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ARTICLE

Deformed Space-Time Neutrons: Spectra and Detection

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In this work we present all the results obtained from 2009 to 2013 regarding the measurement of the neutron spectra coming from new forms of nuclear reactions. In particular, we referred the measurements of such spectra to the neutrons produced in condition of Deformed Space-Time (DST) which are a consequence of the Lorentz violation: when the breakdown of the Local Lorentz Invariance (LLI) occurs. The spectra obtained have completely new unique characteristics and differ from normal known neutron sources. To make a comparison, we reported both spectra is the photographic images of the neutrons emitted by three 'classic sources:' thermal neutrons from a model TRIGA nuclear reactor, fast neutrons from a nuclear reactor, uranium enriched to 94% and neutrons from an Am-Be source. In the light of the results obtained we also have concluded that in presence of DST neutron spectra, and thus in general with new forms of neutrons from nuclear reactions, it is not possible to use detection methods such as indium activation or fission of Uranium. Finally, in this work we have again shown the problem of the 'directionality' of the DST neutron emissions.

KEYWORDS: Neutron Emission, Neutron Spectra, PADC Detectors, Neutron Detectors, Lorentz Violation.

1. FOREWORD

1.1. New DST Nuclear Reactions Generating Neutrons

The new nuclear reactions types experimented far from 1989[1–6] have always presented two problems. The first has been the apparently not-understandable nature of the nuclear transformations produced. The second has been the production of neutrons whose detection and measurement was very difficult. The first problem has been solved when we demonstrated that the Local Lorentz invariance breakdown was necessary to give these new nuclear reactions. That happened in Deformed Space-time (DST) conditions, that means, in a not-minkowskian (not flat) space-time. The second problem has been divided into two parts: firstly, the neutron detection; secondly, the measurement of their characteristics (dose, energy and spectrum). Since the neutron produced by DST nuclear reactions immediately demonstrated to have peculiar characteristics, very different from that known until today, we felt necessary to call them as "DST neutrons," in order to link their new type origin and their new characteristics.

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2. INTRODUCTION

2.1. The Problem of DST Neutron Detection

The neutron emissions of new type, in Deformed Space-Time conditions, that is, at the presence of the Local Lorentz Invariance breakdown, always had peculiar characteristics. Firstly, they occur without γ rays emission, and after, they are limited in time and in space, showing themselves as quick pulses, or bursts, not uniformly distributed, neither in time and intensity, nor in space.[7–11] Among the peculiar characteristics of the neutrons produced by DST nuclear reactions there are anisotropy and asymmetry in the space. When these characteristics contemporarily occur, they make the detection much more difficult. The asymmetry of the emission may give clearly different, or also null, measurements, due to the different detector position; the anisotropy makes worse this situation.[13–15] Nevertheless, we have experimentally seen and verified that the measurement of these emissions along the space showed a trend related to the Local Lorentz Invariance breakdown. That brings us to say in which circumstances the space-time isn't flat. By comparison between the neutron emission and the Lorentz breakdown[14] we may state that the emission happens in Deformed Space-time conditions. Therefore, the decision to give the name of DST neutrons to the neutrons having the subsequent characteristics: asymmetry, anisotropy, emission in bursts, origin from DST nuclear reactions.[16–19] To go on with the detection of such neutron emissions we employed three different techniques: the first based on the detection by means of thermodynamic bubble detectors Defender and Defender XL; the second with the use of photographic detectors with Boric acid, PADC CR-39 AB; the third using of Boron Trifluoride (BF_3) electronic detectors. The thermodynamic bubble detectors Defender and Defender XL are made from a hybrid system of aromatic hydrocarbon oversaturated droplets dispersed throughout an elastic polymer, that, when crossed by neutrons, evaporate generating bubbles. By means of an adequate calibration, counting the bubble number it is possible to perform not only the neutron detection, but also an evaluation of the energy released by the neutrons into the detector.[20–23] The photographic detectors with Boric acid PADC CR-39 AB are an evolution of known detectors (PADC CR-39), specific for the DST neutron detection requirements. They are constituted of a polycarbonate plate coupled with a layer of adequate thickness of Boric acid. When the boric acid is crossed by the neutrons they produce α particles leaving traces on polycarbonate. The traces may be put in evidence by a chemical etching so giving a typical photographic image. In this way, by means of an adequate calibration, measuring the extension of the traces produced by every neutron pulse, it is possible to obtain both detection and evaluation of the energy for neutrons released into the detector.[24,25] The Boron Trifluoride electronic detectors are, between the three detectors described, the more classical instrument to detect neutrons. They give the detection signal by means of electrical pulses due to the protons backscattered produced in the boron trifluoride when crossed by neutrons. By this technique it is possible to have only a time sequence of the neutrons signals, but it is not possible neither to distinguish a single neutron by a neutron pulse nor to evaluate how many neutrons are present in each pulse.[9] After we solved the problem of the DST neutrons detection, that is, to verify in an absolutely clear manner that the DST reactions are coupled with the neutron emission, we faced up the measurement of their main characteristics: the energy spectra and the fluence.

