KM steering and Dispersion bump simulation in RTML upstream of BC1

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Introduction

- Emittance preservation in “Old” RTML (no >10 km straight line), up to BC1 entrance
- Try to reproduce (check) results by P.Tenenbaum, presented in Valencia
  - Kick Minimization steering
  - Dispersion bumps
- And add
  - Coupling bumps
- Macro-particle tracking using computer code SAD

Kick Minimization

Quad magnet, BPM and steering magnets should be attached.

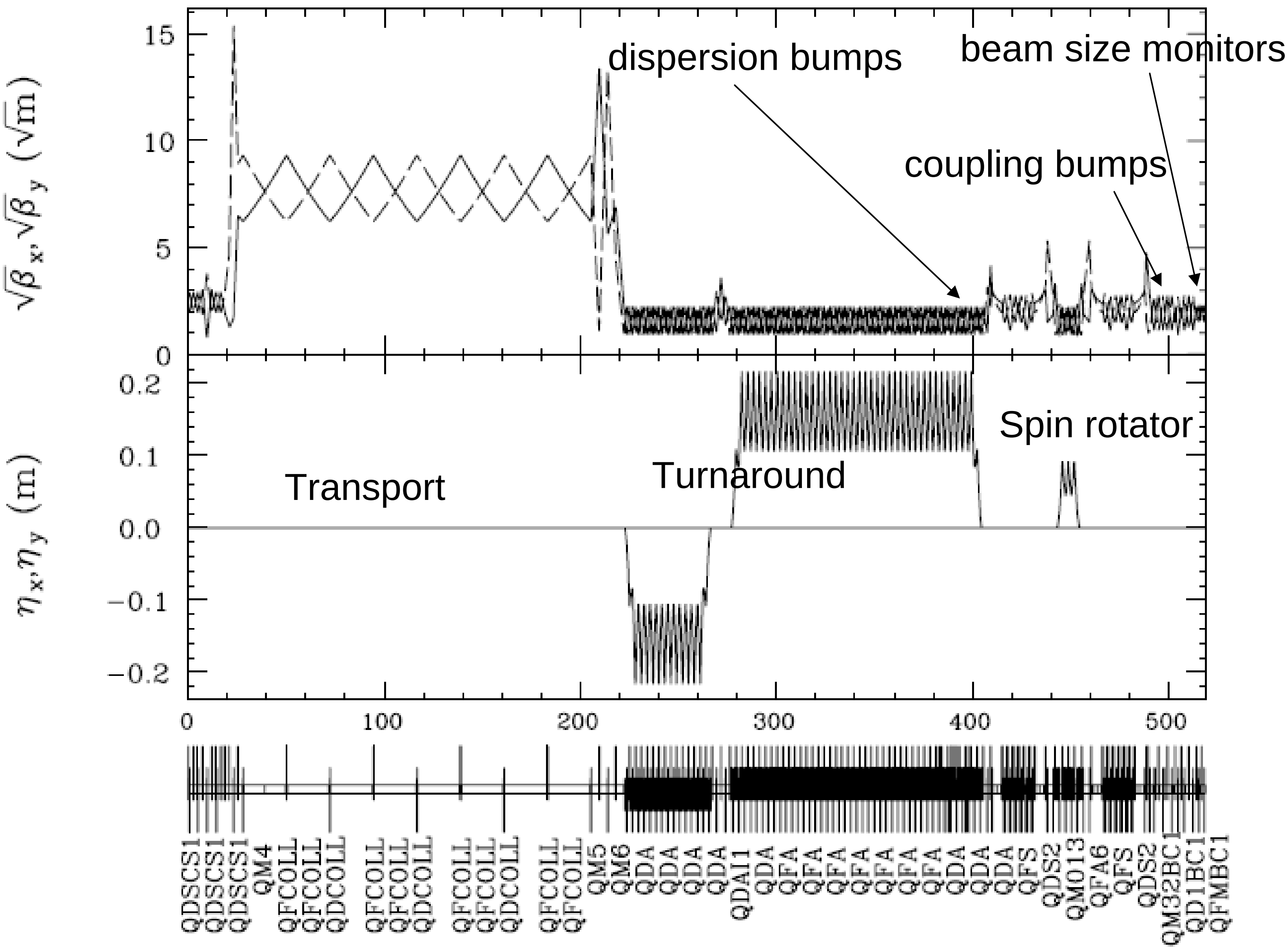
$$\text{Minimize } \; r\sum_i (x_i^2 + y_i^2) + \sum_i \left[\left(\theta_{x,i} + k_i x_i\right)^2 + \left(\theta_{y,i} - k_i y_i\right)^2 \right],$$

