THE FOUNDERS OF MODERN PHYSICS IN ROMANIA AS SEEN FROM THE ARCHIVE OF *REVUE ROUMAINE DE PHYSIQUE*

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Abstract. Motivated by a study of the archive of Revue Roumaine de Physique, published under this name in the period 1964-1992 and afterwards under the name Romanian Journal of Physics, we present here a series of short scientific portraits of the founders of Modern Physics in Romania: Eugen Bădărău (1887-1975), Horia Hulubei (1896-1972), Ion I. Agârbiceanu (1907-1971), Şerban Țițeica (1908-1985), Radu Grigorovici (1911-2008), and Ioan Ursu (1928-2007). The aforementioned founders of Modern Physics in Romania were the heirs of the traditions in education and research from the historical provinces of Romania. These traditions rekindled after the Second World War and bloomed through the foundation and subsequent development of the Măgurele Physics Campus, now a Historic Site of the European Physical Society. Studying the archive of *Revue Roumaine de Physique*, we have identified eleven Laureates of the Nobel Prize, either for Physics or for Chemistry, who were closely connected with the development of physics in Romania and published in Revue Roumaine de Physique: C.V. Raman (1888-1970), L. de Broglie (1892-1987), L. Pauling (1901-1994), N.F. Mott (1905-1996), I.M. Frank (1908-1990), G.T. Seaborg (1912-1999), A.M. Prokhorov (1916-2002), K. Siegbahn (1918-2007), N.G. Basov (1922-2001), A. Salam (1926-1996), and C. Rubbia. This article is intended as a personal contribution to the centennial celebrations that mark 100 years that have passed since 1918 when all Romanian historical provinces were united in a single nation state.

Key words: Revue Roumaine de Physique, physics in Romania, physics history.

1. INTRODUCTION

The establishment of the first Romanian universities precedes the formation of the modern Romanian nation state in 1918 and was instrumental in the transformation of our society over the past century and in shaping the future of the Romanian nation for the decades to come. The appearance of the major Romanian universities in the XIXth century follows the academic tradition established through the Princely Academies in București and Iași in the XVIIth century, which were institutions of

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higher education similar in many respects to their European counterparts. Alongside with the Romanian universities we have The Romanian Academy, established in 1/13 April 1866, and Romanian Academy of Sciences, established in 29 March 1935, which were the most important Romanian learned societies that contributed immensely to the development of the modern Romanian nation state. The Romanian Academy acted as a symbol of national culture, a forum of recognition and a space of fundamental research, being in fact the driving force behind most of the large-scale projects that shaped modern Romania. The Romanian Academy of Sciences was a prominent learned society with outstanding international collaborations on the side of exact sciences, physics in particular, up to The Second World War. The Romanian Academy of Sciences was rekindled in 2007 under the name Academy of Romanian Scientists.

The History of Physics in Romania over the last century, see references [1–6], overlaps almost perfectly with what we understand today through Modern Physics. Due to a fortunate coincidence, 1918 also marks the establishment of the quantum paradigm in physics. The Nobel Prize for Physics that was awarded to Max Planck in recognition of the impact that the idea of energy quanta had, marks the beginning of modern physics and the abandonment of some seemingly immutable ideas of Newtonian mechanics. Let us also note that the first issue of the prestigious *Reviews of Modern Physics* was published in 1929, establishing a scientific and editorial tradition that has deeply impacted the development of physics [7].

Returning to the actual history of physics education and research in Romania, let us note that it has a long history, commonly structured in four distinct periods (see Ref. [8]). The first period covers the years 1860-1890 and begins with the introduction of physics courses in the curriculum and sporadic research activities at university level. The second period covers the years 1890-1940 and marks the strengthening of research activities, which are now correlated with didactic activity. During this second period, the first research physics centers are established within the Romanian universities. After the Second World War, at the beginning of the third period of physics development in Romania, we note the activity of a series of exceptional physicists, both remarkable researchers and dedicated teachers, namely: Eugen Bădărău, Horia Hulubei, Ion I. Agârbiceanu, Șerban Titeica, Radu Grigorovici, and Ioan Ursu. The aforementioned founders of Modern Physics in Romania were the heirs of the traditions in education and research from all across Romanian historical provinces: Eugen Bădărău was a Professor at University of Cernăuti, Bucovina, where he established his first research laboratory; Horia Hulubei was a graduate of University of Iasi, Moldova, where he returned after his doctoral studies in France, first as an Associate Professor, then Professor, before moving to Bucharest; Ion I. Agârbiceanu, a native of Transylvania, graduated from "George Barițiu" high school in Cluj-Napoca before moving to Bucharest for university studies; Serban Titeica was a native of Bucharest, where he graduated from University of Bucharest and later on became Professor of Theoretical Physics at his home university; Radu Grigorovici was a native of Cernăuți, Bucovina, where he finished his university studies and later on became Assistant in the laboratory of Eugen Bădărău at University of Cernăuți; Ioan Ursu, a native of Transylvania, graduated from University of Cluj-Napoca where he became Professor. The scientific traditions that were rekindled after the Second World War later bloomed through the foundation and subsequent development of the Măgurele Physics Campus, now a Historic Site of the European Physical Society. This historical article is mainly devoted to the founders of Modern Physics in Romania and to the Măgurele Physics Campus, but we will discuss in a distinct future publication the development of the physics community in Romania, focusing both on the traditional education and research centers in Bucharest, Iași, Cluj-Napoca, and Timișoara, and on the more recent ones such as those in Arad, Bacău, Constanta, Craiova, Oradea, Pitesti, Râmnicu Vâlcea, Sibiu, and Târgoviste.

The central institution of Măgurele Physics Campus was the Institute of Atomic Physics (IFA) between 1956-1974 and then after 1990. Between 1974 and 1990 the activity of the Măgurele Physics Campus was coordinated by the Central Institute of Physics (commonly know through its Romanian abbreviation ICEFIZ), which included the Institute of Atomic Physics (Bucharest-Măgurele), the Institute for Nuclear Technologies (Pitesti-Colibasi), the Institute of Stable Isotopes (Cluj-Napoca), the Institute of Physics (initially based in Bucharest and in afterwards Bucharest-Măgurele), the Institute for Scientific and Technical Creation (Bucharest-Măgurele), the Physics Laboratories of the Technical and Physical Research Center (Iasi), the Center for Documentation and Nuclear Publications (Bucharest-Mägurele), and the Center for Training and Specialization in Nuclear Physics (Bucharest-Măgurele). Following the reorganization of the Central Institute of Physics, the Măgurele Physics Campus included during 1977-1990 the Institute of Physics and Nuclear Engineering (unit with legal personality), the Institute of Physics and Materials Technology (unit without legal personality), the Institute of Physics and Technology of Radiation Devices (unit without legal personality), the Center for Astronomy and Spatial Sciences (unit without legal personality), the Earth Physics Center (unit without legal personality), along with the Nuclear Apparatus Factory (unit without legal personality). During the same period, we find under the coordination of the Central Institute of Physics the following institutions: the Institute of Nuclear Energy Reactors (a unit with legal personality, headquartered in Pitesti), the Institute of Isotopic and Molecular Technology (a unit with legal personality, with headquarters in the city of Cluj-Napoca), together with the Center of Technical Physics (unit with legal personality, based in Iasi). After 1990, when the Institute of Atomic Physics was re-established, the institutes on the Măgurele Physics Campus became National Research and Development Institutes. As part of this process, the National Institute of Physics and Nuclear Engineering

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"Horia Hulubei" (IFIN-HH), the National Institute for Physics of Lasers, Plasma and Radiation Physics (INFLPR), the National Institute for Earth Physics (INFP), and the National Institute for Optoelectronics (INOE), have obtained legal personality, while the Institute of Space Science (ISS) was established as a subsidiary of INFLPR. In this context, let us add to the list of important research institutes the National Institute for Cryogenic and Isotopic Technologies, Râmnicu Vâlcea, which is the institutional heir of the scientific tradition established in Râmnicu Vâlcea through the so-called "G" Plant in 1970, where heavy water was first produced in Romania in August 1976. On university level, we mention here the traditional university centers in Bucharest, Iaşi, Cluj-Napoca, and Timişoara, where didactic and research activities in physics have undergone substantial development in the post-World War II era, along with more recent university centers, as are those from Arad, Bacău, Constanța, Craiova, Oradea, Piteşti, Sibiu, and Târgovişte.

1.1. THE FOREFATHERS OF PHYSICS EDUCATION AND RESEARCH IN ROMANIA

Before the establishment of the Măgurele Physics Campus in the outskirts of Bucharest after The Second World War, physics research was carried out in relatively small groups formed around a series of remarkable Romanian scientists, whom we now regard as the forefathers of physics in Romania. Physics itself was quite different in the XIXth century, as it overlapped considerably with other fields in natural sciences and one cannot distinguish as easily between the research topics that belonged to physics or chemistry, to give just one example. In fact, most of the educational programs were devoted to physicochemical sciences, with little differentiation between physics and chemistry. Similarly, the first Romanian scientific journal that published physics articles was Buletinul Societății de Șciințe Fizice, where he have used the original old-fashioned spelling of that time, which translates to English as the Bulletin of the Romanian Society of Physical Sciences. The journal was published starting 1892 and had a very broad thematic coverage. A brief survey of the first volumes of the journal [9] reveals articles dedicated to atomic physics, chemistry at large, including subjects that now belong to materials sciences and articles dedicated to petroleum, engineering applications (electrotechnics in particular), meteorological observations at the Bucharest Meteorological Institute at that time, geological studies dedicated to the South Carpathians Mountains and to the counties of Mehedinți, Muscel, Dâmbovita, and Prahova, etc.

Among the most important forefathers of physics education and research in Romania we mention here, in chronological order, following the work of Nicolae Ionescu-Pallas [5], a series of outstanding figures is the history of Romanian physics. Our account includes: Ștefan Micle (born 1820 – deceased 1879), Professor of Physics and Chemistry at University of Iași, established in 1860, where he delivered

courses on electricity and optics; Emanuel Bacaloglu (born 1830 – deceased 1891), whose textbook "Elemente de fizică" received The Romanian Academy award; Ștefan Hepites (born 1851 – deceased 1922), who founded the first seismological center in Bucharest and published some of the first articles on the physics of the Earth; Dimitrie Negreanu (born 1858 - deceased 1908), who tackled numerous research problems, wrote a series of physics textbooks, and suggested a study of drinking water in Bucharest based on its electrical resistivity; Dimitrie Bungeteanu (born 1860 - deceased 1932), who carried out the first X-rays experiments in Romania, shortly after those of Wilhelm Conrad Röntgen; Constantin Miculescu (born 1863 - deceased 1937), widely appreciated for his doctoral work on the precise determination of the mechanical equivalent of heat (in Romanian: "Determinarea echivalentului mecanic al caloriei"); Dragomir Hurmuzescu (born 1865 – deceased 1954), Professor of Physics in Iași and Bucharest, known for his contribution to the development of the modern electroscope and for his presidency of the Romanian Radio Broadcasting Company, which started in 1928; Nicolae Donici (born 1874 - deceased 1956), known for the first astrophysical observations, in particular solar prominences; Augustin Maior (born 1882 – deceased 1963), whose research focused on numerous topics such as cosmology, relativity, thermodynamics, electrodynamics, multiple telephony, etc.; Enric Otetelisanu (born 1885 – deceased 1948), one of the founders of meteorological education and research in Romania, and director of the Central Meteorological Institute of Bucharest; Gheorghe Demetrescu (born 1885 - deceased 1969), a founder of the Romanian school of astronomy, who also had outstanding contributions to the development of earthquake science in Romania; Stefan Procopiu (born 1890 – deceased 1972), an outstanding experimental physicist, a graduate of University of Iași with a Doctorate in Physics from Sorbonne University, widely known for the Procopiu-Bohr magneton; Gheorghe Athanasiu (born 1893 - deceased 1972), a remarkable scientist who focused on the photovoltaic effect, geomagnetism, and geophysics at large; Victor Marian (born 1896 – deceased 1971), a dedicated professor at the universities in Cluj-Napoca and Timisoara, who translated in Romanian Newton's "Philosophiae Naturalis Principia Mathematica", wrote a classic book on the history of physics in Romania, and investigated the magnetism of metallic alloys; Stefan Vencov (born 1899 – deceased 1955), a gifted professor both at University of Bucharest and at the Polytechnic Institute of Bucharest; Theodor V. Ionescu (born 1899 - deceased 1988), an outstanding experimental physicist, who graduated from University of Iasi, where he was appointed Professor of Physics before moving to University of Bucharest, author of numerous patents, who contributed to the problem of the speed of sounds in fluids, quantitative spectroscopy, the study of negative ions of oxygen, etc.

We end the previous list with a few brief notes on some physicists who are not in the gallery of the forefathers of physics education and research in Romania, but who have had nonetheless a significant impact on the development of physics in Romania. First on our selection is Aurel Ionescu (born 1902 – deceased 1954), who focused his research activities on molecular spectroscopy, obtaining acetylene by cracking methane in electric arch (at a factory in Râșnov), then we mention Mircea Heroveanu (born 1904 – deceased 1960), a remakable physicist who worked on atmospheric physics at large, Iosef Ausländer (born 1911 – deceased 1978) who contributed significantly to the physics of nuclear emulsions, and Florin Ciorăscu (born 1914 – deceased 1977), both a brilliant physicist and gifted engineer whose research interests span a broad series of subjects, which range from electric discharges in gases to the deposition of thin metallic films and radiation metrology and applications.

1.2. METHODOLOGICAL CONSIDERATIONS

In our selection of articles published by *Revue Roumaine de Physique* we have focused on those either authored or co-authored by prominent Romanian physicists after The Second World War, with special emphasis on the works of the founders of Modern Physics in Romania, and on the articles of outstanding foreign scientists that were in contact with the Romanian physics community. There are three notable exceptions to this approach, namely the sections dedicated to Alexandru Proca, Gheorghe Manu, and Radu Bălescu, who were remarkable theoretical physicists, but did not publish in *Revue Roumaine de Physique*. We felt that without briefly outlining their intelectual profiles and their major achievements our account of Modern Physics in Romania would be incomplete.

In addition to *Revue Roumaine de Physique* there is a series of other journals edited in Romanian that publish physics articles. The most important ones that are published today are *Romanian Reports in Physics* and The Physics Section of *Proceedings of the Romanian Academy – Series A*, which have a broad international coverage, but are also other physics journals published within the Romanian universities. Among these journals we mention here the *Scientific Bulletin Series A: Applied Mathematics and Physics* published by University POLITEHNICA of Bucharest, *Studia Universitatis Babeş-Bolyai, Series Studia Physica* published by Babeş-Bolyai University, and *Annals of West University of Timişoara – Physics*, to give only a few examples. A special note is dedicated to *Annales Scientifiques de l'Université de Jassy*, initially published in 1901 under the editorship of Dragomir Hurmuzescu. The *Annales* changed its name to *Scientific Annals of the "Alexandru Ioan Cuza" University of Iași*, and starting 1962, when the Faculty of Physics was established within the university, a distinct section of the journal was dedicated to physics.

In this article we will focus mainly on the special anniversary issues of *Re-vue Roumaine de Physique* dedicated to Eugen Bădărău (1887-1975), Horia Hulubei (1896-1972), Ion I. Agârbiceanu (1907-1971), Șerban Țițeica (1908-1985), Radu

Grigorovici (1911-2008), and Ioan Ursu (1928-2007), who are now widely considered as the founders of Modern Physics in Romania. To show the level of international recognition and cooperation, we have emphasized the articles published in *Revue Roumaine de Physique* by an impressive series of Nobel Laureates, either for Physics or for Chemistry, namely C.V. Raman (1888-1970), L. de Broglie (1892-1987), L. Pauling (1901-1994), N.F. Mott (1905-1996), I.M. Frank (1908-1990), G.T. Seaborg (1912-1999), A.M. Prokhorov (1916-2002), K. Siegbahn (1918-2007), N.G. Basov (1922-2001), A. Salam (1926-1996), and C. Rubbia. Any selection is intrinsically subjective and in writting this article we did not aim at a comprehensive survey of the publication record of *Revue Roumaine de Physique*, a task that is still ongoing.



Fig. 1 – The cover of the first issue of Tome I of *Revue de Physique*, published in French in 1956 by The Publishing House of The Romanian Academy.

Our study of the entire archive of *Revue de Physique*, published in the period 1956-1964, see Fig. 1 for the cover of the first issue, the archive of *Revue Roumaine de Physique*, published in the period 1964-1992, see Fig. 2 for the cover of the first issue published under this name, and the archive of *Romanian Journal of Physics*, published from 1992 onward, see Figs. 3 and 4, will be reported in a separate future publication. This forthcoming publication will survey the articles from the regular volumes of the journal, as well the articles that appeared in special volumes.

