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A FEEDBACK SYSTEM FOR STEERING AND CORRECTING THE ENERGY OF THE SLAC BEAM IN THE BEAM SWITCHYARD*

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ABSTRACT

This system provides closed loop feedback position and energy steering of the SLAC beam line 'A'. The position monitoring and control mechanisms include 4 pairs of non-intercepting position monitors and 4 corresponding steering magnet pairs, and 2 non-intercepting charge monitors. The energy monitoring and control mechanism consists of a non-intercepting position monitor placed where the beam's horizontal displacement is proportional to its momentum, and a device for controlling the energy contribution to the beam of two of the accelerator klystrons. All of these are read and set by CAMAC modules accessible to an LSI-11 microcomputer which performs the feedback control.

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INTRODUCTION

In the recent SLAC experiment that measured parity violating effects in inelastic electron scattering (Ref. 1), it was crucial to minimize all sources of systematic error. In this experiment the SLAC polarized electron beam was accelerated, momentum analyzed, and steered onto liquid deuterium and liquid hydrogen targets. The beam pulse spill time was 1.5 microseconds, and the beam energies ranged between 16 and 22.2 GeV. The accelerator could deliver up to 60 pps from each of 6 time slots. Typically, pulses from different time slots had different characteristics, so that it was advantageous to steer pulses from a single time slot only. The pulse repetition rate in the experiment was up to 180 pps, although 120 pps was the more usual rate. Small changes in the energy or position steering which were correlated with the beam's polarization could lead to a potentially serious source of systematic errors. The resolutions per pulse were about 0.01% in energy, 10 microns in position, and 0.3 microradians in angle. However, drifts in magnet power supplies and instabilities in the accelerator resulted in resolutions, measured over periods of a few minutes, which were factors of 10 to 100 times worse than the per pulse values.

To overcome these long term drifts, a microcomputer based system has been implemented to provide closed loop feedback position and energy steering of the beam in beam line 'A' of the SLAC beam switchyard (see Fig. 1). This system provides position and energy steering on a pulse to pulse basis and holds the long term beam position spread at the target to a few tens of microns and the energy spread to a few hundredths of a percent.

COMPONENTS

Beam pulse position information comes from four pairs of non-intercepting microwave beam position monitors (BPMs) (Ref. 2). Each BPM consists of a rectangular resonant cavity placed in the beam line (see Fig. 2). The beam induced signal from the cavity varies approximately linearly (footnote) with the product of the beam pulse's charge and its horizontal or vertical displacement (X) from the nominal beam center line. Upstream of each BPM pair is a steering magnet (SM) pair. Two of the SM pair/BPM pair stations are placed at the beginning of the beam switchyard and the other two are placed at the end of the beam switchyard (see Fig. 3). The beam pulse charge (Q) is measured by a cylindrical resonant cavity (see Fig. 2) whose induced signal is independent of the beam position and proportional to the beam current (footnote). One of the charge monitors is placed at the beginning of the beam switchyard and the other is placed just prior to the target. A further BPM is placed halfway along the beam switchyard, at a position where the beam's horizontal displacement is proportional to its energy difference (dE) from the nominal beam energy. The BPMs have a resolution of 10 microns at beam currents down to 100 microamps. The microwave circuitry for the BPMs and Q monitor at P28 and P0 are located in the klystron gallery, and their video signals are sent by low loss coaxial cable to the counting house. The microwave circuitry for the P13, P15 and 3P2 BPMs and Q monitor are located in the counting house. The video signals from all the BPMs are amplified, integrated, held, and then digitized by the electronics shown in Fig. 4. The digitized readings are then read via a CAMAC module. The SM currents are read and controlled by means of two CAMAC modules. The beam energy is adjusted by changing the energy contribution of two of the klystrons towards the end of the accelerator. Fig. 5 shows the electronics for the steering and energy control system.

In general, no attempt was made to miniaturize the electronics, but rather the intention was to provide the experimentor with as many system checks as possible. A picture of the steering and control electronics is shown in Fig. 6.

The system is organized around a DEC LSI-11 (Ref. 3) microcomputer which serves as the controller. A picture of the controller, its terminal, and CAMAC crate is shown in Fig. 7. All steering controls and beam position information are available to two CAMAC crates. One crate is under the control of the LSI-11. The other crate is connected to the XDS 9300 computer which controls the experiment. The use of two CAMAC crates was dictated by the fact that only a dedicated crate controller was available for the LSI-11 at the time of construction, and we wished the two computers to be able to run independently.

The LSI-11 has 24k 16 bit words of RAM and 4k 16 bit words of Intel 2708 EPROM. It also has a floating point unit, extended arithmetic unit, and a Schlumberger JLSI-10 CAMAC type U crate controller connected directly to the Q-bus. In addition, there are two serial line interfaces, one to an ASCII terminal and the other to the SLAC IBM 360/370 computer center (TRIPLEX). The latter is used to enable the LSI-11 to look like a terminal to the TRIPLEX, for the purposes of program development, and also to allow down line loading into RAM of the LSI-11. The program controlling the LSI-11 is called LACHESIS after the mythological fate who determined the length of the thread of life.

a) Read Electronics

The block diagram of the read electronics is shown in Fig. 4. The analog signals (X′s, Q′s, dE) are amplified by the x3 amplifier. Each amplifier has two outputs. One output goes to the integrator, and the other is used for monitoring purposes. The integrator is reset just before beam time and is then gated with a 3 microsecond pulse. The integrator time constant is approximately 0.5 microseconds. The integrator has two switched monitor outputs which allows the user to view either inputs, outputs, or gating signals. The integrator output is then digitized by the scanning ADC module which can provide up to 16 digitizations. The ADC is a 2′s complement 12 bit bipolar unit, Datel Model HZ-12 BGC, with an 8 microsecond digitizing time. The analog switching is accomplished with four Siliconix DG509 differential multiplexers. The scanning ADC digitizes at a rate of 12 microseconds per channel, allowing 8 microseconds for the ADC and 4 microseconds for the multiplexer. The digitized outputs are sent to two single width scanning ADC read modules, one in the LSI-11 CAMAC crate, and one in the XDS 9300

CAMAC crate. The scanning ADC read module contains a 16 word-12 bit multiport RAM for storing each of the 16 channels of digitized data. The read module also generates a LAM when the last channel has been digitized. The time slot of each beam pulse may be read by a single width scanning ADC read CAMAC module.

b) Control Electronics

There are four SM control units, each containing two 12 bit bipolar 2's complement DACs. One drives the vertical output and the other the horizontal output, with a maximum voltage of -1.28 Volts. Each output may be adjusted using a front panel attenuator. There are also front panel 7 segment LED displays which show the setting of each DAC. The SM control units are driven by the single width CAMAC SM WRITE module and read via the single width CAMAC SM READ module. The SM control units each drive a pair of X, Y steering magnets. In the case of the up-stream steering,(i.e., accelerator sectors 28 and 29), each unit's output drives its steering coil via the pulse steering power supply. The pulse steering power supply multiplexes control of beam steering according to the accelerator pattern. The units that drive the down-stream steering (i.e., at the end of the beam switchyard), drive auxiliary windings on steering magnets A10/11 and A12/13 via their respective current power amplifiers. Each amplifier has a maximum output of +- 12.8 Amps with a voltage compliance to 23 Volts.

