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

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# Outline

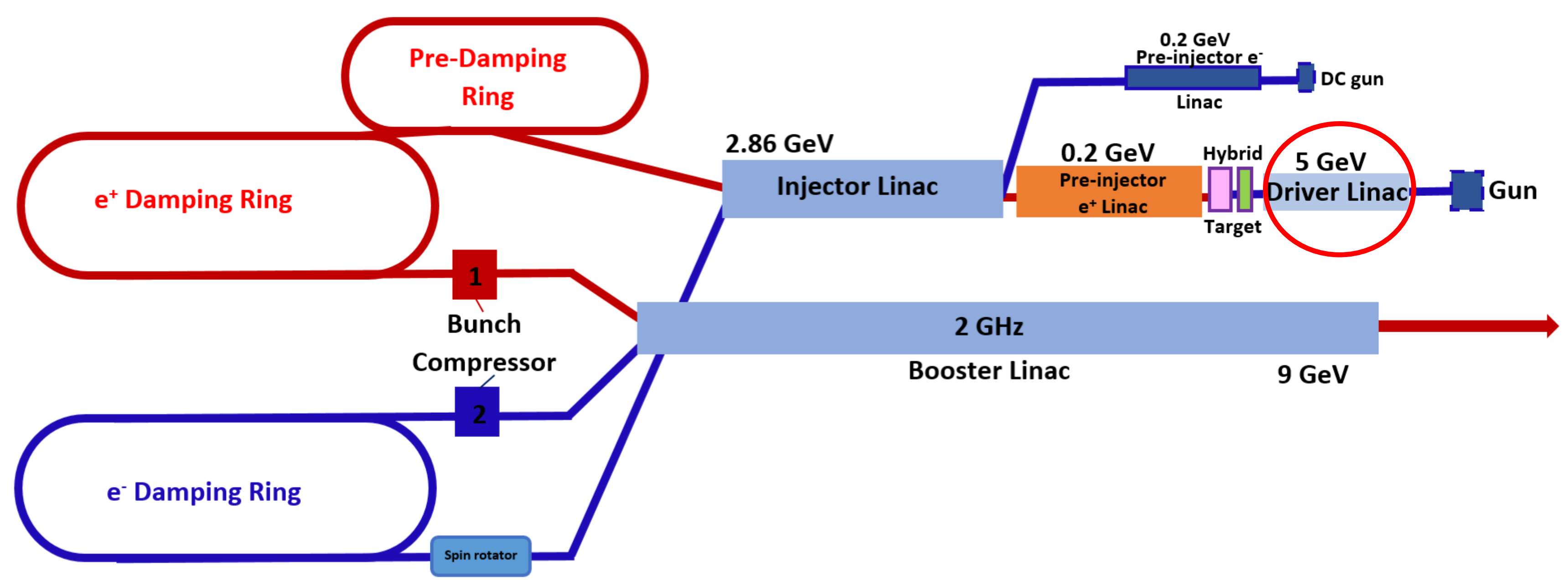
1) Introduction

2) Beam Parameters and FoDo Cell Designs

3) Impact of Misalignments

4) Conclusion

5) Outlook




- Our motivation for this work is to design and optimize the primary 5 GeV $e^-$ linac.
- This is an important task because this linac will consume higher power than any other linac in the CLIC main beam injector complex.
- Also, explore further information about this machine such as possibilities for new set of parameters etc.

*BUNCH PARAMETERS*

- *Bunch length, $\sigma_z$ = 300 μm*
- *Energy spread = 1%*
- *Number of particles : 1x$10^{10}$*
- *Beam radius = 2.5 mm*
- *$\varepsilon_x$ = 832x$10^{-7}$ m.rad*
- *$\varepsilon_y$ = 4384x$10^{-7}$ m.rad*

