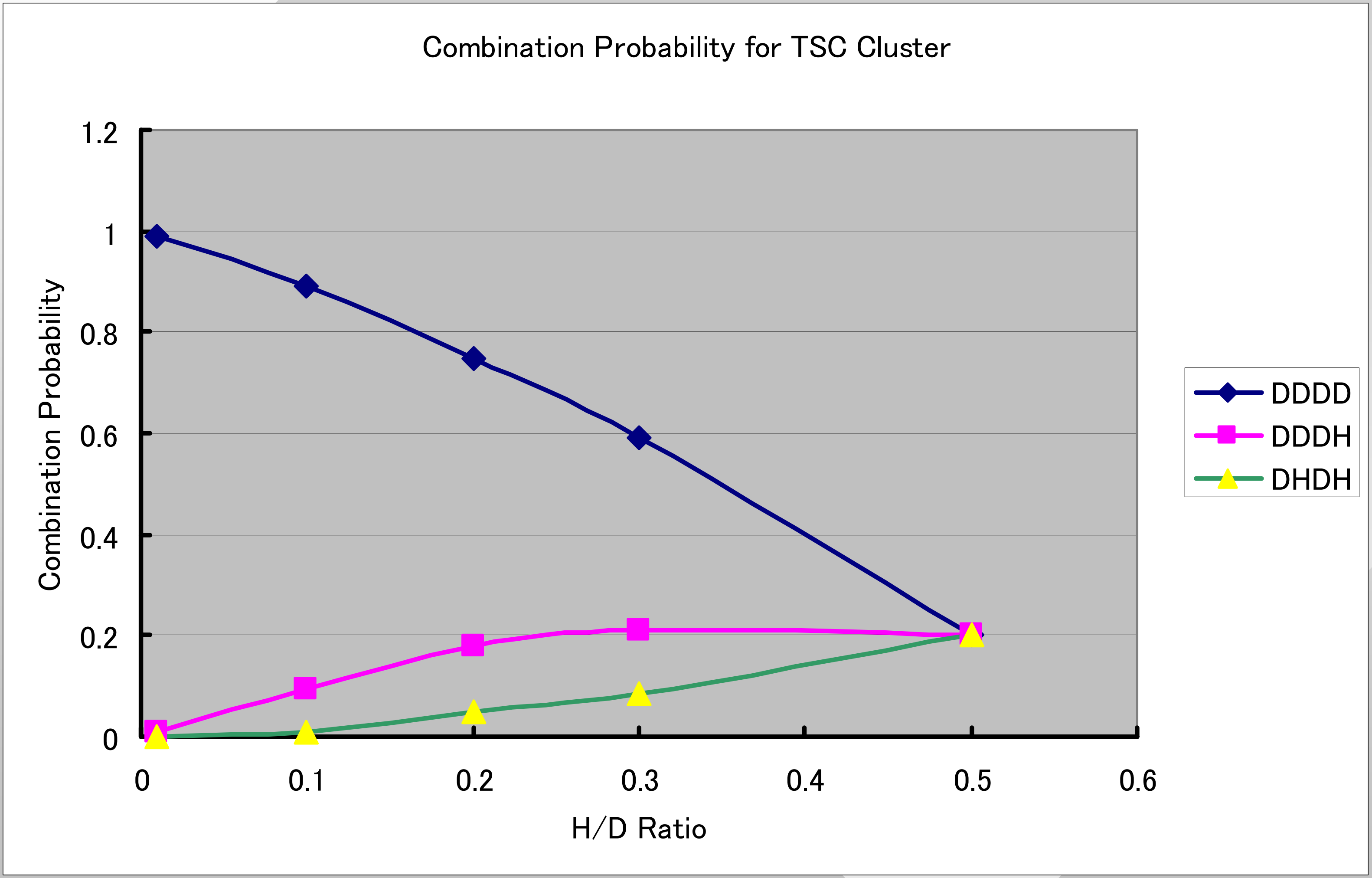
- $D+D+D+D \rightarrow {}^{8}Be^{*} \rightarrow {}^{4}He + {}^{4}He + 47.6MeV$
- $D+D+D+H \rightarrow {}^{7}Be^{*} \rightarrow {}^{3}He + {}^{4}He + 29.3MeV$
- $D+H+D+H \rightarrow {}^{6}Be^{*} \rightarrow {}^{3}He + {}^{3}He + 11MeV$

Combination Probability of H/D Mixed TSC Cluster

- $Y = H/D$
- DDDD: $(1-Y)^4$
- DDDH: $(1-Y)^3Y$
- DHDH: $(1-Y)^2Y^2$
- DHHH: $(1-Y)Y^3$

Normalize sum probability to be 1.0

Combination Probability for TSC Cluster



Fusion Rate Calculation for EQPET Molecule

- $\lambda_{dddp} = (S_{dddp}/E)vP(dd)P(dp)$
- $\lambda_{dpdp} = (S_{dpdp}/E)vP(dp)P(dp)$
- $S_{dddp} = 10^9$ keVb
- $S_{dpdp} = 10^8$ keVb
- P(dp): Barrier factor for d-p fusion with dpe* molecule: $\exp(-2\Gamma_n)$
- $\Gamma_n = \int (V_s-E)^{1/2}dE/((h/\pi)/(2\mu)^{1/2})$

Fusion Rate for EQPET Molecule

EQP	DDe* (f/s/cl)	DHe* (f/s/cl)	DDDDe* (f/s/cl)	DDDHe* (f/s/cl)	DHDHe* (f/s/cl)
e(1,1)	1E-137	1E-120	1E-252	1E-232	1E-228
e*(2,2)	1E-20	1E-23	1E-17	5E-16	2E-14
e*(4,4)	(1E-16)	(1E-21)	1E-9	1E-10	1E-10

Calculation of Modal Fusion Rate

- Wave function for TSC cluster:

$$\Psi_t = a_1 \Psi(1,1) + a_2 \Psi(2,2) + a_4 \Psi(4,4)$$

- Modal Fusion Rate:

$$\lambda = a_1^2 \lambda(1,1) + a_2^2 \lambda(2,2) + a_4^2 \lambda(4,4)$$

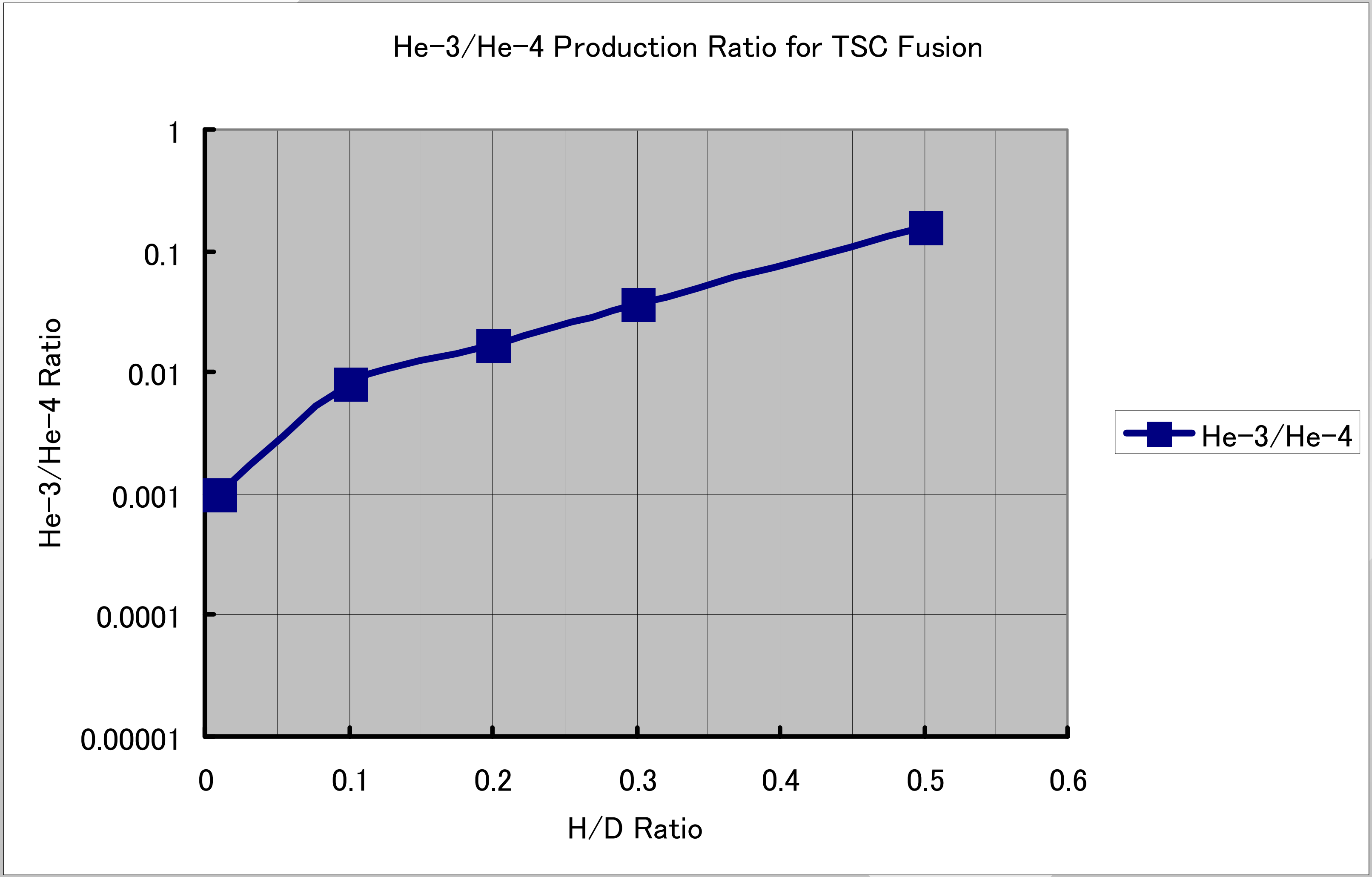
- By taking into account spin arrangement only, $a_1^2=0.78$, $a_2^2=0.19$, $a_4^2=0.03$

Modal Fusion Rate

- Considering statistical weights for spin arrangement, modal fusion rates were calculated using FRs of EQPET molecules

DDDD-TSC	DDDH-TSC	DHDH-TSC
λ_{dd} = 2E-21 (f/s/cl)	λ_{dp} = 1E-23 (f/s/cl)	λ_{dp} = 1E-23 (f/s/cl)
λ_{dddd} = 3E-11 (f/s/cl)	λ_{dddp} = 4E-12 (f/s/cl)	λ_{dpdp} = 3E-12 (f/s/cl)

Using combination probabilities of H/D mixed clusters and modal fusion rates, ^{3}He/^{4}He ratios were calculated



Comparison with Experiment

- Arata-Zhang; ^{3}He/^{4}He ca. 0.25

  Proc. Jpn. Acad., 73, Ser.B(1997)1-7

- Present Theory;

  ^{3}He/^{4}He ca. 0.25 for H/D = 0.6

^{3}He for Stable Nuclear Fuel

- Stable Resource to produce Tritium:

  $^3\text{He} + n \rightarrow p + t + 0.765\ \text{MeV}$

  Easy to extract T from gas-pase.

  Tritium decays with 12.3 yrs half life.

  For DT reactors and H-bomb.

  (neutron detector)

- Fuel for D-^{3}He reactors.

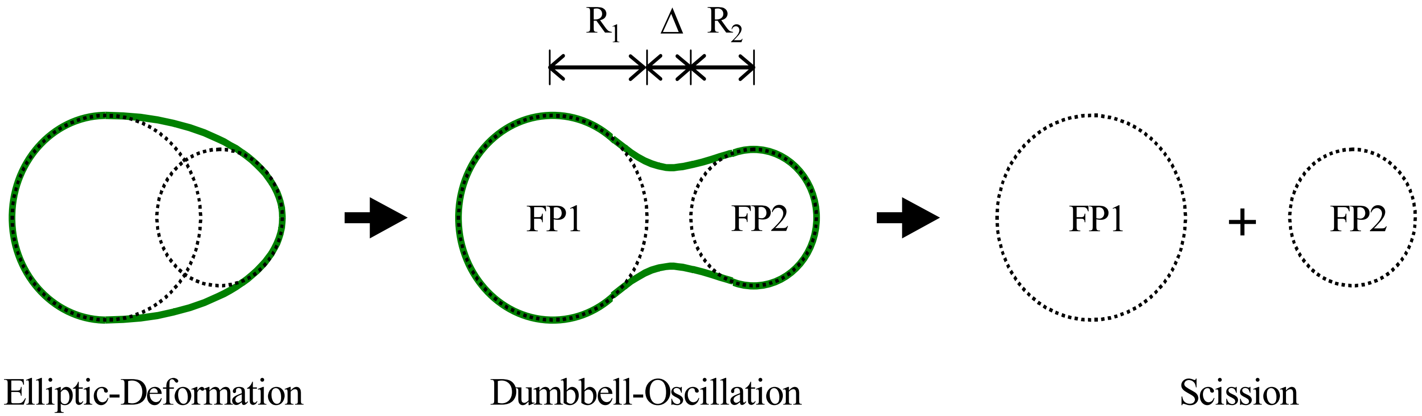
Summary for ^{3}He/^{4}He Ratio

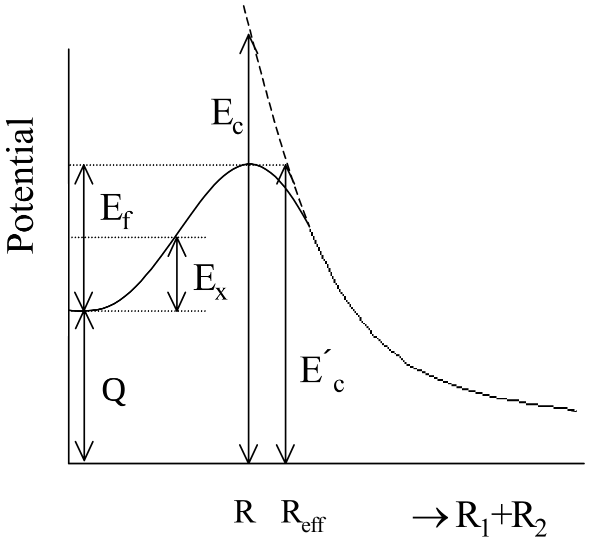
- H should be contained with some amount in usual CMNS deuterium-experiment.
- EQPET model was applied to 4-body fusion of mixed H/D TSC-system.
- ^{3}He/^{4}He production ratio was 0.001 for 1 % H-contamination.
- ^{3}He/^{4}He production ratio was 0.16 for 50 % H-contamination.

