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PSB BEAM OBSERVATION AND MEASUREMENTS

(Status and medium term developments)

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1. INTRODUCTION

The PS instrumentation[1] was reviewed by MAC No. 88 [2]. Within the framework established by this meeting, a detailed review of the PSB aspects is being made to ensure effective implementation of the MAC decisions. To this effect the overall context is recalled. Some technical details are given for items where there is a backlog of reporting or new development results have become available. The emphasis is however on the programme of work for the near and medium term future.

One of the measures taken to ensure the success of the PS Booster was to invest an unusually high amount (∿ 10%) of the total resources in beam observation equipment[3]. Besides proton intensity, proton density, particularly in the longitudinal and vertical planes, was an aim in itself and this partly also influenced the choice of the measurement methods and the equipment. Almost all of this equipment met the performance specifications and is in continued use since[1]. A summary of this use is given in Fig. 1.

Some improvements and additions became necessary because the real needs had initially been underestimated or the original gear did not perform as expected; others resulted from the new uses of the PS as SPS injector and $\bar{p}$ producer. The electrostatic injection line beam position monitors were replaced by magnetic ones, the injection beam current transformer electronics was redesigned, the Ionic Beam Scanners in the ring were replaced by the Beamscope, while the 800 MeV spectrometer proved unnecessary. Additions include: display of calculated Q-values; experimental energy distribution measurements by scanning buckets, cross-checked by Schottky scans; a longitudinal mode analyzer; extra beam position monitors in the Rings (for optimizing injection trajectories) as well as in the 800 MeV lines; and a substantially improved data treatment of the 800 MeV beam position and emittance measurement. An automated measurement of the longitudinal emittance of bunches with any distribution is under development. The definitive design of a beam loss monitor system is progressing. Information gathering from beam response to transverse excitation is planned for the near future .

The latter set up is clearly intended to be used for machine studies. Other diagnostic tools, like the 800 MeV beam position and emittance measurements, are nowadays mainly used for setting up and checks during normal operation. With the experience gained, this difference is more and more reflected in the user-instrument interface: for studies, great flexibility and a wide spectrum of possibilities is often provided (and the resulting complexity of use accepted) whereas for use in operation, limitation to the (standard) job on hand and simple (automatic) control are aimed at.

Another trend is linked with the changing electronics technology. As is well known, in the last decade, inexpensive fast ADCs, sizeable local memories and recently microprocessors have become available. As a consequence, the tendency is to replace specific custom-designed instruments by a distributed multi-purpose data acquisition and treatment system.

The PSB equipment existing or under construction is summarized in Section 2, the evolution of the measurement tasks and instrument developments for the Injection line, the Rings and the Transfer line are described in Sections 3 to 5, the role of the computer is dealt with in Section 6 and the conclusions and the outlook given in Section 7.

2. SYNOPSIS OF PSB BEAM INSTRUMENTATION

The characteristics of this equipment, both existing and under construction, are given in Table 1, together with the names of the persons concerned* and references. Almost all equipment needs some modifications to adapt it to the NORD control system[8,9,10,20,34,40,61]. Additional comments are as follows.

2.1 Injection line

On the whole the instrumentation of this line has by now reached a satisfactory state, at least for linac currents < 100 mA (see Section 3 for the implications of higher beam currents). The exceptions are:

*) The tasks of the MCR linkman are (i) to be a storehouse of information on the measurement system concerned, (ii) to initiate action in case of malfunctioning, including tests, (iii) to sponsor, and in any case to be involved in, indispensable improvements, (iv) to ascertain that the conversion to the NORD system works as specified.

a) *I-TR2 :* it would be very desirable to make digital values available to the NORD system. This would allow computing the transmission efficiency (separately for each part of the linac beam pulse filling a different ring)

$$\eta_{i\ 3,2} = \frac{I_i\ TR3}{I_i\ TR2} \qquad (i = 1,2,3,4).$$

Note that the transmission efficiencies further downstream (and particularly through the distribution) are available, and that measurement of $\eta_{i\ 3,2}$ has also been requested by the OAS (for a later date).

b) *I-U9 :* these four superposed magnetic position monitors are installed very near to I-KS (16L4). The electromagnetic field generated by pulsing I-KS leaks into the magnetic monitors and cannot be eliminated by filtering as it falls in the frequency domain of the beam signal. This perturbation creates an error of up to 3 mm in the apparent linac beam position. Can I-KS (and its power cables) be shielded better ? If not, several "electronic" solutions would be evaluated.

c) *Scrapers :* at present only 18 (out of 34) scraper signals are available in the MCR due to lack of multiplexing channels. The sixteen remaining signals come from scrapers at the exit of the new I-SVs and are observable in the BCER. They will be integrated into the SOS in 1980.

d) *Further beam position monitor :* adding an I-U downstream of DIST, as far as possible without restricting the vertical aperture, may be interesting. A spare electrode with 200 mm diameter and the "half turn" electronics would probably be suitable.

2.2 PSB Rings

The Ring equipment comprises a large variety of devices, which have to cope (in ppm*) with a wide range of beam properties. The trend both towards higher intensity (for SPS and APA) and towards proton density control (for ISR and APA) require further improvements and developments (see Section 4).

As the sophistication of beam diagnostics grew in recent years, the use of the computer became increasingly important (see Section 6). Clearly, these vital measurement tools should be transferred to the new control system from the beginning.

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*) Pulse to pulse modulation, i.e. programmed change of measurement settings from pulse to pulse.

A shortcoming remaining from the past is being removed partly with the provision of one set of PU electrodes (Fig. 2) for measuring injection trajectories by way of injecting half a turn (see also Section 7). - The mean radial position at injection is at present estimated by extrapolating backward in time the analog position signal used for radial beam control.

Apart from a complete overhaul and upgrading of the orbit observation system (see Section 4), the following actions are necessary:

a) *Measurement targets :* after the scheduled overhaul and bench tests, the specified measurement precision of ± 0.3 mm is to be checked in the ring.

b) *New BLMs :* experiments aimed at selecting type and number of detectors as well as their location to continue with appropriately high priority[14].

2.3 Transfer line

The equipment developed for the original tasks gives satisfactory service. A calibration signal for the fast transformers T-TR1 and T-TR2 will be made available and the related NORD software will take advantage of the operational experience[20]. New tasks require further instrumentation (see Section 5).

