

# B-factory Programme Advisory Committee

## Focused Review on Online and DAQ Integration Status

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### **Full Report**

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## **1 Executive Summary**

This review focused on the Belle II online system and the status of the sub-detector integration. The meeting started with a short presentation on the current status and plan of the experiment in general. The sub-detector installation and related commissioning work is progressing well. The detector magnet was switched on for several weeks to measure the magnetic field in the tracking volume. It was then found that the field generated mechanical stress on the photon detectors of the barrel particle identification system, TOP. As a result, a small number of TOP photon detectors moved enough to produce optical decoupling at the PMT/wedge interface and affect the photon detection capability of these detectors. Provided that the number of decoupled PMTs remains small and stable, the over-all deterioration of particle identification in TOP should be small and the collaboration has decided to continue with the detector installation and commissioning. Similar mechanical stress is expected on the ARICH photon detectors too, but studies show that no movement of the photon detectors would occur. The committee supports the decision by the collaboration but urges them to carefully monitor the performance of TOP and ARICH and to develop a repair strategy for possible intervention in the future if the performance deteriorates. The committee also takes note of a tight production schedule for the layer-six of the Silicon-strip Vertex Detector (SVD). There was a setback in the production of readout ASIC chips for the Pixel Detector (PXD) resulting in a delay of three months for the start of the installation of the Vertex Detector system (VXD), i.e. PXD and SVD, to Summer 2018.

The Belle II online system performs many functions. It generates the trigger signal based on the  $K_L$ -muon detector (KLM), Electromagnetic Calorimeter (ECL), TOP and Central Drift Chamber (CDC), and distributes the readout timing signal. It also controls the data acquisition, operates the detector by controlling and monitoring the functionalities of the sub-detectors as well as providing the machine-related parameters near the interaction point to the machine group. The overall system is well designed and implemented by a relatively small number of competent people working very effectively and also providing services to the sub-detector groups who are responsible for commissioning and integration of their system into the central Belle II online system. The general framework is ready for the integration work by the sub-detector teams.

In the Belle II data acquisition system (DAQ), the front-end electronics of all sub-detectors, except the PXD, are read out by common custom-made boards (COPPER) through optical cables with a common protocol followed by the first level of event building without PXD. COPPER is based on off-the-shelf equipment. A scaled down version of this system, so called POCKET DAQ, is provided by the online team for the sub-detector groups. The POCKET DAQs are being used for the standalone commissioning of the individual sub-detectors in a way compatible with the central Belle II DAQ system. This is an excellent idea and has allowed a smooth transition from the commissioning of individual detectors to the integration of the entire system. Several sub-detectors have already been successfully integrated into the central DAQ system. The forthcoming important milestone is the global cosmic-ray run starting in April 2017, initially with all the installed sub-systems but the ARICH and Forward End-cap ECL, which will join for the “second campaign” taking place in the second half of 2017. After the standalone cosmic-ray run, the VXD placed outside the Belle structures will join the global cosmic-ray run followed by the installation in Summer 2018.

With the information from the first level of event building, an event is fully reconstructed for an event selection (HLT) and track parameters are sent to a dedicated PXD readout electronics (ONSEN). Using those parameters, narrow “regions of interest” (RoIs) are defined in the pixel sensors, whereby only the clusters inside of the regions are read out in order to reduce the amount of data by a factor of ten. These clusters are then added in the second level of event building and the complete event is sent to a storage device. This readout scheme, based on RoIs, was successfully tested during test beam data taking at DESY with a VXD prototype, using SVD data to define the RoIs. The HLT structure has been well designed and implemented, and benchmark algorithm studies show very encouraging results.

The Belle II experiment deploys NSM2 and EPICS for the Slow Control system. The former is the main system for the experiment also used by the run control. The latter is used by the VXD and related items such as the  $CO_2$  cooling system where much of the control software already exists in EPICS. EPICS is also used by the SuperKEKB machine. A gateway was made connecting the two systems and a common user interface is being developed using Control System Studio for the controlling and monitoring of the sub-detectors.

The committee congratulates the central online team for the successful implementation of the complex online system for the Belle II experiment. It is now important to

prepare for stress tests of the system with the complexity, size and rate of data following realistic patterns expected from the experiment. The global cosmic-ray test in 2017 will be an ideal occasion. The committee considers that the size of the central online team is worryingly small. In addition to finding more people for the team, DAQ experts of the sub-detector groups are encouraged to extend their scope to some of the central online work in parallel with the integration work of their sub-detectors.

The committee recognises the practical reasons for deploying NSM2 and EPICS for the Slow Control system. However, the overhead required to integrate and maintain two systems smoothly in a coherent manner should not be underestimated. Special care must be given to the user interface so that all sub-detectors are controlled and monitored in a unified manner independent of hardware differences. Continuous discussion must be maintained with the machine group to identify necessary information from the experiment for optimising the machine operation. It should be noted that some of those inputs may need to be provided with a much higher rate than usually foreseen in a slow control system. For the interlock system, the committee recommends case studies of the system behaviour for all possible incidents in order to ensure the safe operation of the experiment and machine. It is important that some of the machine elements in the detector, such as the superconducting focusing magnets, should be taken into account in the studies.

In the KLM system, the operation procedure of the newly installed scintillator detector and existing Resistive Plate Chamber detectors must be well integrated. A detailed plan for the overall commissioning and integration of the system is still missing. The ECL system is at a very advanced state and it would be useful to test the longterm stability of the DAQ and Slow Control systems with this sub-detector. The CDC is also in an advanced state and the committee is looking forward to seeing tests with more channels. The progress made by the TOP group was impressive including the recent advancement in the firmware development. The committee encourages the group to keep the momentum for the commissioning and integration effort. An intense firmware effort is still required until feature extraction is operational and the TOP is integrated into the central DAQ system. The committee encourages the ARICH group to advance with the purchase of the high-voltage cables and power supplies, which limit the scale of the commissioning activities. Compared to the effort still needed for the DAQ integration, human resources allocated appear to be too small and the committee suggests the ARICH group and the Belle II collaboration address this issue. Operation of the SVD and that of PXD are very closely related and coherent operation procedures must be developed in a close collaboration. A system test of VXD with the Permanent Running System at DESY (PERSY) should be fully exploited for this purpose and it will also help for validating the readout electronics and providing smooth integration of the VXD system into the central DAQ system.

In the following sections, Belle II Online System, Detector Operation and Sub-system Integration Status are described in detail.

## 2 Belle II Online System

The committee is very pleased with the enormous progress made in the Belle II online system, which for the purpose of this review it is divided into Readout System and Data Acquisition.

### 2.0.0.1 Concern

- While there are no major worries on the readiness of any of the components reviewed in this section, there is a concern regarding the critical dependence of all these systems on a very small team based at and employed by KEK. This team will be even more busy in the imminent commissioning phase of the experiment, being frequently solicited by the sub-system groups.

### 2.0.0.2 Recommendation

- It is recommended that the collaboration encourages suitable members to be trained as DAQ and readout experts to be able to offload the central team and to act as DAQ integration experts.

