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Tribute to Arnulfo Zepeda Domínguez

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On November 30, 2020, the world of High Energy Physics lost one of its most brilliant research professors. Dr. Arnulfo Zepeda Domínguez left a great legacy of scientific results, new researchers' training, schools' creation, new experiments, new research centers, and invaluable scientific outreach work. In this contribution, a group of his students, colleagues, and friends describe him as a professor and leader through several anecdotes.

Keywords: Arnulfo Zepeda; high energy physics; HAWC; auger; MCTP; MAIS; LRCAD; CERN; ALICE.

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1. Semblance

Arnulfo Zepeda was born in the colonial city of San Luis Potosí, Mexico, on January 15, 1943. He became interested in nuclear physics during his days in the secondary school. After finishing the high school in 1961 at the Escuela Preparatoria Nocturna Dr. Mariano Narváez in Saltillo, Coahuila, Mexico, Arnulfo Zepeda looked for a scholarship to study nuclear physics abroad.

FIGURE 1. Dr. Arnulfo Zepeda getting his MSc degree in Prague, 1967.

During the years 1962-1967, he received financial support to study at the Faculty of Nuclear and Technical Physics of the Czech Technical University in Prague, Czech Republic, one of the oldest institutes of technology in Europe and the only one in the Czech Republic where nuclear physics was offered in those years. There, he graduated as Nuclear Physics Engineer on June 14, 1967, with a thesis about stripping nuclear reactions [1], and got his degree in Master of Science, with a specialization in Nuclear Physics Engineering, on November 20, 1967 [2].

Then he returned to Mexico, joining CINVESTAV of the Instituto Polit´ecnico Nacional. Arnulfo Zepeda became interested in elementary particle physics after attending the excellent lectures on this topic by Drs. Mirza Abdul Baqui Beg and Guido Altarelli, as well as Dr. Alberto Sirlin, which were imparted in the first Advanced Summer School at CINVESTAV in 1969. Consequently, he did a Ph.D. thesis on particle physics entitled Production of W mesons in charged leptons-pion collisions under the supervision of Dr. Mumtaz Zaidi [3]. As a result, he obtained his Ph.D. in Science in September 3, 1970.

In the summer of 1970, Arnulfo Zepeda moved to the Rockefeller University in New York supported by CINVESTAV, and obtained another Ph.D. in Elementary Particle Physics on October 31, 1972, under the supervision of Dr. Mirza Baqui Beg with a thesis on chiral theorems [2,4].

FIGURE 2. Dr. Arnulfo Zepeda (lower left side of the picture) at the Physics Department of CINVESTAV, 1967.

Dr. Zepeda returned the same year to Mexico as a professor in physics at CINVESTAV, becoming one of the founding members of the Particle Physics Group at the Department of Physics of that institution. There, Arnulfo Zepeda devoted his research interests to different theoretical high energy physics topics, giving significant contributions to the field. These works were soon recognized by his colleagues in Mexico and abroad. In particular, he made interesting and high-quality studies in chiral symmetry, nuclear form factors, and properties of baryons, quarks, and leptons. In this regard, one of his works with title Mass of the up quark, published on July 17, 1978 [6], became the most cited paper of a Latin American physicist in the field of high energy physics between 1978 and 1982. As a result, he obtained his Ph.D. in Science on September 3, 1970.

He did another pioneering work with José Luis Lucio, and Alfonso Rosado in the '80s that dealt with a clever definition of the neutrino charge radius in the Standard Model by means of an effective one-loop neutrino-photon vertex [8,9].

Later at the beginning of the 90s, Arnulfo Zepeda, together with several colleagues and students (for example, William Ponce, Albino Hernández Galeana, Ricardo Gaitán, Roberto Martínez, and Abdel Pérez Lorenzana) published some of the first papers in Mexico in the area of Grand Unified Theories, some of them involving supersymmetry [10]. He also explored different Beyond Standard Model scenarios like leftright symmetric models and technicolor theories [11]. Implications of technicolor scenarios for the production and development of extensive air showers were studied in 2008 with Rodrigo Pelayo in the Ph.D. thesis entitled *Technicolor theories and ultra-high-energy cosmic rays* [12].

During this fruitful period at CINVESTAV, Arnulfo Zepeda, together with another of his colleagues, promoted different actions focused on developing of high-energy physics in Mexico. For example, Arnulfo Zepeda along with José Luis Lucio Martínez and Matías Moreno founded the Mexican School on Particles and Fields, which happened in 1984 [13]. On the other hand, together with Augusto García González and Miguel Ángel Pérez Angón started some talks with Dr. Leon Lederman, which was head of the Fermi National Laboratory (Fermilab) and future Nobel laureate, to promote the experimental particle physics in Mexico [2,13]. First talks were carried out during the first Pan-American Symposium on Experimental Physics, which Dr. Lederman organized in Cocoyoc, Mexico, in 1982 [2]. Those actions led to the development of a program at CINVESTAV to train Ph.D. students in experimental particle physics at Fermilab, which was later supported also by CONACYT. Furthermore, the program led to further collaborations to train students at different particle physics laboratories around the world, which continues up to now [13]. It is also the precedent of the Laboratory Summer Student Program that is supported nowadays by the Division of Particles and Fields of the Mexican Physical Society.

