SESSION 6 – MACHINE PROTECTION IN 2011 AND BEYOND

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Abstract

The programme of session 6 was designed to provide a synthesis of the experience acquired during the commissioning and operation of the LHC machine protection system during the initial run in 2010. While the focus was on reaching the initial goal for the stored energy of 30MJ, the session aimed as well at identifying possible limitations or show-stoppers to increase the beam intensities beyond the 2010/11 targets. Special attention was given to ongoing work for the understanding of fast beam loss events observed for the first time in the LHC during the 2010 run as well as improvements for injection protection to overcome the present limitation of 48 bunches.

LIST OF PRESENTATIONS

The following presentations were made in session 6:

- Experience with MPS during the 2010 run, J.Wenninger.
- Can operations put the MPS into an unsafe state? , L. Ponce.
- Preparing the Machine Protection Systems for the 2011 run, J. Uythoven.
- Is the BLM system ready to go to higher intensities?, M. Sapinski.
- What are the issues with injecting unsafe beam into the LHC?, C. Bracco.
- Is there a limitation to the stored beam energy for 2011 and beyond?, R.Schmidt.

EXPERIENCE WITH MPS DURING 2010 RUN

Understanding and assessing the performance of the LHC machine protection system (MPS) has been one of the key factors driving the LHC commissioning and operation during 2010. With beam intensities and stored energies being increased along the year by more than a factor of 10.000, many valuable lessons have been learnt which will serve to further enhance the dependability of the protection systems and to further improve the operational procedures. Not a single accidental beam induced quench with circulating beam has been observed in 2010 (still some 20 high current quenches happened during activities related to hardware commissioning), which was not at least thanks to the very good stability of the orbit and the efficiency of beam cleaning. The end of the run was however dominated by yet not fully understood fast losses (UFOs), which eventually also limited the final slope of the intensity increase (shown in Figure 1). Nonetheless all of these events were captured by the machine protection systems, confirming the very good performance in 2010.

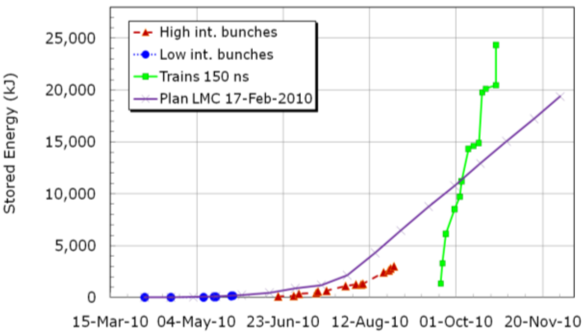

Figure 1: LHC run 2010: planned versus achieved stored energy.

No major loopholes in the machine protection system architecture were identified, still, when moving to higher intensities in 2011 beam induced magnet quenches will become more likely. Therefore the lessons learnt with the intensity increase in 2010 should be used to re-optimize the plans for 2011. More rigour has to be applied for tracking the changes related to protection systems as of 2011, including special running periods such as MDs or special physics run for TOTEM or at 1.38 TeV.

Discussion:

M.Ferro-Luzzi: Is there an estimate of how long it will take to get the MPS back in function, i.e. for the re-commissioning? **J.Wenninger**: J.Uythoven will answer this question in detail during his talk, but it is estimated to about one week. Slightly more time will be needed if the chosen energy will be above 3.5 TeV. **M.Zerlauth**: There is quite an impressive list of changes to the MPS that need to be re-commissioned.

F.Bordry: What about the UFO size, 10 um, how was this calculated? **J.Wenninger**: It was guessed from scaling losses from the wire scanner tests. It remains a rough guess, only to get the order of magnitude. In addition only a (small) part of the object actually sees the beam; it could be bigger than the observed losses suggest. The FLUKA team simulated the wire scanner quench test so far, next on the list is to try and nail down a more detailed UFO simulation.

