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RHIC Luminosity Optimization

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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
$q = \frac{1}{2}\alpha\sigma_\ell/\sigma_H^*$	0	8.9	11.5	
$\Delta\nu_{BB}$	3.1	4	4	$\times 10^{-3}$
$\Delta\nu_{LR}$	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