OUTLINE-2:
Selective Channel Fission Theory

- 2.1 Channel Dependent Fission Barrier
- 2.2 Rotating Liquid Drop Model
- 2.3 Selective Channel Scissions
- 2.4 Test by U-235 + n Fission
- 2.5 Pd, W, Au
- 2.7 A-Distribution, Z-Distribution, Isotopes and Radioactivity

Fission Barrier by Rotating Liquid Drop Model





$E_c \propto Z_1Z_2/(R_1+R_2)$
:Coulomb repulsion

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

E'_c : Effective Coulomb Energy

E_x: Excitation Energy

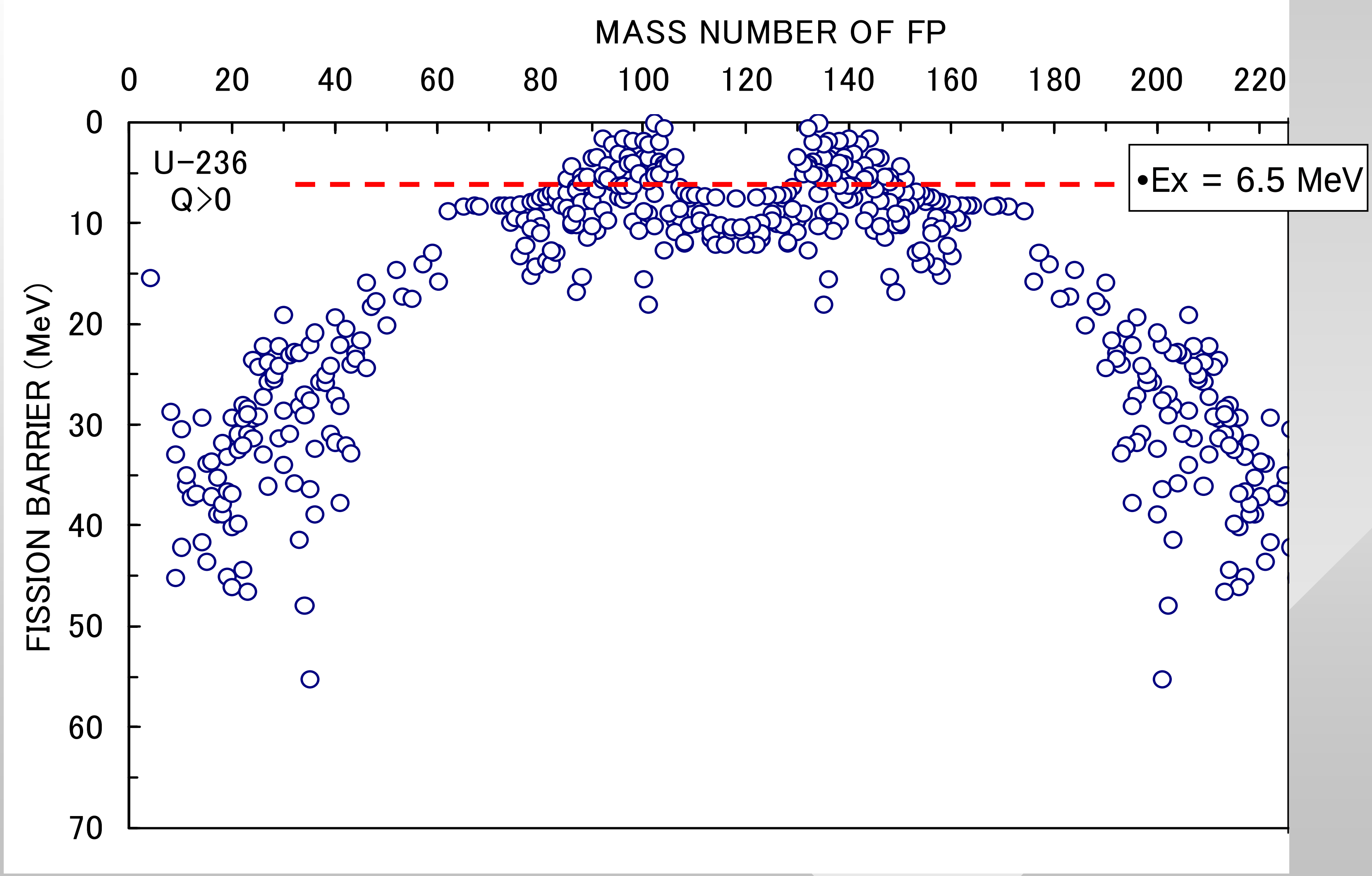
E_f: Fission Barrier

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

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

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

Channel Dependent Fission Barriers for U-235 +n



$$\left.\begin{array}{l} {}^{236}\mathrm{U} \to {}^{92}\mathrm{Kr} + {}^{144}\mathrm{Ba} \\ {}^{236}\mathrm{U} \to {}^{102}\mathrm{Zr} + {}^{134}\mathrm{Te} \\ {}^{236}\mathrm{U} \to {}^{104}\mathrm{Mo} + {}^{132}\mathrm{Sn} \\ \qquad \vdots \end{array}\right\} E_f \le E_x \Rightarrow$$

Channel-open probability

1

$$\left.\begin{array}{l} {}^{236}\mathrm{U} \to {}^{79}\mathrm{Ga} + {}^{157}\mathrm{Pm} \\ {}^{236}\mathrm{U} \to {}^{88}\mathrm{Kr} + {}^{148}\mathrm{Ba} \\ {}^{236}\mathrm{U} \to {}^{90}\mathrm{Rb} + {}^{146}\mathrm{Cs} \\ \qquad \vdots \end{array}\right\} E_f > E_x \Rightarrow 0 < P_i(E_x) < 1$$

(Prompt Neutron Emission)

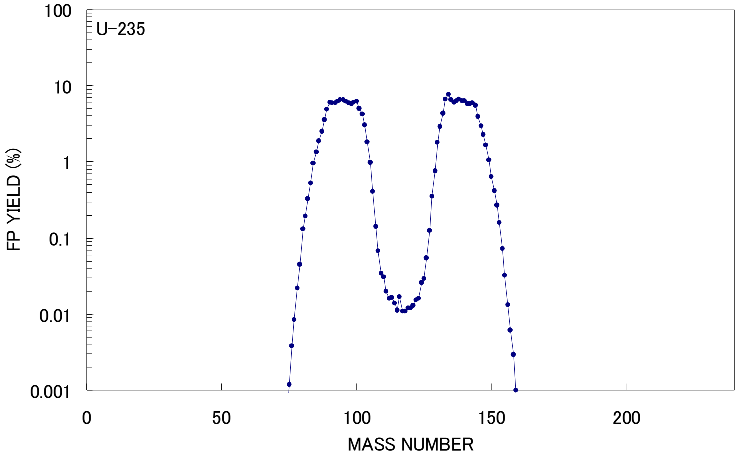
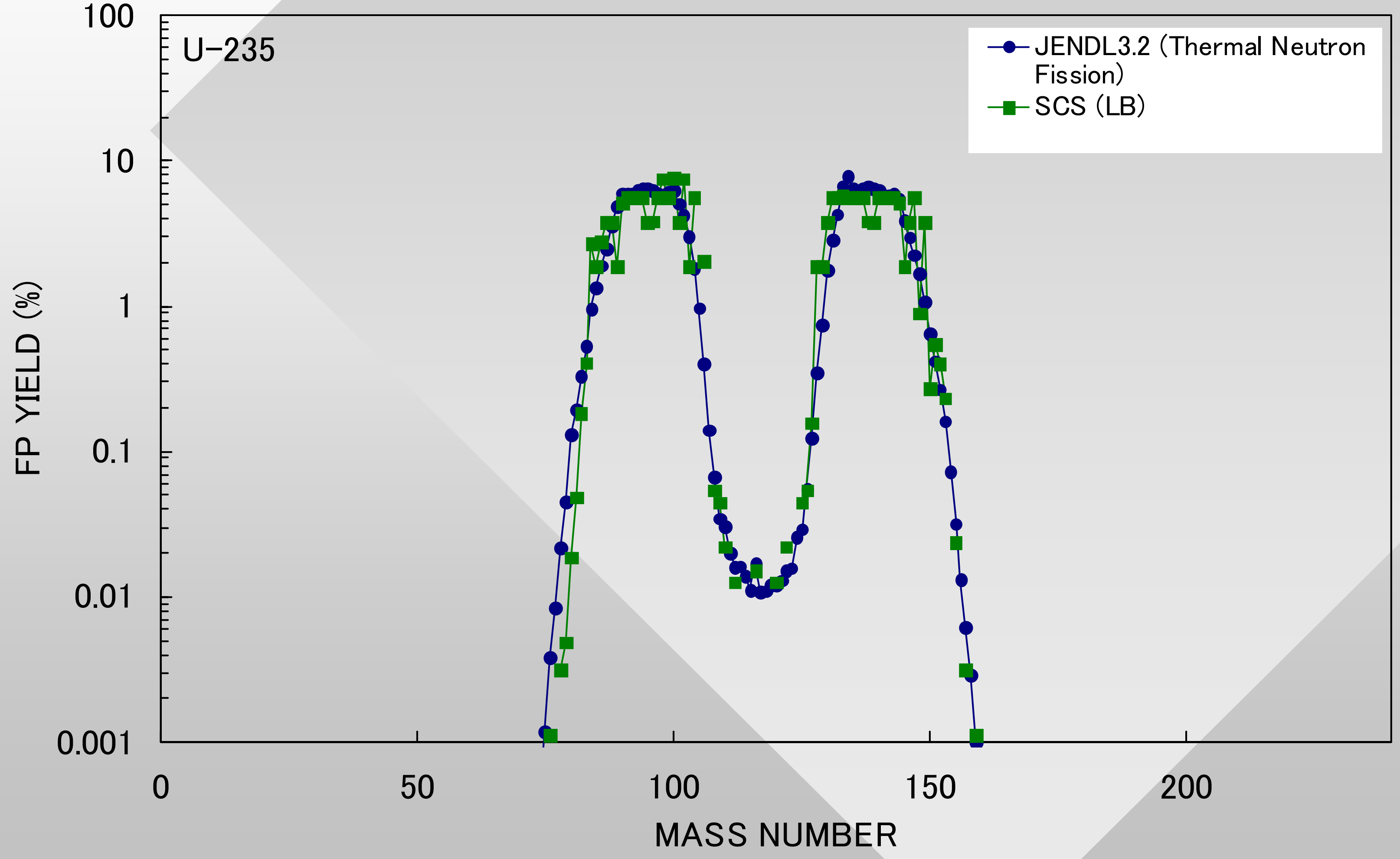
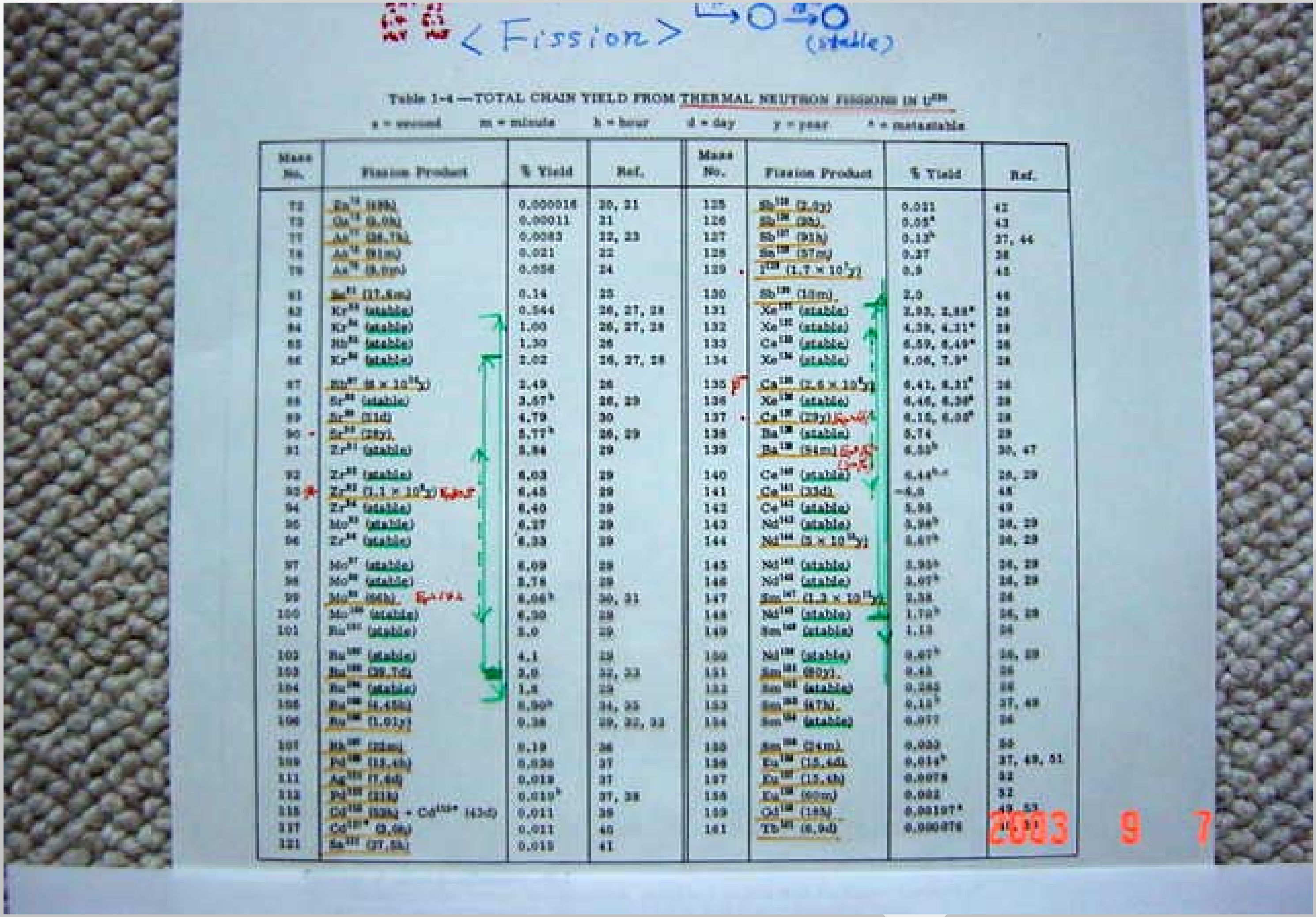


Fig. 1-3: Selective Channel Scission

FP Distribution for U-235 + n Fission



•At Two Peaks, Many Stable Isotopes while Many RI's at valley and edges



< Fission > → ○ → ○ (stable)

