B-factory Programme Advisory Committee
Special Review of PXD2

19 October 2022, Remote Meeting

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A special meeting of the B-factory Programme Advisory Committee (BPAC) was held remotely, with a small number of experts, on 19 October 2022 to review the production status of the new Belle II Pixel Detector with two completed layers (PXD2), to be installed during Long Shutdown 1 (LS1). The PXD group gave a presentation summarising the situation with emphasis on a recently discovered problem that emerged during the laboratory test of the half-shells at DESY.

Status

The two half-shells of the PXD2 have been completed at MPI Munich and transported to DESY for further electrical tests to ensure that no damage occurred during ladder mounting and transport, and to optimise its working point by performing measurements with a ^{90}Sr source. The testing conditions at DESY were not optimal. Only ten Power Supply Units were available due to delays in their production and only half of one half-shell could be powered at a time, resulting in an asymmetric thermal condition during operation. There were also issues with the MARCO CO_2 cooling unit, where a defective CO_2 flowmeter led to unstable operation with multiple abrupt temperature changes and where a dry-out led to temperature increase of the DHPs from 45 °C to 85 °C for about 30 seconds in several modules. There were additional issues with the software and a cooling line, which caused the dry-out mentioned before.

When the first half-shell was about to be dismounted from the setup after testing, it was found that two L1 ladders had a visible kink at the glue joint and are considered "broken". The glue was expected to be much more rigid than the silicon, but the silicon modules did not break. The team has started to address the following issues:

- The durability of the glue joint under mechanical and thermal stress;
- The properties of the new self-adhesive foil introduced for the PXD2;

- The gliding mechanisms for both the SCB and ladders;
- Quantitative differences in the operating conditions in the commissioning setup and the standard operation in Belle II;
- A safe range of ladder fixation torques to simultaneously satisfy the thermal and mechanical requirements;
- Proper functioning of the gliding mechanism during pulling and pushing;
- Stability over thermal cycles;
- Replacement of the broken ladders;

It has now been established that the glue joint was not as stiff as previously assumed and that the "face-up" method used for gluing the modules for the PXD2 may result in a less strong glue joint than the "face-down" method used for PXD1. The glue itself also loses shear strength at higher temperatures, which should be avoided. A key source of the problem seems to be the sliding mechanism. For the PXD2, the mylar foil is a one-sided self-adhesive foil, contrary to the PXD1 where the foil was not adhesive and where for the lower half-shell there was no foil at all. The torque to be applied to the screws for the ladder gliding mechanism was determined only in a pull-configuration rather than a push-configuration without foil. Ladder sliding tests are ongoing and a new value for the torque will be determined while ensuring good thermal conductivity of the ladder with the SCB.

The SCB gliding mechanism with respect to the beam pipe did not work in the DESY setup, possibly due to the asymmetric operation of the half-shell. Higher temperature caused by the problem of the MARCO cooling unit has most likely resulted in a thermal expansion of the dummy beam pipe, which might have significantly contributed to the issues observed. Ladder gliding, foil and cooling studies will be conducted both at MPI and DESY and better monitoring and control of the beam pipe temperature in the DESY setup will be implemented.

To minimise handling of ladders, it was proposed that the removal of the two broken Layer 1 ladders was done without removal of the Layer 2 ladders. When such a procedure was performed on a dummy half shell, after the first ladders were removed, two broken Layer 2 ladders were uncovered. It has been decided that Layer 2 ladders will be removed, but that the (dis-)mounting procedure will be revised to minimise the number of handling steps.

Concerns

The focus of the corrective actions are to determine the right torque for the bolts attaching the ladders to the SCB. This involves validation of the new value over a range of temperatures, validating the thermal conductance, its reproducibility, and its implementation in the real detector. Although an incorrect value of the torque for the ladder sliding mechanism seems to be a most likely source of the issues observed, additional

causes of the ladder deformations are not excluded. To avoid further damage, the team is also changing the ladder (dis-)mounting procedure in the expectation that it will mitigate risks. There is a concern that, due to various pressures, the consequences of design changes may not be fully understood which could lead to further negative effects. The spare ladder count is almost inadequate to recover from further accidents in assembly and testing.

It must be noted that the PXD2 detector has an extremely high programmatic value for the physics program of Belle II. The PXD1 is taking data satisfactorily and provides good physics results. It would be a mistake to replace the PXD1 with PXD2 that is not adequately verified and could not match the performance of the PXD1. The safety of the PXD2 should be the highest priority of the experiment.

Recommendations

- Have all actions (tests, measurements, etc.) to be made on the PXD2 reviewed by a small task force to ensure that the procedures are safe and meaningful. More than half the members of this task force should be non-PXD members so that the actions can be evaluated from multiple viewpoints.
- Verify modifications in a holistic manner when multiple changes are made, evaluating the system as a whole and not piece by piece and revisit the implications of prior decisions.
- In order to be prudent, impose no deadline for the PXD2 installation at this moment.
- Develop, by the next BPAC meeting, different PXD2 installation scenarios with an evaluation of the pros and cons of each scenario taking into account experimental, economic as well as physics constraints.
- Establish a safe storage and operation environment for testing (temperature and humidity) as soon as possible; every effort should be made to keep these environmental specifications.
- Verify that any further modification to the PXD2 design is safe, addresses a well-defined issue and does not cause any adverse effects on the PXD2.