NLC - The Next Linear Collider

COLLIMATION
HALO 03
May 19-23, 2003

Nonlinear Optics in the Next Linear Collider Collimation System

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SLAC

HALO 03
May 21, 2003

NLC layout and optics

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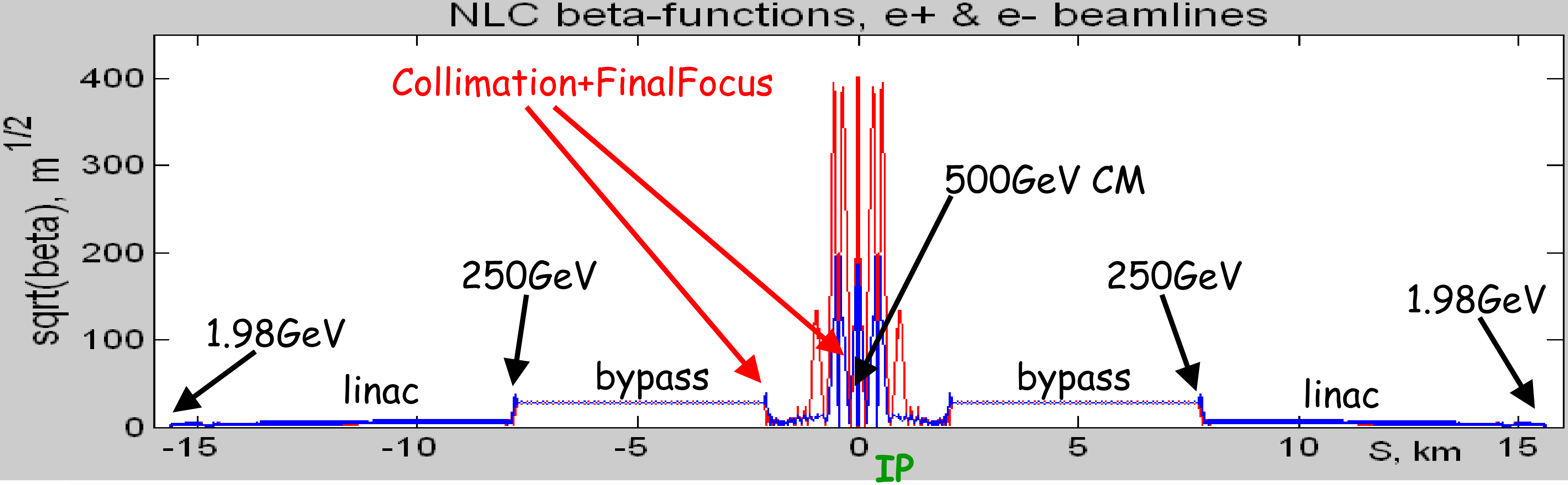
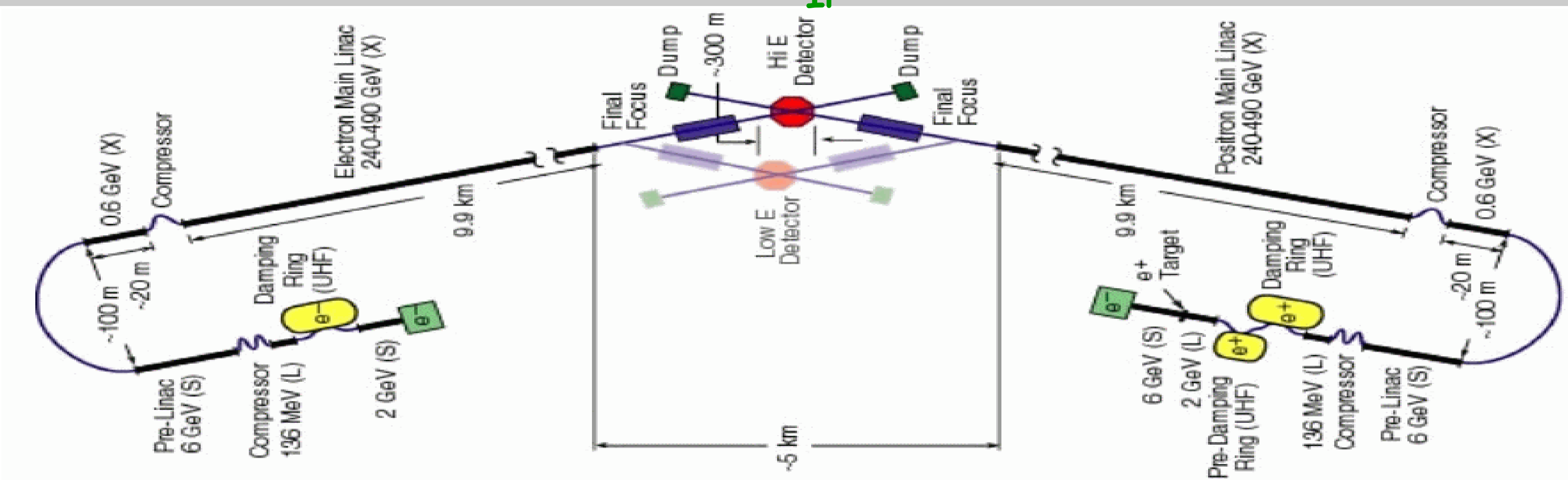
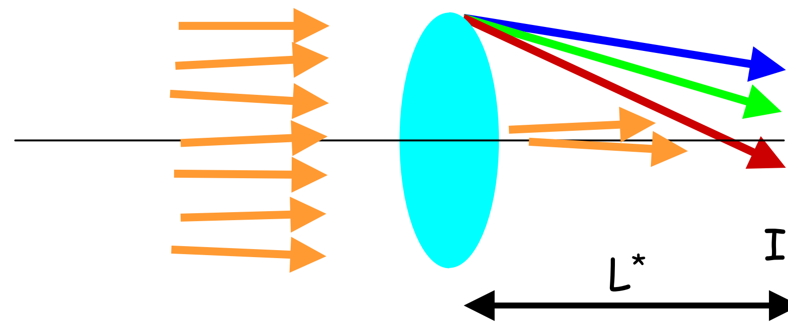
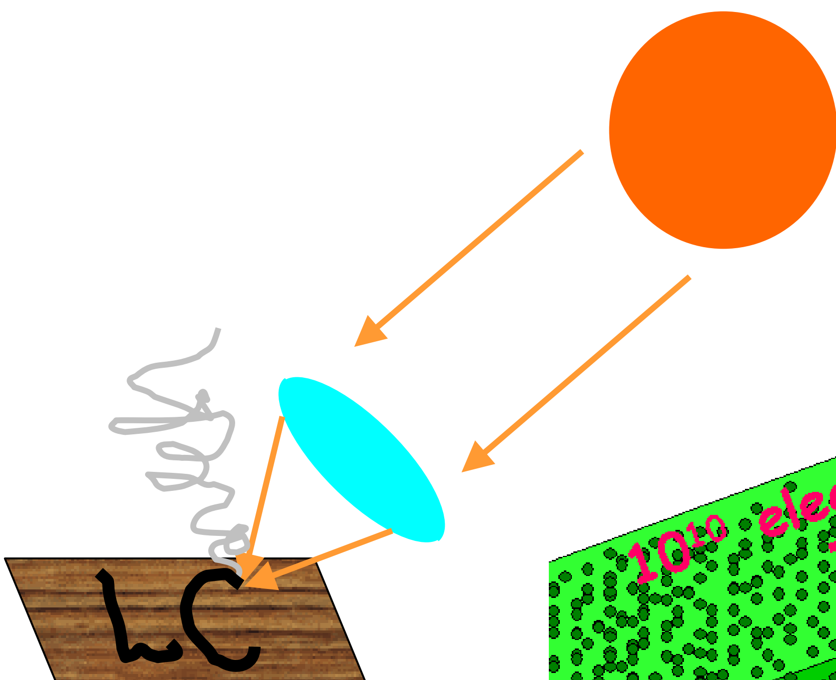