S.Redaelli: Referring to the table where the dump statistics are presented, what is meant by false dumps? **J.Wenninger**: This includes dumps triggered by the MP system without reason. An example is when we had crate failures for the BLMs, problems with the connection between the BIC FESA and the SIS, or in one case the LBDS system having some problems with vacuum readings. Basically it was failures of the internal surveillance of MP components. **M.Zerlauth**: For example, if we lose one channel of a fail safe 1 out of 2 logic we decide to dump for safety reasons. **J.Uythoven**: We call them internal failures of the system.

R.Assmann: How do you get "half a false dump" in the dependability statistics of the MPS? **J.Wenninger**: That was an agreement between me and Bruno Puccio; we share the responsibility of one dump between the SIS and the BIC due to communication problems.

M.Ferro-Luzzi: A comment on this idea that the UFOs are charged up and then repelled: Can this be checked with the wire scanners in some way? **R.Schmidt**: Probably not, as the wire scanner is fixed on the fork. **J.Wenninger**: One idea would be to build a device that allows having small (dust) particles falling through the beam in a particular location, and thus creating similar events/loss patterns. **F.Zimmermann:** Such a device exists already at KEK.

R.Assmann: The statistics are very useful. It would be even more so if we could distinguish further in "expected/programmed dumps": some of the dumps originate for e.g. from testing thresholds by moving collimators on purpose, loss maps, end of fill studies etc. This should be treated separately from real dump-triggered losses. **M.Zerlauth**: More granularities will be added in the Post Mortem classifications for exactly this purpose, so to be able to produce more significant statistics next year.

CAN OPERATIONS PUT THE MPS INTO AN UNSAFE STATE?

In parallel with the commissioning and validation of the LHC equipment system, the operational procedure has been improved and commissioned throughout this first year of operation with beam. While the MPS system was never (demonstrably) put into an unsafe state, a number of operational mistakes and/or an incorrect operational procedure have resulted in a degraded running of the protection systems, where for e.g. a redundant level of protection was bypassed. A number of improvements (mostly related to avoid erroneous manipulations) have been identified and already are or will soon be applied for the 2011 run. The major improvements are a rationalization and further automation of the nominal sequence and procedure, automatic unmasking of SW interlocks, additional interlocks for e.g. injection protection and further improvements for the orbit control and the related collimator alignment. Emphasis should be given to the development of an online aperture-meter, which will allow highlighting potential bottlenecks and limitations. The main remaining dangers are non-interlocked elements such as the abort gap cleaning, gas injection for BGI,… as well as non-standard operation such as during MDs or special physic runs. More rigorous procedures have to be put in place to make sure to recover the initial state of MPS and settings before returning from MDs, HW interventions or technical stops to normal physics.

Discussion:

R.Schmidt: Concerning the automatic HDS interlock, it would be wise to wait a certain time before dumping the beams (to allow for actions by operations), as it is not advisable to immediately dump under all conditions (e.g. with beam in the abort gap). **M.Zerlauth**: Such timeouts are configurable in the CIRCUIT synoptic supervision application. Currently the state of all HDS is read every 15 minutes. As soon as an alarm state is detected, e-mail warnings are sent and the alarm is clearly visible on the display. The actual removal of the power permit (and the following beam dump) would only be triggered in case no action is taken in the following 3 hours (current settings).

L.Ponce: Be careful, the QPS state not ok is already one of the Laser alarms, which is not necessarily always looked at. In addition a false QPS_OK is part of the injection permit in the SIS.

R.Assmann: We always said that the Sequencer is not a Machine Protection device, but clearly we must make sure that we execute the things in the right order: currently there is no protection against executing the wrong task at the wrong moment. It is reassuring to see that the state machine will start playing an important role. Obviously operations needs flexibility for certain phases of running, therefore a 100% strict order cannot be enforced. **L.Ponce**: It has to be noted how operations improved as time passed by. Jumping back and forth in the sequence happened often before the summer and in the beginning of the run, but not so much afterwards i.e. after a careful rationalization of the nominal sequence. In autumn, the only mistakes that remained were related to changes of references for the feedbacks. Indeed no more errors from not having executed a given task were made from this point. Certainly, the state machine will help in enforcing the execution of tasks in the right order.

