"There are more things on earth, Horatio, than are dreamed of in your philosophy "
Shakespeare

E.N. Tsyganov

Cold Fusion Power, International
OSNovation Systems, Inc., Santa Clara, CA

Cold Nuclear Fusion

Russian-speaking Academic Science Association (RASA)
November 8 - 10, 2013 , Clearwater Beach, FL

Look beyond the horizon…

Flammarion, 1888
On the ideas of
the 16th century

Julian Schwinger

Tried to "look beyond the horizon ..."

"The pressure for conformity is enormous. I have experienced it in editors' rejection of submitted papers, based on venomous criticism of anonymous referees. The replacement of impartial reviewing by censorship will be the death of science".

Statement made while resigning from the American Physical Society

"Physics is the experimental science"
Richard Feynman

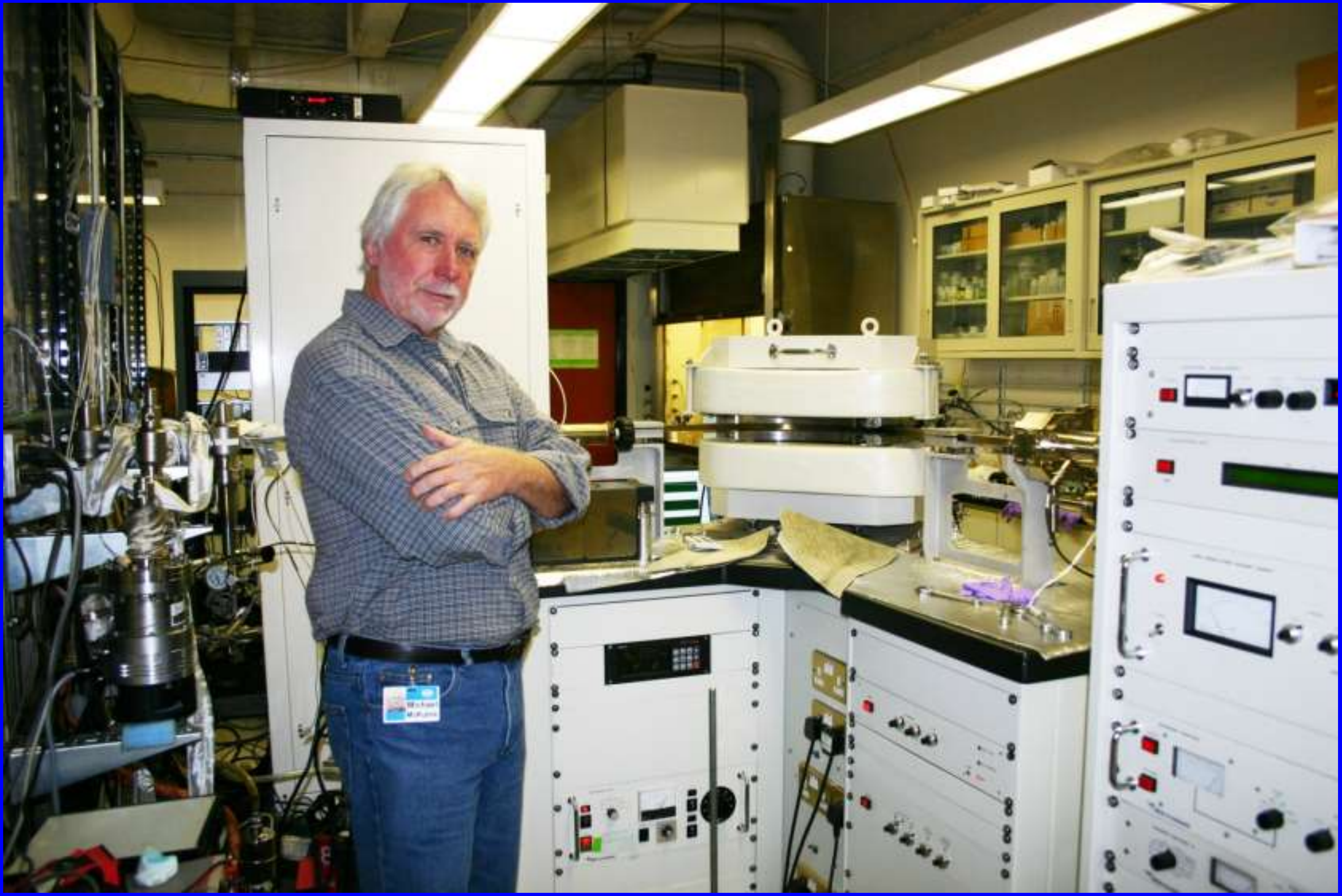
Currently, humanity has reached a stage of development when the struggle for energy resources is particularly relevant. All the known sources of energy in the near future will not be able to meet our needs. Chemical energy is also limited by the so-called “greenhouse effect.” Nuclear energy, based on the use of fissile materials, is not a long-term solution to the problem, because the stocks of these materials are limited.

The initial optimistic expectation of the transition to the process of controlled nuclear fusion has not yet materialized. Technical difficulties obtaining sustainable superhot plasma and the damaging effects of the enormous neutron flux arising as a result of fusion reactions back down the solution to this problem on a more distant and uncertain future.

The term “cold fusion” describes a number of processes at a relatively low temperature, leading to the generation of heat by the fusion of two nuclei. Under normal conditions, these processes are restricted by the Coulomb barrier, which prevents the convergence of nuclei. However, about 25 years ago Fleischmann and Pons performed experiments that demonstrated the possibility of cold fusion, if the nuclear agents implanted in metallic crystals.

Quickly rejected by most scientists as unrepeatable, these experiments gradually began to give reproducible results. Classic examples are the experiments made by Dr. McKubre and his colleagues at the Stanford Research Institute (SRI) International. The results of these experiments again demonstrated the heat of nonchemical origin, with the effect spread out beyond 100 experimental errors.

Dr. McKubre in his laboratory



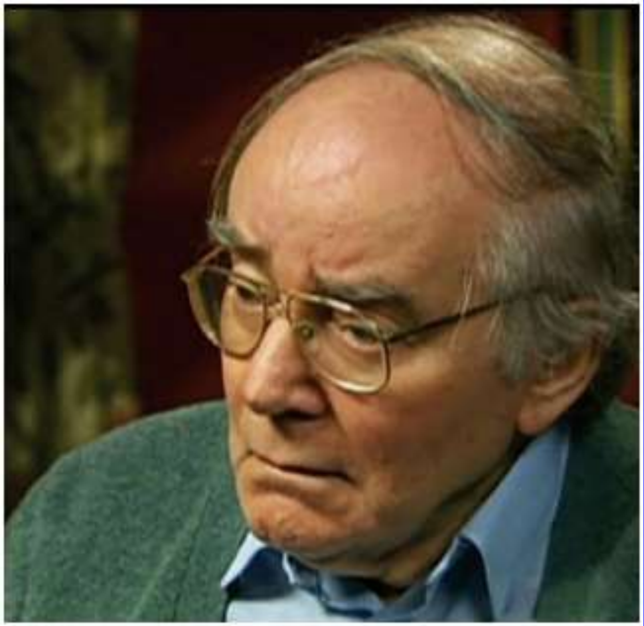
Brief history of cold fusion "in vitro"

1. Martin Fleischmann	1989–2012
2. Michael McKubre	1992–today
3. Yoshiaki Arata	1998–2008
4. Hagelstein and Swartz (MIT)	1992–today

About 20–30 groups are working in the United States, Europe, Russia, Japan, and China.

Over the last few months, the first 4 patents were issued on cold fusion (United States, Europe, and China).

The history of cold fusion - the main participants



Martin Fleischmann
(1927-2012)
D + D in palladium, 1989

Michael McKubre
D + D in palladium
1992 - to date

Yoshiaki Arata
D + D at palladium - ZrO2
1998-2008

Confirmation of the idea of cold fusion suddenly came from experiments in accelerators

Ya.B. Zeldovich, S.S. Gershtein, Uspekhi , LXXI, v. 4, 1960, p. 581.
Consideration of piezo-fusion.

Ya.B. Zeldovich

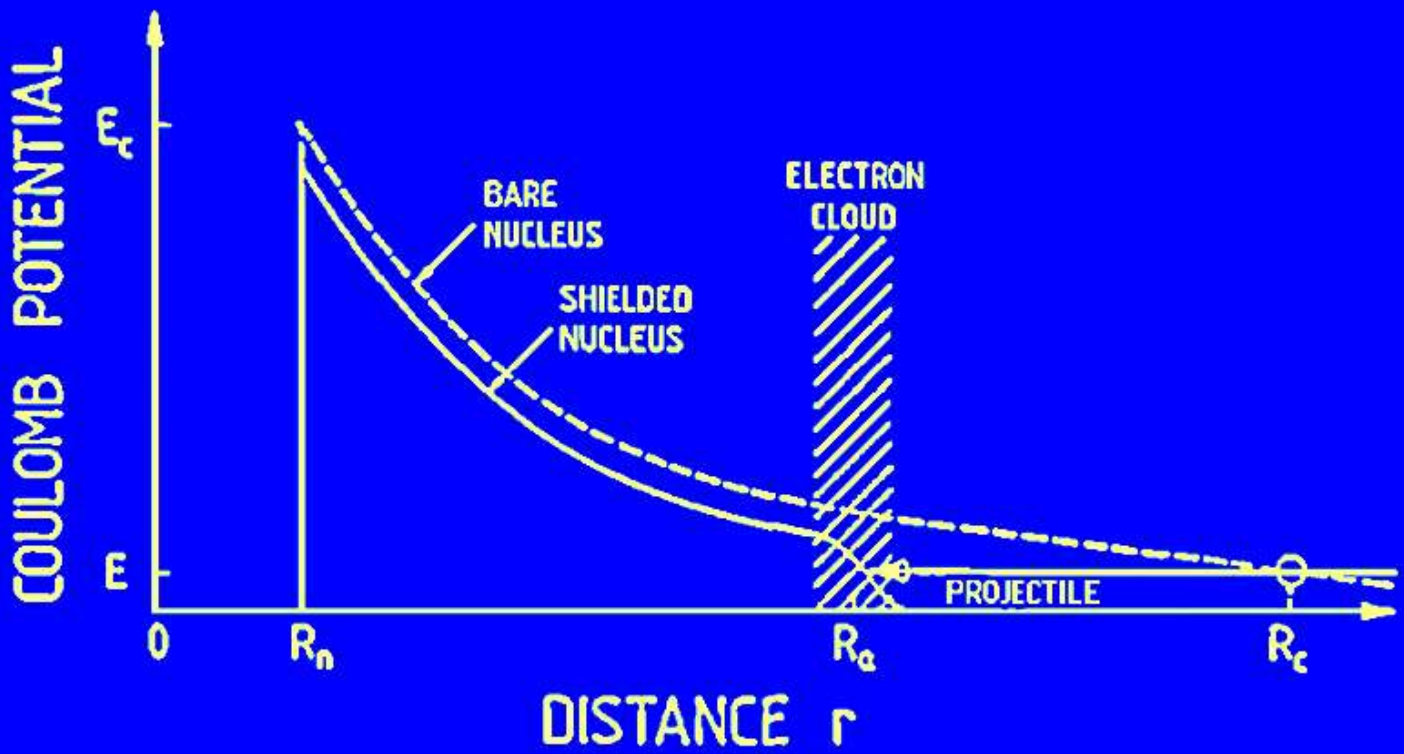
S.S. Gershtein

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

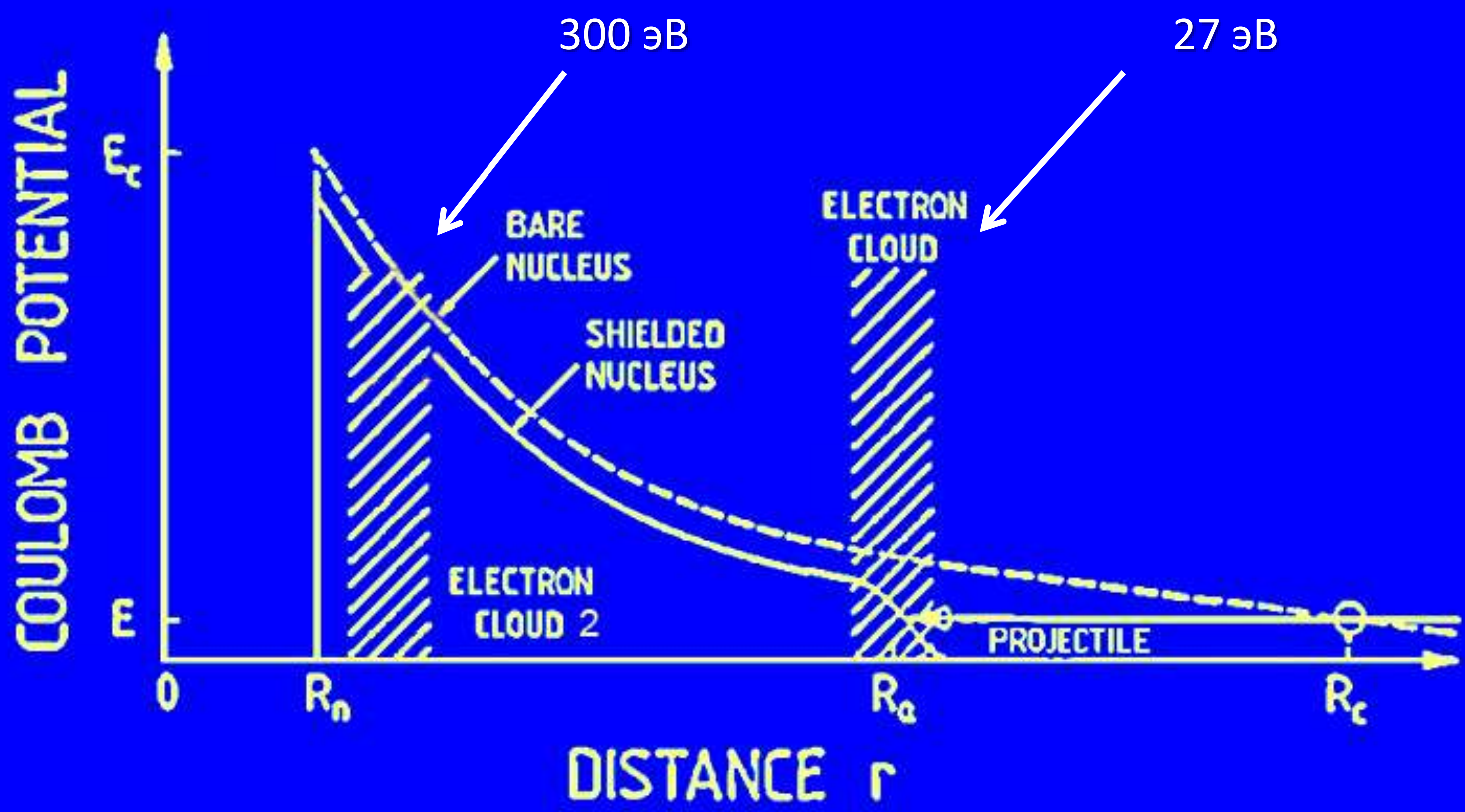
The necessary pressure happen to be too high to reach a measurable effect

In the quantum mechanical consideration of the fusion process, the electron screening potential U_a is equivalent to additional energy (Assenbaum, Langanke and Rolfs, 1987). “The penetration through a shielded Coulomb barrier at projectile energy E is equivalent to that of bare nuclei at energy $E_{eff} = E + U_e$”.

