BEAM DIAGNOSTICS IN THE RING CYCLOTRON

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Abstract

Beam diagnostic components are newly designed for the ring cyclotron. They are distributed over the beam injection or extraction line and in the acceleration chamber.

Injection line

The beam from the AVF cyclotron, which is selected in momentum, emittance and in phase, enters the ring cyclotron. There are two variable width slits (VSL-1,-2), three three-wire-profile monitors (TPM-1,-2,-3), one emittance monitor system(ESL+EPM) and one phase probe (PP-INJ) in the beam injection hall.

The beam shapes in transversal phase space are defined by the VSL-1, and -2 to fit the eigenellipse of the beam of the ring cyclotron. The transverse beam shape and position are measured with the TPM-1, -2 and -3, while the beam emittance both in horizontal and vertical planes are measured with a single slit (ESL) and a harp-type monitor (EPM).

At the entrance of the valley chamber of the ring cyclotron, TPM-4, TV-monitor (TVM-INJ) and the beam stop (BS-INJ) are located, housed in the one unit of a diagnostic chamber. The beam is investigated in size and position once more with the TPM-4 and TVM-INJ. When necessary, the beam is interrupted by BS-INJ. The actual phase of the beam from the AVF cyclotron relative to the acceleration r.f., is measured by the non-intercepting capacitive pick-up (PP-INJ).

In the valley chamber, a fast rotary scanner (RPM-INJ) driven by a supersonic motor is used for the beam to travel to the bending magnet (BM-2) through a narrow space between EIC-1 and EIC-2.

Beam diagnostic components distributed along the beam injection line up to the 1st sector magnet are shown in Fig. 1.

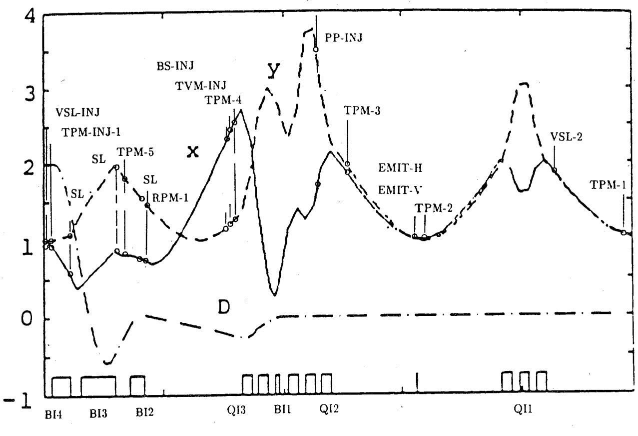

Fig. 1. Beam diagnostic components distributed along the beam injection line up to the 1st sector magnet. They are shown with calculated beam envelopes. Horizontal and vertical beam envelopes are described in x and y respectively.

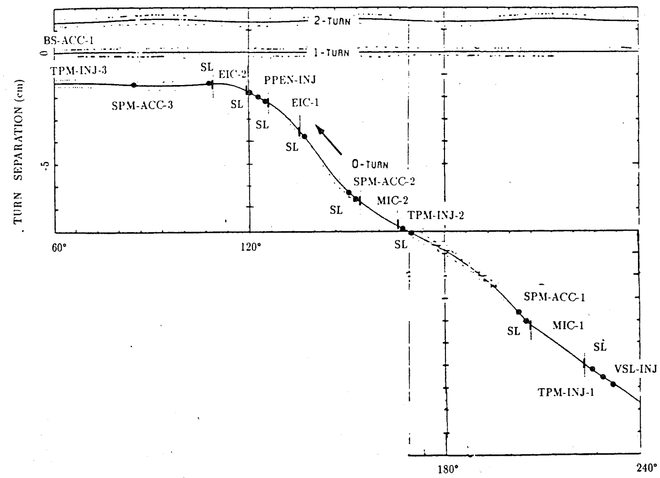

Fig. 2. Beam diagnostic components along the beam injection orbit. Injection line, 1st-turn and 2nd-turn in a half part of full orbit are shown to clear the turn separation between them.

They are located at efficient points for the various beam diagnositcs, as they are expected positions from the calculated optics[1].