It was at the end of the 90s when Dr. Arnulfo Zepeda engaged in another scientific adventure. The detection of a yet enigmatic form of extraterrestrial radiation known as ultrahigh-energy cosmic rays [14], whose energies can be as high as ~ 10 million times those found in the beams of the LHC at CERN [15]. By the end of the 90s Alan Watson and the Nobel Prize James Cronin were leading an experimental proposal to build an enormous air shower detector array, called the Pierre Auger observatory, with a surface of 3000 km^2 dedicated to measure cosmic rays of the highest energies ever observed [16]. Due to the low flux of these particles, measurements in this energy range had large uncertainties, and the physical implications were not clear. Measurements with the Fly's Eye observatory pointed out the existence of a cutoff in the cosmic ray spectrum at around 10^{20} eV [17], but data from the AGASA detector did not seem to show such feature in the spectrum of cosmic rays [18]. Precision measurements with improved statistics were needed to solve this experimental discrepancy and to investigate the origin, source and composition of ultra-high-energy cosmic rays. The idea behind the Pierre Auger observatory was to address these issues. Several colleagues in Mexico, among them Arnulfo Zepeda, joined the Pierre Auger collaboration in 1996 [19] after a meeting held in Puebla, Mexico, with the leader of the Pierre Auger project, James Cronin.

FIGURE 3. Dr. Arnulfo Zepeda (the second line from the bottom and third column from the left) in one of the firsts Pierre Auger Meetings [20].

FIGURE 4. Arnulfo Zepeda (the second from the left), Arturo Fernández (the third from the left) and Leon Lederman (center) at the 7th Mexican Workshop of Particles and Fields, Mérida, Mexico, 1999.

Arnulfo Zepeda was a key player, coordinator, and lead figure in the Mexican Collaboration of the Pierre Auger Observatory from the formation of the Mexican group until his last day. Within the Mexican collaboration, which was composed by Luis Villaseñor, Humberto Salazar, Juan Carlos D'Olivo, Lukas Nellen, and José Valdés among others, he participated in the development of the Cherenkov tanks, the search for financial support, the technical design, and as a Mexican representative for the International Collaboration among other activities. Here we would like also to recognize the important participation of the Mexican group for the design and construction of the Pierre Auger observatory, which has had outstanding contributions to the experiment [19]. For example, in the development of the optical design of the fluorescence telescopes, the electronics of the surface detectors and the Cherenkov tanks [19]. The latter was based on a simple design involving plastic tanks built by ROTOPLAS. Mexico also provided one third of the surface detectors for the observatory and helped with the installation and operation of the observatory among other contributions. Today, the Auger observatory has demonstrated the existence of a cut-off in the spectrum of cosmic rays [21] and has shown that they have an extragalactic origin [22], among other important discoveries [23].

Undoubtedly, the participation in the Pierre Auger project boosted the field of experimental and theoretical astroparticle physics in Mexico and the involvement of Mexican students and researchers in the field of very high-energy cosmic rays. Here, Dr. Arnulfo Zepeda was also actively involved, helping professors and students to join efforts in Mexico and connecting local groups with international collaborations working in the field.

One of the most important activities of Arnulfo Zepeda within the Pierre Auger Collaboration was in the Outreach task. He was co-leader, giving outreach and informative talks to elementary schools in the province of Mendoza, Argentina, Chile, as well as in Mexico, from the beginning of the project. In addition, for many years, he organized the Science Fair during the Collaboration meetings in November. Students of primary and secondary schools from all over Mendoza participated in these contests.

