B-factory Programme Advisory Committee
Full report of
the Annual Review Meeting

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A. Andreazza* (Milano), P. Collins*& (CERN), G. Corti& (CERN),
M. Demarteau (ORNL), R. Forty (CERN), S. Gori (UCSC),
W. Hulsbergen* (NIKHEF), G. Isidori (Zurich), P. Mato* (IFAE, Barcelona),
F. Meijers (CERN), N. Neufeld (CERN), R. Patterson (Cornell)
A. Petrov* (USC), M. Sullivan (SLAC), H. Tajima+ (Nagoya),
O. Tajima (Kyoto), M. Titov* (Saclay)
and chaired by T. Nakada (EPFL)
& Remote participation
+ Partly absent
* Expert member.

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1 Short summary

An annual review meeting of the B-Factory Programme Advisory Committee (BPAC) was held at KEK from 9th to 11th February 2026, during which the status of SuperKEKB and Belle II was presented. Progress on the Belle II detector and on machine–detector interface work for the upgrade planned during the two-year shutdown envisaged from 2032 to 2034 was also reported. On the afternoon of 10th February, a special review session dedicated to the upgrade programme was held, with particular emphasis on accelerator-related issues. The BPAC members participated in this session as observers.

Here are the charges given by the Director of the Institute for Particle and Nuclear Studies (IPNS) and the committee's responses:

I. Physics Exploitation of the 1/ab Dataset
Review the physics activities and progress. Provide advice on areas requiring focus to fully exploit the anticipated 1/ab data.

The analysis activities of the Belle II collaboration are well organised, with appropriate emphasis on topical subjects where Belle II can make significant impact, particularly through the development of novel analysis techniques. The consideration of an energy scan programme is scientifically interesting and should be pursued at an appropriate stage. However, the first priority should remain the accumulation of 1 ab^{-1} of data and the achievement of peak luminosities of 1×10^{35} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and above.

II. Readiness for Rapid Physics Output in 2026ab

Review and suggest the procedures to deliver physics results promptly using the data recorded in 2026ab.

Preparation for rapid data processing and physics analysis is progressing well. Efforts to improve reconstruction software in order to maintain detector performance under increasing luminosity are appreciated and should be further encouraged.

III. Beam Background, Stability, and Detector Protection

Review the strategy and coordination among each subgroup for addressing the issues related to the beam background and sudden beam loss from the perspectives of the detector damage, lifetime, operation stability, performance and luminosity.

While background arising from beam–gas interactions is still significant, it is expected to decrease as the vacuum quality improves over time through beam scrubbing. Injection background remains a concern and could limit further increases in beam currents, particularly with respect to potential radiation damage to the Central Drift Chamber (CDC). The CDC background level is currently estimated to be at the detector limit, both in terms of particle rates and the projected total accumulated charge on wires. A deeper understanding of the causes of low injection efficiency is essential. Consolidation of ageing infrastructure and further improvements in beam-diagnostics systems are strongly encouraged. Progress in simulation studies, carried out in collaboration with laboratories such as CERN and DESY, is encouraging and should be further strengthened.

Although the number of sudden beam loss (SBL) events has been drastically reduced following the removal of Vacseal from the beam pipes, SBL remains a concern for the safe operation of both Belle II and the SuperKEKB rings. As it has been successfully demonstrated in the machine detector interface work, continued close collaboration between the Belle II and accelerator teams is essential to mitigate this risk. Stronger coordination among all elements of the SuperKEKB complex and the Belle II detector will be necessary to achieve the project's goals.

IV. Upgrade R&D Readiness toward the 2026 Baseline and 2027 TDR

The upgrade baseline configuration is planned to be finalized in July 2026 and to be documented in a TDR by 2027. Review the progress and plan for each subsystem upgrade R&D, and provide advice on matters requiring adjustment.

The committee is impressed by the substantial progress made on the vertex detector system (VTX), particularly regarding technology choices and design studies. Reaching a well-defined baseline by July 2026 appears realistic. The committee also welcomes the decision to construct a new central drift chamber for the upgrade.

It is noted that the collaboration is considering the introduction of an intermediate tracking and timing system (ITT) between the VTX and the drift chamber. Based on experience with the current CDC, the committee considers the ITT to be mandatory in order to ensure sustainable operation of the drift chamber in the radiation environment expected after LS2. The collaboration is encouraged to optimise the ITT design promptly for the baseline decision, taking into account particle identification capabilities for low transverse momentum tracks.

For the definition of the new tracking system, careful consideration of space constraints in the interaction region is required. The design of the interaction region is crucial for SuperKEKB performance, and a comprehensive evaluation, including the design of new final focusing quadrupole magnets (QCS), should be performed. A strong management structure covering both the accelerator complex and the Belle II detector should oversee overall optimisation and priority setting of the upgrade project.

Given the number of decisions still to be made, completion of the TDR by 2027 represents a tight schedule and carries schedule risk. The schedule must be made taking into account the available resources and with some buffer. The progress should be carefully monitored so that any delays can be dealt with in a timely manner.

V. Adequacy of Computing Resource Projections

Point out any concerns regarding the computing resource estimates if any.

The adequacy of computing resources will be reviewed by a separate committee once the formal request for 2027 is finalised. In parallel with GRID computing, LHC experiments have increasingly adopted High Performance Computing (HPC) resources, whose availability continues to grow. Although additional development effort will be required to exploit HPC efficiently, the Belle II collaboration is encouraged to explore this option proactively as part of its long-term computing strategy.

2 Machine and machine-detector interface

2.1 Status

Several improvements were made to the injector complex and to the High and Low Energy rings (HER and LER) of SuperKEKB during the ten month shutdown of last year. The main improvements entailed mitigation of the Sudden Beam Loss (SBL) event rate, increasing the shielding around the Non-Linear Collimator (NLC) to allow full usage of the collimator, and several items to improve injection efficiency. The LER injection beam pipe was replaced and realigned. In addition, one collimator in the LER was moved to the Interaction Region (IR) to improve detector protection along with other collimator improvements in both rings. All known locations of Vacseal usage were checked and cleaned of any residue. A new RF gun was installed to mitigate arcing and allow two bunch injection. A diagnostic beam line was commissioned enabling real time monitoring of injection parameters for the HER. A kicker magnet was repositioned and a new kicker was installed in the Damping Ring and the Energy Compression System was installed in the HER Beam Transport (BTe) line.