3. DST-NEUTRONS. EARLY SPECTRA

3.1. The Neutron Spectra in the Milan Experiments

During the year 2009 we performed a set of experiments aimed to produce neutrons from sonicated steel bar. We put in contact the sonotrode and the tip of the bar and applied a pressing force on it, so that the transferred ultrasonic power into the bar was 19 Watt. The frequency of ultrasounds was 20 KHz like in the previous experiments with solutions,[9,10] and the amplitude of the vibration of the sonotrode tip was 15 μm. We treated two different types of cylindrical bars: bars made of sintered Ferrite (α-iron)

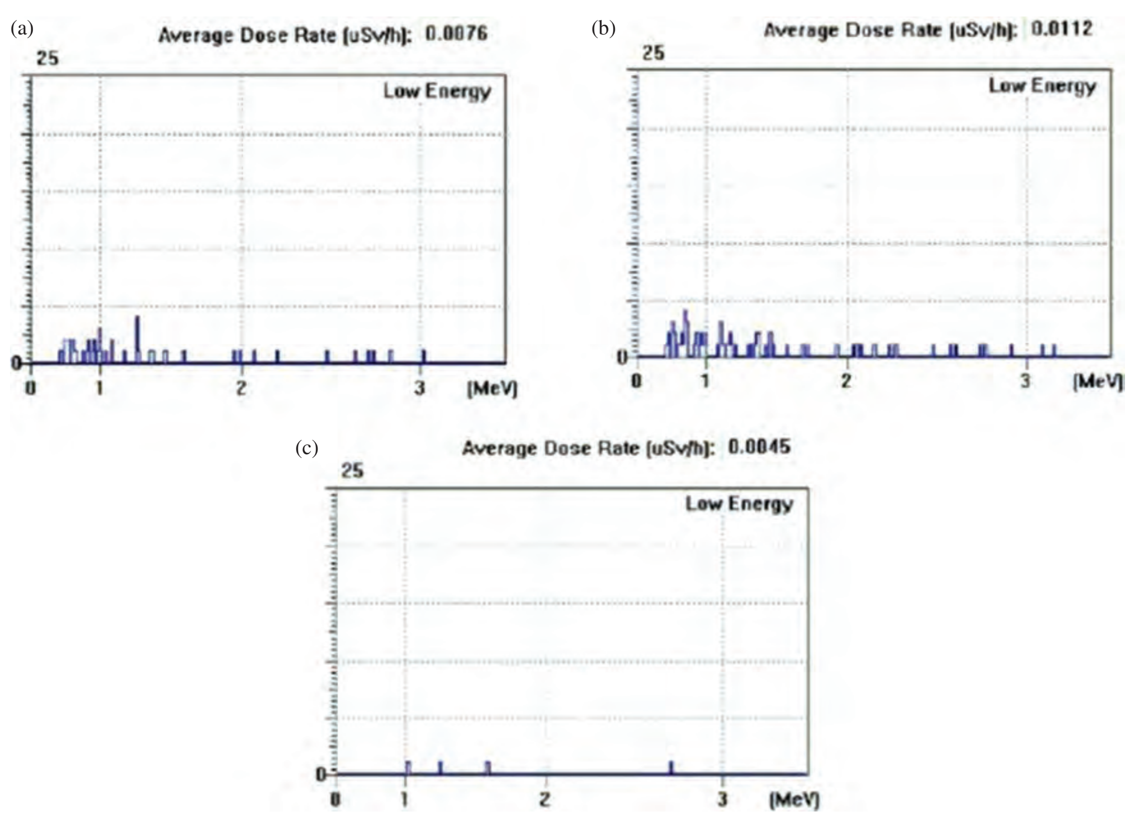

Fig. 1. Left, neutron spectrum from the bar of ferrite; right, neutron spectrum from the bar of steel; bottom, neutron spectrum of the background. For all of them we have MeV on the abscissa, counts on the ordinate.

and bars made of steel with hardened surface by carbon steel and dysprosium carbide. Both types had the same dimensions: circular cross-section of 20 mm of diameter and a length of 200 mm. All of them were treated with the same ultrasonic parameters just mentioned. We used two types of neutron detectors: a neutron counter HDS-100GN by Mirion™ and a neutron spectrometer MICROSPEC2™ Neutron Probe by BTI.[26,27] The former is a gamma detector and spectrometer with CsI(Tl) scintillator for low energy gamma rays and silicon diode for the high-energy ones. Besides, it contained also a neutron detector with a LiI(Eu) scintillator. The latter is made up of two parts: the multichannel MICROSPEC2™ and the neutron detector Neutron Probe with an He-3 counter for thermal neutrons up to 800 KeV and a liquid scintillator for neutrons from 500 KeV to 5 MeV. In each measurement, these detectors were placed at 20 cm from the external surface of the dielectric cylinder containing the bar. In Figure 1 we present two neutron spectra obtained during one hour of application of ultrasounds to one bar of ferrite (a) and one bar of steel (b) and in (c) the neutron spectrum of the background, i.e., with ultrasounds turned off. The difference between the two spectra (a) and (b) with the spectrum (c) can be easily spotted. Moreover the spectra (a) and (b) have a fairly clear lognormal shape which, from an intuitive and qualitative point of view, gives a fairly sound evidence of the existence of the phenomenon.[28]

