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MPP Procedure

Procedure in case of issues with sparking RF fingers

ABSTRACT:

This document describes the procedure to follow in case of an issue developing in the RF fingers of the vacuum modules in the LHC.

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1. INTRODUCTION

End of May 2023 beam losses have been observed at the triplet left of IP1, leading to beam aborts during the ramp. These beam losses have been traced back to a rise of the vacuum pressure in the warm vacuum modules in cell four left of IP1, upstream of the triplet. The vacuum spikes were caused by sparking of RF fingers in one of the vacuum modules due to a damage of the spring. The damage of the spring is believed to be caused by beam induced heating. The module was repaired, and operation continued with bunch intensities limited to 1.6e11 ppb.

Investigations during the 2023 LHC run and the EYETS 2023/24 showed degradations in the springs and RF fingers in further eight warm vacuum modules of the same type (VMBG). 37 of these modules have been consolidated during the EYETS 2023/24 by DRF and anchored modules, however, 24 VMBG remain in the LHC during 2024 and can only be consolidated in the EYETS 2024/25.

Furthermore, the investigations showed that three out of 24 warm vacuum modules with elliptical shape (VMCK) in the recombination areas of IP1 and 5 had developed defects in the springs. The springs of the concerned modules have been replaced. These modules will remain unchanged in the LHC during Run3 and will only be consolidated during LS3.

There remains a significant number of warm vacuum modules in the LHC in 2024 and 2025, which are potentially vulnerable to beam induced heating with increased bunch intensities and short bunch lengths. In addition, similar modules exist in the cold parts of the LHC. Therefore, these parameters must be carefully monitored in 2024 and beyond.

Furthermore, this motivates the preparation of a procedure of steps to be followed in case a failure of a spring and of RF fingers develops in a vacuum module. This procedure also covers under which conditions operation can be continued.

2. Procedure

Following detection of a supposed issue in a vacuum module with suspected sparking of RF fingers (vacuum spikes, unexpected beam losses, etc.), the following steps should be performed.

Note: Due to its criticality, this procedure has a special focus on the case of an issue close to the triplets. Namely the energy deposition limits from the beam-gas interactions in the coils of the sc. magnets mentioned below are concerning the triplet magnets and might be significantly different for other sc. magnets.

1. Following diagnostics of vacuum pressure rise or unexplained beam losses, stop operation with high intensity beams.
2. Perform X-rays of the RF fingers of the suspected vacuum modules and identify the damage module. Verify bunch length over the previous fills and make

corrections to the RF system and bunch length interlocking if a bunch shortening has been observed.

3. Perform FLUKA studies to estimate the expected energy deposition in the downstream sc. magnets to identify possible safe beam intensity levels for operation, without risk of quenching.
4. Continue operation with beam intensities, which do not show any relevant increase in vacuum and beam losses. Based on previous experience these should directly be visible during the injection of trains. This period should cover the time for FLUKA studies and/or the preparation of the replacement of a module.
5. Perform tests at injection with increasing number of trains to characterise the onset of sparking. Stay below the maximum bunch intensity and above the minimum bunch length used before the incident.
6. Based on the outcome of the FLUKA simulations and in agreement with BLMTWG, MP3 and MPP, increment the thresholds of the concerned BLMs where necessary. Ensure that the thresholds are chosen to avoid quenches of downstream sc. magnets due to the beam gas interactions. Furthermore, ensure that the adjusted BLM thresholds provide sufficient protection against other critical failure cases or that these are covered by other (nearby) BLMs.
    a. In case of triplet magnets, the energy deposition due to beam-gas interactions should be limited to 2 mW/cm^3 in the triplet coils in a first step (providing about a factor 5 margin to the expected quench level).
7. If required and considered safe increment vacuum interlock thresholds in the concerned region (< 2e-5 mbar).

Check point: Based on the above observations, tests and simulations, can the LHC operate with the observed vacuum levels and without quenching with > 2000 bunches? If no, the replacement of the defect module has to be triggered. If yes, go to the next steps.

8. Perform a validation fill with 400 bunches and the nominal maximum train length to stable beams (> 2h). Check beam losses and vacuum levels and compare to the expectations from the simulations. Compare the observed BLM signals with the expectations from the FLUKA simulations and extrapolate to the pre-issue intensity, respectively the full machine. Increment the thresholds of the concerned BLMs based on the observed losses and the evolutions of the vacuum pressure.
    a. In case of triplet magnets and if required for reliable operation, the BLM thresholds can be adapted to allow an energy deposition in the sc. magnet coils from the beam-gas interaction of 3.5 – 5 mW/cm^3 with full intensity.
    b. In the case the issue appears close to an experiment, get feedback on the observed background levels in the experiment.

9. Step to half the pre-issue intensity and go to stable beams (> 2h). Check beam losses and vacuum levels and compare to expectations from simulations. Compare the observed BLM responses with the expectations from the FLUKA simulations and extrapolate to the pre-issue intensity. If required, adapt the BLM thresholds based on the observed losses and the evolutions of the vacuum pressure.

    a. In case of triplet magnets and if required for reliable operation the BLM thresholds can be adapted to allow an energy deposition from the beam-gas interaction of 3.5 – 5 mW/cm3 with full intensity.

    b. In the case the issue appears close to an experiment, get feedback on the observed background levels in the experiment.

10. Perform X-rays of the RF fingers of the damaged module and verify that the geometry has not changed significantly as compared to first X-ray.

11. Step to the pre-issue intensity and go for standard operation.

12. Observe the evolution of the vacuum activity and the losses from beam-gas interactions. If the situation degrades, perform X-rays of the RF fingers of the damaged module and verify that the geometry has not changed significantly in comparison to the first X-ray.

REFERENCES

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