233rd Meeting of the Machine Protection Panel - Join meeting with the Collimation Working group

LHC topics

March 10th, 2023, via Zoom

Participants:
F. Alessio (EP-LBC, R. Bruce (BE-ABP), V. Coco (EP-LBC), M. D'Andrea (BE-ABP), R. de Maria (BE-ABP), Y. Dutheil (SY-ABT), P. Dyrcz (HSE-RP), R. Ferreira (TE-VSC), P. Hermes (BE-ABP), C. Hernalsteens (TE-MPE), H. Hillemanns(EP-AID), A. Lechner (SY-STI), B. Lindstrom (BE-ABP), A. Marcone (SY-STI), F. Moortgat (EP-CMG), N. Mounet (BE-ABP), M. Morrone (TE-VSC), G. Pigny (TE-VSC), J. Uythoven (TE-MPE), A. Radeva Poncet (BE-CSS), S. Redaelli (BE-ABP), B. Salvachua (SY-BI), B. Salvant (BE-ABP), R. Secondo (TE-MPE), J. Sestak (TE-VSC), G. Smirnov (SY-STI), E. Thomas (EP-LBO), F. Van Der Veken (BE-ABP), C. Wiesner (TE-MPE), D. Wollmann (TE-MPE).

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (233rd meeting).

Minutes and actions from the 232nd meeting (LHC topics)

The minutes of the 232nd MPP meeting have been distributed. Daniel recalled the open actions. It is agreed that the BCCM will be validated during the startup but that the BIS inputs will be activated only after TS1. No comment was received, and the minutes are approved.

LHCb VeLo vacuum recovery and vacuum safety system for 2023 (R. Ferreira)

Rodrigo summarized the sequence of events that lead to the issue and to the recovery process, as presented at the LMC.

The vacuum system was designed and built by Nikhef. The responsibility for the system was taken over by TE-VSC in 2011. The electrical design was left unchanged while a new control system software (PLC/SCADA) was developed using the TE-VSC Vacuum framework and deployed during LS2. The PLCs were replaced with newer versions. Upgrades and improvements were also performed during LS2 regarding the pump controllers and the addition of redundancy to the main power supplies .

The balancing mode is one of the main roles of the safety system to safeguard the integrity of the RF foil/box. The differential pressure between the detector volume and the beam volume must always remain with +2/-5 mbar. When the detector is vented the balancing mode becomes active. If the beam volume is in overpressure the pumping starts; if in underpressure, ultra-pure neon is injected in the beam volume.

In case the balancing fails or cannot cope with the differential pressure, an independent overpressure safety system protects the RF foil. The electrically hardwired safety system does not rely on the PLCs. In case the differential pressure reaches 10 mbar, a valve (SV421) is opened, putting the volumes in contact and equalising the pressures. This protects the foil but pollution of the beam vacuum due to outgassing from the detector volumes can take place.

Daniel asked how fast these mechanisms are. Rodrigo replied that this is not limited by the control software but by the mechanical parts.

Jan asked if the redundant power supplies are monitored. Rodrigo confirmed.

The differential pressure between the volumes is monitored with pressure switches. The balancing switches are read by the PLC using optocouplers. The safety switches are read by the PLC and by the safety system using mechanical relays. The pressure switches are electrically isolated from the rest of the system and are read using a dedicated power supply. The power supply failure is detected using the same type of mechanical relay as for the safety system. If a power supply failure is detected, the readings from the switches cannot be trusted and the system will prevent the actuation of any equipment; the balancing will stop.

The detailed sequence of events and its recovery is summarized in EDMS-2820759. Due to a fault of the relay, which is required to read the pressure switches, the power supply is partially shortened causing wrong readings of the pressure switches by the PLC leading finally to a differential pressure between the two volumes between 200 and 220 mbar.

The design of a new (temporary) safety system started on January 15th. It is based on the existing design with more reliable components and improved failure detection and was installed on February 1st. Redundant power supplies were added and a reliable way to detect power supply failures was introduced. The safety system logic was re-implemented using SIL3-rated safety relays and replacing existing time-relays with a modern version.

