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Asymmetric neutron emissions from sonicated steel

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Following up published works in which we studied and experimentally verified the assumptions of the theory of "Deformed Space-Time" in relation to piezonuclear emissions, and according to previous experiments of sonication by ultrasounds performed on solid materials with high density, cylindrical bars of AISI 304 steel have been sonicated by ultrasounds of the power of 330 Watts and frequency of 20 KHz. We verified by means of passive detectors CR39 (PADC) pulsed emissions of neutrons. In this work, following a recent proposal, it was decided to perform a stereoscopic measurement of neutron emission. It has been verified that they are characterized by a distribution which is anisotropic and asymmetric in the space. The work shows a wide and accurate description of the experiment and the results of neutron emissions, and we stress that there exist two directions corresponding to maximum emission (maximum dose) and zero emission (null dose).

Keywords: Neutron emission; asymmetry; anisotropy; piezonuclear; deformed space-time.

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1. Introduction

The waves generated by ultrasound of appropriate frequency and power, may give nuclear reactions triggered by pressure by means of cavitation in liquids and sonication in solids. This possibility was more than once and by many authors expected and experimentally tested. P. W. Bridgman in 1927, H. Frenzel and H. Schultes in 1934 were the first to propose, respectively for solids and liquids, a hypothesis of this type.[1,2] The intense and implosive collapse of gas or vapor bubbles in liquids, including cavitation bubbles produced by means of acoustic waves, can lead to high pressures and high temperatures and to the occurrence of light flashes due to the sonoluminescence.[3,4] The significant increase in power during the implosion may give rise to a large and sudden increase of the temperature inside the bubbles that implode, and to the emission of nuclear particles detectable and measurable.[3,4] Inside the bubbles that collapse temperatures can reach more than $10^6\,^\circ$K and a very high energy concentration per unit of time can be produced,[5,6] to quickly reach bubble dimensions near those of the atomic radius (10^{-10} m) and temperatures of $10^{11}\,^\circ$K (corresponding to the energy of a 10 MeV particle). In these conditions, thermonuclear reactions may occur. Such kind of experiments were undertaken many times in the past.[7–13] If the cavitation in liquids is the means to raise pressure waves which act on the chemical elements of diluted solutions causing the nuclear transformation, it is undoubtedly possible to hypothesize that even in solids mechanical waves generated by ultrasounds may cause nuclear effects of a new kind[14–17] which we are going to call from now on *Deformed Space-Time emissions* DST emissions.[18] A possible mechanism able to explain these new nuclear phenomena can include two parts: One essentially classic-based on the already described fact regarding the reaching of high energy concentration for unit of time in the collapsing bubbles.[5,6] The second, non-classic, based on the phenomenological formalism of the Local Lorentz Invariance breakdown, and based on the mathematical aspect on the Minkowski space-time deformation.[18,19] According to the classical model, the cavitation allows to achieve extreme energy concentration per unit of time, in the way to be (above all the sonoluminescence) a valid start point for the fusion through inertial confinement by bubbles collapse (sonofusion). In fact, the temperatures that are achieved are far higher than those foreseen by a simple thermal model (10^4°K). Given a sound speed of about 10^3 m $\times$ s^{-1}, which for a frequency of 10^4 Hz corresponds to a wavelength of about 10^{-1} m, the pressure wave of the ultrasounds is converted onto the bubble surface in a shock spherical-symmetrical wave. Since the wavelength is greater than the bubble dimensions (10 μm) an implosive collapse occurs.

The surface of the bubble that collapses acts like a neutral atoms inertial accelerator and the dramatic reduction of the bubble itself up to the dimensions of the atomic nucleus produces on its surface the energy required to activate the fusion.[11,20] This model shows some limits: (a) the dispersion of the power of the ultrasounds, which is depleted by means of other concomitant processes, such as

