Beam Dynamics in PIP2 Linac with 10 mA

HOM effects on Transverse Beam Dynamics in HB650

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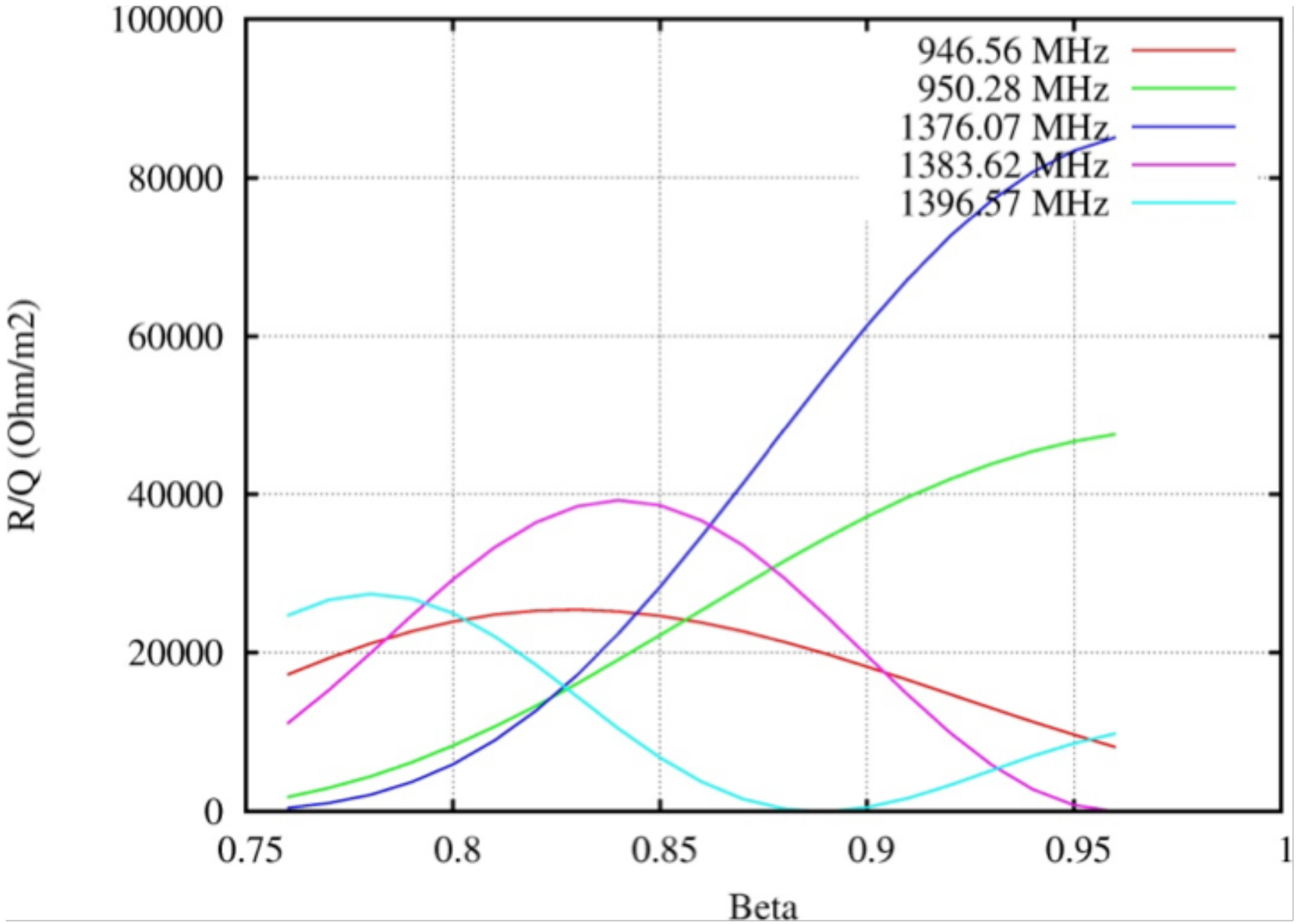
Motivation

