FUTURE CIRCULAR COLLIDER

# Meeting Minutes of the
140th FCC-ee optics design meeting
and 11th FCCIS WP2.2 meeting

Indico: `https://indico.cern.ch/event/1038220/`
When: 03.06.2021 14:00-16:00 CET

## Agenda

| Presenter | Title |
|---|---|
| R. Tomás | **BPM Noise in different accelerators** |
| T. Lefèvre | **Laser-wire scanner: review and prospects for FCC-ee** |
| K. Oide | **An estimation for vibration tolerance** |

## 1 General information

No news or general announcements were reported by any of the participants.

## 2 BPM Noise in different accelerators

In continuation of the discussion in the previous FCC-ee optics meeting, **R. Tomás** presents a short review of the Turn-by-turn (TbT) noise of the Beam Position Monitors (BPM) in different accelerators. The method of cleaning the BPM data using Singular Value Decomposition is briefly reviewed and how the level of noise in the data is estimated. The noise in TbT measurement in different machines is then summarised, and it is observed that with increasing beam screen diameter, the noise in these measurements increases.

On the topic of the nomenclature, **T. Lefèvre** clarifies that resolution refers to the smallest change of the orbit that can be measured by the BPM system. The precision is then determined also by other factors such as the readout electronics. **R. Tomás** adds that what is measured then is the precision, that is, the difference of the reading between two measurements for the same conditions.

**F. Zimmermann** asks if the LHC numbers are in the case of a pilot bunch with $10^{10}$ $p^+$ and if better noise level can be expected for a nominal bunch with $> 10^{11}$ $p^+$. **R. Tomás** confirms that this is the case. **M. Wendt** adds that there is another method to determine the noise of the BPM system, however this requires hardware changes. Furthermore, some sources such as the power supply frequency may add correlated noise on the measurement, which may be difficult to clean. For the presented numbers, the measurement time is quoted nowhere, which is also a critical factor in the BPM performance. Larger machines such as the LHC will have some advantage here compared to smaller machines such as IOTA and the noise should be normalized to both the aperture and the measurement time. This measurement time depends in parts also on the processing electronics, as the signal is broadened to provide more samples on the ADC.

**F. Zimmermann** asks if the number presented for ESRF is obtained by averaging over the 330 bunches. **R. Tomás** confirms that all bunches are kicked simultaneously and the average values is then used. **F. Zimmermann** asks why multi-bunch TbT measurements were not performed in SKEKB since those should perform better. **R. Tomás** comments that multi-bunch TbT measurements were performed at some point in the SKEKB and proved to be significantly better. However, due to machine protection reasons, this mode is not allowed anymore. He suggests that a similar reason could be the case for SKEKB. **T. Lefèvre** adds that some performance characteristics can be attributed to design features of the specific system. For example, the LHC system was designed for high intensity bunches, which naturally sacrifices the performance when operating with a single low intensity bunch. **M. Wendt** adds that the design of the PETRA III BPM system was developed about 15 years after the LHC, and some improvements on the technical side have to be taken into account too. **R. Tomás** concludes that when designing a BPM system, all modes of operations (including optics measurements) should be considered, and in view of FCC-ee, these modes should be carefully defined before, taking into account other factors such as machine protection limitations. **M. Wendt** asks if multi-bunch operation for optics measurements is feasible in the FCC-ee, as the precision should increase with $\sqrt{N_b}$. **R. Tomás** answers that this has to be taken into account in the design of many components. In SKEKB, the limitation could for example come from damage limits of the BELLE-2 detector system. He adds that in the LHC, such problems can partly be avoided by choosing a appropriate collimator settings and using detector interlocks. **F. Zimmermann** comments that it would be very interesting to come up with a plan on how measurements can be performed in the FCC-ee and if measurements with colliding bunches could be possible. **R. Tomás** notes that measurements with colliding bunches were performed in LHC and that indeed it could be possible in FCC-ee.

**M. Wendt** comments that the resolution limit can also be estimated using a simple formula and it could be interesting to compare it to the measurements. **R. Tomás** agrees and will follow up offline.

## 3 Laser-wire scanner: review and prospects for FCC-ee

In **T. Lefèvre**'s presentation, the developments of Laser wire scanner (LWS) in the past 10 years is reviewed and how those could be used in the FCC-ee. The beam size in FCC-ee will be around 100 $\mu$m/10 $\mu$m $(H/V)$, which can be measured using conventional wire scanners. However, those will not be able to withstand the impact of full intensity beams. The current baseline option is the use of X-ray Synchrotron radiation interferometry, with two techniques currently under investigation as part of the FCC framework. The method studied at KEK uses micro slits, whereas the CERN-ALBA collaboration relies on nanoporous materials. The LWS principle is explained and the system used in the past in ATF2 and PETRA III and its achieved performance is reviewed. The R&D performed on fiber laser amplifiers and on fast scanning system is then presented. Due to the significantly higher energy in the FCC-ee than in the other machines where LWS were used, the cross-section for Compton scattering will be smaller, though it should still be sufficient.

**F. Zimmermann** asks which laser wavelength has been assumed for the curve of the cross-section versus beam energy. **T. Lefèvre** replies that this is independent of the wavelength.

**T. Lefèvre** continues that for this high energy case, the energy transferred to the photon will be higher, making the detection and background removal easier. In summary, the LWS appears to be a good option to measure the beamsize in the FCC-ee, and shares also some of the hardware requirements with the laser for the polarimeter, but more R&D is required.