Vernier energy control is accomplished by shifting the phase on two klystrons in sector 27. The phase shifters for each are contained within their respective IOA (isolator, phase shifter, attenuator) units and are those originally purchased when SLAC was built. The phase shifters have been modified to include stepping motors and are driven by the remote phase control units. The motor drivers are incremented/decremented from the counting house by the energy vernier controller, which in turn is controlled by a double width CAMAC unit.

c) Miscellaneous Devices

The LSI-11 CAMAC crate contains the following single width CAMAC modules, in addition to the beam steering hardware interfaces mentioned above:

1. a Kinetics (Ref. 4) 3061 Input Gated Output Register to provide a CAMAC to CAMAC link between the LSI-11 and the XDS 9300 controlling the experiment;

2. an Experiment Control Panel (ECP) interface, to provide an easy way to select and update displays and control the beam steering;

3. an output module (Kinetics 3072) to provide status signals;

4. an input module (Kinetics 3470) to provide the user with push buttons for requesting calibrations; it can also provide a LAM that can be used as an alternative way to invoke the beam handling procedure.

STEERING ALGORITHM

The steering algorithm is designed to be self adaptive to the conditions in the beam parameters. These parameters may change in the short (pulse-to-pulse) term due to instabilities in the components of the beam source, the accelerator, and the beam switchyard. Longer term instabilities also lead to slow drifts in the beam parameters. To first order, it is desirable that the algorithm should not require operator intervention to compensate for any of these changes in beam parameters. A further complication is involved since, due to the eddy currents in the steering magnets, there is a time delay of several hundred milliseconds between applying the current and the field settling down. Thus, even presuming all other things were stable, it is not possible, at normal beam pulse repetition rates (>10HZ), to apply a correction on one pulse and expect it to be in effect by the next pulse. The algorithm successfully takes account of the above factors.

After the beam pulse, the position and energy monitor readings are digitized, and when ready, the LSI-11 is interrupted and the BEAMLAM procedure entered. BEAMLAM reads all the beam associated devices and checks the data and whether the pulse's data should contribute to the steering; if so, the BSTEER procedure is called. BSTEER subtracts pedestals from the readings and accumulates sums of the charges and positions. After MST pulses (called a 'block' of pulses) have been accumulated in this manner, then the average position measurements for the last block are extracted from the sums by dividing by the charge sums. These positions are compared to the dynamic position cuts XC, and tallies are kept of the number of beam pulses outside the various cuts, and the extreme excursions of the beam. If an average position measurement is found to be outside a cut, then the current on the appropriate steering magnet is adjusted, by a fixed amount, to move the beam towards the desired position. There are both fine and coarse cuts and corresponding step sizes, so as to enable rapid corrections for large displacements and vice versa. After MXC blocks of pulses, it is deemed that sufficient statistics have been accumulated so that the cuts themselves can be reevaluated. The CUTLAM procedure is then invoked at a lower priority level. Based on the fraction of the last MXC blocks lying outside the cuts, CUTLAM then adjusts the cuts to be about 2 standard deviations from the required center of the beam position distribution. The steering algorithm also notes whether any encoder is near the limit of its range or if the centroid of the last MXC pulses is outside the fine cuts, and,if so, an audible warning is emitted. Apart from minor differences in the klystron control hardware, the energy adjustment procedure uses the same algorithm as the position steering procedure. The time required to execute the time critical portion of the algorithm, in the worst case, is about 7.5 milliseconds. Since it is desireable to steer only on pulses from a single time slot (i.e., at a maximum of 60 pps), this is adequate for our purposes. The optimum values of MST and MXC are empirically determined to be MXC=(rep rate of pulses in time slot being steered on / 20) +1 and MXC=(MST*2+1)*50.

COMMUNICATION BETWEEN THE LSI-11 AND THE XDS 9300

Communication between the two computers is required to provide synchronization for calibration type measurements, to provide warnings if the beam is outside specified limits, and to ensure that the steering is still operative. These communications are provided by a CAMAC to CAMAC link incorporating two 24 bit parallel input gated output registers (Kinetics 3061) connected by a 52 pin conductor cable. These modules permit 16 bit transfers to be made in both directions with simple handshaking capabilities.

HISTOGRAM FACILITIES

Since this is a new technique for controlling the beam it is necessary that statistics on the beam profiles, etc. be easily generated and displayed. A simple integer bin histogram facility is, therefore, incorporated in LACHESIS. When LACHESIS is started a set of histograms are automatically defined. Further histograms may be defined and old histograms deleted or redefined via a terminal dialogue at execution time. A list of the histograms currently defined can be found via a terminal user dialogue. The histograms are accumulated by calls to a procedure HCUMF. Histogram output is in graphic form (see Fig. 7) on a display terminal (we used a Tektronix 4013), or in tabular form. The output is selected from the ECP by selecting the appropriate ID in the DISPLAY ID thumbwheels, then pushing DISPLAY UPD or LST on the ECP or typing CTRL U at the terminal. Histograms may be cleared (contents set to zero) by pushing the CLR button on the ECP. Histograms are also cleared in the begin run procedure that is initiated by pushing the ECP BEGIN button. All histograms are saved in a buffer that can expand to take all available resident memory.

CONSTANTS

Even though the system is designed for minimum operator intervention, during the development stage it is necessary to be able to interactively view many parameters, CAMAC addresses and tallies, and also to easily adjust the parameters and addresses (these parameters, CAMAC addresses and tallies are given the generic name constants henceforth). At the same time it is necessary in a real time program to carefully protect parameters against the user entering out of range values. There are about 500 integer constants that are used for controlling the beam steering. With so many constants being available it is highly desirable to be able to interrogate LACHESIS to find the constant names, short descriptions of each one′s purpose, their current values, and their allowed ranges.