## 2.1 Readout System

### 2.1.1 Trigger and Timing Distribution

#### 2.1.1.1 Status

The Trigger-Timing-Distribution system (TTD) for Belle II consists of a set of hardware board, Front-end Timing SWitch (FTSW), and a dedicated link protocol (*b2tt*). The system has been used for the global detector commissioning as well as for the individual sub-system tests (Pocket-DAQ). The central TTD system is completed and the sub-detector TTD system for CDC, TOP, ECL and KLM is fully or partially integrated to the central system. The other sub-detector DAQ system, PXD, SVD and ARICH, has been running with the TTD system in the framework of a Pocket-DAQ. The Belle II TTD system is able to support multiple DAQ partitions run in parallel. One combined DAQ partition runs in parallel to multiple individual sub-system partitions without recabling. The excellent flexibility covers most of the requirements from the experiment.

Concerning to the link protocol of TTD, *b2tt*, instability was reported in the past, however after fixing problems, *b2tt* shows good stability and no problem has been reported from various commissioning programs. The FTSW board also performs the function of configuring the FPGAs on the sub-detector Front End Electronics. The JTAG sequence is implemented in the *b2tt* protocol and used to configure the FEEs of the CDC, ECL and KLM.

#### 2.1.1.2 Concerns

- As part of the central DAQ system, the Trigger-Timing-Distribution system (TTD) for Belle II is in good shape and integration and commissioning of the sub-detector DAQ system are progressing, therefore no major concern has been identified.

- However there is an issue with configuring the FPGAs of the TOP via JTAG. This must be addressed between the TOP and DAQ teams.

### **2.1.1.3 Recommendations**

- At every major step to increase the size of the global DAQ system, stress tests with a pseudo-Poisson random trigger of 30 kHz or more with a relevant hit occupancy are essential. Weak points in the TTD system may appear as well as a better way to minimise DAQ dead-time will be developed through the tests.

## **2.1.2 Belle2link**

### **2.1.2.1 Status**

The committee notes with great satisfaction that all problems with the Belle2link, a critical common item of (almost) the entire Belle II readout, have been successfully resolved. The team is to be congratulated for their efforts.

### **2.1.2.2 Concern**

None.

### **2.1.2.3 Recommendations**

- A lot of expertise has been accumulated during the debugging and early commissioning phase. It is recommended that the already existing documentation is augmented as much as possible with this knowledge to create a comprehensive debugging and configuration guide, which will be very useful for eventual future applications of the Belle2link, for example if new sub-detectors should ever be added to Belle II.

## **2.1.3 COPPER and Readout Sub-systems**

### **2.1.3.1 Status**

The COPPER board is one of the key elements of the pocket DAQ, which is used to commission the trigger and DAQ systems of the sub-detectors. During the review no major concerns have been noted in the operation of the COPPER board, beyond known limitations of the hardware itself, which is working well within its specifications.

### **2.1.3.2 Concerns**

- The COPPER hardware is well tested but relatively old, and while it was prudent from an economical standpoint, to reuse the existing design, it became clear during this review that the board has its limitations, owed mostly to its original design. For instance the output-speed is limited to 1 Gigabit/s, which is below the capacity of a single Belle2link. If no data-reduction can be performed, a rebalancing of the data is required, which in the case of the SVD would mean increasing the number

of FADC boards, only because of this bandwidth limitation. This seems somewhat unfortunate and costly.

### 2.1.3.3 Recommendations

- It is recommended that the DAQ team starts to consider, at low priority, a new version of the COPPER board. Since the specifications are very well defined, this could also be an interesting project for a new group joining Belle II, which has the required expertise in electronics. Such a board should ideally have larger output buffering, at least 10 Gigabit output bandwidth to match the Belle2links and an upgraded MCU for local processing and data-flow steering. Using modern technologies it should be possible to create such a board within the same cost envelope as the existing one.

## 2.2 DAQ System

### 2.2.1 Run Control

#### 2.2.1.1 Status

The responsibility of the run control is the coherent configuration and steering of all elements of the Belle II detector participating in the data taking process. These elements may be hardware based such as individual sub-detectors or sub-components thereof or software components such as the High Level Trigger (HLT). In a simplified picture this configuration must be able to handle these discrete steps:

- Firstly the desired configuration is retrieved from the DAQ database.
- Then the hardware is configured according to the retrieved parameters. In the data flow, data sinks are prepared and activated.
- Data sources are prepared and connected to the corresponding data sinks.
- The trigger is enabled and data taking starts.

The run control configures multiple components as components of a Petri-grid according to the presented state diagram. It is unclear from the scheme that was presented what is the procedure in the event of the failure of one or several sub-components. The state of the run control itself is some combination of the states of all sub-components. The committee agrees that in general the presented state diagram of the Belle II run control can handle these required aspects.

It is understood by the committee, that if one or several components fail a transition the overall DAQ state of the run control is NOT-READY though only the failing components is actually NOT-READY and all others are in the desired target state (READY, RUNNING, PAUSED). To recover this situation and continue with the experiment configuration the failed components subsequently must re-execute the failed transitions. From diagram shown, it is unclear how procedure works in practice. If the recovery

procedure uses the “Abort” command, which is described in the text, though not part of the figure, then this triggers a forced transition of ALL components from any state to NOT-READY, a so-called “Reset-system” command. Such a behaviour in the absence of a well defined component recovery mechanism may lead to slow and painful startup and recovery procedures in the event of failure of one or multiple components.

### 2.2.1.2 Concerns

- The current design of the state machine of the Run-Control does not support the recovery of individual subcomponents in the event of failing a transition. Given that firstly the Belle II DAQ is a fairly complex system with many components and secondly the chance of any component may fail is finite this may lead to problems configuring the whole system in a timely manner. In particular during the startup of the experiment the configuration phase before taking data are typically lengthy and rarely without problems. Hence, the recovery of individual components should firstly be as quick as possible and secondly not have side effects on other sub-detectors or sub-systems in order to minimise the startup time. Such localised recovery procedures are currently not supported.

### 2.2.1.3 Recommendations

- The presented concept has no fundamental errors. As always, the difficulties are in the details, and handling exceptions is always challenging and difficult to anticipate exhaustively. However, identifying all these exceptions (component failures, etc.) is clearly beyond such a review. These can only be identified during the commissioning and the integration of the sub-detectors. A clear commissioning check-list together with each sub-detector can help.

## 2.2.2 Online Databases

**2.2.2.1 Status** There are four major databases, which provide the basic information to steer and configure the experiment hardware components as well as the corresponding software components such as the HLT or the storage and store information obtained during the data taking activity necessary to later interpret the event data from particle collisions:

- DAQ DB. Repository of readout configurations. Accessed by the run control to configure sub-systems. This database is implemented and interfaces to the run control software. The data is used to steer the data taking activity and command line tools, which allow extraction of this information from the database exist. The committee concludes that the DAQ DB is a well-designed module describing sub-systems. Since this should be a rather small database  $O(10)$  gigabytes, no problems are expected. Thorough enhanced testing during the commissioning phase of the sub-detectors will help to identify potentially hidden problems.

