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"OPERATION STRAIGHT FLUSH"

A programme of supplementary fast ejection facilities

by

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0. Summary

This paper proposes new pulse generators that can be more flexibly programmed for the mobile small aperture kicker magnet in SS 97. The new features include: (1) A so-called "multibunching" facility, i.e. the choice by remote selection of any number of bunches between 1 and 20, with both polarities of the kick; (2) a so-called "sequencing" facility, i.e. change of the number of bunches to be ejected, the polarity of the kick and the ejection timing from one machine cycle to another; (3) a so-called "multiple shot" facility, i.e. change of the programme (cp. 2) within the same machine cycle. Obviously (2) and (3) can be combined to (4) the so-called "mixed operation". The kicker will be able to induce a radial beam "jump" adequate for fast ejection in <u>any</u> straight section of the CPS, in particular SS's 1,2,16,58,62,74. It is aimed to reduce the dead time between two fast ejection bursts to less than 100 ms and the dead time between a fast ejection and a target burst to less than 50 ms. The paper describes the pulse generators for excitation of the kicker magnet, the fast charging power supply, the electronic programming system and the essential monitoring and beam diagnostic tools. It states the organizational and financial implications when aiming for installation of this equipment during the summer shutdown of 1968.

1. Introductory Outline

This paper is not so much a technical report but rather a proposal resulting from a design study with elaborations on why, what, how, when and at what price.

1.1 History

The fast ejection system, as installed in 1963 [1,2] could eject at choice either one bunch or twenty bunches. In 1964 a facility was added to eject also 17,18,19 bunches [3] and in 1965 a facility for 1 to 5 bunches was incorporated for machine energies up to 12 GeV. End 1965 this facility was also made available up to full machine energy. Going from the 1 - 6 bunch to the 17 - 20 bunch operation required a transformation during a CPS routine shutdown. This situation arose, since these adhoc facilities were added on requests for specific experiments, as these came in, and on a short term. Despite their provisional character, these facilities have been in continuous use since their installation. In 1965 the need arose for ejecting also intermediate numbers of bunches between 6 and 17, without transformation [4], and a start was made with construction of new pulse generators to meet this demand [5]. In 1966 requests were made for a cycle to cycle change of this number [6]; later in the year the need started to be felt for more than one fast ejection burst inside one acceleration cycle [7], as proposed already earlier [8]. It then became clear that a thorough survey was due of the probable needs of fast ejection around the CPS in the coming few years, and the means to meet these. The timescale of the 1 - 20 bunch facility had meanwhile slipped beyond the programme and, as a consequence of the above deliberations the work was temporarily stopped in autumn 1966, pending a conclusion. This paper is the result of the survey.

1.2 Philosophy

The previous section shows the need to break the vicious circle where a project group is immobilized by providing one adhoc facility after another, each one almost obsolete at delivery. A good proposal must therefore be aimed far enough ahead, accepting the consequences in budget, effort and time.

An ideal solution would combine a flexible electronic programming system as proposed in this paper with a set of full aperture kicker magnets [9] or flap magnets [10] located in short straight sections four units upstream from the septum magnets of each ejection channel. The ideal solution, however, seems presently out on account of the timescale, hence not "Royal Straight Flush" [11].

In projects requiring substantial installation work in the accelerator, time is quantized in periods of the order of one year (shutdowns). Progress on the other hand is also quantized since only discrete degrees of progress make sense: The next better solution must be a significant step forward to make action worthwhile at all. In the present case the quantums of progress and time do not correspond: we think that this proposal is the next logical step on a one year timescale, but for guaranteed delivery at least one and a half year would be quoted (end 1968). There is however an 80 - 90 % probability that the system is operational in summer 1968. We propose therefore, in view of the urgency, to work on a "best-we-can-do"basis and accept the ensueing risk.

Four years of operational experience have taught us to view ejection facilities as a whole i.e. with all the auxiliaries, even peripheral ones. This means in particular that together with the new ejection equipment proper an infrastructure of supporting electronics and beam diagnostics must be created.

When deciding what facilities to provide statements of the form "such and such a facility will not be used" should be viewed with reserve, since the past has shown that every available facility finds an eager customer before one expects it. By choosing one should therefore not only be led by the question of what is needed but within reason, also by what could be made available in a certain time.

We feel that in another spirit the project should not even be started.

Possible completion of other material, such as the full aperture kicker magnet should not alter the philosophy. It should even in its first version form a welcome compliment, facilitating some beam sharing schemes and it should give the redundancy appropriate for an accelerator like the CPS.

1.3 Framework

This proposal aims to meet the major part of the fast ejection needs around the CPS for, say, three years after its installation. The proposal is a compromise between what ideally would be wanted and what can be constructed with a reasonable timescale using existing experience. The timescale is tentatively adapted to installation in the long shutdown of summer 1968. While too great extrapolations will be avoided, it will be tried to incorporate the improvements suggested by the four years of operational experience. In particular a substantial effort will be devoted to making the operation simple and foolproof.

1.4 Scope

The proposal consists mainly in construction of new pulse generators and their accessories for the present fast kicker magnet in SS 97, with its electronics and fast charging power supply. This system differs from the one installed in 1963 in six main aspects:

1. The pulse forming networks will have spark gaps at either end such that by programming the relative trigger moments of front and tail gap the pulse length can be changed.
2. The pulse generators shall be moved out of the ring and will be installed in the Computer Room, giving easy access during a run.
3. For multiple shot application the power supply must be able to recharge the pulse forming network within, say, 100 ms. This will be achieved in two stages. In the first stage the present power supply will be modified for a charging time of 300 ms. Specification and ordering of a new fast charging power supply to meet the aim of 100 ms will form stage 2.
4. The flexible programming and timing system will constitute an essential part of the project.
5. A substantial effort will be devoted to make the beam diagnostics around the ejection channels adequate, and even redundant.
6. The kicker magnet will be provided with fast field inverters and a rapid closed orbit bump.

2. High Voltage Pulse Generators

It will be tried to deviate as little as possible from the old proved design to keep maximum likelihood of correct functioning from the onset. On the other hand, besides the modifications necessary for the new facility, advantage will be taken of the experience with the old pulse generators to incorporate several smaller improvements and simplifications.

The new pulse generator (like the old ones) will consist of two line type pulsers, each generating the current pulse to excite one of the two kicker magnet units. The two pulse circuits (cp. fig. 1) are entirely independent such that each can be operated separately. The pulse forming networks (PFN), having the same impedance level than the old ones, i.e. 10 ohms, consist of 11 lumped LC sections, preceded by one RC section, the so-called adaptor, giving a fast rise of the current pulse. The variable pulse length shall be obtained using a spark gap at each end of the pulse forming network [12,13]. One gap (front gap) will be connected to the transmission cable to the kicker magnet and terminating resistor. The other gap (tail gap) will connect the pulse forming network to a second terminating resistor (dumping resistor). By the relative timing of the separate triggers of these gaps the pulse duration can be continuously varied between 0.1 and 2.1 μs, corresponding respectively to single bunch and total beam extraction. A 100 kV (line) model pulser using a front and tail gap to obtain a variable pulse length has functioned successfully in the laboratory [14]. The short rise of 15 ns of the current pulse is insured by the RC section (adaptor) between front gap and PFN. The sharp fall of 15 ns of the current pulse is obtained by clipping the tail of the pulse at the required moment. This is done by short circuiting the line with a short-circuit spark gap (clipping gap). There exists by now around two years experience in operating such gaps.

A first sketch of the execution of the pulse generators is given in fig. 2. A possible different version is shown in fig. 3. A decision will be taken after some preliminary tests. Each line type pulser is contained in a gas pressurized drum ensuring simultaneously good insulation of the high voltage parts and shielding, such that interference in the immediate vicinity can be kept to a minimum. The upper part of each pressure drum contains the PFN. The adaptor and the three spark gaps are mounted on the bottom plate. Behind the pulse forming networks are the charging resistors, the voltage dividers and their grading capacitors. Lifting off the drum leaves the entire interior accessible for inspection and maintenance. The front gap and tail gap differ in that the clipping gap is contained in a cavity of the front gap. Apart from this the two gaps are identical. Each of the three sparkgaps of one pulser will have a separate trigger, thus allowing easy adjustment of the pulse duration and synchronisation by entirely low level electronics. For reasons given further on it will be possible to operate the pulsers independently so that there will be six trigger generators in total. These will, to keep connections short and symmetric, be located in a rack between the two pulsers. This rack will also contain the channel selector box for the fast monitoring system (cp. section 4.2) as well as the pressure regulation system for spark gaps, pressure drums and field inverters.

The gas pressure in the spark gaps will be made to follow automatically the chosen line voltage. The gap pressures as well as the line voltages are therefore made to follow a reference voltage coming from the programming system. For single channel single shot operation this will present no problem, since the voltage and the pressure are constant. For sequencing between two widely different ejection energies, the line voltage will be changed accordingly. Since the time between two shots is then 0.5 sec or more, a classical pressure regulation can still follow the changing of the reference voltage. For multiple shot operation however inside one acceleration cycle the attainable rates of change with any classical pressure regulation are marginal. Therefore, unless a more sophisticated pressure regulation can be found in the meantime, it will be better to quantize the kick strength in two steps, i.e. one line or two line operation, for CPS energies up to, say, 13 GeV respectively 26 GeV proton energy. The kick may then in certain operations be too strong, but this can be dealt with by programming the placing perturbation further away from the septum.

3. Triggers

The three sparkgaps of each pulse generator will be triggered with a 30 kV trigger generator. Two ways of doing this seem to have a certain attraction. These are: (1) 30 kV deuterium filled thyratrons and (2) a 30 kV trigger using the Marx pulse generator principle.

The first has the advantage that thyratrons can be readily bought and require no maintenance. They will have nanosecond or sub-nanosecond jitter. They have the disadvantage that only negative pulses can simply be derived from such triggers. Also the 30 kV charging and heating supplies would be more voluminous so that it would be more convenient to use one central supply for all six thyratrons.

The Marx trigger could give at choice pulses of the two polarities and is a very low impedance source, hence can easily supply more than one 50 Ohm line in parallel. Since its charging voltage can be as low as 5 - 6 kV the supply is more compact and can be built into the trigger unit. This would then yield an autonomous standard trigger unit for the laboratory as a byproduct. The Marx generator will however at best have a few nanoseconds of jitter and will require periodical maintenance (sparkgaps).

The required rack space for both solutions is comparable, if two thyratrons are being built into one unit. Three such double thyratron units with their common 30 kV charging supply will then require around 1.20 m rack height. Six autonomous Marx-triggers will require about the same.

It is at present difficult to make a choice between the two, but the programme allows to do so as late as a few months from now. A prototype shall be built of each type of trigger and a decision will be taken after a few months of continuous testing of these.

4. Electronics

As evoked in the introductory outline the electronics is a major part of this project. The electronic system can roughly be divided into four parts: (1) programming and timing; (2) the controls and interlocks; (3) the fast monitoring; (4) the beam diagnostics around the ejection channels. These parts do partly overlap.

The following directives are derived from operational experience. The controls should be:

a) automatic where possible;

b) as simple and foolproof as feasible.

The monitoring and diagnostics should be:

c) not only adequate but even redundant;

d) not only visible, but obvious and grouped together,

e) some decent audible warning signals should be included.

4.1 Programming and timing

On the panels belonging to this part the particular beam sharing scheme in question can be programmed. The logic circuits of this part then provide the appropriate timing pulses to initiate the sequence of operations of the relevant parts of the system. These parts therefore overlap somewhat with the controls, (cp. section 4.3). The programming and timing consist of three parts: (1) the programme sequencer; (2) the kick and bunch selector; (3) the pre-and post pulse units. The functions of these can most easily be explained from the front panels.

The programme sequencer panel (cp. fig. 4) has three rectangular boxes marked programme 1, programme 2 and programme 3 etc..., each controlling and displaying one particular beam sharing scheme. Each ejection operation in that programme can be switched on or off on that panel. The lighted left hand lamp then means that the operation of the channel in question is foreseen in that particular programme. In addition a second bulb flashes on whenever the channel is actually operating. The number of cycles that each programme will be repeated can be selected on the digital switches. The nixie read-out counts the cycles for each programme and resets each time a new master cycle begins, i.e. each time before programme 1 starts anew. The programme can at choice come from this panel ("Intern") or from the CPS programming system ("Extern"). In the latter case the panel works as a display only.

The sequencer always switches from one programme to the next when the pre-selected number of cycles in the previous programme has been completed. When the last programme has completed its number of cycles, programme 1 starts again. This is called master cycle or sequence.

After fast ejection in a certain area has been included in one or more programmes on the programme sequencer panel, its timing, the ejected number of bunches and the kick strength is chosen on the kick and bunch selector panel (cp. fig. 5). The kick and bunch selector consist of three identical panels each serving one ejection area. These panels permit also the choice of one or two kicker magnet units, hence kick strengths, the polarity of the field, hence the direction of the deflection. There is also a fine adjustment (delay) of the timing of the kicker pulse front and the pulse tail, and adjustment of the delays compensating for the phase jump at transition, beginning of flat top and end of flat top.

The fast kicker magnet and its accessories cannot eject the beam alone but they do this in conjunction with other equipment and facilities in the CPS such as septum magnets, bump coils, horizontal and vertical kicker pairs, RF beam steering perturbations, etc... It may be convenient for operation to lock the starting signals for these to the ejection moment such that, if ejection timing is changed, timing for these facilities automatically slides with it. Also, gating signals are required for beam diagnostics around the moment of ejection (cp. section 4.4). Finally, experiments in the extracted beam have always shown to require a multitude of locking pulses for starting, stopping, and gating. All these applications can be divided into two groups: (a) those applications where a time quantization of 3 ms (M or T pulses) or 1 ms (B pulses) can be accepted, with their concomitant time jitter of max. 2 μs with respect to the first extracted bunch; (b) those requiring a time quantization of 2 μs and a time jitter of not more than a few nanoseconds with respect to the first extracted bunch.

To meet these varying requirements a flexible system of locking pulses has been foreseen. It can provide pulses before ejection (pre-pulses) or after ejection (post pulses). For application (a) M or B pulses are used, whereas for application (b) a signal is derived from the RF system. The front panel of the system is depicted in fig. 6, in which three rows of units are visible. By means of the decade switch the number before, respectively after the ejection moment, can be chosen. If its decade switch is set to n, and N represents the ejection pulse, then each unit gives off a trigger at the pulse number N - n, or N + n, depending upon whether it is a pre or a post pulse unit. The units of each row are referred to the timing of one ejection channel. There are four types of units: pre M pulse, post M pulse, pre RF pulse and post RF pulse. They can be plugged in anywhere in the row.

