Chapter 5
Towards the Study of New Nuclear Energies

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1 Introduction

In 2012 a contribution dealing with a new process for the generation of new nuclear energies has been published by U. Di Caprio in *Hadronic Journal* [9]. Here we recapitulate the main results. The work deals with the dynamical structure of the deuteron and with the illustration of a chain nuclear reaction.

In Chap. 1 is illustrated the dynamical structure of the deuteron; in Chap. 2 it is explained the meaning of the binding energy; in Chap. 3 the values of the spin and of the electric charge. Finally in Chap. 4 we point out a chain nuclear reaction obtained by disintegrating the deuteron by hitting it with the photon of energy 193 MeV.

2 Dynamical Structure of a Deuteron

We postulate that the deuteron consists of two protons p_1, p_2 (conventionally denominated "external proton" and "antipodic proton") plus an "intermediate" electron, in circular rotation around their center of mass within a plane Π_d (Fig. 5.1 (right)). The rotations are synchronous and, at any time proton p_1 is distant R_1 from the center O, proton p_2 is at the antipodes of p_1, at a distance R_2 from O, with

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$R_2 < R_1$. The electron is in turn at the antipodes of p_1 (and then is aligned with p_2) at a distance R_3 from O such that $R_3 < R_2 < R_1$. Denoting V_1, V_2, V_3 the three rotation speeds we assume

$$V_1 = const; \qquad V_2 = const; \qquad V_3 = const \tag{5.1}$$

$$\frac{V_3}{R_3} = \frac{V_2}{R_2} = \frac{V_1}{R_1} \; (synchrony). \tag{5.2}$$

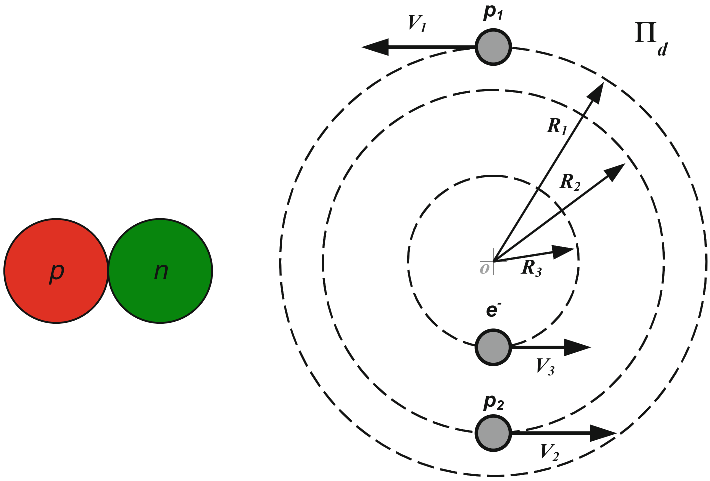

Fig. 5.1: Deuteron structure: SM model of deuteron (*left*), dynamic model of deuteron (*right*)

Another fundamental assumption based upon collateral studies [5, 6], is that each of the two protons is a composite particle formed by three rotating quarks plus a pion, contained within a plane. We assume that planes Π_1 and Π_2 respectively containing p_1 and p_2 form an angle $\psi = 30°$ with plane Π_d of the deuteron (i.e. the horizontal plane of motion of the "point-form" particles p_1, p_2, e). We also assume that in the three-dimensional structure of the deuteron the electron remains pointform (within an approximation of 10^{-19} m) and that its spin and its magnetic moment are perpendicular to Π_d. At any time the center of mass of composite particle p_1 belongs to the intersection of Π_1 with Π_d and represents a mobil point on the circle with radius R_1 and center O (in plane Π_d). Analogously, the center of mass of composite particle p_2 belongs to intersection of Π_2 with Π_d and represents a mobil point on a circle with radius R_2 and center O (in plane Π_d). All in all, the deuteron has a *three-dimensional structure* (Fig. 5.2) and in plane Π_d the distance between the centers of mass of the two protons is in the order 10^{-18} m. It is clear that no overlapping among particles exists in spite of the fact the proton radius (which is about $1.4 \cdot 10^{-15}$ m) is larger than the *distance* between Π_1 and Π_2.

