LHC Studies Working Group

Notes from the meeting held on 8 December 2011

The meeting was dedicated to the results of LHC MD#4 and floating MDs, and a first outlook to the requests for 2012. The agenda and slides can be found at the following link: https://indico.cern.ch/conferenceDisplay.py?confId=161035

It was noted that the currently published LHC schedule is not final yet, in particular the first MD block will possibly be postponed to increase the chances for physics data taking before the HEP summer conferences.

1. 25 ns scrubbing (E. Metral)

The 24-hour floating MD that took place on 24-25 Oct was devoted to 25 ns beam, in particular injection (the problems encountered are described in the next presentation) and ecloud/scrubbing observations. The goal of the MD was to store the same total beam intensity as used operationally for physics (i.e. ~2e14 p, or about 2000 bunches per ring of ~1e11 ppb). In order to achieve this, the ADT was setup for 25 ns spaced beams; a high chromaticity was used first, to avoid the fast TMCI-like instability; after some scrubbing, the chromaticity could be reduced. The Secondary Electron Yield (SEY) and the reflectivity were benchmarked. A total of 3 fills were accumulated, the first two were dumped by bad orbit readings in the pt6 BPMs due to too low intensity bunches. In the first fill, V blow up was observed; in the second one, H blow up was observed. In the third fill, after reducing the horizontal chromaticity coherent instabilities were observed. In this last fill 2100 bunches were accumulated in ring 1 (max for this filling scheme), but only 1020 bunches were accumulated in ring 2 due to limitations in the MKI8 vacuum: the interlock thresholds were relaxed from 2e-9 to 2.5e-9 mbar, solenoids on the interconnects between kicker magnets (VIESA.193.5R8.C) were turned off but should not have been. The RF experts commissioned the 1-turn feedback in the shadow of the MD. More MD time in 2012 is requested to carry on the studies. M. Lamont recalled that 5 days are allocated to scrubbing in the LHC schedule, E. Metral pointed out that the required extra time will depend on the results of the scrubbing run. It was also noted that it will be important to perform one energy ramp and collisions with 25 ns beams (MD allocated but lost in 2011), to observe the long-range beam-beam effects, effects on scrubbing by the change in bunch length and possibly the orbit. P. Baudrenghien recalled that time is needed for the setup of new klystron power settings. R. Assmann concluded by pointing out that 25 ns studies got the biggest amount of MD time in 2011 (motivated by being the nominal beam defined in the LHC Design Report).

2. Quench margin of Q6.L8 and 25 ns injection matters (C. Bracco)

During the Q6.L8 MD, the TCLIB BLM was calibrated by performing a full beam scraping and a calibration factor for the FLUKA simulations was found (1 Gy ~= 8.73e10 p). Note that further understanding is needed concerning a TCLIB BLM with an RC filter: the reduction factor was expected to be 180 for the 40 us running sum, but a factor 20 was observed at the previous MD and a factor 2 in this one (follow-up **ACTION**: M. Sapinski). M. Sapinski added that this monitor will be inspected during the Xmas stop and in 2012 ionization chambers will be added in this location. From an

