Disruption Effects on the Beam Size Measurement*

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Abstract

At the SLC Final Focus with higher currents and smaller beam sizes, the disruption parameter D_y is close to one and so the pinch effect should produce a luminosity enhancement. Since a flat beam-beam function is fit to deflection scan data to measure the beam size, disruption can affect the measurement. Here we discuss the quantitative effects of disruption for typical SLC beam parameters. With $3.5*10^{10}$ particles per pulse, bunch length of 0.8 mm and beam sizes of 2.1 μm horizontally and 0.55 μm vertically, the measured vertical size can be as much as 25% bigger than the real one. Furthermore during the collision the spot size actually decrease, producing an enhancement factor H_D of about 1.25. This would yield to a true luminosity which is 1.6 times that which is estimated from the beam-beam deflection fit.

Disruption Effects

The disruption originates several desired and undesired effects. The desired one is the extra focusing that the two beam exercises during their interaction due to their attractive fields and the finite bunch lengths.

Of course the extra focusing produces a direct increase of the luminosity, however, since the fields are not linear (radially) and do vary during the interaction, the angular spread and emittance of the beam do increase during the interaction. This can affect the extraction of the two beams, increasing the current losses in the extraction-lines.

The extra focusing is desired, but the related luminosity enhancement becomes very difficult to measure. On top of that the beam-beam deflection scans [1] are also distorted by the disruption, in such a way that the spot sizes measured with this technique are in general bigger than the original, undisrupted ones.

Furthermore it is also possible that the disruption alters the optimization of the beam spots leading to a luminosity lower than the optimal.

Experimental Evidence

In the last SLC-SLD run the discrepancy between the estimated luminosity by using beam-beam deflection scans (SLC) and the effective one by counting the number of Z_0 effectively found (SLD) has become evident.

In particular, this discrepancy has become quite large (about 30%) after an improvement of the beam-beam deflection fits was made, in order to make it insensitive to beam position jitter at the IP. The estimated luminosity measurement has become much more stable since then, permitting a much more reliable comparison with the SLD data. In Fig. 1 the SLD/SLC luminosity ratio for the last two months of run is shown.

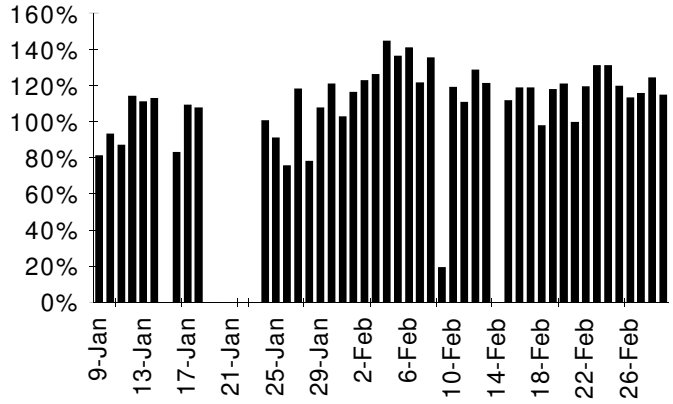


Fig. 1: SLD/SLC luminosity ratio history

Moreover one expects that the discrepancy has to become bigger for higher luminosity, Fig.2 shows the SLD/SLC ratio as a function of the luminosity itself.