Table 1-4—TOTAL CHAIN YIELD FROM THERMAL NEUTRON FISSIONS IN U^{235}

s = second m = minute h = hour d = day y = year * = metastable

Mass No.	Fission Product	% Yield	Ref.	Mass No.	Fission Product	% Yield	Ref.
72	Zn^{72} (49h)	0.000016	20, 21	125	Sb^{125} (2.0y)	0.021	42
73	Ga^{73} (5.0h)	0.00011	21	126	Sb^{126} (9h)	0.05^a	43
77	As^{77} (38.7h)	0.0083	22, 23	127	Sb^{127} (91h)	0.13^b	37, 44
78	As^{78} (91m)	0.021	22	128	Sn^{128} (57m)	0.37	38
79	As^{79} (9.0m)	0.056	24	129	I^{129} (1.7 × 10^7y)	0.9	45
81	Se^{81} (17.5m)	0.14	25	130	Sb^{130} (10m)	2.0	46
83	Kr^{83} (stable)	0.544	26, 27, 28	131	Xe^{131} (stable)	2.93, 2.88^a	28
84	Kr^{84} (stable)	1.00	26, 27, 28	132	Xe^{132} (stable)	4.38, 4.31^a	28
85	Rb^{85} (stable)	1.30	26	133	Cs^{133} (stable)	6.59, 6.49^a	28
86	Kr^{86} (stable)	2.02	26, 27, 28	134	Xe^{134} (stable)	8.06, 7.9^a	28
87	Rb^{87} (6 × 10^{10}y)	2.49	26	135	Cs^{135} (2.6 × 10^6y)	6.41, 6.31^a	28
88	Sr^{88} (stable)	3.57^b	26, 29	136	Xe^{136} (stable)	6.46, 6.36^a	28
89	Sr^{89} (51d)	4.79	30	137	Cs^{137} (29y)	6.15, 6.05^a	28
90	Sr^{90} (28y)	5.77^b	26, 29	138	Ba^{138} (stable)	5.74	29
91	Zr^{91} (stable)	5.84	29	139	Ba^{139} (84m)	6.55^b	30, 47
92	Zr^{92} (stable)	6.03	29	140	Ce^{140} (stable)	6.44^{b,c}	26, 29
93	Zr^{93} (1.1 × 10^6y)	6.45	29	141	Ce^{141} (33d)	~6.0	48
94	Zr^{94} (stable)	6.40	29	142	Ce^{142} (stable)	5.95	49
95	Mo^{95} (stable)	6.27	29	143	Nd^{143} (stable)	5.98^b	26, 29
96	Zr^{96} (stable)	6.33	29	144	Nd^{144} (5 × 10^{15}y)	5.67^b	26, 29
97	Mo^{97} (stable)	6.09	29	145	Nd^{145} (stable)	3.93^b	26, 29
98	Mo^{98} (stable)	5.78	29	146	Nd^{146} (stable)	3.07^b	26, 29
99	Mo^{99} (66h)	6.06^b	30, 31	147	Sm^{147} (1.3 × 10^{11}y)	2.38	26
100	Mo^{100} (stable)	6.30	29	148	Nd^{148} (stable)	1.70^b	26, 29
101	Ru^{101} (stable)	5.0	29	149	Sm^{149} (stable)	1.13	26
102	Ru^{102} (stable)	4.1	29	150	Nd^{150} (stable)	0.67^b	26, 29
103	Ru^{103} (39.7d)	3.0	32, 33	151	Sm^{151} (80y)	0.45	26
104	Ru^{104} (stable)	1.8	29	152	Sm^{152} (stable)	0.285	26
105	Ru^{105} (4.45h)	0.90^b	34, 35	153	Sm^{153} (47h)	0.15^b	37, 49
106	Ru^{106} (1.01y)	0.38	29, 32, 33	154	Sm^{154} (stable)	0.077	26
107	Rh^{107} (22m)	0.19	36	155	Sm^{155} (24m)	0.033	50
109	Pd^{109} (13.4h)	0.030	37	156	Eu^{156} (15.4d)	0.014^b	37, 49, 51
111	Ag^{111} (7.6d)	0.019	37	157	Eu^{157} (15.4h)	0.0078	52
112	Pd^{112} (21h)	0.010^b	37, 38	158	Eu^{158} (60m)	0.002	52
115	Cd^{115} (53h) + Cd^{115*} (43d)	0.011	39	159	Gd^{159} (18h)	0.00107^a	49, 53
117	Cd^{117*} (3.0h)	0.011	40	161	Tb^{161} (6.9d)	0.000078	
121	Sn^{121} (27.5h)	0.015	41				

FP of U-fission becomes CLEANER IF Lower Excitation (5MeV) by Multi-Photons Absorption Process

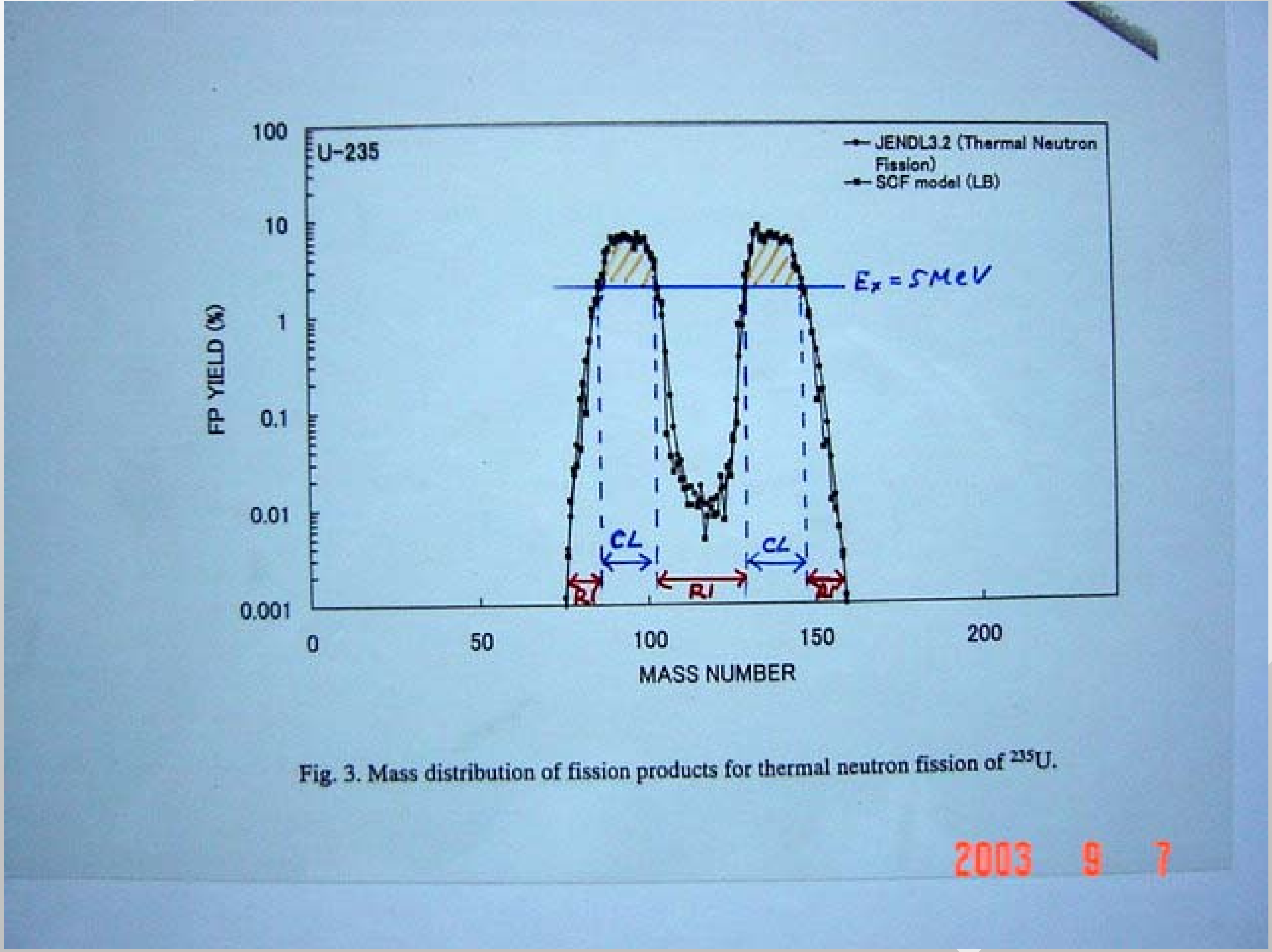


Fig. 3. Mass distribution of fission products for thermal neutron fission of ^{235}U.

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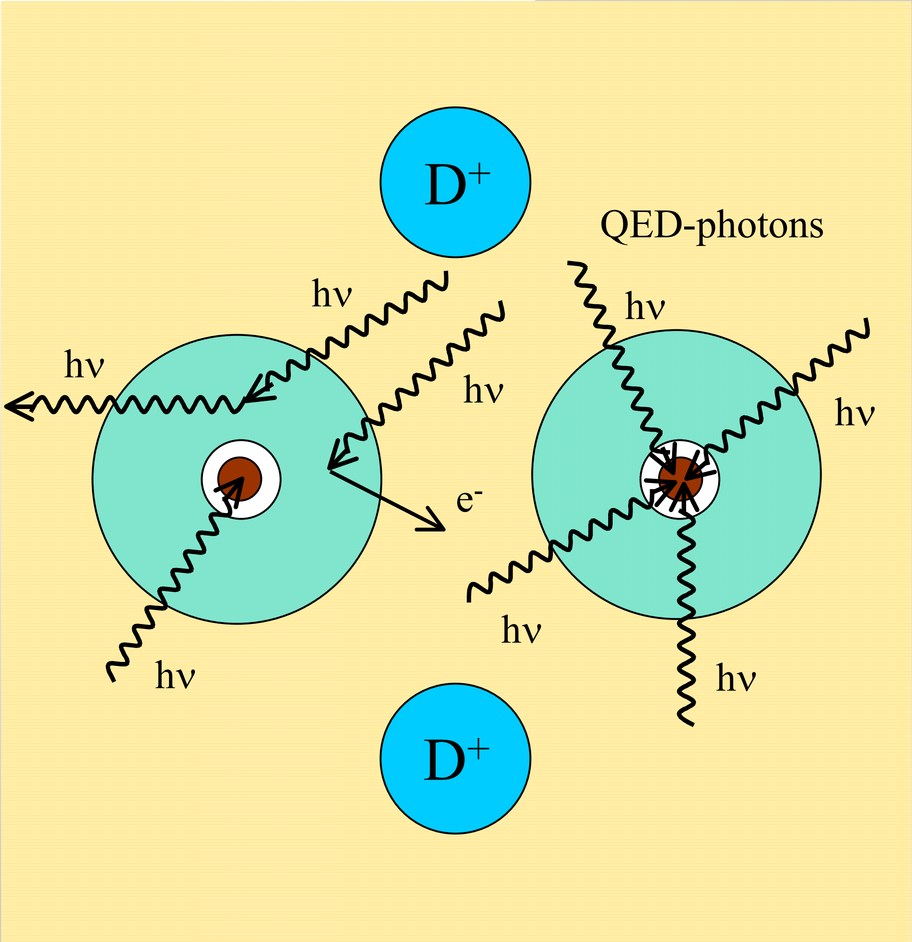
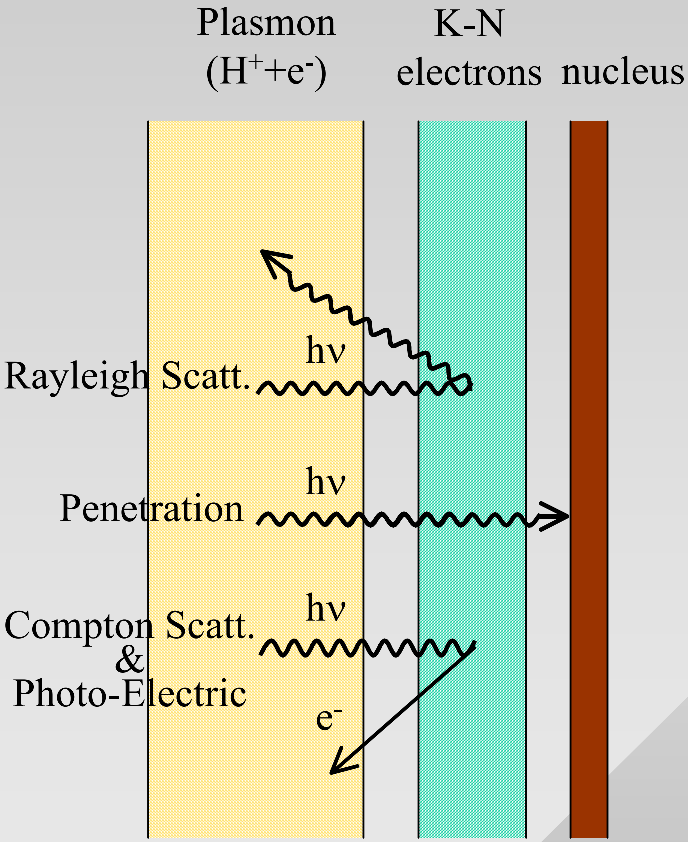
Multi-Photon Absorption Process in PdDx



2D-model



1D-model

Fig.1 : Multi-Photon Absorption in Pd-nucleus by QED Coupling to PdDx Plasma Oscillation

