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Interaction Between an Accelerated Electron and a Quark up to Transform the Quark up into a Down Quark, so that the Proton Practically Becomes a Neutron

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Abstract: The paper briefly examines the possibility of transforming a proton into a neutron, by introducing an accelerated electron inside the proton, in order to penetrate it into one of the two up quarks in order to transform it into a down quark, thus transforming the initial state of the proton into a new state of a neutron. Such an achievement can be extremely important in the nuclear fusion energy industry, but also in many other energy fields. It is easy to see that an accelerated electron can penetrate a proton in order to transform it into a neutron if the minimum kinetic energy of the penetrating by the accelerating electron is between the values of (10-103 [MeV]).

Keywords: Proton, Electron, Neutron, A Down Quark, An up Quark, Nuclear Fusion, Hydrogen Proton, Kinetic Energy

Introduction

A nuclear reactor is a technological installation in which a nuclear fission reaction takes place in a chain under controlled conditions so that the heat resulting from the fission process can be harnessed.

Nuclear reactors have three types of applications.

The most significant commercial application is the production of electricity or heat (district heating, industrial processes).

Another application is naval propulsion (especially for military purposes).

There are also nuclear reactors for research where neutron beams are used for scientific activities or for the production of radioisotopes for civilian (medical, industrial, research) or military (nuclear weapons) uses.

Enrico Fermi and Leó Szilárd, both of the University of Chicago, were the first to build a nuclear cell and presented a controlled chain reaction on December 2, 1942. In 1955 they shared their patent for the U.S. nuclear reactor. Patent 2,708,656. The first US nuclear reactor was used to produce plutonium for a nuclear weapon. Other reactors were used in naval propulsion (submarines, military ships).

On December 20, 1951, in the USA, electricity was generated for the first time using nuclear fission at the fast Experimental Reactor (EBR-1) located near Arco, Idaho. On June 26, 1954, the Obninsk nuclear reactor began generating electricity. Other power reactors began operating at Calder Hall in 1956 and Shippingport - Pennsylvania in 1957. The expression of optimism about nuclear power was the famous phrase of Lewis Strauss, president of USAEC "too cheap to matter".

Commercial use of nuclear power begins with the 250 MWe Yankee Rowe Prototype Reactor (PWR) commissioned by Westinghouse in 1960 and the 250 MWe Dresden-1 reactor (BWR) designed by General Electric and fully commissioned in 1960. Canada developed the CANDU reactor, with the first unit commissioned in 1962. France began the development of the graphite gas reactor and commissioned the first commercial reactor in 1959. It later adopted the PWR line, which it still develops today. The Soviet Union launched the first commercial prototype (graphite and boiling water) of 100 MW in Beloyarsk. He later developed the light water supply chain known as VVER. The 1973 oil embargo gave a strong impetus to nuclear power. The most spectacular nuclear program was the French one, which totals 34,900 MWe. In addition to the USA (20% of electricity production), major nuclear programs have been launched in many European countries (Germany, Sweden, Spain, Belgium, Italy, Switzerland, Finland, the Czech Republic) or Asia (Japan, South Korea).

Stagnation and the decline of nuclear energy began in the late 1970s and are determined by several factors:

- The discovery in the North Sea of huge quantities of natural gas which represented in Europe a cheaper energy alternative to nuclear energy

- The detonation of the nuclear weapon by India in 1964, representing the beginning of nuclear proliferation in the military field
- The birth of the ecological movement that generally opposed the construction of new reactors
- The introduction in the USA of a new authorization regime for environmental protection that has made the construction of nuclear power plants uneconomical
- The accidents at Three Miles Island (1979) and Chernobyl (1986) with impressive consequences for the public image of nuclear energy

Despite the problems of the 1980s and 1990s, nuclear power has not disappeared from the market. On the contrary, the third generation of nuclear reactors has been developed in the USA (ABWR, System +), France (EPR), Canada (ACR), Russia and South Korea.

In 2001, the charter of the International Forum for Generation IV (GIF) was signed. The purpose of this association is to develop six nuclear power systems (thermalized neutron reactors: VHTR, SCWR, MSR and fast neutron reactors: GFR, SFR, LFR) to a commercial level so that they can be built in 2015-2023 or later.

The renaissance of nuclear energy began to take shape at the beginning of the third millennium, is determined by two factors:

- Rapid economic growth in large developing countries (China, India, Brazil)
- Climate change caused by greenhouse gases from burning fossil fuels

Research into nuclear fusion began in 1920 when physicist F.W. Aston discovers that four hydrogen atoms are heavier than one helium atom. Astrophysicist Edmund Eddington immediately noticed that the difference in mass is converted into energy by the reactions that take place in the Sun. After the construction of the thermonuclear weapon, since the 1958 Geneva Conference, controlled nuclear fusion has become a field of research supported by the governments of the great powers (USA, USSR) and international organizations (EURATOM). An important moment in the development of nuclear fusion research is the construction in the USSR (1968) of the TOKAMAK facility, which was later adopted by almost all countries. The largest fusion experiment was performed by the JET plant in England where the fusion reaction of deuterium and tritium produced more energy than it consumed (16 MW for 1 sec).

The ITER project launched in 2003 is a scientific experiment aimed at demonstrating the feasibility of commercial production of fusion energy. The ITER plant is designed to generate a net power of 500 MW, i.e., ten times the power consumed. The ITER plant is expected to be operational in 2020, with a commercial prototype fusion reactor set to be operational in 2040.

