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

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AIMS

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

Basic Mechanism will be:

- **Formation of**

Tetrahedral Symmetric Condensate (TSC):

4 deuterons + 4 electrons make
a transient Bose-type condensation
by 3-dimensionaly
constraint squeezing motion

How small can TSC size become?

The Place where TSC is born?

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

→ Possible at very low temperature?

(Bose-Einstein Condensation)

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

→ (Dynamic Bose Condensation of TSC)

Phonon Excitation by Laser

- Dielectric Response Function of Metal:

  (Classical Drude-Model for free electron gas)

  $\varepsilon(\omega) = 1 - (\omega_p \tau)^2 / (1 + (\omega \tau)^2)$

  $\approx 1 - (\omega_p / \omega)^2$

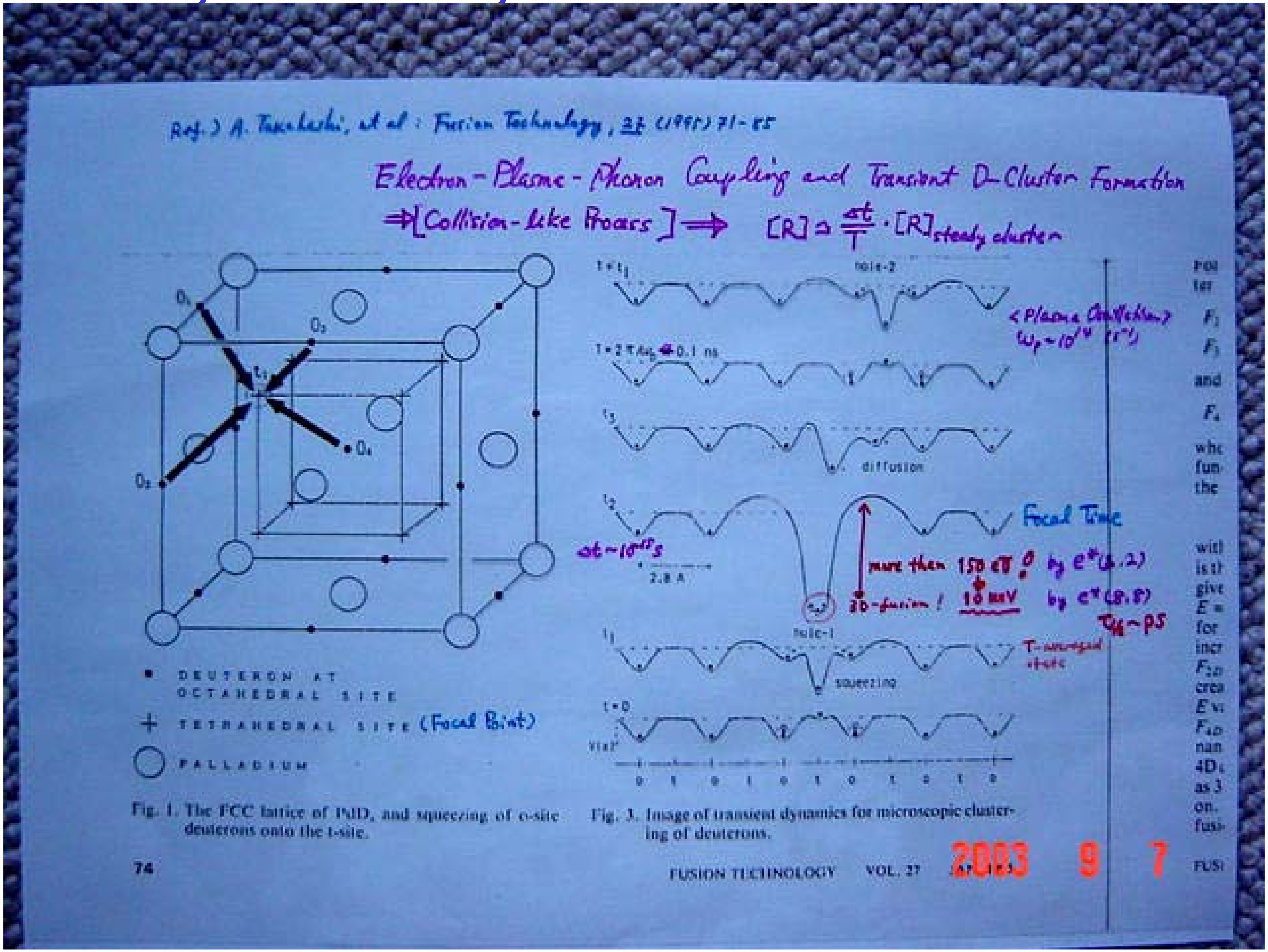
  with $\omega_p = (4\pi Ne^2/m)^{1/2}$: plasma frequency

  which is over UV region (1E+15 (1/s))

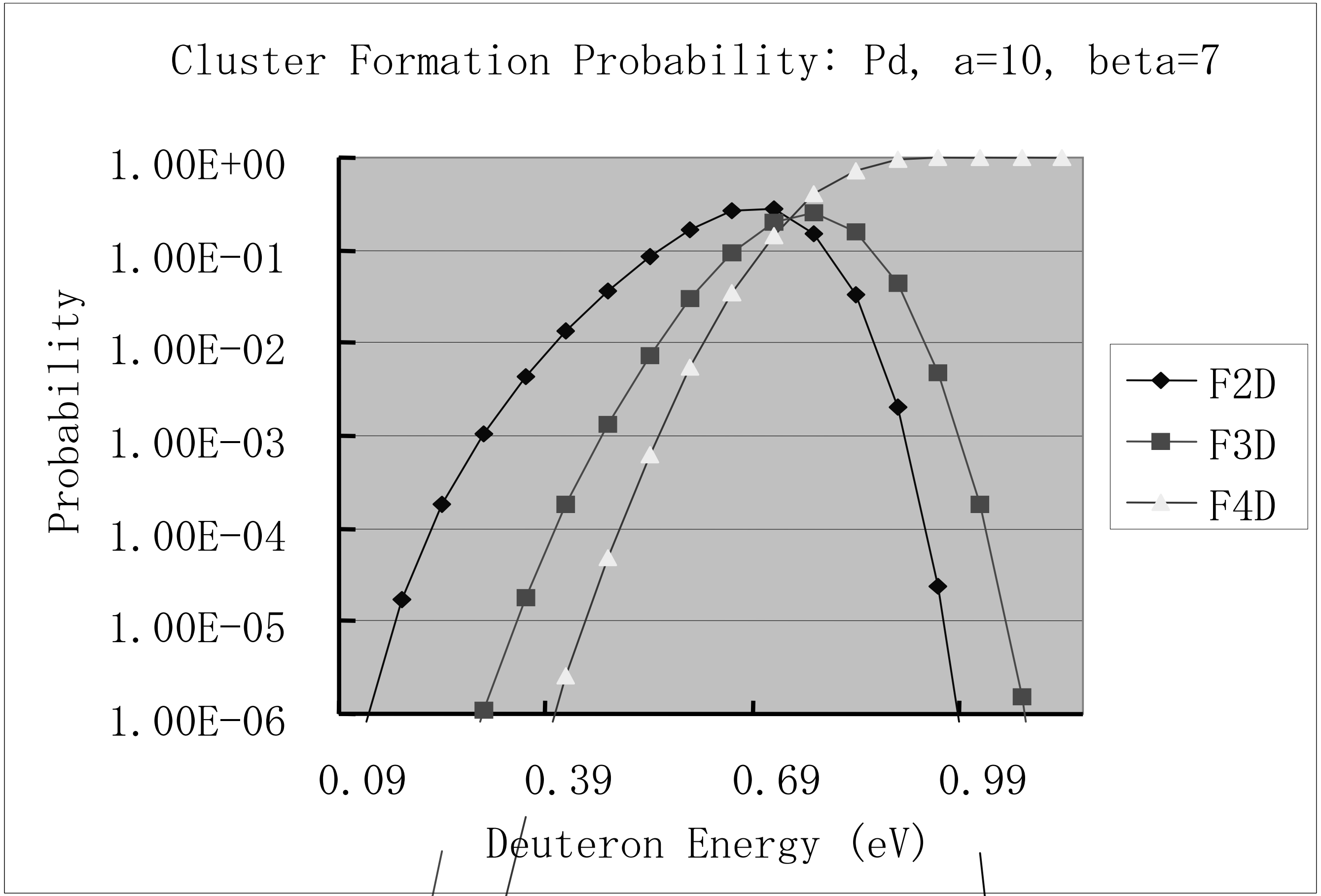
- 100 % penetration by $\omega > \omega_p$

EUV-Laser irradiation can excite phonons inside bulk metal!

