198th Meeting of the Machine Protection Panel

LHC topics

November 20th, 2020 via Zoom

Participants:

Federico Alessio (EP-LBC), Oscar Augusto (EP-ULB), Claudia Bertella (EP-LBC), Roderik Bruce (BE-ABP), Wiktor Byczynski (EP-LBD), Victor Coco (EP-LBD), Paula Collins (EP-LBD), Cedric Hernalsteens (TE-MPE), Jannik Lassen (TE-MPE), Edgar Lemos Cid (EP-ULB), Dragoslav Lazic (EP-UCM), Marko Milovanovic (EP-LBD), Filip Moortgat (EP-CMG), Xavier Pons (EP-DT), Belen Salvachua (BE-BI), Benoit Salvant (BE-ABP), Freek Sanders (EP-LBD), Brad Schofield (BE-ICS), Andrzej Siemko (TE-MPE), Jan Uythoven (TE-MPE), Jorg Wenninger (BE-OP), Christoph Wiesner (TE-MPE), Daniel Wollmann (TE-MPE).

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (198th meeting).

Minutes from the 196th MPP meeting (LHC topics)

- The minutes of the 196th MPP meeting were not available at the time of the meeting.

LHCb velo motion system

Motion control and interlocking (Xavier Pons)

Xavier first detailed the Velo position control system at LHCb. The two halves of the detector are moved horizontally in a range from -5mm to up to 30mm. The two parts can be moved independently. In addition, the whole assembly can be moved vertically by 4.7mm in both directions. Three independent motion axes with radiation hard stepper motors are used.

For the horizontal motion, one stepper motor is used per side, providing a displacement of 50 microns per revolution at a speed of 0.125 mm per second. Three potentiometers (per side) provide feedback on the linear displacement. Three microswitches indicate the absolute "out" position of both halves with one used as a reference at 29.8 mm and the other two as end switches at 30.0 mm from the central axis. The "in" position is obtained by switches providing the relative position of the two sides. They act as anti-collision switches.

For the vertical motion, a stepper motor provides a displacement of 250 microns per revolution at a velocity of 0.25 mm per second. Four potentiometers indicate the "up" position, with one acting as a reference at 4.8 mm and the others being end switches at 5.0 mm.

The control system saw a major change from the previous PLC-based system. The new control system is based on National Instruments PXI-FPGA. One PXIe-1082 chassis is fitted with a PXIe-8840 real time controller, two PXIe-7861 FPGA IO boards and one PXIe-7861 FPGA per plane. The real time controller performs the communication with the VELO DCS. A set of electronic interface circuit boards have been implemented to translate the physical signals (motor control signals, switches, resolvers and potentiometers).

The VELO motion interlock signals are exchanged with the VSS (Velo Safety System). The VSS is producing the beam permit signal for the CIBU. In the previous control system, the CIBU was directly connected to the PLC of the motion control system. The VSS handles the VELO interlocks (*e.g.* RF foil temperatures) and the motion control system interlocks. The VSS interlocks logic can be found in EDMS 2051570.

Failure cases have been evaluated for the components of the motion control hardware. In case of failure of a microswitch, an intervention for repair is first requested, in a second stage, the switch can be overridden by software. For the potentiometers, given the redundancy, they can be disabled by software as a first measure. For the motor power drives, the electronics interface or the FPGA, a single set of spares can be used to replace the failing component. As a second measure, the VELO should be moved to the OUT position to allow the beam permit.

The VELO motion control system has been successfully installed and tested. The commissioning took place with a local control software from the PXI. The hardware and software interlocks between the motion control system and the VSS are pending implementation.

Questions and comments

Jan commented on the CIBU interface requirements and asked if it has been tested. Xavier replied that the teams are in close contact with Christophe Martin. Jan added that the connection of the previous system was conform.

Daniel asked about the interlock logic and about the precise meaning of the "open position" condition. Xavier replied that the "out" switches are meant to be used. However, Xavier added that the fully "out" position might not be ideal from an impedance point of view. The optimal open position of the VELO is yet to be determined.

Daniel asked if the same signals are used for the motion control and for the interlocking. Xavier replied that the resolver is evaluated and compared with the stepper motor command and the LVDT. Daniel added that the interlocking should be fully independent from the motion control. Xavier commented that the interlocks are triggered by the LVDT position.

Andrzej asked if a document is available for the failure mode analysis. Xavier replied that there is none for the moment.

Action: Prepare a specifications document for the motion control, failures and interlocks (X. Pons).