*RF PARAMETERS*

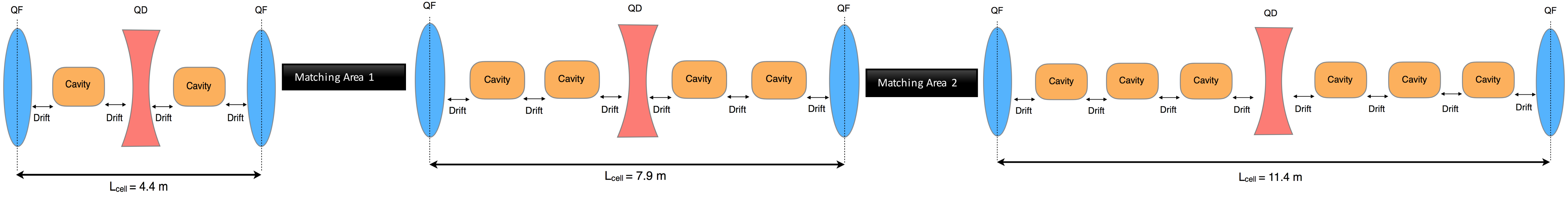
- *Gradient = 30 MV/m*
- *Cavity Length = 1.5 m*
- *f = 2.0 GHz*
- *Phase advance per cell = 2π / 3*
- *Filling factor = 71.58%*

*LATTICE PARAMETERS*

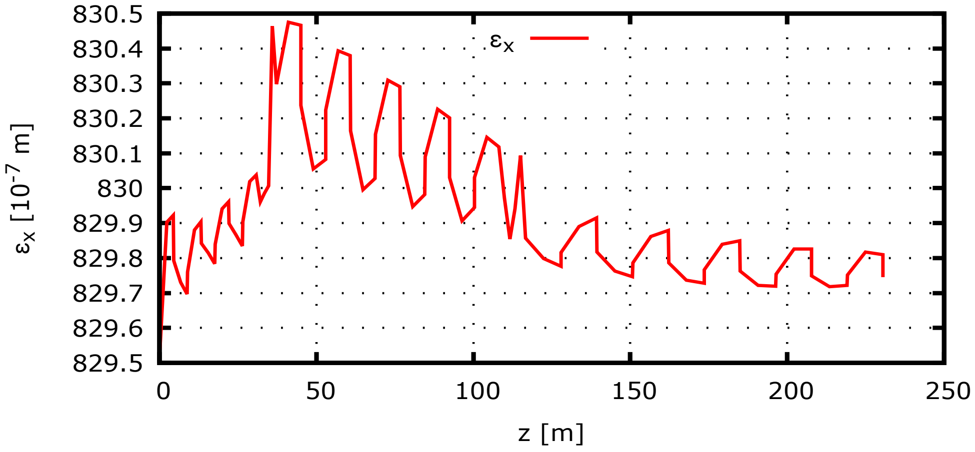
- *Phase advance, μ = $90^o$*
- *Quadrupole length = 0.2m*
- *Drift length = 0.25 m*
- *Beam pipe = 2 cm*
- *Quadrupole radius = 5 cm*

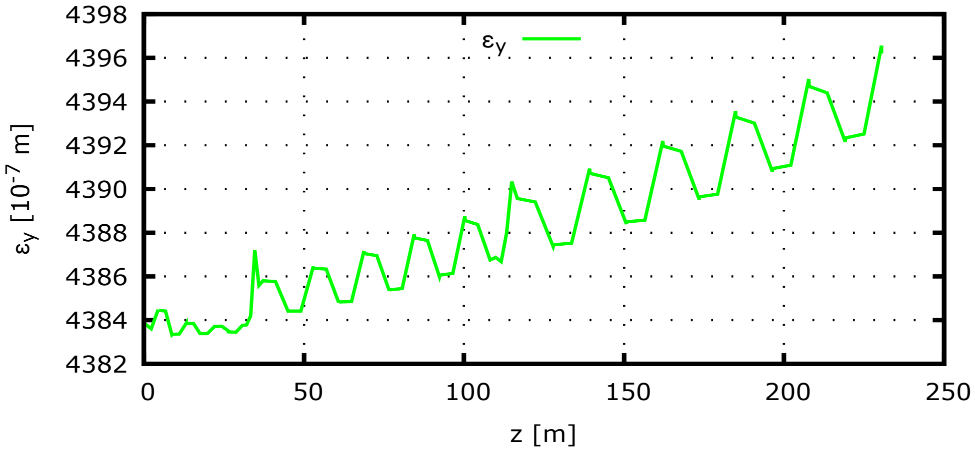
| **Parameter** | **Value** |
| --- | --- |
| Energy [GeV] | 5 |
| Number of $e^-$ / bunch | $1.1 \times 10^{10}$ |
| Charge per bunch [nC] | 1.8 |
| Bunches per pulse | 312 |
| Pulse repetition rate [Hz] | 50 |
| Beam radius (r.m.s.) [mm] | 2.5 |
| Bunch length (r.m.s.) [ps] | 1 |
| Beam power [kW]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