Injection Orbit

At the entrance of the first magnetic inflection channel (MIC-1), the beam should match the eigenellipses of the accelerator orbit. To define the beam size correctly, the horizontal and vertical beam widths are redefined with a horizontal slit with variable width (VSL-INJ) and a vertical slit with a fixed width (FSL-INJ). These are combined with a profile monitor (TPM-INJ-1,-2). At the entrances and exits of the two magnetic inflection channels, buffer slits are also installed as diagnostic devices in the horizontal plane (SL-5 $\sim$ 12). To measure the vertical positions of the beam, single-wire profile monitors (SPM-ACC-1,-2,-3) are available. Fig. 2 shows these diagnostic components on the injection orbit.

Energy-Phase Probe (PPEN-INJ,EXT)

The energy-phase probe is prepared to measure the time structure of the beam at the radius of the injection orbit and to measure the correlation of the beam phase and beam radius (energy)[2]. The same device is installed in the extraction orbit to observe the beam phase at final few turns. A thin single wire target is driven radially. Scattered particles are detected by a plastic scintillator. The time interval between the particle signal and r.f. of the accelerator is measured with a time to pulse height converter and the signals are processed digitally. Two dimensional (time-radius) analysis becomes available.

All these monitors are to be used while the beam is stopping at the beam stop (BS-ACC-1).

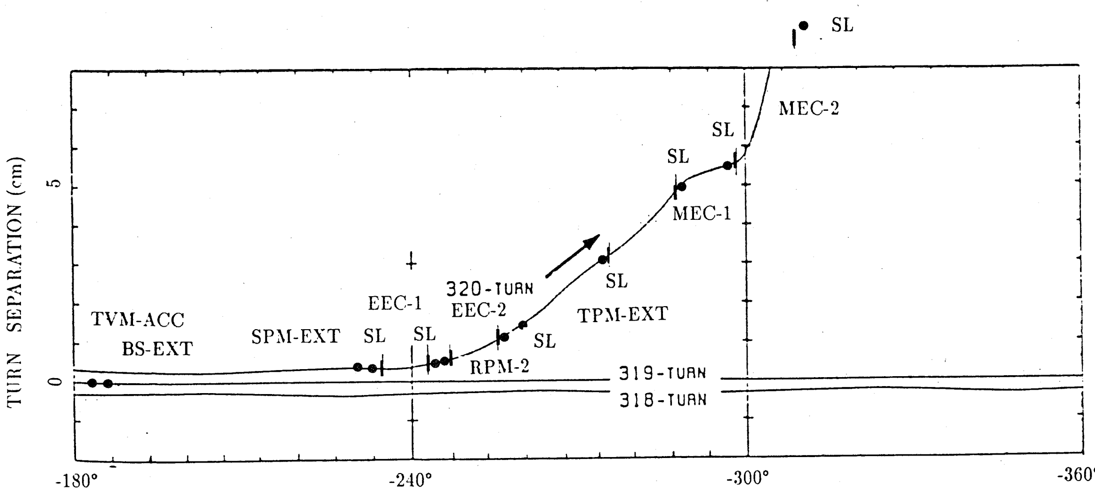

Fig. 3. Beam diagnostic components along the extraction orbit. The beam extraction orbit (320-turn) and the last accelerated orbit (319-turn) and the 318-turn are shown to clear the turn separation between them.

Acceleration Orbit

In the valley chamber, there are several beam diagnostic devices for the accelerating beam; main probe (M.P), phase probe (PP-ACC) and three additional beam stops (BS-ACC-2,-3,-4).

Extraction Orbit

Along the extraction orbit, several types of beam diagnostics devices are located; single-wire energy-phase monitor (PPEN-EXT), TV-monitor (TVM-ACC), beam stop (BS-ACC-5), single-wire profile monitor (SPM-EXT), a fast rotary scanner (RPM-EXT), and three-wire profile monitor (TPM-EXT). The TPM and the RPM are used to measure the orbit separation and beam width, while the SPM set in front of the first extraction channel is used to see whether the separation is sufficient for the septum. Buffer slits (SL-13 ~ 20) for all the extraction elements are helpful to protect these elements and to guide the beam correctly. All these components are shown in Fig. 3.

