PREMATURE BEAM DUMPS IN 2011

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Abstract

The statistical analysis of all non-programmed beam dumps during the 2011 proton run is presented. The selection criteria of fills that got considered were that the beam intensity of each of the two beams exceeded at least 1e12 particles per beam in order to exclude all probe beam dumps and most of the MPS test dumps. A distribution of beam dump causes by system is shown, as well as the time it took to re-establish injection after a non-programmed dump for fills which made it into STABLE BEAMS. This was done in an attempt to evaluate the cost of those non-programmed dumps in terms of time.

INTRODUCTION

Every beam dump generates a multitude of post mortem data from the various LHC systems and is systematically analysed by the operations shift crew via the Post Mortem Online application. The result of this first assessment and the associated data which classifies and categorises the beam dump event is stored in the Post Mortem Online ORACLE database and can be accessed for browsing (www.lhc-postmortem.cern.ch). The Post Mortem database offers via its APEX interface an easy and intuitive way of browsing the data, building and storing queries in the form of reports for later use and downloading the data for offline analysis. All dumps occurring at high energy are furthermore analysed in more detail by a group of machine protection experts who, if needed, correct and complement the beam dump event data. For this study, only non-programmed dumps which occurred during the 2011 proton run of the LHC have been taken into consideration. Only dumps where the beam intensity of beam 1 and beam 2 exceeded 1e12 particles per beam have been considered, in order to filter all dumps with probe beams (low intensity beam to check out the machine before injecting trains of high intensity bunches) and those which were performed to test the machine protection system itself.

BEAM DUMP STATISTICS BY MODE

Applying the above criteria, one obtains 375 non-programmed beam dump events which correspond to 78% of all beam dumps (482), including the programmed dumps (107). The distribution of those events by beam mode is shown in Figure 1. Table 1 lists the absolute numbers of non-programmed beam dumps by beam mode.

The majority of beam dumps occurred during collisions of proton beams, i.e. while being in beam mode STABLE BEAMS and while filling the machine with trains of high intensity bunches (INJECTION PHYSICS BEAM).

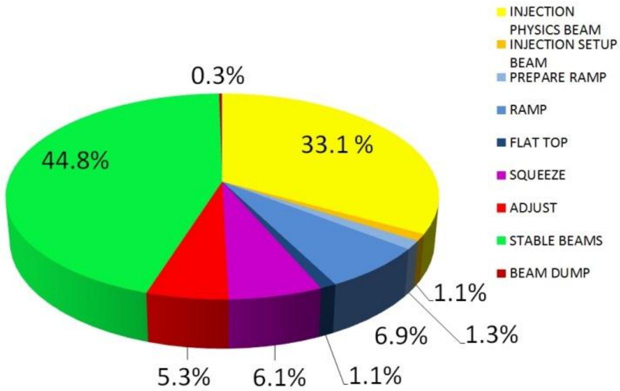

Figure 1: Distribution of non-programmed dumps by beam mode.

Table 1: Non-programmed dumps by mode.

Beam mode	**Number of non-programmed beam dumps**
INJECTION SETUP BEAM	4
INJECTION PHYSICS BEAM	124
PREPARE RAMP	5
RAMP	26
FLAT TOP	4
SQUEEZE	23
ADJUST	20
STABLE BEAMS	168
BEAM DUMP	1

BEAM DUMP CAUSES

When analysing the distribution of what caused the beam dumps in Table 1, one can distinguish between three groups. The first group contains all dumps related to beam monitoring (orbit, beam loss, feedbacks, etc.), the second groups those dumps related to failures in the various components of the machine protection system itself (Beam dump system, Power Interlock Controller, Beam Loss Monitoring, Beam Interlock Control, Software Interlock Control) and finally the third group contains all other equipment (Cryogenics, Quench Protection System, Power Converters, etc.).

The vast majority of dumps were triggered by failures of equipment in the latter group. In this group one finds that the top five failing systems were (the number of dumps which happened in STABLE BEAMS is indicated in parenthesis):

1. Quench Protection System (36 dumps)
2. Cryogenics (23 dumps)
3. Power Converters (22 dumps)
4. Radiofrequency System (19 dumps)
5. Electrical Network (17 dumps)

Together these five systems accounted for 77% of all beam dumps that occurred during STABLE BEAMS.
The failing system however is not necessarily the one which triggers the beam abort. Most of the triggers were issued by the Power Interlock Controller (PIC), which is a normal behaviour as the Quench Protection System and the Power Converters are connected to the PIC. The triggers by the Beam Loss Monitoring (BLM) system followed second. Both PIC and BLM constitute part of the Machine Protection System of the LHC.

BEAM DUMPS IN "STABLE BEAMS"

Analysing the histogram of all 168 beam dumps that occurred during beam mode STABLE BEAMS reveals that half of all fills lasted only less than 3h. The same observation was made for the subset of fills with the full number of bunches (1380) for both beams. The calculated arithmetic average fill lengths are 4.9 h and 4.6 h respectively.

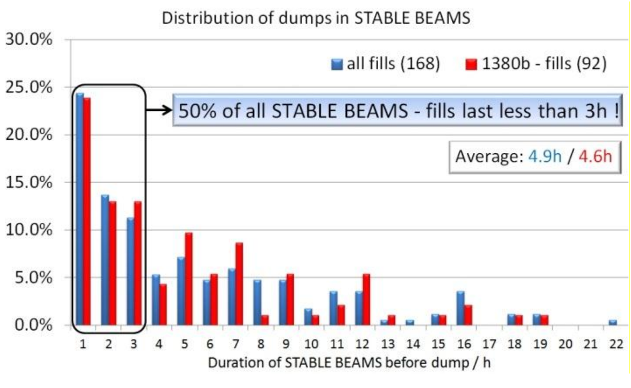

Figure 2: Distribution of beam dumps in STABLE BEAMS.

Out of these 168 protective beam dumps, about 22% were initiated due to effects related to Single Event Upsets (SEU). The systems which suffered most SEUs were the Cryogenic System (16 dumps) and the Quench Protection System (15 dumps).

RECOVERY AFTER BEAM DUMPS IN "STABLE BEAMS"

When analysing the time to establish the conditions to be able to inject probe beams again after a beam dump in STABLE BEAMS, it was found that on average it took 4.6 h to prepare the LHC for a new injection. For some systems which triggered beam dumps in STABLE BEAMS this time was always shorter than the average, however for other systems like for example Cryogenics or QPS this time was often significantly longer.

CONCLUSION

The study revealed that the majority of non-programmed beam dumps were triggered during beam mode STABLE BEAMS. The five most contributing systems to those beam aborts (Quench Protection System, Cryogenics, Power Converters, Radiofrequency System and Electrical Network) together accounted for 77% of all dumps in STABLE BEAMS. SEU related effects were at the origin of 22% of all beam aborts in STABLE BEAMS and they mainly affected the Cryogenics and Quench Protection systems. Half of all fills in STABLE BEAMS did not last longer than 3 h. On average it took about 4.6 h to prepare the machine for injection after a non- programmed beam dump.

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