*. Work supported by the Department of Energy, contract DE-AC03-76SF00515

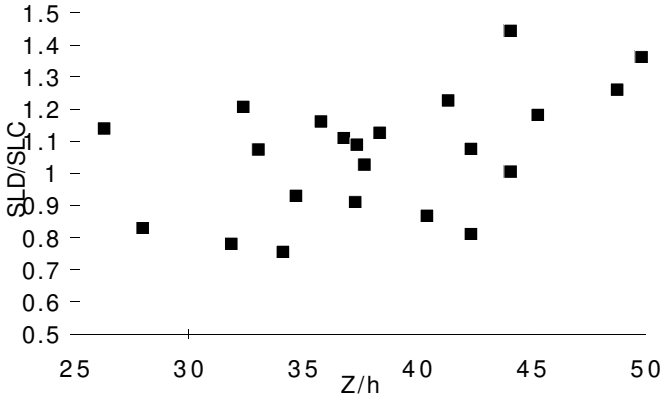
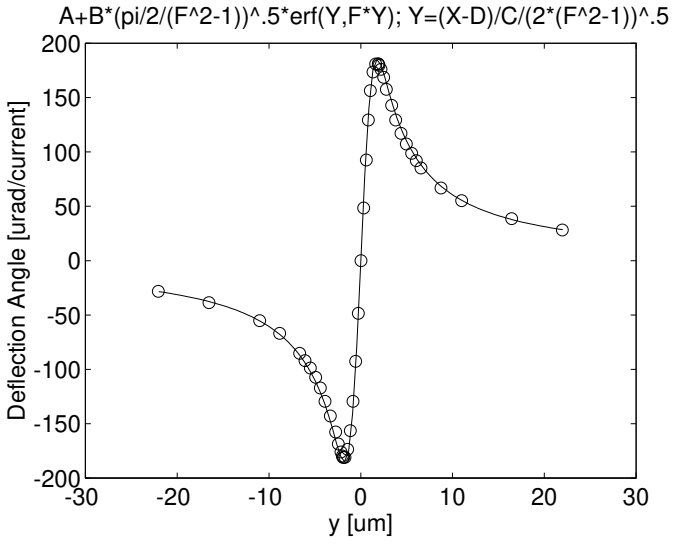


Fig. 2: SLD/SLC luminosity ratio vs luminosity

Theoretical Estimates

In order to estimate the pinch effect, a full tracking code to simulate the beams dynamics during the interaction has been developed [2]. The simulation predicts typical luminosity enhancement of about 25% for our normal running conditions.

Moreover with the same code it is possible to simulate a beam-beam scan. Fig.3 shows the theoretical beam-beam deflection as function of the y offsets of the two beam and the fit with the beam-beam formula. It is noticeable that the fit is not perfect, and the fitted Σ_y is 25% bigger than the original one, while the other plane Σ is 20% smaller. For a horizontal scan the difference is negligible.



Σ_y, incoming = 0.780 µm Σ_x incoming = 2.98 µm

Σ_y, fitted value = 0.990 µm Σ_x fitted value = 2.42 µm

Fig. 3: Simulated *Disrupted* b-b scan, and deflection fit

Fig. 4 shows the relative increase in the overestimation of the unfocused Σ_y, while the effective Σ_y (the average spot size during the interaction) decreases proportionally more and more for smaller spots, leading to a large underestimate of the luminosity. A similiar effect is visible for Σ_y when Σ_x changes (see Fig. 5).

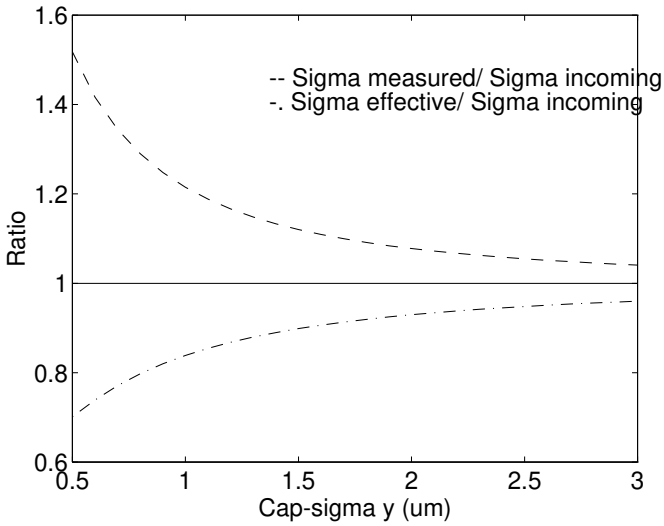


Fig. 4: Σ_y, (measured) /Σ_y, (incoming) and Σ_y, (effective) /Σ_y, (incoming) versus Σ_y,

