Interviewee: Claudio Pellegrini | By: David Zierler

Place: Videoconference | Date: April 2nd, 2020

ZIERLER: Okay, it is April 2nd, 2020. This is David Zierler, oral historian for the American Institute of Physics. It is my great pleasure to be here today with Dr. Claudio Pellegrini. Dr. Pellegrini, thank you so much for being with me today.

PELLEGRINI: Oh, it's my pleasure. Thank you for inviting me.

ZIERLER: Would you please tell us your title and your current affiliation?

PELLEGRINI: I am a distinguished professor of physics emeritus at UCLA. I retired from UCLA some years ago. Now, I'm working at the SLAC National Accelerator Laboratory. My main area of research is the development of the x-ray free-electron lasers, which has been built here following a proposal that I made in 1992.

ZIERLER: So let's start right at the beginning. Tell us about your childhood and your birthplace in Italy.

PELLEGRINI: I was born in Rome in 1935. I spent the war years, when I was a kid, 5 to 10 years old, in a mountain area, east of Rome. My family decided to move out of Rome when the war started, and we went to live in a small village, Villa Santa Maria, up in the mountains in Abruzzo. We went back to Rome at the end of the war, so I did my elementary schools in this little place. And then--

ZIERLER: So you went out of Rome because of the war?

PELLEGRINI: Yes, because of the war.

ZIERLER: It was dangerous? It was dangerous to be in Rome during the war?

PELLEGRINI: Well, Rome was bombed by the Allied and the Nazis, in 1943 and 1944, and thousands of civilians were killed. It was occupied by the Nazis from September 1943 to June 1944, when the Allied arrived. It was not easy to live in Rome during that time. Before the Americans arrived there wasn't enough food, women were killed trying to get a loaf of bread and there was fighting between the Italian partisans and the German occupying forces. When the war started my father was in Egypt, where he stayed as a prisoner of the English to the end of the war, my mother was alone with three children and she decided that it would be easier to go to live in the small village where my mother and father families came from. In the village she knew everybody, you know how it is in a small town. It's usually considered a safer place. But in reality it was not so. During the war the village and the surrounding areas, the valley of the river Sangro, were occupied by the Germans and the front line passed exactly where we were. Most of the villages in the valley were burned down, and there was almost no food, no anything for many months. But my mother was able to provide for us. For a kid it was also a kind of adventure, I have good memories of that period. After the Germans and the Allied moved North, my friends, other little kids, and I collected in secret ammunition and hand grenades left by the German and Allied soldiers. We learned how to play with the ammunition, disassemble cartridges and have fun with gun powder. We were lucky that no one was really hurt.

ZIERLER: What did your father do for a living?

PELLEGRINI: My father was a Maitre d'Hotel and he traveled a lot. After the war he also worked on cruise ships for many years.

ZIERLER: What was your early schooling? Did you go to a public school or a private school?

PELLEGRINI: Oh, I always went to public schools,

ZIERLER: A public school.

PELLEGRINI: The local elementary school in Villa Santa Maria and the middle and high school in Rome. The high school was named after a physicist, Augusto Righi, who worked on electromagnetic waves and X-rays between the end of the 19th and the beginning of the 20th centuries. After high school I continued my studies at the university of Rome.

ZIERLER: Now, I'm unfamiliar with the Italian system. Did you concentrate in math and science as a high school student or was it a more general education?

PELLEGRINI: It was a more general education. The high school in Italy is called lyceo and, at that time, there were two kinds of lyceo. One was the classical and one was the scientific. The only difference was that in the classical high school, they studied Greek, and in the scientific high school, we did more mathematics. But in the scientific high school, we had to study philosophy and Latin. I still remember Latin poems by heart. And we studied history and literature.

ZIERLER: Now, in high school, were you already strong in math and science?

PELLEGRINI: Yes, I did pretty well.

ZIERLER: And your decision to go to college, was it, were you always planning on staying close to home, or did you think about going farther away?

PELLEGRINI: No, in Italy at that time, if you lived in a city where there was a university, you went to that university. So I--

ZIERLER: So it was an easy decision.

PELLEGRINI: Yes, it was an easy decision.

ZIERLER: And you lived at home, I assume?

PELLEGRINI: Yes, yes.

ZIERLER: When did you declare your major in physics?

PELLEGRINI: Oh, again, the university in Italy is different. When you join the university, when you apply to the university, you select a major. What I did was initially to select engineering. I really wanted to do physics. That's what was my interest. At that time, physics, just after the war, was very popular for all the developments that had been important during the war. But I thought that doing physics was a real challenge, because the possibility of employment were not too many. So I decided to join engineering, and try the first year. Because the first two years for engineering and physics were essentially the same. You did the same courses in mathematics and physics. When I did my exams, I did pretty well, so I decided that I was good enough to do physics.

ZIERLER: Now when you say--

PELLEGRINI: --Physics requires a higher standard to have opportunity of employment.

ZIERLER: Now, when you say that physics was popular after the war, how was it popular to you? Did you read about it in magazines? Were you listening to people that you looked up to? What was your connection that made physics attractive to you?

PELLEGRINI: Well, of course, the atomic bomb, that terminated the war, made physics popular. People were talking about nuclear reactors that would generate energy for everybody at no cost, to cheap to meter. In Italy in high school, I had to take physics, chemistry, and biology. Everybody had to do it. I also had to take philosophy, Latin, literature, all of that. I had been reading a number of books. I remember one book by Gamow, "One, Two, Three...Infinity", that I really liked a lot. This idea of being able to explore the universe, nature, how it works, and do these things which were wonderful or terrible, like an atomic bomb, was very exciting. I'm sure also in the U.S. at that time, a lot of people, a lot of young students went into sciences, in physics in particular.

ZIERLER: So your original--

PELLEGRINI: But I also had a philosophical interest. In philosophy, we studied, of course, the scientific revolution, the positivist philosophers of the 19th century, and I was very interested in all of that, how we could understand nature. At the same time, in the humanities part of the school, we had been reading Lucretius' De Rerum Natura, On the Nature of Things, a wonderful poem. I had a very good teacher in the humanities. And this idea, the connection between literature, poetry, science and the capability of understanding nature and escape superstition, as Lucretius told his disciples: "You escape superstition by studying nature". So to study philosophy of nature, as physics was called in the old days, is important, according to Lucretius, because it gives you an understanding of life and you can live escaping superstition and with peace of mind. So all of this came together, and it pushed me to do physics.