Roderik asked if the VELO will be aligned with respect to the beam at every fill, how this will be done and how it is linked to the interlock. Victor replied that the VELO starts while fully open, performs the track reconstructions and determines the interaction point. It is then closed in steps until fully closed and centered around the beam. If the interaction point changes slightly, this is thus corrected for. There is no interlock on the position (except for the two end positions). Roderik followed up on the possibility that the two halves would not be at the same distance from the beam and reduce the aperture. Victor and Paula replied that the tracks reconstruction is quite precise and is performed by both sides independently. The distance between the beam and the two detectors is plotted continuously. Jan then asked if that means that some human intervention takes place to enter new values to further close the VELO. Paula commented that this was done manually at the beginning, but it is now fully automatic, with a human confirmation. Victor confirmed that given the way the reconstruction is performed; it would be very difficult to center the two detector parts with an offset with respect to the beam. A human confirmation that the tracking reconstruction is indeed correct could be added in case one side would close over the 0 position.

Roderik asked about the precision of the alignment. Victor replied that it is in the order of tenths of microns in the transverse plane. Jorg added that even, if the VELO is closed, the aperture still corresponds to many tens of beam sigmas.

Benoit asked if the SMOG2 upgrade makes the alignment more difficult. Victor replied that it does not change anything for the primary vertex reconstruction. Freek commented that with the SMOG2 the aperture is always larger.

Action: Evaluate if a warning could be produced if the VELO alignment algorithm attempts to move one side beyond the 0 mm point (V. Coco).

Manual VELO opening and procedure (Freek Sanders)

Freek summarized the original problem. Two years ago, the control hardware failed, spares were not available, and this led to a downtime of half a day before a fix could be implemented. The question of the manual movement of the VELO arose. With the "old" VELO the manual movement was difficult, mainly due to the dust cover which was making the access to the drive belt difficult. With the upgrade a new dust and protection cover is needed due to conflicts with the new vacuum and SMOG2 equipment.

The manual retraction is a highly sensitive operation, which would take a full day. The belt is difficult to reach and is located in a high radiation zone. In addition, there are no active interlocks nor position readings available during the manual movement. Thus, there is a risk of damaging the equipment, i.e. mainly the end-switches. A VELO expert would be required.

It is possible to reach the belt, but applying the force is not easy. To reach a fully open position, it would be necessary to move the belt by 60 meters. This can be achieved in steps of 150 mm and would take about one hour. The manual movement has been tested during the de-installation of the old RF foils.

Different improvements have been proposed during the discussion to facilitate the manual retraction:

- Add open/close directions on the frame where the belt can be reached.
- Test the access to the belt during/after installation.
- Document the procedure on EDMS.

Questions and comments

Jan asked how often it is foreseen to test the procedure. Freek replied that we could avoid testing it manually because the normal VELO motion test will be sufficient and that we do not gain anything by testing the movement by hand, as the motors move the velo using the same belt. Jan commented that the procedure should be tested in full prior to beam operation after longer stops. Freek proposed to test it once in a controlled situation with a limited range of motion.
Jan asked how it is possible to know that the open position has been reached in case the manual retraction is performed and that no feedback on the position is available. Freek replied that the open position is reached, when the movement is blocked.

Christoph commented that, even if the procedure is not performed regularly, it would be beneficial to test that one can still access the belt physically.

Victor commented that the test of the full motion could be decoupled from the test checking that the belt can be accessed. The full motion test could then be performed before the full detector is installed. Freek added that when performing the movement procedure, there is a risk of damaging the limit switches. Jan confirmed that it is necessary to consider the whole situation for the procedure, especially to ensure that we can confirm that the VELO is fully open at the end. Daniel added that during the test, the control system will be operational, and it will be possible to ensure that the limit switch position is reached without hitting the limit switches too hard.

Cedric asked how the VSS can provide the beam permit to the CIBU in case the electronics of the motion control system fails. If the VELO has to be moved manually and reaches the "out" position, the interlock logic should allow the beam permit. Xavier commented that this is related to the idea of "holiday mode" coming from the Roman pots: if the interlock board knows that the VELO is in a safe position, reached manually, the beam permit can be provided. A mechanism with a key switch could provide the signal, once the power to the motors has been disconnected. The difference with the Roman pots is that in the case of the VELO, the limit switches are connected to the motion control system, not to the safety system. Therefore, the VSS will not know the position in case the motion control electronics is in fault. Jan commented that this is a good option to implement. Jorg added that the "holiday mode" might not be necessary as the VELO is in use for every fill, unlike the Roman pots. Daniel commented that another possibility is to also send the limit switch signal directly to the VSS, which gives the beam permit if the VELO is in OUT position and the motors are powerless. This could even be done without the key solution. Xavier replied that this is feasible.