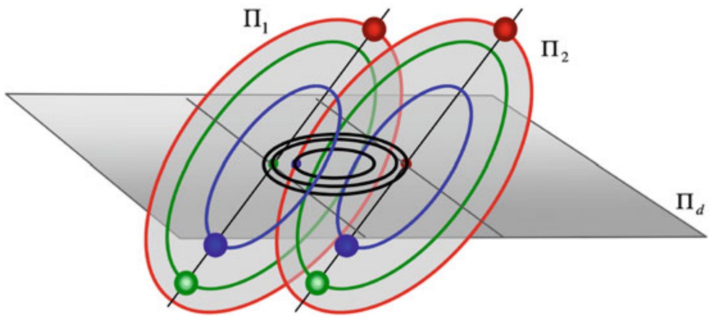

Fig. 5.2: Three dimensional structure of the deuteron

We call *solution of the deuteron problem* any set of values R_1, R_2, R_3, V_1, V_2, V_3, ψ so that the three-body structure in object gives the experimental values of charge, mass, magnetic moment, spin of the deuteron. In addition we want to explain the character of the strong interaction and the experimental value $g_d \sim 14$. Furthermore, we require that the three-body dynamic structure in object be *stable*.

To solve the problem, we use relativistic equations derived from Special Relativity (SR) and the principle of equivalence Potential energy/mass. In particular, for each particle we determine its contribution to the total mass by equations of type

$$\hat{m} = \gamma \left(m + \frac{E_p}{c^2} \right) \tag{5.3}$$

where γ is the relativistic coefficient

$$\gamma = \frac{1}{\sqrt{1-(v^2/c^2)}} \tag{5.4}$$

and E_p is the Coulomb potential energy. So we have three distinct contributions, one for each particle and, in vie of determining total mass we add a fourth contribution (E_H/c^2) that accounts for the inertial effects of the binding electromagnetic energy. The meaning of E_H is explained in Sect. 3. All in all, the mass of the deuteron is given by

$$m_d = (m_1 + m_2 + m_3) + m_4 \tag{5.5}$$

$$m_1 = \gamma_1 \left[m_p + \frac{E_{12}}{c^2} + \frac{E_{13}}{c^2} \right] \; ; \quad m_2 = \gamma_2 \left[m_p + \frac{E_{12}}{c^2} + \frac{E_{23}}{c^2} \right] \tag{5.6}$$

$$m_3 = \gamma_3 \left[m_0 + \frac{E_{13}}{c^2} + \frac{E_{23}}{c^2} \right] \; ; \; m_4 = \frac{E_H}{c^2}$$

$$E_{12} = \frac{kq^2}{R_1 + R_2} \; ; \qquad E_{13} = -\frac{kq^2}{R_1 + R_3} \; ; \qquad E_{23} = -\frac{kq^2}{R_2 - R_3} \tag{5.7}$$

where $k = 1/(4\pi\varepsilon_0)$; ε_0 is the permittivity in vacuum. The rotation speed of p_1 is the maximum allowed by relativistic stability [7, 8]

$$V_1 = v_{\max} = 0.78615\,c \tag{5.8}$$

while the rotation speeds of the other two particles are determined by the isochrony condition (5.2):

$$V_2 = V_1 \cdot \frac{R_2}{R_1}\,; \qquad V_3 = V_1 \cdot \frac{R_3}{R_1}\,. \tag{5.9}$$

The relativistic coefficients γ_1, γ_2, γ_3 are given by

$$\gamma_1 = \frac{1}{\sqrt{1 - V_1^2/c^2}} = \gamma_{\max} = 1.618 \tag{5.10}$$

$$\gamma_2 = \frac{1}{\sqrt{1 - V_2^2/c^2}}\,; \qquad \gamma_3 = \frac{1}{\sqrt{1 - V_3^2/c^2}}\,.$$