As the current historical article is largely dedicated to the special volumes of



Fig. 2 – The cover of Tome 9, number 1, of the former *Revue de Physique*, published starting 1964 under the name *Revue Roumaine de Physique*. Please note that the change of name that took place in 1964 did not modify the numbering of the volumes of the journal.

Revue Roumaine de Physique devoted to the founders of Modern Physics in Romania, we mention here that there are also special volumes that focus on emerging research directions, as is the special volume of *Romanian Journal of Physics*, namely vol. 49, nos. 9-10, 2004, which gathers the works presented at the "National Symposium of Engineering and Nanosciences". This special volume was edited by Emil Burzo, Titulary Member of The Romanian Academy (since 2009), an outstanding materials scientist whose research activity is devoted to permanent magnets based on alloys containing rare-earth elements. The special volume of *Romanian Journal of Physics* devoted to nanosciences opens with a foreword on "Nanotechnology: A new challenge" by Ioan Dumitrache, Titulary Member of The Romanian Academy (since 2017).

Our analysis of the articles published by *Revue de Physique* (1956-1964), *Revue Roumaine de Physique* (1964-1992), and *Romanian Journal of Physics* (1992 onward) showed that the most cited papers published by the journal under the name *Revue Roumaine de Physique* are those of Peter Sigmund, an outstanding Danish physicist who published in three subsequent issues of the 1972 volume of the journal his lectures presented at the "Summer School on Interaction of Radiation with Matter" that took place in Predeal, Romania, in July 14-24, 1971, see Refs. [10–12]. We



Fig. 3 – The covers of number 6 of *Revue Roumaine de Physique* (left panel) and number 7 of *Romanian Journal of Physics* (right panel), which were published in 1992. This is the second change of name of the journal, after that in 1964, and marks the transition towards publication of articles in English, with very few exceptions.

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note that each of these three articles [10–12] reached more than 200 citations and are still cited today. From the papers published in *Romanian Journal of Physics* the most cited ones are the topical reviews of Dumitru Mihalache on linear and nonlinear light bullets [13] and on localized nonlinear waveforms in optics and Bose-Einstein condensates [14]. These two articles of Dumitru Mihalache have more than 100 citations each and appear as Highly Cited Papers on the Web of Science database of Clarivate Analytics.

We point out that the present historical article is different from the previous survey of the publication record of *Studii și Cercetări de Fizică* [15], a journal that continues the tradition established in 1940 by *Disquisitiones Mathematicae et Physicae*, an inter-war precursory of actual *Romanian Journal of Physics* and is known after 1992 under the name *Romanian Reports in Physics* [16, 17], and the article dedicated to *Proceedings of the Romanian Academy – Series A: An account of the Physics Section* [18], due to narrow focus of the current historical article on the founders of Modern Physics in Romania.



Fig. 4 – The current cover of *Romanian Journal of Physics*, volume 63, numbers 9-10, 2018, which marks the 70th anniversary of The Publishing House of The Romanian Academy.

2. MODERN ROMANIAN PHYSICS

2.1. ATOMIC AND NUCLEAR PHYSICS

2.1.1. Horia Hulubei

Horia Hulubei (born 1896 – deceased 1972), a native of Iași, was the founder of Romanian schools of atomic physics and nuclear physics [19]. He began his university studies in 1922 at University of Iași in physicochemical sciences, and after his degree in 1926 he worked as a researcher, with some interruptions, until 1938, at the Sorbonne physics laboratory in Paris led by Jean Baptiste Perrin. After returning to Romania he first became professor in Iași and then in Bucharest, between 1941 and 1944 being Rector of University of Bucharest. Horia Hulubei was elected Corresponding Member of the Romanian Academy of Sciences in 1935 and in 1937 he became Corresponding Member of the Romanian Academy, being elected Titulary Member of the Romanian Academy in 1946. In 1949 he founded the Institute of Physics of the Academy (IFA), which became in 1956 the Institute of Atomic Physics (IFA).

A selection of the scientific papers published by Horia Hulubei appeared in 1986 at the Romanian Academy Publishing House [20] under the close care of a wealth of brilliant collaborators of the great Romanian scientist: Ioan Ursu, Marin Ivașcu, Alexandru Berinde, Călin Beșliu, Aretin Corciovei, Oliviu Gherman, Theodor V. Ionescu, Tatiana Magda, Nicolae Martalogu, Victor Mercea, Alexandru Mihul, Marius Peculea, Marius Petrașcu, Ionel Purica, and Vasile Tutovan. These, together with Dorel Bucurescu, Corresponding Member of the Romanian Academy, Nicolae-Victor Zamfir, Titulary Member of The Romanian Academy, Emilian Drăgulescu, Mihai Petrovici, Cătălin Borcea, Alexandrina Petrovici, Marilena Avrigeanu, Vlad Avrigeanu, Livius Trache, Gheorghe Căta-Danil, Nicolae Mărginean, Călin Alexa, Călin Alexandru Ur, Florin Negoiță and many other younger researchers continue the tradition started by Horia Hulubei at the National Institute of Physics and Nuclear Engineering, which today is named after him. In addition to the symbolic legacy that all of them carry on and the many research infrastructures that are working within the institute, we mention in particular the realization of the European facility Extreme Light Infrastructure – Nuclear Physics (ELI-NP), a project led by Nicolae-Victor Zamfir.

We note here that there are numerous articles dedicated to Horia Hulubei and point out the contributions of M.T. Magda, Petre T. Frangopol, Ana-Maria Stan, Bogdan Constantinescu, Dorin Poenaru, and Gheorghe Stratan, regarding the exceptional contributions of Horia Hulubei to the development of atomic and nuclear physics in Romania, the creation of the Romanian Academy Physics Institute in 1949, as well as the creation of the Institute of Atomic Physics at Măgurele in 1956 [21-26]. We note that in 1969, Horia Hulubei published in the journal Studii si Cercetări de Fizică an article with a significant title: "20 Years of Physics and Nuclear Physics Research at the Institute of Atomic Physics" [27], celebrating two decades from the founding of the Institute of Physics of the Romanian Academy. As an arch over time, Petre T. Frangopol published in 2016 an article with a related title: "The Institute of Atomic Physics at the 60th Anniversary" [28], marking six decades since the foundation of the Institute of Atomic Physics from Măgurele. Also in 2016 a volume entitled "Horia Hulubei – Yvette Cauchois Scientific Cooperation and the Spirituality in Maramures" was published at the Publishing House of the Science Book of Cluj-Napoca, edited by Petre T. Frangopol and Ioan I. Ursu [29]. In that volume dedicated to the scientific collaboration between two great personalities of XXth century physics in Romania and France, the editors gather a series of impressive essays authored by very prominent personalities of the Romanian cultural and scientific life: Iustin Hodea Sigheteanul, Nicolae-Victor Zamfir, Petre T. Frangopol, Mihail Bălănescu, Emil Burzo, Dorin N. Poenaru, Dorel Bucurescu, Gheorghe Benga, Ioan I. Ursu, Florin-Dorian Buzatu, Bogdan Constantinescu, Ana-Maria Stan, Daniel David, Teodor Ardelean, and Simion Bogîldea.

Horia Hulubei understood very well that one of the most important economic development factors of a country is scientific research, and this belief guided all his

activity dedicated to increasing the visibility of Romanian science internationally. In support of this idea we quote here a fragment from a letter addressed by Horia Hulubei to a colleague on November 30, 1935: "It would be a happiness to be understood once and for all that one of the most important economic factors of a country is pure scientific research". Horia Hulubei's letter was reproduced in L. Kalustian's "Simple Note", Eminescu Publishing House, 1983, and can be found on the website of the Institute of Atomic Physics at Măgurele [30].

Nicolae Ionescu-Pallas published in Ref. [5] a comprehensive synthesis of the biography of the great Romanian scholar, along with a brief overview of Horia Hulubei's main scientific results. In the following, we will only point out the most significant aspects of the scientific personality of Horia Hulubei, using the biographical notes published by Nicolae Ionescu-Pallas [5] and Petre T. Frangopol [23]. After graduating from the Physics and Chemistry Section of the Faculty of Physics and Chemistry of Iasi in 1926, Horia Hulubei worked in the Physico-Chemistry Laboratory of the Faculty of Sciences as Assistant of Professor Petre Bogdan. He went to France in 1926 and worked in the laboratory of Jean Baptiste Perrin (born 1870 - deceased 1942), Nobel Prize Laureate for Physics in 1926 "for his work on the discontinuous structure of matter, and especially for his discovery of sedimentation equilibrium". In 1933, Horia Hulubei finished his doctorate in experimental physics with a dissertation in the field of multiple Compton effect. In the examination committee of Horia Hulubei's doctoral dissertation, entitled "Contribution à l'étude de la diffusion quantique des rayons X", chaired by Marie Curie (born 1867 - deceased 1934), double laureate of the Nobel Prize for Physics (in 1903) and for Chemistry (in 1911), we find Jean Baptiste Perrin and Charles Mauguin. Horia Hulubei's doctoral thesis was particularly appreciated by the Swedish physicist Karl Manne Georg Siegbahn (born 1886 - deceased 1978), Nobel Prize Laureate for Physics in 1924, for "his discoveries and research in the field of X-ray spectroscopy". Horia Hulubei has published, both as a single author and in collaboration with Yvette Cauchois, a series of remarkable articles in the field of atomic spectroscopy using X-rays in Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences and Journal of Physique et Le Radium, between 1931-1948. In 1947 he published a short scientific article in Physical Review, entitled "Search for element 87" [31]. According to our knowledge, this scientific work is the first article published in the *Physical* Review by a Romanian physicist. Horia Hulubei studies in Ref. [31] the validity of the scientific results published in 1943 in the same journal by the American physicist F.R. Hirsh (namely The search for element 87, Phys. Rev. 63, 93 (1943)). We mention that in 1936, Horia Hulubei published a first study on the chemical element 87 [32]. Subsequently, in another work by Horia Hulubei, this presumed chemical element with atomic number 87 was named Moldavium [33]. However, the French physicist Marguerite Perey, Curie Institute, Paris, was credited with the discovery in 1939 of the chemical element with atomic number Z = 87; the name Francium (Fr) was formally adopted for this chemical element in 1949 by the International Union of Pure and Applied Chemistry. It is noteworthy that in an extensive article published in 2010 by Brett F. Thornton and Shawn C. Burdette [34], the history of the radioactive chemical element with atomic number Z = 85, astatine (At), which is similar to iodine and is considered to be the rarest element on Earth, is discussed at large. The important scientific contributions of Horia Hulubei and Yvette Cauchois [35, 36], in the direction of highlighting that new chemical element, have been extensively exposed in Ref. [34].

On the occasion of the 70th anniversary of the great Romanian scientist Horia Hulubei, a special volume of *Revue Roumaine de Physique* was published in 1966, namely Volume 11, Number 9-10. In that volume were published a series of scientific articles dedicated to Horia Hulubei, having as authors scientific personalities from all over the world who have known him. It is extremely important to note that in this special volume of Revue Roumaine de Physique, dedicated to Horia Hulubei, we find as authors five Nobel Prize Laureates: Chandrasekhara Venkata Raman (born 1888 - deceased 1970), Louis de Broglie (born 1892 - deceased 1987), Kai Siegbahn (born 1918 – deceased 2007), Linus Pauling (born 1901 – deceased 1994), and Carlo Rubbia. Chandrasekhara Venkata Raman received the Nobel Prize in Physics in 1930 for his work on the scattering of light and for the discovery of the Raman effect. Louis de Broglie was awarded the Nobel Prize for Physics in 1929 for his discovery of the wave nature of electrons. Kai Manne Siegbahn received the Nobel Prize in Physics in 1981 for his contribution to the development of high-resolution electron spectroscopy. Linus Carl Pauling received the Nobel Prize for Chemistry in 1954 for his researches into the nature of the chemical bond and its application to the elucidation of the structure of complex substances and the Nobel Peace Prize in 1962 (awarded in October 1963). Carlo Rubbia was awarded the Nobel Prize in Physics in 1984, jointly with Simon van der Meer, "for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction."

Chandrasekhara Venkata Raman published in the volume of *Revue Roumaine de Physique*, an article on the fluorescence properties of calcium fluoride (CaF₂) [37]. Louis de Broglie published an article with historical overtones, on the scientific field of thermodynamics of an isolated particle ("Thermodynamique de la particule isolée") [38]. Kai Siegbahn published in collaboration with Carl Nordling a review paper on high precision electron spectroscopy methods for atom and molecule investigation [39]. Linus Pauling published a paper on the structure and stability of atomic nuclei, developing a new theory of nuclear structure, which he called the "closed-packed-spheron theory of nuclear structure" [40]. Carlo Rubbia published a paper on the very rare events of four-lepton decays of electrically charged pions and kaons [41]. This work was co-authored by two outstanding physicists from the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, namely Lev Okun (born 1929 – deceased 2015) and Bruno Pontecorvo (born 1913 – deceased 1993).

We continue our survey of the special volume dedicated to Horia Hulubei with the article of Ph. Briandet, dedicated to the evolution of hydrogen bubble chambers [42], used in the study of elemental particle interaction at the major experimental facilities at CERN, Geneva, Switzerland, and at JINR, Dubna, Russia, and the article of J.D. Bernal and S.V. King that reviews the research mainly conducted by J.D. Bernal on the theory of simple liquids [43]. Sigvard Eklund (born 1911 - deceased 2000) published an article on the status of nuclear power plants at that time and the prospects for further developments in the field [44]. We mention that Sigvard Eklund has worked for a long time (1961-1981) as Director-General of the International Atomic Energy Agency (IAEA), based in Vienna, Austria. In the article published in Revue Roumaine de Physique, S. Eklund mentions the following aspects of Horia Hulubei's contribution to the development of IAEA: "Professor Hulubei was a member of the Board of Governors and once Vice-Chairman of the Board. On the General Conference, too, Professor Hulubei has represented his country and was two years ago the chairman of the General Conference's Technical and Budget Committee. The Agency has greatly benefited from having Professor Hulubei's scientific knowledge and experience and international outlook to take part in all these meetings" [44]. In the volume we also find an article written by A. Lösche, from the Institute of Physics, University of Leipzig, on nuclear magnetic resonance researches carried out on a complex molecular chemical compound, namely "triglycine sulfate" [45].

We mention as well the series of scientific articles published by brilliant Romanian physicists. Eugen Bădărău published in collaboration with Athanasie Truția and O. Zamfir an experimental work on the characteristics of gas discharges in three different environments: (a) argon and water vapors, (b) nitrogen and water vapors, and (c) oxygen and water vapors [46]. Serban Titeica, D.H. Constantinescu, and Viorica Florescu have published a work in the field of mathematical physics, regarding representations of infinitesimal orthogonal groups using infinitesimal canonic transformations [47]. The results obtained in the above-mentioned paper are useful in constructing linear representations of Lie algebras. Radu Grigorovici, Nathan Croitoru, and Andrei Dévényi published a study of the temperature variation of the thermoelectric power coefficient of the thin layers of amorphous germanium [48]. A work on the banned hyperfine transitions that are highlighted in the electron spin resonance spectra of Mn^{2+} ions in calcite monocrystals (CaCO₃) was published by Ioan Ursu, Voicu Lupei, and Aurelia Lupei [49], the authors having University of Cluj as institutional affiliation at that time (1966). Aretin Corciovei (born 1930 - deceased 1992), founder of the solid state theory school in Romania [50], published with Gheorghe Costache

some theoretical results on magnetic anisotropy in cobalt ferromagnetic thin layers [51]. George Comsa, a world-renowed scientist who worked at the beginning of his brilliant scientific career at the Institute of Atomic Physics in Magurele, published an article on the status of research at that time on the energy distribution of ions at the time of their production, and the practical methods of obtaining and measuring very low pressures [52]. Adrian Gelberg, C. Nistor, and C. Protop published an article dedicated to the calculation of the intensity and form of X-rays produced in the resonant gamma-ray absorption process [53]. R.V. Deutsch has published a theoretical study on the influence of Hall effect on the propagation of monochromatic waves in relativistic magnetohydrodynamics [54]. Ioan-Iovitz Popescu, Geavid Musa, A. Popescu, and A. Baltog published a study on the possibility of using the photo ionization effect as a ionization imbalance process in plasma-based electric generators [55]. A research team led by Petre T. Frangopol and Alexandru T. Balaban, from the Institute of Atomic Physics and a group of chemists from the Institute of Petrochemical Research in Ploiești, published a series of studies on the radiolysis of some Romanian oil products, which were performed at the VVR-S nuclear reactor of the Institute of Atomic Physics [56]. Another series of works dedicated to Horia Hulubei was published in *Revue Roumaine de Physique* at the beginning of 1967 in Volume 12, Number 1. The first work, published in that anniversary volume, had Eugen Bădărău, C. Popovici, and Maria Someșan as authors and was dedicated to investigating the physical mechanisms of a hollow catode effect [57]. Alexandru Cișman, from the Polytechnic Institute of Timisoara, published a review article on lamellar structure and magnetic and electrochemical characteristics of thin ferromagnetic films containing Fe, Ni, and Co [58]. Victor Mercea (born 1924 – deceased 1987) from the Cluj-Napoca Section of the Institute of Atomic Physics, Corresponding Member of The Romanian Academy (elected in 1963), published in collaboration with E. Grecu and A. Olariu, an article on some innovative methods of isotope separation with applications to heavy water production [59]. Nicolae Grama, L. Marinescu, I. Mihai, Marius Petrașcu, Aureliu Săndulescu, and G. Voiculescu published an article in which they reported the results of the measurements of the effective fission sections of the ²³⁹Pu in the 0.7–4 meV energy range of the neutrons [60]. Ionel Purica published a synthesis of the neutron spectra research conducted at the VVR-S nuclear reactor at the Măgurele Institute of Atomic Physics [61]. Claude Nicolau, Octavian Körner, and Alexandru Cristea, from the Center for Radiobiology and Molecular Biology, Bucharest, published some results on the electron spin resonance spectra of gamma-irradiated biomolecular complexes [62]. Athanasie Trutia, M. Vodă, and A. Vasile, of the Institute of Physics of the Romanian Academy, published a paper on optical spectra of molecular complexes that contain cobalt [63].

