Beam Diagnostics and their Control Systems

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CERN

- Definitions
- Brief outline of Accelerator Operation
- Controls in general, higher level issues
- Control of certain specific diagnostic devices
  - BCT's, BPM's, Scintillator Screens, etc
  - switches and commercial devices (GPIB) etc
- Diagnostics in the Control Room
- Diagnostics from machine physics point of view
- controls : current trends for diagnostics

CAT-CAS Course on Accelerator Systems
Indore, India, 7-16 November,1993

Definitions for beam diagnostics & control for this talk:

- beam & beam related measurements via specific hardware devices built for that purpose
- Ensemble of diagnostic systems used in higher level application programs
  - Application Programs defined as higher level tasks which utilise all base-level supervisory & on/off controls and diag. devices to manipulate beams
- use of commercial devices via the control system in conjunction with beam measurement devices (e.g., spectrum analysers, fast digital 'scopes or equivalent , image freezers, *all connected to appropriate beam measurement sources, etc..*) or for trouble-shooting, timing surveillance etc

Accelerator operation : a brief interlude

- Concerns a wide spectrum of operating conditions and uses {***and beam diagnostics is intimately linked***} *during & after commissioning and normal operation*. The activities include:
  - Start-up (or shutdown)
  - Setting up of the accelerator (modes & adjustment)
  - machine experiment and development
  - routine operation/beam production
  - trouble-shooting/fault-repair

- Operation implies manipulation of beams and related processes/situations USING diagnostic devices and BEAM *is the final criterion for all actions*

Controls issues: general

- **ANALYSES OF REQUIREMENTS**
  - for all base-line equipment like power converters, RF, vacuum equipment and base-level diagnostics devices like scintillator screens, position pickups, beam current transformers etc, needed VITALLY to commission the accelerator
- **Uniformisation & firm policy**
  - use the analyses & results to come to a standardisation philosophy with say a *minimum* number of interfaces and module types to be used (e.g., PS Division in late '70's) for all control needs ,hence reduce the hardware & software 'proliferation' or variety overheads
- **HENCE, Beam Diagnostics devices follow & use similar interfaces & modules where possible (H/W & S/W)**

MINIMUM No. OF MODULES + "going Commercial"
ESRF Quote (1991 Conf. Japan)

G64 and FBUS interfacing has been used for control of main magnet power supplies, beam position monitors, magnet interlocks, corrector magnet power supplies, and injection/extraction elements. Other significant subsystems that include G64 crates are the system to distribute the slow timing pulses, the video cross point switch, and the video multiplexors for fluorescent screen monitors. The rest of devices is directly interfaced to the VME systems; either by asynchronous serial lines or digital I/Os.

As a result of an early taken policy, to stick to industry standards, *only a few* boards had to be designed by the ESRF Digital Electronics team:

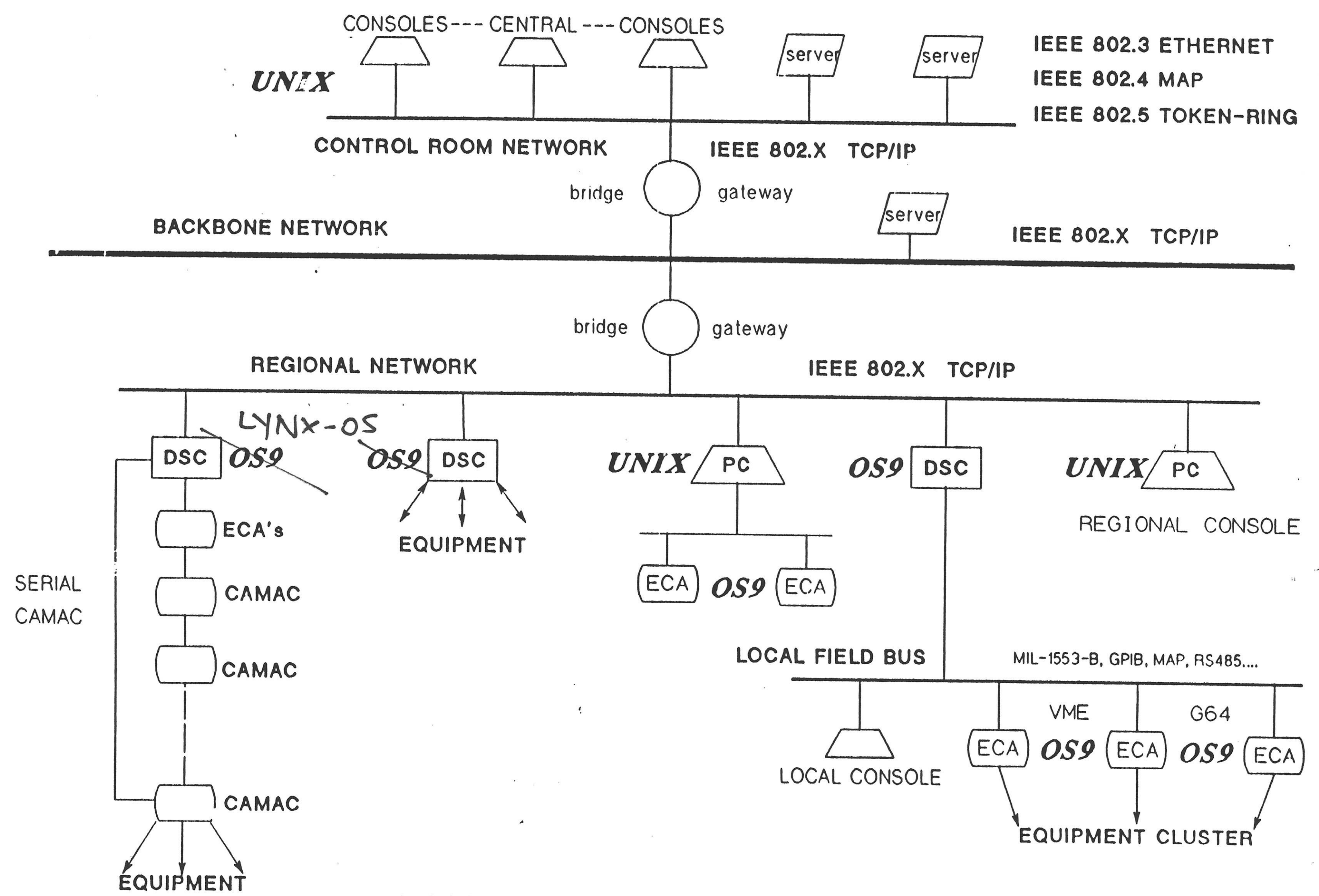
- video multiplexor[11] (VME)
- delay unit[12] (VME)
- ADC with on-board memory (G64)
- FBUS master (VME and PC/ATbus)
- FBUS slave (G64)
- clock divider[13]

Unavoidably some other dedicated electronics had to be designed to adapt some exotic devices to the standards chosen.

Table 1 gives an overview of interfacing.

Some Software implications:

- Few standard hardware modules imply few low-level software interface modules
- Hiding of equipment details in software through so-called software data modules (SPS:1973) or Equipment Modules(PS:1979, revamped 1987 and 1992 with new architectures)
- availability of interpreters for hardware tests as well as programming by non-software experts(machine physicists, operators etc.)



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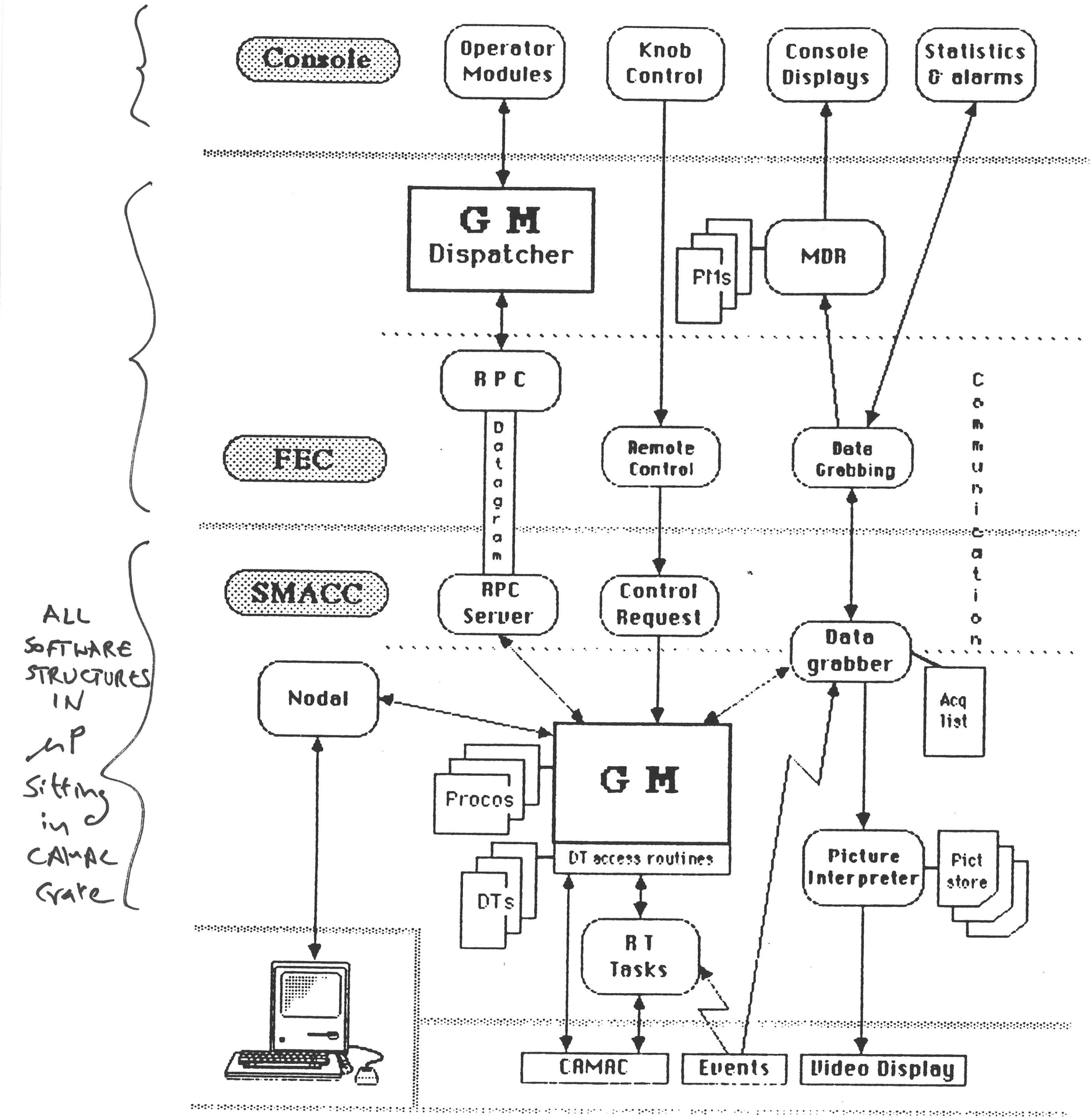
CONTROL SYSTEM ARCHITECTURE

FIG. 1

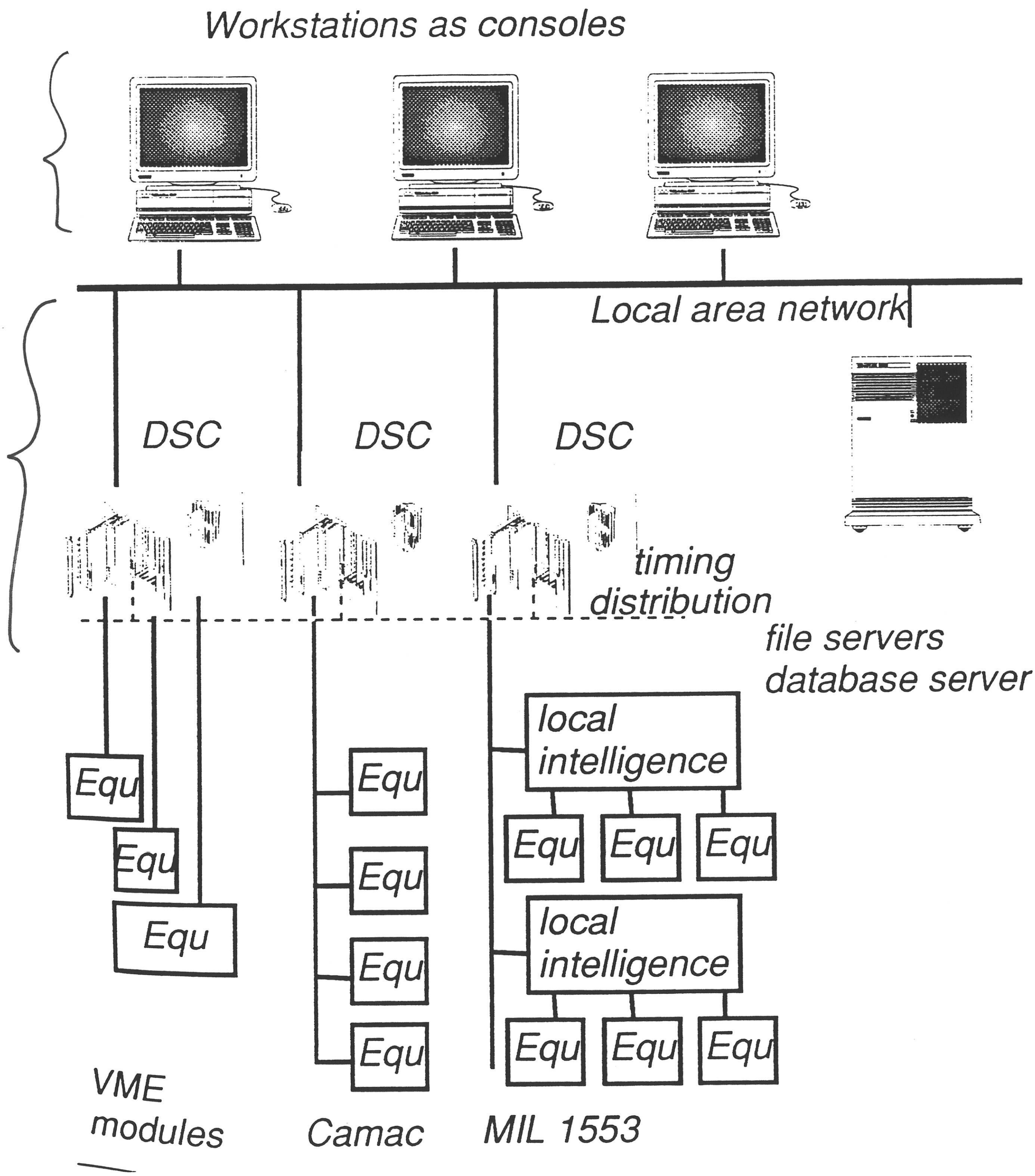
"3 layer" Model 1985 →
PS Controls

Example of equipment layer architecture



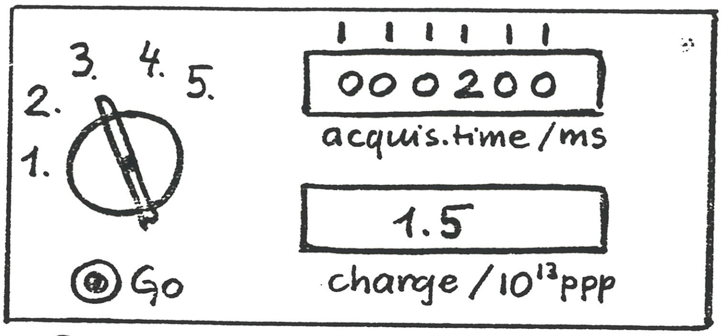
"2-layer" Model (PS CNTRLS
1991 →

The proposed Architecture



Concept of standard & easy access procedures:Equipment Modules

The modules can be thought of as giving the operator the same facilities for doing remotely those things he could do locally or directly like turning dials or looking at a meter , etc....



Beam Current Transformer
Control panel.

CONTROL TIMING

SET TRAFO(2,TRIG,0, ER)=200

– *sets BCT no.2 acquis. trigger to 200 msecs*

ACQ

SET V= TRAFO(2, AQN,0,ER)

– *reads a current transformer value into V, that is 1.5E13 particles*

What does easy software access mean?

- **Simple access from high level for single values OR Array of values**
- **details of scaling factors , calibration , etc. hidden away so answer directly in engineering units**

Single calls: *{example of power converters}*

POW(N, AQN, LN, C)

N=*eq no;* AQN=*property,* LN=*ppm line,* C= *completion error code*

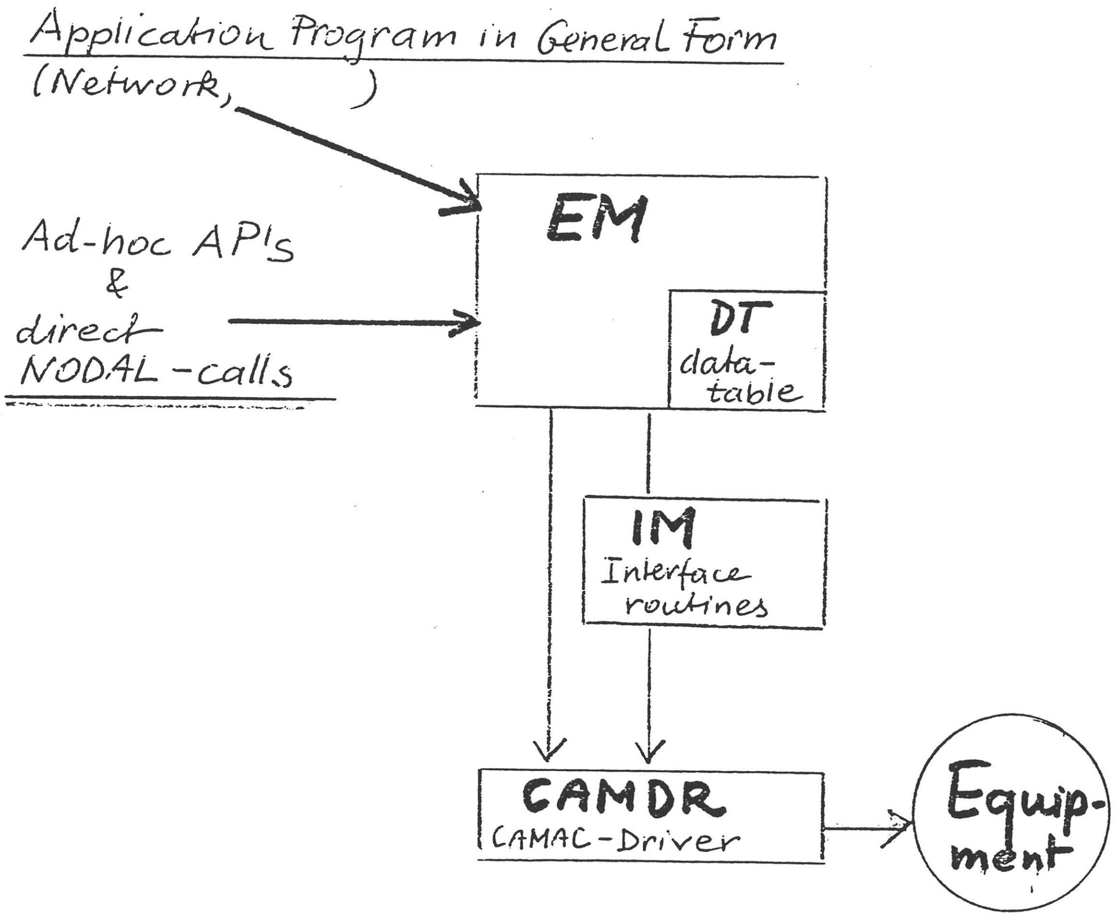
Array Call:

APOW(VA, FL, EA, PROP, LN,CA)

VA=*value array,*FL=*read/write flag,*

EA=*array of power supply nos.,*PROP*erty,* LN=*PPM line,*CA=*completion err. code array*

What is an EM software wise?



"Module" ≅ Set of Routines with the exclusive right of access to a datastructure (DT).

"Frame" (all EM's are "similar")

Deviations from the Frame cause:

- maintenance problems
- additional errors in the code.

The PS Division at CERN is probably the unique facility in the world for the diversity of accelerators under one roof ranging from electron/positron source linacs to hadron linacs, booster and main synchrotron, antiproton storage rings, etc.

This talk will attempt to show examples of the most common beam diagnostic devices in the PS Complex and the related system integration into the control system

References: { For Beam Diagnostics in general and comprehensive coverage }

- *H. Koziol: " Beam Diagnostics for Accelerators" , CERN/PS/92-56(BD) , Dec.1992 & presented at Cern Accelerator School, 7-18 Sept.1992,Finland*
- *"Beam Instrumentation" CERN PE -ED 001-92, { Edited by J. Bosser } Series of Lectures given by various experts in the field as part of CERN Technical Training Course Series in 1990 & 1991*

Example of Control of a fast beam current transformer

Apart from the sheer proof of its existence, the most basic measurement on a beam is that of its intensity. A widely used device is the "beam transformer" (an older name, Rogowski coil, is still sometimes used) which allows one to determine the electric current that a beam constitutes or, depending on the circumstances, the electric charge contained in a burst of beam [1,2]. Figure 1 shows the principle.

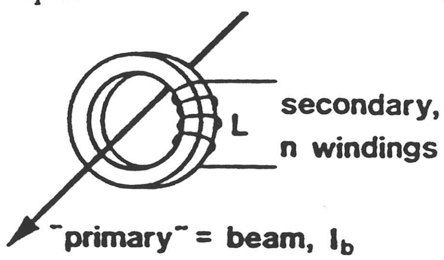
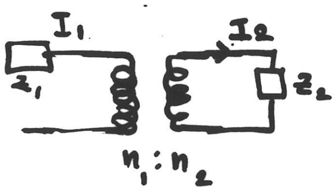


Fig. 1 Principle of the beam transformer.



$\{ n_1 = 1 \text{ (beam)} \}$

$$\frac{I_2}{I_1} = \frac{n_1}{n_2}$$

In reality $\frac{I_2}{I_1}$ is of the form: $\left(\frac{j\omega X}{1 + j\omega Y} \right)$

Since $i = \frac{dQ}{dt}$ so $\int i \, dt = \int \frac{dQ}{dt} \cdot dt$ $= Q$ Coulombs

Q = coulombs (charge)

INTEGRATE CHARGE OVER A GIVEN TIME

Since integration makes the bunch structure disappear anyway, it will also produce an intensity signal for an unbunched beam, without any longitudinal density structure, provided that signal observation begins before injection of the beam.

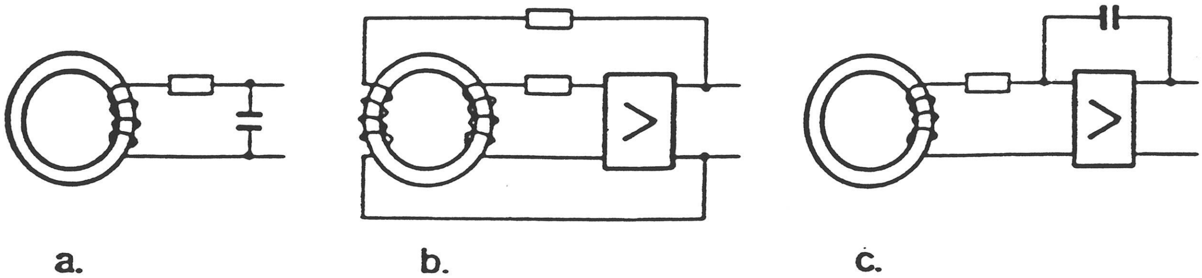


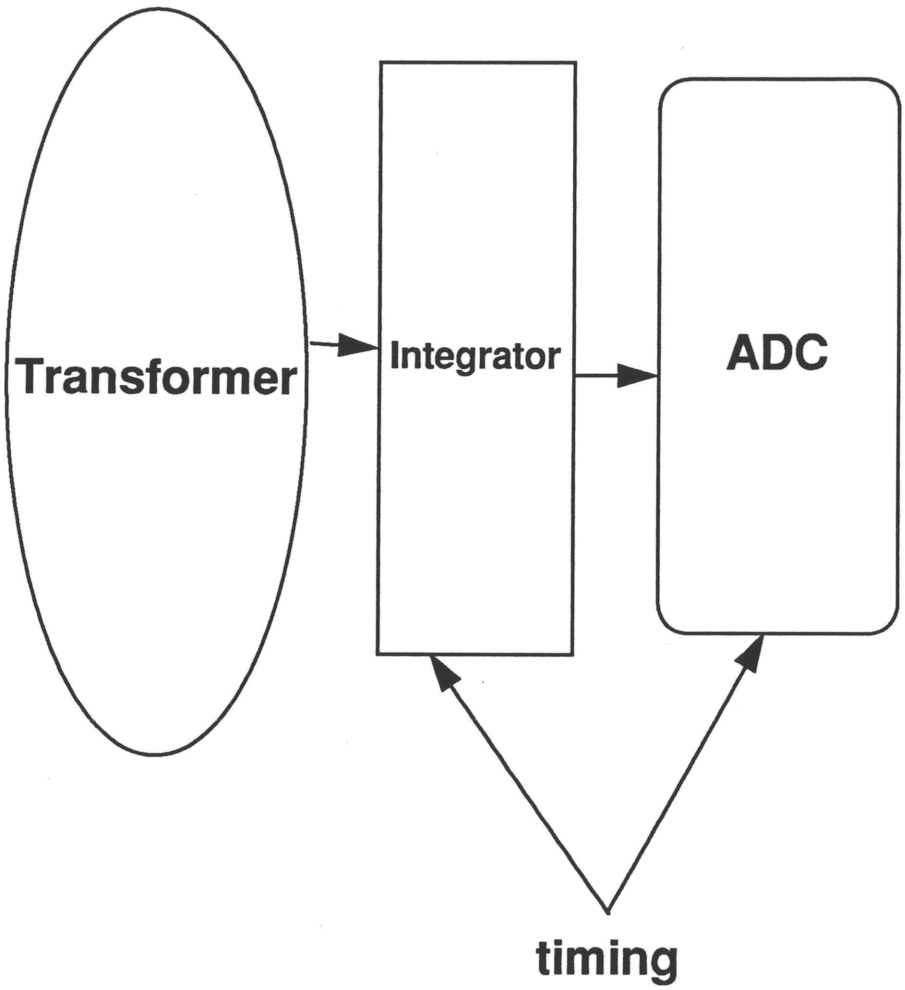
Fig. 6 Integration of signal from a beam transformer.

a) Simple RC circuit. b) Inductive feedback (Hereward transformer).
c) Capacitive feedback (Miller integrator).