A block diagram of the programming and timing system is given in Fig. 7. The main functions are explained in the figure caption.

4.2 Monitoring

For adjustment and checking of the correct functioning of the various parts of the fast low level and high voltage pulse circuits it is crucial to have the key signals coming from these parts displayed on a fast oscilloscope . They are partly direct voltage signals from the low level electronics and partly time derivatives of the high voltage pulses, differentiation and reintegration being used for voltage division.

Fig. 8 shows a block diagram for the proposed monitoring system. All signal cables come together in a selector unit in the Computer Room. The signals are there processed, i.e. integrated, amplified, or attenuated, added or subtracted, and a series of Reed-relais permits selection of at choice two signals that are transmitted over two low loss cables to a fast oscilloscope in the Main Control Room. From there the Reed-relais can be actuated by push-buttons on a remote signal selector panel.

The monitoring system also contains a simulator permitting its calibration and a rapid check on the correct functioning of all its channels.

As in the case of the beam diagnostic it is found adviseable to incorporate a certain measure of redundancy of displays.

4.3 Controls and interlocks

The controls permit the switching on and off of the installation, the setting of the operational values and the indications and measurement of certain quantities. The controls are partly included in the kick and bunch selector panel.

Like in most systems the interlocks can provide warning signals, inhibit signals and switch off signals. A block diagram of the system is shown in fig. 9.

All interlocks are incorporated in one rack situated near the pulse generators in the Computer Room. Only the most important summary signals will be repeated on a panel in the Main Control Room.

Interlocks will be grouped together according to their function and summary interlocks will close if the entire group is O.K. The interlocks will be constructed in a form of identical plug-in units. Additional functions may then be added by including more units and certain functions may be by-passed by inserting dummy units. This approach avoids recabling in case of change and facilitates checks and maintenance.

4.4 Beam diagnostics

As stated elsewhere the additional complications of sequencing and multiple shot operation requires adequate and even redundant diagnostics to judge the correct functioning of the system. The fast monitoring system provides such for the electrical part of the system. Special beam diagnostic is required to monitor the response of the CPS beam to the ejection operations. There must be enough diagnostic to judge this starting from the first perturbation of the undisturbed orbit until the first accessible point of the extracted beam, say, one CPS magnet unit downstream from the septum magnet. These diagnostics for the various channels should be as far as possible identical and should be grouped together in one rack near the control panels of the F.E. system, so that the operators can see what they do when turning the buttons.

The diagnostic functions must include: (1) monitoring of beam positions by pick-up electrodes and closed circuit television; (2) means for the accurate book-keeping of internal and ejected protons, including ejection efficiency and an analogue display of internal and ejected beam time structure; (3) radiation monitors spotting beam loss; (4) adequate logging facilities to obtain reliable long term statistics of the performance.

Ad (1): the internal beam position should be measured locally by pick-up electrodes close to the septum magnet. This measurement could be gated right before and again during the kick such as to yield the "placing" position and the radial beam displacement ("jump") due to the kick. An electromagnetic pick-up loop in the kicker magnet, gated shortly before the kick should indicate correct positioning of the magnet with respect to the beam. Television cameras should survey upstream and downstream ends of the septum magnet, as well as the first screen in the ejected beam. A possible beam position display panel is shown in fig. 10.

Ad (2): Four special beam transformers should be installed in the ejection channels and in the ring itself. The signals from these, duely phased by cable delays, are the basis for a bunch to bunch measurement and comparison of internal and external beam intensities. These data are stored. All other desired displays can be derived from these signals by suitable fast logic circuits. Such derived quantities are e.g. ejection efficiency, number of protons ejected, integrated number of ejected protons, analogue displays of the time structure of internal and external beam, etc... A possible display panel for the proton account is shown in fig. 11 and a proposal for analogue display of the bunch to bunch ejection efficiency is given in fig. 12.

Ad (3): Fast directive counters should permanently look at the septums and at the kicker magnet. Their signal strength must be standardized and their position fixed such that calibration is possible. Each could feed two detection and alarm channels, the sensitivity of which can be chosen by means of adjusting the threshold of discriminators. One channel connected over a high pass filter and gated with a short pulse around the instant of the kick, could discern radiation of the correct time structure indicating interception of the kicked beam ("fast interception"). The other channel connected over a low pass filter and gated with a longish pulse, should react to longer radiation bursts, indicating interception on the septum by the unkicked beam around the ejection moment, ("slow interception"). A possible radiation monitor panel is shown in fig. 13.

Ad (4): Two logging facilities should be considered. A multichannel pen recorder could provide a quick impression of the evolution of some crucial parameters in the last few hours. A more flexible output system should permit a choice of print-outs at chosen intervals. As signals will be largely digital a tape puncher could be considered, and the presence of the CPS computer should be kept in mind. A possible data output selector panel with a pulse or time preset unit are shown in fig. 14.

A tentative block diagram for a complete and flexible fast ejection beam diagnostic system is proposed in fig. 15.

Fig. 16 shows the proposed layout of the panels of the new electronics in the racks of the Main Control Room.

5. Fast Charging H.V. Power Supply

As mentioned in the introductory outline it is essential for the multiple shot operation to reduce the dead time between the two shots inside an acceleration cycle to less than hundred milliseconds. As said before, two stages are being envisaged.

Stage 1: Measurements on our present power supply show that the two pulse forming networks can be charged to around 80 kV in around 350 ms. An average operating voltage of 60 kV could be reached in less than 300 ms. In the case of single line operation the two pulse forming networks can be recharged from half voltage to full voltage in, say, 200 ms. The present power supply therefore yields already limited but extremely useful double pulse possibilities. It will be equipped with a new servo-regulation acting on the phase cut of the primary current (cp. fig. 17) such as to make the supply charge up to a value given by a programmed reference voltage. This power supply could then supply all new facilities up to double shot with 200 to 300 ms of dead time.

Stage 2: For further reduction of the dead time to, say, 100 ms a new power supply must be specified and ordered. For the high required charging rate the voltage multiplier circuit of the present system must be abandoned and single stage double sided rectifiers must be used with a three-phase full 140 kV (peak) transformer. Further measurements of charging characteristics on our present supply, followed by a study of the behaviour of a prototype servo-regulation will enable us to define and specify the characteristics of a new supply such that tenders can be called and an order placed. Delivery time for such sort of apparatus is tentatively estimated to be one year.

6. Kicker Magnet and Accessories

The remote controlled mechanical field inverters, installed with the new "bare" kicker magnet in the 1967 spring shutdown of the CPS are not designed for sequencing, nor for multiple shot operation. For that purpose they will have to be improved such as to switch (including bouncing phenomena) in less than 100 ms and they must be able to perform many millions of operations without maintenance.

It is aimed to order a new H.V. power supply permitting a charging time of 100 ms or less. This figure will then also be the dead time for sharing between two fast ejection channels. If no other beam sharing takes place between these two fast ejection bursts, the kicker magnet can remain in position. For intervals of a few hundred ms between fast ejection bursts the magnet could be moved slightly back so as to give space for the beam blow-up during possible intermediate targetting. Such movements are possible thanks to the flexible programming system of the hydraulic servo-actuators [17].

If targetting is foreseen in the programme before or after a fast ejection burst, the dead time between fast ejection and targetting is given by the magnet movement for introducing or withdrawing the magnet. The characteristic time constant for this is also 100 ms. It is interesting and possible to reduce this dead time by a radial closed orbit bump, centered around SS 97, created by bump magnets, say, in SS 93 and SS 9. The kicker could then be moved before the first fast ejection burst to an excentric position, say, 5 cm outside the central orbit, and could stay there until after the flat top. The beam would be bumped into and out of the aperture shortly before and after the kick. If this reduction of dead time is to be effective, the time constants of the bump coils centered around the septum magnets must also be reduced to this value.

7. Performance

If the performance of the newly installed "bare" kicker magnet is around 20 % higher than the previous version, ejection in defocusing straight sections, one magnet unit before or after the maximum of the kicker-induced betatron oscillation (e.g. SS 58 and SS 74 now marginal for operation above 20 GeV), should be possible up to full machine energy without subtleties. The larger vertical and radial aperture of this kicker magnet allows for operation over more than one turn. In fact all straight sections in the CPS can then be supplied with a kicker-induced beam displacement ("jump") of at least as great as in the above mentioned straight sections, within either the first or the second turn after the kick (cp. fig. 18). Though not all of them have at present been laid open for fast ejection, nor will be by mid 1968, it is interesting to note that this includes SS 1 (kick outward 1st rev. jump = defined 100 %), SS 2 (kick outward, 1st rev. jump = 65 %), SS 16 (kick outward, 1st rev. jump = 65 %), SS 58 (kick inward, 1st rev. jump = 65 %), SS 62 (kick outward, 2nd rev. jump = 65 %), SS 74 (kick inward, 1st rev. jump = 65 %).

Due to the inherent flexibility of the proposed system the number of possible schemes is substantial and it would be unpractical and fall out of the scope of this report to enumerate them all.

A separate internal report should be issued with a fairly complete catalogue of the more probable applications and proposing means for their most efficient use. Such a study, containing considerations on strategy and tactics of beam consumption as well as a catalogue of practical schemes, issued timely, could be a very useful directive for PS coordinators, experimental planning group, operators and experimenters.

To illustrate what could be done we give an example of a "mixed operation" (cp. fig. 19) where 3 programmes are sequenced, each programme combining a different multiple shot operation with targetting and slow ejection.

In particular, also a fast cycling bubble chamber could be served with, say, 3 bursts of 3 bunches at 100 ms intervals.

8. Planning

Despite a conservative approach, the existing experience and careful design, this project inevitably contains some mild imponderables. These are mainly related to the high voltage pulse generators, more in particular to the changed configurations and to the fast repetition required for the multiple shot operation.

The main strategy will then be to have the pulse generators with their basic accessories ready assembled for tests by the 1st February 1968. This means that the pulse generators proper, their trigger units, part of the electronics and the modified Früngel power supply must then be operational. For the tail gaps a second set of electrolytic terminating resistors will have been manufactured and tested before this target date. This will give us several months before installation, for long term reliability tests, debugging and even modifications, if these prove necessary. The whole programme must be tuned to achieve this early testing.

The planning is presented in the tentative network (cp. fig. 20) giving the logic interrelation of the parts of the project as well as the timescale.

For the pulse generators this seems possible. If adequate time is spent on preliminary tests and a careful design, a well organized and concentrated construction effort is possible in autumn 1967 and all parts can be completed before Christmas. Assembly will cover the month of January.

For the triggers a choice must be made between the use of deuterium thyratrons and the Marx pulse generator principle. One prototype of each sort will therefore be built. These prototypes will be run continuously, debugged and modified if necessary, during three months. A choice will then be made and the final triggers and spares will be manufactured before Christmas and tested during January.

In the electronic sector a compromise must be made between meeting the target date for early testing and the inevitably slow build-up of the group (cp. the organogram). The first part, including programming and timing, controls and interlocks, is functionally interrelated with the pulse generators and must therefore be operational (if maybe not entirely completed) by the first February. A second part, including monitoring and beam diagnostics is only used for convenient remote observation of the functioning of the high voltage pulse generators, respectively the response of the beam to the ejection operations. These are not essential for the first tests and their manufacture therefore extends after the target date. The monitoring will be finished first; manufacture of the beam diagnostics will extend right up till the moment of installation.

As stated in section 5 the fast charging power supply is arrived at in two stages. In stage 1 the old Früngel power supply will be supplied with a servo voltage regulation and long term tested before the 1st February. Specifications will be written in summer and it is hoped to place an order for a new fast charging supply by the 1st October. Delivery i.e. completion of stage 2 could then be expected in autumn 1968.

Improved field inverters will be ready by the target date. They will by then have undergone long term fatigue testing and preliminary high voltage testing.

Obviously, a vacuum tank with at least a dummy magnet must be available by the target date for connecting and testing of the field inverters with the pulse generators. This could conveniently be combined with further tests of the spare "bare" kicker magnet. A vacuum tank of the type as in SS 97 should hence constantly be available for at least another year. By the same token the present test pulse generators with their triggers and auxiliary equipment should remain in perfect working order during the same period.

9. Organization

Due to its diversity and the short available time the project shall be divided into several more or less independent parts, according to subject, each being dealt with by specialists in the field. Though personally this may in some cases be slightly less attractive it is a concession that must be made to achieve efficient progress and avoid amateurism at CERN expense. The three subjects are (1) high voltage pulse engineering, (2) mechanical engineering, and (3) electronic engineering.

The fields do obviously overlap, since the triggers include electronics and triggers and electronics contain some mechanical engineering. The electronics in the triggers shall therefore be made by electronic engineers and the mechanical engineer shall also have a hand in the mechanics he is not actually designing. This horizontal specialization in addition to the vertical one, goes even somewhat further inside the electronic sector. Layout, installation and coordination of manufacture shall be done by one person, printed circuits by another, wiring shop and electromechanics and documentation again by another.

Such a procedure saves time and forces effective cross information.

An engineering team with representatives from each field shall be at least roughly informed about the whole project. For effective cross information this group shall meet periodically to examine proposals, designs and assembly drawings, before manufacture is commenced. Proposals and designs shall for that purpose be presented in a moderately readable form a few days beforehand.

In particular a more elaborate design study of the equipment described in sections 2.3,4.1,4.2,4.3,4.4 and 5 will be published in the form of an internal report before starting the detailed design and manufacture.

Diagrams and drawings shall be made systematically, according to agreed lines, as soon as they are more or less final. They shall be numbered and centrally filed. Completion of each piece of equipment shall be followed shortly by a readable description of its function, special tricks included and its performance, together with a complete set of drawings and diagrams. If so justified by its content, this will be in the form of an internal report.

The organogram (cp. fig. 2) gives a preliminary division of functions and responsibilities.

10. Budget

A synoptic version of the budget is given in Fig. 22. It is based on more detailed estimates for the items 1 through 10. The total cost of the project is in principle Sfr. 750'000.-. This includes material, services obtained outside and inside CERN and possible hired labour for assembly, installation etc... The figure does not include staff salaries. The included reserve of Sfr. 50'000.- may come handy for surprises during the testing period or during the installation. The greater part of the resulting budget of Sfr. 800'000.- will be spent in 1967. The budget is therefore divided between 1967 and the first half of 1968, with respectively Sfr. 440'000.- and Sfr. 360'000.-. The contribution of the NPA fast ejection group for this project (considering its other commitments) can be Sfr. 140'000.- in 1967 and extrapolating on its budget in previous years around Sfr. 160'000.- in 1968. The remaining Sfr. 500'000.- i.e. Sfr. 300'000.- in 1967 and Sfr. 200'000.- in the first half of 1968 must be found elsewhere.

