PHYSICS IN EUROPE

Research contributions since the war

Two respected leaders of physics— one from Europe and one from the US— discuss areas in which the continent excels in an exclusive interview with PHYSICS TODAY.

Edoardo Amaldi and Victor F. Weisskopf

Edoardo Amaldi (left in the photo above) is a professor at the "Guglielmo Marconi" Institute of Physics of the University of Rome and **Victor F. Weisskopf** (right) is professor and chairman of the physics department of the Massachusetts Institute of Technology.

PHYSICS TODAY—Can we say that in the last few years European physics has come into its own again and in a number of areas may be leading the world or close to it? Do you agree that there has been a strong upswing in the level of European physics in the last few years?

Amaldi—It is always very difficult to say how good physicists in Europe are compared to the US, even if we limit our talk to fundamental research. I think, however, that in high-energy physics the level of the European effort is comparable to the US and there are many other areas one could mention where the comparison seems to be balanced. But sometimes I have the impression that, in general, the US has been more efficient and quicker in deriving applications from discoveries or new results obtained in fundamental physics. The European response is not as flexible or as quick as in the United States, so that we take more time to derive or develop important new applications from the results of basic experiments and corresponding theories.

Weisskopf—But still, Europe has a population of 300 million—50% more than the US. It has a very high level of civilization and a long tradition. It's the cradle of science—so one should not be surprised that the Europeans traditionally have been very productive in science. In fact, one should have been surprised (although there is good reason for it) that the importance of European science actually submerged in the 1940's and 50's in favor of American science. Of course the reason was the war and the resulting economic effects and social and political disorders. Today, however, Western Europe has again become quite prosperous. The standard of living is going up—in fact, the income *per capita* in some countries is now larger than in the United States. So that we might even ask at this point why European science isn't even more productive than it is.

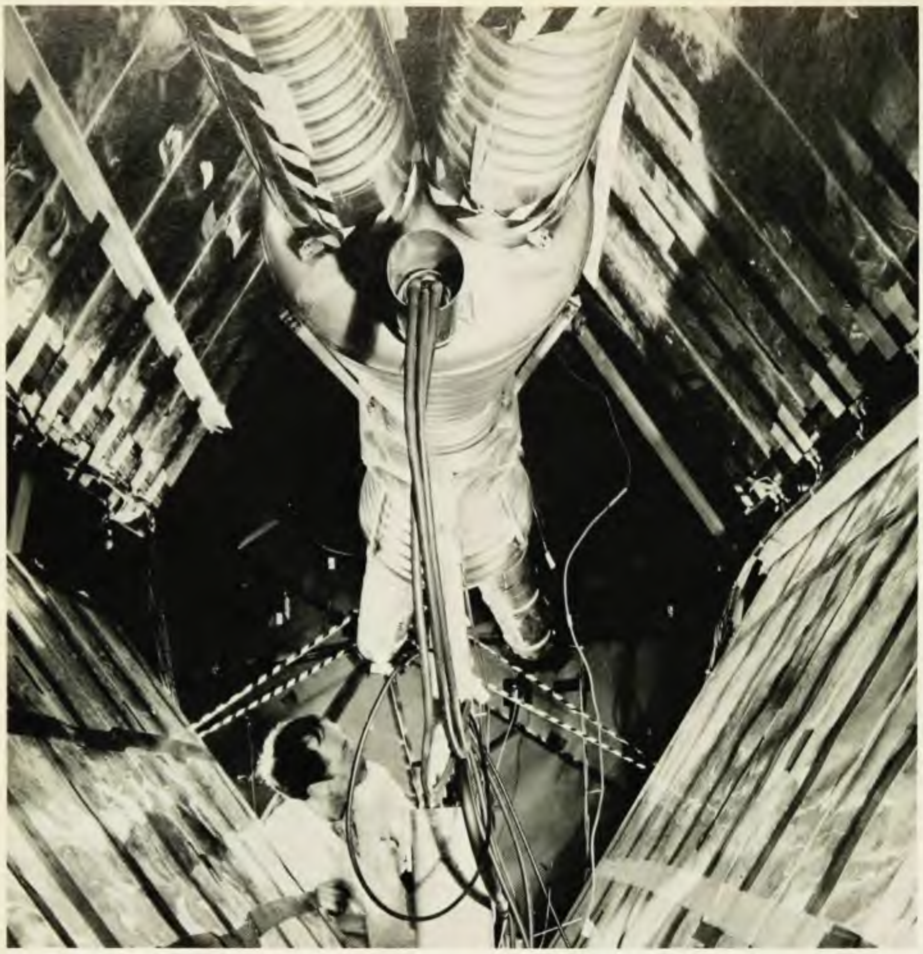
The reason is, as Edoardo said, there are too many countries in Europe—there are bureaucratic obstacles to collaboration that cause delays.

PHYSICS TODAY—But these delays don't seem to be bothering the Europeans in high-energy physics. Aren't we seeing the new discoveries coming from Europe first now?

Weisskopf—Yes, to a large measure, the success of the European high-energy physics is based upon the fact that the scale of the instruments forced Europe to unite its efforts and attack the problem on an international scale. Thus CERN was set up.

