BI GROUP COMMITMENTS AND MAJOR ISSUES FOR DISTRIBUTED SYSTEMS

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Abstract

This presentation will detail BI responsibility and organization for LHC distributed instrumentation, i.e. the beam position monitoring system (BPM), the beam loss monitoring system (BLM) and the beam synchronous timing system (BOB). It will also present BI commitments on the requirements listed in the 2 previous sessions. In particular, it will address the BPM and BLM functionality and performance expected for the different operation stages and the procedures and tests foreseen to reach these objectives. Finally, current major issues (i.e. uncovered requirements) and possible alternatives will be presented.

BI RESPONSIBILITIES

AB/BI will provide the monitors, the electronics, the front end software and corresponding expert applications necessary to develop, test, deploy, diagnose and maintain the different instruments produced by the group.

AB/BI is not responsible for any software above the BDI front end servers necessary to operate the machine. Therefore, the BPM and BLM concentrators, the real-time feedback loops, the fixed displays, the middle tier black boxes, the operational applications, the post-mortem applications, the video and the analog signal transmission are outside the responsibility of the AB/BI group.

Table 1 gives a list of the people in the AB/BI group responsible for the different components of the BPM system, the BLM system and the BST system. All components of the BI mandate are covered. The commissioning experts for the BPM and the BLM system from the AB/ABP and AB/OP group are also shown in the table. The BOB system will be commissioned by AB/BI experts.

BEAM SYNCHRONOUS TIMING

Commitments

The beam synchronous timing (BOB) consists of the master (BOBM) and receivers (BOBR). The BOB system is based on TTC technology. It will provide the 40 MHz bunch synchronous clock and the 11 kHz LHC revolution frequency to the LHC beam instrumentation. In addition to these two basic clocks, it will allow the encoding of beam synchronous messages which can be updated on every LHC turn. They will be used for LHC instrumentation triggering and broadcasting of the machine status (mode, intensity, energy, turn number, ...). The BOB system is expected to be available right from the start-up of the LHC, as soon as it receives the RF signal.

Clients

The BPM system relies on the BOB for orbit, trajectories and multi-turn acquisitions as well as for the post mortem freeze trigger. The BLM will rely on the BOB only for the post-mortem freeze and the logging trigger. The BOB will be used by other instruments to synchronize themselves or to synchronize amongst each other (BTVM, BWS, BSRT, ...). The machine status has also proven to be of interest to the LHC experiments. They will receive this information using their standard TTC receivers and decoders [1].

Testing Plans

The BOB system is a collaboration between the AB/CO group and the AB/BI group. AB/CO is responsible for the master hardware and the master firmware. AB/BI is responsible for the master server, the master real-time task as well as for the receiver hardware, firmware and software. In total, three BOB systems are foreseen, one for the SPS, and one for each of the two LHC beams. The functionality of the recent BOB version two covers all the requirements. The system is being tested at the moment, and it will be commissioned on the SPS in 2006. Its performance will be assessed during the LHC sector test, using the SPS BOB master.

BEAM POSITION MONITOR SYSTEM

Status of the BPM Electronic Components

The network infrastructure, i.e. the optical cables, the coaxial cables and the WorldFIP control links have already been installed. The analogue front-end part of the BPM system, the Wide Band Time Normalizer, was successfully tested in TI8 and the SPS in 2004. Series production of the 4500 units is currently being launched. The Digital Acquisition Board, DAB64x, was designed by TRIUMF. Series production of the 1800 units has now started. The DAB64x card is the BI standard module for the digital data acquisition of the BPM system, the BLM system, the fast beam current transformer, the tune measurement system, the wire scanners and the luminosity monitors. The BPM acquisition hardware is expected to be fully functional for the LHC start-up.

Performance

Figure 1 gives the linearity and the noise level for the BPM system as a function of the number of charges per bunch. It can be seen that the BPM operating threshold of approximately 10^9 charges per bunch corresponds to 17%

Table 1: Responsibilities for the system components.

Equipment	**Project Leader**	**Monitor**	**Electronics**	**FE Software Exp. Appl.**	**Commissioning**
BOB	J.J. Savioz	n.a.	J.J. Savioz	P. Karlsson	BLM, BPM experts
BPM	R. Jones	C. Boccard	E. Calvo	L. Jensen	J. Wenninger (OP), W. Herr (ABP), Y. Papaphilippou (ABP)
BLM	B. Dehning	E.B. Holzer	C. Zamantzas, E. Effinger, J. Emery	S. Jackson	R. Assmann (ABP), H. Burkhardt (ABP), J.B. Jeanneret (ABP), S. Gilardoni (ABP)

of the nominal ion bunch intensity. This does not leave much margin for the ion commissioning. Table 2 shows the rms resolution for pilot beams and for nominal intensity beams. It should be possible to reach the nominal resolution of 5 μm on the global orbit measurement for Stage I running with 43 pilot bunches.

