Design and Beam Dynamics Studies for Primary 5 GeV e^- Linac

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Outline

1) Introduction
2) Beam Parameters and FoDo Cell Designs
3) Impact of Misalignments
4) Conclusion
5) Outlook

1) Introduction

2) Beam Parameters and FoDo Cell Designs

3) Impact of Misalignments

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- Our motivation for this work is review the design of primary 5 GeV e^- linac.
- Also, optimizing the previous design for this linac.
- Explore further information about this machine such as possibilities for new set of parameters etc.

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BUNCH PARAMETERS

- *Bunch Length, σ_z = 300 μm*
- *Energy spread = 1%*
- *Number of Particles : 1x10^{10}*
- *Beam radius = 2.5 mm*
- *ε_x = 832x10^{-7} m.rad*
- *ε_y = 4365x10^{-7} m.rad*

RF PARAMETERS

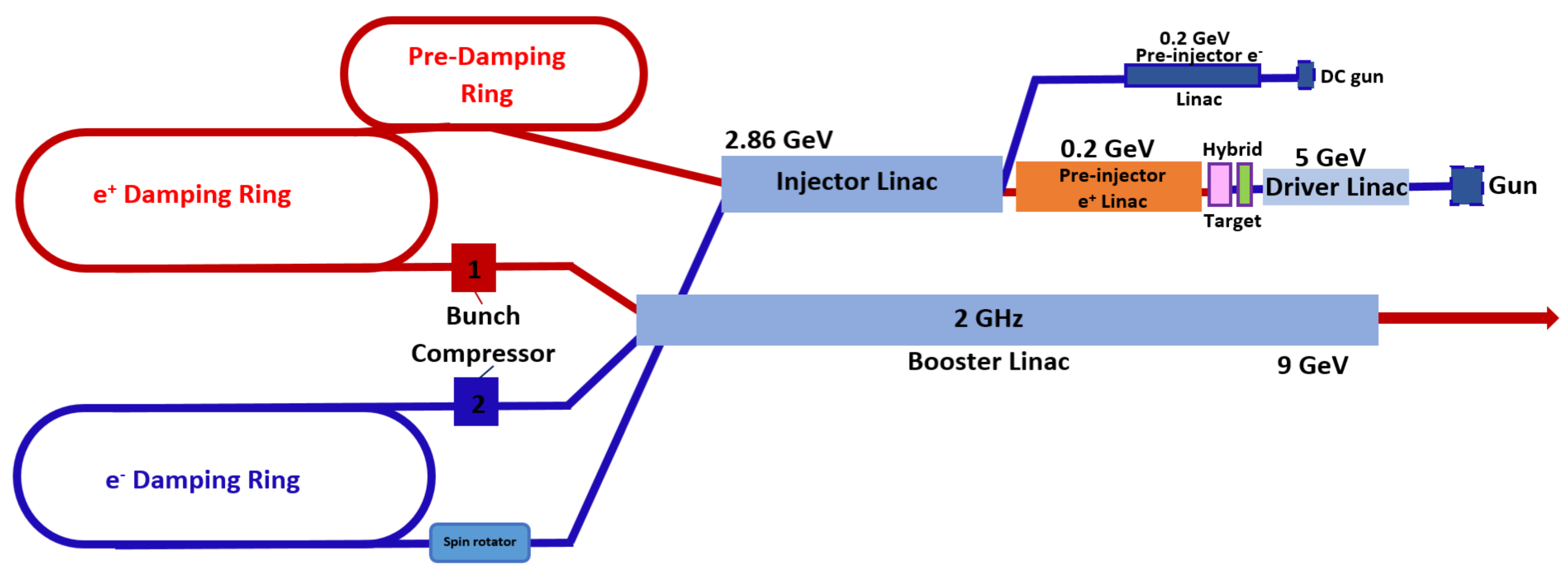
- *Gradient = 30 MV/m*
- *Cavity Length = 1.5 m*
- *f = 2.0 GHz*
- *Phase Advance / Cell = 2π / 3*
- *Filling factor = 71.58%*

