RHIC BPM PERFORMANCE: COMPARISON OF RUN 2003 AND 2004

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Abstract

Identification of malfunctioning beam position monitors (BPMs) play an important role in any orbit or turn-by-turn analysis. Singular value decomposition (SVD) and Fourier transform methods were recently employed to identify malfunctioning BPMs at RHIC. A detailed statistical comparison between the two methods for Run 2003 was in good agreement and proved to be a robust method to identify faulty BPMs. We evaluate detailed BPM performance for different upgrades of BPM low-level software during Run 2003 and 2004.

INTRODUCTION

BPMs are widely used in accelerators to record the average orbit and transverse turn-by-turn positions of the bunch centroid motion. RHIC consists of two three-fold symmetric rings with six interaction regions. There are 160 BPMs per plane per ring (yellow & blue): 72 dual-plane BPMs distributed through the IRs, and 176 single-plane BPMs distributed in the arcs [1]. Each BPM channel acquires 1024 consecutive turn-by-turn positions.

A detailed statistical analysis using SVD and FFT techniques aided in evaluating the performance of RHIC BPMs during Run 2002-03 [2]. Statistical behavior of each BPM was extracted to help identify possible failure modes and working condition of the BPM system. A comparison between the two techniques was further helpful in determining the appropriate statistical cuts on observables to identify faulty BPMs in each data set. Statistics on failure rates were crucial in distinguishing different failure modes and behavior of BPMs around the ring.

Some of the failure modes were identified to be low level software issues of the BPM data acquisition system and radiation damage of BPM electronics. In this paper we evaluate the performance of the pick-ups during Run 2003 and Run 2004 (Au-Au and Polarized Protons) to understand the effect of software upgrades to the BPM system to help identify and address instrumentation failures.

SVD Technique In the presence of faulty BPMs, spatial vectors of singular value decomposition of BPM turn-by-turn data exhibit sharp spikes. The signals manifested in these modes are localized to a specific BPM locations indicating a potentially noisy BPMs. The Fourier spectrum of the temporal pattern yields a noisy spectrum confirming a noisy BPM. Since, spatial vectors are normalized, localized peaks above certain threshold value can be used as observables to identify faulty BPMs. Multiple peaks are observed in the spatial vectors, due to random correlations between the noisy BPMs.

FFT Technique The FFT technique relies on the fact that the Fourier spectrum of an ideal signal has well localized peaks while noisy or faulty signals show a randomly populated Fourier spectrum. The rms of the background of the Fourier spectrum is larger for noisier BPMs and its dependence with other parameters is negligible. This observable is therefore used to identify the noisy pick–ups. It is estimated by computing the rms of the amplitudes of the background spectrum.

A signal is considered faulty if its rms noise observable is larger than a certain threshold. The value of the threshold is extracted from statistics over a large number of signals. A histogram of rms observables from all signals is constructed. Typically a large peak containing the largest percentage of the data is observed in the low rms values. This peak contains the set of physical signals, while its long tail with larger rms values contains the faulty signals. A suitable threshold is chosen towards the end of the tail.

Statistics from a large set of data further enhance the determination of more accurate thresholds for both techniques and understand BPM behavior around the ring.

ANALYSIS

BPM turn-by-turn data taken during Run 2003 were analyzed in detail and failure modes in the BPM system were studied [2]. Low level software upgrades were implemented as a part of BPM system improvement during the commissioning period of Run 2004. FFT and SVD techniques then applied to Run 2004 data split into Au-Au run and polarized proton run. A comparison between different sections of Run 2004 and 2003 was done in order to understand the extent of system improvements and identifying failure modes related to different operations conditions.

Hardware Status Bit

A status bit internally set by the BPM electronics helps determine obvious hardware failures during data acquisition. BPMs failing this cut are removed from the data and are not included in further analysis. Histograms of BPMs that fail the hardware status bit (status = 0) are presented in Fig. 1 for the different runs to compare and determine consistent hardware failures. These percentages of system failure are in general larger in Run 2004 than those observed in Run 2003. This is partly due to the fact that the system improvements lead to a better recognition of system failures. The abnormal abundance of system failures at specific locations is presently under investigation. BPM data acquisition is managed by front end computer systems (FEC), each responsible for region of BPMs around the ring. Such abundance in a particular region points to either a failure in FEC hardware or the software manager. It is interesting to note that the bundle of failures seems to have moved between the two runs pointing to a possible software issue.