analysis performed on data from the previous MD, it is estimated that the leakage from the TCLIB to the Q6 is between 10 and 20%. During this MD, pilot bunches were injected on the closed TCLIB and the current on the Q6 was increased in steps of 200 A until 2200 A (the 5 TeV operational current). No quenches were observed, possibly because the energy deposition at the Q6 is too diluted as the TCLIB intercepts the full beam. This opens the possibility to raise the BLM thresholds locally or set the TCLIB to nominal aperture (6.8 σ, versus the present 8.3 σ). Results from FLUKA simulations are required before taking further steps. The reconstructed BLM signal exceeded the estimated Q6 quench level by a factor ~8 at 450 GeV and ~40 at 5 TeV; similarly, a factor 5 was found for the Q7 quench level at 5 TeV (E. Nebot Del Busto). The QPS signal observed in a previous MD was possibly due to showers on the electronics components, further analysis is ongoing (M. Bednarek). V. Kain asked if it is known whether the losses come from the inside or the outside. C. Bracco answered that the answer is not known, but this also is the case at injection, and she suggested repeating the measurements with local orbit bumps at the Q6. R. Assmann pointed out that these losses are a limitation at injection (e.g. thresholds on the TCTs were raised for all energies due to the increase needed at injection), possibly alternative solutions for injection should be devised. M. Sapinski recalled that the feasibility of “sunglasses” is being studied within the BLM team, but local ionization chambers could already improve the situation. More MD time is requested for 2012 to inject higher intensity, use orbit bumps and study other magnets (like Q4). R. Assmann added that if the BLM thresholds are too tight, they could be raised to provide more room for operation.
For the 25 ns beam MD, the beam characteristics at the SPS were the following: 1.05e11 ppb, 2.5-2.7 μm transverse emittance, abundant scraping (>10%). High chromaticity (>20 units) was required to accumulate the beams starting from 48 bunch trains. Injection of up to 288 bunches was achieved (1.05e11 ppb, i.e. 3e13 p and 2.2 MJ); the losses recorded had reached about 30% of the dump threshold.
A list of requests for 2012 was also presented (see slides), including dedicated studies on transfer line steering margins, in particular after the MKI and MKE improvements foreseen during the Xmas stop; TCDQ/TCT relative position studies and asynchronous dump in view of tight collimator settings; impedance of TCDQ and TDI. T. Baer clarified that further UFO studies would be interesting due to the strong activity observed with 25 ns beams. R. Assmann asked about the priorities in the list. C. Bracco answered that for example TL stability margin studies would be useful already for 2012, while loss studies with injection of 288 bunches would be for after LS1.

3. Beam shape measurements (F. Burkart)

Four full beam scrapings were performed during the MD, with different step sizes of 20, 60 and 80 μm, and the loss rate at the scraping primary collimator was used to calculate the emittance. The calculated emittance was then compared to the emittance from the wire scanners (e.g. for one case: ε_{WS}=1.4 μm and ε_{calc}=1.7 μm). It is concluded that the transverse tails are highly populated with 3.6% of the intensity sitting beyond 4 σ. The results were also compared to EoF scraping tests performed with 912 bunches, the measured tail population being lower at EoF. H, V and skew scrapings were performed. The next step would be to combine all data into a 2-

dimentional description of the beam shape. R. Tomas asked whether all particles are absorbed and if possible effects from scattering off the collimator jaw back into the bunch should be taken into account, R. Assmann answered that it takes about 200 turns to clean and that very few particles can be kicked back into the bunch (the collimator "kick" is at the maximum amplitude of the oscillation).

4. Tight collimator settings (R. Bruce)

Tight collimator settings consist of 4-6-8 σ for the IR7 collimators and 9.3 σ for the TCTs (with σ defined as 3.5 micron normalized emittance at 3.5 TeV). They are the gap settings (~2 mm) needed for the primaries at nominal 7 TeV operation and in 2012 would allow a smaller β^* and better efficiency (thus higher stored intensity). The long-term stability of the cleaning performance with tight settings was verified by comparing new loss maps with the ones performed in MD#1 and MD#3: the hierarchy was well preserved (centers from the March setup were used), and the cleaning inefficiency was found to be consistent with the previous MDs. Note that the collimators were moved to tight settings already during the energy ramp; 1% losses were observed during the ramp and 5% during the squeeze. This would not be acceptable for high-intensity operation. The losses are mostly due to orbit oscillations that caused unintentional scraping, and work is ongoing to improve the orbit control (see LBOC 29 Nov 2011). R. Assmann pointed out that in the "tight settings" only the primaries have the nominal 7 TeV operation gaps, while all other collimators have wider gaps: work will continue in 2012 towards achieving nominal settings for the whole hierarchy.