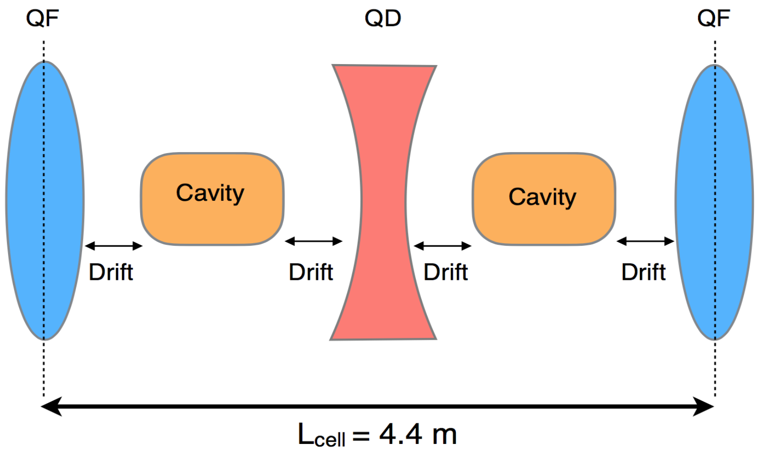
LATTICE PARAMETERS

- *Phase Advance, μ = 90°*
- *Quadrupole length = 0.2m*
- *Drift length = 0.25 m*
- *Beam pipe = 2 cm*
- *Quadrupole radius = 5 cm*

Parameter	Value
Energy [GeV]	5
Number of e^- / bunch	1.1×10^{10}
Charge per bunch [nC]	1.8
Bunches per pulse	312
Pulse repetition rate [Hz]	50
Beam radius (r.m.s.) [mm]	2.5
Bunch length (r.m.s.) [ps]	1
Beam power [kW]	140

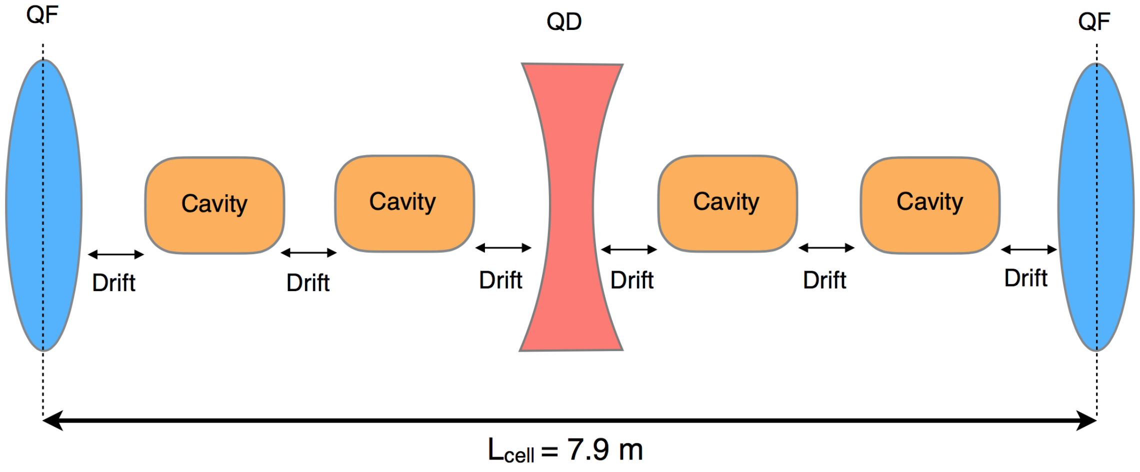
Primary 5 GeV e^- beam parameters from CLIC-CDR.





