les which do not always mesh well with any individual nation's own planning. Thus any nation attempting to balance national and international programmes must face the fact that the latter are only partially within its control.

Another difficulty stems fundamentally from the changing nature of science, but has been exacerbated by the financial problems of the universities, and in particular the virtual extinction of the UGC equipment grant. These financial problems have been particularly severe for physics departments, where declining student numbers have led universities to switch resources to more popular areas. As a result, departments are seeking SRC support for things which once would have been funded by their universities, and in particular for the replacement of equipment bought in the boom time of the mid 'sixties and now becoming obsolete.

This has sharpened for us the problem of sophistication, whereby scientific equipment becomes bigger and more complex, until it can no longer be provided for every university, but must be provided regionally, nationally, or internationally. It was in areas of physics (such as astronomy, high energy physics, and space science) that this trend first became apparent, but it is now spreading to the traditionally "small" sciences. It could well be, for example, that by the 'eighties research lasers will have to be provided centrally, and much crystallography will be done on central synchrotron radiation sources. With such a change must go major changes in organization and in scientists' methods of working.

I should not like to end this article on too gloomy a note. Physics in Britain is still alive and relatively healthy. But its continued good health depends very much on our having sufficient stability to plan a forward-looking scientific programme.

Research with CERN 400 GeV Accelerator

Research with Europe's new 400 GeV proton synchrotron, the CERN SPS, has now begun, comfortably within the programme schedule which all but the most sanguine of the high energy physicists had at one time thought unrealistically optimistic. When the '300 GeV Programme', to give it its official title, was given its first airing in the report of the newly formed European Committee for Future Accelerators published in 1963, the target date for completion was 1976, but as the years passed and the fortunes of the project fluctuated back and forth, punctuated by the decision of the CERN Council in 1965 to give priority to the building of the ISR, the withdrawal of the UK from the project in 1968, the break-down of negotiations in 1969 over the choice of site for the reduced project .... the completion date seemed to recede ever faster into the distance. However, the proposal of J.B. Adams (then Director-General designate of the project and now joint Director-General with L. Van Hove of a re-integrated CERN) to build a 2.2 km diameter synchrotron alongside the existing CERN laboratories, using the existing 25 GeV PS as injector, led to a re-unification of the CERN Member States and all the "wasted" years to be recouped.

The project to which the CERN Council gave its assent in February 1971 was for an 8-years programme of construction, which included under the 1150 M Sw.Fr. ceiling (1971 prices), about 750 M Sw.Fr. for the accelerator, about 130 M Sw.Fr. for operation during the programme leaving the rest for experimental facilities and contingencies. Final costs may well be lower than the estimates.

First priority was given to the construction of the synchrotron up to its full design potential of 400 GeV and the transformation of an existing experimental zone (the west area) to accommodate neutrino beams of full energy and hadron beams up to an energy of 200 GeV. Attention has now moved to the equipping of a second experimental zone (the north area) where construction work is already well advanced. In the north area the accent will be on muon physics using a high flux muon beam and on hadron physics at the highest energies.

First beam tests on the SPS were scheduled to begin in April. The month before, following the annual shutdown of the PS when the final components of the ejection system had been installed in the PS ring, the continuous transfer system had been tested and shown to deliver a 10 GeV/c beam over 10 turns of good uniformity and with high efficiency. Beam guidance and focusing through the 1330 m of tunnel which links the PS to the SPS presented no problems and for

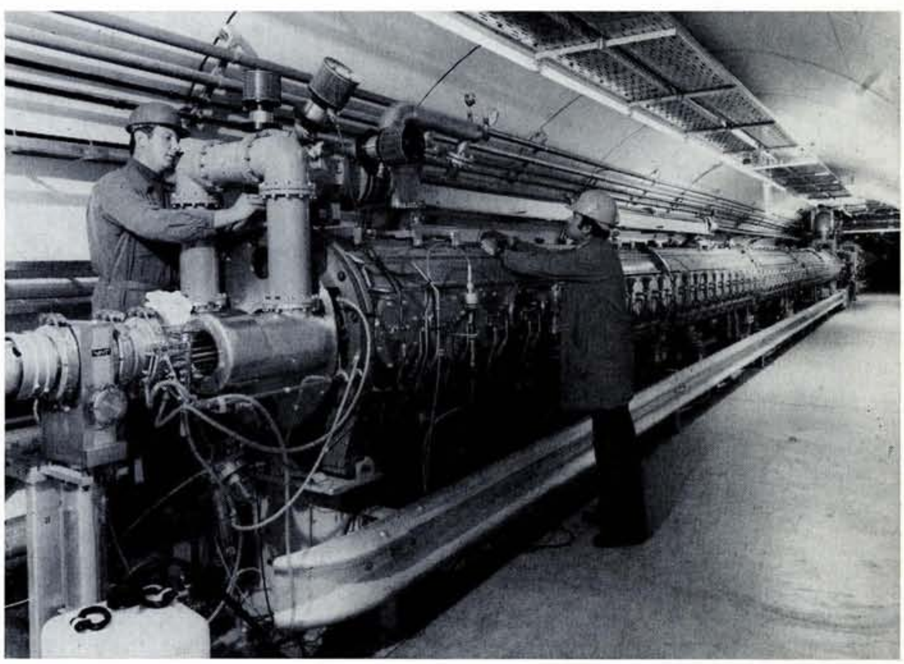

Fig. 1 One of the two accelerating cavities of the CERN SPS.

