

*Luminosity Optimization Using Automated IR
Steering At RHIC*

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Luminosity Optimization Using Automated IR Steering at RHIC*A. Drees[†], Ted D'Ottavio, BNL, Upton, NY 11973**Abstract**

The goal of the RHIC 2004 Au-Au run was to maximize the achieved integrated luminosity. One way is to increase beam currents and minimize beam transverse emittances. Another important ingredient is the minimization of time spent on activities postponing the declaration of 'physics conditions', i.e. stable beam conditions allowing the experimental detectors to take data. Since collision rates are particularly high in the beginning of the store the integrated luminosity benefits considerably from any minute saved early in the store. In the RHIC run 2004 a new IR steering application uses luminosity monitor signals as a feedback for a fully automated steering procedure. This report gives an overview of the used procedure and summarizes the achieved results.

MANUAL STEERING

In a collider it is generally useful to have both orbits around an Interaction Region (IR) from the clockwise (RHIC: "blue") and the counterclockwise (RHIC: "yellow") beam available in one display. The RHIC

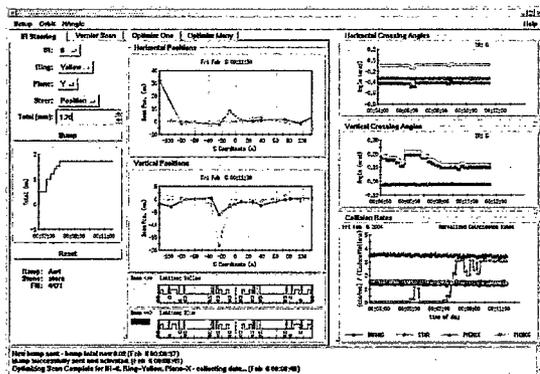


Figure 1: IR steering panel of the LISA application for manual steering in

Luminosity and IR Steering Application (LISA) offers this to facilitate any kind of manual IR steering. Fig. 1 shows the front panel of LISA for manual steering. Selectable options are the IR (2,4,6,8,10,12), the Ring (blue or yellow), the plane (X or Y) and the bump type (position or angle). Beams are steered by using local orbit bumps in the respective planes ("4-bump"). In the shown example position steering is done in IR6 using the vertical plane in

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the yellow ring. The total amount is 1.7 mm, monitored in the lower left corner. Beam position measurements from the blue and yellow RHIC BPMs inside the IR, the DX BPMs (indicated by open symbols), and the neighboring quadrupoles (up to Q7) are displayed. The center of the IR is located between the two DX BPMs. Crossing angles for the two beams based on the DX BPM measurements are displayed together with the normalized collision signal on the right part of the panel. As can be seen in the lower right graph collision rates could be established in IR6 where the STAR experiment is located. Note that the manual steering time is about 5 minutes resulting in a total time of the order of 20 minutes if all experiments have to be steered. Steering for collision rate optimization can be automated using the collision signal from the Zero Degree Calorimeters, R_{ZDC} , 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.

THE OPTIMIZATION PROCEDURE

LISA offers two general approaches to optimize the collision rates in the four RHIC detectors: "manual" steering, i.e. no automatic feedback on luminosity monitors, or automatic optimization using the ZDC coincidence signals

index	beam position	collision rate
0	no step	take a measurement over n_x seconds
1	no step	compute average and RMS collision rate
2	step beam by δ	take a measurement over n_x seconds
3	no change	compute average and RMS collision rate, compare to (1).
4	step by $+\delta$ or -2δ sign depends on (3)	take a measurement over n_x seconds
5	keep stepping by δ .	take measurement, compute average and RMS compare result to step before.
6	stop if result is less than step before	apply parabolic fit to last 3 points
7	move to location of maximum from fit in (6)	take confirmation measurement

Table 1: Steps of the automatic optimization using feedback from the ZDC measurements.

as feedback. Automatic optimization requires that the coincidence signal $R_{ZDC} > 0$ before the automatic procedure begins. Tab. 1 lists the steps for the automatic optimization procedure. A measurement here refers to integrating the 1 Hz data from the ZDC coincidence signal. The length of the integration interval, n_x seconds, is determined by the requested accuracy of the measurement. This accuracy, or threshold, is a configuration parameter for LISA together with the step size δ . If then chosen threshold cannot be reached an upper limit of 60 sec applies. δ should be chosen large enough to ensure a significant difference between two measurements 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. Fig. 2 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

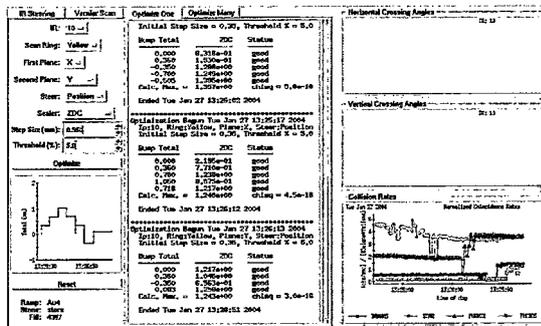


Figure 2: Application panel for optimization of a single IR.

is shown in the lower right graph on the panel. The green squares correspond to the data from the IR where the shown optimization takes place (IR10 = PHOBOS).