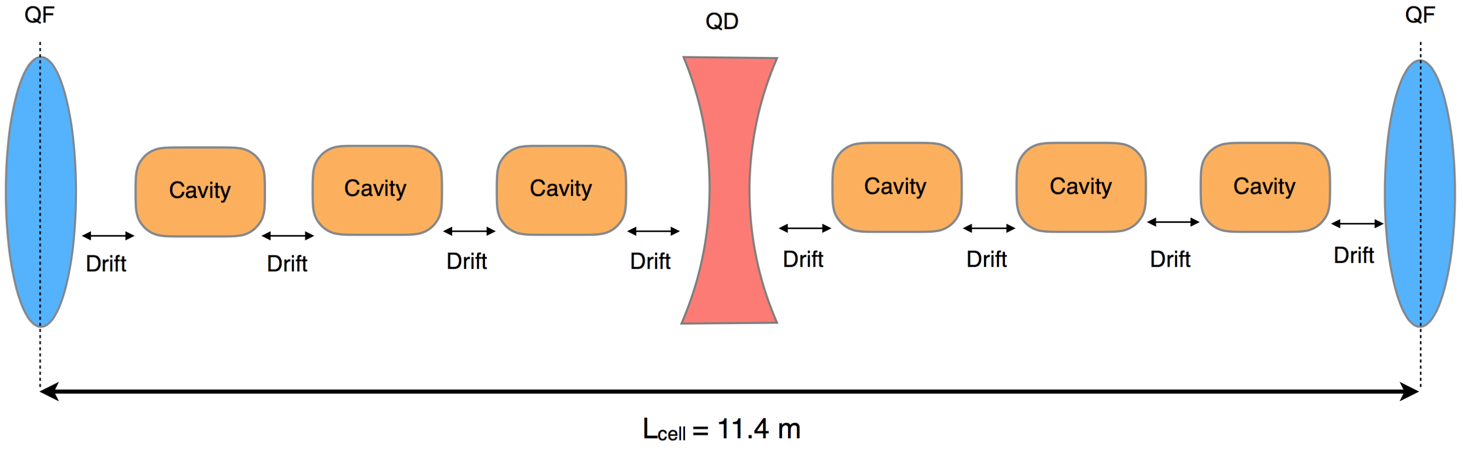
→ Parameters

- *Focusing strength, $k = 3.2141\ m^{-2}$*
- *$\beta_x = 7.3511\ m$*
- *$\beta_y = 1.4016\ m$*
- *Phase Advance, $\mu = 90^o$*
- *Gradient = 30 MV/m*
- *Each drift = 0.25 m*
- *Each cavity = 1.5 m*
- *Each quadrupole = 0.2 m*
- *Accelerating in one structure = 0.045 GeV*
- *Accelerating in one cell = 0.09 GeV*



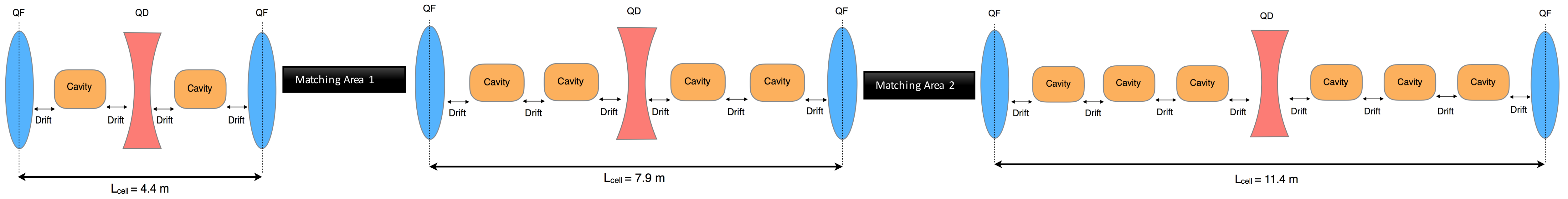
→ Parameters

- *Focusing strength, k = 1.7901 m⁻²*
- $\beta_x = 13.3195$ *m*
- $\beta_y = 2.4245$ *m*
- *Phase Advance, μ = 90°*
- *Gradient = 30 MV/m*
- *Each drift = 0.25 m*
- *Each cavity = 1.5 m*
- *Each quadrupole = 0.2 m*
- *Accelerating in one structure = 0.045 GeV*
- *Accelerating in one cell = 0.18 GeV*



→ Parameters

- *Focusing strength, k = 1.2405 m^{-2}*
- *β_x = 19.2919 m*
- *β_y = 3.4488 m*
- *Phase Advance, $\mu = 90^o$*
- *Gradient = 30 MV/m*
- *Each drift = 0.25 m*
- *Each cavity = 1.5 m*
- *Each quadrupole = 0.2 m*
- *Accelerating in one structure = 0.045 GeV*
- *Accelerating in one cell = 0.27 GeV*