$\theta_{x(y)i}$: Additional kick angle (additional to designed kick) of steering at i-th quad

$x(y)_i$: Offset from designed orbit at i-th quad

k_i : K-value (inverse of focal length) of the i-th quad

r : Weight ratio : (Quad-BPM offset)^2/(Quad offset)^2



dispersion bumps
beam size monitors
coupling bumps
Spin rotator
Transport
Turnaround
$\sqrt{\beta_x}, \sqrt{\beta_y}$ ($\sqrt{m}$)
η_x, η_y (m)
15
10
5
0
0.2
0.1
0.0
−0.1
−0.2
0
100
200
300
400
500
QDSCS1
QDSCS1
QDSCS1
QM4
QFCOLL
QFCOLL
QDCOLL
QFCOLL
QFCOLL
QDCOLL
QFCOLL
QFCOLL
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QFCOLL
QFCOLL
QM5
QM6
QDA
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QFA
QFA
QFA
QFA
QDA
QDA
QDA
QFS
QDS2
QM013
QFA6
QFS
QDS2
QM32BC1
QD1BC1
QFMBC1

Dispersion bumps

- Knobs

4 skew quads at the end of turnaround

(a) Set opposite strength of a pair of skew quads in turn around, -I between them.

(b) Set opposite strength of another pair of skew quads in turn around, -I between them. 90 degree phase difference from the first pair.

Knob 1: (a) + (b)

Knob 2: (a) - (b)

- Monitors

At the end of the beam line (before BC1)

Use three laser wire monitors (beam size monitors) at the end of the line (before BC1), 45 degree phase advance between two.

- Minimize projected emittance calculated from beam sizes at three locations.

Coupling bumps

- Knobs

4 skew quads added at n ear the end of the beam line.

Each skew quad is a knob.

