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Cold nuclear fusion

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ABSTRACT

If target deuterium atoms were implanted in a metal crystal in accelerator experiments, a sharp increase in the probability of DD-fusion reaction was clearly observed when compared with the reaction's theoretical value. The electronic screening potential, which for a collision of free deuterium atoms is about 27 eV, reached 300–700 eV in the case of the DD-fusion in metallic crystals. These data leads to the conclusion that a ban must exist for deuterium atoms to be in the ground state *1s* in a niche filled with free conduction electrons. At the same time, the state *2p* whose energy level is only 10 eV above that of state *1s* is allowed in these conditions. With anisotropy of *2p*, *3p* or above orbitals, their spatial positions are strictly determined in the lattice coordinate system. When filling out the same potential niches with two deuterium atoms in the states *2p*, *3p* or higher, the nuclei of these atoms can be permanently positioned without creating much Coulomb repulsion at a very short distance from each other. In this case, the transparency of the potential barrier increases dramatically compared to the ground state *1s* for these atoms. The probability of the deuterium nuclei penetrating the Coulomb barrier by zero quantum vibration of the DD-system also increases dramatically. The so-called cold nuclear DD-fusion for a number of years was registered in many experiments, however, was still rejected by mainstream science for allegedly having no consistent scientific explanation. Finally, it received the validation. Below, we outline the concept of this explanation and give the necessary calculations. This paper also considers the further destiny of the formed intermediate state of $^4He^*$.

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1. Introduction

During 21–27 July 2013, the University of Missouri, Columbia, hosted the 18th International Conference on Cold Fusion (ICCF-18). This conference demonstrated increasing scientific interest in this natural phenomenon, first noted in the work of Fleischmann and Pons [1] in 1989. The Conference presented new experimental data on cold fusion while possible theoretical interpretations of these results were given. The next conference ICCF-19 will be held in April 2015 in Padua, Italy. A breakthrough in the recognition of cold fusion can occur just after the Conference.

As noted above, in numerous experiments on low-energy accelerators [2–14], it has been observed for some time that an increase in the probability of DD fusion reactions occurs, as compared to their calculated value, when a target deuterium atom is implanted in metallic crystals. This effect is not observed in cases where the target deuterium atom is free or implanted in semiconductors, insulator-crystals, or amorphous bodies. The so-called electronic screening potential U_e, which, in the case of the collision of free deuterium atoms, is about 27 eV [15] and substantially characterizes the size of unexcited deuterium atom, is equal to about 300–700 eV in the case of DD-fusion in a metal crystal environment. Essentially, this means that in a conducting crystal media, deuterium atoms can converge without Coulomb repulsion at a distance of 1/10–1/20 of the nominal dimensions of these atoms. The development of this approach was set out in our papers [16–20].

2. The orbitals of the hydrogen atom

Fig. 1, left, graphically depicts the orbital of a hydrogen atom in a state of *1s*. On the right side of the same figure, the representation of the orbital of the first excited state of the hydrogen atom *2p* is shown. This figure is taken from the Encyclopedia Britannica of 2013. The excitation energy of the atom in the *2p* state is about 10 eV. The extensive experimental data on the large electron

