CLOSING ADDRESS

H. Schopper
Director-General of CERN
Geneva, Switzerland

You have reached the end of two very charged weeks which, I hope, were not only instructive but also pleasant. Let me spare you the conventional concluding remarks made on such occasions and, instead, tell you what prompted us to establish such an Accelerator School at CERN and how this fits into the perspective I have of future developments in the world of accelerators.

For the next ten years or so the programme is fairly clear. Of immediate concern for us here will be the realization of a p̅p collider improvement scheme whose main part will be an additional collector, ACOL. No definite decision has yet been taken and difficult problems of financing and manpower will first have to be solved, but I am reasonably hopeful that we can do it. Then there is, of course, LEP now under construction with highest priority. Phase 1 of this machine is in preparation and to eventually reach Phase 2 - which means to go beyond 50 GeV per beam - should prove to be a smooth transition by virtue of the addition of accelerating cavities, and I very much hope that these will be superconducting ones. Recent progress in the development of such cavities has been most encouraging, and successful tests have been carried out at the PETRA ring on cavities built at Karlsruhe and at CERN. Not long ago I heard of further advances made at CERN so that one may be confident that a change to superconducting elements is within reach. We even aim to introduce a few of them into the beam of the Phase 1 machine to see how they behave.

Now that the use of superconducting magnets in large systems has been proved feasible at the Tevatron, the first comparable application of this technique in Europe will be realized in the HERA project at DESY. This should provide valuable experience not only for accelerator laboratories but also have wide implications for industry.

As for the near future outside Europe, there are Tevatron 2 and Tevatron 1, in that order, in the USA. Their big advance has been, as already mentioned, the commissioning of the superconducting magnets, and an energy of 700 GeV has now been reached. The other very interesting machine project is the linear collider at SLAC, where the principle of producing intense colliding beams by means of linacs will be tested for the first time. In Japan there is the TRISTAN project which, in its first phase, will produce e⁺e⁻ collisions and in its second stage, if approved, ep collisions. The UNK project in the USSR is going forward. A large magnet factory for the superconducting magnets has been built, benefiting no doubt from the lessons learnt at Fermilab. Engineering work has started recently, but it is not quite clear what their schedule is, so that this machine might not come into operation within the ten-year period I have considered so far.

Let me now jump ahead and look at what lies beyond the year 2000. From all the recent meetings where new techniques, such as wake-field accelerators, plasma-laser heat-wave accelerators, and other systems, were discussed I have gained the impression that no such novel project can be realized before the end of the century, and it may even be some time after 2000 when any of these new acceleration methods become practical propositions. This may seem rather pessimistic, but enormous problems still remain to be solved.
What can we hope to accomplish in the intervening period? From the physics point of view the achievement of pp or p p collisions in the multi-TeV range promises to render accessible the mass range of 1 or 2 TeV in quark-antiquark interactions. Several projects are under discussion, of which one is the Fermilab site filler, a dedicated collider of about 2 TeV. In the United States a big drive is going on in favour of the so-called Superconducting Super-Collider (SSC) which, according to HEPAP (High-Energy Physics Advisory Panel) recommendations, should lie in the range between 10 and 20 TeV per beam. Such things are now also being discussed in Europe, and what some people are calling the Juratron would be based on a proton ring in the LEP tunnel. When we proposed the LEP project to CERN Council we kept it in mind to retain the option of adding at some later stage a second ring in the tunnel which would have a sufficiently large cross-section to accommodate magnets of the size used for the Tevatron. This sort of discussion comes somewhat prematurely for us, as we are fully engaged in the realization of LEP, but we cannot avoid participating in the debate of future possibilities now being started on a world-wide scale.