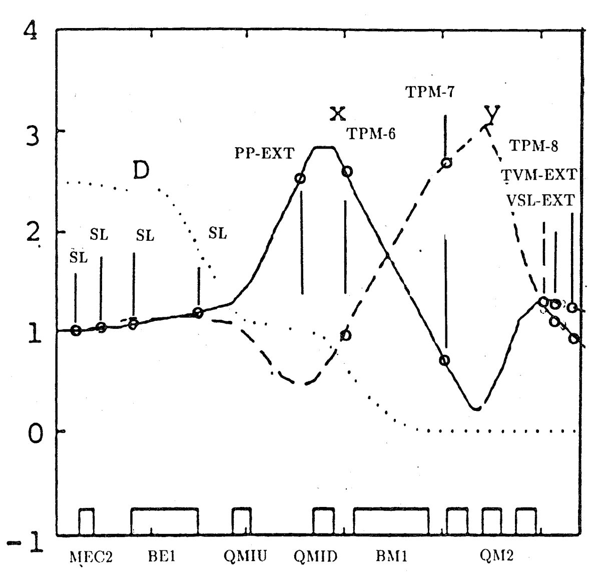

Fig. 4. Typical beam optics from the extraction system of the SSC to the transfer point (right extreme in this figure) of the further beam transport. By scanning the current of the quadrupole magnets and by using two or three TPMs the transverse beam emittance can be measured.

The extracted beam is finally monitored with three TPM (TPM-6, -7, -8), variable width slits (VSL-EXT), phase probe (PP-EXT) and TV-monitor (TVM-EXT). They are shown in Fig. 4.

By scanning the current of the quadrupole magnets and by using two or three TPMs the transverse beam emittance can be measured.[3].

Main Probe (MP)

A main probe measures the current and the transverse shape of the beam in the cyclotron. It consists of a tomography head of three thin wires (W) and an indirectly cooled beam stop. The probe can be adjusted for the head to face the tangential direction of the beam orbit at any radius. The driving speeds can be chosen between 20 mm/sec and 200 mm/sec.

Beam Stop (BS)

There are two types of beam-stops; differential type in injection or extraction orbit and integral type in the accelerator chamber. These are set at the radius of r=2000, 2395, 2872, 3350 and 4000 mm. At minimum and maximum radii two beam stops can be moved in radial direction about a few tens mm. And the other three stops can be moved pneumatically up and down. All the heads are thick enough to stop the beam at each radius. The total beam current intercepted can be measured. These stops are used to optimize the accelerator condition without serious activation of other accelerator components.

Phase Probe

The beam phases relative to the accelerator r.f. phase are measured by eight capacitive phase detectors, mounted on a single carriage, separated by 300 mm from each other. They are installed along the line at the same azimuthal position as each accelerating gap between the sectors. They cover the full

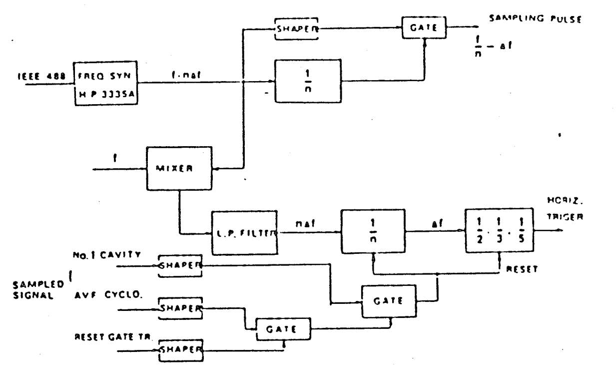

Fig. 5. Circuits for sampling pulses and horizontal trigger pulses.

radius continuously by driving the carriage. One unit of the detector has two electrodes (upper and lower).

The beam phases are measured by the sampling method. Sampling pulses and horizontal trigger pulses are generated by the circuits shown in Fig. 5. The sampled signals are digitally processed with a digital oscilloscope and transmitted the computer control system.

We have tested some components of the diagnostic instruments as mentioned above.

i) In order to move the single wire up and down in the magnet vacuum chamber (SPM-ACC-1,-2,-3), ferrofluidic seals are considered for use. We examined two types of the seals in the presence of the strong magnetic field. One of them showed the clear defect; the vacuum leak started at the magnetic field about 100 Gauss. The other was stably operated at more than 600 Gauss.

ii) The supersonic motor without water cooling was found usable at the magnetic field of 1.6 kG inside the vacuum chamber.