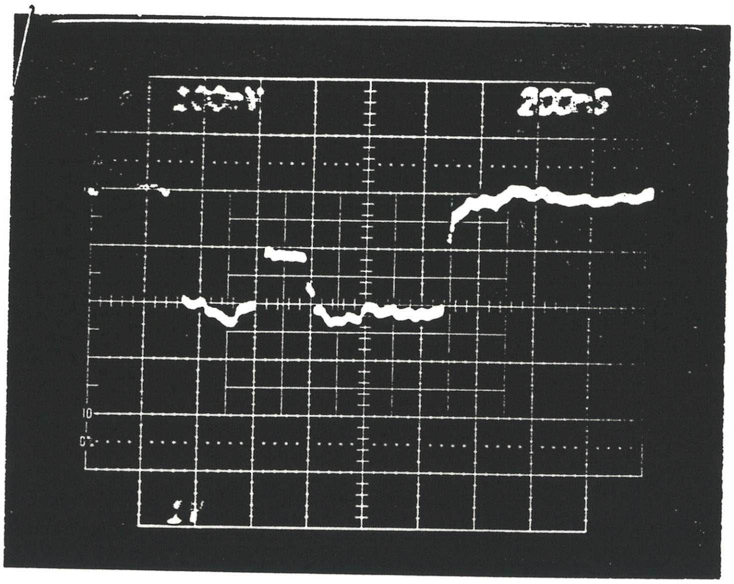
INTEGRATING THE SECONDARY CURRENT I_2 GIVES A VALUE PROPORTIONAL TO TOTAL CHARGE Q IN THE PRIMARY, i.e., number of particles in the beam.

NEED an INTEGRATOR and an ADC or an INTEGRATING ADC

Timing aspects very important (integrating charge within a specific length gate)



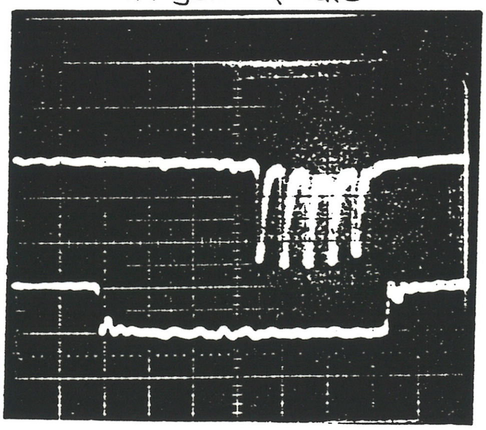
E.g. Gate & Beam. AA Prod. beam
26 GeV
5 Bunches
1.5×10^{13} p's



TFA 9012 & Gate

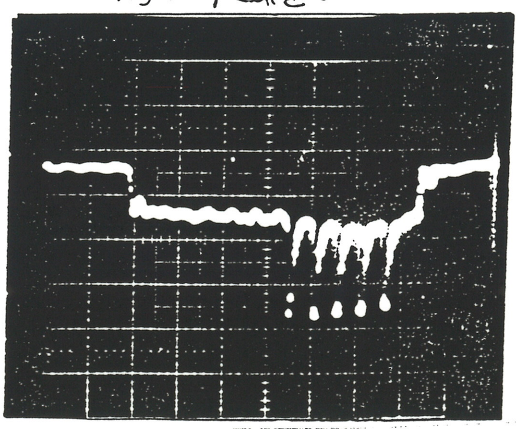
BEAM →

GATE. →



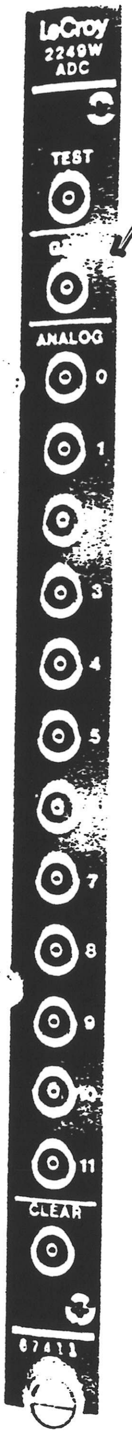
See satellite bunches in the first half of the gate

TFA 9012 + Gate



20 bun kick in the PS.

LeCroy



CAMAC Model 2249W
12 Channel Analog-to-Digital Converter

GATE INPUT

The LeCroy Model 2249W is a 12 channel, 11-bit integrating-type analog-to-digital converter. It features excellent linearity and unprecedented stability, thus allowing operation at wide gates of up to 10 μsec. Thus, the 2249W is compatible with CsI and NaI crystal detectors. Its minimum gate of 30 nsec makes its use with organic scintillators and Cerenkov detectors possible in all but the highest rate conditions.

The 2249W has been optimized for dynamic range and linearity. By AC-coupling the input, 11-bit (1980 counts) operation has been achieved with ± 2 count integral linearity. This excellent linearity is maintained from the smallest signal size to signals as large as − 2 V.

The test feature allows all 12 ADC's to simultaneously digitize a charge proportional to a DC level provided to a front-panel connector or patched into the CAMAC Dataway connector. In addition, the pedestals alone can be checked on-line by the same test feature by removing the CAMAC inhibit (I) during the test.

The Model 2249W offers an excellent event rate capability through the incorporation of a 2 μsec fast clear, which permits the ADC's to begin digitizing and then be cleared upon receipt of later trigger information rather than delaying the analog signals with long cables while the trigger decision is being made. In addition, rapid readout is made possible by a convenient Q and LAM suppress feature, side-panel adjustable between 0 and 100 counts. This feature permits an empty 2249W to be overlooked in a CAMAC readout cycle.

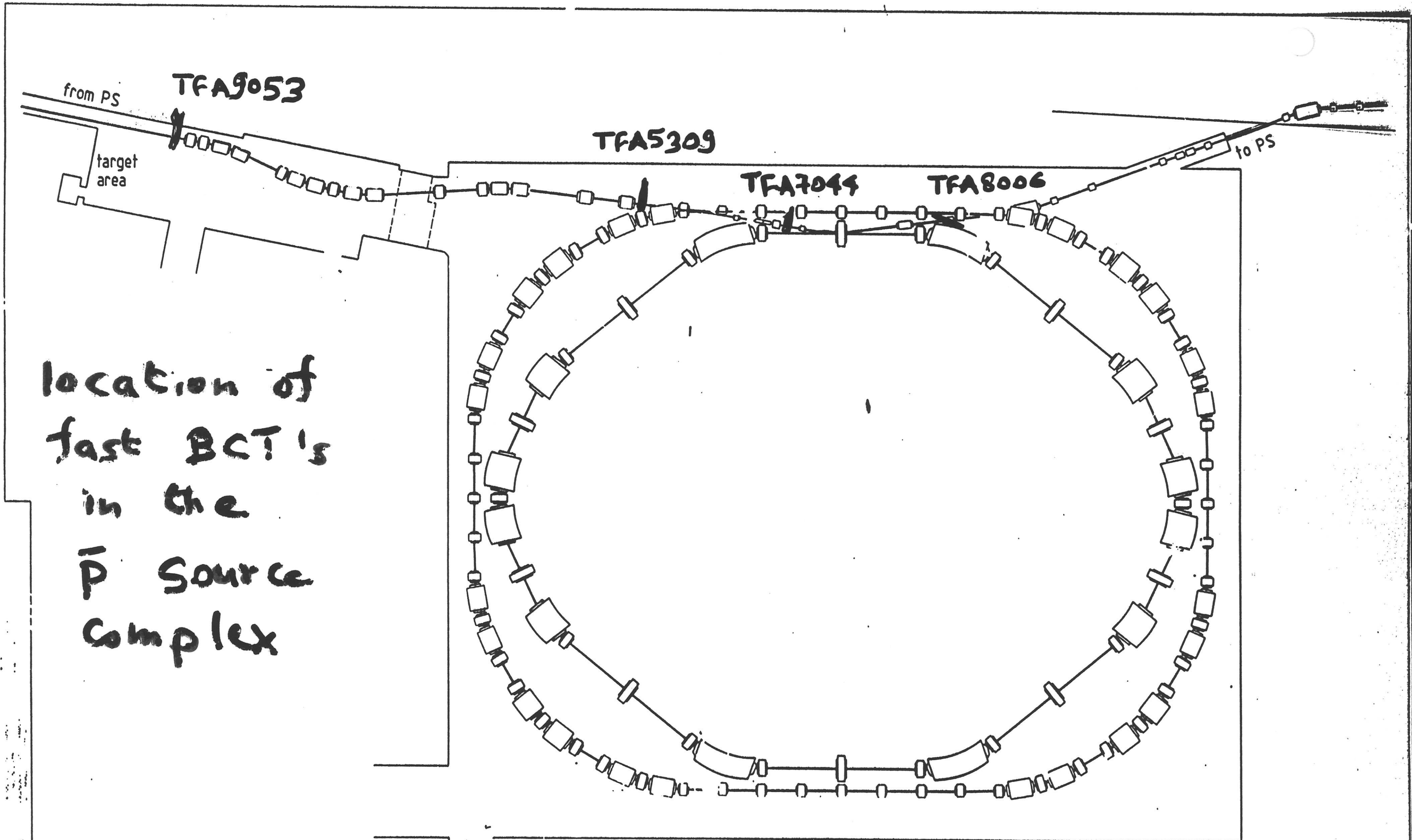
THIS INTEGRATING ADC WITH GATE GIVES DIGITAL VALUE DIRECTLY.

(SO ADC IN CAMAC CRATE DIRECTLY CONNECTED TO THE CONTROL SYSTEM)

SPECIFICATIONS
CAMAC Model 2249W
12 CHANNEL ANALOG-TO-DIGITAL CONVERTER

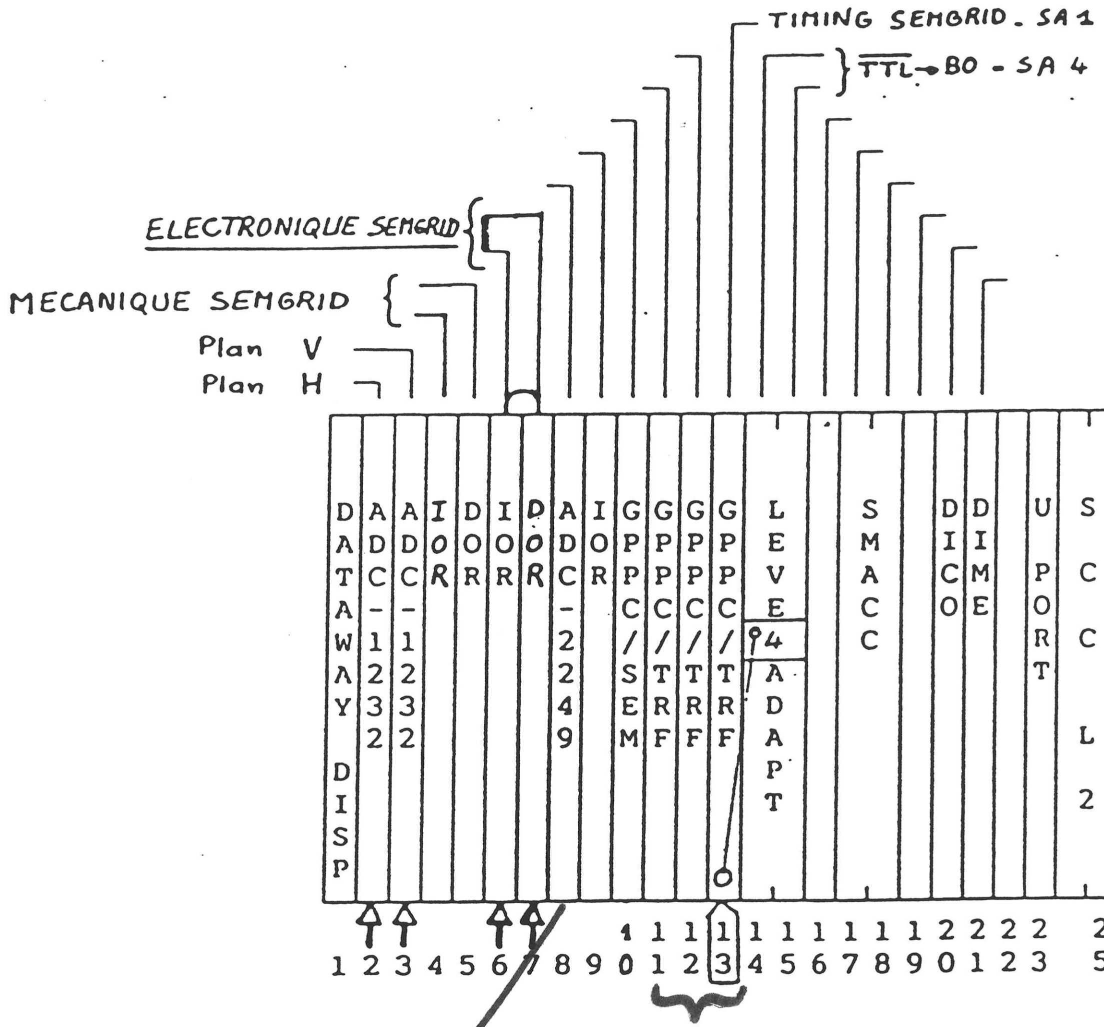
Analog Inputs:	12; Lemo type connectors; charge sensitive (current integrating); AC coupled (2 msec time constant, field changeable); 50 Ω impedance; linear range normally 0 to −2.0 V; protected to ±50 V against 1 μsec transients.
Gain:	−0.25 pC/count ±5%
Full-Scale Range:	Approximately −500 pC (maximum count ≅ 1980)
Integral Non-Linearity:	±0.05% ±(0.5 pC +0.1%)
ADC Resolution:	0.05% (1980 total counts)
Long Term Stability:	Better than 0.25% of reading ±0.5 pC/week (at constant temperature)
ADC Isolation:	A 5 V, 20 nsec overload pulse in any one ADC disturbs data in any other ADC by no more than 0.5 pC (2 counts).
Gate Input:	One gate common to all ADC's; Lemo type connector; 50 Ω impedance; −600 mV or greater enables; minimum duration, 30 nsec; maximum recommended duration up to 10 μsec; partial analog input must occur within 0.5 μsec after opening gate to preserve accuracy; effective opening and closing times, 5 nsec; internal delay, 7 nsec.
Fast Clear:	One front panel input common to all ADC's Lemo type connector; 50 Ω impedance; −600 mV or greater clears, minimum duration, 50 nsec. Requires additional 2.0 μ sec settling time.
Pedestal:	Adjustable over approximately 100 counts via side-panel accessed trimmer capacitor. Somewhat higher for wide gate.
Test Function:	With CAMAC I present, the positive DC level applied to front panel "Test" input (internal high impedance connection to +12 V) or optional rear connector P1, P2, or P5 patch points will inject charge with a proportionality constant of −15 pC/V into all inputs at F(25)•S2 time. (With CAMAC I not present, F(25)•S2 will generate the gate only, providing a measure of the pedestal.)
Digitizing Time:	106 μsec
Readout Time:	Readout may proceed at the fastest rate permitted by the CAMAC standard after digitization is complete.
Readout Control:	Ready for readout when LAM signal appears. Refer to ESONE Committee Report EUR4100e and EUR4600e for additional timing details, voltages, logic levels, impedances, and other standards.
Data:	The proper CAMAC function and address command normally gates the 11 binary bits of the selected channel onto the the R1 to R11 (2^0 to 2^{10}) Dataway bus lines.
CAMAC Commands:	Z or C: ADC's and LAM are cleared by the CAMAC "Clear" or "Initialize" command; requires S2. Z also disables LAM. I: Gate input is inhibited during CAMAC "Inhibit" command. (Test function is enabled.) Q: A Q=1 response is generated in recognition of an F(0) or F(2) Read function or an F(8) function if LAM is set for a valid "N" and "A", but there will be no response (Q=0) under any other condition. The Q response for empty modules can be suppressed (see Q and LAM suppression). X: An X=1 (Command Accepted) response is generated when a valid F, N, and A command is generated. L: A Look-At-Me signal is generated from end of conversion until a module Clear or Clear LAM. LAM is disabled for the duration of N, can be permanently enabled or disabled by the Enable and Disable function command, and can be tested by test LAM. Standard option causes LAM to be suppressed for empty modules.
CAMAC Function Codes:	F(0): Read registers; requires N and A; A(0) through A(11) are used for channel address. F(2): Read registers and Clear module and LAM; requires N and A: (clears on A(11) only). F(8): Test Look-At-Me; requires N and any A from A(0) to A(11) independent of Disable Look-At-Me. Q response is generated if LAM is set. F(9): Clear module and LAM: requires N, S2, and any A from A(0) to A(11). F(10): Clear Look-At-Me; requires N, S2 and any A from A(0) to A(11). F(24): Disable Look-At-Me; requires N, S2, and any A from A(0) to A(11). F(25): Test module; requires N, S2 and any A from A(0) to A(11). F(26): Enable Look-At-Me; requires N, S2 and any A from A(0) to A(11). Remains enabled until Z or F(24) applied. Caution: the state of the LAM mask will be arbitrary after power turn-on.
Q and LAM Suppression:	Adjustable potentiometer (accessed from side of module) sets count level required (from 0 to 100) before data is considered useful. A module in which all channels contain less than set amount will produce no Q-response or LAM and appears during readout as an empty CAMAC slot, thus reducing readout time. A Command Accept response is still generated. The LAM suppress portion can be disabled with a solder jumper option.
Packaging:	In conformance with CAMAC standard for nuclear modules (ESONE Committee Report EUR4100e). RF shielded CAMAC #1 module.
Current Requirements:	143 mA at +24 V; 75 mA at −24 V; 725 mA at +6 V; 155 mA at −6 V

SPECIFICATIONS SUBJECT TO CHANGE



AAC ANTIPROTON ACCUMULATOR COMPLEX
AC (Antiproton Collector, outer ring.)
AA (Antiproton Accumulator, inner ring)
General Layout; magnetic elements only.

FAST BCT Crate layout



Single ADC Module

1 gate + 12 chnls.

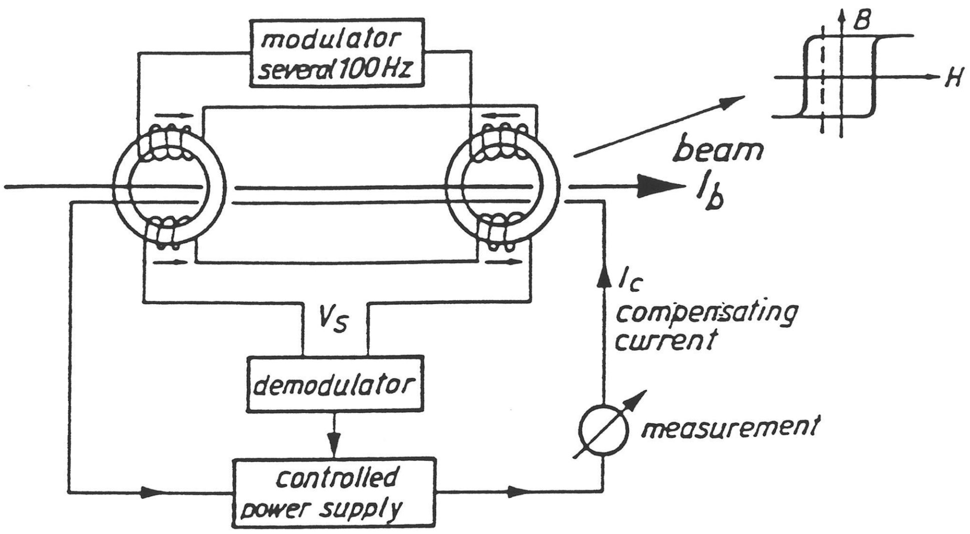
several Timing Modules

High level software access for fast beam current transformers: example for AAC transfer lines

- TYPE TRF(1, AQN,0, C)
- TYPE TRF(2,AQN,0,C)
- TYPE TRF(3,AQN,0,C)
- TYPE TRF(4,AQN,0, C)
- TYPE TRF(5,AQN,0,C)

  - *gives BCT values in units of E07 particles directly*
  - *all scaling & calib. factors inside EM*

Example of Control of a d.c. beam current transformer

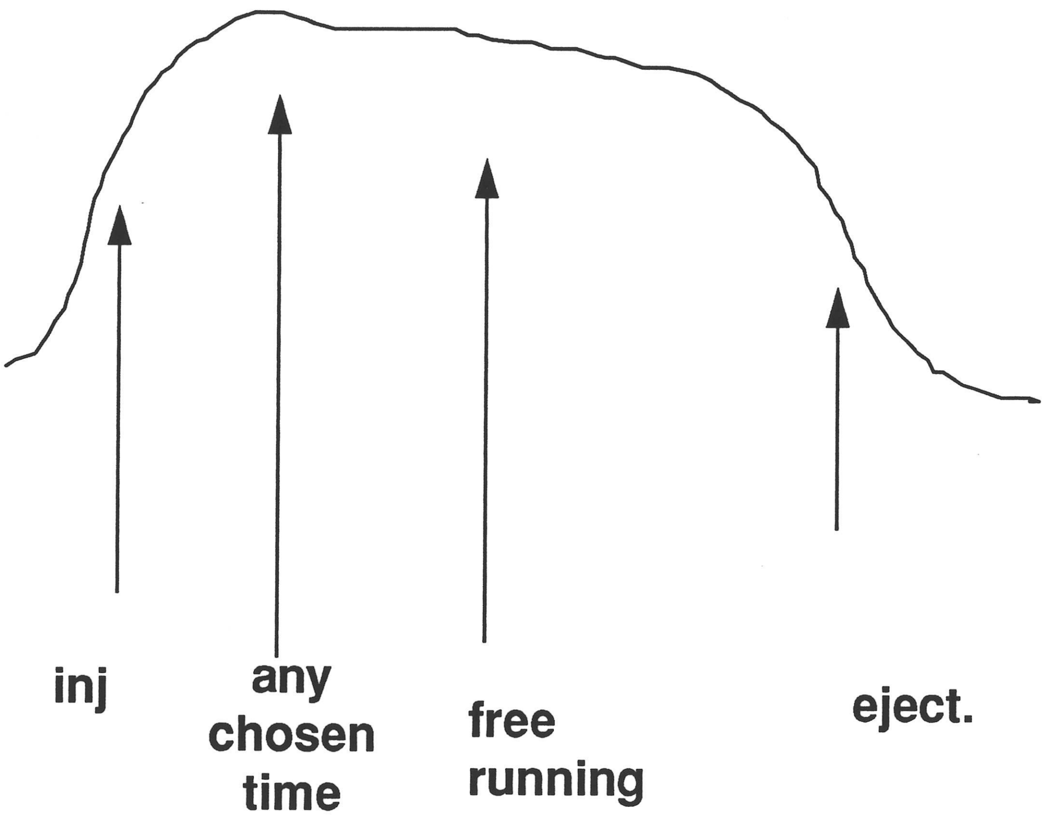


Basic scheme of a dc beam transformer and rectangular hysteresis of core material.

