RESUME OF A SERIES OF TESTS WITH THE SPARE PS INTERNAL SLOW BEAM CURRENT TRANSFORMER

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1. BACKGROUND

In the near future (from summer 1980 on) a slow beam current transformer (BCT) will be needed in the PS for the measurement of low intensities (α-particle acceleration, $\bar{p}$ acceleration and deceleration).

Since a new transformer system will not be available before the end of 1980, a series of MD's and tests were performed with the existing spare slow BCT (SS72) to find out its present limits and improve its low intensity response by appropriate signal processing. A first MD took place on the 27.6.79 (see MD-notes by S. Battisti et al.). The BCT characteristics were then adjusted to give theoretically 50 mV/10^9 protons in a range from 10^{+8} p up to 3.10^{11} p. However, parasitic and systematic errors were limiting the transformer resolution to $\pm$ 2.10^9 p. The following MD's and tests carried through by EI from end of November up to now proved that a resolution better than 10^9 p seems possible. Hence the requirements for the α-acceleration run can eventually be met with the existing PS-BCT (see PS/EI/Min. 79-6).

2. MEASUREMENT SET-UP.

It was decided to exclude from the beginning any hardware modifications of the existing transformer system itself (including the monitor, the electronic circuitry and the transmission cables). The transformer signal, as it arrives in the CCR, is optimized by the existing manual controls in the CCR (adjustment of ampli-offsets, etc.) and then, before being displayed in the MCR, passed through several signal processing units (transient digitizers, filters, amplifiers, etc.). The basic idea consists in transmitting the beam current signals properly from CCR to MCR and substracting there a reference signal representing the sum of all reproducible errors (Fig. 1).

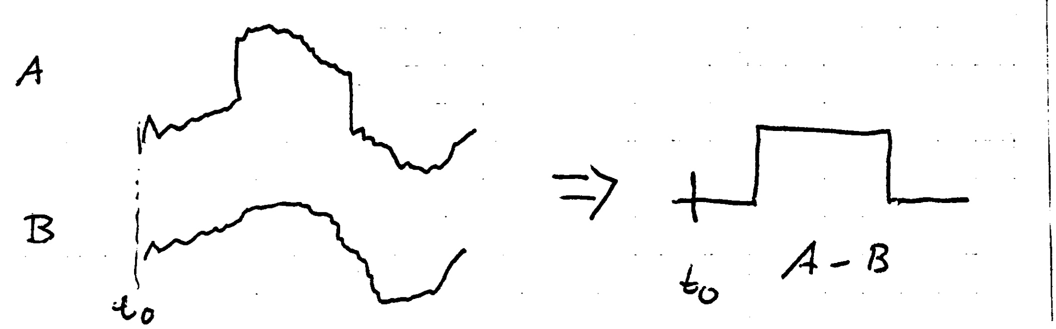
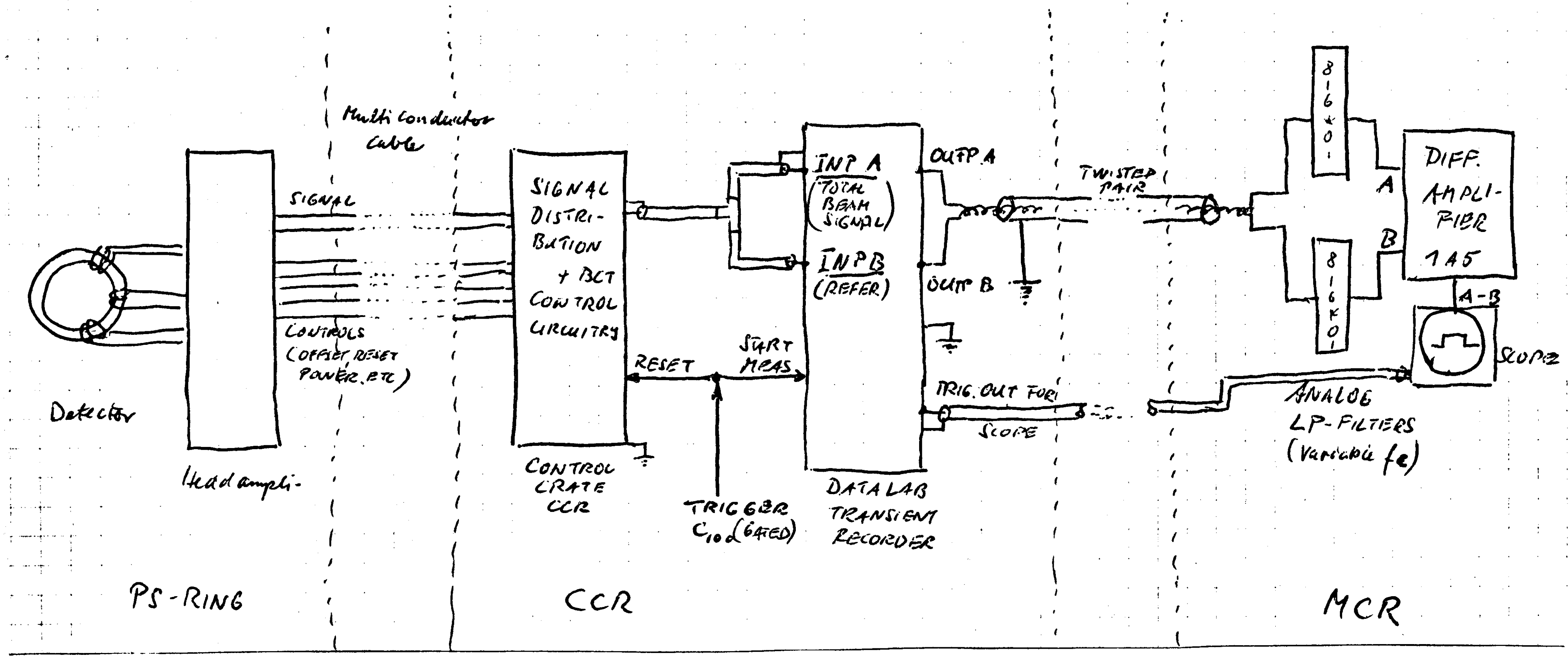