The 800 MeV emittance measurement (based on three SEMs) is now used routinely in operation

- to measure the transverse beam quality of the recombined beam (e.g. during setting up)
- to monitor this quality (and hence the settings of the recombination part of the 800 MeV transfer line) on parasite cycles.

In contrast, use of the spectrometer (which employs the TS-BH magnet provided for beam dumping) was discontinued, after it turned out that the RF synchronization and the control of the mean radial beam position (via the current through the magnet trim windings) ensure a higher precision of the equality of the mean momentum from ring to ring than can be measured ($\Delta p/p = 10^{-4}$).

3. INJECTION LINE : OPEN POINTS

The emittance and spectrometer lines upstream of the shielding wall can be considered sufficient for Linac beams up to ∿ 75 mA but space-charge effects change these parameters in an increasingly noticeable manner for the more intense, higher density (and more stable) beams from the new Linac.

In the last 40 m of this line no means for measuring beam matching, emittances or energy spread are provided.

a) *Horizontal emittance and matching :* these parameters are crucial for multiturn injection. Should SEM's be added (4 x 3) upstream of the PSB injection point ? (To be considered when effort available.)

b) *Vertical emittance and matching :* somewhat less critical. An indirect measurement is possible via Beamscope (targets) provided the vertical injection steering is properly adjusted (see Sub-section 2.2). Adding SEM's as above may also be interesting*.

c) *Distribution in $\Delta p/p$:* very important for performance (RF trapping, "hollow" ΔE beam, etc.). With the advent of 50 MeV parasite cycles, empty buckets scans or possibly Schottky scans could provide this information (see Sub-section 4.1).

4. PSB RINGS

Apart from higher intensity, one is increasingly interested in the accurate measurement and control of six-dimensional proton distributions.

4.1 New measuring devices already available or under test in ME conditions

a) *Empty bucket scan (EBS) :* because of its comparative speed and relative ease of implementation this method is being used for measuring the energy spectrum of the injected (coasting) beam (Fig. 3a). It is useable even in the presence of some residual beam structure. The main disadvantage is the limited accuracy as the beam is to some extent perturbed by the scanning bucket.

The required detuning of the RF cavity (for low impedance) and the provision of the scanning RF (20 to 70 V at the 5th or 6th harmonic of the revolution frequency) are being readied for single pulse operation in the ppm mode, allowing use of EBS in parasite 50 MeV cycles. - The data treatment is at present done on the DPO (Digital Processing Oscilloscope), but, with additional hardware and software, it could be transferred to the NORD system.

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*) Matching may also be controlled by observing the quadrupolar PU electrode in the ring. Exploratory studies have shown, however, that the signals are rather difficult to interprete.

Observing an empty bucket on a difference (Δ) electrode permits an accurate measurement of the mean magnetic guide field along a closed orbit passing through the centre of the electrode[50] (Fig. 3b).

b) *Longitudinal Schottky Scan (LSS) :* this is the most accurate method for measuring the momentum distribution of a coasting beam (Fig. 4). There are however some limitations, both basic and practical. The basic limitation is that the beam must be completely debunched (i.e. stationary Schottky noise, no structure) before beginning the measurement. This debunching time depends on the intensity of the circulating beam. For a 500 ms debunching time, this limits the intensity to $\sim 2\ 10^{11}$ for an energy spread of ± 160 keV. Beams of higher intensities take longer or may even not debunch at all. On the practical side a suitable high impedance PU electrode is required (obtained for test purposes by resonating the wide band PU electrode with a cable).

Useful results can be obtained with an ordinary spectrum analyzer. This normally implies averaging over a number of pulses in order to obtain a total beam observation time of the order of fifty seconds; hence pulse to pulse jitter cannot be observed.

Much better results, with a time reduced by a factor of perhaps 500, could be obtained (Fig. 4b) with specialized electronics and an FFT device[51] (which could also be used elsewhere). Such an upgrading would presumably in many cases lead to the replacement of EBSs by LSSs.

4.2 Measuring devices in preparation or under study

a) *Transverse RF-knockout :* provides (after digital processing) information about [51]

- distribution of incoherent betatron frequencies (main field of interest for the PSB)
- transverse coupling impedance (natural and total incl. feedback)
- performance of transverse feedback.

Has never been tried in earnest on a bunched beam. Hardware required for experiments is now complete, experiments will be started soon.

b) *Transverse Schottky scan of bunched beams :* provides the distribution of incoherent betatron frequencies folded with squared betatron amplitudes. Has never been tried before. Requires (dedicated) resonant pick-up electrode and electronic suppression of closed-orbit (as in the transverse feedback system), and averaging.

c) *On-line computed Laslett Q-shift :* displays the area occupied in the Q_H/Q_V plane, for instance as an option of the Q-calculation program.

Requires transverse emittances: provided by either

- separate target or Beamscope measurement (∿ 10% losses), or
- automated Beamscope measurement (10% beam loss), or
- automated IBS measurement. (In view of the limited accuracy of, and the idealizations involved in the computation, IBS emittances measured at injection energy might be sufficiently accurate.)

d) *Ring PU electrodes (R-U) :* existing system, although operational, cannot cope with to-day's operation requirements : problems with ppm, dynamic range, measurement channels, etc.

A complete remake of at least the electronics part is proposed for 1981-83, with the following objectives:

- possibility to observe the evolution of closed orbits during all types of PSB cycles
- possibility to observe ½ turn injection trajectories and closed orbits at injection, using all stations (pass band extended to very low frequencies)
- full ppm capability (large dynamic range)
- provision of adequate measurement channels (within same cycle)
- full compatibility with standards of new computer system.

e) *Quadrupolar PU electrode :* such an electrode is used at Saclay to observe the beam blow-up due to a stopband; to be considered for the existing electrode (see footnote page 5).

5. TRANSFER LINE

5.1 Evolution of requirements

Since the construction of the line, several new factors have necessitated a revision or extension of the original instrumentation:

i) continuous operation, requiring monitoring and adjustment of beam parameters, without perturbing the users.

ii) Doubled beam intensity and vertical emittance, requiring more complicated trajectories to improve the acceptance of the line and greater precision of the adjustments in order to maintain a good transmission efficiency.

iii) A new recombination mode for which two beams are superposed vertically, requiring an even more precise adjustment of the trajectories and also a pulse to pulse change of steering and matching.

