Instrumentation Needs for LTI

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Abstract

The general layout of the LHC injection transfer lines, TI 2 and TI 8, is presented, together with the other beam lines branching off from TI 2 and TI 8. The instrumentation needs for the beam transfer to LHC are reviewed. The location of the beam instrumentation in the lines is discussed, from the extraction in the SPS to the injection into the LHC.

1 INTRODUCTION

The general layout of the LHC injection transfer lines (TI 2 and TI 8) is sketched in Fig.1, together with the transfer line (TT41) to the CERN Neutrino to Gran Sasso (CNGS) target. In the following an overview of the beam instrumentation foreseen for the beam transfer to LHC is given. The required instrumentation will be first presented for the extraction channels in the SPS (in LSS4 and LSS6), then for the transfer lines TT40 and TT60, followed by the transfer lines TI 2 and TI 8, and finally for the injection channels into LHC. The list of the required equipment, their mandatory precision, and their position in the lines are presented.

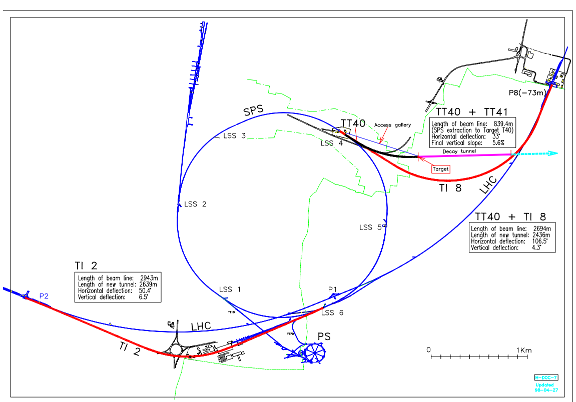

Figure 1: Overall layout of the LHC injection transfer lines TI 2 and TI 8 and of the proton beam line TT41 of the CNGS facility.

2 BEAM CHARACTERISTICS

In the two LHC injection transfer lines TI 2 and TI 8, the LHC beam structure will vary from a single pilot bunch to 4 trains of 72 bunches, which in terms of intensity varies from $5*10^9$ (pilot) to $1.7*10^{11}$ protons per bunch (ultimate). In addition to this large dynamic range, the SPS extraction channels (LSS4 and LSS6) and the beginning of the LHC transfer lines (TT40 and TT60) will be shared with different beam structures. The LHC beam has a 40 MHz structure (25 ns bunch spacing), the fast extracted beam for the CNGS has a 200 MHz structure (5 ns bunch spacing), and finally the slowly extracted beam impinging the T1 target has no RF structure. In these common parts only few beam instrumentation equipment is concerned and most of them will be recuperated equipment. It is proposed to use separate signal processing for each different beam structure, which shall provide homogeneity in interpreting the results over the full length of the lines, and ease operation.

3 REQUIRED INSTRUMENTS AND PRECISION

3.1 Beam position monitors

3.2 Beam position monitors in TI 2 and TI 8

In Fig. 2, the beam position monitor (BPM) set up for TI 2 and TI 8 is shown. Each BPM will be equipped with 4 buttons, which are recuperated from the LEP BPMs. However most of the BPMs will only have one plane equipped with cabling and read-out. Their precision is $\pm$ 0.1 mm within a radius of 20 mm [1]. Few BPMs will be equipped in both planes, permitting intensity measurements with good precision, as discussed later. For each BPM, it is foreseen to have a small crate near the quadrupole where the BPM is attached and to transport the beam position information by optical fibers to the surface buildings. The BPM body and support are new and will be built in 2001. The contract will be awarded early 2001, the pre-series finished in September 2001 and the complete delivery is expected by January

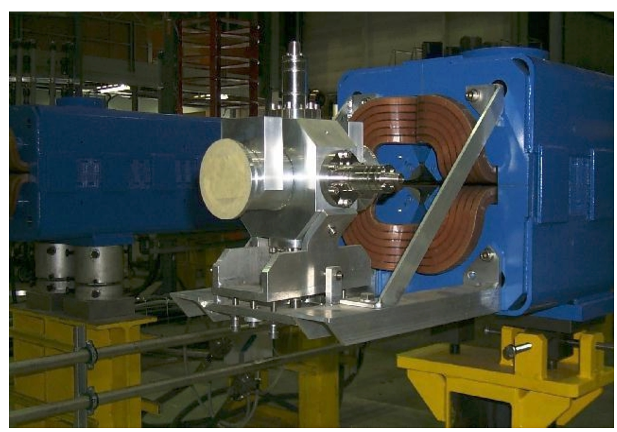

Figure 2: Transfer line BPM and support.

