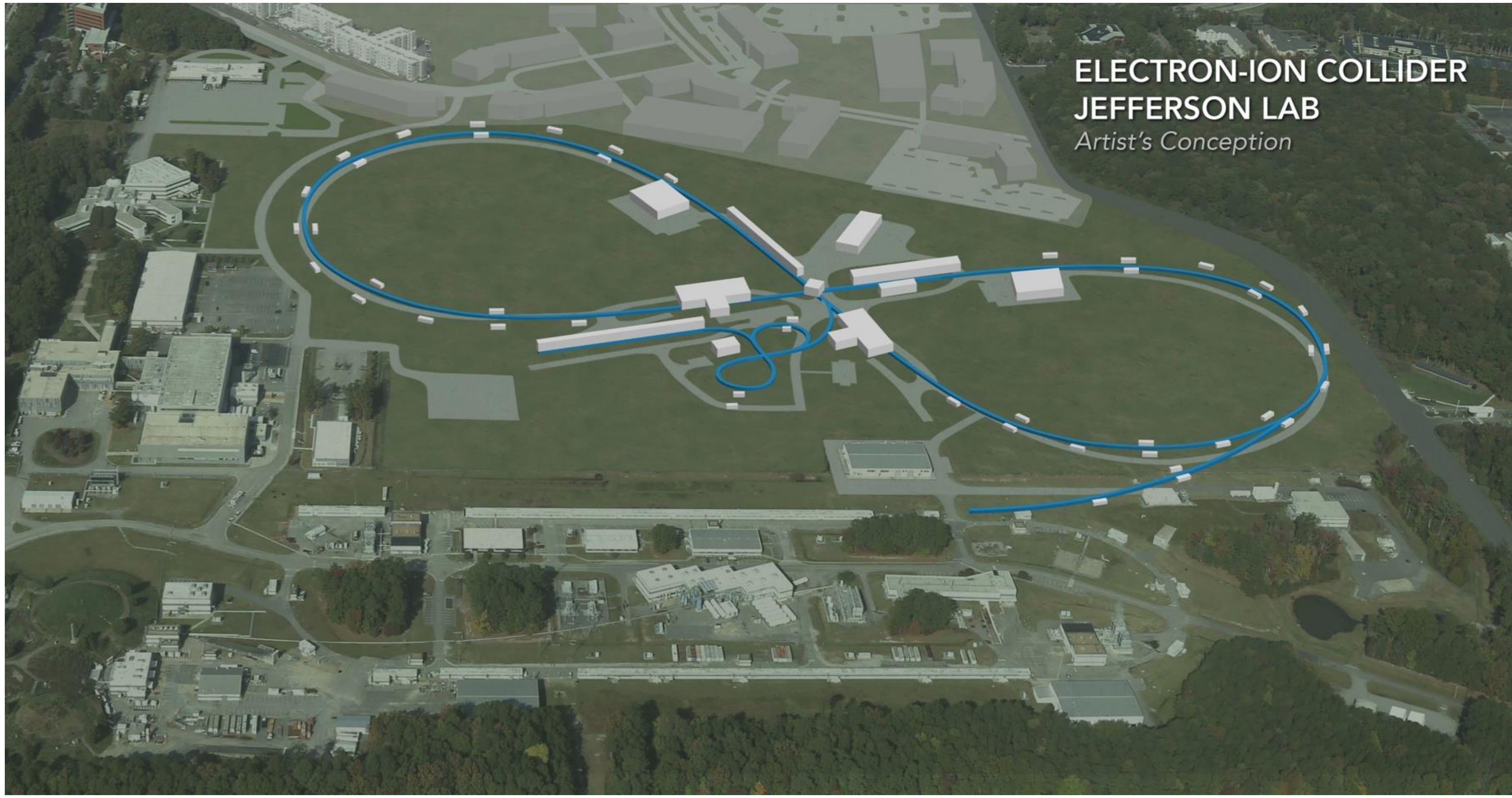
JLEIC Ion Booster

Edith Nissen



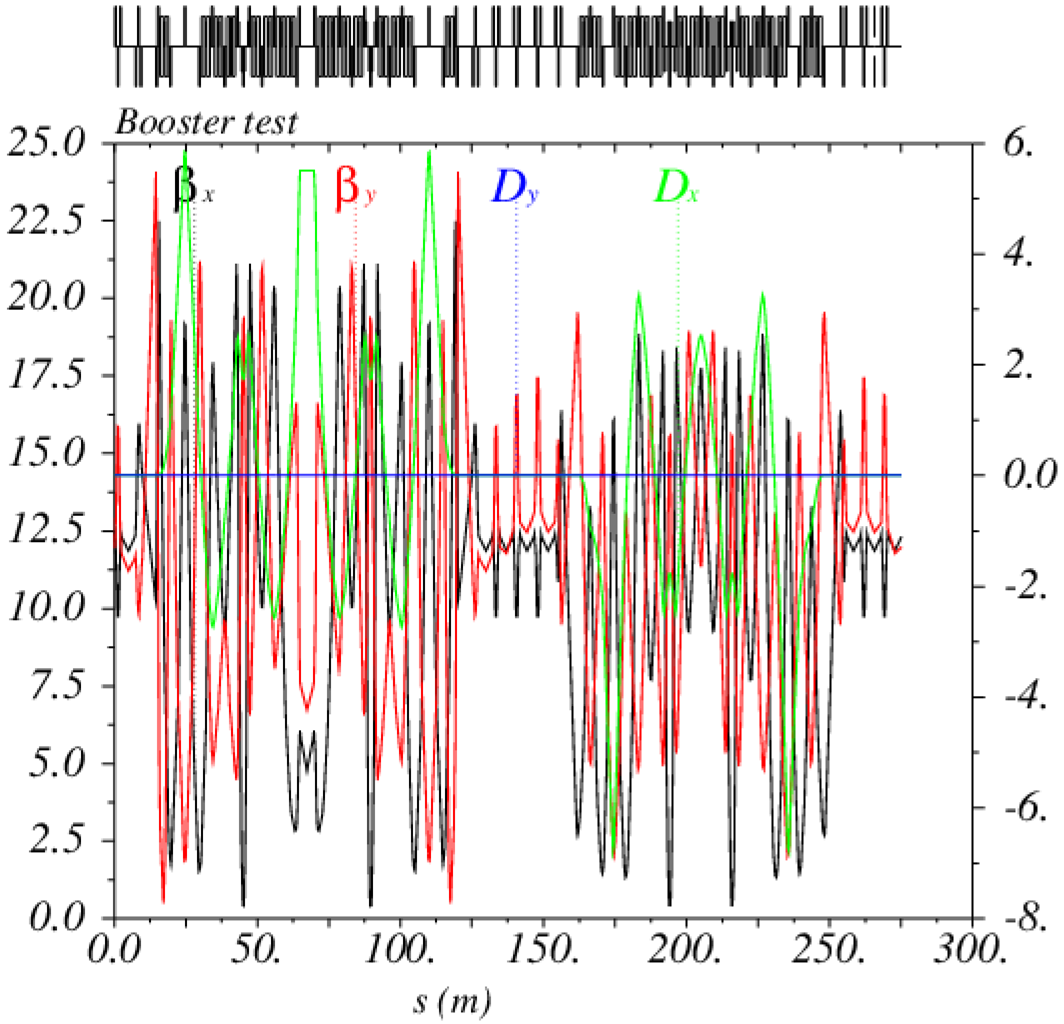
EIC Accelerator Collaboration Meeting

October 29 - November 1, 2018

Outline

- A look at the previous design, as well as the criteria for a redesign
- Background on the Lattice types in use
- The booster lattice
- How the booster fits into the larger complex
- Injection Simulations
- RF ramping simulations
- Future work

Previous Design



Terminal

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++++++ table: summ

         length             orbit5               alfa            gammatr
      275.08692                 -0   -0.005170832766       -13.90656128

             q1                dq1            betxmax              dxmax
    7.570925229        1.556940388        22.49295125        6.781225699

          dxrms             xcomax             xcorms                 q2
    2.104554404                  0                  0        5.574495795

            dq2            betymax              dymax              dyrms
    1.073452627        24.09503927                  0                  0

         ycomax             ycorms             deltap            synch_1
              0                  0                  0                  0

