Minutes of the 28th WP2 Task Leader Meeting held on 23/05/2014

Present: G. Arduini, O. Brüning, R. De Maria, D. Draskovic, M. Giovannozzi, E. Métral, T. Pieloni, A. Valishev, A. Wolski, P. Fessia, R. Jones, L. Esposito, Y. Papaphilippou, R. Tomas, T. Lefevre

Minutes, Follow-up of Actions, General Information (Gianluigi)

- The minutes were approved without comments
- Actions
  - Action E. Métral: *estimate on the instability threshold in the presence of electron cloud in the triplets, matching sections and main quadrupoles assuming that cryogenics can cope with the heat load*. Elias replied that they will try to provide an answer for the Hi-Lumi annual meeting.
  - Action A. Valishev: *Provide an estimate of the intensity loss/luminosity lifetime for the 2012 LHC beam parameters*. Lifetrac multiparticle tracking was cross-checked with the LHC 2012 performance data and demonstrated good agreement: the simulated intensity loss rate was approx. 2% per hour, which agrees with the observed 1-3% (burn-off excluded). The same applies for the luminosity degradation (IBS excluded). A systematic analysis of the 2012 data for intermediate intensity and before the observation of instabilities is being pursued by Y. Papaphilippou in collaboration with OP to provide benchmarking.
- General Information:
  - Milestone report 31 on the initial estimate of beam-beam effects has been submitted to L. Rossi. Milestone report 30 on the initial estimate of intensity limits is being finalized.
  - The new layout has been presented at the HL-PLC and it is being finalized in collaboration with the Integration team. As compared to the version presented at the WP2 Task Leader meeting held on 28th March the TAS aperture has been reduced to 54 mm on request of L. Rossi. The 11T dipoles will be included as option in the optics repository. The minimum separation between the two Q5 quadrupoles in IR6 will need to be reviewed with integration. The requirements from the optics team will be specified. The layout/optics including these updates will be presented at the WP2 Task Leaders meeting on 27/6 so that it can then be used as reference for simulations.

Status of the design of the HL-LHC triplet BPMs (T. Lefevre)

Thibaut started with an overview of the present issues with the LHC triplet BPMs:

- Limited number not allowing for redundancy in case of failure although no serious failure occurred so far.
- The warm BPM upstream of Q1 has a limited alignment accuracy (~ 1 mm)
- A dependence of the reading on the temperature of the electronics has been observed. This is going to be addressed during the present shut-down.
- Limited directivity (20dB) imposing constraints on the positioning of the monitors. These need to be installed in the middle between two consecutive long range encounters within a band of +/- 80 cm. In this case the resolution of the orbit measurement is expected to be 100 μm in bunch-by-bunch mode and 10 μm in orbit mode.

The resolution of the orbit measurement depends on the electronics and the new acquisition electronics DOROS could reach resolutions of 100 nm. That solution would be less sensitive to directivity issues and gating on individual bunches could be considered. The synchronous orbit mode, reading the positions of the non-colliding bunches, could be used to overcome the problem of a limited directivity.

Thibaut continued by reviewing the main changes considered for HL-LHC: three BPMs (those between Q2a and Q2b, Q2b and Q3a, Q3b and corrector package) will have striplines at 45 degrees and tungsten (Inermet) shielding in the vertical and horizontal planes to minimize radiation. This will imply a larger weight. It is proposed to anchor the cold BPM to the cold mass of the nearby magnet and their position should be measured with respect to the magnetic centre of the magnet and with respect to its aperture. Gianluigi asked whether the warm BPM in front of Q1 could be anchored to the cryostat of the quadrupole. Thibaut replied that this should be possible. The powering scheme should include the possibility of performing k-modulation. This should be taken into account for the specifications of the power converters.

The design of the BPM striplines is ongoing with the aim of minimizing the impedance and the directivity of the BPMs.

In the present design the BPM between Q2b and Q3a is located close to a parasitic long-range encounter. In general the position of the BPMs should be verified in the new layout. Riccardo will provide a table with the position of the BPMs and their distance from the long range encounters. **Action: Riccardo**

For the new HL-LHC BPMs the performance could be equal of better than that of the present LHC triplet BPMs

Oliver asked whether the BPM performance is sensitive to the transverse angle of the bunch at the BPM. This effect will be studied. **Action: Riccardo** to provide Thibaut the transverse angle of the bunch at the BPMs in the presence/absence of crossing angle compensation by means of the crab cavities.

<u>Status of BPM requirements for orbit correction – R. De Maria</u>

For the HL-LHC β*-levelling in IR1/5 is foreseen resulting in continuous optics changes and frequent luminosity scans are to be avoided to minimize losses in terms of integrated luminosity and possible emittance blow-up.

Ideally three BPMs could provide measurements:

- to find collisions at the beginning of the fill bringing the beams to less than 2.8 sigma beam-beam separation to obtain a luminosity corresponding to more than 1% of the peak luminosity
- to keep the beams in collision without loss of luminosity (less than 1% loss) with a beam-beam separation of less than 0.13 sigmas.

