Peculiarities in behavior of impurity atoms in conducting crystals

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Cold fusion now

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"There is no such theory - cold fusion"
Prof. E. Velikhov (2005)

"Physics is the experimental science"
Prof. R. Feynman

History of cold fusion
Key players in cold fusion

Martin Fleischmann (1927-2012)
D+D in Pd
1989

Michael McKubre
D+D in Pd
1992-now

Yoshiaki Arata
D+D in Pd (ZrO_2)
1998-2008

Melvin H. Miles presentation at National Meeting of American Chemical Society, 2010

FUSION ENERGY CALCULATION

$${}^{2}_{1}D + {}^{2}_{1}D \longrightarrow {}^{4}_{2}He + 23.8\ \text{MeV}$$

$$(1.5\text{x}10^{43}\ \text{D atoms})\left(\frac{1\text{fusion}}{2\text{Datom}}\right)\left(23.8\text{x}10^{6}\frac{eV}{fusion}\right)\left(1.602\text{x}10^{-19}\frac{J}{eV}\right) = 2.9 \text{ x } 10^{31}\ \text{J}$$

Energy per person per year (USA)

$$\left(10.0\ \frac{kW}{person}\right)\left(1000\frac{W}{kW}\right)\left(365\ \frac{days}{year}\right)(24\ \text{hr/day})(60\ \text{min/hr})(60\ \text{s/min}) = 3.15 \text{ x } 10^{11}\ \text{J}$$

World (7 billion) Energy per year

$$(7 \text{ x } 10^{9})\ (3.15 \text{ x } 10^{11}\ \text{J}) = 2.2 \text{ x } 10^{21}\ \text{J/year}$$

Years Fueled by D + D Fusion

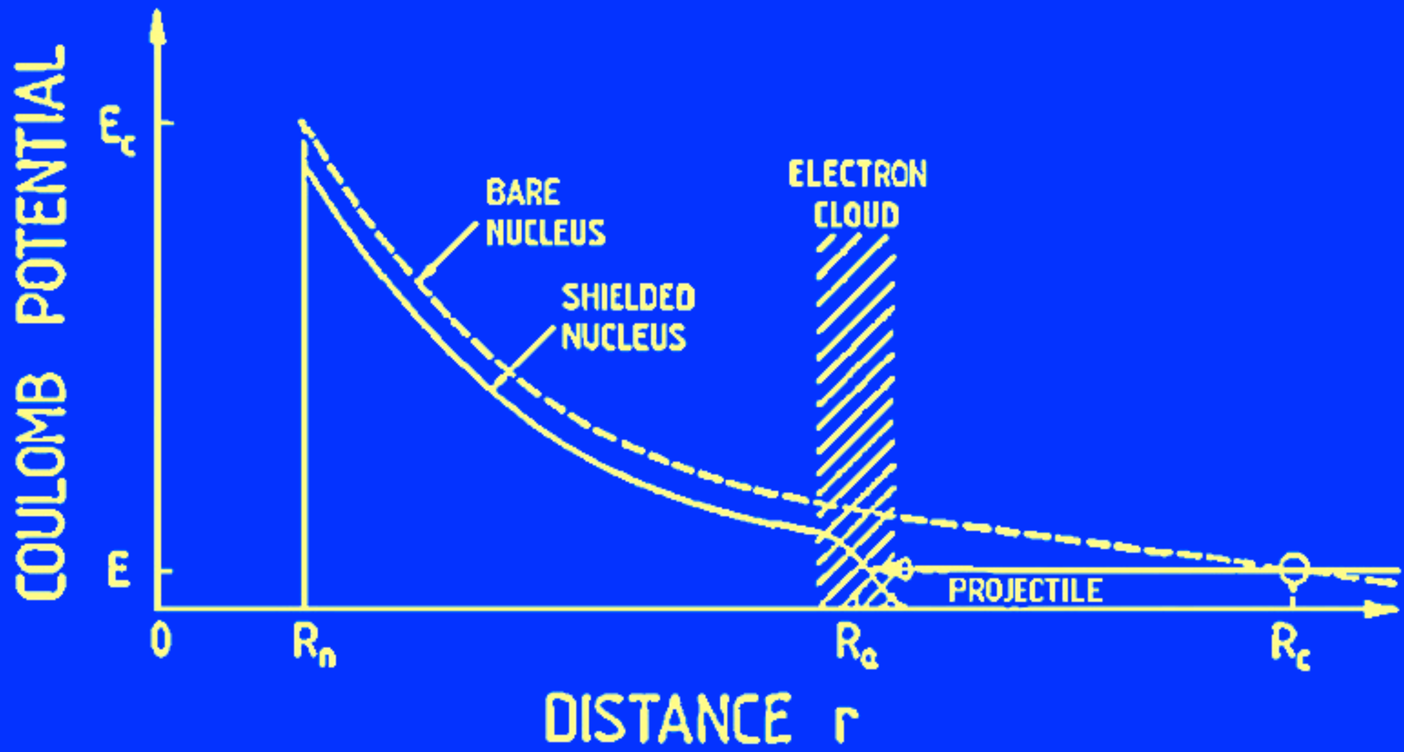
$$(2.9 \text{ x } 10^{31}\ \text{J}) / (2.2 \text{ x } 10^{21}\ \text{J/year}) = 1.3 \text{ x } 10^{10}\ \text{years}$$

(13 billion years!)

“Four ounces of heavy water today costs about $50 and contains enough energy when converted to electricity to supply the average American with electricity for a lifetime”

What is the “prime secret” of Cold Fusion?

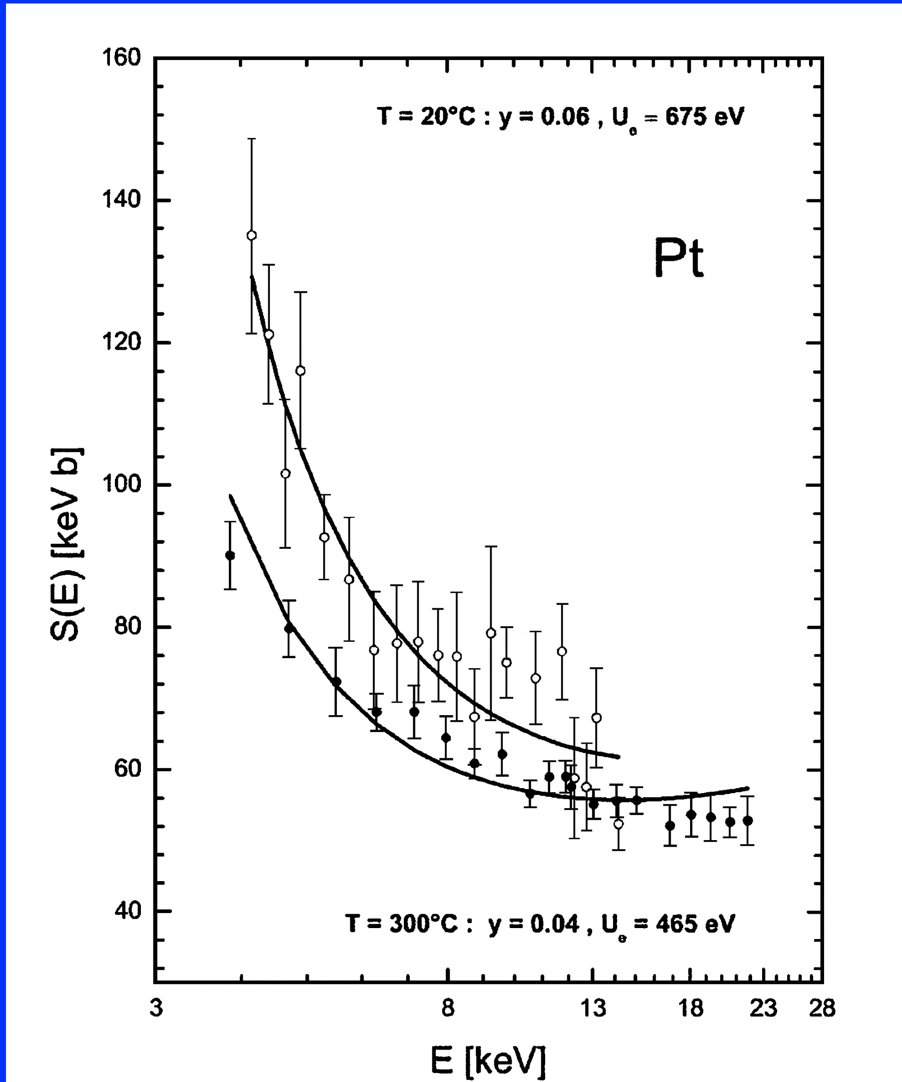
In quantum mechanical consideration the screening potential in the fusion process is equivalent to additional energy (H.J. Assenbaum, K. Langanke and C. Rolfs)



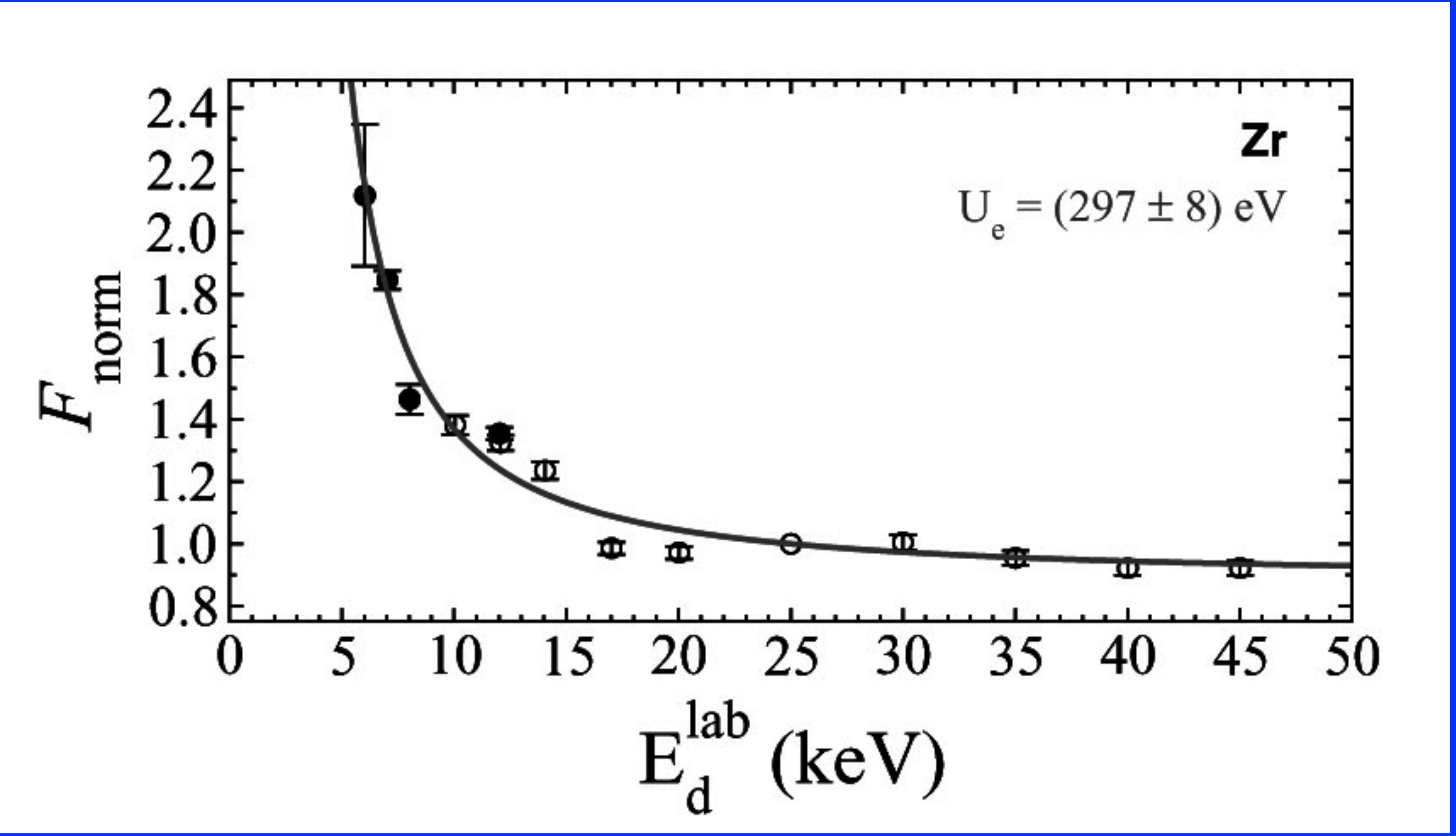
For interactions of free deuterium atoms this additional energy equals 27 eV