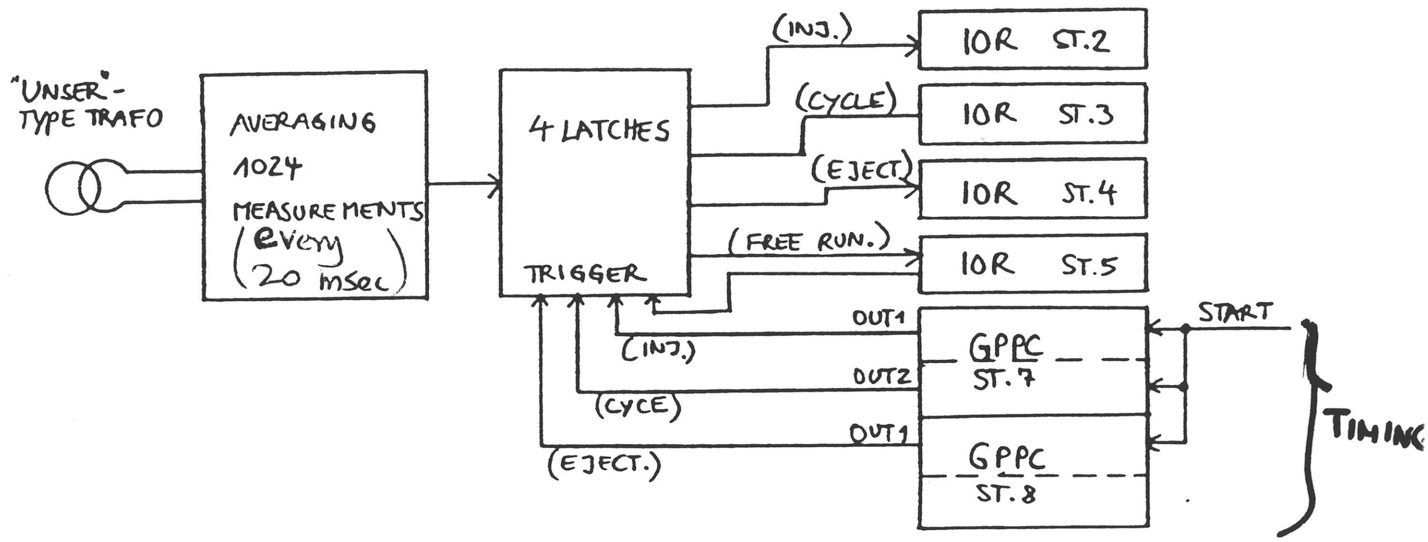
more complex and need considerations of :

- noise and ripple reduction/suppression
- DVM usage
- fast averaging over 20ms mains period
- zero line offsets /drifts caused by magnetic fields so memorization without beam and subtraction etc
- autoranging (also in fast BCT)

beam current measured at say, 4 time points



example of Circulating beam current trafo in AC Ring



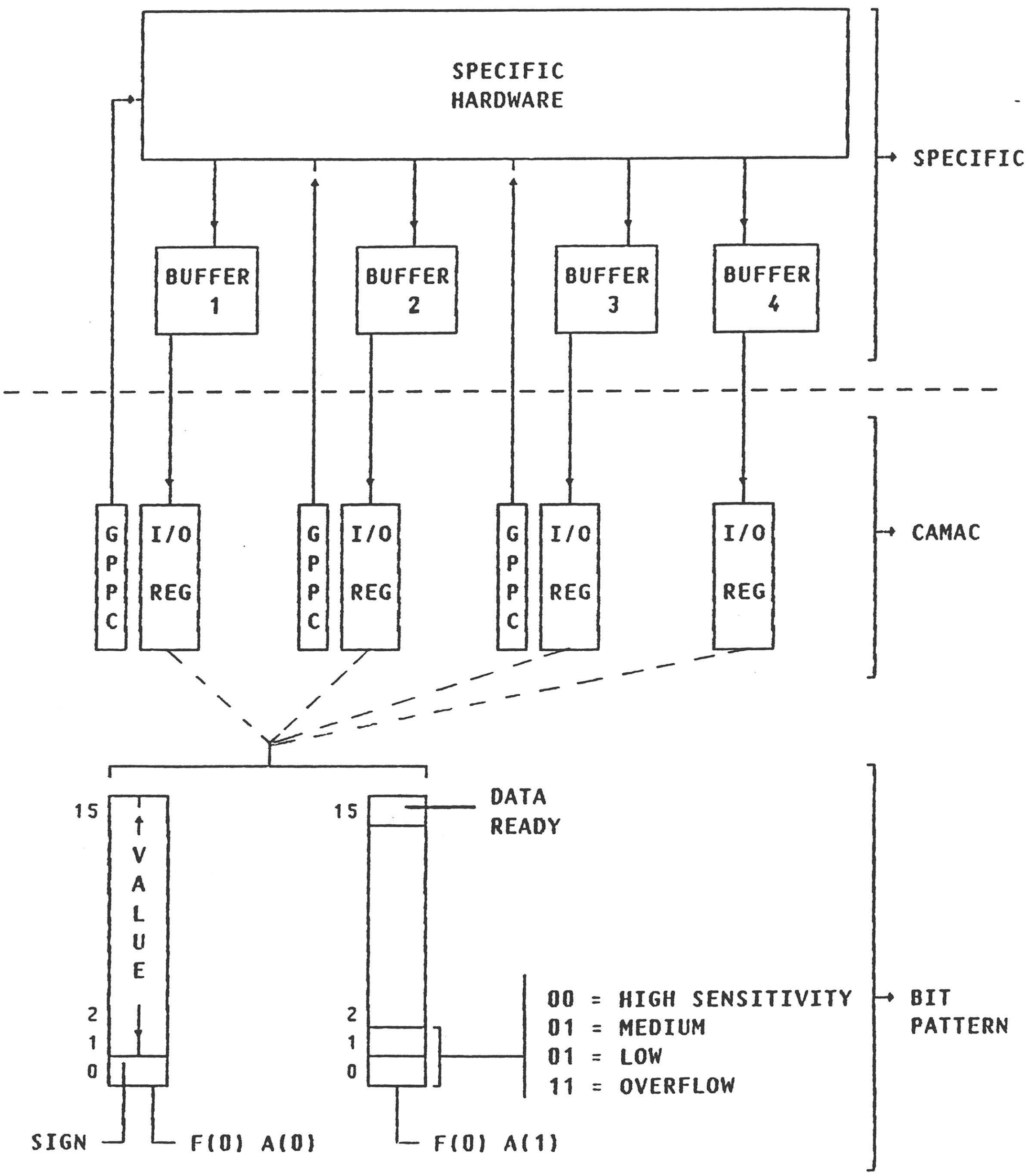
So need 4 intensity registers

4 range registers

i.e., 4 sets of 2 numbers

THE CAMAC IOR MODULE provides such 2 registers , so need 4 IOR Modules

ACOL
D.C. TRANSFORMER



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borer

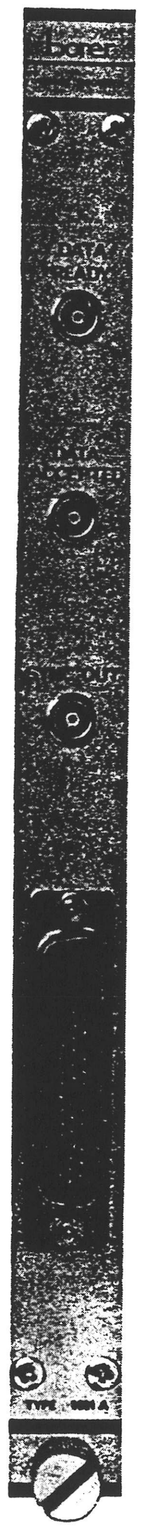
TYPE 1031A

2 Inputs from H/w into Computer

IN/OUT REGISTER

2x16-BIT & 1x16-BIT

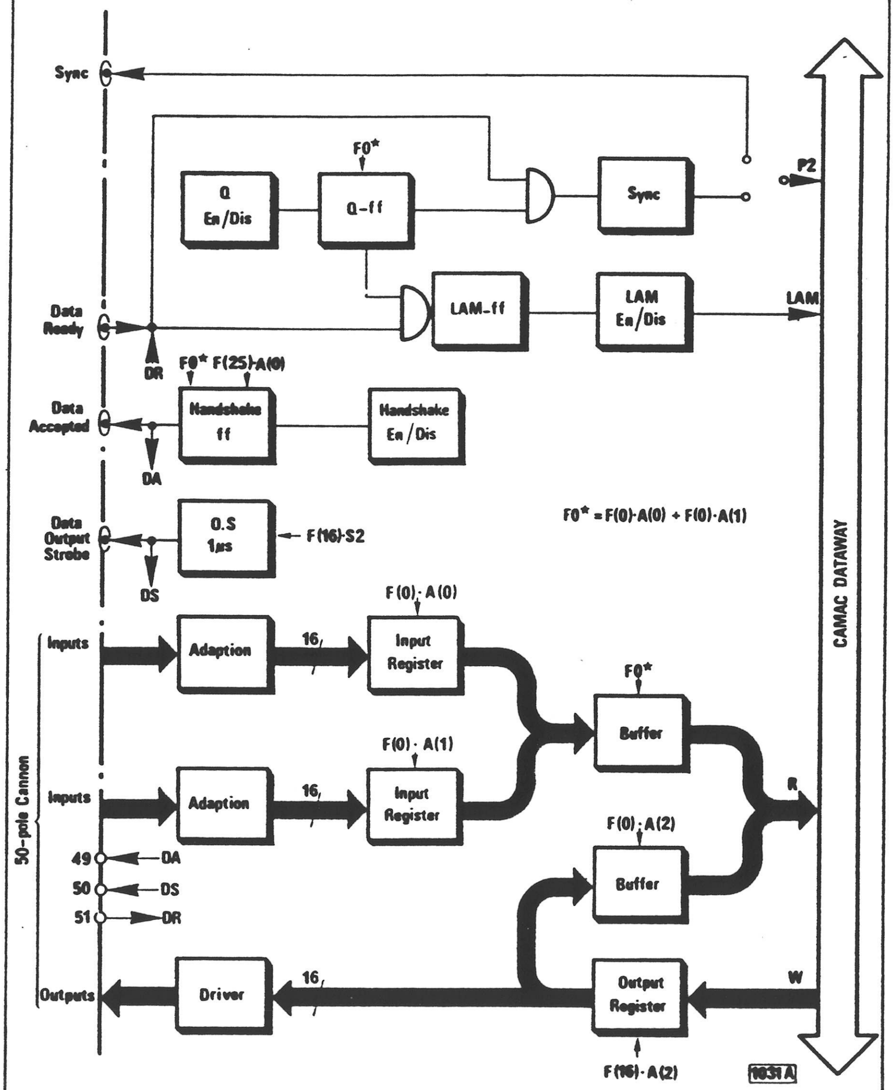
Ref: 603.3.021.4.78



- DUAL 16-BIT INPUTS
- 16-BIT RE-READABLE OUTPUT
- HANDSHAKE SYNC FOR THE INPUTS
- DMA SYNCHRO FACILITY FOR EXTERNAL BUFFERS
- RELAY ISOLATION UPON REQUEST

The Input/Output Register Type 1031A has been designed to be a very universal Camac instrument through both its concept and the number of options available. Its 16-bit format matches the 1031A to the majority of modern mini-computers while the ancillary logic ensures that it is ideal for fast data transfers. The 1031A offers a DMA synchro facility to couple external buffers and provides handshake synchronisation for the inputs. Additionally the module is able to perform fast block transfers in the Stop Mode (EUR4100, Section 5.4.3.3) with a suitable Crate Controller/Interface such as the Borer Type 1531A.

The 1031A provides two independent input channels, each of 16 bits, and an output channel also of 16 bits. An important feature of the instrument is the ability to be able to read back the content of the register in the output channel which simplifies the software.



TYPE 1031A

borer

A number of wire links on the p.c. board allows the user to choose the logic and in/out configuration to suit the particular application. For example, ground or positive-true inputs can be accepted, as can TTL or +24V signals. Outputs are normally for TTL applications but can optionally be supplied as open-collectors for more industrial purposes. When complete electrical isolation is essential, the module can even be delivered with relays in the inputs and/or outputs.

FUNCTIONS

- **F(0).A(0)** **Reads content of input register 1.** Gives Q and X.
- F(0).A(1) Reads content of input register 2. Gives Q and X
- F(0).A(2) Reads back content of output register. Gives Q and X
- F(8).A(0) Tests LAM f-f. Gives X. Gives Q if LAM is set
- F(10).A(0) Clears LAM f-f. Gives Q and X
- F(16).A(2) Loads output register. Gives Q and X
- F(24).A(0) Disables handshake (hs). Gives Q and X
- F(24).A(1) Disables Q f-f. Gives Q and X
- F(24).A(2) Disables LAM. Gives Q and X
- F(25).A(0) Starts block transfer. Gives Q and X
- F(26).A(0) Enables handshake (hs). Gives Q and X
- F(26).A(1) Enables Q f-f. Gives Q and X
- F(26).A(2) Enables LAM. Gives Q and X
- F(27).A(0) Tests hs enable/disable. Gives X. Gives Q if enabled
- F(27).A(1) Tests Q f-f enable/disable. Gives X. Gives Q if enabled
- F(27).A(2) Tests LAM enable/disable. Gives X. Gives Q if enabled

COMMANDS

N Selects Station Number
Suppresses LAM

Z Clears the input/output registers
Clears LAM
Disables the handshake f-f
Disables LAM
Disables the Q f-f

C, I, B } Not used

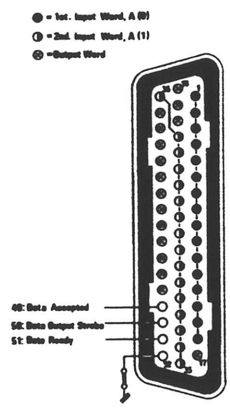
GENERATION

L LAM is set (if enabled) by the external Data Ready signal

SPECIFICATIONS

Figures quoted are for the standard model 1031A throughout. Options include adjustment for 24V signals, for positive-true signals and relay isolation of inputs and outputs. Further details upon request.

Data Inputs	
Number	2x16
Level	TTL, ground-true
Hysteresis	2,2V max
Over-Voltage	+24V max, short-term
Fan-in	1
Data Outputs	
Number	16
Level	TTL, ground-true
Fan-out	10
Data Output Strobe	Generated by F(16).A(0).S2
Level	TTL, ground-true
Duration	1μs
Fan-out	10
Data Accepted Output	
Level	TTL, ground-true
Fan-out	10
Data Ready Input	
Level	TTL, ground-true
Fan-in	1
Sync Output	
Level	TTL, ground-true
Duration	1μs
Fan-out	10
Mating connectors	
Multi-way, 52-pole (see below)	Cannon 2DB-52S, supplied with the module
Coaxial	Lemo 00250F, not supplied with the module (order Borer Stock No. 141-514).
Power Requirement	1,1A at +6V
Dimensions	1 x Camac norm



Bit	1st. Input Word, A(Ø)	2nd. Input Word, A(1)	Output Word
Bit Ø	1	25	37
Bit 1	2	26	38
Bit 2	3	27	39
Bit 3	4	28	40
Bit 4	5	29	41
Bit 5	6	30	42
Bit 6	7	31	43
Bit 7	8	32	44
Bit 8	9	33	45
Bit 9	10	34	46
Bit 1Ø	11	35	47
Bit 11	12	36	48
Bit 12	13	21	17
Bit 13	14	22	18
Bit 14	15	23	19
Bit 15	16	24	20

Pin Numbers

EM access for DC BCT

- Acq. of free running channel:

SET V=TRAC(1,AQN,0,C)

  - value given directly in E7 particles

- Range reading if needed

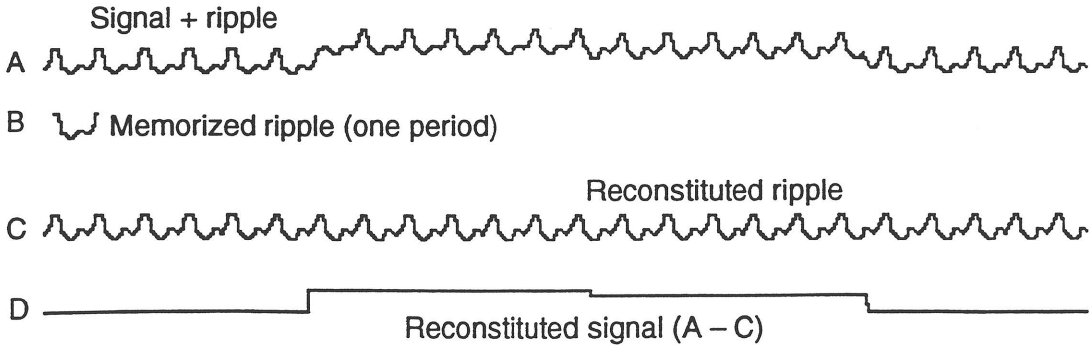
SET R= TRAC(1,SCL,0,C)

  - where R = 1= 1E11 low sensitivity
  - =2 = 1E10 med. "
  - =3 = 1E09 high "

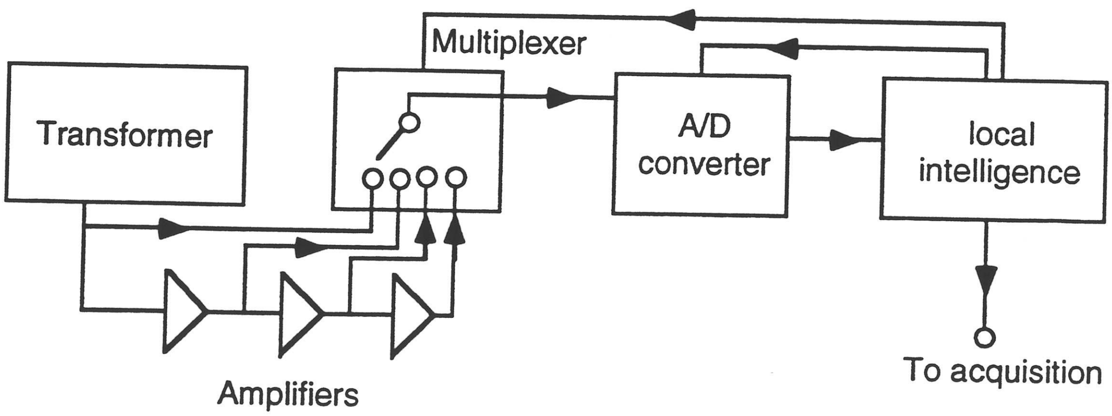
- for hardware checks ,acquire direct IOR reading using property AQND
- For other channels:
- INJECTION = property AQN1 & SCL1
- EJECTION = " AQN3 & SCL3
- etc..

The DC BCT gives an example of lots of sophisticated hardware and software at the local level and giving only a final result to the control system; this sort of local signal treatment/processing is also valid in some fast BCT's, e.g., current measurement per turn etc

e.g. ① Ripple Suppression

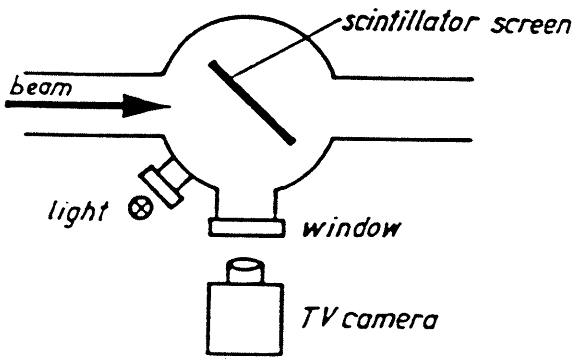


e.g. ② Auto Ranging

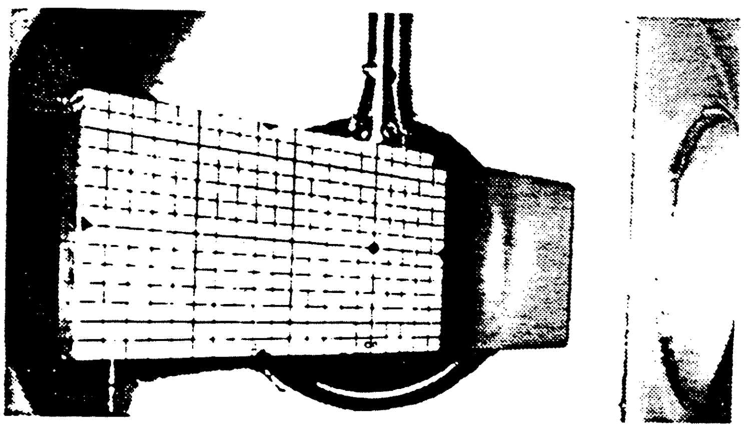


Example of Control of Scintillator Screens

As any operator would say, "Nothing as convincing as a flash of light in the middle of an observation screen as the proof of beam coming upto there "



Typical arrangement for observation of beam position and size with a movable scintillator screen and a TV camera.



Scintillator screen made from a Cr-doped Al_2O_3 plate with imprinted graticule.

Elements to be controlled:

Screen: IN & OUT {of beam}

LIGHT: Switch ON/OFF & optional intensity

CAMERA: Switch ON/OFF

FOR A LARGE NUMBER OF SCREEN STATIONS (MTV STATIONS) TO BE CONTROLLED, ONE NEEDS TO ECONOMIZE ON BITS NEEDED AND EASY ADDRESSING. AN OUTPUT MODULE THAT PERMITS *ADDRESSING DIRECTLY 4 BITS AT A TIME (OUT OF A 16 BIT WORD)* WAS SELECTED AS IDEAL; HENCE THE DUAL OUTPUT REGISTER MODULE(DOR) .

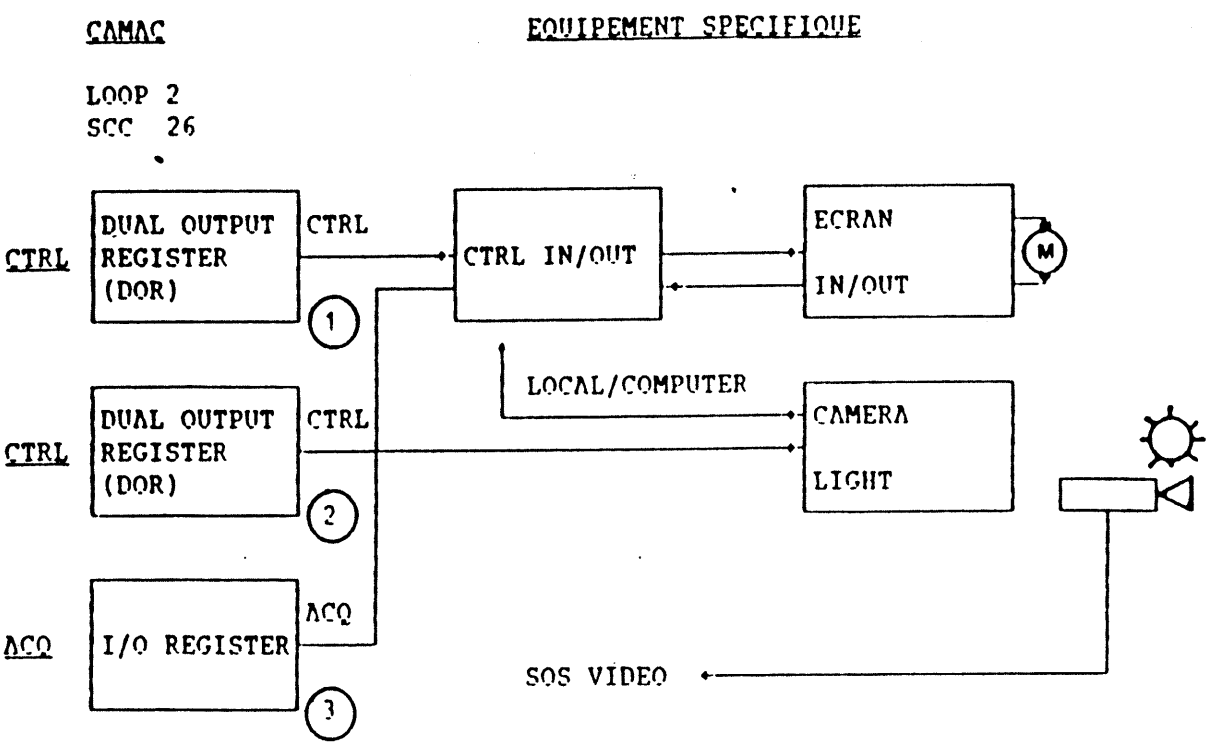
Assign 4 Bits for ***SCREEN CONTROL***

4 SCREENS CONTROLLED BY ONE OUTPUT WORD

Assign another set of 4 Bits for ***LIGHT & CAMERA CONTROL***

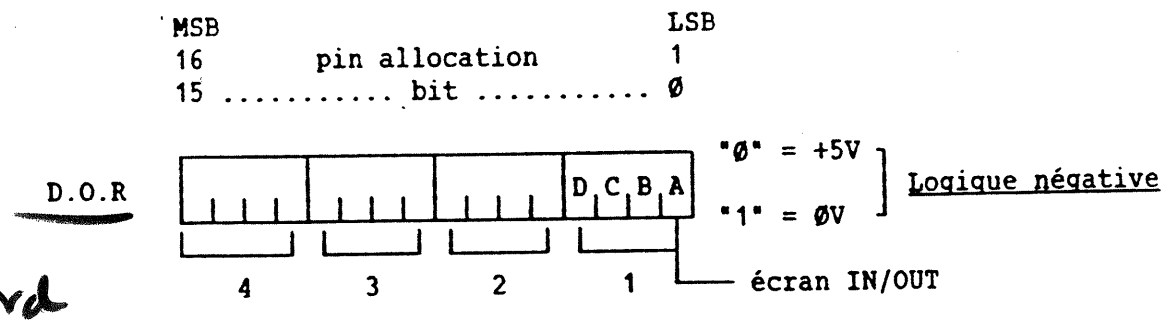
4 respective LIGHTS & CAMERAS CONTROLLED BY ANOTHER OUTPUT WORD

ACQUISITION OF SCREEN STATUS DONE INDEPENDENTLY

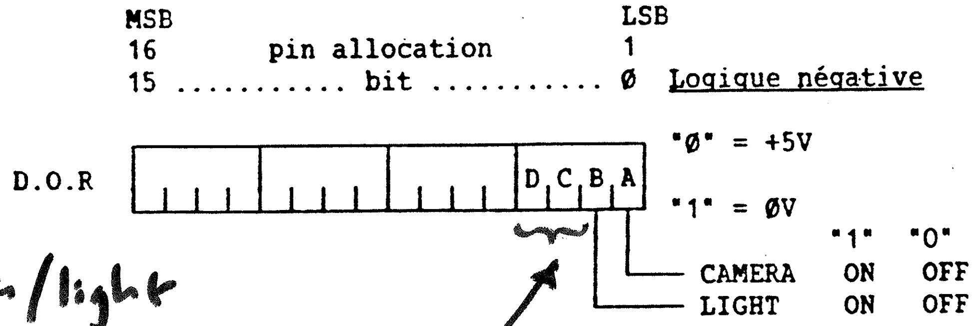


3.1.2 Code de commande des écrans IN/OUT

4 screens per 1 word



Code de commande des caméras, "lights" et intensificateur



4 camera/light per 1 word.

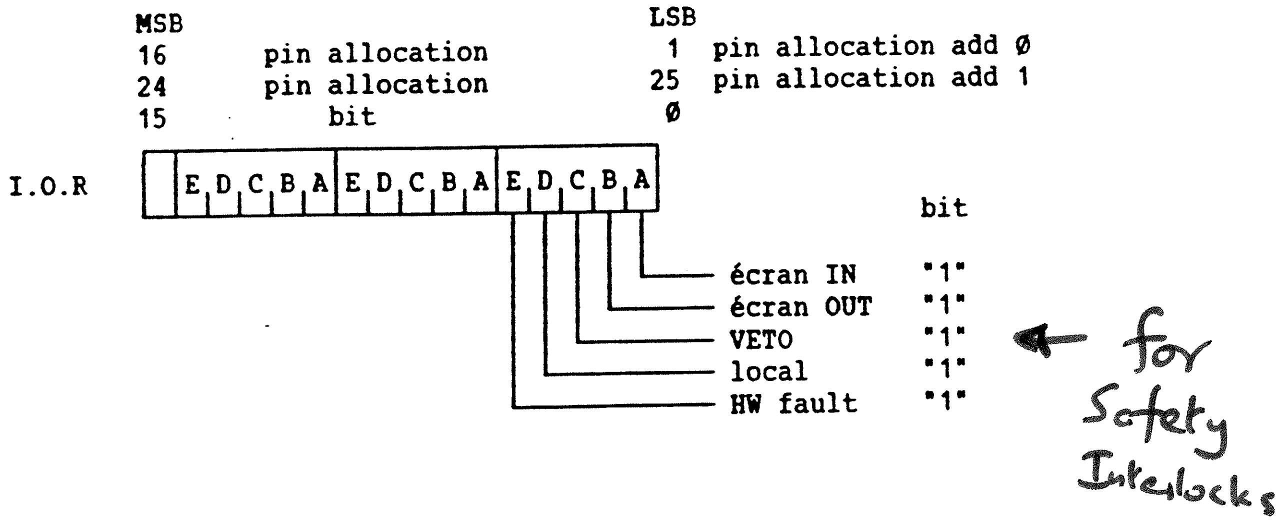
for light intensity (CCD applic.)

ACQUISITION OF SCREEN STATUS IS IMPORTANT (destructive for beam !) , while LIGHT or CAMERA status deemed not important enough.. So use IOR MODULE. Each screen needs 5 STATUS bits as follows , hence 3 Screens can be acquired by one IOR 16-bit WORD:

Screen

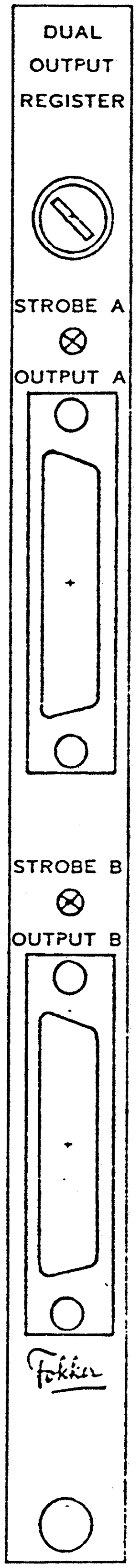
Code d'acquisition écran IN/OUT

ACQ



USE the 2nd IOR WORD for acquisition of power supply status of different elements in the system

DUAL OUTPUT REGISTER (C)



1. General Description

The Dual Output Register is a single width CAMAC module which contains two identical 16 bit output registers A and B. Parallel outputs are provided on two front panel connectors. The module can service up to 8 peripherals independently because the registers can be loaded in groups of 16, 8 or 4 bits. The register content can be read back as 16 bit words.

