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SINGLE PASS COLLIDER MEMO	
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TITLE : DISRUPTION AND LUMINOSITY OF FLAT BEAMS .

It has been suggested (ref.1) that high energy linear colliders might operate with non-round beam profiles, i.e. with different σ_x and σ_y, described by an aspect ratio

$$R = \frac{\sigma_x}{\sigma_y}$$

The advantage of flat beams is the expectation, that "beamstrahlung", i.e. beam-beam synchrotron radiation is reduced with increasing R (ref.2). The reason for this reduction comes from the fact that for constant bunch area and therefore constant luminosity the mean physical distance between the particles increases with R. When the physical distances are larger, the electromagnetic fields and therefore particle acceleration and radiation decrease. This would be of particular importance for very large linear colliders (VLC), where beamstrahlung may consume an appreciable fraction of the incident energy. The underlying assumption is that the emittance quality can be preserved in the deformed bunch.

Beam disruption during the collision of intense relativistic bunches has been studied by R.Hollebeek (ref.3). The penetration of two electron bunches with opposite charge produces focussing forces. The resulting deflection causes a reduction of the effective bunch cross section and thereby an increase of luminosity by an enhancement factor H. The term disruption derives from the fact that the beam emittance changes markedly during the collision.

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The behaviour of the bunches during the this process is parametrized by a dimensionless beam disruption parameter

$$D = \frac{N r_e \sigma_z}{\gamma \sigma_x^2}$$

with	N	number of electrons in the bunch
	r_e	classical electron radius $2.818.10^{-15}$ m
	σ_x, σ_y	transverse bunch dimensions
	σ_z	longitudinal bunch dimension
	γ	relativistic factor

Numerical values for the effect of beam disruption are obtained by means of a simulation program (ref.3). In this note we extend these results to cases where the aspect ratio is between 1.0 and 20.0.

In order to treat flat beams in the simulation procedure, the lattice coordinates representing the bunch are scaled accordingly, and fields, deflections, density and luminosity are computed through the penetration. The results of the simulation are corrected for the limited containment of the beams in lattices extending only to 2.5 σ.

Table 1 and Fig.1 show the variation of the luminosity enhancement factor $H = L/L_0$ with R and D, where L_0 is the luminosity without any enhancement. The normalisation is such that the smaller bunch dimension σ_y is kept constant, in which case the luminosity without enhancement scales as $1/R$. This turns out to be the dominant effect with rising R, although there is still a luminosity increase with D.

Naturally there is no merit in reducing luminosity by increasing the beam width σ_x. The more sensible choice of normalisation is that of constant beam cross section $\sigma^2 = \sigma_x \sigma_y$. In this case the unenhanced luminosity is kept constant.

For large aspect ratios, focussing occurs only in the smaller dimension and therefore the enhancement in luminosity is reduced in magnitude. Note that even in the limit of infinite aspect ratio and vanishing forces, enhancement persists since the necessary deflection angle needed becomes also infinitesimal. Table 2 and Fig.2 show the values of the enhancement factor H for this normalisation.

Table 3 and Fig.3 show the development of luminosity and beamstrahlung with increasing acceptance ratio R. The conditions are a constant beam density, with $\sigma_x\sigma_y = 1.44$ micron^2,$\sigma_z = 1$ millimeter, with 5.10^{10} particles per bunch, and at an energy of 50 Gev, giving a disruption parameter $D = 1.0$. Beamstrahlung is computed during the simulation of the disruption process. For each lattice cell and each step in time, the local curvature $1/r(x, y, z)$ is determined, and local values for radiated intensity, photon spectrum and angle are accumulated (ref.4). Results are retained for the luminosity enhancement, total radiated energy per electron, and mean critical energy (as a measure of the photon spectrum). As stated above, the increased mean distance between electrons with increasing aspect ratio leads to reduced electromagnetic fields, and therefore to reduced deflection, resulting in a gradual disappearance of radiation.

