LUMINOSITY LIMITATIONS

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- A generic approach to ring-ring and linac-ring scenarios ...
- ... suitable for machine comparisons ??

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ULTIMATE PERFORMANCE

Beam-beam parameters (equal size round beams):

$$\xi_e = \frac{N_i}{\epsilon_e} \left(\frac{r_e Z}{4\pi\gamma_e} \right) \tag{1}$$

$$\xi_i = \frac{N_e}{\epsilon_i} \left(\frac{r_i (v/c)_i}{4\pi Z} \right) \tag{2}$$

Emittance subscripts are correct!

- e-cooling reduces ϵ_i and allows N_e to be reduced.!!

Electron-ion luminosity can be written

$$L = F_c \, \xi_e \xi_i \, \sigma_e'^* \sigma_i'^* \left(\frac{4\pi\gamma_e\gamma_i}{r_e r_i} \right) \tag{3}$$

- When beam-beam limits and angular apertures have been met, $\xi_e \xi_i \sigma_e'^* \sigma_i'^*$ is fixed.
- Then the only way to increase the luminosity is to increase the collision frequency F_c (more bunches)
- Linac-ring collisions allow the usual $\xi_e \approx 0.06$ limit to be violated.

	THERA	**EPIC 2**	**eRHIC**	**eRHIC**	**HER**
Scenario	linac-ring	linac-ring	linac-ring	ring-ring	(SLAC)
Ion specie	protons	protons	protons/gold	protons/gold	–
Luminosity, $[10^{32}\text{cm}^{-2}\text{s}^{-1}]$	.041	21	4.6/.036	3.5/.086	–
Dipole bend radius, [m]	608	$\sim$ 50	243	243	165
RMS beam size, σ^* [μm]	10	25	21/60	40/50	157
Bunch spacing, [ns]	211	6.7	35.5	35.5	4.2
IONS					
Ion energy, [GeV/u]	1,000	50	100/250	250/100	–
Ion rms emittance, [μm]	1.0	2.0	0.8/1.0	0.8/1.0	–
Ion average current, [A]	.071	2.4	.14/.68	.42/.42	–
Ion IP beta, β_e^* [m]	.10	.10	.15/.39	.53/.27	–
Ion b-b parameter, ξ_i	.0023	.004	.0046/.0015	.004/.004	–
Laslett SC tune shift	.0003	.024	.001/.003	.003/.003	–
ELECTRONS					
Electron energy, [GeV]	250	5	10	10	9
Electron emittance, [nm]	.2	6	3	18	49
Electron beam current, [A]	.000084	.264	.135/.135	.12/.37	1.5
Electron beam power, [GW]	.023	1.32	1.35/1.35	1.2/3.7	13.5
Synch. rad. power, [MW]	–	$\sim$ .29	.49/.49	.43/1.3	7.2
Electron IP beta, β_e^* [m]	.50	.10	.15/1.2	.089/.139	.05/.50
Electron b-b parameter, ξ_e	.23	.35	.11/.57	.06/.06	.055

Laslett space charge tune shift.

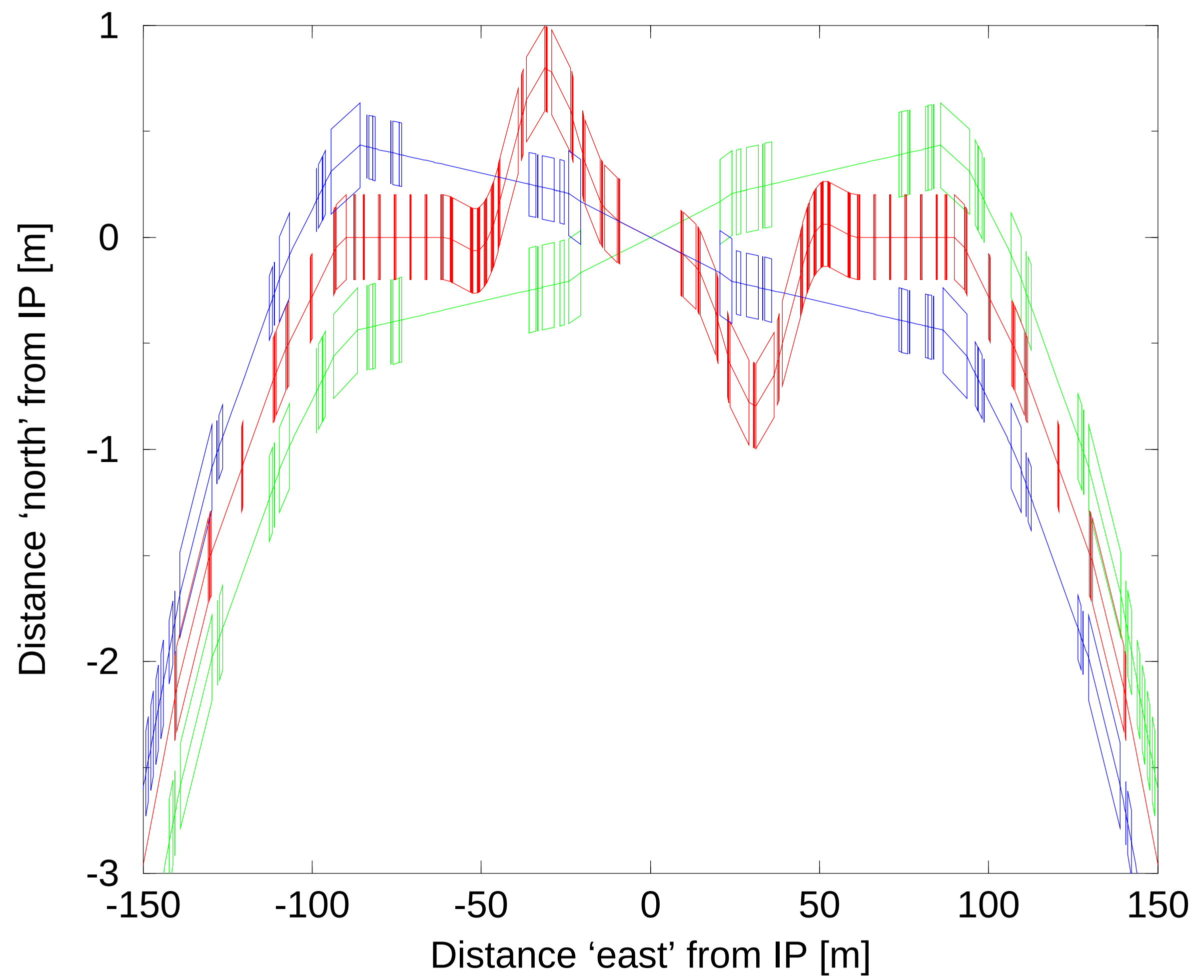
$$\Delta Q_{\rm sc} \approx -\frac{N_i}{\epsilon_i}\frac{C}{\sigma_L\beta\gamma^2}\left(\frac{r_i}{2(2\pi)^{3/2}}\right) \tag{4}$$

Strong dependence on circumference C, RMS bunch length σ_L, and the Lorentz factor $\beta\gamma^2$.

- Make the bunch longer at injection (eRHIC: 28 MHz to inject, 197 MHz to collide).

- The bunch must be shorter than β^* in collision (hourglass effect).

Interaction Region optics – spin rotators.



- Spin rotator dipoles tend to be stronger than arc dipoles – must keep linear synchrotron radiation load to < 15 kW/m.