BNL-94205-2011-CP

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Presented at the 2011 Particle Accelerator Conference (PAC'11)
New York, N.Y.
March 28 – April 1, 2011

Collider-Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy
Office of Science

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MEDIUM ENERGY HEAVY ION OPERATIONS AT RHIC *

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Abstract

As part of the search for a phase transition or critical point on the QCD phase diagram, an energy scan including 5 different energy settings was performed during the 2010 RHIC heavy ion run. While the top beam energy for heavy ions is at 100 GeV/n and the lowest achieved energy setpoint was significantly below RHICs injection energy of approximately 10 GeV/n, we also provided beams for data taking in a medium energy range above injection energy and below top beam energy. This paper reviews RHIC experience and challenges for RHIC medium energy operations that produced full experimental data sets at beam energies of 31.2 GeV/n and 19.5 GeV/n.

INTRODUCTION

The medium energy AuAu run covered two beam energies, both above the RHIC injection energy of 9.8 GeV but well below the standard store energy of 100 GeV (see table 1). The low energy and full energy runs with heavy ions

Energy $[GeV]$	start date end date	duration	stores	γ_{store}	β^* $[m]$
31.2	03-18-2010 04-08-2010	3 weeks	11935 - 12103	33.5	2.5
19.5	04-08-2010 04-22-2010	2 weeks	12106 - 12217	20.9	3.0

Table 1: The two medium energy Au-Au runs in 2010.

in FY10 are summarized in [1] and [2]. Stochastic Cooling ([3]) was only used for 100 GeV beams and not used in the medium energy run. The efficiency of the transition from 100 GeV operation to 31.2 GeV and then to 19.5 GeV was remarkable. Setup took 32 h and 19 h respectively for the two energy settings. The time in store, defined to be the percentage of time RHIC provides beams in physics conditions versus calendar time, was approximately 52% for the entire FY10 heavy ion run. In both medium energy runs it was well above this average, 68% for 31.5 GeV and 82% for 19.5 GeV. For both energies RHIC was filled with 111 bunches with 1.2 10^9 and 1.3 10^9 ions per bunch respectively.

LUMINOSITY

Luminosity Monitoring

In RHIC, a forward ("zero-degree") calorimeter, the ZDC([4]), is used for luminosity monitoring. Each interaction region (IR) has a ZDC detector installed. The ZDCs are installed between the two beam pipes behind the DX magnets, approx. 18 m from the vertex point. The detectors are largely identical but still have some minor differences such as readout electronics and HV settings. The collision rate from the ZDCs is defined to be the coincidence signal from the two units on either side of the IRs. Figure 1 shows the coincidence rate from the STAR ZDC for the entire 19.5 GeV run. Initial peak rates were very repeatable around 2.5 kHz. Time between stores was about 25 minutes, store length was kept to about 4 h. The picture

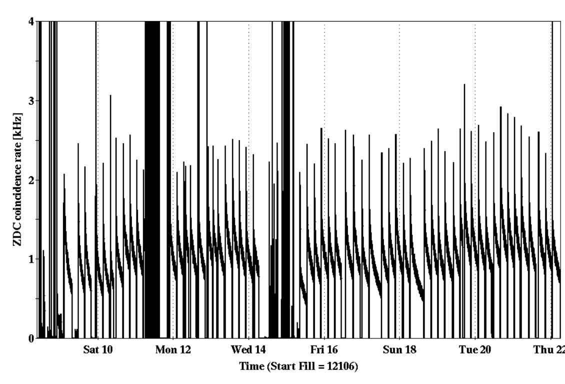

Figure 1: Luminosity monitoring using the ZDC coincidence rate for the full 19.5 GeV operation.

* Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the US Department of Energy.

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demonstrates the reproducibility, the up-time of over 80% as well as the smooth transition from the earlier 31.2 GeV run. The first physics store is provided after only 19 hours of setup, reaching almost the average peak rate already.

During the 31.5 GeV run, stores were also kept to 4 hours with the same refill and ramping time as for 19.5 GeV, i.e. approximately 25 minutes. Peak rates were around 4.5 kHz. However, in order to derive instantaneous and integrated luminosity from the coincidence rate, the ZDC detectors need to be calibrated.