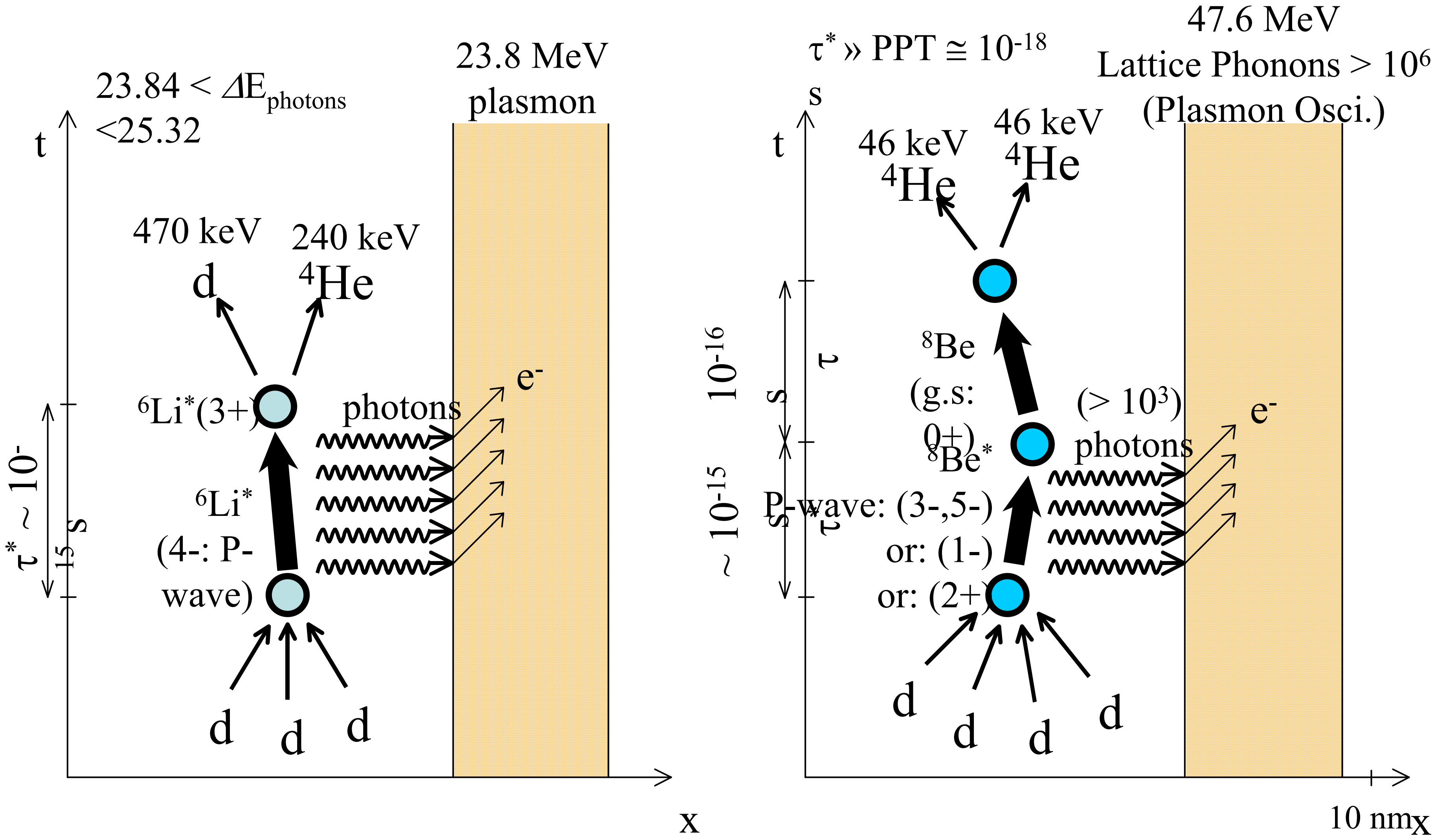


Fig. 2-2: Coherent X-rays for PdDx system

Multi-Photon Induced Fission Model

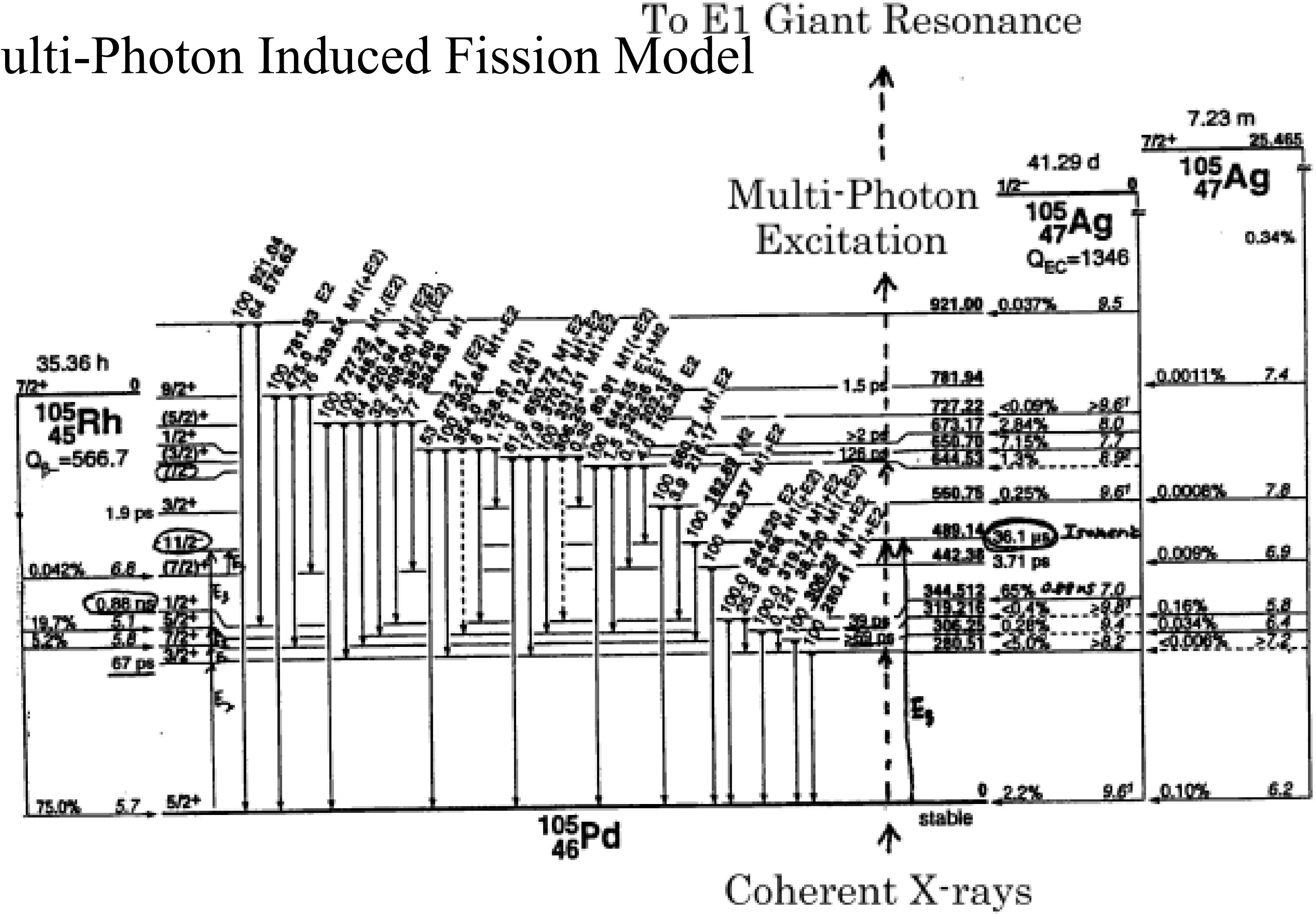
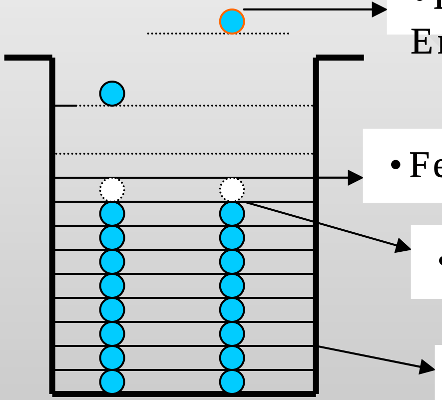
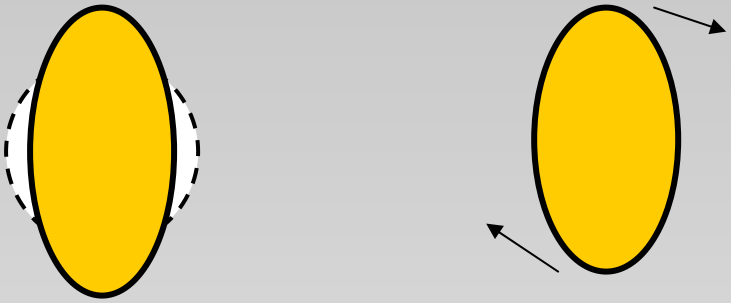


Fig. 2-3: Multi-Photon Excitation



- Particle Emission
- Fermi Level
- Hole
- Well Potential

- a) Excitation by Nuclear Shell Structure



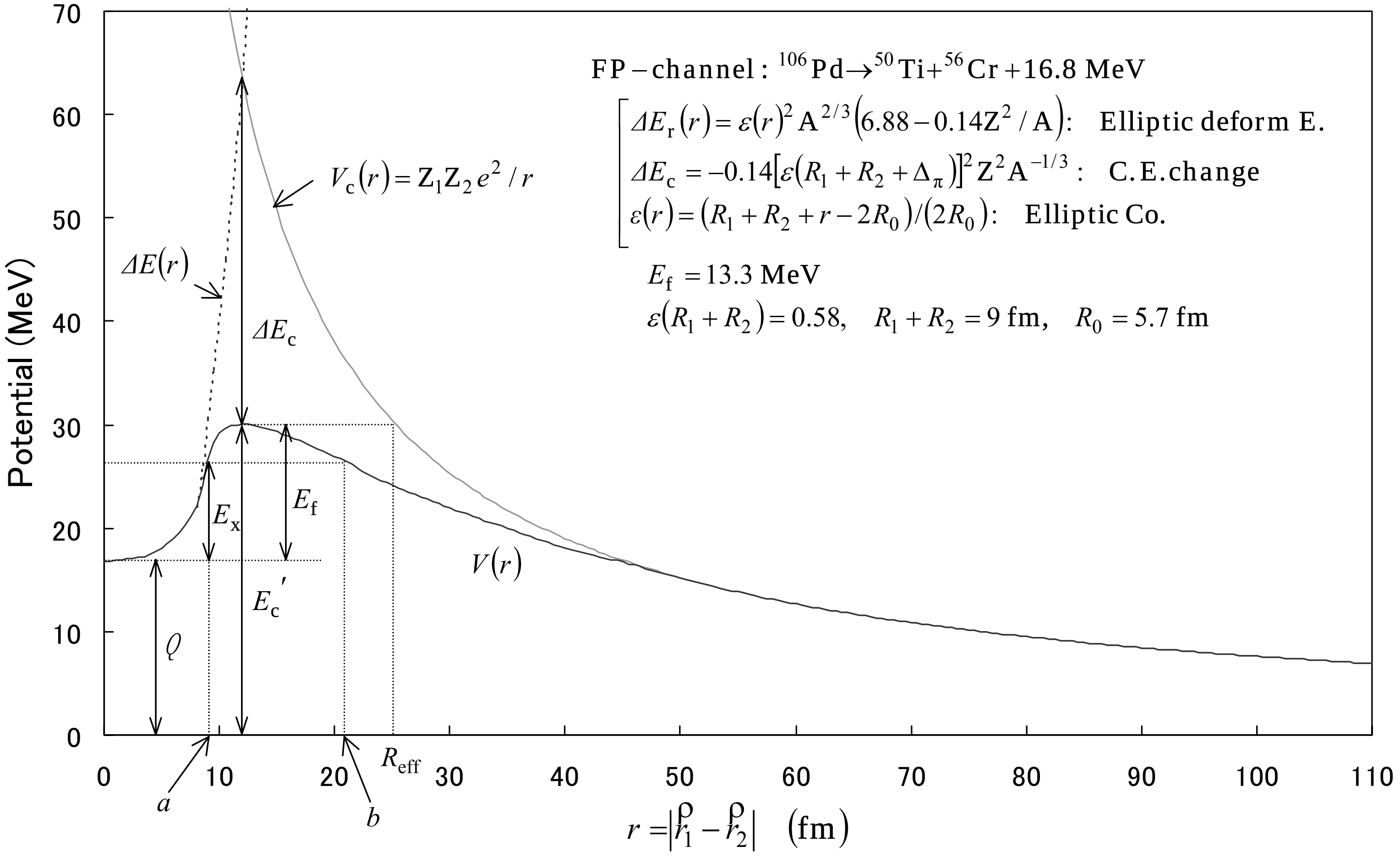
- vibration
- rotation

- b) Excitation by Collective Deformation
- (starting with low lying level states)

Excitation to E1 Giant Resonance

- Excitation by Low Energy (<5MeV) Photons to avoid nucleon (neutron; ca. 5 MeV separation energy) emission
- Multi-Photon Absorption to make Collective Deformation (Dumbbell =E1 +E3)
- Excitation Pumping-up via Random Level Transition (Enhanced Cross Section for Excited State Photon-Absorption)

Determination of Fission Barrier Height for Pd



FP − channel : $^{106}\mathrm{Pd} \rightarrow {}^{50}\mathrm{Ti} + {}^{56}\mathrm{Cr} + 16.8\ \mathrm{MeV}$

$\Delta E_r(r) = \varepsilon(r)^2 A^{2/3}(6.88 - 0.14 Z^2 / A)$: Elliptic deform E.

$\Delta E_c = -0.14[\varepsilon(R_1 + R_2 + \Delta_\pi)]^2 Z^2 A^{-1/3}$: C.E.change

$\varepsilon(r) = (R_1 + R_2 + r - 2R_0)/(2R_0)$: Elliptic Co.

$E_f = 13.3\ \mathrm{MeV}$

$\varepsilon(R_1 + R_2) = 0.58$, $R_1 + R_2 = 9\ \mathrm{fm}$, $R_0 = 5.7\ \mathrm{fm}$

