Model Mechanism for AHE by Nano-Metal and H(D)-Gas

Akito Takahashi

Technova Inc., Tokyo, Japan

Professor Emeritus, Osaka University

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AHE at Higher Temperatures by Binary Ni-based Nano-Metals and H(D)-gas

By ICCF20 papers of Takahashi et al, Kitamura et al and Iwamura et al

Anomalous Heat Effect (AHE) : Data have been obtained by Ni-based binary nano-metals (PNZ and CNZ) at 200-300 deg C range :

Summary:

1) AHE has been observed at elevated temperatures in 200-300 deg C.
2) AHE has been confirmed by repeated observation of excess heat-power
3) AHE was lasting for long time span as several days.

4) **AHE has been seen after D(H) loading ratios saturated.**
5) **AHE is therefore some surface sited effect by in/out of D(H)-gas**.

6) Observed long lasting heat gave **several GJ/mol-H (or several tens keV/atom-H)**.
7) Level is not H(D) absorption energy.

8) AHE at 200-300 deg C is **impossible to explain by known chemical reactions**.
9) Pd only nano-metals do not work at higher temperatures than 100 deg C.
10) Ni only nano-metals do not work well at room temperature and elevated temperatue

[1] A. Takahashi, A. Kitamura, K. Takahashi, R. Seto, T. Yokose, A. Taniike and Y. Furuyama: Anomalous Heat Effect by interaction of nano-metals and H(D)-gas, Proc. ICCF20 to be published in JCMNS

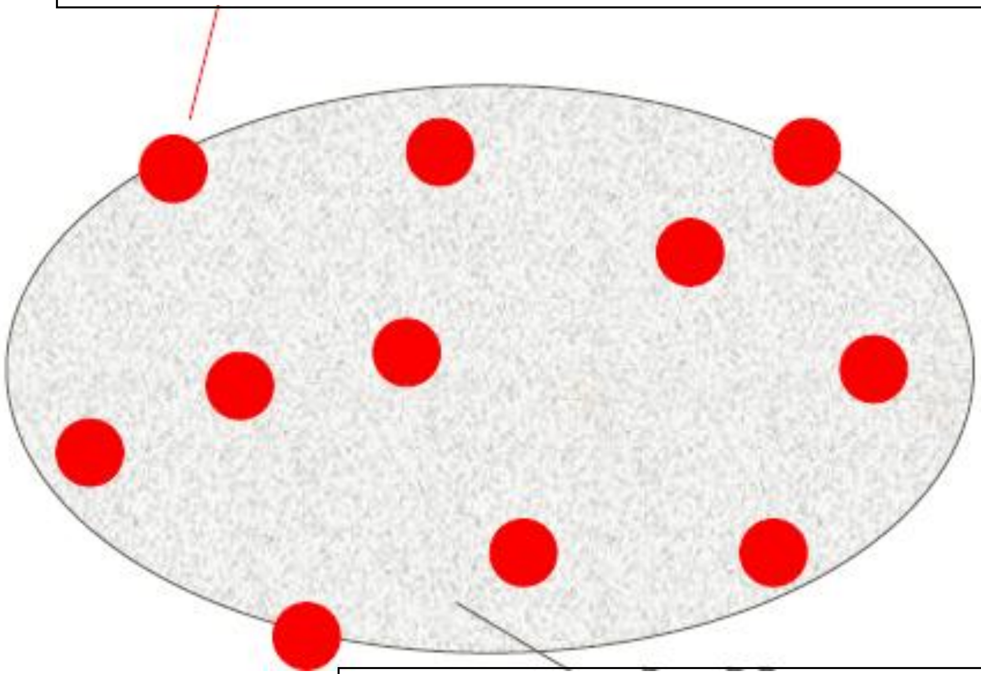
[2] Akira Kitamura, Akito Takahashi , Koh Takahashi, Reiko Seto, Yuki Matsuda, Yasuhiro Iwamura, Takehiko Itoh, Jirohta Kasagi, Masanori Nakamura, Masanobu Uchimura, Hidekazu Takahashi, Tatsumi Hioki, Tomoyoshi Motohiro, Yuichi Furuyama, Masahiro Kishida: Collaborative Examination on Anomalous Heat Effect Using Nickel-Based Binary Nanocomposites Supported by Zirconia, Proc. ICCF20 to be published in JCMNS

[3] Y. Iwamura, T. Itoh, J. Kasagi, A. Kitamura, A. Takahashi and K. Takahashi: Replication Experiments at Tohoku University on Anomalous Heat Generation Using Nickel-Based Binary Nanocomposites and Hydrogen Isotope Gas, Proc. ICCF20 to be published in JCMNS

[4-5] Papers by A. Kitamura and Y. Iwamura, this workshop

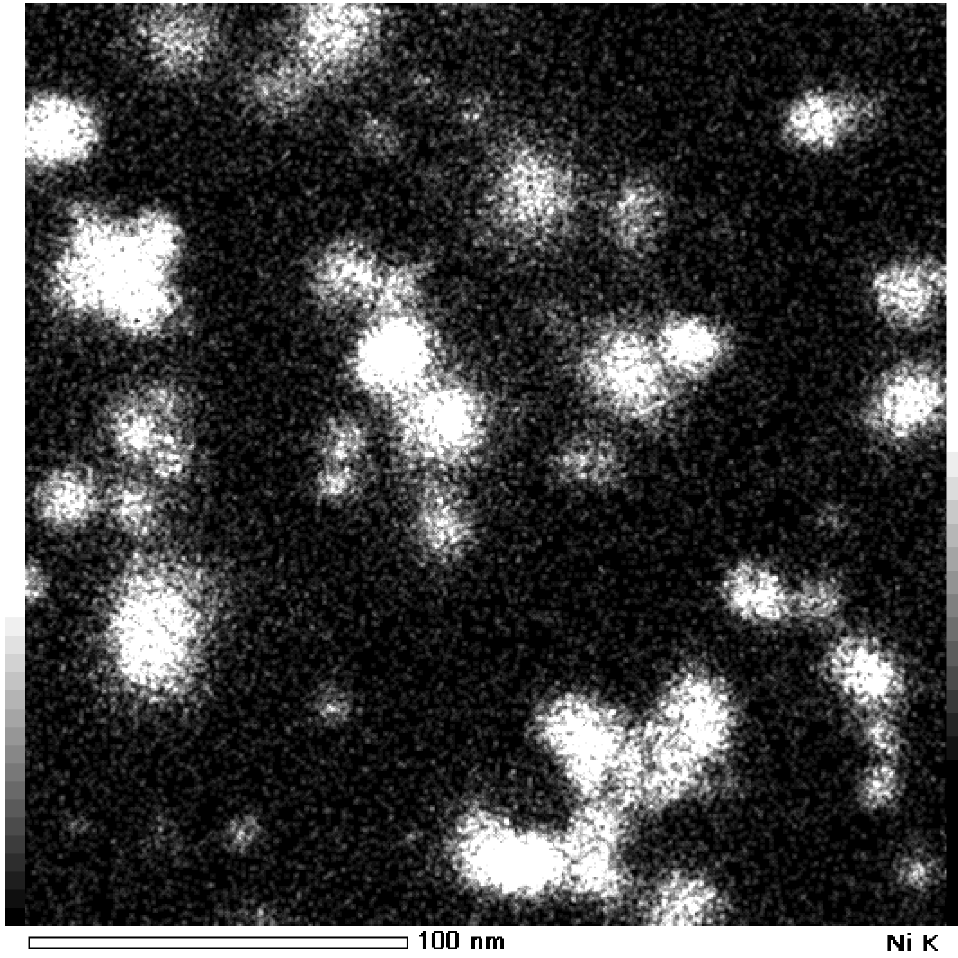
The Making of Mesoscopic Catalyst
To Scope CMNR Anomalous Heat Effect (AHE)
on/in Nano-Composite Metal-particles

Meso-Catalyst: as Core/"Incomplete"-Shell Structure
Mono-Metal (with oxide-surface layer) Pd
Or Pd-Ni Binary-metal nano-particles: mesoscopic size = 2-10 nm diam.

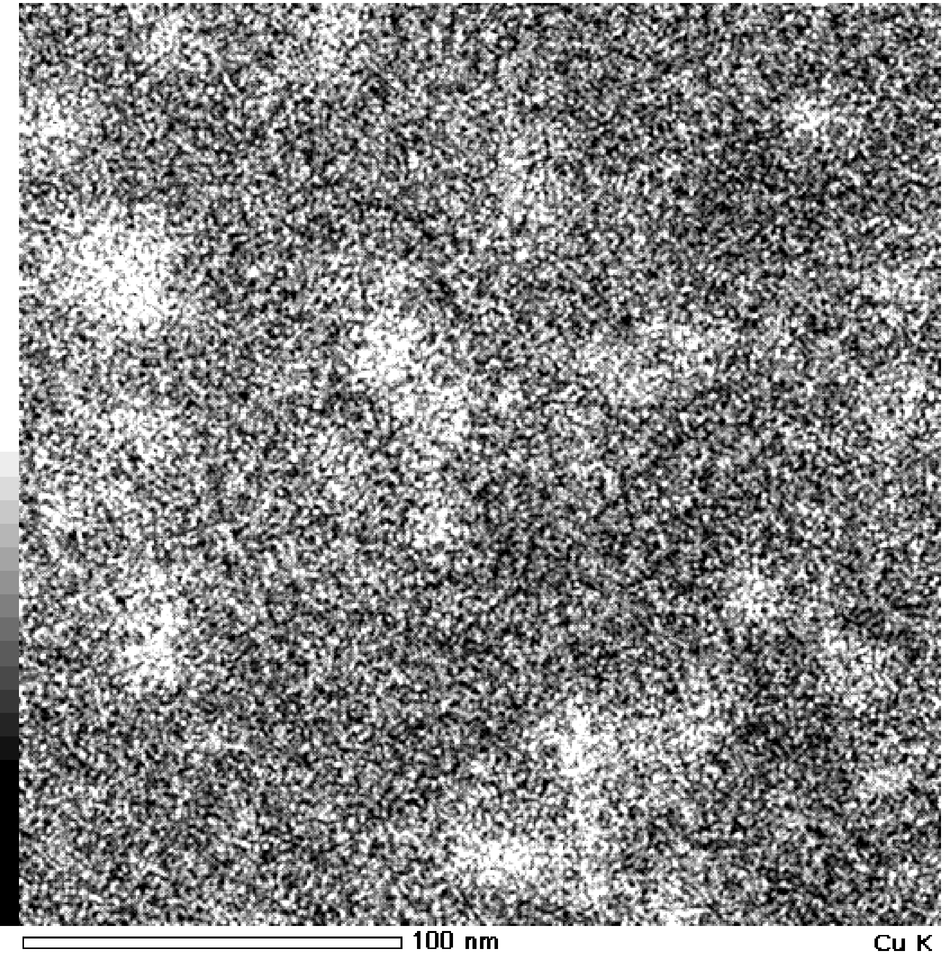


Ceramics Supporter: several microns flake
(ZrO_2, zeolite, γ-Al_2O_3, meso-porous SiO_2 etc.)

STEM/EDS mapping for CNS2 sample, showing that Ni and Cu atoms are included in the same pores of the mp-silica with a density ratio approximately equal to the mixing ratio (Cu1/Ni7).

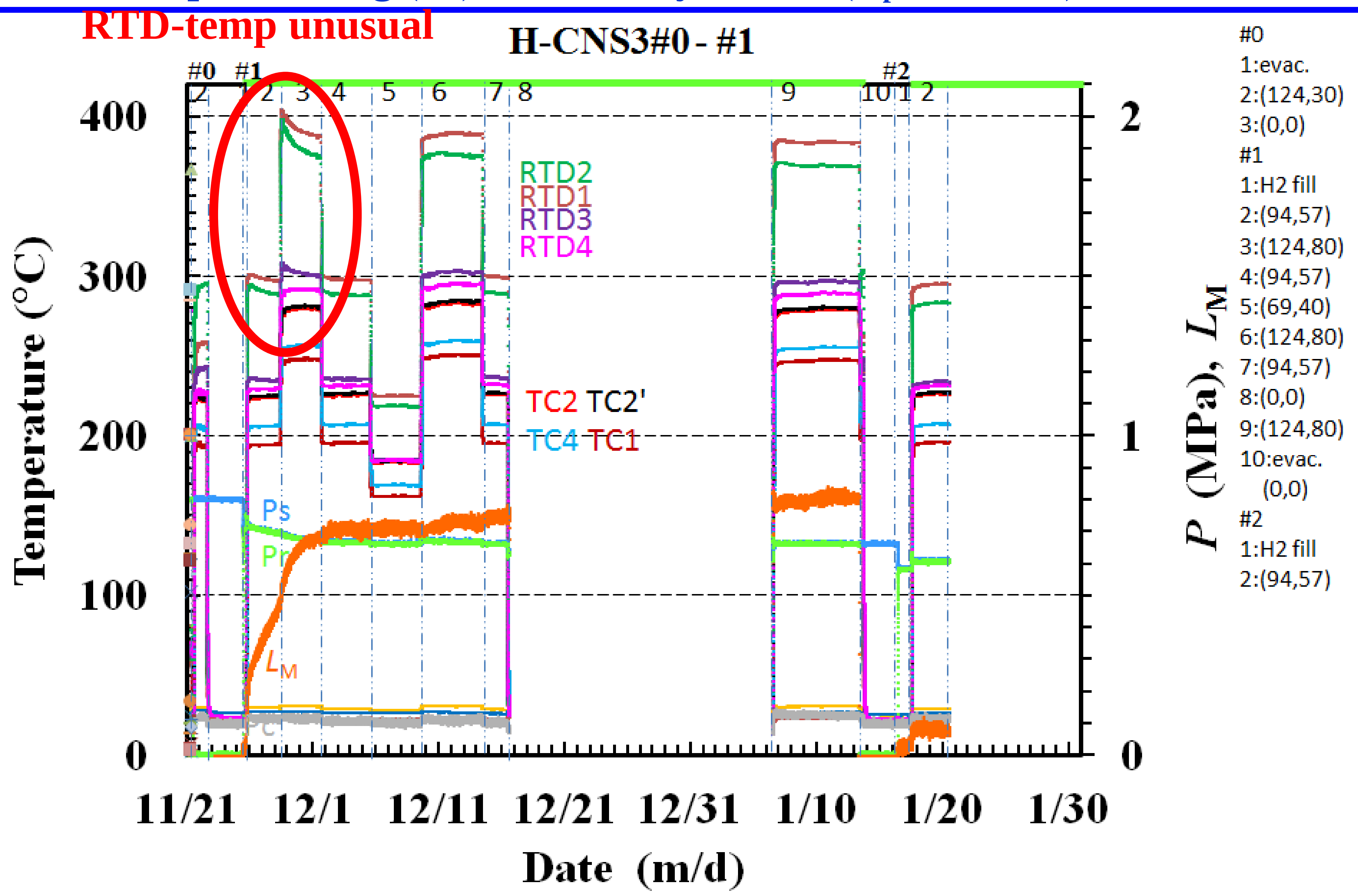


Ni

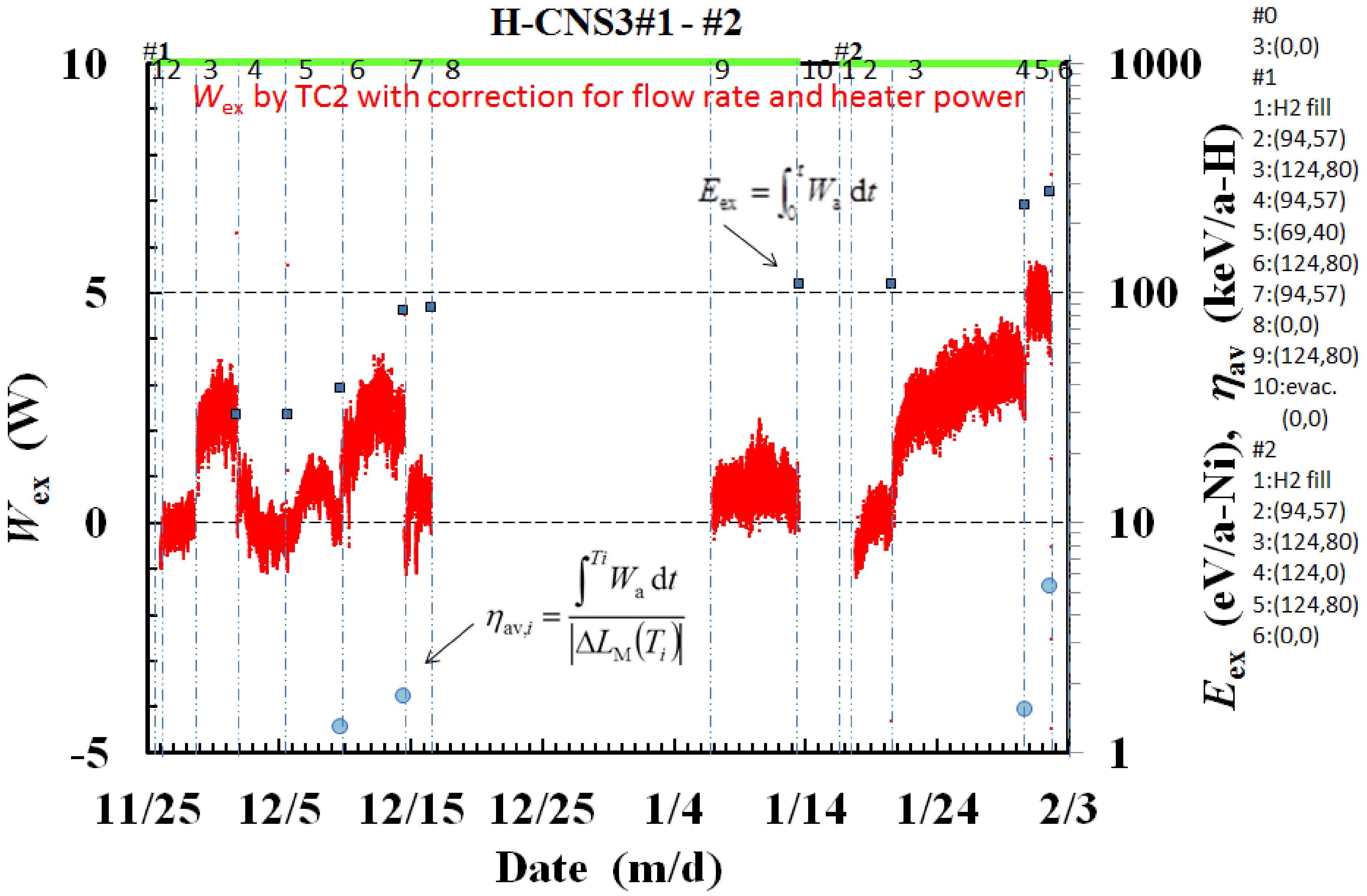


Cu

CNS3 sample: baking (#0) followed by #1 run (R_f = 20 ccm)