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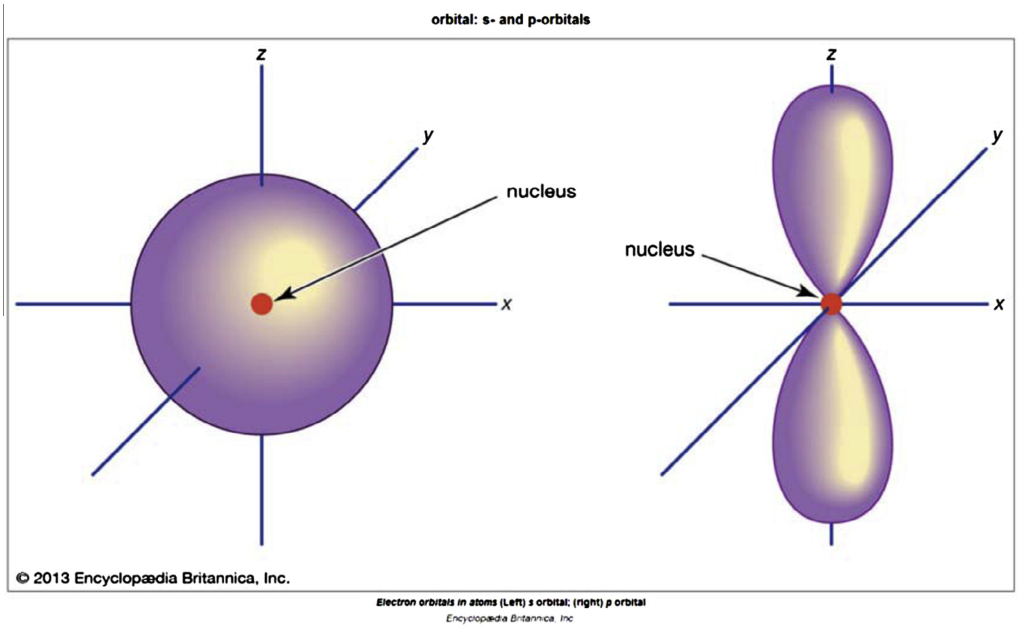

Fig. 1. Hydrogen atom orbitals *1s* (left) and *2p* (right). Picture taken from the Encyclopedia Britannica, 2013. Presented contours include 95% of the possible positions of the electron.

screening potential (300–700 eV) in DD-fusion—obtained from the low-energy accelerators when the target deuterium atoms are implanted in conducting crystals—indicate that there is a ban imposed on deuterium atoms in the state of *1s* in the crystal by a cloud of free conduction electrons. At the same time, the state of the *2p*, *3p* and higher in this environment are allowed.

Fig. 2 gives graphical representation of the first excited orbitals of the hydrogen atom and the corresponding energy levels of the electron. Fig. 3 presents the orbitals of the hydrogen atom (the solution of the Schrödinger equation) in Winter's work [21].

Given the fact that the spatial orientation of the *2p*, *3p* state or higher in the structure of the crystal cell is strictly deterministic, two deuterium nuclei can be placed in a potential niche of two crystallographic deuterium atoms in the state *2p*, *3p* or higher at a very close distance. The cold fusion process begins when all octahedral crystallographic vacancies have been filled once with deuterium nuclei. This is illustrated in Fig. 4, taken from [23]. The so-called "zero" quantum vibrations between the nuclei of deuterium atoms cause a sharp increase in the reaction probability of DD-fusion, followed by further filling of the octahedral niches. This effect is also illustrated in Fig. 5, which shows success of registration of the additional heat created in about 40 experiments on cold fusion, depending on the degree of concentration of deuterium atoms in Palladium crystals.

The color scale on the left of Fig. 6 in the plane $Z = 0$ shows the distribution of electric potentials in the crystal cells of Platinum; the scale of the coordinates X and Y are given in nanometers. At the center of Fig. 6, in the plane $Z = 0$, is shown the arrangement of the deuterium atoms in the *2p* state in the crystal cells of Platinum. The spatial arrangement of the deuterium atoms in the