R.Assmann: EquipState is the most powerful tool in the CCC, and because of that it is also very dangerous. **L.Ponce**: Its use is currently still not restricted, and restricting it for example with the use of RBAC EIC role would not be very useful. What is more important is that its use is avoided as much as possible, leaving it just as the ultimate tool to recover in extreme and weird situations. What we need to move in this direction is for example a dedicated "recovery" sequence, to reset tripped PCs and allowing precycling them directly through the sequencer.

PREPARING THE MPS SYSTEMS FOR THE 2011 RUN

The LHC machine protection systems have been undergoing an impressive amount of changes during the Technical Stop, and more than 65 items with sizable impact have been identified. To maintain the desired dependability of the MPS system, it is essential to rigorously track all relevant changes during technical stops and later machine operation. A clear need for better / dedicated tools for the 2011 run has been highlighted, as a first start any changes should be documented in the

MPS commissioning Website [1]. The applied improvements of the MP systems focus on known weaknesses observed during 2010 operation and aim at further improving the safety and availability of the protection systems.

Due to the amount of changes, a full re-commissioning of almost all systems will be required, estimated to last a total of around 12 days during the cold checkout and beam commissioning phases.

Due to some remaining non conformities, the operational envelope for 2011 as seen by machine protection systems is defined as follows:

- **Energy:** 4–5 TeV due to some noisy BLM cables and 4.5 TeV due to a high-voltage breakdown of a beam dump generator MKD (to be solved during 2011)
- **Intensity:**
  - Limited to 144 bunches per injection in present configuration
  - Nominal for circulating beam, but small risk of limited TCDQ damage in case of asynchronous dumps
- Effect of small **emittances** on TCDQ needs more studies
- **Limit $\beta^* \approx 1.5$ m** due to the increased risk of exposing collimators (depending on orbit stability, beta-beat etc.)

The latter limitation clearly needs to be balanced with the risk of further increasing the energy, which most likely could lead to more severe damage in case of quenches propagating to the magnet interconnects.

Discussion:

M.Pojer: Please remember that we need one extra week for the hardware commissioning if we decide to operate at 4 TeV, with the HWC campaign already starting next week. **R.Schmidt**: That is correct; we have to account for around 6 hours of additional tests per sector, with an additional overhead attached to perform the installation and instrumentation (assuming no bad surprises are revealed).

R.Jacobsson: As I understood it, the injection gap cleaning will not be available for the start-up. **J.Uythoven**: It needs time to be commissioned; it was not operational at the end of the last run.

B.Goddard: Concerning the problem of the TCDQ, we know about the fragility for the 7 TeV 25 ns spacing beam. We hope to be in the position to replace it with a more robust solution during the 2012 shutdown, if the simulations show that this can be done in the currently already available space.

M.Ferro-Luzzi: Are the snubber capacitors needed for 4 TeV operations? **J.Uythoven**: Yes, for the main dipole circuit the snubber capacitors are considered mandatory beyond 3.5 TeV. The time required to test them will be allocated during hardware commissioning / cold checkout. **R.Schmidt**: They are needed for operations, and an additional week of time is needed to test them properly for all sectors, as M.Pojer pointed out earlier.

M.Ferro-Luzzi: What about the possibility to inject 144 bunches; what will be the impact on when we can scrub? When can we do that efficiently? **G.Arduini**: We need the 144-bunch injection for scrubbing (four times 50 ns trains). **V.Kain**: We will need some time for injection setup, before we can inject 144 bunches in one shot: it will not be available one week after start-up. The BLM sunglasses will be available much later, but they are in principle not mandatory for 144 bunch injection. **B.Goddard**: At least a couple of weeks will be needed before we can inject 144 bunches in one shot.

