LHC Timing Working Group
A first look at the requirements from the RF

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1 Cern wide reference.

A *common fine time reference* (say a 10 MHz atomic clock) should be used as a time reference for *all timings* (CPS , SPS MTG, LHC) and as external ref. for *all RF synthesizers* in the various RF groups (CPS,SPS,LHC). This will remove any offset in the frequency measurements done at transfer in the injector chain.

2 The so-called fine timing.

2.1 Matching the SPS-LHC transfers.

The SPS injects 12 batches into the LHC. During this long process, the LHC field is likely to drift. It is therefore essential to measure, *for each batch, the first turn at injection.* Measurement of the slowly drifting closed orbit of the previously injected batches (circulating beam) is also needed. We recall that the transfer of the successive batches will be done at *constant energy* and *constant revolution frequency.* Good capture in the LHC will thus be possible only if the dipole field is compensated to keep closed orbit centered. To monitor this, we need:

- **Closed orbit measurement:** The LHC revolution frequency (train of pulses at around 11.2 kHz) and the LHC RF (400.8 MHz) so that we can eventually measure individual bunches. (If the bunch spacing is never to be changed, the 10th sub-harmonic of the LHC RF can do: 40.08 MHz). Of course such a measurement can also be done during ramping and physics. (The RF signals will remain in phase with the bunches). **Caution:** If the centered path of the clockwise and counter-clockwise LHC beams are significantly different, it has been suggested to have different injection frequencies for the two beams. In such a case, the above two signals must be available for each beam.

- **First turn of each batch:** In addition to the LHC RF, a pulse must be provided with a fixed delay with respect to the injected batch. This pulse can be a copy of the one sent to the SPS-LHC kickers. (In the absence of this pulse, measurement electronics must know the filling pattern in order to measure on the correct bunches, i.e. not on the circulating beam. We think that this is best kept transparent.)

2.2 Kicker pulses.

In the CPS-SPS-LEP injector chain, transfer is first *requested* by a slow signal sent from the operation of the receiving machine to the sending one. Thereafter, cycle after cycle, the sending machine will extract beam into its output transfer line by triggering its kickers upon reception of events from *its own timing*. (A different philosophy was tried at the start-up of LEP: an event called LEP REQUEST was sent by the LEP timing onto the SPS MTG and the SPS kickers were triggered by that event. This linking of the 2 machines was difficult to operate and quickly abandonned). A few ms before the SPS to LEP transfer, the position of the SPS bunches is measured and compared with the correct location for transfer in the desired 4 LEP buckets. In case of deviation, a *veto* inhibits the generation of kicker pulses.

We think that the same method can be used for SPS-LHC transfer: When ready for filling, the LHC sends a *request* to the SPS. Thereafter, cycle after cycle, the SPS RF generates kicker pulses triggered by the SPS MTG. A facility to veto this transfer (similar to the one used for SPS-LEP) is essential: In the RF we will check correct rephasing before transfer. Some additional tests (measurement of emittance, ...) may have to be done and could eventually generate vetos on the generation of these pulses as well. In such a case, proper handling of the dumping of the beam on the SPS flat top must be studied. (Leptons are just lost in the vacuum chamber.)

2.3 Selection of LHC bucket and LHC beam.

2.4 Injecting the batches in the rigth LHC locations.

We think that one should not rely on a predefined filling sequence for the LHC because some transfers may be aborted and re-tried in the next SPS cycle. The *bucket number* (an integer number indicating in what LHC bucket the first bunch of the batch must be transfered) must be generated by the LHC control system and received by the LHC RF at least 300 ms before the CPS-SPS transfer. Beam, kicker pulses (and first turn pulses) will then be properly phased for transfer in the desired LHC buckets.

2.5 Choosing the LHC beam.

In order to generate the correct delays for kicker and first turn pulses we need to know the LHC injection line.

3 The coarse timing.

3.1 Event driven.

During *filling*, the RF processes (capture, damping of transverse and longitudinal oscillations, ...) are best event driven. The LHC timing must be synchronous with the SPS timing during filling, and we wish to pilot the LHC RF with a sequence of events similar to the ones we use in the SPS MTG. A 1 ms granularity is sufficient for the LHC timing. The precision of the SPS MTG (250 ns due to the encoding/decoding at 4 MHz) is OK for the LHC MTG. Facilities of the present TG3 and TG8 must be available.

3.2 Momentum driven.

During *ramping*, most RF parameters can depend on the variable Momentum only. This means that they can be encoded in tables (Voltage vs Momentum for example) so that a *freeze* of the ramp gives constant output. Technical details need to be solved: Are the ROCS going to implement that? How do we deal with transients when a rising function is suddenly frozen at a fixed value? In any case, we do not wish to develop special hardware for this: We want functions. The mechanism to freeze them should be under the responsibility of the control.

3.3 Problems.

Unfortunately, some RF processes will take place during ramping and they involve the dynamics of the beam so that a *freeze* of the RF parameters will not freeze the beam parameters: These include the transfer from a 200 MHz bucket to a 400 MHz bucket, the blow-up of the beam around 6 TeV, ... These processes are best event driven. One possibility is to have events generated at a fixed value of the *momemtum*. Freezing the ramp during RF gymnastic is likely to destroy the beam.