The 2025c run (Nov.-Dec.) had an issue with the abort kicker power supplies that unexpectedly caused a large beam loss in the IR. This quenched the QCS magnets, produced a high radiation level in Belle II and damaged an IR collimator (D01V1). The

QCS left side cryostat subsequently developed a drop of the helium level that affected running after the event. The 2025c run was shortened by two days and the start of run 2026a was delayed by almost three weeks in order to evaluate the effect of the He level drop on the QCS operation. Adjustment of the cooling procedure for the cryostats has eliminated the He level drop. The suspected cause is a malfunctioning valve which will be addressed after the 2026ab run. The beam abort procedure, which was applied when a kicker power supply failure occurred, has been changed. This should prevent another high radiation beam loss event in the IR region from this failure.

An attempt was made to use synchrotron injection in which the bunch is injected on axis with the stored bunch. This injection worked down to a β_y^* of 3 mm. But when β_y^* was lowered below 3 mm, beam backgrounds got too high. In addition, some of the injected particles spread over nearby RF buckets.

The SBL event rate was dramatically reduced during run 2025c, from 454 beam losses during the 80 days of the 2024c run to 66 during the 48 days of 2025c. This is attributed to the cleaning out of the Vacseal. This is a major step forward and should greatly improve machine running stability. Furthermore in LER, beam abort can now be performed within 20 μs after the start of beam loss is detected in the ring, reducing radiation damage due to SBL.

The MDI group found that the LER background level had increased by as much as a factor of ten after the ten month shutdown last year, and the predominant increase is coming from Beam-Gas interactions. This is attributed to the deterioration of the beam pipe vacuum. Many sections of the LER beam pipe were opened up in order to remove the residual Vacseal to prevent SBL.

The MDI team managed to obtain information for single beam background through opportunistic events where one of the beams (HER or LER) was aborted leaving the other beam in the machine. The team has also found that injection backgrounds have also increased compared to 2024 running. This data is from the early 2026a running and the injection and linac teams have not had much time to optimize injection parameters.

2.2 Concerns

- The excellent effort to minimize the SBL rate through the Vacseal cleaning is a great step forward, but there will be more SBL events especially as beam currents increase. In particular there are still SBL events in the LER accompanied by pressure burst and large dose delivery at the IR.

- The HER beam current is higher than design for a given LER beam current under present operating conditions. If this ratio of the HER over LER currents must be kept, the maximum HER beam current that can be reliably delivered using the present RF system may be reached before LS2 limiting further luminosity increases.

- The injection backgrounds are high.

2.3 Recommendations

- The committee urges continuing efforts to study and localize SBL events in both rings and also to continue with efforts to minimize the radiation levels encountered in the IR and in Belle II from SBL events.
- The effort to find an early abort signal should continue to be pursued.
- The committee suggests the accelerator team begin to consider possible alternative operating scenarios to regain the design beam current ratios and also consider a plan to install, before LS2, some of the HER RF systems planned for the LS2-upgrade.
- The committee considers that some dedicated time may be needed to optimize injection efficiency and minimize injection backgrounds in Belle II. The committee also urges the MDI team to continue to assist the injection studies.
- Dedicated background measurements in order to extrapolate the machine condition to higher luminosities should wait until scrubbing improves the vacuum in both rings.

3 Belle II detector

3.1 Vertex detector (VXD)

3.1.1 Pixel detector (PXD)

3.1.1.1 Status

To avoid further damage to the pixel detector due to the sudden beam loss events, the PXD was turned off on May 7, 2024 and has remained off ever since. To protect the detector during future running, the collaboration is developing a fast hardware shutdown system that will turn the power to the PXD off much faster than the current shutdown time of about 500 μs. An appropriate and reliable precursor signal that could be used to trigger the fast PXD shut-off, about 18 μs before beam loss starts at a minimum, has not yet been identified. The current system based on the signals from the CLAWS and diamond detectors does not, in most cases, provide a signal early enough.

A fast shutdown board that rapidly discharges capacitors on power lines through resistors by switching MOSFETs has been developed and has been tested with the full cable path at Bonn University with non-irradiated and irradiated modules with good results. No damage has been observed after thousands of power cycles.

Tests were done at the Mainz Microtron (MAMI), an electron accelerator, to verify the fast shutdown and to determine how early the shutdown must be triggered. A total of 264 shots were performed with varying timing of the shutdown trigger before beam arrival. When the shutdown trigger arrived more than 9 μs before beam arrival damage was observed in about 2 % of the shots. A higher occurrence of damage was observed for earlier signals. Taking into account the profile of the beam at MAMI and adding a safety margin, a shutdown signal 18 μs or later is considered safe.

Ordering and assembly of all the components has started and delivery to KEK is expected by May 2026 at the earliest. Preparation for the modifications to the Belle II system are scheduled for June, with reinstallation of the power supplies after the end of the 2026ab run. Running with the PXD will thus not be possible in the 2026ab run.

The PXD team is actively collaborating with the MDI group to identify reliable precursor signals. Three candidate signals are under investigation: a beam-pipe clearing electrode signal indicative of abnormal current or voltage patterns; beam orbit fluctuation that could indicate the start of an instability; and a beam size blow-up signal. During the 2026a run one LER SBL event occurred with an abnormal clearing electrode signal. More studies are required.

The conditions for when the PXD can be turned on again are difficult to quantify but are actively being discussed within the collaboration. This is a multi-dimensional problem driven by the performance of the accelerator and will require a risk versus benefit analysis regarding physics impact. A PXD expert will be resident at KEK when the collaboration has decided to turn the PXD on again.

3.1.1.2 Concerns

- As noted in the previous report, although there is good progress on the investigation of the sudden beam loss events and excellent improvement in the frequency of these events, the origin of the remaining SBLs is at the moment still not confirmed. There is a non-negligible probability that the SBLs may never be completely eliminated. Turning the PXD on thus carries an inherent risk that further damage to the detector will be incurred.

- Although the team has strengthened the management of the PXD project, the personpower to operate, maintain and analyse the data remains marginal. The ability of the collaboration to ensure adequate strength of the PXD team remains a concern.

3.1.1.3 Recommendations

- Carry out the plan to install the fast shutdown system during the 2026 summer shutdown; at the same time, continue testing of the fast ramp down of the HV to put the detector in a safe state at Bonn University and MAMI to increase the level of confidence.

- Continue the search for a reliable precursor signal that can be used for a fast shutdown of the PXD detector.

- Continue to develop a strategy to turn the PXD on again through a risk-benefit analysis based on physics impact.

3.1.2 Silicon strip vertex detector (SVD)

3.1.2.1 Status

The SVD has been running very stably even in high background conditions. No occupancy issues were observed and the hit efficiency was excellent with all layers having a hit efficiency exceeding 98.5 %. In run 2024c the SVD contributed 6.5 % to the total number of accidental stops in the data acquisition due to SEU events. A firmware-based automatic SEU detection and recovery function has been developed and deployed to recover the SEU without stopping the data acquisition system. This implementation is stable under frequent SEUs during machine tuning and high-injection backgrounds. The team is to be congratulated on this achievement. The contribution of the SVD to the overall downtime has been reduced to a negligible level.

