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# **COLD NUCLEAR FUSION**

6th International Conference “Charged & Neutral Particles Channeling  
Phenomena - Channeling 2014” (Capri, Italy, October 5-10, 2014)

# Cold Nuclear Fusion

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# Cold nuclear fusion. *Look beyond the horizon ...*



Flammarion, 1888,  
based on the 16th  
century vision



# 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**



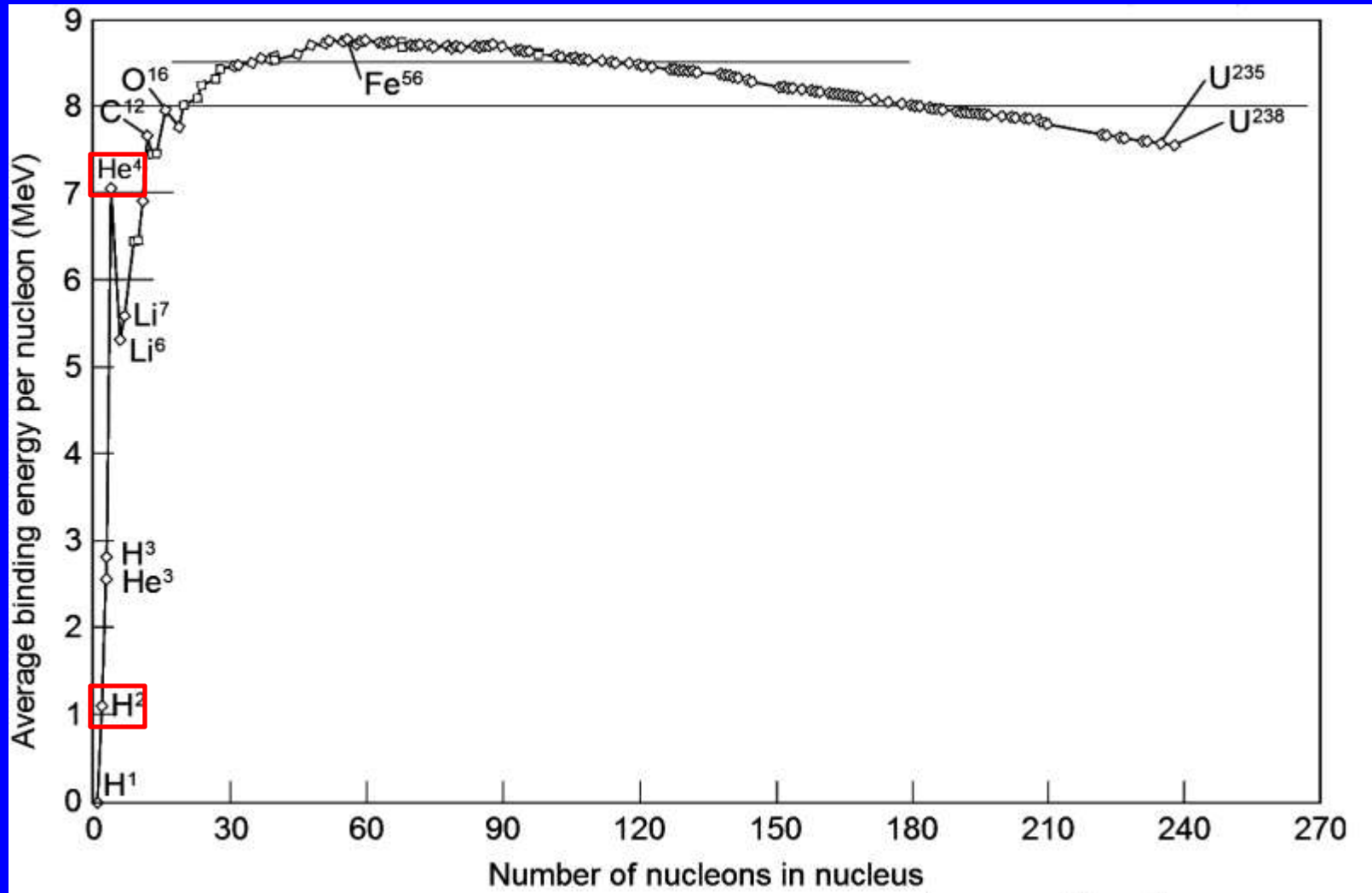
# Richard Feynman



**“Physics is the experimental science.”**

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# Binding energy



Currently, humanity has come to a stage of development when the struggle for energy resources is becoming especially important. All known sources of energy together will not be able to provide for our demand in the near future. Chemical energy is additionally limited by the so-called greenhouse effect.

Nuclear energy that based on the use of fissile materials is not the long-term solution to the problem, because stocks of these materials are limited. In addition, the required safe preservation of the radioactive waste for about 10,000 years is a serious problem.



Cross-section of fusion in the collision of two deuterium nuclei:

$$\sigma(E) = S(E) E^{-1} \exp(-2\pi\eta(E))$$
$$2\pi\eta = 31.41/E^{1/2}$$

Here, the kinetic energy of the deuteron  $E$  is shown in the center of mass in keV.  $S(E)$  — astrophysical factor at low energies; it can be assumed to be constant. The main energy dependence of the cold fusion cross-section is contained in the expression  $\exp(-2\pi\eta(E))$ , which determines the probability of penetration of the deuteron through the Coulomb barrier in a single collision. In the event of a collision of atoms, the energy  $E$  must be replaced by  $E_{eff} = E + U_e$ , where  $U_e = e^2/R_a$ . For the unexcited hydrogen atom,  $U_e = 27 \text{ eV}$ .

**Initial optimistic expectations of a transition to the controlled thermonuclear fusion process never materialized.**

**Technical difficulties of obtaining viable super-hot plasma and the damaging effects of the enormous neutron flux arising as a result of thermonuclear reactions are pushing this development to the more distant and uncertain future.**

**The term “cold fusion” describes a number of processes at relatively low temperature, leading to the generation of heat due to the fusion of two nuclei.**

**Under normal conditions, such processes are prevented by the Coulomb barrier, which precludes the convergence of nuclei.**



**Zeldovich, Ya.B., Gerstein, S.S. (1960). U. F. N., LXXI(4), 1960, 581.**

## **Consideration of piezo-fusion**



**Ya.B. Zeldovich**



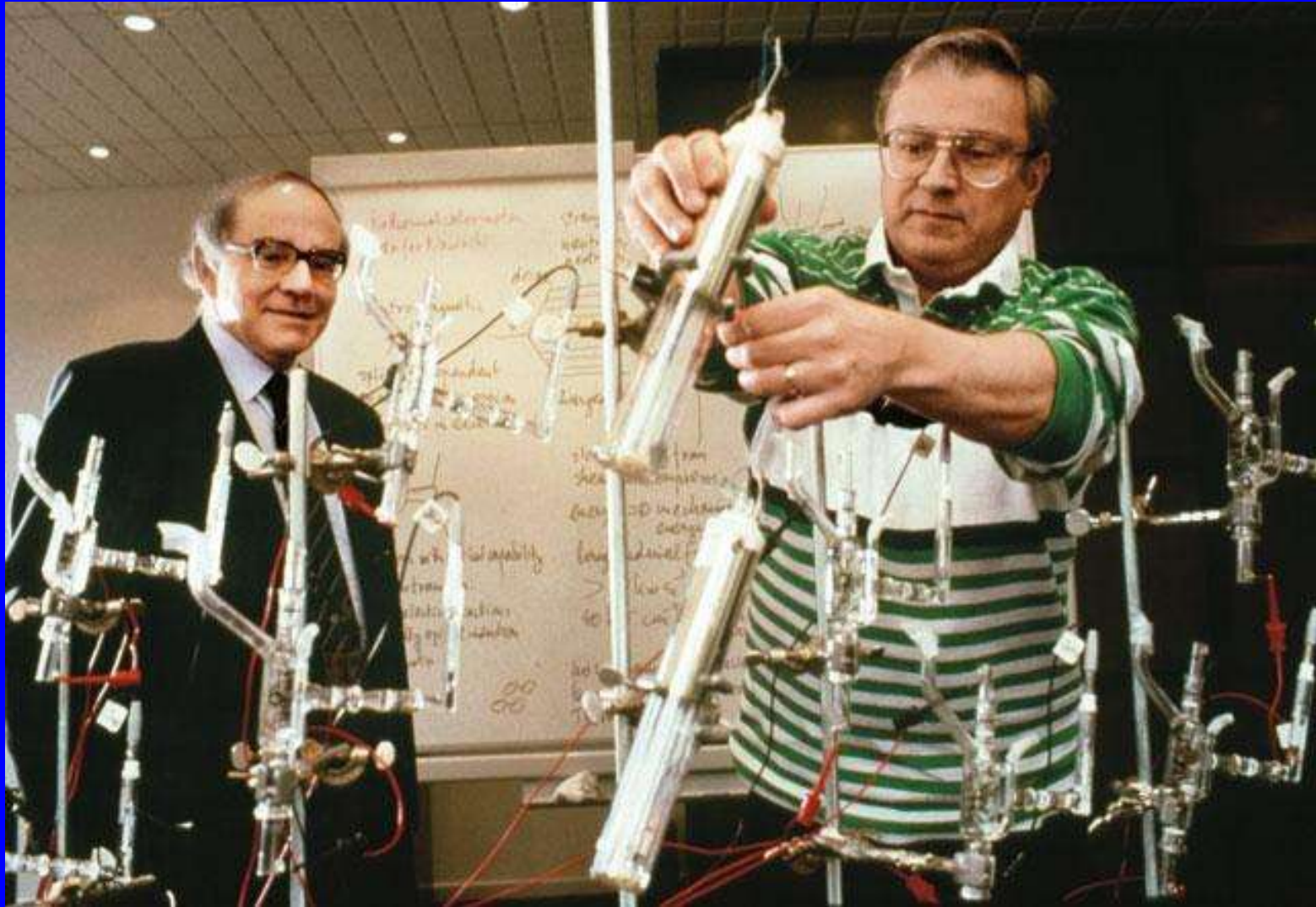
**S.S. Gerstein**

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

**The pressure needed to achieve the effect of piezo-fusion happens to be too high.**

**About 25 years ago Fleischmann and Pons performed experiments that demonstrated the possibility of “cold” DD fusion when nuclear reagents are implanted in metallic crystals.**

# Martin Fleischmann and Stanley Pons, 1989



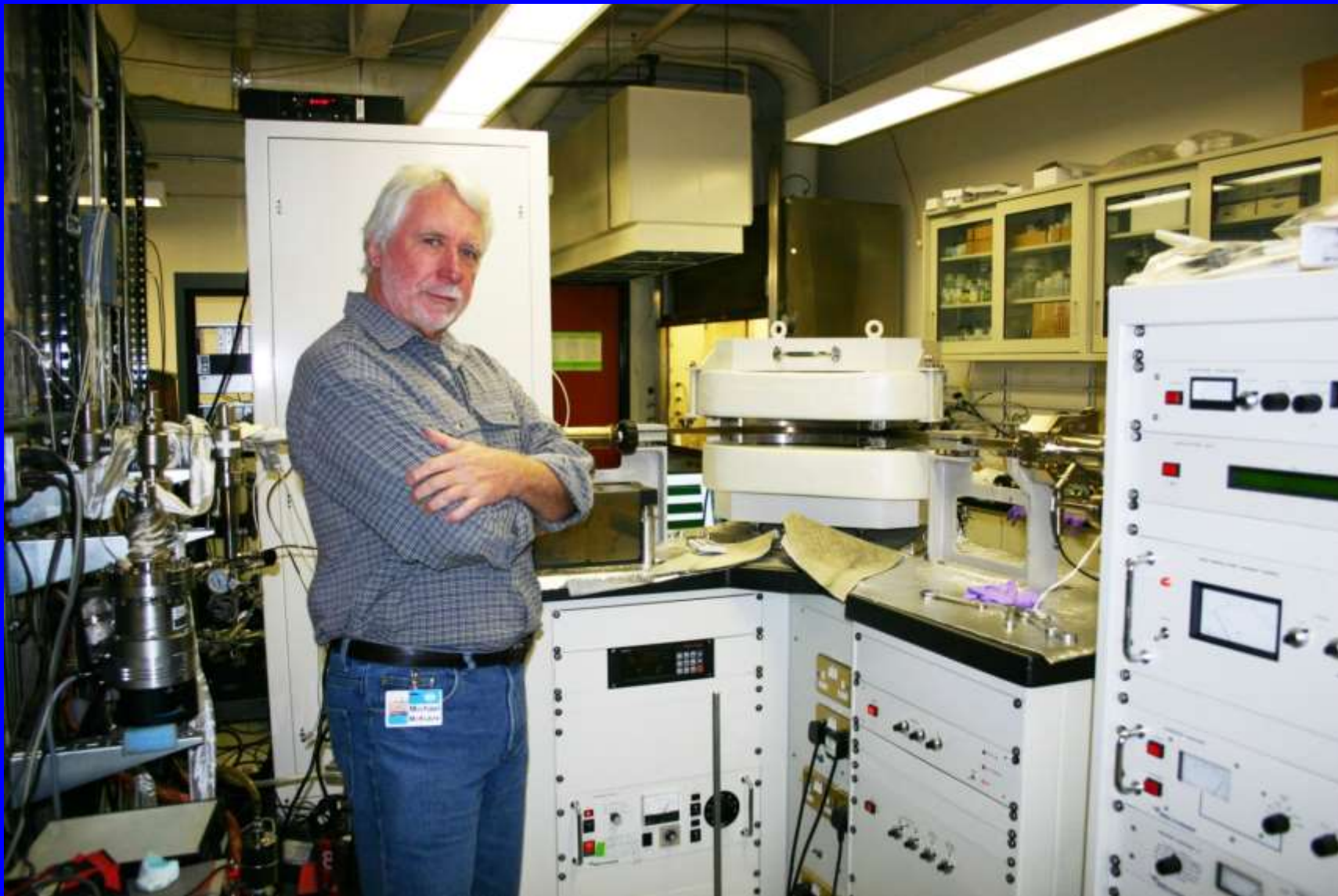
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**Quickly rejected by most scholars as irreproducible and not having a consistent theoretical interpretation, these experiments, however, gradually began to give consistent results.**

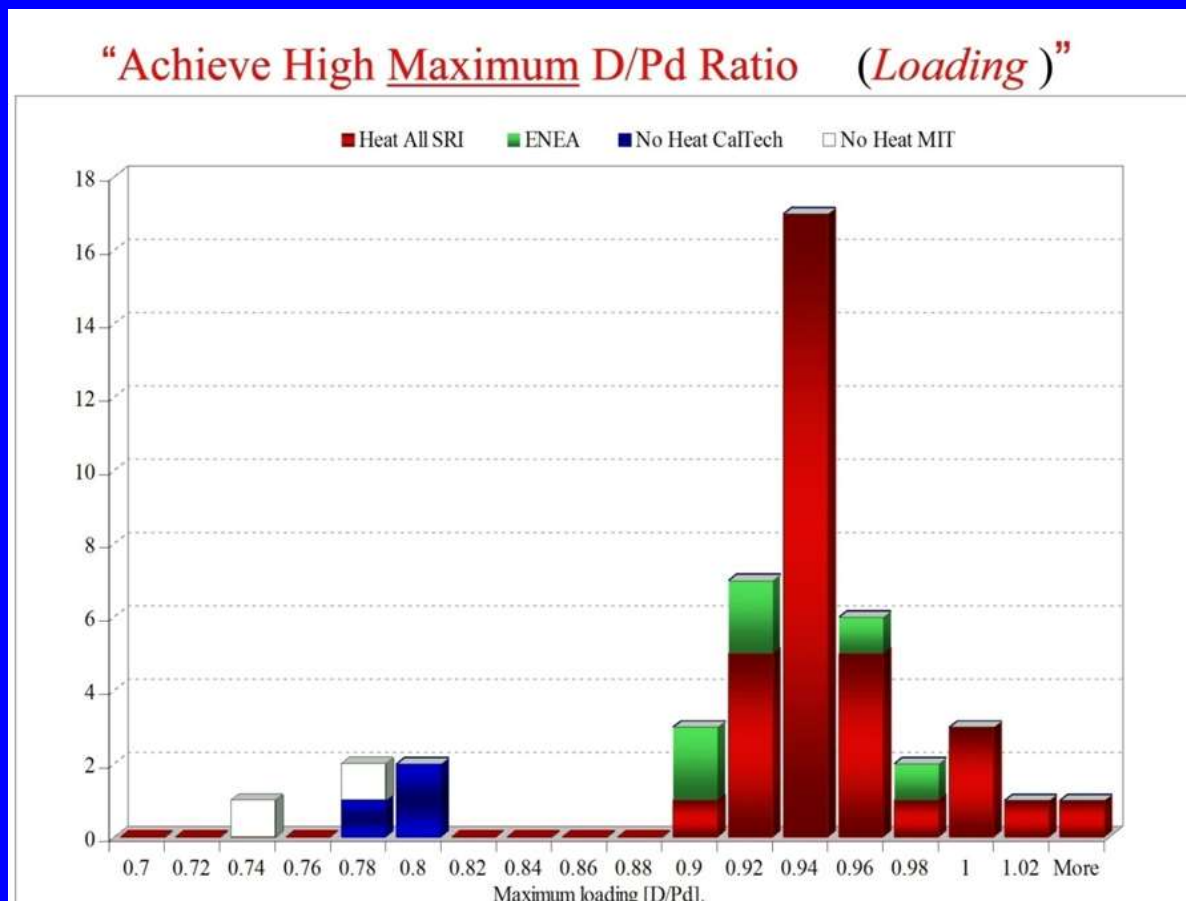
**Classic examples are the experiments made by Dr. McKubre and his colleagues at the Stanford Research Institute, International. The results of these experiments demonstrated a reliable heat of nonchemical origin, whereby the effect exceeded about 100 experimental errors.**

# Dr. McKubre in his laboratory.



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# The success of the experiment depends on the concentration of deuterium.

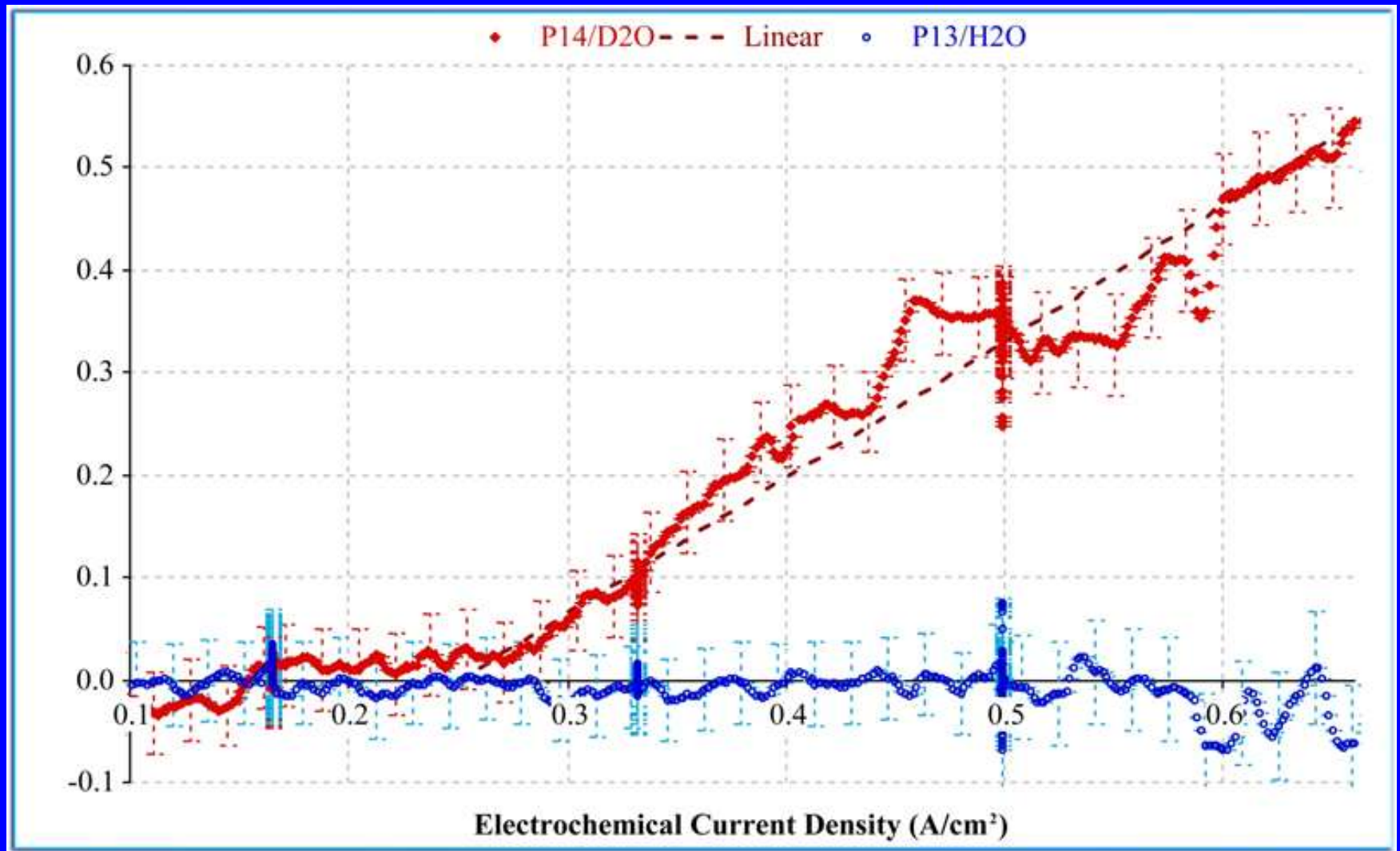


**Michael C.H. McKubre, Francis L. Tanzella, and Vittorio Violante, Journal of Condensed Matter Nuclear Science, Volume 8, May 2012, p. 187**

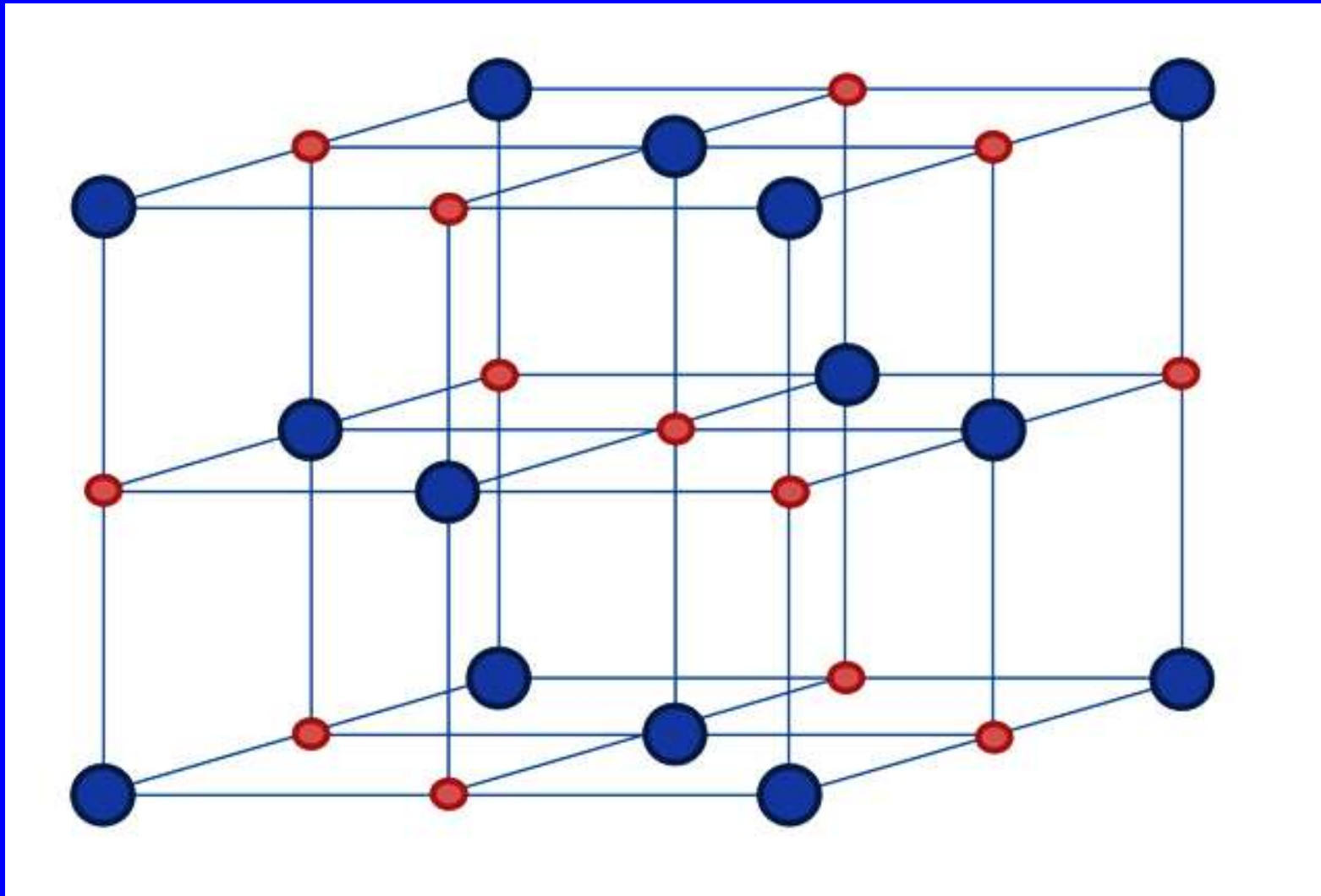
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# Excess heat in W, depending on the value of the electrochemical current, in the experiments of Dr. McKubre



# The fcc crystal structure. Small circles marked octahedral (the deepest) niches.



# 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 working groups in the US, Western Europe, Russia, Japan, and China.