The constants are divided into groups, each group containing a logically related set of constants. The names and contents of the constants in each group may be displayed in tabular form by selecting Display ID′s 100-117 on the ECP and pushing DISPLAY UPD. A list of the constant group displays available can be obtained by typing CONLIS and responding with a question mark ′?′ to the group number prompt. Constants may also be individually examined to determine their purpose and contents by pushing the CON ECP button or typing ′CONSET′. This will result in the prompt ′CONST NAME=′ appearing at the terminal. The user then enters the 4 character name of the constant followed by a carriage return. LACHESIS responds with the current value if the name is valid. The user may then enter a new value, or type a question mark ′?′ to obtain the definition and limits associated with the constant, or simply type a carriage return to back out of the ′CONST NAME=′ prompt. New values entered by the user are checked versus the limits to ensure they are valid. One can exit the CONSET procedure by depressing the DELETE (or RUBOUT) key.

SELF HELP

Besides the constant manipulation and histogram definition commands, many other LACHESIS commands can be entered from the terminal. These commands are mainly used as an aid in debugging. A list of all these commands (including the constant manipulation and histogram commands) can be obtained by typing 'HELP' at the terminal.

STATUS INDICATORS ETC.

In addition to the relatively detailed information available on request from the histogram and constants displays, status outputs in the form of digital 7 segment LED's, status lights, and TTL signal levels are provided. The status lights tell the operator at a glance whether LACHESIS is steering the beam, whether the beam pulse charge is sufficient, whether the energy vernier reading is in tolerance, and whether the encoders are being moved etc. The 7 segment LED's provide continuous display monitoring of the encoder positions and the contents of user selectable (via a thumbwheel) variables in LACHESIS. The TTL level outputs are used to provide timing signals to aid in measuring and optimizing time critical sections of LACHESIS. The TTL levels are also used to generate audible and visual (flashing lights) warnings of LACHESIS detected problems, such as if the klystron or position encoders have reached their limits, or if the beam position is a long way out of tolerance.

SOFTWARE CONSIDERATIONS

The software for this system has been written in PL-11 (Ref. 5). It is a programming language supporting structured programming. It includes bit, byte, integer (16 bit), logical, and CAMAC type variables. All variables must be declared and full type checking is made by the compiler. It is designed for efficient execution with the PDP-11 instruction set. This allows the programmer to have both the power, speed, and data manipulatibility of assembly language and the readability of higher level structured programming languages. The readability, along with the syntax checking and type checking facilities of the compiler, assist us in generating very reliable code. The steering algorithm is extremely time critical due to the requirement of steering at 60 Hz, the relatively large number of elements involved, and the amount of computation that must be made for each element. Thus, the ability to write a large fraction of the code so that it excutes at close to maximum speed is essential.

The PL-11 compiler is a cross compiler which runs on the SLAC IBM 360/370 TRIPLEX system and generates relocatable object modules. Text is entered, modified, compiled, and maintained using the SLAC WYLBUR text editor (Ref. 6) and file system. A cross linker is used to link the various object modules together into an absolute load module which is then downloaded into the LSI-11 via a WYLBUR execfile and a downline loading program contained in the EPROM of the LSI-11. It takes 7.5 minutes to download the LACHESIS program at 2400 baud. The program length is about 16.5k 16 bit words. More details on the code preparation can be found in Ref. 7.

The LSI-11 used contains 28k words of memory. The first 20k words are RAM. The next 4k is EPROM (composed of 8 2708 EPROMS). The next 4k is RAM. In general, the first 20k will contain the users program, the 4k EPROM contains the various 'system' routines, and the final 4k is the system stack area and histogram buffer space. This memory configuration contributes greatly to the system debugging ease. For example, if the stack starts to overflow because of an excessive interrupt rate or a program error, it will run into the EPROM and the LSI-11 will stop executing before the stack can destroy any of the code.

Contained in the EPROM are various system routines such as:

a) the terminal input and output handlers for printing to the terminal and reading input from the keyboard

b) ASCII to binary and binary to ASCII conversion routines

c) a terminal handler which is interrupt driven and can operate while one is executing a program which has been downloaded or all by itself

d) a routine which allows the contents of the RAM to be dumped to a floppy disk and later restored

e) a set of routines to identify and handle execution errors and some machine errors

f) a non-destructive memory test diagnostic program.

RESULTS

Each position monitor was calibrated by using a steering magnet upstream of the position monitor to displace the beam by a known distance. This distance was originally determined by observing the beam spot on a flourescent screen viewed by a TV camera. The energy monitor was calibrated by adjusting (by a known amount) the phase of two klystrons and hence their energy contribution to the beam.

Fig. 8 shows an LSI-11 accumulated beam histogram of the beam's horizontal position as measured by the beam monitor closest to the target. The peak in the center (X=0) is obtained with the LSI-11 steering the beam. The vertical bars are the dynamic position cuts, XC, which are at roughly +/- 2 standard deviations for the distribution of the last MXC=200 beam pulses. The standard deviation of the central distribution in Fig. 8 is roughly +/- 25 microns. The peak to the right was obtained with the beam steered off by 200 microns. The standard deviations of the beam distributions shown in Tables 1 and 2, essentially indicate the long term stability of the beam steering. A measure of the beam's pulse to pulse instability was obtained by accumulating the position differences from one pulse to the next pulse and measuring the standard deviations of these distributions. The long term instability with the steering feedback loop closed is typically 1.5 times the pulse to pulse instability.

In the past with no position steering feedback, the long term drifts of the beam centroid built up until visable on a flourescent screen viewed by a TV camera, at which point a human operator would stop the experiment and apply a manual correction. Such a drift at the target would typically amount to 4 mm, and might take anywhere from a few pulses to a few hours to reach such a magnitude depending on the stability of the beam. With the steering feedback loop closed, the beam position was held constant to a few microns (see Table 3), and the angular deviations to fractions of a micro radian, without operator intervention. For a typical 'stable' beam, some idea of the shift in the centroids obtained with and without closed loop feedback steering over a period of 30 minutes can be obtained from Table 2. There it is seen that at the target the beam's positions with the steering feedback loop closed were closer to zero by almost two orders of magnitude.

With the steering feedback loop open the energy is defined by slits in the beam switchyard. These slits were seldom set to less than 0.1%, at which value the beam current is typically attenuated by a factor of 3, due to the beam scraping on the slits. With the energy feedback loop closed the slits were opened all the way (1.5%), hence, giving no beam attenuation, yet the beam energy (as seen in Table 1) was held constant to a few hundredths of a percent.

