



Spanish women with degrees in physics or engineering researchers in modern engineering physics

Spanish women researchers in engineering physics

Juan Núñez Valdés

Department of Geometry and Topology
University of Seville
Seville, Spain

Abstract: Physics engineering is a discipline in Spain that, unlike in other countries, is not yet studied at public universities, being offered only at some private universities in major cities. This has resulted in few researchers dedicated to its study. This article, whose main objective is to present them as role models and examples for others, features the biographies of six Spanish women: three with engineering degrees: Ana García Armada, Nuria María Oliver Ramírez, and Elena García Armada, and three with physics degrees, Montserrat Calleja Gómez, Marta Sales Pardo, and Teresa Rodrigo Onoro, who focused their research on this discipline, achieving significant results, which have earned the recognition of the entire global scientific community.

Keywords—*Physics engineering, Spanish female physicists or engineering, pioneering women scientists, history of physics and engineering.*

I. INTRODUCTION

Currently, not many Spanish graduates focus their research on engineering physics, since this discipline, if it can even be considered as such in Spain, is only studied at a few private universities, mainly in Madrid and Barcelona, and has not yet been incorporated into the curricula of public universities. Physics graduates, on the one hand, and engineering graduates, on the other, tend to pursue research in other respective branches of physics and engineering, but not in engineering physics, which means that it still does not enjoy much prominence in Spanish science.

However, this does not mean that there are not some researchers who have had brilliant research careers in this subject, including women, although in a much smaller proportion than men, who have distinguished themselves through their almost exclusive dedication to this discipline, making groundbreaking discoveries.

This article presents the biographies of six Spanish women—three with degrees in engineering and three with degrees in physics—who have made significant contributions to this field and achieved important milestones in their research.

The main objective is to highlight these women's contributions to society, recognizing their pioneering work in these fields and their role in paving the way for many other university graduates to follow in their footsteps. The three engineering graduates, Ana García Armada, Nuria María Oliver Ramírez, and Elena García Armada hold the highest academic distinction, as also the three physics graduates, Montserrat Calleja Gómez, Marta Sales Pardo, and Teresa Rodrigo Onoro, do.

Although all of them have received numerous awards and accolades for their outstanding work in this discipline, they remain relatively unknown to the general public, who are unaware of their scientific contributions and dedication.

The methodology employed in this research is standard for this type of work: gathering information from all available sources about the lives and work of these women.

The article is structured as follows: after this introduction, and for contextual purposes, a section II is included that provides a brief overview of the beginnings of physics engineering studies worldwide, which, as can be seen, are very recent compared to the beginnings of other branches of engineering or physics. In section III, divided into two subsections, the biographies of these women are shown, emphasizing the brilliance of their results. Finally, a concluding section and the corresponding bibliography complete this contribution.

II. A BRIEF OVERVIEW OF THE BEGINNINGS OF PHYSICS ENGINEERING IN THE WORLD

To provide context for the content of this article, this section presents a brief historical overview of the beginnings of physics engineering worldwide. All paragraphs herein have been adapted and modified by the author from the following sources: [1] to [5]. The Encyclopedia Britannica was also used for the biographies cited.

In very general terms, though somewhat loosely, it can be said that the origins of physics date back to antiquity, the 7th and 6th centuries BC, when some Greek philosophers, such as Thales of Miletus, attempted to explain natural phenomena rationally. Later, after a series of isolated individual contributions, physics became a modern science in the 17th century, thanks to the scientific revolution brought about by the contributions of Galileo Galilei (1564-1642) and Isaac Newton (1643-1727), among others. Meanwhile, the origins of engineering, defined as the application of science to the optimal conversion of natural resources for human use, are also very ancient and linked to practical needs, appearing in places like Egypt, Mesopotamia, and Rome, with the construction of structures such as pyramids and aqueducts. Much later, in the 18th and 19th centuries, engineering consolidated as a modern discipline with the emergence of technical training schools and the professionalization of engineers.

As for engineering physics, it formally emerged in the United States in the 1920s as a response to the need to integrate modern physics into engineering education. Its development is closely linked to institutions such as Massachusetts Institute of Technology, founded in 1861 (from here on MIT) and California Institute of Technology, founded in 1891 (from here on Caltech), where an educational model based on the interaction between fundamental science (physics) and applied technology (engineering) was consolidated. In 1924, the subject of "Engineering Physics" appeared in the academic programs of some American universities, with the aim of combining physics, as a theoretical science, with engineering, as an applied discipline.