Certainly, the existence of CERN itself has a lot to do with the prominence of European high-energy physics. The idea of CERN is 25 years old; it came from the recognition that the war had slowed down and even stopped basic research in Europe and that America had been strengthened in basic research as a result of the war. Europe had to do something to recuperate and recapture the position in basic research that it has traditionally held. This situation was particularly acute in high-energy physics—in other fields it is easier to get going again because the facilities are smaller. But in high-energy physics, an international collaboration was necessary. CERN is not only an institution for the discovery of fundamental laws but also a pilot plant for experiments in international collaboration. I think that CERN has been unusually successful in both respects. Later, the pattern of CERN was followed in biology with EMBO (European Molecular Biology Organization) in astronomy with ESO (European Southern Observatory), and in space science with ESRO.

Recently CERN has made two important contributions: the discovery of



One of the intersection regions of the Intersecting Storage Rings at CERN, near Geneva, where the circulating beams of protons meet in almost head-on collision. Emitted secondary particles traverse the thin double stainless-steel walls of the vacuum vessel before entering the surrounding detectors. The discovery that cross sections rise with energy was made with the ISR.

neutral currents in weak interactions and the discovery of the rising cross sections at high energy. The latter was made with the ISR (intersecting storage rings). The construction of the ISR was a very important step forward for Europe because it was the first time in the field of high-energy physics that Europe was pioneering with a new instrumental idea. This courageous and risky step provided Europe with a monopoly on a method of research, which paid off handsomely. Not only does the ISR give the highest energy in the world between two colliding protons today but it represents a new way of doing high-energy physics. We were aware when we first planned the ISR in 1963 that this project will change the picture and it did. It gave European high-energy physics the needed self-confidence and independence. It is not the ISR alone that represents CERN's claim to originality—the neutral current discovery was not made with the ISR. It was made with the Gargamelle Bubble Chamber, which received a proton beam from the proton synchrotron.

One should emphasize that the rebirth of European science after the war was not restricted to high-energy physics. It is true that in high-energy physics, Europe has become more or less on a par with America, but in nuclear-structure physics Europe may even be ahead of the US, particularly due to work at the centers in France, Sweden, Denmark, Germany and England.

Amaldi—At Copenhagen you have Aage Bohr and Ben Mottelson, who did fundamental work to relate the shell model with the collective model. There are strong groups too in Sweden and Germany as, for example, the Max-Planck Institut für Kernphysik at Heidelberg.

Weisskof—Yes, recently Backenstoss's group from Karlsruhe has been doing some fascinating experiments with so-called "exotic" atoms (atoms consisting of muons, pions or hyperons instead of electrons) at CERN and there is also the work on hypernuclei physics being done at CERN initiated by Jerzy Pniewski and coworkers from Poland. Bressani and his coworkers from Turin and Povh et al from Heidelberg have continued this line with a kaon beam to excite states of hypernuclei. So, looking at all these activities, I think it is fair to say that in nuclear-structure physics the European effort is broader than the American one.

Amaldi—As long as we are still on the part of this conversation devoted to nuclear physics, we should mention the Institut Laue–Langevin at Grenoble, where a very important laboratory has been constructed as a joint project of France and Germany, into which recently the UK also entered. The main facility of the laboratory, which is now under the direction of Rudolf Mössbauer, is a high-flux reactor that is the best existing today. They do outstanding researches in many domains, going from solid-state—as, for example, investigation of the dynamics of crystals by scattering of slow neutrons—to nuclear physics. Even subnuclear-particle problems are occasionally tackled. As an example of collaboration between Europe and the US, I might mention that Norman Ramsay is at present leading a group attempting to push down the very low upper limit he established years ago on the value of the electric dipole moment of the neutron. This quantity is of great interest in connection with the limits of validity of the fundamental symmetry operations underlying our present views on subnuclear particles.

PHYSICS TODAY—Do you have any reasons why Europe has become so strong in nuclear-structure physics?

Weisskopf—As usual, it is a matter of personalities—there were, for example, Bohr and Mottelson in Copenhagen, Karl Siegbahn in Sweden, James Chadwick at Harwell, Teillac in France and in Germany we had Gentner and Maier-Leibnitz.

Another promising development in nuclear physics is a very interesting machine that will soon be put into operation at Darmstadt—Schmelzer is just starting up a linear accelerator for heavy ions—the UNILAC. It is a challenging design and it will become a unique facility. For instance, it will be able to accelerate ions of krypton to quite a high energy, about 20 MeV/nucleon.

Amaldi—That reminds me that, talking about high-energy physics, we should mention, besides the discoveries made at CERN, the results obtained with electron–positron rings, which represent a development made in great part in Europe. The feasibility of this type of machine and the understanding that they would provide a unique tool for tackling many problems, are due to the Austrian physicist Bruno Touschek, working in Rome. A first model (ADA) was designed and constructed at Frascati. As a result of its success, a few machines, with higher energies and greater intensities, were built in Paris and Novosibirsk. From these e^+e^- rings, a number of first-class results came out. A machine belonging to the next generation because of its still higher energy and luminosity (ADONE) later entered into operation in Frascati. It was with ADONE that the anomalous production of hadrons in e^+e^- collisions was discovered in Frascati by four groups using different detection techniques. Their results were confirmed and extended to higher energies by a group working at CEA, where the Cambridge (Massachusetts) Synchrotron had been modified in such a way as to allow the exploitation of electron–positron collisions. The evidence of this effect was further strengthened later by physicists working at SPEAR (Stanford). This discovery, in my opinion, is just as important as the neutral current discovery made at CERN.

