

# SINGLE PASS ANTIPROTON BEAM DIAGNOSTICS OF THE CERN PS ACCELERATOR COMPLEX

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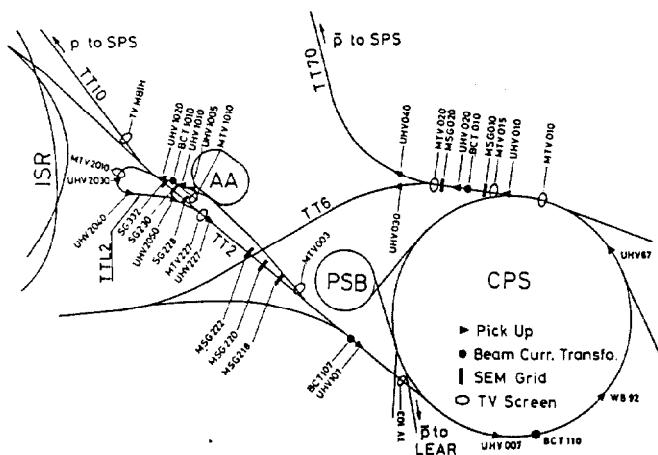
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## Summary

The beam characteristics of every  $\bar{p}$  bunch in the transfer lines and the CPS can be acquired by various monitors during a single pass and the information stored. The signals emanate from high sensitivity transformers, pick-ups, secondary emission grids and TV screens. After fast analysis and treatment the beam intensity, trajectory (positions), shape, transverse and longitudinal distributions are displayed in analog and/or digital form. Multiple shot storage is provided for some of these parameters. This paper describes the monitors and the signal processing, gives the special features of the storage systems, and presents typical results.

## Introduction

Antiprotons which have been stacked and cooled in the accumulator AA are transferred<sup>1)</sup> via the beam lines TTL2 and TT2 to the CPS ring at 3.5 GeV/c (Fig. 1). After acceleration to 26 GeV/c they are ejected via TT70 to the SPS or TT6 to the ISR<sup>2)</sup>. The various beam diagnostic monitors which are shown must function for single pass  $\bar{p}$  and p beams of intensity



### Pick-Ups (PU)

The electrostatic PU's are of the combined type shown in Fig. 6 and 7<sup>3)</sup>.

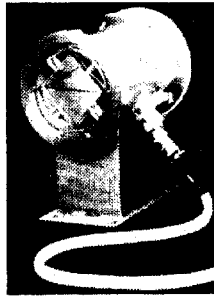
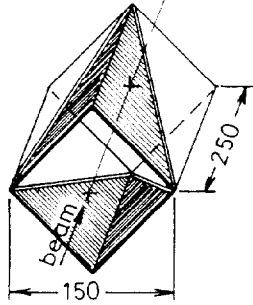


Fig. 6: Pick-Up Electrodes Fig. 7: Pick-Up Station

The horizontal and vertical electrode pairs (stainless steel) together form a straight prism and if correctly screened have, simultaneously, perfect linearity in both planes<sup>4)</sup>. This configuration, compared with diagonally cut cylinders, gives better beam intensity and position resolution due to smaller capacity and higher position sensitivity. The input circuit connected to each electrode is a 2<sup>nd</sup> order low pass filter shown in Fig. 8.

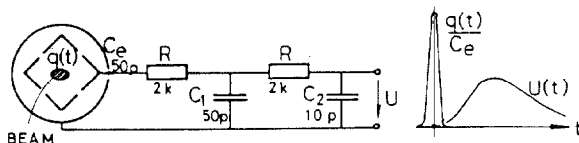


Fig. 8: Pick-Up Filter + In and Output Signals

This filter decreases the dynamic range due to different bunch lengths ( $4 \pm 100$  ns) from 25 : 1 to 1.3 : 1 and stretches all pulses to about 250 ns length. After gain controlled amplification the signals are fed to bipolar peak detectors<sup>3)</sup>. The sum and difference signals are kept in sample and holds (self triggered via comparator) and sent through a common multiplexer to a CAMAC ADC (Fig. 3). A micro processor controls the acquisition procedure, performs the necessary multiplication with the calibration factors, does the normalization and offset correction before displaying the beam positions by an event triggered software routine<sup>3)</sup>. The complete trajectories and intensities are stored for the last 24 shots in a push down memory. Fig. 5 (left) shows the horizontal and vertical beam positions in 13 PU's of a  $\bar{p}$  transfer to the SPS. Previous trajectories (Pulse No. 2 to 24) can be presented for comparison. A calibration generator can simulate beams of 3 intensities, 3 positions and 2 polarities ( $\bar{p}$  and  $p$ ).

The position resolution of the system is about 0.1 mm at  $10^{10}$  ppb.