ZIERLER: Now, originally, you studied engineering. Was your original plan to become an engineer?

PELLEGRINI: Yes, it was a test. If in the exams I did very well, I would go to physics. If I didn't do very well in my exams, I would do engineering. That was my plan. Engineering gives you always a job.

ZIERLER: Right, right.

PELLEGRINI: I was the first in my family to go to college, too, to enter university.

ZIERLER: How did your parents--

PELLEGRINI: And for me it was important to have some possibilities to work after graduation.

ZIERLER: When you decided to study physics, how did your parents take that news? Were they concerned?

PELLEGRINI: They said, "Physics? What?" (both laugh) This was their reaction. But they let me do it. They said, " Claudio if you want to do this, just do it."

ZIERLER: And undergraduate is four years? It's a four-year program?

PELLEGRINI: Again, the high school is five years, in Italy, compared to four in the high school here. And the undergrad with the university was four years. Now it is different, they made other changes, but at that time, it was four years. And after that, if you wanted an academic career, after the four years you had to publish and take an examination called the “Libera Docenza”, which was a title allowing teaching in a university. It was the equivalent of a PhD, with more requirements on published papers.

ZIERLER: Uh-huh, uh-huh.

PELLEGRINI: So I started doing research, published, and then took this examination. It went well and that I had my Libera Docenza.

ZIERLER: Was there an undergraduate thesis requirement?

PELLEGRINI: Oh yes.

ZIERLER: Do you remember what you wrote on?

PELLEGRINI: I did my thesis in a new laboratory, which had been built in Frascti, near Rome. My advisor, Professor Salvini, was the director of the lab and a professor in the department of physics in Rome. For my thesis, I built a diffusion cloud chamber to do an experiment on double pion photoproduction using the electron synchrotron, which had been built in Frascati.

ZIERLER: This was your undergraduate thesis?

PELLEGRINI: Yes.

ZIERLER: That sounds pretty advanced for an undergraduate.

PELLEGRINI: Well, It was. We were 20 physics students in my year. We had a good connection with everybody, students and faculty, so we were really pushed to do things.

ZIERLER: Now, did you continue on immediately? Did you take time off before starting graduate school, or you went right into graduate school?

PELLEGRINI: After my four degree, the Laurea, I was given a position at the laboratory and continued to work at Frascati. Initially I continued to do research in the area of high energy physics. Then I went for one year to the Institute of Theoretical Physics in Copenhagen. I won a scholarship to go there, and I went twice, for two periods. It was a very exciting time, because at that time, Niels Bohr was still alive. So I had the privilege to meet him. Every year, he had a big party for people at the Institute of Theoretical Physics. He was living in a Carlsberg Foundation mansion, which the Foundation gives to the most prominent citizen of Denmark. He had a party for all the people of the Institute of Theoretical Physics, I was invited and shook his hand. In the Institute there were many people from the time before the war, when quantum mechanics in Copenhagen was the center of the world in physics. They always talked about the old times, and told many anecdotes about the scientists that played a major role. It was very exciting to be there. In Copenhagen I worked on general relativity with professor Christian Möller and published some papers on general relativity. Then I went back to Rome.

ZIERLER: Was Frascati National Laboratory, what would be the closest analog in the United States to what was going on at Frascati?

PELLEGRINI: Perhaps Lawrence Berkeley Lab, on a larger scale, or Cornell. The idea was to start a lab that would allow Italian physicists to do experimental high energy physics in Italy. Amaldi and some other physicists decided, in the 1950s and 60s, to build a 1 GeV electron synchrotron, which at that time was a high energy accelerator. It was done successfully and it was used for many experiments. In the end, all this activity led to the development of electron-positron colliders at Frascati. Many students from the University of Rome, did their thesis at Frascati, because it offered very good experimental possibilities. I did my thesis with Professor Salvini and worked with him on the double pion photoproduction experiment.

ZIERLER: Did you ever think about leaving Rome for your graduate degree? Or you always planned on staying at the University of Rome for graduate school?

PELLEGRINI: Well, it was natural, I studied in Rome, because that was the clear, I mean, the natural thing to do. It was also less expensive, because I could live at home. I started doing my thesis in Frascati and when I finished and graduated, Salvini offered me a job there. I had a choice, because at that time everything was expanding in Italy and Europe, and I received several Job offers from industry and from Euratom, which was starting also at that time. But I was very involved at that point with the research going on in Frascati, so I decided to accept Salvini’s offer.

ZIERLER: Now, as an employee of the lab, were you a government employee? What was the arrangement between the government and the laboratory?

PELLEGRINI: I was not employed by the state directly. The lab was run as a kind of state agency. I was not a state employee, the rules were different, but it was still public employment.

ZIERLER: Now, did you continue the research from your dissertation at

Frascati, or were you tasked with different research?

PELLEGRINI: For a while, I did. Then, I decided to accept a scholarship from Denmark at the Institute of Theoretical Physics. I wanted to move around a little bit. So at that point I changed my area of research to general relativity, working with Professor Möller. I wasn't certain whether to work on theory or experiments, so I tried both areas. After the time in Copenhagen at the Institute for Theoretical Physics, I went back to Frascati. Just at that time Bruno Touschek had proposed a new idea, to build an electron-positron collider. The idea of colliders had been around for a while, but everybody had been thinking that having matter and antimatter colliding would be too hard. So, for instance, at Stanford Burt Richter had been building an electron-electron collider, with the idea of exploring the limits of quantum electron dynamics. There were similar experiments in Russia, in Novosibirsk, and there was the idea of a proton-proton collider at CERN. What Bruno Touschek proposed was to build an electron-positron collider, because generating positron is not too hard. And electron-positron collider have an important advantage. When an electron and a positron collide they generate a virtual photon that decays in any pair of particle-antiparticle . So the process goes through a state with well-defined quantum numbers, and the final state also has well-defined properties, which makes it easier to understand the physics of the final state. Touschek proposed to build a test collider, called AdA, at Frascati. In a week, the proposal was approved by the lab, and in one year it was ready. AdA had a two-meter diameter magnet, where you could circulate electrons and positrons, and was meant to be a prototype for a bigger collider. Initially, it operated at Frascati, then it was moved to Orsay, in Paris, where they had an electron linear accelerator, which could produce more positron than we could do at Frascati. They moved AdA to Orsay and they operated it. They observed the first electron-positron scattering and discovered what is now called the Touschek effect. It was a very exciting program that in the end lead from the small AdA ring to the 27-kilometer circumference Large Electron Positron collider at CERN. In Frascati, because of AdA success, it was decided to build a bigger collider, with an energy of 1.5 GeV and large luminosity, called Adone. When I went back to Frascati, there was much excitement about the new project. Touschek asked me if I would like to join the project and work on it. I decided to accept, a decision that started my career in colliders, accelerator, and later free-electron lasers.