Weisskopf—I agree.

PHYSICS TODAY—What about other fields of physics such as solid state? How do you feel Europe measures up?

Weisskopf—In other fields I am less competent to judge. But it is my impression that Europe has been very strong in laser physics, especially in subjects connected with superconductivity. For instance, the Rutherford Lab has made some very original advances in applied superconductivity, which are being used in the US.

Amaldi—All we can do is mention a few examples of important work in the various fields—there is no way we can be complete in this kind of conversation. First, in the field of superconductivity, of course, we have to recall the work of Brian Josephson at Cambridge. The prediction by Josephson—while he was still a student at Cambridge—of an ac supercurrent between superconductors was a big achievement. Brian Pippard, also at Cambridge, a few years earlier had introduced the concept of coherence length. Incidentally, Herbert Frohlich, who is at Liverpool, was spending a year at Purdue when he developed his theory of electron–phonon interactions, which represents a basic step toward the development of this theory of superconductivity. Other important advances in superconductivity are due to Lev Landau, Alexei Abrikosov and David Shoenberg. John Clark developed the SQUID, a superconductive device for measuring small magnetic fields, while at Cambridge.

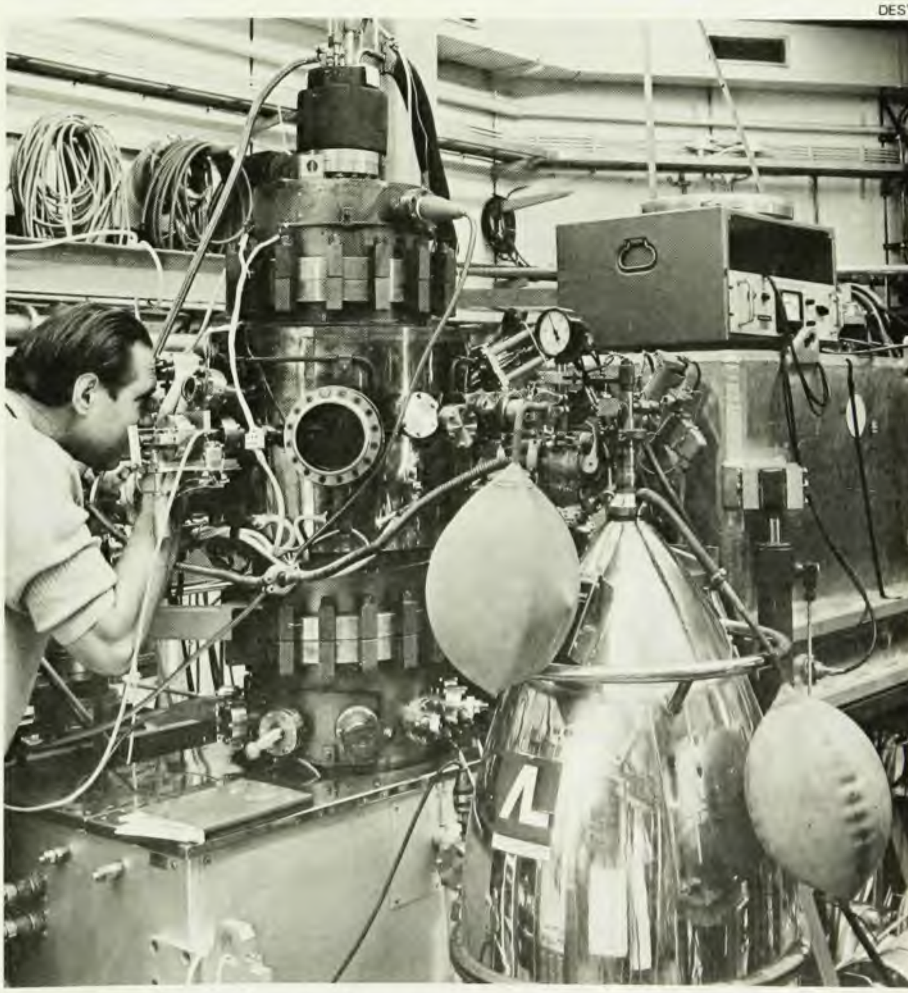
Another aspect of low-temperature physics is liquid helium. Before the war there was Kurt Mendelssohn at Oxford, who studied the liquid-helium film, and in Leiden the contribution goes back to Clusius and Willem Keesom who found the helium lambda point and Peter Kapitza's experiments, first at Cambridge and later in Moscow. The superfluid flow of liquid was discovered independently by Kapitza and Jack Allen at St. Andrew's. It seems to me appropriate to recall at this point that Kapitza constitutes one of the many extraordinary links between Western European physics and USSR physics. Another example is Landau, who, in the period of his scientific formation, worked in Göttingen and Copenhagen, just at the time when the foundations of quantum mechanics had been established, and the new generation of theoreticians was facing the fascinating problem of applying to the description of the extremely vast phenomenology observed in atoms, molecules and solid matter.

