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Basics of Deuteron-Cluster Dynamics by Langevin Equation

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To be presented at ACS2009
NET Symposium, Salt Lake City
March 2009

1. Outline

- Generation and condensation of 4D/TSC as seed of clean fusion in condensed matter was previously studied by Langevin equation
- Basics of Langevin Equation for D-cluster is treated in this study
- Known D-systems: D, D_2, D_2^+, D_3^+
- 4D/TSC and 6D/OSC
- Barrier factors and fusion rates

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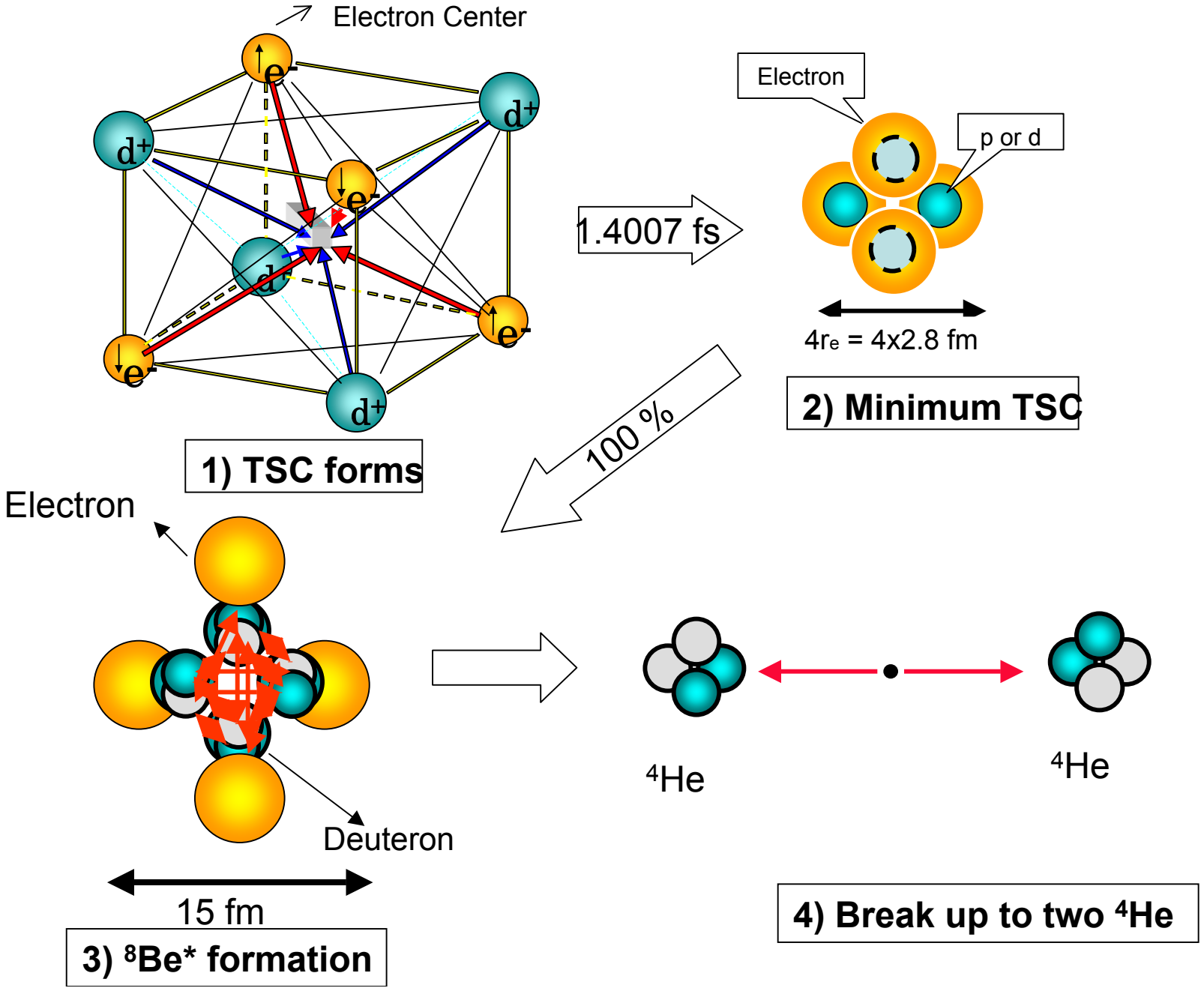
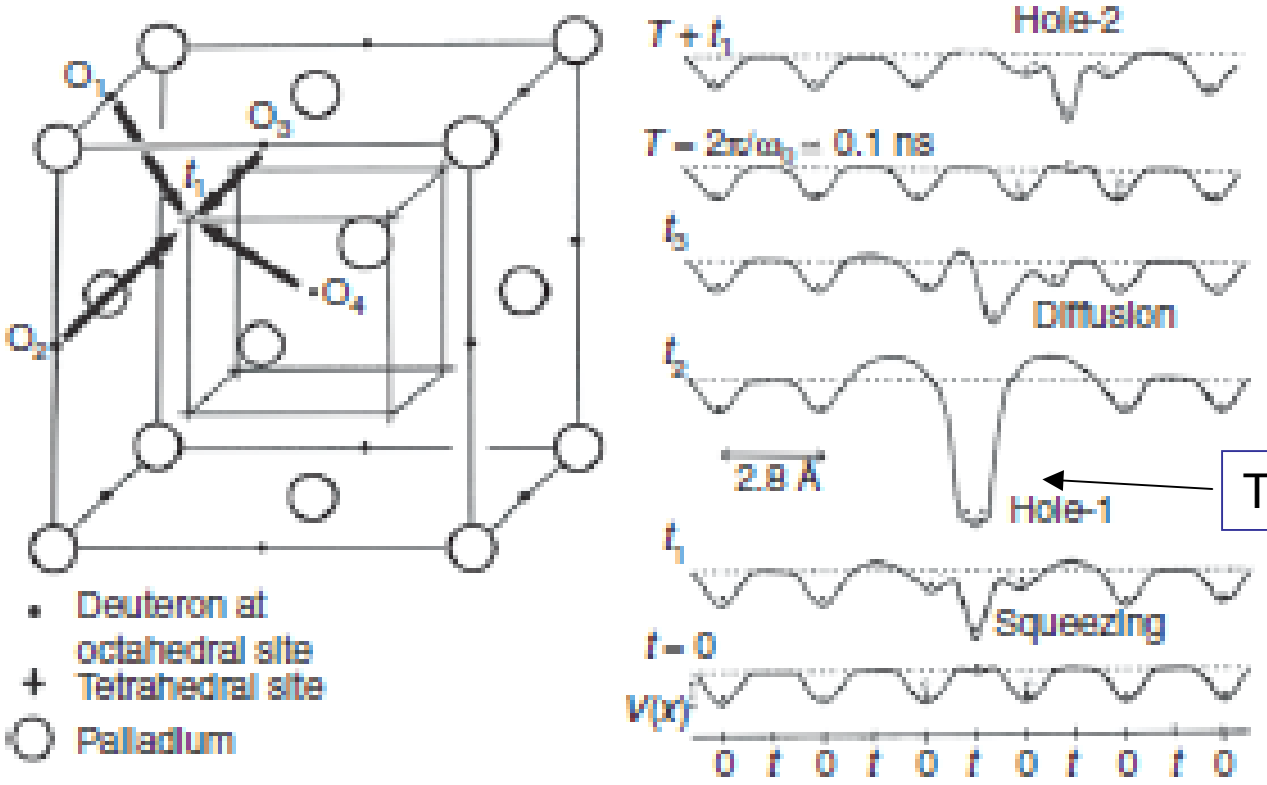
Result of Dynamic Condensation of 4D/TSC by Langevin Equation



Case-1

Model for generating 4D/TSC (t=0) cluster in excited state dynamics of O-site Deuterons in PdD lattice, where D behaves as a harmonic oscillator

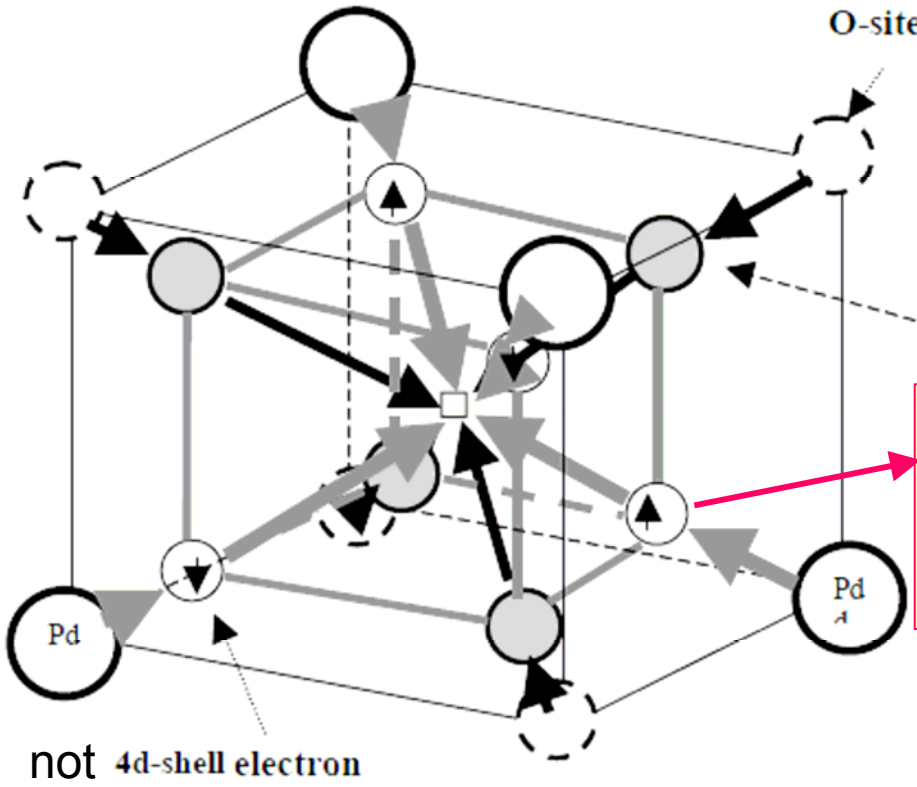
A. Takahashi and N. Yabuuchi / Journal of Condensed Matter Nuclear Science 1 (2007) 1–23



TSC (t=0)

Figure 8. Image of lattice potential change by D-phonon excitation.

Under the stimulation of D-phonon excitation in PdDx (suppose locally x=1) lattice, transient 4D-cluster will be formed with certain probability [28]. We know the trapping periodical potential height for D in PdDx lattice is about 0.22 eV, and we use kinetic energy of deuteron E_d =0.22eV for numerical estimation in the following. To keep charge neutral sate in average, orthogonal combination of two transient D_2 molecules will be formed when 4 deuterons are squeezing from O-sites to central T-sites taking (conveying) 4 electrons from Pd 4d-shell (conduction band), as shown in Fig.1, under the TSC condition and the cluster of $4D^+$s and $4e^-$s makes a regular cube as shown in Fig.2.

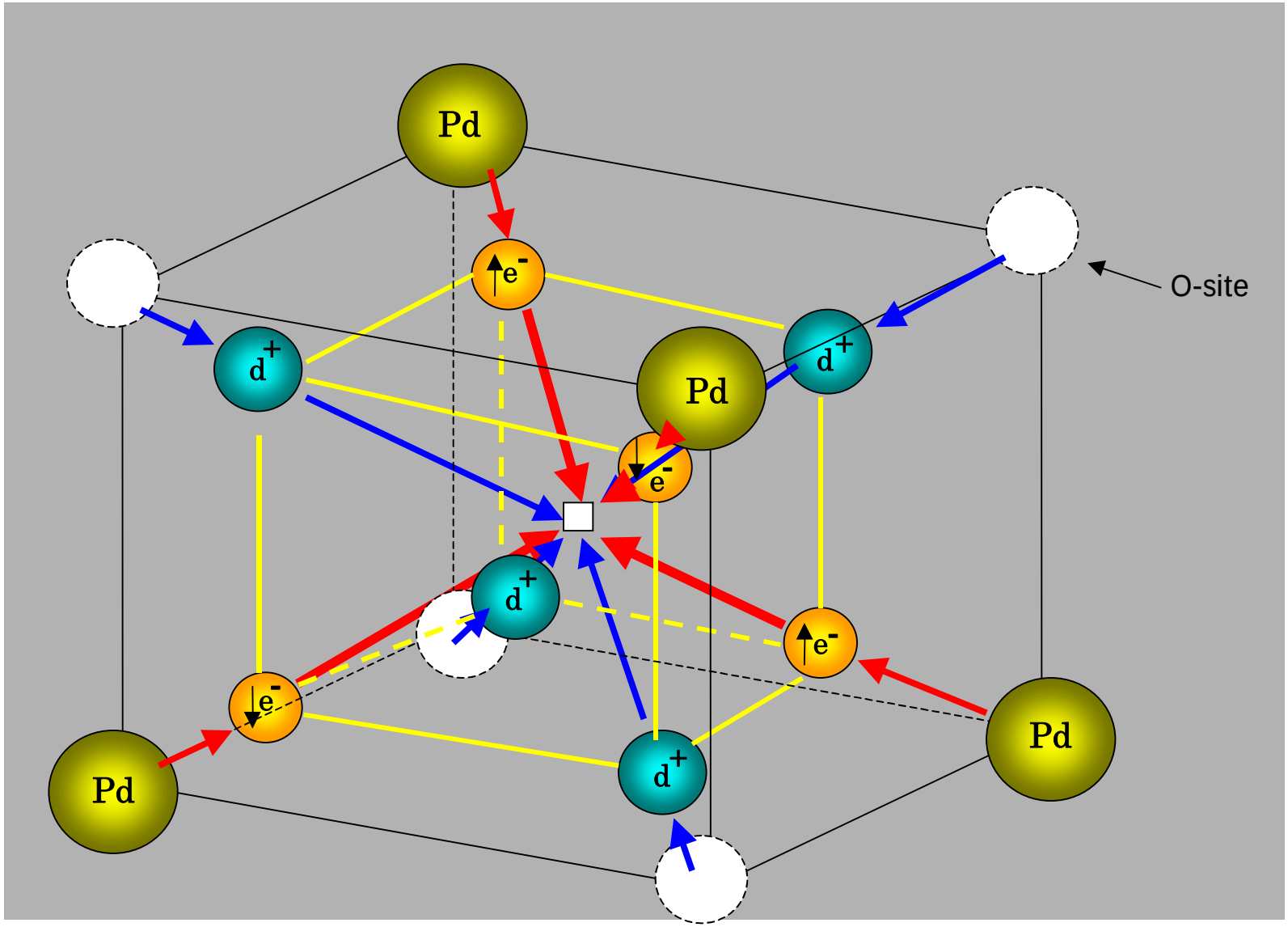


1s electron state for d^+ and attracted 4f (or 5s) electron state for Pd^- :
This exchange will make order for TSC arrangement.

Comment on Feb. 2008

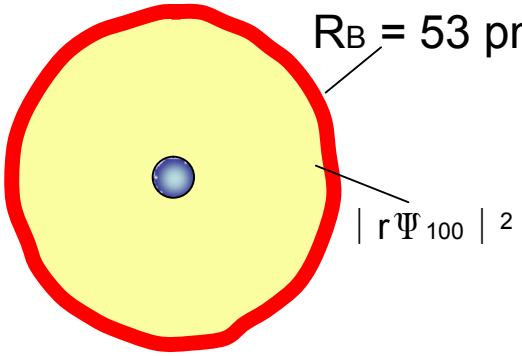
Figure 1. Tetrahedral condensation of deuterons in PdD lattice

Tetrahedral Condensation of Deuterons in PdDx

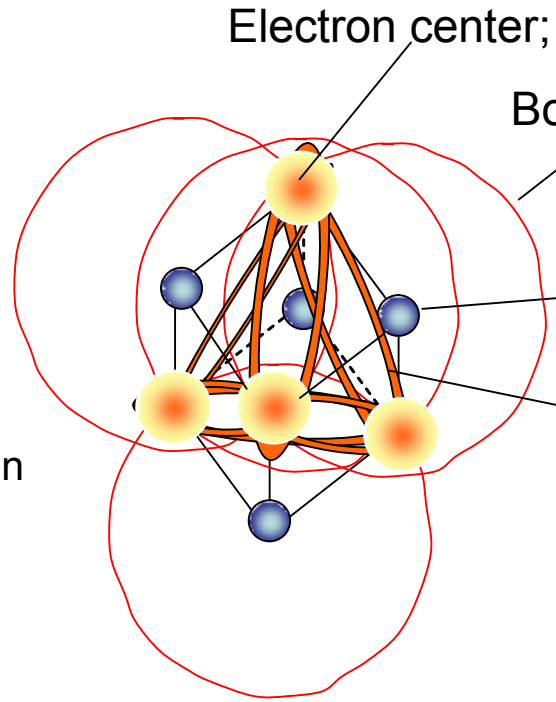


A. Takahashi: Proc. ICCF10, pp.809-818, World Scientific PC, 2006

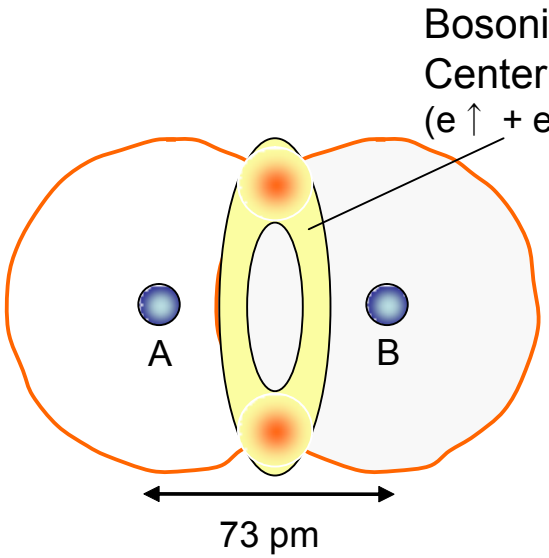
Feature of QM Electron Cloud



a) D atom (stable)



c) 4D/TSC (life time about 60 fs)



b) D_2 molecule (stable): $\Psi_{2D} = (2+2\Delta)^{-1/2}[\Psi_{100}(r_{A1})\ \Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2})\ \Psi_{100}(r_{B1})]\chi_s(S1,S2)$

Elaboration of 4D/TSC Models

- A. Takahashi: Deuteron cluster fusion and related nuclear reactions in metal-deuterium/hydrogen systems, *Recent. Res. Dev. Physics*, 6(2005)pp.1-28
- A. Takahashi: A theoretical summary of condensed matter nuclear effects, Proc. Siena05 Workshop, to be published in *JCMNS (2007)*
- A. Takahashi, N. Yabuuchi: Condensed matter nuclear effects under Platonic symmetry, Proc. ICCF13
- A. Takahshi, N. Yabuuchi: Study on 4D/TSC condensation motion by non-linear Langevin equation, Proc. New Energy Technologies, ACS, 2007 (published from Oxford U. Press, August 2008)
- And others in Proceedings of ICCF11-14.

This work: Milestones for solving the problem

- **So many body problem**: 4d +4x(D1s-electron)+ 4x10x(Pd 4d-shell electron)+4Pd + surrounding lattice atoms
- **Platonic Symmetry helps** the problem make simpler
- Formulate one-dimensional **Langevin equation for D-cluster dynamics**

One-Dimensional Langevin Equation for Molecule with Platonic Symmetry

- Formulate Langevin Equation with one-dimensional R_{dd} (d-d distance).
- Treat electron wave by combination of "dede" or "dde" type potentials.
- Solve Langevin Equation for D-clusters with Platonic symmetry for deuterons and electrons: D, D_2, D_2^+, D_3^+, 4D/TSC, $6D^{--}$ /OSC.