the sonoluminescence and the sonochemical endothermic reactions; (b) the fact that at energies below the coulombian barrier the probability of the fusion is low, though it exponentially grows with the energy; (c) the compound nucleus, characterized by a strongly excited state, and by a high angular momentum, is highly instable and it may immediately undergo to spontaneous fission.[11,20] The not classical model is based on the formalism of the Deformed Special Relativity (DSR), a generalization of the Special Relativity (SR), based on the deformation of the Minkowski space-time.[18,21] Recently, it has been also verified how the nuclear emissions, triggered by pressure, fully satisfy the constrains foreseen by the deformed space-time theory, it is therefore correct to use the term DST emissions. The main characteristic of the deformed space-time reactions (DST-reactions) is to produce emissions of neutrons, as well as α rays,[22–25] in total absence of γ rays production. The goal of the present experimental work is to verify a possible macroscopic neutron production and its thermal effect. Therefore, following also a recent proposal,[26,27] an experimental setup has been realized able to measure photographically in stereoscopic mode the neutron emission at 360° on a plane, and to evaluate the calorimetry together with the neutron spectrometry at least along one direction, as well as to verify the total absence of γ rays during the neutrons production.

2. Experimental Setup

The experimental tests have been performed using a cylindrical bar made by steel AISI 304 having the following dimensions: 90.5 mm high, 18.8 mm diameter, 181 g weight. The composition of this bar has been measured by XRF performed on the external surface: Fe 69.99%, Cr 18.57%, Ni 8.71%, Mn 2.20%, Mo 0.32%, Ti 0.109%, V 0.077%, Cu 0.034%. The AISI 304 cylinder has been inserted inside a supporting cylindrical block made by PTFE (Teflon) 7 cm high, 6 cm diameter, and 188 g weight. The Teflon cylinder containing the steel bar has been set vertically inside the Neoprene frame and has been fixed on the base of the sonicating device constituted by the R-0-L/S reactor, realized by the Italian Army in collaboration with Startec Ltd. (Italian company operating in the ultrasonic machines field). The Teflon cylinder goal was to act as calorimeter; for this reason, from here, we will refer to it as "Teflon Calorimeter". The R-0-L/S sonication equipment was constituted by a AISI 304 steel sonotrode, connected with a piezoelectric column placed into a steel jacket, blocked by means of a screw flange on the upper plate of the retention system sonotrode-sample. This retention system was constituted by two duralumin square plates connected together by means of four posts made of the same material (Fig. 1). All equipment referenced was constituted by stable and supporting elements having as their objective to ensure during the sonication the system stability and immobility, as well as a complete and almost perfect contact between the sonotrode tip plane surface and the AISI 304 cylinder surface.

The piezoelectric column was connected to the generator, operating at the maximum power of 2 KW and at frequency of 20 KHz, by means of high frequency cables.

The experiment was performed for 3 min of duration. All the sonication system had been cooled with a compressed air jet generated by a Vortec mod. 610 OSHA compressor. In front of the system AISI 304 steel cylinder — PTFE support, on the same plane, 30 cm away, were placed, parallel to each other, two neutron detectors (Fig. 1). The first one was a BTI Microspec Neutron Probe, measuring the n emission and their energy, the neutron fluence, and the dose. The second one was the HDS 101 Mirion, for the neutron count rate and for the dose measurement, equipped with LiI(Eu) n detector, as well as with a CsI(Tl) scintillation detector for γ rays measurement. The Teflon cylinder acting as calorimeter was externally surrounded, to about half of its height, with a continuous circle of 16 passive neutron detectors model CR39-AB (PADC), as shown in Fig. 2. The CR39-AB are PADC detectors corrected with boric acid (from which the AB name) which will be discussed later.[28] Replicate measurements of the laboratory background have been performed both with HDS Mirion and with BTI Microspec, as well as with four CR39-AB detectors, placed in the same laboratory in which the experience has been realized, at a distance of 20 m from the equipment. The time specified for each experience has been of 3 min of steel rod sonication. The HDS Mirion and BTI Microspec measurements have been acquired, stored and computed by means of Olivetti "Punto it" computer. At the end of the experience the CR39-AB detectors were taken, and observed and photographed under an optical microscope