5.2 Modifications under way

a) *Six new pick up electrodes (Fig. 2) :* to be installed in four locations, in the vertical recombination region of the line. They are similar to those used in the ring for transverse feedback and for ½ turn injection observation. With their improved low frequency response, they do not require any base line restitution, and thus permit simplification of the electronics while improving the quality of the signals. - The other ten electrodes will be replaced or modified to be compatible with the new electronics.

b) *Digitization of PU signals, at present available for some of the existing electrodes :* the new system will cover all the electrodes. This feature is particularly useful in regions where the beam is far displaced from the center, in which case interpretation of analogue signals becomes too inconvenient, due to their intensity dependence.

c) *Provision of beam loss monitors (see point 2.2 c).*

6. ROLE OF THE COMPUTER

As the PSB operates very close to the limits set by collective effects, in particular space-charge, consolidation of the peak performance and further improvements have become increasingly more difficult. They require notably more and more sophisticated instrumentation and adequate computer assistance. In particular, when measuring particle distributions, there is often a base line problem. To obtain the required accuracy, one must extend the measurement over a wide range, resulting in arrays of up to 500 or even 1500 points. The equipment and the computer must be able to handle such arrays with a minimum of fuss.

As the IBM 1800 with its transmission system and the single IMLAC console in the MCR had insufficient capacity for this work, a (temporary) beam measurement computer[62)] (T-BMC, now a NORD 10S), a serial CAMAC loop and two TEKTRONIX 4014 consoles were added[63)]. The two systems are connected via a unidirectional link which enables the IBM 1800 to use the NORD 10 as a slave for data treatment and display.

The general hardware and software layout of the computer assisted measurement systems is shown in Fig. 5, and the layout of the systems directly connected to the NORD 10 in Fig. 6.

Clearly, the upgraded 800 MeV emittance measurement, the definitive Beamscope, the Q-calculation and the automated measurement of the longitudinal emittance of beams with any density distribution could not have been developed and implemented without the T-BMC[64)].

In 1980 all these measurement programs are scheduled to be transferred to the new control system. In that system the Temporary Experiments Computer (TEMPEX) is to take over the task of assisting ad hoc ME set-ups and development of new beam instrumentation.

7. CONCLUSIONS AND OUTLOOK

On the whole the existing beam instrumentation fulfills by now its assigned tasks. In this the T-BMC plays a substantial role. The remaining major shortcoming is the impossibility of measuring accurately the injection trajectories and the mean radial position at injection. This because, to save cost, the orbit observation system was designed for use with a suitably "chopped" (simulating a bunched beam) linac beam but this modulation never materialized. As a first step of remedial action, a set of orbit observation stations with a lower cut-off frequency is being provided. The complete solution has to await the overhaul and upgrading of the entire system. - Provision of a beam loss monitor system will fill another gap.

The major current effort concerns the transfer to the new computer control system. Partly because of obsolescence of the existing electronics, partly because of its incompatibility with the new standards, and partly because of new performance requirements, this adaptation leads to some modifications in most cases, and to extensive modifications in a few cases.

The trends towards higher intensity and proton density control make for refined observation and measurement. This requires further developments like the use of transverse RF-knockout, of scanning buckets and of Schottky scans in the time domain with subsequent Fast Fourier Transform.

A method for measuring accurately but non-destructively the transverse proton distribution remains highly desirable but has not yet appeared. In the mean time, relative measurements with a "calibrated" IBS will be considered.

The technological trend is clearly towards automatic digitization (by means of transient recorders, etc.), data transmission via a general purpose instrument bus and local treatment by microprocessor. It is expected that PSB beam observation and measurement will in due course also benefit from these developments.

Looking further afield, one could think about closed loop control in certain cases once the appropriate digital reference signals available. For instance, when the beam position monitors of the injection and/or the transfer line feed the NORD system with suitable digital position signals, automatic beam position correction for high efficiency beam transmission/ low loss could be envisaged.

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Distribution (open)

MAC

and as requested to Miss M. Innocenti.

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LINAC							
50 MeV measurement line	•		I	I		I	I
INJECTION							
Screens & TV stations	I	I	I				I
Beam current transformers	I	I	I	I			I
Position monitors	I	I	I				I
Beam scrapers	I	I	P				I
Beam loss monitors	F	F					F
RING							
Screens & TV stations	I	I	I				I
Fast beam current transf.	I	I					I
Medium beam current transf.	P	P					
Slow beam current transf.							
β-normalized transf.	I	I					I
PU electrodes	I	I		I	I	P	I
Idem "½ turn inj.	F	F					F
Quadrupolar electrode			P				
Q-calculation		P					P
Q-measurement		I					I
Measurement targets	P	I	I				I
Beamscope	P	P	I				F
Transverse knockout							
Long. wide band electrode				I			
Accelerating frequency meas.						P	P
Long. mode analyzer							
Empty bucket scans, Σ-PU				I		P	
Empty bucket scans, Δ-PU					I		
Long. Schottky scans				I			
Beam loss monitors	F	F	P_F				F
TRANSFER							
Screens & TV stations	NOT CONCERNED						
Beam current transformers							
Position monitors							
800 MeV measurement line							
Beam loss monitors							
GENERAL FACILITIES							
On-line data processing			I	I	I	I	I
Off-line data processing		I	I	I			
Transient digitizer	I	I	I				I
Spectrum analyzer				I	I	I	
Network analyzer		F					

Beam observation systems	RING: Transverse emittance	Closed orbit correction	Stop band compensation	New working point	Transverse damping studies	Transv. coupling impedance	Incoherent ε-tron frequencies	Longitudinal emittance	Beam control studies	Longitudinal damping	Longitudinal coupling imp.	Beam loading compensation	Fast acceleration	Normal operation
LINAC														
50 MeV measurement line														
INJECTION														
Screens & TV stations	INJECTION ALREADY ADJUSTED													
Beam current transformers														
Position monitors														
Beam scrapers														
Beam loss monitors														
RING														
Screens & TV stations														I
Fast beam current transf.													P	I
Medium beam current transf.	i		i	i	i		p'						P	P
Slow beam current transf.	i		i	i	i								P	i
β-normalized transf.	I		I	I	I		p'	I	I	I	I	I	I	I
PU electrodes		I			I								I	I
Idem "½ turn inj.		P_F												F
Quadrupolar electrode			f											
Q-calculation	P	P	I	I	I								P	I
Q-measurement	I	I	I	I	I								I	I
Measurement targets	I		I	I									I	I
Beamscope	I		I	I									F	F
Transverse knockout			F	F	F	F	F							F
Long. wide band electrode								I	I	I	I	I	I	I
Accelerating frequency meas.	f		f	f	f	f	f		I			I	I	I
Long. mode analyzer									I	I	I		P	P
Empty bucket scans, Σ-PU								I						F
Empty bucket scans, Δ-PU														
Long. Schottky scans								I					F	F
Beam loss monitors			F	F	P									F
TRANSFER														
Screens & TV stations														
Beam current transformers														
Position monitors														
800 MeV measurement line	P		P											
Beam loss monitors														
GENERAL FACILITIES														
On-line data processing	I	I	I	I	F	F	F	F	I	F				I
Off-line data processing	I	I	I	I	I		I	I		I	I		I	I
Transient digitizer							F							I
Spectrum analyzer					I									
Network analyzer			F	F	F	F	F		F					

