

The linac beam emittance as it appears on a TV screen. A new very rapid system of emittance monitoring is described in the article.

The diagram illustrates the units of the system. Magnets (A) deflect the beam across a slit (B). A focusing arrangement (C) precedes an array of 20 Faraday cup detectors (D) and electronics (E) link the system to a computer. Applying triangular pulses in opposite polarity to the magnets K1 and K2 causes the beam to sweep across the slit in 10 μ s.

pulses it is not possible to obtain very exact data on the beam.

The new system is being developed to give automatic measurement of the beam emittance taking only 10 μ s per pulse. This will not only use much less of the beam, but will also allow a more exact and rapid determination of beam characteristics. This will be particularly important when the Booster is commissioned, both because the Linac-Booster injection line is more complex than that between the Linac and the PS, and also because very accurate beam emittance adjustment will be necessary.

The new system will be linked to an on-line computer for direct data processing. The design principles are illustrated in the diagram.

The mechanically operated slit is replaced by a fixed slit, and the beam is deflected radially by means of two magnets excited in opposite polarity by a triangular pulse. The beam is thus made to sweep across the aperture in 10 μ s. Through a focusing arrangement the beam is then directed onto a series of twenty thin elongated (1 mm $\times$ 80 mm) Faraday cups. With one sweep of the beam over the slit lasting only 10 μ s it will be possible to select a part of the linac pulse (which lasts 20 μ s at present, and is to be extended to 100 μ s in the course of the PS Improvement Programme).

The optics of the focusing system between the slit and the Faraday cups are such that, from the signals received, the emittance of the beam and other beam characteristics such as the charge distribution over the beam cross-section, can be calculated (the voltage signal from the Faraday cups is proportional to the beam

intensity). The signal from the Faraday cups will be divided into twenty 0.5 μ s pulses, each giving an integrated value of the signal received in this time interval. This process will be controlled by a quartz crystal oscillator.

The number of 20 readings (10 μ s divided by 0.5 μ s) and of 20 Faraday cups were chosen arbitrarily, and could be made higher; they do, however, ensure sufficient accuracy (400 separate measurements). The emittance ellipse and the main parameters can be displayed on a TV screen.

The system can be used for measurements on high intensity beams, provided that corrections are made for the effect of space charge which arises between the slit and the cups.

The system opens two novel possibilities:

1. The voltage from the Faraday cups can be compared with a standard voltage of opposite sign so that a signal will then appear only above a certain threshold. Hence, by selecting the level of the standard voltage, it is possible to determine emittance ellipses corresponding to different proton densities, or to determine the beam intensity within a given emittance.

2. It is also possible, by a little readjustment of the focusing system, to obtain a zooming effect, as in a variable-focus camera, and to 'magnify' a chosen emittance area for more detailed study.

The new system is scheduled to be installed by the spring of 1971. It will be used on a special beam line, at the output end of the linac, so designed that its characteristics correspond exactly to those of the main beam. In conjunction with it

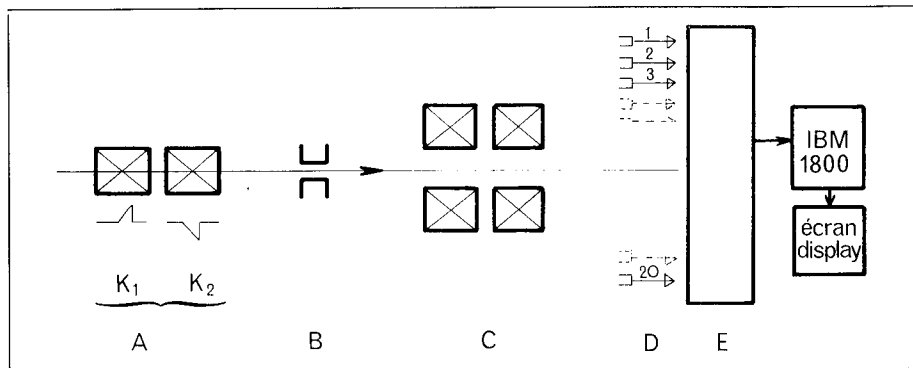
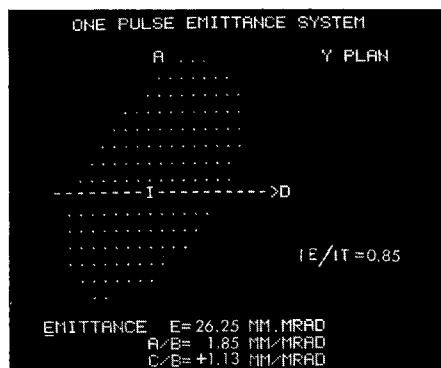
will be installed a system for measuring the energy spread which we shall be discussing shortly. At a later stage it is planned to control the beam automatically, by a servo-loop fed by data from the systems measuring emittance and energy spread.