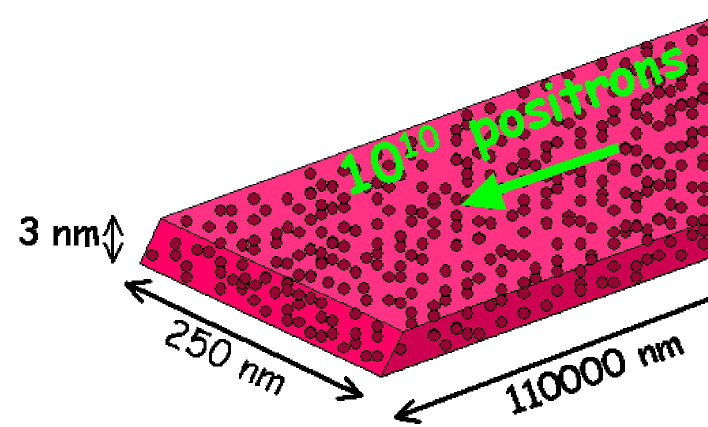


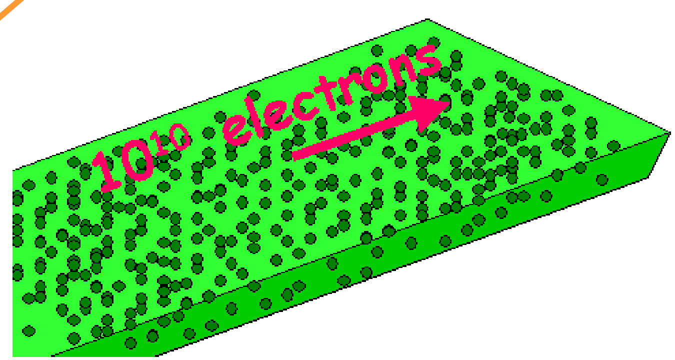
Final Focus design drivers

- Need small beams at IP
  ($\beta^* \sim$ 0.1 mm)
- Strongest Final Doublet
- Large chromaticity
  chrom. dilution $\Delta\sigma/\sigma \sim \sigma_E L^*/\beta^*$ ~300 !







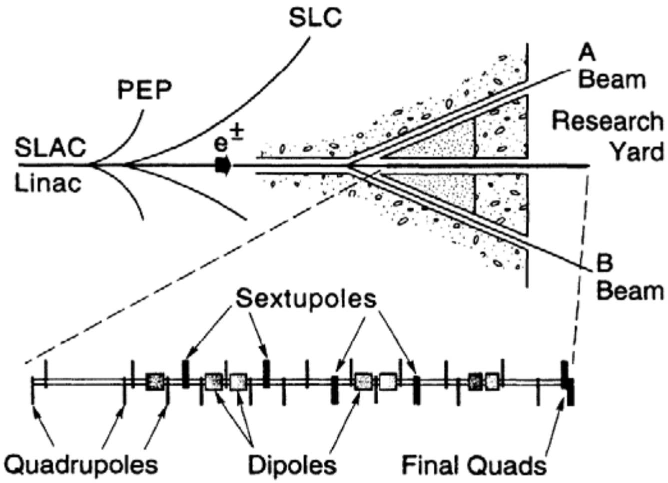


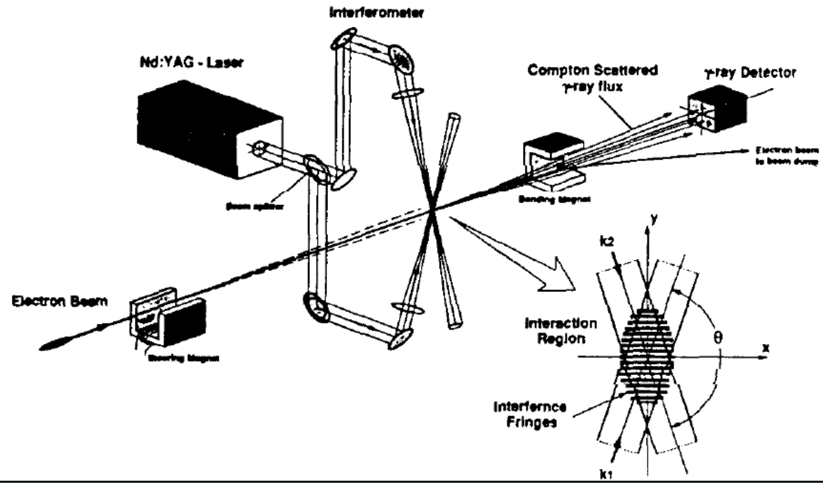
$$L = \frac{f_{rep}}{4\pi}\frac{n_b N^2}{\sigma_x \sigma_y} H_D$$

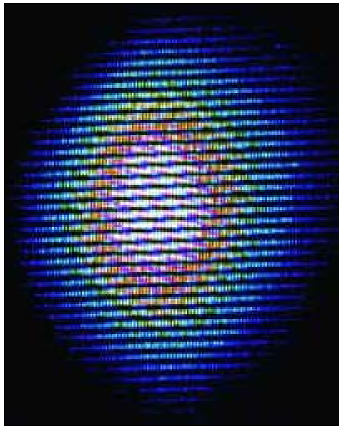
Final Focus Test Beam

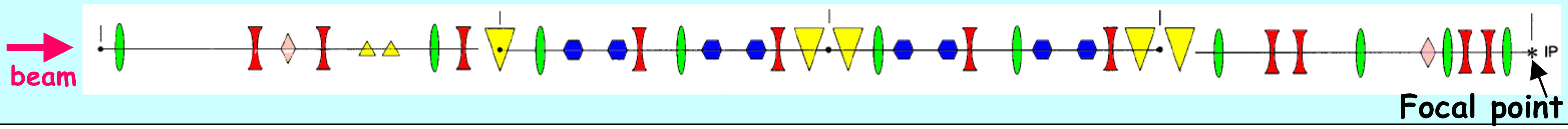
Achieved ~70nm vertical beam size

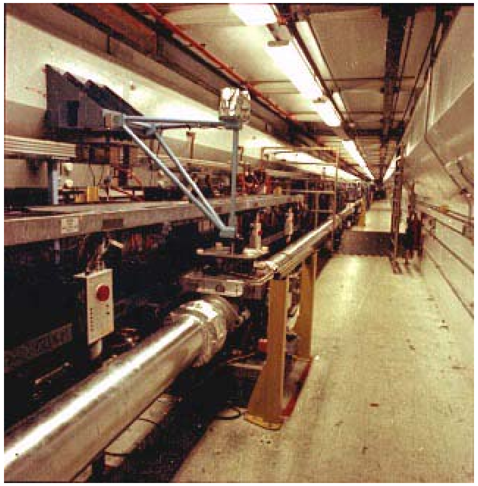
[FFTB Collaboration]

