FIRST THOUGHTS ON MD PRIORITIES FOR 2012

F. Zimmermann, Ralph Assmann, Giulia Papotti

CERN, Geneva, Switzerland

Abstract

In 2012, 22 days of beam time will be allocated for LHC MDs. In this paper, after recalling the 2011 LHC MD experience, the MD requests for 2012 are reviewed. Three primary MD themes for 2012 can be identified: (1) pushing performance in 2012, (2) preparing for 2014/15, and (3) towards maximum luminosity. Example topics include emittance growth in collision or enhanced satellites for theme (1), 25 ns operation for (2), and ATS optics for (3). Structured lists of MD requests and topics for each theme as well as some initial thoughts on the MD priorities are presented. For certain topics, "start-of-fill MDs" are proposed in order to most efficiently use of the available beam time.

2011 MD HIGHLIGHTS

In 2011 the MDs were organized in 4 MD blocks of 5 days, and 2 floating MDs with a length of 24 h each. The 2011 MDs delivered numerous outstanding and important results, for example:

- a high beam-beam tune shift of 0.034 total in two IPs;
- high brightness beams: 1 micron emittance with $2x10^{11}$ protons per bunch;
- a high bunch intensity $2.5x10^{11}$ protons, with all beam instrumentation working;
- "25-ns" beams with up to 2100 bunches circulating;
- injection of up to 288 nominal bunches;
- tight collimation settings;
- 0.5 MW beam losses at collimators without quench;
- *p-Pb* MD: feasibility of mixed beams in LHC;
- high pile-up of up to 35 events per crossing;
- ATS optics β* down 40 cm;
- UFO events after injection-kicker firing, occurring much faster than expected from gravity; and
- a limiting IR aperture which his about a factor ~1.5 bigger than expected;

Figure 1 illustrates some of the luminosity-related beam parameters explored during the 2011 LHC MDs.

Several of the lessons learnt from the MDs have immediately benefitted the 2011 machine operation and luminosity operation, e.g. through a reduction of β* from 1.5 m to 1.0 m in IPs 1 and 5. Others will modify the future path towards maximum luminosity.

The LHC MD coordination with the injectors, organized by Giulia Papotti and Giovanni Rumolo, has been extremely efficient, and has greatly contributed to the successful MDs in 2011.

So far the 2011 MD results have been documented in about 30 MD notes [1], which are listed in the appendix.

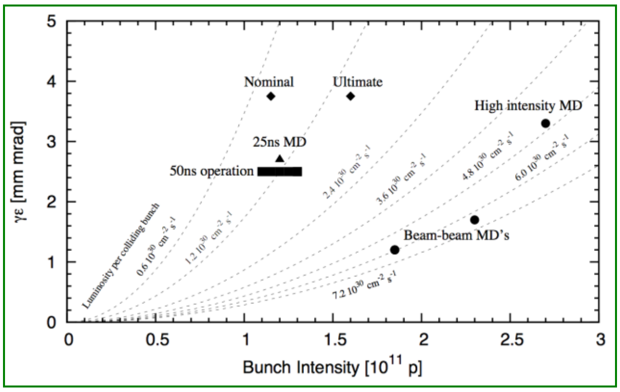

Figure 1: Bunch parameters explored by LHC MDs in the emittance-intensity plane [2]. The curves represent iso-luminosity lines, with numerical values referring to the luminosity per colliding bunch at β*=1.5 m.

2011 MD TIME ALLOCATION

The time allocated in 2011 for different MD topics is indicated in Table 1, where we list the time, including the time allocated for ramp & cycle after the MD (except for dry runs), which was attributed to various topics prior to the start of each MD block. We caution that the assignment to different topics is not always unique, and also that the same MD may have been scheduled several times due to beam non-availability.

Table 1: MD time allocation per topic in 2011, not reflecting the actual time with beam (as the latter may or may not have been available during the scheduled MD period). Numbers in parentheses include parasitic studies performed during other MDs. The numbers include the time allocated for ramping and cycling after those MDs which were performed above injection energy, excluding the case of dry runs.

