THE LEP BEAM ORBIT MEASUREMENT SYSTEM : STATUS AND RUNNING-IN RESULTS.

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ABSTRACT

The BOM System with its 504 Beam Position Monitors and 40 Processing Electronics Racks distributed along the 27 km of the LEP tunnel and linked by the Control System's Token Ring has been installed and pré-tested with simulated beam signals. A first test with beam was successfully performed on a single station equiped for 12 monitors during the injection test of july 1988. It did validate the hardware and processing design. But complete results could only be reached in July 1989 when the proper triggering of all electronic stations could be adjusted on the ciculating beam, via the Beam Synchronous Timing System. Local memories allow the recording of data at each bunch passage for more than 1000 revolutions. Most of the data analysis is done simultaneously in 40 microprocessors which communicate with a data collector. Performance results are presented. The BOM System has been a key instrument for the building up of LEP performance.

1. INTRODUCTION

The Beam Orbit Measurement (BOM) system has been described in Ref. 1 which can be summarised as follows:

The BOM instrument records the beam position data for each bunch and both beams from the 504 Beam Position Monitors (BPM) located near quadrupoles (QDs) along the 28 km of the LEP machine. Each LEP BPM has 4 electrostatic demountable buttons (Fig. 6) with specially designed high precision feedthrough [1, 2 and 3]. For radiation reasons the processing electronics is located in 24 shielded underground areas (Fig 2), which implies long cables for low level analogue signal transmission and no access for most of the equipment during machine operation.

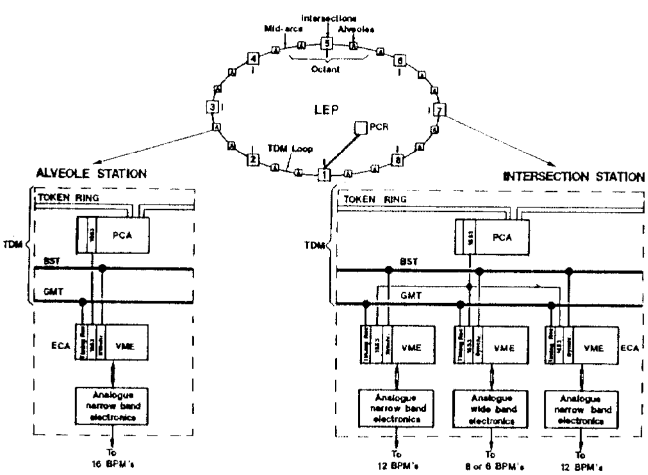

Fig. 1 BOM system layout

The BOM system was designed to measure trajectories (single passage) and closed orbits (average over many bunches and turns). This implies a synchronising mean for unambiguous capture of the same bunch signal all around the 24 stations. A special Beam Synchronous Timing (BST) system has been implemented [4] for this triggering and also provides for real time control of the BOM system (Fig. 1). The bunch induced pulse on the button electrode has a range of 1 to 2500 V (8.7 pF capacity, ± 25 mm excursion) and a short duration of about 100 ps at mid-height. Since the average time between bunches is 11 μs all signals can be recorded and stored in a local memory for up to 1000 revolutions.

The BOM analogue processing and acquisition electronics is of two kinds :

i) The Narrow Band system is used for most monitors (448) where the time between e^+ and e^- bunches > 600 ns. Its principle is given in Fig. 2 : the bunch signals are integrated by four ringing circuits (Fig. 3), the differences of the two diagonal pairs are processed by two normalizers based on phase modulation by