M.Ferro-Luzzi: The 10 days that are scheduled for machine protection, does that already include machine availability? **J.Uythoven**: That is effective time. So it is about two weeks of checks in total before you can think of increasing intensity. **M.Ferro-Luzzi**: From experience of machine availability, this would mean at least 3 weeks.

S.Myers: Is the limit on beta star a real hard limit, or how could it be further reduced. **J.Uythoven**: It comes from collimation. **R.Assmann**: The limits come from orbit stability; it was extensively presented by R.Bruce in Evian. **S.Myers**: The danger last year was related to the TCTs. If we should increase the energy to 4 TeV in 2011, we also increase the risk for an interconnect to burn through. What we also saw from Laurent is that this would still require an 8-12 months shutdown for repair. So the risk factor that comes from multiplying those two is still a fairly high number to go to 4 TeV. But if you go down from 1.5 m to 1 m, you get the 30% for the Higgs by increased luminosity that you lose in not increasing the energy. I am trying to compare those two risks and to me it seems that one risk is a much smaller risk than the other one. **R.Assmann**: We saw it in A. Bertarelli's presentation earlier: one bunch impacting on a TCT is not a catastrophic damage; we could then use the in situ spare surface. Accepting such an increased risk, we could move one sigma closer. **R.Bruce**: One sigma closer represents around 0.2 m in beta star. **S.Myers**: There seems to be a big difference in the two risks. **R.Assmann**: It is correct that the collimators are designed to protect: it is not catastrophic if they are hit. We can measure the aperture locally, and there we can probably gain more. In view of the results, we should revisit the assumptions, and we can give better estimates. **B.Goddard**: Maybe we have some margin and we could move in the TCDQ a bit, to gain a fraction of a sigma. **R.Assmann**: But we already have losses in IR6. We do not know the aperture IR by IR, so there is some assumption in there. We will follow this up with R.Bruce. **B.Goddard**: We should also evaluate the risks originating from other causes (for example RF trips) and not only asynchronous dump, as they might happen more often. **R.Assmann**: Agreed, but it is much less damage than from one bunch.

M.Deile: Do not forget the moveable devices interlock test, for Totem and ATLAS pots. They need time without beam and it is not entirely transparent as it needs playing with the SMP flags.

IS THE BLM SYSTEM READY TO GO TO HIGHER INTENSITIES?

2010 has seen an excellent performance of the Beam Loss Monitoring System (BLM), both catching and accurately measuring as well unforeseen loss events such as triggered by the UFOs. Still, the loss patterns related to a few events remain to be fully understood, so do the rather large observed variations of losses between identical fills. Fast losses (UFOs) have certainly been the surprise in 2010 and, despite the still unclear origin of the events, much more is today known about these events, i.e.:

- Events are equally distributed around the ring
- More events are observed at higher intensities
- The loss signal shortens, i.e. the losses are faster at higher intensity
- Speed is different from the free fall, i.e. electromagnetic forces seem involved (1-2 'bouncing' UFOs observed)
- Signal amplitude does not increase with intensity

Although the latter point still remains to be finally confirmed through additional statistics, it suggests that a revision of the BLM thresholds on superconducting magnets could make the UFO effects acceptable for high intensity operation. BLM thresholds are raised for losses in the ms-scale (to be more immune against UFOs), but have to be reduced for losses longer than 1 s due to the outcome of the latest quench tests. The changes will be applied before the start of beam operation in 2011, provided the new thresholds are cross-checked against the losses observed during the latest fills with high intensities. Additional quench tests to benchmark the new simulations and thresholds should be included in the 2011 program.

Discussion:

M.Zerlauth: If I understood correctly, you need to increase another factor of 5 the thresholds, in addition to what was already done during 2010. **M.Sapinski**: In fact not. We had increased a factor 5 everywhere, now we want to bring everything back and we increase only the running sums concerned by the UFOs. **R.Schmidt**: The thresholds of the different running sums should be set as a function of the failure cases. Timescales are different for different events, for example in the millisecond range for UFOs, while losses at the aperture for MP are in much longer timescales. Playing with the shape of the curve allows adjusting the system for different failure scenarios. **M.Sapinski**: Losses from UFOs could produce very similar thresholds to losses on the beam screen.