In Europe, this idea of combining physics and engineering arose before it did in the United States, although not with its current name. It cannot be said to have a single, fixed moment of origin; rather, it emerged more gradually under other names such as technical physics or applied physics. Its origins lie in the German university model (19th century) introduced by Alexander von Humboldt (1769-1859) and the emergence of polytechnic schools, such as the École Polytechnique in Paris (founded in 1794) and other technical schools, which trained engineers with a very solid scientific foundation.

Later, in the 20th century, European universities (in several countries: Germany, the Netherlands, Switzerland, and the United Kingdom) began offering programs with names like "applied physics" or "technical physics," precursors to today's engineering physics programs.

Regarding who were the first European researchers in Engineering Physics as such, there are several pioneers who combined physical theory and technological application, laying the foundations of the modern specialty. Among them can be cited: James Clerk Maxwell (1831-1879), William Thomson Kelvin, 1824-1907), Heinrich Hertz (1857-1894), Nikola Tesla (1856-1943), Robert A. Millikan (1868-1953), Marie Curie, (1867-1934), Hertha Ayrton (1854-1923), Albert Einstein (1879-1955), John Bardeen (1908-1991), Richard Feynman (1918-1988), Lise Meitner (1878-1968), Chien-Shiung Wu (1912-1997), William Shockley (1910-1989), Claude Shannon (1916-2001), Mildred Dresselhaus (1930-2017) and Shirley Ann Jackson (1946-), who, although belonging to different eras, all share having had a deep training in physics, having worked on real problems (energy, materials, telecommunications), having had a technological application of their discoveries and having greatly influenced the emergence of new industries, reasons why they all fit into the current concept of Engineering Physics, even though that discipline did not yet exist in their times.

Finally, with regard to Spain and in comparison with the US or some other European countries, Physics Engineering is a relatively recent degree program in Spain. Its presence was consolidated mainly within the framework of the European Higher Education Area (early 21st century), and the degree, which is geared towards the design of emerging technologies such as nanotechnology and biomaterials, is currently only offered at a few private Spanish universities, primarily located in Madrid and Barcelona.

The Spanish scientist whose academic work is most closely associated with modern physics engineering was the physicist Blas Cabrera y Felipe (1878-1945), who was director of the Laboratory of Physical Research from its creation in 1910 until 1937, and rector of the Central University of Madrid in 1931. He was primarily an experimental physicist, and his greatest work was in the field of the magnetic properties of matter, achieving a unique position in the physics of his time. In 1903 he participated in the founding of the Spanish Society of Physics and Chemistry and its journal, the *Annals of said Society*. In 1905 he obtained the chair of Electricity and Magnetism at the Central University of Madrid.

III. SPANISH WOMEN GRADUATES PIONEERS IN PHYSICS ENGINEERING

This section presents in the first subsection the biographies of six Spanish women born between the 1950s and 1970s of the 20th century, with the exception of one of them, three of whom graduated in architecture and three others with degrees in physics in the second subsection with particular emphasis on their academic activities related to physics engineering. These biographies are arranged chronologically by the women's birth dates.

3.1 *Spanish women engineers*

This subsection shows the biographies of three Spanish engineers who have stood out in Physical Engineering.

3.1.1 *Ana García Armada*

Born in Santiago de Compostela on June 17, 1970, Ana García Armada graduated in Telecommunications Engineering from the Higher Technical School of Telecommunications Engineers at the Polytechnic University of Madrid in 1994, and subsequently obtained her doctorate from the Department of Signals, Systems and Radiocommunications at the same university in 1998. Her doctoral thesis was entitled "Contribution to the development of rapid prototyping techniques for communication systems" and was supervised by Professor Miguel Calvo Ramón [6].

After completing her doctorate, she began working as a lecturer and researcher at Carlos III University of Madrid. There, she continues to work in her current position as Professor of Signal Theory and Communications, where she is head of the Communications Group and a lecturer in the same department.