The development of new astroparticle physics groups in Mexico with experience in high-energy cosmic rays opened the opportunity to participate in new and exciting international projects in this area. For example, at the High Altitude Gamma Ray Observatory, HAWC, a last generation air shower Cherenkov detector dedicated to investigate the gamma-ray sky at energies from 10 TeV to 100 TeV. The detector is installed between the volcanoes Sierra Negra and Pico de Orizaba in Puebla, Mexico, at 4100mof altitude [24]. The HAWC observatory aims to look for the origin of the very high-energy cosmic rays that we observed on Earth. The usage of the TeV gamma-ray window can reveal potential astrophysical sources of galactic cosmic ray particles, which have eluded us for more than one century. Arnulfo Zepeda was a member of the international HAWC Collaboration from July 8, 2007, until November 2020. But his participation started years before, in 2002 when several members of the MILAGRO collaboration were planning the construction of the next generation of gamma-ray Cherenkov detectors. Arnulfo Zepeda and Humberto Salazar heard about this effort at the 1st ICFA instrumentation school/workshop from Dr. Brenda Dingus, who was run manager of the MILAGRO detector at Los Alamos National Laboratory and also a leading figure in TeV astronomy. The event was held at the Universidad Michoacana in Morelia, Mexico, from November 18 to 29, 2002 [25]. She was introduced to them by Dr. Luis Villaseñor, knowing the interest of the group in astroparticle physics and their probed experience in the Pierre Auger observatory [16]. At that time, the University of Puebla was installing an array of 2.25 km^2 at the Pico de Orizaba, Puebla, at 4200 m a.s.l [26]. The site was promising for the installation of HAWC due to the altitude and existing infrastructure. Hence, Dr. Dingus became interested, and Arnulfo Zepeda and Humberto Salazar took her to visit the site after finishing the ICFA School [27]. After that, Arnulfo Zepeda and other Mexican colleagues like Alberto Carramiñana, Magdalena González, Arturo Menchaca, and Andrés Sandoval, among others, joined efforts to convince the MILAGRO collaboration to bring HAWC to Mexico [28]. That required dedicated studies of the site, environmental impact, etc. [29-31]. The Mexican group of the HAWC collaboration was officially born in the Workshop of High-Energy Astroparticle Physics held in April 2006, at INAOE, Puebla, Mexico, and Arnulfo Zepeda was an active member of it [32] . The Mexican proposal to build HAWC at the volcano Sierra Negra was finally accepted in July 2007, during the development of the International Cosmic Ray Conference (ICRC) held in Mérida, Yucatáan [33]. The Cosmic Rays Division of the Mexican Physical Society was born during these years to organize the 30th ICRC in Mexico, and Dr. Arnulfo Zepeda was one of the founders.

FIGURE 5. Dr. Arnulfo Zepeda at MCTP, Chiapas, Mexico, ca. 2015 [7].

Definitely, HAWC has contributed to the further creation and consolidation of several groups on high energy astroparticle physics in Mexico, which have participated in constructing the detector and have made significant scientific contributions to this field. Nowadays, HAWC has led to important scientific discoveries by providing the first image of the sky in TeV gamma rays [34], showing the existence of new gamma-ray objects, like TeV halos around pulsars [35], by pointing out to potential sources of PeV cosmic rays [36-39], and by observing new structures in the all-particle energy spectrum [40] and the individual spectra of elemental cosmic ray nuclei at TeV energies [41].

There are more contributions of Dr. Zepeda to astroparticle physics in Mexico. One of the latest was his participation in the foundation of the Annual Meeting of the Cosmic Rays Division of the Mexican Physical Society, which started in November 2018. In the last versions of this meeting, he participated actively in the organizing committee. Unfortunately, his death occurred on November 30, 2020, just four days after finishing the Cosmic Ray Division Annual meeting of 2020.

Arnulfo was also among the initiators of Mexican scientists' participation in CERN, particularly in the ALICE experiment, where he participated between 2002 and 2009. In addition, he was involved in the design and installation of the ACORDE detector, a cosmic-ray trigger for ALICE [42].

Dr. Zepeda was an associate (1982-1988) and senior associate (1998-2003) at ICTP, Trieste, and was elected fellow of the American Physical Society in 1993 for his original research in High-Energy Physics and phenomenology, his leadership in Mexico, and his initiatives in promoting closer communication among physicists in North America. He chaired the Division of Particles and Fields of the Mexican Physical Society (SMF) from 1991 through 1992. He was president of the SMF between 1992 and 1994, initiating the Canadian-American-Mexican (CAM) Graduate Student Physics Conference in 1994.

From 2005 to 2016, Dr. Zepeda and Luciano Maiani promoted Europe-Latin America scientific exchanges through programs of the European Commission: HELEN (High- Energy Physics Latin-American European Network), and after that with EPLANET (European Particle Physics Latin American Network), making possible the mobility of several physicists from Latin America and encouraging significant participation in the discoveries made at LHC, DESY, Pierre Auger Observatory, and other experiments [43].

Arnulfo also promoted the School on Cosmic Rays and Astrophysics all over Latin America since 2004, devoted to young researchers and graduate students, organizing the 2nd and 6th editions of this school in Puebla (2006) and Tuxtla Guti´errez (2015), Mexico. He also aided in the organization of the personal library of Manuel Sandoval Vallarta at the historical archive dedicated to this scientist at the Universidad Autónoma Metropolitana (UAM), another pioneer in cosmic ray physics in Mexico. From 2011 to 2018, Arnulfo worked very hard to create MAIS (Mesoamerican Instituto for Science) at the Universidad Autónoma de Chiapas (UNACH), an initiative started by ICTP to establish a network of partner UNESCO Institutes around the globe. Furthermore, he was a very enthusiastic founding director organizing several international schools, looking for funds and positions for international researchers. As a result, MAIS became a category-two UNESCO institute in 2020 [43]. Furthermore, being MAIS director, he supported the creation of LARCAD (Regional High-Performance Computing Center) at UNACH. After a donation of equipment from CERN, this center is the only one of its kind in the region and recently got the Level III by ICREA (International Computer Room Experts Association).

