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Editorial

Neutrino Physics in the Frontiers of Intensities and Very High Sensitivities 2018

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Neutrinos continue being widely studied, just as many decades ago, and have generated an intense scientific interest due to the wide variety of potential applications in particle physics, astro-nuclear physics, and cosmology based on the amassing properties they exhibit like their extremely small mass, their extremely small weak interaction with matter, the neutrino oscillations, and many others. Also, the neutrino production sources at the Earth and in other structures of the Universe are an essential cornerstone for the description of the structure and evolution of the stars.

After the very recent measurement, for the first time, coherent elastic neutrino-nucleus scattering (CEνNS) events COHERENT experiment at Oak Ridge laboratory, neutrinos are understood to be involved in many aspects of the physics processes that are in the forefront of modern theoretical and experimental research. In particular, they play key role in probing physics beyond the Standard Model, explaining the matter-antimatter imbalance in the observable universe, and in operating as messengers from far objects like supernova, quasars, and many others. Furthermore, they have a place in national security applications and provide the research subject of a large number of new physicists around the world.

In the present special issue, we have once again collected, a list of articles showcasing the various themes of neutrino frontier research, from theoretical calculations on precision estimation of their interaction cross-section to ideas for mechanisms of pinpointing the neutrino mass in accelerators. We followed again the worldwide hunt for the neutrino parameters. The parameter space has been reduced to even narrower ranges of values at regularly increasing confidence levels. The values of the mixing angles are now a common-place product of the neutrino sector research industry. Improved detailed simulations and ever increasing data samples, from the running experiments, exclude now the maximal mixing of theta-13 and the lower octant of the theta-23. Therefore, they are favoring the normal neutrino mass hierarchy for the moment, but if this is not the case, then this will cause the serious exclusion of CP violation in the neutrino sector. These ideas affect, critically, the grand-unified theories and the interpretation of the numerous neutrinoless double beta decay experiments.

This special issue consists 10 original research articles. Various open problems are investigated, like coherent elastic neutrino-nucleus scattering, conventional and exotic neutrino phenomena, neutrino properties including neutrino oscillations, nontrivial neutrino electromagnetic properties, neutrino-floor in dark matter detection experiments, and more. The last type is also employed to probe potential applications for unraveling a large variety of theories, within and beyond the standard model, that have appeared during the last decades, in an effort to answer the open questions through current neutrino searches.

In modeling neutrino properties and specifically neutrino mass and neutrino mass hierarchy, *M. K. Parida and R. Satpathy*, inspired by the new implementation of type-II seesaw mechanism in SU(5) grand unified theory, examine a possible application of the type-I seesaw cancellation mechanism in this SU(5) framework. The authors show that, in this context, they may predict, among other things, verifiable lepton flavor violation decays and phenomena predicted by theories beyond the standard model (assuming normal or inverted hierarchy with/without heavy or light neutrino mass) as for example dominant double beta decay within the Cosmological Bound.

The emission of high energy neutrinos from astrophysical sources like Active Galactic Nuclei, binary stars, core collapse supernova, and others may be studied by 3D relativistic magneto-hydro-dynamical simulations. Using as a main computational tool the PLUTO hydrocode, *O. Kosmas and T. Smponias* studied the high energy γ-ray and high energy neutrino emission from hadronic jets of binary stellar systems. They focus on black hole microquasar jets like those of the SS433 microquasar which consists of a compact object (BH) and a companion (donor) star. The authors primarily explore through simulations the dependence of the neutrino and γ-ray emissivity on the dynamical and radiative properties of the jet (the mass-flow density, gas-pressure, temperature of the ejected matter, high energy proton population inside the jet plasma, etc.).

In order to investigate the neutrino-floor in dark matter detection experiments, *D. K. Papoulias et. al.* studied the potential efficiency of various promising nuclear isotopes (like ^{71}Ga, ^{73}Ge, ^{75}As etc.) as direct dark matter detectors in WIMP-nucleus interaction experiments. They carried out extensive calculations for the event detection rates of WIMP-nucleus reactions on the basis of the deformed shell model. One of the main aims of this investigation is to explore how important is the neutrino-floor as a source of background to dark matter searches within coherent elastic neutrino-nucleus scattering (CEνNS). As it is known, events of this process have only recently been measured at Oak Ridge laboratory. The method employed for the required nuclear structure calculation was the deformed nuclear shell model based on the self-consistent solutions of the Hatree-Fock single particle equations in order to obtain the nuclear states.