2. Detailed Description

The registers can be loaded in groups of 16, 8 or 4 bits depending on the CAMAC function. A group always corresponds to the least significant bits on the CAMAC Write Lines. A load (or reset) function generates strobe pulses (according to the part of the register which is loaded) available at the front panel connectors. One strobe line corresponds to each group of 4 bits, STR1 for the 4 least significant output bits, STR2 for the next 4 bits, etc.

The registers can be read as 16 bit words (for diagnostic purpose).

7. CAMAC Function Table

ANUFACTURER: FOKKER
ODULE: OUT-REG
ATE: 26-7-1979

(.)	A(.)	X	Q	R/W	BITS	MULT	COMMENTS
0	0	1	0	1	16	1	READ REG. A (A1....A16)
0	1	1	0	2	16	1	READ REG. B (B1....B16)
9	0	1	0	0	0	0	RESET BOTH REG.
16	0	1	0	1	16	1	WRITE REG. A (A1....A16) WITH W1....W16
16	1	1	0	2	16	1	WRITE REG. B (B1....B16) WITH W1....W16
16	2	1	0	0	0	0	WRITE REG. A (A1.....A8) WITH W1....W8
16	3	1	0	0	0	0	WRITE REG. A (A9....A16) WITH W1.....W8
16	4	1	0	0	0	0	WRITE REG. B (B1.....B8) WITH W1.....W8
16	5	1	0	0	0	0	WRITE REG. B (B9....B16) WITH W1.....W8
16	6	1	0	0	0	0	WRITE REG. A (A1.....A4) WITH W1.....W4
16	7	1	0	0	0	0	WRITE REG. A (A5.....A8) WITH W1.....W4
16	8	1	0	0	0	0	WRITE REG. A (A9....A12) WITH W1.....W4
16	9	1	0	0	0	0	WRITE REG. A (A13...A16) WITH W1.....W4
16	10	1	0	0	0	0	WRITE REG. B (B1.....B4) WITH W1.....W4
16	11	1	0	0	0	0	WRITE REG. B (B5.....B8) WITH W1.....W4
16	12	1	0	0	0	0	WRITE REG. B (B9....B12) WITH W1.....W4
16	13	1	0	0	0	0	WRITE REG. B (B13...B16) WITH W1.....W4

4 bit WRITE

OTE:-
---RESET BOTH REGISTERS
ALL STROBES ARE GENERATED

Screens And High-level Software

EQUIPMENT MODULE CALLED: "MTV"

{ example for screen no.2 }

CONTROL ACTIONS:

SET MTV(2,SCRN1,0,C)=1 ; %.....IN
=0 OUT

SET MTV(2, CAMRA,0,C)=1 ; %...ON
=0 OFF

SET MTV(2, LIGHT,0,C)=1 ; %......ON
= 0 OFF

Status Acquisition:

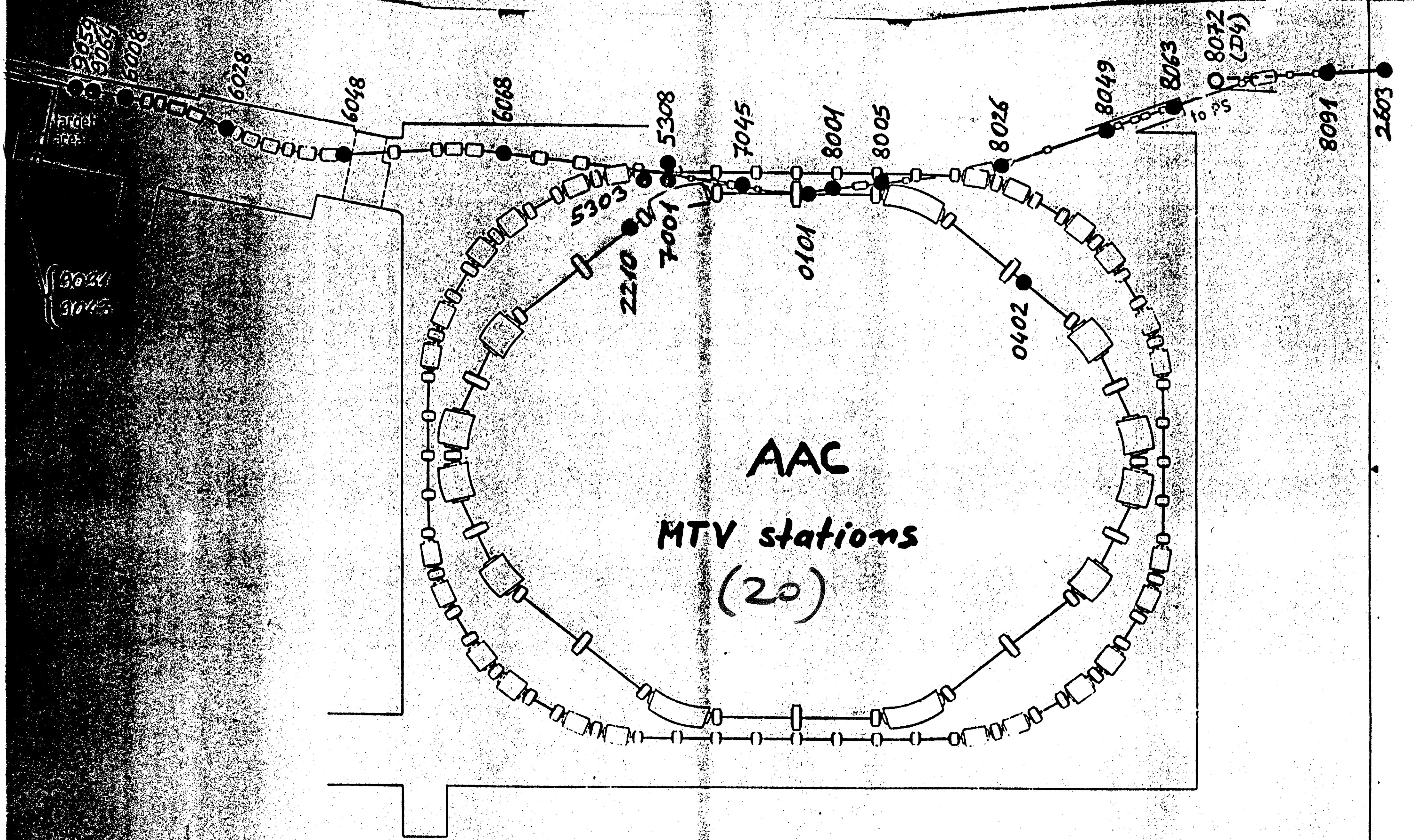
TYPE MTV(2,SCRN1,0,C)

– gives independent status of screen

TYPE MTV(2,CAMRA,0,C)

TYPE MTV(2,LIGHT,0,C)

– give status of last COMMAND registers for Camera and Light



General Layout; magnetic elements only

Crate layout : 20 stations case AAC

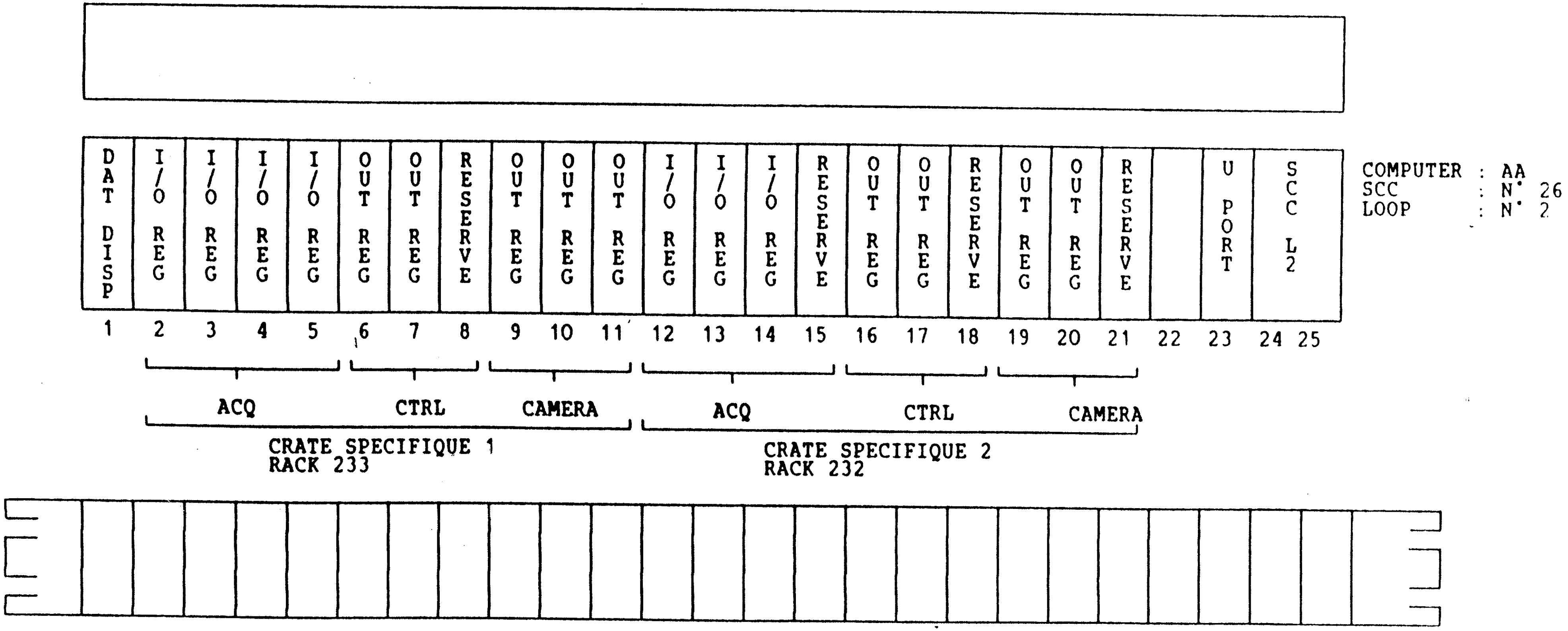
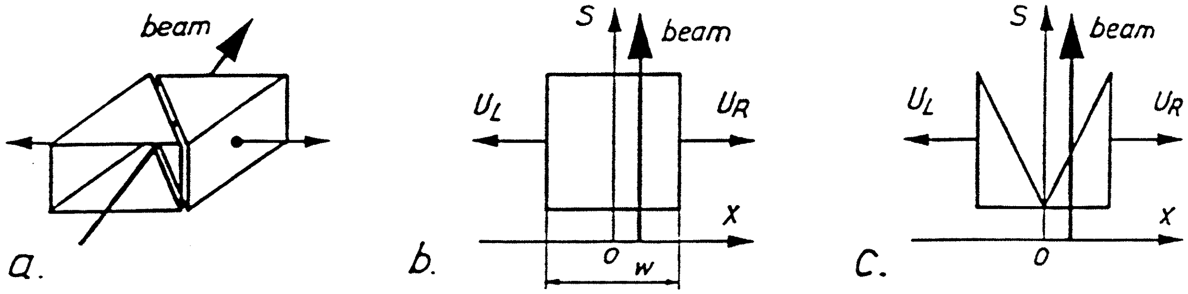


Fig. B1 INTERFACE CAMAC - LAYOUT (ECRANS AA)

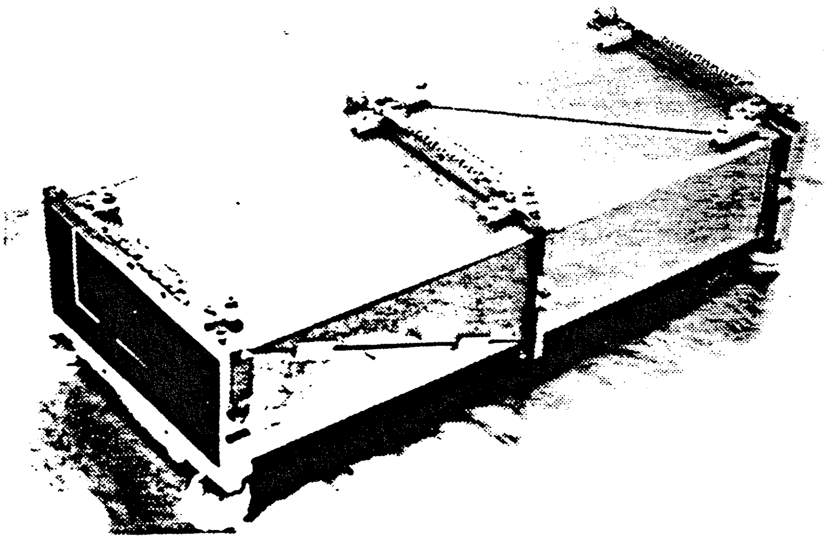
CAMAC INTERFACE

CAMAC INTERFACE

Example of Control of Beam Position Monitors



a) Diagonally cut "shoe-box" PU. b) Basic geometry and tapping of signals.
c) A variant which allows interleaving of a horizontal and a vertical PU.



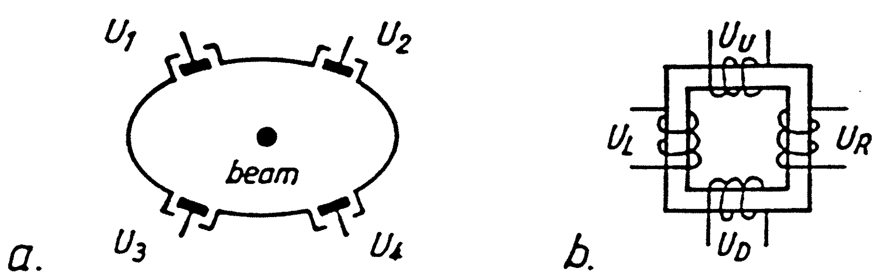
Combination of a horizontal and a vertical PU, mounted in the vacuum chamber of the Antiproton Accumulator at CERN.

$$x = \frac{w}{2}\frac{U_R - U_L}{U_R + U_L}$$

Frequently, the jargon terms "Δ" and "Σ" are used

$\Delta = U_R - U_L$ and $\Sigma = U_R + U_L$.

$$x = \frac{w}{2}\frac{\Delta}{\Sigma}$$



a) PU with "button" electrodes. b) Magnetic PU.

Number of BPM's depend on machine tunes (for each plane) and at least 4 times the Q value

for example:

machine	*~tune(H)*	*installed BPM's*
PS Ring CERN	6.26	40 H & 40 V
AA Ring CERN	2.254	12 H & 12 V
AC Ring CERN	5.56	32 H & 28 V
Elletra(Trieste)		96
CRYRING(Stockholm)	2.3	9 H & 9 V
INDUS-2	6-9	48 (?)

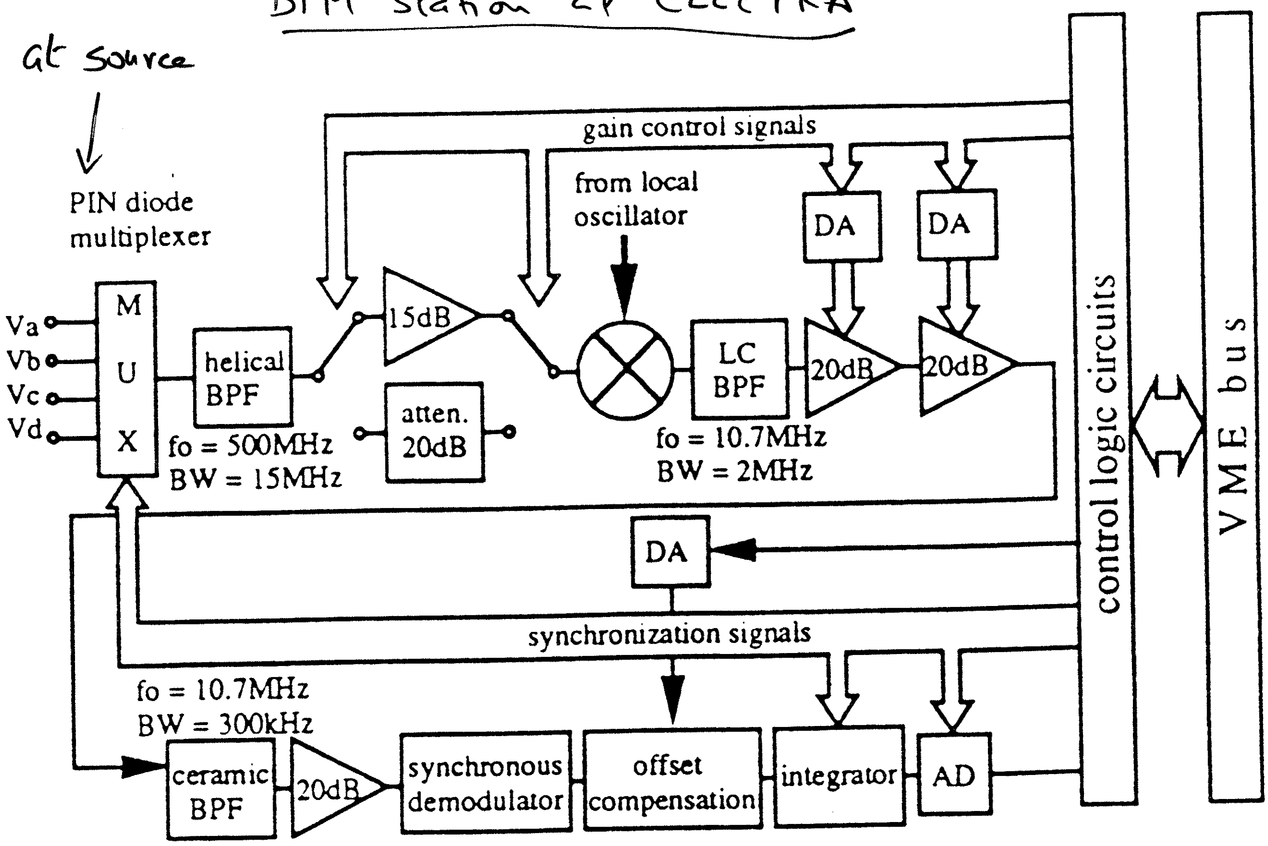
LARGER THE NUMBER OF BPM stations, MULTIPLEXING becomes a MUST to reduce the electronics and a fair COMPROMISE has to be found in MULTIPLEXING versus SPEED of RESPONSE , the latter very much dependent on HOW OFTEN THE CLOSED ORBIT IS MEASURED AND CORRECTED - which again is dependent on the accelerator concerned

- *Hadron machines not too often except setting up etc*
- *Hadron storage rings even less than in pulsed synchrotrons*
- *electron rings - can be very often with auto f.b. etc..*

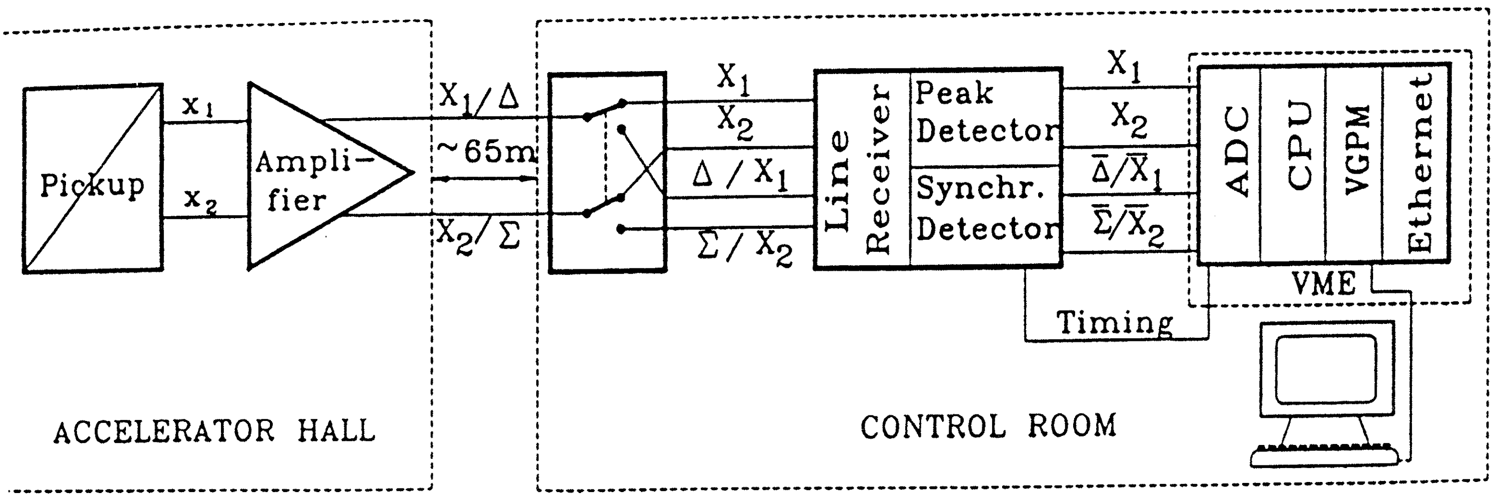
Each Station gives the difference (delta) and sum(sigma) signal and the Normalizer does the (delta/sigma) , so the internal logic may also need multiplexing to save too many normalizers !

Example :

BPM station at ELLETRA



CRYRING BPM Example : No MUX !



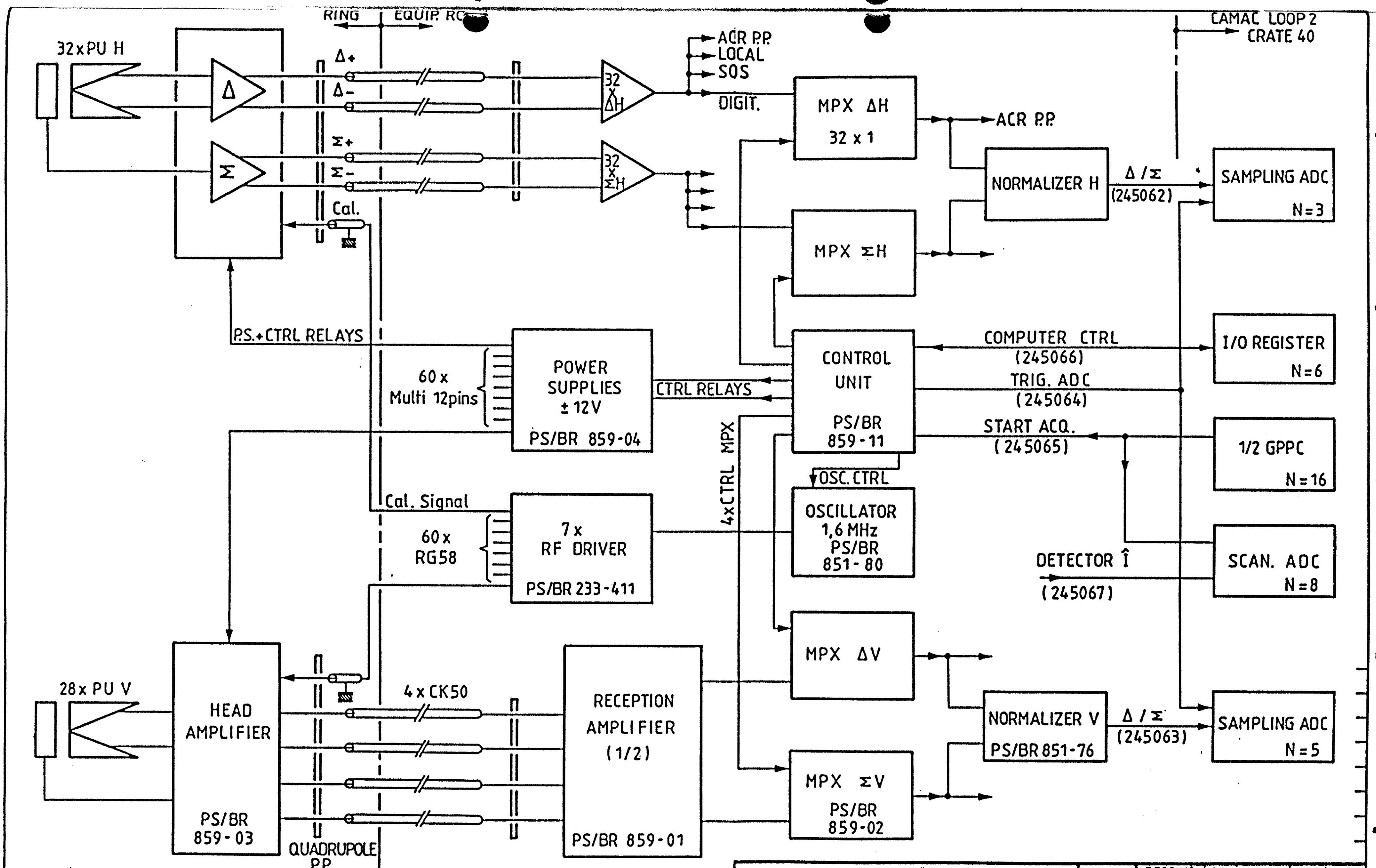


Fig. 1
ACOL BLOCK DIAGRAM

INDICE	DATE	NOM	ZONE	MODIFICATION

ECHELLE SCALE

DESSINÉ	D. VINCENT	Sept 87
CONTRÔLÉ		
REMPLACE		
REMPLACÉ PAR		
RÉDUCTION		

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN-DIV: ....

PS/BR859-00-1001

INDICE

Example of control of BPM's of the CERN AC Ring(last small size ring built at CERN)

- *Separation of planes :* ***32 H , 28 V Stations***
  - One Normaliser per plane, each giving (delta/sigma)
- ***Control:***
  - local / Computer
  - Active calibration of the electronic chain for each station
- ***Acquisition***
  - of Normaliser Output (delta/sigma) for each station
- ***Local Data Treatment***
  - Calibration Data (3 words per station)
  - offset data (4 words per station)

Hence use IOR Module & Sampling ADC

FINAL HIGH LEVEL ACQUISITION DIRECTLY IN MILLIMETRES OF BEAM POSITION

CALIBRATION ISSUES: Due to the electronics chain per station consisting of pre-amplifier, amplifier etc. etc, & unique for each station

In this case where active calibration takes place before every usage, the electrodes are disconnected by relays (hence Control using IOR Module) and sending the calibration signal to the active chain and measuring the output, i.e., Y_{c0}, Y_{c+} & Y_{c-}.

Cal_0 is calib. signal between Sum & D- & D+

Cal_+ is " " " Sum & D+

Cal_- is " " " Sum & D-

hence, if Y_m = Measured (Delta/Sigma) signal from any one station , then this Y_m has to be corrected by active calibration data such that the true value Y is :

$$Y = (Y_m - Y_{c0}) / ((Y_+ - Y_{c-})/2)$$

Hence, this calib. correction has to be applied per station using the 3 calib. data stored in data tables

Offset issues: Due to different mechanical geometries etc and the different shapes and sizes (6 different ones in AC Ring) governed by the vacuum pipe. Lab. test stand needed with simulation of beam etc.