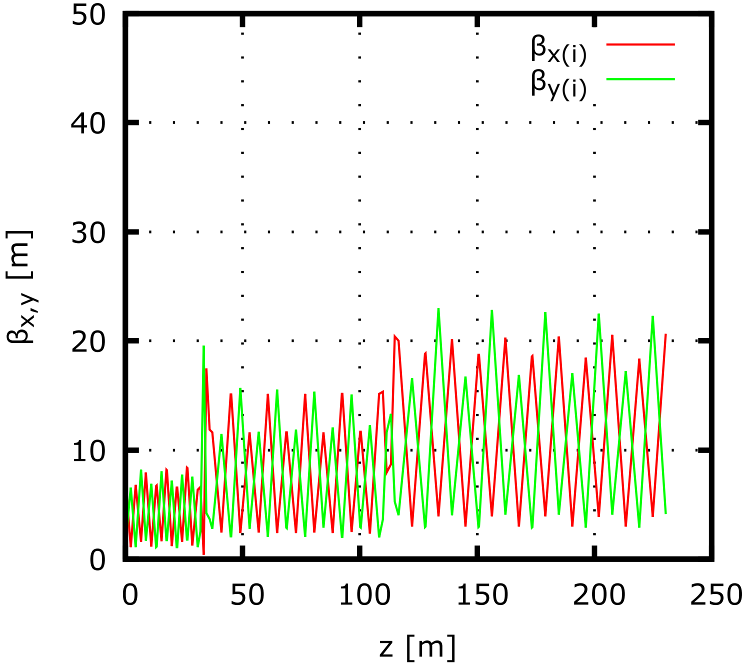
Primary 5 GeV $e^-$ beam parameters from CLIC-CDR.

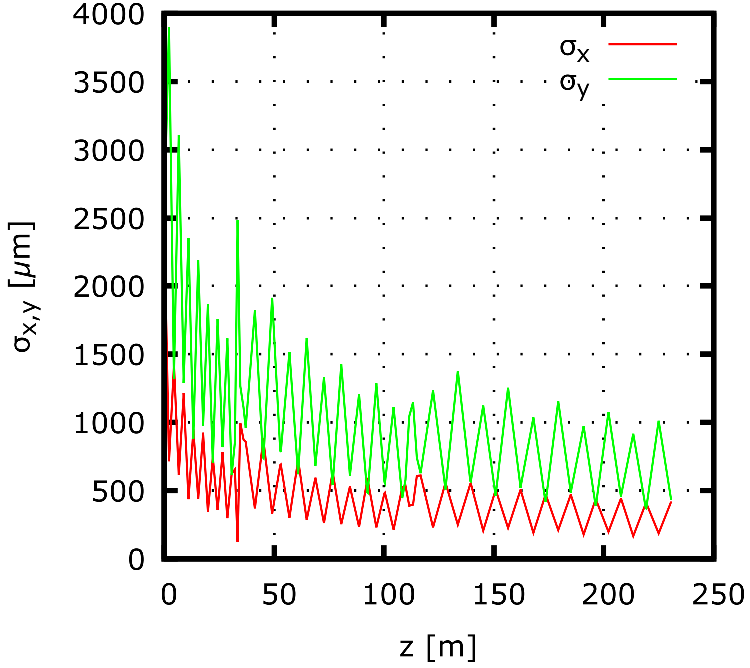



- 7 FoDo cells with one accelerating structure *(30.8 m)* → 50 MeV to 0.68 GeV
- 9 FoDo cells with two accelerating structures *(71.1 m)* → 0.68 GeV to 2.30 GeV
- 10 FoDo cells with three accelerating structures *(114 m)* → 2.30 GeV to 5.00 GeV
- Total length of the linac = ***230.5 m***
- Total number of quadrupoles = ***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 reachs about *1.03 T* maximum at the last quadrupole which is also lover than *≤ 1.2 T* limit.



