

Condensed Matter Nuclear Effects

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Fusion of Hydrogen Isotopes

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

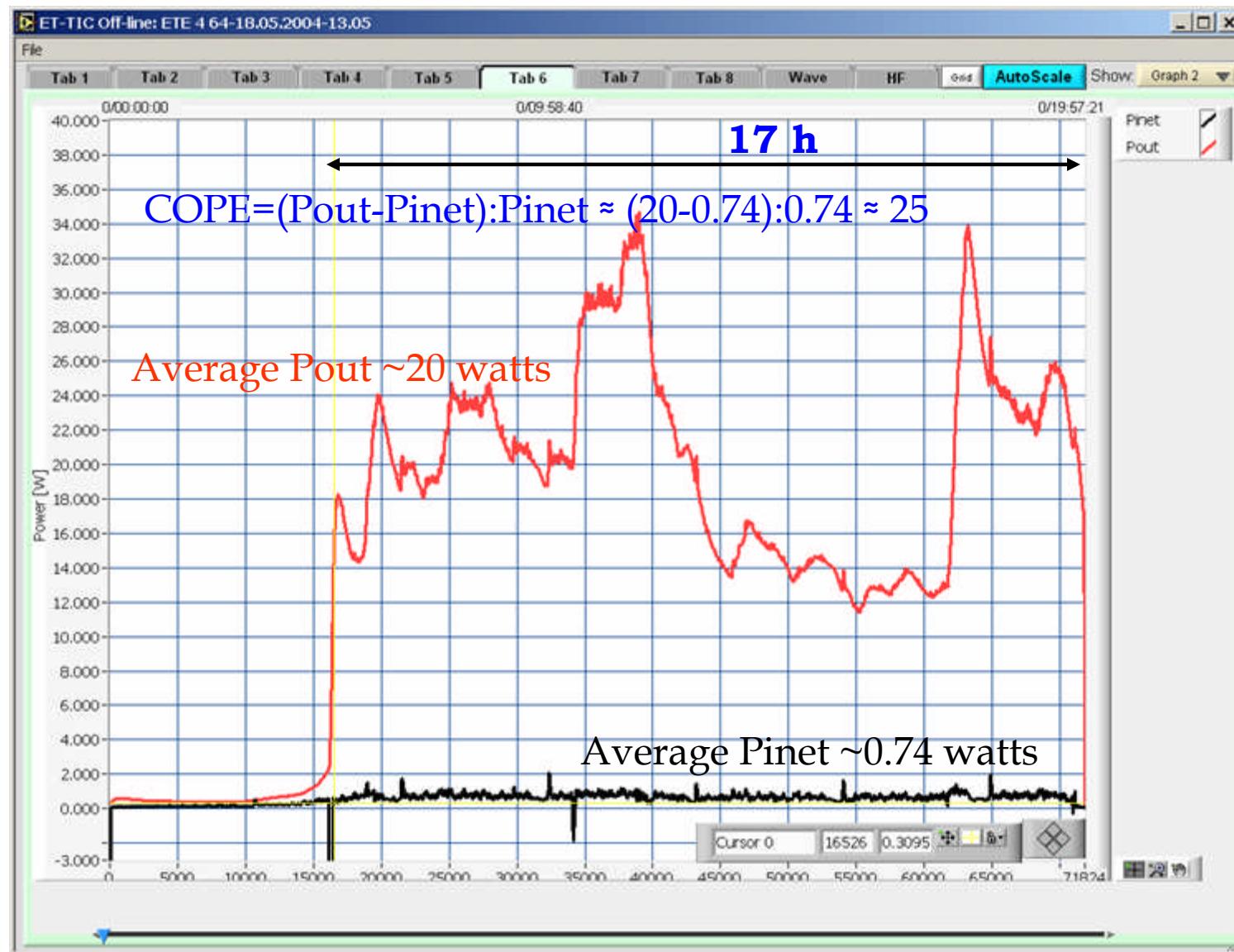
Major Results: Experiments vs. Theory

Item	Experiment Author/ Method/ Results	EQPET/TSC Model
Screening of d-d	Kasagi/beam/310eV Takahashi/3D/1E+9 <dd>	360eV by dde*(2,2) (1E+13) τ (0.1ms)
^4He Production	McKubre/Electrolysis/ 30+-13MeV/ ^4He	23.8MeV/ ^4He by $4\text{D} \rightarrow ^4\text{He} + 2 + 47.6\text{MeV}$
Maximum Heat	EI Boher/EI./24.8keV/Pd Gain \approx 25	23 keV/Pd 46MeV/cc by 4d/TSC
Transmutation	Iwamura/Perm./Cs \rightarrow Pr Miley/NiH/Fission-like Pro.	4d/TSC + M 4p/TSC + M reaction

Major Experimental Results of CMNS Research suggest us

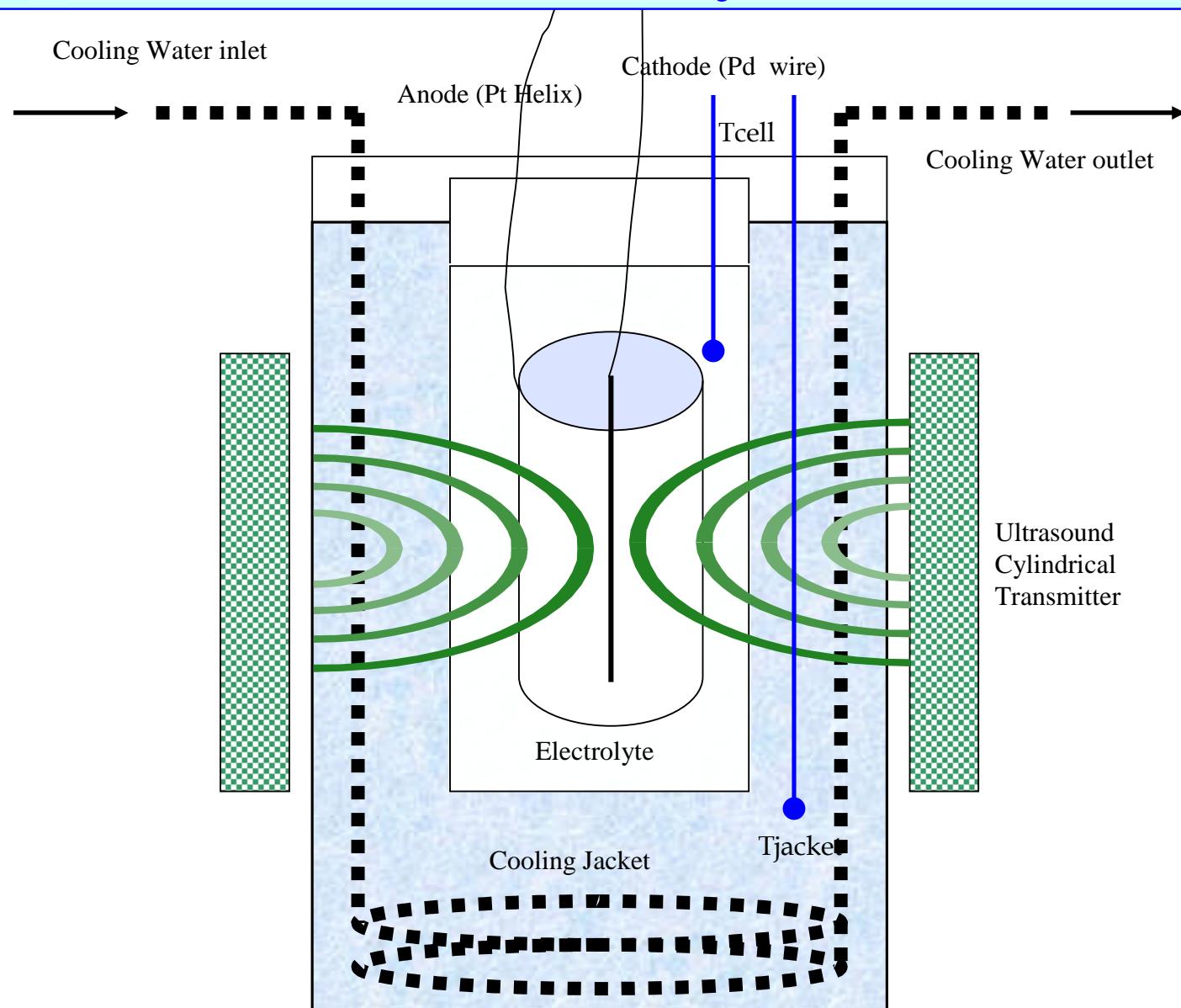
- “COLD FUSION” of known fusion reactions by hydrogen isotopes is NOT the Case.
- We should consider NEW NUCLEAR REACTIONS in Condensed Matter.

Excess Power; Exp. # 64a; El-Boher, ICCF11



Excess Power of up to 34 watts; Average ~20 watts for 17 h

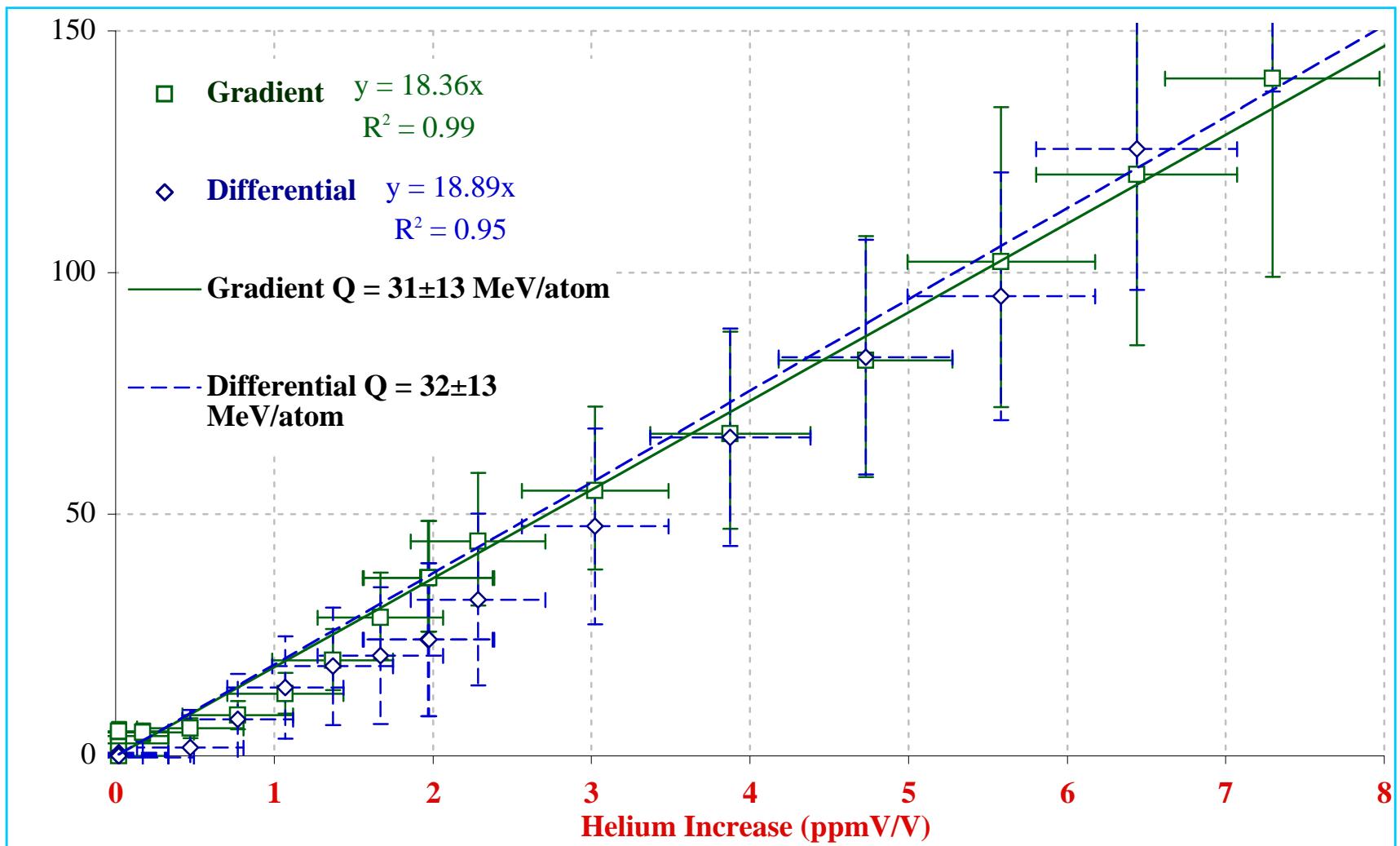
Ultra Sound - Electrolytic Cell overview



Schematic View of Ultra Sound Cell

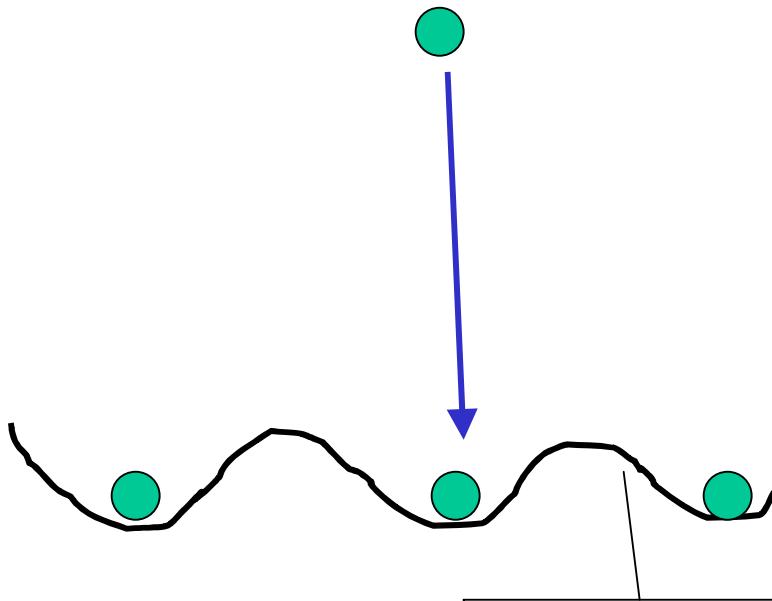
•After M. McKubre, ICCF11, 2004

Case: “Q”-Value - Energy vs. ${}^4\text{He}$



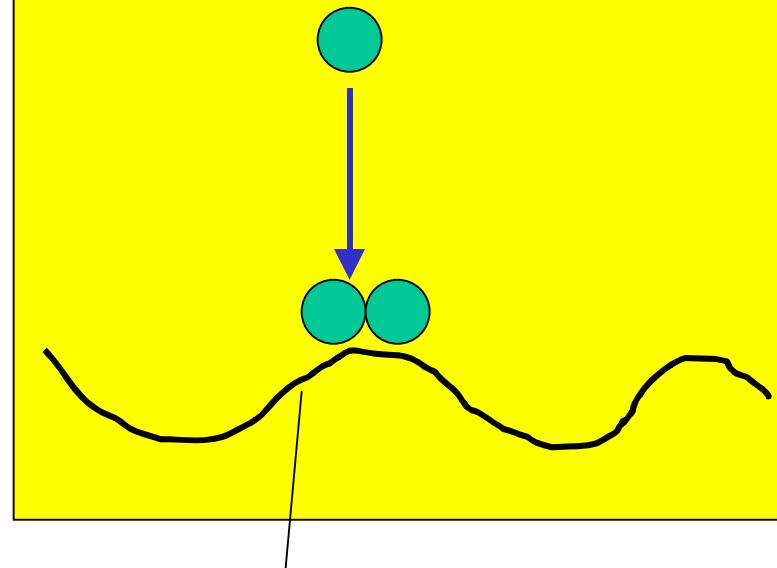
D-Beam Enhances 3D-Fusion if CF DD Fusion is Stimulated

- Without Stimulation results in 2D fusion

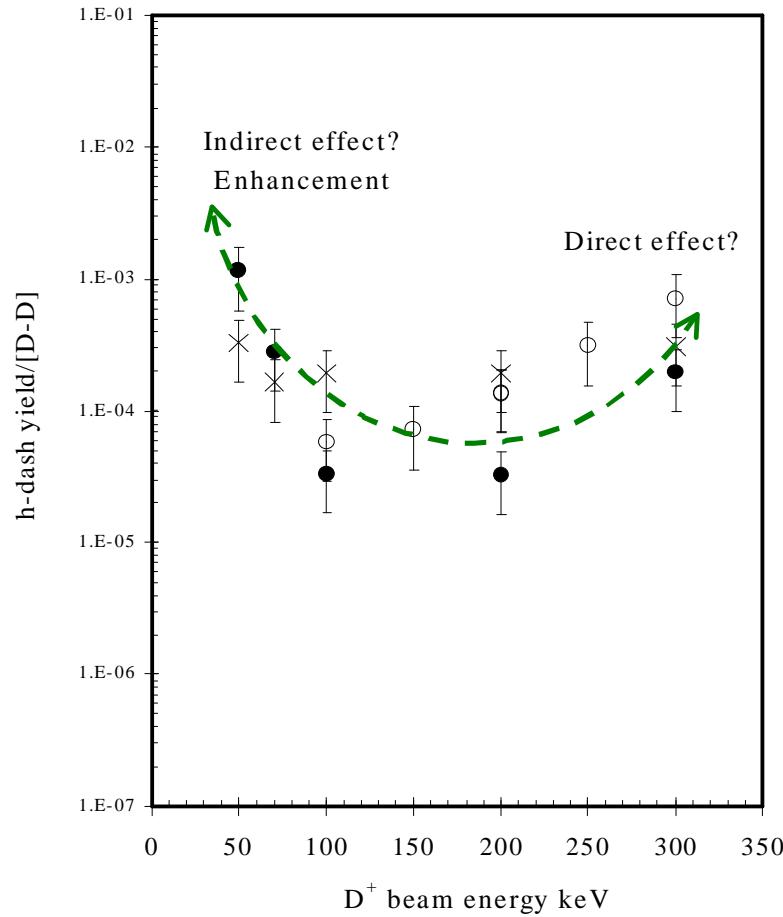


Lattice Trapping Potential

With Stimulation enhances
3D Fusion Rate



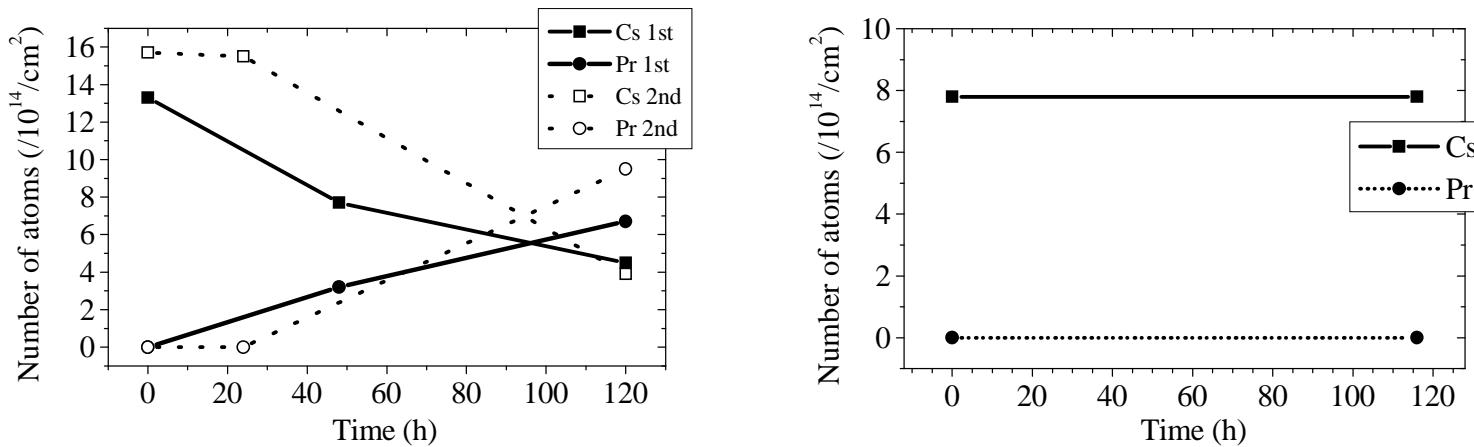
D-Beam Energy Dependence of [3D]/[2D] Ratios



- [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

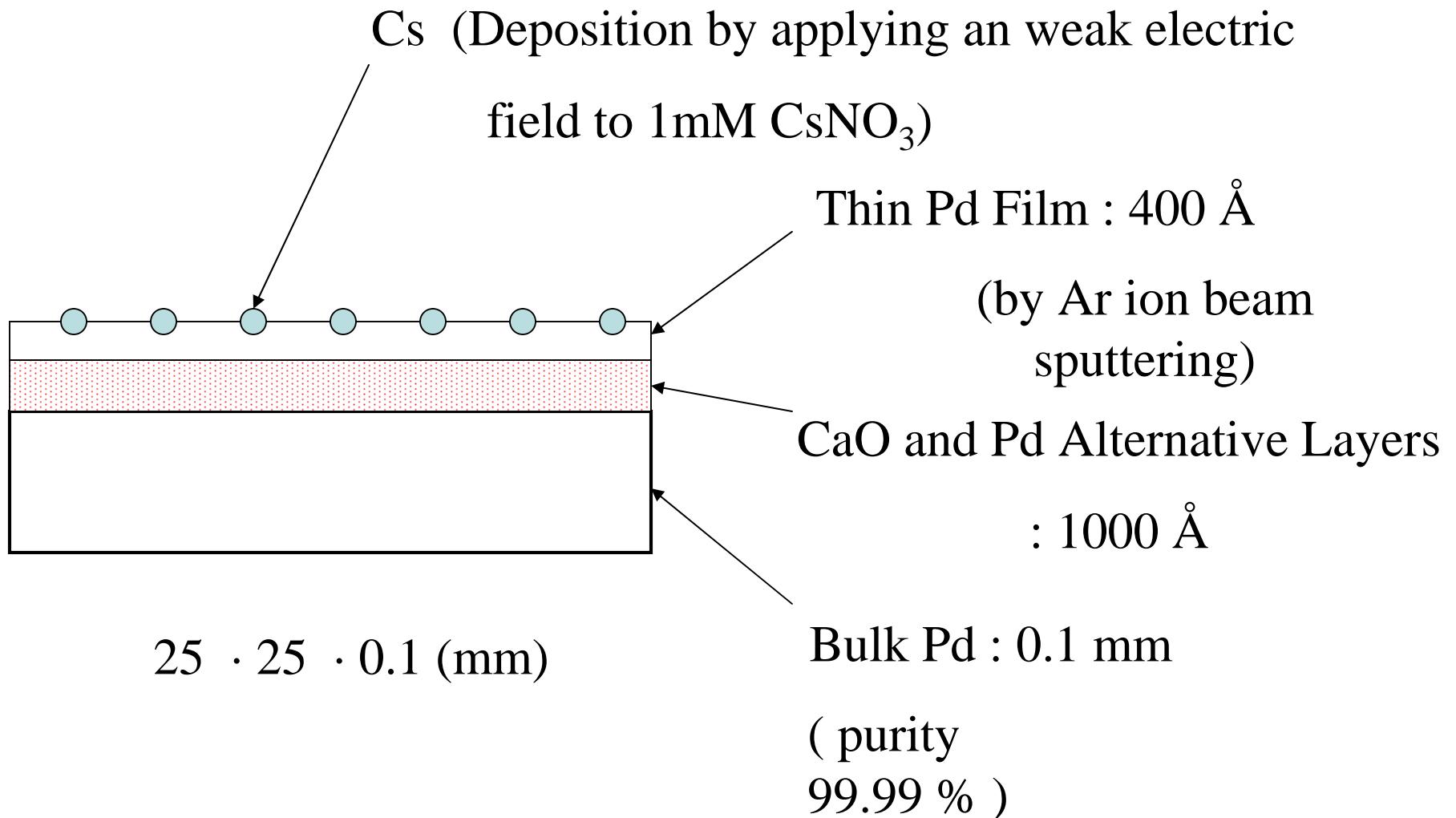


D permeation
through Pd complex
 ^{133}Cs to ^{141}Pr

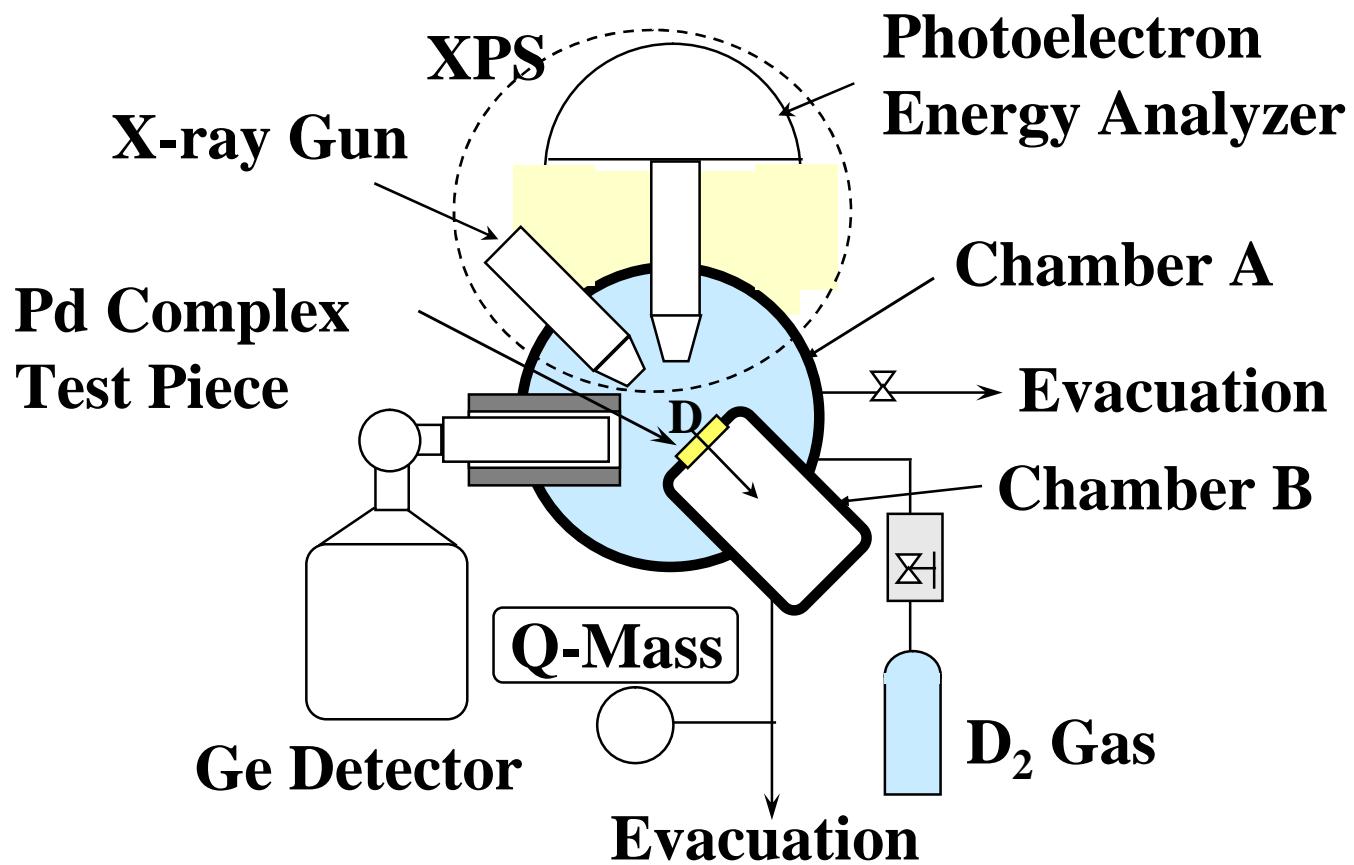
H permeation
through Pd complex
NO CHANGE