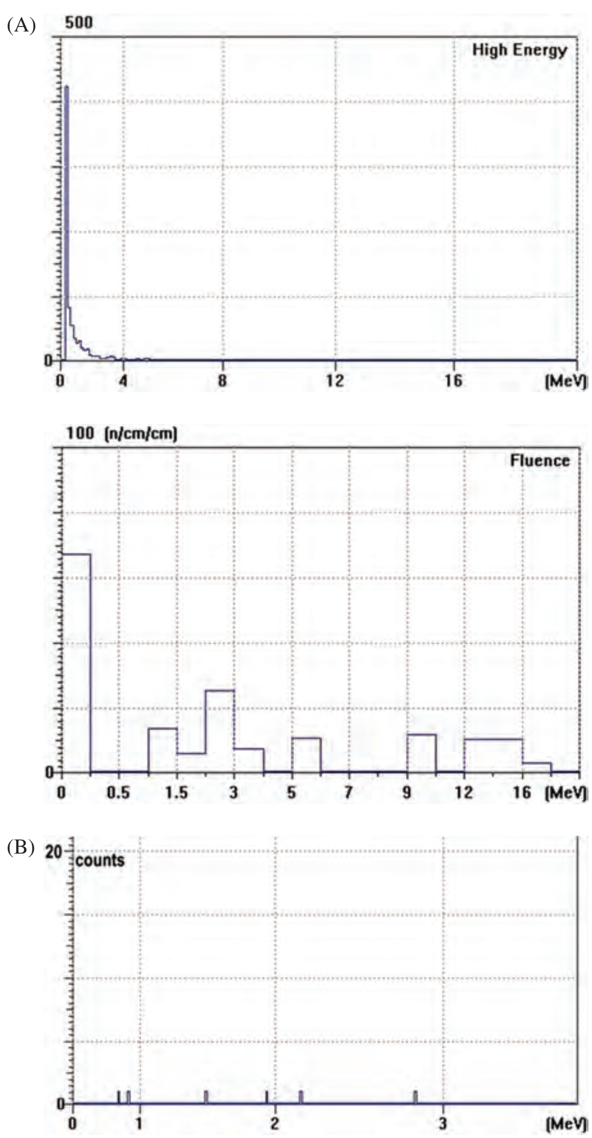

Fig. 2. Deformed space time (DST) neutrons energy spectrum and related fluence (A). Background (B).

4. DST NEUTRONS SPECTRA

4.1. The Neutron Spectra in the Rome Experiments

During the period 2010–2013 we subjected some cylindrical steel bars (AISI 304) with mass 180 g to sonication by ultrasounds with a frequency of 20 kHz and power of 330 W for a time interval of 180 sec. We measured the DST-neutron emissions using a double system of detection. The first system was the PADC Polycarbonate-CR39 (Boric Acid) developed and calibrated at the ENEA Research Centre of Rome-Casaccia. The PADC-CR39 (AB) were placed around the sonicated steel bar to record the signature of the actual neutron emission. The second system we used was the MICROSPEC2 Neutron

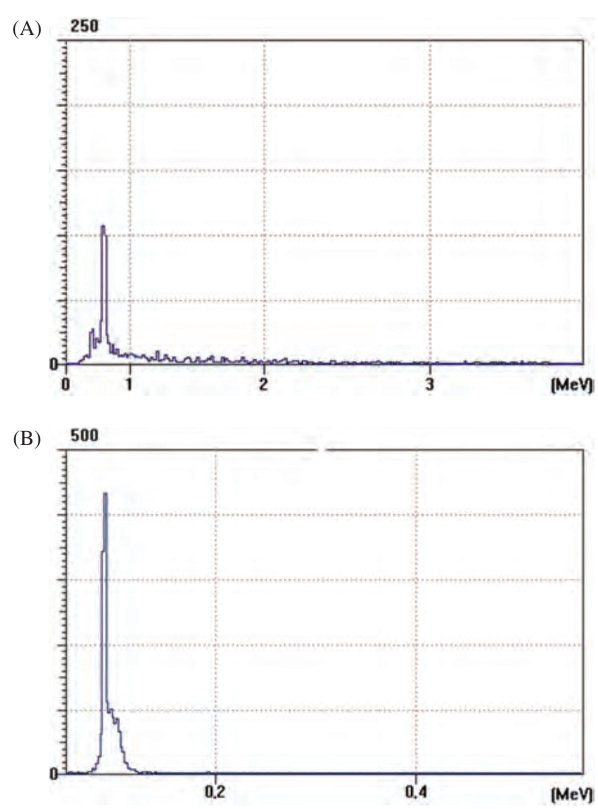

Fig. 3. Deformed space time (DST) neutron spectrum in details: (A) 0.3–3 MeV, NaI(Tl) liquid scintillator detector, (B) 0–0.3 MeV, Helium-3 gas detector.