- Transverse misalignment of SRF cavities and beam offset lead to excitation of dipole HOMs
  - depends on bunch charge, mode (R/Q), Qext
  - excited dipole HOMs introduce additional kick on beam particles
  - increase of transverse beam emittance
  - small effect in a steady state (CW beam, no variations in beam current and/or bunch timing pattern)
- Study transverse emittance variations due to transitions (beam turn on) and bunch charge variations in HB650 section of PIP2 linac
  - (R/Q) of dipole modes in LB650 are much smaller compared to HB650

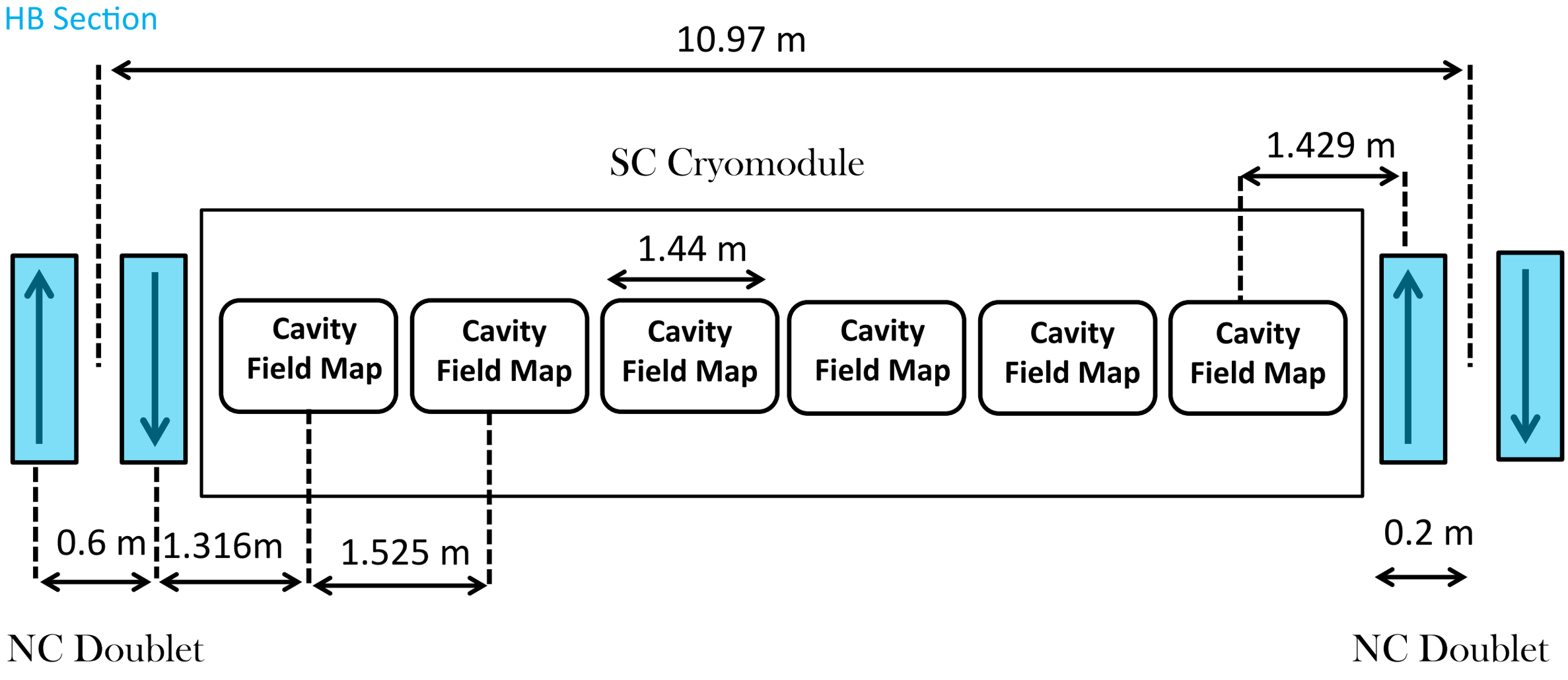
Dipole modes in HB650