D-Cluster Formation in PdD Transient Dynamics by Phonon Excitation

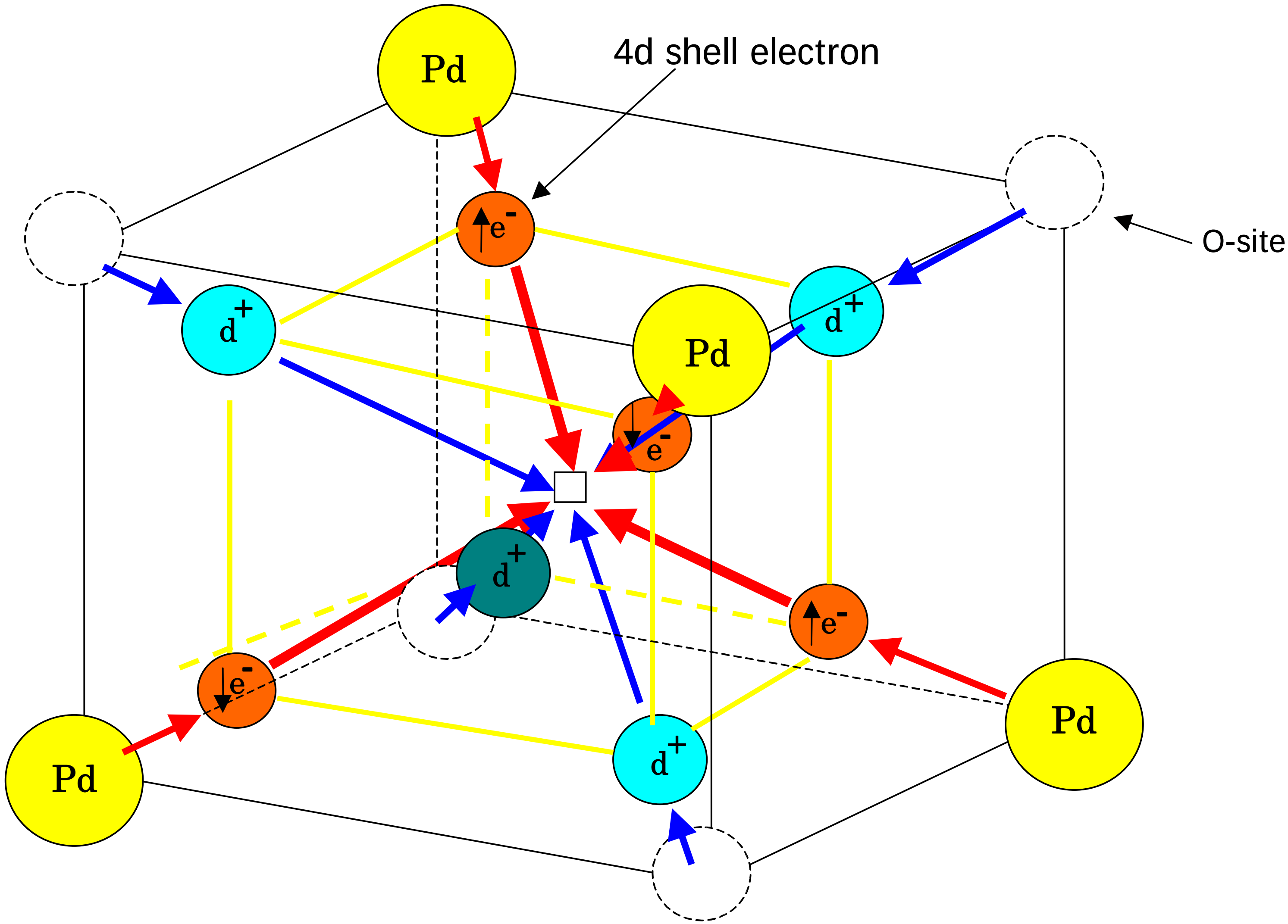


Cluster Formation Probability in Atomic Level



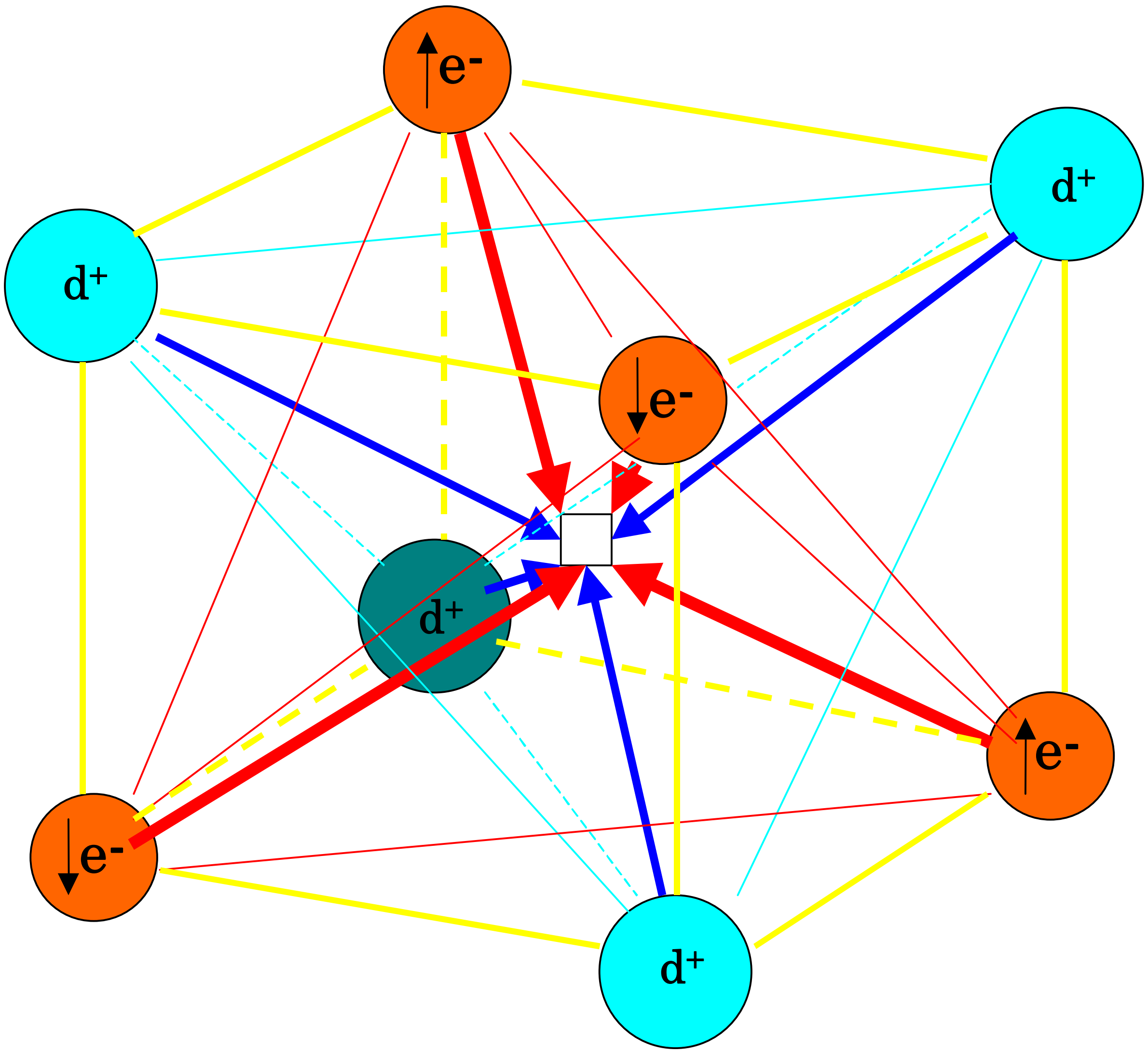
•Calculation by Excitation Screening Model, Fusion Tec. 1991

Tetrahedral Condensation of Deuterons in PdDx



Classical View of Tetrahedral Condensation

Orthogonal Coupling of Two D_2 Molecule makes Miracle !