Dr. Arnulfo Zepeda received several awards during his life due to his important contributions to science, for example, the Guggenheim Fellowship (1982-1983), the 2001 award to the Development of Physics in Mexico by the SMF, the 2002 award of the Division of Particles and Fields of the Mexican Physical Society [44], the award Líder en Formación de Investigadores at CINVESTAV, Emeritus profes-

FIGURE 6. Dr. Arnulfo Zepeda when he was awarded the "Roberto Herrera Hernández Extraordinary Chair", Universidad Juárez Autónoma de Tabasco, 2018.

sor at CINVESTAV (2003), Emeritus distinction at the National System of researches (2010), and the 2019 award of the Cosmic Rays Division of the Mexican Physical Society, among others.

He also published more than 110 papers in journals with peer review, 20 technical reports, 4 papers in books, etc., and graduated more than 15 Ph.D. students and 14 Master students. It was an outstanding characteristic of him to encourage and fully support his students.

Arnulfo was a very rigorous and committed researcher and a professor very devoted to the training of his students. He was close to young researchers and support projects that were apparently impossible, but he made them come true.

2. From Mexico City to Chiapas, Mexico

By Karen Salomé Caballero Mora

In this section, I want to describe how I met Dr. Zepeda and how he became a great advisor and constant support for my career as a scientist. During the Particles and Fields Division annual meeting in 2004, it was the first time that I would present results for a specialized audience, and I was very nervous. However, when I arrived to register, I was received by a very friendly and easy-going man, who gave me a kind welcome and made me feel confident. He was Dr. Arnulfo Zepeda, who was in charge of the registration table. At that time, I was about to leave Mexico to start my Ph.D. studies in Karlsruhe, Germany, but I decided to keep in mind the name of such a nice professor. After some months of being in Karlsruhe, I knew a former Ph.D. student of Dr. Zepeda was about to start a postdoctoral stay there; then, I decided to help him adapt to the institute. He became a very good friend of mine and a very hard worker colleague until now. Afterward, during my PhD. studies, I had the chance to meet Dr. Zepeda during a visit from him to the institute where I asked him for advice on Quantum Field Theory; since then, we exchanged emails on several topics, especially on Cosmic Rays. I also attended the Second School on Cosmic Rays and Astrophysics in Puebla, Mexico, organized together by Dr. Oscar Saavedra and Dr. Zepeda. In this school, I can say I understood very clearly the real goals of Astroparticle Physics. I continued asking for advice from Dr. Zepeda after my Ph.D. Finally, when I came back to Mexico, he granted me a scholarship for a postdoctoral stay at CINVESTAV in Mexico City. I continued working on the Auger experiment and joined the HAWC experiment there. He supported me to apply for the For Women in Science Scholarship by L?OR´ EAL, which I got in 2014. Dr. Zepeda also encouraged me to apply for a position at UNACH, where I joined in 2014. At that time, he was the General Coordinator of MCTP in Chiapas. There we had the chance to continue working together on several projects like, for example, the organization of the Sixth School on Cosmic Rays and Astrophysics in Chiapas, and the creation of LARCAD (High-Performance Computing Center) from UNACH after a donation by CERN. Among the anecdotes I can describe where Dr. Zepeda showed his great interest in helping Latin American students to have access to high-quality lectures on Physics, I can mention the preparatory course he organized, which was attended by students from Venezuela and Guatemala when the course finished, the students had the chance to stay a bit longer, and he encouraged them to take the most advantage of being in Mexico; he financed from his pocket some of the books they bought and the printing of several papers and other documents interesting for them. The empathy Dr. Zepeda showed with the students from Latin America will be very much missed. I continue remembering his advice and what I was able to learn from him for my work as a scientist; I will be very thankful to him for my life.

3. Remembering Arnulfo

By Rebeca López Ramírez

Arnulfo was always working and thinking about his students and projects, even sick in his last days, with the little time he had, he worked and was waiting for the 2020 Meeting of the Cosmic Ray Division of the Mexican Physical Society. The last conference that he could attend a little was that of Dr. Antonella, his guest. He was also aware of the medal ceremony, and he was delighted. Many thanks to the organizers.

