LUMINOSITY OPTIMIZATION USING AUTOMATED IR STEERING AT RHIC*

A. Drees†,Ted D'Ottavio, BNL, Upton, NY 11973

MANUAL STEERING

As a convenience, it is generally useful to have both orbits around an Interaction Region (IR) from the clockwise ("blue") and the counterclockwise ("yellow") beam available in one display. It is especially helpful for collision steering. The RHIC **L**uminosity and **I**R **S**teering **A**pplication (LISA) offers this to facilitate any kind of manual IR steering. LISA allows collision steering in the four RHIC detectors by "manual" steering, i.e. no automatic feedback on luminosity monitors, or automatic optimization using the ZDC [1] coincidence signals as feedback. Selectable options are the IR the Ring, the plane and the bump type (position or angle). Beams are steered by using local orbit bumps in the respective planes ("4-bump"). Beam position measurements from the blue and yellow RHIC BPMs [2] inside the IR, the DX BPMs, and the neighboring quadrupoles (up to Q7) are displayed together. The center of the IR is located between the two DX BPMs that are represented by different symbols than the other BPMs. Crossing angles for the two beams based on the DX BPM measurements are displayed together with the normalized collision signal as part of the application. The manual steering time using this application is about 5 minutes per IR resulting in an estimated total time of about 20 minutes if all experiments have to be steered.

AUTOMATIC OPTIMIZATION

Steering for collision rate optimization can be automated using the collision signal from the Zero Degree Calorimeters as a feedback. Details about the calorimeter can be found in [1]. The ZDCs are especially suitable for this purpose since they are available in all IRs which are equipped with experimental detectors. In addition, they are less sensitive to background since they are located between and shielded by the DX and D0 dipole magnets on either side of the IR. The collision rate, which is based on a coincidence signal from both sides of the IR, furthermore improves the signal to noise ratio. Automatic optimization requires that the coincidence signal is above 0 before the automatic procedure begins. The steps for the automatic optimization procedure are as follows:

1 define current position as 0, integrate collision signal over n_x seconds

2 compute average collision rate and RMS in integration interval

3 step one beam (blue or yellow) by δ (preselected)

4 repeat (2)

5 compare result with previous average collision rate

6 step further in same direction if new average > previous
step by -2 δ in opposite direction if new average < previous

7 repeat (3) to (5) until new average < previous

8 apply parabolic fit to last 3 data points, derive maximum

9 move beam to location of maximum and confirm rates

The collision signals are online available at a 1 Hz frequency. The length of the integration interval, n_x, is determined by the requested accuracy or RMS value of the measurement, a configuration parameter for LISA together with the step size δ. If the requested RMS value, given in % of the average, cannot be reached, an upper limit of 60 s applies. δ should be chosen large enough to ensure a significant difference between two measurement and small enough to allow a decent parabolic fit and to be operationally safe. The beam profile is generally Gaussian but around the center can be approximated fairly well by a parabola.

OPERATION

Single IR

Fig. 1 shows the application panel for a successful optimization in one IR (here: IR10). The center part of the panel is used to print out a list of the steps and their results. The collision rate as a function of time is shown in the lower right graph on the panel. The squares correspond to the data from the IR where the shown optimization takes place (IR10 = PHOBOS).

The automatic optimization mode in LISA allows the choice of single IR optimization (as shown above, Fig. 1), and serial optimization or parallel optimization of more than one IR.

Serial Optimization

For the first part of the RHIC FY04 Au-Au run serial optimization was the choice. The goal was to establish collisions for the experiments as early as possible in a store and to speed up this process. However, uncertainties such as the coupling between the "4-bumps" in the various IRs, kept us using the serial approach rather the parallel one.

Fig. 2 shows an example of consecutive optimization in all four IRs. Single IR optimization was used for all of them. The total time needed for optimization amounts to approximately 10 minutes and required an operator initiating every single process. Fig. 3 is done automatically. The serial order is a configuration parameter and here chosen to

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† drees@bnl.gov

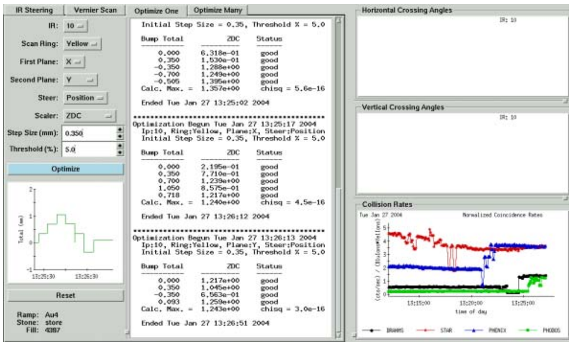

Figure 1: Application panel for optimization of a single IR.