ZIERLER: Now, what were the circumstances leading to you becoming a visiting scientist at Berkeley National Laboratory?

PELLEGRINI: When we built Adone at Frascati, we had a big collaboration with people here in the U.S. who were also interested in that new area. We had many people from SLAC, from Berkeley, from Cornell, visiting and working with us. I met and worked with many of them. From SLAC, we had Matthew Sands, which had been deputy director of SLAC, and we did work together. From Berkeley, we had Andy Sessler. I started working with Andy and we got along very well. He invited me to come to Berkeley in 1969 to work on a project which they had just started, the electron ring accelerator. It was a novel idea and Berkeley was really trying to push it. I went to Berkeley. It was a very exciting time, 1969-70 in Berkeley, for the science and the political climate.

ZIERLER: Yeah, yeah.

PELLEGRINI: You can imagine.

ZIERLER: Yeah.

PELLEGRINI: I worked on that project with Andy and we remained friends for life, essentially.

ZIERLER: Was this your first time to America? In 1969?

PELLEGRINI: Well, I came to SLAC in '65, for a workshop on electron-positron colliders. It was an important workshop, two weeks long. At that time, we took our time to study a new problem. That was my first visit in 1965. I still have the proceedings from the workshop. After that, I came again in '69, '70, to Berkeley. My daughter, my youngest child, was born in Berkeley in 1970.

ZIERLER: Oh when were you married?

PELLEGRINI: 1961.

ZIERLER: 1961.

PELLEGRINI: When I was working in Copenhagen.

ZIERLER: How did Berkeley compare to Frascati? In terms of the equipment, in terms of the funding... How did it compare?

PELLEGRINI: Well, of course, Berkeley was a much bigger lab. And funding was available at that time. It was a very exciting place, as it was working on a new project. In the end the idea of the electron ring accelerator didn't work out, and we studied why it wouldn't work. But it was a very exciting experience, and it was a very exciting human experience.

ZIERLER: Did it occur to you that you might want to build a career and a life in America at this point?

PELLEGRINI: Before I left to go back to Rome, they offered me a job at Berkeley. I talked about it with my wife, and we decided at that time that we wanted to go back. There were things to do in Italy and we wanted to go back trying to help to develop science in Italy. There were also family reasons. We refused the offer, and we went back to Rome and Frascati.

ZIERLER: Did you feel that pursuing a career in physics in Italy would not limit you? That you could do all that you wanted to do in Italy?

PELLEGRINI: I hoped so. And in a way, I could, but later on, there were some real problems, because of the bureaucracy, the way things were organized. That was much later, and that is the time when we decided to accept another offer and cross the ocean once again.

ZIERLER: But first, in 1974, you became a physicist and division leader at Ente Nationale Energia Nucleare?

PELLEGRINI: Yes.

ZIERLER: This is a different laboratory?

PELLEGRINI: No, it was the same laboratory, in Frascati, but it had been split in two parts.

ZIERLER: Oh, I see.

PELLEGRINI: One was essentially dedicated to high energy physics. In the other lab there was work in plasma physics, fusion, and there was this idea of starting a new division for laser developments and applications.

ZIERLER: So this was a promotion for you?

PELLEGRINI: Yes, it was a promotion. I was given the task to organize the division and define its scientific program. At that time, In the middle of the 1970s, I became interested in free-electron laser. John Madey had successfully demonstrated the first free-electron laser in 1976 at Stanford, following his previous theoretical work of 1971.

ZIERLER: What exactly did he demonstrate?

PELLEGRINI: Here at Stanford he had a superconducting linear accelerator, which had been built on campus, with support from the Navy, for nuclear physics, He used the accelerator to drive a free-electron laser, first as an amplifier and then as an oscillator, at about, 10 micron wavelength. It was an important development, because it demonstrated that the new system, the free-electron laser, could work. It attracted the interest of many people, including myself. Around that time I was given the task to start the new division at Frascati to develop lasers in all areas from high-power lasers for technical applications, to areas of my own interest, which was free-electron lasers. I organized a group of people, the new division, to start this work. I organized it, we were ready to start the work, but then there were bureaucratic problems and delays, which unfortunately stopped everything. I was really frustrated by that, because we were ready to work, we had bought instruments, people were ready to do the research, and in practice, we couldn't do anything. Just for bureaucratic reason. It was really frustrating. At that point, in 1978, I received a job offer from Brookhaven. I had already received one from SLAC in the summer of 1976, that we decided not to accept. But when later, in 1978, I received another offer from...

ZIERLER: Brookhaven.

PELLEGRINI: Brookhaven. And at that point, we were really frustrated by the inefficiency of the system in Italy. It was not even lack of money. We had bought all that we needed, what we needed was laboratory space, some civil engineering construction work. But there were all these obstacles to really do what we needed, bureaucratic problems. I was really frustrated. So, at that point, I did two things. I applied for a position for a professorship in the university. And--

ZIERLER: At Trento, you mean?

PELLEGRINI: At Trento.

ZIERLER: Yeah.

PELLEGRINI: And I decided also, after a discussion in the family, to accept this offer from Brookhaven. When we moved to Brookhaven, I was also given the professorship in Trento, and we had to take another decision. Are we going back to Trento? It is a nice place, up in the Dolomites. Beautiful area. Or stay here. In this country.

ZIERLER: Now, what are the tenure considerations like? Is there, what's the tenure system in Italy? Were they offering you tenure at Trento?

PELLEGRINI: Oh yes, it was a tenured position. I even went to Trento and gave a lecture. But then, together with my wife, we decided to stay on this side of the Atlantic. And--

ZIERLER: And what were some of the big projects that were going on at Brookhaven at that time?

PELLEGRINI: That was the time of Isabelle, a large proton-proton collider, the largest in the world. You know about Isabelle?

ZIERLER: Yeah.

