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MEASUREMENT AND PROCESSING OF LOW PS BEAM CURRENT SIGNALS

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The measurement of beam intensities below 10^{10} protons per pulse in the PS not only requires a new slow beam current transformer (BCT), but also special signal processing methods for noise reduction and signal reconstruction. During two PS machine development runs, when alpha-particles were accelerated, we profited from the presence of rather low intensity α-beams in order to assemble a measurement and signal processing system, which we will use later together with the new slow PS BCT for measuring antiproton beam intensities. We show the first results of α-beam current and α-particle number measurements.

1. INTRODUCTION

Since the beginning of this year we were faced with the problem of measuring beam current intensities in the PS below 10^{10} ppp [1,2]. The first application seemed to be the α-run in July, 1980, followed by antiproton tests later in the year. In the meantime, the α-run turned out to be not a particular low intensity problem, since the Linac achieved to inject more than 10^{11} ppp into the PS. However, in the case of antiprotons we will certainly have to handle beam intensities below 10^9 ppp. Even with the more sensitive new BCT we will have to deal with filtering, noise reduction and other signal treatment methods. The simple measurement scheme[1] originally put together for the preliminary α-MD's will not be adequate for the antiproton tests. Hence we have set up a new measurement and data treatment system, which we could test together with the old slow PS BCT during the past MDs.

2. MEASUREMENT METHOD

The specific problems encountered with low beam intensities are:

- filtering of random noise
- subtraction of systematic errors from the measured signal
- waveform time-averaging (to obtain a representative error reference signal)
- waveform reconstruction.

All these problems can be solved much more easily in a digital than in an analog way. The digital method also allows to determine the number of particles as function of time and not only the current, which strongly depends on the velocity v of the particles.

Figure 1 shows the block diagram of the preliminary measuring system. The current signal is transported from the BCT in ss 72 via the CCR to the MCR. After passing a low-pass filter ($f_c \approx 10$ kHz), the current signal is digitized by a fast CAMAC sampling ADC with 1 kword of memory. The sampling frequency of 1 kHz is simply given by the C-train. A programmed C-trigger passes a programmable gate and starts the measuring sequence of the ADC. The CAMAC crate is controlled by a CAVIAR processor operated from a terminal. The results are displayed on two parallel TV screens. Program and data storage as well as program development is done via Index on the IBM of the CERN computer centre. If Index is not available data and programs can be stored on and retrieved from an audio-cassette.

3. RESULTS

With the measurement equipment described above the beam current of α-particles was measured as a function of time between the injection and the ejection moments. Figure 2 shows a typical waveform. One clearly recognizes the magnetic field flat top and the strong dependence of current on $\beta = v/c$ of the α's. Due to the rather high α-intensities injected from the Linac, noise and signal correction were superfluous. The only data treatment on the measured current waveforms was a transformation of beam current into the number of α-particles.

For twice ionized Helium ions the relation between current i_α and number of particles n_α is given by

$$n_\alpha(t) = \frac{\pi R_0}{e \cdot c} \sqrt{1 + \frac{E_{o\alpha}^2 (1+k)^2}{(0.2997925 \cdot R_0)^2} \cdot \frac{1}{B(t)^2}} \cdot i_\alpha(t)$$

where R_o	=	PS radius	= 100	[m]
k	=	circumference factor	= 1.429	
e	=	elementary charge	= $1.602 \cdot 10^{-19}$	[C]
c	=	velocity of light	= $2.997925 \cdot 10^{8}$	[m/s]
$E_{o\alpha}$	=	rest energy of α	= 3.7557	[GeV]
B	=	PS magnetic field		[Tesla]
t	=	time		[s]

The function B(t) of the chosen PS-cycle (No. 24) was introduced into the CAVIAR system in the form of a 1000 word-table. Figure 3 shows the field of the PS magnet B(t) reconstructed as function of time. Measured current and calculated particle number waveforms are given in Figure 4a) and 4b).

The current $i_\alpha(t)$ and $n_\alpha(t)$ waveforms can be either obtained off-line from previously stored beam current data or they can be displayed on-line during operation.

