Beam Delivery Systems (BDS) for Pedestrians

A brief overview to set the scene

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BDS Functionality

- Focus and collide *nanobeams* at the interaction point (IP)
- Remove (collimate) the beam halo to reduce detector background
- Provide beam diagnostics for the upstream machine (linac)

Focusing and Colliding Nanobeams

- Final Focus Systems (FFS) need to provide very strong defocusing of the beams
- Correction of chromatic and geometric aberrations becomes principle design challenge
- A consequence: systems have extremely tight alignment (*vibration*) tolerances
  - stabilisation techniques a must!

FFS solutions: two approaches

Primary aberration is strong chromaticity of final lens (f = ~meters)

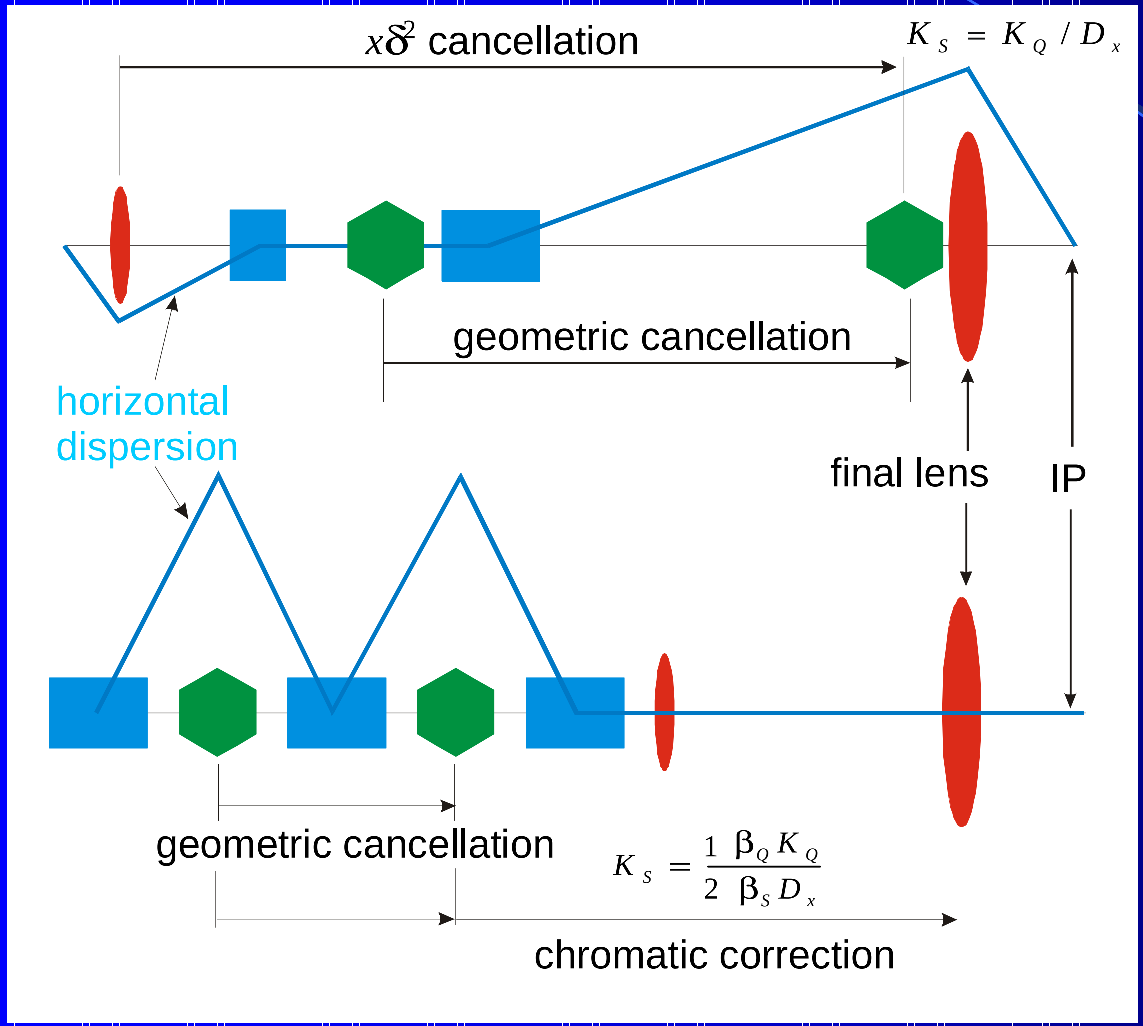
- Non-local correction using dedicated *chromatic correction sections* (CCS) upstream of final telescope

Used at SLC and FFTB (*tested*)

- Local correction at final doublet

Currently proposed for next gen. LC (*not tested*)