Fission nuclear reactors, regardless of their destination, have the following common elements:

Nuclear fuel the fission chain reaction takes place in nuclear fuel. Almost all nuclear reactors use uranium as fuel. Commercial reactors, with a few exceptions, use 2-5% enriched uranium in the U235 isotope. Some reactors use a fuel that contains in addition to uranium and plutonium MOX, another fissile element. The fuel and the mechanical structure in which it is placed form the active area (heart) of the reactor.

Moderator The neutron moderator is needed to slow down neutrons resulting from fission (thermal neutrons) to increase their efficiency to produce new fission reactions. The moderator must be a light element that allows neutrons to collide without being captured. Ordinary water, heavy water, or graphite is used as moderators.

Coolant to keep the fuel temperature within technically acceptable limits (below the melting point) the heat released by fission or radioactive decay must be extracted from the reactor using a coolant (ordinary water, heavy water, carbon dioxide, helium, metals melted, etc.). The heat taken up and transferred by the coolant can power a turbine to generate electricity.

Control bars Control bars are made of neutron-absorbing material such as boron, silver, indium, cadmium and hafnium. They are introduced into the reactor to reduce the number of neutrons and stop the fission reaction when necessary, or to regulate the level and spatial distribution of power in the reactor.

Other components some reactors have an active area coated with a reflector that aims to return neutrons leaving the reactor and maximize their efficient use. Often the coolant and/or the moderator also act as a reflector. The active area and the reflector are arranged inside a pressure-resistant vessel (reactor vessel). To reduce the level of radiation produced by fission, the active area is surrounded by thick screens that absorb radiation: Concrete, ordinary water, lead, etc. The control and regulation of the reactor operation are performed with the help of numerous instruments and logistic support systems that monitor (monitor) the temperature, pressure, radiation level, power level and other parameters.

A nuclear fusion reactor heats the fuel composed of deuterium and tritium until it is transformed into very hot plasma in which the fusion reaction takes place. Outside the plasma, the chamber is a Lithium mantle that absorbs energy neutrons from fusion to produce tritium fuel. In the mantle, the neutrons also produce heat which is discharged with a water cooling loop and transferred to a heat exchanger to produce steam. The steam drives a turbine producing electricity.

Nuclear reactors can be classified according to the type of nuclear reaction used, the materials used in the

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construction of the plant, the use of energy produced and the stage of development of the technology.

Depending on the nuclear reaction used, reactors are classified into:

- Fission reactors (with thermal neutrons or fast neutrons)
- Fusion reactors

Depending on the nuclear fuel used, the reactors are classified into:

- Solid fuel reactors (uranium oxide, plutonium oxide, thorium oxide or combinations)
- Liquid fuel reactors (molten uranium or thorium salts)

Depending on the moderator used, the reactors are classified into:

- Light water reactors
- Heavy water reactors
- Reactors with the organic moderator (PCB)
- Graphite reactors
- Reactors with light elements (Lif, BeF2)
- Reactors without a moderator (with fast neutrons)

Depending on the coolant used, the reactors are classified into:

- Light water reactors (under pressure or boiling)
- Heavy water reactors
- Gas reactors (helium, carbon dioxide, nitrogen)
- Liquid metal reactors (sodium, NaK, lead, eutectic lead-bismuth, mercury)
- Reactors with molten salts (fluorine salts)

Depending on the use, the reactors are classified into:

- Reactors for electricity production
- Reactors for the production of thermal energy (process heat, desalination, hydrogen production, district heating)
- Propulsion reactors (ships, submarines)
- Reactors for the production of radioisotopes by transmutation (plutonium, U233, radioisotopes for medical or industrial use)
- Research reactors

Depending on the state of the art, the reactors are classified into:

- First-generation reactors, first prototypes (Shippingport, Magnox, Fermi 1, Dresden)
- generation II reactors, designed before 1990 (PWR, BWR, PHWR, AGR, WWER)
- generation III reactors, upgrades of generation two reactors (ABWR, APWR, EC-6, VVER 1000/392, AHWR-thorium)
- Generation III + reactors, projects with significant improvements in safety and economy (advanced CANDU, EPR, VVER 1200, APWR, ABWR)
- Generation IV reactors, designed to be built after 2030 (very high-temperature thermal reactor, supercritical water heat reactor, molten salt thermal reactor, gas-cooled rapid reactor, sodium-cooled reactor, sodium-cooled reactor lead)

Commercial Reactors

Pressurized Water Reactor (PWR), the most widespread worldwide, uses ordinary water as a moderator and coolant. The cooling water is kept under high pressure so as not to boil inside the reactor pressure vessel and the primary circuit. The heat taken from the active area is transferred to a heat exchanger where steam is produced to drive the turbine and generate electricity. The Russian name for this type of reactor is VVER.

Boiling Water Reactor (BWR) Ordinary water is used as a moderator and coolant. The cooling water is maintained at a much lower pressure than the PWR allowing it to boil in the reactor vessel and the steam is sent directly to the turbine to generate electricity. The absence of the steam generator simplifies the project but causes contamination of the turbine.

Pressure Heavy Water Reactor (PHWR) as with the PWR reactor, in this reactor the coolant (heavy water) circulates through steam generators where the thermal energy taken from the fission reaction is transferred to ordinary boiling water producing steam. The PHWR reactor has a particular structure consisting of the moderator vessel (Calandria) maintained at low pressure and temperature, which is traversed by tubes containing fuel and through which heavy cooling water flows at high pressure. This individually accessible fuel tube structure allows the fuel to be changed without shutting down the reactor. This feature of the reactor increases its availability but also the complexity of an operation. Gas-Cooled Reactor (GCR) is still used only in the UK. There are two types of this reactor: Magnox (with natural uranium) and AGR (with enriched uranium). Both use carbon dioxide as a coolant and graphite as a moderator. Having a structure similar to CANDU can be refueled without stopping.