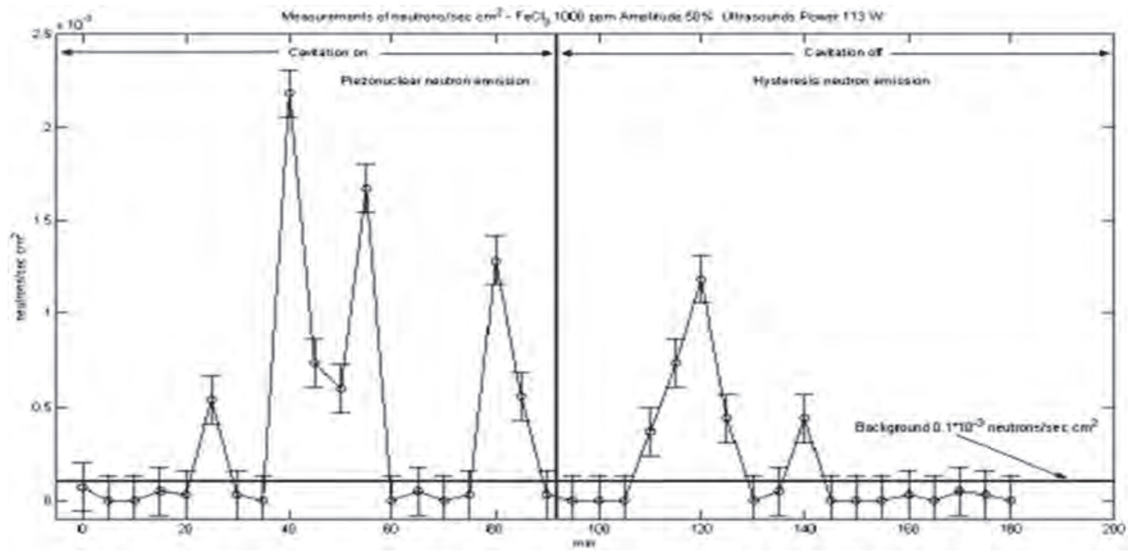

Fig. 4. Time asymmetry of neutron bursts from DST emissions.

Probe made by firm BTI, which was utilized to measure dose, fluence and spectrum of DST-neutrons coming from the sonicated steel bars. For a more comprehensive evaluation we also used a gamma-ray detector, the HDS 101 GN by MIRION, to confirm the absence of gammas above laboratory background during the DST-neutron emission, as recorded in all past experiments. The MICROSPEC2 Neutron Probe is a rather complex system.[26, 27] Therefore, this system was tested and its unique features reported by the firm-maker were verified during measurements performed at the ENEA Research Centre of Rome-Casaccia using three different neutron sources: nuclear reactor TRIGA, nuclear reactor TAPIRO and Americium-Beryllium (for information about these sources see e.g., Refs. [24 and 25]). The Deformed Space-Time theory states that an interaction violating LLI (Local Lorentz invariance) in a nucleus results in a reaction characterized by emissions of nuclear particles in DST conditions.[18] However, once produced, such particles travel in a flat minkowskian space-time, which is also the space-time of the detector and of the physical processes giving rise to detection.[7] Consequently we positioned a PADC Polycarbonate-CR39 (AB) along the base connecting the neutron probe with the surface of the sonicated