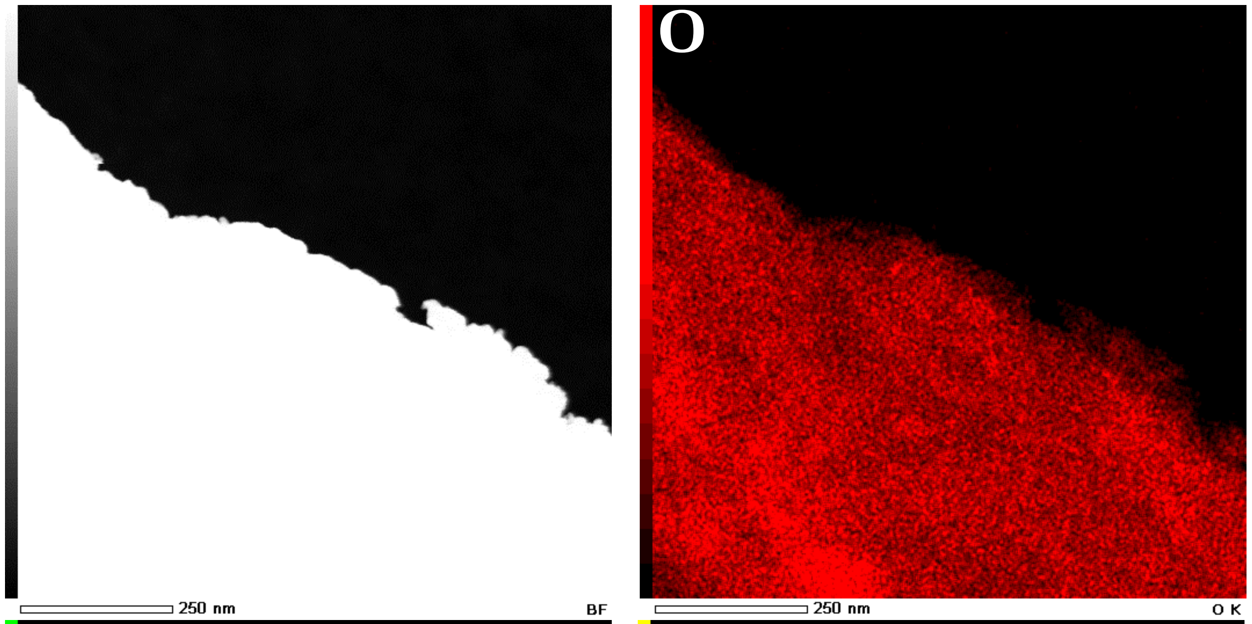


Excess power and energy by Cu1Ni10/meso-silica with H-gas at ca. 300 C

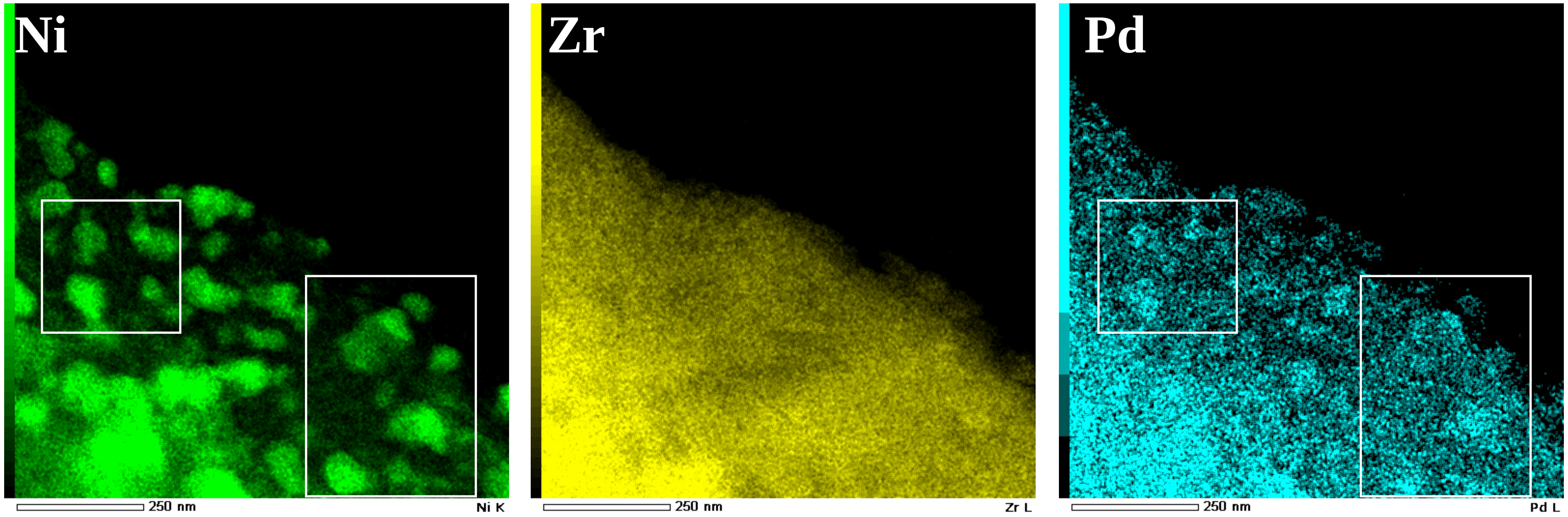


One of the typical examples of STEM/EDS pictures : PNZ3r-A_000

(After absorption exp.)

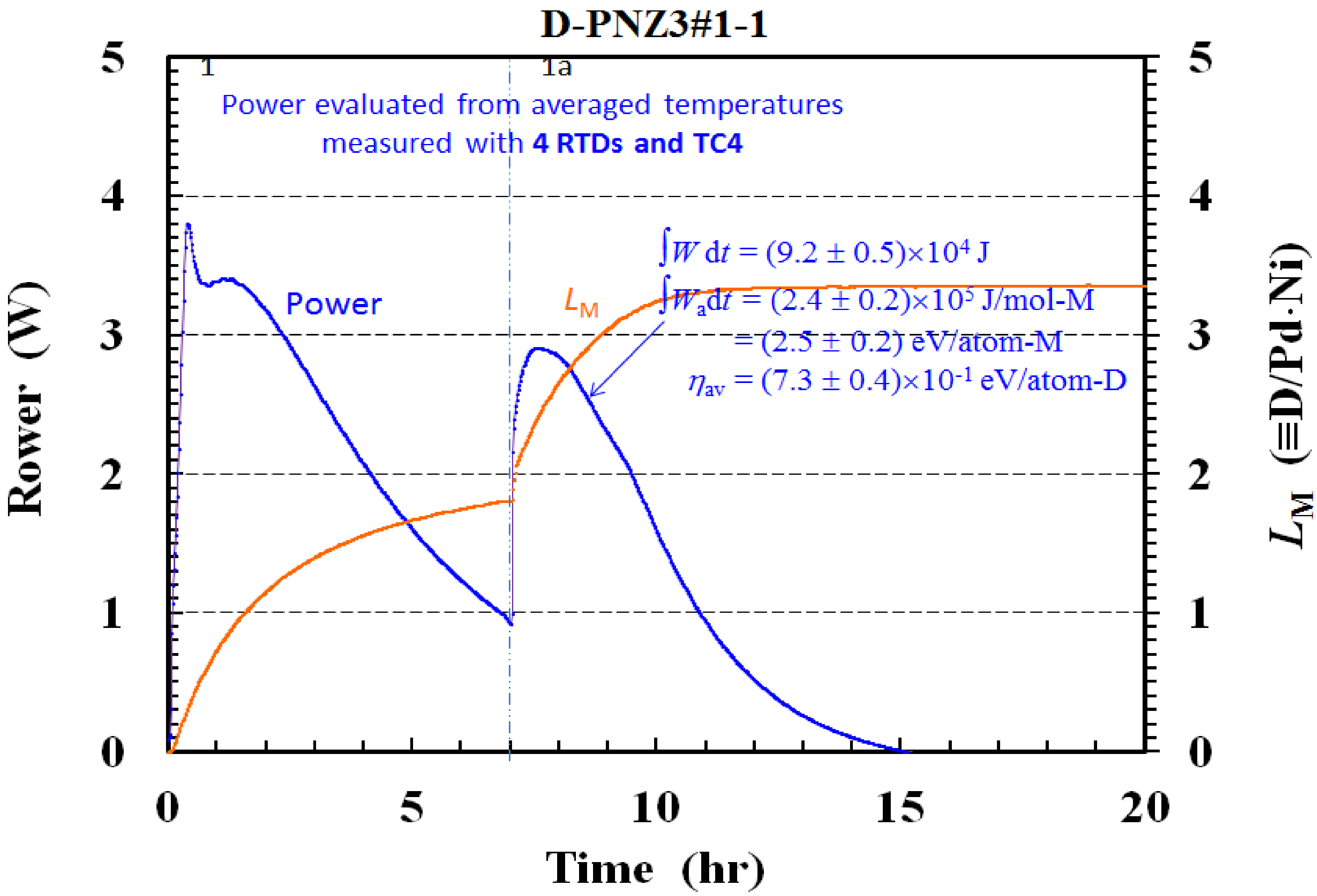


Reduced Ni and Pd occupying almost the same position, and separated from ZrO_2 bulk. Pd1Ni7/ZrO2



250nm

Room Temperature Run: Large Loading Ratio, Heat Burst



#0
3:(0,0)
#1
1:D2 fill
1a: refill

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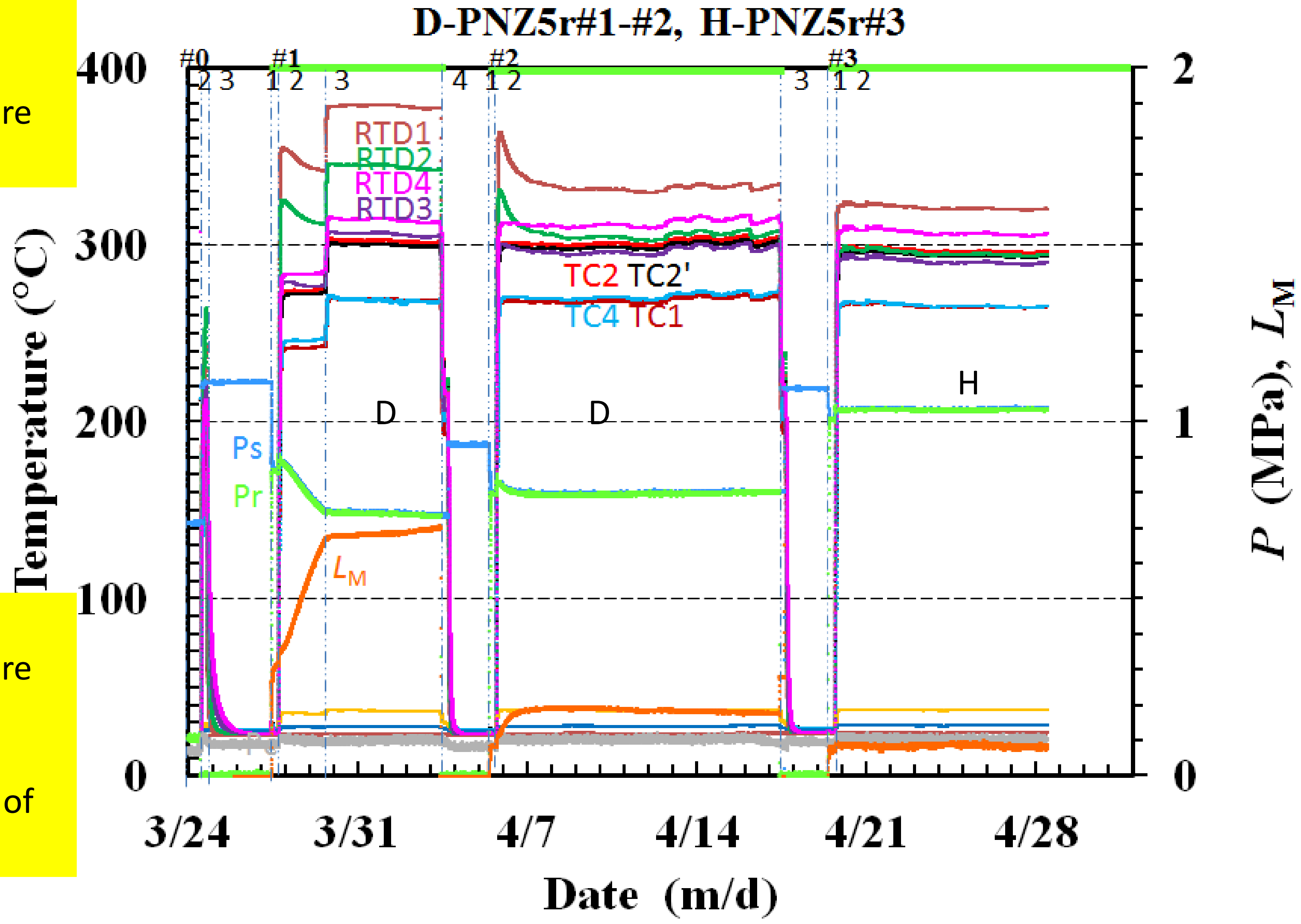
PNZ5r sample (Pd1Ni7/zirconia, re-oxidized): Kitamura et al, this workshop

Local
Larger
Temperature
Elevation



#0
1:evac.
2:(124,30)
3:(0,0)
#1
1:D2 fill
2:(124,80)
3:(140,90)
4:(124,30)
evac.
(0,0)
#2
1:D2 fill
2:(140,90)
3:(124,30)
evac.
(0,0)
#3
1:H2 fill
2:(140,90)

Excess
Temperature
Elevation
After
Saturation of
D-loading

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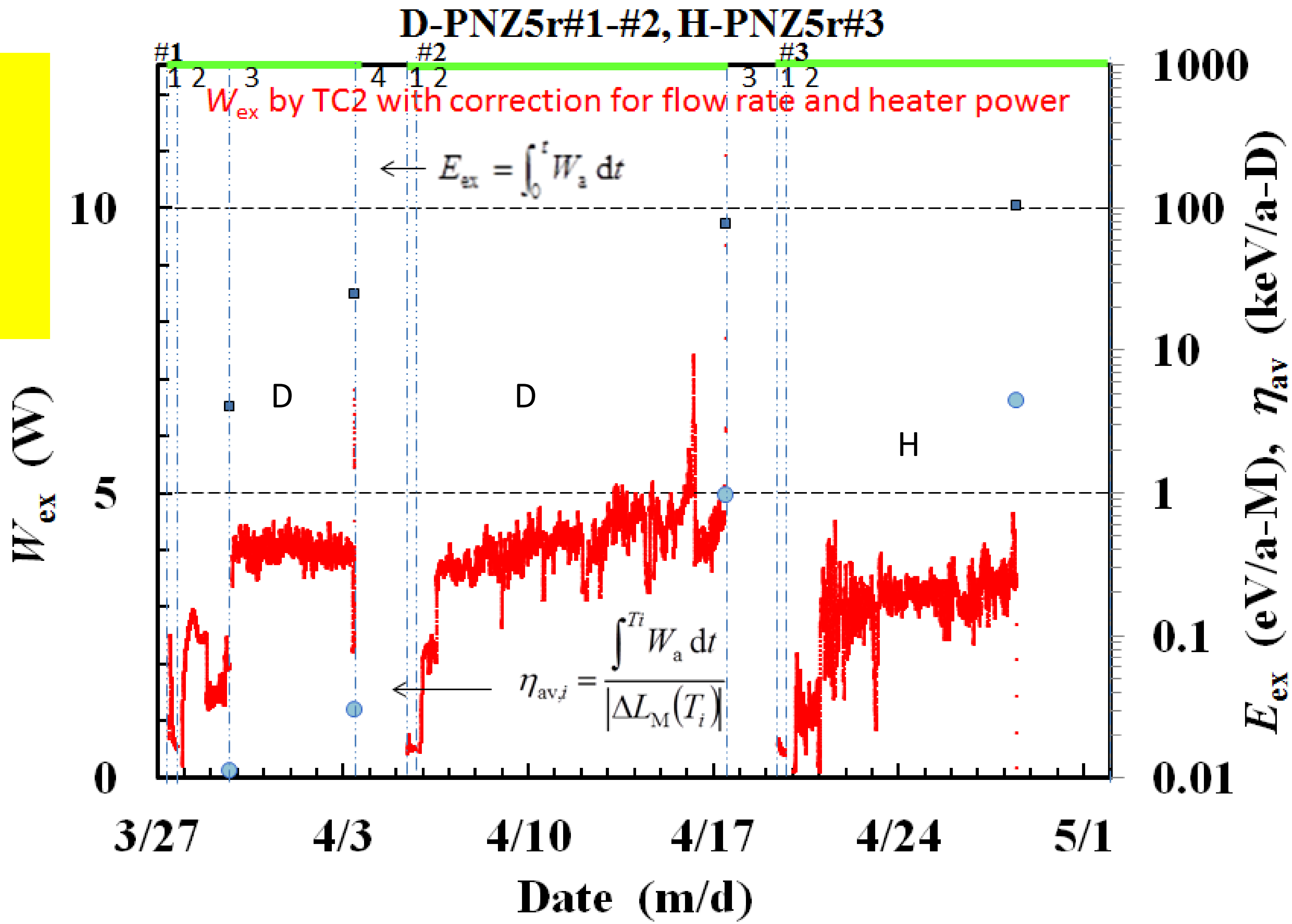
Excess heat-power evolution for D and H gas: Kitamura et al, this Workshop

Total power
Of
Reaction
Chamber
By oil flow
calorimetry

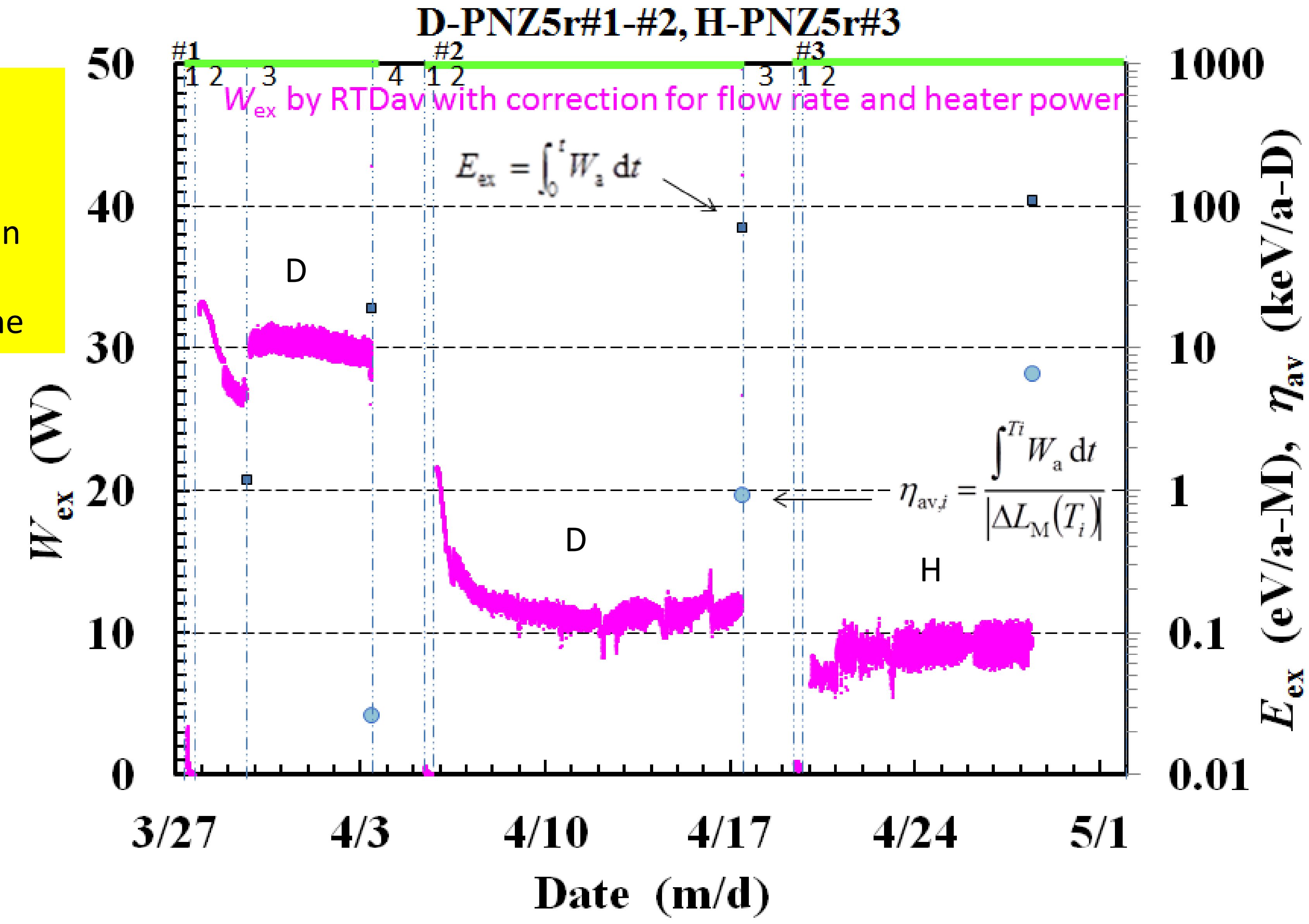


#0
3:(0,0)
#1
1:D2 fill
2:(124,80)
3:(140,90)
4:(124,30)
evac.
(0,0)
#2
1:D2 fill
2:(140,90)
3:(124,30)
evac.
(0,0)
#3
1:H2 fill
2:(140,90)

