THE USE OF A SECONDARY EMISSION MONITOR IN THE EXTRACTION CHANNEL OF THE CERN SYNCHRO-CYCLOTRON

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Abstract

In order to understand and check the performance of the new extraction system of the CERN SC it was decided that measurements of the beam profile should be made at a number of positions along the channel. For this purpose secondary emission monitors of a novel design were installed, both fixed in the channel and able to be moved remotely in front of the septum.

Introduction

One of the important elements in the improvement programme of the CERN synchro-cyclotron[1])[2]) was the installation of a new extraction system[3]) designed to allow a very high proportion of the accelerated protons to be extracted from the accelerator. The improvement programme has recently been successfully concluded and extraction efficiencies of greater than 70% have been achieved[4]).

The successful extraction system[4]) consists of an active section, a curved septum carrying 12,000 amperes forming part of a co-axial coil, followed by a passive iron channel. The protons are accelerated to 600 MeV in the accelerator and then feel a magnetic field bump due to the regenerator[3]) causing them to be deflected into the first, active section of the extraction channel; they thence pass into the passive iron channel, itself consisting of three adjustable sections such that the protons emerge on the correct axis on leaving the accelerator.

In order to understand how the extraction system was functioning it was necessary to make measurements of the beam profile at various places along the channel. The aim was to measure the angle with which the beam entered the extraction system, its size on entering, and its profile as it entered the passive part of the channel; by varying the channel parameters (e.g. regenerator position, septum position, septum current, etc.) the whole system could then be studied and the extraction efficiency optimized using an external monitor of the extracted current.

The Monitors

It was decided to use secondary emission monitors for the measurements in the extraction channel. Although these are standard equipment at large accelerators, the difficulty for the present application was the severe space restriction which meant that any monitor had to be no longer than 15 mm in the beam direction and it had to function in close proximity to numerous earthed metal surfaces. The presence of a large vertical magnetic field throughout the extraction channel region (up to ~18 Kgauss) was utilised in the monitors' design, but there were worries originally about the possible presence of r.f. noise signals due to stray field from the dee. In practice, however, this was not a problem.

A photograph of the monitor is shown in Fig. 1. The only acceptable geometry

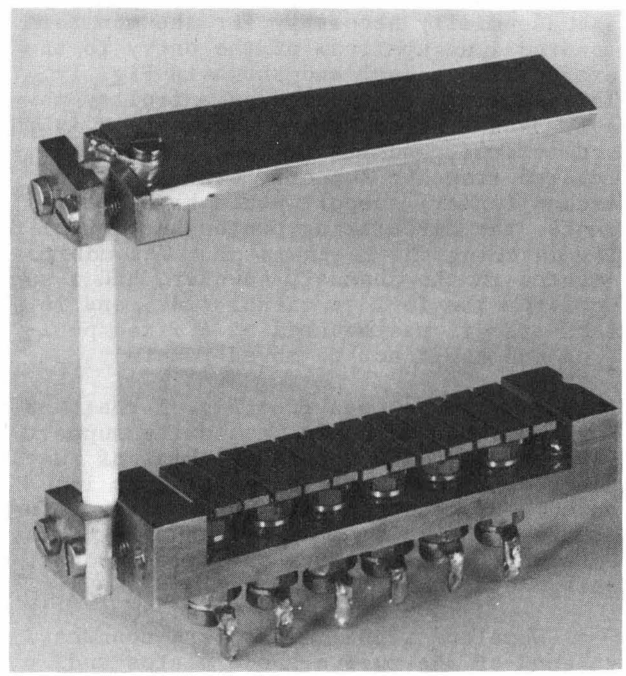

Fig. 1 : The secondary emission monitor

consisted of a thin aluminium foil placed in the beam and inclined to it at 15°, which acted as the source of secondary electrons; the foil was 0.15 mm thick and 10 mm long in the beam direction, and its

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inclination meant that it intercepted only about 25% of the vertical spread of the beam. The foil is seen at the top of the photograph and was not simply a flat foil but was bent at the edges to give it rigidity.

Electrons escaped from the foil, forming tight spirals in the vertical magnetic field until they were collected on the anode surface placed 40 mm vertically below the emitting foil. There were in fact twelve separate, brass anodes, each 3 mm wide and 10 mm long, and placed side by side transverse to the beam direction with gaps of 0.5 mm. Thus the monitor was a multi-channel device fed from a single emitting foil, with the result that a horizontal (radial) beam profile was obtained directly for that portion of the vertical beam distribution intercepted by the foil.

The angle of the foil (15°) was chosen as a compromise between the desire for the electrons emitted from the surface not to be recaptured after one spiral orbit, and the need to keep the foil thin in the beam direction to avoid over-heating. As mentioned above, the foils were in fact corrugated to give them some rigidity, which was especially necessary for the monitor mounted just upstream of the entry to the extraction channel and shown in Fig. 1. This monitor was mounted on a trolley movable both vertically and azimuthally in the accelerator, and its foil had to be cantilevered from one support, otherwise the second (inner) support would have interrupted the circulating proton beam prior to its entering the regenerator. The monitor mounted in the channel, however, had a support for the foil at either side, and in this case it was mounted at a fixed position and could not be moved remotely.