        synch_2            synch_3            synch_4            synch_5
              0                  0                  0                  0
stop;
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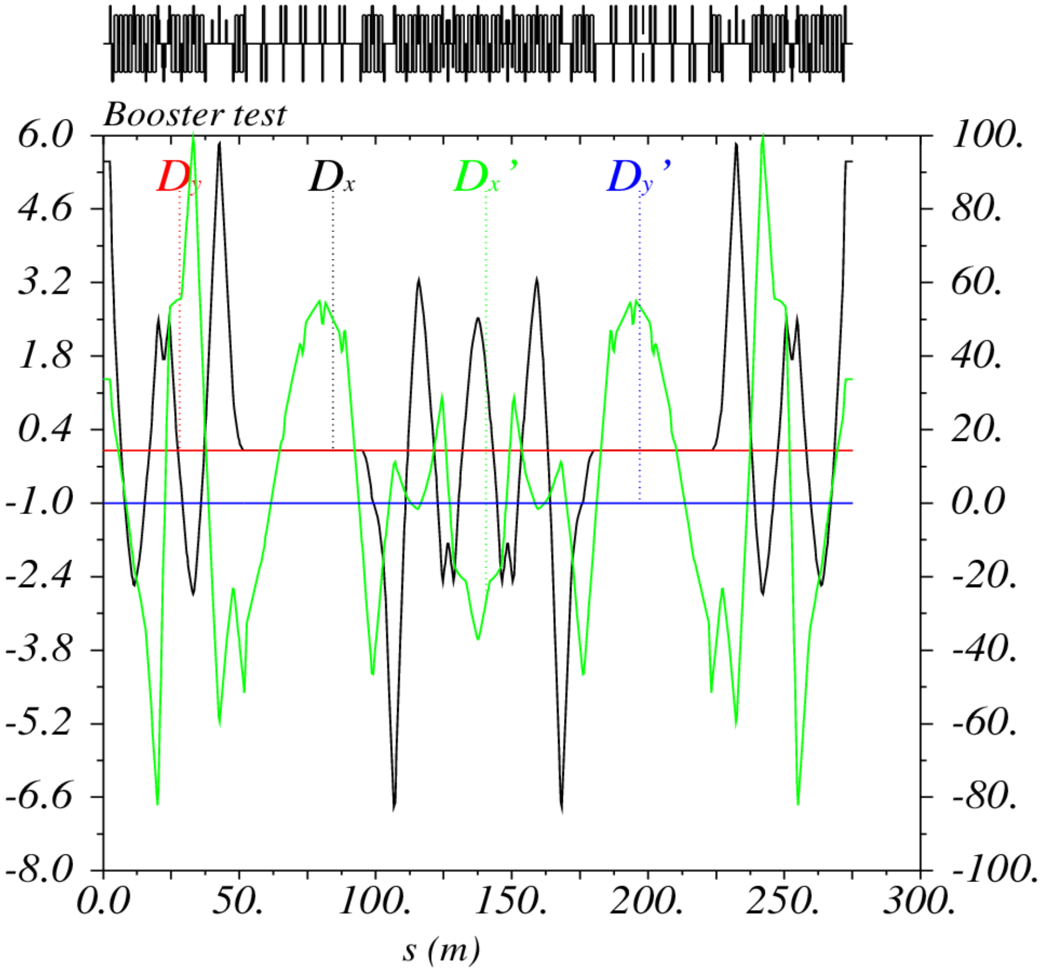
Imaginary Transition and Nonlinear Dispersion



- The same methods which allow the lattice to have an imaginary transition crossing also give rise to a nonlinear dispersion.
- In this particular case we ended up with the RF cavity right at the peak, but it still leads to synchrobetatron issues.

New Design (goals)

- Increase in top energy from 7.1 GeV to 8 GeV
  - Requires increase in dipole length, due to fixed 3T dipole requirement.
- Imaginary transition not required, but transition crossing not allowed
  - Opens up other lattice possibilities

Flexible γ_t background

$$\alpha = \frac{1}{L}\int \frac{D}{\rho} ds$$

- The momentum compaction is the rate of change of the path length with respect to momentum

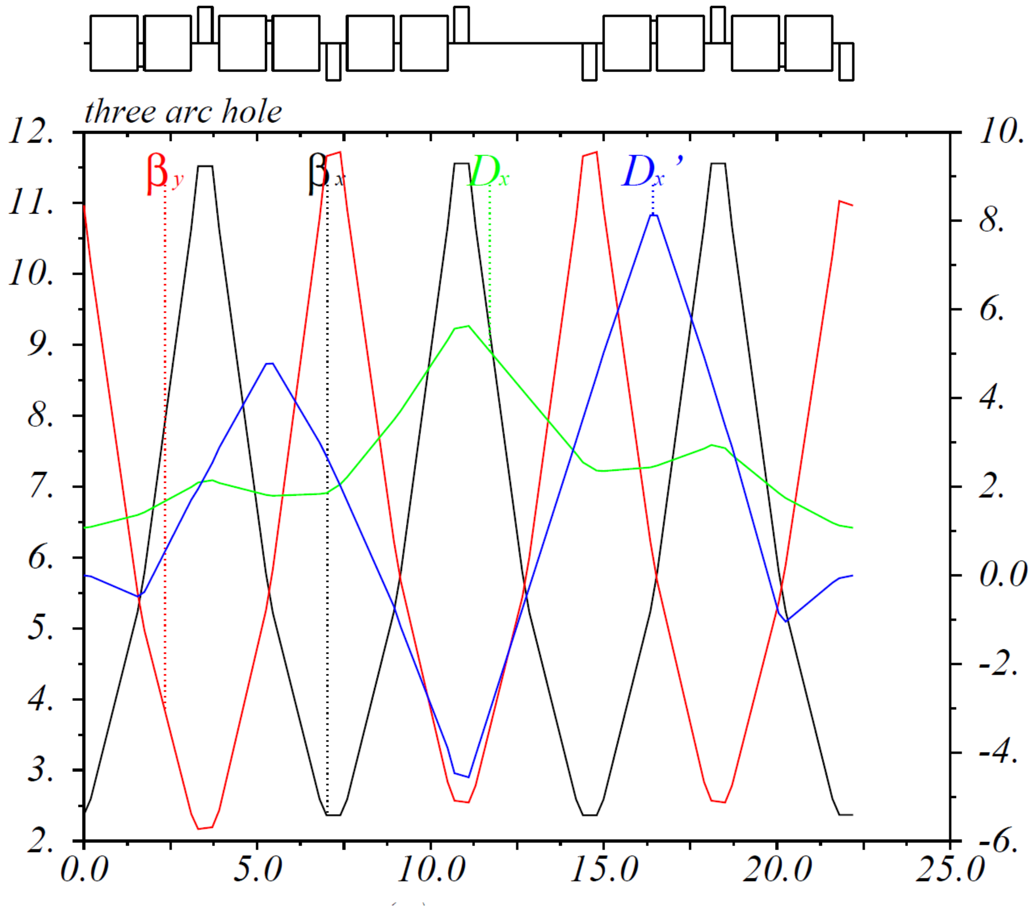
$$\frac{\Delta t}{t} = \eta \frac{\Delta p}{p} = \left(\alpha - \frac{1}{\gamma^2}\right)\frac{\Delta p}{p}$$

$$\alpha = \frac{1}{\gamma_t^2}$$

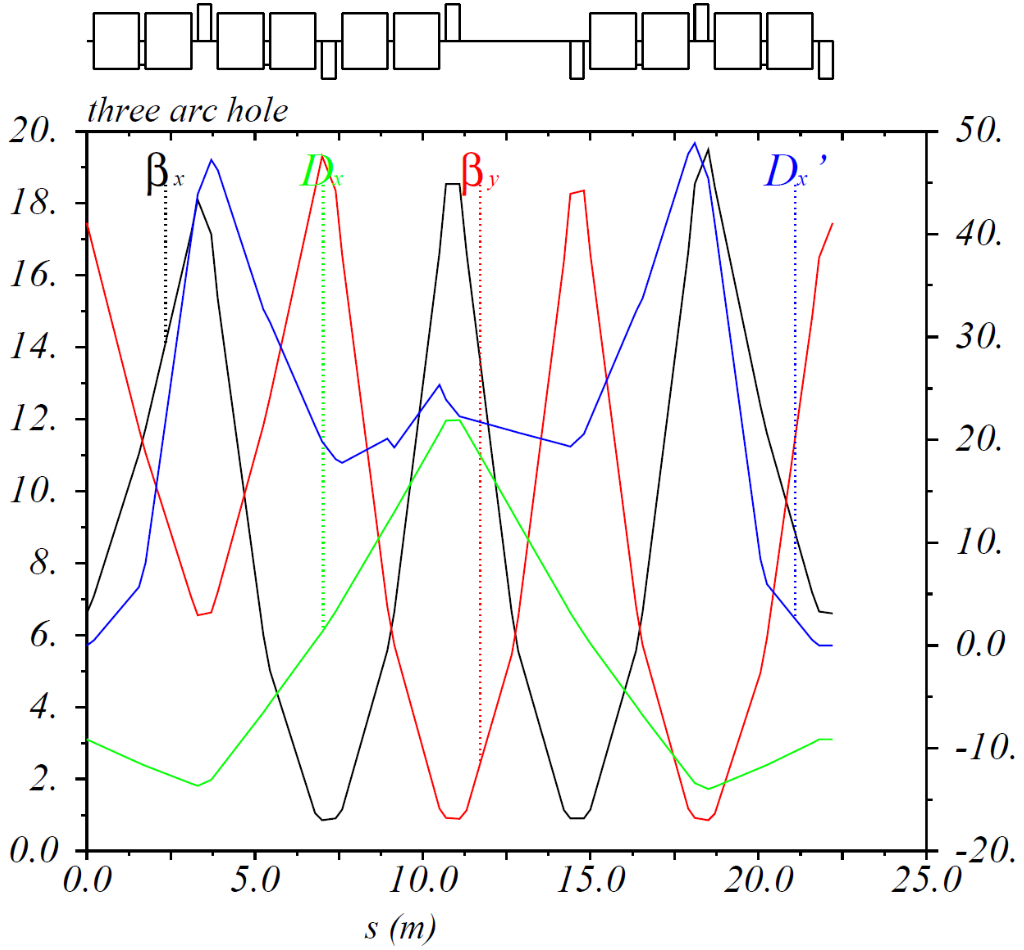
- Three possible cases:
  - $\gamma>\gamma_t$, $\eta>0$, Δt increases with energy, revolution frequency decreases with energy.
  - $\gamma<\gamma_t$, $\eta<0$, Δt decreases with energy, revolution frequency increases with energy.
  - $\gamma=\gamma_t$, $\eta=0$, Δt and revolution frequency do not vary with energy, also known as isochronous.