The scientific tradition started by Horia Hulubei is continued today at the Institute of Physics and Nuclear Engineering "Horia Hulubei" (IFIN-HH), through scientific research and development activities that cover a very broad thematic area. One of the most important figures of the Măgurele Physics Campus, which continued the tradition of Horia Hulubei and strengthened the community of physicists and engineeris in Măgurele, was that of Marin Ivașcu (born 1931 – deceased 2013), an outstanding experimental nuclear physicist and a mentor of numerous young scientists who later turned into reputed researchers [64–70]. The contributions of Marin Ivașcu range from investigations into nucleon-induced nuclear reaction mechanisms in light and medium-mass nuclei, elastic and inelastic scattering of alpha particles and (α ,p) reactions, investigations into (d, α) reactions for spectroscopy of excited states and lifetime measurements using Doppler shift techniques to cluster radioactivity, jointly with Dorin Poenaru and Aureliu Săndulescu [71–73].

The research and development fields of the institute now cover theoretical physics, atomic and nuclear physics, elementary particle physics, the physics of life sciences and the environment, along with inter- and multidisciplinary domains such as computational physics, nuclear astrophysics, physics of the condensed state of matter, radiochemistry and the interaction of radiation with matter, etc. We mention the research on the study and preservation of the Romanian national cultural heritage coordinated in IFIN-HH by Bogdan Constantinescu (Department of Applied Nuclear Physics), Valentin Moise (IRASM), and Corneliu Ponta (IRASM). Using a wide range of physicochemical methods, researchers from IFIN-HH have contributed decisively in recent years to authenticating the Dacian bracelets discovered in the former Sarmizegetusa Regia fortresses, Hunedoara County, and to preserve and restore a large number of historical and religious artifacts from the national patrimony of Romania. Among the most important contributions to the preservation and restoration of the national heritage, we mention here, in a brief selection, the studies on the Pietroasele Hoard, the elemental analysis of the Dacian cosons, the investigations dedicated to Byzantine ceramics in Hârsova, the study of the gold samples from the Cavnic mine (Baia Mare), the analysis of the premonetary signs in Histria (Dobrogea), the researches on the Agighiol hoard and the glass bracelets from Nufăru, as well as the use of X-ray fluorescence in the restoration of the painting made by Gheorghe Tattarescu at the Otetelesanu church in Măgurele. The aforementioned results, which are outlined, in chronological order, in Refs. [74–93], were obtained over the past two decades by a research group of IFIN-HH coordinated by Bogdan Constantinescu, which includes R. Bugoi, F. Constantin, D. Cristea-Stan, M.M. Manea, C. Pauna, and A. Vasilescu. This research direction is not only inter- and multidisciplinary, but also involves many national collaborations (e.g., those with the National History Museum of Romania and the Faculty of Geology and Geophysics of the University of Bucharest) and international ones (e.g., those with Institute of Ion Beam Physics and Materials Research, Dresden, Germany, Istituto Nazionali di Fisica Nucleare, Laboratori Nazionali di Legnaro, Padova, Italia, *Daresbury Laboratory*, Warrington, UK, and *Centre de Recherche et de Restauration des Musées de France*, Paris, France). We end our discussion on the scientific legacy of Horia Hulubei, mentioning the setting up within IFIN-HH of the first Nuclear Forensic Laboratory in Romania, coordinated by Nicolae Marius Mărginean, in which a wide range of state-of-the-art equipment will be used (for example: gamma spectroscopy systems, X-ray diffractometer, electronic microscope, three-dimensional scanner, etc.).

2.1.2. Ioan Ursu

Ioan Ursu (born 1928 – deceased 2007), Titulary Member of The Romanian Academy (elected in 1974), is considered one of the founders of the Atomic and Nuclear Physics School of Romania. He graduated from Cluj-Napoca University and did post-doctoral studies at Princeton University, USA. After returning to Romania he contributed decisively to the development of the Romanian Nuclear Program in close collaboration with Horia Hulubei, Marius-Sabin Peculea, Gheorghe Văsaru, Victor Mercea (born 1924 – deceased 1987), Alexandru Olariu, Ionel I. Purica (born 1925 – deceased 1990), Mărgărit Pavelescu, Nicolae Andreescu, S. Lungu, and Mihail Bălănescu. Among the collaborators of Ioan Ursu, we note here Victor Mercea, Corresponding Member of The Romanian Academy (elected in 1963), an outstanding experimental physicist who started his research activity with studies on viscous gases and by making precise viscometers for gases. Victor Mercea later on shifted his research interests towards the separation of stable isotopes, particularly on heavy water production, jointly with M. Peculea, A. Olaru, T. Fodor, and P. Mărginean.

In the first period of his scientific work he studied the physicochemical properties of oxygen gas mixtures under the influence of magnetic fields [94]. At Princeton University he specialized in electron spin resonance and later on formed in Cluj-Napoca a research group of impressive international visibility that included V.V. Grecu, V. Lupei, S.V. Nistor, A. Nicula, D. Strugaru, G. Cristea, I. Barbur, and L. Giurgiu. In 1965 Ioan Ursu published in Romanian the monograph "Rezonanța electronică de spin" (in English: "Electron spin resonance") [95] at the Publishing House of The Romanian Academy, Bucharest, while in 1968 he published the French edition at the Dunod Publishing House, Paris [96]. Ioan Ursu also made substantial contributions to the field of nuclear magnetic resonance (NMR), publishing in 1979 a monograph on the study of uranium compounds using the NMR technique [97]. He also conducted studies on the physics and technology of nuclear materials, publishing in 1985 a monograph at Pergamon Press Publishing, United Kingdom [98].

In 1990, Ioan Ursu published in Adam Hilger Publishing, UK, in collaboration with A.M. Prokhorov (Nobel Prize Laureate for Physics in 1964), V.I. Konov, and I.N. Mihăilescu, a reference book in the field of metal processing using highpower laser radiation [99]. We mention here that Aleksandr Mikhailovich Prokhorov won the Nobel Prize for Physics in 1964 "for fundamental work in the field of quantum electronics, which led to the construction of oscillators and amplifiers based on the maser-laser principle." The fruitful scientific collaboration between the group in Bucharest headed by Ioan Ursu and Ion N. Mihăilescu and the group of the General Physics Institute of Moscow, Russia, led by A.M. Prokhorov and V.I. Konov has resulted into a series of valuable scientific articles published in prestigious journals from Romania and abroad: *Revue Roumaine of Physique, Applied Physics Letters, Journal of Applied Physics, Applied Optics, Journal of Physics D: Applied Physics, Infrared Physics*, etc. Ioan Ursu was elected president of the European Physical Society (EPS) for the term 1976-1978, being the fourth president of EPS, after G. Bernardini (1968-1970), Erik Gustav Rydberg (1970-1972), and H.B.G. Casimir (1972-1976). The European Physical Society, founded in 1968, celebrated in 2018 five decades of service to the scientific community of physicists in Europe.

The 3rd General Conference of the European Physical Society "Energy and Physics" took place in Bucharest, on the Măgurele Physics Campus, between September 9-12, 1975. There were 750 physicists from 27 countries, including over 300 physicists from Western European countries and more than 130 physicists from Eastern European countries other than Romania. The local organizing committee was led by Ioan Ursu and Ion Andrei Dorobantu. Among the conference participants, we mention Pyotr Leonidovich Kapitsa (born in 1894 - deceased 1984), Nobel Prize Laureate for Physics in 1978 "for his basic inventions and discoveries in the field of low-temperature physics" and H.B.G. Casimir. The works of the conference were publicized in Europhysics News, volume 6, issue 9/10, September / October 1975, in a document titled "EPS Third General Conference. Bucharest, Romania, 9-12 September 1975". On the first page of that publication appears a motto signed by Ioan Ursu, a text that is still relevant today: "Science and technology have essential forces of progress [...]. Physics must respond to the energy crisis, converting it from an apparent dead end into a turning point, leading to a new and steady equilibrium." Among the organizers of the aforementioned conference we mention Ion N. Mihăilescu and Dan V. Vamanu. Ion N. Mihăilescu continued with great success the research directions initiated by Ioan Ursu on the side of the interaction of laser radiation with metals [100, 101]. In recent years, the Măgurele research group led by Ion N. Mihăilescu has expanded its topical coverage of research subjects by including a series of topics that combine materials science and physics and laser technology: innovative biomaterial deposition methods as well as nanoscience and nanotechnology studies, in particular research into nanoparticles and nanostructured thin layers [102]. It is our pleasure to mention here a plethora of Romanian researchers who participated to aforementioned Romanian-Russian scientific cooperation: Rodica Alexandrescu, V.S. Teodorescu, I. Morjan, V. Crăciun, M.I. Bîrjega, Laura C. Nistor, M. Popescu, N. Chițică, Eniko György, and Carmen Ristoscu. Ion N. Mihăilescu received the "Galileo Galilei Award" in 1994, being the first scientist in the world to receive this high scientific distinction awarded by the International Commission for Optics, a professional organization affiliated to the International Union of Pure and Applied Physics (IUPAP). After him two other Romanian researchers were rewarded with the "Galileo Galilei Award", namely Ionel-Valentin Vlad, in 2005, and Dumitru Mihalache, in 2009. Recently, on 17 September 2018, The Optical Society (OSA), Washington, DC, USA, elected Ion N. Mihăilescu as OSA Fellow "for outstanding contributions to the field of high pulsed energy laser radiation, with groundbreaking applications in nano-biomedicine, chemistry, and metalurgy". We note here the remarkable fact that two other Romanian researchers were elected over time as OSA Fellows: Ionel-Valentin Vlad, in 1978, "in recognition of distinguished service in the advancement of optics" and Dumitru Mihalache, in the year 2012, "for significant theoretical contributions to nonlinear wave phenomena at single and multiple interfaces including surface solitons and spatiotemporal optical solitons."

On the occasion of the 60th anniversary of Ioan Ursu, a special volume of Revue Roumaine de Physique was published in 1988 in Tome 33, Number 4-6, of the journal. A long series of scientific articles have been dedicated to Ioan Ursu, all authored by leading scientific personalities from abroad and from Romania who have known him over the years. Three Nobel Prize Laureates published articles in the aforementioned volume, namely Glenn T. Seaborg (born 1912 - deceased 1999), Nobel Prize winner for Chemistry in 1951 jointly with Edwin Mattison McMillan "for their discoveries in the chemistry of the transuranium elements", Aleksandr Mikhailovich Prokhorov (born 1916 – deceased 2002), Nobel Prize Laureate for Physics in 1964, and Abdus Salam (born in 1926 – deceased 1996), Nobel Prize Laureate for Physics in 1979, along with S.L. Glashow and S. Weinberg, "for their contributions to the theory of unified weak and electromagnetic interaction between elementary particles, including, *inter alia*, the prediction of the weak neutral current." G.T. Seaborg and W. Loveland published in that volume a review article in which they analyzed the mass distributions specific to nuclear collisions of C and Ne light nuclei with atomic targets that range over a large spectrum (from Cu to U) [103]. The group of A.M. Prokhorov, from the Institute of General Physics of Moscow, Russia, which included first of all V.I. Konov, Member of the Russian Academy of Sciences, and the Măgurele Group, which consisted of I.N. Mihăilescu, L.C. Nistor, V.S. Teodorescu, R. Alexandrescu, I. Morian, M.I. Bîriega, V. Drăgănescu, and V. Crăciun published jointly a review paper on their long-term scientific collaborations in the field of surface physics using high-power laser pulses with applications in material processing and the separation isotopes of chemical elements [104]. The group led by A.M. Prokhorov also published another article in collaboration with the group led by Voicu Lupei, a work focused on the luminescence of Er ions in YAG laser crystals [105]. In the article published by Abdus Salam in that volume, the Nobel Prize Laureate of Physics in 1979 overviewed the main results of the research done worldwide in the field of elementary particle physics at the level of 1987 [106]. Prominent physicists of the XXth century, both from Romania and from countries on all continents, contributed scientific articles to the special volume dedicated to Ioan Ursu. We mention here a number of foreign physicists who published relevant scientific articles, some of which reviewed their respective research fields in the years 1987-1988 and their prospects for development in the years to come. The Russian Physicist G.N. Flerov has published a substantial paper on the status of research carried out on the synthesis of chemical elements with atomic numbers 102-110, using heavy ions, at the Joint Institute for Nuclear Research, Dubna, Russia [107]. The American physicist E.R. Andrew of the University of Florida, Gainesville, published a paper in which he reviewed his own results on NMR research [108], a field in which Ioan Ursu had scientific contributions appreciated by the international physics community at large. The American physicist C.P. Slichter of Illinois University published an article summarizing the development of the field of nuclear magnetic resonance [109]. Let us mention that at that time C.P. Slichter was the president of the International Society of Magnetic Resonance. The Chinese physicist Gan Fuxi, from the Institute of Optics and Fine Mechanics, Shanghai, China, has published a comprehensive work in which he overviewed the existing results on the development of high-power lasers [110]. The group of physicists from Japan, which consisted of H. Takuma, K. Shimizu, and F. Shimizu, contributed with an ample article that reviewed the various optical spectroscopy methods used at that time in the study of atomic and molecular spectra [111]. F.R. Ausseneg of the University of Graz, Austria, published a work on the fluorescence of molecules positioned in the proximity of submicron metallic particles, which anticipated the spectacular development of the fields of nanooptics and nanoplasmonics in the decades that followed that pioneering research [112].

We mention here also the work of G.J. Béné of the University of Geneva on nuclear magnetic resonance applications for the identification of environments containing significant amounts of water, particularly in the field of exploration of live tissue composition and diagnosis of diseases [113]. The group of the University of Rome, Italy, led by Mario Bertolotti, published an experimental article on nonlinear optics of liquid crystals [114]. R. Blinc, from the University of Liubliana, contributed with an article on the determination of some order parameters in spin glasses using nuclear magnetic resonance [115]. We also mention the material published by Sigvard Eklund [116], at that time the Emeritus General Director of the International Atomic Energy Agency in Vienna, in which he praises the contributions of Horia Hulubei and Ioan Ursu to the development of the institutional links between Romania and the various professional organizations of physicists from all over the world. S. Eklund mentions, in the material published in *Revue Roumaine de Physique*, the fundamental

contributions of Ioan Ursu to strengthening Romania's institutional ties with international professional organizations: "I would emphasize his role as President of the European Physical Society and his active participation in different international organizations, with particular reference to the Scientific Advisory Committee of the IAEA and the Scientific Council of the Joint Institute for Nuclear Research, Dubna, in the USSR."

We would like to mention the names of other world class physicists who have published articles in the volume dedicated to Ioan Ursu: E.L. Andronikashvili (specialist in low-temperature physics), V.P. Chebotaev (nonlinear laser spectroscopy specialist), W.E. Wallace (specialist in magnetism and neodymium-based magnetic alloys), A. Faessler (prestigious nuclear physicist), A.A. Friessem (specialist in optics and holography), F.K. Kneubühl (specialist in lasers), A. Lösche (specialist in the use of nuclear magnetic resonance methods in liquid crystal studies), D. Schoemaker (specialist in condensed matter physics), W. Greiner and J. Reinhardt (renowed physicists in the field of nuclear physics), V. Sochor (specialist in optics), V.G. Soloviev (specialist in the field of theoretical nuclear physics), M.L. Ter-Mikaelian (specialist in the field of nonlinear optics), B. Wilhelmi (specialist in the field of high-energy laser pulse physics), and A. Zichichi (specialist in elementary particle physics).