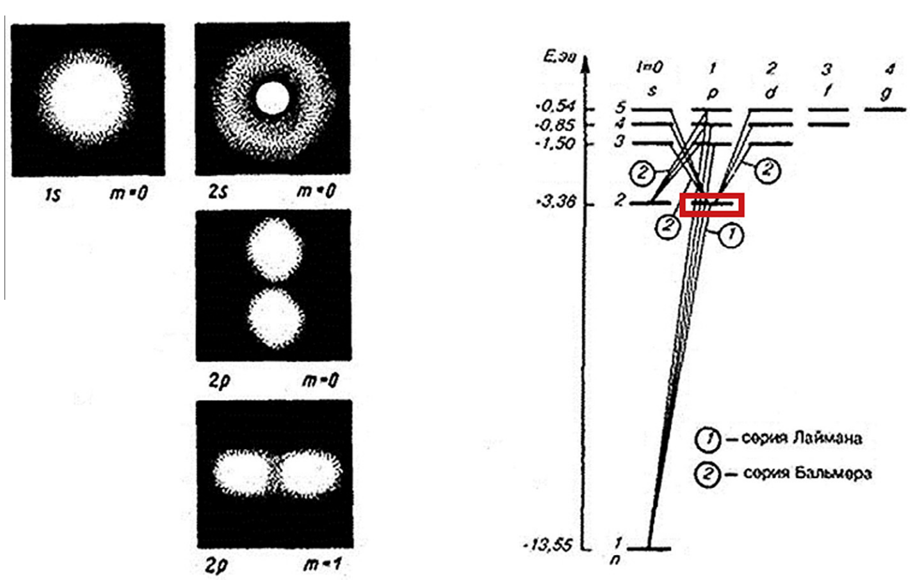

Fig. 2. Graphical representation of the first excited orbitals of the hydrogen atom and the corresponding energy levels of the electron.