5. High pile-up fill observations (G. Trad)

High brightness bunches were collided twice (fills 2201 and 2252) to provide the experiments with high pile-up collisions (μ~35 was reached in the second fill): beam parameter evolution was studied parasitically and the observations were presented. In fill 2201 1 bunch/ring was collided with ~2.45e11 ppb in ~3 μm (~2 μm at injection, ~10% blow up was observed at the flat bottom and up to 40% during the ramp). The expected luminosity was recalculated from the measured emittances (the BSRT was calibrated with WS) and fBCT intensity, the disagreement with the values published by the experiments is probably within the achievable precision. F. Zimmermann commented that the higher than expected transverse tail population could partly explain the missing luminosity. The loss rate for beam 1 shows two different regimes: at first the luminosity burn off accounts for 75% of the total losses, and then only for 43% (increased total losses); for beam 2 only one regime is observed in which 40% of the total losses are explained by burn off. The beam parameter evolution was cross-checked against the predictions from the modified Tevatron luminosity model: a good agreement for the longitudinal and transverse emittance was found, while the intensity behaviour is not fully explained. J. Jowett added that in the case of ions the losses from the bucket are important. E. Chapochnikova asked about the modeling of the beam-beam interaction, G. Trad explained that it is missing, but the losses from beam-beam would be highest at the start of fill and then decay, while the agreement is best at the start of fill for this simulation. In fill 2252 10 bunches per ring were injected and the SPS was in "almost dedicated" LHC filling in order to help minimize the time at the LHC flat bottom. On average, the bunch parameters were 2.3e11 ppb in ~2.5 μm. The loss behaviour could be classified in 3 families depending on head-on collisions. The bunches with shorter initial bunch length had the highest loss rates. Luminosity leveling was performed at both IP1 and 5 successfully. During the IP5 separation, rapid losses were observed for one single bunch experiencing only long-range interactions at that IP; the phenomenon is not fully explained yet.

6. Transfer line stability (L. Norderhaug Drosdal)

Dedicated TL studies were performed during LHC downtime: MKE waveform scans and TI8 stability studies; more dedicated time is requested for next year. G. Papotti asked whether any analysis of operational beam transfers is being performed. The MKE4 waveform (b2) shows voltage ripples (up to 4%, exceeding the 1% specifications), which have a similar shape to the bunch-by-bunch variations observed in TL trajectory data. The TI8 stability was studied by taking 12 bunch transfers repeatedly (177 shots): the variation from the average trajectory was up to 770 μm, the analysis pointing to the SPS extraction as main source (MSE and MKE, earlier studies for TI2 also pointed to the MSE). The MSEs will be improved during the Xmas stop and stability studies should be repeated early in 2012, possibly already during the beam commissioning given the strong effect on operational efficiency. B. Holzer asked whether there is a jitter also on the amplitude of MKE4 in addition to the timing jitter, V. Kain answered that this is not known as only the pulse itself was measured (not versus the beam), more information could be gathered with further beam studies sampling the whole kicker waveform (e.g. 144 bunches with 50 ns). Further studies include investigations on the sensitivity to steering at TL collimators and studies of the effect of SPS super cycle changes.

7. 2012 MD requests (roundtable)

The MD teams presented overviews of 2012 MD requests, For details all slides are available on the Indico page.

D. Valuch presented the ADT requests: compatibility between ADT and Q/Q' diagnostics (possibly feeding a Q measurement from 12 freely oscillating bunches to the QFB), noise properties of the ADT in closed and open loop, optimization of the ADT gain in the ramp to minimize the emittance increase, the possibility to measure the tune from the ADT signals in closed loop. It was also pointed out that the ADT will need to be re-commissioned after the Xmas stop and for higher bunch intensity, additionally the selective blow-up for loss maps needs to be commissioned (all activities to be performed before the intensity ramp-up). M. Lamont asked about the possibility to gate the BBQ signals. D. Valuch answered that it seems easier to gate the ADT signals.

W. Herr presented the beam-beam requests, among which: finding possible head-on limits from unequal beam sizes, finding possible long-range limits for 25 ns beams and 50 ns beams (with high intensity or different β^*) which would give a criteria for the required separation, colliding at the half integer working point, collisions and leveling with pseudo-flat beams (β_x different from β_y), leveling with β^*, studies on coherent

modes and passive compensation. Priorities were also given (studies relevant for 2012 operation, for after LS1 and for HL-LHC).
F. Zimmermann recalled also a request on the Large Piwinski Angle MD.