A number of Romanian researchers have contributed with articles in that volume. Here we mention D. Barb, D. Bally, N.M. Grecu, A. Berinde, I. Piticu, C. Ciortea, Daniela Fluerașu, A. Enulescu, I.C. Legrand, V. Zoran, C. Beșliu, A. Jipa, G. Ciobanu, E. Cruceanu, Gh. Aldica, M. Popescu, S. Popa, D.E. Demco, I. Dima, C. Plăvițu, E. Drăgulescu, G. Semenescu, D. Popescu, M. Duma, Z. Gábos, O. Gherman, L. Saliu, A. Glodeanu, V. Iancu, V.V. Grecu, F.F. Popescu, R. Grigorovici, P. Gartner, I. Corcoțoi, R. Grosescu, Mihaela Lupu, N. Ionescu-Pallas, I. Gottlieb, L. Sofonea, A. Corciovei, D. Mihalache, D. Mazilu, A. Mihul, T. Angelescu, I. Lazanu, A. Nenciu, G. Nenciu, A. Nicula, S.V. Nistor, M.L. Pascu, M. Pavelescu, M. Peculea, M. Petrașcu, I. Brâncuș, A. Buță, V. Simion, I. Mihai, I. Pop, I.-I. Popescu, A. Ludu, I.M. Popescu, A.G. Podoleanu, P.E. Sterian, E.N. Ștefănescu, I.A. Dorobanțu, S. Țibuleac, A.A. Răduță, I.I. Ursu, I. Pădureanu, Gh. Rotărescu, S.N. Râpeanu, L. Schächter, A.I. Bădescu-Singureanu, I. Iova, T. Tudor, D.V. Vamanu, S. Georgescu, C. Ionescu, A. Lupei, V. Lupei, C. Bratu, and G. Văsaru.

We will briefly review some of the papers published by Romanian researchers in that volume. Nicolae Andreescu, M. Alecu, I. Arimescu, O. Budan, C. Gheorghiu, S. Lungu, I. Mirion, and A. Pascu published a paper that surveyed the physicochemical equipment and methods for fuel testing in a nuclear power plant [117], which are required for the operation of CANDU-type nuclear reactors that use natural uranium as fuel and heavy water as a neutron moderator and coolant. CANDU nuclear reactors were subsequently built in Romania at the Cernavodă Nuclear Power Plant as a result of the scientific and technical collaboration between the Romanian and Canadian governments. Emil Burzo, Sanda Adam, Gheorghe Adam, and W.E. Wallace published a paper on specific magnetic phenomena that appear in a series of intermetallic compounds based on Nd-Fe-B [118]. We mention that magnetic alloys containing Nd in combination with other rare earths (Tb and Dy) are extremely important in the international market of permanent magnets. Vasile Drăgănescu, I. Guțu, Dan C. Dumitraș, Dan Apostol, Ionel-Valentin Vlad, and Virgil Vasiliu published an article in which they reviewed the experimental researches conducted in Romania for the production of high-power gas CO_2 lasers [119], which are commonly used in various industrial applications. Marin Ivașcu, Dorin N. Poenaru, Dumitru Mazilu, and Irina Ivașcu have published some theoretical developments of a unified model for C, Ne, Mg, and other heavy ion radioactivities, cold fission, and alpha decay [120].

Alexandru Mihul (born 1928 – deceased 2015), Tatiana Angelescu, T. Preda, and I. Lazanu published an article on the absorption of electrically charged pions in light atomic nuclei, in particular in ³He nuclei [121]. Alexandru Mihul worked for a long time at JINR, Dubna, being a distinguished member of the group of physicists led by the great Russian scholar V.I. Veksler. It is noteworthy that in 1960, at JINR Dubna, V.I. Veksler, Alexandru Mihul, and their collaborators from Russia, China, Vietnam, North Korea, Poland, and Czechoslovakia have discovered a new elementary particle, the anti-sigma-minus hyperon [122]. This outstanding experimental discovery was widely acknowledged in the scientific literature and it is noteworthy that there was an article dedicated to it in the issue of The New Scientist that was published on April 7th, 1960, in the section "Trends and Discoveries" [123]. The experimental discovery of the anti-sigma-minus hyperon is described as follows: "The first electrically charged antihyperon has been detected – yet another nuclear particle to be added to the catalogue. The anti-sigma-minus hyperon, whose existence has been anticipated by theoretical physicists, has turned up in photographs of a bubble chamber subjected to bombardment by an atom-smashing machine at Dubna, near Moscow. A team of Chinese, Soviet, Vietnamese, North Korean, Polish, Roumanian and Czech scientists discovered the particle last month after examining 40,000 photographs. The mass of the particle is about 2,300 times the mass of the electron (that is, it is heavier than a proton or neutron) and it decays in about 100 micromicroseconds into an antineutron and a positive pi-meson. Such is the system of nomenclature, the anti-sigma-minus particle is positively charged, being the antiparticle of the negatively charged sigma-minus particle. The work will be described in the Soviet Journal of Experimental and Theoretical Physics".

Dan V. Vamanu, a close collaborator of Ioan Ursu, published in the special volume a paper on some theoretical models for spatial distribution of radiation doses in the case of emission scenarios of radioactive chemical elements from possible nuclear accidents [124]. Gheorghe Văsaru and Corneliu Bratu from the Institute of Isotopic and Molecular Technologies, Cluj-Napoca, published a review article on the researches carried out in Romania and worldwide in the field of stable isotope separation by the method of thermodiffusion columns [125]. It is worth mentioning that the Romanian scientist Gheorghe Văsaru, a world renowned specialist in the field of isotope separation by the thermodiffusion method, published in 1967 a comprehensive review article titled "Thermal diffusion in isotopic gas mixtures" in the journal *Fortschritte der Physik* [126]. Also, Marius Peculea, Titulary Member of The Romanian Academy (elected in 1993), published a topical overview on the industrial scale production of the heavy water required for Romania's Nuclear Program [127].

We end our survey of articles published in the special volume of Revue Roumaine de Physique dedicated to Ioan Ursu with Aureliu Săndulescu, Titulary Member of The Romanian Academy (elected in 1992) whose contribution is focused on a new type of radioactive decay: "cluster radioactivity" or "heavy-ion radioactivity". This new type of radioactivity is intermediate between the classical phenomena of alpha decay and spontaneous fission [128, 129]. The first experimental confirmation of heavy-ion radioactivity, published in Nature in 1984, was due to H.J. Rose and G.A. Jones, from the Department of Nuclear Physics, University of Oxford, UK, who have performed a systematic study of nuclei heavier than lead and showed the emission of ¹⁴C from ²²³Ra [130]. These experimental results were followed in 1985 by a series of studies carried out at the Joint Institute for Nuclear Research, Dubna, Russia, Laboratory of Nuclear Reactions, by a group of researchers led by S.P. Tretyakova and Aureliu Săndulescu. The group included, in alphabetical order, Dumitru Hasegan, Yu.S. Korotkin, V.N. Kovantsev, I.A. Lebedev, V.L. Mikheev, B.F. Myasoyedov, G.A. Timofeev, and Yu.S. Zamyatnin, who published their results in JINR Rapid Communications [131, 132], Izvestiya Akademii Nauk SSSR Seriya Fizicheskaya [133], and Zeitschrift für Physik A – Atomic Nuclei [134].

The scientific results dedicated to this new type of radioactive decay, obtained by Aureliu Săndulescu in collaboration with Dorin N. Poenaru and Walter Greiner [129, 135], are well known worldwide and have been included in the Encyclopaedia Britannica, in a comprehensive article by J.O. Rasmussen and E.P. Steinberg: "In 1980 A. Sandulescu, D.N. Poenaru and W. Greiner described calculations indicating the possibility of a new type of decay of heavy nuclei intermediate between alpha decay and spontaneous fission. The first observation of heavy-ion radioactivity was that of a 30-MeV, carbon-14 emission from radium-223 by H.J. Rose and G.A. Jones in 1984. The ratio of carbon-14 decay to alpha decay is about 5×10^{-10} . Observations have also been made of carbon-14 from radium-222, radium-224, and radium-226, as well as neon-24 from thorium-230, protactinium-231, and uranium-232. Such heavy-ion radioactivity, like alpha decay and spontaneous fission, involves quantummechanical tunneling through the potential-energy barrier".

2.1.3. Marius Petrașcu

Marius Petrascu (born 1929 - deceased 2007) graduated from "Mihai Viteazul" high school in Alba-Iulia and then attended the Physics Faculty in Cluj-Napoca. After three years of study he moved to the Faculty of Physics of the Bucharest University, to follow the courses given by Horia Hulubei, and to specialize in Nuclear Physics. After graduating the Physics Faculty in 1951, he started to work in the period 1951-1953 as assistant professor at the Thermodynamics chair of the Bucharest University and in the interval 1953-1957 as assistant professor and lecturer at the Structure of Matter chair leaded by Horia Hulubei. Here he started to develop new methods for particle identification and Z number identification of heavy ions by using nuclear emulsions. He was hired in 1957 as researcher and afterwards as senior scientist at the Joint Institute for Nuclear Research (JINR), Dubna, Russia, where he initiated a series of experimental researches in the field of ²³⁸U and ²³²Th fission induced by μ^- muons and π pions. This research, which represented the bulk of his PhD thesis defended at JINR in 1960, was quoted in the textbook of Hyde, Perelman, and Seaborg on "The Nuclear Properties of Heavy Elements". In 1962, after returning from JINR he was appointed head of the Nuclear Reactions Laboratory at the Institute of Atomic Physics in Măgurele.

Marius Petrașcu initiated the construction of a neutron polarizer in Măgurele by means of which the dipole moment of the neutron has been determined in 1970. Norman F. Ramsey, Nobel Prize Laureate for Physics in 1989, quoted this impressive experimental achievement in "Search for an electric dipole moment of the neutron", published in *Physical Review D* in 1977 [136]. We point out that the article of Norman F. Ramsey and collaborators [136] cites the work of S. Apostolescu, D.R. Ionescu, M. Ionescu-Bujor, S. Meitert, and M. Petrașcu, entitled "Upper limit of the electric dipole moment of the neutron" and published in *Revue Roumaine de Physique*, volume 15, page 343, 1970, see Ref. [137]. Looking at Fig. 1 of Ref. [136] we find the experimental results of the group of Marius Petrașcu under the label "ROMANIA (1970)", alongside with the experimental results obtained at Oak Ridge National Laboratory (labeled "ORNL (1973)"), Brookhaven National Laboratory (labeled "BNL (1969)"), and those comming from the collaboration between the Massachusetts Institute of Technology and Brookhaven National Laboratory (labeled "MIT–BNL (1967)").

By continuing the cooperation with Dubna, he measured for the first time, to the best of our knowledge, the negative muon lifetime in ²³⁹Pu for which he and his group were awarded the "Dragomir Hurmuzescu" prize of The Romanian Academy in 1968. Based on a new method, proposed by M. Petrașcu, both the ²³⁹Pu and ²³⁵U fission cross-section σ_f have been determinated within the frame of several contracts supported by the International Atomic Energy Agency (IAEA), Vienna, Austria. A procedure derived from this work, for absolute determination of neutron fluxes, was awarded a second "Dragomir Hurmuzescu" prize in 1982. In the period 1967-1977, M. Petrașcu as head of the Nuclear Reactions Laboratory of the Institute of Atomic Physics (1967-1970) and later as Deputy Director of the Institute of Atomic Physics (1970-1977), was involved in the preparatory activities for the acquisition and installation of the new 7.5 MV Van de Graaf TANDEM accelerator [138].

Milestone contributions, as the investigation of "implementation of a slow chopper" [139], "probable isobaric analog resonances in the actinide nuclei" [140], "calibration in energy of a TANDEM accelerator" [141], "fission from isobaric analog states" [142] and "intermediate structure of isobaric analog resonances" [143] are the first or among the first in the published literature. In the period 1977-1981, M. Petrașcu was involved in the preparatory activities for the installation of the new post-accelerator system. In this quality he succeeded to test some of the equipment produced for this facility (one resonant cavity and two analyzing magnets). These tests results were published in *Revue Roumaine de Physique* [144]. M. Petrașcu has been promoted as Associate Professor at the Faculty of Physics in Bucharest in 1963 and Full Professor in 1969. He has coordinated numerous graduate and undergraduate theses. For many years, 1972-1992, Marius Petrașcu was the Scientific Secretary of *Revue Roumaine de Physique* and *Studii și Cercetări de Fizică*.

2.2. THEORETICAL PHYSICS

2.2.1. Şerban Ţiţeica

Serban Titeica (born 1908 – deceased 1985), a Titulary Member of the Romanian Academy (elected in 1955), was an outstanding representative of the Romanian physics community, the founder of the Romanian Theoretical Physics School. He was elected a foreign member of the Academy of Sciences of the USSR in 1969 and a member of the Saxon Academy of Sciences in Leipzig in 1967. He graduated from "Mihai Viteazul" High School in Bucharest in 1926 and in the period 1926-1929 studied at the Faculty of Sciences of the University of Bucharest, obtaining two degrees, one in physics and chemical sciences and another one in mathematical sciences. In the period 1930-1934 he was a doctoral student at the University of Leipzig, where he was working on a doctoral thesis under the coordination of the famous German physicist Werner Heisenberg (born in 1901 – deceased 1976), Nobel Prize Laureate in 1932 for the creation of quantum mechanics. The doctoral thesis of Serban Titeica, entitled Über die Widerstandsängung von Metallen im Magnetfeld, was published in 1934 and appeared in Annalen der Physik (Leipzig) in 1935 [145]. The doctoral thesis was appreciated by Werner Heisenberg and Friedrich Hund as gut. After the oral doctoral examinations with Werner Heisenberg (Physics), Bartel Leendert van der Waerden (Mathematics), and Ludwig Weickmann (Geophysics), Serban

Titeica received the grade ausgezeichnet. In his doctoral thesis, Serban Titeica studied the effects of static magnetic fields on the electrical resistance of metals, using modern methods of quantum statistical mechanics. Serban Titeica studied the electron gas in the magnetic field and in interaction with the harmonic oscillations of the crystalline lattice in thermal equilibrium. He has established an analytical expression of the variation of the electrical resistance of metals in magnetic fields, which today is called the Titeica formula, see, for example, Yuri A. Firsov, Small Polarons: Transport Phenomena, in Polarons in Advanced Materials, ed. A.S. Alexandrov, Springer, 2007, where the phrase "Titeica formula" appears at page 68. Serban Titeica's doctoral thesis remained a fundamental work in the literature and is still frequently quoted as a source of inspiration for many further research, both theoretical and experimental. It is noteworthy that the fundamental work of Serban Titeica was immediately taken over and developed by some of the great physicists of the XXth century: Arnold Sommerfeld and Boyd Wheeler Bartlett [Physikalische Zeitschrift 36, 894-899 (1935)], Friedrich Hund [Annalen der Physik 32, 102-114 (1938)] and B.I. Davydov and I.Ya. Pomeranchuk [Journal of Physics-USSR 2, 147-160 (1940)].

In the monumental work, Theoretical Physics Course: L.D. Landau, E.M. Lifshitz, Vol. 10, entitled "Physical Kinetics", edited by E.M. Lifshitz and L.P. Pitaevskii, published in 1981 at Pergamon Press Publishing House, UK, in Chapter 90: "Quantum oscillations of the conductivity of metals in a magnetic field", page 386, one finds the mathematical expression of the conductivity of metals in magnetic fields. This remarkable scientific result is attributed to Serban Titeica (1935) and two other Soviet researchers, namely B.I. Davydov and I.Ya. Pomeranchuk, who used and developed the remarkable results obtained by Titeica four years before them. In fact, the two Soviet physicists cited the fundamental work of Serban Titeica in their work published in English in 1940 [Journal of Physics-USSR 2, 147-160 (1940)]. We note that in the Theoretical Physics Course: L.D. Landau and E.M. Lifshitz one finds together with Serban Titeica three other outstanding Romanian scientists: Radu Bălescu (born in 1932 – deceased 2006), Honorary Member of The Romanian Academy (since 1990), Elie Carafoli (born 1901 - deceased 1983), Titulary Member of the Romanian Academy of Sciences (elected in 1937), Titulary Member of The Romanian Academy (elected in 1948), and Alexandru Proca (born 1897 – deceased 1955), Correspondent Member of the Romanian Academy of Sciences (elected in 1937), and Post-Mortem Member of The Romanian Academy (elected in 1990). The outstanding scientific results of the aforementioned four Romanian scientists are detailed in Ref. [146].