4. A few words for Arnulfo

By Rodrigo Pelayo Ramos

I met Arnulfo in 1993 when he was the president of the SMF and I was in my last semester of high school, but I was also a member of the Physics Olympiad National Team. That year Mexico would participate for the first time in the International Physics Olympiad to be held in Williamsburg, Virginia, United States. Thanks to Arnulfo, the coach of the Cuban team, Dr. Raúl Portuondo Duany, was brought to Mexico, not only for that occasion, but also for the training of the next team that participated in China in 1994. Thanks to him our first participation was quite decent. This was perhaps the best way to meet Arnulfo not only as the outstanding researcher that he was, but as the human being always willing to support others unconditionally, especially young people. That is why starting so many teaching programs, such as Mexican particle and field schools and workshops, as well as the CAM, the Latin American schools of Cosmic Rays and Astrophysics and summer courses at CINVESTAV. Also seeking international mobility support such as HELEN and EPLANET, which benefited not only Mexicans but also physicists from many countries in Latin America and Europe. The foundation of the MCTP, a research center associated with the ICTP located in a region that required a strong push for the development of science, and leaving the comfort of Mexico City and large institutions, a center that would benefit not only the state of Chiapas but to the entire southeast of

Mexico, the Central American and Caribbean countries. He had a vision of how beneficial participation in the great international experiments in high-energy physics could be for Mexico, first encouraging students from CINVESTAV to go to CERN and Fermilab in the 1980s, and later inviting large number of Mexican researchers and institutions to join the Pierre Auger Observatory, and Alice in the LHC and HAWC in the last 20 years. He was never selfish and always wanted to share these opportunities with the community. Thanks to these examples, the participation of other groups of Mexican physicists in other experiments was extended.

I started working as a student of Arnulfo when I started in the CINVESTAV Doctorate program in 1999. For Arnulfo, his students were not only people who should learn from him, but we were considered as his Colleagues and Collaborators, we had all his unconditional support. Arnulfo wanted his students to get to know each other and to live together and learn from important personalities in physics. Just as an example, for the defense of Juan Carlos Arteaga's doctoral exam he invited David Cline and Francis Halzen as synodals. He involved his students in organizing events and preparing projects, which, after all, is also an important part of the researchers' work.

Finally, we will have to talk about Arnulfo's peculiar personality, which made him be so charismatic and win the sympathy of his colleagues in Mexico and abroad. When he took out the bottle of tequila, people came to talk and spend time with him. I will always remember when, anywhere in Mexico or other countries, some renowned professor asked me who my thesis director was and I answered that it was Arnulfo Zepeda, they were always happy and sent him the most sincere greetings for him. We will always remember him all.

5. Arnulfo Zepeda: a Mexican scientist to aspire to be

By Humberto Martínez-Huerta

I met Arnulfo at CINVESTAV in 2007 when I was an undergraduate student, thanks to a scientific summer program by the AMC. The first day I met him, I was nervous about the uncertainty of what I may find in Mexico City, then at CINVESTAV, and later at his office. Fortunately, what I found was way beyond any expectation. I encountered a man sitting at his desk, very modest, unpretentious, and fully immersed in his work. His office was literally filled with piles of files, books, science journals, and papers everyplace; that didn?t change too much in all the time I knew him, and neither did he. I knocked on the door very slowly, I didn't want to interrupt him, but when he saw me, he immediately stopped everything he was doing to welcome me; that custom never changed either. He showed me around the facility and diligently tasked me with the assignments I would be doing that summer. That was also Arnulfo, a receptive, friendly, and very cheerful man, passionate about his work and pleased about it, with a deep commitment with each one of his students, always working with the responsibility he felt about each of us. That way and work environment were invariant in the 13 years to come, on which I was fortunate to continue to meet him and work closely. I remember he told me once that he was aware that having a student is a lifetime project: they are stars meant to shine. I witnessed that philosophy passing from his students to their own, and happy to say, mine too. After that internship, I met with him almost every weekend for a long time to study physics and learn about the shapes and details of Academy; his teaching was never less than integral. With the closing of each workday, I also met an incredibly human and cultured person, very interested in the world's traditions, history, music, cultures, and people, especially those in Mexico. Always looking to learn something new, never closed to undertaking new projects and looking to open paths and connecting people. He was highly committed to his work and sharing science with everyone; he truly committed until his last day.

That summer in 2007, I met not only the area of physics in which I wanted to develop but also the type of scientist I would like to be later; his advice, commitments with his work and people, especially with students, his cheerful and optimistic personality I will always be missed.

6. Memories about Arnulfo Zepeda

By Juan Carlos Arteaga-Veláazquez

With these words I would like to give honor to the memory of a good friend, mentor, colleague and human being, an enthusiastic supporter of the development of particle and astroparticle physics in Mexico, so much appreciated by our particle physics community, Dr. Arnulfo Zepeda Domínguez.

For those who had the opportunity to work, talk, or collaborate with him, it will become evident, why we dedicated this space to remember him. Memories may come to your minds discussing with him about physics, the future of our physics community, history of science, projects of outreach, ideas to support students, or other interesting topics with a glass of tequila in one of the different particle physics events in which he participated. Always enthusiastic and proactive, with the purpose of contributing to the development of particle physics in our country.

