380 GeV CLIC - RTML Stray Field Simulations

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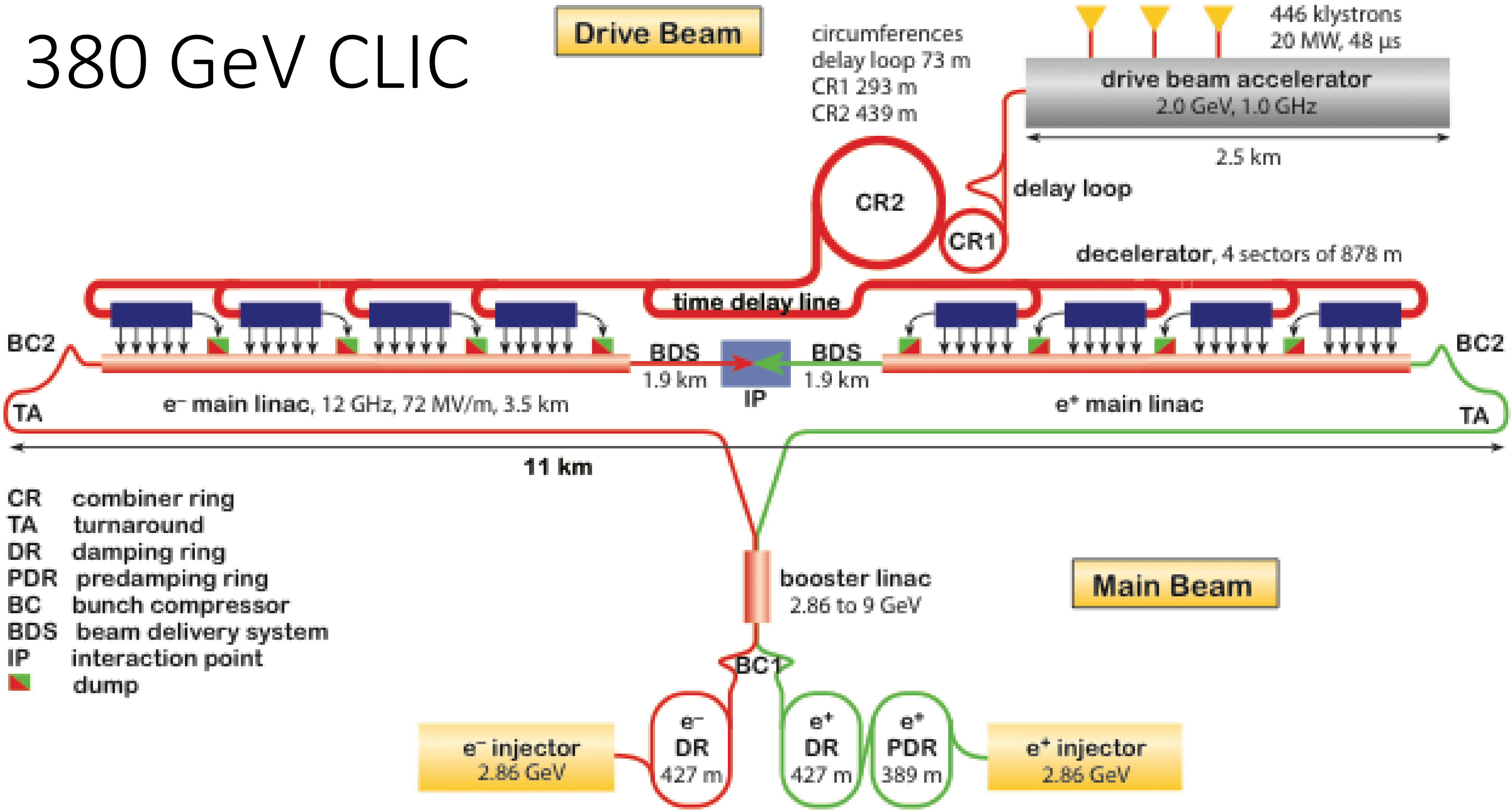
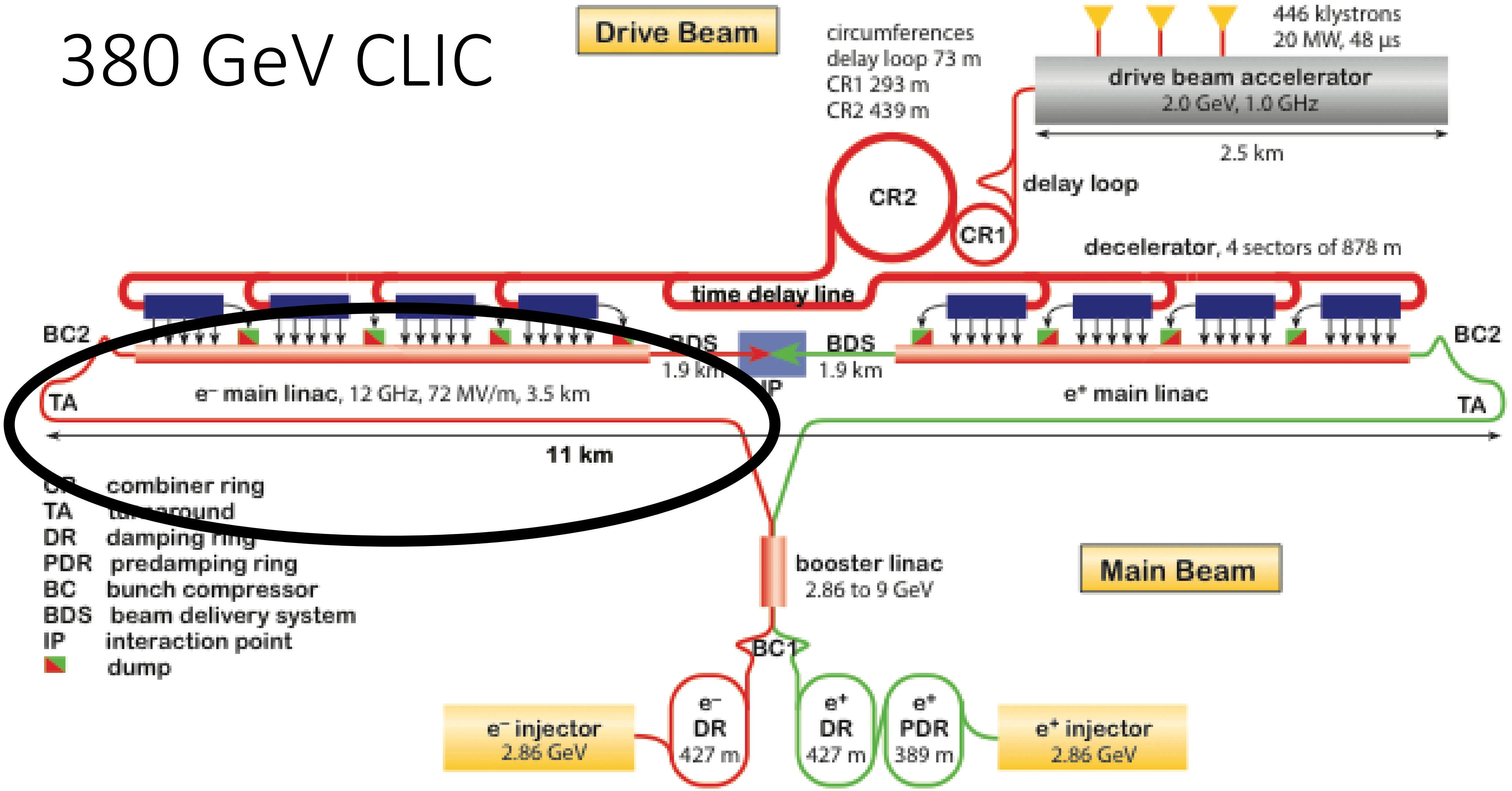
380 GeV CLIC


