Mitigation of the Oide effect

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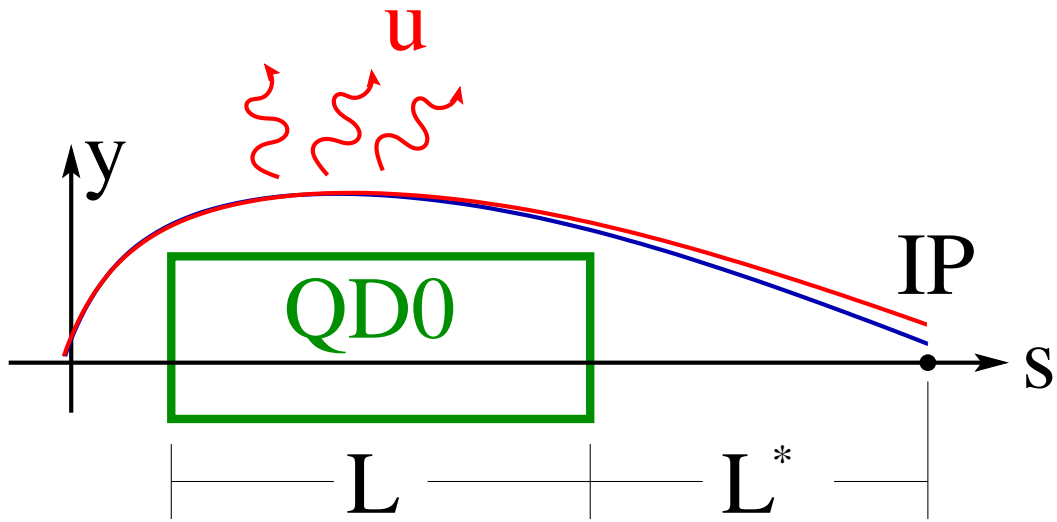
Oide effect

Radiation in a focusing magnet changes the energy of the particle and limits the focusing effect.



Designed particle trajectory, trajectory of a particle due to radiation in the quadrupole.

Oide effect (cont.)

The beam size will be :

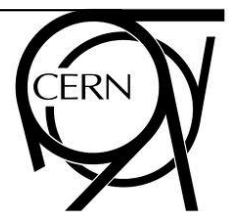
$$\sigma_y^2 = \beta_y^* \epsilon_y + c_1 \gamma^5 F(\sqrt{K}L, \sqrt{K}L^*) \left(\frac{\epsilon_y}{\beta_y^*} \right)^{\frac{5}{2}}$$

and the minimum beamsize is independent of of energy.

$$\sigma_{y\ \mathrm{min}}^* = c_2 \left[F(\sqrt{K}L, \sqrt{K}L^*) \right]^{\frac{1}{7}} (\epsilon_{Ny})^{\frac{5}{7}}$$

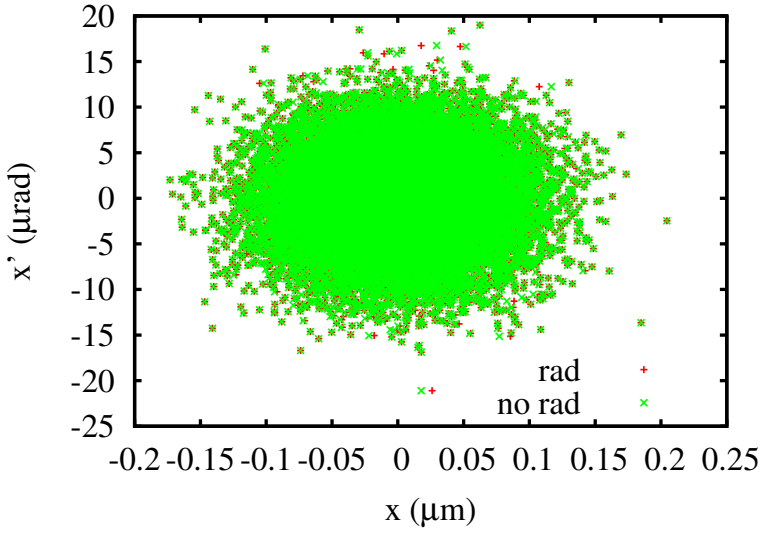
Lattice	ϵ_N (nm)	γ (10^3)	σ_0 (nm)	k (m^{-2})	L (m)	L^* (m)	F	σ_{oide} (nm)
CLIC 3 TeV	20	2935.0	0.7	0.116	2.73	3.5	4.086	0.85
CLIC 500 GeV	25	489.2	2.3	0.077	3.35	4.3	4.115	0.08
ILC 500 GeV	40	489.2	5.7	0.170	2.20	4.3	9.567	0.04