- Conditions DB. This database is used by HLT and the Express Reconstruction (ER). In the online system this database is read-only and entirely imported as a snapshot.
- Run/File DB. A repository of all runs/files created while taking data in the experiment. (Logically a part of the data storage!)  
The database is implemented and interfaced to the storage applications. Users can retrieve information from the database either using a web based GUI or a command line application.
- Logger DB. The purpose of this database is to save logging messages of all components participating in the data taking activity for later analysis and correlation to incidents while taking data. The components populating this database are the run control, the front-end hardware as well as software based components such as the slow control toolkit based on EPICS or the HLT using the data processing framework basf2.

#### 2.2.2.2 Concerns

- Whereas logging operational messages from the steering of the experiment should be very well feasible using a database, the logging database may easily be swamped with many messages from the HLT simply because identical copies of the processes produce roughly identical messages. As an example: LHCb produces  $O(1-3)$  gigabytes of output logs per day from  $\sim 50k$  cores. Scaling down a factor of 10 (Belle II has less HLT cores) leads to  $700 - 2000 \times 10^3$  message table rows per day, or at least  $70 - 200 \times 10^6$  rows per year assuming 100 days of physics. This is not a small database. The committee sees a clear need to log output messages in order to allow in-retro investigations of failures. Whether a database as the unique message logging medium is the most effective approach is less clear.
- The Run/File DB as a relatively small application probably consisting of one single table. However, if the offline data processing requires access to more data specifying the event content of a file the implementation may require further sophistication. It must be ensured that the basic required functionality and performance of registering recorded data files is not compromised by the implementation of possibly upcoming future requirements.

#### 2.2.2.3 Recommendations

- The need may arise to also feed the conditions DB from online data sources such as real-time online calibrations, which should be activated quickly, i.e. during a run-change. The proposed model of importing such calibrations using well tested conditions DB snapshots is very robust. By nature of the implemented robustness, it is also relatively slow: updates take  $O(1)$  day. The Belle II online team should verify that this snapshot update frequency is sufficient to operate the HLT and the ER.



- The online team should verify if the advantages to correlate output messages from various sources is technically feasible without problems if the message data should stay accessible in the long term. Otherwise they should decide if it is worth the effort of saving all the logger messages in a database.

### 2.2.3 Event Builder

#### 2.2.3.1 Status

The first stage of event building is performed in the COPPER boards and consists of a merge of maximal four input links into one output stream. Since this level of event building is tested during all standalone sub-detector hardware tests the committee is confident that this approach would cause no fundamental problems.

The second level of event building happens at the input stage of each HLT worker node and assembles the data originating from one particle collision of all sub-detectors except the pixel device PXD. The final size of the HLT with 6400 cores or  $O(100)$  physical CPUs leaves us with a event fragment rate of 90 kHz per node.

For all events accepted by the HLT filter, the actual raw data are sent to the storage layer and a descriptor containing the decision is sent to the ONSEN box, where a temporary buffer for the pixel data is awaiting for the HLT decision to either be discarded or sent to the 3<sup>rd</sup> layer event building in storage layer.

The third level of event building takes place in the storage layer when merging the HLT accepted events received from the HLT facility with pixel data received from the ONSEN box as part of the pixel readout. The committee feels that given the HLT demands are satisfied, the fragment rates per storage device are relatively modest and should not impose a problem. The handling of the corresponding data rate of  $(1\text{MB} + 200\text{kB}) \times 10\text{kHz}$  is feasible with available technology and should also be achievable within budget using COTS networking components.

The event-building implementation was tested both under laboratory conditions and while commissioning the first sub-detectors. The mechanism seems to work quite reliably according to its design and within the required specifications. Possible hidden bottlenecks will have to be identified and solved during the commissioning phase.

#### 2.2.3.2 Concerns

- The ONSEN system must be capable of buffering the pixel data across all possible delays arising from the data transfer and decision transfer paths between the front-end, the COPPER boards, the HLT and finally the ONSEN. Whereas the amount of input data from the HLT to the ONSEN is very moderate, the buffering capabilities may be substantial. The above mentioned delays can potentially be large assuming that, e.g. the detection of missing sources in general is solely possible by timeout mechanisms.
- During the review a long duration test was presented concerning bit error rates. The committee feels that in general the bit error rate is not a concern. However for a sizeable fraction of the events ( $\approx 40\%$ ) these errors concerned the event headers

and trailers. Simple bit errors should affect randomly the entire data payload and should not favour the relatively small data headers and trailers. Header and trailer errors are much more serious than normal transmission errors, since these provoke a halt of the DAQ data flow and require externally triggered re-synchronisation. The committee feels that these errors have a different origin (timing problems, timeouts, etc.) at some stage during the data transmission from the front-ends and the HLT, in particular because the data patterns of these occasions did not suggest single bit errors. A rough calculation extrapolating the test setup to the full experiment size (input sources and rate) lead to  $O(10)$  minutes between such occurrences, which can be a significant problem if the recovery time is anything longer than a couple of seconds.

### 2.2.3.3 Recommendations

- The source of the bad event header- and trailer-data should be investigated. The estimated occurrence of such events of  $O(10)$  minutes could seriously affect the data taking efficiency.
- The ONSEN buffering capabilities should be checked against the maximum estimated fluctuations.

## 2.2.4 High Level Trigger and Express Reconstruction

### 2.2.4.1 Status

The committee is very pleased by the presentation of a preliminary implementation of the HLT filtering algorithms together with timing measurements based on the expected mixture of the various physics channels. The committee feels that the chosen approach using multi-threaded in-process parallelisation is an adequate solution to achieve a scalable behaviour even in view of possibly upcoming new generations of CPU designs. The presented design is scalable up to processors with  $O(20)$  cores per worker node. The thorough re-use of components (socket senders, socket receivers, ring buffers etc) between the various software based processing elements (HLT, ONSEN, Storage, ER) ensures high reliability, minimises the implementation effort and last not least the maintenance burden.

The presented CPU usage of the various physics channels with an average of 0.24 second per event for one core is within the available budget of 0.33 second and leaves some margin to cope with worse than assumed beam conditions or more sophisticated selection algorithms.

### 2.2.4.2 Concerns

None.

### 2.2.4.3 Recommendations

- If access to modern machines is possible, tests should be performed on new architectures to ensure that the presented scalability is preserved. Such tests would also allow to access new hardware features such as wide registers (AVX), NUMA, and others.

## 2.2.5 Express Reconstruction and Data Monitoring

### 2.2.5.1 Status

The basic data processing framework of the ER based on basf2 is identical to the HLT. From this point of view nothing should go wrong. However, the software configuration in the prompt reconstruction may become a sociological exercise, since many developers will contribute numerous modules to one single application. On one hand, this is very efficient in terms of data access, since data have to be unpacked only once, but on the other hand it must be ensured that the resulting application (and there is only one flavour of it), is solid and coherent. One bad module has the potential to cripple the data monitoring based on reconstructed objects. Depending on the number of developers contributing physics modules to the HLT application, there the same argument applies. The data transport from the storage facility to the ER is of a different nature than the data transport from the HLT to the storage: Whereas the HLT pushes ALL data to the storage, the ER either uses a pull mechanism to retrieve the data from the storage or a dedicated push mechanism ensures that the pipelines on the storage are not blocked, i.e. automatically throws away events in the ER ring-buffer if they cannot be handled by the ER in a timely manner.

### 2.2.5.2 Concerns

None.