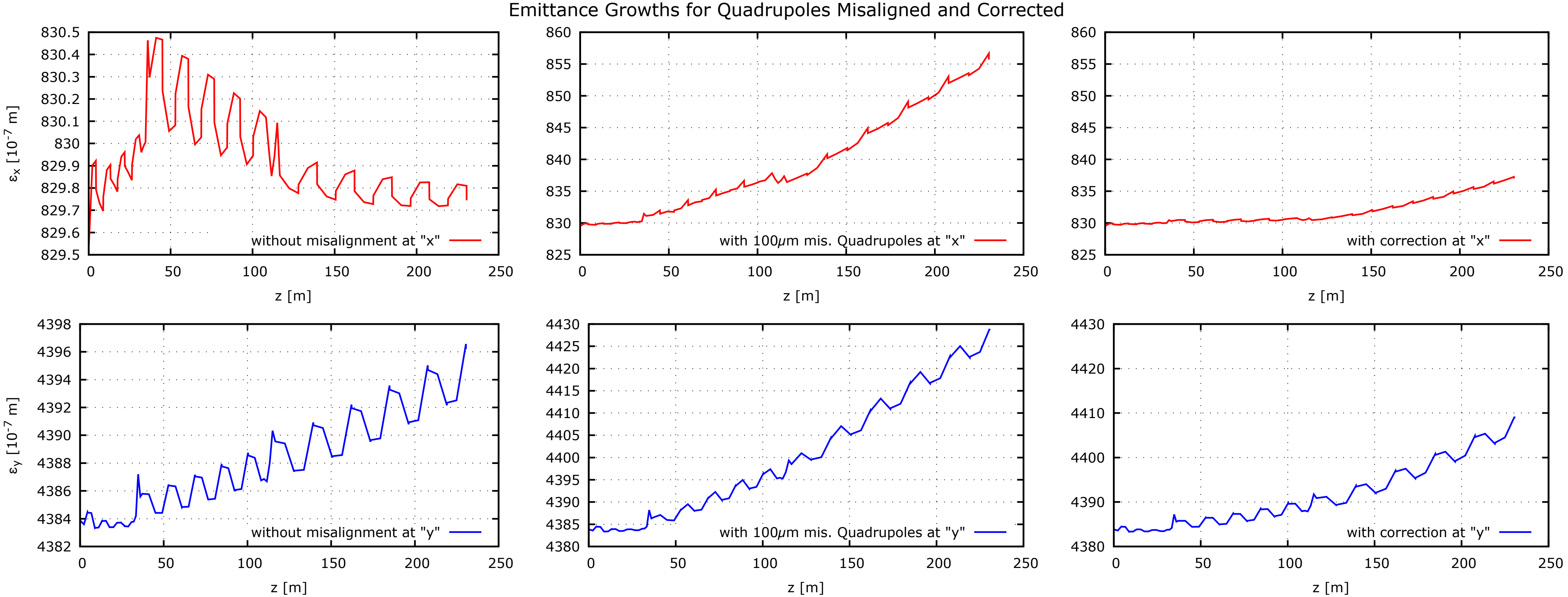




- Little fluctuation in emittance growth for default beam with no misalignments.
- Emittance growths → Nearly 0.0% at "x" and 0.3% at "y" (energy spread = 1%)