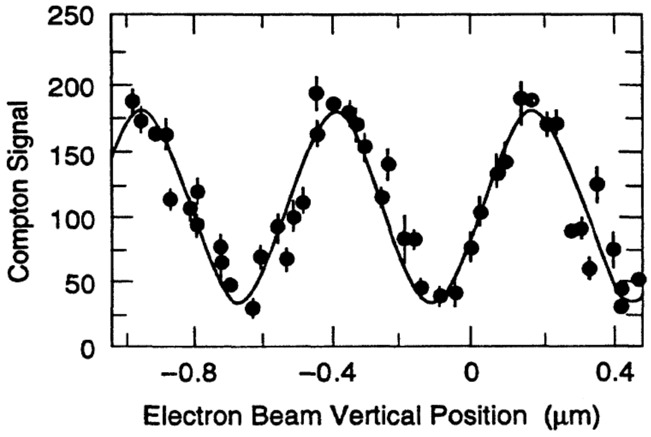










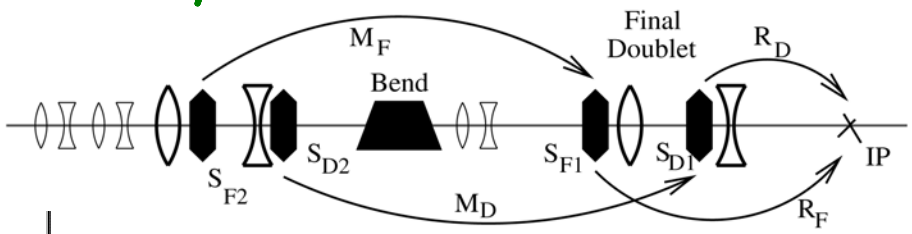


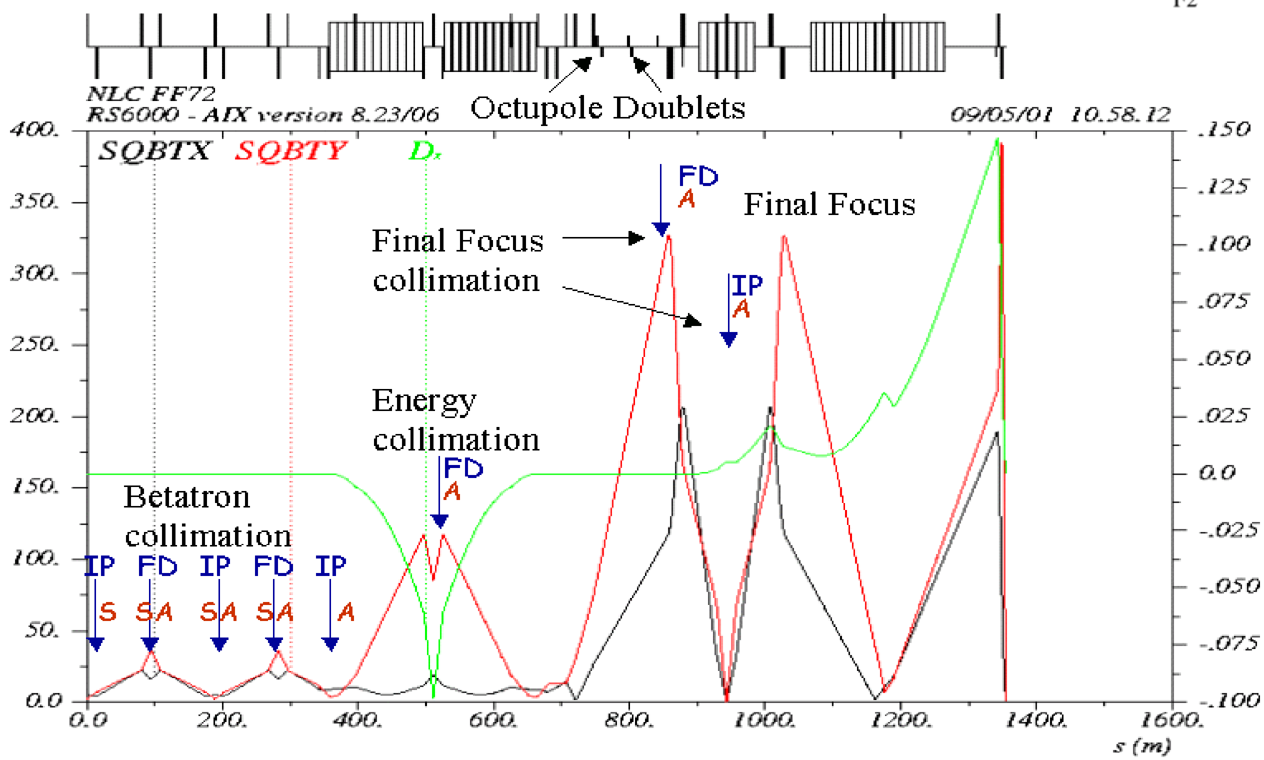
NLC Beam Delivery System

(BDS=Collimation+Final Focus)

Based on new (2000) design (local correction of chromaticity in FD)

Incorporates energy and betatron collimation system



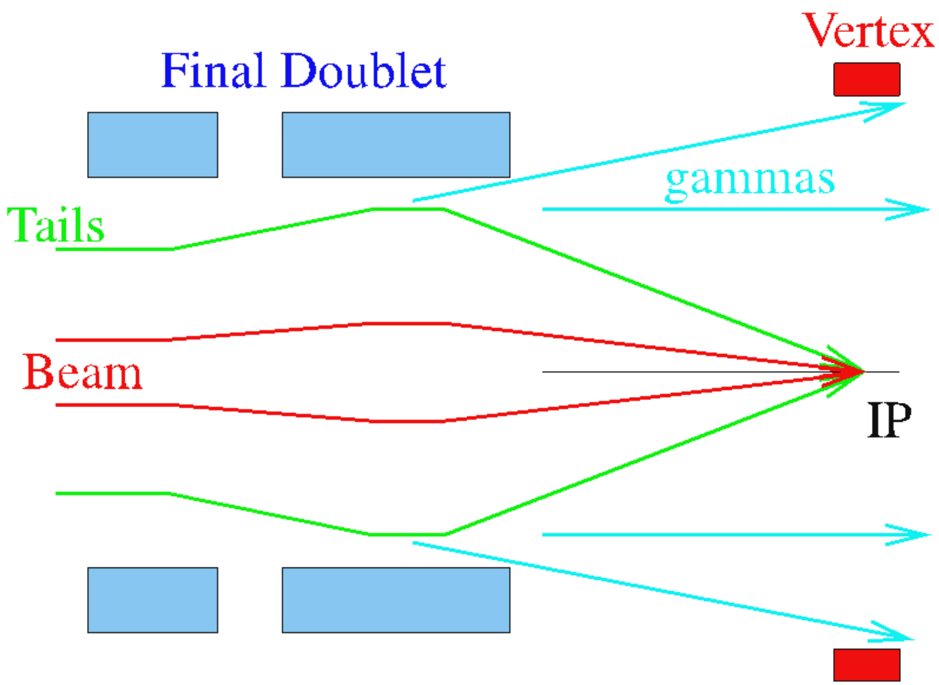


[P.Raimondi, A.Seryi, PRL **86**, 3779 (2001)]

- **Note that we mostly worry about collimation in FD betatron phase!**

Beam halo & background

- Major source of detector background:
  - particles in the beam tail which hit FD and/or emit photons that hit vertex detector
- Tails can come
  - From FF, due to aberrations
  - From linac, etc.
- Tails must be collimated, amount of collimation usually determined by
  - Ratio : FD bore / beam size at FD
- Most tough in x-plane => collimation at just ~10 sigmas (collimation depth)



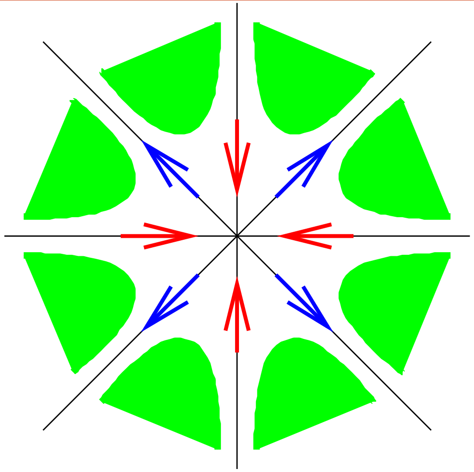
Nonlinear handling of beam tails in NLC BDS

- **Can we ameliorate the incoming beam tails to relax the required collimation depth?**

- One wants to **focus beam tails** but not to change the core of the beam
  - use **nonlinear** elements

- **Several** nonlinear elements needs to be **combined** to provide **focusing in all directions**
  - (analogy with **strong focusing by FODO**)

- **Octupole Doublets (OD)** can be used for **nonlinear tail folding** in NLC FF



Single octupole focus in planes and defocus on diagonals.

An octupole doublet can focus in all directions !