Experiments in Gran Sasso Laboratory (LUNA Collaboration)
Prof. Claus Rolfs

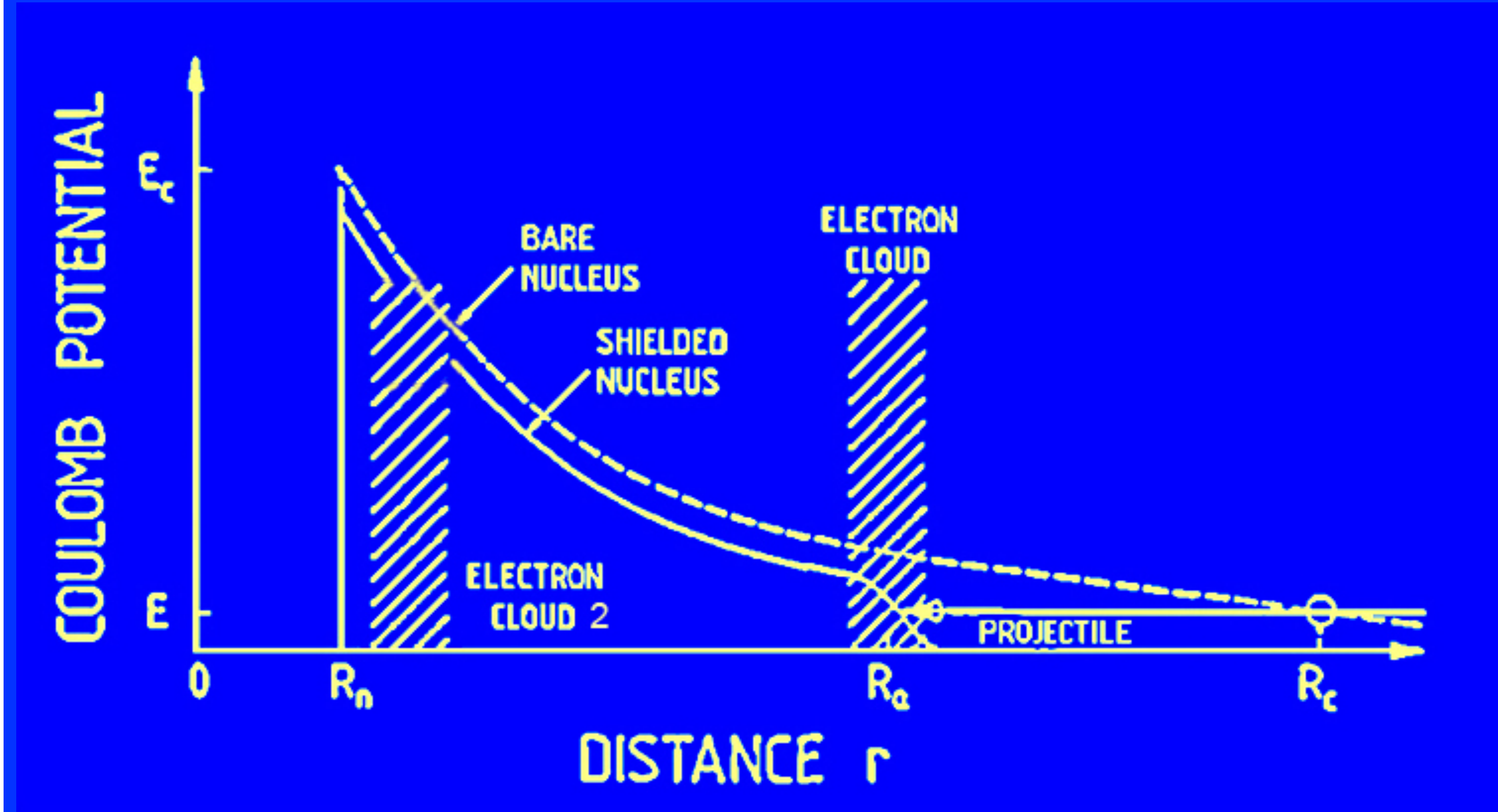
S(E) for DD fusion, target is imbedded in Pt
(F. Raiola et al., J. Phys. G: Nucl. Part. Phys. 31, 2005, pp 1141–1149)
U_e=675 eV



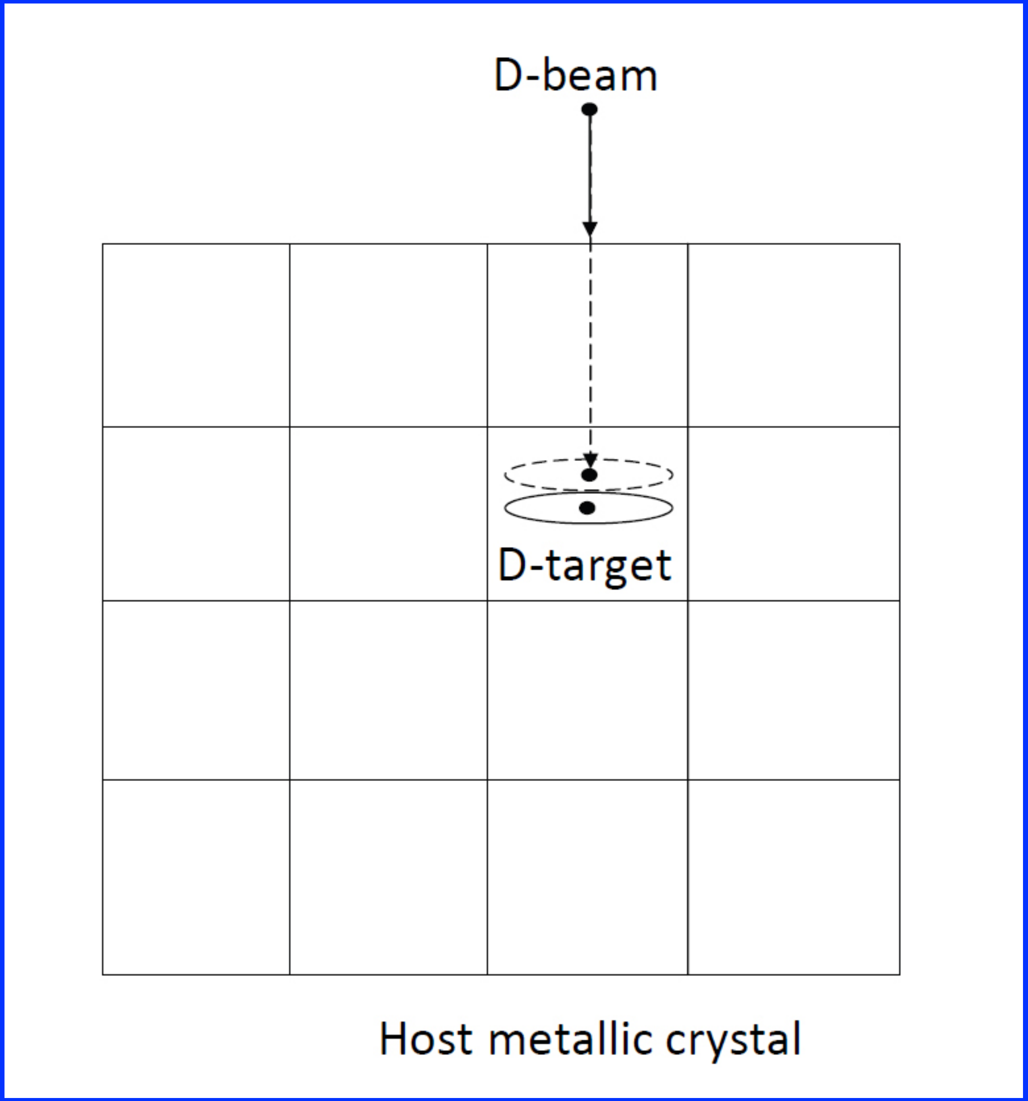
Normalized astrophysical factor *S(E)* for DD fusion, when target is imbedded in Zr. *Unusually* high electron screening potential, about 10 times larger than that for free atoms (A. Huke, K. Czerski et al., Physical Review C 78, 015803, 2008)



Screening potential characterizes dimensions of the atom



Gran Sasso experiments



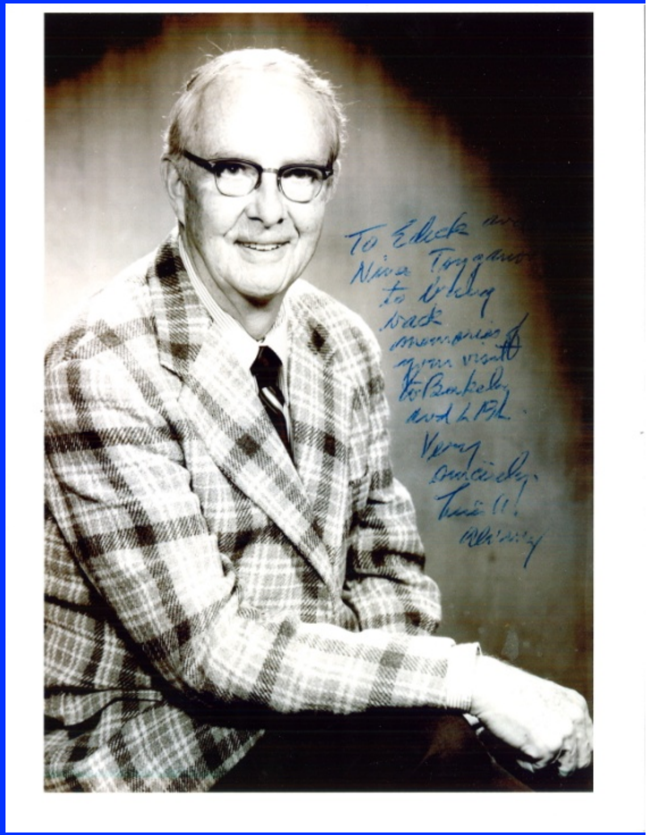
Ya.B. Zeldovich, S.S. Gershtein, 1960
Dreams on piezo-fusion:

Ya.B. Zeldovich

S.S. Gershtein

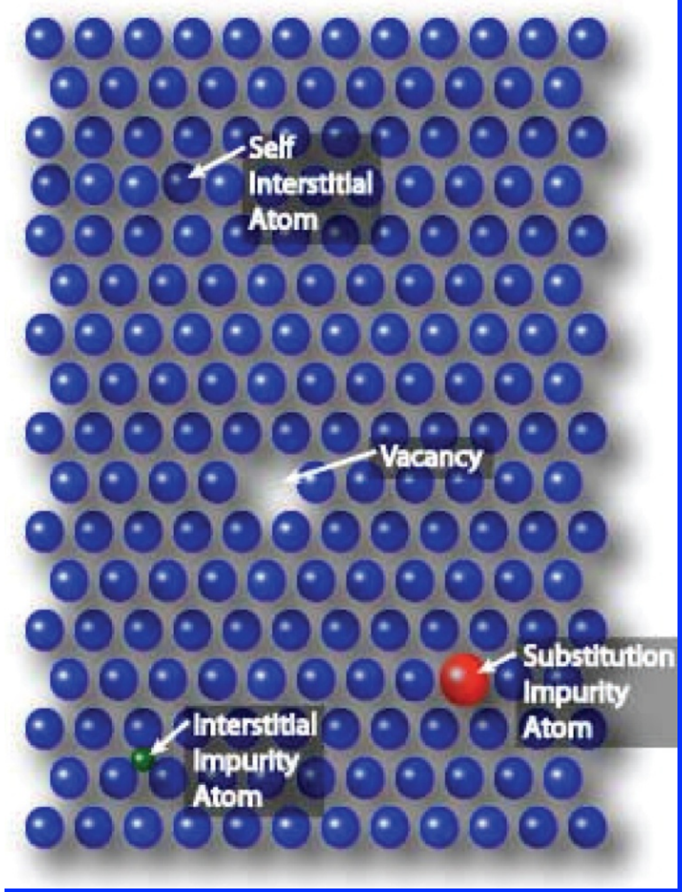
$$B = \exp\left\{-\frac{2}{\hbar}\int_{x_1}^{x_2}\sqrt{2M\left(U(x)-E\right)}\,dx\right\} = \exp\left\{-\frac{2}{\hbar}\sqrt{2M\overline{U}}\,(x_2-x_1)\right\}$$