A system involving the use of an on-line computer for the rapid calculation and display of beam emittance and proton density characteristics is in use at Batavia during the commissioning of their 200 MeV linac and an equivalent system is also being developed for LAMPF at Los Alamos.

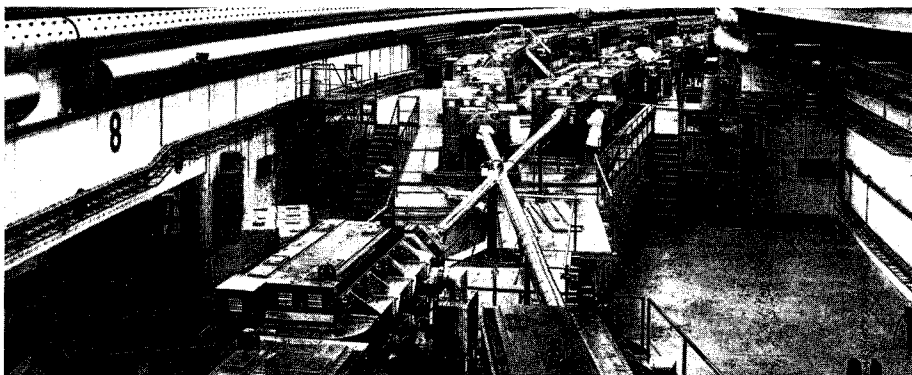
Beam to ISR

On 3 September, a 15 GeV proton beam was passed for the first time from the PS along the full length of a transfer channel (TT2) to the ISR. It crossed the frontier without the usual customs formalities through a 450 m long underground tunnel and finished in a concrete block placed at the entrance to the storage rings. The block is being used temporarily to absorb the beam until things are ready for injection into a ring of the ISR themselves. The positioning of the beam at this point was achieved with an accuracy of 5 mm in both the horizontal and vertical planes. This was also the first time that a proton beam of this energy had travelled over French territory — the most powerful up to then being the 3 GeV proton beams at Saturne.

The accuracy of beam positioning, remarkable for a first shot, stems from all from the precise alignment (to within one or two tenths of a millimetre) of the



By the middle of September three of the intersection regions of the ISR were equipped with their vacuum chambers. The photographs from top to bottom are of 18, 12 and 16. By the end of October it is scheduled to have the vacuum chambers in all eight intersection regions and one ring will be 'closed' and baked out. Completion and baking out of the second ring will follow soon after.



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70 magnetic elements in the transfer lines; this was in itself an achievement as, unlike the situation in normal accelerators, it was necessary to align in three-dimensions since the transfer channels climb up a gradient rising 11.4 m between the PS and the ISR. The performance of the bending magnets (Alsthom), and focusing lenses (Brown Boveri), and of the power supplies (Brentford Electric) also contributed to this high accuracy.

Hitherto the beam had been confined to a 30 m long section adjacent to the PS (CERN COURIER vol. 10, page 147) where since April 1970 a series of tests has been carried out, enabling the finishing touches to be applied to the power supplies and their remote control and also to the beam detectors. The power supplies (of which there are 30 as some elements are connected in series) are linked to the ISR Argus computer. For the time being the computer is used to set up the beam-line conditions and not to control them via a feedback loop, although it is planned to introduce control at a later stage in a semi-automatic mode.