During the last year, the first four patents were issued for cold fusion (US, Europe, China)

# History of cold fusion – the main participants



Martin Fleischmann (1927–  
2012)  $D + D$  in palladium  
1989



Michael McKubre  
 $D + D$  in palladium  
1992–present



Yoshiaki Arata  
 $D + D$  a palladium ( $ZrO_2$ )  
1998–2008

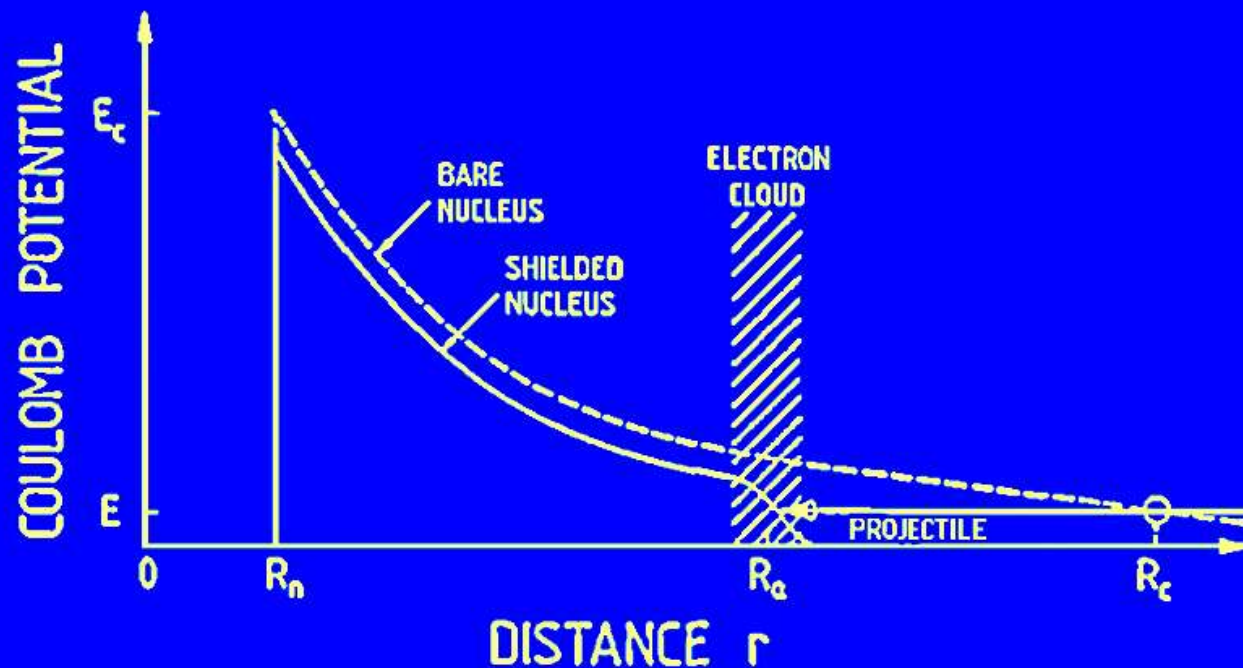
**Proof of concept of cold fusion suddenly came from  
experiments performed with accelerators.**

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

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

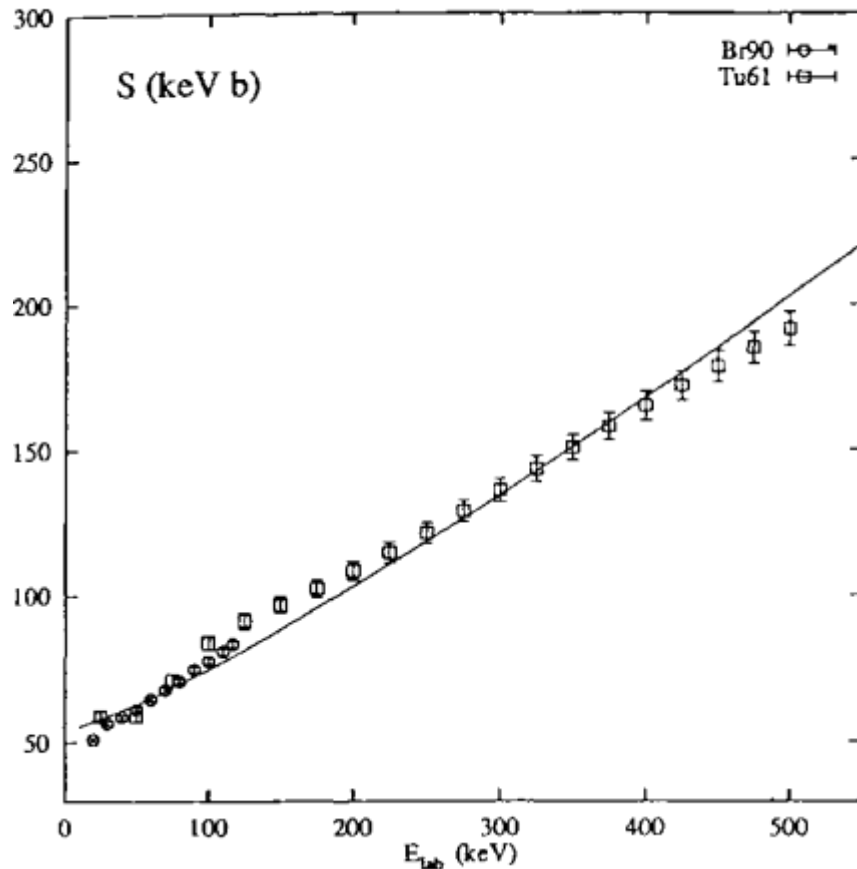


It should be noted that during irradiation of solid state with a beam of charged particles, incident particle captures an electron from the solid body and moves like an atom, if its velocity does not exceed the so-called Bohr velocity.

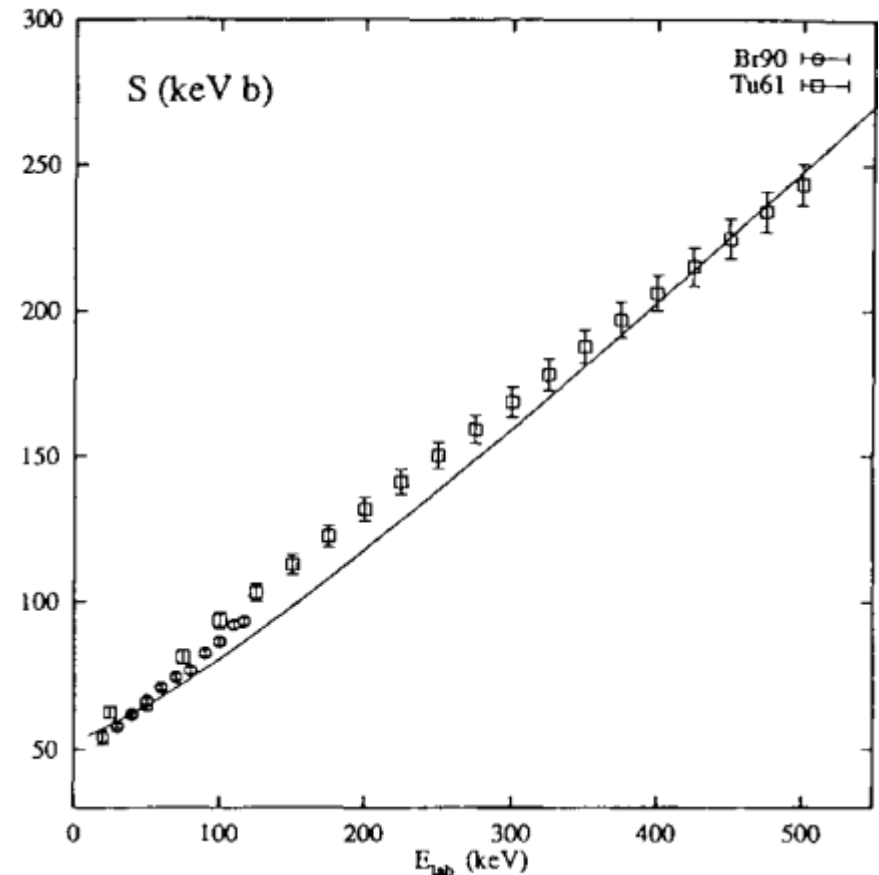
For deuterons this threshold energy is  $\sim 50$  keV. This interesting observation was made in the paper: *Y.A. Baranov, Yu. Martynenko, S.O. Tsepelevich, Yu.N. Yavlinsky, "Inelastic sputtering of solids by ions", Physics-Uspekhi, November 1988, Volume 156, no. 3, p. 477.*

**$S(E)$  – astrophysical factor for reactions  $D(d,p)^3H$  and  $D(d,n)^3He$ ,  
Lemaitre, S. and Paetz gen. Schieck, H., *Ann. Physik 2* (1993), 503.**

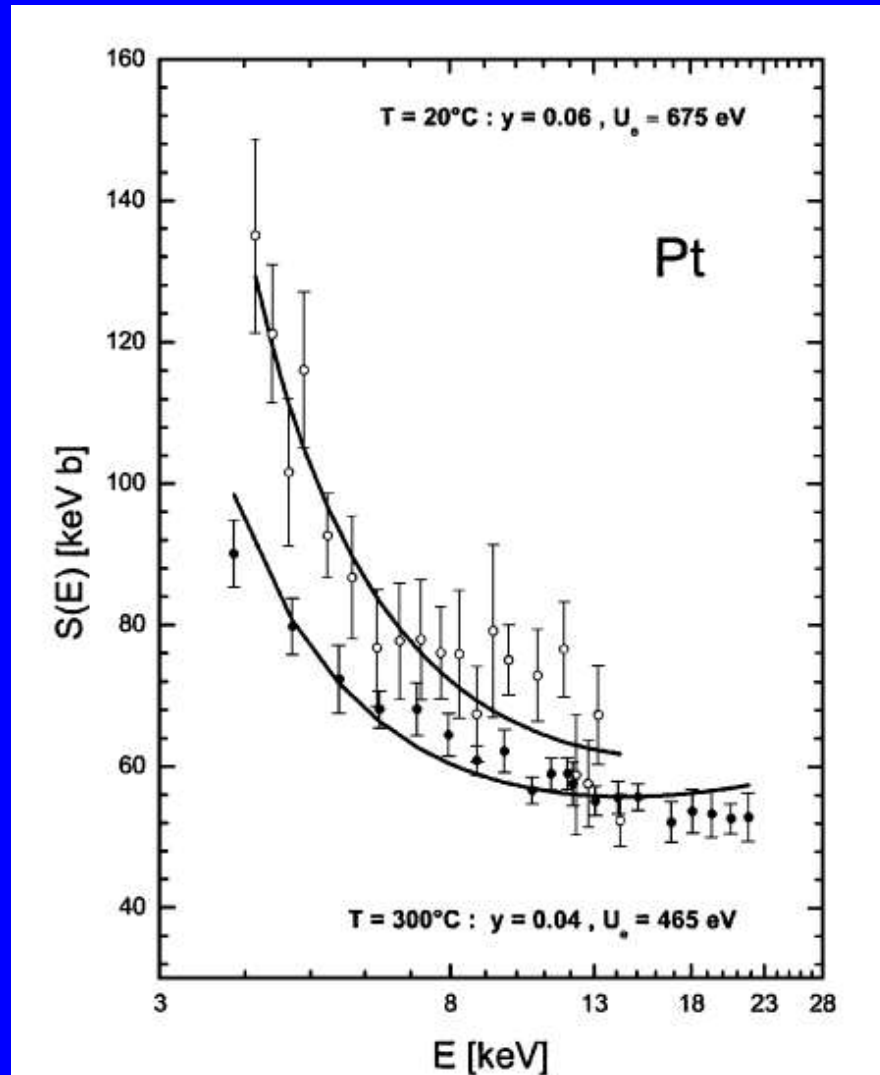
$D(d,p)^3H$



$D(d,n)^3He$

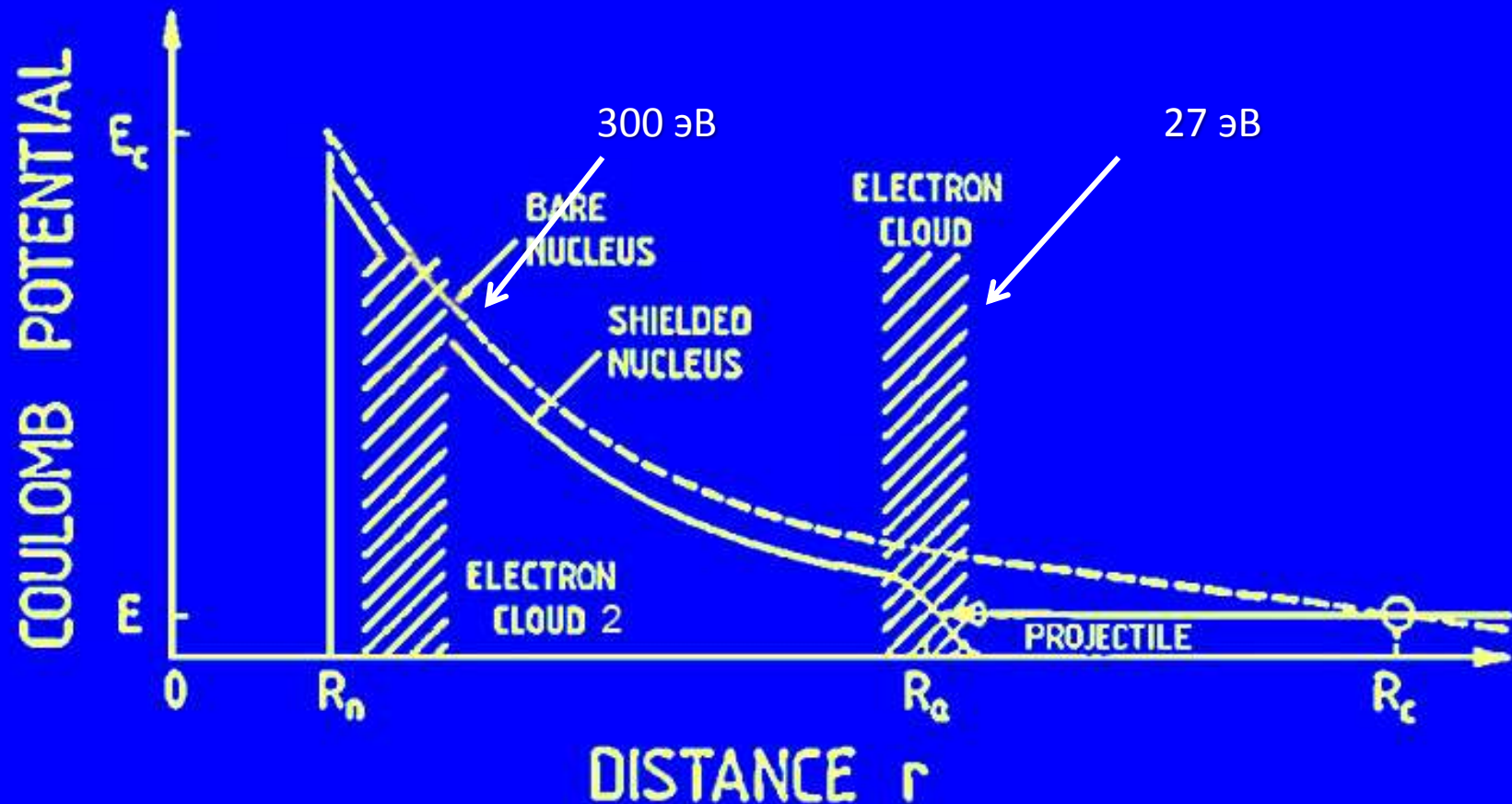


C. Rolfs et al., J. Phys. G: Nucl. Part. Phys. 31, 2005, pp 1141–1149. (Gran Sasso).  
 $S(E)$  for DD-fusion, the target is implanted in Platinum,  $U_e = 675$  eV.





**Screening potential defines the distance to which the atoms are not experiencing Coulomb repulsion.**



The accelerator experiments have shown that the magnitude of the screening potential of the impurity atoms in metallic crystals can reach *300 eV and even more*. This means that in the DD-reaction occurring in the medium of the metal crystal, the implanted deuterium atoms are excited and no longer spherical. They have more sophisticated *electronic orbitals*, and they are oriented relative to each other in a certain crystallographic manner. *In this case, the nuclei of these atoms can approach each other at the distance substantially less than for a nominal size of the atom without Coulomb repulsion.*

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

**The main secret of cold fusion process—overcoming the Coulomb barrier—finally happened to be surprisingly simple. It was first noted by Prof. Bressani in 1998 at ICCF-7 conference on the basis of a series of Japanese accelerator experiments being performed since 1995.**

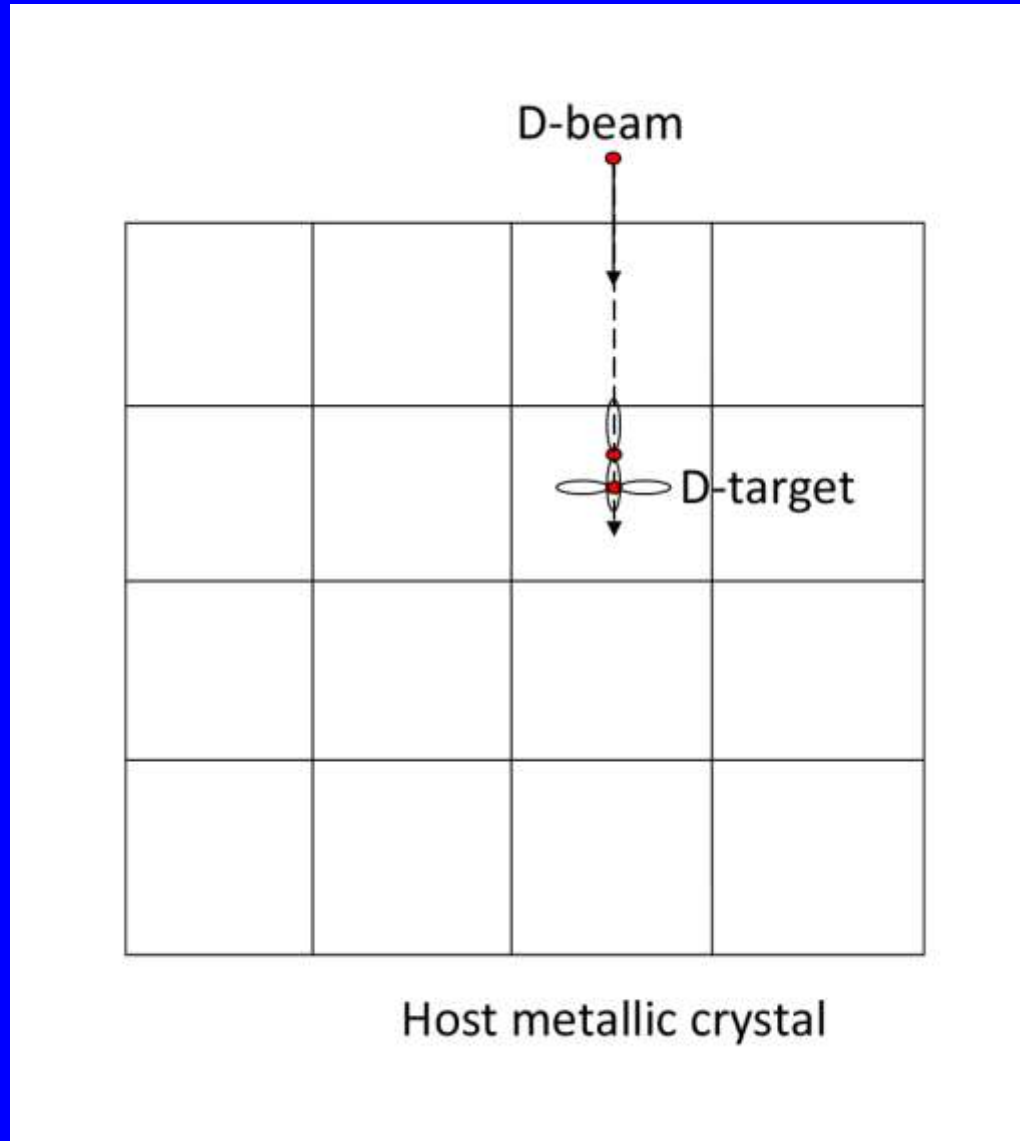
**Unfortunately, the cold fusion community at that time did not follow the call of Prof. Bressani.**

Target deuterium atoms implanted into metals *are no longer in 1s-state*. The free electron cloud in a metal causes the electron of an implanted atom *to take up the excited p-state*. The magnitude of the screening potential of 300 eV and above in experiments on DD-fusion accelerator experiments indicates that the incident deuterium atoms in the conducting crystal are *also moving in p-state*.