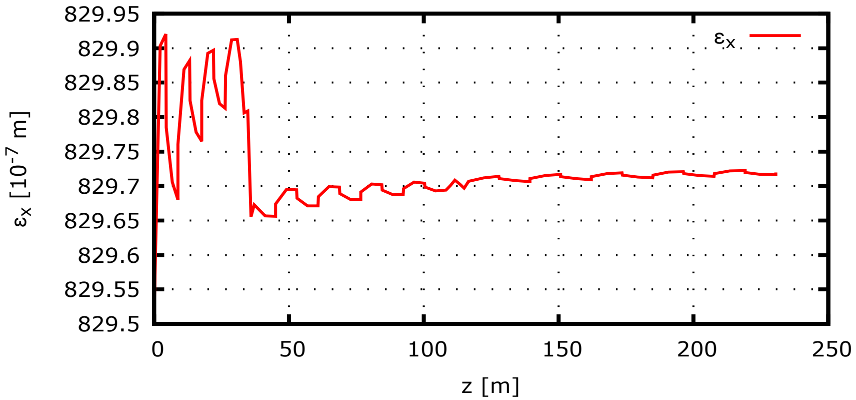
- 7 FoDo cells with one accelerating structure *(30.8 m)* → 50 MeV to 0.68 GeV
- 9 FoDo cells with two accelerating structures *(71.1 m)* → 0.68 GeV to 2.30 GeV
- 10 FoDo cells with three accelerating structures *(114 m)* → 2.3 GeV to 5.00 GeV

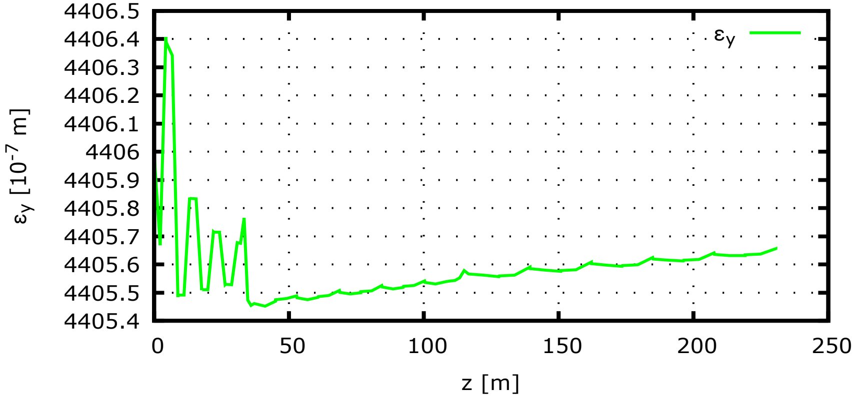
Total length of the linac without matching areas = 215.9 m

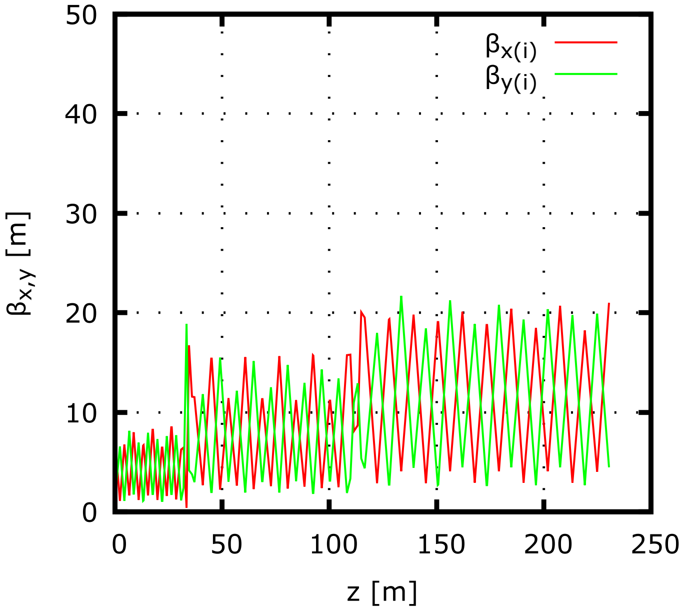
- For the *"Matching Area 1"*
  - 4 quadrupoles (*0.2 m* each) and 5 drifts (*1.1 m* each)
  - Total length of *Matching Area 1 = 6.3 m*
  - Matching done with PLACET