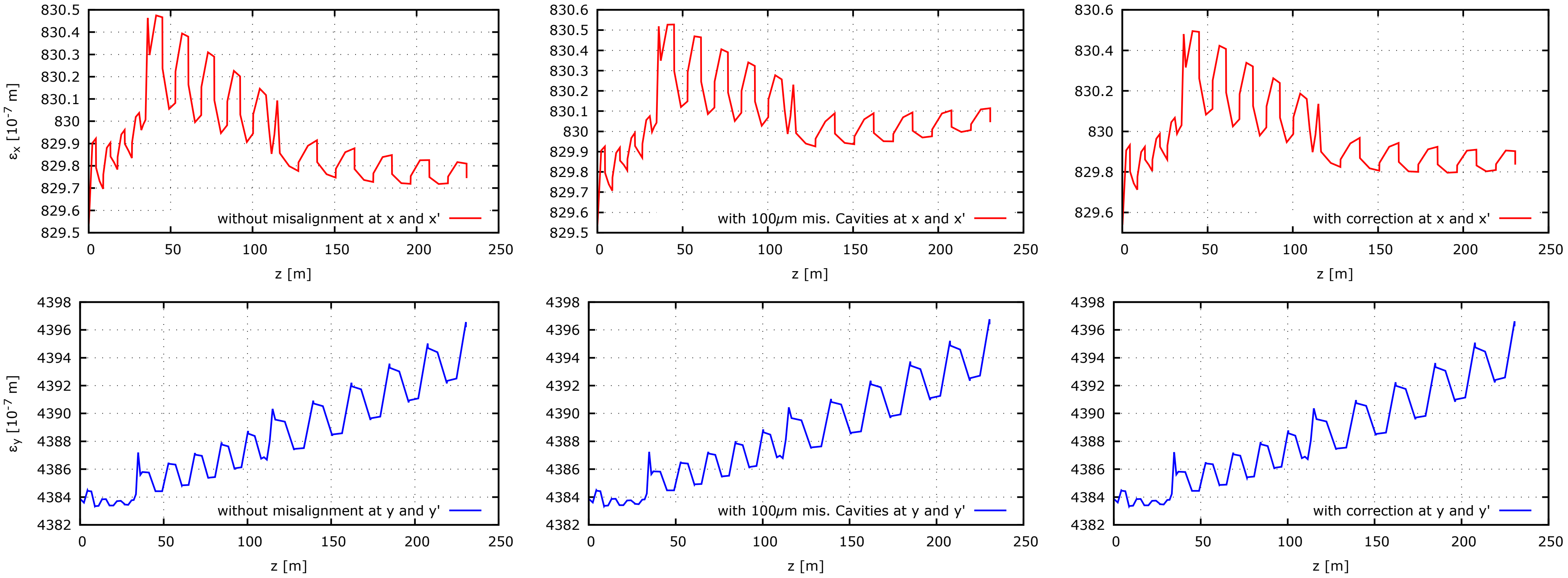
- Elements such as quadrupoles, cavities and BPMs were misaligned randomly ;
  - 100 µm random misalignment for each quadrupole
  - 100 µm random misalignment for each cavity
  - 100 µm random misalignment for each BPM
  - And 100 µm random misalignment for all elements at once
- For correcting these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