Drive Beam
circumferences
delay loop 73 m
CR1 293 m
CR2 439 m
446 klystrons
20 MW, 48 μs
drive beam accelerator
2.0 GeV, 1.0 GHz
2.5 km
delay loop
CR2
CR1
decelerator, 4 sectors of 878 m
time delay line
BC2
BDS
1.9 km
IP
BDS
1.9 km
BC2
TA
e⁻ main linac, 12 GHz, 72 MV/m, 3.5 km
e⁺ main linac
TA
11 km
CR combiner ring
TA turnaround
DR damping ring
PDR predamping ring
BC bunch compressor
BDS beam delivery system
IP interaction point
dump
booster linac
2.86 to 9 GeV
Main Beam
BC1
e⁻ injector
2.86 GeV
e⁻
DR
427 m
e⁺
DR
427 m
e⁺
PDR
389 m
e⁺ injector
2.86 GeV

380 GeV CLIC



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2.86 to 9 GeV
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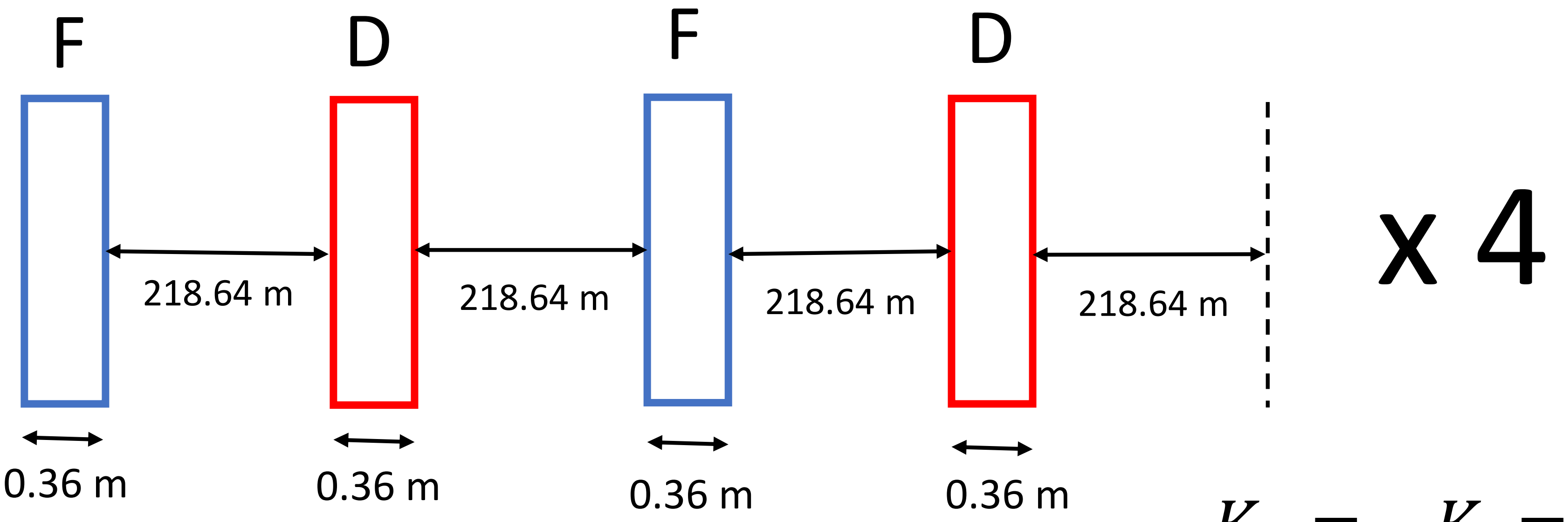
e⁻ injector
2.86 GeV
e⁻ DR 427 m
e⁺ DR 427 m
e⁺ PDR 389 m
e⁺ injector
2.86 GeV

RTML Transfer Line

- Length = 3,504 m
- Consists of one cell repeated four times:



$$K_F = -K_D = 0.0035\, m^{-1}$$

Stray Fields

$$\begin{aligned}\boldsymbol{B}(\boldsymbol{s},t) &= B_0 \sin(\boldsymbol{k}.\boldsymbol{s} - \omega t)\hat{\boldsymbol{x}} \\ &= B_0 \sin(\boldsymbol{k}.\boldsymbol{s}) \cos(\omega t)\hat{\boldsymbol{x}} + B_0 \sin(\omega t) \cos(\boldsymbol{k}.\boldsymbol{s})\hat{\boldsymbol{x}} \\ &\approx B_0 \sin(\boldsymbol{k}.\boldsymbol{s})\,\hat{\boldsymbol{x}}\end{aligned}$$