Each group member shall keep account of his spendings and financial commitments, including the material drawn from the stores and services obtained inside CERN. This will be periodically compared to the monthly statements from the Finance Division.

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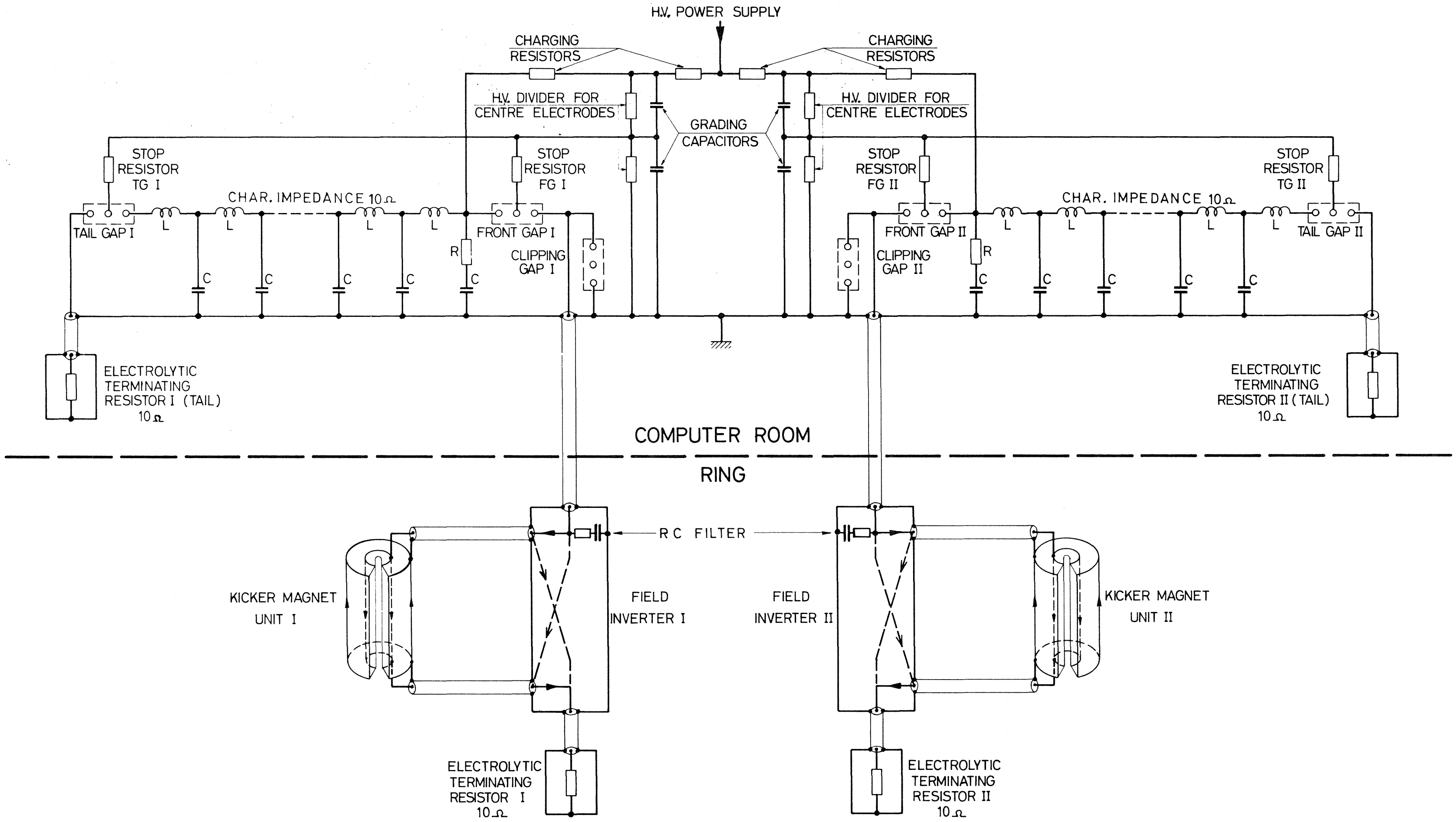

FIGURE 1 SIMPLIFIED DIAGRAM OF THE H.V. PULSE CIRCUITS. The kicker magnet consists of two units, each with a mechanical field inverter, permitting inversion of the current. Each unit is excited by its own line type pulser. The pulse duration can be adjusted by relative timing of front gap, tailgap and clipping gap.

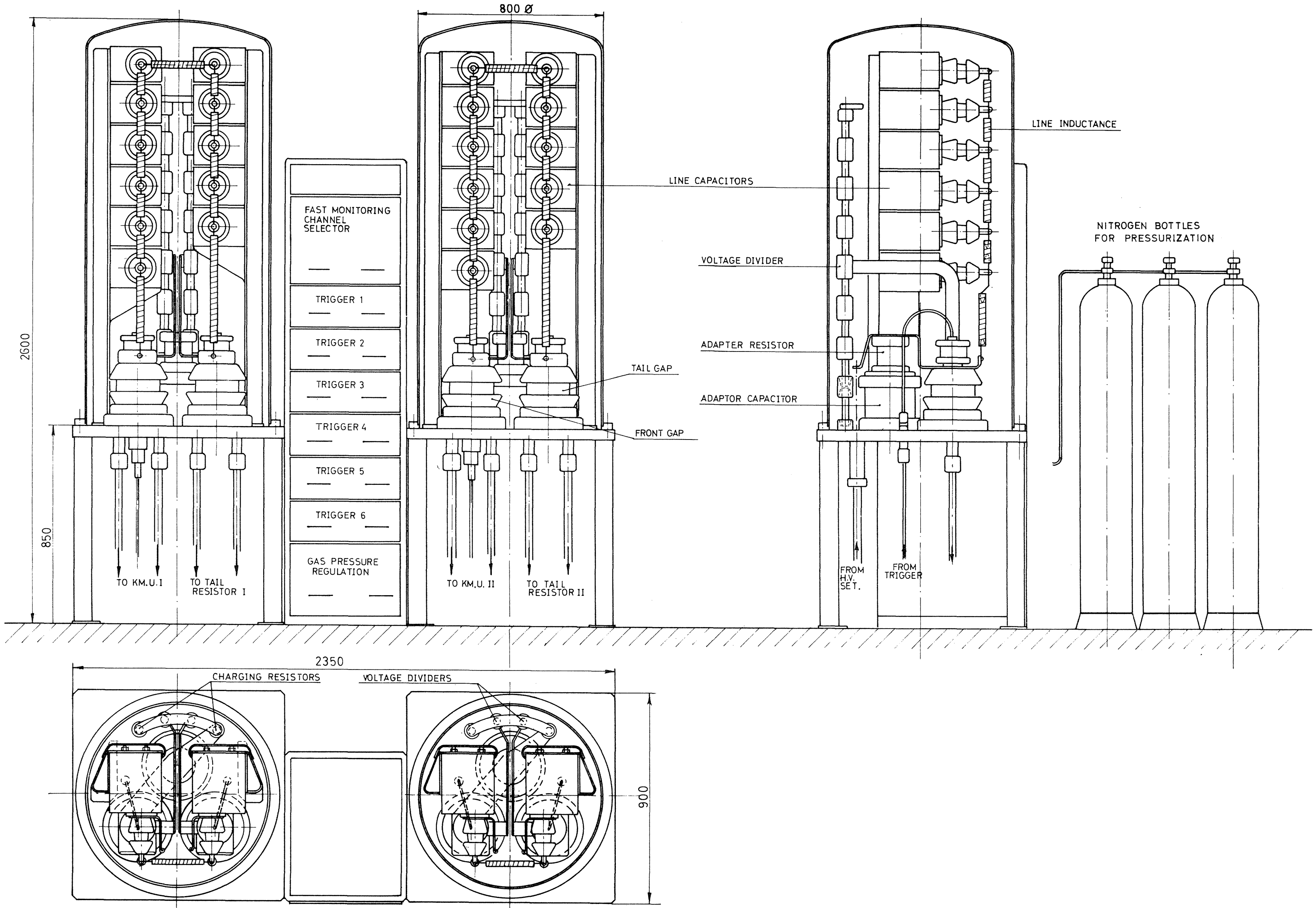

FIGURE 2 ASSEMBLED HIGH VOLTAGE PULSE GENERATORS (Version 1)

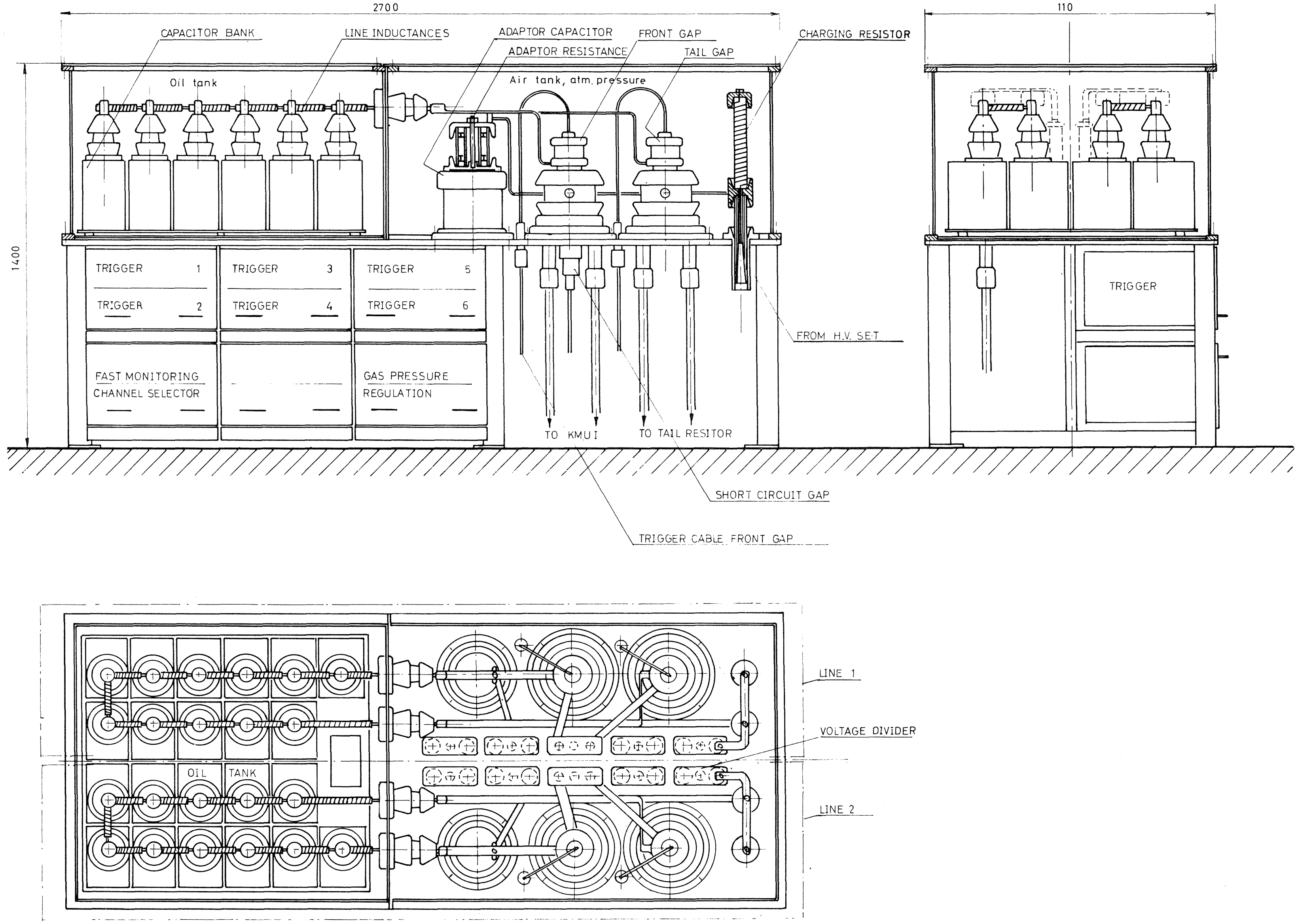

FIGURE 3 ASSEMBLED HIGH VOLTAGE PULSE GENERATORS (Version 2)

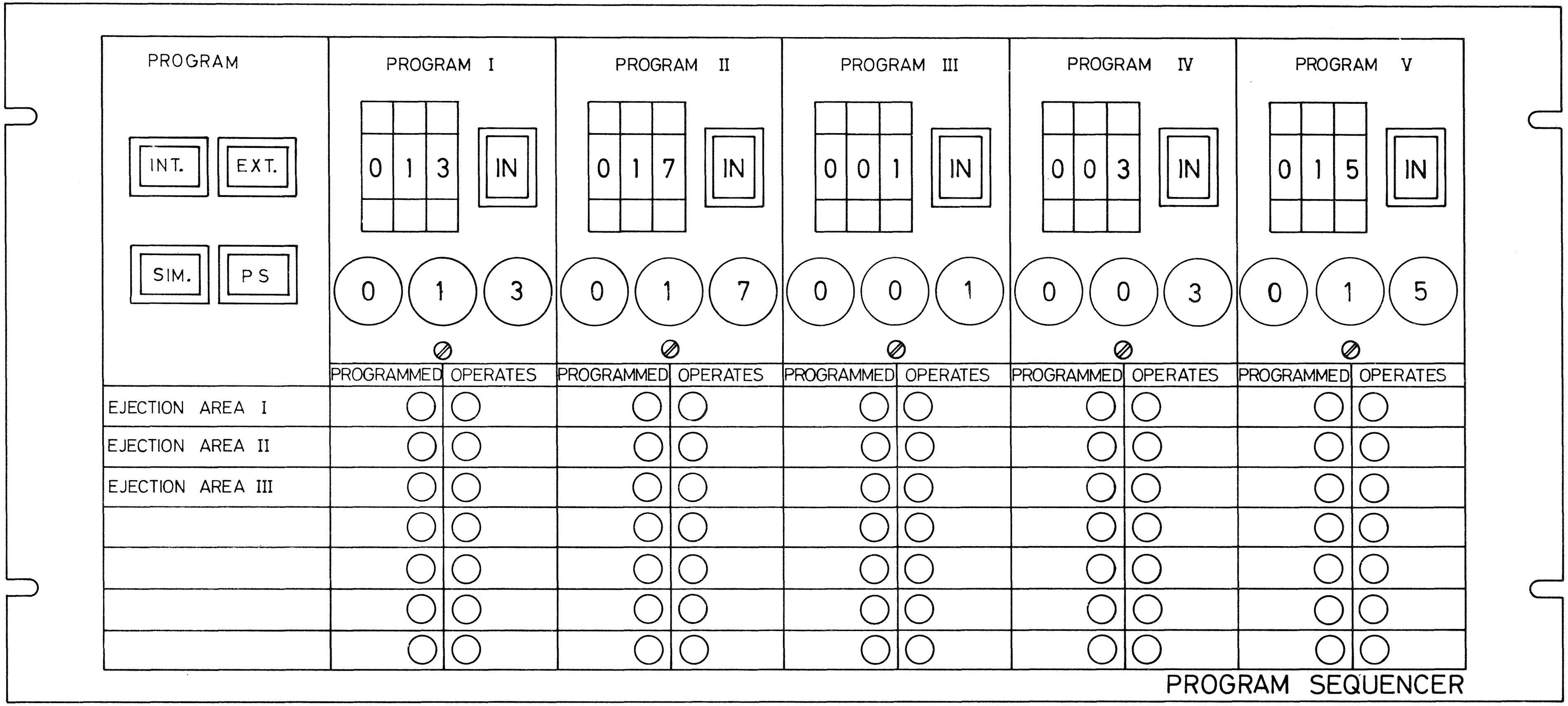

FIGURE 4 PROGRAM SEQUENCER PANEL. Programs I, II, III etc., are repeated a pre-selected number of acceleration cycles, say, 13, 17, 1, etc. Nixies displays counted cycles for each program. After program V has completed its say, 15 cycles, Nixies are re-set and program I starts again. In each program, ejection is switched on with left-hand knob, right-hand light flashes when this actually operates.