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

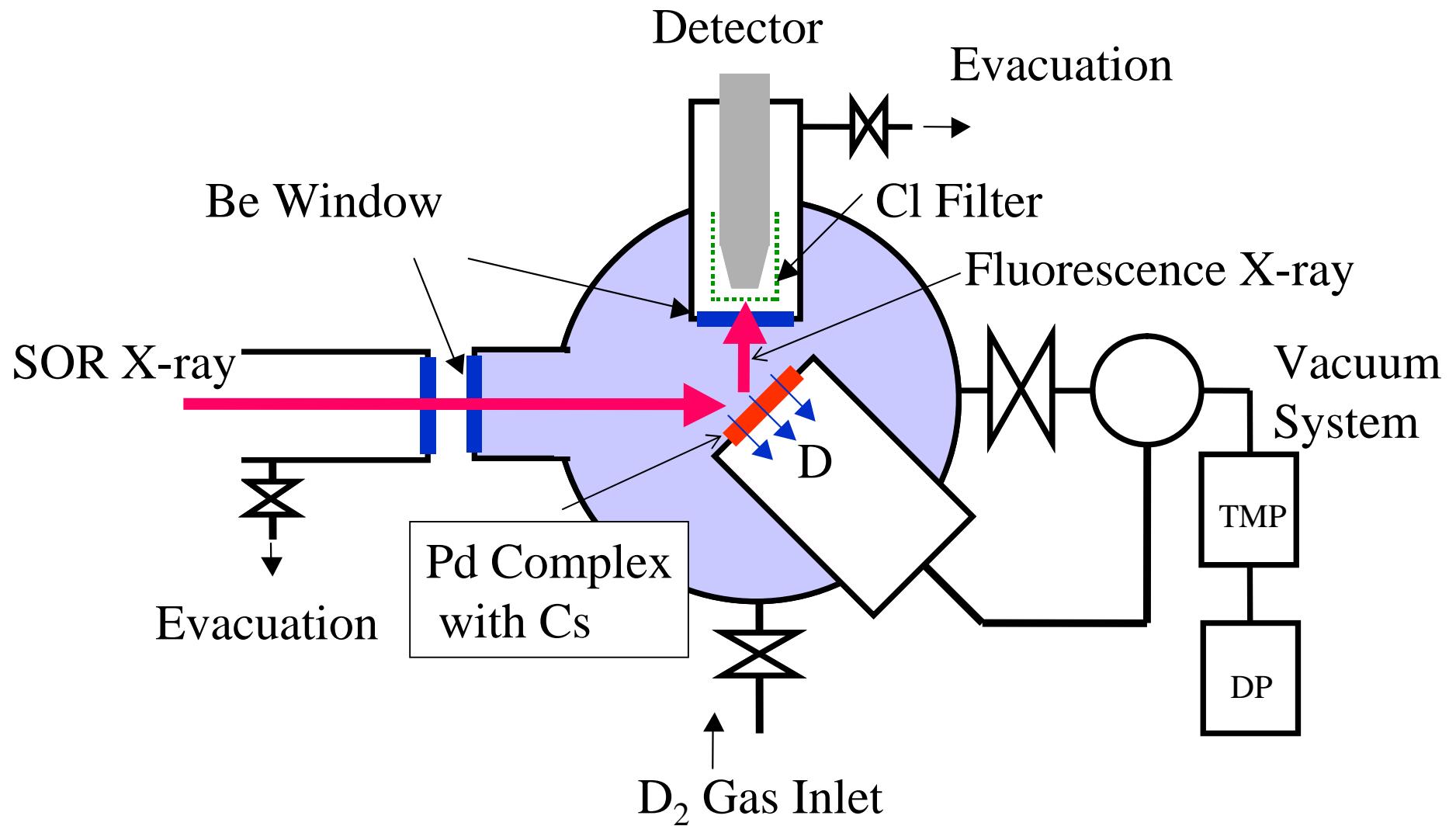
Sample



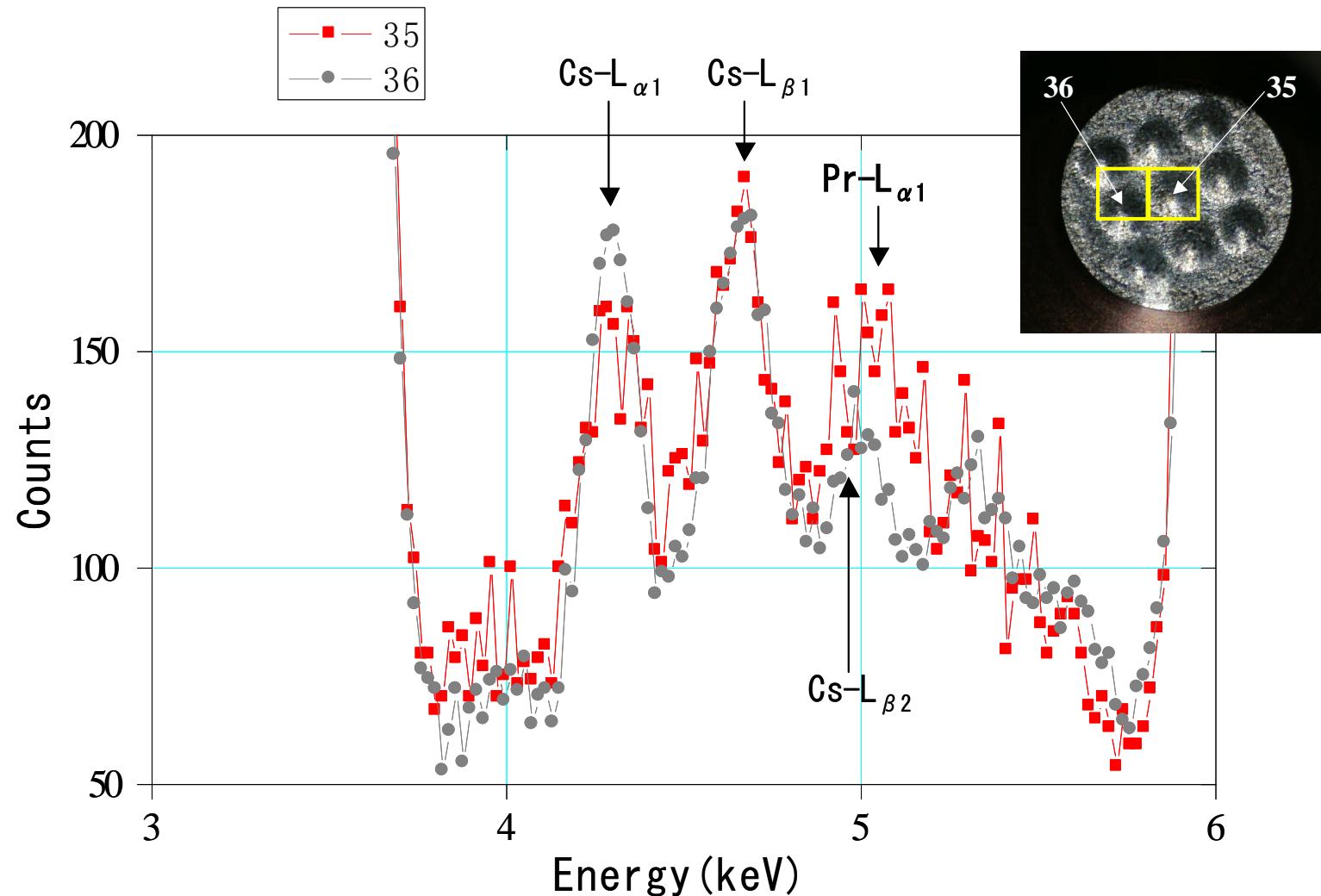
Schematic View of the Experimental Apparatus



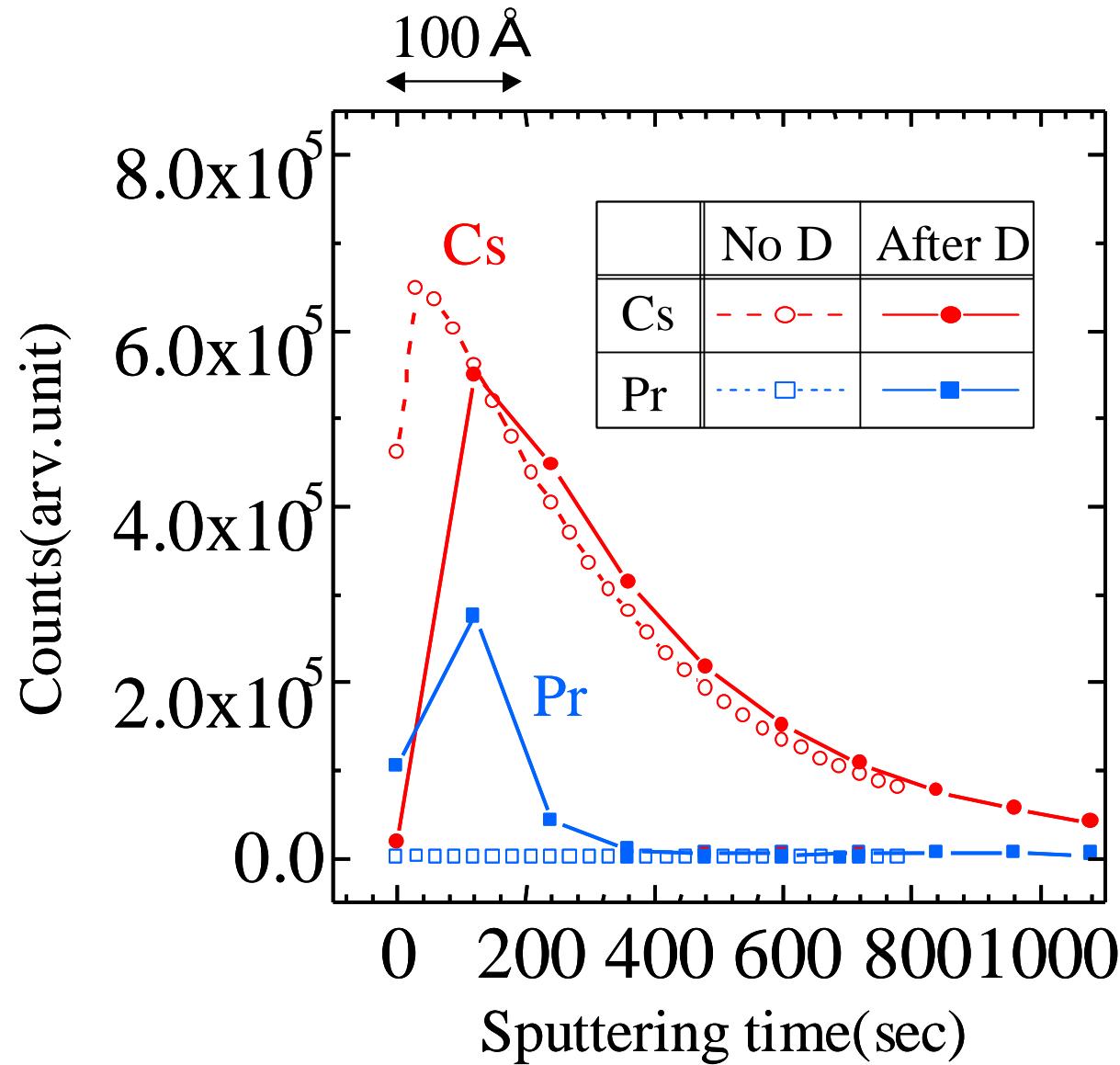
Experimental Set-up for *in-situ* Measurement located at SPring-8



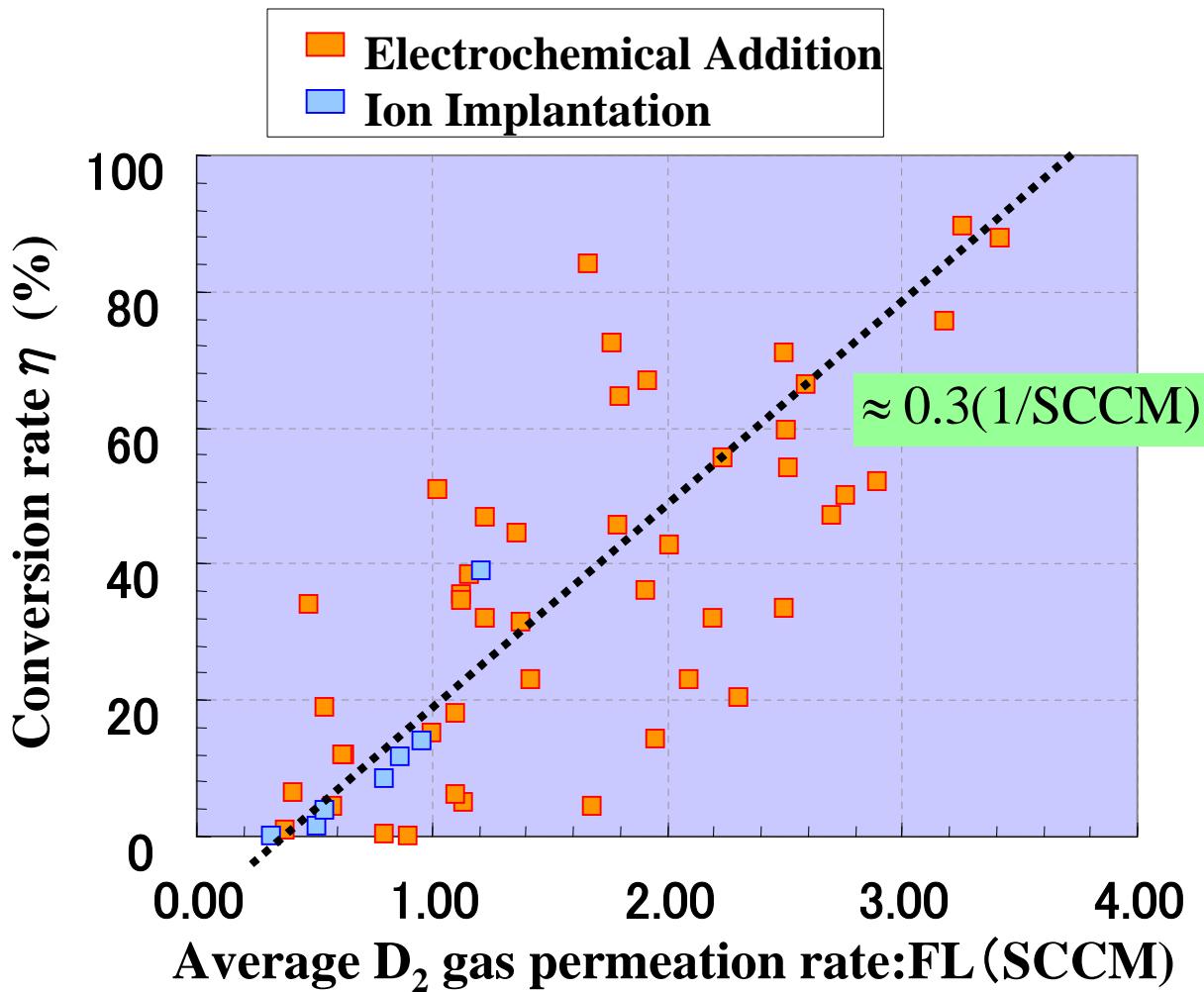
An Example of Pr Detection by the Experiments at SPring-8



Depth Profile of Cs and Pr by TOF-SIMS



Correlation between D₂ Permeation and Conversion Rate



$$\eta = \frac{N_{\text{Pr}}}{N_{\text{Cs}}} \times 100\%$$

$$= \frac{N_{\text{Pr}}}{N'_{\text{Cs}} + N_{\text{Pr}}} \times 100\%$$

η : conversion rate(%)

N_{Pr} : detected Pr (ng)

N_{Cs} : given Cs (ng)

N'_{Cs} : detected Cs after
an experiment (ng)

$C_s \rightarrow \text{Pr}$

Positive Correlation between D₂ permeation and Conversion Rate

Major Claims by Experiments

1) Excess Heat with ${}^4\text{He}$ 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?

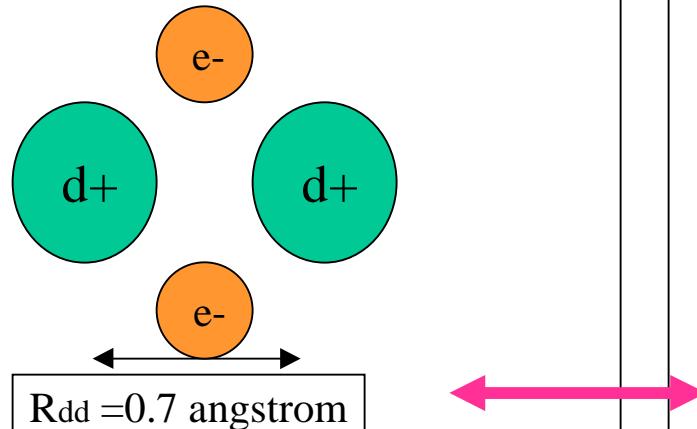
- Excess Heat:
100% by D/Pd ratio GE. 1.0
- Nuclear Products:
By nano-scale modification of Pd surface,
nano-particle,
stimulation with Laser, Ultra-Sonic,
Plasma-Discharge, etc.

Problems in Theorization

- How to construct a Consistent Theory which can explain anomalous results (heat with ${}^4\text{He}$, 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 D₂ 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,

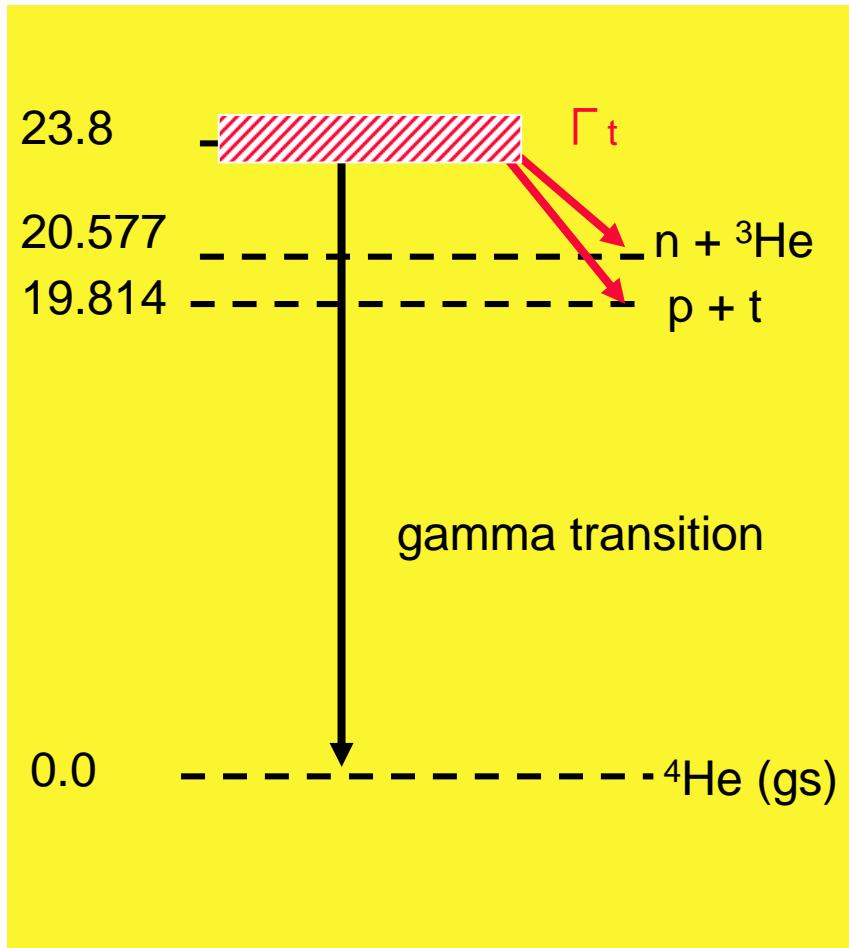
D + D → He-4 + lattice energy(23.8MeV)

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

IS NOT POSSIBLE by nuclear physics theory!

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.

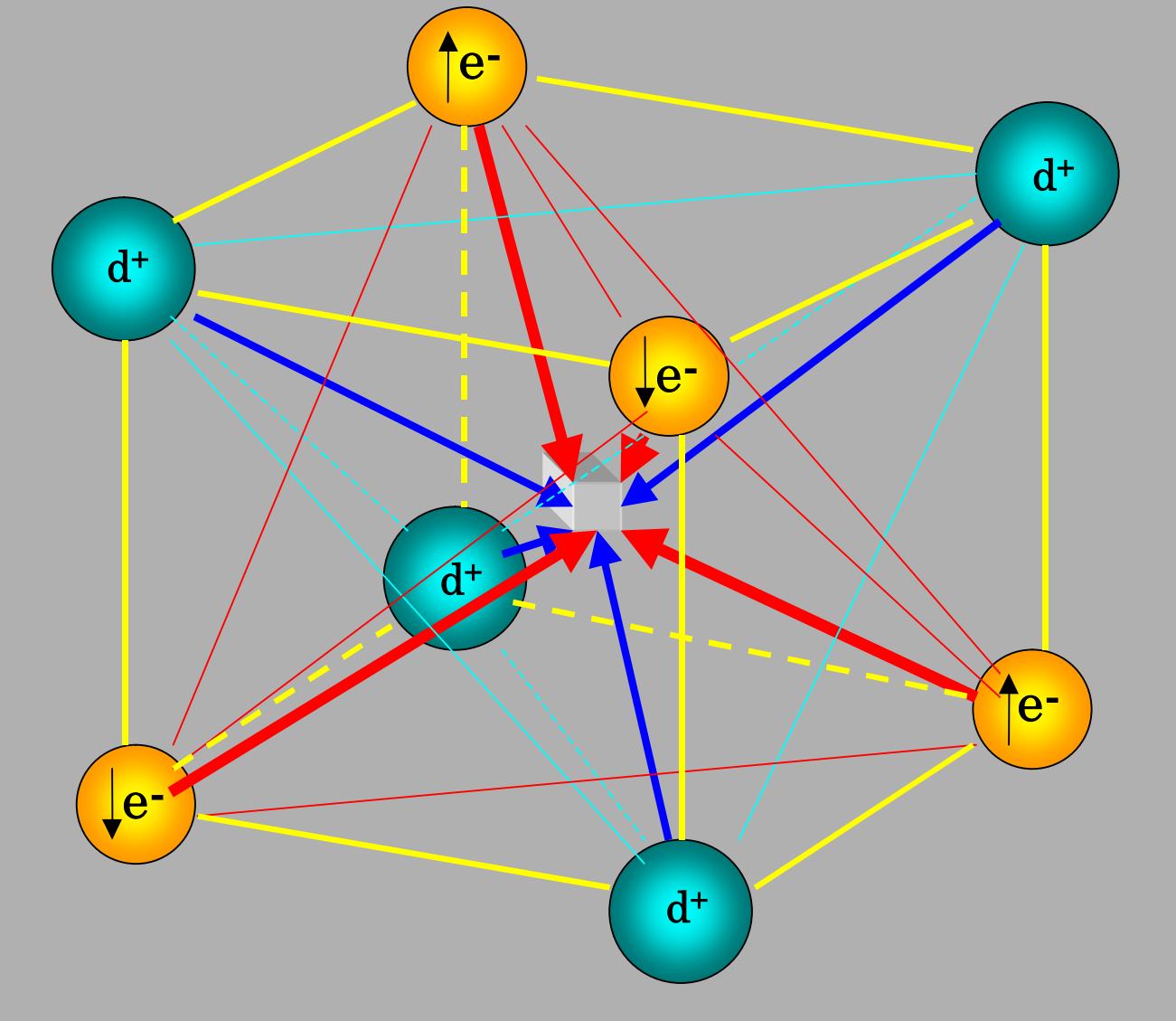
$d + d \rightarrow {}^4\text{He}^*(23.8\text{MeV}) \rightarrow \text{Break-up}$



- Branching Ratio :
 $S_n(0)/S_p(0)/S_g(0) = \Gamma_n/\Gamma_p/\Gamma_g = 0.5/0.5/0.0000001$
- $\Gamma_n = \Gamma_p = 0.2 \text{ MeV}$
- $\Gamma_g = 0.04 \text{ eV}$
- $\Gamma_t = \Gamma_n + \Gamma_p + \Gamma_g$
- $\tau = h/\Gamma_t = 1E-22 \text{ s}$
- No forces to change
BRs have ever been proposed!