At the last review it was recommended to work with the accelerator group to mitigate the IR losses during SBLs. The team is to be commended for establishing regular meetings with the accelerator team studying possibilities to enhance the background monitoring and creating a dedicated EPCIS panel on the SuperKEKB side.

3.1.2.2 Concern

No particular concern is raised by the performance of the SVD.

3.1.2.3 Recommendation

- Continue the joint studies with the SuperKEKB and MDI teams to integrate the diamond picoscope data in the background monitor.

3.2 Central drift chamber (CDC)

3.2.1 Status

In order to develop a strategy to ensure stable CDC operation till the next long shutdown, the CDC Task Force continues to investigate gas gain drop and Malter currents, and performs ageing studies with the CDC test chamber.

CDC operation has been stable during 2025c run, with no significant ageing effects or new Malter current issues observed.[1] During the 2024c run, the gas gain dependence on the chamber current and gas conditions (e.g. oxygen, water and hydrogen content) was observed. Cosmic ray studies performed under different levels of $O_2/H_2O/H_2$ in 2025 allowed to disentangle contributions of the different additives to the gain drop observed during the beam operation. Analysis of the 2025c data taken under different operating conditions and levels of additives revealed that the accumulated gas contamination produced in gas avalanches might be the dominant reason for the slow gas gain drift towards lower values during beam operation. A single-wire proportional chamber installed in the CDC gas recirculation system showed overall trends consistent with the gain analysis

[1] During 2026ab run, residual Malter-like currents have been observed, in February 2026, in several CDC layers which had not shown the effect before.

results based on dE/dx information during beam operation. Observed gain recovery after shutdown and the increase of gain with increased fresh-gas flow rate also indicate that the gas exchange is important. If gas contamination is the dominant factor of gas gain drop during beam operation, the onset of potential anode wire ageing effects might be masked and not clearly visible.

Several improvements have been implemented for the CDC gas distribution system. A new O_2 injection system has been added and the H_2O bubbler, which temporarily was replaced by a Nafion membrane in summer 2024, has been brought back into operation. This enables CDC operation with oxygen (100–1000 ppm) and water concentrations (3000–4500 ppm) to prevent the onset of Malter currents. The increase of the fresh gas flow rate by a factor of three to four in the 2026ab-run[2] and by ten after the summer shutdown is being envisaged. The time necessary for a full exchange of CDC gas volume will be reduced from one month to approximately three days. This will allow the purging of gas pollution due to avalanche processes. An increase of the fresh gas flow rate is also an effective measure to minimize the ageing effects by removing free radicals produced in the avalanches. A newly installed single-wire proportional chamber allows for non-invasive research to find suitable filter options for removing contaminants from the gas.

For long-term operation at higher background levels, operation of the two innermost CDC super-layers (SL 0/1, Layers L0-13) with HV reduced by 100 V (50% gain reduction) is under investigation. This should mitigate the risk of Malter effects and minimize total accumulated charge in the CDC. Two sets of data, one with reduced HV for SL 0/1 and the other for all SLs, were taken in December 2025 to assess the impact of CDC performance degradation on tracking and triggering, and to explore operating scenario. For the lower HV in SL 0/1, the CDC track-trigger efficiency is decreased by $\sim$2 to 7 %, while operating the entire chamber at reduced HV leads to a much larger efficiency drop of $\sim$5 to 20 %.

Studies on how to mitigate performance degradation due to cross-talk effects and beam background hits are also ongoing. The stand-alone CDC track-finding efficiency at a reduced gain becomes less robust against high occupancy and depends more strongly on specific ionization (e.g. electrons vs muons). Further efforts are needed to improve software robustness against background hits and to reduce cross-talk by optimizing the TDC signal thresholds. The impact on CDC performance and operation with reduced HV/gain needs to be evaluated for the electronics upgrade that has shown to suppress cross-talk.

The total accumulated charge in the CDC innermost layers has already reached 165 mC/cm per wire after run 2025c. Assuming the maximum operating current limit per CDC layer of 300 μA remains unchanged, additional charge of up to 60 (120) mC/cm with reduced (nominal) HV will be accumulated in the innermost CDC layers by the end of the run 2026ab.

To help understanding the effect of accumulated charges, ageing test are being carried out with electron-beam at Tohoku University and X-rays using a generator at KEK.

[2] At the current background level in run 2026ab, gain drop due to the gas contamination has been mostly suppressed after increasing the fresh gas flow rate to 800 cc/min.

An initial ageing test at Tohoku University has been carried out in November 2025, accumulating approximately 0.35 C/cm/wire during 6 days. The gain of the irradiated wire had decreased just after transportation from KEK to Tohoku, possibly due to gas leak. During irradiation, the gain remained stable. Additional beam time at Tohoku University is foreseen in early JPY2026, with the goal of reaching 1 C/cm/wire by summer 2026.

3.2.2 Concerns

- The machine background level for the CDC is estimated to be at the detector limit, both in terms of particle rates, the risk of re-appearance of Malter effect, and the projected total accumulated charge on wires.
- Given the total accumulated charge of up to 150 mC/cm/wire for the innermost layers, there could be already permanent gain loss that is masked by the gas contamination produced in gas avalanches.
- The CDC performance may not stay at the level adequate for a competitive physics programme until the LS2 starts in 2032.

3.2.3 Recommendations

- Achieving stable conditions with high luminosity during run 2026ab is central for better understanding of the scope for the LS2 CDC upgrade. Prompt decision about CDC operation with a reduced HV, at least in the innermost superlayers, is important to mitigate the risk of Malter effect and to minimize the total accumulated charge on wires. On a longer term, all possible efforts should be made to optimize CDC operating conditions (e.g. water/oxygen content, increase of fresh gas flow rate, change of gas mixture, etc.) to ensure successful CDC operation until LS2.
- Redundant real-time monitoring and alarm systems for sporadic activity, such as HV trips, increase of residual currents during beam operation and after the beam abort, has to be implemented and available to the shift crew.
- Ageing studies with a test chamber should be strengthened. Even if such a study will not fully resemble CDC performance degradation (anode ageing and/or Malter effects), it could facilitate development of strategies for performance recovery, and help to explore the use of alternative gas mixtures, on a longer term.
- The study with alternative gas mixtures needs to be extended from simulation activities to the measurements, using a test chamber that resembles the CDC cell structure. Collaboration with groups developing drift chambers for the future Higgs factories could be further explored.