PELLEGRINI: It was an exciting project, but it was also disappointing, because of the technical problems with the Isabelle superconducting magnets, the main component of the accelerator. The magnets were based on a new design, but they failed before reaching the design magnetic field. This problem in the end stopped the project. I was working on Isabelle and when the project was stopped I moved to another project, the National Synchrotron Light Source, which was also new at Brookhaven. I worked on that until 1985-86 when I went for one year to CERN. Back to Brookhaven I started a new project together with Robert Palmer. The idea was to have a lab, a small lab, called the Accelerator Test

Facility, ATF, with an accelerator and advanced electron source where you could do experiments on the physics of electron beams, laser acceleration of electrons, free-electron lasers . Bob Palmer and I were the co-director of this new initiative. We built the ATF. It is still today a very active lab at Brookhaven, I was also continuing my work on free-electron lasers. One of the ATF project was the development of a new electron source, the photoinjector, which had been proposed initially at Los Alamos and was very important for X-ray free-electron research. One of my most important papers, the high gain, collective instability theory of the free-electron laser was done when I was at Brookhaven in collaboration with an Italian friend, Rodolfo Bonifacio, of the University of Milan, and Lorenzo Narducci of Drexel University. This paper opened the way for me to an X-ray free-electron laser. We wanted to use the Accelerator Test Facility to do free-electron laser work, and laser acceleration experiments. We decided to use for the new lab a small electron linear accelerator, 60 MeV of electron energy, an advanced injector, called the photoinjector, which had been developed at Los Alamos by Richard Sheffield and others, as part of the Star War program. Because at that time there was a lot of interest in following the work of John Madey on free-electron laser, to generate really high average radiation power for the Star Wars program. A lot of money was coming into free-electron laser research at Los Alamos and Livermore and some industries to develop this very high average power free-electron laser for military application. And as part of that program at Los Alamos they developed this new type of injector, which has been a key element in the success x-ray free-electron laser, because it could generate an electron beam which was really much better than anything else one could have at that time. So we started also to design one at Brookhaven adapted to the ATF accelerator, but we really didn't build it for the time being. It was built later. In the early period of free-electron laser work I was not interested in the high power production. Many people went to work in that area because there was very large funding and the interest of two major laboratories. My own interest was in doing something else, which I believed was also possible with free-electron lasers, making a very short wavelength, X-ray wavelength, coherent radiation source. So I kept working to develop an x-ray free-electron laser. In the end, we did one free-electron laser experiment using the accelerator test facility at Brookhaven in the year 2000. It was called VISA . But. before that, in 1989, I was offered a professor position at UCLA , to start something new there. So I decided it was time to change and move to a new environment. National Labs are great for the technical support they offer. This is true at Brookhaven, Berkeley, here at SLAC. On the other hand, you also have to follow the guidelines of the lab. So, you're not totally free. I tried to start a program to develop short wavelengths, free-electron laser at Brookhaven, but I couldn't convince, really, the management to do that. They wanted to do something smaller in the infrared. I said: "Well, that's not interesting." So when I had the offer from UCLA, I decided to go to a university, where I had more freedom to do whatever I wanted.

ZIERLER: Now, was the idea that you would build a lab at UCLA, or were you going to move away from lab work?

PELLEGRINI: No, no I built a lab at UCLA, a small lab on the scale of national laboratories, because I wanted to test the theory that we had developed, the high gain SASE, Self-Amplified Spontaneous Emission, collective instability theory. I wanted to have a test to demonstrate experimentally that the theory was valid. Because that theory, if valid, would, in my opinion, allow us to really reach the x-ray region, to build an x-ray free-electron laser.

The high gain was needed because you couldn't build very good laser oscillators, since there were no optical cavities at X-ray wavelength. According to Madey's free electron laser theory the gain was too small for X-rays. But if you used the high gain SASE theory, you could essentially reach very high power in a single pass in a long undulator magnet without need of an optical cavity. That was my idea, but it was based on the SASE theory, which had never been demonstrated experimentally. When I went to UCLA, I wanted to set up a lab to have an experimental demonstration of the theory. I received the support of the UCLA department of physics and of the dean to build the lab. I remember the discussion with the dean. I told him what I would need to build the lab and why, and, at the end, he said, "Yes, we'll give you the setup money to do it.". UCLA was very helpful, very supportive. So I built the small lab in the basement of the department of physics, and we did there the first demonstration of the self-amplified spontaneous emission theory.

ZIERLER: Now, I assume that the lab that you built was much smaller than the labs you were working in on a national level. (**PELLEGRINI**: Oh yes.) So how is it--

PELLEGRINI: It was my lab.

ZIERLER: How is it that such a small lab can be suitable for testing this theory? How does that work?

PELLEGRINI: One important characteristic of the SASE theory that we developed is that it doesn't depend explicitly on the wavelength of the electromagnetic radiation generated.

The theory is the same for an infrared free electron laser or an X-ray free electron laser. On the other hand the accelerator and other element of the system are quite different in the two cases. In the infrared case a small accelerator with an electron energy of ten to twenty MeV, about one meter long, and a few meter long undulator magnet, is good enough. For X-rays the energy needed is one thousand time higher, the accelerator is one thousand times longer and the undulator is about one hundred meters long. So, we could test the theory in the infrared in a small lab and use the results for the X-ray free electron laser.

In 1992 I proposed to build the X-ray free electron laser, now called LCLS, at SLAC where a one km long accelerator was available, and there was the scientific and technical knowledge needed. From the time I moved to UCLA to 1999 we successfully tested the theory. What we did was to build one of the photoinjector that originated at Los Alamos. The idea was from Los Alamos. I had the drawings which we had been developing at Brookhaven. I took the drawing with me, and I built it at UCLA. At UCLA, there is a very good mechanical shop, it's subsidized. We could build it and we didn't need too much money. We started a collaboration with SLAC to braze the photoinjector, and we were able to put it together. We built it before they did it at Brookhaven. A university is much more flexible than a national laboratory. I could use students, I had a post doc working with me, and I had the support from UCLA, the setup money. When I was at Brookhaven I already had grants from the Department of Energy to work on photoinjectors. When I moved to UCLA, I continued to have the DoE grants. So I had some money to support the people working at the lab.

ZIERLER: Now another, I would imagine, another advantage at a national laboratory is that your colleagues are at your level of seniority, but I assume at UCLA, you're working with graduate students and post docs. Is that correct?