These processes allow the two deuterium nuclei to get close without the Coulomb repulsion in the potential niche of the crystal cell at a very close distance.



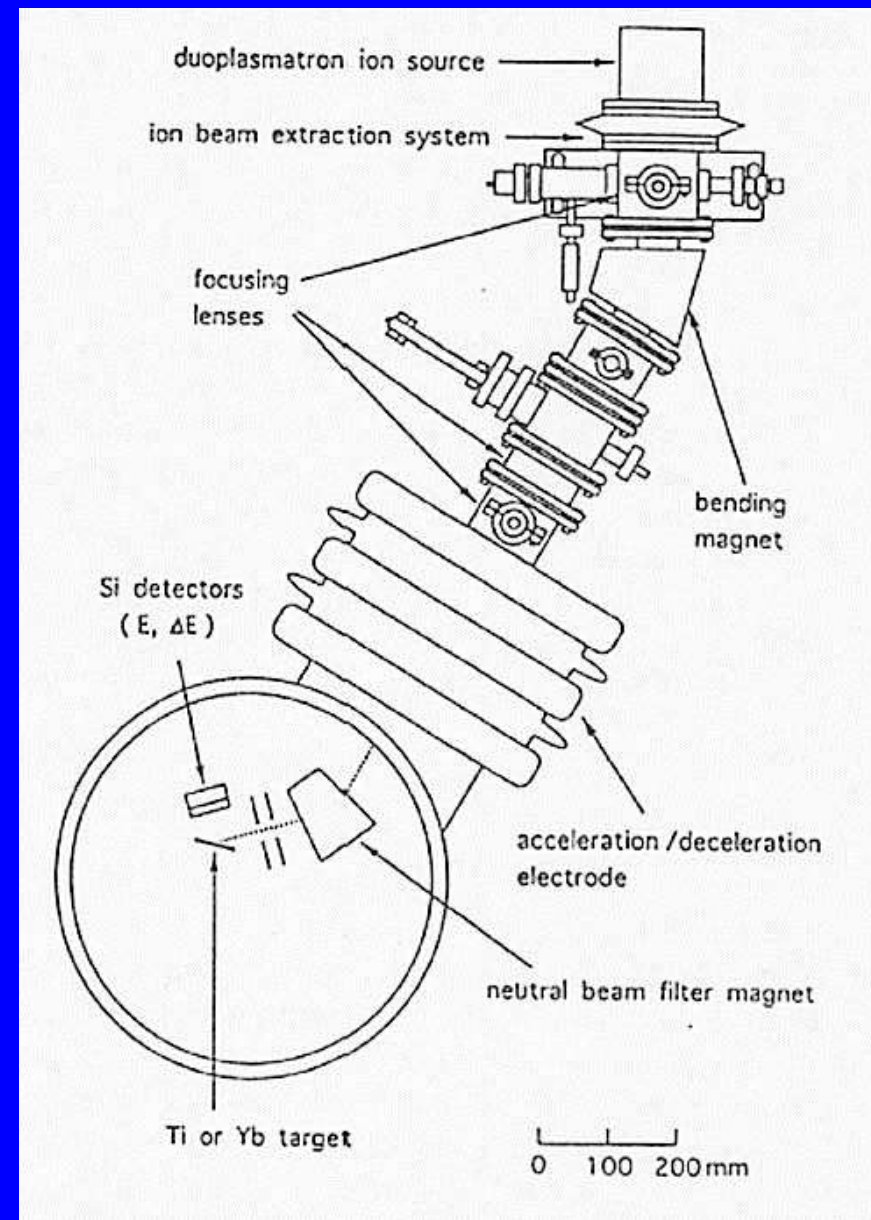
# Accelerator experiments



One of the first DD experiments on accelerators.

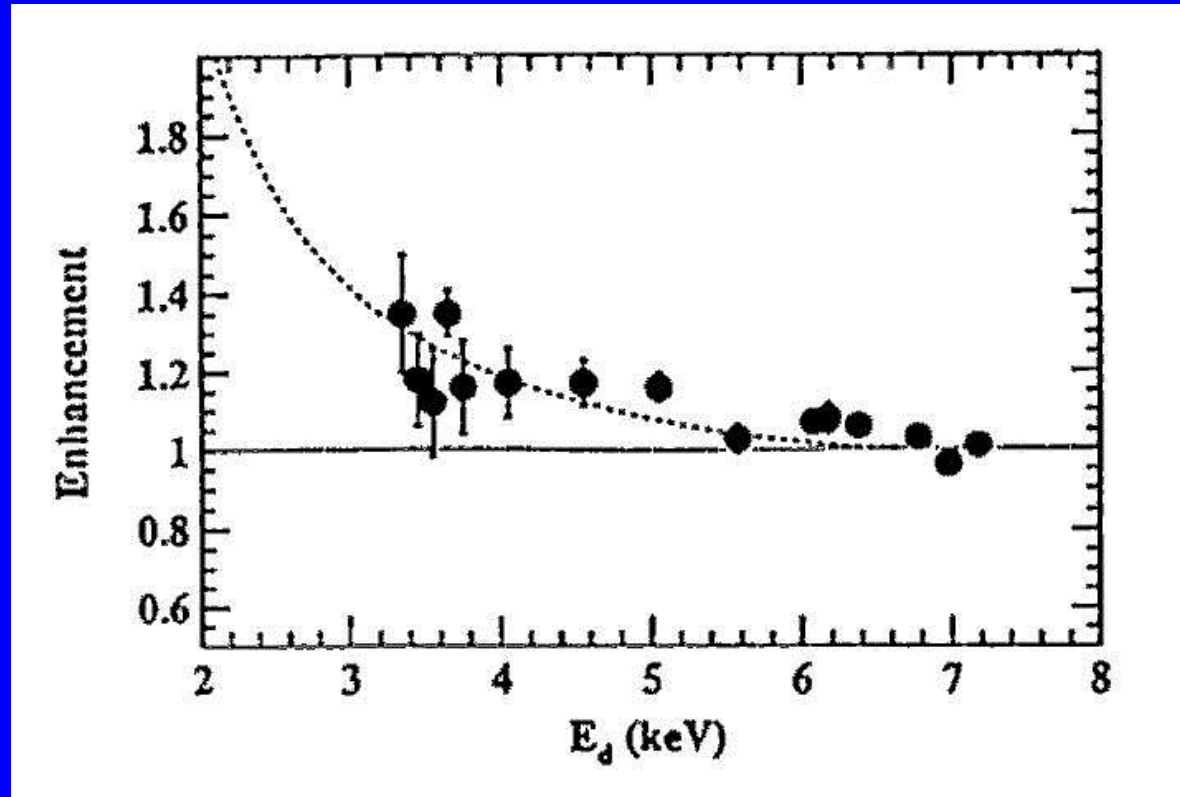
Yuki, H., Satoh, T., Ohtsuki, T., Yorita, T., Aoki, Y., Yamazaki, H., Kasagi, J. (1996).

ICCF-6, 13–18 October, Japan.



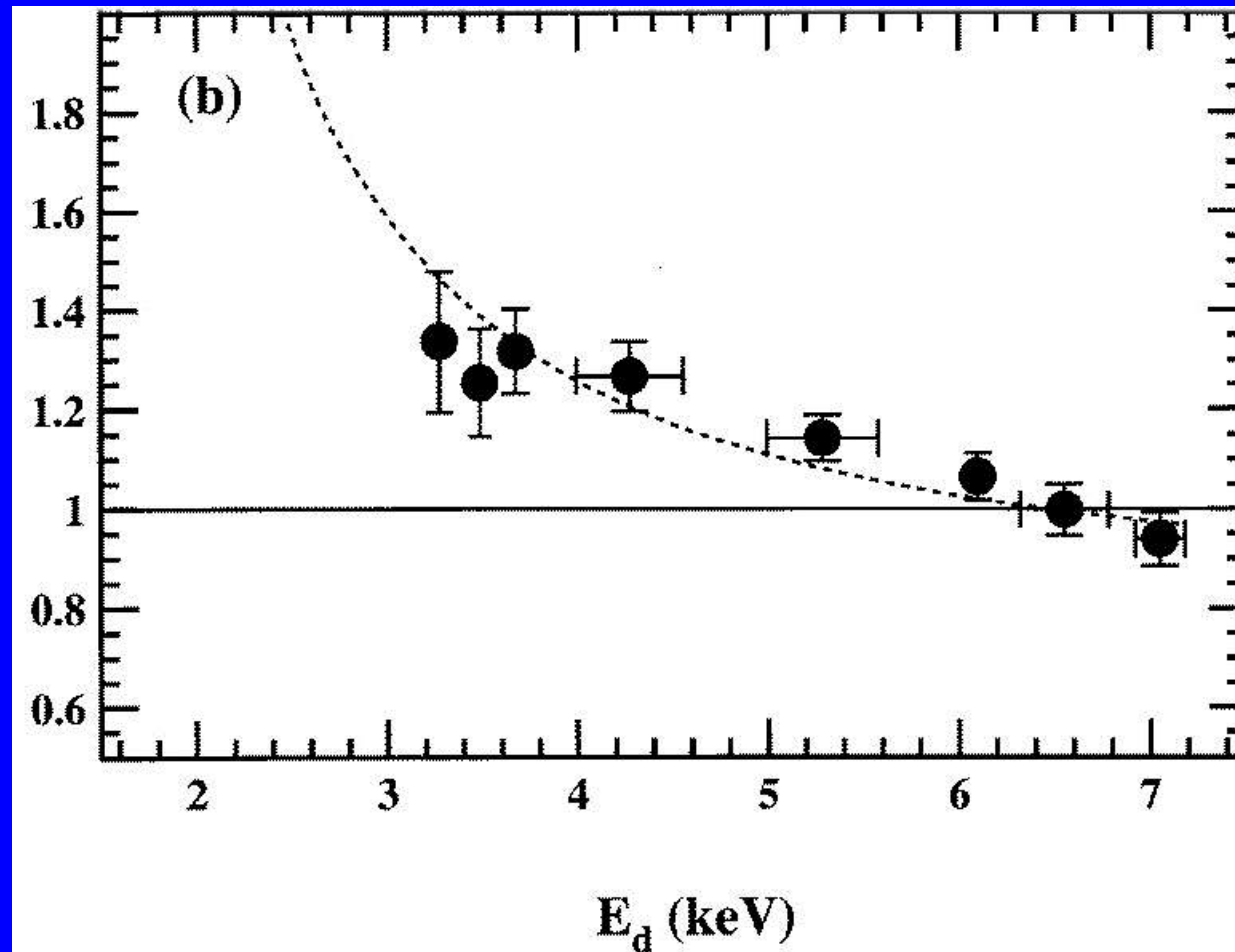
Yuki, H., Satoh, T., Ohtsuki, T., Yorita, T., Aoki, Y., Yamazaki, H.,  
Kasagi, J. (1996). ICCF-6, 13–18 October, Japan.

This is one of the early works on electron screening in metals.



Ratio of the yield of the reaction  $D(d, p)T$  in the thick target to the estimated yield value in ytterbium (Yb). The dashed line shows the value of electron screening potential of 60 eV.

Yuki, H., Satoh, T., Ohtsuki, T., Yorita, T., Aoki, Y., Yamazaki, H., Kasagi, J. (1997). Phys. G: Nucl. Part. Phys., 23, 1,459–1,464. Increasing cross-section in ytterbium (rare earth element with a metallic conductivity)—electron screening potential reaches  $81 \pm 10$  eV.





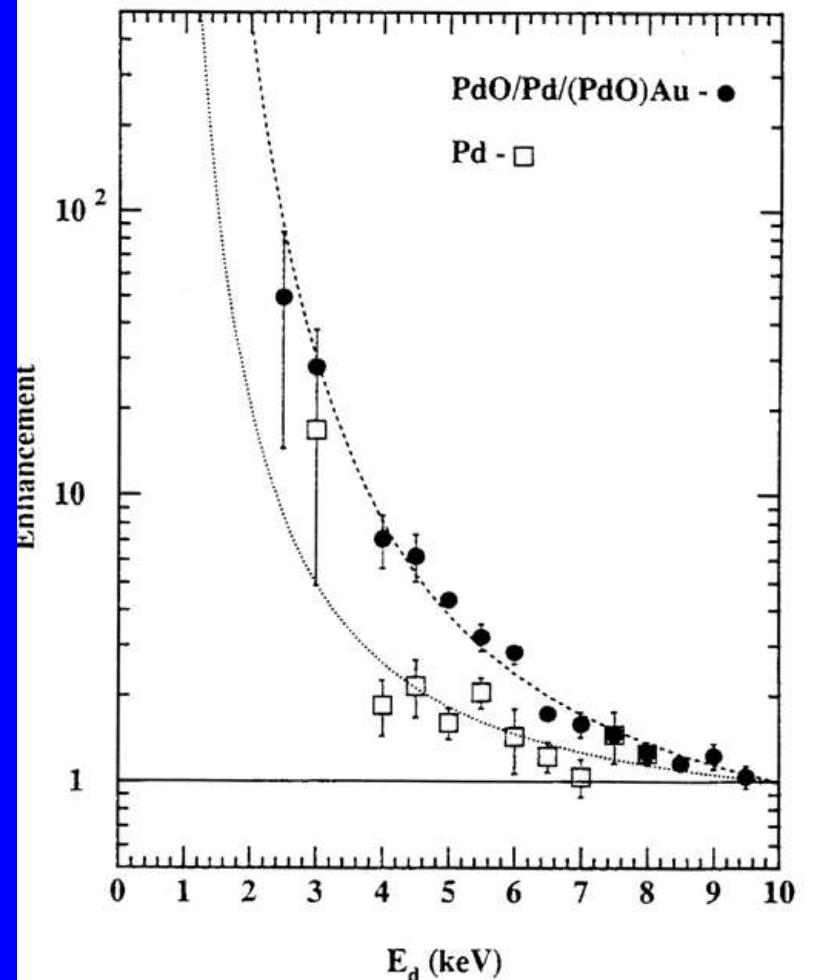
The Seventh International Conference on Cold Fusion. 1998. Vancouver, Canada:; ENECO, Inc., Salt Lake City, UT. p. 180.

“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



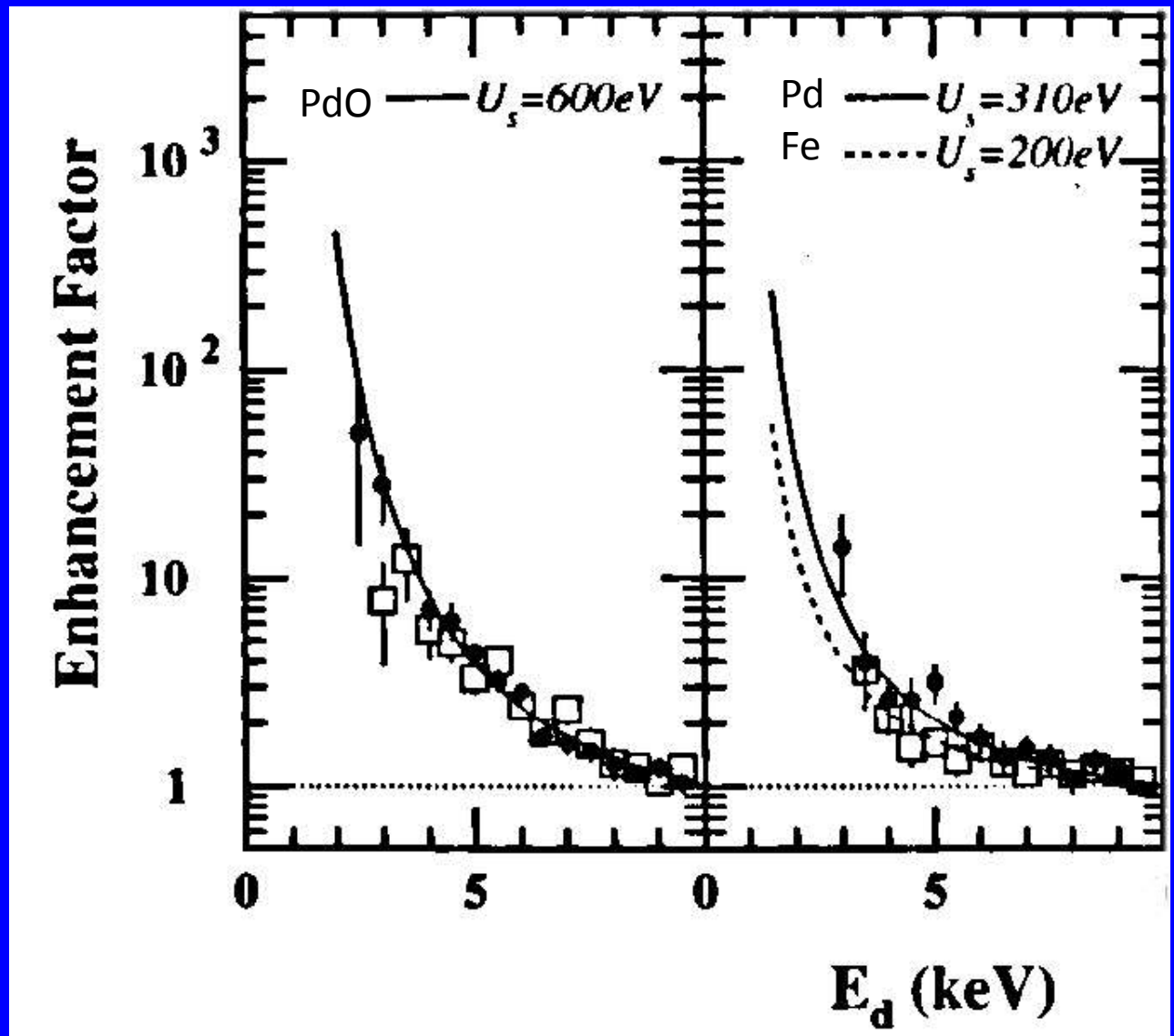
The dotted and dashed curves are those with the screening potential  $U_e = 250$  and  $600$  eV, respectively.

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

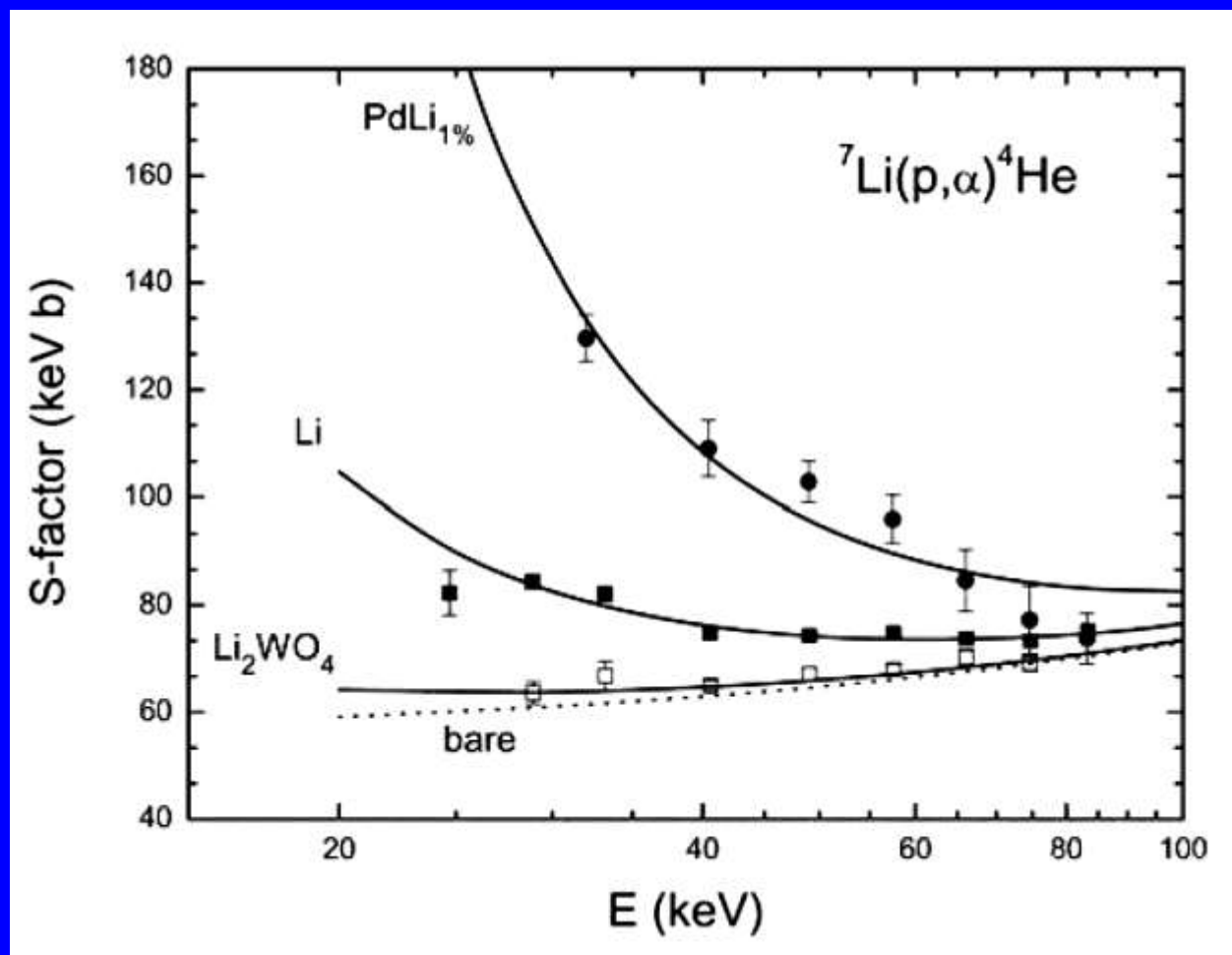
Jirohta Kasagi, Hideyuki Yuki, Taiji Baba, Takashi Noda, Tsutomu Ohtsuki and Andrey G. Lipson

“Strongly Enhanced DD Fusion Reaction in Metals Observed for keV  $D^+$  Bombardment”

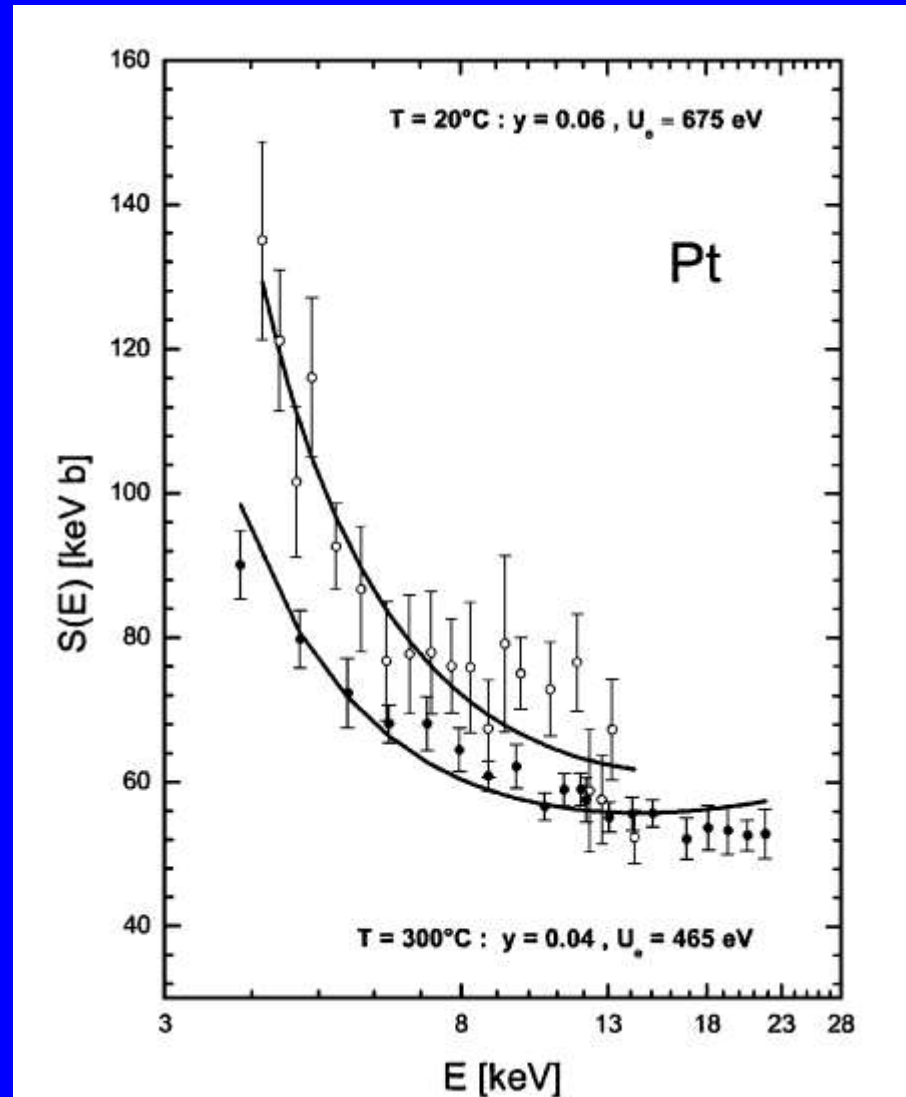
Journal of the Physical Society of Japan, Vol. 71, No. 12, December, 2002, pp. 2881-2885.