In the AC Ring 60 stations' case, the lab. measurements gave non-linear relationship between actual position and the output Y_m of (delta/sigma) normaliser such that:

$$x[mm] = a_0 + a_1 Y + a_2 Y^2 + a_3 Y^3$$

So 4 Coefficients to be stored per BPM station in the data table. So per BPM station we have:

4 offset coefficients

3 Calibration numbers

– *TOTAL 7 Numbers x 60 = 240*

240 Numbers to be stored for the local data processing usage

From the Control system point of view

- *IOR Module for control of :*

(a)manual or computer control

(b) Real measurement or calibration

such that 2 bits in IOR Register(F16A2)

00	Orbit M'ment
11	Calib. 0
01	Calib +
10	Calib -

{ STATUS OF THESE TWO CONTROLS ACTIONS: F0A1 , F0A2 }

- *Calibration*

SET PUAC(1,INITL,0,C)= 1; timing & init

SET PUAC(n,CALIB,0,C)=1;

with n=1, 2, or 3 for putting calib. values in data table for all 60 BPM's;

For the 4 offset coeffs., use arrays to write in :

APUAC(AV,-1,EL,symbol(OFFSET),0,CA)

APUAC(AV,-1,EL,symbol(SCL1),0,CA)

APUAC(AV,-1,EL,symbol(SCL2),0,CA)

APUAC(AV,-1,EL,symbol(SCL3),0,CA)

- *ACQUISITION USING Sampling ADC*

SET PUAC(1,INITL,0,C)= 0; orbit measure+trig

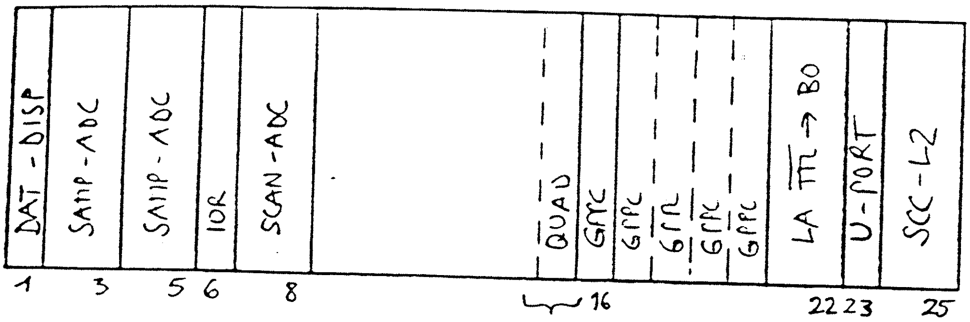
APUAC(AV,1,EL,Symbol(AQN),0,CA)

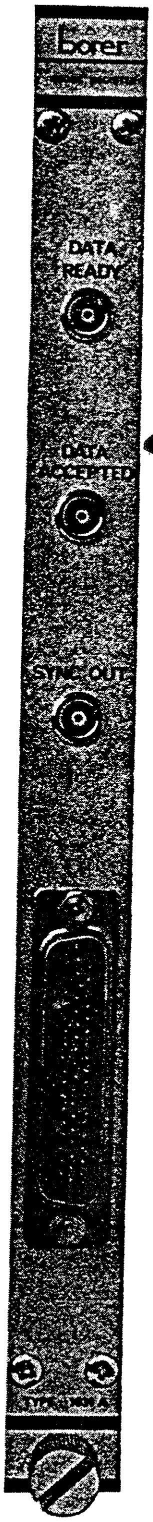
where, AV(0) = word count

AV(1,...32) Horiz 32 positions

AV(33,60) Ver. 28 positions

L2 C40 Equ. Room
RA-K-221

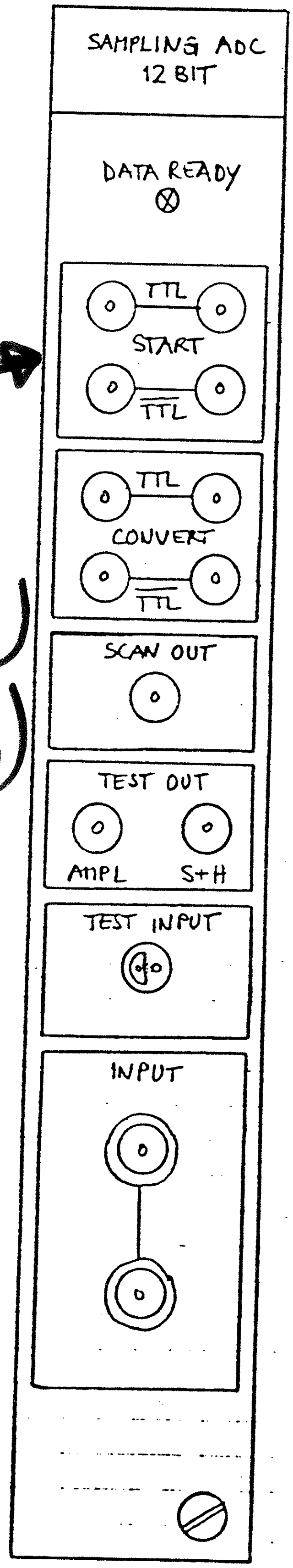




← IOR

For Control
a) Manual/Comp.
b) Calib. or M'ment

For each plane (Δ/Σ) (1024 Memory) →



1987-10-06-19:06:48 AC CLOSED ORBIT DISTORTIONS IN MM

HORIZONTAL POSITIONS
(+ MEANS OUTSIDE)

PU 2	1.6	PU 30	.5
PU 4	1.7	PU 32	.6
PU 6	1.3	PU 34	-3.1
PU 7	-.9	PU 35	-.7
PU 9	-2.6	PU 37	-2.7
PU 11	.4	PU 39	0
PU 12	1.9	PU 40	2.2
PU 14	4.0	PU 42	-1.7
PU 16	3.3	PU 44	.5
PU 18	-3.4	PU 46	-.5
PU 19	-.6	PU 47	1.7
PU 21	-1.3	PU 49	-2.0
PU 23	-.1	PU 51	-6.7
PU 24	3.0	PU 52	-1.4
PU 26	1.1	PU 54	10.5
PU 28	1.8	PU 56	-2.2

VERTICAL POSITIONS
(+ MEANS ABOVE)

PU 1	.1	PU 29	-.3
PU 3	-.9	PU 31	.8
PU 5	-.1	PU 33	-1.7
PU 7	-.3	PU 35	-.1
PU 9	2.1	PU 37	-.2
PU 11	1.5	PU 39	-1.5
PU 13	1.8	PU 41	1.7
PU 15	-1.2	PU 43	1.8
PU 17	-.8	PU 45	-1.3
PU 19	.9	PU 47	-1.0
PU 21	-1.5	PU 49	-1.0
PU 23	1.8	PU 51	-.3
PU 25	1.6	PU 53	0
PU 27	0	PU 55	1.3

Ip BUNCHED= .3881 E10

DP/P (FROM FREQUENCY)= 0 E-3 MEAS FREQUENCY =1589.477 kHZ
DP/P (FROM PU AVERAGE)= -.6 E-3 TRIM = .1 mm

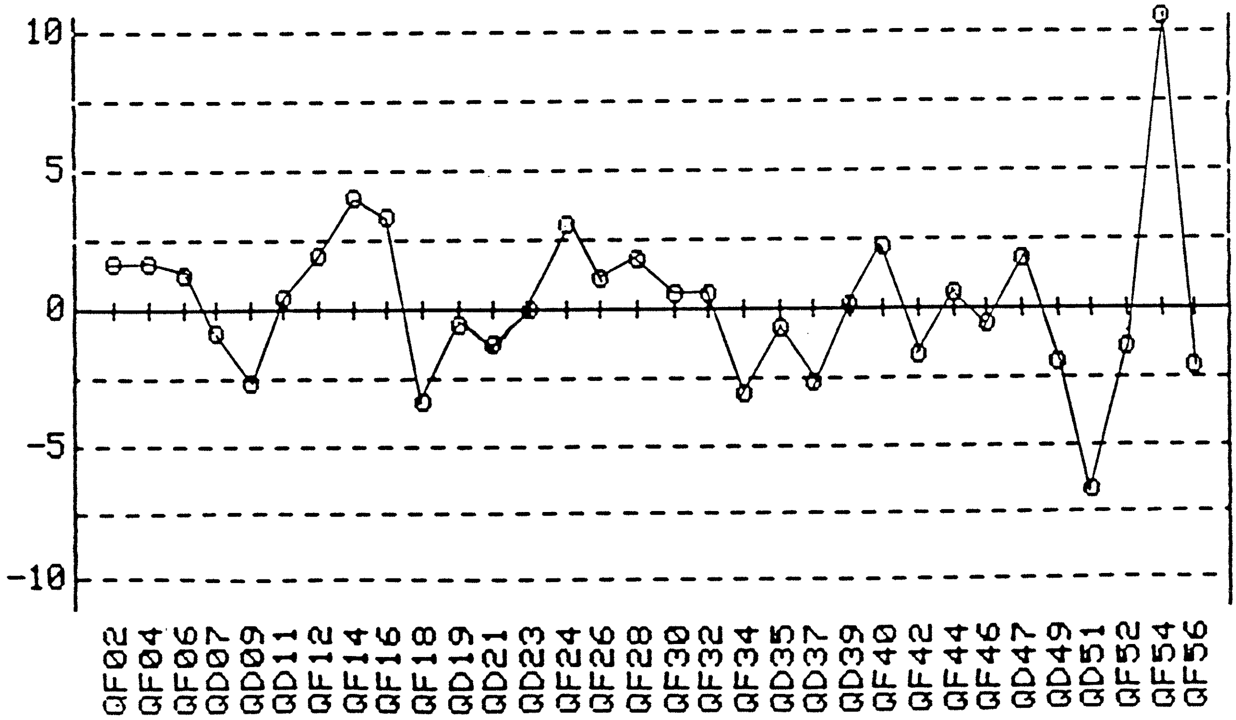


Fig. 3

Closed Orbit Correction for the AC Ring:

Done by Orbit Measurement, Offline Analyses which gives the dipole corrections which are achieved by moving the Quadrupoles in the AC Ring - hence needs the help of surveyors to do so, to do it right !

However, for the zero-dispersion regions and with the help of special power supplies installed on dipoles which TRIMs the current, the local orbit correction in these regions is possible.

Automatized Corrections with installed Correctors are a must in Light Sources (ELLETRA, ESRF, ... etc

ORBIT CORRECTION METHODS, TECHNIQUES, SOFTWARE etc IS A VAST SUBJECT IN ITS OWN RIGHT , not dealt here

Beam Diagnostics in the Control Room:

Ease of Use MOST IMPORTANT,

hence automation primordial; even non-experts should be able to use sophisticated beam observation/measurement systems

Examples:

- Control Oscilloscopes & other sophisticated commercial devices (Spectrum Analysers, Dynamic Signal Analysers , etc) for observation of fast, transient phenomena & so on...

- Control of INPUTS to the above devices (multiple signal sources using the same expensive instrument; so Software controlled Contacts or Switches)

- Control of Timing and Triggers to Instruments

- Video Image Freezing or frame-grabbing Commercial Devices (e.g., on a PC) and treatment/evaluation of exact spot, size, etc etc..

- FOR FAST TRANSIENT PHENOMENA, NEED HIGH SAMPLE-RATE DIGITAL 'SCOPES or EASY TO USE SYSTEM OF HIGH FREQUENCY DIGITIZERS (e.g., 8 bit FLASH ADC's ruggedly tested and established in CAMAC or VME with high enough SAMPLE RATE) . In the CERN ANTIPROTON COMPLEX of AC & AA Ring, beam bunches of 60 to 80 nsec means sampling at 10nsec at least (100 MHz) to observe sufficient number of points per extracted bunch to discern useful information.
- Need a GOOD GPIB to CAMAC or VME Interface for all commercial Instruments; trade-off simplicity & one-to-one mapping in 'dumb' modules versus complexity & software complications in intelligent modules and issues of number of devices hooked per interface module, daisy chaining, 'talk-listen' arbitration, restrictions on device-to-interface distance , etc

KineticSystems Corporation

CAMAC Example.

Standardized Data Acquisition and Control Systems

3388

* Simple "dumb" Module

GPIB Interface

provides one-to-one mapping

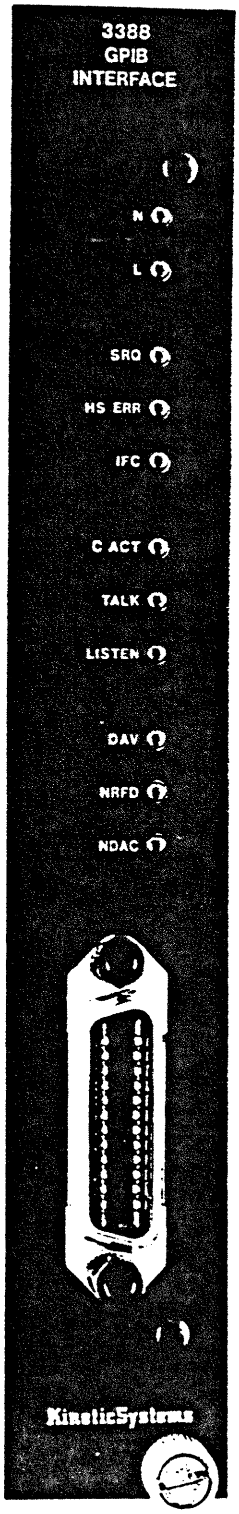
May 77
(Rev. June 84)

FEATURES

- PROVIDES FOR INTERFACE BETWEEN A CAMAC SYSTEM AND GPIB-INTERFACED INSTRUMENTS
- MEETS IEEE 488 AND 583 REQUIREMENTS
- PROVIDES GPIB T8, L4, C1 - C4, C25, SH1, AH1, SR0, RL0, PP0, DC0, DT0 INTERFACE FUNCTIONS
- GPIB T6, SR1, DC1, C5 - 25 INTERFACE FUNCTIONS CAN BE IMPLEMENTED BY ADDITIONAL USER SOFTWARE
- SWITCH-SELECTABLE TALK/LISTEN ADDRESS

APPLICATIONS

- INSTRUMENTS SUCH AS DVM'S, COUNTERS, ETC., INTERFACED TO A COMPUTER
- DATA LOGGERS



GENERAL DESCRIPTION

The Model 3388 is a double-width CAMAC module that provides the interface between a CAMAC system (IEEE Standard 583-1982) and the General Purpose Interface Bus (also called "GPIB" or "ASCII Bus", IEEE Standard 488). This module allows digital multimeters, counters, printers, calculators, display terminals or other devices that meet the GPIB standard to be connected to a CAMAC system. In the past, the interfacing of such instruments to CAMAC often required special modules and engineering effort on a case-by-case basis. With the 3388, up to fourteen other GPIB-interfaced instruments can be connected via the standard GPIB cables.

The Model 3388 GPIB Interface Module functions as a CONTROLLER, TALKER, and LISTENER as described in IEEE Standard 488. For example, it can cause a digital multimeter to be in the TALK mode and be in the LISTEN mode itself. The DMM would then transmit data to the 3388 to be processed by the computer associated with the CAMAC system. The computer could then cause the 3388 to be in the TALK mode and a GPIB-interfaced printer to be in the LISTEN mode. Processed data from the computer would then be printed on the printer.

The 3388 can be set to the CONTROLLER IDLE state so that it can be a TALKER or LISTENER in a system that contains another CONTROLLER (such as an intelligent terminal or a desk-top calculator).

GPIB SPECIFICATION SUMMARY

Item	Description
Interconnected Devices	Up to 15 maximum on one contiguous bus.
Interconnection Path	Star or linear bus network up to 20 meters total transmission path length.
Active Signal Lines	Sixteen total: 8 data lines, 3 data transfer control lines, and 5 bus management message lines.
Message Transfer Scheme	Byte-serial, bit-parallel asynchronous data transfer using interlocked 3-wire handshake technique.
Data Rate	Depends upon host computer program and external devices.
Address Capability	Primary addresses, 31 TALK and 31 LISTEN.

11 Maryknoll Drive • Lockport, IL 60441 • (815) 838 0005 • TWX 910 638 2831

VME Example

The front panel of the TSVME404 and components layout are shown in Figure 2-2.

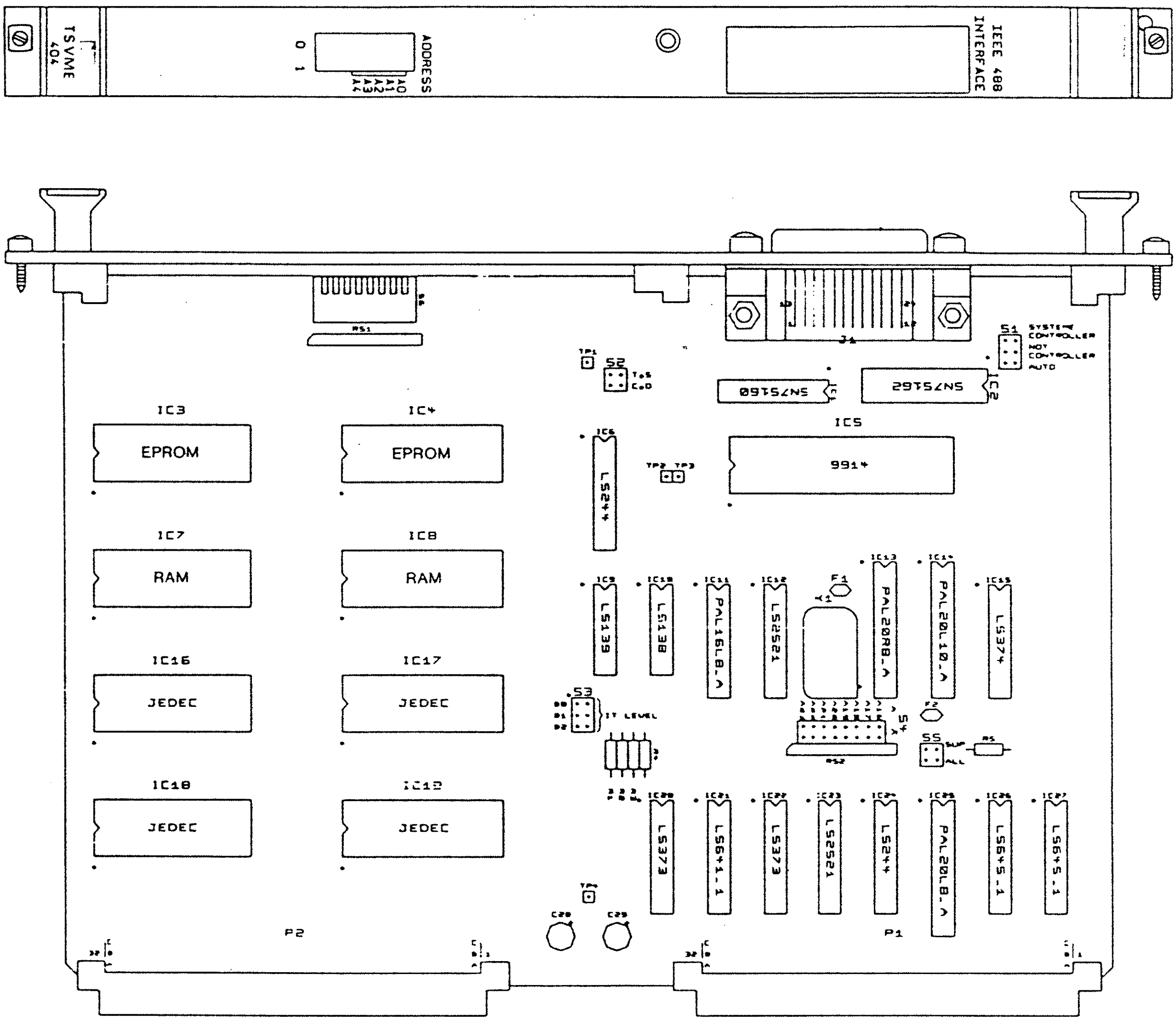


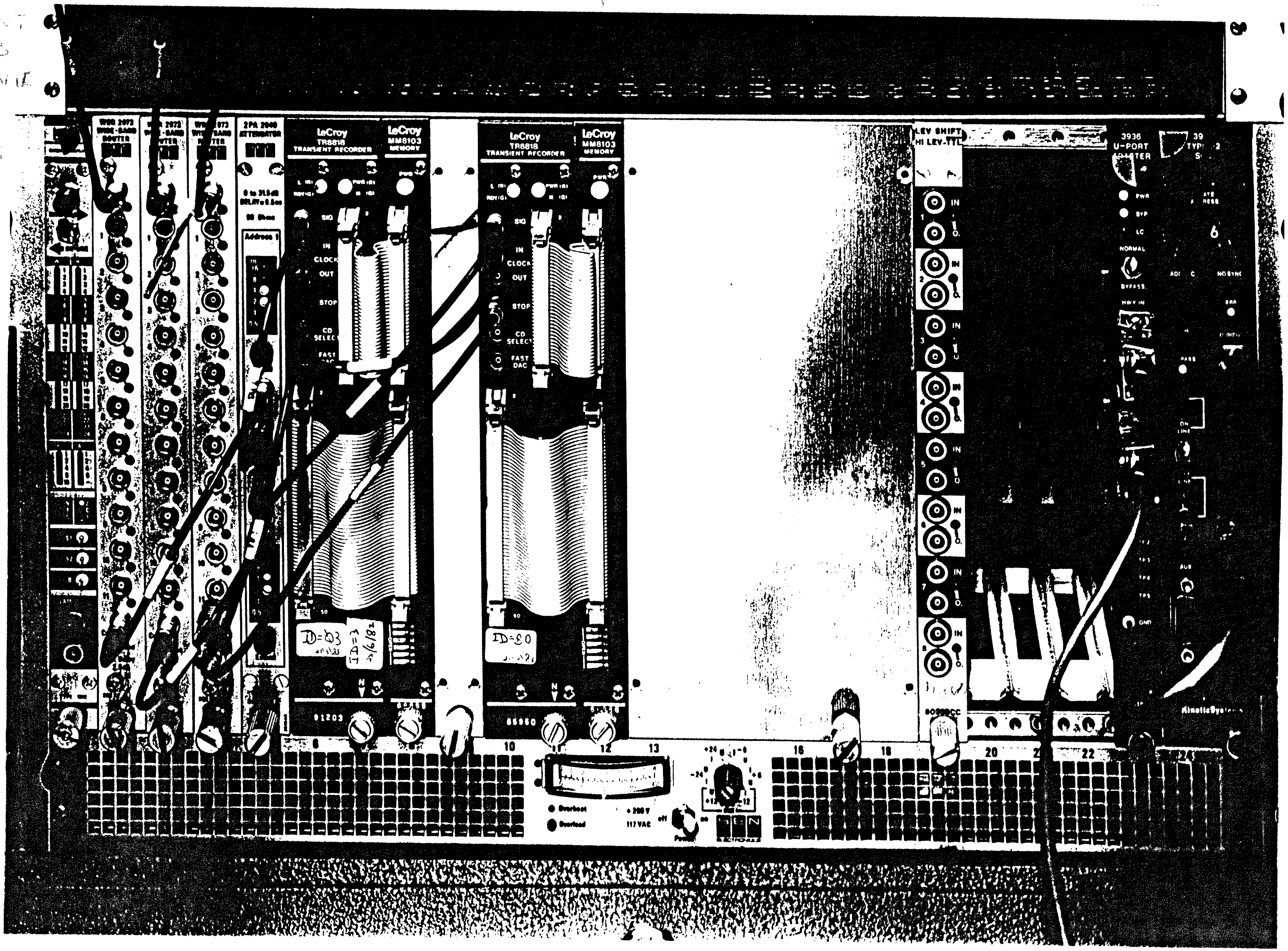
FIGURE 2-2. TSVME404 Board Layout

- *EXAMPLES*
- *PS-COMPLEX*
  MEASUREMENT OF BUNCH LENGTH & SHAPE for ALL THE MULTIFARIOUS PARTICLES THAT PS DEALS WITH (protons,antiprotons, electrons, positrons, oxygen, etc)
- FAST DIGITIZERS IN CAMAC & ROUTINE CONTROL ROOM USE FOR TROUBLE-SHOOTING, TOGETHER WITH CONTROL OF TRIGGERS AND SWITCHES
- CONTROLLING A GPIB DIGITAL100 MHz 'SCOPE FOR HIGH LEVEL APPLICATION

Switching to connect different sources to same H.F. digitisers

Attenuator

HF Digitisers (one per plane)



