# Response to the BCM PDR recommendations

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# PDR recommendations

EUROPEAN SPALLATION SOURCE

A BCM PDR meeting was held on Nov. 12$^{th}$ 2015. The outcome was 51 recommendations by the PDR committee.

These recommendations have been taken into account in the recent BCM design and developments.

The following pages give a summary of the recommendations and the response to them.

Blue: The recommendation has been implemented in the updated design and/or the existing design already fulfils the recommendation.

Red: The recommendation is currently being implemented (not complete yet), or it will be implemented at a later stage.

# BCM no/location and the information in DOORS

1- Verify number and location of BCMs.

BCM number and location have been confirmed. See page 3 of the presentation on the BCM electronics and cables.

2- Make sure all requirements are confirmed and uploaded to DOORs.

3- Confirm MPS requirements and place in DOORs.

A comprehensive list of BCM requirements including those relevant to machine protection has been confirmed and uploaded to DOORS.

Some new MPS requirements are still under discussion with the MPS group and the external partners (see the “BIS-BCM interface” presentation by S. Kövecses).

4- Reconfirm bandwidth requirement based on confirmed MPS/errant beam scenarios.

The ACCT BW of 1 MHz is consistent with the MPS requirements. In the warm linac, the toroid cable is expected to be as long as ~40 m. Nevertheless, a total response time of <2 us will be achievable. In the high energy linac, the response time can be longer than 2 us, but this is not expected to be a major issue for machine protection, because in these areas, the BLMs will serve as the primary means for measuring beam losses.

# BCM no/location and the information in DOORS

5- Define the low latency link to LLRF.

The low latency link to the LLRF will be similar to the one foreseen for differential current measurement. This link will have a fixed and known latency.

6- Define the need for calibration more detailed, given that temperature changes in the stubs.

7- Address issues of temperature stability, including effect of the cables in the stubs, and droop dependency on temperature. (similar to 5)

8- Droop correction will need to be done independently for each ACCT, and should be part of calibration.

Calibration requirements have become clearer after some long-term tests in the BCM lab. (see pages 10-12 of the presentation on the BCM electronics and cables).

The foreseen calibration method can compensate drifts in baseline level, scale factor as well as droop rate.

The new BCM FW supports droop rate correction independently for each ACCT.

# BCM no/location and the information in DOORS

9- Define and design complete calibration circuit.

Three calibrator circuit prototypes has already been built at ESS. The most recent one has been successfully tested under laboratory conditions. It is foreseen to send the design and the test results to an external partner for any further modifications before series production.

10- Consider safety implications related to floating systems.

The calibrator circuit has been designed to withstand voltage variations larger than 100 V on the cable shield. The BCM rack including the chassis of the electronics will be connected to the protection ground. Other parts of the system (including toroid, cables and the FE unit) will be grounded as appropriate without creating ground loops.

11- Protocol for machine mode interface needs to be defined.

This will be a common interface for many systems at ESS. ICS is the main stakeholder. Preliminary discussions have already started.

12- Consider additional stakeholders for BCMs e.g. Beam accounting function, time of arrival w.r.t to target, choppers, Traceability/accountability.

BCM requirements have been discussed to a large extent with the main stakeholders being the Beam Physics and the MPS. These have been considered in the updated BCM design. New features will be added in the future with a minimum impact on the existing design.

# BCM no/location and the information in DOORS

13- Resolve if there is a requirement to calibrate the calibration system (for traceability, required by SNS) (Vim).

So far, we haven't seen a need to calibrate the calibration system.

14- Define core process variables.

Process variables have already been defined for the updated (i.e. 'LEBT upgrade' version) of the BCM FW/SW.

15- Address other noise sources than electronics (ground loops, Interference from other equipment).

Ground loops (and the ways to avoid them) has been discussed with Bergoz and other experts. These are (or will be) considered in the final design of the electronics and the chassis. Ferrite beads will be used on the toroid and the ACCT-E cables. Analog and digital filters will also be used for noise reduction.