Fig. 1 : Principle of signal treatment

A = Beam current signal + sum of error signals

B = "Reference" signal (= average sum of all error signals in absence of beam).

The measurement set-up shown in Fig. 2 gives the best results observed under present conditions. The transformer signal coming out from the CCR control crate is fed once as "reference" signal (without beam) to input B and then repeatedly (with beam) to input A of a DATALAB transient recorder. Both signals are digitized, stored each in one half of the internal memory, and sent out to the MCR at a much higher frequency (typically 5 kHz) via a shielded twisted pair cable. Before entering a differential amplifier each signal passes an active low-pass filter (f_c typically set between 20 and 40 kHz). The difference signal A-B is finally displayed on a scope screen.



<u>Fig. 2</u> : Measuring arrangement.

A trigger pulse (C_{100} gated into the chosen subcycle) takes the reset off the BCT head-amplifier and starts a measuring sweep of the DATALAB digitizer. At C_w of the same subcycle the head-amplifier is again reset to zero.

3. MEASUREMENTS AND LIMITS ACHIEVED.

Fig. 3 shows several superimposed BCT signals transmitted from the CCR distribution crate to the MCR via a coaxial cable passing through a low-pass filter. On the original photo (not on the reproduction !) one can distinguish pulse-to-pulse variations of the error background of the order of ± 20 mV.