- Model the stray field as a standing wave in the horizontal direction.
- This will kick the beam in the vertical direction:

$$\boxed{\delta(s) = A\sin(ks) = A\sin\left(\frac{2\pi s}{\lambda}\right),} \quad \text{where} \quad \boxed{A = \frac{B_0 ec}{E}}$$

Simulation of Stray Fields

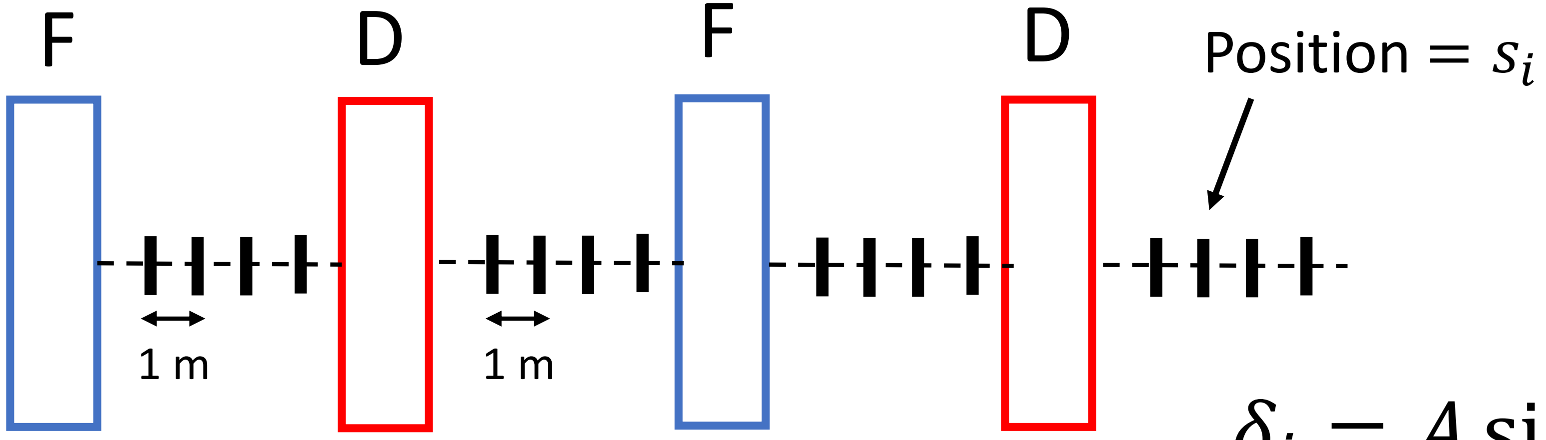
- Simulations were done with particle tracking code PLACET.
- This tracks a number of particles in a Gaussian beam.
- It computes the emittance at the end of a beamline using the final positions and divergence of each particle in the beam.
- 10,000 particles were used in the simulations.

- Simulation of the RTML with no stray fields gives final emittances:

$$\varepsilon_{x,0} = 7.74 \times 10^{-7}\ \mathrm{m}, \quad \varepsilon_{y,0} = 0.057 \times 10^{-7}\ \mathrm{m}$$

Simulation of Stray Fields

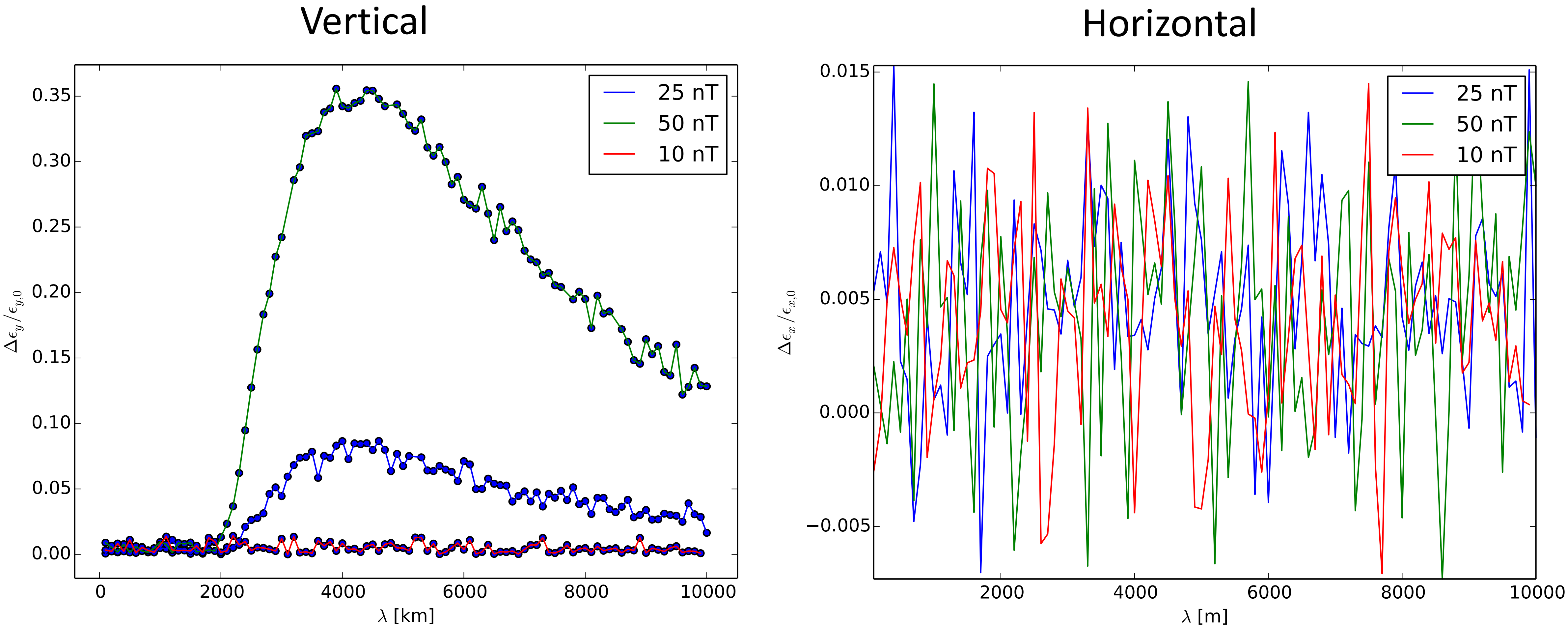
- Kicks are applied at discrete locations using dipole elements of zero length:



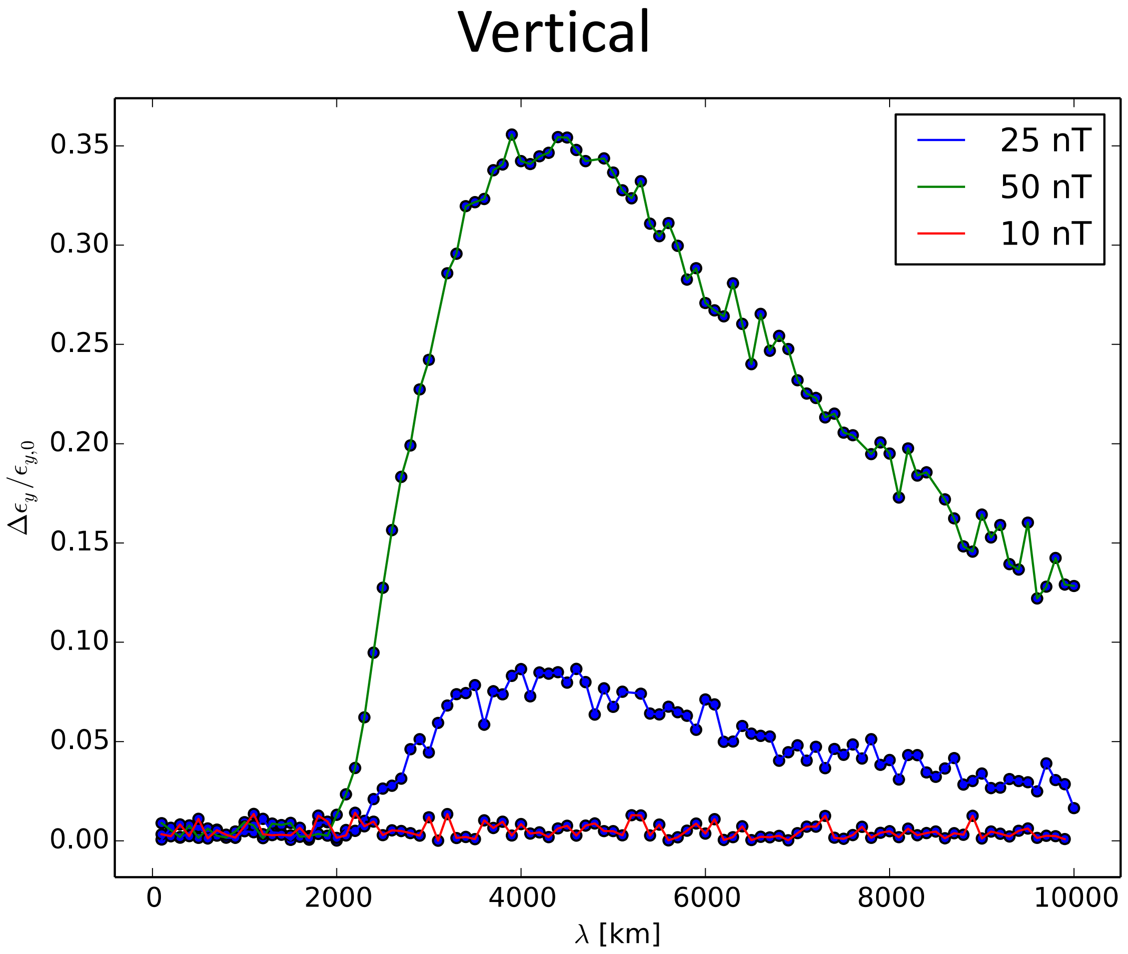
$$\delta_i = A \sin(\frac{2\pi s_i}{\lambda})$$

- We need to specify A and λ.
- Dipole are spaced 1 m apart, therefore can't simulate $\lambda < 1$ m.

Fractional Emittance Growth

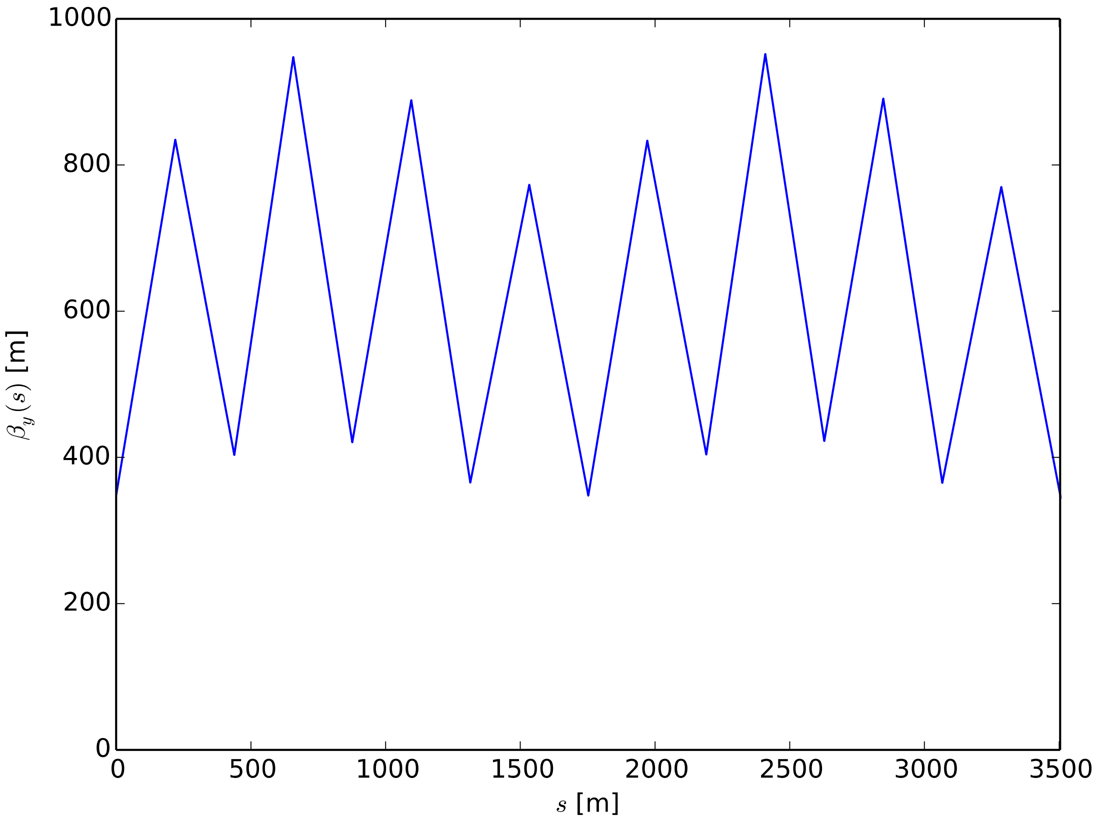


Fractional Emittance Growth



- Sensitivity occurs for $B_0 > 10$ nT.
- Resonance around $\lambda = 4000$ m.
- Emittance growth scales with A^2.