We claim that the following set of values identifies a *solution of the deuteron problem*

$$R_1 = 8.955 \cdot 10^{-18}\,\text{m}\,; \quad R_2 = 4.835 \cdot 10^{-18}\,\text{m}\,; \quad R_3 = 0.915 \cdot 10^{-18}\,\text{m} \tag{5.11}$$

$$V_1 = 0.78615 \cdot c\,; \qquad V_2 = 0.42446 \cdot c\,; \qquad V_3 = 0.0803 \cdot c \tag{5.12}$$

$$\psi = 0.786\ [\text{rad}]. \tag{5.13}$$

In fact, they give us

$$E_{12} = 104.41\,[\text{MeV}]\,; \qquad E_{13} = -145.9\,[\text{MeV}]\,; \qquad E_{23} = -367.3\,[\text{MeV}] \tag{5.14}$$

$$\gamma_1 = 1.618\,; \qquad \gamma_2 = 1.1044\,; \qquad \gamma_3 = 1.0032\,. \tag{5.15}$$

Moreover, (see Sect. 3) the electromagnetic energy E_H turns out equal to

$$E_H = 193\ [\text{MeV}]. \tag{5.16}$$

Then

$$m_1 = \gamma_1\,(938.27 + 104.46 - 145.9)\ [\text{MeV}/c^2] = \gamma_1\ 896.83\ [\text{MeV}/c^2] \tag{5.17}$$

$$m_2 = \gamma_2\,(938.27 + 104.46 - 367.33)\ [\text{MeV}/c^2] = \gamma_2\ 675.39\ [\text{MeV}/c^2] \tag{5.18}$$

$$m_3 = \gamma_3\,(0.511 - 145.9 - 367.33)\,[\text{MeV}/c^2] = \gamma_3\ (-512.72)\ [\text{MeV}/c^2] \tag{5.19}$$

$$\begin{aligned} m_1 + m_2 + m_3 &= 1.618 \times 896.83 + 1.1044 \times 675.39 + 1.0032 \times (-512.72) \\ &= 1682.57\ [\text{MeV}/c^2] \end{aligned} \tag{5.20}$$

$$(m_1 + m_2 + m_3) + m_4 = (1682.57) + E_H/c^2 = 1875.57\ [\text{MeV}/c^2] \equiv m_d\,.$$

This proves that the total relativistic mass is equal to the experimental value. Also,

$$m_1 + m_3 = 937.3\ [\mathrm{MeV}] = m_n - 2.26\ [\mathrm{MeV}/c^2] \tag{5.21}$$

$$m_2 + E_H/c^2 = 938.27\ [\mathrm{MeV}/c^2] = m_p \tag{5.22}$$

with $m_n = 939.56\ [\mathrm{MeV}/c^2]$ mass of the neutron. That fully explains the so-called mass deficit of the deuteron.

With regards to the magnetic moment of the deuteron, which is a vector quantity, we assume that the direction is perpendicular to planes Π_1 and Π_2, and since these planes form an angle ψ with the deuteron plane Π_d, we further assume that the magnitude of $\overline{\mu}_d$ is given by

$$\mu_d = \mu_p + \mu_n + \left(-\frac{qV_1R_1}{2} + \frac{qV_2R_2}{2} + \frac{qV_3R_3}{2} \sin\psi \right) \tag{5.23}$$

where

$$\psi = \frac{\pi}{6} = 0.5236 = 30^\circ\,; \qquad \sin\psi = 0.5 \tag{5.24}$$

$$\mu_p = 2.7928 \frac{q\hbar}{2m_p}\,; \qquad \mu_n = -1.913 \frac{q\hbar}{2m_p}\,. \tag{5.25}$$

As

$$\frac{qV_1R_1}{2} = 0.0334 \frac{q\hbar}{2m_p}\,; \ \frac{qV_2R_2}{2} = 0.00979 \frac{q\hbar}{2m_p}\,; \ \frac{qV_3R_3}{2} = 3.45 \times 10^{-4} \frac{q\hbar}{2m_p} \tag{5.26}$$

we find

$$\mu_d = \frac{(2.7928 - 1.913) - 0.0236 + 3.45 \cdot 10^{-4} \sin\psi}{2m_p} q\hbar = 0.85637 \frac{q\hbar}{2m_p} \tag{5.27}$$

in accordance with the experimental value.

