SUMMARY AS VIEWED BY THE MACHINE

P. Collier, M. Ferro-Luzzi CERN, Geneva, Switzerland

Abstract

The last session included a discussion of the issues concerning the machine. These covered three areas; hardware, beam studies and dedicated beam time requests. During the discussion requirements in each case as well as the necessary resources were identified. The summary of these discussions is presented here.

HARDWARE AND SOFTWARE

A number of areas where effort is needed on the machine hardware and software were addressed.

DC Current Transformers

Two issues were addressed, namely the bunch pattern dependence of the DCCT readings and the stability of the DCCT scale factor. The first issue is a hardware problem that was identified during the 2010 running period. Investigations are underway and it is hoped to have a working solution before the start-up. The stability of the DCCT scale factors will be studied carefully in 2011 based on regular precise calibration campaign results. It was agreed that an upgrade of the current calibration quick check allowing automated and online precise calibrations would be extremely useful in this context and BI will investigate the feasibility of such an improvement in 2011.

Fast Beam Current Transformers

The FBCT's can measure the bunch population of the individual bunches in the machine and have generally worked very well during the 2010 run. There are two issues to be addressed. The first concerns the observed bunch length and position dependence of the FBCT reading, the second concerns improving our understanding of the offset and linearity of these devices.
The first problem is being actively worked on by the team. It is coming from the transformer itself and it is not clear yet that it can be fixed entirely with the current monitors. Fortunately, the bunch length and positions are reasonably controlled during physics and we should be able to control the error introduced in these conditions. The understanding of the offset and linearity requires a more long-term effort essentially based on comparison with the other instruments that will be commissioned this year, i.e. the Longitudinal Density Monitors and the Wall Current Monitors.
An FBCT calibration independent of the DCCT, if achievable with precision comparable to that of the DCCT, would be useful.

Longitudinal Density Monitor

The LDM is a very promising device to measure the population in satellite bunches. Initial tests and measurements indicate a high degree of precision should be possible from this device. The work here during the coming run will concentrate on the commissioning and performance assessment of this system. It was also noted that the linearity of the device needs in particular to be checked.

BPMWF

These pickups sit close to the experiments and need to be commissioned and calibrated in time for the high-β operation.

Lumi Scan Application

This application allows scanning of the beam collisions in each IP. This functionality covers mini-scans used during routine operation as well as the large range Van de Meer scans. A number of cosmetic and functional improvements to the application were discussed and agreed. Other items require more study before an implementation can be envisaged. A suggestion was made to drive the scan using a generic, file-driven sequence. This would easily allow different scan types to be performed and would cover the needs for VdM as well as length scale scans. However, machine protection issues mean that quality checks on the contents of the file would have to be made before such a file could be driven into the machine. Complete freedom to scan cannot be given. Having the TCT collimators move during the scan could ease the restrictions here. The work to prepare for the TCT's to move during the scan is already done, but requires testing and qualification before it can be used routinely.

Transverse Emittance Measurement

The cross-calibration of the various emittance measuring devices was discussed at length as well as the absolute calibration of each. Studies and work in BI will continue on these issues. An additional request to allow selection of bunches for the wirescanner application was agreed and will be implemented.

BEAM STUDIES

A number of machine studies will be needed for the calibration of the luminosity and other matters within the scope of the workshop. Requests will have to be prepared and proposed for consideration following the procedure now set-up by the LMC. The prioritization of these requests will then be considered in relation to all other requests for machine development time.

The list or machine studies topics that was discussed included

- Parallel scans (simultaneously in more than one IP) and systematic effects due to cross-talk between IPs,

- Position reproducibility effects coming from hysteresis in the correctors,
- Synchronized movement of the TCT's with the scan in order to keep the beam centered and the protection optimized throughout the scan,
- Minimizing (and measuring) the amount of beam outside the nominal RF buckets,
- Bunch-by-bunch emittance control (to equalize emittances between beams and bunches),
- VdM scan reproducibility tests.

DEDICATED BEAM TIME REQUESTS

There are a number of areas where "parasitic" (or end-of-fill) studies not sufficient to achieve the requested goals and dedicated machine time will have to be requested and granted. The following is a list of the requests that are of direct relevance to the workshop:

- The commissioning and optics measurements of the 90m β optics as well as the qualification of the protection systems to allow physics operation with this. Approximately 5 shifts will be needed for this,
- Following this there will need to be about 4 special physics fills with the 90m β optics in IP1 and 5,
- There will need to be a few (2?) dedicated fills during 2011 for VdM scans,
- Precise calibrations of the β* are also requested and would require dedicated time. Here it was noted that the β* should be measured (and if necessary corrected) during the machine commissioning. However, it is not clear if the precision will be high enough for the calibration measurements.