The system has been in regular use since Summer 1977 and is typically used 24 hours a day, 7 days a week for periods of several weeks. After ironing out the usual initial hardware problems the system has been extremely reliable. Once the system is set up, operator intervention is required only occasionally (typically every few hours) to ensure that the BPM gains and phases are correct, and that the magnet and/or klystron encoders have not reached their limits. At one time a floppy disk was provided to enable the operator to restore the program in the case of a catastrophic crash. This was only used once when a site wide power outage destroyed the contents of the LSI-11 RAM. In hindsight, even this was unnecessary since following the outage, the accelerator was off for longer than the TRIPLEX so we could have reloaded from the TRIPLEX without difficulty. After the initial checkout and understanding of the system was completed, the graphics terminal was replaced by a 30 character/sec hard copy terminal. This facilitated keeping a log of events while graphs of beam profiles etc. could be displayed on the XDS 9300. The system will in the future be a standard facility incorporated in the SLAC beam line 'A'. If it is desired to increase the speed of execution of the program, the LSI-11 can be replaced by a faster PDP-11, while the rest of the system, both software and hardware, is unaffected. For example, the program was transported to a PDP-11/34 and measured to run just over three times faster.

ACKNOWLEDGEMENTS

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FOOTNOTE

The beam induced signal power is actually proportional to the square of the current, but for small displacements a linear relation is sufficiently accurate. In the case of the BPMs the proportionality constant is 40 uW/mA**2 mm**2, and for the Q monitors it is 40mW/mA**2.

REFERENCES

1. C. Y. Prescott *et al.*, SLAC-PUB-1823 (1978).
2. Z. D. Farkas *et al.*, SLAC-PUB-1823 (1976).
3. Microcomputer Handbook, Digital Equipment Corporation Maynard, Massachusetts (1977).
4. Kinetic Systems Corporation, 11 Maryknoll Drive, Lockport, Illinois 60441.
5. R. Russell and T. C. Streeter, CERN 74-24 (1974).
6. WYLBUR/370, The Stanford Timesharing Reference Manual, Third Edition (Nov. 1975).
7. R. L. A. Cottrell and C. A. Logg, Proceedings of the Digital Equipment Computer Users Society Vol 4 No. 4 p 985 (1978).

Table 1

Standard deviations (SIG) of the beam position (X,Y) and differential energy (dE) monitor distributions with the steering feedback loop closed. The numbers in brackets ([]) are the standard deviations of the position differences from pulse to pulse.

STATION	SIG(X) microns	SIG(Y) microns
P29	46	18
P0	19	10
P15	59 [26]	33 [26]
3P2	42 [17]	35 [31]

	SIG(dE) %
dE	.033 [.01]

Table 2

Typical angular resolutions (in micro radians) of the beam at the target, with the steering loop closed.

	Mean	Standard Deviations long term	 pulse to pulse
Horizontal Angle	-0.07	0.79	0.57
Vertical Angle	0.1	0.54	0.39

Table 3

Beam position centroids measured with a stable beam over a period of 30 minutes, with the steering feedback loop closed and opened.

STATION	CLOSED	OPEN
	<X>,<Y> microns	<X>,<Y> microns
P29	-4.4,-2.9	-73,-51
P0	-1.6,-1.31	-3.5,-60
P15	-0.7,-0.5	138,32
3P2	-1.3,-0.6	107,-70

FIGURE CAPTIONS

1. Aerial view of the SLAC beam switchyard. The beam enters from the top of the picture and follows the arrowed path from the accelerator through the beam switchyard to the target. After passing through the target it proceeds on to the beam dump at the bottom of the picture.

2. Photograph of a charge monitor followed by 2 BPMs installed in the beam line about 6 meters from the target. The distance between the charge monitor and the midpoint of the 2 BPMs is about 0.5 meters.

3. Layout of the beam components of the steering and energy feedback system. The beam pulse enters from the left passing first through sector 27 where the two LSI-11 controlled klystrons apply their energy to the beam pulse. It then passes through steering magnet pairs in sectors 28 and 29 and a position monitor pair towards the end of sector 29. The beam leaves the accelerator and enters the

beam switchyard passing through the P0 position monitor pair. The steering at P29 is mainly controlled by sector 28, and at P0 by sector 29. Halfway through the switchyard, the P13 position monitor measures the deviation of the beam's energy from the nominal value. Towards the end of the switchyard, the beam pulse passes through the A10/11, A12/13 steering magnets and the P15 position monitor. It then enters the end station and passing through the final position monitor pair at 3P2 on its way to the target.

4. Block diagram of the BPM electronics readout. It shows the analog signal path for 1 of the 11 monitors, digitization for 1 of the 16 possible inputs, and the CAMAC interface. The analog signal is amplified then integrated and held. The held voltage is then muliplexed to the ADC, digitized and the reading made available via the scanning ADC read modules (shown shaded).

5. Block diagram of the electronics used in control of the steering magnets and klystrons.

6. The control and readout electronics located in counting house A. PM = position monitor, SM = steering magnet.

7. The LSI-11 based controller. The LSI-11 is the crate at the upper left labelled "COMPUTER FRONT PANEL". Below this appears in order: the experiment control panel (ECP), the CAMAC crate with the steering modules in place, a floppy disk used for backup purposes, and a set of BNCs used to output TTL levels. To the right is shown the Tektronix 4013 storage scope terminal with a picture of two beam energy profiles separated by 1% in dE/E.

8. Beam profiles.

a) Shows the horizontal beam position profile measured close to the target. The peak to the right was obtained by deliberately steering the beam off by 200 microns. The standard deviations of these distributions are about 45 microns. Beam pulses outside the fine cuts are steered back towards the center. The fine cuts are constantly adjusted to be about 2 standard deviations, for the distribution obtained from the last 200 beam pulses. b) Shows the beam's differential energy profile. The peak to the right was obtained by deliberately increasing the beams energy by about 1%. The standard deviations of these distributions are roughly 0.03%.