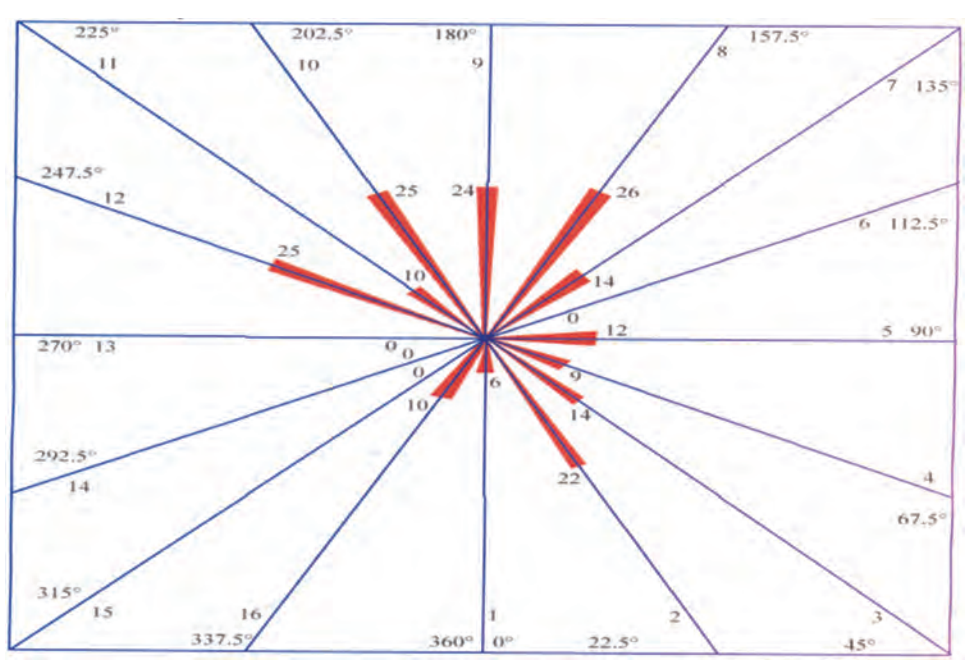

Fig. 5. Spatial asymmetry of neutron bursts from DST emission.

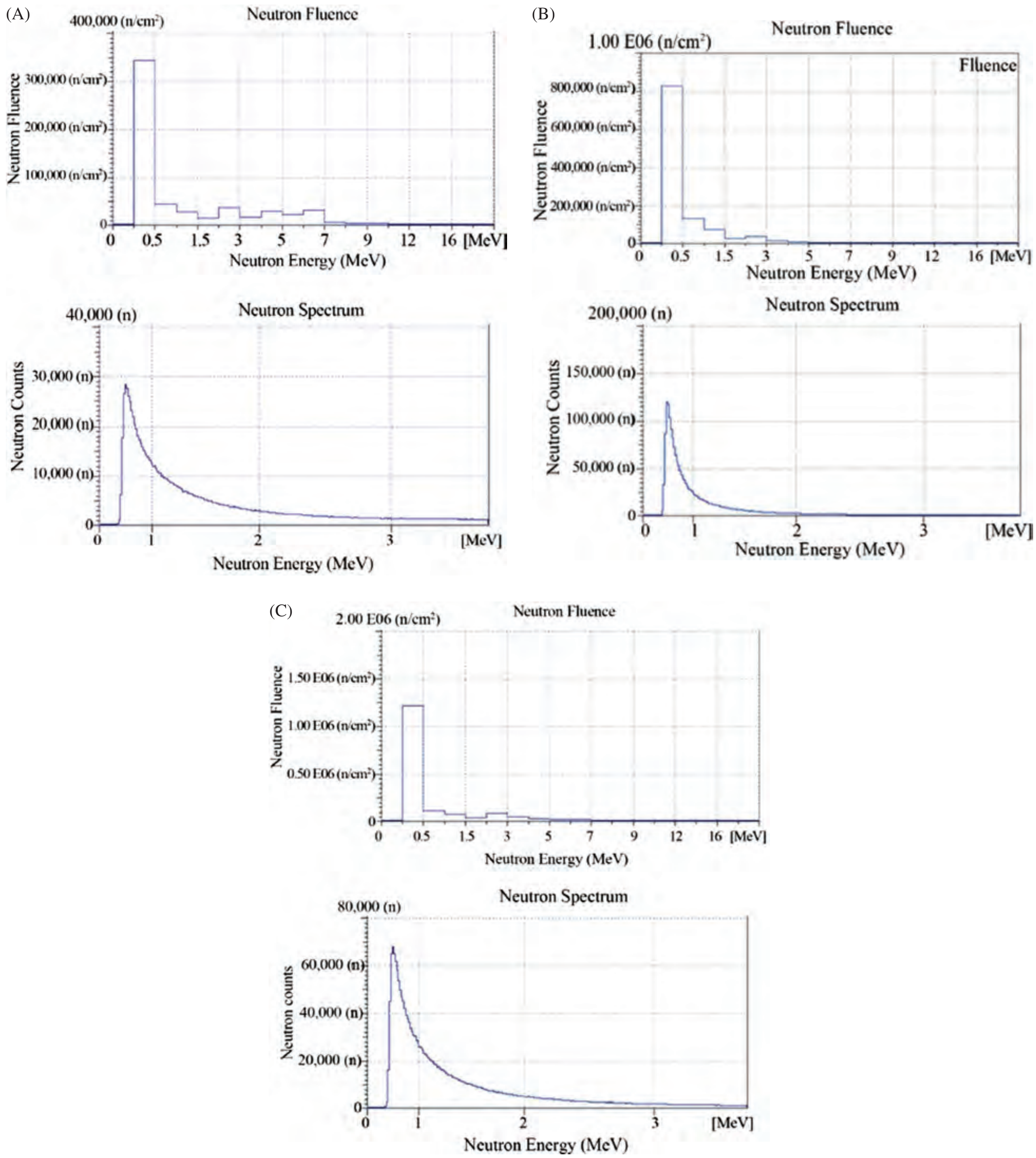

Fig. 6. (A) Fluence and neutron spectrum of the source TRIGA thermal column horizontal channel (long slid diaphragm). (B) Fluence and neutron spectrum of the source TAPIRO radial channel 2 (circular diaphragm). (C) Fluence and neutron spectrum of the Am-241-Be source (without any diaphragm).