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Bunch by bunch reading is provided, as long as the same electronics as used in LHC is installed. There will be two processes running in parallel, one accumulating the average data, and one for a particular bunch or all bunches individually.

3.3 *Beam position monitors for TT40 and TT60*

For the lines TT40 and TT60 (transferring different beam structures) short directional couplers (BPCK) will be recuperated during the shutdown 2000/2001 from TT10 and meanwhile decommissioned beam lines (TT70, TI12 and TI18). It has been proposed [2] to short-circuit the electrodes in the middle part to obtain two independent signal sources (Fig. 3). This modification is foreseen during the year 2001, the installation in TT60 in the shutdown 2001/2002 and in TT40 in 2002/2003. It has to be noted that the double signal source will only be used in TT40. In TT60 the slowly extracted beam has no structure and therefore the existing SEM foils will be continued to be used. However the proposal to modify all the BPCKs needed in both the TT40 and TT60 lines was taken in order to standardize the equipment. The feasibility of this proposal re-

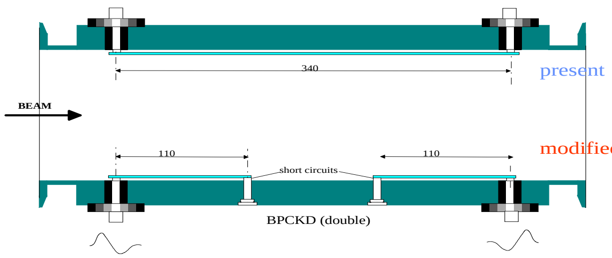

Figure 3: Recuperated short directional couplers (BPCK).

mains to be studied (depending on the radiation level of the recuperated equipment). The precision (ratio signal to noise) and the calibration of the system (always difficult for transfer lines) need to be evaluated.

3.4 *Intensity measurements*

The beam intensity will be mainly measured by the beam current transformers (BCT) for which a very good absolute precision is difficult to obtain. This is mainly due to the difficult calibration for a single path system. The intrinsic precision (calibration of the integrators) is about 1-2 %, the generation, transmission and measurements of calibration pulse add an error of about 1-2 %. Finally unpredictable capture of parasitic signals (i.e. kicker firing) might further degrade the precision [3]. The relative precision given by the beam current transformer is better (about 1 %).
As already mentioned, intensity measurements can also be provided by the beam position monitor system, if it is equipped with read-out in both planes. In this case the precision on the intensity is $\pm$ 1 % within a radius of 15 mm and $\pm$ 2 % within a radius of 20 mm. If the BPMs are only equipped in one plane, the intensity measurement is not recommended due to lack of precision. It is proposed to equip some BPMs in both planes, as they will provide means to check the intensity along the line, where losses might occur. Therefore, in order to monitor the intensity, the LHC injection transfer lines shall be equipped with two beam current transformers (at the entrance and exit of each line) and with few BPMs equipped with read-out systems in both planes.

3.5 *Beam Loss detection*

To detect beam losses, it is foreseen to use ionization chambers (Fig. 4). Their sensitivity and resolution are about

Figure 4: Ionization chambers.

3000 electrons per primary charge [4]. Their dynamic range is very broad and with the lowest gain, intensity of the order of 0.1 % of $5{*}10^9$ can be detected, as with the higher gain up to the full intensity can be measured. To cover this large dynamic range, different capacitors (from 1 nF to 100 nF) will be used depending on the beam intensity, as well as different gains, depending on the noise level. The gain level could also be linked to the cycle used (as it is done for the SPS cycle). About 30 beam loss monitors will be installed along each beam line at strategic location. The electronics will be located on both sides of the line, in the surface buildings (BA4 and SR8 for TI 8 and BA6 and SR2 for TI 2).

3.6 *Profile measurements*

Fig. 5 represents the setup which will be installed in the transfer lines in order to locate the beam, to get the beam profile values and to finally obtain a measurement of the emittance [5]. For the transfer line setting up, with the pilot beam, the Alumina screen (1 mm width) will be used. For the pilot beam there will not be enough signal to use the optical transition radiation (OTR) monitors. For the nominal beam, OTR monitors will be used. The mirror is made of Titanium (12 μm) or Mylar (12 μm and a slice of 250 A^0 of Alumina) [6].
The profile measurements will be essential for the optical parameter checks. The precision on the sigma, for the pilot beam (with the Alumina screen) was estimated to 5 % [5].