The figure taken from Assenbaum schematically illustrates the collision of an incident deuterium nucleus with a deuterium atom. In a collision of two free deuterium atoms this additional energy is equal to 27 eV.



Screening potential characterizes the distance to which the converging atoms do not experience Coulomb repulsion.



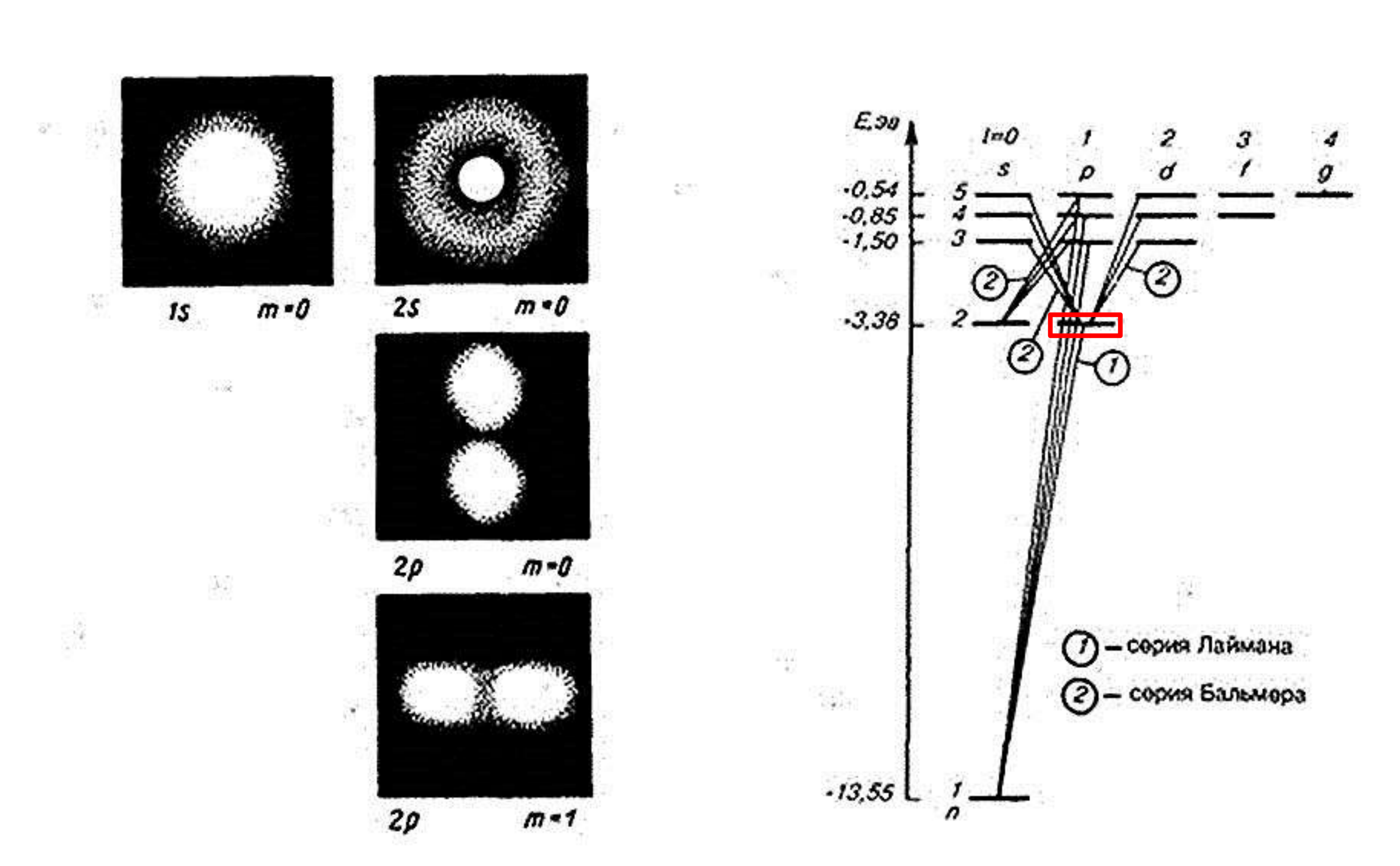
The main secret of the cold fusion process — how to overcome the Coulomb barrier — turned out to be surprisingly simple. It was first noted by Professor Bressani at the 1998 conference, ICCF–7, on the basis of a series of Japanese accelerator experiments that have been carried out since 1996. Prof. Bressani quite clearly laid out the path to an explanation of the process of cold fusion. Unfortunately, the cold fusion community has not followed Bressani call.

Today, 16 years later, we know that the deuterium atoms implanted into metals are not more at the ground state. A cloud of free electrons in the metal causes the electron of an implanted atom to be excited and to take a *p*-state. This allows two deuterium nuclei located in one of the potential crystal cell niche to be at a very close distance from each other.

Accelerator experiments showed that the magnitude of screening potential of impurity atoms in metallic crystals could reach 300 eV or even more. This means that for the DD reaction occurring in a medium of metallic crystal, impurity deuterium atoms are excited, and their electron orbits are elliptical and oriented relative to each other by a certain order in space. In this case, the nuclei of these atoms can converge at a distance substantially less than the conventional size of the atom R_a, without the Coulomb repulsion.

Similar processes are known in the science and are the cause of chemical catalysis. Johannes Rydberg first quantitatively described these processes in 1888.

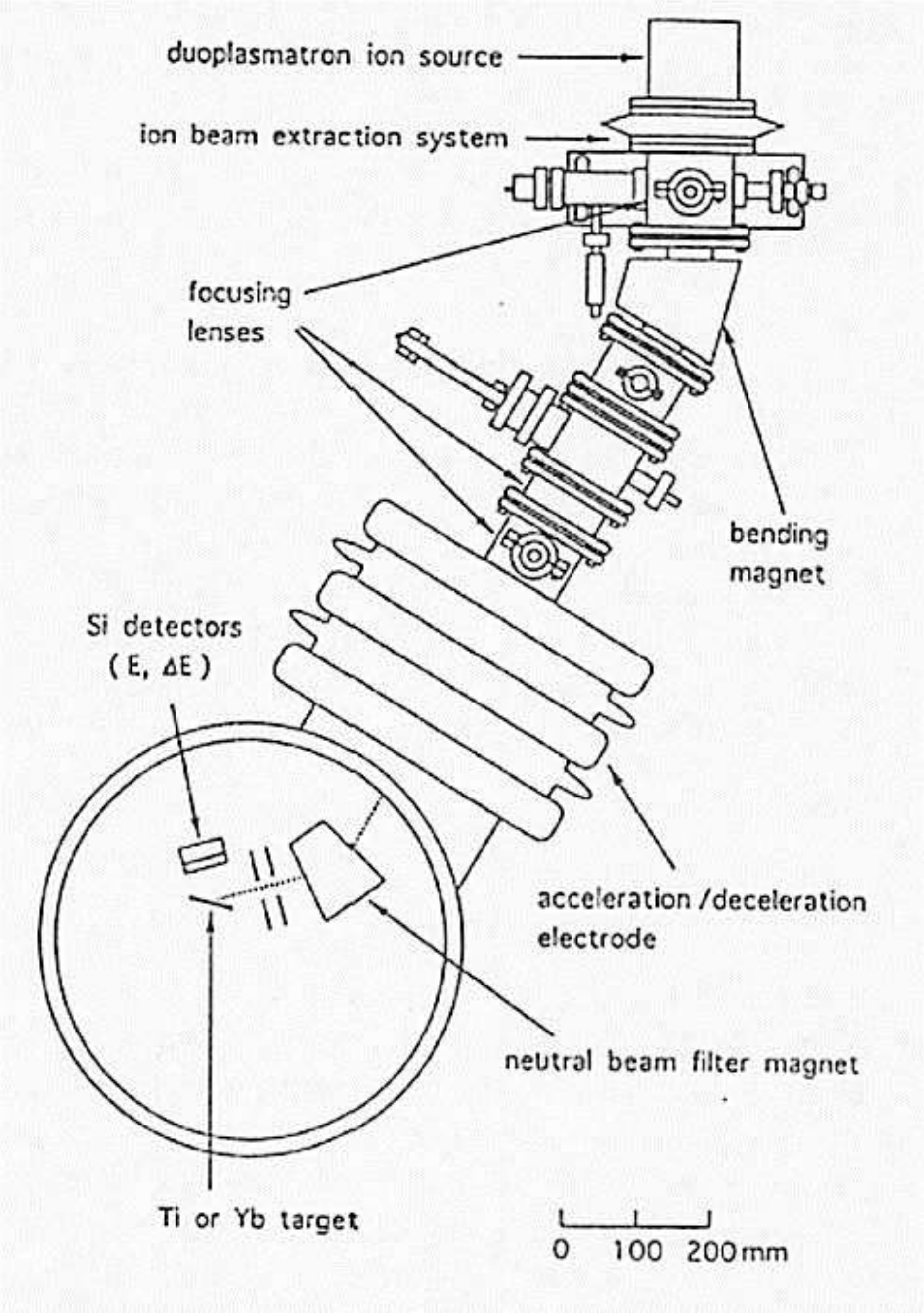
Schematics of Rydberg mechanism for hydrogen atom. Electron orbit in *2p*-state is no longer a circle.



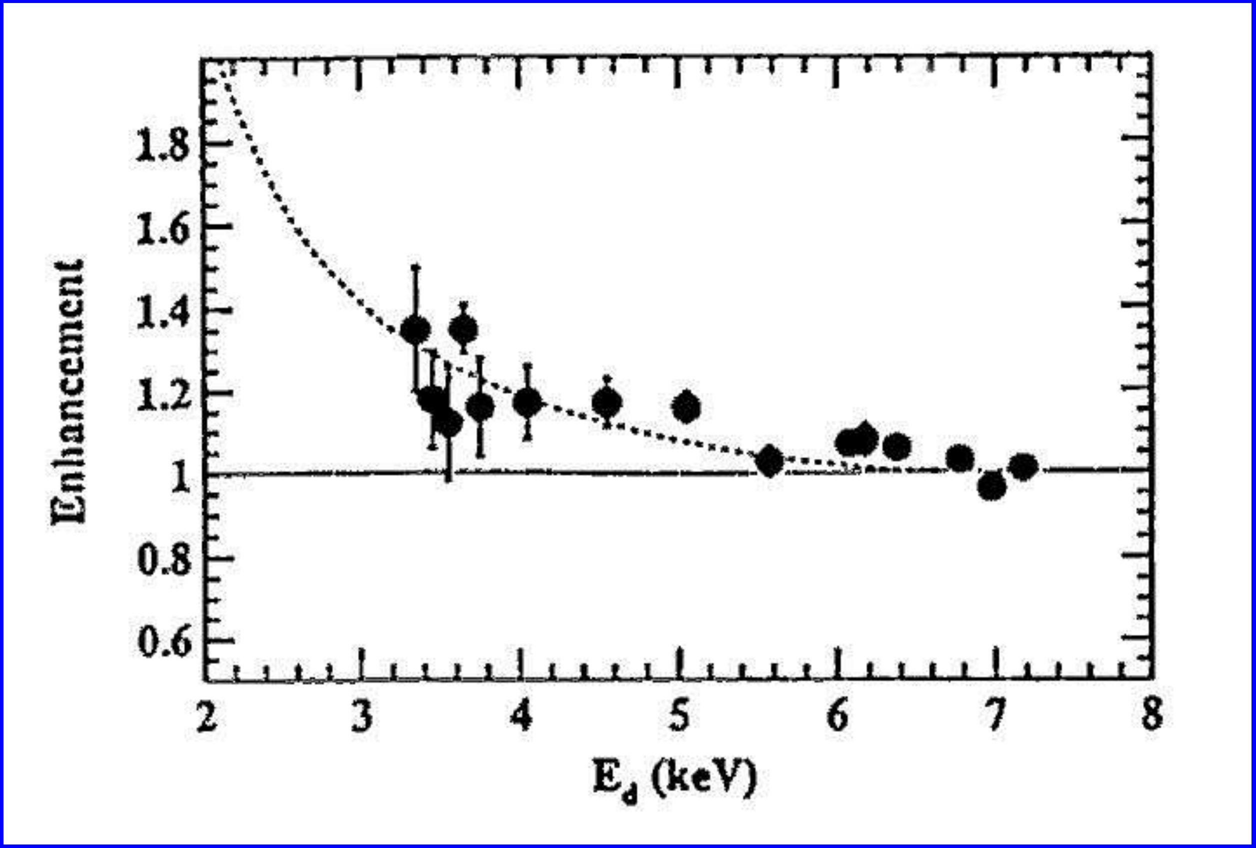
One of the first DD fusion experiments on the accelerator.

H. Yuki, T. Satoh, T. Ohtsuki, T. Yorita, Y. Aoki, H. Yamazaki, J. Kasagi

ICCF-6 October 13-18, 1996, Japan



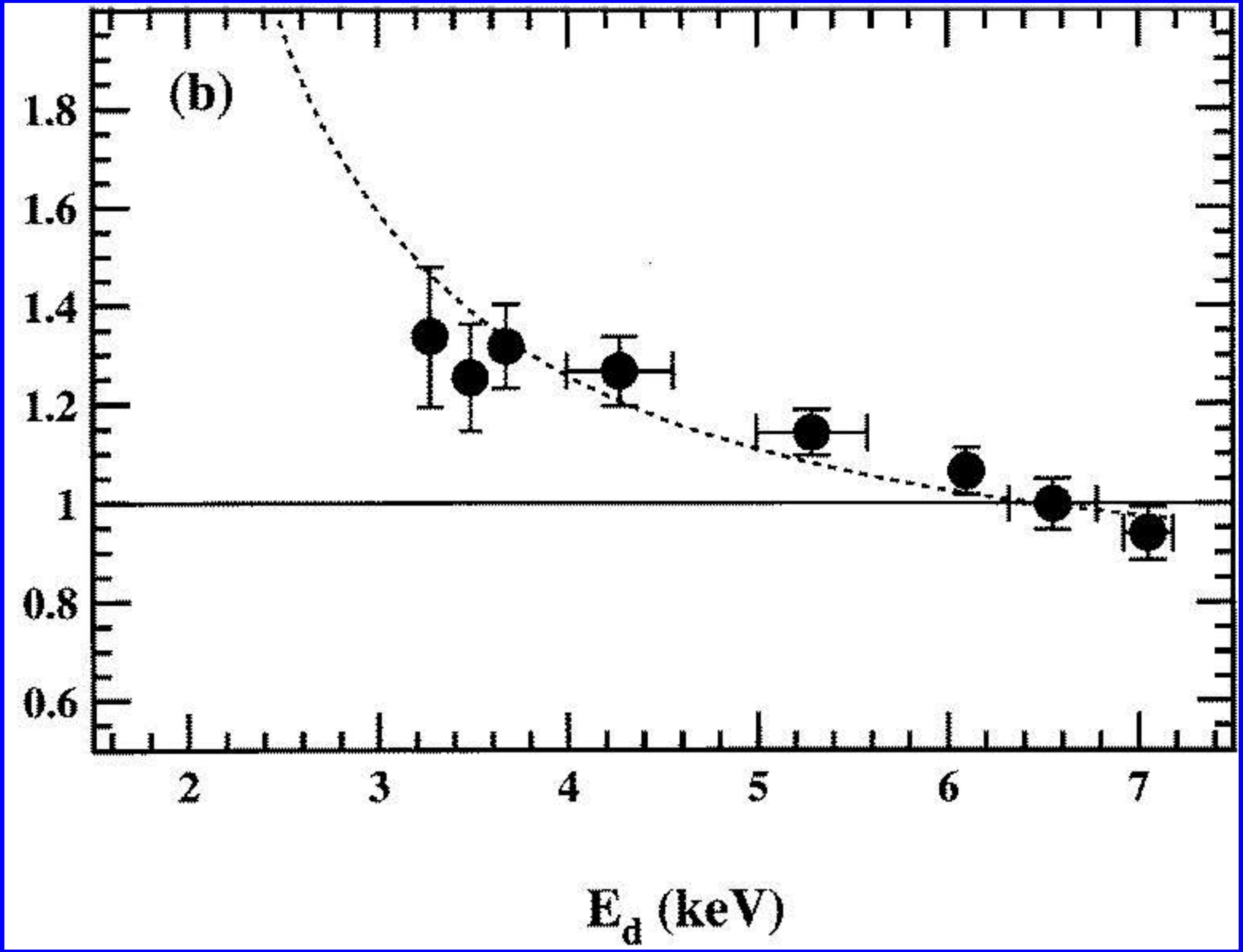
H. Yuki, T. Satoh, T. Ohtsuki, T. Yorita, Y. Aoki, H. Yamazaki, J. Kasagi, ICCF-6 October 13-18, 1996 Japan. This is probably the earliest experiment on electron screening in metals.