2: D(H)-atom

- 1S-wave function

$$\Psi_{100}(r) = \frac{1}{\sqrt{\pi a^3}} e^{-r/a}$$

System Coulomb Energy

$$\left\langle \Psi_{100} \middle| E_{C-D} \middle| \Psi_{100} \right\rangle = \int_0^\infty (-e^2/r)\Psi_{100}{}^2 4\pi r^2 dr = -1.44/r$$

With r = Bohr radius (52.9 pm), we get

$$\left\langle E_{C-D} \right\rangle = -27.2eV$$

D(H)-atom-II

- Total system energy is given by Hamiltonian integral:

$$\langle H \rangle = \langle \Psi_{100} | H | \Psi_{100} \rangle = \langle \Psi_{100} | -\frac{\hbar^2}{2m}\nabla^2 - \frac{e^2}{r} | \Psi_{100} \rangle = E_0 = -13.6eV$$

$$\langle H \rangle = \langle E_k \rangle + \langle E_{C-D} \rangle$$

Kinetic energy Coulomb energy

$$\langle E_k \rangle = \frac{1}{2}mv^2 (r = a_B) = \frac{e^2}{2r} = 13.6eV$$

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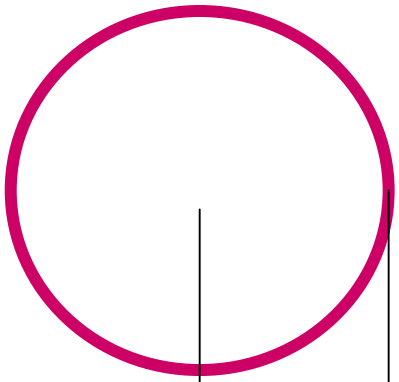
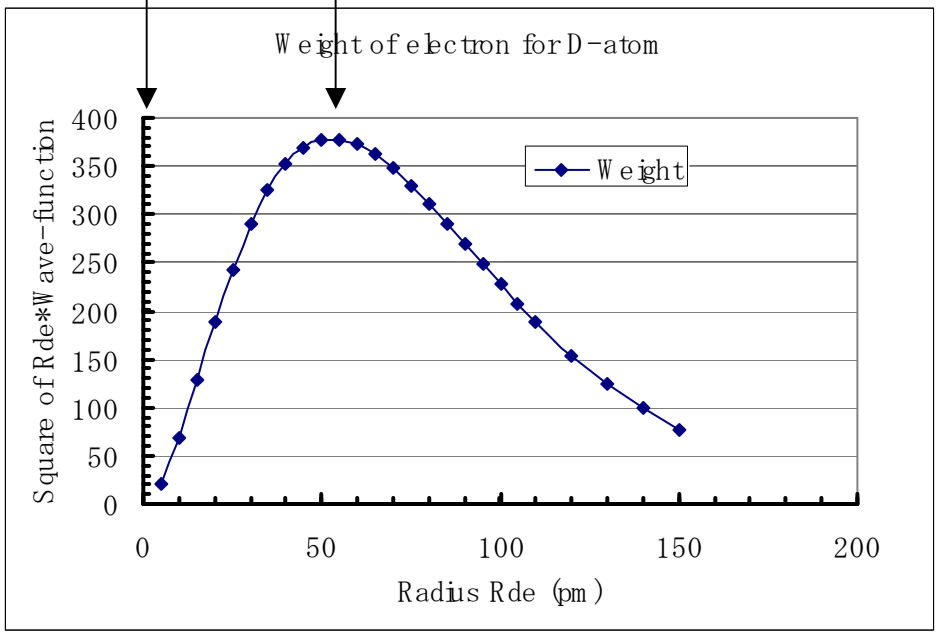
D-Atom: Point-Sphere Coupling



$$\Psi_{100}(r) = \frac{1}{\sqrt{\pi a^3}} e^{-r/a}$$

$$\int_0^\infty (\Psi_{100}(r))^2 4\pi r^2 dr = \int_0^\infty 4\pi (r\Psi(r))^2 dr = 1$$

Peak at $R_{de}=a=R_B$
(52.9 pm)



Electron Weight Peak Localizes at

$R_{de} = a = R_B = 52.9$ pm

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2.2) D-atom Langevin Equation

Regarding QM average = Ensemble Av.

$$m_e \frac{d^2 R_{de}}{dt^2} = -\frac{e^2}{[R_{de}]^2} + \frac{m_e v_e^2}{R_{de}} + f(t)$$

$$\langle G \rangle_{ensemble} = \langle \Psi | G | \Psi \rangle$$

$$m_e \frac{d^2 \langle R_{de} \rangle}{dt^2} = -\left\langle \frac{e^2}{R_{de}^2} \right\rangle + \left\langle \frac{m_e v_e^2}{R_{de}} \right\rangle = 0$$

$$\langle E_{KE} \rangle = \frac{1}{2} m_e \langle v_e^2 \rangle = \frac{e^2}{2R_B} = 13.6eV$$

$$\langle E_C \rangle = -\frac{e^2}{R_B} = -27.2eV$$

$$m_e \frac{d\langle R_{de} \rangle}{dt} = F(T) = \int_0^T f(t)dt = \langle f(t) \rangle = 0$$

$$\langle H \rangle = \langle E_{KE} \rangle + \langle E_C \rangle = -13.6eV$$

Due to the ergodic process

$$\langle R_{de} \rangle (t) = R_0 = R_B = 52.9\,pm$$

Balance of centripetal
And centrifugal force

Mean Electron Kinetic Energy = 13.6 eV ; 332 pm Wave Length= 2 π R_B

3. D_2 molecule

- System wave function:

$$\Psi_{2D} = \frac{1}{\sqrt{(2+2\Delta)}}\left[\Psi_{100}(r_{A1})\Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2})\Psi_{100}(r_{B1})\right]X_s(S1,S2)$$

System Energy at ground state

$$\left\langle \Psi_{2D} \middle| H \middle| \Psi_{2D} \right\rangle = -35.1eV$$

System Coulomb Energy: Semi-Classical model

$$\left\langle E_{C-2D} \right\rangle = 4(-\frac{e^2}{a_B}) + 2(\frac{e^2}{\sqrt{2}a_B}) = -70.3eV$$

17.6 eV per e

Electron Kinetic E

$$\left\langle E_{ke-2D} \right\rangle = \left\langle H_{2D} \right\rangle - \left\langle E_{C-2D} \right\rangle = 70.3eV - 35.1eV = 35.2eV$$

Quantum-Mechanical Ensemble-Averaging

$$\langle G \rangle_{ensemble} = \langle \Psi | G | \Psi \rangle$$

Born-Oppenheimer Approximation; for D_2 molecule:

$$\Psi(R_{dd}; r_{A1}, r_{A2}, r_{B1}, r_{B2}) = \Psi_{2D} \cdot X(R_{dd})$$

Electron Wave Function for D_2:

$$\Psi_{2D} = \frac{1}{\sqrt{(2+2\Delta)}}\left[\Psi_{100}(r_{A1})\Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2})\Psi_{100}(r_{B1})\right]X_s(S1, S2)$$

Deuteron Wave Function: Gaussian approximation:

$$\mathrm{X}^2(R'_{dd}; R_{dd}(t)) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp[-(R'_{dd} - R_{dd}(t))^2/(2\sigma^2)]$$

D_2 Molecule Electron Localization; 1/2

$$\Psi_{2D} = \frac{1}{\sqrt{(2+2\Delta)}}\left[\Psi_{100}(r_{A1})\Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2})\Psi_{100}(r_{B1})\right]X_s(S1,S2)$$

$$(4\pi)^4 \int_0^\infty \int_0^\infty \int_0^\infty \int_0^\infty \Psi_{2D}^2(r_{A1},r_{A2},r_{B1},r_{B2}) r_{A1}^2 r_{A2}^2 r_{B1}^2 r_{B2}^2 dr_{A1} dr_{A2} dr_{B1} dr_{B2} = 1$$

$$\int_0^\infty \int_0^\infty \int_0^\infty \int_0^\infty \rho(r_{A1},r_{A2},r_{B1},r_{B2}) dr_{A1} dr_{A2} dr_{B1} dr_{B2} = 1$$

$$\rho(r_{A1},r_{A2},r_{B1},r_{B2}) = \frac{(4\pi)^4}{2+2\Delta}\left\{\begin{array}{l}\left[r_{A1}^2\Psi_{100}^2(r_{A1})r_{B2}^2\Psi_{100}^2(r_{B2})\right]r_{A2}^2 r_{B1}^2 \\ +2\left[r_{A1}\Psi_{100}(r_{A1})r_{A2}\Psi_{100}(r_{A2})r_{B1}\Psi_{100}(r_{B1})r_{B2}\Psi_{100}(r_{B2})\right]r_{A1}r_{A2}r_{B1}r_{B2} \\ +\left[r_{A2}^2\Psi_{100}^2(r_{A2})r_{B1}^2\Psi_{100}^2(r_{B1})\right]r_{A1}^2 r_{B2}^2\end{array}\right\}$$

$(r\Psi)^2$ is a measure of electron weight localization

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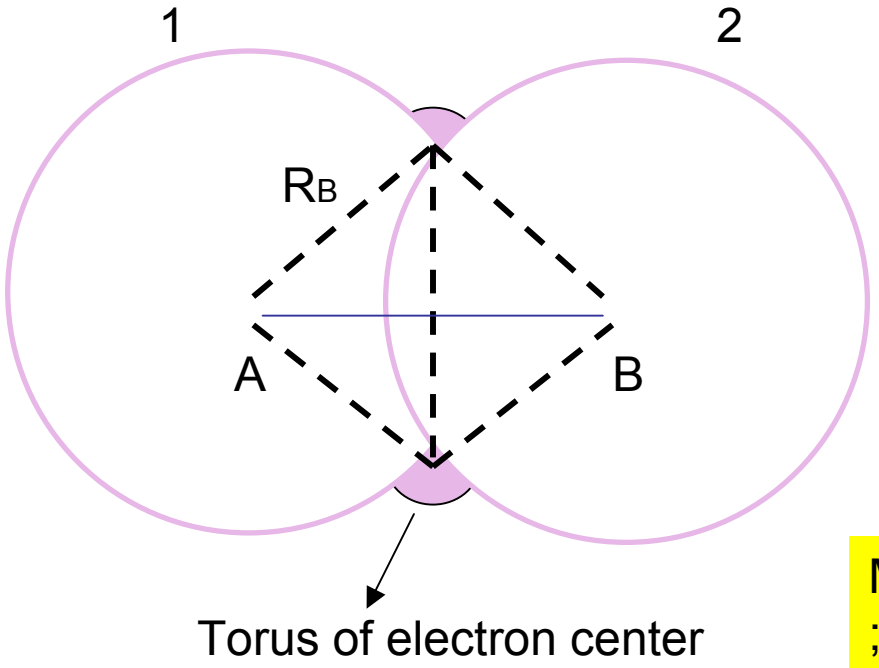
D_2 Molecule Electron Localization: 2/2

At $r_{A1} = r_{B1}$ and $r_{A2} = r_{B2}$:

$$\rho(r_{A1}, r_{A2}, r_{A1}, r_{A2}) = \frac{4(4\pi)^4}{2+2\Delta}\left[\left|r_{A1}\Psi_{100}(r_{A1})\right|^2\left|r_{A2}\Psi_{100}(r_{A2})\right|^2\right]r_{A1}^2 r_{A2}^2$$

Platonic System:
"Di-Cone"
Dipole-Circle Coupling



At $r_{A1} = r_{A2} = r_{B1} = r_{B2} = a$
Maximum appears.

$$\rho(a,a,a,a) = \frac{4(4\pi)^4}{2+2\Delta}a^4\left|a\Psi_{100}(a)\right|^4$$

$R_B = a = 52.9$ pm

$R_{dd} = R_{AB} = 74.1$ pm

Classical view:
Electrons rotate around R_{dd} axis.

Mean Electron Kinetic Energy =17.6 eV ; Wave length = 223 pm = 2π Re

3.2) D_2 Langevin Equation

$$m_d \frac{d^2 R_{dd}}{dt^2} = -(4\sqrt{2}-2)\frac{e^2}{R_{dd}^2} + \frac{2m_e v_e^2}{(R_{ee}/2)} - \frac{\partial V_{s2}(R_{dd};1,1)}{\partial R_{dd}} + f(t)$$

Coulomb F | Centrifugal F | Constraint

$$m_d \frac{d^2 \langle R_{dd} \rangle}{dt^2} = -\left\langle \frac{5.26}{R_{dd}^2} \right\rangle + 4\left\langle \frac{m_e v_e^2}{R_{ee}} \right\rangle - \frac{\partial V_{s2}(R_{dd};1,1)}{\partial \langle R_{dd} \rangle} + \langle f(t) \rangle$$

(= 0)

By e-wave averaging

$$m_d \frac{d^2 \langle R_{dd} \rangle}{dt^2} = -\frac{\partial V_{s2}(R_{dd};1,1)}{\partial \langle R_{dd} \rangle} + \langle f(t) \rangle$$

=0 by X-averaging

; = 0 at $R_{dd} = R_{gs} = 74.1$pm

; > 0 for $R_{dd} < R_{gs}$, deceleration

; < 0 for $R_{dd} > R_{gs}$, acceleration

$R_{dd}(t)$ converges to $R_{dd}(\infty) = R_{gs} = 74.1$ pm

Potential of “dede”-type Molecule

with a_0= 0.053 nm (Bohr radius) and $Z = e^*/e$.

We also solved an atomic de* system to obtain ground state energy $V_h$as:

$$V_h = -13.6Z^2/(m_c/m^*). \tag{3.26}$$

For dde*e* molecule state with double electrons or e* s, we also extend the solution for ddee given in the text [45] and we have obtained screened potential function $V_{sc^*e^*}$ as:

$$V_{sc^*e^*}(R) = 2V_h + e^2/R + (2J + J' + 2\Delta K + K')/(1 + \Delta^2). \tag{3.27}$$

Here the cross-Coulomb integral J' and cross exchange integral K' are given as:

$$J' = (Z^2e^2/a)(1/y - \exp(-2y))(1/y + 11/8 + 3y/4 + y^2/6), \tag{3.28}$$

$$\begin{aligned} K' = (Z^2e^2/5/a)[&-\exp(-2y)(-25/8 + 23y/4 + 3y^2 + y^3/3) \\ &+(y/6)((0.5772 + \log y)\Delta^2 \\ &+(\Delta')^2 E_i(-4y) - 2\Delta\Delta' E_i(-2y))] \end{aligned} \tag{3.29}$$

with

$$\Delta' = \exp(-y)(1 - y + y^2/3), \tag{3.30}$$

$$E_i(y) = -\int_0^{\exp(-y)} (1/\log x)\, dx. \tag{3.31}$$

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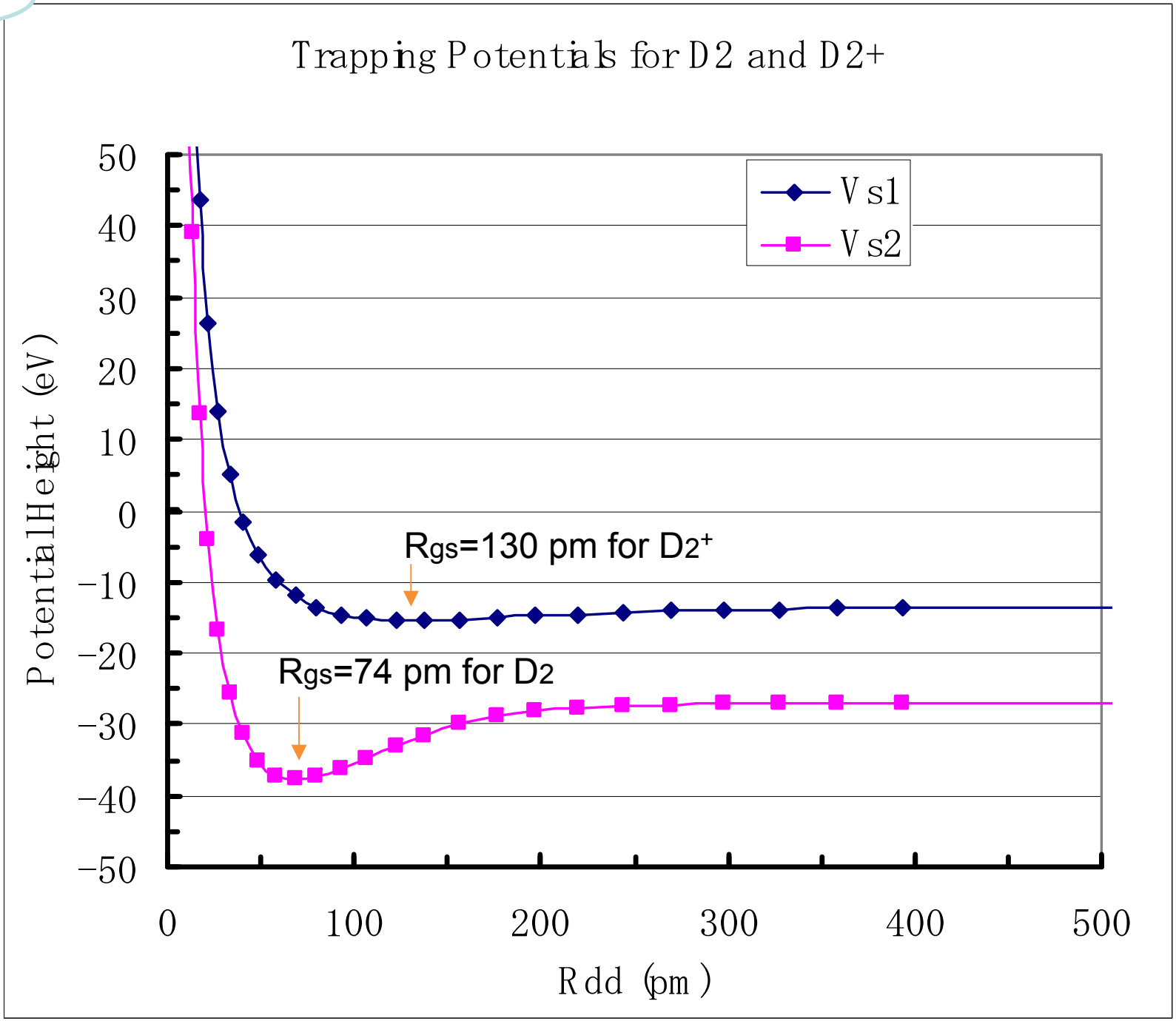

Trapping Potentials for D2 and D2+
Vs1
Vs2
Rgs=130 pm for D2+
Rgs=74 pm for D2
Potential Height (eV)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
100
200
300
400
500
Rdd (pm)

3.3) D_2^+ (dde) Langevin Equation

$$m_d \frac{d^2 R_{dd}}{dt^2} = -2\frac{e^2}{R_{de}^2} + \frac{e^2}{R_{dd}^2} + \frac{m_e v_e^2}{R_e} - \frac{\partial V_s(R_{dd};1,1)}{\partial R_{dd}} + f(t)$$

$$-e^2\left\langle \frac{2}{R_{de}^2} - \frac{1}{R_{dd}^2} \right\rangle + \left\langle \frac{m_e v_e^2}{R_e} \right\rangle = 0$$

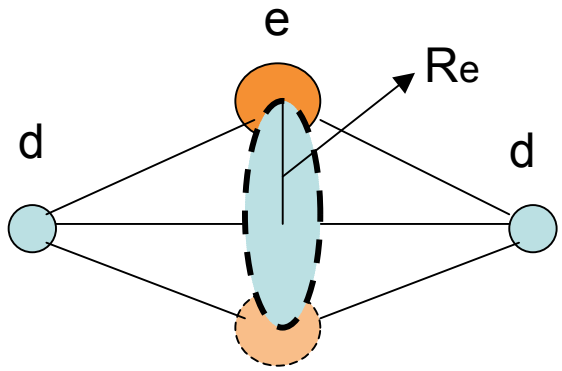
$$m_d \frac{d^2 \langle R_{dd} \rangle}{dt^2} = -\frac{\partial V_s(R_{dd};1,1)}{\partial \langle R_{dd} \rangle}$$

<R_{dd}> = 138 pm

<R_{de}> = 86.9 pm

<R_e> = 52.9 pm

Elongated Di-Cone



<R_{dd}>(∞)=R_{gs}=138 pm
<H>=-15.1eV
<Electron K.E>=13.6eV

Potential for “dde”-type Molecule

Screened potentials $V_s n(m^*/m_e, e^*/e)(R)$ were calculated for dde* molecular states using extended solutions for dde state given in a text of quantum mechanics by the well-known technique of variational method [45] as:

$$V_{s(m^*/m_e,e^*/e)}(R) = V_h + e^2/R + (J+K)/(1+\Delta), \tag{3.20}$$

where the Coulomb integral J, the exchange integral K, and the non-orthogonal integral Δ are given as [45]:

$$J = Z(e^2/a)[-1/y + (1+1/y)\exp(-2y)], \tag{3.21}$$

$$K = -Z(e^2/a)(1+y)\exp(-y), \tag{3.22}$$

$$\Delta = (1+y+y^2/3)\exp(-y). \tag{3.23}$$

With

$$Y = R/a, \tag{3.24}$$

$$a = a_0/Z/(m^*/m_e) \tag{3.25}$$

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4. QM-Average for Complex D-cluster under Platonic Symmetry

