BEAM DUMPING SYSTEM AND ABORT GAP

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Abstract

The performance of the beam dumping systems and the abort gap cleaning are reviewed in the context of the general machine protection system. Details of the commissioning experience and setting up, encountered equipment problems, the experience with and status of the eXternal Post Operational Checks (XPOC) and the importance of operational procedures are presented for the beam dumping system. The brief experience with the abort gap cleaning is also presented.

BEAM DUMPING SYSTEM

General Operational Experience

At 450 GeV the beams were dumped correctly, showing the expected pattern on the beam screen just in front of the beam dump block (BTVDD), see Fig. 1, and no significant beam losses in the extraction area and beam dump channel were measured.

For a beam energy of 1.2 TeV the beam was found to be 7 – 8 mm low on the BTVDD for both beams. This could be an MSD (extraction septum) calibration issue and will be corrected during 2010 operation when required.

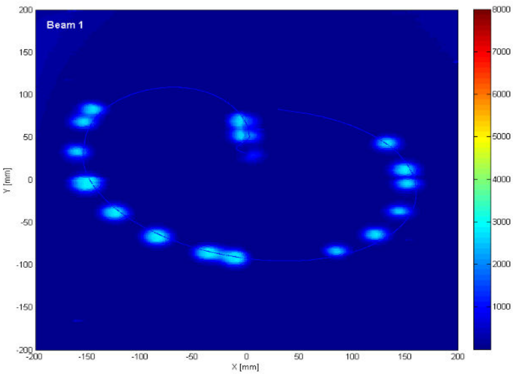

Figure 1: BTVDD image of beam 1, for a beam dump of 16 bunches plus one pilot bunch (14/12/09 around 21:00).

Beam Dumping System Failures

All beam dumping system failures were caught by the XPOC (eXternal Post Operational Check) system and/or IPOC (Internal Post Operational Check) system [1]. There were no beam dump failures which were 'unacceptable', meaning that none of them would have caused damage with the TCDQ correctly positioned. Normally the TCDQ is supposed to protect against about one asynchronous beam dump per year, however, eleven asynchronous beam dumps occurred during about 1 month of operation.

This fault was traced back to a problem with the TSU (Trigger Synchronisation Unit) of the beam dumping system in the case that a dump request was received during the 1.5 μs of the f_{rf} pulse duration. This caused a synchronous trigger of the 15 MKD generators, but asynchronous relative to the circulating beam (that's why it was called a 'synchronous – asynchronous'). The TSU firmware was upgraded during the 2009 operational period and tested successfully.

Other beam dumping system hardware problems encountered were:

- Twice a fuse on an MKB power trigger converter failed. The power consumption of the converter was reduced during the technical stop.
- The BPM signal used for synchronisation with the beam was found to have a 2 μs off-set. This is most likely caused by being connected to the wrong BPM and remains to be corrected.
- Resistors used for detecting a conducting of the switch not via the GTO stack: 15 out of the 60 resistors were broken. As they are redundant, 2 per generator, protection is still active, but new resistors have been ordered. About two weeks are required to make the change.
  Because of the missing redundancy, the beam dumping system should not be used with unsafe beam above 5 TeV beam energy before replacing the resistors.
- Break down of the 'inverter' in the Peltier cooling elements of the MKD generators. Weaknesses have been identified and an improved system is being developed.

The XPOC system and kicker failures

The XPOC system was used to analyse all beam dumps. Checks included the MKD (extraction), MKB (dilution) kicker waveforms, the vacuum in the dump lines and the beam losses from the BLMs in the extraction region and the dump lines. In 2009 the XPOC system was used for the first time within the Post Mortem framework.

During the operational period of 20 November to 16 December 2009 a total 1366 dumps were analysed for beam 1 and 1175 dumps for beam 2, of which only 7 dumps at 1.2 TeV for both beams. The number of false XPOC results as a function of time are shown in Fig. 2. It shows that for both beams there were no false XPOCs over the last 10 days of operation.

For the MKD beam 1 system about 50 faults occurred on a single day, due to a varying pulse length on generator K. This was temporarily solved by doubling the XPOC acceptance window of the pulse length of this generator. Inspection during the technical stop over Christmas showed a loose contact on this generator, which was repaired.

For the MKD B2 system the faults or more distributed. They were partly due to noise on the XPOC1 signals (solved by doubling the acceptance window, which are now the standard settings for both beams) and an ‘energy error’ in the analysis, solved during operation by applying the correct tolerances.

Some other ‘false’ XPOC errors occurred due to time stamps errors between MKD and MKB IPOC analysis and some IPOC analysis errors with points left ‘dangling in the air’. This was all sorted out by some minor software changes. These false XPOCs were annoying for both the operators and the experts, but it is important to maintain the ‘Expert Reset’ of any false XPOC as the beam dumping system is too safety critical and experience has to be gained with safe beams.

No errors were signalled on the MKB analysis, which can partly be explained by the larger acceptance window within XPOC for the MKB systems, which are less critical for operation.

The BLM systems gave an XPOC error on several occasions. The ‘errors’ were always caused by dumping an unbunched beam, exactly one of the faults it is designed to detect.

It is foreseen to develop and commission with beam the modules analysing the BCTD data (dumped beam current), the BTVDD image, the BPMD data and the Abort Gap monitor data during 2010 operation.

