Minutes of the 2nd meeting on high harmonic RF system in the LHC on 27.05.2013

Present: G. Arduini, T. Argyropoulos, P. Baudrenghien, R. Calaga, S. Fartoukh, E. Jensen, W. Hofle, T. Mastoridis, E. Montesinos, J. E. Muller, E. Shaposhnikova, F. Zimmermann, M. Zobov

0.) **Reminder of the open actions from the 1st meeting** – Elena Shaposhnikova

- Study transverse stability in a double RF system - ABP
- Look for possible solutions for tilted bunches in a double RF - RF
- Simulate (flat) bunch shape evolution in a single RF with IBS, RF noise, beam-beam... – ABP

1**.) LHC cavity phase modulation algorithm** – Themis Mastoridis

Current LLRF setup (half-detuning) is not applicable for the ultimate beam, due to the limited klystron power.
The new LLRF uses the full detuning scheme, an iterative, adaptive algorithm of phase modulation leading to small peak-to-peak displacement in physics (~55 ps).

The klystron forward power was successfully reduced in LHC MDs in 2012.
The system is ready to be commissioned.
With a longer abort gap, more power will be needed. Closer to the design value of 3.2 us would be better.

Impact on a higher-harmonic RF system:
- phase modulation would be mirrored in the set point
- power requirements (see talk 2)
All tools to estimate the requirements for a harmonic system are available.

2**.) Power requirements for the harmonic cavities in the full detuning scheme** – Philippe Baudrenghien

The harmonic cavity phase will be locked to the fundamental RF.
The design of the harmonic cavity and its detuning can be adjusted to minimise the klystron power required for the high harmonic system.
Compensating for the beam loading in the harmonic cavity is easier in bunch-shortening (BS) mode; more power required in bunch-lengthening (BL) mode. For minimum power, we need high Q_L in the BS mode and lower Q_L in the BL mode.

Enormous power saving could be achieved in the BS mode (an estimate is a minimum power of 55 kW instead of 300 kW).
It is preferable to design system for the BL mode, which is the worst case, and more relevant for the application in physics.

Adjusting well both the loaded Q and the R/Q is important, for coupling and for the power requirement, respectively.

It is planned to use a more accurate beam current model for the power calculations in the future.

Comments:
- Stephane: In Philippe's proposal, the optimal phase is calculated for the fundamental RF only and the harmonic system is forced. Why not optimize both?
- Philippe: The fundamental RF system already exists and it has power limitations.
- Elena: To avoid problems like in the SPS, should not use the 3rd or higher harmonic RF, even if power requirements would be in this case easier.
- Stephane: Why not use 440 MHz (okay for 25 ns and 50 ns spacing)? Acceleration could be done on the stable phase of the 440 MHz. Like this, there would be 1 bunch every 11 buckets. This RF system

can be useful for bunch splitting and recombination.
- Philippe: The fundamental power gain should be similar even for a 440 MHz system.
- Themis: A bunching factor of 0.9 was assumed. In reality, should be different with the higher-harmonic RF system and is probably much less.
- Elena: Also the difference in bunch distribution in different operation modes should be taken into account.

3.) Double-harmonic cavity design – Rama Calaga

First attempt, just a scaled model of the 400 MHz cavity design. Bulk Nb could be an option.
8 MV total per beam, 1 MV/cavity, 4 cavities/cryomodule are assumed.

Challenges:
- power coupler at 800 MHz, cavity size is reduced, fields are increased, required power 200-250 kW
- HOM couplers

Several options for HOM couplers are available, amongst others a hybrid HOM coupler (a "combination" of narrow & broad-band couplers).

To be checked:
placement, impedance, resonant excitation, compatibility with crab crossing, mechanical design, the option of coating.

Discussion:
- Stephane: Why not to use a multi-cell structure?
- Rama: Wouldn't help much with the integration, but the tunability is better for a 1-cell structure.

4.) Preliminary considerations on 800 MHz cavity HOM-free design – Mikhail Zobov

No clear cavity specifications so far.

HOM free design for a single cavity has been achieved. There are 2 dipole and 2 quadrupole modes, which cannot be damped just by changing the beam pipe radius.

No stable trajectories for multipacting.

Two cavities in the same cryostat, which leads to a field in-between them; this is not a real HOM, but it can be a problem. Could be mitigated by a different beam pipe radius, notch filter etc.

Comments:
- Wolfgang: Should change the alpha parameter from 20° to 10°.
- Rama: Was calculated from the maximum force that can be applied to detune the cavity.

5.) SUMMARY

- Erk: We don't know yet if we can shake the beam continuously at 4 TeV in a single RF system, and how long the bunch shape is conserved after the noise is applied. => Probably a higher harmonic system is required for flat bunches.
The full detuning scheme has been proven to work well and to be compatible with the higher harmonic cavity.
The conceptual design of the cavities is well advanced, but studies need to be continued.

- Rama: Need to know the total voltage required to decide the number of cavities and the number of couplers (1 or 2). Coupling the same power with half-sized couplers could be a problem.

- Erk: local CC scheme can be done, elliptical crab cavities have been eliminated.

- Themis: The power requirements are higher with the phase modulation, but they are high even without it.

- Rama will provide Mikhail with specifications. Eric also needs more specifications to study the feasibility of couplers (maybe someone from Berkley could help).

- Elena: Actions.
(i) Provide cavity specifications (voltage, power, tunability…)
(ii) Provide available space in P4 - Rama
(iii) For the 800 MHz option, check the feasibility of couplers - Eric
(iv) Study compatibility of the 800 MHz system with crab cavities and possible phase modulation of the CCs – Themis, Philippe
(v) Consider (dis)advantages of the lower frequencies, e.g. 600 MHz and 440 MHz suggested by Stephane - Elena