STUDIES AND HISTORICAL ANALYSIS OF ALBA BEAM LOSS MONITORS

A. A. Nosych, U. Iriso, ALBA-CELLS, Barcelona, Spain

Abstract

During 5 years of operation in the 3 GeV storage ring of ALBA, the 124 beam loss monitors (BLMs) have provided stable measurements of relative losses around the machine, with around 10% breakdown of units. We have analyzed these BLM failures and correlated the integrated received dose with any special conditions of each BLM location which might have led to their breakdown.

We also show studies of beam losses in the insertion devices, with particular attention to the results in the multipole wiggler (MPW), where the vacuum chamber is (suspected to be) misaligned and high BLMs counts are detected.

INTRODUCTION

ALBA is a 3 GeV 3rd-generation synchrotron light source, operational since 2011. Currently it is running in top-up mode with beam current of up to 150 mA and the horizontal emittance of 4.6 nmrad. During 5 years of operation the 124 beam loss monitors have been generally doing a very good service in measuring the loss distribution around the 269 m storage ring (SR). Nevertheless, several units did get out of order, some others did get detuned and some more did change their positions over time. A campaign to re-organize the BLM units and understand their health state has been conducted.

LAYOUT OF ALBA BLMS

Common to other synchrotrons [1], the beam loss detection system of ALBA consists of a pair of compact PIN-diode Bergoz BLMs connected to a two-channel beam signal conditioner (BSC). The BSC provides electrical power and signal readout to- and from- the BLMs. The BLMs are evenly spread around the storage ring at approximately every 2.5 m, coinciding with BPM locations. For maximum sensitivity the active part of BLMs has been positioned in the beam orbit plane and is perpendicular to the beam direction. Besides, placed in the inner side of the ring, they are subjected from the X-ray background.

In total there are 66 BSCs and 124 corresponding BLMs spread around 16 sectors of the machine: 7 or 8 per sector (depending on sector type), plus a few additional units around the injection line from booster. A typical 8-BLM connectivity schematic per sector is shown in Fig. 1.

The BLM detector is sensitive to minimum ionizing particles (MIP) produced when an accelerated particle hits the vacuum chamber [2]. The detector is composed of two PIN-diodes mounted face to face to form a 2-channel coincidence detector. When an ionizing particle hits a PIN-diode, an electric charge is produced, and a bias voltage allows collection of this charge. A particle energy of > 700 keV is required to get the PIN-diode ionized and it is detected with an efficiency of > 30%. MIPs cause ionization in both PIN-diodes, while photons do not, which excludes BLMs from being affected by synchrotron radiation.

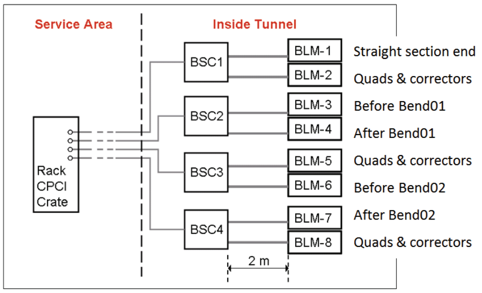

Figure 1: Beam loss detection system of ALBA per storage ring sector.

The size of the PIN-diodes mounted on the circuit determines the detector's solid angle. The coincidence scheme effectively rejects the spurious noise from each channel well below 1 counts per second (cps). The amplification gain of each channel is adjusted with a potentiometer [2].

Beam Loss Monitors in Operation

The nominal counts in the majority of BLM locations during SR operation is around 10-20 cps, which slightly rise during injections, reaching some 10s and 100s in the vicinity of the booster-to-storage transfer line and the injection kickers.

Figure 2 shows a typical loss distribution map around the ring during decay and injection modes, updated at 1 Hz rate. In each sector the lowest losses correspond to the beginning/end of the sector (straight sections), while the highest are systematically read downstream of both dipoles in each sector.

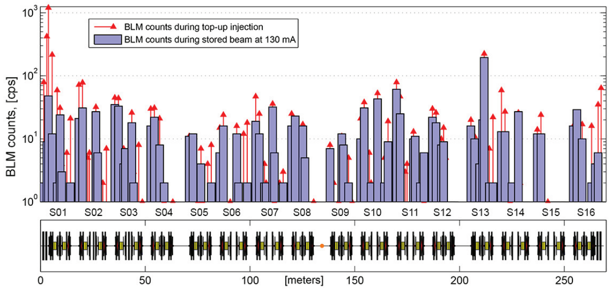

Figure 2: Operational beam loss distribution (log scale) on the ALBA storage ring as observed in the control room.

