



Brookhaven
National Laboratory

BNL-101688-2014-TECH

RHIC/AP/32;BNL-101688-2013-IR

RHIC Luminosity Optimization

H. Hahn

October 1986

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-AC02-76CH00016 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

RHIC Luminosity Optimization

H. Hahn

BNL

October 9, 1986

RHIC LUMINOSITY OPTIMIZATION

Luminosity:

$$L = \frac{3}{2} f_{\text{rev}} \frac{(\beta\gamma)}{\beta^*} \frac{B N_B^2}{\epsilon_N} \frac{1}{\sqrt{1+q^2}}$$
$$q = \frac{1}{2} \frac{\alpha \sigma_z}{\sigma_H^*}$$

Beam-Beam Tune Shift:

$$\Delta\nu_{\text{BB}} = \frac{3}{2} r_0 \frac{Z^2}{A} \frac{N_B}{\epsilon_N} \frac{2}{1 + \sqrt{1 + q^2}}$$

$\leq 4 \times 10^{-3}$ from SPS experience

Long-Range Tune Shift:

$$\Delta\nu_{\text{LR}} = \frac{1}{2\pi} r_0 \frac{Z^2}{A} \frac{1}{\gamma \beta^*} n N_B \frac{1}{\alpha^2}$$

where

N_B = number of particles/bunch

B = number of bunches/ring

n = Number of long-range interactions

Maximum luminosity at beam-beam limit:

$$\frac{L}{\Delta\nu_{BB}} = \frac{f_{rev}}{r_0} \frac{A}{Z^2} \frac{(\beta\gamma)}{\beta^*} B N_B \frac{1 + \sqrt{1 + q^2}}{2 \sqrt{1 + q^2}}$$

$$\frac{1 + \sqrt{1 + q^2}}{2 \sqrt{1 + q^2}} = \begin{cases} 1 & q = 0 \\ \frac{1}{2} & q \gg 1 \end{cases}$$

- L weakly dependent on α
- increase N_B
chose α to limit beam-beam tune shift: $q \gg 1$
- increase B, i.e., fill all buckets
 $B = 6 \times 57$ by rebunching in RHIC or AGS
- β^* small
 $\beta^* = 3$ m is limit due to magnet aperture in Q1, Q2

Long-range tune shift at beam-beam limit:

$$\frac{\Delta\nu_{LR}}{\Delta\nu_{BB}} \cong \frac{1}{12} \frac{1}{\gamma \beta^*} n \frac{\epsilon_N}{\pi} \frac{\sigma_l}{\alpha \sigma_H^*} \quad (q \gg 1)$$

Avoid long-range effects by

- ϵ_N small
 ϵ_N limited by intrabeam scattering
- α large
 $\alpha \cong 6$ mrad is limit due to BC1
maximum α is practical limit on N_B

RHIC Parameter List
pp Operation @ 10h

N_B	10^{11}	10^{12}	$1.4 \times 10^{12}*$	
B	57	57	6×57	
E_{kin}	250	300	300	GeV
γ	266	320	320	
ϵ_N/π	23.5	36.9	43.4	$\times 10^{-6}$ m
σ_H ($\beta=50m$)	0.88	0.98	1.06	mm
$A_{SL}=6\sigma_H$	5.3	5.9	6.4	mm
σ_H^* ($\beta^*=3m$)	0.22	0.24	0.26	mm
Δ_B ($V=1.2MV$)	± 2.6	± 2.3	± 2.3	$\times 10^{-3}$
$\Delta E/E$	± 0.80	± 1.4	± 1.5	$\times 10^{-3}$
σ_ℓ	0.50	0.92	1.0	m
α	0	4.6	6	mrad
$q=1/2\alpha\sigma_\ell/\sigma_H^*$	0	8.9	11.5	
Δv_{BB}	3.1	4	4	$\times 10^{-3}$
Δv_{LR}	0	0	2	$\times 10^{-5}$
L	0.84	6.9	60	$\times 10^{31}$ $cm^{-2}sec^{-1}$
σ_I	35	7.3	6.1	cm
B in Barc	3.45	4.15	4.15	T
B in BC1	4.63	3.97	3.48	T
B in BC2	2.73	2.61	2.41	T
Beam energy	0.23	2.7	23	MJ

*RHIC limit is reached with 10^{14} protons/AGS pulse