# Impact of Misalignments

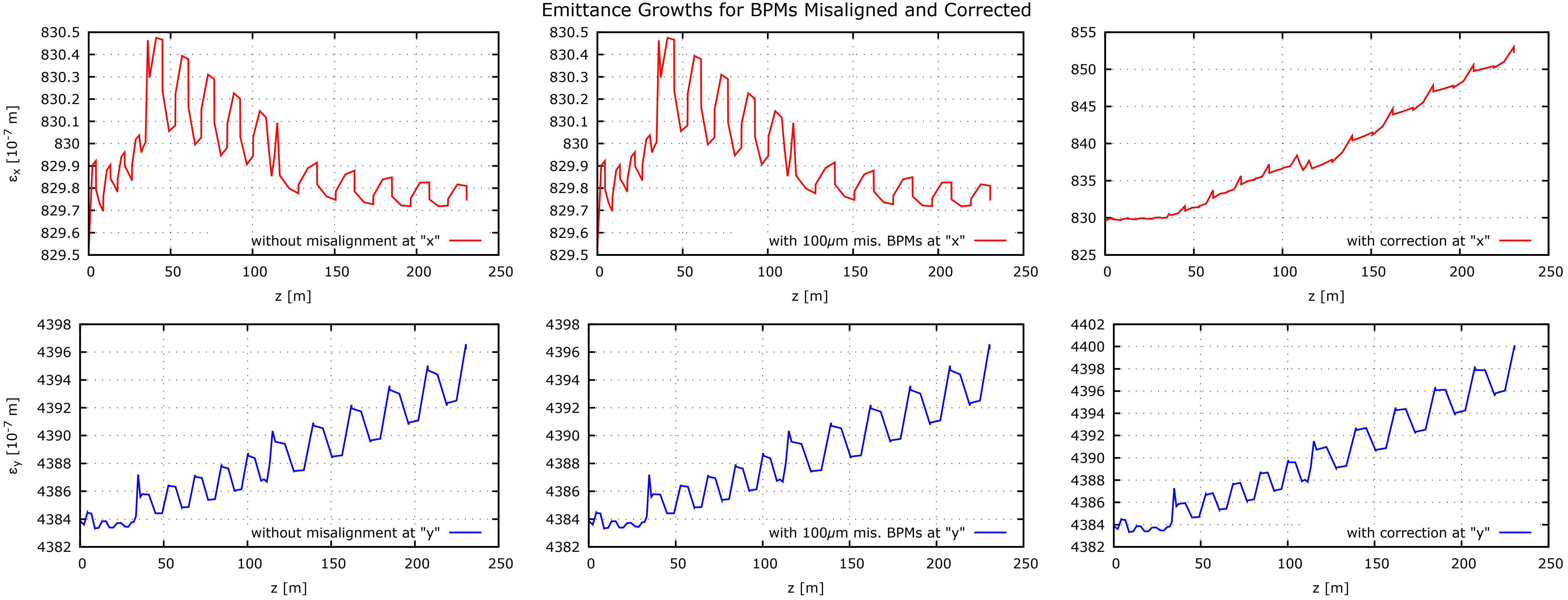



- This graphs show simulations of 100 machines average.
- 100 μm random misalignment for each quadrupole in the beamline.
- 1 to 1 correction works well.
- 100 μm BPM resolution was used.