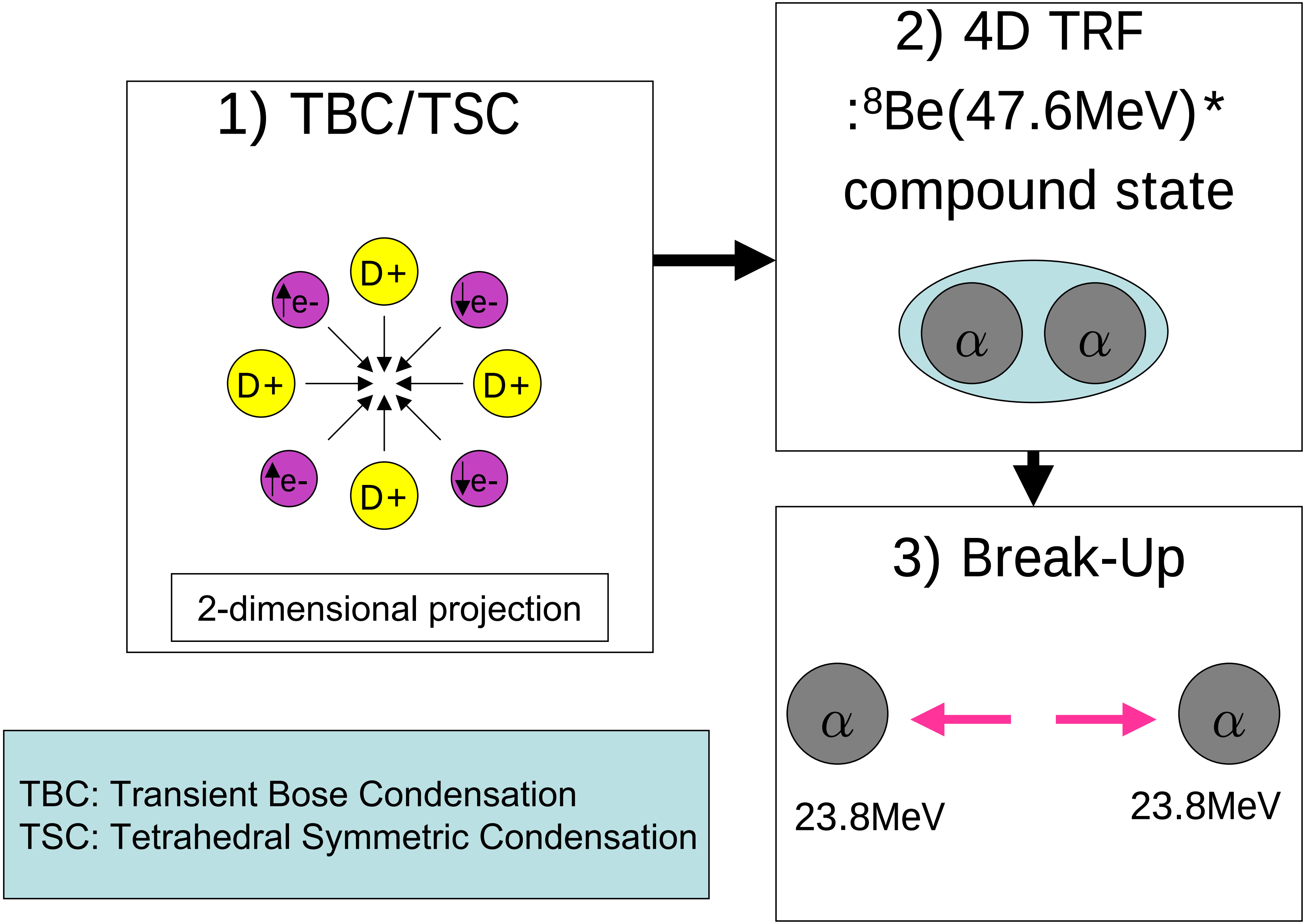
Transient Combination of Two D2 Molecules (upper and lower)

Squeezing only from O-Sites to T-site

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

Quadruplet e* (4,4)

Formation of Electrons around T-site



1) TBC/TSC
D+
e-
2-dimensional projection
2) 4D TRF
:^{8}Be(47.6MeV)*
compound state
α
3) Break-Up
23.8MeV
23.8MeV
TBC: Transient Bose Condensation
TSC: Tetrahedral Symmetric Condensation

Assumptions

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

Basic 4-body Fusion by TSC

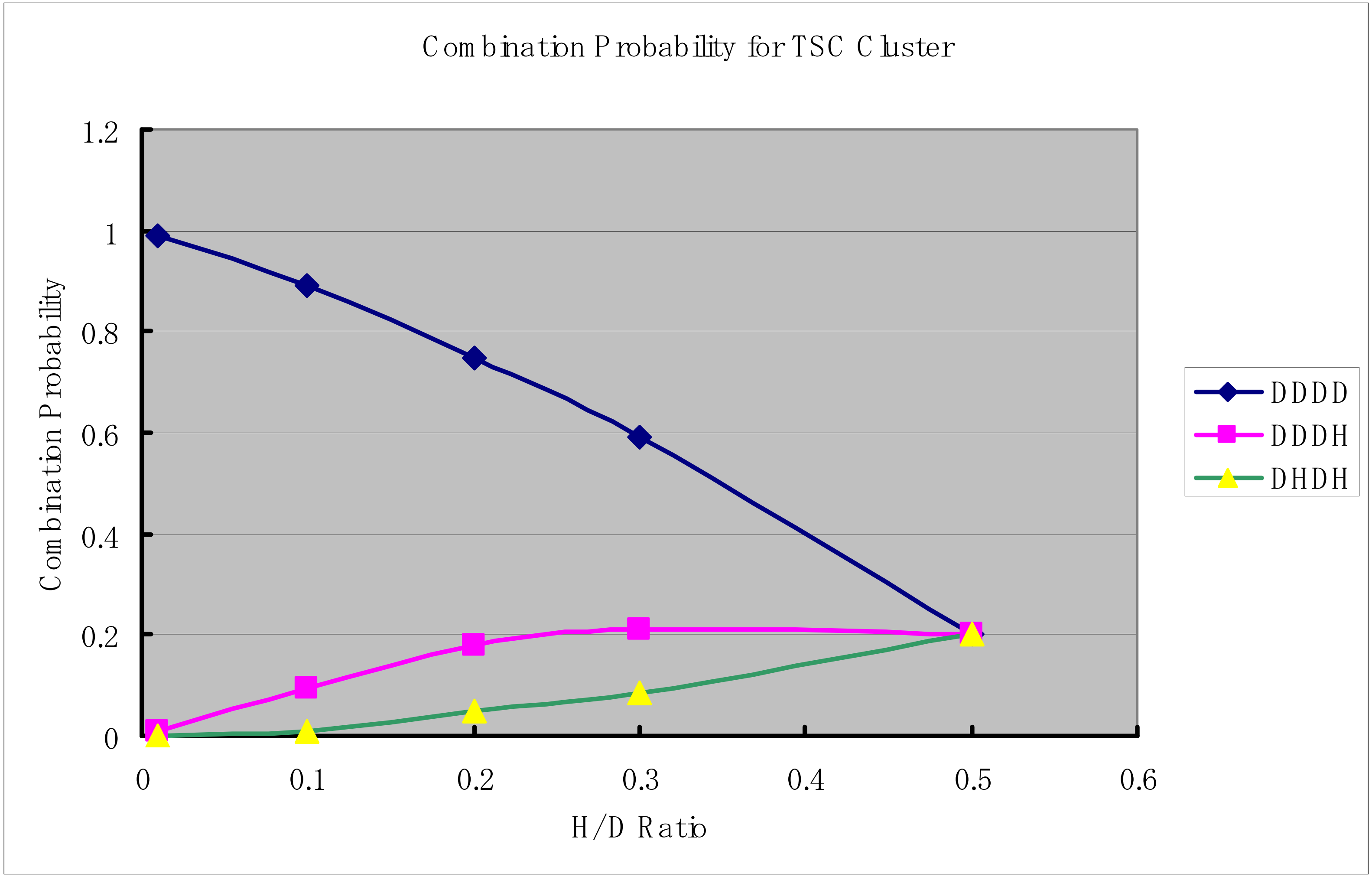
- $D+D+D+D \rightarrow {}^{8}Be^{*} \rightarrow {}^{4}He + {}^{4}He + 47.6MeV$
- $D+D+D+H \rightarrow {}^{7}Be^{*} \rightarrow {}^{3}He + {}^{4}He + 29.3MeV$
- $D+H+D+H \rightarrow {}^{6}Be^{*} \rightarrow {}^{3}He + {}^{3}He + 11MeV$