The total beam diagnostic components are shown in Fig. 6.

References

1) A. Ando, RCNP Annual Report (1987).

2) S. Adam and M. Humbel, Proc. of the 11th International Conference on Cyclotrons and their Applications, Tokyo, Japan, Oct., 1986, p.418.

3) P. Strahl, Proc. of the 9th International Conference on Cyclotrons and their Applications, Caen, France, Sep., 1981, p.545.

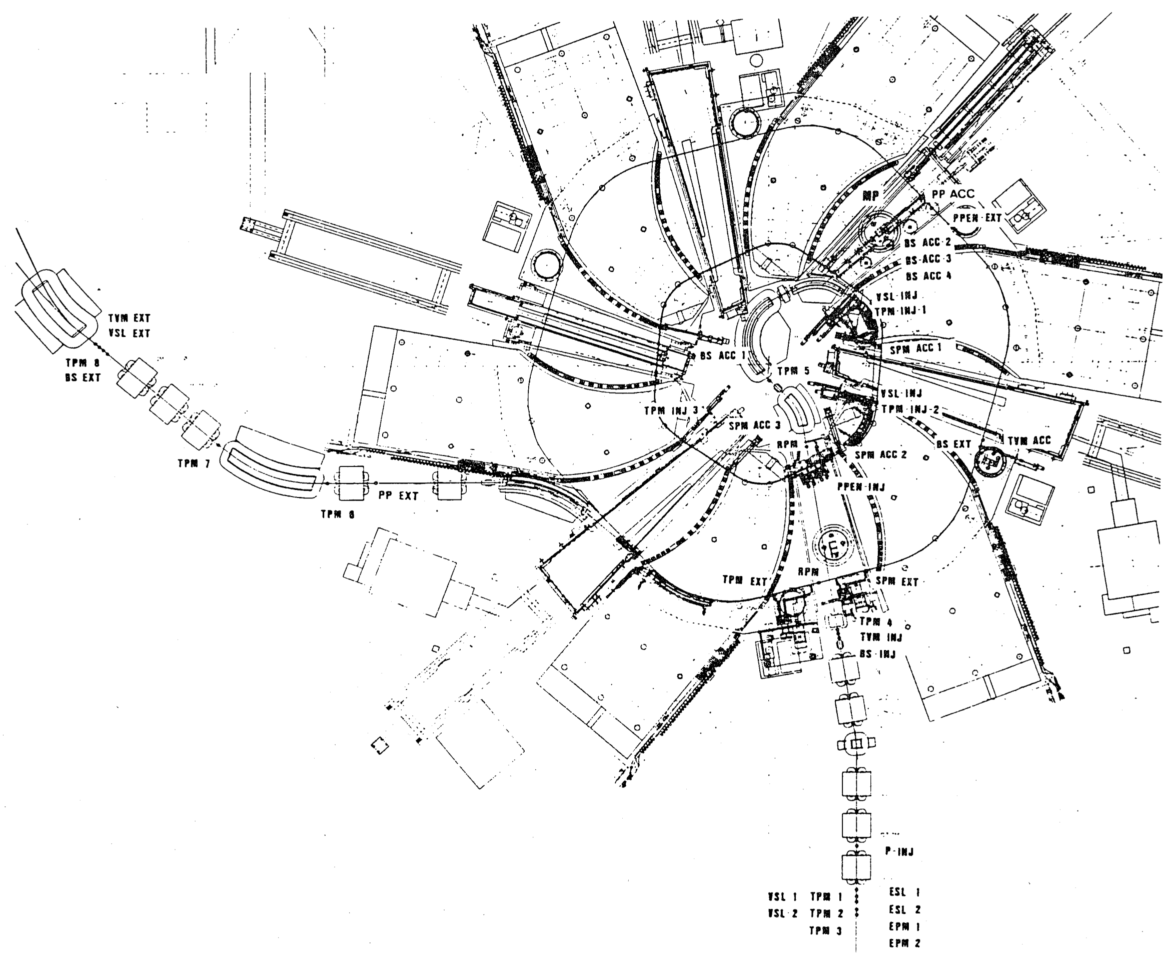

Fig. 6. The layout of the beam diagnostic components.