Topic	time allocation
electron cloud	55 h
beam-beam	54 h
RF & longitudinal dynamics	51 h
magnets including quench tests	49 h
injection & injection protection	40 h
ATS optics	40 h
BI	40 h
collimation	26 h
β*=1 m (optics & collimation)	26 h
IR MDs	18 h
nonlinear dynamics	18 h
p-Pb feasibility	18 h
R2E	16 h

impedance	10 (15) h
UFO studies	10 (14) h
β*=90 m	10 h
combined ramp & squeeze	10 h
collision tunes at inj.&ramp	8 h
p-p rephasing	8 h
½ integer tune	8 h
TDI vacuum	8 h
beam shape	6 h
ADT blow up at injection	6 h
high pile up	1 h

2012 MD SCHEDULE & REQUESTS

A draft LHC schedule for 2012 is available. As it has been the case in 2011, 4 MD blocks of 5 days each and 2 times 24 h of floating MDs are foreseen during the year.

MD requests for 2012 had been submitted in November & December 2011. A total of 76 requests had been received by 13 December 2011, with the total time requested amounting to 913.5 h, not including possible post-MD ramp-down and cycle times. This should be compared with a total available time of 528 h. The ratio of requested to available time close to two is similar to the situation at the start of the previous run, in early 2011. The distribution of MD requests by topic is illustrated in Fig. 2. In further detail, the individual MDs requested for each topic are summarized in Table 2.

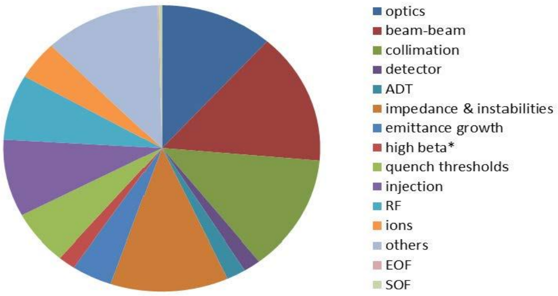

Figure 2: Distribution of 2012 MD requests by topic.

Table 2 also introduces a new MD category. Namely, in addition to end-of-fill (EOF) MDs, already performed during the 2011 LHC run, we are proposing to consider start-of-fill (SOF) MDs, to be performed either only at injection or also at top energy. The purpose of the SOF MDs is to maximize the efficient use of LHC beam time. Disucssions in Evian revealed that start-of-fill runs would be of considerable interest for several groups of studies, e.g. not only the one addressing the chromaticity decay on the flat top, but also for several RF related MDs [3,4].

The 76 MDs requested for 2012 belong to the four different MPS classes [5] as follows: 19 MDs require only setup beams and fall into class A (automatically approved); 34 MDs with unsafe beams in physics conditions at any energy are are in class B ("quick" approval); 22 MDs requiring unsafe beams and changes of orbit/optics belong to class C (approval with EDMS document); and 1 MD involving new 'machine territory' falls under class D (downgraded to Setup Beam unless full failure analysis is performed, in which case the MD would move to class C).

Table 2: MD time per topic requested for 2011. Shown in bold italic are the net requests for the main topics, which are further detailed below.

Topic	time requested
optics MDs	***106 h***
ATS optics	16 h
tune close to ½ integer	16 h
compensation of IR nonlinearities	12 h
nonlinear beam dynamics	12 h
movements IT with beams at injection	8 h
RF cavity nonlinearities	16 h
aperture measurements at 3.5 TeV w ADT blow up	8 h
LHC linear chromaticity	6 h
chromaticity measurement w. longitudinal kick	8 h
beam-beam MDs	***136 h***
head-on beam-beam limit w unequal beams	16 h
beam-beam limit for LR separation	24 h
beam-beam limit for LR intensity	8 h
Large Piwinski angle	16 h
transverse noise & coherent beam-beam	16 h
beam-beam emittance growth due to transverse noise	16 h
LR beam-beam with flat beams	24 h
HV passive compensation	16 h
collimation MDs	***120 h***
chromatic aberrations & collimation	8 h
asynchronous dump in collimation set up	8 h
scraping scan for beam shape	8 h
collimation studies with different settings	24 h
scraping with tune excitation	16 h
loss maps with transverse damper	8 h
collimation with beta*=40 cm	8 h
fast collimator setup at 3.5 TeV	8 h
proton collimation loss mitigation	16 h
collimation cleaning eff. on ramp w ADT blow up	8 h
fast beam losses at the collimators	8 h
detector MDs	***16 h***
high pile up	8 h
luminosity levelling with beta* change	8 h
ADT MDs	***18 h***
noise properties of ADT w FB on & off	6 h
residual tune signal in damper signal	6 h
ADT Q/Q' diagnostics compatibility	6 h
impedance & instability MDs	***126 h***
TCBI at flat top and octupole stabilization	20 h
impedance budget at injection	6 h
multibunch tune shift at flat top	8 h
multibunch tune shift at injection	8 h
probing the single bunch limits in LHC	6 h