The complete scientific works of Şerban Țițeica were published in 2008 by The Publishing House of The Romanian Academy [147]. The volume was edited by Tudor A. Marian, Professor at the Faculty of Physics, University of Bucharest, one of the outstanding students of Şerban Țițeica. As a conclusion of this succinct presentation of the scientific activity of Şerban Țițeica, we refer the interested readers to the biographical articles written by Maria Țițeica [148], Tudor A. Marian [149], and Mihai Gavrilă [150].

On the occasion of the 70th anniversary of Serban Titeica a special issue of Revue Roumaine de Physique was dedicated to him, namely Tome 23, Nos. 7-8, 1978. The preface of that anniversary volume was signed by Ioan Ursu and is followed by distinguished contributions from some of the most important physicists of that time. First of all, we mention Ilya Mikhailovich Frank (born 1908 – deceased 1990), Nobel Prize Laureate for Physics in 1958, together with Pavel Alekseyevich Cherenkov and Igor Tamm, for the experimental discovery and theoretical explanation of the Cherenkov radiation. I.M. Frank published in the special issue of Revue Roumaine de Physique dedicated to Serban Titeica an article [151] in which he performs a classical and quantum analysis of the Doppler effect in dielectric environments. The analysis by I.M. Frank in Ref. [151] had a direct connection with a work published in 1940 on the quantum theory of the Vavilov-Cherenkov effect by V.L. Ginzburg (born 1916 - deceased 2009), Laureate of the Nobel Prize for Physics in 2003. Among the other prominent scientists who published in the special issue of *Revue Roumaine de Physique* dedicated to Serban Titeica we mention here G.N. Flerov, H.B.G. Casimir, B. Pontecorvo, V.G. Soloviev, and E. Schmutzer, G.N. Flerov (born 1913 - deceased 1990) published in that volume an extremely relevant article on superheavy elements [152]. Flerov was a brilliant Russian physicist, wellknown in the literature for the discovery of spontaneous fission in 1940, together with K.A. Petrzhak, as well as for the discovery of several superheavy elements, as part of an international group of researchers from the JINR, Dubna, Russia. In 2012, the superheavy element with the atomic number Z = 114 that was discovered in Dubna in 1998 by a group of researchers led by Yu.Ts. Oganessian, was named Flerovium (Fl) by the international professional organization International Union of Pure and Applied Chemistry. H.B.G. Casimir published a relatively brief article on the prominent role played by the fine structure constant $\alpha = 1/137$ in modern quantum physics [153]. H.B.G. Casimir (born 1909 - deceased 2000) was a world-class Dutch physicist, well-known in the scientific community for the Casimir effect. Let us mention here that the phenomenon of attraction between two perfectly conductive plates (Casimir-Polder force) can be explained using the principles of quantum mechanics and quantum field theory [154, 155]. Bruno Pontecorvo, in collaboration with G. Michelmacher, published an article on the possible experimental evidence of axion (a hypothetical elementary particle, extremely light, with zero charge and zero spin) in experiments at nuclear reactors [156]. The article title published by G. Micelmacher and B. Pontecorvo reflects the fact that, at the time of writing, the experimental data did not confirm the axion existence [156], while now axions are considered a possible component of cold dark matter. We also mention here the work

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in the field of theoretical nuclear physics [157] by the Russian scientist V.G. Soloviev (born 1925 – deceased 1998), from JINR, Dubna, Russia, as well as the article of E. Schmutzer [158], from Friedrich Schiller University of Jena, on the geomagnetic field of the Earth.

From the Romanian scientists who published in the special issue of Revue Roumaine de Physique dedicated to Serban Titeica we mention in particular Ioan Ursu, Titulary Member of The Romanian Academy (elected in 1974), Ioan-Iovitz Popescu, Corresponding Member of The Romanian Academy at that time (elected in 1974), Emil Burzo (elected Titulary Member of The Romanian Academy in 2009), Voicu Lupei (elected Corresponding Member of The Romanian Academy in 2009 and Titulary Member in 2018), Dan E. Demco (elected Corresponding Member of The Romanian Academy in 2011), Nicolae Ionescu-Pallas (elected Honorary Member of The Romanian Academy in 2016), Dorin N. Poenaru (elected Honorary Member of The Romanian Academy in 2017), Dorel Bucurescu (elected Corresponding Member of The Romanian Academy in 2016), and Dumitru Mihalache (elected Corresponding Member of The Romanian Academy in 2014). We continue the list of Romanian scientists who contributed to the special issue of *Revue Roumaine* de Physique dedicated to Serban Titeica with Marin Ivascu, Marius Petrascu, P. Drăghicescu, Oliviu Gherman, Radu Grosescu, Ioan Gottlieb, Ion Silișteanu, Cătălin Borcea, Mărgărit Rizea, Iliana Brâncuş, Mihai Petrovici, Victor Simion, Mărgărit Pavelescu, Liviu Dinu, Ileana Berceanu, Florin Cârstoiu, Radu Paul Lungu, M. Velter-Stefănescu, Dragos Popa, C.D. Ciubotariu, A. Bută, I. Lazăr, A. Isbăsescu, and L. Saliu.

At the end of this short presentation of Şerban Țițeica, as well as of the volume published in 1978 in *Revue Roumaine de Physique*, we bring to the attention of the readers the publication in 2018 at the Horia Hulubei Publishing House of a volume that marks the 110th anniversary of the birth of Şerban Țițeica [159]. The purpose of the volume was the publication in Romanian and English of the doctoral thesis of Şerban Țițeica. The German-Romanian translation of Şerban Țițeica's doctoral thesis was done by Maria Țițeica, the daughter of the great scientist, while the translation from Romanian into English was done by Victor Bârsan.

The tradition started by Professor Şerban Țițeica is now continued by the professors and researchers from the Faculty of Physics in Bucharest, the Department of Physics and Mathematics, Optics, Plasma and Lasers, and at the "Horia Hulubei" National Institute of Physics and Nuclear Engineering, in the Department of Theoretical Physics. Without proposing an exhaustive overview of the research groups in these two departments, we mention the research groups formed around several internationally recognized remarkable professors and researchers. We began the enumeration with Aretin Corciovei (born 1930 – deceased 1992), Corresponding Member of The Romanian Academy (elected in 1974), the founder of the condensed matter

theory school in Romania, which was continued by Dan Grecu and Marian Apostol, both distinguished researchers who covered a broad range of research topics. We continue the enumeration with Mircea Micu (born 1932 - deceased 2010), who had remarkable contributions in the field of theoretical nuclear physics, elementary particle physics, and mathematical physics, Mircea Iosifescu (born 1929 - deceased 2015), with contributions on the theory of atomic nuclei and mathematical physics, Horia Scutaru (born 1943 – deceased 2014), elected Corresponding Member of The Romanian Academy in 1993 and Titulary Member in 1995, the founder of Romanian school of open systems and physics of information, Constantin Vrejoiu (born 1935 – deceased 2018), who had a remarkable activity in the formation of young researchers, Lucian Burlacu and Adrian Costescu, remarkable professors and scientists known for their works on theoretical atomic physics, Silviu Olariu (born 1955 - deceased 2013), known for his contributions to mathematical physics and theoretical physics at large, Ioan-Iovitz Popescu (elected Corresponding Member of The Romanian Academy in 1974 and Titulary Member in 1990), whose research covers numerous fields in modern physics, as well as mathematical linguistics, Sorin Ciulli, specialized in particle physics, and Mihai Gavrilă, Corresponding Member of The Romanian Academy (elected in 1974), with contributions in atomic physics. We also mention Gheorghe Ciobanu, a researcher specialized in statistical physics and author of several monographs dedicated to solid state physics and statistical physics, Gheorghe Nenciu, Corresponding Member of The Romanian Academy (elected in 2015), specialized in mathematical physics, Aristotel Apolodor Rădută, a remarkable professor and mentor for numerous young researchers, with substantial contributions to the field of theoretical nuclear physics, Viorica Florescu, an outstanding scientist with wide international recognition in the field of atomic physics and mentor of many generations of researchers, Tudor A. Marian, specialized in quantum theory at large, Tiberiu Tudor, specialized in classical and quantum optics, and Iulia Ghiu, specialized in quantum information theory. We conclude this incomplete enumeration with some remarkable theoretical physicists from "Horia Hulubei" National Institute of Physics and Nuclear Engineering, namely: Gheorghe Adam, Sanda Adam, Dragos Victor Anghel, Victor Bârsan, Virgil Băran, Ștefan Berceanu, Irinel Caprini, Florin Cârstoiu, Sergiu Cojocaru, Doru Sabin Delion, Petre Diță, Cezar Alexandru Gheorghe, Grigore Ghika, Nicolae Grama, Dan Radu Grigore, Aurelian Isar, Radu Ionicioiu, Liliana Micu, Mihai Mirea, Serban Misicu, Nicolae Săndulescu, Ion Silisteanu, Sabin Stoica, and Mihai Visinescu. A special note is necessary for the founders of computational physics in Romania, a field at the boundary between theoretical physics and applied mathematics, in which we mention the contributions of Dragos Vaida, Ion Zamfirescu, Liviu Gr. Ixaru, Gheorghe Adam, Mărgărit Rizea, Dumitru Mazilu, and Mărgărit Pavelescu. Besides the remarkable figure of Serban Titeica, we also mention that of Valeriu Novacu (born 1909 – deceased 1992), Cor-

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responding Member of The Romanian Academy (elected in 1948), Professor of Theoretical Physics at University of Bucharest and researcher at the Institute of Physics Bucharest. Of particular interest for the history of theoretical physics in Romania are two outstanding personalities, little known to the general public, as well as to the physics community, namely: Alexandru Proca and Gheorghe Manu. In the following pages, we summarize the bio-bibliographic profiles of these two outstanding Romanian scientists.

2.2.2. Alexandru Proca

Alexandru Proca (born 1897 – deceased 1955) is considered to be the most important Romanian theoretical physicist, who has made substantial contributions to the development of theoretical physics in the first half of the XXth century [160]. He was a student at the "Gheorghe Lazăr" High School in Bucharest, from where he graduated in 1916. In 1917, during the First World War, as part of the general mobilization, he was conscripted and admitted to the Military School for Officers in Reserve from Iași, from where he was sent to the front. Alexandru Proca fought on the front until June 1918, being left to the rank of second lieutenant. This episode of Alexandru Proca's youth is described in detail by his son, Georges A. Proca, in the special volume published by him in 1988 [161]. The extensive preface of that volume, written in French, contains numerous information on the life of Alexandru Proca and is followed by his scientific articles.

Alexandru Proca graduated in 1922 from the Polytechnic School of Bucharest, Electromechanical Section, as head of his class, and was appointed Assistant Professor and at the same time was hired as engineer by the Electric Company in Câmpina. He has been attracted by the field of theoretical physics since his engineering studies, and in 1923 he left for Paris where he graduated from the Faculty of Sciences, Sorbonne. Marie Curie (the two-time Nobel Prize Laureate for Physics in 1903 and for Chemistry in 1911) offered him in 1925 the position of researcher at the Institut du Radium. Under the guidance of Marie Curie, he conducted experimental nuclear physics research on the beta radiation emitted by the descendants of thorium (Th). He is attracted by the field of theoretical physics and published in the period 1930-1933 a series of works on the Dirac equation in the journal Comptes rendus de l'Académie des Sciences at the editorial recommendation of Louis de Broglie, Nobel Prize Laureate for Physics in 1929. In 1933 he defended his PhD thesis having Jean Perrin (Nobel Prize Laureate for Physics in 1926) as president of the doctoral committee and Louis de Broglie and Léon Brillouin as committee members. Alexandru Proca was elected in 1937 Corresponding Member of the Romanian Academy of Sciences, and in 1990 he was elected Post-Mortem Honorary Member of The Romanian Academy.

Between 1936 and 1941, he published a series of theoretical works in Journal

of Physique et Le Radium and Comptes rendus de l'Académie des Sciences, see, for example, references [162–165] on the fundamental equations that describe the elementary particles known at that time as well as the fundamental equation describing the massive vectorial boson fields (with spin 1), known in the literature as the Proca equation. Massive vector boson fields govern the weak interaction (electroweak interaction) and describe the mesons with spin 1. Wolfgang Pauli, Nobel Prize Laureate for Physics in 1945, praised Proca's fundamental contribution to the theory of massive vector boson fields in his Nobel Lecture [W. Pauli, Nobel lecture, December 13, 1946]: "The simplest cases of one-valued fields are the scalar field and a field consisting of a four-vector and an antisymmetric tensor like the potentials and field strengths in Maxwell's theory. While the scalar field is simply fulfilling the usual wave equation of the second order in which the term proportional to m^2 is to be included, the other field has to satisfy equations due to Proca, which is the generalization of Maxwell's equations." The interested readers find detailed information on the life and the scientific work of Alexandru Proca in Refs. [166-168] written by Dorin N. Poenaru and Alexandru Calboreanu.

In order to illustrate the huge impact that Alexandru Proca's results have had in the scientific community, and marking irreversibly the history of physics and becoming a classic of theoretical physics, we mention here how his contributions are reflected in the two reference courses of modern physics, the one initiated by L.D. Landau and E.M. Lifshitz and the one coordinated by W. Greiner, as well as in the literature of recent years. In the "Quantum Electrodynamics" [169], which constitutes Volume 4 of "Course of Theoretical Physics", by L.D. Landau, E.M. Lifshitz, published in English in 1982, in its revised version, coordinated by V.B. Berestetskii, E.M. Lifshitz, and L.P. Pitaevskii, one finds A. Proca's contribution to the introduction of the wave equation for spin-1 particles. Thus, in chapter 14, entitled "The wave equation for a particle with spin one", page 50, A. Proca is credited with the discovery of the wave equations that describe the massive spin-1 particles, the so-called vector bosons, see Ref. [169]. Looking at the physics course coordinated by Walter Greiner we note the volume "Relativistic Quantum Mechanics" by Walter Greiner, where Proca's equations are mentioned in chapter 15, entitled "Wave equations for particles with arbitrary spins", subchapter 15.3 "Spin-1 fields for particles with finite mass: Proca equations", and the volume "Field Quantization", authored jointly by Walter Greiner and Joachim Reinhardt, where Proca's equations are mentioned in chapter 6 "Spin-1 fields: The Maxwell and Proca equations", and are discussed extensively in subchapter 6.3 "Proca equation".

Currently, most of the scientific papers that cite the contributions of Alexandru Proca mention Proca's name either in the abstract or the title of the articles, a clear proof that Alexandru Proca became one of the founding fathers of modern theoretical physics. A quick survey of the Web of Science Clarivate Analytics database shows numerous recent developments of Alexandru Proca's pioneering articles on a wide range of themes, explicitly mentioned in the titles of the papers. As typical examples we mention here the "Einstein-Proca theory", the "Proca action", the "Klein-Gordon-Maxwell Proca systems", the "Proca field", the "Proca-Maxwell equations", the "Proca-Stueckelberg formalism", the "Chern-Simons-Proca-Higgs equations", the "Proca hair", the "Proca stars", etc. Over the past five years, approximately 250 scientific articles dedicated to theories derived from Alexandru Proca's articles have been published, all of which explicitly mention the Proca name in the abstract or title. These articles have been published in prestigious international journals such as *Physical Review Letters*, *Physics Letters B*, *Physical Review D*, *Classical and Quantum Gravity*, *Journal of Cosmology and Astroparticle Physics, Journal of High Energy Physics, General Relativity and Gravitation*, etc.

