Booster Upgrade Requirements and Possibilities

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ASD/OAG

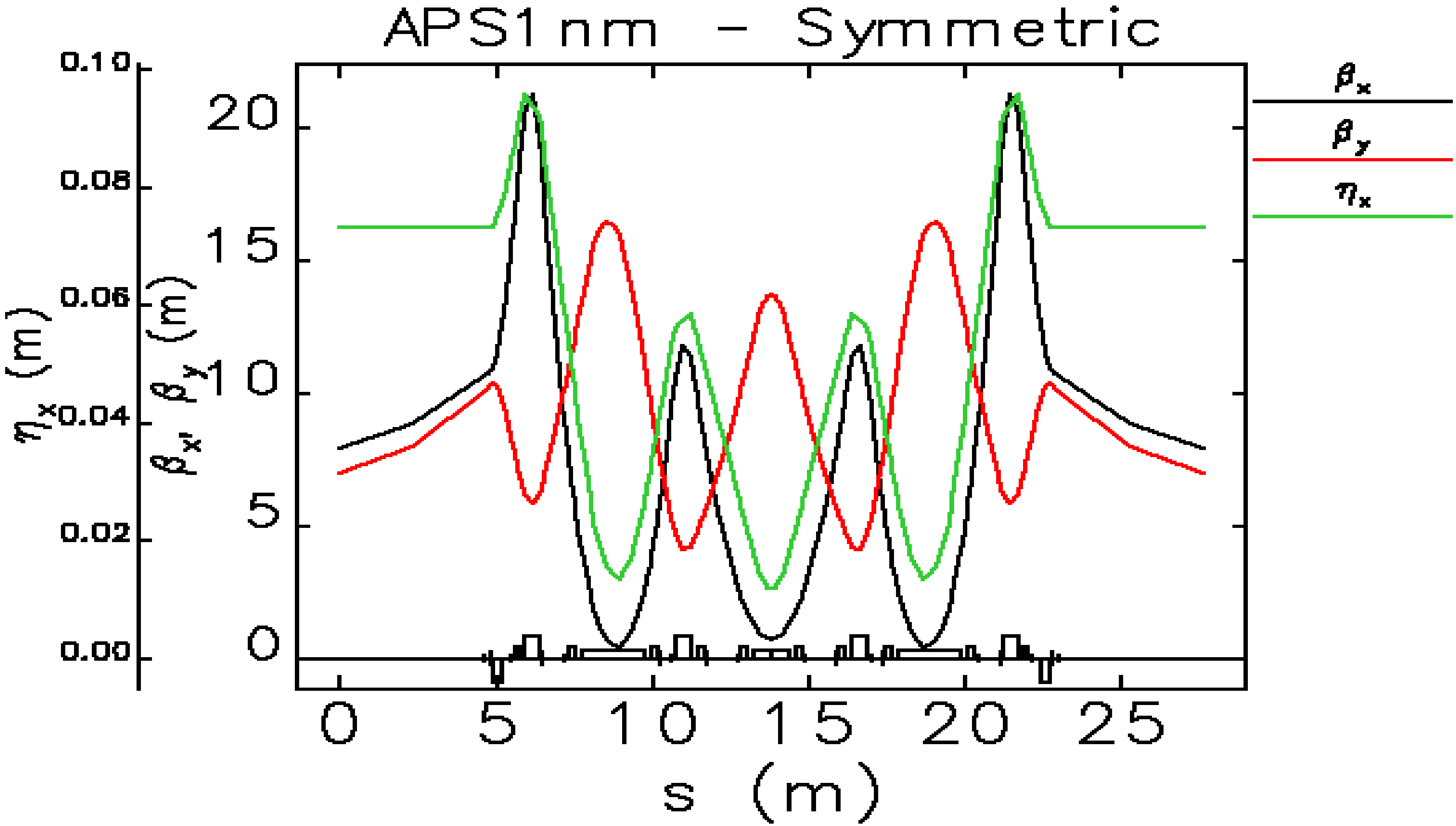
Outline

- Booster upgrade requirements
- APS 1 nm lattices used for injection simulations
- Injection straight section layout
- Injection simulation parameters/setup
- Injection simulation results
- Low emittance booster lattice design
- Conclusion