Classical View of Tetrahedral Sym. Condensation

Orthogonal Coupling of Two D₂ 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

The Place where TSC is born?

1) In Natural Gas-Phase of D₂ (H₂): Very small probability for two D₂(H₂) molecules to make orthogonally coupled state.

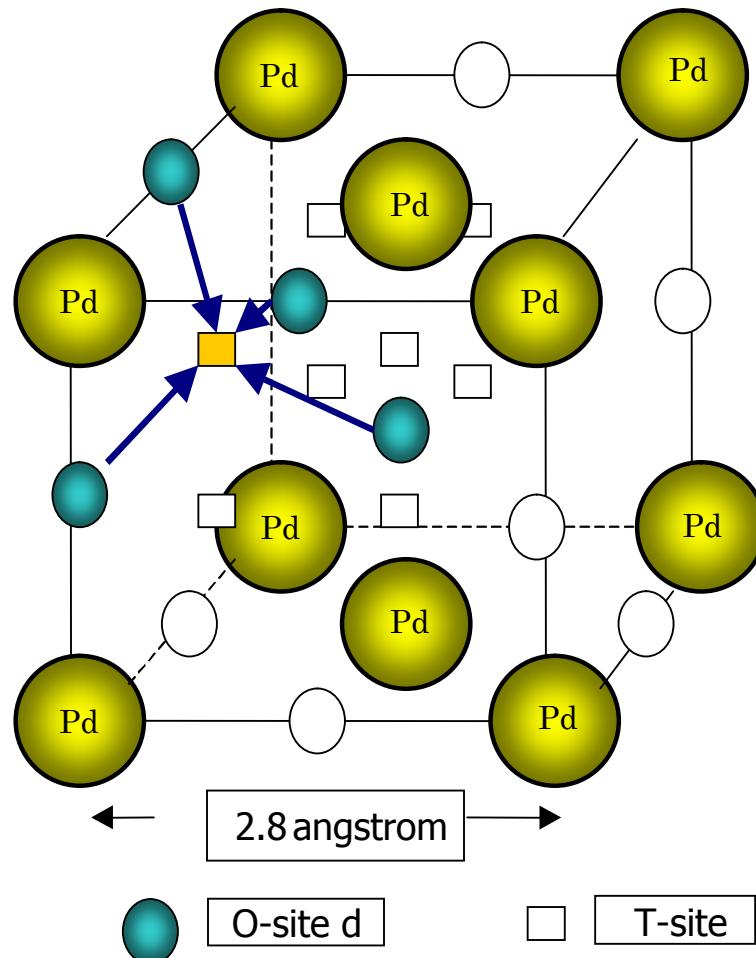
→ Possible at very low temperature?

(Bose-Einstein Condensation)

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

→ (Dynamic Bose Condensation of TSC)

Tetrahedral Condensation of D-Cluster



Some FC Pd omitted

**Transient Bose
Condensation of Deuterons**

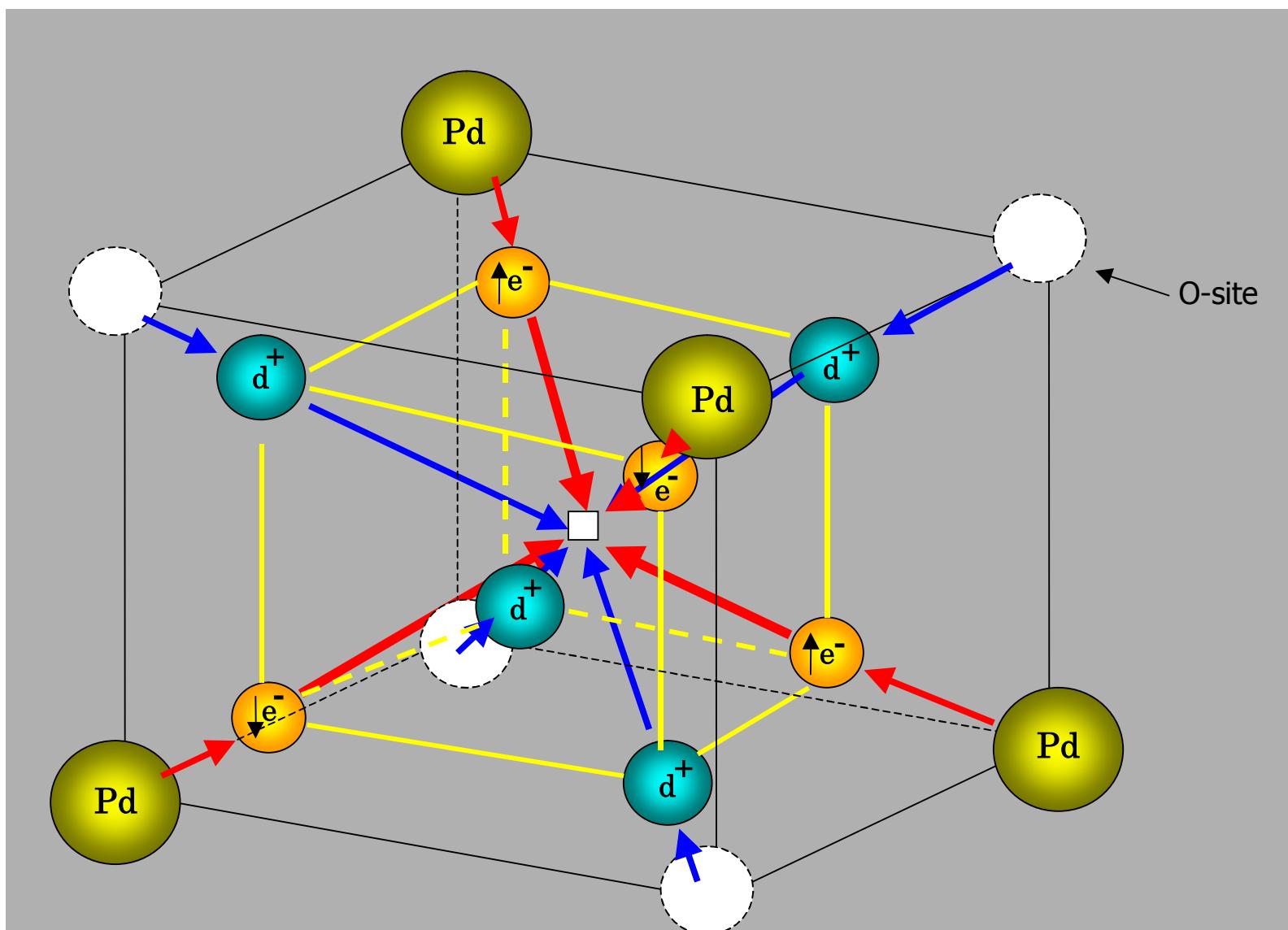
From O-site to T-site

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

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

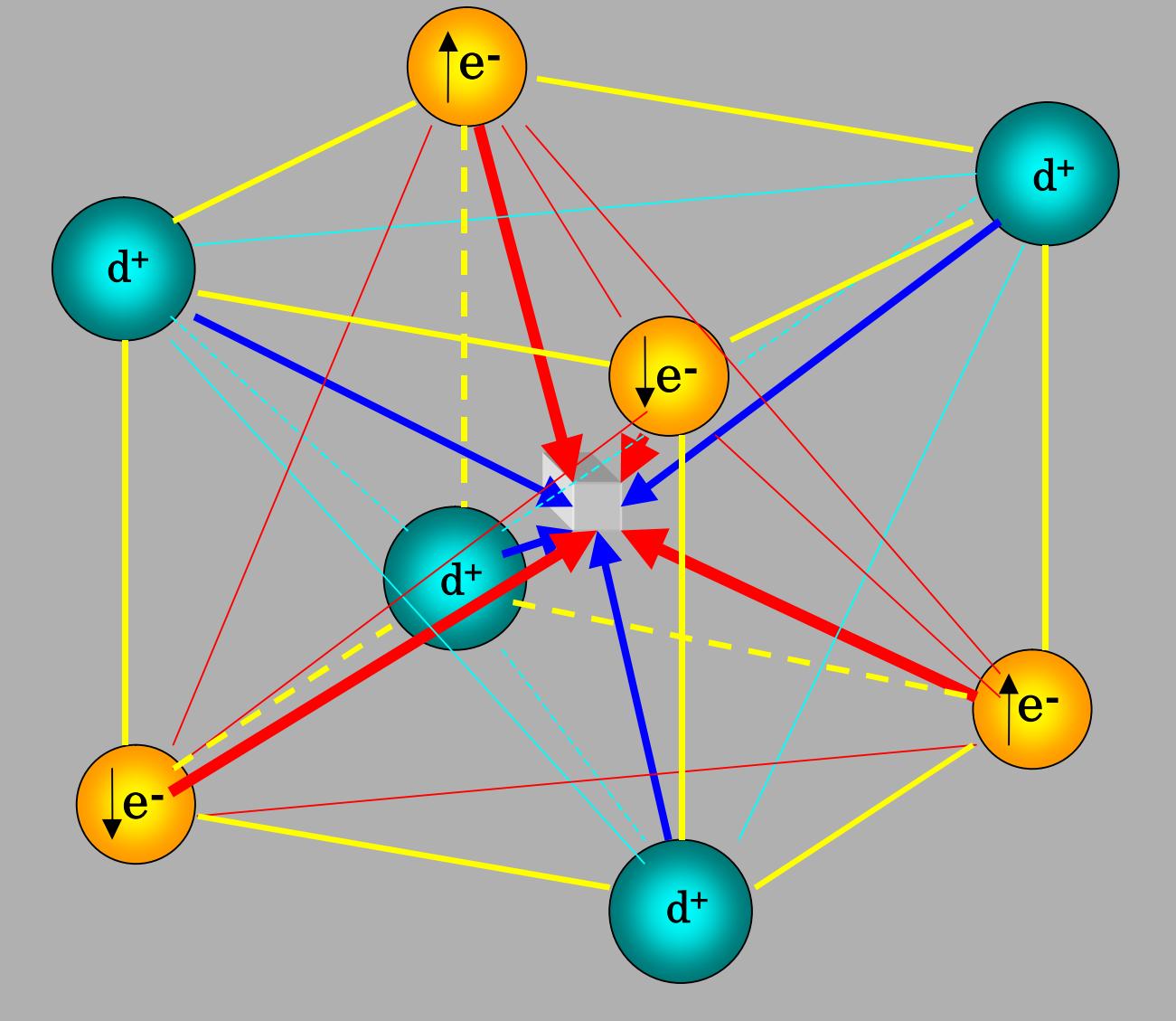
**D-Cluster as Mixture of
DDe, DDee, DDe*, DDe* e^***

Tetrahedral Condensation of Deuterons in PdDx



Classical View of Tetrahedral Sym. Condensation

Orthogonal Coupling of Two D₂ Molecule makes Miracle !



Transient
Combination
of Two D₂
Molecules
(upper and
lower)

Squeezing only
from O-Sites to
T-site

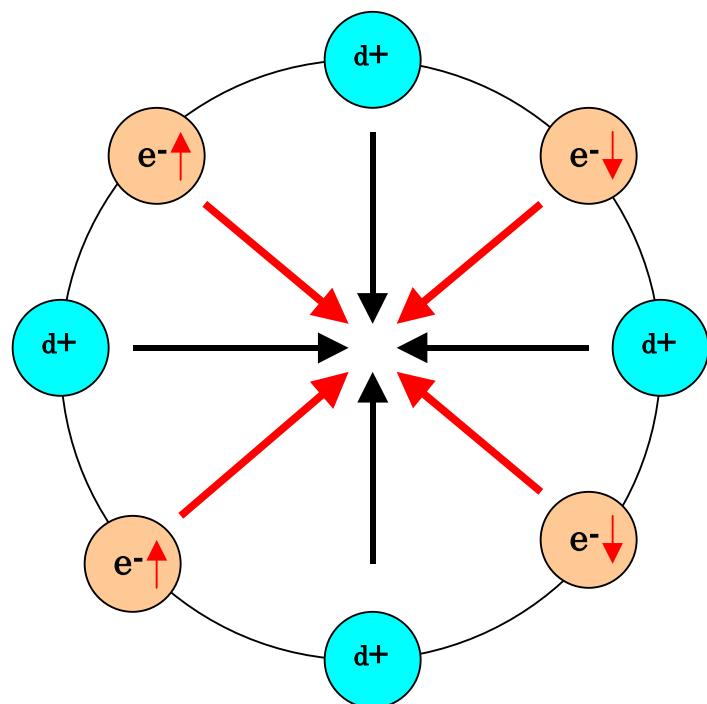
3-dimension
Frozen State for
4d+s and 4e-s

Quadruplet e^*
(4,4)

Formation of
Electrons
around
T-site

2-dimensional View of Tetrahedral Condensation

- Symmetric TCC

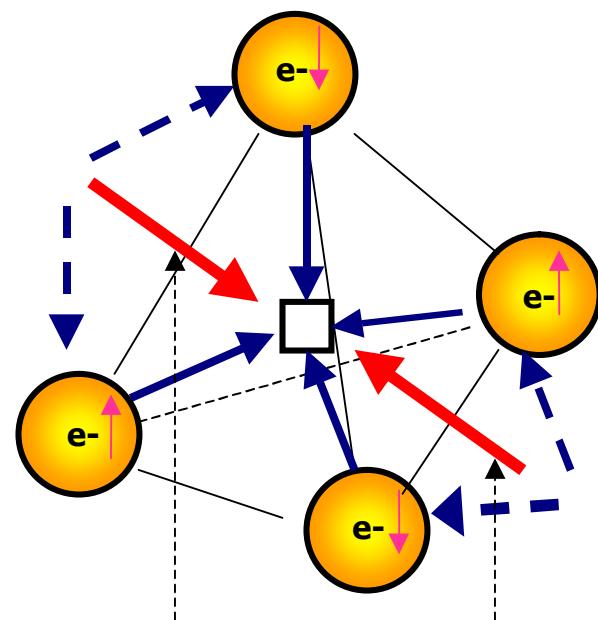


- Charge Neutral
Condensation in Average is possible
- Quadruplet $e^*(4,4)$ is formed as *Single Particle* at central focal point (T-site) of **0.01 nm diameter domain**
- **<Life Time of $e^*(4,4)$ >**
- $> (1.0E-9) \text{cm/Ve}$
- $= 1.0E-9 / 4.3E5 = 2.3E-15$
- **= 2.3 fs**

Life Time of TSC is about 60 fs

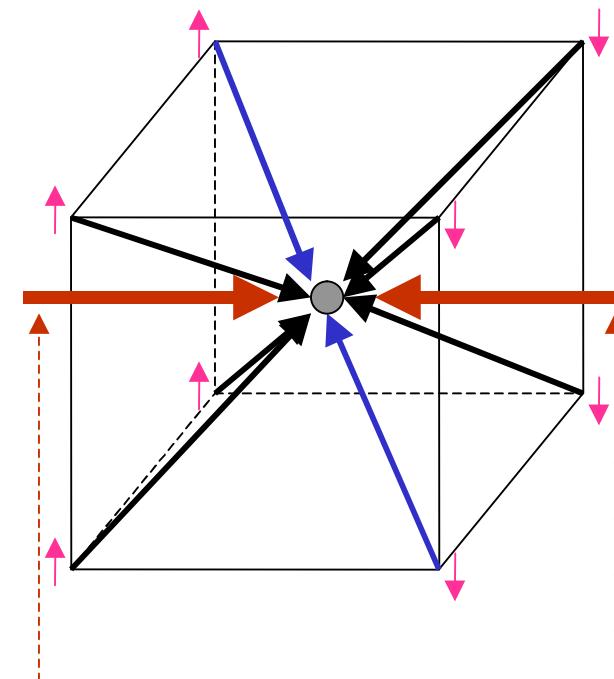
Quadruplet and Octal-Coupling of Electrons

Quadruplet $e^*(4,4)$



Sum Momentum Vector

Octal-Coupling $e^*(8,8)$

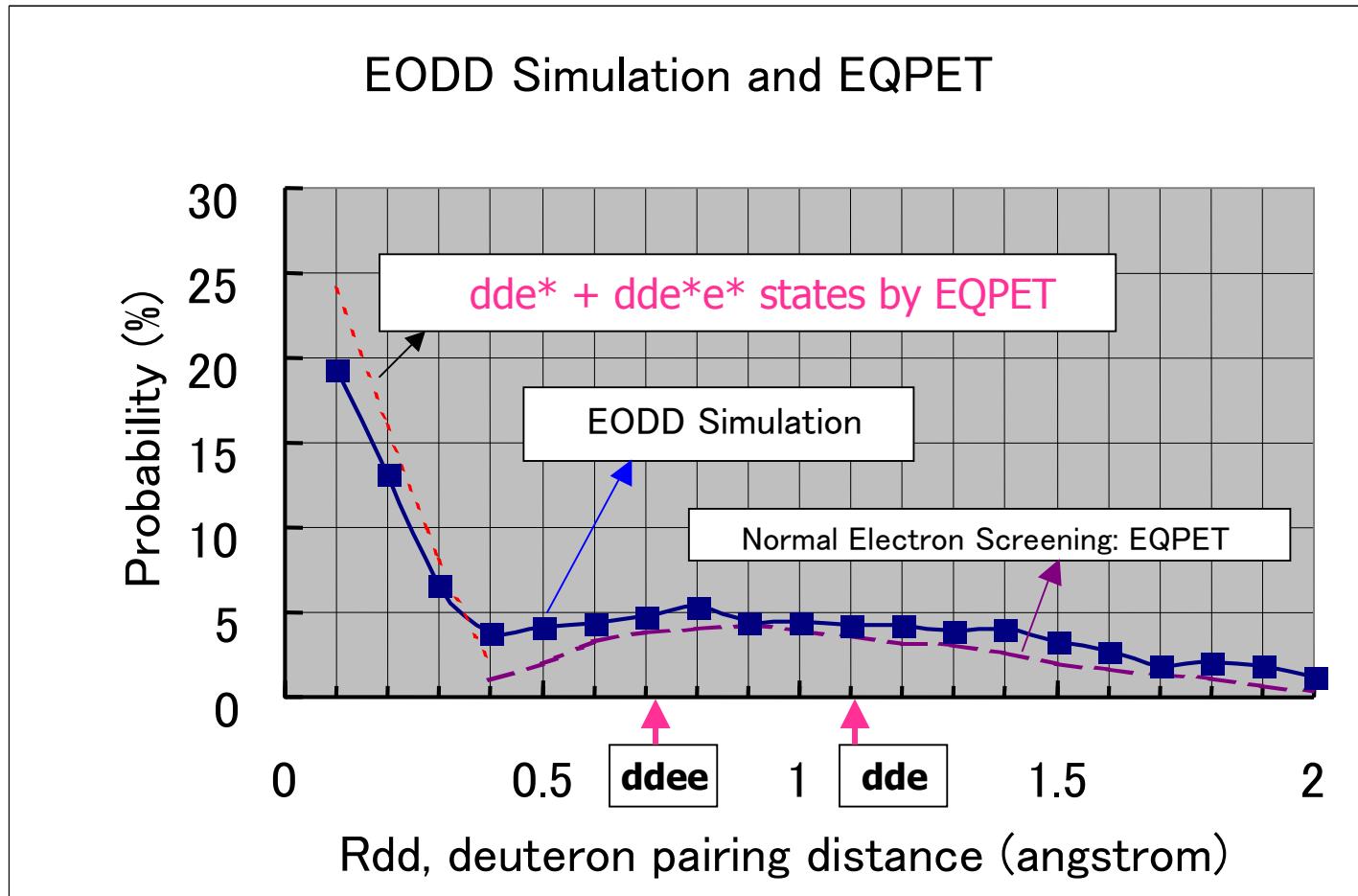


Sum Momentum Vector

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:

$$F_{nD} = \langle \Psi_1^2 \rangle \langle \Psi_2^2 \rangle \langle \Psi_3^2 \rangle \dots \langle \Psi_n^2 \rangle$$

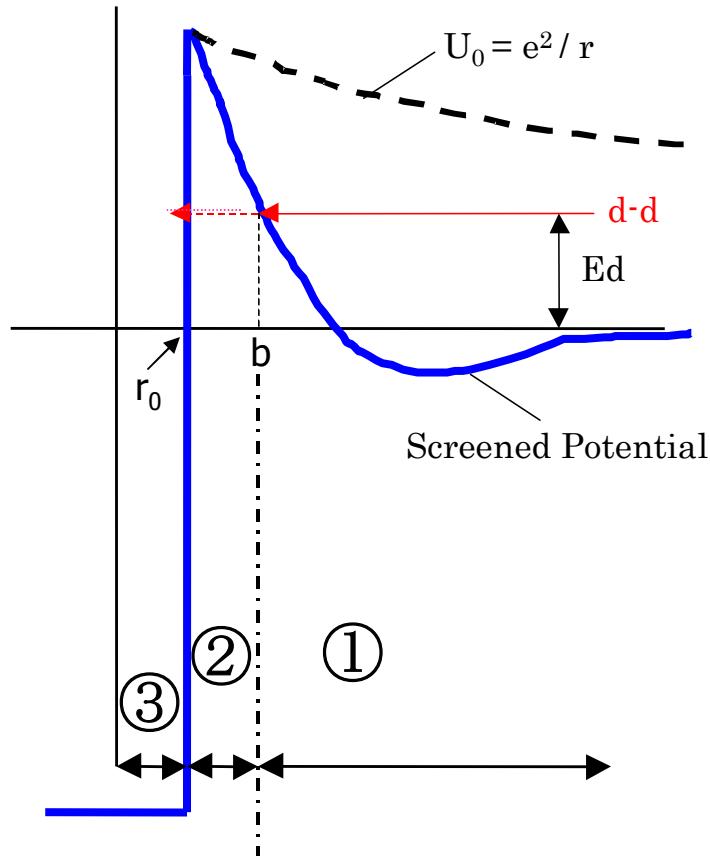
② : Barrier Penetration Process:

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

③ : Nuclear Fusion Process

$$\sigma = S_{nD} / E_d$$

$$\boxed{\langle \text{Fusion Rate} \rangle = \sigma v * P_B * F_{nD}}$$

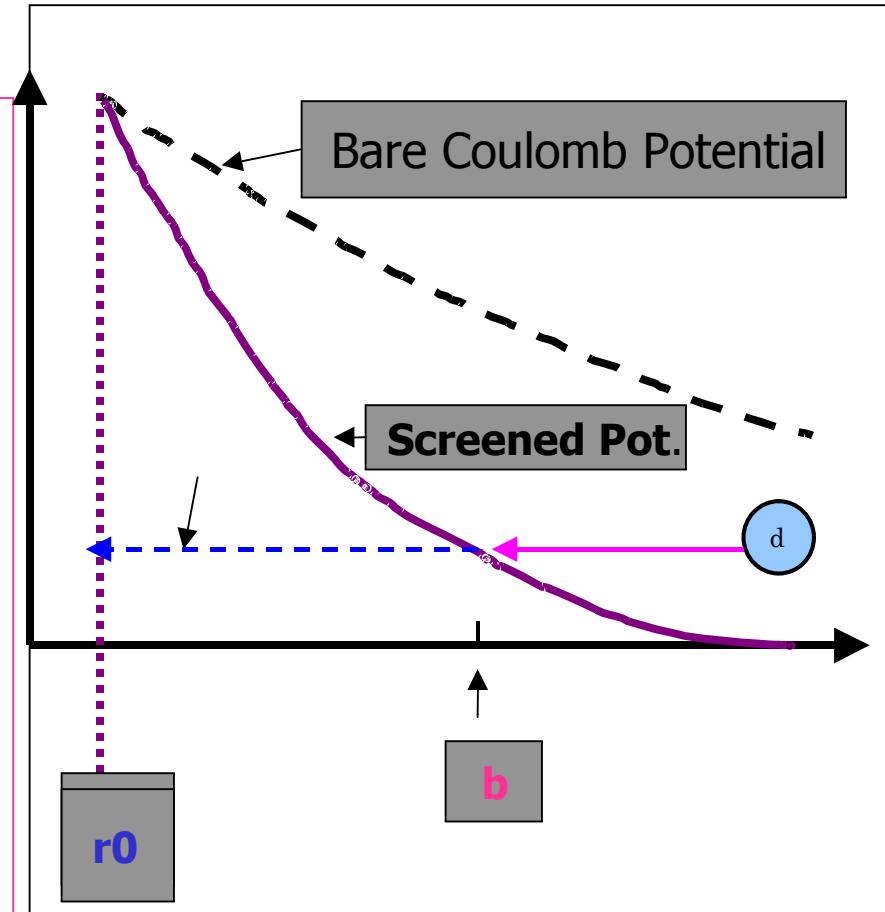


Barrier Factor for Screened Potential

Gamow Integral over b to r0

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

- $V_s(r)$: 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
- r_0 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;

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

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:

$$(-\hbar^2/(8\pi\mu))\nabla^2 X(R) + (V_n(R) + V_s(R))X(R) = E_X(R) \quad (11)$$

By Born-Oppenheimer approximation, we assume as,

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

Overlapping rate of $X(R)$ at $R = r_0$ gives estimation of **d-d fusion rate** λ_{2d} as:

$$\begin{aligned} \lambda_{2d} &= G |X(R)|^2 \Big|_{R=r_0} \\ &= G |X_n(R)|^2 \Big|_{R=r_0} |X_s(R)|^2 \Big|_{R=r_0} \quad (13) \end{aligned}$$