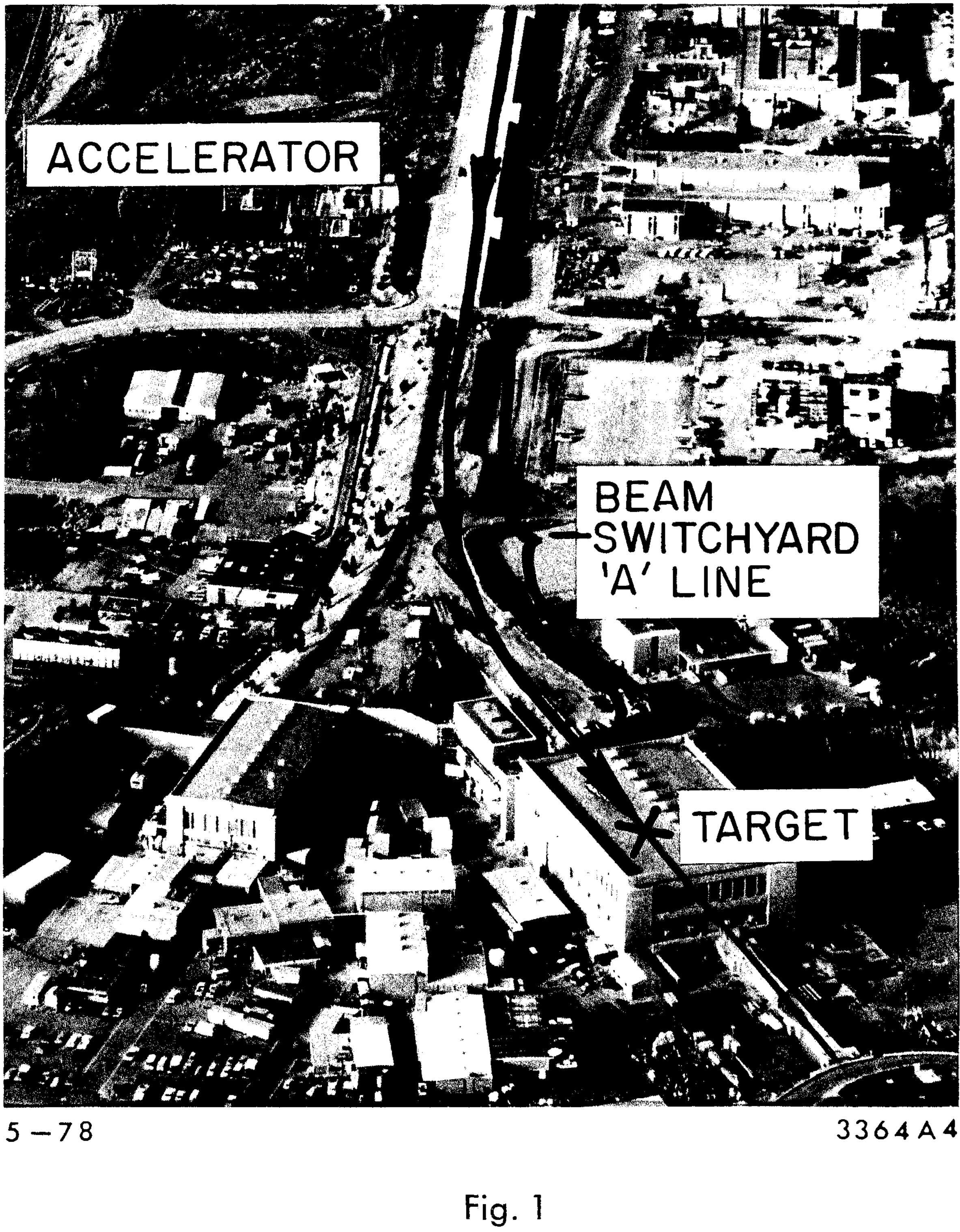

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Fig. 1

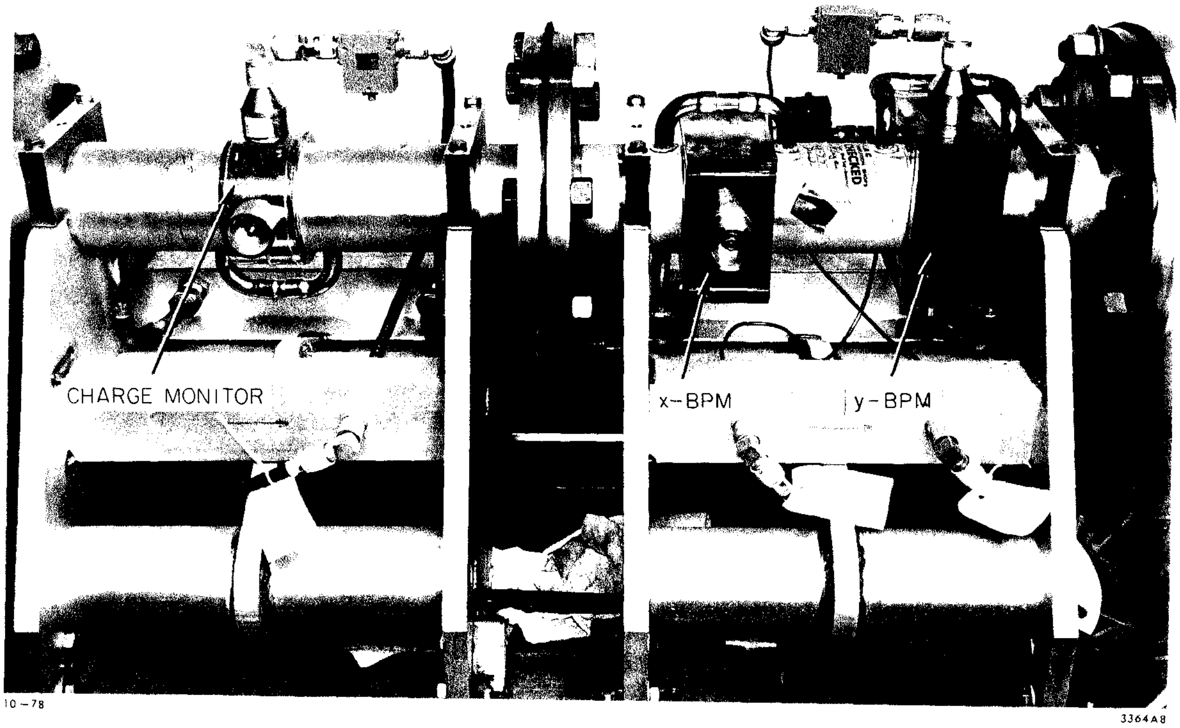


Fig. 2

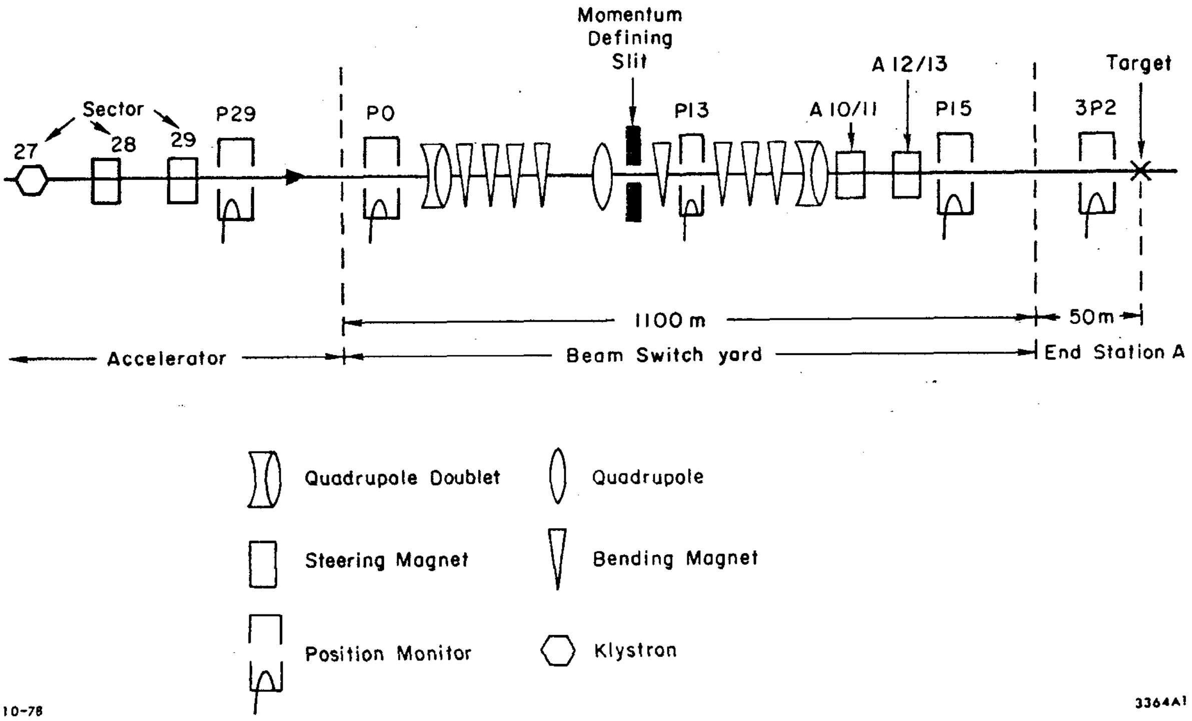

Momentum Defining Slit
A 12/13
Target
Sector
P29
P0
P13
A 10/11
P15
3P2
27
28
29
1100 m
50m
Accelerator
Beam Switch yard
End Station A
Quadrupole Doublet
Quadrupole
Steering Magnet
Bending Magnet