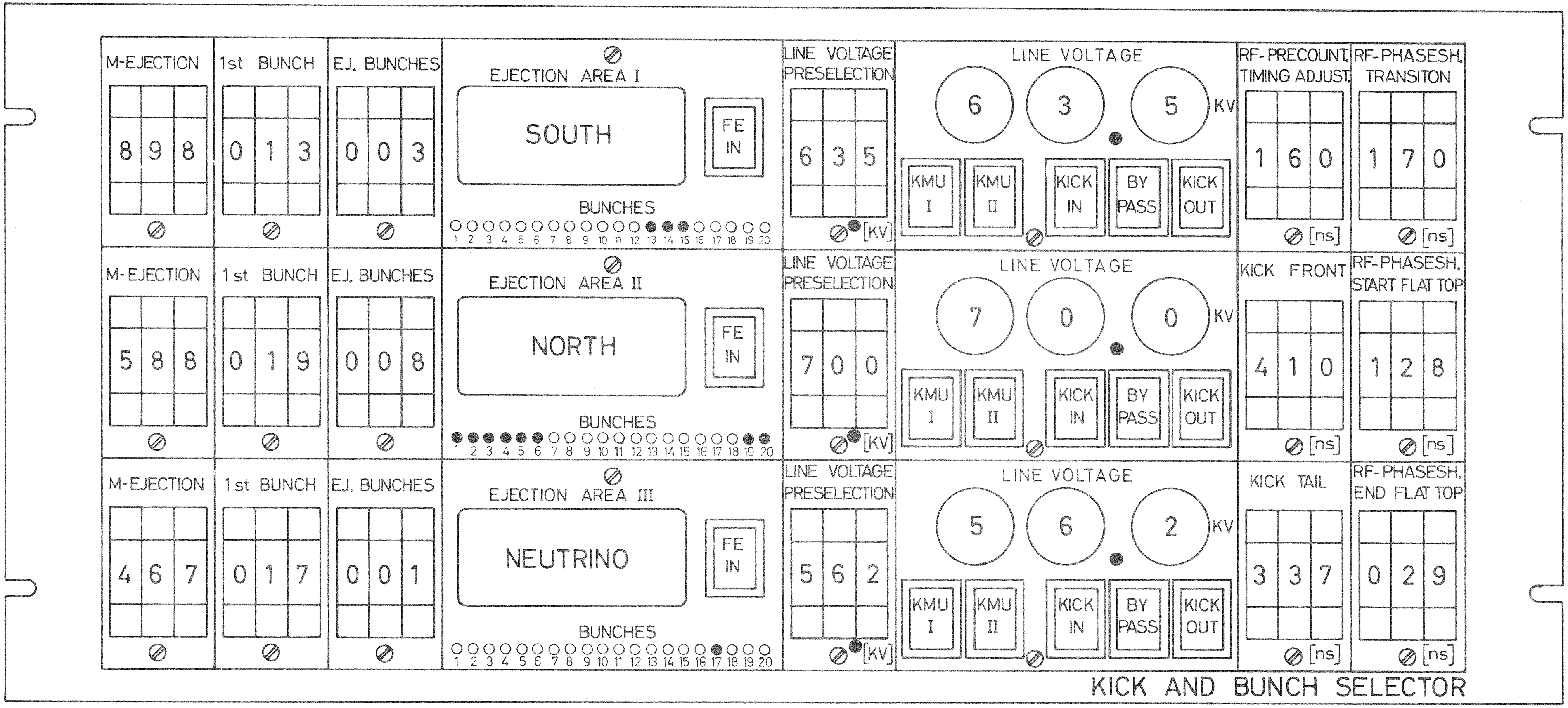

FIGURE 5 KICK AND BUNCH SELECTOR PANEL. First digital switch selects rough ejection timing by M or T Pulse; second digital switch selects first bunch to be ejected, counted from inflector pulse; third digital switch selects number of bunches to be ejected; fourth digital switch selects line voltage; Nixies displays line voltage sampled shortly before ejection; push-buttons under Nixies select one or two line operation and polarity of the kick; further digital switches permit fine time adjustment of front and tail, of kick and compensation for phase-jumps of RF system.

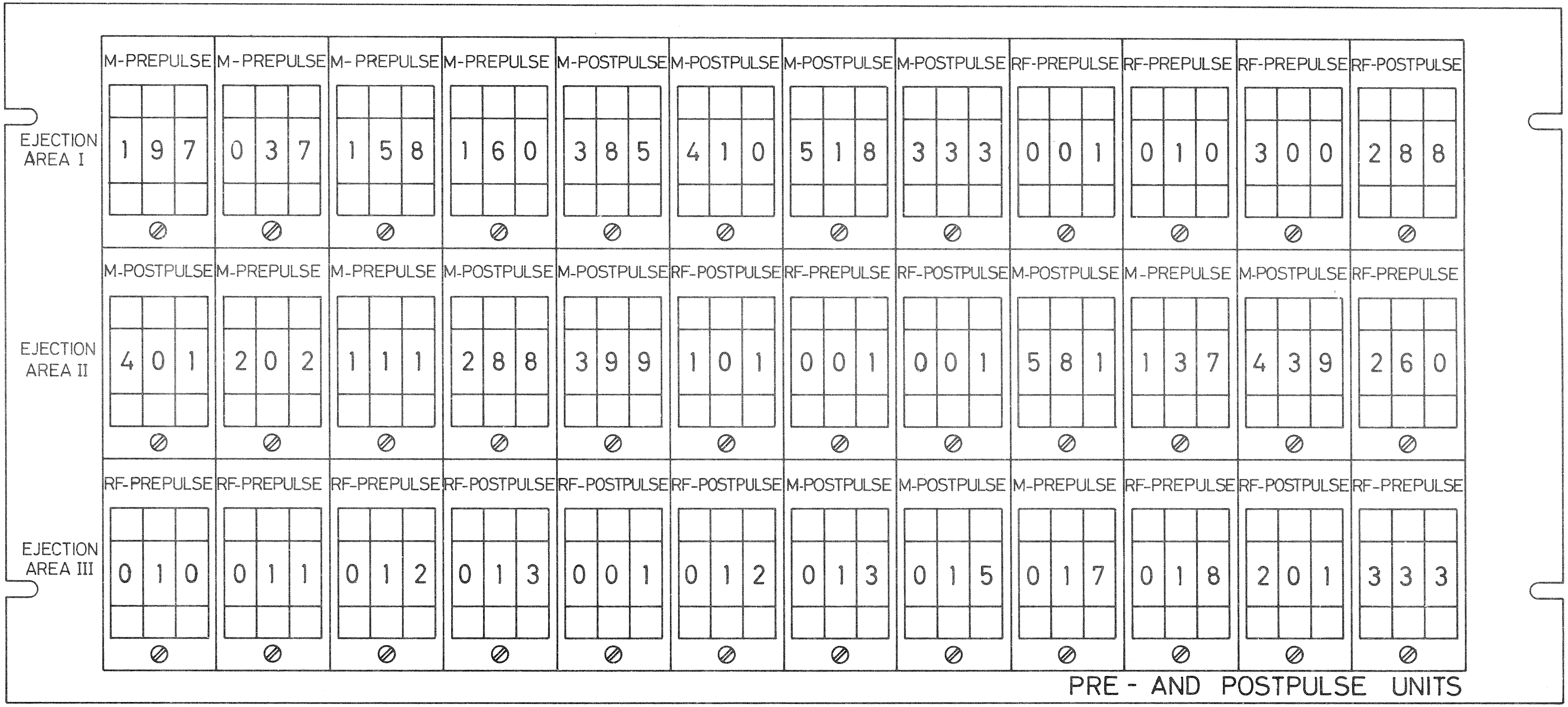

FIGURE 6 PRE AND POST PULSE UNITS. If N is the ejection pulse and n is selected on digital switch, the unit produces a pulse at N-n or N+n depending on whether it is a pre or post pulse unit. Each row refers to the timing of the ejection area in question, as selected on kick and bunch selector panels.

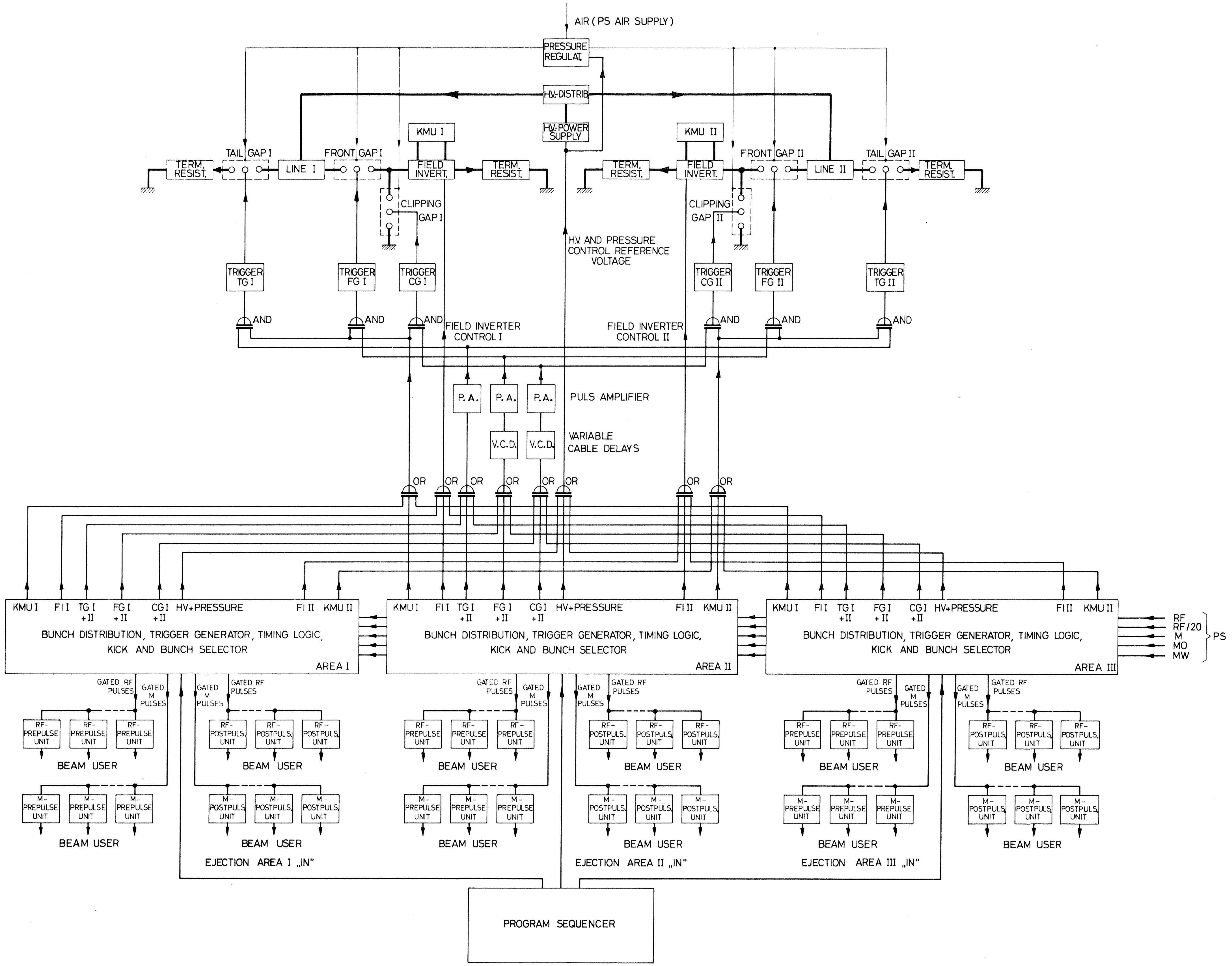

FIGURE 7 BLOCK DIAGRAM OF PROGRAMMING AND TIMING SYSTEM. Program sequencer repeats subsequently programs I, II, III etc., each a pre-selected number of times. In each program, one or more units (for ejection areas 1, 2, 3) of the kick and bunch selector produce the relevant logic signals for one or two line operation, for polarity of the kick, for triggering of the spark gaps and for setting high voltage and pressure of these gaps.

