

**THE CERN ANTIPROTON SOURCE:
CONTROLS ASPECTS OF THE ADDITIONAL COLLECTOR RING
AND FAST SAMPLING DEVICES**

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Abstract

The upgrade of the CERN antiproton source, to gain an order of magnitude in antiproton flux, meant the construction of an additional ring to complement the existing Antiproton Accumulator (AA) and an entire rebuild of the target zone. The AA also needed major modifications to handle the increased flux and perform purely as an accumulator, preceded by collection in the Collector ring (AC). The upgrade, known as the ACOL-Antiproton Collector project, was approved under strict time and budgetary constraints and the existing AA Controls system, based on the Proton Synchrotron (PS) Divisional norms of CAMAC and Norsk-Data computers, had to be extended in the light of this. The limited (9 months) installation period for the whole upgrade meant that substantial preparatory and planning activities had to be carried out during the normal running of the AA. Advantage was taken of the upgrade to improve and consolidate the AA. Some aspects of the controls system related to this upgrade are discussed together with the integration of new applications and instrumentation. The overall machine installation and running-in was carried out within the defined milestones and the project has now achieved the physics design goals.

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The upgrade of the CERN antiproton source, to gain an order of magnitude in antiproton flux, meant the construction of an additional ring to complement the existing Antiproton Accumulator (AA) and an entire rebuild of the target zone. The AA also needed major modifications to handle the increased flux and perform purely as an accumulator, preceded by collection in the Collector ring (AC). The upgrade, known as the ACOL-Antiproton Collector project, was approved under strict time and budgetary constraints and the existing AA Controls system, based on the Proton Synchrotron (PS) Divisional norms of CAMAC and Norsk-Data computers, had to be extended in the light of this. The limited (9 months) installation period for the whole upgrade meant that substantial preparatory and planning activities had to be carried out during the normal running of the AA. Advantage was taken of the upgrade to improve and consolidate the AA. Some aspects of the controls system related to this upgrade are discussed together with the integration of new applications and instrumentation. The overall machine installation and running-in was carried out within the defined milestones and the project has now achieved the physics design goals.

1. Background

The AA had been the mainstay of the Collider (SPS) programme and the low-energy physics (LEAR) at CERN from 1981 to August 1986. The ACOL project was approved under strict conditions of budget and shut-down time to minimize the physics down-time. The controls system had to conform to requirement and be readily available for the overall upgrade with a minimum of perturbation. The ACOL design report [1] expected no major changes but only pure extensions to the existing system [2]. With rack space limited, it was expected to make no major extensions to the local control room. From

the beginning, it was clear that all the application and operation level effort would have to come from the machine builders and operators of this Collector-Accumulator complex; the close operational coupling of the two rings, the same commissioning and operating staff and the similarity of the two rings in many respects of beam measurement devices, instrumentation and other equipment made it even an obvious choice. The modifications in lower-level software equipment modules had to be kept to an absolute minimum especially as all of the existing equipment modules were written in assembler-like NPL language by long-gone temporary staff. However, a small number of new modules had to be foreseen.

2. Salient Controls Aspects

Many of the upgrade activities that did not need the actual machine shut-down could be done earlier and in parallel with the normal running of the AA. The AA touch terminals were upgraded [3] in this manner starting in 1985 and were replaced by more powerful ones based on a Motorola 68000 microprocessor and permitting colour monitors for displays. A spare unit of this type was prepared for later use in the AA development laboratory during the nine month installation shut-down.

The AA had been running on a Norsk-Data NORD-10 front-end processor since 1979. The computer was upgraded [4] to a newer ND-100 during normal running of the AA in 1986. This was achieved successfully in-between two successive LEAR antiproton transfer operations. The ND-100, being a faster processor, permitted speed augmentation on certain touch terminals as well as an increased number of terminal lines. This meant that some of the lines could be connected to the telephone-like computer exchange (PACX), with obvious advantages in access from offices and elsewhere for software development and maintenance.

The AA and AC being two concentric rings, it was necessary to modify the extraction channel from the AA to go under the AC (see Fig. 1). This involved the installation of some new power supplies and beam observation screens as far as the controls system was concerned. All this was commissioned and operated prior to the installation shut-down.

