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RECENT DEVELOPMENTS AFFECTING THE LONG-TERM PROGRAMME OF CERN

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Since the last Scientific Policy Committee meeting at which papers on the long-term programme of CERN were discussed (see CERN/SPC/125 + Add.) there have been several developments affecting the thinking about this problem. Most notably there has been an International Conference at CERN on the Theoretical Aspects of High Energy Phenomena, a summary of which is presented in a separate paper (CERN/SPC/134/Add.) by Professor Van Hove, who acted as chairman of this Conference.

Admittedly there was not such evidence presented at the conference that clear and firm conclusions can be made to guide CERN along a royal road to an unquestionably wise future programme. Our knowledge is very limited. Nevertheless it did seem evident that the majority of the experimental and theoretical physicists present were more interested in machines that would provide higher intensities than in machines to provide higher energies in the centre of mass system. Consequently the proposal of the Accelerator Research Division to apply stacking techniques to an intersecting beam machine by adding storage rings to the present CERN PS did not find much favour. The criticism was not so much that high energies in the c.m.s. are uninteresting but that intersecting beam machines seem very limited in the range of nuclear interactions that can be studied. To gamble the future of the Laboratory on say p-p interactions and a few others even at a c.m.s. energy of 50 GeV was less attractive than say the safer course of building a 100 GeV proton synchrotron with an intensity of 10^{13} - 10^{14} particles per second which would permit a great extension of the present experimentation by virtue of the higher secondary beam intensities and at the same time allow some additions to the present programme by virtue of the higher energy. If money was limited, the preference apparently would be to drop the primary energy rather than the intensity but not, of course, lower than about 15 GeV.

The work done to date on machines that might satisfy the above trends of interest suggest that the use of high repetition rate linear accelerators injecting into similarly high repetition rate booster synchrotrons which can stack particles in a large synchrotron, which then accelerates the particles to peak energy at a rate of one pulse every three seconds might result in output intensities greater than 10^{13}p/sec. The intensity limitations seem likely to be ion source intensity, space-charge limitations at the various stages of acceleration and serious radioactive contamination of the machine particularly near the target regions. From other studies that have been in progress for some time now on very high intensity cyclotrons for π-meson production it is clear that unless the circulating protons can be ejected from the machine with ejection efficiencies very near 100% the contamination problems may well be insuperable or at least place so many restrictions on the use of the machine that experimentation becomes a slow and dangerous business. Linear accelerators, now coming back into consideration due to the proposal to use super-conducting cavities, eject all the accelerated proton beam, and may therefore be the only satisfactory way of achieving intensities in the 10^{15} p/sec range. Whether these proposals will be found as attractive after the results of the present series of experiments with single "cold" cavities are known, remains to be seen. Even though a 600 MeV proton linac giving a continuous output of 10^{15}-10^{16} p/sec for use as a very intense meson source might be feasible if these super-conducting ideas can be applied, a high energy, multi-GeV, linear accelerator, giving say 100 GeV and 10^{15} p/sec would still be at least 10 km long since the permissible voltage gradients in the machine limit the maximum acceleration to about 10 MeV/m and no improvement can be expected in this respect by using super-conducting cavities.

The scientific merits of experimental projects are often compared without regard to their cost and this is in general the right way to begin to make a choice. Unfortunately the cost of the accelerators which are now being considered is very high and the proposed machines differ so very much in cost that rather unrealistic comparisons can be made if the financial implications in each case are completely ignored. Consequently an attempt has been made to estimate, <u>very approximately,</u> the total costs (i.e. capital for machine building, capital and staff expenses for development and construction) of the various types of machines based on tentative figures put forward by groups outside CERN and by CERN staff. It must be emphasized, however, that these cost figures cannot, at this stage, be more than guesses, but they at least serve to classify the proposals into cost ranges as follows :

<u>Range A)</u>

In the 2 000 million Sw. Fr. range there is the 1 000 GeV proton synchrotron project now being jointly considered by a group in the USA (at Brookhaven) and an other in the USSR. It is not known precisely how these studies are developing but a physicist from CERN is joining in this study project in August this year and, no doubt, the project will be thoroughly discussed at the Brookhaven conference in September. A super-conducting proton linear accelerator of 10-20 GeV and 10^{16} p/sec is probably also in this price range.

Range B)

In the 700 million Sw. Fr. range there is at present the 300 GeV cascade synchrotron study initiated by the Californian Institute of Technology which seems to aim at an intensity of about 10^{12} p/sec and anotehr similar project being studied at Berkeley. Physicists from CERN are also taking part in these studies this summer. Because of the interest in high intensities mentioned above it may be preferable to consider, for about the same cost, a 100 GeV proton synchrotron with intensities in the 10^{13} - 10^{14} p/sec range. It is to be noted that the Stanford 2 mile electron linear accelerator (maximum energy 45 GeV) is in this price range. A study project for a 10 GeV proton linear accelerator of a "conventional pulsed" type, made some time ago, with an intensity of about 10^{14} p/sec also mentioned total costs in this range.