Effective Cross Section Measurement

The calibration of the ZDC detectors is done by means of vernier scans [5]. During such a scan one beam is swept across the other in small steps. At the same time, the coincidence rate as a function of stepsize is measured and recorded. Details about the concept and the process can be found in [5]. Each vernier scan provides an effective cross section according to:

$$\sigma_{ZDC} = 2\pi \; R_{max} \; \sigma_{Vx} \; \sigma_{Vy} \; k_b/(f_{rev} N_1 N_2) \qquad (1)$$

where f_{rev} is the revolution frequency and k_b the number of bunches per ring. Note that in Eq. 1 R_{max} is not normalized and it is assumed that bunch to bunch variations are small and all bunches collide at the IP.N_1 and N_2 are the numbers of Ions per bunch in the two rings. The emittance can be calculated from the width of the beam overlap region, σ_V. Note that the measurement cannot distinguish between the contributions from the two beams, giving an average beam size per plane.

Depending on species and energy, changes are made to the read-out electronics and HV settings to maintain sensitivity and similar background conditions. This requires re-calibrations of the detector every year. Figure 2 shows a store, 12081, during the 31.2 GeV run. At the end of the store two vernier scans are performed, one in each IR. In order to compare the emittance measurement from the

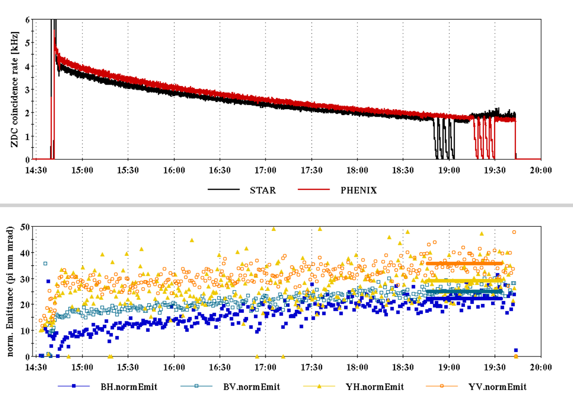

Figure 2: Store 12081 during the 31.2 GeV run with two vernier scans at the end. ZDC coincidence rate (top) and IPM emittance measurements (bottom).

vernier scan with an emittance from the IPM detector [6], the emittance from the four IPM detectors is averaged over the time of the vernier scans. The IPMs provide individual measurements per plane and per ring (unlike the vernier scan). Fig. 2 shows all 4 planes. While the emittance is growing at the beginning of the store it is typically rather constant at the end, allowing one average value during the time of the vernier scans, in this example about 40 minutes total.

Results

Table 2 summarizes the results using one (average) emittance value per plane from the IPM. Note that according to the IPM the blue emittances are always rather small while the yellow emittances had the tendency to appear larger. The statistical errors for the emittance measurements from

fill	σ_6	σ_8	VS:ϵ_H	VS:ϵ_V	IPM:ϵ_H	IPM:ϵ_V
	[b]	[b]	π mm mrad			
11953	9.6	9.7	31	28	28	31
12028	10.7	10.5	31	30	22	31
12055	10.7	10.5	28	27	26	31
12081	10.7	10.5	31	29	26	31
12140	9.6	8.7	34	32	-	-
12208	9.5	9.1	35	32	-	-
12214	9.7	9.2	36	33	-	-

Table 2: Results from medium Energy vernier scan compared with IPM measurements.

the vernier scans are $\pm$ 2, the typical error for the cross section measurement 0.4 b. The statistical errors for the IPM measurements (see fig. 2) are slightly larger, about $\pm$ 4. During the 19.5 GeV the beam size at the location of the IPM was larger than its acceptance and thus we could not obtain valid measurements at this energy setting.

The first cross section measurement with 31.2 GeV, fill 11953, will be disregarded in the following since read-out electronics and HV were not adjusted yet for the new beam energy. However, it still provides a valid emittance measurement. Beam sizes at the IR (and at the end of the stores) were typically 600 μm at 31.2 GeV and 900 μm at 19.5 GeV. There was no evidence for a difference in the β-function between the IRs in either run. In general, the horizontal emittance was slightly larger than the vertical, indicating more beam growth in the horizontal plane during the store than in the vertical plane. The IPM seems to systematically measure a somewhat smaller beam size in the horizontal plane while the results are consistent with the vernier scans in the vertical plane. Emittances achieved during the 19.5 GeV run were 20-36 π mm mrad and 18-31 π mm mrad during the 31.2 GeV run.

