

Minutes of the HL-LHC WP2 Task 2.4

10th (VIDYO) meeting on Wednesday 16/04/2014 (11:00-12:30, 6/R-018)

Task 2.4 members: Alexey Burov (AB), Alessandro Drago (AD), Alessandro Gallo (AG), Andrea Mostacci (AM), Alessandro Vivoli (AV), Benoit Salvant (BS), Bruno Spataro (BrunoS), David Alesini (DA), Deepa Angal-kalinin (DAK), Elias Metral (EM), Elena Shaposhnikova (ES), Fabio Marcellini (FM), Fritz Caspers (FC), Frank Zimmermann (FZ), Gianluigi Arduini (GA), Giovanni Rumolo (GR), Hugo Alistair Day (HAD), John Jowett (JJ), Kevin Li (KL), Luigi Palumbo (LP), Mauro Migliorati (MM), Michel Martini (MM), Mikhail Zobov (MZ), Nicolas Mounet (NM), Nicolo Biancacci (NB), Oliver Boine-Frankenheim (OBF), Olga Zagorodnova (OZ), Oscar Frasciello (OF), Paul Goergen (PG), Rainer Wanzenberg (RW), Uwe Niedermayer (UN), Wolfgang Hofle (WH).

Present/Excused: AB, AD, AG, AM, AV, BS, BrunoS, DA, DAK, EM, ES, FM, FC, FZ, GA, GR, HAD, JJ, KL, LP, MM, MichelM, MZ, NM, NB, OBF, OZ, OF, PG, RW, UN, WH, **Juan Esteban Muller, RamaC, CarloZ, KevinL.**

1) General information (EliasM):

- Nothing special => Slides from KevinL will come back soon as KevinL improved some of his plots.
- Some info from BenoitS:
 - Ongoing discussions about simulations with GdFidL with our colleagues from INFN.
 - TCTP measurements => The predicted modes have been seen.

2) Crab Cavity impedance (Rama Calaga and Benoit Salvant): <https://indico.cern.ch/event/310705/contribution/0/material/slides/1.pdf>

- The talk was divided into 2 parts: 1) SPS crab cavity tests and 2) LHC operation.
- There will be a HiLumi-LHC/LARP Crab Cavity System External Review at BNL on 05-06/05/2014:
<https://indico.bnl.gov/conferenceDisplay.py?confId=728>.
- SPS crab cavity tests

- Impedance of the new Y chambers (16 deg tapering angle instead of 12).

 - => Should be OK after recent study from Phoevos and AlickM.

 - The new Y chamber would be slightly worse than the current chamber for longitudinal modes => It would make sense to profit from the change of Y chamber to reduce its impedance.

 - The increase of the low-frequency imaginary parts of the longitudinal and transverse impedances is very small compare to the impedance budgets: $\sim 0.035\%$ for longitudinal and $\sim 0.1\%$ for transverse.

 - Reminder: There are already 3 Y-chambers in the SPS: 2 around the bypass and 1 for the dump.

- It is very unlikely that any SPS operation will occur with crab cavities IN (information: AlickM and KarelC). However, even if this would be the case, the impact of two crab cavities is not expected to be a critical issue for the SPS operation with LHC beam. Therefore, crab cavities are not expected to limit significantly the dedicated MD beams (if the modes are well damped => Zenghai Li, LHC-CC13).

- As concerns the beam-induced RF heating in the CC, it could be very high (in the few kW range) for the critical case of a line of the beam spectrum hitting a mode...

- LHC operation

 - Shunt impedance of resonant modes

 - Different values recommended over the years => Need to converge with the theoretical models and guidance of macroparticle simulations.

 - Ongoing work (N. Mounet) => Perform DELPHI and HEADTAIL simulations to assess intensity limits with the HL-LHC impedance model with and without additional resonant modes.

 - The current limit for installation into LHC is set to max $R_s \sim 200$ kOhm per resonant mode up to 1.5 GHz (agreed with BE/RF-BR) => This limit is known to be conservative (in particular since the bunch length is longer than the design bunch length) and could be revised following the results of the study.

 - Longitudinal impedance limit for coupled-bunch instabilities

 - Making the previous assumption, it would mean, for 16 CC, a limit of 12 kOhms per cavity.