Her research has focused on the field of mobile broadband communications [7]. Specifically, she works on the design of information encoding algorithms used by technologies such as Digital Terrestrial Television, Wi-Fi connections, and ADSL. She is also responsible for the European project TeleRescuer, which developed a teleoperated robot capable of performing rescues inside a mine [8].

In her ongoing pursuit of further training, García (Figure 1) has undertaken research stays at Stanford University, at Bell Labs, as part of the team that won third place in the 2014 Bell Labs Innovation Prize, and at the University of Southampton.



Fig. 1. Ana García Armada.

In 2015, she was part of the working group that obtained the MIMO HUB patent from Carlos III University: a jacket capable of increasing the upload speed of mobile devices tenfold. This jacket, concealing dozens of antennas, allows a garment to connect to any mobile terminal, boosting data transfer speeds, reducing energy consumption, and improving reliability [9].

She has also been the lead researcher on a project capable of equipping streetlights with Li-Fi capability, a technique that uses light-emitting diodes to transmit data in binary code through rapid, imperceptible flashes. Additionally, she coordinated the TeamUp5G project, a European initiative to research and provide training in 5G mobile networks [10].

Thanks to her excellent research and numerous valuable contributions, García has received many awards and accolades throughout her scientific career, including the following

2010: Excellence Award from the Social Council of the Carlos III University of Madrid in the Young Researchers category.

2014: Third place in the Bell Labs Innovation Prize.

2019: Outstanding Service Award, IEEE Communications Society Signal Processing and Communications Electronics Technical Committee.

2020: Outstanding Service Award, IEEE Communications Society Women in Communications Engineering Standing Committee.

3.1.2 *Nuria Maria Oliver Ramírez*

Nuria María Oliver Ramírez, born in Alicante on October 31, 1970, graduated in Telecommunications Engineering from the Polytechnic University of Madrid in 1994 and that same year was awarded the First Spanish National Prize for Telecommunications Engineers.

Next year she received a scholarship from the La Caixa Foundation to pursue postgraduate studies at the MIT, where she earned a doctorate in Media Arts and Sciences, specializing in perceptual intelligence.

In 2000, she worked as a researcher at Microsoft's research laboratories in Redmond, USA, where she remained for twelve years. She returned to Spain in 2007, settling in Barcelona, to work at Telefónica R&D as Scientific Director of Multimedia, becoming the first and only female scientific director hired by Telefónica R&D at that time [11]. Nine years later, in November 2016, she left her job at Telefónica, after being named the first female Chief Data Scientist at DataPop Alliance, an international non-profit organization created by the Harvard Humanitarian Initiative, MIT Media Lab and Overseas Development Institute, dedicated to harnessing Big Data to improve the world.

In January 2017, Oliver (Figure 2) joined the Vodafone Group as its first Director of Data Science Research (a position she held until May 2019). That same year, she was appointed scientific advisor to the Vodafone Institute (a position she held until 2024). She was also appointed by the Spanish Secretary of State for Information Society and Digital Agenda as a member and spokesperson for the Group of Wise Men, composed of nine experts from various sectors, to address the social, legal, and ethical ramifications of Artificial Intelligence and Big Data, with the aim of producing a White Paper on the subject [12].



Fig. 2. Nuria Oliver

She has been a Fellow of the Association for Computing Machinery and the Institute of Electrical and Electronics Engineers since 2017, and in 2019, she co-founded and became Vice President of the European Laboratory for Learning and Intelligent Systems. In 2020, she was appointed an independent director of Bankia, a position she held until its merger with Caixabank, and since 2023, she has served as an advisor to the Spanish Agency for the Supervision of Artificial Intelligence.

Her outstanding contributions to physics engineering to date and her numerous brilliant scientific contributions have earned her numerous awards and recognitions. Among the more than 20 awards received between 1994, when she won the First Spanish National Telecommunications Engineering Award, and 2026, when King Felipe VI officially presented her with the 2025 National Research Award in Spain in Barcelona, the following stand out [13].

2004: she was the first Spanish woman recognized as one of the world's 100 innovators under 35 by MIT Technology Review for her work on intelligent human-computer interfaces.

2015: she was named a Distinguished Scientist by the Association for Computing Machinery, becoming the first Spanish computer scientist to receive this award.

2016: National Computer Science Award.

2021: King Jaime I Award in the New Technologies category.

