BEAM DIAGNOSTICS OF THE TRANSFER LINES

G.C. Schneider
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1. INTRODUCTION

The antiprotons are generated on a target in the AA injection line by 26 GeV/c protons and accumulated in the AA ring at 3.5 GeV/c. They are then transferred via the lines TTL2 and TT2 to the PS where they are accelerated to 26 GeV/c and ejected and transferred via the lines FA58 and TT70 to the SPS or via TT6 to the ISR.

The antiprotons are transferred between the different machines in single pass short bunches of 4 to 100 ns length. The beam intensity and horizontal and vertical positions of the trajectory are measured non-destructively and the transverse beam profiles partially destructive.

The small $\bar{p}$ beam intensity of $10^9$ p/pulse which is used for testing of the lines (pilot shot) requires high sensitivity of the monitors, low noise of the preamplifiers and good noise immunity to high voltage and high current disturbance sources of the environment.

The beam diagnostic (BD) system comprises: pick-ups (PU), beam current transformers (BCT), secondary emission grids (SG) and television screens (TV).

All monitors are capable of working with antiprotons and protons. The latter are transferred in the opposite direction for test and setting up purposes.

The beam diagnostic system has been in operation since the first $\bar{p}$-transfers in spring 1981.

Some essential features of this system have already been published in reference 1).

2. MONITORS

2.1 Monitor Locations

Fig. 1 shows the antiproton transfer lines and the chosen monitor locations.

There are 12 PU's:

2 PU's in the AA Ejection Line (UHV 1005, -1010)
4 PU's in the Loop TTL2 (UHV 1020, -2030, -2040, -2050)
Fig. 1

\( \overline{p} \) Beam Diagnostic
Monitors of Transfer Lines
Three beam current transformers are provided:

BCT 1010 between AA and TT2
BCT 107 in TT2 near PS
BCT 010 in the ejection line FA 58.

Two groups of 3 SEM grids are installed in TT2.

1. Group SG 228, SG 230, SG 332 and
2. Group MSG 218, MSG 220, MSG 222.

Furthermore, there are 2 SEM grids in the FA58 line:

MSG 010 and MSG 020.

The locations of 10 TV monitors of high sensitivity are also shown in Fig. 1.

The different monitors are described in the following.

2.2 Pick-Ups

The PU's are of the electrostatic type. The shape\(^1\) is shown in Fig. 2.

The horizontal and vertical electrode pairs form a straight prism. The projection in the horizontal and vertical plane give straight separation lines and hence theoretically perfect linearity all over the cross-section.
Fig. 4

Fig. 5
PU LINEARITY

Fig. 6
Fig. 3 gives the mechanical dimensions, and shows how the electrodes and guard rhombi are fixed with ceramic isolators, and also the signal feed-through.

Fig. 4 shows the total PU connected to the signal processing unit and Fig. 5 the installed PU in the transfer tunnel.

Fig. 6 gives the PU sensitivity in the horizontal direction for 3 different vertical beam positions. The measured linearity error in the extreme position ($\Delta x = 6$ cm, $\Delta y = 0$) is 1.4%, measured with a rod of diameter of 3 mm.

2.3 Beam Current Transformers

The transformer core consists of 30 \( \mu \)m Ultraperm 10 tape. Two rings of dimensions $\Phi 200 \times \Phi 140 \times 25$ mm are fixed together (Fig. 7). On this toroid a coil of 10 equally spaced turns is mounted. A further 1 turn coil serves for calibration.

The transformer is double screened against external magnetic fields with ANHYSTER M iron sheets ($\mu = 50000$).

The transformer is outside the vacuum. The necessary gap to keep the image current outside the transformer is made by a ceramic insulating layer between the flanges (13) in Fig. 7. These flanges are part of a standard vacuum quick connector (Fig. 8). Fig. 9 shows the transformer connected to the signal processing unit.

2.4 SEM-Grids

There are 2 types of SG's in the transfer lines.

The first SG's were originally developed for the ISR\(^1\). Figs. 10 and 11 show the grid arrangement. 15 horizontal and 15 vertical wires are separated by a thin biasing foil (6 \( \mu \)m Al). This foil, and the end rings, collect the liberated electrons using a positive potential of +250 V. The distance between the wires ($\Phi = 0.3$ mm Al) is 2.5 mm. The whole assembly can be moved 45° to the vertical by compressed air in such
Fig. 7

la soudure de la pos.13 se fera après le montage de la bobine et le câblage sur les connecteurs.
away that the horizontal and vertical wires go simultaneously in a mean interpolate position. Hence the horizontal and vertical resolution is 1,25 mm.

The second type of SG's (MSG 218, -220, -222) comes from the SPS. These SG's are described in reference 4. The position resolution of these monitors is 1,5 mm (no mechanical interpolation).

2.5 TV monitors

The low antiproton intensities require TV screens with high sensitivity. The selected screen material, aluminium oxide (AL₂O₃) from DESMARQUEST (AF995R) has a resolution of about 10⁸ particles for beam sizes of 1 cm² at an energy of 26 GeV. All screens of Fig. 1 are made of this material.

3. SIGNAL PROCESSING

3.1 Block Diagram Description

Fig. 12 shows the three types of monitors and the essential signal processing elements.

The PU signals pass first through Bessel filters which limit the signal dynamic due to different bunch lengths (100 to 5 ns). For adaptation to different beam intensities 3 gains are provided. The polarity of the peak detector can be controlled for proton or antiproton operation. The sum and the differences of the peak detected signals are self captured with 3 Sample and Holds (S&H) when triggered by the sum signal (via comparator). The output signals, of 100 ms length, are symmetrically transmitted over twisted pair cables to the standard CAMAC acquisition system (4 multiplexers, 1 ADC and 1 ACC).

The μ-processor of the ACC starts the acquisition when triggered by the interrupt signal and calculates the beam coordinates of all PU stations. This information can then be periodically displayed on a TV monitor, gated by the selected PLS line.

A calibration generator allows the beam position coefficients to be determined for each gain and beam polarity with pulses similar to the
The beam current transformer signal is directly integrated by a passive resonance integrator. The output signal is amplified, peak detected, and self captured with a S&H with similar elements as used for the PU signals and is then fed to the same CAMAC acquisition multiplexer set.

The calibration is performed by a pulse generator connected to the transformer via the one turn winding. The calibration pulse is derived from a charged cable of which the capacity and voltage are adjusted with an accuracy better than 1%. Four calibration intensities ($10^1$, $10^4$, $10^5$, and $10^6$ particles/pulse) are produced by high precision attenuators. The highest attenuation of the generator signal is combined with the highest gain of the amplifier. Hence the calibration output signal is constant for all calibration intensities.

The 30 signals of one Secondary Emission Grid (SG) are fed to gated integrators (15 horizontal and 15 vertical) and then to a 32 channel multiplexer. On channels 16 and 32 are 1 V reference signals which allow the acquisition system to be tested. The output signal of this multiplexer is transmitted via several hundred meter long twisted pair cables to the same CAMAC and PU multiplexer set as the BCT signals.

All the control functions of the 3 monitor types are performed via standard I/O registers and specific control interfaces. The required timing pulses are derived from a -100 μs pretrigger for the PU and BCT and a -7 ms pretrigger for the SG acquisition via standard preset counters. These trigger pulses can be replaced for calibration and test purposes by pulses from a standard pulse generator.

### 3.2 Timing

Fig. 13 shows the timing diagram.

About 20 μs before ejection the comparator of the self capture circuit is armed for 50 μs. The intensity signal of the transformer or the sum signal of the PU peak detector triggers, when higher than an adjustable reference DC voltage, the S&H 5 μs after the
TIMING

PU + BCT

WAP (-100μs)* or WP56(-100μs)**

ENABLE COMPARATOR

T1 ≤ 80μs

COMP. ARM

50μs

BEAM

20μs

PEAK HOLD

1.5μs

S + H TRIG. FROM COMPAR.

100 ms

S + H OUT

ACC INTERRUPT 1 FOR MUX-
ADVANCE + ADC TRIG.