If we talk more about postwar developments, we should also recall that great contribution of Lars Onsager and Richard Feynman in America who introduced the quantified vorticity around 1950. This phenomenon was confirmed at Cambridge by Vinen and Hall, at Berkeley by Rayfield and Reif and in Rome by Giorgio Careri, who observed the motion of ions in liquid helium.

Weisskopf—In the field of quantum optics we have to mention Alfred Kastler and his group in Paris. He invented differential optical pumping, in which you selectively populate closely lying excited states by using polarized radiation. Pierre Jacquinot and André Marechal at the Institute of Optics at Bellevue, Paris, are leaders in the fields of infrared optics and interferometry. And of course we all know that Dennis Gabor invented holography while he was working at the Imperial College in London.

Amaldi—Another contribution from Great Britain was the work of Nevill Mott and John Ziman on amorphous solids. After amorphous semiconductors were discovered by Kolomiets in the USSR they developed the theory—Ziman worked on the basic theory of transport in liquid metals and Mott on the theory of transport in amorphous semiconductors. John Enderby, at Leicester, got some important experimental results on the structure of liquids and Jan Tauc did outstanding

DESY



Studying photoemission from liquid lithium at the 7.5-GeV Deutsches Elektronen Synchrotron is tricky, as the oxide skin at the surface must first be scraped away. The synchrotron radiation passes through a monochromator of unique design, matched to the characteristics of this light.

work on the optical properties of amorphous semiconductors. He has been working in the US since the Czech revolt but he had already made his reputation before he left Prague.

Weisskopf—There have been very important theoretical developments in France in solid state. Pierre deGennes contributed importantly to the development of Type II superconductors, which are now being used in superconducting magnets. DeGennes' theory is based on that of Ginzburg and Landau which, as Gor'kov showed, can be derived from the Bardeen–Cooper–Schrieffer theory. DeGennes and his coworkers at Orsay are now using the same mathematical techniques on liquid crystals, possibly doing the foremost theoretical work in this field. DeGennes' new book, just published by Oxford, is the only book that covers the entire subject of the physics of liquid crystals.

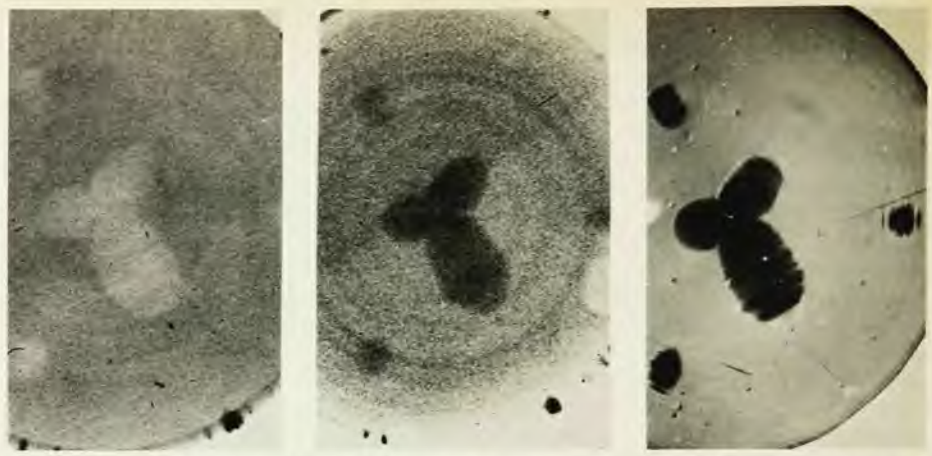
Amaldi—If you look at the Fermi surfaces of metals then you can point to Pippard, Shoenberg and Ziman at Cambridge, again. Pippard studied the relation of Fermi-surface characteristics to a whole range of phenomena such as magnetic susceptibility and magnetoresistance. Shoenberg has also done important work on magnetic susceptibility and Ziman has worked on the theory of all these effects. In the area of crystal vibrations, Cochran, at Edinburgh, is an example of a European who has done outstanding work on the shell model of crystal vibrations.

Then we can mention spectroscopy with synchrotron radiation—the groups at DESY in Hamburg and at NINA in Daresbury.

Weisskopf—Several institutions in the US have planned to do such research, but so far, work of this kind is beginning at the SPEAR facility at SLAC; the Europeans are clearly ahead because they are already doing it for some time.

Amaldi—There have been pioneering results from Frascati but later the activity in this field was not permanent and vast as at DESY. The efforts at Frascati and the ones in the US with synchrotron radiation only involved a few people, not like the German effort, which is a strong attack with the participation of many groups.

If we look at the optical properties of the solid state, examples of outstanding work are easy to find. After Gross first observed excitons at Leningrad, Nikitine at Strasbourg looked at excitons in a number of compounds. On the theoretical side Davydov in the USSR worked out the theory of excitons in molecular crystals and Elliot at Cambridge developed the theory of indirect optical transitions in semiconductors as well as that of excitons in cuprous oxide.