- A strategy should be developed for the case where a major intervention is needed for the current CDC in order to maintain an adequate physics performance until the end of Run 2.

3.3 Particle identification system

3.3.1 Barrel system (TOP)

3.3.1.1 Status

There were no dedicated talks on the particle identification system at this meeting. From the general detector operational status, firmware bugs in the TOP event FIFO (which frequently caused losses of the b2link) have been fixed. In run 2025c, there was no trouble due to this reason, even though conditions of the injection background were worse than the previous run. Frequent DAQ errors due to single-event upsets (SEU) on the Processing System (PS) in the detector electronics have not been fixed yet. The team tried to fix them by deploying the migration of the feature extraction scheme, however it was not successful due to several bugs that are still being addressed. For shortening the dead time during the data taking, the team is working on a robust recovery to mitigate it in run 2026ab.

3.3.1.2 Concerns

- The TOP currently remains one of the major reasons for stopping the DAQ in Belle II.
- The rate of quantum efficiency (QE) degradation in the TOP PMTs is not yet fully understood, as well as the performance comparison to simulation, leading to uncertainty in the lifetime extrapolation and the tolerance of background.

3.3.1.3 Recommendations

- Continue the work to mitigate the SEU issues in the TOP with high priority.
- Continue the systematic study of the reasons for QE loss in the TOP PMTs.

3.3.2 Endcap system (ARICH)

3.3.2.1 Status

The ARICH team resolved the cooling problem during 2025 summer shutdown. They replaced connectors in the cooling water circuit, and also replaced the chiller with a copper-less version.

3.3.2.2 Concern

No particular concern.

3.3.2.3 Recommendation

- Continue the study of alternative photon detectors in case they are needed in the long term.

3.4 Electromagnetic calorimeter (ECL)

3.4.1 Status

Overall operation of the ECL is fine. The team implemented detailed background occupancy monitoring in DQM, which had been encouraged in the recommendations in the last BPAC report (June 2025). The firmware improvements in the collector and the shaperDSP have still been under development. This will reduce the pileup noise and background. The team plans to test them during the 2026ab run, and assess the performance; however, they will not use it in physics running yet.

3.4.2 Concern

No particular concern.

3.4.3 Recommendation

- Tests for the firmware improvements in the collector and the shaperDSP should be pursued as planned.

3.5 K-long Muon Detector (KLM)

3.5.1 Status

The function for masking individual FEE modules of the KLM has not been implemented in the current firmware. Because of this, the team had to mask many more modules than the number of problematic modules. The team reduced its impact by cabling work, but this problem still remains. For solving this, firmware development is ongoing to enable flexible masking. There is still a lack of spare "old-type CAEN crates" (SY1527) and the team plans to negotiate with the STAR experiment (BNL) to secure them. The team will resume the investigation to use the new-type crate (CAEN SY4527) during the coming summer shutdown. The team performed a refurbishment of the gas circulation system and increased its reliability. According to the recommendations given in the last BPAC (June 2025), R&D for switching to the proportional mode from the streamer mode of RPC operation is still ongoing. It should enable mitigating the efficiency drop with increasing hit rate.

3.5.2 Concerns

- The lack of spare old-type CAEN crate (SY1527). The committee would like to hear the updated status at the next BPAC.

- The test chamber used to study proportional mode may not fully replicate the performance of the real chambers, e.g. because of changes in the wall resistance.
- It may be challenging to install new preamplifier boards near the chambers.
- The use of a new gas in the KLM is required, but the impact has not been fully studied.

3.5.3 Recommendations

- Firmware developments for flexible module masking should proceed.
- R&D for switching to the proportional mode from the streamer mode is strongly encouraged.

3.6 Trigger, data acquisition system (DAQ) and Detector control

3.6.1 Status

There was no dedicated presentation on DAQ, Trigger and Detector Controls during this meeting. The overall data-taking efficiency (as a percentage of the beam-time dedicated to physics production) remained quite high at 87.5 %. This is a bit below the target of the collaboration at 90 %, however it should be noted that the injection veto alone corresponds to almost 5 % of the missing efficiency, which therefore has to be gained in the remaining 7 %. Various factors contributed to the dead-time, quite a few of them singular or rare specific problems which weighed high because of the limited overall run-time.

The collaboration successfully addressed several problems and introduced fast recovery in several subsystems. Adding this possibility to the remaining subsystems will increase data-taking efficiency.

It is noted that there are still some problems due to SEUs, this should be kept in mind for system optimisations in view of future increase in instantaneous luminosity.

A strategy for HLT load mitigation has been established, with various improvements in the HLT code, as well as new triggers to reduce the L1 rate, ready to be put into operation when needed.

3.6.2 Concern

No specific concern.

3.6.3 Recommendation

- Mitigations against SEUs should be continued in view of future luminosity increase, even if the impact at present is small. This involves the central DAQ group and firmware developments by the relevant subdetector people.

4 Software, data processing and computing

4.1 Software

4.1.1 Status

The committee was informed of several changes in responsibility in the Software and Performance groups, including of coordinators. The two groups continue to collaborate closely on particle identification (PID), neutrals, tracking, trigger and event properties, and analysis tools. Physics analyses are migrating to use samples processed with *release-08* with improved Monte Carlo (MC) modeling and particle ID. Preliminary recommendations for the winter conferences were nearly ready at the time of the meeting. Centralized access to up-to-date performance recommendations is provided via a common tool/web interface to simplify usage and ensure uniformity across analyses. Effort continues to extend the kinematic coverage of corrections and make them more optimal and easier to use. The software group maintains a common tool to propagate uncertainties, called *SysVar*, which allows to provide standardized inputs across different performance subgroups.

The committee was informed of new efforts to improve MC-data agreement on all fronts: from low-level variables by improving the Geant4-based simulation, to resampling high-level variables using calibration data, and reweighting events. Studies were underway with *2025c* data processed with *release-09*; additional reconstruction improvements have been identified for reprocessing and run *2026ab* data taking.

An update was presented on the *release-10* plan outlined in the February 2025 BPAC. New reconstruction and calibration features were frozen in July as scheduled. They included C++20 support and a major ROOT update. New features not yet ready, including adopting the latest Pythia version, were dropped. MC validation samples were available one week after freezing. Fast feedback from the Physics and Performance groups revealed a major KLM PID issue that required investigation over the whole summer. The software group then had to shift its focus to the preparation of *2025c* data taking, so *release-10* could not be validated on data. Due to the shortness of the winter break, the software groups decided to backport relevant features to *release-09* and use *proc16* for *2026ab* data taking. The committee was informed of the new plan to freeze features for future releases in May, allowing validation before the summer holidays. The goal is to complete the validation of *release-11* by October 2026; it will be used by *proc17* to reprocess 2026 data and *2027a* data taking.