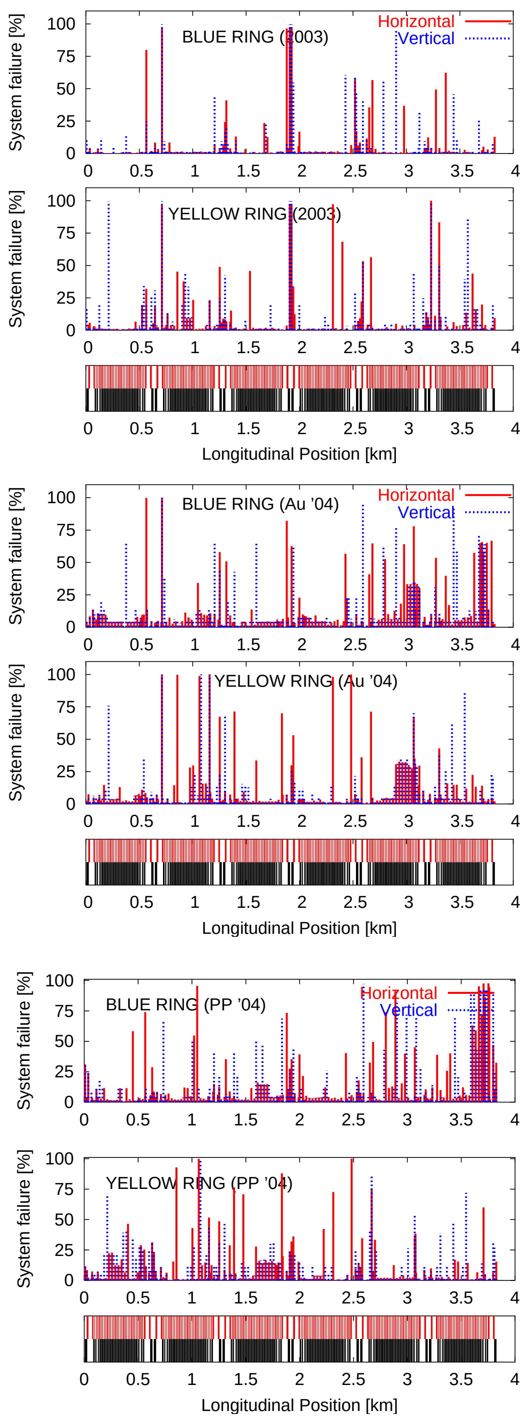

Figure 1: Percentage of occurrences of system failure per BPM versus longitudinal location. Top to bottom: Run 2003, Run 2004 (Au-Au), and Run 2004 (PP). A representation of the lattice (dipoles in black and quadrupoles in red)in the bottom.

Numerical Techniques

It was determined that preprocessing of BPM data, using peak-to-peak signal information was effective before application of numerical techniques [2]. Fig. 2 shows one such illustration of peak-to-peak signal information in a histogram. An appropriate cut has to be determined from the histogram to eliminate BPM signals with very small or flat signal.

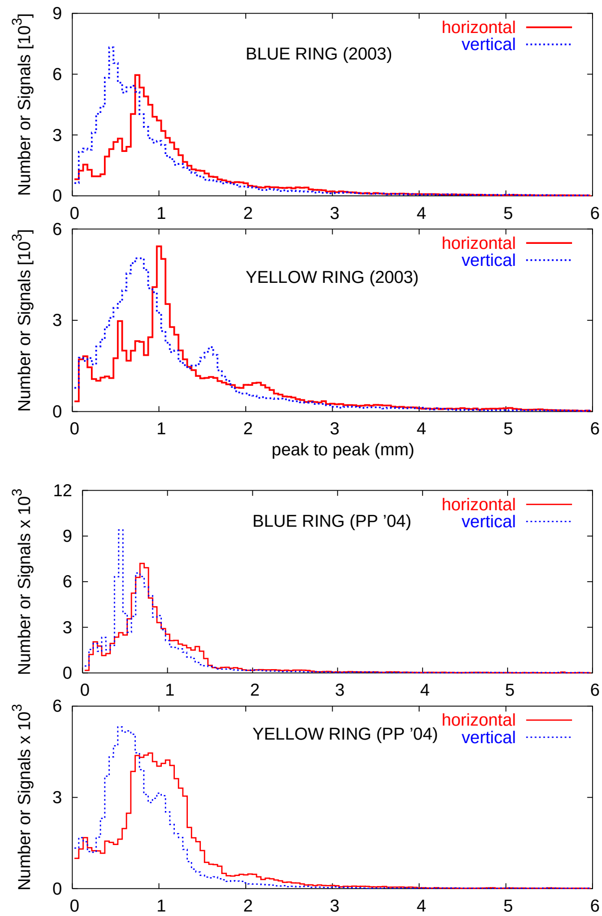

Figure 2: Histogram of peak-to-peak signal values. Top to bottom: Run 2003 and Run 2004 (Polarized Protons).

After the application of hardware cut and peak-to-peak signal cut, FFT and SVD techniques are independently applied to identify appropriate observables and infer faulty BPMs using appropriate thresholds. For a set of optimized thresholds, it was found that the agreement between the two techniques is excellent [2]. For the comparison of faulty BPMs for different runs, we only present the results from the SVD technique. Fig. 3 shows histograms for horizontal BPMs in blue ring for three different run periods explained earlier.