Combination Probability of H/D Mixed TSC Cluster

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

K: Normalize sum probability to be 1.0

Combination Probability for TSC Cluster



Fusion Rate Calculation for EQPET Molecule

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

Fusion Rate for EQPET Molecule

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

Calculation of Modal Fusion Rate

- Wave function for TSC cluster:

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

- Modal Fusion Rate:

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

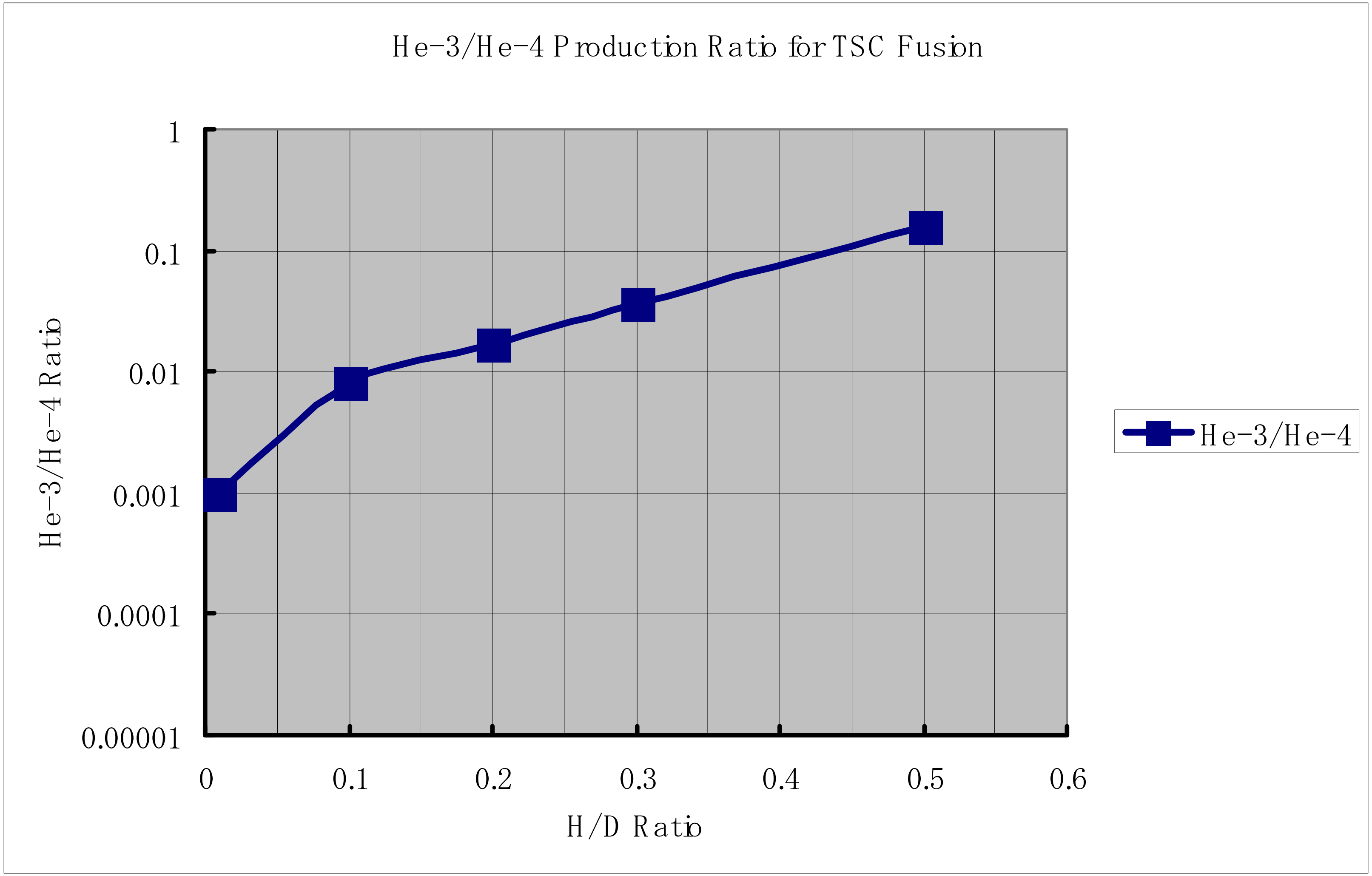
- By taking into account spin arrangement only, $a_1^2=0.78$, $a_2^2=0.19$, $a_4^2=0.03$

Modal Fusion Rate

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

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

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



Comparison with Experiment

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

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

- Present Theory;

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

Parameters for Deep Potential Hole : by EQPET

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

- DTP values approximately correspond to Screening Energy

Emission of Photons from TSC

- Hydrogen TSC (pepepepe system) causes no nuclear fusion, but weak interaction.
- When TSC forms from normal electron state, we may have specific photon emission, e.g., at energies of 260 eV, 446 eV, 2460 eV, 2950 eV, etc.
- If we can detect these photons by hydrogen experiment, it may be proof.

Minimum Size of TSC is far less than 1 pm!

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

V_s Potential for e*(4,4) $\alpha\ \alpha$ molecule

$_{min}$ = -9.83 keV

$_{dd}$(GS) = 13 pm

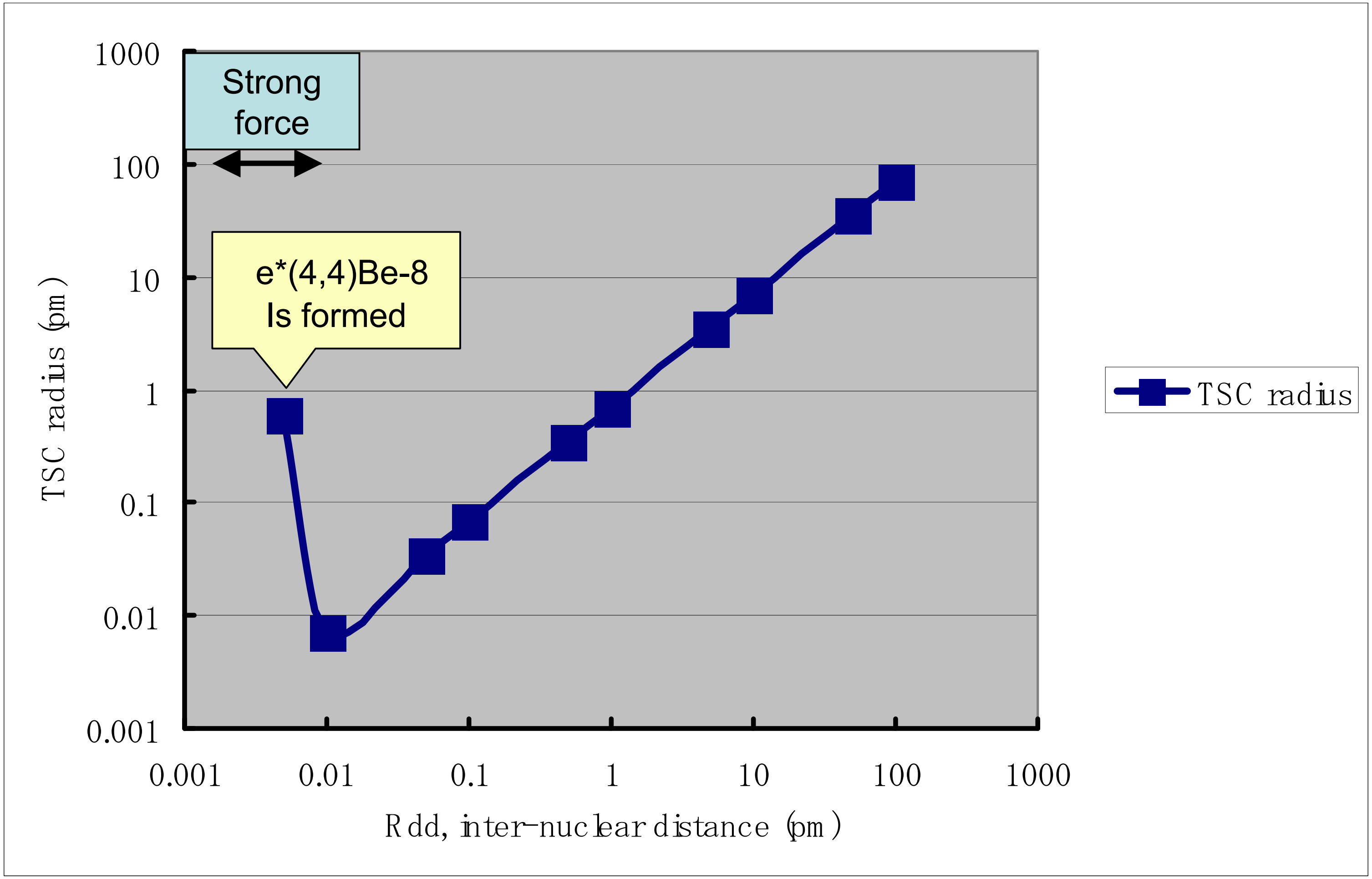
V_s Potential for e*(8,8)$^8Be^8Be$ molecule