The cross section measurements are summarized in fig. 3. The following effective cross sections were used for the 31.2 GeV run:

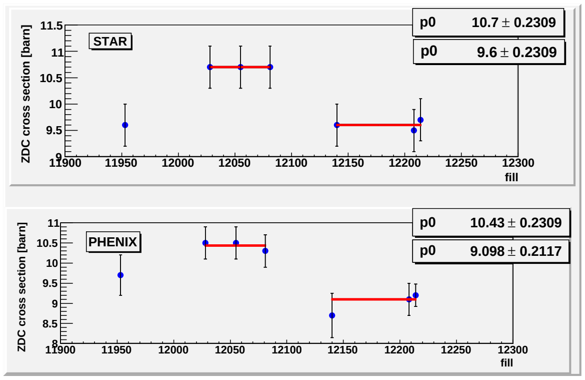

Figure 3: Effective ZDC cross sections during the two medium energy runs for the two experiments in FY10.

- STAR $\sigma_{ZDC} = 10.7 \pm 0.2$ barn and
- PHENIX $\sigma_{ZDC} = 10.4 \pm 0.2$ barn.

and for the 19.5 GeV run:

- STAR $\sigma_{ZDC} = 9.6 \pm 0.2$ barn and
- PHENIX $\sigma_{ZDC} = 9.1 \pm 0.2$ barn.

The difference between the two IRs can be attributed to small differences between the two experiments in the read-out electronics and the HV settings used to operate the ZDCs.

SUMMARY

Using the above effective cross sections as calibration factors, the ZDC coincidence rate can be translated into luminosity and the integrated delivered luminosity can be derived. Fig. 4 and Fig. 5 show the resulting integrated luminosities for the two medium energy runs. A peak luminosity per store of 2.2 $10^{26} cm^{-2} s^{-1}$ resulted in an average store luminosity of 1.3 $10^{26} cm^{-2} s^{-1}$ during the 19.5 GeV run. A total integrated luminosity of 107 μb^{-1} (PHENIX) and 99 μb^{-1} (STAR) could be delivered to the experiments. Note that the experiments use the delivered luminosity to a varying degree.

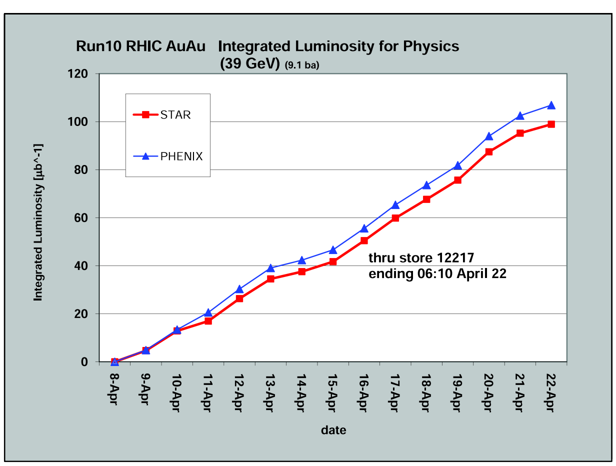

Figure 4: Integrated luminosity for RHIC operation at 19.5 GeV.

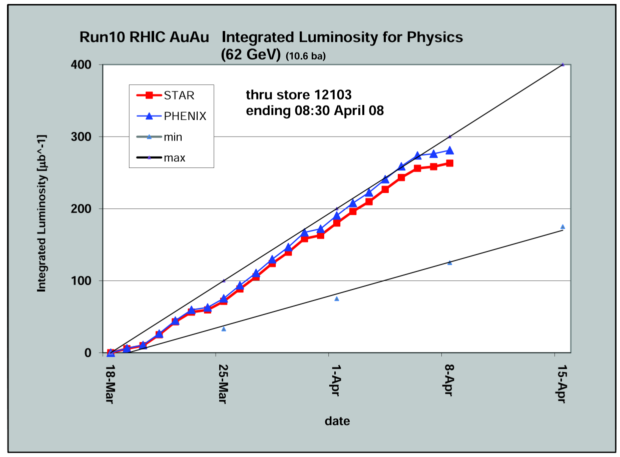

Figure 5: Integrated luminosity for RHIC operation at 31.2 GeV.

During the 31.2 GeV run the peak luminosity per store of 4.5 $10^{26} cm^{-2} s^{-1}$ resulted in an average store luminosity of 3.0 $10^{26} cm^{-2} s^{-1}$ and a total integrated luminosity of 281 μb^{-1} (PHENIX) and 263 μb^{-1} (STAR). Given the achieved emittances and luminosity lifetimes RHIC delivered luminosities well above minimum predictions.

ACKNOWLEDGMENT

Many thanks to the RHIC operations crew for their remarkably efficient and professional operation of RHIC in FY10!

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