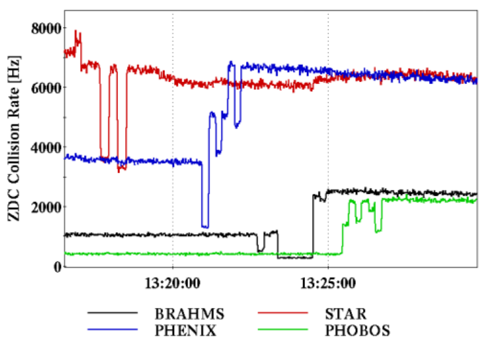

Figure 2: ZDC collision rates from the four experiments as a function of time during serial but manual optimization.

be PHENIX, STAR, PHOBOS and BRAHMS. The particular step sizes should match the value of the β-function at the IRs. The total time, which also depends on the selected threshold accuracy and therefore on the available statistic, is approximately 7 minutes. Note that the collision rate at the time is about x3 less than in Fig. 2.

The typical duration of the serial optimization was about 6 minutes, gaining in the order of 5 minutes every time automatic serial optimization is done compared to manual serial optimization. In addition, the automatic process, once started, does not require an operators attention.

Parallel Optimization

Considering the exponential decay of the luminosity in the beginning of the store every minute, which can be safed to establish collisions, matters. Given the statistical limitations, i.e. a certain integration time is simply needed to keep the statistical error of a measurement small, the only alternative is optimizing all IRs at once. This was tried for the first time in store 4486 on Feb. 7, 2004. Fig. 4 shows the normalized collision rate as a function of bump amplitude for the four IRs. Open squares correspond to the horizontal data and star symbols to the vertical data. Each graph shows both planes at once. The experiments were all steered out of collisions deliberately. The amount varied between experiments and planes. Some residual rates were maintained to guarantee the automatic optimization to work properly. The horizontal plane is done first in all

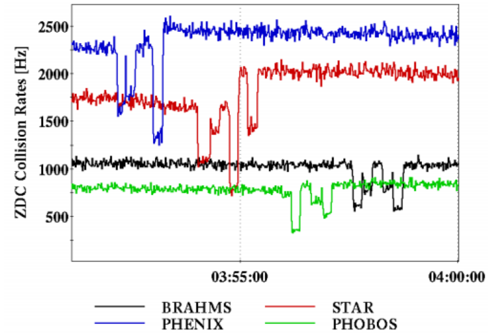

Figure 3: ZDC collision rates from the four experiments as a function of time during an automatic serial optimization.

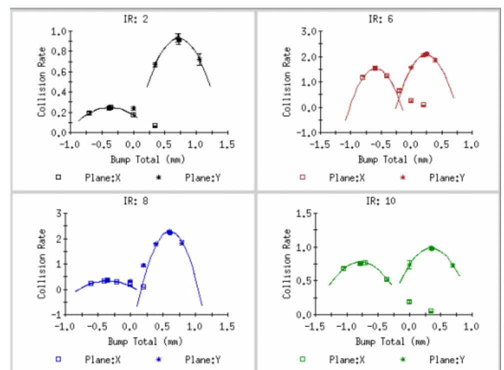

Figure 4: Normalized collision rates for the four experiments as a function of bump amplitude. Both planes are shown for each IR.

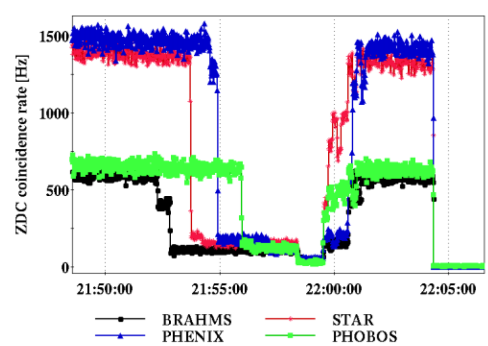

Figure 5: Collision rates for all experiments as a function of time during the first successful attempt of parallel optimization on Feb. 7, 2004.

