BEAM COMMISSIONING OF INSTRUMENTATION

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Abstract

It is clear that proper functioning of the beam instrumentation is vital to effective commissioning. How the key instrumentation is to be commissioned is described including a description of measurements and tests to be perform with beam during the various commissioning phases. The demands on other systems [controls] are clearly stipulated. The procedures to be followed to ensure proper preparation and pre-testing are also outlined.

PREREQUISITES

In order to have any of the LHC instruments working a minimum controls infrastructure will be needed. In detail:

- Ethernet connections with the specified deterministic bandwidth in all SR buildings
- Ethernet-WorldFIP gateways in all SR buildings
- slow timing (so called machine events) in all SR buildings

This is the "classical" list of requirements with "beam synchronous timing" missing. The design of many instruments has been made such that these will work with reduced performance even when beam synchronous timing signals are not applied. This feature will help enormously to bootstrap the LHC machine, the instruments and the controls signals.

The newly made FESAII real time framework has as a built-in functionality the emulation of missing hardware. With this feature software developers will be able to start developing their code even before the system engineers have built the prototypes. This should help in particular for the small (unique) systems, for which the hardware is usually built quite late in the project.

SYSTEM INTEGRATION

A principal worry is the complexity of the systems, which are most relevant for the commissioning of the beams. In particular the two large systems (BPMs and BLMs) demand an enourmous effort beyond the actual con-struction of the sensors and the acquisition electronics. Application programs have to be specified, designed, coded and tested. Operational parameters for the system have to be pre-computed and implemented. Application software has to be tested in an environment, which is comparable to the operation conditions later in the LHC machine, i.e. the software has to be tested by emulating the access to multiple front-ends with additional load on the controls infrastructure. Many more tasks are needed, which go often beyond the direct responsibility of the beam instrumentation group. In order to make some progress the following concept is proposed: Individual people at CERN get selected as "system commissioners" for various beam instrumentation and other important accelerator equipment. Those system commissioners are mandated to organise and streamline the efforts in various equipment groups with the aim of having the minimum functionality ready and tested for the first beam commissioning. Those commissioners should be experienced people, which are made responsible for not more than 3 different objects.

INDIVIDUAL SYSTEMS

DC transformers

The DC transformers will be further developments of the existing and installed DC transformers. The new developments will be aimed at reducing the noise, thus allowing to measure the lifetime of a single pilot bunch. Presently a factor 4 is missing to comply with the specifications. The DC transformers need no external timing and are expected to work from the first moment. The bandwidth is well below 1 KHz, in other words well below a turn by turn resolution. These monitors can not be used for injection studies.

Bunch to Bunch transformers

The monitors will be identical in design with the bunch to bunch transformers presently installed in the SPS:

- The systems are based on a high bandwidth sensor followed by 2 channels of fast integrators with 10 ns integration time and 12.5 ns time separation between the channels.
  If properly adjusted relative to the beam signals, the difference of the integrator outputs gives the bunch charge. From this it is clear that this system need beam synchronous timing to work and will hence not be available for the start-up of the machine.
- The integrators are followed by 12 bit 40 MHZ ADCs. The corresponding dynamic range is not sufficient to give low quantization noise for pilot intensities; hence the life time measurement of the pilot bunch will be difficult. A solution to this is presently studied by having a second acquisition channel, for which the pilot intensity represents full scale. The issue there is the protection of the input electronics in case of nominal bunch intensities.
- The sensors are not sensitive to uncaptured (DC) beam.
- The system based on the difference of two 10 ns long integrations is sensitive to ghost bunches and will give wrong results in case those are present.

Wall Current monitor

The AB-RF group has developed a fast wall current monitor for each ring. The signals will be made available in the control room for direct observation with an oscilloscope.

The BPM system

The functionality of the BPM system is described elsewhere.

Since the year 2001 prototypes of the BPM system sensors and electronics are installed in the SPS. These BPMs work to full satisfaction of the users for LHC type beams. Even real time orbit feedback is implemented and tested on a part of the machine (6 BPMs and correctors). Therefore in general it is expected that the LHC BPM system will work from the beginning of machine commissioning.

The following features of the BPM system are recalled:

a) External timing:
In normal operation the BPM system will need the beam synchronous timing information in order to give a time stamp to each measurement and hence being able to identify individual bunches.
Since the front end electronics is self-triggered, a mode of operation without beam synchronous timing has been foreseen in order to facilitate the LHC bootstrap.
In this mode the digital acquisition board will accept any input signal and store it in its buffer memories. This mode of acquisition is identical to calibration mode, in which the system measures the signals from internal signal generators.
One potential problem can be anticipated in this mode: If the bunch intensity is very low, such that the system will not trigger at every turn, non coherent capture data can be expected with signals from some turns missing. In this case multi-turn acquisitions for tune measurements or phase advance studies will have to be checked for consistency.
On the contrary averaged orbit data should be very reliable.