Fig 2 One of the three consoles in the main control room from which the entire machine can be controlled.

the first time the remarkable versatility of the distributed computer control system could be demonstrated. Within an hour of powering the deflection magnet directing the beam to the SPS, all the instrumentation in the line had been checked through and the beam characteristics in four dimensions, including the emittance, determined.

The whole of the SPS is controlled from one of three consoles in the main control room through a system of 24 computers some of which are dedicated to special functions such as the RF control or magnet power supplies while the rest are general purpose computers serving a given area. (The other consoles can be simultaneously employed for special function activities). Each computer is headed by an interpreter and is commanded in a basic English language that has been given the name Nodal. Data modules stored in the computers form part of a distributed data base. Consequently during the commissioning of the equipment it was possible to work independently on specific groups of equipment and prepare subroutines (and debug them) which were then stored locally so that subsequent access did not load the main data highway. These sub-routines and then the control programs were written by the people responsible for the equipment design, the philosophy being that they were in the best position to know the inner logic of the equipment, and the command language was readily learned. Each console is provided with CRT screens in both colour and black and white on which can be generated alpha-numeric information, mimic diagrams and graphical displays. Commands can be sent via a typewriter or more simply by using a series of touch buttons which, through a tree structure can reach any of the components and apply operational routines stored in the data base or central library.

Commissioning of the inflector system went smoothly and rapidly and was crowned on May 3 by a successful series of single-turn tests round the SPS main ring at the first attempt with no correction magnets powered. A few hours later, the beam was circulating over the scheduled injection period of 300 ms without appreciable loss. RF trapping was achieved during the next run, after which a systematic programme of beam measurement was carried out to optimize the closed orbit and adjust the Q-values. After only eight days testing with a beam, 80 GeV was attained, the maximum energy possible with the power supplies then available. Transition energy at 24 GeV was crossed without hesitation. As more power supplies were brought in, the peak energy attained moved up correspondingly and, with impeccable timing, 400 GeV was reached for the first time as the delegates from the CERN Member States to the bi-annual Council meeting were listening to a report from the Directors-General on the progress at the Laboratory.

Work on proving out the ejection system to the west area went equally rapidly and was followed by the progressive commissioning of the target areas and beam lines. Meanwhile, tuning of the accelerator continued and during October, beams of 10^{13} protons were accelerated up to the full energy of 400 GeV by filling half the SPS ring from the PS injector on one pulse, extracted over five turns and the second half on the following pulse. (While the SPS is running through the rest of its cycle, the PS returns to its other tasks of providing beams for 25 GeV physics or filling the ISR.) By the beginning of November, the SPS was ready for the experimentalists to start taking data.

From the SPS ring, two tunnels lead towards the west area — one for neutrino beams and the other for hadron beams. The west area was already equipped with two major fixed detectors, the 3.7 m low temperature bubble chamber, BEBC, built under a tripartite agreement between France, F.R. of Germany and CERN,, and a large volume versatile spectrometer, Omega. The latter is installed in one corner of a hall 160 x 65 m connected to buildings suitable for targets, power supplies and so on. BEBC has become the target at which the neutrino line is aimed while the hall has become the housing for the electronic experiments on hadrons. Behind BEBC is a massive spark chamber assembly and behind that again the heavy liquid bubble chamber with which neutral currents were discovered, Gargamelle, having been moved from its site at the end of the PS neutrino line. Gargamelle will be ready for its first runs in March of next year.

Considerable care has been taken in the design of the neutrino lines to define as far as possible the neutrino energy spectrum. Following the targets in which hadrons are produced from the incident proton beam, is a 300 m long evacuated tunnel in which hadrons decay into neutrinos and muons. The muons are absorbed in a 400 m shield which consists over the first 170 m of 2.5 m diameter iron disks and over the rest of earth and building foundations. Between the disks at a number of points, are muon detectors which will give information on the muon spectrum. Two beams have been planned :

1. a wide-band beam where the hadrons are focused into the decay line by two pulsed horns
2. a narrow-band beam where the hadrons are momentum analysed before they pass into the decay tunnel.