To reduce the influence on existing equipment, it was decided to install a second CAMAC serial highway to control new equipment for the AC. The new loop had to take into account the geographical location of additional surface buildings for new power supplies, high-current pulsers and

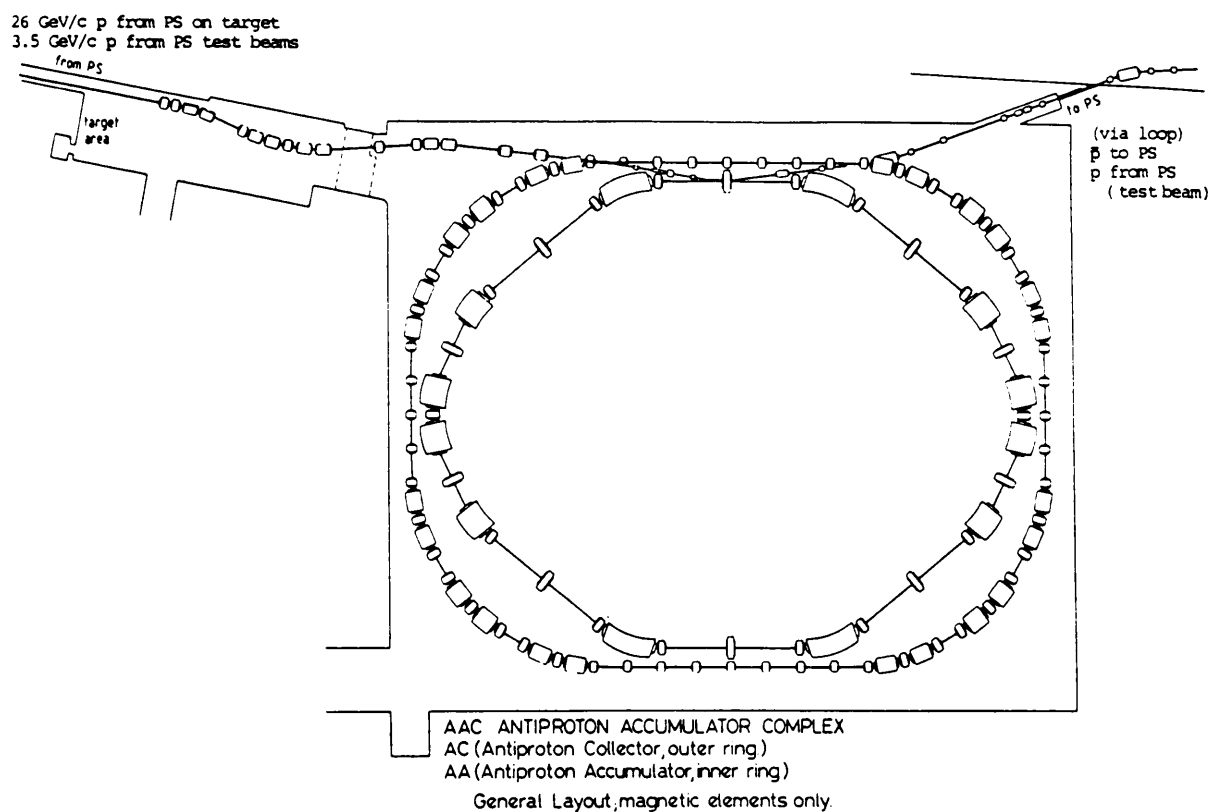


Fig. 1 Antiproton Accumulator Complex.

equipment used for the production target area and also had to respect the transmission limitations without repeaters for the serial highway.

The major activities were the detailed evaluation and analyses needed to retro-fit a new accelerator into a control system with hardware, software and application level protocols defined and well entrenched for an existing accelerator.

3. Analyses of Requirements

The general evaluation and analysis of requirements is relatively easy for devices identical to existing ones or for devices for which new hardware and software development is necessary. For the ACOL project, the aim was to limit the latter cases to a minimum. For most systems involving utilities and supervisory on/off controls, it was possible to achieve the former. These include the pulsed and dc magnet power supplies, vacuum system, cryogenics, function generators and radio-frequency (rf) systems. It was also possible to do so for some beam diagnostics devices such as scintillation screens, beam current transformers and beam scrapers using

stepping motors. However, for the packaged systems like fast kicker magnets and their ancillary controls of fine delay timings, selections and activation, much effort had to be put in to achieve the conversion of 2 sets of kicker magnets, totalling 16 modules, as used in the AA into 4 separate sets for different injection and ejection purposes of the AC and the AA [5]. The ubiquitous stochastic cooling systems in the AA and AC were a similar case.