These long-term programmes are being discussed at two levels. One is that of ICFA (the International Committee for Future Accelerators) which plans to hold a meeting next May at KEK in Japan to consider the global situation. The other is the follow-up of the Head-of-State summit meeting at Versailles and Williamsburg, where it had been decided to establish 18 groups to look into the possibilities of intensifying the intercontinental collaboration. One of these groups is concerned with high-energy physics, and a first meeting took place in October in Washington. There are two prerequisites for a precise definition of a project to be decided on. First the physics case must be argued, and to be able to do this, one might have to await further results from p p experiments at CERN and from the Tevatron. Secondly, it is most important that a great deal of technical development is carried out. The range of possibilities is, of course, wide. One could stay at lower energies and with present-day techniques keep the machine cost down. However, even the use of niobium-titanium magnets, at least as far as the SSC is concerned, requires some research and development work to be done in order to lower the price from present levels to a reasonable figure. On the other hand, if one wishes to go to the highest energies conceivable at present, say with 10 T fields, niobium-tin magnets have to be used, and much more development work will become necessary. In the LEP tunnel we could accommodate a 5 TeV per beam machine with 5 T magnets and one could get close to 10 TeV with about 10 T. In any case research and development work is necessary for such a multi-TeV machine and it was agreed that it should be carried out in very close collaboration between the United States, Canada, Japan, and Europe. It is to be hoped that this can be realized in the coming years, and CERN will assist in coordinating the development in Europe.

At these high energies gluon-gluon collisions will gain importance as an interesting phenomenon, but what one really aims to study are collisions between fundamental leptons: quarks, electrons, positrons. Electrons and positrons could prove advantageous because, even if our p p results have been remarkably free of background effects caused by "spectator" quarks, there may be some fundamental processes difficult to separate from the debris unavoidable in colliders of complex particles. So one could envisage the use of electron linacs as colliders where only "Fundamental" structureless projectiles are involved. Whether this is worth further consideration will depend largely on the results obtained at the Stanford Linear Collider.
It is therefore clear that, for some time to come, there will be very interesting work to do and I doubt whether accelerator experts will find themselves without a job. On the contrary, I believe that we need even more accelerator experts than are now available. This is not only because of the potential developments for high-energy physics that I have outlined, but there is also an unfavourable age structure of skilled personnel in the old established laboratories such as CERN and Fermilab. A glance at the CERN retirement figures for the coming years shows that the present small number of annual departures will very soon start to rise almost exponentially to reach a peak of about 170 members of the total staff per year at the turn of the century and then it will begin to fall. A large proportion of these, maybe 20%, are professionally trained experts or at least experienced accelerator staff, as the high-energy physicists at CERN come mostly from outside institutions. This means that around the year 2000 about 20 to 30 people will be needed annually at CERN alone to replace our skilled accelerator specialists, and one can only hope that some of them will prove as excellent as those who are fortunately still among us. Where are they to come from? We must prepare now to meet that future need, and this is one of the principal motivations for setting up such an accelerator school to interest young people and to attract them to our field.

It would, however, be too narrow-minded to single out high-energy physics as presenting a promising future. Accelerators are attracting interest in quite a number of fields of research. For instance, neutron spallation sources are becoming popular in Europe: one is being built at the Rutherford Appleton Laboratory in the UK, and another is being envisaged in Germany. The growing importance of synchrotron radiation sources for research in solid-state physics, biology and other fields is also remarkable. As regards nuclear fusion, some experts believe that the best way to achieve it would be by way of the inertial fusion process using accelerated heavy or light ions, protons, etc. Medicine is another example. When I was a young student only two betatrons existed in the whole of Europe and they were considered to be such huge and complicated machines that only very few laboratories could manage to use them for research. Nowadays almost every big hospital possesses a betatron or a linac.

A few days ago, in Germany, I heard from people in industry that they are considering building compact synchrotron radiation sources for industrial applications such as lithography. Such sources, about 1 m in diameter and using a 5 T field, could produce about 1 GeV at critical wavelengths of a few tenths of a nanometre. This increasing use of accelerator techniques for research and industrial applications is bound to render the staffing of new projects even more difficult than it is already. In some instances, where the money was available, no experienced staff could be found to build the machines.