Strong focusing by octupoles

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

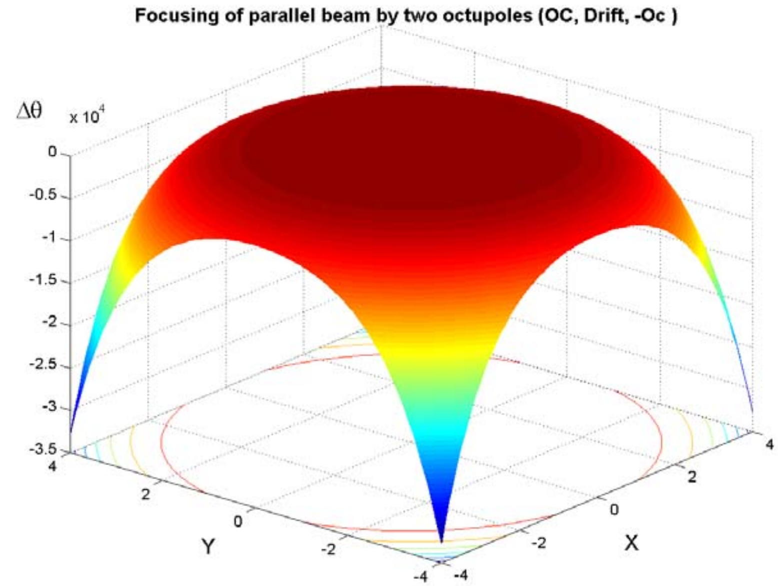
$$\Delta\theta = \alpha r^3 e^{-i3\varphi} - \left(\alpha r^3 e^{i3\varphi}\left(1+\alpha r^2 L e^{-i4\varphi}\right)^3\right)^*$$

$$x + iy = re^{i\varphi}$$

$$\Delta\theta \approx -3\alpha^2 r^5 e^{i\varphi} - 3\alpha^3 r^7 L^2 e^{i5\varphi}$$

Focusing in **<u>all directions</u>**

Next nonlinear term focusing – defocusing depends on φ



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

- For this to work, the beam should have **small angles**, i.e. it should be parallel or **diverging**

Schematic of folding with Octupole or OD

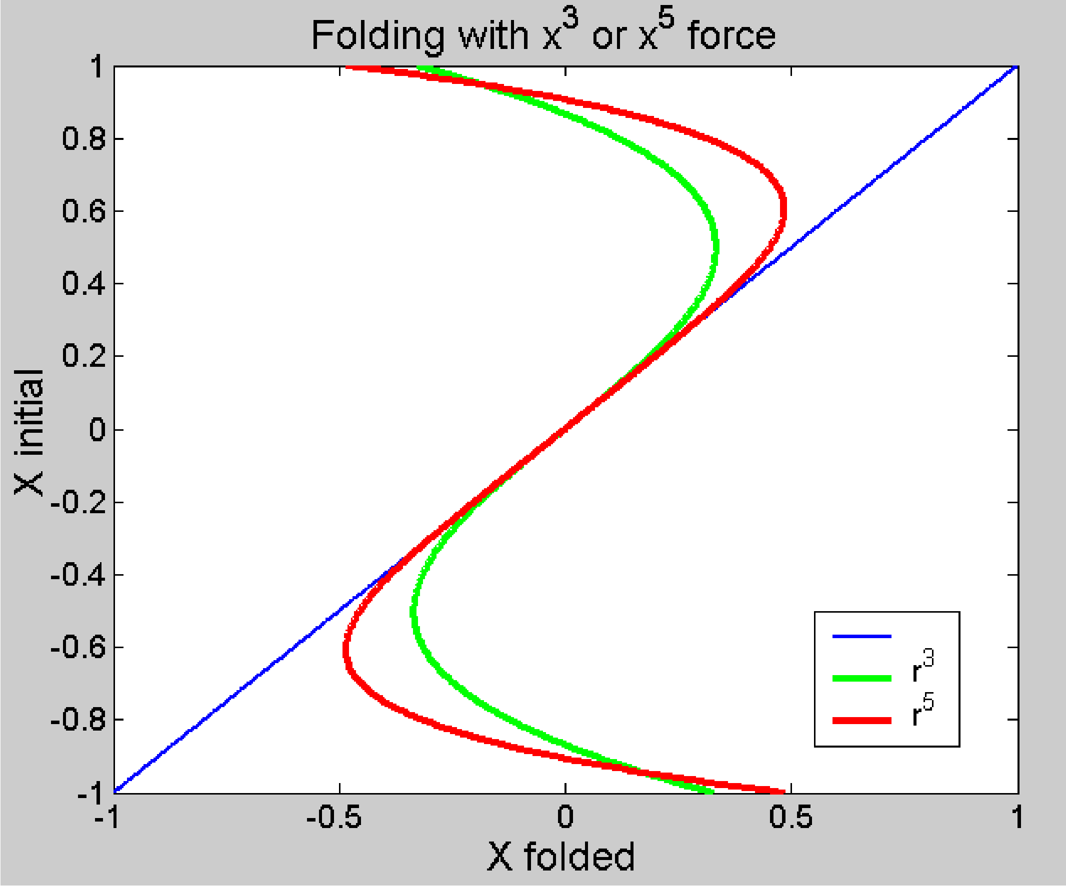


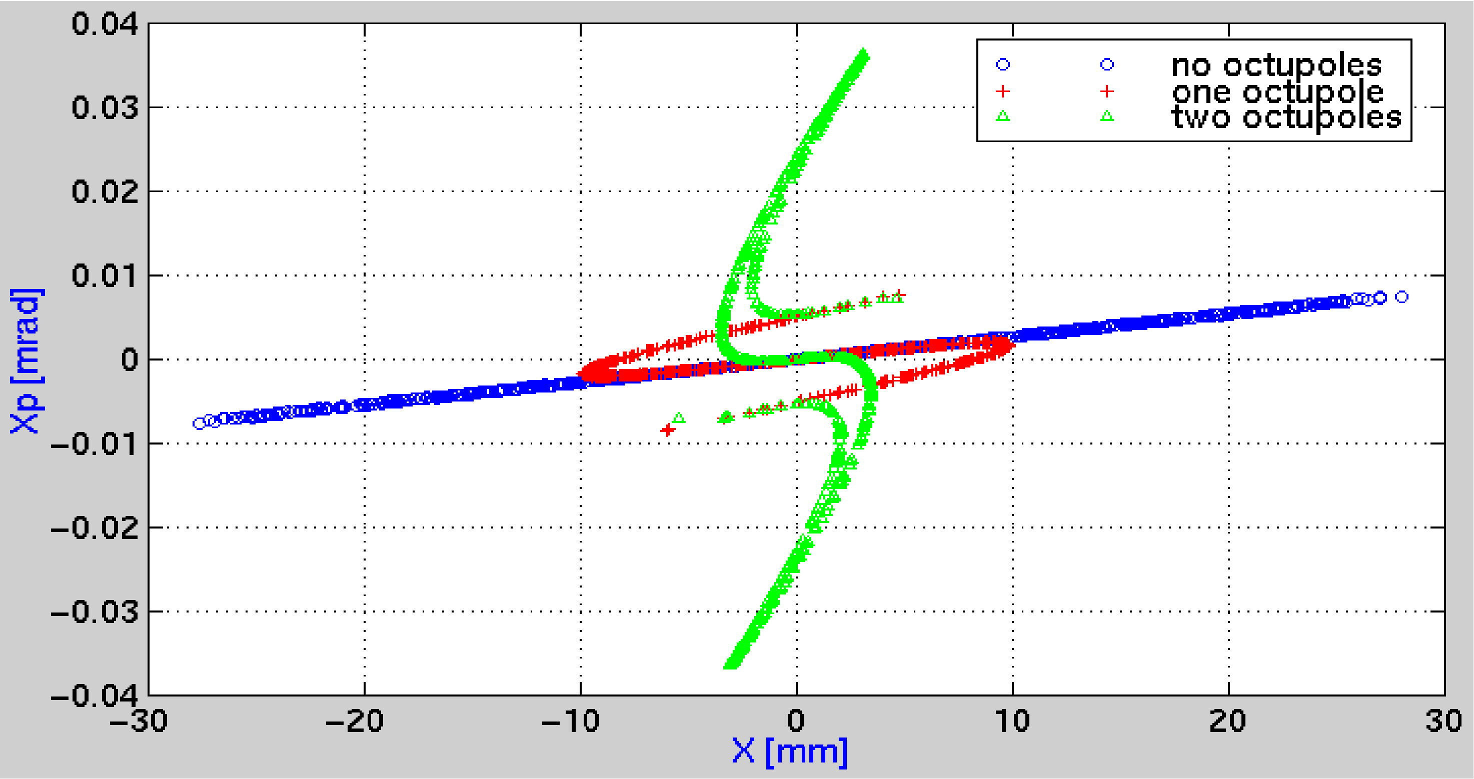
Illustration of folding of the horizontal phase space.

Octupole like force give factor of 3 (but distort diagonal planes)

OD-like force give factor of 2 (OK for all planes)

"Chebyshev Arrangement" of strength.

Schematic of double folding (with two doublets)



Folding of the horizontal phase space distribution at the entrance of the Final Doublet with one or two octupoles in a "Chebyshev Arrangement".