Commissioning

This section describes the functionality and availability of the BPM system during the different stages of commissioning.

Before Beam The system has been tested in the SPS and in the TI8 transfer line. The testing will continue in 2006. The full calibration of the LHC acquisition chain is part of the BPM hardware commissioning.

First Turn As long as the beam synchronous timing (BST) is not available, the BPM will acquire data in an asynchronous mode. In this mode the system is auto-triggered and does not depend on any external timing.

It is intended to have the BPM intensity measurement operational for the start-up of the LHC, but at this moment it is not sure if the goal will be attained. The efforts are currently concentrated on the completion of the position monitoring system. The intensity measurement has the next highest priority and the work on the required acquisition card will be started as soon as manpower becomes available. This measurement implies a considerable amount of additional software as it uses the acquisition system of the position measurement of the other LHC ring. During this measurement the positions in the second ring cannot be measured. Should the intensity measurement not be ready in time, it would not affect the position measurement.

First few to 1000 Turns As soon as the BST system becomes available, the BPM will be phased-in with the BST 40 MHz bunch synchronous clock. This can take place in parallel to the asynchronous acquisition of the beam position. Once the BPM system is timed-in it will allow bunch tagging and turn tagging.

Circulating Beam at 450 GeV Two modes of operation will be available, the global orbit mode and the capture mode. The global orbit mode requires the timing-in of the BST to be completed. It will provide the real-time orbit data at 10 Hz and the full functionality of the post-mortem. The capture mode can be triggered on request. It will give bunch to bunch and turn by turn data on a selected number of turns. This mode of operation can generate a large amount of data and will require concentrators and powerful analysis software to be exploited.

Snapback, Ramp and Squeeze At that time of commissioning the real-time global orbit data will be available as input to the orbit feedback correction. The concentrator, the feed-back algorithm and the real-time orbit correction need to be available to implement the orbit feedback.

Cuts proposed on the Capture Mode for Stage I

The AB/BI group proposes the following limitations on the capture mode for stage I of the commissioning, in order to reduce the workload. The multi turn acquisition will be able to capture the position readings of either one user selected bunch or of the beam average for a maximum of up to 10000 turns. The acquisition will always be on consecutive turns and always on all BPMs at the same time.

BEAM LOSS MONITOR SYSTEM

Status

The network infrastructure has been completed.

Almost all detector components have been received. The production of 40 ionization chambers has started at CERN in January 2006. In February 2006 the series production of about 3800 chambers will start in IHEP, Prodvino, Russia. A production rate of 20 chambers per day is foreseen in Prodvino. The total production time is about one year.

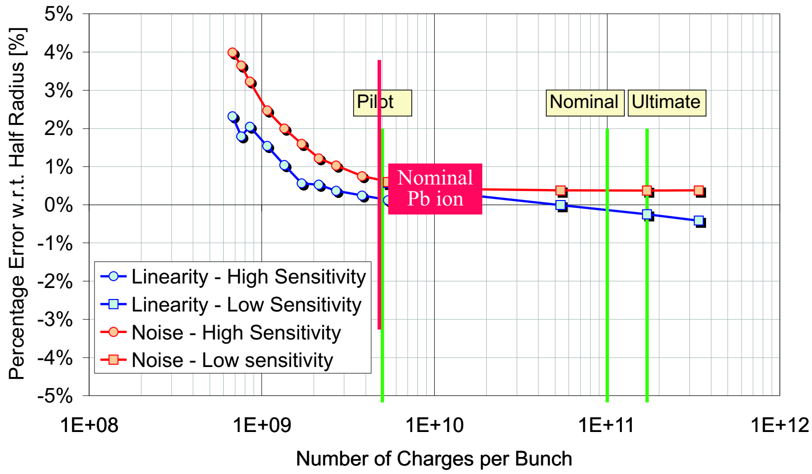

Figure 1: Linearity and noise level as a function of the number of charges per bunch.

