

The frozen spin target, in its cryostat, inserted between the poles of the high field magnet. This magnet is situated in one corner of a large volume magnet where the target is moved for experiments.

New record in mental arithmetic

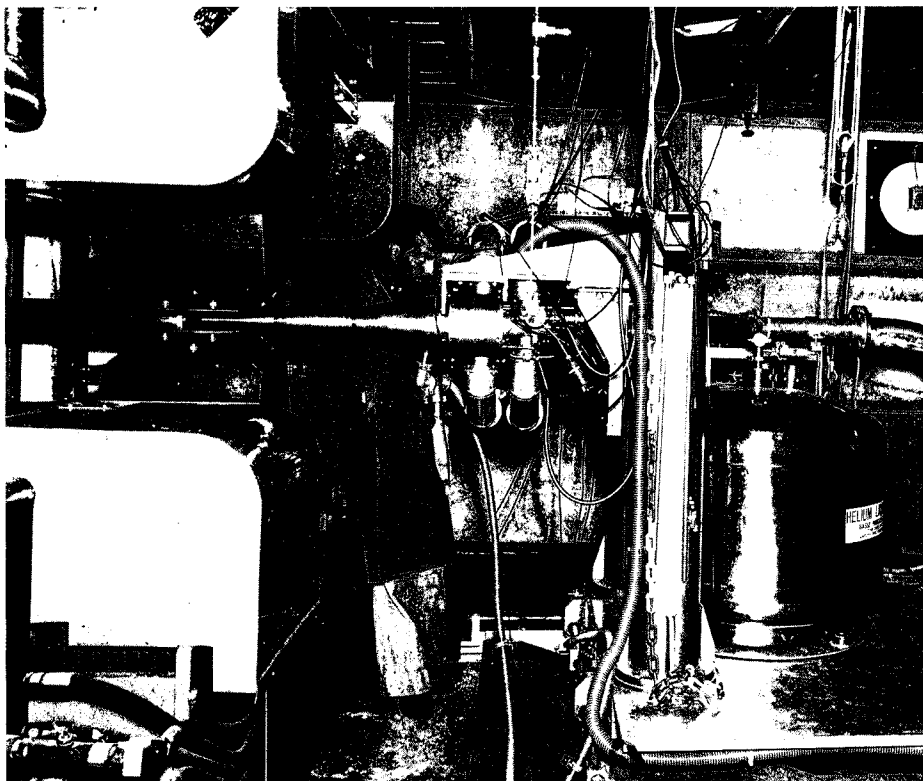
Although in modern scientific circles, the trend is more and more, to reach for the computer when there are any sums to do, there is still one man at CERN who can use his own brain and compete with the electronic usurpers. As a traditional item in the series of lectures given to summer students, Willem Klein demonstrated his powers of mental arithmetic, showing his prowess in memory exercises, rapid calculations, constructing magic squares, and lacing it all with his own special brand of humour. But he kept his pièce de résistance for the end.

In the September, 1973, issue (page 258) we reported his extraction of the 19th root of a 133-digit number. This year he wanted to go one better.

Six papers were passed around among the audience, on which members wrote down one figure. The six-digit number thus composed was fed into a computer which, somewhat laboriously, multiplied the number by itself thirty-seven times to give a 220-digit number. A team of people was needed to write this down on the row of blackboards, lined up side by side. Willem Klein then turned around to look at the number and, three minutes and twenty-six seconds later, he staggered the audience by writing out the six figures of the 37th root — figures confirmed by the computer and by the members of the audience who had selected them.

Frozen spins

The construction of a frozen spin target at CERN was proposed in November 1971 based on preliminary investigations described in CERN COURIER vol. 11, p. 353. One of the difficulties of traditional polarized



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targets — that is targets in which as many protons as possible are lined up in a particular direction — is that the target has to be contained between the poles of a very strong magnet and the space around in which detectors can be set up is rather limited.

In the frozen spin system, the target is first polarized dynamically at near zero temperatures in an intense uniform field of 2.5 T by irradiating it with microwaves. The microwaves are then switched off, following which the target cools still further and it can now be moved gently into a less intense and less uniform field of about 1.0 T. This field is created by a magnet with a large volume between the pole pieces, which can be filled with detectors covering a solid angle of almost 4π . The temperature of the target during the irradiation is about 0.5 K settling to 0.05 K when the microwave power is cut off and the target has been moved into the beam.

At such a temperature the target remains almost permanently polarized.

The large volume magnet employed is the old ETH magnet, which has had a long and honourable career at CERN. Within it, over to one corner, the polarizing magnet has been built. The target, 15 cm long and 1.6 cm diameter consists of small propanediol spheres which are loaded into the cryostat at liquid nitrogen temperatures. During tests in July, less than 1 % decay in polarization was observed in a target which had been polarized to some 90 %, moved into the main magnet volume, kept there for eight hours and then returned.