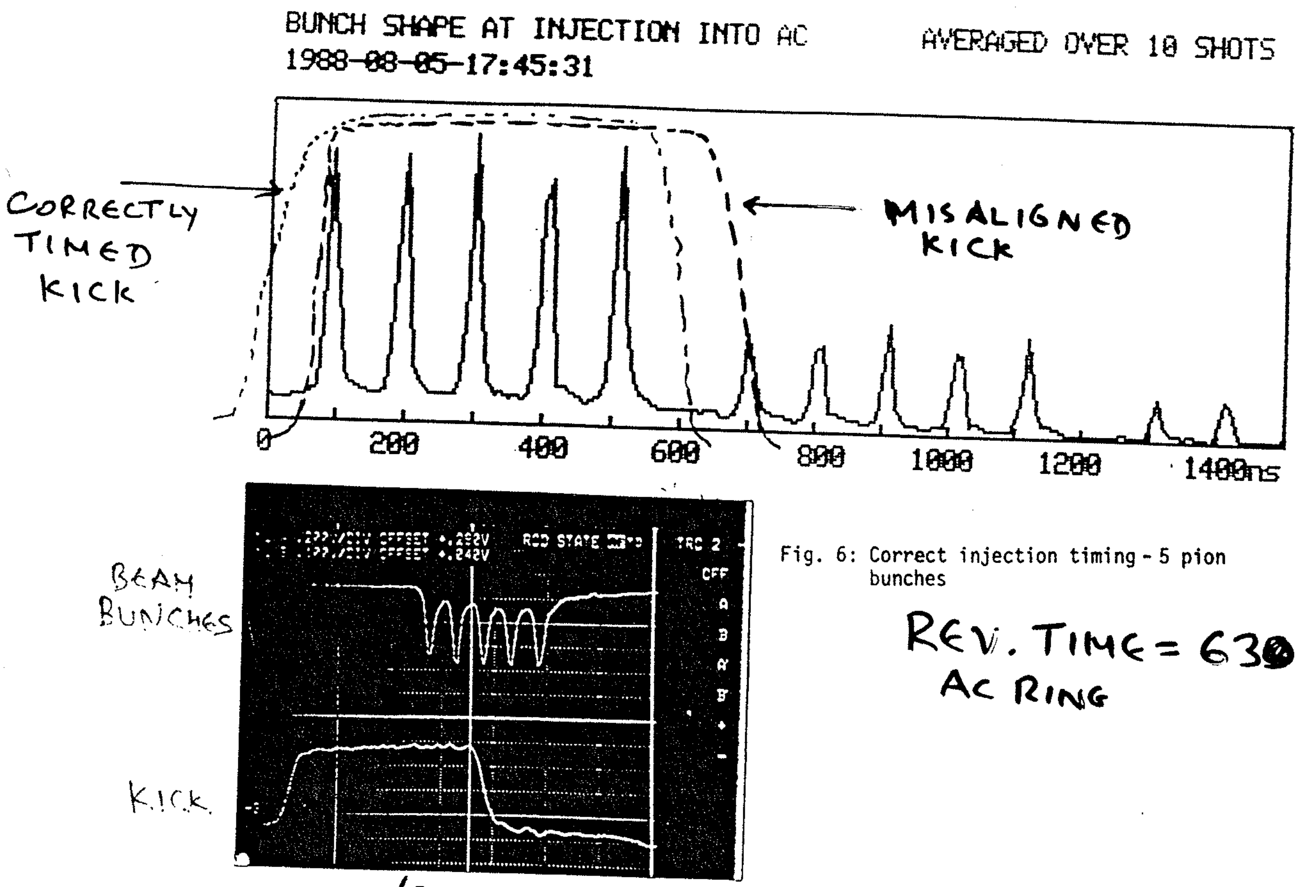
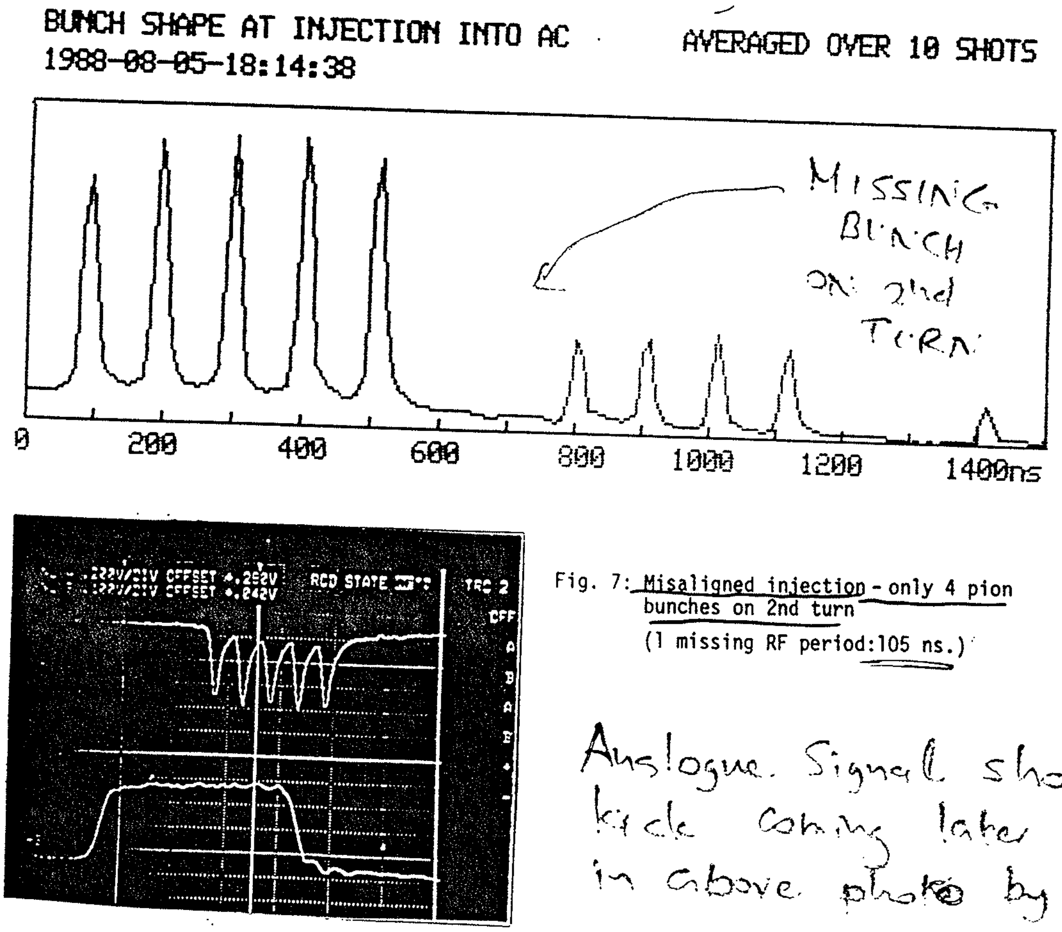


Fig. 6: Correct injection timing - 5 pion bunches

REV. TIME = 630 nsecs
AC RING

(Due to cable lengths: analogue signals NOT positioned as in reality → superimposition of beam within kick



MISALIGNED KICK EXAMPLE: THE KICKER "FALL" TOUCHES THE BEAM ON SECOND TURN.

Fig. 7: Misaligned injection - only 4 pion bunches on 2nd turn
(1 missing RF period: 105 ns.)

Analogue signal shows kick coming later than in above photo by ~105 nsecs.

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 a single-pulse output for each of the ten machine operational modes. Fig. 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.

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 digitized and stored. Fig. 4 illustrates this for a typical antiproton extraction; the circulating bunch in the AA, with a 540 ns revolution period, is clearly seen for a few turns prior to the kicker rise, extraction and the kicker fall-time noise. This measurements 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 nonfiring of the kicker magnet (fig. 5)

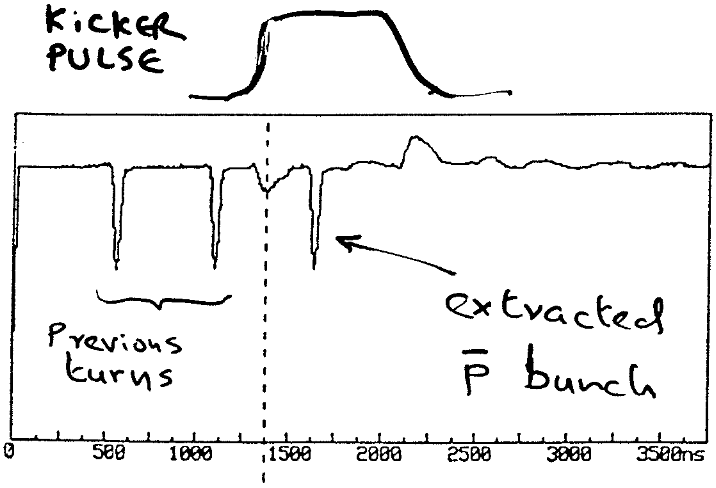


Fig. 4. Last ejected bunch and kicker at AA sigma 22 pickup [with correct ejection kicker activation; reference line at 1375 ns].

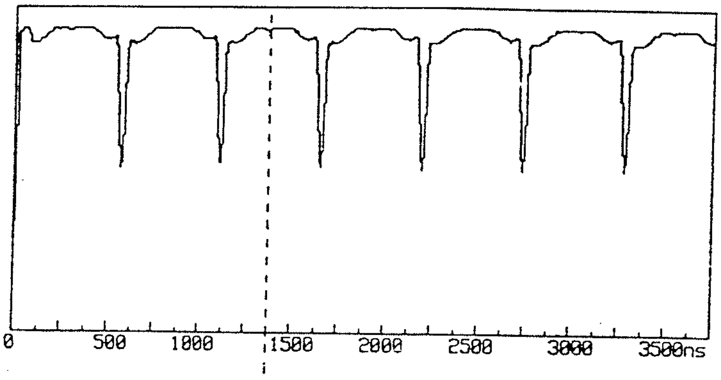


Fig. 5. Last ejected bunch and kicker at AA sigma 22 pickup [ejection kicker did not fire, bunch still circulating; reference line is at 1375 ns].

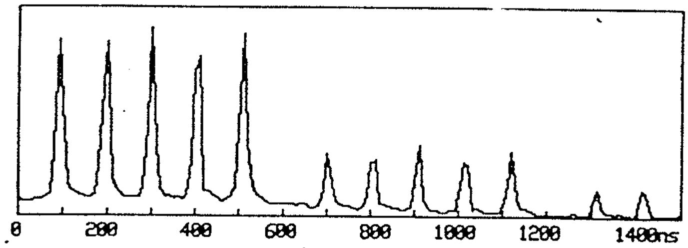


Fig. 6. Bunch shape at injection into the AC, averaged over 10 shots correct injection timing with five pion bunches.

or the mistiming of the rise of the kicker pulse, bringing it too close to the circulating bunch in the previous turn.

Fig. 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 7×10^7 antiprotons is too weak to be seen on the AC beam position pickups, the pion beam is clearly visible over the first 2–3 turns before the pions decay; the AC has a revolution period of 630 ns 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 five pion bunches lying within the prescribed 630 ns revolution period window. If the

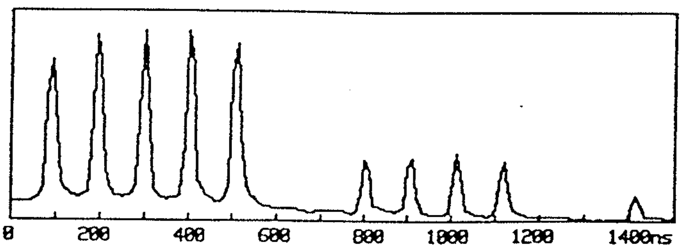


Fig. 7. Bunch shape at injection into the AC, averaged over 10 shots; misaligned injection: only four pion bunches on the second turn.

EXAMPLE: TIMING FAULT DETECTION USING DIGITIZED/TREATED SIGNAL.

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

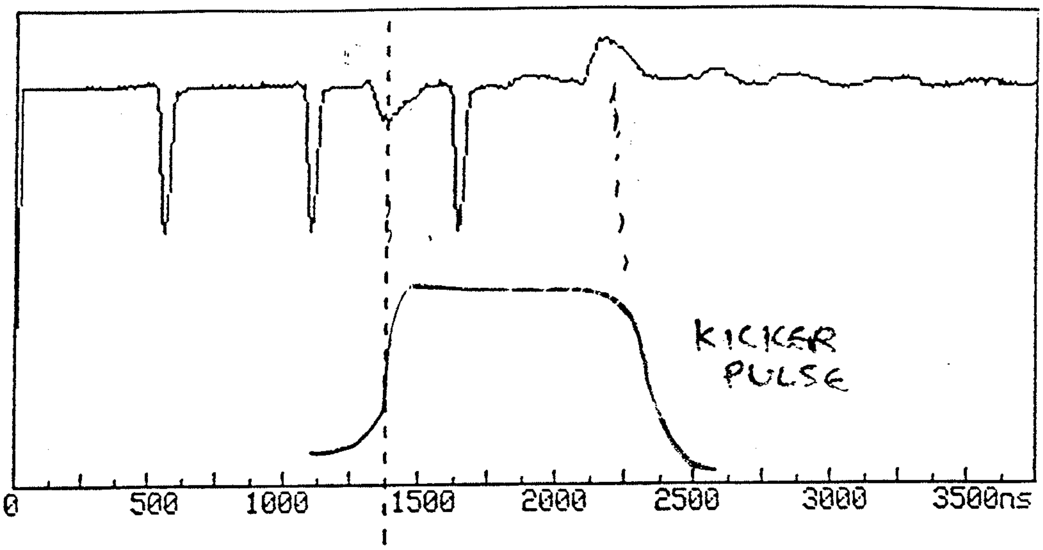
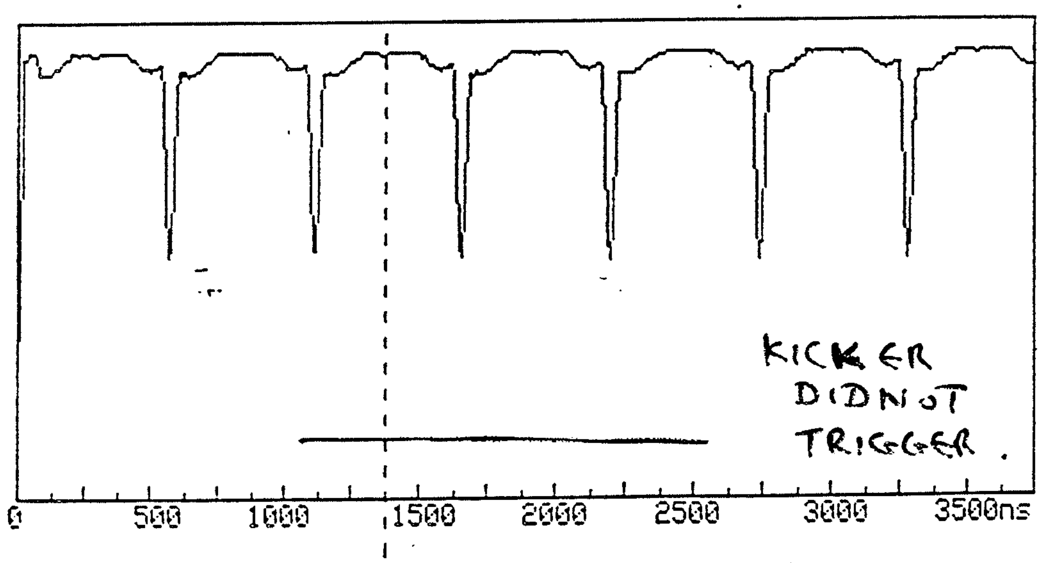


Fig. 4. With Correct Ejection Kicker Activation

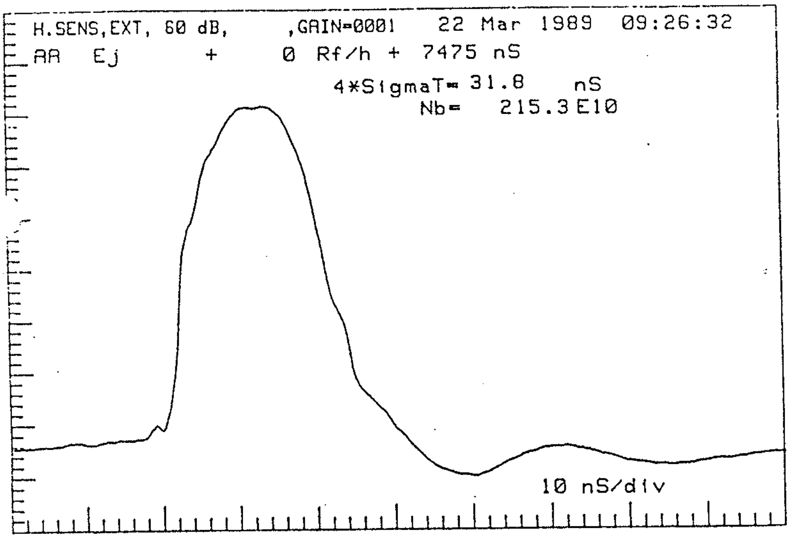
Last Ejected Bunch & Kicker at AA sigma22 Pickup
1989-09-20-11:30



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

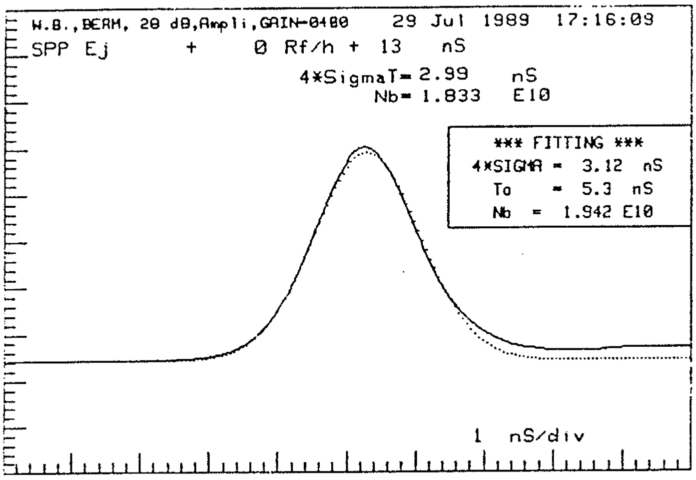
VARIABLE >>>>> EKICK-MSW TIM(20) AQN = 2754
VARIABLE >>>>> Ej. Kicker Fine Delay = 290 ns
PE timing PX.WLP (ccv) & (aqn) from (TT): -2768 -2768

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



Protons (production)
Ejection
Trig: external
(Px.016+7475 ns)

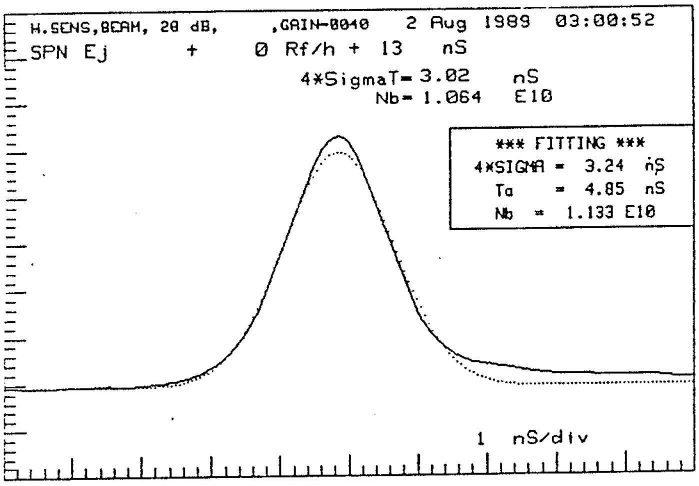
~ 30 nsec bunch



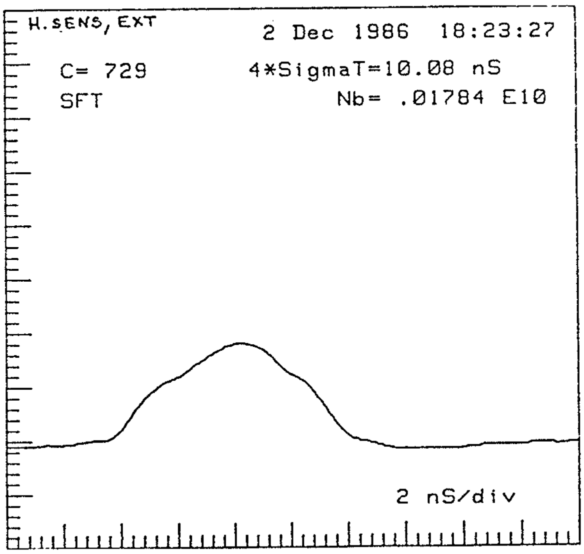
Electrons-Ejection
Trig: beam mode
(Px.058)

Leptons

~ 3 nsec bunch



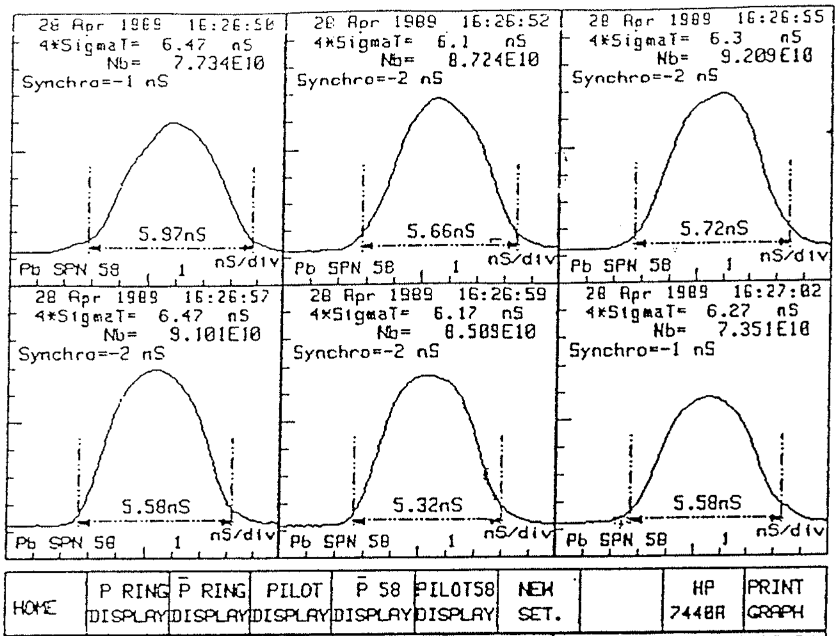
Positons - Ejection
Trig: beam mode
(Px.016)



Oxygen
Trig: external
(C729+64 ns)

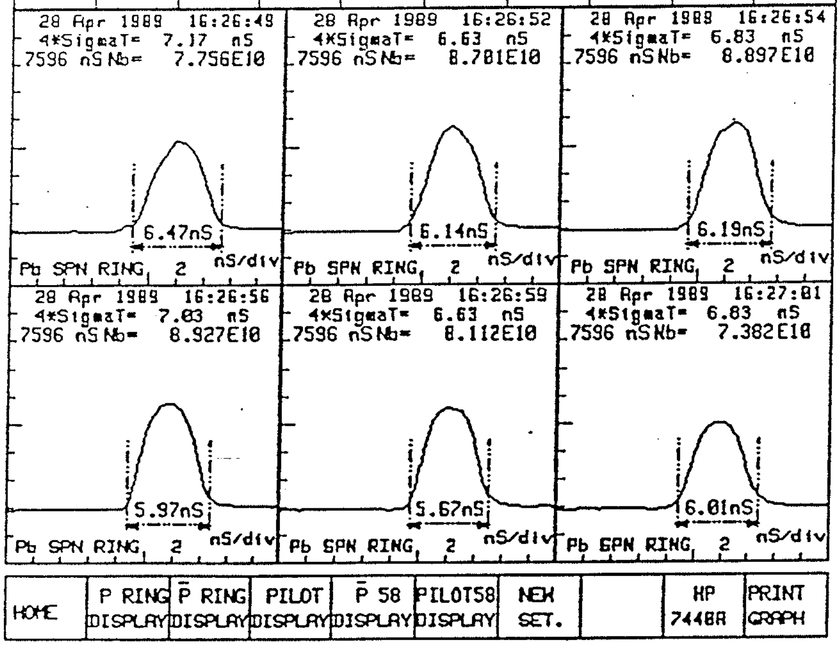
~ 8 nsec bunch

Multishot



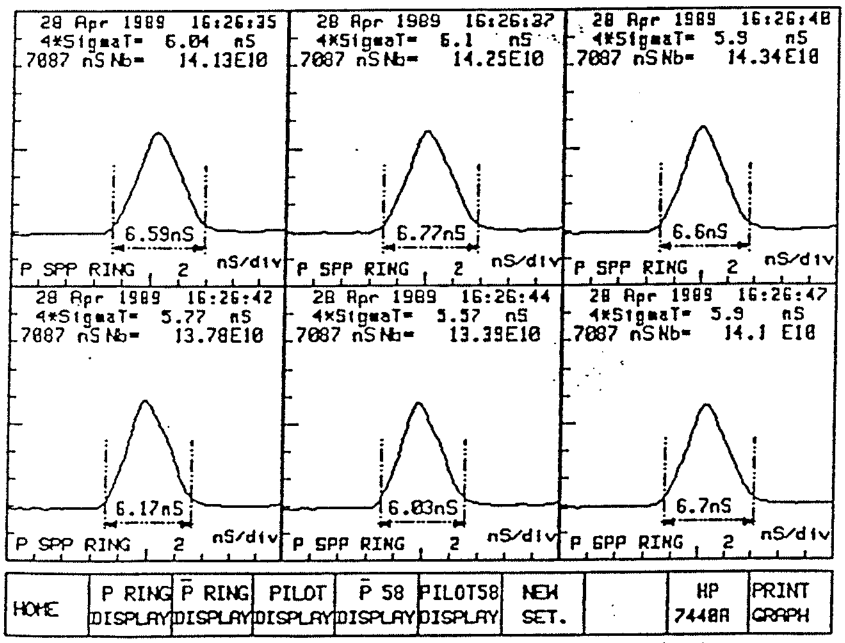
6 pbar FA58
Trig: beam mode

In Extraction line to SPS Collider



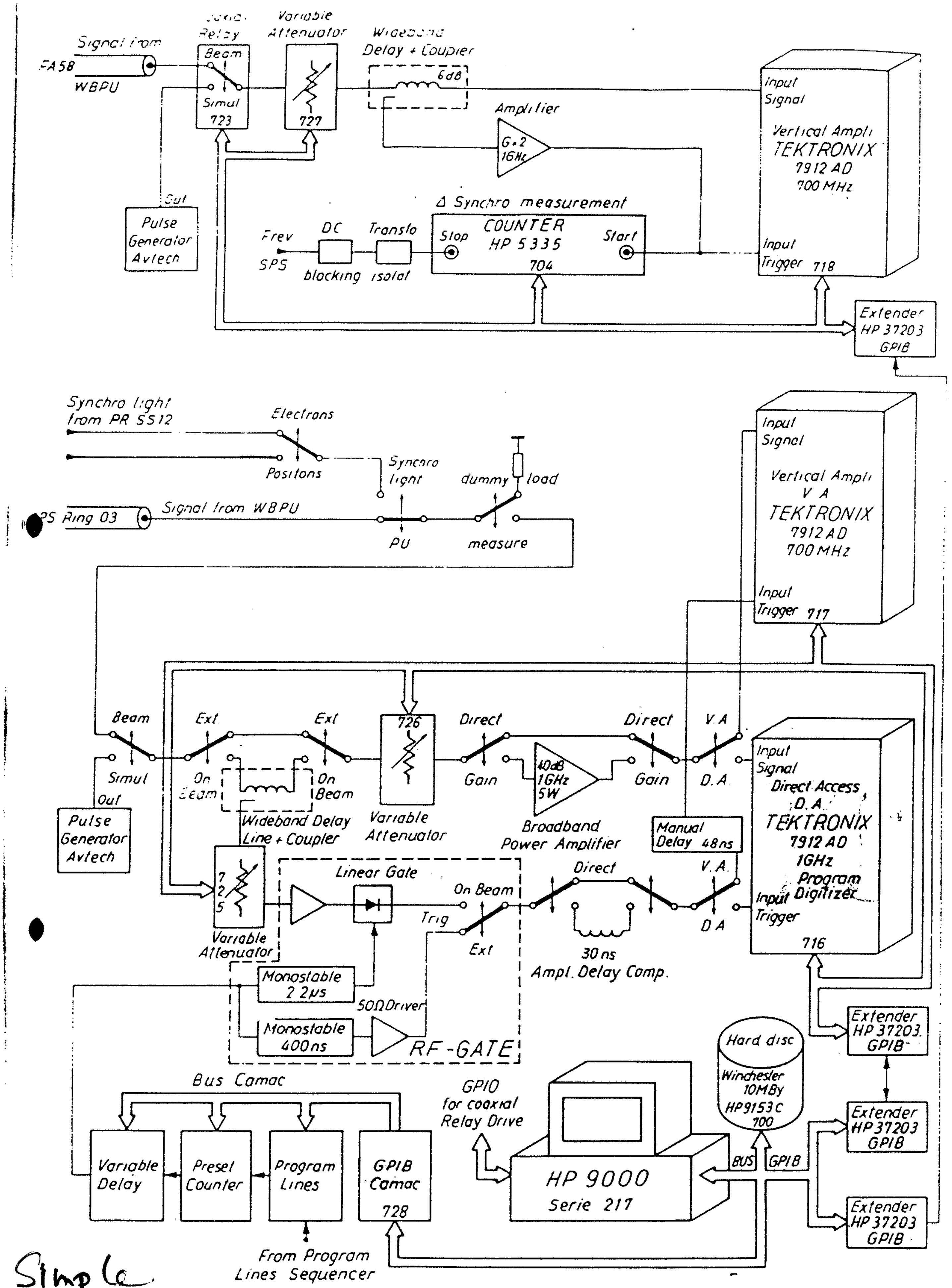
6 pbar ring (ejection)
Trig: external
(Px.058 + 7596 ns)

In PS Ring before Extraction



6 proton ring (ejection)

Trig: external
(Px.016+7087 ns)



Simple HPIB Control using "STRINGS" in BASIC & done by non-software experts !

