# BEAM POSITION MEASUREMENT DURING FAST EJECTION

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A series of electrostatic pick-up electrodes is used to measure the horizontal position of a single bunch during fast ejection in the Serpukhov proton synchrotron. Anyone of the 30 circulating bunches can be followed, whether it is being ejected or stays in the accelerator. The electrode signals go directly into long coaxial cables and no active components are present in the radioactive zone. The signals are digitalized and go to a minicomputer. The response of the system is linear over the whole width of the electrodes (200 mm).

## INTRODUCTION

The fast ejection system for the Serpukhov accelerator [1] was made by CERN as part of the CERN/Serpukhov collaboration. Part of the system is a series of 5 electrostatic pick-up stations (PU) which measures the position of a single bunch as it progresses through the ejection system.

The beam intensity of the Serpukhov accelerator is about $10^{12}$ protons per cycle. The beam is divided in 30 bunches, each approximately 20 ns long at ejection and separated by 165 ns. The bunch-shape is approximately triangular.

The fast ejection system can make 3 ejections per machine cycle, each time ejecting a different number of bunches in anyone of the three channels. During each ejection a selected bunch can be traced. This can be one of the ejected bunches or a bunch that is not ejected (closed orbit).

The PU is composed of two electrodes, separated by a diagonal cut. The signal from each electrode is digitalized separately. Both signals have the same form but their amplitude is different. Any linear operation on the signals, such as integration or differentiation, is allowed, provided it is identical for both signals. In that case, their relative magnitude is not changed.

In most systems, a cathode-follower matches the high impedance of the PU electrodes to the impedance of a coaxial cable. For measurements at ejection, however, a large time-constant is not necessary. Therefore, the signals go directly into long coaxial cables and, consequently, they are strongly differentiated. This method has several advantages: there are no active components in the radioactive zone, the base-line of the signal does not move and the PU is insensitive to stray particles. The penalty to pay for this are signals which are more difficult to digitalize.

## THE PU STATIONS

The PU electrodes are of the type described by Sherwood [2]. They have a rectangular cross section and are 200 mm wide, 106 mm high and 120 mm long. They are made of folded inox sheet, insulated with ceramic spacers. Only the horizontal position is measured. The equivalent diagram is given in Figure 1. The position P of the beam, calculated from the center of the PU, is given by:

$$P = \frac{Q_A - Q_B}{Q_A + Q_B} \, \frac{W}{2} \, \frac{R_{AB} + 2Z}{R_{AB}}$$

where $Q_A$ and $Q_B$ are the charge of the positive part of the output pulses or anything linearily related to this charge.

Each PU is connected to analog-to-time converters (ATC) via two low-loss coaxial cables of about 200 m length. Both the PU and the ATC are connected to the local ground. To prevent circulation currents, a cable filter is inserted between the PU and the low-loss cable. This filter consists of a short length of miniature coaxial cable, wound ten times around a few toroidal ferrites. Moreover, the outer conductors of the miniature cable and the low-loss cable are interconnected only via a 20 nF capacitor.

## THE ATC

Figure 2 shows the circuit diagram of the ATC. At the input is a high-pass filter, to stop the parasites which are always present during ejection. Then the signal goes through a remote-controlled step attenuator. A fast diode gate opens for 165 ns to let one bunch through. Trimpotentiometer P1 adjusts the offset of the gate, P2 the front commutation transient and P3 the tail commutation transient. The input is adapted to the cable when the gate is blocking. When the gate is conducting, there is a reflection but the gate is blocking again when the reflection comes back. The gate has a virtual earth in order to make the commutation independent of power supply variations.

The selected bunch passes a current amplifier with a high output impedance (T6, T7, T8). The hot-carrier diodes D11 and D12 allow the negative part of the output pulse to charge C1. A differential amplifier (T10 to T16) charges capacitor C2 to the voltage of C1. A voltage offset of this amplifier has no influence on the precision of the ATC. Transistor T20 generates an output pulse for the duration of the discharge of C2. The length, $T_o$, of this pulse is proportional to the PU electrode signal. It is sent, together with a 3 MHz clockpulse, to the computer interface where it is converted to a proportional number.

Due to the presence of diodes D11 and D12, the converter reacts to commutation transients of the gate, even when their integral is zero. In the present gate these transients can be adjusted to very low values.

Two ATC's fit into a 2-unit wide NIM. The two gates are driven in parallel by one 75 ohm coaxial cable.

The maximum range of the ATC is $T_o$ = 85 μs or 256 counts with a 3 MHz clockpulse. This corresponds approximately to an input charge $Q_A$ = 67 pC. The deviation of the response from a straight line, going through zero and maximum range, is maximum 1 count (except for the lower 5 % of the range). Tracking of two ATC's is within 1 count and this for wide variations in bunch length.