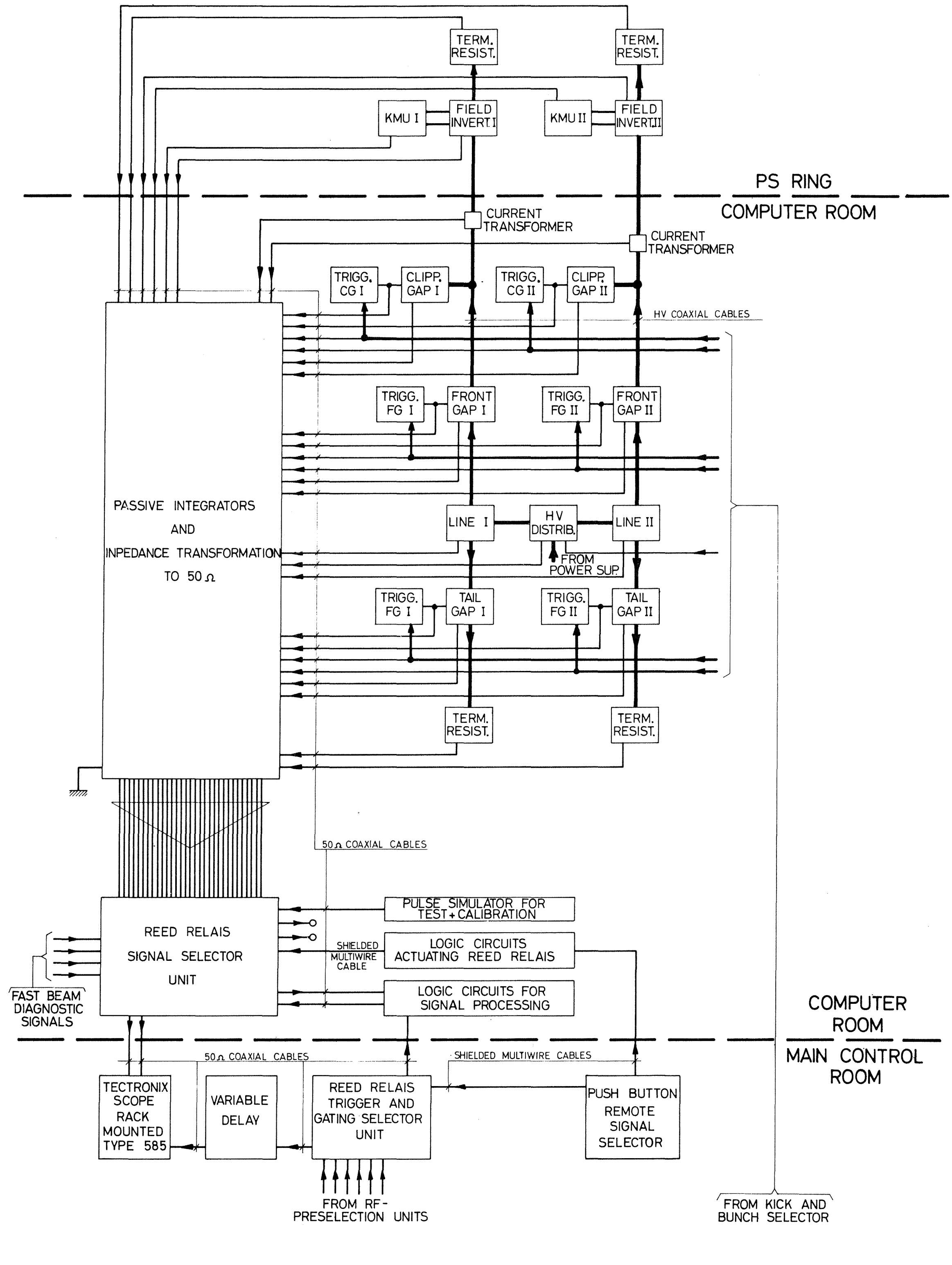

FIGURE 8 BLOCK DIAGRAM OF THE FAST MONITORING SYSTEM.

Pulse signals, in differentiated form, from capacitive or inductive probes, come together in the integrator and impedance transformer box. Reed-Relais in the signal selector unit (operated from remote signal selector panel in M.C.R.) can select two signals to be transmitted to fast scope in M.C.R. Signals are partly in processed form, i.e. sums, differences etc. Their voltages are normalized and delays are automatically compensated for.

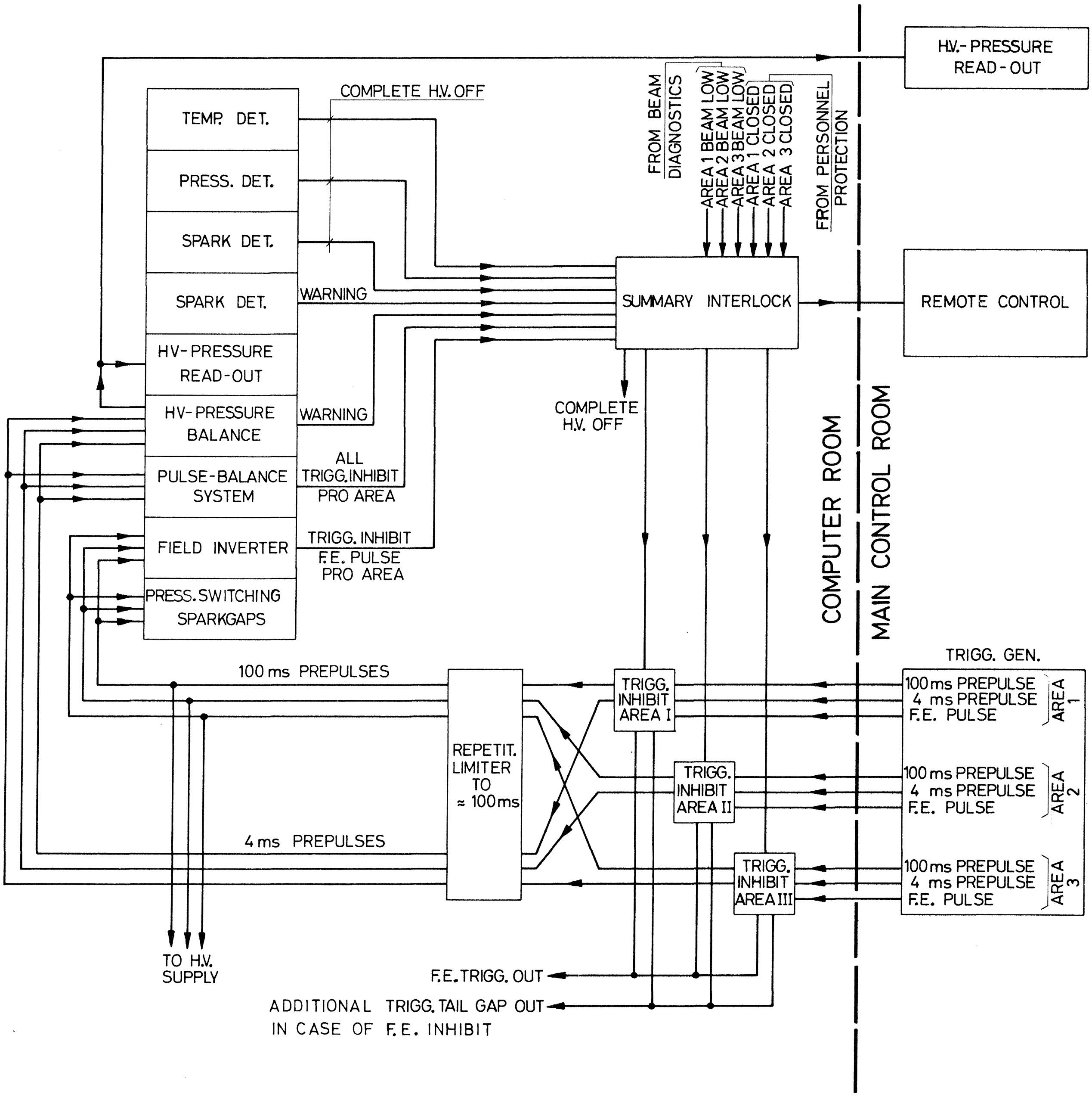

FIGURE 9 BLOCK DIAGRAM OF CONTROLS AND INTER-LOCKS.

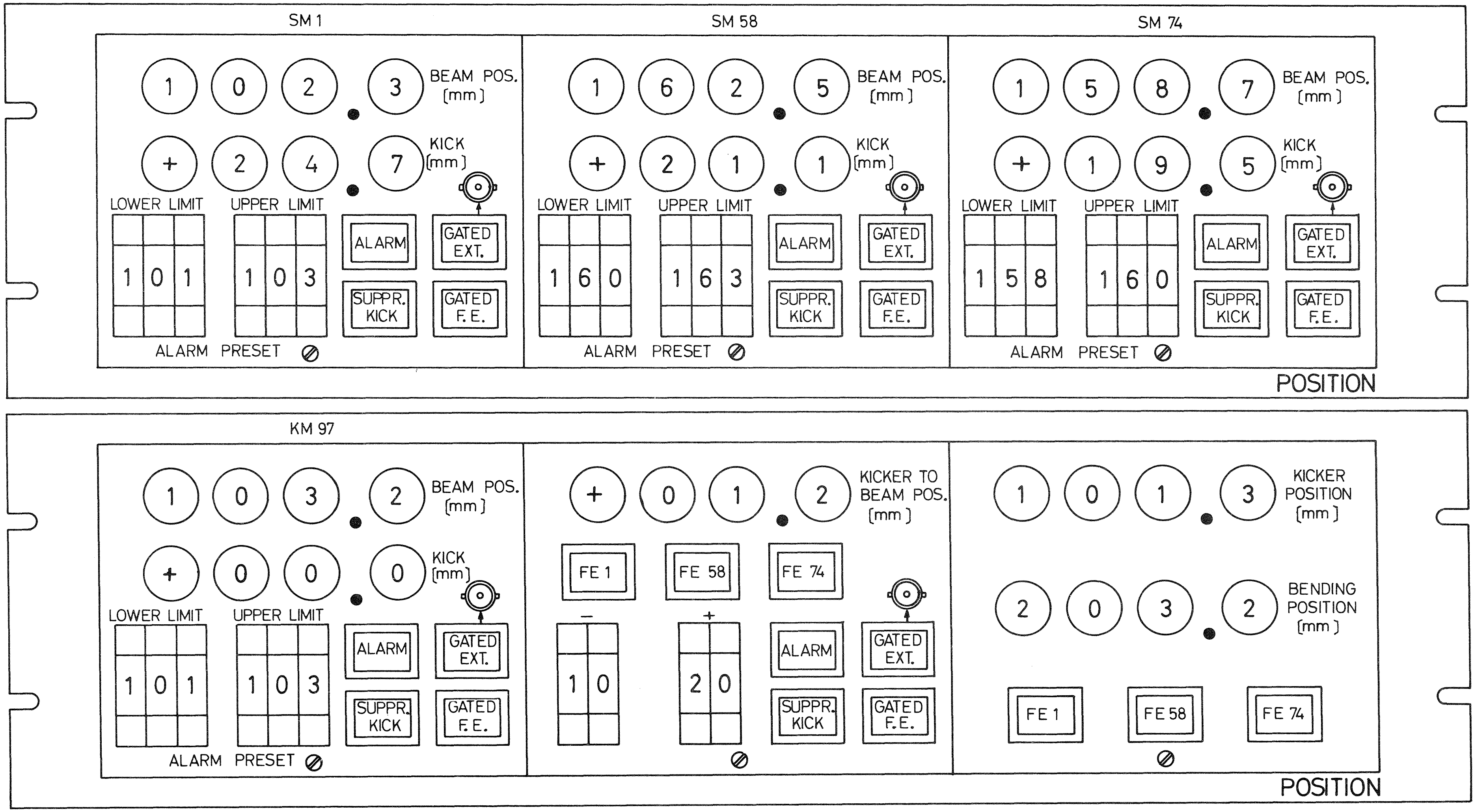

FIGURE 10 BEAM POSITION PANELS contain 4 units giving a digital read-out of the local radial beam position shortly before ejection and the local amplitude of the kicker induced "Betatron" Oscillation. Alarm is given if beam positions exceed pre-selected limiting values. Kick can be inhibited to check zero. The fifth unit displays relative position of beam to kicker magnet and the sixth unit displays absolute position of the two moving magnets. The two latter as well as the beam position unit in SS 97 make their measurement around ejection moment of the chosen channel.

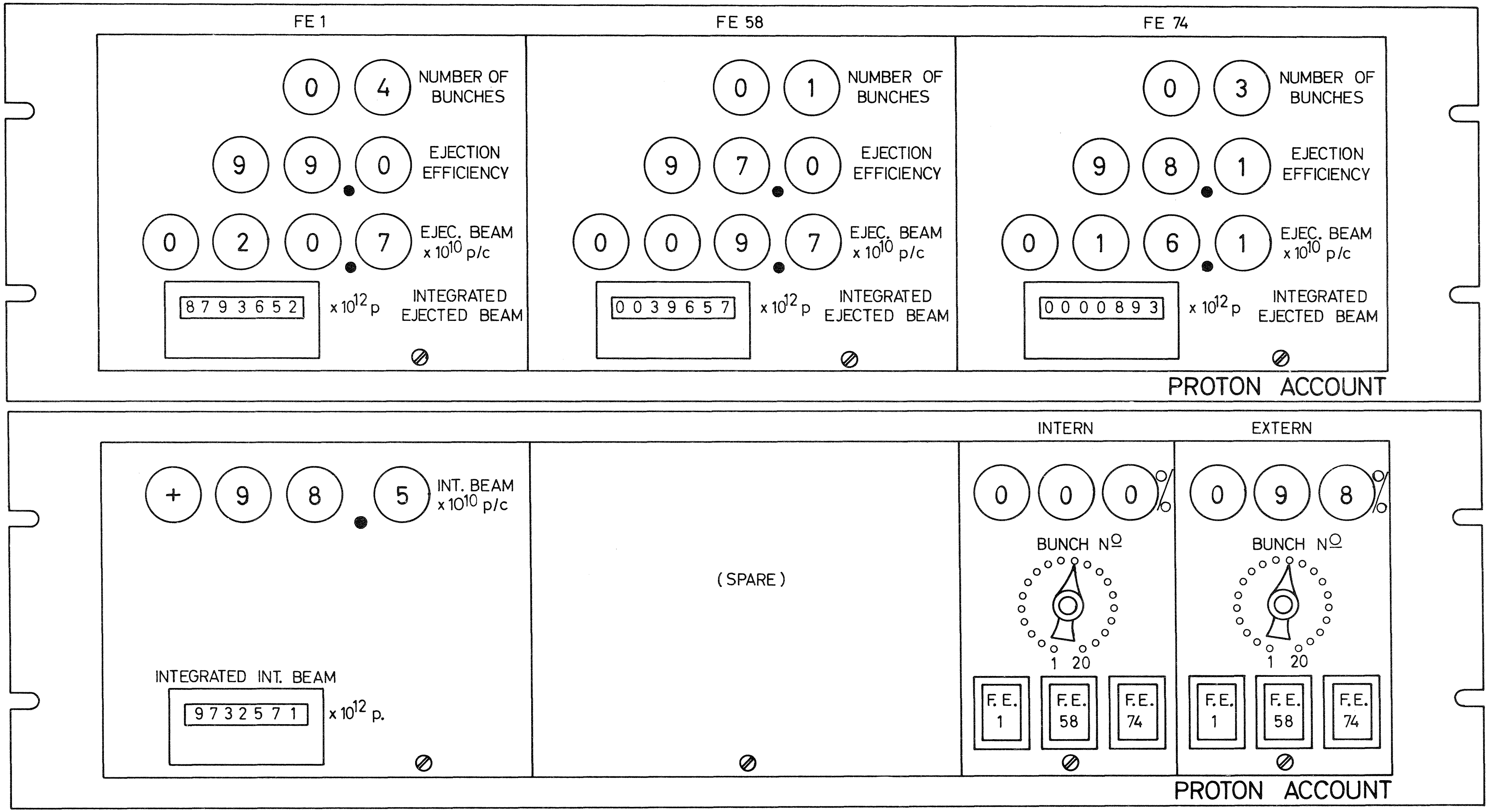

FIGURE 11 PROTON ACCOUNT PANELS. One unit for each ejection area gives digital displays of the number of ejected bunches, the ejection percentage referred to the total beam, the ejection efficiency, the number of ejected protons and the integrated number of ejected protons. A fourth unit gives the internal number of protons as measured early in the acceleration cycle and the integrated internal beam. The two small units give for any chosen bunch, its intensity after the kick as a percentage of its intensity before the kick, either for the internal, or the ejected beam. These units are helpful for fine adjustment of the rise and fall of the kick.

