NLC - The Next Linear Collider Project

NLC Beam Delivery System Developments

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Outline

- **Final Focus upgrades**
  - Weaker quadrupoles and sextupoles
  - Looser magnet tolerances
  - Reduced non-linearities and “halo-amplification”
- **Collimation upgrades**
  - Halo reduction by means of non-linear optical elements
  - Integrated Collimation System and Final Focus designs
- **Conclusions**

2000 Optics of the new NLC-FF

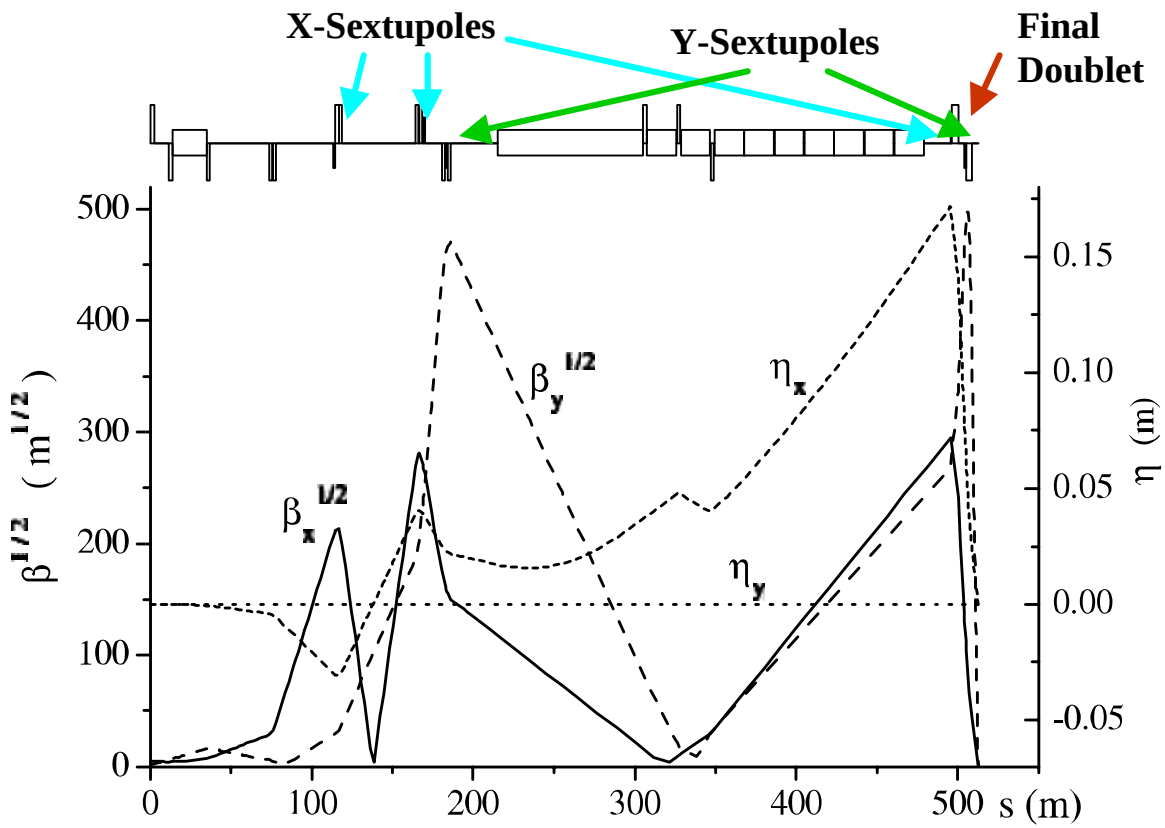
Chromaticity locally compensated at the Final Doublet with sextupoles

Additional sextupoles upstream cancel the geometric aberrations.

Disadvantages:

Strong X-focusing quads in the Beta-matching section in order to cancel chromaticity (T126) and second order dispersion (T166)

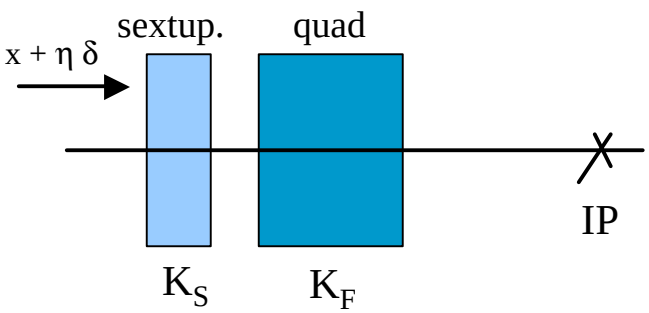
3 X-sextupoles and 2 Y-sextupoles needed to cancel all the significant 2nd and 3rd order aberrations.



2000 Optics of the new NLC FF. L* =4.3m

X and Y sextupoles are interleaved and they could generate higher order aberrations

Chromatic correction in 2000 FF



- Straightforward in the Y plane
- Trickier in X plane:

Quad: $$\Delta x' = \frac{K_F}{(1+d)}(x + ?d) \Rightarrow K_F(-dx - ?d^2)$$

chromaticity

Second order dispersion

Sextupole: $$\Delta x' = \frac{K_S}{2}(x + ?d)^2 \Rightarrow K_S ?(dx + \frac{?d^2}{2})$$

$$\Delta x' = \frac{K_F}{(1+d)}(x + ?d) + \frac{K_{b\text{-match}}}{(1+d)}x \Rightarrow 2K_F(-dx - \frac{?d^2}{2})$$

$$K_{b\text{-match}} = K_F \qquad K_S = \frac{2K_F}{?}$$

If we require $K_S h = K_F$ to cancel FD chromaticity, then half of the **second order dispersion** remains.

Solution:
The *b*-matching section produces as much X chromaticity as the FD, so the X sextupoles run twice stronger and cancel the **second order dispersion** as well.