Rolfs, C. (2006). Nuclear Physics News, 16(2), 9. Normalized astrophysical factor  $S(E)$  for the synthesis of  $p+{}^7\text{Li}$  when a target  ${}^7\text{Li}$  implanted into Palladium.

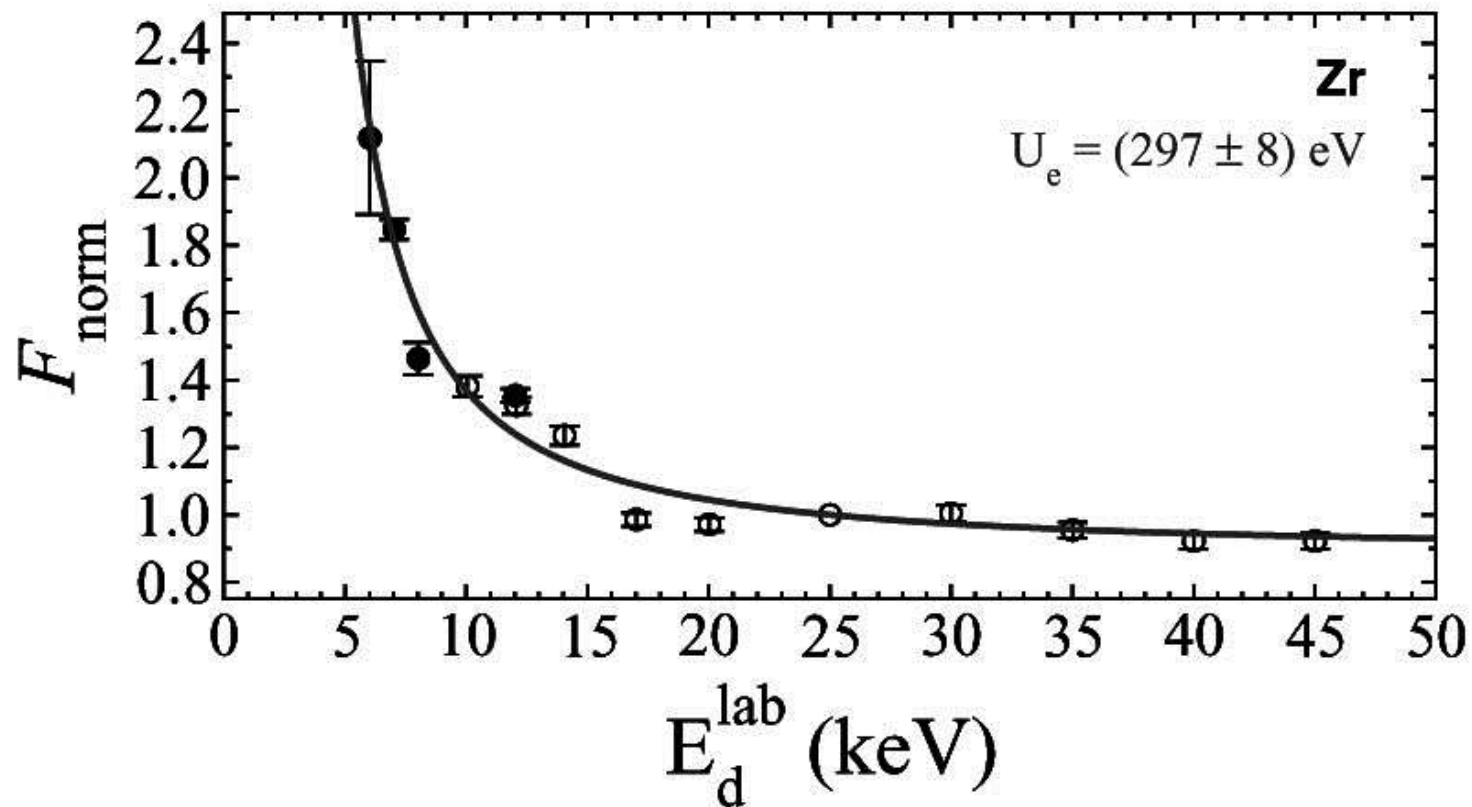


Rolfs, C. et al. (2005). J. Phys. G: Nucl. Part. Phys., 31, 1,141–1,149. (Gran Sasso).  $S(E)$  for DD-fusion, targets are implanted in Platinum,  $U_e = 675$  eV.



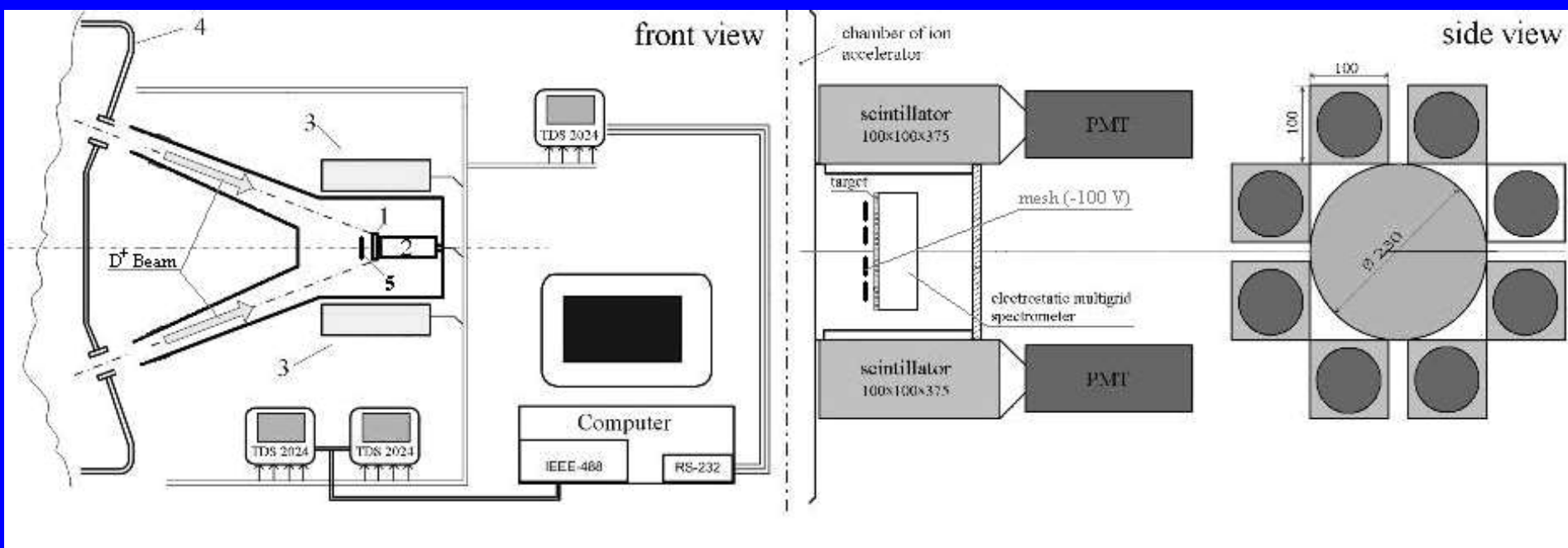


Czerski, K. et al., (2008). Physical Review C., 78, 015803, (Berlin).  
Normalized astrophysical factor  $S(E)$  for DD-fusion, when the target is implanted in zirconium. Screening potential is about 10 times greater than for the free atoms of deuterium.



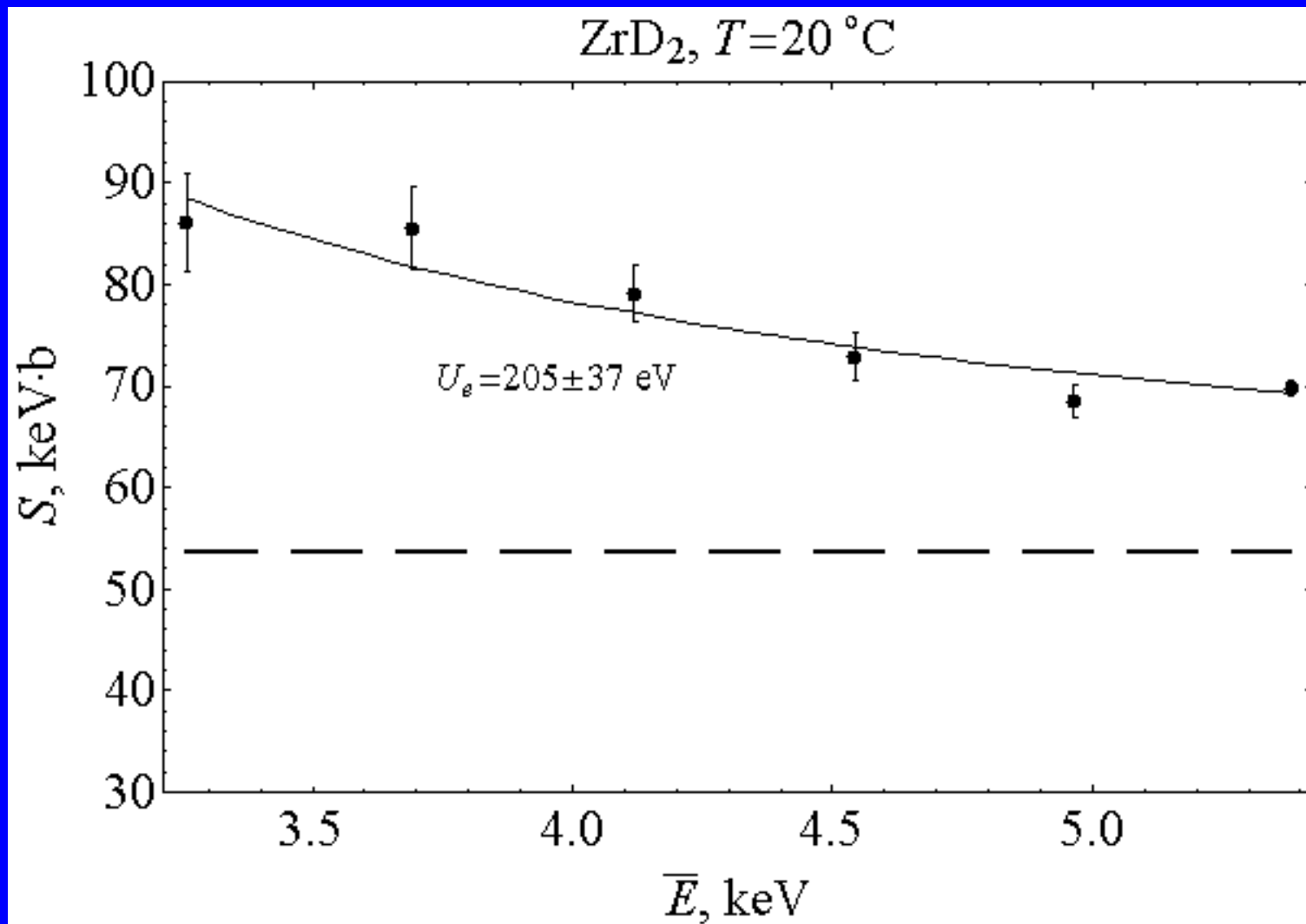
V. M. Bystritsky, Vit. M. Bystritskii, G. N. Dudkin, M. Filipowicz, S. Gazi, J. Huran, A. P. Kobzev, G. A. Mesyats, B. A. Nechaev, V. N. Padalko, S. S. Parzhitskii, F. M. Pen'kov, A. V. Philippov, V. L. Kaminskii, Yu. Zh. Tuleushev, J. Wozniak et al. (2012).

National Scientific Research—Tomsk Polytechnical University, Russia, Nuclear Physics, A 889, 93–104.

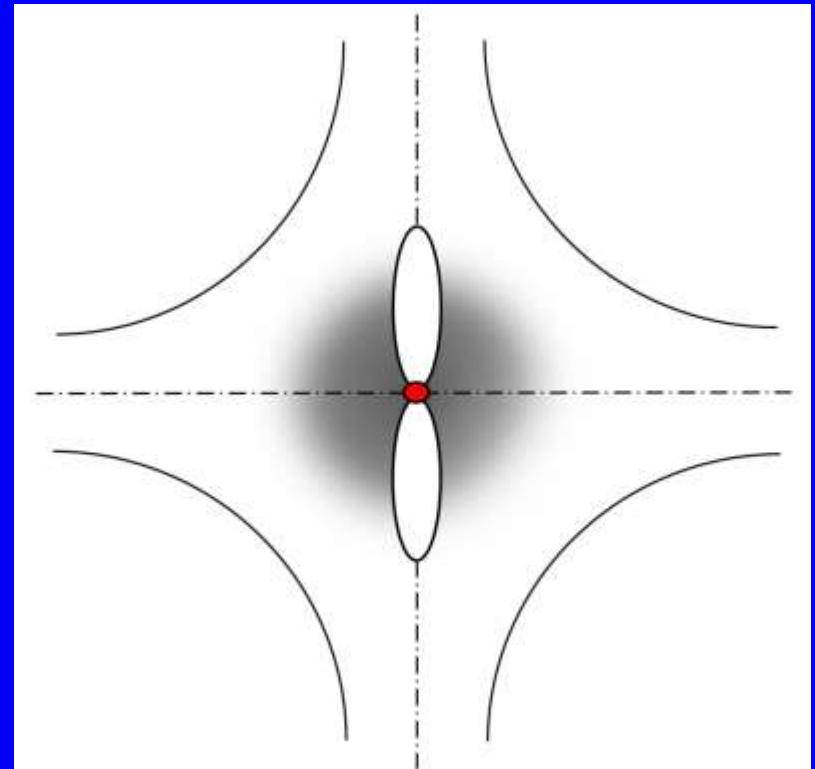
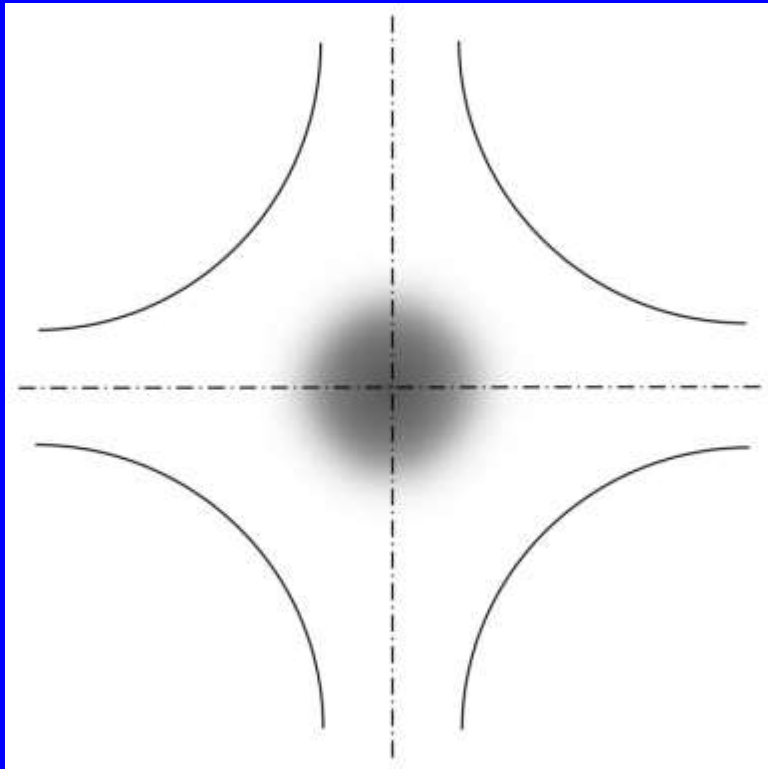


Bystritsky, V. M.  
et al., National  
Scientific  
Research—  
Tomsk  
Polytechnical  
University,  
Russia.

Nuclear Physics,  
A 889 (2012)  
93–104.



**Crystal cell of conductor. The simple cubic structure is used as a didactic example. The shaded area shows the location of free electrons. Free electrons of conducting crystal are unwilling to vacate their positions completely, and the deuterium atom is transferred from  $1s$ -state to  $2p$ -state or higher.**

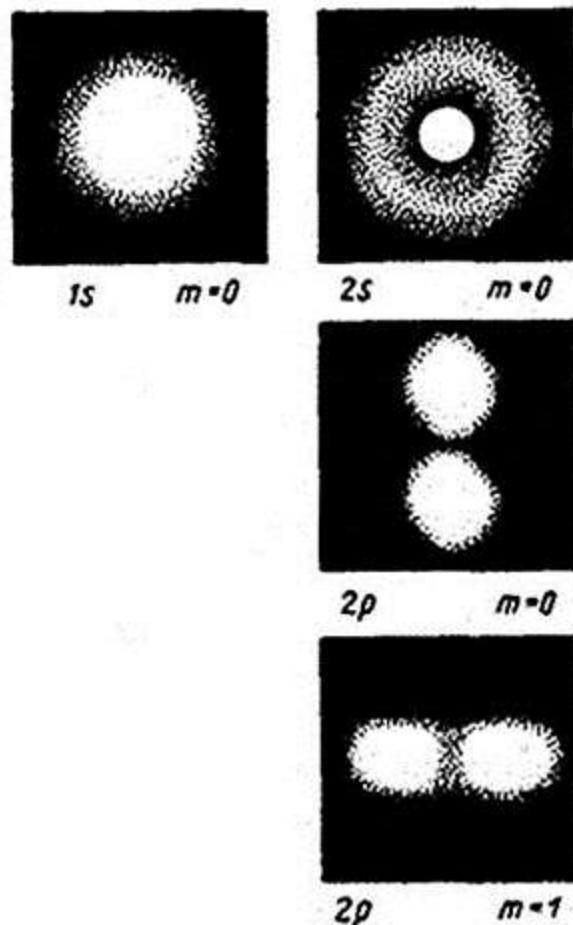




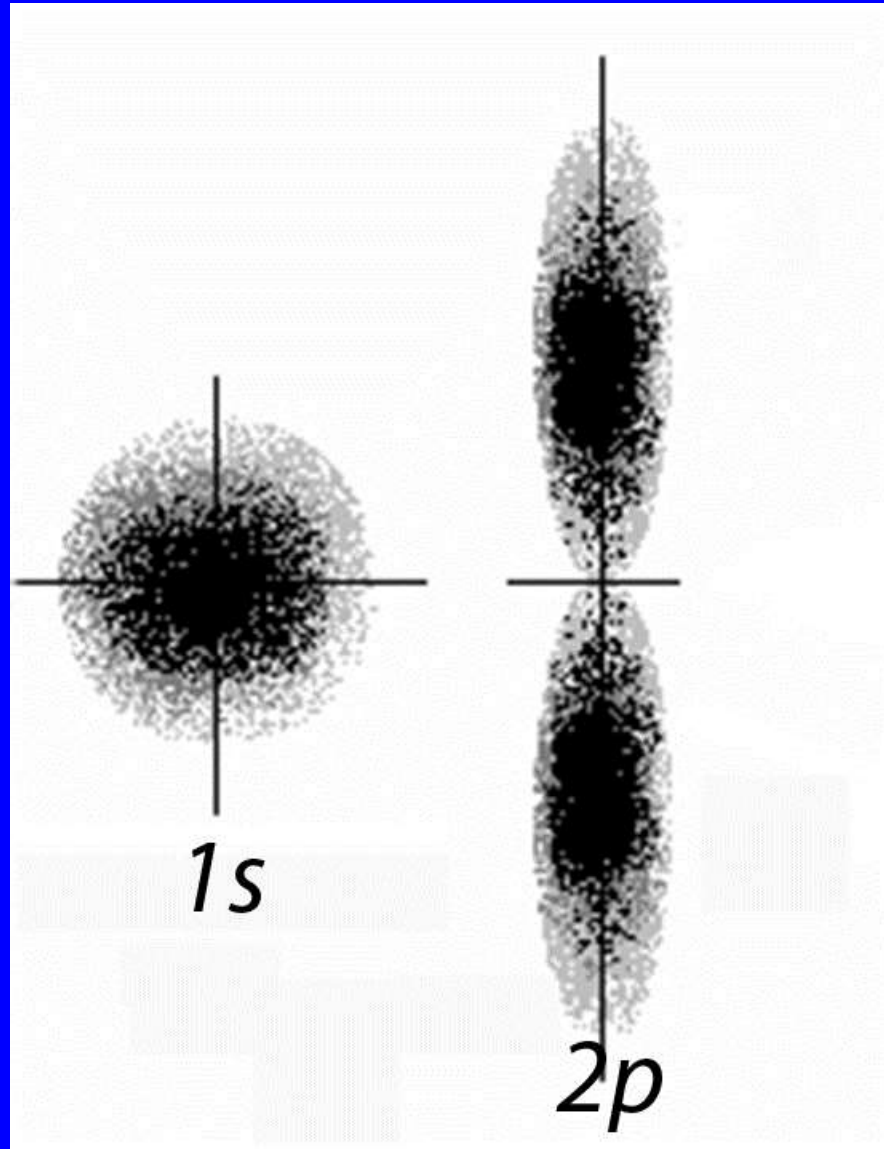
Thus, the convergence distance of two deuterium nuclei of impurity caught in the same crystalline niche of metal is at least an order of magnitude smaller than the size of the free atom of deuterium.

