jection. Friday night and Saturday were spent in tuning up the linac and the transfer line to the synchrotron to produce the negative hydrogen ions which are converted to protons by the 0.25 micron alumina foil in the injection straight. The magnet system was powered DC by the power supply which will provide the bias for the 50 Hz magnet excitation. At 15.10 hrs on Sunday the 15th, a 1.5 microsec pulse of protons, equivalent to about half the circumference of the SNS, had been injected and was seen to circulate for some 300 turns before it became debunched and could not be detected.

A later run repeated the performance and betatron Q-values were measured for different magnet system fields and for different excitation of the Q-correction quadrupoles. The results proved as expected from the design. The magnet system has since been powered with its biassed 50 Hz waveform to the 550 MeV level which will be used as an intermediate energy towards the SNS design of 800 MeV.

The aim is to accelerate to 550 MeV and extract beam by the middle of the year, and to have first neutrons from the complex target station by the end of the year. After obtaining circulating beam at the first attempt, confidence is high.

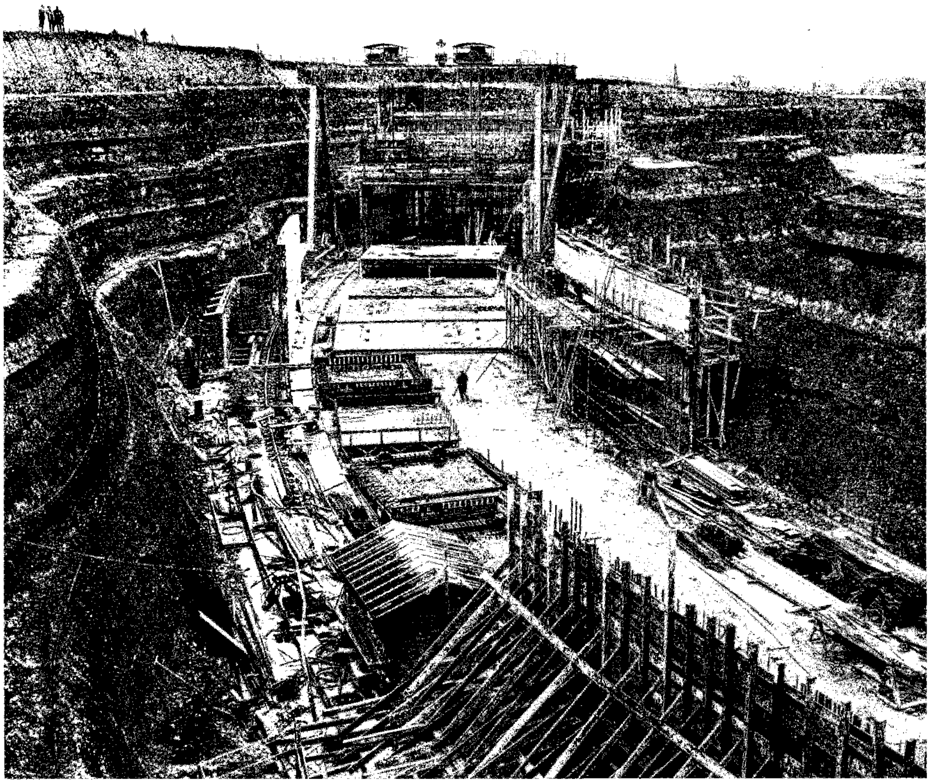
(From David A. Gray)

CERN
A survey of machines

During CERN's 30-year history, the size of particle accelerators and storage rings has increased 50-fold, from a diameter of 200 m for the 28 GeV Proton Synchrotron, to 8.5 km for the LEP electron-positron ring now under construction.

For geodesic work, such a scale explosion is challenging enough on its own. But for particle accelerators, the tolerances on the positioning of the magnets which guide the particles always demand accuracies to within a small fraction of a millimetre. For the geodesists who survey the terrain for these machines and the subsequent installation of their components, this calls for a demanding combination of precision measurement over long distances, frequently under difficult conditions, with literally pinpoint accuracy.

Over the years, the CERN Applied Geodesy / Survey Group under Jean Gervaise has never failed to rise to the occasion, providing solutions which have more than matched the exacting demands of the machine builders. As well as benefiting from technological progress made during this time, the group has made several ingenious contributions of its own, some of which have gone on to be used outside CERN.



Excavation under way for the CERN PS in 1967, showing the enormous amount of earth which has to be moved in such 'cut-and-fill' operations.