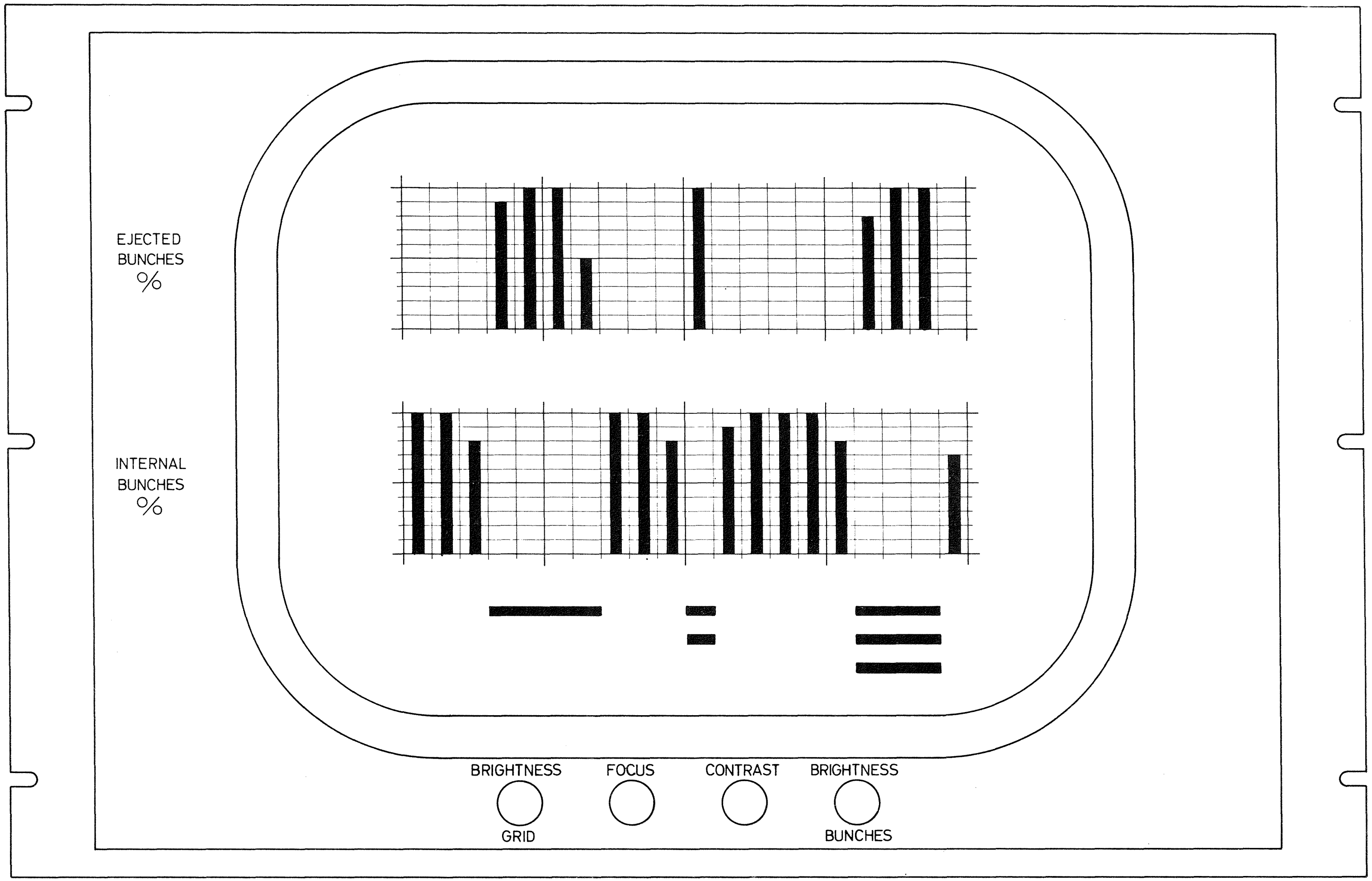

FIGURE 12 ANALOG DISPLAY OF EJECTION EFFICIENCY.

A television tube displays two lines of vertical bars. The height of each bar in the first row gives the intensity of the ejected bunch as a percentage of its value in the machine before the kick. The height of each bar in the second line gives the internal intensity of that particular bunch after the kick as a percentage of its value measured early in the cycle. Each bunch is labelled with the ejection area into which it is kicked.

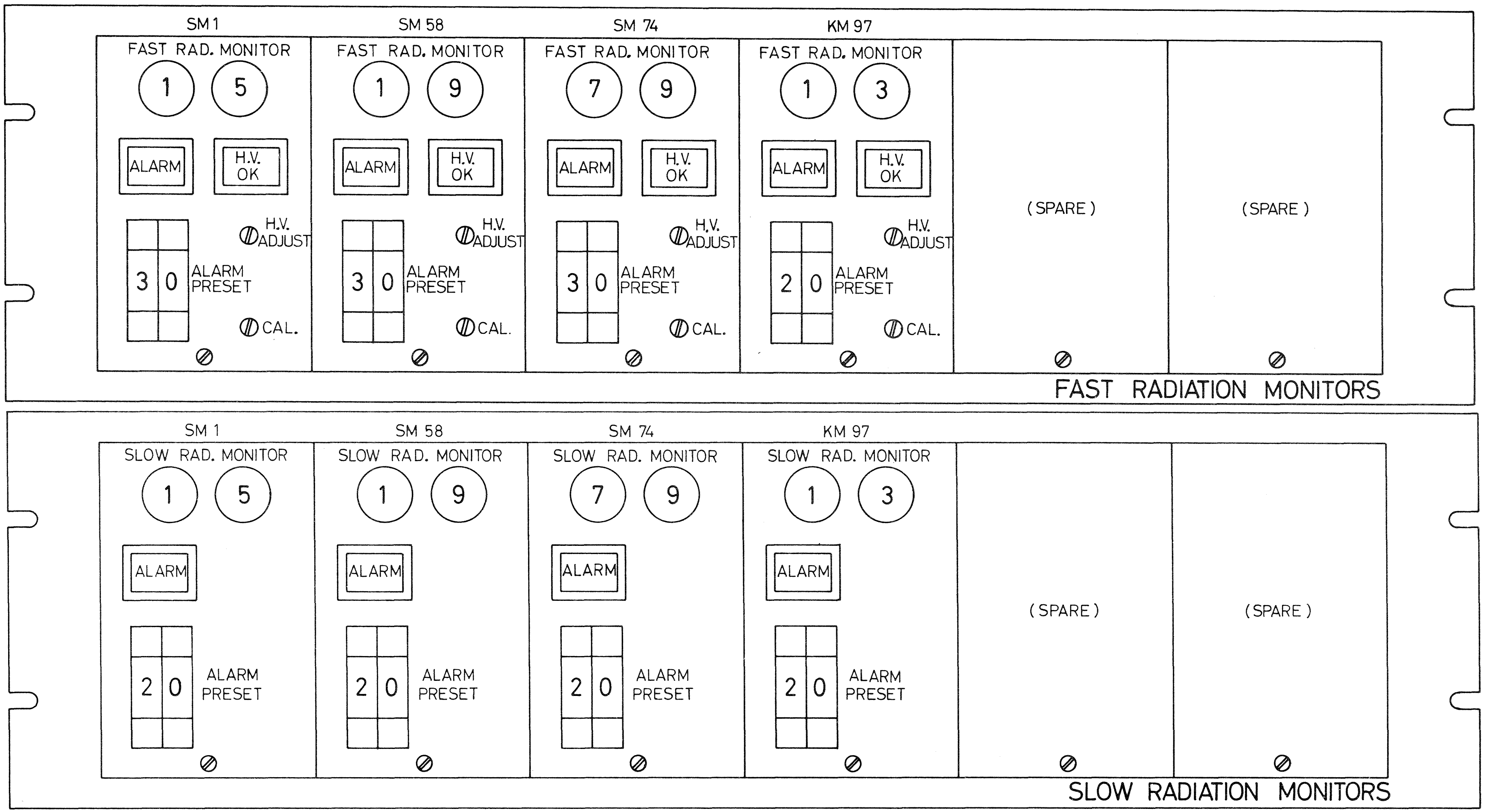

FIGURE 13 RADIATION ALARM PANELS. Each unit gives a digital display of the radiation burst integrated over a typical time around the moment of ejection of the channel in question. Alarm is given if that integral exceeds a pre-set value. The fast radiation monitors react only to bursts of 2µs or less, hence indicate interception of the kicked beam. The slow radiation monitors react only to bursts of the order of 1 ms, hence indicate interception of unkicked beam.

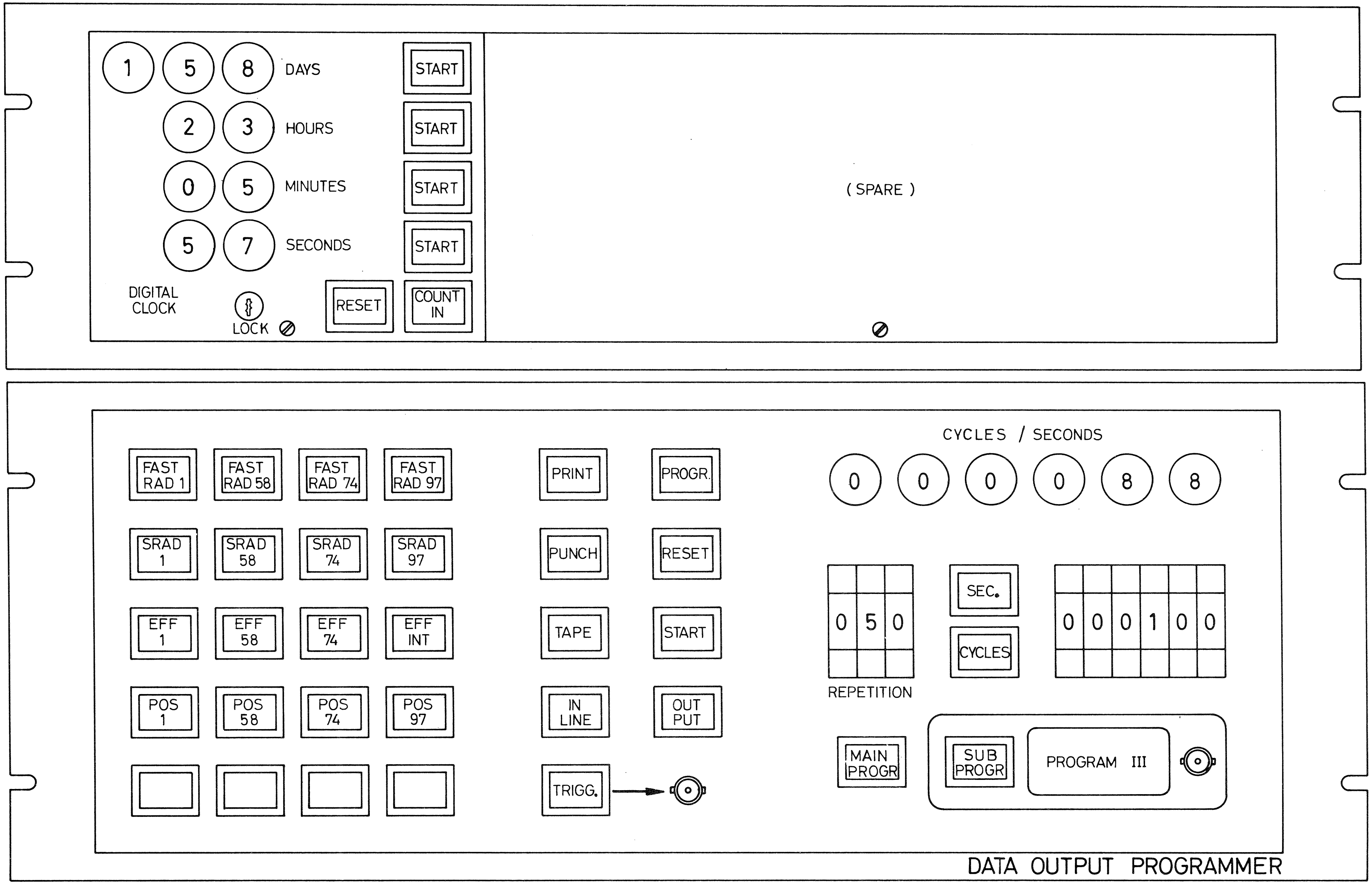

FIGURE 14 DATA OUTPUT SELECTOR PANEL permits a periodic print-out of selected signals either after a pre-selected number of acceleration cycles or after a pre-selected number of seconds from the digital clock.