Emittance Growths for Cavities Misaligned and Corrected

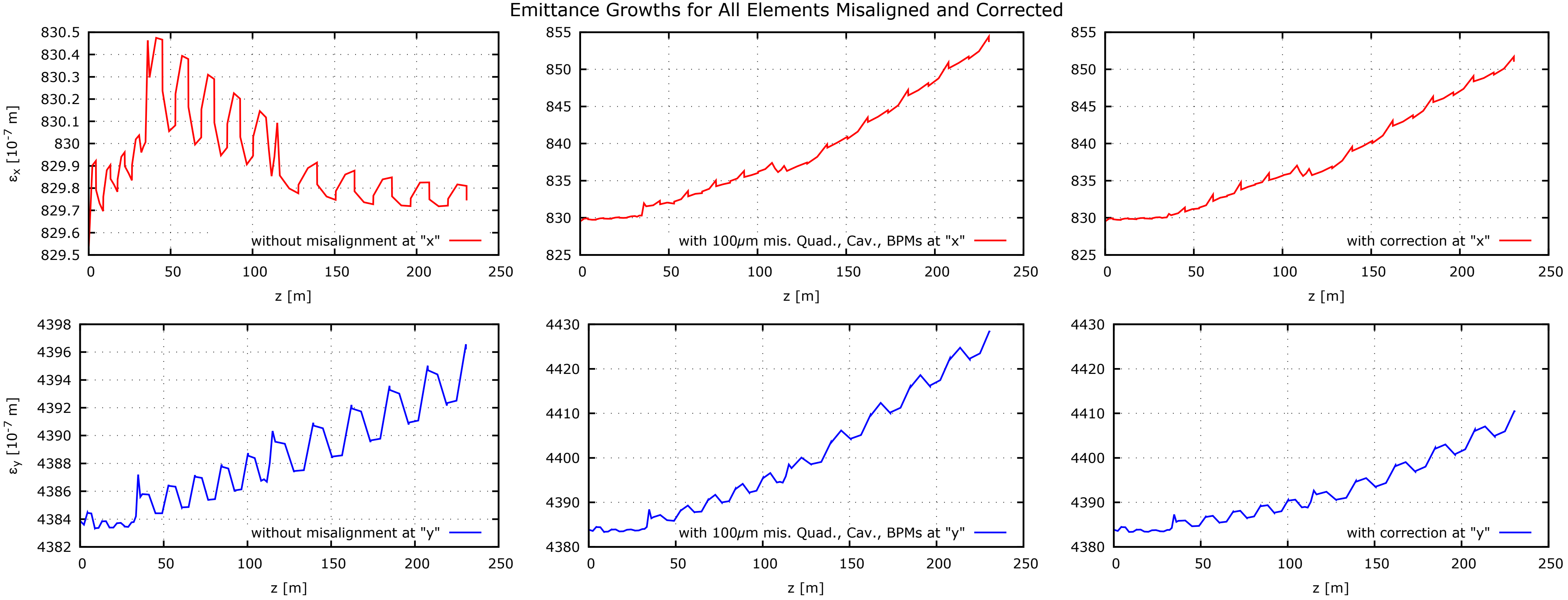



- Wakefield effects <u>included</u> for 2 GHz S-band structures and each cavity misaligned 100 μm randomly.
- This graphs also show simulations for average of 100 machines.
- BPMs were added before each quadrupole and 100 μm BPM resolution was used.




- 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 can be seen comparing to default and it is about 2.5%.
- BPM resolution also 100 µm.

# Impact of Misalignments




- When all the elements in the beamline were misaligned all together about 100 µm randomly, emittance was grown about 2.95% at x and 1.5% at y.
- Even there is no correction, this growth is not too much for all elements misaligned together.

# Conclusion

- Beam dynamics studies and first design of primary 5 GeV $e^-$ linac for CLIC main beam injector complex were done.
- Impacts of misalignments on the beamline for this preliminary design were studied also.
- With these results we can deliver beam in the beamline, but a real optimization study for that design and further possible design options must be done.

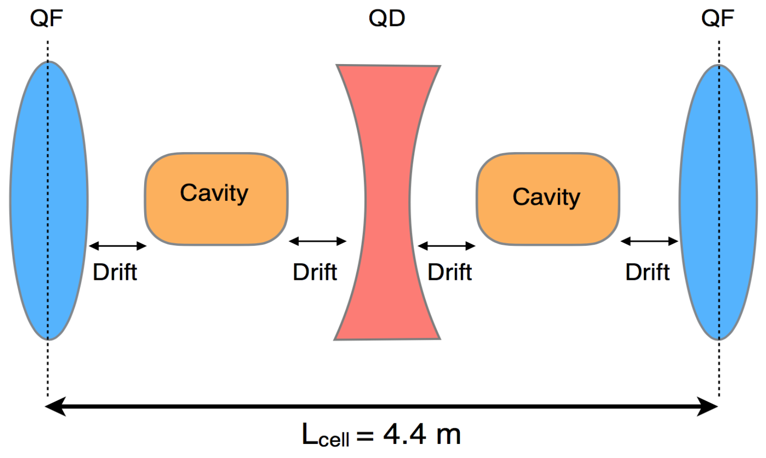
- Aim of the further work about this study is to improve the design, maybe with multiple design options.

- This design uses very high gradient for cavities, what is next in the further work with is a real optimization for this machine with multiple design options.

- With real optimizations in the further work, the main goal is lowering the power consumption and cost of this linac.

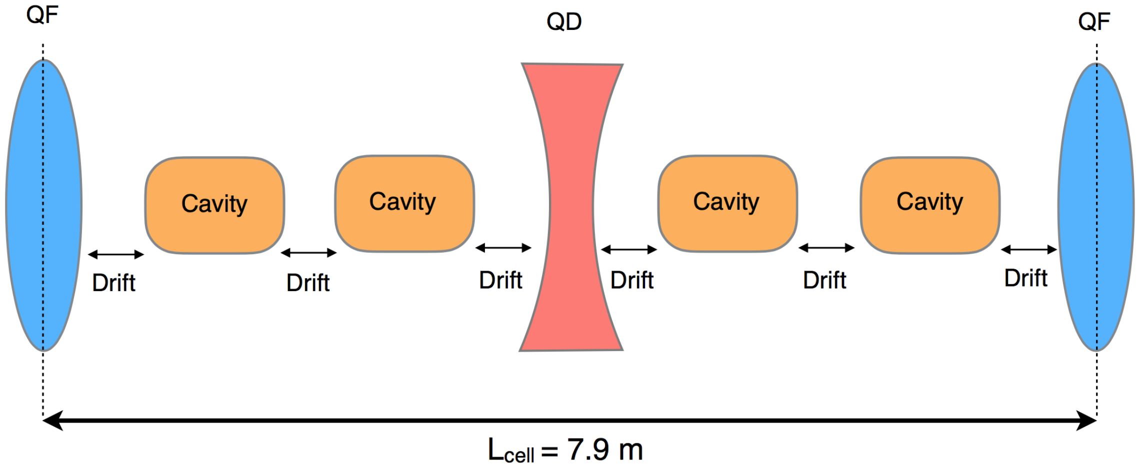
- Also evaluating the requirements from the point of view of the target which electrons impinging on and maybe possible lover energy linac designs such as 3 GeV and 4 GeV after that study.