The quantity within brackets in Eq. (5.24) represents the dynamical contribution to the deuteron's magnetic moment owing to the rotation of the three point-form particles that form the deuteron in plane Π_d. The direction of $\overline{\mu}_d$ is the famous z direction of particle physics.

We shall subsequently prove that the spin of the deuteron in the direction z is $\hbar$, provided that the direction of the electron spin, as well as that of the electron's magnetic moment, is z (Fig. 5.4).

3 The Meaning of the Electromagnetic Energy (Binding Energy)

Any proton is formed by three rotating particles (with charges $2q/3$, $-q/3$, $2q/3$) and hence generates a magnetic field (Fig. 5.3(right)) [4, 5]. (The three fields are responsible for the well-known magnetic moment of the proton and for quantization of the electron orbits in hydrogen.) In particular, the two protons of the deuteron give rise to two magnetic fields H_1 and H_2 which, owing to the structure of the model are "rotating" fields. So, they induce an electromotive force on the electron and the related electromagnetic energy is:

$$E_H = E_{H_1} + E_{H_2} \tag{5.28}$$

$$E_{H_1} = (\mu_0 H_1) \cdot \frac{qV_1 R_3}{2}\,; \qquad E_{H_2} = (\mu_0 H_2) \cdot \frac{qV_2 R_3}{2} \tag{5.29}$$

μ_0 magnetic permeability in vacuum, with

$$H_1 = \frac{[(2q/3)\, v_1 r_1 - (q/3)\, v_2 r_2 + (2q/3)\, v_3 r_3]}{4\pi (R_1 - R_3)^3} \cdot f(\psi) \tag{5.30}$$

$$H_2 = \frac{[(2q/3)\, v_1 r_1 - (q/3)\, v_2 r_2 + (2q/3)\, v_3 r_3]}{4\pi (R_2 - R_3)^3} \cdot f(\psi) \tag{5.31}$$

where, for each proton, r_1, r_2 and r_3 are the distances of the three constituent particles from the center of mass of the proton while v_1, v_2 and v_3 are the rotation speeds of such particles (see Fig. 5.1(right)). Also ψ is the angle formed by each of the two protons planes with the plane of the deuteron Π_d and according to preceding assumptions $\psi = 30°$ (Fig. 5.2).

The numerical values of the aforesaid quantities are reported in a study by Di Caprio about the dynamical structure of the proton [5]

$$r_1 = 1.399 \times 10^{-15}\,[\text{m}]; \quad r_2 = 1.3788 \times 10^{-15}\,[\text{m}]; \quad r_3 = 1.4 \times 10^{-15}\,[\text{m}] \tag{5.32}$$

$$v_1 = 0.95775\, c; \qquad v_2 = 0.94477\, c; \qquad v_3 = 0.9599\, c. \tag{5.33}$$

The form of function $f(\psi)$ can be deducted from the numerical analysis of the general results on electro-magnetism illustrated by Arenhövel in [1, 2]

$$f(\psi) = \left[1 + \tan\left(\frac{\pi}{2} - \psi\right)\right] \cdot \left[\tan\left(\frac{\psi}{2}\right)\right]^{32/9}. \tag{5.34}$$

Inserting $\psi = \pi/6$ we find the numerical value $f(\psi) = 0.025$. With the above values (and with R_1, R_2, R_3, V_1, V_2, V_3 as given by (5.11), (5.12))

$$E_{H_1} = 5.4664 \times 10^{-12}\,[\text{J}] = 34.12\,[\text{MeV}] \tag{5.35}$$

$$E_{H_2} = 25.4 \times 10^{-12}\,[\text{J}] = 158.93\,[\text{MeV}] \tag{5.36}$$

$$E_H = E_{H_1} + E_{H_2} = 193\,[\text{MeV}] \tag{5.37}$$

in accordance with (5.16).
We claim that E_H is but the binding energy E_B, namely