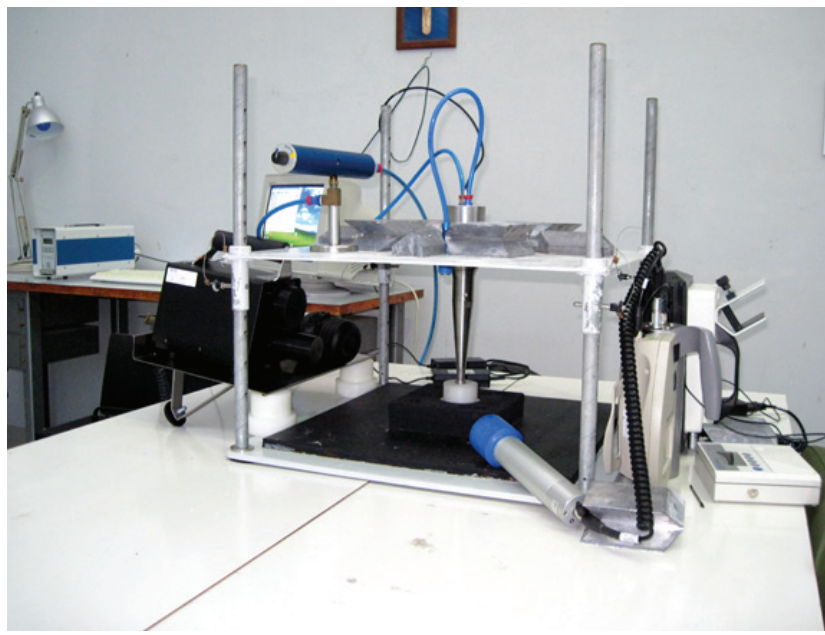

Fig. 1. General view of the Italian Army (E.I.) R-0-L/S piezonuclear reactor used during all the experiments performed in the years 2010–2012 with kind permission by State Undersecretary of the Defence and the Head of Staff of Defence (currently, 2014, dismantled).

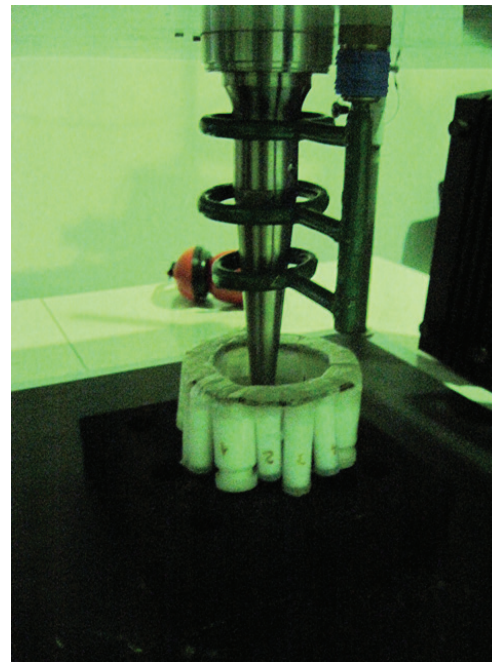

Fig. 2. Experimental devices close up: R-0-L/S details, sonotrode and cooling rings; Teflon calorimeter surrounded by CR39-AB.

(100×) and under an electronic microscope. In a previous and separate phase of the experience calibrations of all the three detector types have been performed by means of the TRIGA Mark II and TAPIRO nuclear reactors of the Casaccia Research Center (ENEA), as well as with an Am-Be source; exposing at a neutron flux of $1.3 \times 10^{10}\,\mathrm{n} \times \mathrm{cm}^{-2} \times \mathrm{s}^{-1}$ and $4 \times 10^{12}\,\mathrm{n} \times \mathrm{cm}^{-2} \times \mathrm{s}^{-1}$, coming from the horizontal of the thermal column and radial 2 channels respectively, for 15 min of measurement time. The photographic technique on neutron filtered by boric acid has been individually developed, since 2006, at the ENEA Casaccia Research Center in collaboration with CNR-ISMN, and has been employed during previous experiments of piezonuclear neutrons emission.[29] The photographic neutron measurement technique with boric acid has been recently further developed and definitively tested as safe and reliable.[28]