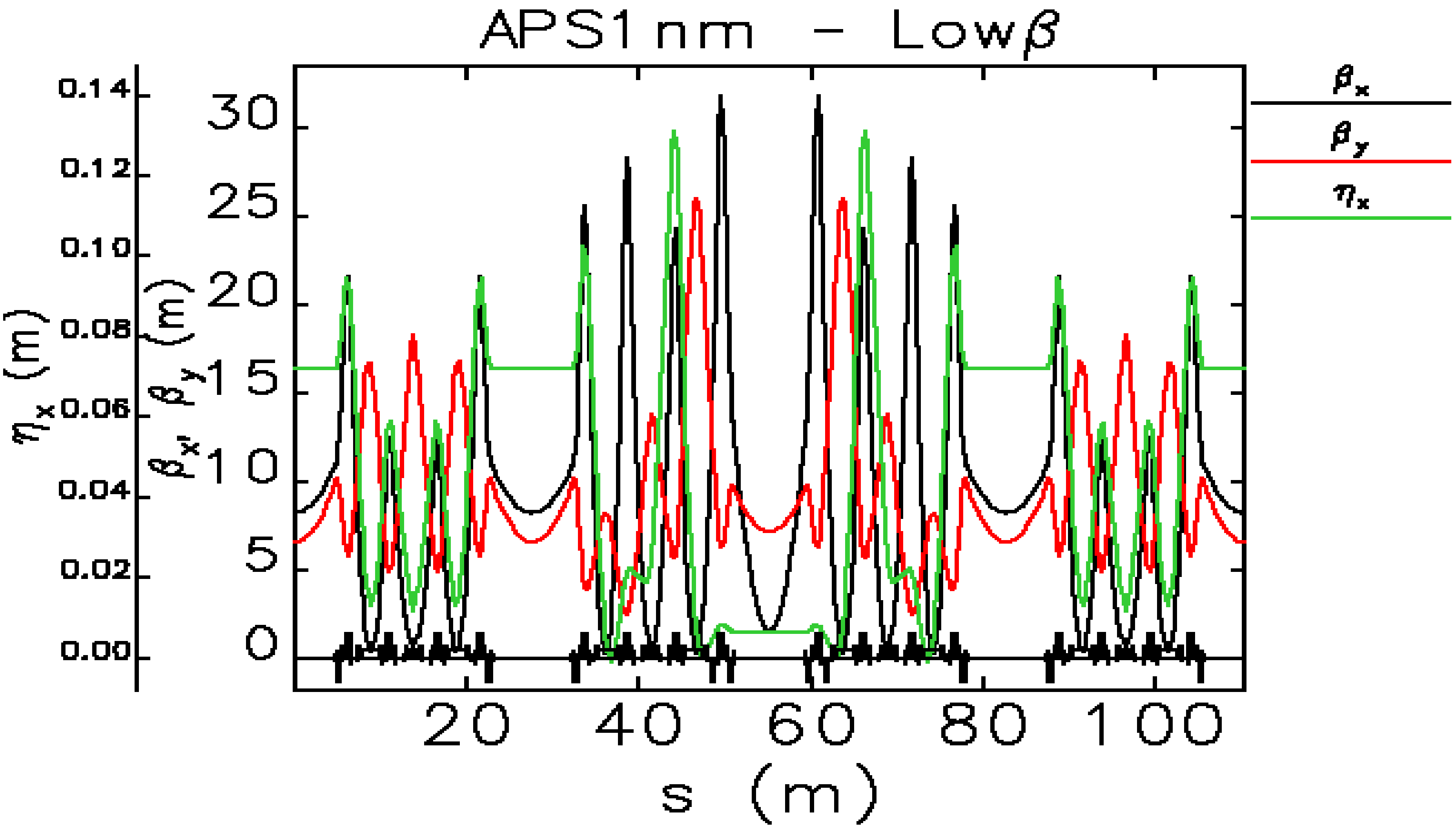
Requirements

- Estimate requirements based on properties of both APS 1 nm emittance upgrade lattices developed by M. Borland, A. Xiao
- Requires at least 1.25 nC charge/shot to do top-up for:
  - 200 mA stored beam current
  - 30 seconds (or less) top-up interval
  - Lifetime for both lattices is approximately 5 hours
- Maximum booster emittance determined by evaluating injection losses/efficiency as a function of booster emittance for:
  - Two different injection bumps for each lattice
  - All relevant ID straight section/septum apertures
  - Include multipole, strength and misalignment errors