RBMK Reactor The acronym is in Russian and refers to a reactor with moderate boiling water with graphite and having a structure with pressure tubes similar to CANDU. Such a reactor exploded at Chernobyl with known consequences. Fast reactor - FBR The fast reactor operates on the basis of the fast neutron fission reaction. The fission reaction with fast neutrons releases more neutrons than the one with thermal neutrons. Excess neutrons are used to transmute ^{238}U or ^{232}Th into fissile isotopes (^{239}Pu and ^{233}U, respectively). For this reason, fast non-neutron reactors are also called reproducers (they generate more fissile material than they consume). Rapid reactors are cooled with molten metals (sodium, lead) or gases (helium).

The operation of the nuclear reactor is based on the neutron-induced fission reaction through which energy is released and the process can be controlled by controlling the number of available neutrons:

^{235}U + n → 2 fission fragments +2 or 3 neutrons + β, γ + energy

Because neutrons released by fission can induce other fissions, the possibility of perpetuating the reaction (chain fission) arises. Under optimal conditions, the fission reaction is maintained at a constant level and we have a controlled chain reaction.

Neutrons expelled by fission have a kinetic energy corresponding to a speed of about 13,800 km/s (fast neutrons). In order to produce uranium fission, the neutrons must have much lower energies, i.e., be in thermal equilibrium with the environment (thermal neutrons). Rapid neutrons are slowed down by colliding with the moderator atoms. Hydrogen (from light water) with a mass equal to that of the neutron would seem the best moderator but it can easily absorb neutrons by decreasing their number. Deuterium (from heavy water) has the advantage that it absorbs fewer neutrons making it easier to perpetuate the chain reaction.

In the reactor, the number of neutrons is the result of the competition between the fission process (which generates neutrons) and the unproductive processes of absorption in the reactor materials or leakage out of the reactor. The self-maintenance of the fission reaction depends on the speeds of the mentioned processes which determine the multiplication constant:

- keff = Production speed/(absorption rate in materials + reactor discharge rate)
- keff <1 The number of neutrons decreases over time and the reactor shuts down (subcritical regime)
- keff = 1 Car chain reaction maintained (critical steady-state)
- keff> 1 The number of neutrons is constantly increasing (supercritical regime)

Nuclear Reactor Kinetics

The notion of reactivity is used in the physics of the nuclear reactor:

ρ = 1-1/keff (real net neutron production)

The nuclear reactor usually operates in a steady-state (ρ = 0). When it is desired to reduce the power of the reactor or to stop it, negative reactivity is introduced, with the help of neutron-absorbing devices containing boron, cadmium, or gadolinium. When starting the reactor, positive reactivity is introduced for a short time, by removing the neutron absorption devices. Neutrons produced by fission can be prompt or delayed. For prompt neutrons, the time interval between their birth and absorption in a fission reaction is about 0.9 milliseconds. Delayed neutrons are generated by the beta decay of fission fragments with a lifespan of between 0.2 and 50 sec. Delayed neutrons have a great influence on the evolution of the reactor power and considerably facilitate its control. Among the fission fragments, the ^{135}Xe isotope has an important role in the operation of the nuclear reactor because it has a high capacity to absorb thermal neutrons. This radioactive isotope is produced by the beta decay of ^{135}I (half-life of 9.169 h) and disappears in two ways: By decay and by absorption of a neutron with the transformation into ^{136}Xe. When the reactor is stopped, the balance between the generation and consumption of ^{135}Xe is disturbed because the transformation path in ^{136}Xe disappears. The result is a sharp decrease in reactivity (xenon poisoning) about 10 h after shutting down the reactor. The reactor can only be restarted after 35-40 h when the xenon concentration decreases by decay to the level before shutdown.

By fission a part of the mass of the fissile atom is transformed into energy: -85% in the form of the kinetic energy of fission fragments, -15% as the kinetic energy of neutrons and β or γ particles; Kinetic energy is converted into heat that must be removed from the fuel by the coolant. Fission fragments are nuclei with a mass equal to about half that of uranium that are unstable and disintegrate radioactively. Typical radioisotopes resulting from the disintegration of fission fragments are ^{137}Cs and ^{90}Sr.

Because the decay reaction generates heat (decay heat) even after the reactor is shut down, it must be evacuated permanently, otherwise, the fuel overheats leading to a nuclear accident. The cumulative amount of energy generated in the fuel is called the degree of combustion and is expressed in MW.day/tonne of Uranium or MW.hour/kg of uranium. The degree of combustion is a quantity inversely proportional to the fuel consumption expressed in Mg (U)/GW (e).

In addition to the radioisotopes resulting from fission in the reactor, the transmutation of U^{238} into Pu^{239} takes place by the reaction:

$$^{238}U + n \rightarrow {}^{239}U \rightarrow {}^{239}Np + \beta \rightarrow {}^{239}Pu + 2\beta$$

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^{239}Pu is a fissile isotope and contributes to energy production. By successive neutron uptake, it can be transformed into ^{240}Pu (non-fissile) and ^{241}Pu (fissile). The half-life of ^{239}Pu is 24,000 years.