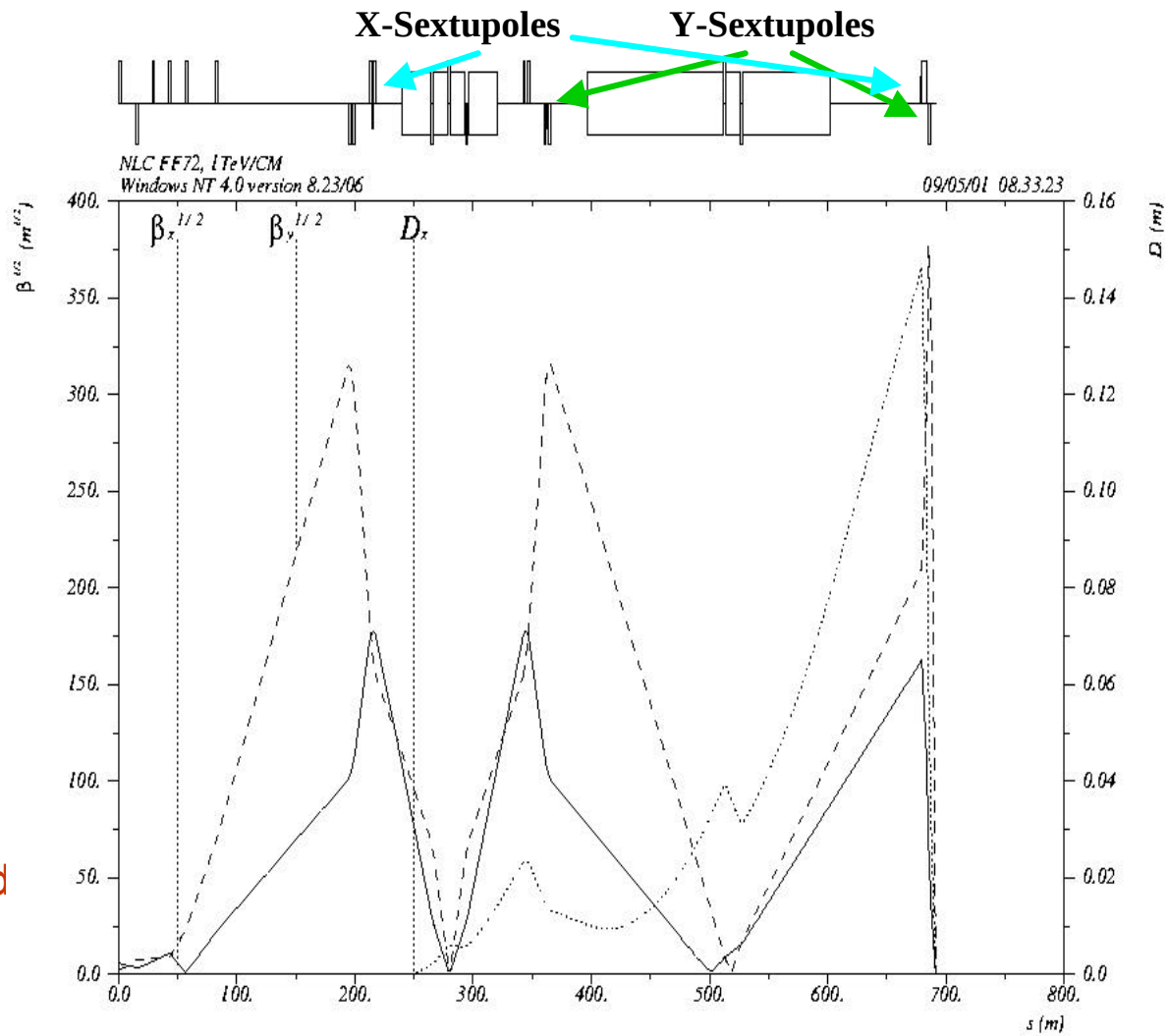
2001 Optic of the new NLC-FF

New:

A bend and a triplet have been added between the X and Y sextupoles in the "Geometric Correction Section" (GCS)

The dispersion in the GCS is set so the Y-sextupole and the X-quads together cancel the T166 generated in the FD, so strong X-quads are no longer needed.

The triplet ensures the optimal phase advance between the X-sextupoles, so only 4 sextupoles are needed to cancel the 2nd and 3rd order aberrations.



2001 Optics of the new NLC FF. L* =3.8m

Chromatic correction in 2001 FF

More advantages:

Quads and Sexts are weaker, tolerances on field errors and vibrations are relaxed.

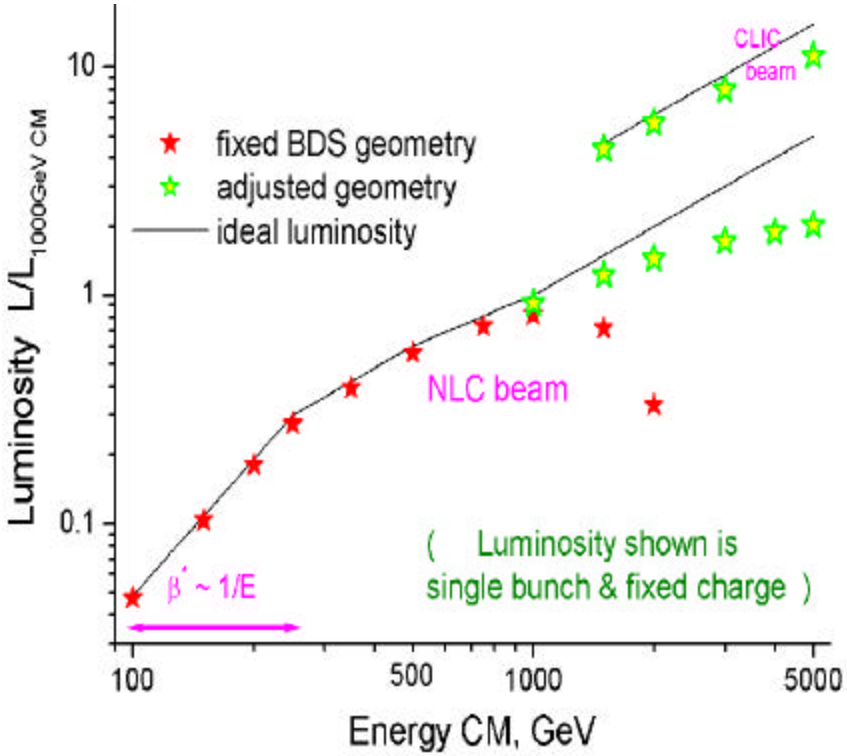
Almost no "Halo amplification" from high order aberrations because:

All the quads needed to build the –I between the sextupoles are in low-b points, so the FD-phase chromaticity is negligible.

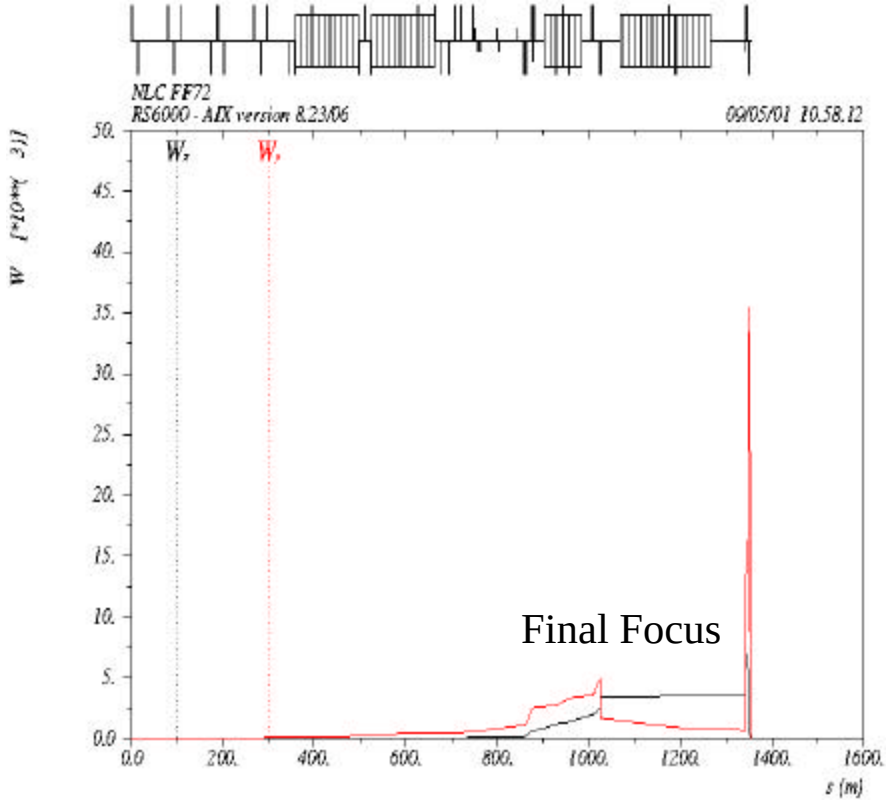
The chromaticity through the system and the geometric non-linearities in the FD-phase are reduced to a minimum.

All residual significative 4th order aberrations can be canceled with decapoles, leaving space for luminosity upgrades in the due years.