The hoped for decoupling between the AA and AC by means of a second CAMAC serial loop installation was not a sufficient condition for many of the equipment extenders/providers; for them, the costs, effort and expediency were the ultimate criteria in extension and installation of their additional equipment. For example, the AA and AC complex has 18 different stochastic cooling systems involving hundreds of relay contact switches and power amplifiers; the power amplifiers have analogue power and current acquisitions as well as on/off controls. The different cooling systems have pico-second delay adjustments controlled by stepping motors. One of the major tasks was to stream-line and simplify existing stochastic cooling controls and to introduce all the new cooling equipment under the simplified structures [6]. For the AC ring, the 9 stochastic cooling systems have an added requirement for mechanical movement of the pickup and kicker electrodes to follow the beam size according to a prescribed function. Some control aspects of this are given in [7,8,13].

For the completely new equipment, the needs were somewhat easier to cater for. The completed requirements evaluation [9] including these resulted in a detailed layout, installation [10] and commissioning which was carried out in the nine-month shut-down. Some aspects of high-level definitions, machine modes of operation and timings are given in [11].

4. Implications of ACOL on Fast Sampling Devices

Fast CAMAC-based digitizers, working at a 10 nsec repetition rate, had been used routinely in the AA since 1984. The main application was to sample the position of a single-bunch, proton test beam signal over several turns and correct the horizontal and vertical coherent oscillations at injection [12]. The system used 2 CAMAC modules (with memory), one for each plane, with clock synchronisation at 100 MHz. The modules have a single stop-trigger input to terminate the sampling process. The AA was normally adjusted using test beams via the loop as shown in Fig. 1 and the transverse coherent oscillations reduced, using the kicker/septum deflection

magnets or the vertical steering elements in the beam transport line.

With the two rings AC and AA, and the different machine modes [11] under which the test beams could be obtained in either of the rings, the coherent oscillations had to be observed and corrected in each of the relevant modes and machines. Rather than having a separate set of digitizer modules for each ring, it was cheaper to use the original pair of modules and to switch dynamically the relevant input signals and timings for different sources and modes. The input signal routing was done by means of a wide-band routing module in CAMAC. However, in the case of the stop-trigger inputs, extensive timing combinations had to be catered for and generated by a cascaded set of preset counters, connected in a precise manner and yielding the single pulse output for each of the ten machine operational modes. Figure 2 illustrates a typical injection coherent oscillation plot and correction for one of these modes while Fig. 3 shows the complex timing preset connections necessary for the system.