Practical solution of BDS with ODs

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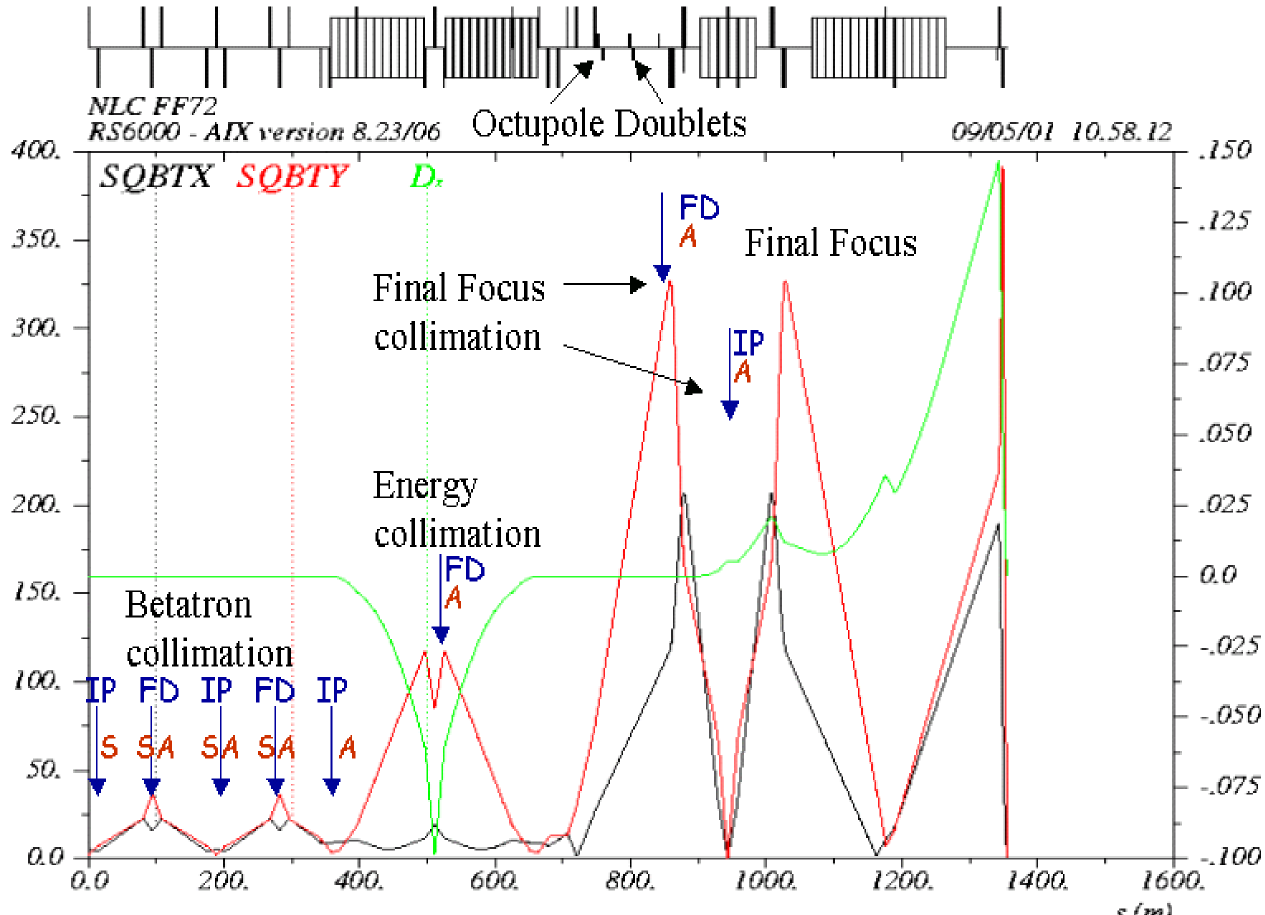
Two octupole doublets give ~4 times folding in terms of beam size in FD (i.e. open the spoiler gaps by same amount)

Works because:

- use Oct. Doublets
- in dispersion free region
- only FD phase essential
- in place where the beam is parallel (=divergent) and aberration free
- the FF optics is nearly aberration free



Collimation system has been built in the Final Focus system

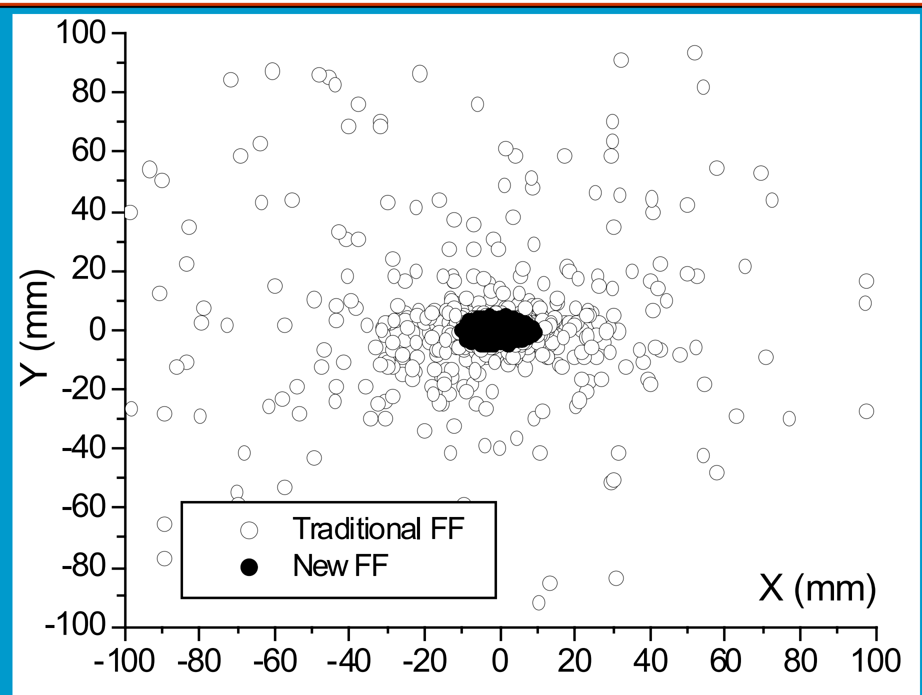
- NLC Beam Delivery System Optics

[P.Raimondi, A.Seryi, 2001] (v.FF72 is not the latest)

Beam Halo in the New and Old FF

The tail folding solution probably would not be developed if not inspired by earlier enthusiastic work of Kathy Thomson, Dick Helm, Rainer Pitthan, Tor Raubenheimer, Frank Zimmermann, Reinhard Brinkmann, et al. in 1999-2000

One of the reasons why this earlier work did not result in practical solution is that the attempts were focused on the old "traditional" final focus, which is known to be less "aberration free" and may repopulate the tails

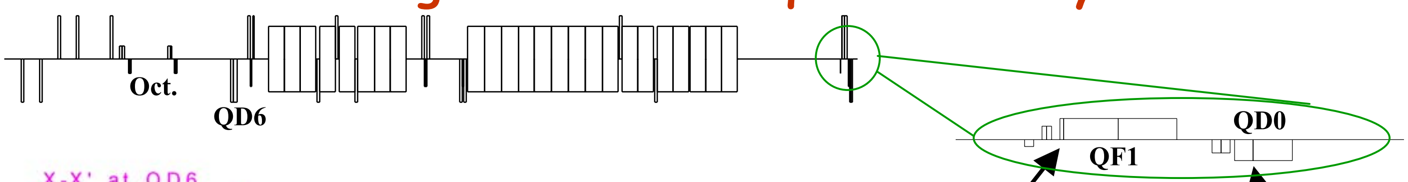


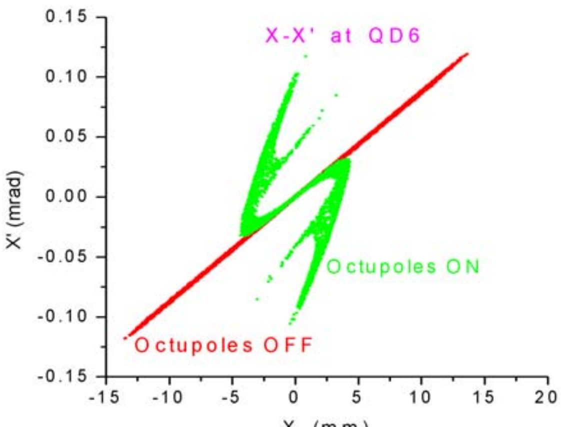
Halo beam at the FD entrance.
Incoming beam is ~ 100 times larger than nominal beam