**F. Zimmermann** adds that the current FCC-ee polarimeter design by BINP does not use a high power laser and that the current design could be reviewed taking LWS requirements into consideration as well as potential improvements in the near future.

**A. Faus Golfe** asks in what mode the LWS may be used, either in a low intensity single bunch case or on a shot-by-shot basis. **T. Lefèvre** replies that this has not yet been determined. He emphasizes that although

LWS are presently not used in any machine, given the excellent progress in the last years and with the problems also expected in other systems, further investigations are clearly justified as this system could be a good fit for the FCC-ee.

**R. Wanzenberg** points to an IPAC paper from 2010, where the status of the LWS in PETRA III is reviewed. Additionally, he comments that the installation will require windows which will need to withstand the high power laser, which could become problematic. In PETRA III, in part due to this problems, the system never become operational, however the hardware is still there and activities there to study the LWS could be relaunched. **T. Lefèvre** agrees that some problems need to be overcome, however similar problems are also expected with other methods. **M. Wendt** comments that for the HERA-e polarimeter, a high power laser was used, and similar problems with the windows there also didn't prove to be any showstopper. **T. Lefèvre** comments that the laser in PETRA III was actually used in the LEP polarimeter before.

**F. Poirier** asks what were the issues with LWS in PETRA III and if those were mainly due to manpower or other reason which prevented to system from becoming operational. **R. Wanzenberg** replies that the measurements never agreed well with the expectations, though exact reasons remain unclear. The study was part of a DESY-RHUL collaboration, and this activity ended when the collaboration was discontinued. **T. Lefèvre** comments that restarting studies at PETRA III would certainly be interesting, however the feasibility and basic design for FCC-ee should be checked before.

## 4 An estimation for vibration tolerance

**K. Oide** presents the tolerances on quadrupole vibration in the FCC-ee collider ring. In the beginning, a basic formula for the change of the vertical beam orbit in the interaction point (IP) due to quadrupole displacement is presented. In the following, this is then used to estimate the displacement due to coherent motion of the quadrupoles, induced by a seismic wave. It is found that this displacement can be neglected as it is significantly smaller than the random component of the quadrupole motion. The displacement near a betatron resonance is then presented, and using measurement of ground vibration in LHC and at LAPP, the effect at the IP is about 7.8 pm, which is smaller than the beam size at the IP. For the non-resonant case above the critical frequency above $\omega_c = 2\pi$ Hz, the displacement at the IP is about 2.8 nm. Here, an ideal orbit feedback system is assumed to suppress the beam oscillation below the critical frequency.

**I. Agapov** asks if he understood correctly that motion above $f > 1$ Hz is not damped by the feedback system. **K. Oide** confirms that this has been the pessimistic assumption for the calculation. He adds that here, on the other hand, the simple spectrum is used, and when taking into account some resonances above 1 Hz, the presented numbers may worsen.

**D. Shatilov** asks if assuming that the motion of quadrupoles for the two apertures is coupled, some improvement could be expected from that. **K. Oide** replies that he is not sure if it will improve, as although the twin aperture quadrupoles will move together, one will be focusing whereas in the other beam it will defocusing. As such, the response will not be equal. More detailed checks could be done using the actual optics of the ring. The presented numbers are about 10% of the IP beamsize and are quite encouraging. With an even faster feedback operation up to 10 Hz, these number could improve dramatically due to the cubic dependence. **J. Wenninger** warns that with such large rings, the achievable sampling frequency of the system will not be quite as high as in the smaller machines and that the orbit correctors have to be quite fast. One option would be to install few air-core correctors around the ring to provide a good dampening of the high frequency component. **K. Oide** adds that these should also be installed around the IPs.

**F. Poirier** asks if the orbit correctors around the IPs have been looked into before. **K. Oide** replies that those will be required anyway for the IP beam-beam feedback. They will be installed close to the final focus quadrupoles on either side, at a proper phase advance from the IP.

**J. Bauche** asks if specifications (strength, length) for the fast orbit correctors in the arcs are already available and if those could be added as trim coils to the sextupoles. **K. Oide** replies that this has not been looked into in detail. However, adding them as trim coils into the sextupoles is not feasible as those trims would then not be able to act fast enough.

## Follow-up items

| TASK |
| --- |
| Define orbit and optics measurement modes in the FCC-ee and its implications on the BPM system, compare results from analytical formulas to the obtained noise in TbT measurements |
| Continued studies on the feasibility and potential design of the LWS in FCC-ee, review of the laser system of the Compton polarimeter; possible beam tests with the LWS at PETRA III; review of past PETRA III LWS results and difficulties |
| Investigate orbit feedback system including orbit corrector placement and design and feasible operating frequency |

**47 Participants:**
A. Abramov, I. Agapov, J. Bauche, A. Blondel, M. Boscolo, T. Brezina, X. Buffat, H. Burkhardt, P. Burrows, E. Carideo, T. Charles, B. Dalena, Y. Dutheil, O. Etisken, A. Faus-Golfe, H. de Grandsaignes d'Hauterives, K. Hanke, M. Hofer, B. Humann, P. Karataev, M. Karppinen, J. Keintzel, R. Kersevan, M. Koratzinos, T. Lefèvre, C. Li, R. Losito, M. Migliorati, N. Mirian, E. Montbarbon, N. Nikolopoulus, K. Oide, T. Pieloni, F. Poirier, T. Raubenheimer, M. Reissig, L. van Riesen-Haupt, G. Roy, A. Schlögelhofer, D. Shatilov, R. Tomás, R. Wanzenberg, M. Wendt, J. Wenninger, Y. Zhang, F. Zimmermann, and M. Zobov