- Monitors

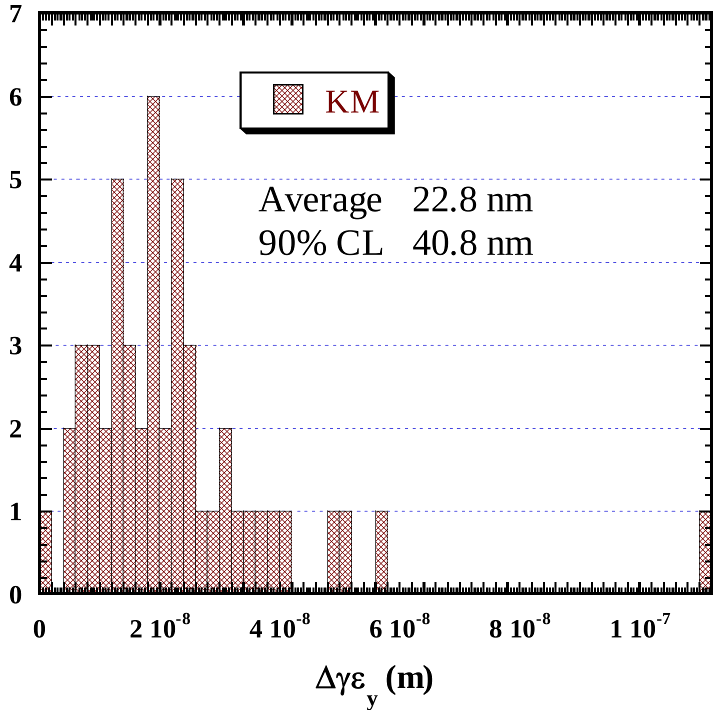
Same for dispersion bumps

Errors - same as PT's (at Valencia meeting), except beam size monitor

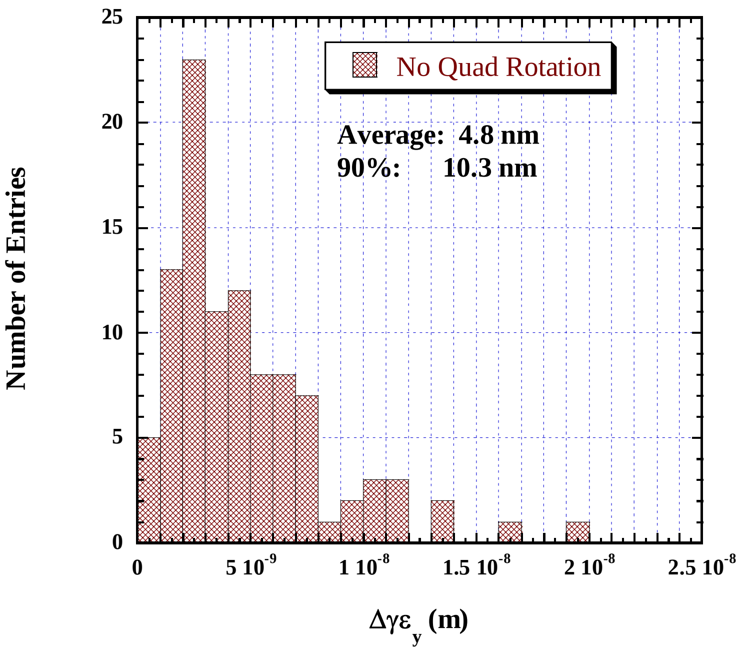
Tolerance Type	RMS Value
Quad Misalignments (x,y)	150 um WRT survey line
BPM Offsets (x,y)	7 um WRT quad center
Quad Strength Errors	0.25%
Bend Strength Errors	0.5%
Quad Rotation	300 urad
Bend Rotation	300 urad
Beam size monitor	perfect, or 0.2 um

Result of KM steering

Final vertical emittance increase,
50 random seeds



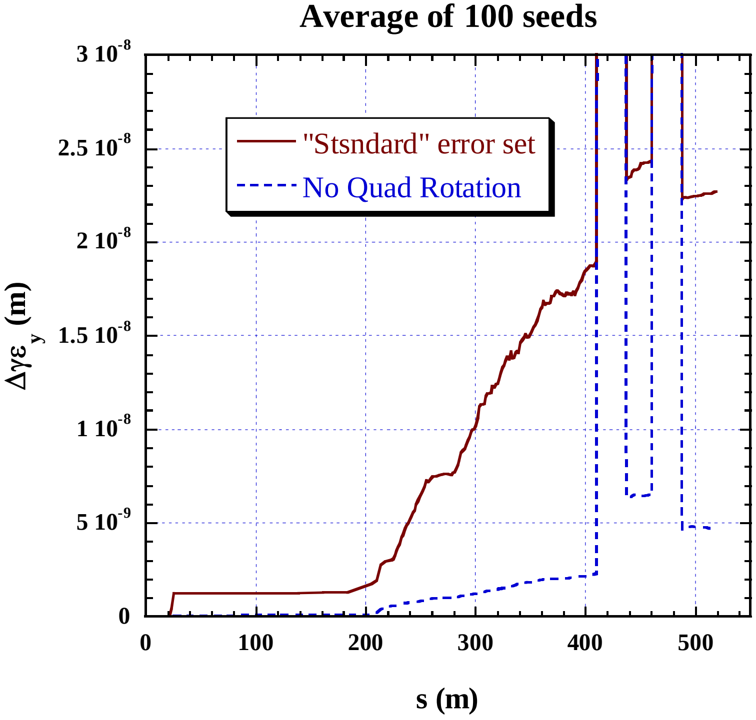
Distribution without quad rotation
(with other errors)
(Dominant source of emittance
increase is quad rotation.)