longitudinal stability for batch	16 h
LHC transverse impedance	10 h
impedance and beam heating of long protection devices	16 h
intensity limitations for 25 ns operation (electron cloud)	24 h
effective longitudinal broadband impedance	6 h
loss of Landau damping during ramp	6 h
emittance growth MDs	***38 h***
source of transverse emittance blow up	16 h
transverse emittance blow up at injection	10 h
optimization of ADT in the ramp	12 h
high beta* MDs	***16 h***
de-squeeze to beta*=500 m	8 h
scraping to 1 micron emittance at top energy	8 h
quench threshold MDs	***56 h***
quench margin at top energy in DS of IR7 & IR3	16 h
quench limit investigations with beam at injection at Q6.L8 & Q4.L6	16 h
wire scanner quench test at flat top for ms losses	8 h
quench test at injection energy for MQ/MB with horizontal bump	8 h
quench test at nominal energy at C14R2 with bumps	8 h
injection MDs	***80 h***
beam losses at injection	16 h
protection from long devices	16 h
injection matching & emittance preservation	16 h
LHC transfer line stability	16 h
transfer and injection of high brightness bunches with SPS Q20	16 h
RF MDs	***52 h***
longitudinal blow-up studies	16 h
RF feedback optimization with circulating beam	4 h
commissioning of longitudinal damper	16 h
voltage modulation to minimize klystron power	16 h
ion MDs	***40 h***
ion collimation loss mitigation	16 h
proton lead intensity limit	16 h
commissioning of *p-Pb* rephasing using *p*	8 h
other MD requests	***108 h***
BI MDs	36 h
UFO MDs	8 h
operational development MDs	48 h
sensitivity of QPS thresholds to FB systems	8 h
combined ramp & squeeze	8 h
EOF MDs	***>2.5h***
halo scraping	0.5 h
TCBI at flat top and injection	1 h
single bunch parameter evolution	?
automatic K modulation for beta*	1 h
SOF MDs	***3 h***
chromaticity decay at flat top	3 h

2012 MAIN MD THEMES

The three main MD themes for 2012 are (1) pushing performance in 2012, (2) preparing for the time after the long shutdown 1, and (3) towards maximum luminosity. A rough grouping of the 76 MD requests received according to these three themes yields the distribution shown in Fig. 3.

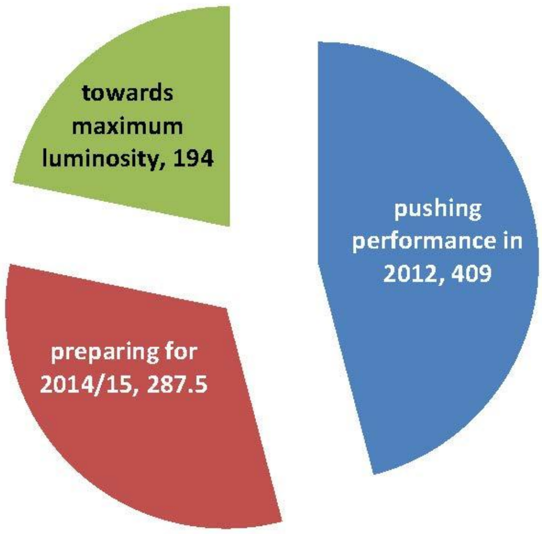

Figure 3: Distribution of MD requests according to the three 2012 main MD themes; the last number represents the total MD time in hours.

Naturally, the MDs of theme (1) - pushing the 2012 performance - should be scheduled early during the run. Theme-1 MDs include studies of the beam transfer (injection lines, transfer stability; injection protection), BI MDs, MDs for operational efficiency (e.g. combined ramp & squeeze), MDs addressing the emittance growth at injection and ramp as well as emittance growth in collision (e.g. beam-beam & noise; collisions without ADT or with different ADT gains), and *p-Pb* MDs (*p-Pb* feasibility, *p-Pb* re-phasing with protons, ATS IBS studies [no explicit MD request]).

Important theme-(2) MDs – preparing for 2014/15 – address running at 6.5 TeV energy (quench margin; combined ramp & squeeze; BI limits; collimation with nominal 6.5/7-TeV settings), high pile up (ATS optics; collimation with β^*=40 cm & low emittance), 25-ns performance (electron cloud; UFOs; long-range beam-beam effects; maximum current with regard to vacuum, cryo, impedance; RF & longitudinal dynamics MDs), shorter bunches (heating, vacuum; loss of Landau damping), and high beta* optics (maximum β^*, injection with β^*=200 m, ATS de-squeeze). The 25-ns MDs should be scheduled after the 25-ns scrubbing run.