APS 1 nm Upgrade Lattices (A. Xiao, M. Borland)



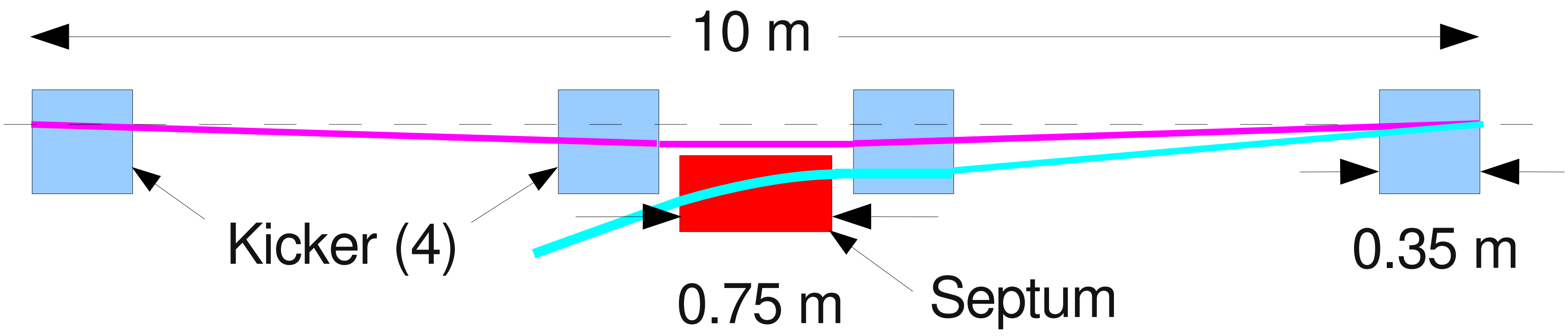
APS 1 nm Upgrade Lattices (A. Xiao, M. Borland)



APS 1 nm Lattices (A. Xiao, M. Borland)

- Common lattice half-aperture elements used in injection simulations:
  - ID – 3 cm horizontal, 4 mm vertical
  - Vacuum chamber – 3 cm horizontal, 1.5 cm vertical
  - Septum – 6 mm (5 mm bump), 10 mm horizontal (9 mm bump)
- Only used errors generated using one seed.
- Error levels used resulted in ~5 and ~10 % beta function beat for each lattice
- Symmetric four kicker injection bump in one 10 m straight section

Injection Straight Section Layout



h = bump height (5, 9 mm)