References :

1. B.Richter, FNAL Accelerator Summer School 1984
2. M.Bassetti and M.Gygi-Hanney, LEP Note 221 (1980)
3. R.Hollebeek, NIM 184 (1981), pages 333-347.
4. G.Bonvicini, C.Field and A.Minten, Beamstrahlung Monitors for the SLC Final Focus (private communication)

Table 1. **Enhancement Factor H normalised to fixed σ_y**

aspect ratio R		1.0	5.0	10.0	20.0
disruption parameter $D =$	0.00	1.00	0.20	0.10	0.05
	0.50	1.46	0.21	0.10	0.05
	1.00	3.67	0.22	0.10	0.05
	3.00	6.81	0.33	0.12	0.06
	5.00	5.63	0.44	0.16	0.06
	10.0	5.55	0.57	0.21	0.09
	20.0	4.72	0.82	0.24	0.11

Table 2. Enhancement Factor H normalised to fixed σ^2

aspect ratio R		1.0	5.0	10.0	20.0
disruption parameter $D =$	0.00	1.00	1.00	1.00	1.00
	0.50	1.46	1.85	2.13	2.15
	1.00	3.69	2.15	2.10	2.09
	3.00	5.81	2.36	2.27	2.26
	5.00	5.67	2.65	2.28	2.26
	10.0	5.58	2.92	2.15	2.16
	20.0	4.74	2.44	1.82	1.89

Table 3. Enhancement Factor and Beamstrahlung for $D = 1$

aspect ratio R	1.0	5.0	10.0	20.0
enhancement factor H	3.69	2.15	2.10	2.09
mean critical energy [Mev]	129.	51.0	29.7	17.7
radiated energy [Mev]	65.6	8.24	2.19	0.54

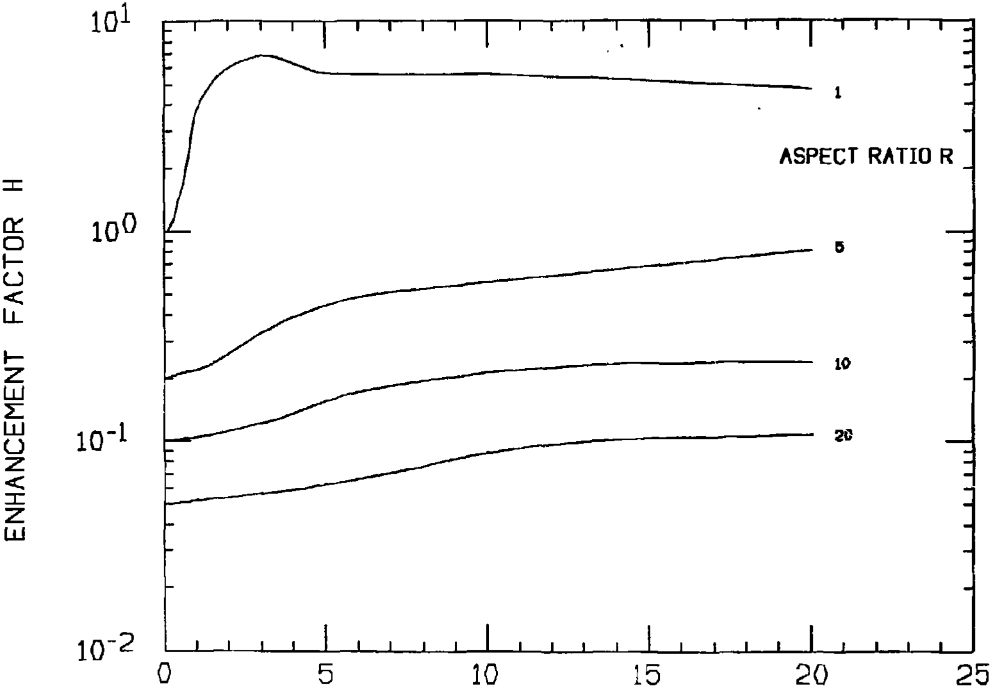
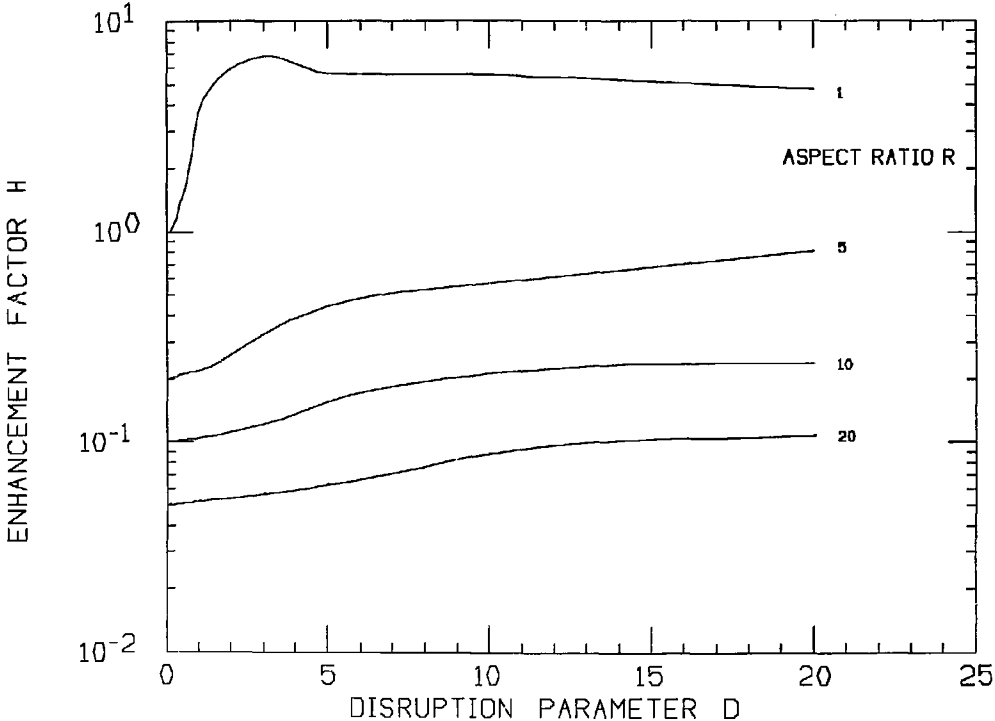