3. Experimental Results

It is first necessary to say that the HDS Mirion detector did not record γ rays emission significantly higher than the environmental background: During the experiment, no γ rays emission was measured and the HDS Mirion detector did detect neutron emission. The BTI Microspec detector has instead measured an emission characterized by a 110 pulses spike, at the maximum peak height, corresponding to a neutron energy of about 0.7 MeV. The whole dose measured

during the experiment has been of 0.024 μSv. The background measurement, performed for 15 min, resulted in a dose of 0.003 μSv (Fig. 3, lower left frame). The CR39-AB detectors (indicated below only as CR39) were taken from their positions around the Teflon cylinder and were subjected to the specific treatment, which was to highlight the neutron traces by soaking the film for 4 h in a NaOH thermostated bath at the controlled temperature of 82°C. After

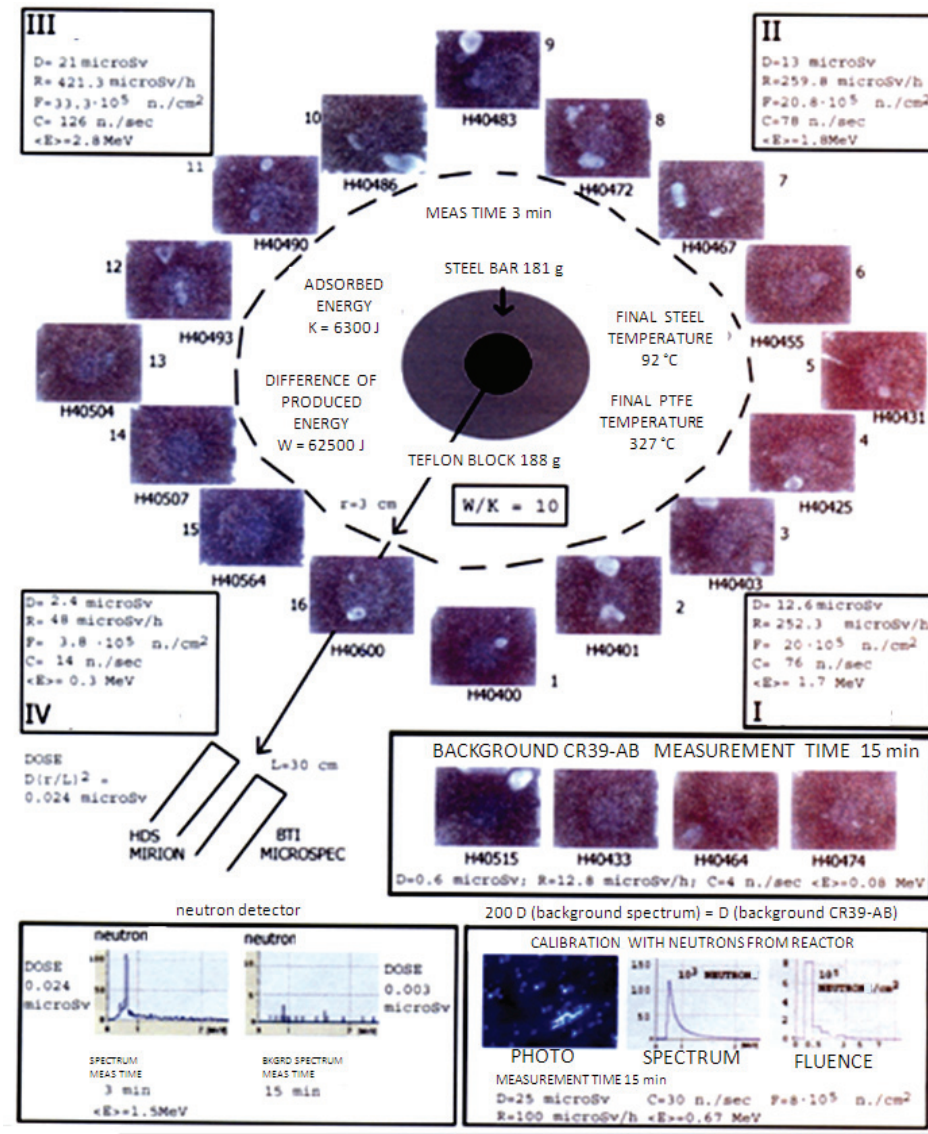

Fig. 3. R-0-L/S reactor horizontal view. AISI 304 steel bar inserted in and surrounded by PTFE cylinder. Externally, moving anticlockwise from n.1 to n.16 the icons of the CR39-AB detectors with the traces of the alpha particles generated by the neutron impact.