In the latter case current displays are actually refreshed every 4 seconds and n_α displays every 6 seconds. The slow speed results from the use of a semi-compilable interpreter language in the CAVIAR processor. For future antiproton tests the speed of data acquisition and processing seems to be sufficient. However, apart from more extensive signal processing we will have to handle additional problems related to the control, synchronization and surveillance of the future new BCT electronics.

REFERENCES

1. H. Riege, "Résumé of a series of tests with the spare PS internal slow beam current transformer", PS/EI/Note 80-8, 1980.

2. H. Riege, "Minutes of the instrumentation meeting held on 18th October, 1979", PS/EI/Min. 79-6.

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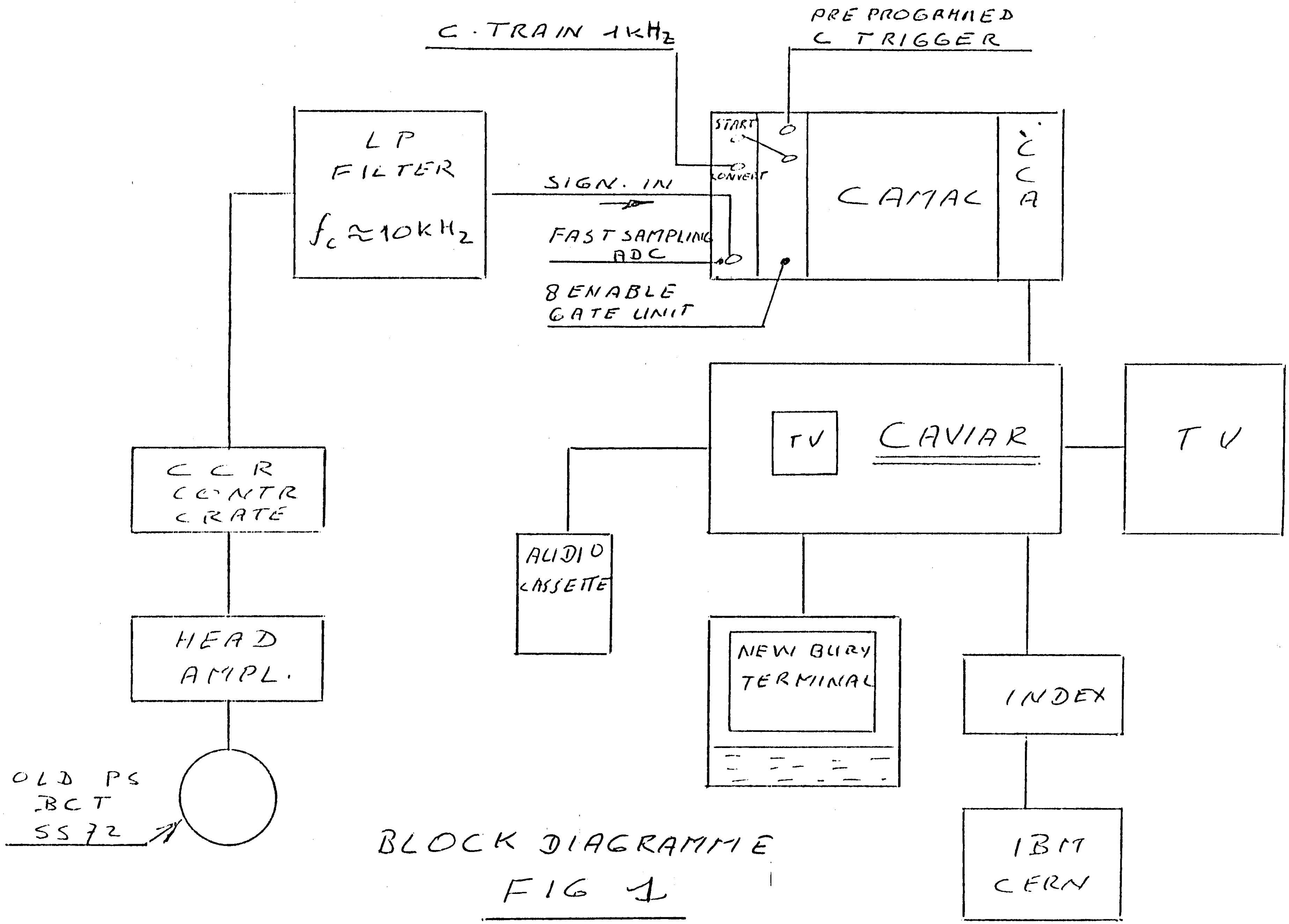