2023: Gold Honorary Distinction, "Top 100 Women Leaders in Spain," in the academics and researcher category.

2023: European Science Prize Hypatia from the Barcelona City Council and the Academia Europaea, for her outstanding research in artificial intelligence and its international impact

2025: Julio Rey Pastor National Research Award (Mathematics and ICT), from the Spanish Ministry of Science and Innovation. This is the highest scientific distinction in Spain.

2025: Talgo Award for Excellence in Engineering.

3.1.3 *Elena García Armada*

Elena García Armada was born in Valladolid in 1971 into a highly educated family. Her father was a professor of Electromagnetism and the driving force behind the School of Telecommunications Engineering at the University of Cantabria, while her mother held a doctorate in Physics and was a university professor. Despite sharing the same surname, there is no evidence in the literature that Elena García Armada is the sister of the aforementioned Ana García Armada.

Elena García graduated in Industrial Engineering from the Polytechnic University of Madrid and subsequently earned her doctorate from the same university in 2002 with a dissertation entitled "Optimization of the Stability and Speed of Walking Robots," supervised by Professors Fernando Matía Espada and Pablo González de Santos [14].

Prior to her doctoral thesis, in 2002 she presented the SILO 4 project, a 30-kilogram robot with high autonomy and terrain adaptability, designed for use in disaster reconnaissance and rescue operations, as well as for demining.

In 2007, she completed a training period at the MIT and joined the Spanish National Research Council (from here on CSIC), where she has led 22 technological innovation and technology transfer projects.

In 2009, she met Daniela, a 9-year-old girl who was quadriplegic due to a traffic accident. After several years working on her case, García presented in 2012 the first pediatric exoskeleton, which can be adapted to the child's growth and muscle condition [15].

In 2013, García founded Marsi Bionics as a spin-off of the Center for Automation and Robotics, a joint center of the Polytechnic University of Madrid and CSIC. Marsi Bionics focuses on the development of lower limb exoskeletons for medical applications. The company has received numerous awards for its technological innovation and social impact, including the 2015 Cepyme Award for Best Entrepreneurial Project, the 2017 FENIN Award for Entrepreneurship in Healthcare Technology, and the 2019 ONCE Foundation Discapnet Award. Currently, García serves on the Board of Directors of the Spanish State Research Agency, is a member of numerous national and international organizations, and is a member of the jury for the Princess of Asturias Awards for Scientific and Technical Research and the Juan de la Cierva National Research Awards for Technology Transfer.

Her research has resulted in eight patents, three of which have been licensed and extended internationally to the United States and Europe, and in over one hundred scientific publications in journals and conference proceedings. She has published a total of 120 scientific papers with an H-index of 26 (i10-index of 49), and his work has received 2,735 citations, according to Google Scholar.

Since 2019, Oliver (Figure 3) has been an honorary corresponding member of the Royal Academy of Medicine of Cantabria, and her research has earned her numerous awards and distinctions, including the European Inventor Award in 2022, granted by the European Patent Office, for her adaptable exoskeleton, a prestigious international recognition shared by only two other Spaniards: biochemist Margarita Salas and engineer José Luis López Gómez.

On April 9, 2021, a newly established secondary and high school in Jerez de la Frontera (Cádiz) was named after her.



Fig. 3. Elena García at her investiture as Doctor Honoris Causa at the European University Miguel de Cervantes in Valladolid

3.2 *Spanish women physicists*

This subsection shows the biographies of three Spanish physicists who have stood out in Physical Engineering.

3.2.1 *Montserrat Calleja Gómez*

Montserrat Calleja Gómez was born in the province of Ourense (Galicia) in 1973. She graduated in Physics from the University of Santiago de Compostela in 1998, completed a master's degree in 2000, and earned her doctorate in the same field from the same university in 2002.

Her doctoral thesis, entitled “Study of the local oxidation of silicon surfaces using atomic force microscopy and its applications to nanolithography,” was supervised by Ricardo García García at the Institute of Microelectronics in Madrid. In it, Montserrat García studied local oxidations on silicon surfaces using an atomic force microscope, as well as various applications in nanolithography [16].

Determined to work in nanotechnology and tensor science, Montserrat Calleja (Figure 4) obtained a postdoctoral position through a Marie Curie fellowship at the Technical University of Denmark-MIC, where she worked on the nanofabrication of cantilever-based sensors, under the supervision of Annia Boysen.