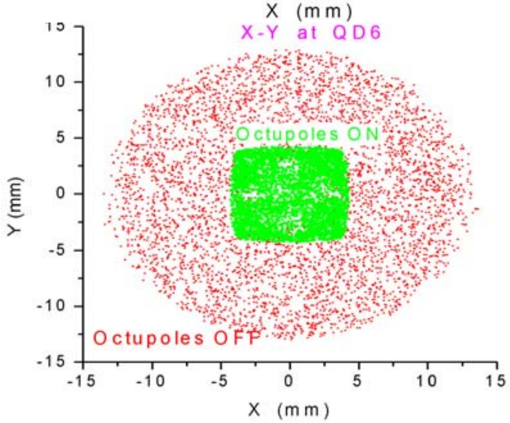
- Traditional FF **regenerate beam tails** due to **aberrations**
- New FF is virtually **aberration free**

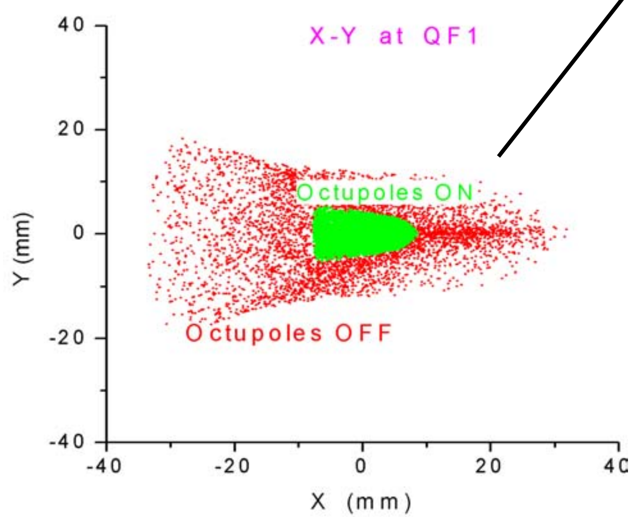
Tail folding in new NLC FF

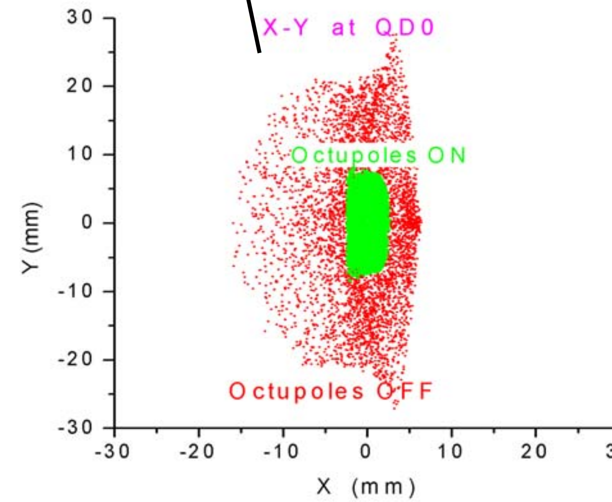
- Two octupole doublets give tail folding by ~ 4 times in terms of beam size in FD
- This can lead to relaxing collimation requirements by ~ a factor of 4





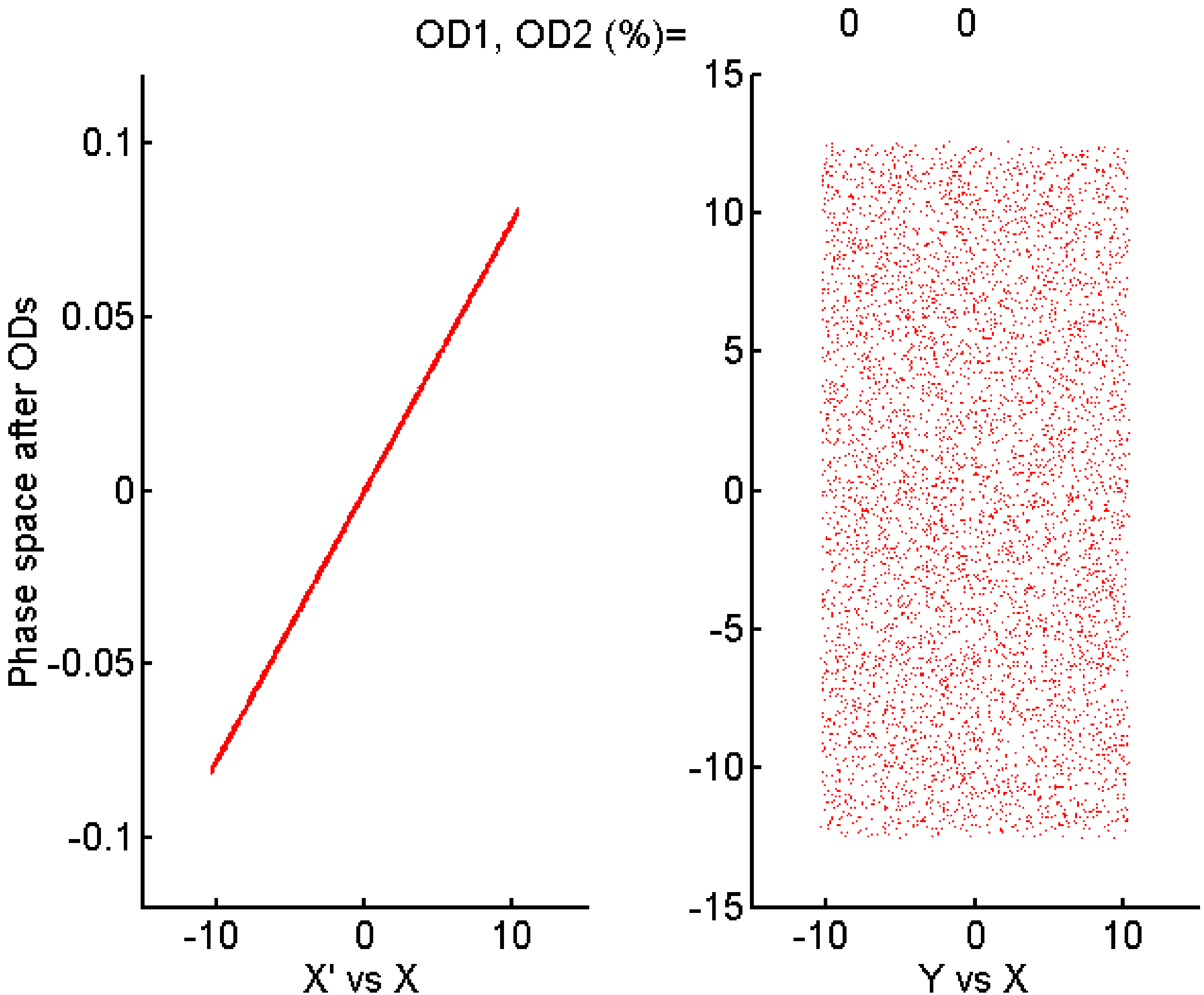






Tail folding by means of two octupole doublets in the new NLC final focus
Input beam has (x,x',y,y') = (14µm,1.2mrad,0.63µm,5.2mrad) in IP units (flat distribution, half width) and ±2% energy spread, that corresponds approximately to N_σ=(65,65,230,230) sigmas with respect to the nominal NLC beam

Vary the ODs



OD1, OD2 (%)= 0 0
Phase space after ODs
0.1
0.05
0
-0.05
-0.1
-10
0
10
X' vs X
15
10
5
0
-5
-10
-15
-10
0
10
Y vs X