Tritium, a highly mobile radioisotope, can be generated by fission (1/10,000) as well as by the absorption of a neutron by deuterium from heavy water. Tritium is a low-energy beta emitter, its radiation does not penetrate the skin, but when inhaled or ingested with food or water it presents the danger of internal irradiation.

Nuclear fusion is the combination of two light nuclei into a heavier nucleus. The fusion or thermonuclear reactions of light elements are typical reactions that take place in the Sun and other stars. Indeed, in the Sun, every second, 657 million tons of hydrogen is converted into 653 million tons of helium. The missing 4 million tons are then converted into radiation - this phenomenon ensuring the brightness of the Sun. Extreme temperatures and high pressure create a state of matter, strongly ionized, called plasma and which is maintained in that volume by gravitational forces.

A fusion reaction in which a relatively large amount of energy (27.7 MeV) is released is one in which four protons interact leading to the formation of a helium nucleus (an alpha particle). Because hydrogen isotopes are used in this process and hydrogen is practically all around us, the idea of obtaining energy from its fusion is extremely attractive: It basically provides an unlimited source of energy for future generations!

Fusion reactions, however, are not easy to accomplish on Earth. It must be borne in mind that the required temperatures are extremely high, generally in the order of hundreds of millions of degrees Kelvin. and once the hot plasma is created, the problem of maintaining it remains, which is not an easy one.

To initiate the fusion reaction, the Coulomb repulsion between the nuclei must be defeated. Thus they must have high incident kinetic energies from a few keV to a few hundred keV (we neglect here the possibility of initiating fusion at low temperatures through the so-called meson-catalyzed fusion). It is relatively simple to accelerate light particles to these energies. However, the energy required for the operation of particle accelerators far exceeds the energy accumulated in the fusion process. It is more efficient to use an alternative solution: The kinetic energy of the reactants can occur as a result of the high temperature of a particulate gas. At temperatures of tens or hundreds of millions of degrees Kelvin, electrons are expelled from atoms, the reactants existing as hot plasma. This is why we talk about "thermonuclear" reactions.

The main technical problem is related to the generation of extremely high temperatures and pressures in the ionized gas - plasma - and its isolation for a long enough time, so as to trigger the release of energy. Once this is done and sufficient fusion reactions take place, the conditions are self-sustaining so that continuous energy production can be achieved.

The condition for the release of energy from a thermonuclear reactor is given by Lawson's criterion that the product between the density of plasma nuclei and the time of confinement at the ignition temperature must exceed a certain threshold value.

The need to have a high temperature means that the plasma does not come into contact with the walls. Therefore, special plasma isolation techniques must be used.

There are three methods of isolating plasma: Gravitational, magnetic and inertial. In stars, the insulation is due to gravity, which creates sufficiently high pressure. This type of isolation cannot be applied on Earth. Instead, strong magnetic fields can be used to capture plasma by the magnetic confinement method or the inertial confinement method by compressing hydrogen granules with a powerful laser or a particle beam.

In the case of magnetic confinement, where the particle density is higher, about $10^{20}/m^3$, the confinement time given by the Lawson criterion must be greater than 1s. In the case of inertial confinement, the typical density is $10^{31}/m^3$ and the confinement time must be of the order of 10^{-11}s.

Deuterium can be easily obtained from water (30 grams per cubic meter). Tritium must be produced in either a nuclear reactor or a lithium fusion reactor, an element that can be found in the earth's crust in large quantities.

This can be achieved by making a thick layer of lithium (about 1 m), which also contains beryllium and which surrounds the reactor core. Lithium will absorb neutrons that are slowed down in this layer and turn into tritium and helium. The energy thus released heats the blanket, thus starting to generate conventional energy. The use of beryllium is motivated by maintaining a sufficient number of neutrons in the system.

The motion of the charged particles in the plasma can be controlled by an external magnetic field. In systems with magnetic confinement, called Tokamak reactors, plasma (D-T for example) is heated and confined to a density of about 1021 particles per cubic meter. The magnetic field is designed so that the particles remain inside the enclosure, otherwise, the temperature would drop below the value at which the fusion occurs.

At such temperature values, the pressure due to the magnetic field is also impressive. For a particle density such as that in the atmosphere of approximately 10^{27} particles per cubic meter and for thermal energy of 10 keV, the magnetic pressure must exceed 10^8 hPa. The field generating coils and their mechanical supports cannot withstand such pressures! To reduce the pressure it is necessary to reduce the particle density. In order to meet

Lawson's plasma ignition criterion, it must be maintained under these conditions for a longer period of time.

The most efficient configuration of the magnetic field proved to be the toroidal one. The reactor chamber resembled a donut and had a closed shape like a "magnetic bottle". In fact, to ensure the stability of the plasma, the magnetic field lines follow a helical path. Such isolation is provided by devices known as Tokamak, stellarator and Reverse Pinch Field (RFP).

In a tokamak, a series of coils are placed around the torus-shaped reaction chamber. The transformer core passes through the center of the Tokamak, while the plasma current forms a secondary circuit. The perpendicular, the so-called poloidal field is induced both internally by the plasma current and externally by the poloidal coils arranged along the perimeter of the chamber.

This current heats the plasma to a very high required temperature of about 10 million K. The idea for the tokamak came from Russian physicists Andrei Sakharov and Igor Tamm. The main disadvantage of a tokamak is the relatively narrow range of parameters. The largest Tokamak built so far is the Joint European Torus (JET).

In devices called stellarators, plasma conditions are regulated by currents flowing outside it. The helical lines of the stellar field are produced by a series of coils, which are in turn helical.