ISBN 978-3-95450-177-9

HISTORIC BLM DATA ANALYSIS

Since the installation of the storage ring in 2009, through its commissioning in March 2011, and after 5 years of operation by the end of 2015, we have made an attempt to analyze the evolution of BLM readings and estimate the degradation and survival rate of the physical BLM units. We look for possible correlation between BLM mortality, various operational conditions, and total received counts.

Evolution of Dark Counts, 2009-2015

The dynamic range of a PIN-diode BLM is determined by the spurious noise of the detector and the maximum count rate. The spurious noise is below 1 cps in the absence of any background. The detector recovers 100 ns after a hit, leading to 10 MHz maximum count rate.

The Bergoz BLM circuits are shipped pre-calibrated for a spurious count rate of 10 kHz. By forcing one PIN-diode to be always True (i.e. always reading a hit), the spurious counts calibration of the other PIN-diode can be checked. The control system of ALBA allows simultaneous switching of all available BLM PIN-diodes to False-False (FF) operational mode, and True-False (TF) or False-True (FT) calibration modes. The readings in two latter modes are called "dark counts".

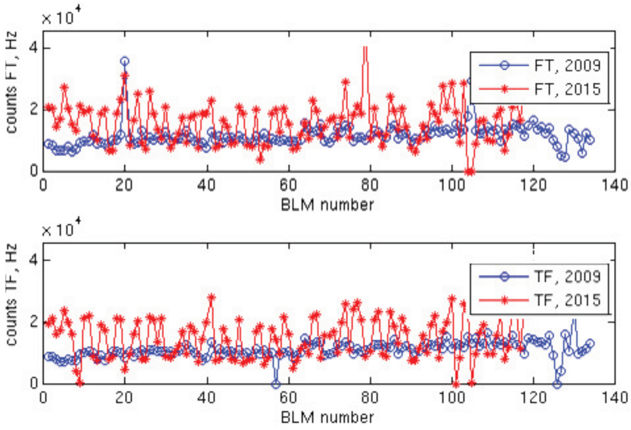

Figure 3: Dark counts in TF and FT calibration modes: 2009 vs. 2015 (without beam).

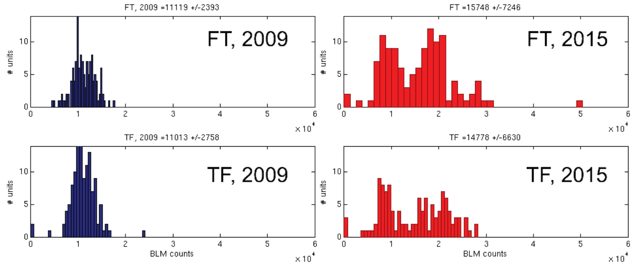

Figure 4: Histograms of dark count measurements in TF and FT modes in Fig 3: 2009 vs. 2015 (without beam).

When a BLM shows zero or extraordinarily high or low counts, most likely it has been detuned. Its PIN-diodes can be re-calibrated back to 10 kHz by adjusting the potentiometers and measuring the dark counts.

Figure 3 compares the dark counts of all SR BLM units after installation in 2009 with the ones measured in the end of 2015 without beam. There is a clear increase in TF and FT modes for some BLMs, possibly those receiving higher radiation doses leading to their slow detuning over time.

In Fig. 4 the histograms highlight an increase in the spread (more units read more spurious counts) and in the average (more units read higher spurious counts than average) of dark count measurements in 2015 versus 2009.

By doing periodic checks we regularly monitor BLM calibrations and tune the potentiometers if needed.

Integrated Counts of ALBA BLMs, 2011-2015

We calculate and analyze the total amount of counts received by each BLM location and correlate the results with BLM failures.

The data archiver of ALBA control system logs the BLM counts at 0.1 Hz rate. Since the SR commissioning there are 13 million data points recorded for each of the 124 BLM locations (not for particular BLM unit). Integrating over these points gives an estimate of the total counts received in 5 years. They are shown in Fig. 5, where the intermediate values corresponding to FT/TF modes, as well as those taken with beam current < 1 mA, have been filtered out.