AHE of
8 MJ/mol-Ni
100 MJ/mol-D
Generation

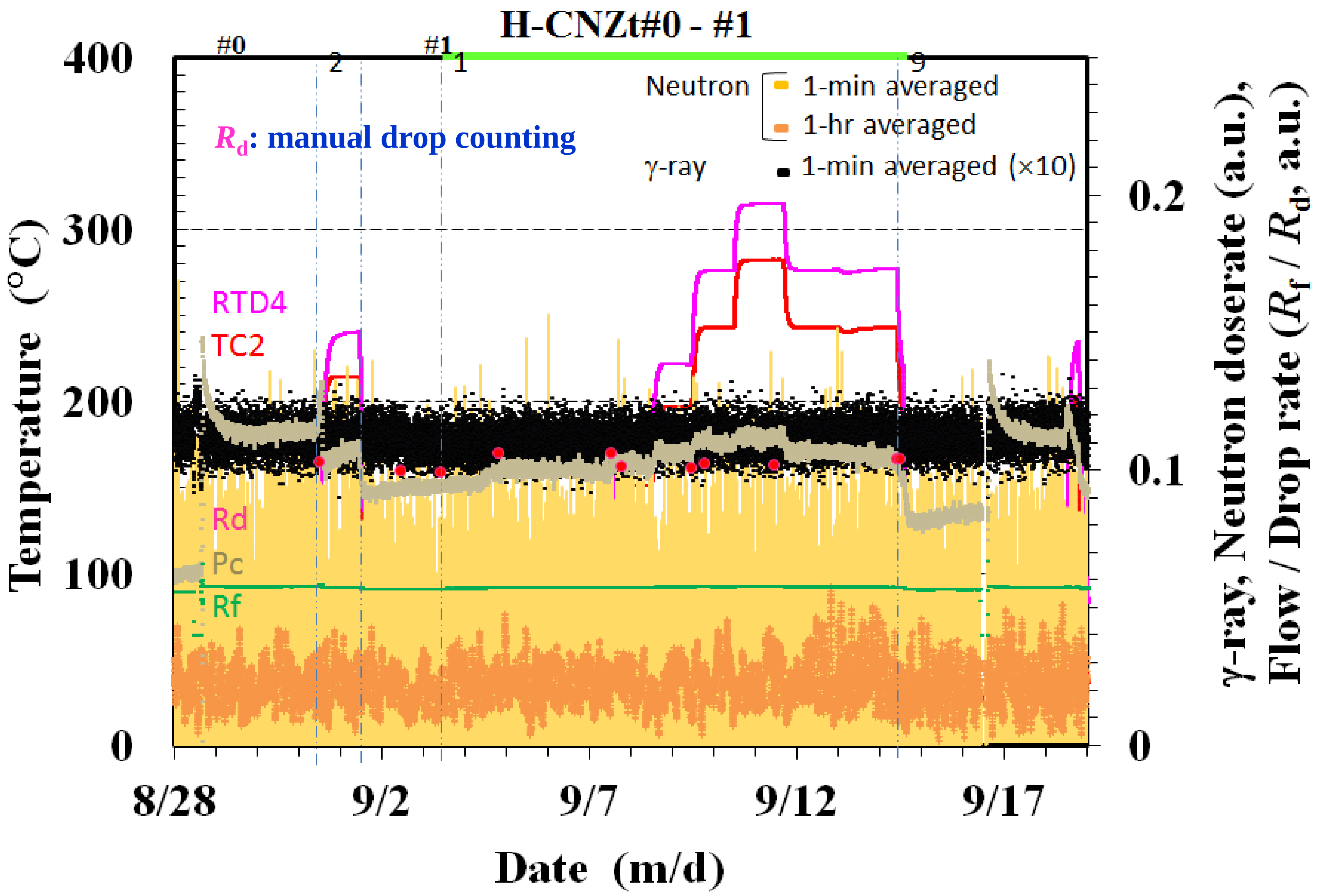
Local excess power by PNZ5r sample with D-gas and H-gas (Kitamura, et al, this WS)

Local
Larger
Power
Generation
In RC
Lower zone



#0
3:(0,0)
#1
1:D2 fill
2:(124,80)
3:(140,90)
4:(124,30)
evac.
(0,0)
#2
1:D2 fill
2:(140,90)
3:(124,30)
evac.
(0,0)
#3
1:H2 fill
2:(140,90)

Radiations and flow rate of the coolant: No excess of n and gamma over NBG



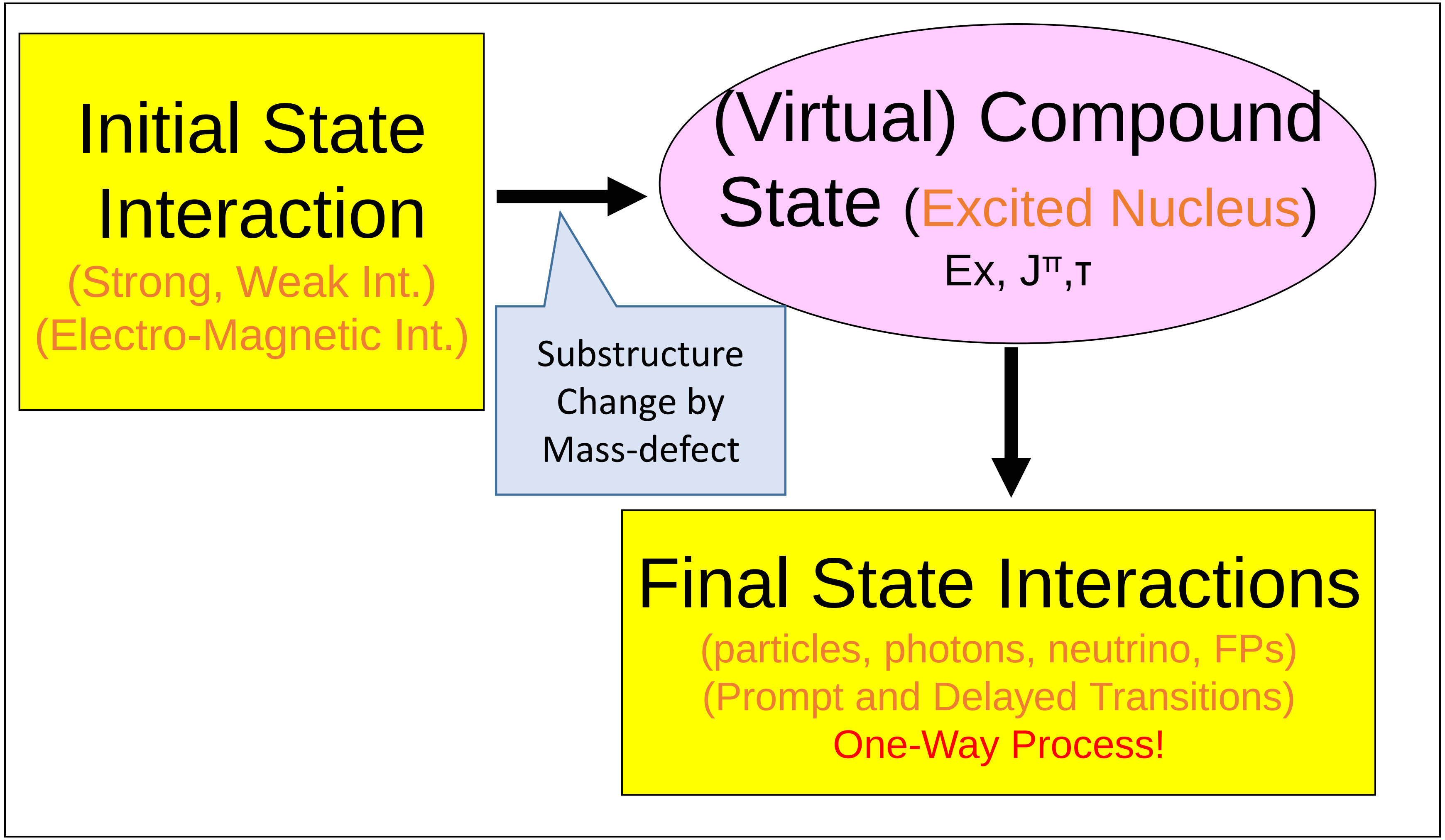
Review of Theoretical Modeling

http://vixra.org/author/akito_takahashi [1]-[16]

- Model principle of cold fusion processes in nano-metal mesoscopic catalysts (Pd, Ni, alloys) are proposed and discussed
- Brief show on modeling transient/dynamic D(H)-cluster formation on/in a nano-metal particle with **surface sub-nano-holes (SNH)**
- comparison is made between **4D/TSC and 4H/TSC condensation/collapse** motions and resultant strong and weak nuclear interactions.
- **4D/TSC fusion or 4H/TSC WS fusion** and their products
- (**Condensed D(H)-Cluster Fusion**)
- 4H/TSC induced clean fission of host metal nuclei
- Latest TSC related papers are downloadable at:

  http://vixra.org/author/akito_takahashi

Three Steps in Nuclear Reaction should be quantitatively taken into account.



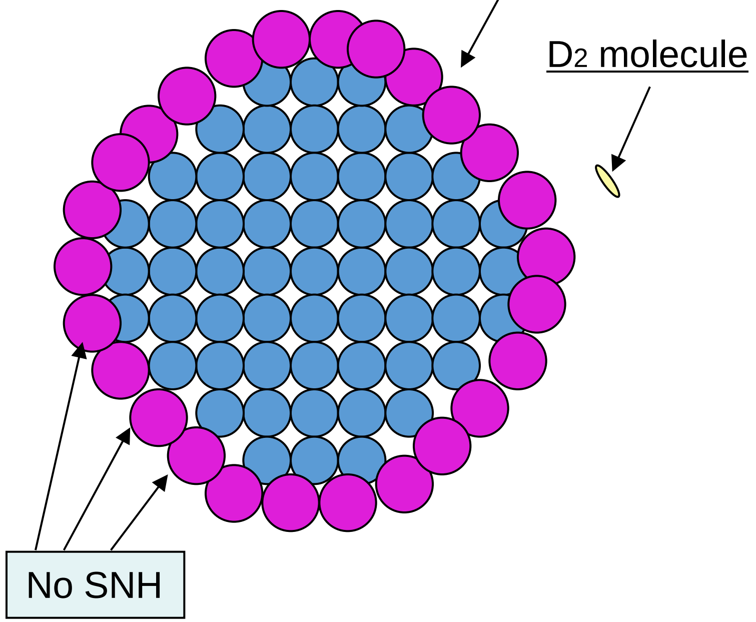
Binary-Element Metal Nano-Particle Catalyst