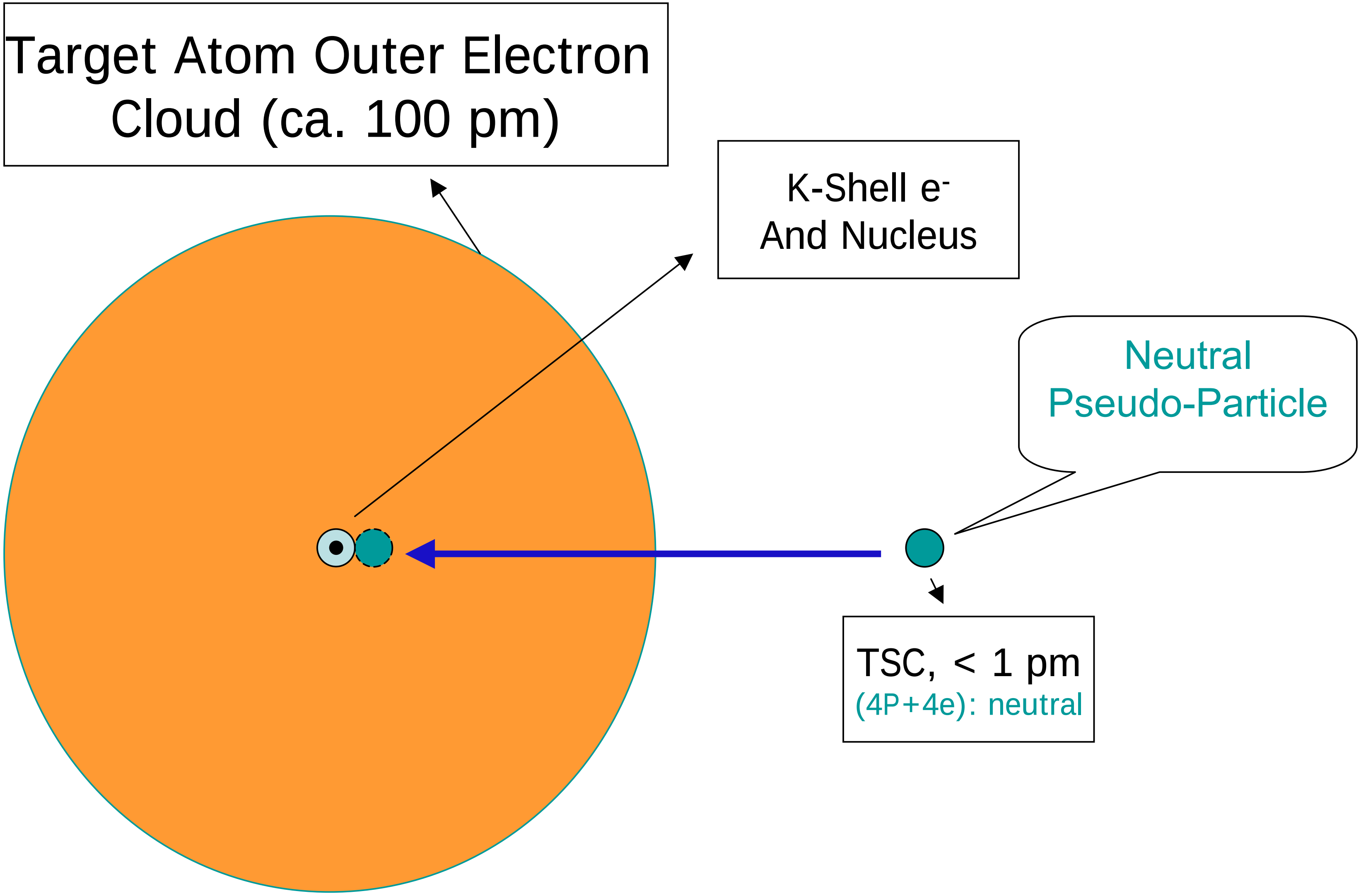
V_{min} = -32.9 keV

R_{dd}(GS) = 5 pm

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

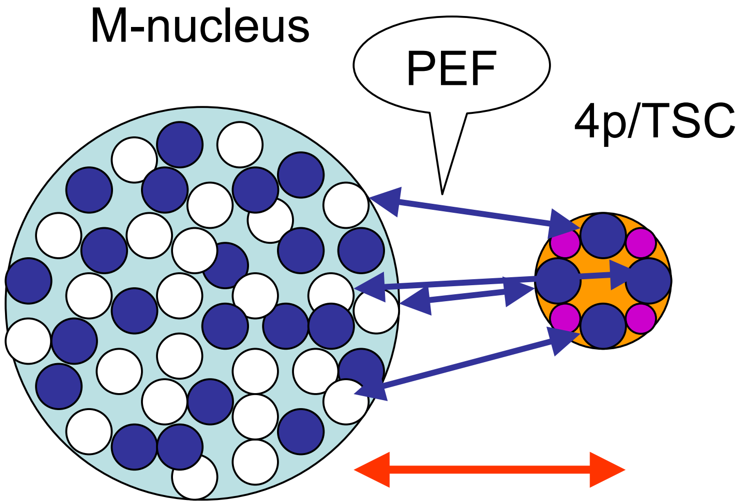
TSC Size by Dynamic Condensation





ow deep can TSC penetrate through e-cloud?

M + TSC
Nuclear Interaction Mechanism

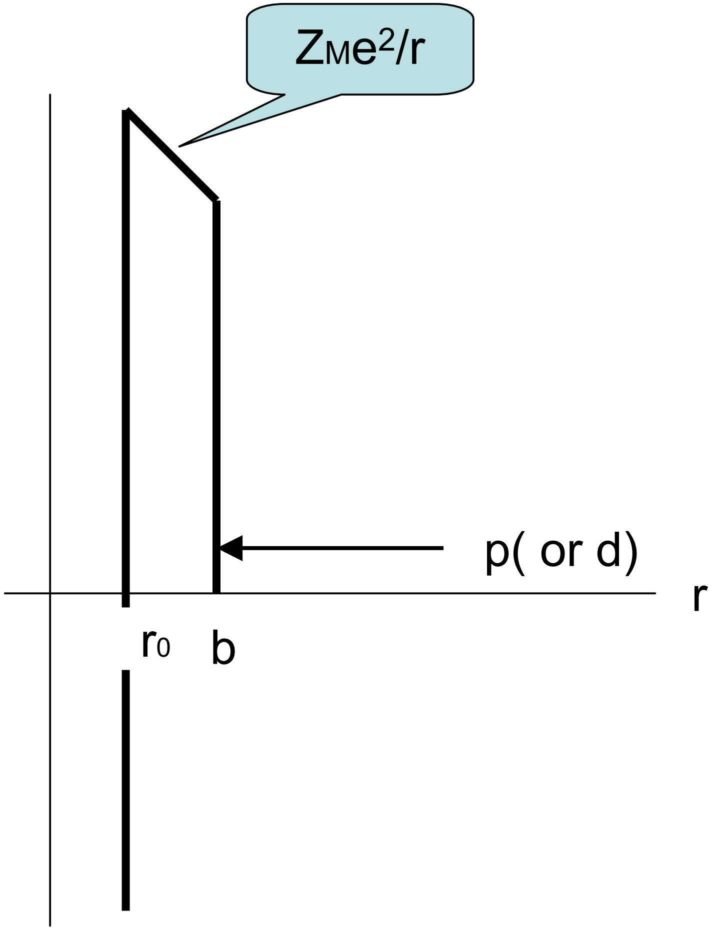


Range of
Strong interaction
(3-5 fm)

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

Sudden Tall Thin Barrier Approx.