Fig.4 : Fission potential for a scission channel of ^{106}Pd

Channel Dependent Fission Barriers for Pd-104

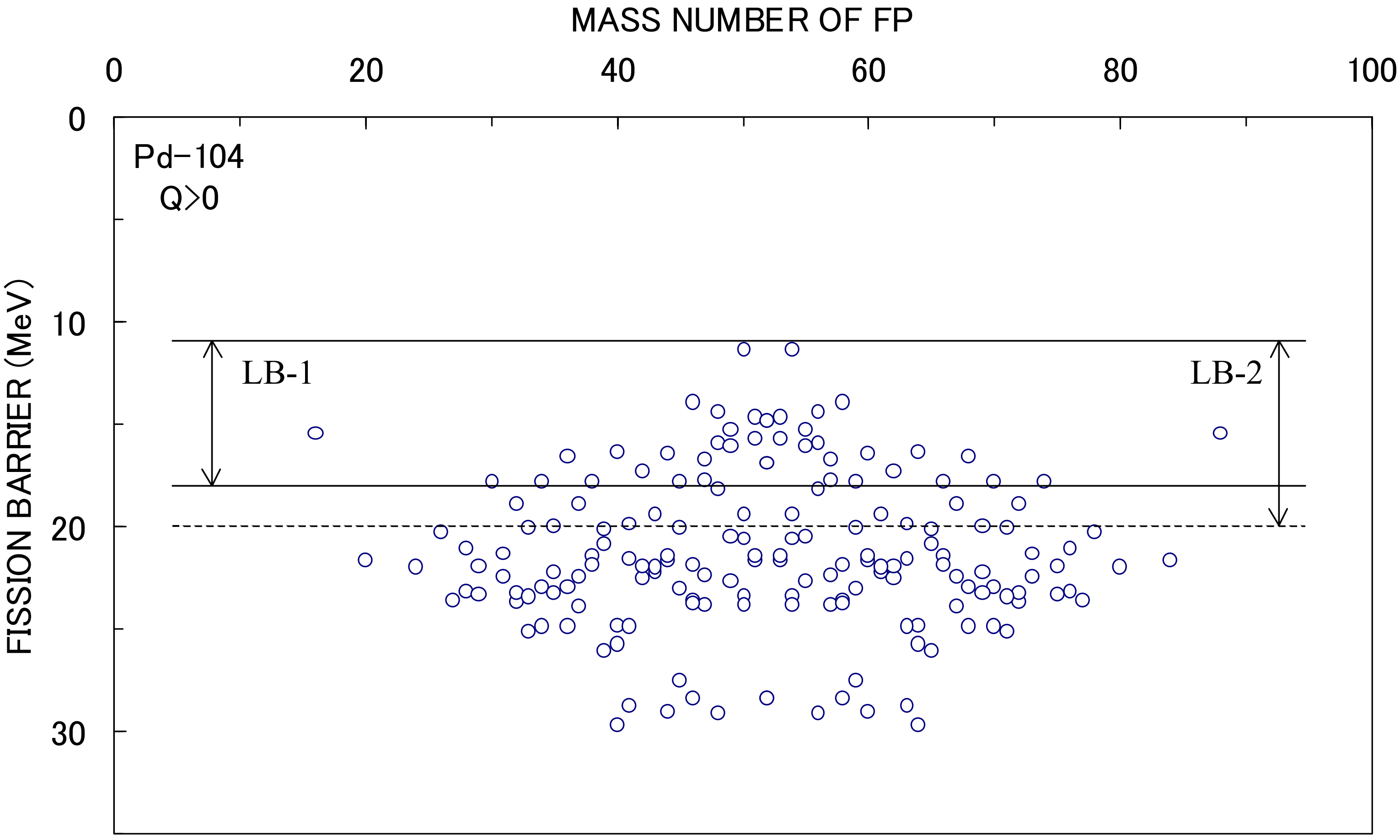


Fig.6-b : Pattern of channel-dependent fission barriers, for ^{104}Pd

Channel Dependent Fission Barriers for Pd-105

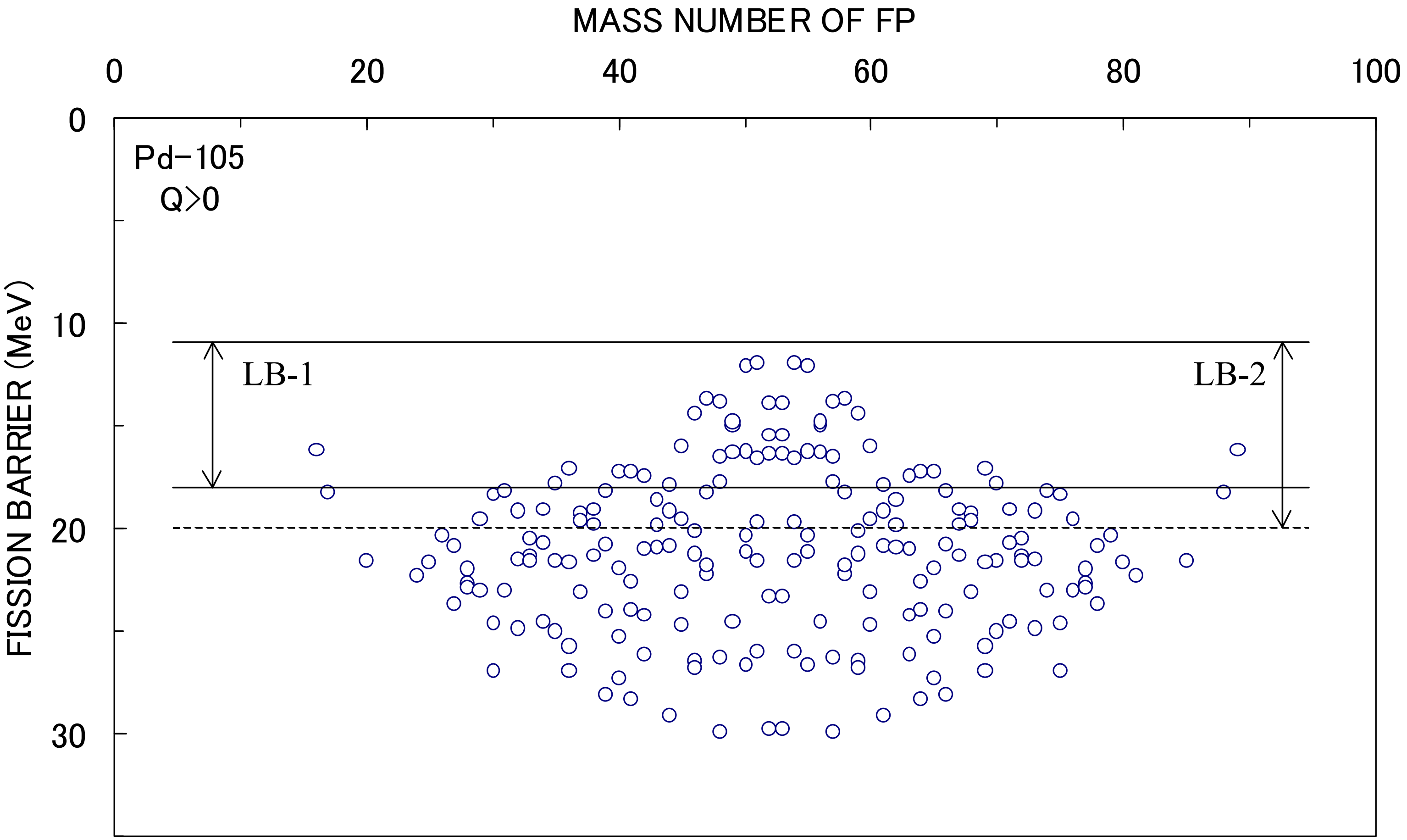
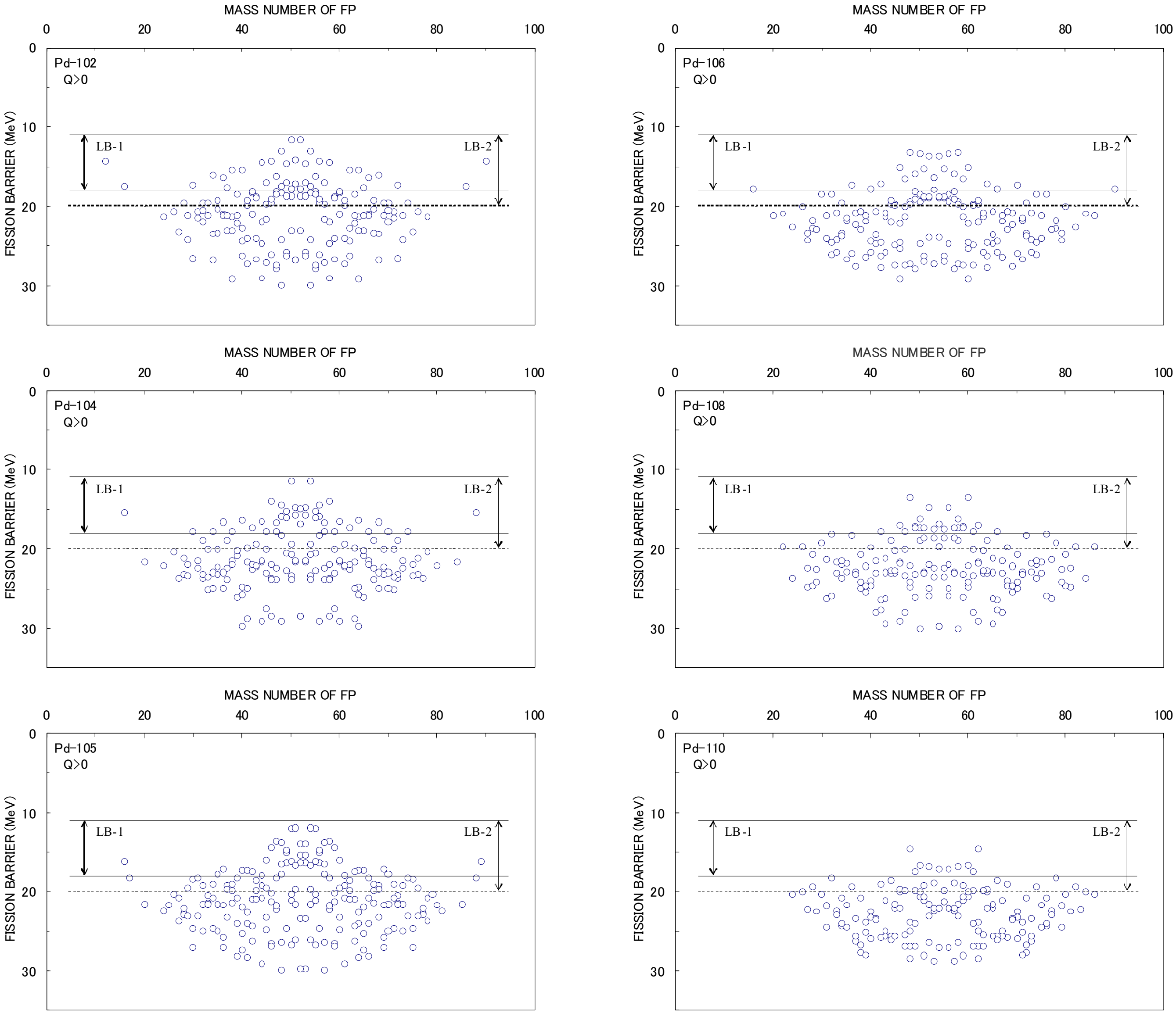


Fig.6-c : Pattern of channel-dependent fission barriers, for ^{105}Pd



$_{46}$Pd	abundance i C
102	1.02
104	11.14
105	22.33
106	27.33
108	26.46
110	11.72

Fig. 2-4: Fission barriers for Pd isotopes

Channel Dependent Fission Barriers for Au-197

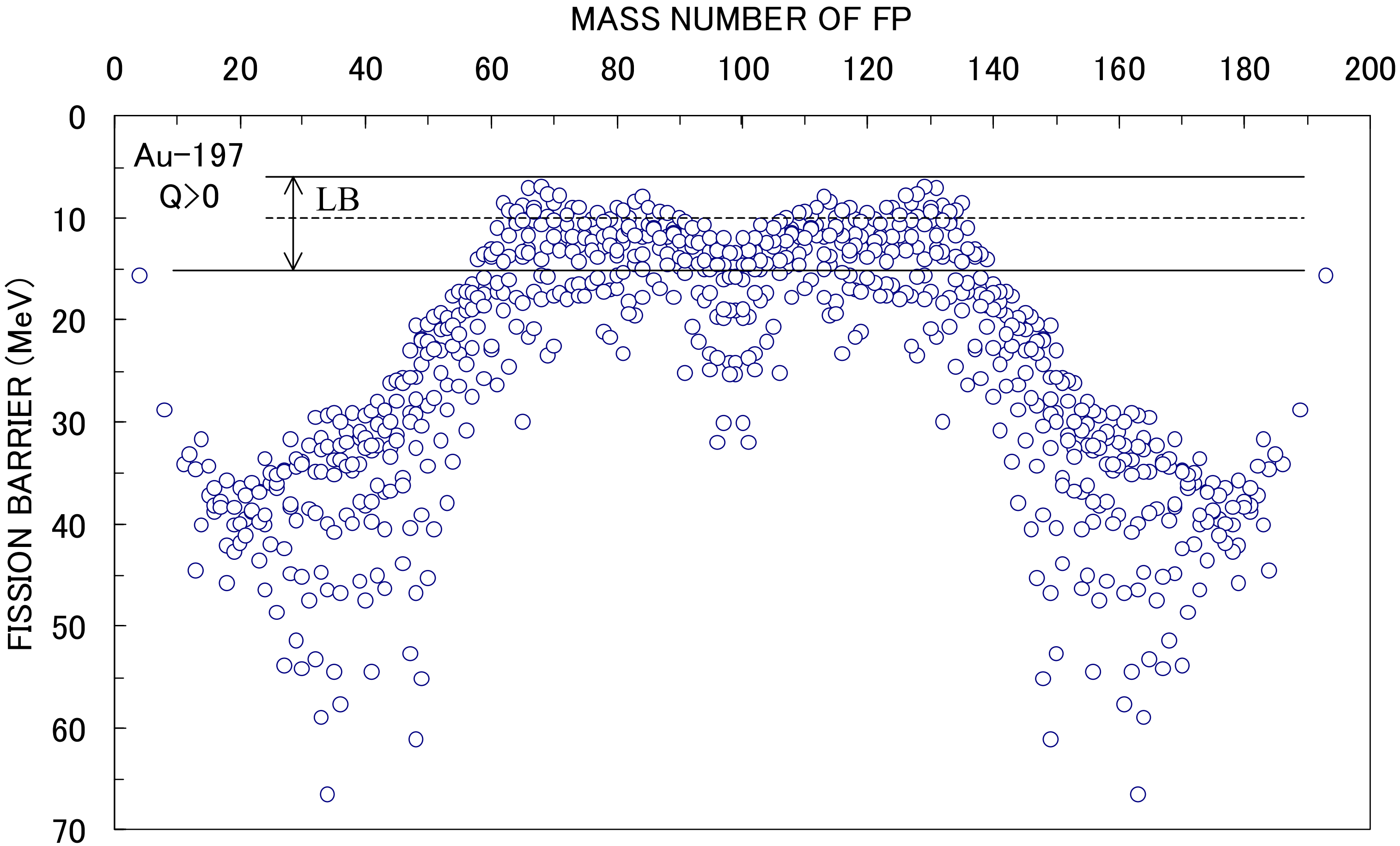
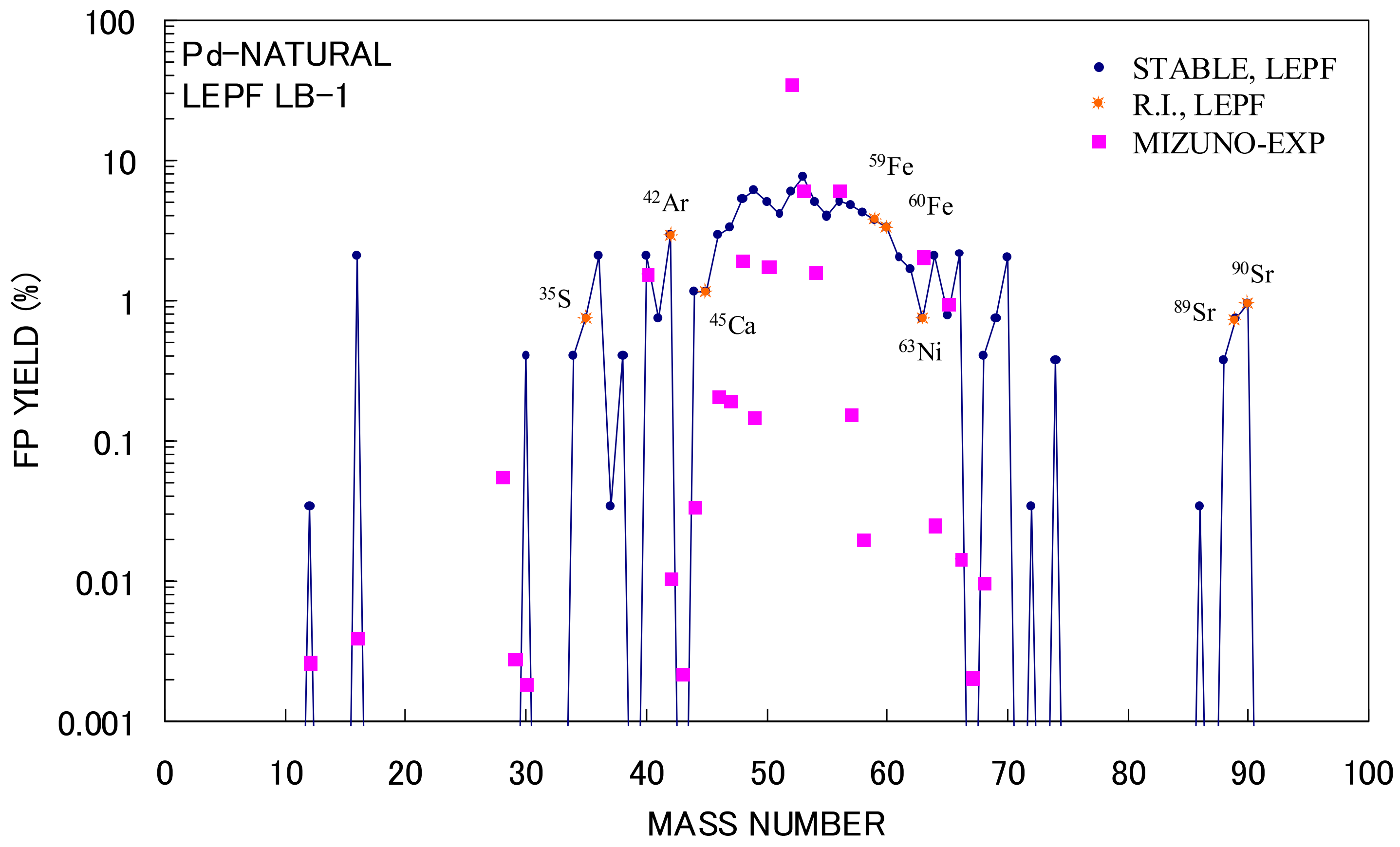


