Tracking Studies with Frequency Ramp for the APS-U Booster

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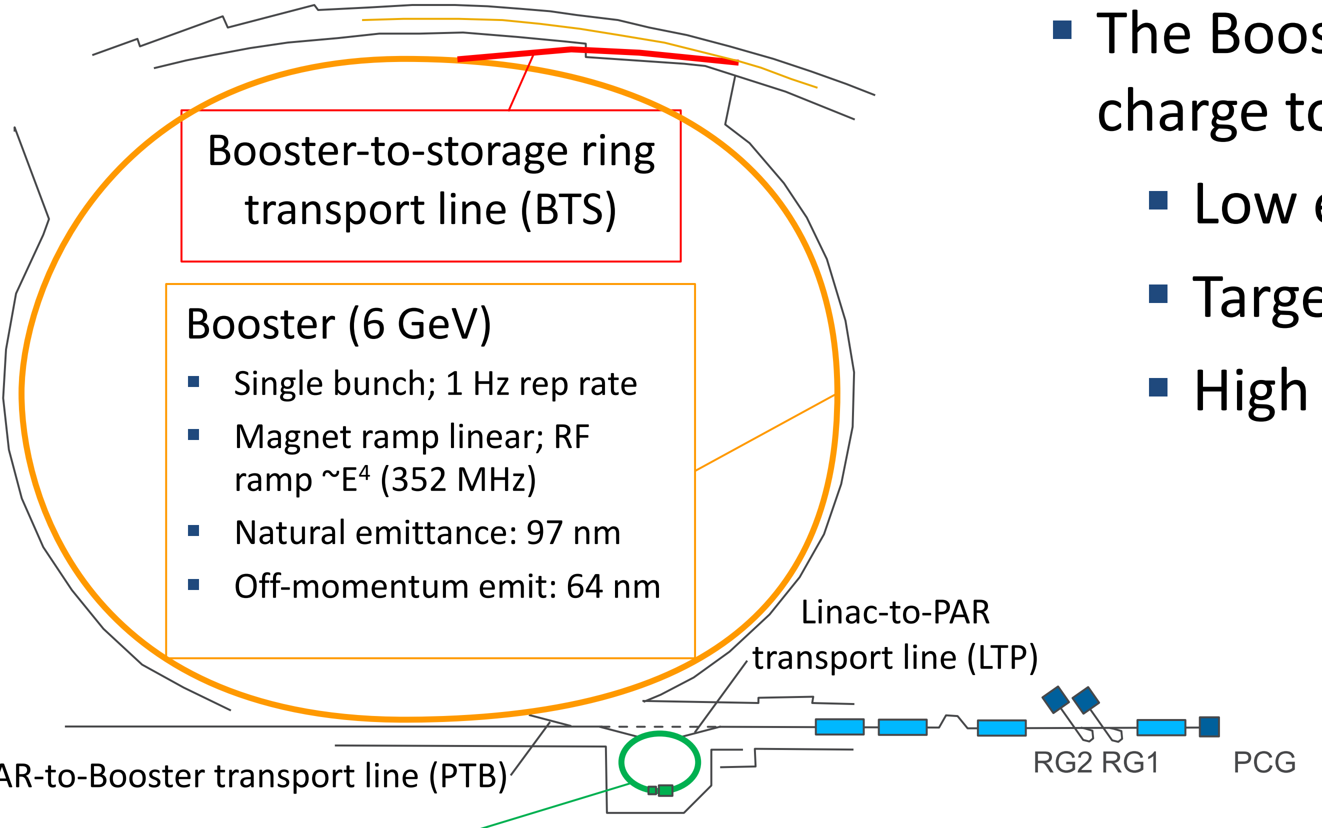
Overview

- Goals: study APS-U Booster synchrotron behavior at high injection charge (>18nC)
- Approach: *elegant* simulation, study transmission for various bunch charges and frequency ramps (optimize RF cavity parameters)
- Discussion of results
- Further work, and concluding statements

APS-U Injector Complex

- The Booster needs to reliably deliver high charge to the storage ring
  - Low emittance
  - Target efficiency >85%
  - High charge >17nC

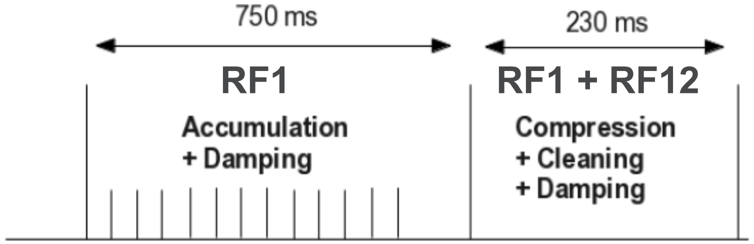


Particle accumulator ring (PAR) (>450 MeV)

- Single bunch; 1-Hz rep rate
- Captures linac pulses in RF1 (9.8 MHz); compresses damped beam in RF12 (117 MHz)