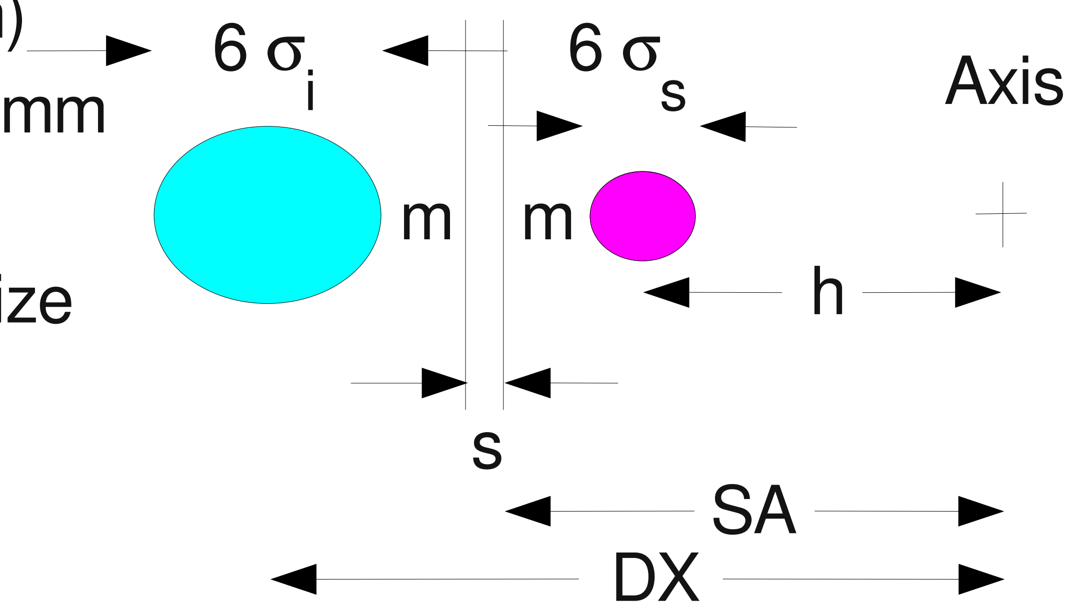
s = septum thickness = 2 mm

m = margin = 0.5 mm

σ = inj/stored beam rms size

SA = septum aperture

DX = injected beam disp.

