177th WP2 Meeting

Tue 16 June

2020, 10:00 – 12:00

Chairs:	Gianluigi Arduini, Rogelio Tomás
Speakers:	Barbara Dalena, Hector Garcia Morales
Participants (vidyo):	Simon Bagnis, Roderik Bruce, Xavier Buffat, Elena Chapochnikova, Riccardo De Maria, Ilias Efthymiopoulos, Davide Gamba, Massimo Giovannozzi, Sofia Kostoglou, Ewen Maclean, Elias Métral, Nicolas Mounet, Yannis Papaphilippou, Konstantinos Paraschou, Thomas Pugnat, Galina Skripka, Guido Sterbini, Ezio Todesco, Frederik Van Der Veken, Carlo Zannini

AGENDA

MEETING ACTIONS

Ezio	**Provide field components of Heads and Body for MQXB.**
Ezio	Provide new field profiles with interconnections and an update of the Heads and Body model taking into account the latest design for MQXFA and MQXFB.
Hector, Ilias	Report to the experiments working group about 1) the need to check past luminous region data, in particular regarding the tail population, and 2) the need for better luminous region measurements.

GENERAL INFORMATION (GIANLUIGI ARDUINI, ROGELIO TOMÁS)

The minutes of the two previous WP2 meetings (on May 26th and June 2nd) were circulated, and there was one comment from **Nicolas** on the minutes of the Special WP2/WP4 meeting on May 26th, regarding his talk on the status of the longitudinal impedance model. **Nicolas** clarified that the LHC and HL-LHC longitudinal impedance are actually different (rather than "almost identical" as specified during the talk), as also pointed out by **Elena** during the discussion - see the plot in the AOB at the end of the meeting.

Rogelio then reviewed the presentations of the previous WP2 meetings and the related actions. The special WP2/WP4 meeting on May 26th was devoted to longitudinal impedance, with a first talk on the status of the impedance model by **Nicolas**; two new actions came out for **Nicolas** and **Benoît Salvant** (longitudinal model for Run 2, and update of the HL model). The talk by **Ivan Karpov** then showed new results on the loss of Landau damping, which are not yet fully conclusive and will be followed-up. The third presentation by **Luis Eduardo Medina Medrano** tried to address the issue of the available power and voltage at injection, following-up on several previous presentations stating that we are at the limit. Simulations show that there is no big issue with losses (less than 2% with 6 MV); **Gianluigi** mentioned that one could also try with 5 MV. Finally, the last talk by **Benoît** was on impedance estimates of a new design for RF fingers in the crab cavities, which successfully alleviate their impedance. A meeting occurred later on, to finalize the choice of design.

Regarding the 176th WP2 meeting on June 2nd, the first presentation by **Manfred Wendt**, highlighted the LHC BPMs R&D efforts and plans. On most BPMs the resolution looks very good (10-15 microns even at low intensity, i.e. one order of magnitude better than the current BPMs). Only stripline BPMs will be slightly less good, with an accuracy error in two-beam sections between 10 and 100 microns (it is very difficult to go below 10 microns). The second talk by **Riccardo** showed the optics point of view on BPMs, in particular the document under preparation and soon to be circulated (also to BPM people) and discussed. One action for **Davide** concerns the impact of the BPM tolerances on the crossing angle measurements, which are not mentioned in the document - evaluation is now ongoing. The third talk by **Nicolas** provided estimates about transverse instability margins from non-conformities, which were evaluated as requiring at worst 15 to 20% extra amps in the Landau octupoles, hence not a dramatic increase. Discussions went on regarding the baseline (from this and previous talks), and one action is expected from **Nicolas** to provide the impact of possible collimator misalignments. Finally, the last talk from **Alessio** provided the offsets at collimators during impedance MDs, and discarded two hypotheses to explain the discrepancy between two measurements (namely, effects from irradiation on materials, and collimator misalignments). An action is expected from **Carlotta Accettura** on the impact of irradiation. Concerning the discrepancy, it seems we ran off on hypotheses to explain it, so the measurements should be repeated.