- Average on Electron-wave function is replaced with Friction (Constraint) as

$$\left\langle Constra\,\mathrm{int}\right\rangle_{electron-wave} = -N_f \frac{\partial V_{si}(R_{dd};1,1)}{\partial R_{dd}}$$

N_f : Number of faces for Platonic polyhedron
V_{si}: D_2 (i=2) or D_2^+ (i=1) trapping potential

- Average on d-d wave function: using

$$\Psi(R,R') = \frac{1}{\sqrt{2\pi\sigma^2}} \exp(-(R'-R)^2/(2\sigma^2))$$

QM Average of Langevin Equation: for $N_e > 2$

$$N_e m_d \frac{d^2 R}{dt^2} = -\frac{k}{R^2} - N_f \frac{\partial V_s}{\partial R} + f(t)$$

N_e: Number of d-d edges

$$N_e m_d \left\langle \Psi(R,R') \left| \frac{d^2 R}{dt^2} \right| \Psi(R,R') \right\rangle = -\left\langle \Psi(R,R') \left| \frac{k}{R^2} \right| \Psi(R,R') \right\rangle$$
$$- N_f \left\langle \Psi(R,R') \left| \frac{\partial V_s}{\partial R} \right| \Psi(R,R') \right\rangle + \left\langle \Psi(R,R') \left| f(t) \right| \Psi(R,R') \right\rangle$$

$$\Psi(R,R') = \frac{1}{\sqrt{2\pi\sigma^2}} \exp(-(R'-R)^2/(2\sigma^2))$$

Gaussian Wave Function

$$N_e m_d \frac{d^2 < R >}{dt^2} = -\frac{k}{R^2} - N_f \frac{\partial V_s}{\partial R} + < f(t) >$$

Equation for Expectation Value

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$$N_e m_d \frac{d^2 R}{dt^2} = -\frac{k}{R^2} - N_f \frac{\partial V_s}{\partial R} + f(t)$$

Centripetal Coulomb Force

Friction by Electron Cloud

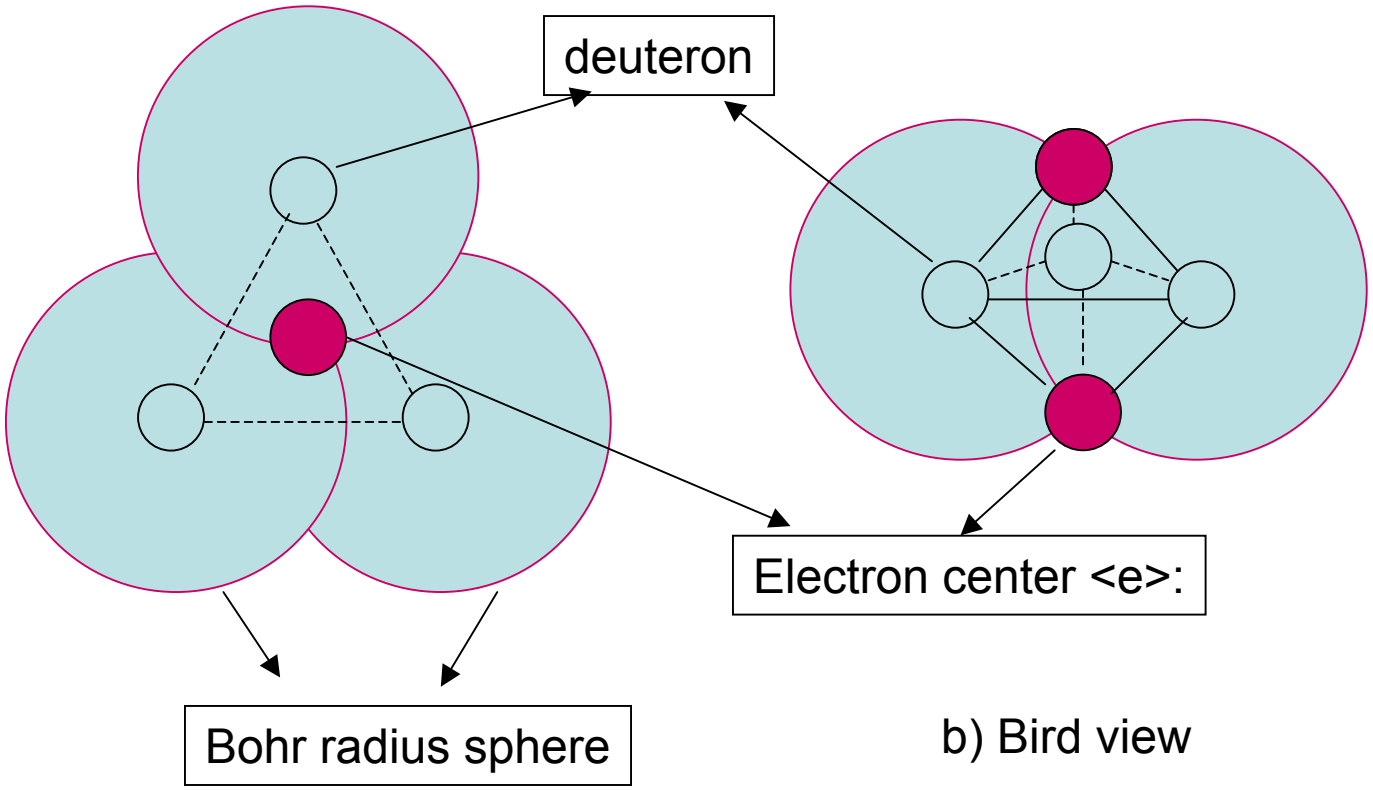
QM Fluctuation Of Force

Table-1: parameters of D-cluster Langevin equation

cluster	N_e: Number of d-d edges	k: Total Coulomb Force parameter (keVpm)	Type of electron trapping potential on a surface	N_f: number of faces
D_2	1	0	i = 2	1
D_2^+	1	0	i = 1	1
D_3^+	3	6.13	i = 1	6
4D/TSC	6	11.85	i = 2	6
$6D^{2-}$/OSC	12	29.3	i = 1	24

4.2) Application to Tri-Atomic Molecule

$3D^+$ Ion ; Semi-classical view of particle arrangement



a) Top View

b) Bird view

Trigonal Dipyramid
: Triangle-Dipole Coupling

$3D^+$ Molecule

- Coulomb Energy:

$$E_C = -6\frac{e^2}{R_{de}} + 3\frac{e^2}{R_{dd}} + \frac{e^2}{R_{ee}}$$

For Platonic arrangement:

$$E_C = -(6\sqrt{2} - 3 - \frac{\sqrt{6}}{2})\frac{e^2}{R_{dd}} = -\frac{6.13}{R_{dd}}$$

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D_3^+ Ion Langevin Equation

$$3m_d \frac{d^2 R_{dd}}{dt^2} = -\frac{6.13}{R_{dd}^2} - 6\frac{\partial V_s(R_{dd};1,1)}{\partial R_{dd}} + f(t)$$

Coulomb F

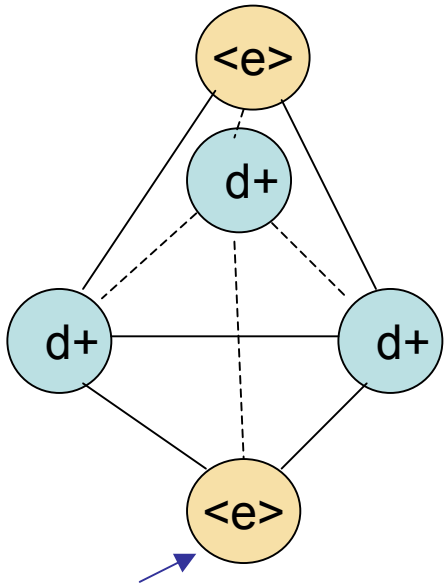
Constraint

6 dde faces

$$V_{3D+main}(R_{dd}) = -\frac{6.13}{R_{dd}} + 6V_s(R_{dd};1,1)$$

3D+ Trapping Potential

+ <f(t)> bias



Electron-Ball

Ratio =6.13/6 = 1.02 CF: 1.975 for 4D/TSC

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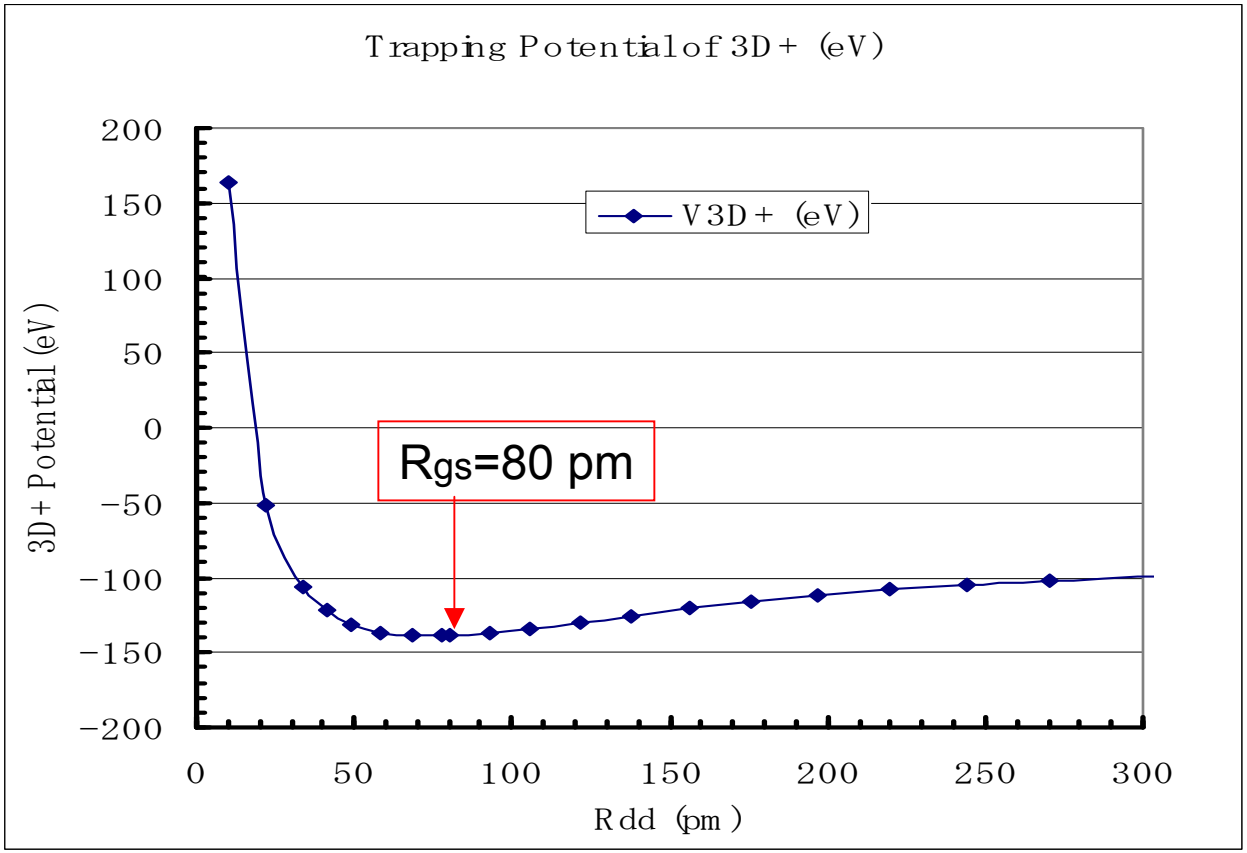

$$3m_d \frac{d^2\langle R_{dd}\rangle}{dt^2} = -\frac{6.13}{\langle R_{dd}\rangle^2} - 6\frac{\partial V_s(R_{dd};1,1)}{\partial\langle R_{dd}\rangle} + \langle f(t)\rangle$$

$$\langle f(t)\rangle = \left\langle -\frac{\partial \Delta E_C}{\partial R'} X^2(R_{dd};\sigma,t)\right\rangle$$

:Distortion of Coulomb force from 3D
Regular triangle arrangement (about 30%)

Summary of Known D-molecules

- Known D-molecules are regarded as Platonic Symmetric System with orthogonal coupling of electron wave function and deuteron wave function
- Due to the Platonic symmetry, 3-dim. Dynamics can be treated by 1-dim. Dynamics using Langevin equation
- Deuteron Trapping Potential is estimated from individual Langevin equation

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5.Now the Methodology is applied for 4D/TSC and 6D/OSC

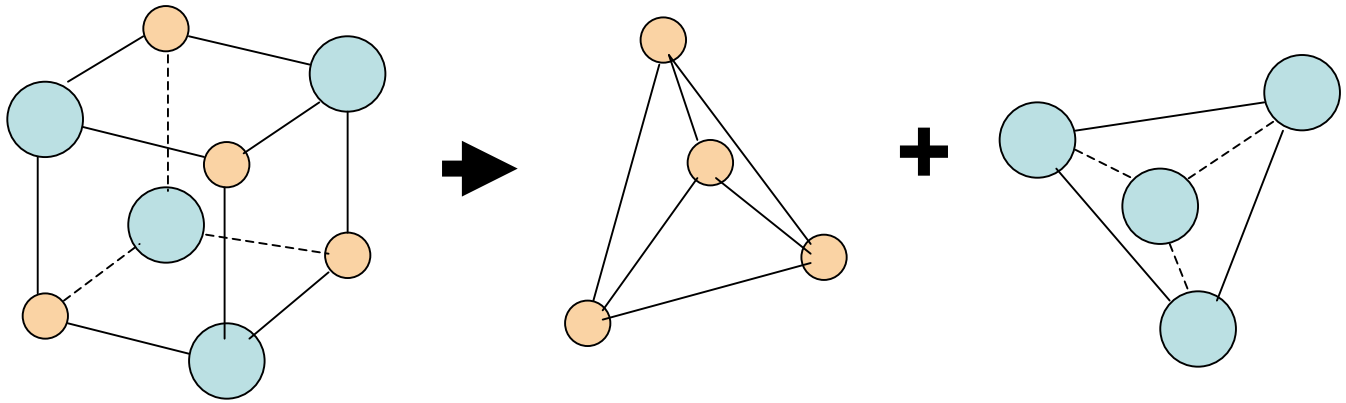
- Formulate the central condensation force (CCF) by Coulombic interaction
- Formulate the fluctuation force term by change of CCF in deformed state from the Platonic symmetry
- Define cluster trapping potential (time-dependent)
- Excute numerical calculation

Double Platonic Arrangement
: Tetrahedron-Tetrahedron Coupling

a) TSC

b) Electron tetrahedron

c) Deuteron tetrahedron



12 Attractive Coulomb forces Between d-e pairs on 6 surfaces And 4 Attractive Forces between 4 diagonal d-e pairs

6 repulsive Coulomb Forces Between electrons

6 repulsive Coulomb Forces Between deuterons

Coulomb Energy of TSC

- System Coulomb Energy for CCF

$$\langle E_{C-TSC} \rangle = 12(-\frac{e^2}{R_{de}}) + 12(\frac{e^2}{R_{dd}}) + 4(-\frac{e^2}{\sqrt{3}R_{de}}) = -\frac{8.38}{R_{de}}$$

In keV unit with R in pm unit

$$R_{dd} = \sqrt{2}R_{de}$$

$$\langle E_{k,e-ball} \rangle = 4(\frac{1}{2}m_e v_d{}^2) = 4\left(\frac{m_e}{M_d}\right)E_d \leq 0.88eV$$

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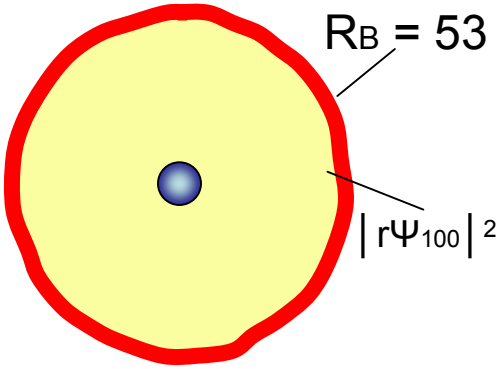
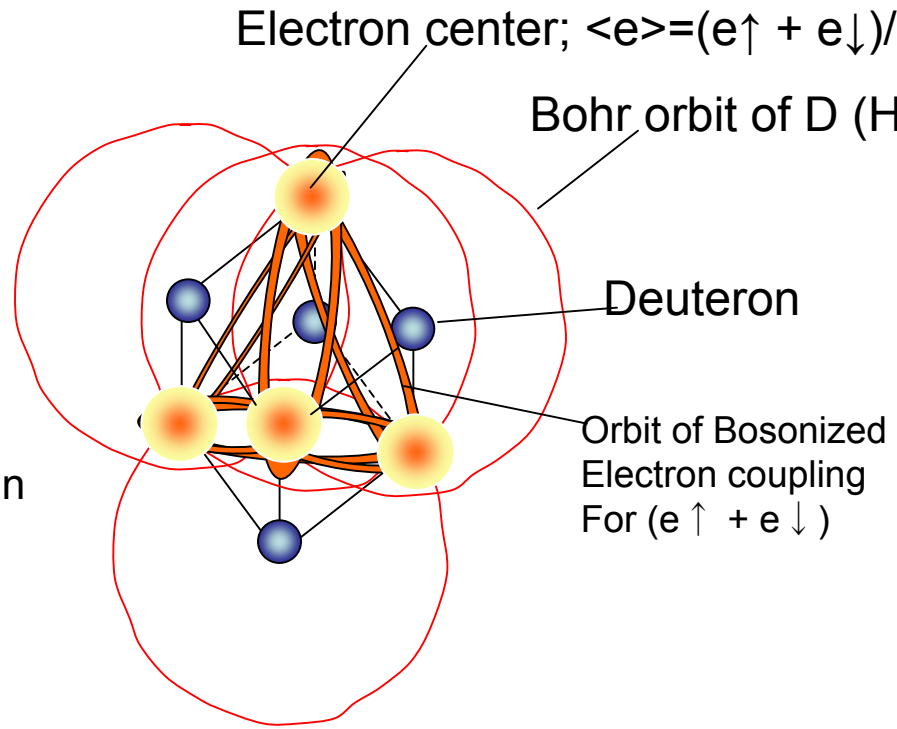
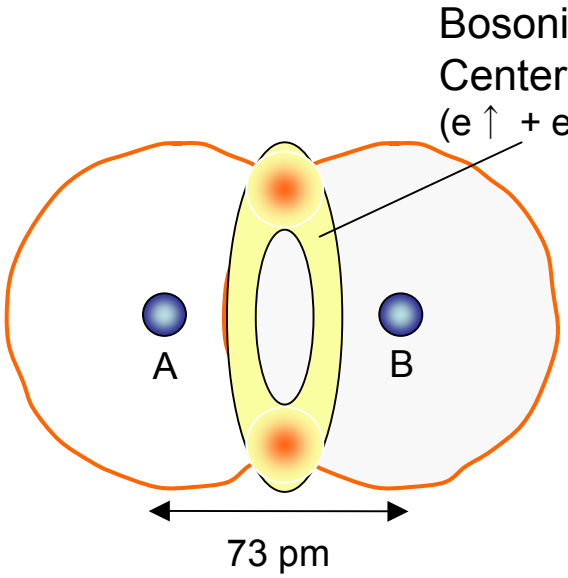
Feature of QM Electron Cloud



a) D atom (stable)



c) 4D/TSC (life time about 60 fs)



b) D_2 molecule (stable): $\Psi_{2D} = (2+2\Delta)^{-1/2}[\Psi_{100}(r_{A1})\ \Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2})\ \Psi_{100}(r_{B1})]X_s(S1,S2)$