Finally, the MDs of theme (3) – towards maximum luminosity – cover SPS Q20 optics (transfer and injection matching), ATS optics (enhanced Landau damping; beam-beam limit for ATS; effect on IBS rates), collimation MDs (maximum acceptable chromatic aberrations; halo diffusion control by tune modulation, beam loss mitigation), beam-beam limits & optimization (HV passive compensation; half integer tune; flat beams; large Piwinski angle), and alternative levelling methods.

The following possible improvements for the 2012 MD scheduling are considered: more EOF MDs, new SOF MDs, and making use of the intensity ramp-up during the start of the run. It is assumed that there will be no “operational development” outside the MD time.

MD VERSUS COMMISSIONING

Two examples from 2011 illustrate the answer to the question “what is MD and what is commissioning?”:

A) For the 90 m optics the feasibility was shown in an MD, while the commissioning for physics running was done in physics time.

B) For the high pile up studies, the first test and feasibility were demonstrated in an MD, whereas the subsequent data taking was scheduled in physics time.

In 2011, great flexibility from all colleagues involved concerning the sharing between MD, commissioning and physics times has helped to accomplish major goals. A similar flexibility is hoped for in 2012.

PRELIMINARY PRIORITIES

The most important topics appear to be those which are part of the preparation for 6.5 TeV and those which are needed to advance new hardware for the HL-LHC.

The former includes BI with potential hardware improvements such as achieving the BPM stability needed for β^*=0.55 m & nominal collimation and resolving BSRT systematics at 4 TeV in view of 6.5 TeV; the upgrade of the longitudinal blow up (to mitigate heating problems, and including changes in the SPS), resolution of RF klystron power issues, voltage modulation for transient beam loading compensation, pushing the transverse damper to its ultimate performance, and, possibly, commissioning of the longitudinal damper for 25-ns operation; the feedback stabilization of orbit in squeeze by OP; establishing collimation settings with nominal 1-σ retraction, and qualifying the resulting impedance; determining the actual quench thresholds and relevant BLM thresholds at different beam energies; understanding heating issues, in particular HOMs and the longitudinal beam spectrum; fast & accurate steering of the transfer line for injection efficiency, addressing the question of future operation with 50-ns or 25-ns spacing, which includes the high pile up limit, bunch intensity & emittance growth limits, electron-cloud effects, crossing angle & LR beam-beam separation; and the high beta optics, where limits with present hardware are to be identified.

Concerning future hardware, experiments on nonlinear dynamics limits should deliver the required field specification for 11-T dipoles and for crab cavities.

START-OF-FILL MDS

Measuring effects at the start of flat top, like the chromaticity decay, could conceivably be done in the form of start-of-fill MDs.

Other SOF studies might be performed – more easily – already at injection energy.

For RF studies, end-of-fill studies are not suitable, since these imply high intensity beam and almost full buckets. On the other hand, many RF MDs could be conducted at 450 GeV, with nominal batch injection and no changes in the rest of the machine. In such situation a 2-4 hour time slot with the machine at injection settings could very effectively be used for short SOF MDs. The MD beam would afterwards be dumped and the machine could proceed with physics fills. A list of RF MDs that would be good candidates for SOF studies at injection has been provided following the Evian workshop [4]:

1. Longitudinal stability for batch: The only changes with respect to physics fills are the LHC capture voltage, the SPS longitudinal emittance and the filling pattern.
2. Longitudinal blow-up studies. At least the batch per batch blow-up at injection (potential reduction of the transverse emittance growth caused by IBS) can be tested with a series of nominal batches injected as SOF MD.
3. The longitudinal damper is active at injection only. It must be commissioned with the nominal batch at injection.
4. Voltage modulation around 1 turn, which in the final implementation will be made active after the filling is complete, but which must first be tested (MP concerns) at injection with 2 or more nominal batches.
5. RF feedback optimization with circulating beam. Also here the first tests should be done with 1 or few nominal batches at injection (again for MP concerns). The feedback optimization would later be used in ramp and physics as well.

It appears likely that BT, BI and ADT could also benefit from SOF MDs in a similar fashion.

The SOF concept needs be formalized (by limiting the accepted deviation from nominal parameters, e.g. for a quick rollback to injection for physics) [4]. If accepted by the users SOF studies could be an efficient alternative to the "operational development" proposed in 2011.