a) Complete-Pd-shell/Ni-core

Ni-atom; r_0 = 0.138 nm

Pd-atom; r_0 =0.152 nm

2nm diameter $\mathbf{Pd_2Ni_6}$ particle

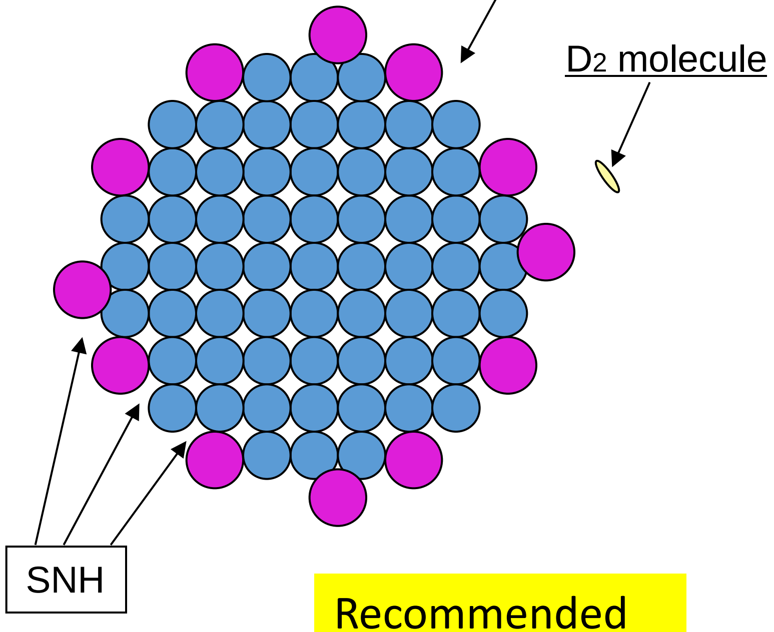


b) Incomplete-Pd-shell/Ni-core

Ni-atom; r_0 = 0.138 nm

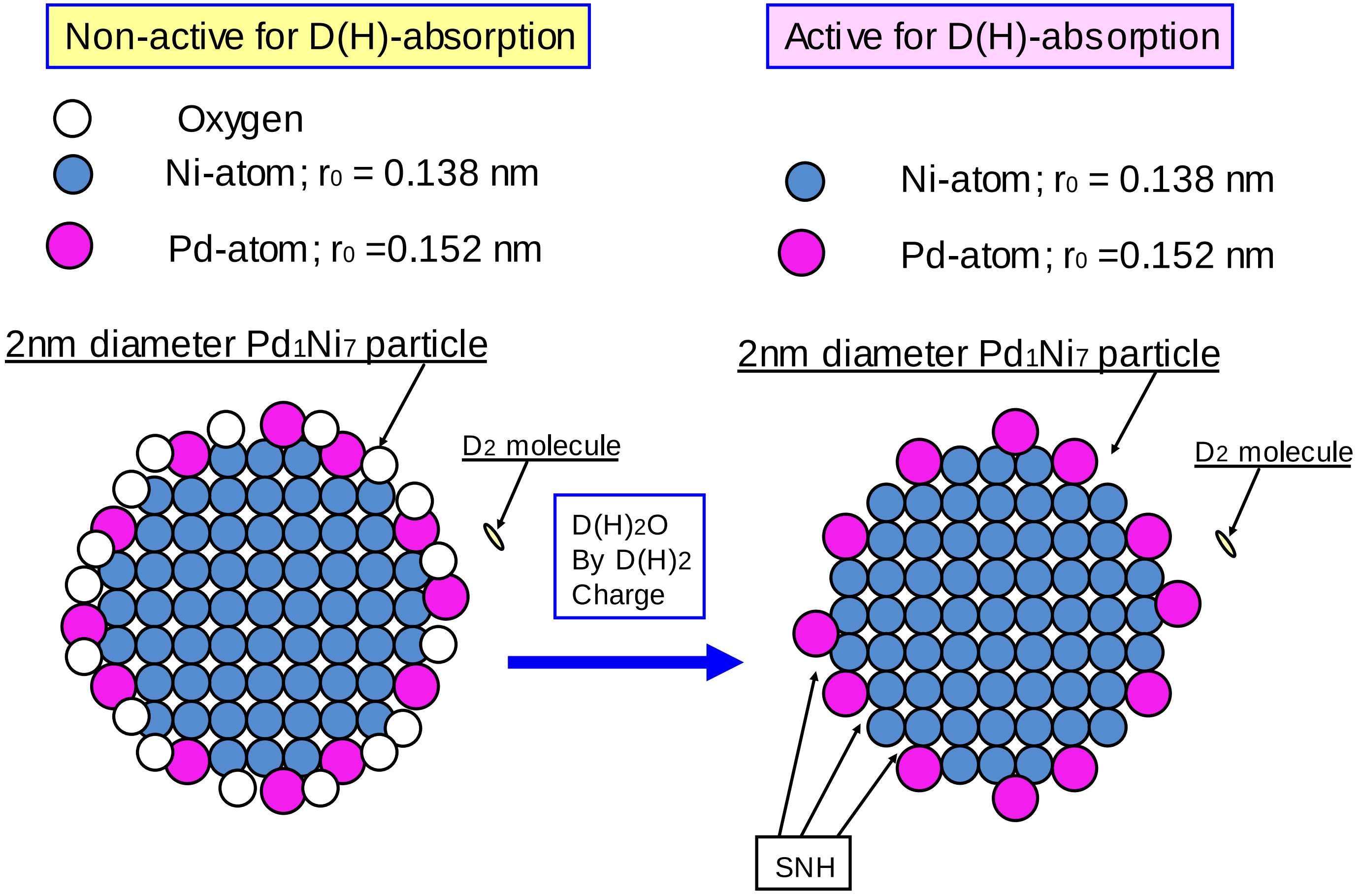
Pd-atom; r_0 =0.152 nm

2nm diameter Pd_1Ni_7 particle

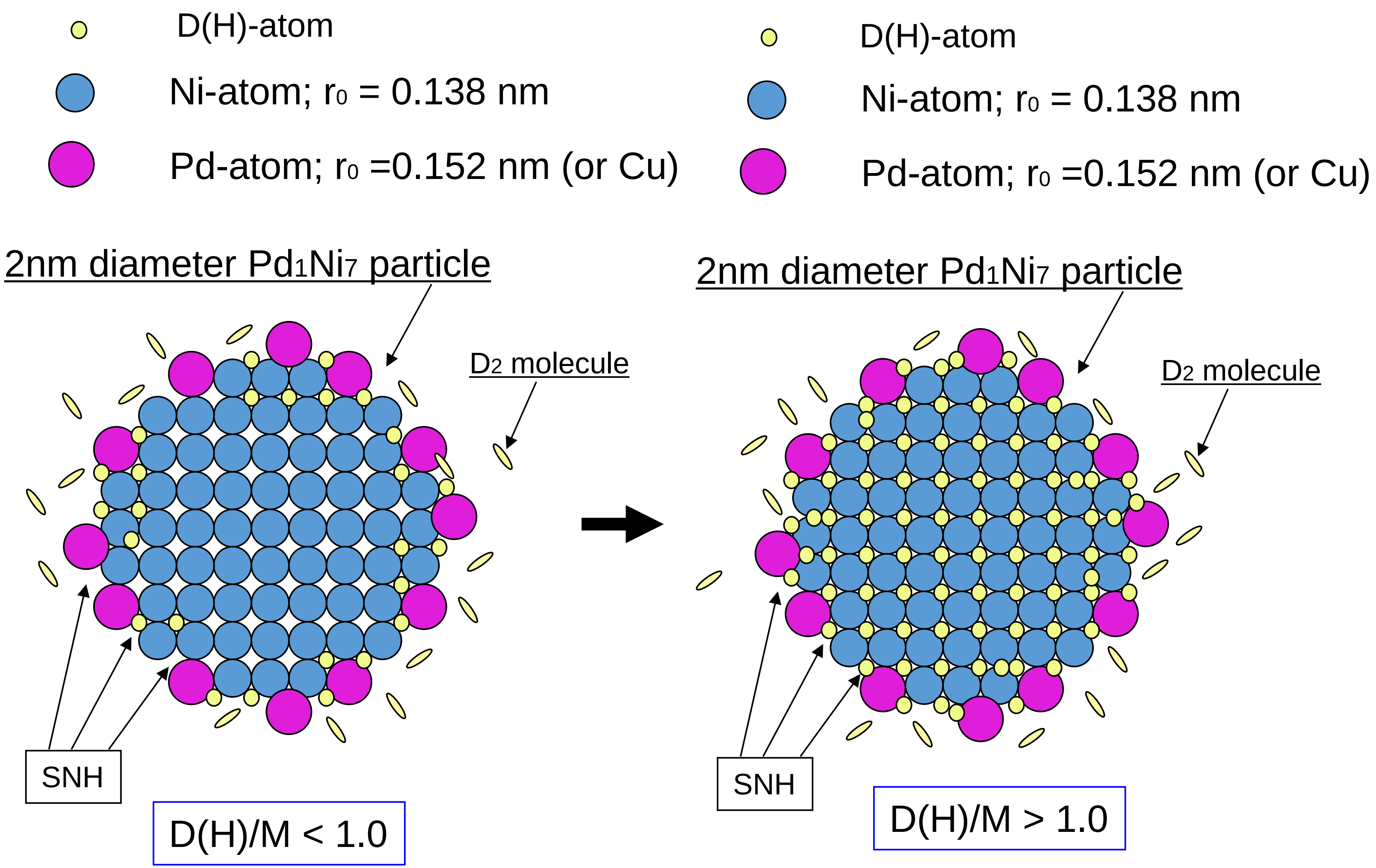


Recommended

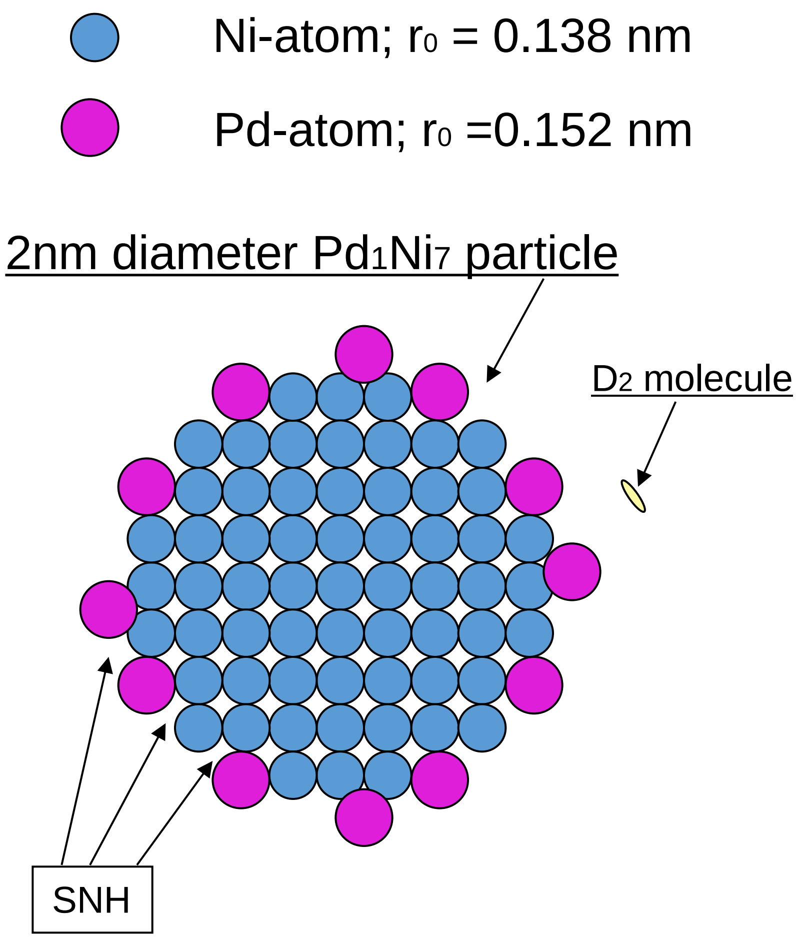
Surface oxygen blocks D(H)-absorption by filling SNH.



SNHs are prepared by O-reduction to start D(H) absorption (left)
And D(H)/M loading ratio exceeds 1.0 level (right)



Binary-Element Metal Nano-Particle Catalyst : Core + ad-atoms/surface works well for D(or H)-gas uptake



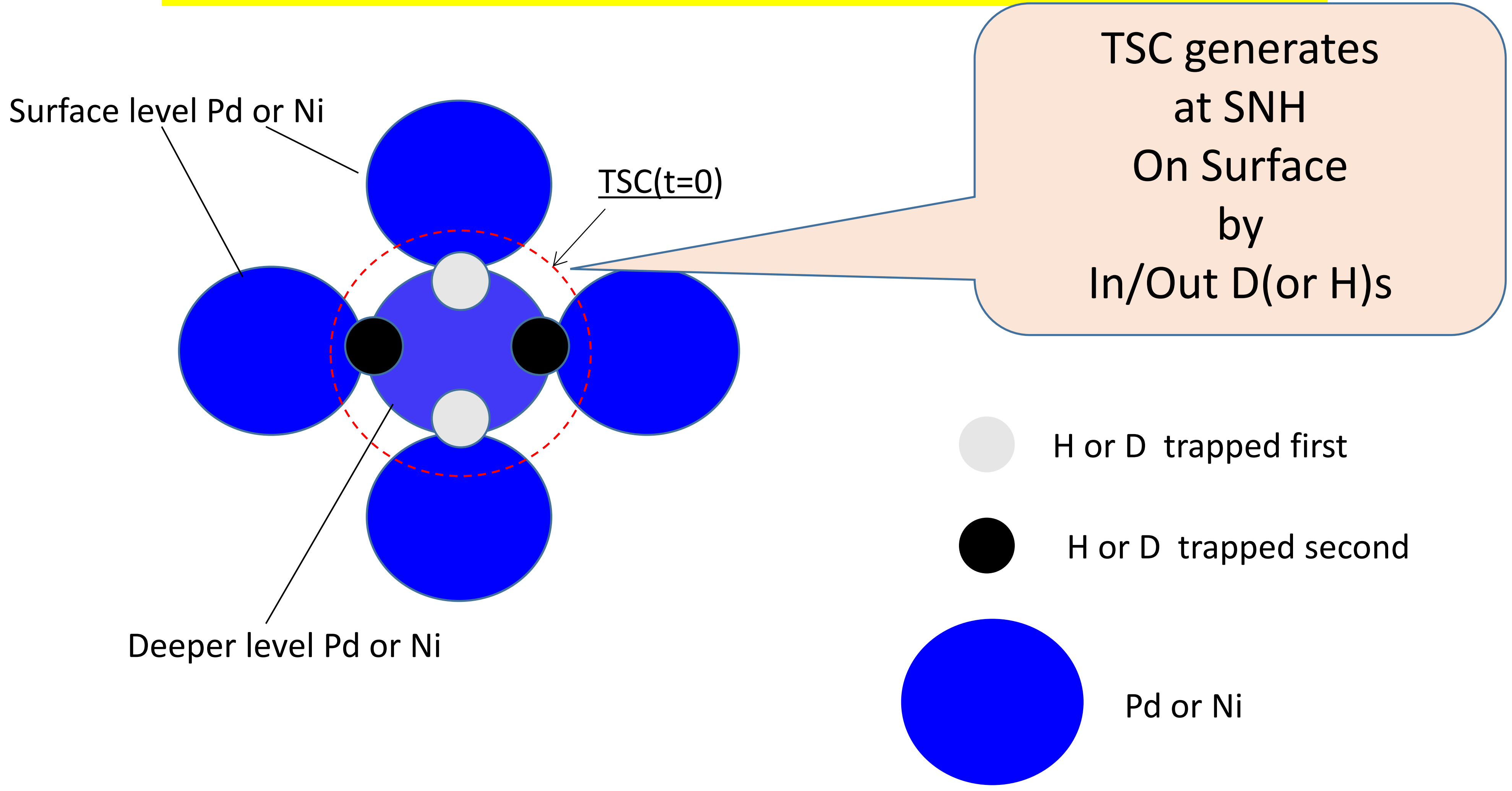
- Surface Pd adsorbs easier H(D).
- Pd ad-atom makes deeper adsorption potential for Ni-core lattice, due to fractal-dip's e-dangling bonds (**SNH**) on surface.
- Enhanced H(D) absorption into Ni-lattice sites (O-sites and T-sites)
- [H(D)]/[Pd+Ni] > 3.0

  ; 1.0 for O-sites, 2.0 for T-sites

  plus alpha for surface D(H)-clusters
- 4D(H)/TSC formation at surface sub-nano-dips (holes) (**SNH**); at defects and fractal dips
- **Pd ad-atom works "similarly " to Oxygen of PdO-coated Pd-nano-particle.**

JCF-11, 2011

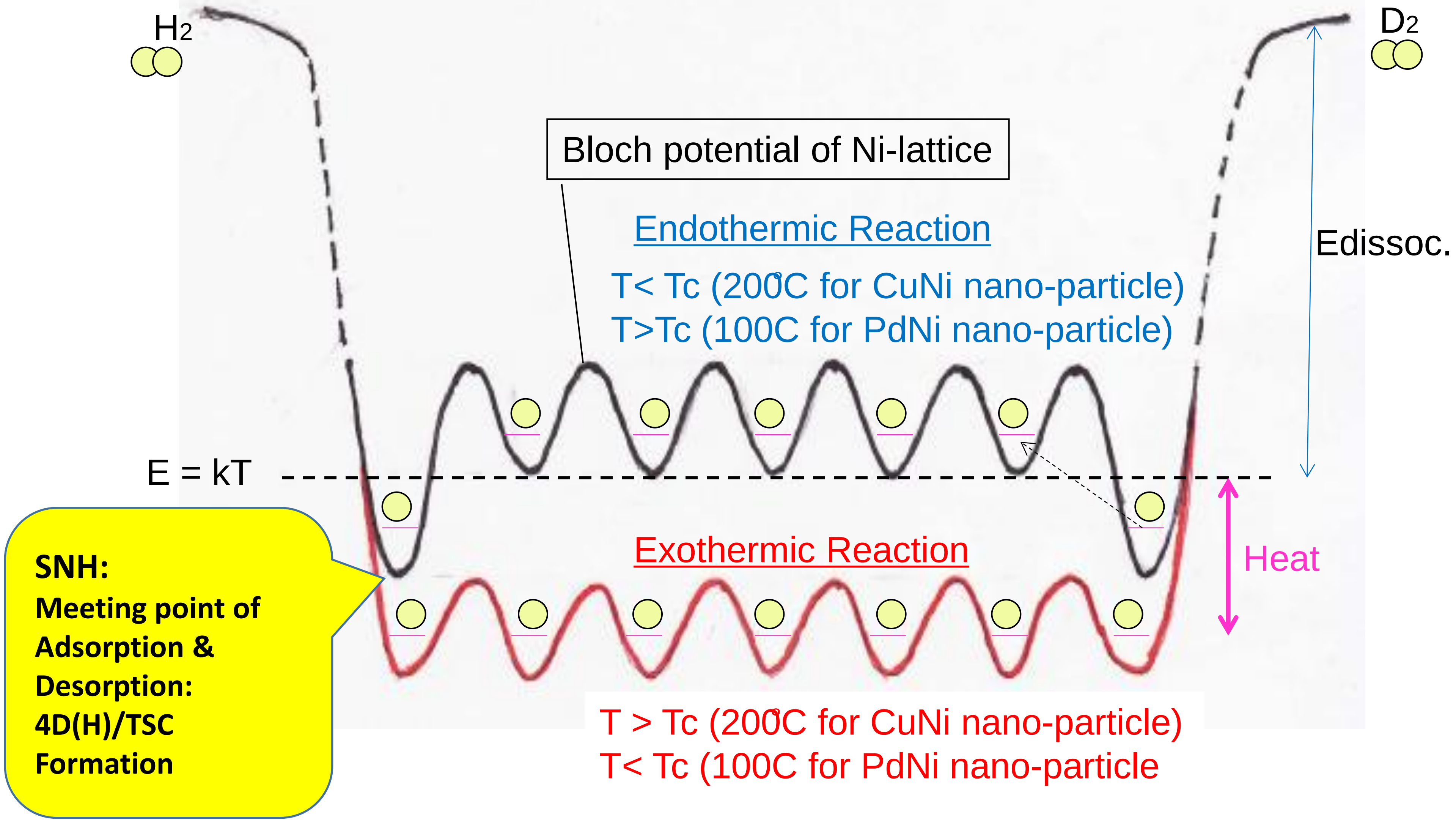
Image on Formation of TSC(t=0) at **Sub-Nano-Hole** (SNH) Of Nano (**Mesoscopic) Catalyst** Surface/defects



Speculative image of **GMPW** (Global Mesoscopic Potential Well)

For **CNZ (Cu-Ni-ZrO2) and PNS (Pd-Ni-SiO2)** nano-composite powder

+ D(H) absorption and **TSC** (tetrahedral symmetric condensate), **After saturated LM**



No good to use the rate theory of free particle collision for CMNR

- Despite the importance of reaction rate estimation in modeled CMNS theories, only a few authors have treated nuclear reaction rates properly.
- Some theories have borrowed rate formulas (using cross section) of two body collision process which is the case of nuclear reactions for the random free particle motion as in plasma and gas phase or beam-target interactions.

CMNR (condensed matter nuclear reactions) needs to use rate estimation for trapped state H(D)s

- Intrinsically the **CMNS nuclear reactions should happen between trapped particles of proton and deuteron (H or D) in negative potential wells** organized by the ordering of condensed matter such as periodic lattice, mesoscopic nano-particle and surface fractal conditions. Such trapped H(D)-particles should have **finite lifetime** or **co-existing time** in the negative potential well and are keeping mutual inter-nuclear distances for finite time-intervals before fusion reactions.
- **Cluster QM wave function is near Gaussian type by co-existence, not plane wave as used for two body collision**. Application of cross section formula is bad idea so far.

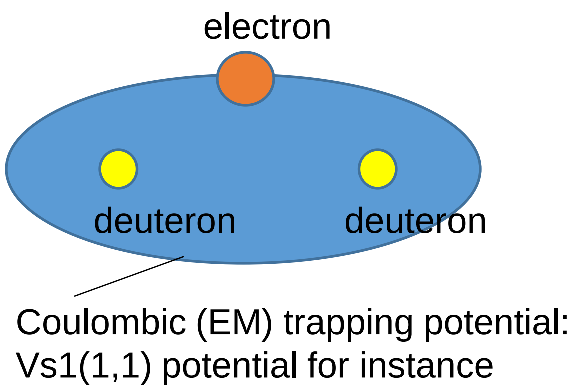
Rate Formula by Fermi's First Golden Rule should be used for CMNR

- We need therefore to use formulas based on the **Fermi's first golden rule for rate estimation**, due to the finite life time of co-existing trapped particles.
- The paper (A. Takahashi, Proc. ICCF19, JCMNS Vol.19) recalls the procedure and formulas for the fundamental of rate theory for CMNS, as has been used in the TSC theory development.
- As the condensed cluster fusion process is dynamic, we **need time-dependent rate estimation during effective life time of condensing cluster of D(H)s.**

Image of
QM treatment

2) Fusion rate theory for trapped D(H) particles
Trapped particles in EM-potential make nuclear reactions by QM superposition

- Pair or cluster trapped in Electro-Magnetic (chemical) potential



- Overlapping weight within strong/weak nuclear interaction range (1.4fm/2.4am) should be estimated by QM.