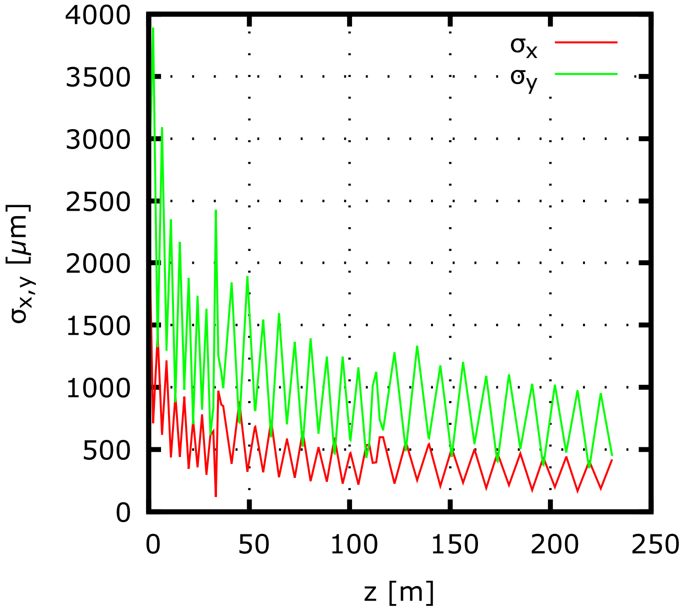
- For the *"Matching Area 2"*
  - 4 quadrupoles (*0.2 m* each) and 5 drifts (*1.5 m* each)
  - Total length of *Matching Area 2 = 8.3 m*
  - Matching done with PLACET

- After matching, total length of the linac with all structures and matching areas together becomes = ***230.5 m***
- Total number of quadrupoles through the machine including matching areas = ***61***
- With this design, in first and second sections, the design can not exceeds quadrupole field more than *0.5 T* which is maximum limit of *≤ 1.2 T*. At the third section, the machine reaches at the last quadrupole about *1.03 T* maximum which is also lover than *≤ 1.2 T* limit.









- ß parameters through the machine for three different FoDo cells added together were matched perfectly with the PLACET
- Emittance growth of the machine also at a very reasonable level; nearly 0.0% (energy spread = 1%)
- Beam size is also at a very good level for our beam pipe which was considered as 2 cm. Beam size is maximum ≈ 4000 μm as shown in the graph.

1) Introduction

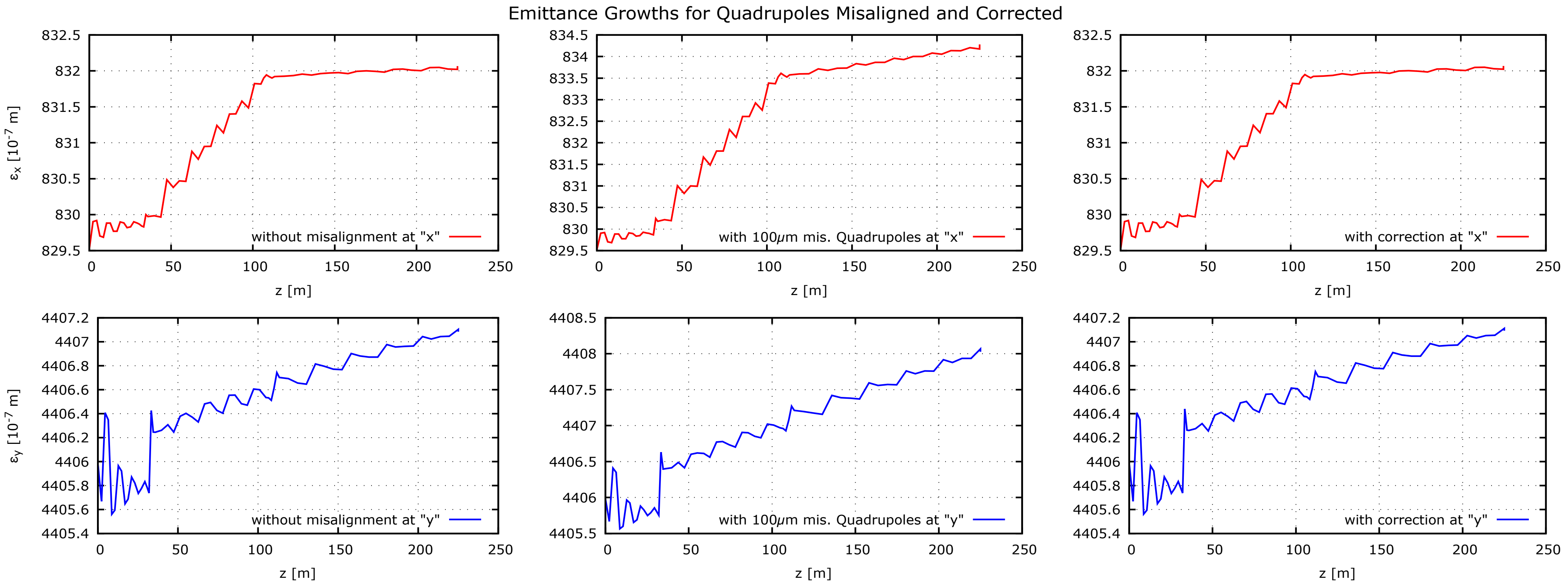
2) Beam Parameters and FoDo Cell Designs