Table 2: BPM rms resolutions for different intensities

Intensity		**rms Resolution**
Pilot Bunch	Trajectory (single shot)	200 μm
	Orbit (224 turn average)	20 μm
Nominal Bunch Intensity	Trajectory (single shot, single bunch)	50 μm
	Trajectory (average of all 2808 bunches)	5 μm
	Orbit (average of all bunches over 224 turns)	5 μm

The total production rate could possibly be increased, to balance unforeseen delays. In case of problems with the production or installation, it would also be possible to install a smaller number of monitors without compromising the beam loss measurements too much. However, it seems unlikely that this option needs to be adopted. In addition to the ionization chambers, 320 secondary emission monitors will have to be produced. Prototypes have been successfully tested. Currently, improvements to the design are being tested. The production is foreseen to start beginning of 2007 and is expected to last two months. The secondary emission monitors are expected to be ready for LHC commissioning, but not for the sector test. The intensity of the sector test beam is expected to just about reach the saturation level of the ionization chambers, in case the total beam intensity is lost within one meter. Therefore, the secondary emission monitors are not critical for the sector test.

The installation of the electronic crates (456 in the tunnel and 105 on the surface) and of their power supplies has started. Pre-series (50 out of 750 cards) production of the tunnel acquisition card has started in December 2005. For the digital surface acquisition, series production of the DAB64x cards has started and pre-series (30 out of 400 cards) production has started of the mezzanine card. The 25 combiner cards for interlock and testing are still in the design phase.

In summary, the BLM hardware is expected to be ready for LHC start-up. The tasks which are still to be performed before the start-up, are: The post-mortem has to be added to the DAB program. The testing of the communication of the FPGA with the threshold tables has to be finished. The combiner card has to be designed. And one additional high voltage system test has to be implemented in the charge-to-frequency converter program.

Threshold Calibration

For the BLM system to fulfill the specifications, the threshold tables have to be calibrated. These calibrations are based on simulations [2]. In case the calibrations are not precise enough, calibration measurements with the LHC beam will have to be performed. The analysis effort of the BLM logging and post-mortem data will have to be started in 2006. The required tools are needed for the sector test already. This analysis is essential for the calibration of threshold tables on one hand and for the interpretation of BLM signal patterns (beam particle loss patterns) on the other hand. Very large amounts of data will have to be analyzed, when the beam commissioning starts. Extensive software tools for data analysis will be required to fulfill the specifications. We have to start now to specify and implement them. Equally important is an operational logging and post-mortem system for the Sector Test.

System Tests

The testing procedure are described in [3]. They have been defined in order to achieve the required reliability and availability of the system. The functionality of all components will be tested before installation. Thereafter, there are three different inspection frequencies: tests after installation and during yearly maintenance, test before (each) fill and tests which take place with beam, in parallel to the data taking. Figure 2 lists the most important tests and their frequency.

Updating the Threshold Tables

The threshold tables can be downloaded on the charge-to-frequency converter card via the VME interface. This possibility will only be used in the lab. Before installation it will be disabled by a hardware switch. During LHC commissioning and operation the threshold tables can only be changed locally (i.e. in the surface buildings which houses the electronics cards) via a dedicated interface.

Conceptually, two different approaches will have to be used when changing the threshold tables. An empirical procedure needs to be defined to apply fast changes according to the needs of the LHC operation and within certain safety limits. After an analysis of loss data, more fundamental changes can be applied. They can then also affect the energy and loss duration dependence of the threshold values.

For the generation, the failsafe management and the archiving of the threshold tables software tools will have to be specified and developed. It should be possible to group monitors according to magnet type for a faster changing of the threshold tables.

Synchronization

For reliability reasons the BLM system does not use any external timing (other than the post-mortem and logging trigger). So the different DAB cards are not synchronized amongst each other. Table 3 gives the duration of the 12 time intervals over which the losses are integrated and the rate with which the integrated values are refreshed. Every second an external logging trigger prompts the read out of the loss values. For the intervals below one second, the maximum value over the last second is sent for logging and data display. For the larger intervals, the most recent value is sent. E.g. the integration window of 5.5 s is updated every 82 ms. At the time of the readout this value can therefore not be older than 82 ms on any of the DAB cards. Hence, the maximum time jitter of all the 5.5 s values on all the DAB cards is 82 ms.

Table 3: Refreshing rate of the 12 integration intervals of the BLM system.