Final Focus performance

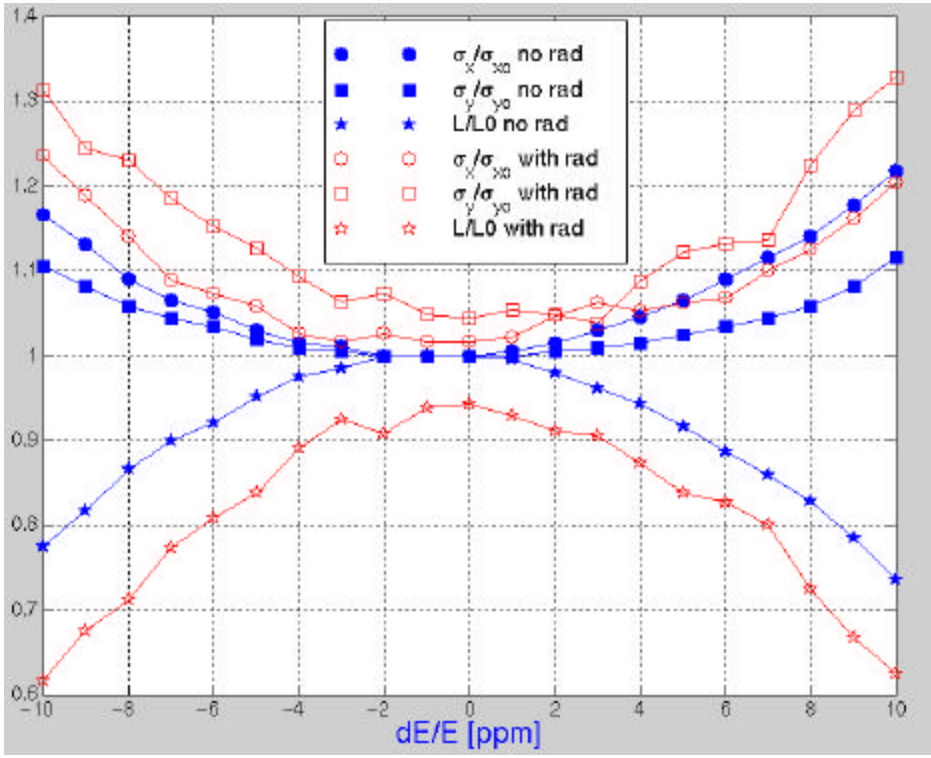


BDS energy reach

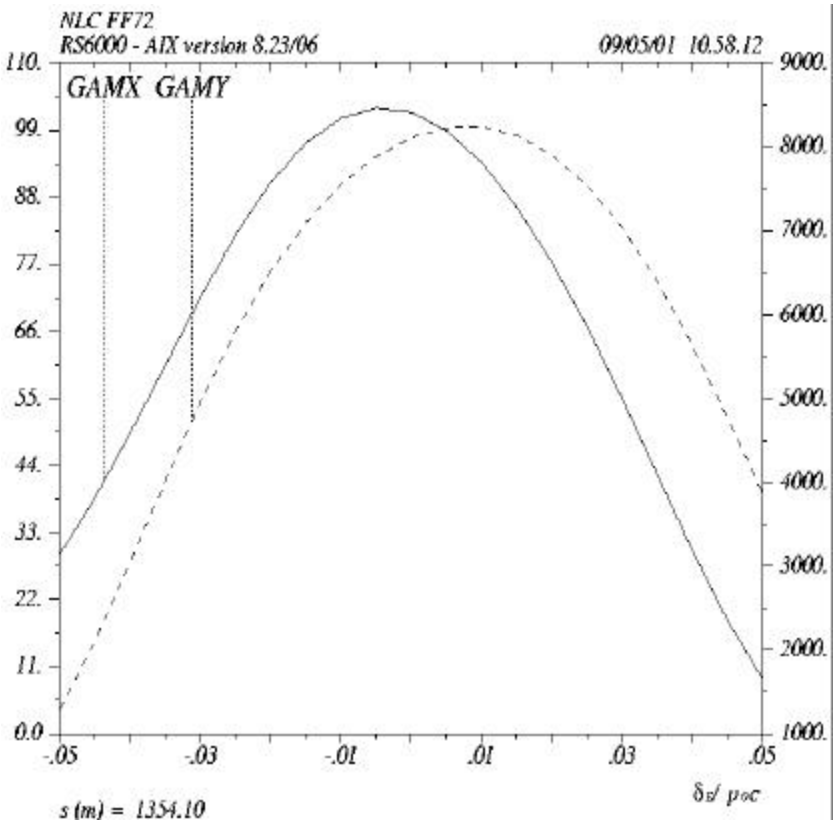


Chromaticity through the BDS

Final Focus performance

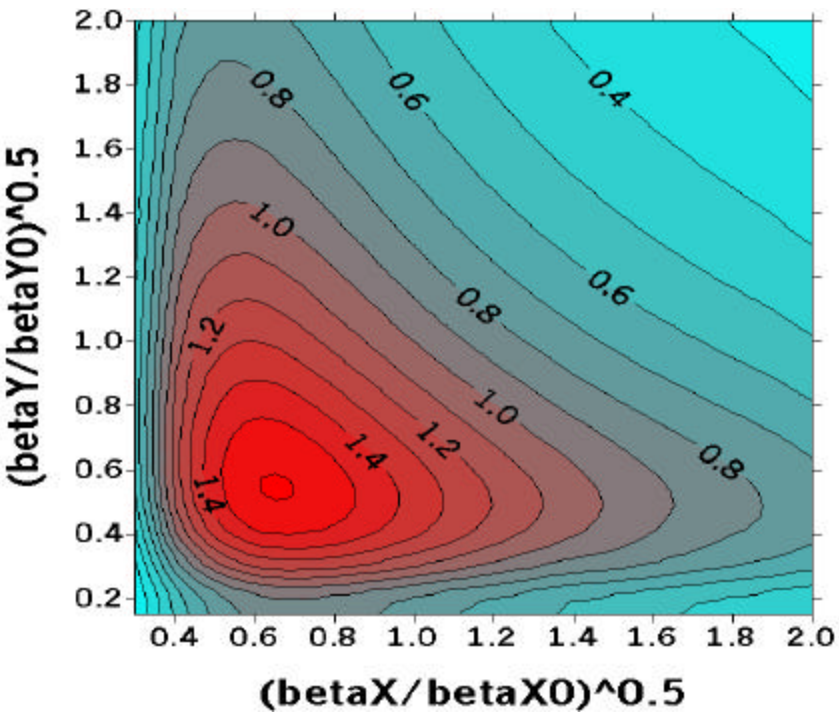


Luminosity and IP beam spot sizes vs beam energy-offset

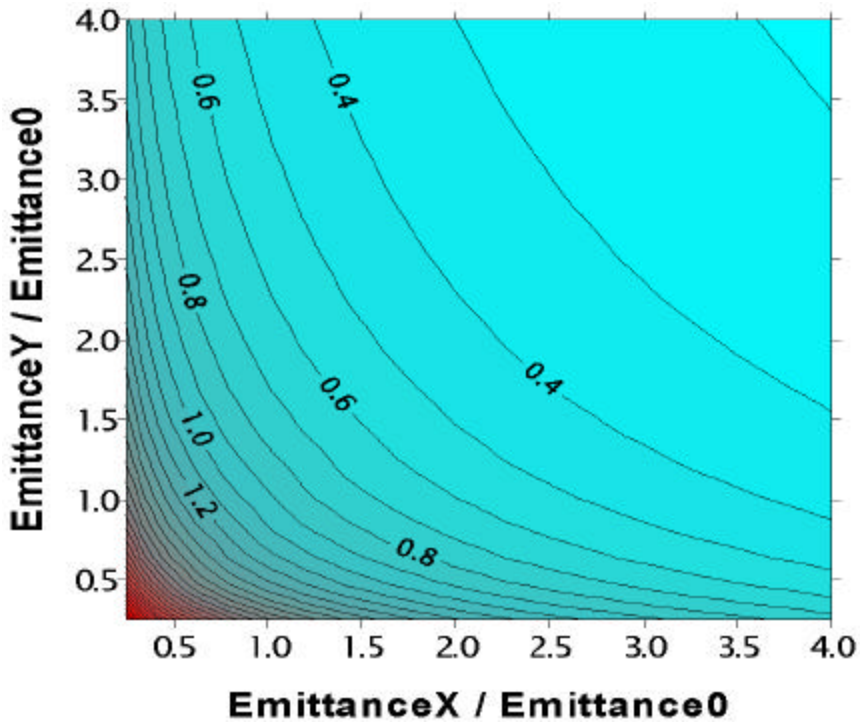


Beam size across the FD for off-energy particles

Final Focus performance

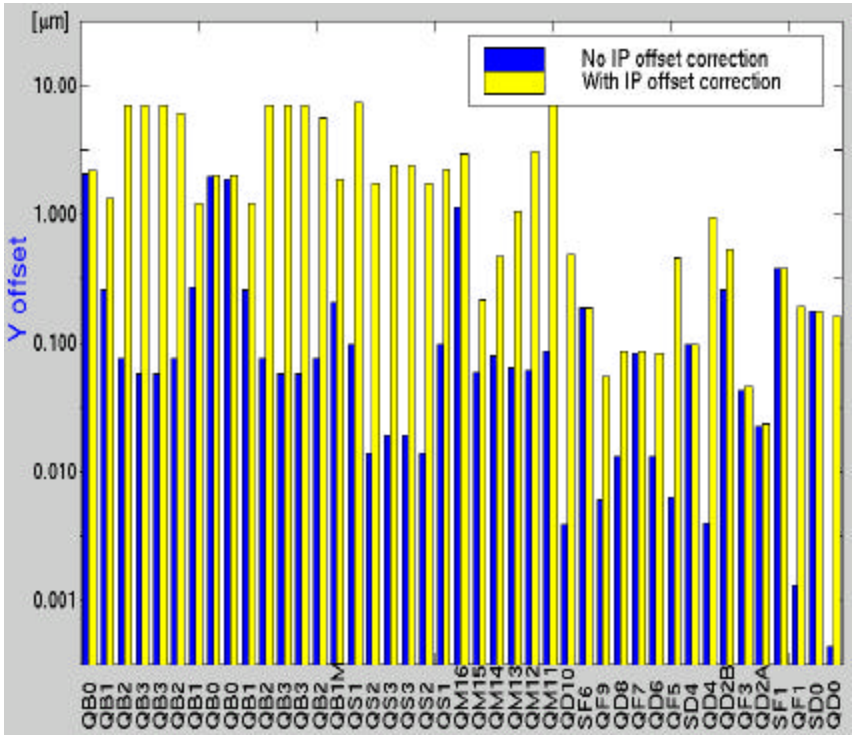


BDS luminosity reach at design emittances

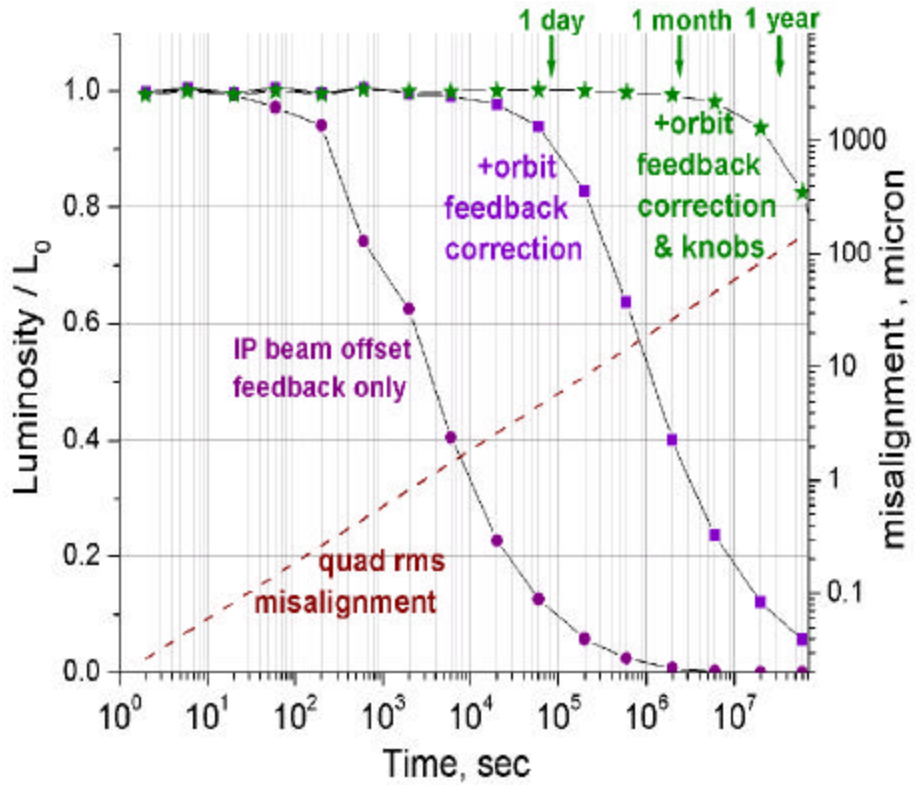


BDS luminosity vs emittances

Final Focus performance

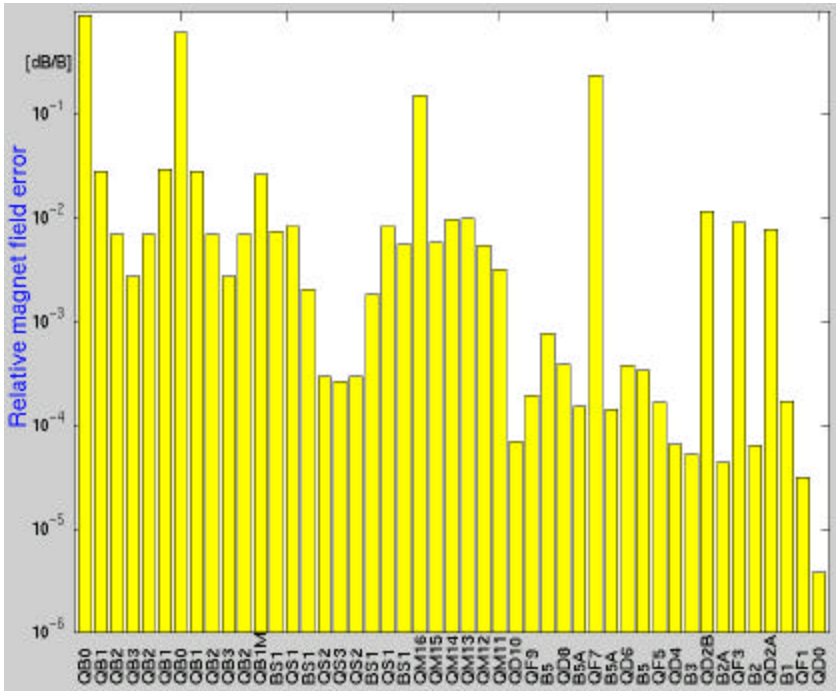


BDS vertical quadrupole position tolerances for 2% luminosity loss

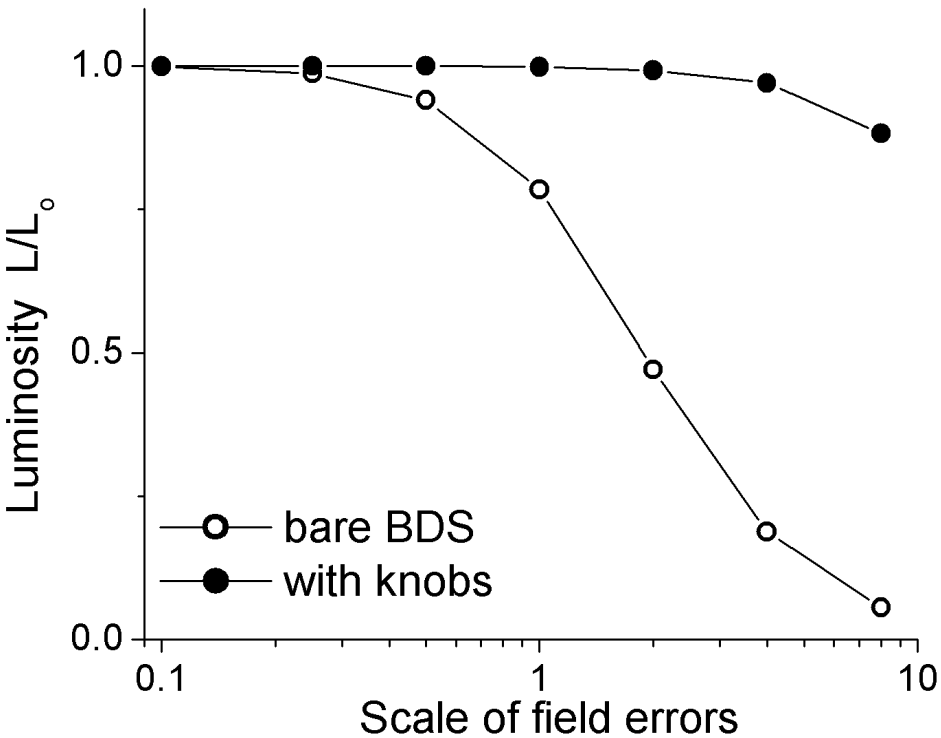


BDS luminosity degradation vs time. The value of the ATL coefficient is assumed to be $A=5*10^{-7}\mu m^2/m/s$