FIG. 1 ENHANCEMENT FACTOR FOR FIXED σ_Y



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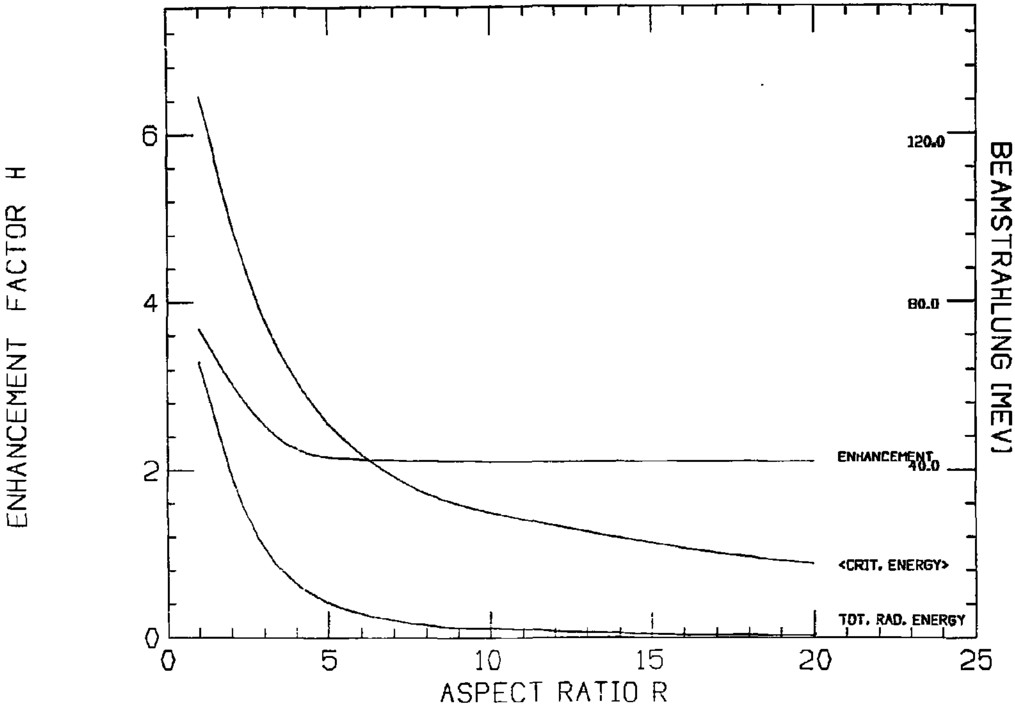

FIG. 3 ENHANCEMENT FACTOR AND BEAMSTRAHLUNG FOR D=1.

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