The conceptual difference



$x\delta^2$ cancellation

$K_S = K_Q / D_x$

geometric cancellation

horizontal dispersion

final lens

IP

geometric cancellation

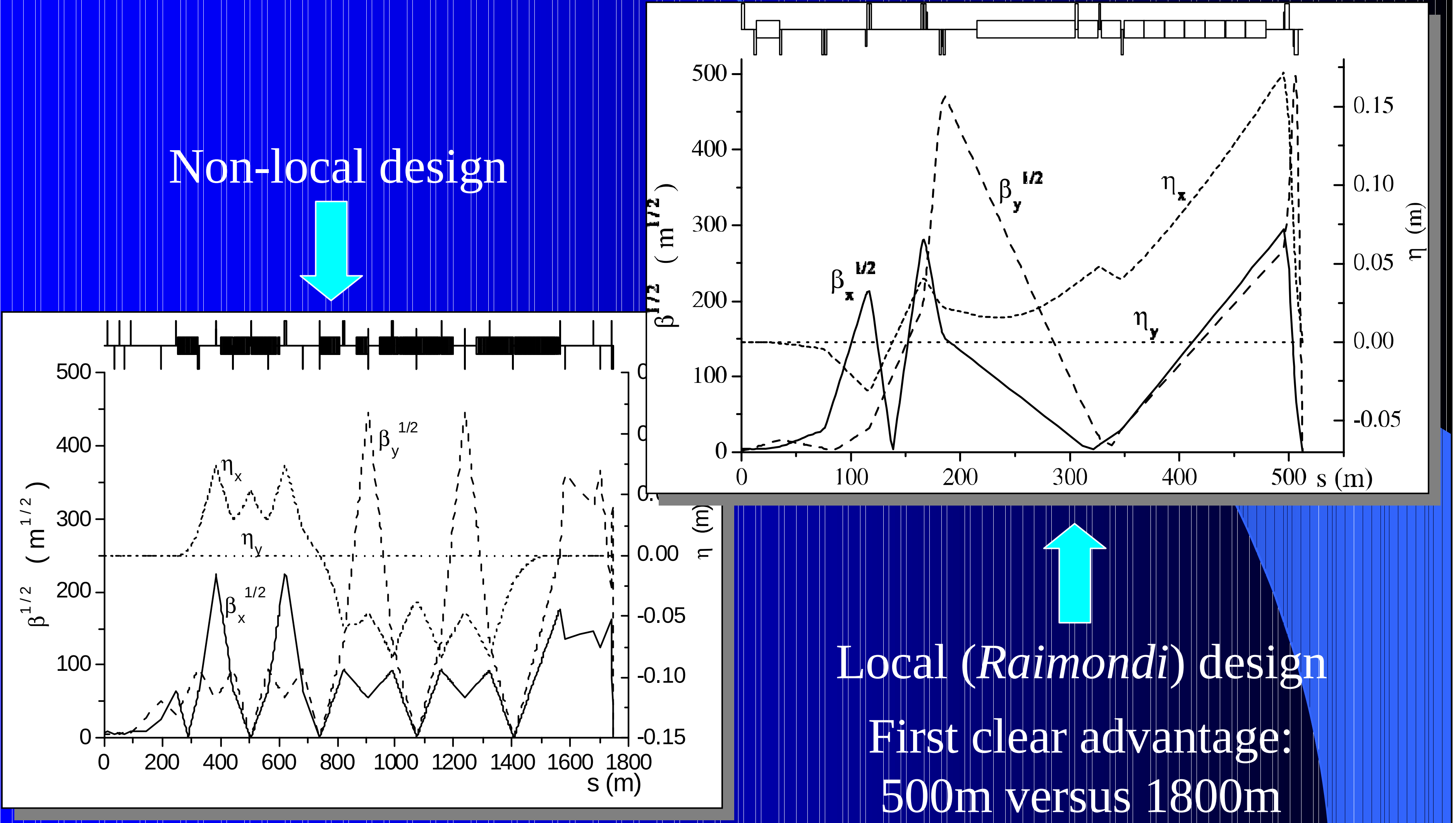
$K_S = \frac{1}{2}\frac{\beta_Q K_Q}{\beta_S D_x}$

chromatic correction

Local correction with *D*’ at IP [*Raimondi*, 2000]

Non-local correction (CCS) [*Brown*, 1985]

Real world solutions (NLC)



Non-local design

Local (*Raimondi*) design

First clear advantage:
500m versus 1800m

Pros and Cons

FFTB-type

- Advantages
  - high symmetry (orthogonal tuning)
  - conceptually simple, ease of design
  - experimentally tested (SLC/FFTB)
- Disadvantages
  - non-local correction results in high-order aberrations (bandwidth limit)
  - shorter L*
  - system is long (~kilometers)
  - bad scaling to higher E

Raimondi-type

- Advantages
  - high-bandwidth system
  - very short (~500m)
  - longer L* possible
- Disadvantages
  - balance of geometric and δ^2 terms difficult
  - conceptually difficult to design! (*there is only one*…)
  - no test

Stability Issues

- Stability tolerances driven by nm beam sizes at the IP
- No (or little) difference between two FFS systems
- need to worry about
  - ~100 nm vibration amplitudes for most magnets
  - ~10 nm for a few sensitive magnets
  - ~nm for final lens (final doublet)
- Must have:
  - mechanical stabilisation
  - beam-based feedback

large part of nanobeams dedicated to this subject!

Collimation Issues

- Must efficiently remove 'halo' by physically scraping it away
- IR layout and choice of FFS optics defines collimation requirements (synch. radiation etc.)
- Mechanical collimator jaws with typical gaps of tens of beam σ (few hundred μm to ~1 mm)
- Constraints:
  - must not degrade luminosity (optical aberrations, collimator wakefields)
  - mechanical protection issues (typical average beam power densities are several GW.mm^{-2})

Collimation solutions

- Optically blow up beam sizes so collimators have big gaps and can survive a hit by the beam:
  - systems became long (kilometers), with very large β-functions and tight optical tolerances
  - Non-linear problems
- Keep β-functions relatively small
  - shorter, manageable systems
  - better optical and wakefield performance
  - looser tolerances
  - beam will destroy collimator
    (NLC approach: use ‘consumable collimators’)

Can we do better?

- Two systems to date – are there more solutions?
- What are the fundamental limits:
  - synchrotron radiation effects (e.g. Oide limit) – *see talk by F. Zimmermann*
  - magnet (focusing technology); other novel (radical?) approaches have been proposed:
    - plasma lens
    - two-beam (so-called dynamic) focusing
  - stabilisation technology – where are the limits?
- Let’s see what comes out of this workshop ☺