Position Monitor
Klystron
10-78
3364A1

Fig. 3

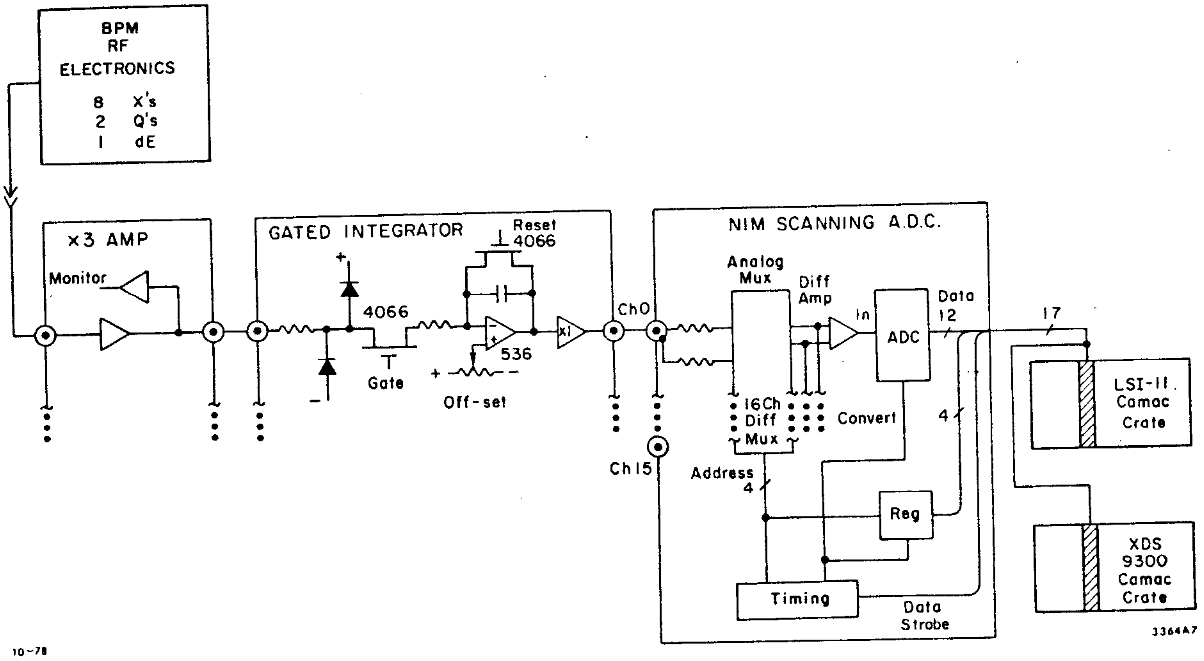

BPM
RF
ELECTRONICS
8 X's
2 Q's
1 dE
×3 AMP
Monitor
GATED INTEGRATOR
+
−
4066
Gate
Reset
4066
536
+
−
Off-set
×1
Ch0
Ch15
NIM SCANNING A.D.C.
Analog
Mux
16Ch
Diff
Mux
Diff
Amp
In
ADC
Data
12
17
Convert
4
Address
4
Reg
Timing
Data
Strobe
LSI-11
Camac
Crate
XDS
9300
Camac
Crate
10-78
3364A7