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

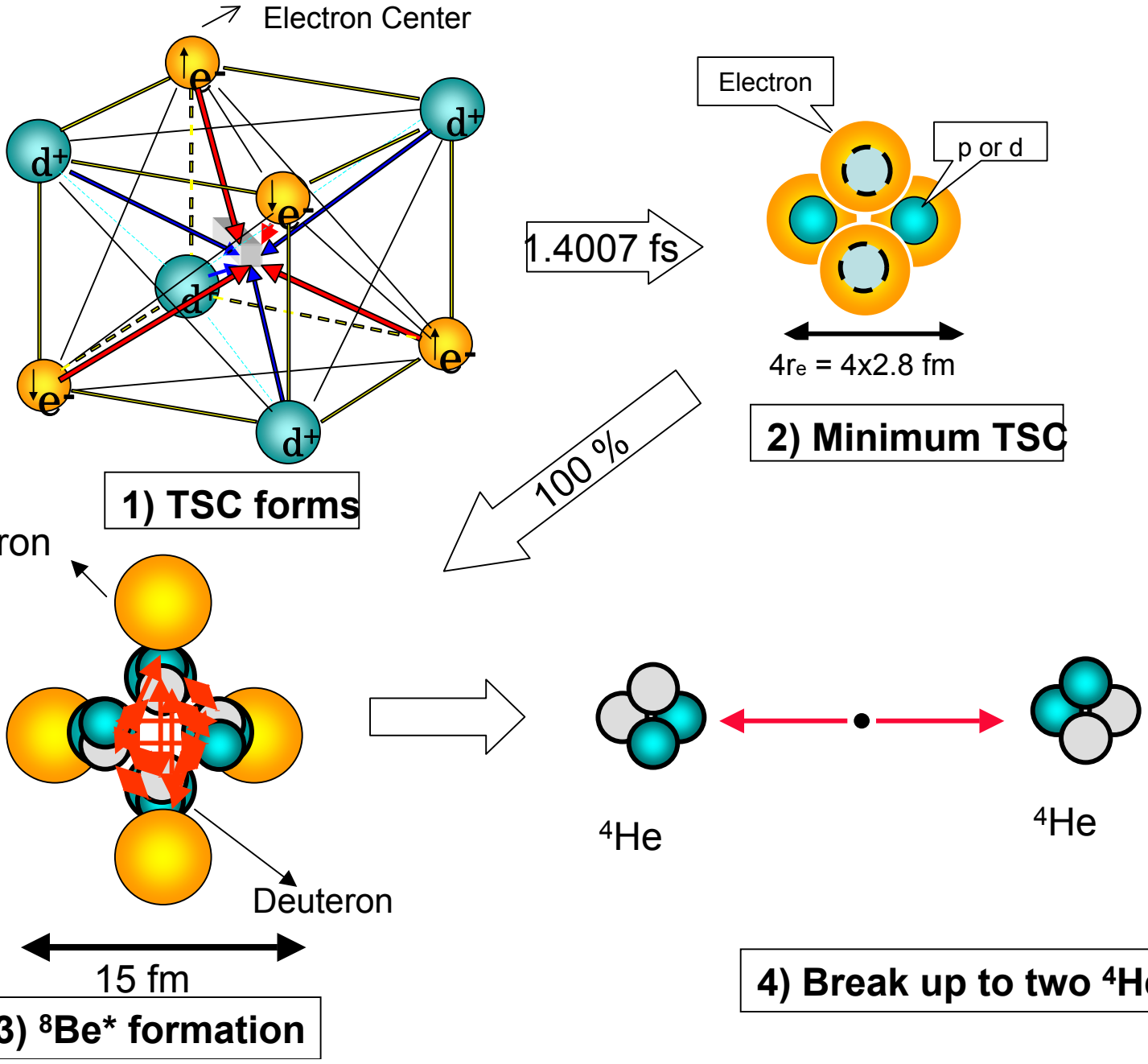
- Ψ_{4D} ~**a1** $[\Psi_{100}(r_{A1})\,\Psi_{100}(r_{B2}) + \Psi_{100}(r_{A2})\,\Psi_{100}(r_{B1})]X_s(S1,S2)$
  +a2 $[\Psi_{100}(r_{A1})\,\Psi_{100}(r_{D4}) + \Psi_{100}(r_{A4})\,\Psi_{100}(r_{D1})]X_s(S1,S4)$
  +a3 $[\Psi_{100}(r_{A2})\,\Psi_{100}(r_{C4}) + \Psi_{100}(r_{A4})\,\Psi_{100}(r_{C2})]X_s(S2,S4)$
  +a4 $[\Psi_{100}(r_{B1})\,\Psi_{100}(r_{D3}) + \Psi_{100}(r_{B3})\,\Psi_{100}(r_{D1})]X_s(S1,S3)$
  +a5 $[\Psi_{100}(r_{B2})\,\Psi_{100}(r_{C3}) + \Psi_{100}(r_{B3})\,\Psi_{100}(r_{C2})]X_s(S2,S3)$
  +a6 $[\Psi_{100}(r_{C3})\,\Psi_{100}(r_{D4}) + \Psi_{100}(r_{C4})\,\Psi_{100}(r_{D3})]X_s(S3,S4)$

6-Bonds of “Bosonozed” electron-pairs (e↑+ e↓), which forms **Regular Tetrahedron (PA)**

4-Electron-Centers at Vertexes of **Regular Tetrahedron (PA)**

$u_{1s1}(r) = \Psi_{100}(r) = (1/\pi)^{1/2}(1/a_B)^{3/2}\exp(-r/a_B)$

Result of Dynamic Condensation of 4D/TSC by Langevin Equation



5.2 4D/TSC Langevin Equation for Monte-Carlo Calculation

$$6m_d \frac{d^2 R_{dd}(t)}{dt^2} = -\frac{11.85}{[R_{dd}(t)]^2} - 6\frac{\partial V_{s2}(R_{dd}(t);1,1)}{\partial R_{dd}(t)} + \langle f(t)\rangle + f'(t)$$

$$f'(t) = f(t) - \langle f(t)\rangle$$

$$V_{tsc-main} = -\frac{11.85}{R_{dd}} + 6V_{s2}(R_{dd};1,1)$$

$$f(t) = [-\frac{\partial \Delta E_c(R_{dd})}{\partial R_{dd}}] \mathrm{mod}[X^2(R'_{dd}; R_{dd}(t))]$$

$$\mathrm{X}^2(R'_{dd}; R_{dd}(t)) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-(R'_{dd} - R_{dd}(t))^2/(2\sigma^2)]$$

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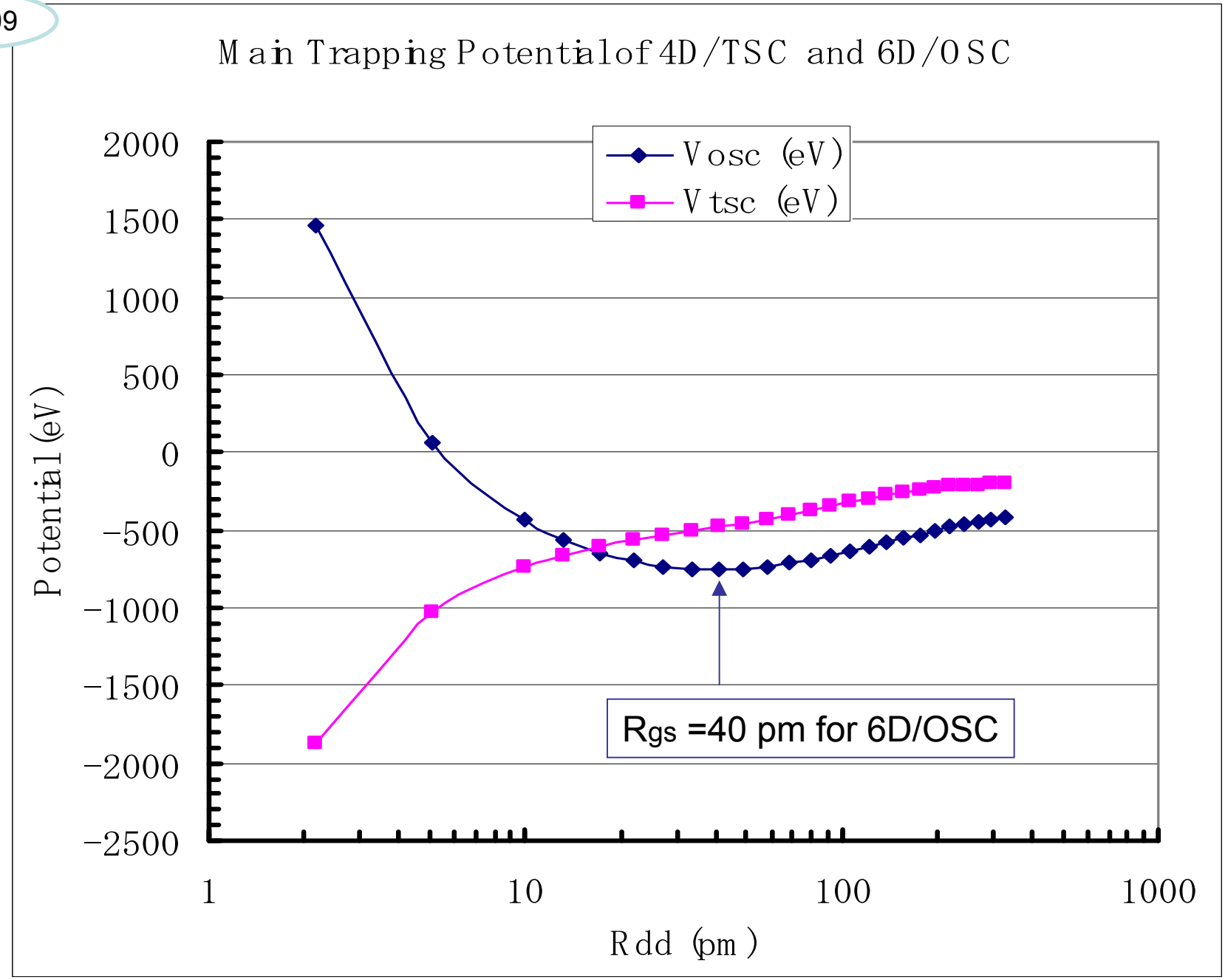
Main Trapping Potential of 4D/TSC and 6D/OSC
Vosc (eV)
Vtsc (eV)
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
Potential (eV)
1
10
100
1000
Rdd (pm)
Rgs =40 pm for 6D/OSC

Langevin Equation for Total TSC System with Maximum-Estimated Friction

$$6m_d \frac{d^2 R_{dd}(t)}{dt^2} = -BA \times \frac{11.85}{[R_{dd}(t)]^2} - 6\frac{\partial V_s(R_{dd}(t); m, Z)}{\partial R_{dd}(t)} + f(t)$$

Main Condensation Force

6 d-d edges of Deuteron tetrahedron

6 dede surfaces of TSC Constraint by electron waves

QM-fluctuation of deuterons

Always Acceleration for R_{dd} > 10 fm

BA: parameter (< 1.0) to merge <f(t)> bias

Verlet's Method

$$G(r,t) = \frac{1.975}{m_d[R(0) - r(t)]^2} + \frac{1}{m_d}\frac{\partial V_s(R_{dd};m,Z)}{\partial R_{dd}}$$

$$R_{dd}(t) = R_0 - r(t)$$

$$\frac{d^2 r(t)}{dt^2} = G(r,t)$$

$$r(t+\Delta t) = r(t) + v(t)\Delta(t) + \frac{1}{2}G(r,t)(\Delta t)^2$$

$$v(t+\Delta t) = v(t) + \frac{\Delta t}{2}\left[G(r,t+\Delta t) + G(r,t)\right]$$

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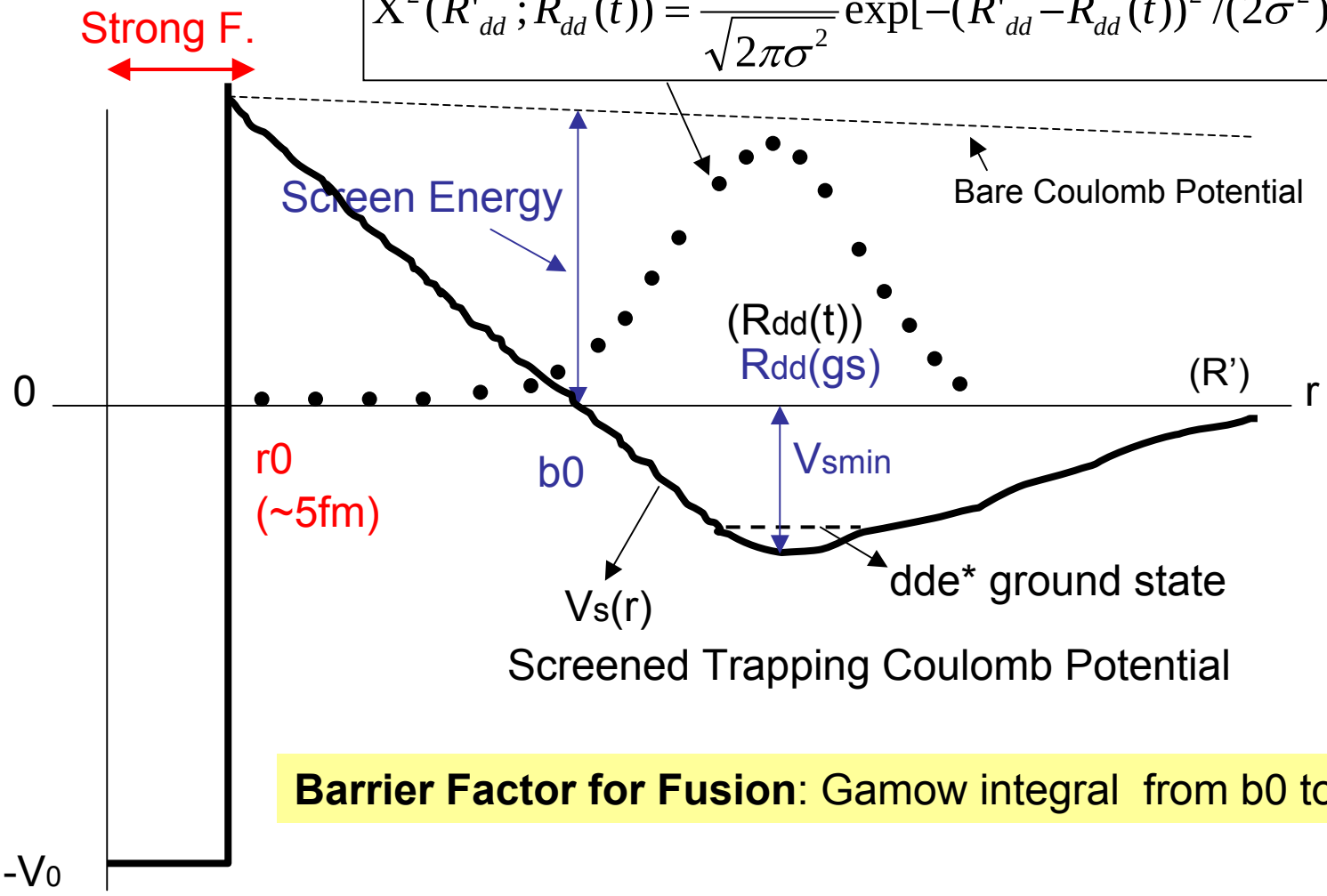
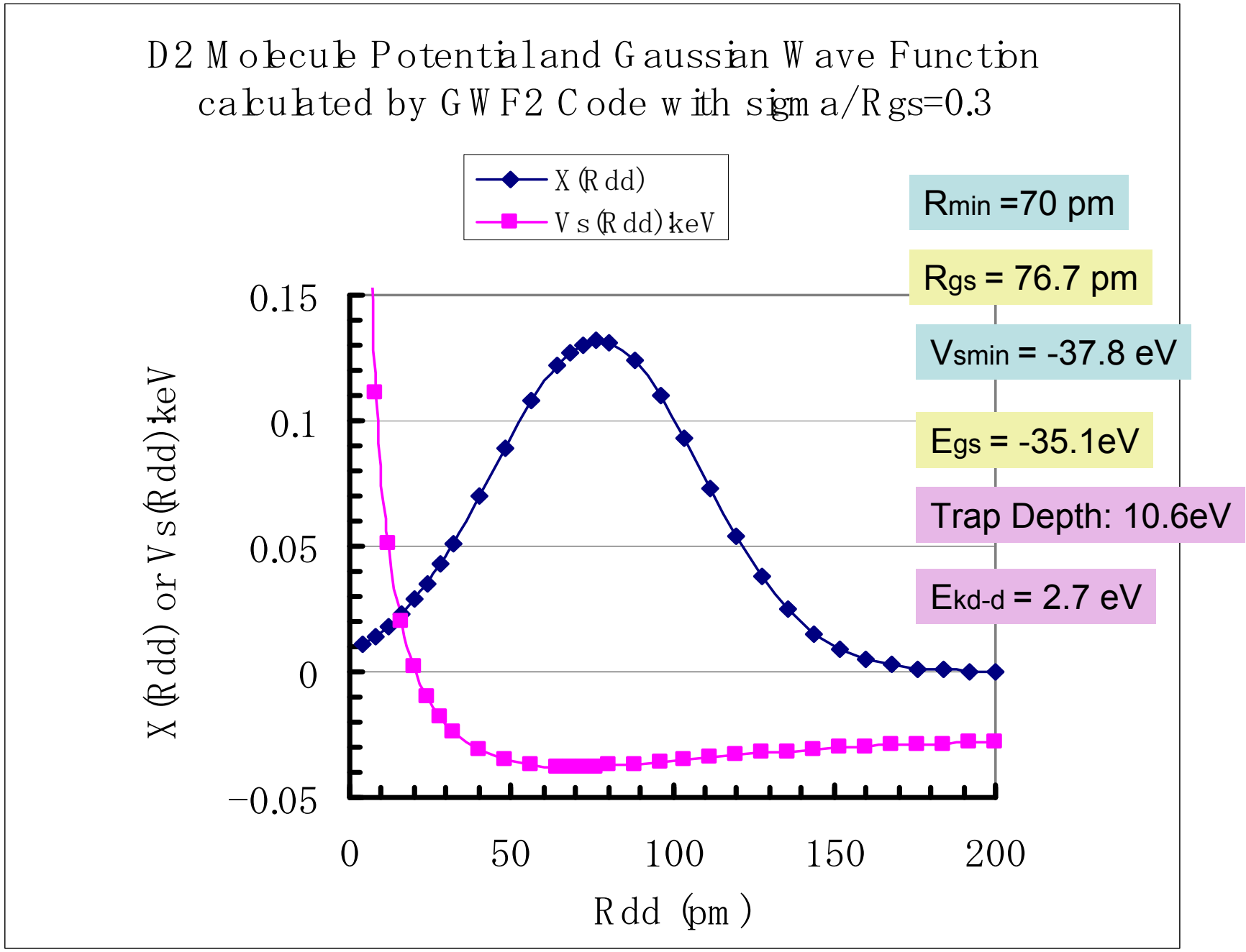
Adiabatic Potential for Molecule dde* and its ground state squared wave function

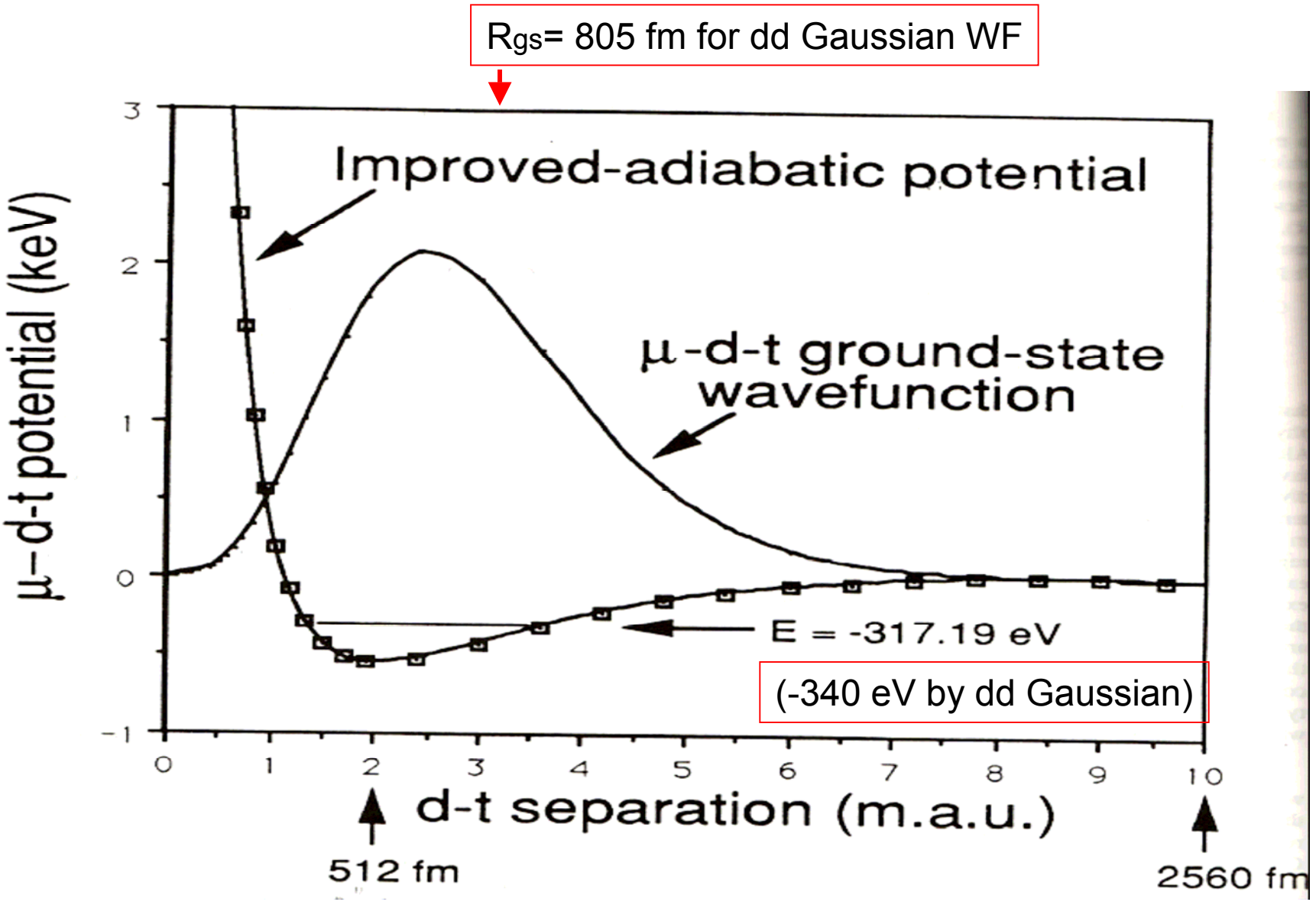
$$X^2(R'_{dd}; R_{dd}(t)) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-(R'_{dd} - R_{dd}(t))^2 / (2\sigma^2)]$$