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



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

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

- $P_n =$

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

: 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:

- λ_{Mp} = 3.7E-8 (f/s/pair)
- λ_{Md} = 2.1E-7 (f/s/pair)
- λ_{M4p} = 1.0E-8 (f/s/pair)
- λ_{M4d} = 3.4E-9 (f/s/pair)
- <Macroscopic Reaction Rate> = $\lambda x N_{M+TSC}$
- With N_{M+tsc} = 1.0E+17 in 10μnm area, Ni+4p Rate = 1E+9 f/s/cm2 and Y_{4p} = 1E+15 in 1E+6 sec.
- 1 watt = 2E+11 f/s, and 1E+9 f/s/cm^2 is 5 mW/cm^2

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

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

λ_{4d} = 4.9E-5

Estimation of N_{M+TSC}

- $N_{M+TSC} = \sigma_A N_M \langle N_{TSC} \rangle v \tau_{TSC}$
- N_M : Host metal atom density
- N_{TSC} : Time-averaged TSC density
- σ_A : Atomic level cross section for M+TSC combination
- τ_{TSC} : mean life time of TSC
- Note: approximated by the squeezing time of TSC from 1 angstrom domain to 5 fm domain, because strong interaction breaks TSC.

- τ_{TSC} = 45 fs (for p), 66 fs (for d)
- σ_A = 1E−16 (cm^2)
- N_M = 1E+23 (cm^{-3})
- N_{TSC} = 1E+20 (cm^{-3}) is assumed here

- N_{M+TSC} = 1E+19 (cm^{-3})

Products by Ni + p reactions

^{8}Ni+p→
^{59}Cu*(1.36m, EC)^{59}Ni*(7E4 y)

^{0}Ni + p →
^{61}Cu*(3.3h, EC)^{61}Ni

^{1}Ni + p →
^{62}Cu*(9.7m, EC)^{62}Ni

^{2}Ni + p →
^{63}Cu(6.12MeV);Eg=669keV

^{4}Ni + p → ^{65}Cu(7.45MeV)

i-H gas system exp.
By Piantelli (ASTI5)
; 660 keV peak by NaI
detector

- 660 MJ Excess Energy

Fission by M + TSC is possible!

^{8}Ni + 4p →
^{62}Ge(11MeV) →FP

^{8}Ni + 4d →
^{66}Ge(54MeV) →FP

^{05}Pd + 4p →
^{109}Sn(23MeV) →?

^{05}Pd +4d →
^{113}Sn(52MeV) →FP

^{04}Pd+4d →
^{112}Sn(52MeV) →FP

any foreign elements were detected by
Piantelli, Karabut, Yamada, Ohmori,
Mizuno, Miley, etc.

ission can be induced by TSC capture!

^{133}Cs + TSC Reactions

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

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

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

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

  with PEF = 2 for dd

  and PEF = 1 for pd

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

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

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

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

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

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

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

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

  or FPs

STTBA Prediction for Cs-to-Pr

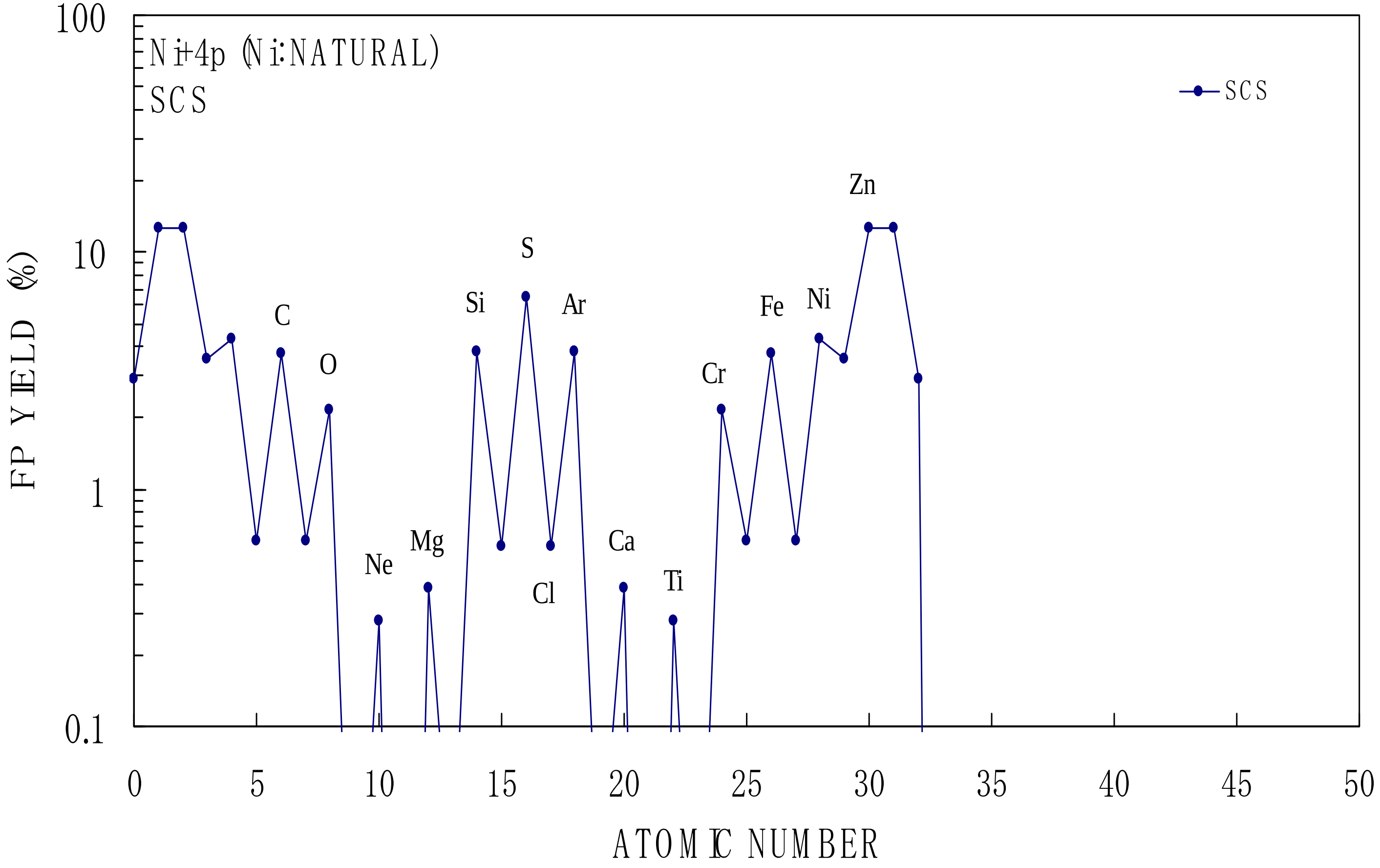
- S_{Mp} = 1E+8 kevb
- S_{Md} = 1E+9 keVb
- λ_{Mp} = 8.4E-10 f/s/pair
- λ_{M4p} = 2.3E-10 f/s/pair
- λ_{Md} = 2.8E-8 f/s/pair
- λ_{M4d} = 7.6E-9 f/s/pair
- Where combination probability of anti-parallel spin was used for 4p/TSC.