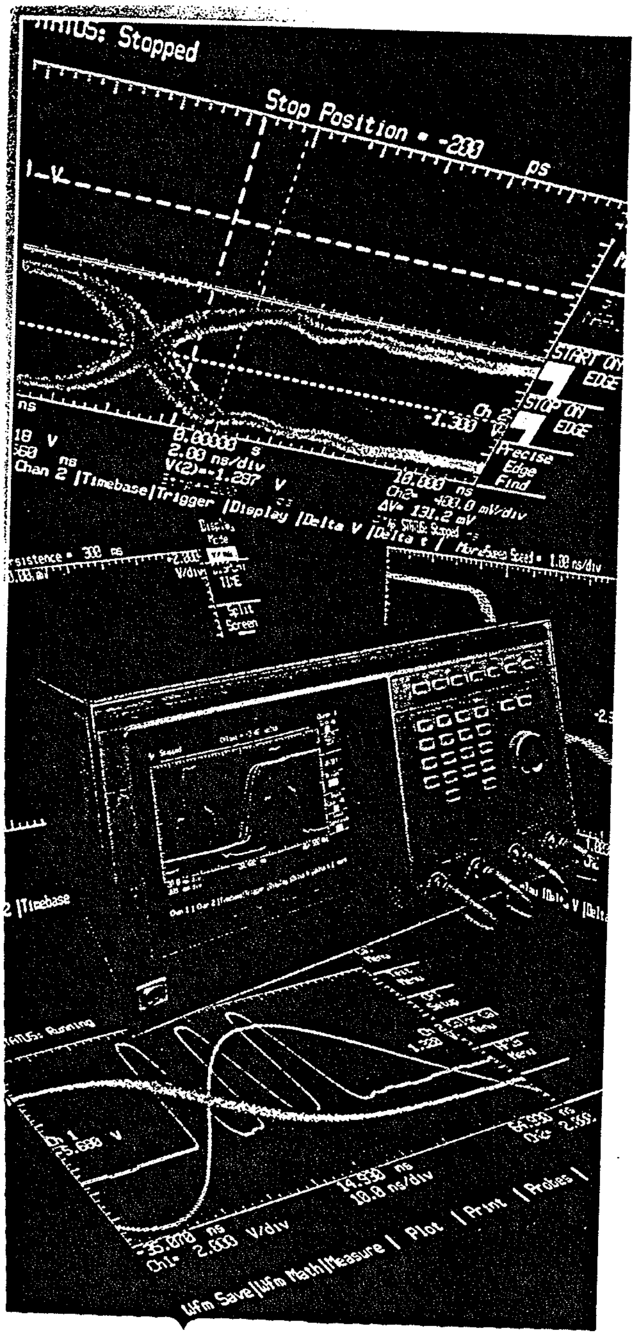
Bunch length measurement IN PS

Annexe 1

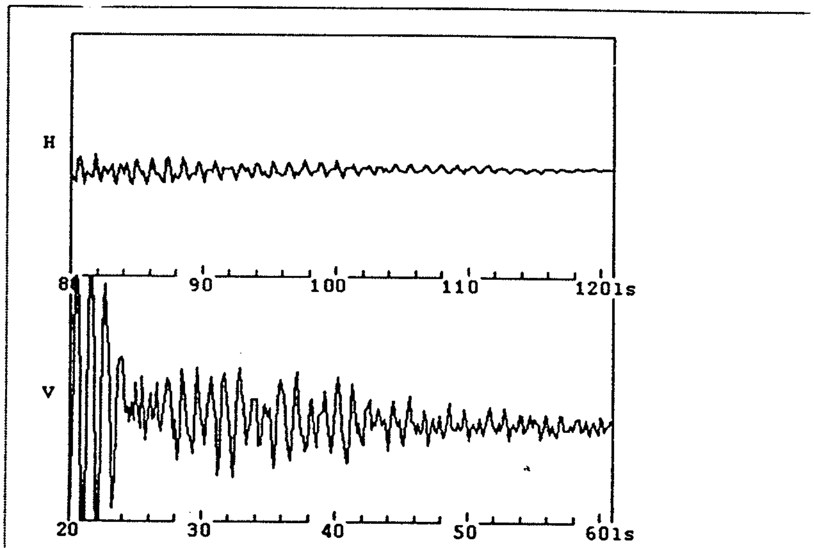
100 MHz DIGITAL SCOPE &

HIGH LEVEL APPLICATION PROGRAM

GPIB → KS3388 "dumb" module & Eq. M
for high level.



HP541 11 12



ONLY THE INTERVAL USED FOR ANALYSIS IS SHOWN

COHERENT OSCILLATIONS (pbars to AC)
1993-04-08-09:08:02

	pbars E7	HOR. ampl. mm	HOR. cos	HOR. sin	VERT. ampl. mm	VERT. cos	VERT. sin
pulse no. 9	6.2	3.7	1.2	-3.5			
average	6.3	1.4	.9	-1.1			
st. deviation			.7	1.1			

Horiz & Vert. CORRECTIONS

		REQUIRED	MEASURED	CHANGE	
H	INJ.KICKER	68.0	67.7	-.3	kV (*6)
H	INJ.SEPTUM	39000.1	39012.3	.9	A
V	DVT6067	.9	.8		A
V	DVT6081	-119.9	-120.0		A

The coherent oscillations of muons are measured.
The pbar orbits may be somewhat different.

GPIB Instrument(s) Control using "simple" module

CONTROL of DIGITAL 'SCOPE

```
3.01 %set up scope (AC only)
 3.03 IF RI=1; G 4
 3.05 SE HPIB(3,CCV2)=4; SE HPIB(3,CCV1)=7;    %scope listen, HPIB talk
 3.10 SE HPIB(3,COM1)=20;                      %clear scope
 3.15 $S CM="RST EOI OFF"; DO 76; WA-T .2
 3.20 $S CM="BLAN CHAN1 BLAN CHAN2 BLAN CHAN3"; DO 76
 3.30 $S CM="CHAN4 COUP DCF RANG 2 OFFS .5"; DO 76
 3.40 $S CM="DISP FORM SING GRAT GRID"; DO 76
 3.50 $S CM="TIM MODE SING RANG 2E-6 DEL 4.8E-6 REF LEFT"; DO 76
 3.60 $S CM="TRIG MODE EDGE SOUR TRIG 5 LEV 1"; DO 76
 3.70 $S CM="ACQ TYPE NORM LENGTH 8192"; DO 76
 3.80 $S CM="WAV SOUR MEM4 FORM WORD"; DO 76
 3.85 IF ER>0; G 4.25
 3.90 OVE(VDM)RELAY 1,-169; DO 97;    %scope trigger
```

HPIB STRINGS AS FOR 'SCOPE HP54112

```
76.01 %send command to scope
76.05 SE HPIB(3,REMOTE)=0
76.10 SE V(1)=SIZE(CM)+1; SE V(V(1)+1)=10
76.20 F I=2,V(1); SE V(I)=ASCII(SUBS(I-1,I-1,CM))
76.30 SE HPIB(3,CCV2)=4; SE HPIB(3,CCV1)=7;         %scope listen, HPIB talk
76.40 AHPIB(V,-1,EL,SYMBOL(CCV3),0,CC); IF CC(1)=0; RET
76.50 $S OO="dig.scope: "EMMESS(CC(2)); DO 80
```

>CONTROL OF SPECTRUM ANALYSER

```
 11.01 %Combined choice of source and settings
11.10 SE SR=SO(B1); DO 39
11.20 $S CM=COM(B1); DO 75; IF B1<>8; RET
11.30 SE B7=3; DO 24.7; SE EQU("TIM",-73,"CCV")=0
>li75

75.01 %Send string command to SPA
75.10 SE SPA(1,RESERV)=1
75.20 SSPA(CM,-1,E,SYMBOL(STRT),0,CC)
75.30 SE SPA(1,RELEAS)=1; IF CC(2)=0; RET
75.40 $S TEXT=\8\11\24\15 EMMESS(CC(2))\14; T\7; SE ER=1
>>
```

Eq. Module Access with STRINGS as needed by Device.

```
   f i=1,13; ty com(i)!
IP,CF72.2865MZ,SP195KZ,RL-40DM,RB3KZ,VB30,LG5DB
IP,FA80.918MZ,FB81.27MZ,RL-55DM,RB3KZ,VB30,LG5DB
IP,FA76.29MZ,FB76.63MZ,RL-55DM,RB3KZ,VB30,LG5DB
IP,FA71.916MZ,FB72.384MZ,RL-40DM,VB30,ST2.35,LG5DB
IP,CF319.358MZ,SP850KZ,RL1.72MV,RB30KZ,VB30,LN
IP,CF184.6MZ,SP50KZ,RL100MV,RB3KZ,VB10
IP,CF49.2683MZ,SP92KZ,RL50UV,RB3KZ,VB10,LN
IP,CF9.5369MZ,SP0,RL-16DM,RB10KZ,VB10KZ,ST20MS,LG2DB,S1,T3
IP,FA0,FB50MZ,RL70MV,VB300
IP,FA0,FB50MZ,RL70MV,VB300
IP,FA0,FB50MZ,RL70MV,VB300
IP,FA0,FB50MZ,RL70MV,VB300
IP,FA470KZ,FB520KZ,RB1KZ,VB30HZ
```

STRINGS AS NEEDED BY HP Spectrum Analyser

Video Image Processing systems*(for beam profiles, shape ,size, centre of gravity........)*

- **Frame grabbing and averaging from a Video Source**
  - used to enhance an image for human viewing by eliminating noise
- **Convolutions on Pixels**
  - are a class of neighbourhood operations on pixels ; effectively, they enhance particular features of an image at the expense of others ; Used for Edge Detection or Contours.
- **Operations on Stored Images**
  - Erosion (replace a pixel by its minimum neighbour) or Dilation(replace a pixel by its maximum neighbour) to shrink or expand an object, etc....
- **Analyses of treated Images**
  - HISTOGRAMS produce a count of the number of Pixels at each intensity in an image, enabling the development of lookup table enhancement algorithms , use of false Colours etc....
  - PROFILES produce a count of the total intensity of each Line or Column in an image (useful for locating objects)
- **Area of Interest Processing**
  - Zoom, Scroll etc...

Beam Diagnostics from the Accelerator Physics point of view

- For a machine physicist, beam diagnostics systems are a means to an end and not vice versa !!
- Diagnostics used to understand the accelerator and improve its performance
- Ensemble of Measurement & diagnostics Devices are used in conjunction with other controlled parameters { e.g., currents in magnets, R.F. phase correctors, beam blow-up hardware, etc } in high level automated processes or application programs for routine operation.
- For a new accelerator, a measure of its lattice parameters like beta or eta , acceptances, coupling etc and energy calibration need different techniques as well as diagnostics on a routine basis.

Examples:

- Injection Coherent Oscillations Correction needs 1 pickup per plane, fast digitizing, and transverse corrections using H & V correctors and similarly a RF phase signal detector and corrector for longitudinal plane.
- Acceptance Measurement needs beam blow up system to fill the aperture & scrapers to evaluate the limits of aperture and calculate the acceptance
- For tunes versus energy (chromaticity) for bunched beams, one varies the RF freq. and keeps the magnets constant , measuring the tune at each freq.
- For automatic adjustment of an accelerator at its central energy (e.g. the AA), one needs to inject beam correctly, correct coh. Osc., adjust tunes by changing quad currents, verify central energy from RF freq. , adjust orbits where possible with trim supplies, etc... all at the press of a single button.

Nuclear Instruments and Methods in Physics Research A293 (1990) 98–102
North-Holland

ASPECTS OF AUTOMATION AND APPLICATIONS IN THE CERN ANTIPROTON SOURCE

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The CERN antiproton source is comprised of two concentric accelerators and a production target zone. The Collector is a large-acceptance ring which acts as a buffer between the target and the Accumulator ring where the antiprotons are stored before being extracted. From the early days of the Accumulator (AA), various automatic procedures and tools have been introduced to assist in machine studies and diagnostics and to facilitate day-to-day operations for antiproton production and transfers to the CERN Collider. With the upgrade of the source in 1987 by the addition of the Collector ring (AC), the complexity of the source has at least doubled. New facilities have been added and the existing ones improved. This paper describes some of the applications, techniques and tools used for beam diagnostics, setting-up and routine operation of the antiproton source complex at CERN.

1. Introduction

The antiproton source, its upgrade and the performance of the CERN collider have been amply described elsewhere [1,2]. In 1989 considerable progress has been made towards achieving a performance close to the design specifications for the upgrade [3]. While the complexity of operations has increased substantially with the addition of the Collector ring (AC) operating in conjunction with the Accumulator (AA), the same operating crew and interaction means have been used to carry out routine operations. Relying mainly on experience gained from the operation of the single-ring AA over the previous seven years, several aspects have been streamlined, and highly automated methods and procedures have been introduced. Fig. 1 shows the schematic layout of the two rings and the production target area. The control system [4] had to be extended for the new

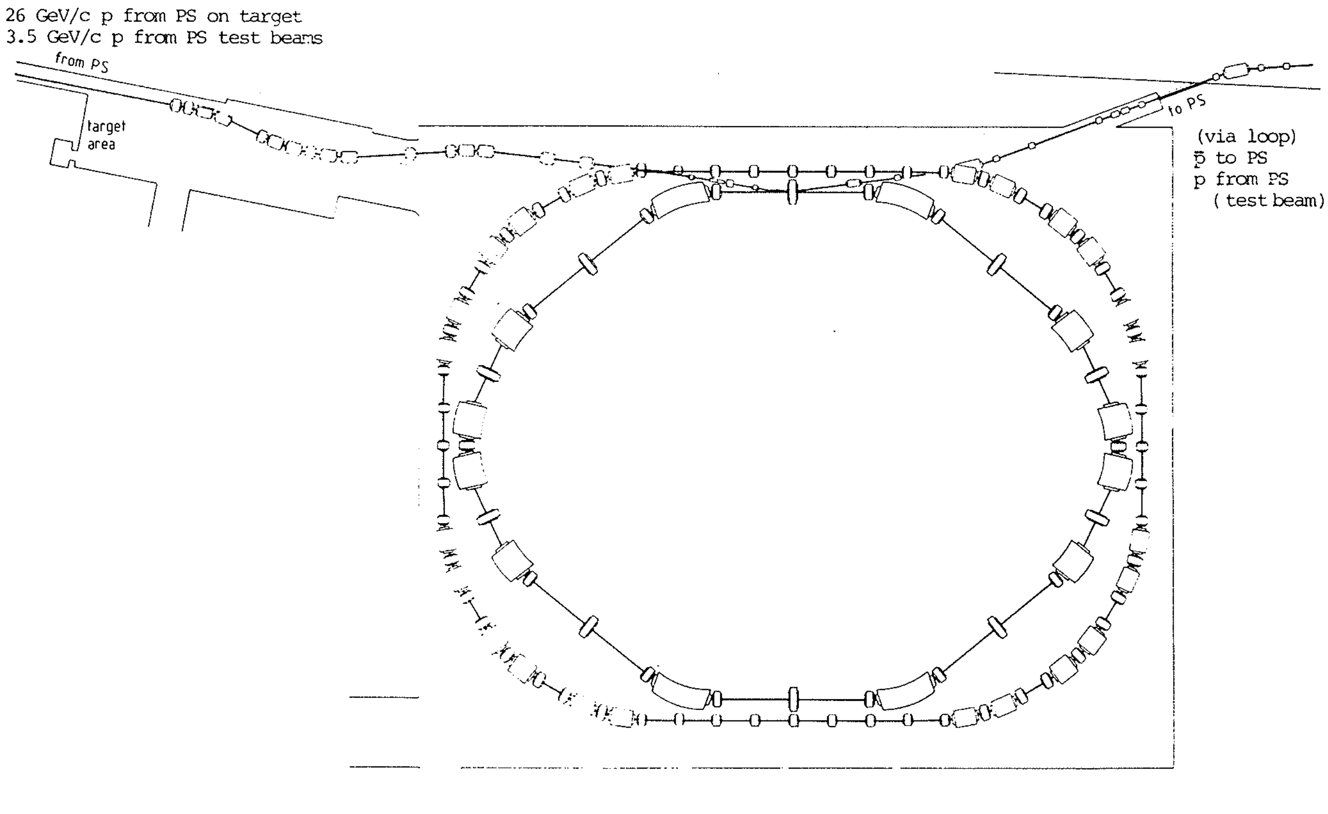

Fig. 1. General layout (magnetic elements only) of the antiproton accumulator complex (AAC): outer ring – Antiproton Collector (AC), inner ring – Antiproton Accumulator (AA).

CHOHAN
aac

EXAMPLE OF SINGLE BUTTON "SETTING UP"

SEPARATE PROGRAMS FOR AC & AA & applicable for different Mal[illegible]

- Rf Synch.

*** AA** ADJUSTMENT 1990-04-17-17:29

	REQUIRED	MEASURED
QH } 1855.09	2.2545	2.2543
QV } kHz	2.26	2.2600
TRIM	-.2	-.1 mm
DP/P	0	0 E-3
COH.OSC. H	0	.2 mm
V	0	0 mm
COS COMP.L	0	0 deg

Coherent oscillations are adjusted with cooldown tunes. Accumulation tunes restored now.

RESULTING VALUES	SAVED IN
BENDING 1944.15 A	
TRIM 8.65 A	REFERENCE
QD 1057.75 A	+ FILE
QF 1464.57 A	
SEPTUM 3912.84 A	REFERENCE
DVT8022 -1.79 A	+ FILE
BTI8002 411.62 A	
EJ.KICKER 55.62 kV	
SYNC PH. 81.6 deg	FILE
f INJ. 1845.92kHz	
INJ.EFFICIENCY 90 %	

The tunes have been adjusted to accumulation values on the stack orbit. These values are saved.

Each program:

1. Requests beam
2. Measures & adjusts TUNES at CENTRE FREQ
3. Measures orbits
4. Adjusts Central field, Trim etc..
5. Corrects Inj. Coherent Oscillations in H, V & L using Digitizers
6. Verify Energy Matching (AA & PS)

*** AC** ADJUSTMENT 1990-04-17-18:20

	REQUIRED	MEASURED
QH } CENTRAL	5.455	5.4544
QV } ORBIT	5.435	5.4355
TRIM	-.3	-.3 mm
DISP. LSS	0	.9 mm
COH.OSC. H	0	0 mm
V	0	.1 mm
L	0	1 deg

RESULTING VALUES	SAVED IN
B-TRIM4 4.03 A	
BENDING 2285.64 A	
Q-TRIM1 -12.97 A	REFERENCE
Q-TRIM2 72.07 A	+ FILE
Q-TRIM3 -48.28 A	
Q-MAIN 1871.33 A	
SM-EJ 22838.1 A	REFERENCE
DVT7013 -.43 A	+ FILE
DVT7042 .46 A	
EJ.KICKER 4*64.2 kV	
SYNC PH. -9deg	FILE
DP/P -.56E-3	FILE
INJ.EFFICIENCY 92%	

	DP/P	FREQ.
FROM FREQ.MEAS.	.04E-3	1850.36
FROM PU AVERAGE	.15E-3	1850.34

TRIM. mm	
DESIRED	0
MEASURED	.1

Idc	1.2E10
Ib	0 E10

P-U	H	V
[illegible]2	1.5	-3.0
QFW04	-3.0	-3.8
QFW06	-22.4	-1.1
QFW08	-1.9	.2
QFW10	10.6	-6.1
BLG11	4.0	-4.0
BLG14	-2.6	-1.0
QFW16	-1.0	-.4
QFW18	23.3	3.1
QFW20	8.4	2.6
QFW22	-2.2	.3
BLG23	-2.1	-1.9

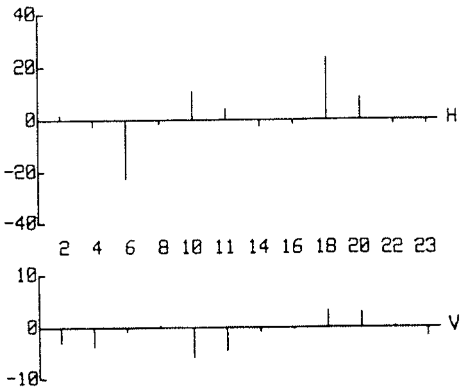

Fig. 7. Results from the AA closed-orbit measurement.

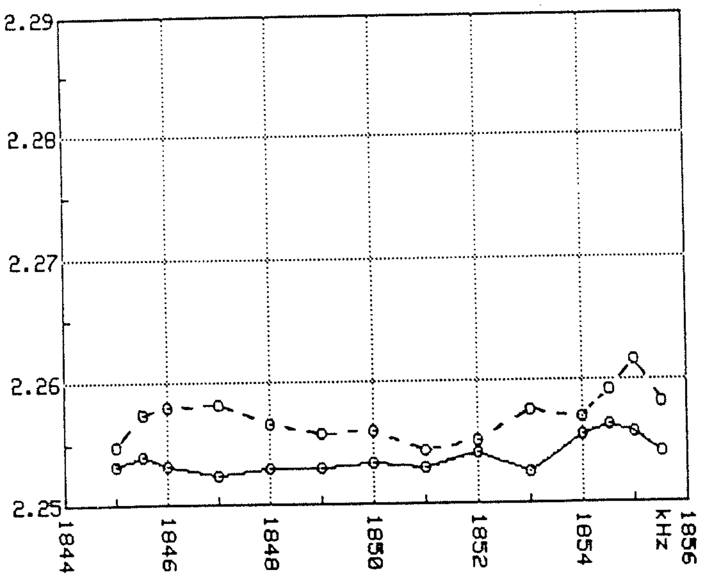

Fig. 8. Tunes versus momentum in the AA ring: — Q_{hor}, --- Q_{vert}.

f_0 kHz	A_h/π mm mrad	A_v/π mm mrad
1588.5	177	199
1588.75	194	205
1589	201	203
1589.25	198	202
1589.5	191	205
1589.75	198	200
1590	197	206
1590.25	191	204
1589.5	195	

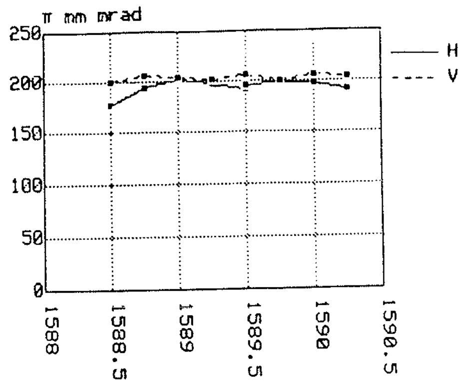

Fig. 9. AC acceptance versus frequency (25 August 1989, 23:43).

Finally, automatic obstruction search programs have been implemented using controlled radial bumps in the AA and motorised displacement jacks for quadrupoles.

6. Conclusions

Of all the CERN accelerators, the AAC complex is one of the most highly automated machines, especially for all the beam-measurement, machine-experiment and setting-up procedures necessary for this complex. One of the main reasons for being able to achieve and maintain this high degree of automation is the restricted number of intermediate levels (hardware or software) between the application programs and the equipment. The AAC touch-terminals [13] operate directly from the front-end computer connected to the CAMAC serial highway, which avoids any communication overheads or problems. Similarly, CAMAC modules access the hardware directly without any front-end microprocessors sitting in the same crate, which would otherwise introduce another intermediate level. Even the sophisticated GPIB devices like the spectrum analysers are connected directly, via a simple GPIB–CAMAC interface, thus avoiding the arbitration problems or complications of an intelligent module, but at the expense of an elaborate software equipment module.

Acknowledgements

The high-level applications described here would not have been possible without the active support of many beam-instrumentation experts and the necessary low-level hardware and software support provided by the Controls Group. Particular mention should be made of Remy Dube and Michel Martini for all their efforts over the years in providing many sophisticated equipment software modules.

