Commissioning of Beam Loss Monitors

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Abstract

The commissioning task of the LHC beam loss monitors can be done in periods before the start-up with beams, parasitically during operation and with dedicated beams. It is foreseen to commission the detectors, the acquisition electronics, the analysis electronics and the beam permit inhibiting system before the start-up. The analysis of beam loss events together with the generation of beam permit inhibits will be used to verify the foreseen operation of the system. To check the integrity of the system automatic test procedures will be executed during and in between of periods with beams.

A calibration of the system is needed to cope with the varying quench levels for different magnet types and varying response of the detectors depending on the secondary shower spectrum and other sources. These calibration factors will be absorbed in the threshold tables and they will be based on measurements and simulations. Dedicated quench level measurements during the sector test could be used to verify the models. In case of excessive number of quenches or beam aborts, beam induced quench tests could be used to improve the models.

INTRODUCTION

The efforts for the LHC beam loss monitoring (BLM) system are motivated by the required protection and prevention function of the system. The protection function is given by the beam permit inhibit in case of potentially damaging losses (see Fig. 1). The number of beam dump

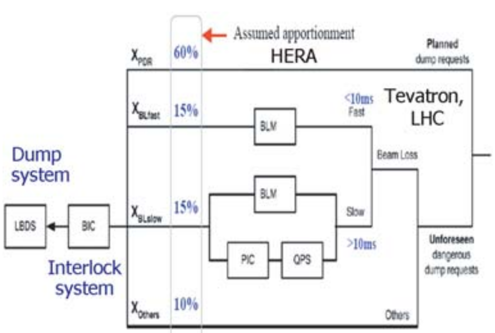

Figure 1: Dump request distribution and the employment of the beam loss system [1].

requests, which reaches the dump system over the machine interlock, is to 60 % operator initiated request (inspired distribution by HERA [2]). The remaining dump requests are to 30 % caused by beam loss initiated dumps and to 10 % by various other reasons. The beam initiated requests are equally subdivided in losses with a duration below 10 ms and above. The short losses can only be detected by the beam loss system except losses with durations shorter than 4 turns. The loss measurements, the signal transmission and the dump system response require these few turn for the beam extraction. In case of shorter loss durations protection will be given by absorbers and collimators. The long losses can be detected in addition to the BLM system with the quench protection system (QPS, PIC). In this case two independent systems are available for the detection.

The prevention function is given by the beam permit inhibit in case that the losses exceed quench level thresholds. The quench level thresholds are 2 to 3 orders of magnitude below the damage levels in most cases insuring a large safety margin. For the beam permit inhibit generation the BLM system is the only one in the range of the quench levels.

STEPS OF COMMISSIONING

The commissioning steps are divided in environmental tests before the installation, functional tests before and during installation and tests during the operation (see Fig. 2).

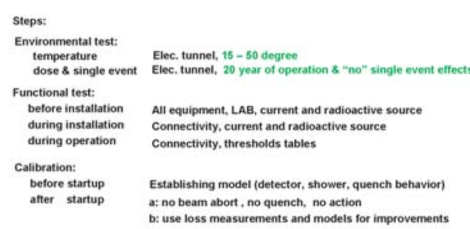

Figure 2: Commissioning steps of the beam loss system.

The environmental tests are done on the detector and tunnel electronic components, because they are exposed to large temperature changes and potential radiation damage (see Fig. 3).

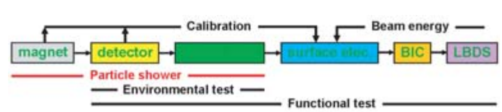

Figure 3: Test and commissioning scheme of the beam loss measurement system.

Functional tests are done before the installation with all BLM equipment. The detectors are tested with a radioactive source and the electronic acquisition chain is tested with a current source simulating the detector signal. These tests are repeated in the tunnel with the final cabling and set-up. Especially the source test, done shortly before start-up, should ensure the correct identity of each channel. The connectivity of the channels can also be tested remotely by modulating the high voltage supply of the detectors. The capacitive coupling between high voltage electrodes and signal electrodes allows the induction of a current in the system used to check the whole acquisition chain (see Fig. 3). An offset current induced in the tunnel electronic or the use of a redundant signal transmission path allows to survey the system during the operation [3].

The commissioning procedure includes the determination of the calibration of the BLM system. A model of the detector, shower and quench behavior based on simulation and measurements is determined before the start-up (see Fig. 4). The left column shows the elements to which a

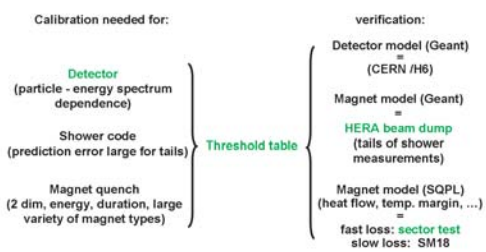

Figure 4: Scheme of the BLM calibration.

calibration has to be applied. The right column indicates the used simulation programs and their verification procedure. The different calibration results are combined in the quench level threshold tables.