steel bar, at a distance between the neutron probe and the bar. In this way, the bar-PADC and bar-Neutron Probe distances were different but oriented along the same direction. We verified that the doses measured by the two systems had an inverse square relationship with the above defined distances. We concluded that this was evidence of the movement of DST-neutrons after their production and of them being in conditions of a flat minkowskian space-time. So the conditions of the DST theory had been fulfilled. Before and after the sonication tests we performed background measurement runs each lasting an interval time of 15 min, i.e., 3 times the time interval of sonication, using the MICROSPEC2 Neutron Probe. The background resulted quite negligible since in each run few

Fig. 7. All these neutron images are released on boric acid imaging support.[24] (A) Neutron image of the source TRIGA thermal column horizontal channel (long slid diaphragm). (B) Neutron image of the source TAPIRO radial channel 2 (circular diaphragm). (C) Neutron image of the Am-241-Be source no diaphragm, the image completely covers the whole active surface.

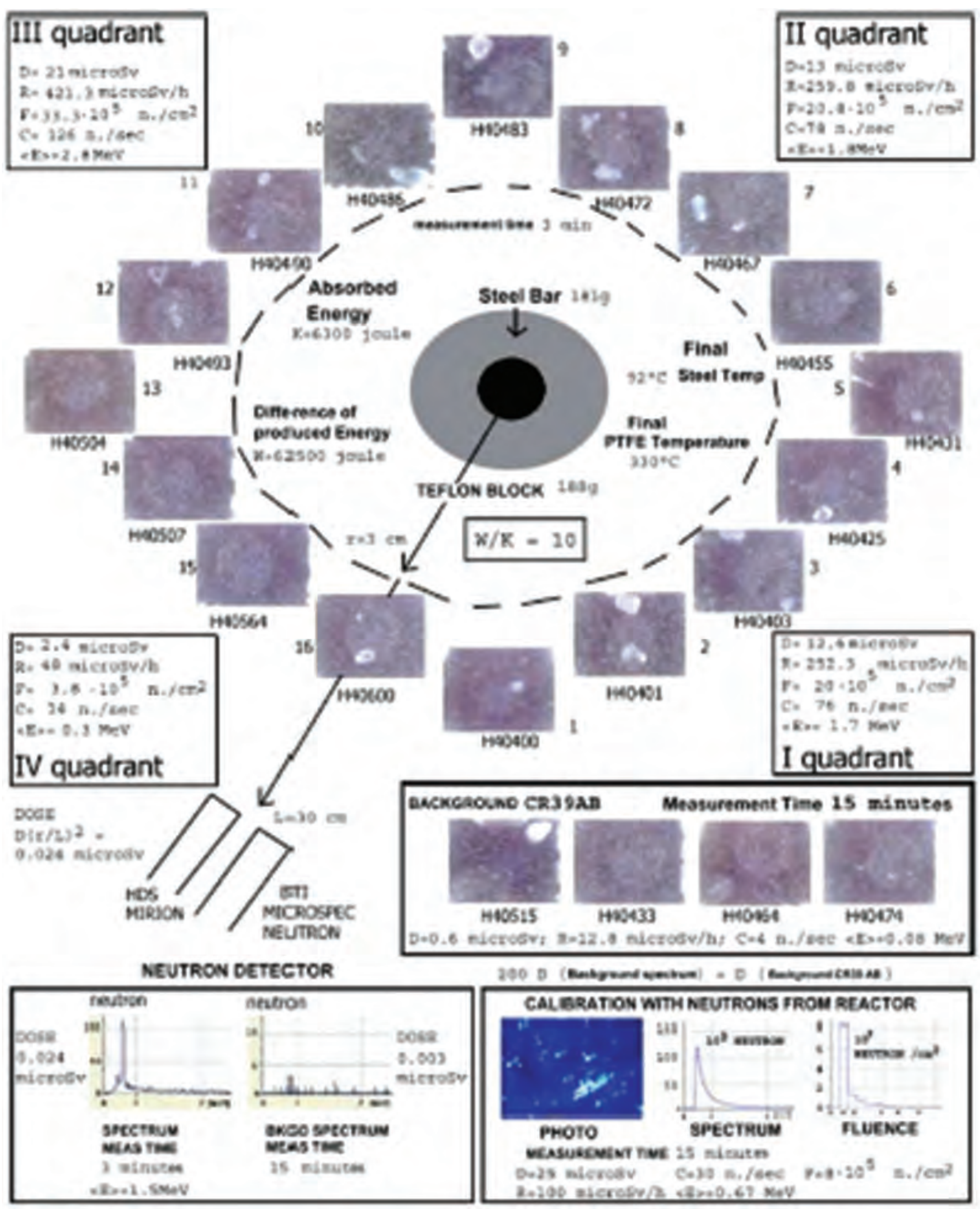

Fig. 8. R-0-L/S reactor horizontal view, showing the AISI 304 steel bar inserted in and surrounded by PTFE cylinder, and synoptic summary of measurements. Externally, by moving anticlockwise from n.1 to n.16, the icons of the CR39 AB detectors with the traces of the alpha particles generated by the neutron impact.

