Notes from the meeting on the LIU-PSB injection (27/10/2014)

Present: J. Abelleira, H. Bartosik, E. Benedetto, C. Bracco, G.P. di Giovanni, V. Forte, B. Jones, M. Kowalska, M. Meddahi, B. Mikulec, G. Rumolo

Malika highlighted that the systematic activity of this WG is planned to finish at the end of 2014. From 2015 onwards, the Linac4-PSB injection studies should have enough momentum to continue independently and be followed up within the LIU-PSB framework. Until the end of 2014 we will try to increase the frequency of the meetings.

Simulations of the longitudinal evolution for injection of LHC beams from Linac4 into PSB – Vincenzo

The beam coming from Linac4 is made of micropulses spaced by 2.8 ns (nominally, but potentially also overlapping by the time of injection for large energy spread), whose energy spread can be changed through the debuncher and has a waterbag type distribution.
When injecting into the PSB, two scenarios are considered:

1. Longitudinal painting, in which the longitudinal phase space is uniformly filled by the incoming micropulses with offset energies and tiny energy spreads. This requires several turns of injection for complete phase space coverage (at least 40) and implies the complication of the energy modulation while injecting. It is potentially applied to high intensity beams and the gain with respect to direct injection (scenario 2) needs to be assessed in order to justify the hardware and controls complications it implies. **Action: Vincenzo**
2. The train of micropulses is injected centered in the PSB bucket (h1+2) over consecutive turns. The amount of micropulses that are injected consecutively into the PSB (which determines the chopping factor) depends on the energy spread, because, when the energy spread is increased, it is necessary to chop more beam from Linac4 in order to limit capture losses at the edges of the bucket.

Only scenario 2 has been taken into consideration in the present analysis. Three cases were studied in simulations: ΔE=113 keV, 336 keV, 592 keV. The bunch is injected in one go in the simulation, as it was studied that the synchrotron motion during the turns of injection (up to ~20 for an LHC beam) does not change the picture significantly. The case 592 keV has been quickly dropped, as it was found to require an increased chopping and consequently about 60% more injected turns, which is not desirable for transverse beam quality. The other two cases are compared in terms of line density evolution that they exhibit during filamentation. ΔE=113 keV has a transient with a high peak line density and levels off at a higher value of maximum line density, as it preserves a two-peak distribution after matching itself to the bucket. ΔE=336 keV has a smoother line density evolution and comes to a flat bunch type equilibrium with lower line density than the previous case. The final values reached for the longitudinal

parameters in this case are Bl=650 ns, εz = 1.1 eVs and $\delta p/p_0$=1.4e-3. The simulations have been run without longitudinal space charge. Switching on longitudinal space charge (assuming a certain pipe radius over beam radius ratio, but anyway the dependence on this parameter is logarithmic) shows the formation of islands in the longitudinal phase space already for LHC beam type intensities. However, ESME and PyORBIT give different results for the bunch evolution under the effect of space charge, which is especially evident for ISOLDE-type beam intensities. That's why the effect of space charge needs to be investigated in further detail and understood. **Action: Vincenzo**. Another interesting study that could be done is to simulate the injection of the present LHC and ISOLDE beams (with the capture and the voltage ramp up) in order to understand the role of space charge and benchmark with the presently used codes. **Action: Vincenzo**

Simulations of multi-turn injection into the PSB from Linac2: brief review and future plans – Gian Piero

The study was initiated by V. Raginel within the LIU-PSB in the framework of the fallback scenario considering a Linac2 breakdown and its replacement by Linac4 with protons at 50 MeV. The first step envisaged in this study was to reproduce by simulations the present PSB performance in terms of multi-turn efficiency. Simulations were done with the ORBIT code. Several beam types were investigated (LHC25, ISOLDE and MD@160MeV) tracking 100k macroparticles over 100 turns (the multiturn injection in the PSB lasts maximum 13 turns and the injection bump decays in 20 turns). The beam from Linac2 was assumed to have 1.2um transverse emittances in both planes. For the LHC25, simulations were optimized to reach the maximum intensity within the emittance budget. Like in the real machine, the main parameters that were tuned were H & V beam position and angle as well as the injection delay between the peak of the injection kicker pulse and the time. It was found that normalized rms emittance of 1.88 and 1.70 μm could be achieved (compared to the measured 1.90 and 1.75 μm) with an injection efficiency of 61% (measured 57%) and an injected current of 1.98e12 p (compared to 1.85e12 p measured). Although simulations showed to be able to provide an excellent matching with the measured parameters, there was no measurement to show that the optimized initial horizontal and vertical offsets corresponded to the real ones and operational values used in the simulation would yield an injection bump not closed. Another problem encountered in this study was that simulations of high intensity beams (e.g. ISOLDE) would always predict vertical emittances much lower than those obtained in the machine. The idea now is to continue these studies using PyORBIT in order to both validate the use of this code for the simulation of the injection from Linac4 and also for the purely operational benefit to find more optimized settings to improve the PSB performance. **Action: Gian Piero**.

Some follow-ups (list of actions)

Simplified model of transfer line optics – Chiara

The model is now limited to the part of the line downstream of BHZ40, as agreed, and some differences previously found seem to be due not only to inclusion of space charge but also to some naming conventions which led to misinterpretations. The dispersion still has to be checked with Alessandra. Some results will be presented at the next meeting.

Tracking studies with the LHC beam – Elena

The study is proceeding. Changing the longitudinal emittance, as was expected, the slope of the brightness line becomes larger but still below the one so far assumed attainable from Linac4.

Injection studies for High intensity beam – José

Some more parameter scans were made for injection of future ISOLDE beams. In particular, the vertical offset was changed (8-9-10 mm), which yields different final vertical emittances (6-7-8 μm, respectively) and different losses (2.5-4-5.2%, respectively). Varying the horizontal offset (33-35-37 mm) did not appear to have a large impact on the final beam emittances nor on the losses. Also an unmatched beta function in the horizontal plane (2.5 instead of 5.5 m) did not change the injection performance.

Losses of high intensity beams in the PSB – Magda

Magda got the distribution from Chiara and Jose and for now she has all that she needs to perform her loss studies.

During the next meeting the progress from Chiara, Elena, José and Magda will be reviewed in more detail.

Next meeting: Tentatively Wednesday 5 November, 16h30 to 17h30, 865-1B03