Tail folding or Origami Zoo

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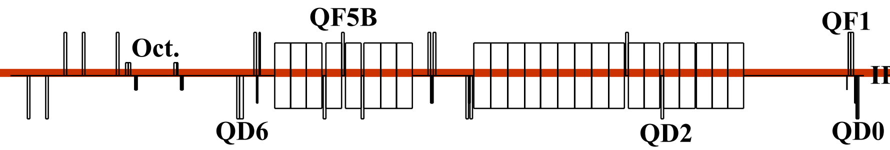
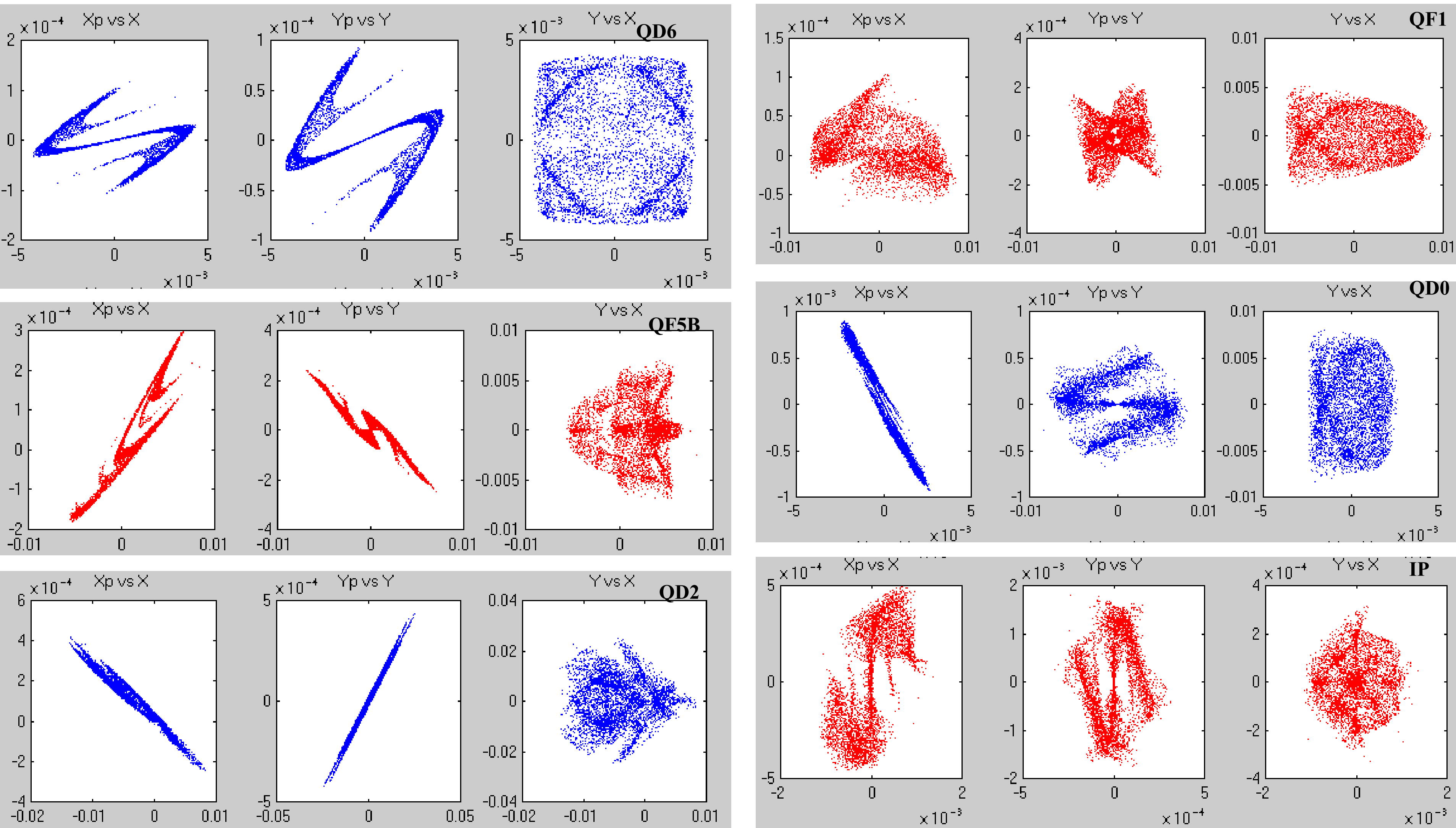
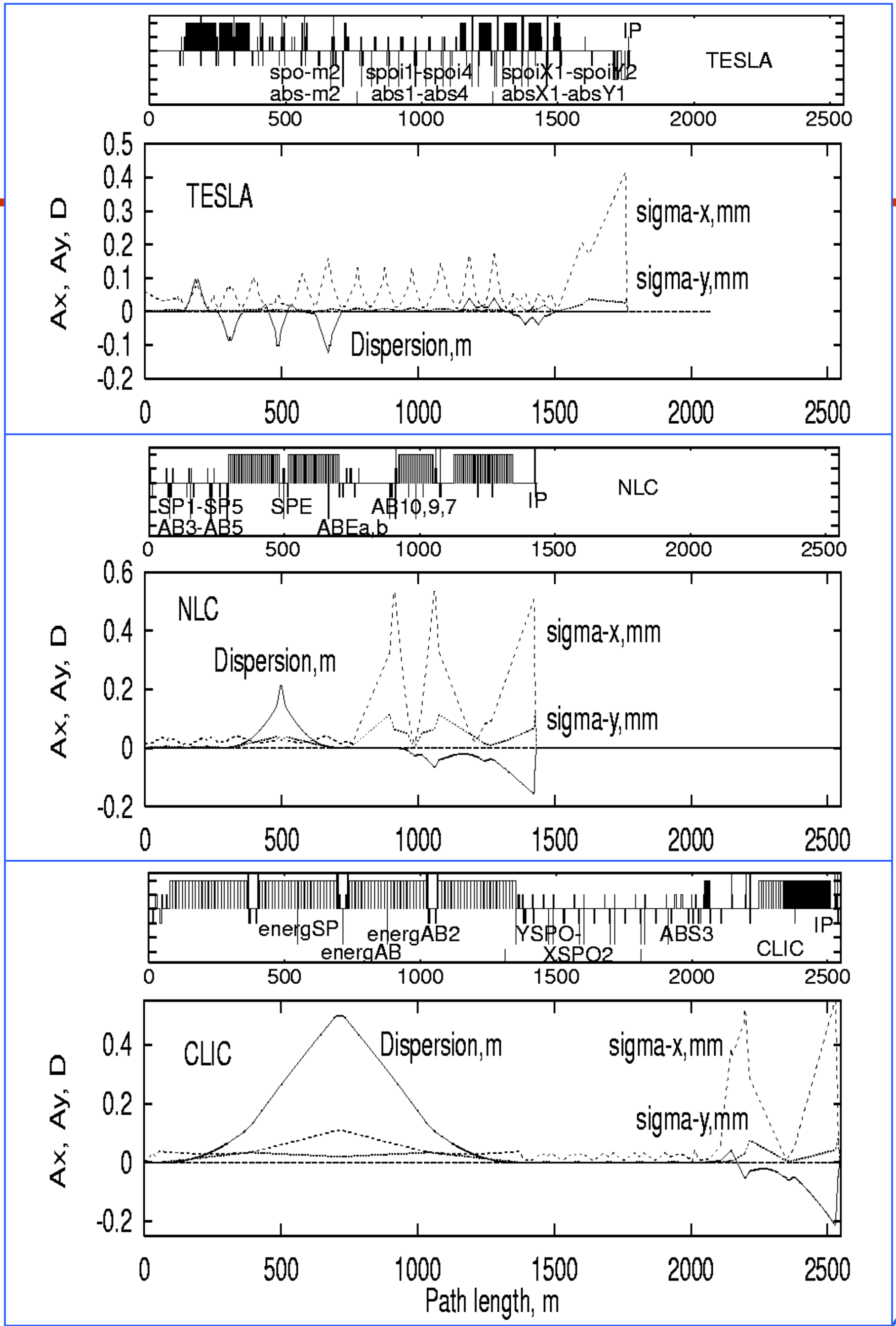




Interlaboratory Collaboration for R&D Towards TeV-scale Electron-Positron Linear Colliders

International Linear Collider Technical Review Committee

ILC-TRC



Beam delivery systems reviewed by the Collimation Task Force

Collimation Task Force group work for TRC

Especially a lot of thanks to Sasha Drozhdin

LCC-0111
CERN-AB-Report-2003-006
CLIC Note 555, CERN
Fermilab-TM-2200
TESLA Report 2003-02
March 2003