Although complete interpretation of this phenomenon is still lacking, many accelerator experiments leave no doubt for its existence. Coulomb barrier permeability in such conditions during the cold DD-fusion is *very strongly increased* as compared to the permeability of the barrier in the case of the free molecule of deuterium.

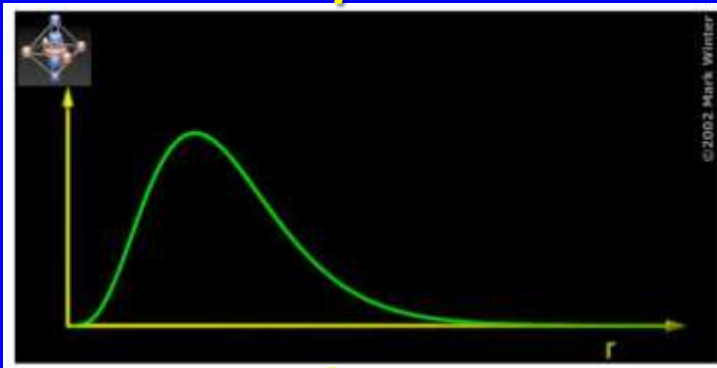
# Rydberg mechanism for the hydrogen atom. Electron orbital in $2p$ -state is no longer circular.



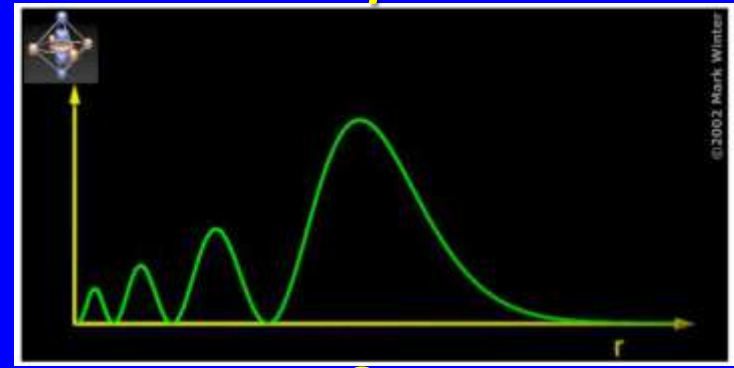
# Orbitals of the hydrogen atom



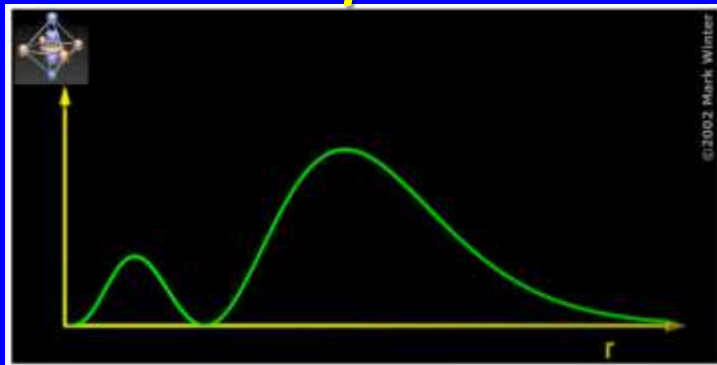
**2p**



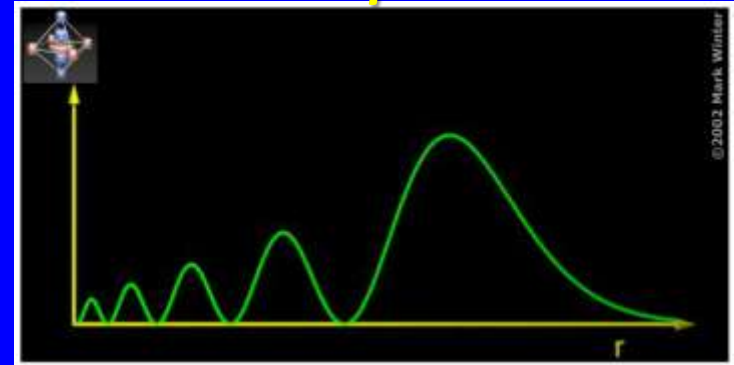
**5p**



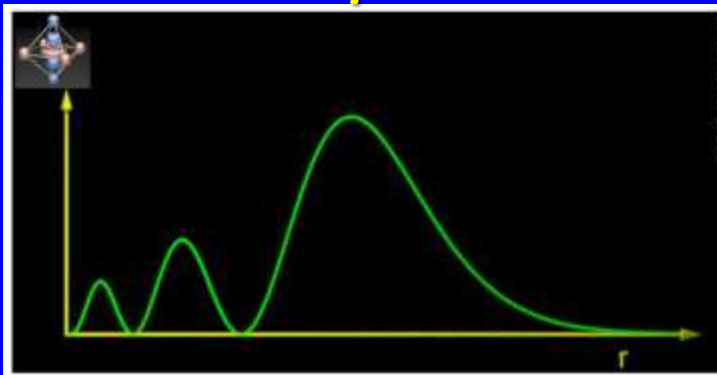
**3p**



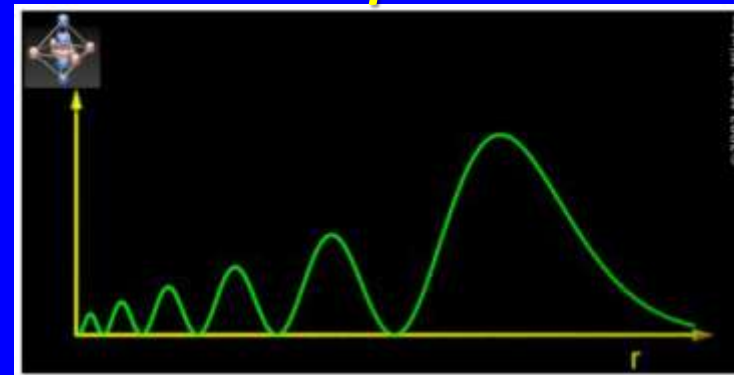
**6p**



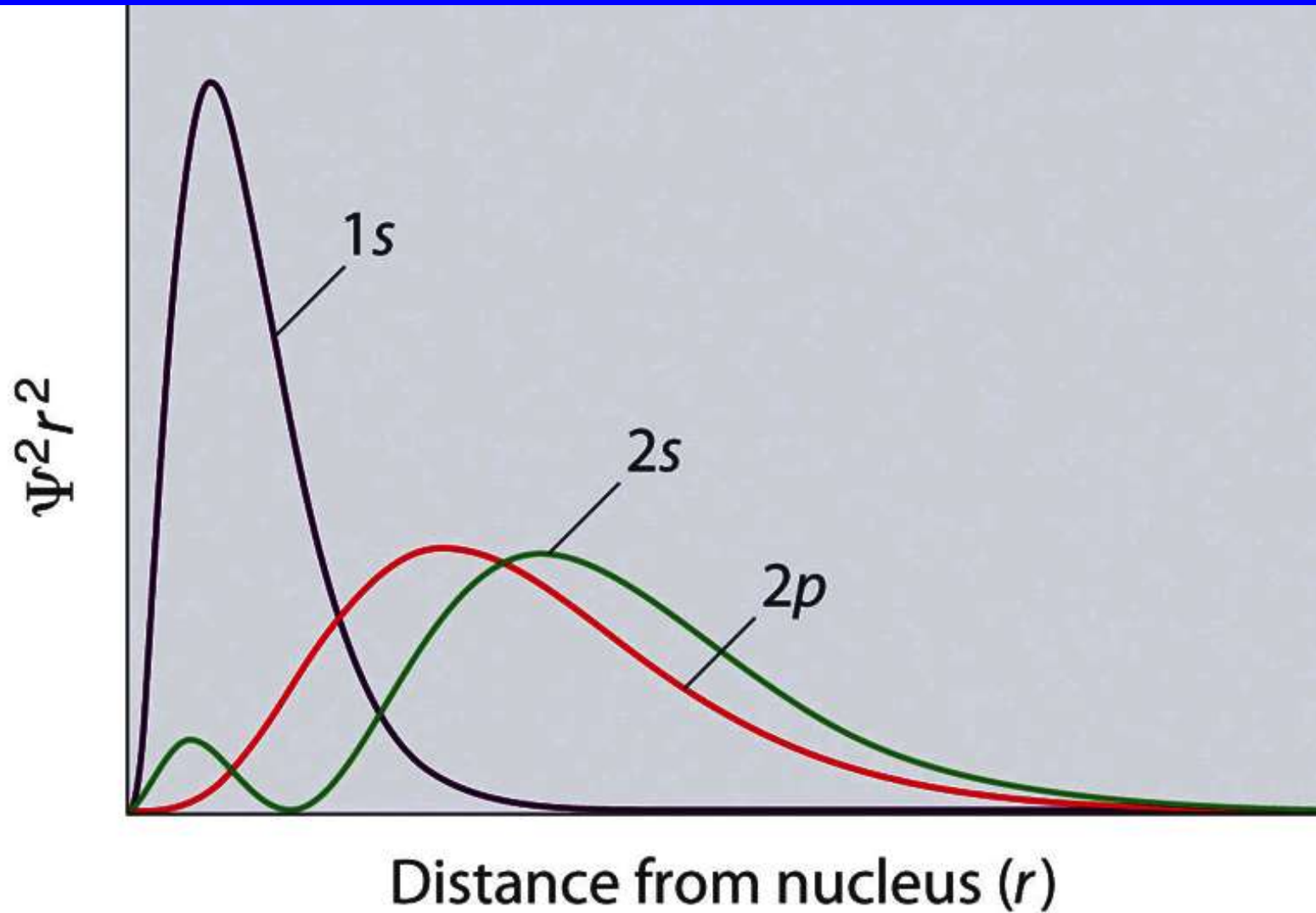
**4p**



**7p**



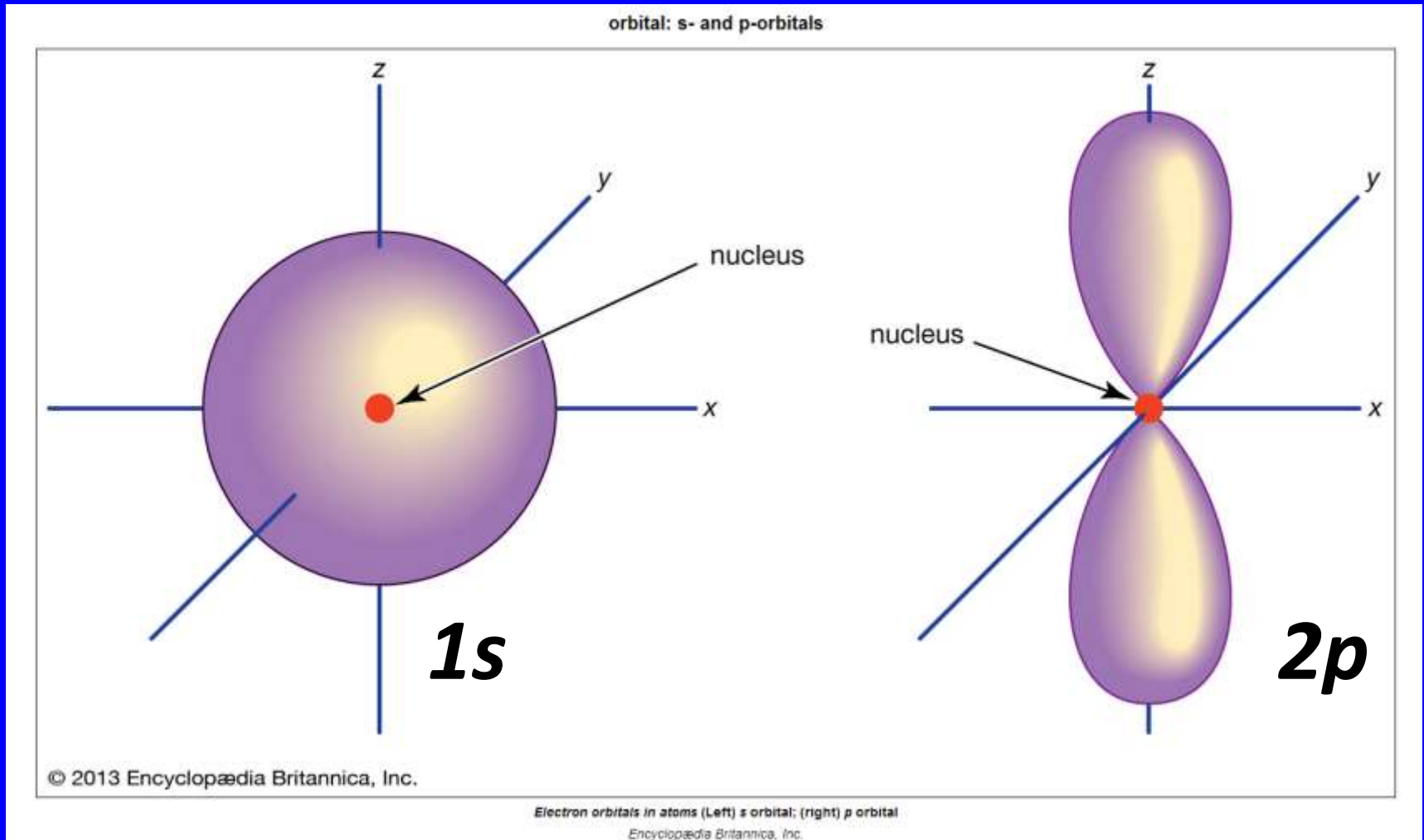
# ***1s, 2s and 2p orbitals of hydrogen atoms***



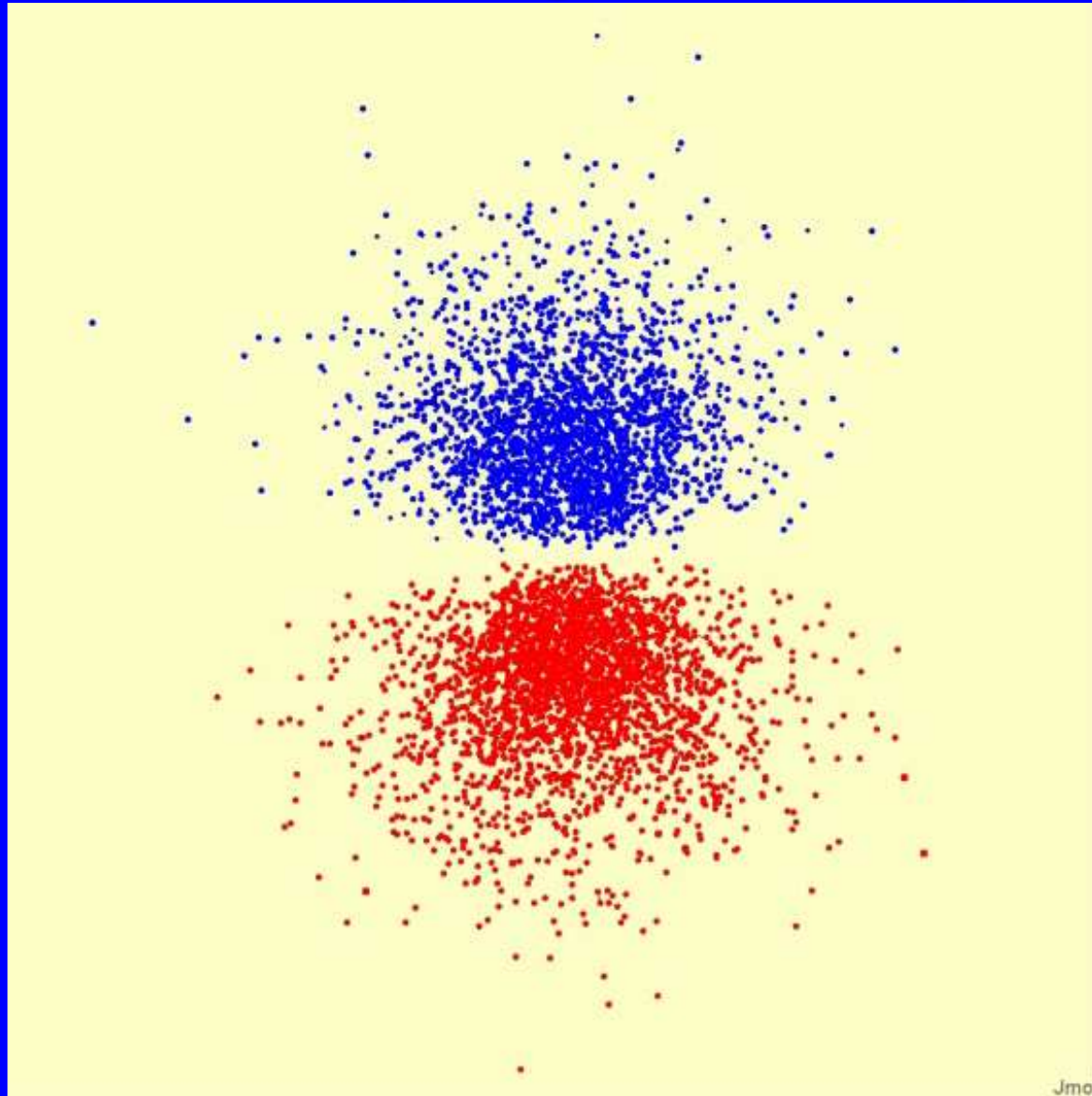


# Orbitals of the hydrogen atom.

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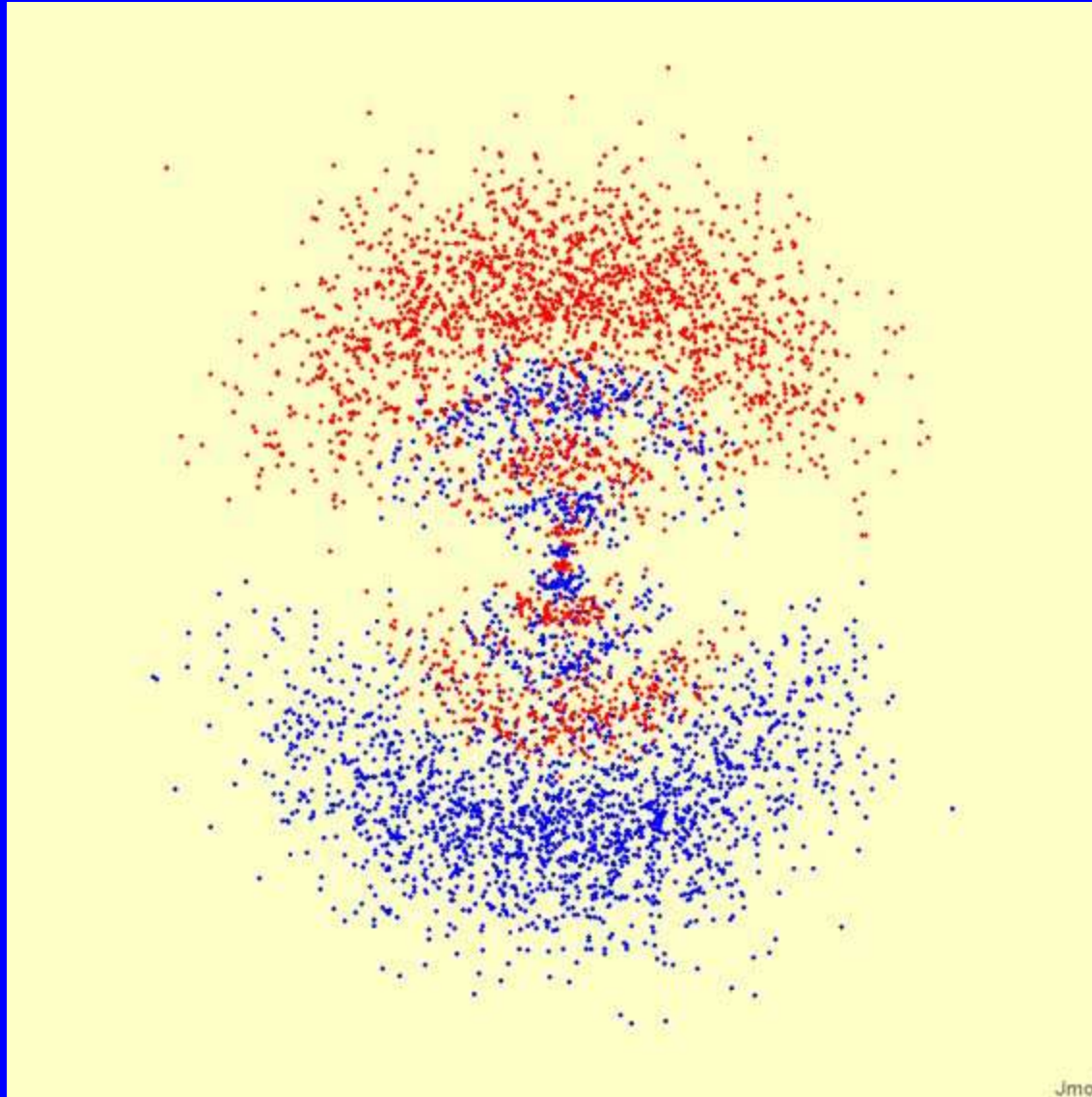