b) Threshold setting:
The analog front end electronics is a 40 MHz wide-band system. With 1% tolerances on components it is very difficult to control signal reflections better than at the 2…3 % level.
In that case the signal reflection of a nominal bunch can easily attain the signal level of a pilot bunch and would hence be measured as a second bunch. In order to avoid this a signal threshold has been introduced into the system, with just two values for "low" and "high" bunch intensities. These settings can be changed via a world-fip command, but due to the speed of this fieldbus, it will take a few seconds to change the threshold for all BPMs. This has significant consequences for the injection scenario, in which a circulating pilot bunch gets ejected at the same time, when a full batch with nominal intensity is injected.
Getting continuous orbit reading in this case from the pilot and then immediately from the full batch will not be possible. The only possible solution for the moment is to have half the BPMs on low intensity threshold and the other half on high intensity threshold.

c) Dependence of position reading on bunch intensity
A variation of the bunch intensities over the full range of specified intensities will change the reading of the beam position by typically 1% of the normalized aperture, i.e .for the arc BPMs by about 130 um. This effect originates from the differential linearity of two signal comparators in the front-end electronics. Since it does not only depend on intensity, but also on the absolute position, it will be very difficult to correct this effect offline. The major implication will be, if the BPM readings in the collimation regions will be used to control the collimator positions.

d) Calibration constants: The system will have many calibration constants. Only a few will be mentioned here:
- Mechanical offsets: During the assembly of the SSS the alignment of the BPM body with respect to the mechanical center of the quadrupoles will be measured and reported into a database. These values will have to be downloaded into the BPM system for corrections. A refinement of these corrections with the k-modulation technique will only be possible for the quadrupoles with individual power converters, i.e. in the insertions.
As during LEP operation, it will take several weeks of stable running to measure these constants.
- calibration constants of the input electronics can be measured by using the integrated calibration system. This system can only work, if there is no bema in the machine.
The necessary frequency of these calibrations will still have to be determined, but first experience in the PS indicates, that this issue is not critical.
- some calibration constants are specific for the front-end electronics. In case of a repair by exchange, new values have to be loaded into the system.

e) Intensity reading:
The BPM system will be capable of measuring bunch intensity turn by turn as the sum of the 4 signals from the sensors. Within a factor 2 this is proportional to beam intensity independent of the beam position. The BPM system has to be

switched by a field-bus command into this mode. This action again takes a few seconds.
During intensity measurements the beam position can NOT be measured. On the contrary the transmission channel of the BPM system of the second ring can be used for intensity reading of the other machine.
Hence in this specific configuration, bunch positions AND bunch intensity can be measured simultaneously, but without having any information from the second ring.

Transverse Profile Monitors

In total four different systems are foreseen to cover the needs for transverse profile measurements:

1) Screens
   More than screens will be installed on various locations. These monitors have a classical aluminium-oxid screen for low beam intensities and OTR foils for nominal intensities.
   The emitted light passes through variable grey filters onto a TV camera for direct observation and also to a digital frame-grabber.
   These systems have been used during the extraction tests in the year 2003 (without variable grey-filters) and these systems are expected to work from the first day.
   A few days of commissioning will be needed to make the timing of the frame grabbers work.
2) Wire scanners
   These instruments will be installed to establish an absolute reference for beam size measurements. The scanners can be used up to about 10% of total nominal intensity. The scanners will need a few days of commissioning, basically again in order to adjust timings. As a doctoral thesis the BDI group studies presently the systematic differences of the wire scanners, which are installed in the injector chain. The results of this study will allow the cross-comparison of beam sizes measured in different accelerators.
3) Synchrotron light telescope
   Based on synchrotron light from a superconducting undulator these telescopes are aimed at a similar role as the BEUV telescopes at LEP: a real time display of the LHC beam sizes. An online image of the beams is expected rather soon after the establishment of circulating beam, but a correct calibration and correction of the measured beam profiles will take several weeks including specific machine studies.

In particular it will take some effort to understand the energy dependent correction factors.

The BLM system

The BLM system is a large and important system and it is described in detail elsewhere.
For this presentation it is important to retain:

- The system has its sensors outside of the cryostat and the functionality and identity of each channel will be tested by creating as signal in the ionisation chambers with a radioactive source
- The system has more than 3000 channels.
- Each channel can be enabled to dump the beam.
- The dependence of the dump thresholds as function of duration of the loss is implemented as 11 different signal integrators (time constants roughly staggered as exponential series).
- This gives more than 11 x 3000 dump thresholds to be dealt with in an application software
- The energy dependence of the dump thresholds (more than 2 orders of magnitude) is implemented as a multiplicative factor, which is changed by the front-end software when receiving telegrams with the beam energy.

The overall system complexity is very high. A system commissioner has to be assigned immediately for this project.