Defects in crystal platelets are made visible in three different ways at the Philips Research Laboratories in Eindhoven, the Netherlands. They are **(left)** fluorescence under x-ray irradiation, **(center)** thermoluminescence topography after excitation at 77 K and **(right)** x-ray diffraction.

Related to optical properties is a whole new field—modulation spectroscopy. With the development of lock-in amplifiers, you can determine the effect of a sinusoidal variation of some parameter, such as electric field or pressure on the transmission or reflection spectrum of semiconductors. Both Europeans and Americans helped start the field but on the European side, Manuel Cardona, who is from Spain, worked in the US, and is now at Stuttgart, has written a book on the whole subject and Bassani, Chiarotti and Frova, for instance, have been doing good work in Italy.

Weisskopf—There is a great contribution by Phillipe Noziéres and his student Combescot in Paris to the many-body theory applied to electrons. They were able to predict the energy levels of the liquid phase of electron–hole plasmas. Then again in Paris, Claude Benoit à la Guillaume and Michel Voos actually measured the binding energy of the electron–hole liquid—the energy of the phase transition between the liquid and the gas.

Amaldi—I would like to call attention to magnetism—at the Grenoble school Louis Neél has made many basic contributions to understanding magnetism. He elaborated the concept of magnetic domains and was the first to recognize the significance of antiferromagnetic materials. We refer today to the Neél temperature, which is the transition temperature in antiferromagnetic materials, equivalent to the Curie temperature in ferromagnetic materials. While we are at Grenoble, we should point out Mössbauer, who is director there—his discovery is certainly of major importance. Other important contributions to magnetism as well as to many other fields of atomic, molecular and solid state physics have been given by Anatole Abragam in Paris.

In the study of solid-state imperfections some samples of important work by Europeans are first of all Friedel at Orsay, who has written the classic work on the theory of dislocations and done fundamental work on the electronic states associated with imperfections. Then there is Seeger at Stuttgart who has done interesting work on the kinetics of imperfections as well as other contributions to the theory of imperfections. In fact, Seeger has been the first to get information about point defects from positron annihilation. Another example in this area is the work of Alan Lidiard at Harwell, studying the relationship of diffusion and imperfections in the solid state.

Still another example is Frank at Bristol, who has worked on the theory of imperfections in surfaces. He actually originated the dislocation theory of crystal growth and in surface physics worked out the statistical mechanics of the attachments of atoms to surfaces.

On the experimental side a good example of important work is that done by Amelinckx in Belgium on the relation of crystal growth to dislocations. Then there are Bourdan and Tabor's experiments at Cambridge on surface friction. They made this subject into an exact science.

It is impossible to say Europe is better than the US in this area or that—except when there is a big difference. But when good work is going on on both sides you can not say one is better than the other.

Weisskopf—But as I said before, it is my opinion that the European effort could and should be even better . . .

Amaldi—I have much respect for Vikki's remarks—he is an American but also a European so he has a wide knowledge on this subject—but I would like to argue with him a little. I believe that, in a certain sense, after the war we had a repetition of what happened in

Germany after the first world war. This time it wasn't Germany alone that was beaten or devastated but all of Europe. Unlike the US, most countries in Europe were invaded by enemy troops or crossed by friendly troops in combat and they suffered from the destruction and social disorder that comes from being in the middle of a war like this. But we should not forget that even during the war there were a number of discoveries by physicists in Europe—in high energy the development of emulsions by Park and Levy.

Weisskopf—At the end of the war, Marcello Conversi, Ettore Pancini and Oreste Piccioni used cosmic rays to investigate the nature of pi meson. It was quite an achievement to do that kind of experiment during that terrible time.

Amaldi—They found that the mesons that were studied up to that time were not the mesons of Hideki Yukawa. After a few months, however, Cecil Powell, Giuseppe Occhialini and G. G. Lattes, working in Bristol, solved the puzzle raised by the Italian group by showing that there were two types of mesons—the pion and the muon—and proving that the pions were the real Yukawa particles. These discoveries and a few others of the same type were completely European, and took place at a time when Europe was in an almost incredible situation of destruction and depression. I always felt that the development of the nuclear-emulsion technique and its wide application to the study of cosmic rays has a kind of parallel with the development of quantum mechanics in Germany, after the first world war. In 1924 or 25 Germany had been defeated and was economically and politically depressed, but in this landscape of recent destruction you could find people like Werner Heisenberg, Max Born, Pascual Jordan and Wolfgang Pauli constructing quantum mechanics.

It's true that good economic conditions favor the development of science with big laboratories and big machines and so on. But it seems to me that history also teaches us that sometimes very important scientific steps take place in almost impossible life conditions. This happened twice in the recent history of Europe.

Weisskopf—At about the same time, George Rochester and Clifford Butler at Manchester discovered the strange particles, and the French group led by Leprince-Ringuet made important contributions, which clarified the situation. Yes, we have to agree the beginnings of high-energy physics using cosmic rays were made in Europe after the war, and not in America.