BLOCK DIAGRAMME

FIG 1

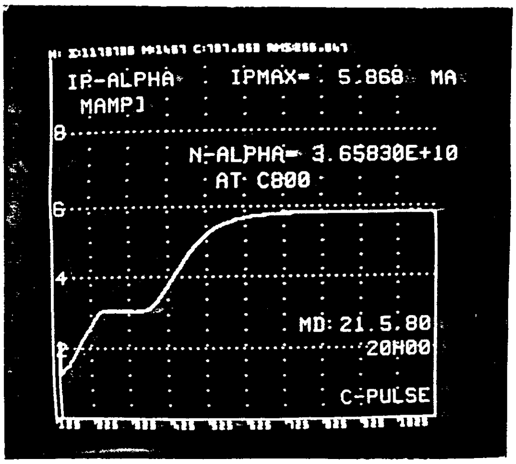


Figure 2. Typical α-beam current waveform photographed from CAVIAR TV screen.

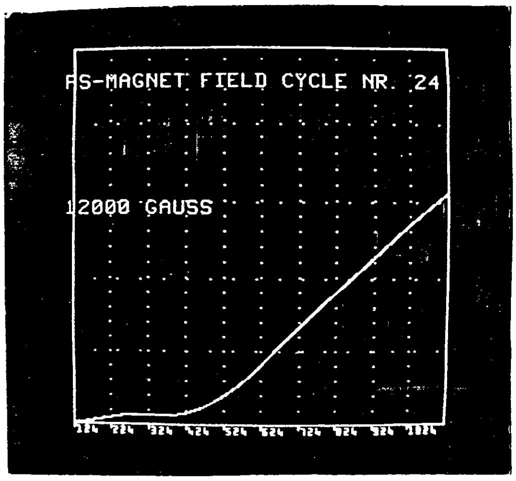
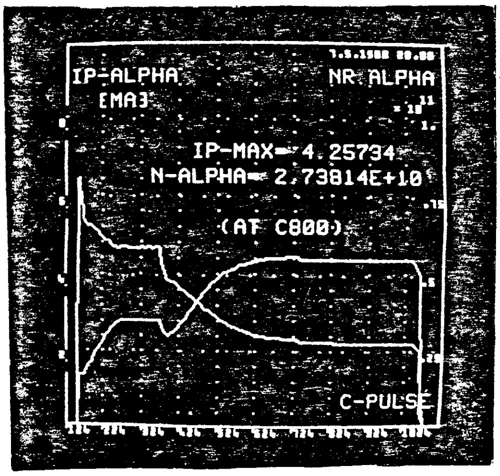
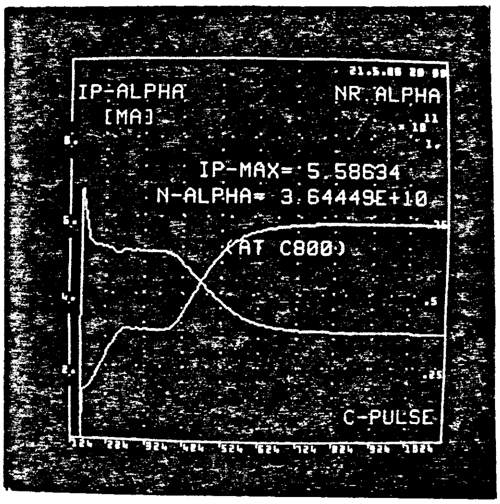


Figure 3. PS magnetic field of cycle No. 24 as a function of time (C-pulse).



a) Measuredduring MD 7.5.80. The dip at the end of the flat top results from particle losses when changing the harmonic number.



b) Measured during MD 21.5.80. Note the improved performance.

Figure 4. Beam current i_α and number of α-particles n_α as function of time.