2.2.3. Gheorghe Manu

Gheorghe Manu (born 1903 - deceased 1961) was a remarkable Romanian theoretical physicist, little known today to the public due to his political involvement and premature death in detention [170]. The general coordinates of Gheorghe Manu's biography still require clarifications from historians of that tumultuous period in Romania's history, but his scientific achievements and the professional impact he has had on Serban Titeica can not be disputed. Gheorghe Manu was born on February 13, 1903 in Bucharest, as a son of magistrate Ioan Manu, and was a private student, except for the last two years of high school, which he graduated in Nancy, France. He studied at the Faculty of Sciences of the University of Bucharest with a double degree in Physicochemical Sciences and Mathematical Sciences in 1925. During 1927-1934 he elaborated his doctoral thesis in the laboratory of Marie Curie at the Institute of Radium, Paris. Following the completion of his doctoral studies he returns to Romania in autumn 1935 at the Department of Molecular Physics, Acoustics and Optics at the Faculty of Sciences of the University of Bucharest. At the end of 1935 he was elected Corresponding Member of the Academy of Sciences of Romania (1935-1948). In addition to Gheorghe Manu's intellectual profile, we also mention his work on the administration of the Romanian Physical Society during 1936-1945, as well as the popular science articles published in the Natura magazine. In the pages of this magazine, whose first issue appears in Bucharest in October 1905 under the editorial coordination of Gheorghe Titeica, Gheorghe Gh. Longinescu, and Octav Onicescu, Gheorghe Manu published a series of articles of general interest dealing, among others with "Cosmic rays", "The evolution of ideas in physics from 1800 to today", etc. We also mention Gheorghe Manu's beautiful intellectual friendship with the brothers Radu and Serban Titeica, visible especially in the pages of Serban Titeica's articles [171]. As an illustrative example of this intellectual friendship, we mention here the article of S. Titeica entitled Über die Absorbtion der Korpuskularstrahlen, Zeitschrift für Physik **101**, 378-397 (1936), see reference [172], citing two of Gheorghe Manu's classical works, namely [173] and [174]. Şerban Țițeica thanks Gheorghe Manu, in his paper [172] for the help Gheorghe Manu provided for the calculation and the discussion of the results: "Für seine Hilfe bei der Durchführung der Sehr langwierigen Rechnung und für die Diskussion der Ergebnisse möchte ich auch an dieser Stelle meinem Freund G. Mano danken."

2.2.4. Aretin Corciovei

Aretin Corciovei (born 1930 - deceased 1992) was a brilliant Romanian theoretical physicist, widely recognized by the international scientific community. Following a first degree in Physics (1953) and a second one Mathematics (1954) at University of Bucharest, he defended his PhD thesis in physics in 1958, under the guidance of Şerban Titeica, at University of Bucharest. In 1974 he was elected Corresponding Member of The Romanian Academy. He coordinated the VIth Section of the Institute of Atomic Physics, Măgurele, which consisted of three distinct laboratories: Laboratory of Theoretical Physics, High Energy Laboratory, and Cosmic Radiation Laboratory. These research laboratories were led by: Aureliu Săndulescu, a theoretical nuclear physicist with broad international recognition, the founder of the Romanian Theoretical Nuclear Physics School, Ovidiu Balea, a well-known researcher in the field of high energy physics, and Erwin M. Friedlander (born 1925 – deceased 2004), a renowned specialist in cosmic rays and elementary particles. In the mid 70s of the XXth century, Aretin Corciovei became the head of the Department of Fundamental Physics of the Institute for Physics and Nuclear Engineering, later on renamed Department of Theoretical Physics, which he headed until 1990. Aretin Corciovei has made substantial contributions in condensed matter theory and solid state physics, focusing on the properties of thin ferromagnetic films, the properties of solids under irradiation, order-disorder phenomena in crystals, the study of energy-bands in binary alloys, the plasma frequency of electron gases in partially finite systems, the study of the Mössbauer effect in thin films with cubic symmetry, etc. Aretin Corciovei was greatly appreciated by his colleagues and due to his solid engineering knowledge was frequently consulted not only by theoretical physicists but also by the experimental physicists, chemists, and engineers from the Măgurele Physics Campus in connection with their research problems.

One of the first papers published by Aretin Corciovei in prestigious foreign journals (*Nuovo Cimento*, 1959) refers to the study of the effects of short- and long-range order on residual resistivity in binary alloys [175]. This article was considered as a reference work in the field, and was mentioned in the monograph "Insulators, Semiconductors, and Metals – Quantum Theory of Molecules and Solids", third volume, published at McGraw-Hill, by John C. Slater [176]. We mention the articles published by Aretin Corciovei in collaboration with Dan Grecu at the be-

ginning of the 60s of the last century on the effects of the long-range order on the energy bands of binary alloys [177, 178]. These articles have been considered as reference papers in the second volume of the monumental course "Quantum Theory of Molecules and Solids – Symmetry and Energy Bands in Crystals" of John C. Slater [179]. In this context, we also mention the articles of Aretin Corciovei on the residual resistivity of metals (in collaboration with A. Babcenco) [180], the paper on the specific heat of thin films done in collaboration with Cornelia Motoc [181], who subsequently created her own research group in the field of solid-state physics, the articles on Mössbauer effect in thin films, which were written jointly with Alexandru Berinde [182] and with Dan Grecu and Eugen E. Rădescu (born 1942 - deceased 2007) [183], as well as the article on crystalline lattice distortions near a free surface, written jointly with Marianne Croitoru and Dan Grecu [184]. Eugen E. Rădescu was an outstanding theoretical physicist, who made important contributions to elementary particle physics and scattering theory, electromagnetic properties of Majorana fermions, nucleon polarizabilities, dispersion relations, and toroidal polarizabilities [185–187].

On a different research direction we mention here the contributions of Aretin Corciovei and his collaborators published in the 70s and 80s of the XXth century. During this period, Aretin Corciovei focused on the interaction of radiation with matter and published a series of articles dedicated to the channeling phenomenon (planar or axial) of electrically charged particles in crystals, in collaboration with Marian Apostol, Dumitru Mihalache, and Anca Visinescu [188-191]. These works were cited in the monograph "Interaction of radiation with solids and elementary defect production", published by Chr. Lehmann in 1977 at the North-Holland Publishing House [192]. Among the other research contributions of Aretin Corciovei we mention here his works (jointly with Marian Apostol) on plasma gas frequency of electrons in partially finite systems, the study of two-dimensional electron systems, and the study of collective excitations in electron systems [193–197]. We also mention the works of Aretin Corciovei in collaboration with Gheorghe Adam and Sanda Adam on effective interatomic forces from one-particle crystal field parameters [198], as well as his articles jointly with Nicolae Angelescu (born 1942 deceased 2012) [199], Vladimir Protopopescu [200], Cecil Pompiliu Grünfeld [201], Gheorghe Adam and Liviu Gr. Ixaru [202]. Nicolae Angelescu was an outstanding representative of the Romanian theoretical physics school specialized in statistical physics, well known for his work, jointly with Mircea Bundaru, Gheorghe Costache, and Gheorghe Nenciu, on a series of research topics such as molecular field theory and phase transitions in partially finite systems, ground state of Ising chains with finite range interactions, perturbations of Gibbs semigroups, and Landau diamagnetism [203-207].

The field in which Aretin Corciovei made important scientific contributions and

created a competitive international research school was that of ferromagnetic thin films, which was devoted to: (a) the study of the Curie temperature dependence on the number of monoatomic layers (jointly with Grigore Ghika) [208], (b) the study of the spontaneous magnetization of ferromagnetic thin films and the computation of the Curie temperature using Green functions and the Euler method of series summation (jointly with Gheorghe Costache) [209], (c) the study of the direction of spontaneous magnetization in ferromagnetic thin films considering in the Hamiltonian of the system both the dipolar terms and those that describe the magnetic anisotropy of the physical system, in addition to the terms that describe the exchange interaction (in collaboration with Dan Vamanu) [210], (d) micromagnetism studies (in collaboration with Gheorghe Adam) [211]; and (e) study of thin-film ferromagnetic resonance in the case of a mixture of uniaxial and biaxial anisotropy (in collaboration with Raimond Grimberg, who created his own research group in the field of solid-state physics at the Institute of Technical Physics in Iasi) [212].

One of the highlights of Aretin Corciovei's remarkable scientific career was his participation at the "Third International Colloquium on Magnetic Films", MIT Lincoln Laboratory, Boston, USA, 18-20 September, 1967. He presented the paper "Saturation magnetization in ferromagnetic thin films", which latter appeared in *IEEE Transactions on Magnetics* [213], being the first article published in the volume dedicated to the conference. The previously-mentioned paper is a review of the scientific results obtained in Romania by Aretin Corciovei, either as sole author or in collaboration with Gheorghe Ciobanu, Grigore Ghika, Dan Vamanu, and Gheorghe Costache. We note as well that Ref. [213] briefly presents the spin-wave theory of ferromagnetic thin films, which was developed in a pioneering work published by Aretin Corciovei in 1963 in the *Physical Review* [214]. The article in Ref. [213] also presents the method of time and temperature dependent Green functions used in the study of ferromagnetic thin films. This efficient method employed in the description of critical phenomena and phase transitions was introduced in 1965 in the study of the magnetic properties of thin films by Aretin Corciovei and Gheorghe Ciobanu [215] and independently by a group of physicists from the German Democratic Republic [216]. In fact, the group at the Institute of Atomic Physics, Măgurele, namely A. Corciovei and Gheorghe Costache (born 1942 – deceased 2002), and the group in German Democratic Republic, namely W. Brodkorb and W. Haubenreisser, published joinly in 1972 a review on the use of Green functions to the study of uniaxial ferromagnetic thin films [217], which is well cited in the literature. Gheorghe Costache was an outstanding theoretical physicist with contributions on solid state physics, ferromagnetic thin films in particular [218, 219], and statistical physics [220, 221]. The article entitled "Spherical model of ferromagnetic films" [219], published as a Letter in Journal of Physics C – Solid State Physics, complemented the existing theoretical results on the spherical model in layered geometries with free-

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edge boundary conditions that was proposed by Barber and Fisher (1973) [222] and Knops (1973) [223], and is cited in the classical series "Phase transitions and Critical Phenomena", edited by C. Domb and J.L. Lebowitz [224].

Aretin Corciovei published in 1963 in *Physical Review* a pioneering work [214] in the field of ferromagnetism of thin films of nanometric thickness, an article that is still cited in recent literature. Aretin Corciovei developed the theory of spin waves in the Holstein-Primakoff formulation of ferromagnetic thin films, introducing the magnetic anisotropy term in the Hamiltonian of the system. The interactions between the spin waves have been neglected since the corresponding corrective terms are quite small at low temperatures, see the paper previously published in *Physical Review* [225] by the famous theoretical physicist F.J. Dyson of the Institute for Advanced Study, Princeton, USA.

The scientific articles on ferromagnetic thin films that were published by Aretin Corciovei and his collaborators were reviewed in an extended book chapter of 114 pages that was published in 1972 [226] in the prestigious series *Solid State Physics: Advances in Research and Applications*, edited by H. Ehrenreich, F. Seitz, and D. Turnbull. The review was co-authored by Aretin Corciovei, Gheorghe Costache, and Dan Vamanu, while the Appendix of the review was authored by Gheorghe Adam. The articles previously discussed briefly outline the foundations of the Romanian theoretical solid state physics school that was established on the Măgurele Physics Campus by Aretin Corciovei.

2.2.5. Radu Bălescu

Radu Bălescu (born 1932 - deceased 2006), Honorary Member of The Romanian Academy (since 1990), was a word-class Romanian physicist specialized in plasma physics. He graduated from "Titu Maiorescu" High School in Bucharest in 1948 and then studied chemistry at l'Université Libre de Bruxelles from 1950 to 1958, obtaining his PhD in 1958. Since 1957 he has worked as assistant of the famous scientist Ilya Prigogine, Nobel Prize Laureate of Chemistry in 1977 for "his contributions to non-equilibrium thermodynamics, particularly the theory of dissipative structures". In 1964 he became Full Professor at l'Université Libre de Bruxelles. In 2000 he was awarded the prestigious Hannes Alfvén Prize by the European Physical Society (Plasma Physics Division) for "his outstanding scientific work in the field of statistical physics of charged particles and of controlled fusion" [227]. Radu Bălescu is recognized in the scientific community for his remarkable contributions to the field of statistical mechanics, especially for the study of physical phenomena in far-fromequilibrium thermodynamic systems [228]. He made remarkable contributions to the field of plasma physics, see the monographs [229, 230], and is widely acclaimed in the scientific literature for the famous "Balescu-Lenard collision operator" that was introduced in 1960 for the study of transport phenomena in plasma, independently by Radu Bălescu and the famous American physicist Andrew Lenard from Princeton University, Princeton, New Jersey, USA, see Refs. [231, 232]. Surveying the scientific literature, we find the following concepts that eloquently demonstrate the impact of Radu Bălescu's remarkable scientific work in plasma physics, nuclear physics at high energies (study of relativistic heavy-ion collisions), etc.: "Balescu-Lenard-Vlasov approach" [233], "Braginskii and Balescu kinetic coefficients" [234], "the Lenard-Balescu equation" [235], "generalized Balescu-Lenard transport formalism" [236], "Balescu-Lenard-type kinetic equation" [237], "Balescu-Lenard master equation" [238], "Lenard-Balescu collision operator" [239], "generalized Lenard-Balescu collision operator" [240], etc.

In Landau and Lifshitz's "Physical Kinetics" [241], which was first published in English in 1981 at Pergamon Press Publishing House, UK, in chapter 47, entitled "Interaction via plasma waves", page 193, one finds the mathematical expression of Balescu-Lenard collision integral, which is a special form of Landau's collision integral. This concept is also discussed in chapter 51 of Landau and Lifshitz's "Physical Kinetics" [241], entitled "Fluctuations in plasma", at page 216.

2.3. PLASMA AND LASER PHYSICS

2.3.1. Eugen Bădărău

Eugen Bădărău (born 1887 – deceased 1975) was the founder of the Romanian School of Plasma Physics. He made remarkable scientific contributions to the physics of gas discharges, physics of ionized gases, and modern acoustics [242–248]. The complete list of papers published by Eugen Bădărău was compiled by Ioan-Iovitz Popescu, one of the brilliant collaborators of the great scientist and is available in Ref. [249]. We mention as well the article published by Ioan-Iovitz Popescu in *Academica* in 1998, regarding the scientific achievements of Eugen Bădărău [250] and a related one authored by Radu Grigorovici entitled *Eugen Bădărău – The Creator of the Physics School in Cernăuți and Bucharest* [251]. Eugen Bădărău published in 1965, in collaboration with Ioan-Iovitz Popescu, a monograph entitled *Ionized Gases. Electric discharge in gases* [247] that appeared in 1968 at the Dunod Publishing House, Paris, France, under the French title *Gaz Ionisés. Décharges électriques dans les gaz* [248].

Eugen Bădărău was a student in Pisa, Italy, between 1907-1911, and then Assistant Professor at the Institute of Physics of the University of Pisa, from 1912-1914. He was awarded a doctorate in 1912, under the coordination of A. Battelli, with a thesis on the dielectric constants of gases and gas mixtures. Between 1915 and 1920, he worked in St. Petersburg, Russia, as assistant of the famous physicists A.F. Ioffe (1914-1918) and D.S. Rozhdestvensky (1918-1920). Starting 1918 he was Associate Professor at the Faculty of Sciences and at the Institute of Physics of the University of St. Petersburg. At that time the scientific mentors of Eugen Bădărău were O.D. Chwolson, A.F. Ioffe (one of the pioneers of semiconductor physics), and D.S. Rozhdestvensky, a leading representative of the Optics and Optical Engineering School in Russia. We mention that starting 1990 the Optical Society of Russia was renamed Rozhdestvensky Optical Society. During the period 1921-1934, Eugen Bădărău worked at the Faculty of Sciences of the University of Cernăuti. He was a Professor in the Department of Experimental Physics of the Faculty of Sciences between the years 1924-1934. In 1935, he transferred to the Faculty of Sciences of University of Bucharest, succeeding Constantin Miculescu (born 1863 - deceased 1937) and becoming the head of the Molecular Physics, Acoustics and Optics Laboratory. Eugen Bădărău was a founding member of the Romanian Academy of Sciences, now known as Academy of Romanian Scientists, an important learned society founded in 1935, which functioned until 1948, when it was closed by the new political establishment. Numerous illustrious Romanian physicists were members of the Romanian Academy of Sciences, such as Constantin Miculescu, Gheorghe Atanasiu, Eugen Bădărău, Constantin Bedreag, Horia Hulubei, Dragomir Hurmuzescu, Theodor V. Ionescu, Augustin Maior, Nicolae Bărbulescu, Alexandru Cișman, Traian Gheorghiu, Aurel Ionescu, Gheorghe Manu, Herbert Mayer, Stefania Mărăcineanu, Constantin Mihul, Alexandru Proca, Sabba S. Stefănescu, and Stefan Vencov.

In 1948, Eugen Bădărău was elected Titulary Member of the Romanian Academy. In the period 1949-1956 he served as president of the Scientific Council of the Institute of Physics of The Romanian Academy, and during 1956-1970 he headed the Institute of Physics Bucharest. In 1969 he published in *Studii și Cercetări de Fizică* a historical article dedicated to the thirteen years of development of the Institute of Physics Bucharest [252]. In the same year, he organized in Bucharest the *IXth International Conference on Phenomena in Ionized Gases*, which enjoyed a wide participation of physicists from 32 countries. For a complete overview of the professional activity of Eugen Bădărău, one can consult the public document [249] by Ioan-Iovitz Popescu.