The new safety system is a temporary solution. Before the replacement of the RF foil, a new system that adheres closely to functional safety principles will be designed and installed. An important limitation of the original design is that it does not allow a complete test of the safety system chain. Addressing this limitation to allow regular testing of the safety system would be considerable improvement to the reliability. This will be evaluated for the final redesign.

Daniel asked about the consequences in case the foil breaks. Josef replied that gases from the detector volume will contaminate the beam volume, leading to a saturation of the NEG. The details will depend on how the foil would break. Victor commented that it would also be a catastrophic event for the LHCb detector.

Daniel commented that the team should come back to the MPP when advancing with the design of the new safety system. The support of the RAWG is also proposed.

Action: Report to the MPP on the design of the new safety system (TE-VSC).

Status and plans for the LHCb VeLo motion system re-validation (V. Coco)

The monitoring of the motion system behaviour was turned off during the event, in preparation for the AUG tests. The pressure difference pulled on the two halves and movement is seen on the potentiometer. No significant movement is seen on the motor resolvers. The position relaxed during the pressure rebalancing. It is expected that the beam-based reconstruction ("tomography") will provide a clear answer on the deformation of the foil and displacement of the motion system.

Daniel asked if the displacement can be corrected. Victor replied that first the root cause would need to be understood in more details.

Victor described the tests and the investigation process. The main hypothesis is the deformation of the mechanical coupling pieces. A re-qualification procedure will be defined. The inspection of the coupling pieces needs to be performed with the VeLo half closed. This will only be possible after the tomography, with one foil open and one closed. There is a residual displacement of the top support by 1.25 mm on the C side and 0.9 mm on the A side; so a risk of collision cannot be excluded, which could cause damage to the detector and therefore the tomography must take place first.

If the motion system can be re-qualified, it is expected that the VeLo could be closed to 10 mm (exact number depends on the measured foil deformation), opening the possibility for a 2023 physics program.

If the motion system is not fully re-qualified the VeLo will remain open for 2023.

Christoph asked what beam conditions are required for the tomography. Victor replied that proton collisions using the SMOG would be ideal. It should potentially be feasible also at injection energy. The interaction rate is not affected much by the opening and single bunch collisions would be enough. A detailed request will be formulated at a later stage.

Daniel asked if there is a risk that the half-closure for the visual inspection would imply that the motion system would be stuck in half-closed position. Victor replied that a procedure will be defined to ensure that in any case the VeLo could be opened manually.

Josef proposed to proceed in small steps and extending the motion range while monitoring the reaction of the system.

Simulations of the LHCb VeLo RF foil deformation (M. Morrone)

The RF foil is a vacuum aluminum box which separates the detector vacuum from the LHC beam vacuum.

A highly nonlinear model has been developed in COMSOL Multiphysics. Computation steps are performed at each 10 mbar differential pressure steps, as summarized in EDMS-2820818.

The benchmarking of the FEM model was performed on a prototype provided by Nikhef, which has half the size of the actual velo box.

The residual deformation from simulations following the 200 mbar overpressure shown experimentally, is in good agreement with the tests performed on the prototype. The deviation is within 1 mm.

The validated simulation model was then used to estimate the deformation of the full VeLo box.

Benoit asked what the impact of the buckling is on the coating on either side of the aluminium. Josef replied that a peel off phenomena is unlikely. Marco asked if that is still the case with plastic deformations. Josef confirmed that then only cracking is expected.

Benoit commented that the buckling could lead to impedance issues.

Status of LHCb VeLo aperture at injection and top energy (B. Lindstrom)

The bulging observed in 2022 already reduced the closed aperture at top energy from 3.5 mm to 2.9 mm.

The deformation of the foil following the incident reduced the aperture in the open position of the velo from 49 mm to 38.5 mm.

The general aperture limit for unprotected elements in the LHC is 16.4 sigma. The available velo aperture is far beyond this limit, so no issue is expected for aperture at injection.

At top energy, the fully open VeLo with the simulated deformation still provides more than 300 sigmas of aperture. Enough aperture is available even with VdM scans up to 4.5 sigma.