EQPET: continues-3

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

$$|X_s(R)|^2_{R=r_0} = \exp(-2\Gamma_n(E_d)) \quad (14)$$

;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:

$$\Gamma_n(E_d) = (2\mu)^{1/2}/(h/\pi) \int_{r_0}^{\infty} (V_s(R) - E_d)^{1/2} dR \quad (15)$$

Using astrophysical S-factor for strong interaction,

$$G |X_n(R)|^2_{R=r_0} = vS_{2d}(E_d)/E_d \quad (16)$$

Consequently we can approximately define fusion rate as:

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

Screened Potential of EQPET Molecule

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

For de^* ,

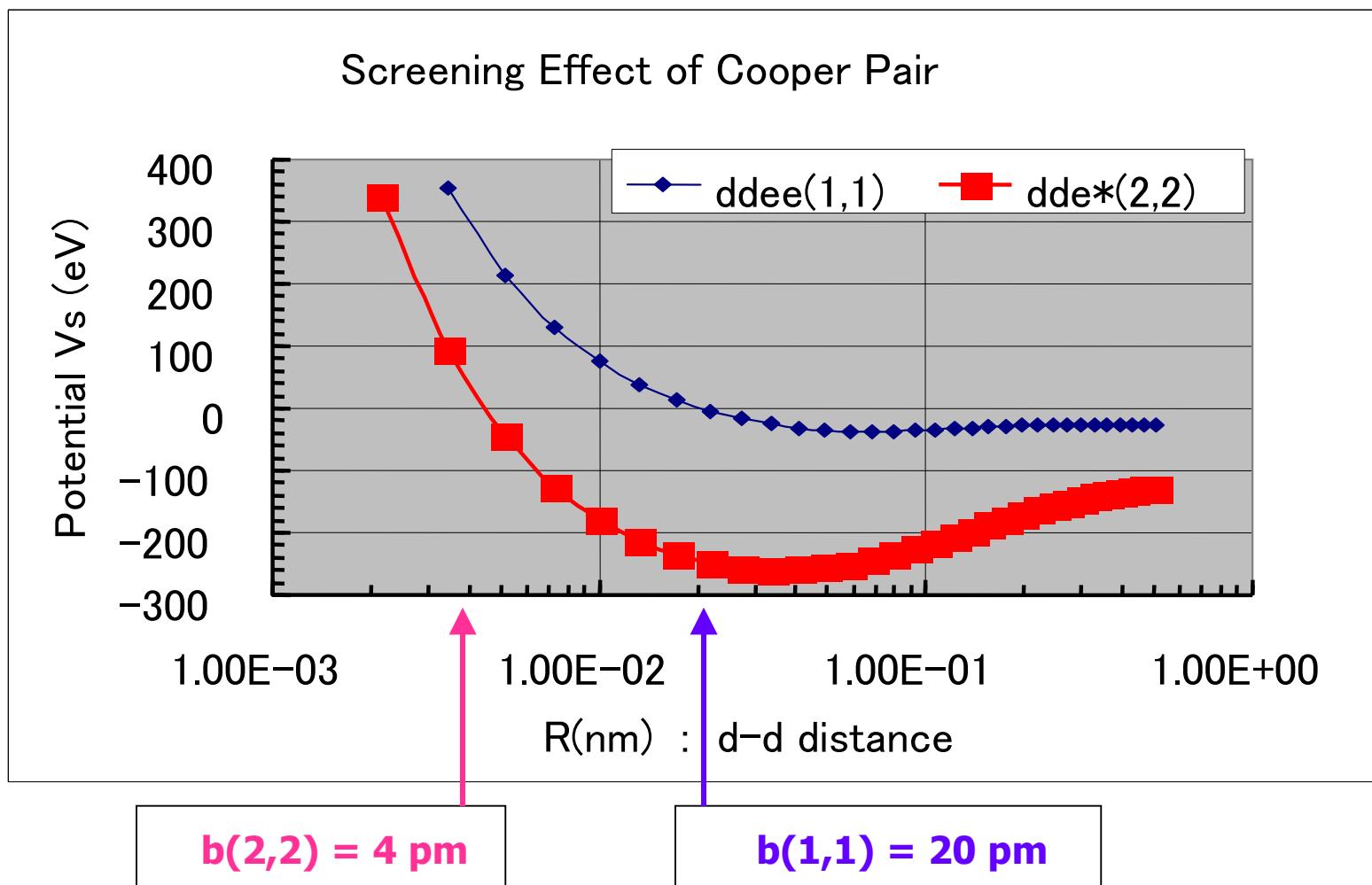
$$Vs(R) = Vh + e^2/R + (J + K)/(1 + \Delta)$$

For dde^*e^* ,

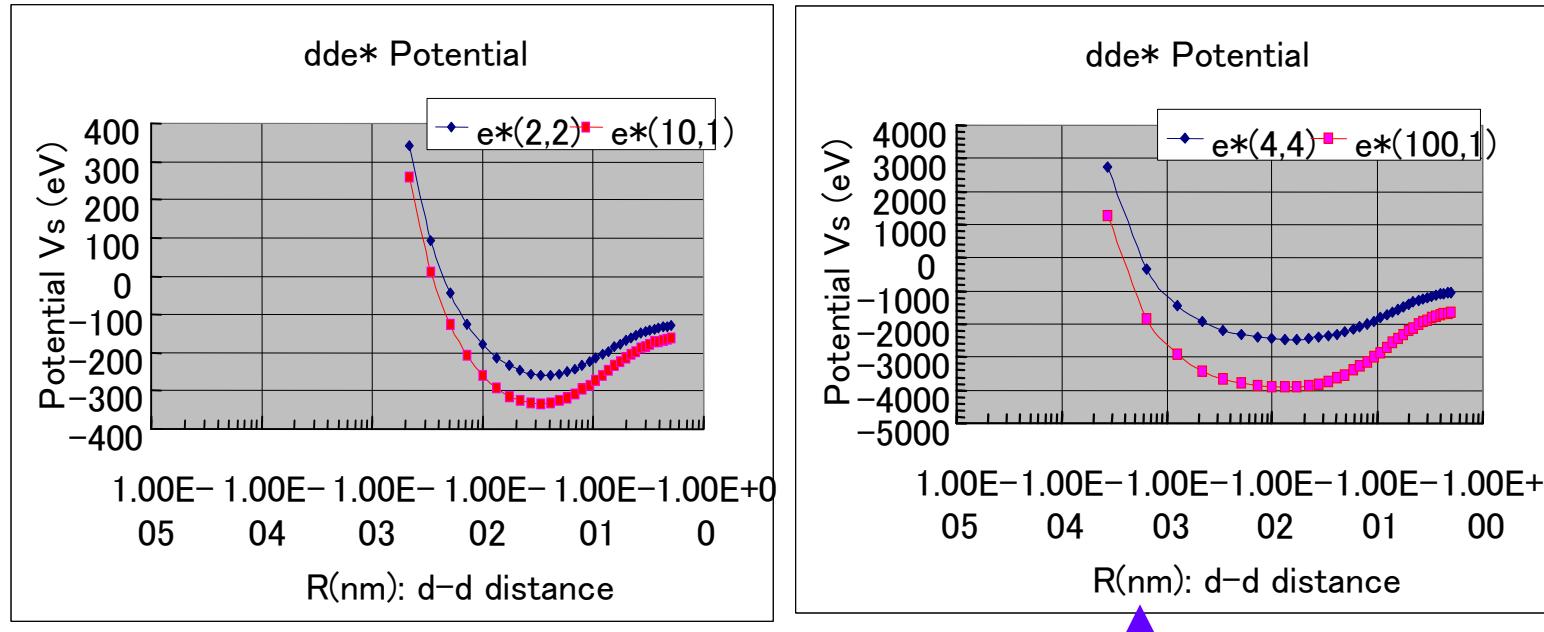
$$Vs(R) = 2Vh + e^2/R + (2J + J' + 2\Delta K + K')/(1 + \Delta^2)$$

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

Screening Effect by EQPET Molecules



Screening Effect: EQPET Molecule vs. Heavy Fermion



Cooper pair (single particle) works as strong as mass 10 fermion
Pairing of $e^*(2,2)$ s works as strong as mass 100 fermion

$$e^*(4,4) < \mu (208,1) < e^*(8,8)$$

Screening Energy of EQPET Molecules

$$U_s = - e^2/b_0 \text{ for } V_s(b_0) = 0$$

	U_s (eV)	U_s (eV)	b_0 (pm)	b_0 (pm)
e^*	dde*	dde*e*	dde*	dde*e*
(1,1)	36	72	40	20
(2,2)	360	411	4	3.5
(4,4)	4,000	1,108	0.36	1.3
(8,8)	22,154	960	0.065	1.5
(208,1)	7,579	7,200	0.19	0.20
(6, 6)	9,600		0.15	

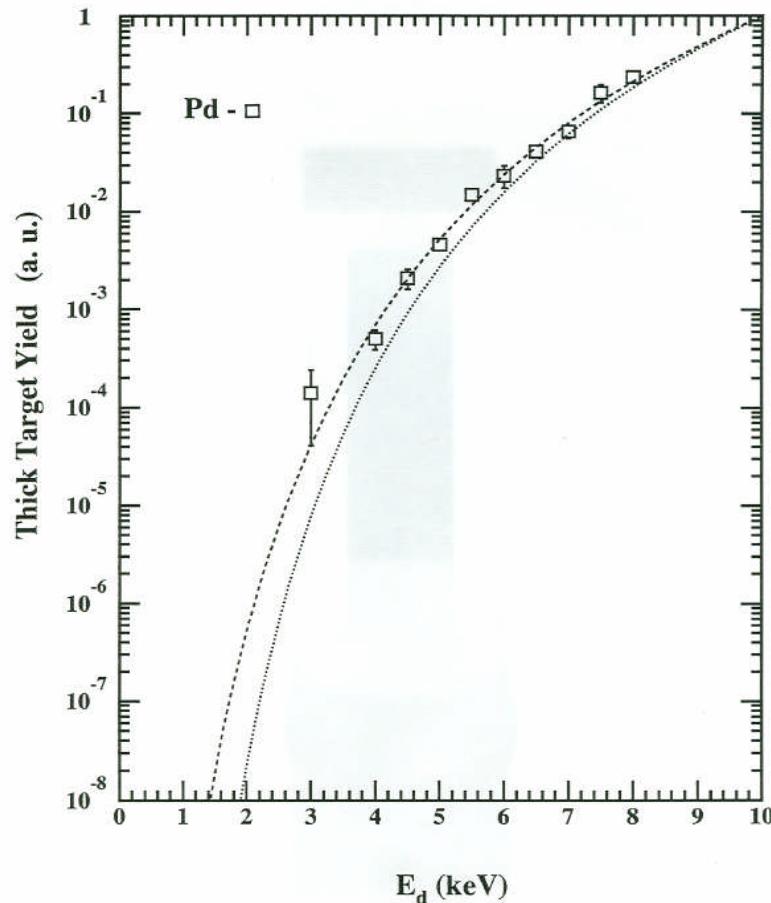
Parameters of dde* potentials

$e^*(m, Z)$	V_{SMIN} (eV)	b_0 (pm)	$R_{dd}(\text{gs})$ (pm)
(1, 1)	- 15.4	40	101
(1, 1)x2; D ₂	- 37.8	20	73
(2, 2)	- 259.0	4	33.8
(4, 4)	- 2,460	0.36	15.1

Trapping
Depth

Ground
State

**Protein yield (α cross section)
from $D(d,p)^3H$ reaction with
deuterated
Pd target**

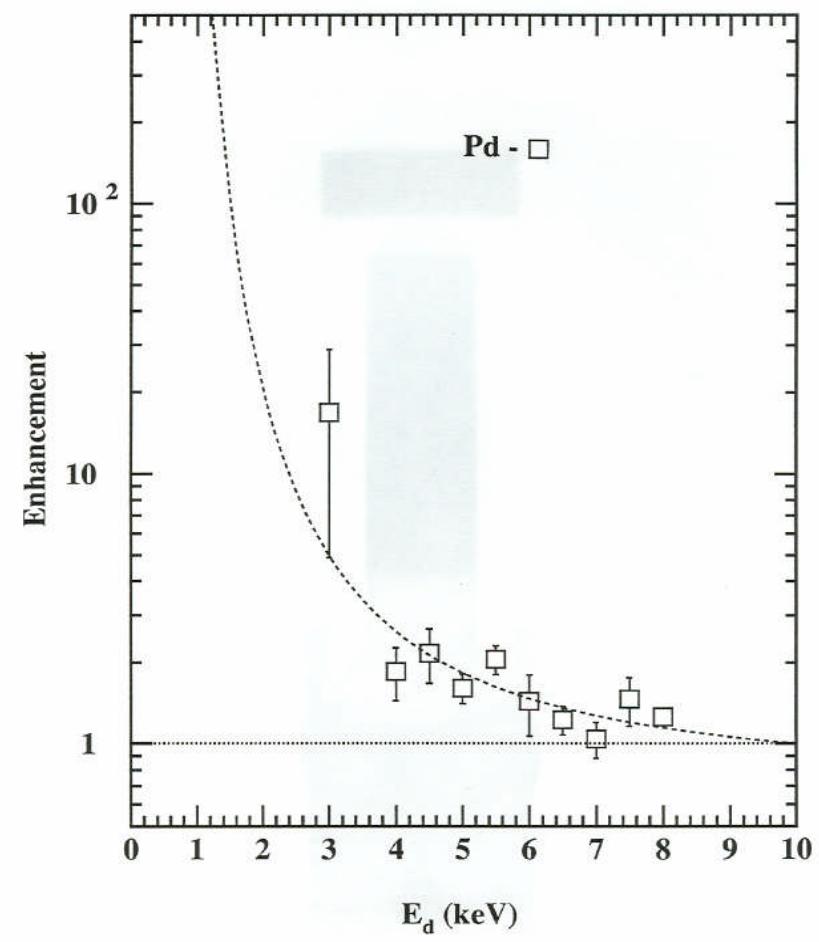


Deuteron Beam

Kasagi et al: JPSJ, 71(2002)2881

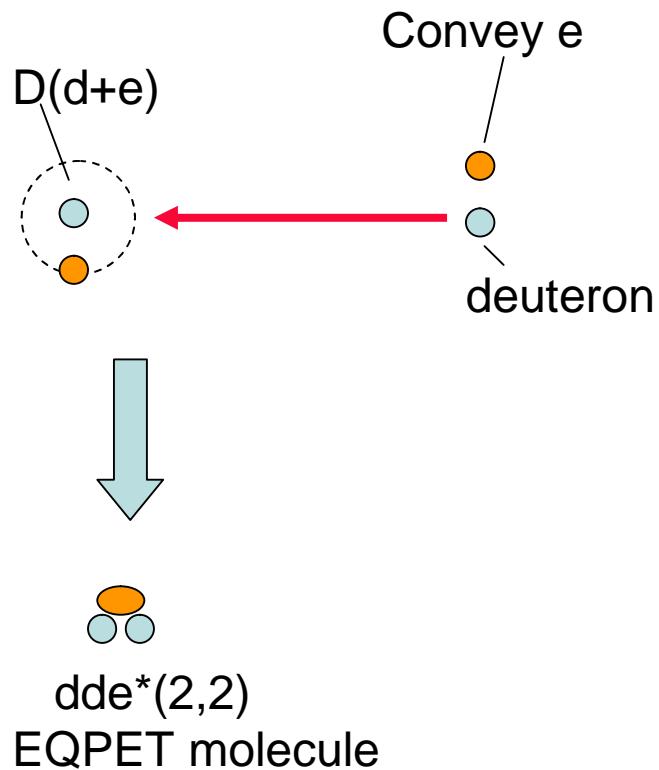
Enhancement Factor:
 $\exp(-\sqrt{E_G/(E+U_e)})/\exp(-\sqrt{E_G/E})$

$U_s = 310$ eV



Deuteron Beam

Beam-Solid-Target reaction



- Formation of **EQPET** molecule $dde^*(2,2)$ with 50% anti-parallel spin arrangement for two electrons:
 U_s (Screening E) = 360eV
- Exp. with 1-10 keV D+ beam to PdDx, by **Kasagi** (2002):
JSPS 71(2002)2881
 $U_s = 310 \pm 30$ eV

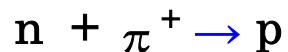
3D Fusion Rate by Takahashi

$$[3D]/[2D] \approx 1E-4$$

- D+ beam ≈ 1 micro-amp $\approx 2E13$ d/s
- Assuming $dde^*(2,2)$ life time $\tau < 1$ s,
- [Density of $dde^*(2,2)$] $\approx 2E13 \times \tau$ in range.
- Takahashi exp. paper (Physics Letters A 255(1999)89-97) on 3D concluded; $1E+9$ close d-d pair density in TiDx target (1 micron range).
- We see considerable agreement, with $\tau \approx 0.1$ ms!

Scaling of PEF (Pion Exchange Force) for Nuclear Fusion

Two Body Interaction: $\text{PEF} = 1$



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

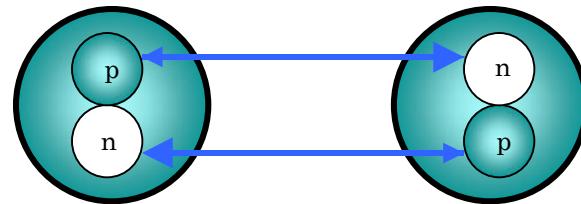


: d ; down quark

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

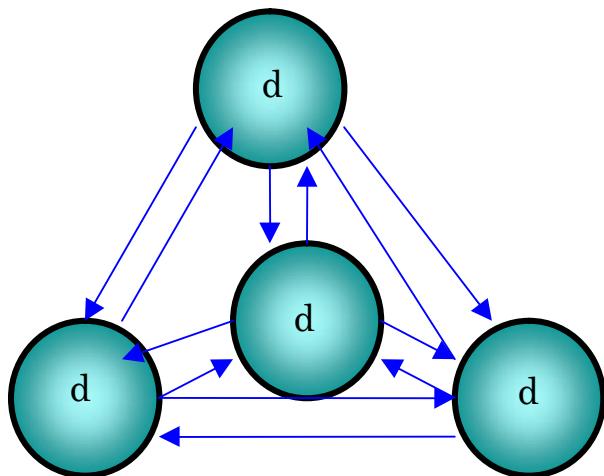
: d^* ; anti-down quark

For D + D Fusion; $\text{PEF} = 2$

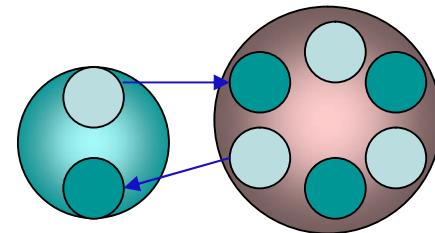


4D \rightarrow ⁸Be* vs. D+⁶Li \rightarrow ⁸Be* ; for strong interaction

4D Fusion; PEF = 12

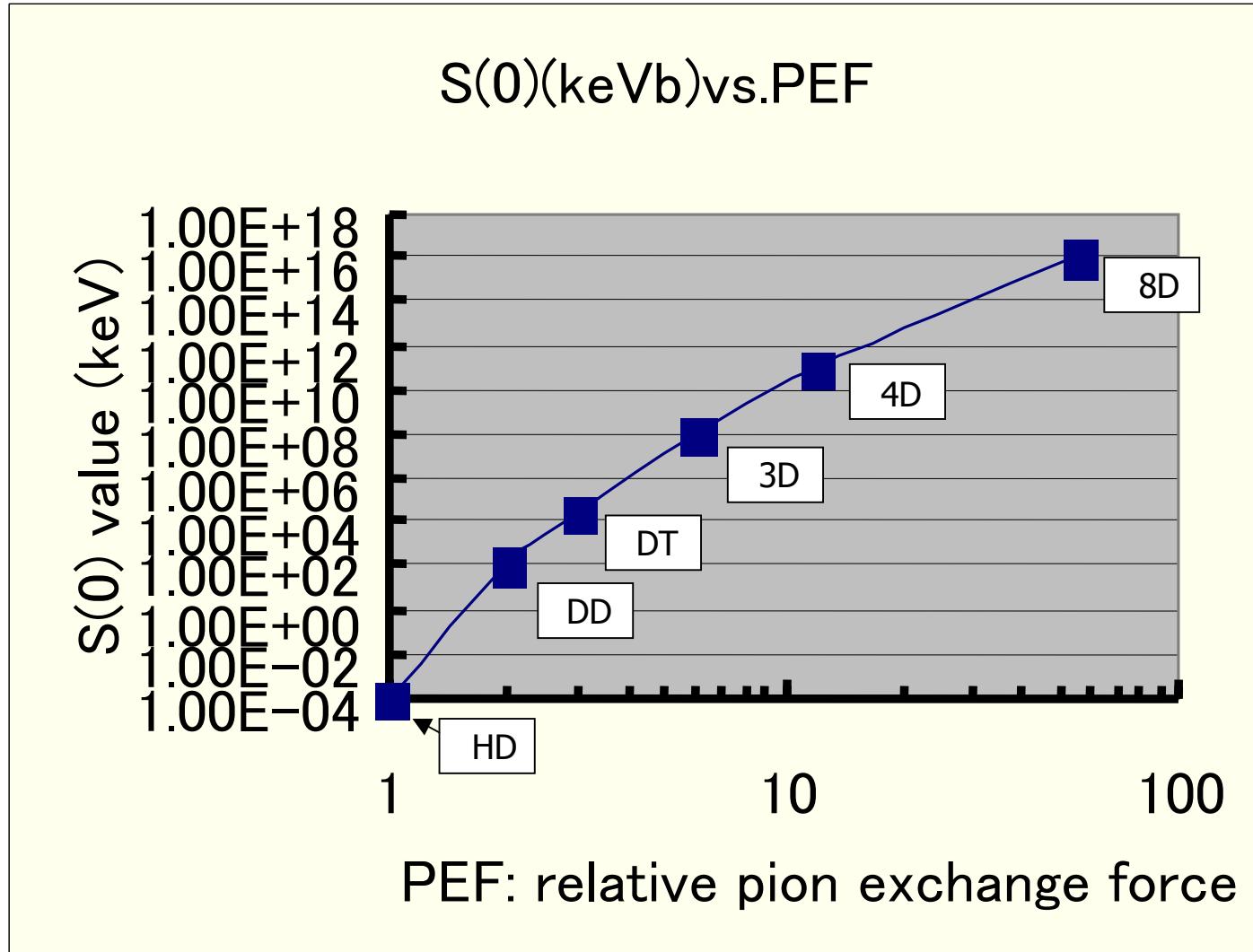


D + ⁶Li Fusion: PEF = 2+ α



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

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



Barrier Factors (BF) and Fusion Rates (FR)

$E_d = 0.22\text{eV}$

(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

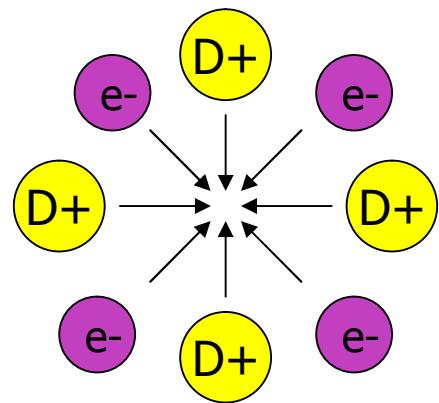
() is virtual rate

Major Products of D-Cluster Fusion

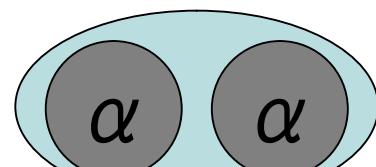
- 1) $3D \rightarrow Li\text{-}6^* \rightarrow d + He\text{-}4 + 23.8 \text{ MeV}$,
 $t\text{-}3 + He\text{-}3 + 9.5 \text{ MeV}$
- 2) $4D \rightarrow Be\text{-}8^* \rightarrow 2xHe\text{-}4 + 47.6 \text{ MeV}$
- 3) $5D \rightarrow B\text{-}10^* (53.7 \text{ MeV})$
- 4) $6D \rightarrow C\text{-}12^*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

- 4D and 8D Fusion can be selective because of resonant pion exchange
- 5D, 6D and 7D processes partially attain 4D resonance.