The largest star is the Large Helical Device (LHD), which began operating in 1998 at the National Fusion Research Institute in Japan. As no current is induced in the stellar plasma, heating must be obtained by other means, for example, by electromagnetic radiation. Such a technique was developed in Greifswald, Germany. These devices are similar to tokamaks in terms of toroidal and poloidal fields. However, the currents are much stronger and at the same time, the direction of the toroidal field in the plasma is reversed at the edge of the plasma. This type of system works for example in Padua, Italy.

The technique of fusion by inertial confinement consists of the preparation of a D-T pellet which is then heated rapidly to reach temperature and pressure which ensures that the plasma state is reached.

This is done when the pills are compressed by bombarding them with strong, focused laser pulses. Under these conditions, the surface of the pills evaporates and forms a crown-shaped plasma. The plasma expands and generates an inner compression front that causes the pills to implode creating an instantaneous fusion reaction.

The most advanced fusion system for inertial confinement is NOVA from the Lawrence Livermore Laboratory in the United States. NOVA researchers have shown that densities 600 times higher than D-T liquid and 20 times higher than lead density can be achieved.

The European Community started the Joint European Torus (JET) program in 1978. The main purpose of the JET was to test fusion, plasma physics and stability conditions. Culham in Great Britain was chosen as the headquarters of JET.

The device, the largest tokamak produced to date, was put into operation in 1983 and the first controlled fusion was produced in November 1991. In 1997 a record power of 16 MW was obtained for one second with a deuterium fuel. tritium. JET's experience has shown that a controlled merger is possible.

Its successor is the ITER - International Tokamak Experimental Reactor, an international scientific and engineering project that builds the largest nuclear tokamak fusion reactor in Cadarache, France. The ITER project aims to make the transition from experimental studies of plasma physics to large-scale energy production in fusion power plants.

The National Ignition Facility (NIF) located in California, USA is the facility with the largest and most powerful laser in the world. One of its goals is to achieve nuclear fusion and a positive energy balance for the first time - in essence, it aims to achieve a miniature star on Earth.

NIF uses very powerful lasers to heat and compresses a small amount of hydrogen-based fuel to the point where nuclear fusion reactions take place. The NIF is the largest and most powerful inertial confinement device ever built and the first to reach the regime of producing more energy than was used to ignite. Its mission is to carry out nuclear fusion in the laboratory and to support the nuclear military program by studying the behavior of matter under the conditions found inside nuclear weapons.

Extreme temperatures and pressures in the NIF target chamber will allow researchers to conduct unique experiments in high-energy-density physics and obtain new information about astrophysics such as supernovae, giant planets, or black holes.

Fusion is the opposite process of the nuclear fission reaction. In the latter, nuclei with smaller masses are obtained from a heavy nucleus and the sum of the masses produced is less than the mass of the heavy nucleus. In the case of the fusion process, the mass of the heavy nucleus is less than the sum of the initial masses of the colliding nuclei.

In order to initiate the fusion reaction, the relative energies of the colliding nuclei (positively charged particles!) Must be large enough to overcome the electrical repulsion. Therefore, in order to form helium atoms by fusing deuterium and tritium, for example, the nuclei that form the fuel must be kept under extremely high temperature and pressure conditions.

In the mentioned reaction a neutron is produced. This neutron has a very high kinetic energy, which is released during the deceleration process. This energy can be converted into heat to produce steam, which in turn can then pass into the turbine to generate electricity. Neutrons produced in such fusion reactions can also be used to produce depleted uranium nuclear fuel, i.e., uranium containing less than ^{235}U than natural (0.72%).

When fusion will be mastered, the planet's energy problems will be solved for a long time in a sustainable and non-polluting way (Aversa *et al*., 2017a-b; 2016a-b; Halliday and Robert, 1966; Kramer, 2011; Krane and Halliday, 1987; Moses *et al*., 2009; Petrescu, 2020a-c; 2019; 2014; 2012a-c; Petrescu and Petrescu, 2019; Petrescu *et al*., 2016a-d; Petrescu and Calautit, 2016a-b; Shultis and Faw, 2002).

Materials and Methods

As we already said in order to discuss in more detail the fusion of two hydrogen protons, it could be interesting to study more widely the quarks inside the proton and other elementary particles with which they can interact.

Protons (from the Greek πρῶτον = first) are subatomic particles in the nuclei of all atoms, with mass mp = $1{,}673\cdot10^{-27}$ kg and positive electric charge qp = e = $1{,}602\cdot10^{-19}$ C (Fig. 1).

The number of protons is characteristic of all atoms of an element chemical. It represents the number of nuclear charges Z (the number of positive electrical charges). The number of protons determines the position of the element in Mendeleev's periodic system: The number of protons = the number of nuclear charges = the order number. The proton is symbolized by p +.

Because all the protons of an atom have a positive charge and are all in the nucleus, the question arises why they do not repel, a common physical phenomenon in particles with the same sign of electric charge. The answer is given by the quantum field theory: Protons interact not only by electrostatic force but also by strong nuclear forces. The latter is transmitted by gluons.

Protons were discovered in 1919 by physicist Ernest Rutherford.

The problem of defining the radius of a nucleus is similar to the problem of atomic radius, in the sense that neither atoms nor their nucleus has clear delimitations. However, the nucleus can be represented as a positive charge sphere to analyze the results of electron beam scattering experiments. Because the nucleus has no well-defined limits, electrons "see" a series of effective sections that can be considered an average.

A proton (Fig. 1) is composed of three quarks, two up and one down. Each up quark has a positive charge of 2/3e + and the down quark has a negative charge of 1/3e-.