The investigation of the various effects of nuclear structure impacting the neutrino-nucleus scattering processes is an interesting open issue. Towards this aim, *P. Pirinen et al.* made an attempt to contribute to the importance of distinguishing the neutrino backgrounds in various dark matter (DM) detection experiments focusing on the large liquid xenon detectors used in DM direct detection. The nuclear structure calculations are performed in the nuclear shell model (for elastic scattering) and also in the quasi-particle random-phase approximation (QRPA) and microscopic quasi-particle phonon model (MQPM) for both elastic and inelastic scattering of Xe isotopes. For neutrino sources, these authors consider the ^{8}B solar neutrinos and supernova neutrinos.

A. Chatla et al. investigate the degeneracy resolution capabilities of the NOνA and DUNE neutrino experiments in the presence of light sterile neutrino. They investigate implications of a sterile neutrino on the physics potential of the proposed experiment DUNE and the future runs of NOνA using the latest results. This work is of interest to the experimental study of the possible sterile neutrino.

G. Ghosh and K. Bora study the possibility of existence of (small) effects on lepton flavor violation, neutrino oscillation, leptogenesis, and lightest neutrino mass, due to the fact that up to now the unitarity in the leptonic sector (leptonic mixing matrix) has not yet been established, despite the precise measurements of the neutrino oscillations and neutrino mixing parameters (mass squared differences, mixing angles, etc.) existing from many experiments. The authors extract the bounds on the nonunitarity parameters from the existing experimental data (e.g., on the cLFV processes like the $\mu \longrightarrow e\gamma$, $\mu \longrightarrow e$ conversion).

C.-W. Loh et al. describe how deep learning improves the event reconstruction performance of photon sensors in an antineutrino detector. The Daya Bay detector's vertex position resolution follows a multiexponential relationship with respect to the number of PMTs. This work shows the power of deep learning in helping in the detector design, which is crucial for high-sensitivity neutrino experiments.

In the various neutrino-sources, neutrinos are produced through several emission mechanisms. *L. B. Leinson* investigate the case of neutrino emission from breaking and formation of Cooper-pairs at finite temperatures through a neutral currents weak process. This reaction may take place in superfluid baryon matter at thermal equilibrium in neutron stars and collapsing stellar interior that considerably slows down the cooling rate of neutron stars with superfluid cores. The relevant phenomena play an important role for the correct description of the anomalous weak interactions in both the vector and axial channels.

The possibilities of detecting a heavy sterile neutrino (with mass about 50 keV) in dark matter experiments through several detection mechanisms and experimental techniques are examined in the contribution of *P. C. Divari and J. D. Vergados*. Some examples are the measuring of electron recoils in materials with low electron binding, the low-temperature crystal bolometers, the spin induced atomic excitations at low temperatures, observation of resonances in antineutrino absorption resonances in electron capture on nuclei, and β^{-} decay induced by neutrinos (e.g., KATRIN experiment).

Among the most attractive cold dark matter candidates, the weakly interacting massive particles (WIMPs) have attracted the investigation of many authors the last decades. In their contribution, *J. D. Vergados et al.* focus on light WIMP searches involving electron scattering. They examined the possibility for detecting electrons in light dark matter searches. These detectors are appropriate for light dark matter particles with a mass of the MeV region. The authors analyze theoretically key issues of such a detector for a specific particle model involving scalar particles as WIMPs communicating with both electrons and quarks with Higgs exchange. They also examine experimental aspects of detecting low energy electrons in these dark matter searches. This work presents interesting theoretical and experimental views on possible studies of light dark matter particles.

In summary, this special issue provides a detailed account of the present status of neutrino physics. It highlights recent developments on the novel and important aspects of these particles and their studies with the ongoing and the planned, remarkably sensitive, experiments. The race for the determination of the mass hierarchy at an observation level is expected to conclude in next few years, while the effort for coverage of the CP violation range will last a decade more as it is understood now. Regardless, each step of understanding that comes from the work of groups (large and small) published in articles, like the ones we include in this special issue, brings us one step closer towards unraveling the last of the mysteries of the Standard Model and open the chapter to the New Physics beyond.