PELLEGRINI: As part of my hiring at UCLA, I told them that I wanted to have an assistant professor working with me, and to have money for two post docs. UCLA opened this position for an assistant professor, which I offered to James Rosenzweig. He is still at UCLA and is now a Distinguished Professor. We had a Zoom meeting this morning before this interview. (laughs) Jamie came and I told him, "You take care of the photoinjector, that is your part. I'll take care of the remaining part of the lab." We worked together, we could hire post docs, we had graduate students. Many of them you find around now in many places, labs and universities. Universities are a very flexible organization. You can do things without having to go through all the management that you have in a national lab. If you want to build something big and difficult, you have to do it in a national lab. But if you want to do research to demonstrate something on a small scale, I think a university is a better place. You have more freedom, you have more flexibility.

ZIERLER: So in looking to demonstrate this theory, what was the big research question you were looking to answer?

PELLEGRINI: Well, you have a theory. When you develop a theory, you use a model and introduce some simplifications, as we always do. You get some conclusions, some results from the theory, but until you show that the results agree with the experiments, you're never sure that your initial model is correct, that you have not forgotten something.

ZIERLER: Were you able to do that?

PELLEGRINI: Sorry?

ZIERLER: Were you able to do that?

PELLEGRINI: Oh yes. It took some time, because we had to start from scratch, we had to build a new lab in the basement. We needed concrete shielding for the radiation generated by the accelerator, that was not there. We needed everything. But in the end, we were able to do it. We built the photoinjector, we built the linear accelerator producing 20 MeV electrons. The accelerator is still in operation, and the lab is still working. In the end, we did the experiment, and we demonstrated that we could get exponential gain according to the results of the theory, with very good agreement. We also looked at some other aspects of the theory, some other characteristics that we expected, like intensity fluctuation, the temporal and spectral properties of the radiation. We had a good agreement on all of these aspects. It was really very nice to see. That encouraged us to continue with another experiment. The first experiment was at 16 micrometer wavelength. We only could experiment in the infrared, because of the limited electron energy in our lab. For the second experiment, we decided to do it in collaboration with Los Alamos. During this time, in addition to building the linear accelerator and the photoinjector electron source, we also needed to build undulators. We had some money, but not much. So for the undulator we decided to collaborate with a group in Russia, at the Kurchatov Institute. The scientist in charge of the group was Alexander Varfolomeev and he built with Kurchatov resources an undulator for the experiment. We defined the characteristics together. He built it and brought it to UCLA. The collaboration with Alexander was very fruitful. The undulator is still in my office at UCLA. It's 60 centimeters long.

ZIERLER: Wow.

PELLEGRINI: Very nice, very well-built. On top, there is still written, "CCCP", for Soyuz Sovetskikh Sotsialisticheskikh Respublik. It's a very nice memory of that time. This collaboration with Alexander Varfolomeev was very important for us and was a good contribution to the success of the experiment. Alexander was happy to come to UCLA, especially in wintertime.

ZIERLER: Now, during this time, were you teaching? Were you taking on graduate students?

PELLEGRINI: Oh yes. I was teaching full time.

ZIERLER: Did you enjoy teaching?

PELLEGRINI: Yes. I did.

ZIERLER: And how many graduate students did you usually take on every year?

PELLEGRINI: At that time? Three, four? And Jamie took some more. I think this lab at UCLA has produced the largest number of PhD in this area of research than any other lab.

ZIERLER: Uh-huh.

PELLEGRINI: We have many people from UCLA here at SLAC. And in other labs.

ZIERLER: Now, when you received the honor of becoming a distinguished professor in 1999, what did you feel like this was in recognition of? Was it everything? Was it your teaching? Was it your commitment to the field? Was it your theory? Or was it specifically related to one aspect of your work?

PELLEGRINI: Well, usually, at UCLA, what they used to say is, you have to be good in research, you have to be good in teaching, and you have to be good in social activities in the university. They required all of these things.

ZIERLER: When you were offered to become chair in 2001, were you concerned ever that the bureaucratic responsibilities would take you away from your research?

PELLEGRINI: Of course, yes. In fact, it took much of my time. It's a big department with 60 faculties. You have much to do.

ZIERLER: And it's not just physics, it's physics and astronomy.

PELLEGRINI: Physics and astronomy, yes. On the other hand, I had received much support from UCLA and the department. I thought I needed to give back something.

ZIERLER: Right, right.

PELLEGRINI: Also, it was a good time, because we had done all the initial experiments that demonstrated the feasibility of an x-ray free-electron laser, but on a small scale. The next step was to build a real one here at SLAC, and that's a big engineering job. Where I really didn't want to get involved. So, it was a good time to wait for the engineering part to be done, and the X-ray free-electron laser to be built. And I could use that time to be the chair.

ZIERLER: And what year did you retire from UCLA?

PELLEGRINI: 2010.

ZIERLER: 2010. And so it was the year after, 2011, when you came up to SLAC?

PELLEGRINI: Yes.

ZIERLER: And were you... What was the arrangement? Were you part time, were you full time? How did that work?

PELLEGRINI: I was retired and didn't want to have a full time job. But I liked to be connected to the lab. So the arrangement was that I would take a part time job and I could work at the lab. Initially, I had a grant through UCLA, and had students from UCLA doing their PhD work here at SLAC. I continued to have grants directly through SLAC to support more students and post docs. So I have my own money, I have students, I have post docs. We could do some nice work, and do it on my own time.

ZIERLER: Do you look at your work at SLAC currently as a continuation of what you were doing at UCLA, or these are new projects mostly now?

PELLEGRINI: They are new projects, but they are essentially in the same area. So, they are developments of what we were doing before.

ZIERLER: I'd like to talk a little bit about the awards that you've received, because I'm curious what each of them meant to you, both personally and professionally. So we'll start with when you became a Fulbright Fellow in 1997.

PELLEGRINI: Ah okay. Just let me tell you something before answering that question. Two of my graduate students I had while at UCLA, are now at SLAC. One is now an assistant professor here at SLAC/Stanford. The other is a senior scientist at SLAC. My last graduate student from UCLA is Claudio Emma, who did his thesis here at SLAC. I believe he will be my last PhD student. Usually it takes five years to go through a PhD program. At this point, I don't have that time.

ZIERLER: Right. Right.