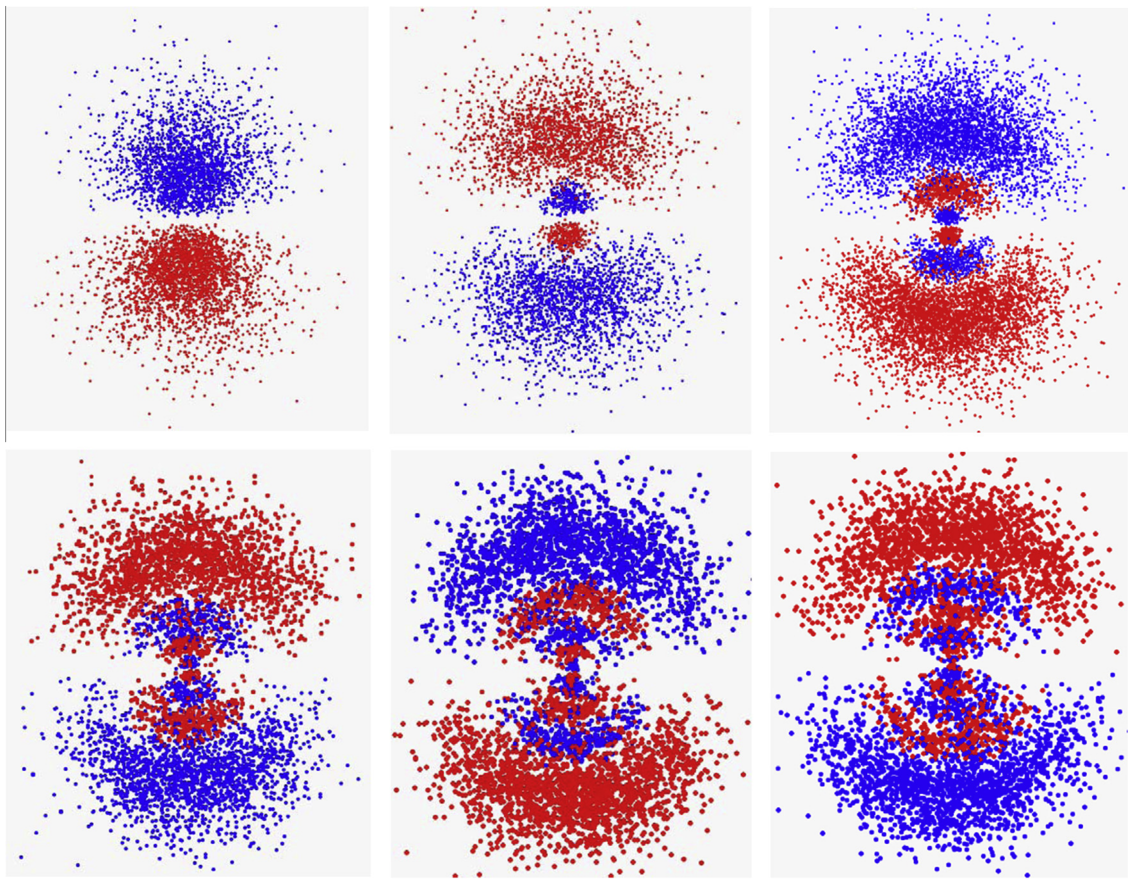

Fig. 3. Presentation of the orbitals of the hydrogen atom (the solution of the Schrödinger equation) in Dr. Winter work [21]. Upper row, left to right: *2p*, *3p*, *4p*; lower row: *5p*, *6p*, *7p*. The color coding corresponds to the positive and to the negative values of the wave function.

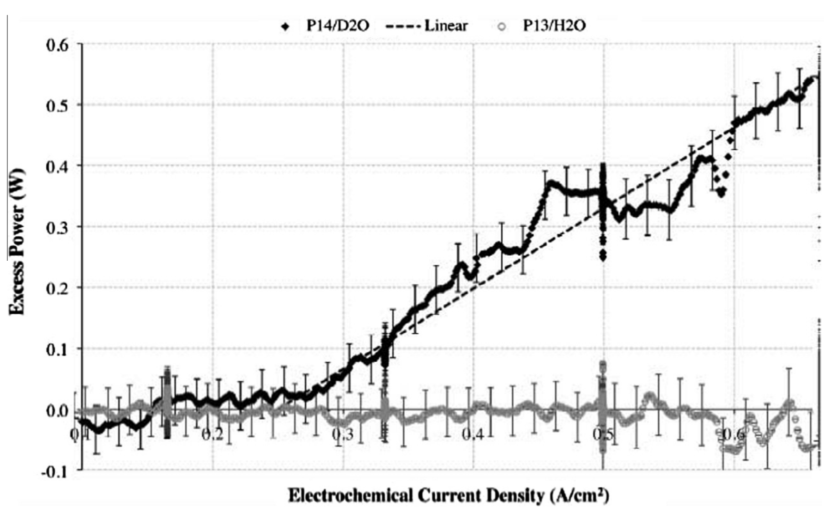

Fig. 4. Excess heat in Watts depending on the value of the electrochemical current in the experiments of Dr. McKubre et al. [23].

crystal state *2p* is strictly deterministic in one of the three dimensions. Fig. 6 on the right shows the possible combination of locations of two deuterium atoms in the position *2p* in this cell.

Fig. 7 schematically shows the arrangement of two deuterium atoms in the *2p* state in one crystallographic niche along the *Z* axis around $Z = 0$ [20].

Fig. 8 shows the dependence of the Coulomb barrier's transparency on the potential of electron screening for the reaction of DD-fusion. The permeability of the Coulomb barrier for DD-fusion is as follows:

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

For cold fusion ($E \cong 0.040$ eV), the transparency of the Coulomb barrier is Pt/D2 $\cong 10^{65}$ for deuterium atoms that are in the same niche of Platinum crystal as the corresponding value of free

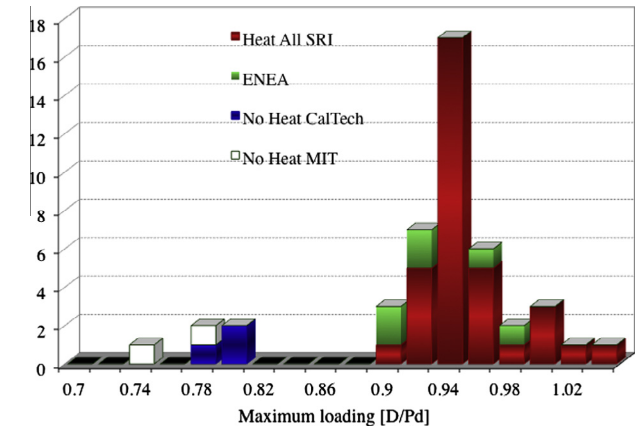

Fig. 5. The success of the experiments on cold fusion depending on the concentration of deuterium in palladium crystals [24].

deuterium molecules. In the case of a metallic crystal, the penetration of the deuterium nuclei through the Coulomb barrier becomes practically possible due to *zero quantum vibrations* of the system. The characteristics of the cold DD-fusion process [16], are as follows: DD fusion reaction rates λ are $0.95 \times 10^{-8}\ \mathrm{s}^{-1}$ for Palladium and $4.2\ \mathrm{s}^{-1}$ for Platinum.