# **$2p$ orbital of the hydrogen atom by Dr. Winter**



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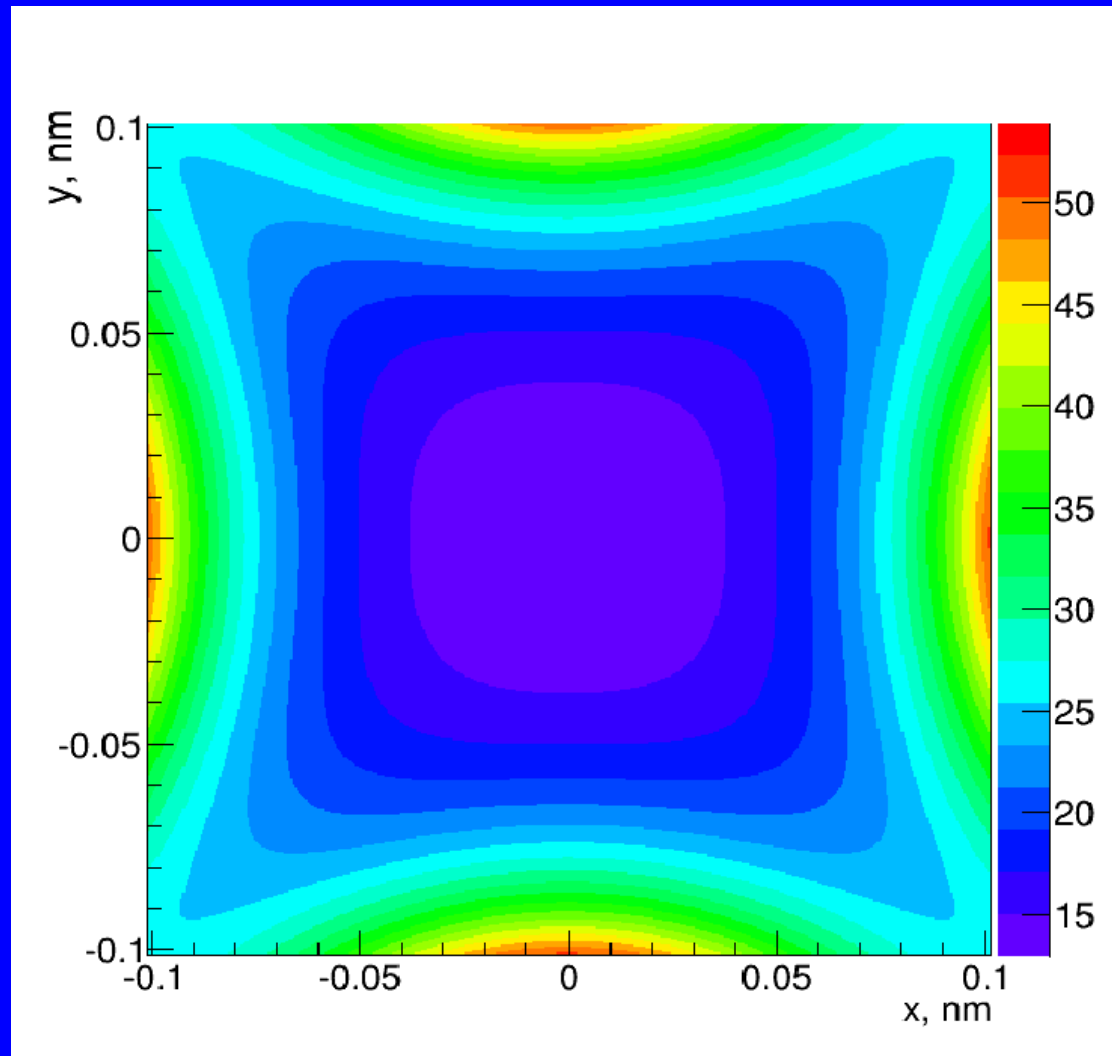
# 7p orbital of the hydrogen atom by Dr. Winter



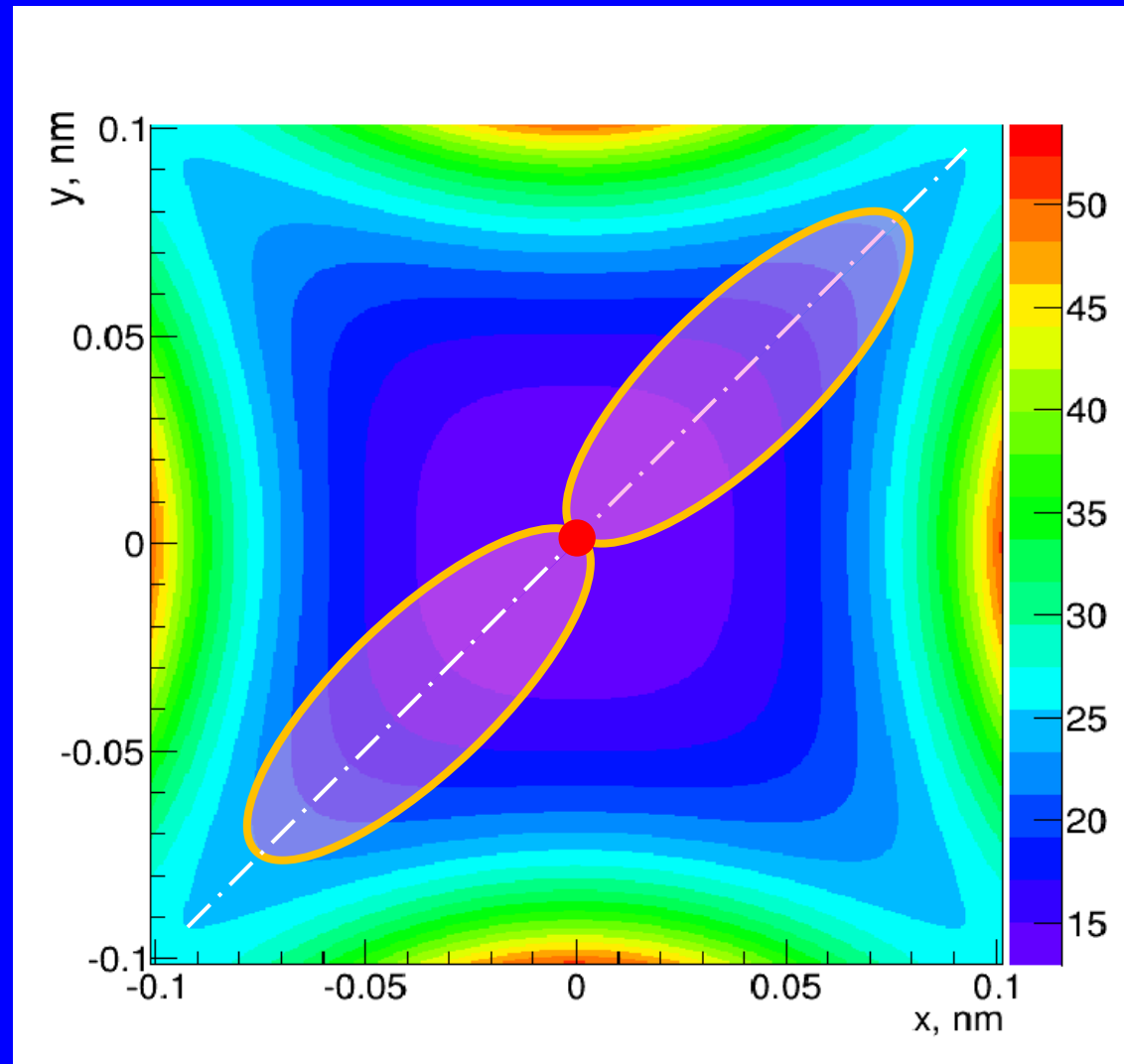
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# Structure of octahedral niche in platinum crystal.

## Color scale is in Volts.

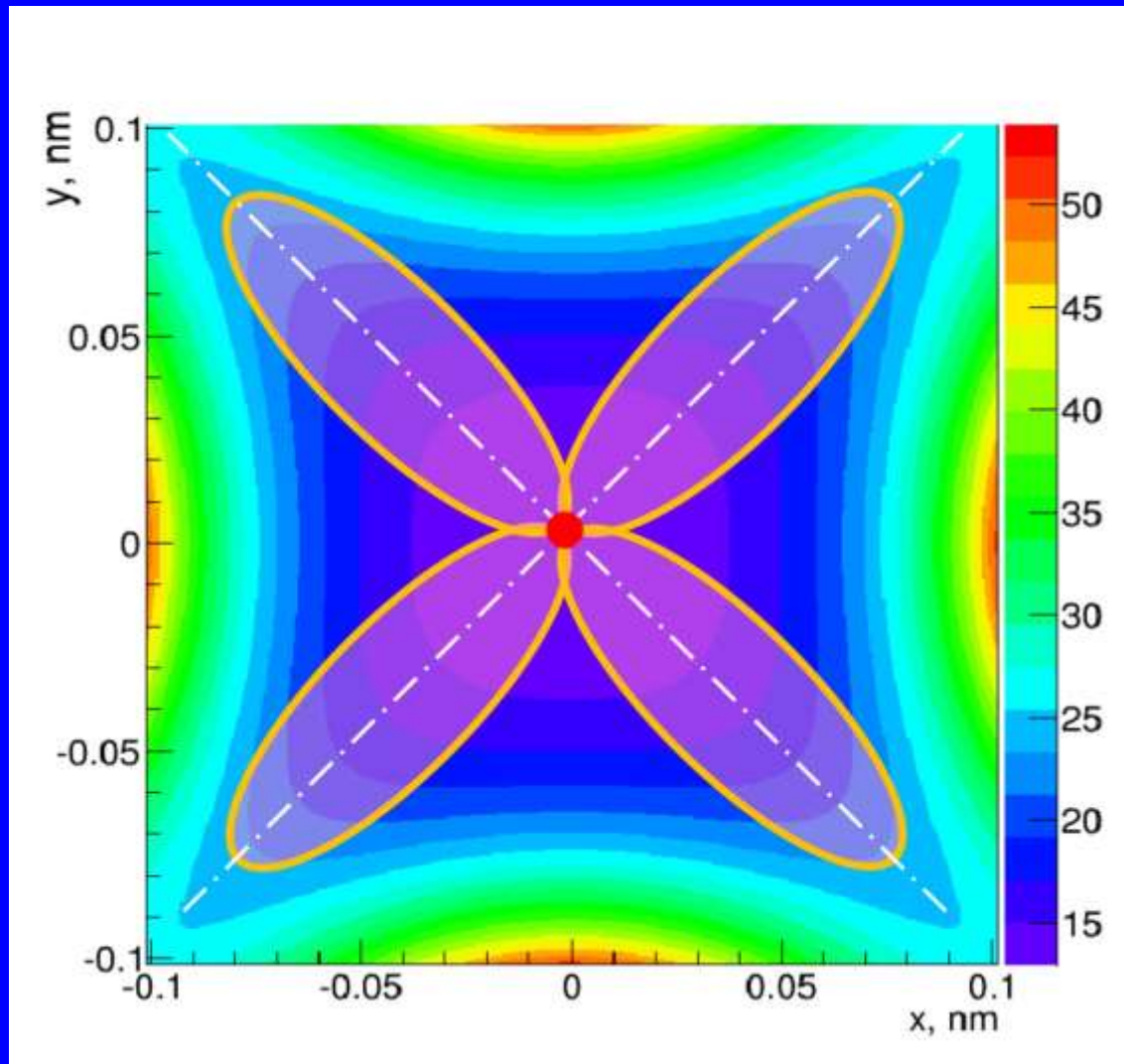


# Octahedral platinum crystal niche filled with a deuterium atom in $2p$ -state

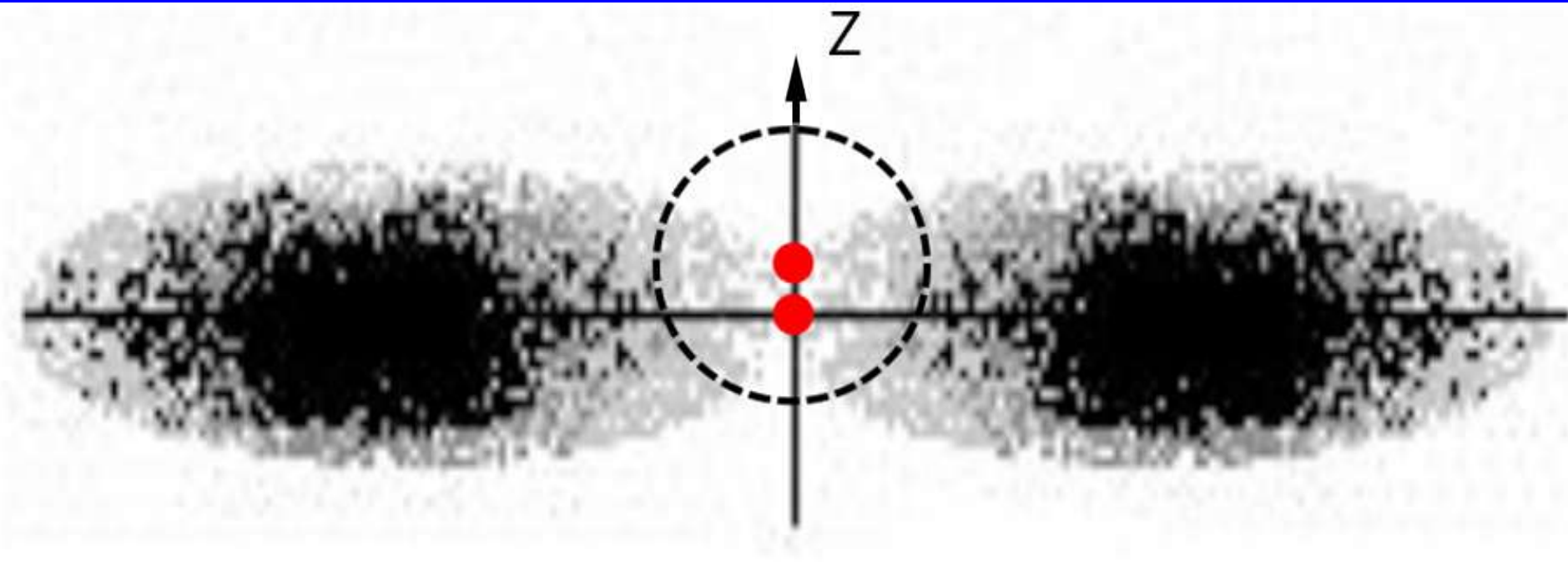




# Octahedral platinum crystal niche filled with two deuterium atoms in $2p$ -state



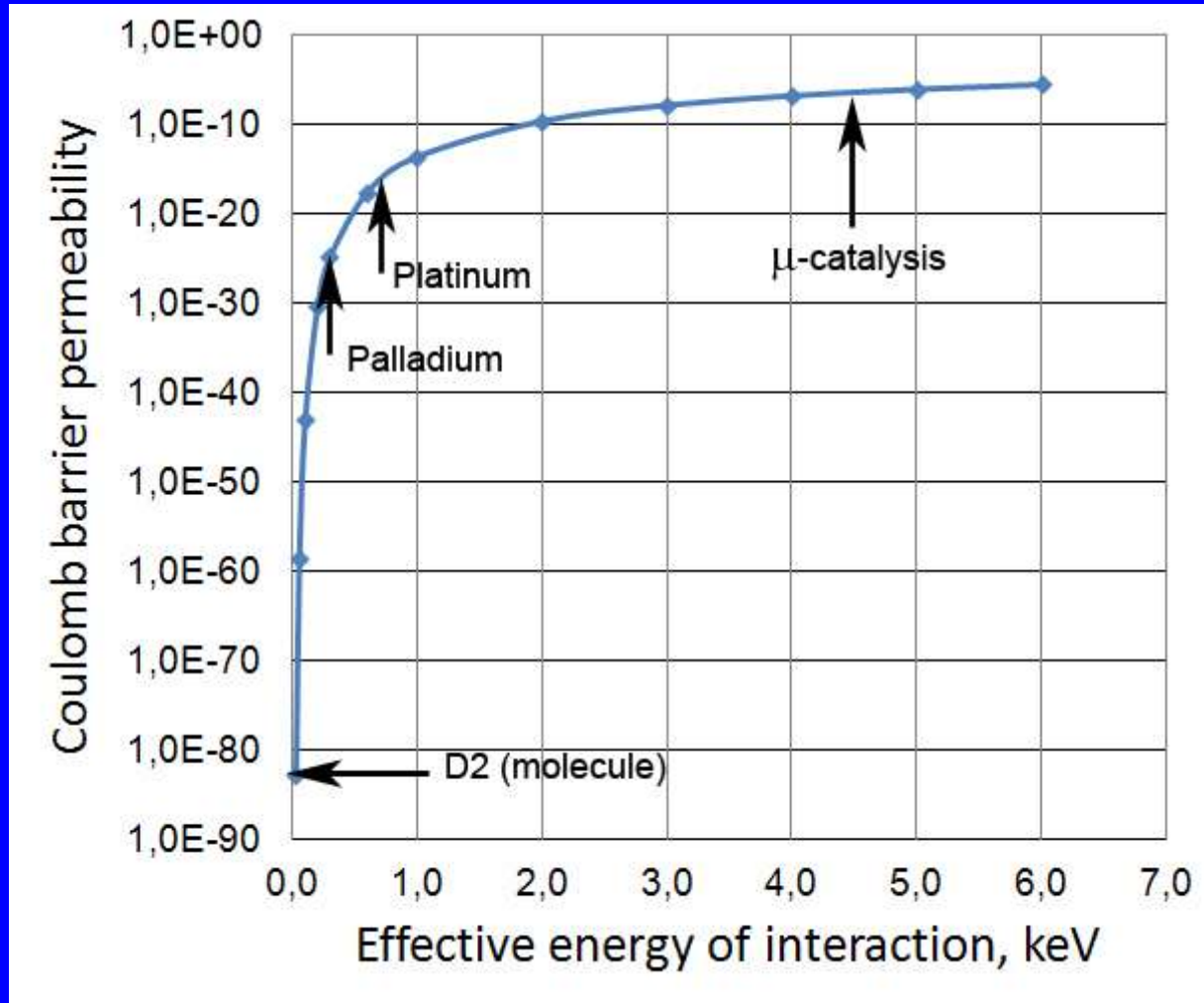
**The case when two atoms of deuterium in  $2p$ -state are located in the same octahedral niche of conducting fcc crystal.**



**The situation is quite similar to the process of  $\mu$ -catalysis**

## Coulomb barrier permeability for DD fusion:

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



For cold fusion,  
 $E \cong 0.040 \text{ eV}$

$$\text{Pt/D2} \cong 10^{65}$$

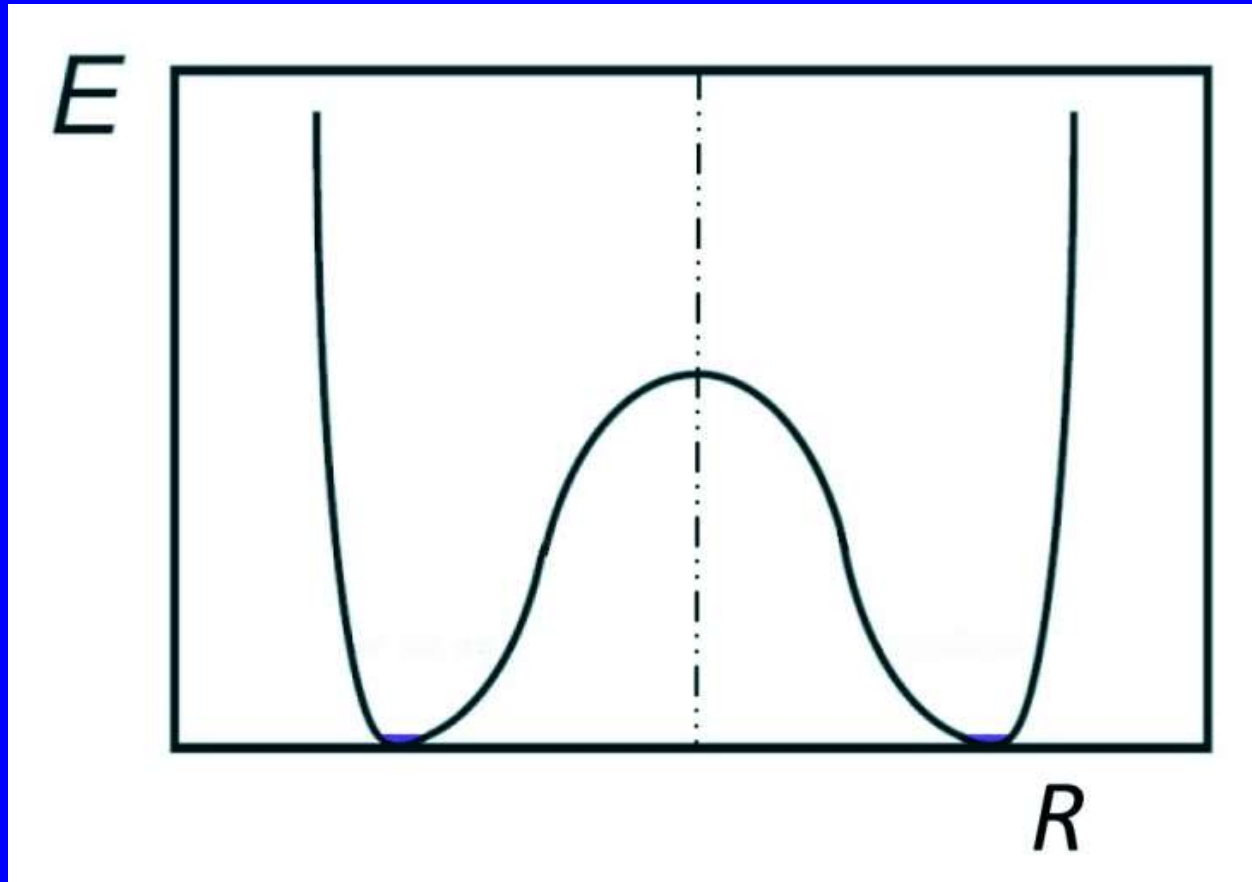


So, the first secret of cold fusion which necessarily results in the fusion of deuterium nuclei deuterium saturation in conducting crystal today can be considered practically solved.



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

A possible cause of slowing of nuclear decay rate with decreasing of the excitation energy: a *residual Coulomb barrier* between the deuterium nuclei that already in the potential well of the strong interactions.





Дорогой Эдуард Николаевич!

Я никогда не отрицал возможности того, что при электролизе могут происходить очень редкие реакции синтеза  $dd$  за счёт, например, ускорения дейтонов до энергий несколько кэВ в образующихся в кристалле щелях, на границе которых накапливаются заряды различного знака. Идея каналирования может повысить эту вероятность, подобно тому, как повышается светимость коллайдеров за счёт сжатия встречных пучков. Однако Ваше объяснение отсутствия наблюдаемых нейтронов от реакции  $dd \rightarrow {}_3\text{He} + n$  совершенно неприемлемо. Уровни энергии ядра гелия 4 хорошо известны и от 1-го возбуждённого уровня ( $\sim 20$  МэВ) нет промежуточных уровней. Поэтому нет возможности передачи энергии решётке через  $\gamma$ -кванты.

Тем не менее, относясь серьёзно к Вашим наблюдениям, хотел бы высказать Вам одну гипотезу: реакции  $dd \rightarrow {}_3\text{He} + n$  и  $dd \rightarrow t + p$  идут при энергиях несколько кэВ с одинаковой вероятностью. Однако внутри кристаллического канала положительно заряженная частица обладает большой потенциальной энергией. *Поэтому реакция с образованием  ${}_3\text{He}$  при переходе протона из одного ядра дейтерия к другому может иметь дополнительный порог и будет подавлена. Таким образом, синтез будет происходить с образованием протона и ядра трития.* А убедиться на опыте, что получается выход трития, значительно сложнее, чем выход нейтронов.

Я не интересовался и не знаю последних данных: наблюдали или нет выход трития в экспериментах по холодному синтезу?

Вы сами можете это оценить.

С приветом, С Герштейн

One can assume that the potential inside of the Coulomb barrier well after the strong interactions of the fusion reaction is no longer a retaining factor for neutrons, and neutrons can almost freely move from one proton to another. In this case, the *metastable DD-system* goes into a *metastable PT-system*. However, that “almost free” needs the additional energy of about 2 MeV, due to the binding energy of the deuteron. Let us recall that in our case the energy of the deuterons in the well of strong interactions is very small, much less than 1 eV.

Also, “*Statistical principle of correlation weakening with distance*” (N. N. Bogolubov, *Selected works on statistical physics*, M., 1979) may be working for neutrons.

