A GENERAL OVERVIEW OF THE MCBI 2019 ICFA MINI-WORKSHOP

E. Métral† and G. Rumolo, CERN, Geneva, Switzerland
T. Pieloni, EPFL, Lausanne, Switzerland

Abstract

After the ICFA Mini-Workshop on "Electromagnetic Wake Fields and Impedances in Particle Accelerators" (organised by Vittorio Vaccaro, Maria Rosaria Masullo and Elias Métral) held in Erice (Sicily) from 24 to 28 April, 2014, and the ICFA Mini-Workshop on "Impedances and Beam Instabilities in Particle Accelerators" (organised by Giovanni Rumolo, Maria Rosaria Masullo and Stefania Petracca), held in Benevento (Italy) from 18 to 22 September, 2017, this third workshop of the series was organised jointly between CERN and EPFL and it took place in Zermatt (Switzerland) from 23 to 27 September, 2019.

This ICFA Mini-Workshop on "Mitigation of Coherent Beam Instabilities in Particle Accelerators" (MCBI2019) focused on all the mitigation methods for all the coherent beam instabilities, reviewing in detail the theories (and underlying assumptions), simulations and measurements on one hand, but on the other hand trying to compare the different mitigation methods (e.g. with respect to other effects such as beam lifetime) to provide the simplest and more robust solutions for the day-to-day operation of the machines.

INTRODUCTION

The programme of the MCBI 2019 workshop was made with the active participation of the 27 members of the International Advisory Committee. It was sponsored and supported by ICFA, the LHC Collimation project, the FCC study, CHART (Swiss Accelerator Research and Technology), the HL-LHC project, ARIES and the University of Sannio (where the previous workshop of the series took place).

The workshop was attended by 92 participants, with 12% of students, who came from all over the world and who shared their experience to address the various subjects of the workshop. Beam stabilization is an increasingly interesting subject across the accelerator community, with new challenging beam parameters targeted for future or upgraded accelerators (high beam current, low emittance, ultra-short bunches, tight bunch spacing) and the following questions were therefore raised:

- Which tools do we have to ensure that new and upgraded machines are able to operate within their desired beam parameter range?
- Is the current modeling of all these items satisfactory or should it be improved in any of the cases?
- Are we covering all types of instabilities?
- What are the limits of current active feedback systems?
- Can we rank the methods to introduce stabilizing Landau damping?
- How far can we take impedance identification and reduction?
- Can we always disentangle the stabilizing effect of Landau damping from that of head-tail dephasing?
- Are there alternative and efficient ways to introduce Landau damping (e.g. beam-beam collisions, electron lens, RFQ)?
- Can we fold in new techniques of machine learning?
- Etc.

MCBI 2019 WORKSHOP DEDICATED TO Y.H. CHIN AND A. HOFMANN

The MCBI 2019 workshop was dedicated to two outstanding accelerator physicists, who recently passed away (https://cds.cern.ch/record/2668914/files/vol59-issue2-p059-e.pdf): Yong Ho Chin (Fig. 1) and Albert Hofmann (Fig. 2)

Yong Ho Chin obtained his PhD in accelerator physics from University of Tokyo (Japan). He was a leading theoretical accelerator physicist from KEK and he made numerous essential contributions in the fields of beam-coupling impedances, coherent beam instabilities, RF klystron development, space-charge and beam-beam collective effects. His name is linked, in particular, to 2 computer codes he wrote and which have been widely used over the past decades: MOSES (MOde-coupling Single bunch instabilities in an Electron Storage ring) and ABCI (Azimuthal Beam Cavity Interaction). Since November 2016, he has been the chair of the ICFA beam dynamics panel.

Albert Hofmann performed his studies at ETH Zurich (Switzerland) and first worked on the Cambridge Electron Accelerator (CEA) at Harvard. He had a lifelong interest in the new discipline of Synchrotron Radiation, which he explained in detailed in his book "The Physics of Synchrotron Radiation". He moved to CERN to work on the ISR collider and when the ISR was closed, he returned to the USA, accepting a professorship at Stanford, where he could work on SLC. He came back to CERN to work on LEP and served as advisor for a number of synchrotron-radiation facilities. Albert gave many inspiring lectures at the CERN Accelerator School, simplifying, as only he could, some of the most difficult concepts in accelerator physics.

