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BEAM CURRENT TRANSFORMERS IN TT2 FOR LEAD IONS AND POSSIBLE USE FOR LHC-TYPE BEAMS

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Abstract

Two new beam current transformers were installed in TT2 during the 1993/94 shut down. This note gives details, preliminary results and possible future changes and improvements including the use of one of these transformers for LHC-type beams.

1. INTRODUCTION

The location of the two transformers, TRA 372 and TRA 379, was defined by the necessity of having an existing magnet between them [1, 2]. This bending magnet, BHZ 377/378, serves as a spectrometer, and with the stripping foil just downstream of TRA 372, accounts for the stripping "gain" between the two transformers (Fig. 1).

A measurement of the beam intensity in TRA 372 and TRA 379 with their ratio was required [3]. This beam of 20 bunches ejected over ~ 2.2 μs was to have a nominal intensity of $1 \cdot 10^{10}$ charges.

2. REALISATION

Transfer line beam transformers often suffer from noise caused by ejection kickers, septa, etc. inherent (and synchronous) to the ejection procedure. A method used with success in the PSB transfer line involves using a digitizer to "memorise" the noise without beam and then subsequently subtract this from the measurement with beam. In the PSB the amplitude of the kicker transients were greater than the beam current signal. A low pass filter reduced these transients so that they were within the full scale range of the digitizer.

Expecting certain noise problems in the TT2 transfer line, the PSB method was envisaged, the only difference being that the filter and amplifier are in the tunnel and the digitizer is a VME module instead of CAMAC based one.

Due to hardware and software delays, measurements of efficiency for the first Machine Developments were obtained simply by measuring the area of the filtered analogue signal using an "intelligent" scope (Fig. 2). Despite the fact that the image was transmitted by video link to the MCR, this is an uncomfortable solution and the information is volatile. Anyway, this solution was available during the first Pb ion ejection trials in Aug. 1994. As the noise was much less than anticipated, a second "ad hoc" solution was envisaged using classical integrators and sample/hold circuits (Fig. 3). The signals from the latter were then connected to two channels of a MPV908 ADC. This solution profited from the experience gained in the East Hall energy amplifier experiment and uses similar software.

This solution was up and running for the Machine Development session of 21/10/94. Measurements of the ejected beam and another transformer (TRA 203) upstream were included in the program which is in the form of a rolling display on a work station (Fig. 4). It was the inclusion of TRA 203 in the TT2 beam transport line in the display that enabled the secondary emission phenomenon to be observed, and the detection of the stripping ratio to be lower than expected [4]. This error was obviously not seen when only TRA 372 and 379 were acquired as in the area measurement above. Ratio measurements are not only affected by the secondary emission from the stripper but also by MTV 679 downstream of TRA 379.

Experience will show if this conventional solution could become permanent or whether the digital version will replace it. The present system is more critical to ejection timing than one using a digitizer, where a signal searching algorithm would normally be used.

3. VME CRATE LAYOUT

Figure 5 shows the layout of the VME crate called DCPSTRPB, installed in the equipment room next to the AA Control Room, mainly for proximity reasons for cables into the TT2 tunnel. Two layouts are shown in Fig. 5, one valid till Dec. 94 for the 1994 lead ion run and the new one implemented and successfully tried out in early 1995. The MPV 908A is a 32 differential analogue input channel ADC with 12 bit resolution and with 10 μs sampling period (100 kHz sampling) and 30 K words of data buffer on board. In this application, the sampling rate plays little importance since it is the sample and hold level from a NIM module which gets converted by this ADC. For the two transformers in the vicinity of the stripper, two channels only were used.

4. TIMING ASPECTS

As shown in Fig. 5, the ADC needs a trigger to convert the data and this was provided through the standard PS timing system using a programmable channel using PTIM on the <TT> ND computer and a hardware cable coming to the VME crate. In 1994, PTIM (52) was used while in early 1995, a definitive timing PS.SPBTR as PTIM (64) on <TT> computer has been installed so as to be independent of the PTIM (52) = PX.016 timing used in 1994 which has also been used for other observations. It is planned that on the phase-out of the <TT> computer in 1996, PTIM (64) will have to be replaced by a TG8 based timing providing the same trigger to the ADC and using a new VME based PTIM channel, PTIM (6966) = PX.ATRPB.