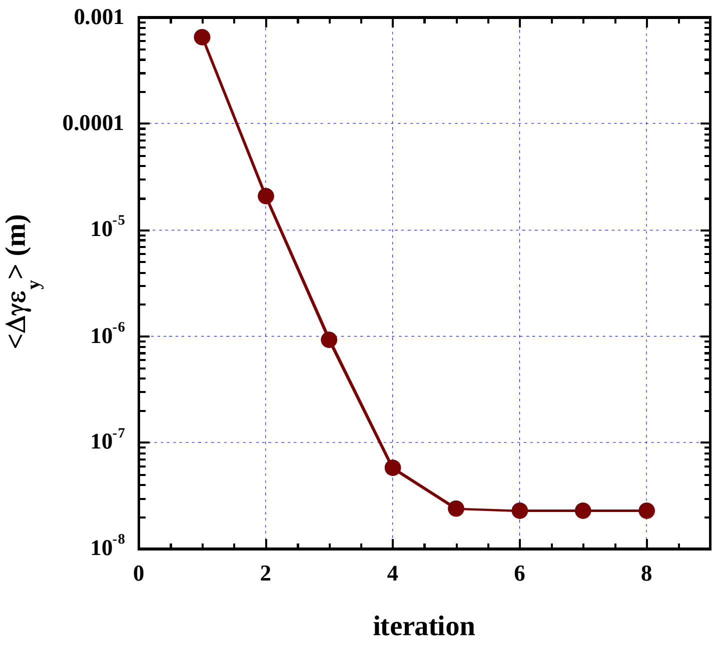
KM is not effective for quad rotation errors.
Not perfect even without quad rotation.

Result of KM steering - 2

Emittance vs. distance
(Emittance increase dominantly in turnaround.)