T2 ≤ 20 ms

ACC ACTIVE

ca 70 ms for PU+BCT

SEMGGRID

BEAM

TRIG

7 ms

INIT INTERRUPT 2 (ACC)

120 ms

CONV INTERRUPT 3 (ACC)

>150μs

32 CONV PULSES

SG 1, 2, 3

CLOCK

* EQUIPMENT 1
** EQUIPMENT 2

Fig. 13
beam passage. The S&H maintains the signal constant for 100 ms. 20 ms later the Auxiliary Crate Controller is triggered at interrupt input 1 to acquire all PU and BCT signals and to compute the beam positions and intensities. This needs about 70 ms.

The SG integrators are armed 7 ms before the beam has passed the detector. They maintain the integrated signals during 500 ms. 120 ms after the beam passage the local multiplexer and the ACC are initiated and then clocked. During the 150 μs interval between the clock pulses the ACC switches the CAMAC multiplexer through the 3 SG signals of the 3 monitors.

Fig. 14 shows the CAMAC crate (equipment 1, Y building) with the 2 interface crates below for the 3 systems (PU, BCT and SG).
3.3 PU Signal Processing

3.3.1 Transfer Function of the PU Input Circuit (Fig. 15)

The transfer function $U_2/U_1$ can be found from the two port theory where

$$\begin{pmatrix} U_1 \\ J_1 \end{pmatrix} = \begin{pmatrix} A_1 \\ A_{II} \end{pmatrix} \begin{pmatrix} U_2 \\ J_2 \end{pmatrix}$$  \hspace{1cm} (1)

and $A_1$ respectively $A_{II}$ are the matrices of the encircled parts I and II (Fig. 8).

Hence

$$\begin{pmatrix} U_1 \\ J_1 \end{pmatrix} = \begin{pmatrix} 1; R + \frac{1}{pC_e} \\ 0; 1 \end{pmatrix} \begin{pmatrix} 1 + RpC_2 \\ p(C_1 + C_2) + p^2C_1C_2R; 1 + pC_1R \end{pmatrix} \begin{pmatrix} U_2 \\ J_2 \end{pmatrix}$$  \hspace{1cm} (2)

For $J_2 = 0$ it follows

$$\frac{U_2}{U_1} = \frac{1}{a_{11}}$$  \hspace{1cm} (3)

Where

$$a_{11} = (1 + RpC_2) + \frac{R}{pC_e} \left[ p(C_1 + C_2) + p^2C_1C_2R \right]$$  \hspace{1cm} (4)

From equation (3) and (4)

$$\frac{U_2}{U_1} = \frac{1}{C_1 + C_2 + \frac{C_e}{pR \left( \frac{C_1C_2}{C_e} + C_1 + 2C_2 \right) + p^2C_1C_2R^2}}$$  \hspace{1cm} (5)

This complex transfer function can be transferred into the time domain with the inverse Laplace transform. For a unit input pulse of length $\tau$
From equation (5) and (6) and with reference 5 it follows

for $t \leq \tau$

$$U_2(t) = L^{-1}\left\{U_2(p)\right\} = \frac{1}{ab} + \frac{be^{at} - ae^{bt}}{ab(a - b)}$$

(7)

and for $t > \tau$

$$U_2(t) = \frac{1}{ab(a - b)} \left[ be^{at} (1 - e^{-at}) - ae^{bt} (1 - e^{-bt}) \right]$$

(8)

where

$$a = -\frac{B + D}{2A}; \quad b = -\frac{B - D}{2A}$$

and

$$A = C_1C_2R^2; \quad B = \left(\frac{C_1C_2}{C_e} + C_1 + 2C_2\right) R$$

$$C = \frac{C_1 + C_2 + C_e}{C_e}; \quad D = \sqrt{B^2 - 4AC}$$

The time response $U_2(t)$ (equation (7) and (8)) is plotted in Fig. 16 for rectangular input pulses of different lengths $\tau$ normalized for

$$\int_0^\tau U_1 \, dt = U_1 \tau = \text{const.}$$

(9)

Fig. 16 shows that an input dynamic range of

$$100 : 5 = 20$$

is compressed at the output of the filter to about

$$0.3 : 0.24 = 1.25$$

**REMARK**: 

(The first $R$ and $C_1$ are mounted in the connector and cable between PU and chassis. The second $R$ is on the printed base carte and $C_2$ on the peak detector card.).
Aims

$U_1(t)$

$C_1 = 50 \text{ pF}$
$C_2 = 25 \text{ pF}$
$C_e = 50 \text{ pF}$
$R = 2.0 \text{ k}$

Fig. 16
3.3.2 Circuit Description of PU Signal Processing

A) Peak Detector

The principle of the peak detector is shown in Fig. 17.

A fast differential amplifier controls a fast current source proportional to \( U_{in} - U_{out} \). The current charges \( C \) via Diode \( D \) to the peak voltage of \( U_{in} \).

The circuit diagram is given in Fig. 18. 2 channels are mounted on 1 card.

The input signal (from B2, lower channel) is applied to the source follower (T1 + T2). The gain of this input stage is 1 as the source resistor is replaced by a high impedance current source. The relay switches S2 and S3 allow the insertion of an amplifier stage (x 30) (T3, T4, T5) in the direct path. A low pass filter (R15 + C17) limits the noise bandwidth. The signal is then taken to the peak detector (T6, T7, D2, C15) for positive proton signals or (T6, T8, D4, C15) for negative \( \bar{p} \) signals). The relay switches S4 and S5 are used to distinguish between these 2 operations. The loop is closed via the diodes D2 or D4 to the gate of T6 (pin 6). The condenser C15 holds the peak detected signal. The voltage follower A1 transmits this signal to the output (A40).

The functions of the different potentiometers are:

- P1 adjusts working point and gain of the x 30 stage.
- P2 balances the gain of peak detectors.
- P3, P4 adjusts output offset to zero.
- P5 balances low frequency discharge time constants.
The peak detector requires for correct settling a flat top of the signal of 10 ns. For short pulses this is guaranteed by the input filter (Fig. 15). The dynamic range of the peak detector is about 500 (±8 mV to 4 V).

There are two identical cards, one for the 2 horizontal channels and one for the 2 vertical channels.

In front of the peak detector there is an analog signal branch-off via R35 (to pin A9). This signal goes to the difference and sum amplifier card (Fig. 20).

B) Sample and Hold (Fig. 19)

The 4 peak detected signals are fed to the amplifier inputs (A2, A4, A6, A8) of the S&H card.

The differential operational amplifiers IC1 and IC1' amplify the horizontal and vertical differences by a factor of 2.5. The amplifier IC1" produces the sum of the 4 input signals. The 3 output signals are fed to 3 monolythic S&H's IC2, IC2' and IC2". The storage elements are the 1 nF capacitors C4, C4' and C4".

The output signal of the sum amplifier is used to trigger the S&H's (self triggering). This signal passes via the buffer FET T1, a diode clipper (D6, D7) to a dual comparator IC4. The signal polarity can be chosen by the switch S5. The comparator reference voltages (20, 40, 80, 160 mV) can be selected by 4 bits (via relay switches S1 to S4).

The comparator triggers the first one-shot IC6 (with a negative going signal) if the sum signal becomes higher than the reference voltage. After 5 µs the second one-shot of IC6 is triggered (at pin 14) and produces a 100 ms hold signal for the 3 S&H's.

The comparator IC4 must be armed by a strobe signal a few µs before the beam. This signal comes from IC5 when started by a S&H enable trigger (B38). The enable signal disappears after 50 µs if it is not earlier reset by a sum signal from Q2 (pin 12 of IC6) to CLR1 of IC5. In this case a second one-shot of IC5 is triggered and produces a LED light signal.
The trigger signal of the S&H causes a small error offset in the output signal. This is compensated by a high pass feedback (C16, P8, R7) to the positive input (pin 3 of IC2). In the case of the sum S&H this is done by the trimmer C5'.

The three 100 ms long output signals of the S&H's are inverted by the op. amplifiers IC3, IC3' and IC3'' to obtain a symmetrical signal transmission for a better signal to noise ratio.

C) Wide Band Analog Signal Processing (Fig. 20)

The input signals (H1+, H1-, V1+, V1-) of this differential and sum amplifier card come from the peak detector card.

Two FET differential stages (T10, T12) produce the horizontal and vertical difference signals. These signals are amplified by further differential stages (T7, T9).