According to our *hypothesis*, the rate of nuclear decay of a compound nucleus  ${}^4\text{He}^*$  is a function of the excitation energy of the nucleus  $E_k$ . We *assume* that when the  $E_k \sim 0$  (thermal energy), the compound nucleus  ${}^4\text{He}^*$  is metastable with a lifetime of about  $10^{-15}$  s. After a time of  $\sim 10^{-16}$  seconds, the compound nucleus is no longer an isolated system, since virtual photons  $\gamma^*$  from the  ${}^4\text{He}^*$  can reach the nearest electrons in a crystal, and carry away the excitation energy of the compound nucleus  ${}^4\text{He}^*$ . It must be emphasized that the above hypothesis is merely an attempt to explain *the well-established experimental fact* of the virtual absence of nuclear decay channels of the intermediate compound nucleus  ${}^4\text{He}^*$  in the process of cold fusion.

# First publication

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.

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## NUCLEI Experiment

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### 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 the crystalline cell

Crystal type	Screening potential, eV	Oscillation frequency $\nu$ , s <sup>-1</sup>	Barrier permeability $e^{-2\pi\eta}$	Rate of DD fusion $\lambda$ , s <sup>-1</sup>
Palladium	300	$0.74 \times 10^{17}$	$1.29 \times 10^{-25}$	$0.95 \times 10^{-8}$
Platinum	675	$1.67 \times 10^{17}$	$2.52 \times 10^{-17}$	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.




In our recent articles, we discuss the possibility of experimental detection of the “cold” DD-fusion process using low-energy electrons, which are the result of the fusion reaction of two deuterons in palladium crystals at very low (thermal) excitation energies of the compound nucleus  $^4\text{He}^*$ .

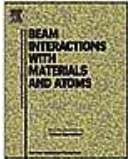
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journal homepage: [www.elsevier.com/locate/nimb](http://www.elsevier.com/locate/nimb)



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

E.N. Tsyganov<sup>a,\*</sup>, V.M. Golovatyuk<sup>b</sup>, S.P. Lobastov<sup>b</sup>, M.D. Bavizhev<sup>c</sup>, S.B. Dabagov<sup>d</sup>

<sup>a</sup>University of Texas Southwestern Medical Center at Dallas, USA  
<sup>b</sup>Joint Institute for Nuclear Research, Dubna, Russia  
<sup>c</sup>North-Caucasus Federal University, Stavropol, Russia  
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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.

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# Engineering Physics, 2013

**УЧРЕДИТЕЛЬ  
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# Engineering Physics, 2014

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DD-синтез в проводящих кристаллах ..... 6



**E. N. TSYGANOV**

*Doctor of Phys.-Math. Sciences, Professor, President*

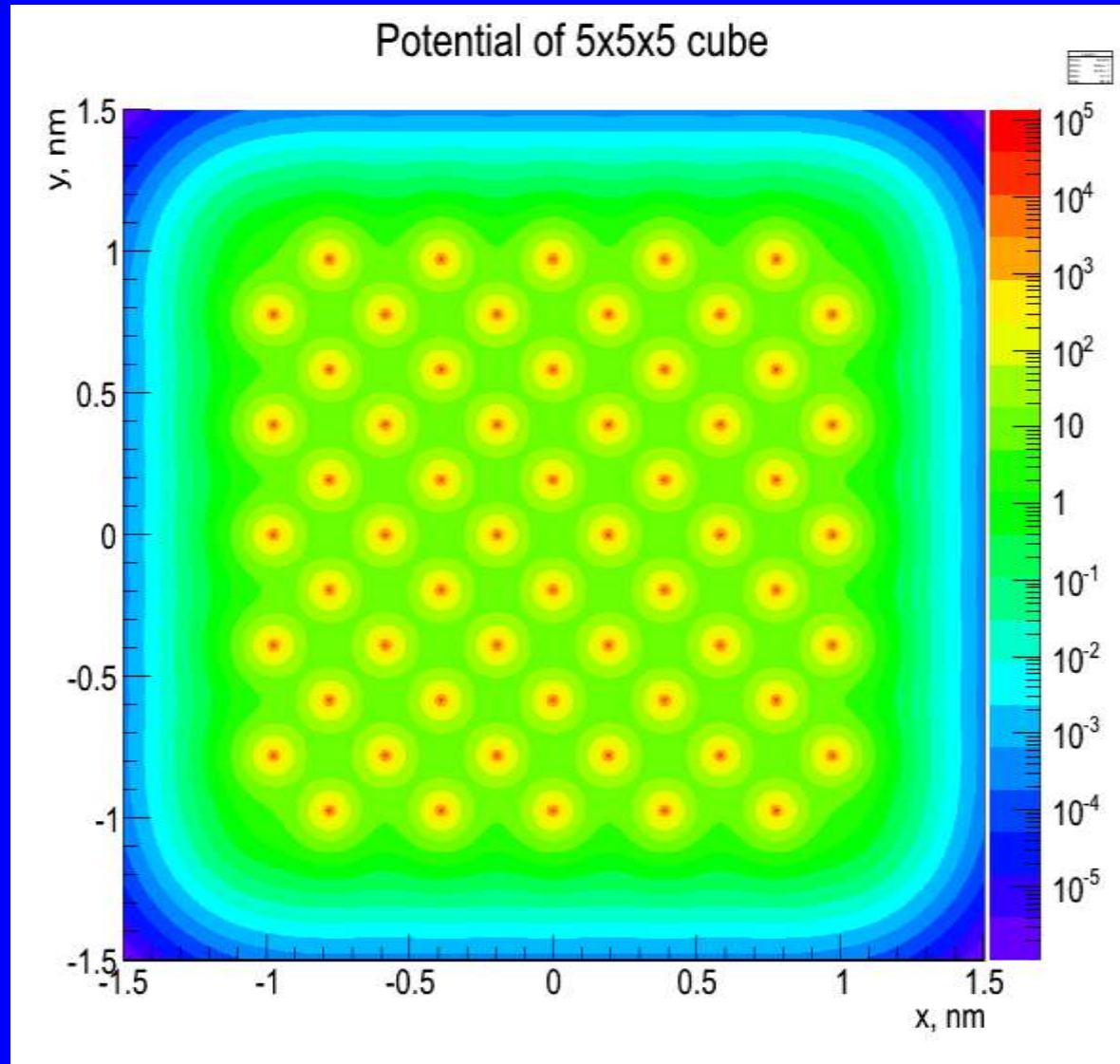
*E-mail: edward.tsyganov@coldfusion-power.com*

*Cold Fusion Power, International  
USA*

## DD FUSION IN CONDUCTING CRYSTALS

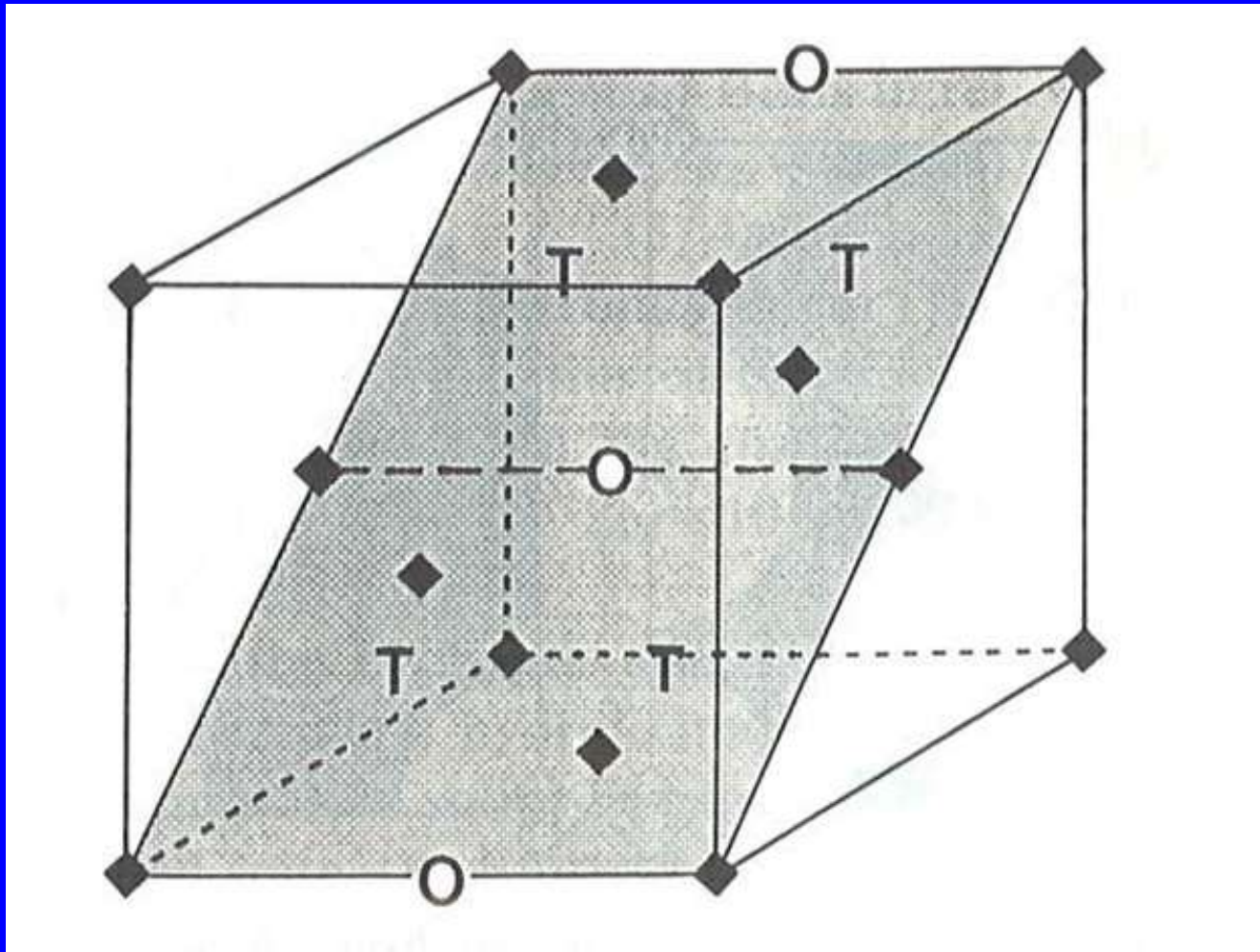
*The paper presents a brief background on cold fusion leading to a discussion on some aspects of atomic physics. We are explaining the selection of the only permitted orbitals of deuterium atoms in conducting crystals when saturated with deuterium. Conduction electrons in metallic crystal are grouped in potential niches of the crystal lattice, resulting in a ban for s-states of hydrogen to occupy these same niches. At the same time, the filling of these niches with deuterium atoms is allowed for the excited atomic states of level 2p and above. As has been shown in experiments on deuterium-deuterium (DD) fusion with low-energy accelerators, if an atom of deuterium target is located within a conducting crystal, this reaction is much more probable than in the case of free atoms of deuterium. When a single crystal niche gets two such atoms of deuterium, the distance between the nuclei of these atoms becomes equal to 1/10...1/20 of the nominal size of these atoms. Theoretical calculations show that this is equivalent to the additional energy 300...700 eV for the fusion reaction  $DD \rightarrow {}^4\text{He}^*$ . We believe that this process of excitation of atomic states to the 2p level and above explains the first stage of the so-called cold fusion.*

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

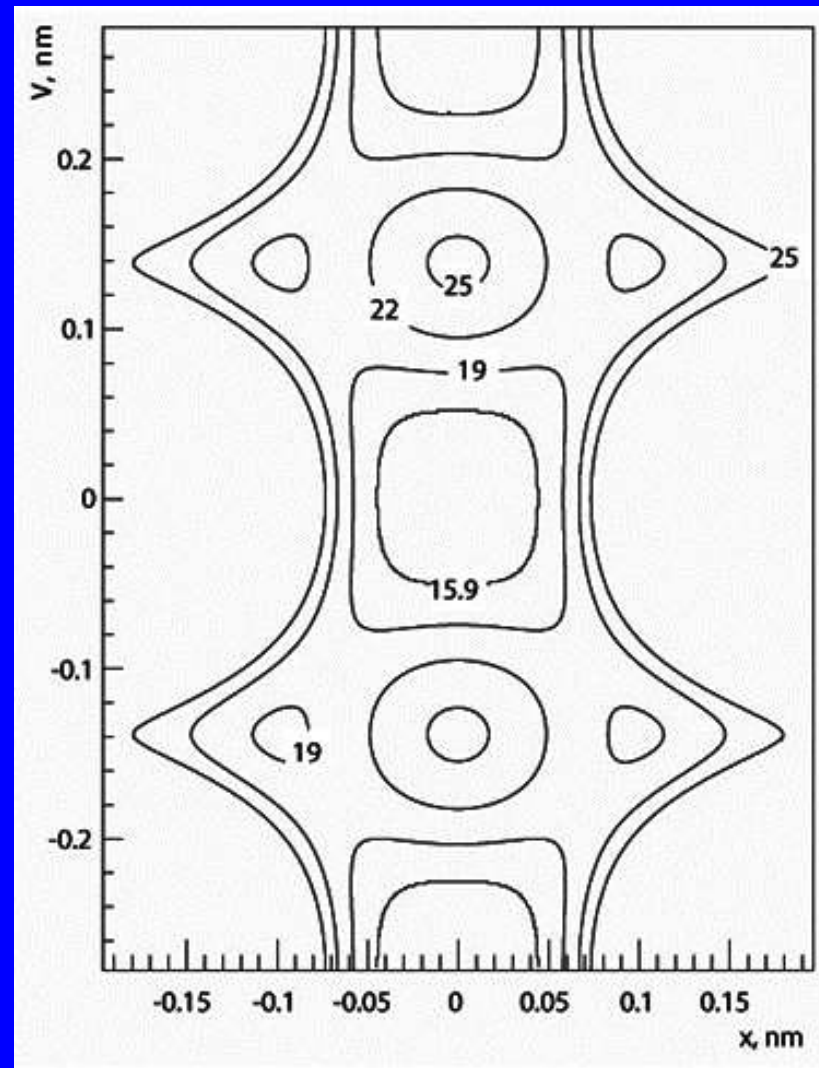




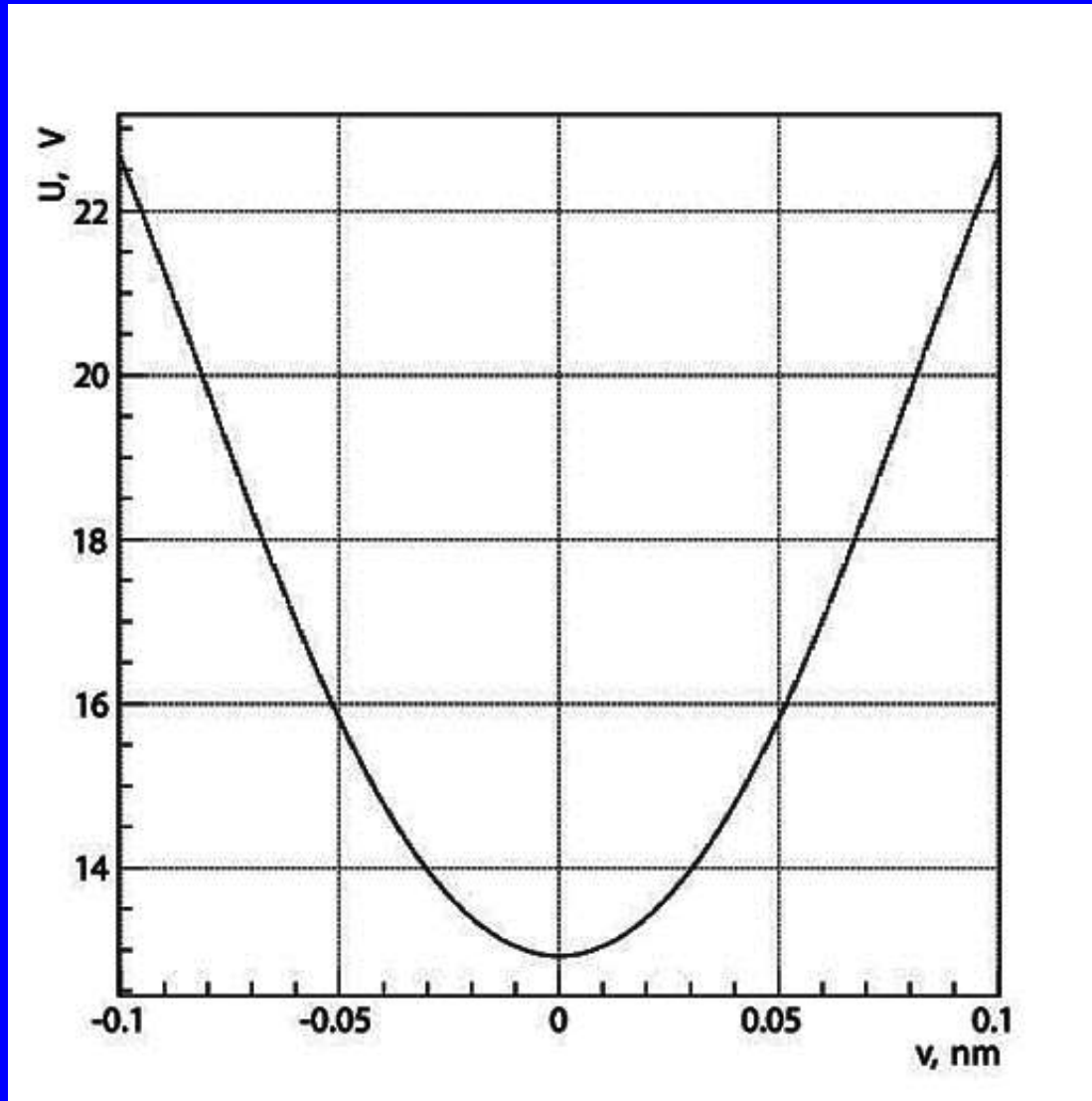
**Diagonal X-V plane of fcc crystals. Signs O marks octahedral vacancies; signs T – tetrahedral ones.**



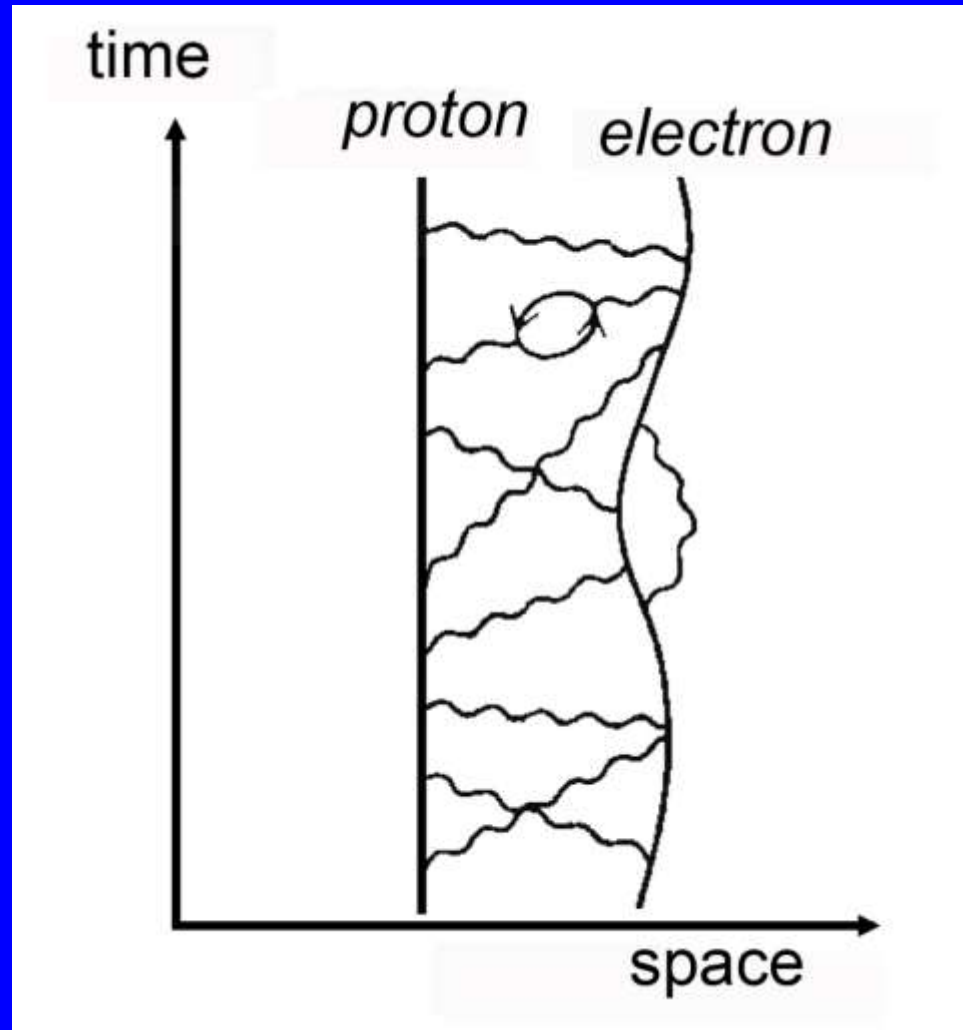
# Potential contours in the diagonal $X$ - $V$ plane for Platinum.