We believe that the results given above fully explain the process of cold fusion, which had remained an intriguing mystery for science over the course of the last 25 years.

3. The discharge of the excess energy of the nucleus $^4\mathrm{He}^*$ with virtual photons

We have shown that due to the presence of free electrons in the metal crystals, saturation of the crystals with deuterium causes the atoms to be capable of taking stabile states *2p*, *3p* or higher. When all the octahedral niches are filled with deuterium atoms in the state *2p*, *3p* or higher, niches containing more than one atom begin to appear. The probability of the DD system penetrating through the potential barrier becomes quite large. For platinum crystals, the rate of DD-fusion in such a niche can reach $4\ \mathrm{s}^{-1}$.

Fig. 9 shows the potential well of the strong interactions for reaction DD $\rightarrow$ $^4\mathrm{He}^*$. Deuterons, penetrating into the potential well, are still separated by the residual Coulomb barrier, the value of which, apparently, can reach hundreds of electron-volts. In this case, the standard nuclear decay rates of the intermediate nucleus $^4\mathrm{He}^*$ are significantly slowed.

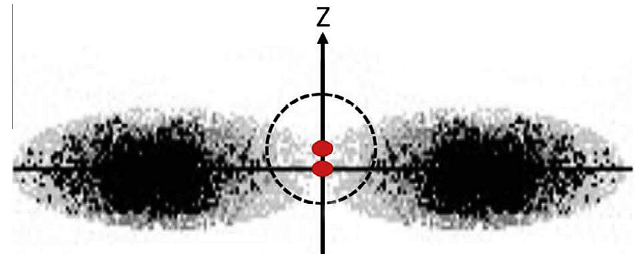

Fig. 7. Location of two deuterium atoms in the *2p* state in one crystallographic niche along the vertical axis *Z*.

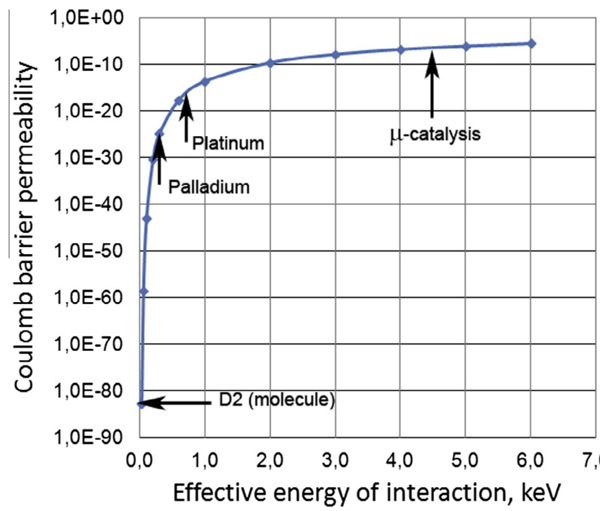

Fig. 8. The Coulomb barrier transparency's dependence on the electron screening potential U_e for the DD-fusion process.

It can be assumed that after the fusion reaction, the Coulomb potential barrier within a common well of strong interactions is no longer the retention factor for neutrons, and they can almost freely move from one proton to the other. However, the fact that it is "almost freely," rather than "completely free," means that additional energy of about 2 MeV is needed for this process. Let us recall that, in the case we are dealing with here, the deuterons' kinetic energy in the well of the strong interactions is very small, far less than 1 eV.