Linear Collider Collaboration Tech Notes

Comparison of the TESLA, NLC and CLIC Beam Collimation System Performance

A. Drozhdin [4], G. Blair[6], L. Keller[5], W. Kozanecki[2], T. Markiewicz[5], T. Murayama[5], N. Mokhov[4], O. Napoly[2], T. Raubenheimer[5], D. Schulte[3], A. Seryi[5], P. Tenenbaum[5], N. Walker[1], M. Woodley[5], F. Zimmermann[3]

1. DESY, Hamburg, Germany
2. CEA-Saclay, Paris, France
3. CERN, Geneva, Switzerland
4. Fermilab, Batavia, Illinois, USA
5. SLAC, Menlo Park, CA, USA
6. University of London, London, United Kingdom

March 2003

Current performance in terms of halo particle losses along the beamline and halo size at the FD

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International Linear Collider Technical Review Committee
ILC-TRC

From TRC report

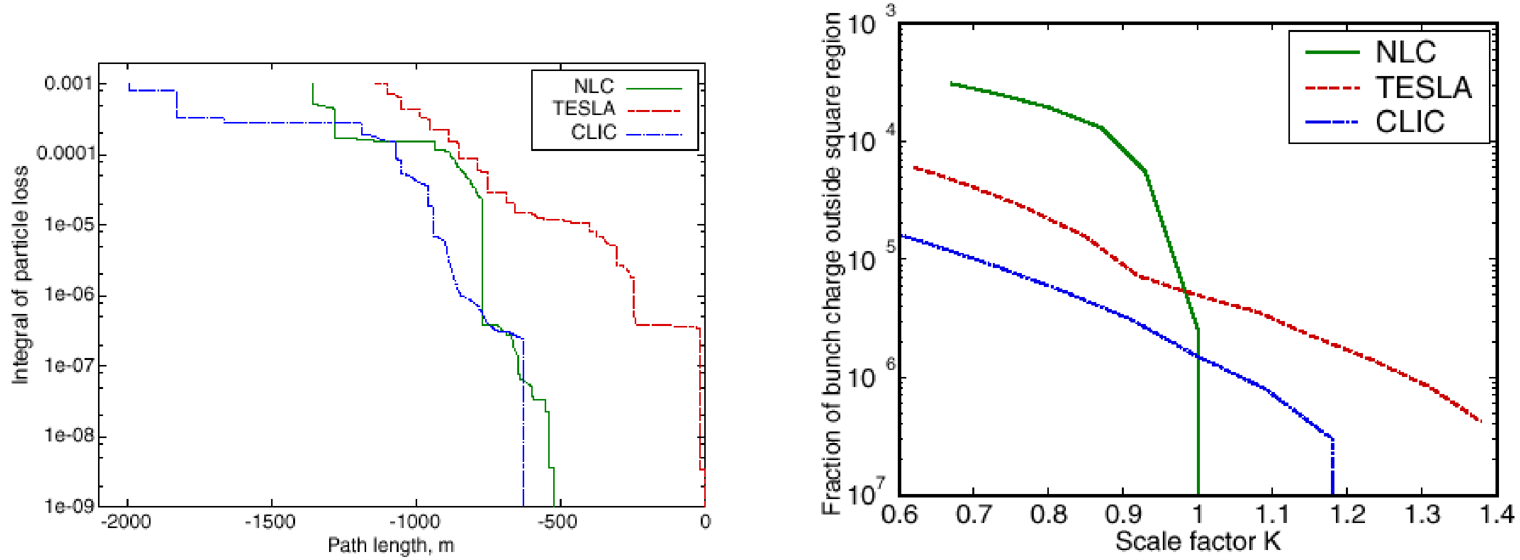
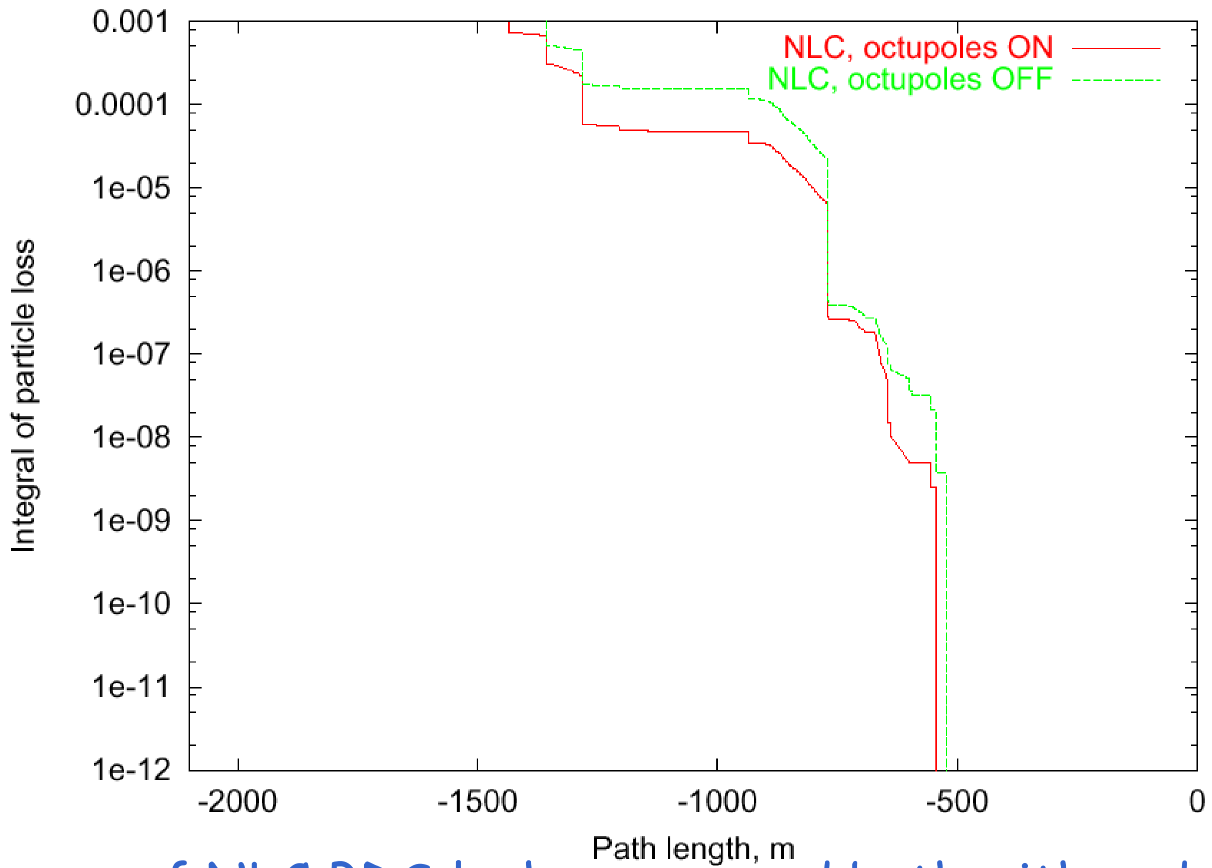


FIGURE 7.28. Collimation-system performance [104] assuming an incident fractional halo of 10^{-3}. Left: fractional loss of charged-halo particles, integrating back, starting at the IP, and normalized to the nominal bunch charge. The horizontal scale shows the distance from the IP. The upstream edge of the secondary-collimation system is located at -543 and -583 m in NLC and TESLA respectively. In CLIC, the last betatron absorber is located at -632 m. Right: number of charged-halo particles per bunch, normalized to the nominal bunch charge, in a rectangular $x-y$ window at the entrance to the final doublet, as a function of the collimation depth. The scale factor K defines the window dimension: for K=1, the window size corresponds to the effective collimation depth listed, for each machine, in Table 7.27.

NLC BDS with and w/o octupoles



Performance of NLC BDS looks very good both with and without octupoles. The Oct ON case allow to open the collimation gaps and reduce the collimation wake fields to an acceptable level

Conclusion

- A tail folding with Octupole Doublets was developed and incorporated into the NLC Beam Delivery System
- This allow opening the collimation gaps almost 4 times
- ODs helps to make the collimation wake-fields to be non issue
- Implementation of ODs was possible because:
  - The new almost aberration free FF optics was developed
  - The optics has a region where the beam is nearly parallel and is not distorted by dispersion, chromaticity or higher order aberrations
  - Our concerns are mostly FD betatron phase
  - Single pass system
    - These set of conditions seem to be rather unique. Can it be applied to rings or lower energy linacs? ???, but…