### 2.2.5.3 Recommendations

- Verify that the data transport from the storage to the ER nodes is truly parasitic and does not affect the storage performance significantly. Monitoring failures are more tolerable than storage failures, since usually remaining data-quality issues can also be resolved offline.

## 2.2.6 Storage

### 2.2.6.1 Status

The prototype achieved the required data transfer rates of 300 MB/s. With 10 units the required event rate of 30 kHz should be feasible. The prototype system was successfully tested during the VXD beam test at DESY in April 2016. Discovered technical bottlenecks were identified and start to become relevant around an event rate of 7 kHz for one

single storage unit. This looks to be comfortably above the required event rate of 3 kHz per storage unit. Also the measured disk throughput for one storage unit of 660 MB/s, which is twice the required data rate of 300 MB/s gives a comfortable margin.

#### **2.2.6.2 Concerns**

None.

#### **2.2.6.3 Recommendations**

- Confirm scalability tests with multiple storage units running in parallel.

### **2.3 Data Transport Protocol**

#### **2.3.1 Status**

Both the output of the HLT and combined output of the HLT and ONSSEN are sequential files consisting of TMessage objects. The committee recognises the advantage of this approach, namely that the event stream may at any time be interrupted or stopped without any loss of data. In particular this approach does not require file recovery procedures, as it would be the case for true ROOT files (TTree based) in the event of anomalous process terminations or crashes.

The data output streaming using ROOT is elegant, but not for free. This was also discovered by the Belle II online team while implementing the serialisation mechanism. Depending on the sophistication of the event data model ROOT may use considerable amounts of CPU to perform the data streaming. CPU is required for both: stream from objects and streaming to objects i.e. whenever objects are passed from one process to another. The committee is assured that the required CPU power for the (de)-serialisation is well under control and is not problematic.

The committee wants to point out that the sequential buffers created using the TMessages mechanism are vulnerable to changes of the event object model used (schema evolution). The online recorded files do not contain any information about the contained data streamed like other ROOT files. If these files are archived reading them at a later time may become problematic.

Since in HEP generally, raw data files recorded online are “sacrosanct” and typically are never deleted this may be problematic in the long term if the raw data files recorded online are expected to be read in the distant future. The ROOT tree files, which are created as the first offline processing step do not suffer from this limitation, since these files contain the object’s schema information.

#### **2.3.2 Concerns**

- As a corollary of the pure technical aspects of the chosen file- and data-transport format there is also a managerial consequence:  
The Belle II online- and offline-teams must ensure that for both the online streaming and the offline TTree creation process at all times the absolutely identical

software is used (ROOT + basf2 versions). This requirement must be ensured for the entire lifetime of the online recorded data. If the data should stay read- and interpretable for the distant future along the lines of recent data preservation initiatives, this requires maintenance even beyond the lifetime of the experiment.

### 2.3.3 Recommendations

- The chosen online file- and data exchange format imposes both technical and managerial consequences. Whereas the technical aspects seem well addressed, a solution to the managerial consequences were not presented to the committee. The online team should verify that the benefits of multiple serialisation and de-serialisation of the data ( $\approx 4$  times: HLT-out, RoI-Extractor, Storage-in, Storage-out, ONSSEN-out, ER-in) of each event several times until the data are written to disk out-number the disadvantages.

## 3 Detector Operation

### 3.1 Slow Controls, Monitoring and Interlock

#### 3.1.1 Status

The slow control, monitoring and interlock systems consist of two frameworks, NSM2 and EPICS, running on a common network dedicated to slow control and monitoring. NSM2 is the primary program for detector monitoring and run control and EPICS is used by the VXD sub-detector and by the accelerator people. A common GUI application for NSM2 and EPICS is provided by the Control System Studio framework (CSS), which includes an archiver and is the default GUI for EPICS. To display NSM2 information in CSS, a plugin for CSS has been created that supports NSM2 natively. One of the major functions of the slow control system is the operation of the power supplies. In the case of the outer detectors, the high voltage can be applied independently of the DAQ state, whereas for the vertex detectors the state of both low-voltage and high-voltage depends on both the machine state and the run state. The presentations were very thorough and it was clear that a lot of work and thought has gone into these systems. The committee is very pleased to see the progress, and in particular the EPICS state diagram which had been developed and implemented in the DESY beam-test. It was also pointed out in the presentations that more needs to be done to have a system that is ready to be utilised for the upcoming cosmic ray run, and eventually Belle II running. The committee is pleased with the progress that has been made and, at the same time, agrees with the team members that more needs to be done.

#### 3.1.2 Concerns

- As shown by the presenters, a good foundation has been built for the slow control, monitoring and interlock systems, and there is no major concern about the readiness for integration. The immediate concern will now be to complete enough of the

system to be able to safely run the detector for cosmic rays. There are a number of sub-sections of each sub-detector that need careful monitoring and interlocking: from power supply information to temperature checks.

### 3.1.3 Recommendations

- The committee recommends that the monitoring and interlock team work closely with the sub-detector groups (including of course the CO<sub>2</sub> cooling plant) and develop a list of signals needed for monitoring and for interlocking from each group as soon as possible. In addition, the lists should be made with the signals prioritised and described in a uniform way, for example specifying the default status on/off for each set of machine and run states. The interaction with the cooling system is delicate and must be specified as fully as possible, including the relationship between the powering and cooling circuits in the case of the various systems being on/off/start-up/standby/configured modes and so on, and how the systems react in case of power cuts, in particular the definition of the fail safe state for each signal. These detailed specifications will give the team the needed information to be able to list the signals to be hooked into the monitoring system as well as develop a list of critical signals needed for the interlock system. As time goes on and sub-detector knowledge increases, new signals will be formed that will need to be implemented into the monitoring and/or interlocking systems. Especially as each sub-detector becomes fully instrumented, the sub-detector teams will no doubt find new signals that will need to be checked and archived on a regular basis. Each sub-detector group will need to remain in close contact with the monitoring/interlock team to make sure the important signals for their sub-detector are properly installed and handled.
- As far as possible there should be a relationship between the hardware interlock and the same signals entering into the software interlock system, such that the software interlock is designed to interlock in a controlled manner in advance of a hardware interlock being triggered.
- The committee would like to also suggest that the interlock team consult and meet with the accelerator team for the possible sharing of some accelerator signals from machine components near the detector, in particular, some information from the final focus cryostats located inside the detector. The detector will need protective measures when the local cryostats start to drop out of their running state. There are other possible machine sensors near the detector that might be useful, for instance, temperature sensors that are perhaps less than 20 m either upstream or downstream of the detector. Or possibly, the status of power supplies associated with magnets not too far from the detector, again perhaps about 30-40 m from the IP. This recommendation is obviously not needed for the upcoming cosmic ray run but some thought on this subject and some discussions with the accelerator group is highly encouraged.

## 3.2 Communication with the Machine

### 3.2.1 Status

A good conduit of communication has already been established between the detector group and the accelerator group. This was started through the detector background group and in particular through the excellent BEAST team. The BEAST signals were of significant interest to the accelerator team and there were several machine signals that the BEAST team found very helpful. It was mentioned in the presentation that several channels have been agreed upon between the machine and the detector. In particular, a luminosity signal will go from the detector to the machine. There was also a very good summary of present abort signal status. The committee looks forward to further close communication between these groups and see this as extending to the entire detector team at some level.