### SEM Grids (SG)

For transverse emittance measurements of low intensity  $\bar{p}$  beams special secondary emission grid triplets are used. Fifteen 10  $\mu$ m thick titanium strips of 1 mm width and 1.5 mm center spacing cover the cross-section horizontally and a further 15 vertically. The current generated on each strip by the traversing beam is integrated by 30 gated active integrators located 200 m away from the SG (Fig. 9).

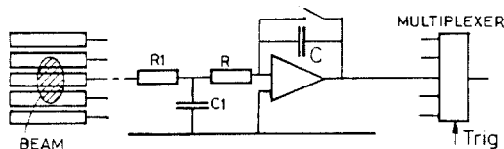


Fig. 9: SEM Grid Integrator

The capacitance  $C$  can be adapted to the beam intensity via computer control. The integrated output signals are multiplexed, amplified with gain controlled amplifiers and then digitized<sup>5)</sup>.

The microprocessor based acquisition system permits 16 consecutive measurements with minimum interval of 20 ms. To eliminate 50 Hz ripple the measurements are made in multiples of 20 ms e.g. at the same 50 Hz phase. The difference between two such acquisitions (without and with beam) is offset and 50 Hz noise free.

Fig. 10 shows the horizontal and vertical beam profiles of a low intensity  $\bar{p}$  beam of 80 ns length.

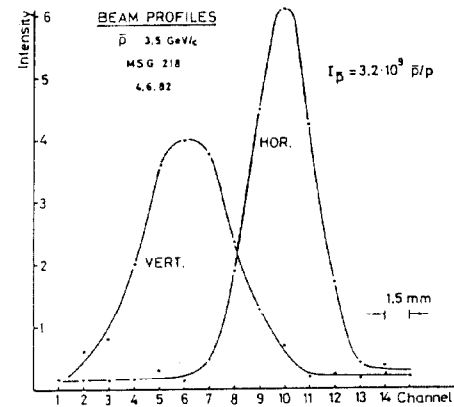


Fig. 10: Transverse  $\bar{p}$  Profiles

### Longitudinal Bunch Shape Measurement

The longitudinal  $\bar{p}$  bunch shape, obtained from an electrostatic CPS wideband (1 GHz) pick-up<sup>5)</sup>, can be acquired twice per acceleration cycle with 300 ms interval. Both bunch amplitude and length vary strongly with user requirements. Data from up to 40 bunches can be stored for later analysis in addition to the immediate presentation. The automatic measurement device consists of a programmable fast amplifier/attenuator followed by a Tektronix 7912 A waveform digitizer, driven through a GPIB link by an external 6800 based controller, which performs input amplitude adjustment, trigger selection, data storage and analysis plus analog output display (Fig. 11). The overall bandwidth is 500 MHz.

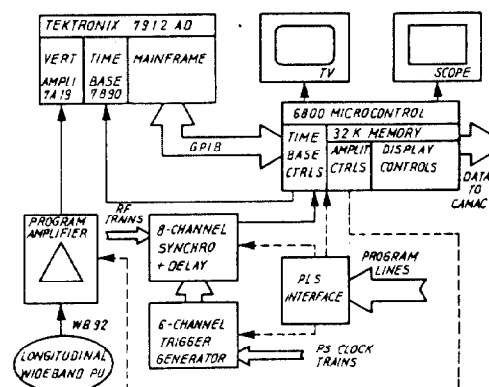
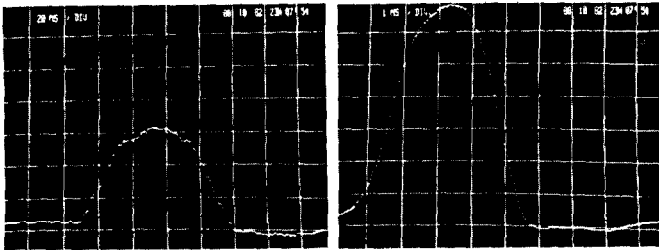


Fig. 11: Longitudinal Bunch Shape Measurement

The triggers are delivered by a multichannel pulse generator which is synchronized to the PS timing. Radio-frequencies serve for fine nanosecond delay adjustment. Every trigger channel is adjusted for a special type of operation and selection is automatically performed according to the PS general Program Line Sequencer (PLS).

After every trigger, digital data (1 K, 9 bits) are transferred to the memory of the micro-controller, checked for validity and stored if the signal peak amplitude is more than 3% of full scale. New settings are prepared for the vertical input amplifier, the time base and main-frame of the digitizer.

Apart from data collection and digitizer driving, the micro-controller generates two displays (TV and scope) from one of the 40 stored bunch shapes. The first is a video signal including calibrated graticule, record time and time base; the second is a 60 Hz repetitive  $y = f(t)$  signal for oscilloscope viewing. Fig. 12 shows two  $\bar{p}$  bunch shapes of the same bunch a) before and b) after acceleration in the CPS.



a) 20 ns/div (injection) b) 1 ns/div (ejection)  
Fig. 12: Longitudinal  $\bar{p}$  Bunch Shapes

On request, digital data can be transferred to PS computers for long term reference and for longitudinal emittance calculations.