Flexible γ_t background

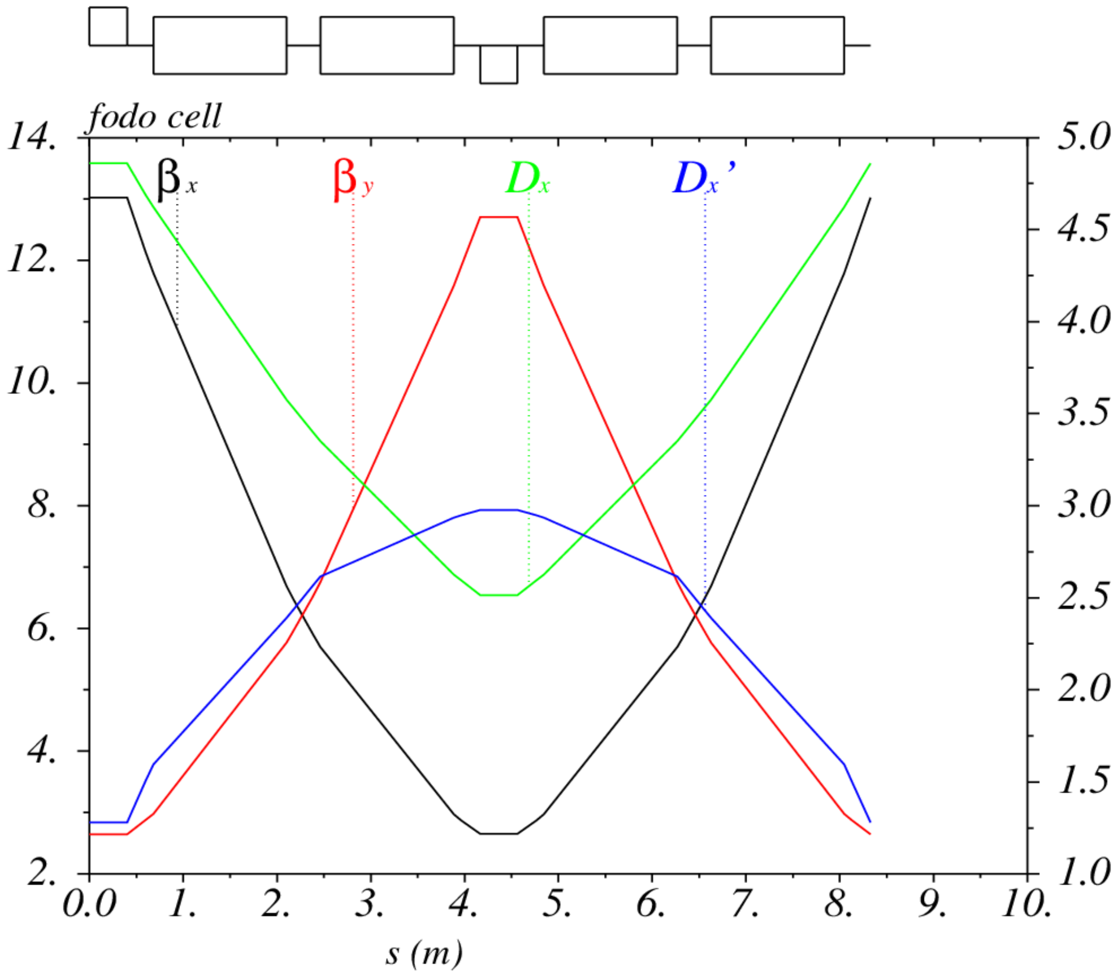
γ_t=3.29



γt=2.3i

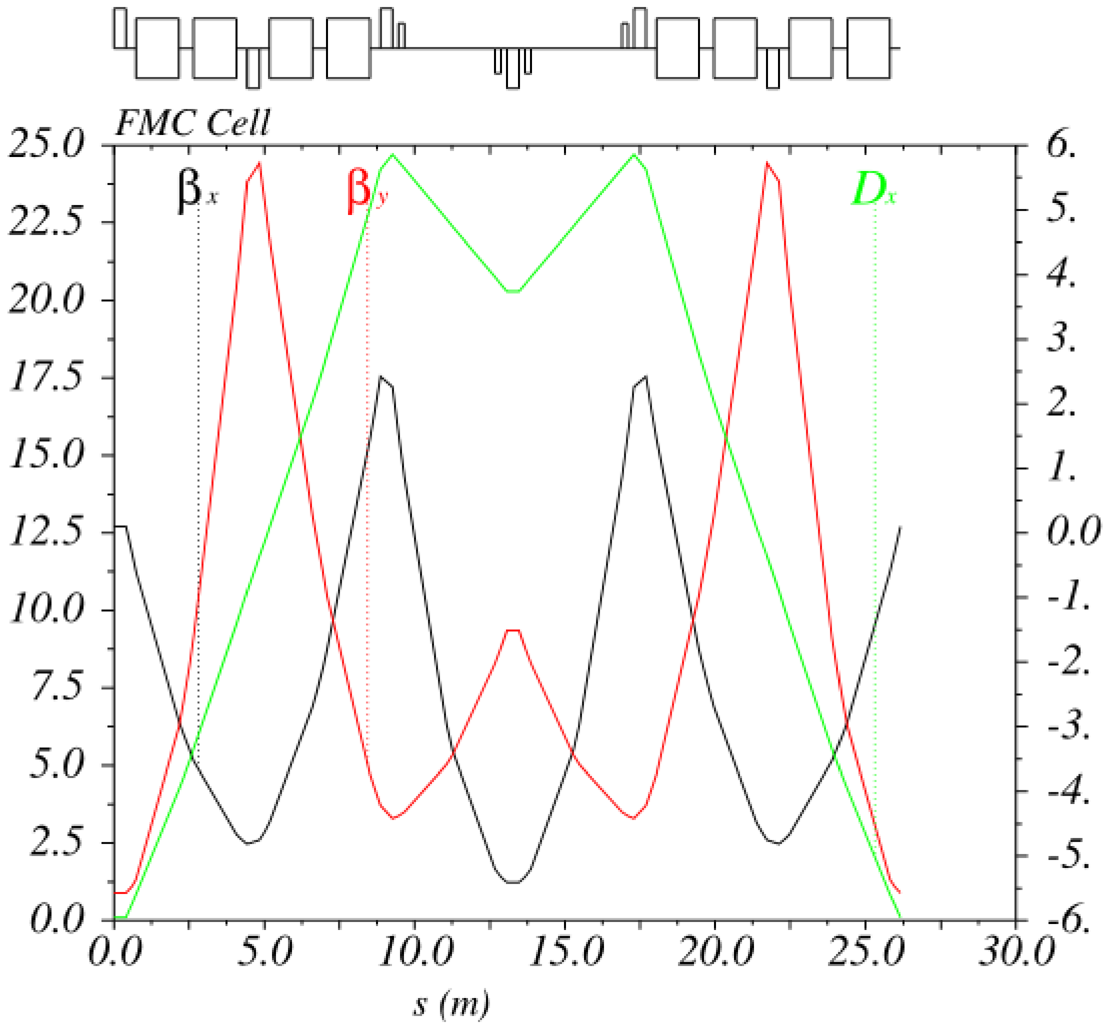


Arcs: FMC Cell



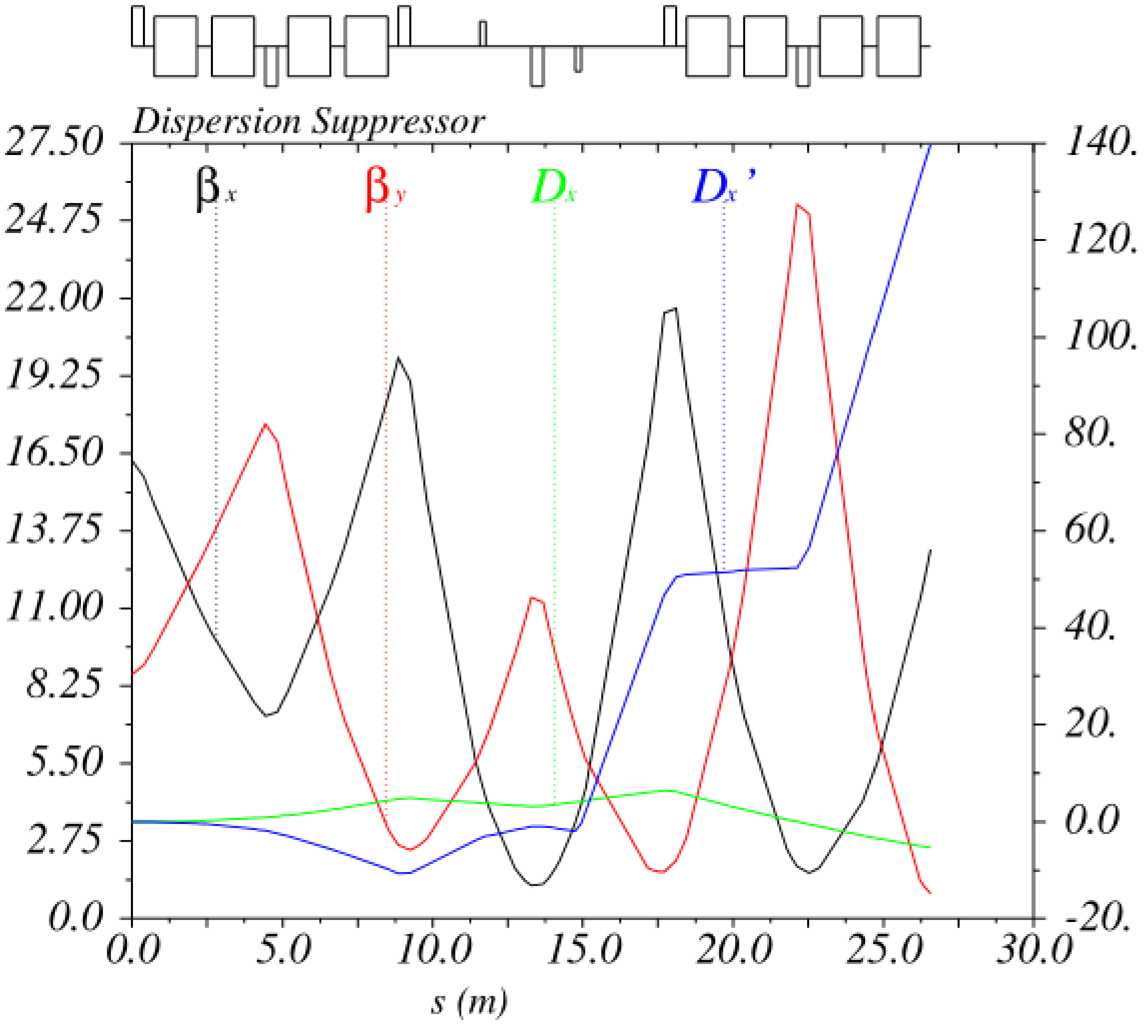
- Building block of the new design is a FODO cell