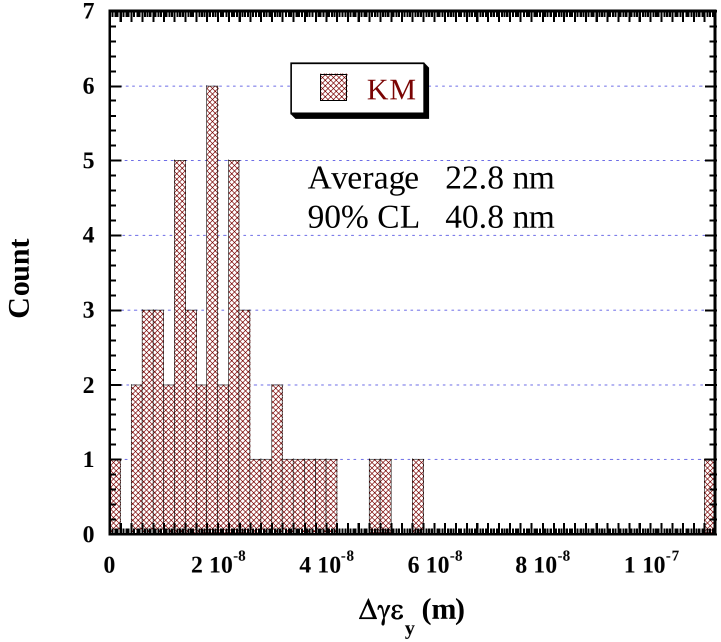


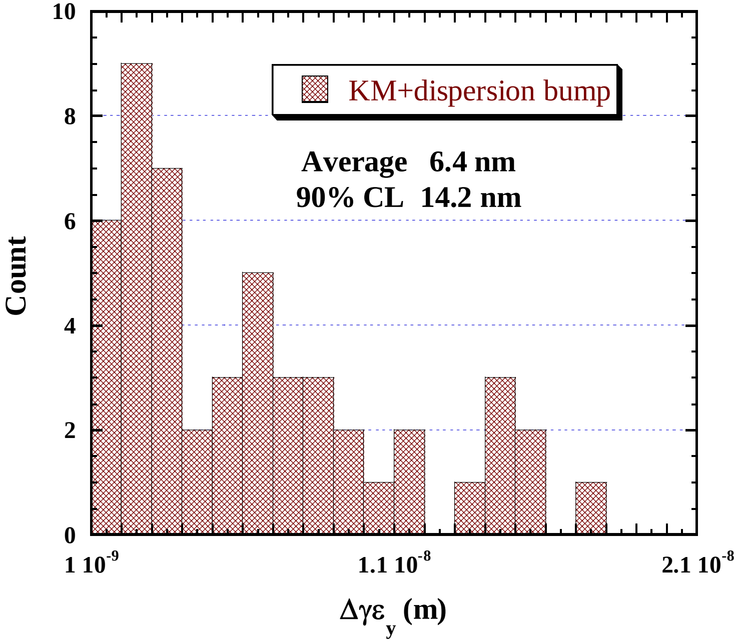
Need several iteration of KM steering



Result of KM steering
+ Dispersion Bumps

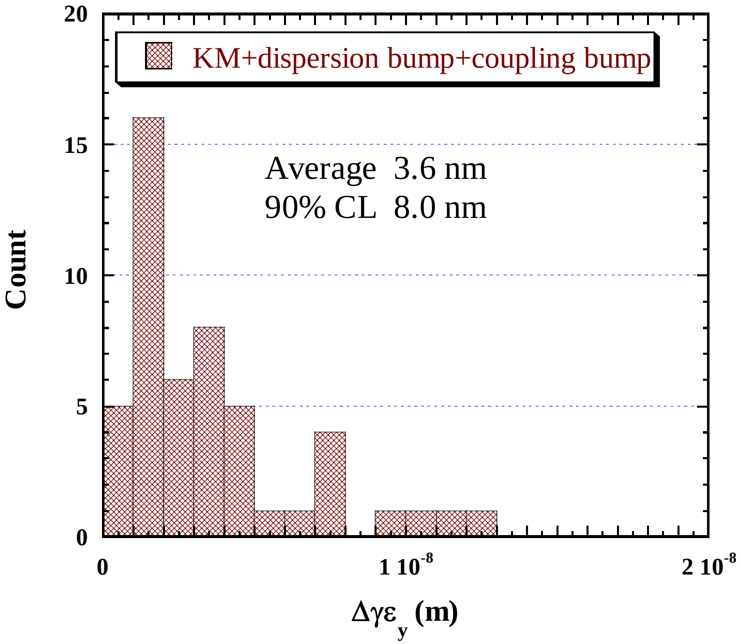
Final vertical emittance increase,
50 random seeds