Barrier Factor for Fusion: Gamow integral from b0 to r0


D2 Molecule Potential and Gaussian Wave Function
calculated by GWF2 Code with sigma/Rgs=0.3
X(Rdd)
Vs(Rdd) keV
Rmin =70 pm
Rgs = 76.7 pm
Vsmin = -37.8 eV
Egs = -35.1eV
Trap Depth: 10.6eV
Ekd-d = 2.7 eV
X(Rdd) or Vs(Rdd) keV
0.15
0.1
0.05
0
-0.05
0
50
100
150
200
Rdd (pm)

After Hale-Tally, Proc. ICCF4, Trans. Fusion Technology, 26,4T (1994)448

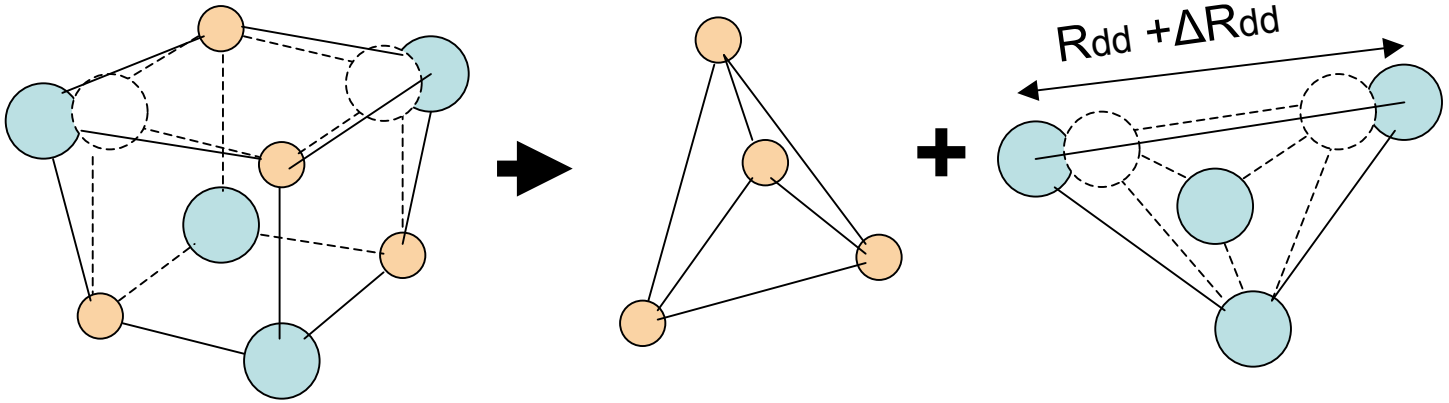


Distortion of Double Platonic Arrangement

a) TSC

b) Electron tetrahedron

c) Deuteron tetrahedron



12 Attractive Coulomb forces Between d-e pairs on 6 surfaces And 4 Attractive Forces between 4 diagonal d-e pairs

6 repulsive Coulomb Forces Between electrons

6 repulsive Coulomb Forces Between deuterons

Exercise

$$-\frac{\partial \Delta E_C}{\partial R} \approx -k\frac{1}{2}\left(\frac{1}{(R+\Delta R)^2}+\frac{1}{(R-\Delta R)^2}\right)+k\frac{1}{R^2}$$

$$\approx -\frac{k}{2R^2}\left(1-\frac{2\Delta R}{R}-\left(\frac{\Delta R}{R}\right)^2+1+\frac{2\Delta R}{R}-\left(\frac{\Delta R}{R}\right)^2\right)+\frac{k}{R^2}$$

$$=\frac{k}{R^2}\left(\frac{\Delta R}{R}\right)^2$$

TSC Langevin Step2

$$6m_d \frac{d^2 R_{dd}(t)}{dt^2} = -BA \times \frac{11.85}{[R_{dd}(t)]^2} - 6\frac{\partial V_s(R_{dd}(t); m, Z)}{\partial R_{dd}(t)} + f(t)$$

$$f(t) = [-\frac{\partial \Delta E_c(R_{dd})}{\partial R_{dd}}] \mathrm{mod}[X^2(R'_{dd}; R_{dd}(t))]$$

f(t)=0 for $R'_{dd}=R_{dd}$

$$X^2(R'_{dd}; R_{dd}(t)) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-(R'_{dd} - R_{dd}(t))^2 / (2\sigma^2)]$$

$$\sigma = 0.372 R_{dd}(t)$$

$$\Delta R_{dd} = R'_{dd} - R_{dd}(t)$$

$$-\frac{\partial \Delta E_c(R'_{dd})}{\partial R_{dd}} = 6.60 \frac{[\Delta R_{dd}]^2}{[R_{dd}(t)]^4}$$

Change of TSC Coulomb Energy by Distortion of Platonic Symmetry

$$f(t) = f_{up}(t) + f_{down}(t)$$

Fluctuation of 2 d-d pairs of TSC

Averaged Treatment of <f(t)>

$$\langle f(t)\rangle = 2\times 6.6\int_0^{\infty}\frac{[R'-R_{dd}(t)]^2}{[R_{dd}(t)]^4}\mathrm{X}^2(R')dR'$$

$$\langle f(t)\rangle = \frac{13.2\sigma^2}{\sqrt{\pi}[R_{dd}(t)]^4}\int_0^{\infty}\sqrt{x}\exp(-x)dx = 13.2\frac{\sigma^2}{[R_{dd}(t)]^4}$$

$$\sigma = 0.372R_{dd}(t)$$

$$6m_d\frac{d^2\langle R_{dd}\rangle}{dt} = -BA\frac{11.85}{\langle R_{dd}\rangle^2} - 6\frac{\partial V_s(R_{dd};m,Z)}{\partial\langle R_{dd}\rangle}$$

BA = 0.846

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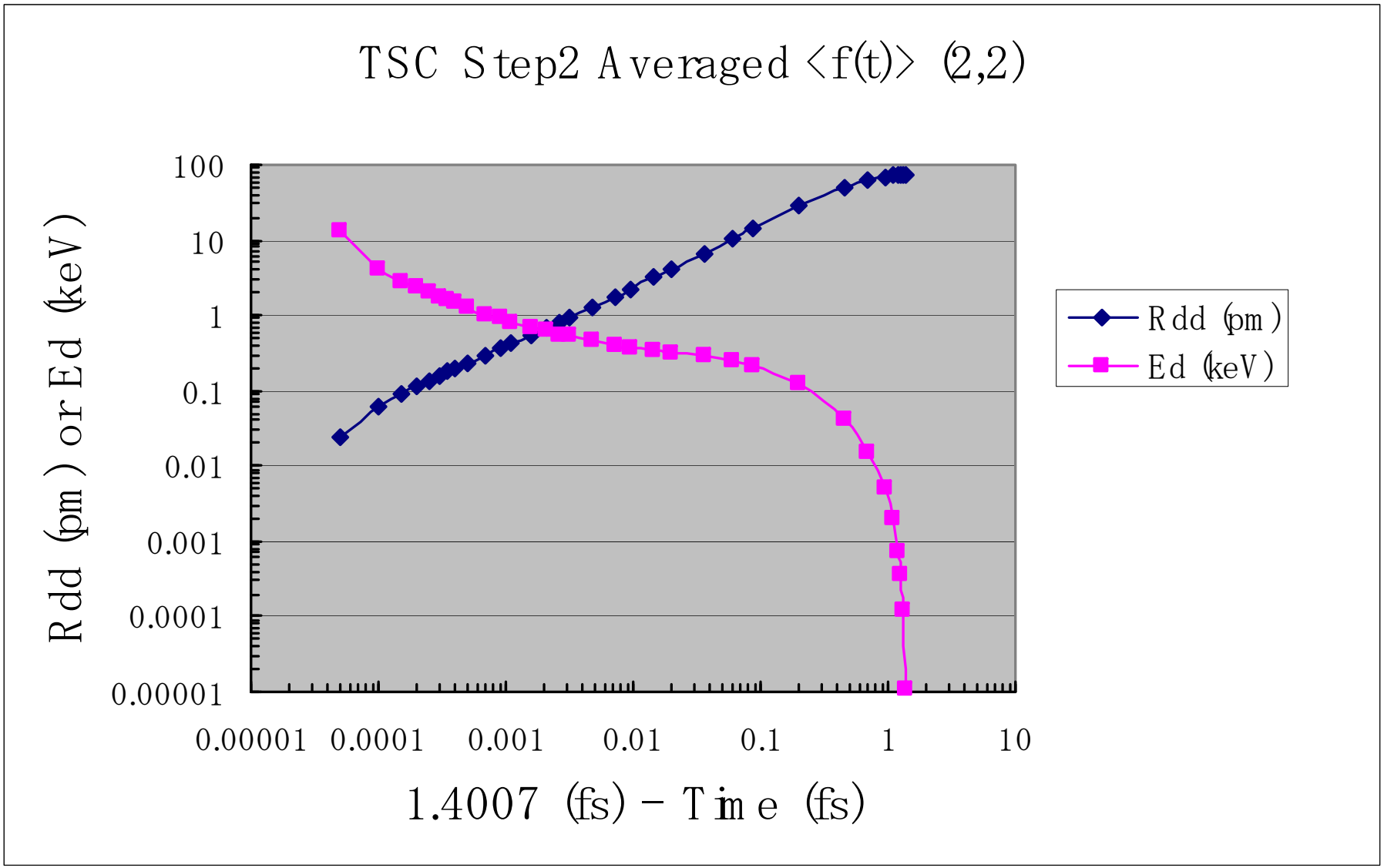
BA=0.846



E_d = 13.68 keV at R_{dd} = 24.97 fm, with Vtrap = -130.4 keV

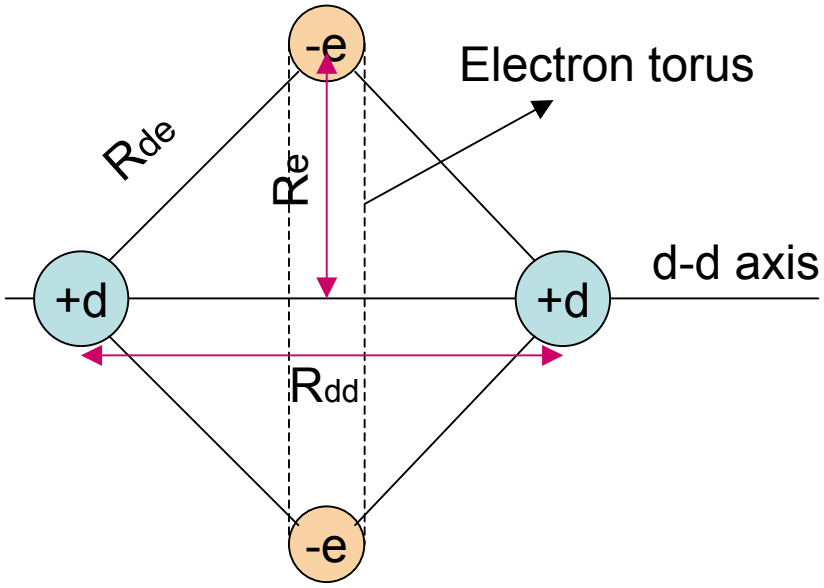
5.3 Time Dependent dd Trapping Potential of TSC

$$6m_d \frac{d^2\langle R_{dd}\rangle}{dt^2} = -\frac{11.85}{\langle R_{dd}\rangle^2} - 6\frac{\partial V_s(\langle R_{dd}\rangle; m, Z)}{\partial\langle R_{dd}\rangle} + 6.6\left\langle \frac{(R' - R_{dd})^2}{R_{dd}{}^4} \right\rangle$$

Approximate TSC Trapping Potential is given as

$$V_{tsc}(R' : R_{dd}(t)) = -\frac{11.85}{R_{dd}(t)} + 6V_s(R_{dd}(t); m, Z) + 2.2\frac{\left|R' - R_{dd}(t)\right|^3}{[R_{dd}(t)]^4}$$

Mean Particle Kinetic Energies of the “dede” System of TSC



$(e^2/R_e^2)=(m_e v_e^2/R_e)=(2E_{ke}/R_e)$

$R_e = R_{dd}/2$

$E_{ke} = 1.44/R_{dd}$: [keV] by R in pm

At R_{dd}=0.025 pm (25 fm)

E_{ke} = 57.6 keV
$E_{kd\text{-}d}$= 13.68 keV

$V_{tsc\text{-}min}$ = -130.4 keV

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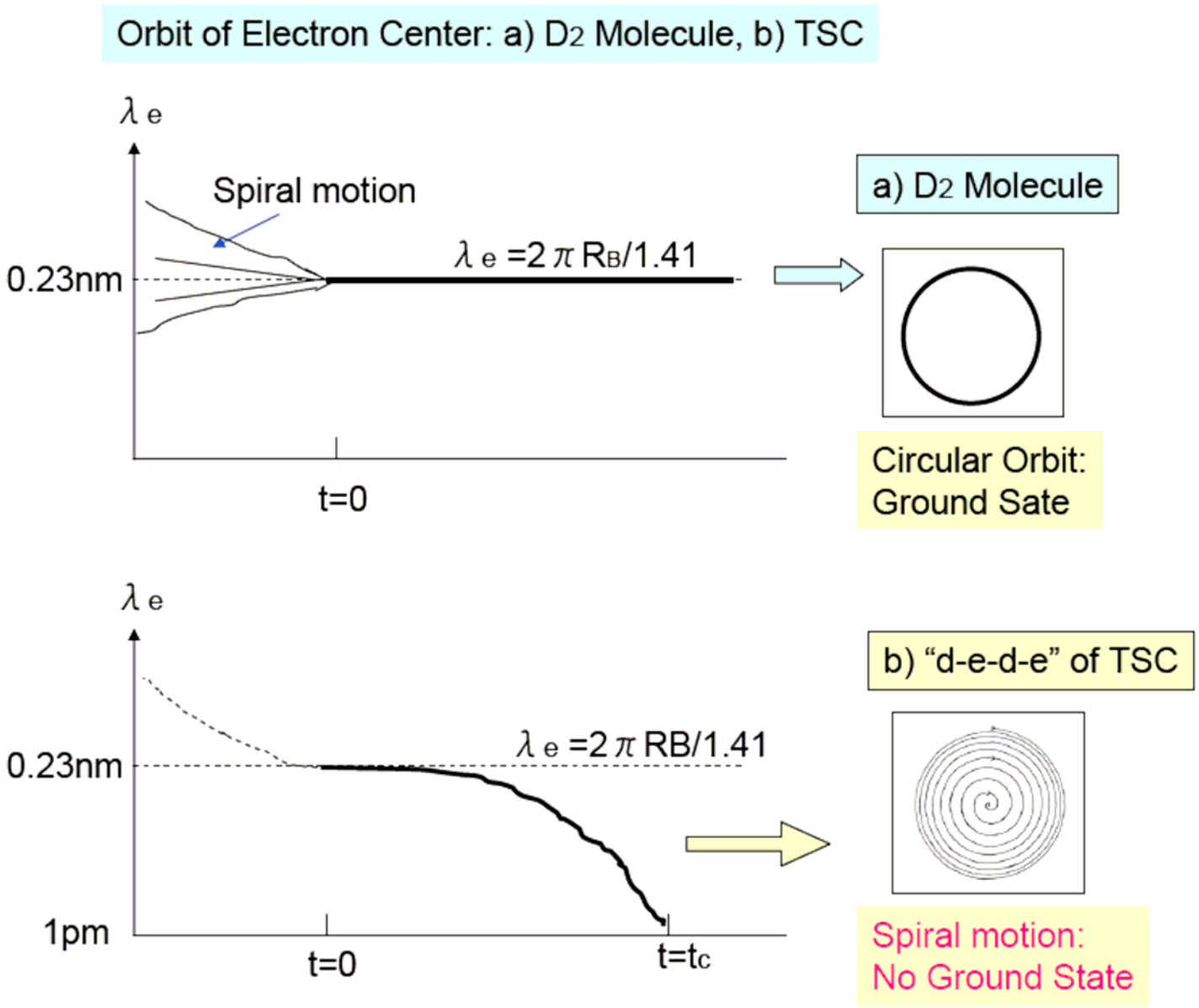


Fig.4: Time dependent behavior of effective electron wave length, a) D2 molecule, b) "d-e-d-e" EQPET molecule of 4D/TSC