Ratios of the thick target yield of the D(d,p)T reaction to the calculated one in Yb. A dashed curve shows the calculation with the electron screening potential of 60 eV.

H. Yuki, T. Satoh, T. Ohtsuki, T. Yorita, Y. Aoki, H. Yamazaki and J. Kasagi "D+D reaction in metal at bombarding energies below 5 keV", J. Phys. G: Nucl. Part. Phys. 23 (1997) 1459–1464.

Cross-section increase in Ytterbium (rare earth element with a metallic conductivity) – electronic screening is 81 ± 10 eV.



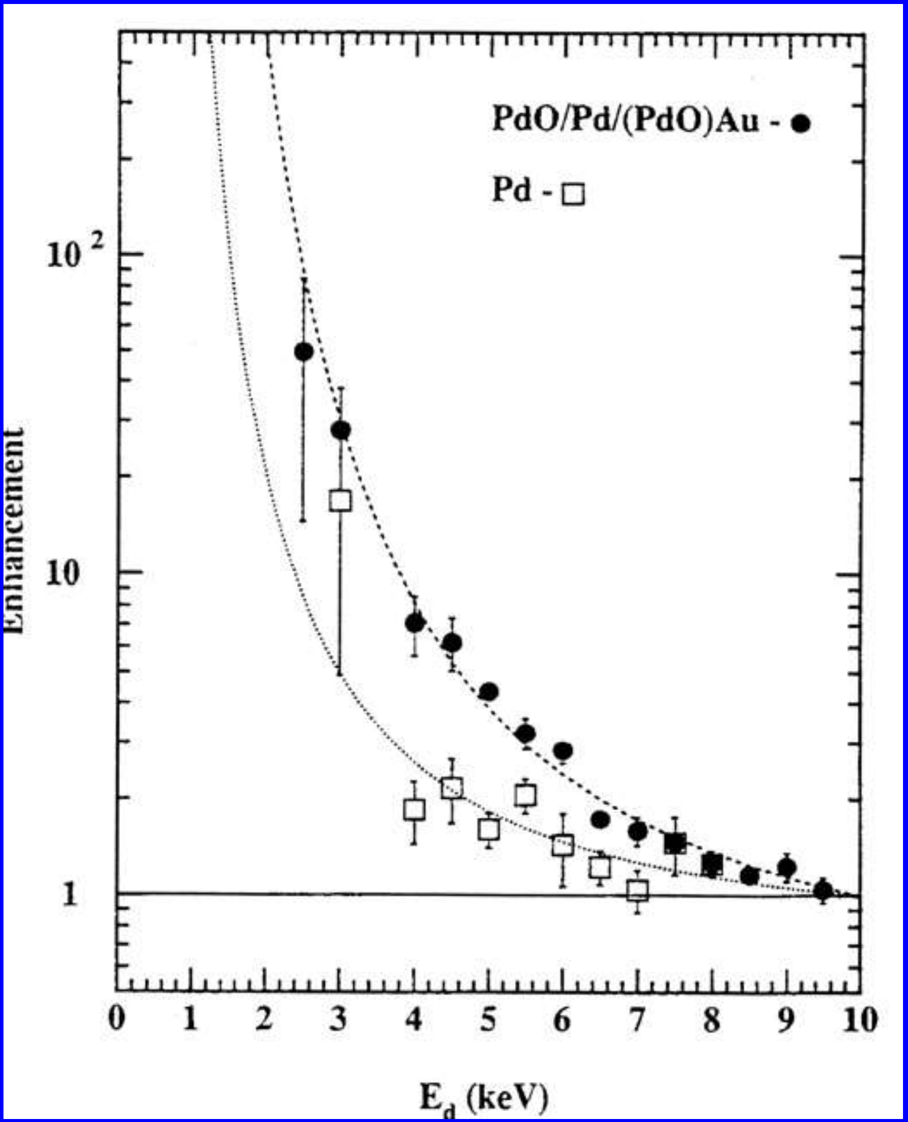
The Seventh International Conference on Cold Fusion. 1998. Vancouver, Canada: ENECO, Inc., Salt Lake City, UT. : p. 180.

"Anomalously enhanced d(d,p)t reaction in Pd and PdO observed at very low bombarding energies"

J. Kasagi, H. Yuki, T. Itoh, N. Kasajima, T. Ohtsuki, and A.G. Lipson *

Laboratory of Nuclear Science, Tohoku University, Japan

* Institute of Physical Chemistry, The Russian Academy of Sciences, Moscow, Russia



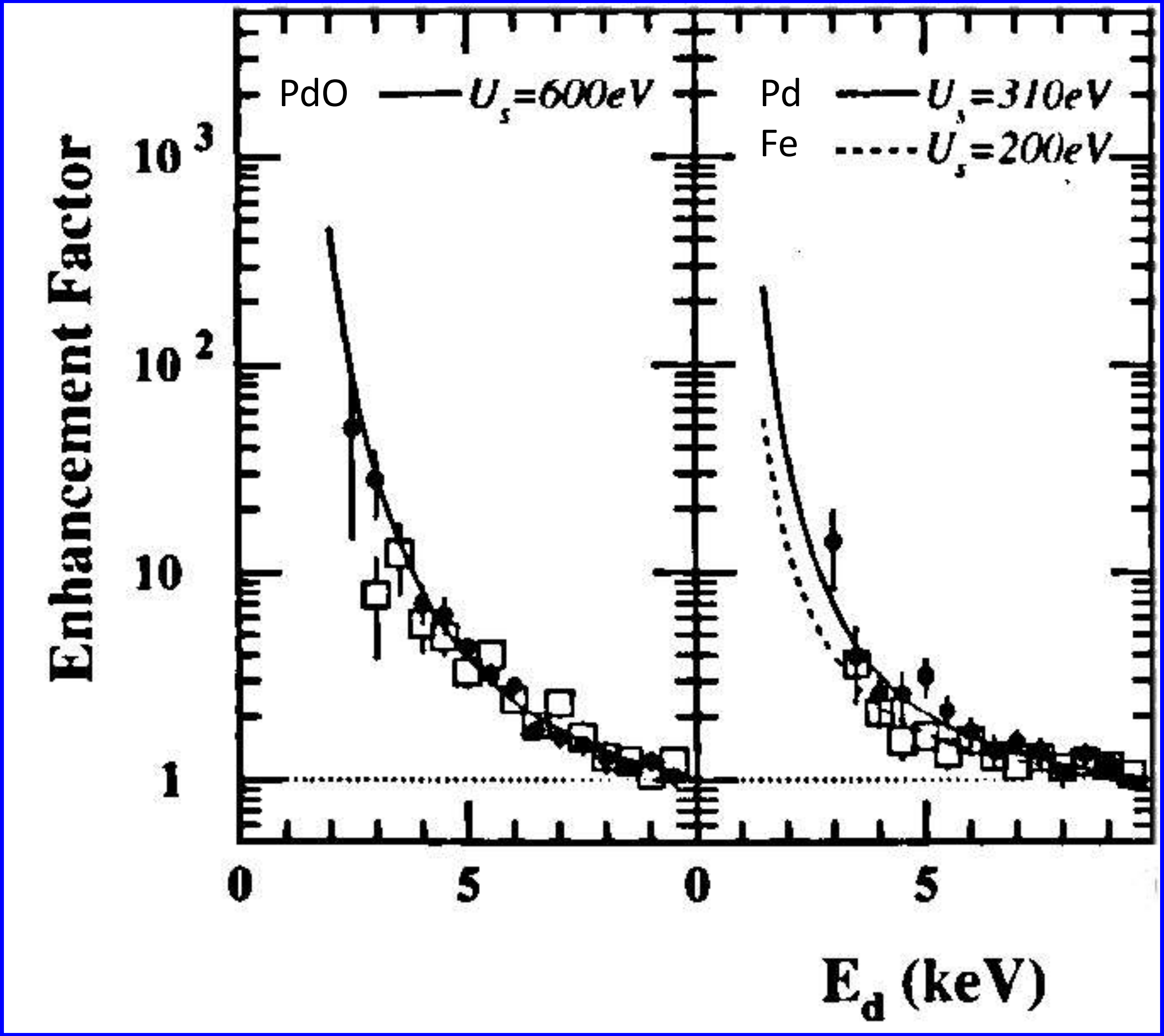
The dotted and dashed curves are those with the screening potential U_e = 250 and 600 eV, respectively.

One of the latest (2002) Japanese DD experiments at the accelerator

Jirohta Kasagi, Hideyuki Yuki, Taiji Baba, Takashi Noda, Tsutomu Ohtsuki and Andrey G. Lipson

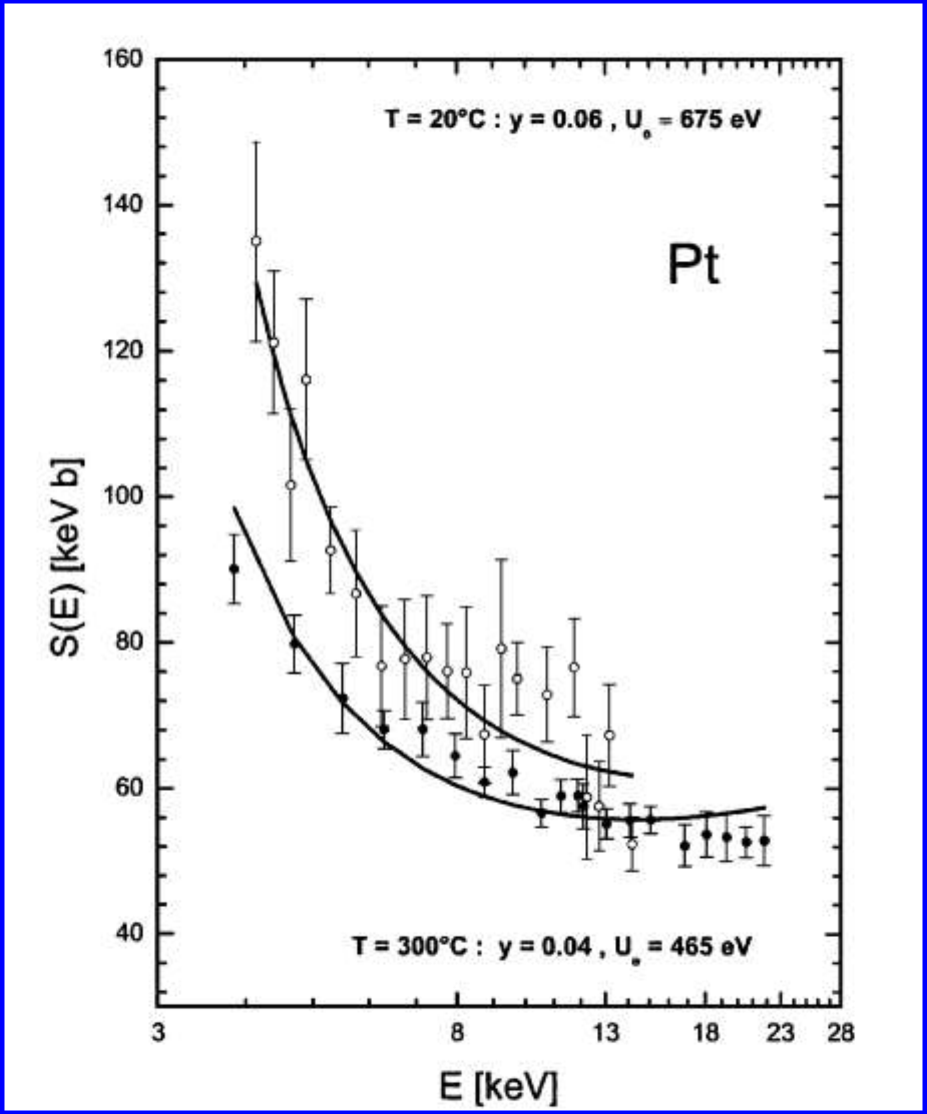
"Strongly Enhanced DD Fusion Reaction in Metals Observed for keV D^+ Bombardment"

Journal of the Physical Society of Japan, Vol. 71, No. 12, December, 2002, pp. 2881-2885.