Final Focus performance



BDS quadrupole and bend field errors tolerances for a 2% luminosity loss



BDS luminosity degradation due to random quad field errors as a function of the error magnitude (scaled from errors tolerances).

Nonlinear handling of beam halo

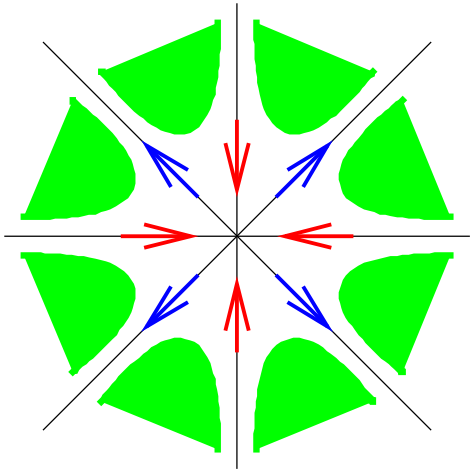
- One wants to **focus beam tails** leaving the core of the beam unchanged

  use **nonlinear** elements (e.g. octupoles)

- **Several** nonlinear elements needed to provide **focusing in all directions**

  Similar to **FODO** strong focusing

- A very simple and elegant solution is to use **Octupole Doublets** (**OD**) in series



An octupole focuses along the X and Y axes and defocuses on the diagonals.

An octupole doublet can focus in all directions !

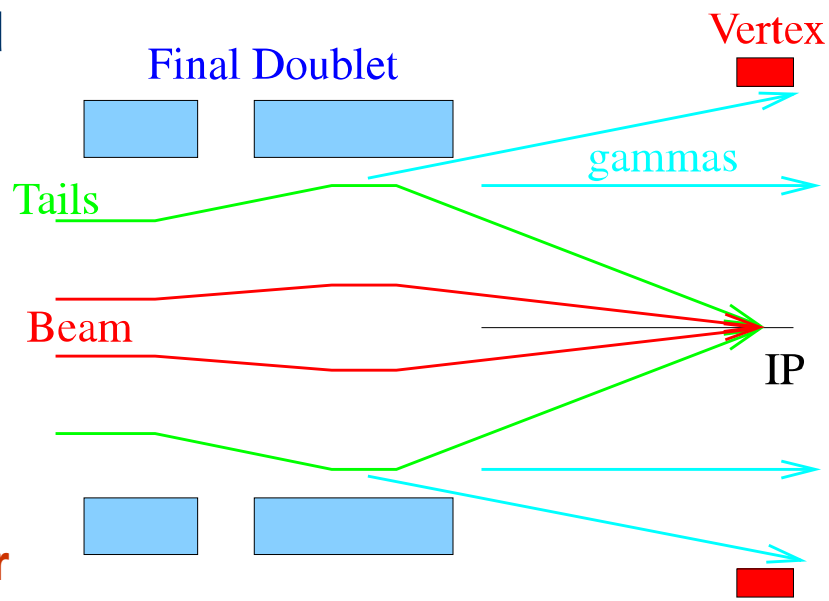
Background and collimation