The common mode of the input signals appears between the 2 sources of the input stages and represents the sum signal. The horizontal and vertical sum signals are branched off at the cursors of P6 and P10. The sum of these two signals appears at the cursor of P9 in the summing stage with T11 and T6. This signal is amplified by the dual FET T8.

The amplified sum and difference signals which appear symmetrically at the drains of T8, T7 and T9 are transmitted to symmetrical cables via 6 line drivers LH0033.

The bandwidth of the amplifiers is about 25 MHz. The max. output signal is ± 2V.

D) The Calibration Generator and the Controls

Fig. 21 shows on the lower left the calibration generator. An enable calibration trigger pulse generates a rectangular pulse of 100 ns corresponding to the bunch length (IC17). The polarity is changed by the contact of relay RL3. The signals are clipped by a diode/zener diode network. By means of the relay contacts of RL7 and RL10 the signal amplitude can be attenuated in 3 steps according to the gain setting.
The calibration pulse can then be fed to the PU inputs via relay contacts of RL 4, 5, 8 and 11 in such a way that the horizontal and vertical balance and calibration positions can be simulated.

On the same card is also the surveillance of the power supply (on the right of Fig. 21). It excites relay RL20 if one of the 4 stabilized voltages deviates more than 10% from its nominal value.

The upper right side shows the HF Station Selector, which allows by digital addressing (B₀, B₁, B₂, B₃) the selection of the 3 analog signals ΔR, ΔV and Δ of one of 15 PU stations. These signals are then transmitted via 3 common coaxial cables to the observation point.

The digital control and acquisition indicated on circuit diagram Fig. 21 are made via a common, twisted pair multiwire cable, which passes by daisy chaining through all PU station chassis in the tunnel.
Fig. 22 shows the complete local PU electronics mounted in a plug-in. Fig. 23 is a picture with the 4 cards (2 Peak Detectors, 1 S&H, 1 Analog A and 2 amplifiers) pulled out.

The module which controls the local PU electronics via the control cable is shown in Figs. 24 and 25. It allows manual control by switches (LOCAL) or computer control via input/output register (COMPUTER) of all 16 bits. The bit allocations are given in section 4.

### 3.4 BCT Signal Integration and Transmission

The integrated beam current corresponding to the number of passed particles ($\bar{p}$ or $p$) is obtained by a symmetrical, passive third order resonance circuit shown in Fig. 26. The small bandwidth of this circuit leads to a high signal to noise ratio.

![Fig. 26](image)

It can be shown that the amplitude $A$ of the output voltage $U$ is proportional to the integrated beam current $I_B$ if $T/\tau >> 1$.

$(\tau = $ bunch length, $T = $ delay of peak voltage $U(t)$ )

Fig. 27 shows half of the symmetrical circuit of Fig. 26 with the corresponding element values.

\[
\begin{align*}
L &= \frac{1}{2} \text{ inductance of BCT} \\
R_1 &= \frac{1}{2} \text{ loss resistance of BCT} \\
I &= \frac{I_B}{N}; \quad U' = \frac{U}{2}
\end{align*}
\]
Fig. 27

**COMPLEX FUNCTION SPECTR(P)**

- COMPLEX P \_V
- DATA R/10000./;C1/4.;C2/.54/;EL/6.35E6/;RL/500./
- SPECTR=(1.-CEXP(-P*TAU))/(P*TAU)
- I=P*C2
- V=(P*C1+1./RL+1./P*EL)*V+I
- RETURN=SPECTR/I
- END

**Resonance Integrator**

- \( I(t) \)
- \( C = \frac{100\text{ns}}{1} \)
- \( R = 10\text{k} \)
- \( L = 6.35\text{mH} \)
- \( R_1 = 500 \)
- \( C_1 = 4\text{nF} \)
- \( C_2 = 540\text{pF} \)

**Graph**

- Time scale: 0.00 to 1.00
- Voltage scale: 0.00 to 6.00

**Equation**

\[ U(t) = \frac{1}{1 + (\theta)^2} \]

\[ \theta = \frac{R}{2\pi fL} \]
The input signal spectrum of a rectangular current pulse ($\tau = 100$ ns)

$$I(p) = \frac{1 - e^{-pt}}{pt}$$  \hspace{1cm} (10)

is transformed by the complex transfer function $Z(p)$ of the circuit and gives

$$U(p) = I(p).Z(p)$$  \hspace{1cm} (11)

The inverse Laplace transform is performed by the program LAPLACE$^{14}$ with the Complex Function SPECTR(P), given in Fig. 27.

The result $U'(t)$ is plotted in the same figure.

Fig. 28 shows the output response for a much shorter input pulse ($\tau = 1$ ns) but the same charge

$$Q = \int I(t) \, dt.$$  

The peak values, indicated by arrows, for $\tau = 100$ ns and $\tau = 1$ ns differ by

$$\frac{4.722 - 4.720}{4.722} = 0.42\%$$

This means that the ratio

$$\frac{T}{\tau} = \frac{2.8 \, \mu s}{0.1 \, \mu s} = 28$$

is big enough for an integration error of $< 1 \%$.

The sensitivity of the transformer, including symmetrical resonance filter, can be derived from the peak signal $U_p' = 4.72 \times 10^{-2} \text{ V}$. (Fig. 27).

The number of particles $N$ contained in the rectangular current pulse ($i = 1A, \tau = 1$ ns) is given by

$$N = \frac{1}{e} \int i \, dt \hspace{1cm} (e = 1.6 \times 10^{-19} \text{ As}).$$  \hspace{1cm} (12)

The peak output voltage $U_p$ of the symmetrical filter leads to the sensitivity

$$S = \frac{2U_p'}{N} = \frac{2U_p' \cdot e}{i \cdot \Delta t} = \frac{2 \times 4.72 \times 10^{-2} \times 1.6 \times 10^{-19}}{1 \times 10^{-9}}$$

$$S = 0.151 \text{ V}/10^{10} \text{ particles}$$  \hspace{1cm} (10^{10})
RESONANCE INTEGRATOR

Fig. 28

Complex function SPECTR(P)

Complex P, I, V

Data R/10000, C1/4, C2/54, EL/6.35E6, RL/500

Data TAU/1.0

SPECTR=(1-C*EXP(-P*TAU)))/(P*TAU)

IF P<C2

V=I*R+1

I=(P*C1+1/RL+1)/(P*EL)*V+I

SPECTR=SPECTR/I

RETURN

END
The output signal is symmetrically amplified (x10) by 2 low noise FET amplifiers (Fig. 30, on the left), and then by a differential amplifier\textsuperscript{1}) whose gain can be controlled x1, x10, and x100. The higher signals are attenuated (1/10) by changing the integrator capacitor (Fig. 30, RL8).

The total dynamic range $10^7 - 10^{12}$ ppp is covered by the following total gain settings: (see Table 1).

<table>
<thead>
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<th>Intensity</th>
<th>$10^8$</th>
<th>$10^9$</th>
<th>$10^{10}$</th>
<th>$10^{11}$</th>
<th>$10^{12}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{tot}$ ppp</td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1

The amplified signal is peak detected, further stretched by a S&H and then digitized as already mentioned.

The analog signals are transmitted via symmetrical, magnetically shielded cables and differential amplifiers to transient recorders.

To avoid unsymmetrical magnetic coupling from external noise currents to the transformer core, the case is isolated from its support.

3.4.1 BCT Calibration Generator

Each transformer is equipped with a local calibration generator.
The principle is shown in Fig. 29.

A cable with impedance $Z_1$, length $l$ and capacitance $C = 2000$ pF is charged via $R_L$ to $U = 8V$ (FET switch OFF). By turning the FET ON the charge $C\cdot U$ flows through a transformer calibration winding, nearly matched as $R + Z_2 = Z_1$. The number of particles contained in this rectangular current pulse of length $2\tau$ is

$$N = \frac{C\cdot U}{e} = \frac{2\cdot10^{-9}\cdot8}{1.6\cdot10^{-19}} = 10^{11}$$  (14)

($e = 1.6\cdot10^{-19}$ As, $\tau =$ cable propagation time).

The complete circuit is shown on the right of Fig. 30. A controlled precision attenuator 0, 20, 40 and 60 db allows calibration with 4 different pulse amplitudes in steps of $1/10$. The four calibration intensities are $10^{11}$, $10^{10}$, $10^9$ and $10^8$ ppp.