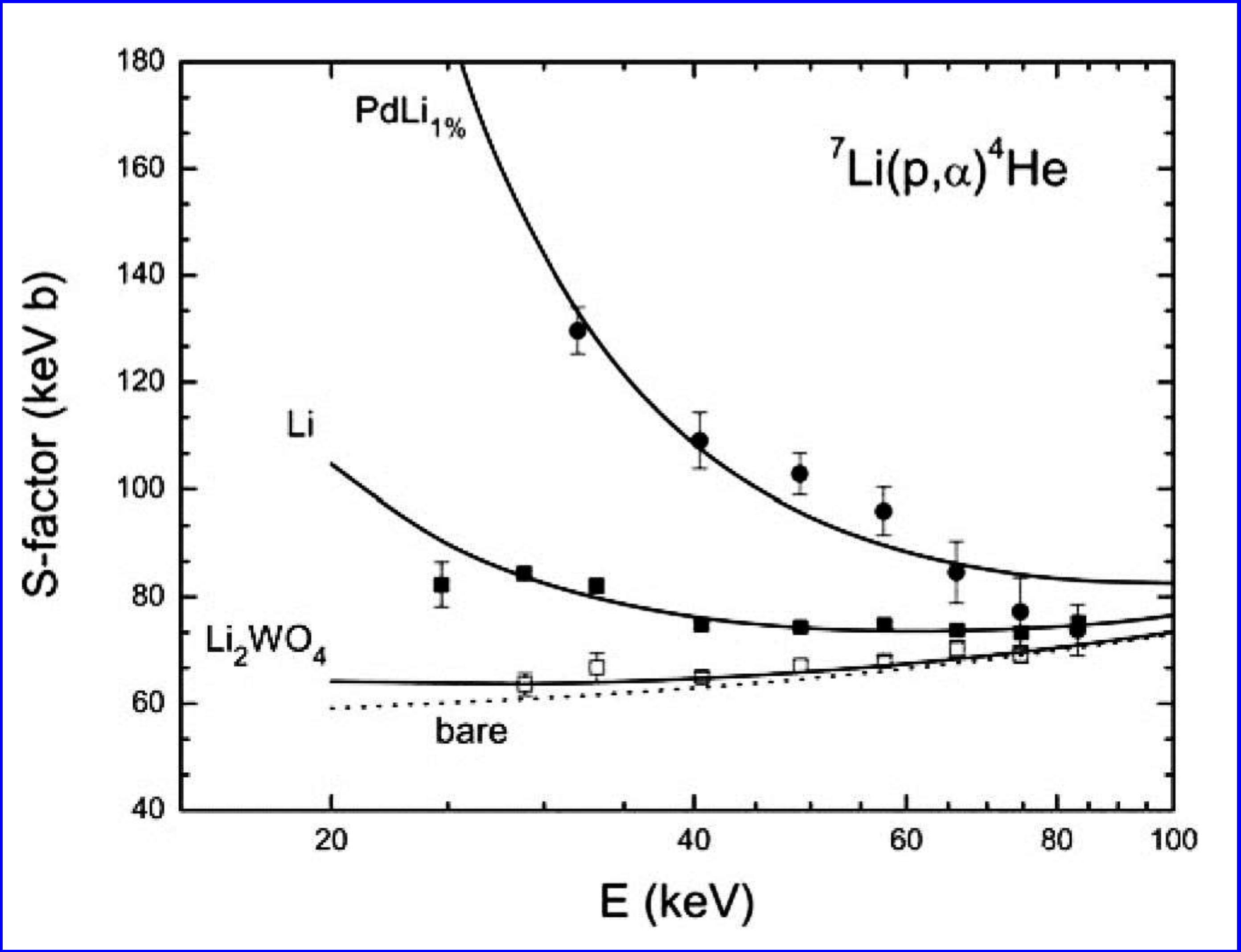
C. Rolfs et al., J. Phys. G: Nucl. Part. Phys. 31, 2005, pp 1141–1149. (Gran Sasso)

S (E) for DD fusion, the target is implanted in platinum, U_e = 675 eV

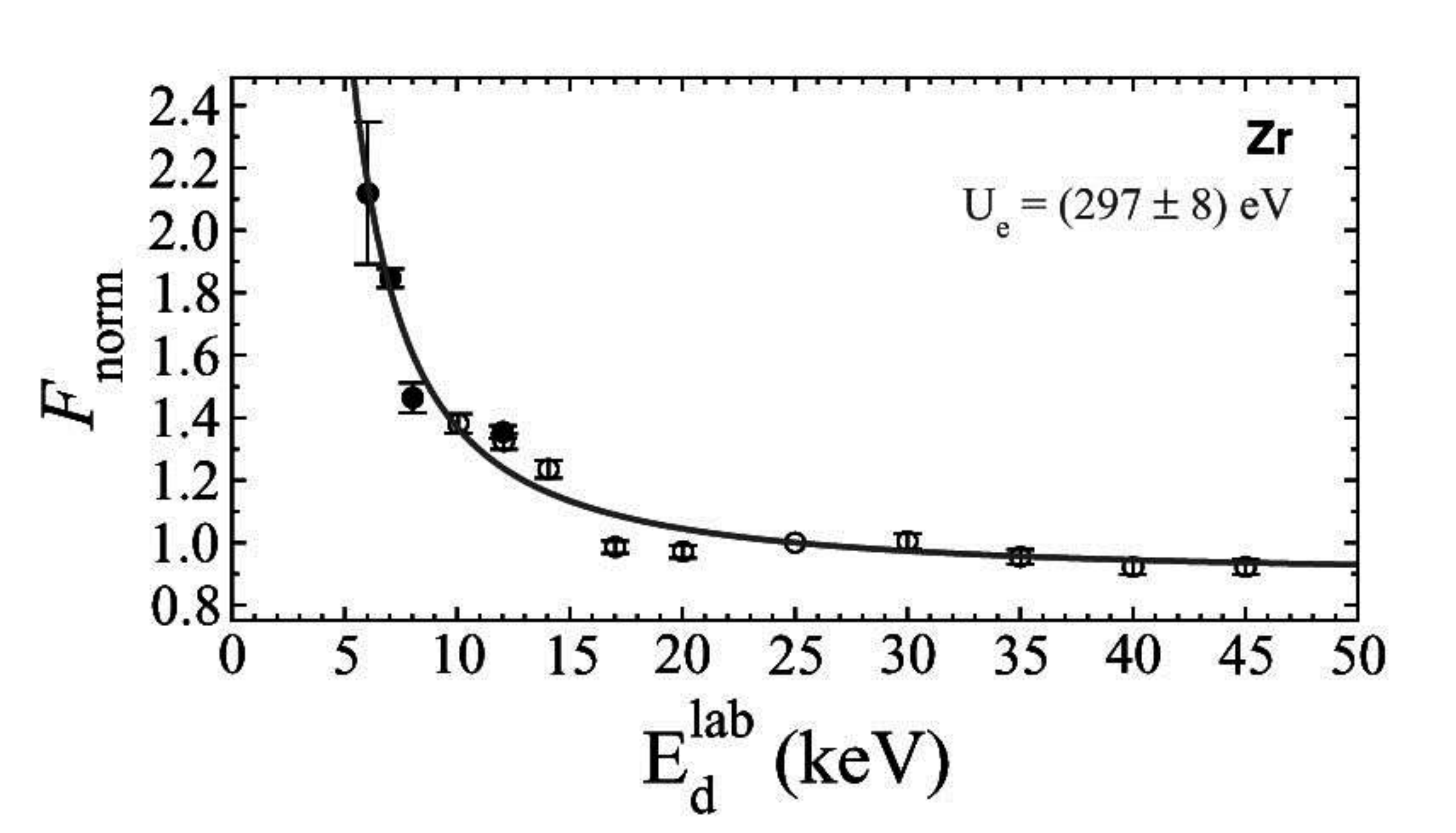


Claus Rolfs, Vol. 16, No. 2, 2006, Nuclear Physics News, p. 9.

Normalized astrophysical factor *S(E)* for the fusion of p +^{7}Li when the target ^{7}Li is implanted in palladium.

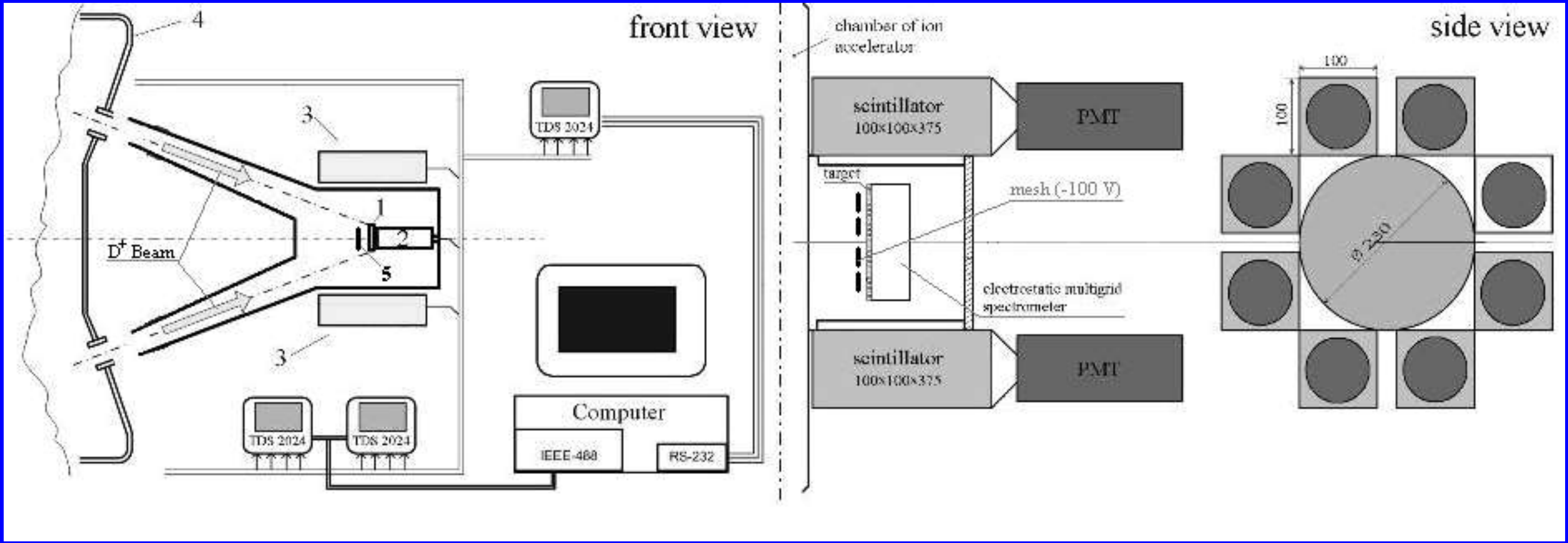


K. Czerski et al., Physical Review C 78, 015803, 2008 (Berlin).
Normalized astrophysical factor *S(E)* for DD fusion when the target is implanted in zirconium. Screening potential is about 10 times greater than for the free atoms of deuterium. What does this mean?



V. M. Bystritsky, Vit. M. Bystritskii, G. N. Dudkin, M. Filipowicz, S. Gazi, J. Huran, A. P. Kobzev, G. A. Mesyats, B. A. Nechaev, V. N. Padalko, S. S. Parzhitskii, F. M. Pen'kov, A. V. Philippov, V. L. Kaminskii, Yu. Zh. Tuleushev, J. Wozniak

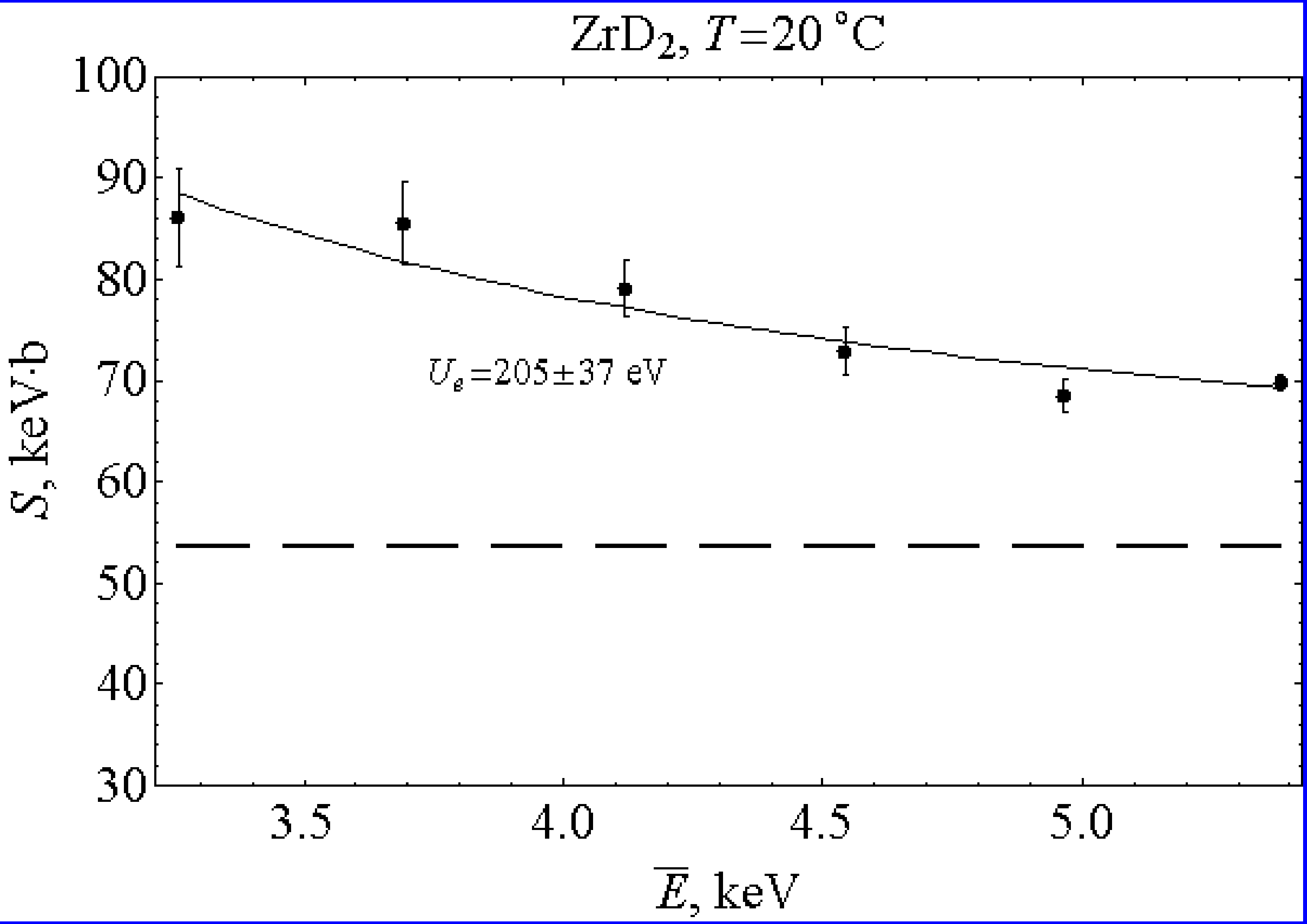
National Scientific Research – Tomsk Polytechnical University, Russia, Nuclear Physics, 2013 (in press)



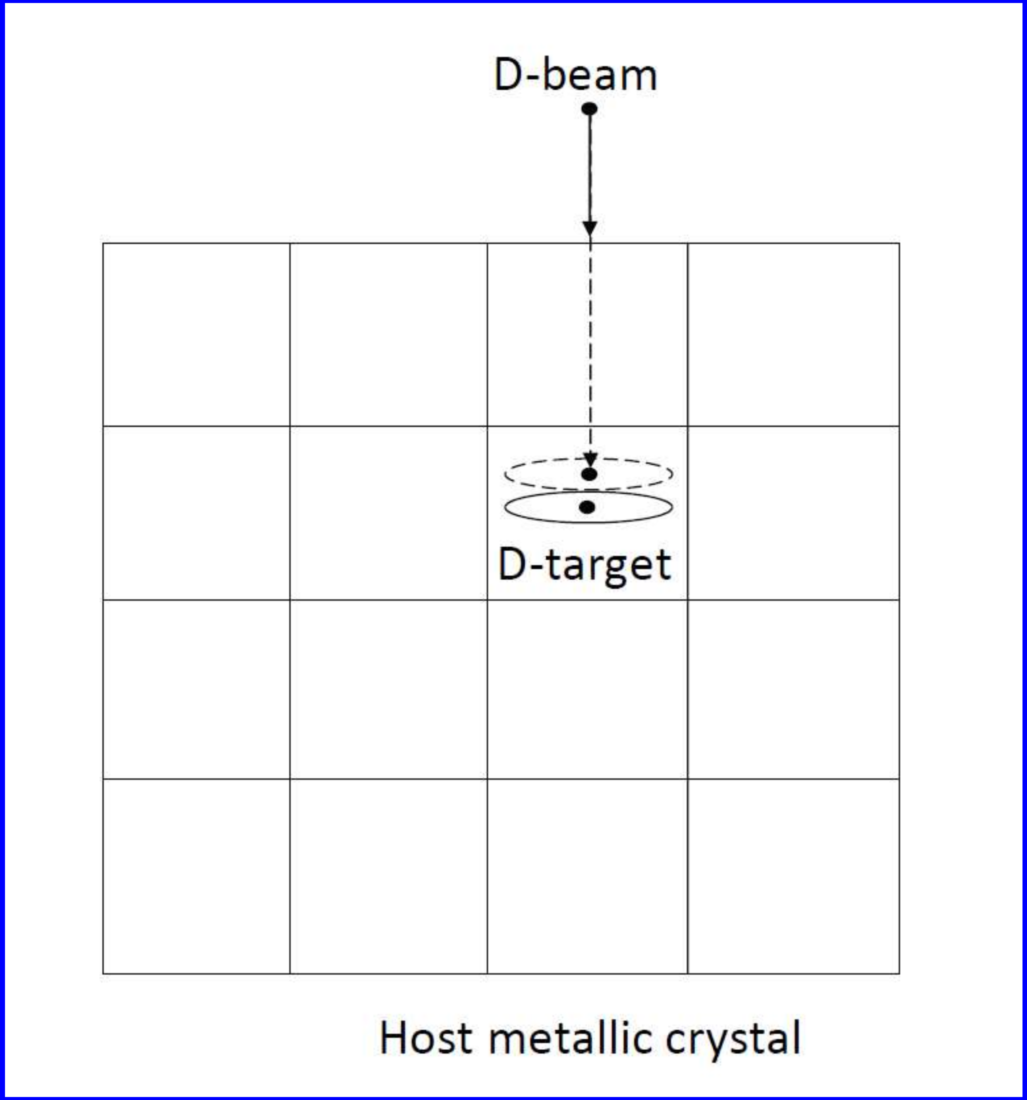
V. M. Bystritsky et al,

National Scientific Research - Tomsk Polytechnical University, Russia,

Nuclear Physics, 2013 (in press)



Experiments at accelerators



Thereby, the convergence distance of two deuterium nuclei, caught in the same crystalline niche of metal, happen to be an order of magnitude smaller than the size of the free atom of deuterium.