- **Major source of detector background in the new FF:**

  Large offset particles which hit the FD and/or emit photons that hit the vertex detector

  Such particles can originate in the linac (wakefields, gas-scattering, multipole-fields aberrations) or…

  can originate in the Collimation Section or in the Final Focus, because of high order aberrations



Beam halo produces background in the vertex detector

- **Two possible solutions:**

  Reduce halo size by means of non-linear optical elements (Halo Folding)

  Stop halo on physical scrapers (Collimation)

Strong focusing by ODs

- **Two octupoles** opposite in sign separated by a **drift** provide **focusing in all directions for a parallel beam:**

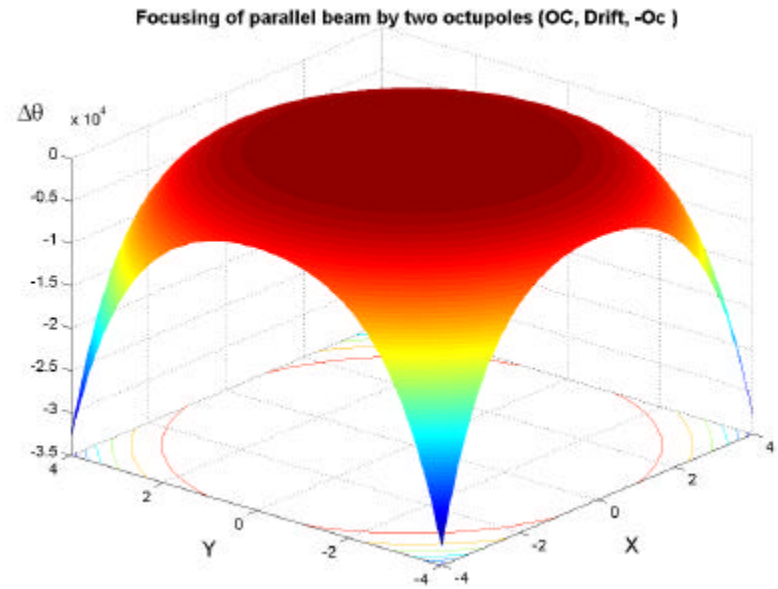
$$\Delta q = a\, r^3 e^{-i3j} - \left(a\, r^3 e^{i3j}\left(1 + a\, r^2 L\, e^{-i4j}\right)^3\right)^*$$