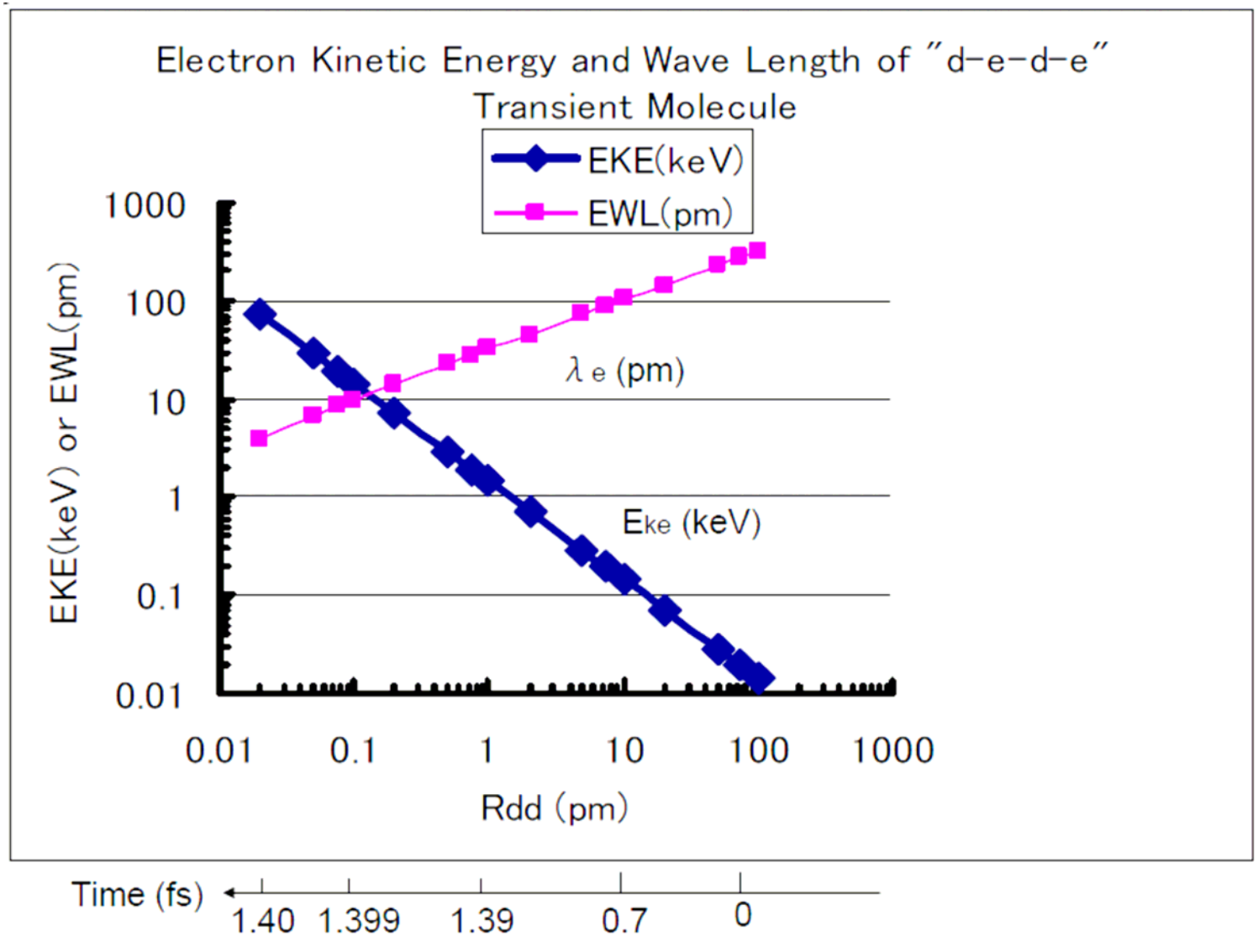
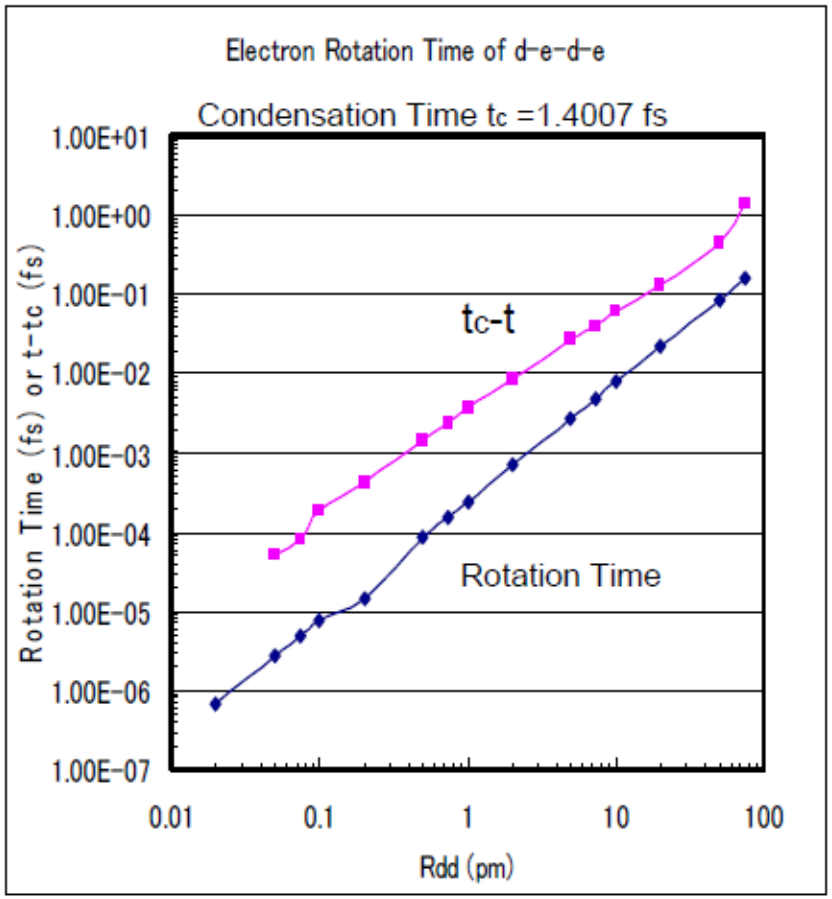
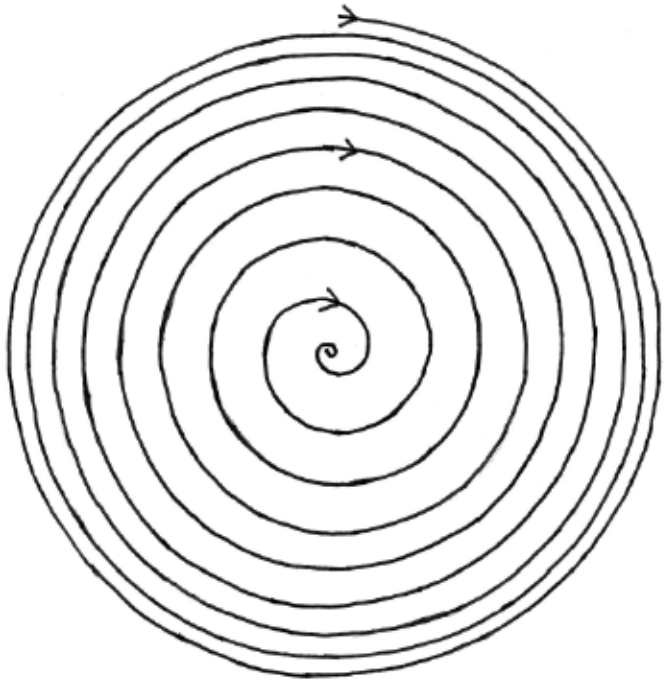


Fig.6: Time variation of mean electron kinetic energy (EKE) and its wave length (EWL) during the 4D/TSC condensation motion in 1.4007fs condensation time.

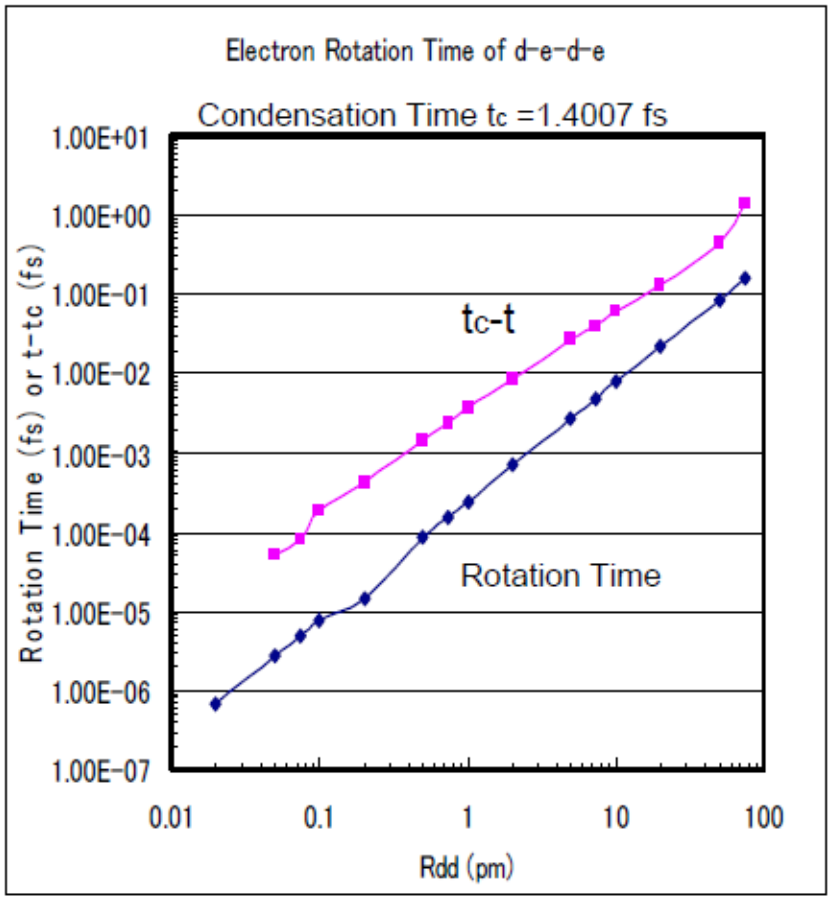


a) Mean rotation time of electron in "d-e-d-e" of TSC, mean rotation number is about 6 at every R_{dd} step

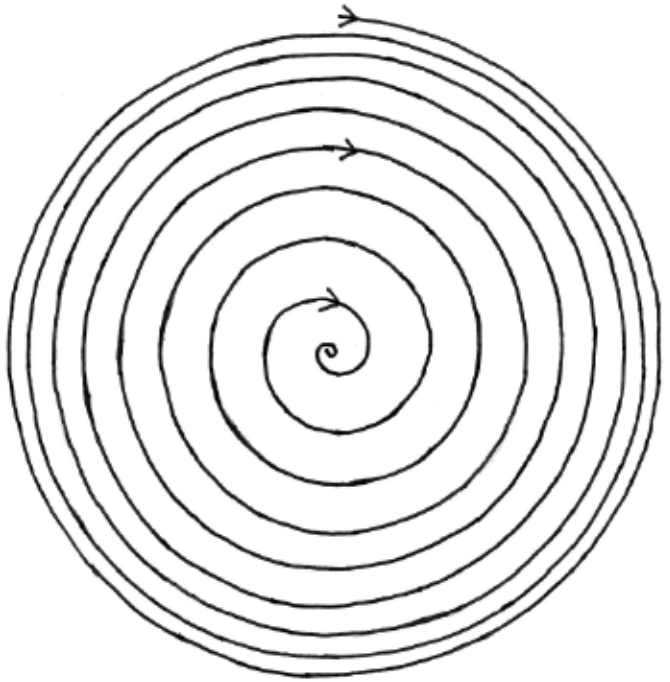


b) Feature of spiral motion of electron in 1.4007 fs condensation time interval

Fig.7: Mean rotation time of electron cloud center under 4D/TSC condensation motion (left) and expanded feature of electron spiral motion (right)



a) Mean rotation time of electron in "d-e-d-e" of TSC, mean rotation number is about 6 at every R_{dd} step



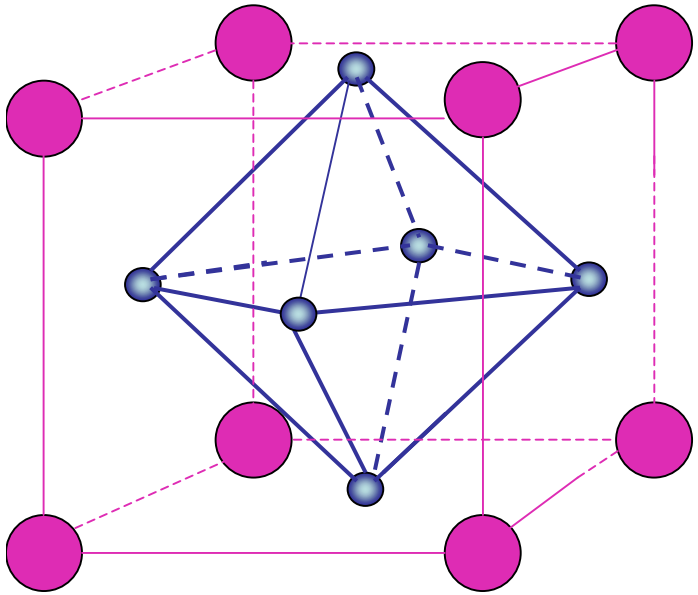
b) Feature of spiral motion of electron in 1.4007 fs condensation time interval

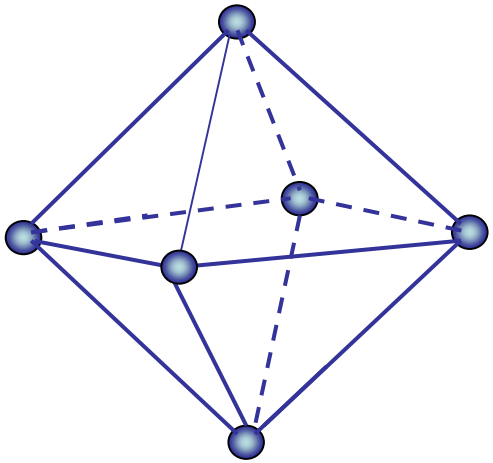
Fig.7: Mean rotation time of electron cloud center under 4D/TSC condensation motion (left) and expanded feature of electron spiral motion (right)

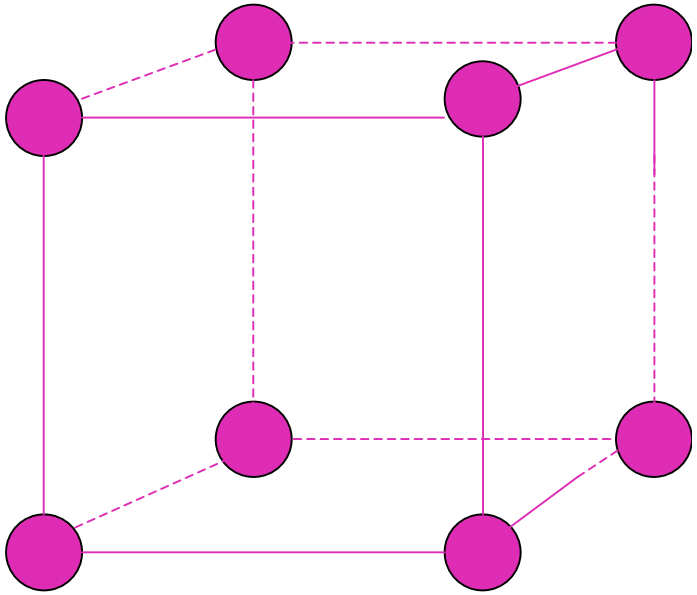
5.4 Application to 6D/OSC

Triaxis Octahedron

D_6^{2-} : 6D/OSC = 6D Octahedron + 8e Hexahedron







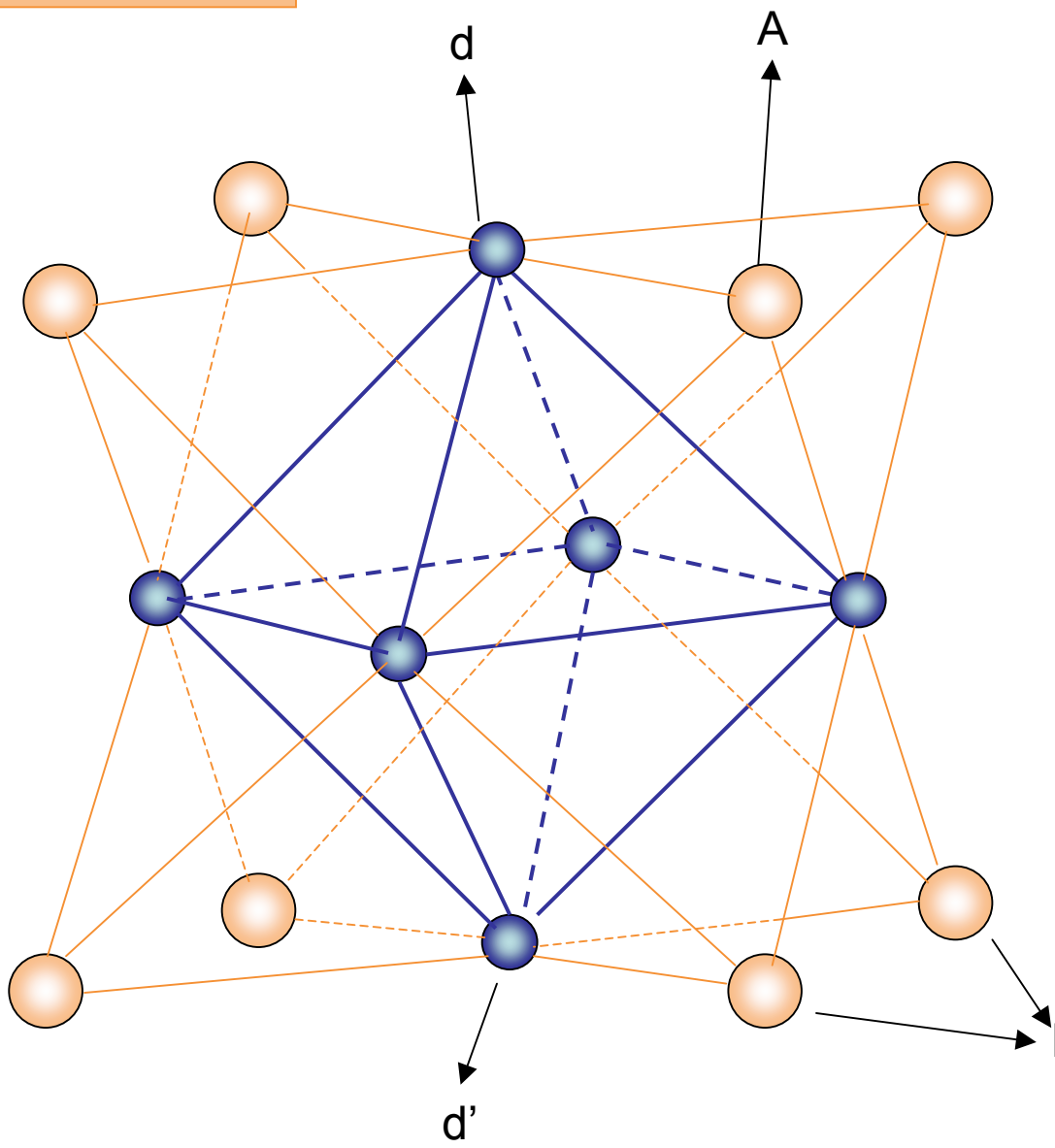
$-24(e^2/R_{de})$
$-24(e^2/R_{d'e})$

$12(e^2/R_{dd})$
$+4e^2/(1.414R_{dd})$

$12(e^2/R_{ee})$
$+ 12e^2/(1.414R_{ee})$
$+4e^2/(1.732/R_{ee})$

$R_{de}=0.707R_{dd}$ $R_{d'e}=1.22R_{dd}$ $R_{ee}=R_{dd}$

24 dde faces



6D(2-)/OSC

R_B =52.9 pm

R_{dd} = 1 (=1.414R_B)

$R_{d\text{-}cross}$= 1.414

$R_{d\text{-}CM}$ =1/1.732

R_{dA} = 1/1.414(=R_B)

$R_{A\text{-}CM}$ = 1/2.449

$R_{ed'}$ = 1.732/1.414

Langevin Equation for 6D(2-)/OSC

$$12m_d \frac{d^2 R_{dd}(t)}{dt^2} = -BA\frac{29.3}{[R_{dd}(t)]^2} - 24\frac{\partial V_s(R_{dd}(t);1,1)}{\partial R_{dd}(t)} + f(t)$$

12 (d-d) edges

Main condensation force of $6D^{2-}$

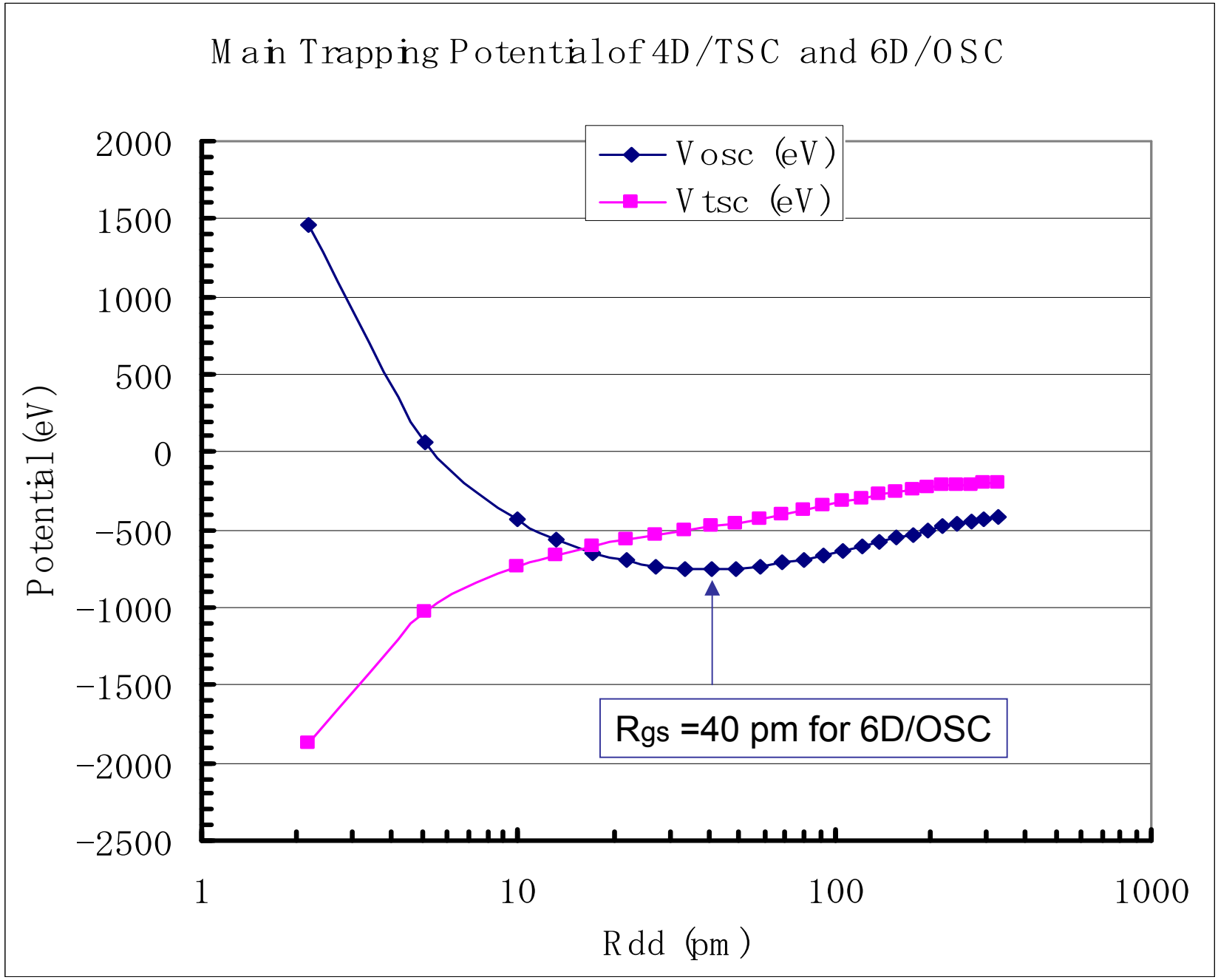
Constraint by 24 “dde” faces

$$f(t) = [-\frac{\partial \Delta E_c(R_{dd})}{\partial R_{dd}}] \mathrm{mod}[X^2(R'_{dd}; R_{dd}(t))]$$

Ratio=29.3/24=1.22
CF: 1.98 for 4D/TSC

Marginal!