Arcs: FMC Cell



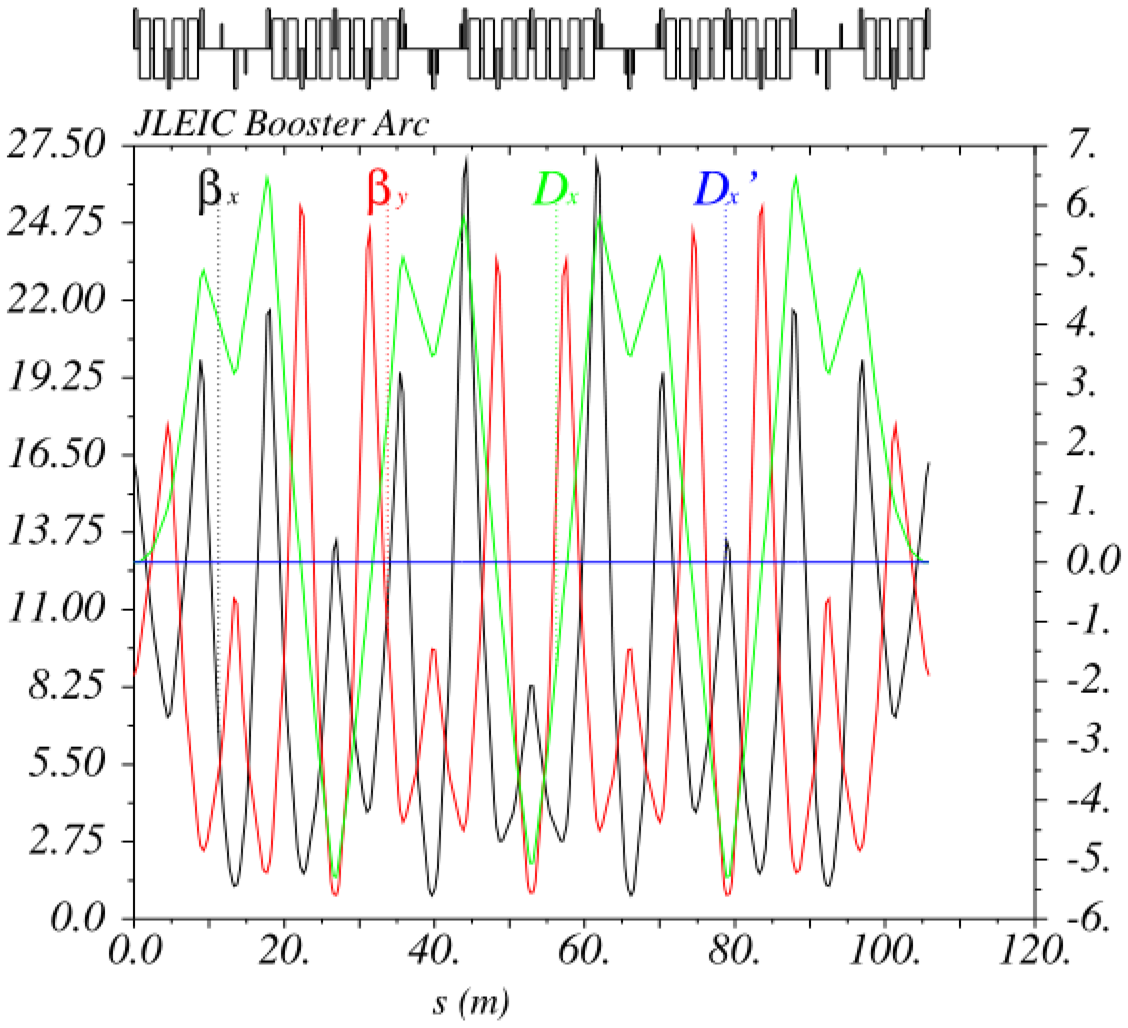
- Produced here using three identical FODO cells
- The dipoles are removed from the center FODO cell
- The quad strengths are varied on either end of the empty cell to alter the momentum compaction of the lattice.

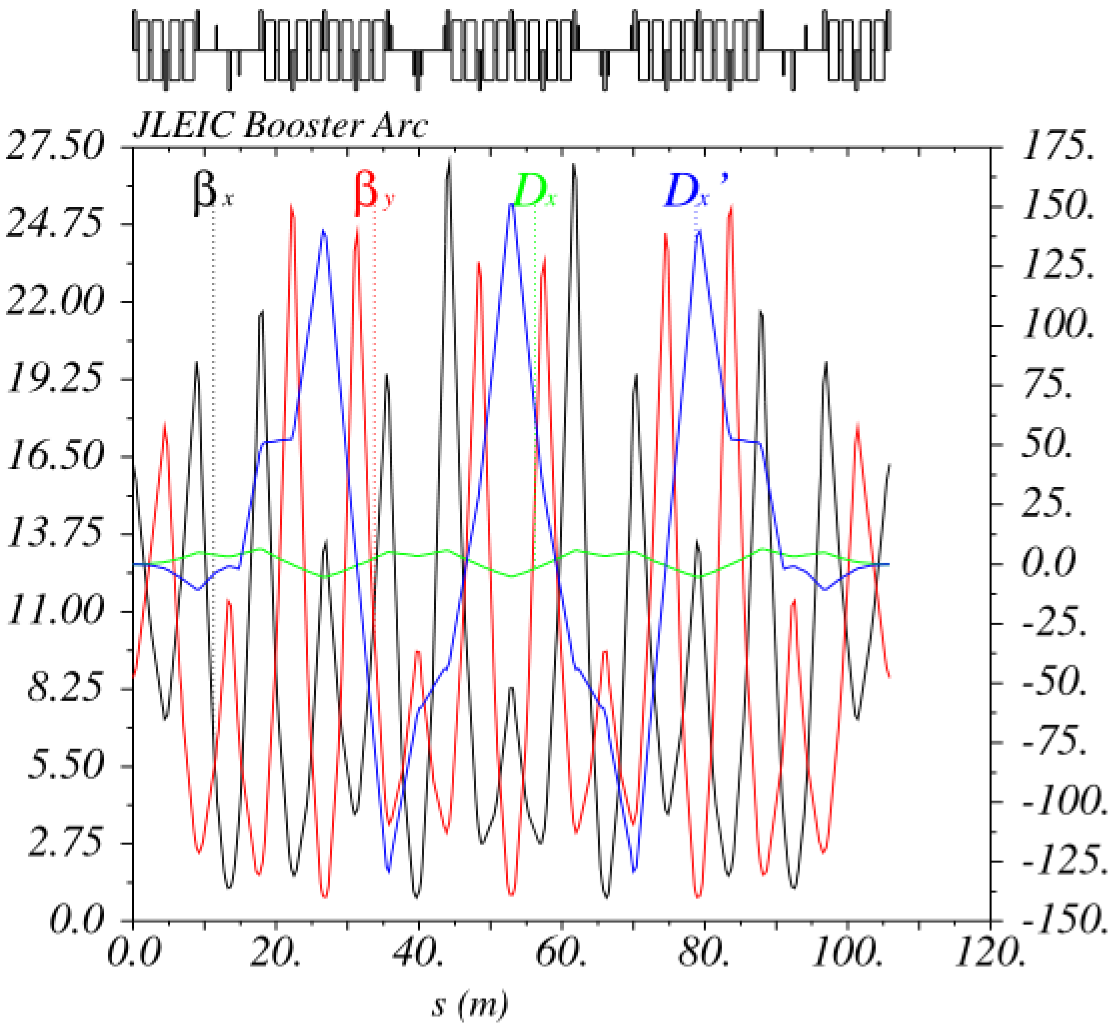
Arcs: FMC Cell (Control of Nonlinear Dispersion)



- Using sextupoles placed in the empty cell, the nonlinear dispersion can be controlled and zeroed out for the arcs