O.Bruning: If UFOs are thought to be micrometer dust particles sitting on the inside of the beam screen, should sector 34 not be different? **M.Sapinski**: The UFOs are indeed seen everywhere, and sector 34 is not special in this respect.

P.Collier: For me the UFOs at low energy is still a mystery, have we seen any at this energy? **M.Sapinski**: One UFO was seen at injection, but at this energy they generate a much smaller signal. So in fact, it is possible that BLM system is insensitive to UFOs at such lower energies. **M.Zerlauth**: It could also be that for some (unknown) reason there are much less event at low energy. **P.Collier**: which is what worries me: if we go up in energy, there could be even more. **E.B.Holzer**: I would add that the data is consistent, but the statistics are extremely low, and from scaling the signals, we cannot exclude that there is a dependence on energy. Basically, we have one UFO expected, and one observed.

L.Rossi: Which magnet did you use for the quench test? **M.Sapinski**: It was the D4, and in another test, the MQ was used. **L.Rossi**: An error of a factor 3 for the thresholds seems too generous; the FLUKA simulations are more precise than that. **M.Sapinski**: The test on the D4 is not yet fully analysed. The factor 3 applied to the MQ magnet test, and we also have to take into account that some of the assumptions were not true. The loss shape is more peaked in the magnet longitudinally. Also the analysis was done for beam 1, while the test was done in the end with beam 2 (for which there was no BPM available in front of the magnet). The factor 3 difference could be understood, the analysis is ongoing, and the magnet is not less stable. **A.Siemko**: Remember that one case was not a real quench, but the QPS electronics detected a voltage signal and fired the quench heaters. **M.Sapinski**: In the D4 test however, we actually quenched the magnets, according to QPS experts. **B.Dehning**: The accuracy comes from the SM18 quench test, done some years ago. The agreement on heat flow for steady state seems to be very good. **L.Rossi**: Also measurements in Fresca were very precise, which should be complemented by new measurements which are available now.

R.Assmann: On the longer term, it would be useful to have some kind of pattern recognition, or logic functionality in the BLMs, for example to address the problem we have with losses at injection, which would allow the use of different thresholds for different scenarios. **M.Sapinski**: We have in fact a PhD student working on that.

V. Shiltshev: Given that UFOs are so important, is it plausible to install a dust generator, that drops a particle of know material and size? **M.Sapinski**: They have one in KEK. **V.Shiltshev**: Are there any other processes that lead to an increase in the losses? For example, in Tevatron, the loss spikes are mainly caused by orbit variations on the scale of 10 microns. **M.Sapinski**: We see some fast spikes on the collimators. **R.Schmidt**: From all the analysis, the UFO losses are completely different. **R.Assmann**: For orbit variations, losses would be at the primary collimators in IR 7, not in the middle of the arc.

WHAT ARE THE ISSUES WITH INJECTING UNSAFE BEAM INTO THE LHC?

For circulating beams the MP systems provide redundancy for capturing the most frequent failure cases (for example a failure of a power converter of a normal conducting circuit is captured by the powering interlock system, a Fast Magnet Current Change Monitor and eventually the BLM system). Injecting safely into the LHC however fundamentally depends on the correctness of the state machine and the setup of the injection protection collimators, in particular the TDI (which assures a safe machine even in case of other system failures). Already in 2010 unsafe beam was injected into the LHC, but injection was limited to 38 bunches mainly due to losses at the end of the transfer lines triggering Beam Loss Monitors in the LHC ring. The introduction of abort gap and injection cleaning as well as additional shielding which has been installed in TI2 during the technical stop should allow to inject in 2011 up to 144 bunches.

