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SOME REMARKS ON PERFORMANCE OF VERY-HIGH-ENERGY COLLIDERS*

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We have heard from R.R. Wilson of the exciting possibility of a huge "desert machine" with 20-TeV protons and antiprotons, and N. Samios has stressed that high luminosity is desirable, especially at very high energies.

I want to discuss how the luminosity in a very large $p\bar{p}$ storage ring scales with the magnetic field of the ring magnets, among other parameters.

One of the limitations on performance is given by the beam-beam tune shift. Experience at the SPS seems to indicate that, with colliding bunched p and $\bar{p}$ beams, this tune shift should not exceed 0.003 per crossing.

With round beams colliding head on, the tune shift equals

$$\Delta v = \frac{Rr_p I/e}{2kc\epsilon_t} = \frac{Nr_p}{4\pi\epsilon_t}$$

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and the luminosity is

$$L = \frac{\nu(I/e)^2 R}{2k\epsilon_t \beta^*} = \frac{2k\epsilon_t c \gamma}{r_p^2 R \beta^*} (\Delta\nu)^2$$

where ϵ_t is the invariant transverse beam emittance at the rms oscillation amplitude, β^* the amplitude function at the crossing point, k the number of bunches in each beam, each containing N particles, and r_p is the proton radius.

Keeping ϵ_t and k constant, we see that the current for constant $\Delta\nu$ scales as $1/R$, i.e. the number of particles per bunch is constant, while the luminosity scales with $1/R$ and $1/\beta^*$.

How does β^* scale? The low-beta crossing point is obtained by focusing the beam to a small size with a quadrupole doublet (or triplet or quadruplet) near the crossing point. For comparable machine lattices, β scales with the focal length of the quadrupoles. If magnet apertures are fixed, and quadrupoles are assumed to have pole fields proportional to the magnetic field of the ring magnets, then the focal length, and hence β^* , scales as $R^{1/2}$ (the tune ν then also scales as $R^{1/2}$), and the luminosity scales as $R^{-3/2}$ i.e. stronger field and smaller radius gives enhanced performance.

Numerically, what do we get?

Assume the invariant emittance is blown up to 10 mm-mr (as compared to about 2.5 in most existing machines). With $\Delta v = 0.003$ we then get 2.3×10^{11} particles per bunch. With eight crossing regions ($k = 4$) and β^* scaling from 2m for $R = .5$ km we find:

B	2T	5T	10T
R	50 km	20 km	10 km
β^*	22 m	14 m	10 m
R	50 km	20 km	10 km
L^*	1.8×10^{29}	6.9×10^{29}	1.9×10^{30}

Better design parameters can undoubtedly be found, and the scaling laws, especially for β^* , may well be modified. But it is clear that the performance capability of very high energy storage ring colliders is very much enhanced by building them with the strongest feasible magnetic fields and smallest circumferences.

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