CMS Beam and Radiation Monitoring:

Guidelines for a Baseline Planning

Draft Document. Please send all comments to Alick Macpherson and David Stickland

Version November 17, 2005

Purpose of this Document

A number of detector systems are foreseen to monitor beam-related radiation in the CMS cavern, including instrumentation for safety, tuning and for luminosity measurement. This work has been initiated within the CMS Technical Coordination activity (steered by Austin Ball) in conjunction with the Luminosity working group (steered by Dan Marlow); though neither of these organizations are explicitly detector construction projects.

The CMS-SC has endorsed (See Appendix I) the BCM, and partially the PLT (that the mechanical planning should take into account an eventual PLT), activity in its April 2005 meeting. The BCM recently underwent a largely positive procurement readiness review. Nevertheless, various integration issues need to be resolved, particularly in the very forward region near the beam-pipe and forward pixel detectors. An organization for coordinating plans, developments, construction and for proposing decisions needs to be put into place.

With this document we describe in broad strokes the major components and a possible baseline. We propose a schedule for developing full baseline planning and for its endorsement by CMS management. We request that the CMS management endorse this schedule and planning. We request that the CMS management establish the Beam and Radiation Monitoring activity in a formal way and that it encourages this group of collaborators to carry this ensemble of activities forward; preferably within some agreed form of CMS management structure, taking into account the tight linkages required between this activity, the CMS Technical Coordinators and the CMS Luminosity group.

Introduction

From the first day of LHC operation CMS must have in place robust systems for the measurement of radiation in and around CMS and the Point-5 experimental area; and for the online monitoring of beam conditions. These must include: beam conditions measurement to guide CMS operational decisions; beam-bunch monitoring to pre-detect dangerous conditions (such as filling of the abort gap) directly communicated to CMS and LHC operations; background and beam-halo monitoring to inform the LHC operations staff optimizing the machine; luminosity measurements for Physics and for LHC/CMS optimizations; geographically distributed integrated dose measurements for detector damage analysis.

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CMS management has identified these items as high-priority and CMS-TC has recently carried out a PRR of critical procurements for the Beam Conditions Monitor. Following this review a baseline planning guideline is herein proposed for the CMS Beam and Radiation Monitoring program. This, executive-summary, document does not give technical details, but notes the different subsystems and areas where technology developments and choices are still required. The actual baseline plan must specify these technical details. We propose henceforth to refer to all these systems as CMS-BRM (CMS Beam and Radiation Monitoring), with acronyms such as BCM1_L, BCM2_L, BCM1_F, BCM2_F, PLT, RADMON etc., to refer to particular stations where some of this functionality is implemented.

In the sections below we very briefly describe the main components of the CMS-BRM. We then propose a schedule and organization to lead to a submitted baseline plan that can satisfy the physics, engineering, integration, and resource constraints.

**Cavern Radiation Field Measurement**

Simulations of the effects of the expected radiation doses for critical components of CMS have been established [Mika Huhtenen]. It is vital to normalize these simulations by measuring the actual doses and fluences throughout the cavern. Further, a sufficiently granular monitoring system must be in place at the start of commissioning, so as to allow for the early identification of unforeseen defects in the CMS shielding.

We expect the baseline to consist of:

- **Passive Dosimeters**: Passive dosimeter units composed of TLD, RPL, and Alanine dosimeters will be mounted within CMS, and extracted at each opening of the detector. The three types of dosimeter are used so to have a full coverage of the potential range, and also to provide redundancy and cross calibration for the mixed field environment. The package containing three sensor types is to be $1 \times 1 \times 3\text{cm}^3$ in size, and is to be used throughout CMS. (Some concerns exist related to the current resources at CERN to extract the devices and to measure the doses at suitable intervals and in a timely manner, but this issue is to be addressed in a dedicated work package with CERN-TS.)

- **RADMON**: The LHC-RADMON system comprises a set of monitors that can be distributed throughout the CMS cavern. The RADMON monitors are primarily installed around the LHC for radiation monitoring, and provide dose, dose rate, charged hadron flux, 1 MeV neutron equivalent fluence, and SEU rates, making them ideal for assessing the the radiation field exterior to CMS. The RADMON boxes are $10 \times 10 \times 20\text{cm}$ in size, and have a maximum readout rate of 1Hz, with data going to a local CMS database. It is envisaged that a total of 18 RADMON monitors are to be installed in the UXC in a symmetric pattern, so that CMS has an online mapping of the radiation field. In order to ensure installation and integration of these monitors into the RADMON system, CMS will work closely with the TS/LEA group to manage this deployment and to ensure that the information from these monitors and from RADMON systems in the long-straight-sections, flows to the CMS and LHC control rooms correctly.

- **RAMSES**: The RAMSES project is installing ionization chambers in the CMS Cavern to monitor the Cavern radiation environment for the primary purpose of per-
sonnel protection. However these monitors have a dynamic range that is also suitable for cavern radiation monitoring, so that it is envisaged that data taken by the RAMSES monitors be integrated into the CMS BRM. Eight monitors are to be deployed in the CMS Cavern, in locations in accordance with personnel protection requirements, but several are to overlap with the RADMON and passive monitors to provide a calibration cross check.