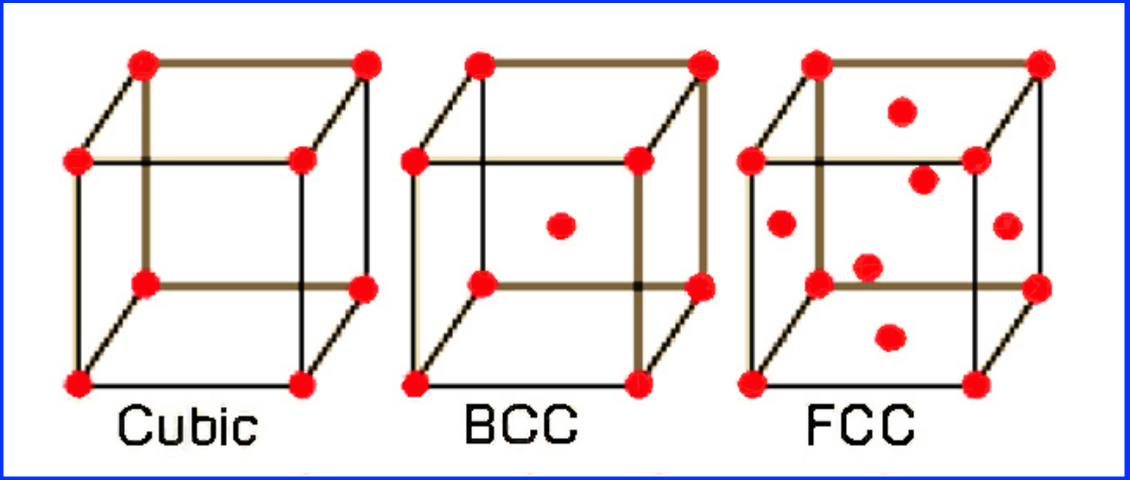
In addition to direct interaction of two single nuclei, discussions began about 50 years ago on a different type of processes (μ-catalysis), that lead to the fusion of elements with release of energy. In this connection it is interesting to quote the first experimental work on μ-catalysis by L. W. Alvarez, who examines the event in the liquid hydrogen chamber, indicative H + D μ-catalysis. (*L.W. Alvarez et al., Physical Review Series II, v. 105, 1957, p. 1127-1128).* Referring to the 1954 theoretical work of Ya. B. Zeldovich, Alvarez wrote:

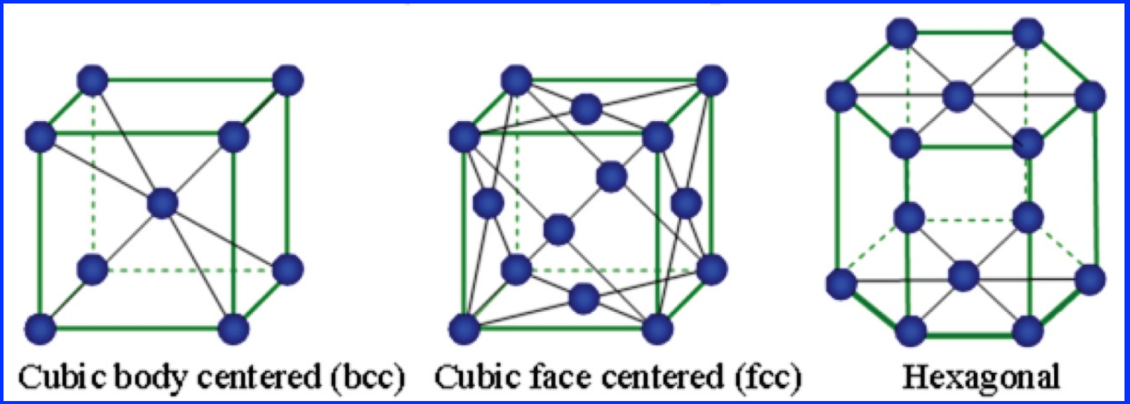


"The meson, in effect, ***confines the two nuclei in a small box.*** Rough estimates of the barrier penetration factor (approximately 10^{-5}) and the vibration frequency (approximately 10^{17} per second) indicate that the time required for a nuclear reaction between H and D should be small compared with the life of the μ-meson."

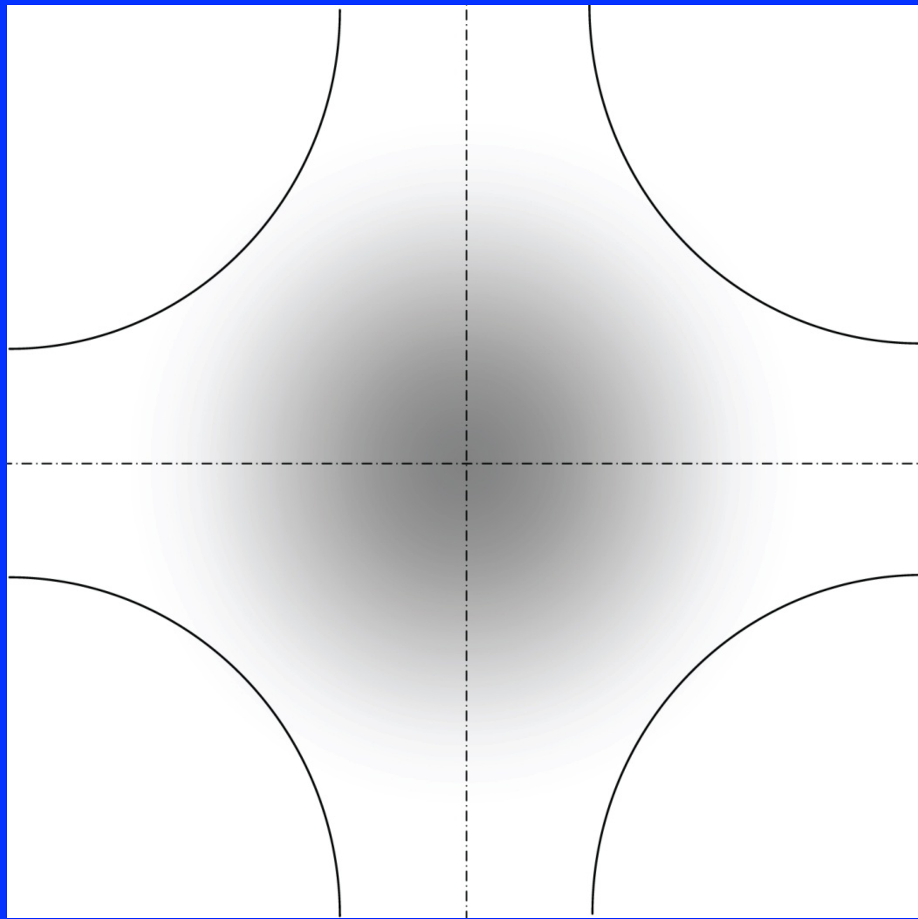
Left – several types of defects in crystals.
Interstitial impurity is typical for smaller atoms.
Types of crystalline structures. Upper right – FCC structure (platinum, with melting point +1772 C^o). Lower right – hexagonal HPC (palladium).





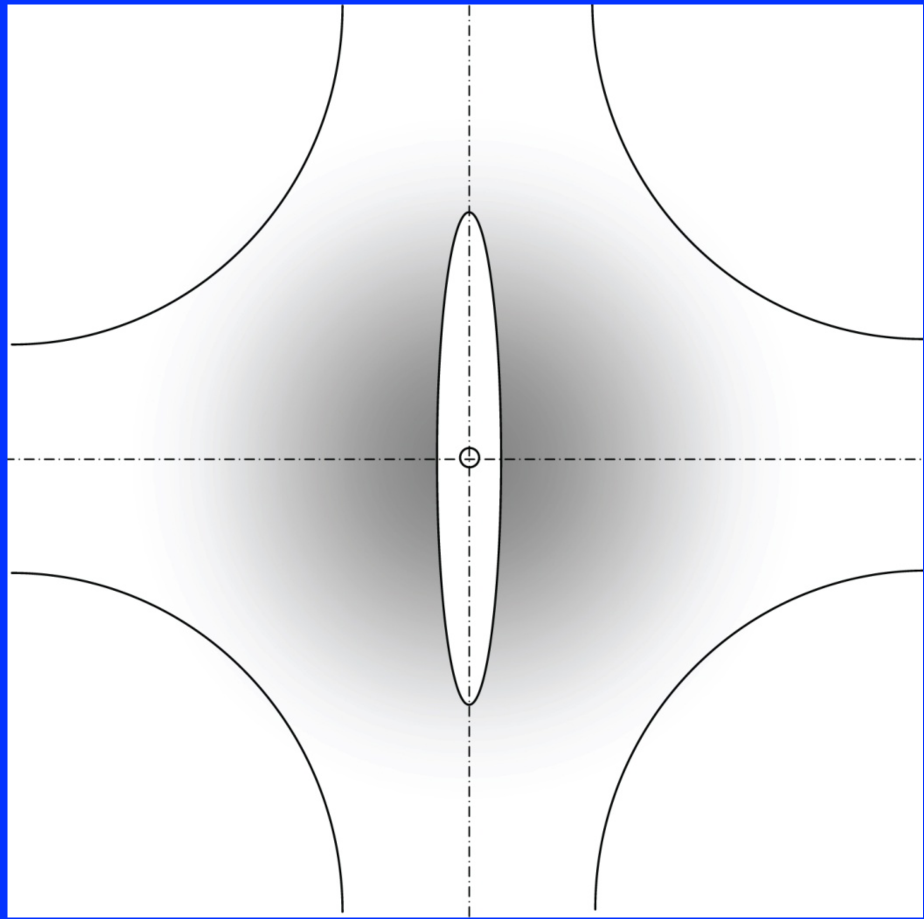


A single conductive crystalline cell.
Shadow region represents a cloud of free electrons.

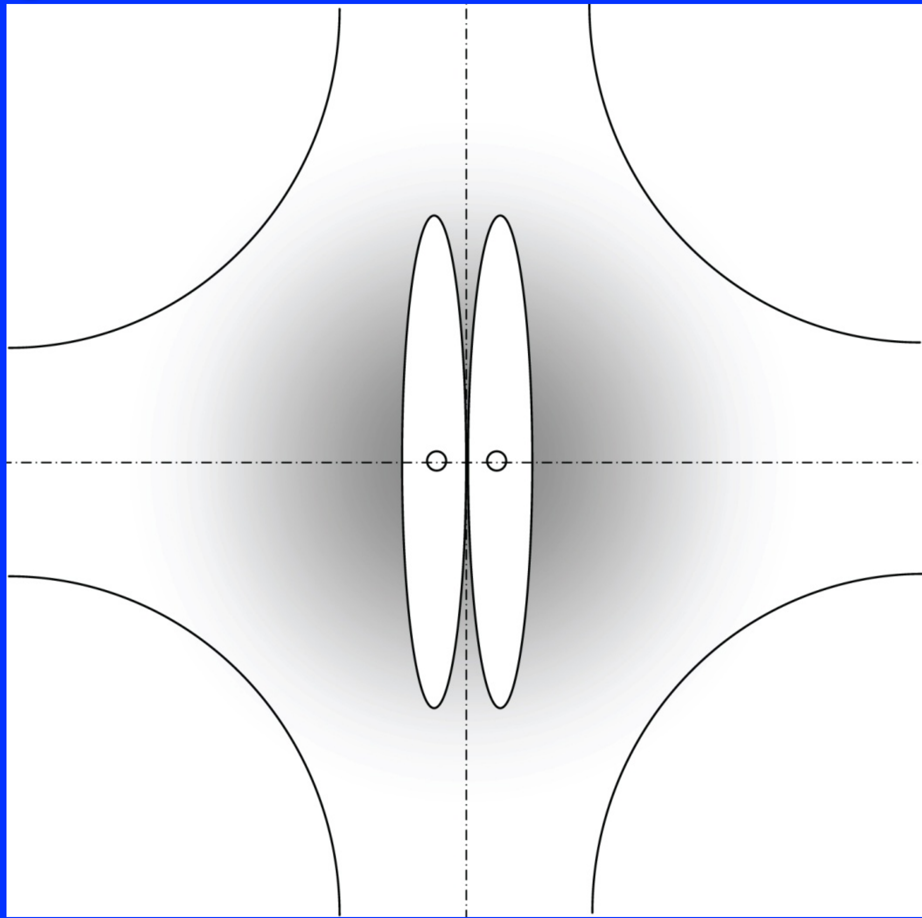


Single conductive crystalline cell with one deuterium atom. The Rydberg mechanism distorts electron shell.

$$1/\lambda = R[(1/n_1^2) - (1/n_2^2)]$$



Single conductive crystalline cell with two deuterium atoms.
Rydberg mechanism distorts electron shells.