PELLEGRINI: But Claudio Emma is now working at SLAC with one of my old graduate students who is also at SLAC, Mark Hogan, who is the first author in the first infrared free electron laser experiment that we did at UCLA. We had recently a picture together, three generations of scientists. It's quite nice for me.

ZIERLER: That's very special.

PELLEGRINI: Yes. Anyway.

ZIERLER: So to go back to the awards. So what, how was it that you became a Fulbright Fellow in 1997? How did that work out?

PELLEGRINI: Well, I like to travel. (both laugh) I had this opportunity to go to Brazil, where they built a very nice synchrotron radiation lab near Campinas, which is not far from Sao Paulo. I liked the idea of going there for three months. During that time, I gave lectures on free-electron lasers, and collaborated with the Campinas group. They have set up a very beautiful lab. They have done a very good job. It's really good, what they've done.

ZIERLER: As a Fulbright Fellow, did you feel as if you were an ambassador of the United States, because it has that component to it as a cultural exchange?

PELLEGRINI: Yes. It also gave me the possibility of traveling through Brazil, a wonderful country.

ZIERLER: Yeah.

PELLEGRINI: We went to the Amazon, we went all around the country and I gave some seminars. I was normally teaching and staying at the lab for three to four days, and then I was taking the last few days of the week to move around. I took some time to go to the Amazon, which had always been a dream for me. We had a great time. (laughs)

ZIERLER: And the free-electron laser prize in 1999, was this in specific recognition of your work at UCLA? The lab that you had built?

PELLEGRINI: Yes. My contribution to the development of X-ray free-electron lasers.

ZIERLER: And R.R. Wilson, the R.R. Wilson Prize, from APS. What did that mean to you? Because that's more of a, like more of a broader achievement award, right?

PELLEGRINI: Well, that also recognized my work when I was at Frascati and Adone was starting to work, the one point five GeV electron-positron collider. This was in '68. We had a lot of problems, because it really was something totally new. One thing that we discovered is that the electron and positron beam that we were trying to put into the ring were subject to a lot of collective effects, collective instabilities. So, it was really a learning experience on how these electron beams really are many body systems with many, many degrees of freedom. And that they can self-organize in many ways. Some of which we like and some of which we don't like. In particular, some of the innstabilities had been already studied by a group at Berkeley with Andy Sessler and some people here at SLAC. But we were the first to observe them in action in Adone. And we found that there was one effect that could not be explained by the work that had been done until that point. It was a really destructive effect, which really limited the beam current and so the luminosity of the collider and the high enrgy physics that you could do. I was able to understand what was going on. I wrote a paper and called this the head-tail instability. And also to show a way to avoid this instability, to control this effect. After that was done, we were able, really, to increase the electron and positron current in the beam. The design value was 100 milliamps. What we were able to do at the beginning was 50, 100 microamps. So it was really, really limiting the performance. But taking care of that instability, we were able to increase the current, overcome this limitation and push the current to the design value. The method that I proposed to control the instability, has been used in all storage rings built after that time, because this effect was everywhere. The prize was in recognition of that contribution, the study of the collective modes of electron beams, and also of the contribution to the free-electron laser theory. Now, the high gain theory of the free-electron lasers, is again based on a collective instability. The electron beam self-organizes. The beam going through the undulator and interacting with an electromagnetic field self-organizes in a certain way that leads to very high X-ray radiation intensity. So it's again a collective instability, one particular mode of collective behavior. In this case, we like it. It's what leads to the success of the x-ray free-electron laser. So the Wilson prize was in recognition of all the contributions to understanding the collective behavior of electron beams with application to storage rings and free-electron lasers.

ZIERLER: Now, in 2014, what did it feel like to win the Enrico Fermi Award?

PELLEGRINI: Oh that was great. I received a call from Ernie Moniz, who was the Secretary of Energy at that time.

ZIERLER: Yeah.

PELLEGRINI: He said, "Hi, Claudio, I have some good news for you, but you should be careful. Don't say anything to anyone, because before this can move ahead, you have to go through an FBI check." (laughs) He said, "You will be called by the FBI, and you should say yes, that you want the check." So that's when I had the first idea. The FBI check was okay and we had the meeting with the president in October. It was really quite wonderful.

ZIERLER: President Obama, you mean?

PELLEGRINI: Yes.

ZIERLER: Was he engaged--

PELLEGRINI: It was very exciting to be in the Oval Office.

ZIERLER: Was he engaged--

PELLEGRINI: Very much. He asked questions on the work I had done, why it was important. Obama was really a wonderful person.

ZIERLER: Yeah?

PELLEGRINI: We, my wife and I, went there, with Moniz, and Holdren, the head of the White House Office of Science and Technology Policy. The meeting was supposed to be at 11. We went there a few minutes before, I was with my wife. Obama opened the door of the Oval Office, and said, "Please, come in!" It was exactly at 11. Just very, very friendly. We shook hand. He hugged my wife. Then we talked for a while, we both discussed what I had done and why I believed it was important. He wanted to know what it could be used for. He was very friendly. We talked for some time. He asked my wife what she had been doing, what work she did. He is really a great person, with a lot of human feelings. Very interested in everything.

ZIERLER: And when did you become a member of the National Academy?

PELLEGRINI: That was in 2017.

ZIERLER: 2017. And besides being, you know, obviously, I'm sure it was very satisfying to be recognized. Did becoming a member of the National Academy of Sciences, did it open up doors for you? Did it create opportunities that might not have been available?

PELLEGRINI: Well, at that point in 2017, I was already retired.

ZIERLER: Yeah.

PELLEGRINI: I had done my career, essentially.

ZIERLER: Yeah.

PELLEGRINI: So it wasn't very helpful to me. But for people who receive that earlier, during the development of their career, it can certainly help. In my case, it didn't help that much. But I really am very honored to be a member, it's a great recognition, so I'm very happy about it.

ZIERLER: So Claudio, now I'd like to ask you, we've gone through the narrative. I'd like to ask you some questions now that survey your career in its entirety. And my first question is, what do you see as your main achievements and contributions to the field?

PELLEGRINI: Let me go back for a moment on the Academy membership.

ZIERLER: Yeah.

PELLEGRINI: What I could do was to go to Washington with my grandchildren, show them the National Academy. And perhaps push them to think about a career in science. In that sense, it was good. One of them will go to college this year in Berkeley and he might do physics.

ZIERLER: I'm sure you're very proud.