The overall amount of counts for the majority of BLM locations since 2011 are < 10 million, with only a couple of them exceeding this dose (BLM-0103: 15M counts, BLM-1609: 60M counts) for unknown reason.

The locations of 9 failed BLM units are also highlighted, together with the color-coded failure type and detuned units: 2 fatal (red, non-repairable), 7 with failed on-board electronics (black, repairable), and 8 detuned (green, repaired in-situ). In particular, among the units with failed electronics, 4 had lost video amplifiers, one had lost an inductor, and one more - a transistor [3].

Unfortunately, by comparing the total amount of counts with the BLM failure type no correlation could be established: the high amount of received counts does not lead a loss of BLM unit.

To cross-check further, we super-impose the operational counts at 1 Hz (during stored beam and a top-up injection) with the total integrated counts, Fig. 6. However, again we see no correlation between the operational counts and BLM failures: no indication of constant high-loss region systematically affecting the BLMs in the area.

Furthermore, comparing the dark counts (taken during beamtime) with the total integrated counts in Fig. 7, neither reveals any correlation between these data sets and particular BLM failure locations.

Finally, we correlate the BLM unit failures with some location specifics around the ring: the high radiation environment around the RF plants and the injection sector, Fig. 8. The majority of failed (7/9) and half of the detuned (4/8) BLM units were located in the highlighted areas, which can hint on their degradation.

ISBN 978-3-95450-177-9

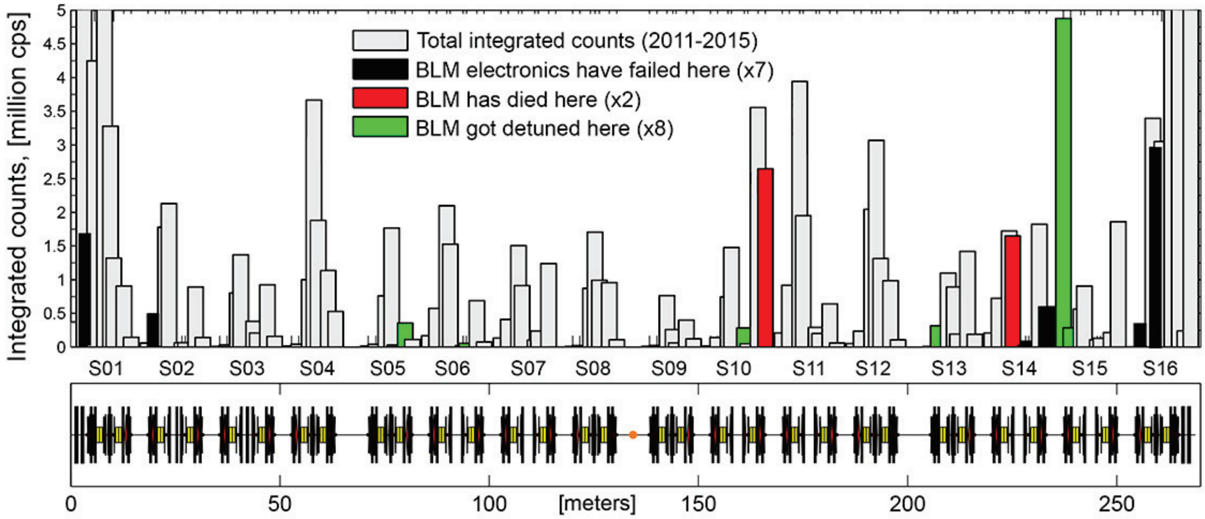

Figure 5: Overall integrated counts (2011-2015) for every BLM location vs. BLM failures.

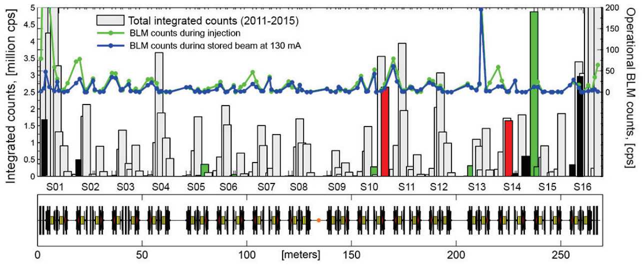

Figure 6: Overall integrated counts vs. loss patterns during injection and stored beam.