Fig. 4

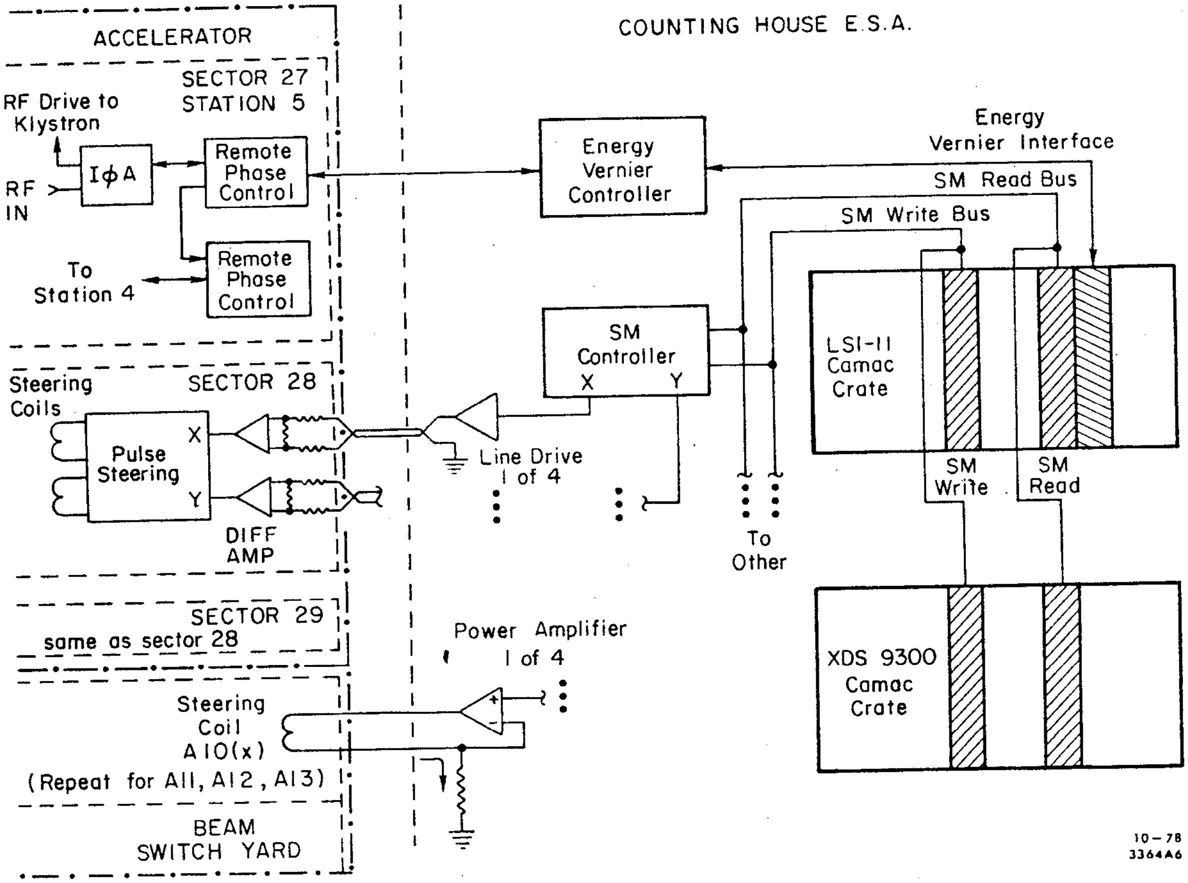

ACCELERATOR
SECTOR 27
STATION 5
RF Drive to Klystron
IφA
RF IN
Remote Phase Control
To Station 4
Remote Phase Control
Steering Coils
SECTOR 28
Pulse Steering
X
Y
DIFF AMP
SECTOR 29
same as sector 28
Steering Coil
A10(x)
(Repeat for A11, A12, A13)
BEAM SWITCH YARD
COUNTING HOUSE E.S.A.
Energy Vernier Controller
Energy Vernier Interface
SM Read Bus
SM Write Bus
SM Controller
X
Y
Line Drive
1 of 4
LSI-11 Camac Crate
SM Write
SM Read
To Other
Power Amplifier
1 of 4
XDS 9300 Camac Crate
10-78
3364A6

Fig. 5

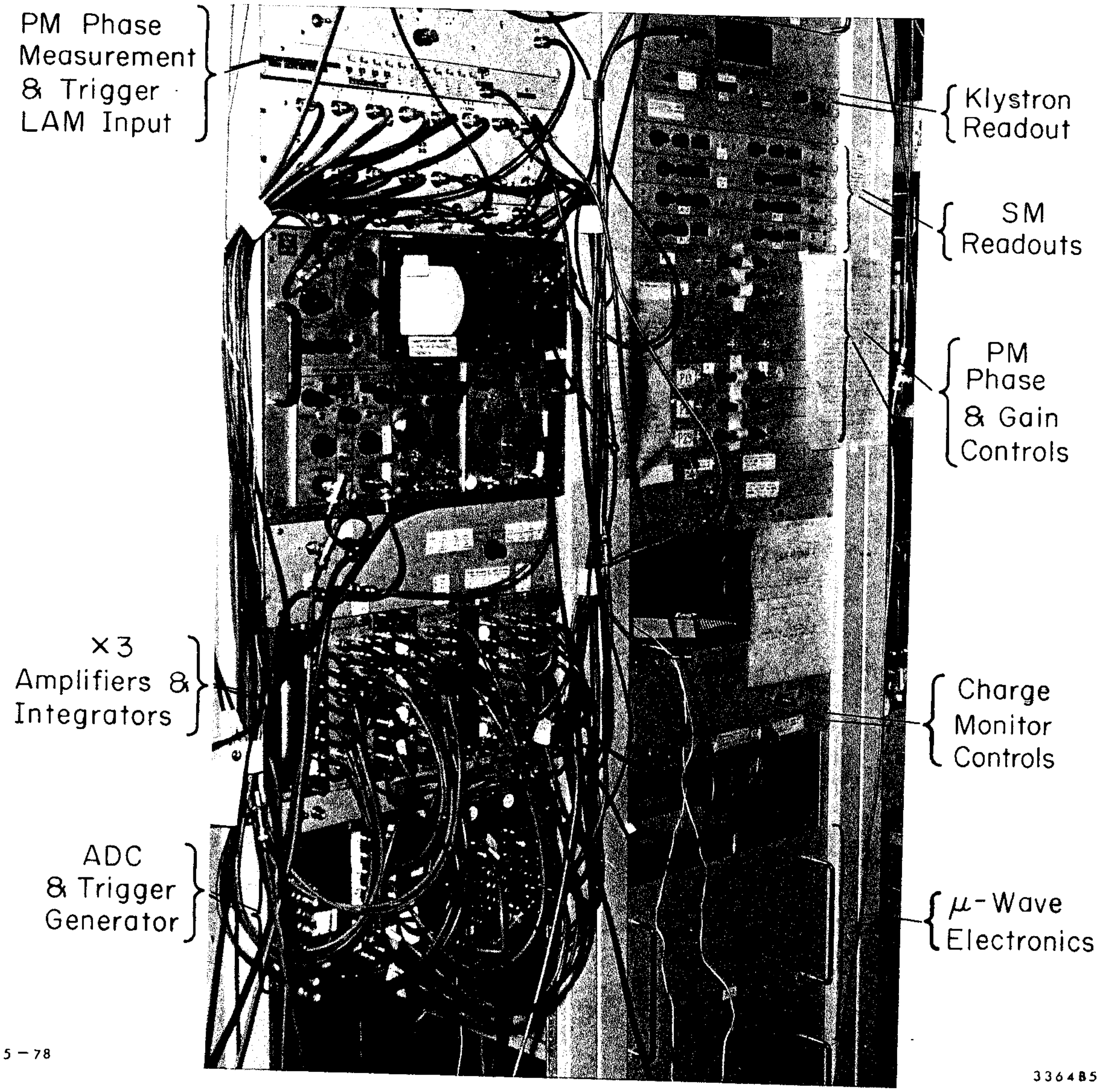
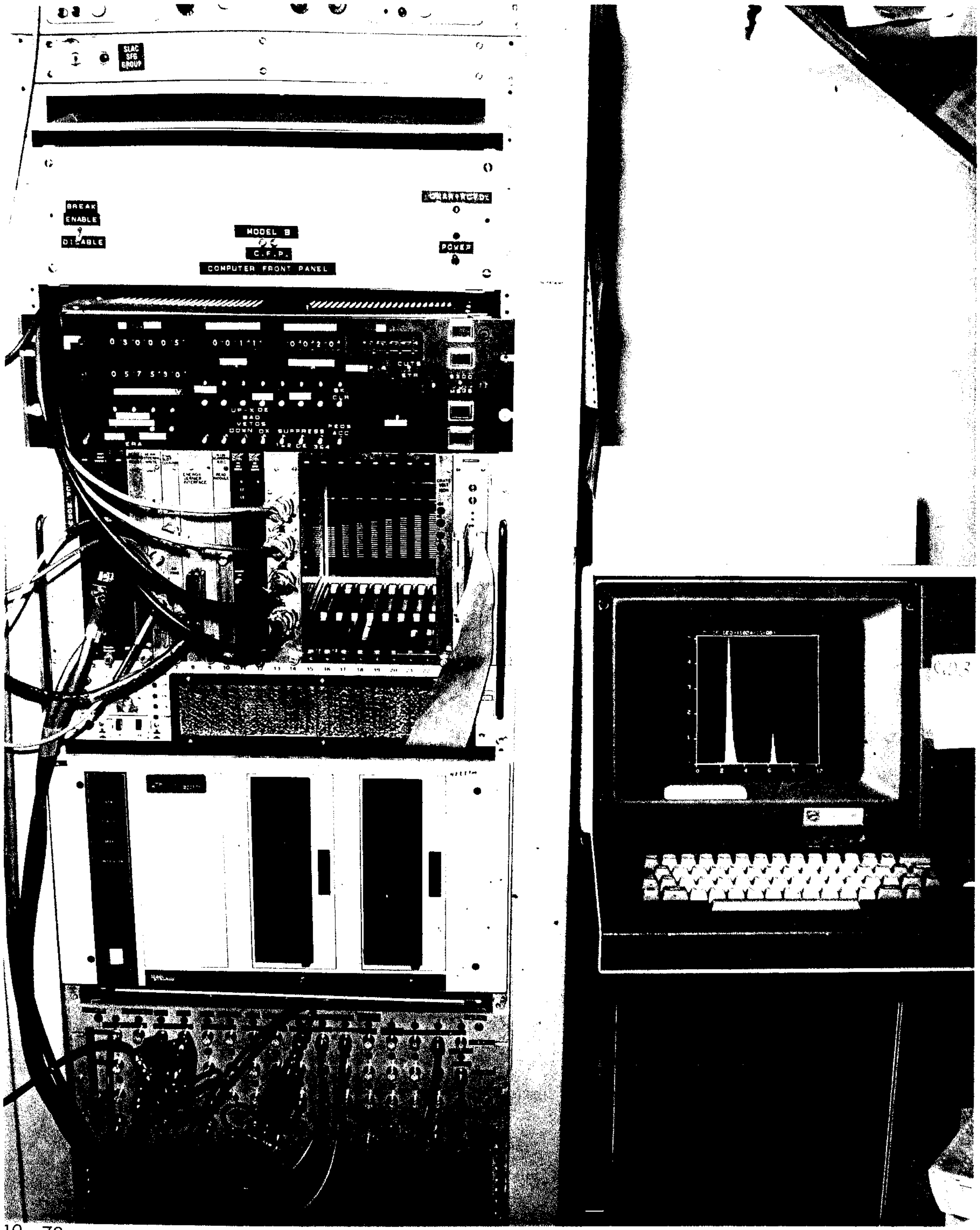
PM Phase Measurement & Trigger LAM Input
x3 Amplifiers & Integrators
ADC & Trigger Generator
Klystron Readout
SM Readouts
PM Phase & Gain Controls
Charge Monitor Controls
μ-Wave Electronics
5 – 78
3364B5

