Minutes of the 2nd Meeting of the Quench-Test Analysis Working Group, 07.06.2013

Present: Bernhard Auchmann, Tobias Baer, Francesco Cerutti, Vera Chetvertkova, Bernd Dehning, Belen Ferrando, Pier-Paolo Granieri, Wolfgang Hofle, Anton Lechner, Agnieska Priebe, Mariusz Sapinski, Nikhil Shetty, Eleftherios Skordis, Ezio Todesco, Arjan Verweij, Daniel Wollmann, Markus Zerlauth

Mariusz: Introduction

In addition to three presentations we discuss two proposals:

1. To streamline the use of terminology and physical units inquench-test related publications and presentations.
2. To publish a joint journal paper on the results of all 2013 quench tests.

With regard to physical units, it was agreed that a concrete proposal should be presented and discussed in the coming QTAWG meeting. As for the joint paper, the present participants were overall positive, questioning only the scope of the paper, as a full documentation of all technical aspects of the individual tests could easily fill 100+ pages. Absent key persons will be questioned on the principal of a joint paper, and a concrete proposal as to scope/length/journal could be discussed at the coming meeting.

Vera: Updates on MAD-X simulations of ADT fast losses quench test

MAD-X simulations are compared to ADT beam-position monitor and beam-loss monitor data. Losses should start ~100 turns after the MKQ kick. However, in the MAD-X simulation losses start 100 turns later.

MAD-X studies show that an increase of the offset in the ADT excitation function can accelerate the losses.

Also the time distribution of losses is different in MAD-X and BLMs: whereas BLM data shows loss spikes every three turns, MAD-X shows an additional modulation with two peaks (3 turns apart) every 20 turns. The origin of this structure in the simulation is not yet understood.

Comparison with tests during an MD in Oct 2012 and the Feb 2013 quench-test data shows that presumably identical MKQ and ADT settings produced very different results on the beam.

Vera: could some of the above effects be due to inaccuracy in the tune simulation?

> *Mariusz*: One would expect loss spikes every three turns, linked to the tune close to 1/3. The observed tune spread was only 1E-4.
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> *Wolfgang*: In the simulation a lost particle is removed from the lot, whereas in reality it might continue to revolve and be lost in following turns. Collimation people might have more information.
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> *Tobias*: If the tune in the simulation would be set to precisely 1/3, the losses should appear every third turn. The modulation with a seven times lower frequency is most likely explained by the not exactly 1/3 tune.
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> *Wolfgang*: The ADT produces the fastest excitation if the feedback loop is on; the excitation is always synchronous with the maximum of the passing bunch. This is not the case in the simulation. Using the ADT in

open-loop mode, they would also see beating between the actual and the assumed tune.

Wolfgang: An FFT of the actual and simulated losses, or even an FFT of the BPM signals, might help.

Daniel: Even though the time evolution of the losses is not yet reproduced/understood, the spatial loss distribution could already be used for FLUKA simulations. The goal is still to fully understand the simulation, but a parallel FLUKA track could already be started based on the existing results. (Action Vera, Daniel, Anton?)

Anton: If the spatial distribution is stable within reasonable limits before the quench, then we could go ahead with FLUKA simulations.

Mariusz: The BLM data showed variations in the longitudinal distribution over time, but the effect was small and likely negligible given other uncertainties.

Anton: The losses extend only over approximately a meter, so the variation cannot possibly be very large.

Arjan: Anyways the quench start is only known with 5 ms precision, so we need not overdo it on the MAD-X side of the simulation sequence.

Vera: is it permissible to use the ADT offset as a free parameter to match the onset of losses in MAD-X?

Vera: what is the reason for the apparent inconsistency between Oct 2012 and Feb 2013 tests?

Wolfgang: We need to perform some forensics for both, the ADT gain and the MKQ kick in both tests. There are different ways to influence the ADT gain and produce the missing factor two (Action Wolfgang).

Tobias: Recall that also the ADT amplitude was changed.

Wolfgang: This is correct, but does not account for the missing factor two.

Tobias: For the MKQ kick the difference between tests should not exceed 10%. More forensics is required. (Action Tobias, Wolfgang?)

Mariusz: With the fast-losses ADT test working in MAD-X, it would also be interesting to simulate the slow-losses ADT test.

Daniel: We will look into this. The problem is with the tracking of particles over a time range of 20 s. We will study the feasibility.

Wolfgang: Notice that white noise means that all particles in a bunch receive the same random kick, and not each particle individually. This could make simulations easier.

Agnieszka: For the 2010 quench test there were only 3 BLMs, resulting in a poor spatial resolution. A MAD-X analysis of that test would be very interesting as input for the GEANT4 model!

Nikhil: FLUKA simulations of the Q6 quench test

The intention of the Q6 quench test was to determine the quench limit of the Q6.L8 using variable magnet currents and exposing it to showers from the fully closed TCLIB. Six shots were fired on the TCLIB. The magnet current was increased from shot to shot. A quench finally occurred at 2500 A.

FLUKA was used to compute the energy deposition in the coil and to reproduce the BLM signal. The simulations proved very sensitive to geometrical details.

According to the FLUKA simulations, the peak energy deposited in the coil was 30 mJ/cm^3. The peak losses were found at the front end of the magnet on the horizontal plane. As the magnet is horizontally focussing, the losses at the back end of the magnet were significantly lower.
As for BLM signals, many BLMs were saturated in the vicinity of the collimator and Q6. Some signals were close to saturation around the Q7, and more unsaturated signals are available from the MBs. Comparison of the unsaturated signals yields a clear discrepancy by a factor 15-20 between simulation and measurements, the simulation giving larger signals.
Nikhil: FLUKA used to be quite accurate in predicting BLM signals, but mostly for either steady-state or ultra-fast losses. What could be different this time? Are we sure that the voltages on the BLMs were stable during the tests?

