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Time correlation between low-energy, high-energy x-rays and neutron emission in plasma focus in the context of nuclear fusion mechanisms

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Neutrons along with x-rays emission have been reported in plasma focus (PF) devices, if the filled gas is deuterium 1. The origin of neutron emission is the subject of debate, due to occurring of complex physical phenomena during pinch phase. Most of the PF scientific community believe that neutron production takes place due to beam-target fusion mechanism [2]. Some investigators reported a fraction of thermonuclear neutrons [3]. Neutrons emitted in axial direction were reported with the higher energies than that in radial direction [4] that makes thermonuclear fusion reactions suspicious in PF devices. Both nuclear fusion reactions, the beam-target and thermonuclear are considered at the time of pinch. To estimate the neutron origin time, it is mandatory to take into account all the time delays that neutrons take to reach the detector. If neutrons would have been originated during the pinch phase, the beam-target and/or thermonuclear fusion reactions could be the possible mechanisms. Otherwise, other processes should be included.

To study the neutron origin time, in the present work, the temporal correlations between low, and high-energy x-ray and high-energy x-rays and neutron signals were obtained for a hundred joules plasma focus device (PF-400J). A method, time history analysis (THA) to estimate the time of origin of neutrons and low energy x-rays with respect to high-energy x-rays was developed and applied. Figure 1 shows the variations in neutrons kinetic energies with neutrons origin time (tn,o) –high-energy x-rays (HXR) origin time (txry,o) in axial and radial directions. Figure 1 reveals that the higher energies of neutron correspond to the neutrons that were originated after HXR (tn,o > txry,o). An interesting observation is that neutrons energies increase from the compression to after pinch phases, assuming that the HXR origin time coincide within the pinch. It seems that the longer the time of the acceleration of deuterons, higher the energies of neutrons. Figure 1 suggests that deuterons start to gain energy during the compression phase. It seems, before pinch, Fermi acceleration dominates. During pinch, main source of energy gain will be the induced electromagnetic fields. It can be imagine that during compression not all deuterons that are accelerated by Fermi acceleration participate in fusion processes. During pinch phase, these deuterons further accelerate by the induced electromagnetic fields along with Fermi acceleration inside the pinch. Similarly, not all deuterons that are gaining energy within pinch take part in fusion processes. The remaining deuterons accelerate further, at the moment of the decay of the pinch. The higher neutron energies after the decay of the pinch appeared because deuterons are already energized during compression and pinch phases. However, the dependence of neutrons energy on collision angle and deuterons energy has to be thoroughly study. Present study is limited to experimental observations that are obtained because of time history analysis (THA). Interpretations of THA reveals that in axial direction, neutrons originate mainly before HXR. On the other hand, in radial direction, neutron origin time is mainly after HXR. In addition, it was found that neutrons energies are lower that are produced before HXR and higher that are produced after HXR. This trend is observed in both directions radial as well as axial. In axial direction, neutron energies are fitted exponentially. While, in radial direction second order polynomial fits neutron energies. These fittings suggest that in axial direction, neutron energies increase faster from compression to after pinch phases. On the other hand, in radial direction this increment is relatively slower. In fact, after 10 ns the increment changes much faster, in axial direction. Nonetheless, in radial direction, this change is not visible instead keep growing linearly. At present, the reason for this behavior is not clear. A similar analysis was performed for temporal correlation between low-energy x-rays and HXR. The results of these findings will discussed during the conference.

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