DD in a single conductive crystalline cell.

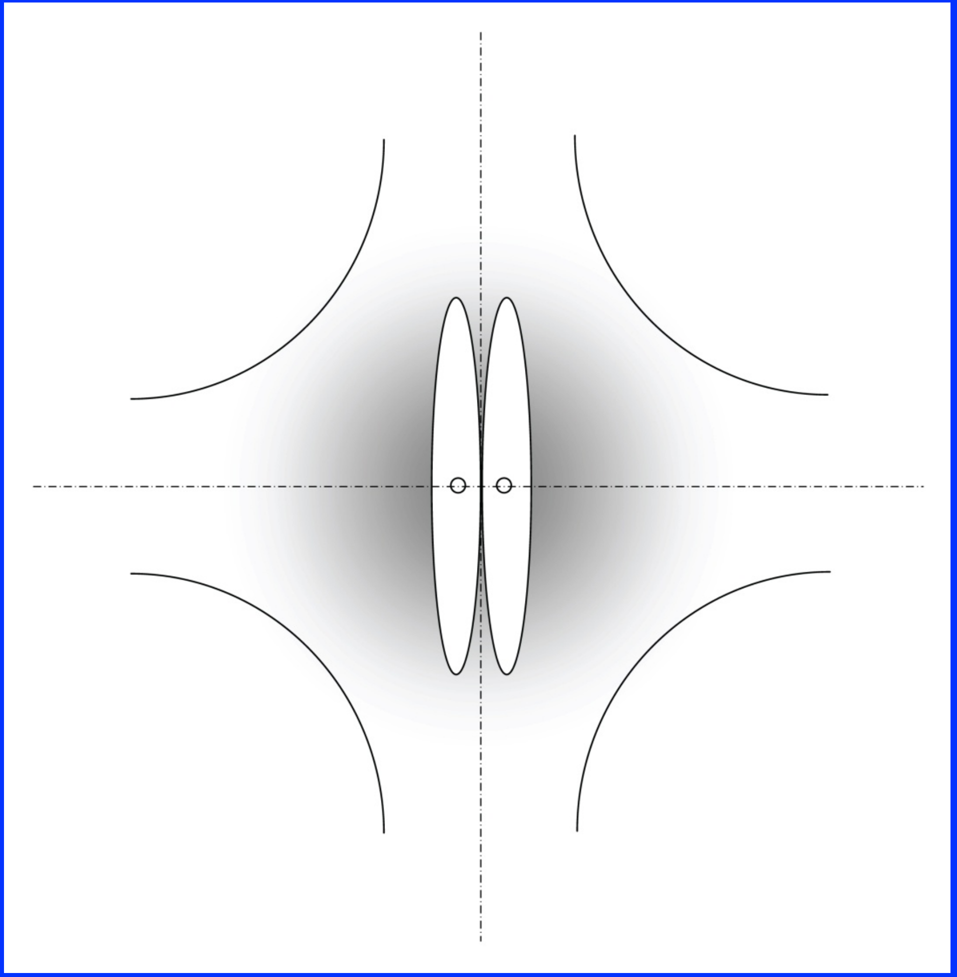
Chemical catalysis is the beginning of the process.

(Simple cube is used for didactical purpose, no material has this structure)

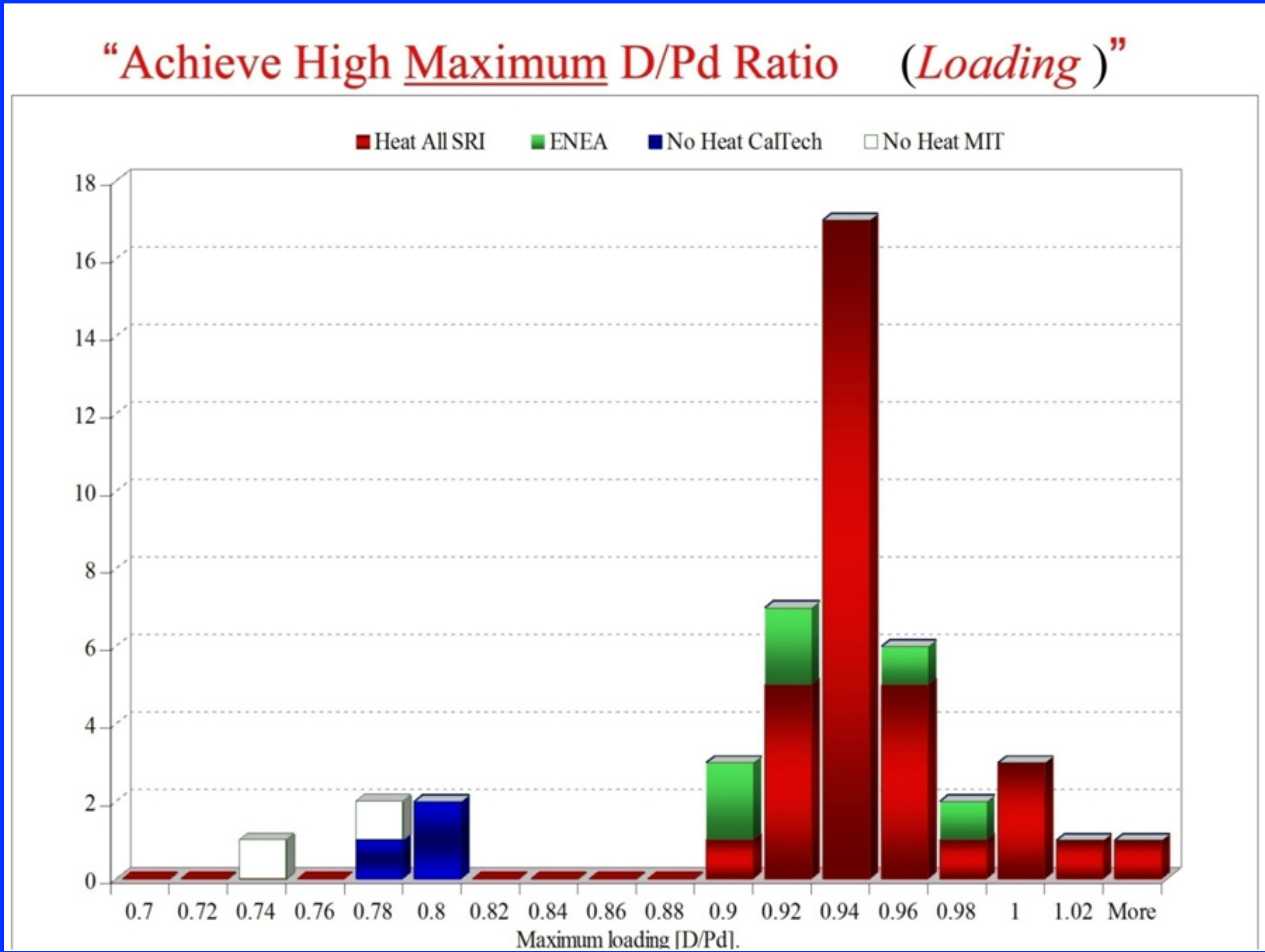
Rydberg formula (1888):

$$1/\lambda = R[(1/n_1^2) - (1/n_2^2)]$$

n_1	n_2	Name	Converge toward
1	$2 \rightarrow \infty$	Lyman series	91.13 nm (UV)
2	$3 \rightarrow \infty$	Balmer series	364.51 nm (Visible)
3	$4 \rightarrow \infty$	Paschen series	820.14 nm (IR)
4	$5 \rightarrow \infty$	Brackett series	1458.03 nm (Far IR)
5	$6 \rightarrow \infty$	Pfund series	2278.17 nm (Far IR)
6	$7 \rightarrow \infty$	Humphreys series	3280.56 nm (Far IR)

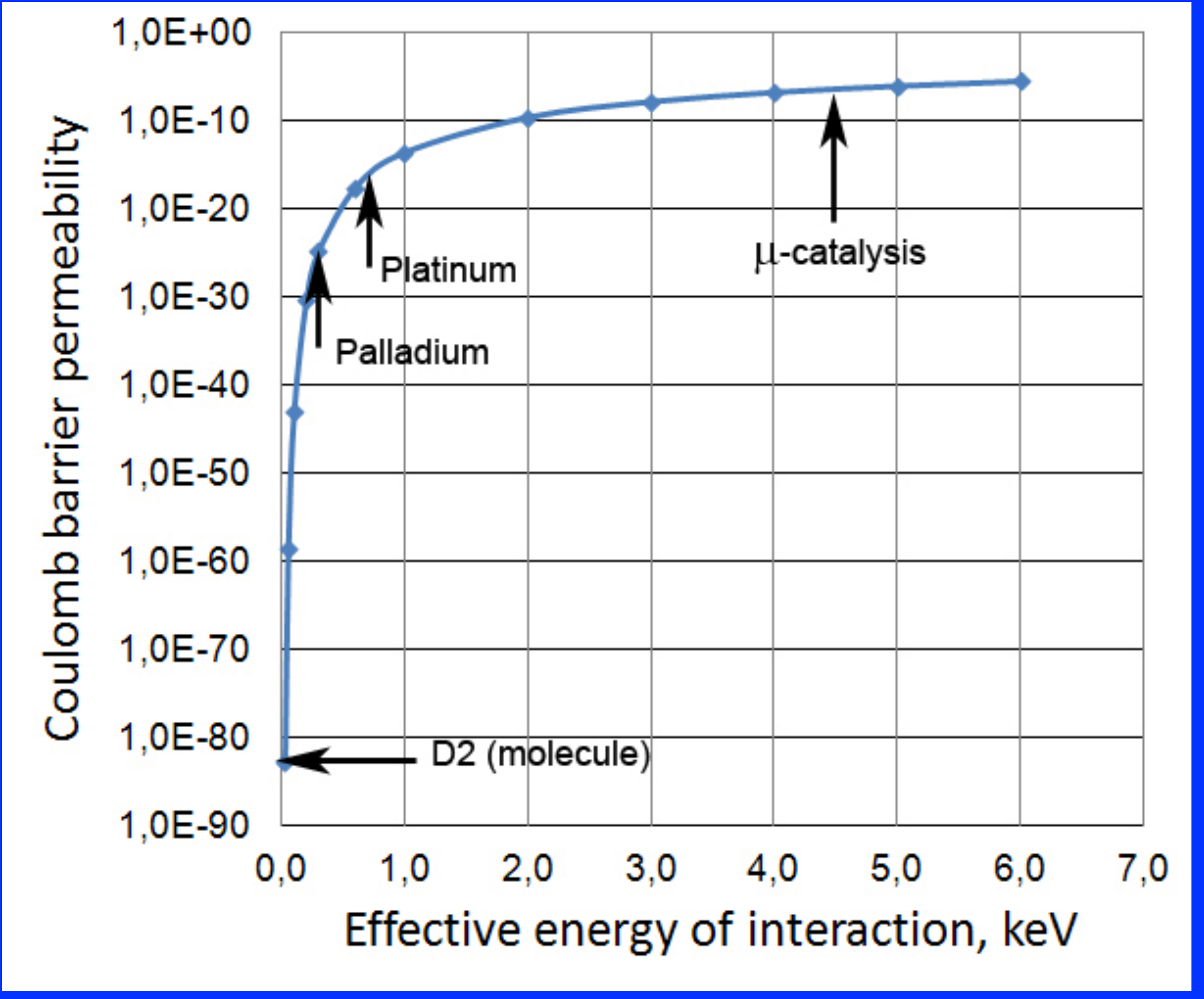


How much deuterium could be placed in palladium crystal?