A similar mobile calibration generator, where the FET is replaced by a mercury relay and the attenuator by a switch which varies the source voltage $U$, serves as reference before installation.
Fig. 30

2 x AMPLI GX 10 + CAL
GENERATEUR (BCT)
3.5 SEM Grid Input Circuit

A schematic diagram of this circuit\(^1\) is shown in Fig. 31.

![Fig. 31](image)

The passing protons or antiprotons excite the electrons of the aluminium atoms of the wire. The number of ejected electrons is proportional to the local beam intensity. These electrons are collected on a +250 V biased electrode. The corresponding positive current is integrated on the condensor C. A high input impedance voltage follower transmits this signal to the multiplexer.

The SG's MSG 218, 220, 222 use active operational integrators where the capacitance C is in the feedback loop of the amplifier\(^1\).\(^4\).

3.6 TV Signal Processing

The luminescent screens with high sensitivity have relative short remanence time constants e.g. the light signal disappears quickly. High attention of the observer is required.

To make the observation more comfortable an inexpensive video frame storage device has been developed\(^4\).

The principle is shown in Fig. 32.

![Fig. 32](image)
The video signal of the camera is digitized some milliseconds after the beam passage by an analog to digital converter (ADC). One complete picture is put in memory (8 K, 1 bit) and afterwards periodically displayed on the monitor. An adjustable reference level permits to vary the contour equi-luminosity. The dotted line corresponds to a smaller reference luminosity. Fig. 33 shows a stored 1 bit $\bar{p}$ signal with this device. A video picture hold device with higher resolution (6 bits) is in preparation.

Fig. 33

3.7 CAMAC Equipment

Two CAMAC crates are used for the BD system. They belong to Loop 3 (TT computer). Crate No. 2 for equipment 1 is installed in the Y building (269) and Crate No. 20 for equipment 2 in the east ejection hall (356). Table 2 gives the installed CAMAC modules, their locations and purpose.
4. DESCRIPTION OF THE DATA MODULE FUNCTIONS

The necessary controls and status acquisitions are performed via 3 16 bit I/O Registers (1031 A) which are controlled by the data modules TTU for the PU's and BCT for the transformers and GRID for the SG's.

4.1 PU Controls and Acquisitions

The PU control functions are given in Table 3.

The gain setting x1 is obtained by bit 2 and 3 equal to zero. A simulated centred beam for the calibration balance is set by bit 4 and 5 equal to 1.

The acquisition of the control bit settings (Table 3) is done by the input register with A(0).

The power status of the PU's can be acquired by the second input register with A(1). The bit allocations are given in Table 4.
### PU Control BIT FUNCTIONS

<table>
<thead>
<tr>
<th>Bit Nr.</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$p/\overline{p}$ (on $\Delta p$)</td>
</tr>
<tr>
<td>2</td>
<td>gain x 30</td>
</tr>
<tr>
<td>3</td>
<td>gain x 0,1</td>
</tr>
<tr>
<td>4</td>
<td>Cal. 1</td>
</tr>
<tr>
<td>5</td>
<td>Cal. 2</td>
</tr>
<tr>
<td>6</td>
<td>Enable Measurement (S&amp;H)</td>
</tr>
<tr>
<td>7</td>
<td>Enable Cal. Trigger</td>
</tr>
<tr>
<td>8</td>
<td>160 mV</td>
</tr>
<tr>
<td>9</td>
<td>80 mV</td>
</tr>
<tr>
<td>10</td>
<td>40 mV</td>
</tr>
<tr>
<td>11</td>
<td>20 mV</td>
</tr>
<tr>
<td>12</td>
<td>(8)</td>
</tr>
<tr>
<td>13</td>
<td>(4) for analog observation</td>
</tr>
<tr>
<td>14</td>
<td>(2) (HF Relay)</td>
</tr>
<tr>
<td>15</td>
<td>(1)</td>
</tr>
</tbody>
</table>

Table 3

### PU STATUS ACQUISITION BITS

(Power Status)

<table>
<thead>
<tr>
<th>Bit Nr.</th>
<th>PU Nr.</th>
<th>Equipment</th>
<th>Y-Building PU Name</th>
<th>East Ejection Hall PU Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td>UHV 107</td>
<td>UHV 010</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td></td>
<td>UHV 227</td>
<td>UHV 020</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td></td>
<td>UHV 2050</td>
<td>UHV 030</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td></td>
<td>UHV 2040</td>
<td>UHV 040</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td></td>
<td>UHV 2030</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td></td>
<td>UHV 1020</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td></td>
<td>UHV 1010</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td></td>
<td>UHV 1005</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>12</td>
<td>12</td>
<td></td>
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<td></td>
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<tr>
<td>13</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4
4.2 BCT Controls and Acquisition

The BCT control functions are given in Table 5. Gain x 1 is obtained by bit 2 and 3 equal to zero.

The acquisition of the control bit settings (Table 5) is done by the input register with A(0).

The power status of the BCT's can be acquired by the input register with A(1). The bit allocations are given in Table 6.

BCT CONTROL BIT FUNCTIONS (Output Register)

<table>
<thead>
<tr>
<th>Bit Nr.</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Gain x10</td>
</tr>
<tr>
<td>3</td>
<td>Gain x0.1</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Enable Measurement</td>
</tr>
<tr>
<td>7</td>
<td>Enable Cal. Trigger</td>
</tr>
<tr>
<td>8</td>
<td>160 mV</td>
</tr>
<tr>
<td>9</td>
<td>80 mV { U_{ref} \text{ for comparator}</td>
</tr>
<tr>
<td>10</td>
<td>40 mV</td>
</tr>
<tr>
<td>11</td>
<td>20 mV</td>
</tr>
<tr>
<td>16</td>
<td>Attenuator 1/10</td>
</tr>
</tbody>
</table>

Table 5.

BCT STATUS ACQUISITION (Input register A(1))

<table>
<thead>
<tr>
<th>Bit Nr.</th>
<th>BCT Nr.</th>
<th>Y-Building BCT Name</th>
<th>East Ejection Hall BCT Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>TRA 107</td>
<td>TRA 010</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>TRA 110</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.
4.3 Calculations and operations of the ACC microprocessor program BCTPU

When the ACC is triggered (LAM interrupt 1) it acquires the following direct signals:

from BCT: $S_n$ (intensity)

and PU: $\Delta \rho$, $\Sigma_n$ (position, sum)

The index $n$ (1 to 15) indicates the monitor station number and $\rho$ the horizontal (h) or vertical (v) plane.

The following values are then calculated.

The BCT beam intensities

$$I_n = K_{\mu n} \cdot S_n \quad , \quad (15)$$

the beam positions

$$X_{\rho n} = k_{\mu \nu \rho n} \cdot \frac{\Delta \rho_n}{I_n} - \Delta x_{\mu \nu \rho n} \quad (16)$$

and the PU sums

$$J_n = K_{\mu \nu n} \cdot \Sigma_n \quad (17)$$

The indices $\mu$ and $\nu$ mean

$\mu$ : gains (1 to 4 for BCT)

(1 to 3 for PU)

$\nu$ : proton or antiproton

The coefficients $K$, $k$, $\Delta x$, $\kappa$ are taken from data tables in the FEC Memory. After calibration measurements these coefficients had been determined by the following formulae.

<table>
<thead>
<tr>
<th>Intensity Coefficient $K_{\mu n}$</th>
<th>$I_\mu$</th>
<th>$S_\mu$</th>
</tr>
</thead>
</table>

(I$\mu$ = calibration intensity, $10^{11}$, $10^9$, $10^8$, $10^7$ ppp) depending on gain $G_\mu$ (1, 10, $10^2$, $10^3$).

$S_\mu$ = signal with calibration intensity, constant for all gains $\mu$ (as $I_\mu \cdot G_\mu = S_\mu$).
Position coefficient

\[ k_{\mu \nu \rho \sigma} = \frac{X_0}{2} \left( \frac{\Sigma_{C1}}{\Delta_{C1}} + \frac{\Sigma_{C2}}{\Delta_{C2}} \right) \]  
(19)

\( X_0 = 84 \text{ mm} = \text{position constant (}\Delta = \Sigma\), (Fig. 6)).