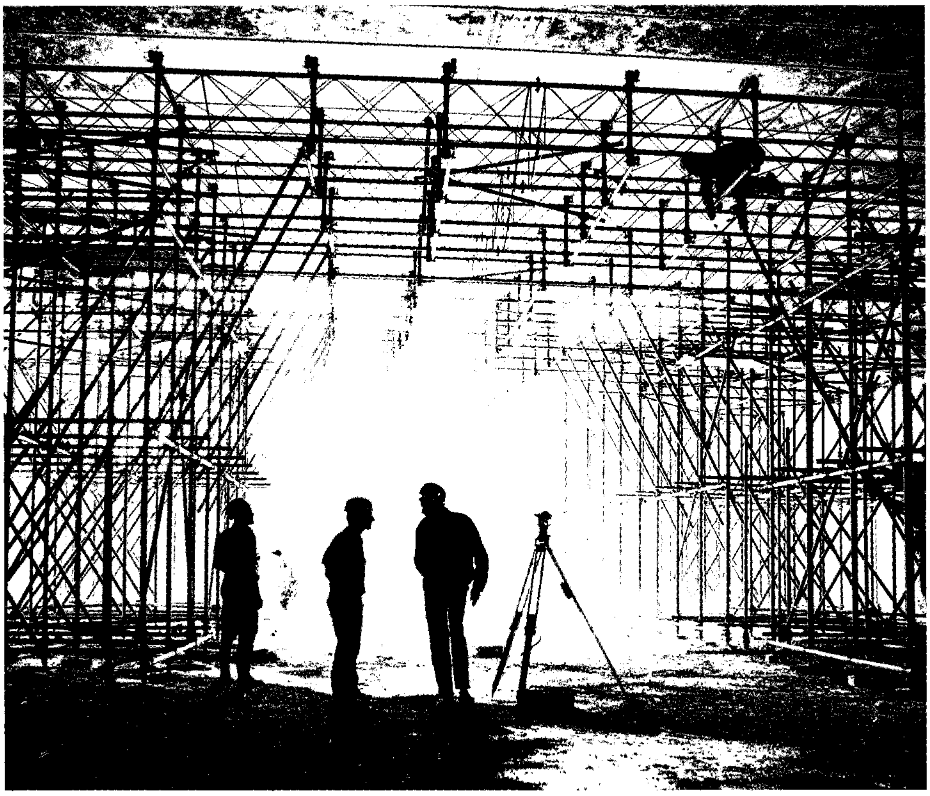
(Photo CERN 301.11.67)

For the construction of all particle machines, a geodetic system has to be set up at the start, and with the ring in place, the magnets then have to be accurately positioned. As tunnels encountered more difficult terrain, it became clear that 'cut-and-fill' was no longer the most economic solution. For bored tunnels, such as for the 450 GeV Super Proton Synchrotron and for LEP, a system is required to guide the tunnel builders.

When the PS was built in the 1950s, things were relatively primitive. Computers were still in their infancy, and least-squares adjustment required patient labour with calculating machines. Geodesy relied on angular measurement with theodolites. Thus for the PS, the geodetic reference system had to be based on the centre of the machine, requiring radial tunnels to permit the angular

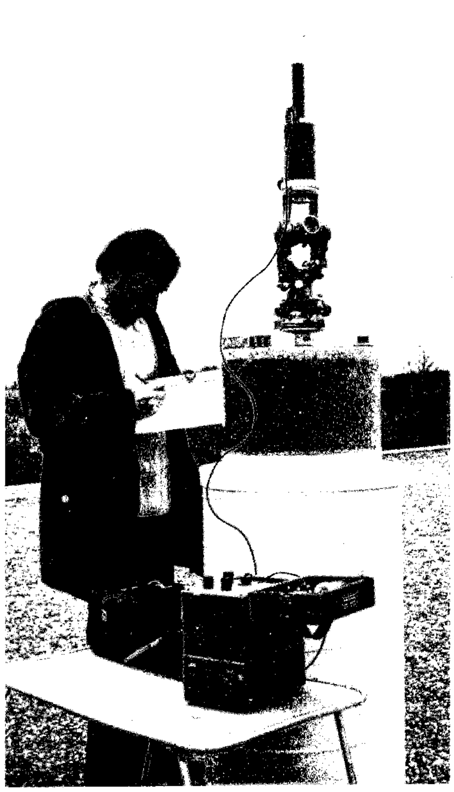
A striking view of the tunnel being built for the CERN Intersecting Storage Rings in 1968. For the ISR, new measurement techniques and the advent of digital computers made their impact on geodetic work.

(Photo CERN 164.4.68)



For the SPS, survey results still had to be written down. LEP data will be recorded automatically.

(Photo CERN 162.1.74)



measurements to be made.

There were other restrictions as well. To avoid temperature gradients which would affect light by refraction, an expensive air conditioning system was installed. At the time, accurate distance measurement was only just making an appearance with the geodimeter (modulated light signals) and the tellurometer (infra-red signals).

For the Intersecting Storage Rings in the 1960s, the availability of new measurement techniques and the advent of powerful digital computers meant that it was no longer necessary to have access to the physical centre of the ring. To meet the ISR construction deadlines, tedious angular measurement was dispensed with, all distances being measured with the 'distinvar', a new automatic precision length measuring device, developed at CERN.