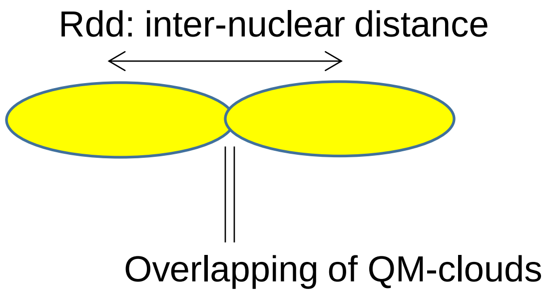


Image of
QM treatment

Nuclear Optical Potential is used for reaction rate formula by using the QM density balance

- Forward Equation:

$$i\hbar\frac{\partial\Psi}{\partial t}=\left[-\frac{\hbar^2}{2M}\nabla^2+V+iW\right]\Psi$$

- Adjoint Equation:

$$-i\hbar\frac{\partial\Psi^*}{\partial t}=\left[-\frac{\hbar^2}{2M}\nabla^2+V-iW\right]\Psi^*$$

$$i\hbar\left(\Psi^*\frac{\partial\Psi}{\partial t}+\Psi\frac{\partial\Psi^*}{\partial t}\right)=i\hbar\frac{\partial\Psi\Psi^*}{\partial t}=i\hbar\frac{\partial\rho}{\partial t}$$

- Ψ*x(1) – Ψx(2):

Fusion term

$$i\hbar\frac{\partial\rho}{\partial t}=-\frac{\hbar^2}{2M}\left[\Psi^*\nabla^2\Psi-\Psi\nabla^2\Psi^*\right]+i\left[2W\rho\right]=-i\hbar\,div\,\vec{j}+i\left[2W\rho\right]$$

Image of
QM treatment

Fusion Rate Formula by Fermi's Golden Rule

$$< FusionRate >= \frac{2}{\hbar}\left\langle \Psi_f \middle| W(r) \middle| \Psi_i \right\rangle$$

$$-\frac{\hbar^2}{2m}\nabla^2\Psi + [V_{nr}(r) + iW(r)]\Psi + V_c(r)\Psi = E\Psi$$

Nuclear Potential ($V_{nr}(r)$)

Coulomb Potential ($V_c(r)$)

$$\Psi(r) = \Psi_n(r)\cdot\Psi_c(r)$$

Inter-nuclear wave function (Ψ_n)

EM Field wave function (Ψ_c)

Born-Oppenheimer Approximation

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AT ICCF17 TSC theory

Fusion Rate Formula by Fermi's First Golden Rule with Born-Oppenheimer Approximation

Image of
QM treatment

Barrier Factor

$$< FusionRate >= \frac{2}{\hbar} \left\langle \Psi_{nf} \middle| W(r) \middle| \Psi_{ni} \right\rangle_{Vn} \cdot \left\langle \Psi_{cf} \middle| \Psi_{ci} \right\rangle_{Vn}$$

$$Vn \approx 4\pi R_n^2 \lambdabar_\pi$$

: Effective Volume of Nuclear Strong (Weak) Interaction Domain

$\lambdabar_\pi$: Compton wave length of pion (1.4 fm) (weak boson: 2.5 am)

Rn : Radius of Interaction surface of strong (weak) force exchange

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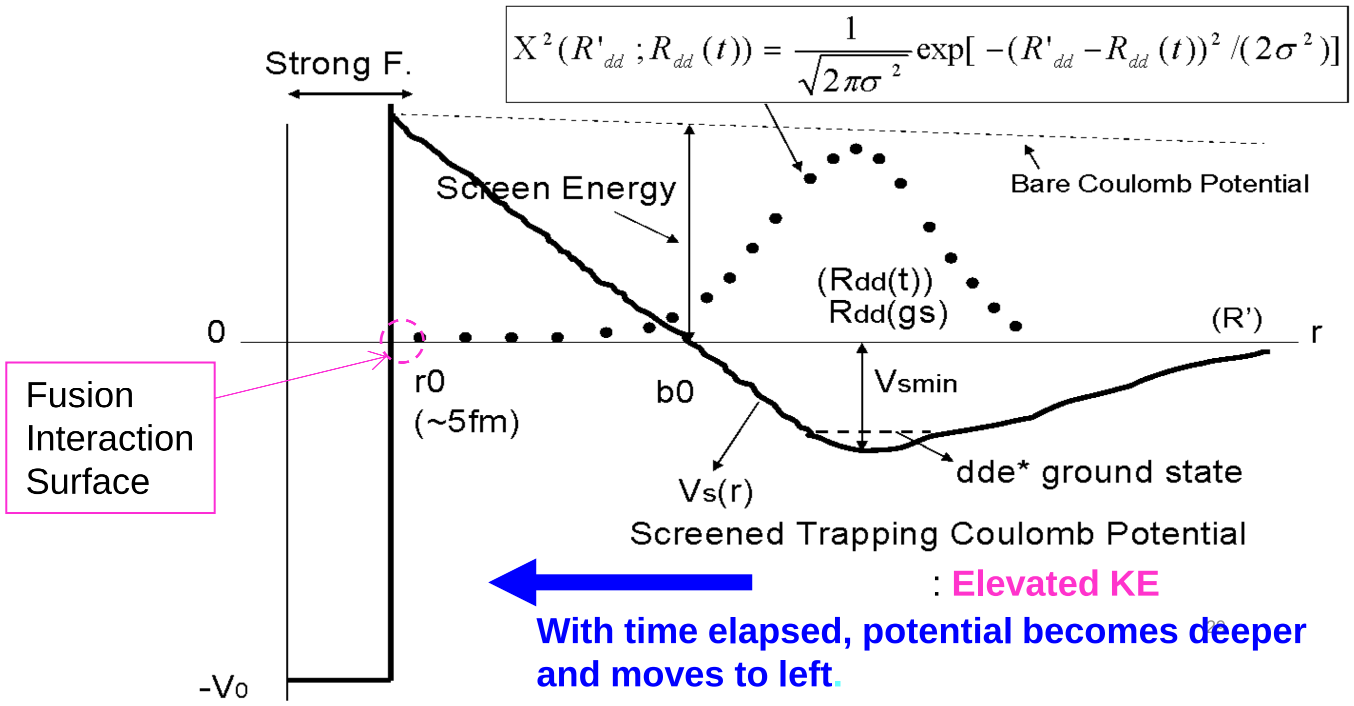
AT ICCF17 TSC theory

Image of QM treatment

Fusion rate should be estimated time-dependently, e.g. for TSC Condensation: No Stable State, but into sub-pm entity

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



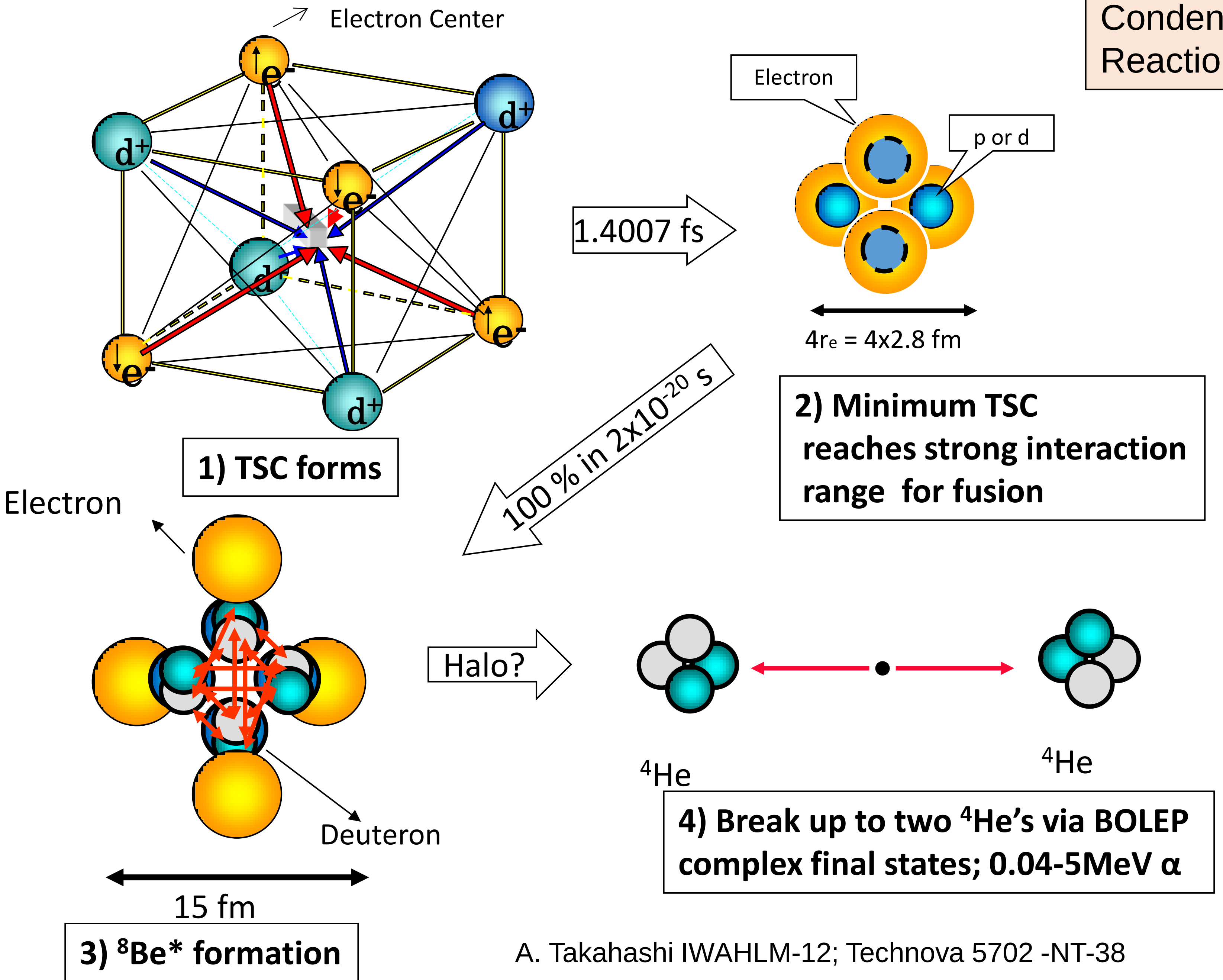
Collision Rate Formula UNDERESTIMATES fusion rate of steady molecule/cluster Drastically as around 20 orders of magnitude (A. Takahashi, ICCF19)

Cluster	R_{dd} = R_{gs} (pm)	Barrier Factor	Steady Cluster d-d Fusion Rate (f/s)	Steady Cluster 4d Fusion rate (f/s)	Fusion Rate for d-d collision formula (f/s)
D_2	74.1	1.0E-85	2.4E-66		3.6E-86 (4.0E-72)*
dde*(2,2)	21.8	1.3E-46	3.2E-27		1.0E-46 (1.0E-31)*
ddμ	0.805	1.0E-9	2.4E+10		1.5E-9 (1.0E+8)*
4D/TSC-minimum	0.021	1.98E-3		3.7E+20	

* Frequency of d-d pair oscillation by QM-Langevin calculation was considered.

TSC: Tetrahedral Symmetric Condensate

4D/TSC
Condensation
Reactions



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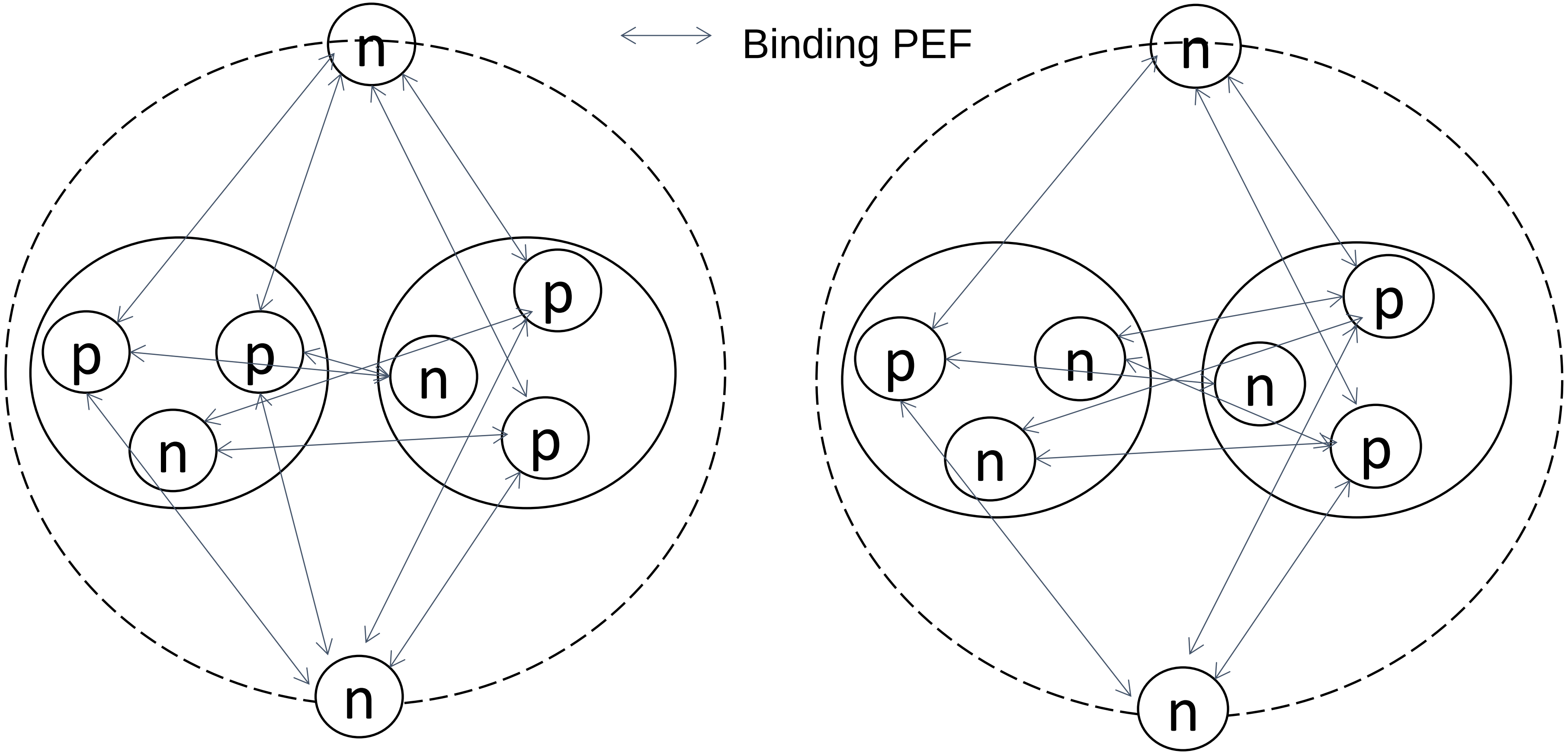
$^8Be^*$ and ^8Li are similar n-halo states

$^8Be^*$ = n + h + h + n Halo

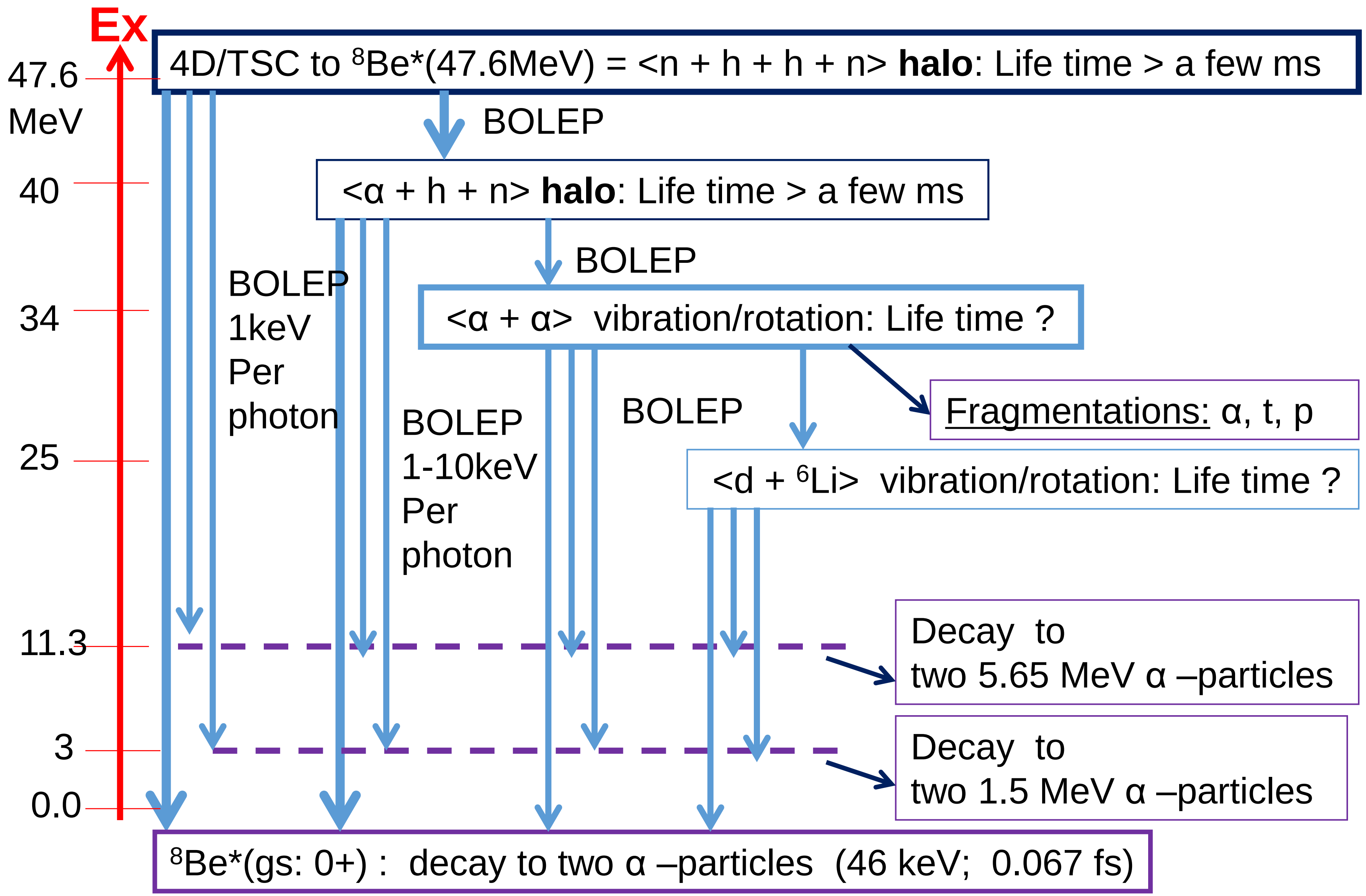
^8Li = n + h + t + n Halo

Binding PEF = 8 + 4 = 12

Binding PEF = 6 + 5 = 11

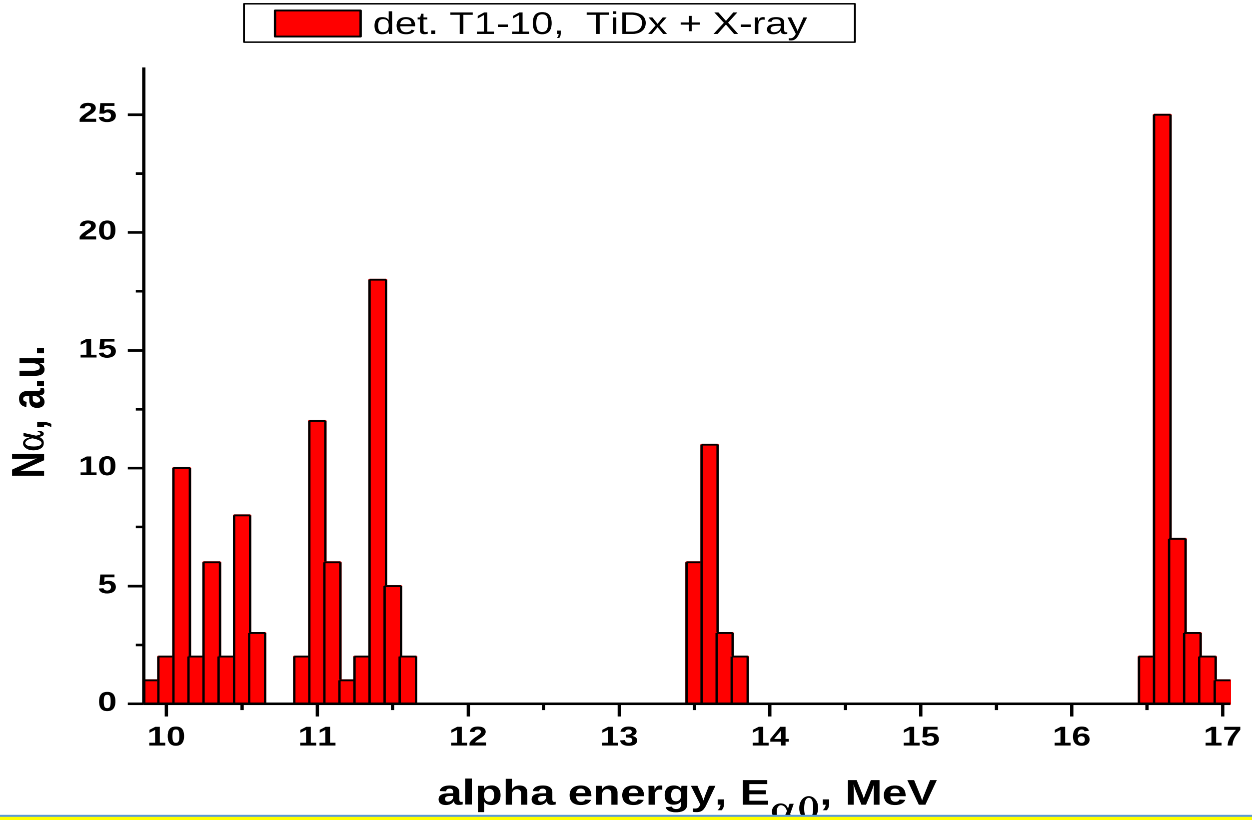


Predicted Final State Interactions of $^{8}Be^{*}$(Ex=47.6MeV): ICCF18
BOLEP: burst of Low Energy Photons: will be dominant channels