5. REAL-TIME SOFTWARE ASPECTS

The new VME based PS controls system inherently implies pulse-to-pulse modulation and data structures automatically covering the PPM aspects. This also means that the PLS telegram and an interrupt must be provided through a standard module sitting in the VME crate, as an obligatory requirement for the real time tasks in that crate. In 1994, in the absence of the TG8 module, the FPI-PLS module with 8 front-panel interrupts had to be used to provide this functionality. The FPI-PLS has a PLS telegram input (blocking) which was provided from a <TT> computer Timing Distribution rack in ACR Equipment Room. The front-panel interrupt was provided through the same PTIM channel as used for the ADC but delayed by 20 ms, using Delay Modules in NIM. On receiving the interrupt, the real-time task would go and read the ADC converted data and appropriately store it in the data tables on a pulse to pulse basis based on the PLS telegram information. The real-time task and access from higher level was provided through a standard controls group input/output Equipment Module called AIO and the associated task AIORT1 running in the VME crate.

In February 1995, the FPI-PLS module was replaced by the new TG8 module and the PLS telegram arrives to the crate via the MTG cable. The external interrupt provided to the real-time task has been replaced by a software interrupt on the TG8 without using any TG8 outputs, i.e., the real-time task uses the "end-of-last-flat-top" (ELFT) as an interrupt to interrogate the ADC and store the data in the tables. A new version of the AIO Equipment Module, called AIOX has been used to acquire the transformer values at the high level through the real-time task AIOXRT running in DCPSTRPB.

6. CONTROL ROOM APPLICATION

The workstation level application program acquires both the stripper ion transformers as well as the PS Ring transformer (PS:D-IP) and the TT2 multi-purpose fast transformer TRA 203. The PS:D-IP value from the PS ring is the difference in reading on the Ring DC transformer "before" and "after" ejection of ions towards TT2. While the transformers near the stripper were on the new VME based system, both PS Ring and TT2 (TRA 203) were on the old Norsk Data systems in 1994. Hence, special attention had to be given to synchronising all these "mixed" acquisitions on a shot-to-shot basis for the single, uniform display of Fig. 4, synchronising also with the number of PLS-programmed extraction cycles in the super-cycle. In 1995, PS:D-IP will also come from a VME-based system but the TRA 203 still remains on the Norsk Data System till 1996.

7. RESULTS, ACCURACY, CALIBRATION AND NOISE

Figure 4 shows a typical page of results. Operational experience started just before the Machine Developments of 21.10.1994 so statistics are poor, but some preliminary conclusions can be drawn. It is the ratio measurement of the two new transformers used to find the stripping efficiency which is of primary interest. This was the original design request.

The ratio measured during the MachineDevelopments (38 shots) gave a mean efficiency of 144.2% (Stripper In), with a standard deviation of 1.45. This "spread" translates to ± 1.9% of the nominal beam of $0.9 \cdot 10^{10}$, i.e.approximately $\pm 2 \cdot 10^8$.

Statistics are poor for "Stripper Out" ratios but a mean of 101.4% was obtained (11 shots), with a standard deviation of 1.3 which compares with the above.

For completeness ΔIp and TRA 203 were included in the display and similar mean and standard deviation measurements were made as above. The TRA 372/203 ratio "spread" is similar to the TRA 379/372 but 203/ΔIp is poor.