the treatment, CR39 was dried at ambient temperature, observed under an optical microscope at 100×, and photographed. On the detectors photos, having dimensions of 10 to 10 centimeters, the neutron traces counting was performed by subdividing each photographic image in 400 equal panes by means of a grid of small squares of 0.5 cm side. Identical procedure has been performed for the four blank CR39 detectors. As well as for the reference images from the same type of detectors coming from n irradiation in the horizontal of the thermal column of the TRIGA reactor and radial 2 of the TAPIRO reactor channels respectively. For the neutron traces' visual counting in the CR39, for each pane of the grid a yes/no criterion was adopted (emission trace = yes, trace absence = no). The results are highlighted in Fig. 3 where, in horizontal view, the CR39 disposal, with the respective abbreviations, and the HDS Mirion e BTI Microspec detectors arrangement, is reported with respect to the steel bar and to the Teflon calorimeter. Subdividing the plant in four quadrants of 90° of amplitude, each comprising four CR39, with a precise orientation South–North and moving anticlockwise we get the following results. In the first quadrant, a 12.6 μSv dose, corresponding to a dose rate of 253.3 μSv/h, and to an integrated neutron flux (3 minutes measurement) of 2×10^6 n $\times$ cm^{-2}, equivalent to 76 n $\times$ sec^{-1} was measured; the neutron energy maximum was 1.7 MeV. The integrated flux was calculated by direct proportion from the calibration executed by means of the corresponding TAPIRO reactor neutron flux. In correspondence of the second quadrant a 13 μSv dose, corresponding to a dose rate of 259.8 μSv/h, and to an integrated neutron flux of 2.08×10^6 n $\times$ cm^{-2}, equivalent to 78 n $\times$ sec^{-1} was measured; the neutron energy maximum was 1.8 MeV. In the third quadrant, a 21 μSv dose, corresponding to a dose rate of 421.3 μSv/h, and to an integrated neutron flux of 3.33×10^6 n $\times$ cm^{-2}, equivalent to 126 n $\times$ sec^{-1} was measured; the neutron energy maximum was 2.8 MeV. In the fourth quadrant, a 2.4 μSv dose, corresponding to a dose rate of 48 μSv/h, and to an integrated neutron flux of 3.8×10^5 n $\times$ cm^{-2}, equivalent to 14 n $\times$ sec^{-1} was measured; the neutron energy maximum was 0.3 MeV. For the whole plane angle (360°) the total dose measured by means of the CR39 was 49 μSv, corresponding to a dose rate of 981 μSv/h, and to an integrated neutron flux of 5.8×10^6 n $\times$ cm^{-2}, equivalent to 294 n $\times$ sec^{-1}; the neutron energy maximum was 2.8 MeV. The concomitant absence of counts for the HDS Mirion detector can be explained by the fact that it converts, as the majority of the active detectors, the neutron energy in an electrical signal: For this reason, because of the dead time due to the pulses electrical conversion, it may have failed the detection.[30] Moreover, a further explanation is given by the dramatic decrease of the detector efficiency with the square of the distance from the source ($1/R^2$). Always through the square of the distance law can be justified the difference between the neutron measurements executed in the fourth quadrant by means of the BTI Microspec detector with respect to the CR39. Note that while the distance of the CR39 from the AISI 304 steel bar was 3 cm (Teflon calorimeter radius), the distance of both the active detectors was 30 cm, as can easily seen in Fig. 1. This *defaillance* of the active neutron detectors with respect to the passive ones is