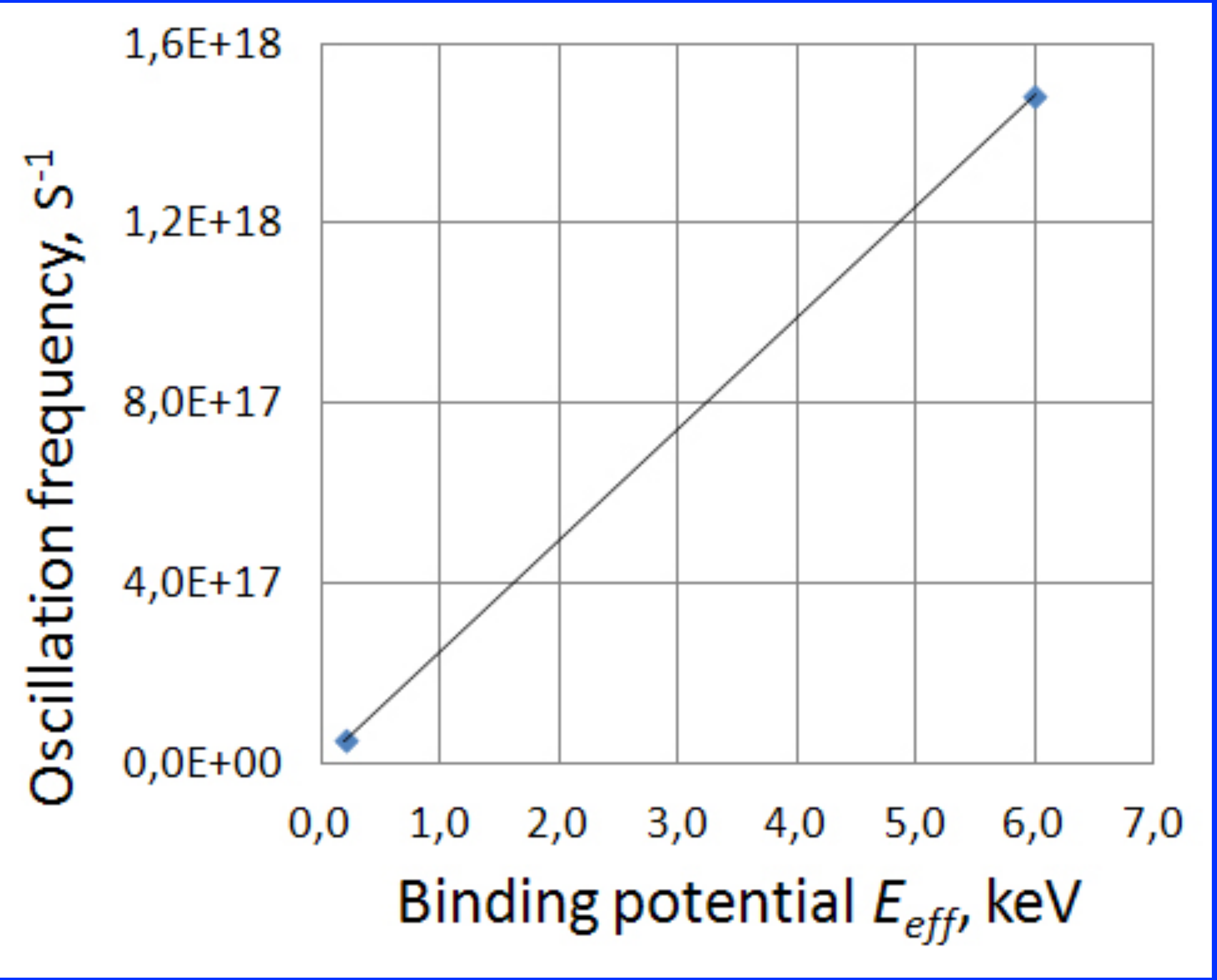


Coulomb barrier permeability for DD fusion

$$P = e^{-2\pi\eta} \quad (2\pi\eta = 31.41/E_{eff}^{1/2},\ E_{eff} \text{ in keV})$$



Oscillation frequency $\nu \cong E_{eff} / h$ ($h=6.5\times10^{-34}$ Js, 1 eV = 1.6×10^{-19} J)



Rate of DD fusion in a crystalline cell

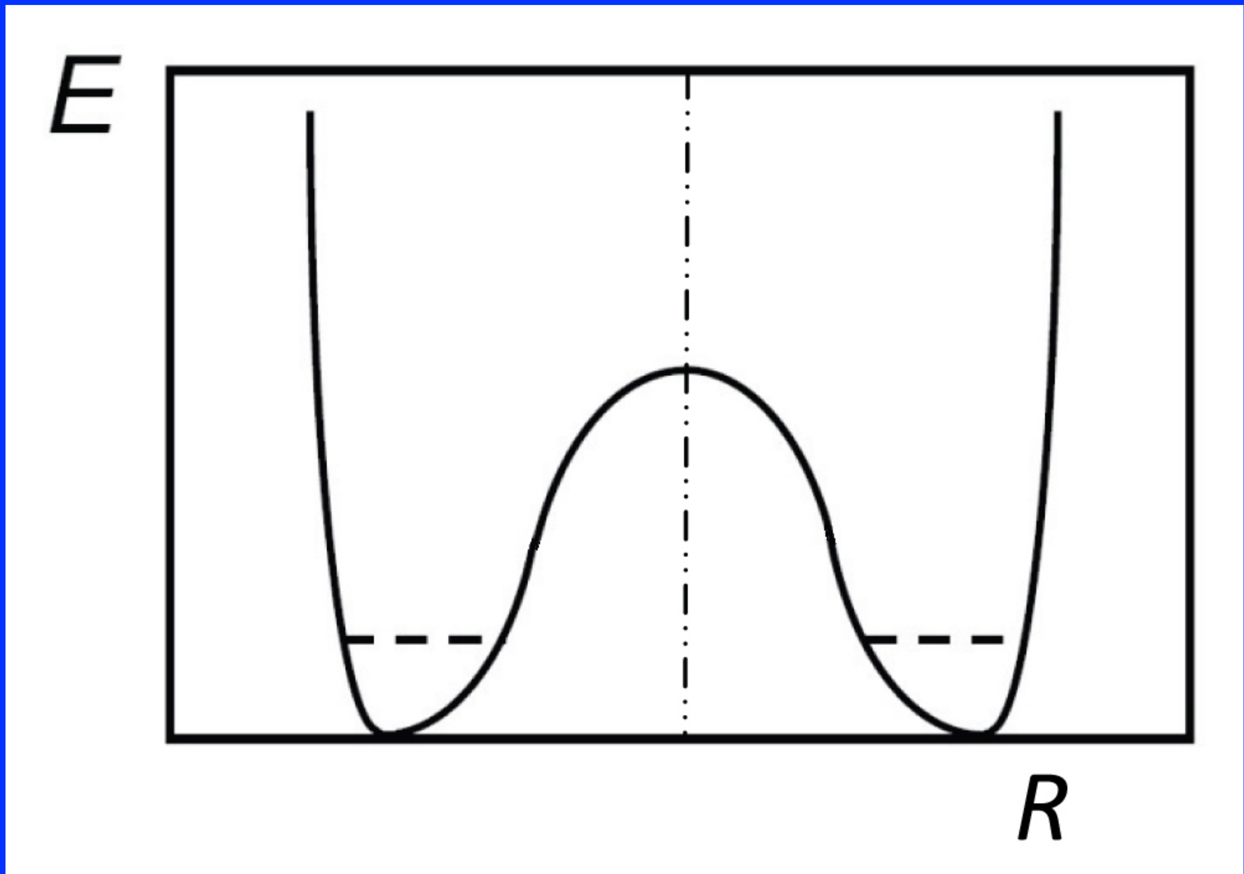
Crystal type	*Screening potential, eV*	*Oscillation frequency* ν*, s*$^{-1}$	*Barrier permeability* $e^{-2\pi\eta}$	*Rate of DD fusion* λ*, s*$^{-1}$
Palladium	*300*	0.74×10^{17}	1.29×10^{-25}	0.95×10^{-8}
Platinum	*675*	1.67×10^{17}	2.52×10^{-17}	*4.21*

E.N. Tsyganov, *Physics of Atomic Nuclei, 2012, Vol. 75, No. 2, pp. 153–159.*
Э.Н. Цыганов, *ЯДЕРНАЯ ФИЗИКА, 2012, том 75, № 2, с. 174–180.*

The mechanism providing nuclear decay rate decline at low excitation energy.

Residual "Coulomb barrier" inside the strong interaction potential well.

System is meta-stable at near zero excitation energy.



Virtual photons in a stable system (R. Feynman)