Condensation might converge at R_{dd}=10pm !
This small negative entity nuclear-reacts with host metal nucleus by attraction?


Main Trapping Potential of 4D/TSC and 6D/OSC
Vosc (eV)
Vtsc (eV)
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
Potential (eV)
1
10
100
1000
Rdd (pm)
Rgs =40 pm for 6D/OSC

6. HMEQPET Method for Fusion Rate Quantification

- The role and merit of HMEQPET (heavy mass electronic quasi-particle expansion theory) method for approximating time-dependent TSC trapping potential and relating to the estimation of time-dependent Coulomb barrier penetration probabilities of 4d cluster is explained. HMEQPET provides a practical method for calculating time-dependent (hence time-averaged) fusion rate under TSC condensation, based on the Fermi's first golden rule.

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A Slice of Time-Dependent TSC Trapping Potential, which keeps balancing back to the Platonic Symmetric State

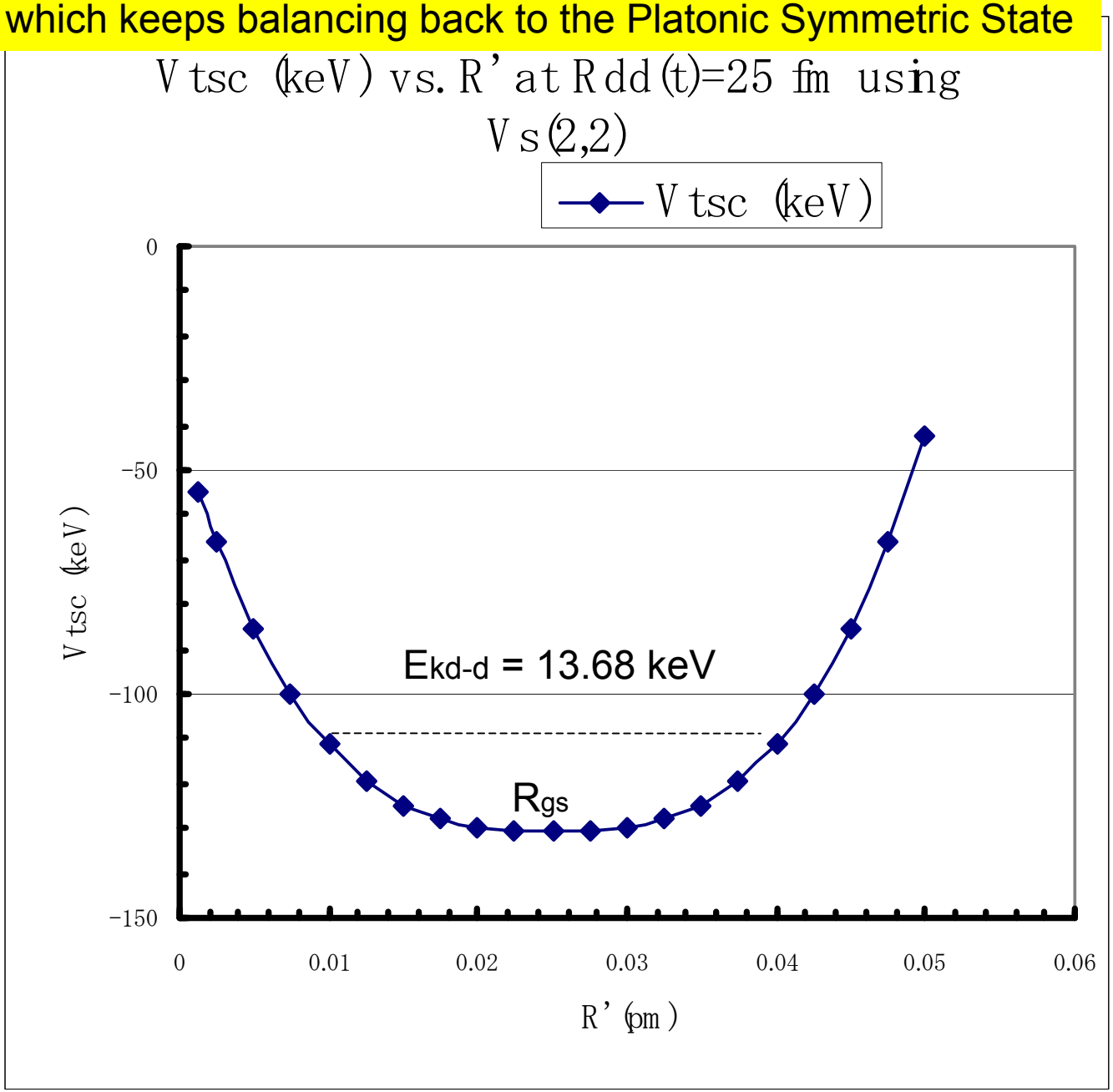

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Table-3: Calculated HMEQPET potentials and their parameters,
Egs-Vs-min gives mean relative kinetic energy of trapped d-d pair

Molecule	b0 (pm)	Rmin (pm)	Vs-min (keV)	E_{d-d} (keV)	**Rgs (pm)**	Egs (keV)
D_2	22	70	-0.03782	0.00268	**76.69**	-0.03514
dde*(2,2)	4.5	19.3	-0.1804	0.01013	**21.82**	-0.17027
dde*(5,2)	1.9	7.6	-0.4509	0.0208	**8.72**	-0.43007
dde*(10,2)	0.90	3.8	-0.9019	0.0418	**4.36**	-0.86012
dde*(20,2)	0.45	1.9	-1.8039	0.0837	**2.18**	-1.7202
dde*(50,2)	0.18	0.76	-4.5097	0.2094	**0.873**	-4.3003
dde*(100,2)	0.09	0.38	-9.0194	0.4196	**0.436**	-8.5998
dde*(200,2)	0.045	0.19	-18.039	0.843	**0.218**	-17.196
dde*(500,2)	0.018	0.076	-45.097	2.135	**0.0873**	-42.968
dde*(1000,2)	0.009	0.038	-90.194	4.336	**0.0436**	-85.858
dde*(2000,2)	0.0045	0.019	-180.39	8.984	**0.0218**	-171.406

Due to HUP, relative d-d kinetic energy should go up finally to about 10keV.

HMEQPET Method

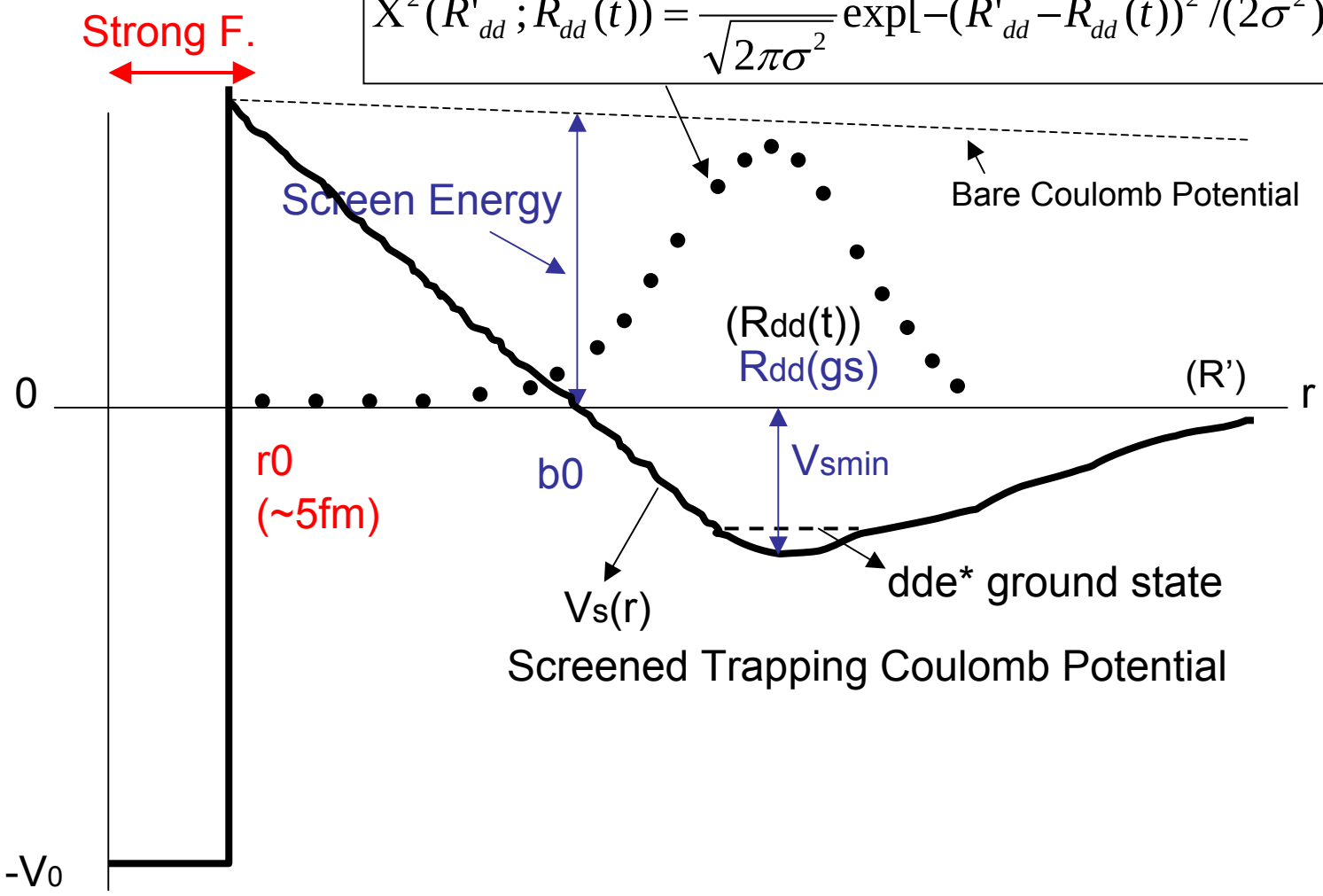
- Time-dependent (R_{dd}-dependent) d-d trapping potential of TSC can be approximated by $V_s(R;m,2)$ potential for dde*(m,2) EQPET molecule.
- Heavy Mass Cooper Pair Concept: e*(m,2)
- We got empirical relations:

$$b_0(m,2) = 0.206 R_{gs}(m,2)$$

$$m = 9000 / b_0(m,2)$$

Adiabatic Potential for Molecule dde*
and its ground state squared wave function

$$X^2(R'_{dd}; R_{dd}(t)) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-(R'_{dd} - R_{dd}(t))^2 / (2\sigma^2)]$$



Barrier Factor by Heavy Mass EQPET (HMEQPET)

$$b_0(m,2) = 0.206 R_{gs}(m,2)$$

$$m = 9000 \,/\, b_0(m,2)$$

$$\Gamma_{dd}(m,Z) = 0.218\sqrt{\mu}\int_{r_0}^{b_0(m,Z)} \sqrt{V_s(R_{dd};m,Z) - E_d}\, dR_{dd}$$

$$P_{nd}(m,Z) = \exp(-n\Gamma_{dd}(m,Z))$$

Instead of biasing V_s potential with $-V_{s\text{-}min}$, we regard that
Γ_{dd} for $R_{gs}=b_0$ is approximate solution.

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Table-2: Calculated time-dependent (equivalently R_{dd} dependent) barrier factors of 4D/TSC condensation motion

Elapsed Time (fs)	R_{dd} (pm)	P_{2d}: 2D barrier facotor	P_{4d}: 4D barrier factor
0	74.1 (D_2 molecule)	1.00E-85	1.00E-170
1.259	21.8 (dde*(2,2); Cooper pair	1.30E-46	1.69E-92
1.342	10.3	2.16E-32	4.67E-64
1.3805	4.12	9.38E-21	8.79E-41
1.3920	2.06	6.89E-15	4.75E-29
1.3970	1.03	9.69E-11	9.40E-21
1.39805	0.805 (muon-dd molecule)	1.00E-9	1.00E-18
1.39960	0.412	9.40E-7	2.16E-13
1.40027	0.206	3.35E-5	1.12E-9
1.40047	0.103	1.43E-3	2.05E-6
1.40062	0.0412	1.05E-2	1.12E-4
1.40070	0.0206 (TSC-min)	4.44E-2	1.98E-3

7.1.Fusion Rate for Steady dde* molecule

- **<Fusion Rate per pair> = $T_n \left| \Psi(r0) \right|^2$**

$T_n = (4\pi/h)\langle \Psi_f \left| W(R) \right| \Psi_i \rangle / \langle \Psi_f \left| \Psi_i \right\rangle$

W(R) : imaginary part of nuclear optical potential

$H_{int} = U(R) = V(R) + iW(R)$

$\left| \Psi(r0) \right|^2$: (Coulomb barrier penetration probability at R=r0)

R: d-d distance

Fusion Rates of Steady State dde* Molecules:

$$\lambda_{nd} = \frac{2}{\hbar}\langle W \rangle P_{nd}(r_0) = 3.04 \times 10^{21} P_{nd}(r_0)\langle W \rangle$$

Regarding b_0 as R_{gs}, we get $P_{nd}(r_0)$ values.

Here r_0 is 5 fm.

Molecule	$R_{dd}=R_{gs}$ (pm)	$P_{nd}(r_0)$; Barrier-Factor	<W> (MeV)	λ_{2d} (f/s)	λ_{4d} (f/s)
D_2	74.1	1.0E-85	0.008	2.4E-66	
dde*(2,2)	21.8	1.3E-46	0.008	3.2E-27	
μ dd	0.805	1.0E-9	0.008	2.4E+10	
4D/TSC-min	0.021	1.9E-3	62		3.7E+20

4D/TSC-min exists within $\Delta t=2\times10^{-20}$ s at final stage of condensation:
Decay of TSC: $\exp(-\lambda_{4d}\Delta t)= \exp(-7.6)=0.0006\rightarrow$ **4D fusion by 100% per TSC Generation. 4D Fusion Rate (1/s) becomes 4D/TSC Production Rate (1/s).**

<W> value Estimation

- Using $T_n \sim (PEF)^5$ in S-value analysis:

Cluster	<W> (MeV)
DD	0.008
DT	0.115
3D	1.93
4D	62.0

Scaling of PEF (Pion Exchange Force) for Nuclear Fusion by Strong Interaction

Two Body Interaction: PEF = 1

$n + \pi^+ \rightarrow p$

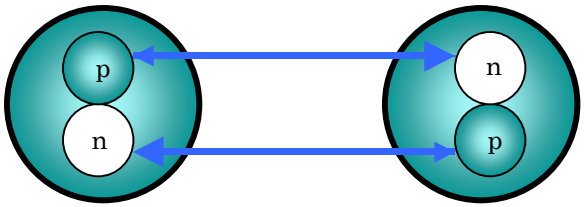
(udd) (ud*) (uud) : u ; up quark

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

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

: d* ; anti-down quark

For D + D Fusion; PEF = 2



One Pion Exchange Potential and PEF

One Pion Exchange Potential (Hamada-Johnston Potential)

$$V_{OPEP}(x) = v_0 \cdot (\vec{\tau}_1 \cdot \vec{\tau}_2)\left\{\vec{\sigma}_1 \cdot \vec{\sigma}_2 + (1 + \frac{3}{x} + \frac{3}{x^2})S_{12}\right\}\frac{\exp(-x)}{x}$$

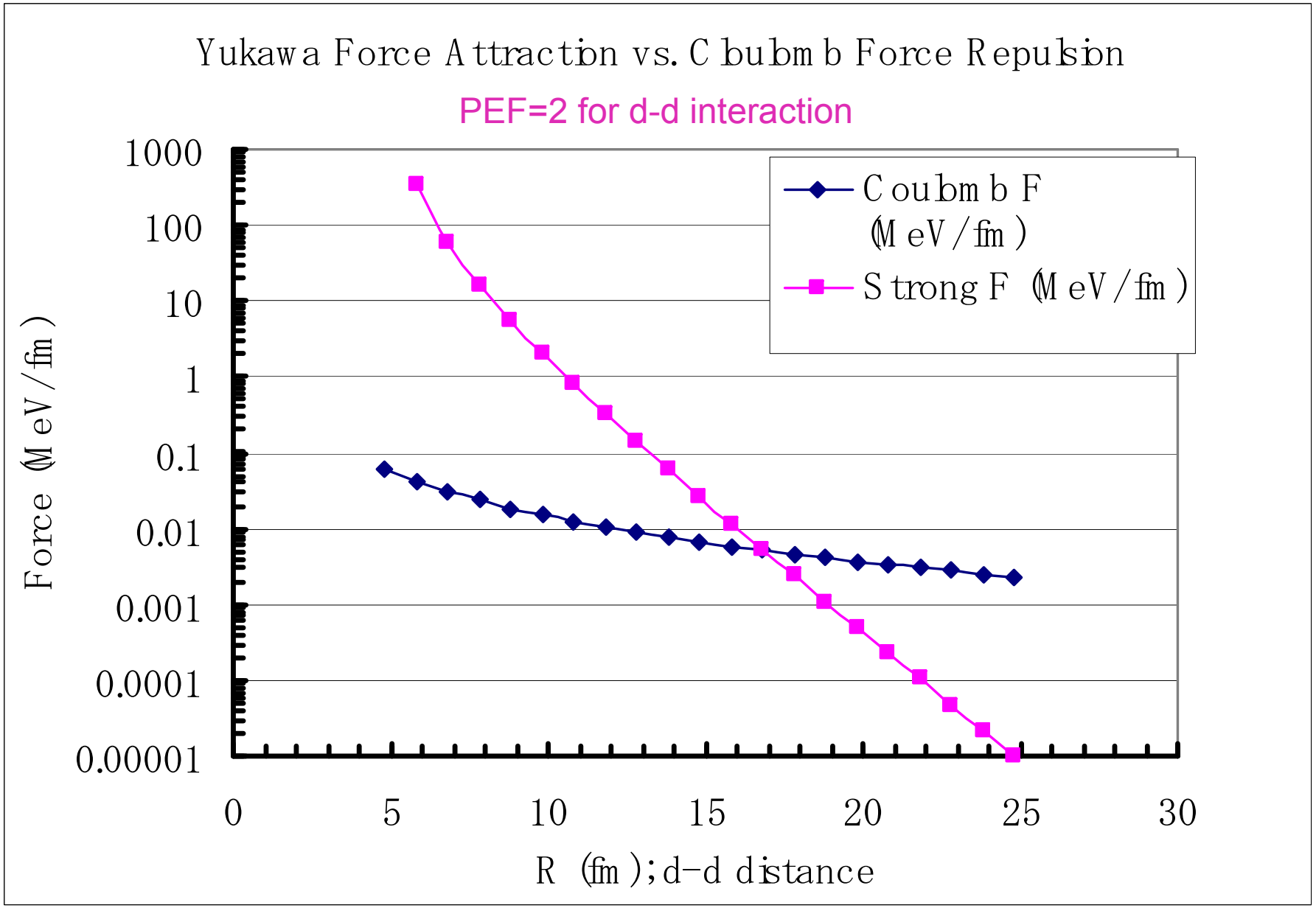
$$x = \frac{m_\pi c}{\hbar} r = \frac{r}{1.43}[fm]$$