Beam observation systems	TRANSFER: Beam ejection	Recombination 10 bunches	Recombination 20 bunches	Transverse emittance	Beam matching 10 bunches	Beam matching 20 bunches	Kicker performance	Normal operation
LINAC								
50 MeV measurement line								
INJECTION								
Screens & TV stations	INJECTION ALREADY ADJUSTED							
Beam current transformers								
Position monitors								
Beam scrapers								
Beam loss monitors								
RING								
Screens & TV stations	I							I
Fast beam current transf.	RINGS ALREADY ADJUSTED							
Medium beam current transf.								
Slow beam current transf.								
β-normalized transf.								
PU electrodes								
Idem "½ turn inj.								
Quadrupolar electrode								
Q-calculation								
Q-measurement								
Measurement targets								
Beamscope								
Transverse knockout								
Long. wide band electrode								
Accelerating frequency meas.								
Long. mode analyzer								
Empty bucket scans, Σ-PU								
Empty bucket scans, Δ-PU								
Long. Schottky scans								
Beam loss monitors	F							F
TRANSFER								
Screens & TV stations	I	I	I					I
Beam current transformers	I	I	I	i				I
Position monitors	I	I	I				P	I
800 MeV measurement line		I	I	I	I	I	P	I
Beam loss monitors	F	F	F				F	F
GENERAL FACILITIES								
On-line data processing		I	I	I	I	I	P	I
Off-line data processing	P				P	P	P	
Transient digitizer	I	I	I				I	I
Spectrum analyzer								
Network analyzer								

FIG. 1 - USE OF PSB BEAM OBSERVATION EQUIPMENT

I = in use; i = in auxiliary use; P = use possible; p' = auxiliary use possible; F = future use; f = future auxiliary use.

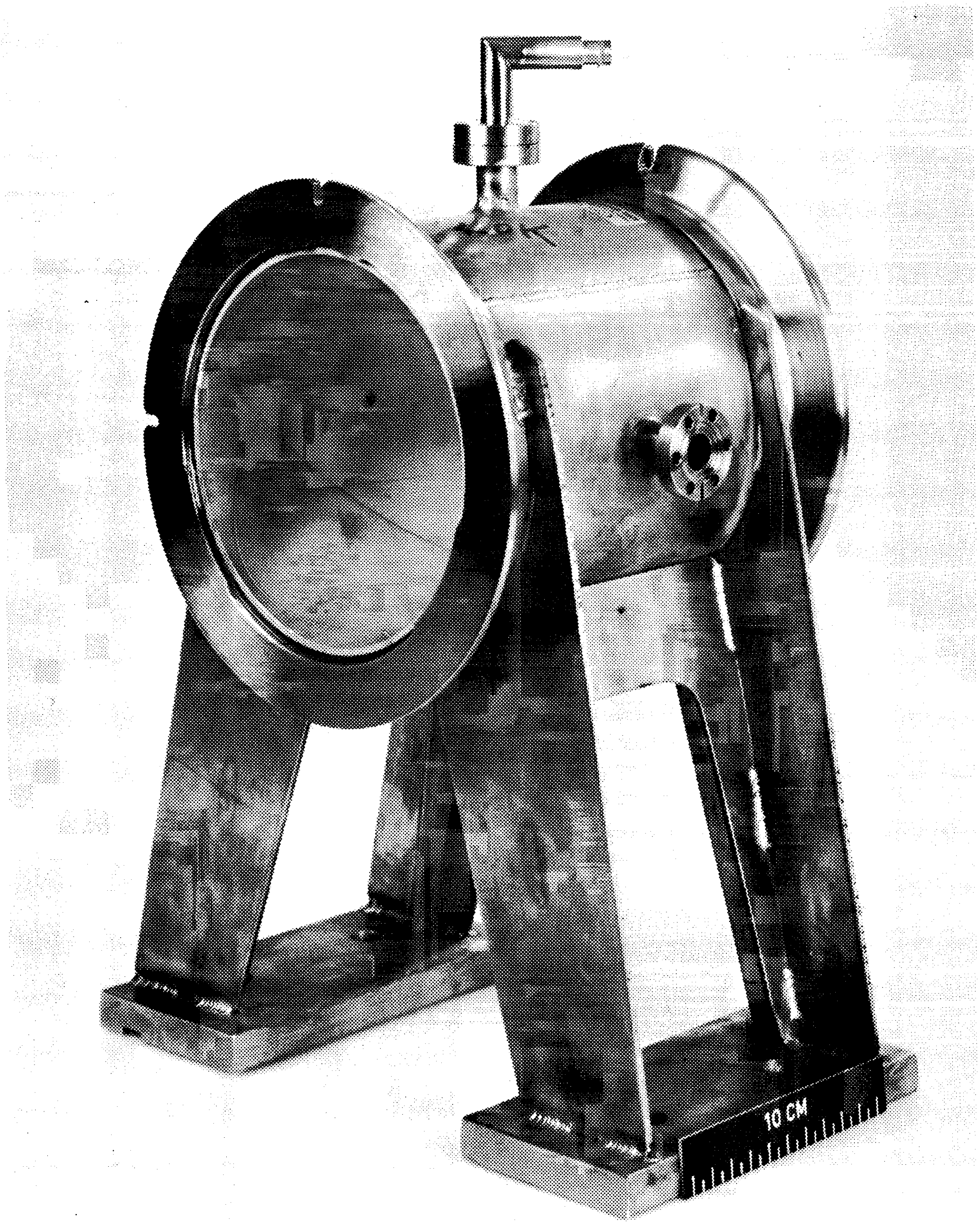

Figure 2 - New PSB (type F) pick-up electrode (electrostatic beam position monitor) and standard support, to be used for the measurement of injection and transfer trajectories as well as in the transverse active damping system. Single electrodes will be mounted in the position shown ; in the case of stacked electrodes the assembly will be rotated through 90° and attached to a common vertical pillar.