The most logical thing is to position the three quarks of a proton glued together, with no space between them, as we noticed that the whole world of particles is constituted, similar to those in Fig. 2, in which case between the radius of a quark *r* and that of the proton *R* appears relation (1):

$$r = \left(2\cdot\sqrt{3}-3\right)\cdot R \quad (1)$$

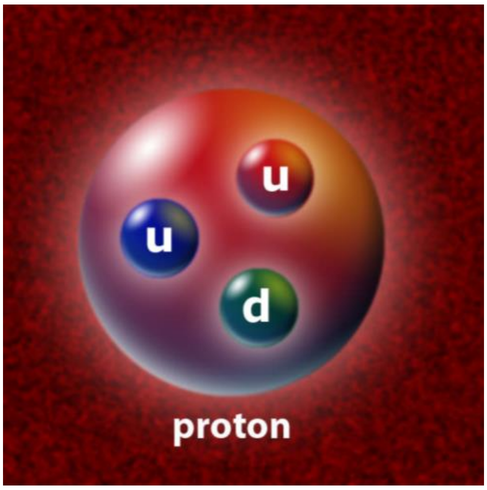

Fig. 1: A proton

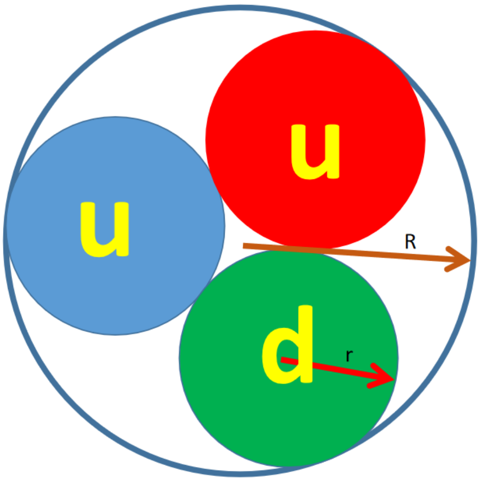

Fig. 2: A proton imagined by the authors

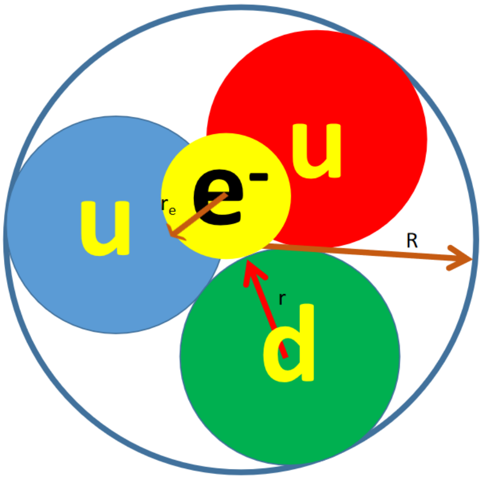

Fig. 3: A proton imagined by the authors penetrated by an electron accelerated until the limit to that, the electron can be a neighbor with the negative down quark

The minimum kinetic energy required for an accelerated electron to penetrate the proton to join the down quark (negative as a charge) is calculated by the relation (2), Fig. 3, so that the accelerated electron can stick even to the negative quark, at a distance *r* from it, considering the radius of the electron r_e being negligible in relation to that of a quark, *r*:

$$U_{\min}[J] = \frac{1}{4\pi \cdot 8.8541853E-12} \cdot \frac{(-)1.602E-19 \cdot (-)\frac{1}{3}1.602E-19}{\left(2\sqrt{3}-3\right) \cdot R} \quad (2)$$

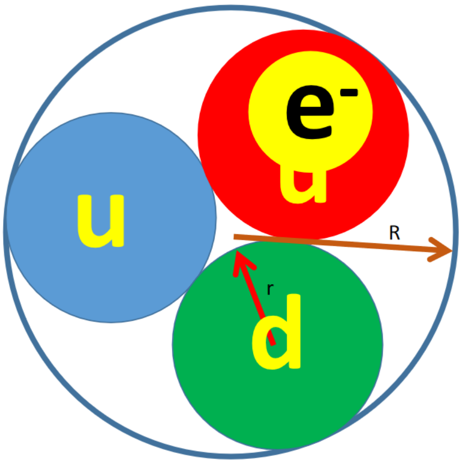

Fig. 4: Under these conditions the electron can penetrate an up quark, which become a down quark

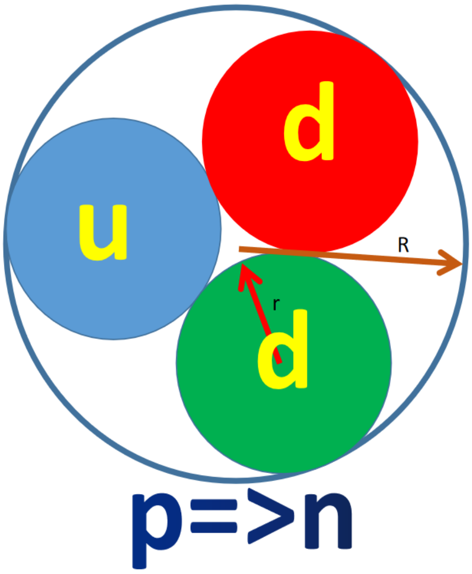

Fig. 5: Under these conditions the electron can penetrate an up quark, which become a down quark, so that the proton practically becomes a neutron

It results immediately from relation (2) relation (3) which shows the value of the product between the minimum kinetic energy $U_{\min}$ (of electron acceleration, given in J) and the proton radius *R*, in m:

$$U_{\min}[J] \cdot R[m] = \frac{1.602^2 E-26}{12\pi \cdot \left(2\sqrt{3}-3\right) \cdot 8.8541853} \quad (3)$$

It is more convenient to express the minimum kinetic energy required in eV, the relation (3) thus acquiring the form (4):

$$U_{\min}[eV] \cdot R[m] = \frac{1.602^2 \cdot 6.242E-8}{12\pi \cdot \left(2\sqrt{3}-3\right) \cdot 8.8541853} \quad (4)$$

Under these conditions the electron can penetrate an up quark (Fig. 4) and transform it into a down quark (Fig. 5), so that the proton practically becomes a neutron.