Range C)

For about 200-300 million Sw. Fr. i.e. about twice the cost of the CPS, there remains the storage ring and intersecting beam proposal outlined in paper CERN/SPC/126. Also one can consider a 25 GeV, 10^{13} - 10^{14} p/sec proton synchrotron which has the same energy as the CPS but 100 times the intensity. Although a 50 GeV, 10^{11} - 10^{12} p/sec proton synchrotron would also be in this price range there is unlikely to be much support for such a machine, bearing in mind the USSR 70 GeV project, now under construction, and the present interest in high intensities.

Range D)

In the 100 million Sw. Fr. range there is the recent proposal of a 600 MeV super-conducting proton linear accelerator with a continuous output of over 10^{15} p/sec which would give CERN a π-meson source several orders of magnitude more intense than any existing source. It is assumed that further developments of the CPS to raise the intensity to 10^{12} p/sec or more are part of the present programme of CERN but these modifications may be expensive if, for example, a new linear accelerator injector is found necessary. The intensity limitation of the CPS is likely to be space charge effects at injection and radioactive contamination of the machine in the target zones.

In trying to come to some proposal for a future accelerator programme for CERN the price ranges for different machines given above can give some guidance. It has already been admitted that the 1 000 GeV PS in the Range A is beyond the financial and man-power possibilities of either the USA or the USSR and the idea of building one such machine jointly by these two continents has been suggested at least by the physicists. It is safe to assume therefore that Europe, i.e. CERN, would take the same attitude to such a costly machine. Physicists from these two continents also agreed that 300 GeV proton synchrotrons could be considered as "national" machines, i.e. a machine that the USA or USSR could build alone. Now that more is known about the costs of machines in this energy range it might be found that this agreement was somewhat hastly and presumed too much on government financial backing for high energy physics. If some idea could be obtained of the price region in which accelerators become "intercontinental" i.e. world projects, rather than "continental" such as the CPS, then some of the machines listed above could be eliminated for the CERN Laboratory on the grounds of cost. In private discussions with physicists from America and the Soviet Union it appeared that a 300 GeV PS of normal intensities might now be considered a world project. If this is so, then both Range A and Range B machines might be considered too big for CERN. However, the Stanford 2 mile electron linac seems likely to get government approval in the near future and the cost of this machine is quoted as 450 million Sw. Fr.

Another way to approach the problem is to consider what machines will be running by 1970 and to search for a complementary accelerator to those machines on the basis that high energy physics is becoming more and more a world activity, and machines should be chosen on a world basis rather than a continental basis. This approach is consistent with the idea of a world project for the next very expensive machine mentioned above.

Well before 1970, probably by 1967, the largest machine in the USSR will be the 70 GeV proton synchrotron and the intensity should be at least as good as that of the CPS today, i.e. 10^{11} p/sec. In the USA, assuming approval is given, there will be the Stanford electron linear accelerator. Thus unless any steps are taken now by Europe, USA or the USSR, the highest energy proton accelerator will be in the USSR and the highest energy electron accelerator in the USA. Furthermore the highest intensity proton synchrotron at this time will probably be the Argonne 12 GeV PS at 10^{13} - 10^{14} p/sec. Europe will only have the CPS (28 GeV) and the USA a similar machine, namely the AGS (33 GeV), at Brookhaven.

A "complementary" machine to the 70 GeV Russian PS and the Stanford linac could be a high intensity proton synchrotron of an energy comparable with the CPS. Such a machine apparently would have the support of the physicists attending the recent CERN conference. Applying the conclusions of the two approaches to the problem mentioned above we then arrive at a 25-50 GeV proton synchrotron with an intensity of $10^{13} - 10^{14}$ p/sec. It would be wise at this stage to introduce another restriction and say that it should be built on the natural extension of the present site of CERN, to avoid the cost and delay of setting up another laboratory in Europe. It appears that such a machine could be built on an extension of the site, namely on the field adjoining the CPS. Between the energy limits 25-50 GeV there would clearly be pressure to aim at the higher figure in view of the Argonne PS at 12 GeV (high intensity) and the Russian PS at 70 GeV (normal intensity). The cost of a 50 GeV high intensity PS would however be near 400 million Sw.Fr., and is comparable with the Stanford 2 mile electron linac.

To complete the world picture of high energy physics facilities in 1970 it is necessary to guess at a world accelerator that would be complementary to the continental machines of that epoch. A good possibility would be a 300-500 GeV proton synchrotron with an intensity of at least 10^{12} p/sec and preferably 10^{13} p/sec. Such a machine would probably cost about 1 000 million Sw. Fr. but it would have a field of high energy physics of its own.

The above arguments are plausible but highly speculative depending as they do on the present interests of nuclear physics, which may change as new experimental results are obtained from the CPS and the AGS, and upon political events that are out of the control of physicists.

Whether or not a world project is ever launched it is clear that the idea of seeking complementary machines for the next building programme can do only good so long as CERN takes an active part. A third share in a world accelerator, if it comes off, will hardly satisfy all the demands of European physicists in the next decade. Some such machine as the 50 GeV high intensity proton synchrotron or an intersecting beam machine, should this come back into favour, coupled with a share in a world accelerator, would maintain equality between the three continents and at the same time give a good balance in world facilities for high energy physics research.

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