R. Tomas reviewed the list of optics studies: the continuation with half-integer tune (e.g. dispersion and off-momentum optics and the investigations of why the stopband was wider after correction than before); the non-linear triplet correction (for β*=0.7 m); studies to understand the linear chromaticity at injection (there is at present a discrepancy of 10 units, possibly due to natural Q' or spool pieces, more academic study than the other requests, but quickly performed). He also recalled the dynamic aperture and non-linear studies requests from M. Giovannozzi. B. Holzer stressed the importance of these measurements for HL-LHC simulations and for the Nb_3Ti 11-T dipoles design.

H. Burkhardt presented the requests to continue the high β* developments in 2012 for TOTEM and ALFA aiming at measuring σ_{TOT} and the luminosity to 1% precision. A first proposal is to de-squeeze to ~500 m and reduce the beam emittance to 1 μm by scraping to allow the Roman Pots to get close enough. Achieving β*>500 m is considered rather difficult in 2012, while for β*>1 km additional cabling is needed (could be done in LS1). TOTEM is interested only in β*>850 m and B. Gorini confirmed that the priority of this physics program is still being discussed for 2012 (it had been agreed on for 14 TeV). R. Assmann confirmed that feasibility studies can be done during MD time, while the remaining setup (e.g. collimator and RP alignment) would be done in physics time.

M. Sapinski presented 3 requests aiming at understanding the quantity of deposited energy needed to quench: with the wire scanner (for ms timescales, to be done towards the end of the run due to the risk of wire damage; a previous test needs to be repeated with higher wire speed and higher beam intensity); with orbit bumps in 14R2 at injection and at flat top (for 1 and 5 s timescales, the tests would be the continuation of previous successful MDs). These tests would allow a better understanding of the quench thresholds thanks to the precise FLUKA and Geant4 simulations available.

P. Baudrenghien summarized the RF and longitudinal beam requests, among which: the continuation of studies on the loss of Landau damping, measurements of the longitudinal broad-band impedance, the longitudinal stability for batch injections; longitudinal blow-up studies, the commissioning of the longitudinal damper, voltage modulation studies to mitigate the effect of beam loading, RF feedback optimization, the commissioning of an automated p-Pb rephasing (using p only, for 2012 Q3). It was noted that accelerating 25 ns beams will steer some of the MD priorities: e.g. the commissioning of the longitudinal damper will be needed in case of high capture losses; the voltage modulation will be required if the klystrons will saturate. For up to 1.1e11 ppb at 25 ns spacing the klystron high voltage can just be pushed to the maximum, the voltage modulation is required above that (essential after LS1). It was recalled that currently the system is running at 1.5 MV/cavity and 150 KW/klystron, while nominal values are 2 MV/cavity and 250 kW/klystron (the klystrons are specified for 300 KW). R. Assmann pointed out the importance of checking before LS1 whether the RF system can be run stably at design parameters, P. Baudrenghien suggested the possibility of getting statistics during the ramp down time.

M. Strzelczyk presented two requests: one to test an application that was prepared to automate the β^* measurement by K modulation; the second one to measure the uncorrected chromaticity at the beginning of the flat-top as a function of time and then correct it with the FiDeL mechanism (this would allow reducing the flat top length by 300 s).

J. Jowett presented a few Pb related requests: the continuation of the p-Pb feasibility test, a Pb collimation quench test, as well as Pb and p collimation tests to reduce the local energy deposition (extension of the BFPP technique to IR7 and 3).

F. Roncarolo presented a preliminary list of instrumentation requests for BCT/fBCT, BPM, BGI, BSRT, matching monitors, BLM, LDM, WS, Q/Q' measurements and OFC/OFSU, headtail, WCM, AGM. Ideally, an 8-h block per MD is allocated and many instruments can be worked upon in parallel (already successful in 2011). Note that for the BSRT, fast scanning is being considered for 2012 (25 Hz versus the present 1 Hz).

The next meeting will be devoted to the discussion of the 2012 MD requests and priorities, date and place are yet to be decided.

Giulia Papotti

List of participants

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Excused: G. Arduini, M. Giovannozzi, J. Wenninger.