3) **Impact of Misalignments**

4) Conclusion

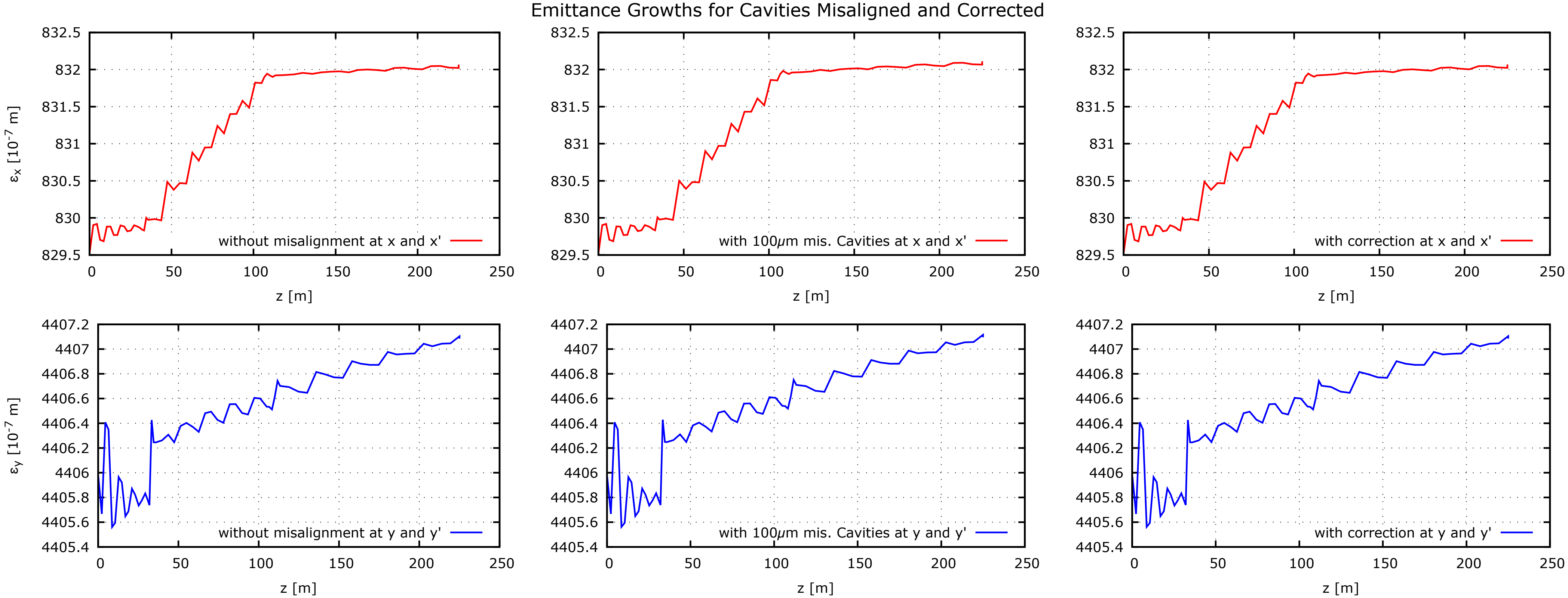
5) Outlook

- Elements such as quadrupoles, cavities and BPMs were misaligned randomly ;
  - 100 µm random misalignment for each quadrupole
  - 100 µm random misalignment for each cavity
  - 100 µm random misalignment for each BPM
  - And 100 µm random misalignment for all elements at once
- For correcting these misalignments ;
  - BPMs were set to 1 µm and 100 µm resolution
  - And after each quadrupole, dipole correctors were added to the beamline for correction