The agenda of the meeting, plus the aforementioned AOB, then followed, except for the talk by **Lucio Fiscarelli** who was postponed to a later meeting, as he could not join today.

1 UPDATES ON THE IMPACT OF FRINGE FIELDS ON CORRECTOR STRENGTH (BARBARA DALENA)

This is a follow-up of what was presented by **Thomas** during the 166th WP2 meeting. Because of the longitudinal variation of the beta functions along the magnets in the HL-LHC IRs, an accurate modelling of the fringe fields is required to improve the corrections of non-linear effects, and ultimately a number of observables, e.g. dynamic aperture. Three kinds of model are used for the non-linear maps: hard edge (HE), hard edge with heads (HE+Heads) and Lie2 (see also 122th and 166th WP2 meetings). Such 3D representation of both the main field and the errors of the inner triplet, have various impacts on the non-linear correctors' strength.

The 1st and 2nd derivatives of the main quadrupolar field of the HL-LHC triplets, induce a small shift of the b4 corrector strength (4% of the octupole correctors specification). On top of that, the longitudinal distribution of b6 (which can be well approximated by splitting the magnet in 2 Heads plus the Body), results in a 11% shift w.r.t. to the dodecapole correctors specification (with optics v1.4 and the latest error tables). Still, it also depends on the definition of the magnet Body and Heads. In general, accurate measurements of the longitudinal harmonics are needed to compare accelerator models with beam-based values, in particular for the not allowed high order multipoles (i.e. b3, b4, b5, b7, etc. for quadrupoles) which are typically computed with a 2D model in ROXIE.

Regarding the current LHC, the MQXA b4 longitudinal distribution induces a small shift of the corrector strength; taking into account the beam screen contribution with the WISE values, does not solve the discrepancy w.r.t. beam-based measurements. The MQXA b6 longitudinal distribution has a strong impact on the dodecapole correctors strength, but the exact value is difficult to predict because of the ambiguity in the definition of Body and Heads and because of missing values for the Heads in the case of MQXB (Action: **Ezio** – Provide field components of Heads and Body for MQXB).

The remaining open questions are on the impact on the second order amplitude detuning, of the derivatives of the systematic b4 in the MQXA, and on the MQXB b4 and b6 longitudinal distributions, which cannot be guessed from that of MQXA which is a very different magnet.

- On slide 8, **Gianluigi** asked what "13%" mean, and with respect to which quantity. **Barbara** answered this is the difference between the two models, divided by the maximum corrector strength (the latter is from the IPAC paper cited). **Gianluigi** then wondered if we exceed the maximum. **Barbara** answered in the negative. On slide 9, the maximum corrector strength (i.e. the specification) could be materialized as two lines around respectively -1.4e3 m^{-5} and 1.4e3 m^{-5} for respectively K5L left and K5L right (see also slide 11), so we even go in the right direction. **Thomas** further specified that the maximum is around 1.5 what was needed for the 2013 MQXFs error table. **Barbara** commented that with the new error values the correctors' strength approaches the specification without exceeding it.
- **Riccardo** commented that the most puzzling part is the discrepancy between models with different body and heads definitions. He said that on slide 11, the second table is from the error table, and should have been computed by **Ezio** (integral of b6 according to 3D model, up to the

threshold length he defined), and he wondered what is the difference w.r.t. the values reported, in particular related to a possible increase of the integration path. **Barbara** answered that indeed the equivalent magnetic length is shorter, but, in principle, they did the same as **Ezio** (going up to the center) - in the prototype the constant (hard edge) part is very short as one wants to be sure to get all the harmonics starting and ending with constant values on the longitudinal axis. **Barbara** wondered how **Ezio** defined the subdivision *(**Ezio** had connection issues and could not answer during the meeting)*. **Riccardo** said it is possible that the field map is different. **Barbara** answered the field map is the one **Ezio** provided to them. **Thomas** specified this corresponds to the last design of the prototype. **Barbara** highlighted again her main message: the way one divides the magnet into body and heads, is very important and changes the corrector strength. **Rogelio** then asked what happens if one tries using the same length as **Ezio**. **Barbara** answered that the Heads lengths are equivalent lengths computed with equations in slide 10, in particular, they are defined as the region where the Ax and Ay components of the vector potential are not negligible. In order to compare with the more accurate model (integration with step of 2cm), one has to ensure the integration is done on the same path length. **Rogelio** suggested to integrate with 0.2m less. **Barbara** agreed but didn't know if 0.2m are to the right or to the left, so where the cut is exactly. For her it remains to be understood how the values in the second table of slide 11, were found. **Gianluigi** concluded that the best is to contact **Ezio** and clarify with him. **Riccardo** insisted that this is very important for the modeling, and there is a clear discrepancy with what they have.