### 3.2.2 Concerns

Since detector backgrounds are the primary concern of both teams (accelerator and detector) the background group of the detector will be in the best position to be the liaison between the two major teams. The goal of each team is essentially the same: delivering the highest luminosity without damaging the detector or making it impossible for the detector to operate. However, each team (accelerator and detector) comes from a different perspective and sometimes this can lead to communication difficulties. It is very important for both teams to try to be as clear as possible about the issue at hand so that both sides can understand the other viewpoint.

- A single luminosity signal may not be adequate. The machine group will also have a luminosity signal and the detector group may want to record that signal also.
- While the accelerator group may prefer a minimum number of background signals, there can be conditions where there is interest in a particular sub-detector signal if that sub-detector is the primary source of the background signal from Belle II. In the PEP-II B-factory, there was a case where the muon system was experiencing unusually high backgrounds and it was useful for the accelerator group to see this special background signal in order to understand what machine conditions affected the signal. This was also true for a couple of instances when the silicon vertex tracker had unusually high background signals. This was also of importance when the accelerator switched to continuous injection. In this case, the detector was able to send information about the background level in the detector for every injected bunch from the Linac and this was crucial in identifying specific injected bunches that caused unusually high backgrounds in the detector.

### 3.2.3 Recommendations

- It may be useful to have a full trigger rate luminosity signal, as well as a slower signal but with larger statistics, to be sent to the accelerator group. The accelerator group can do its own averaging from the fast signal, but a slow signal may

still be useful. It would also be helpful for the machine group to get an individual bunch luminosity. The machine group may already be working toward this goal with their own luminosity monitor but Belle II detector components may also be able to supply this information.

- The committee would like to encourage the background group and the accelerator team to consider discussing what kinds of real-time background signals coming from the detector might be useful for the accelerator team. For instance, can the detector produce background information for specific bunches stored in the ring? Would this be useful for the accelerator? Or perhaps separate bunch information about the collision point location? This later suggestion would not be in real time.
- In the specific case of the beam abort, the committee recommends that all of the abort signals be set to ON for no abort and OFF for initiating a beam abort: a fail-safe system in that if a signal line fails then the beam will abort.

## 4 Sub-system Implementation Status

### 4.1 Vertex Detector

#### 4.1.1 Status

The VXD schedule has shifted in line with the new re-optimised general schedule. Cabling and piping preparations as well as a VXD installation test are scheduled in the coming months, and the PXD and VXD elements for the Phase 2 detector system will be constructed by February 2017. The completed VXD will be shipped to KEK by early spring 2018, in order to meet a June 2018 installation date.

The global status of the hardware was summarised. The PXD sensor production including contingency will be completed by December 2016 and all final ASICs are available apart from the DHPT which is in resubmission following a known error. A new bump bonding process is being developed with IZM Berlin for the SWB2.1, which is the current bottleneck. A recent milestone was the arrival of the IBelle cooling unit at KEK, which is currently undergoing installation and integration. The SVD ladder production is ongoing; the FW/BW and L3 layers are completed, L4 and L5 are in full production swing, and L6 remains on the critical path with 3 out of the 16+4 ladders completed. This is being addressed with a new assembly shift system and detailed schedule.

#### 4.1.2 PXD Readout

The PXD readout is different from the rest of the Belle II experiment due to the enormous event size which cannot be shipped out through the standard COPPER readout boards. Instead, a special data reduction scheme is implemented using track information from the HLT to define regions of interest (RoIs) such that only clusters in proximity to the extrapolated tracks are sent downstream, giving a reduction of 1/10 in the event size.



In addition, the full HLT operation was exercised in the DESY test beam. Many important goals were achieved, but also many important issues were discovered, in particular operational ones. These will be the subject of the planned permanent setup (PERSY) and they will be tested in the next DESY test beam.

### 4.1.3 SVD Readout

The SVD is read out with APV25 chips, whose signals are transferred via a repeater/junction board to the FADC cards for zero suppression and data formatting. The signals are then passed to the FTB which performs the transfer of the data to the HSLB receiver board mounted on the COPPER readout board, and sends the same data to the DATCON of the PXD system described above. The clock and trigger signals are distributed from the FTSW via the FADC controller. The APV25 can provide a 6 sample readout which would limit the readout to 30 kHz (nominal Belle II maximum readout rate) with a 3% loss, which is found to be acceptable. However, it is also possible to selectively trigger with three samples, which can be suitable for precisely timed triggers, which would allow the rate to be pushed to beyond 50 kHz (for a 70% fraction of precise triggers). Provision exists to read out the SVD full APV/hit information mode for detector studies and a future extension will allow a zero suppressed plus time window selection mode which in principle allows further data size reduction.

The group are to be congratulated on the very successful operation of the DAQ chain in the beam test, where the complete data flow and link communication was demonstrated to work stably up to 1 kHz trigger rate. The most recent test beam successfully operated ladders from 4 layers and demonstrated signal to noise performances of 18(31) for the p-strips (n-strips) with further improvement when CO<sub>2</sub> cooling is applied. The ladders reached design spatial resolution and demonstrated excellent efficiencies of more than 99%. This excellent performance gives a very high degree of confidence in the final SVD operation and integration in to the Belle II readout system. In addition the implementation of a larger capacitor on the APV25 ground was demonstrated to greatly suppress noise from an external source which had been seen in a previous test beam.

Various issues were uncovered during this exercise and further developments are planned. The robustness of the system to external noise sources will be improved in two ways: As described above, a capacitor on the APV25 ground input has been increased from 10 nF to 100 nF. It has also been decided to tie the p and n LV source of the modules to the same junction board, which will eliminate many loops, in addition to providing a unique grounding point at the detector level. This requires a redesign of the Junction and FADC board, with the new version of the FADC expected for March 2017, with the rest of the boards already produced or on schedule. Another problem was found, an event number shift, which was fixed within the *b2tt* firmware. On the voltage supply side, the HV and LV hardware have been procured, including spares, and the EPICS remote control software has been developed.

The data rate was limited in the test beam for random triggers due to the filling of the APV buffer; this will be protected against in the future by implementing an APV emulator in the master FTSW to prevent triggers to be issued, allowing the system to

reach 30 kHz.

Due to the SVD event fragment size, the number of HSLB receiver boards is limited to one per COPPER readout board, resulting in a throughput per COPPER of 40 megabytes and a reasonable CPU usage. Latest estimations of the SVD event size show a small increase from the initial assumptions but should still be well within limits. If the data size were to increase still further there remains the possibility of increasing the number of FADC modules per layer.

#### 4.1.4 Concerns

- A minor concern is the connection between the ONSEN and the Event Builder 2 PCs. This was shown to be very sensitive to fluctuations in occupancy and is believed to be caused by the lack of Ethernet flow-control in the firmware used by the ONSEN system to implement this link connecting the ONSEN to the readout PCs.

The firmware fully implements TCP/IP and it performs flow-control of TCP layer, but doesn't perform Ethernet flow-control IEEE 802.3x. As TCP retransmits data after any ethernet packet is lost, TCP is free from loss of data. But TCP by itself is not free from the loss of ethernet packet. TCP reduces the sending speed for a while after the ethernet packet loss, so the actual throughput will be unstable if packets are lost frequently. Ethernet flow-control is necessary to the lossless transmit of ethernet packet. This firmware is called SiTCP, which started out as a KEK project, but is now closed source, and therefore cannot be easily modified.