To further understand the sensitivity of the numerical cuts, each histogram is presented with two different SVD thresholds. We observe that in Fig. 3 (top), BPMs in the arc regions between 0-0.5 km and 3.2-3.8 km have a strikingly larger background than the rest of the arcs. It was found that BPMs in these arcs were exhibiting sporadic noise (“hairs”) of ten to thousands of μm on BPM position data. This effect was caused due to unforeseen and untested conditions in low-level DSP code leading to noise jumps on some raw sampled data [6]. Low level software upgrades were implemented as a part of BPM system improvement during the commissioning period of Run 2004. Analysis of kicked data after upgrades is shown in Fig. 3b. which clearly shows the elimination of “hairs”. A change of DSP timing parameters was particularly important in resolving this phenomena. Fig. 3 (middle and bottom), represents data from different periods of Run 2004. The background in PP run is smaller than in Au run, which seems to indicate failure rate of good BPMs are lower.

Peak-to-peak signals in PP run show a smaller occurrence close to zero amplitude than the Au-Au run indicating fewer BPMs with flat signals possibly contributing to the lower background. However, we find more faulty BPMs in IR8 (0.5 km) in PP run which might point to possible damage of BPMs due to radiation or other operation conditions. Also, BPMs located within the interaction regions in all three histograms show poorer performance than the rest of the ring despite similar BPM electronics around the ring.

CONCLUSION

Two numerical algorithms, the FFT and the SVD, have been successfully implemented to analyze RHIC BPM system using kicked data acquired during regular operations. The observables thresholds above which a signal is identified as faulty are obtained from statistics over a large set of RHIC BPM data. A comparison between different stages of RHIC operation data proved useful in concluding successful elimination of “hairs”. Also it was useful in assessing the global performance of every BPM, and identifying those BPMs that systematically provide faulty data as well as point to new failure modes that are under investigation.

ACKNOWLEDGEMENTS

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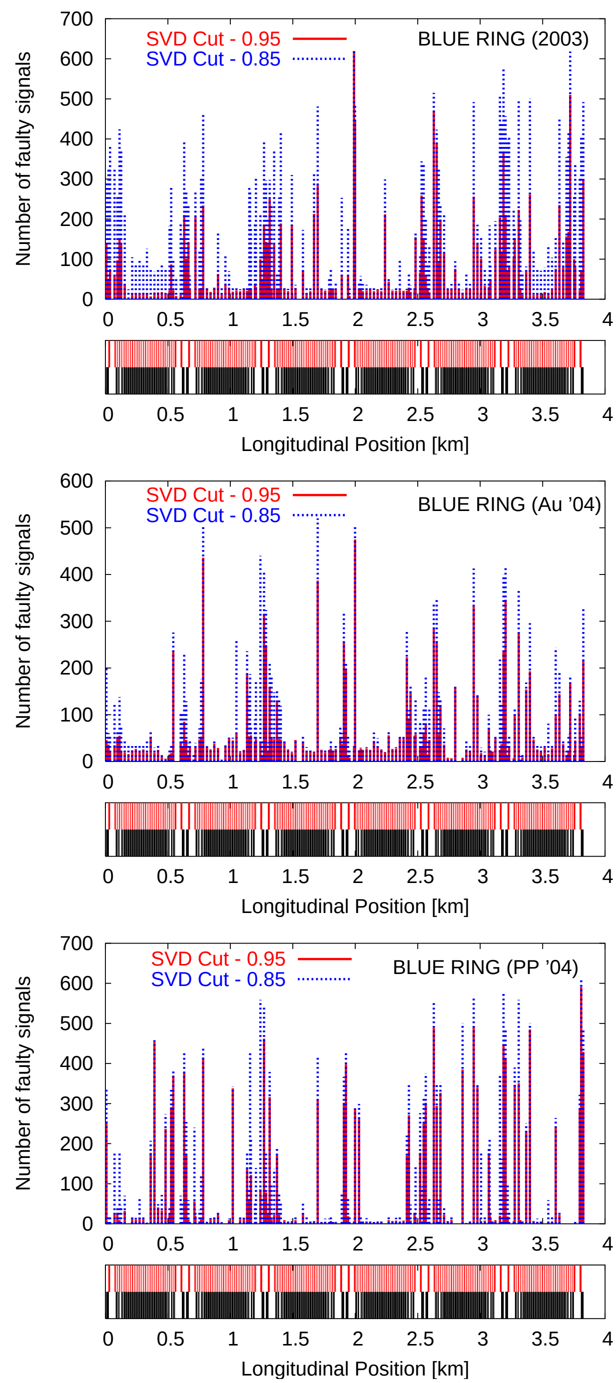

Figure 3: Histogram showing number of occurrences of faulty BPMs around the ring. Top to bottom: Run 2003, Run 2004 (Au-Au), and Run 2004 (PP). A representation of the lattice (dipoles in black and quadrupoles in red) in the bottom.

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