$$E_B = E_H = 193\,[\text{MeV}]. \tag{5.38}$$

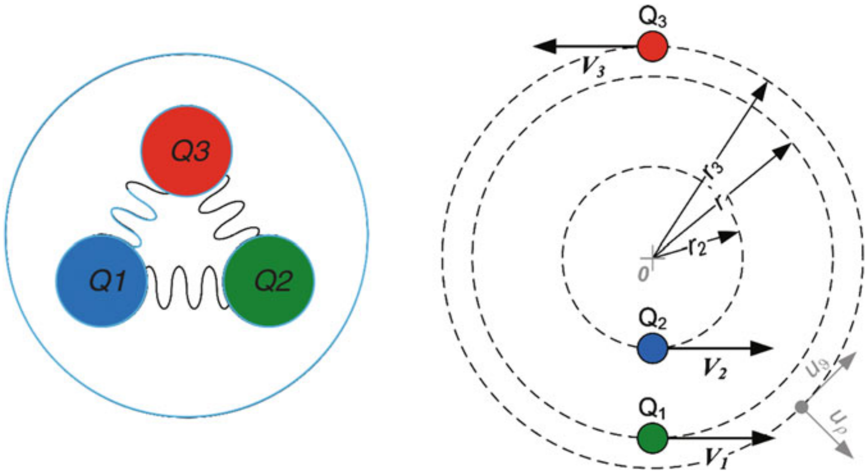

Fig. 5.3: Proton structure: SM model of the proton (*left*), dynamic model of the proton (*right*)

As a matter of fact, setting

$$g_d = \frac{1}{\alpha} \frac{E_B}{m_d c^2} \tag{5.39}$$

where α is the *fine structure constant* we find

$$g_d = 137 \cdot \frac{193\,[\mathrm{MeV}]}{1875.57\,[\mathrm{MeV}]} = 14.1 \sim 14\,. \tag{5.40}$$

So, g_d is the experimental value of the *strong interaction constant*. In second place, 193 MeV is the experimental value of a resonance energy for photodisintegration of the deuteron [3].

4 The Spin and the Electric Charge

The deuteron spin is $s_d = \hbar$. In our model the spin is the sum of three contributions owing to the spins of three particles (two protons and an electron). Furthermore, the spin is a vectorial quantity. Considering the direction z identified by the perpendicular to the plane of motion of the three pointform particles we find that the spin of the deuteron in the direction z is given by (see Fig. 5.4)

$$spin\, d\,(in\; the\; direction\; z) = spin\, p_1 \cdot \sin\psi + spin\, p_2 \cdot \sin\psi + electron\, spin \tag{5.41}$$

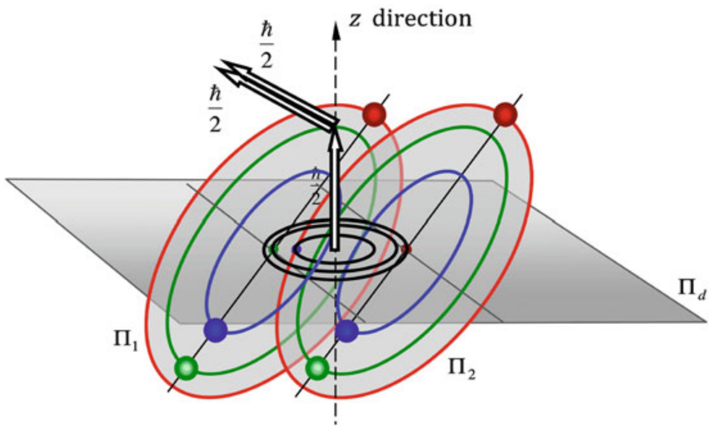

Fig. 5.4: Deuteron spin: vectorial composition of the spins of the three particles

with $\psi = \pi/6$. Therefore,

$$spin\,d\,(in\,the\,direction\;z) = \frac{\hbar}{2}\sin\frac{\pi}{6} + \frac{\hbar}{2}\sin\frac{\pi}{6} + \frac{\hbar}{2} = \frac{\hbar}{4} + \frac{\hbar}{4} + \frac{\hbar}{2} = \hbar\,. \tag{5.42}$$

This sum equals $\hbar$ in agreement with the experimental value.
As regards the electric charge we have

$$charge\;of\;deuteron = q + q - q = q \tag{5.43}$$

which is o.k.