- (R/Q) depends on beam velocity
- Mode 1376 MHz: (R/Q)=80kOhm/m2, Qext=1e7



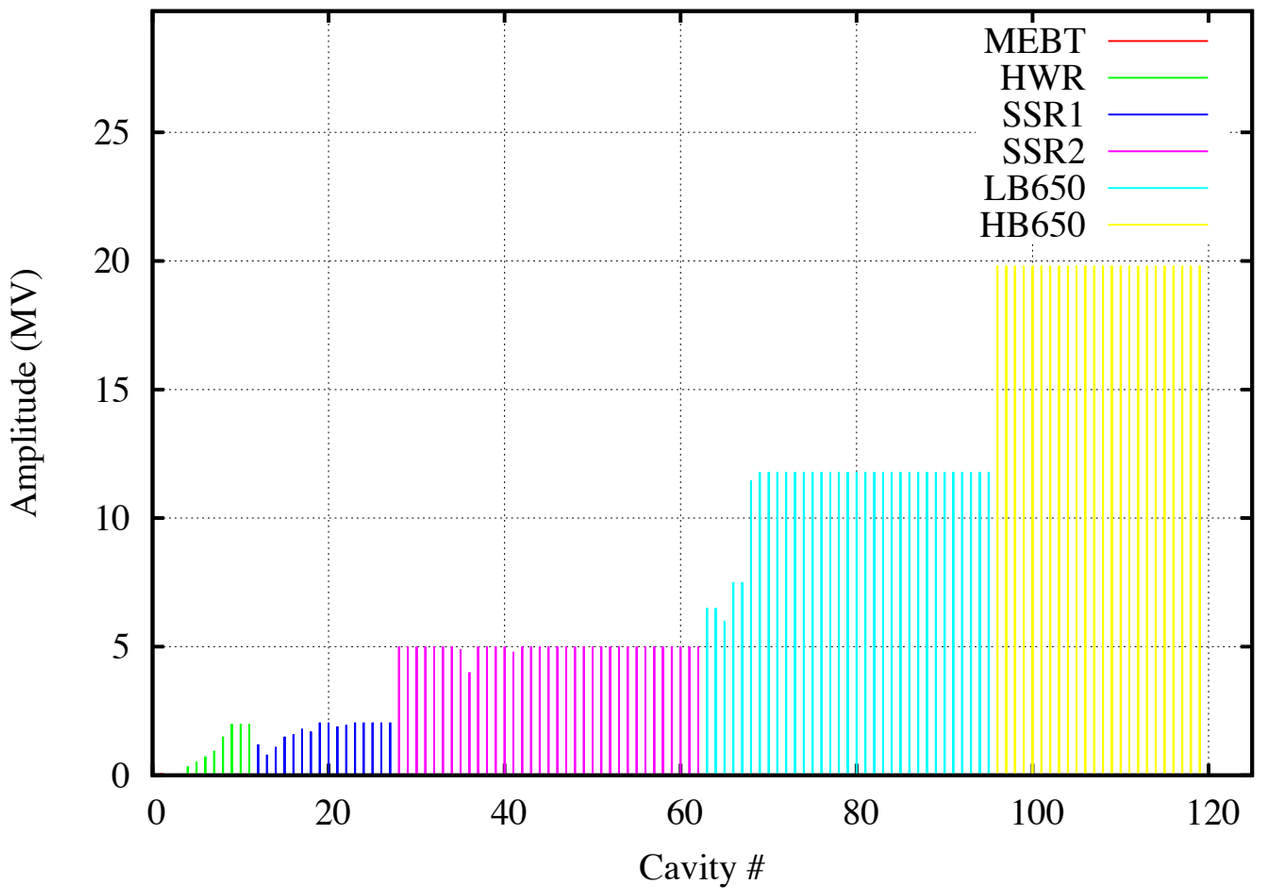
Linac layout

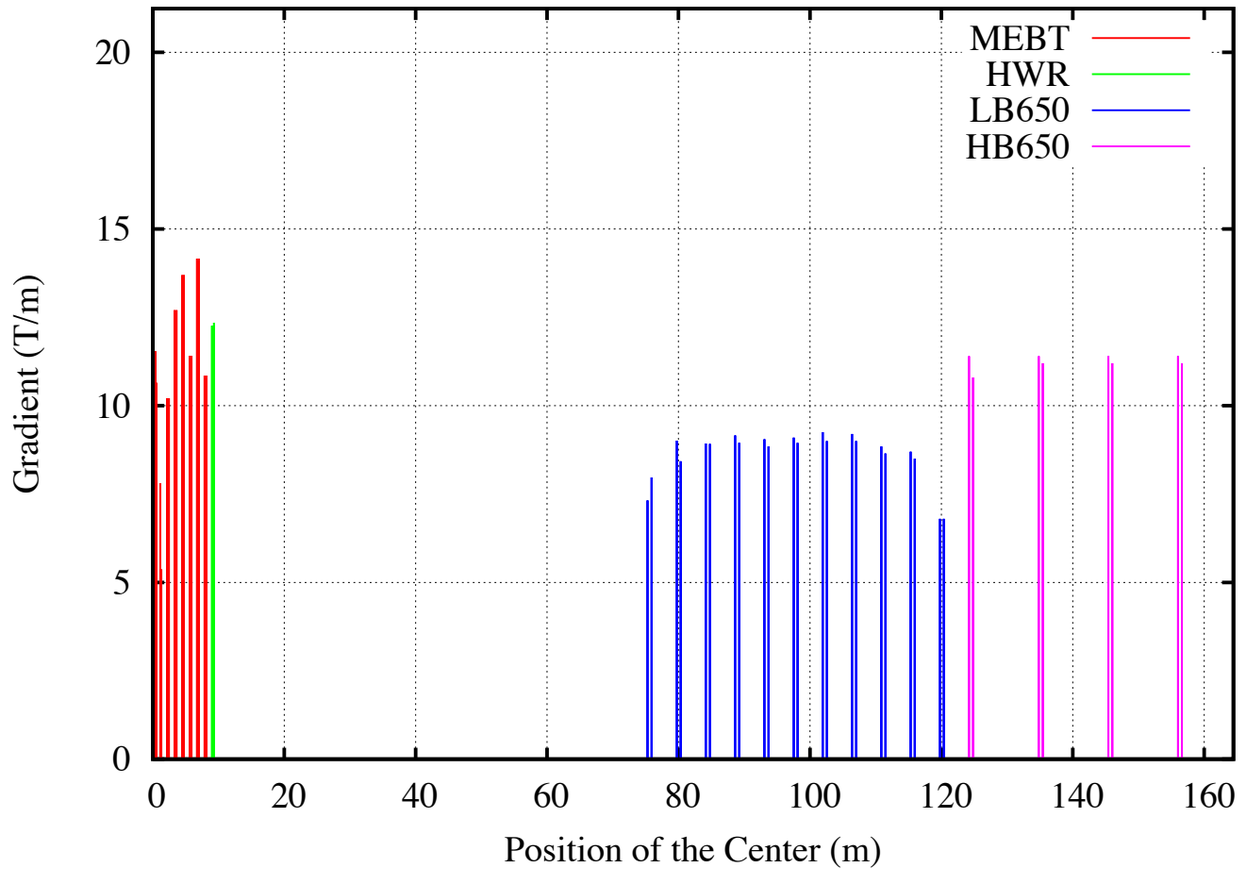
- HB650 beta=0.92 section: 4 cryo-modules, 24 cavities (6 cavities per CM)
- Matrix tracking through linac elements