Fig. 4. Montserrat Calleja

After subsequently receiving one of the prestigious European Research Council Starting Grants, Calleja led the NANOFORCELLS project, which aimed to study the mechanical properties of cells and their relationship to cancer [17].

From 2008 to 2012, she was director of the Devices, Sensors, and Biosensors Department at the CSIC's MMI. She patented a nanomechanical mass spectrometer for weighing individual proteins in cells.

She was also a co-founder of Mecwins, a pioneering company in the commercialization of nanomechanical biosensors.

Thanks to her brilliant research and patent output, she has received several awards throughout her academic career. Among them are the following [18]

2018: Women to Follow Award.

2021: Miguel Catalán Award for researchers under 40.

2022: King Jaime I Award in the area of New Technologies.

Currently, Calleja is a research scientist at CSIC at the Institute of Microelectronics in Madrid.

3.2.2 *Marta Sales Pardo*

Marta Sales Pardo, born in Barcelona in 1976, graduated in Physics in 1998, from the University of Barcelona and in 2002 obtained her PhD in the same discipline and university with a doctoral thesis directed by Félix Ritort Farran, entitled “Large Scale Excitations in Disordered Systems.” In it, she studied how some disordered materials evolve over time and respond to different temperature changes, observing that in these systems, the interactions between particles are chaotic and generate very complex and difficult-to-predict states [19].

During her doctoral studies, she completed two research stays abroad, one at the University of Rome I “La Sapienza” in Italy, and another at CEA-Saclay in France. After obtaining her doctorate, she began working in January 2003 at Northwestern University, where she remained as a professor until 2009, the year in which she returned to Spain to work at the Rovira i Virgili University of Tarragona.

From the outset, her research has focused on contemporary statistical physics, a field that has grown enormously in recent decades, extending into biology, sociology, computer science, and closely linked to data science.

Specifically, her research encompasses network statistical physics, focused on applying principles of statistical mechanics, such as probability, entropy, and collective states, to the study of complex graphs representing social interactions, information networks, biochemical networks (e.g., metabolic networks), or multi-agent systems; the study of the contribution of each individual node in a network to the overall functioning of real-world networks; complex interdisciplinary systems, in which he studies how interactions generate collective patterns; and finally, the application of statistical methods to the study of real-world systems, which, due to noise, incomplete data, and high dimensionality, require advanced inference methods.

Sales (Figure 5) is the author of numerous contributions that combine statistical physics, inferential statistics, network science, and computational biology, which has led to her receiving numerous honorary appointments to date, including the following

2021: she was named a Fellow of the Network Science Society “for her contributions to the understanding of large-scale network organization and for the development of generative models and inference methodologies for complex networks.” She was the first Spanish woman to receive this recognition.

2024: European Research Council (ERC) awarded her an ERC Synergy Grant, a grant that aims to foster collaboration between elite research teams to address complex scientific challenges. She will be one of the directors, for six years, of the Circuit Evolution project, along with two teams from the Laboratory of Molecular Biology at the University of Cambridge in the United Kingdom and Rockefeller University in the United States. The project focuses on the connectivity of various fly species, to decipher how neural circuits change with behavior and what aspects

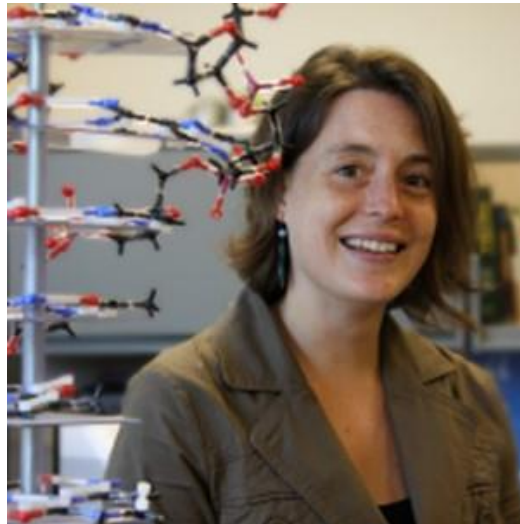


Fig. 5. Marta Sales

3.2.3 Teresa Rodrigo Onoro

Teresa Rodrigo Anoro, considered the "Spanish mother" of the Higgs boson [20], was born in Lleida on December 28, 1956. In 1980, she graduated with a degree in Physics from the University of Zaragoza, and in 1985, she earned her doctorate in the same discipline from the Autonomous University of Madrid. Her doctoral thesis, titled "Inclusive Production of Strange Particles in pp Interactions at 360 GeV-c," was supervised by Professor Antonio Ferrando [21].