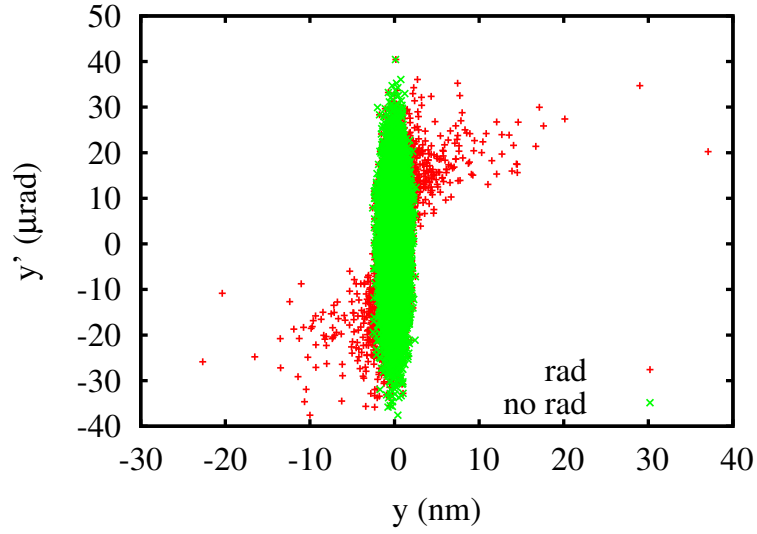
Beam size and radiation beam size contribution for three lattices. ϵ_N is the normalized emittance.

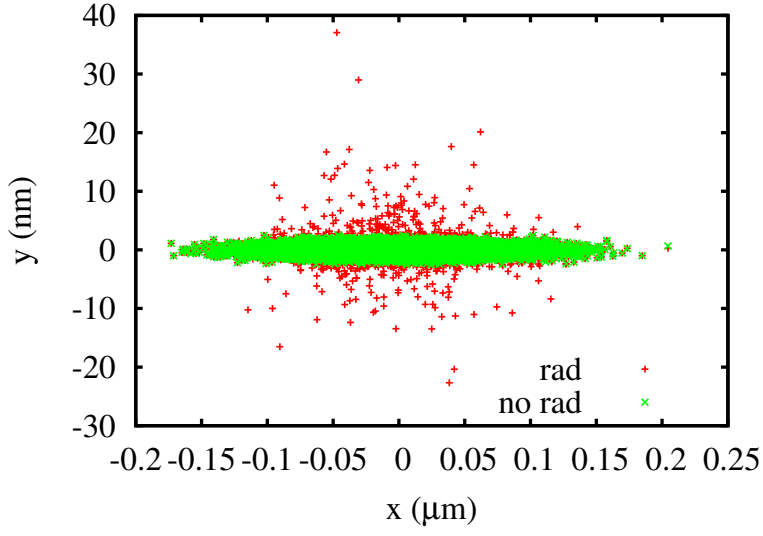


Oide in CLIC 3TeV

The current particle distribution in CLIC 3TeV at the IP.







The ideal would be to remove $\Delta y = y_{\text{rad}} - y_0$.

