Reply to “Comment on “Instability Studies at the CERN Proton Synchrotron during transition crossing””

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In the Comments to the article [1], the Author asks why we do not mention a possible role of transverse mode coupling instability (TMCI) as mechanism which could explain the instability observed during transition crossing in the proton synchrotron (PS).

The aim of the article was to experimentally characterize the measured instability thresholds under different machine configurations in order to determine possible issues for the upgrade program of the PS (LIU project). Moreover, we wanted to identify the main sources of the instability, which resulted to be the kickers. Finally, simulations were performed to check the validity of the impedance model of the machine and to find some actions to eventually mitigate the instability.

In Sec. V we briefly discuss the instability mechanism. The idea behind the simple approach [beam break-up (BBU)] was that each PyHEADTAIL simulation, as those reported in Fig. 13 of [1], took about one day, and, with the inclusion of space charge effect, as in Fig. 14 of [1], one week by using Graphics Processing Units (GPU). The simple BBU code takes a few seconds, giving the possibility to test in a completely independent way the impedance model of the PS and quickly investigate the sensitivity of some parameters.

In conclusion, in the article we did not mention the TMCI because we did not investigate deeply the mechanism of the instability and did not perform any modal analysis, which would have brought us beyond the intention of the paper. Therefore, the answer to the question of the Author of the Comment is that we neither refute, nor confirm that the PS instability is the TMCI because we did not investigate that.

It is worth mentioning that in the first paper published in 2000 about this “fast vertical instability” of the PS machine at transition, it was already described as a “Beam-BreakUp instability” (see <https://cds.cern.ch/record/446599/files/ps-2000-017.pdf>). However, as the BBU and TMCI should be similar in a synchrotron without space charge (see e.g., <https://cds.cern.ch/record/477074/files/sl-2000-075.pdf>), this instability was studied within these two frameworks over the past decades as TMCI seems more appropriate when we approach the intensity threshold from below, whereas BBU seems more appropriate when we approach the intensity threshold from above (without space charge), but both approaches should lead to the same result. This was studied in more details for the “fast vertical instability” at SPS injection, i.e., close to transition but at a fixed distance from it (see, e.g., <http://icap2018.vrws.de/papers/supag01.pdf>). In the presence of space charge, things were much more involved as the previous more advanced theories predicted no instability for such a case (see references in <http://icap2018.vrws.de/papers/supag01.pdf>). With Ref. [2], a new understanding has certainly been achieved.

As suggested by the Author in the conclusion, if, apparently, we deal here with new physics, it could be very useful to check if the theory developed in [2] can reproduce the thresholds, as those reported in Fig. 14 of [1], under the different conditions of the machine, determining also the role of the space change in this instability at different longitudinal emittances.

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- [1] M. Migliorati, S. Aumon, E. Koukovini-Platia, A. Huschauer, E. Métral, G. Sterbini, and N. Wang, preceding Comment, Instability studies at the CERN Proton Synchrotron during transition crossing, *Phys. Rev. Accel. Beams* **21**, 120101 (2018).
 - [2] A. Burov, Convective instabilities of bunched beams with space charge, *Phys. Rev. Accel. Beams* **22**, 034202 (2019).