83d Meeting of the Machine Protection Panel

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1 Presentations

The slides of all presentations can be found on the website of the LHC and SPS Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

1.1 Update on failure cases for asynchronous dump – worst case vs realistic phase advance, changes due to ATS optics – (L. Lari).

- The goal of the study is to understand the beam loads in different collimators in case of asynchronous beam dump, in order to improve the LHC collimation system design by understanding realistic loss cases.
- Asynchronous dumps result in fast losses, which could lead to severe damage on LHC equipment in case protection elements are not correctly positioned. The case discussed here is the so-called synchronous-asynchronous beam dump, i.e. all the 15 MKDs are firing at the same time.
    - Jan states that the asynchronous- asynchronous beam dump, where one of the 15 MKIs comes first and the other 14 or retriggered a bit later (~84ns) can be considered the worst case of asynchronous beam dumps.
- The tool used for these simulations is a modified version of SixTrack. A measured MKD pulse form was applied to all 15 MKDs.
- In 2012 (June and November) experiments with different collimation settings have been performed and the measurements were reproduced by simulations.
- Luisella gives an overview of the optics parameters for Beam1 and Beam2. Three cases were studied: 7 TeV nominal optics (physics run with 0.55m β*

in IP1/IP5), Achromatic Telescopic Squeeze at 7 TeV (physics run with 0.15m β* in IP1/IP5), ATS improved (HL-LHC case).

- Luisella shows a table with the phase advances at the hor. TCTs for the 3 studied cases. For the HL-LHC case the bottle neck is at P5 for both beams.
- Luisella shows a table of the nominal collimator settings and the ones with 2σ-retraction as used in the simulations.
- Different scenarios were simulated (the following scenario includes all previous changes):
    - 1) Perfect machine.
    - 2) Retraction of IP6 collimators by 1.2mm (corresponding to max tolerance).
    - 3) Retraction of the 3 critical collimators in IR7 by 1mm and moving TCTs in IP1 and IP5 further in by 1sigma.
    - 4) Adding optics errors: worst case out of 1000 optics configurations with random errors
        - Roderick comments that random errors on the magnets reproduce beta-beat of 10%. If the worst case phase advance is picked and the normal beta-function is considered, the result is an amplification of the losses.
    - 5) TCDQ angular misalignment by 100urad.
        - Bernd comments that nominal collimators have offset.
- Results (Beam1):
    - Note, onset of plastic deformation in (tungsten) TCTs is expected to happen at 5e9p impacting on a jaw (derived from recent HiRadMat experiments). The expected limit for ejection of fragments is 2e10p.
        - Roderick comments that in the latter case the vacuum pipe will need to be cleaned in addition to the required exchange of the collimator.
        - Anton asks how these two cases will be distinguishable in case of such an accident?
        - Jan comments that there is a third axis installed at the TCT collimators, which allows a transverse movement

which could be used if e.g. the surface is only slightly damaged.

- Chiara explains that for the TCDQ it is planned to check the absorption coefficient after a beam impact with a defined scenario, which has been benchmarked before to detect degradation.
- Markus and Daniel comment that a significant scratch or plastic deformation maybe already visible during a realignment of the TCTs (different position found).

  - Perfect machine: No problems found.
    - Roderick comments that in this case all bunches impact at the same spot on the collimator jaw.
  - Case 2 (Retraction of IP6 collimators by 1.2mm): No damage to TCTs expected but in IP7 the critical secondary collimators, which take a significant part of the impact, are clearly visible.
  - Case 3: The limit of plastic deformation for tungsten is reached in the TCTHs at IP5.
- Results (Beam2):
  - Case 1(Perfect machine for B2): No problems found.
  - Case 2 and 3: the limit of plastic deformation for tungsten is reached in TCTHs at IP5.
- Case 4 (with optical errors): The limit of plastic deformation is reached in TCTH at IP5 (Beam 2, HL-LHC) and IP1 (Beam 1, post LS1, 7TeV).
    - Roderick comments that for HL-LHC it's enough to have one failure (e.g. IP6 dump protection misalignment, optics errors ...) to cause damage to the TCTH.4R5. For post LS1 operation several of the studied failures need to appear at the same time.
    - Markus states that for 7 TeV and for HL-LHC the collimator position thresholds could be reduced and therefore the assumptions are not fully realistic. In reality we should be better protected. Chiara agrees that the IP6 orbit interlock of 1.2 mm was for 4TeV (2 sigma) and will definitely be smaller for 7 TeV.

    - Roderik states that this is clearly true for the collimators in IP6 and IP7. As the orbit stability also plays an important role the real danger is difficult to predict. Collimators with in-jaw BPMs will certainly help for interlocking on the required orbit stability in the collimators.

- Case 5 (TCDQs angular misalignment): In case of HL-LHC, the limit of plastic deformation is reached also for this case (note the TCSG is not misaligned). The losses on the TCTH in IP5 are dominated by the secondary protons from the TCSG in IR6.
- Possible mitigation / actions:
    - New collimation materials with higher damage limits.
    - Benchmark simulations for B2 (IP5) with experiments in the LHC.
    - BPM buttons in collimators would allow for tighter interlocking of the orbit in the collimators.
    - Tighter collimation position limits/interlocks.
    - Improve the phase advance between TCDQ/MKDs and TCTH in IP5 for HL-LHC.
        - Roderick comments that in 2012 orbit movements of up to 500um have been observed.
        - Anton asks how one would use the BPM buttons: Roderik replies that for the moment it is only planned to align once and then monitor the orbit in the collimators. Daniel states that in principle one could re-align the TCTs at every fill. Roderik points out that the problem is that the settings would in this case not have been qualified by loss maps. Jan proposes to define a position window where-in the button alignment could be done without a full loss-map qualification.
        - Anton asks if the new material is able to improve the situation. Luisella replies yes. Roderick comments that for extreme cases carbon collimator could be used: trade between absorption and length.