#### TV Signal Processing

For the measurement of a single shot bunch with a high sensitivity luminescent screens ( $AL_2O_3$ ) having only short remanance time constants, an inexpensive video sample and hold was developed. The principle is shown in Fig. 13.

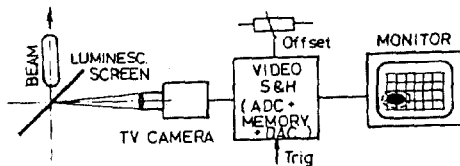


Fig. 13: TV Picture Sample & Hold

The video signal of the TV camera is digitized by an ADC some milliseconds after the beam has passed the screen. One complete picture (256 x 256 dots) is put into memory and then continuously displayed on the monitor via a DAC.

Fig. 14 shows the block diagram of the video frame sample and hold. The video signal applied to the buffer is split in 3 channels. The first goes directly to the video mixer and then to the monitor. The second is treated (variable gain and offset) to adjust range and level of the signal before it is applied to the ADC. The third is sent to the sync separator.

A store trigger arms the shift register (SR1) and the memory. The next vertical sync pulse starts the acquisition or read procedure. The burst generator, triggered with the horizontal sync pulse, produces 256 clock pulses for the ADC and the shift register (SR1). After 8 clock pulses (via divider 1/8) the contents of SR1 are loaded into the memory. This is repeated 32 times per line. After 256 lines, the memory contains 8 K bytes and the system switches from the read to the write mode. SR2 is then triggered in a similar way so that the memorized bit sequence is repeated and converted by the DAC. This signal is added to the direct video signal in the mixer. Thus the monitor displays the real time TV

screen picture plus, superimposed, a stored previous one.

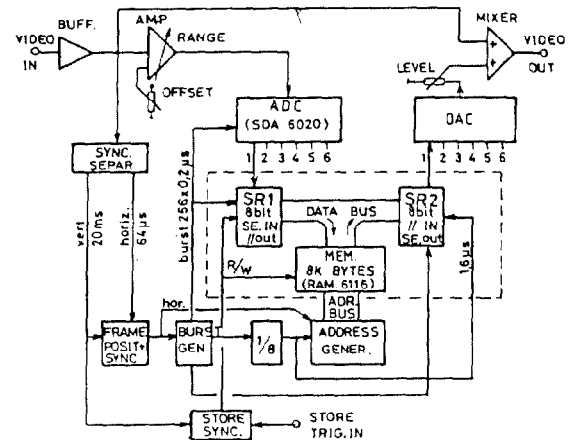


Fig. 14: Video Frame Sample & Hold

Fig. 15 shows a typical TV picture of a  $\bar{p}$  bunch ( $10^9$  ppb) captured with such a device with only 1 bit of the ADC equipped.

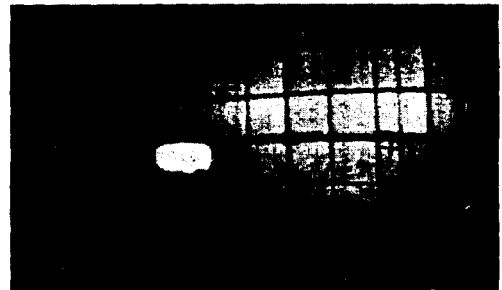


Fig. 15 : Stored  $\bar{p}$  TV Signal

Frequency division 1/8 permits use of slow memories (1.6  $\mu$ s clock) leading to the relatively low cost of the device.

#### Conclusion

Diagnostics of the  $p/\bar{p}$  transfers require monitors which combine high sensitivity with high noise immunity and wide dynamic range. Signal processing relies on micro-processor based techniques.

The system has been in operation for about two years. Its performance and reliability allows fast set-up and optimisation of single shot transfers.

#### Acknowledgements

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#### References

1. J. Gareyte, The CERN  $p/\bar{p}$  Complex, Proc. XI International Accelerator Conf. CERN 1980, p.79
2. The PS Staff, The CERN PS Complex as an Antiproton Source, this Conference.
3. G.C. Schneider,  $\bar{p}$  Beam Diagnostics of the Transfer Lines, CERN/PS/BT/83-4.
4. G.C. Schneider, Messwerferfassung und Übertragung zum Strahlagebestimmung beim 28 GeV Protonen Synchrotron von CERN, p. 36, thesis 1971, Techn. Universität Hannover.
5. J. Dieperink, private communication.
6. H.H. Umstätter, The New Wideband Pick-Up Station of the PS, CERN/PS/SR/70-1.