We propose that all of the above systems are part of the initial installation for LHC running in 2007.

**Diamond Leakage Current Systems**

Measurements of the leakage currents in Polycrystalline Diamond (PCD) have been demonstrated at CDF to be effective tools to monitor beam conditions and to be fast enough to enable a response to some potentially dangerous beam conditions. An example of this would be the migration of particles into the LHC abort gap thus rendering the LHC abort itself to be a dangerous condition for the CMS detector. Early identification of such conditions is a clear goal of the CMS-BRM.

CMS expects to install PCD-leakage measurement systems, BCM1_L (Note change of nomenclature over previous documents: BCM, First station, Leakage measurement), close to the forward pixel detectors and the beam pipe, and at a second location behind the HF-plug close to the CASTOR detector (called BCM2_L). Cabling infrastructure, mechanics and integration issues have been addressed, and are close to being specified. The detail and location of the BCM1_L and BCM2_L are as follows:

- **BCM1_L**: In the Pixel Service tube volume. This is to be a set of 4 synthetic diamond sensors mounted around the beam pipe. The mechanical support structure is to be an independent carriage and rail system places the sensors underneath the pixel service tube volume system at a z position past that of the beam pipe support collar. BCM1_L services merge with the Pixel services only at the Pixel patch panel zero on the tracker bulkhead.

- **BCM2_L**: A second set of 8 synthetic diamond sensor mounted around the beam pipe and attached to the HF collor at the rear of the HF calorimeter. This location is shielded from the interaction point but open to particle flux coming from upstream of the experiment and should be sensitive to the both the onset of adverse beam conditions and X-Y skewed tertiary halo losses. Services and readout are provided for within the CASTOR rack and via the HF cable chain.

For readout and processing of the leakage currents from the diamond, the DAQ is to be modeled on existing cards from the LHC accelerator division, so to ensure a “standard LHC look” to the information and action requests generated by the BCM units. It appears that the LHC FBCT (Fast Bunch Current Transformer) cards and DAB64 readout boards can be used for the readout of these devices, with a sub 1µS timing resolution (c.f. an abort gap length of 3µS)

CMS is preparing plans together with CDF to install a prototype BCM1_L in CDF during the shutdown foreseen around April/May 2006. Such a system with almost, or actual, final LHC/CMS electronics will demonstrate overall viability and give operational experience.

We propose that the complete leakage current diamond systems described above are part
of the initial installation for LHC running in 2007.

**Beam Scintillator Counters**

This is a set of timing scintillators (BSC) that is to be mounted in front of the HF subsystem ($z=10.5m$), and is a set of scintillator tiles that surround the beam pipe. This scintillator system is to provide a crosscheck on beam timing and provide halo-muon trigger inputs for TK alignment. It has a large cross-sectional area, and as it is not particularly radiation hard, is expected to provide information only in the initial low luminosity running period.

**CMS considers this to be an important initial system** with quite different technical risks to the other systems envisaged and thus expects this to part of the baseline solution for commissioning and initial LHC running in 2007.

**Fast Diamond Signal Measurements**

Measurement of the fast-signals from diamond sensors offer a way to accumulate information even on a bunch-by-bunch basis from the in-situ particle fluxes. This would be a powerful conditions monitoring and optimization tool. Such a system would consist of synthetic diamond sensors mounted on shielded PCBs and coupled to fast trans-impedance amplifiers. The system is to monitor particle flux on a bunch by bunch basis, as well as detect out of bunch particle flux. Readout of the BCM signals is to be asynchronous, and only matched up with the bunch crossing clock at the back-end DAQ.

For the purpose of monitoring the beam conditions, two locations are envisaged very similar to that of BCM1$_L$ and BCM2$_L$, and are:

- The Inner Tracker BCM1$_F$ (BCM, First station, Fast). A set of four synthetic diamond sensors mounted around the beam pipe on the BCM mechanical support structure. Readout and services merge with the Pixel services only at patch panel zero on the tracker bulkhead.

- HF Collar BCM2$_F$ (BCM, Second station, Fast). Signals from the BCM2$_L$ are to be taken into an amplifier readout chain and then process through the a similar readout chain to that of the BCM1$_F$. The location of the BCM2$_F$ is identical to that of the BCM2$_L$, it is only the modification of readout and service channels that has to be addressed.

A candidate amplifier chain, based on the NA60 Active-Feedback-Preamplifier (AFP) is being evaluated as a radiation hard candidate for the BCM$_F$ amplifier chain. Once amplified the signal is passed to the UXC via standard CMS optical link components and then converted and processed by the DAB64 board with custom mezzanine cards. Development of this custom mezzanine card is still required.

The signal to noise of PCD is however marginal at this time, while that from single crystal (SCD) samples has the potential to be sufficient and to match the AFP specifications. Technical issues related to radiation damage, readout etc of SCD are under active study in CMS and promising results have been obtained. The exact arrangement of sensors, amplifiers, optohybrids, cables has still to be optimized, but so far no show-stoppers have been uncovered.