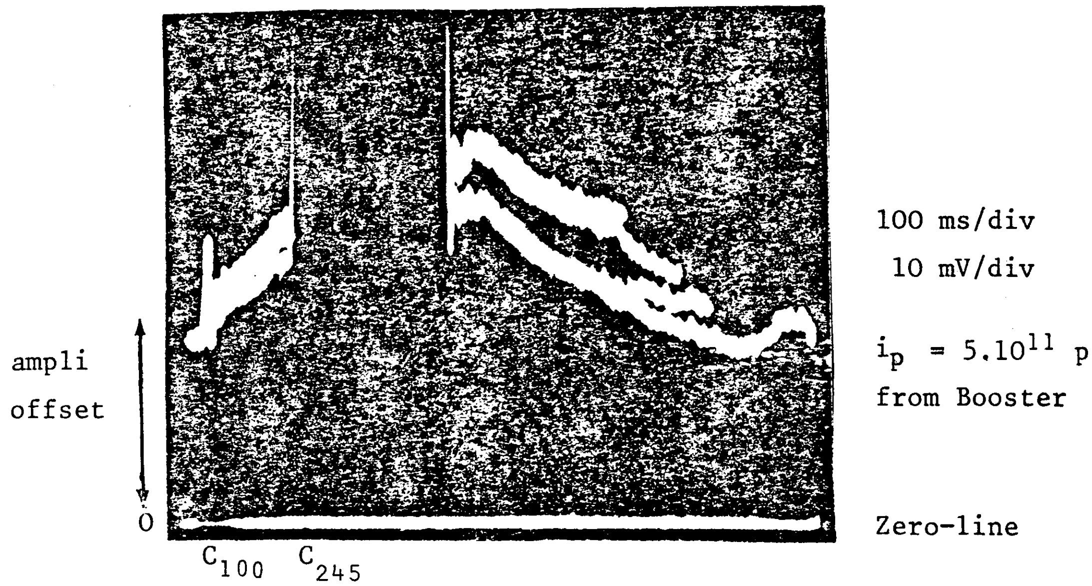


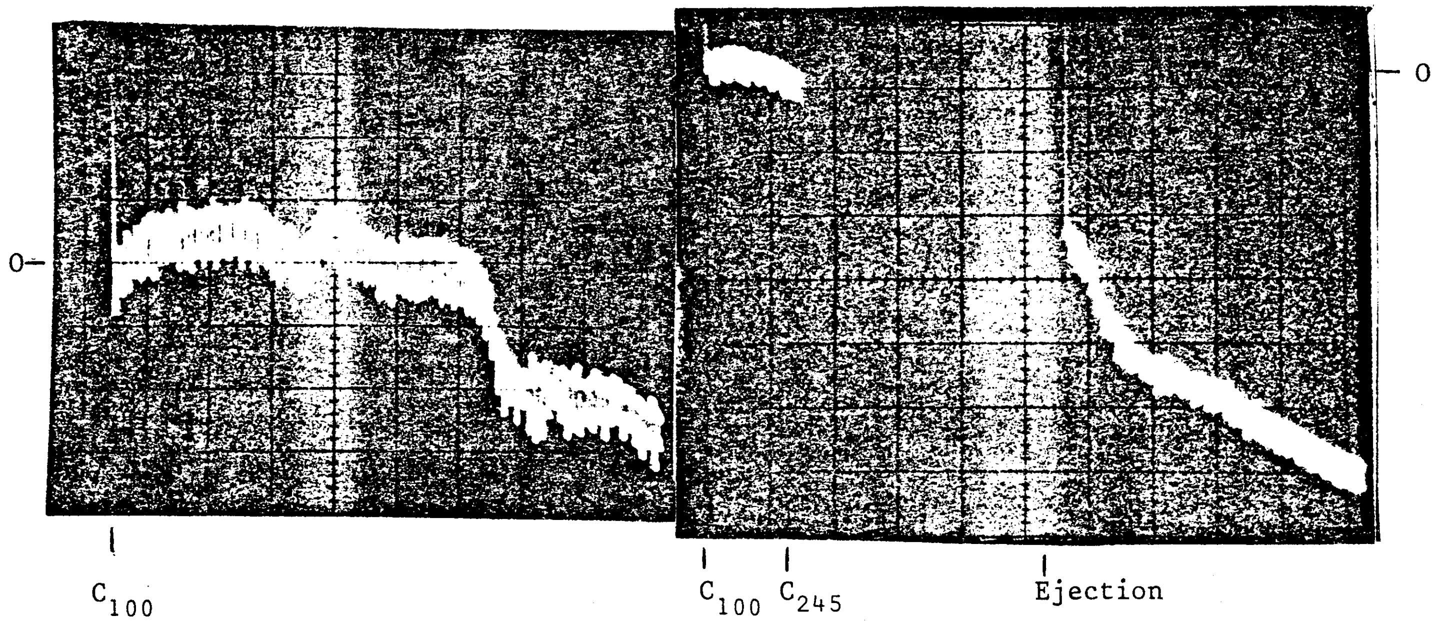
Fig. 3 Typical signal of the BCT with beam superimposed on error background.

The total error background signal is the sum of contributions produced by different error sources listed below according to their relative importance :

3.1. Reproducible errors :

a) influence of high beam intensity in adjacent PS-machine cycles.

With maximum variations of ± 80 mV it is by far the most important error. Fig. 4 demonstrates the BCT-behaviour in case of total absence of beam in all PS-cycles (Fig. 4a) and in case of high beam intensities (ip > $1.5.10^{13}$ ppp) in the 2 adjacent A_1-cycles and 5.10^{10} ppp in the measurement cycle (Fig. 4b).



100 mS/div	100 mS/div
10 mV/div	20 mV/div (!)
without beam in all cycles	with beam in all cycles
total variation = ± 20 mV.	total variation = ± 70 mV
a)	b)

Fig. 4 Influence of circulating beam current on BCT background noise.