Noise measurements on TRA 379 during the Machine Developments, when the beam was sent to the dump showed a jitter of approximately $\pm 2.5 \cdot 10^8$. Similar measurements made between 17/11/1994 and 21/11/1994 gave $\pm 1 \cdot 10^9$ for TRA 372 and TRA 379, $\pm 3 \cdot 10^7$ for TRA 203 and $\pm 5 \cdot 10^8$ for ΔIp. This increase in noise on TRA 372 and TRA 379 is as yet unexplained. However the noise is synchronous, that is to say the "ratio" noise is still below $\pm 2 \cdot 10^8$ so that TRA 379/372 ratio measurements are unaffected. This noise however influences the TRA 372/203 ratio. This will be investigated.

8. CONCLUSIONS

The authors believe that the results have fulfilled the original design request, with the bonus that the information displayed shows more than a simple ratio and that, eventually, beams up to $2 \cdot 10^{12}$ can be measured on TRA 372 using a third channel of the MPV 908 ADC, i.e., LHC-type beam, studies, etc. This has indeed been done in early 1995. During Machine Development of 31/05/1995, this has been tested with a pencil beam in TT2 and gave encouraging results as shown in Fig. 6. The display shows all the relevant transformers up to TT10 for the LHC-type beam operation.

Overall transmission from ΔIp to TRA 379 during the Oct. 94 Machine Development was 100% ± 2%. Improvements have been made but need to be verified. It is difficult to see how recalibration can improve the existing situation, and the present precision of ± 2% is quite capable of looking for losses of 20% to 80% downstream. Calibrating with a proton beam would simply change the ranges of all 3 transformers (TRA 379 will not work at high intensities). so that any problems at ion intensity will still remain.

9. ACKNOWLEDGEMENTS

Thanks are due to L. Petty and F. Nanni for their transformer design which, except for the winding details, was essentially the same as those used in the Lead Linac. N. De Metz-Noblat, M. Arruat and I. Deloose are also gratefully acknowledged for their help in getting the VME based systems operational.