Where \( \Sigma_{C1} \) and \( \Delta_{C1} \) are the sum and difference signals with a simulated beam in calibration position 1. The index 2 means calibration position 2 (Fig. 34).

The position offset coefficient

\[ \Delta X_{\mu \nu \rho \sigma} = k_{\mu \nu \rho \sigma} \cdot \frac{\Delta_{C3}}{\Sigma_{C3}} \]  
(20)

(index C3 for balance position 3) and the PU sum coefficient

\[ \kappa_{\mu \nu \rho \sigma} = \frac{J_{\mu \nu \rho \sigma}}{\Sigma_{C3}} \]  
(21)

Fig. 35 shows schematically the different PU data tables for the parameters, coefficients and results and how they are accessed by the programs. It gives the names of the coefficient arrays under which they can be addressed from the data module and the occupied space.

Fig. 36, shows a similar block diagram for the BCT data tables.

The direct signals and the computed results of 16 PU's and 16 BCT's are stored for the last 24 acquisitions (machine cycles) in such a manner that the oldest cycle information is lost when a new acquisition is made.
PU APPLICATION PROGRAM

Direct Signal Data

Cycle Nr.

ARRA1

ARRA2

ARRA3

Result

Posit. Sum

N = 24

nN

1080

Fig. 35
BCT DATA TABLES

BCT APPLICATION PROGRAM

<table>
<thead>
<tr>
<th>Cycle Nr.</th>
<th>Data</th>
<th>Result Beam Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>AQND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = 24</td>
<td>384</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R Direct Signal</td>
<td>R</td>
<td>W</td>
</tr>
<tr>
<td>ARRA3 n·μ</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>384</td>
<td>384</td>
</tr>
</tbody>
</table>

RT PROGRAM

PROCESS (BCT)

Fig. 36
4.4 SG Control and acquisitions

The SG control functions are given in table 7.

Three single step advance pulses of 18 ms length (24 V) and 150 ms interval transport the grid assembly to the interpolate position, three further pulses bring it back to normal position.

The bit allocations of the SG status acquisition are listed in table 8.

The data module GRID allows to move the SG's and to read the data tables.

The ACC µP program TTGRID1) performs the acquisition and writes the profile data of 3 SG's into the data tables.

This happens in the following sequence: 120 ms after the beam passage the ACC receives from the SG control unit the INIT information at its interrupt 2 input. This prepares the ACC, MUX and ADC for the first

<table>
<thead>
<tr>
<th>Bit Nr.</th>
<th>Function</th>
<th>SG Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Go INTO beam</td>
<td>)</td>
</tr>
<tr>
<td>2</td>
<td>Go OUT of beam</td>
<td>) SG 228</td>
</tr>
<tr>
<td>3</td>
<td>Single step advances</td>
<td>)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>) SG 230</td>
</tr>
<tr>
<td>5</td>
<td>Go INTO beam</td>
<td>)</td>
</tr>
<tr>
<td>6</td>
<td>Go OUT of beam</td>
<td>) SG 332</td>
</tr>
<tr>
<td>7</td>
<td>Single step advance</td>
<td>)</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>) MSG 020</td>
</tr>
<tr>
<td>9</td>
<td>Go INTO beam</td>
<td>)</td>
</tr>
<tr>
<td>10</td>
<td>Go OUT of beam</td>
<td>)</td>
</tr>
<tr>
<td>11</td>
<td>Single step advance</td>
<td>)</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>)</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>)</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>)</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>)</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>)</td>
</tr>
</tbody>
</table>

Table 7.
SG STATUS ACQUISITION BITS

<table>
<thead>
<tr>
<th>Bit Nr.</th>
<th>Function</th>
<th>SG Name</th>
<th>Y-Building</th>
<th>East Ejection Hall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IN beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>OUT of beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>NORMAL Position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>INTERPOL. &quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>IN beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>OUT of beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>NORMAL Position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>INTERPOL. &quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>IN beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>OUT of beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>NORMAL Position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>INTERPOL. &quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Manual Control</td>
<td></td>
<td>All 3</td>
<td>All 3</td>
</tr>
<tr>
<td>14</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8.

Conversion pulse (CONV at interrupt 3 input). About 150 μs after the INIT pulse, the 3 local SG multiplexers are triggered by the 32 CLOCK pulses which are generated at the same time and interval (150 μs) as the CONV pulses (see Fig. 13). Each conversion pulse implies 3 successive measurements (software advanced). The multiplexer is switched with a delay of about 40 μs through the 3 SG signals. 32 CLOCK (CONV) pulses perform thus 3 x 32 = 96 ADC conversions. The program writes these data in 3 data tables which represent the horizontal and vertical profiles of the 3 SG's.

5. APPLICATION SOFTWARE

The application programs used in the BD system are all written in NODAL (TT Computer, User (G-S)). Most of the programs can be called from the MAIN menu (see encircled numbers in Fig. 37) by overlay commands. The program names are given in List 1. The principle functions of each program are shown in the flow-charts of Fig. 38 to 52.
MAIN

--- APA 16 + APA 58 + NEUTRINO TRANSFER LINES ---

---

2 = BEAM DIAGNOSTIC APST 16 (PROTON) 8 = VACUUM TT2 + TTL2
3 = BEAM DIAGNOSTIC APA 58 (PROTON) 18 = HARDWARE SPECIALIST
4 = BEAM DIAGNOSTIC APA 16+58 (PDAR) 11 = INIT AFTER POW-FAIL
5 = EMITTANCES + BEAM PROFILES 12 = POWER SUPPLIES FTH
6 = POWER SUPPLIES ATP(TTL2) 16 = NOXAL
7 = POWER SUPPLIES FA58(TT78)

WHICH PROGRAM?

---

Fig. 37

BD APPLICATION PROGRAMS

1. BDINIT
2. BDIAG
3. BD58
4. BD
5. DISPOS
6. DISP58
7. DISP
8. DIP01
9. DIP058
10. DIPAR
11. CALIB
12. CAL58
13. SPTEST
14. SPT58
15. SPTE
16. BDTIM16
17. BDTIM58
18. SAVDAT
19. SAVD58
20. SAVDAT:DATN
21. SAVD58:DATN
22. DATLIST
23. PUSEL
24. PUSEL58
25. GRID-INIT (A-P)
26. SEM3

List 1
5.1 **BDINIT** (Fig. 38)

initialises the CAMAC part of the system.
(Equipment 1 in Y-Building, Equipment 2 in Building 356)
It must be RUN after every mains power fail.

5.2 **BDIAG** (Fig. 39)

is the main BD program for the 2 operations:
- proton test beam PS - AA via loop TTL2 (FE16T)
- proton fast beam PS - SPS (FE16S).

When all conditions are set interactively BDIAG displays periodically
the PU positions and transformer intensities in the transfer lines.

A similar program **BD58** does the same for the p reinjection 58 from the
SPS (FI58T).

5.3 **BD** (Fig. 40)

is a combined program which displays repetitively the complete p
transfer trajectories and intensities between AA - PS and PS - SPS/ISR for
the P5AR operation.

5.4 **DISPOS, DISP58 and DISP** (Fig. 41)

Are the programs which display frame and lables in the 3 preceeding
main programs.

DISPOS in BDIAG
DISP58 in BD58 and
DISP in BD.
LOAD ACC μP Programs
1. BCTPU
2. TTGRID
for Equipments 1 + 2

SET Addresses for Coefficient Tables

Restore Calibration Coefficient Tables in ACC from SAVDAT + SAVD58

Disable Beam + Cal. Trig. of SG, BCT + PU
SET TIMINGS (BDTIM16 + BDTIM58,)

SG INITIALISATION GRID-INIT

Fig. 38
START

Menu 1
WHICH OPERATION
SPS or 16T?

SET PLS GATE

Menu 2
WHICH INTENSITY? 1 ... 4
SPECIALIST PROGRAM? 9
STOP DISPLAY REFRESH 10
END 0 = CR

1 ... 4 0 9 10

SET GAIN

DISPLAY FRAME (DISPOS/DISP58)

START PERIODIC REFRESHED PARAM. DISPLAY DIP01/DIP058

WAIT CYCLE

DISPLAY POSITIONS AND INTENSITIES (DIP01/DIP058)

Menu 3
FORMER CYCLES 2
TEST WITH CALIB SIGNALS 6
CALIBRATION 7
STOP DISPLAY REFRESH 9
RESTART AFTER POWER FAIL 10
END 0 = CR

Menu 4
WHICH CYCLE?