On the 80th anniversary of Eugen Bădărău a few issues of *Revue Roumaine de Physique* were dedicated to this event, and several consecutive numbers of the journal (namely, numbers 1, 2, 3, 4, and 5, of Tome 13, 1968), gathered scientific articles dedicated to Eugen Bădărău. Among the authors who contributed to these special issues of *Revue Roumaine de Physique* we find two Nobel Prize Laureates for Physics, namely C.V. Raman (born 1888 – deceased 1970) and N.G. Basov (born 1922 – deceased 2001). It is worth reminding that C.V. Raman, Nobel Prize Laureate for Physics in 1930, previously published in 1966 another article in *Revue Roumaine de Physique* in the anniversary issue dedicated to Horia Hulubei. Nikolay G. Basov received the Nobel Prize for Physics in 1964, together with Aleksandr N. Prokhorov and Charles Hard Townes "for contributions to fundamental work in quantum elec-

tronics leading to the development of the maser and laser".

The anniversary volume dedicated to Eugen Bădărău opens with a brief note by the great scientist A. von Engel, entitled "On the 80th Anniversary of Professor Eugen Badareu". We mention that A. von Engel is well known in the literature as the author of the monumental treatise "Ionized gases", Oxford at the Clarendon Press, 1965. C.V. Raman published in that volume an article on diamond physics [253], while N.G. Basov and his collaborators at the Institute of Physics "P. N. Lebedev" in Moscow published an article on the use of laser radiation in the study of spectra of atoms with high ionization states. We also mention the articles by Leonard M. Loeb, Department of Physics, University of California, Berkeley, USA [254], the paper of L. Pekarek and V.L. Exner from Institute of Physics, Prague [255], and the article by K.G. Emeleus, Queen's University, Belfast, UK, and H.M. Grimley, Physics Department, University College, Dublin, Ireland, see Ref. [256], on various aspects of plasma physics and electrical discharges in gases. In the issues of *Revue* Roumaine de Physique dedicated to Eugen Bădărău we also find articles authored by the most important Romanian physicists of that time, namely Margareta Giurgea, Radu Grigorovici, Ioan Ursu, Ioan-Iovitz Popescu, Denisa Popescu, Theodor V. Ionescu, Nathan Croitoru, Ioan Baltog, Geavit Musa, Vladimir Topa, Voicu Lupei, Aurelia Lupei, C. Ghiță, R.V. Deutsch, Maria Someșan, Constantin Popovici, Iancu Iova, L. Blänaru, V. Petrescu, N. Rezlescu, and M. Ianovici. We point out that number 2 of volume 13 of Revue Roumaine de Physique, 1968, included as well a preliminary note entitled "La réalisation d'un laser à CO₂" authored by Ion I. Agârbiceanu, A. Agafitei, L. Blănaru, V. Drăgănescu, I.M. Popescu, and V. Vasiliu [257], which represents a pioneering work in Romania in the field of CO₂ lasers.

2.3.2. Ion I. Agârbiceanu

Ion I. Agârbiceanu (born 1907 – deceased 1971), Corresponding Member of The Romanian Academy (elected in 1963), was the founder of the Romanian School of Laser Physics and Engineering [258]. Born in Bucium, Alba County, as the son of the priest and writer Ion Agârbiceanu, Ion I. Agârbiceanu continues his studies at "George Barițiu" High School in Cluj-Napoca and then at the Polytechnic Institute in Bucharest, graduating in 1929. He then leaves for Paris, where he writes a doctoral thesis, under the supervision of Professor Aimé Cotton, entitled "Fluorescence Spectroscopy and I₂ Vapor Absorption Spectroscopy", which he finished in 1934. The articles published in this period are not well known in the Romanian physics community, so we have gathered in Refs. [259–264]. After a specialization at the Spectroscopy Laboratories of the Vickers-Armstrong Weapons Trust in 1935, Ion I. Agârbiceanu is first employed at the Petroleum and Gas Institute in Bucharest (from which the current Petroleum-Gas University of Ploiești had developed), then at the Faculty of Physics and Mathematics of University of Bucharest, and lastly at the Polytechnic Institute of Bucharest. Starting 1955, Ion I. Agârbiceanu coordinates one of the physics department of the Polytechnic Institute of Bucharest, and in 1956 he joins Horia Hulubei at the Măgurele Physics Campus, where he establishes the laboratory of "Optical Methods in Nuclear Physics" at the Institute of Atomic Physics. The research activity of Ion I. Agârbiceanu within the laboratory is mainly focused on hyperfine and isotopic atomic structure, magneto-optical resonance, and thin dielectric films (see Refs. [265–267]), which are crowned by the first Romanian laser, of He-Ne type with infrared radiation. The first laser light was observed on October 20th, 1962 (see Refs. [268, 269]). The laboratory of Ion I. Agârbiceanu was transformed into the Radiation and Plasma Section of the Institute of Atomic Physics in 1969, and was, in fact, the forerunner of the current National Institute for Lasers, Plasma and Radiation Physics.

The achievement of the first Romanian laser only two years after Theodore Harold Maiman obtained the first laser pulse on May 16th, 1960, represented a remarkable success of the Romanian community of physicists and engineers. The laser made in the group of Ion I. Agârbiceanu reflected the maturity of the research groups on the Magurele Physics Campus. In this context, we emphasize the extraordinary role played by A. Agafitei, L. Blănaru, N. Ionescu-Pallas, I.M. Popescu, V. Vasiliu, and V.G. Velculescu, all coauthors of the article that presented the realization of the first laser in Romania [268]. We mention in particular the collaboration of Ion I. Agârbiceanu with Laurentiu Blănaru and Ion M. Popescu. Laurentiu Blănaru was an outstanding researcher of the Măgurele Physics Campus, formed at the Technische Universität Clausthal in the group of Herbert Mayer, who specialized in the deposition of the thin layers required for laser mirrors. Ion M. Popescu is a Romanian physicist and engineer, specialized in the Hertzian Spectroscopy Laboratory of Alfred Kastler (Nobel Prize Laureate for Physics in 1966), who has distinguished himself over the years through his research on optical methods of hertzian spectroscopy and physics and laser engineering (see Refs. [270-280]). We note in this context the monograph on "Optical Methods of the Hertzian Spectroscopy", published together with Ion I. Agârbiceanu in 1970, in Romanian, at The Publishing House of The Romanian Academy [281], which was translated in 1975 in English and published by John Wiley & Sons under the name "Optical methods of radio-frequency spectroscopy" [282]. Ion M. Popescu also devoted himself to the teaching and training of young researchers at POLITEHNICA University in Bucharest, where he founded a strong research group. From the gallery of researchers from POLITEHNICA University of Bucharest dedicated to the physics and engineering of lasers and holography we mention here: Alexandru Preda, a brilliant collaborator of Ion I. Agârbiceanu, A. Podoleanu, N. Puscas, P. Sterian, V.A. Popescu, Mona Mihăilescu, etc. The career of Ion I. Agârbiceanu ended suddenly due to an incurable disease, but the intellectual tradition that he established on the Măgurele Physics Campus was continued by

a brilliant generation of Romanian physicists and engineers. The research on laser physics and engineering from the early 60s to the late 80s consists of three main directions, namely: i) lasers with solid-state active media, a research direction initiated by Ionel-Valentin Vlad and George Nemeş and then continued by the group of Voicu Lupei, ii) carbon dioxide lasers, to which A. Agafiței, L. Blănaru, V. Drăgănescu, D.C. Dumitraş, D.C.A. Duțu, I. Guțu, and V.G. Velculescu contributed substantially, and iii) ionized argon lasers, a research direction for which we mention C. Berenyi, I. Gutu, and V.G. Velculescu.

The tradition started by Ion I. Agârbiceanu is continued by the researchers at the National Institute for Lasers, Plasma, and Radiation Physics (INFLPR) and, more recently, at the European Extreme Light Infrastructure – Nuclear Physics (ELI-NP) facility. Among the leading researchers of INFLPR we mention Răzvan Dabu, Valentin Crăciun, Traian Dascălu, Maria Dinescu, Nicolae Pavel, Mihail Lucian Pascu, Adrian Petriş, and Marian Zamfirescu. The construction on the Măgurele Physics Campus, within the premises of the "Horia Hulubei" National Institute for Physics and Nuclear Engineering of the European ELI-NP facility, a project coordinated by Nicolae-Victor Zamfir, opens new horizons of scientific knowledge in the field of laser physics and engineering, as well as on the side of the applications of lasers in industry and medicine. Among the researchers working at ELI-NP in the field of laser physics and engineering and related domains, we mention Dan Stutman, Edmond Turcu, Ioan Dăncuş, Petru Ghenuche, and Daniel Ursescu.

2.4. CONDENSED MATTER PHYSICS. MATERIALS SCIENCE AND APPLICATIONS

2.4.1. Radu Grigorovici

Radu Grigorovici (born 1911 – deceased 2008), Titulary Member of The Romanian Academy (elected in 1990) and vice-president of The Romanian Academy in the period 1990-1994 was an outstanding Romanian scientist with broad international recognition, widely considered as the founder of the Romanian school of amorphous disordered materials. The works of Radu Grigorovici were published in 2011 at the Publishing House of The Romanian Academy in a volume edited by Mihai Popescu and Andrei Dévényi [283]. Radu Grigorovici was born in Cernăuți in 1911, in the historical province of Bucovina, and after graduating from "Aron Pumnul" high school in 1928 he enrolled at University of Cernăuți, obtaining a first degree in chemical sciences in 1931 and a second degree in physical sciences in 1934. He was an assistant at University of Cernăuți in the laboratory of experimental physics of Eugen Bădărău. Bucovina was very dear to Radu Grigorovici and this can be best seen in the series of studies and documents that he published in 2006 at the Publishing House of The Romanian Academy [284]. In 1936 he moved to University of Bucharest, where Eugen Bădărău was appointed head of the Department of Molecular Physics, Acoustics and Optics. In 1939 Radu Grigorovici obtained his doctorate in physical sciences, with a thesis on "The disruptive potential in mercury vapors". Radu Grigorovici became the head of the semiconductor physics group at the Institute of Physics Bucharest in 1960, and in 1963 he became Deputy Scientific Director of the institute. The same year (1963), he was elected Corresponding Member of The Romanian Academy.

In number 63 of *Curierul de Fizică*, published in 2009, shortly after Radu Grigorovici passed away, the collaborators who knew him closely wrote a series of articles that focused on the personal, cultural, and scientific profiles of Radu Grigorovici. Margareta Giurgea, Dan H. Constantinescu, Andrei Dévényi, Rodica Mănăilă, and Cornel Popescu published touching essays about Radu Grigorovici [285–288]. We also mention the personal recollections on Radu Grigorovici of Nadia-Ruxandra Mezincescu, focused both on the man and the scientist, published in 2012 in *Glasul Bucovinei* [289].

On the side of the scientific profile of Radu Grigorovici, we mention here that in the period 1937-1959 Radu Grigorovici tackled new problems in the field of gas discharges, having Eugen Bădărău as mentor. During the period 1944-1945 he dealt with spectral flame analysis, while in the period 1952-1961 he approached new aspects of physiological and instrumental optics. After 1959, Radu Grigorovici focused mainly on the physics of disordered materials, becoming a leading international researcher in that field.

Radu Grigorovici and Andrei Dévényi published in 1962 in Studii și Cercetări de Fizică a pioneering article on the electrical properties of cadmium-evaporated layers [290]. Later on, in 1964, Radu Grigorovici published, jointly with Nathan Croitoru, Andrei Dévényi, and A. Teleman, the results of their research on the amorphous germanium band structure and electrical conductivity [291]. The results of these pioneering researches carried out in Romania on the optical properties and the electronic structure of amorphous germanium were included in a comprehensive review published in 1966 in *Physica Status Solidi* [292], in collaboration with Jan Tauc (born 1922 – deceased 2010), a world-renowned researcher born and educated in the former republic of Czechoslovakia, who later moved to the USA, and Ana (Anina) Vancu, a close collaborator of Radu Grigorovici from Institute of Physics Bucharest. To the best of our knowledge, this article of Radu Grigorovici and his collaborators, which now reaches approximately 6000 citations on Google Academic [293], and slightly less on the Web of Science database of Clarivate Analytics, is the most cited article ever published by Romanian scientists affiliated with a Romanian institution. We mention that we have not taken into account the articles comming from CERN, which are co-authored by Romanian scientists. The spectacular growth of the citation rate of Ref. [292] in the last decade can be attributed to the increase of the scientific and technical interest in the germanium detectors that are used in gamma-ray spectroscopy, for the detection of photons in the range of energies 0.1–10 MeV.

The year 1966 can be considered a turning point for Radu Grigorovici, as the landmarking article [292] was accompanied by a series of papers, also on the subject of disordered materials, some of which are in collaboration with Ana Vancu, Rodica Mănăilă, Nathan Croitoru, and Andrei Dévényi, which had a strong impact on scientific community [294-300]. It is also very important to emphasize that in 1970 Radu Grigorovici published an article jointly with Rodica Mănăilă in the prestigious journal *Nature*, in which they analyzed some physical properties specific to germanium in amorphous state [301]. To the best of our knowledge, this work is the first physics article published in Nature by Romanian scientists with Romanian affiliations. We point out that experimental and theoretical researches in the field of amorphous semiconductors have substantially increased in the years that followed the publication of the pioneering article [292], due to their practical applications, as highlighted by physicist and inventor Stanford R. Ovshinsky (USA) in his classical article on "Reversible electrical switching phenomena in disordered structures" [302]. Stanford R. Ovshinsky was a friend of Radu Grigorovici and knew well the contributions of the school he established in Bucharest and latter on in Măgurele Physics Campus. The appreciation of Stanford R. Ovshinsky for the results of Radu Grigorivici is welldocumented: "He has been one of the outstanding contributors and builders of the whole field of amorphous disordered materials. His work has never been trivial but always basic, always fundamental, and always clearing the way for understanding at that time a young and developing area of science that is now so well accepted and well thought of" [303].

On the occasion of the 70th birthday of Radu Grigorovici in 1981, a special issue of *Revue Roumaine de Physique*, Tome 26, No. 8-9, gathered contributions from the leading scientists of that time. The volume opens with the Nobel Prize Laureate for Physics in 1977, Nevill F. Mott (born 1905 – deceased 1996), entitled "The properties of the mobility edge". We mention that Philip Warren Anderson, Sir Nevill Francis Mott, and John Hasbrouck van Vleck received the Nobel Prize for Physics in 1977 "for their fundamental theoretical investigations of the electronic structure of magnetic and disordered systems".

The article published by N.F. Mott in *Revue Roumaine de Physique* [304] takes the form of a review focused on the properties of electrons near the mobility edge in amorphous semiconductors. The first paragraph of the aforementioned article of N.F. Mott [304] includes an impressive laudation for Radu Grigorovici, namely: "Professor Grigorovici was one of the first to see the potentialities of the study of noncrystalline materials, [so] it is a special pleasure to contribute to a special issue in the honor of his seventieth birthday. Certainly he chose a subject in which there are problems, and I think that many of them will remain unsolved for several years. These problems seem to me of two kinds. The first is the actual structure of glasses and deposited films. The second involves the laws governing the motion of electrons in a field of which the potential energy has a random element. If both were understood, it would be possible to give a convincing description of conduction, photoconduction and photoluminescence in non-crystalline materials of practical importance, such as hydrogenated amorphous silicon. In this paper, I will confine myself to the second problem, in which some questions arise that have not yet been answered".

In the Nobel Lecture of Nevill F. Mott there is strong appreciation for the pioneering results of B.T. Kolomiets, as well as those of Radu Grigorovici and Jan Tauc. These remarkable results were synthesized by N.F. Mott as follows: "Actually our curiosity was stimulated by the investigation of the Leningrad School under Kolomiets (4) from 1950 onwards rather than the optical properties of the glassy semiconductors. These are black glasses, containing arsenic, tellurium and other elements, and for them the band gap lies in the infrared. [...] the properties of glass are in sharp contrast to the behavior of crystals, where the whole of silicon technology depends on the fact that if, for example, phosphorus with its five electrons is added, four form bonds but the the fifth is very loosely bound. The discovery of this property of glasses certainly makes Kolomiets one of the fathers of the branch of science that I am describing, as were others in Eastern European countries, notably Grigorovici in București and Tauc in Prague", see Ref. [305].

In the same anniversary volume of *Revue Roumaine de Physique* there is an article on "Picosecond dynamics of carriers in amorphous semiconductors" by Jan Tauc [306] and one by the group of B.T. Kolomiets from the A.F. Ioffe Institute, Sankt Petersburg, Russia, on "Configuration approach to photostructural transformations in chalcogenide vitreous semiconductors: further development" [307].

