Notes from meeting on Linac4 (15/02/2018)

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This dedicated Linac4 follow up meeting has been organised following the LIU Beam Performance meeting on 8 February, 2018, in which the various aspects related to the Linac4 beam performance could not be fully discussed due to lack of time.
The main questions to be addressed are:

- What are the beam specifications in the EDMS document under approval (pulse shape, position, energy, phase, …): rationale, priorities, timelines when they can be expected to be reached, common agreement on requirements;
- Where are we standing with simulations of PSB injection, what sensitivity studies do we still need to do (e.g. in terms of position/angle jitter along the pulse for bunch-to-bucket transfer - to provide input for the Linac4 beam quality), what injection scenarios do we still need to cover (production of FT beams);
- What are the beam quality goals to be achieved in 2018 and, consequently, the milestones along the year.

The EDMS document sent by Bettina, and agreed with Chiara and Alessandra, has been uploaded on the Indico web page and can be found here. A few questions arose while reviewing the collected requirements:

1. The chopping factor depends on the type of beam that is being produced. In particular it is different for beams requiring longitudinal painting and will probably be different for very low intensity beams like LHCINDIV and LHCPROBE. However, in general for bunch-to-bucket transfer, it will always be around 60-65% in order to best fit the incoming Linac4 beam into the double harmonic bucket in the PSB (what about the injection into h=1+2+3?). At some point the chopping factor was also used as variable parameter to optimize the production of LHC beams. It could be useful to quote the beam current required from Linac4 before chopping and then quote the chopping factor assumed for the production of the LHC beams. However, it is not important to change the phrasing, but to be sure that we all

agree on what the quoted numbers mean in terms of operation or simulations to be set up.

2. Production of LHC beams is the focus of LIU, but of course LIU is also responsible to produce again after LS2 all the pre-LS2 FT beams. In this sense, the minimum beam requirement for the PSB would be 1e13 p/ring. The ultimate value of 1.6e13 p/ring, which has been also born in mind when designing the distributor with 600 us (150 turns injectable per ring) and when upgrading the PSB RF systems, is also a goal but to be considered with lower priority (would benefit ISOLDE some time in the future)
3. Shape/position of the Linac4 pulse. The intensity flatness of +/-2% is certainly important for producing LHC beams (should be therefore ensured over ~160 us), but it could be overspecified for ISOLDE beams (for which the ring equalization is less critical). For these beams, one could require +/-5% flatness. However, the effect of the droop in the beam current pulse over 600 us can be compensated, if necessary, by injecting different numbers of turns in different rings – provided that the pulse is reproducible shot-to-shot. Actually, the shot-to-shot reproducibility of the pulse shape is also requested to be +/-2%. But what is most important is also that pulses with different length can be served to the PSB on a PPM basis, as the PSB in the future will have supercycle with ISOLDE, LHC, AD, TOF, East users, MTE, etc – each requiring a certain number of turns to be injected. Alessandra said this is not easy to achieve, as changing the pulse length requires adjustments at low energy, however, one can always produce the maximum length pulses (600 us) and then chop them to the desired length. This requires that the chopper amplifier should be compatible with this operation, which needs to be checked. In this case, the +/-2% specification over shorter pulses means that the 600 us pulse, specified to a global flatness of +/-5%, should satisfy locally a flatness of +/-2%.
4. The tolerable offset error at the entrance of the PSB (1 mm at the foil position) was determined with simulations, as the one that blows up LHC beams at injection not beyond the values specified in the LIU beam parameter table. Vincenzo and Chiara showed the simulation scan. By backtracking, it should be possible to check what this value would translate into at the current measurement point – and compare it then to the measurement of position variation along the pulse. We

should take care anyway that if the tolerance is taken by the position variation along the pulse, less margin is left for injection (steering) errors.

5. The phase change along the pulse from the Linac4 does not play any role for the PSB injection, it only quantifies how much the single bunchlets composing the Linac4 pulse (spaced nominally by 2.8 ns) are at nominal distance or overlapping. Any structure is washed away by the debuncher anyway and is unlikely to result in strange peaks in the distribution at the PSB entrance. It was mentioned that the phase swing along the pulse can cause problem in the energy spread measurement. To be checked with Jocelyn.
6. The energy spread of the beam injected into the PSB is defined with the debuncher and should be the desired one as found with simulations of the LHC beam production. Measurements after the debuncher can only be performed in 2019.
7. Concerning the chopper and the request of minimum pulse length to be produced with 100% extinction, it would be useful to assess the minimum value needed (probably for the production of very low intensity beams, LHCPROBE) instead of requiring the design value of 15 ns, which could be very difficult to achieve.
8. All the specifications for energy painting should be considered as lower priority for the moment. It would be desirable to check at least some of the functionalities (energy swing, swing rate, etc.), but this should not be critical in general. It could be worth checking in simulations whether the present ISOLDE beam can be produced anyway without longitudinal energy painting or where we are limited if we do not apply it.

From the tables shown by Vincenzo, if the chopped current is 15 mA, the number of turns required to produce ISOLDE beams can exceed 150 to reach 1.6e13 p/ring but slightly exceeds 100 turns for 1e13 p/ring. The simulations were run allowing for a horizontal emittance of 12-13 um, however even including the limitation to 9 um from the aperture at injection, losses would be lower but the ISOLDE beam could be equally produced, as space charge does not play an important role for these ‘fat’ beams (in spite of the high intensity). More simulations can be run for the LHC beams with the reduced Linac4 current and also for the production of ISOLDE beams (starting from the pre-

LS2 target and then moving into higher values) assuming a realistic pulse shape (length and flatness) with optics and steering errors.

Plan for simulation work: Production of present ISOLDE beam without longitudinal painting, production of LHC beams with lower Linac4 current, production of high intensity beams (present and high intensity ISOLDE) with realistic pulse shape.

Alessandra said that over the next 2.5 months Linac4 goes back to ABP to work on beam quality (demonstrate with high priority the feasibility and reproducibility of the pulse to produce LHC beams). At the same time OP will keep learning and do measurements when possible without perturbing the ongoing work for the beam performance. Bettina asked whether the Extended Technical Stop during summer (3.5 months scheduled at the moment for RF work) could be shortened to allow for more time for beam commissioning afterwards, during which ideally it should be possible to perform a mock-up of the future operation, running for a few days with a typical supercycle to produce different beams (with different pulse lengths cycle by cycle and with the right beam conditions) and tracking the reliability/availability in these conditions. Giulia said that the RF team requires a minimum of three months to finalise their work, so there is not much room for shortening. Malika underlined that it is important to make sure that all the remaining RF work is completed, but it is also important to execute a ‘real’ reliability run as requested by Bettina (in which the future operation is tested for a few days) with all the final configuration in place.

Malika added that it would be desirable to add to the EDMS document a table summarizing all the requirements.

The subjects discussed at this special meeting will be followed at the LIU-PSB BD WG meetings and then at the LIU Beam Performance meetings, which will take place on Thursdays with a bi-weekly frequency.