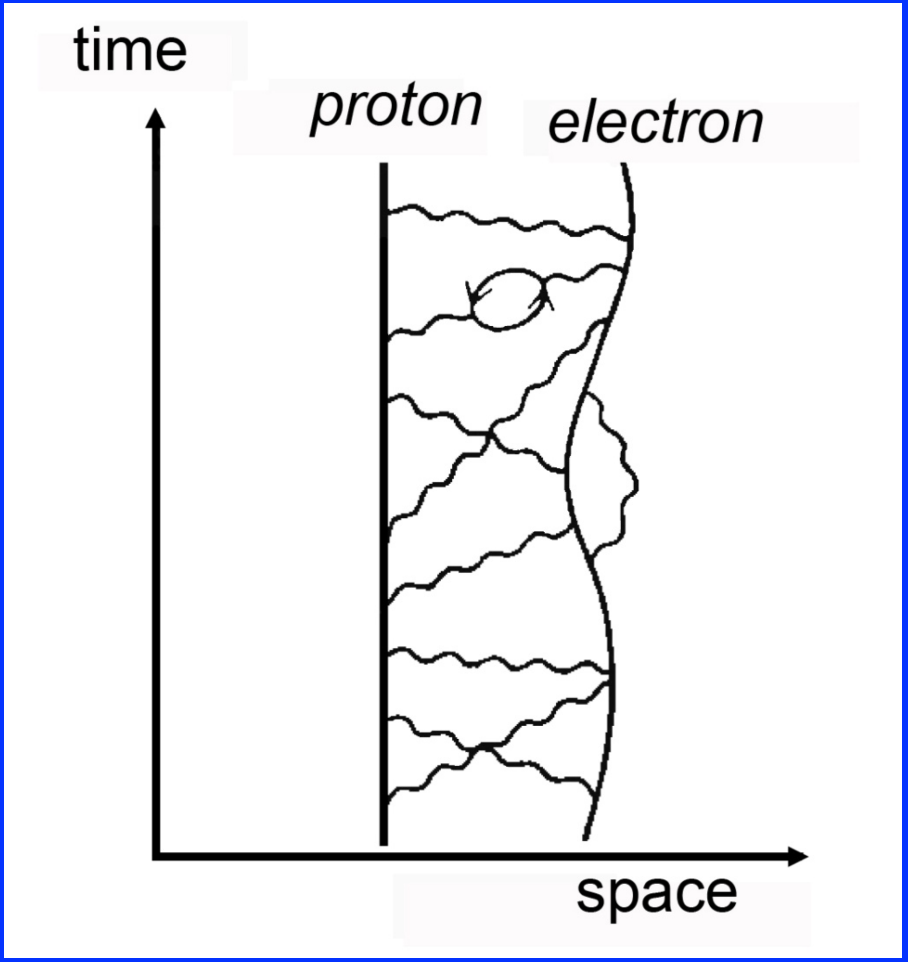
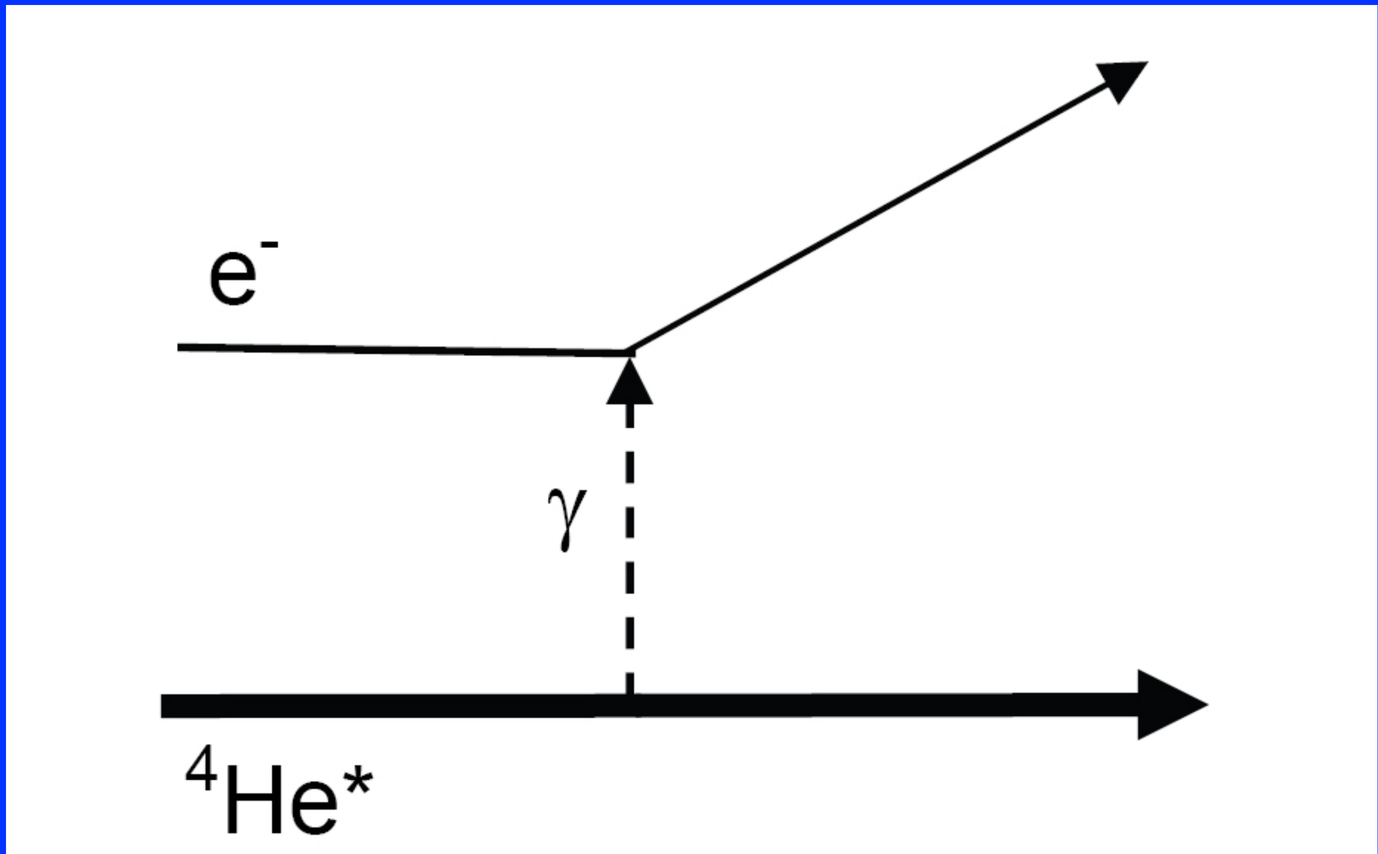
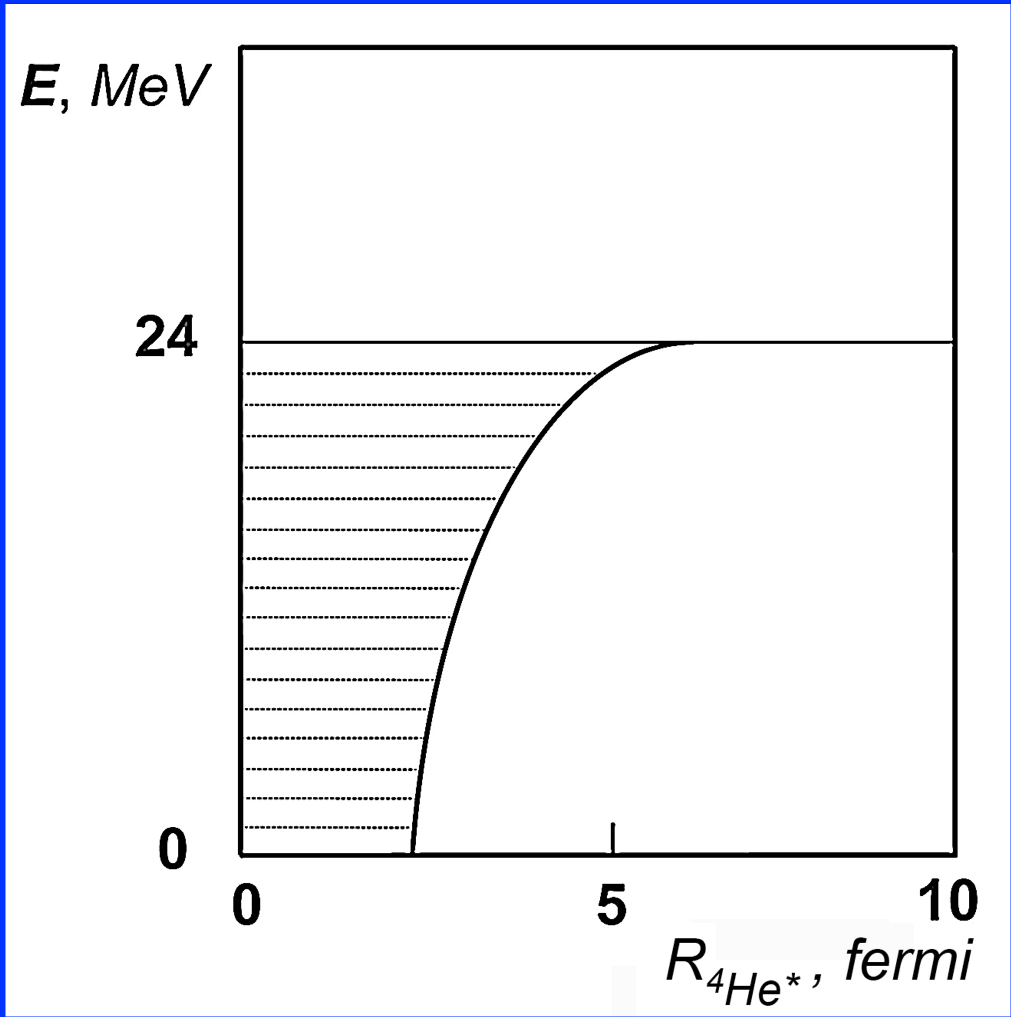


Diagram of process providing "thermalization" of the DD-fusion in the crystals. A virtual photon is emitted by the compound nucleus $^4He^*$.



Possible energy diagram of excited $^4He^*$.



Perhaps, in this long-standing cold fusion history the mystery of this curious and enigmatic phenomenon finally is gradually being revealed. Besides possible benefits that practical applications of this discovery will bring, the scientific community should take into account the social lessons that we have gained during such a long ordeal of rejection of this brilliant, though largely accidental scientific discovery. We would like to express special appreciation to the scientists that actively resisted the negative verdict imposed on this topic about twenty years ago by the vast majority of nuclear physicists.

Peculiarities in the behavior of impurity atoms in the conducting crystals

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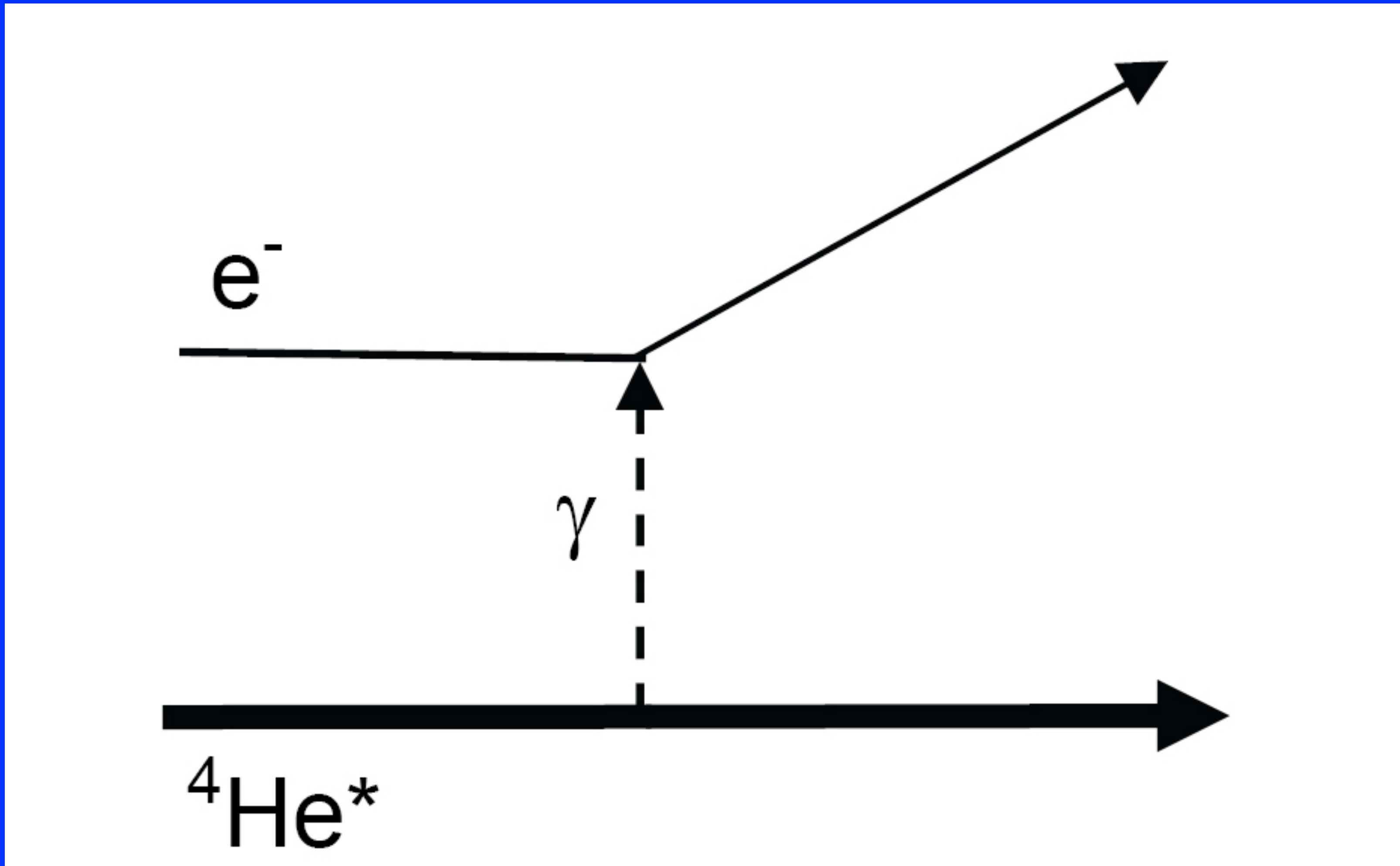
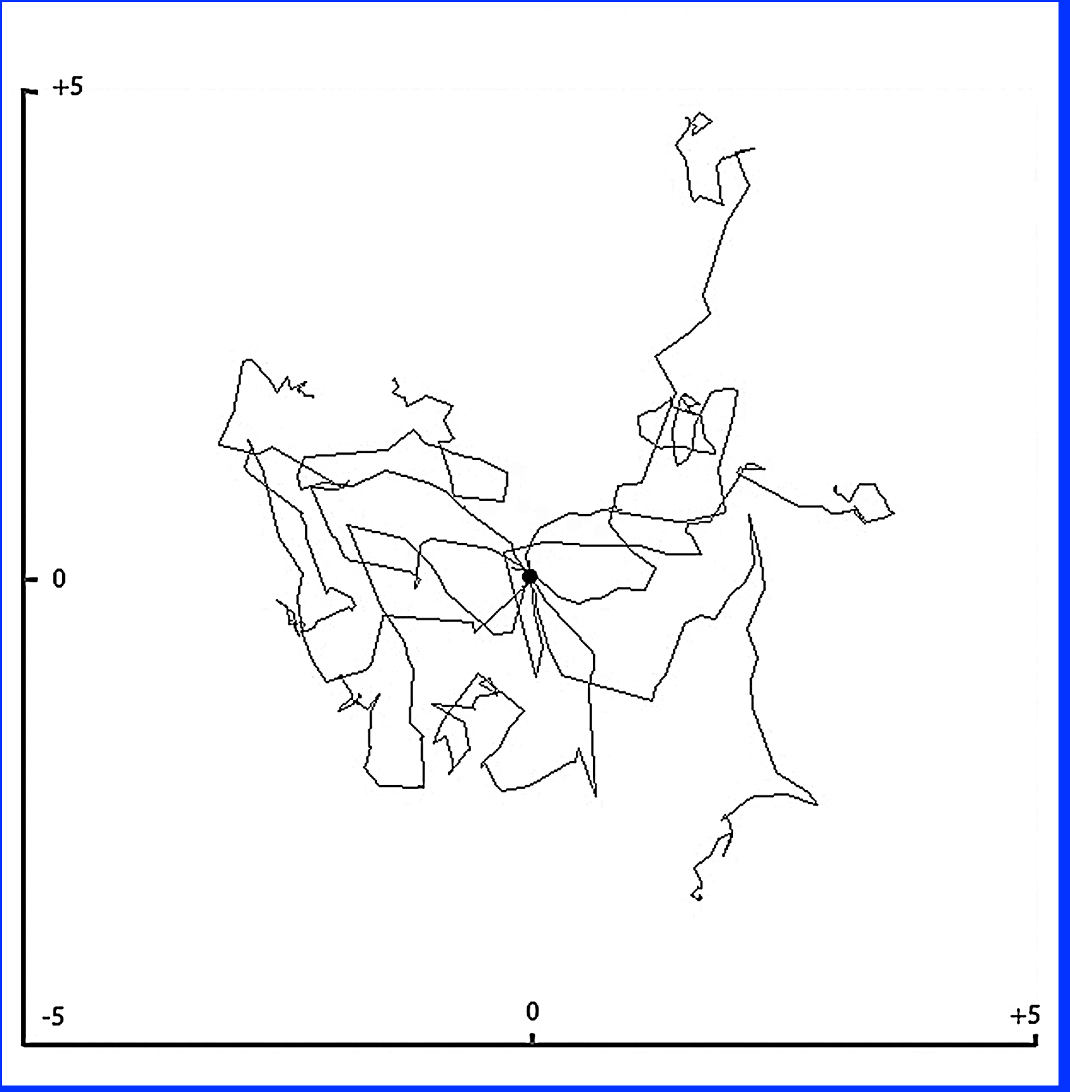
Abstract

The experiment on registration of low-energy electrons which occur after the fusion reaction of two deuterons in the palladium crystal at very low excitation energies, was modeled using Monte Carlo simulations.