# THANK YOU
# FOR YOUR ATTENTION !




→ Parameters

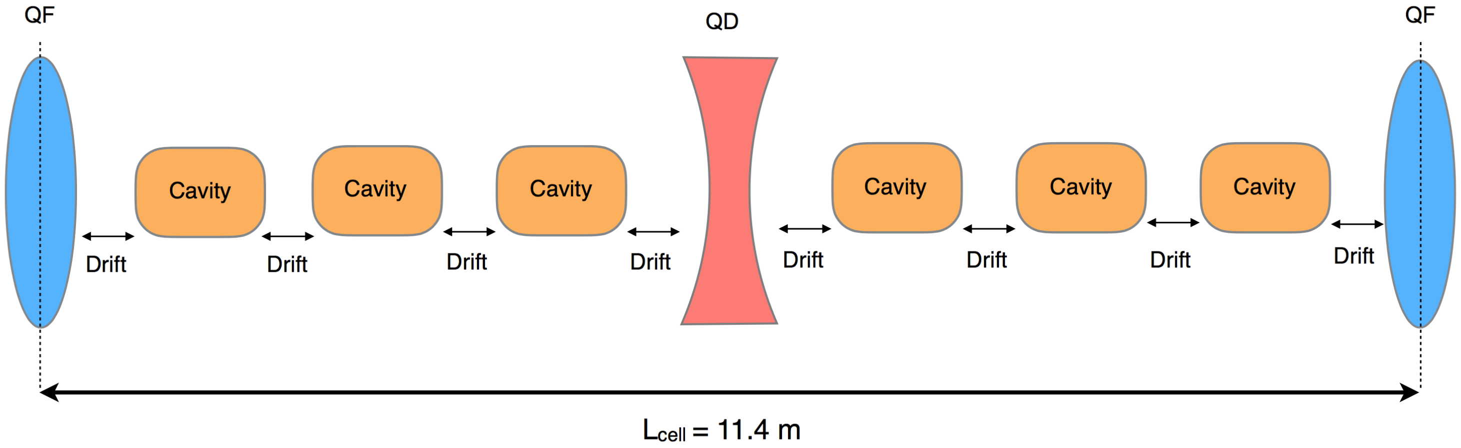
- *Focusing strength, k = 3.2141 $m^{-2}$*
- *$\beta_x$ = 7.3511 m*
- *$\beta_y$ = 1.4016 m*
- *Phase Advance, $\mu = 90^o$*
- *Gradient = 30 MV/m*
- *Each drift = 0.25 m*
- *Each cavity = 1.5 m*
- *Each quadrupole = 0.2 m*
- *Accelerating in one structure = 0.045 GeV*
- *Accelerating in one cell = 0.09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




→ Parameters

- *Focusing strength, k = 1.7901 $m^{-2}$*
- *$\beta_x$ = 13.3195 m*
- *$\beta_y$ = 2.4245 m*
- *Phase Advance, $\mu$ = $90^o$*
- *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 = 0.18 GeV*

# BACKUP: FoDo Cell Designs




→ Parameters

- *Focusing strength, $k = 1.2405\ m^{-2}$*
- *$\beta_x = 19.2919\ m$*
- *$\beta_y = 3.4488\ m$*
- *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*