SET CYCLE NUMBER

DISPLAY PARAMETERS (DIP01)

Menu 5
AUTOMATIC CALIBR. 1
SAVE CALIBR. DATA 3
RESTORE CAL. DATA 4
NO CALIBRATION 0

OVERLAY SPECIAL TEST PROGRAM
BEAM OR CAL?

SET BEAM TRIGGER

SET CAL TRIGGER

OVERLAY SPECIAL TEST PROGRAM SFTE

OVERLAY PROGRAM SAVDAT (READ MODE)

OVERLAY PROGRAM SAVDAT (WRITE MODE)

INITIALISE BD SYSTEM (BDINIT)

OVERLAY PROGRAM CALIB

DISCONNECT PROGRAM DIP01/DIP058

DISCONNECT DIP01/DIP058

STOP µP READINGS

Fig. 39
DISPOS / DISP58 / DISP

START

READ SETTINGS

DISPLAY FRAME + LABELS

ACQUISITION OF BCT + PU SIGNALS

DISPLAY UNTREATED SIGNALS + SETTINGS

END

Fig. 41
5.5 DIP01 and DIP058 (Fig. 42)

are the repeated programs which display every cycle the new parameters. 

DIP01 in program BDIAG 
and DIP058 in program BD58.

5.6 DIPAR (Fig. 43)

is the program which displays every cycle the new parameters in the 2 equipments. It is called from the BD program.

5.7 CALIB and CAL58 (Fig. 44)

are the calibration programs for the 2 equipments which determine the calibration coefficients in the data modul tables.

5.8 SPTEST, SPTE58 and SPTE (Fig. 45)

are 3 versions of a test program which are called from the main programs BDIAG, BD58 respectively BD.

On request the beam can be simulated in an offset (± 42 mm) or balance position. The BCT calibration intensity depends on the selected intensity range (Table 9).

<table>
<thead>
<tr>
<th>Range</th>
<th>Cal. Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{11} - 10^{12}$</td>
<td>$10^{11}$ ppp</td>
</tr>
<tr>
<td>$10^{10} - 10^{11}$</td>
<td>$10^{10}$ &quot;</td>
</tr>
<tr>
<td>$10^{9} - 10^{10}$</td>
<td>$10^{9}$ &quot;</td>
</tr>
<tr>
<td>$10^{8} - 10^{9}$</td>
<td>$10^{8}$ &quot;</td>
</tr>
</tbody>
</table>

Table 9.

5.9 BDTIM16 and BDTIM58 (Fig. 46)

are programs belonging to the 2 equipments which allow delay adjustment and trigger switching for the calibration.
START

READ GAIN SETTING

CLOSE GATE

ACQUISITION OF PU + BCT Signals

LIMIT DISCRIMINATION

DISPLAY PARAMETERS ON MONITOR

OPEN GATE

END

Fig. 42
DIPAR

START

READ GAIN SETTING

CLOSE MEASUREMENT GATES

SET EQ = 1 (TT2)

READ PU + BCT VALUES

LIMIT DISCRIMINATION

SET EQ = 2

DISPLAY VALUES

Y

EQ = 1 ?

EQ = 1

N

OPEN MEASUREMENT GATES

END

Fig. 43
CALIB / CAL58

START

SET INIT. CONDITION (OFFSET, MODE, 1, GAIN. G = 1)

TRIG. CAL. GENERATOR
SUCCESSIVE ACQUISITIONS OF 3 POSITIONS (PU)
+ 1 INTENSITY (BCT)

CALCULATION OF PU POSITION, OFFSET + INTENS. COEFFICIENTS

+ BCT INTENSITY COEFFICIENTS

WRITE COEFF. IN TABLES

G = G + 1

Y

G ≥ 8 ?

N

SET GAIN = f(G)

END

Fig. 44

Figure 31.
START

DISPLAY MENU
1 TEST POSITION 1
2 TEST POSITION 2
3 BALANCE TEST
5 CHANGE PARAMETER
0 END

SET CAL1 CONDITION
SET CAL2 CONDITION
SET BALANCE CONDITION

TRIG PU + BCT
CALIBR. GENERATOR

DISPLAY FRAME

ACQUIS. + DISPLAY of
PU + BCT VALUES

NEW TEST 1
OR
CHANGE PARAM. 0

Fig. 45
START

INITIAL SETTINGS

ARG(1) = ?

Menu

WHICH TRIGGER AND DELAY?

BEAM

GATE

DELAY

END

BEAM

DELAY

ADJUST.

CAL

GATE

DELAY

ADJUST.

GATE

DELAY for CAL.

TRIG.

SETTING

SAVE VARIABLES

ARG(1) = ?

SET ARG (1) = 0

END

Fig. 46
By an exclusive OR gate (GPPC) 2 triggers can be selected from

1. beam - 100 μs
2. free running pulse generator (1 Hz).

These triggers can be executed by a software overlay command (ARG (1)) or by terminal selection.

5.10 SAVDAT and SAVD58 (Fig. 47)

are 2 programs which allow the data files of the equipment modules TTU and BCT to be saved on disk or the inverse to restore the data files from disk.

5.11 DATLIST (Fig. 48)

is a program which permits to print out all coefficients of the data tables of equipment 1 or 2.

5.12 PUSEL and PUSEL58 (Trig. 49)

are programs which allow analog signal selection (ΔR, ΔV, Σ) of the PU stations.

5.13 GRID-INIT (Fig. 50)

is the initialisation program of the SEM grid CAMAC equipments 1 and 2.

5.14 SEM3 (Fig. 51)

is the interactive SEM grid program which needs only the information about the operation type. It does the settings, acquires the beam profiles via the correspondant equipment, displays the profiles, calculates the emittances \( E_H, E_V \) and the Hereward parameters \( L_H, L_V, S_H, S_V \) and displays these with date and operation. (See next section).

The emittance calculation is based on 3 profile measurements at position 1, 2 and 3 where the transfer matrices \( (A) \) and \( (B) \) of the vector \( (X, X') \) are known. The beam half widths \( (2α) \) at these positions are \( W_1, W_2 \) and \( W_3 \) (Fig. 52).
SAVDAT / SAVD58

START

LOAD DATAFILE
SAVDAT:DATN

G = 1

SET MED. GAIN

READ or WRITE?

ULTRA HIGH GAIN

LOW GAIN

READ COEFF. OF TABLES

WRITE COEFF. IN TABLES

G = G + 1

G = 4?

CHANGE MODE
(p → p)

SAVE DATAFILE
SAVDAT:DATN

Fig. 47

END
DATLIST

START

WHICH EQUIPMENT?

TT2

LOAD TT2 DATAFILE

EJ58

LOAD EJ58 DATAFILE

PRINT ALL CALIBRATION COEFFICIENTS OF µP TABLES

END

Fig. 48
PUSEL / PUSEL58

START

READ +
DISPLAY
PU NR.
(ANALOG SIGNAL)

ASK
WHICH NEW PU? (1 ... 15)

1... 15
0

SET
SWITCH
TO
NEW PU

END

Fig. 49
GRID-INIT

START

SET UP ARRAYS

RESERVATION

RESERVATION OK?

YES

SET STATION NR.

SET LOOP + CRATE

SET STATUS BIT POINTER

SET MUX IDENTIFIER

OK?

YES

ERROR MESSAGE

END

END

Fig. 50
Menu

WHICH OPERATION? (1...9)

SET PLS CODE TT2 EQUIPM.

SET PLS CODE EJ58 EQUIPM.

DISP. FRAME

NORMAL POSITION

SG IN BEAM

SET INTERPOLATE POSITION

TRIGGER GATING ACCORDING PLS CODE

ACQUISITION + DISPLAY OF PROFILES

1. 1. OR 2. ACQUISITION?

2.

SG OUT OF BEAM

FETCH $\beta +$ MATRIX PARAMETERS.