In this case, the discharge process of releasing nuclear energy of 24 MeV in the reaction DD $\rightarrow$ $^4\mathrm{He}^*$ can be performed with the

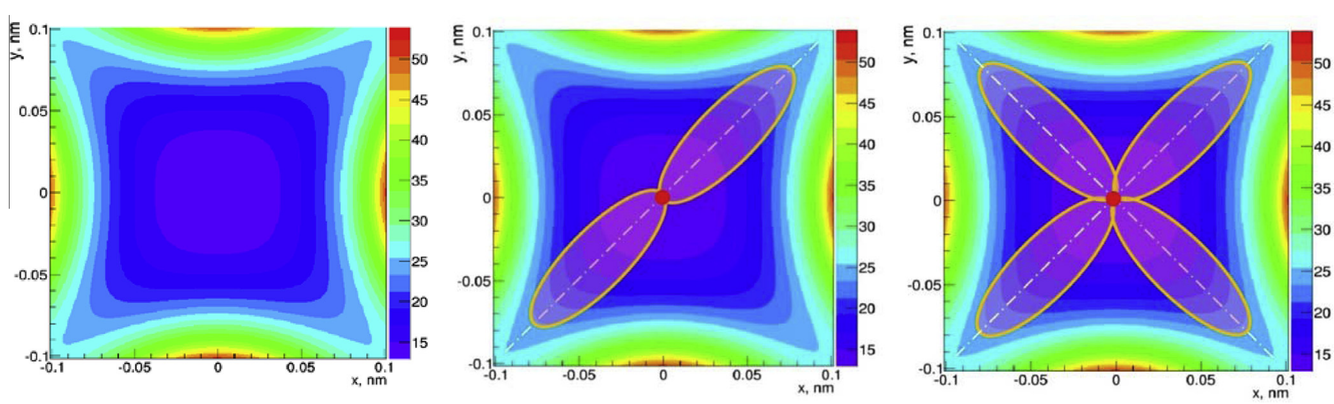

Fig. 6. On the left, in the projection XY, the unfilled octahedral niche potential is shown. The center shows a possible arrangement of the single deuterium atom of the *2p* state in this niche. The figure on the right shows one of the possible combinations of two such atoms located in this niche. Color gradation characterizes the potential of the electric field in the central region of the Platinum crystal cell.

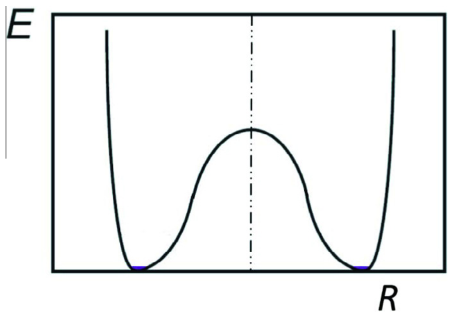

Fig. 9. Schematic representation of the potential at the bottom of the potential well for strong interactions in the case of DD cold fusion in conducting crystals. The heat excitation energy of the nucleus $^4He^*$ is about 0.040 eV. Deuterons in a potential well, penetrated by the mechanism of cold fusion, are still separated by the residual Coulomb barrier.

consequent release of *virtual* photons, whose spins *could be directed along the time axis*. We assume that the rate of the penetration of protons through the residual Coulomb barrier is much less than $10^{-15}\,s^{-1}$ due to the very small (thermal) excitation energy of the nucleus $^4He^*$. During this time, all the excess energy of the intermediate compound nucleus $^4He^*$ manages to give up *via virtual photons*. Fig. 10, left, shows a hydrogen atom in Richard Feynman's representation. Virtual photons carry away the excess excitation energy in reaction DD → $^4He^*$, as it could be possibly portray by Richard Feynman, are presented in this figure to the right.

The discharge process of the excess energy of the intermediate nucleus $^4He^*$ is going with a series of consecutive virtual photon exchanges between this nucleus and the surrounding environment in conducting crystals. In order for this mechanism to work, the existence of a metastable state of $^4He^*$ is necessary. The trajectories of the first 10 electrons generated using Monte Carlo during cold DD-fusion in Palladium [16] shows that ranges of recoil electrons are well within several micrometers.