- During the review it was clear that all the individual components of the PXD readout and DAQ chain are well under control, which is all the more remarkable because it is without doubt the most complex of all in Belle II. Nevertheless at the boundaries between PXD DAQ components and outside systems, the reviewers got the impression that the understanding of mutual constraints and difficulties can be improved.
- The recent simulation campaign has shown a rise in backgrounds, and in addition there were indications of increased backgrounds observed during BEAST Phase I. The HER Touschek backgrounds may be controlled by optimising the collimators, however an increase in two photon production of  $e^+e^-$  pairs may produce showering which could affect the VXD occupancy.
- Many items are happening in parallel which require communication or expertise from the same teams. For example, in the coming months hardware integration at KEK of the cooling plant and the installation tests and cabling is happening in parallel with the DAQ and beam-test preparations for the February beam test (final sensor test). At the same time the Phase 2 detector system is undergoing construction and the SVD ladder construction is ongoing, and there will be many demands on the VXD teams from the central DAQ and Readout Integration co-

ordination. The VXD management is encouraged to coordinate closely to protect and optimise resources.

- A detailed ad-hoc presentation on error handling shows that the team has given already a lot of thought to the various possible errors and how to handle them.
- The SVD firmware developments have been very successful and there are many improvements planned. On the control side the state diagram for the slow control and GUIs has to be finalised and the database developed. The MARCO and eventually IBelle must be integrated in EPICS with the detector, a full powering scheme in operation conditions developed and a very detailed interlock system implemented. The team is well aware of all these challenges and they are in the schedule. However, we emphasise that care must be taken to protect the effort and keep it focused as the team moves rapidly towards the goal of cosmic-ray data taking with the full VXD by the end of 2017.

#### 4.1.5 Recommendations

- Concerning the ONSEN communication, there are other simplified TCP/IP implementations for FPGAs available, both commercial and non-commercial<sup>1</sup> and the team is encouraged to consider changing the TCP/IP driver in the ONSEN output FPGA to use one of those. This would greatly ease the burden on the network switches in the Event Builder 2, which also may reduce the cost<sup>2</sup>.
- To ensure the best possible integration of the PXD DAQ into the whole of the Belle II readout and DAQ would be the role of a PXD DAQ coordinator. If no such role exists, appointment of a suitable person is recommended. (S)he would also be a useful contact for the central DAQ team.
- The committee encourages the team to implement, as planned, the special data taking mode which would allow further event size reduction for the SVD
- The PERSY is seen as a very positive development which will help in the further debugging of the readout slice. The committee encourages the team to progress to the integration of the SVD as well as PXD into PERSY as the schedule permits.
- The committee recommends that, as planned, the new background estimations are integrated and compared with the Belle I simulations and measurements, in order to assess any possible effect of the new backgrounds on the detector performance.

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<sup>1</sup>For instance the CMS collaboration has created a very similar firmware component, which might be obtained.

<sup>2</sup>It must be verified of course, if the back-pressure from Ethernet can be matched by sufficient buffer-space in the ONSEN system, but this seemed to be the case.

## 4.2 Central Drift Chamber

### 4.2.1 Status

The committee commends the Central Drift Chamber (CDC) group for its successful cosmic-ray test (CRT) of the CDC outside of the Belle II detector and the just-completed installation of the detector in Belle II. Currently the group is cabling and piping the CDC to prepare it for integration with the rest of the outer detector and an extended in-situ cosmic-ray test.

The 14,336 sense wires are connected to 299 front end boards (FEBs). Each FEB consists of 6 ASICs, each amplifying, shaping, and discriminating signals from 8 signal wires. The discriminator outputs are sent to the L1 trigger system. Simultaneously each signal is processed in a common FPGA, which samples the signal shape with a FADC for  $dE/dx$  measurements and establishes the time signal with a TDC for drift time measurements. The  $dE/dx$  and time signals are sent via a Belle2Link to the DAQ for further processing. During the course of the external CRT, the CDC was operated with the Pocket DAQ and the Global DAQ systems, providing valuable experience with both of these systems and demonstrating that the FEBs work well with these DAQs.

In the external CRT, the number of long cables between the CDC and the DAQ system limited the number of FEBs being readout at one time to 60. Even with this limitation, the group was able to test all 299 FEBs by recabling between test runs. The CDC group verified that all FEBs and all active sense wires are working.

Tracking software was also exercised during the tests. Clean tracks obtained from the tracker were used to study drift distance resolution and relative positions of the inner and outer drift chambers. The drift distance resolutions measured in the centres of cells varied between  $90\ \mu\text{m}$  and  $150\ \mu\text{m}$ , depending on the layer. These excellent preliminary results are in accord with understanding of the effects contributing to the resolution.

Drift chamber alignment and overall performance were studied by treating each of the two segments of a track above and below the centre of the chamber as separate tracks. Using this technique, a tiny rotation of the inner CDC relative to the outer CDC was detected. The results for transverse and longitudinal impact parameter differences between the two tracks were quite respectable,  $124\ \mu\text{m}$  and  $2.1\ \text{mm}$ , respectively.

Unfortunately, the proposed CRT test with a TOP module was not possible, due to difficulties encountered with the TOP system that are described below.

### 4.2.2 Concerns

- Although the external CRTs with a limited number of active FEBs at any one time were very successful, complications may still arise when the entire CDC is active and integrated with other Belle II detectors.
- Integration of the CRC and TOP systems is essential for establishing the performance of the TOP system.

### 4.2.3 Recommendations

- As efficiently as possible, the CDC group should continue its effort toward completing the installation of the CDC in the Belle II environment and integration of it with the Global DAQ and other detectors.
- Working with the TOP group to efficiently achieve this integration and enabling of high quality testing the TOP in the Global CRT should remain a priority of the CDC group.

## 4.3 Barrel Particle Identification

### 4.3.1 Status

The TOP group must be congratulated for their very hard work and substantial achievements since the last BPAC review in February 2016. Though the specific subject of this review is the Online and DAQ status, this work has been much impacted by the larger TOP installation and commissioning effort in which it is embedded, as was briefly discussed at the review and described below.

The TOP has been fully installed, and high statistics laser calibrations and cosmic-ray runs without precise tracking have demonstrated that the modules survived installation well, and that the readout system is in a stable, if not fully operational, configuration. Much of the time since installation has been devoted to making the electronic and DAQ systems function correctly. Numerous bugs have been uncovered and fixed. The planned combined cosmic-ray run with the CDC outside the detector, while very successful for the CDC, failed for the TOP due to various DAQ issues. The show-stopper was data corruption internal to the TOP board-stacks. This particular issue has been resolved. There has been significant progress on the TOP firmware, but feature extraction is not yet correctly functioning.