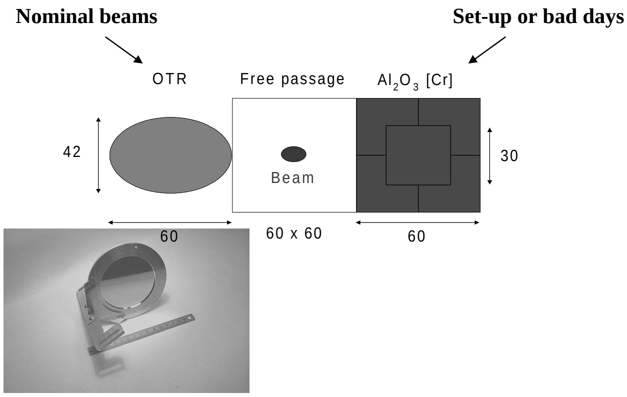

Figure 5: Screens (dimensions in mm).

The precision is affected by a halo of light which adds up to about 0.5 mm to the 1 σ width. This effect can be estimated and corrected, such that the residual error is about 5 %. For the nominal beam, if the beam is Gaussian, the sigma is estimated by a fit to a proper Gaussian, taking into account the beam tails, and the precision is estimated to about 4 %. This precision comes from the statistical errors (2 %, mainly because the light distribution is not fully representing the particle distribution, but these errors can be diminished by averaging over many measurements) and the calibration of the camera optics (2 %). If the beam is non-Gaussian, the r.m.s. will be measured (ignoring the tails) and can be provided with a better precision. Concerning

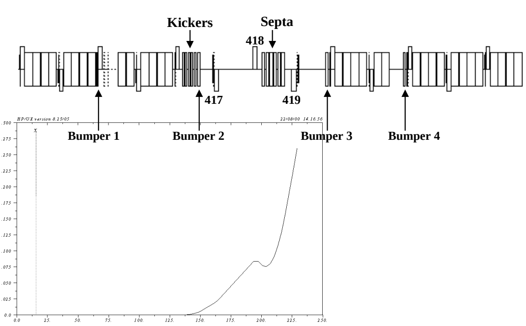

Figure 6: SPS LSS4 extraction layout and horizontal extracted trajectory.

the selection, it will be possible to select the pilot (20 ms integration) or to integrate over a full batch of 3 or 4 trains of 72 bunches. If a particular bunch within a train, or a particular train within a batch needs be selected, then the screen will have to be equipped with a photomultiplier or an electronic shutter.

The emittance can be deduced, taking into account the error on the size and on the Twiss parameters. From the experience accumulated with measurements in TT10, it is assumed that the emittance could be measured to a precision of about 10 % [7].

4 BEAM INSTRUMENTATION LAYOUT

4.1 SPS extraction

The fast extraction is done by establishing a horizontal closed orbit bump in the SPS (4 dedicated bumpers) and by fast pulsed extraction kicker magnets and slowly pulsed magnetic septa (Fig. 6) [8]. A vertical closed orbit bump is also necessary. The measurement of the bumped beam position is essential [9] and the confidence in the absolute position with respect to the centre of the adjacent quadrupole is mandatory. It was suggested to use two separate couplers, the first one electrically centered at the position of the bumped beam and the second one electrically centered on the quadrupole axis. The simultaneous horizontal and vertical orbit acquisition at quadrupoles 417, 418, 419 is necessary. This is where the horizontal bump is and where the vertical steering through the channel is tight.

The extracted beam profile and position at the entrance and exit of the septum are required. In terms of constraints on the instrumentation, the most challenging issue is the special BPM required in front of the septum magnet. At this location the aperture radius is 100 to 200 mm and the required precision and linearity is 100 to 200 μm over 50 % of the aperture, i.e 0.1 to 0.2 %, which is a factor 20 lower than what is currently done with the available technologies. The use of OTR around the septum magnet is investigated (difficulties from the demanding dynamic range and radioactive environment). The beam loss monitors will also be an important instrument for the setting up of the extraction (low intensity), for post mortem of the extracted beam and for interlocking with the beam dump for circulating beam (bad bumper setting or septum position).

4.2 TT40 and the Start of TI 8

The layout of the requested beam instrumentation for TT40 and TI 8 is presented in Fig. 7 [10]. It has also been done for TT60 and TI 2 but the philosophy being the same, it is only explained for one line. The extracted beam will be first stopped on the first TED (beam dump) of TT40. Upstream of this TED, it is proposed to install a BCT as well as three OTRs, which can be used to check the optical parameters. The OTRs have been positioned at a phase advance difference of about 60 degrees. Beam loss monitors are also foreseen around the dipole magnets at the entrance of TT40, in order to monitor the quality of the extracted beam. Three modified short directional couplers will provide the beam position information in TT40. At the entrance of TI 8, two other OTRs have been installed, one being at a maximum horizontal dispersion (also a good place for momentum collimation if required).