We continue our survey of the works published in the special volume of Revue Roumaine de Physique dedicated to Radu Grigorovici with the article by H.K. Henisch, USA, on "Macroscopic aspects of carrier transport in ordered and disordered solids", the work co-authored by W.E. Spear and P.G. Le Comber, from the UK, entitled "Fundamental and applied developments in the amorphous silicon field", the paper of Marie-Luce Theye, France, focused on a "Contribution à l'étude des composées III-V amorphes". Among the other articles published in Revue Roumaine de *Physique* we mention that of C.B. Collins and W.M. Tepfenhart, from University of Texas at Dallas, USA, in collaboration with I. Iovit Popescu and I. Schneider, as well as the articles authored by the most important Romanian physicists of that time: Ioan Ursu, Margareta Giurgea, Emil Burzo, Alexandru Glodeanu, I. Ardelean, D. Ungur, Alexandru Nicula, M. Peteanu, I. Schneider, Andrei M. Andries (born 1933 – deceased 2012), Honorary Member of The Romanian Academy (elected in 1991), Rodica Mănăilă, Andrei Dévényi, Gheorghe Ciobanu, L. Bányai, Alexandru Emil Aldea, I. Corcotoi, Paul Gartner, A.B. Fazakas, Magdalena-Lidia Ciurea, Toni Botilă, Mihai Mihăilă, Corresponding Member of The Romanian Academy (elected in 1999), N. Ionescu-Pallas, Lucia V. Constantinescu, Corneliu Popescu, L. Nasta, Mihai Popescu, Cristian Constantinescu, A. Goldenblum, Athanasie Truția, M. Vodă, Florentina Iova, Voicu Dolocan, I. Dima, M.I. Bîrjega, and C. Sârbu.

The scientific tradition started by Radu Grigorovici is continued today mainly at the National Institute of Materials Physics and at the Faculty of Physics of the University of Bucharest. A brief survey of the researchers who have contributed to the development of materials physics in Romania over the last decades reveals, in a short selection, the following ones: Margareta Giurgea (born 1915 – deceased 2011), Titulary Member of The Romanian Academy (elected in 1992), Rodica Mănăilă (born 1935 – deceased 2002), Corresponding Member of The Romanian Academy (elected in 1992), Ioan Baltog (born 1939 – deceased 2016), Corresponding Member of The Romanian Academy (elected 2016), Andrei Dévényi (born 1932 – deceased 2015), Ștefan Frunză (born 1945 – deceased 2018), Toni Boțilă, Alexandru Emil Aldea, Horia V. Alexandru, Magdalena-Lidia Ciurea, Valentin Șerban Teodorescu, Paul Gartner, Ioana Pintilie, Ștefan Antohe, Lucian Pintilie, Cristian Mihail Teodorescu, Valeriu Moldoveanu, Lucian Ion, and George Alexandru Nemneş.

2.4.2. Engineering contributions to materials science

The development of the broad research field of materials science is marked by its prominent multidisciplinarity and in this subsection we discuss the engineering contributions to the field. These are mostly due to the researchers at the Polytechnic Institute in Bucharest, now POLITEHNICA University of Bucharest, the Research Institute for Electronic Components, and the Center for Microtechnologies, which was founded in 1991 by Dan Dascălu. The Center for Microtechnologies became the Institute of Microtechnologies (IMT) in 1993 and in 1996 IMT merged with the Research Institute for Electronic Components and became the National Institute for Research and Development in Microtechnologies (IMT Bucharest), which had Dan Dascălu as Director General until 2011. The interested reader can find in Refs. [308, 309] a history of the Romanian school of micro- and nanoelectronics and a survey of its most recent results. We particularly point out chapter 7 of Ref. [308] authored by Gheorghe Pascovici, former Director General of the Institute of Atomic Physics, which is focused on the Romanian school of nuclear electronics (in Romanian: "Scoala românească de electronică nucleară") that discusses the strong community of engineers on the Măgurele Physics Campus. One of the messages conveyed by Gheorghe Pascovici is that experimental physics has a pronounced engineering component, which is most visible in the case of the collaboration of Romanian scientists with CERN, to give only one example.

The survey of the archive of *Revue Roumaine de Physique* shows numerous articles with a pronounced engineering focus, which prove the substantial scientific collaborations between the community of physicists and that of engineers. We start our survey of articles published by engineers in *Revue Roumaine de Physique* with

that co-authored by Dan Dascalu, N. Marin, and Gheorghe Brezeanu on "Bulk breakdown in mesa IMPATT structures" [310] that was followed by related articles in prestigious journals such as *Applied Physics Letters*, *Solid-State Electronics*, *Microelectronics and Reliability*, etc., see Refs. [311–316]. The aforementioned articles follow the research direction initiated by Mihai Drăgănescu (born 1929 – deceased 2010), Titulary Member of The Romanian Academy, founder of the school of electron semiconductor devices within the Faculty of Electronics and Communications, Polytechnic Institute of Bucharest (now University POLITEHNICA of Bucharest), well known for electronic processes in semiconductor devices (p-n junctions and bipolar transistors) [317] and solid state electronics [318]. Among the authors of the previous articles we mentioned Dan Dascălu, Titulary Member of The Romanian Academy, with important contributions on transit-time effects in unipolar solid-state devices [319] and electronic processes in unipolar solid-state devices [320], to name only two.

A detailed survey of the engineering contributions to materials science is outside the scope of this article, but we mention here some of the prominent researchers from IMT Bucharest, specialized in micro- and nanoelectronics, nanomaterials, and nanotechnologies, namely: Adrian Rusu (born 1946 – deceased 2012), Corresponding Member of The Romanian Academy (elected in 1994), whose research contributions include a widely appreciated work on deep-depletion breakdown voltage of silicon-dioxide/silicon MOS capacitors [321]; Constantin Bulucea, Honorary Member of The Romanian Academy (elected in 2001), who contributed, among many other subjects, to the first-order theory of the static induction transistor [322]; Mihai Mihăilă, Corresponding Member of The Romanian Academy (elected in 1999), who collaborated with the group of Marius Petrascu from Măgurele Physics Campus [323], and contributed substantially to the theory of 1/f noise [324, 325]; Cornel Cobianu, a gifted research from whose research profile we mention here the work on tin dioxide sol-gel derived thin films deposited on porous silicon [326]; Dan Neculoiu, a distinguished researcher at IMT Bucharest and dedicated professor at University POLITEHNICA of Bucharest from whose publication record we note here the work on aluminium nitride films deposited on silicon substrate for the construction of surface acoustic wave resonators [327]; Mircea Dragoman, a brilliant physicist and engineer whose research is focused on nanoelectronics and nanomaterials at large, see Refs. [328-331] for his main results; Adrian Ionescu, a graduate of the Polytechnic Institute of Bucharest, an outstanding researcher who has received broad international recognition for his works on beyond-CMOS technologies and devices, more-than-Moore devices and circuits, and non-silicon devices and circuits, see Refs. [332, 333] for some of his most important results. In this context, we also mention the remakable contributions of Raluca Müller, Adrian Dinescu, Alexandru Müller, and Radu Cristian Popa, see Refs. [334-336].

3. NEW HORIZONS

The scientific expertise and international collaborations in nuclear physics and engineering, as well as laser physics and engineering, fostered on The Măgurele Physics Campus an extraordinary community of physicists and engineers, which is now re-establishing itself on the international research landscape through the Extreme Light Infrastructure – Nuclear Physics (ELI-NP) European facility [337]. This facility is located within the premises of Horia Hulubei National Institute of Physics and Nuclear Engineering and is expected to go operational in the near future. The ELI-NP European facility reflects the vision of the future on high-power lasers of Gérard Mourou, who established the field of high-power laser in 1985 in a landmark article, co-authored jointly with Donna Strickland, entitled "Compression of amplified chirped optical pulses" [338], which introduced the so-called chirped pulse amplification technique for optical pulses. "For their method of generating high-intensity, ultra-short optical pulses" Gérard Mourou and Donna Strickland shared, jointly with Arthur Ashkin, the 2018 Nobel Prize for Physics.

3.1. EXTREME LIGHT INFRASTRUCTURE - NUCLEAR PHYSICS

We have gathered in Refs. [339–346] some of the Technical Design Reports (TDRs) of ELI-NP European research facility, which describe the experiments scheduled to take place in the early operational phase. The first TDR in our selection, see Ref. [339], is that co-authored by Negoiță *et al.* on laser-driven nuclear physics at ELI-NP. Second in our selection is that co-authored by Turcu *et al.* on high field physics and quantum electrodynamics experiments at ELI-NP [340]. Weller *et al.* describe in Ref. [341] gamma beam delivery and diagnostics at ELI-NP, while Camera *et al.* discuss the gamma above the neutron threshold experiments at ELI-NP [342]. The photofission experiments at ELI-NP are detailed by Balabanski *et al.* in Ref. [343]. Teşileanu *et al.* overview charged particle detection at ELI-NP in Ref. [344], while Djourelov *et al.* [345] discuss positron production by gamma beams at ELI-NP and Mitu *et al.* [346] describe radiation protection and safety at ELI-NP.

4. CONCLUDING REMARKS

The scientific and editorial tradition that was established in Romania in 1956 with the publication of the first number of *Revue de Physique* continued uninterrupted to this day, though the journal changed name twice. The journal was first renamed *Revue Roumaine de Physique* in 1964 and then *Romanian Journal of Physics* in 1992. Our study of the archives of the journal located at the National Physics Library in Măgurele showed that during the period 1964-1992, when the journal was known

under the French name *Revue Roumaine de Physique*, it reached broad international visibility. This can be inferred from the numerous articles published by the founders of Modern Physics in Romania jointly with their collaborators, as well as from the numerous articles co-authored entirely by foreign scientists. In 1992 the journal was reinvented under the English name *Romanian Journal of Physics* to reflect the prominent position of the English language on the international research landscape, as well as the changes in the Romanian society. A survey of the publication record of *Romanian Journal of Physics* over the past few years shows an impressive diversity of research topics, which include experimental, computational, and theoretical physics articles, authored by Romanian and foreign scientists.

A quick inspection of the articles published by Romanian Journal of Physics in 2015 includes the one of Nicolin *et al.* on the ground state of Bose-Einstein condensates with inhomogeneous scattering lengths [347], the work of Silisteanu and Anghel on the competition between alpha-decay and spontaneous fission in Rf, Db, and Sg isotopes [348], the paper of Galeriu et al. on nuclear meteorology at IFIN-HH [349], that of Băleanu et al. on the modified Korteweg-de Vries-Zakharov-Kuznetsov and Hirota equations [350], the article of Aranghel and Săndulescu on shell effects in the fragmentation potential for superheavy elements [351], and that of Mirea on momentum of inertia for the ²⁴⁰Pu alpha decay [352]. Our selection of the articles published in 2015 continues with that of Buganu and Răduță on energy spectra, E2 transition probabilities and shape deformations for the even-even isotopes ^{180–196}Pt [353], the article of Rădulescu et al. on the assessment of heavy metals content in water and mud of several salt lakes from Romania [354], the paper of Silisteanu and Anghel on alpha-decay and spontaneous fission half-lives of superheavy nuclei around the double magic nucleus ²⁷⁰Hs [355], the work of Anitas on scattering structure factor from fat fractals [356], the contribution of V. Băran et al. on collective dynamics and fragmentation in nuclear systems [357] and the related one of Croitoru et al. on pygmy dipole resonance in a schematic model [358], the article of Mihăescu and Isar on suppression of entanglement in two-mode Gaussian open systems [359], the article of Suciu and Isar on Gaussian geometric discord of two-mode systems in a thermal environment [360], the contribution of Rădulescu et al. on risk assessment of heavy metals on public health [361], and the two articles on computational physics at large by Tabacu et al. [362] and Ionel [363].

Our survey of the articles published in 2016 in *Romanian Journal of Physics* starts with that of Constantinescu, on generalized conditional symmetries, related solutions of the Klein-Gordon-Fock equation with central symmetry [364], the article of Cristea-Stan *et al.* on XRF and micro-PIXE as investigation tools for ancient metallurgy [365], the paper of Anițaș *et al.* focused on the influence of randomness on small-angle scattering from deterministic mass fractals [366], the contribution of Li *et al.* on nonlinear parity-time-symmetry breaking in optical waveguides [367],

the topical review of He *et al.* on the dynamics of spatial solitons in parity-timesymmetric optical lattices [368], the analysis of Ioan on the radiation induced damage to optical glasses by using online heating laser measurements [369], the article of Ghiu and Isar on the analytical expression of the Chernoff polarization of the Werner state [370], the paper of Bica on microparticles and electroconductive magnetorheological suspensions [371], the work of Li and Mihalache on the asymmetric solitons in parity-time-symmetric potentials [372], the research of Calin *et al.* on radiochemical investigations on natural mineral waters from Bucovina region, Romania [373], the study of Constantin *et al.* on macroseismic intensity distribution of some recent Romanian earthquakes [374], and lastly that of Mihalcea *et al.* on multipole traps as tools in environmental studies [375].

From the publication record of 2017, we have selected the article of Cristescu on numerical resolution of coupled two-dimensional Burgers' equation [376], that of Mihăescu and Isar on Gaussian quantum steering of two bosonic modes in a thermal environment [377], the contribution of Mihalcea on quasiclassical dynamics of trapped ions [378], the work of Silișteanu and Anghel on simple empirical relations for α -decay half lives of superheavy nuclei [379], the paper of Cristea-Stan *et al.* on the application of X-ray fluorescence elemental analysis for mural painting restoration [380], and lastly the work of Postolache on the extinction coefficient used as parameter in gamma-ray dosimetry [381].

Among the papers published in 2018 we mention here that of Anițaș *et al.* on microstructural characterization of surface fractals using small-angle scattering [382], the work of Isar on generation of quantum steering in Gaussian open systems [383], the contribution of Apostol and Cune that reports a detailed analysis of the cross-section of charge scattering by electromagnetic radiation [384], the paper of Sergentu and Ursaki on scattering of a two-dimensional self-healing beam at the interface of a nanostructured medium with vacuum [385], the study of Țugulan on a determination of dielectric constant variation due to the exposure to gamma-ray [386], the article of Dumitru *et al.* on the influence of nitrogen environment on the performance of microbial fuel cells [387], the analysis of Bercea *et al.* on optical coatings for ELI experiments prepared by laser ablation [388], and lastly that of Fugaru *et al.* on low-power photovoltaic cells batteries used as gamma radiation dose estimators [389].

As we have shown in the previous sections, *Revue Roumaine de Physique* was the most important Romanian research journal dedicated to physics, which had an impressive publication record that includes articles co-authored by 11 Nobel Prize Laureates for Physics and Chemistry: Louis de Broglie, Chandrasekhara Venkata Raman, Kai Siegbahn, Linus Pauling, Ilya Mikhailovich Frank, Nevill Francis Mott, Glenn Theodore Seaborg, Nikolay Gennadiyevich Basov, Alexander Mikhailovich Prokhorov, Abdus Salam, and Carlo Rubbia. The aforementioned list of Nobel Laureates shows the remarkable international collaborations of the Romanian physics community after The Second World War, which was made possible by the founders of Modern Physics in Romania: Eugen Bădărău, Horia Hulubei, Ion I. Agârbiceanu, Şerban Țițeica, Radu Grigorovici, and Ioan Ursu.

At the centennial anniversary that mark 100 years passed since 1918, when all Romanian historical provinces were united in a single nation state, the community of Romanian physicists can be proud of its achivements over the past century and look forward with optimism at the decades to come. In our opinion, the foundation of the Măgurele Physics Campus in the outskirts of Bucharest, almost seven decades ago, represents a pivotal moment in the history of physics in Romania. In recognition of the crucial role played by the Măgurele Physics Campus in both research and education, The European Physical Society included the Campus on its prestigious list of Historical Sites alongside with Physikalisch-Technische Bundesanstalt -PTB (Braunschweig and Berlin, Germany), The Curie Laboratory of the "Institut du Radium" (Paris, France), Frascati National Laboratory (Frascati, Italy), Kamerlingh Onnes Laboratory and the Instituut-Lorentz (Leiden, Netherlands), Niels Bohr Institute (Copenhagen, Denmark), CERN Synchrocyclotron (Geneva, Switzerland), Joint Institute for Nuclear Research (Dubna, Russia), and The Blackett Laboratory (London, UK), to name only a few. On the side of the international recognition of the community of Romanian physicists, we consider that the best indicator is represented by the aforementioned Nobel Prize Laureates, all of whom had a strong connection to Romania, both as Honorary Members of The Romanian Academy (founded on 1/13 April 1866) and Romanian Academy of Sciences (1935-1948), and as authors of articles published in *Revue Roumaine de Physique*. Looking at the bright future ahead, it is our great honor and pleasure to include Gérard Mourou, the scientific father of the European project Extreme Light Infrastructure - Nuclear Physics, in the gallery of Nobel Prize Laureates deeply attached to the scientific community in Romania.

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