Let me go back to explaining the purpose of this school. When, some time ago, I invited Knell Johnsen to organize and direct such a school, one important motivation was the essential change that has occurred at the universities with regard to what I call 'accelerator science'. Some 25 years ago universities were still building a lot of small accelerators, and this went hand in hand with the development of appropriate teaching there. Unfortunately this is no longer so: at only a very few European universities are people now being trained in this field, be it in theoretical or in practical terms. It will therefore become very difficult during the next decades to meet the growing needs I have outlined above. From this arises a certain obligation for CERN to try and stimulate a renewed interest in accelerator science, particularly outside the laboratories already in the field.
An enormous amount of expertise is stored in the brains of quite a number of people at places such as CERN and Fermilab. However very little of this knowledge has so far been documented or published in book form. A few very good books exist but they tend to be outdated in view of the considerable advance in techniques. It would be a great pity if the present, very experienced generation of accelerator scientists would leave the field over the next ten or twenty years without passing on their store of knowledge. One role of the CERN Accelerator School could be to help in documenting this know-how either in proceedings or by encouraging lecturers who prepare courses and seminars even to write some textbooks.

Apart from attracting young people from the universities to interest themselves in accelerator science, the school could help to stimulate education in this field and, in line with this, to promote collaboration between laboratories, universities, and industry. Some obstacles, however, still have to be overcome. There are universities where the accelerator domain is considered to be unsuitable for theses or diplomas. Quite a lot of re-education of faculty members will be necessary to convince them that work in accelerator science is as scientific as good physics and as exciting as developing a detector for an experiment.

The school should, of course, also aim to raise the level of expertise inside the accelerator laboratories, and this may best be achieved by closer collaboration between laboratories even across the continents. Mel Month of Brookhaven National Laboratory has made the good suggestion of school courses organized in common with the USA once in a while. In view of future developments it would be very fruitful to improve the interaction between experimental physicists and accelerator experts. The trend is towards colliders, and this implies a much greater integration of the experiments. Whereas in fixed-target physics, once the beam shutter is closed, the experimentalists are little concerned with what goes on behind it, that cannot be so in colliders where the experiment is practically part of the machine.

We must remember that financial and human resources for high-energy physics accelerators will be severely limited in years to come, and to make the best of this difficult situation high-energy physicists may, on occasion, have to be prepared to help in building an accelerator. Likewise, when an accelerator has come into operation, those who constructed it may have to participate in an experiment. Such an intensified collaboration could well benefit both sides. Collaboration and contacts with other fields, such as informatics, microprocessors, and data handling should also be encouraged in the framework of future courses, as progress in these support fields is likely to be rapid and may revolutionize accelerator science.

A final point, which should not be underestimated, is that of publication. Experimental and theoretical physicists are very keen to present their results in publications accessible to the outside world. Scientists and their laboratories are mostly judged by what they have published in refereed journals. Accelerator scientists tend to point to their successful machine as their achievement, and are satisfied with producing internal laboratory reports. They should also think of the external world ignorant of such reports, and make the effort of publishing accounts of their work in recognized and widely accessible journals. This attitude also applies to verbal communications. Physicists, particularly those at universities, are exposed to students who ask naive questions, and they have therefore become more adept at presenting their ideas and results to non-experts. In the accelerator world the
danger is that expert talks to expert and they are unable to explain their work to the outside world. The school might offer the occasions for the knowledgeable to talk to those not yet in the field and eager to learn.

There is clearly a lot more to be done. This was the first course of our new school, rather specialized in view of the great interest created by our exciting $p\bar{p}$ collider facilities. In future the courses are likely to be at a somewhat lower and more purely educational level, and your ideas and suggestions for future activities will be welcomed by Kjell Johnsen and myself. Let me thank you all, and particularly those from outside CERN who joined us for this fortnight, for helping to make this a successful beginning.