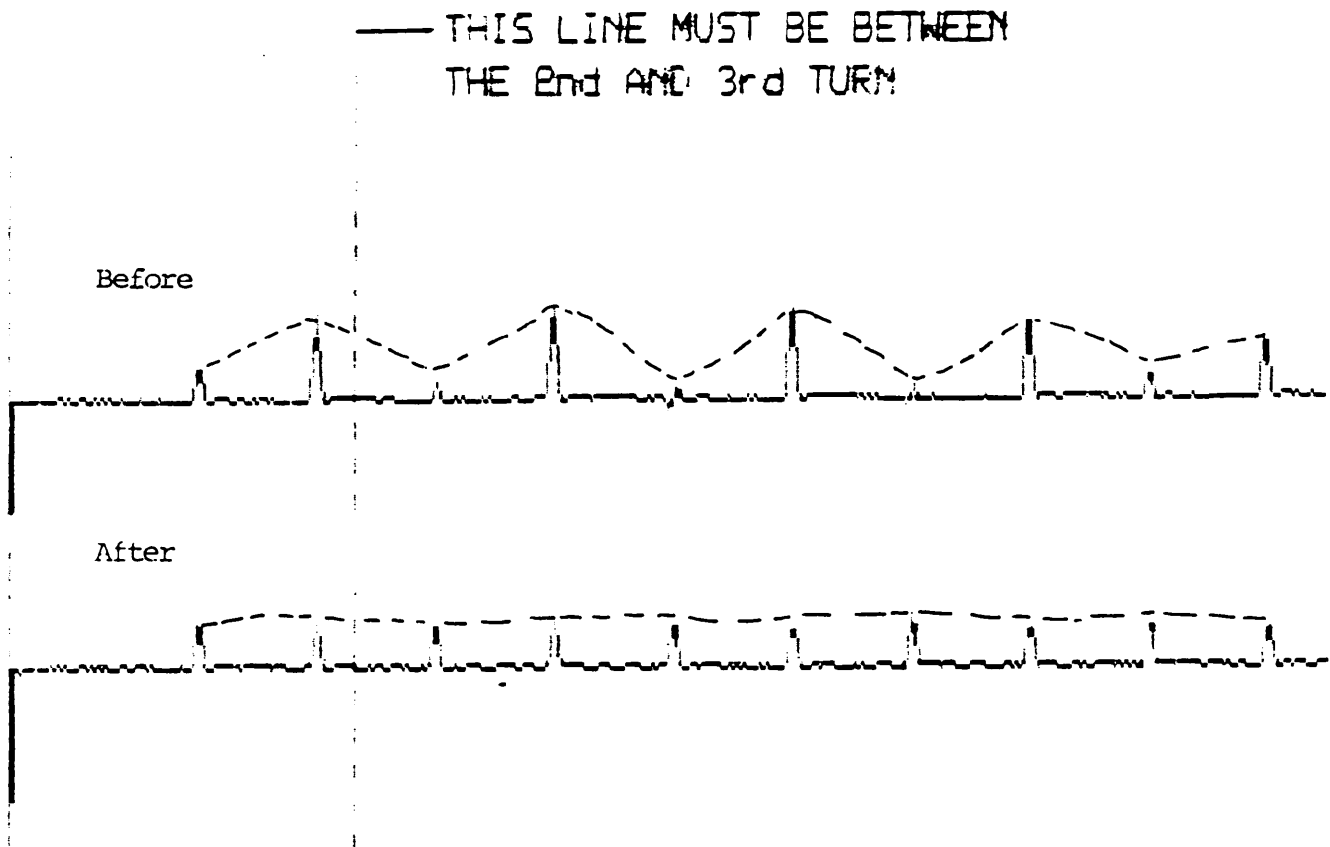
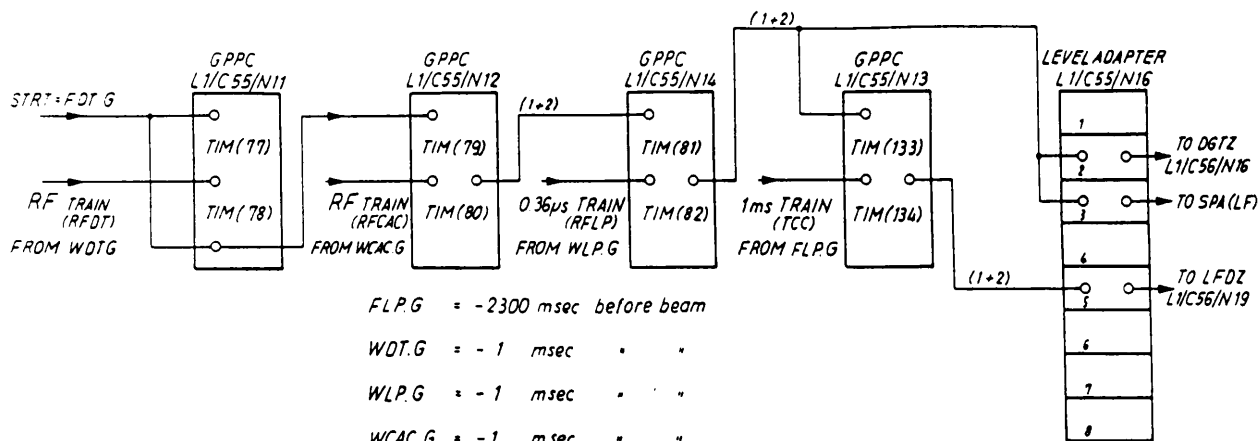


Fig. 2 Example of horizontal coherent oscillation correction in the AA using 100 MHz digitizers.