Additional modifications having an impact on the MP systems are currently under discussion, such as the installation of sunglasses/blind outs on the affected BLM channels or an increase of the TCDI aperture.

An upgrade of the logic for the injection protection collimators has been agreed between the injection and collimation teams, but will require a careful re-commissioning before high intensity injections can take place in 2011.

Discussion:

E.B.Holzer: There were two open issues/questions concerning BLMs. Firstly, concerning BLMs with filters and sunglasses - the filters should be removed for all BLMs which will have sunglasses, whereas we can continue using filters on BLMs for measurement purposes only. **B.Goddard**: Doing so we would probably run out of dynamic range, and we would need additional monitors installed for measuring the losses. **E.B.Holzer:** We have extra monitors for measurements already. We can keep the functionality separate: Machine protection and measurement, which is what we do in other locations. Secondly, concerning the possibility to use nearby monitors, the answer is no. We are already at the limit. **C.Bracco**: The point is that these losses are very localized. They are distinct from losses with circulating beams where the losses also appear in other locations, for example in point 7.

S.Redaelli: I think this was already discussed in Evian, but it seems still not completely clear to me. Why is it not possible to safely profit from the bigger aperture of the LHC ring, where we have 5σ more in the arc? I think it should be possible to open the TCDIs more? **C.Bracco**: For MP tests, we set the collimators to 5σ and for some phases we are already at the limit as we could observe some leakage at the LHC, especially at the septum. **V.Kain**: 5σ should be ok. The TCDI settings are for injected beam aperture, not for circulating beam aperture. We need the margin on energy errors and injection oscillations. We are currently still not well in control of injection oscillations, as we thought them to be much less.

R.Jacobsson: If you think of sunglasses, you would think of something that temporarily puts a higher threshold, which is what for example has been put in the logic of the LHCb BCM. Is it true that you will be blinding out the BLMs completely for the time of injection? **C.Bracco**: Well, unfortunately for some of the BLMs the thresholds are already at the maximum, so there is nothing more we can do on that side. **M.Zerlauth**: The current approach to blind-out the signal at the entry of the BIS is mainly motivated by the requirement not to touch the critical internals (FPGA code) of the BLM system. **B.Goddard**: In fact, the responsible for both BIS and BLMs do not want to change the core of their systems. Additionally, concerning the tolerances, we chose them so that we can tolerate injection oscillations of about 2 mm. We could correct them back to 0.5 mm systematically, and have more opening in the TCDIs, but that would mean much less availability. **V.Kain:** We also know that the transfer lines are drifting all the time and correction is not straightforward.

R.Assmann: I think we must understand why the transfer lines are drifting, and correct this effect at the source. For the BLM sunglasses, if the blinding time has to be in the order of 1 second it would be definitely too long! We can only afford blinding for a few turns. Additionally, you mentioned the risk to damage the tertiary collimators with an asynchronous dump, which I believe not to be a big issue as they are in the shadow of the arc. **C.Bracco**: In our assumption the TCTs are moved to 4σ by mistake and that we 288 bunches are injected. **R.Assmann**: Then we have to make sure that the TCTs cannot be sitting at 4σ at injection. **B.Goddard**: We had the case that the TCDQ was in, so unfortunately such failure cases are possible. **R.Assmann**: In the IRs we are in the shadow of the arc as long as we are not squeezed. I do not see a reason why we need to have really tight thresholds for the TCTs at 450 GeV. For a subset of these devices we can increase the thresholds as they are in the shadow of the arcs, and so they are not limiting anymore. We can put this on the list of possible measures.

R.Schmidt: Maybe we could use the less sensitive ionization chambers, and put them in the interlock chain for when the BLMs saturate. Another question is whether the beam can be better prepared at the SPS, to reduce the losses? **C.Bracco**: We know that scraping helps. **B.Goddard**: Last year the SPS shift crews worked hard and prepared the beams very well, still this was not sufficient. We will verify whether we can move out the collimators at the very end of the transfer lines by a few mm. We might have to add an extra Fast Magnet Current Change Monitor (FMCM) on some circuits, but it could be a way around the need for scraping. But this cannot be envisaged for this year.