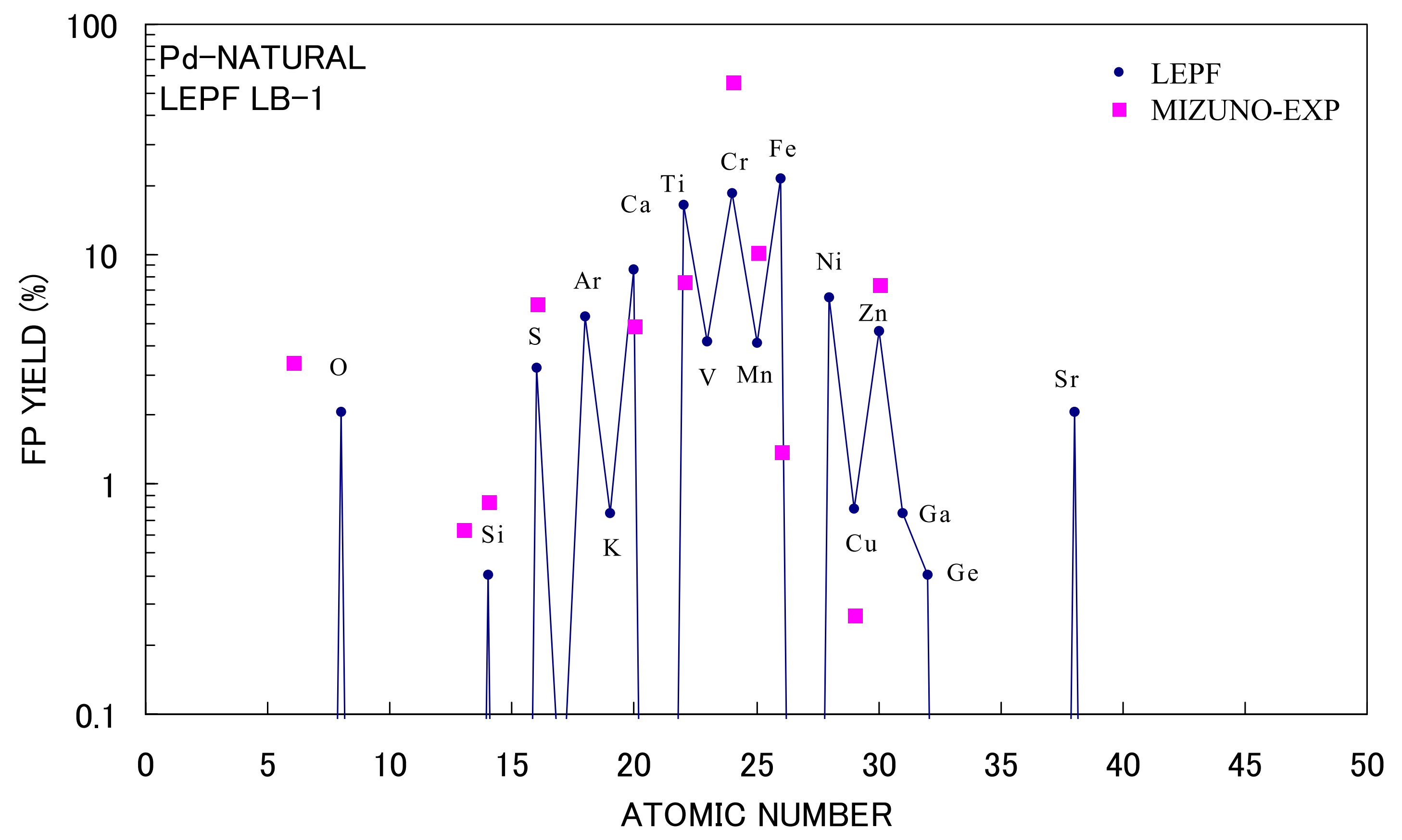
Fig.7 : Pattern of channel-dependent fission barriers, for ^{197}Au

Fission Products Mass-Distribution for Pd



- LEPF: Low Energy Photo-Fission
- Mizuno Exp.: D2O/Pd Electrolysis

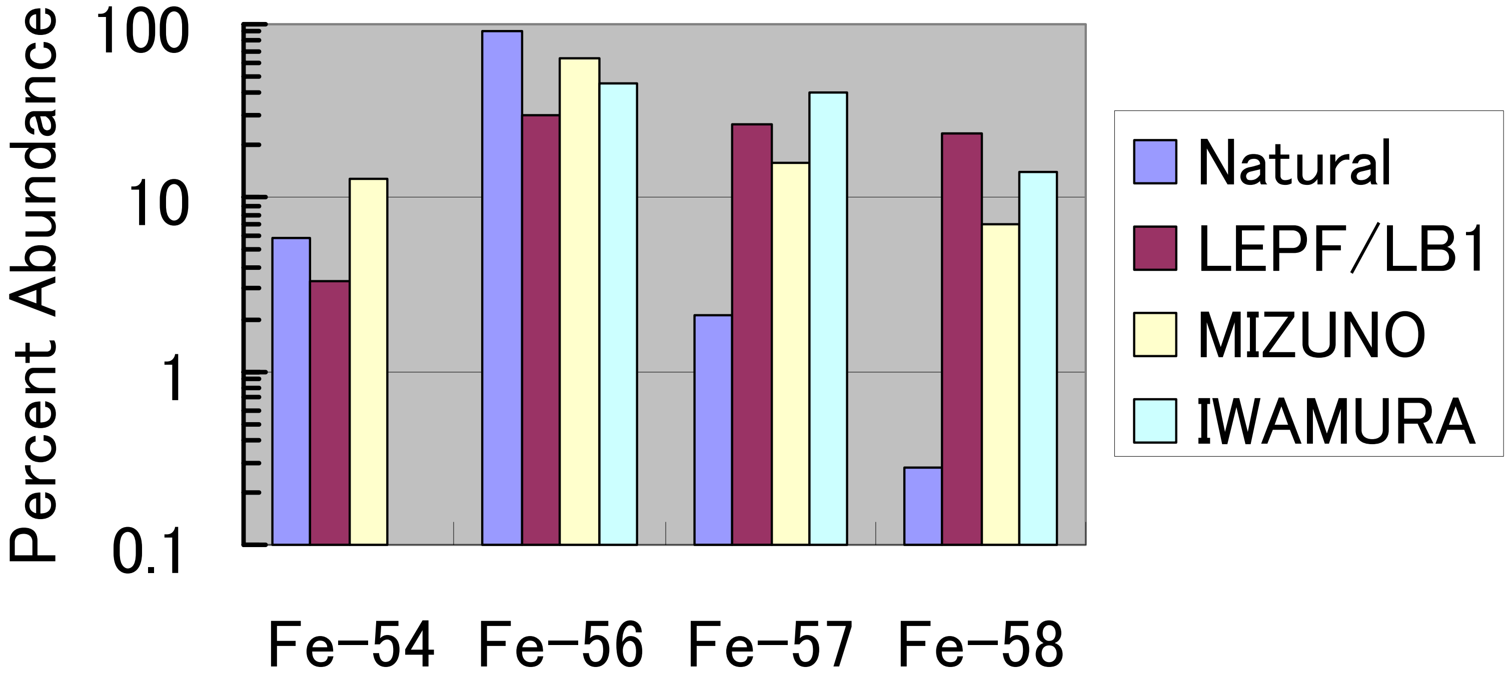
FP Element-Distribution for Pd



- LEPF: Low Energy Photo-Fission
- Mizuno Exp.: D2O/Pd Electrolysis

Anomaly of Isotopic Ratios

Fig. : Comparison of Isotopic ratios between natural Fe, LEPF/LB1 and experiment



Top 10 FP Channels for Pd Photo-Fission

- (1) $^{104}Pd \rightarrow {}^{50}Ti + {}^{54}Cr + 18.96$ MeV ($E_f = 11.36$ MeV)
- (2) $^{102}Pd \rightarrow {}^{50}Ti + {}^{52}Cr + 18.91$ MeV ($E_f = 11.60$ MeV)
- (3) $^{105}Pd \rightarrow {}^{51}Ti(\ 5.8\ m\ )^{51}V + {}^{54}Cr + 18.24$ MeV ($E_f = 11.98$ MeV)
- (4) $^{105}Pd \rightarrow {}^{50}Ti + {}^{55}Cr(\ 3.5\ m\ )^{55}Mn + 18.12$ MeV ($E_f = 12.11$ MeV)
- (5) $^{102}Pd \rightarrow {}^{48}Ti + {}^{54}Cr + 17.49$ MeV ($E_f = 13.03$ MeV)
- (6) $^{106}Pd \rightarrow {}^{48}Ca + {}^{58}Fe + 16.46$ MeV ($E_f = 13.23$ MeV)
- (7) $^{106}Pd \rightarrow {}^{50}Ti + {}^{56}Cr(\ 6\ m\ )^{56}Mn(\ 2.6\ h\ )^{56}Fe + 16.81$ MeV
- ($E_f = 13.32$ MeV)
- (8) $^{108}Pd \rightarrow {}^{48}Ca + {}^{60}Fe(\ 1.6\times10^{6}\ y\ )^{*} + 16.10$ MeV ($E_f = 13.42$ MeV)
- (9) $^{106}Pd \rightarrow {}^{52}Ti(\ 1.7\ m\ )^{52}V(\ 3.7\ m\ )^{52}Cr + {}^{54}Cr + 16.49$ MeV
- ($E_f = 13.63$ MeV)
- (10) $^{105}Pd \rightarrow {}^{48}Ca + {}^{57}Fe + 15.98$ MeV ($E_f = 13.81$ MeV)

Fission Products for A<200 become clean.

- FP of Pd LEPF Becomes Very CLEAN

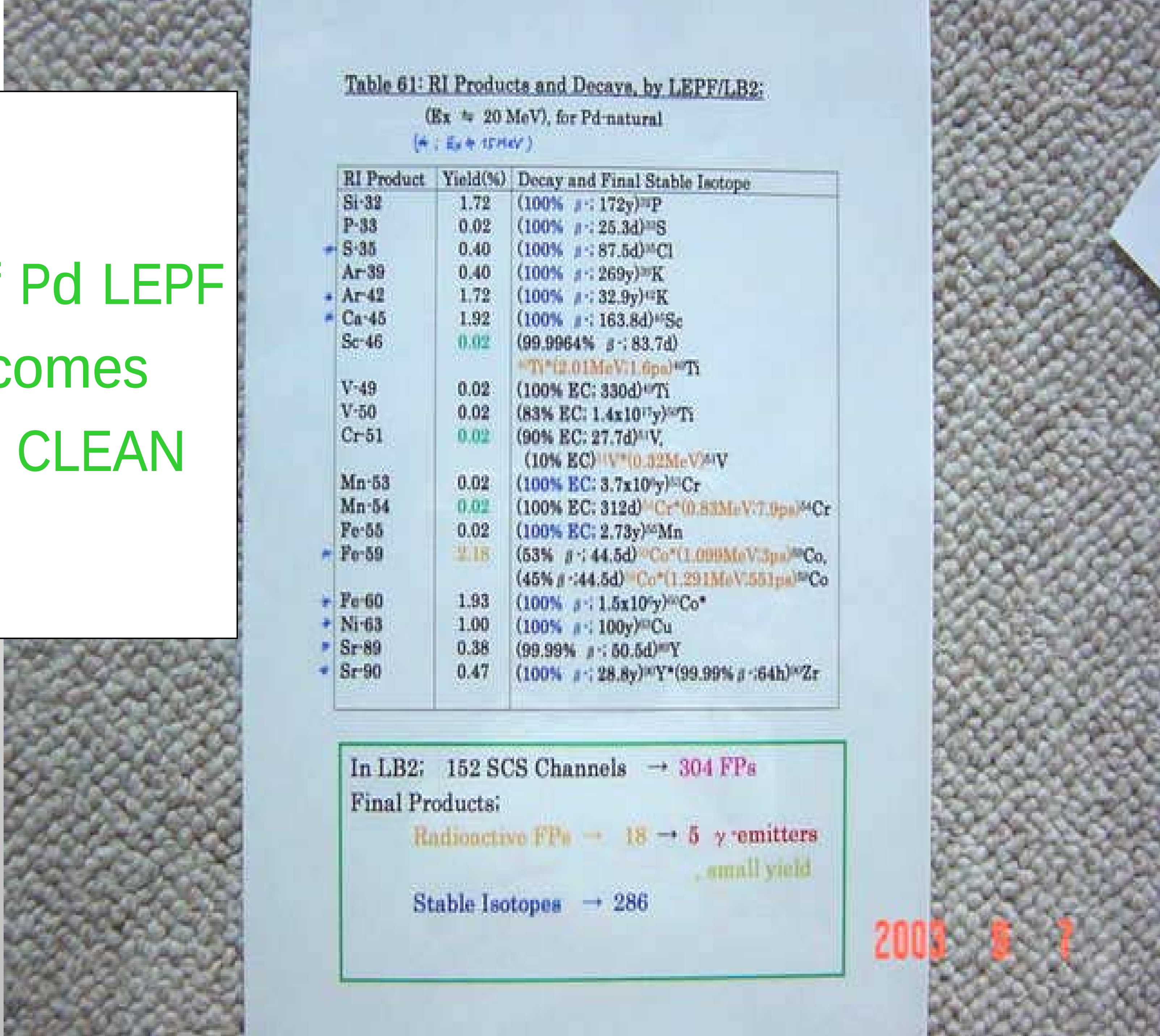


Table 61: RI Products and Decays, by LEPF/LB2:

(Ex ≒ 20 MeV), for Pd-natural

(*: Ex ≒ 15MeV)

RI Product	Yield(%)	Decay and Final Stable Isotope
Si-32	1.72	(100% β^-: 172y)^{32}P
P-33	0.02	(100% β^-: 25.3d)^{33}S
* S-35	0.40	(100% β^-: 87.5d)^{35}Cl
Ar-39	0.40	(100% β^-: 269y)^{39}K
* Ar-42	1.72	(100% β^-: 32.9y)^{42}K
* Ca-45	1.92	(100% β^-: 163.8d)^{45}Sc
Sc-46	0.02	(99.9964% β^-: 83.7d) ^{46}Ti*(2.01MeV:1.6ps)^{46}Ti
V-49	0.02	(100% EC: 330d)^{49}Ti
V-50	0.02	(83% EC: 1.4x10^{17}y)^{50}Ti
Cr-51	0.02	(90% EC: 27.7d)^{51}V, (10% EC)^{51}V*(0.32MeV)^{51}V
Mn-53	0.02	(100% EC: 3.7x10^{6}y)^{53}Cr
Mn-54	0.02	(100% EC: 312d)^{54}Cr*(0.83MeV:7.0ps)^{54}Cr
Fe-55	0.02	(100% EC: 2.73y)^{55}Mn
* Fe-59	2.18	(53% β^-: 44.5d)^{59}Co*(1.099MeV:3ps)^{59}Co, (45% β^-:44.5d)^{59}Co*(1.291MeV:551ps)^{59}Co
* Fe-60	1.93	(100% β^-: 1.5x10^{6}y)^{60}Co*
* Ni-63	1.00	(100% β^-: 100y)^{63}Cu
* Sr-89	0.38	(99.99% β^-: 50.5d)^{89}Y
* Sr-90	0.47	(100% β^-: 28.8y)^{90}Y*(99.99% β^-:64h)^{90}Zr

In LB2: 152 SCS Channels → 304 FPs

Final Products:

Radioactive FPs → 18 → 5 γ-emitters

, small yield

Stable Isotopes → 286

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Summary of Low Energy Photo-Fission and Discussion

- Multi-Photon Induced Fission by Low Energy (<5MeV = Neutron Separation Energy) Photon Burst (X-ray or Gamma-ray Laser)
- Clean Fission Products for 100<A<200
- Less Radioactive Fission for Th-232 and U-238 with Energy Gain
- Application for Transmutation

Cleaner Fission Mini-Reactor

- ^{238}UDx System, ^{232}ThDx System
- Stimulation by Laser, Plasma Electrolysis, etc.
- TRF(4D) and ORF(8D) Fusion with X-ray Burst and High Energy Alpha-Particles
- Low Energy Photo-Fission with Gain = ca. 50 to 100
- No Neutron-Chain Reaction: Intrinsic Safe

Multi-body Fusion Reaction

(1) $3D \rightarrow {}^6Li^* \rightarrow d + {}^4He + 23.8$ MeV

(2) **$4D \rightarrow {}^8Be^* \rightarrow 2\ {}^4He + 47.6$ MeV**

(3) **$8D \rightarrow {}^{16}O^*$ (109.84 MeV) $\rightarrow 2\ {}^8Be + 95.2$ Me**

4D and 8D Fusions can be selective. 1)

$^8Be^* \rightarrow 2\ {}^4He + 47.6$

MeV

References:

[1]: A. Takahashi, *Proc. JCF4*, 74 (2002).