- Suppose N_{M+tsc} = 1E+17 in 100 nm layer of surface
- Macro Yield = $\lambda x N_{tsc}$ = (7.6E-9) x (1E+17) = 7.6E+8 (f/s/cm^2)
- Cs-to-Pr rate = 4.6E+14 (atoms per week) per cm^2
- Here we assumed; <N_{TSC}> = 1E+22 (cm^{-3}), due to high D_2-flux condition in experiment

Table : Natural abundance of Ni isotopes and

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

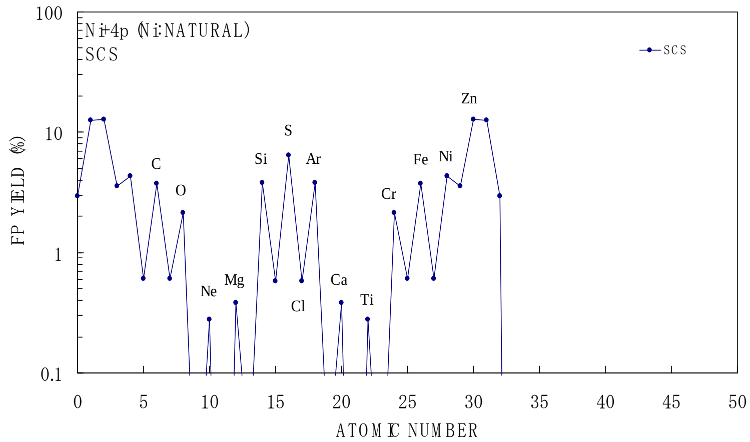
Nuclides	Natural abundance (%)	+ 4p	Excitation energy (MeV)	+ 4d	Excitation energy (MeV)
^{58}Ni	68.077	$^{62}Ge^{*}$	11.2	$^{66}Ge^{*}$	53.9
^{60}Ni	26.223	$^{64}Ge^{*}$	19.1	$^{68}Ge^{*}$	55.1
^{61}Ni	1.140	$^{65}Ge^{*}$	21.3	$^{69}Ge^{*}$	55.4
^{62}Ni	3.634	$^{66}Ge^{*}$	24.0	$^{70}Ge^{*}$	56.4
^{64}Ni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

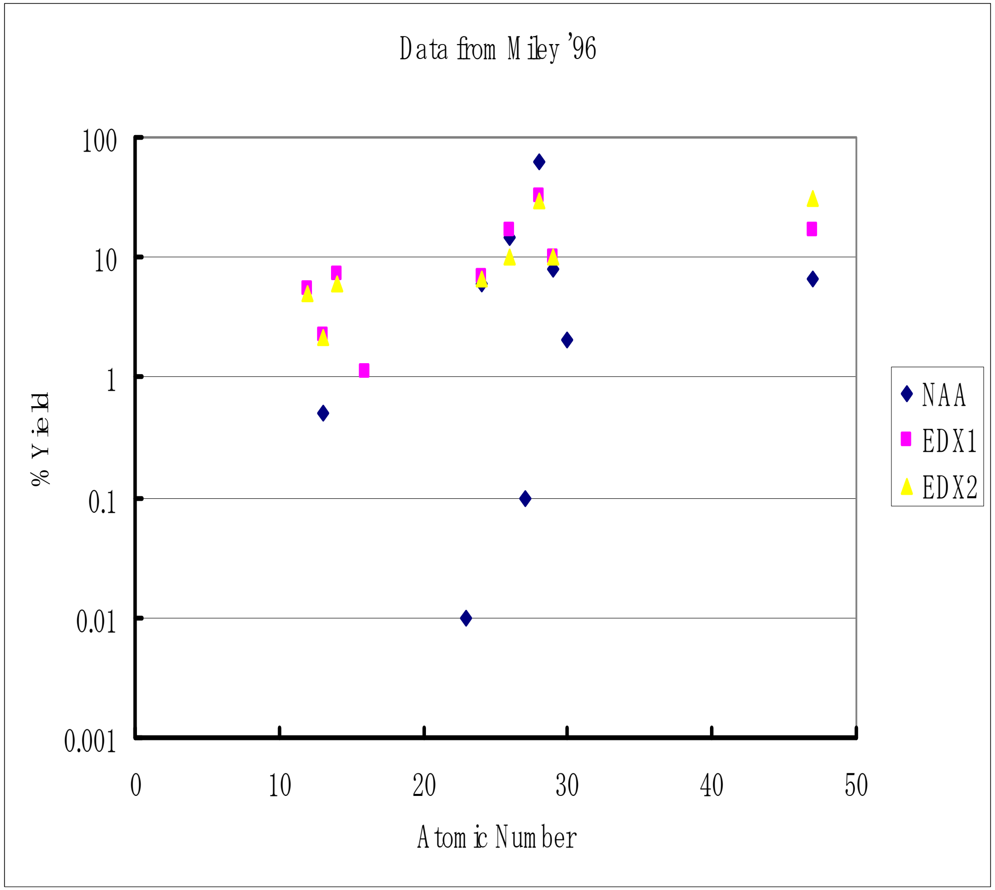


Ni+4p (Ni:NATURAL)
SCS
SCS
FP YIELD (%)
ATOMIC NUMBER
100
10
1
0.1
0
5
10
15
20
25
30
35
40
45
50
C
O
Ne
Mg
Si
S
Cl
Ar
Ca
Ti
Cr
Fe
Ni
Zn

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

(1) ^{58}Ni(68%) + 4p → ^{62}Ge(Ex=11.2MeV)

→ 8.8MeV + ^{4}He + ^{58}Zn(EC)^{58}Cu(EC)^{58}Ni
→ 8.8MeV + ^{28}Si + ^{34}Ar(EC)^{34}Cl(EC)^{34}S

(2) ^{60}Ni(26.2%) + 4p → ^{64}Ge(Ex=19.1MeV)

→ 16.4MeV + ^{4}He + ^{60}Zn(EC)^{60}Cu(EC)^{60}Ni
→ 13.6MeV + ^{8}Be + ^{56}Ni(EC)^{56}Co(EC)^{56}Fe
→ 13.0MeV + ^{12}C + ^{52}Fe(EC)^{52}Mn(EC)^{52}Cr
→ 12.2MeV + ^{16}O + ^{48}Cr(EC)^{48}V(EC)^{48}Ti
→ 13.5MeV + ^{24}Mg + ^{40}Ca
→ 16.4MeV + ^{28}Si + ^{36}Ar
→ 16.7MeV + ^{32}S + ^{32}S
→ 6.5MeV + ^{38}Ar + ^{26}Si(EC)Al(10^5y)

(3) ^{61}Ni(1.1%) + 4p → ^{65}Ge(Ex=21.3MeV)

→ 18.9MeV + ^{4}He + ^{61}Zn(EC)^{61}Cu(EC)^{61}Ni
→ 15.9MeV + ^{12}C + ^{53}Fe(EC)^{53}Mn(3.7x10^6 y)
→ 11.0MeV + ^{20}Ne + ^{45}Ti(EC)^{45}Sc
→ 17.4MeV + ^{28}Si + ^{37}Ar(EC)^{37}Cl
→ 12.0MeV + ^{27}Si(EC)^{27}Al + ^{38}Ar
→ 17.5MeV + ^{32}S + ^{33}S

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

Major Fission Channels from Ni + 4p (2)

