Minutes of the LIU-PS BD WG #38 on the 13th of December 2019

Agenda *(https://indico.cern.ch/event/869894/)*

0. ***Introduction***
1. ***Zero dispersion optics for horizontal emittance measurements (Alexander Huschauer)***
2. ***Update on space charge studies at injection (Haroon Rafique)***
3. ***Topics in 2019 and outlook to 2020 (Heiko Damerau)***
4. ***AOB***

Present:

Simon Albright, Foteini Asvesta, Heiko Damerau, Giorgia Favia, Matthew A. Fraser, Oliver Hans, Cedric Hernalsteens, Alexander Huschauer, Eirini Koukovini Platia, Alexandre Lasheen, Salim Ogur, Matteo Pagin, Branko K. Popovic, Elliot Ramoisiaux, Mihaly Vadai

1. Zero dispersion optics for horizontal emittance measurements (Alexander Huschauer)

Alexander put forward a zero-dispersion optics for the PS to remove the dispersive contribution to the beam size. Referring to Matthew's presentation (https://indico.cern.ch/event/857161/), Alexander's motivation is to measure only the betatronic beam emittance to address the emittance blow-up in the PS and to avoid using a complex de-convolution algorithm.

In Slide # 2, Alexander compared the bare PS optics with the LHC low-chroma optics. With the low-chroma optics, pole face windings (PFW) are used to correct the chromaticity, and low energy quadrupoles (LEQ) are added to recover the tune change and reach the operational working point. Alex emphasized that the use of the LEQ in the low-chroma configuration leads to a small perturbation of both the beta and the dispersion functions. Heiko asked if the LEQ were periodically located? Alexander explained that they were not periodic and that this was why beating was observed.

Alexander continued by showing an example of optics modification used at extraction of the nTOF cycle. Zero-dispersion is achieved at the extraction septum using the QKE magnets, as presented in Slide #3. Alexander stated that the two QKE magnets are powered in series and therefore provide only limited flexibility to control the optics. For this reason, to achieve zero-dispersion at the SEM grids and the wire scanners in the PS, Alexander suggests using the LEQs which are equipped with individual power supplies. Proper choice of the LEQ strengths allows to reduce the dispersion at the different BI monitors and up to 10 LEQs had to be used to achieve zero dispersion at the desired locations. Zero dispersion at a given location can be achieved using different sets of LEQs, with different impact on beta-beating and modification of the working point. An optimum solution will therefore be carefully studied to be eventually implemented in the machine.

On Slide #12, Alexander showed results of simulations performed by Haroon, where low-chroma and zero-dispersion optics are compared. The exchange of horizontal and vertical emittances is observed in the case of space charge (SC). Furthermore, negative dispersion is observed when reconstructing the value of the dispersion function from the distribution in simulations. Matthew asked how non-linear the dispersion dependence was with x? This remains to be checked. Matthew asked Haroon for the dispersion in the presence of space charge. Alexander concluded that using LEQ provides more flexibility and several measurements are needed to validate the optics.

Then Alexander showed the space charge tune spreads for nominal and zero dispersion cases (link). However, the reconstruction of the tune spread for the zero-dispersion case has to be reviewed. Heiko asked if anybody had already used such an optics in the past for other studies? Alexander explained that he was not aware of any similar study done in the past.

2. Update on space charge studies at injection (Haroon Rafique)

Haroon started his presentation by reminding the MD and the validation of his simulation tool with measurements. In contrast to previous studies, when the LEQs were used to control the tune, Haroon motivated the use of the PFWs in simulations in order to avoid any beating of the optics functions due to the regular placement of the PFW. The current understanding is that the bunch is interacting with the quadrupolar stop-band, which is exacerbated using the LEQs to modify the tune. Then he continued by comparison of two different optics for the same working point, one being controlled with the LEQs and the other one with the PFWs. Very large beating of the optics functions is clearly visible in the case of using the LEQs. As shown on slide #16, the optics functions, if controlled with the PFW, are only slightly perturbed when modifying the working point. Looking at slide #18, it is clear that the beam doesn't suffer from emittance blow-up in this case, only emittance exchange due to the space charge-induced Montague resonance is visible.

Haroon continued his presentation by discussing if a single quadrupolar error can reproduce the emittance growth. He added a quadrupolar error to a single LEQ (i.e. QDN72), then performed a scan in beta-beating. As a result, he concluded that the analytical beta-beating formula matches with the PTC simulations. Also the results presented on slide #25 show that the simulation setup leading to 15% beta-beating agrees well with the emittance blow-up observed at the working point closest to the integer resonance when controlling the tune with the LEQs. He furthermore showed the footprint for the different simulations (link) and Matthew pointed out that in 10 turns the vertical phase space filaments when Haroon showed the video of the vertical phase space.

Alexander added that it will be tried to operate the LHC cycle with PFW only.

Haroon furthermore discussed the impact of a betatronic mismatch on the emittance growth. He concluded that it is indeed the quadrupole error that is driving the emittance growth and not the mismatch, as the emittance growth is in perfect agreement with analytical calculations.

2.1. Haroon switched to PS LIU Tune spread (link)

He started by citing Alexandre for the initial longitudinal phase space distribution. Then Haroon concluded that the PyORBIT simulations of 4 cases (BCMS and nominal for PreLIU and LIU) appear stable over 1000 turns. Cedric asked why a small window in FFT has not been used and get rid of the halo particles in the LIU tune-spread (video a screenshot of it can be seen on Slide # 10). Haroon said he did for some tune-plots but not for this one. Alexander asked if a modification of the initial condition of dispersion to reduce beating has been tried. Haroon replied that it was not yet tested.

Most of cases are not with very strong beating, but this can be tested in case of strong beating. Alexander suggested that one could possibly compute the integral of the distribution and set a criterion on % of particles. In the animation it looks like the dispersion gives some breathing but no sign of Montague resonance. In the animations presented by Haroon the colour scale was changing from frame to frame which may give a wrong impression of the population of the halo.

2.2. Haroon switched to PS Transfer Line Dispersion Mismatch (link)

Haroon started by presenting the turn by turn (TbT) data acquired in 2018. Firstly, he showed dispersion values for the bare lattice case, operational and re-matched case up to slide 11. After the consistency check, he added space charge to 5D according to the aforementioned presentation by Matthew. In slide #16, detuning is observed in the simulations, consistent with measurements shown in Matthew's analysis. Matthew added that there seemed to be little betatronic mismatch and the tune agreed very well with the measurements. Alexander commented that maybe more than 30 turns would be useful to see the filamentation. Matthew pointed out that the next step should be to plot measurement and simulation together.

3. Topics in 2019 and outlook to 2020 (Heiko Damerau)

- The studies for KFA45 are consistent and measurements agree well with the model. However this does not address the emittance blow-up.
- PSB-to-PS: Turn-by-turn measurements have been performed with the SEM grids. Complementary BGI measurements turn by turn are very promising.
- The kicker KFA14 is not the culprit for emittance blow at PSB-PS transfer.
- Injection bump closure studies indicate potential issues which is now being checked by the hardware experts.
- The validation of the new wire-scanners has been successfully completed for all relevant low- and high intensity beams/
- Space charge studies are progressing.
- More attention should be drawn to the identification of the impedances, which is especially important during transition crossing
- Machine learning for RF manipulations as used by Alexandre is highlighted as a tool for automatic optimization

4. AOB – Montreux

Emittance blow-up at injection and impedance model for longitudinal instability simulations still need to be understood.

Minutes by [S. Ogur](#) and [A. Lasheen](#)