TIMING CONFIGURATION: DIGITISERS <DGTZ>, <LFDZ>, & LOW FREQUENCY SPECTRUM ANALYSER



RF Train dependence on RF of beam sending machine, therefore

RF Period selection
done by Central
Timing based on MODE/PLS
Selection User control
therefore limited to
keeping "Train" in
"TIM" to = 4 (RFTrain)
for relevant GPPC's

$RFDT = 0.105 \mu\text{sec}$ (Normal Polarity, \bar{p} production modes, $PSRF = 9.5 \text{ MHz}$)
 $= 0.36 \mu\text{sec}$ (Protons direct to AC, Modes 6 & 7, $PSRF = 2.7 \text{ MHz}$)
 $RFCAC = 0.36 \mu\text{sec}$ (P direct to AA with 1 Turn in AC (Mode 7), so use $PSRF = 2.7 \text{ MHz}$)
 $0.63 \mu\text{sec}$ (P direct to AA, delayed in AC (Mode 10), so use $ACRF = 1.6 \text{ MHz}$)
 $0.54 \mu\text{sec}$ (P via loop to AC (Mode 3), so use $AARF = 1.85 \text{ MHz}$)

Note: TIM (79), TIM (81) & TIM (133) USED AS GATES

Fig. 3 Timings layout.

5. New Applications Using Fast Digitizers

With the successful use of the signal routing modules and cascaded timing preset arrangements, it was relatively easy to extend the use of the fast digitizer modules for other applications. In the AA, the firing of the ejection kicker magnet is discernable as a fast rise- and fall-time noise on a pickup in close proximity to this kicker magnet. It is this kicker that gets fired everytime the antiprotons are extracted from the AA to the Collider or LEAR via the PS.

The complexity and the sequencing necessary to arrive finally at the proton-antiproton collisions in the SPS, via all the different systems in the AA, PS, SPS and the beam transport lines, means that every diagnostic tool available is used to analyse any failure in the antiproton transfer process. The correct firing of the AA fast ejection kicker is absolutely vital and is systematically observed at each transfer. Using the 100 MHz digitizers, this signal is digitised and stored. Figure 4 illustrates this for a typical antiproton extraction; the circulating bunch with a 540 nsec revolution period in the AA is clearly seen for a few turns prior to the

kicker rise, extraction and the kicker fall-time noise. This measurement has been put into routine operation for the automatic extraction program in the AA. In case of timing anomalies, it is possible to locate the fault, whether it be the non-firing of the kicker magnet (Fig. 5) or the mistiming of the rise of the kicker pulse, bringing it too close to the circulating bunch in the previous turn.

Last Ejected Bunch & Kicker at AA sigma22 Pickup
1989-09-20-12:03

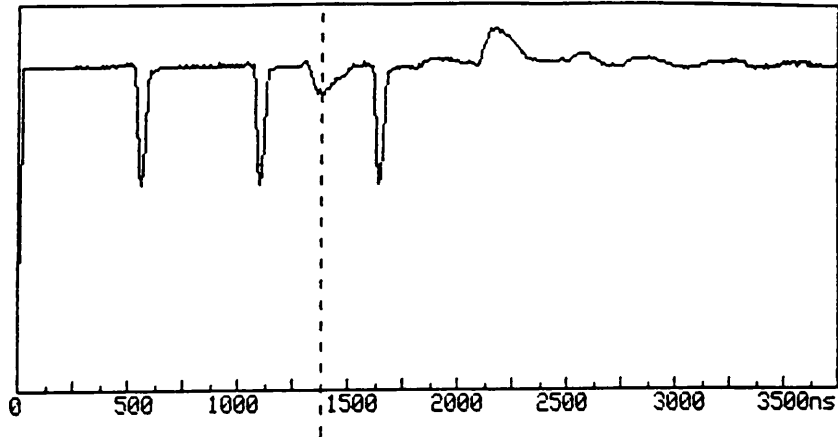
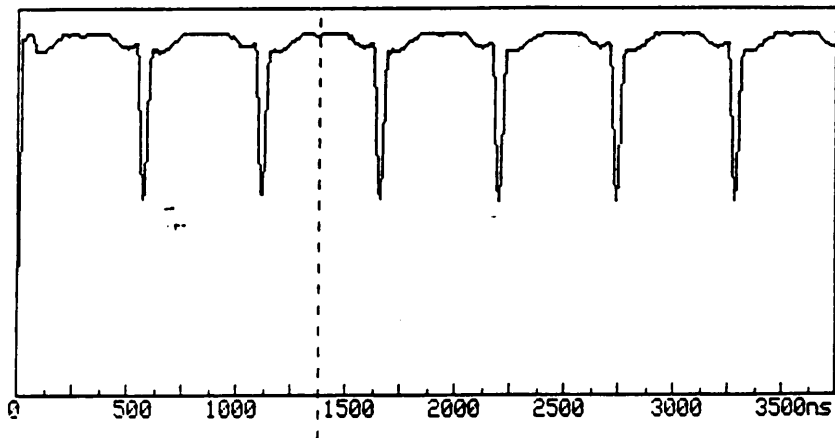