CALIBRATION AND VERIFICATION OF THE MODELS

The detector response has been tested with different beams ranging from the very short exposure time of 100 ns and $1 \cdot 10^{10}$ protons to exposure times of seconds with a few $1 \cdot 10^{7}$ protons (see. Fig. 5). The momentum range was between a few GeV to 450 GeV. The observed relative variations were about a factor 2 [4]. The response variation is identical to the specified uncertainty of the whole system, therefore it is not acceptable for a single component.

The shower code prediction uncertainty is largest in the transverse tails of the showers where the loss monitors are located (outside of the cryostat) (see Fig. 6: blue rectangles and lower shower distributions). These uncertainties will be determined with a set-up at the inline dump of HERA. Monitors are located along the dump to determine the longitudinal shower profile. The impacting proton density is accurately measured by the beam current transformer shortly before the abort of the beam. It is expected that the remaining uncertainty will be below 50 % as for the uncertainty in the shower core .

The quench level uncertainties are determined by GEANT simulations of the energy deposition in magnet

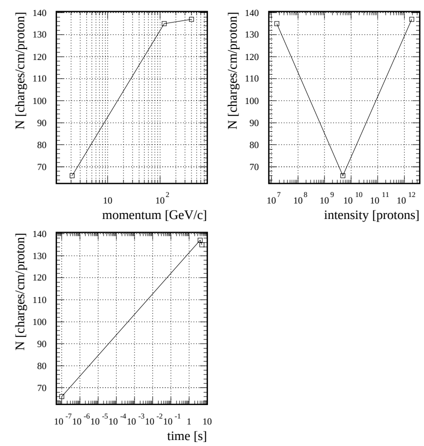

Figure 5: Signal response of a ionisation chamber as function of proton momentum, intensity and exposure time.

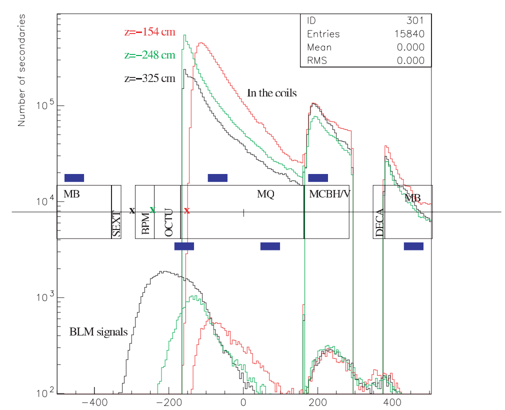

Figure 6: Number of secondary shower particles in coils (top curves) and along the outside cryostat (bottom curves). The location of the detectors are indicated by blue rectangles.

coils (see Fig. 6, top curves) and verified by quench tests with short duration beams. This procedure will mainly verify the GEANT predictions for the case of a negligible heat flow out of the shower area. These tests are foreseen to be done during the sector test period of the LHC [5]. For losses with durations longer than 0.1 ms the heat flow in the coils and from the coil into the helium bath has to be taken into account. In the extreme case of steady loss duration the heat flow limitation will determine the temperature increase and therefore the quench levels [6]. To simulate this behavior a model is under development and a verification is foreseen to be done by using the quench heater system of the coil for a defined deposition of heat into the magnet coil.

COMMISSIONING TASKS

The above mentioned calibration steps are treated by several teams. The following list indicates the tasks and their actual status.

- Before start-up:
  - Proton loss studies to identify uncovered loss locations: Team R. Assmann; ongoing.
  - Establishing of models for damage thresholds:
    - Collimators - Absorbers: Team A. Ferrari, B. Goddard; ongoing.
    - Cold equipment: not defined yet.
    - Warm equipment, damage test in the SPS: V. Kain, R. Schmidt; ongoing.
  - Establishing of models for quench thresholds:
    - Enthalpy, heat flow and steady state limit determination: Team A. Siemko; ongoing.
    - Energy deposition in coils and detectors: Team B. Dehning; ongoing.
  - Ion thresholds:
    - Energy deposition in coils and detectors, Team J. Jowett; ongoing.
  - Preparation for the appearance of the excessive numbers of beam aborts or quenches:
    - Preparation of analysis tools for data treatment (logging and post mortem data bases are required as well as the tool for the managing of critical settings (MCS)): responsibility not defined yet.
- After start-up:
  - Analysis of beam losses causing beam aborts or quenches to identify/verify model uncertainties (parasitic to operation)
  - Beam quench tests to optimise threshold tables (sector test quench measurements will establish the procedure)

SUMMARY

The different steps of the calibration, the environmental tests, the functional tests and the calibration of channels have been defined. The environmental tests and most of the functional tests are done before start-up without beam. The calibration of the system is established by a model of the quench levels of the magnet coils also before start-up. Theses models are partially tested to verify the appropriate prediction power. In the case that the models uncertainties are not acceptable parasitically taken data are used for their correction. Only in the case that the remaining model uncertainties are to large test with beam have to be done.

REFERENCES

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