$$x + iy = re^{ij}$$

$$\Delta q \approx -3a^2 r^5 e^{ij} - 3a^3 r^7 L^2 e^{i5j}$$

5th order Focusing in <u>all directions</u>

Next nonlinear term focusing – defocusing depends on j



Effect of octupole doublet (Oc,Drift,-Oc) on parallel beam, DQ**(x,y).**

- Works best if the phase advance in the doublet is small

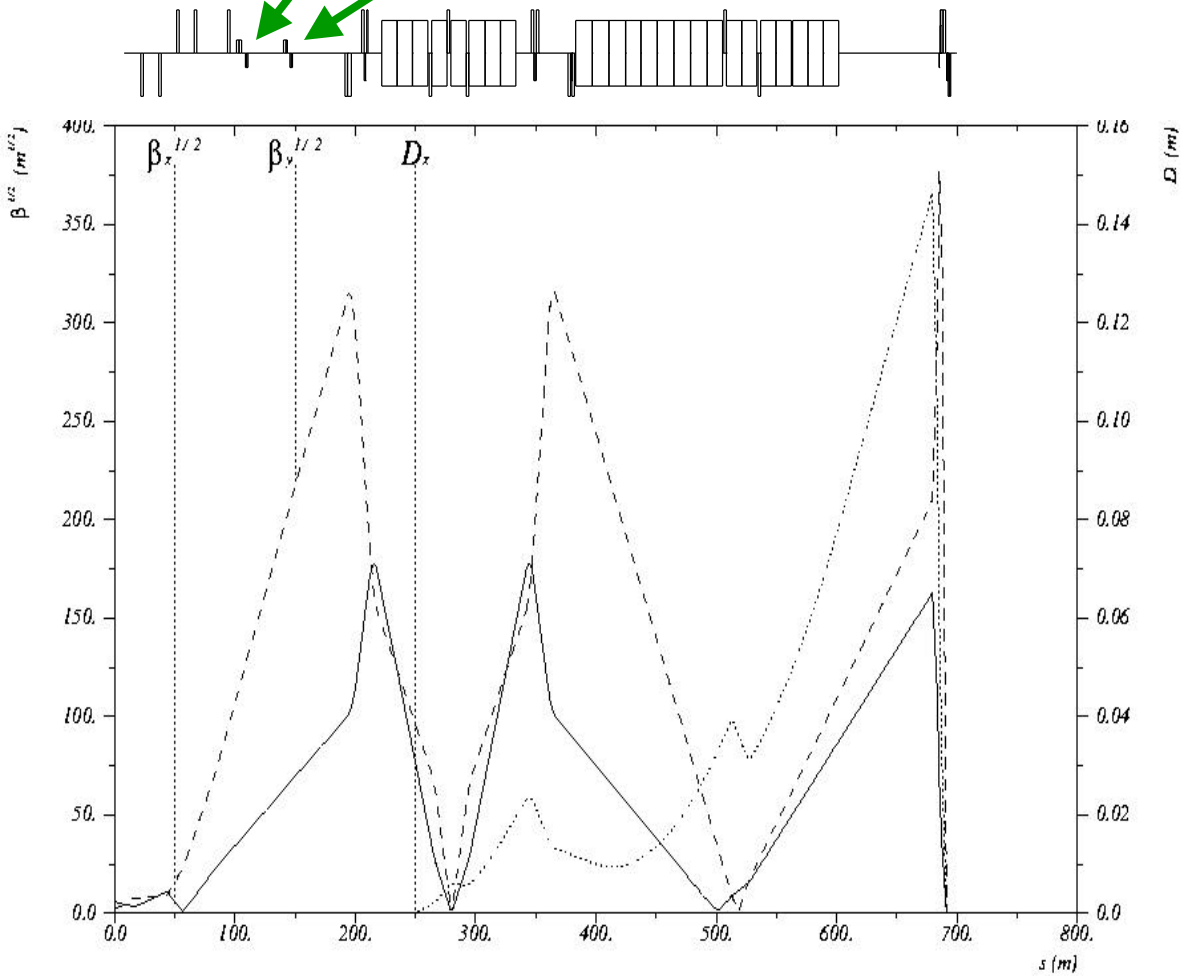
NLC FF with two ODs

Two ODs are placed in NLC FF for active folding of beam tails

b_x/b_y chosen to have the optimal folding across QF1/QD0

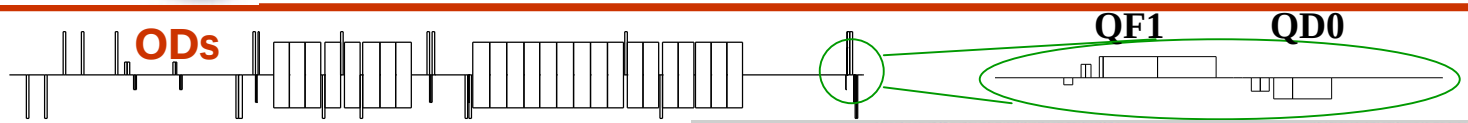
Halo size across the FD decreases by ~ 4 times in both planes

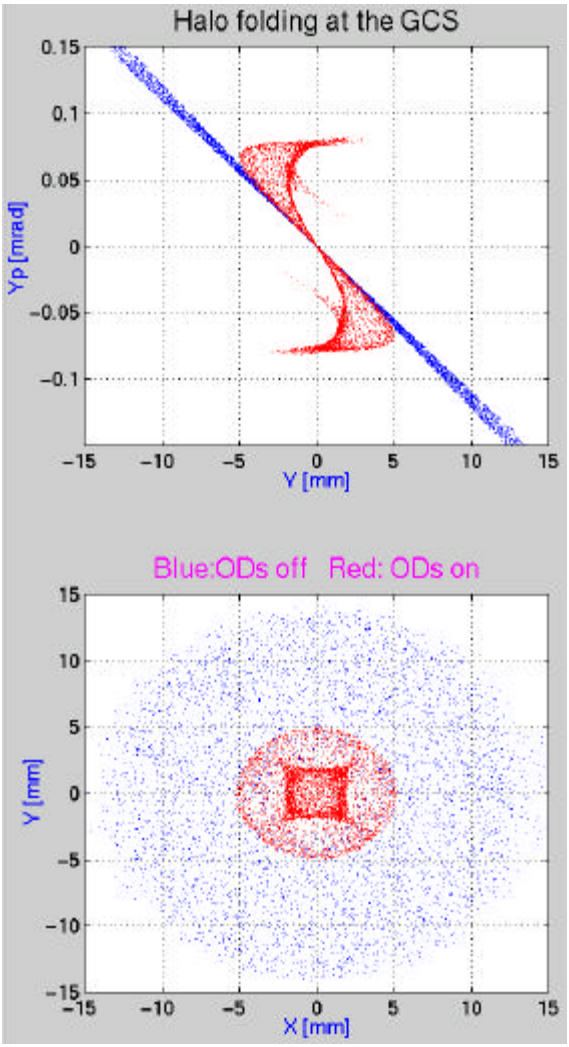
This leads to relaxation of the collimator depth by about a factor of 4

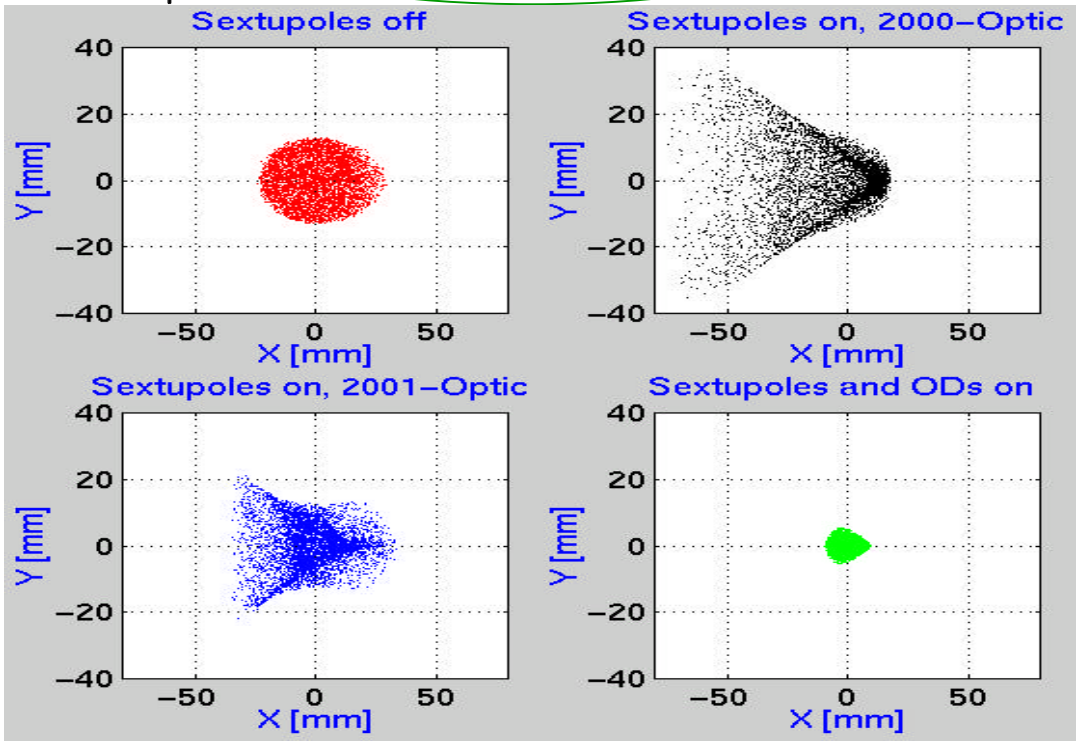


NLC FF with two octupole doublets placed between the b-matching section and the GCS