OUTLOOK

The lists & thoughts presented in this paper are meant as a basis for discussion. Iteration will be performed during January 2012 and a revised draft MD schedule will be presented at the Chamonix 2012 LHC Performance Workshop for further discussion and approval.

Feedback is welcome at any time. Pertinent comments should be sent to Giulia Papotti, Ralph Assmann and/or Frank Zimmermann.

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APPENDIX

List of 2011 LHC MD notes published as of 13 December 2011:

1) BI MD studies on August 25th 2011, D. Belohrad et al, CERN-ATS-Note-2011-130 MD
2) End-of-fill study on collimator tight settings, R. Assmann et al, CERN-ATS-Note-2011-125 MD
3) Optics measurement and correction close to the half integer resonance, R. Calaga et al,CERN-ATS-Note-2011-124 MD
4) Results of long range beam-beam studies and observations during operation in the LHC, Alemany et al, CERN-ATS-Note-2011-120 MD
5) IR1 and IR5 aperture at 3.5 TeV, C. Alabau Pons, CERN-ATS-Note-2011-110 MD
6) Beam parameters observations during a high pile-up collisions fill, G. Trad et al, CERN-ATS-Note-2011-105 MD
7) Longitudinal Oscillations with Batch Injection in the LHC, T. Argyropoulos et al, CERN-ATS-Note-2011-031 MD
8) Dependence of single beam lifetime on bunch length, P. Baudrenghien et al, CERN-ATS-Note-2011-083 MD
9) Tight collimator settings with beta* = 1.0 m, R. Assmann et al, CERN-ATS-Note-2011-079 MD
10) R2E-related MD: slow controlled losses for RadMon/BLM cross-checks , M. Calviani et al, CERN-ATS-Note-2011-070 MD
11) BI MD Studies on June 29th 2011, D. Belohrad et al.CERN-ATS-Note-2011-069 MD
12) Quench Margin at Injection, W. Bartmann et al, CERN-ATS-Note-2011-067 MD
13) MKI UFOs at Injection, T. Baer et al, CERN-ATS-Note-2011-065 MD
14) MD on Injection Quality – Longitudinal and Transverse Parameters , L. Drosdal et al, CERN-ATS-Note-2011-063 MD
15) Improving LHC Collimator Setup Efficiency at 3.5 TeV, R. Assmann et al, CERN-ATS-Note-2011-062 MD
16) IR3 combined cleaning test at 3.5 TeV, R. Assmann et al, CERN-ATS-Note-2011-061 MD.
17) LHC Transvers Profile Monitors studies (MD on May 6th, 2011), E. Bravin et al, CERN-ATS-Note-2011-049 MD
18) Transverse coupled-bunch instability rise times in the LHC at injection and top energy, N. Mounet et al, CERN-ATS-Note-2011- 035 MD
19) Head-on beam-beam tune shifts with high brightness beams in the LHC, R. Alemany et al, CERN-ATS-Note-2011-029 MD
20) Test of luminosity levelling with separated collisions , R. Alemany et al, CERN-ATS-Note-2011-028 MD
21) 50 and 75 ns operation in the LHC: Vacuum and Cryogenics observations, G. Arduini et al, CERN-ATS-Note-2011-046 MD
22) BPM Offset Determination by Sinusoidal Quadrupole K-modulation, T. Baer et al, CERN-ATS-Note-2011-043 MD
23) The Achromatic Telescopic Squeezing (ATS) MD part I, S. Fartoukh et al, CERN-ATS-Note-2011-033 MD
24) Summary of MD on nominal collimator settings, R. Assmann et al, CERN-ATS-Note-2011-036 MD
25) Un-squeeze to 90 m, H. Burkhardt et al, CERN-ATS-Note-2011-032 MD
26) Collimator losses in the DS of IR7 and quench test at 3.5 TeV, R. Assmann et al,CERN-ATS-Note-2011-042 MD
27) Studies of longitudinal single bunch stability, T. Argyropoulos et al, CERN-ATS-Note-2011-041 MD
28) TI8 shielding studies and angular alignment of TDI and TCDQ, W. Bartmann et al, CERN-ATS-Note-2011-040 MD

REFERENCES

[1] LHC MD notes are available from the LSWG web site at https://cern.ch/lhc-md
[2] R. Assmann, “Results from the first two MD study periods,” CERN-MAC, 22 August 2011
[3] P. Baudrenghien, private communication, Evian 13 December 2011
[4] P. Baudrenghien, email from 21.12.2011
[5] R. Assmann, “LHC MD’s,” LMC meeting no. 87, 13 April 2011