Results and Discussion

The paper (Petrescu and Calautit, 2016a) presents at the end a table with the normal dimensions of the proton radius at its various speeds, dimensions that are between 1E-16 and 1E-17 [m].

Using the Equation (4) one obtains the values of the accelerated electron minimal kinetic energy ($U_{\min}$) which may transform a proton into a neutron:

R = 1E-016 [m], $E_c = U_{mine}$ = 10.3408439079 [MeV]
R = 1E-017 [m], $E_c = U_{mine}$ = 103.4084390786 [MeV]

It is easy to see that an accelerated electron can penetrate a proton in order to transform it into a neutron if the minimum kinetic energy of the penetrating by the accelerating electron is between the values of (10-103 [MeV]).

The observation is extremely important and useful in the processes of industrial fusion of matter.

About one in every 6,000 hydrogen atoms around us (including hydrogen in water) is a deuterium atom. This abundance motivates research to design fusion reactors - fuel resources would be provided for billions of years!

For comparison: In order to produce 1 GW-year, about 35 tons of UO^2 is needed in the case of fission and about 100 kg of deuterium and 150 kg of tritium for fusion. Another aspect that makes fusion more attractive is the almost complete absence of any radioactive residue. In particular, no material that could be used for the production of nuclear weapons will result from the operation of such a fusion power plant. Also, unlike nuclear reactors, in which fission is used, an explosion of the plant is practically impossible: If an explosion occurs, the plasma would start to expand and cool, thus stopping the fusion process.

But this does not mean that there are no risks associated with fusion reactors. In particular, the mass production of neutrons and tritium, which is radioactive, must be taken into account. The presence of molten lithium salts and carcinogenic beryllium can also be a problem.

As in fission reactors, quite a lot of ionizing radiation (neutrons, in particular) is produced. Therefore, an important issue related to the protection against radioactivity induced throughout the installation is expected.

A possible accident in the magnetic system, which stores extremely large amounts of energy, must be seriously considered. In 1992 a team called the European Safety Assessment of Environmental and Merger Power (SEAFP) was formed.

The aim of the team is to comment on the design of nuclear fusion power plants, on the safety conditions and to assess their impact on the environment. According to SEAFP assessments, the main advantages of fusion compared to fission are that in the worst-case scenario of an accident, the radiation emission produced will not cause the population in the area to be displaced. In addition, radioactive waste produced in fusion plants decomposes relatively quickly and does not require isolation from the environment.

A possible problem is related to the release of radioactive tritium into the environment. This radioactive gas is very penetrating, dissolves easily in water and can act for a long time (the half-life of tritium is about 12 years).

It is important to check if the size of the accelerated electron corresponds to the proton so that the electron can approach the proton and have the possibility to slip right inside it to turn it into a neutron.

We use Equation (5) to determine on Beta the ratio between the speed of the accelerated electron and the speed of light, with the help of the minimum necessary kinetic energy, 103 MeV and the rest mass of the electron m_0, where c represents the speed of light in vacuum:

$$\beta^2 = -\frac{2 \cdot E_c^2}{c^4 \cdot m_0^2} + \frac{2 \cdot E_c}{c^2 \cdot m_0} \cdot \sqrt{1 + \frac{E_c^2}{c^4 \cdot m_0^2}} \quad (5)$$

A corresponding minimum value of 0.9999969468 is obtained for Beta, with the help of which from the corresponding table (Petrescu and Calautit, 2016a), we extract the approximate value of the accelerated electron radius as being 8E-16 [m], a value close to that of the proton (1E-16 [m]), but slightly higher than this, but this value corresponds to the minimum kinetic energy required to accelerate the electron, so we can increase this value accordingly so that the electron radius continues to fall below the value of the proton and even below the radius of a quark inside the proton, in order faster penetration. We do not want to further develop other calculations on this topic because only the experiment used together with the theory proposed in this study will speak for itself.

Nuclear Safety

The production of electricity using nuclear reactors, like any complex technology, has a number of associated risks: Radiological risk to personnel and the public, nuclear accidents, radioactive environmental pollution and radioactive waste. In order to prevent the risks from materializing, the design and operation of the nuclear reactor use the concept of Deep Defense, which provides for measures to prevent defects and accidents, protect workers and the public against radiation, safe management of radioactive waste, ensure the safety of nuclear materials (Safety Design of NPP).

Deep defense is achieved by supplementing the intrinsic safety features of reactors with measures to prevent, monitor and mitigate the consequences of accidents. Depth defense is structured on five levels, so that if one level does not cope it is corrected or offset by the next. The goal of the first level of protection is to prevent abnormal operation or system failure. If the first level falls, the second level of protection monitors abnormal operation or detects system failure. When the second level falls, the security functions are provided by the third level that activates specific security systems. When the third level falls, the development of the accident is kept under the control of the fourth level to prevent the aggravation of the accident and the release of radioactive substances outside. The last level aims to reduce the radiological consequences of the accident outside the premises by implementing emergency plans.