Halo folding in the NLC FF







Beam at QF1 entrance

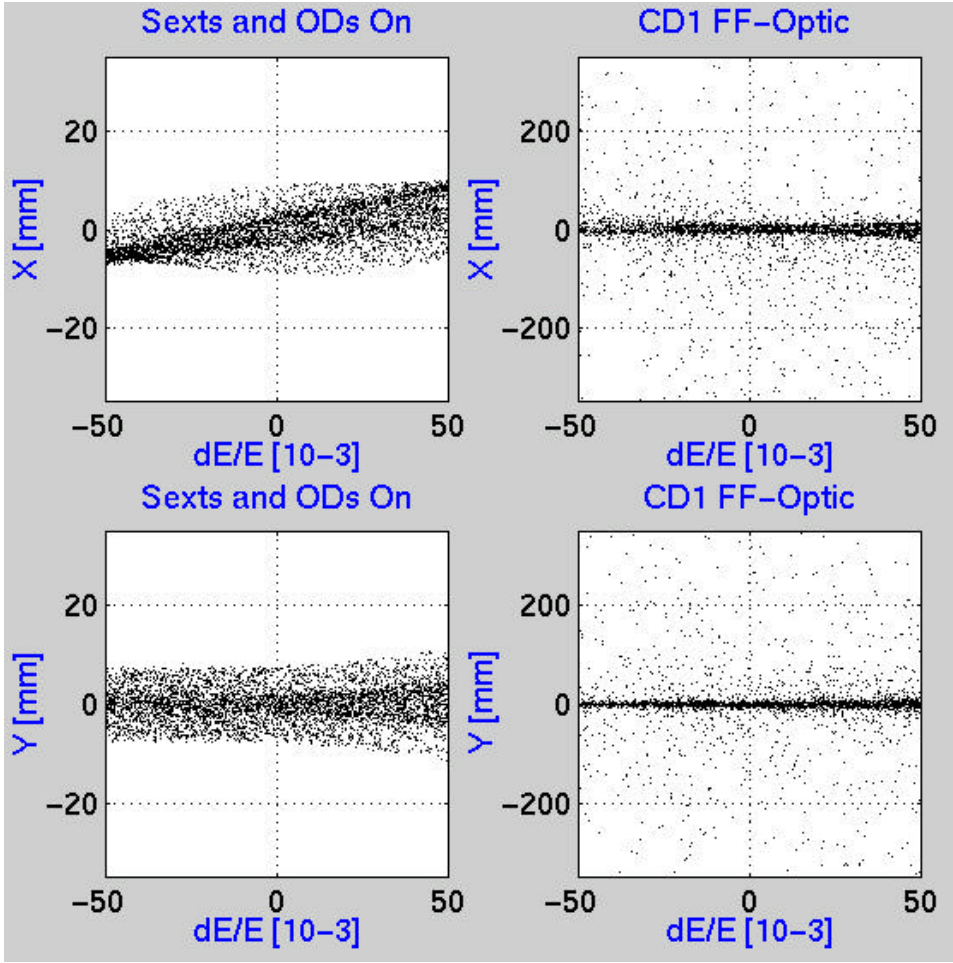
Flat Distributed Input beam (in IP units):

$(\sigma_x, \sigma_{x'}, \sigma_y, \sigma_{y'}, \sigma_e)$ = (24μm,1.1mrad,5.4μm,4.5mrad,3%)

roughly corresponding to N_s=**(120,60,2000,200,15)**

larger size than the nominal NLC beam

Collimation System requirements



2000-Collimation System still designed for CD1-FF

NOW much less demanding requirements in terms of scraping, BUT:

Much more demanding requirements in terms of OPTICAL PROPERTIES

Chromo-geometric non-linearities have to be smaller than in the FF, otherwise Collimation depth defined by the Collimation System itself(!)

FD halo vs energy for 2001-FF and CD1-FF

(in CD1-FF plots, 40% of the beam lies outside the limits of the vertical scale)

2001 Collimation System design

(in progress)

High order aberrations smaller then in the FF

Clear, understandable, phase relation between collimator jaws and FD and IP

Linear system easy to understand, model and TUNE

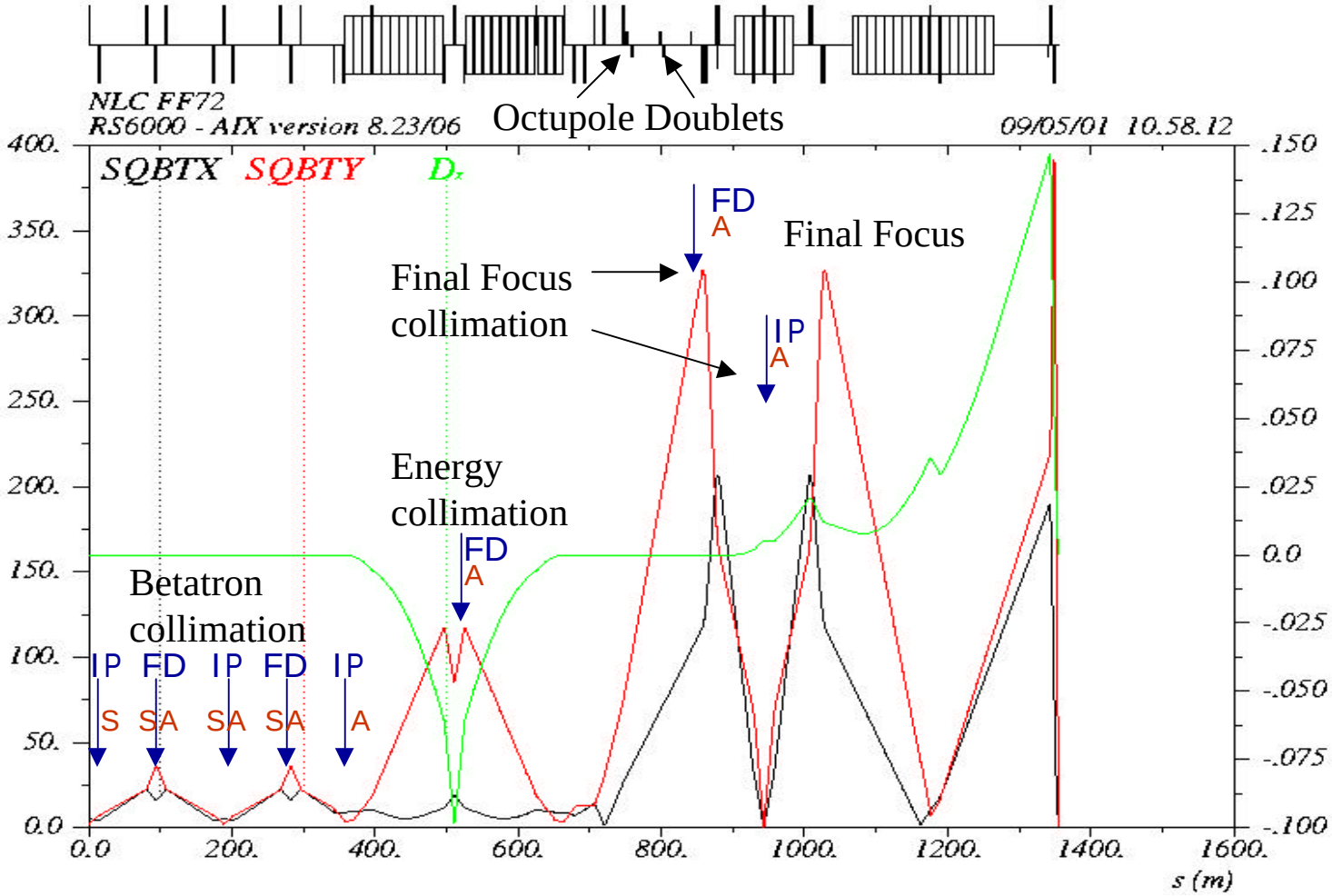
FD-collimators need high b's, IP-collimators low b's