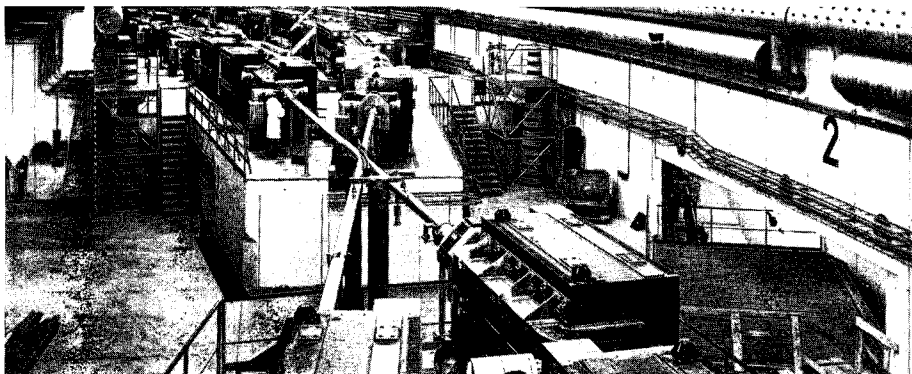
Intensity losses along the transfer line have been almost non-existent (not detectable). This has enabled work in the channels to be continued without problems due to induced radioactivity.

At the end of September channel TTI (400 m) is due to take a beam along its full length. Both transfer channels will then be ready to feed proton beams into the rings of the ISR. First injection into the ISR is planned for this coming November.

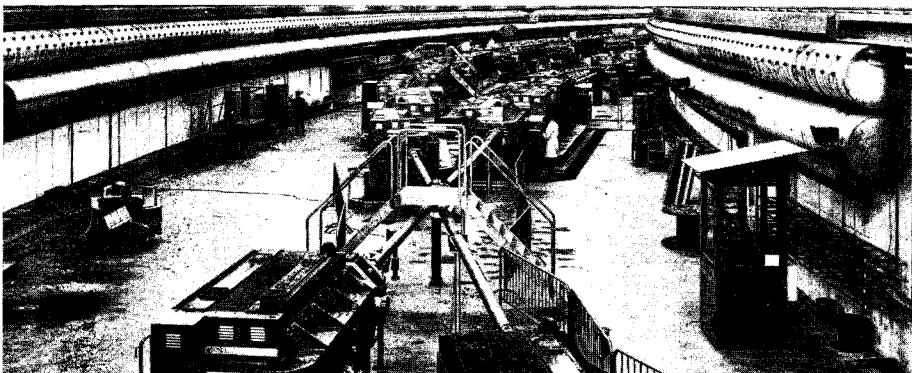
Small superconducting lenses

In connection with the development of a negative hyperon beam which could provide the basis for an important series of experiments (involving collaboration between Orsay, the Ecole Polytechnique and CERN), the Engineering Group of the Nuclear Physics Division have designed two superconducting quadrupole lenses. The quadrupoles are now being constructed.

In view of the short lifetime of hyperons, and especially of the sigma minus whose mean free path does not exceed 60 cm at 16 GeV/c, it is desirable to make the



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beam line between the target where the hyperons are produced and the detectors as short as possible. The aim was therefore to construct short quadrupoles, giving a high field gradient and having an external diameter small enough to be accommodated in the space between the coils of two larger magnets used for deflecting the beam.

The two quadrupoles, respectively 30 cm and 60 cm in length, have cobalt-steel cores, which means that a field of 25 kG can be produced at the poles without reaching saturation. The field gradient is designed to be 11 kG/cm. The external diameter of both lenses is 13.5 cm with an aperture for the beam of 3 cm.

The superconductor is of the intrinsically stable type and is supplied by IMI (UK). It is 0.5 mm in diameter and contains 61 twisted niobium-titanium filaments of 50 micron diameter, carrying a current of 120 A (i.e. a current density of approximately 40 000 A/cm²). With conventional coils the current density would be several times smaller, necessitating physically larger lenses which could not have been fitted into the beam line.

The superconducting coils with their cobalt-steel cores are immersed in liquid helium (4.2° K at atmospheric pressure) in a thin-walled cryostat. Heat shields cooled by liquid nitrogen reduce radiation heat losses.

Since the quantities of helium in the cryostats are very small it is proposed to feed in the helium continuously through a long transfer line. The daily helium consumption is estimated at 100 litres, the gas being recovered.

Correction

A correction needs to be made to the information given in the August issue:

In reviewing the experimental programme at Serpukhov (page 258) we mentioned that a link between the small computer on-line to the CERN-Serpukhov missing mass experiment, and the main Serpukhov computer (BEMC 6) was being developed. The computer which is on-line at Serpukhov is an IBM 1800 not, as was stated, a CDC 3100.