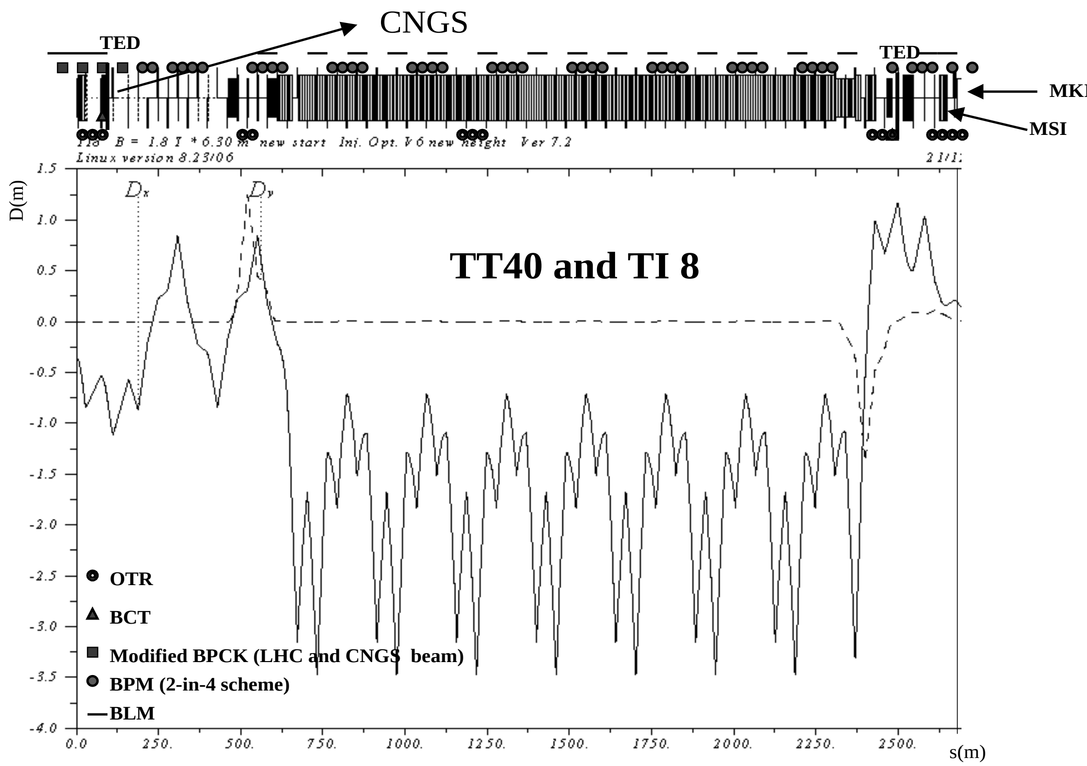

Figure 7: Proposed instrumentation layout for TT40 and TI 8.

4.3 TI 8

In the regular cell structure, the trajectory correction will be done using monitors and correctors which are arranged in a 2-in-4 scheme (per plane), which means that 2 adjacent short straight section per plane will be equipped out of 4 [11]. Three OTRs screens are foreseen after three consecutive quadrupoles (phase advance of about 60 degrees in both planes) for a second optical check. Beam loss monitors have regularly been installed along the beam line.

4.4 Injection into LHC

The last TED downstream of TI 8 will be used as a final check point before the injection into the LHC. Another three sets of OTRs have been positioned between the last set of tilted dipoles and the TED. In front of the TED, it is proposed to install the second BCT. From this last TED onwards, each quadrupole will be equipped with BPMs. The septa and kicker magnets will be equipped with OTR screens at their entrances and exits. The TDI, injection beam stopper, (protection against miskicked bunches), will be equipped with an OTR at its entrance and a beam loss monitor which will check the quality of the injected beam into the LHC. An additional collimator for the protection of D1, in addition to TDI is the TCDD. This additional protection allowed to reduce the size of the TDI.

5 SUMMARY

The baseline layout of the beam instrumentation for the TI 2 and TI 8 lines has been presented. The list of the necessary equipment (beam position, intensity, beam loss and profile monitors) and their required precision is given. The presented instrumentation scheme reflects the equipment needed in order to monitor the beam for its transfer to the LHC. If there is a need for more detailed measurements (i.e. for a better knowledge of the LHC beams for the collider), the addition of more beam instrumentation can be considered. For example, it has been mentioned for the profile monitors that the selection of one particular bunch or train within a batch is not envisaged in the frame of the beam instrumentation required in the transfer lines. If it would be needed to check the beam properties for the LHC ring, it would require to equip some screens with a photomultiplier.

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