Fig. 4 With correct ejection kicker activation.

Last Ejected Bunch & Kicker at AA sigma22 Pickup
1989-09-20-11:30



Reference Line = 1375 ns
With TIM(82)=2766 x (0.36 μ s) in Mode 5
From FLP.Gated for above Measurement

VARIABLE >>>> EKICK-MSW TIM(20) AQN = 2754
VARIABLE >>>> Ei. Kicker Fine Delay = 290 ns
PS timing PX.MLP (cov) & (aon) from <TD>: -2768 -2768

Fig. 5 Ejection kicker did not fire: bunch still circulating.

BUNCH SHAPE AT INJECTION INTO AC AVERAGED OVER 10 SHOTS
 1988-08-05-17:45:31

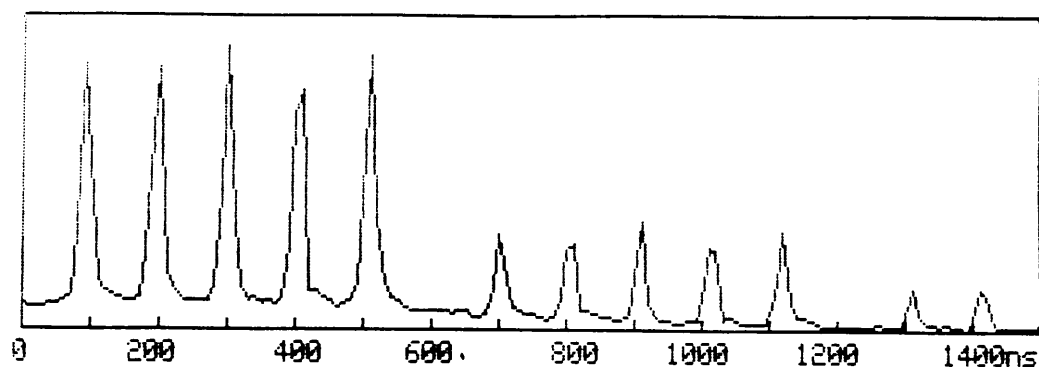


Fig. 6 Correct injection timing with 5 pion bunches.

Figure 6 illustrates another application of the 100 MHz digitizer system. For each antiproton produced in the target and injected into the AC ring, there are around 300 negative pions injected. While the beam of $7 \cdot 10^7$ antiprotons is too weak to be seen on the AC beam position pickups, the pion beam is clearly visible over the first 2 to 3 turns before the pions decay; the AC has a revolution period of 630 nsec and one can observe the fine bunch structure of the 26 GeV/c proton production beam in the secondary pion beam. On the second turn, the pion decay is already observed as a reduction in amplitude. The digitizer system is triggered continuously to carry out this observation during antiproton production. One of the main purposes of this is to ensure correct timing synchronisation for every production pulse with 5 pion bunches lying within the prescribed 630 nsec revolution period window. If the PS to AC timing synchronisation is misaligned, the pion bunch display quickly indicates the fault (Fig. 7), leading to corrective operator action. The calibration and integration of