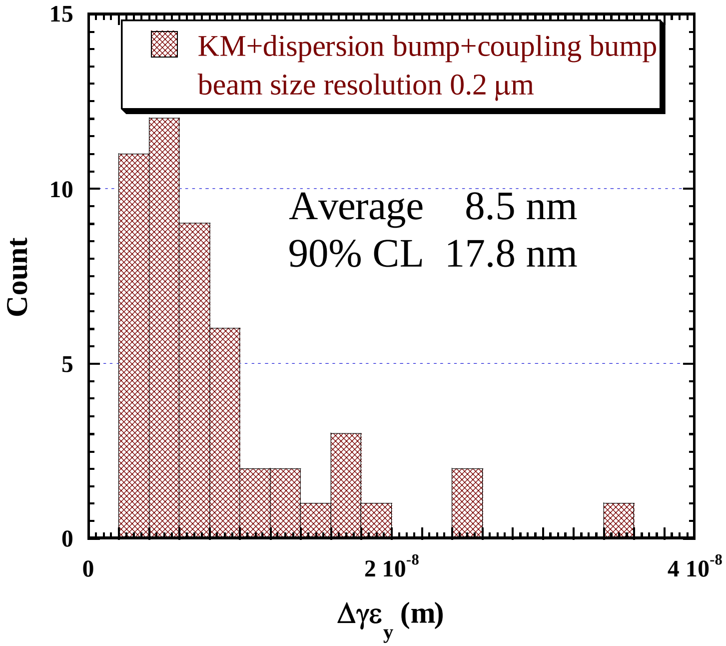




Result of KM steering
+ Dispersion Bumps + Coupling Bumps

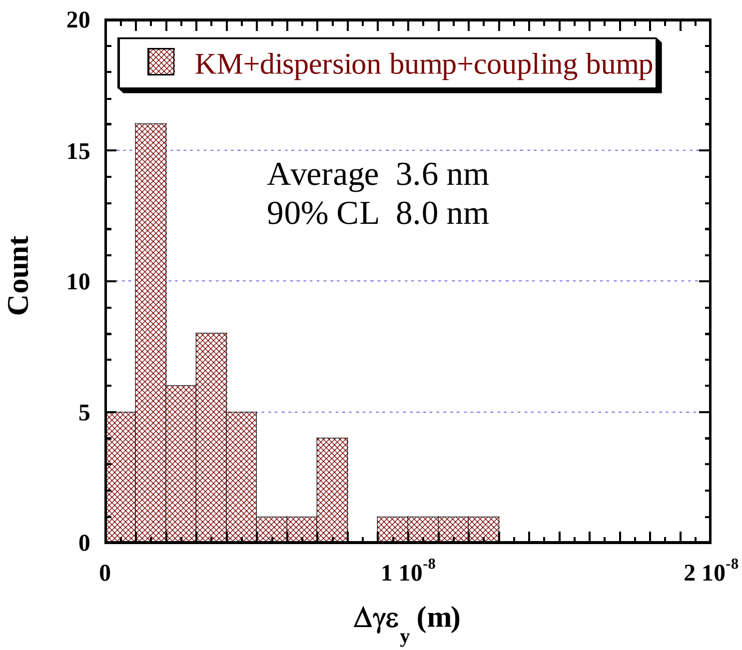
Final vertical emittance increase,
50 random seeds,
Perfect beam size monitor and resolution 0.2 micron