Alpha particle energy spectra (fine structure): Minor Products of 4D/TSC fusion demonstrates few bands in the range 10 – 17 MeV: ICCF18

After A. Roussetski et al, Siena WS 2012: for TiDx system under e-X beam stimulation
JETP Vol.112 (2011) 952

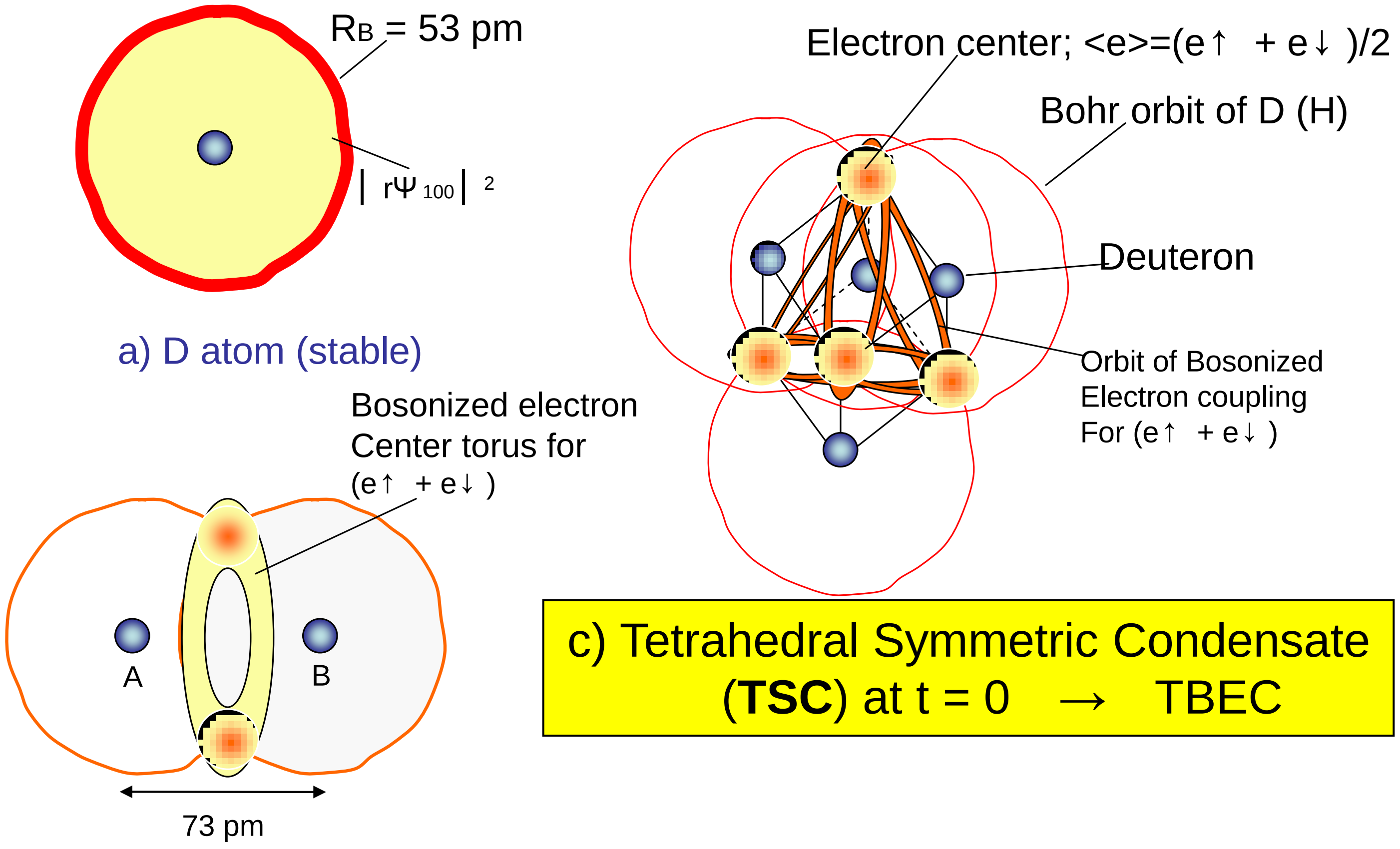


Prediction by N-Halo Model: 17, 13.8, 11.5, 11, 10, 8.3, 5.7, 1.55 and 0.046 (in MeV): Good Agreement with Roussetski Exp.

Cold Fusion: Confinement of High KE D(H)-cluster in an extremely microscopic domain of multi-particle QM trapping in “long” life time

Image of QM treatment

Feature of QM Electron Cloud



a) D atom (stable)

c) Tetrahedral Symmetric Condensate (**TSC**) at t = 0 → TBEC

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

Quantum-Mechanical Ensemble-Averaging

Image of
QM treatment

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

Born-Oppenheimer Approximation for H2 molecule:

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

Electron Wave Function for H_2:

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

Proton-Pair Wave Function: Gaussian approximation:

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

D2 Trapping Potential: Vs2(1,1) can be replaced with Vs1(1,1.41)

Image of
QM treatment

Pseudo Potential for TSC one-way condensation can be replaced with Vs1(m, 1.41) Using continuously varying m corresponding to varying p-p distance

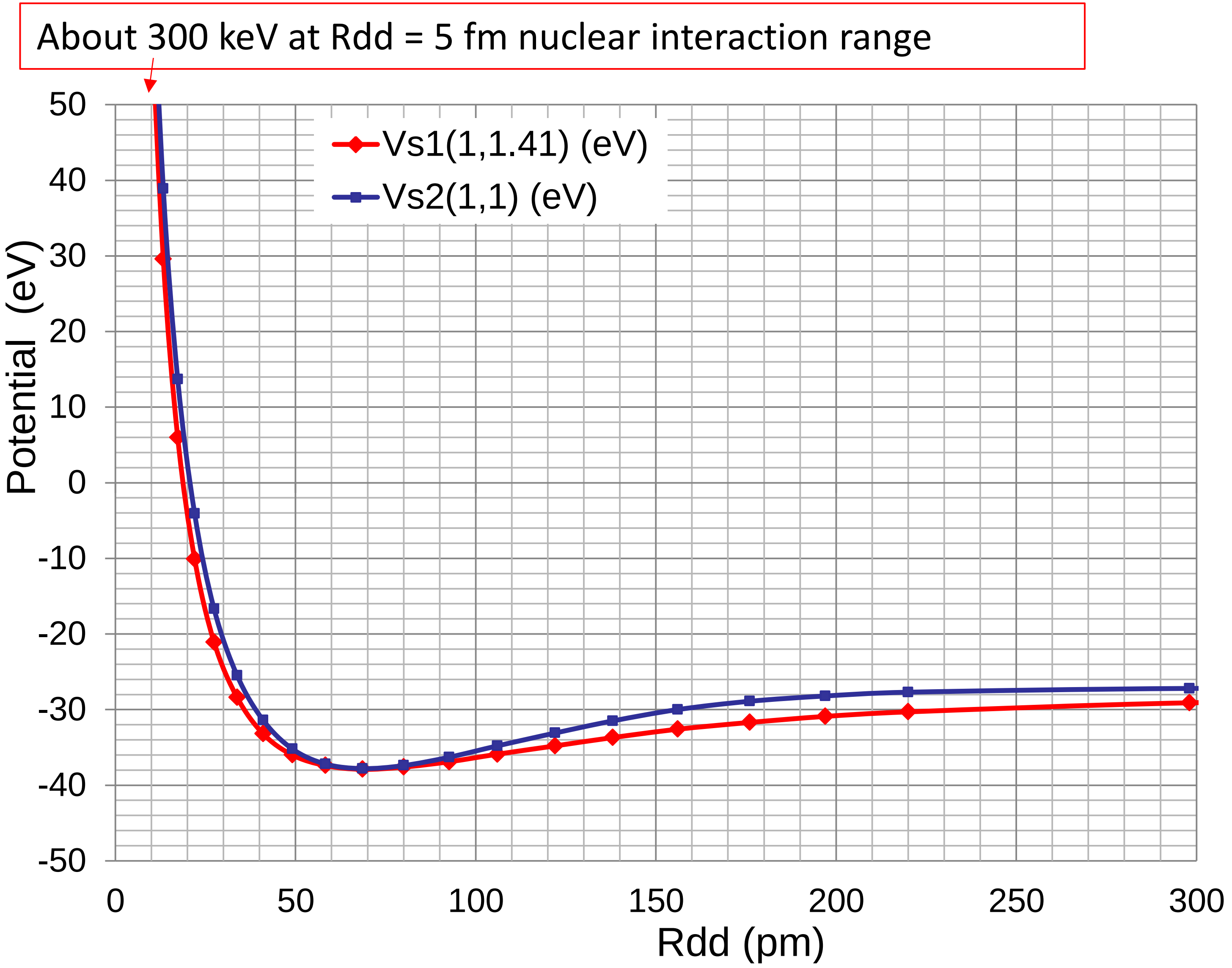


Image of
QM treatment

QM-Average for Complex H-cluster under Platonic Symmetry

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

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

N_f : Number of faces for Platonic polyhedron
V_{si}: H_2 (i=2) or H_2^+ (i=1) trapping potential
Vs1(m,Z) EQPET potential for TSC dynamics

- Average on p-p wave function: using

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

Image of QM treatment

QM Average of Langevin Equation for D(H) Cluster

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

N_e: Number of p-p edges
N_f : Number of faces

$$N_e m_d \left\langle \Psi(R,R') \middle| \frac{d^2 R}{dt^2} \middle| \Psi(R,R') \right\rangle = -\left\langle \Psi(R,R') \middle| \frac{k}{R^2} \middle| \Psi(R,R') \right\rangle$$

$$- N_f \left\langle \Psi(R,R') \middle| \frac{\partial V_s}{\partial R} \middle| \Psi(R,R') \right\rangle + \left\langle \Psi(R,R') \middle| f(t) \middle| \Psi(R,R') \right\rangle$$

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

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

Verlet's Method for numerical solution

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

For 4D/TSC with sigma 0.39
Different value for other cluster

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

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

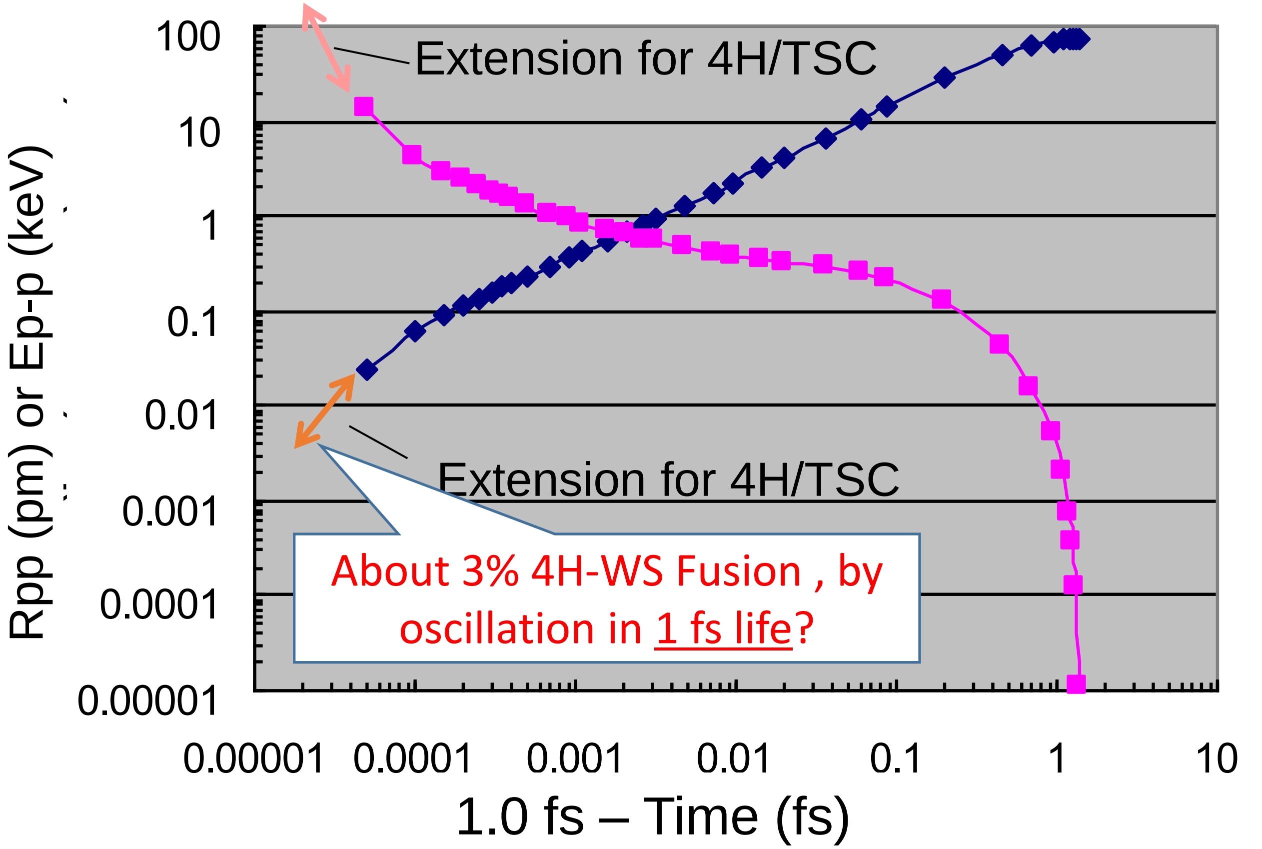
$$r(t+\Delta t) = r(t) + v(t)\Delta(t) + \frac{1}{2}G(r,t)(\Delta t)^2$$

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

TSC Condensation Motion; by the Langevin Eq.:

Condensation Time = 1.4 fs for 4D and 1.0 fs for 4H

Proton Kinetic Energy INCREASES as Rpp decreases.

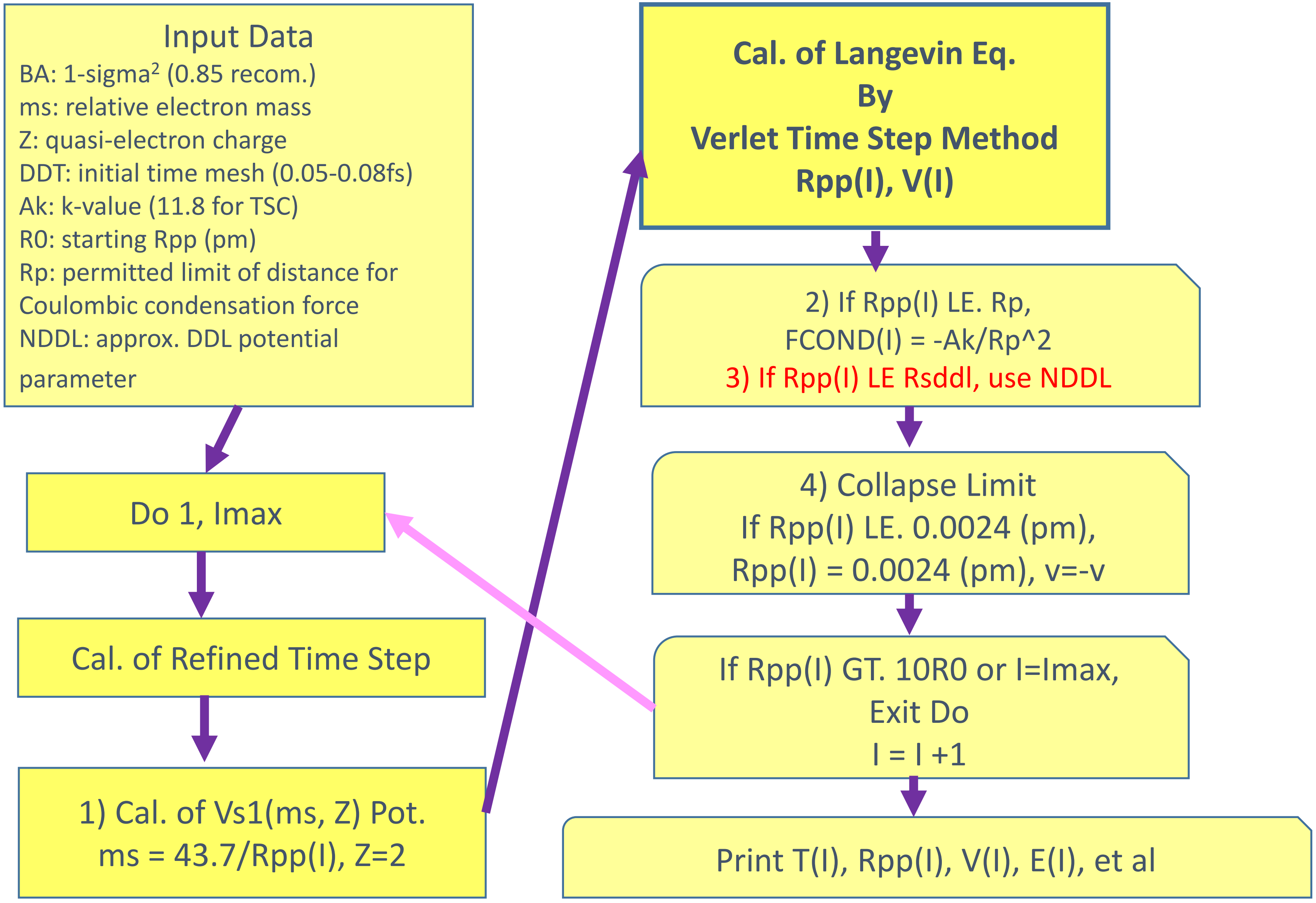


QM-Langevin Code cal. With Vs1(2,2)