# Potential in the vicinity of the center of octahedral niche of platinum crystal cell along the $V$ -direction.



# Virtual photons in the hydrogen atom (Richard Feynman)



# Virtual photons from $^4\text{He}^*$ , Feynman's representation (guess)

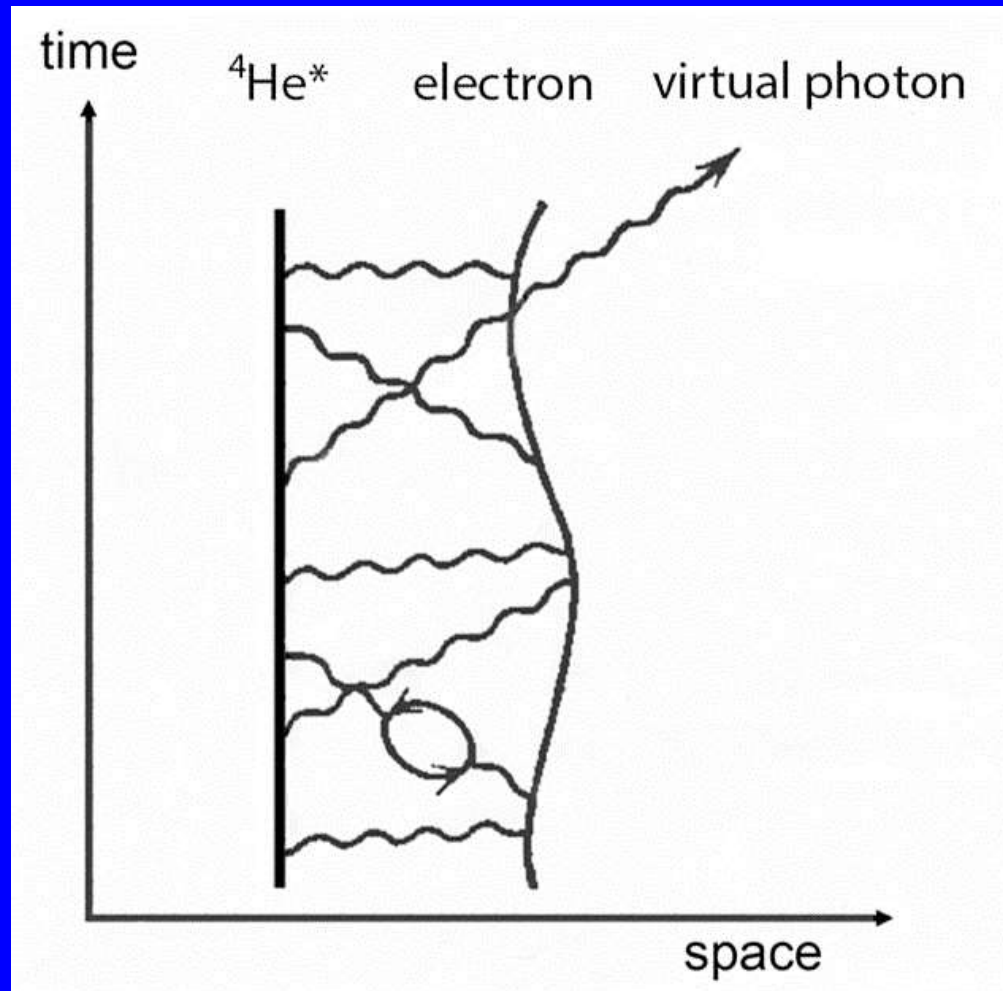
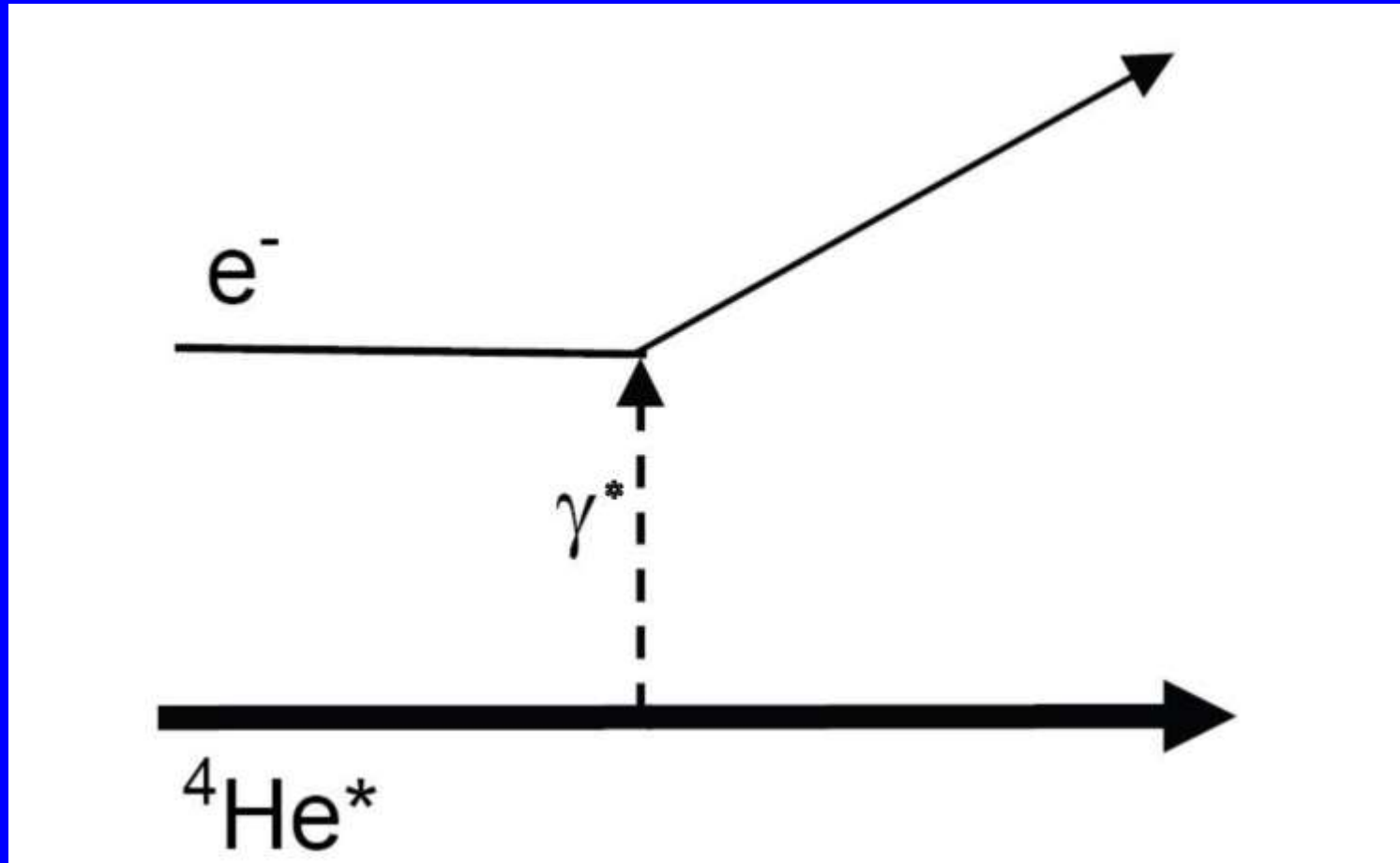
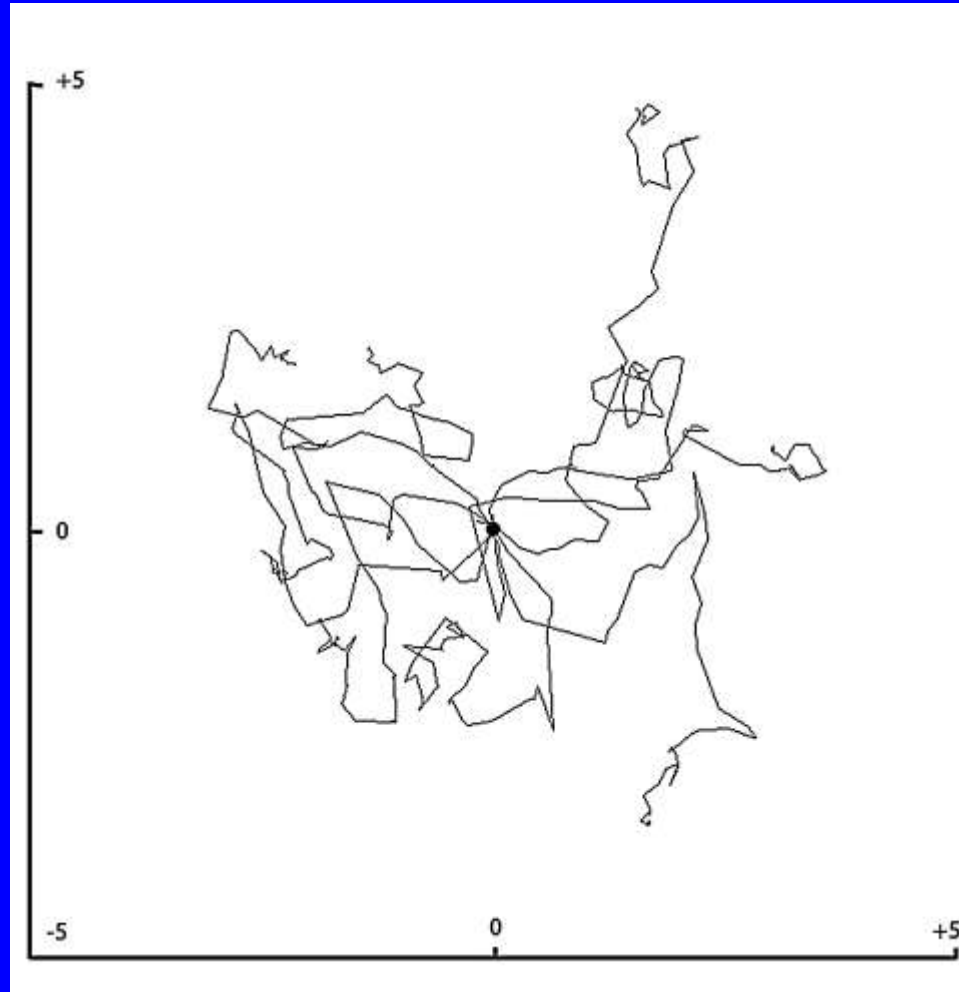




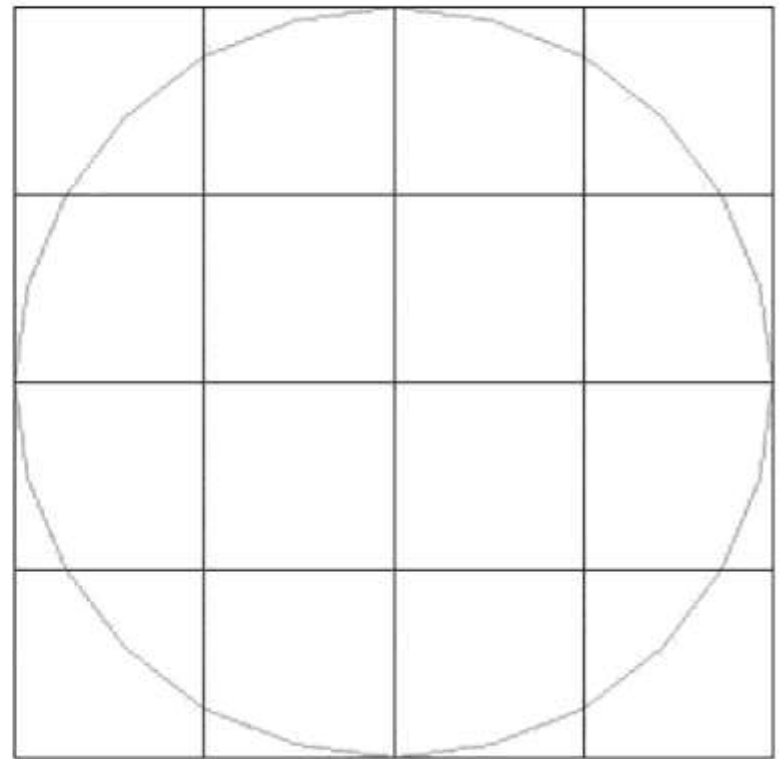
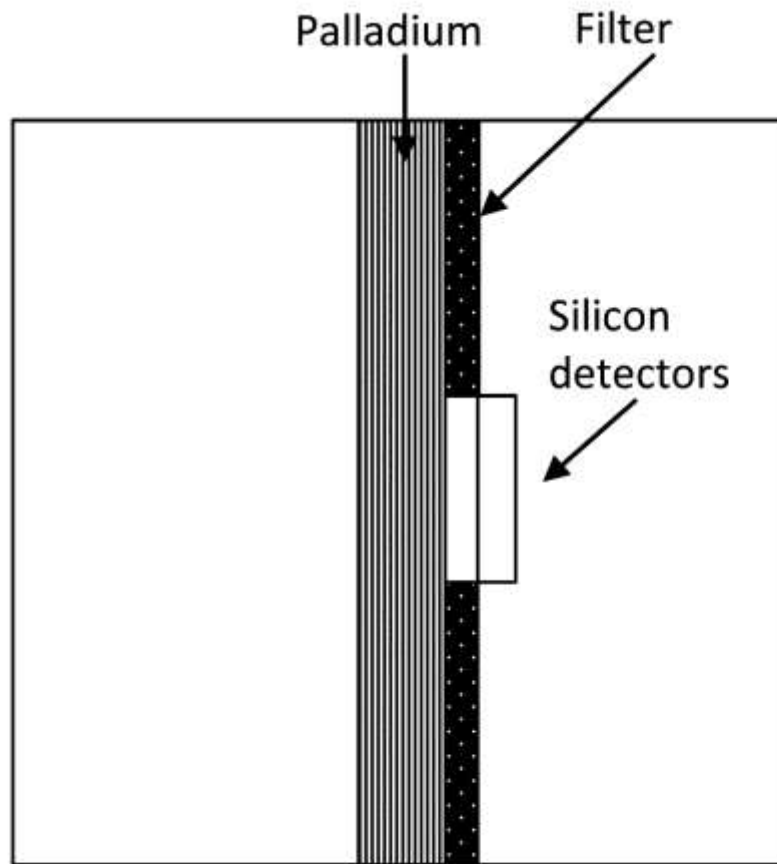
Diagram of “thermalization” process of  ${}^4\text{He}^*$  with multiple virtual photon exchanges. In order for this process to work, the existence of a metastable state of  ${}^4\text{He}^*$  is necessary.



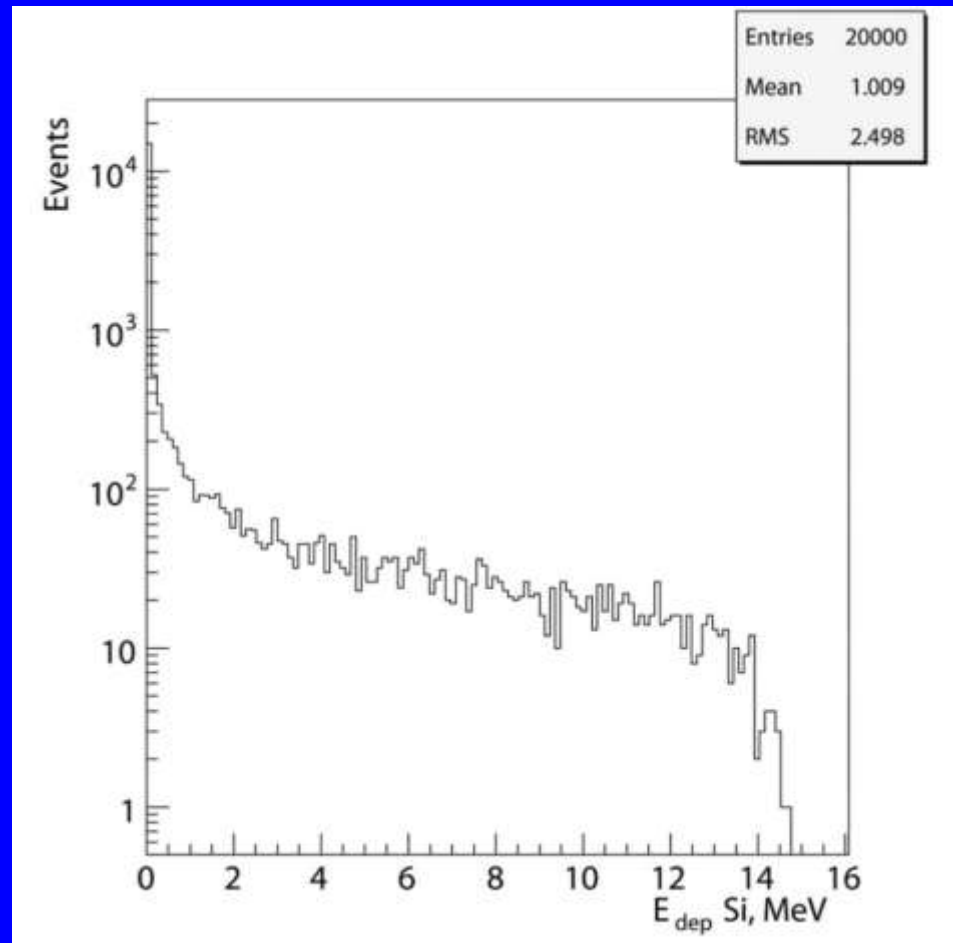
**The trajectories of electrons (Monte Carlo) generated  
in the process of DD cold fusion in palladium.  
Dimensions are in micrometers.**



**One-side scheme of the experiment. Several silicon detectors are placed on the same side of the palladium foil and included in coincidence. Left — side view, right — the relative positions of the aperture and detectors.**



Energy emitted by *60 keV* electrons in detectors placed on one side of the palladium foil. The spectrum extends up to *14 MeV*, because some of the electrons are scattered in palladium at angles up to 180 degrees.



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  - V. M. Bystritsky et al, National Scientific Research - Tomsk Polytechnical University, Russia, Nuclear Physics, 2013 (in press)



# Conclusion - 1

1. Existence of the phenomenon of cold fusion now is conclusively proven by the experiments, including experiments on low-energy accelerators.

2. The absence of nuclear products observed in cold fusion experiments can be explained by slowing down the decay speed of a compound nucleus  ${}^4\text{He}^*$  *via* nuclear channels with decreasing energy of its excitation. Energy release is due to virtual photons.

3. Prejudice of many nuclear physicists toward the cold fusion phenomenon is associated with this unusual nuclear process. In the cold fusion process, the resulting intermediate compound nucleus  ${}^4\text{He}^*$  is in a metastable state.

## Conclusion - 2

4. The accumulated empirical rules of nuclear physics are considered by the nuclear physics community as indisputable, while the range of application of these rules is limited.

5. Cold fusion provides sufficiently more practical opportunities than the expected traditional thermonuclear fusion.

Some of the applications of cold fusion (ships, aircraft, and space travel) are simply unavailable for devices of cyclopean scale—tokamaks and other hypothetical facilities using thermonuclear fusion.

# LPHE, November 15, 2012



6th International Conference "Charged & Neutral Particles Channeling Phenomena - Channeling 2014" (Capri, Italy, October 5-10, 2014)

# LPHE, November 15, 2012



6th International Conference "Charged & Neutral Particles Channeling Phenomena - Channeling 2014" (Capri, Italy, October 5-10, 2014)



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



6th International Conference “Charged & Neutral Particles Channeling Phenomena - Channeling 2014” (Capri, Italy, October 5-10, 2014)



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



6th International Conference "Charged & Neutral Particles Channeling  
Phenomena - Channeling 2014" (Capri, Italy, October 5-10, 2014)



***Recently (July 7, 2014) the talk on cold fusion process was presented in Bogolyubov Theoretical Physics Laboratory, JINR, Dubna. My report “DD fusion in conducting crystals” has caused a fruitful debate.***

***Additional information:***

<http://science-tv.jinr.ru/?p=2442#more-2442>

<https://www.youtube.com/watch?v=oVREaeowqJ8&list=PLHorZmSbM-E4Xydx6Z6xmYPDur5ZBLCvj>

<http://www.coldfusion-power.com/dubna-jinr.html>

<http://coldfusionnow.org/joint-institute-of-nuclear-research-cold-fusion-seminar-video>



# *Joint Institute for Nuclear Research, Bogolyubov Laboratory of Theoretical Physics, Dubna, July 7, 2014*



6th International Conference “Charged & Neutral Particles Channeling  
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# ITER Project

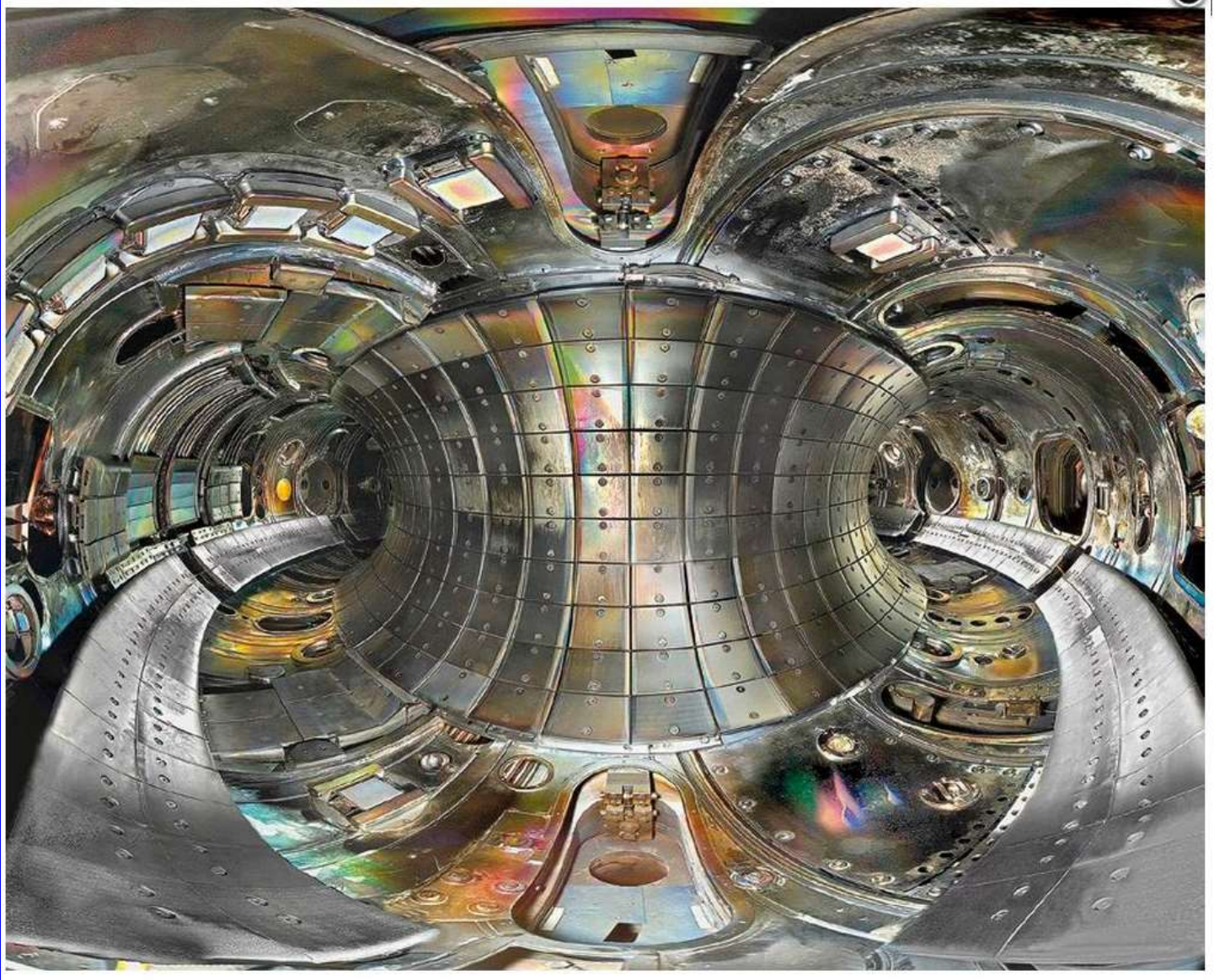
Tokamaks were invented in the 1950s by Soviet physicists Igor Tamm and Andrei Sakharov, inspired by an original idea of Oleg Lavrentiev.

ITER:  $^2\text{D} + ^3\text{T} \rightarrow ^4\text{He} + \text{n} + 17.6 \text{ MeV}$

Predicted: Start of deuterium-tritium operation on 2027.



# Joint European Torus, UK



6th International Conference "Charged & Neutral Particles Channeling Phenomena - Channeling 2014" (Capri, Italy, October 5-10, 2014)



# ITER, May 2014



6th International Conference “Charged & Neutral Particles Channeling Phenomena - Channeling 2014” (Capri, Italy, October 5-10, 2014)



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# ITER project



6th International Conference “Charged & Neutral Particles Channeling Phenomena - Channeling 2014” (Capri, Italy, October 5-10, 2014)

# ITER project

According to E.P. Velikhov estimations, ITER project could be ready to 2050



6th International Conference “Charged & Neutral Particles Channeling Phenomena - Channeling 2014” (Capri, Italy, October 5-10, 2014)

**Thank you for your attention!**