Arcs: Full Design

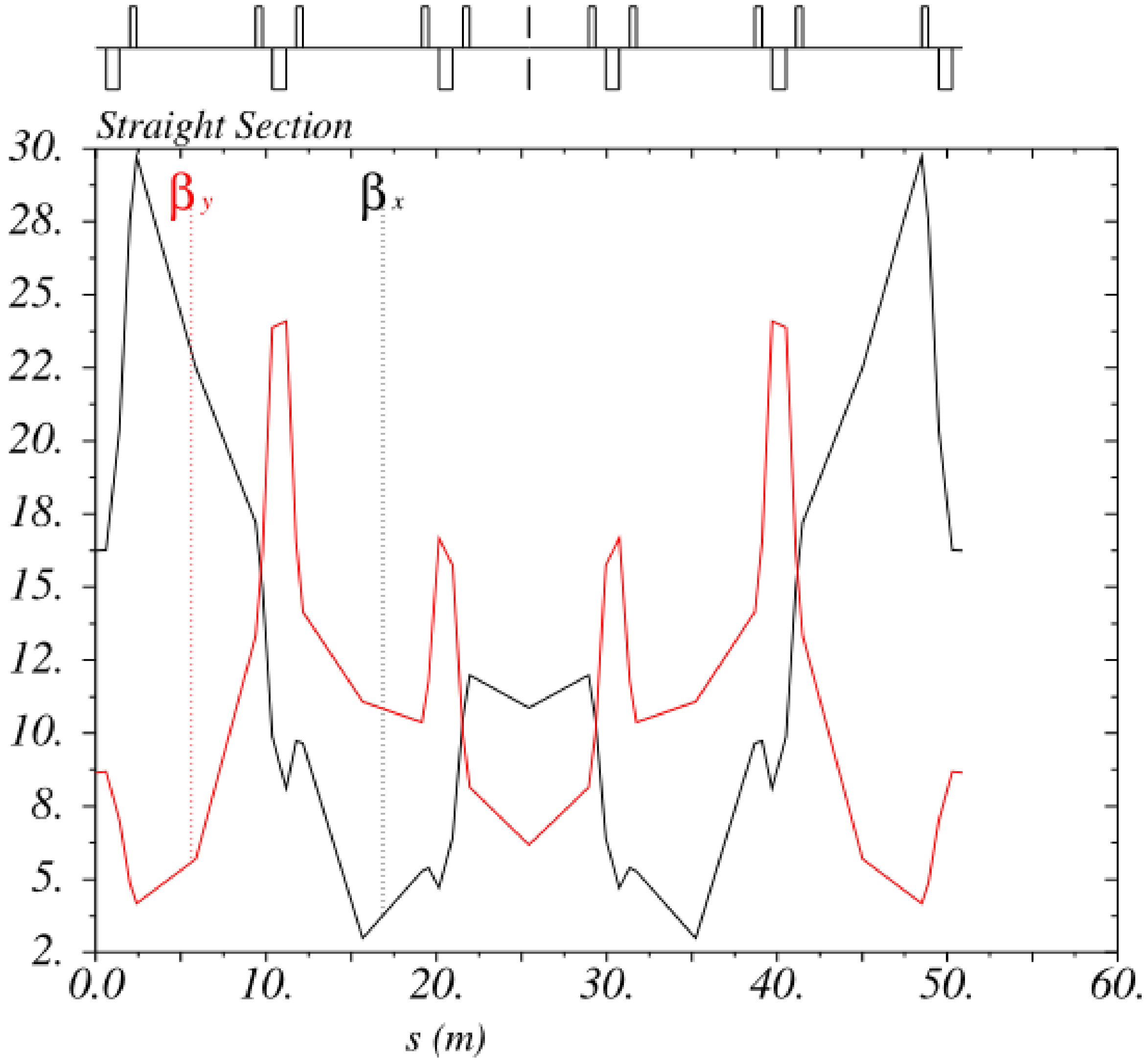




Straights: Goals

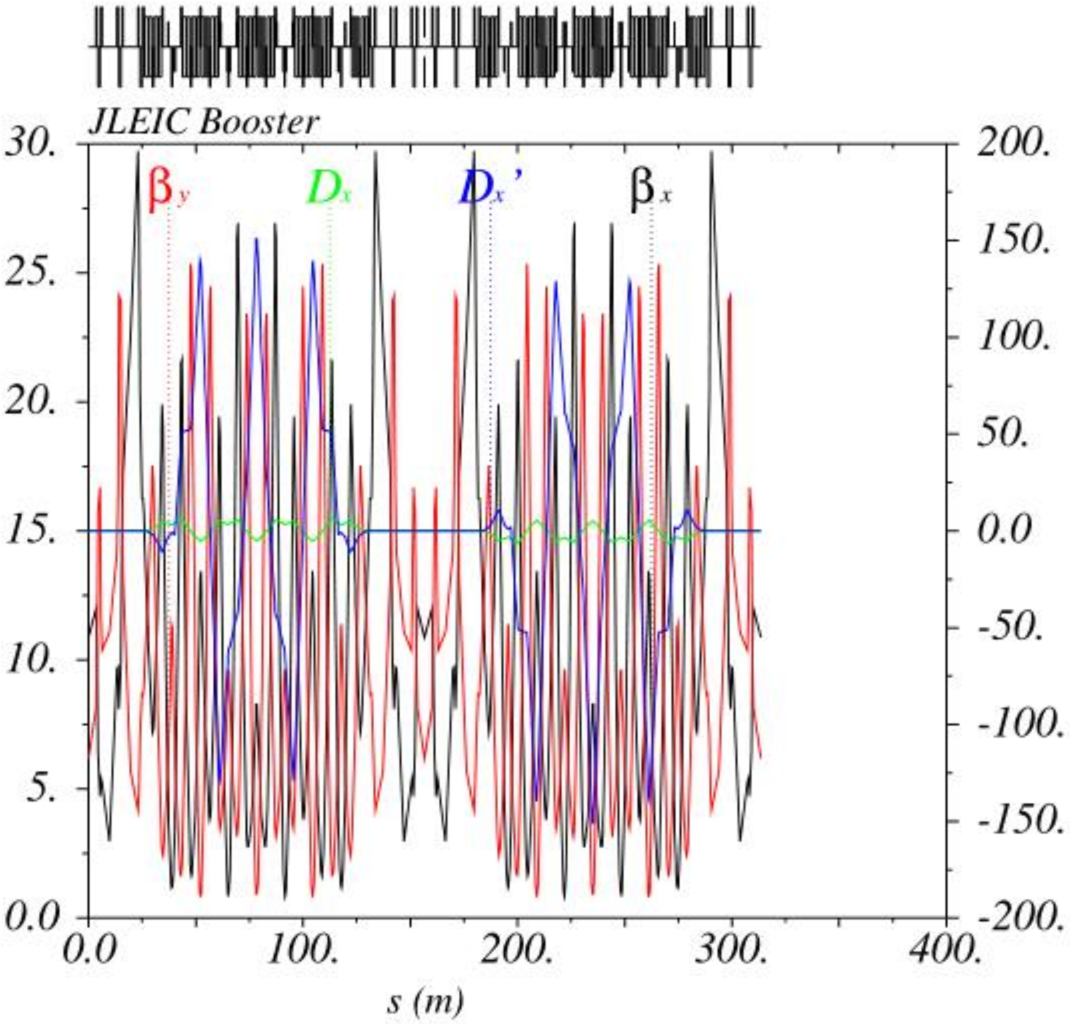
- The straights require enough length to close the arcs of the figure-8
- Require sufficient gaps to hold RF cavities, injection and extraction as well as possible cooling
- Also require sufficient space for bypassing at the crossing point
- Triplets were chosen to achieve this

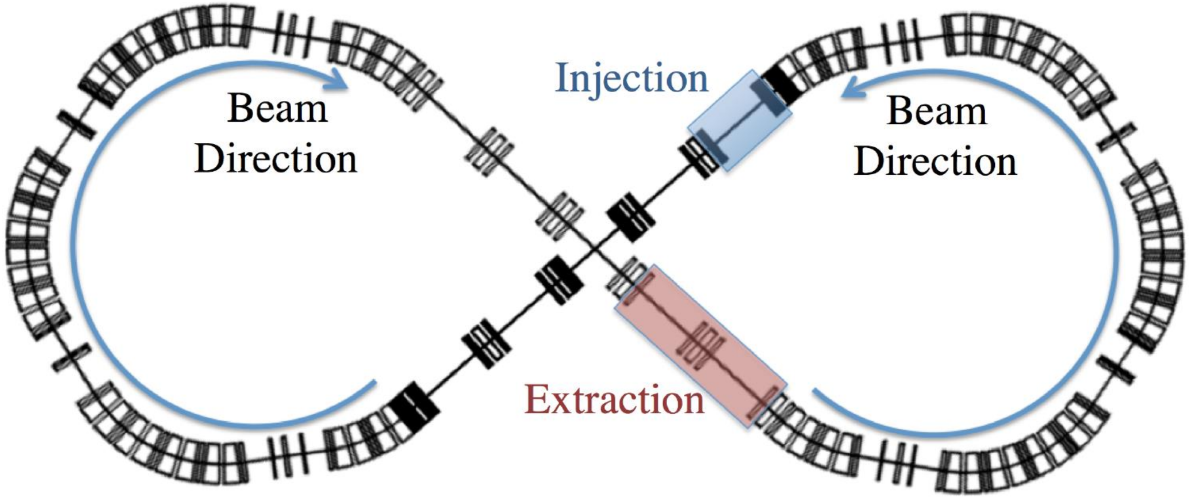
Straights Design



- The entrance and exit Twiss parameters were matched, with the total sections to be used to tune the machine.
- A 5 cell design was chosen so that elements would not interfere at the crossing point