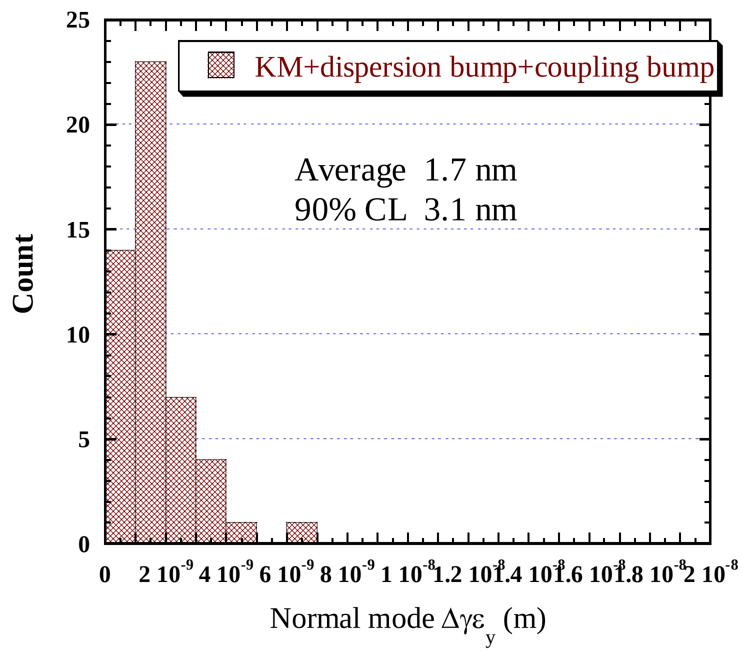




Result of KM steering + Dispersion Bumps + Coupling Bumps

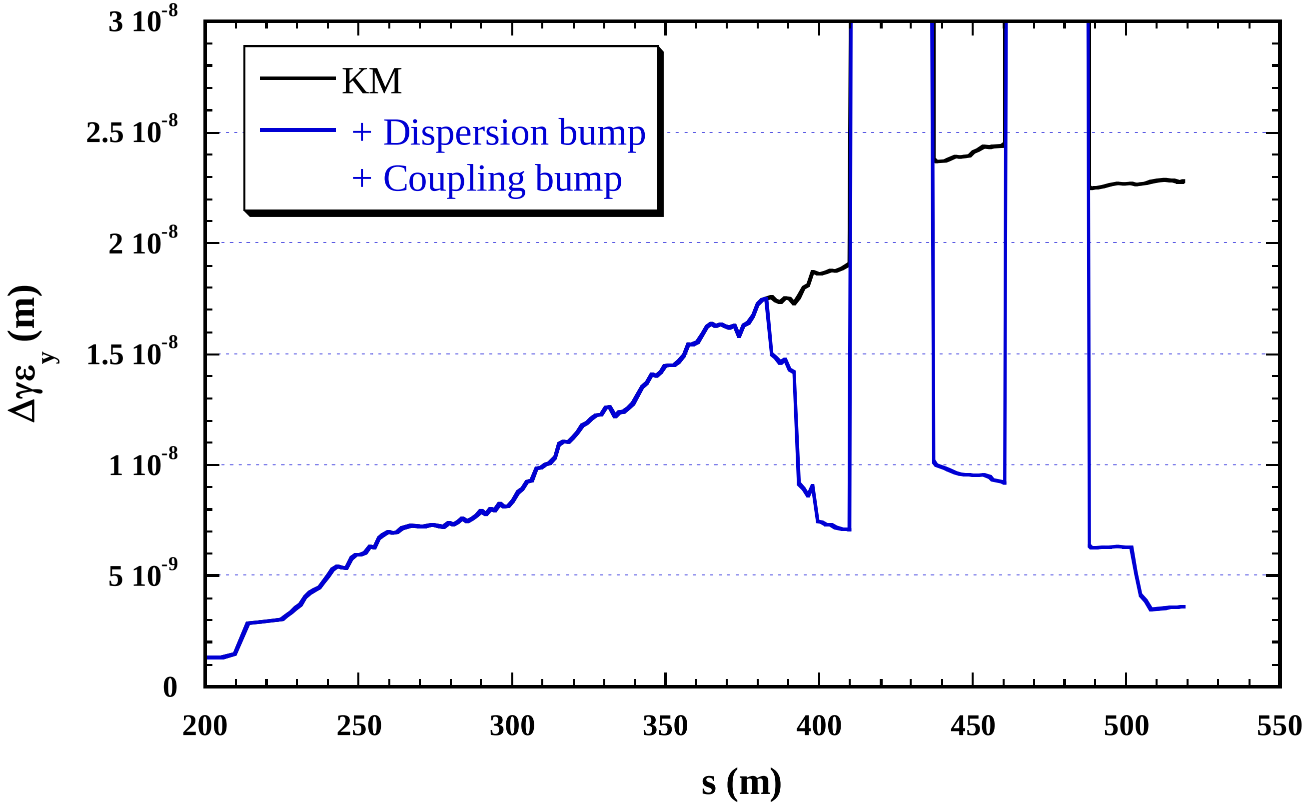
Final vertical emittance increase,
50 random seeds
Projected emittance and normal mode emittance





Result of KM steering + Bumps

Vertical emittance increase vs. s,
average of 50 random seeds



Emittance increase

	This simulation	PT
KM steering Mean / 90%CL	23 / 41 nm	23 / 44 nm
+ Dispersion Bump Mean / 90%CL	6.4 / 14.2 nm	7.6 / 13.2 nm
+ Coupling bump Mean / 90%CL Beam size resolution 0.2 μm Mean / 90%CL (Normal mode emittance) (Mean / 90%CL)	3.6 / 8.0 nm 8.5 / 17.8 nm (1.7 / 3.1 nm)	

SUMMARY

- Result agreed with PT's simulation
- Beam size monitor resolution should be very small for good bump corrections. 0.2 um seems not good enough.
- Result is not satisfactory.
  - 8 nm emittance increase, 90% CL with perfect beam size monitors
    - Emittance budget 4 nm (5 nm?) in RTML
  - Normal mode emittance (need perfect coupling correction) is less than half of projected emittance after bump corrections. (It means coupling correction is far from perfect.) But not small enough. (means dispersion correction is also not good enough.)

Need more studies