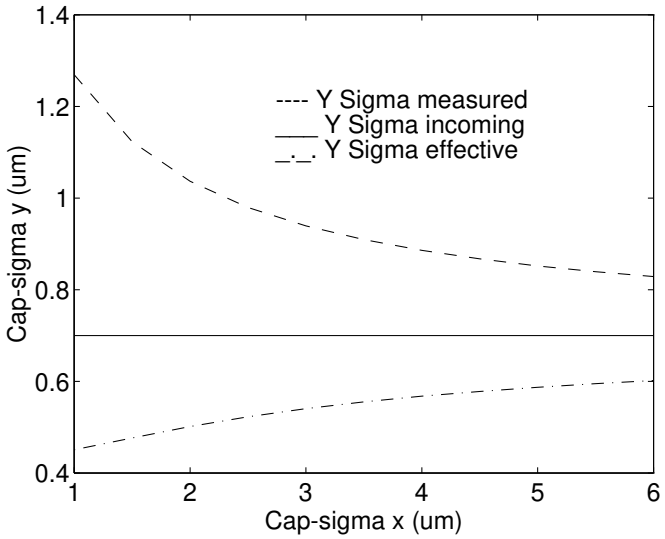


Fig. 5: Σ_y, (measured) and Σ_y, (effective) versus Σ_x

In order to get in real time the correct beam spot sizes, it has been developed a b-b deflection expression that, with some approximations, takes into account for the disruption.

The following assumptions are made:

a) the fields seen by the two beams are always the linear expansion of the true fields around the centroid beam positions,

b) the fields are constant during the interactions, in other words the focusing effects does not change them appreciably.

c) the beam longitudinal distribution is rectangular (in the real case the longitudinal distribution is something between rectangular and gaussian).

With this assumption, it is straightforward to compute the luminosity enhancement. Indeed the focusing effect is now simply like a pure linear focusing lens, and the effective average beam spot size during the interaction can be estimated according to:

$$\sigma_{yEFF} = \sigma_y \frac{\sqrt{2+\sin(2\phi)}}{4\phi}$$

ϕ is the phase advance in the interaction region:

$$\phi = \sqrt{K\,\sigma_b}$$

K is the derivative of the electric field (colliding beams):

$$K = \frac{631\,N}{\sigma_y(\sigma_y+\sigma_x)}$$

N is the target beam number of particles (10^{10} units),
σ_b the bunch length (in meters),
σ_y and σ_x the target beam spot sizes (in μm).

The luminosity enhancement so evaluated differs from the one estimated with full tracking by less the 5% up to luminosities of 3 times bigger than the achieved ones.

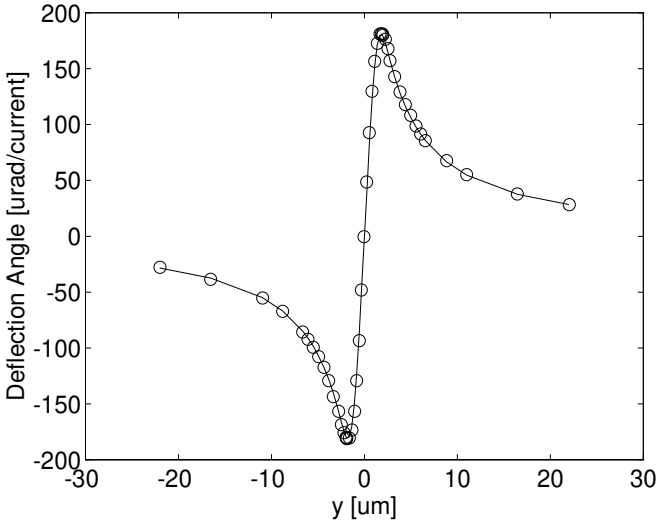
The deflection angle can be evaluated starting from the fields generated by the effective spot sizes (at the relative distance) and considering that the beams do move in a focusing lens, hence:

$$\Theta_{yEFF} = \Theta_y \frac{\sin(2\phi_{EFF})}{2\phi_{EFF}}$$

being θ_y the deflection angle computed using the effective beam spot sizes and zero bunch length.

With such formulas (see Fig. 6) the fit of the beam-beam deflection computed with the tracking gives much better agreement for the on plane and off plane sigmas and in general the function fits the points much better than the previous one.

Unfortunately the difference between the undisrupted and disrupted deflection is not impressive and probably difficult to see in a fit of real data.



Σ_y, incoming = 0.780 μm Σ_x incoming = 2.98 μm
Σ_y, fitted value = 0.781 μm Σ_x fitted value = 2.98 μm

Fig. 6: Simulated *Disrupted* b-b scan, and *Disrupted* deflection fit

Conclusions

The disruption has been shown to be a possible cause of the discrepancy between the SLC estimated luminosity and the SLD one. Moreover it can explain a part of the degradation in the measured luminosity as a function of the beam current. In the next run we hope to have a clearer signature