- Below are the requested Q values

Worst longitudinal mode	Cavity I (Lancaster)	Cavity II (ODU)	Cavity III (BNL)
Frequency (MHz)	375	772	577
R/Q (Ω)	125	180	108
Min Q to reach 12 kOhm/cavity	100	70	110
Min Q to reach 200 kOhm/cavity	1600	1100	1850
Required separation $\Delta f > f/Q$ (MHz)	0.2	0.7	0.3

- 16 CC per beam would add $\sim 40\%$ to the total LHC longitudinal impedance (imaginary part) below 500 MHz \Rightarrow Is it acceptable for LHC beam stability?

- 16 CC per beam would add $\sim 25\%$ to the total LHC transverse impedance (imaginary part) below 400 MHz \Rightarrow Is it acceptable for LHC beam stability?

- As concerns the beam-induced RF heating in the CC, it could be very high (in the hundred kW range) for the critical case of a line of the beam spectrum hitting a mode...

- Summary:

- It would be useful to collect all updates on geometries and resonant parameters of all crab cavities.

- The impact on SPS beam seems limited but the impact on LHC beam seems significant (due to the 16 cavities + very large beta functions).

- We need to converge on the acceptable limits for resonant modes, but the parameters and options are changing very quickly.

- The current longitudinal limit for all new LHC hardware is 200 kOhm (conservative). Relaxing this limit would mean freezing some parameters. Are we in a position to do this now?

3) Some answers to the actions (Nicolas Mounet) \Rightarrow Update on intensity limitations from HL-LHC transverse impedance:
<https://indico.cern.ch/event/310705/contribution/3/material/slides/0.pdf>

- Will HL-LHC be stable for positive chromaticities, even without Landau damping?

\Rightarrow No. This effect was due to the broad-band model used with a cut-off frequency at 5 GHz... \Rightarrow We use now a broad-band model with a cut-off frequency of 50 GHz. This is a "quick fix" that is unphysical and ultimately the broad-band model should be removed and replaced

by the real impedances of the different elements.

- Updated (with the new cut-off) comparison between LHC and HL-LHC
 - With damper
 - The multi-bunch growth rates (50 ns beam) vs. Q' with 50 turns damper, for LHC (typical 2012 settings, 4TeV) and HL-LHC (7TeV), with $1.5 \cdot 10^{11}$ p+/bunch (horizontal), are \sim similar (better).
 - Without damper
 - The multi-bunch growth rates (25 ns beam) vs. Q' with 50 turns damper, for LHC (typical 2012 settings, 4TeV) and HL-LHC (7TeV), with $1.5 \cdot 10^{11}$ p+/bunch (vertical), are \sim similar for $Q' \sim 15$.
 - TMCI at injection
 - The LHC (typical 2012 settings, 4TeV) and HL-LHC (7TeV), with $Q'=0$ (horizontal), are quite similar \Rightarrow HL-LHC threshold at $\sim 3.5E11$ p/b.
- Effect of non-linear bucket and other impedance terms on TMCI threshold
 - Single-bunch growth rate vs intensity without damper, for HL-LHC (7TeV) with $Q'=0$, from HEADTAIL, with updated model \Rightarrow Threshold goes slightly down.
 - Single-bunch growth rate vs intensity with damper, for HL-LHC (7TeV) with $Q'=15$, 50 turns damper, from HEADTAIL, with updated model \Rightarrow Very small effect.
- Effect of higher temperature in triplet beam-screens
 - The HL-LHC impedance with 50 K copper in the triplet beam screens is the same as with 20 K (negligible effect). Note that the magnetoresistance has been taken into account ($B = 11$ T from E. Todesco).
- Effect of Molybdenum on instabilities
 - There is a clear impact / improvement with Mo or Mo-C collimators as concerns the impedance.
 - As concerns the effect on instabilities, this has to be redone as it has been studied on slide 15 with a model of the crab cavities, which raised a lot of questions during the meeting \Rightarrow RamaC proposed to re-make the study without the fundamental / deflecting mode. But how should we do? Should we remove everything? Should we remove only the mode but keep the low-frequency part (R/Q), which in this case would

remain constant whatever we do? Ongoing discussions...

- HL-LHC TMCI threshold at injection

- Single-bunch imaginary tune shift vs intensity without damper, for HL-LHC (7TeV), with $Q'=0$ (horizontal) => Intensity threshold $\sim 4.5E11$ p/b.

4) Next meeting

- The next (11th) VIDYO meeting will take place on Wednesday 30/04/2014 from 11:00 to 12:30 in the room 6/R-018 for the CERN people. The agenda is

- 1) General information (EliasM)
- 2) Follow-up of ecloud effects (GiovanniI)
- 3) Some answers to the actions (NicolasM and others)
- 4) AOB (EliasM)

Minutes by EliasM, 05/05/2014.