> *Bernd*: A voltage drop may indeed be the culprit. Saturation on many BLMs could influence the voltage on other elements down the chain.
> *Mariusz*: A preliminary analysis with Christos did not give a clear indication that BLM voltages were unstable.
> *Markus*: Did we see a similar effect in the simulation of TDI losses?
>> *Anton*: Then BLM signals were not simulated.
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> *Anton*: We found that the BLM signals were consistent with previous similar tests, but also then a significant portion of BLMs saturated.
> *Anton*: Also interesting is that the only input factor is the loss intensity of the TCLIB. Other simulations had been much more complex and the results had been better.
> *Bernd*: It is known that there is cross-talk between BLMs via voltages. The team will study the effect and give a worst-case limit to quantify the effect (Action Bernd).
> *Belen*: Was the simulation also done for shots prior to the quenching one?
>> *Anton*: The BLM signals did not change significantly from shot to shot.
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> *Arjan*: Would it make sense to include even more BLMs downstream?
>> *Anton*: The MBs were included to test this effect. No improvement of the simulation/measurement discrepancy was found further downstream.
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> *Markus*: Have all sanity-checks been done like checking the energy balance?
>> *Anton*: Yes, no hints for bugs in the model were found.
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> *Mariusz*: Was there a RADMON present that could give an independent calibration?
>> *Anton*: The RADMON gives only an integrated dose. That makes a comparison to simulations more difficult.
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> *Arjan*: Checking previous QP3 simulations for MQM magnets, the minimum quench energy on the inner coil diameter was 20 mJ/cm3.
>> *Francesco&Anton*: That is encouraging as it would exclude that simulations are wrong by a factor 10 or more.

Eleftherios: FLUKA energy deposition simulations for the 4TeV collimation quench test and post-LS1 6.5TeV operation

The IR7 FLUKA model of beam 2 comprises the LSS and DS regions up to cell 14. LSS and DS are separated by the TCLA collimator and a wall.

Important factors in the model are the actual BLM position, the surrounding geometry, and the simulation of cross-talk showers. Every BLM is unique. The simulation strategy uses Sixtrack and FLUKA. A study of losses at collimators in IR1 and IR5 had validated this approach and shown that the combined model gives vastly improved results model over a Sixtrack-only approach.

For the simulation of the warm section, the observed loss rate of 1.6E12 protons/s (1 MW on the primary) at 4 TeV with very relaxed collimator settings was used. For the simulation at 6.5 TeV a beam life-time of 0.2 hours and relaxed collimator settings were assumed, representing a pessimistic operation loss scenario (with 100 kW on the primary). Comparison of simulated and measured BLM signals shows very good agreement. Some differences are seen on Q5. Perhaps the losses from the collimators are underestimated. As the losses were rather constant over several seconds, the low running-sum signals were used to compute the loss rate.

The losses in the cold section of the model were simulated separately. The reason for this approach is that only one proton in 1000 protons lost on the primary collimator ends up in the DS region. In order to obtain reasonable statistics in the DS region, the particle-distribution at the section between warm and cold region was generated form the FLUKA model of the warm region, and these losses were combined with the Sixtrack results for the DS region and the TCLA collimator.

The simulations show that the highest losses are on the TCLA, but also in cells 8-9. The losses in cell 8 are reduced in the 6.5 TeV case due to the different collimator settings. For the 4 TeV case the peak losses are registered in MB.A9L7. This magnet sees about 10x larger losses than any other. FLUKA produces a peak loss desity in the of 135 mW/cm^3 on the inner radius of the coil. This is to be compared to a QP3 estimate of the minimal loss rate to quench of 210 mW/cm^3. These results are consistent with the fact that no magnet quenched during the test.

The simulation at 6.5 TeV showed a factor two between the QP3 minimal loss rate to quench and the predicted losses in the coil. However, at 7 TeV QP3 predicts the minimal loss rate to quench to be reduced by 50% w.r.t. the 6.5 TeV case. At 7 TeV we may, thus, expect beam-induced quenches under the above pessimistic assumptions.

Comparison of BLM signals and simulation results shows that the qualitative behavior is reproduced well, but the loss rate is underestimated up to cell 11 by a factor 2-3.

> *Francesco*: The discrepancy may come from showers at the end of the LSS that are not taken into account in the model. The factor 2-3 is found for a very open collimator setting, which makes it difficult to make accurate predictions for 6.5 TeV. We could simulate loss-maps to validate the model for tighter collimator settings.
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> *Belen*: It would be interesting to see if the discrepancy starts at the TCLA or it would already be present at the end of the LSS.

Bernd: are the overall losses, integrated over the magnet volume, relevant?

> *Arjan*: This would be a question for cryogenics, but the 10 s time scale of the losses does not seem to be relevant for the cryogenics system.

Mariusz: The results are very impressive. Should the simulations be considered as completed?

Eleftherios: The model could be further improved, for example around Q5.
Francesco: A further refinement might improve the prediction of BLM signals, but it wouldn't change the predictions of losses in the coils. A next step could indeed be a comparison with 4 TeV loss maps.

Next meeting, date to be confirmed

The next meeting in August will likely cover:

- Vera, more updates on MAD-X simulations for ADT quench tests.
- Anton?, FLUKA UFO simulations.
- Mateusz, Q6 quench test oscilloscope measurements.
- Bernhard, QP3 simulations for Q6 quench test.
- Mariusz?, study of BLM HV behavior during Q6 quench test.
- Discussion of:
    - Proposal of a glossary for quench-test related publications and presentations.
    - Proposal of the structure for a common quench-test paper in a reviewed journal.

Minutes by Bernhard.