It will be seen from Fig. 1 that the foil was mounted on an insulating support in order to allow a positive bias of some hundreds of volts to be applied, as is normal in secondary emission monitors. In practice, however, it was found that this bias was not necessary, sufficient signal being obtained without it.

Shielded signal leads were connected to each of the twelve anode plates and thence via a vacuum feedthrough to an electronics rack situated at about 20 m from the monitors. Here the signals were amplified by FET input d.C. amplifiers and the twelve analogue outputs multiplexed at a suitable frequency to an oscilloscope display in the main control room a further 150 m distant. A block diagram of the electronics is shown in Fig. 2.

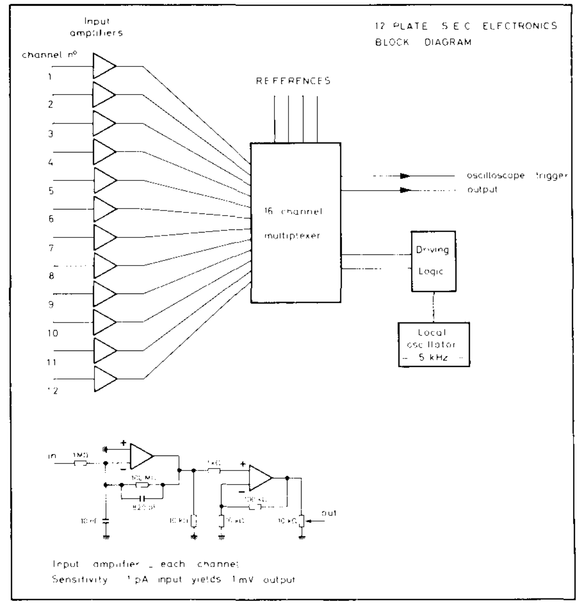

Fig. 2 : Block diagram of electronics

Results

Typical shapes of the observed beam profile in the extraction channel region are shown in Figs. 3 and 4. Each photograph shows essentially a histogram of the beam intensity in the median plane of the accelerator, as a function of radial position across the gap of the extraction channel; in both cases the left side of the picture is towards the centre of the accelerator.

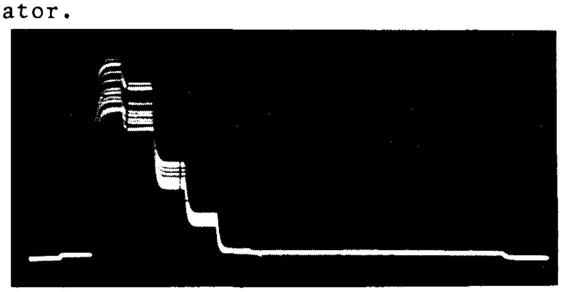

Fig. 3 : Typical CRO display taken just in front of septum

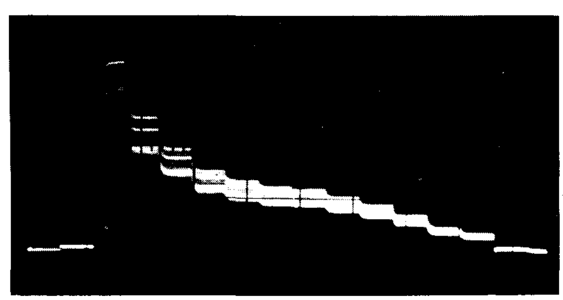

Fig. 4 : Display taken upstream of that shown in Fig. 3

Both these photographs were taken .sing the monitor in front of the first ·lement of the extraction system, the sep- .um. Fig. 3 shows a typical distribution mmediately before the septum, where the 'irst few channels show the beam prior to ·egeneration, the septum is in channel 5, .nd the intensity drops monotonically hereafter, filling most of the channel. 'ig. 4 shows the situation about 50 cm .pstream, where the monitor has been posi- ioned so that the foil intercepts the irculating beam as well as the beam after egeneration, seen as a tail to the right. he absence of signal in the higher chan- els was real and could be used as a check hat the system was working correctly, ince the beam could be put in any channel y appropriately positioning the trolley arrying the monitor. The spread in the ignal levels observed in each channel was ue to beam instabilities rather than to oise pick-up, but it did not prevent quan- itative measurements being made; in fact he beam was scanned vertically and an in- egration performed in each channel.

The results obtained with this monitor positioned at various azimuthal positions nd for various heights in the beam) demon- trated that the extraction system was 'unctioning as predicted; the details are iven in Ref. [4]).

The other monitor, mounted in the hannel, between the septum and the iron hannel, did not function as well as the 'irst one, being very much less stable. 'onsequently it was used in a qualitative ay to demonstrate that the beam did in 'act fill the channel according to predic- ions.

A typical example of the distribution nside the channel as seen by the second ıonitor is shown in Fig. 5.

'ig. 5 : Distribution inside the channel

Conclusion

These secondary emission monitors performed well in the cyclotron and they allowed the demonstration that the extraction system was working as predicted.

References

[1]) MSC Staff, Proc. 5th International Cyclotron Conference, Oxford, 1969, p.719

[2]) E. G. Michaelis, AIP Conference Proceedings No. 9, Cyclotrons 1972, p.141

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[4]) B. Allardyce, R. Giannini, B. Hedin, A. Susini, N. Vogt-Nilsen, S. Lindbäck and P. Mandrillon, contribution to this conference, D.38