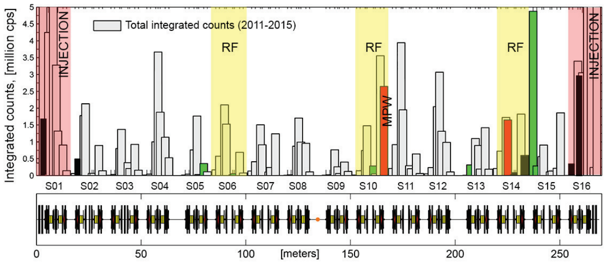

Figure 8: Overall integrated counts vs. location specifics.

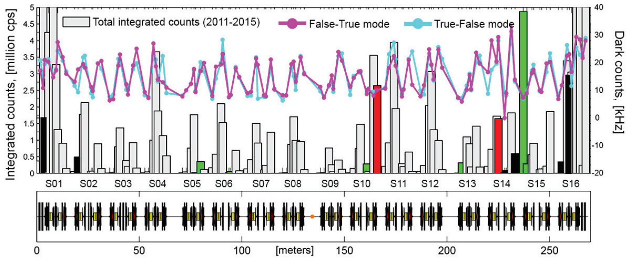

Figure 7: Overall integrated counts vs. operational dark counts pattern during beam time.

MISALIGNMENT DIAGNOSTICS WITH BLMS

The ALBA storage ring operates several insertion devices (IDs) to produce high-brilliance X-rays for its 6 beamlines (plus two beamlines using bending dipoles). These IDs are the multi-pole wiggler (MPW), the super-conducting wiggler, two in-air elliptic undulators (EU), and two in-vacuum undulators.

The MPW, in particular, is placed in a straight section between two sectors. The 2 m long vacuum chamber of MPW is elliptic, machined in an 8 mm thick rectangular aluminum block. It is attached to an upstream and downstream SR vacuum chambers (28 mm thick) with the so-called *distributed absorbers*, which bear the octagonal-to-elliptic transitions. Figure 9 shows the distribution of all these elements.

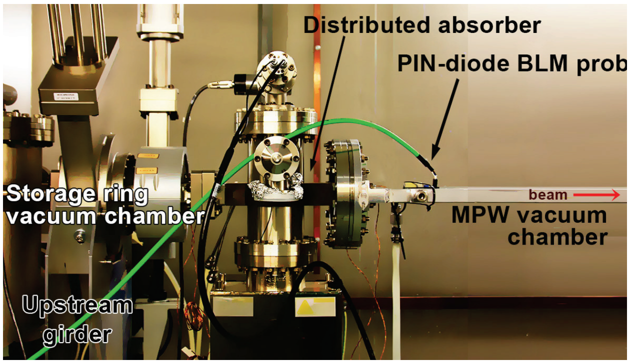

Figure 9: Side view of the storage ring vacuum chamber connection with the MPW straight section.

An alignment survey had indicated that the SR girder, upstream of the MPW, is misaligned by 0.8 mm downwards with respect to the downstream girder. A BLM was placed on top of the MPW vacuum chamber (Fig. 10) to monitor beam losses, possibly induced by electrons interacting with misaligned vacuum chambers or the absorber.

ISBN 978-3-95450-177-9

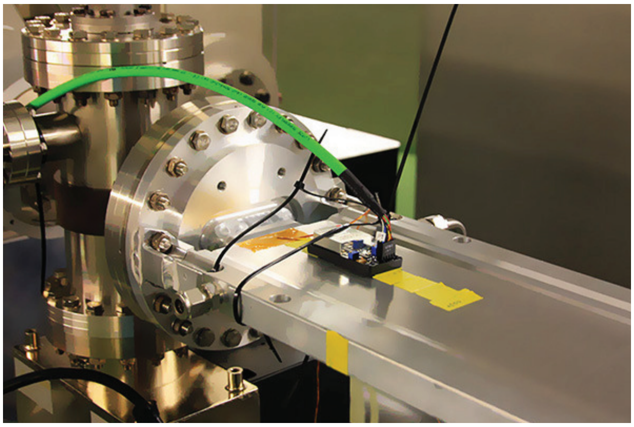

Figure 10: Beam loss monitor placed on top of the MPW vacuum chamber to study losses induced by misaligned storage ring sections.