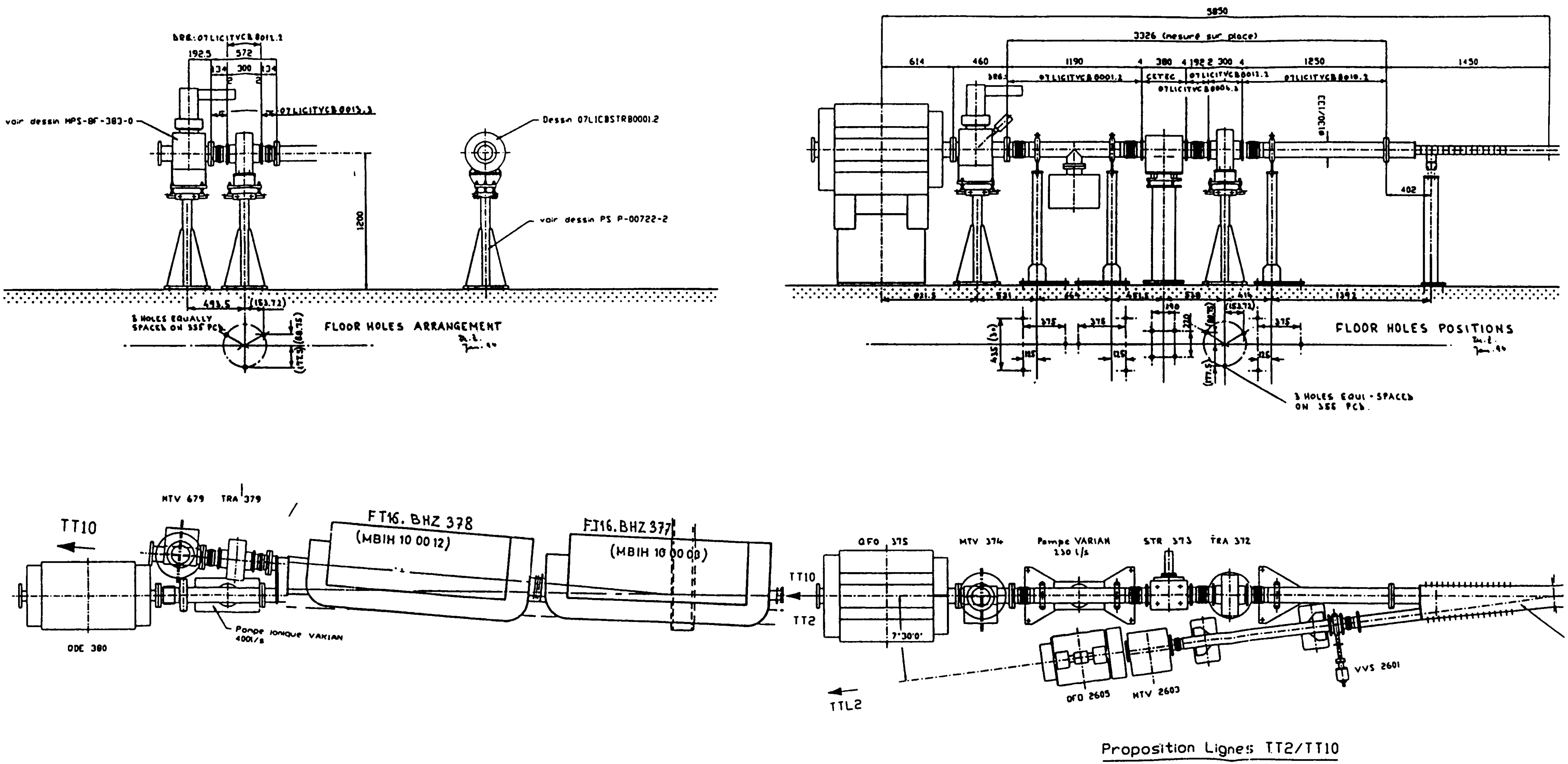
10. REFERENCES

[1] M. Zanolli, PS/PA Memo 90-37.

[2] D. Warner (Ed.), CERN Heavy-Ion Facility Design report, CERN 