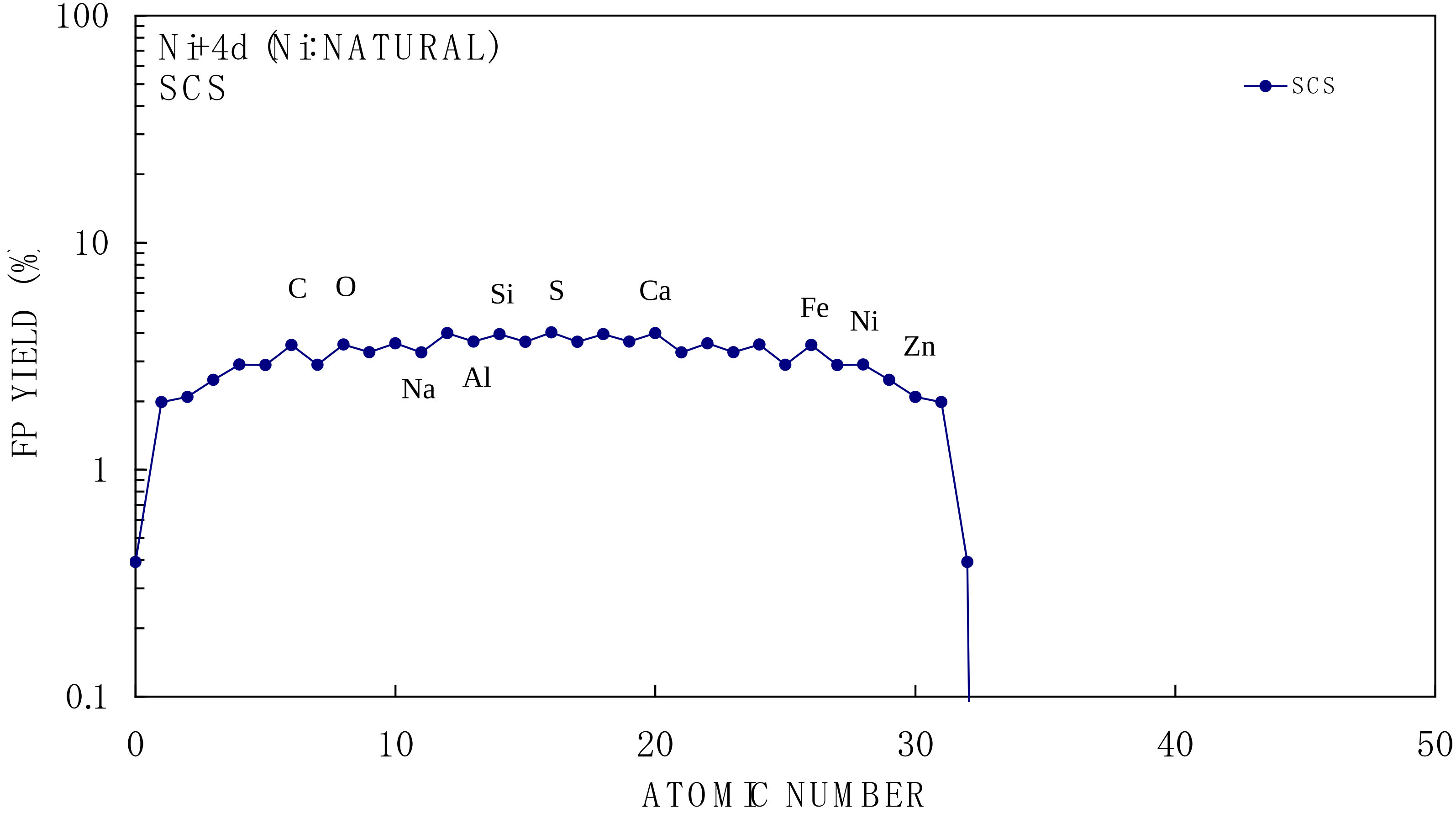
- ^{62}Ni(3.6%) + 4p → ^{66}Ge(Ex=24.0MeV)

→ 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

- 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.

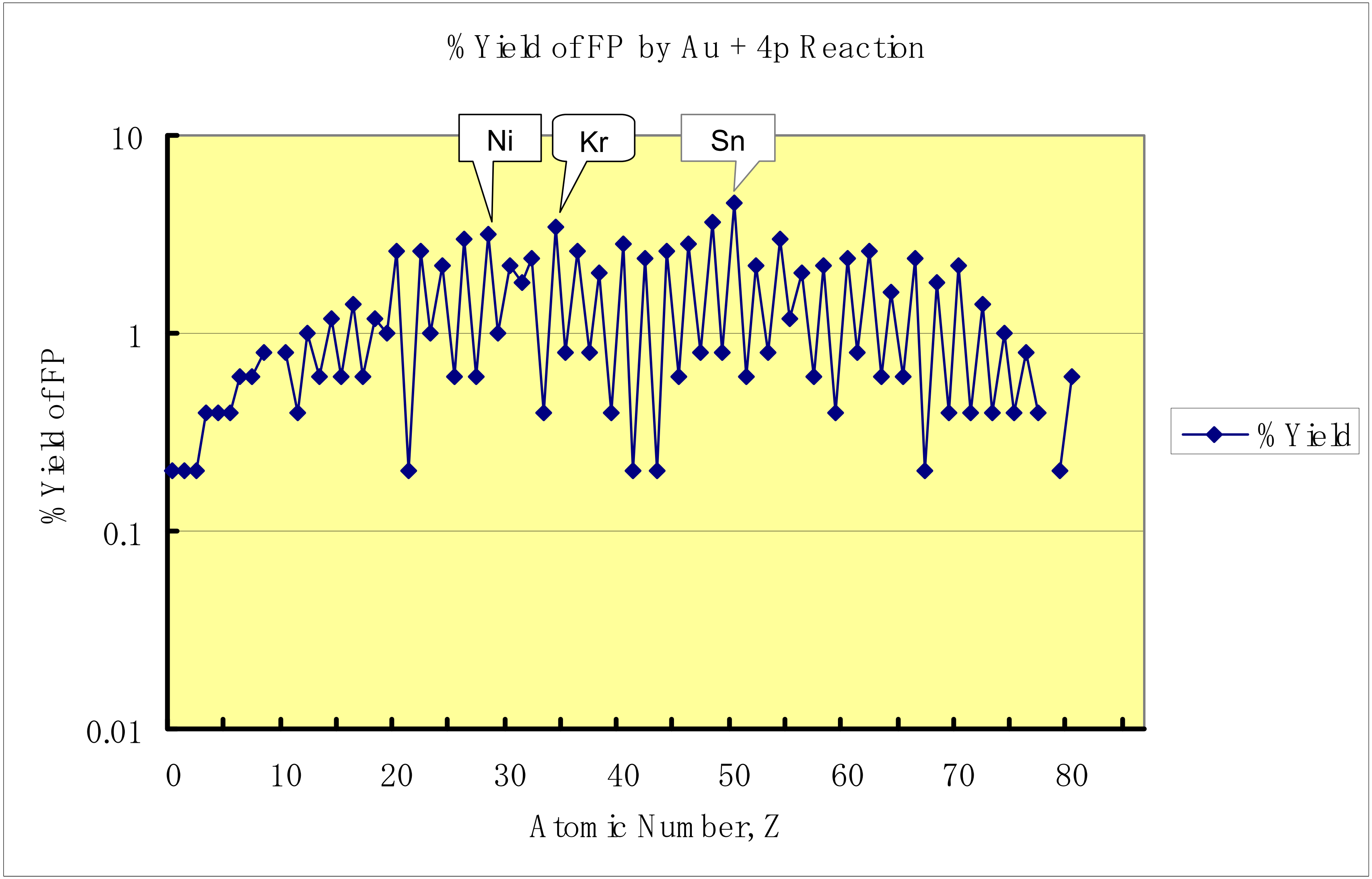
- ^{64}Ni(0.93%) + 4P → ^{68}Ge(Ex=29MeV)

→ 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



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

FP Distribution vs. Z, for Au + 4p/TSC



Secondary Reactions by ^3He

- ^3He by D+D+D+H fusion has 16.7 MeV, and by D+H+D+H fusion 5.5 MeV.
- Coulomb Barriers:

  Cs + ^3He : 15.7 MeV

  Pd + ^3He : 14.1 MeV
- Small reaction is predicted by 16.7 MeV ^3He during its slowing down,
- and nothing by 5.5 MeV ^3He.

^{3}He for Stable Nuclear Fuel

- Stable Resource to produce Tritium:

  ^{3}He + n $\rightarrow$ p + t + 0.765 MeV: in fission reactor or spallation source. Easy to extract T from gas-phase.

  Tritium decays with 12.3 yrs half life.

  For DT reactors and H-bomb.

  (neutron detector)
- Fuel for D-^{3}He reactors.

Conclusions

- H should be contained with some amount in usual CMNS deuterium-experiment.
- EQPET model was applied to 4-body fusion of mixed H/D TSC-system.
- $^{3}He/^{4}He$ production ratio was 0.16 for 50 % H-contamination.
- ^{3}He is useful nuclear fuel.
- Formation of TSC is Key!
- Possibility of direct nuclear reaction for M+TSC. (Further study is expected.)