TRAJECTORY MEASUREMENT OF BUNCHES EJECTED FROM THE CERN PSB

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Abstract

The transfer line of the PS Booster(PSB) recombines beams from the 4 vertically stacked rings of the PSB and sends them to 1 of 3 possible destinations: the 26 GeV PS, ISOLDE, or the measurement line. To acquire the transverse positions of the beam, 18 electrostatic pick-ups are distributed along the lines and variable gain triple-channel amplifiers (ΔH, ΔV and Σ), equipped with a calibration system that operates every cycle, are mounted on each pick-up. The digitisation is achieved with 8-bit 250MHz ADC VME modules. Data treatment allows simultaneous calculations of the beam position corresponding to each ring to be made for all pick-ups on every cycle as well as allowing calibration, base-line correction and auto-ranging for optimising the resolution of the fast ADCs. Measurements are made with a resolution of 0.3 mm (full scale 33 mm) over an intensity range of 100 for a maximum of 10^{13} protons per ring. The data treatment is performed as a real-time task in a VME crate equipped with a Motorola MVME147 CPU board and conforms to the standard instrumentation protocol as well as the PS control system.

HISTORICAL CONTEXT

The PSB was built in the early 1970s with the aim of increasing the proton intensity in the PS machine by a factor of 10.

The PSB comprises 4 vertically stacked rings, each having a circumference ¼ of that of the PS. Protons, injected at 50 MeV are accelerated to 800 MeV, 1 GeV or, in the future, to 1.4 GeV. To extract the beams from the 4 PSB rings and recombine them to a single one in the PS requires good instrumentation and the capability of measuring positions that can be attributed to the individual rings of the PSB. Fig. 1 shows schematically the relative positions of the pick-ups in the recombination and transfer lines.

The original system of beam position measurement in the PSB transfer lines used the same electrostatic pick-ups, with transformer impedance conversion, as are used for the closed orbit measurement of the PSB rings. It suffered interference from the ejection and recombination kickers, making it difficult to keep the base line steady. This system was replaced in 1981. New pick-ups were made with high-capacitance electrodes (~500 pF); the smaller signals produced could be handled directly by high-impedance electronic circuits installed close to each pick-up. The position of only one bunch was derived from integrators installed remotely in the equipment room. The problem of kicker interference was overcome, but a further problem appeared, arising from secondary emission particles causing charge build-up on the electrodes and producing serious errors in the integrated signal values.