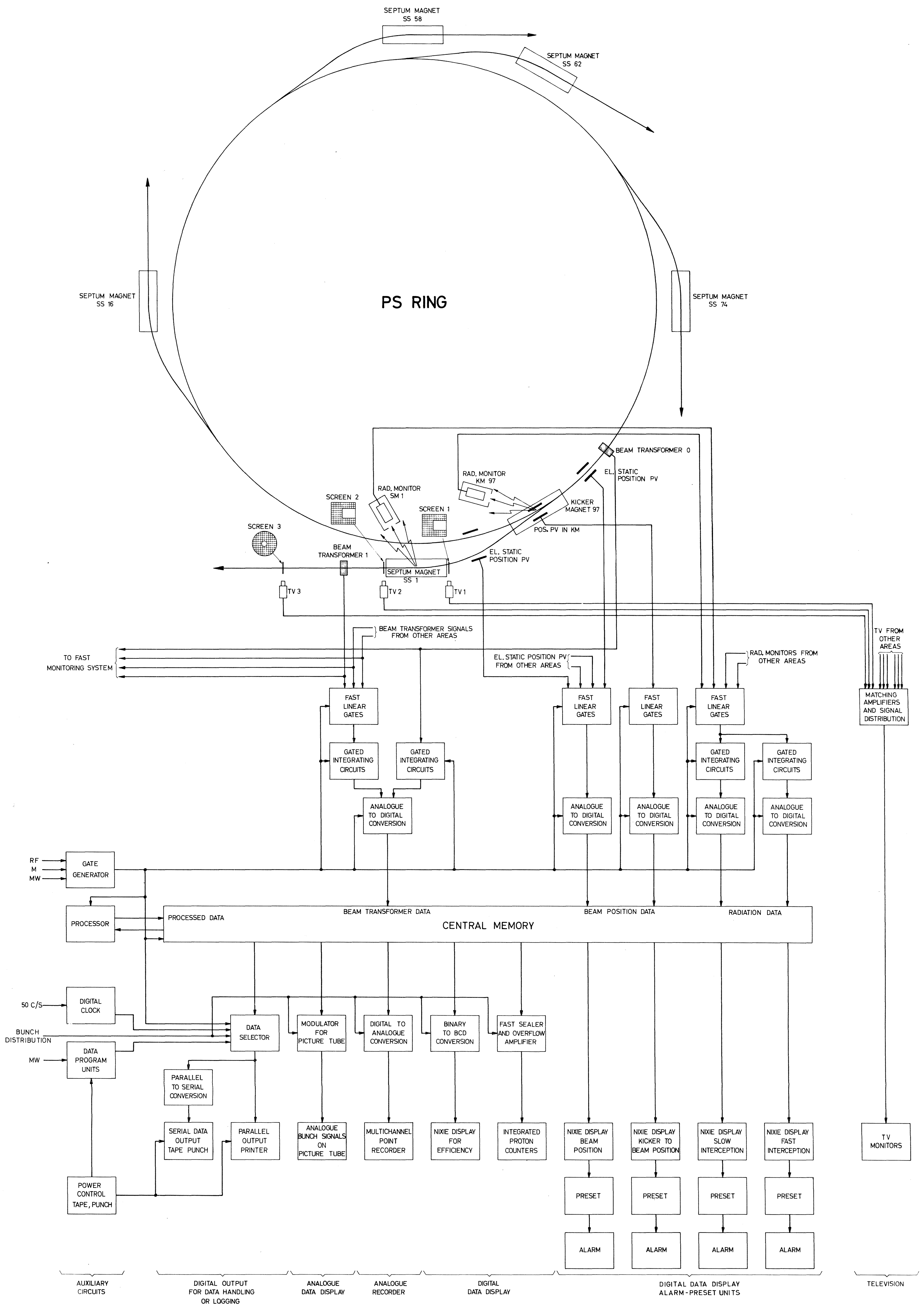

FIGURE 15 BLOCK DIAGRAM OF BEAM DIAGNOSTICS. All measured signals such as beam positions, bunch intensities and radiation bursts, are stored in a central memory after analog to digital conversion. They are partially processed and stored again. They can then be read from the memory to serve for displays, recording or alarm.

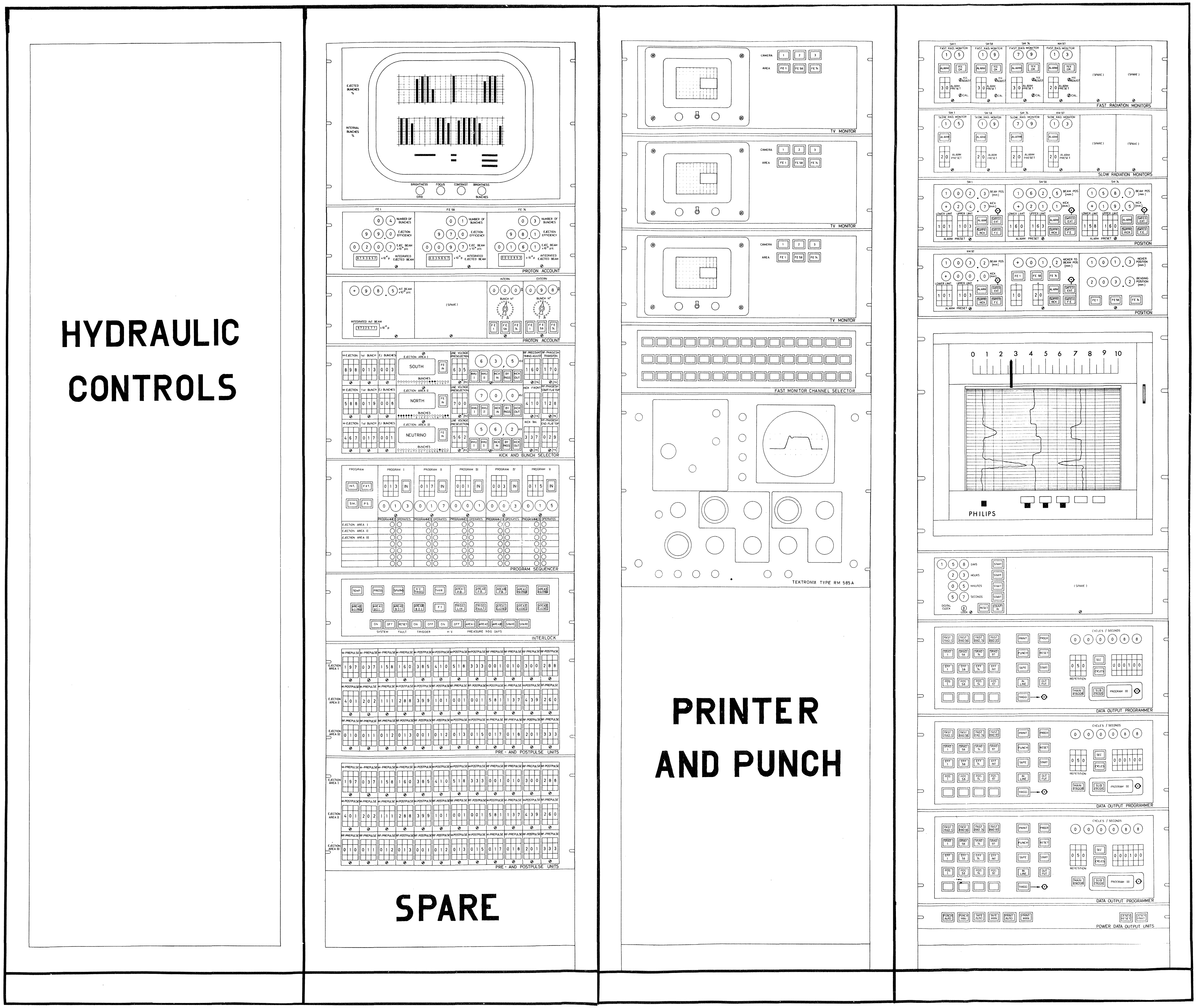

FIGURE 16 ARRANGEMENT OF ELECTRONIC RACKS IN THE M.C.R. The new electronics will fill almost three racks, situated to the right of the controls for the hydraulic actuators.

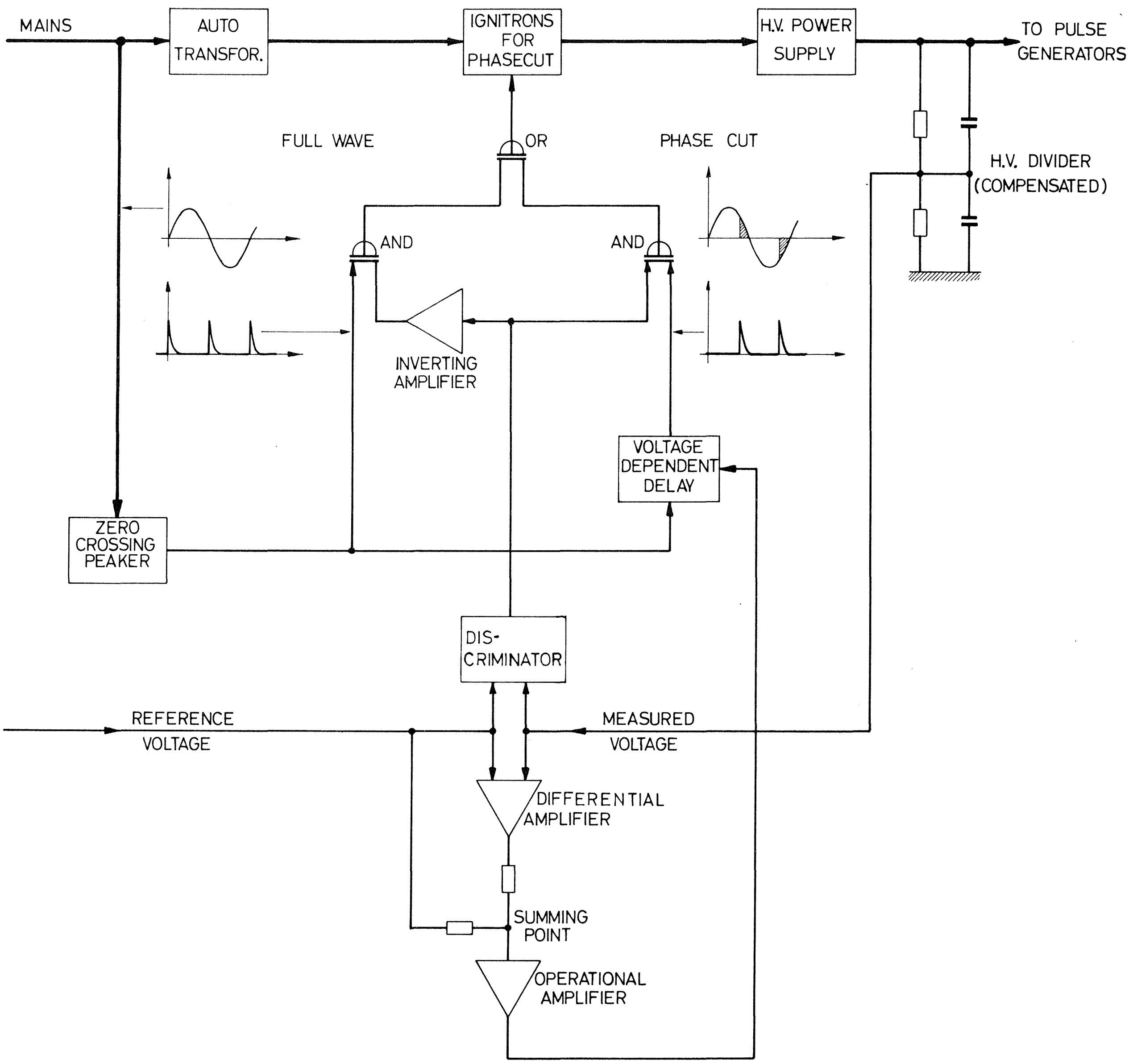

FIGURE 17 PRINCIPLE OF THE H.V. SERVO REGULATION.

Pulses from zero crossing peaker can either trigger the ignitrons directly (full wave) or over a voltage dependent delay (phase-cut). Only one of the two branches transmits, depending on output of discriminator, comparing measured voltage to reference voltage. Trigger jumps from full wave to phase cut when difference voltage is smaller than discriminator level. Voltage dependent delay controls phase cut, hence peak charging voltage. It is controlled by the sum of reference and amplified difference voltage.

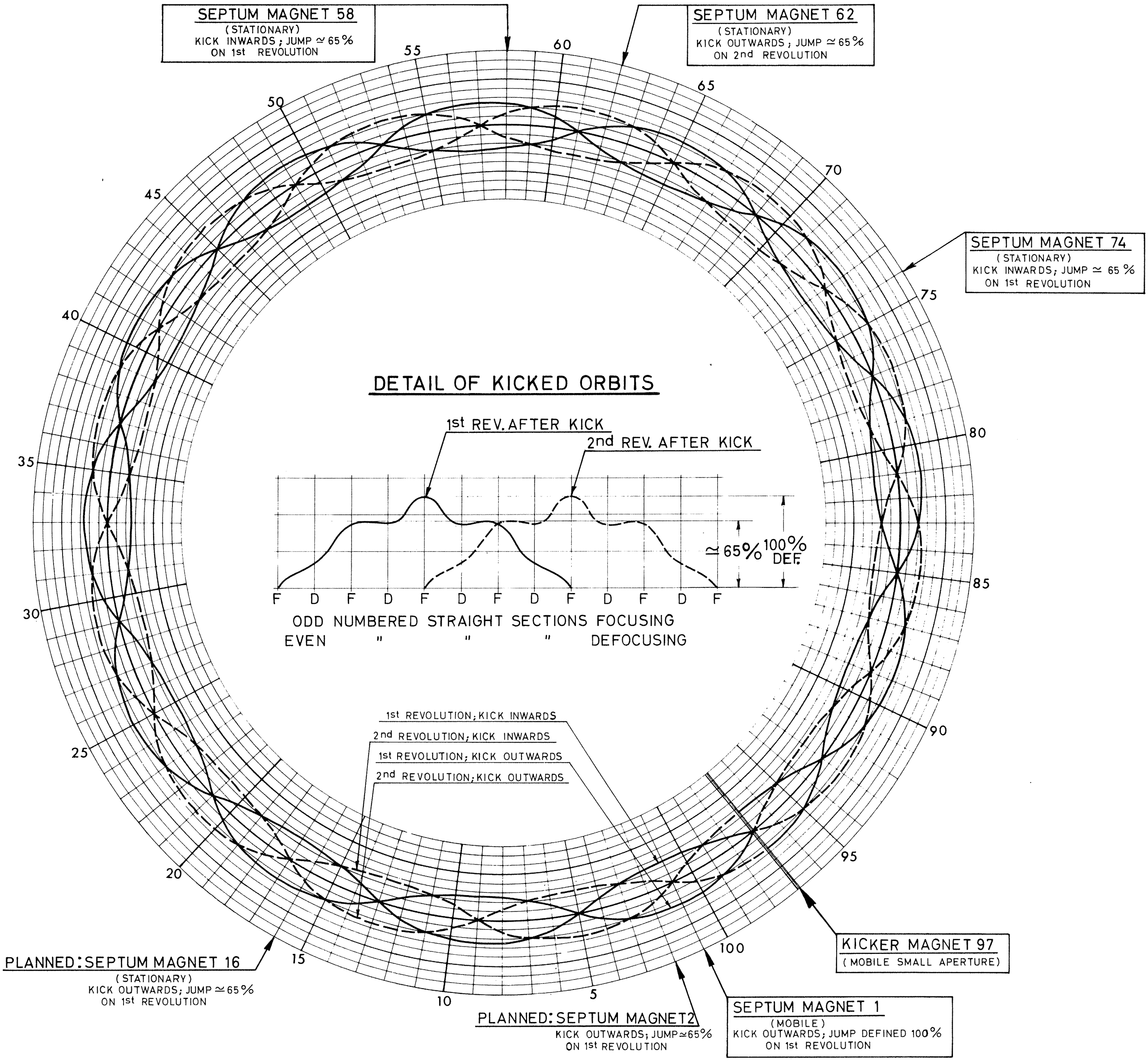

FIGURE 18 TWO TURNS OF KICKED BEAM IN THE CPS.