Residual Chromaticity (only at the IP phase) easily compensated in the FF with no loss in Bandwidth.

Wakefield dilution only from FD-jaws

Energy Collimators at the FD phase ⇨ the residual T166 helps(!) to cancel the T166 from the FD…

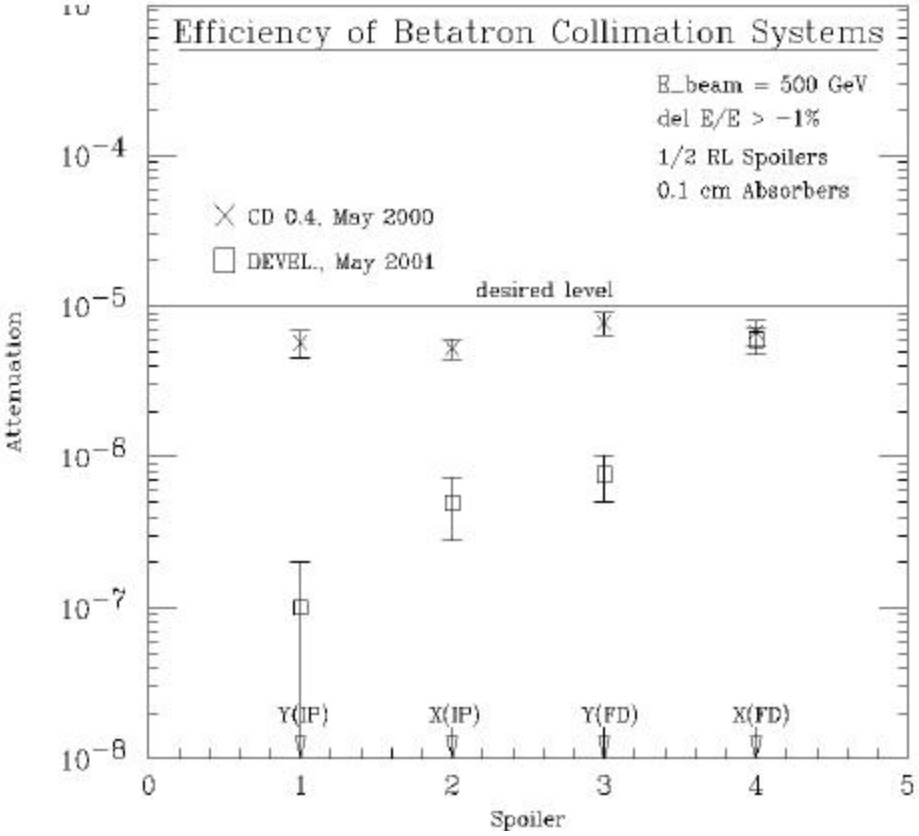
2001 Collimation System & FF integrated design

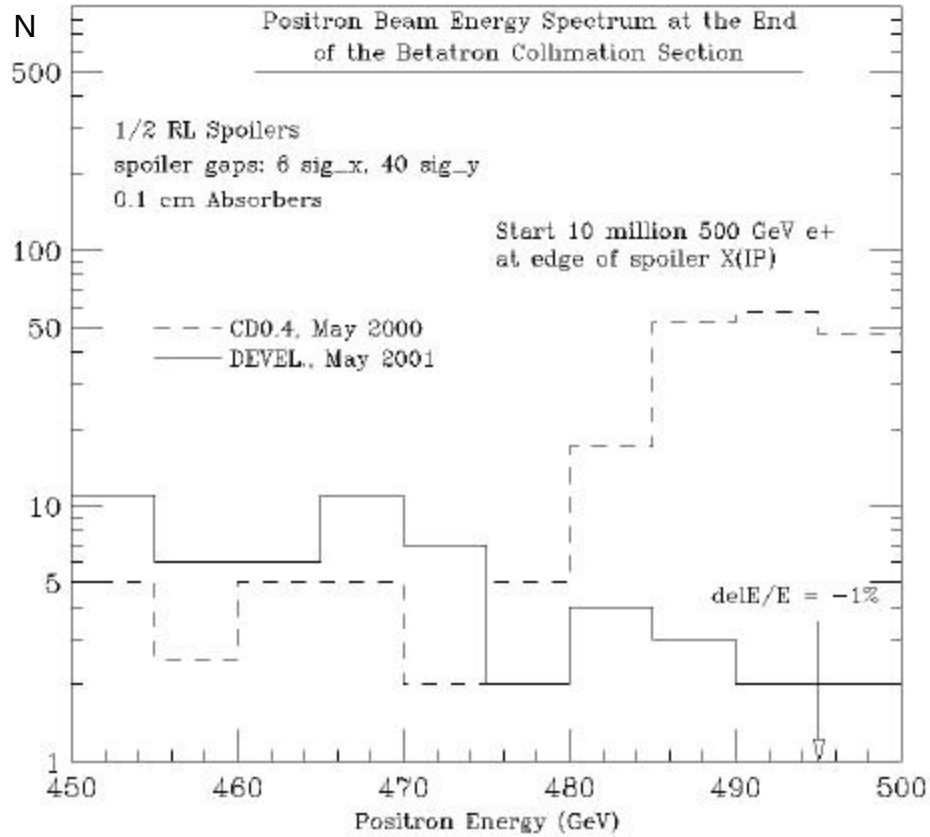


New scheme of the Collimation Section and Final Focus with ODs

All the tracking results shown in the previous slides include the CS

Efficiency of the 2001-CS





Up to 10^9 particles/pulse can be collimated in the CS, leaving about 10^4 residual particles easily collimated in the FF with less then 10 residual muons hitting the detector

L.P.Keller

CS additional properties

- Collimator depth relaxed by at least a factor of 6
  - Wakefields reduced ~ 6-36 times
  - All half-gaps > 1mm, spoiler gaps ~ absorber gaps => spoilers just to protect absorbers
  - Much less likely to hit the jaws with spurious beam
  - Beam fraction to be collimated reduced ~ 10-1000 times
- Energy acceptance much larger then 2%
  - no need to collimate when a klystron 8-pack trips
- BDS total deviation from a straight line ~ 3.5m
  - tunnel can be aligned with the linac
- If the FF bends have to be rescaled at higher energies, the upstream bends can be readjusted, so the IP will not move
- BDS about 1 mile long

Conclusions

- Final Focus properties improved, better tolerances, less non-linearities, better understanding and handling of the background sources
- Non-linear collimation relaxes the Collimation System, simpler optics, less particles to collimate, less stress on the hardware, less wakefields, better tolerances and tunability
- Preliminary studies on the new BDS show promising results