Amaldi—Although the situation was bad all over Europe it was still possible to make these big discoveries and this gave us great confidence in the possibility of rebuilding science in Europe. These discoveries also stressed the necessity of starting something like CERN. A few years later cosmic rays started to become a second-class source of particles compared to the accelerators that in the meantime had been invented, developed and constructed in the US.

Weisskopf—These discoveries were used as an argument for CERN. Here we have made these wonderful discoveries but we cannot go on because we don't have the equipment.

Amaldi—During the post-war period, Europeans, using the poor man's technique of emulsions, discovered many new particles. At the same time, however, the US was building synchrotrons and betatrons—all based on new ideas—the inventions of Edwin McMillan, Donald Kerst, M. Stanley Livingston and others. But the fact that they concentrated their efforts on these instruments means that they did not concentrate enough effort on the poor-man emulsion technique that led to the discoveries of the first particles. This has a parallel with what happened in the 1930's when Ernest O. Lawrence invented the cyclotron and Robert Van de Graaff built his first electrostatic accelerator. Many scientists in the US were very active in building these "big" machines, which gave very significant developments a few years later. But at that time in Europe there was a strong concentration of effort on experiments with little sources of neutrons, which yielded many early discoveries.

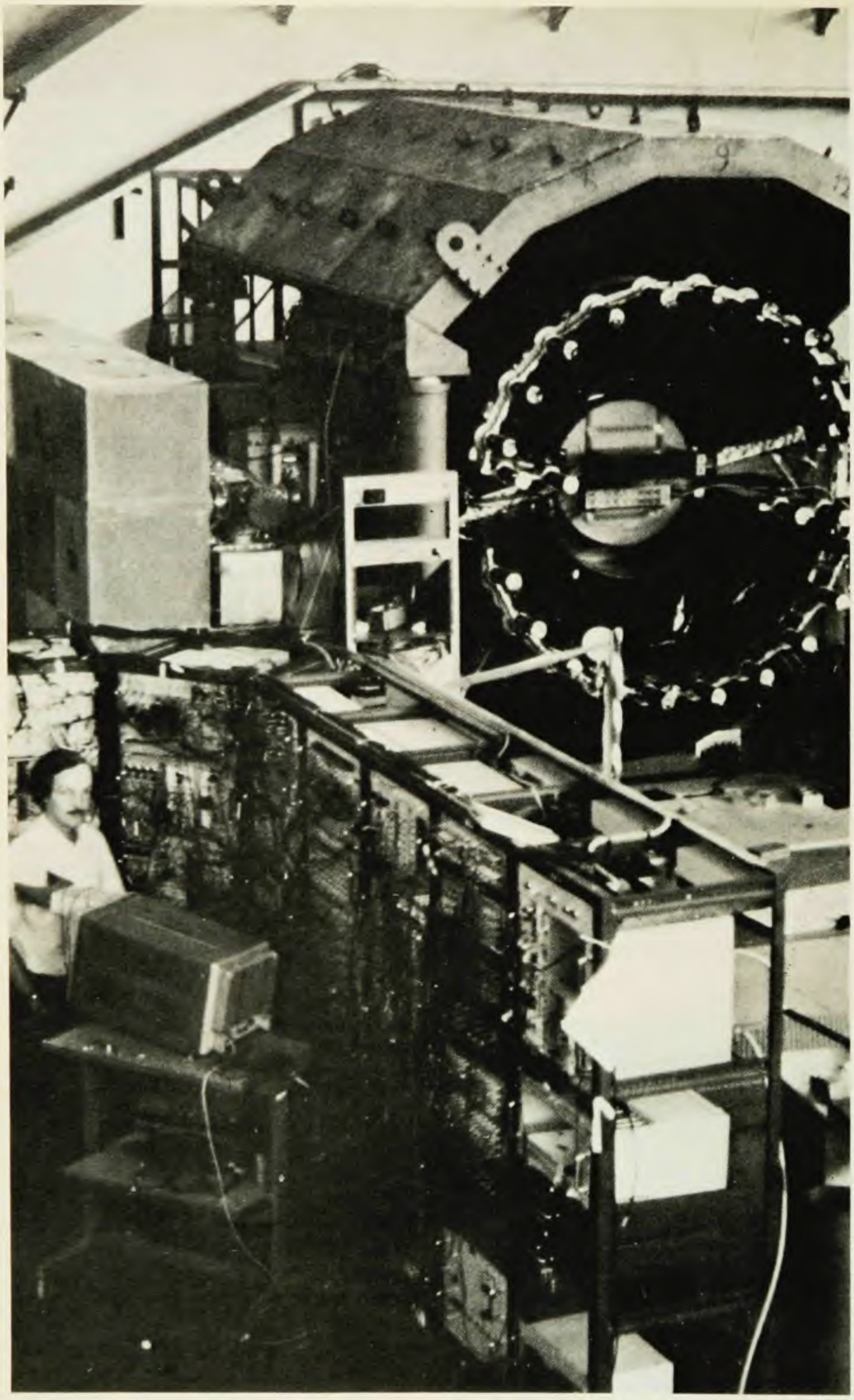
Weisskopf—Right. Enrico Fermi made all his early discoveries with a little radioactive source.