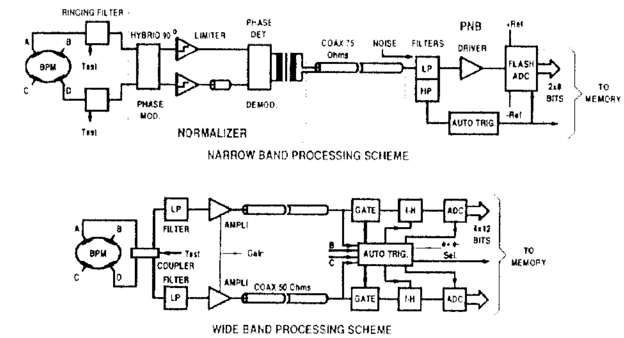

Fig. 2 BOM analogue acquisition electronics

quadrature hybrids and sent along two coaxial cables to the electronic stations. The position information is then in the form of the magnitude of a pulse of 150 to 450 ns duration (Fig. 8). The Narrow Band Processor (PNB) acquires both the base line and amplitude of the incoming pulse by self-triggering, converts them with an 8 bits FADC whose output is connected to the local VME buffer memory.

ii) The Wide Band system has been especialy designed for the monitors (56) close to intersections where the time between e^+ and e^- is < 600 ns. Its principle is given in Fig 2,the 4 bunch signals are processed separately by Low Pass integration, by variable gain amplification, by analogue gating for e^+/e^- selection and by Integrate & Hold acquisition. The fast analogue gate and I&H circuits are bunch signal self-triggered by a fast logic which selects signals according to their polarity. A 12 bits ADC is also triggered for conversion and its output is connected to the local VME buffer memory.

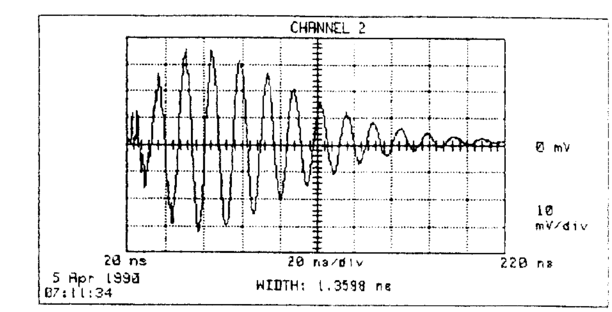

Fig. 3 Beam induced signal at the output of the ringing filter

2. BOM SOFTWARE DESCRIPTION

The software has represented about 20 % of the overall effort for the BOM realisation. Its concept is strongly influenced by the system distribution (Fig. 1) and by the BOM control scheme [5] which depends fully on the LEP Control System [6]. Its development took place while the Control System features were progressively frozen.

The request from the user on an APOLLO console is processed by the BOM Server (not yet fully implemented) which asks the BST Master to initiate a measurement sequence, see Fig. 4. The BOM

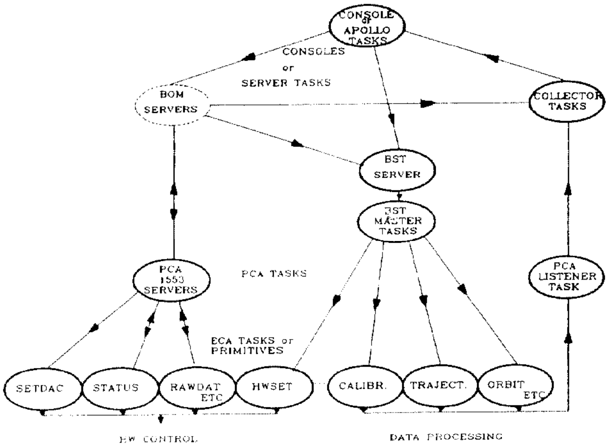

Fig. 4 BOM application software organisation

hardware is set accordingly and raw beam position data are acquired and stored in the local ECA memory under beam synchronous commands. Once the acquisition is performed, the ECA CPU retrieves the data of the desired beam and bunches and rejects bad data as parasitic ones according to their acquisition time label. It processes the data with the use of calibration and linearisation tables or coefficients in order to correct for errors and non linearity of electronics and monitors, i.e. for the NB system : the Normalisers inverse transfer function (distorted arctan) as established by laboratory measurements and that of the FADCs.