After obtaining her doctorate, she began working at the Center for Energy, Environmental and Technological Research between 1981 and 1987. The following year, she undertook a postdoctoral fellowship at the European Organization for Nuclear Research (from here on CERN, founded in 1954, so named from its French acronym: Conseil Européen pour la Recherche Nucléaire) in Switzerland, where she spent two years. She then moved to the Fermi National Accelerator Laboratory in the United States, where she remained between 1990 and 1993.

Upon returning to Spain, she began working as a professor of Atomic and Nuclear Physics Department at the University of Cantabria in 1994, eventually obtaining a full professorship in 2002. From 1994, she worked at the Institute of Physics, affiliated with the university and CSIC, where she was head of the Department of Structure of Matter between 2001 and 2007. In 2016, she was appointed director of the institute.

Rodrigo participated in two exceptionally important experiments. One, at the CDF of the Tevatron at Fermilab, led to the detection of the top quark, and the other, in the discovery of the Higgs boson in 2012.

This last experiment was carried out at the Large Hadron Collider (LHC), the large particle accelerator at the European Organization for Nuclear Research (from here on CERN) in Geneva. For her dedication and results in this experiment, in 2010 she was elected Chair of the International Collaboration Council for the Compact Muon Solenoid, which includes institutions from 40 countries. From 2012 to 2017 she was a member of CERN's Science Policy Committee [22].

Her contributions to physics engineering focused on the design and development of particle detectors, the study of energy measurement systems (calorimeters), the alignment of high-precision detectors, the integration of scientific hardware and software, and the construction and operation of large experimental infrastructures.

In 2018, she was included in The Periodic Table of Women Scientists, published to commemorate the 150th anniversary of Mendeleev's publication and the declaration of 2019 as the International Year of the Periodic Table of Chemical Elements [23].

In 2016, Rodrigo ([22]) received the first Julio Peláez Award for Pioneers in Physical, Chemical, and Mathematical Sciences, granted by the Tatiana Pérez de Guzmán el Bueno Foundation.

Chosen in the Top 100 Women Leaders in Spain 2014 ranking, Doctor Honoris Causa from the Menéndez Pelayo International University and Silver Medal of the University of Cantabria, Rodrigo sadly passed away in Santander on April 21, 2020, at the age of 63, due to the serious health problems she suffered from (references to all the situations and events indicated in that biography can be found in [22]).



Fig.6. Teresa Rodrigo

4. CONCLUSIONS

As already mentioned, the beginnings of physics engineering in Spain were later than those of other disciplines, and all of these, in turn, were later than their counterparts in other European countries and the United States. Furthermore, the researchers who initially dedicated themselves to these studies were mostly men, with very few women focusing their research in this field.

The most important common characteristics of these women, among which are the six discussed in this article, include the following.

First, these women had exceptionally strong scientific backgrounds, quite unusual for the time. Specifically, they primarily held degrees in physics or engineering, although there were also some with degrees in mathematics, and to a lesser extent, some in medicine or biology. This background allowed them to access research grants and positions in Spain with a relatively high probability of success.

Second, these women conducted their research at established institutions, such as the CSIC, Nuclear Energy Board, and the country's leading universities.

Third, several of these women had the opportunity to undertake research stays at foreign universities or centers, which greatly benefited Spanish research in general, given the very limited scientific infrastructure in the country at that time.

Fourth, many of them combined their research activity with university teaching, often due to the lack at that time of positions exclusively for researchers, for both men and women.

And fifth, these women began working in teams led by men who already enjoyed a certain degree of recognition, although almost all of them later managed to create their own lines of research and lead their own groups.

For all these reasons, these women, particularly these dealt with in this article, can be considered pioneers of physics engineering research in Spain and deserve to be recognized as such by society. They paved the way for subsequent generations and served as female role models in technical disciplines, generally considered by society to be exclusively for men.

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