5 Chain Nuclear Reaction

The energized proton ($\gamma_1 p_1$) has a kinetic energy about three times the binding energy of the deuteron. In fact,

$$T_1 = (\gamma_1 - 1)\,m_p \cdot c^2 = 0.618 \cdot 938.27\ [\text{MeV}] = 579.97\ [\text{MeV}] \tag{5.44}$$

while

$$3 \cdot E_B = 3 \cdot 193\ [\text{MeV}] = 579\ [\text{MeV}]. \tag{5.45}$$

Consequently,

$$T_1 \sim 3 \cdot E_B\,. \tag{5.46}$$

That means that after disintegrating a deuteron by hitting it with a photon of energy 193 MeV we get an energized proton (plus a particle η and a particle ν_e) which in turn can break three more deuterons, and so on. The reaction is divergent and then, in this manner, we can produce clean nuclear energy, provided we control the

reaction. The control can be eventually achieved with the use of cadmium bars the purpose of which is simply to intercept part of the energized proton (not to moderate neutrons, since this is not the philosophy of our fission procedure; it is clear that we are dealing with fission, not with fusion). The following example illustrates a controlled chain reaction in two stages.
STAGE 1: fission of a first nucleus according to

$$193\,[\mathrm{MeV}]+d_1=2068.6\,[\mathrm{MeV}]\rightarrow 1.618\,m_p+\eta+3e^{+}+3e^{-} \tag{5.47}$$

$$\eta=547.5\,[\mathrm{MeV}] \tag{5.48}$$

$$1.618\,m_p+\eta\rightarrow p+\eta+0.618\,m_p=p+\eta+578.86\,[\mathrm{MeV}]. \tag{5.49}$$

STAGE 2: fission of a second nucleus, according to

$$578.86\;[\mathrm{MeV}]+d_2=2455.45\;[\mathrm{MeV}]\rightarrow\Omega^{-}+2e^{+}+193\;[\mathrm{MeV}] \tag{5.50}$$

$$\Omega^{-}=2261\;[\mathrm{MeV}]. \tag{5.51}$$

SUBSEQUENT Decay

$$\Omega^{-}=N_{1530}+K^{-}+236\;[\mathrm{MeV}] \tag{5.52}$$

Released energy 236 [MeV].

6 The Center of Mass

The following equation proves that the geometric center of the deuteron (point O) is the center of mass:

$$m_1\,(r_2-r_3)=m_{23}\cdot r_1+\frac{E_H}{c^2}\,(r_2-r_3\cos\psi) \tag{5.53}$$

with

$$m_{23}=\frac{m_2r_2+m_3r_3}{r_2+r_3}. \tag{5.54}$$

We can check that Eq. (5.54) turns out satisfied. In fact it is

$$m_1\;=1.618\cdot 896.836\;[\mathrm{MeV}/c^2]=1451.07\;[\mathrm{MeV}/c^2] \tag{5.55}$$

$$m_2\;=1.1044\cdot 675.39\;[\mathrm{MeV}/c^2]=745.9\;[\mathrm{MeV}/c^2] \tag{5.56}$$

$$m_3\;=1.0032\cdot(-512.79)\;[\mathrm{MeV}/c^2]=-514.38\;[\mathrm{MeV}/c^2] \tag{5.57}$$

and then

$$m_{23} = \frac{745.9 \cdot 4.835 - 514.38 \cdot 0.915}{4.835 + 0.915} \, [\mathrm{MeV}/c^2] \tag{5.58}$$
$$= 545.35 \, [\mathrm{MeV}/c^2]$$
$$m_1 \, (r_2 - r_3) = 1451.07 \cdot 3.92 \times 10^{-18} \, [\mathrm{MeV}/c^2] \cdot m \tag{5.59}$$
$$= 5688 \times 10^{-18} [\mathrm{MeV}/c^2] \times m$$
$$m_{23} \cdot r_1 = 545.35 \cdot 8.955 \times 10^{-18} \, [\mathrm{MeV}/c^2] \cdot m \tag{5.60}$$
$$= 4883.6 \times 10^{-18} \, [\mathrm{MeV}/c^2] \cdot m$$
$$\frac{E_H}{c^2} \, (r_2 - r_3 \cos \psi) = 193 \, [\mathrm{MeV}/c^2] \cdot 4.17 \times 10^{-18} m \tag{5.61}$$
$$= 805.47 \times 10^{-18} \, [\mathrm{MeV}/c^2] \cdot m \, .$$