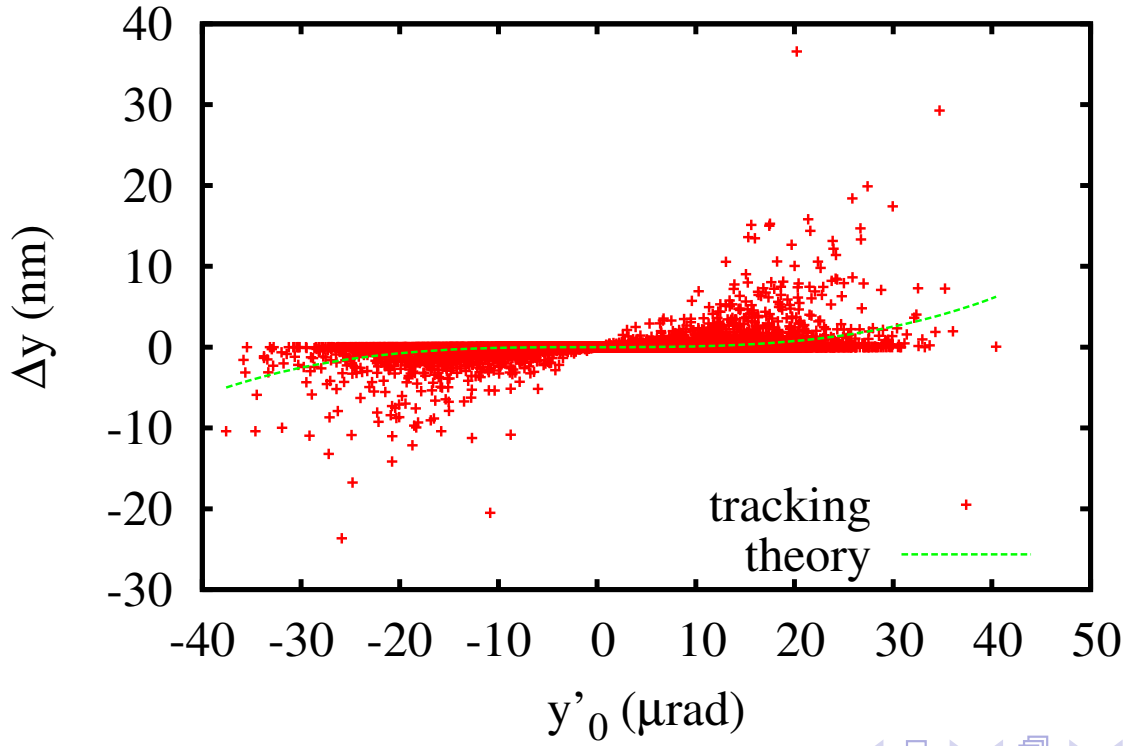
Δy due to radiation

Oide averages over u, s, y, y', obtaining $\langle \Delta y \rangle = 0$.
But this result hides a correlation between $\Delta y, y'$:

$$\langle \Delta y(y_0') \rangle = \frac{2}{3} r_e \gamma^3 G(\sqrt{K}L, \sqrt{K}L^*)(y_0')^3$$

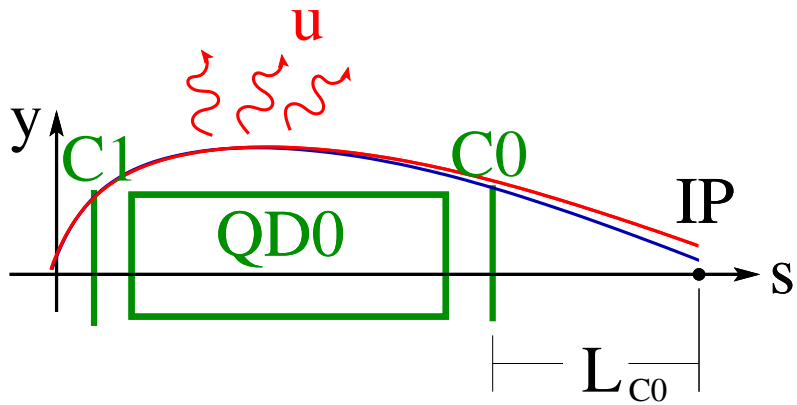
r_e is the clasical electron radius and

$$G(\sqrt{K}L, \sqrt{K}L^*) = \int_0^{\sqrt{K}L} (\sin\phi + \sqrt{K}L^* \cos\phi)^2 \int_0^{\phi} (\sin\phi' + \sqrt{K}L^* \cos\phi')^2 d\phi' d\phi$$



Corrector

A pair of correctors is added to the strong focusing in order to mitigate the radiation effect.



nominal trajectory: the kick in C1 must cancel the kick in C0.
all particles that radiate: the difference in kicks should cancel Δy.

Procedure:

- Scan the best position and gradient (s, k) for C0.
- Set C1 at QD0 input to cancel the effect of C0.