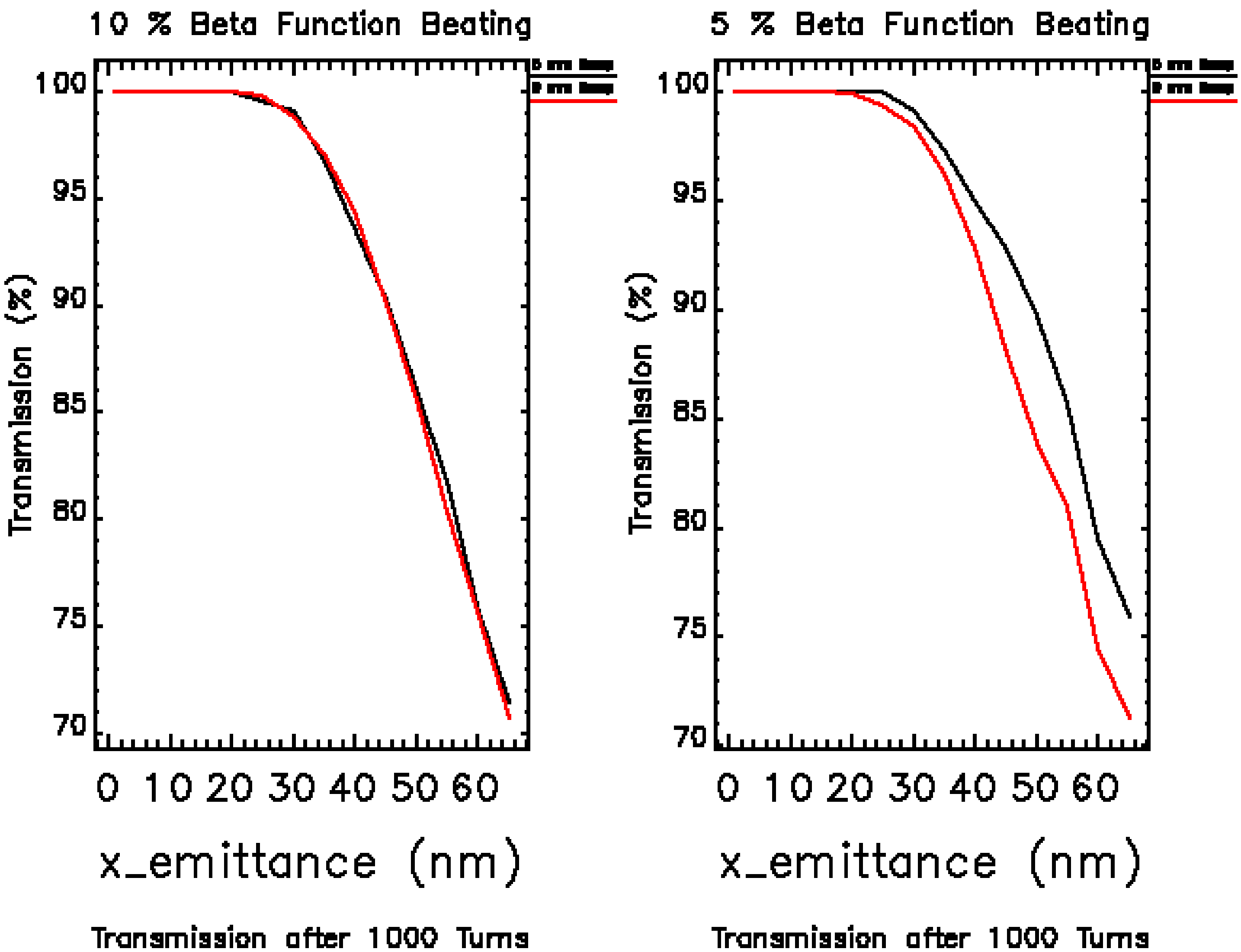


Simulation Parameters/Setup

- Use two bumps:
  - 5 mm bump, 1.3 mrad kicker angle (what we have now)
  - 9 mm bump, 2.3 mrad kicker angle (77 % more than we have now)
- Track for 1000 turns (~1/2 a damping time)
- Used kicker waveform for present APS kickers (assume the same for all kickers)
- Used matched beta functions (inc. longitudinal) for the injected beam
- Vary the injected beam horizontal emittance between 1 and 65 nm (present booster)
- Used 5 % coupling for injected beam
- Use 10 MV RF voltage and synchrotron radiation effects (including quantum excitation)

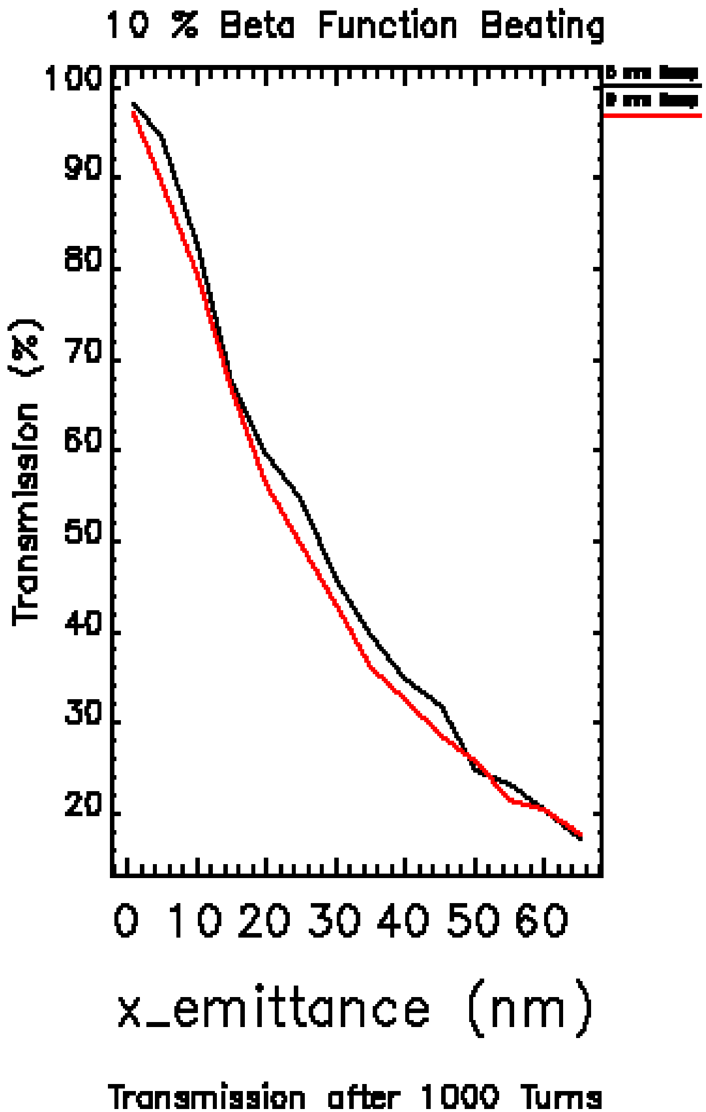
Results for symmetric lattice with 5 and 10 % beta beat

