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)

DISCLAIMER

RHIC-AP-32

RHIC Luminosity Optimization

H. Hahn

BNL

October 9, 1986

H. Hahn
10/9/86

RHIC LUMINOSITY OPTIMIZATION

Luminosity:

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

$$q = \frac{1}{2} \frac{\alpha\ \sigma_\ell}{\sigma_H^*}$$

Beam-Beam Tune Shift:

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

$\leq 4\times10^{-3}$ from SPS experience

Long-Range Tune Shift:

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

where

N_B = number of particles/bunch

B = number of bunches/ring

n = Number of long-range interactions

hh/86/10/8.a

H. Hahn
10/9/86

Maximum luminosity at beam-beam limit:

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

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

- 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:

$$\frac{\Delta\nu_{LR}}{\Delta\nu_{BB}} \cong \frac{1}{12} \frac{1}{\gamma\,\beta^*}\, n\, \frac{\varepsilon_N}{\pi} \frac{\sigma_\ell}{\alpha\,\sigma_H^*} \qquad (q \gg 1)$$

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

H. Hahn
10/9/86

RHIC Parameter List
pp Operation @ 10h

N_B	10^{11}	10^{12}	1.4×10^{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	$\times10^{-6}$ m
σ_H (β=50m)	0.88	0.98	1.06	mm
$A_{SL}=6\sigma_H$	5.3	5.9	6.4	mm
σ_H^* (β^*=3m)	0.22	0.24	0.26	mm
Δ_B (V=1.2MV)	±2.6	±2.3	±2.3	$\times10^{-3}$
$\Delta E/E$	±0.80	±1.4	±1.5	$\times10^{-3}$
σ_ℓ	0.50	0.92	1.0	m
α	0	4.6	6	mrad
$q=\frac{1}{2}\alpha\sigma_\ell/\sigma_H^*$	0	8.9	11.5	
$\Delta\nu_{BB}$	3.1	4	4	$\times10^{-3}$
$\Delta\nu_{LR}$	0	0	2	$\times10^{-5}$
L	0.84	6.9	60	$\times10^{31}$ cm^{-2}sec^{-1}
σ_I	35	7.3	6.1	cm
B in B_{arc}	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

HH/86/10/8.C