Cavity Gradient and Quadrupole Fields

- HB650 Vacc(beta_G) = 20 MV
- HB650 Quad gradient 12 T/m



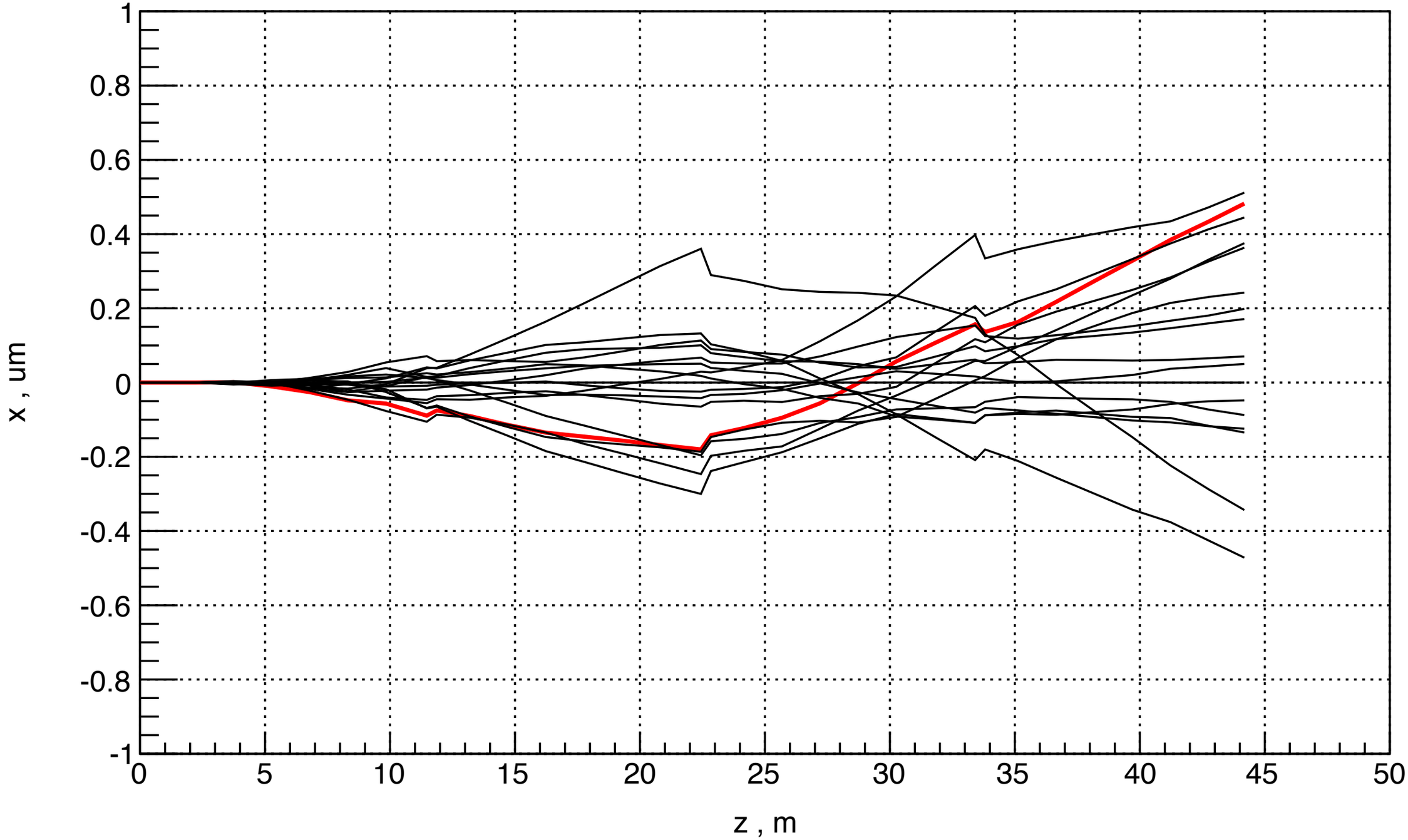


Model

- 60 pC bunches with 10% variation, 162.5 MHz bunch frequency
  - train of 5e6 bunches
- Transverse misalignment of cavities R.M.S. = 0.5 mm
- Matrix tracking through linac
- Consider one dipole mode with highest (R/Q)
- Each bunch introduces voltage V[i] = jcq(R/Q)x
  - bunch sees half of this kick voltage
- Total kick seen by bunch is sum of voltages from all previous bunches with proper time dependent factors: ~exp(jwTb)*exp(-wTb/2Q)
- Simulate 100 linac configurations (time consuming)
  - random variations of transverse displacement of cavities and HOM frequency with 1 MHz RMS
- Calculate effective RMS emittance at the end of linac from variations of (x,x') of bunches
  - compare to nominal emittance 0.3 mm*mrad (relative emittance)