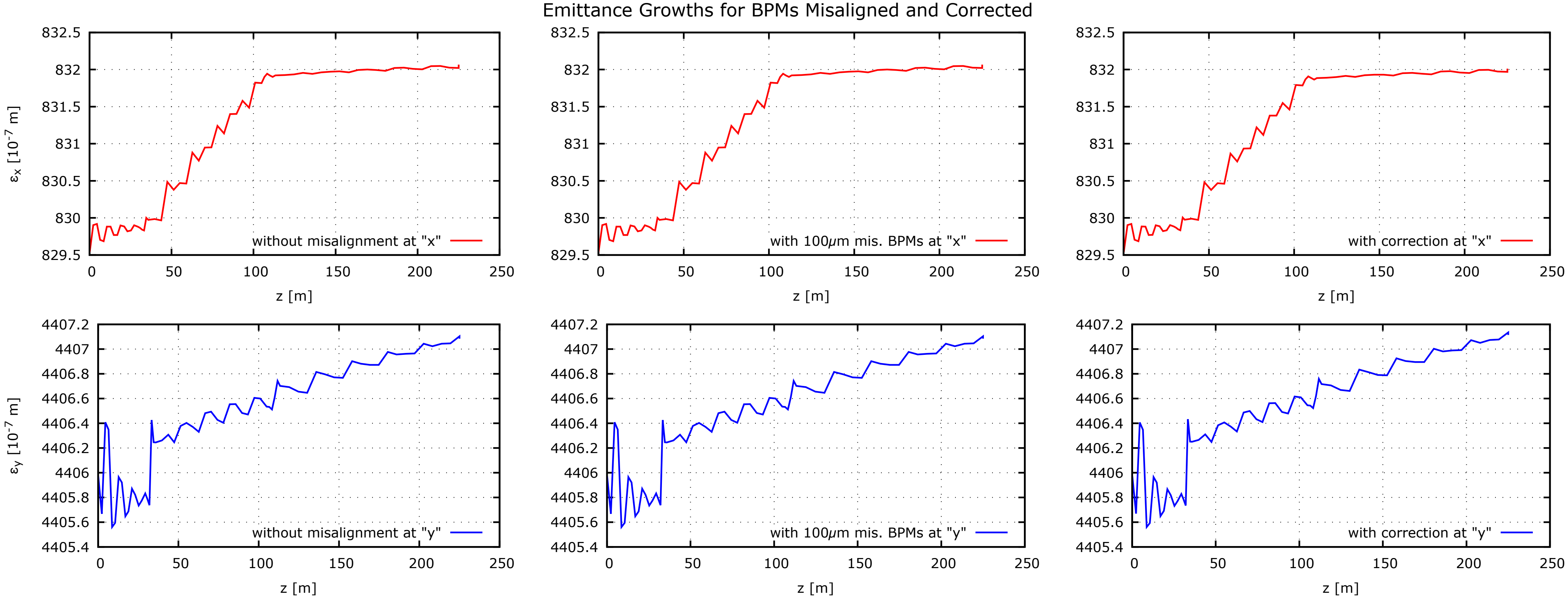


- This graphs show simulation of 100 machines average.
- 100 µm misalignment for each quadrupole.
- 1 to 1 correction works well.
- BPMs were added before each quadrupole.
- 100 µm BPM resolution was used.