93-01 (28.04.1993).

[3] D. Manglunki, PS/PA Note 93-20 (PPC).

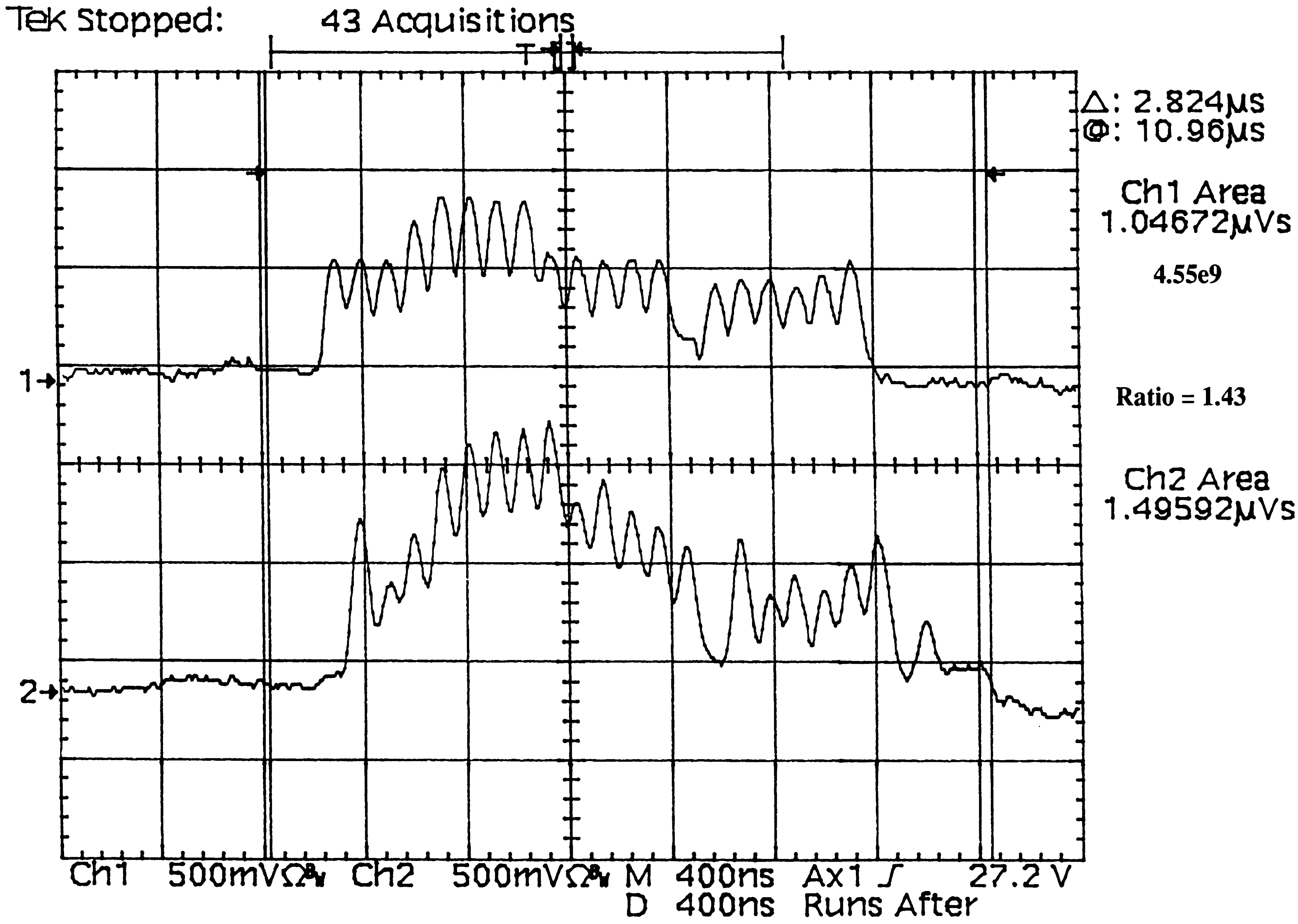
[4] C. Carter, Memo MD of 22.10.1994.