## RESULTS

In good working conditions and with a stable beam, statistics were obtained over several hundreds of cycles, with RMS deviations of less than 0.3 mm and this for all PU's.

With a centered beam and $3.10^{10}$ protons per bunch, the ATC output is approximately 50 μs (150 counts). The resolution is then 0.4 mm.

For three PU's, the measurements could be compared with position information from luminescent screens and beam profile monitors. The discrepancies were 0.5, 1 and 2 mm respectively.

The bunch separation at Serpukhov is 165 ns. The system was tested at CERN with a bunch separation of 105 ns and should work well with separations as small as 80 ns.

Due to the short time constant, the PU is not sensitive to stray particles. The measurement is impossible only when the beam touches the electrodes.

## REFERENCES

1. B. Kuiper, B. Langeseth, K.P. Myznikov: Proc. Intern. Conf. on High-Energy Acc., Yerevan 1969, Vol. 1, p. 549

2. A.J. Sherwood, IEEE Trans. on Nucl. Sci., Vol. 12, Nr 3, p. 925 (1965).

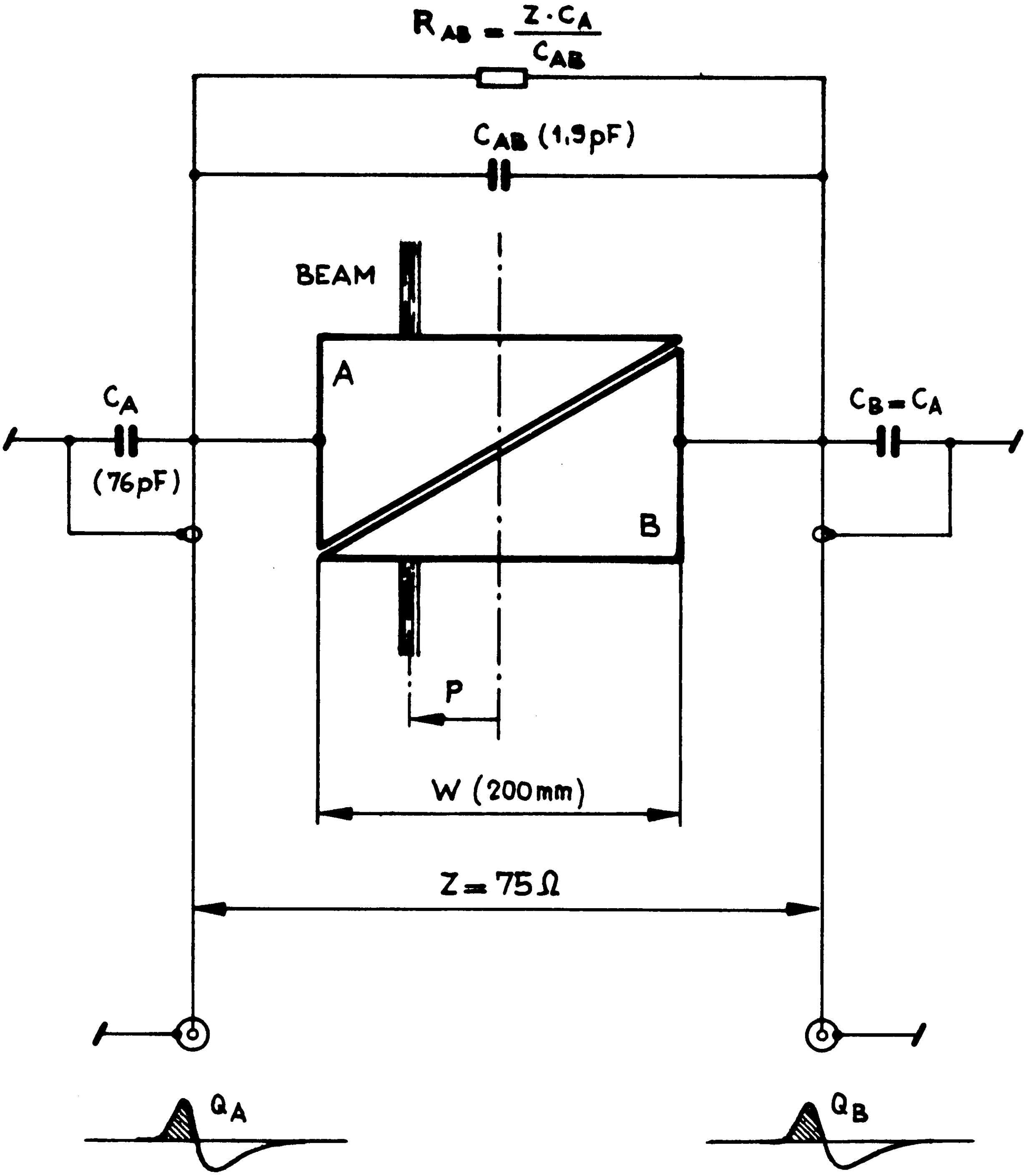


Fig. 1 Equivalent diagram of the PU. The inter-electrode capacitance $C_{AB}$ is kept small by mounting an earthed strip, 1 cm wide, between the electrodes (not shown). $R_{AB}$ is added to make the measurement frequency-independent.

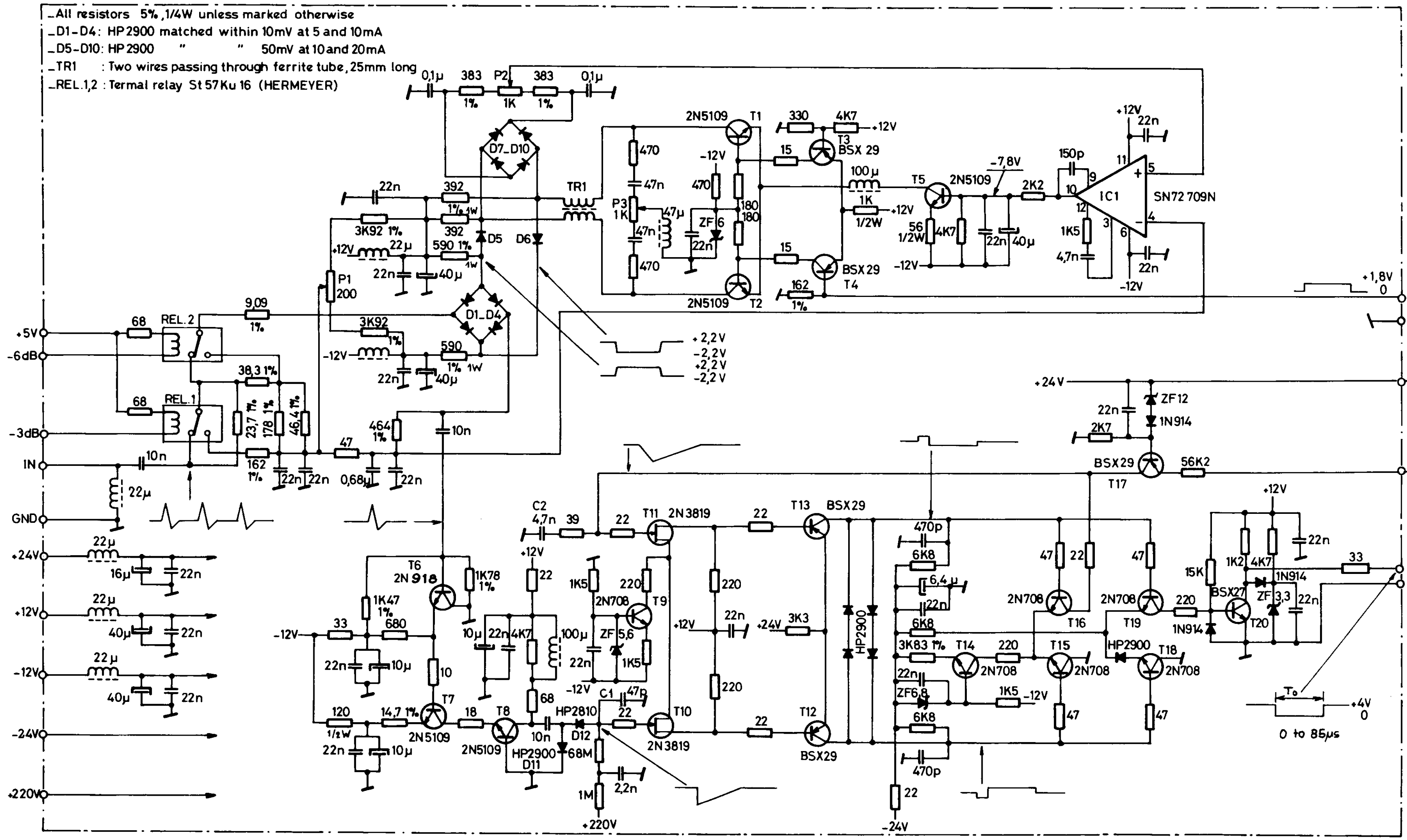


Fig. 2 Circuit diagram of the ATC.