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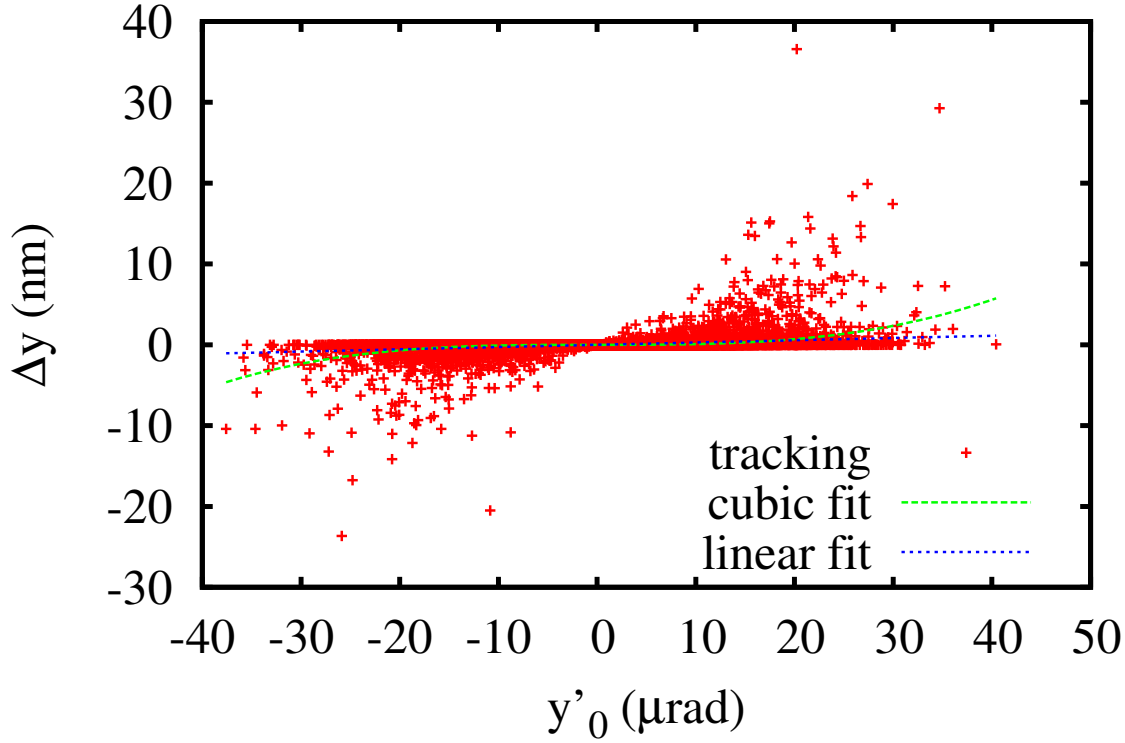
Corrector (cont.)

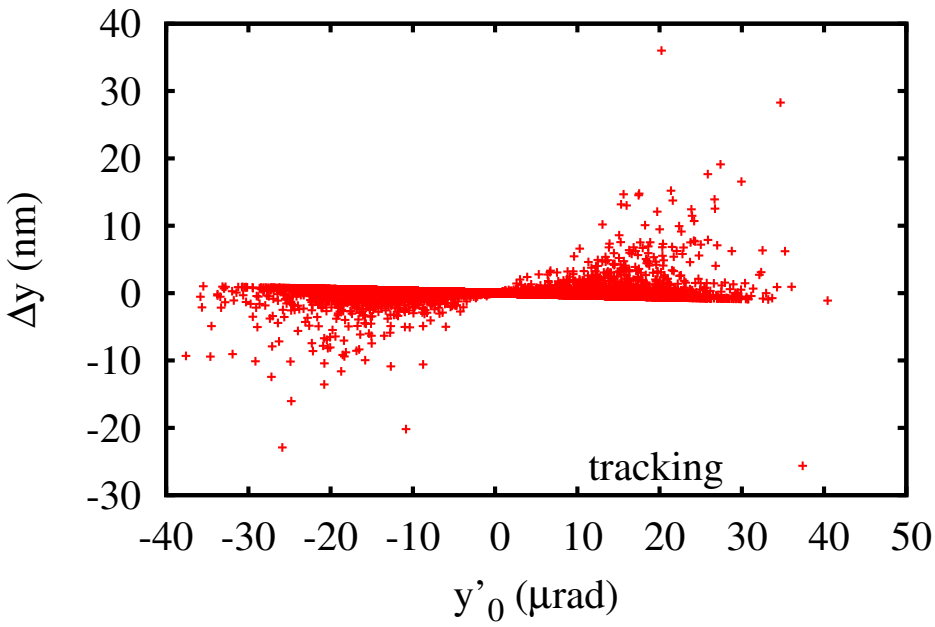


Two sets of corrector could be used :