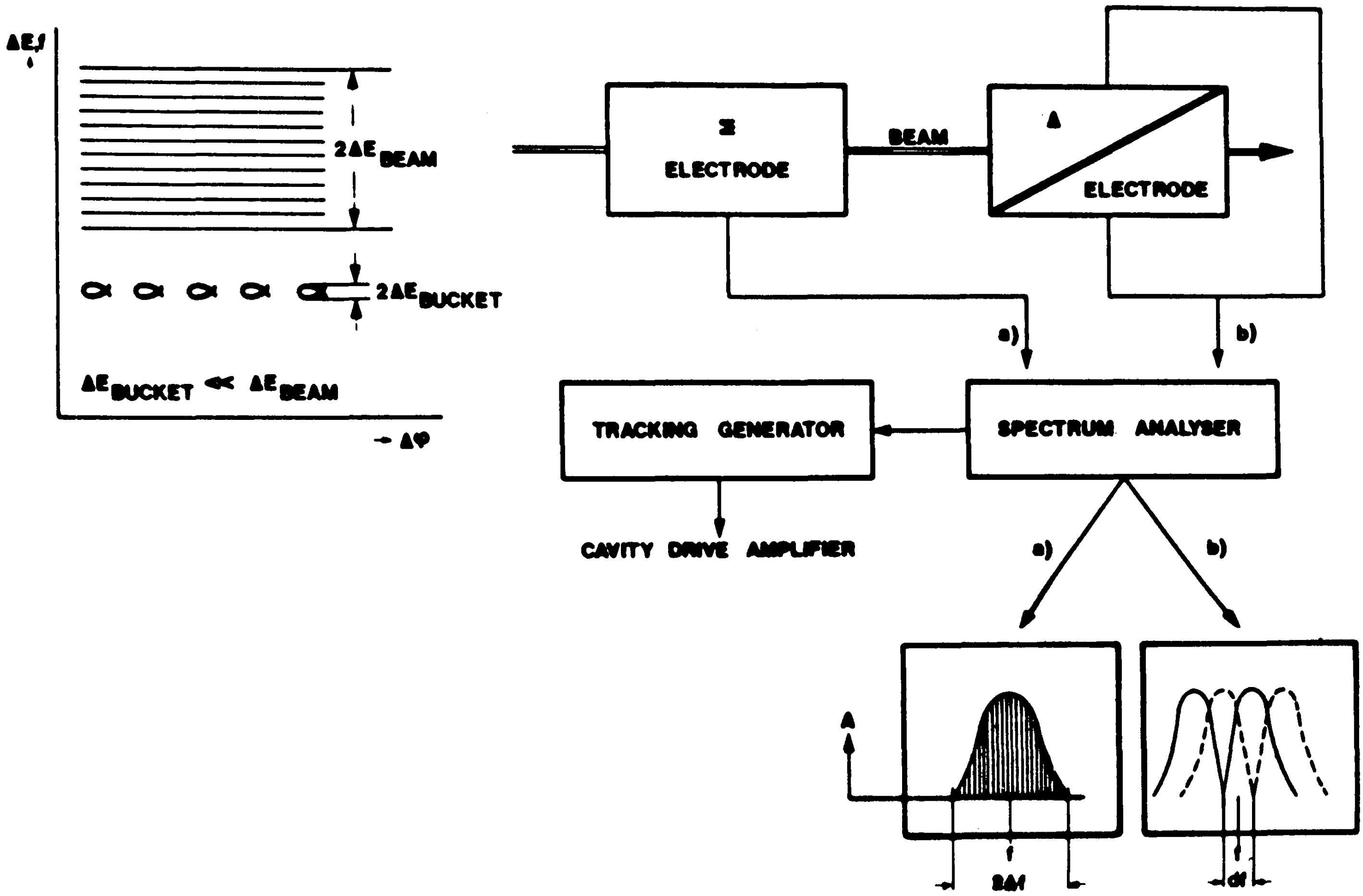

FIG. 3 - Empty bucket scans (see text for fuller explanation). As the empty bucket scans through the beam (in longitudinal phase space, left hand side), either $\pm \Delta E_{BEAM} = \pm [E\beta^2/(\eta f)]\Delta f$ is observed [right hand side, case a)], or $dB_{mean} = [B_{mean}/(\gamma^2 f)]df$ [case b)]. The amplitude A is proportional to the proton density in longitudinal phase space (p/eV). (At any given moment, only one frequency is present, that of the scanning RF).

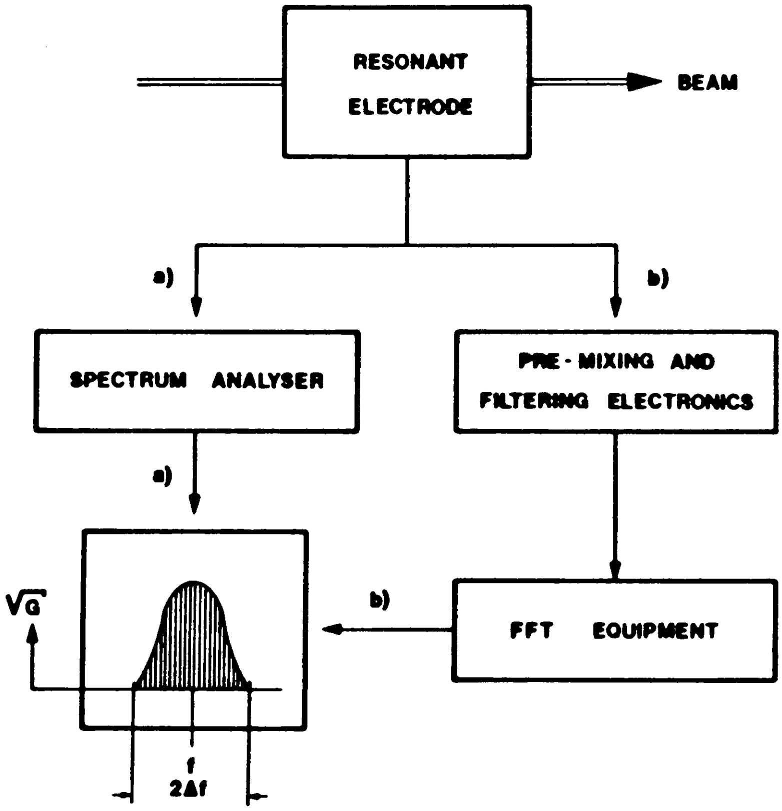

FIG. 4 - Schottky scans (see text for fuller explanation). The a.c. beam component needed for observation is in this case provided by the natural (statistical) Schottky noise. Perfect debunching, a resonant electrode and adequate measurement statistics are required to ensure accuracy. In the case a) this leads to beam observation during 100 to 400 normal machine cycles. This time could be reduced to a few or even a single cycle through working in the time domain and using subsequent FFT[51] [case b)]. One has again (see Fig. 3) $\pm \Delta E_{BEAM} = \pm [E\beta^2/(\eta f)]\Delta f$, but here the amplitude spectral density $\sqrt{G}$ (where G is the power spectral density) is proportional to the square root of the proton density (p/Hz).