† Elias.Metral@cern.ch

Figure 1: Picture of Yong Ho Chin who passed away in 2019.

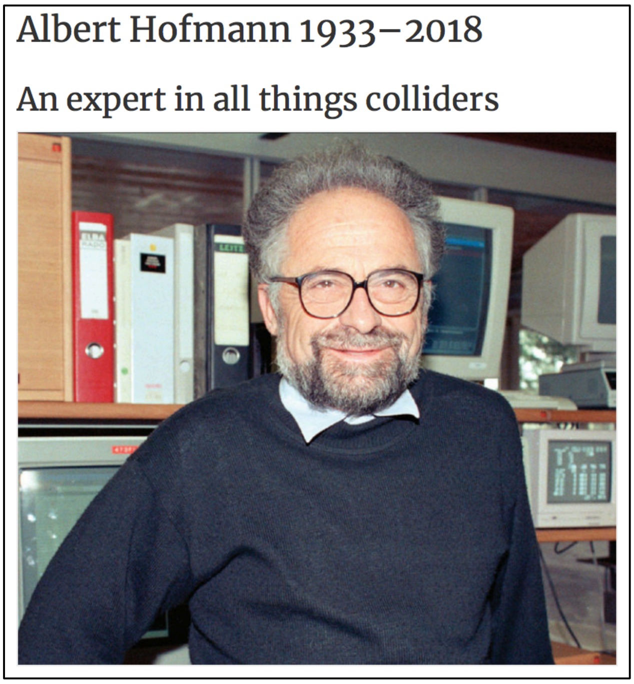

Figure 2: Picture of Albert Hofmann who passed away in 2018.

WORKSHOP STRUCTURE AND TOPICS

During the four-day workshop, 56 talks were given distributed in 8 sessions set up by the 27 members of the International Advisory Committee: (1) Review of beam instability mechanisms and mitigations, convened by G. Rumolo (CERN); (2) Landau and BNS damping, convened by E. Métral (CERN); (3) Optics and RF knobs, convened by E. Shaposhnikova (CERN); (4) Feedbacks, convened by G. Stupakov (SLAC); (5) Identification and reduction of instability sources, convened by M. Zobov (INFN LNF); (6) Diagnostics for instability observations, convened by T. Pieloni (EPFL); (7) Interplay between coherent and incoherent effects, convened by G. Franchetti (GSI); (8) Future challenges for MCBI, convened by F. Zimmermann (CERN).

In addition to the talks, 24 posters were presented. Student posters, 14 in total, have participated to the "Best Student Poster Award", which was awarded to M. Schenk (Fig. 3). The Poster Award Committee was composed of all the session conveners and was chaired by Q. Qin (IHEP).

Figure 3: "Best Student Poster Award" awarded to M. Schenk for his work on "Longitudinal- to-transverse Landau damping: RFQ (or Q")". Next to him: Q. Qin (IHEP), chair of the Poster Award Committee.

DISCUSSIONS AND OUTCOME

Beam instabilities, and their mitigation, cover a wide range of effects in particle accelerators and they have been the subjects of intense research for several decades. As the machines performance was pushed new mechanisms were revealed and nowadays the challenge consists in studying the interplays between all these intricate phenomena, as it is very often not possible to treat the different effects separately.

The beam coupling impedance is the first cause of coherent beam instabilities but many other mechanisms are important to take into account to quantitatively describe the observed instability mechanisms and thresholds of our particle accelerators. And not only all these mechanisms have to be understood separately, but all the possible interplays between the different phenomena need to be analyzed in detail, including the beam coupling impedance (both driving and detuning ones in the transverse planes), the linear and nonlinear chromaticity, the transverse damper (including a detailed description versus frequency of the gain, the bandwidth and the noise), the Landau octupoles (and other intrinsic nonlinearities), space charge, beam-beam (with both long-range and head-on effects for colliders), electron cloud or/and ions, linear coupling strength, tune separation between the transverse planes (bunch by bunch), tune split between the two beams (bunch by bunch, for colliders), transverse beam separation between the two beams (for colliders), noise, etc.