Actions:

- Prepare a detailed procedure for manual movement and perform the procedure in full when the detector is installed with active control system to monitor the movement and avoid damage to the limit switches (F. Sanders, V. Coco).
- Implement signal from limit switches to the VSS (X. Pons).

LHCb velo CO2 cooling system (Marko Milovanovic)

Marko recalled the action from the 174th MPP meeting to provide the functional specifications for the new CO_2 cooling safety system. The document EDMS-2138558 is now available. The safety system is being developed to quickly react in case of a CO_2 leak and to minimize the pressure rise.

A new dedicated pressure switch will be used for CO_2 leak detection. The differential pressure limit between the beam volume and the detector volumes is set to 10 mbar to protect the RF foil. In case that limit is reached, a safety valve will open and connect the beam and detector volumes. The leak detection pressure switch is set to -6 mbar to provide sufficient margin.

To guarantee the response time of the system it has been decided to install a dedicated pressure sensor on the detector side. The new sensor will be tested to ensure that the response time is adequate. It will be read by a FPGA and provides a Boolean input to the VSS.

The sensor will be tested in a few weeks and further studies are on-going regarding the maximum differential pressure before foil damage. The results might allow to move the venting levels further away.

The different conditions taken into account in the risk analysis are extremely difficult to simulate while taking into account all the variables and constraints. It is therefore vital to minimize the reaction of the safety system.

Another consideration is the SEY after exposure to CO_2. It will rise from 1.1 to 1.3 after 2 hours. It is difficult to estimate how much CO_2 would end up in the beam volume but the constraints on the SEY are also not clearly defined.

Questions and comments

Jan asked if these specifications have been discussed with the vacuum group. Marko replied that there have been extensive discussions with the vacuum group on these topics. The procedures and limits have been agreed upon with the vacuum group.

Operation of LHCb velo at 450 GeV (Victor Coco)

Victor presented possible scenarios for operation with the VELO at 450 GeV. Victor made it clear that this is not an official request from the collaboration. The VELO could be moved in for physics at 450 GeV later during Run III when the detector is fully commissioned. Different physics cases would be of interest: QCD production in proton-proton collisions and QCD in proton-Helium collisions (beam-gas interactions, SMOG).

These operational modes can use the VELO not in a fully closed position. A 3.5 mm gap would still provide enough resolution for the reconstruction. A back of the envelope calculation of the available aperture (for a 15-sigma clearance, also taking into account the full crossing angle) shows that closing to 3.5 mm should be achievable. This should be evaluated in detail in collaboration with the optics and collimation teams.

Questions and comments

Jorg commented that the 15-sigma value is not a final and approved constraint. Jorg also commented that more aperture can be gained by reducing the spectrometer current. Victor replied that this might indeed be a possibility for the detector.

Roderik commented that a more detailed aperture calculation, including the variation of the beta function in the VELO, the beta-beating and other possible effects.

Federico asked if it is possible to squeeze the beam at 450 GeV. Jorg replied that the aperture in the triplets is the limiting factor. Roderik mentioned that local aperture measurements in IR8 have not been performed so far but would be helpful for this evaluation of the limitations.

Jorg asked if the full intensity and number of bunches would be required. Victor replied that the "soft QCD measurements" will not require a lot of data and that a limited number of bunches would be sufficient. Jorg added that, with a very low total intensity, the Roman pots were operated at injection energy at only a few sigmas from the beam. This could be considered if one wants to further close the VELO at injection energy.

Action:

- Estimate the available aperture for a velo closing at 450 GeV in collaboration with optics and collimation teams and propose the measurement of the aperture in IP8 at injection before any physics operation at injection (V. Coco).

Summary of actions

The actions from the meeting are:

- LHCb velo motion system:
    1. Prepare a specifications document for the motion control, failures and interlocks (X. Pons).
    2. Evaluate if a warning could be produced if the VELO alignment algorithm attempts to move one side beyond the 0 mm point (V. Coco).
    3. Prepare a detailed procedure for manual movement and perform the procedure in full when the detector is installed with active control system to monitor the movement and avoid damage to the limit switches (F. Sanders, V. Coco).
    4. Implement signal from limit switches to the VSS (X. Pons).
- Operation of LHCb velo at 450 GeV:
    1. Estimate the available aperture for a velo closing at 450 GeV in collaboration with optics and collimation teams and propose the measurement of the aperture in IP8 at injection before any physics operation at injection (V. Coco).