From the point of view of safety, the nuclear reactor has three basic functions:

- Reactivity control
- Fuel cooling
- Isolation of radioactive substances

In order to keep the power of the reactor under control, it is equipped with reactivity control systems that keep the fission reaction rate constant and if necessary stop the reactor immediately by inserting negative reactivity. The fission and disintegration heat must be evacuated from the reactor beforehand, even after the reactor has been switched off, otherwise the fuel melting accident will occur. To prevent this accident, the reactor has emergency systems that inject cooling water. The isolation of radioactive materials inside the reactor and the prevention of their spread in the environment is achieved through multiple barriers: The fuel and the fuel element sheath, the reactor vessel, the reactor envelope and the reactor location area.

Environment Protection

The nuclear reactor generates four streams of radioactive substances (waste) that can affect the environment:

- Spent nuclear fuel containing most fission-generated radioisotopes
- Mining and uranium waste containing uranium decay products
- Release of radionuclides during operation (gaseous and liquid emissions)
- Release of large amounts of radioactivity during accidents

In addition to radioactive substances, the nuclear reactor also releases large amounts of heat into the environment, which thermally pollutes the water or the atmosphere. The main objective of radioactive waste management is to protect people and the environment from the harmful effects of nuclear radiation. This is done by isolating or diluting the radioactive waste so that the concentration of any radionuclide that reaches the biosphere is not harmful. The management of radioactive substances (waste) generated by the nuclear reactor is based on three principles:

- Concentration and isolation
- Storage for disintegration
- Dilution and dispersion

Some weakly radioactive liquid waste resulting from the operation of the nuclear reactor is released under controlled surface water provided that the associated dose is only a small fraction of the natural background. The nuclear reactor releases small amounts of radioactive gases (^{85}Kr, ^{133}Xe, ^{131}I, tritium) on average under controlled conditions. The most difficult issue is the management of spent nuclear fuel, which contains most of the radioactivity generated in the nuclear reactor. A major difficulty is the extremely long half-life of certain radionuclides: ^{129}I (15.7 million years), ^{99}Tc (220,000 years), ^{237}Np (2 million years), ^{239}Pu (24,000 years). Therefore, the isolation of this waste from the biosphere requires their disposal in deep geological structures where the decay of radionuclides takes place without affecting the biosphere. Transuranic elements in the radioactive waste can be separated and transformed by transmutation into other radionuclides with short half-lives, which are easier to manage.

Conclusion

The fusion processes of matter are difficult to achieve and control today, but they are extremely necessary for humanity.

It is imperative that theoretical and experimental studies be further supported by all possible efforts because the completion of these processes will lead to clean, friendly energy, endlessly, bringing great benefits to mankind in the future, a future that we hope will be as close as possible.

The final resolution of energy crises in the future so that they do not occur will effectively lead to a better life for all people, but also to some important achievements for humanity in the most essential areas of life.

Using the Equation (4) one obtains the values of the accelerated electron minimal kinetic energy (U_{min}) which may transform a proton into a neutron.

It is easy to see that an accelerated electron can penetrate a proton in order to transform it into a neutron if the minimum kinetic energy of the penetrating by the accelerating electron is between the values of (10-103 [MeV]).

The observation is extremely important and useful in the processes of industrial fusion of matter.

So far, all the promises and hopes for energy production have proved to be premature - it has not been long since the first successful experiments in which the energy obtained was equal to that introduced (first to the American TFTR system and the Japanese JT60 and then the Joint European Torus - JET).

The main difficulties are: Producing a stable plasma configuration, finding materials that can withstand the large fluxes of neutrons produced and extracting as much energy as possible, more than is introduced.

Currently, the most advanced commercial energy production project is ITER, which started in 1985. The project has seen new progress since the establishment of ITER in 2007, joined by China, the EU, India, Japan, South Korea, Russia and the USA. The plant is being built in Cadarache, France and is estimated to reach a power of 500MW and a gain factor of Q = 5-10 over a period of 30 years.

Construction of the foundation for the building of the future Tokamak - Cadarache reactor, February 2014.

Unfortunately, thermonuclear energy (as well as other forms of energy) has already been used for military purposes, namely in the creation of the hydrogen bomb.

This paper seeks to bring a scientific contribution to the realization of fusion energy on an industrial scale in the future that we hope to be as close as possible.

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Author's Contributions

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Ethics

This article is original and contains unpublished material. Authors declare that are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

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Nomenclature

h => The Planck constant: h = 6.626 E-34 [Js]

q => Electrical elementary load: qe = -1.6021 E-19[C] qp = +1.6021 E-19[C]

c = The light speed in vacuum: c = 2.997925 E+08 [m/s]

The permissive constant (the permittivity):

$$\varepsilon_0 = 8.85418 \cdot 10^{-12} \left[\frac{C^2}{N \cdot m^2} \right]$$

n = The principal quantum number (the Bohr quantum number);

Z = The number of protons from the atomic nucleus (the atomic number);

m0[kg] => The rest mass of one particle

m0electron = 9.11E-31 [kg]

m0proton = 1.672621898(21) E-27 [kg]

m0neutron = 1.674927471(21) E-27 [kg]

m0deuteron = 3.34449 E-27 [kg]

m0triton = 5.00827 E-27 [kg]

Source of Figures:

Fig. 1
https://www.universetoday.com/56013/proton-parts/

Fig. 2-5
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