THE INSTRUMENTATION OF THE TI8 SPS TO LHC TRANSFER LINE

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Abstract

The new TI8 transfer-line between the SPS and the future LHC was commissioned during two long machine development sessions in autumn 2004. This paper will present the beam instrumentation linked to the extraction region and along the line from the design and installation up to the tests with beam. After minor modifications copies of these systems will be used for the TI2 transfer-line to be commissioned with beam in 2007.

INTRODUCTION

The LHC Transfer & Injection (LTI) project started for the BDI group in 2002 with the arrival of the functional specifications [1] and the beginning of the official coordination meetings.

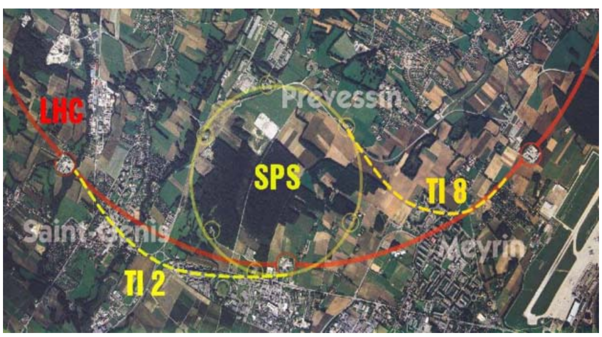

Figure 1: Aerial view of the SPS to LHC transfer-lines

BDI INSTRUMENTS

From the user requirements, the hardware implementation choices for the different systems were made. Some of the systems below had already been tested with beam in 2003 during tests of the extraction system and the first ~100m of the TI8 transfer line (TT40) [2]. The systems involved are:

- A beam position interlock linked to a pickup in the extraction region (named BPCE) that should allow the extraction of the beam only if the bumped position (nominally close to 30mm) is within pre-programmed limits. To acquire the turn-by-turn position data, the existing SPS orbit system (MOPOS) was used. A dedicated real-time action utilising the pickup linearization algorithm described in [3] was developed and the interface to the interlock system took place through the prototype LHC beam interlock controller (BIC) module [4].
- A beam-loss interlock monitoring the losses during the extraction process. If a problem occurs during the slow (~100 msec) ramping of the orbit corrector bumpers, this system should dump the circulating beam to avoid damaging the downstream extraction elements (septa etc). To cover this requirement, 8 dedicated ionisation chambers were installed in the extraction region, with the fast loss detection system [5] connected to the SPS emergency beam dump.
- A total of 15 beam profile monitors (BTVI) (see figure 2) were requested from the SPS extraction region through to the end of the TI8 transfer-line. They are used to acquire the 3D images of the signal produced when the beam passes through a screen made of either alumina (for luminescence) or titanium (for OTR). New mechanisms to select the filter (for signal attenuation) and the screen position were designed and could be controlled from the newly designed BTVI VME acquisition and control card [6]. To avoid signal cable lengths of more than 3km, VME acquisition systems were positioned at either end of the transfer-line. A dedicated PC system with digital video transmission over Ethernet was provided to allow the remote real-time observation of a selected screen.

Figure 2: A TI8 beam profile monitor (BTVI)

- Fast beam current transformer devices (see Figure 3) installed at either end of the TI8 transfer-line to measure the transmission of the beam through the line. Fast 40MHz integrators allow the measurement of individual bunches spaced by a multiple of 25ns. More information about the Fast BCT systems can be found in [7].

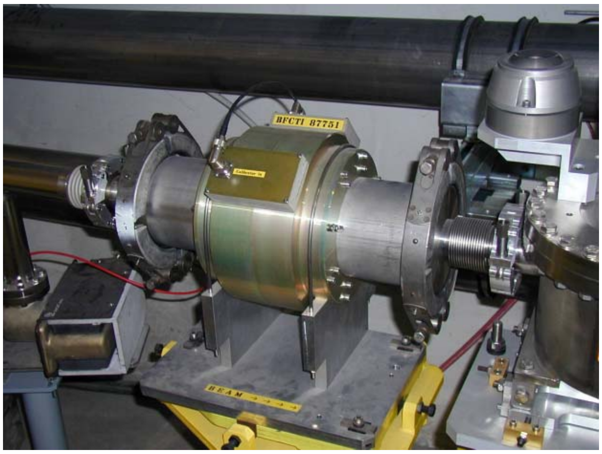

Figure 3: A Fast BCT device on in the TI8 line.

- A total of 44 beam position pickups were installed along the line. These consisted of 4 large aperture strip-line couplers in the first part, followed by 40 button electrode pickups using recuperated LEP buttons. For the majority of pickups, only the measurement plane corresponding to the maximum transverse beta-value was connected. In certain strategic places though, both measurement planes were equipped. Different configurations of the distributed front-end electronics meant that a total of 40 front-end crates (see Figure 4) were installed in the tunnel equipped with power-supply, WorldFIP and WBTN modules. More information about the BPMI system layout can be found in [8].

Figure 4: A BPMI front-end crate before installation in the tunnel. On the top can be seen the optical fibre patch panel.

- Beam loss monitors for detecting of losses produced by the passage of the beam through the line. A total of 28 standard SPS type ionisation chambers were used for this purpose.