After the meeting, the question about the way the Heads are defined was asked to **Ezio** (et al) by e-mail. It was clarified that they define the Heads as **Barbara** and **Thomas** do, as the region that starts and ends when the main field and higher order harmonics have constant values along the longitudinal axis. **Ezio** didn't go up to the magnet center as **Barbara** did, but for the map they had this would not explain the difference between the values reported in the tables of slide 10.
Since the latest data of the prototype was sent, **Barbara** could also verify that actually the magnetic model of the prototype is different from what was used in their study, which would explain the discrepancy between the two tables in slide 11 (as guessed by **Riccardo**).
Having the new data, it was also noticed that, for the last prototype model, **Ezio** et al stopped before the harmonics were back to zero on the longitudinal axis in one of the Head. They explained that they didn't have a model for the interconnect region yet; they will re-compute the Heads and Body part for the last optimization of the magnet, including the interconnect region in the model (Action: **Ezio** – Provide an update of the Heads and Body model taking into account the latest design for MQXFA and MQXFB).

2 HALO MEASUREMENTS USING COLLIMATOR SCANS: STATUS AND PLANS FOR RUN 3 (HECTOR GARCIA MORALES)

This presentation follows what **Sofia** showed at the 175th WP2 meeting, where some assumptions on the beam transverse profile were shown and used. The idea here is to present what was measured to date, using collimators, and define possible future measurements.

The transverse beam profile (and in particular the tail population) is important to know for several kinds of studies, related to e.g. collimation, crab cavities, ground motion, or noise. Various effects are responsible for its deviation from a simple Gaussian profile, and in the LHC it remains largely unknown. The most accurate way to measure it is through collimator scraping, by steps of 5 microns, recording the BLM data at each step *(note: 50 microns were indicated in slide 5 instead of 5 microns, this is a typo - see discussion below)*. Nevertheless, such slow and destructive measurements can be made only when a few bunches are present in the machine.

18 such measurements were made as end-of-fill MDs in 2018, mainly at injection and in horizontal. A strong tail population was observed in all measurements. The beam profile is then modelled using a double-Gaussian or a Levy-student distribution, the parameters of which being rather non-reproducible. More statistics are clearly needed, especially at flat top where only one vertical measurement is available for each beam.

The current model used at injection is a double-Gaussian, with a ratio between the intensities of the two Gaussians of 0.65/0.35, and of 0.5 between the two standard deviations. Several cases with much more populated tails were still observed, and at flat top the model might be significantly different.

Diffusion rates were also measured between 2016 and 2018 at flat top, and halo re-population found to be faster than at 4TeV. As it was a concern for HL-LHC, an active halo control is foreseen (hollow electron lens). In general, a better understanding of the beam profile is needed, hence new measurements should be performed in the LHC, in various machine configurations and for all beams and planes (including skew), in collaboration with other teams.