Table I. Neutron measurement for each PADC CR-39AB.

PADC CR39-AB progressive number	H40400	H40401	H40403	H40425	H40431	H40455	H40467	H40472	H40483	H40486	H40490	H40493	H40504	H40507	H40564	H40600
Detector number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Angle (°)	0	22.5	45	67.5	135	90	112.5	135	157.5	202.5	225	247.5	270	292.5	315	337.5
Dose μSv	14	8	12	0	14	26	24	25	10	25	0	0	0	10	6	22
Dose rate μSv/h	280	160	240	0	280	520	480	500	200	500	0	0	0	200	120	440
Counts n/sec	**82**	**47**	**70**	**0**	**82**	**152**	**140**	**146**	**58**	**146**	**0**	**0**	**0**	**58**	**35**	**128**

neutrons (less than 10) have been registered only over the energy interval 0.5–3 MeV, see Figure 2(B). This result was compatible with the electronic noise of the system used.[29,30] For each spectrum, we performed a set of measurements which proved consistent, displaying neither significant nor substantial differences among them. In Figure 2(A) we report the energy spectrum and the fluence. In Figure 2(B) we report the energy spectrum of the neutron background. In Figure 3 we show the high energy, i.e., up to 4 MeV (Fig. 3(A)), and low energy, i.e., less than 0.4 MeV (Fig. 3(B)), spectra.

The peculiar features of these spectra deserve further investigations. For now we think they are connected with the asynchrony of the DST-neutron emissions, see e.g., Figure 4, and with asymmetry and anisotropy, see e.g., Figure 5.

Moreover, we have to keep in mind that the emission of nuclear particles in DST conditions was recorded to occur in bursts in all past experiments. Therefore in accordance with the detectors used, a careful study of the energy, space and time effects (including dead-time effect) that these features (asynchrony, asymmetry, anisotropy, burst emission) have on the measurement efficiencies will be necessary in order to ensure improved accuracy of future measurements. Let us compare the graph in Figure 4, showing the asynchrony of DST-neutron emissions, and the diagram in Figure 5, showing the anisotropy of these neutron emissions. Collecting altogether the graphs of the spectra, the diagram of the spatial emission and the graph of the emission in time, we have the first complete, although preliminary, characterization of DST neutrons.

This characterization shows that the DST-neutron emissions have peculiar features not only with respect to space and time, but also with respect to the energy spectrum of the emitted neutrons. These spectra have an irregular trend both at high and low energies. Conversely, the neutron spectra of known sources (Americium-Beryllium, fast neutron reactors, thermal neutrons), present single trend for the whole neutron spectrum (see, for instance, the spectra of these three mentioned sources in Figures 6(A)–(C) and 7(A)–(C), shown in the next paragraph).

5. DST-NEUTRONS AND STANDARD NEUTRONS

5.1. Comparison Between Neutrons from Standard Sources and from DST Reactions

In Figures 6(A)–(C) we report the spectra obtained by the three neutron sources by means of the MICROSPEC 2 BTI neutron detector showing their typical distribution.

In Figures 7(A)–(C) we report the corresponding images released by neutron of the same sources on boric acid imaging support.[24,25]

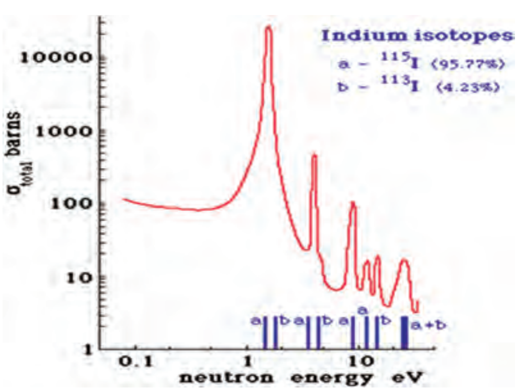

Fig. 9. Indium neutron activation cross section.