- For the linear fit : Quadrupoles (QD00,QD01)
- For the cubic fit : Octupoles (OD0,OD1)

Corrector (quad, oct)

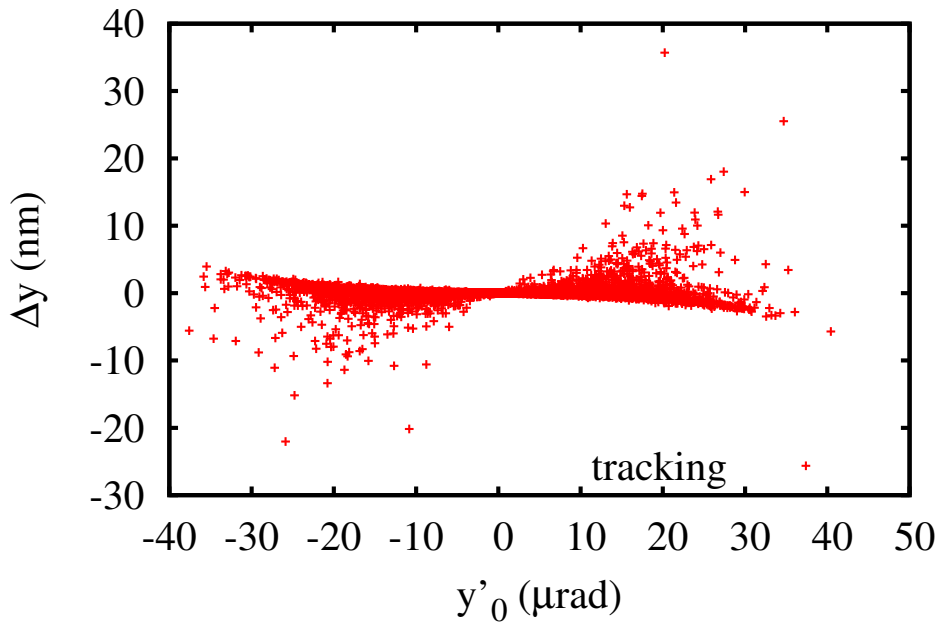
Quadrupoles



Beam size reduction

$3.0\% \pm 0.7$

Octupoles

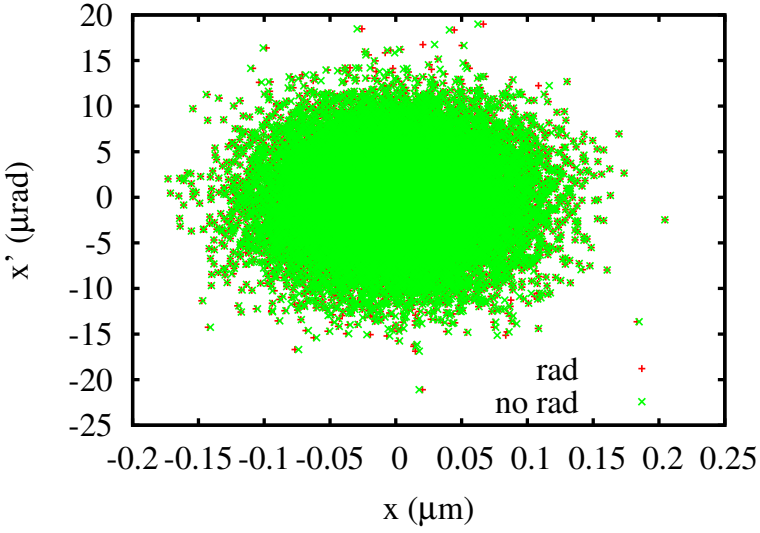


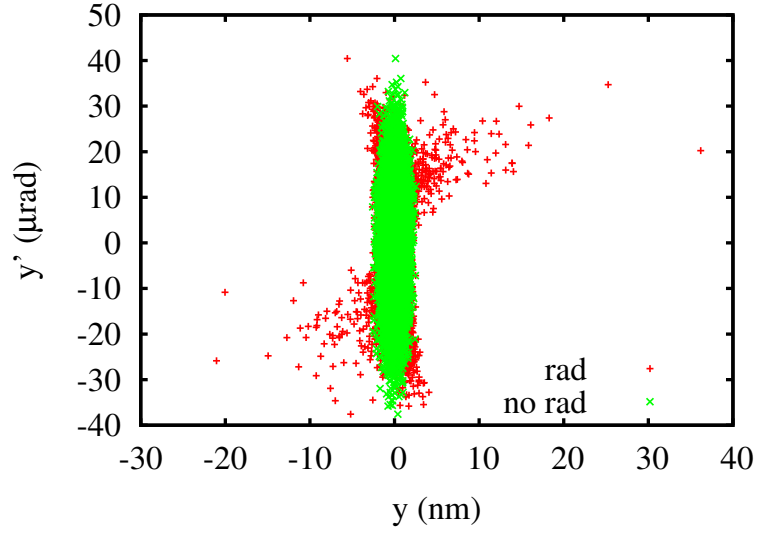
Beam size reduction

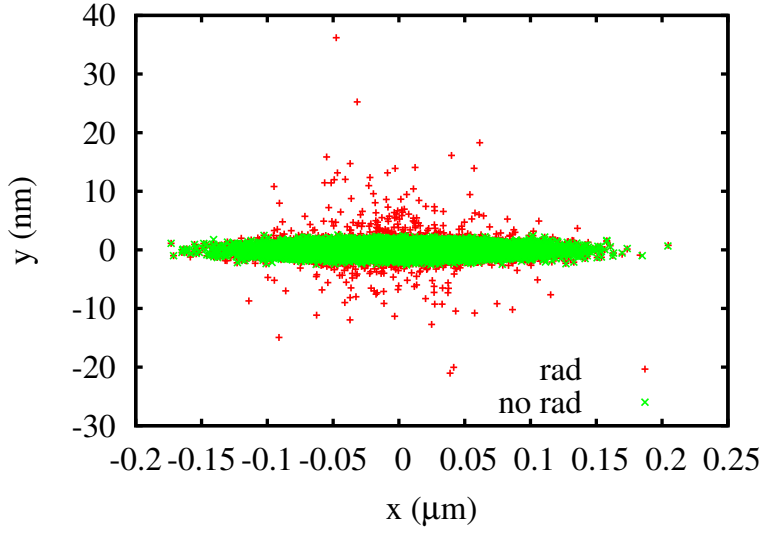
$4.3\% \pm 0.7$

Oide+Oct in CLIC 3TeV

The current particle distribution in CLIC 3TeV at the IP.



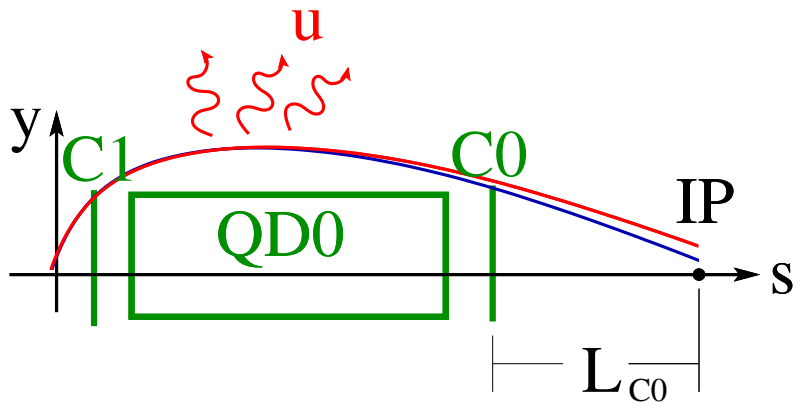




Noticeable change in vertical phase space !

Limitations

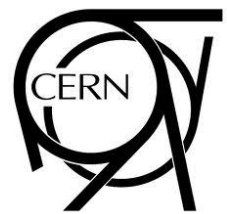
Why it was not possible to reduce the correlation even more ?



- C0 adds very little to radiation. But at some point the radiation in C1 starts to be important. It might be possible to scan C1 (s, k) to find a place where it radiates less.
- Even with perfect C1 to C0 correction there will be a limit when radiation will affect the Horizontal plane. Here the target was set to less than 1% of horizontal beam size increase.
- Mean correlation could be reduced to a minimum as there is not correlation per each particle... (other target?)

Conclusions

- Radiation in the final quad sets a limit on the vertical beamsize, this is called Oide effect
- Even if the mean value of the trajectory change is zero, there is a correlation between the change in trajectory and the angle at the IP due to the energy change.
- This correlation is reduced by correctors before and after QD0. The best result yet has been with octupoles giving a vertical beam size reduction of $4.3\% \pm 0.7$



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