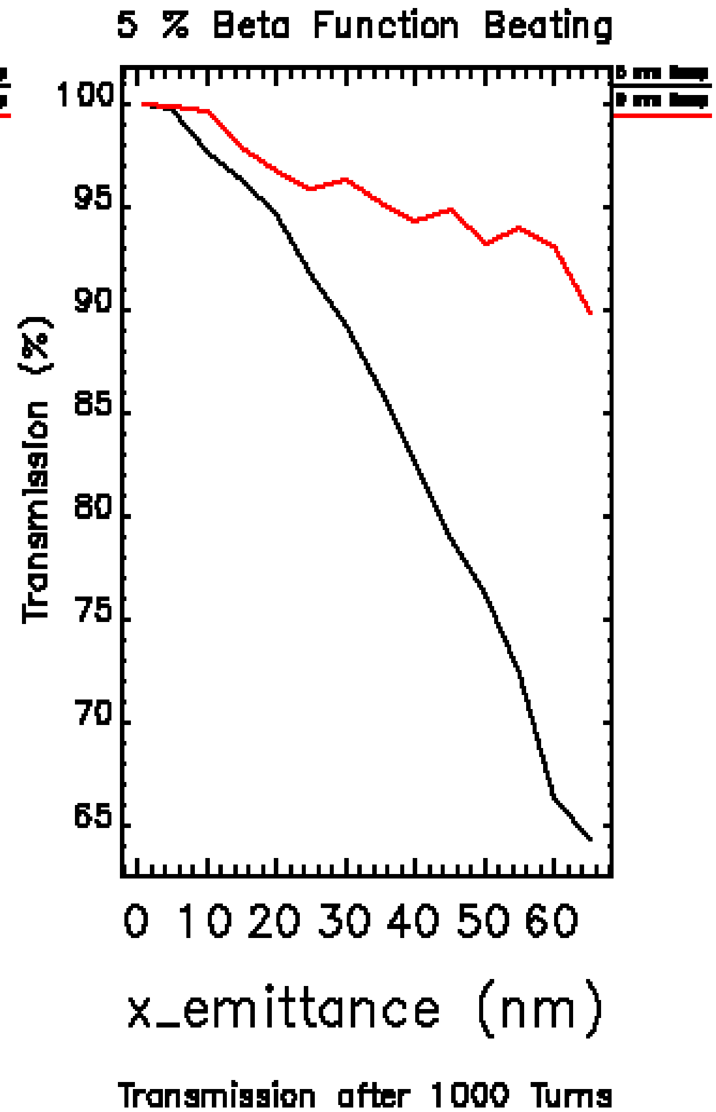
- ~20 nm booster emittance required to avoid losses
- Independent of bump height



Results for low-beta insertion lattice with 5 and 10 % beta beat

- Losses even as low as 1 nm booster emittance for 10 % beta beat
- 5 % beta beat results much better (in terms of transmission)