I met Arnulfo Zepeda in 1997, just after arriving to the department of physics at CINVESTAV, Mexico, to start with my studies in Master of Science in Physics. When I got to CINVESTAV, I had a fascination for particle physics and different branches of it. I finally decided to move to astroparticle physics, when I knew about this topic from Dr. Arnulfo Zepeda and also due to my interest in astrophysics and cosmology. It happens that once, that I was walking outside the office of Dr. Zepeda, I found a magazine on a shelf talking about the mysteries of high-energy cosmic rays, which was written by Arnulfo Zepeda. I found the theme very intriguing and attractive and therefore I decided to talk with Dr. Zepeda about it. At that moment, he was not in his office. So, I

came back after a few days. In the first opportunity that I saw the door of his office opened, I approached to him to discuss about my doubts on cosmic rays. When I met him, he was seated in front of his desk working with his computer and he invited me to come in. My first impression of Dr. Zepeda was of a man that was very polite, kind and willing to attend the doubts of his students. I felt in confidence immediately to talk with him about my concerns on astroparticle physics. He promptly answered to me, briefly explaining the situation of ultra high-energy cosmic rays and the questions that the Pierre Auger project wanted to address. I got immediately interested in the theme and decided to do research on cosmic rays with the guide of Dr. Zepeda. I came back months later, when I finished the basic courses of the Maters's program to start with a thesis under his supervision. That's how I started to work with Dr. Zepeda and to know more about him.

During my M.Sc. and Ph.D. at CINVESTAV and later as a colleague I discovered in Dr. Zepeda the great mentor, person and friend that several of us admired from him. From time to time, I invited Dr. Zepeda to my house to have dinner with my family and closer friends. We always enjoyed his good company and his talks and also discovered his love for the traditional Mexican food. One of the aspects of him that I would like to mention here is the passion for life that he always showed, which enriched his personal life, and his desire to guide, give advice and opportunities to young students and researches. I received several advices from him, and it was through him that I knew about the KASCADE-Grande experiment, in which I later participated. There are different experiences, advices and teachings from him but the space prevents me to go further.

An old poem in nahuatl says that our life is transient, but that as human beings we left behind flowers and songs, which is a metaphor of culture, art and science. Dr. Zepeda left also flowers and songs in his scientific contributions, his family, friends, students, etc.

Farewell Dr. Zepeda, thanks for your friendship and personal support as well as for your invaluable contribution to particle and astroparticle physics in Mexico and abroad. We will miss you.

7. Memories about Arnulfo Zepeda

By Luis Villaseñor

I met Dr. Arnulfo Zepeda while I was studying for my master's degree at the Physics Department at CINVESTAV, and I was greatly impressed by his devotion to make the field of Particle Physics attractive to new students and by his friendly personality. Although I was at that time working on Biophysics with Dr. Magdaleno Medina, Arnulfo invited me to attend the first Mexican School of Particle Physics in 1984 [45]. Arnulfo, along with Augusto García, Miguel Ángel Péerez, Matías Moreno, Clicerio Avile's and José Luis Lucio, had recently started a program to send students to work on their Ph.D. theses at the most important laboratories in Particle Physics around the world. One day during that first Mexican School of Particle Physics, Arnulfo introduced me to David Cline, a famous experimental physicist from the University of Wisconsin-Madison who was also working on the UA1 experiment at CERN. They invited me to go to CERN to do my Ph.D. thesis and I immediately accepted. Upon the approval of Carlo Rubbia I joined UA1 as a member of David Cline?s team. That is how Arnulfo became my thesis co-advisor, along with David Cline, and Arnulfo was always ready to help in any possible ways to make this a successful adventure, so that Arnulfo changed my academic life and I ended loving the fields of experimental particle physics and later, also thanks to Arnulfo, the field of experimental cosmic-ray physics. Later Arnulfo convinced other students to follow the same route by joining the UA1 group, among them Bruno González, who unfortunately had a fatal bike accident while riding near the CERN laboratory, Miguel Vargas, Agustín Enciso and Heriberto Castilla, among others.

Later I had the privilege to co-organize several events along with Arnulfo. I always admired him for his attitude of bringing forward and inviting speakers of the highest level to take part on those events, just as on that first School of 1984 where I was also greatly impressed not only by the high level of the speakers but also by the informal and friendly ambiance of the meeting for the benefit of the students.

As mentioned earlier, a constant goal of Arnulfo was the promotion of the theoretical and experimental facets of Particle Physics in Mexico. His efforts in this area were recognized by the Mexican Physical Society through the Award to the Development of Physics in Mexico in 2001, Particles and Fields Division Medal in 2002 and the Cosmic Rays Division Medal in 2019. He promoted the entrance in 1996 of Mexico to the Pierre Auger Collaboration and later to other experiments, including an experiment led by David Cline to detect dark matter and the HAWC Observatory, among others. He was well aware of the importance of convincing CONACyT to finance the participation of Mexico in these experiments; for that purpose he organized several visits to talk to the directors of CONACyT, accompanied on some of them by Jim Cronin, spokesperson of the Pierre Auger Collaboration. These meetings to CONACyT eventually resulted in the official financing by CONACyT of the participation on Mexico not only in the Pierre Auger Observatory but in many other experimental endeavors, including HAWC, other experiments from the LHC at CERN and many other international laboratories.