ONNX has been successfully integrated into the Belle II external software suite and in *basf2* through a lightweight interface. Two networks were converted to ONNX, reducing the reconstruction memory footprint with no loss in performance. ONNX is now mandatory for any new MVA[3] used for inference in *basf2*.

A primary focus of the software group is reducing the CPU footprint, especially for HLT algorithms. SVD grouping will be introduced for processing *2026a*, as it significantly reduces execution time with high beam background conditions, with only a 0.3%

[3]Multi Variate Analysis.

loss in tracking efficiency. A dedicated profiling campaign is planned to accurately profile the code and guide optimization efforts.

Training of newcomers to the collaboration is also a concern of the Software group: a very successful in-person Starter Kit took place in October as a satellite B2GM event.

The current implementation of the Conditions Database, hosted and maintained by BNL, cannot meet Belle II's future needs and the higher rate of queries from *basf2* jobs. The first stage of migration to OpenShift was completed transparently in June 2025. Work is in progress on migrating the backend to the HSF implementation and determining how to support older *basf2* releases given the changes in Conditions Database API.

4.1.2 Concern

- The committee understood that the migration of the Conditions Database may require adaptation of the code to accommodate the API changes. The code that has to support both versions may become more complex.

4.1.3 Recommendations

- The committee supports the decision to allocate more time for the validation of major software releases to ensure their readiness for prompt data taking.
- Software expertise for in-depth code profiling should be acquired.
- The resources currently being used for ML should be identified to gain a clearer picture of what is required.

4.2 Data Processing

The committee received an update on the plans for calibration and data-processing. The new *b2luca* tool, based on *b2luigi*, is ready and a full dress rehearsal calibrating $11\,\text{fb}^{-1}$ of old data was performed in the fall for training and interaction with subdetector experts. Some issues were identified in both calibration and validation; the few remaining problems from a second full test are being fixed. No problems were found with *b2luca* itself. The *2025c* prompt calibration was performed with the new system in January as planned and finished in only 21 days, with approval provided from all sub-detectors' responsibles. For the first time, all MC run-dependent (*MCrd*) payloads were also produced in the same procedure. Work was in progress to automate the two remaining calibrations not yet included. The committee warmly congratulates the team on this impressive achievement. A problem found in the alignment required 14 extra days to re-run part of the calibration, confirming that the calibration limiting factor is ultimately the time needed to resolve unexpected issues. Reconstruction of *2025c* data, production of the corresponding *MCrd* samples, and skim production for both were planned next. A fraction of *MCrd* samples and related skims had to be regenerated due to an issue with the beam-parameters payload, identified by a user almost nine months after the initial production. This showed that the coverage of the VIBE tool used for standard validation of all datasets must be extended in close cooperation with the Physics Working Groups. It is planned to start *MCrd* for run *2025c* data excluding short runs (i.e. $< 20\text{pb}^{-1}$), after agreement with the Physics Working Groups. Tests show a negligible impact on physics while significantly reducing production complexity. Signal MC production is mostly carried out on local resources, with only 20% on distributed Grid resources, unlike the previous campaign. Local productions are performed by Data Processing liaisons of the Physics Working Groups, greatly relieving the Data Processing team's workload and broadening the expert base. Production of multiple signals per job on Grid resources are ready for deployment, but are currently not needed.

An outline of the plans for processing *2026ab* data was presented: the goal is to process one *bucket* per month, followed by mDST production for data and MCrd, and then skimming. Reprocessing of all data sets and MCrd production with *release-11* is planned from October 2026.

4.2.1 Concern

- No major concern.

4.2.2 Recommendations

- The committee supports the decision to extend the coverage of standard validation. As the number of parameters and distributions to be verified will increase steadily, automatic checks may need to be considered.

- Even if running multiple MC signal productions in the same job on the Grid is not needed, it is recommended to periodically exercise it to be ready in case of need.

4.3 Computing

The committee received a detailed update on the ambitious activity plan presented at the 2025 BPAC, many parts of which were completed. Several improvements were implemented in BelleRawDIRAC, which handles replication of `hRAW` files; it is now independent of BelleDIRAC and based on DIRAC v9. Since run *2025c*, production of `hRAW_physics` has been automated. A minor BelleDIRAC release, now based on DIRAC v8, was deployed in early 2026. The upgrade to DiracX is progressing more slowly than planned, in part because BelleDIRAC must first undergo major changes to adapt to DIRAC v9. Kubernetes clusters required for DiracX deployment have been set up by the Computing team. Team members continue to attend hackathons organized by the DIRAC team.

The computing system experienced intense activity earlier in the year with prompt processing, *MC16rd* was completed by fall. Users' analysis jobs dominated later in the year. Despite lower production activity, CPU usage rose in 2025 compared to 2024 and is expected to grow further with prompt and re-processing. Storage is well under control, and site balance is improving through data re-balancing and adjusted distribution shares. Data replication from KEK to RAW data centers was generally problem-free and usually completed in a few hours. Tape usage increased significantly during the initial data-taking period without HLT filtering, and this must be included in future resource estimates. A separate committee will review the adequacy of 2027 computing resources once the formal request is finalized.

The production system operated smoothly, except for recurring issues with the DIRAC Job DataBase (DB). Although the root cause is still unclear, different actions were taken to fix the problem. The computing team plans to offload some tables to an external OpenSearch service on a longer term. The committee was pleased to hear of the completed migration of the metadata catalog from AMGA to Rucio, concluding a two year long effort; the AMGA service was stopped in November without an impact on end-users. Future work includes removing obsolete code and optimizing metadata access with new Rucio features. Substantial effort is also being made to improve production tools, especially a detailed diagnostic report tool to help users understand job failures.

Determining the popularity of the dataset is another long-term project that was deployed; it covers all distributed computing GRID workflows and provides a chronological view of the access to the dataset.

Multicore jobs are being tested to reduce execution time and improve overall resilience, with *basf2* jobs using 8 parallel processes in 'multicore' queues at the Raw Data Centers. A memory leak in *basf2* was found running in this mode; a workaround is in place, and larger-scale tests are planned.

Several changes affected the certification infrastructure; KEKCC adopted new authentication and authorization systems in accordance with the WLCG plans. Issues with Certification Authorities have been or are being resolved.

Migration of most Belle II Grid sites to EL9 is complete. However, new EL9 packages introduced security constraints that require further site updates.