Nuclear Transmutation

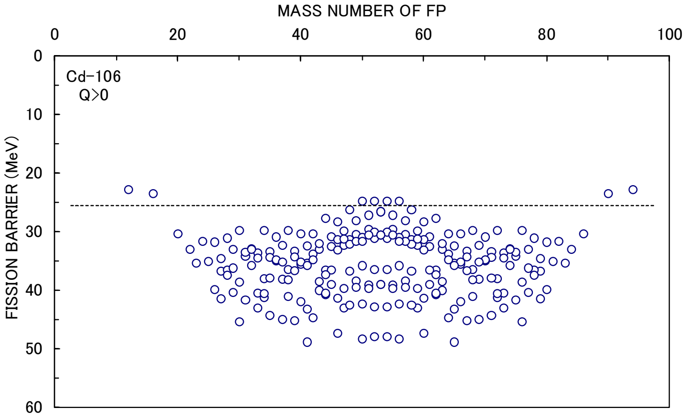
(1) **M + *Photons* → FP1 + FP2** (Ti, Cr, Fe etc.)

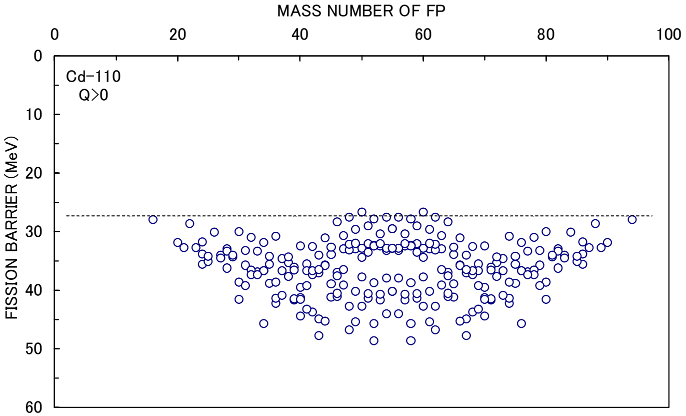
(2) **M + ^{4}He → M'** (Cd for Pd)
→ **FP1' + FP2'** (Ti, Cr, Fe etc.)

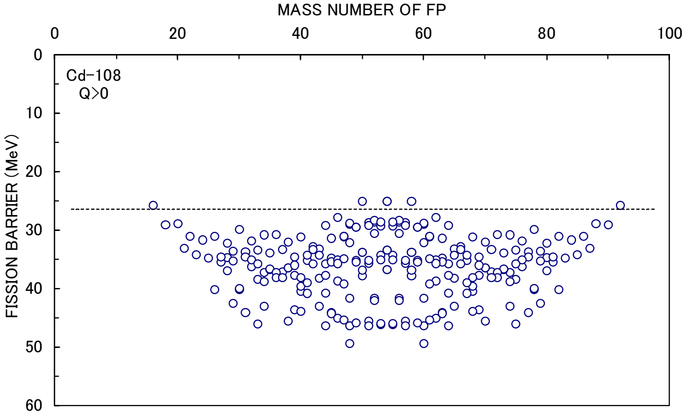
(3) **M + ^{8}Be → M''** (Sn for Pd, Pr for Cs, Mo for Sr)
→ **FP1'' + FP2''** (Ti, Cr, Fe etc.)

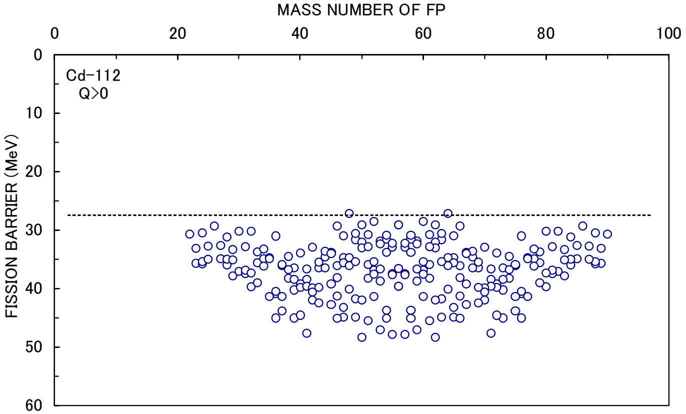
Table 3-1: Natural abundance of Pd isotopes and excitation energies of compound nucleus by + α and + ^{8}Be reactions

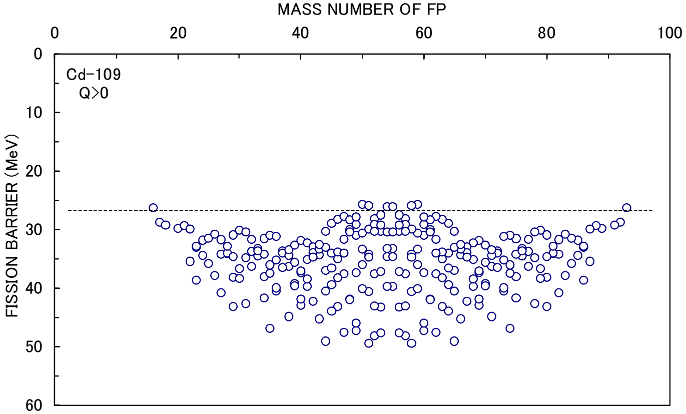
Nuclides	Natural abundance (%)	+ α (23.8 MeV)	Excitation energy (MeV)	+ ^{8}Be (47.6 MeV)	Excitation energy (MeV)
^{102}Pd	1.02	^{106}Cd*	25.4	^{110}Sn*	50.4
^{104}Pd	11.14	^{108}Cd*	26.1	^{112}Sn*	51.8
^{105}Pd	22.33	^{109}Cd*	26.3	^{113}Sn*	52.5
^{106}Pd	27.33	^{110}Cd*	26.7	^{114}Sn*	53.2
^{108}Pd	26.46	^{112}Cd*	27.3	^{116}Sn*	54.5
^{110}Pd	11.72	^{114}Cd*	27.9	^{118}Sn*	55.8

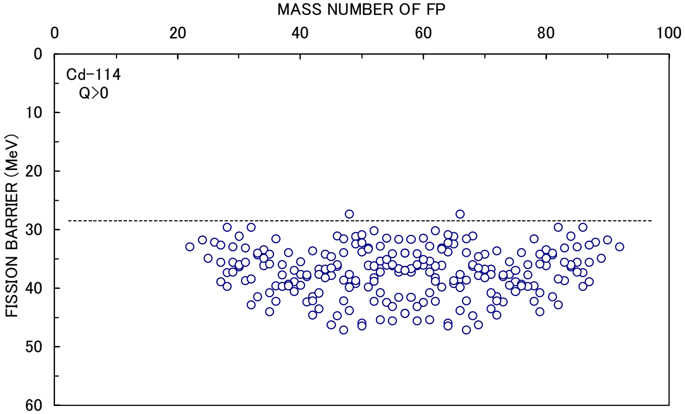












$_{48}$Cd	abundance (%)
106	1.02
108	11.14
109	22.33
110	27.33
112	26.46
114	11.72

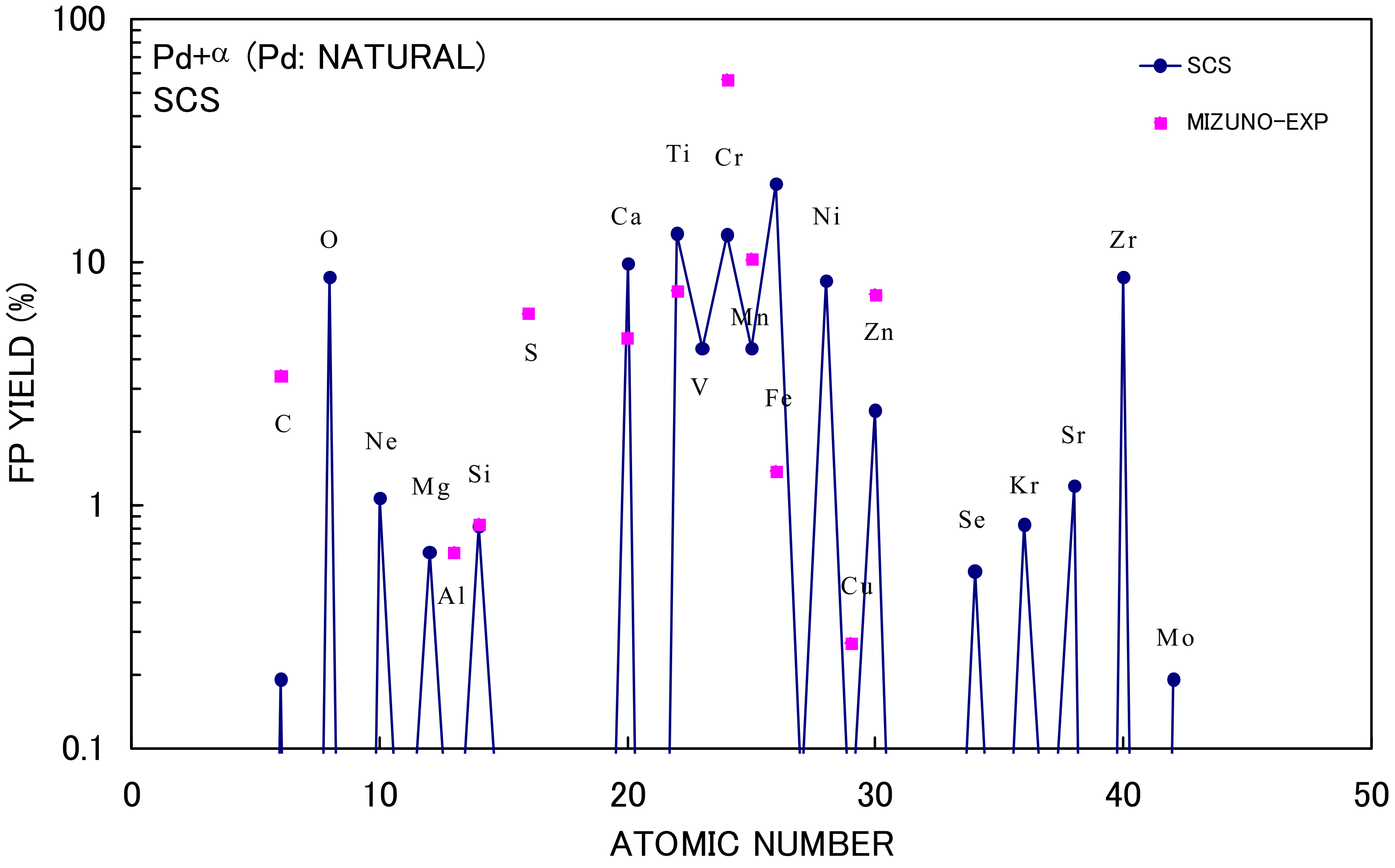


Fig. 4-7 :Fission Product Yield for Atomic number (Pd+α)

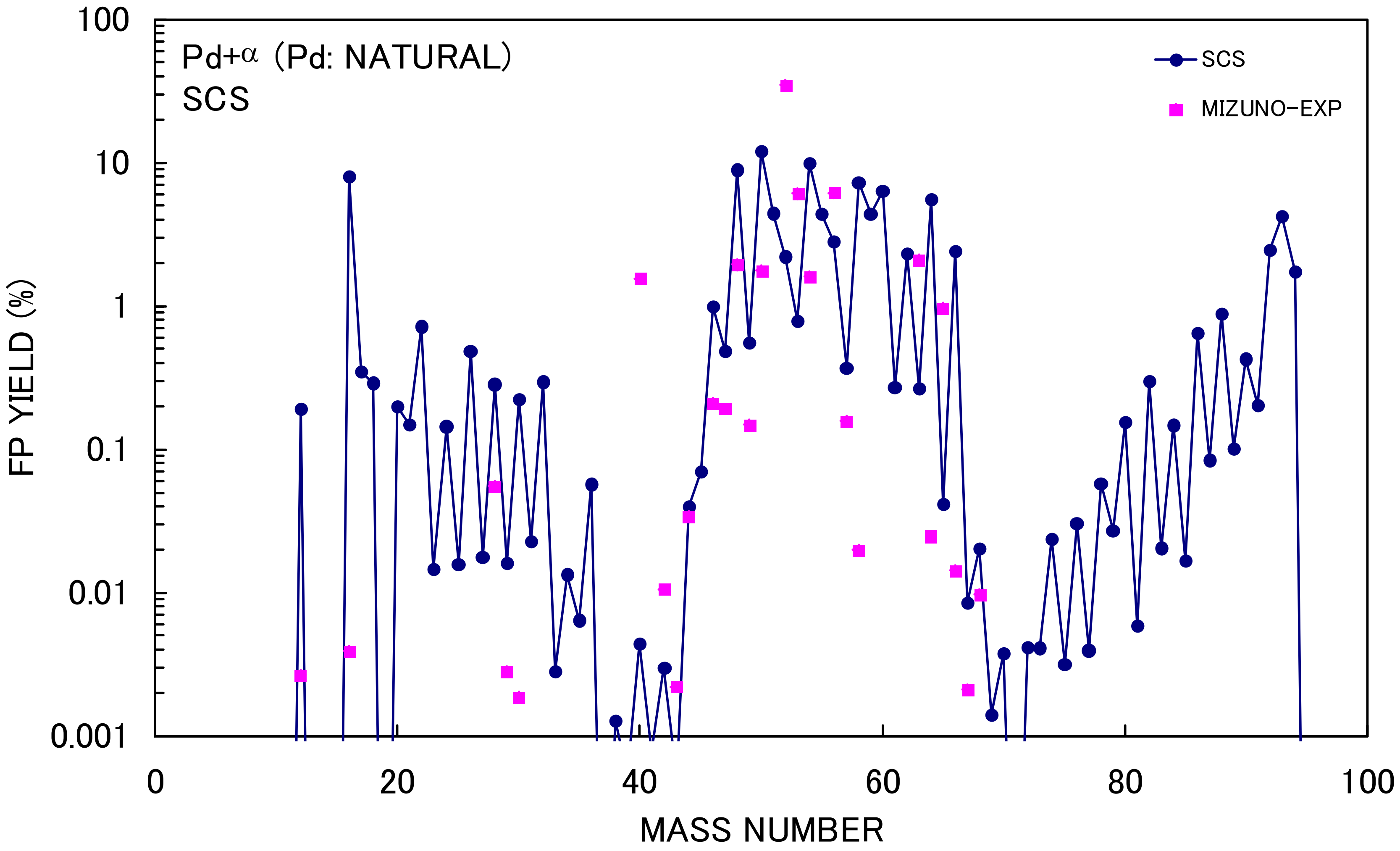


Fig. 4-8: Fission Product Yield for Mass number (Pd+α)