PELLEGRINI: Yes, I'm very proud. Now, let us go back to your last question. What are my main achievement? It's really my contribution to understanding how electron beams can organize in different ways, their collective modes, and to study in detail some of these ways. In particular, to show that you could use the free-electron laser instability to develop successfully the x-ray free-electron laser. Which is really a unique instrument, because it allows for the first time to explore matter at the level of the natural time and length scale of atomic phenomena, one angstrom, one femtosecond, the Bohr radius of the atom and the Bohr time for one valence electron to go around the nucleus. This has really opened some new possibilities in science. People have done molecular movies, showing how atoms move during a chemical process. Scientists have been able to use the x-ray free-electron laser here at SLAC, LCLS, to have a much better understanding of photosynthesis. To understand photo-system two in much greater detail than anything that had been possible before. I think, in this sense, it's my small contribution to better understanding the universe around us. And it also has been very nice to see that, after the success of LCLS, there have been other free-electron lasers, x-ray free-electron laser, being built around the world, in Europe, in Asia. There is now a community working with X-ray free-electron lasers.

ZIERLER: Now, beyond the world of theoretical physics, I wonder if you can explain a little about what is the practical application, or the societal benefit, of your research? How can people understand what your research has done in terms of moving science more broadly forward? And what the benefit of that is.

PELLEGRINI: Well, one good example is that it has allowed to make important progress in understanding photosynthesis. I'm sure that using LCLS we'll be able to have a complete understanding. There is only one small step to take, to have a complete understanding of photosynthesis. Photosynthesis is the basis of life. If we can really understand it in all details, as we are almost doing now, it will be a major contribution to science. Not only to science, but once we understand it, we can likely reproduce photosynthesis in some ways which would help society.

ZIERLER: Which have--

PELLEGRINI: I believe that's a major contribution.

ZIERLER: So if we understand photosynthesis better, does this have implications for energy sources? For--

PELLEGRINI: Oh, for anything.

ZIERLER: For anything.

PELLEGRINI: I mean, we're all alive using the energy from the sun to grow plants and animals. Everything starts with photosynthesis. The whole chain of life depends on that. And it's a good way to transform energy from the sun into plants and fuel. There are other examples of useful research done with the X-ray laser. For instance, one study that was done at LCLS led to better understanding the mechanism that helps us to control blood pressure. At my age, many people take pills to control blood pressure. The mechanism of how this works was not completely clear until this experiment was done here at LCLS. I think that has a big impact for many people. Gaining a better understanding to help us to control blood pressure. Another example is the movie of how one molecule which is part of our vision processes changes when it's hit by a photon. It's part of the processes in our vision system. You have a photon coming, and it hits this particular molecule, which has an hexagonal structure. Because of the interaction, because of this photon arriving, it changes structure and goes from a hexagonal to a linear structure. One can study this process seeing the atoms moving on a time scale of femtoseconds. The whole process takes 30 femtoseconds. So understanding in detail the dynamics of all molecular processes, which are also part of the life system, is a unique capability that we have now. I think that will give benefits for everybody.

ZIERLER: Is there a particular theory in physics or a fundamental concept or law that is very close to you that informs all of the projects that you're involved when, or really informs how you see the world? Something that you might've learned a long time ago, but it's always stayed close with you?

PELLEGRINI: Well, all my work is based on the standard theories of electromagnetism and quantum theory used to really understand processes that occurs when you have a very large number of elements, and collective modes develop. One collective mode of an electron beam is what made a big instruments like LCLS work. So I really found that the fundamental theory of physics, mechanics, electromagnetism, quantum theory, can be used to understand complex systems. What really has always been surprising for me, and it still is, is that you start from these theories, you make a model of some complicated physical system like an electron-positron collider or an X-ray free electron laser, even if with some simplification, develop the model into a theory that gives you predictions, using mathematical analysis. Then you build something, you build magnets, you build all kind of stuff. You put it all together and you get the results that you calculated. It's something really almost unbelievable. This capability of the physics theories to predict successfully what happens in complicated systems, and the capability of mathematics to really describe the world around us is amazing. I think it is one of the big mysteries of science. Galileo said that mathematics is the language of the universe. And it's really amazing to see how well it works. I remember the first time we started designing Adone in Frascati. I was much younger at that time and we spent a few years doing all the calculations for Adone, the electron-positron collider. At that time we used mechanical calculators, it took a very long time. Then technicians and engineers built all these systems according to our calculations. You put it all together, you go and see what is happening and it is exactly, within certain limits, what you had predicted. There were also new phenomena that we had not predicted, like collective instabilities, that we explained later on. But the major part of the prediction were just there, you could see it working, and I always find it amazing.

ZIERLER: On the concept of "mystery," you said something about the "mystery of science." I wonder if you can speak personally about some things that were really mysterious to you early in your career and are no longer mysterious to you now?

PELLEGRINI: I have a better understanding of how things work in the area where I have been working. But there are still many problems left in our understanding of the universe. We don't understand dark matter, dark energy. Another thing that always surprises me is that I live here, I go out, see flowers, see all the different trees, all the different forms of life.

They all follow from the same basic principles. They all work, in my opinion, according to electromagnetic theory, relativity, these theories. So they all work according to some simple equations. But out of these simple equations, you can get an enormous variety of phenomena. When you move to the level of a system, which has many components, you have an incredible richness of possible phenomena. We still have a lot to do to understand how all of this works. If you give me one electron, I can tell you what it will do given certain forces acting on it. If you give me 1000 electrons, I might still be able to do it. If you gave me a billion electrons, there are so many things that they can do, all possible collective modes in which they can organize, that it's hard to predict unless you really start looking at what they do. Then you might be able to explain why they do it. And this is true at the level of life. It all follows from some very simple, basic principles, but then you have this infinite variety of ways in which life expresses itself when you put together some proteins and some DNA. It's wonderful. The richness of the world around us. Following from very basic, simple principles and equations.

ZIERLER: And you're saying that what we still don't understand is how this variety exists?

PELLEGRINI: Yes. Why do you have roses and begonias or, so many other flowers? You go out, go to a park, especially now, in springtime, you're in Washington, you see the cherry blossoms and you see roses, you see all kind of flowers, all kind of animals around you, including the coronavirus. Why?

ZIERLER: Do you think physics and science generally has an answer to that question? Or is that fundamentally a philosophical question?