Fig. 6



10–78

3364A9

Fig. 7

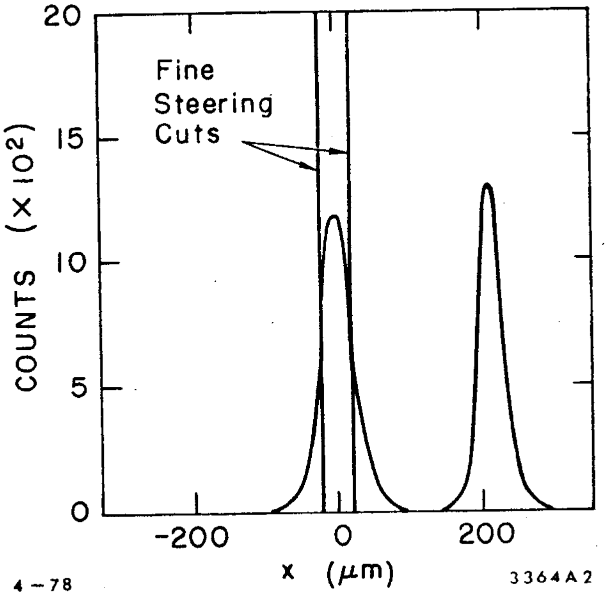

20
15
10
5
0
COUNTS (× 10²)
Fine Steering Cuts
-200
0
200
x (μm)
4-78
3364A2

Fig. 8a

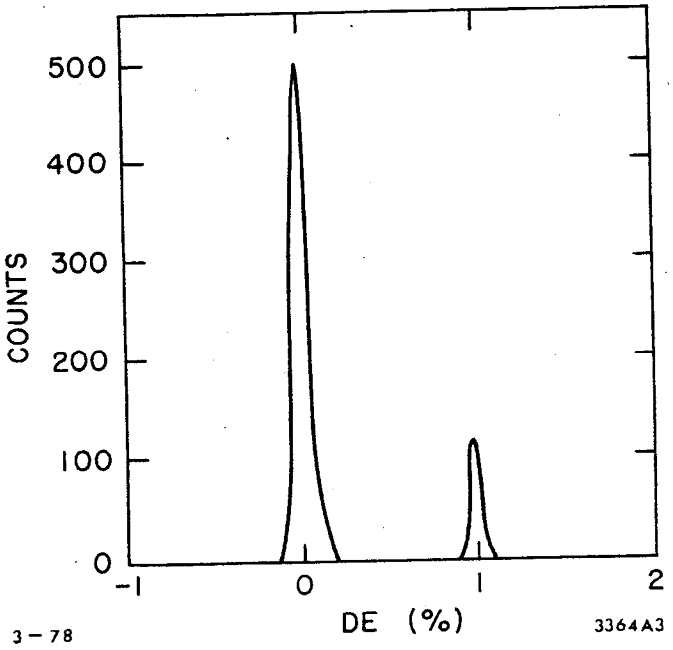


Fig. 8b