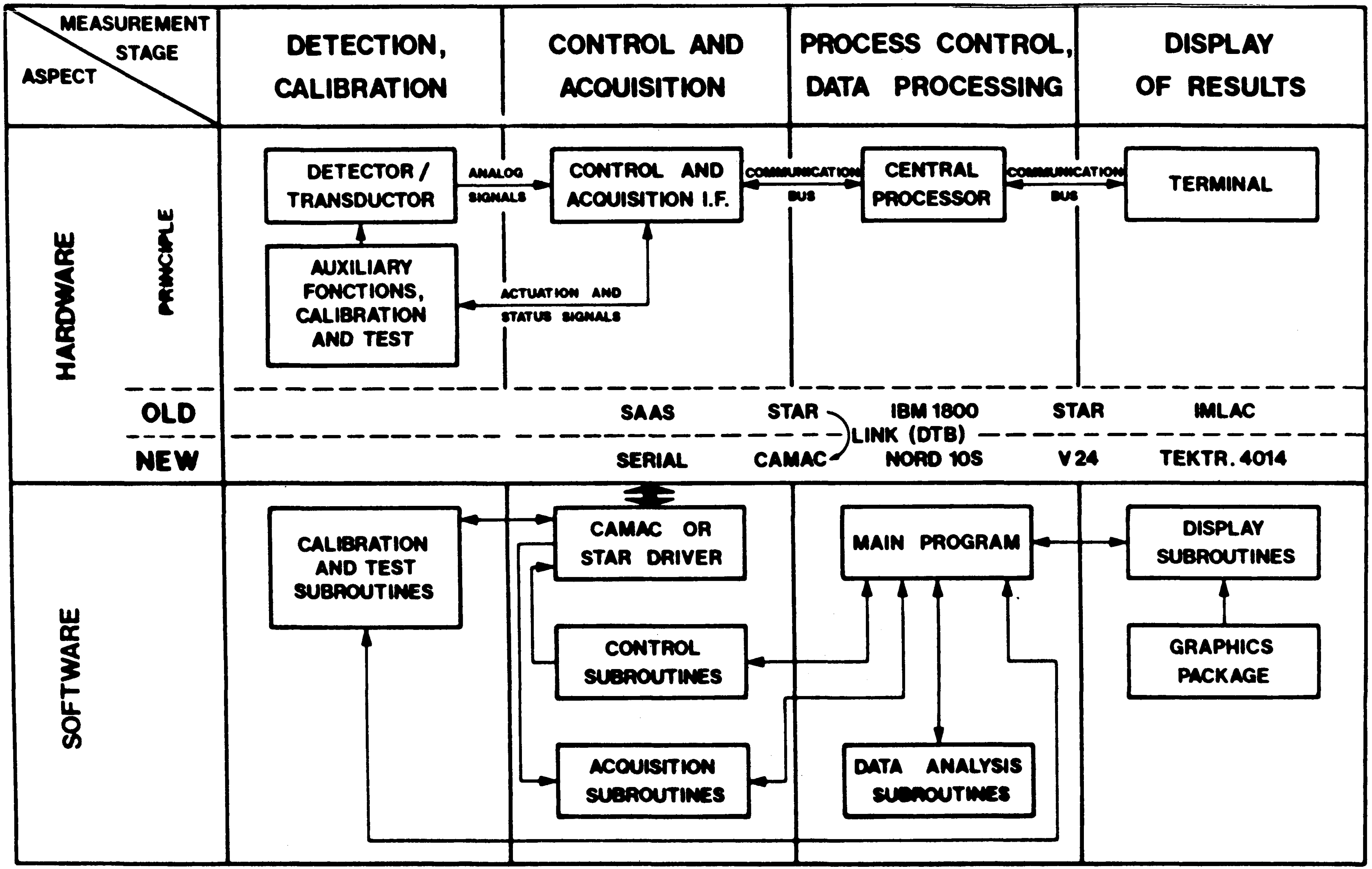

Fig. 5 General hardware and software layout of measurements using the IBM 1800 and/or the T-BMC (NORD 10S)