Beta Function in the Transfer Line



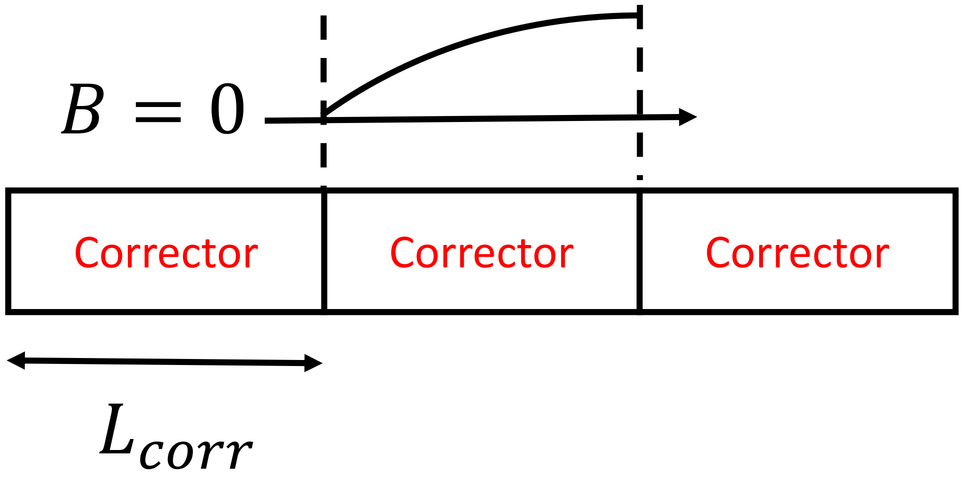
- Calculated at the centres of each quadrupole.
- Shows some beta beating.
- The betatron wavelength is

$$\lambda_\beta = 2\pi < \beta > \approx 3600 \text{ m.}$$

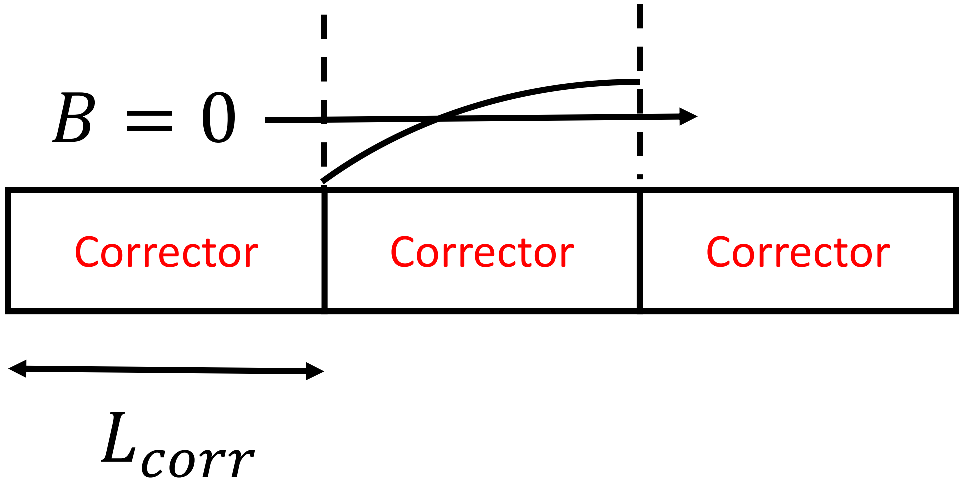
- Emittance growth occurs when λ approaches λ_β.

Corrections

- A series of correctors were place over the entire length of the transfer line.
- A corrector has a finite length and will see the average stray field over its length:



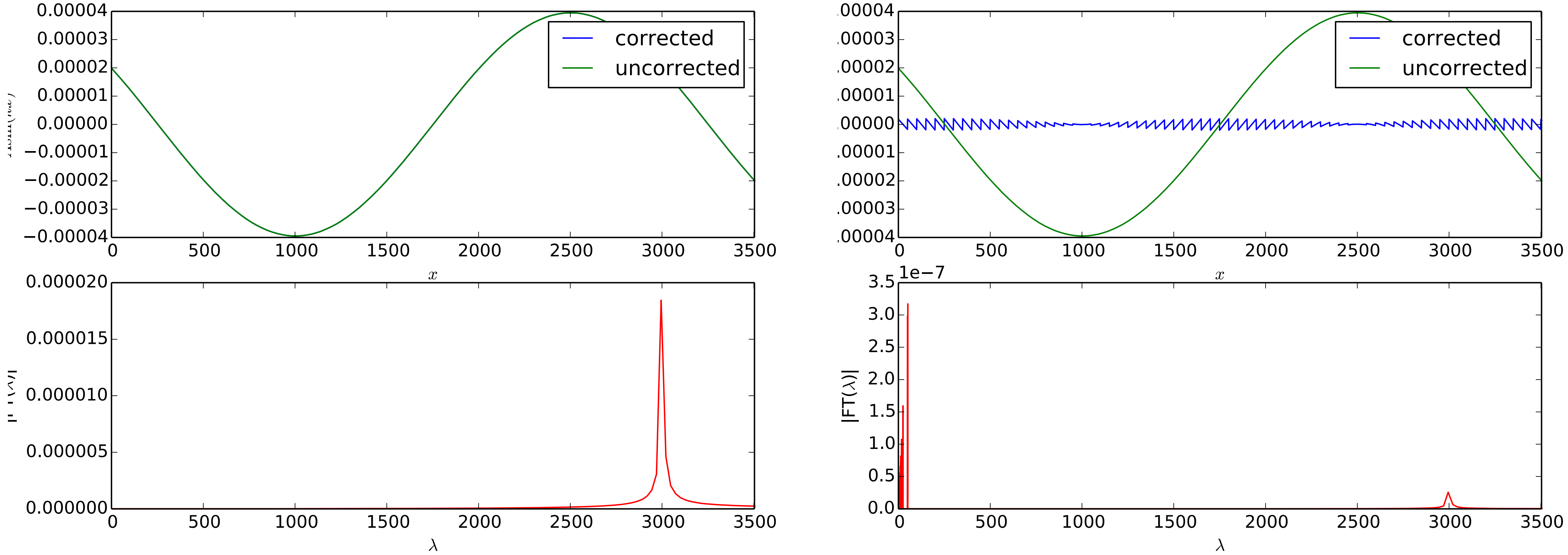
Before correction



After correction

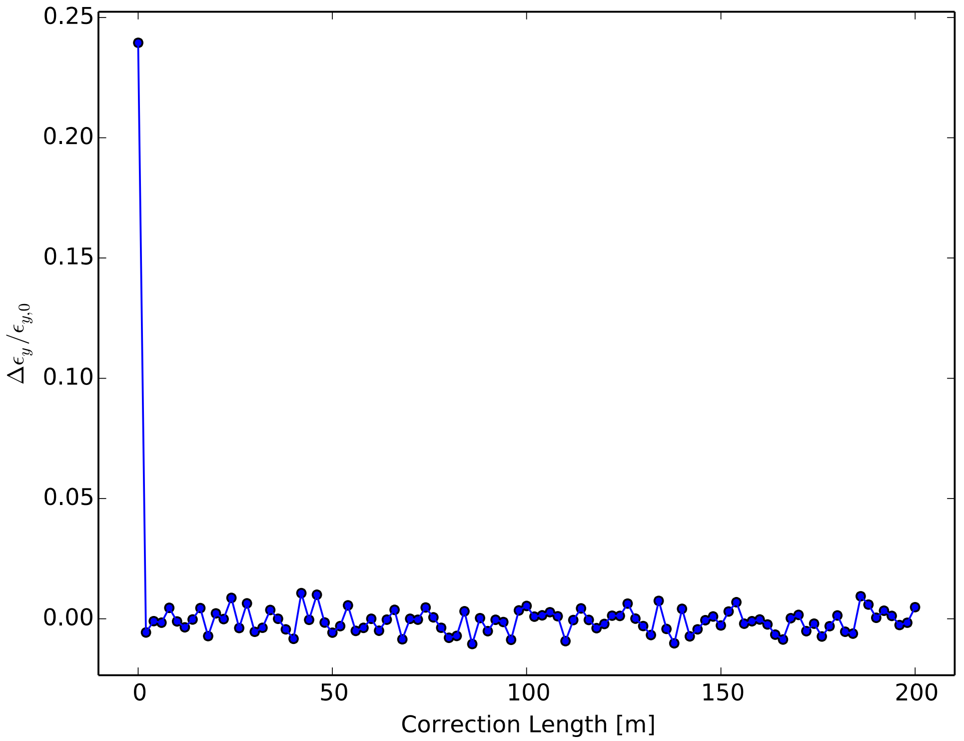
Corrections

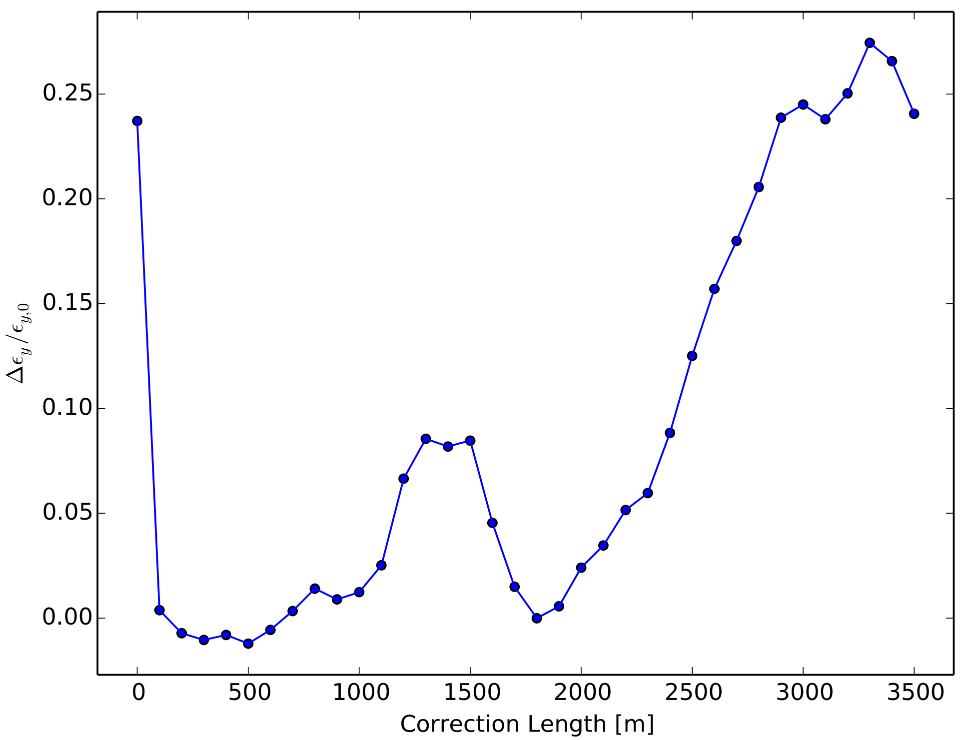
- Correcting like this can introduce discontinuities, which induce new small wavelengths: (below is $L_{corr} = 50$ m)