The system was run with B-field on and off in order to understand possible performance differences. To the surprise of the proponents, this work demonstrated that the PMTs are magnetic, with sufficient forces in play to rotate the  $2 \times 2$  PMT assemblies and peel them away from the bar/PMT filters. The initial problem was addressed by inserting shims between PMT modules and the aluminium enclosure to restrict rotation. However, this fix still allows individual PMTs to rotate and decouple. Some of these specific problems in two modules were fixed, but given the unknown impact of the problem; uncertainty about the best way to fix it; the 4-5 months involved in making a full repair; the lack of remaining float in the critical path schedule to detector assembly; and the crucial importance for the project of global Belle II detector completion and initiation of the full detector cosmic-ray run before the end of the Japanese fiscal year; it was decided that no further repair would be attempted at this time, and that CDC installation would proceed immediately. After Phase II running, it is thought that the extent of the problem will be better understood, and that a more robust repair plan can be understood and prototyped offline. If needed, this plan could be implemented in the six month period between Phase II and Phase III running though it might take

longer and lead to further delay. The proponents argue that the decoupled PMTs remain functional albeit with lesser detection efficiency, though detailed work to understand the actual impact on performance is required (see recommendations).

As a few further remarks on the specific topic of this review, the TOP electronics readout community has made great impact overall, as they have fully supported the successful TOP system installation and monitoring effort and helped to exercise and debug the global DAQ, while continuing to debug their own systems, and to write and debug the remaining required software and firmware for the TOP system running. In particular, there has been substantial progress on the TOP firmware in the last few weeks, with substantial expertise deployed. The key firmware components are structurally ready, as are the unpacker and the converter to hits. A few pieces of front-end firmware code need to be completed. More work is needed on the data quality monitoring, and getting the payloads into the calibration constants database. More debugging, cleanup and testing work is required including a review and update of the PGP/SLAC StdLib. Issues remain with data corruption that must be resolved. These seem to be related to StdLib issues which need further attention. This entire effort was characterised as “nearly” there, but clearly must be pushed along until there is no longer a “nearly” there.

#### 4.3.2 Concerns

- TOP has served as an important testbed for developing and exercising the Pocket DAQs and the Global DAQ. This will continue to be important during the in-situ cosmic-ray running of next few months.
- It is crucial to retain the level of effort and expertise both on the overall TOP DAQ and, more specifically, on the TOP firmware until the initial development and debugging effort is complete and the system is operational.
- A well organised effort needs to continue in order to understand and prototype a robust and efficient methodology for repairing decoupled PMTs should that be required following the Phase II run.

#### 4.3.3 Recommendations

- The planned cosmic-ray running together with the Central Drift Chamber during the next few months is of great importance as an early demonstrator for the Global DAQ and online, as well as to begin to understand the general TOP systems and their performance over the full tracking phase space. The committee urges that the strongest possible effort be maintained to ensure this occurs, and looks forward to a report in February.
- Simulations to more fully understand the impact of decoupled PMTs on TOP performance versus track angle, and any new software issues that may arise from the need to implement angle dependent tube photon efficiencies should be undertaken ASAP.

## 4.4 Endcap Particle Identification

### 4.4.1 Status

The status of the ARICH detector installation was reported. At the time of the report, 79% of the aerogel tiles were installed in the detector. During installation it was realised that some of the tiles showed small light losses at the corner. Additional water-jet cutting is planned to cure these losses. This work is expected to be done in November 2016 and seems to be on a good track.

In earlier meetings, it was reported that a significant fraction of the photosensors (80 HAPDs) showed large output pulses when being operated in a magnetic field leading to dead times of order 0.1 s per pulse. Protection measures for the electronics were developed and implemented. Recently, it was discovered that the problem can be cured by the so-called “getter reactivation”, which significantly improves the vacuum inside the HAPD. So far, 20 out of 80 HAPDs have been already recovered and the recovery of the remaining ones is expected to be complete by end of 2016 so that the HAPDs used in the detector and a significant number of spare HAPDs will all be of high-quality.

The observed torque on the MCP-PMTs in the TOP detector due to the solenoid B-field is a potential problem for the HAPDs as well, since their rings are made out of Kovar (containing ferromagnetic cobalt). Torque measurements in magnetic fields and simulations of the expected torque in the detector have been performed and found to be in agreement. From these studies, it is not expected that the magnetic field would cause a mechanical stress that leads to performance losses. Independent of that, additional stress tests will be performed in the forthcoming months.

At the time of the review meeting, the HV cables, their connectors, and the HV power supplies have not been ordered yet. As a result, currently no large-scale tests of the already installed ARICH detector and its DAQ can be performed. HV cables and connectors are currently under test and these tests are expected to finish very soon so that decisions on ordering can be taken. For the HV power supplies, two vendors are under consideration (CAEN and ISEG). The bidding is expected to start soon and might be combined with ordering the HV cables from the same vendor.

At the meeting, results of a first small-scale cosmic-ray run were presented. For these measurements, the Pocket DAQ was used and the committee congratulates the ARICH team for the first full Cherenkov ring “seen” in the ARICH detector! Up to now, 70 HAPDs are mounted on one ARICH sector but are not yet connected to the DAQ. For the cosmic-ray run, 6 HAPDs in another sector were connected to the HV, the bias voltage, one front-end board, and this to a merger board for readout using one Belle2Link, HSLB and COPPER. The trigger of the readout is provided by plastic scintillator detectors. A GUI for run and slow control was developed and was already used in this cosmic-ray run. For monitoring purposes of the HAPDs, it is planned to perform threshold scans, which were already performed during the cosmic-ray run. It turns out that these threshold scans are rather time-consuming, which needs to be improved in the future. During the cosmic-ray run with trigger rates of 0.2 Hz, it was found that some events have many hits which is suspected to originate from “broken data”. Data was taken successfully for eight hours without errors. The setup will now be expanded to readout about 12

HAPDs and could be increased to 16 HAPDs in the near future. Further extensions are only possible when HV cables and power supplies are delivered.

Additional DAQ tests were performed by adding another merger board with six front-end boards (however without HAPDs). In this setup, cosmic-ray data could be correctly taken from the six installed HAPDs. High-rate tests with only header information, but without data information, were performed without problems at 10 and 30 kHz constant pulse trigger rates for more than eight hours of data taking. While 10 kHz Poisson (random) trigger rates did not pose problems,  $O(10)$  events containing errors were recorded when running at a 30 kHz Poisson trigger rate, which might be caused by non-up-to-date firmware. Inconsistencies between COPPER and merger headers, and event counter jumps in the merger event counter might be correlated and also linked to the observed problems in the cosmic-ray run. Investigations are going on and will be debugged with another Pocket DAQ system.

It is planned to extend the small-scale cosmic-ray run in November 2016 to 16 HAPDs corresponding to three merger boards. The next step would be the readout of one sector (with 70 HAPDs) using the Pocket DAQ system. This system test, however, can only be performed once the HV cables and power supplies are purchased and delivered. The ARICH detector is planned to be fully installed in March 2017 and to be connected with the forward end-cap electromagnetic calorimeter (ECL) in May/June 2017. One sector will then be fully connected to the global DAQ to take part in the global cosmic-ray run.

A NSM2-based HV control system with ethernet connection to the hardware has been developed. HAPDs can produce a large pulse during HV ramp up or down. As a consequence, no bias voltage should be applied when changing the HV. Therefore, in software, the sequence for HV ramping up (down) has been implemented: guard ring  $\rightarrow$  HV  $\rightarrow$  bias voltage or HV  $\rightarrow$  guard ring  $\rightarrow$  HV. Cases like a trip of a HV/bias channel or a magnet quench are still to be addressed.