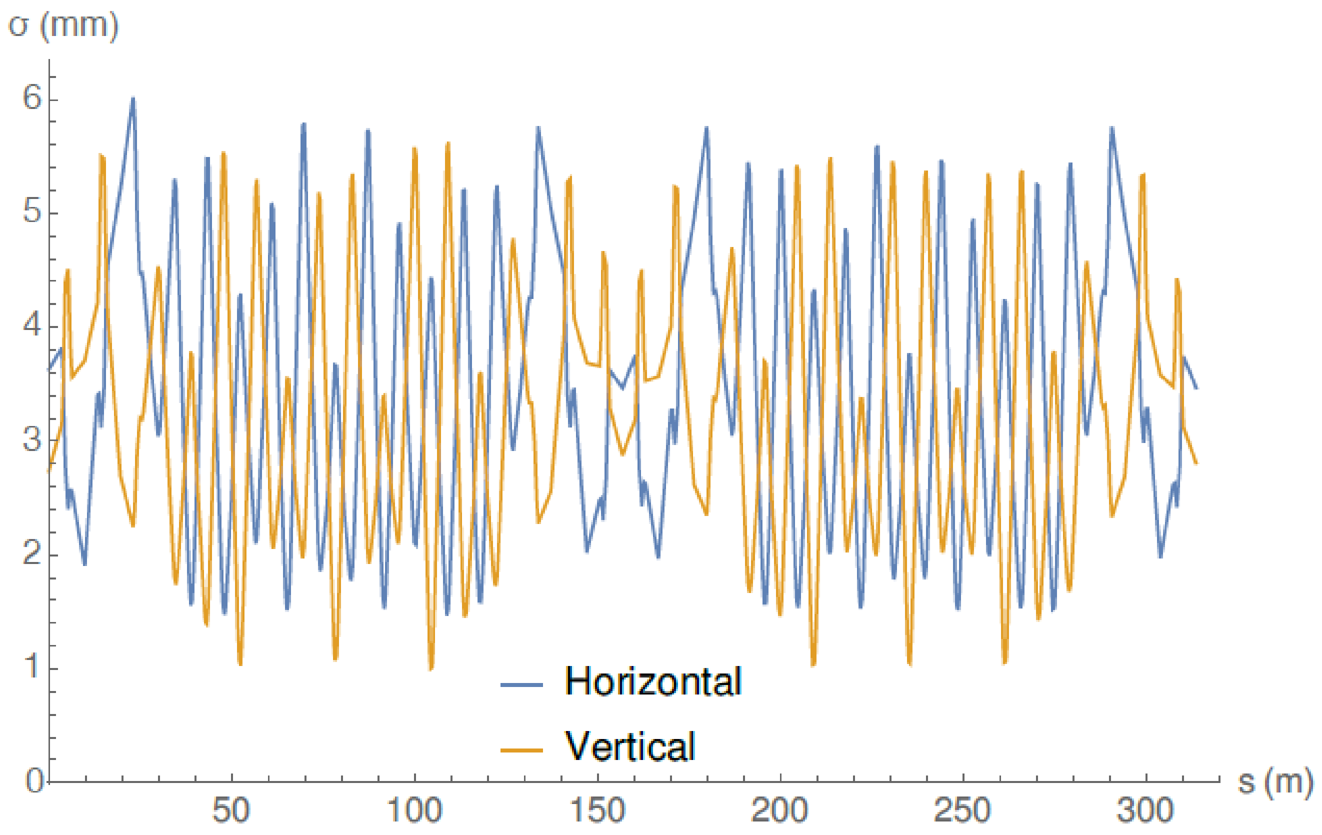
Final Machine





length 313.4894156	orbit5 -0	alfa 0.002875869455	gammatr 18.64727673
q1 8.731866668	dq1 0.0001302997716	betxmax 29.7211382	dxmax 6.457392373
dxrms 3.371835709	xcomax 0	xcorms 0	q2 8.680367778
dq2 0.0001817033293	betymax 25.33442317	dymax 0	dyrms 0
ycomax 0	ycorms 0	deltap 0	synch_1 0
synch_2 0	synch_3 0	synch_4 0	synch_5 0

Final Machine Spot Size



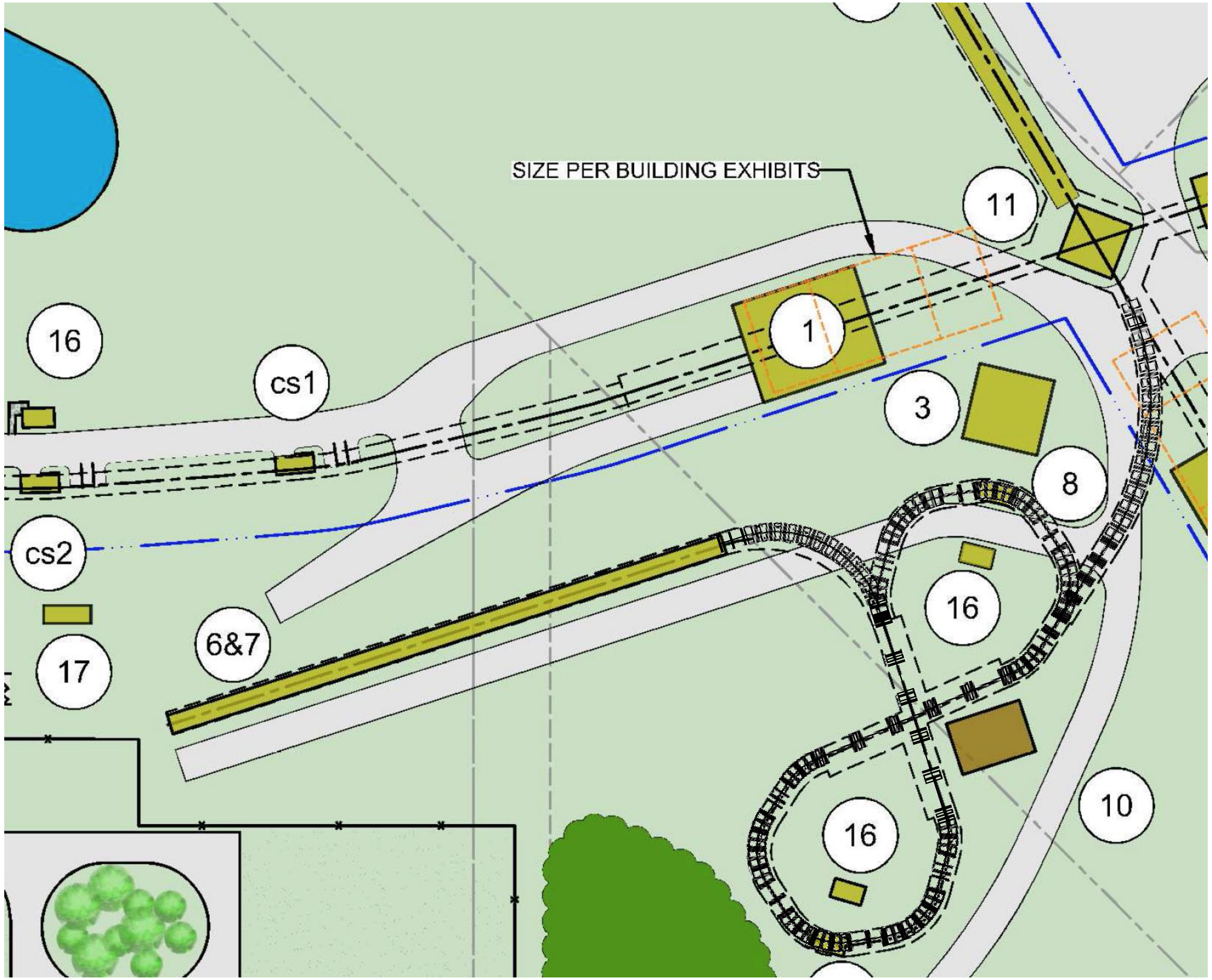
- With an injection emittance of 1.21 mm mr The current lattice is compatible with a 4 cm beam pipe radius

Element Count

Element	Length	Number	T (max)	T/m (max)	T/m^2 (max)
Dipole	142.18cm	64	3		
Quadrupole	40cm	70		29.56	
Quadrupole	80cm	12		21.68	
Sextupole	20cm	24			305.84