BUNCH SHAPE AT INJECTION INTO AC AVERAGED OVER 10 SHOTS
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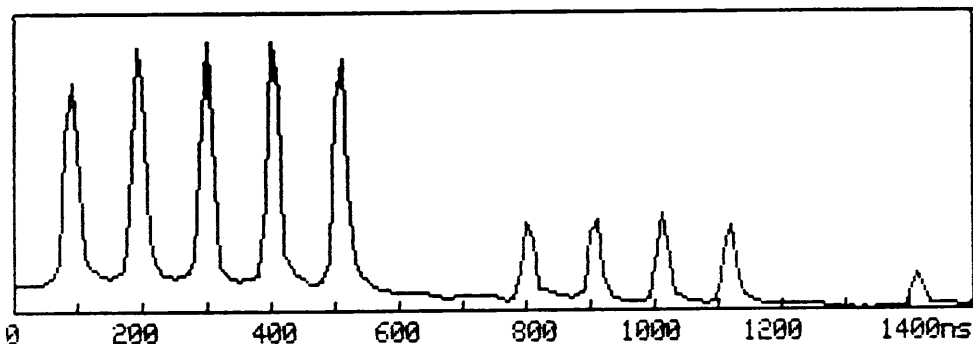


Fig. 7 Misaligned injection - only 4 pion bunches on 2nd turn.

the pion bunch signal over one turn could also lead to an estimate of the number of antiprotons circulating on the first turn in the AC ring and would complement the Schottky pickup estimate.

Recently, a quadrupole pickup has been put into operation in the AA to observe and damp quadrupole mode instabilities. The dipolar components from this quadrupole pickup have also been routed to the digitizer pair and have been successfully used in observation and signal treatment.

Finally, it should be mentioned that a lower sampling-frequency digitizer [13] working at upto 100 kHz is also regularly used together with the 100 MHz system and is triggered by the same cascaded timing presets. For the test beams, this digitizer is used to correct the longitudinal coherent oscillations. For the antiproton extraction mode, an automatic sampling of the rf phase (Fig. 8), frequency or voltage is carried out for each transfer and stored for later verification.

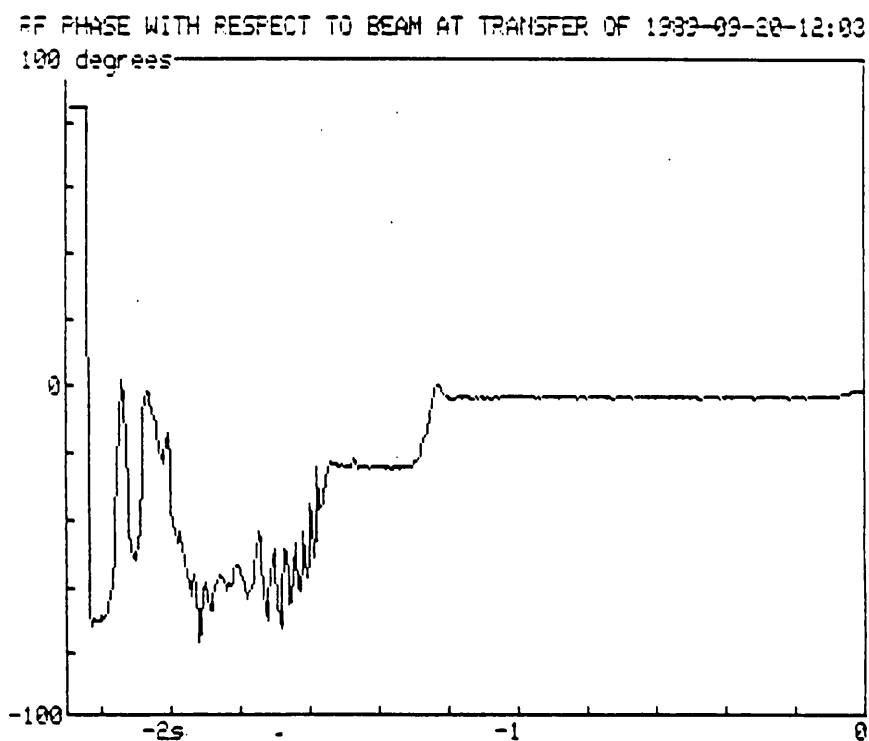


Fig. 8 Rf phase w.r.t. beam at extraction.

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