The Belle II Computing team had to respond swiftly to the threat that key services running at BNL—specifically Rucio and the Conditions Database (CDB)—might be stopped due to the U.S. government shutdown in Autumn. In coordination with the Data Production, Software and Physics groups, the computing team developed a continuity plan with the immediate goal of securing data taking for *2025c*. In the end, the plan did not need to be activated, and the shutdown ended before BNL had to close down. A long-term strategy to set up backup instances of Rucio and the CDB at KEK before the end of the U.S. fiscal year is now underway. Adequate human resources to operate this new service remain a concern.

4.3.1 Concerns

- GPU resources are increasingly common in computing centers, and over time this trend may lead to a decreased availability of other types of resources.
- The computing resources required to train the AI models may be significant and must be factored into the overall resource estimation.
- Belle II uses two instances of DIRAC (BelleDIRAC and BelleRawDIRAC) for off-line and on-line, respectively, which currently run on different major versions.

While this setup offers ad-hoc flexibility, in the long term-term the goal should be to synchronize their versions.

4.3.2 Recommendation

- The long-term continuity plan to ensure uninterrupted Belle II data taking, in the event that the critical service hosted at BNL becomes unavailable, should be fully implemented and the necessary operating personnel secured.

5 Physics

5.1 Status

Since the last remote BPAC meeting in June 2025, the Collaboration has made significant progress across a broad range of analyses. A total of 14 new results have been reported in key physics areas, including (semi)leptonic B decays and missing-energy modes, rare $b \to s\ell^+\ell^-$ transitions, time-dependent CP violation in the B system, charm and tau physics, dark-sector studies, and quarkonium physics, including a new measurement of $R(D^*)$ using hadronic tau decays.

In the short term, approximately 15 new results are expected for the upcoming winter conferences, with a further $\sim$20 results anticipated for the spring/summer 2026. BPAC congratulates the Collaboration on the high scientific output, across several topics, including the core areas of beauty and tau physics, where the impact of Belle II within the international landscape continues to grow.

In the last two years a publication rate of approximately 30 papers per year has been achieved. The ambitious target of 40 publications annually is within reach of the Collaboration, provided that the data sample continues to increase as planned, in particular if an integrated luminosity of about $1\,\mathrm{ab}^{-1}$ is reached by the end of 2026.

A particularly important methodological advancement is the further development of an approach to measure time-dependent CP asymmetries in channels with missing decay vertex, notably in the $B \to \pi^0\pi^0$ mode and the corresponding determination of the $\phi_2(\alpha)$ angle in the CKM Unitarity Triangle. This is possible thanks to the precise location of the interaction vertex at Belle II. This achievement demonstrates the strong potential of the experiment, even with limited statistics, and it highlights the unique capabilities of the experimental setup formed by Belle II and SuperKEKB together. BPAC warmly congratulates the Collaboration on this accomplishment.

The committee also welcomes the proposal to hold a “Belle II & Theory” workshop in July in Vienna. This three-day workshop, planned for the week preceding the collaboration meeting, is intended to foster closer interaction between experimental and theoretical communities and help maximize the scientific impact of future results.

5.2 Concerns

- Achieving an integrated luminosity of approximately $1\,\mathrm{ab}^{-1}$ in 2026 is essential for maintaining, and potentially increasing, the publication rate.
- While the idea of a "Belle II & Theory" workshop is excellent, dedicating each edition to the full Belle-II physics program may limit the depth of discussion achievable within the available time. It may be beneficial to consider alternating these broad-scope workshops with more focused, thematic meetings that foster deeper interactions between theory and the Belle-II experiment in specific areas, along the lines of the Belle-II Physics Week meetings of the past few years.

5.3 Recommendation

- A number of proposed measurements in the area of spectroscopy requiring dedicated energy scans have been presented. While these studies are of clear interest in the longer term, they would entail a reduction of the integrated luminosity collected at the $\Upsilon(4S)$, which remains central to the broader Belle II physics program. For this reason, the committee considers that such measurements should not be prioritized at the present stage.

6 LS2 upgrade

6.1 Physics motivation

6.1.1 Status

The Collaboration presented an updated report on the LS2 upgrade. The upgraded experiment is expected to begin data taking in 2034, with the goal of reaching 50 ab^{-1} of integrated luminosity by 2043. A key upcoming milestone is the completion of the TDR in the summer of 2027. While the physics motivations for the 50 ab^{-1} target remain broadly aligned with the 2018 Belle II Physics Book, the projected physics reach now significantly surpasses those earlier studies. The experiment is poised to deliver world-leading measurements across a broad range of topics, including semi-leptonic B decays to tau physics, EW penguins, dark sectors, and time-dependent CP asymmetries. Highlights were presented on the sensitivity of flavour and dark sector analyses to leptoquark and SUSY scenarios, as well as to models with axion-like particles. BPAC notes that recent studies carried out by the particle physics community worldwide, in the context of the 2026 European Strategy for Particle Physics Update (ESPPU), further underscore the strong impact of the Belle II physics reach at 50 ab^{-1}.

The Collaboration is currently evaluating detector options for the LS2 upgrade, having narrowed the number of candidates since previous meetings. Numerous performance studies are underway, with varying degrees of maturity. The exploration of the physics reach of forward taggers is a particularly novel development.

6.1.2 Concern

- A substantial amount of work remains to finalize a comprehensive TDR. Furthermore, the ambitious timescale for the upgrade and the subsequent collection of 50 ab^{-1} represents a significant concern.

6.1.3 Recommendations

- Ongoing performance studies should be completed as soon as possible to select the optimal detector configuration(s). It is important that the TDR is not delayed beyond the summer of 2027.
- BPAC supports further studies of the ultimate Belle II physics reach, both with and without beam polarization.
- BPAC supports the implementation of week-long test runs for Chiral Belle in the coming years, provided it does not affect the core Belle-II physics program. While Chiral Belle may yield compelling physics results, achieving the 50 ab^{-1} luminosity goal must remain the highest priority.

6.2 Machine-detector interface

6.2.1 Status

The MDI group has become a very important part of the effort to improve machine performance. It has continued to monitor backgrounds and extrapolate present measurements to higher current and higher luminosity conditions. The group has expanded efforts in studying injection backgrounds and in improving standard operating procedures while it continues to help in speeding up abort signals and in locating SBL sources. ML techniques are being applied where they can help with everyday optimization. A group from CERN that uses XSuite (a new accelerator simulation tool) has joined the machine team with the intention of obtaining a better understanding of linac, injection and storage ring performances. Backgrounds in the detector, beam lifetimes and injection efficiency are all contributing to the overall machine performance. The MDI team is well positioned to help the accelerator teams (linac and rings) and the detector team in understanding and controlling these very important issues especially as the LS2 hardware upgrade plans will push all aspects of the SuperKEKB complex into new territory.

6.2.2 Concern

- The SBL beam abort rate has been vastly improved through the removal of all known Vacseal uses. However, SBL events are still occurring, some with pressure bursts and some without a pressure burst signature in both rings.