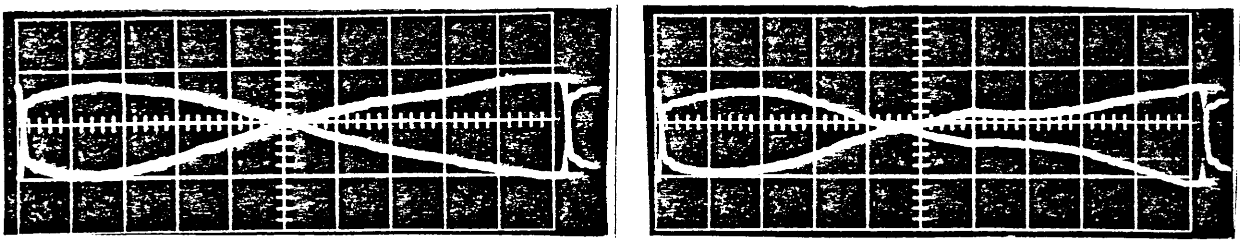
Whenever the beam intensity program remains stable from supercycle to supercycle this error contribution can be eliminated by the signal substraction method described above.

b) PS-magnet field influence.

The maximum contributions to the total error signal by the magnetic field of the PS magnets and by the pole-face windings amount to ± 15 mV, corresponding to ± 3.10^8 ppp during the acceleration period of the cycle (see Fig. 5 a, b).

A

-B



100 ms/div ; 40 mV/div

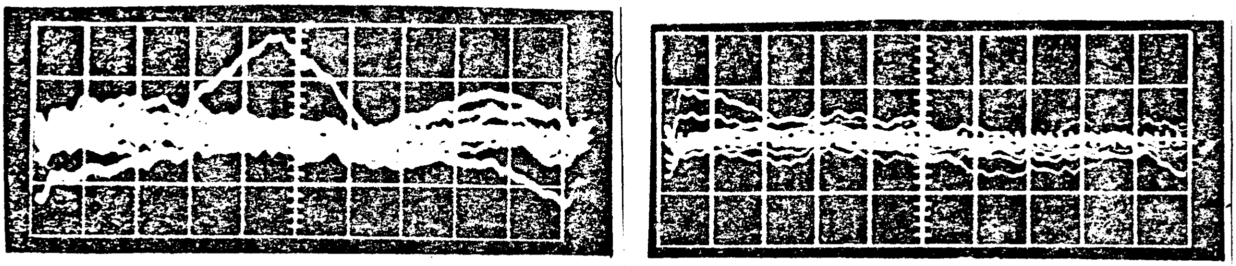
a) No beam, PS magnets off   b) No beam, PS magnets on

Fig. 5 : PS magnetic field influence on BCT-signals A and -B.

c) Other reproducible errors arise from characteristics of the BCT electronics (e.g. amplifier offsets) and from the use of filters (distortions of fast current steps).

3.2. Non-reproducible errors :

Pulse-to-pulse variations of the total error signal are provoked by external mechanical, thermal and electromagnetic noise and by amplifier noise within the BCT electronics. These effects may be enhanced by bad circuit adjustments, poor signal transmission and wrong earthing. Unstable beam conditions during the supercycle also contribute to the non-reproducible part of the error signal. Provided the PS magnetic field and the beam intensity are reproducible functions of time, the pulse-to-pulse stability of the BCT signal obtained with the present measurement system and with well adjusted BCT amplifiers is better than ± 20 mV, or ± 4.10^8 ppp (see Fig. 6a). For more than 90 % of all BCT pulses these variations remain even below ± 10 mV (see Fig. 6b).



a) b)

100 ms/div ; 10 mV/div

Fig. 6 : Pulse-to-pulse variation of the difference signal (background A - reference signal B) in absence of beam.

The 50 Hz noise which builds up between CCR and MCR is eliminated by using a twisted pair cable for transmission and earthing its shielding properly in CCR. HF-parasitic noise and noise due to the finite sampling rate of the DATALAB transient recorder are reduced by lowpass filters with appropriate cut-off frequencies. The measurement quality is clearly best when a "good" reference pulse representing an "average" error signal is used for substraction from the total beam pulse.

4. CONCLUSIONS.

The signal treatment of the existing PS BCT signal allows to extend the intensity resolution down to about $\pm$ 4.10^8 ppp. For the α-run in summer 1980 this limit seems acceptable. Further effort will be made to render the measurement procedure easier than under present conditions. Antiproton acceleration and deceleration require a still better resolution, which can not be reached with the existing system. For this purpose a new slow BCT will be installed in SS10.