Daniel asked how one will proceed to validate the aperture margin. Bjorn replied that local aperture measurements with the bump method are proposed. Victor commented that one would need to assess the sensitivity of the BCM to losses.

Victor asked what aperture bottleneck is present at injection. Pascal replied that IR6 is the bottleneck at injection, so a local aperture measurement is required.

Daniel commented that the losses from the VeLo should be seen by the triplet BLMs and asked if there is any space where a BLM could be installed closer to the VeLo. Stefano commented that the loss rate issue would remain. Victor confirmed that the losses are not an issue for the VeLo itself. Federico commented that the losses would be lower than in case of losing the beam on the TDIS. It could be that the BCM will dump on losses during the measurement. At injection the BCM has “sunglasses”.
Victor asked if one can rely only on the tomography. Eric Thomas also commented that the tomography should provide more information than a local aperture measurement. Daniel commented that it is too early to exclude any option.

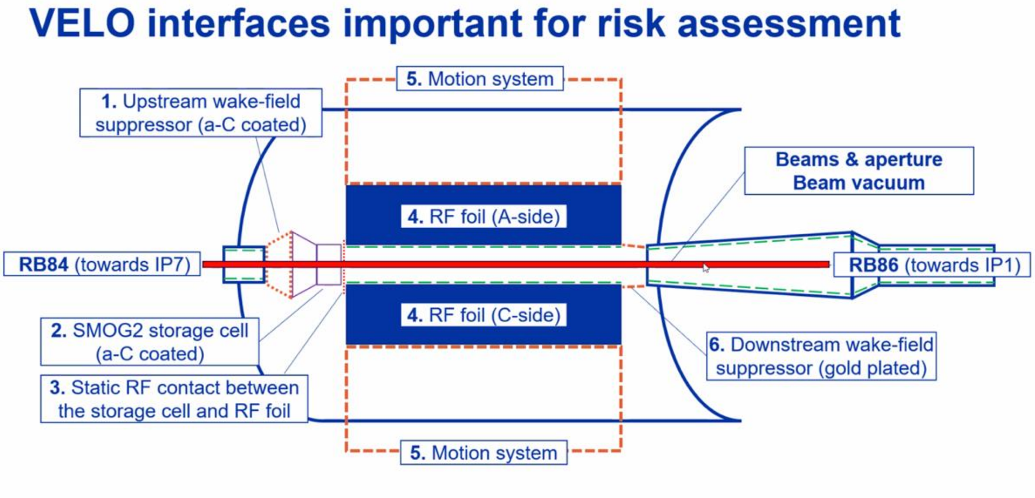
Action: Determine limits on the loss rate that can be tolerated for local aperture measurement (LHCb VeLo team)

Benoit asked if the tomography will also provide information for the other parts (wakefield suppressor and edges). Victor confirmed.

Status and update of LHCb VeLo impedance (J. Sestak)

The impacts concern the possible deformation of the RF contacts upstream and downstream of the RF foil (see figure):

- (1) The upstream wake-field suppressor is not expected to have been affected by the incident.
- (3) The foil contact part has no loose part and is not expected to have been affected.
- (6) The downstream wake-field suppressor offers the possibility to be visually inspected through the downstream viewport. It appears that it has not been affected.



The deformed RF foil shape (as simulated) does not present an issue for the machine impedance. The probability to have a loss of a significant amount of RF contacts due to the incident is low.

Discussion on aperture measurements and LHCb VeLo intensity ramp-up

The aperture measurements are summarized above.

Regarding the ramp-up and mechanical testing that might take place during the TS, the teams will be invited back for a joint MPP / Collimation Working Group meeting.

The Machine Protection Panel endorses the injection of beams with the VeLo open in its current state.

Summary of actions

The actions from the meeting are:

- Status of LHCb VeLo aperture at injection and top energy
    1. Report to the MPP on the design of the new safety system (TE-VSC)
    2. Determine limits on the loss rate that can be tolerated for local aperture measurement (LHCb VeLo team)