# BCM no/location and the information in DOORS

16- Consider RF structure inside pulse in bench tests, to potentially detect e.g. resonant effects. Also take care of output impedance of pulser.

Bergoz proposes an RF bypass between the ceramic and the magnetic core to attenuate higher frequencies of the bunch, thus reducing the heating of the core.

Following a Bergoz recommendation, the calibrator circuit will be disconnected for the toroid (using a relay) when operating with beam.

17- Consider ways to protect (shield) the ceramic breaks (re-check it does not affect the cleaning process)

J. Bergoz believes this is not needed. Nevertheless, Bergoz has confirmed that they can provide extra protection using a dummy vacuum chamber inside the toroid aperture.

This has also been discussed with the vacuum group (M. J. Ferreira) and they confirmed that they could also weld a protection tube inside the toroid if needed. Moreover, it is considered to use a larger toroid thus keeping the ceramic farther from the beam.

# BCM no/location and the information in DOORS

18- Confirm the length of cables, and evaluate the effect of long front end cables. Address as needed.

> A preliminary estimation of the cable length already exists. Calculation of exact cable length will be a new feature of the cable database.
>
> The effect of the toroid cable length has been tested and studied (see page 25 of the presentation on BCM electronics and cables). This will be taken into account in the future versions of the BCM FW.

19- Resolve and document mechanical integration issues for each BCM.

> Mechanical integrations of the BCMs are under the responsibility of the in-kind partners. The issues have already been discussed with them to a large extent.

20. Confirm expected fringe fields at BCM locations, and verify shielding requirements for each BCM.

> Based on some electromagnetics simulations, a double-layer shield (good to >10 mT) will be enough for the RFQ and the LWU BCMs. A Similar study has been done by ESS-Bilbao for the MEBT BCMs, and these BCMs will also be shielded as appropriate.

# BCM no/location and the information in DOORS

21- Resolve need/requirement of halogen free connectors and cables.

22- Beware of e.g. Teflon in connectors inside radiation environment.

The foreseen toroid cable is halogen-free, rad-tolerant and consistent with the ESS cable regulations.

Similarly, the it’s foreseen to use BNO connectors with ETFE (rad-tolerant) dielectric.

23. Quantify effect of using dual SMA connectors for differential output signal. Avoid magnetic coupling of noise from separated cables!

Coaxial cables/connectors might be used for the DTL BCMs. These will then be converted to BNO on a patch panel near the toroid. Short patch cables (tied together) are foreseen to connect the toroid to the patch panel.

24. Clarify need and location of calibration termination resistors.

The calibrator circuit design includes a 50 Ohm output resistor. Cable resistance will slightly add to this resistor, but the effect on the output pulse will be negligible.

The calibrator circuit will be disconnected from the toroid (using an on-board relay) when operating with beam.

# BCM no/location and the information in DOORS

25- Define and document the FCT readout system.

It is foreseen to use either a commercial rack-mount oscilloscope, or the IOxOS AMC/RTM in combination with a fast FMC.

26- Consider effect of failing FE power supply.

This has been considered in the updated design. It is foreseen to use a redundant power source for the Bergoz FE.

27. Resolve situation with Polish in-kind, and if needed find alternative.

Based on some recent discussions, the Polish contribution to the BCM system can be in-kind. A collaboration agreement between ESS and WUT is close to being signed by both parties (if not signed yet). Polish contribution to the BCM project will be described in a technical annex that will be amended to the collaboration agreement.

28. Resolve possible use of FMC differential receiver.

The use of FMC differential receiver (in combination with a customized differential driver at the ACCT-E output) is being considered as a backup solution, or as a future modifications. It is planned to prototype and test the differential link through an external collaboration (possibly with the Polish).

# BCM no/location and the information in DOORS

29- Refine the functionality definition of the firmware (including which comparisons and thresholds to use).

This is specified in details in the “LEBT ACCT “Pre-version” firmware and software requirements” and the “LEBT upgrade ACCT firmware and software specifications”.

30- Foresee a sandbox/test stand in place to allow the testing of functionality and advanced feature without disrupting the existing protection systems.