#### 4.4.2 Concerns

- The ordering of HV cables and power supplies comes quite late and can cause delays in the DAQ commissioning schedule.
- For the DAQ integration, there are still quite some steps to take. Before one can be confident that the inclusion into the Global DAQ system for the global cosmic-ray run will probably work, without serious problems, large-scale tests with more merger boards and at 30 kHz random triggers and larger data block sizes have to be passed using the Pocket DAQ.
- Compared to the effort still needed for the DAQ integration, the manpower allocated appears to be too small.
- Although all studies performed so far don't point to a serious problem, the torque on the HAPDs inside the solenoid field might lead to a performance loss (at least on a longer term).



### 4.4.3 Recommendations

- Ordering the HV cables and power supplies should have now very high priority in order to mitigate any delay in the DAQ commissioning schedule.
- The committee suggests that the ARICH group and the Belle II collaboration should address how the manpower for DAQ integration might be enlarged.
- The committee supports the plan to extend the DAQ integration work to 16 HAPDs with three merger boards using the Pocket DAQ. Stress tests with 30 kHz Poissonian random triggers should be performed as soon as possible.
- The committee supports the stress tests planned to explore whether the torque on the HAPDs in the magnetic field poses a serious problem and encourages the ARICH group to develop a repair strategy for the case that the torque on the HAPDs results in possible performance problems.
- The committee encourages the ARICH group to start considering how to deal with possible interlock scenarios, e.g. how to handle a HV switch-off in case of magnet quench.

## 4.5 Electromagnetic Calorimeter

### 4.5.1 Status

In order to cope with the much higher Belle II luminosity, the ECL group has completely redesigned the Belle readout electronics and DAQ systems. The full waveform is now digitised and fit in order to extract energy and timing in FPGAs.

The committee congratulates the ECL group for the excellent progress they have made toward completing installation and commissioning during the period since the last BPAC review. All barrel electronics have now been produced and installed. The barrel calorimeter has been fully integrated into the Global DAQ, and serves as a full test bed for the detector DAQ system. The trigger is operational, and provides a straightforward cosmic-ray trigger. Signal shape calibration for all barrel channels has been performed. The ECLs are available for installation whenever required.

Thorough system tests have been performed with all components and front end assemblies. All modules have been produced, thoroughly tested on the test bench, installed at the detector, and integrated into the DAQ. All 6624 Barrel counters are operational, though 6 have 1/2 signal due to problems in one of the readout diode chains. Firmware can be uploaded and initialised. Appropriate calibration procedures and database files exist and have been exercised. Signal shape calibrations for all barrel counters using the cosmic-ray trigger have demonstrated a shape description accuracy of  $\sim 10^{-3}$ .

Debugging and development continues on the downstream DAQ. All FAM modules are installed on the detector and have been tested. The present firmware provides a cosmic-ray trigger. Further firmware development and debugging is underway, and

known downstream issues are being resolved. The data quality monitoring system histograms are in place for the barrel but still need to include ECL information. A full event display based on the GEANT geometry awaits implementation.

The forward and backward ECLs are off the critical path and are available for installation whenever required. The backward ECL will be installed starting in December 2016. It will be calibrated after installation. The forward ECL installation is presently scheduled for summer 2017.

#### 4.5.2 Concerns

- As there was no discussion of resources available, it is not quite clear that the software/firmware manpower resources are adequate to complete the tasks described as well as other (more offline) tasks such as simulation. However the recent rate of progress on the ECL DAQ is encouraging.
- Reducing ECL event data size seems feasible and highly desirable, but the plans and schedule for doing so are unclear to the committee.

#### 4.5.3 Recommendations

- Recent progress is excellent and must be maintained until the full ECL system is complete and fully commissioned.
- The ECL system must ensure that the water leaks into the KLM that have occurred are fully understood and repaired, and ensure that monitoring systems are in place to mitigate any future recurrence.

### 4.6 $K_L$ Muon Detector

#### 4.6.1 Status

The RPC and scintillator layers of all KLM detectors are fully installed. At this meeting, the status of the KLM detector and DAQ was presented.

In the barrel, the scintillator readout electronics are fully in place, but the RPC readout electronics are not. The RPC readout electronics are currently being procured by the KLM groups at INFN/LNF. Procurement, tests, delivery to KEK, and installation will be continuously made until full completion, foreseen in July 2017.

All backward- and a part of the forward end-cap KLM readout infrastructure is already in place, the forward end-cap will be completed by December 2016.

A trigger to be provided by the KLM for either muon tracks or  $K_L$  cluster candidates is realised by a Universal Trigger Board (UT3) based on a Virtex6 HXT FPGA that does a 2D track reconstruction in  $r - \phi$  and  $r - z$  projection.

Very recently, a test with the forward barrel using cosmic rays was performed, with one RPC sector operational, using the Global DAQ system. The committee congratulates the KLM group for the first successful reconstruction of cosmic-ray tracks in the

RPC and scintillators. “Missing” hits for some scintillators have been traced back to incorrectly set timing constants in the readout firmware.

The power-supply control software for the barrel and end-cap KLMs has been implemented using for the GUI the DAQ group’s Java interface. The software interlock is functional.

The barrel KLM detector is ready to provide triggers for the planned TOP-KLM cosmic-ray runs based on a special trigger setup using two scintillator layers. In general, the system seems to be ready to participate in the global cosmic-ray run, scheduled to start in April 2017, with a partially complete KLM detector.

Recently, a water leakage from the ECL with a water loss of about 5 l occurred in the vicinity of the backward barrel part of the KLM. As a result, this part of the KLM detector will not be powered until drying is complete. Whether the KLM electronics was affected at all by this incident, is unknown.

In the status report, no details about the schedule and status of the DAQ integration, like behaviour of the system under stress tests using either the Pocket DAQ or the Global DAQ system, were given. Open issues or problems in the DAQ integration, including slow and run control, have not been reported.

#### 4.6.2 Concerns

- While a very detailed report on the various DAQ elements was given and the committee recognises that already the Global DAQ system is in use for the cosmic-ray runs, it was not completely clear from the report which tests have been already performed and successfully passed towards a complete DAQ integration. Similar in line, no overview of a detailed schedule for the forthcoming months was presented that also shows how the scintillator and RPC parts are completely integrated. Therefore, possible risks for delays in the schedule might not be easy to identify.
- Since it seems unclear whether and how much water from the ECL has entered into the KLM boxes or reached the KLM electronics, there is the possible risk of an undiscovered damage or that it takes at least a very long time before all water has evaporated.

#### 4.6.3 Recommendations

- The committee encourages the KLM group and central DAQ group to lay out together the work to be done in the forthcoming months for the commissioning and integration of the KLM DAQ in a unified way for the scintillator and RPC sub-detectors and to estimate the manpower coverage needed.
- The committee supports the decision to remove power from the backward barrel part of the KLM until the electronics are dried out. The committee recommends exploring the possibilities for visual and other inspection measures to better understand the situation inside the KLM detector, such as installation of humidity sensors, before powering again this part of the KLM detector. Moderate heating of this part of the detector to accelerate the dry out might be considered as well.