- Jan comments that the simulations assume the impact of all bunches at the same spot. In reality the beam is moving.

Discussion:

- Roderick comments if we put 180 degree phase advance between MKDs and the triplets, this results in 90 degrees to the experiments. Jörg responds that during physics there is a lot of aperture margin in experiments due to the squeezed beams.
- Bernd asks what the probability is for the synchronous asynchronous beam dump (all 15MKDs) and the asynchronous asynchronous dump. Jan points out that the latter is the most probable and the worst of the two cases.
- Chiara states that the assumed 100urad misalignment is the expected case.

1.2 BLM signals induced by beam-dust particle interactions in the LHC arcs (A. Lecher)

- Final analysis of beam-dust interaction in cell 19R3: In 2011 there were many UFOs observed in B1. Therefore mobile BLMs were added in this cell. 4 BLMs were added around the MBs. These BLMs were the only means to identify the distribution of BLMs inside the MBs.
- The measurements indicate that the beam-dust interactions are distributed over the different MBs. Comparisons with simulations have been performed by simulating the beam-dust interaction in the first, second and third MB. The relative comparison (normalized to highest value) agrees well with the measurements.
- The events seemed to be evenly distributed over the three MBs (MB1/MB2/MB3: 3/3/4). None of the simulated interactions (1-3e6p) would have caused a quench at 7TeV.
- Maximum energy density per proton-dust particle interaction: ~8e-8 mJ/cm^3 at 4 TeV and ~3e-7 mJ/cm^3 at 7 TeV.

  - In MBs there's a distinct peak due to neutral particles hitting the vacuum chamber.
  - Depending on UFO location peak could occur in the next MB.
  - The maximum peak energy density is comparable for B1 and B2.
  - The position of the beam pipe (inner, outer) doesn't play a significant role for the expected energy deposition.
- Dose around MB-MB interconnects (expected dose at the new position of the BLMs, the same scenario as before). The dose values in the vertical plane are a factor 2-3 lower than in the horizontal plane. The advantage of the vertical position is that one can cover both beams with the same BLM. This is compensating for the lower signal.
- Gain due to new BLM position: Anton shows a comparison of the expected signal in the new BLM installation compared to the old position on the MQs. The gain varies between a factor 8 and 30. As the UFOs from both beams can be observed with the installation the gain improves to factor 30 compared to the previous installation.

Discussion:

- Bernd ask if the losses were really only observed in the MBs and not in the MQ? Anton responds that this is true, but there is no reason to have them only in MBs and not in MQs. The statistics is very low.
- Markus comments that the Vacuum group has investigated the vacuum chamber in all regions which were opened (e.g. for exchanges of magnets,..) and tried to correlate UFO hot spots with the density of dirt/dust found in the vacuum chamber. No clear correlation was found.
- Mariusz comments that geometrically a peak from neutral particles should also be observable in the MQ. **Action**: Anton will look into this again.
- Roderik asks if moving some BLMs from the MQ will not blind us for some types of losses. Laurette comments that these 3 BLMs were original placed to cover losses on the interconnect, middle of the MQ and at the end of the MQ. Markus comments that it has been shown in simulation that there is still enough redundancy to measure losses.

1.3 Proposal for LHC BLM disabling rules after LS1 – (E.B. Holzer).

- Barbara reminds us on the disabling rules during Run 1: A maximum of one IC per beam and quadrupole magnet was allowed to be disabled. If one arc IC is disabled in the half cell n, the corresponding monitor of the same family in the half cells n-2, n+2 and n+4 (counted in beam direction) shall remain operational.
    - In the LHC dispersion suppressor no monitors shall be disabled.
    - In the LHC LSS all monitors shall remain operational on the triplet magnets (Q1, Q2 and Q3).
    - All monitors at collimators and absorbers, and all monitors in IR3 and IR7 shall remain operational.
    - At least 2 monitors per beam shall remain operational on each LSS quadrupole.
    - Disabling of any other LSS monitor or another special monitor will have to be decided by the MPP representative and the BLM representative on a case-by-case basis.
- Proposal for After LS1: In addition to the existing rule, one dipole-dipole interconnect IC per half-cell can be disabled, but only if no neighboring quadrupole monitors are disabled. At least one monitor per beam shall remain operational on each quadrupole.
- Barbara shows the text changes to the LHC-OP-MPS-0012.

Discussion:

- Jan asks how many BLMs have been disabled without/with discussion in run1. Barbara replies that only 1 BLM has ever been disabled in run 1 with discussions.
- Markus states that he discussed also with Joerg and he has no objection to the proposed changes of the disabling rules.
- Jan states that in the light that we only disabled one BLM during full run1 it would probably be good to always discuss and distribute the information of changes before deactivating a BLM.

1.4 Miscellaneous

- Next meeting is planned for the 13th of December.