An ACCT test stand has been made at the BCM lab (see page 26 of the presentation on BCM electronics and cables).

A more advanced test stand is foreseen for system test and verification before final installations (see presentation by C. Derrez).

31- Confirm existence and length of optical links.

32- Design and implement optical data transmission protocol (if needed)

Optical link will be needed for crate-to-crate data transfer. Implementation work (in-house) is expected to start soon.

More details are given in the presentation by M. Donna.

# BCM no/location and the information in DOORS

33- Maintainability in the design to compare current between any differential pairs of ACCTs.

This is foreseen in the next version of the FW that will also include the optical link.

34- Confirm use of AD racks in target building (GSA). Routing the signal from GSA to Klystron gallery needs attention.

It is foreseen to use long cables in the tunnel for routing the HEBT/A2T/DmpL BCM signals to the target building.

35- Define and document the Firmware algorithms (e.g. droop filter reset mechanism. Be careful about infinite memory.)

FW algorithms (including droop compensation) has already been implemented, tested and verified.

36- Define how many input channels can be handled by a single FPGA, given the required features (e.g. previous pulse to current pulse comparison requires additional memory resources).

The latest FW supports up to 10 input channels.

Memory resources are being used efficiently by data decimating without limiting the BW.

# BCM no/location and the information in DOORS

37- Clarify the use and reliance on timing trigger and clock.

These requirements are defined in the technical note entitled “Requirements on the MRF external trigger for the ESS BCM system”.

38- Update the plan and budget given recent changes.

See updated planning (Oct. 2016).

39- Resolve protocol for beam and machine modes transmission.

Also recommendation no. 11: This will be a common interface for many systems at ESS. ICS is the main stakeholder. Preliminary discussions have already started.

40- Define acceptance test.

Acceptance tests for the FW, SW and customized HW are defined in the “LEBT upgrade ACCT firmware and software specifications” document.

41- Define spares and operation and obsolescence strategy.

It is foreseen to include >= 20% spares.

Obsolescence strategy will be defined at a later stage.

# BCM no/location and the information in DOORS

42- Make a detailed reliability study.

This is being done by the ICS. Also, see the presentation on system reliability.

43- Define deliverables for Catania test.

Deliverables for the Catania BCM system has been defined, documented and the system has already been shipped to Catania (May 2017).

44- Verify installation dates.

Installation dates are based on general ESS planning. See updated BCM planning.

45- Revise detailed planning and budget to reallocate costs given recent changes and in-kind decisions.

The version from Nov. 2016 reflects recent changes. This is believed to be still valid to a large extent.

46- Confirm the number of standard parts (crate, CPUs, timing card) to be supplied by ICS.

These have been specified through some earlier communications with the ICS (contact person: R. Baron).

# BCM no/location and the information in DOORS

47- Foresee the possibility of voltage surges/leaks from high voltage lines to BCM cables.

It is foreseen to use twin-axial cables (good for differential signals) for the toroid signal. The cable shielding will provide some extra protection. Beads (Ferrite and other type) will be used on the cable. The cables will be grounded as appropriate.

48- Check the radiation hardness of cables

This is checked and verified for the Mulrad-2 (Siltem) cable.

49- Reconsider the use of RJ-45 for signal (e.g. do not use in radiation environment).

RJ-45 is not planned in radiation environments. The Struck AMC/RTM uses RJ-45 for the digital input/output ports, but these cables will be internal to the BCM rack.

50- Update layout to include all signals, including abort (and make distinction between differential transmission and differential current measurement.

The updated “sensor-electronics connection” shows the BCM system interconnections in different parts of the linac.

# BCM no/location and the information in DOORS

51- Carefully evaluate self-diagnosis and other advanced features versus system complexity to optimize robustness and maintainability.

An Ethernet module is foreseen within the ACCT Interface Unit for self-diagnosis. This follows a decision within the BI to add this feature to the customized units. The system will work independent of the Ethernet module. The current design is believed to be a good compromise between complexity and robustness.