4. Set-up for the experiment

The calorimetric approach does not come close to a detailed understanding of the specific mechanism of cold DD-fusion. The mechanisms that can determine the energy transfer of DD-fusion to the bearing crystal without nuclear decays of the composite system $^4He^*$ are necessary for understanding experiments in detail. Proposals for this experiment were formulated by us in [17].

As noted above, the conduction electrons and the influence of the lattice in metallic crystals (orbitals *1s* and *2p* and higher and the spatial orientation of the excited orbitals in the crystal lattice) can significantly modify the potential barrier. An effective screening radius, in this case, can be approximately one order smaller than for the unexcited nuclei.

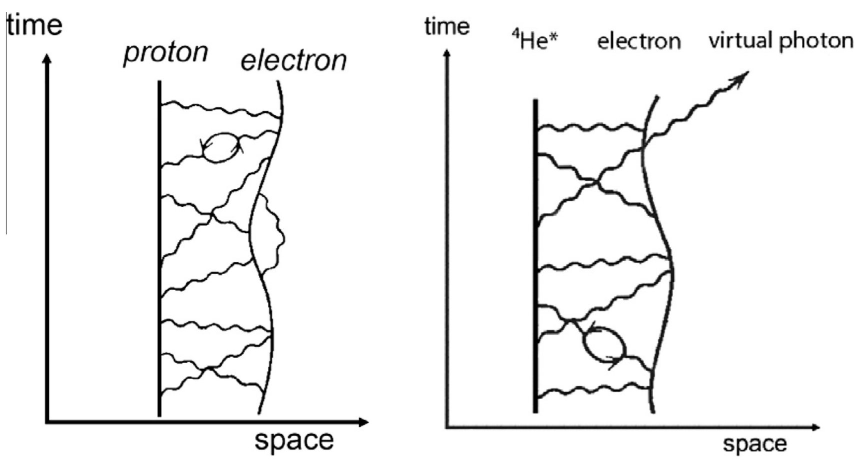

Fig. 10. The figure on the left shows a diagram presented by Richard Feynman and describing the stationary state of the hydrogen atom. The right figure presents virtual photons in the excited state of $^4He^*$ in cold DD-fusion, as they would be portrayed by Richard Feynman.

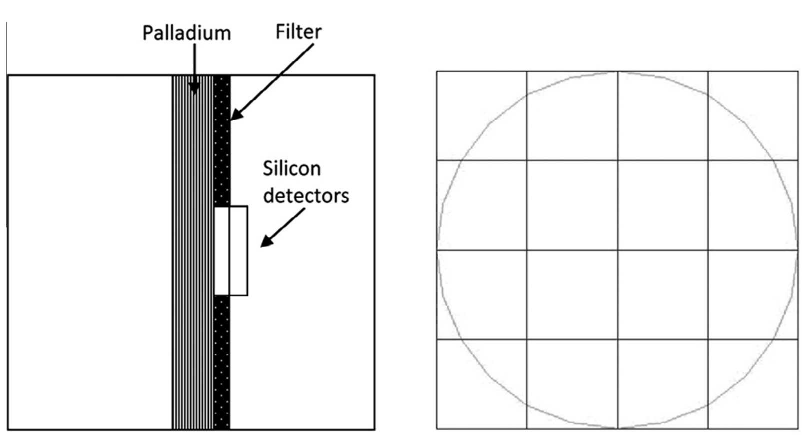

Fig. 11. Unilateral experimental scheme. Several silicon semiconductor detectors are located on one side of the palladium and included in coincidence. On the left is a side view, and on the right are the mutual positions of the aperture and detectors.