CALCULATION OF WIDTH W, E, L, S

DISPLAY RESULT: PARAMETERS + OPERATION

END
The algorithm is the following:\)

The emittance

\[ E = \frac{w_1}{a_{12}} \sqrt{w_2^2 - w_1^2 (a_{12} b_1 - a_{11})^2} \]  \hspace{1cm} (22)

or

\[ E = \frac{w_1}{b_{12}} \sqrt{w_3^2 - w_1^2 (b_{12} b_1 - b_{11})^2} \]  \hspace{1cm} (23)

with

\[ B_1 = \frac{\frac{a_{12}^2 b_{11}^2}{b_{12}} \left( \frac{w_2}{w_1} - \frac{a_{12}^2}{b_{12}^2} \right)}{2(a_{11} a_{12} - \frac{a_{12}^2}{b_{12}^2} \cdot b_{11})} \]  \hspace{1cm} (24)

The transfer matrix coefficients for the present (10.10.1983) settings are given in table 10.

<table>
<thead>
<tr>
<th>Setting</th>
<th>SPS</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hor.</td>
<td>Vert.</td>
</tr>
<tr>
<td>(a_{11})</td>
<td>1.199</td>
<td>-0.006</td>
</tr>
<tr>
<td>(a_{12})</td>
<td>12.35</td>
<td>22.32</td>
</tr>
<tr>
<td>(b_{11})</td>
<td>0.391</td>
<td>-1.152</td>
</tr>
<tr>
<td>(B_{12})</td>
<td>15.20</td>
<td>42.53</td>
</tr>
</tbody>
</table>

Table 10.
The Hereward Parameters, which determine the phase space ellipse in position 1 are

\[ L_1 = \frac{G_1^2}{G_1^2 + B_1^2} \quad \text{and} \quad (25) \]

\[ S_1 = \frac{-B_1}{G_1^2 + B_1^2} \quad (26) \]

with \[ G_1 = \frac{E}{W_1^2} \quad (27) \]

The estimated emittance

\[ E_e = \frac{W^2}{\beta} \quad (28) \]

with the \( \beta \) values for the 3 SEM grid positions of Table 11.

<table>
<thead>
<tr>
<th>Setting TT2</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPS</td>
<td>228</td>
<td>230</td>
<td>332</td>
</tr>
<tr>
<td>( \beta_H ) (m)</td>
<td>14,747</td>
<td>12,90</td>
<td>20,53</td>
</tr>
<tr>
<td>( \beta_V ) (m)</td>
<td>46,22</td>
<td>43,18</td>
<td>48,43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setting ISR</th>
<th>( \beta_H )</th>
<th>( \beta_V )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17,88</td>
<td>29,0</td>
</tr>
<tr>
<td></td>
<td>40,78</td>
<td>28,83</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setting EJ. 58</th>
<th>( \beta_H )</th>
<th>( \beta_V )</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSG 010</td>
<td>3,981</td>
<td>534.0</td>
</tr>
<tr>
<td>MSG 020</td>
<td>35,28</td>
<td>73,63</td>
</tr>
</tbody>
</table>

Table 11.
As the momentum compaction factor $\alpha_p$ is not zero in the SG positions, the measured beam widths $W_m$ had to be corrected for the horizontal emittance calculation by

$$W = \sqrt{\frac{\Delta p^2}{W_m - (\alpha_p \cdot \frac{\Delta p}{p})}}$$  \hspace{1cm} (29)

with $\frac{\Delta p}{p} = 0.0015$

and $\alpha_p$ values from table 12.

<table>
<thead>
<tr>
<th>$\alpha_p$ (m)</th>
<th>Position</th>
<th>SG 228</th>
<th>SG 230</th>
<th>SG 332</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISR</td>
<td></td>
<td>0.70</td>
<td>3.00</td>
<td>3.15</td>
</tr>
<tr>
<td>SPS</td>
<td></td>
<td>1.42</td>
<td>2.03</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 12.

6. PRESENTATION

Fig. 53 shows a combined display of the horizontal and vertical PU positions and BCT intensities of a proton test transfer (PS to AA). This display, called from the BDIAG program, is refreshed every APTST cycle. It allows a steering and stability check of the beam lines with protons before the $\bar{p}$ transfer.

Fig. 54 presents the beam parameters of a single shot $\bar{p}$ transfer to the SPS, called from program BD. The acquisition and display are synchronized to the PBAR operation. The trajectories and intensities before PS injection and after PS ejection are separated by a dashed horizontal line preceded by PS.

The transfer efficiencies are:

TTL2 and TT2 \hspace{1cm} EFF(2/1) = \frac{I_2}{I_1} ,

PS \hspace{1cm} EFF(3/2) = \frac{I_3}{I_2} ,

Overall efficiency \hspace{1cm} EFF(3/1) = \frac{I_3}{I_1}
**Fig. 53**

**APA Beam Diagnostic Program DISPOS**

<table>
<thead>
<tr>
<th>PU NAME</th>
<th>HOR. POS.</th>
<th>VERT. POS.</th>
<th>MM I</th>
<th>PU SUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (107)</td>
<td>-0.1</td>
<td>-1.4</td>
<td>1.90</td>
<td>E10</td>
</tr>
<tr>
<td>2 (227)</td>
<td>0.9</td>
<td>0.4</td>
<td>1.90</td>
<td>E10</td>
</tr>
<tr>
<td>3 (2050)</td>
<td>-9.6</td>
<td>-0.1</td>
<td>1.55</td>
<td>E10</td>
</tr>
<tr>
<td>4 (2040)</td>
<td>-4.1</td>
<td>-1.0</td>
<td>1.86</td>
<td>E10</td>
</tr>
<tr>
<td>5 (2030)</td>
<td>-3.3</td>
<td>-4.1</td>
<td>1.81</td>
<td>E10</td>
</tr>
<tr>
<td>6 (2020)</td>
<td>-0.7</td>
<td>19.9</td>
<td>2.14</td>
<td>E10</td>
</tr>
<tr>
<td>7 (1010)</td>
<td>-1.1</td>
<td>2.10</td>
<td>2.63</td>
<td>E10</td>
</tr>
<tr>
<td>8 (1005)</td>
<td>-4.7</td>
<td>2.5</td>
<td>2.63</td>
<td>E10</td>
</tr>
</tbody>
</table>

**RANGE: (E9-E11)**

**INTENSITY PPP**

**Fig. 54**

**APA Beam Diagnostic of Transfer Lines**

<table>
<thead>
<tr>
<th>PU NAME</th>
<th>HOR. POS.</th>
<th>VERT. POS.</th>
<th>SUM</th>
<th>BCT NAME</th>
<th>INTENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (1085)</td>
<td>-1.8</td>
<td>-3.9</td>
<td>-3.95 E9</td>
<td>1 (1010)</td>
<td>5.35 E9</td>
</tr>
<tr>
<td>2 (1018)</td>
<td>-5.5</td>
<td>-3.3</td>
<td>-3.90 E9</td>
<td>2 (107)</td>
<td>5.20 E9</td>
</tr>
<tr>
<td>3 (1020)</td>
<td>1.0</td>
<td>0.6</td>
<td>-4.21 E9</td>
<td>1 (2050)</td>
<td>-4.53 E9</td>
</tr>
<tr>
<td>4 (2030)</td>
<td>-2.5</td>
<td>-2.5</td>
<td>-4.09 E9</td>
<td>3 (1010)</td>
<td>-4.53 E9</td>
</tr>
<tr>
<td>5 (2040)</td>
<td>2.0</td>
<td>2.0</td>
<td>-3.87 E9</td>
<td>1 (2050)</td>
<td>-4.53 E9</td>
</tr>
<tr>
<td>6 (2050)</td>
<td>-15.1</td>
<td>-15.1</td>
<td>-4.44 E9</td>
<td>RANGE: (E9-E10)</td>
<td></td>
</tr>
<tr>
<td>7 (227)</td>
<td>1.7</td>
<td>-3.0</td>
<td>-3.88 E9</td>
<td>1 (207)</td>
<td>-3.88 E9</td>
</tr>
<tr>
<td>8 (107)</td>
<td>15.1</td>
<td>-1.9</td>
<td>-3.04 E9</td>
<td>PPP</td>
<td>-1.9</td>
</tr>
</tbody>
</table>

**EFFICIENCIES**

**PU GAIN = 3**

**PULSE NR. = 1**

**BCT GAIN = 3**

**SETTING: ANTI PROTON**
and are given on the right lower side.

Fig. 55 gives the display of the FA58 ejection line. The PU 3 and 4 are already behind the ISR/SPS switch magnet and are part of TT6 respectively TT70.