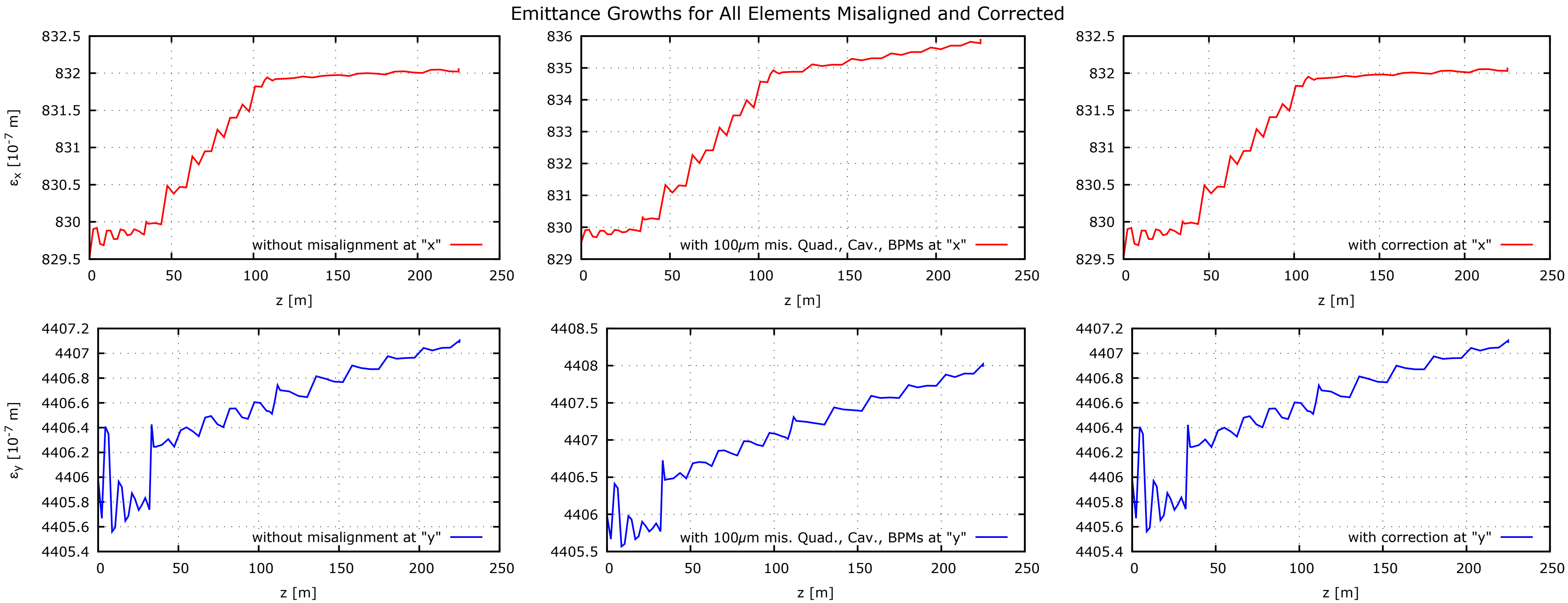
Impact of Misalignments



- No wakefield effects included, just each cavity misaligned 100 µm.
- This graphs also show simulations for average of 100 machines.
- 1 to 1 correction works well too, but there is not so much effects from when just cavities were misaligned.
- BPMs were added before each quadrupole and 100 µm BPM resolution was used.



- BPMs also have very very little effect on the emittance growth.
- But, when correction was made, BPMs act like focusing quadrupoles and a little bit of increasing for the emittance growth comparing to default. It is about 0.006% which was barely seen in the graphics.
- BPM resolution also 100 µm here.



- When all the elements in the beamline were misaligned all together, not a big effect can be seen in the beamline, emittance was grown about 0.35%.
- After the correction with dipoles emittance turn backs to the normal level.
- All the corrections were made with dipoles added after quadrupoles and for seeing the effects BPMs added before each quadrupole in the beamline.

Conclusion

- Beam dynamics studies for design of primary 5 GeV e^- linac were done and also three different FoDo lattices designed for this study.

- Preliminary design of primary 5 GeV e^- linac, which consist of three different FoDo lattice sections, for CLIC main beam injector complex has been done.

- Impacts of misalignments on the beamline for this design were studied also.

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3) Misalignment Work for Testing the Machine Stress for Errors in Setup

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5) **Outlook**

Outlook

- For soon, power consumption will be evaluated for the design with some C++ code or macro.
- Aim of the further work about this study is to improve the design, maybe with multiple design options.
- This design uses very high gradient for cavities, in the further work with multiple options, this gradient value and of course the power consumption will be much more lower than this version of design in the further planned work.
- Evaluating the requirements from the point of view of the target which electrons impinging on.
- After this target consideration, another study can be done about a lower energy linac like 3 GeV or 4 GeV, this linac maybe enough for creating and transferring positrons (positron linac transfers nearly 97% of created positrons from the target).

THANK YOU
FOR YOUR ATTENTION !