6.2.3 Recommendations

- The committee urges continued effort to track down and localize SBL events with faster detectors and diagnostics. This is becoming more important as many of the SBL events do not have a pressure burst signal.
- The committee encourages further efforts by the MDI group to help improving the performances of accelerator and injection, and basic operation procedures.

6.3 Tracking detector

6.3.1 Vertex detector (VTX)

6.3.1.1 Status

An update on the proposal to replace the current vertex detector (VXD), as described in the Framework Conceptual Design Report of 2024, was presented. The new detector, VTX, will replace the current 2-layer PXD and the 4-layer SVD detector. The updated design has two inner layers (iVTX) and three outer layers (oVTX). The team has adopted the new QCS geometry that reduces the forward tracking acceptance from 17° to 22° and limits the space available for the routing of the cables. As a result, the outer detector, oVTX, will only have three layers rather than four as was foreseen earlier. The proposed geometry puts the five layers at radii of 14, 22, 86, 109 and 137 mm. A material budget of 0.3% (0.8%) X_0 per layer is targeted for the inner (outer) layers.

The VTX will use one sensor design for the whole detector, the Obelix (Optimized BELle II pIXel) sensor, a depleted monolithic active pixel sensor in 180 nm technology, with 33 μm square pixel size. The pixel matrix is based on the Tower-Jazz Monopix2 sensor with a redesigned periphery. An external review of the sensor design was held and recommended changes are being implemented with a submission of the Obelix-1 sensor targeted for March 2026. First devices are expected in the fall of this year. Preparations for the characterization are ongoing. A submission date of early 2028 is being targeted for the final sensor design.

Conceptual designs for the inner and outer layers have been proposed. The inner layers will use an “all-silicon” concept with a redistribution layer (RDL) and thermal pyrolytic graphite (TPG) as heat conductor. The outer layers will use an omega-shaped support structure with a cold plate and flex circuit and an embedded water cooling line. Readout will use the CERN-based lpGBT and VTRX+ ASICs.

System integration of the detector is in its early design stage. A workshop is planned for May this year to evaluate the integration with the interaction region.

The team is to be congratulated for significantly advancing the design of the VTX detector and having a strong management team in place with well-defined responsibilities. Submission of a technical design report is scheduled for the third quarter of 2027.

6.3.1.2 Concerns

- The schedule for the VTX is aggressive, especially given the fact that gaps remain in finding collaborators to assume the responsibility for different elements of the detector.
- The design of the VTX detector depends strongly on the final design of the QCS. Different options are still being discussed for the QCS. There is a serious concern that the final design of the QCS may come late and adversely affect the design of the VTX.
- Cooling of the detector is challenging. Demonstration of the cooling principle with dummy devices is highly encouraged before submission of the technical design report.
- The availability of test beams may be limited in the next few years. An evaluation of the test beam needs and access to these facilities is encouraged.

6.3.1.3 Recommendations

- Assemble the VTX team as quickly as possible with firm commitments for the various subtasks.
- Work closely with the QCS team to ensure that all relevant information affecting the VTX detector is shared in a timely way. Having regular in-depth meetings to review each other's design is recommended. Include in the schedule milestones related to the QCS design and construction that impact the VTX.
- Continue to work closely with the physics performance upgrade group to optimize the design, explore trigger strategies and study tolerance to machine backgrounds.

6.3.2 Intermediate tracker (ITT)

6.3.2.1 Status

Two options are being considered for the tracking system between the VXT and a drift chamber, oDC, corresponding to the radial volume (17 cm $< r <$ 34 cm): one is an insertable drift chamber, iDC, and the other a silicon based Inner Tracking and Timing (ITT) detector.

The baseline design of ITT consists of a single Fast Timing Layer (FTL) for enhanced particle identification (PID) and a two-layer Silicon Transition Layer (STL) to maintain and improve tracking performance.

The FTL is designed for low-momentum PID via high-precision time-of-flight measurements. The primary performance targets are a timing resolution of 50 ps and a material budget of 1.5% of X_0, optimized for low-p_{T} tracks ($100 - 200$ MeV/c). Reaching these specifications would significantly extend the PID capabilities of Belle II in the low-energy region. The FTL utilizes AC-LGAD (resistive front side n-implant) technology, which offers a near 100% fill factor alongside simultaneous precision timing and spatial resolution. This effort leverages extensive R&D from the ePIC detector at the Electron Ion Collider (EIC). Based on the ePIC Barrel-TOF baseline detector, the core costs are estimated at 2.8 to 3.2 million Euros, depending on the final radial placement.

The STL serves as a tracking buffer, filling the gap left by the oDC with more radiation-tolerant sensors. The proposed technology utilizes active CMOS strips. By employing a monolithic process, the design minimizes wire-bonding requirements, reduces assembly complexity, and lowers the material budget. The current two-layer configuration requires approximately 2000 modules, with a preliminary cost estimate of 3.7 million Euros.

The project follows a targeted timeline:

- 2026–2027: Sensor design and pre-production.
- 2028–2029: Full-scale chip characterization, final readout architecture, and stave R&D.
- 2030–2031: Full production runs.
- 2032: Installation and commissioning.

The ITT relies on existing technologies, allowing the team to focus on adapting lessons from EIC ePIC and ATLAS ITk rather than fundamental R&D. A baseline design must be finalized for the upcoming summer upgrade workshop.

6.3.2.2 Concerns

- Both the FTL and STL sub-projects currently lack sufficient dedicated development teams. Given that AC-LGAD is a relatively new technology, the participation of experienced experts is critical to project success.
- The project currently lacks a robust contingency plan. The timeline from production to 2032 installation is tight, and any delays could jeopardize the upgrade window.

6.3.2.3 Recommendations

- The choice between the two options, iDC or ITT, should be made fast. Given the anticipated harsh radiation environment, the committee considers that the ITT is the prudent solution.
- The committee strongly recommends aggressively recruiting and formalizing a dedicated technical team with the expertise required to design, prototype, and build the ITT system.

- The committee suggests appointing a dedicated Project Manager to oversee the integration, track milestones, and manage the technical interface between the FTL/STL teams and the broader Belle II upgrade.

- Early-stage prototyping and beam tests should be prioritized in 2026 to validate the 50 ps timing resolution target under Belle II-like conditions.

6.3.3 Drift chamber

6.3.3.1 Status

With luminosities well beyond 10^{35} cm^{-2}s^{-1} after LS2, the baseline of the upgrade foresees replacing the CDC in order to cope with even higher background environment than now. As described in Section 3.2, already the long-term performance of the current CDC is a serious concern for various radiation damages.