SPECIFICATION OF THE REQUIRED ACCURACIES FOR THE LUMINOSITY CALIBRATION

The workshop showed that the total luminosity uncertainty is already at the level of 5%, with a dozen systematic effects contributing to this uncertainty. Most individual contributions are already below 1%. The dominant uncertainty may remain for some time the bunch population product normalization. If we assume this will improve down to the specified accuracy (1-2% on the population product), we should aim at having all other contributions at the level of <0.5%. Clearly, such a requirement may evolve depending on the evolution of the actual uncertainties that will be found during the course of 2011. But it is a reasonable target.

Individually, these are the requirements (all given in terms of 68% confidence levels):

- DCCT: as just said, this is the main contribution. It is used to set the scale of the total proton population in each ring and goes directly into the luminosity (for each beam). The LHC Design Report quotes a design goal of 1% per beam. We take this as a 2011 milestone and a reference for the other systematic uncertainties.
- FBCT: used for determining the relative size of the bunch populations, i.e. offset and linearity errors contribute. These enter in the product of the beam1 and beam2 populations. Therefore, an uncertainty of $dN/N<0.3\%$ for the relative bunch population is desirable. It is important to remind that the experiments care about the bunch population in the nominal 2.5ns RF bucket, while the FBCT integrates over 25ns (including satellites), with some possibly varying efficiency across the 25ns slot. This may contribute to the uncertainty.
- LDM: complements the BCTs to determine the relevant populations from the total beam populations and the 25ns FBCT relative populations. The requirement is therefore linked to the two above. It should be accurate enough to allow the LDM-corrected FBCT relative populations to meet their required accuracy. This includes determination of the ghost charge and of the satellite charge around a nominally filled RF bucket. Most important will be the linearity (error on the extracted satellite/main bunch population ratio).
- WCM (wall current monitor): complements FBCT measurements.
- Position reproducibility: this is important for the VdM scans, including length scale calibrations. Applying the same trims in one plane should bring each beam individually back to the same position, ideally within an accuracy such that the luminosity change is <0.3% (assume all other parameters don't change). This error enters twice, once per plane. Ideally, a position reproducibility of $dD/\sigma_{beam} <1\%$ is desirable (dD is the position error or non-reproducibility) [1].
- Emittance measurement: this does not enter directly the luminosity determination (neither in the VdM nor in the beam-gas method). However,
  a. in the VdM method the emittance measurement is used to monitor and possibly correct for the change in emittance during the scans. The absolute scale is not important, though the relative scale between the devices (especially ring 1 and ring 2) may play a role. It is mainly the relative change $d\varepsilon/\varepsilon$ of a given emittance over time (~1hour) that is needed. It would be useful to have this measured with an accuracy of $d\varepsilon/\varepsilon< \sim 1\%$.
  b. For the beam-gas method, the emittance of the beams plays a role. Beam-gas imaging is used mainly to measure the beam offsets and the ratio of bunch sizes within a colliding bunch pair. The pp collision (much more copious) are used to constrain the other parameters. In this exercise, the more equal the emittances of the colliding bunches (in the same plane), the smaller the resulting error. Therefore, a precise ring1/ring2 relative bunch-by-bunch measurement is required to possibly allow one equalizing the

emittances bunch-by-bunch. An accuracy of <5% is desirable.

c. The BSRT provides a measurement of more than just two orthogonal RMS values. The complete fit results (RMS, orientation of the principal axes, amplitudes, ...) can be useful and the experiments would like to profit from this information (could the date be stored to the logging database ?).

- BPMWF: TOTEM/ALFA will require measurements of the β* and dispersion at the 1% level.

[1] The luminosity depends on the separation D by $r = e^{-(\frac{D}{2\sigma_{beam}})^2}$. Around $D = 0$, a small D error (dD) causes a relative drop $\frac{dr}{r} = -(\frac{dD}{2\sigma_{beam}})^2$. However, around $D = \sqrt{2}\,\sigma_{beam}$ (which is used in some calibration scans), this causes a larger relative drop $\frac{dr}{r} = -\frac{dD}{\sqrt{2}\sigma_{beam}}$.