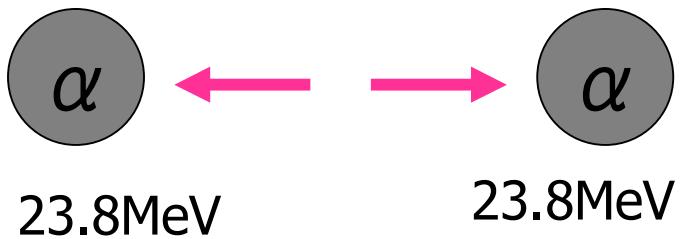
1) TBC/TSC



2) 4D TRF
 $:^8\text{Be}(47.6\text{MeV})^*$
compound state



3) Break-Up



Power Level by TSC and OSC Fusion

D-Cluster Fusion by TSC

- Assume 1E22 TSC-clusters/cc at Ed=0.22eV
- 4D Fusion Rate = $(3.1E-11) \times (1E22) = 3E11 \text{ f/s/cc} =$
3 watts/cc
- 2D Fusion Rate = $(1.9E-21) \times (1E22) = 19 \text{ f/s/cc}$ (**10 n/s/cc**)

D-Cluster Fusion by OSC

- Assume 1E16 OSC- clusters/cc at Ed=0.22 eV (1ppm PdD2)
- 8D Fusion Rate = $(7.8E-4) \times (1E16) = 7.8E12 \text{ f/s/cc} =$
78 watts/cc
- 4D Fusion Rate = $(7E-11) \times (1E16) = 7E5 \text{ f/s/cc}$

Features of the Present Method

D₂ gas permeation through the Pd complex

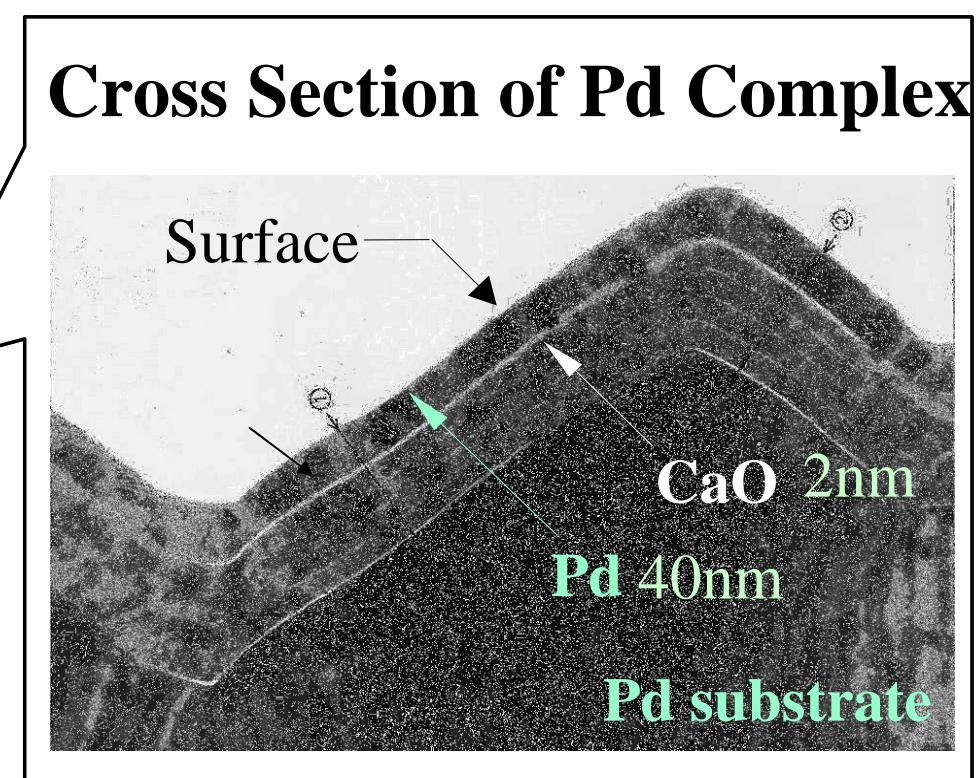
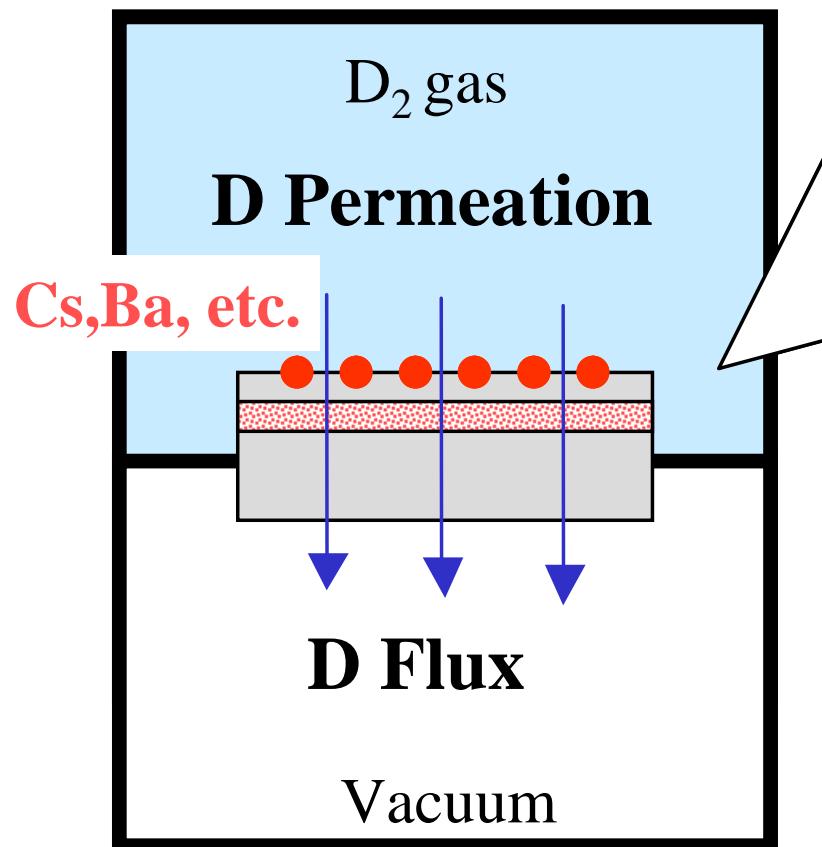
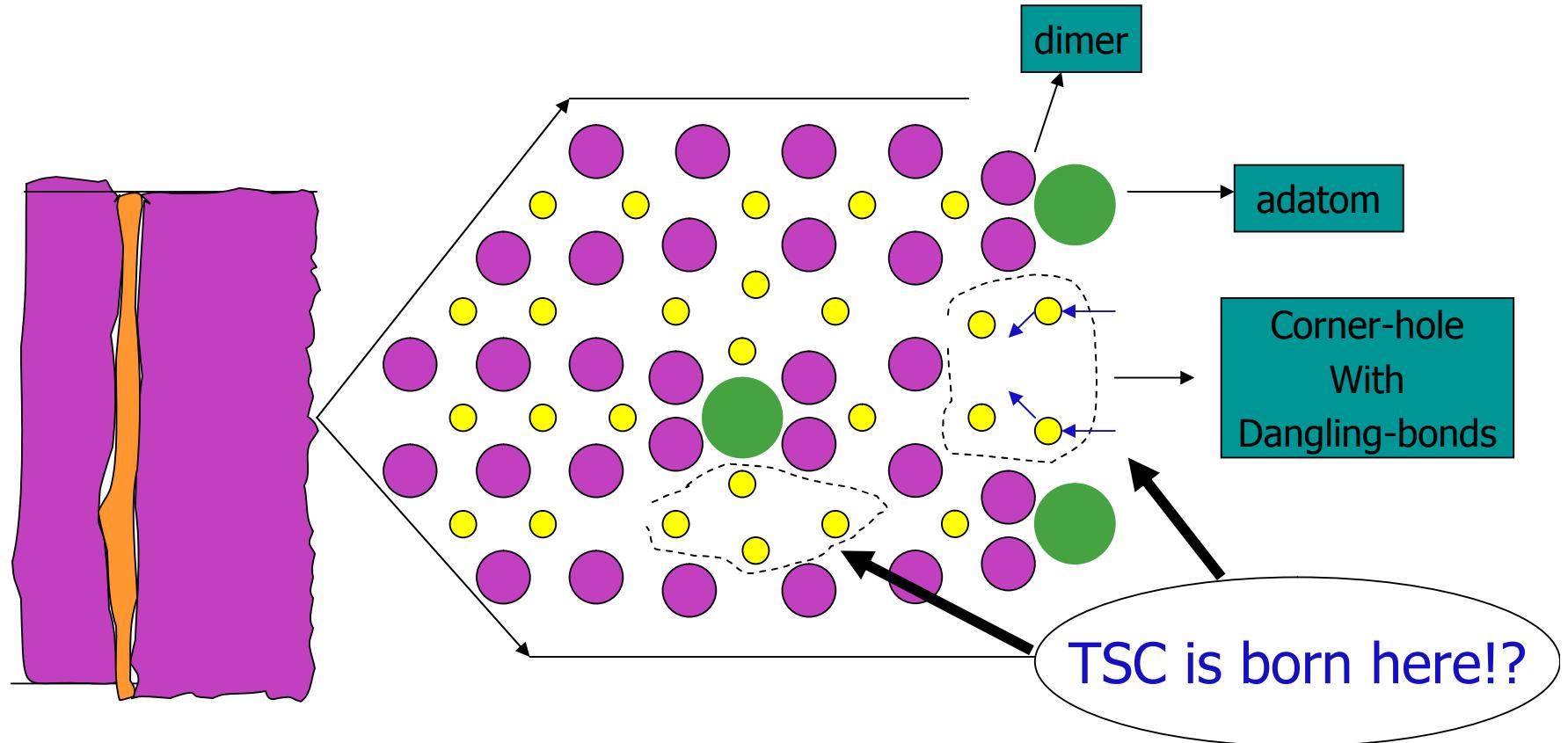


Image of Surface



CaO



Pd



Cs



D

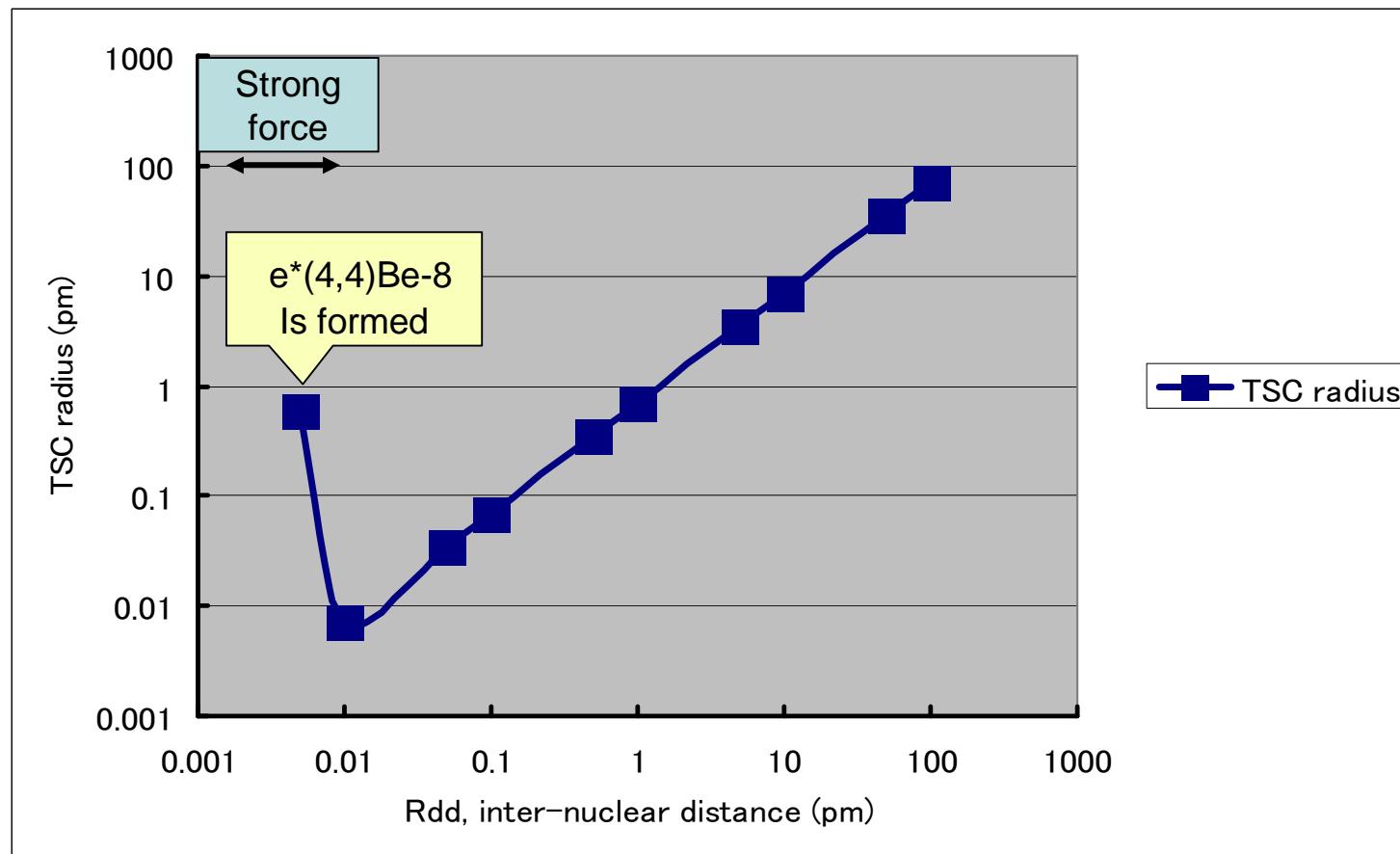
Minimum Size of TSC is far less than 1 pm!

- 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, ${}^8\text{Be}^*$ is formed by QM-penetration through EQPET shielded potential.
- As ${}^8\text{Be}^*$ is formed, 4e are left at outer domain, which size is approximated by $e^*(4,4)\text{Be}$ atom size of 0.8 pm.

c.f.: Classical Electron Radius:

$$\alpha hc/(2 \pi m_e c^2) = 2.8 \text{ fm}$$

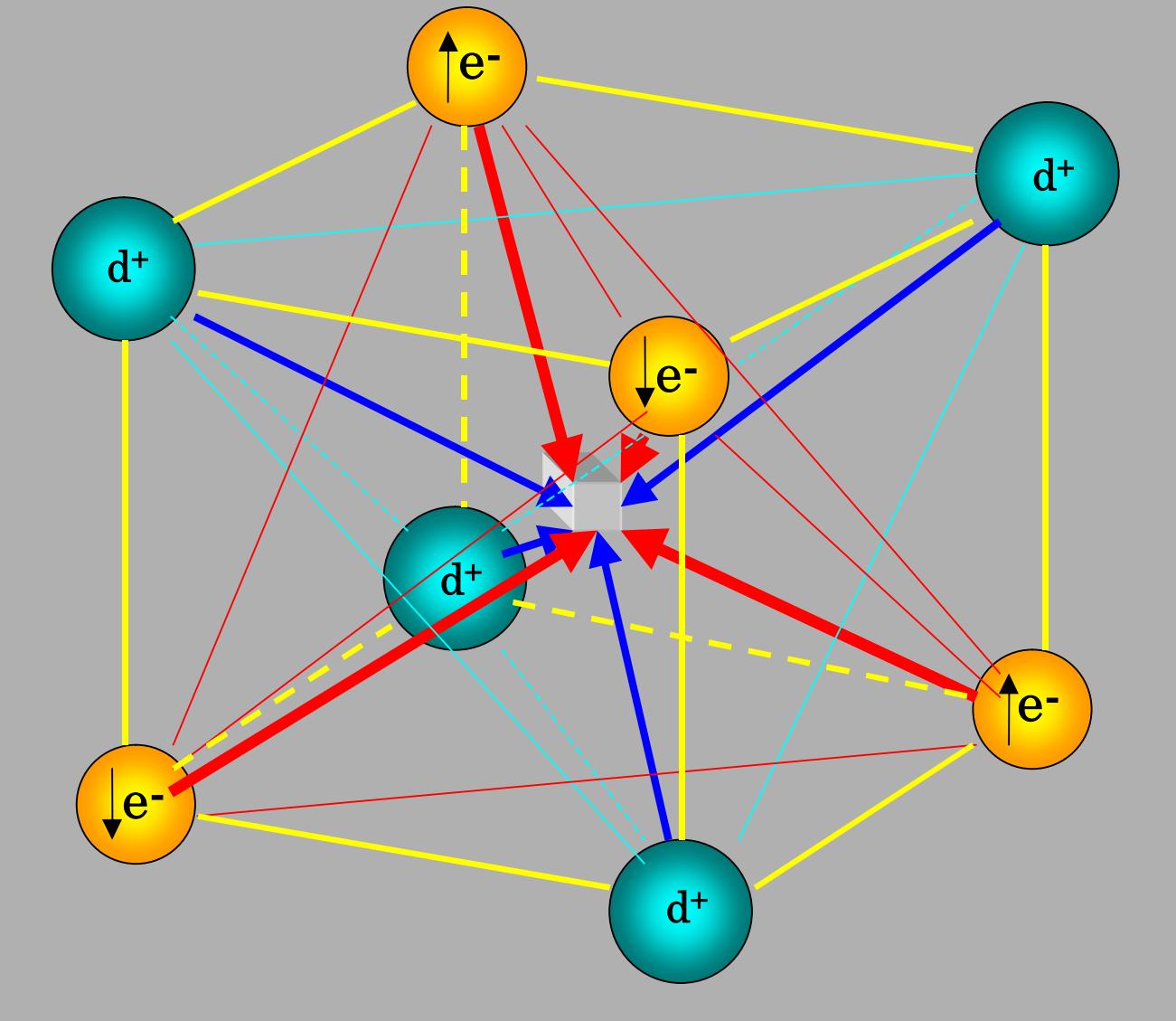
TSC Size by Dynamic Condensation in about 60 fs motion - Semi-Classical Treatment Possible -



$$\langle r(t) \rangle = \langle r(0) \rangle - \langle v \rangle t$$
$$\langle r(0) \rangle = (3^{1/2}/2) R_B = 45.8 \text{ pm}$$

Classical View of Tetrahedral Sym. Condensation

Orthogonal Coupling of Two D₂ Molecule makes Miracle !



Transient
Combination
of Two D₂
Molecules
(upper and
lower)

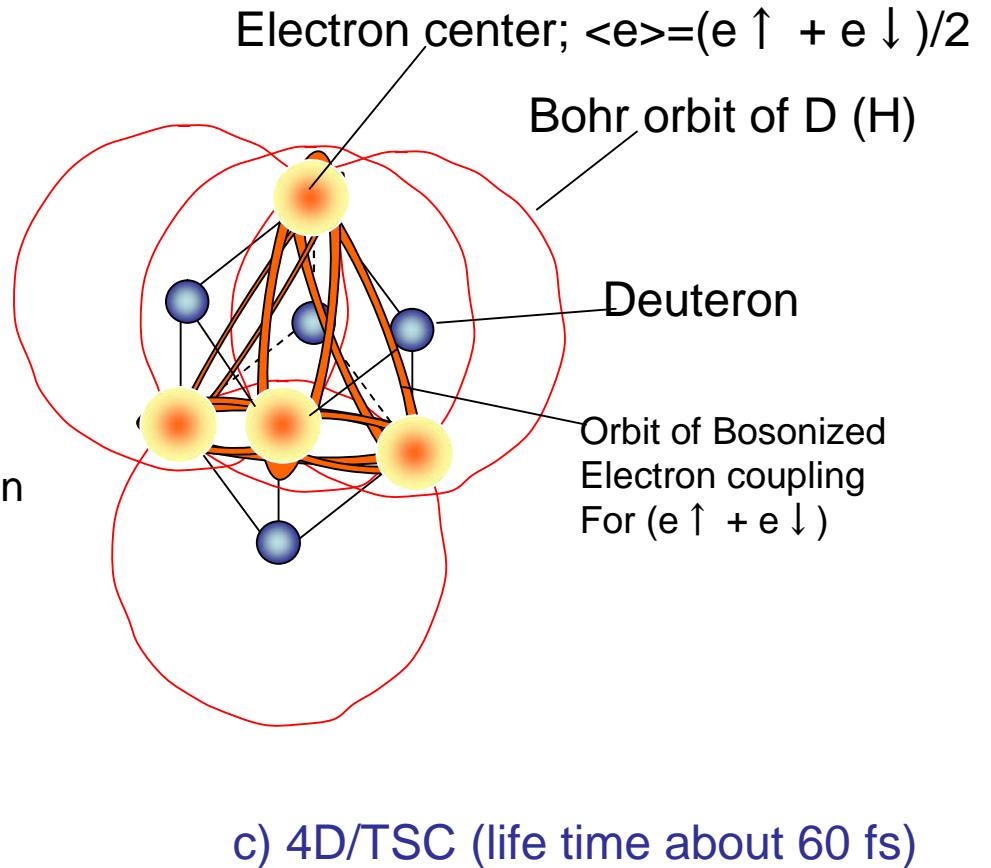
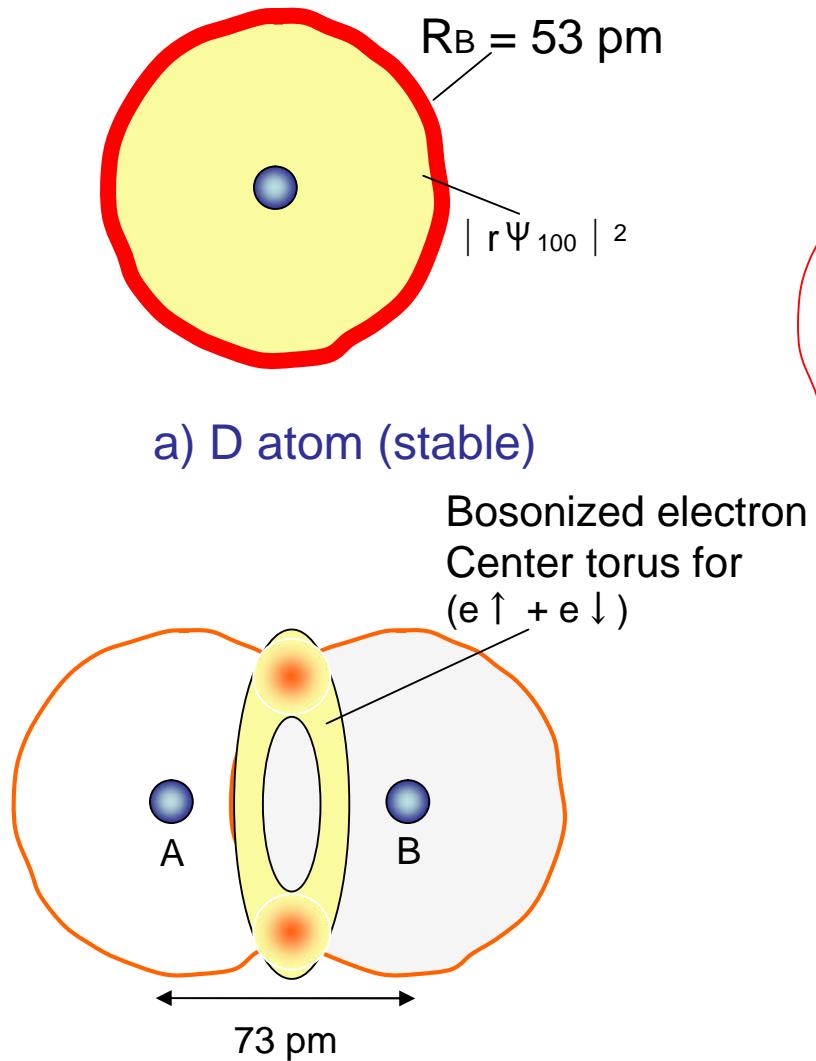
Squeezing only
from O-Sites to
T-site

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

Quadruplet e^*
(4,4)

Formation of
Electrons
around
T-site

Feature of QM Electron Cloud



b) D_2 molecule (stable): $\Psi_{2D} = (2+2\Delta)^{-1/2} [\Psi_{100}(r_{A1}) \Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2}) \Psi_{100}(r_{B1})] X_s(s_1, s_2)$

Wave Function for 4D/TSC (t=0)

- $\Psi_{4D} \sim a_1 [\Psi_{100}(r_{A1}) \Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2}) \Psi_{100}(r_{B1})] X_s(S1, S2)$
 $+ a_2 [\Psi_{100}(r_{A1}) \Psi_{100}(r_{D4}) + \Psi_{100}(r_{A4}) \Psi_{100}(r_{D1})] X_s(S1, S4)$
 $+ a_3 [\Psi_{100}(r_{A2}) \Psi_{100}(r_{C4}) + \Psi_{100}(r_{A4}) \Psi_{100}(r_{C2})] X_s(S2, S4)$
 $+ a_4 [\Psi_{100}(r_{B1}) \Psi_{100}(r_{D3}) + \Psi_{100}(r_{B3}) \Psi_{100}(r_{D1})] X_s(S1, S3)$
 $+ a_5 [\Psi_{100}(r_{B2}) \Psi_{100}(r_{C3}) + \Psi_{100}(r_{B3}) \Psi_{100}(r_{C2})] X_s(S2, S3)$
 $+ a_6 [\Psi_{100}(r_{C3}) \Psi_{100}(r_{D4}) + \Psi_{100}(r_{C4}) \Psi_{100}(r_{D3})] X_s(S3, S4)$
- $a_i a_j = \delta_{ij}$

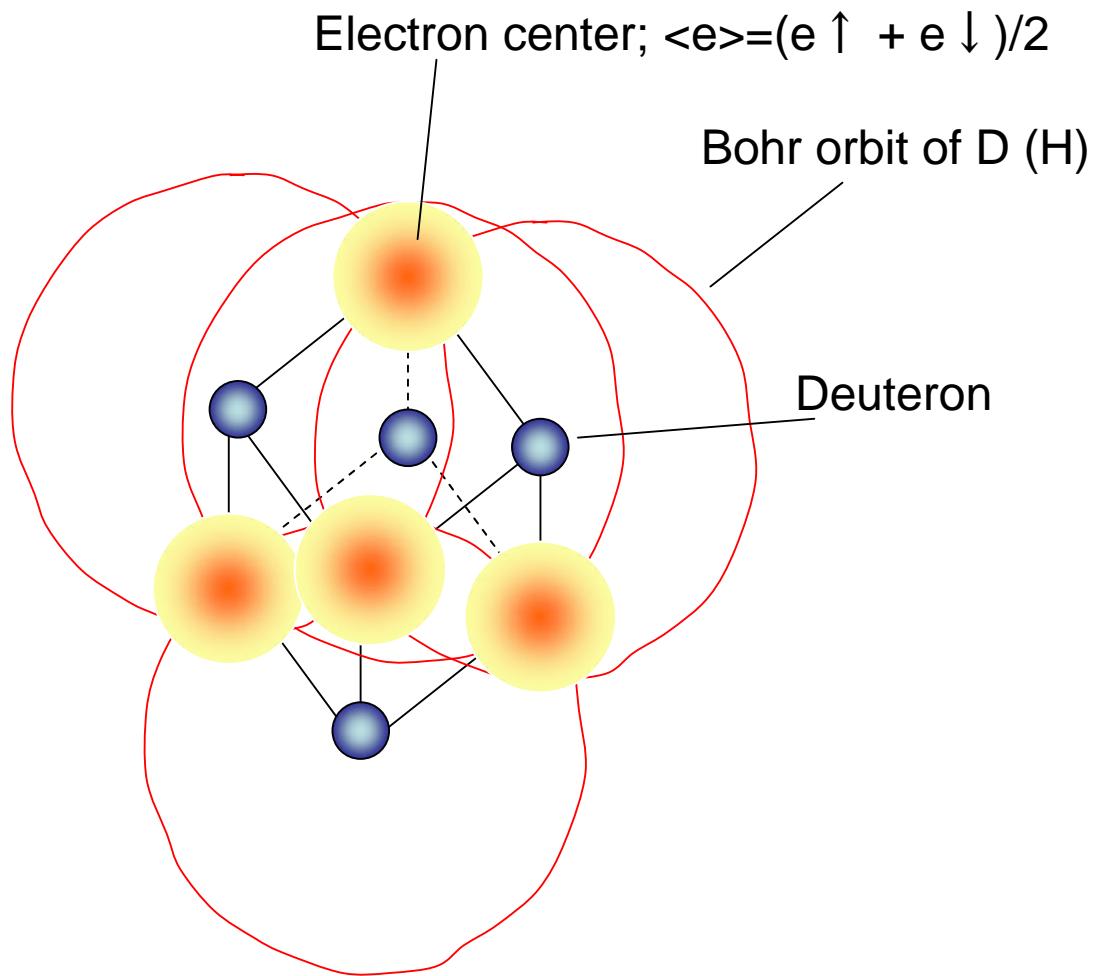
6-Bonds of “Bosonized” electron-pairs ($e \uparrow + e \downarrow$), which forms Regular Tetrahedron