- **Elias** commented that the beam profile is also important for beam instability studies.
- **Yannis** indicated that the Levy-student distribution is just a special case of the q-Gaussian one (*n* is an integer here, while with any exponent - positive or negative - it is a q-Gaussian).
- **Elias** mentioned that measurements versus time are indeed needed.
- **Gianluigi** asked **Hector** and **Sofia** how will the various measurements at injection translate into losses, in other words what is the impact on losses of the range of variability of the models. **Sofia** said they did a simulation at collision with the model suggested and obtained a few hours of lifetime, which is not possible. **Gianluigi** then wondered about the normalization with the higher energy. **Hector** mentioned that the model is giving ratios, so whatever sigma is taken, the tail will be twice larger. **Yannis** further specified that what is important is the percentage of halo, and if the model is correct it is independent of energy. **Davide** asked Sofia if the value she took for sigma1, corresponds to an emittance of 2 microns. **Sofia** answered in the positive.
- **Yannis** wondered how much 50 microns of collimator jaw movement are, in terms of sigmas. **Hector** corrected a typo in the slides - each step is 5 microns rather than 50 microns, and said this is very small since 1 sigma is close to 1 mm.
- **Yannis** wondered how good the calibration with the BCT is. **Hector** answered this is an important question indeed. There are calibration factors for different stages, which he obtained himself to perform the analysis. **Roderik** said that if the calibration factors are recalculated, they should be all similar, and **Yannis** wondered if they indeed are always similar. **Hector** answered they are always in the same order of magnitude.

- **Yannis** wondered about the beam condition, and in particular if it is the nominal injected LHC beam. **Hector** answered in the negative. He was selecting fills that were suitable for the measurement, with a machine far from being full, as one cannot scrape the full beam.
- **Ilias** commented that this is good material for an emittance working group discussion. He then added that the ratios of 0.65/0.35 in intensities and 1/2 in sigmas should be visible in the luminous region profile, and he wondered if one could check (he also mentioned that unfortunately LHCb lost some data from the last year). This could also turn into additional requirements to experiments, in particular to get better luminous profile measurements. **Gianluigi** agreed and said this has to be reported to the experiment working group (Action: **Hector** / **Ilias**).
- **Ilias** said that bunch-by-bunch data would be highly desirable. **Hector** answered that one obviously scrapes the full beam. **Ilias** replied that the BLMs give bunch-by-bunch data. **Roderik** answered that BLM can indeed, in principle, look bunch-by-bunch, but cannot do calibration.
- **Ilias** mentioned that if there is such large ratio in sigmas, one should see it by scraping from far away, e.g. 10 sigmas (because the first distribution should die out fast). He wondered if the rate goes as a Gaussian, or if it is flat. **Roderik** answered that with a normal fill one cannot go that far out, as the collimators would not protect anymore. Hence there is no possibility to go to 10 sigma2, except at a very low intensity (in special fills).
- **Gianluigi** asked **Sofia** if the distribution is cut at 5 collimator sigmas when the beams go in collision, in her simulations. **Sofia** answered in the positive.
- **Rogelio** asked **Hector** if he tried to compare his results with the wire scanner or BSRT. **Hector** answered in the positive, and indeed the core distribution obtained with the wire scanner is similar, but one cannot see any tail there. Regarding the BSRT, he did not get the data for these studies. **Yannis** commented that it is very difficult to get tail data from the BSRT, as a diffraction pattern appears around 3 sigmas. The best would be to make the coronograph work.
- **Gianluigi** concluded that indeed more measurements are needed.

3 AOB - FOLLOW-UP ON LONGITUDINAL IMPEDANCE (COMPARISON LHC/HL-LHC) (NICOLAS MOUNET)

After some investigations with **Benoît Salvant**, it was found that the broad-band, imaginary part of Z/n of HL-LHC (with crab cavities) is different by 15-20% w.r.t to LHC Run 3, just below 1GHz. A plot of the ratio between the two models is shown, and clarifies this point.

- **Elena** agreed and commented that the logarithmic scale used in the plot shown during the WP2/WP4 meeting (on May 26th), was indeed confusing. **Nicolas** agreed.

4 ROUND TABLE (GIANLUIGI ARDUINI)

The next WP2 meeting will be on June 30th, by video-conferencing, with the following agenda:

- Measurement of fringe fields (Lucio Fiscarelli) - to be confirmed,

- Recap on the available BS contribution to the field quality in the triplets for the HL-LHC (Susana Izquierdo Bermudez),
- Update on the field quality of MCBRD (Andrea Musso).

Reported by N. Mounet & B. Dalena