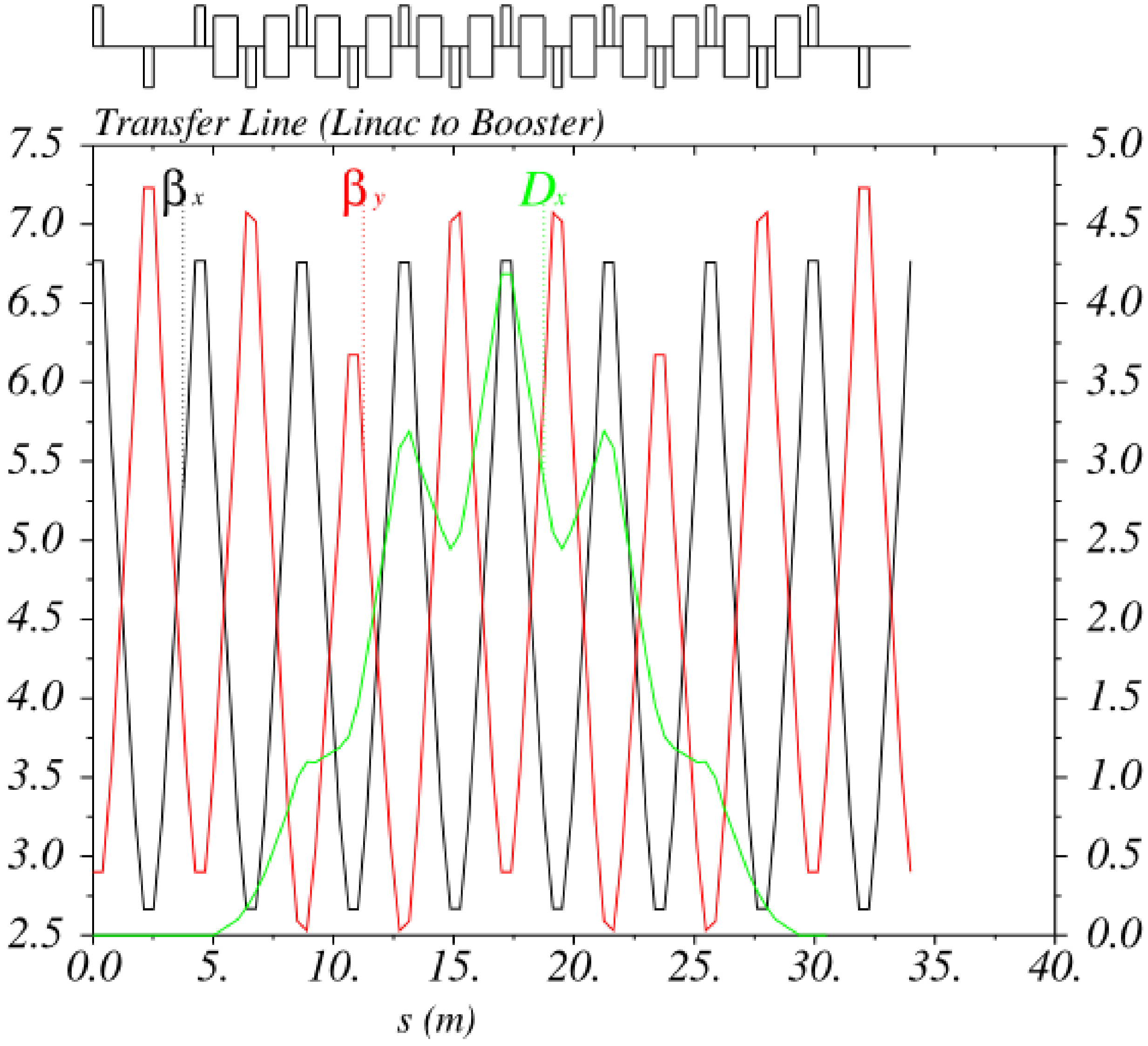
There are 14 distinct quadrupole values (10 in the arcs, 4 in the straights), and 8 distinct sextupole values.

The Larger Complex



- The linac was moved to the West side of the booster to avoid having the injection and extraction lines cross.

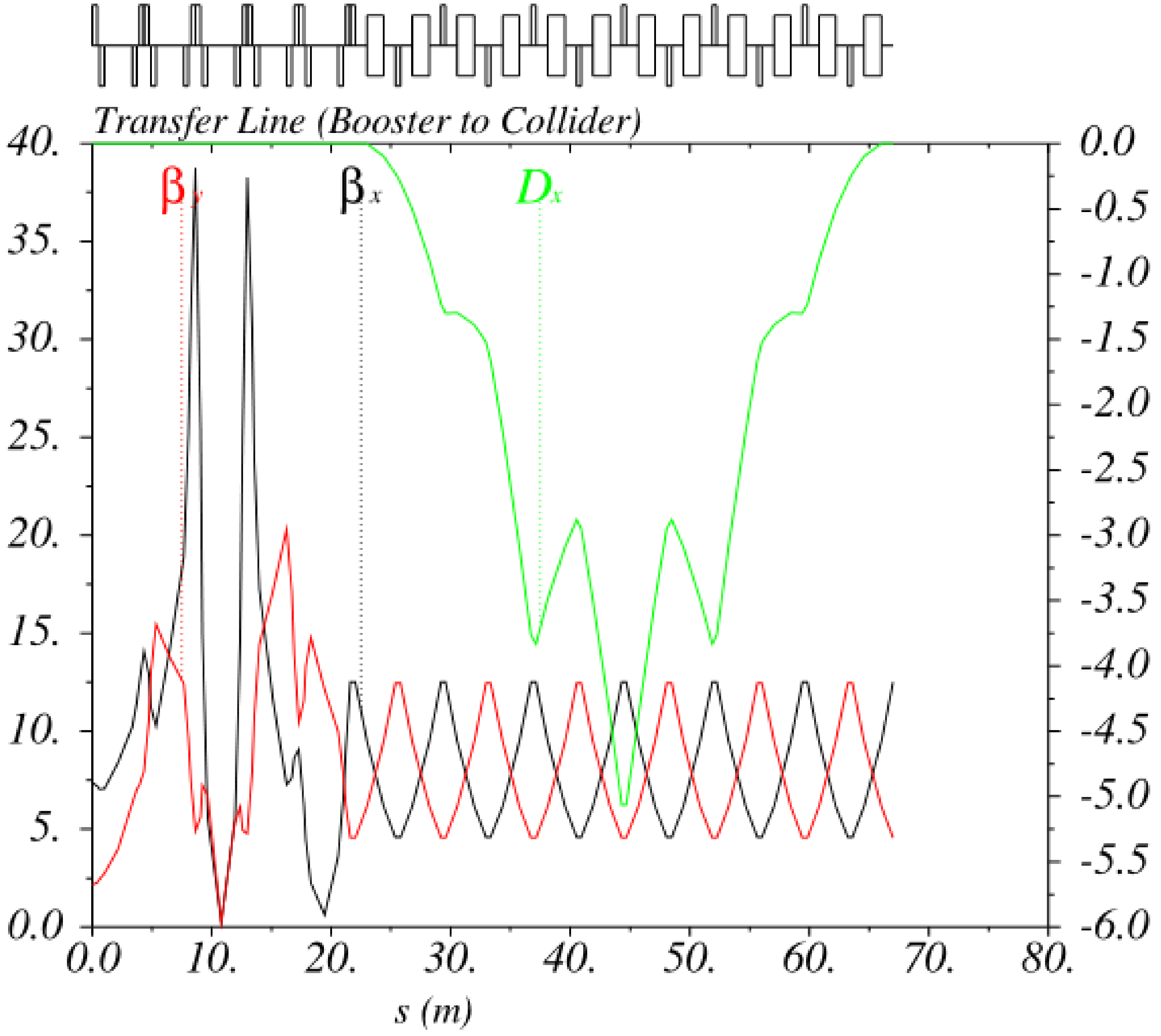
Linac to Booster



- Simple arc with matching straight magnets at either end and an nπ dispersion suppression scheme

Element	Length	Number	T(max)	T/m (max)
Dipole	1.0 m	12	0.34	
Quadrupole	40 cm	16		2.24

Booster to Collider



- A straight section is followed by a simple arc with nπ dispersion suppression.
- The low beta section is used for final stripping of heavy ions.

Element	Length	Number	T(max)	T/m (max)
Dipole	1.422 m	12	1.82	
Quadrupole	40 cm	32		98.14