voir dessin MPS-BF-383-0
Dessin 07LICBSTRB0001.2
voir dessin PS P-00722-2
FLOOR HOLES ARRANGEMENT
3 HOLES EQUALLY SPACED ON 335 PCD
3326 (mesure sur place)
5850
FLOOR HOLES POSITIONS
3 HOLES EQUI-SPACED ON 335 PCD.
MTV 679
TRA 379
TT10
FT16. BHZ 378
(MBIH 10 00 12)
FT16. BHZ 377
(MBIH 10 00 08)
Pompe ionique VARIAN 400l/s
QDE 380
QFO 375
MTV 374
Pompe VARIAN 230 l/s
STR 373
TRA 372
TT10
TT2
7°30'0"
TTL2
QFO 2605
MTV 2603
VVS 2601
Proposition Lignes TT2/TT10

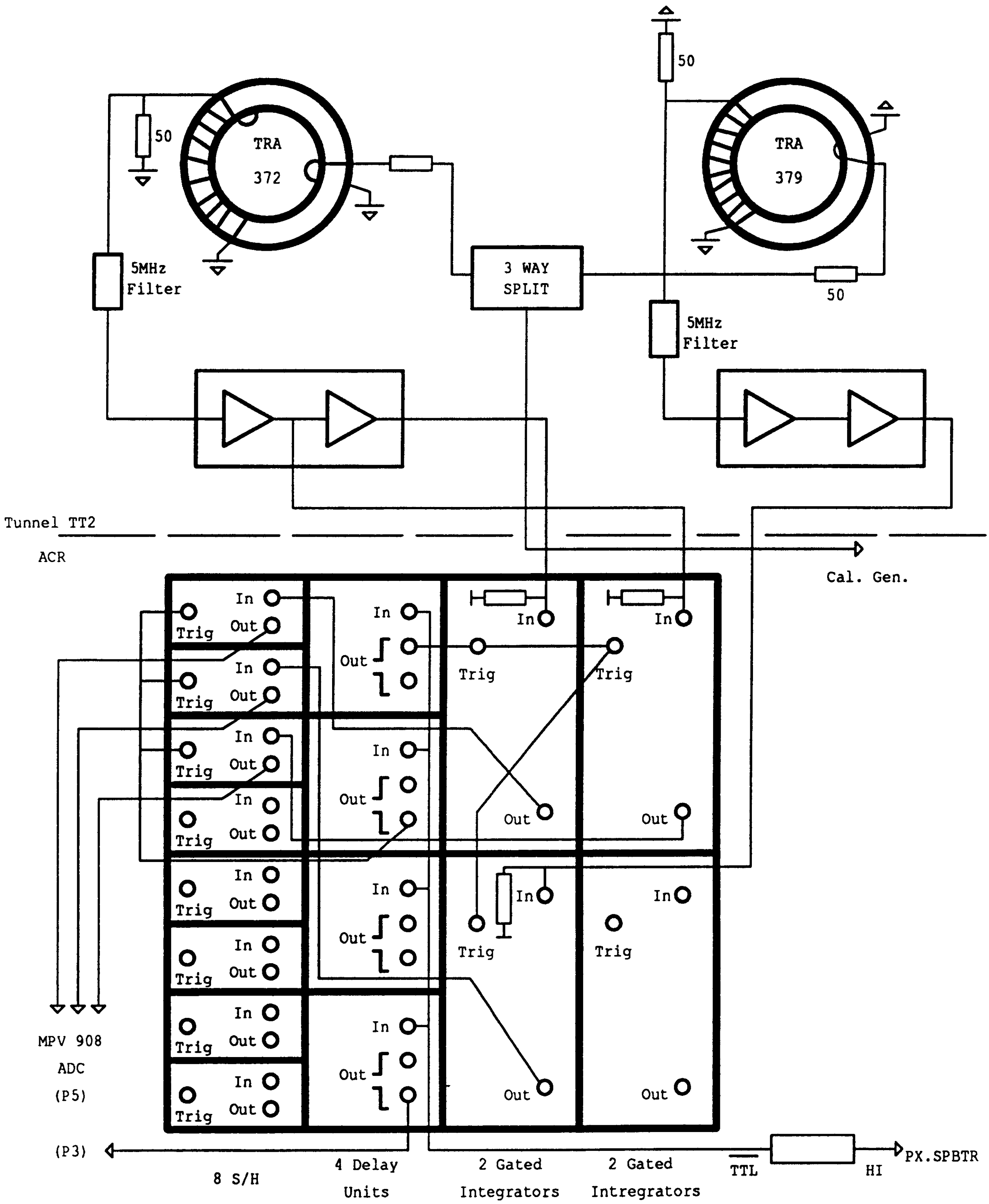
Fig. 1

30.08.94



Tek Stopped:
43 Acquisitions
T
Δ: 2.824μs
@: 10.96μs
Ch1 Area
1.04672μVs
4.55e9
Ratio = 1.43
Ch2 Area
1.49592μVs
1
2
Ch1 500mVΩ Ch2 500mVΩ M 400ns Ax1 ∫ 27.2 V
D 400ns Runs After

Fig. 2



50
TRA
372
5MHz
Filter
3 WAY
SPLIT
50
TRA
379
50
5MHz
Filter
Tunnel TT2
ACR
Cal. Gen.
In
Trig
Out
In
Out
Trig
MPV 908
ADC
(P5)
(P3)
8 S/H
4 Delay
Units
2 Gated
Integrators
2 Gated
Intregrators
TTL
HI
PX.SPBTR