Disclosure

Theocharis Kosmas and Hiroyasu Ejiri are co-first authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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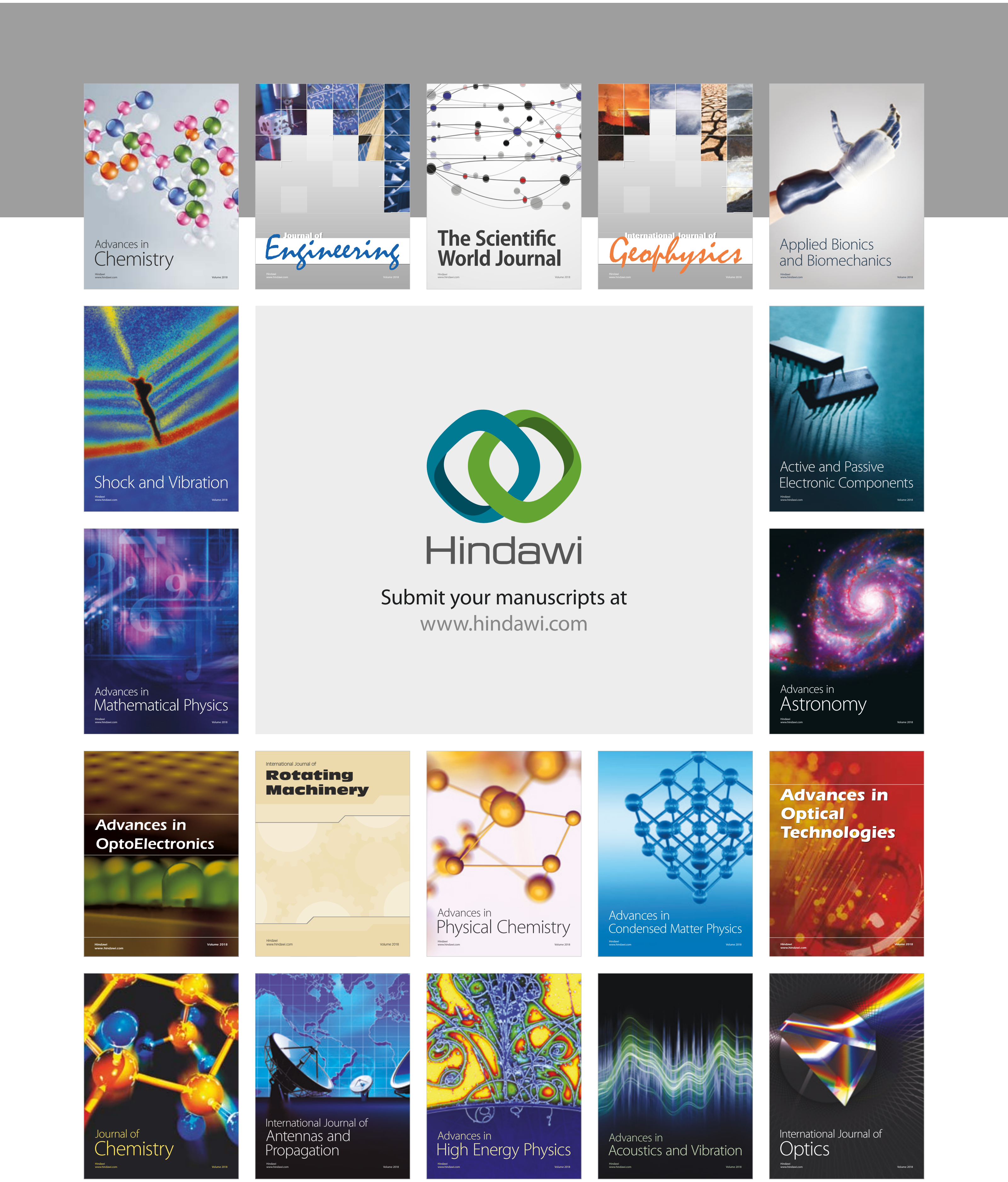
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