Although a quantitative description of this phenomenon is not yet available, numerous experiments in accelerators leave no doubt of its existence. Coulomb barrier permeability in such conditions during DD fusion drastically increased (by 50 to 60 orders of magnitude), as compared to the barrier permeability for the case of the free molecule of deuterium.

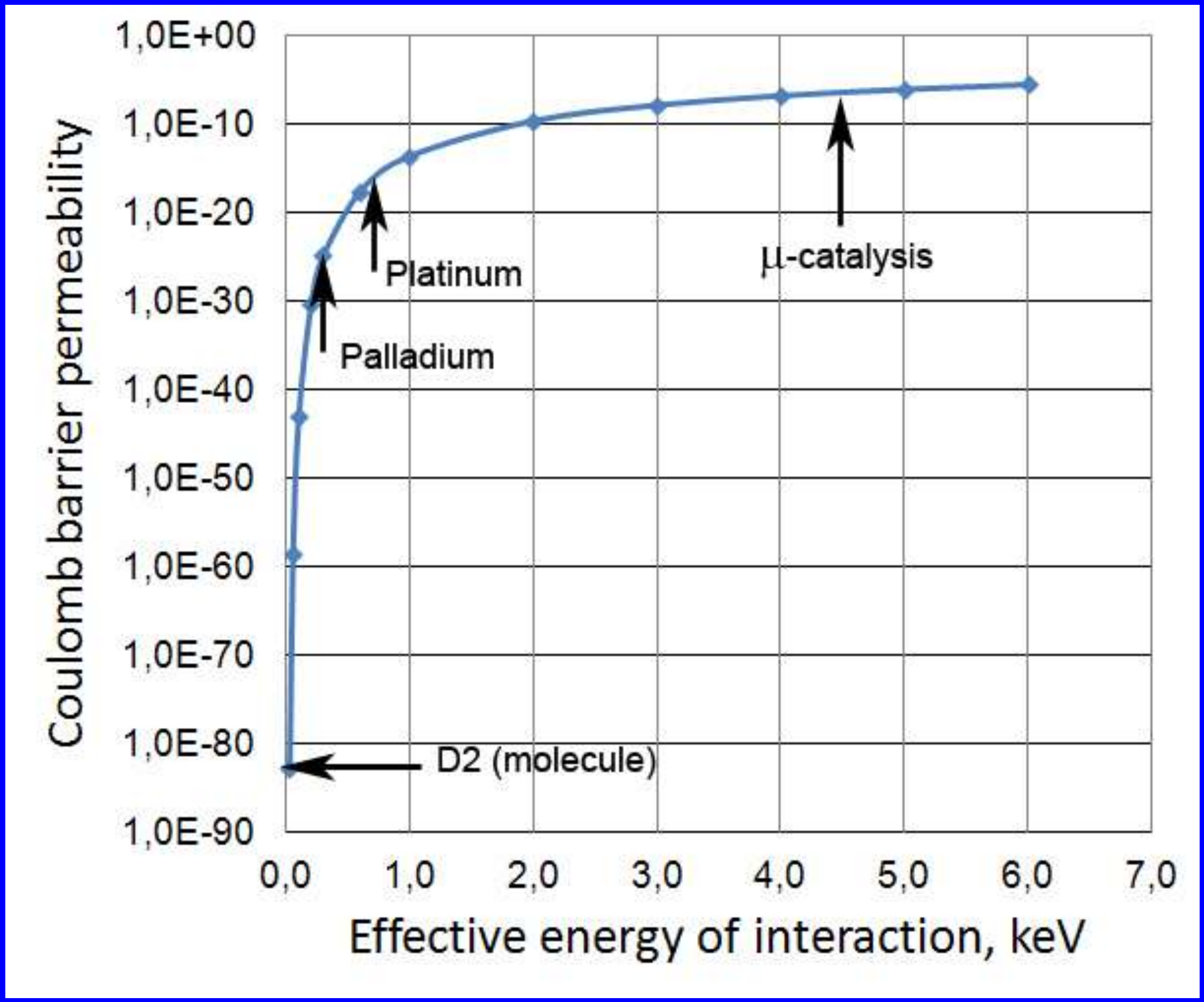
The fusion cross-section in the collision of two deuterium nuclei:

$$\sigma(E) = S(E)\, E^{-1} \exp(-2\pi\eta(E))$$
$$2\pi\eta = 31.4/E^{1/2}$$

Here, the kinetic energy of the deuteron *E* refers to the center of mass in keV. *S(E)* – astrophysical factor, which at low energies can be considered constant. The main fusion cross-section's dependence on the energy is contained in the expression $exp(-2\pi\eta(E))$, which defines the probability of penetration of the deuteron through the Coulomb barrier in a single encounter. In the case of a collision of atoms, the energy *E* should be replaced by $E_{eff} = E + U_e$, where $U_e = e^2/R_a$. As we mentioned already, for the hydrogen atoms in the ground state U_e = 27 eV.

The permeability of the Coulomb barrier for DD fusion:

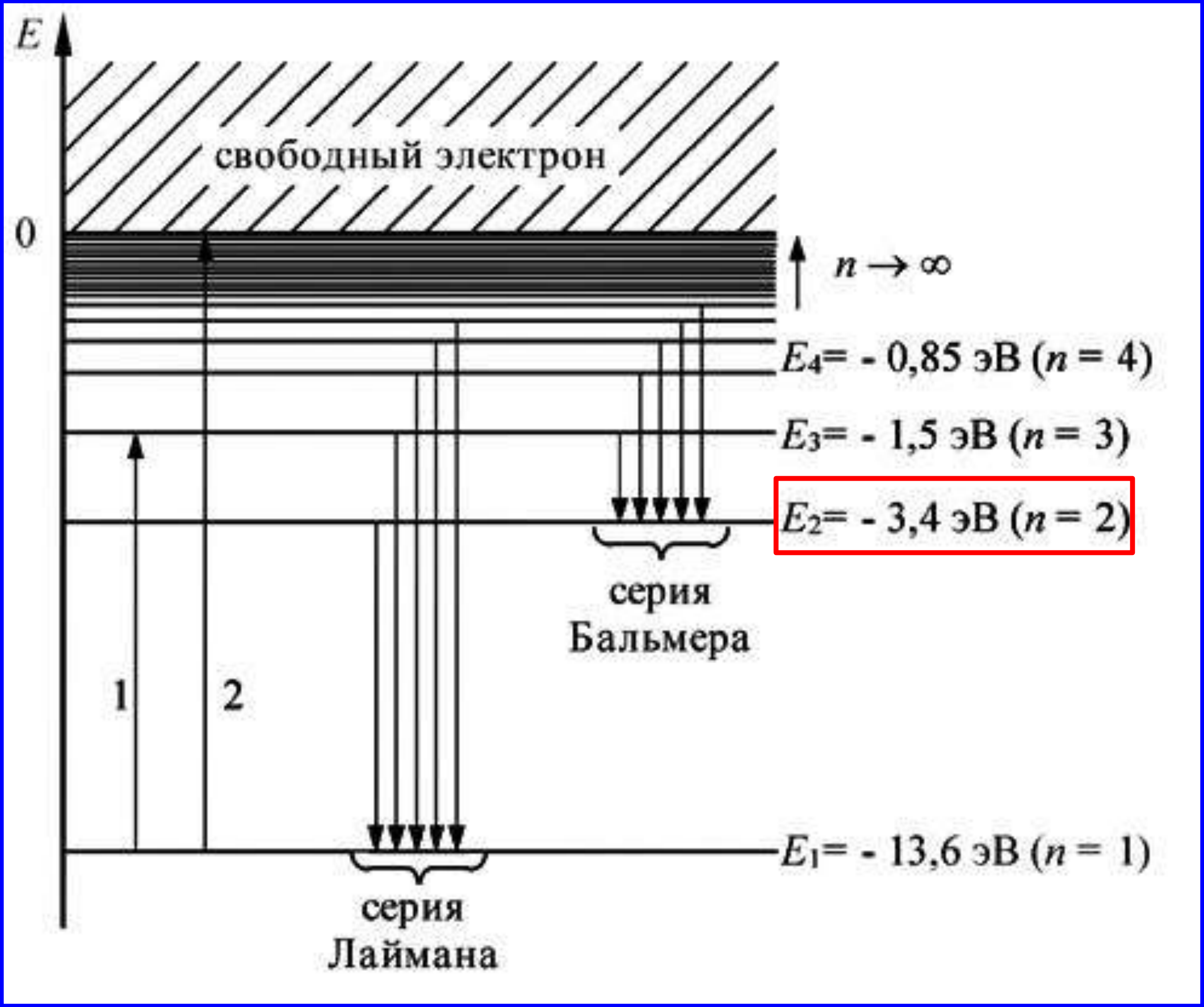
$$P = e^{-2\pi\eta} \quad (2\pi\eta = 31.41/E_{eff}^{1/2},\ E_{eff} = E + U_e)$$



For cold fusion

E ≃ 0.040 эВ

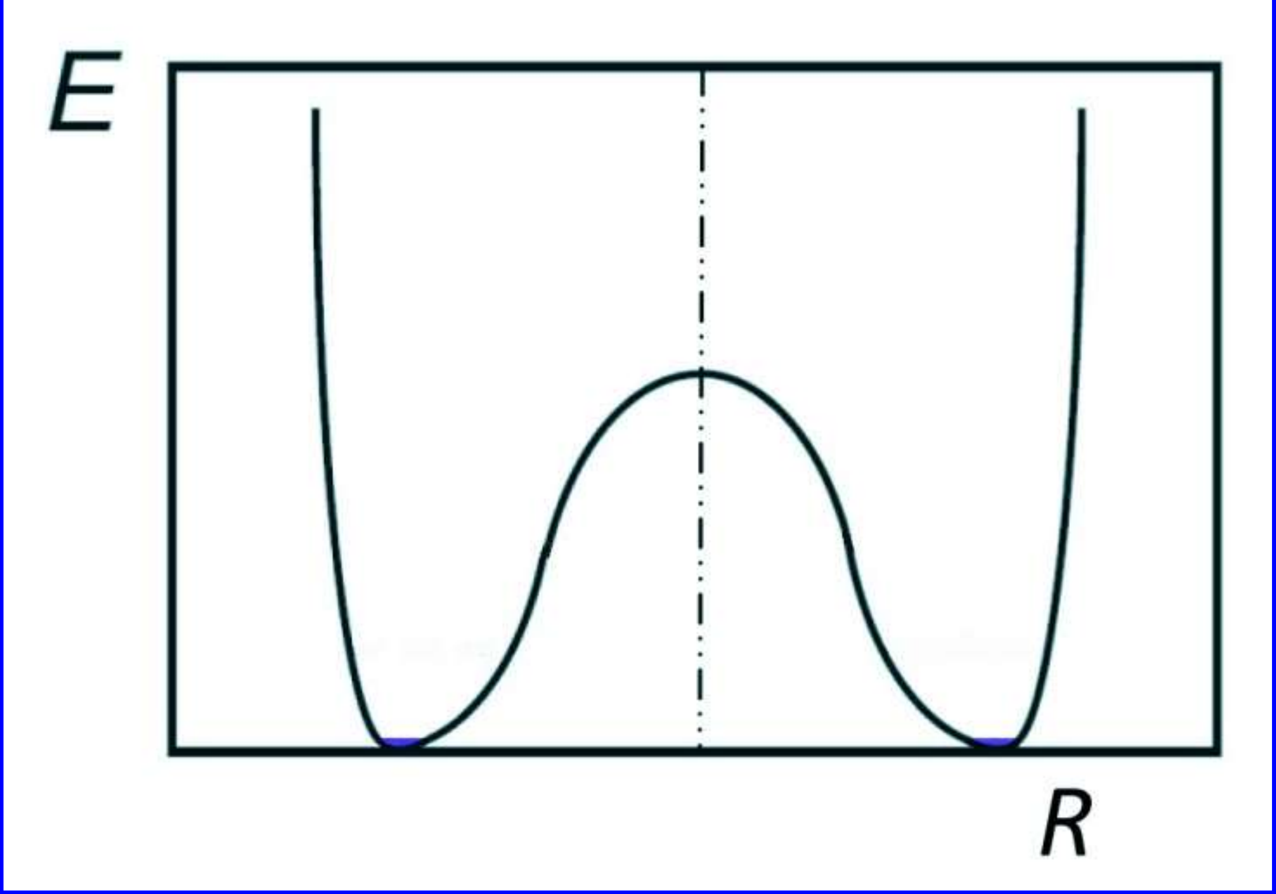
Rydberg mechanism for hydrogen atom



So, the first secret of cold fusion, which necessarily results in the fusion of deuterium nuclei in the case of deuterium saturation of conducting crystal, today can be considered solved.

The second surprise of the process of cold fusion: practically, there are no standard nuclear decay products of $^4He^*$ in these reactions.

A possible reason for the slowing of the nuclear decay rate at levels of small excitation energy is the residual Coulomb barrier between the nuclei of deuterium within the potential well of the strong interactions. Perhaps the “statistical principle of correlations weakening with the distance” works for neutrons (Bogolyubov, Selected Works on Statistical Physics, Moscow, 1979).



According to our hypothesis, the rate of nuclear decay of a compound nucleus $^{4}He^{*}$ is a function of the excitation energy of the compound nucleus, E_k. We assume that when $E_k \sim 0$ (thermal energy), the compound nucleus $^{4}He^{*}$ is metastable with a lifetime of about 10^{-15} seconds. After a time of ~ 10^{-16} seconds, the compound nucleus is no longer an isolated system, since virtual photons from the $^{4}He^{*}$ can reach the nearest electrons in the crystal and carry the excitation energy of the compound nucleus $^{4}He^{*}$.

It should be emphasized that the above hypothesis is an attempt to explain the well-established experimental fact that the traditional nuclear decay channels of the compound nucleus $^{4}He^{*}$ in the process of cold fusion are practically absent.