The resulting X and Y position file for 4 to 16 BPMs is sent to the local PCA where a "Listener" routine sends it to the BOM "Collector" PCA via the Control System. The BOM Collector receives 40 files, checks for consistency, creates the BOM measurement output file and warns the user. The orbit output file is transmitted to an APOLLO display program (Fig. 5) for visual analysis and futher use [8].

The BOM software is also designed for hardware diagnostic, calibration and closed orbit simulation in the absence of beam.

Due to time shortage, only a stripped-down development version could be supplied for the start-up, called version 0, which has been successfully used until now. It does not yet offer the beam and bunch selection and parasitic rejection according to the data time label. This version allows for two first revolutions trajectories measurement (e^+/e^- and first bunch) and closed orbit measurement averaged over 10 revolutions and all bunches (no separation of e^+/e^- beams or single beam measurement).

3. BOM FABRICATION AND INSTALLATION

The injection test of July 1988 validated the BOM hardware design and series production was launched.

The subsequent last year of LEP construction and installation was very loaded. All BPMs were ready and installed as part of the quadrupole vacuum chambers [2] by the Vacuum Group [9]. About 15 leaks on button electrode feedthroughs (total 2200) appeared after transport and tunnel installation but no more since then. The origin of the leaks (tot. about 40) appearing at the central titanium conductor (Fig. 6 and 7) has been investigated with the manufacturer and found to be due to combination of gold-nickel braze

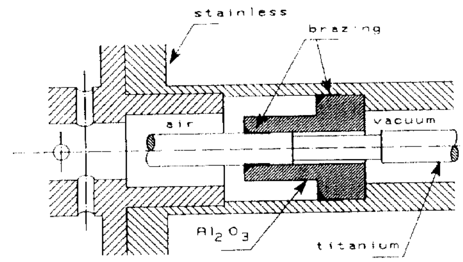

Fig. 6 Button electrode Al_2O_3 feedthrough

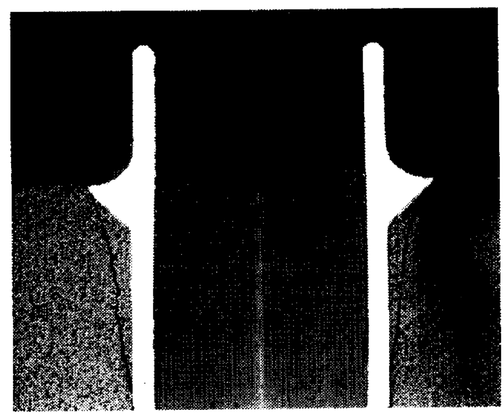

Fig. 7 Feedthrough ceramic crack due to braze ring

(imposed by corrosion resistance) with titanium forming a very hard alloy and too large a chamfer filled with braze and hence reinforcing the thin central condutor tube. A new model will use Monel and very small chamfer. About 10 electrodes presented short-cicuits. They were due to very thin Al fibers produced by scraping the machining grooves at electrode introduction in the BPM block. The shorts could be removed by electrical discharge and current.

The BOM system did require an almost industrial production, testing and calibrating of its 3000 electronic modules and 150 crates. The series production and wiring was executed by industry, but the testing and calibration was done at CERN on especialy developped and computer controlled test benches, which are also needed for BOM maitenance. Just after chamber installation and once the cables were pulled, a first team connected all the front-end electronics next to the BPMs. Two to three other teams assembled and tested the WB and NB stations hardware. The two months foreseen for overall BOM system check-out, with BST and Control system interface, were reduced to nothing due to late delivery of the tunnel under the Jura. It resulted in a tremendous debugging effort in the first weeks of LEP start-up.