Arnulfo also played an important role in promoting public outreach of particle and cosmic-ray physics in Mexico and other countries. He had an official position for this activity at the Pierre Auger Observatory for many years. He also led an initiative to provide teachers from high schools in Mexico with simple equipment and the necessary expertise to detect cosmic rays at their campuses. Along with Juan Carlos D'Olivo, Humberto Salazar and Arturo Fernández we submitted several projects to CONACyT to fund these initiatives.

I consider myself very lucky to have met Arnulfo and I am deeply grateful to him for his willingness to help me, and many other people, to appreciate and make a career in the field of Astroparticle Physics. I had the privilege of sharing many moments with him as my mentor and as a my friend. I will always remember him for his enthusiasm and devotion to develop this field of Physics in Mexico, but most of all, for being one of the best persons I have met in my life.

1. Arnulfo Zepeda Domínguez, Stripping Reaction with the Diffraction Method, M.Sc. thesis, Nuclear Research Institute, Checoslovaquia (1967).
2. Arnulfo Zepeda, Mis vivencias en el inicio de mi estancia en el CINVESTAV, 50 años del departamento de física, CINVESTAV, October 28, 2010.
3. Arnulfo Zepeda Domínguez, Production of W mesons in charged leptons-pion collisions, PhD thesis (in spanish), CINVESTAV, Instituto Politécnico nacional, Mexico city, Mexico (1970), 89 p.
4. Arnulfo Zepeda Domínguez, *A Class of Chiral Theorems*, Ph.D. thesis, the Rockefeller University, New York, N.Y., USA (1972).
5. A.H. Galeana, A. Zepeda, Universally Coupled Extra Z Bosons from Extended Technicolor Models, *Z. Phys. C* **40** (1988) 125
6. A. Zepeda, Mass of the Up Quark, *PRL* **41** (1978) 139.
7. V. Sánchez, Agencia Informativa Conacyt, 2015, `http://www.cienciamx.com/index.php/sociedad/politica-cientifica/3722-reconoce-unesco-centro-mexicano`.
8. J. L. Lucio, A. Rosado, A. Zepeda, Neutrino charge in the linear $R\hat{I}_{\frac{3}{4}}$ gauge, *Phys. Rev. D* **29** (1984) 1539.
9. J. L. Lucio, A. Rosado, A. Zepeda, Characteristic size for the neutrino, *Phys. Rev. D* **31** (1985) 1091.
10. M. Mondragón, Supersymmetry and GUTs in Mexico, AIP *Conference Proceedings* **857** (2006) 66.
11. A.H. Galeana, A. Zepeda, Universally Coupled Extra Z Bosons from Extended Technicolor Models, *Z. Phys. C* **40** (1988) 125
12. Rodrigo Pelayo Ramos, Technicolor theories and ultra highenergy cosmic rays, PhD thesis (in spanish), CINVESTAV, Instituto Politécnico nacional, Mexico city, Mexico (2008).
13. María Elena Luna Morales and Jane M. Russell Bernal, El uso de nuevas tecnologías de información y comunicación científica en el área de partículas elementales: el caso de la física mexicana, UNAM, Centro de investigaciones Bibliotecnológicas, first edition, 2009, 133 p., Mexico, D.F.
14. A.A. Watson, Ultra-high-energy cosmic rays: the experimental situation, *Phys. Rep.* **333** (2000) 309-327.
15. CMS Collaboration, Precision luminosity measurement in proton-proton collisions at $\sqrt{S} = 13$ TeV in 2015 and 2016 at CMS, *Eur. Phys. J. C* **81** (2021) 800.
16. J. Abraham *et al.*, (Pierre Auger Collaboration), Properties and performance of the prototype instrument for the Pierre Auger Observatory, *NIMA* **523** (2004) 50-95.
17. D. Bird *et al.*,, Evidence for correlated changes in the spectrum and composition of cosmic rays at extremely high energies, *Phys. Rev. Lett.* **71** (1993 3401).
18. S. Yoshida *et al.*,, The cosmic ray energy spectrum above 3×10^{18} eV measured by the Akeno Giant Air Shower Array, *Astroparticle Physics* **3** (1995) 105-123.
19. Humberto Salazar Ibarguuen y Luis Manuel Villaseñor Cendejas, Rayos cósmicos ultraenergéticos: el Observatorio Pierre Auger, Ciencia, Enero-Marzo, (2006) 64-72.
20. Credit of the image: Pierre Auger Collaboration `https://www.auger.org/`
21. P. Abreu *et al.*, (Pierre Auger Collaboration), The Energy Spectrum of Cosmic Rays beyond the Turn-Down at 1017 eV as measured with the Surface Detector of the Pierre Auger Observatory, *Eur. Phys. J. C* **81** (2021) 966.
22. A. Aab *et al.*, (Pierre Auger Collaboration), Observation of a large-scale anisotropy in the arrival directions of cosmic rays above 818 eV, *Science* **357** (2017).
23. R. Engel, Highlights from the Pierre Auger Observatory, plenary talk, ICRC 2021.
24. A.U. Abeysekara *et al.*, (HAWC Collaboration), Observation of the Crab Nebula with the HAWC Gamma-Ray Observatory, *ApJ* **843** (2017), 39.
25. Instrumentation in elementary particle physics 674 (2003), proceedings of the 1st ICFA instrumentation school/workshop at the ICFA Instrumentation Center, Morelia, Mexico, November 18-29, 2002, editors: Luis Villaseñor y Víctor Villanueva.
26. E. Ponce *et al.*,, Prototype of a hybrid cosmic ray detector at the Pico de Orizaba: first stage, Instrumentation in elementary particle physics 674 (2003), proceedings of the 1st ICFA instrumentation school/workshop at the ICFA Instrumentation Center, Morelia, Mexico, November 18-29, 2002, editors: Luis Villaseñor y Víctor Villanueva.
27. Humberto Salazar, private communication, April 2021.
28. Oscar Miyamoto Gómez, How HAWC landed in Mexico, Symmetry, an online magazine for particle physics, Magazine, Fermilab/ SLAC publication, 2020.
29. Proyecto CONACYT 55155, HAWC, el primer experimento astrof ísico de altas energías en México, convocatoria ideas para Megaproyectos 2006.
30. HAWC at Mexico, un observatorio de rayos gamma de gran altura, una propuesta de la colaboración HAWC, Megaproyectos CONACYT, convocatoria 2007. `https://www.hawc-observatory.org/publications/docs/protocolo_55155a.pdf`.
31. HAWC Collaboration, HAWC at Mexico, proceedings of the 30th International Cosmic Ray Conference, July 3-11, 2007, Mérida, Mexico, editors: Rogelio Caballero, Juan Carlos Dólivo, Gustavo Medina-Tanco, Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia, Universidad Nacional Autónoma de México, Mexico City, Mexico, (2008) 1567-1570.