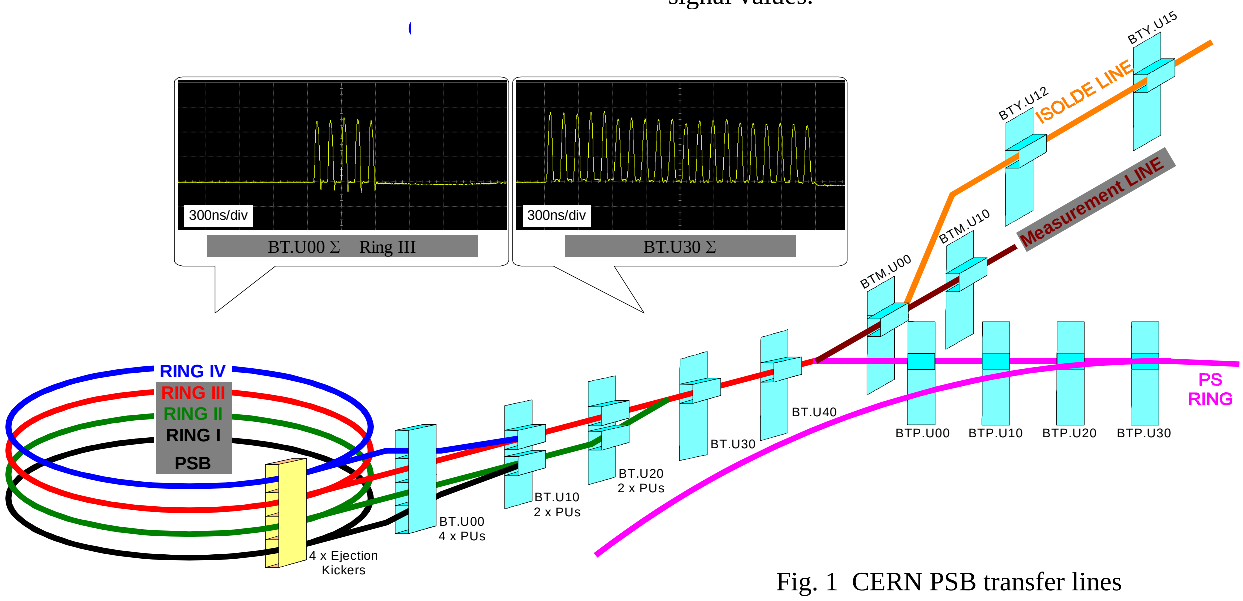


Fig. 1 CERN PSB transfer lines

For many years, careful analogue observation was necessary to confirm or refute the digital data. After 15 years of reasonably satisfactory operation, the reliability of the circuits in the tunnel began to fall; in addition, more complex modes of ejection and recombination had been introduced to meet the demands of other machines and the ejection energies of 800 MeV and 1 GeV required additional complexity in the timing for the integrators. All these factors encouraged a fundamental rethink of this system.

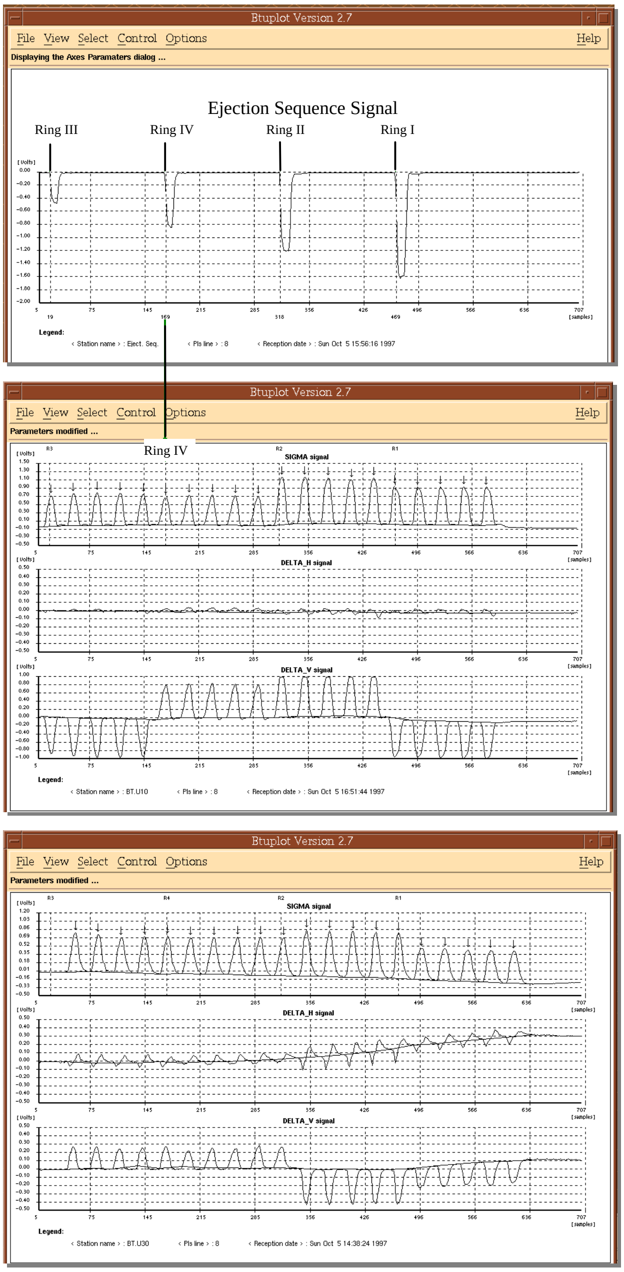
SOLUTION AND REALISATION

By using fast digitizers to acquire the pick-up signals and an “intelligent” interpretation of the data, it has been possible to eliminate the errors arising from stray charges on the electrodes as well as to reduce the complexity of timing for the different ejection energies and modes.