This display, called from the BD58 program is synchronized to the PLS line APA and is used mainly for the proton reinjection from SPS to PS (Minimization of betatron oscillation).

These displays (Figs. 53 to 55) are obtained by selecting the operation in menu 1 (Fig. 37) and the intensity range in menu 2 (Fig. 56).

The PU and BCT analog signals of each monitor can be acquired by transient recorders (2 Data Lab, DL 922, 1 Biomation 8100) via 500 MHz switches (HP 59307A). Two Data-Lab transient recorders, connected in a master-slave combination, allow the display of 4 fast signals simultaneously on 1 screen, where two appear 1 second or more differed in time (different acquisition triggers but same read out clock).

Fig. 57 shows as example the stretched signals of 2 transformers (BCT1 in TTL2 and BCT2 in TT2) before injection into the PS and one (BCT3 in FA58) after the ejection of the PS.

These signals are used mainly for detection of synchronisation errors in the beam transfers (comparison with injection and ejection kicker signals).

Fig. 58 concerns the SEM-Grid profile and emittance measurement performed with the SG's in TT2 or TT70 (FA58). The operator has only to select the operation 1 to 9 and the program SEM3 automatically performs what is shown in flow chart of the SEM3 program (Fig. 51). The result is the display presented in Figs. 59 or 60. The horizontal and vertical profiles of the individual SG's are given in the normal and interpolating positions of the grids. A test signal in channel 16 indicates (292) that the acquisition has been made correctly. The display gives the horizontal and vertical half beam
Fig. 55

Fig. 56
**Fig. 57**

BCT p Signals
(10μs/div, 0.5V/div)

**Fig. 58**

PROFILE - EMITTANCE PROGRAM

PLEASE SELECT OPERATION !

<table>
<thead>
<tr>
<th>CODE OPERATION</th>
<th>GRID GRID NAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1... CT</td>
<td></td>
</tr>
<tr>
<td>2... FEPS</td>
<td></td>
</tr>
<tr>
<td>3... FEIS</td>
<td>SG 228; SG 230; SG 332</td>
</tr>
<tr>
<td>4... FEAA</td>
<td>(TT2)</td>
</tr>
<tr>
<td>5... FI16A</td>
<td></td>
</tr>
<tr>
<td>6... FE16T</td>
<td></td>
</tr>
<tr>
<td>7... FES8A</td>
<td>MSG 010; MSG 020</td>
</tr>
<tr>
<td>8... F158T</td>
<td>(TT70)</td>
</tr>
</tbody>
</table>

9... SPECIAL OPERATION - TEST MEASUREMENT
10... EMERGENCY OUT FOR ALL SENGIRIS
0... CR END

WHICH OPERATION (0,1,2...9)?
widths $2\sigma_H$ and $2\sigma_V$ (HWH and HWV), the horizontal and vertical estimated emittances

$$EEH = \frac{(2\sigma_H)^2}{\beta_H}$$

$$EEV = \frac{(2\sigma_V)^2}{\beta_V}$$

the Hereward parameters L and S and the emittance E in both planes calculated with the formulae given in section 5.14.

Fig. 59 belongs to a fast ejected, low intensity proton beam to the SPS (OP: FESPS) and Fig. 60 to a high intensity transfer to the ISR (OP: FEISR).
### Fig. 59

**SEMGGRID PROFILES + EMITTANCES 1982-07-22-16147:22**

<table>
<thead>
<tr>
<th>NOR</th>
<th>INT</th>
<th>NOR</th>
<th>INT</th>
<th>NOR</th>
<th>INT</th>
<th>NOR</th>
<th>INT</th>
<th>NOR</th>
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<td>11</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>65</td>
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<td>78</td>
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### Fig. 60

**SEMGGRID PROFILES + EMITTANCES 1982-07-03-12118:31**

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7. CHARACTERISTICS OF THE DIFFERENT MONITORS

In the following a summary of the characteristics of the different monitors is given.

7.1 PU

a) Electrode

- Cross-section
- Mechanical length
- Capacity
- Position sensitivity
  (100 ns bunch)
- Linearity error
  within range
  
  \[
  (y = 0; -50 < x < 50 \text{ mm}) 
  \]
  \[
  (y = \pm 30; -30 < x < 30 \text{ mm}) 
  \]
  (same for horizontal and vertical).

b) System

- Intensity dynamic
- Polarity
- Bunch lengths
- Position resolution
- Calibration positions
  horizontal and vertical
- Calibration Intensities
  \[
  (10^8; 3 \cdot 10^8; 3 \cdot 10^9 \text{ ppm}) 
  \]
- Analog out
  (of cable receiver diff. amp. x 2)
- Transmission cable
  Impedance

The intensity range overlapping for the 3 gains is given in the following Table 13.
<table>
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<tr>
<th>Range [ppp]</th>
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**Table 13**

It is important for the position measurement with these electrostatic PU's that no beam particles are lost in the proximity of the PU's. As the PU sum signal is sensitive to beam losses, this parameter should be checked first. (Comparison with other PU sum signals!).

### 7.2 BCT

**a) Transformer**

- Toroid core
  - Ultraperm 10
- Material
  - Ultraperm 10
- Tape thickness
  - 30 µm
- Number of turns
  - 10
- for calibration
  - 1
- Inductance
  - ~ 12.7 mH
- Loss resistance (11)
  - ~ 1 kΩ
- Sensitivity
  - 150 mV/10¹⁰ p

**b) System**

- Dynamic
  - $10^7 - 1.3 \times 10^{12}$ ppp
- Bunch lengths
  - 3 - 200 ns
- Resolution
  - $10^7$ ppp
- Calibration intensities
  - 4
  - $(10^8; 10^9; 10^{10}; 10^{11}$ ppp)
  - (200 ns pulse)
- Analog Out
  - ± 4 Vp
  - (of cable receiver diff. amp. x 2)
- Transmission cable balanced
  - Impedance
  - 95 Ω
Table 14 gives the intensity ranges and calibration intensities for the 4 gain settings.

<table>
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Table 14

The up-down range overlapping is about 30% of the limit values.

7.3 SG

a1) Grid (SG 228, 230, 332)
    (MSG 010, 020)

- Number of wires
  - Horizontal: 15
  - Vertical: 15
- Wire diameter: 0,3 mm
- Wire material: Al
- Center spacing: 2,5 mm
- Distance between normal and interpolate position ($\Delta h = \Delta v$): 1,25 mm
- Insulation resistance: $10^{13}$ Ω
- Biasing voltage of polarisation foils: + 250 V

b1) System

- Dynamic: $10^{11} - 10^{13}$ ppp
a2) Grid (MSG 218, 220, 222)

- Number of strips (plus 1 frame strip)
  - Horizontal
    - Strip width
    - Strip thickness
    - Strip center spacing
    - Strip material
  - Vertical
    - Strip width
    - Strip thickness
    - Strip center spacing
    - Strip material

b2) System

- Dynamic
  - Dynamic
  - Material
  - Thickness

7.4 TV

- Dynamic
  - Dynamic
  - Material
  - Thickness
ACKNOWLEDGEMENTS

It is a pleasure to thank A. Krusche for many stimulating discussions and ideas.

Thanks go also to several colleagues who participated in the development, construction and installation of the systems and the data modules, especially P. Pelletier, M. Corcelle, R. Castella, L. Merard, M. Bennett, M. Martini, J.P. Benincasa, W. Heinze and E. Marcarini.

REFERENCES


3. A. Barlow, private communication.

4. J. Dieperink (to be published).


7. L. Merard, Data Modul TTU (No. 56) and BCT (No. 50).

8. M. Martini, Data Modul μP Program BCTPU. (No. 30)


10. H-H. Umstätter, Program LAPLACE (Private communication)

11. G. Schneider, "Dual Differential Amplifier with Gain Control (X1, X10, X100), (unpublished).

12. M. Bennett, Data Module GRID (No. 47).

13. J.P. Benincasa, Data Module μP Program TTGRID. (No. 36)

Distribution (Open)