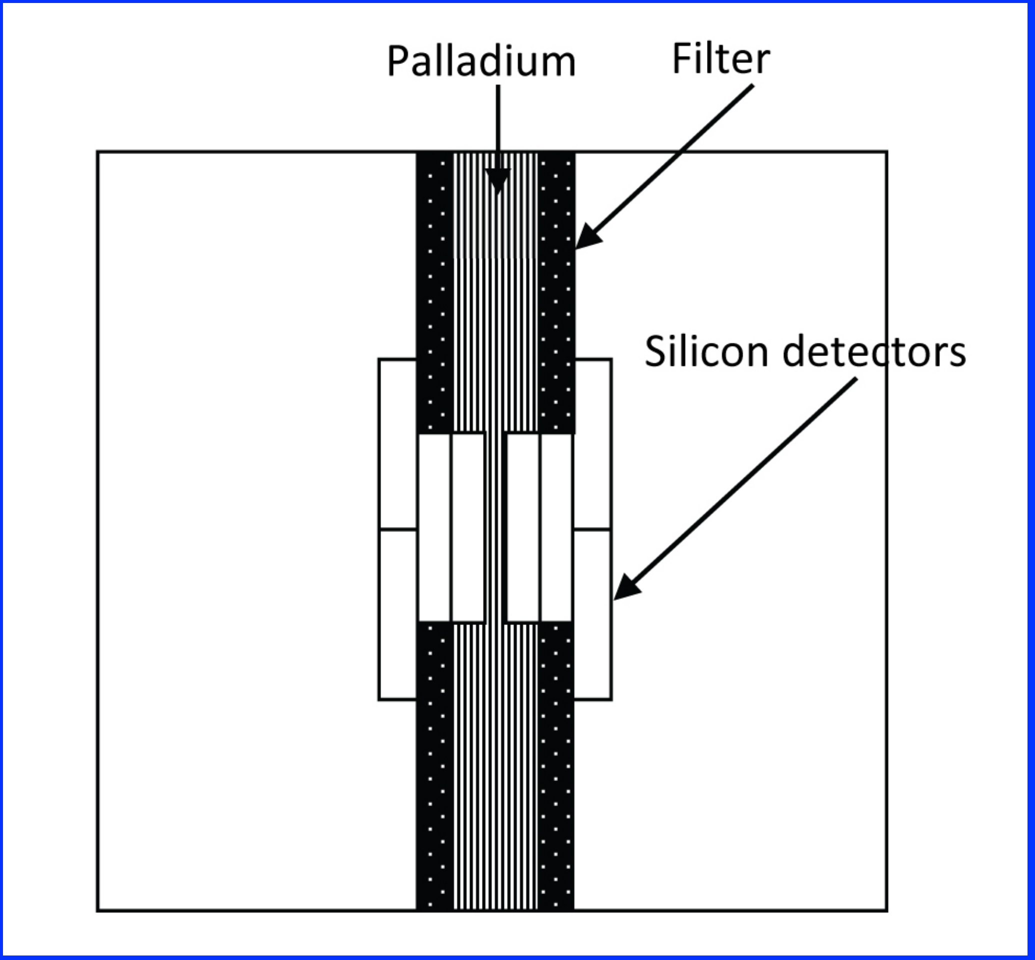
Diagram of process providing "thermalization" of the DD-fusion in the crystals.



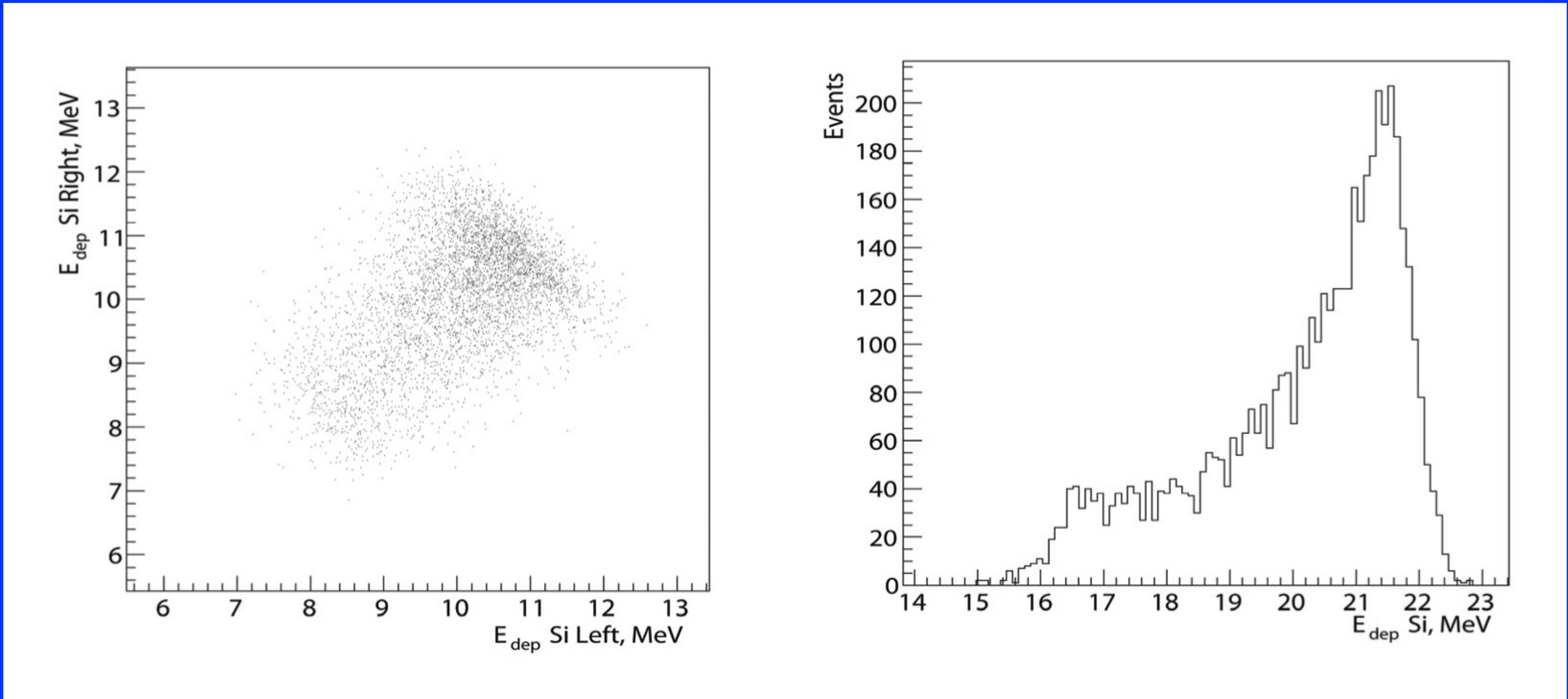
Trajectories (Monte Carlo) of electrons generated in the process of cold DD-fusion in palladium. Dimensions are in micrometers.



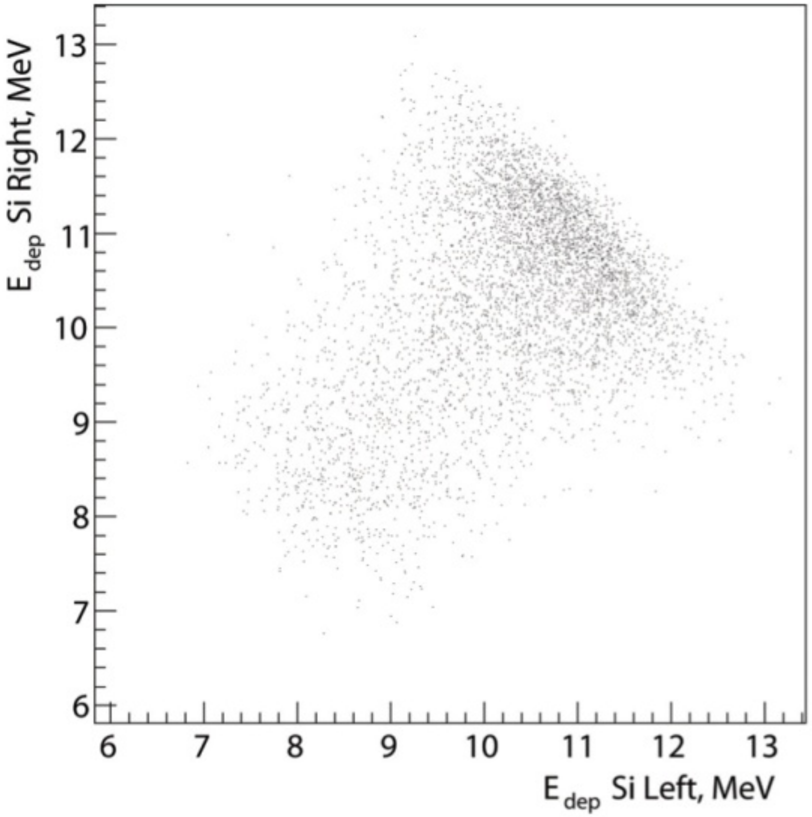
Two-side scheme of the experiment. Several semiconductor silicon detectors are located on both sides of a palladium foil and included in coincidences.