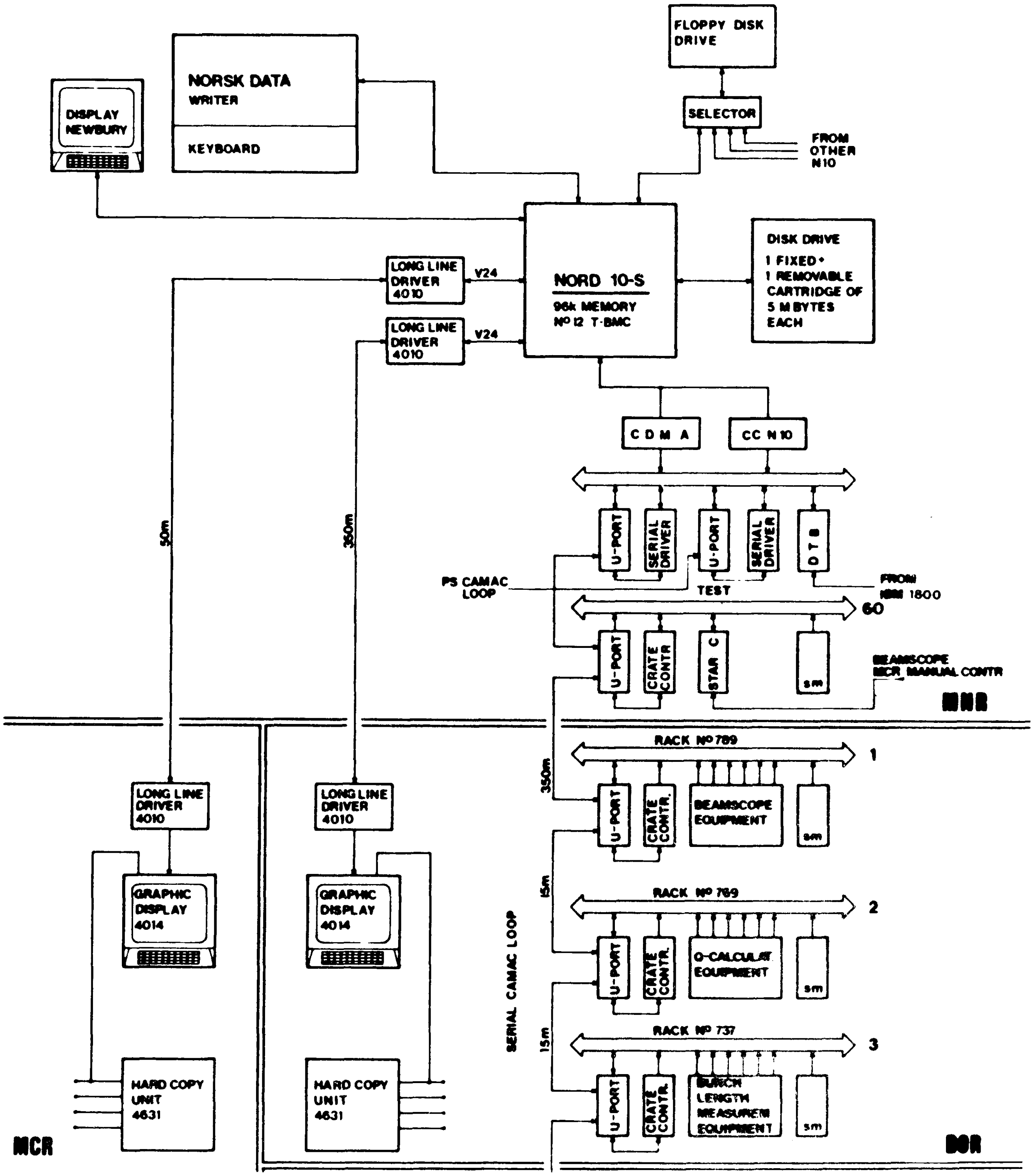

FIG. 6 - Layout of the Temporary Beam Measurement Computer (T-BMC) and its CAMAC loop.

TABLE 1 - SYNOPSIS OF PSB BEAM OBSERVATION SYSTEMS

Group	No.	Device	Number	Measuring	Sensitivity in MCR (Analogue)	Bandwidth (Hz)	Other characteristics	Status Analogue	Status Digital	Person(s) involved Maint. + developm.	Person(s) involved MCR linkman	References
INJECTION LINE	1	Scintillation screens and TV observation *) Cameras	I : 15* R : 8* T : 9*	Transverse beam position + cross section (destructive)	-	-	Reference grid 1 cm/div Minimum detectable intensity 2E9p/cm^2	Operational	-	M. Perrin, J. Robert	I : K. Schindl R : H. Schönauer T : J.P. Delahaye	SI/Note DL/70-2 MPS/SI CO/Note 71-3 MPS/CO Note/72-31 MPS/CCI Note/74-7
INJECTION LINE	2	Injection line current transformer, I-TR3,4	5	Beam current in 50 MeV inj. line	10 V/A	< 0.01 → 1 M	Max. signal 200 mA Resolution ∿ 1 mA Max. for digitization: 3840 (mA × μs)	Operational	Operational, but not yet on IBM	P. Cennini D. Williams	K. Schindl	
INJECTION LINE	3	Magnetic beam position monitors I-U4→9	12	Beam positions in injection line	0.5 V/(mm·A)	16 → 3 M	Resolution 25(mA·mm) Σ signal taken from I-TR	Operational	Operational, but not yet on IBM	M. Le Gras K. Schindl D. Williams	K. Schindl	MPS/BR/LIN/Note 75-12 CERN/PS/BR/77-53
INJECTION LINE	4	"Scrapers" on DIST and I-SV	34	Proton losses on DIST, I-SV	50 mV/mA	DC → 3 M	Resolution ∿ 0.2 mA	Operational (18)	After 1980	J.P. Royer	K. Schindl	
INJECTION LINE	5	Beam loss monitors						Being defined		V. Agoritsas	B. Frammery	MPS/CO Note/71-51 PS/EI/Min. 79-2
RINGS (SEE LINES (1) AND (5) FOR R-TV'S AND BLM'S)	6	Ring current transformers, fast (R-TR) (8L1)	4	Fast variations of ring current	2 V/A	100 K → 30 M	Resolution 1 mA	Operational	Not foreseen	S. Battisti P. Heymans E. Marcarini J. Philippe	B. Frammery	SI/Note DL/70-1 MPS/SI/CO/Note 70-8 MPS/CCI Note 75-25 PS/CO Note/79-12
RINGS	7	R-TR intermediate (8L1)	4	Ring current	0.5 V/A	0.1 → 1 M	Resolution ∿ 4 mA	Operational	Not foreseen			
RINGS	8	R-TR slow (8L1)	4	Accurately beam current in rings	2 V/A	10^{-4} → 10 K	Resolution ∿ 1 mA	Operational	Replaced by (9)			
RINGS	9	R-TR "β-normalized"	4	pp ring	1 V/1E12p	10^{-3} → 10 K	Resolution 1E10 ppr	Operational	Operational	L. Magnani + persons above	L. Magnani	PS/BR Note/77-4
RINGS	10	Ring PU electrodes R-U	68	Ring beam positions	Δ(50mm) = Σ Σ = 1.25E-13 to 1.0 E-12 |V/ppr| *BF^{-1}	50 K → 40 M	Resolution 5.10^{11}*BF (ppr*mm) BF = mean/peak	Operational Restrictions for SOS; Major improvements 1982/84	Operational Restrictions for new system	P. Cennini P. Heymans D. Williams	H. Schönauer	SI/Note EL/69-7,70-13 SI/Note DL/70-11,70-19 CERN/SI/Int. EL/71-2 CERN/MPS/Int.BR/73-4 PS/BR Note/77-36
RINGS	11	R-U for mean radial positions (4L3,6L3,12L3,14L3)	16 (out of 68)	Normalized mean radial position for radial loop	- 50 mV/mm	DC → 5 K	Resolution 0.1 mm if > 10^{11} pp ring	Operational	Planned for 1980	G. Gelato L. Magnani	L. Magnani	CERN/MPS/BR 75-8
RINGS	12	R-U for transverse feedback (4L5 + 6L5)	8	Transverse coherent oscillations	To be measured	5 K → 200 M (in BAT)	No Σ signal; suppression of $\Delta\overline{x}$	In production	Not foreseen	C.Christiansen, G.Gelato M. Le Gras, D. Williams	H. Schönauer	
RINGS	13	R-U for ½-turn injection studies (7L2)	4	Injection trajectory	To be measured	700 → 10 M	Resolution 5(mA mm) Max. signal 100(mA·mm)	In production	After 1980	M. Le Gras D. Williams	K. Schindl	
RINGS	14	R-U quadrupolar (3L1)	1	Beam shape variations (observation in BAT)		1 K → 3 M	Prototype in ring 1	Operational with restrictions	Not foreseen	M. Le Gras D. Williams	K. Schindl	SI/Note EL/70-13 MPS/Mi BR/74-24
RINGS	15	Q-calculation	8	Magnet and quadrupole currents from which set Q-values are computed	-	Min. time between consecutive points 100μs	May be improved by including $\Delta\overline{R}$	-	Operational on TEMP-BMC	J. Donnat C. Metzger	C. Metzger	PS/BR Note 76-6