If all BPMs are used and no errors a precision of +/- 1.5 µm is needed to keep the beam in collision, and a factor 10 more is sufficient to find collisions. Only a selection of BPMs is sufficient, where the two BPMs closest to the IP are most efficient (other BPMs should both be kept for statistics and redundancy).

The required alignment tolerance in the longitudinal position is in the order of 1-2 mm.

Model imperfections occurring in between two measurements will influence the ability to correct the orbit when the BPMs positions and the transfer function reproducibility of the triplet and corrector up to 10^{-4} are acceptable. The question was raised whether this is feasible. **Action: Ezio**

Future work includes:

- Introduction of more realistic BPM imperfection models (including the effect of anon-optimum position of the BPM with respect to long range encounters), input from BI needed. **Action: Thibaut**
- perform correction with perturbed model using the ideal response matrix as done in reality
- validate simulation setup by reproducing LHC orbit correction features
- plan MD to validate the ability to control orbit in the D2 Q4 region as required by crab cavity and at IP as allowed by present and foreseen instrumentation.

Status of BPM requirements for orbit correction – R. Tomas

Triplet BPMs are not used for optics measurement in the LHC. For the HL-LHC 1-2% calibration errors would be useful for fast optics measurements in the triplet area and for β^* of about 60 cm. For smaller β^* lower errors are needed (few per mille).

Further analysis is required with realistic imperfections and given BPM set-up and to determine the requirements for K-modulation. **Action: R. Tomas**.

Expected effective impedance/heat load due to impedance for present design of BPM requirements for orbit correction – E. Métral

Triplet BPMs have a small but visible impact on the total transverse impedance of HL-LHC and provide a larger contribution to the effective impedance as compared to the rest of the BPMs because of the large β functions at the BPM positions. The design of the striplines is being reviewed to minimize the longitudinal and transverse impedances and due to the large aperture and the large crossing angle the impedance should be evaluated taking into account of the large displacements at the BPMs. **Action: Thibaut and Elias** to review the design to minimize impedance and to include the effect of the large displacements/angles at the BPMs. The Inermet inserts seem to reduce the geometric component of the impedance.

For the RF heating, most of the losses due to the geometric part of the impedance (55 W per BPM for the present LHC BPM and for the nominal HL-LHC beam parameters) should be lost in the coaxial port. The resistive component of the impedance generates local losses and an additional load on the cryogenics. These losses amount to about 0.09 W/m assuming Cu coating at 20K and nominal HL-LHC parameters. Other temperatures or coating may change this figure.

Action: Elias to update these numbers for the HL-LHC BPMs taking into account their design for HL-LHC and taking into account the expected operating temperature in the range of 50 K.

The summary of the requests linked to the performance of the triplet BPMs are indicated below.

Aperture diameter [mm]	>98 (Q1) / >118 (others)
Precision	< 1.5 μm
Longitudinal alignment accuracy	1 mm
Transverse alignment accuracy with respect to nearby cold mass	?
Maximum linearity error after calibration	<0.5 %
Maximum non reproducibility of the triplet and correctors transfer functions	$<10^{-4}$
Bunch population range [p/bunch]	$10^{9} – 2.2\times10^{11}$

The degree of compliance of the triplet BPMs with respect to different criteria in order of decreasing compliance is listed below.

Optimum position w.r.t. parasitic encounters	Sensitivity to missing BPM	Suggested locations for optics measurements	Beta function $(\beta_{x,y},\beta_{y,x})$[km] (for impendence effects)
D1downstream (best position)	TAS-Q1a (highest sensitivity)	Q2a-Q2b (most critical)	TAS-Q1a (3.1, 3.1) (smallest beta, smallest effect)

Q1b-Q2a	Q1b-Q2a	Q3b-CP	Q1b-Q2a (4.6, 10)
CP-D1	Q2a-Q2b	TAS-Q1a	Q2b-Q3a (13.5,13.5)
Q2a-Q2b	Q2b-Q3a	Q1b-Q2a	D1 downstream (16.6, 7.1)
TAS-Q1a	Q3b-CP	Q2b-Q3a	CP-D1 (18.8, 7.5)
Q3b-CP	CP-D1	CP-D1	Q2a-Q2b (20.4, 5.3)
Q2b-Q3a (worst position)	D1 downstream (lower sensitivity)	D1 downstream (least critical)	Q3b-CP (20.6, 7.9) (larger beta, largest effect)

The contribution to power deposition in the BPMs is listed below for the present LHC BPMs. This needs to be updated once the design is finalized.

Contribution	Estimated power	Comment
Static heat in-leak [mW/cable]	58	4 cables per BPM
Heat load from geometric impedance [W/BPM]	55	Should be dissipated via the coaxial ports
Heat load from resistive impedance [W/m]	0.09	

No evident insurmountable issue has been identified for any of the BPM locations and the presented specifications defined so far seem within reach. A low impedance design needs to be pursued to minimize the impact in terms of heat load and transverse and longitudinal stability.

Reported by Gianluigi and Riccardo.