Corrections – Varying L_{corr}

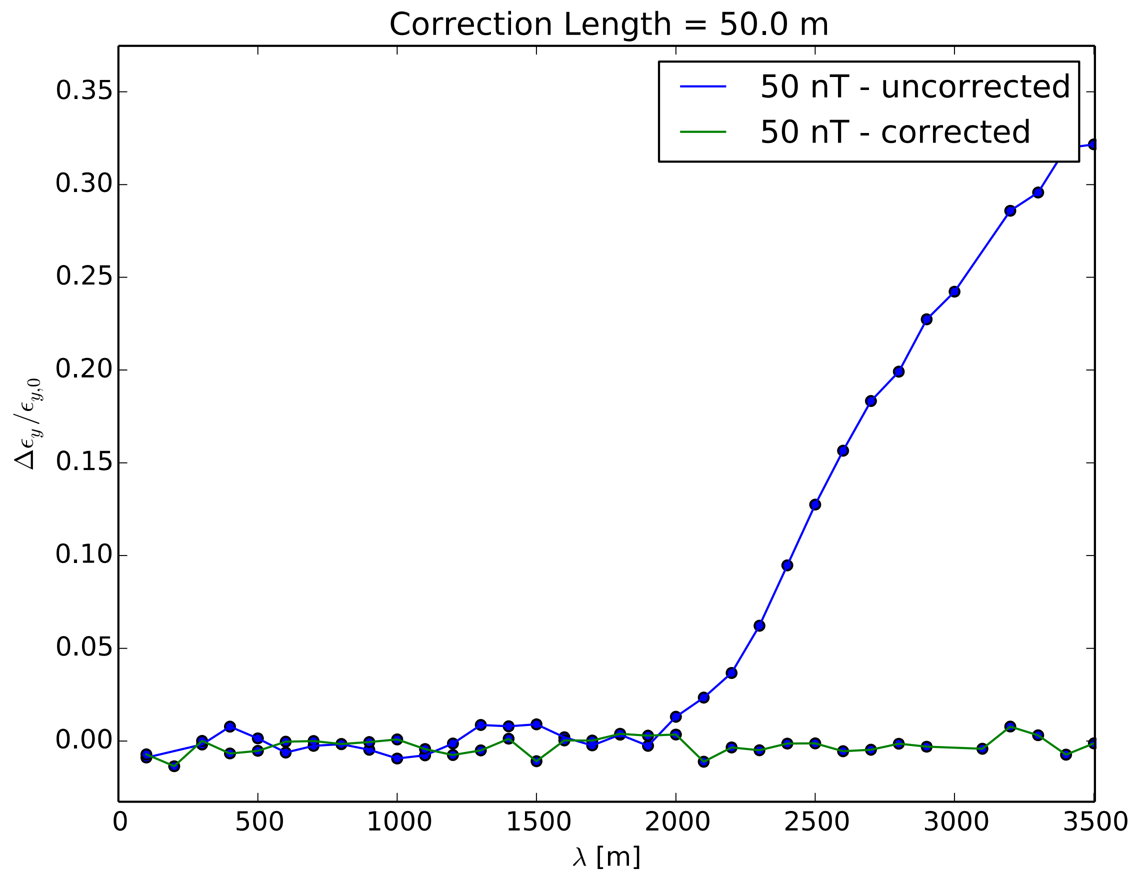
- Stray field with $\lambda = 3000$ m and $B_0 = 50$ nT, which causes emittance growth of ~0.24.

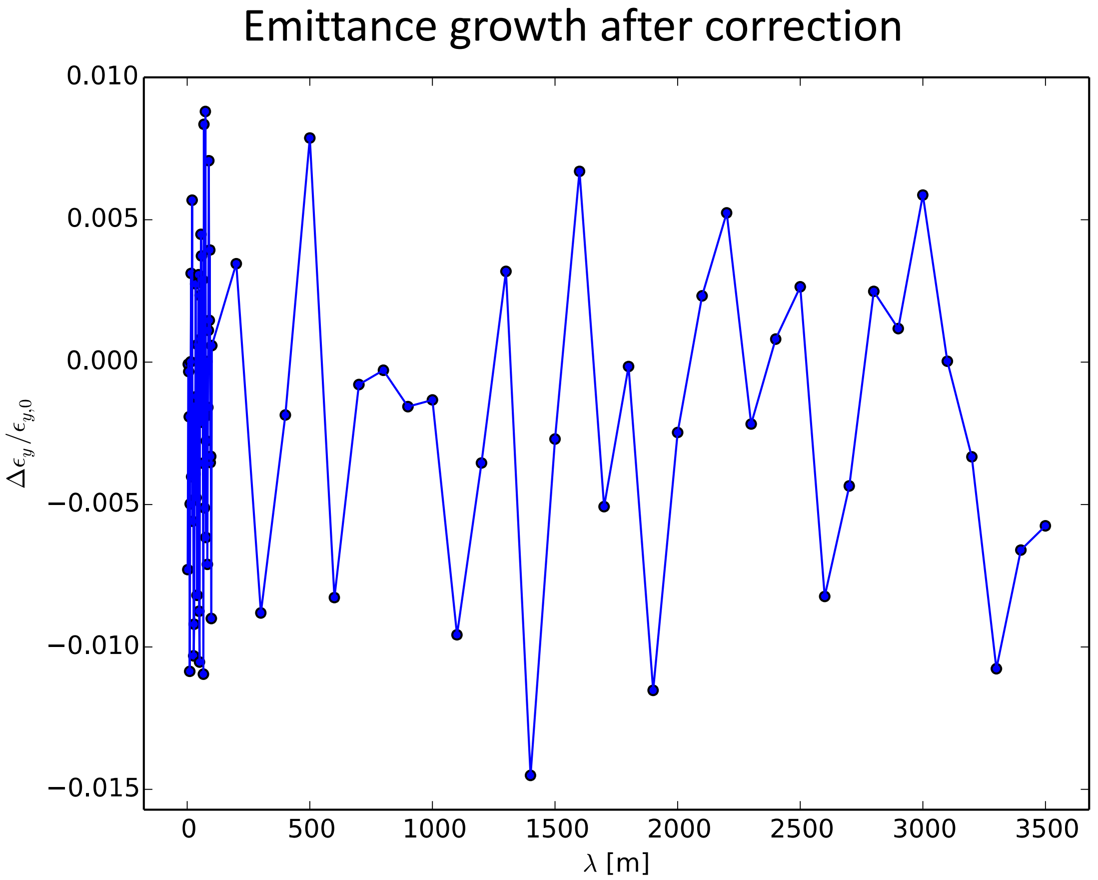




- Correction like this works when the corrector length is small.