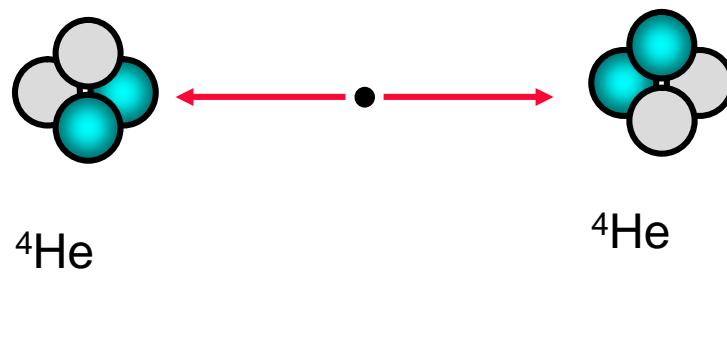
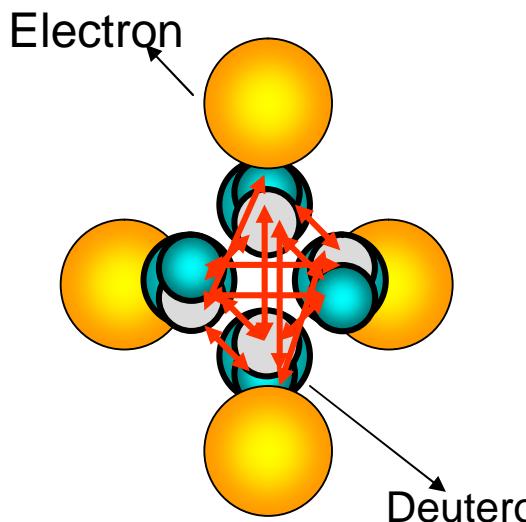
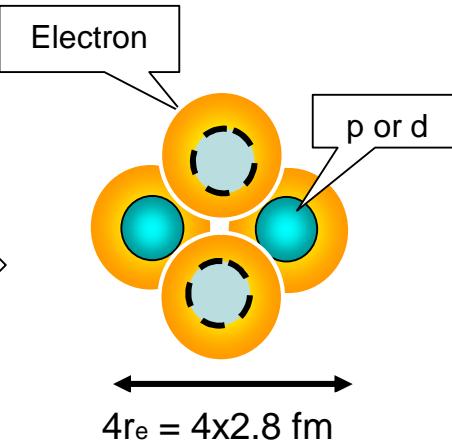
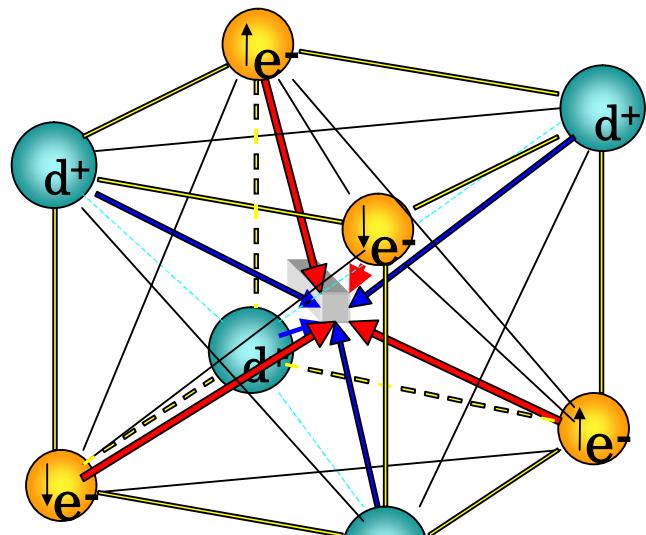
4-Electron-Centers at Vertices of Regular Tetrahedron

Variational Principle

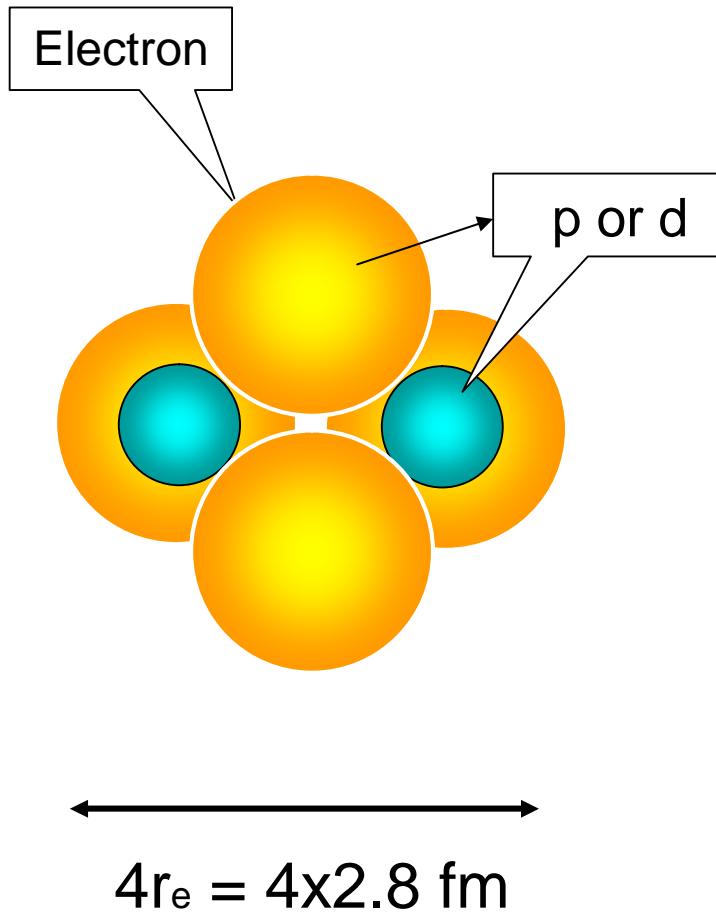
- $\delta \{ \langle \Psi_{4D} | H | \Psi_{4D} \rangle / \langle \Psi_{4D} | \Psi_{4D} \rangle \} = 0$
gives 6th order secular equation, not solvable.
- But, under 3-dimensional symmetric constraint,
we can set absolute values, $a_1 = a_2 = a_3 = a_4 = a_5 = a_6 = a_0$,
with $a_0 = 1/(6(1+\Delta))^{1/2}$
- Orthogonal condition for 6 wing wave functions:
$$a_i a_j = \delta_{ij}$$

Electron Orbits of TSC : at t = 0





Minimum-Size State of TSC



- $e^2/r_e = m_e c^2$
= E
- $r_e = e^2/(m_e c^2)$
= 2.8 fm
; classical e^- radius
- $r_{pp} = r_{dd} = 2r_e = 5.6 \text{ fm}$
- $V_B = e^2 / r_{pp}$
= $1.44/5.6 = 0.257 \text{ MeV}$
- $r_{\text{nucleus}} = 1.2A^{1/3}$

4D Fusion-Rate at Minimum-State TSC

- $P_n = \exp(-0.218n \mu^{1/2} V_B^{1/2} (r_{dd} - r_0))$
- $V_B = 0.257 \text{ MeV}$, $r_{dd} = 5.6 \text{ fm}$,
 $r_0 = 2r_d + \lambda_\pi = 5 \text{ fm}$
- $P_{2p} = 0.91$, $P_{4p} = 0.83$, $P_{2d} = 0.88$, $P_{4d} = 0.77$
- $\lambda_{4d} = (3E-4)P_{4d} = 2.3E-4 \text{ (f/s/cluster)}$

46 MW/cc, for $N_{tsc} = 2E22 \text{ cm}^{-3}$

: 23keV /Pd-atom

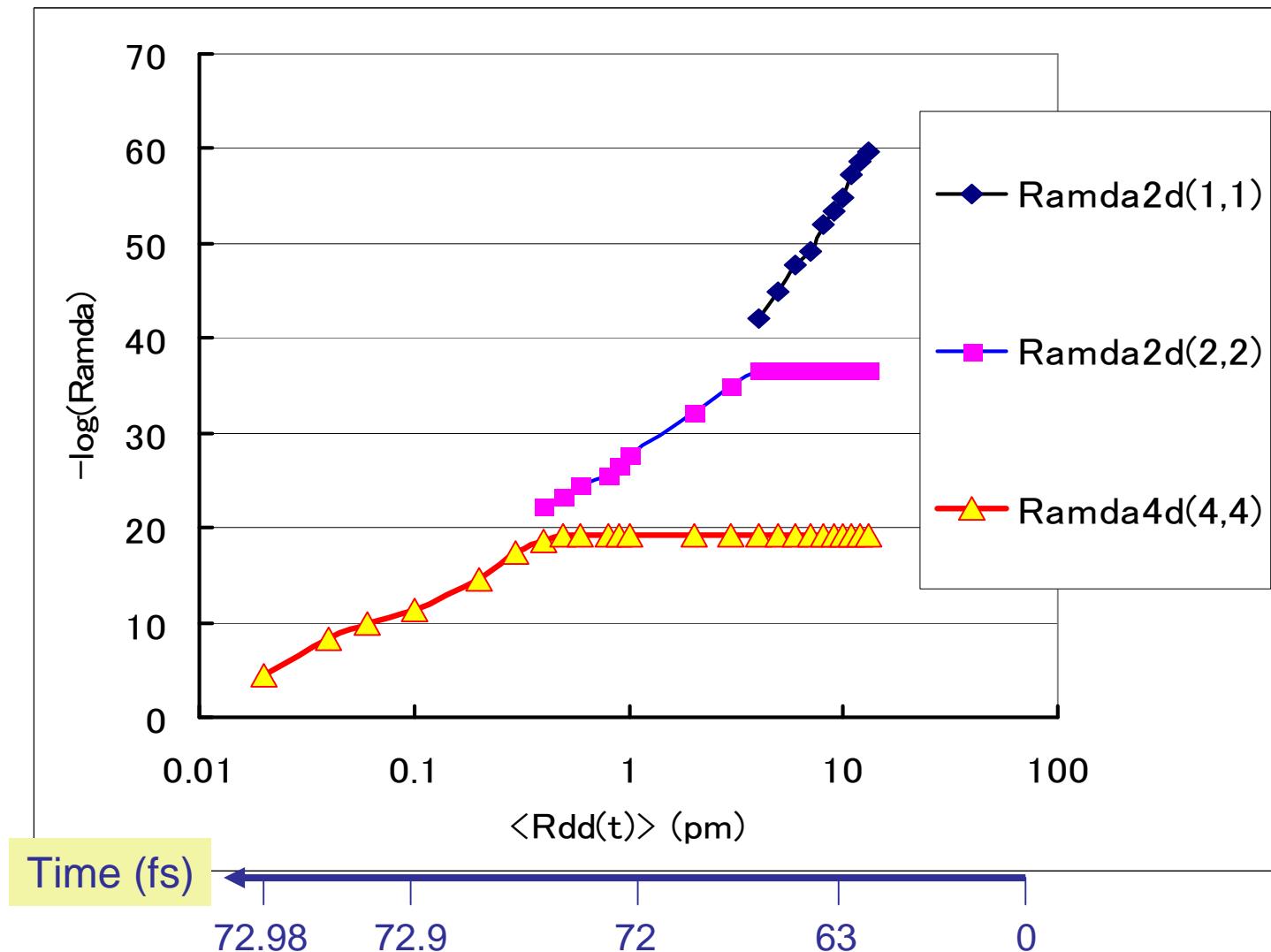
**Life Time of 4D/TSC_{min} = 4.3E+3 sec(71.7 min)!
(We need further study considering fluctuation)**

- El-Boher Exp.: 24.8 keV/Pd-atom (ICCF11)

Basic Equations

- $\Psi_{4D}(r,t) \text{ ai}$
 $= a_1(t) \Psi_{(1,1)}(r,t) + a_2(t) \Psi_{(2,2)}(r,t) + a_4(t) \Psi_{(4,4)}(r,t) \quad (1)$
- $\langle r(t) \rangle = \langle r(0) \rangle - \langle v \rangle t \quad (2)$
- $\langle r(t) \rangle = \langle \Psi^*_{4D}(r,t) | r | \Psi_{4D}(r,t) \rangle \quad (3)$

Time-Dependent EQPET Calculation for TSC : Comparison of $\lambda_{2d(1,1)}(t)$, $\lambda_{2d(2,2)}(t)$ and $\lambda_{4d(4,4)}(t)$



TDEQPET Cal. For EQPET Molecules

$e^*(m, Z)$	$\langle \lambda_{2d} \rangle$ (f/s/cl.)	$\langle \lambda_{4d} \rangle$ (f/s/cl.)	$\lambda_{2d}(0)$ (f/s/cl.)	$\lambda_{4d}(0)$ (f/s/cl.)
(1, 1)	4.3E-44	7.8E-63	1.9E-60	7.3E-93
(2, 2)	2.9E-25	2.5E-24	2.4E-37	1.1E-50
(4, 4)	(2.1E-17)*	5.5E-8	(5.5E-22)*	5.9E-20

()* : virtual value

Summary Results

	EQPET Cal.	TDEQPET Cal. (time-averaged) $\langle \text{Fusion-time} \rangle = 0.04 \text{ fs}$
λ_{2d} (f/s/cl.)	1E-20	2.9E-25
λ_{4d} (f/s/cl.)	1E-9	5.5E-8

TSC-Induced Nuclear Reactions

1) Multi-Body Deuteron (d-p mixed) Fusion within TSC;

2d, dp, 3d, ddp, 4d, dddp, dpdp

; EQPET Model Alalysis

2) TSC+Host-Metal Reactions;

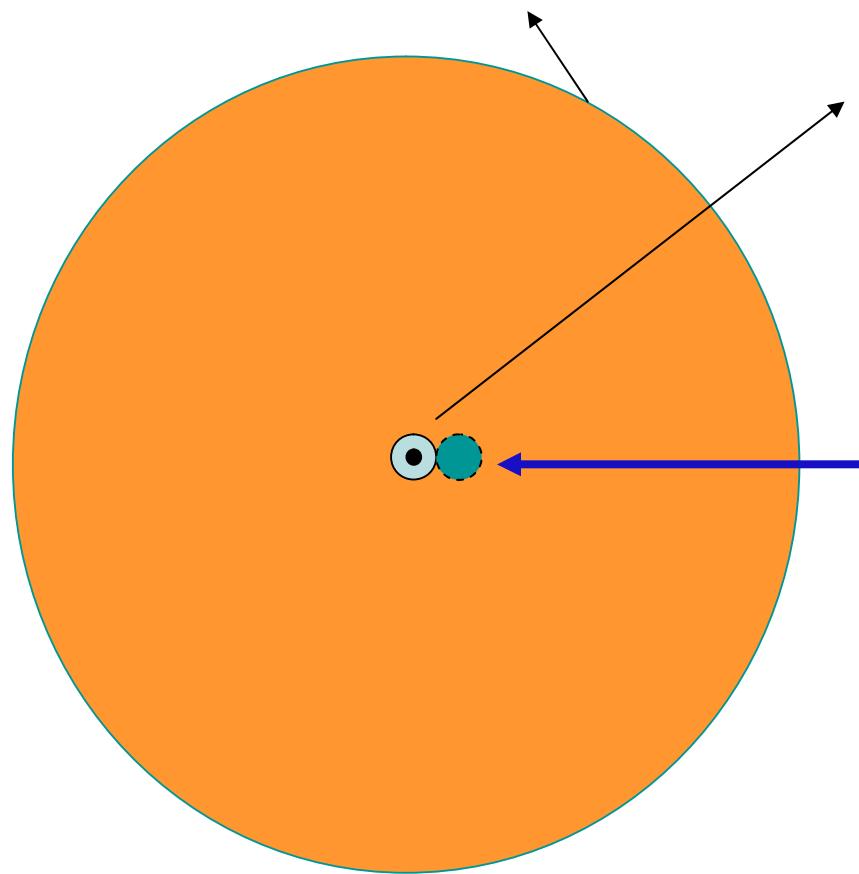
Sudden Tall Thin Barrier Approximation
(STTBA)

Target Atom Outer Electron Cloud (ca. 100 pm)

K-Shell e^- And Nucleus

Neutral Pseudo-Particle

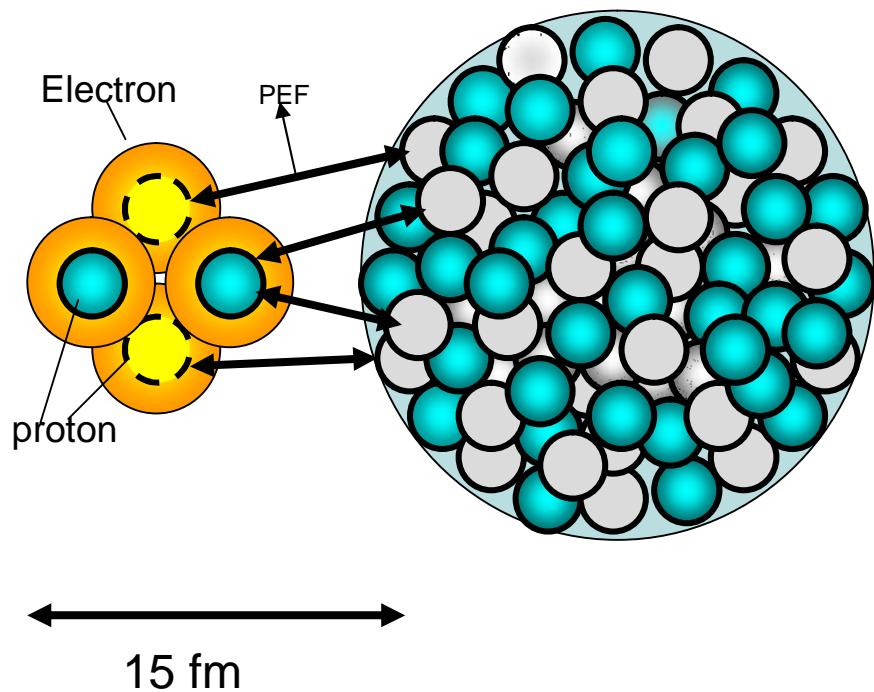
TSC, < 1 pm
(4P+4e): neutral



- How deep can TSC penetrate through e-cloud?

M + TSC

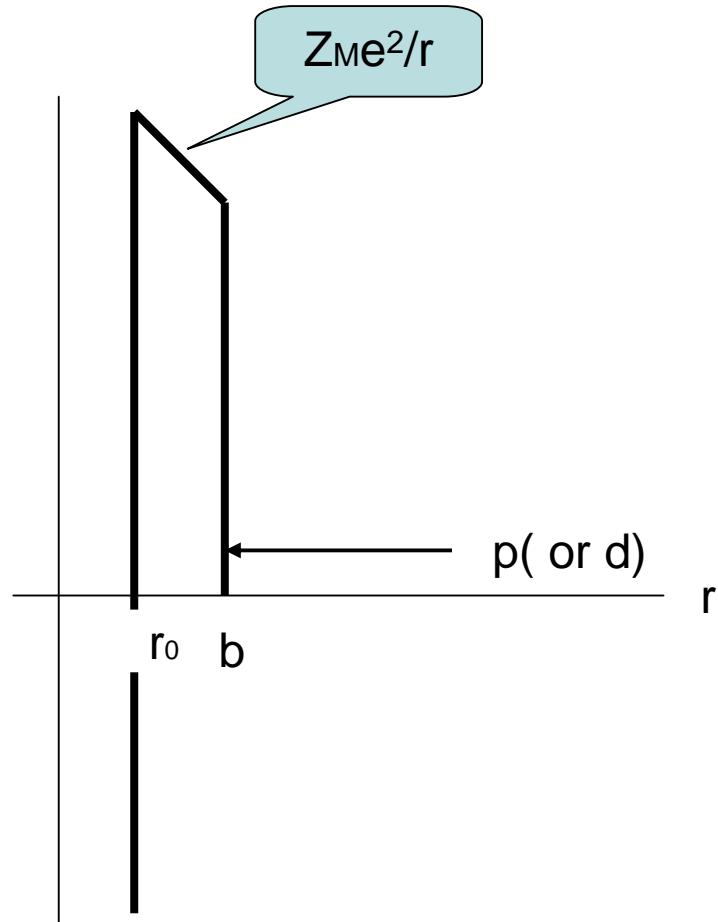
Nuclear Interaction Mechanism



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

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

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

Reaction Rates:

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

$$V_{pp} = 1.44/6 = 0.24 \text{ MeV}$$

$$P_{2p} = 0.527$$

$$P_{2d} = 0.404$$

$$S_{Mp}(0) = 1.0E+8 \text{ kevb}$$

$$S_{Md}(0) = 1.0E+9 \text{ keVb}$$

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

Products by Ni + p reactions

- $^{58}\text{Ni} + \text{p} \rightarrow$
 $^{59}\text{Cu}^*(1.36\text{m}, \text{EC})^{59}\text{Ni}^*(7\text{E4 y})$
- $^{60}\text{Ni} + \text{p} \rightarrow$
 $^{61}\text{Cu}^*(3.3\text{h}, \text{EC})^{61}\text{Ni}$
- $^{61}\text{Ni} + \text{p} \rightarrow$
 $^{62}\text{Cu}^*(9.7\text{m}, \text{EC})^{62}\text{Ni}$
- $^{62}\text{Ni} + \text{p} \rightarrow$
 $^{63}\text{Cu}(6.12\text{MeV}); \text{Eg}=669\text{keV}$
- $^{64}\text{Ni} + \text{p} \rightarrow ^{65}\text{Cu}(7.45\text{MeV})$
- **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!