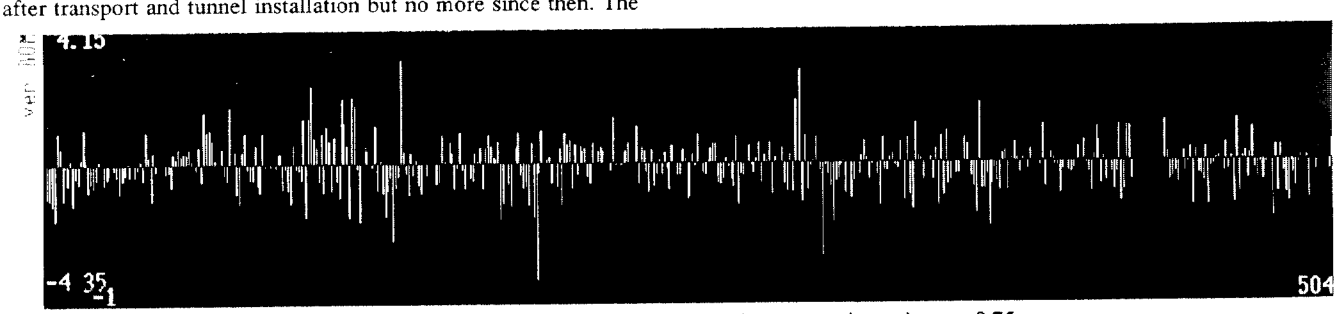

Fig. 5 Display of LEP vertical closed orbits after the best correction : sigma = 0.75 mm

4. BOM PERFORMANCE AND PERSPECTIVES

Since LEP start-up the BOM performance and reliability have gradually improved and after two months "An r.m.s. orbit distortion of about 1 mm was achieved routinely" [7].

The NB part of the system presents an horizontal offset of -1.3 to -1.6 mm relative to its calibration and to other position measuring instruments. This offset is due to the sensitivity of the analogue processing chain to the difference of length between the simulated beam signal (4 ns) used for calibration and the beam signal (100 ps, two polarities). Real beam induced signals in the NB analogue processing chain are shown in Fig. 3.and 8. Since the beam or simulation pulse width has an influence on the auto-triggering of the measurement point, values may fluctuate by a few bits as it can be inferred from Fig. 8. This situation is not satisfactory and a new normaliser generation is under study. For the time being the NB horizontal offset is corrected by a program (BOMCOROFFSET) which assumes that the average horizontal position should be 0 mm in the straight sections with no dispersion.

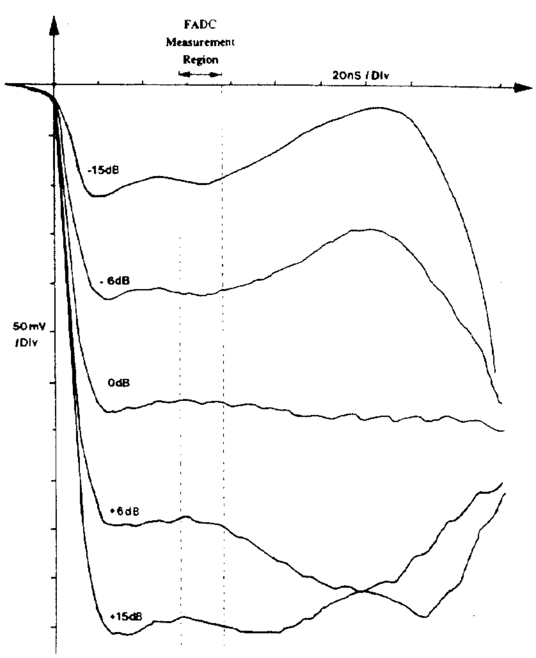

Fig. 8 NB Processor input signal as seen by the FADC at acquisition for different signal ratios from a pair of electrodes

The WB part presents instabilities due to the degradation of gain relay contact. Laboratory investigation showed that these instabilities are due to the aging of a contact lubricant used in this type of coaxial relays. The replacement of the relays is under study and will be implemented for next year start-up.

Except for these two points the BOM HW performance presents good reliability and stability and also has the advantage of its redundance. Calibration rate is of the order of once a month. Special attention has been given to the cables for their EMC noise rejection and insensitivity to large bursts of synchrotron light. After tests the well performing and chosen cable is a CATV product : 75 or 50 Ohm coaxial cable with polythene foam dielectric (0.4 density) and extruded thick Al outer conductor. There has been no problems with cross-talk or picked-up noise.