The next episode was the SPS. This work was complicated by several special factors. For the first time, a particle accelerator was to be built in a bored tunnel. This machine moreover would have links to existing machines, and would be built in hilly terrain where altitudes change by up to 50 m over a few kilometres. In addition, the wooded countryside made line-of-sight measurements difficult.

To guide the tunnel boring machines, a gyrotheodolite, using the earth's axis of rotation as reference, was employed. After being improved and automated at CERN, the accuracy possible with this initially awesome instrument was improved by a factor of two.

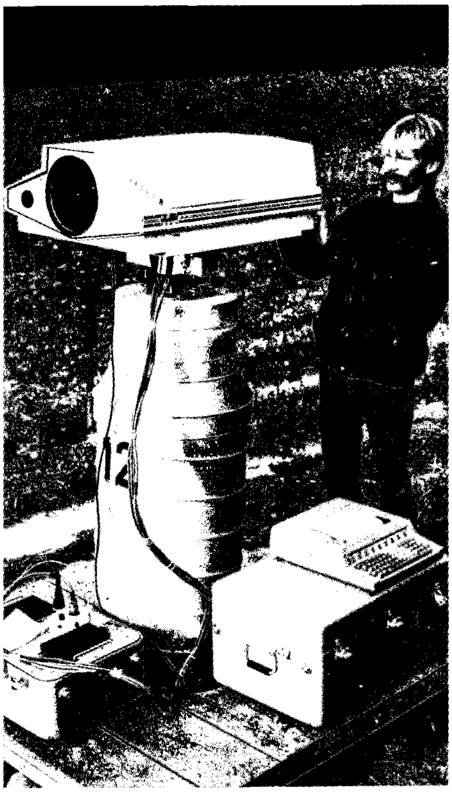
Inside the tunnel, magnets could be sited to within 0.1 mm. When the machine was switched on, the protons were able to circulate without any correction to the orbit, testifying to the remarkable mastery of precision tunnel boring and equipment positioning achieved in the project.

For distances on the LEP scale, additional complications enter. In addition, it is the first machine to be constructed on a slope. But the CERN tradition of supreme precision is nevertheless maintained. To achieve accuracies to within a few parts in ten million, use is made of a 'Terrameter', which takes measurements at two laser frequencies to produce a highly accurate value for the refractive index of air. This avoids the approximations inherent in earlier methods, and is a far cry from the PS, with its air-conditioning system!

Already with the SPS, complications arose due to the curvature of the Earth, requiring slight tilting of the magnets. For LEP, geodetical considerations have to go even further — due to the proximity of mountains and the lake of Geneva, the effective gravitational force changes round

The 'Terrameter' being used for LEP survey work at CERN. This instrument takes simultaneous measurements at two laser frequencies to compute the refractive index of air and permit measurements to a few parts in ten million.

(Photo CERN 125.12.83)



One of the Berkeley contingent in a Berkeley / Corvallis / Studsvik experiment at the CERN Synchro-Cyclotron is Glenn Seaborg, seen here (left) speaking with Chinese Premier Zhao Ziyang (right) when he visited Berkeley during his recent US tour.

(Photo LBL)

the ring, altering the verticals to an extent which produces a variation of over 10 cm across the LEP diameter.

For LEP survey work, manual methods will as far as possible be automated to simplify both the measurement procedures and the recording of the mountain of necessary data. At CERN, a microprocessor-driven unit has been developed which can be used by non-specialists and is programmable in easy-to-use BASIC. Frequently-used routines can be stored in memory and used as required. If necessary, the instrument can communicate with a computer through a standard (RS232) link.

The new techniques developed at CERN over the years have improved the reliability, speed and accuracy of geodetic measurements. Examples are the 'distinvar' device, special magnet alignment jacks, a self-aligning reflector for a laser interferometer, and an alignment system using nylon wire.

Thanks to superb instruments and accumulated expertise, the CERN geodesy experts are able to face each new challenge with confidence.

The new 'forty-niners'

Nucleus-nucleus collisions at intermediate energies (from about 10 - 100 MeV/nucleon) are of great interest to nuclear physicists and chemists. This is a transition region between low energy reaction mechanisms (below 10 MeV/nucleon) with long nuclear mean free paths, and higher energy mechanisms with the short mean free paths of nucleons in nuclear matter.

Increasing the projectile energy from 10 to 100 MeV/nucleon passes several important nuclear milestones (including the velocity of sound in nuclear matter and the Fermi energy) which may trigger changes in reaction mechanisms.

The oldest machine at CERN, the 600 MeV Synchro-Cyclotron (SC), which came into action back in 1957, is playing an important role in these studies. For the past four years, experimental teams from France, West Germany, Sweden, Norway, Denmark and the US have used its intense 85 MeV/nucleon carbon-12 beam to study such diverse phenomena as pion production below threshold, and projectile and target fragmentation.

Recently the SC Accelerator Group has added yet another attraction to the already impressive list of SC heavy-ion options (see next page) with a super intense (500 nA) beam of 49 MeV/nucleon carbon-12 less three electrons. On 9 February, this, the most intense intermediate ener-