Amaldi—Of course, both times people in Europe were aware of the limitations deriving from the use of weak sources of particles and in a few years accelerators took over: Starting from 1936 the cyclotron, and after 1955 the cosmotron, the bevatron, the betatron and the synchroton, started to dominate completely the corresponding fields.

Still another field in which I think Europe has done rather well is the field of macromolecules. We can point to the work with x rays by Lawrence Bragg and his group at the Cavendish at Cambridge. And then after the war, at Cambridge there was the analysis of the structure of DNA by Francis Crick and James Watson and the first protein structure by John Kendrew and hemoglobin by Max Perutz. We can mention other important results on macromolecules by Dorothy Hodgkin at London and Oxford.

Another development that is typical

The wall came down at the Tandem Accelerator Laboratory of the Niels Bohr Institute as the freon–nitrogen pressurized Van de Graaff accelerator tank was rolled into the laboratory's hall.



A second-generation experiment at the ADONE storage ring at Frascati, near Rome. The anomalous production of hadrons in electron–positron collisions was discovered with ADONE.

of Europe is that made in Göttingen by Manfred Eigen. He has developed what are called "relaxation techniques." You have a system, for example, of macromolecules in chemical equilibrium and suddenly change the external conditions, for instance, the temperature. Then the readjustment of the system takes place with a time lag determined by the rate constants of the various processes going on in the system. By measuring a conveniently chosen physical property of the system as a function of time, one can obtain the "relaxation spectrum," that is, the values of the rate constants of the various processes.

Weisskopf—Also we haven't said anything about astrophysics. Actually radioastronomy was born in Holland. It was a Dutch invention by Jan Oort—the work starting in 1945 during the last stages of the German occupation—although he was just beaten by Ewen and Purcell in the US to the first observation, the 21-cm line of hydrogen. Then radioastronomy was picked up in the UK by Bernard Lovell at Manchester, who has steerable dishes of all sizes at the Jodrell Bank Observatory, and by Martin Ryle with his interferometer arrays at Cambridge. The Dutch are still active in radioastronomy, incidentally, with their large array at Westerbork in northeast Holland. At present the European dishes in Germany, the UK, Italy and the Netherlands are at least equivalent if not better than the American ones. One can also mention the contributions of the European Southern Observatory.

Amaldi—In astrophysical theory, you have Fred Hoyle of the British school, Evry Schatzman in Paris, and Dutch, German and Scandinavian astrophysicists such as Hannes Alfvén, who contributed so much with his application of magnetohydrodynamics to astronomical problems.

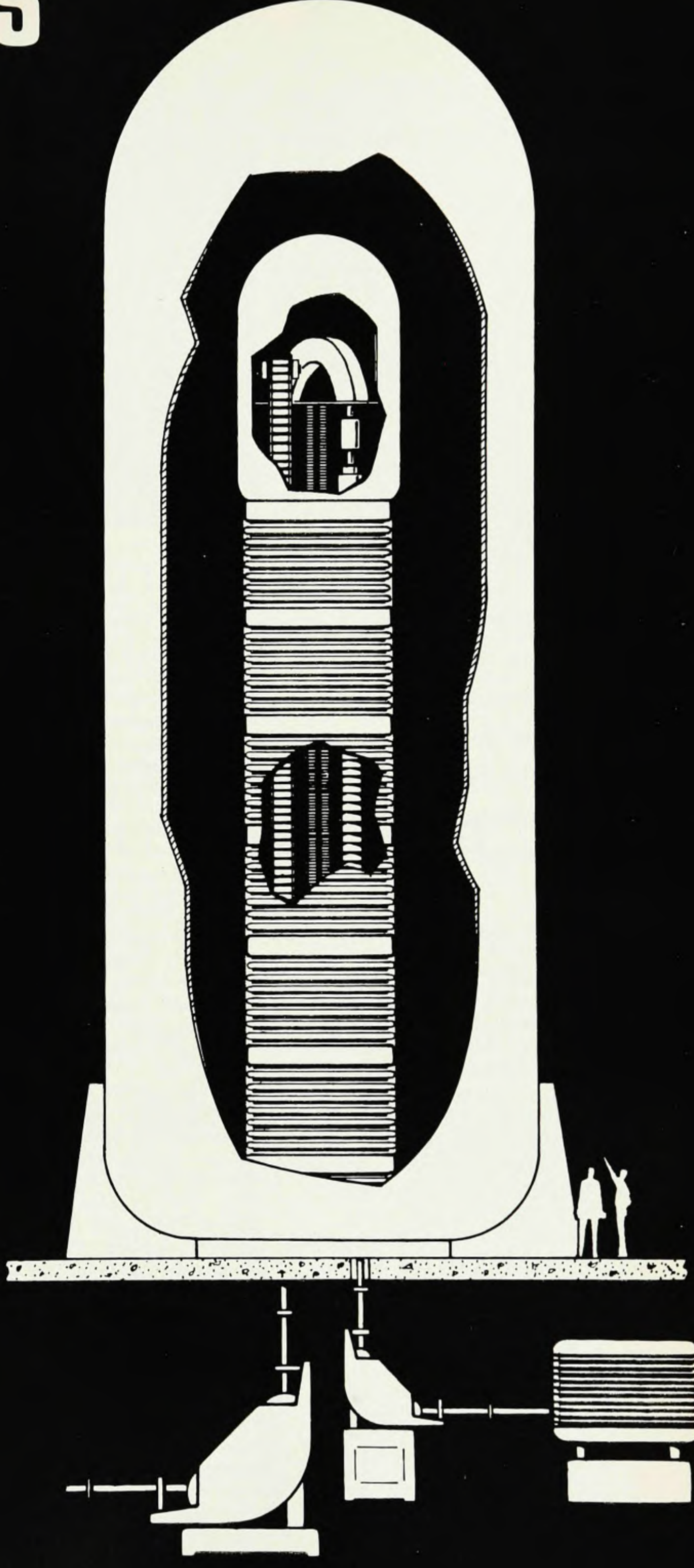
PHYSICS TODAY—What about the European effort in plasma physics?