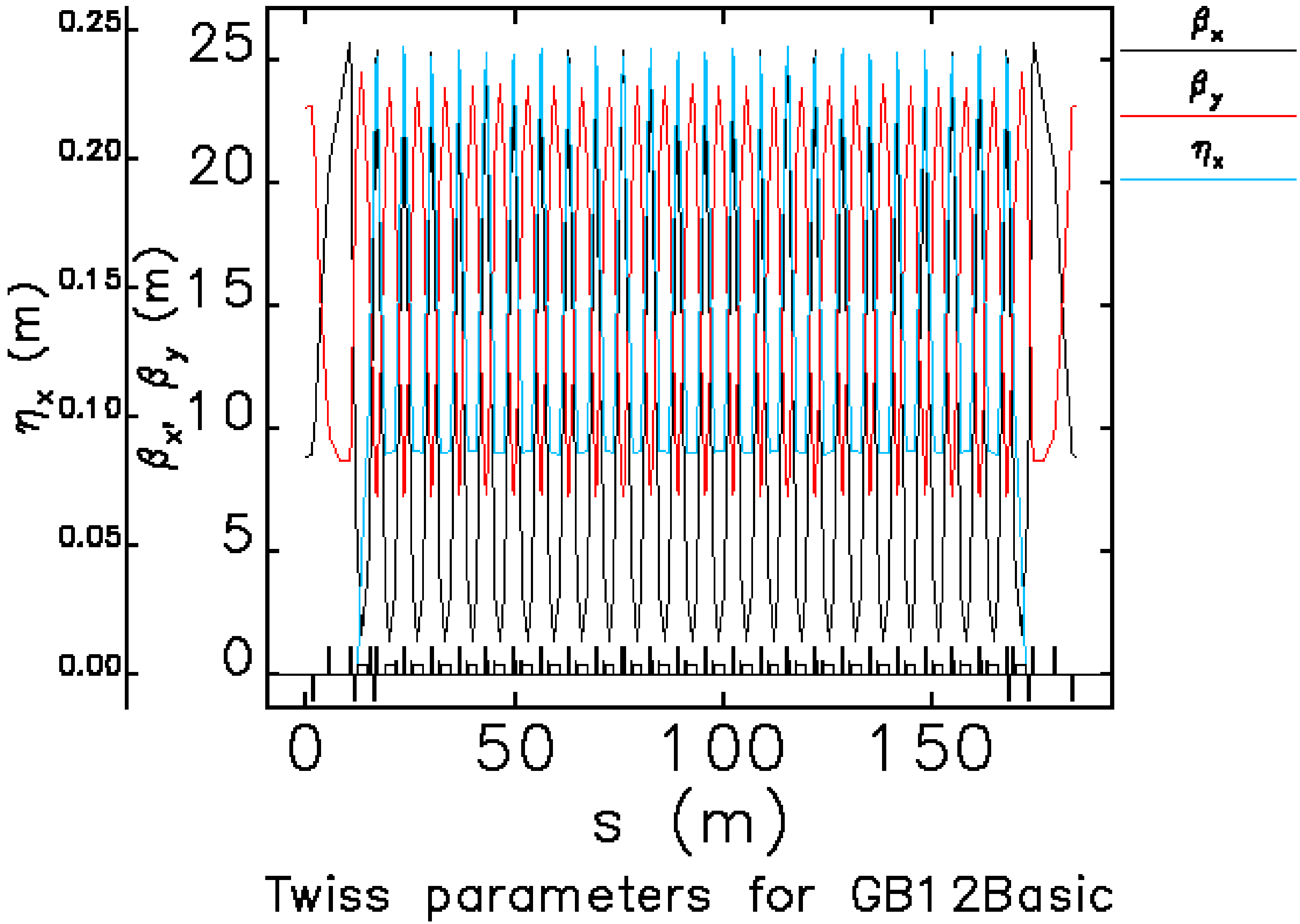




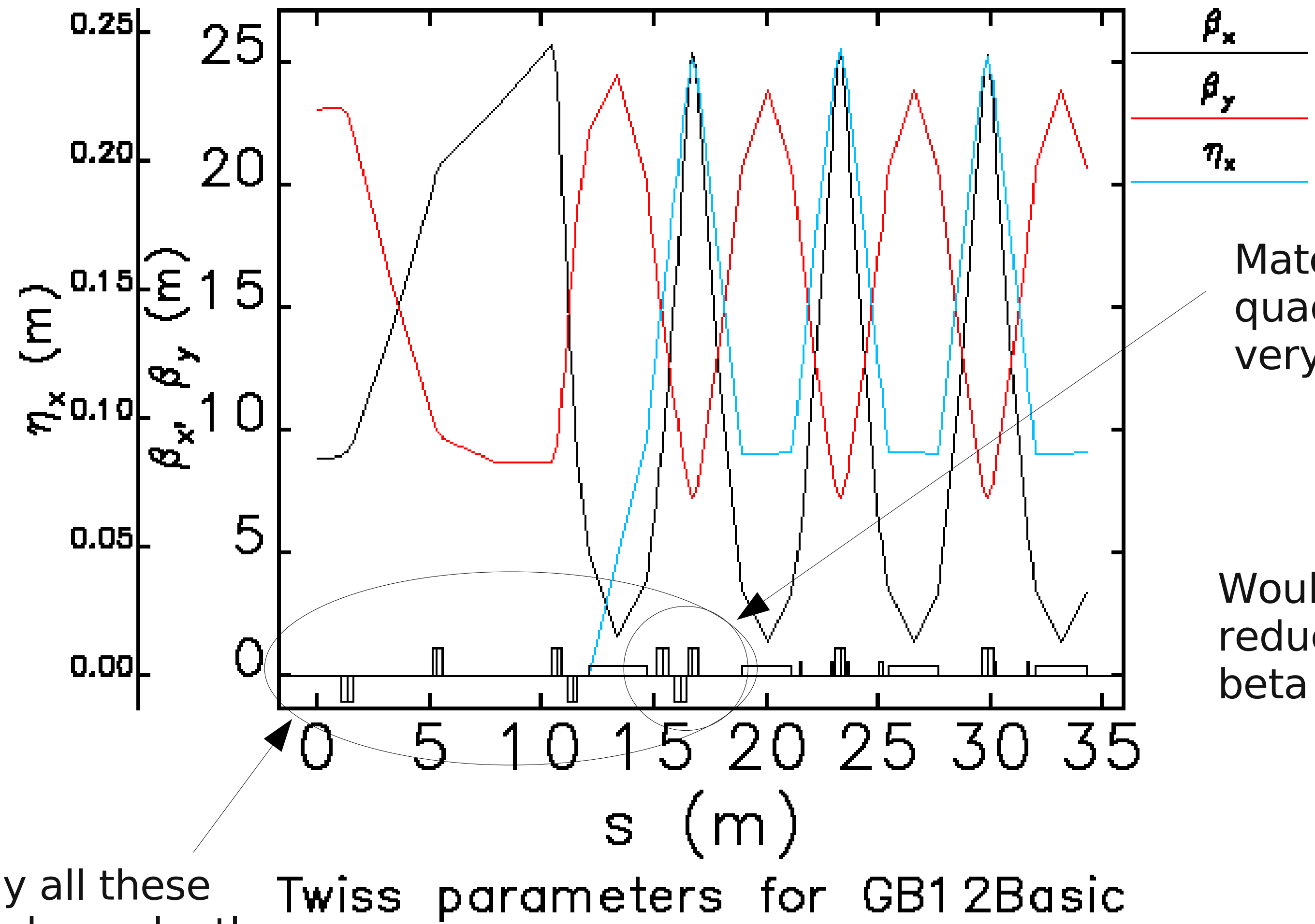
Booster upgrade low emittance lattice (M. Borland)

- FODO-like lattice with gradient dipole
  - QF-SF-SD-QDBEND-QF
  - Make cells longer
  - 50 dipoles, 144 quadrupoles, 92 sextupoles
  - 9.5 nm emittance
  - Relatively weak sextupoles
  - Dynamic and momentum aperture are fine
- Present booster
  - FODO lattice
  - 68 dipoles, 80 quadrupoles, 64 sextupoles
  - 92nm emittance reduced to 65 by off-momentum config.

Booster 9.5 nm emittance lattice arc twiss functions



Booster 9.5 nm emittance lattice straight section matching



Matching quads, two are very weak

Would like to reduce maximum beta functions…

Presently all these quads independently powered

Conclusion

- Symmetric lattice for 5 and 10 % beta beat -
  - 20 nm for both 5 and 9 mm bump heights
  - Transmission/losses the same for both 5 and 10 % beta beat
- Low-beta insertion lattice 10 % beta beat -
  - Large losses for both 5 and 9 mm bump heights even at 1 nm emittance
  - Losses independent of bump height
- Low-beta insertion lattice 5 % beta beat -
  - Greatly reduced losses for 5 mm bump height
  - Best transmission for the 9 mm bump (losses mostly at septum)
  - 20 nm booster emittance would be adequate for the 9 mm bump

Conclusion cont.

- Need to repeat injection simulations with many error level seeds for each emittance
- Upgrade low 10 nm low-emittance booster design exists that would fit inside the booster tunnel
- Simulations indicate a 20 nm booster would be adequate (Present booster is 65 nm)