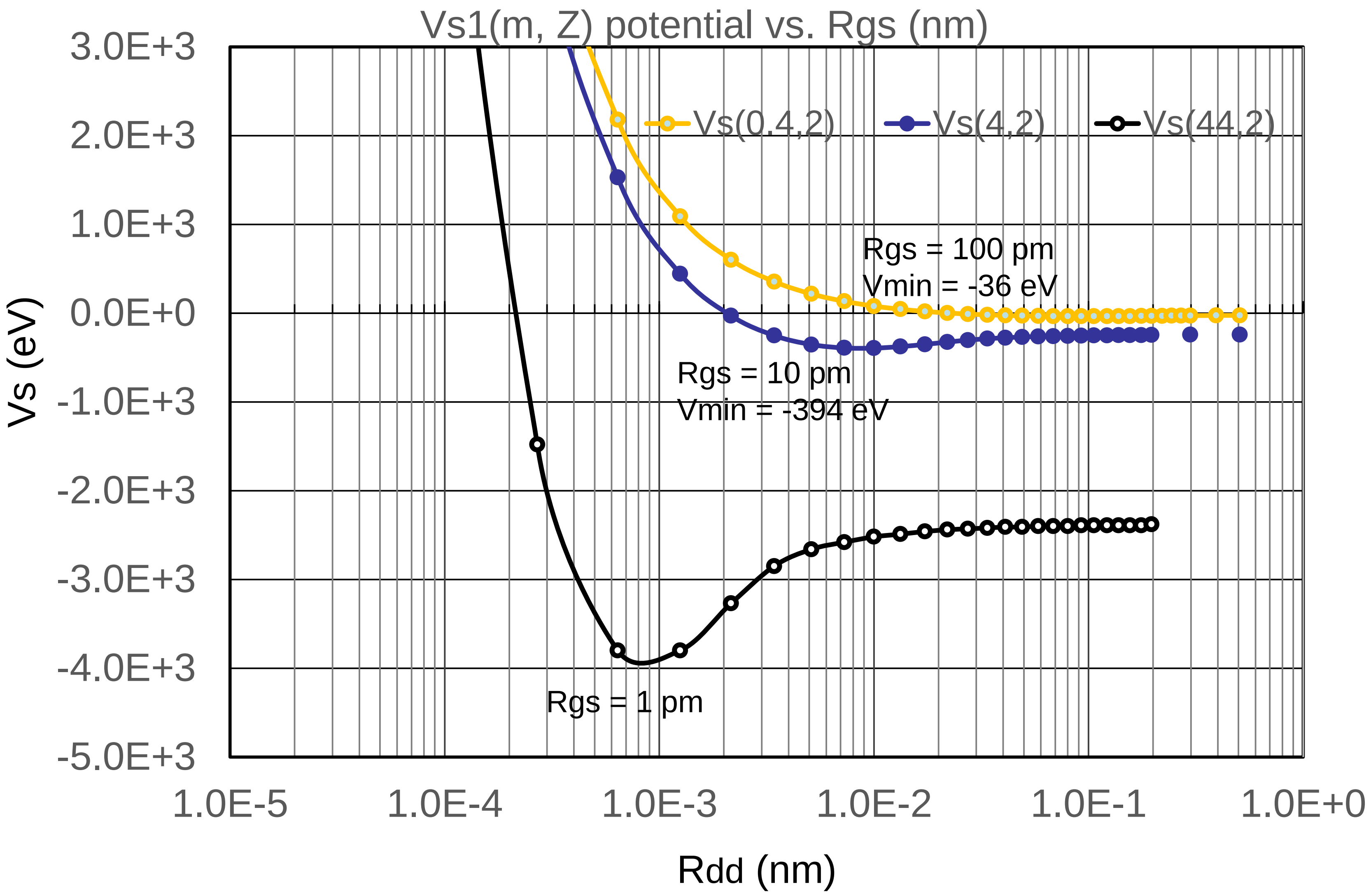
Ep = 100 keV at Rpp = 2.4 fm, Vtrap = - 1.2-2 MeV

Electrons Mean KE : 0.6-1MeV; Relativistic

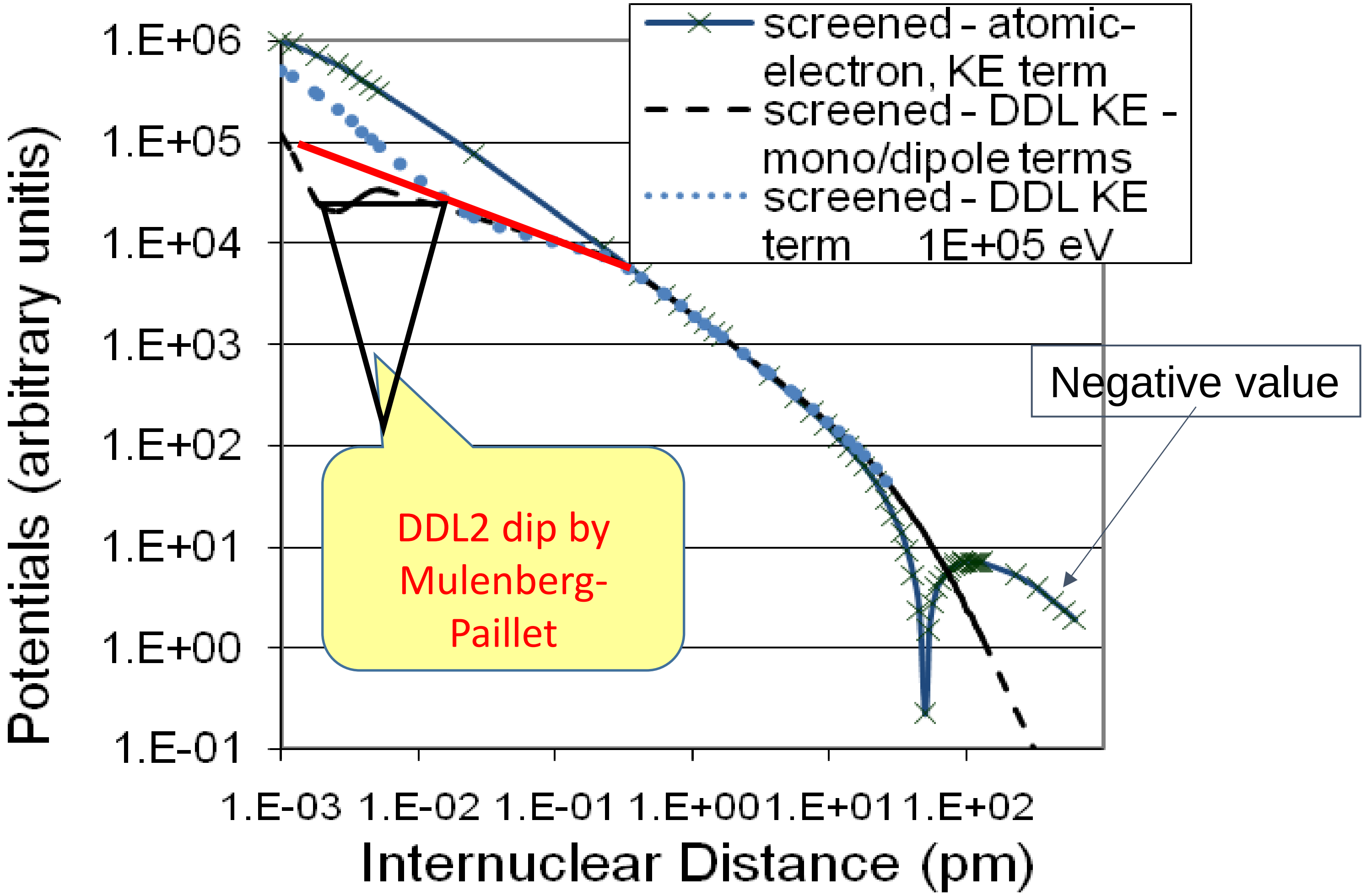
Relativistic Effect is included by HME Langevin DDL Code: A. Takahashi, JCF-16



Some of pseudo-potentials used for simulation calculation

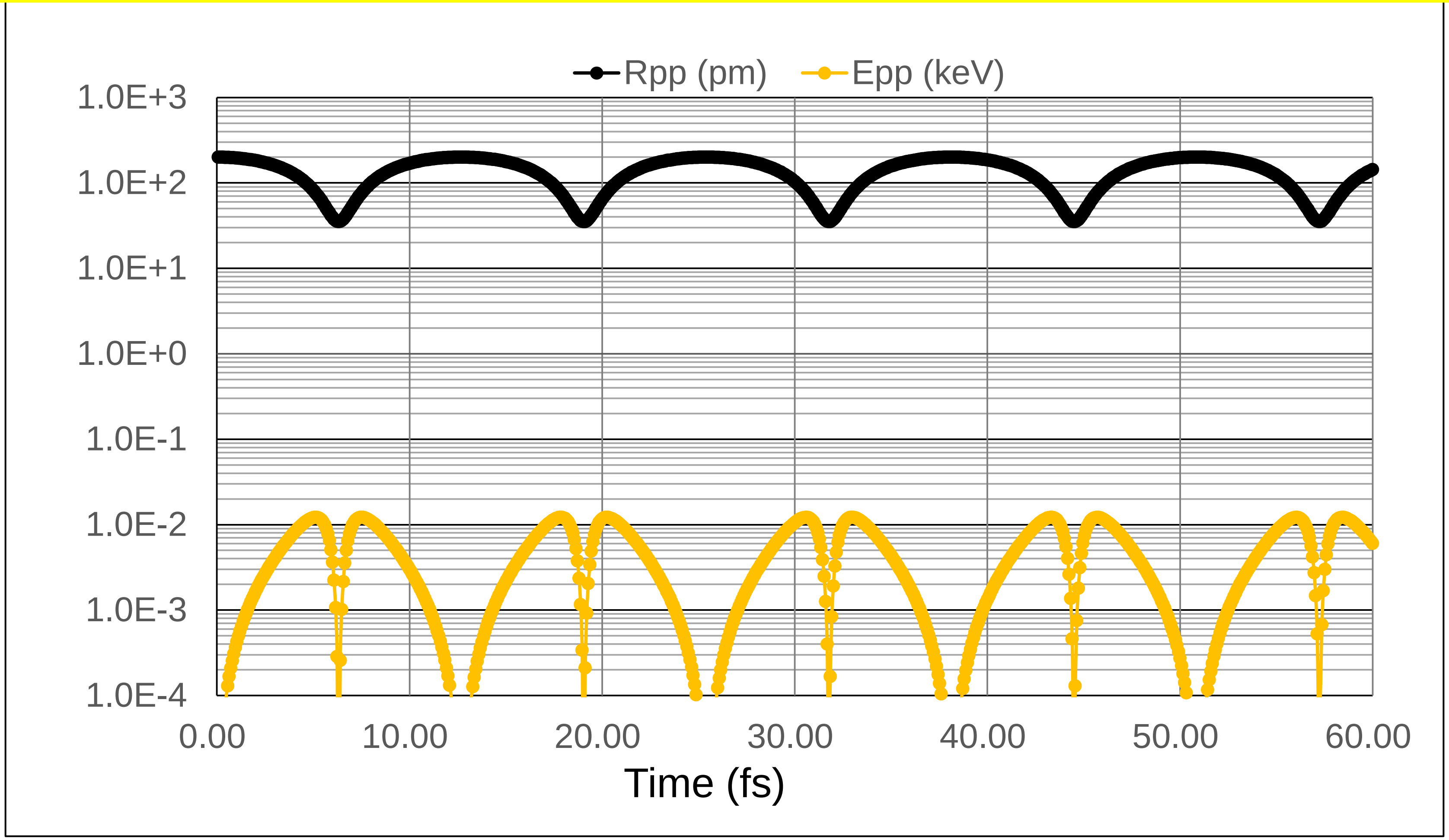


E0 – A type (Feynman) potential with DDL(deep Dirac level) state for A: by Andrew Muelenberg and J. L. Paillet

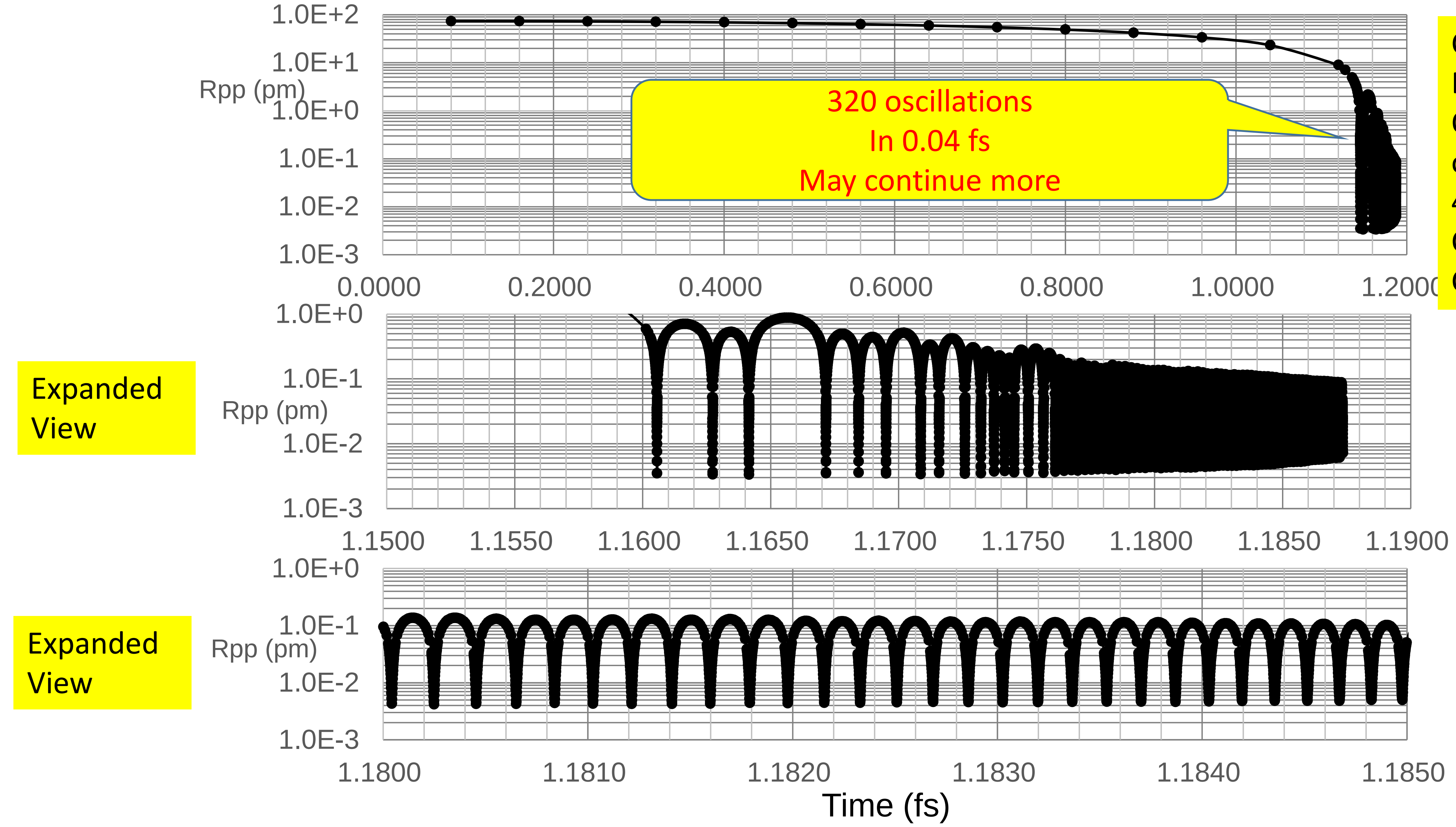


For **p-e-p system**, no effect happens by DDL2 because of highest Epp 11 eV, Though Epp > 35 keV is needed to enter the DDL2 dip.

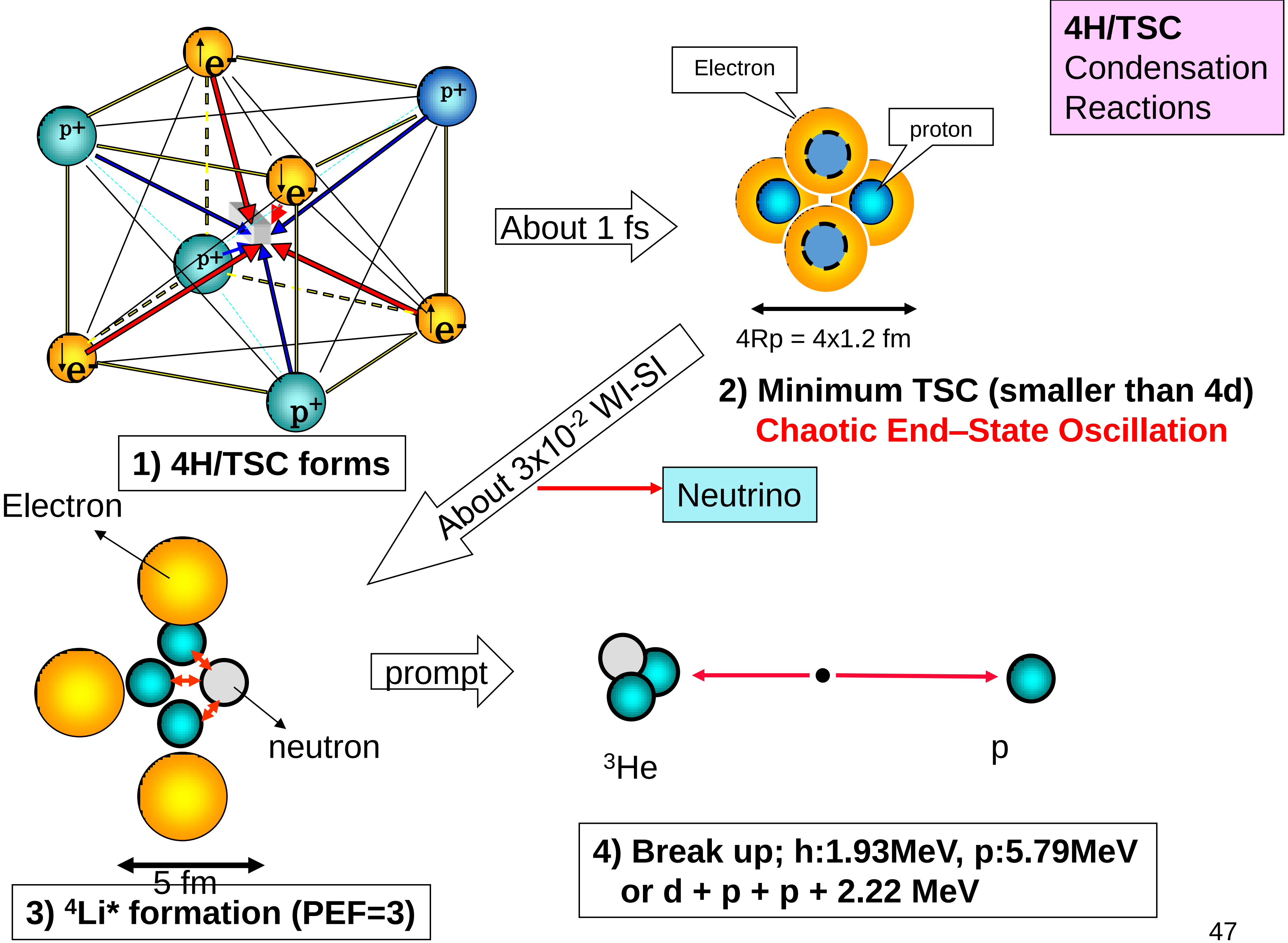
QM tunneling probability to the DDL (Rpp=5fm) state is ca. 10^{-60}, too small to see.