ISSN 1063-7788, Physics of Atomic Nuclei, 2012, Vol. 75, No. 2, pp. 153–159. © Pleiades Publishing, Ltd., 2012.
Original Russian Text © E.N. Tsyganov, 2012, published in Yadernaya Fizika, 2012, Vol. 75, No. 2, pp. 174–180.

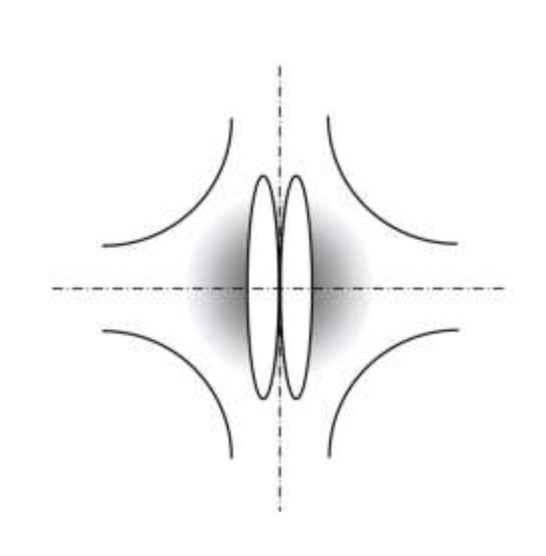
NUCLEI
Experiment

Cold Nuclear Fusion*

E. N. Tsyganov**

University of Texas Southwestern Medical Center at Dallas, Texas, USA

Abstract—Recent accelerator experiments on fusion of various elements have clearly demonstrated that the effective cross-sections of these reactions depend on what material the target particle is placed in. In these experiments, there was a significant increase in the probability of interaction when target nuclei are imbedded in a conducting crystal or are a part of it. These experiments open a new perspective on the problem of so-called cold nuclear fusion.



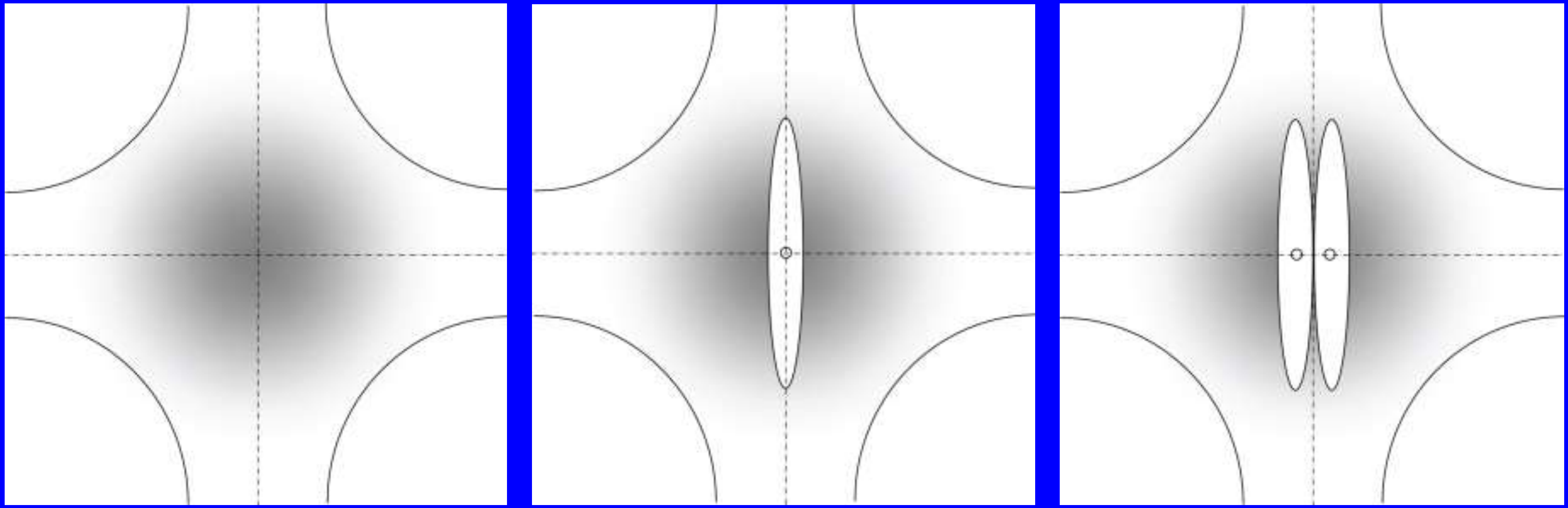
Rate of DD fusion in a crystalline cell

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}	4.2

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 crystal cell of the metallic conductor. Simple cubic structure used as a didactic example. The shaded part of the figure shows the location of the area of free electrons. The Rydberg mechanism works.

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



In our recent articles we discuss the possibility of the experimental detection of the cold DD fusion by detection of low-energy electrons, which are the result of the fusion reaction of two deuterons in palladium crystals with very small (thermal) excitation energies of the compound nucleus $^4He^*$. This process becomes possible by the exchange of the intermediate nucleus and electrons of the crystal lattice by virtual photons.

Nuclear Instruments and Methods in Physics Research B 309 (2013) 95–104

ELSEVIER

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Registration of energy discharge in $D + D \rightarrow {}^4He^*$ reaction in conducting crystals (simulation of experiment)

CrossMark

E.N. Tsyganov[a],*, V.M. Golovatyuk[b], S.P. Lobastov[b], M.D. Bavizhev[c], S.B. Dabagov[d]

[a] University of Texas Southwestern Medical Center at Dallas, USA
[b] Joint Institute for Nuclear Research, Dubna, Russia
[c] North-Caucasus Federal University, Stavropol, Russia
[d] RAS PN Lebedev Physical Institute & NRNU MEPhI, Moscow, Russia

ARTICLE INFO

Article history:
Received 30 November 2012
Received in revised form 29 December 2012
Accepted 12 January 2013
Available online 3 April 2013

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.

**УЧРЕДИТЕЛЬ
И ИЗДАТЕЛЬ ЖУРНАЛА:**
ООО Издательство
«НАУЧТЕХЛИТИЗДАТ».
Журнал зарегистрирован в Федеральной службе по надзору в сфере связи, информационных технологий и массовых коммуникаций (Роскомнадзор). Свидетельство о регистрации средства массовой информации ПИ № ФС77-37278.
Подписной индекс в каталоге
ОАО «Роспечать» 79217
«Пресса России» 34117