LAYOUT

Fig. 3

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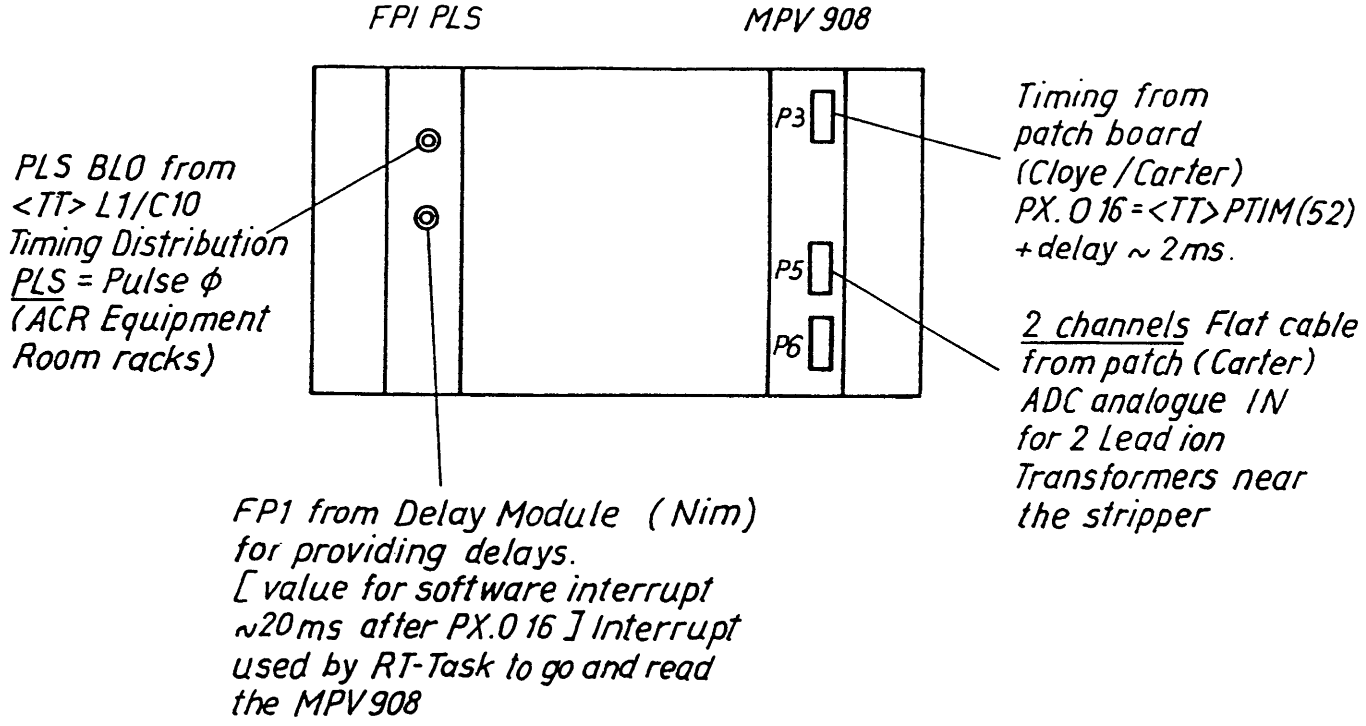
lead ions down the drain (E10 Charges)