Moving Average	**Refreshing Rate**
40 μs	40 μs
80 μs	40 μs
0.3 ms	40 μs
0.6 ms	40 μs
2.6 ms	80 μs
10 ms	80 μs
82 ms	2.6 ms
0.3 s	2.6 ms
1.3 s	82 ms
5.5 s	82 ms
21 s	1.3 s
84 s	1.3 s

BLM for Ions

Considerably less beam loss simulations are available for the ions than for protons. Therefore, the performance of the BLM system for ions has much higher uncertainties. The ions loss maps have been simulated for beam one and beam two [4]. These simulations yielded additional loss positions left and right of the collimation regions in IR3 and IR7. Like in a spectrometer, the loss position of the different ion species (which are produced through interaction in the collimator jaws) are fanned out over the dipole magnets. These simulations lead to the request for additional monitors. Error studies on the loss maps are foreseen to be performed within the AB/ABP group.

The bound free pair production (BFPP) has been simulated for the interaction region of the ALICE experiment [5]. The simulation shows a localized loss position in D6 (Bernd?), which has to be monitored by an additional detector as well. The induced hadronic shower through the dipole magnet has been simulated [6]. This simulation shows that for the LHC main dipole magnets the ratio of energy deposited in the magnet versus the energy deposited in the BLM detector is roughly the same as for protons. The ratio of the quench (damage) level to the BLM signal is, therefore, about the same as for protons. This means that similar threshold tables can be used for protons and ions. Also the shape of the hadronic shower is similar for ions and protons. Hence the standard BLMs, which are installed at local aperture limitations, are also well positioned for ions. Future simulations of other electro-magnetic processes (which have a lower cross section) might lead to additional requests for BLM locations.

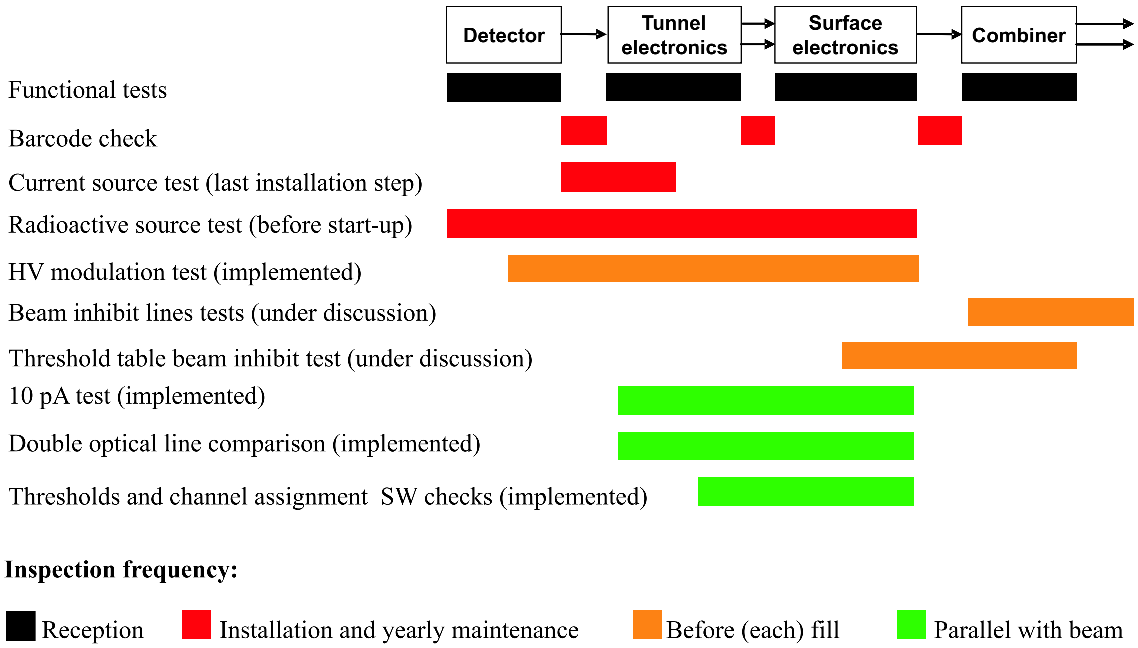

Figure 2: Overview of the most important BLM testing procedures from [3]. The colored bars show what part of the system is tested and at what frequency.

SUMMARY

The BST, the BPM (possibly excluding the intensity measurement) and the BLM hardware systems are expected to be fully operational for the LHC start-up. The various modes of acquisition of the BPM system should allow the necessary data to be available when they are required during the commissioning stages. To fulfill the specification regarding the precision of the measurement of the quench levels, the BLM system needs to be calibrated. The calibration requires the logging, the post-mortem and a system for the management of critical settings to be available already for the Sector Test.

ACKNOWLEDGMENTS

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