During the January to March 1990 shut-down the BOM HW has been further tested and it was found that high voltage command cards created disturbances and that the test generators were desynchronised resulting in noisy calibration. These problems were cured and the BOM calibration precision was improved by a factor of 4 as verified by simulated orbit test. The BOM system was recalibrated for the present running period which resulted in a better vertical orbit distortion of sigma 0.7 mm and reduced emittance [8] using 100 correctors. The orbit resolution is better than 65 microns and its absolute precision is 0.4 mm rms, as estimated from orbits analysis.

The version O software execution speed is too slow to allow for orbit averaging over a large number of revolutions. The version 1 software for the local processors (ECA) is being installed and tested. It will not only offer the full operationnal BOM measurement facilities, like separate orbits for e^+/e^- in presence of the two beams, but also four times faster processing speed, i.e. 27 s for processing of the average orbit over 30 turns and 8 bunches. Further improvement will be sought after in order to reach the aim to acquire an orbit in a few seconds for which the hardware and BST have been designed.

5. CONCLUSION

The main goal of the BOM has been achieved, i.e. to allow for an orbit correction to less than 1 mm r.m.s. and the absolute accuracy of the overwhole system was recently demonstrated when the vertical r.m.s. value was reduced from 1 mm to 0.7 mm, which resulted in an increased luminosity of 20 %. Two shortcomings in the Normalizer of the N.B. and in the gain switching of the W.B. will be eliminated for the next running period by a redesign of the respective modules. Once version 1 of the software will be fully implemented, this summer, further sophistications will be introduced to take advantage of the large acquisition capabilities of the system like 1000 turn memory and second memory allowing to run a background task.

6. ACKNOWLEDGEMENT

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REFERENCES

[1] J. Borer, C. Bovet, D. Cocq, H. Kropf, A.Manarin, C.Paillard, M.Rabany, G.Vismara, **The LEP Beam Orbit Measurement System**, Proceedings of the IEEE Particle Conference, March 16-19, 1987.

[2] J-C. Brunet, **Industrial Fabrication of Ultrahigh Vacuum Quadrupole Chambers for LEP**, 11th Int. Vacuum Congress, Köln, Sept. 25-26,1989, CERN/LEP-VA/89-60.

[3] J-P. Bacher, N. Hilleret, **Corrosion of Accelerator Vacuum System: Risks and Prevention**, 11th Int. Vacuum Congress, Köln, Sept. 25-26, 1989, CERN/LEP-VA/89-52.

[4] G. Baribaud, D. Brahy,A. Cojan, F. Momal, M. Rabany, R. Saban, J-C. Wolles, **The Beam Synchronous Timing System for the LEP Instrumentation**, Int. Conference on Accelerator and Large Experimental Physics Control Systems, Vancouver, Oct.30-Nov.3,1989, CERN/LEP-BI/89-66.

[5] G. Baribaud, D. Brahy, A. Cojan, F. Momal, M. Rabany, R. Saban, A Thys, J-C. Wolles, **A Distributed DATA Acquisition and Monitoring System for the Beam Instrumentation of LEP**, Int. Conference onAccelerator and Large Experimental Physics Control Systems, Vancouver, Oct.30-Nov.3,1989, CERN/LEP-BI/89-66.

[6] P-G. Innocenti, **The LEP Control System: Architecture, Features and Performances**, August 1989, CERN/SPS-ACC/89-35.

[7] D. Brandt et al., **A Description of the Orbit Correction Procedure used for the LEP Start-up**, LEP Commissioning Note 11, Sept. 29th, 1989.

[8] D. Brandt, P. Defert, W. Herr, J-P. Koutchouk, J. Miles, T. Risselada, R. Schmidt, **Orbit Processing for LEP**, this Conference.

[9] A video tape presenting some aspects (mainly the button electrode) of the fabrication, testing and installation is also available.
A complete technical report describing the BOM hardware is in preparation.