32. Workshop of High-Energy Astroparticle Physics, INAOE, Tonantzintla, Puebla, Mexico, april 27-28, 2006. https://www.inaoep.mx/~alberto/taae/.
33. Proceedings of the 30th International Cosmic Ray Conference, July 3-11, 2007, Mérida, Mexico, editors: Rogelio Caballero, Juan Carlos Dólivo, Gustavo Medina-Tanco, Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia, Universidad Nacional Autónoma deMéxico, Mexico City, Mexico, (2008) 570.
34. C. Riviere *et al.,* (HAWC Collaboration), Preliminary HAWC 1st year catalog, *AIP Conference Proceedings* **1792** (2017) 070017.
35. A.U. Abeysekara *et al.,* (HAWC Collaboration), Extended gamma-ray sources around pulsars constrain the origin of the positron flux at Earth, *Science* **6365** (2017) 911-914.
36. A. Albert *et al.,* (HAWC Collaboration), 3hwc: The third HAWC catalog of very-high-energy gamma-ray sources, *ApJ* **905** (2020) 76.
37. A.U. Abeysekara *et al.,*, Multiple Galactic Sources with Emission Above 56 TeV Detected by HAWC, *PRL* **124** (2020) 021102.
38. A. Albert *et al.,* (HAWC Collaboration), Hawc observations of the acceleration of very-high-energy cosmic rays in the cygnus cocoon, *Nature Astron.* **5** (2021) 465-471.
39. A. Albert *et al.,* (HAWC Collaboration), HAWC J2227+610 and Its Association with G106.3+2.7, a New Potential Galactic Pe- Vatron, *ApJL* **896** (2020), L29.
40. R. Alfaro *et al.,* (HAWC Collaboration), All-particle cosmic ray energy spectrum measured by the HAWC experiment from 10 to 500 TeV, *Phys. Rev. D* **96** (2017) 122001.
41. J.C. Arteaga-Velázquez *et al.,* (HAWC Collaboration), HAWC measurements of the energy spectra of cosmic ray protons, helium and heavy nuclei in the TeV range, ICRC 2021, PoS (ICRC2021) 374.
42. A. Fernández *et al.,*, ACORDE a cosmic ray detector for ALICE, *NIMA* **572** (2007) 102-103.
43. P. Giubellino (GSI-FAIR), L. Maiani (Universitá di Roma) and L. Musa (CERN), Obituary, CERN Courier May-June issue, 08/04/2021. https://home.cern/news/obituary/cern/arnulfo-zepeda-dominguez-1943-2020.
44. J. C. D'Olivo, Laudation in Honor of Arnulfo Zepeda, AIP *Conference Proceedings* **670** (2003) 6.
45. José Luis Lucio and Arnulfo Zepeda. Remembrances on the origin of the Mexican School of Particles and Fields, *AIP Conference Proceedings* **857** (2006) 11.