Yukawa Potential $Y(x) = \frac{\exp(-x)}{x}$

$$v_0 = \frac{1}{3}\frac{f^2 m_\pi c^2}{\hbar c} = 3.65[MeV] \qquad S_{12} = 3\frac{(\vec{\sigma}_1 \cdot \vec{r})(\vec{\sigma}_2 \cdot \vec{r})}{r^2} - \vec{\sigma}_1 \cdot \vec{\sigma}_2$$

$$\langle OnePEF \rangle = -\frac{\partial \langle V_{OPEP}(x) \rangle_{\tau,\sigma}}{\partial r} = -\frac{1}{1.43}\frac{\partial \langle V_{OPEP}(x) \rangle_{\tau,\sigma}}{\partial x}$$

D-D Fusion: Strong Force vs. Coulomb Force



Estimation of S-value

- Scaling by PEF-values:

  $U(r) = V(r) + iW(r)$

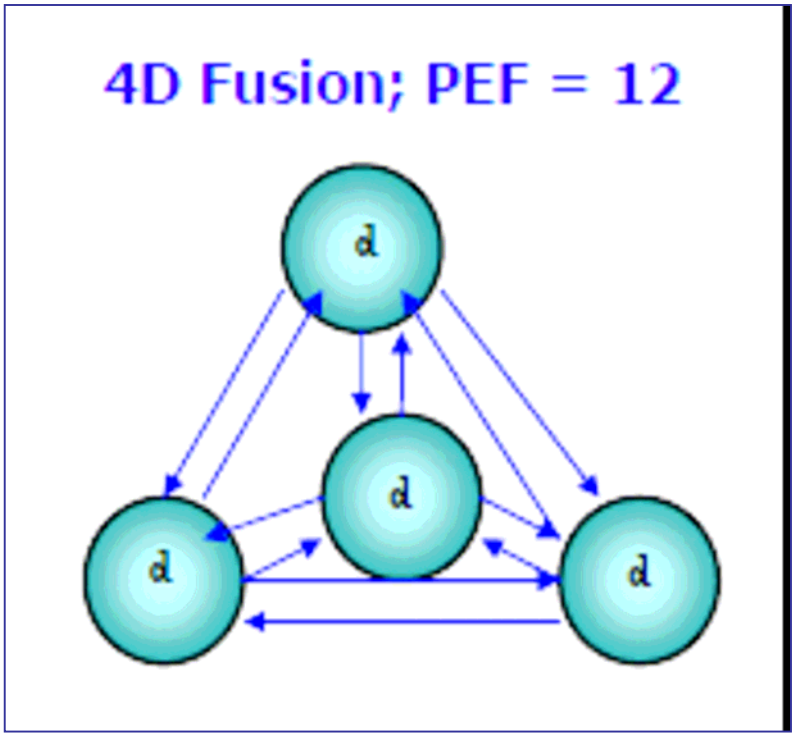
  $W(r) \sim W_0\delta(r - r0)$

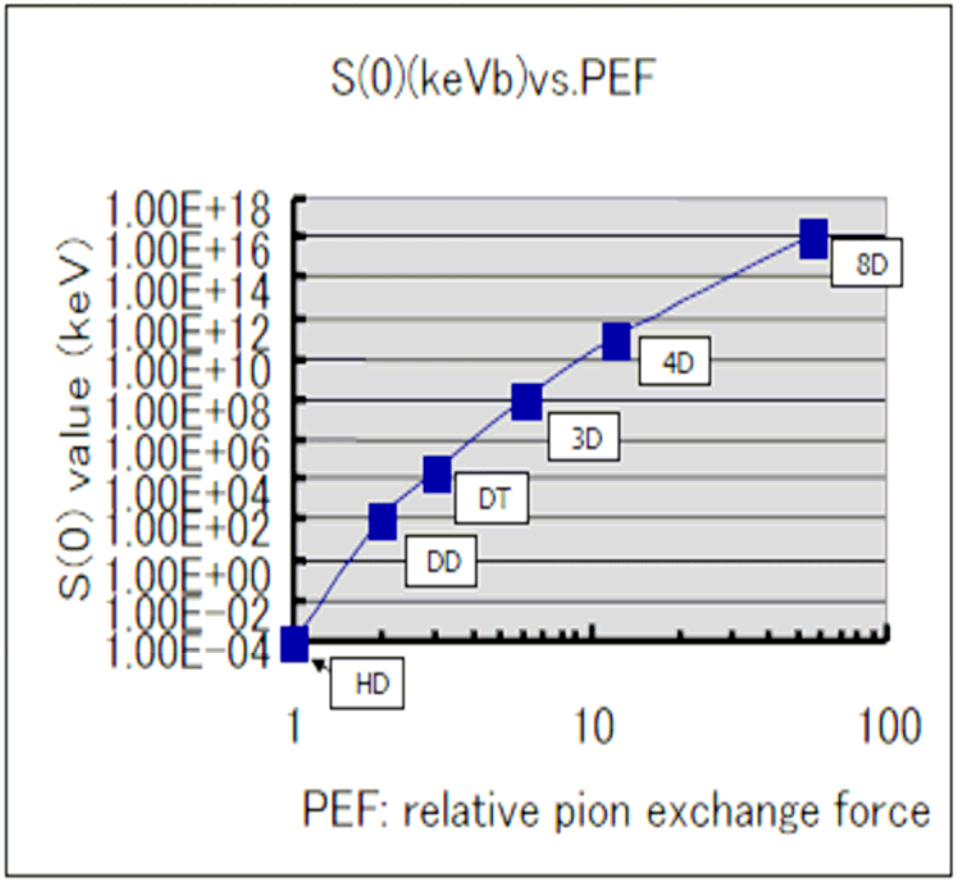
- PEF reflects size of contact sticking surface for fusion reaction by charged pion exchange:

  $S_n(0) \sim T_n^2 \sim (PEF)^N$

- S_{dd}=1.1E2 keVb, S_{dt} = 2E4 keVb, with PEF_{dd} =2, PEF_{dt}=3, PEF_{4d}=12
- N is roughly 11.4 to give S_{4d} = 1E11 keVb

Extrapolation of S(0) to multi-body D-fusion





7.2. 4D Fusion and ^{4}He Production Rate by TSC (Time-Dependent Fusion Rate)

- t_c : Condensation Time of TSC (1.4007 fs)
- η_{4d}: 4D Fusion Yield per TSC

$$\eta_{4d} = 1 - \exp\left(-\int_0^{t_c} \lambda_{4d}(t)dt\right)$$

$$\lambda_{4d}(t) = 3.04\times10^{21}\langle W\rangle P_{4d}(r_0; R_{dd}(t)) = 1.88\times10^{23} P_{4d}(r_0; R_{dd}(t))$$

$$\int_0^{t_c} \lambda_{4d}(t)dt = 1.88\times10^{23}\int_0^{t_c} P_{4d}(r_0; R_{dd}(t))dt \qquad \int_0^{t_c} P_{4d}(r_0 : R_{dd}(t)dt = 2.31\times10^{-22}$$

$$Y_{4d} = Q_{tsc}\eta_{4d}$$

Macroscopic 4D Fusion Production Rate

$\eta_{4d} \cong 1.0$ $\quad Y_{4d} \approx Q_{tsc}$ $\quad$ Q_{tsc} : TSC Generation Rate

8. Decay-Channel of ^{8}Be for S-Wave

4D → ^{8}Be(0+; 47.6 MeV) :

^{8}Be(0+) → ^{4}He(0+) + ^{4}He(0+) + 91.86 keV

Others (below) are forbidden by Spin-Parity Conservation (Odd parity)

- ^{3}He (1/2+)+ ^{5}He(3/2-)(n+^{4}He) – 11.13 MeV
- t (1/2+)+ ^{5}Li(3/2-)(p+^{4}He) - 21.68MeV
- p (1/2+)+ ^{7}Li (3/2-) - 17.26 MeV
- n(1/2+) + ^{7}Be(3/2-) – 18.90 MeV

Initial Spin Combination of 4d/TSC; S-Wave: Only 4d(0+) makes fusion

Entrance Channel

- ↑↑↑↑ ; J^{π}=4+, T=0
  (2 cases)
- ↑↑↑↓ ; J^{π}= 2+, T=0
  (8 cases)
- ↑↓↑↓ ; J^{π}= 0+, T=0
  (6 cases)
- Other cases: J^{π}= 3-, 1-
  for total 4d spin

Deuteron : J^{π}= 1+

Out-going Channel

- ^{8}Be*(4+: 47.6MeV) to 2^{4}He(0+:gs); forbidden
- ^{8}Be(2+:47.6MeV) to ^{4}He(o+: 20.21 MeV) + ^{4}He(2+: 27.42MeV) – 0.03MeV; forbidden
- ^{8}Be(0+:47.6MeV) to 2^{4}He(0+:gs)+47.6MeV is allowed. **(37.5%?)**

Discussion on 2D Fusion Rate

- $\tau_{(2,2)}$: Life Time of dde*(2,2)
- η_{2d} : Fusion Yield per dd pair

$$\eta_{2d} = 1 - \exp(-\lambda_{2d(2,2)}\tau_{(2,2)}) \qquad \eta_{2d} \approx \lambda_{2d(2,2)}\tau_{(2,2)}$$

$$Y_{2d} = Q_{dde*(2,2)}\eta_{2d}$$

a) If $\tau_{(2,2)}$ is 10^4 s (as X. Z. Li asserts), $\eta_{2d}=3.1\times10^{-23}$

Assuming $Q_{dde*}=10^{22}$ (1/s/cc), Y_{2d} = 0.3 (f/s/cc)

b) 2D Fusion rate may be larger, when TSC under condensation would break up to two dde* diminished size molecules. We need Monte-Carlo Langevin cal.

$$d + d + E_k = {}^4He^*(Ex) = {}^4He^*(Q + E_k)$$

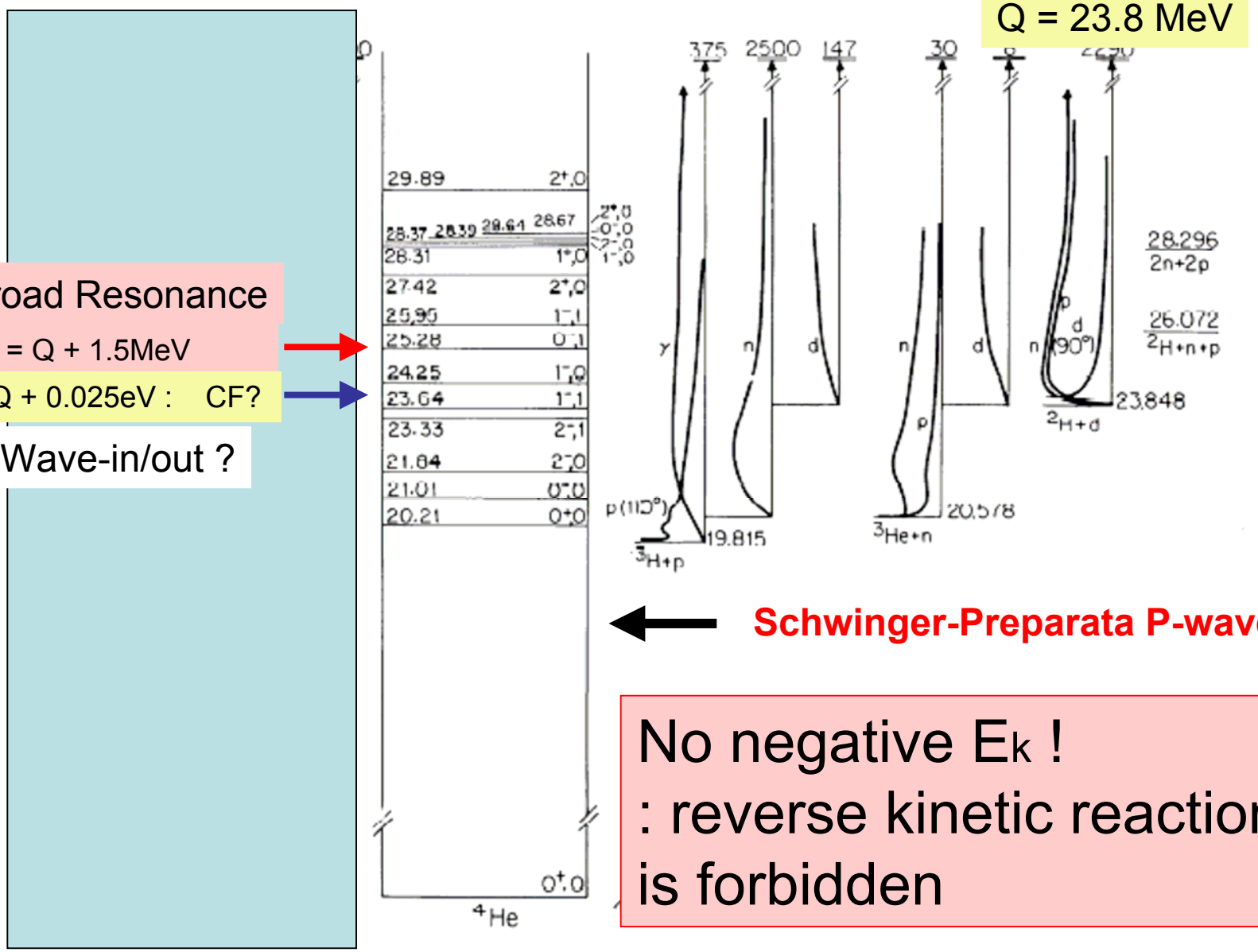
Q = 23.8 MeV

Broad Resonance

Ex = Q + 1.5MeV

Ex = Q + 0.025eV : CF?

P-Wave-in/out ?



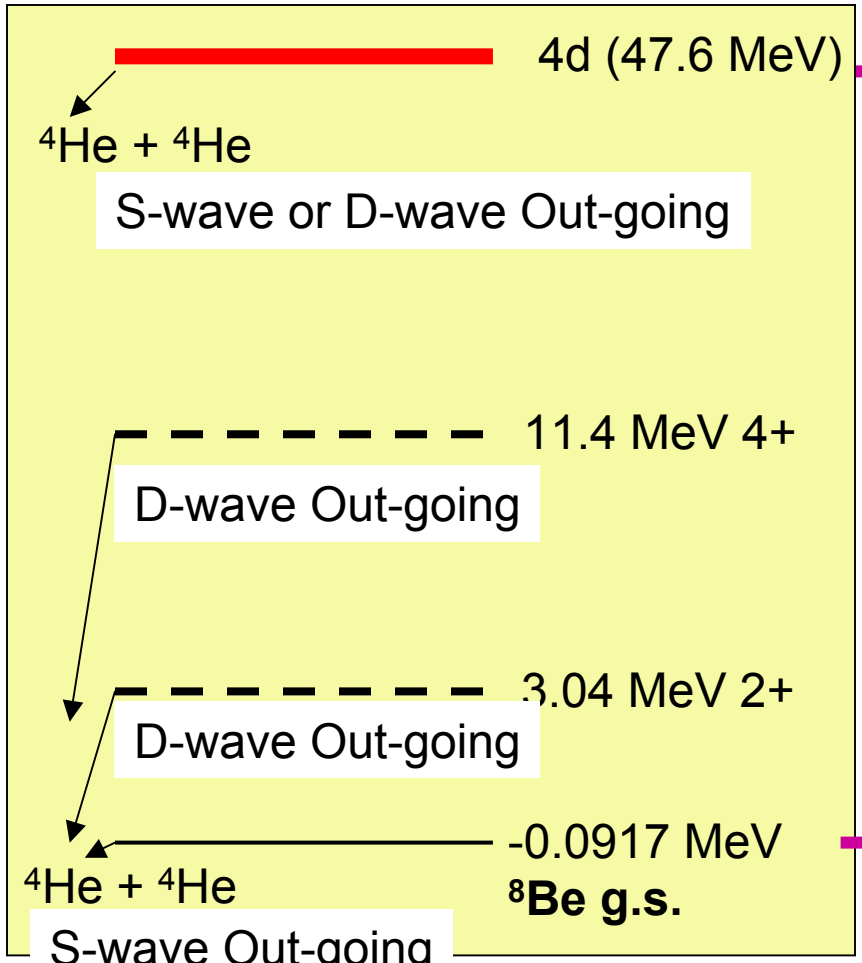
Schwinger-Preparata P-wave State ?

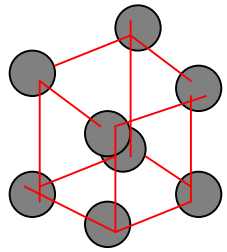
No negative E_k !
: reverse kinetic reaction is forbidden

D. Tilley, H. Weller, G. Hale: Nucl. Phys. A541, (1992)1-104 (Page 15)

Nestled among a series of four negative-parity, $T = 1$ levels in the range $E_x = 23 - 26$ MeV (which were at least 3 MeV higher in (1973FI04)) is a new $1^-, T = 0$ level at $E_x = 24.25$ MeV that has important effects on the d + d reactions at low energies. Isospin mixing between this state and the $^3P_1, T = 1$ level at $E_x = 23.64$ MeV causes significant differences in the p-wave part of the d + d reactions, as have been observed in muon-catalyzed (1984BA1W) and polarized (1981AD07) d + d fusion experiments. The 1^-, $T = 0$ level was seen by (1981GR16) in their $^2H(d, p)^3H$ analyzing-power data, but no evidence of their proposed 4^+ level at $E_x = 24.6$ MeV was found by (1989HA2A) in fitting their measurements.

$4D \rightarrow {}^4He + {}^4He + 47.6MeV$ (Final State Interaction)

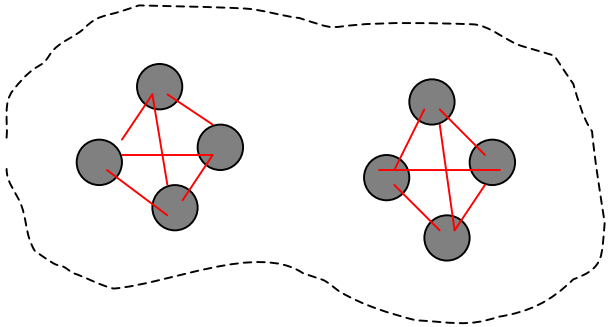




Transient Cube

Transition to
Two regular
Tetrahedrons

Two alpha-clusters



Life time : 6.7E-17 s

Final Sate Interaction of ^{8}Be*(Ex=47.6MeV)

$$
\begin{aligned}
^{8}\mathrm{Be(g.s.)} &\rightarrow {}^{4}\mathrm{He} + {}^{4}\mathrm{He} + 91.86\ \mathrm{keV}, \\
&\rightarrow {}^{3}\mathrm{He} + {}^{5}\mathrm{He}\,(\mathrm{n} + {}^{4}\mathrm{He}) - 11.13\ \mathrm{MeV}, \\
&\rightarrow \mathrm{t} + {}^{5}\mathrm{Li}\,(\mathrm{p} + {}^{4}\mathrm{He}) - 21.68\ \mathrm{MeV}, \\
&\rightarrow \mathrm{d} + {}^{6}\mathrm{Li} - 22.28\ \mathrm{MeV}, \\
&\rightarrow \mathrm{p} + {}^{7}\mathrm{Li} - 17.26\ \mathrm{MeV}, \\
&\rightarrow \mathrm{n} + {}^{7}\mathrm{Be} - 18.90\ \mathrm{MeV}.
\end{aligned}
$$

Summary-1

- **P**latonic Symmetric **A**rrangement realizes Energy-Minimum State of Many-Body System.
- PA appears in D-atom, D_2, D_2^+,D_3^+ ,and 4D/TSC.
- PA appears in CMNS of 4D/TSC for Coulombic Interaction and Strong Interaction.
- Dynamic PA is of key for 4D Cluster Fusion.
- Good solution by Molecular Dynamics with Langevin Eq., for Platonic Systems as, D, D_2, D_3^+ and 4D(H)/TSC.
- About 100% 4D-Fusion per TSC generation!

Summary 2

- Only 4D(H)/TSC can condense ultimately to 10-20 fm radius size.
- Bosonized e(1 /2)+e(-1/2) coupling for dede system makes D_2 type faces of TSC to help ultimate condensation.
- $6D^{2-}$/OSC converges its condensation at about R_{dd}=40 pm, but closer d-d distance in transient.
- Single $<e^->$-center states for dde (D_2^+) faces of OSC enhances constraint (friction) for condensation.

9. Conclusions

- One dimensional **Langevin equations** for treating dynamic motion of D-clusters under Platonic symmetry were formulated.
- **Only 4D/TSC makes ultimate condensation** to form 10-20 fm size charge-neutral entity, among D_2, D_3^+, 4D/TSC and $6D^{2-}$/OSC.
- Almost **100% (Smaller by spin) 4D fusion** with two ^{4}He ashes may take place by one 4D/TSC generation in metal-D system dynamics.