Corrections - $L_{corr} = 50$ m

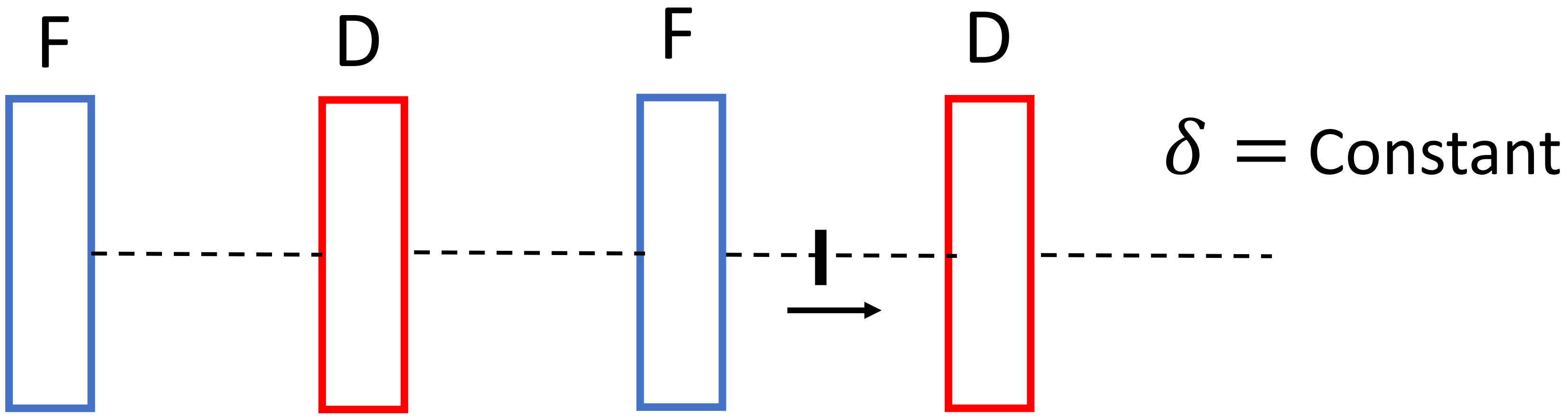




- Simulation with $\lambda = 3000$ m, $B_0 = 50$ nT.

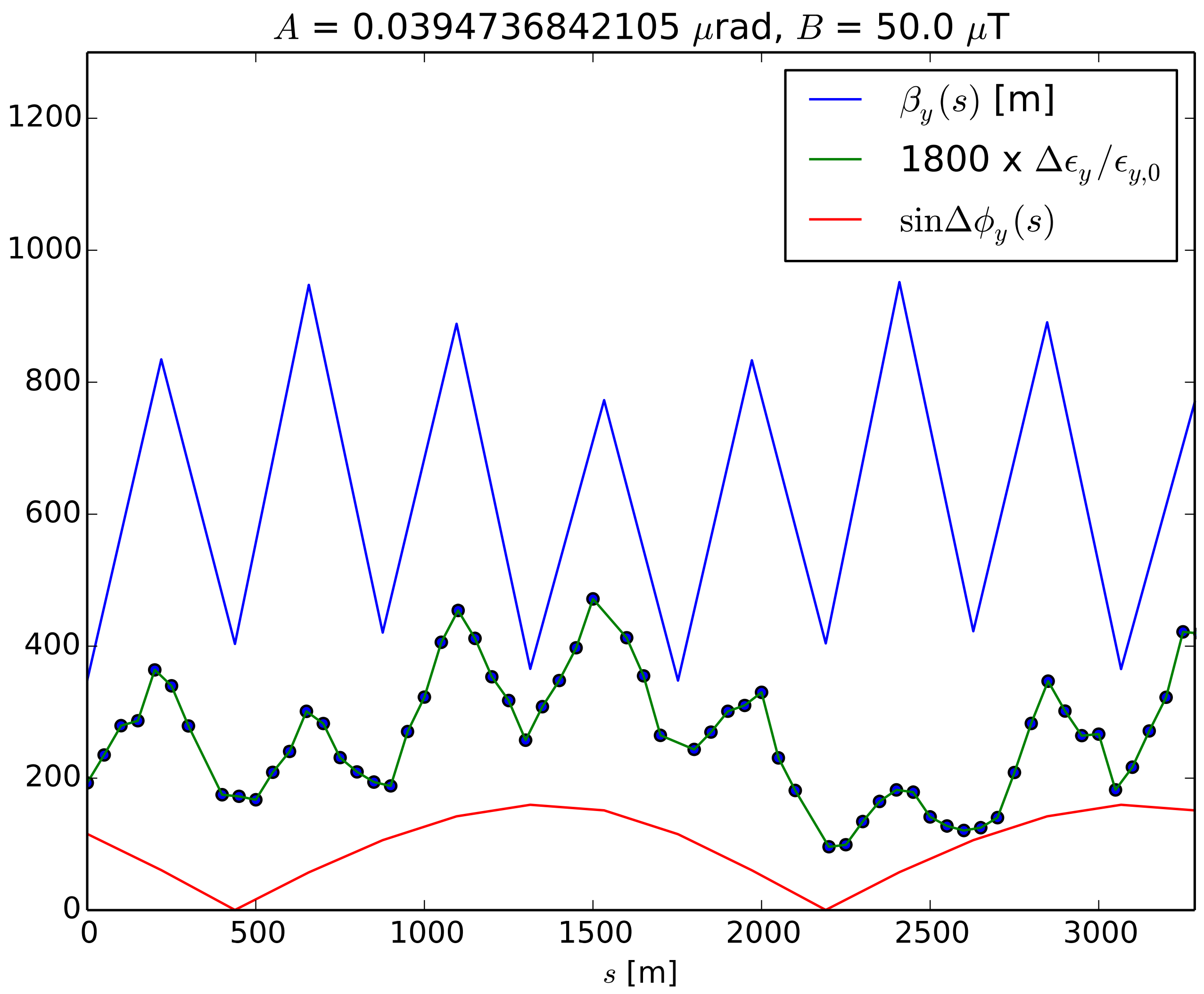
Effect of a Single Kick

- The location of the kick matters.



- The equivalent kick of a 50 μT magnetic field variation was placed at one location.
- This location for moved across the transfer line.

Effect of a Single Kick



- Emittance growth is larger at locations of high beta.
- Locations that effect the beam most are high beta locations which also have a large phase advance.
- Looking into correcting only a fraction of the transfer line.