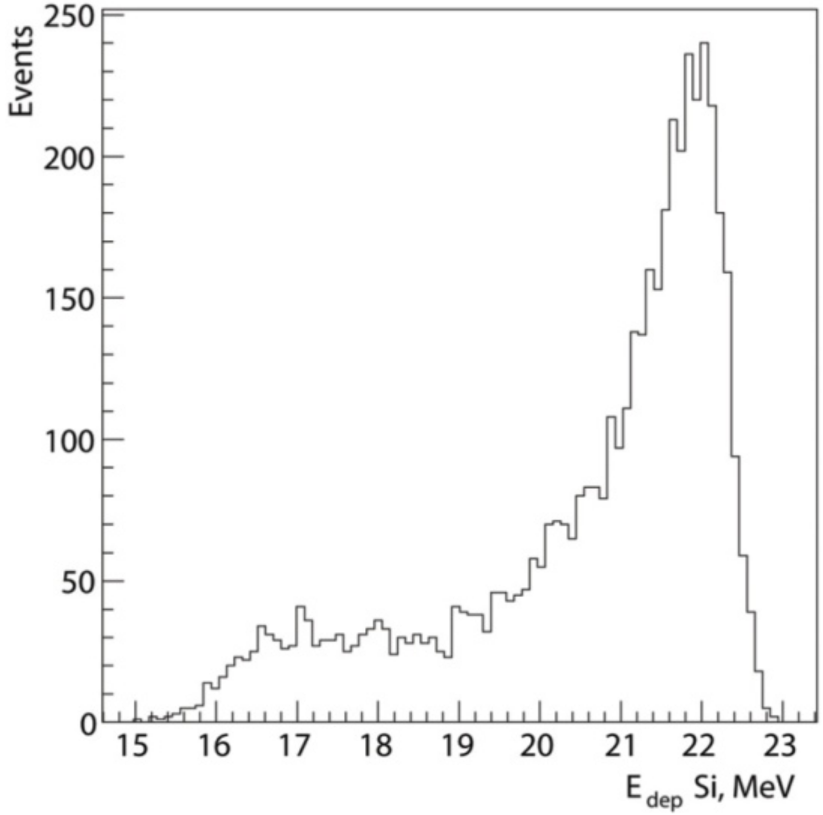


Left - the energy released by 60 keV electrons in detectors on the left and the right sides of palladium foil with a thickness of 0.01 microns. Right - the total energy released in this case

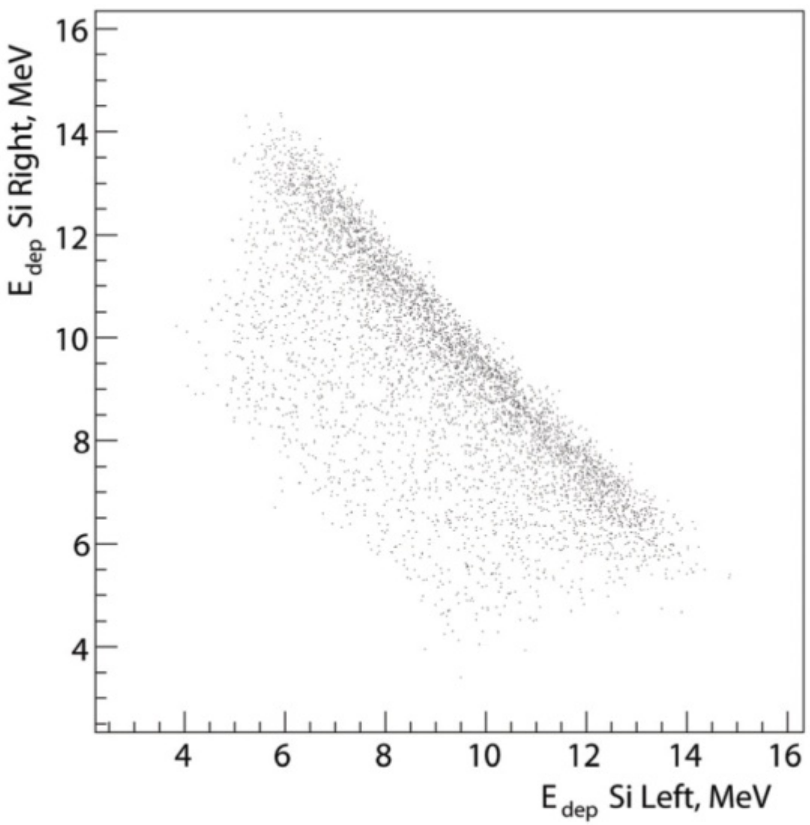


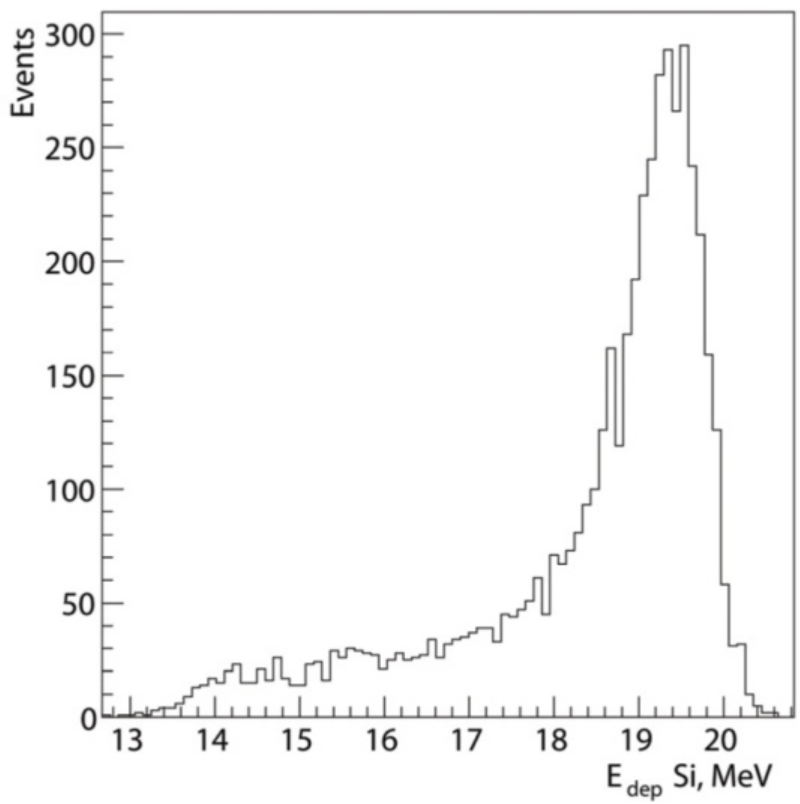
Left - release of 60 keV electrons energy in the left and the right detectors at palladium foil thickness of 0.1 micrometers. Right - total energy released in this case.



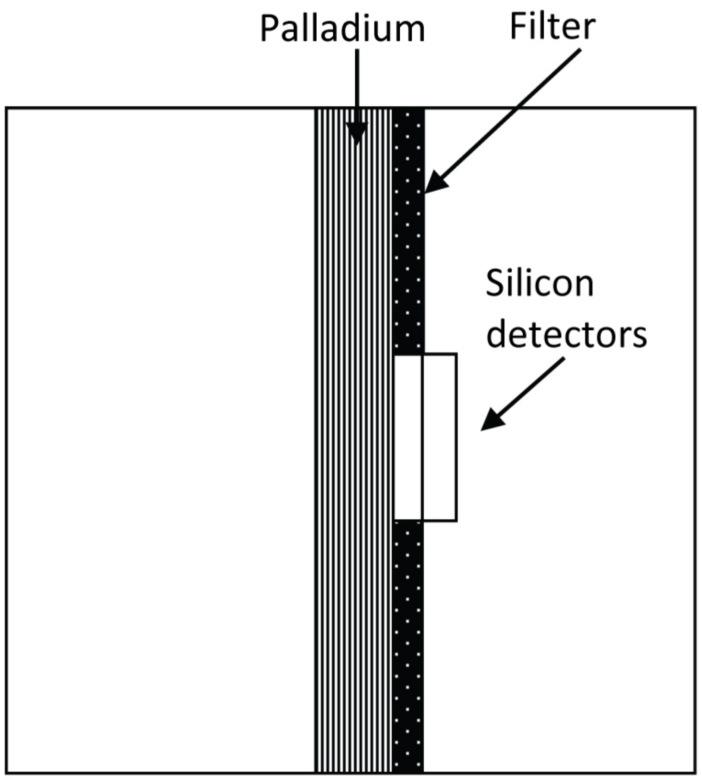


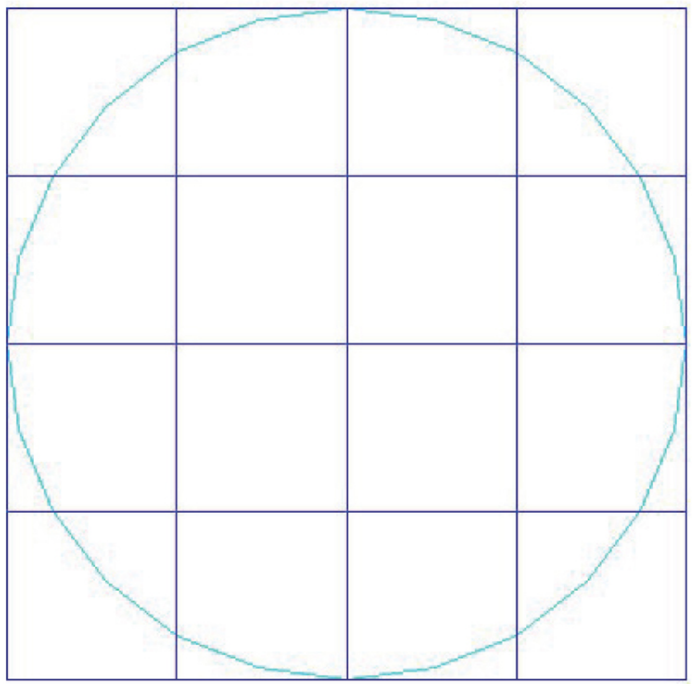
Left - release of 60 keV electrons energy from the left and the right detectors at palladium foil thickness of 1 micrometer. Right - total energy release.



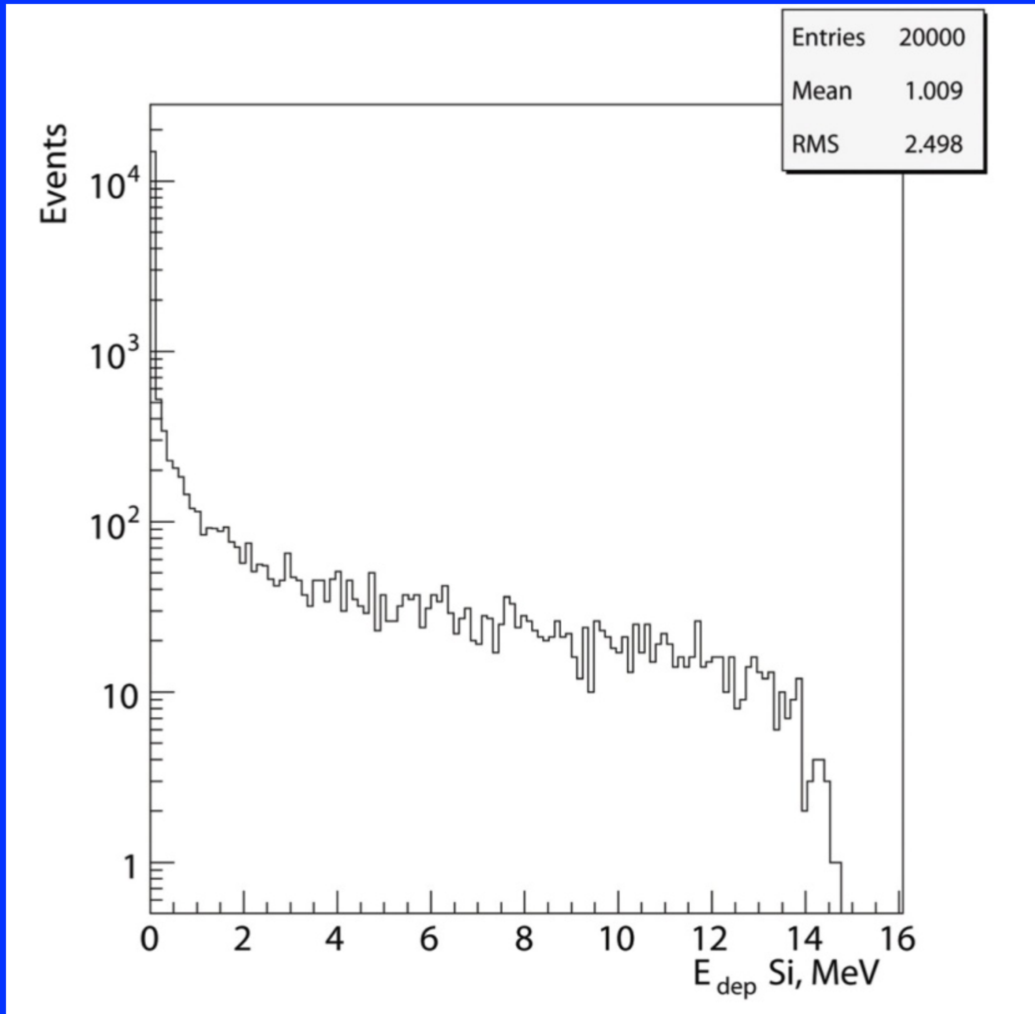


One-side scheme of the experiment. Several semiconductor silicon detectors are located on the one side of palladium foil and included in coincidences. Left – side view, right – relative positions of the aperture and detectors.





The release of energy by 60 keV electrons in detectors located on the one side of the palladium. The spectrum is cut off by about 14 MeV, due to re-scattering of a certain fraction of electrons in the palladium for 180 degrees.



Thank you for your attention

Grazie per la vostra attenzione

Спасибо за внимание