- $^{58}\text{Ni} + 4\text{p} \rightarrow ^{62}\text{Ge}(11\text{MeV}) \rightarrow \text{FP}$
- $^{58}\text{Ni} + 4\text{d} \rightarrow ^{66}\text{Ge}(54\text{MeV}) \rightarrow \text{FP}$
- $^{105}\text{Pd} + 4\text{p} \rightarrow ^{109}\text{Sn}(23\text{MeV}) \rightarrow ?$
- $^{105}\text{Pd} + 4\text{d} \rightarrow ^{113}\text{Sn}(52\text{MeV}) \rightarrow \text{FP}$
- $^{104}\text{Pd} + 4\text{d} \rightarrow ^{112}\text{Sn}(52\text{MeV}) \rightarrow \text{FP}$

- 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	$^{62}\text{Ge}^*$	11.2	$^{66}\text{Ge}^*$	53.9
^{60}Ni	26.223	$^{64}\text{Ge}^*$	19.1	$^{68}\text{Ge}^*$	55.1
^{61}Ni	1.140	$^{65}\text{Ge}^*$	21.3	$^{69}\text{Ge}^*$	55.4
^{62}Ni	3.634	$^{66}\text{Ge}^*$	24.0	$^{70}\text{Ge}^*$	56.4
^{64}Ni	0.926	$^{68}\text{Ge}^*$	29.0	$^{72}\text{Ge}^*$	58.0

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

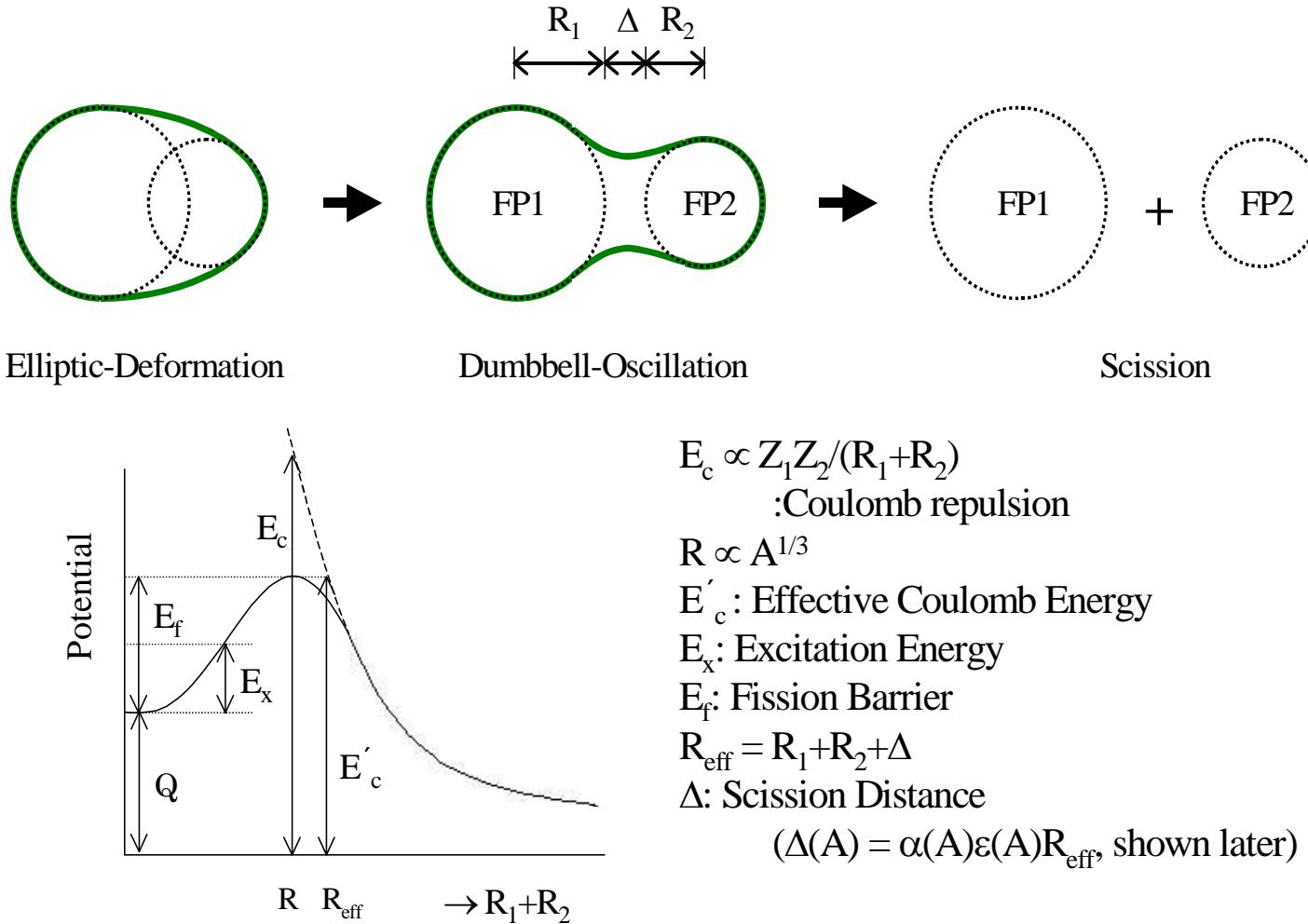
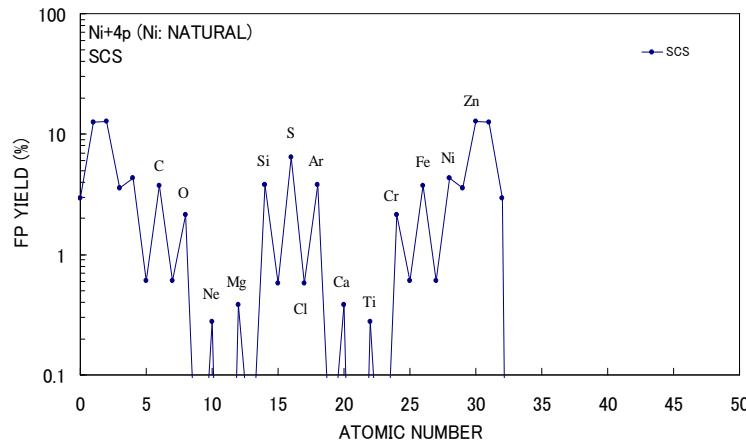


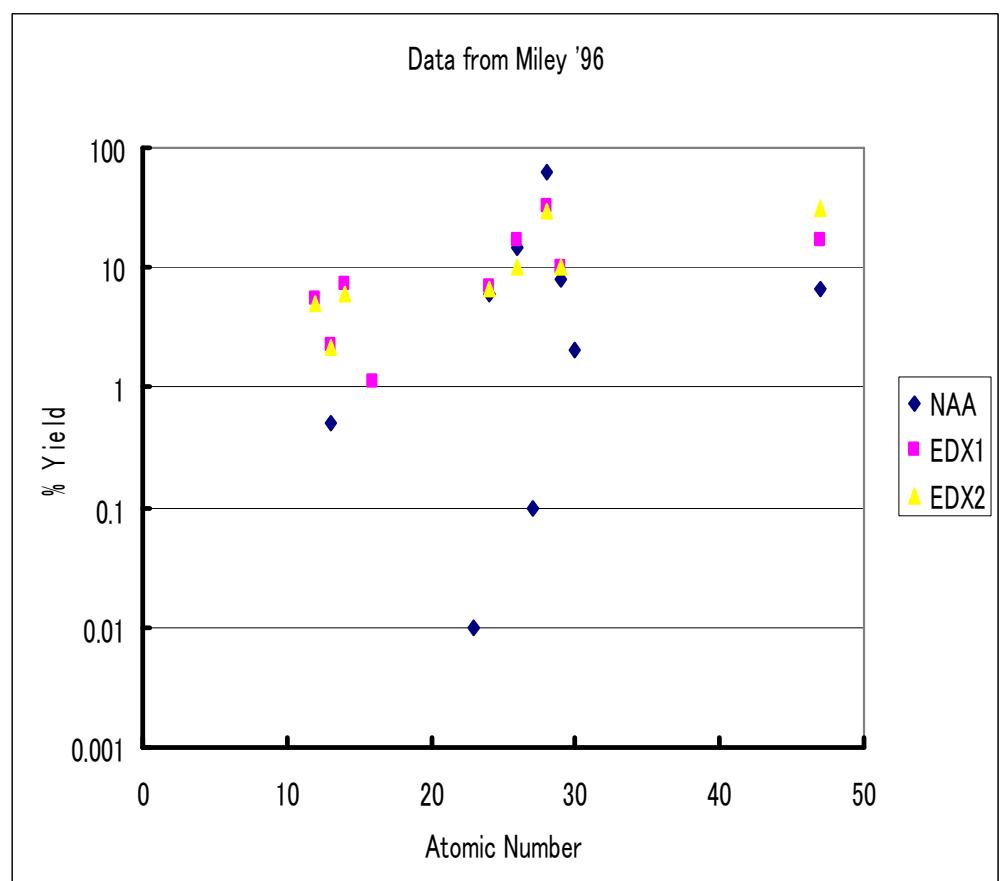
Fig.3 : Tandem (dumbbell dipole) oscillation and scission process

FP Elements by SCS vs. Miley Exp.

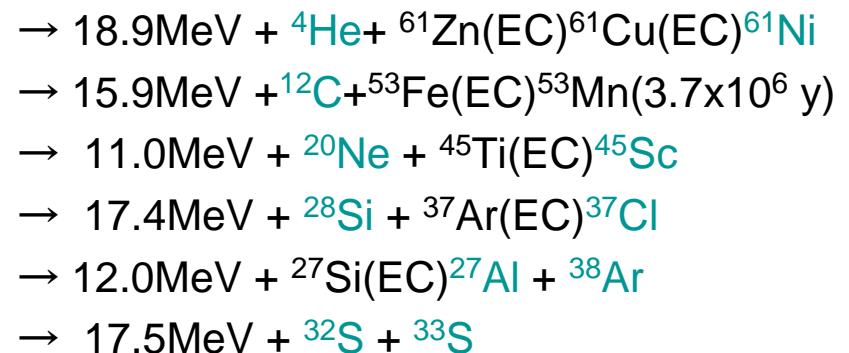
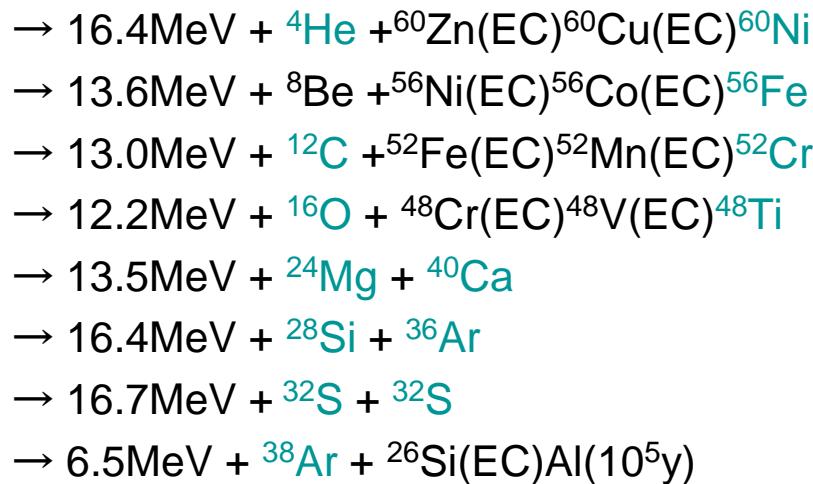
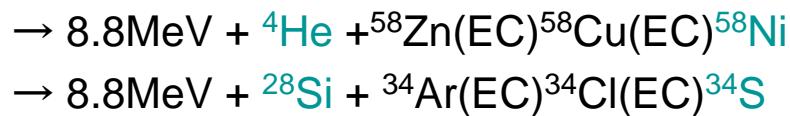
G. Miley and J. Patterson
J. New Energy, 1996, 1, p.5



Ni + 4p/TSC to fission
Calculated by
Selective Channel Fission Model



Major Fission Channels from Ni + 4p



Note:

- Green shows stable isotope.
- Average Kinetic Energy of Fission Product = 9.7 MeV for Ni-natural

Major Fission Channels from Ni + 4p (2)

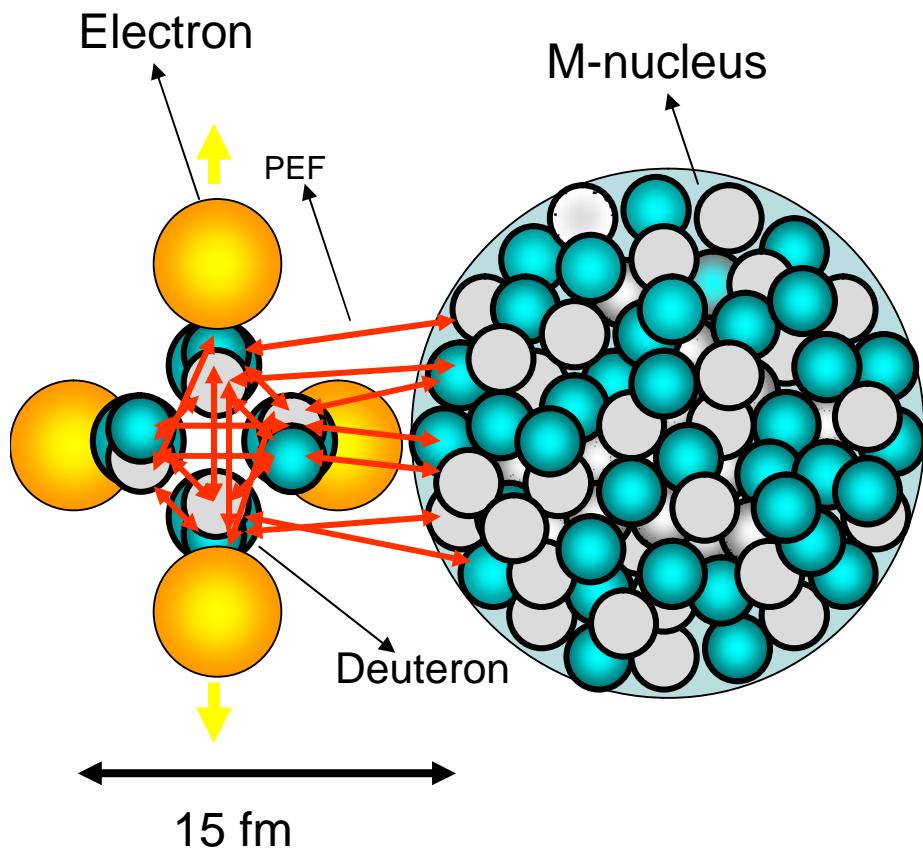
- $^{62}\text{Ni}(3.6\%) + 4\text{p} \rightarrow ^{66}\text{Ge}(\text{Ex}=24.0\text{MeV})$
 $\rightarrow 11.0\text{MeV} + \text{n} + ^{65}\text{Ge}(\text{EC})^{65}\text{Ga}(\text{EC})^{65}\text{Zn}$
 $\rightarrow 21.4\text{MeV} + ^4\text{He} + ^{62}\text{Zn}(\text{EC})^{62}\text{Cu}(\text{EC})^{62}\text{Ni}$
 $\rightarrow 11.5\text{MeV} + ^8\text{Be} + ^{58}\text{Ni}$
 $\rightarrow 18.9\text{MeV} + ^{12}\text{C} + ^{54}\text{Fe}$
 $\rightarrow 10.5\text{MeV} + ^{14}\text{N} + ^{52}\text{Mn}(\text{EC})^{52}\text{Cr}$
 $\rightarrow 8.2\text{MeV} + ^{16}\text{O} + ^{50}\text{Cr}$
 $\rightarrow 13.9\text{MeV} + ^{20}\text{Ne} + ^{46}\text{Ti}$
 $\rightarrow 15.2\text{MeV} + ^{24}\text{Mg} + ^{42}\text{Ca}$
 $\rightarrow 13.7\text{MeV} + ^{27}\text{Al} + ^{39}\text{K}$
 $\rightarrow 18.9\text{MeV} + ^{28}\text{Si} + ^{38}\text{Ar}$
 $\rightarrow 18.6\text{MeV} + ^{32}\text{S} + ^{34}\text{S}$

 - Neutron emission channel may open!
 - S-values for higher mass Ni may be larger than Ni-58 and Ni-60, due to more p-n PEF interaction.

- $^{64}\text{Ni}(0.93\%) + 4\text{P} \rightarrow ^{68}\text{Ge}(\text{Ex}=29\text{MeV})$
 $\rightarrow 16.7\text{MeV} + \text{n} + ^{67}\text{Ge}(\text{EC})^{67}\text{Ga}(\text{EC})^{67}\text{Zn}$
 $\rightarrow 25.6\text{MeV} + ^4\text{He} + ^{64}\text{Zn}$
 $\rightarrow 10.0\text{MeV} + ^6\text{Li} + ^{61}\text{Cu}(\text{EC})^{61}\text{Ni}$
 $\rightarrow 13.2\text{MeV} + ^8\text{Be} + ^{57}\text{Ni}(\text{EC})^{57}\text{Co}(\text{EC})^{57}\text{Fe}$
 $\rightarrow 10.9\text{MeV} + ^9\text{Be} + ^{59}\text{Ni}(\text{EC})^{59}\text{Co}$
 $\rightarrow 9.9\text{MeV} + ^{10}\text{B} + ^{58}\text{Co}(\text{EC})^{58}\text{Fe}$
 $\rightarrow 22.7\text{MeV} + ^{12}\text{C} + ^{56}\text{Fe}$
 $\rightarrow 14.8\text{MeV} + ^{14}\text{N} + ^{54}\text{Mn}(\text{EC})^{54}\text{Cr}$
 $\rightarrow 12.7\text{MeV} + ^{16}\text{O} + ^{52}\text{Cr}$
 $\rightarrow 17.6\text{MeV} + ^{20}\text{Ne} + ^{48}\text{Ti}$
 $\rightarrow 12.7\text{MeV} + ^{23}\text{Na} + ^{45}\text{Sc}$
 $\rightarrow 17.5\text{MeV} + ^{24}\text{Mg} + ^{44}\text{Ca}$
 $\rightarrow 14.8\text{MeV} + ^{27}\text{Al} + ^{41}\text{K}$
 $\rightarrow 18.7\text{MeV} + ^{28}\text{Si} + ^{40}\text{Ar}$
 $\rightarrow 18.7\text{MeV} + ^{32}\text{S} + ^{36}\text{S}$

M + 4d/TSC

Nuclear Interaction Mechanism



- Over-minimum state of 4d/TSC
- Admixture of 4d/TSC to form ${}^8\text{Be}^*$
- M + ${}^8\text{Be}^*$ capture reaction
- Strong force exchange (PEF) between M and ${}^8\text{Be}^*$

^{133}Cs + TSC Reactions

- $^{133}\text{Cs} + \text{d} \rightarrow ^{135}\text{Ba}(\text{Ex}=12.91\text{MeV}) \rightarrow ^{135}\text{Ba(stable)} + \text{gammas}(12.91\text{MeV})$
- $^{133}\text{Cs} + 2\text{d} \rightarrow ^{137}\text{La}(\text{Ex}=25.32\text{MeV}) \rightarrow \text{FPs}$
or $^{137}\text{La}(6\text{E}+4 \text{ y}) + \text{gammas}$
- $^{133}\text{Cs} + 3\text{d} \rightarrow ^{139}\text{Ce}(\text{Ex}=38.29\text{MeV}) \rightarrow \text{FPs}$
or $^{139}\text{La(stable)} + \text{gammas}$
- $^{133}\text{Cs} + 4\text{d} \rightarrow ^{141}\text{Pr}(\text{Ex}=50.49\text{MeV}) \rightarrow \text{FPs}$
or $^{141}\text{Pr(stable)} + \text{gammas}$

Note: (1) + 2d is equivalent to $^4\text{He} + 23.8\text{MeV}$.
(2) We need to detect 50.49 MeV gamma?

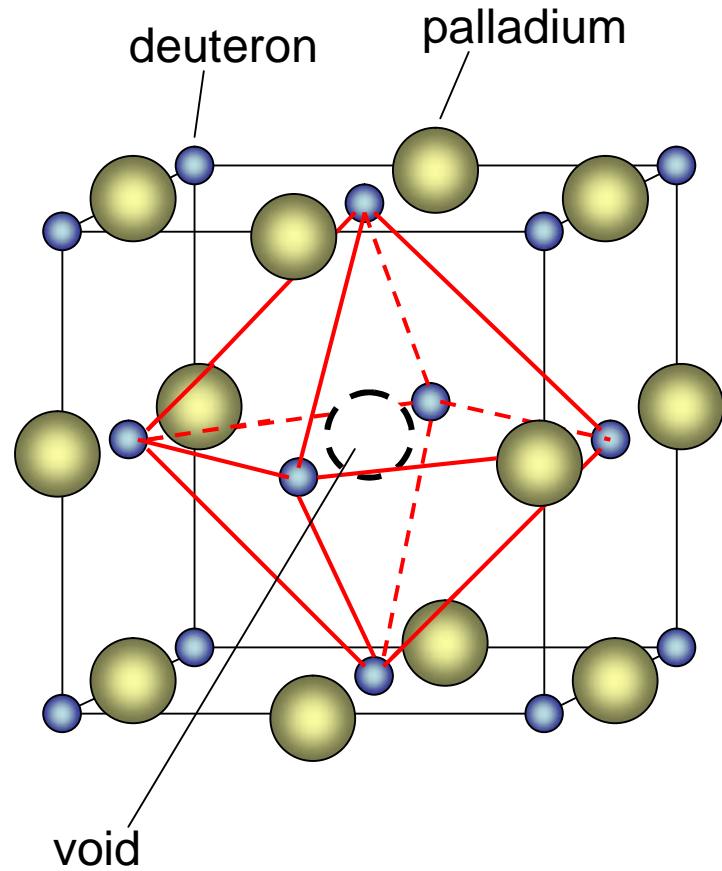
STTBA Prediction for Cs-to-Pr

- $S_{Mp} = 1E+8 \text{ kevb}$
- $S_{Md} = 1E+9 \text{ keVb}$
- $\lambda_{Mp} = 8.4E-10 \text{ f/s/tsc}$
- $\lambda_{M4p} = 2.3E-10 \text{ f/s/tsc}$
- $\lambda_{Md} = 2.8E-8 \text{ f/s/tsc}$
- $\lambda_{M4d} = 7.6E-9 \text{ f/s/tsc}$
- Where combination probability of anti-parallel spin was used for 4p/TSC.

- Suppose $N_{M+tsc} = 1E+17$ in 10 nm layer of surface
- Macro Yield = $\lambda \times N_{tsc} = 7.6E-9 \times 1E+17 = 7.6E+8 \text{ (f/s/cm}^2\text{)}$
- Cs-to-Pr rate = $4.6E+14 \text{ (atoms per week)}$ per cm^2

We see good agreement with Iwamura experiment.

PdD Lattice with void

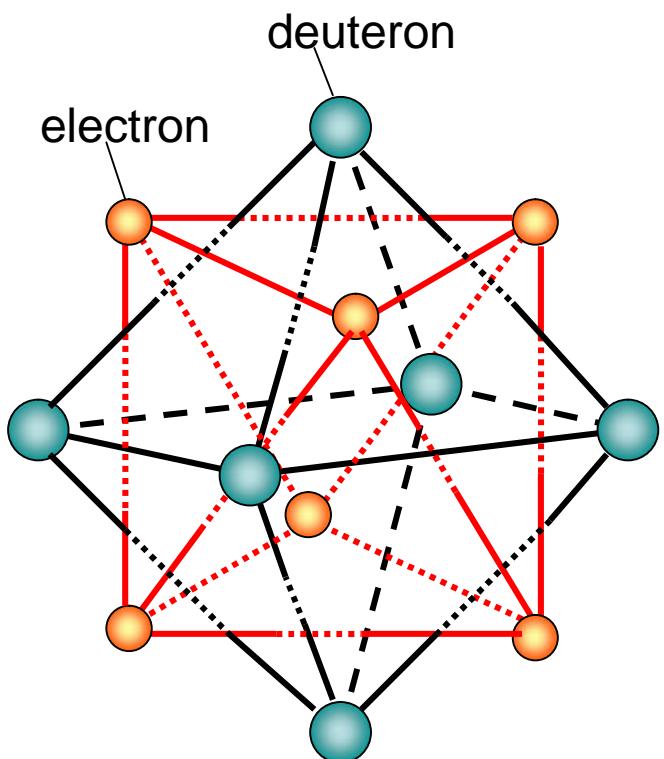


Formation of 6d/OSC

- Void formation in PdD lattice
- Formation of 6d/OSC around Void at center
- Squeezing motion toward the center

Octahedral Symmetric Condensate; 6d/OSC

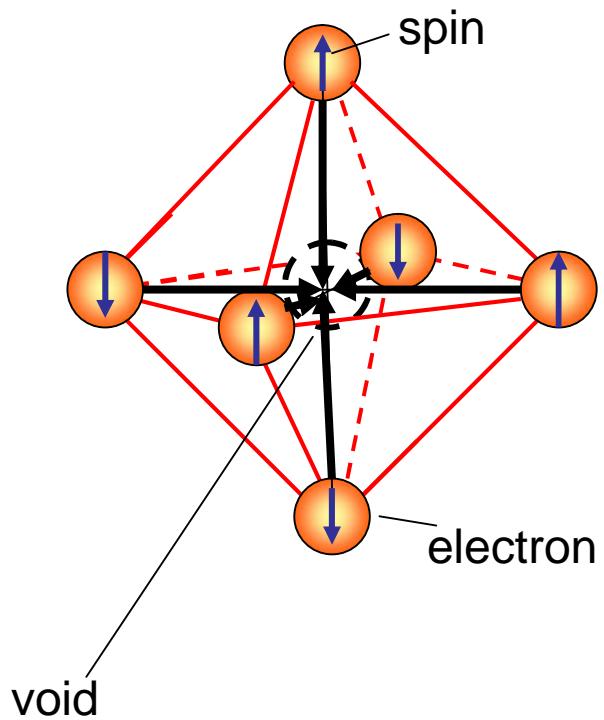
6d/OSC



- Six deuterons sit on heads of regular octahedron
- Six electrons sit on heads of regular octahedron.
- Both octahedrons couple orthogonally

$M(A, Z) + 6D (^{12}C^*)$ capture
Process to make
 $M(A+12, Z+6)$ transmutation

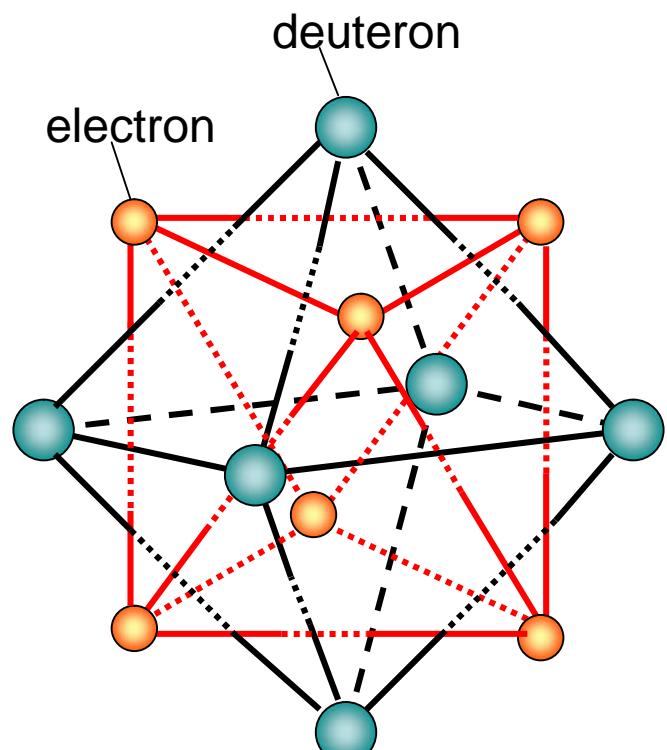
^{137}Ba to ^{149}Sm by Iwamura Exp.