With the wide-band beam, the event rate in BEBC when filled with liquid hydrogen will be about 0.3/SPS pulse for neutrinos and 0.06/SPS pulse for

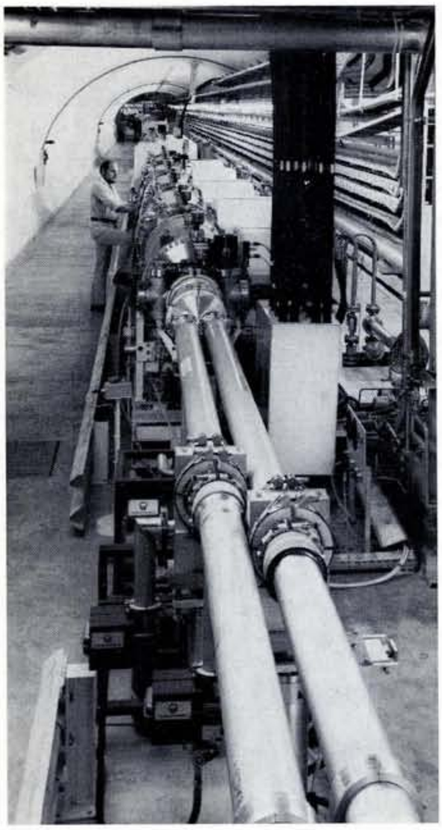

Fig. 3 The final stage in the extraction of the proton beam from the SPS. The ejected beam is deflected down the beam transfer tube (right) towards the targets serving the west area.

anti-neutrinos. The event rate with narrow-band beams will be down by a factor of 10 to 100 depending on the parent hadron energy setting.

First experiments will be with the narrow-band beam and a chamber filling of a neon-hydrogen mixture. The data collected will supplement that already accumulated in Batavia on event mechanisms and relative inclusive cross-sections but should also allow, for the first time, absolute measurements of cross-sections against energy to be made. In the second series of experiments, in the Spring of 1977, the wide-band beam will be in action and BEBC will be operated with a filling of liquid hydrogen. Gargamelle will also be starting up with a long range programme of neutrino and anti-neutrino interaction studies with particular emphasis on neutrino-electron interactions. The electronic experiment in the same line consisting of a massive target-calorimeter, 20 m long and weighing about 1400 ton will be used principally with the narrow-band beam for the study of inclusive reactions in iron and a search for rare processes such as three lepton production or the appearance of an intermediate boson. Other neutrino experiments approved include the operation of BEBC in combination with an emulsion stack (the bubble chamber being used to locate the vertex of an interaction within the stack, so greatly reducing the emulsion scanning time) and a second electronic calorimeter of fine grain, with which semi-leptonic neutral current processes will be investigated.

Although the neutrino programme is the most interesting in this opening phase of the SPS operation, and the one most likely to yield really novel results, there has been no shortage of proposals for experiments with the hadron beams that are becoming available. Here the most popular objective is the search for charm in hadron physics by the detection of otherwise forbidden mechanisms such as three-muon events or the decay of a charmed pair into three pions and a kaon. Amongst the six beam lines that are available is an RF separated line able to produce a pure separated beam of kaons up to an energy of about 75 GeV or anti-protons up to 120 GeV which is directed towards BEBC. The others, which fan out inside the west hall include a 40 GeV/c separated beam, incorporating RF superconducting cavities, an electron beam for the production of tagged photons of energies up to 80 GeV for the study of photo-production, and a hyperon beam.

So far, 29 experiments have been approved for the west area, involving over 40 universities and research institutes and including the participation of teams from the USSR and the USA. In addition, a number of experiments have already been approved for the north area when this starts to become available from the beginning of 1978. Here the accent will be on muon physics using a momentum analysed beam which will be quite unique in terms of intensity and precision. So large is the team that will be performing the first experiment on the inelastic scattering of muons from hydrogen (about 60 physicists) the identities of the parent institutes have become submerged under the general title of the European Muon Collaboration. A team of about half the size, with the participation of Dubna, will also be investigating deep inelastic inclusive muon scattering. From these experiments will come perhaps some clues to the answer to the long-standing question — Why did Nature need to invent the muon ? Even the latest very high precision measurements at CERN on its anomalous magnetic moment, although a tour de force technically, have failed to reveal any significant difference from the electron, apart from its mass and life-time.

Apart though from muon physics there will be an extensive programme of hadron physics undertaken at momenta up to the highest available. Experiments already approved include a comparative study of hadron fragmentation, studies on the production of large transverse momentum leptons and hadrons, and various inelastic scattering phenomena.

From the results that have come out of Batavia since the machine there began to do physics, it seems unlikely that any dramatically new processes will be revealed by other than slow painstaking measurement with a refined and known beam input and good statistics in the detection. In consequence, there is every reason to believe that the four year lee-way between the American and European programmes will be largely compensated by the greater reliability and better beam definition of the SPS.

Fig. 4 The north experimental area. The ejected beam (lower right) goes through a splitter tunnel and target area after which hadron beams are led to the near hall and a muon beam to the far hall.