It follows from the above equations that

$$m_{23} \cdot r_1 + \frac{E_H}{c^2} \, (r_2 - r_3 \cos \psi) = (4883.6 + 805.47) \times 10^{-18} \, [\mathrm{MeV}/c^2] \cdot m$$
$$= 5688 \times 10^{-18} \, [\mathrm{MeV}/c^2] \cdot m \, . \tag{5.62}$$

Equations (5.60) and (5.63) bring about that Eq. (5.54) is satisfied.

7 Remark

Our process is strictly based on *fission* and has *nothing to do with fusion*. By virtue of the relatively low temperatures involved, undesirable and accidental fusions can be excluded. The existing technology for generating electric energy using conventional thermal or even nuclear power plants can easily be utilized. Of course, there is no question about the necessity of convenient and conclusive experiments regarding the practical start of the chain reaction.

8 Conclusions

Our theoretical analysis joined with experimental results (in particular see [3]) prove that the deuteron is formed by three rotating particles, two protons and one electron. The rotations are synchronous and their geometric center coincides with the center of mass. The basic properties of the deuteron are satisfactory reproduced by a three-body relativistic model that marks a substantial advancement with respect to the static two-body standard model (SM) utilized by the international scientific community. We have clearly explained the reasons why the SM fails to indicate correct values for the mass and magnetic moment, and assumes, erroneously, that the binding energy equals the so called mass deficit (multiplied c^2) which, unfortunately, is negative. We have also seen the inefficacy of the SM in view of explaining the various manners of decomposition of the deuteron by the action of convenient excitation energies. In addition, it does not clarify the nature of the tie between the proton and the neutron nor does it prove the stability of such a tie. On the contrary, we have been able to show the stability of the three-particle model and the fact that the binding energy is *positive* and equal to 193 MeV (against −2.26 MeV). Hitting the deuteron with a photon, carrying this amount of energy, we disintegrate the deuteron and eventually trigger a nuclear chain reaction with a gain factor equal to three. We have also identified all of the other ways of decomposition observed in experiments, so that one now has a unique theoretical frame available to explain MEC (meson exchange) and bearing of particles ρ, Δ, N, η, η'. The core of the study is, however, the demonstration that the nuclear force is an electromagnetic force, counteracted by inertial force. Moreover, the binding energy is the electromagnetic energy acquired by the electron because of its rotation in the magnetic field generated by the two protons. By using these fundamental new notions and, in parallel, adopting relativistic equations, we can easily extend the study to other light nuclei, e.g. carbon.

Appendix: Stability Condition

The equation

$$\frac{\gamma v^2}{c^2} = 1 \tag{5.63}$$

determines the rotation speed and the relativistic mass coefficient of proton p_1 in fact as

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \tag{5.64}$$

it is

$$\frac{v^2}{c^2} = \frac{\gamma^2 - 1}{\gamma^2} \qquad \frac{\gamma v^2}{c^2} = \gamma^2 - \gamma \tag{5.65}$$

so that Eq. (5.64) results in

$$\gamma^2 = \gamma + 1 \tag{5.66}$$

which is the classical equation of the golden ratio, namely the positive solution is

$$\gamma = \gamma_r = \frac{1 + \sqrt{5}}{2} = 1.618\,. \tag{5.67}$$

So

$$\frac{\gamma_r v_r^2}{c^2} = 1 \tag{5.68}$$

and v_r, γ_r identify the rotation speed and the relativistic mass coefficient of particle p_1, in accordance with our general assumptions. Now, we show that condition (5.64) is sufficient for the stability of the motion of p_1 and consequently for the stability of the remaining two particle p_2 and e, which rotate synchronously with p_1.

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