Counting Rates during the Spring 2000 RHIC Commissioning Run

Sebastian White
Feb. 20,2000

This is an addendum to an earlier note (Signal and Background In the ZDC's. Implications for beam tuning during RHIC commissioning) which argued for bakeout of the IR's prior to startup. Here we use as a basis for rate calculations the RHIC run plan prepared by D. Trbojevic (http://www.agsrhichome.bnl.gov/AP/DryRun/RUN_PLAN5.pdf).

The main purpose is to estimate rates in various Luminosity monitors under discussion. The primary source for Luminosity monitoring and the ultimate tool for determining absolute luminosity in Au*Au collisions is a two-fold coincidence between ZDC's at either side of the interaction regions. The corresponding cross section is 11.0 barns. The ZDC's will be scaled with a threshold of 25% of the planned 70 GeV/u operating energy.

Other monitors which have been proposed are the BBC's (in PHENIX, BRAHMS and PHOBOS) – again a two-fold coincidence. The effective cross-section seen by the PHENIX BBC's is 96% of 6.15 barns = 5.9 b(H.Ohnishi, private comm.).

An alternative to be used by STAR is a high multiplicity threshold on the STAR barrel scintillators. At a high enough threshold it is hoped that beam-beam events will be clearly distinguishable from beam gas, upstream losses and other forms of background(W. Christie). The appropriate threshold will probably correspond to something like a 2-3b effective cross section.

We assume a residual gas level inside the beam tubes which corresponds to an average, room temperature, vacuum of 10^{-9} torr

Definitions:

For purposes of rate calculations we assume that the residual gas in the vacuum chamber is primarily N_2, H_2O, CO, etc… .We use

$$\sigma_{Au\cdot N}^{single} = 3.0\_barns$$

which is approximate.

Experience during the first RHIC commissioning run has shown that beam gas collisions only give rise to 'out of time' ZDC coincidences.

Therefore all beam-gas collisions are assumed to generate only 'singles rates' in the ZDC's. We use these rates to calculate accidental coincidences in the ZDC's which are an irreducible background to beam-beam signal.

With a vacuum of 10^{-9} torr the effective target density due to residual gas is:

$$\rho_N(vac) = \rho_{N_2}(atm)/m_N \cdot (10^{-9}\,torr)/(760)$$

$$= (5.5 \cdot 10^{19})(1.3 \cdot 10^{-12})$$

$$= 7.2 \cdot 10^{7} \text{ (nuclei/cm}^3\text{)}$$

<u>Beam-Beam Luminosity</u>

The beam-beam luminosity is given by:

$$L_{b\cdot b} = \frac{(N_{Au})^2}{4\pi(\sigma_t)^2} \cdot N_{bunch} \cdot \nu_{rev}$$

and

$$\sigma_t^2 = \frac{\varepsilon_t \cdot \beta^*}{6\pi\gamma}$$

where the Lorentz factor, γ, will range from 10.3 to 74.6 (ie injection to top energy). The plan is to go immediately to top energy before trying to establish collisions.

The emittance, $\varepsilon_\perp$, is assumed to be

$$\varepsilon_\perp = 20\pi \text{ mm.mr}$$

initially.

Let's consider 'blue book' design luminosity. Then

$N_{Au} = 10^9$/bunch

$N_{bunch} = 60$, $\beta^* = 2$m.

We then have

$$\sigma_t^2 = \frac{20\pi \cdot 2}{6\pi \cdot 100} = 0.067x10^{-6}\,m^2$$
$$= (0.26mm)^2$$
$$= (0.0260m)^2$$

and

$$L_{b\cdot b} = \frac{10^{18}}{4\pi \cdot 6.7 \cdot 10^{-4}} 60 \cdot 7.7 \cdot 10^4$$
$$= 5.5 \cdot 10^{26}\,cm^{-2} \cdot s^{-1}$$

In the run plan we find a target for the spring run of:

$N_{Au} = 5*10^8$/bunch

and

$N_{bunch} = 6$

The typical value of β^* will be 3m although 6 o'clock and 10 o'clock could be tuned to 1m after installation of the appropriate power supplies. The only other change from blue book parameters in the run plan is top energy. So the target luminosity for the spring is

$$L_{bb} = 5.5\times10^{26}\times(\frac{N_{bunch}}{60})\times(\frac{N_{Au}}{10^9})^2\times(\frac{\gamma}{100})\times(\frac{2m}{\beta^*})$$
$$= 6.8\times10^{24}\,cm^{-2}s^{-1}$$

Background:

The luminosity for background, $L_{b\cdot g} = \rho_N(\text{vac})\cdot l\cdot N_{Au}\cdot N_{bunch}\cdot \nu_{rev}$.

So using the 'blue book' numbers and l =20m,

$$L_{b\cdot g} = 7.2\times10^7\cdot(2\times10^3 cm)\cdot10^9\cdot60\cdot7.7\times10^4$$
$$= 6.7\times10^3\times10^7\times10^3\times10^9\times10^4$$
$$= 6.7\times10^{26}\,cm^{-2}\cdot s^{-1}$$

With the current target parameters this background luminosity becomes:

$$L_{b\bullet g} = 3.4\times10^{25}\,cm^{-2}s^{-1}$$

So the beam-gas luminosity (in each beam direction) will be 5 times the maximum beam-beam luminosity once beam steering optimizes the luminosity.

Rates:

The beam gas 'singles' rate in a given IR is

$$R^{\sin gle} = L_{b\bullet g}\times o_{Au\bullet N} = 3.4\times10^{25}\times3\times10^{-24}s^{-1} = 100Hz$$

and the accidental coincidence rate is (note the factor of ½ due to the fact that only accidentals between opposite beam directions give false coincidences)

$$R(background) \equiv R^{bkg} = 1.0\times10^2 \times \tfrac{1}{2} \times \left(\tfrac{R^{\sin gle}}{N_b \cdot \nu_{rev}}\right)$$
$$= 10^2 \cdot .5 \cdot \left(1\times10^2\right)/\left(6\cdot 7.7\times10^4\right)$$
$$= 1.0\times10^{-2}\,Hz$$

which is a harmless background when compared to

$$R^{ZDC} = L_{b\cdot b} \cdot \sigma^{ZDC}$$
$$= 6.8\times10^{24} \times 11\times10^{-24} \times s^{-1}$$
$$= 75.Hz$$

Conclusion:

Assuming target parameters for RHIC we will have of order 10 to 100Hz counting rate during beam steering. The accidental rate in the ZDC's will be negligible, so long as other sources (than beam-gas) of background are negligible. During last year's run we only logged rates for relatively short stores. During those periods the ZDC singles rates were significantly higher than the expected beam gas rate. This indicates that beam loss dominated the counting rates. From the above calculation we see that beam tuning could be carried out if beam loss rates are an order of magnitude larger than calculated beam gas. If they are 2 orders of magnitude higher then beam tuning will be difficult since signal to noise will be, at best, 1:1.

Recommendation:

Measurement of singles rate and comparison to expectations from beam gas should be one of the early goals of the commissioning plan. It can be carried out during initial tune up of one of the rings.

If upstream losses dominate, one countermeasure we can use is to install "veto" counters in the tunnel to gate off "noisey" crossings. Of course the other option is to identify and eliminate sources of beam loss.