Сайт издательства: www.tgizd.ru

Инженерная физика № 9 2013

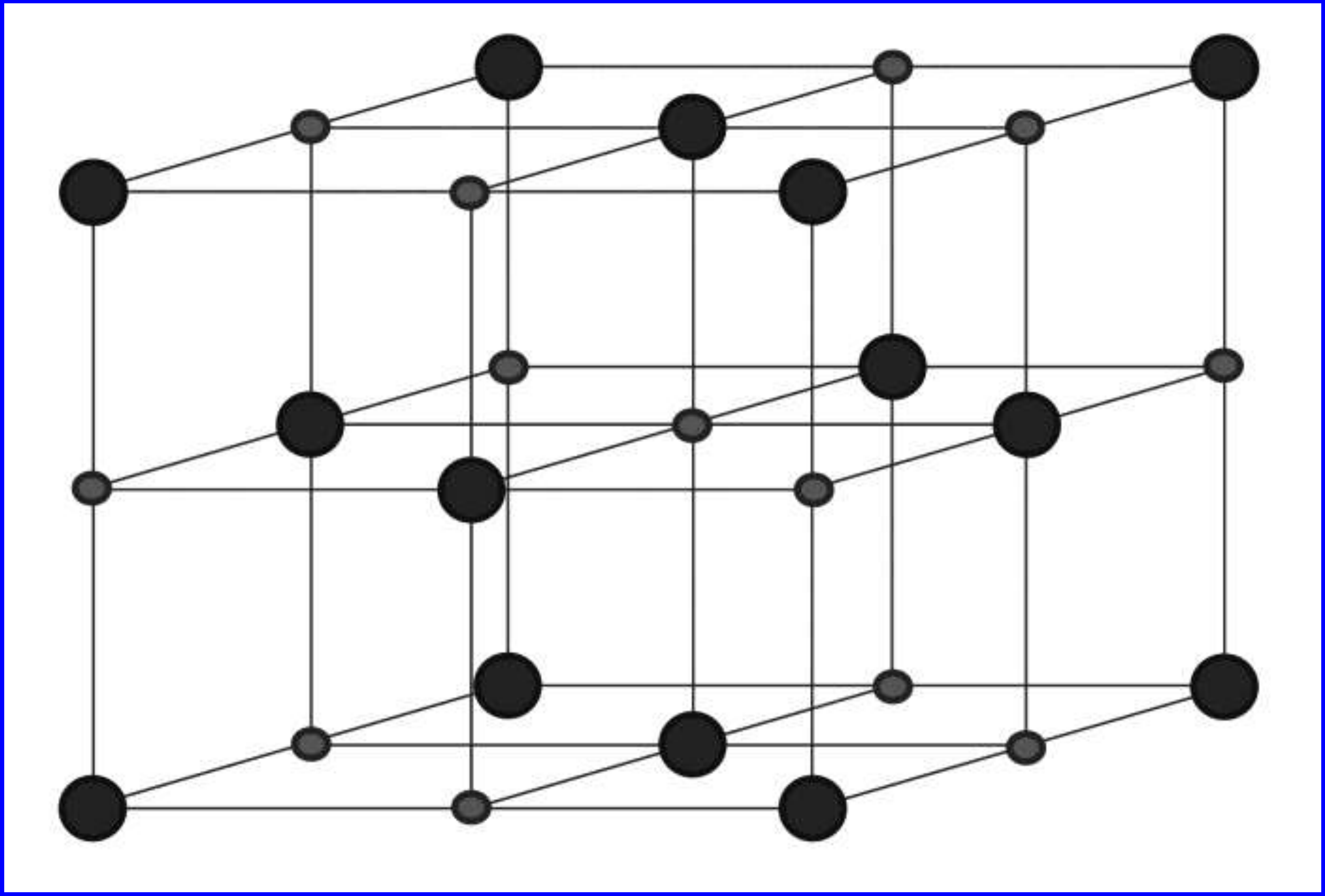
ISSN: 2072-9995

НАУЧНО-ТЕХНИЧЕСКИЙ ЖУРНАЛ

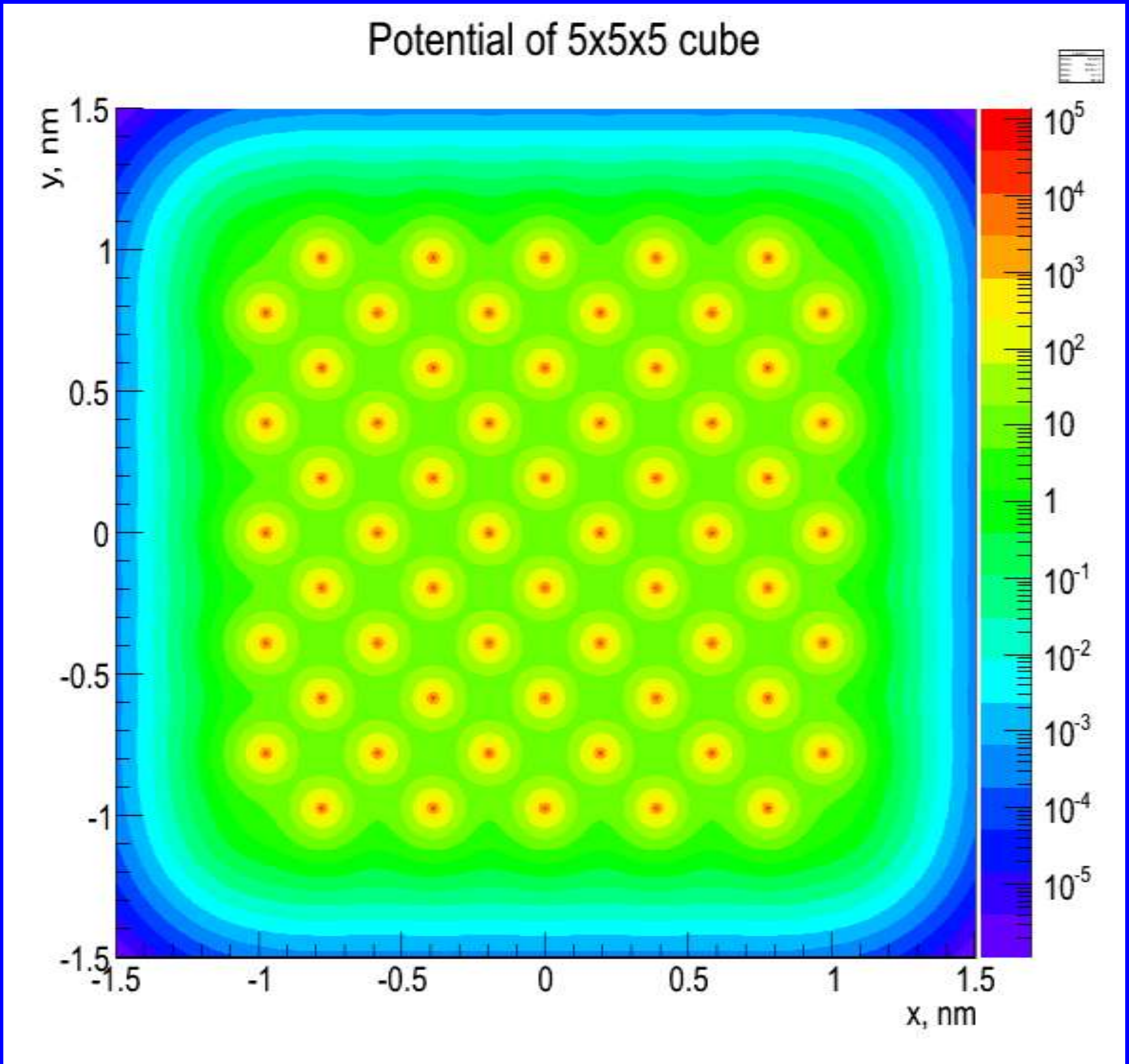
СОДЕРЖАНИЕ

ФИЗИКА АТОМНОГО ЯДРА И ЭЛЕМЕНТАРНЫХ ЧАСТИЦ

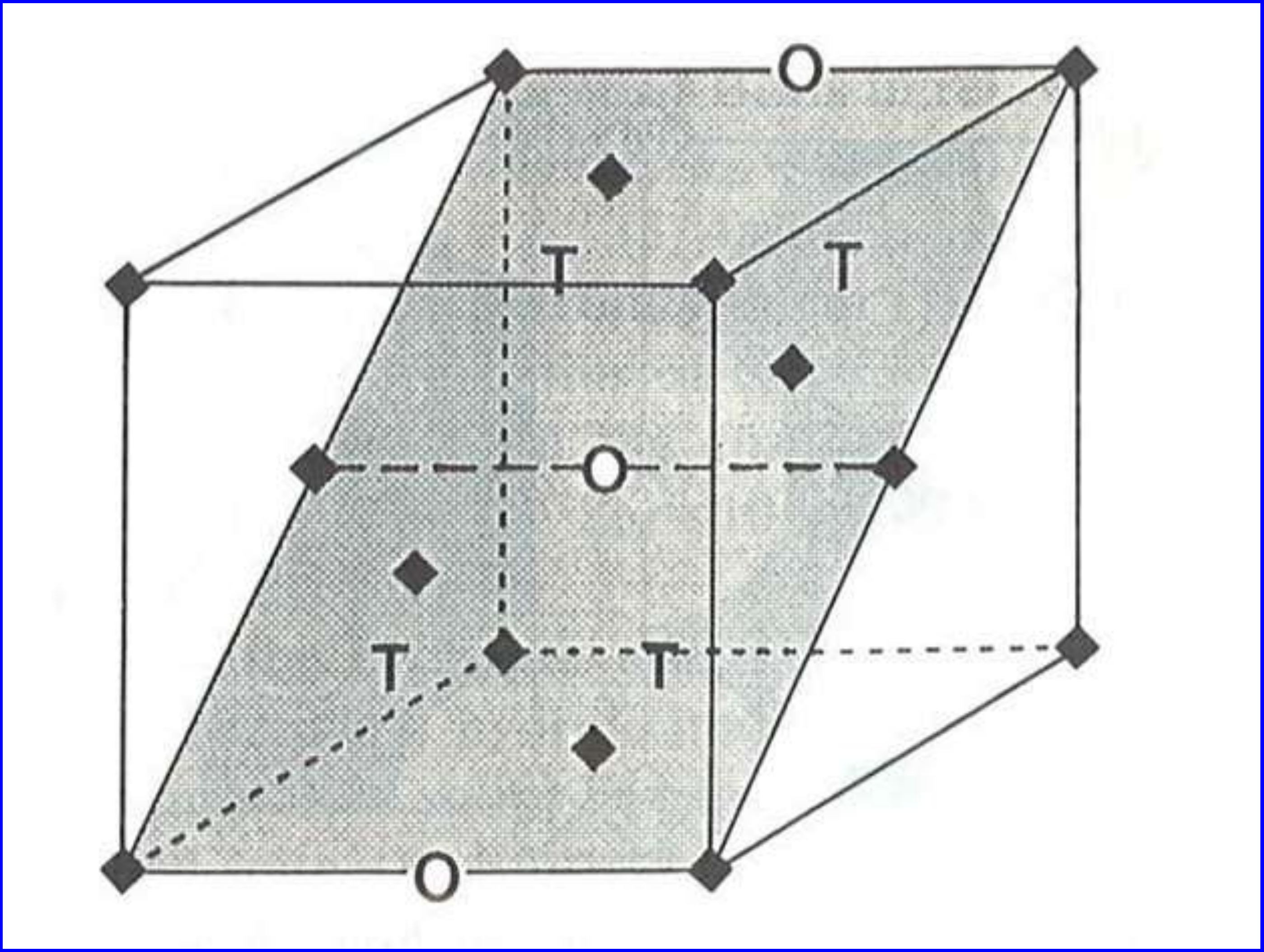
The crystal cell of fcc-type conductor (palladium, platinum). Large circles denote the atoms of the host crystal, small ones - octahedral vacancies.



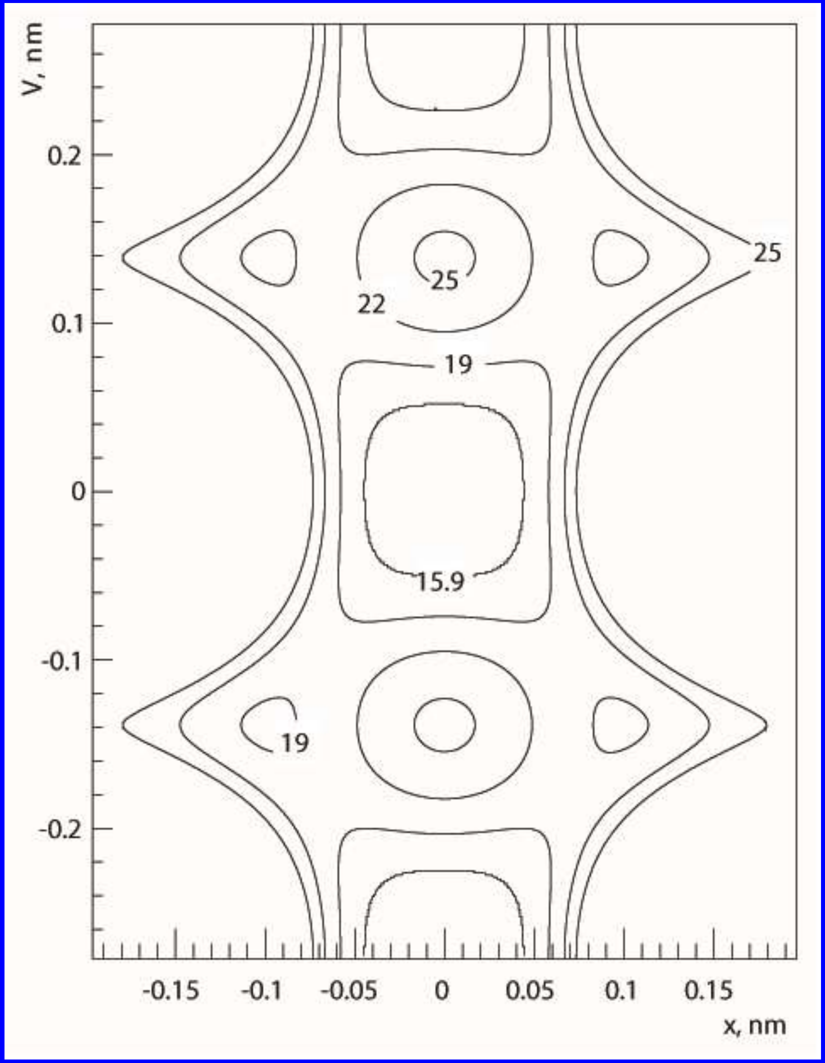
Atomic potentials of the cluster of $5 \times 5 \times 5$ cells in the platinum crystal



Diagonal plane *XV* in fcc crystals. Signs O designate octahedral vacancy, signs T designate tetrahedral vacancy.



The contours of the potentials in the diagonal plane *X-V* for platinum.



Octahedral potential in the vicinity of the center of a platinum crystal cell in the direction of *V*

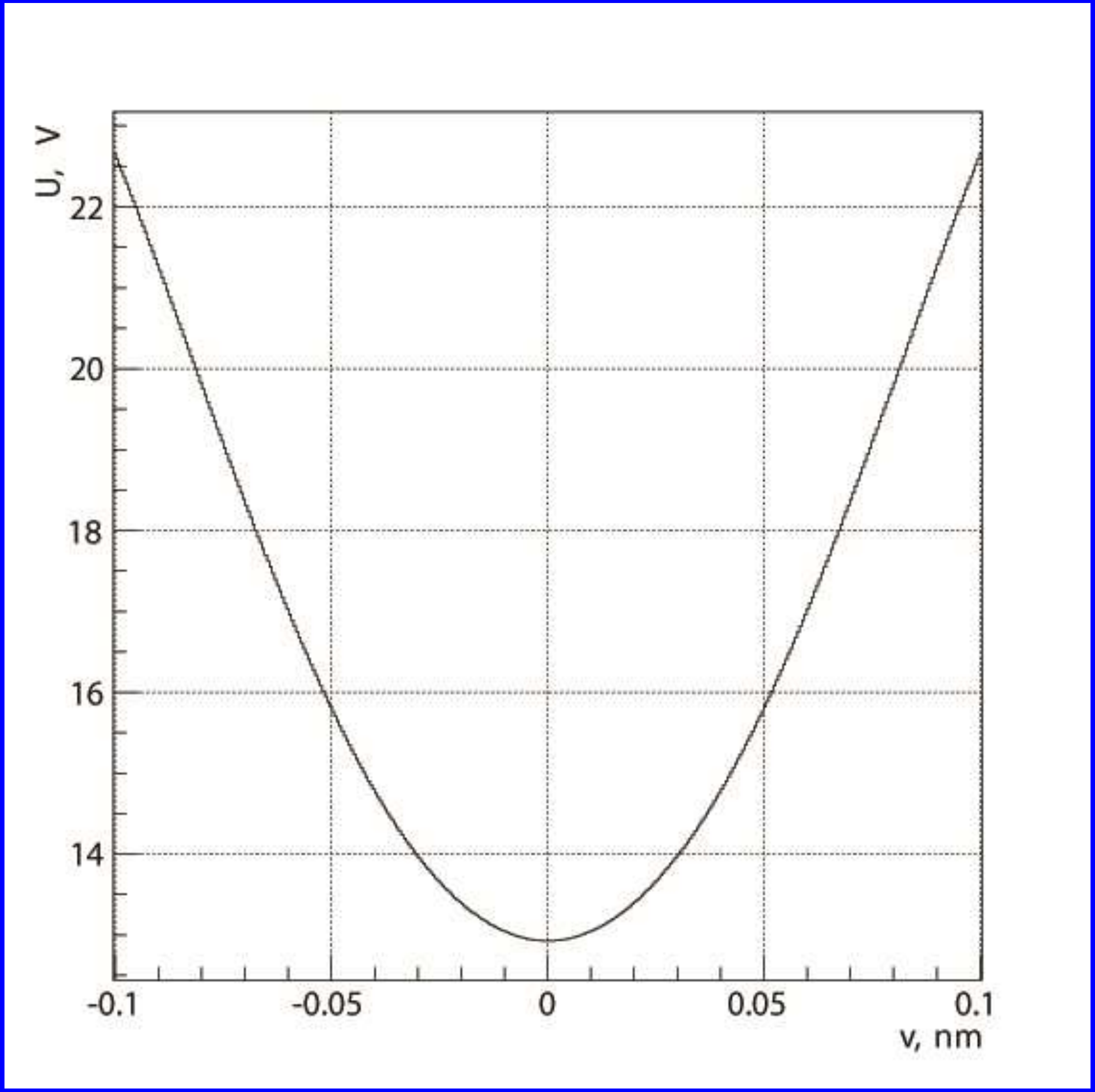
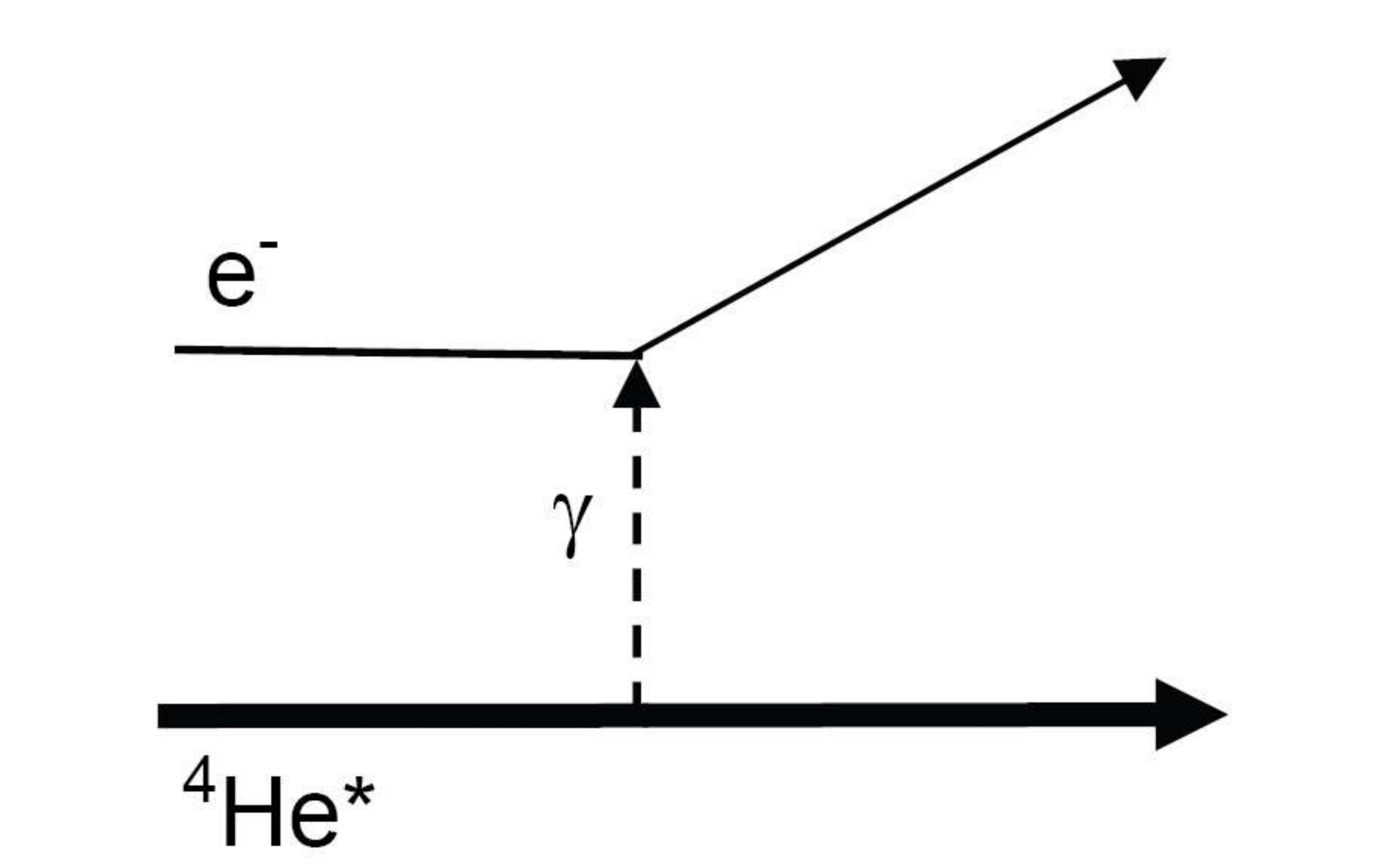
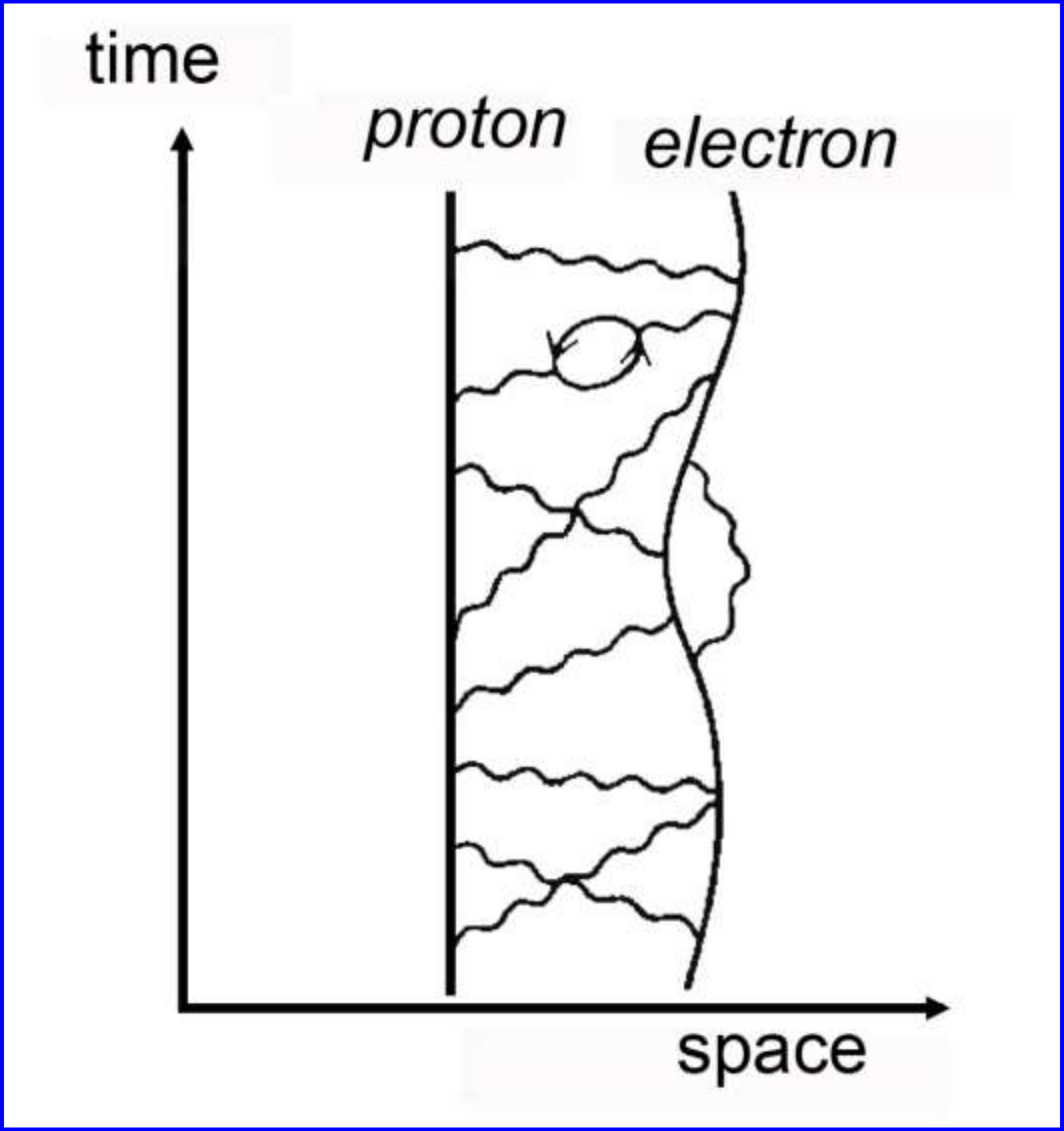