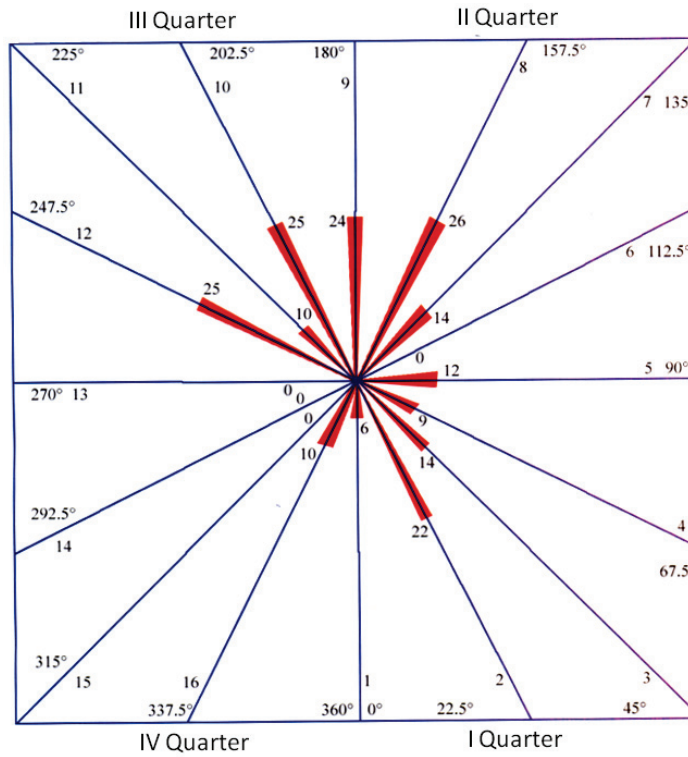

Fig. 4. Polar diagram of the neutron emissions. The length of the bold lines starting from the center in the radial direction give an analog description of the measured dose. In this dose, it has also been computed the energy absorbed by the Teflon calorimeter, which has reached the fusion temperature, $T_{\text{Teflon}} = 327°\text{C}$.

emphasized to the maximum, in the case that we will describe immediately. It has to do with neutron emissions not constant over time, and which occur by means of neutron quick bursts whose mutual temporal distance and amplitude are knowable with difficulty and then, at first sight, random.[29,30] Therefore, it is believed that, in a subsequent further phase of the experiments, it will be appropriate to perform the sonication of a high density material as the AISI 304 inside a He-3 SSNC — Small Samples Neutron Counter (neutron measuring surrounding arrangement, or "measuring head") to evaluate the chronological trend of the neutron bursts.[31] After the CR39 detectors are divided into quadrants measurements, the individual detectors counts were analyzed keeping a strictly two-sided orientation, fixed from now on by a conventional way, and going on counterclockwise. The results are highlighted in Fig. 4; in this figure, for each detector, in addition to the serial number, the μSv dose, and the angle measured with respect to the conventional sided axis, are reported. The length of the bold lines starting from the center in the radial direction gives an analog description of the measured dose. In this dose, the energy absorbed has been computed by the Teflon calorimeter, which has reached