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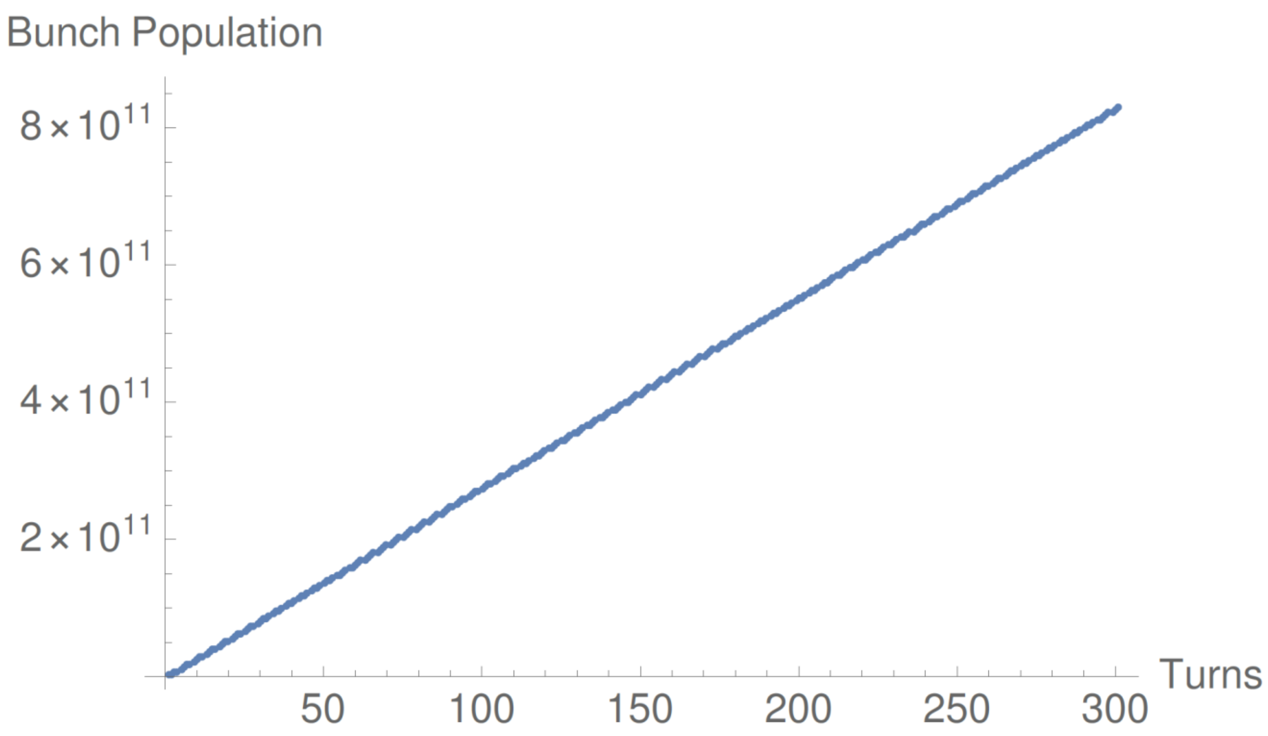
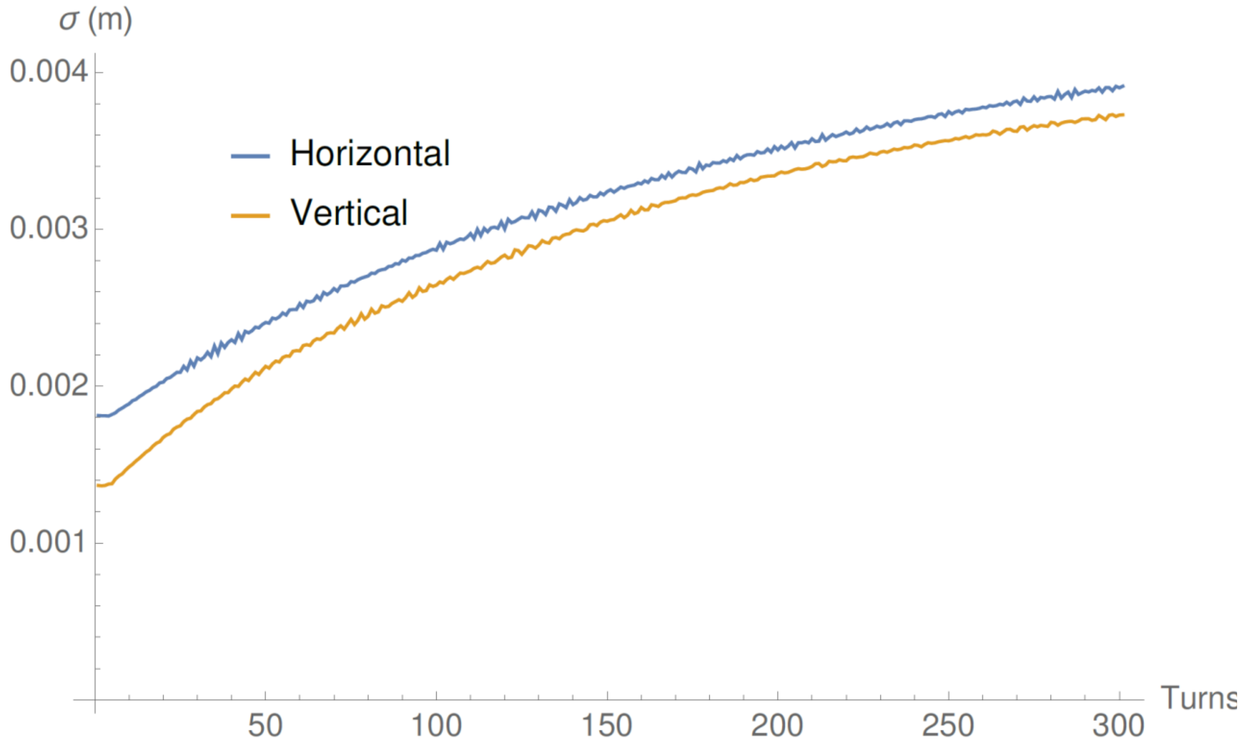
Injection Methods

- The current design calls for foil stripping injection in a dispersion free section of the accelerator.
- Phase-space painting will be utilized via a closed orbit bump
- Closed orbit bump follows:

$$q_{offs} = a\sqrt{\frac{2t}{T} - \left(\frac{t}{T}\right)^2}$$

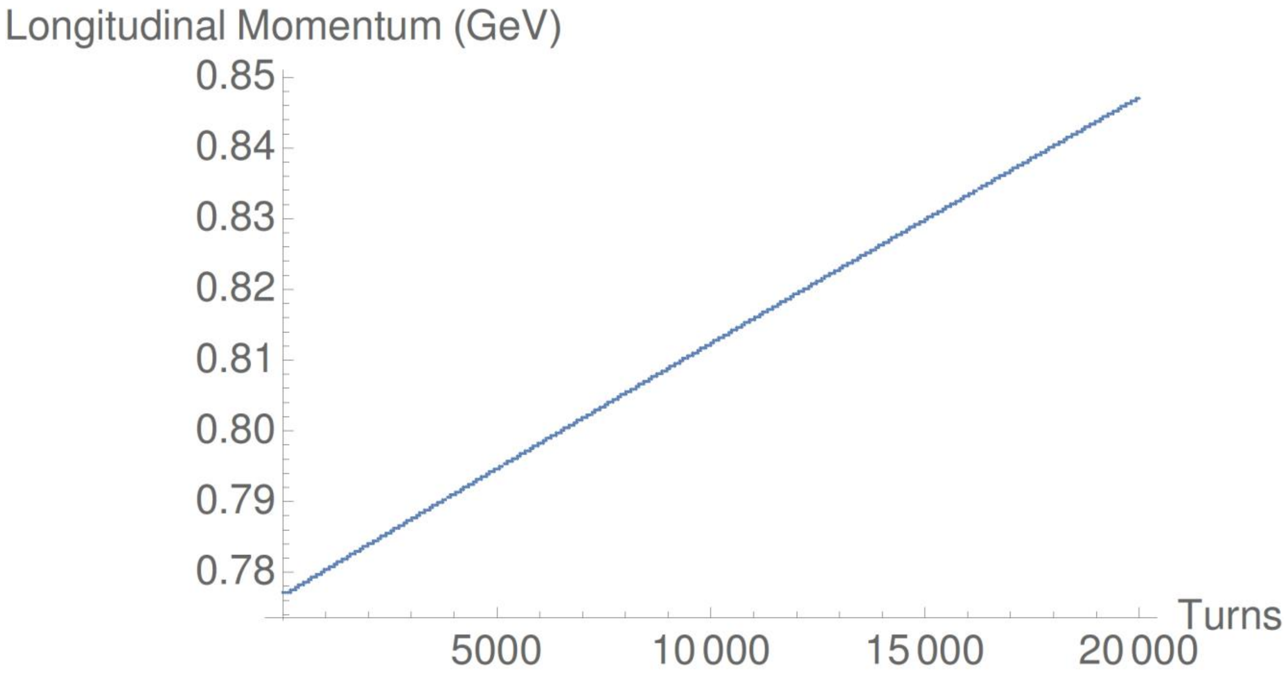
Injection Simulations

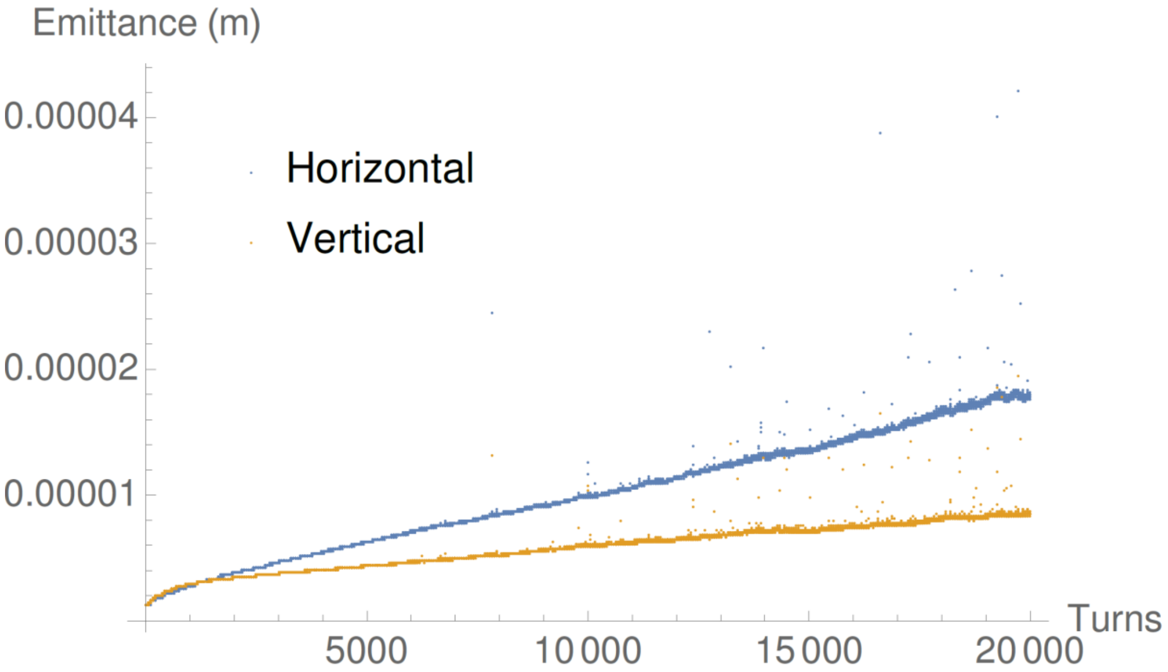




The injection simulations were performed over 300 turns, The offsets were selected such that they match the target beam size after injection.

Ramping Simulations





These simulations used a single injection, followed by 100 turns at injection energy, 10 turns changing the phase of the RF, and a ramp at 5.8° offset for 2.3 KeV of acceleration per turn.

Future Work

- Finish determining the working point
- Design crossing point chicane(s)
- Finalize placement of injection and extraction sections
- Determine placement for potential polarimetry, spin rotators, and electron cooling.
- Prepare for possible energy upgrades

Thank You for Your Attention