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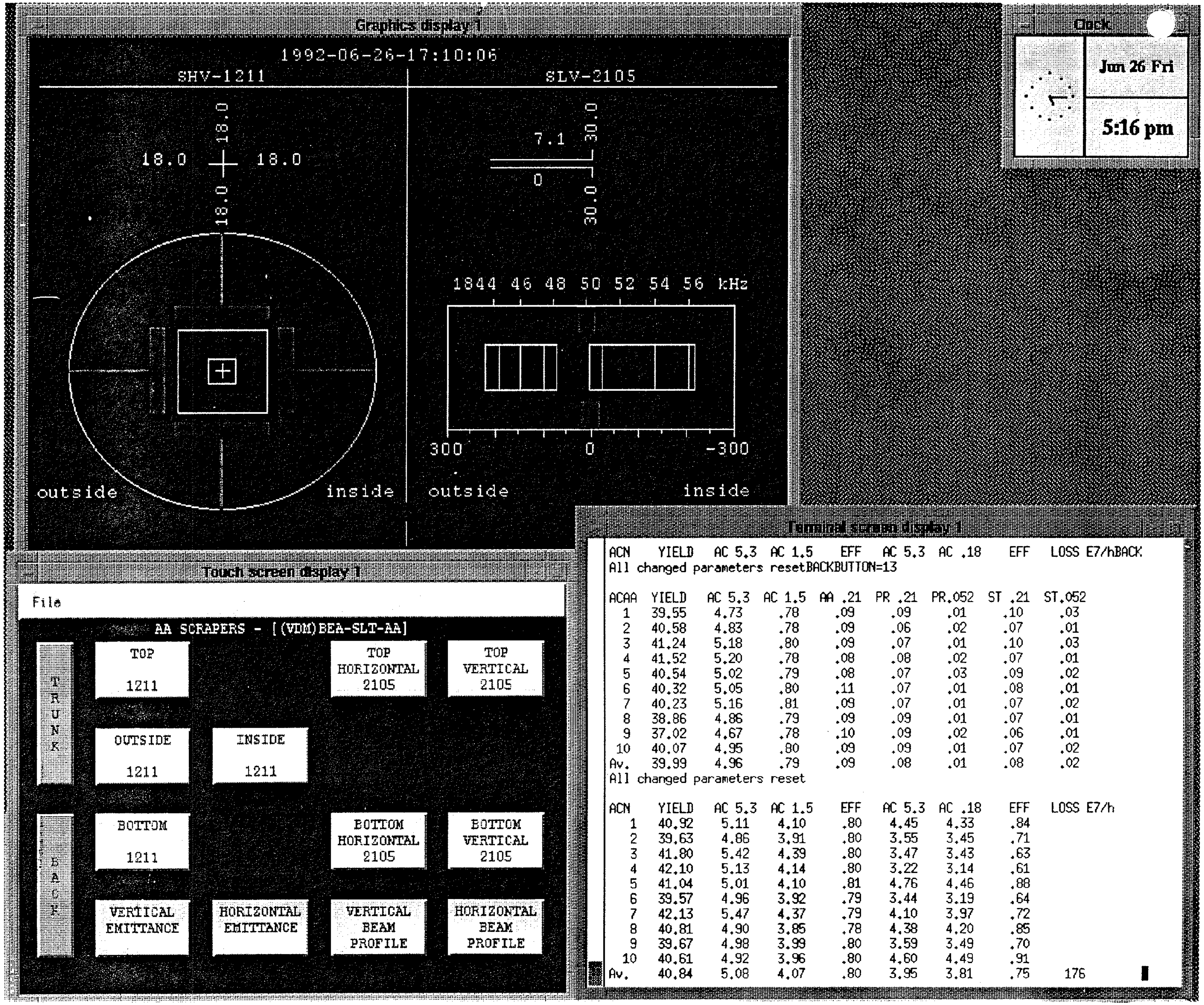
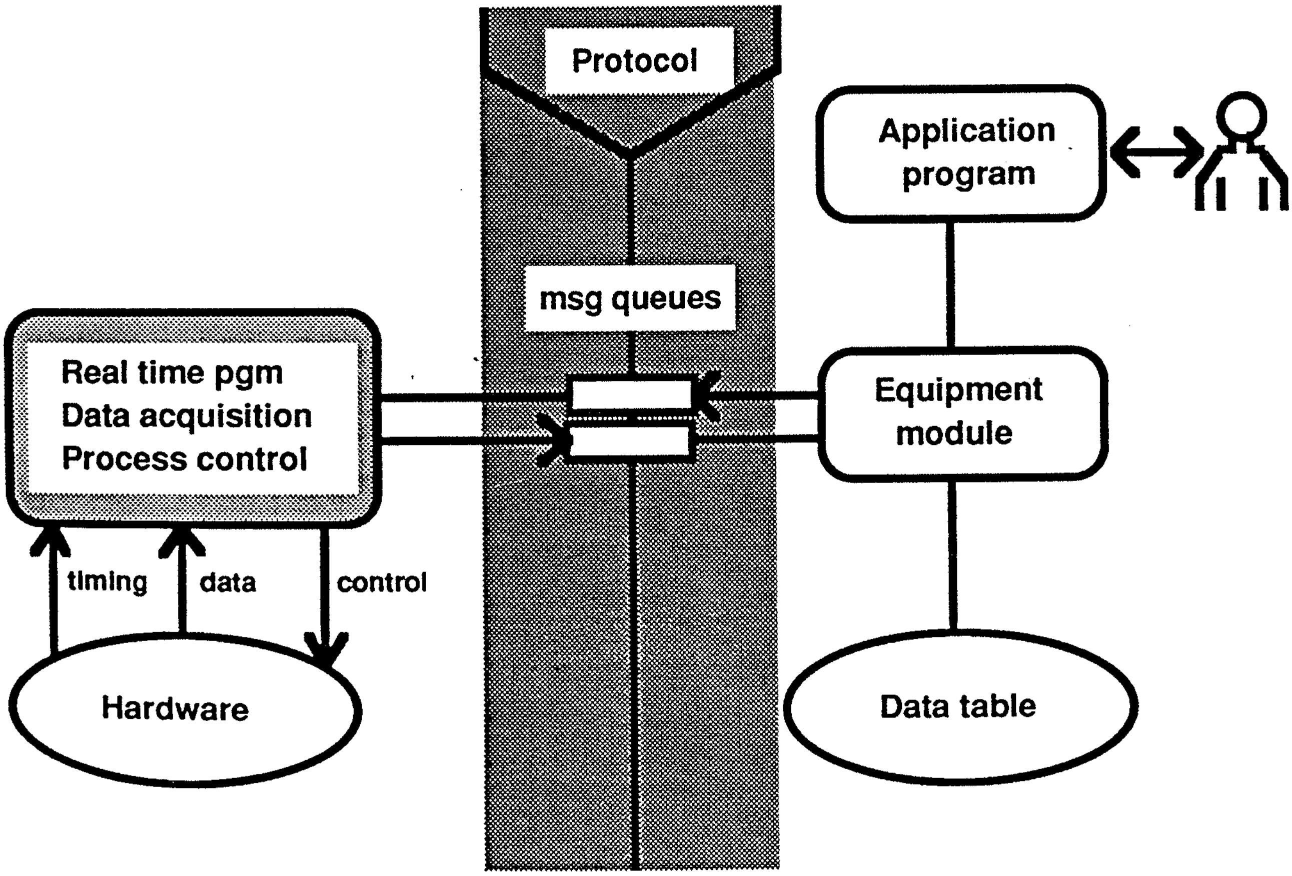

Graphics display 1
1992-06-26-17:10:06
SHV-1211
SLV-2105
18.0
18.0
18.0
18.0
7.1
30.0
0
30.0
1844 46 48 50 52 54 56 kHz
300
0
-300
outside
inside
outside
inside
Clock
Jun 26 Fri
5:16 pm
Touch screen display 1
File
AA SCRAPERS - [(VDM)BEA-SLT-AA]
TRUNK
BACK
TOP 1211
TOP HORIZONTAL 2105
TOP VERTICAL 2105
OUTSIDE 1211
INSIDE 1211
BOTTOM 1211
BOTTOM HORIZONTAL 2105
BOTTOM VERTICAL 2105
VERTICAL EMITTANCE
HORIZONTAL EMITTANCE
VERTICAL BEAM PROFILE
HORIZONTAL BEAM PROFILE
Terminal screen display 1
ACN YIELD AC 5.3 AC 1.5 EFF AC 5.3 AC .18 EFF LOSS E7/hBACK
All changed parameters resetBACKBUTTON=13
ACAA YIELD AC 5.3 AC 1.5 AA .21 PR .21 PR.052 ST .21 ST.052
1 39.55 4.73 .78 .09 .09 .01 .10 .03
2 40.58 4.83 .78 .09 .06 .02 .07 .01
3 41.24 5.18 .80 .09 .07 .01 .10 .03
4 41.52 5.20 .78 .08 .08 .02 .07 .01
5 40.54 5.02 .79 .08 .07 .03 .09 .02
6 40.32 5.05 .80 .11 .07 .01 .08 .01
7 40.23 5.16 .81 .09 .07 .01 .07 .02
8 38.86 4.86 .79 .09 .09 .01 .07 .01
9 37.02 4.67 .78 .10 .09 .02 .06 .01
10 40.07 4.95 .80 .09 .09 .01 .07 .02
Av. 39.99 4.96 .79 .09 .08 .01 .08 .02
All changed parameters reset
ACN YIELD AC 5.3 AC 1.5 EFF AC 5.3 AC .18 EFF LOSS E7/h
1 40.92 5.11 4.10 .80 4.45 4.33 .84
2 39.63 4.86 3.91 .80 3.55 3.45 .71
3 41.80 5.42 4.39 .80 3.47 3.43 .63
4 42.10 5.13 4.14 .80 3.22 3.14 .61
5 41.04 5.01 4.10 .81 4.76 4.46 .88
6 39.57 4.96 3.92 .79 3.44 3.19 .64
7 42.13 5.47 4.37 .79 4.10 3.97 .72
8 40.81 4.90 3.85 .78 4.38 4.20 .85
9 39.67 4.98 3.99 .80 3.59 3.49 .70
10 40.61 4.92 3.96 .80 4.60 4.49 .91
Av. 40.84 5.08 4.07 .80 3.95 3.81 .75 176

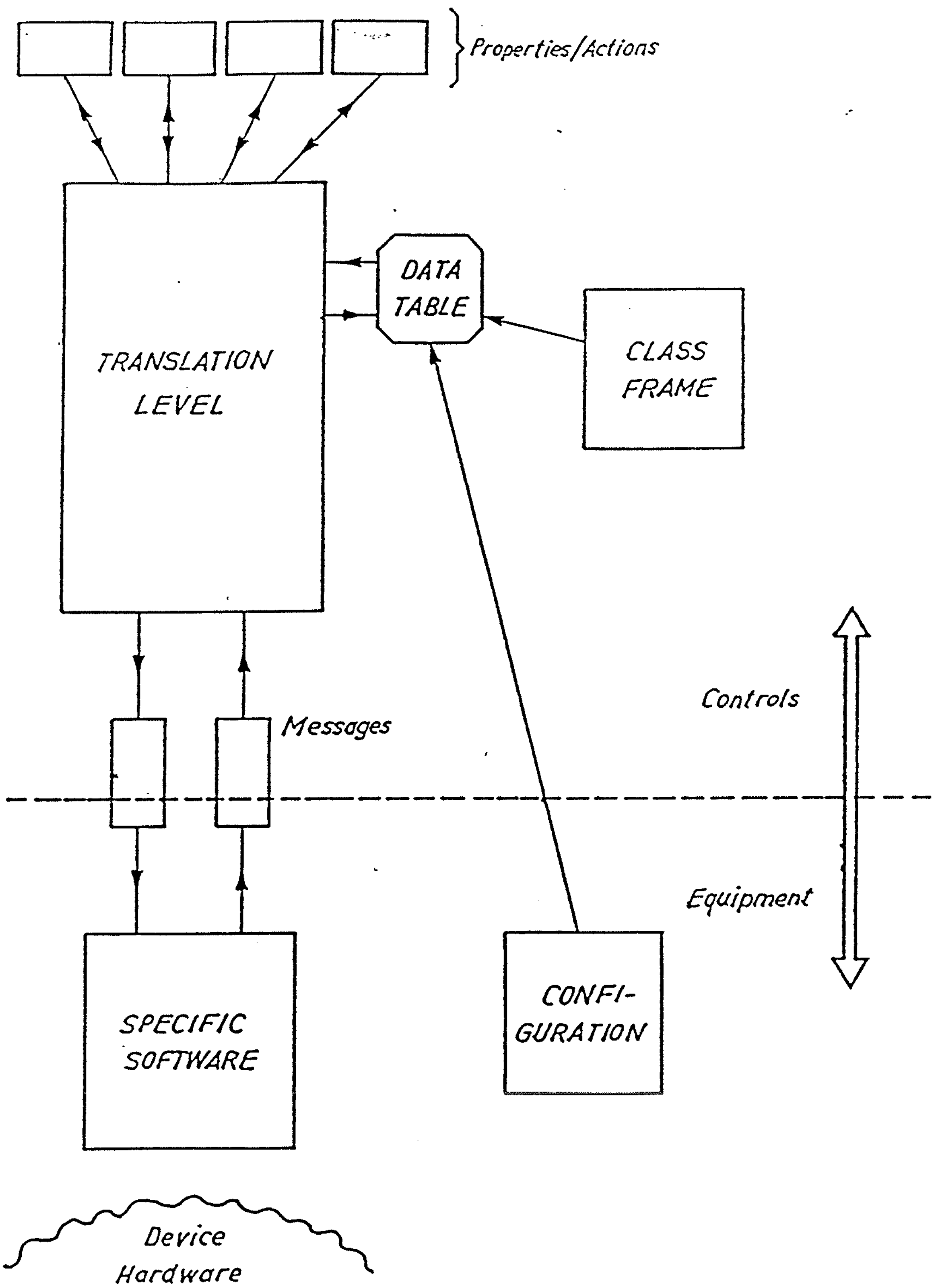
Current Trends in beam diagnostics controls :

In the past a strict demarcation line existed between the instrumentation specialists which had to cope only (or mainly) with the analog signal processing. All the digital part was done by control specialists. This split of responsibilities had the main draw-back that a large quantity of knowledge had to be exchanged and well understood by both parties in order to develop and maintain instruments.

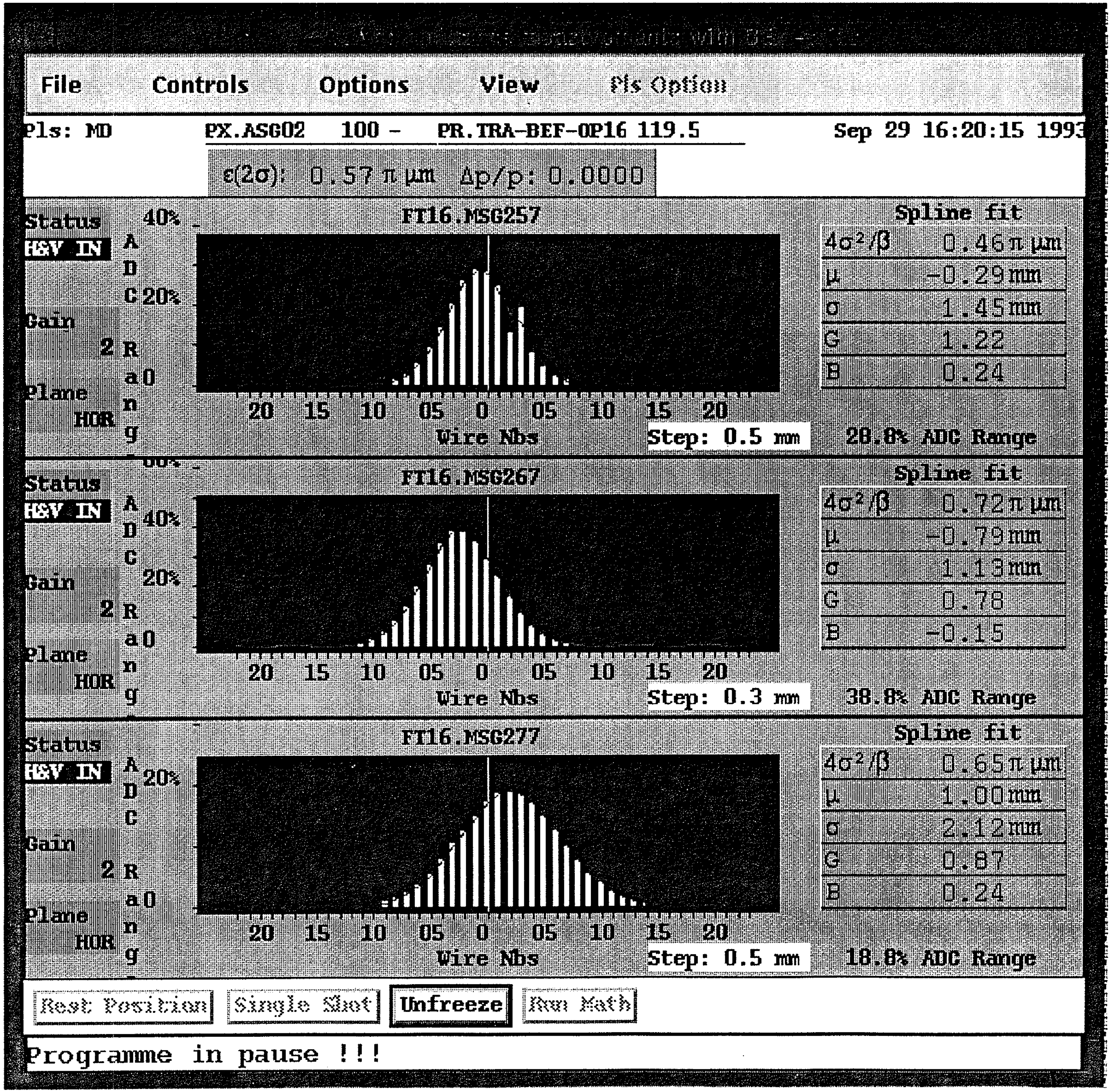
The new trend is to involve more and more the instrumentation specialists in the production of the dedicated instrument software allowing the definition of an abstract instrument which drives the data exchange, the control system and the instrument. This new approach reduces considerably the cross exchange of detailed knowledge and decouples largely the development on both sides of the software. The main drawback is the necessity for the instrumentation specialists to become control software specialists with especially good skills for real time interrupt management. This requires an important initial effort; to keep this effort within reasonable limits, the evolution of the environment should be gradual, planned and documented.

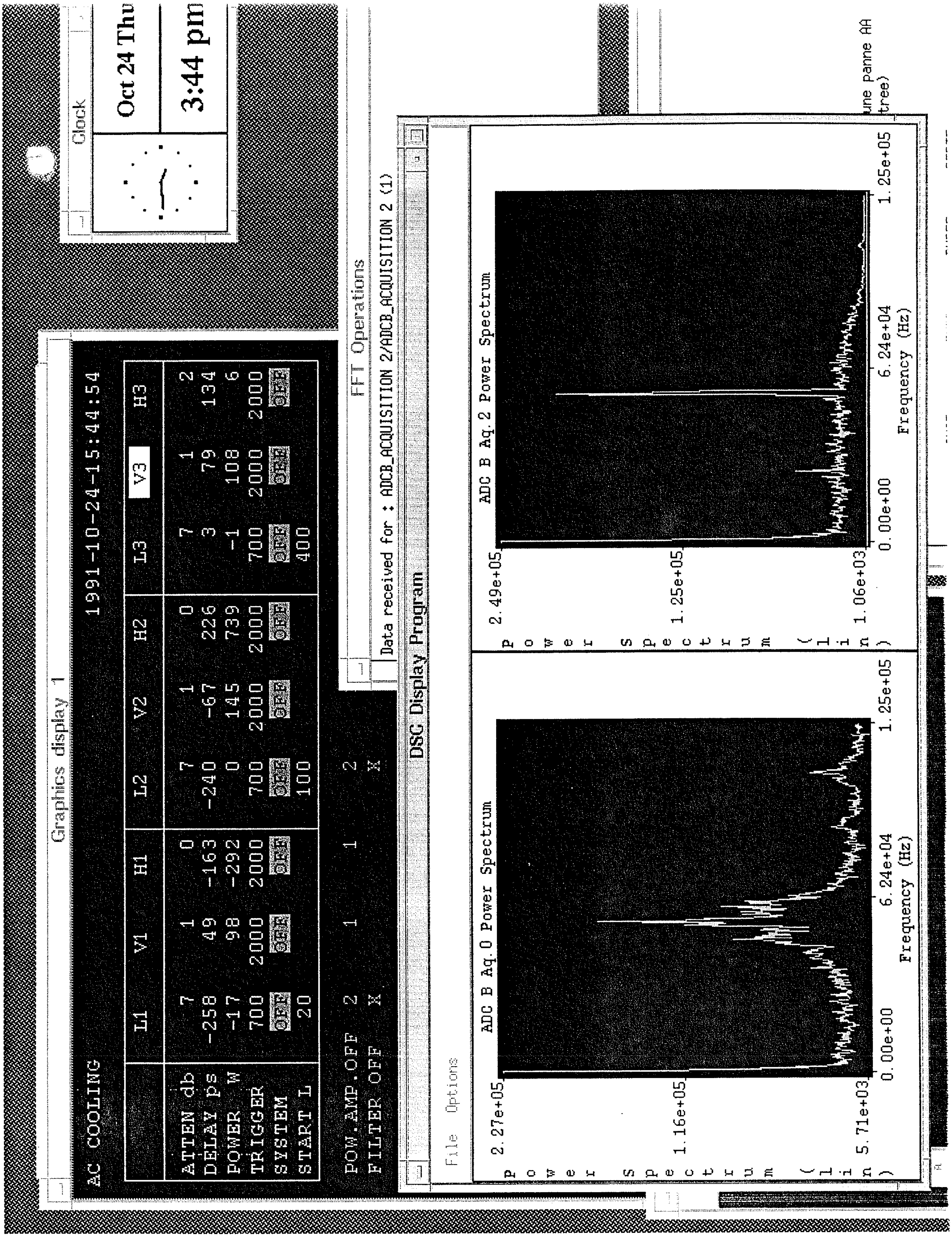

Protocol
Application program
msg queues
Real time pgm
Data acquisition
Process control
Equipment module
timing
data
control
Hardware
Data table

Control Protocols



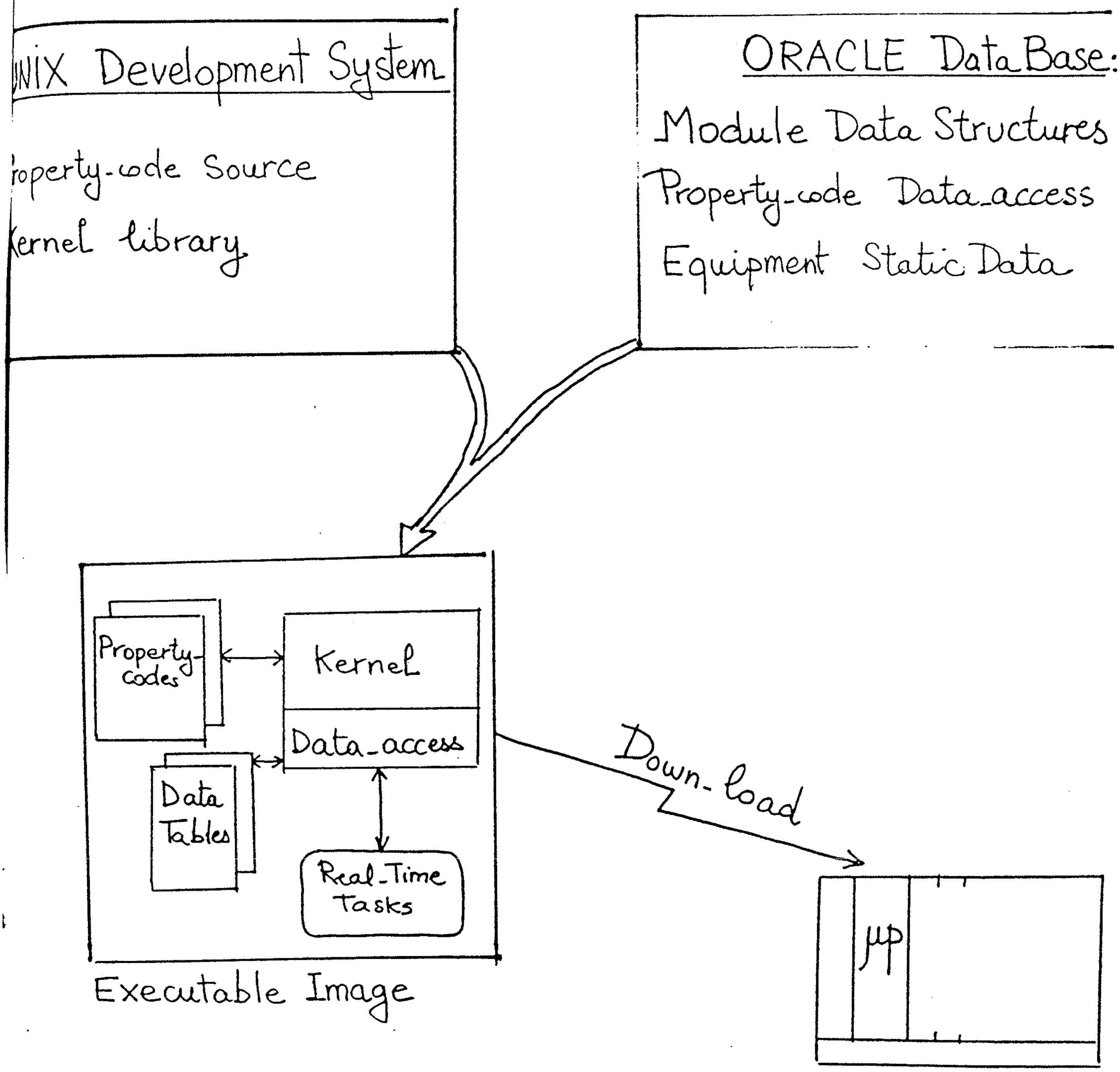
CONTROL PROTOCOL COMPONENTS AND THEIR RELATIONSHIP


File
Controls
Options
View
Pls Option
Pls: MD
PX.ASG02 100 - PR.TRA-BEF-OP16 119.5
Sep 29 16:20:15 1993
ε(2σ): 0.57 π μm Δp/p: 0.0000
Status
H&V IN
Gain
2
Plane
HOR
ADC Range
FT16.MSG257
Wire Nbs
Step: 0.5 mm
Spline fit
4σ²/β 0.46 π μm
μ -0.29 mm
σ 1.45 mm
G 1.22
B 0.24
20.0% ADC Range
FT16.MSG267
Step: 0.3 mm
Spline fit
4σ²/β 0.72 π μm
μ -0.79 mm
σ 1.13 mm
G 0.78
B -0.15
30.0% ADC Range
FT16.MSG277
Step: 0.5 mm
Spline fit
4σ²/β 0.65 π μm
μ 1.00 mm
σ 2.12 mm
G 0.87
B 0.24
10.0% ADC Range
Rest Position
Single Shot
Unfreeze
Run Math
Programme in pause !!!


Graphics display 1
AC COOLING
1991-10-24-15:44:54
FFT Operations
Data received for : ADCB_ACQUISITION 2/ADCB_ACQUISITION 2 (1)
DSC Display Program
File Options
ADC B Aq.0 Power Spectrum
ADC B Aq.2 Power Spectrum
Frequency (Hz)
Clock
Oct 24 Thu
3:44 pm

FFT in VME

NAPS organisation



V. Chohan, [CERN PS Division] Talk on Beam Diagnostics & their Controls: CAS School,Indore ,Nov93

From left : Ted Wilson, CAS, Iyengar, Chairman, Dept Atomic Energy,India, Ramamurthy, Director of CAT, Indore

Front Row : Lyn Evans(LHC Project leader Designate), Hagel (Superconducting RF), V. Chohan (Beam Diagnostics)

2nd Row: from right: F Bordry (power Converters), W. Weingarten (Superconducting RF)

3rd row :1st on left : George Shering (controls)