MULTIPLE OPTIMIZATION

The automatic optimization mode in LISA allows the choice of single IR optimization (as shown above, Fig. 2), and sequential 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. 3 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. 4 is done automatically. The serial

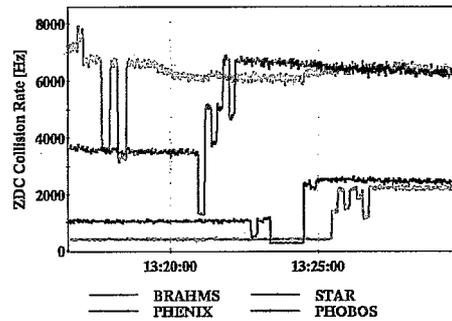


Figure 3: ZDC collision rates from the four experiments as a function of time during serial but manual optimization.

order is a configuration parameter and here chosen to 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. 3. The typical dura-

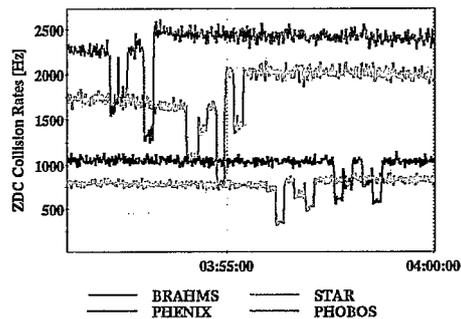


Figure 4: ZDC collision rates from the four experiments as a function of time during an automatic serial optimization.

tion 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. 5 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

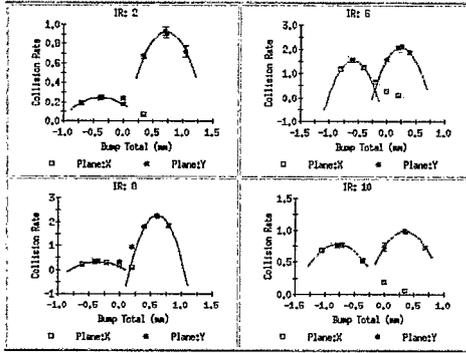


Figure 5: Normalized collision rates for the four experiments as a function of bump amplitude. Both planes are shown for each IR.

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 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. 6 shows the collision rate as a function

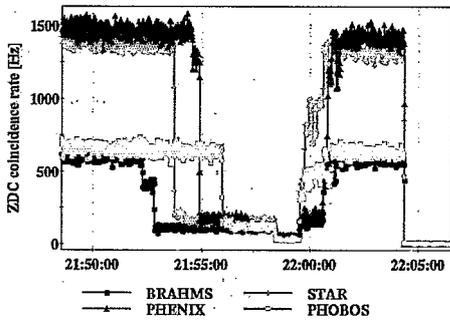


Figure 6: Collision rates for all experiments as a function of time during the first successful attempt of parallel optimization on Feb. 7, 2004.

of time during preparation (i.e. missteering) and parallel optimization in that first successful 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. 7 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. 6. 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

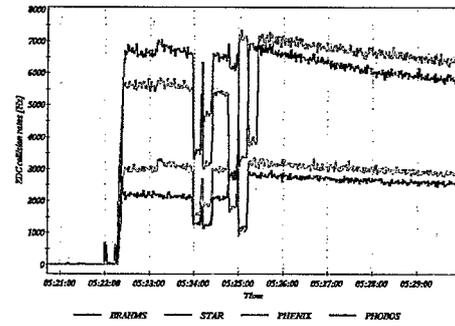


Figure 7: Collision rates of the four experiments during a routine parallel optimization at the beginning of the store on Mar 17, 2004.

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.

OPERATIONAL 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.

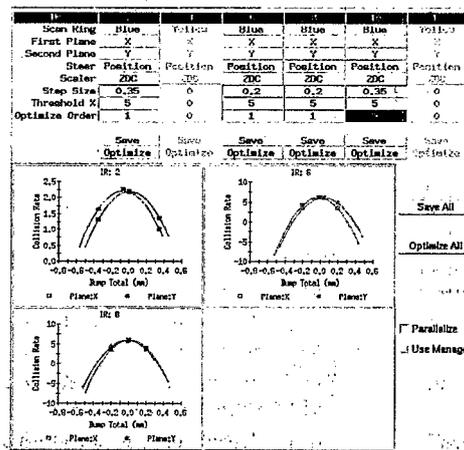


Figure 8: "Optimize Many" panel and normalized collision rates as a function of bump amplitude in 3 IRs.

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 [?] approximately. Therefore we desisted from collision optimization in PHOBOS during that time and optimized the three remaining experiments only. Fig. 8 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 optimization attempt is made. In this particular example all three experiments appeared optimized already indicated by the fact that the maximum of the distributions is close to 0 in both planes.

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.

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