Very high loss counts, shown in Fig. 11, were indeed detected. The losses on top of the MPW chamber appear to be highly beam current-dependent, rising drastically from 1000 cps at 120 mA to 6000 cps at 150 mA. The losses also appear to be very sensitive to top-up injections.

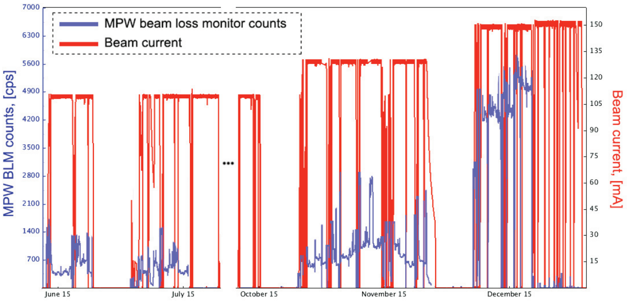

Figure 11: Beam losses measured on top of the MPW vacuum chamber throughout part of 2015, indicating a drastic dependence on beam current.

A BLM placed under the MPW beam pipe did also detect some losses, but less than on top. Another unit did not measure any losses on the side of the beam pipe in the horizontal plane, confirming the vertical plane misalignment theory.

Figure 12 shows the simultaneous measurement of losses above and under the MPW beam pipe at two longitudinal BLM positions: both BLMs at 5 and 10 cm away from the distributed absorber transition. The counts above decrease as the BLM gets farther from the misaligned region, while the counts below stay constant.

As of September 2016 the current state of loss distribution in the ALBA storage ring is shown in Fig. 13. Here one can see several locations with high losses, which are possibly related to misalignment issues of ID vacuum chambers: the MPW (CLAESS beamline), the EU62 (CIRCE beamline) and the recently installed vacuum chamber of another EU for the future LOREA beamline to be commissioned in 2017. The losses in the latter one combine also the losses induced by vacuum conditioning (unknown to-date).

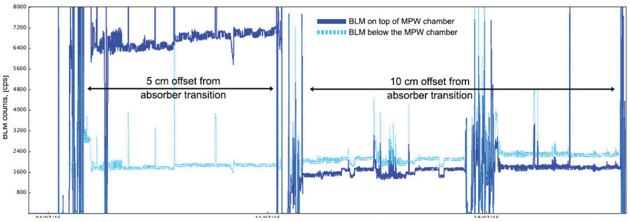

Figure 12: Longitudinal scanning of beam losses on top and bottom of the MPW vacuum chamber.

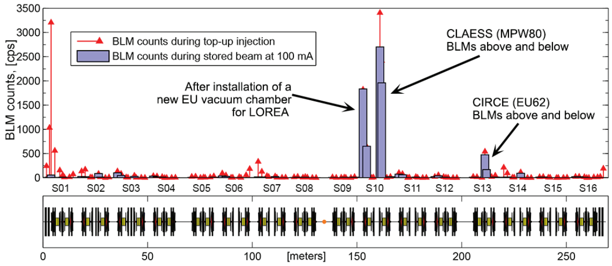

Figure 13: Up-to-date beam loss distribution map of the ALBA storage ring, showing high-loss regions (02.09.2016).

CONCLUSION

We have made an attempt to correlate the BLM failures occurring in the last 5 years with the total counts received by each BLM location, as well as with other BLM-specific measurements. We conclude that the BLMs seem to be having some problems with integrated electronics, mostly failing in the areas of high radiation background. Across 5 years of operation 9 failed BLM units (out of 124) do not make such bad statistics after all.

The PIN-diode BLMs are useful tools in studying vacuum chamber misalignment issues, especially in the regions of vacuum chamber transitions. They are able to indicate the misalignment direction and magnitude. As of end of 2016 we continue monitoring beam losses related to misaligned insertion device vacuum chambers.

REFERENCES

[1] F. Perez, et al., "Studies using Beam loss monitors at ANKA", Proceedings of EPAC 2004, Lucerne, Switzerland

[2] Bergoz Instrumentation, Beam Loss Monitor User's Manual, `http://www.bergoz.com`

[3] Private communication with J. Bergoz

ISBN 978-3-95450-177-9