TABLE 1 - SYNOPSIS OF PSB BEAM OBSERVATION SYSTEMS

		Device	Number	Measuring	Sensitivity in MCR (Analogue)	Bandwidth (Hz)	Other characteristics	Status: Analogue	Status: Digital	Person(s) involved: Maint. + developm.	Person(s) involved: MCR linkman	Refereces
RINGS	16	Q-measurement (kickers in 12L1)	8	Betatron tunes by kicking beam and counting betatron frequency	-	3 ms between consecutive kicks, will be reduced to 1ms	Final resolution in Q ∿ 0.002, perturbations in presence of beam loss	Operational	Full computerization in 1980	G. Benincasa C. Carter	H. Schönauer	CERN/SI/Int. DL/70-7 SI/Note DL/70-13 MPS/Int. BR/74-14, 74-15 PS/BR Note/76-17 PS/Mi BR/78-8
RINGS	17	Measuring targets (9L1)	8	Beam dimensions in rings	-	-	Resolution 0.1 mm in arm position. Plunging time ∿ 20 ms, precision ∿ 0.3 mm	Operational	Control 1980	J.J. Merminod M. Van Rooy	H. Schönauer	MPS/CO Note 73-37 MPS/BR Note 74-18 PS/BR Note 77-29 PS/Mi BR/78-9
RINGS	18	Beamscope (8L3)	8	Amplitude profiles by controlled shaving and analyzing dI/dt	-	Fastest loss ∿ 1 ms	Profiles evaluated by T-BMC. Option for stopping bumper dipoles when 10% of beam lost	-	Almost operational on T-BMC	C. Carter J. Donnat H. Schönauer	H. Schönauer	CERN/PS/BR 79-8 CERN/PS/BR 79-10
RINGS	19	Ionization beam scanner (7L1)	8	Projected beam profiles by collecting electrons freed in collisions	-	Min. time for 1 profile ∿ 50 μs	Turned out unusable for emittance measurements as sensitive to space charge			C. Carter	H. Schönauer	MPS/CCI/Note74-29 MPS/CCI/Note74-42
RINGS	20	Long. wide band PU station (8L1)	4	Fast variations of beam current induced in resistors bridging a gap	3.3 V/A	100K → 900 M (BOR)	Yields bunch shape oscillations when linked to scope scanner system	Operational	-	G. Gelato L. Magnani	L. Magnani	SI/Note EL/71-5 SI/Note EL/7-1
RINGS	21	Longitudinal emittance measurement	4	Bunch length and other relevant data to compute ϵ_L	-	900 M	Evaluated via T-BMC Bunch length resolution ± 1 ns	-	Scheduled for 1980	G. Gelato L. Magnani	L. Magnani	PS/BR Note/7-33
RINGS	22	Longitudinal mode analyzer	4	Envelopes of long. coupled bunch modes n = 1,2,3,4 + m = 1,2,3	2 V/deg for dip. mode	DC → 350	*For > 1E11 ppr; part of long. feedback system; resolution ∿ 0.01 deg.	Operational	-	L. Magnani F. Pedersen	L. Magnani	CERN/PS/OP 75-6 PS/BR Note/7-13 CERN/PS/BR/7-9
RECOMBINATION AND TRANSFER (see (1) and (5) for T-TV and BLM's)	23	Current transf. T-TR	5	Beam current in 800 MeV line	6 V/A	100 K → 30 M	Resolution 1E10 ppr	Operational	Operational	S. Battisti, P. Heymans E. Marcarini, J. Philippe	J.P. Delahaye	MPS/SI CO/Note 70-8 PS/Mi BR/79-15
RECOMBINATION AND TRANSFER	24	Transfer PU electrodes T-U + TS-U	10	Beam positions in 800 MeV lines	Σ = 3.7E-13 to 1.85E-12 (V/ppb)*BF^{-1}	AS R-U (10)	Resolution 6.10^{11}*BF(ppb*mm) BF = mean/peak	Operational	Partly operational	P. Cennini, E. Schulte D. Williams	J.P. Delahaye	SI/Note DL/70-12, 71-2
RECOMBINATION AND TRANSFER	25	Additional T-U	6	Beam position in 800 MeV recombination	compatible with existing T-U	700 → 40 M	Resolution better than existing T-U	In production (6/1980)	1980	P. Cennini, E. Schulte D. Williams	J.P. Delahaye	CERN/PS/BR 8-12
RECOMBINATION AND TRANSFER	26	800 MeV emittance measurement line	1	Steering, matching emittances of recombined beams	-	Allows analysis of 1 ring	Beam profiles of 3SEMs are acquired and evaluated by 1800 + T-BMC	-	Operational in IBM 1800 + T-BMC	G. Baribaud J.P. Delahaye J. Donnat	J.P. Delahaye	CERN/SI/Int DL/69-10 CERN/MPS/Int. BR/73-2 MPS/Int. BR74-1 PS/BR Note/8-7 CERN/PS/BR/DL/OP/79-7