Formation of $e^*(6,6)$

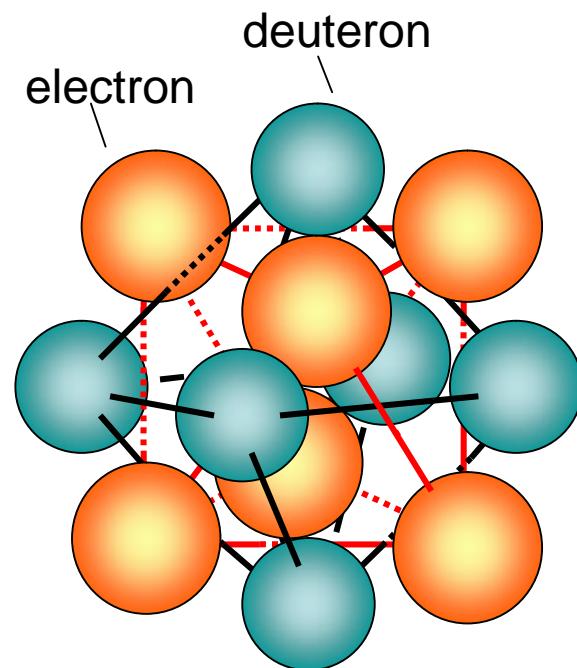
- Formation of OSC by $6d + 6e$
- Anti-parallel spin for Counter-part electrons
- Three Cooper pairs Coupled orthogonally
- Central squeezing Motion with same velocities for 12 particles

6d/OSC

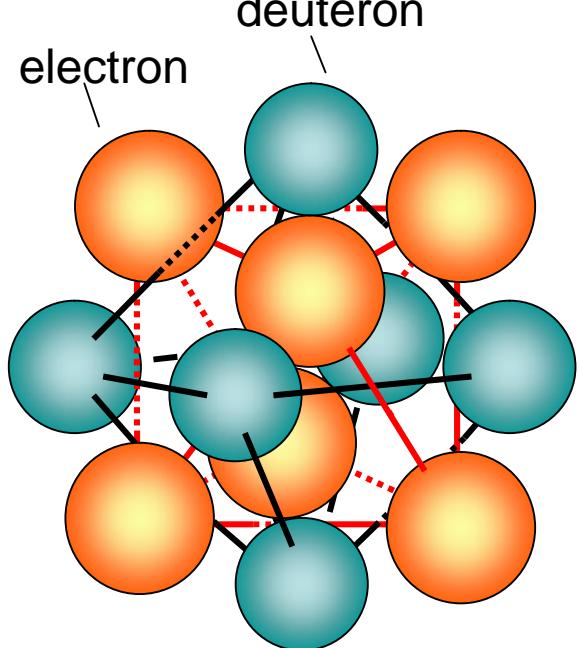


a) 6d/OSC forms

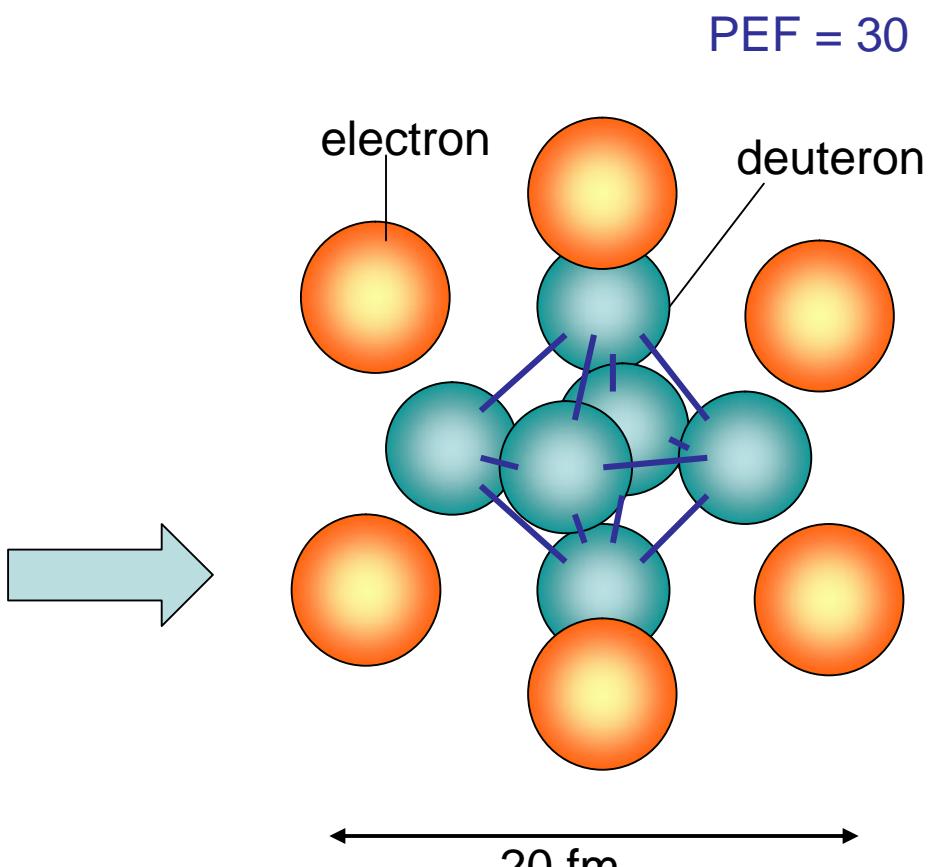
PEF = 30 for 6d-ORF



b) Minimum 6d/OSC

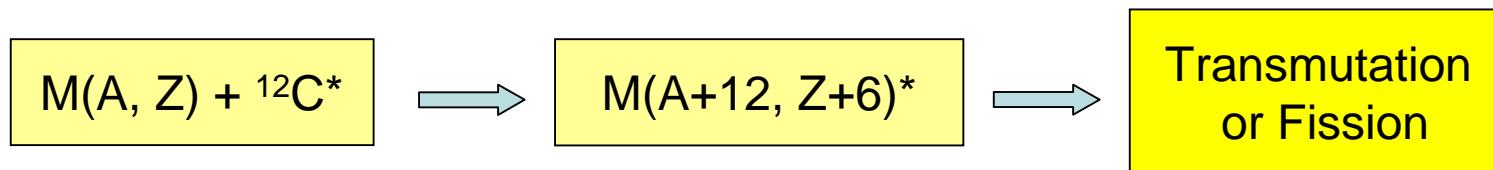
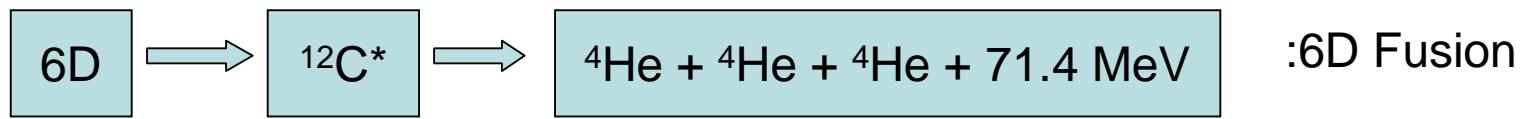


b) Minimum 6d/OSC



c) $^{12}\text{C}^*$ forms

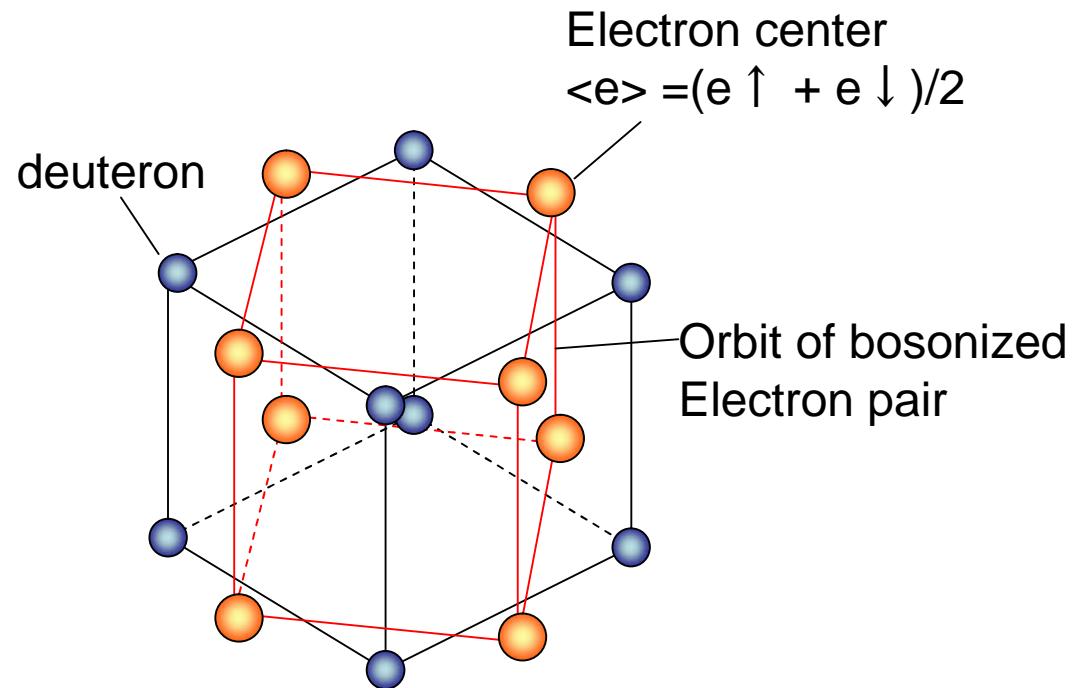
6d/OSC-Induced Reactions



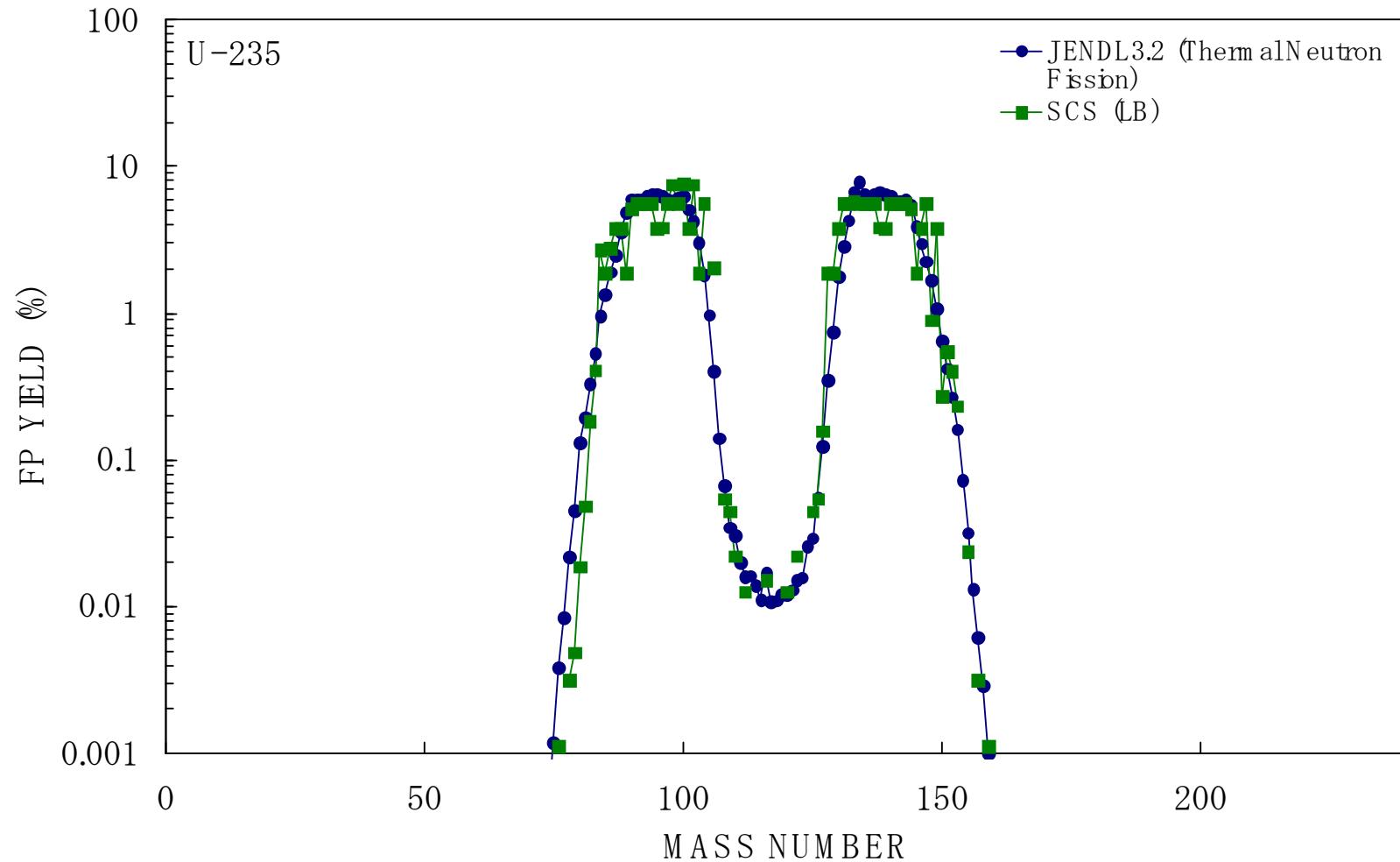
Max. 6D Fusion Rate by 6d/OSC

- $\lambda_{6d} = (S_{6d}v/E)\exp(-6G_{osc})$
- $S_{6d} = 1E+14 \text{ keVbarn}$, for PEF = 30
- $G_{osc} \approx 0.523(b^{1/2} - r_0^{1/2}) = 0.31$
- $b = 8 \text{ fm}$, $r_0 = 5 \text{ fm}$
- $\lambda_{6d} = 4.8E-2 \text{ (f/s/cl)}$
- If $N_{osc} = 1E+13$ (<0.1 ppm) in 10 nm range per cm^2 ,
- $Y_{6d} = 4.8E+11 \text{ (f/s/cm}^2\text{)} = 4.8 \text{ W/cm}^2$

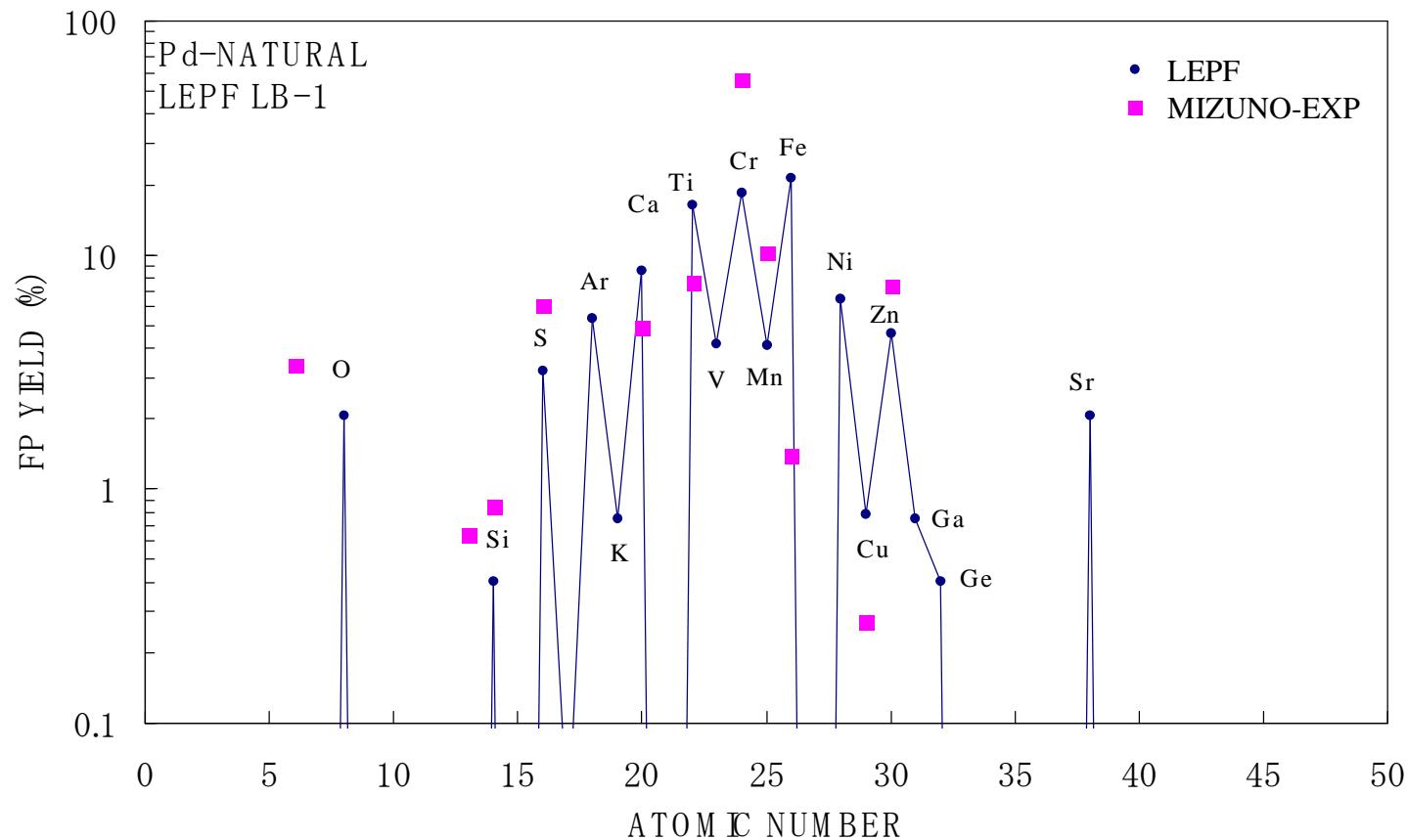
8d/OSC: Regular Octagonal Prism



FP Distribution for U-235 + n Fission



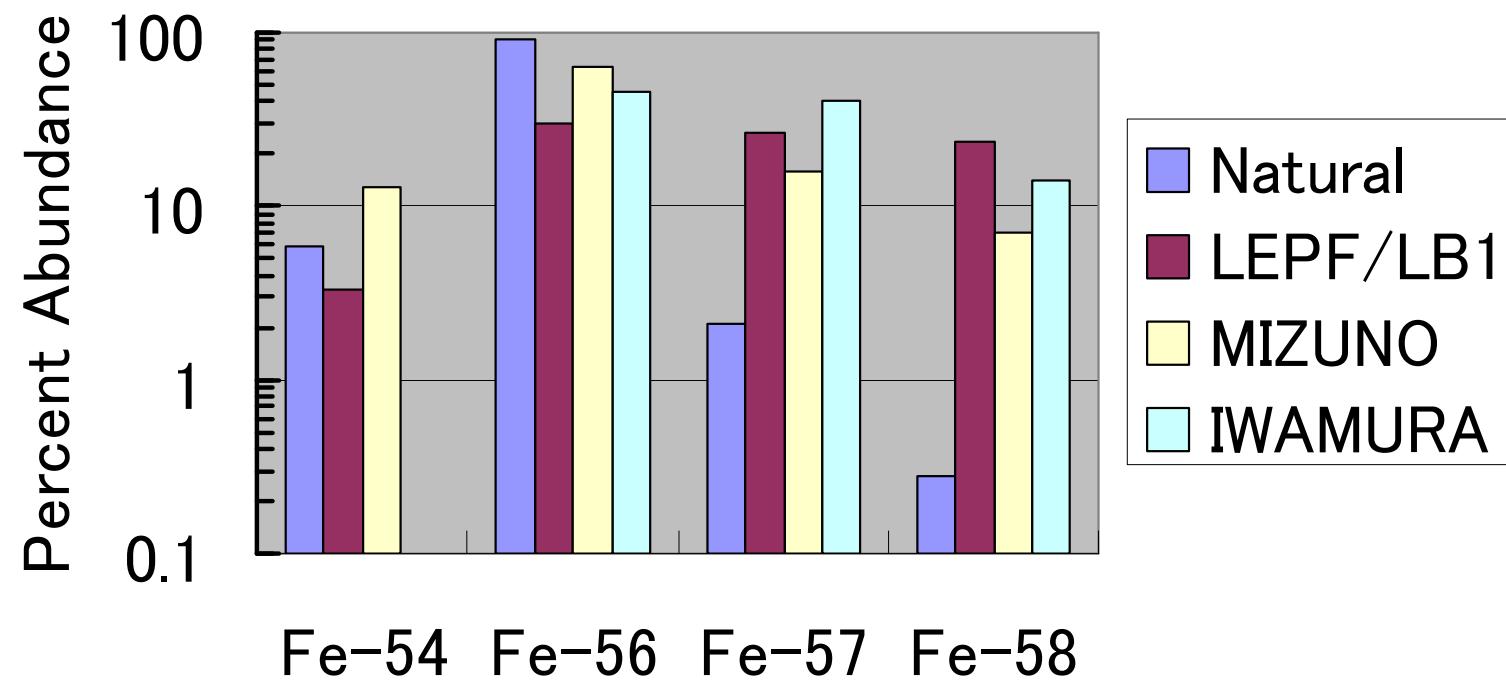
FP Element-Distribution for Pd



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

Anomaly of Isotopic Ratios

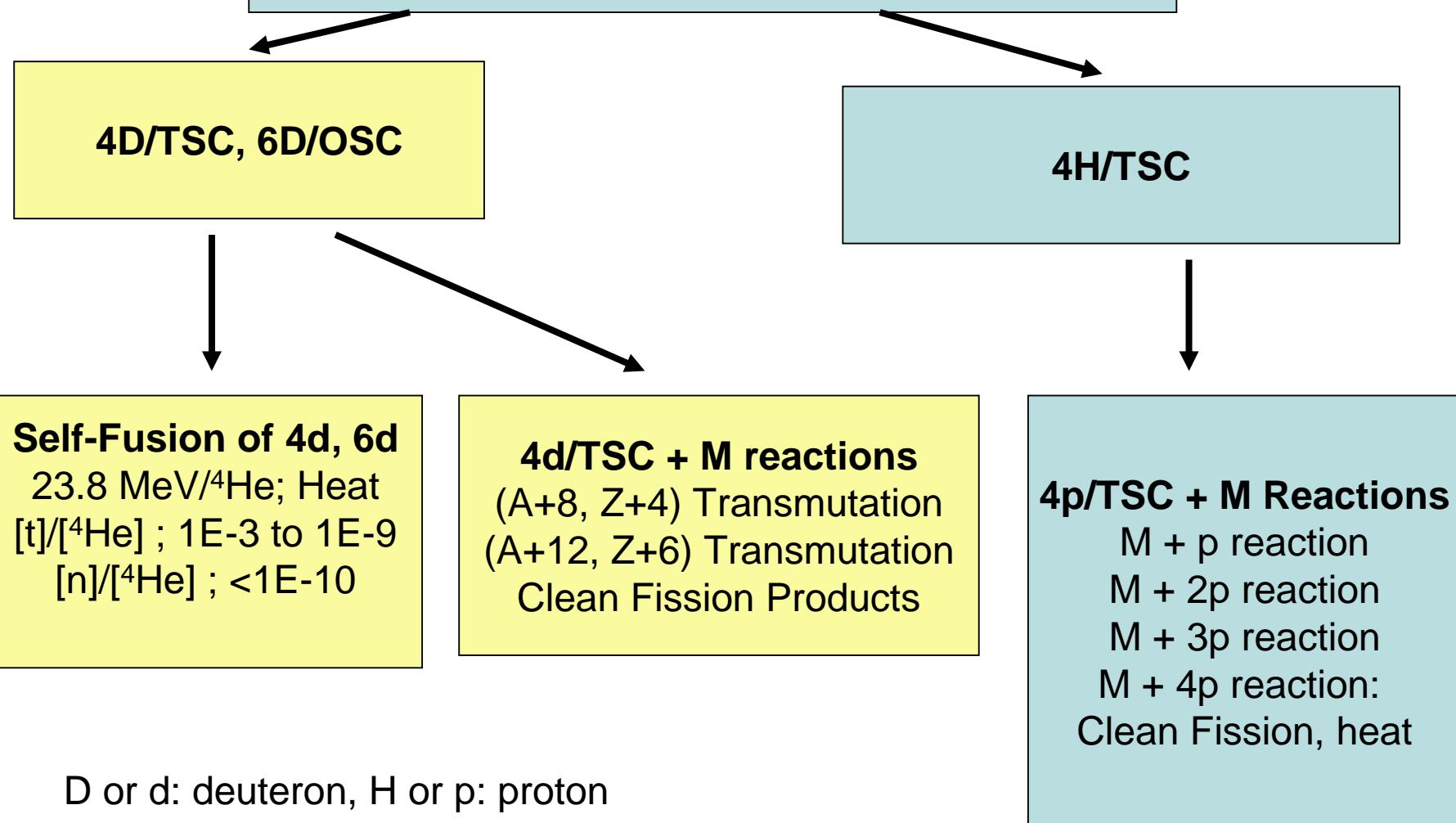
Fig. : Comparison of Isotopic ratios between natural Fe, LEPF/LB1 and experiment



Major Results: Experiments vs. Theory

Item	Experiment Author/ Method/ Results	EQPET/TSC Model
Screening of d-d	Kasagi/beam/310eV Takahashi/3D/1E+9 <dd>	360eV by dde*(2,2) (1E+13) τ (0.1ms)
^4He Production	McKubre/Electrolysis/ 30+-13MeV/ ^4He	23.8MeV/ ^4He by $4\text{D} \rightarrow ^4\text{He} + 2 + 47.6\text{MeV}$
Maximum Heat	EI Boher/EI./24.8keV/Pd Gain \approx 25	23 keV/Pd 46MeV/cc by 4d/TSC
Transmutation	Iwamura/Perm./Cs \rightarrow Pr Miley/NiH/Fission-like Pro.	4d/TSC + M 4p/TSC + M reaction

**Tetrahedral Symmetric Condensate (TSC)
Or
Octahedral Symmetric Condensate (OSC)**



Conclusions (1)

- (1) Experimental results show the existence of linked phenomena between nuclear physics and condensed matter physics.
- (2) The Cluster Fusion Theory was elaborated to give numerical results, and revealed that anomalous experimental results were explained by Clean Fusion with ${}^4\text{He}$ Ash, TSC-induced Nuclear Reactions including Selective Transmutation and Cleaner Fission.

Conclusions (2)

- (3) Tetrahedral Symmetric Condensate (TSC) was proposed as Seed of Condensed Matter Nuclear Effects.
- (4) Further studies on TSC-induced nuclear effects are expected.
- (5) When principles of Clean Fusion, Cleaner Fission and Transmutation will be established, application to portable energy sources and radioactive waste incineration is hopeful.

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