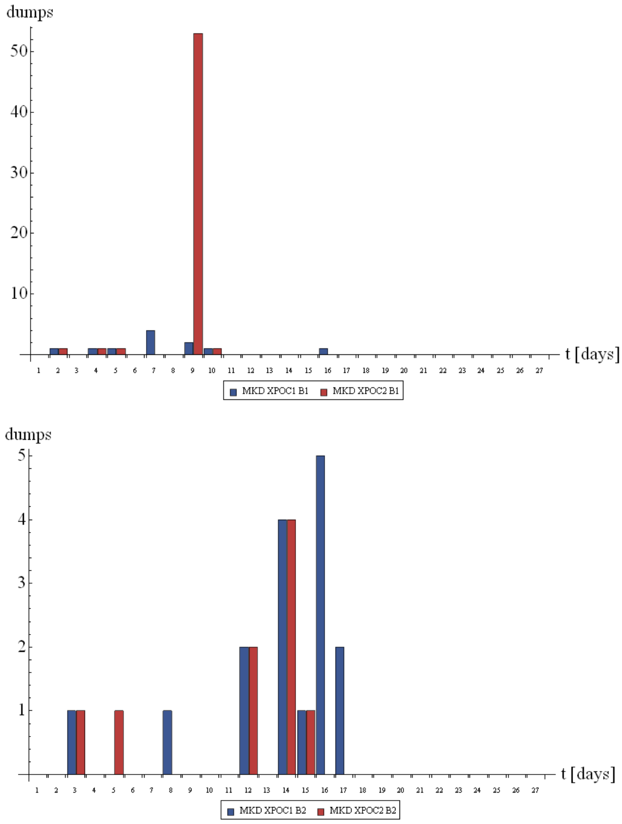

Figure 2: Number of MKD XPOC faults for beam 1 (top) and beam 2 (bottom).

Aperture measurements

The Aperture of the beam dumping channels were measured for both beams in both planes using all phases. The results were as expected, with apertures above 8 σ. The beams could be dumped without losses, with simulated MKD kicks of ± 1.67 MKD equivalent for B1 and +1.33 and -1.67 MKD for B2. This is well above the specification of +0 and -1 MKD. The circulating beam aperture has been checked carefully at the TCDS, TCDQM absorbers and the MSD and MKD magnets using bumps, for both beams in both planes. Beam losses agreed with the aperture model of the region.

ABORT GAP CLEANING TESTS

First functionality tests of the abort gap cleaning were performed during the last days of operation in 2009. The vertical dampers were used on beam 2. The most interesting measurement is shown in Fig. 3: After four injections and some time with stored beam the RF is switched off at moment (1). The BCTFR reading goes to zero and the intensity reading goes to ‘maximum’ immediately, as the four injected bunches were close to the abort gap. After 5 minutes (2) the cleaning is switched on and an equilibrium between cleaning and abort gap repopulation is obtained after 1 – 2 minutes. At (3) the beam was dumped. During the dump, the losses at the BLMs located at the TCDQ and TCDS were reduced to 10 – 12 % of the losses at these elements without cleaning.

From the experience so far it can be concluded that for beam 2 the abort gap cleaning already worked during the first tests, however further optimisation is required to clean over the full 3 μs of the abort gap and limiting the losses outside the abort gap.

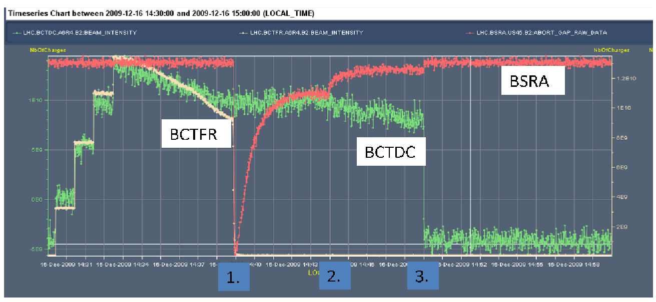

Figure 3: Beam current measurements by the BCTFR and the BCTDC together with BSRA intensity measurements (zero intensity at the top) as a function of time.

CONCLUSIONS AND OUTLOOK

The beam dumping system functioned very well during the 2009 operation with beam. All system failures were caught by the XPOC and IPOC systems. The most serious failure was the ‘Synchronous Asynchronous beam dump’, which was solved after the firmware upgrade of the Triggering Synchronisation Unit of the beam dumping system.

Many tests of the beam dumping system are outstanding, including dumps at intermediate energies and detailed setting up of the protection devices. The vertical off-set of the beam at 1.2 TeV needs to be further investigated.

Operation above 5 TeV should not take place with unsafe beam due to the missing redundancy of erratic trigger detection caused by the broken resistors used for detection. Two weeks are required for replacement.

Further XPOC modules based on Beam Instrumentation measurements are planned to be commissioned during 2010. The latching interlock of the Software Interlock System after a false XPOC is mandatory and the SIS interlock will become unmaskable during the 2010 operation. It is important to have one approved “Master Sequence”, which guarantees a standard way of operating the machine and clear instructions under which conditions certain tasks can be skipped.

The functionality of the abort gap cleaning system has been proven for beam 2. Further optimisation to improve the cleaning is required. Concerning Machine Protection, the Abort Gap Monitor will need to be commissioned and thresholds need to be determined above cleaning will have to take place and another threshold above which the beam will be dumped.

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REFERENCES

[1] J. Uythoven et al., “Experience with the LHC beam dump post-operational checks system”, Proc. Particle Accelerator Conference (PAC09), May 4-8 2009, Vancouver, Canada.