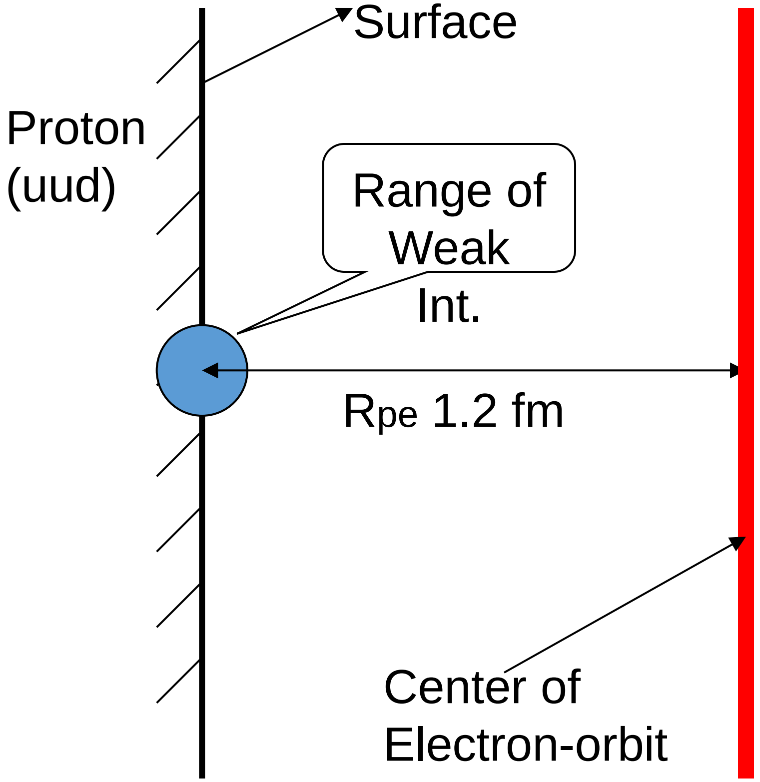
HME Langevin DDL2 cal.;4H/TSC Vs1(m,1.41) Ne=Nf=6, Rddl=0.02pm, SG=0.4



Chaotic End-State Oscillation of 4H/TSC Condensation/ Collapse


4H/TSC
Condensation
Reactions
e-
p+
1) 4H/TSC forms
About 1 fs
Electron
proton
4Rp = 4x1.2 fm
2) Minimum TSC (smaller than 4d)
Chaotic End–State Oscillation
About 3x10-2 WI-SI
Neutrino
Electron
neutron
5 fm
3) 4Li* formation (PEF=3)
prompt
3He
p
4) Break up; h:1.93MeV, p:5.79MeV
or d + p + p + 2.22 MeV

Weak Interaction at 4H/TSC-min
[We assume WI happens at proton surface with W-boson wave length (2.5×10^{-3} fm)]



- E_{ke} = 600 kev exceeds threshold (272 keV) of $p + e^-$ to $n + \nu$ interaction.
- $p + e^- + E_{ke} \rightarrow n + \nu + (E_{ke} - 272\ \text{keV})$

Effective Volume for WI:

$$\Delta V_W = 4\pi R_p^2 \lambda\!\!\!^{-}_W = 4\pi \cdot (1.2\ fm)^2 \cdot 2.5 \times 10^{-3} = 4.5 \times 10^{-2} (fm)^3$$

We assume 1S-type electron wave function for "diminished Bohr radius" = $2R_{pe}$=2.4fm

$$\Psi_e(r) = (\pi a^3)^{-1} \exp(-r/a)$$

Weak Interaction at 4H/TSC-min:

Collision theory cannot be applied due to "long" life time of trapped state

- p + e^- + E_{ke} (600keV)→ n + ν + 328 keV
- Neutrino carries away most of 328 keV.
- **Produced n makes immediately strong interaction with remained 3p of TSC.**

$$< WIrate >= (4\pi / h) < W >_w \langle \Psi_e(r_w) \rangle^2$$

$$\langle \Psi_e(r_w) \rangle^2$$ ~ $\Psi e(R_p)^2 \Delta V_W$ = $(0.6/(3.14 \times 2.4^3)) \times 4.5 \times 10^{-2}$ = **5.9×10^{-5}**

4π/h

$$(4\pi / h) < W >_w = |M_{fi}|_F = (G_F / V) c_V \cos\theta_c$$

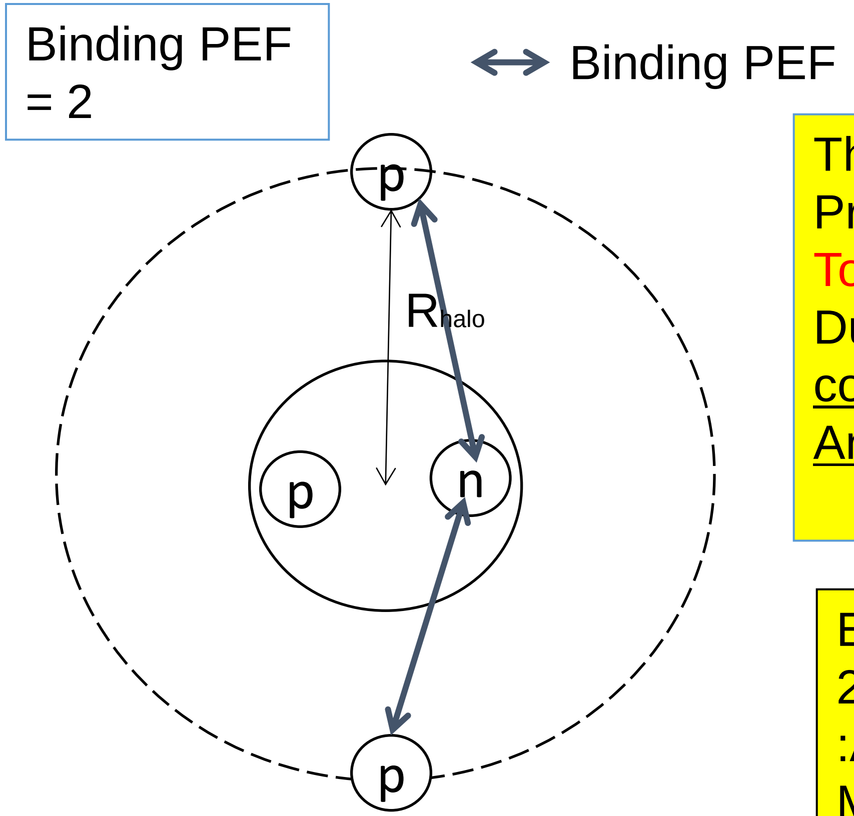
$$G_F = 1.16 x10^{-5} GeV^{-2} (\hbar c)^3 = 89\, eV\, (fm)^3$$

$$\cos\theta_c = 0.88$$: Weinberg angle, and We set c_V=1 and V=1

$$< W >_w = 78\, eV$$

<Real WIrate>=<WIrate><Δt-tsc-min> >= $2.37 \times 10^{17} \times 5.9 \times 10^{-5} \times 1 \times 10^{-15}$ = **1.4×10^{-2}** (1/cluster): (ca.**200W/mol-Ni**)

Nucleon Halo Model of ^{4}Li*(Ex=4.62 MeV: J^π)
Excitation with 2 PEFs spring:
No concrete alpha-core may enhance prompt hadronic break-ups



This state breaks up Promptly in 10^{-22}s
To p + p + d + 2.22 MeV
Due to no hard alpha-core
And weak binding PEF.

E_x < ca.8.4MeV = $2x(1/2)K_1R_{halo}^2$
:And prompt break-up,
Maybe minor channel

Why so radiation-less results?

	Claims by Experiments	Predictions by TSC Models
MDE (Metal Deuterium Energy)	Heat: 24±1MeV/^{4}He (Miles, McKubre, et al) Weak alpha-peaks (Lipson, Roussetskii, etc) Weak neutrons (Takahashi, Boss, etc.) *X-rays burst* (Karabut, et al.)	23.8MeV/^{4}He by 4D/TSC fusion with low-E alphas (46keV) Minor alpha-peaks by nucleon-halo BOLEP minor decay channels High-E neutron by minor triton emission *BOLEP* in ca.1.5keV
MHE (Metal Hydrogen Energy)	Heat w/o n and gamma **unknown ash** (Piantelli, Takahashi-Kitamura, Celani, etc.)	**4H/TSC WS fusion** **7-2MeV/^{3}He and d** **Very weak secondary Gamma and n** **Ca. 10^{-11} of ^{3}He and d**

Concluding Remarks

- Theoretical model of CCF(condensed cluster fusion) looks matching observed AHE(anomalous heat effects) by interaction of nano-composite metal and deuterium (or hydrogen) gas at room and elevated temperatures.
- SNH (sub-nano-holes) on surface of binary nano-composite metal may be major working sites for D- or H-cluster fusion.
- TSC theory predicts that 4D/TSC and 4H/TSC fusions are nuclear reactions for generating AHE.
- TSC-based theories are established to predict quantitative AHE levels and hard-radiation-less nuclear products.

Appendix: Secondary Nuclear Effects

- Metal Nucleus + 4H(D)/TSC Interaction
- Clean Fission Products from Intermediate Excited State of
  Ni + 4H/TSC Nuclear Interaction
- AHE of long running time and Material Damage/annealing
- Damage difference between 4D/TSC induced AHE and 4H/TSC induced AHE

Discussions

- Life Time: At Rpp=2xRp=2.4fm, 4H/TSC condition will be distorted due to limited space for electron rotation. Rpp=2x2$^{1/2}$Rp=3.4fm might be the final point, around which TSC would **oscillate** to have some **enhanced life time (1 fs ; possible by HME Langevin simulation)**. If so 4H/TSC WS fusion rate drastically increase!
- 4D/TSC fusion (47.6MeV/f) event makes much stronger damage than 4H/TSC WS fusion (ca. 4MeV av.), so that **self-recovery of nano-particle works better for Ni-H** system than Ni-D system (ca. 4hrs vs. 1hr of full Ni-lattice atoms displacement by one watt/g level heat-power.)
- Gamma rays: 5.79MeV proton will make Ni(p, γ) reaction with about 100 times the n emission rate, because it happens mainly for ^{58}Ni and ^{60}Ni of high abundance.

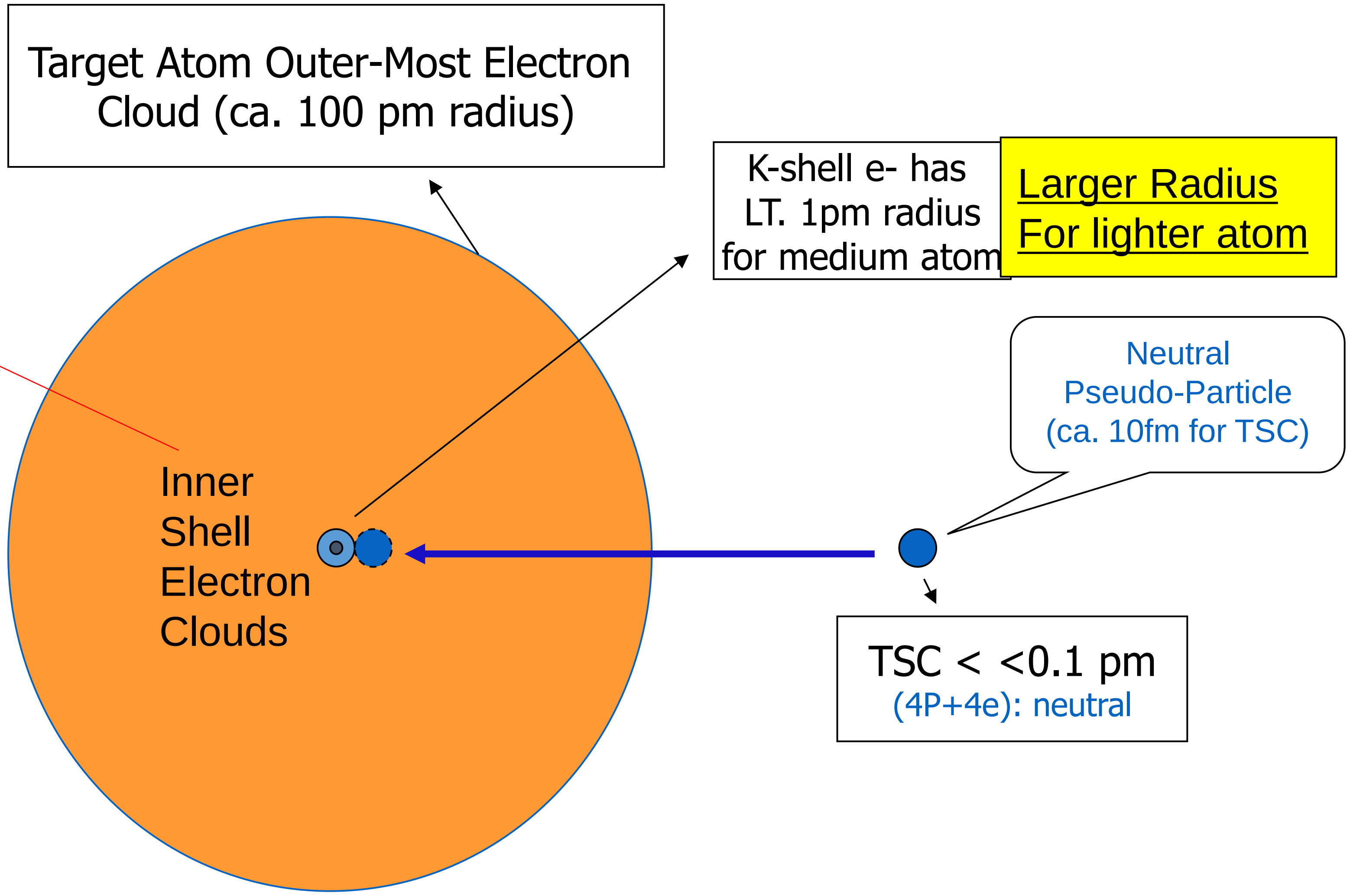
Case-1)TSC-Induced Ni Fission

- The 4H/TSC + Ni-isotope capture-and-fission process, previously proposed, is another plausible scenario. The 4H/TSC-min state may have much longer life than 4D/TSC-min, and Ni has larger K-shell e-cloud radius than Pd. Ni + 4H capture will be enhanced significantly.
- Ni + 4p goes to fission to result in generation of clean fission products in A<100 mass region.

After A. Takahashi: JCMNS, vol.1, 2008

Ni(28)
1s:2
2s:2
2p:6
3s:2
3p:6
3d:8
4s:2

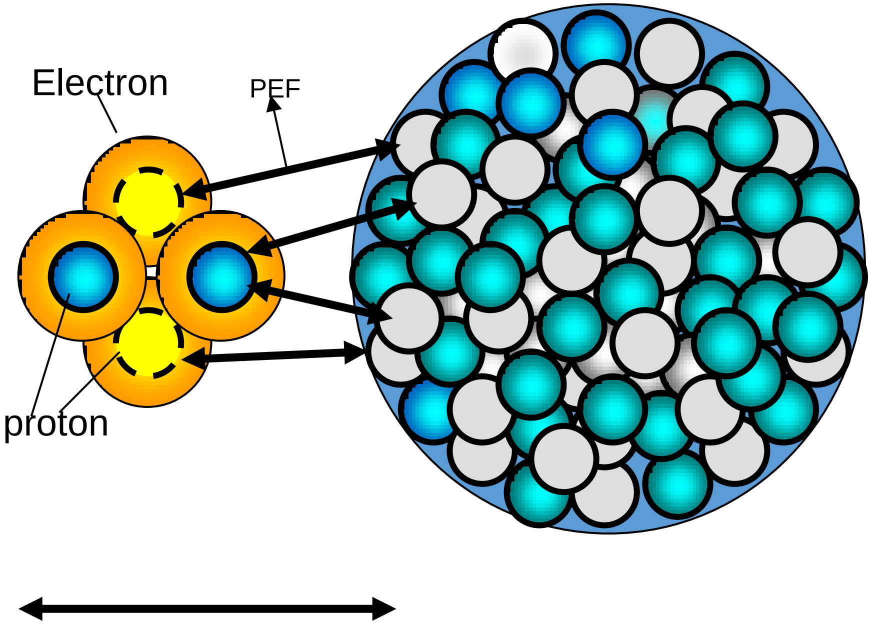
Pd(46)
1s:2
2s:2
2p:6
3s:2
3p:6
3d:10
4s:2
4p:6
4d:10



TSC-min can penetrate through all shell-e-clouds!

After A. Takahashi: JCMNS, vol.1, 2008

M + 4p/TSC Nuclear Interaction Mechanism



- Topological condition for Pion-Exchange (PEF): 4p's are within pion ranges.
- Selection of simultaneous pick-up of 4p looks dominant.
- M + 4p capture reaction.

Major Fission Channels from Ni + 4p (2)

- ^{62}Ni(3.6%) + 4p → ^{66}Ge(Ex=24.0MeV)

  [^{58}Ni + 4d → ^{66}Ge(Ex=53.937MeV)]

→ 11.0MeV + n + $^{65}Ge(EC)^{65}Ga(EC)^{65}Zn$

→ 21.4MeV + ^{4}He + $^{62}Zn(EC)^{62}Cu(EC)^{62}Ni$

→ 11.5MeV + ^{8}Be + ^{58}Ni

→ 18.9MeV + ^{12}C + ^{54}Fe

→ 10.5MeV + ^{14}N + $^{52}Mn(EC)^{52}Cr$

→ 8.2MeV + ^{16}O + ^{50}Cr

→ 13.9MeV + ^{20}Ne + ^{46}Ti

→ 15.2MeV + ^{24}Mg + ^{42}Ca

→ 13.7MeV + ^{27}Al + ^{39}K

→ 18.9MeV + ^{28}Si + ^{38}Ar

→ 18.6MeV + ^{32}S + ^{34}S

Near Symmetric Fragmentation

- 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}Ni(0.93%) + 4P → ^{68}Ge(Ex=29MeV)

  [^{60}Ni + 4d → ^{68}Ge(Ex=55.049MeV)]

→ 16.7MeV + n + $^{67}Ge(EC)^{67}Ga(EC)^{67}Zn$

→ 25.6Mev + ^{4}He + ^{64}Zn

→ 10.0MeV + ^{6}Li + $^{61}Cu(EC)^{61}Ni$

→ 13.2MeV + ^{8}Be + $^{57}Ni(EC)^{57}Co(EC)^{57}Fe$

→ 10.9MeV + ^{9}Be + $^{59}Ni(EC)^{59}Co$

→ 9.9MeV + ^{10}B + $^{58}Co(EC)^{58}Fe$

→ 22.7MeV + ^{12}C + ^{56}Fe

→ 14.8MeV + ^{14}N + $^{54}Mn(EC)^{54}Cr$

→ 12.7MeV + ^{16}O + ^{52}Cr

→ 17.6MeV + ^{20}Ne + ^{48}Ti

→ 12.7MeV + ^{23}Na + ^{45}Sc

→ 17.5MeV + ^{24}Mg + ^{44}Ca

→ 14.8MeV + ^{27}Al + ^{41}K

→ 18.7MeV + ^{28}Si + ^{40}Ar

→ 18.7MeV + ^{32}S + ^{36}S

Near Symmetric Fragmentation

TSC-Induced Fission Products

- FPs can be Mostly Stable Isotopes for A<100 M-targets (Clean Fission) by Near Symmetric Fragmentation (If dominantly selected scission channels).

  It is likely, but precise FP analysis is needed.

- Minor FPs are short-lived decay RIs by EC (K-electron capture process and /or positron decay), for A>50 M-target
- Significant gamma-peaks (prompt and annihilation) should appear for M + 4H/TSC with A<20 M-target