**CMS expects this system to be a “beyond-baseline” system.** If the technical and resource
issues can be addressed there is a reasonable possibility even that some initial version of it could be in place for the 2007 running. **CMS expects this system to be fully operational for the 2008 LHC running.**

**Pixel Luminosity Telescope**

The PLT is designed to deliver fast (time scales of order $1 - 10\,\text{s}$) and accurate (precisions of order $1\%$) relative luminosity measurement. It consists of pixel readout of Single Crystal Diamond signals with pointing geometry telescopes installed mechanically on the same carriage as the BCM1 systems. While this device has clear Physics-luminosity importance, it is also unique in that it can be used for fast luminosity optimization and LHC feedback, and is thus a priority item for CMS operations as well as for physics-extraction.

The R&D for the PLT is well advanced, nevertheless there do remain issues to validate before an eventual decision in construction/installation. The bump-bonded Diamond sensors need to be tested in CMS radiation and field conditions. The exact configuration of the front-end readout, number of opto-hybrids etc is being optimized. Questions on the impact on material and heat budgets need to be answered, though we do not expect them to be show-stoppers. The necessary cables and routing have to be assured, as they are constrained by the available cabling allocated to BRM from the Pixel allocation.

**CMS expects this system to be very important for the Physics running in 2008,** and beyond, to enable us to have a fast optimization of the delivered luminosity. We therefore propose to rapidly establish that no show-stoppers exist while completing the detector development studies necessary to make a final deployment decision.

**Schedule Overview and Proposed Baseline**

We address here the schedule for installations in the central and HF-plug regions. The RAD-MON and passive systems clearly having different constraints which are also under evaluation, and will be incorporated into the BRM planning.

In March 2006 a full BRM EDR is proposed, and would focus on review and approval of a detailed baseline plan for the Pilot run.

In October 2006 a trial installation of a BCM1 mechanical structure within the Tracker volume, before it goes to Point 5, is highly desirable.

From April 2007 the beam pipe and tracker area will be ready to allow a final installation in preparation for LHC running in the 2007 Pilot run. The BCM1 carriage is to be installed within CMS after the Tracker, Pixels, Beam-pipe and Beam-pipe support installation has been completed.

The installation schedule of BCM2 is not yet addressed.

The baseline plan is not yet available, we note below our current thinking that will guide us in detailed preparation of such a plan.

The expected baseline plan will be to install the BSC, Passive systems and RADMON and the Diamond leakage-current systems in time for the 2007 Pilot run. The BCM1_L systems can be installed either on a single-purpose (BCM-only) carriage, or on the combined BCM-PLT carriage. We delay to early 2006 an eventual decision on which mechanics to carry forward in
the EDR. If the BCM-only carriage is used it does not preclude installation of some prototype fast diamond sensors and readout. Likewise, if the BCM-PLT carriage is used, we may be able to install some trial components of the PLT. However, both these possible options are currently considered to be beyond the baseline.

We further expect the baseline for the full first physics run in 2008 to include the Passive and RADMON and Diamond leakage current as above, but to also include the full BCM1_F, BCM2_F, and PLT.

**Engineering Design Review**

We are working towards a full BRM-EDR in March 2006. This EDR would include review and approval of a detailed baseline plan for the Pilot run. While no formal charge for this EDR yet exists, we would expect it to include:

- Baseline proposal including all component choices and any required development planning.
- Resource loaded planning for all baselined BRM systems
- Installation planning
- Cabling, heat load and material budget designs, acceptable to surrounding CMS/LHC systems (Tracker, ECAL, Beam-pipe, etc.)
- Baseline proposal for integration with CMS DCS, DSS and DAQ and related data handling issues.
- Baseline proposal for presentation of CMS-BRM results in CMS and LHC control-room and incorporation of those results in operations decision-making
Appendix I: SC58 decisions on BCM and PLT

Notes extracted from the executive summary of CMS SC58.

BCM and Luminosity Monitor
Build a Radiation Monitoring System: Composed of 5 independent systems

1. On-line Passive sensors (OSLs) + a small number of active monitors
2. Passive Monitors (TLD+RPL+Alanine)
3. The RAMSES system (Cavern) and
4. RADMON system for beamline around IP5. These are not CMS responsibility.
5. BCM

BCM: Purpose
Monitor beam conditions on the bunch to sub orbit time scale.
Measure charged particle flux close to beampipe (for Normal running + startup)
Monitor the interbunch spacing and the abort gap = single MIP detection
Initiate beam abort on onset of adverse beam conditions on the sub-orbit scales (100ns - 89us)
System should not CLK out signal ie no 40MHz
Must have a simple failsafe backup system

BCM: building working collaboration to deliver the diamond BCM : interest in US (tests in CDF).
BCM design quite mature,
Diamond lumi monitor: supported idea but needs more work, funding approval etc Timescale and resource priority are different.
Recent workshop highlighted that integration of BCM1 and proposed lumi monitor is the same problem.

ACTION 5: Decide to go ahead at CERN with design and procurement of a common support structure for BCM and lumi telescopes.