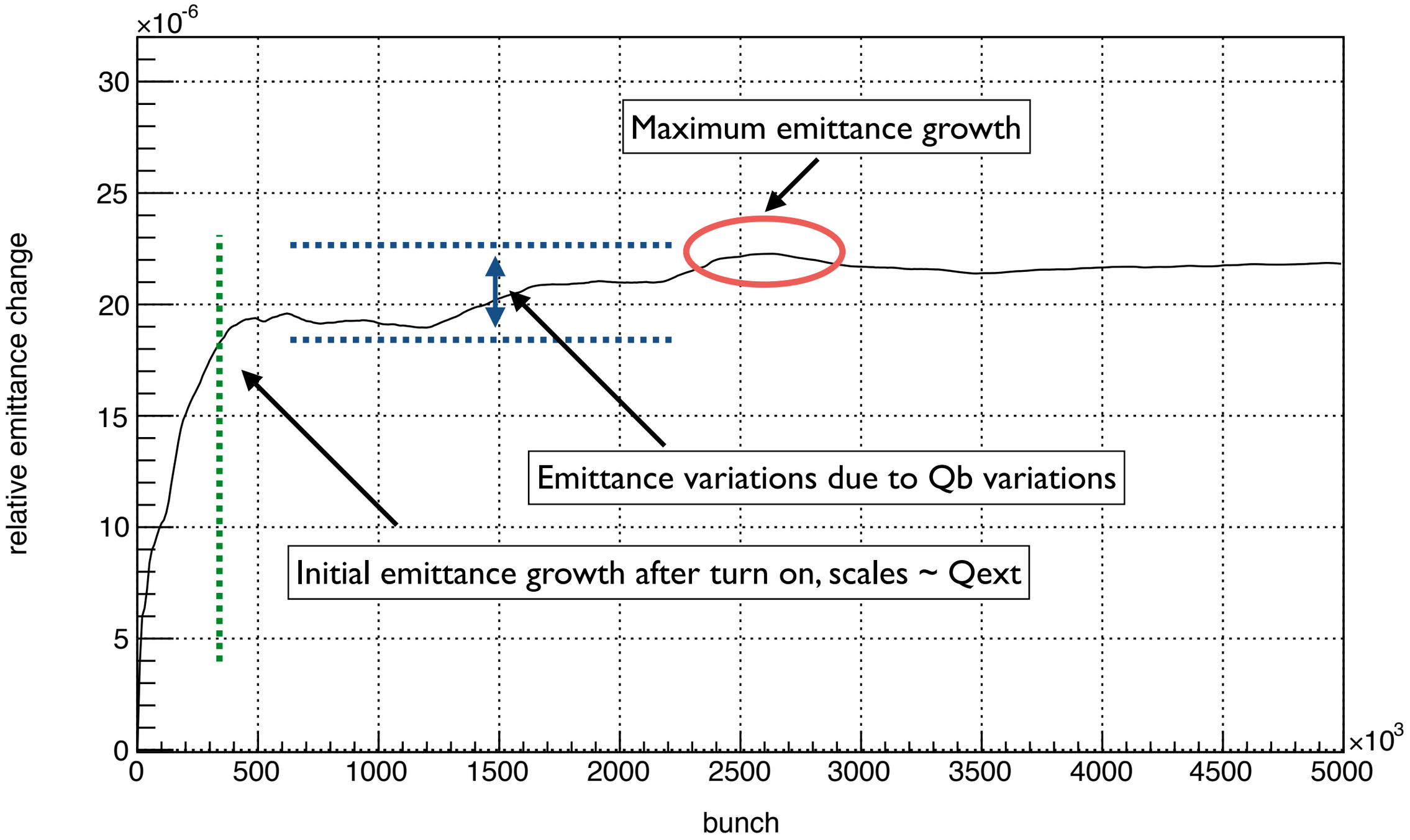
Tracking in linac

- bunch trajectories in linac



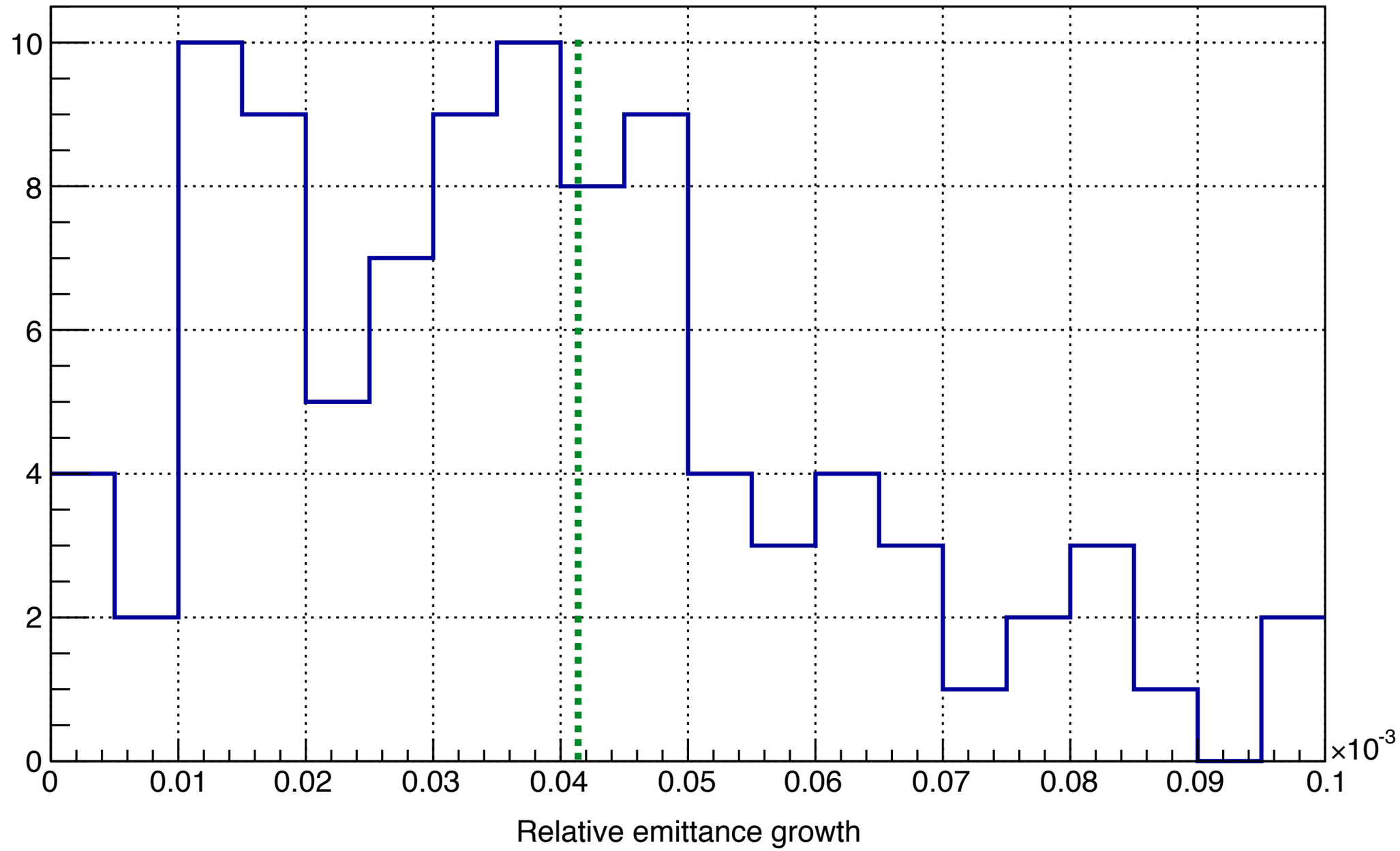
Effective emittance

- Effective emittance at the end of linac for single linac configuration as a function of bunch number