Crucial to the operation of the system is the design of the dilution refrigerator which was developed by T. Niinikoski in the Low Temperature Laboratory of Helsinki University of Technology, while the other cryogenic components, the pumping system, the transport mechanism and the

The two types of conductor used for the BEBC coils. Two companies, Siemens and Thomson-Houston, had shared the manufacturing of the conductor, applying different techniques. The photo shows the different geometrical arrangement of the superconducting filaments in the copper strip; the electrical properties of both types are almost identical.



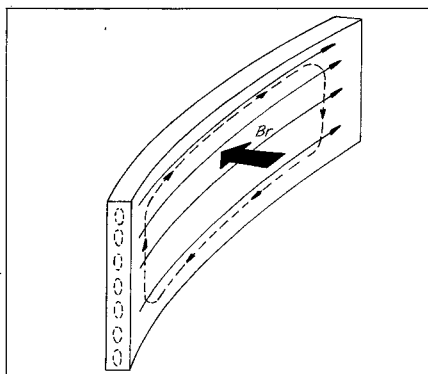
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NMR electronics were made at CERN.

Targets of up to 50 cm³ volume can be accommodated in the cryostat. Through it ³He is circulated at a rate of 25 mmol/s which allows 100 mW of microwave power to be fed in without the temperature exceeding 500 mK. Polarization rates of 15 %/minute have been observed. The rate of cooling is such that after polarizing, 100 mK is achieved in three minutes and 50 mK in eight minutes. The lowest temperature so far attained is below 15 mK but the precise value can not be measured with the present thermometer system. The cryostat works smoothly with no tendency towards instabilities or oscillations under normal operation and it is insensitive to the rapid magnetic field variations to which it is subjected when being moved.

The first experiment to be done with the Frozen Spin Target is the measurement of all the spin para-

This drawing illustrates a simplified model of the persistent currents. The transport current flows through the superconducting filaments (full lines). The radial component of the magnetic field (B_r) penetrates the conductor strip through the side and induces eddy currents which are superimposed on the transport current. The simplest model assumes that the induced currents are concentrated along the edges of the conductor, flowing in one direction along the upper edge and in the opposite direction along the lower one (dashed lines).



meters, P, A and R in the reaction $\pi^- p \rightarrow K^0 \Lambda$ when the Λ emerges in the backward direction and the incident pion beam has a momentum of 5 GeV/c. The incoming beam, which comes to the target along the axis of the cryostat, is monitored by two silicon diodes mounted inside the cryostat where they operate at a temperature of 1 K. An array of optical spark chambers viewed by seven TV cameras, and scintillation counters record the emerging particles. The experiment is a collaboration between CERN, ETH Zurich, Helsinki University of Technology, Imperial College London and Southampton University.

Persistent currents in the BEBC magnet

As previously reported (see March p. 78 and June, p. 170), the magnet of BEBC, the 3.70 m bubble chamber, has since last March been systematically taken to pieces because of intermittent short-circuits between the non-superconducting auxiliary wires and the coils and earth. This did not prevent the magnet from reaching its design field.

After the coils had been examined, various theories were put forward to explain the causes of the short circuits, and we shall now summarize the situation.

General layout of the conductor

The BEBC conductor was a major development in superconducting technology at the time of its design and manufacture in the years 1966-1969. It was Europe's first large scale industrial production, and involved 65 km of strip with more than 200 Nb Ti wires (200 μ m diameter) in unit lengths of 1.5 km (see photo). This type of flat, untwisted conductor has a high aspect ratio (61 mm high by 3 mm thick) for side cooling and reflected the state of the art of manufacturing high d.c. current fully stabilized conductors at that time. Since then, the advanced requirements for pulsed applications have stimulated the development of new types of conductors with twisted filaments. In the meantime, evidence has been accumulating on the existence of the so called 'persistent eddy currents' in d.c. systems.

Origin of persistent currents

In service the conductor usually sees not only the axial (useful) field of the magnet but also a radial field, the strength of which at any point depends on the position of that bit of the conductor relative to the whole coil. The radial field is perpendicular to the flat faces of the conductor. Variations in the field, for example during charging or discharging of the magnet, change the magnetic flux, and induce eddy currents as illustrated in the drawing. If one takes a very simple model, these currents follow the superconducting filaments, the circuit being closed by short bridges in the copper substrate. The induced currents may be very large for a given flux variation, and may be as high as the critical current of the individual filaments. The decay time of the currents is very long, due to the low resistance of copper at a