IS THERE A LIMITATION TO THE STORED BEAM ENERGY FOR 2011 AND BEYOND?

No serious limit for beam energy or intensity could be identified. Still a number of failure scenarios where damage (beyond repair) is still possible should be studied more quantitatively. Such serious failures may especially

occur in the backbone of the MPS such as the beam interlock system or the beam dumping system, i.e. when despite a beam dump request the beams are not (or not fully) removed from the machine.
It was proposed to perform in the light of the 2009-2010 experience quantitative studies of such catastrophic failures using appropriate simulation tools.
These studies would then allow identifying and implementing additional mitigations such as redundant triggering interfaces between the BIC/LBDS, emergency procedures for the CCC, TCDQ consolidation programs and the development of new interlocks such as a Fast Beam Current Change Monitor.

Discussion:

S.Myers: The risk levels associated to the different scenarios are in inverted order with respect to this morning's presentation.
S.Myers: Concerning the asynchronous beam dump, what happens if the kick is too big? **B.Goddard**: In this case the beam would hit the Q4 and the septum.
B.Goddard: For the BLMs in point 6, they are in use and connected, but the thresholds are currently set to the maximum. **R.Schmidt**: We should indeed set the thresholds to a meaningful value. **B.Dehning**: This can be done but we would need beam time for additional tests then.
B.Goddard: Concerning the TCDQ we have to decide soon in case we want to include it in the consolidation. There is no way however that it can be made ready for the end of this year. **R.Schmidt**: Alternatively, we could also consider some additional passive absorbers.
O.Bruning: If at Tevatron and RHIC they had UFOs, would they be able to see them with their BLM system? Could they detect them? **W.Fischer**: RHIC can tolerate much more beam losses than LHC. It would probably be difficult to detect them with the current settings of the BLM system. **B.Dehning**: I can confirm that their monitors are much less sensitive. **M.Zerlauth**: The term UFO is borrowed from the fusion community who also observe UFO-like events, leading to sudden unexplained disruptions of the plasma.
B.Goddard: You mentioned very fast losses and their phase coverage. I seem to remember that the collimator hierarchy was suspect in one case, when there was a very fast loss. **R.Assmann**: The phase coverage was checked with a student of J.Wenninger, and found to be correct. We observed in this case off-momentum losses. The losses were not at the primary collimator, but at a secondary collimator: this is acceptable in the short term, but not in the long run. There was another case at injection, with very fast vertical blow up of a few turns, which you cannot intercept at the collimators. This effect was extremely fast, while you need a reasonably slow process to be able to intercept it. It was not a case of multiturn losses.
B.Dehning: We should keep in mind redundancy and criticality. We have a concentration of channels, and common errors could play a big role. The same code is used everywhere. **R.Schmidt**: That is why in the slides I used the word "unlikely". But I believe a different, independent system would be of interest, like a very fast beam current change monitor, or direct BLMs. Even if they are needed only once every 20 years, we would be very happy to have them activated if the event happens.
T.Petterson: May I recall why we have PLCs for the LHC safety system, and a cable loop. We want the technology to be redundant and different.

CONCLUSIONS AND ACKNOWELGEMENTS

Machine Protection and Safety has become a daily concern not only of MPS experts, but also operations and equipment experts. A lot of work has gone into additional improvements of the machine protection systems in order to make the machine safer and more available during the 2011 run. The good performance in 2010 will however not guarantee a 2011 run free of surprises, whereas special caution should be applied when starting to interleave (high intensity) physic runs with MDs and technical stops.
The session conveyers would like to thank all speakers and the MPS/OP teams for their dedication and hard work during the very successful 2010 run and for all their input and help in preparing this session.

REFERENCES

[1] 'MPS Commissioning Website'
https://espace.cern.ch/LHC-Machine-Protection/default.aspx