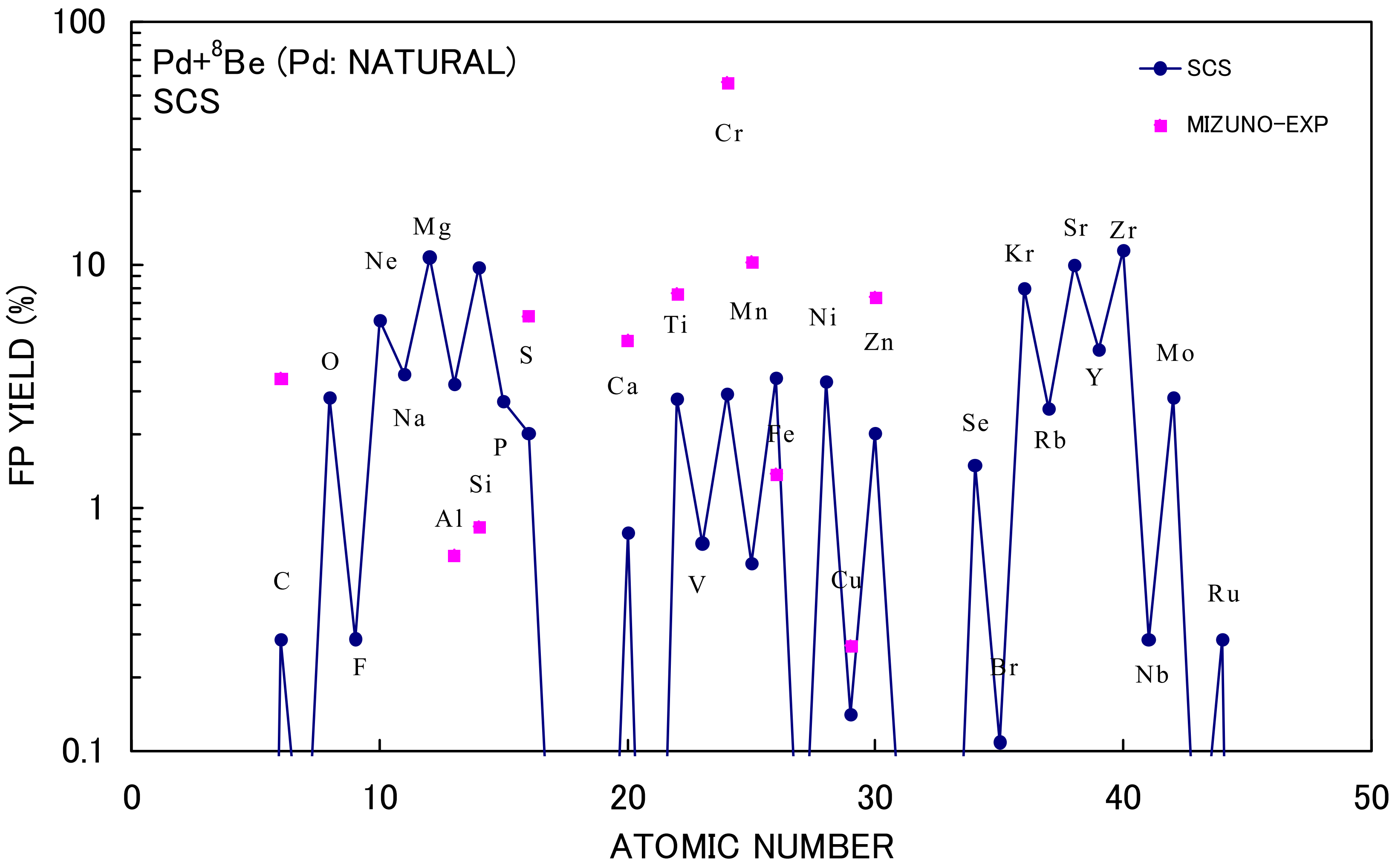


Fig. 5-7 :Fission Product Yield for Atomic number (Pd+^{8}Be)

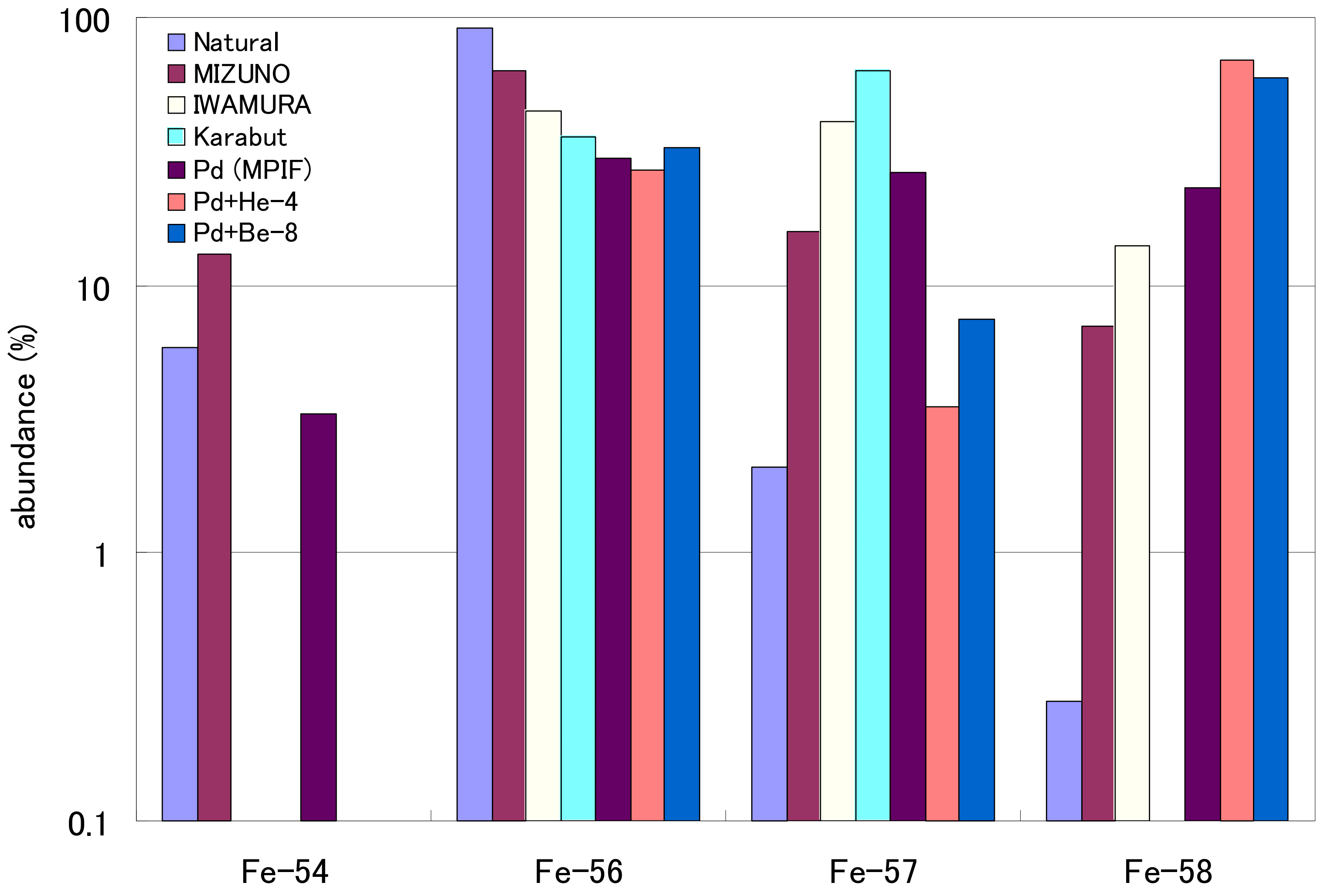
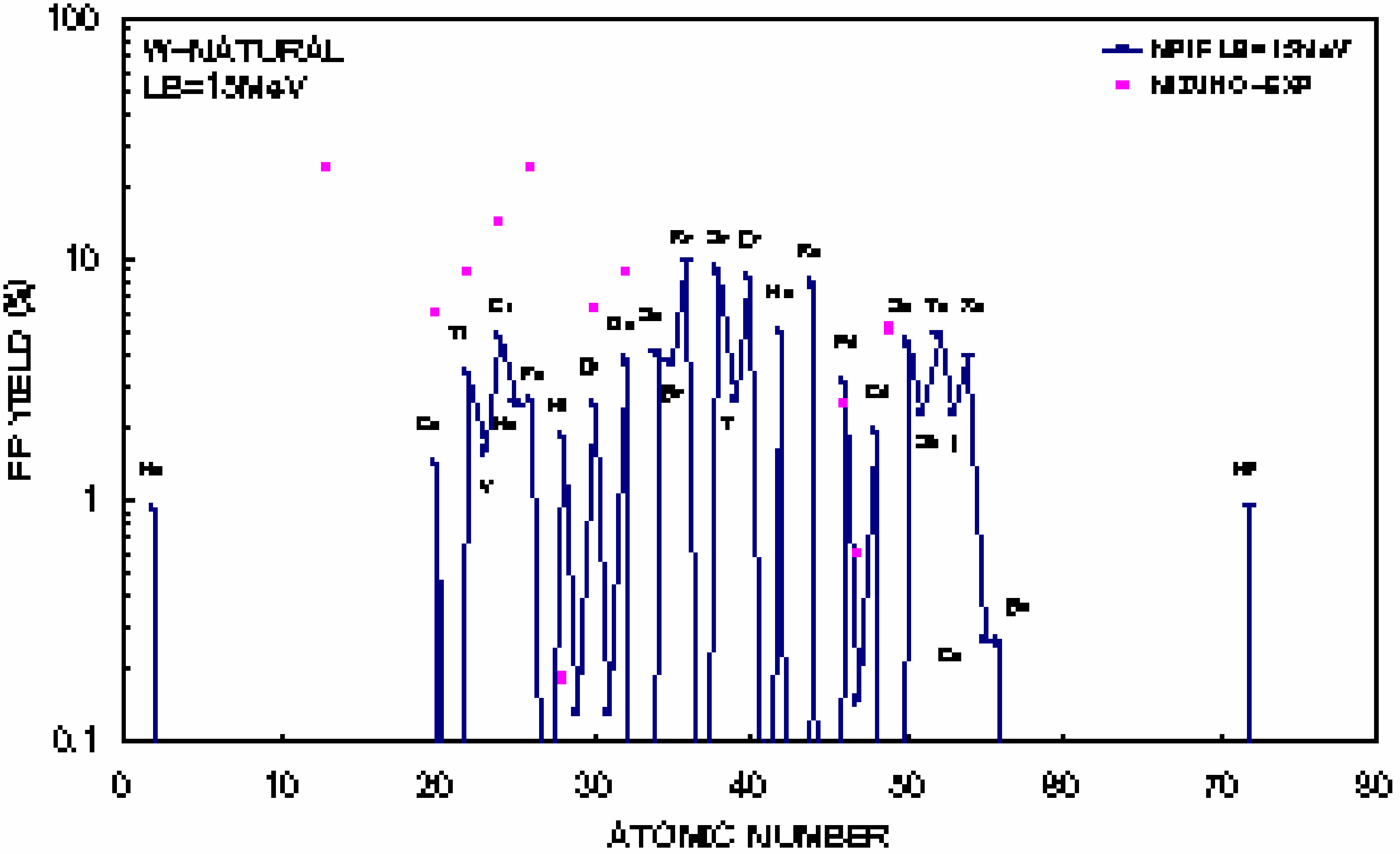


Fig. 6-1: Comparison of isotopic ratio between natural Fe, SCS analysis and experiments.


W-NATURAL
LE=15MeV
NPIF LE=15MeV
NIJIMO-EXP
FP YIELD (%)
ATOMIC NUMBER
100
10
1
0.1
0
10
20
30
40
50
60
70
80
He
Ca
Ti
V
Cr
Mn
Fe
Ni
Zn
Ge
Se
Br
Kr
Sr
Y
Zr
Mo
Ru
Pd
Cd
Sn
Sb
Te
I
Xe
Cs
Ba
Hf

Discussion

Existence of $_{48}$Cd and $_{50}$Sn in some $_{46}$Pd-system experiment

Cs → Pr and Sr → Mo Mitsubishi experiment

Suggestion of Pd + α and Pd + ^{8}Be reactions

Nuclear transmutation (Production of Ti, Cr, Fe etc.)

Suggestion of Fission

(Pd-photo fission or Pd + α or Pd + ^{8}Be ?)

CONCLUSION

- EQPET model was proposed to explain super-screening for d-d fusion in condensed matter
- D-Cluster Fusion can have Resonance for 3D, 4D and 8D Strong Interaction
- ^{4}He is Major Product, with minor t and ^{3}He
- Mass-8 & Charge-4 Increased Transmutation is possible by High-E ^{8}Be by 8D fusion

Conclusion: continued

- Fission Process by low energy multi-photon absorption may take place
- Alpha-induced Fission is also possible
- Fission Products by LEPF may be CLEAN
- Claimed Transmutations could be explained by FP distribution of LEPF
- Application to Transmutation of High Level Nuclear Wastes is expected
- Formation of TSC is Key!

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Future Works

- **Basic strategy;**

The system can split into several components, and using solutions for components we may combine them and understand the total system.

1) The place where **TSC** (Tetrahedral Symmetric Condensate) is born?
   A volumetric (3-dim) region near surface is suggested by many successful recent experiments.
   So, this is Surface-Lattice Problems (**SLP**).
2) Physics of TSC itself shall be studied more accurately;
   TSC-Problems (**TSCP**)
3) Coulomb Interaction Problems (**CIP**) between M (host metal atom) and TSC.
4) Nuclear Interaction Problems (**NIP**) between M and TSC.

- **SLP-1**) Where are lattice focal points for TSC?
  T-site, O-site, defects, voids, etc. can be studied.
  Modeling, equations, numerical solutions, etc., are looked for.

- **SLP-2**) Surface or near-surface conditions incubating TSC?
  Topological and fractal configurations and motion of electrons there with p(d)-cluster are expected to study.

TSCP-1) Mechanism of dynamic Bose-condensation;

What is size of TSC as
charge-neutral-pseudo-particle (CNPP)?
We have a tool like EQPET
(Electronic Quasi-Particle Expansion Theory, by A.T.)
which has given CNPP size as small as
0.5 to 4 pico-meter in radius,
namely much smaller than
atom size of several hundreds pico-meter,
and if so CNPP can penetrate through
electron-shell-cloud of host (metal) atom
to approach nucleus.
And modeling by other ways than EQPET is
also expected.

TSCP-2) Simulation study of TSC-like condensation;

QMD (Quantum Molecular Dynamics)
with Monte-Carlo technique
(as done by Kirkinskii-Novikov)
is expected for 3-dim system of
8-body (4H(D) + 4 electrons) configuration.

CIP-1) Modeling of TSC/CNPP penetration through shell-electron clouds of host M-atom to formulate equations and get numerical results is expected;

How CNPP can penetrate e-clouds ?
Is it analogous to the neutron movement freely approaching central M-nucleus?

CIP-2) Barrier penetration probability for close "united cluster" of M+H(or D) to M+4H(or D) to reach at strong nuclear interaction range (ca. 5 femto-meter);

WKB approximation, i.e.,
Gamow integral can be applied.

NIP-1) Reaction types and products for from 4D TSC to mixed H/D TSC;

- Studies have been initiated by A.T. and B. Collis, etc., and to be continued.

NIP-2) Electron capture probability in TSC; Modeling, equations and getting numerical results are expected.

This is related to neutron generation.

NIP-3) M+p to M+4p reactions;

- modeling of out-going channels, products, numerical reaction rates, etc. are expected.

NIP-4) M+d to M+4d reactions;

- to study ibid.