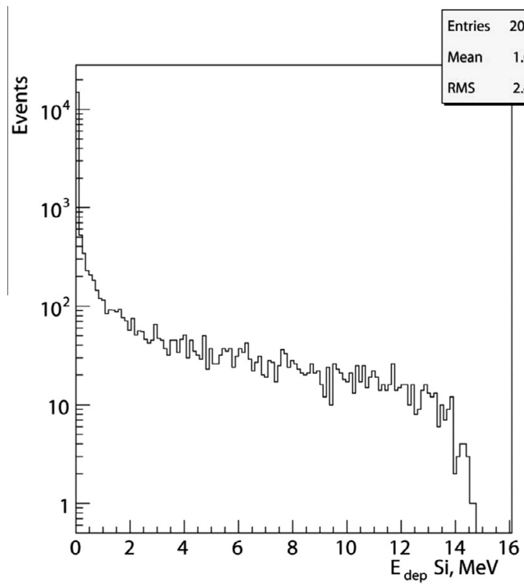

Fig. 12. The total energy of emitted electrons with energy of up to 60 keV in the detectors located on the one side of Palladium. The thickness of the Palladium foil was set to be equal to 20 μm. About 75% of the Monte Carlo events are completely absorbed in the sample of Palladium. The spectrum is cut off by about 14 MeV, which is explained by the back-scattering of a fraction of the electrons in Palladium up to 180°.

We performed calculations concerning two energies, 6 keV and 60 keV, for the emission of electrons.

It is planned at the preliminary stage of the experiment to measure the sum energy of the emitted electrons from only one side of the Palladium crystal. The scheme of the experiment's design is shown in Fig. 11. Sixteen semiconductor silicon detectors are arranged on one side of the Palladium crystal and included in coincidence. On the left is a side view, and on the right are the mutual positions of the aperture and detectors.

The total detected energy was calculated using the Monte Carlo model (GEANT4). For detailed simulation of low-energetic electromagnetic interactions, we used the Livermore Physics model [22] (G4EmLivermorePhysics) package of GEANT4. The model used was a database and Livermore EPDL and EEDL.

It was assumed that, as a result of the fusion occurring during a relatively short time (about 10^{-15} s), approximately 10^3 electrons are allocated to the detector with energies of up to 60 keV, the total energy being 24 MeV. Palladium foil is not an active element, which means that a portion of the electrons' energy resulting from DD-fusion disappears from the measurement process. The calculations optimized the thickness of the Palladium foil and the detector's geometry.

Fig. 12 gives the results of the calculations in the case of the one-sided arrangement of detectors and the emission of electrons with energy of 60 keV. Selection of the events can be made by triggering multiple detectors disposed at one side of a sample of Palladium in coincidence.

In the case where the detectors are arranged on one side of the Palladium, the maximum recorded energy is approximately half of the energy decay $^4He^*$. In our opinion, these measurements could be conclusive evidence of the process of the transfer of excitation energy of the compound nucleus $^4He^*$ to the host crystal *via virtual photons*.

5. Discussion

The scientific community's process of adaptation to new knowledge has never been easy. The current paradigm of nuclear physics does not support effects such as cold fusion, although this phenomenon does not contradict any of the fundamental laws of nature. All this is aggravated by the fact that the attempt to find a solution to controlled nuclear fusion—which has been conducted for nearly half a century—has gone too far. The most advanced attempt in this direction is called the International Project ITER—Tokamak. Currently under construction, the project is cyclopean in size and equally costly. Realists estimate that the construction of the project and the start-up of the facility should be completed within the next 35–50 years. The project is only considered to be a research project and will only be able to operate in a cyclic mode. After its launch, it will be followed by the construction of an even more gargantuan structure: Industrial Tokamak DEMO. The prospect of huge financial and material costs should continue for another half century.

For the global fuel and oil–gas industry, these projects are welcome. In the worst-case scenario, such developments will contribute to climate change and its attendant problems: the reduction of the human population and other social cataclysms.

Cold fusion is a real alternative to this tragic scenario. We believe that in the coming years, the awareness of cold fusion's scientific merits will be recognized, and a radical change will occur in the practical applications of nuclear research.

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