the fusion temperature, $T_{\text{Teflon}} = 327°\text{C}$. The energy has been calculated, in direct proportion with the energy corresponding to each CR39 detector measurement, after the calibration performed by the nuclear reactor TAPIRO radial channel 2 (see Fig. 3, right bottom frame). Going on by 22.5° steps a clear asymmetrical neutron pulses distribution is evidenced. Its emission clusters is evidenced: the relative emission is grouped peaking within an angle of 90° between 157.5° and 247.5° with a total dose of 110 μSv. Within this arc, we clearly see that the emission seems isotropic, but outside it the emission is no longer isotropic (see Fig. 4). In the 90° angle between the 270° and 360° angles the emission is minimal: 16 μSv. Moreover, it is quite evident from Fig. 4 that there are two directions mutually orthogonal having these special features: along one the dose is null, along the other one the emission has the maximum dose. Referring to Fig. 4, these two directions are evidenced according to the convention reported in the same figure: The first one marked by the number 10 upside (3rd quadrant) and number 2 downside (1st quadrant); the other marked with number 6 upside (2nd quadrant); and by number 14 downside (4th quadrant). The neutron emission dose is evidently *anisotropic*: The emission intensifies in fact just in correspondence of the 157.5°–247.5° angle. Such asymmetry and anisotropy of the neutron emission suggest that we are not facing any nuclear fusion or fission reactions which occur according to the well-known classical model. Conversely, we are at the presence of reactions which occur according to the model described by the Deformed Space-Time theory.[22,23] As previously stated, the Teflon block in which the AISI 304 rod was inserted to size had the function of acting as calorimeter. It has been verified that at the end of the experience the steel rod temperature, measured by the infrared thermometer Fluke 69 IR, was found to be 92°C, while the Teflon block temperature at the contact surface with the rod was 330°C. The Teflon appeared melted and somewhere carbonized. It is known that the melting temperature of this material is equal to 327°C.[32] Knowing the steel rod weight (181.1 g), the Teflon block weight (188.0 g), the temperatures reached by both at the end of the experience, using the steel thermal capacity ($\text{Cp}_{\text{AISI304}} = 5\ \text{KJ} \times \text{g}/°\text{C}$) and the Teflon latent heat of fusion ($\text{C} = 68.3 +/- 1.4\ \text{KJ/Kg}$), the energies absorbed by the steel rod and the Teflon block were evaluated. Both the specific heat and the latent heat of fusion values were assumed to be at constant pressure (1 atm). From the evaluation, it appears that the energy consumed to bring the steel rod from the laboratory ambient temperature (20°C) to the measured temperature of 92°C was equal to 6300 joule and was absorbed by the ultrasonic generator from the power supply. In the case of the Teflon, it has been taken into account in the evaluation that a part of it had suffered carbonization, whose temperature, reported in the literature, falls between 400–500°C.[32] The Teflon absorbed energy has been then assessed in 62,500 joule. This is the energy stored by the Teflon mass at 327°C temperature, without taking into account the fact that the Teflon was started by a laboratory ambient temperature of 20°C, since otherwise we should have to estimate the energy corresponding to the partial carbonization. Although this is an underestimation it is considered

preferable to keep to it, also taking into account the temperature difference with respect to the ambient starting temperature and the Teflon carbonization temperature. This evidence leads to exclude an energy transfer due only to the applied ultrasound, but leads to the assumption of a generation of it from nuclear reactions occurred into the steel bar during the sonication. These reactions produced the measured neutrons and could have produced a presumable dose of alpha rays responsible for the measured heat excess.[24,25] In this paper, the authors do not intend to dwell on considerations attaining the major or minor efficiency in the energy possibly produced during the experiments. It is not the goal of the present work which is directed to the experimental verification of the DST reactions.

4. Concluding Remarks

First we wish to underline and draw attention on Fig. 4 anisotropy and the asymmetries of the emitted energy, but in particular on the existence of two mutually orthogonal directions of which one has zero energy, the other maximum energy. In a future paper, the Local Lorentz Invariance breakdown will necessary be compared with the asymmetry of the neutron emission measured in this experiment, and also in relation to the evidences on the α rays emission angles.[25–27] It is evident that in the future an experiment to evaluate the temporal structure of the neutron bursts will be necessary to be built up: Bursts duration, neutron number in each burst, chronology emissions further to the burst. The final scope is to compare the spatial asymmetry of the neutron emissions with their temporal asynchrony bounds to the bursts chronology. In fact, if the spatial asymmetry is compared with Lorentz breakdown equally the time asymmetry should be evaluated.

Finally, attention should be drawn on the SEM analysis executed on the images obtained by means of the CR39 AB. They are the results of an extended PADC damage, evidently due to an energy transfer by the α rays generated by neutrons into the Boron. This damage does not seem to be due to single α particles but to an α particles stream consequent to the neutron bursts. A proof of damage has been executed on PADC by means of the SEM electron beam obtaining damages of similar extension: This seems to demonstrate that the phenomenon is not generated by single particles but by a stream of ionizing particles. This argument may be the object of future studies.

Last but not the least remark is about the possibility, already considered,[33,34] that inside the "Ridolfi cavity" of steel there occurs the formation of a microplasma which gives rise to these nuclear reactions for a time no longer than 50 μs. But these microplasmas too should be subjected to the DST conditions.

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