For existing machines, trying to push the machine performance usually requires a detailed impedance model and a systematic analysis to identify the main contributors and reduce their impedance, which requires a lot of time and resources. In case of instabilities due to additional electrons or ions, all the methods to try and reduce/suppress the later should be put in place (it is worth noting for instance that nanostructuring of material surfaces by laser ablation is a well-established science and manufacturing with more than 25 years of experience). In many machines, longitudinal and transverse feedbacks exist and realistic modellings of them need to be included in the beam stability analyses, as they considerably modify both coupled-bunch and single-bunch motions (it is worth noting that in some machines, many feedbacks are used: 35 feedback loops are used for instance in the CERN PS machine for the LHC-type beams!). Feedbacks are working very well but they cannot, at the moment (this might change in the future if we succeed to reach the necessary bandwidth), damp all types of instabilities. And in some cases, destabilising effects from feedbacks can also be observed. Therefore, the next step is to optimise the machine linear and nonlinear optics (tunes, linear and nonlinear chromaticity, amplitude detuning, linear coupling, transition energy, etc.) and the RF knobs (such as RF voltage or controlled longitudinal emittance) and rely on Landau damping. However, a trade-off between coherent beam stability and single-particle stability (i.e. dynamic aperture) needs to be found and all the sources of Landau damping should be considered and studied carefully together: some interplays can be beneficial and some others can be detrimental. Furthermore, it was recently found that the stability diagram (deduced from the analysis of Landau damping for independent coherent beam modes) can significantly evolve with time in the presence of noise, which could then be detrimental to the "long-term" beam stability. Landau octupoles are usually used to provide Landau damping in the transverse plane but some other proposals have been made, such as using beam-beam (long-range and/or head-on) in colliders, or an electron lens (which is doing something similar in non-collider rings), or an RFQ (which has a similar effect as the second-order chromaticity Q", providing longitudinal-to-transverse Landau damping). I. Hofmann, the chair of the ICFA Beam Dynamics panel, motivated the whole community to work more on the effect of Landau damping, as there is still a lot to be done on Landau damping and its possible loss, looking in more detail to theories, simulations and measurements (e.g. with BTF, Beam Transfer Function, or, as recently proposed, using an anti-damper as a controlled source of impedance).

For future machines, it is recommended to try and integrate all the above aspects already in the design stage, i.e. reduce as much as possible the impedance and electron cloud (surface) effects (in close collaboration with all the equipment groups) and optimise the optics design by including already from the beginning all the collective effects (such as IBS, etc.).

Finally, knowledge transfer and collaboration between experts and operations are key to ensure that all the teams are moving in the same direction to produce stable beams.

CONCLUSIONS AND FUTURE

After a first workshop in 2014 on impedances and a second workshop in 2017 on impedances and instabilities, this third workshop of the series on instability mitigations closed the loop and provided a great platform to expose and debate all the scientific questions raised above.

Beam instabilities and their mitigation have been studied for several decades and many intricate phenomena have been revealed. They were very often treated separately in the past but since some time the need to study several mechanisms together appeared, to try and better explain the reality of our accelerators. With the increasing power of our computers this becomes easier but the need to continue and develop theories remains, to have a better understanding of the interplays between all these effects, which is the current challenge in the study of beam instabilities.

The subject of beam instabilities in particle accelerators is far from being exhausted and the community is motivated to exchange experience and join efforts to advance further. The amount of open questions, the continuing progress recorded on different fronts and the promising outlook of many studies in terms of development and search for solutions fully legitimate the quest to pursue this series of workshops and to envisage a continuation in two or three years' time. More information on this workshop, including program and slides of the single talks, can be found on the web site of the workshop (https://indico.cern.ch/event/775147/).

ACKNOWLEDGEMENTS

We would like to thank all the workshop participants, in particular all the speakers, the poster presenters and the session chairs, who gave their active contributions to the success of this event. Concerning these proceedings, we also would like to warmly thank the many people who took the time to contribute, both as authors and as internal referees, to reach a total of 68 well-written papers. Finally, we would like to express our sincere gratefulness to Alessia Valenza and Hervé Martinet for all the workshop logistics.