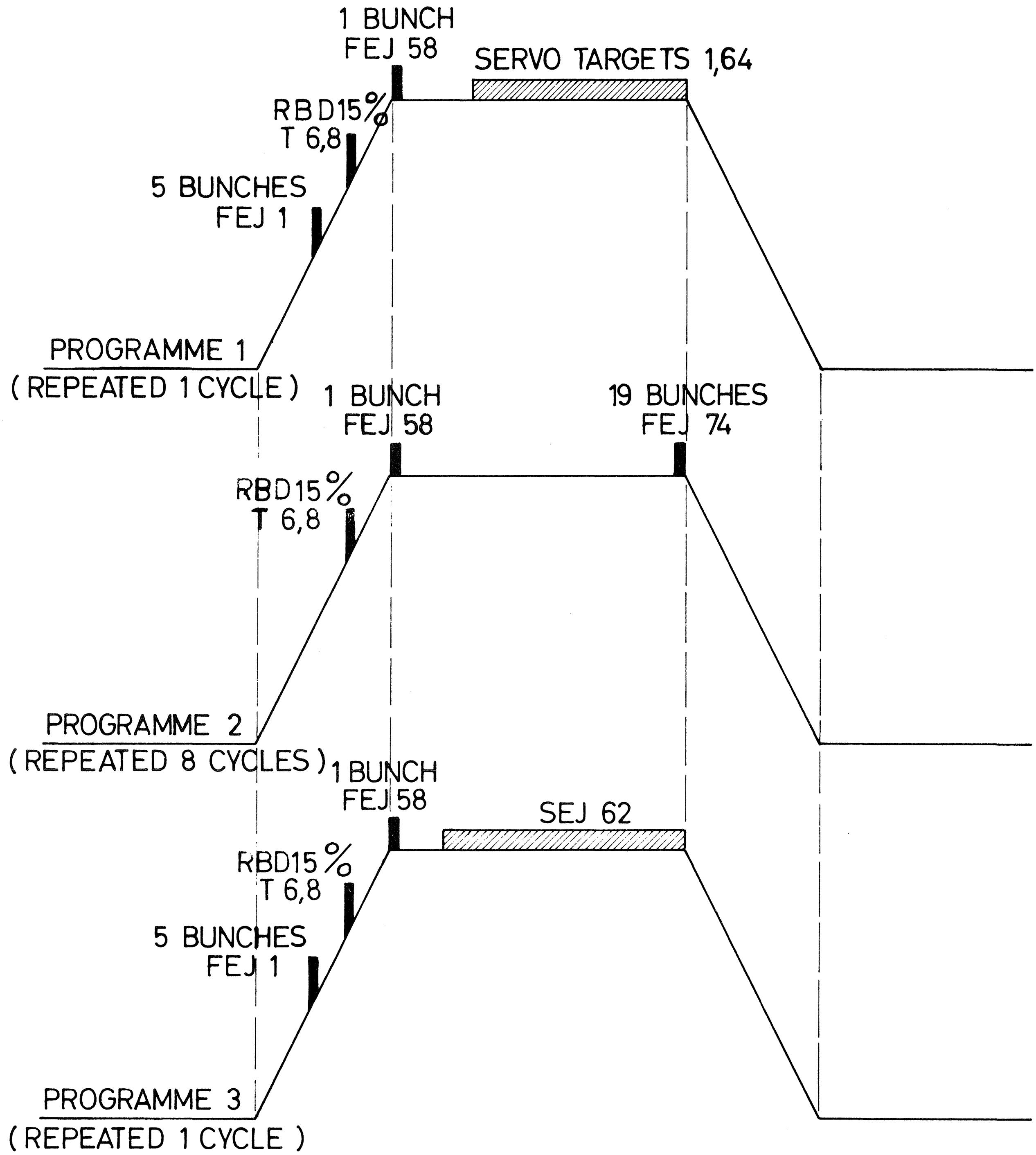

FIGURE 19 AN EXAMPLE OF 'MIXED OPERATION'

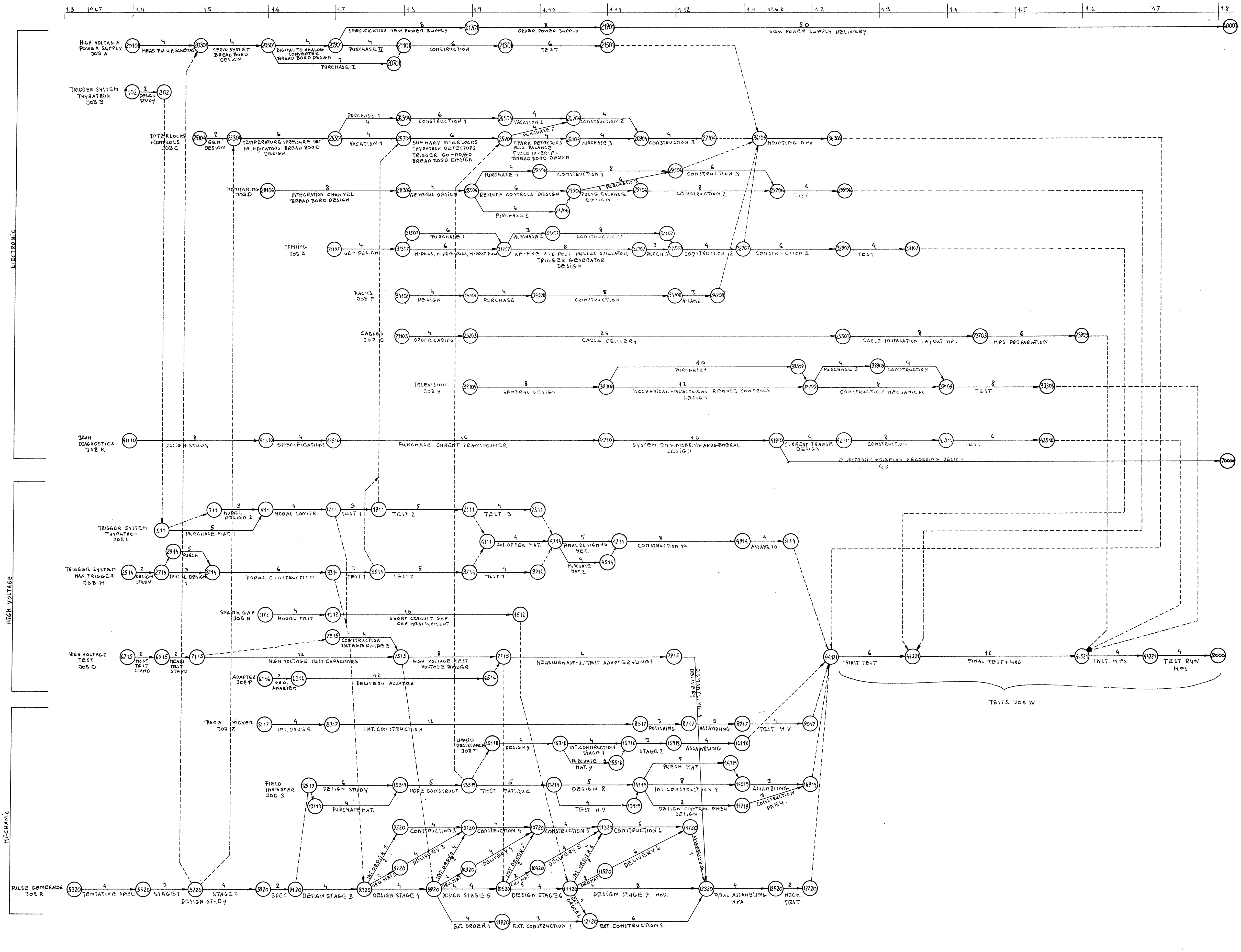

FIGURE 20 TENTATIVE NETWORK PLANNING.

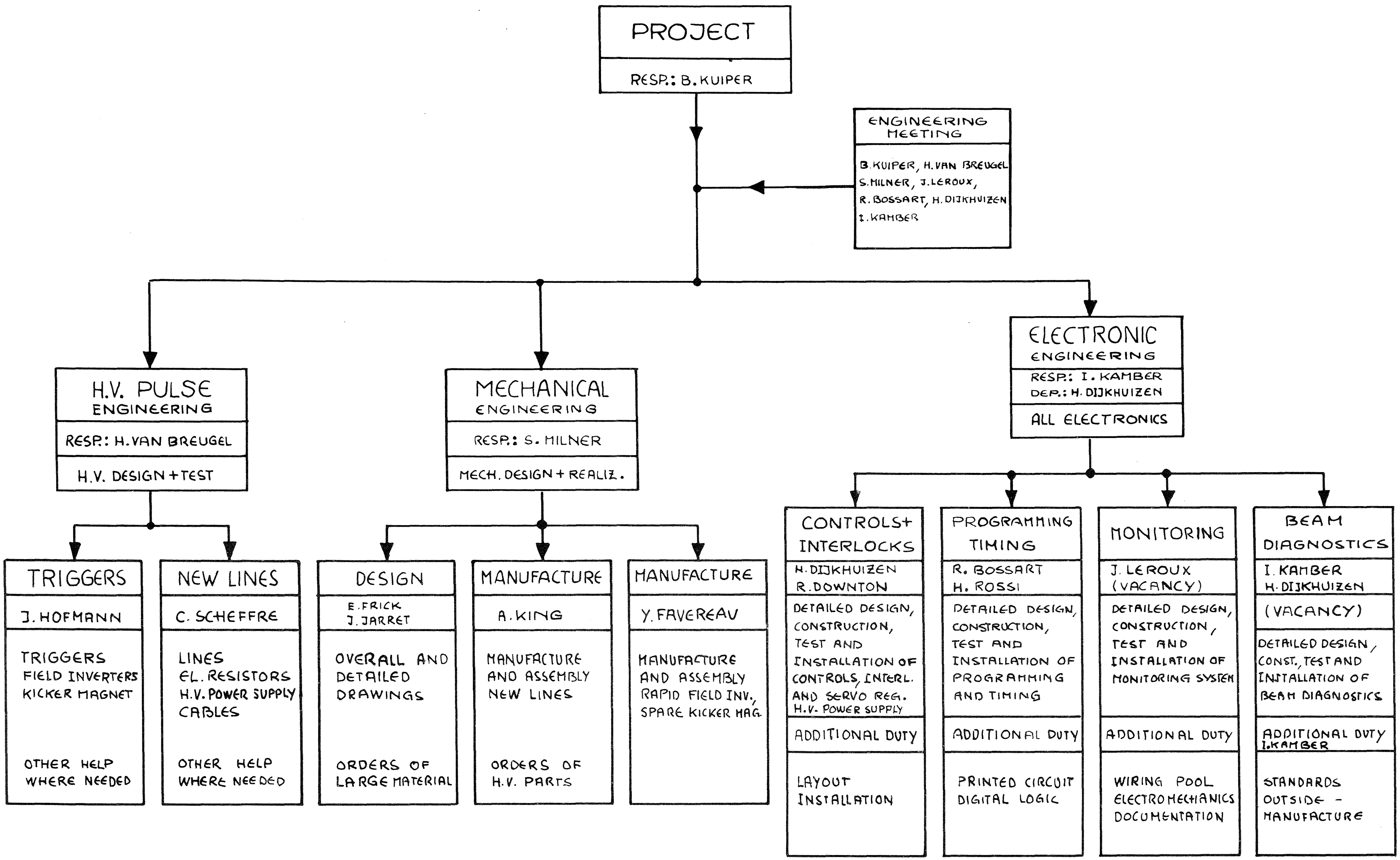

FIGURE 21 PRELIMINARY ORGANOGRAMME (concerns only work on this project)

FIGURE 22 BUDGET FOR NEW FACILITIES AROUND KICKER MAGNET 97

No.	ITEM DESCRIPTION	TOTAL	1967	1968
1.	HIGH VOLTAGE PULSE GENERATORS			
	Spark gaps - pulse forming networks - charging resistors - voltage dividers - H.V. distribution - pressure regulation - rack and drum mounting - man effort	110.000	110.000	-
2.	TRIGGERS			
	Thyratron or Marx assembly - transformers - electronics - effort	90.000	90.000	-
3.	CONTROLS AND INTERLOCKS 1 rack full + effort	50.000	50.000	-
4.	TIMING AND PROGRAMMING			
	Program sequencer + kick bunch selector - pre+ post p.units+effort	65.000	65.000	-
5.	MONITORING			
	Integrators - wide band amplifiers - logic - simulator - effort	45.000	45.000	-
6.	BEAM DIAGNOSTICS			
	Beam transformers - logic - TV - recorder - printer - effort	150.000	50.000	100.000
7.	MODIFICATION H.V. SUPPLY material - effort	15.000	15.000	-
8.	FAST H.V. SUPPLY order	110.000	-	110.000
9.	INSTALLATION I shielded rack mounting - effort	15.000	15.000	-
10.	INSTALLATION II cables etc. - effort	100.000	-	100.000
11.	RESERVE	50.000	-	50.000
	TOTAL	800.000	440.000	360.000
	FINANCING :			
A.	HOPEFULLY IN THE NPA/FE BUDGET	300.000	140.000	160.000
B.	TO BE FOUND (Agreed by P. Germain 14.3.67)	500.000	300.000	200.000