PELLEGRINI: Perhaps the answer might come from science. We've been making a lot of progress using the scientific approach. All of this started about 400 years ago, with the use of instruments to expand the capability of our senses. We had a better understanding of the world with Galileo and the telescope. Galileo also built a microscope, he and one of his collegues did the first microscopic observation. When they did that, I think it was like a step in evolution, because for all the time we, our species, have been present on this planet, we have been looking at the world with our eyes, our ears. They are wonderful instrument, but they have their own limitation. With our eyes we can see things as small as a tenth of millimeter, but not smaller. A tenth of a second is the timescale that we can resolve. Based on that information we made a picture of the world around us. In this picture there were different ways of explaining the universe. For instance, for the solar system, you could have the Ptolemaic system, or you could have the Copernican system. There was no way to say which one was right. But when Galileo built a telescope and looked at the phases of Venus, he demonstrated that the Ptolemaic system is wrong.

So it's by expanding our senses with instruments like the telescope that we can have a better understanding of the universe, and we can escape ignorance and superstition. So building the telescope, the microscope and all other instruments that followed, is like a step in evolution. Because a man with a telescope can see farther away, he can have a better understanding of the universe, than a man without a telescope. And the person using the large hadron collider can see things that you cannot see in any other ways. The development of instruments has been like expanding our senses, we can see more and we can understand more. But seeing more with instruments is the key to better understanding.

ZIERLER: But when you see more, don't you always run into the problem of seeing all that you didn't even know you were looking for in the first place?

PELLEGRINI: Of course. That's a great part. You see things that you never expected.

ZIERLER: Do you think--

PELLEGRINI: In some cases, in a few cases, new things had been predicted by theory. As, for instance, the black hole. It didn't come out of an experimental observation, but it came out of the theory. It is one of the few examples in which something that could have been unimaginable, I don't know of any poet who had been thinking about black holes, was introduced by theory and was later demonstrated experimentally. But it's one of the few cases where the theory was really in advance, predicting something before we could really see it. Normally, it's the opposite. You have better vision, you see more things, and then you try to explain how these new things fit into our understanding.

ZIERLER: Do you see your work as contributing to the unified theory?

PELLEGRINI: Well, in the sense that I have given a contribution to the development of accelerators, big accelerators like the large hadron collider. They've not done it yet, but they could move towards some kind of unified theory.

ZIERLER: Do you think--

PELLEGRINI: I don't know if we will ever get a unified theory of everything.

ZIERLER: Do you think there is-- When you say that we don't know if we'll ever get to a unified theory, is that to say that the unified theory might not exist? Or that humans might not have the capacity to achieve it?

PELLEGRINI: I really don't know. I mean, modern science started, as we were saying before, about 400 years ago. We have made a lot of progress, but it's a really limited time, and we still have a lot to explore. And trying to get a unified theory at this point in time, when things like dark matter and dark energy are unexplained, why should we be able to do that? Why should we be able to have a complete understanding? There is still a long way to go. We should be in a way, humbler. We need more time. We need to work more on these problems. We might get a unified theory. We might get to understand everything, but we might not. We don't know. We have to understand the human brain, how long will that take? In the end, I mean, we also have to understand in detail how we interact with the universe. We have expanded our senses with lasers and accelerator and many other instruments. But all this information is processed through our brain, and we still don't understand how that works. I think we need more time. We'll see.

ZIERLER: Well, Dr. Pellegrini, I'll ask you for my final question of this wonderful conversation we've had, a future-looking question. What are the things that, either in your lifetime or in the foreseeable future of your field, what are the things that you're most excited about? What are the things that you feel that we're on the cusp of discovering and what might those discoveries mean?

PELLEGRINI: That's a big question. (laughs) I don't know. In my own particular field, I have a new project going on, I'm very excited about that, but that's not what you want to know. Well, I can say that we have been learning a lot about how nature works, how to utilize this knowledge to cure sickness and improve our condition. The way we live today is quite different from the way my father or grandfather lived in, not to mention previous generations. Today, I believe we have the capability of giving every human being on this planet a decent life, education, medical care, enough food. But we are not doing it. We are wasting a lot of resources on weapons and wars and in-fighting between ourselves. Overusing the environment in which we live. So there is a disconnect between what we could do, and we know it would be good, and what we are doing, and we know it's bad, but we cannot prevent us from doing the bad things. Instead of doing the good things. So, there is a disconnect between our scientific knowledge and our culture. And I don't know if we will be able to solve this problem, this disconnect, in time, because changing culture takes a long time, on the timescale of generations, while bad things are happening on a much shorter timescale. So if we could do something to help this, I think that would be, at this point, a major contribution. We simply can wait to have a unified theory of everything. If we have the unified theory 50 years from now, or 100 years from now, instead of now, it is not a tragedy. I would like to have it now, of course, because I won't be here in 50 or 100 years, but it's not, I don't think it's urgent. I think we can wait. But if we cannot solve these other problems, my grandchildren will have a real hard life. And I can feel that. Even if I'm not going to be here, my grandchildren will be. And I am afraid for what kind of world they will live in.

ZIERLER: I wonder if your grandparents were concerned about the kind of world you would live in?

PELLEGRINI: Well, I can tell you a story. It's a way to tell the difference in generations. It is about my great-grandfather, well no, my grandfather on my father's side. He was born in the middle of the 19th century. He was living in a small village in the mountains, a very poor area, and his family was poor and not doing very well. So when he was 12 years old, he decided to leave. He took his few things, he put them in a sack, put it on his shoulder, and traveled from his small village to Naples, walking. He walked all the way. That's about 300 kilometers. He crossed all of Italy, essentially, from east to west. And of course, he didn't go to school. Even my father only went to elementary school, when he was 11 years old he was sent to work. So my grandfather, 12 years old, decided to leave and he started walking and went to Naples, and built for himself a life in Naples. I don’t believe he had the time to think about these big problems. I have the luxury of thinking about them because of what he did.

ZIERLER: Yeah.

PELLEGRINI: He had much more practical problems to solve. But he did it, and he went to Naples and then he went to Rome, and gave me the possibility to study, so I can think about the big problems.

ZIERLER: Well, Dr. Pellegrini, it's been an absolute pleasure talking with you today. I really appreciate your time.

PELLEGRINI: Thank you. It's nice to meet you. You'll send me a copy of this?

ZIERLER: I will. I'll cut the interview here.