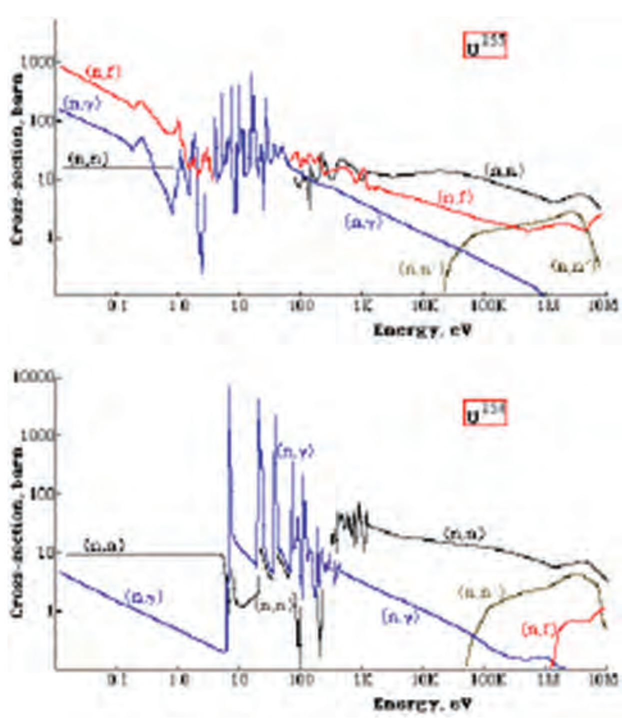

Fig. 10. U-235 and U-238 neutron cross sections.

It is quite clear from a direct comparison between the spectra in Figures 2, 3 and in Figure 6 that the features of the spectra of the DST neutrons are quite different from those ones of the neutrons produced by the standard sources. The PADC CR-39AB were employed in the AISI 304 sonication experiment performed in Rome during 2011 ÷ 2013, using the R-0-R/S reactor, in which asymmetric and anisotropic neutron emission were detected and measured, as shown in Figure 8, and in subsequent Table I where the neutron dose for each angle of measurement is reported.

Again it is quite clear from a direct comparison between the neutron images of CR-39 AB in Figures 7 and 8 that the features of the images of the DST neutrons are quite different from those ones of the neutrons produced by the standard sources, as we are going to specify in the next paragraph.

6. CONCLUDING REMARKS

During all our neutron measurements we contemporarily performed γ rays counting. We always verified the lack of γ rays emission. From the images obtained by Defender detectors, and especially by Defender XL, we can see that the bubbles generated by neutrons are present only in a portion of the detector volumes (Fig. 6). This is a demonstration that neutrons formed single pulses, or a group of pulses, not uniformly distributed all over the space. Otherwise the bubbles have completely filled all the detector volume.[8] The images taken by PADC CR-39AB detectors reported in Figure 8 show that the traces left by the neutrons cover also in this case only a part of the detector. This confirms the consideration done for the Defender and Defender XL measurements. The comparison with the standard known neutron sources and their imaging by boric acid method again confirms the limited nature of the DST neutron emission as seen in CR-39 AB of Figure 8 which resembles more the shape of the image in Figure 7(B). From the sequential distribution of BF_3 signals (Fig. 4) it's possible to follow the evolution in the time of the neutron detection, even if it's not possible to discriminate a single neutron pulse from a group of pulses, and it's also not possible to evaluate how many neutrons are present in each bunch. So this sequence, being impossible to establish if the counts represent single neutrons or groups of them, gives only a detection distribution during the time. Energy spectrum and fluence measurements solve for a great part the problem of determining the DST neutron characteristics, but leaves however open the problem of how many neutrons form a single pulse, or if pulses are formed by more neutron groups. Although a great deal of attention was paid to new types of nuclear reactions, less was given to the fact that they can give rise to particle emissions with new characteristics and peculiar features. Characteristics and features that current detectors, especially active detectors, and available techniques are incapable of adequately detecting, which limits understanding of these new features, see e.g., Refs. [4, 5]. In the case of neutron emissions, some methods have been proposed, including neutron activation of Indium foils and the use of Uranium fission chambers.[31] It is evident that the DST-neutron spectra shown in Figures 3(A) and (B) have a poor, or even no correlation with the behaviors shown in neutron cross-sections of Indium reported in Figure 9 and Uranium, both U-235 and U-238, in Figure 10. Moreover, it is our opinion that it will not be an easy task to plan and prepare an absorber and moderator for use in the detection of DST-neutrons due to the asynchrony, asymmetry and anisotropy of their emissions. Nevertheless, the measurement of these spectra can be an important step toward the exploitation of the energy produced in the DST-reactions.[32–35]

7. CONCLUSIONS

The available neutron detectors are not valid for detecting DST neutrons, being built to detect constant or slow varying in time neutron radiation fields. These are actually the usual characteristics of the neutrons generated by reactions known until today. Furthermore, considering the various methods used for deriving neutron spectra from pulse height distributions, we note that very poor explanation is offered by technical specifications of spectroscopic system (computer based)[26, 27] now commercially available in contrast with those for other detector systems (say Bonner spheres, bubble detectors) discussed in detail in the technical literature. However the difficulty itself encountered in measuring DST neutron demonstrate that there are neutrons whose properties and characteristics must be considered as a new problem, distinguished and separated from the present knowledge on neutrons. This problem must be solved by means of new specific detectors and by means of detector actually in use but adapted to the specific characteristics of these "new" neutrons.

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