INSTALLATION AND COMMISSIONING

The button-type pickups connected to the main transfer-line quadrupoles were aligned and installed before being installed in the tunnel by the vacuum group. All other equipment was installed by members of the BDI group. Priority was given to the equipment under vacuum such that the entire line could be tested for vacuum leaks as quickly as possible. A single leak was found on one of the recuperated LEP buttons. More information can be found here [9][10].

TESTS WITH BEAM

The transfer line was tested with beam during two 48 hour MDs in the autumn of 2004. To keep the induced radiation level to a minimum most of the tests were done using a single LHC bunch at intensities around 5E9 protons. The main problems encountered during the first test period were: a) very noisy downstream BCT readings which meant that the planned transmission tests between the start and end of the line were difficult to do and b) unusable position values obtained for the first two strip-line couplers at the start of the line. It was later discovered that these pickups were incorrectly cabled. Fortunately as the beam went straight through the line this didn't cause any serious problems. It was believed in the beginning, that the beam position system for the upstream part of the line was incorrectly calibrated; giving position readings which were very different from what was expected (see Figure 5).

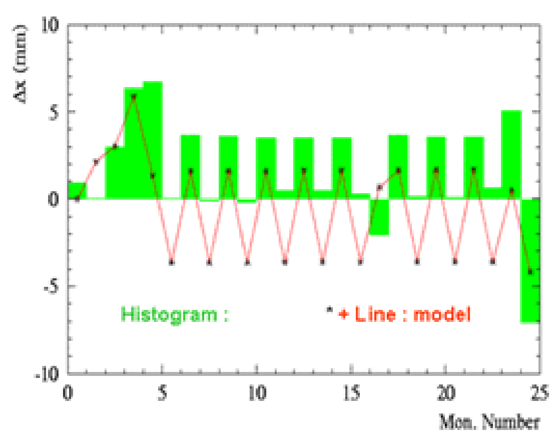

Figure 5: Measured (bars) versus predicted response.

The discrepancy, however, was finally found to come from the wrong current setting in a quadrupole in the beginning of the line. After correcting this problem the entire line fitted the model to better than 10% as expected (Figure 6).

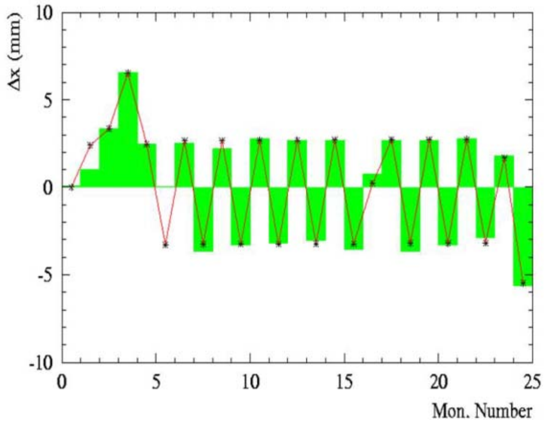

Figure 6: With the quadrupole problem solved the beam response fits the MAD model.

During the second test period some time was spent with a beam of 4 bunches spaced at 525 ns. This beam was used to measure the spread in the bunch to bunch positions and intensities. The operational application to visualize the beam position data in the transfer-line showed the average position rather than that of the individual bunches. However as the spread in the bunch positions were calculated and returned with the data it was possible to get a clear view of the spreads encountered. During these tests, spreads of several 100 microns in beam positions were observed and were judged to come from jitters on the extraction kicker flat-top amplitude. An example of the calibrated intensities acquired in the downstream BCT system at the end of the line can be seen in Figure 7.

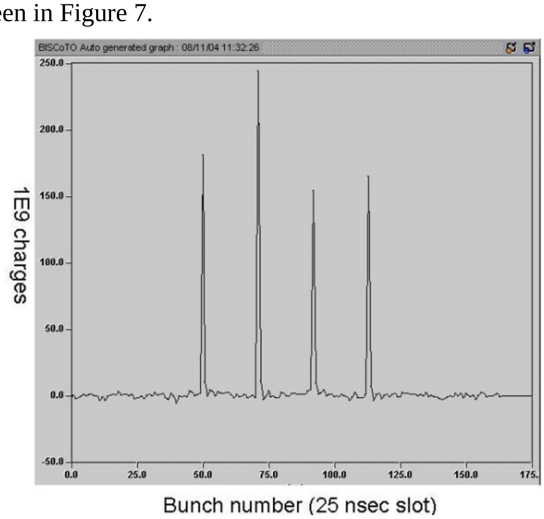

Figure 7: The calibrated intensities of individual LHC bunches spaced by 525 ns.

More information about the results obtained can be found in [9], [11] and [12].

CONCLUSIONS AND THE FUTURE

The instruments installed by the Beam Diagnostics and Instrumentation group allowed the TI8 transfer-line between the SPS and LHC to be thoroughly tested with beam. In addition, since much of this equipment is also destined for the LHC, it provided a first test-bed for LHC instrumentation. Minor design changes were highlighted necessary to make these systems more robust and reliable.

ACKNOWLEDGEMENTS

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