The frequency of bunches ejected from the PSB lies between 8 and 9 MHz and to have a good representation of their form it is necessary to sample at 5 nsec intervals, or less, giving approximately 10 points on an 8 MHz half-sinewave. A commercial fast ADC module (Struck DL515) having 4 input channels has been used, each sampling at 250 MHz and storing the data in its 2 k memory. This memory allows 8 µsec of data to be stored at the sampling rate of 4 nsec. Since the total extraction time for the 4 PSB rings is 2.5 µsec, all the data can be collected with relaxed timing requirements. As all the bunches of the 4 rings are ejected sequentially, the signals from the first 3 stacks of pick-ups have been combined and treated as 3 simple pick-up stations; this allows 9 digitizing channels to be used instead of 24. Since the beam cannot go to the PS, the Measurement Line and ISOLDE simultaneously, additional economies have been made by using an analogue OR for these signals. The total number of VME modules used to acquire the signals from the 18 pick-ups (H &V) is 7.

A limitation of 8 bits dynamic range, imposed by the fast ADC, has been made acceptable by an automatic gain selection, based on the maximum signal measured on the previous cycle of the same type. To cover all the foreseen intensities for proton cycles in the PSB (10^{11} to 10^{13} p/ring), the gain of the Δ and Σ channels can be varied in 16 steps of 2 dB; the small steps of 2 dB allow optimum use of the digitizers’ resolution. Stocking calibration tables for so many pick-ups for all the many possible gain settings would be very cumbersome. Therefore, calibration is established for the selected gain at every cycle during acceleration, before ejection of the beam. The attenuator and calibration signal switches are based on GaAs technology, therefore no wear-out problems exist.

Since it is essential to know from which ring each bunch comes, a module has been made for detecting the sequence of the ejection kickers. This module uses a small signal, fed back from the true kicker pulse, to create a pulse whose amplitude corresponds to a particular kicker and in this way, 4 sequential pulses are created with different amplitudes to identify the 4 ejection kickers (Fig. 2a). By sampling this pulse train, along with the beam signals, the start of the kicker and the relevant ring can be identified.



Figs. 2a, 2b & 2c.
Kicker identification pulses and pick-up signals

The software searches from the start address of each ring, first in its Σ signals, for the address of the ring's bunches and finds the corresponding parts of memory where the difference signals are located. Once the start and end of each bunch have been identified, integrals of the signal values can be made. By dividing the Δ and Σ integrals, the position of the bunches is calculated using the calibration characteristics of each pick-up and amplifier.

Fig. 2b shows typical analogue signals acquired by the digitizers from the first stack of two pick-ups in the recombination line, where a correctly aligned beam has large vertical offsets and Fig. 2c shows the signals from a pick-up following a septum magnet; the accumulation of charges on the electrodes is apparent on the horizontal, vertical and sum signals. In this, and similar cases, the base-line offsets are detected by the software and a reference base-line is established from which it calculates the integral values.

PERFORMANCE

Measurements are made over the specified intensity range with a resolution of 1% of Δ/Σ, corresponding to 0.3 mm for the 140 mm diameter pick-ups. Fig. 3 shows a display of beam positions acquired from all pick-ups in the transfer lines. The position data for each ring are used in an application program for automatically correcting the beam steering [1].

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REFERENCES

[1] B.Autin, G.H.Hemelsoet, M.Martini, E.Wildner, "Automatic Beam Steering in the CERN PS Complex", PAC 95, Dallas, 1995.

Fig. 3 Graphics user interface for the PSB transfer lines