Amaldi—Of course there are important groups in Culham, Grenoble, Munich and Frascati. What they have done is to work in understanding some of the instabilities of plasmas and in developing diagnostics—although I don't think you can say Europeans have contributed such outstanding advances in this field as they have, say, in superconductivity.

Weisskopf—The postwar study of electron, atom and molecular collisions can be traced back to two groups, those of David Bates in Belfast and of Harrie Massey in London, in the early 1950's. Applications of this work in those days were primarily to discharge phenomena and upper-atmosphere physics, but more recently many of the results and methods have become important in the development of gas lasers and plasma diagnostics.

PHYSICS TODAY—Are there areas where you would identify big differences at this point—say where one country is way behind?

Weisskopf—I would say no—it's more a matter of fluctuations—which you can sometimes explain by social factors and sometimes not. One factor, of course, was the unusually lavish support of science in America. We spent 0.3% of the GNP for basic science, whereas in Europe, it was only 0.15%. Now things have changed and it went down in America and up in Europe; at present the relative support of science is about equal. I would like to mention a most beneficial phenomenon during the lav-



J. RAULT, ORSAY

"Fingerprints" are formed when a cholesteric liquid crystal is submitted to a low frequency electric field at the Laboratoire de Physique des Solides at Orsay. Note grain boundary.

ish time in the US—1948–1967—the intermixing of European and American scientists. During this time, forty percent of the graduate students in the US were Europeans who came over for a year, two years, or more. It had a tremendous effect on both American and European science. Most of the leading people in Europe that we have mentioned have spent a year or more in America. In my view, the most fruitful effect of our lavish money supply was not the building of instruments and facilities but the intermixing of the scientific world community in America. That time is over now. At present the number of Europeans in America is way down; it is comparable to the number of Americans in Europe.

PHYSICS TODAY—You mentioned cooperative efforts by Europeans in high-energy physics, biology and astrophysics. Are there other areas where it would pay Europeans to do this?

Amaldi—That's a complex question because a place like CERN, even though it's very satisfactory in many ways and a *necessity* because of the cost and complexity of a big modern accelerator, also has drawbacks. Aside from the advantage of distributing the economical and technical effort among many countries, it has the great advantage that young people from any European university coming for a few days to Geneva get in touch with worldwide developments. For this reason it would be very important for any science to have such a center. On the other hand, there are also negative aspects—the bigger the place, the more committees you need, so that you cannot just have an idea and do the experiment—you first have to write proposals, present them to committees and so on. The experiments are so expensive, the machine time is so precious, that a big laboratory is forced to set up committees to examine proposals and choose among them. But if you have committees making choices you reduce enormously the possibilities for original inventions, as original ideas don't always appear reasonable to every committee member.

Weisskopf—We have the same problem in the US. That's why our committee on the future of high-energy physics is recommending that the US maintain three centers for high-energy physics to get the competition that is missing to some extent at CERN. But if you ask in what other fields Europe should be trying to cooperate, I would mention plasma physics. But plasma physics has a very strong applied component and, once you have that, commercial interests come in that make it much harder to cooperate. For example, Euratom never worked well because there were political and commercial interests involved.

PHYSICS TODAY—Is it fair to say that the US is still pretty far out in front in elementary-particle theory?

Weisskopf—Certainly you are thinking of people like Feynman, Murray Gell-Mann, Steven Weinberg, Kenneth Wilson, T. D. Lee and C. N. Yang? But one could also name many very good and active European theorists, who have contributed a large number of new, essential ideas and concepts to particle physics.

Let me make something in the nature of a concluding remark. I always feel a little uneasy when people discuss the scientific achievements of one region compared to another. In the US we would probably never consider discussing the achievements of the State of New York versus those of Illinois. There is something fundamentally ridiculous about such discussions. This is also true when we try to discuss European science compared to American science. There is only one science, and only one science community. I would like to make a very strong plea to consider the scientific community as a *world* community. It just happens that some live in Europe, and some live in America or Japan or elsewhere. We should think of it as one community, speaking the same language, doing the same work and helping one another if things get difficult here and there. It is more or less accidental and unimportant at what geographical location the advances were made. □