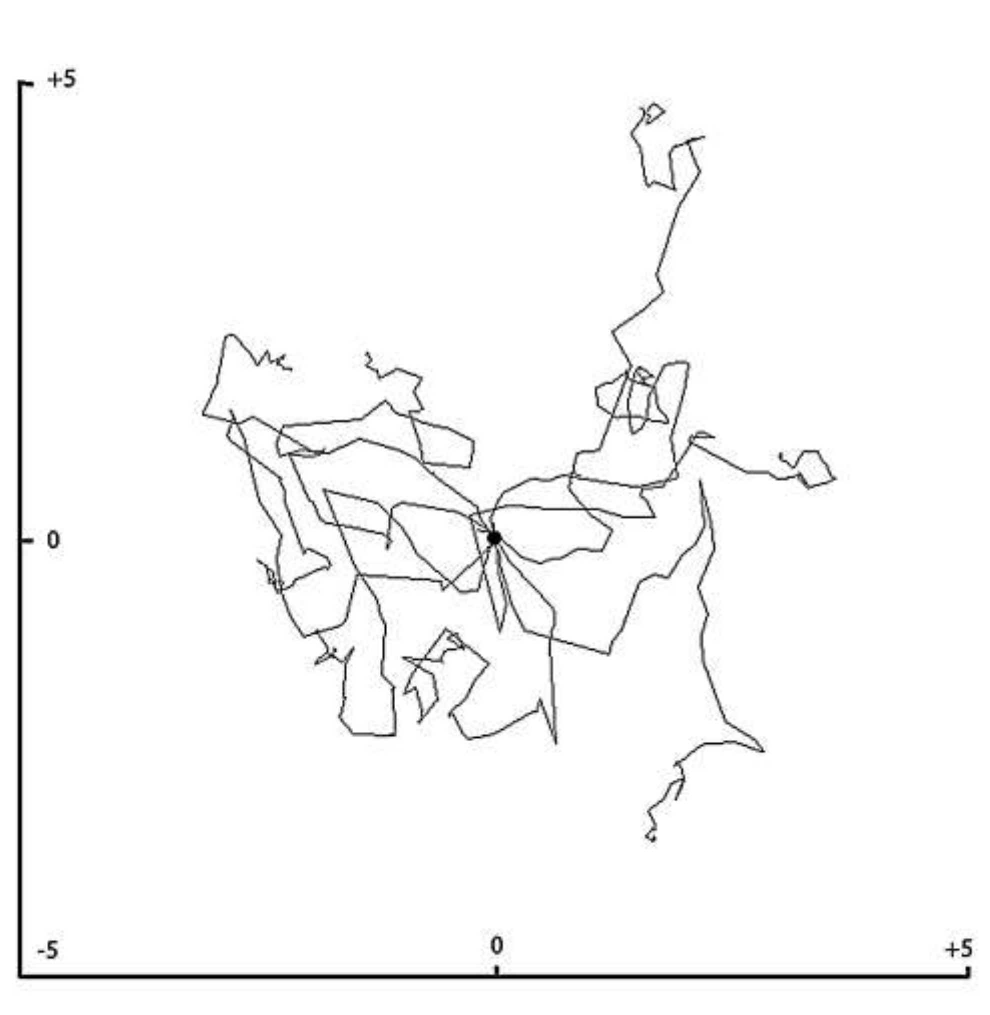
Diagram of the process, providing “thermalization” of DD fusion process with the formation of $^{4}He^{*}$ in conducting crystals. In order for this process to work, the existence of metastable $^{4}He^{*}$ is necessary.



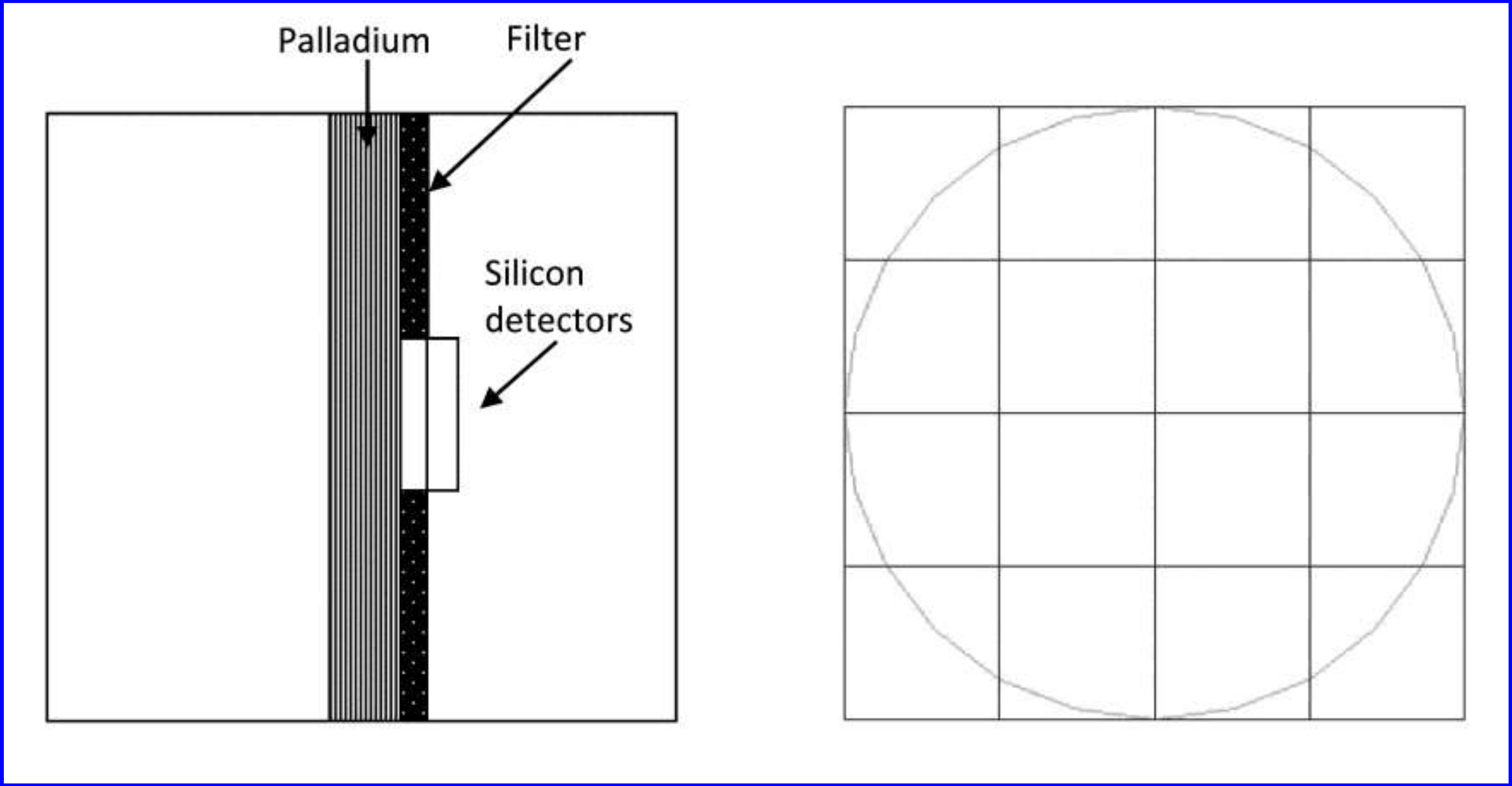
Virtual photons in the hydrogen atom (Richard Feynman)



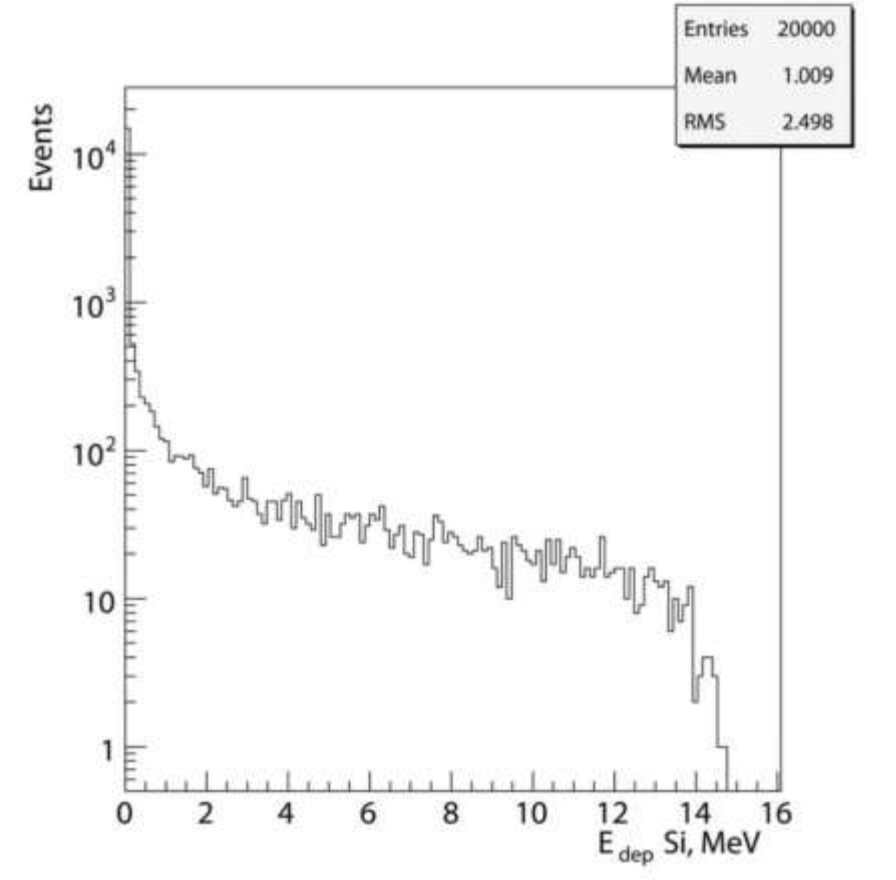
Electron trajectories (Monte Carlo) generated in the process of cold DD fusion in palladium. Dimensions are in microns.



One-side experimental setup. Several silicon detectors are arranged on one side of the palladium foil and included in the coincidences. On the left – side view, right – the relative positions of the aperture and the detectors.



Energy of the emitted electrons of 60 keV delivered to the detectors disposed at one side of the palladium foil. The spectrum extends up to 14 MeV due to the fact that some of the electrons are scattered in palladium at angles up to 180 °.



Accelerator experiments on the DD-fusion in metals

- H Yuki, T Satoh, T Ohtsuki, T Yorita, Y Aoki, H Yamazaki and J Kasagi "D+D reaction in metal at bombarding energies below 5 keV"в журнале J. Phys. G: Nucl. Part. Phys. 23 (1997) 1459–1464.

- J. Kasagi, H. Yuki, T. Itoh, N. Kasajima, T. Ohtsuki and A. G. Lipson* "Anomalously enhanced d(d,p)t reaction in Pd and PdO observed at very low bombarding energies", the Seventh International Conference on Cold Fusion, 1998. Vancouver, Canada:, ENECO, Inc., Salt Lake City, UT : p. 180.

- H. Yuki, J. Kasagi, A.G. Lipson, T. Ohtsuki, T. Baba, T. Noda, B.F. Lyakhov, N. Asami "Anomalous Enhancement of DD Reaction in Pd and Au/Pd/PdO heterostructure targets under a low energy deuteron bombardment", письма в ЖЭТФ, том 68, выпуск 11, 10 декабря,1998.

- J. Kasagi, H. Yuki, T. Baba and T. Noda "Low Energy Nuclear Fusion Reactions in Solids", 8th International Conference on Cold Fusion.,2000. Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy.

- A.G. Lipson, G.H. Miley, A.S. Roussetski, A.B. Karabut "strong enhancement of dd-reaction…" Report was delivered at the ICCF-10 of 2003.
- The work is interesting because in this experiment soft X-ray radiation was recorded.

- Claus Rolfs – Gran Sasso, 2002 – 2006
  - C. Rolfs, "Enhanced electron screening in metals: a plasma of the poor man", Nucl. Phys. News 16 (2) (2006).
  - F. Raiola, (for the LUNA Collaboration), B. Burchard, Z. Fulop, et al., J. Phys. G: Nucl. Part. Phys. 31 (2005) 1141;
  - F. Raiola, (for the LUNA Collaboration), B. Burchard, Z. Fulop, et al., Eur. Phys. J. A27 (2006) 79.
- K. Czerski – Berlin, 2002 – 2009
  - A. Huke, K. Czerski, P. Heide, G. Ruprecht, N. Targosz, W. Zebrowski, Phys. Rev. C 78 (2008) 015803.
  - K. Czerski, A. Huke, P. Heide, et al., J. Phys. G 35, 014012 (2008).
- Tomsk Collaboration, 2012 - 2013
  - V. M. Bystritsky et al, National Scientific Research - Tomsk Polytechnical University, Russia, Physics of Atomic Nuclei, 2012, Vol. 75, No. 1, pp. 53–62.
  - V. M. Bystritsky et al, National Scientific Research - Tomsk Polytechnical University, Russia, Nuclear Physics, 2013 (in press)

Conclusion

1. The existence of the phenomenon of cold fusion is now conclusively proved by the experiments, including experiments at the low energy accelerators.

2. The observed absence of nuclear products for cold fusion can be explained by slowing the decay of a compound nucleus $^4He^*$ *via* nuclear channels while decreasing the energy of its excitation. The release of the binding nuclear energy is mediated by virtual photons.

3. Prejudice of many nuclear experts against the phenomenon of cold fusion is due to the unusual nature of this nuclear process. Cold fusion forms an intermediate compound nucleus $^4He^*$ which is metastable.

4. The accumulated empirical rules of nuclear physics look undisputable for nuclear community, while the range of application of these rules is limited.

RASA, 8-10 November 2013, Clearwater Beach, FL

Thank you for your attention!