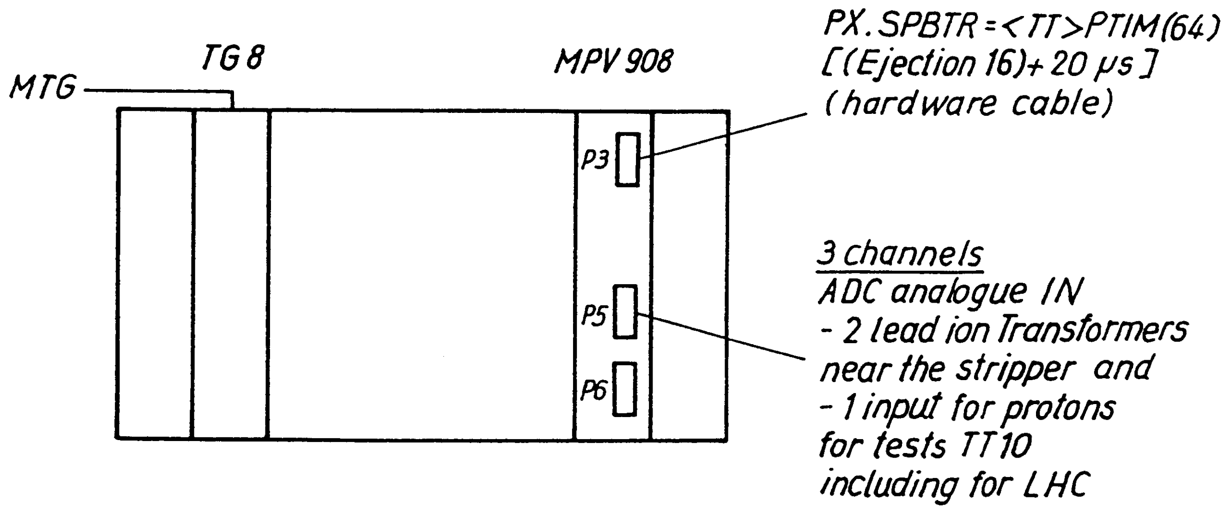
PS:D-IP	TRA203	%	TRA372	%	TRA379	%
0.933	0.95	101.8	0.976	102.8	1.479	151.6
0.973	1.018	104.7	1.015	99.7	1.547	152.5
0.98	0.975	99.5	1.015	104.1	1.518	149.6
0.939	0.943	100.4	0.995	105.6	1.479	148.6
0.952	0.939	98.7	0.986	104.9	1.489	151.1
~~0.016~~	~~0.001~~	~~9.3~~	~~0.01~~	~~200~~	~~0.024~~	~~999~~
0.958	0.956	99.8	1.025	107.2	1.538	150.1
0.924	0.934	101.1	0.966	103.4	1.469	152.1
0.937	0.939	100.2	0.927	98.8	1.411	152.2
0.932	0.933	100.1	0.966	103.6	1.45	150.1
~~0.006~~	~~0~~	~~0~~	~~0.029~~	~~100~~	~~0.044~~	~~152.5~~
0.961	0.997	103.7	0.995	99.9	1.518	152.5
0.931	0.978	105.1	1.005	102.7	1.528	152
~~0.002~~	~~0.001~~	~~33.5~~	~~0.019~~	~~200~~	~~0.053~~	~~999~~
0.951	0.967	101.7	0.927	95.8	1.421	153.2

Fig. 4

Layout of DCPSTRPB up to Dec 1994
(Equipment Module A10)



Layout of DCPSTRPB from 1995 onwards
(Equipment Module A10X)



In 1995 FPI replaced by TG8. No front-panel used for A10X compared to how it was in 1994.

The PLS Telegram comes directly to TG8 Module by MTG cable (for PPM organization)

The interrupt for RT Task to go and read the ADC is now provided by using PX.ELFT distributed by MTG rather than FPI-PLS front-panel interrupt as before.

In 1996, the PX.SPBTR = <TT> PTIM(64) will be replaced by the TG8 produced timing, PX.ATRPB = PTIM(6966) on the DSC System.

Fig. 5

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Protons down the drain (E10 Charges) PLS= 266

PS:D-IP	TRA203	%	TRA372	%	[TRA372/PSDP]%
101.099	102.564	101.4	102.05	99.5	100.9
93.162	94.011	100.9	93.505	99.5	100.4
96.459	97.687	101.3	97.168	99.5	100.7
90.964	91.749	100.9	91.552	99.8	100.6
94.383	95.425	101.1	94.97	99.5	100.6
89.133	89.77	100.7	89.355	99.5	100.2
96.337	97.545	101.3	97.168	99.6	100.9
93.406	94.435	101.1	94.238	99.8	100.9
96.093	97.263	101.2	96.923	99.7	100.9
93.406	94.294	100.9	94.238	99.9	100.9
100.977	102.423	101.4	101.318	98.9	100.3
95.971	97.051	101.1	96.435	99.4	100.5
96.459	97.545	101.1	97.412	99.9	101
93.162	94.082	101	93.994	99.9	100.9
96.703	97.969	101.3	97.412	99.4	100.7
93.651	94.577	101	94.238	99.6	100.6

Fig. 6