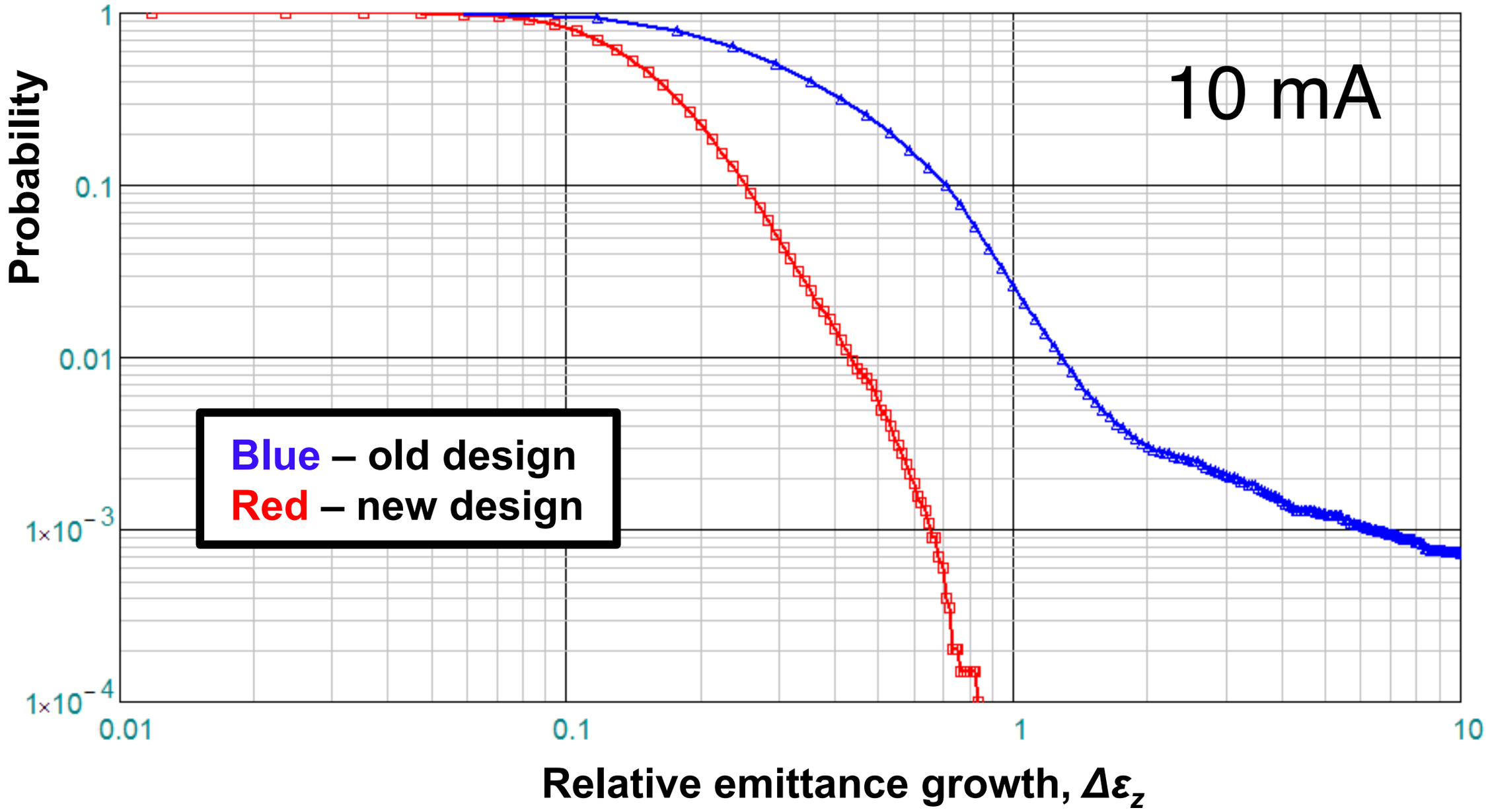
Maximum emittance growth

- 100 configurations of linac with random cavity misalignment of 0.5 mm
  - Median value of relative emittance growth is 4e-5



Longitudinal emittance

- 10 mA (presented in LINAC'12, TUPB054)



Conclusion

- Study effects of dipole HOM excitation on transverse beam dynamics in PIP2 linac with 10 mA peak current
  - Considered mode with largest (R/Q)=80 kOhm/m2, f=1376 MHz, Qext=1e7
  - 0.5 mm random cavity misalignment
  - 10% bunch charge variations
- Relative emittance growth is 4e-5 - should not be a problem in PIP2 linac with 10 mA