As described in Subsection 6.3.2, while the outer region of the current CDC will be replaced by a new drift chamber, oDC, in the baseline design, two options are currently envisaged for the inner part, either an insertable drift chamber, iDC, or a system of solid state detectors, ITT.

The two drift chambers are not considered as clones of the CDC, but rather based on a new design with better performance and capabilities. The upgrade also includes new FE electronics that could be used with the existing CDC. The iDC and oDC will be developed together, being only mechanically distinct. At this stage, there is no engineering design and it is not clear whether iDC and oDC might share the same gas volume or not.

6.3.3.2 Concerns

- Available human resources are not sufficient to continue with both CDC operation during Run 2 and the need to finalize design studies and drawings for the new iDC/oDC drift chamber by end of 2027.

- The inner CDC volume may not be suitable for drift chamber operation beyond LS2, due to the risk of high background rates/occupancy and subsequent ageing effects.

6.3.3.3 Recommendations

- The committee fully supports the baseline design and urges the collaboration finding resources for the chamber design study.

- As already suggested in Subsection 6.3.2.3, the committee considers the ITT to be a better solution for the inner region, rather than iDC. This also allows the drift chamber group to concentrate on the oDC design work.

- Best practices developed for the construction and operation of radiation-hard gaseous detectors at CERN need to be adopted and strictly followed for the design and construction of the new drift chamber. Collaboration with the CERN-DRD1 groups is encouraged.

6.4 Other detectors

6.4.1 Status

Several additional upgrades would improve tolerance to high backgrounds and rates or would extend scientific reach.

- **ECL electronics** upgrade would reduce the shaping time from 500 ns to 150 ns and increase the sampling rate from 1.7 to 7.9 MHz, for a more targeted trigger and less sensitivity to pileup noise and background. A new ECL trigger chain will be needed. Simulations of the impact on performance for γ's and π^0s are commencing. This upgrade is addressed in the section on the ECL above.

- **TOP electronics** would allow lower gain operation and extend the life of the MCP-PMTs, which are already experiencing decreased quantum efficiency. The plan is to develop a high gain, low-noise, low-power amplifier that would enable PMT operation at a lower HV. In addition, the SCROD would be relocated from the detector to the electronics hut to reduce sensitivity to single event upsets and facilitate maintenance. Relocation will reduce the heat load on the detector, but requires a high speed data link to the E-hut.

- **KLM proportional readout** would recover efficiency at high rates. This upgrade, which requires new, possibly relocated pre-amp boards as well as a new, more eco-friendly gas, is addressed in the section on the KLM above.

- **Forward taggers** would increase sensitivity to axion-like particles with 1 - 10 GeV masses. These detectors would need to tolerate high radiation and high rates, and the signal may be buried in backgrounds such as radiative bhabhas.

- **Chiral Belle** is a concept for polarizing one beam in order to access electroweak measurables. No detector upgrades are required.

If successful, these upgrades would bring important improvements to Belle II performance and rate tolerance, and the committee encourages the collaboration to pursue them. However the timeline is short: the baseline is to be defined in just six months (Summer 2026) and the TDR must be complete by mid-2027.

6.4.2 Concerns

- The time available to develop and test its many components is short. In some cases, such as the KLM, a test setup is available but may not fully capture the behaviour of the operating device. For that reason, bench tests should be supplemented with in situ tests wherever possible.

- Changes to electronics located on or near the detector may be awkward or have unforeseen side effects.

6.4.3 Recommendations

- Define the baseline upgrades by Summer 2026, as planned, and proceed promptly to prototype development and testing.
- Where possible, ensure that tests go beyond the bench, and probe the performance of new devices on the working detector and in real operating conditions.

6.5 Expected detector performance

6.5.1 Status

As described above, the upgraded detector will feature new tracking systems, an upgrade of the ECL electronics and more limited upgrades to the other systems. To guarantee the success of the upgraded experiment it is important that the detector maintains or improves upon the existing detector in terms of efficiencies, resolutions and background in the key physics measurements. The time to produce the TDR is short and different detector scenarios still need to be worked out. Hence it seems necessary to take shortcuts in the analysis required to make choices. On the other hand, the impact on the tracking performance from a possible reduced acceptance, extra tracking layers, a heterogenous tracking system, and differences in material distribution may be larger than expected, hence some detailed studies may be required.

The committee is impressed by the activity in the collaboration. The new tracking detector will feature a variety of different technologies, with the most extensive system consisting of up to five different subdetectors (PXD, SVD, FTL, STL and CDC). The foreseen improvement of the new VTX system for single track efficiency is impressive, and the projected performance in for momentum resolution and of the FTL for particle identification is promising.

The momentum resolution of the new tracking system has been studied relatively easily with "MC cheated" track finding. What seems missing is an overall assessment of tracking efficiency and resolution with realistic track pattern recognition and the impact of the new tracking system on the performance of the outer and forward PID systems.

6.5.2 Concerns

- The track reconstruction of the current detectors relies on standalone track finding in the SVD and in the CDC. The performance on the track finding of a system with fewer CDC tracking layers has not been well studied yet.
- It is expected that that to make performance estimates and derive at design choices shortcuts need to be taken in particular on amount and distribution of material. It is expected that for the TDR simplified models for the distribution of material are used. This leads to the risk that performance estimates are not sufficiently accurate, neither to compare different design choices nor to validate that the final design satisfies the physics performance requirements.

6.5.3 Recommendations

- The committee advises to implement as soon as possible a realistic algorithm for global track finding. In addition to the SVD standalone track finder (followed by track following into the other detectors), a single algorithm that can use heterogeneous input from all the different tracking systems simultaneously would be very convenient at this stage. As timing consumption of such an algorithm is not relevant now, it could probably be developed rather quickly, inspired by, but not limited to, what is currently used for the CDC. Automated machine learning can be used to optimize the parameters of such an algorithm (selection of seeds, windows when following seeds, assumed scattering errors, etc.) such that detector scenarios can be compared with reasonably optimized track efficiency and fake rates.

- It will be difficult to obtain final material budgets for each studied scenario leading to an uncertainty in the projections. This also holds for subdetector hit noise rates, hit efficiency loss due to ageing, and machine induced background. It is recommended to parametrize these unknowns as far as this is not yet done (for instance by inserting layers of insensitive material) and study the performance within reasonable bounds of the parameter space, in conjunction with the optimization of the tracking algorithms.

- The impact on neutral reconstruction and the calorimeter and PID systems must be part of the tracker design optimization, yet require expertise beyond that of the tracking developers. It is recommended that standard measures be developed based on key physics measurements in such a way that collaborators working on the upgrade of the tracking system can evaluate the impact on the rest of the system.