IRs and the horizontal fits result in a considerably lower maximum accordingly. The start points for both planes are defined to be “0”. The solid lines are parabolic fits applied to the data. Fig. 5 shows the collision rate as a function of time during preparation (i.e. missteering) and parallel optimization in that first succesful attempt. Optimization begins just before 22:00 and takes less than 2 minutes. While the first attempt is done at the end of a store with relatively low collision rates routine application happens at the very beginning of a store with higher rates and backgrounds. Fig. 6 shows routine parallel optimization at the beginning of store 4794 on Mar 17, 2004. The collision rates are about x4 higher than the rates in Fig. 5. The total time to optimize all IRs amounts to about 1.5 minutes. In this example only the STAR experiment happened to be missteered. Note that the parallel optimization process allows different processing times for the various IRs. Depending on how much an IR is missteered and if the first step is into or away from the right direction the elapsed time may vary. Parallel Optimization of all four IRs at once was routine operation after Feb. 7, 2004.

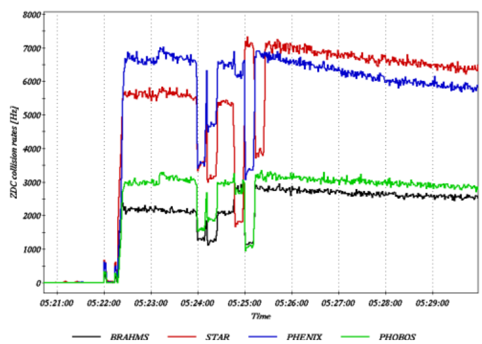

Figure 6: Collision rates of the four experiments during a routine parallel optimization at the beginning of the store on Mar 17, 2004.

LIMITATIONS

Apart from potential coupling between IRs, a challenge which only applies to parallel optimization, high background conditions are a general problem for automated steering. The PHENIX IR bears a particular complication due to the proximity of the collimators. In fact, the collimators are located within the area of the orbit bump used for steering Any move would change the beam position on the collimator jaws if they were inserted. Therefore the collimators are inserted into the beam after collision steering is done. Thus the collision signals can sometimes be contaminated with background.

In addition to background arising from sources outside the IR, there could be background sources from within. A local pressure rise in the beam pipe is one source. During the high intensity and high luminosity FY04 run the PHOBOS IR (IR10) developed a local pressure rise at the beginning of many stores due to a forming electron cloud. On average, with quite some variation though, the pressure rise lasted for the first 30 to 60 minutes [3] approximately. Therefore we desisted from collision optimization in PHOBOS during that time and optimized the three remaining experiments only. Fig. 7 shows the "Optimize Many" panel of the LISA display. The top part shows a table with the configuration parameters, the lower part the normalized collision rate as a function of the bump amplitude. When the parameter "Optimize Order" is set to 0, no

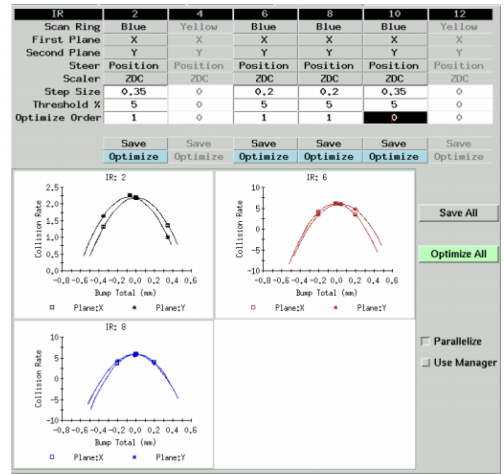

Figure 7: "Optimize Many" panel and normalized collision rates as a function of bump amplitude in 3 IRs.

optimization attempt is made. In this particular example all three experiments appeared optimized.

CONCLUSION

Automatic individual, serial and parallel collision optimization was implemented and tried out for the first time during the FY04 run in RHIC. The optimization relies on a feedback based on the ZDC collision signals, available online with 1 Hz from every experiment. The implementation was quite successful and serial optimization of all IRs was routine operation beginning mid Jan. 2004. From Feb. 7, 2004, on serial optimization was replaced by parallel optimization of all IRs at the same time. Thus the time needed for collision steering could be reduced from the order of 20 minutes (manual individual steering) by more than one order of magnitude to an average of less than 1.5 minutes (parallel steering). The gain of time spent at collision early in the store is especially valuable since the luminosity is the highest at the beginning. However, background conditions limit the use of automatic optimization. This was a particular challenge in the PHOBOS IR where a pressure rise problem developed during the run.

ACKNOWLEDGEMENTS

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