Linac (>450 MeV)

- 1 nC/pulse; 30 Hz rep rate
- Thermionic RF guns: RG1, RG2 (1 hot spare)



PAR cycle

Elegant Modelling

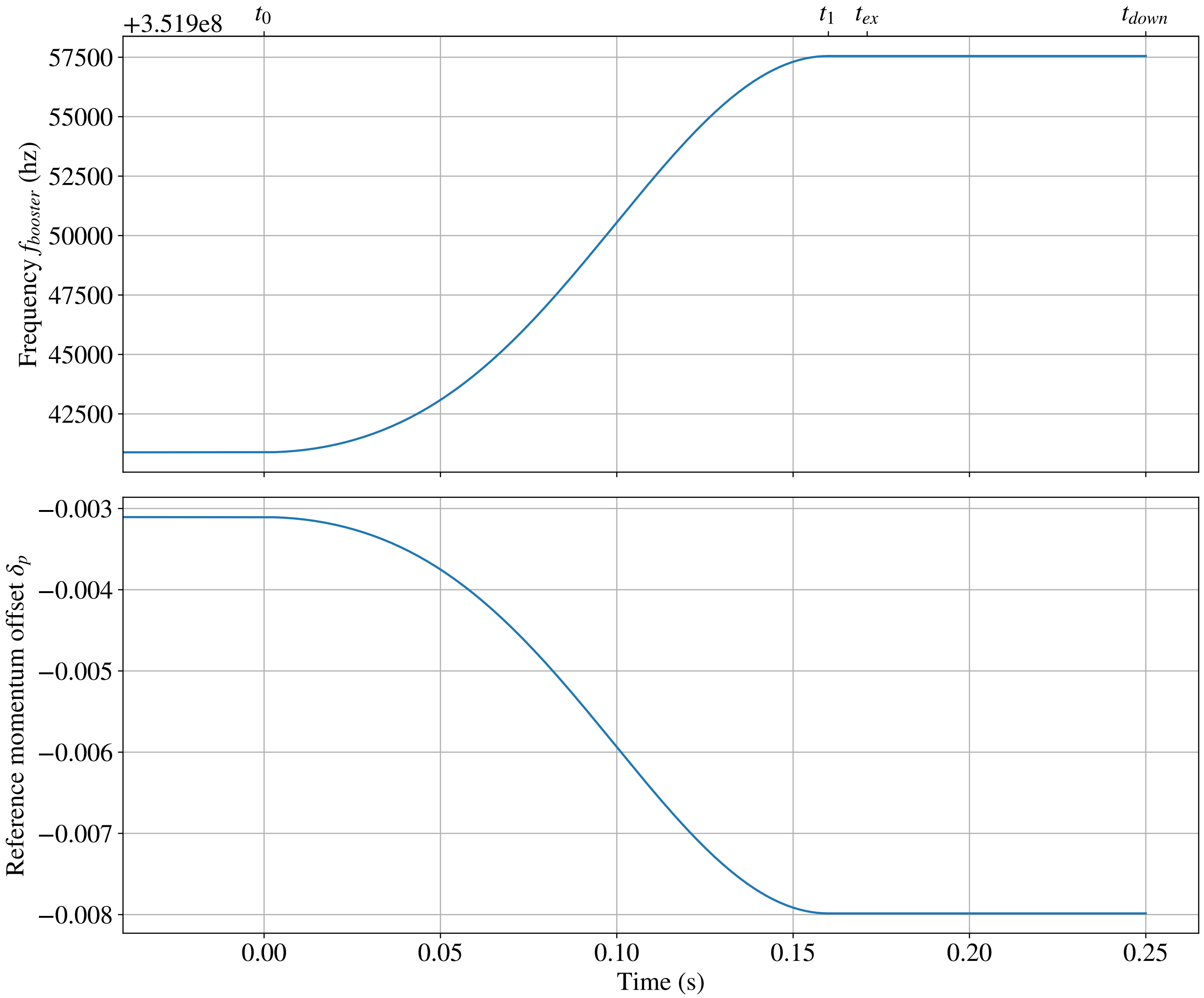
- Model the booster beam optics as a single matrix element
- Include relevant effects not captured by the matrix element:
  - An RF cavity, and beam loading
  - Synchrotron radiation losses and damping
  - Longitudinal impedances – interaction of beam with vacuum system
  - Momentum acceptance of booster modelled as ±0.025

Ramps

- Have a target momentum offset at extraction, can control injection momentum offset $\boldsymbol{\delta_{p,0}}$

$$f = \frac{c}{C_{booster}(1+\eta\delta_p)} \approx \frac{c}{C_{booster}}(1-\alpha_c\delta_p)$$

- A frequency function $f(t)$ (i.e. a frequency *ramp)*



- Need to dump vastly more energy into beam as momentum increases:

$$\Delta U_{sync} \propto -E^4$$

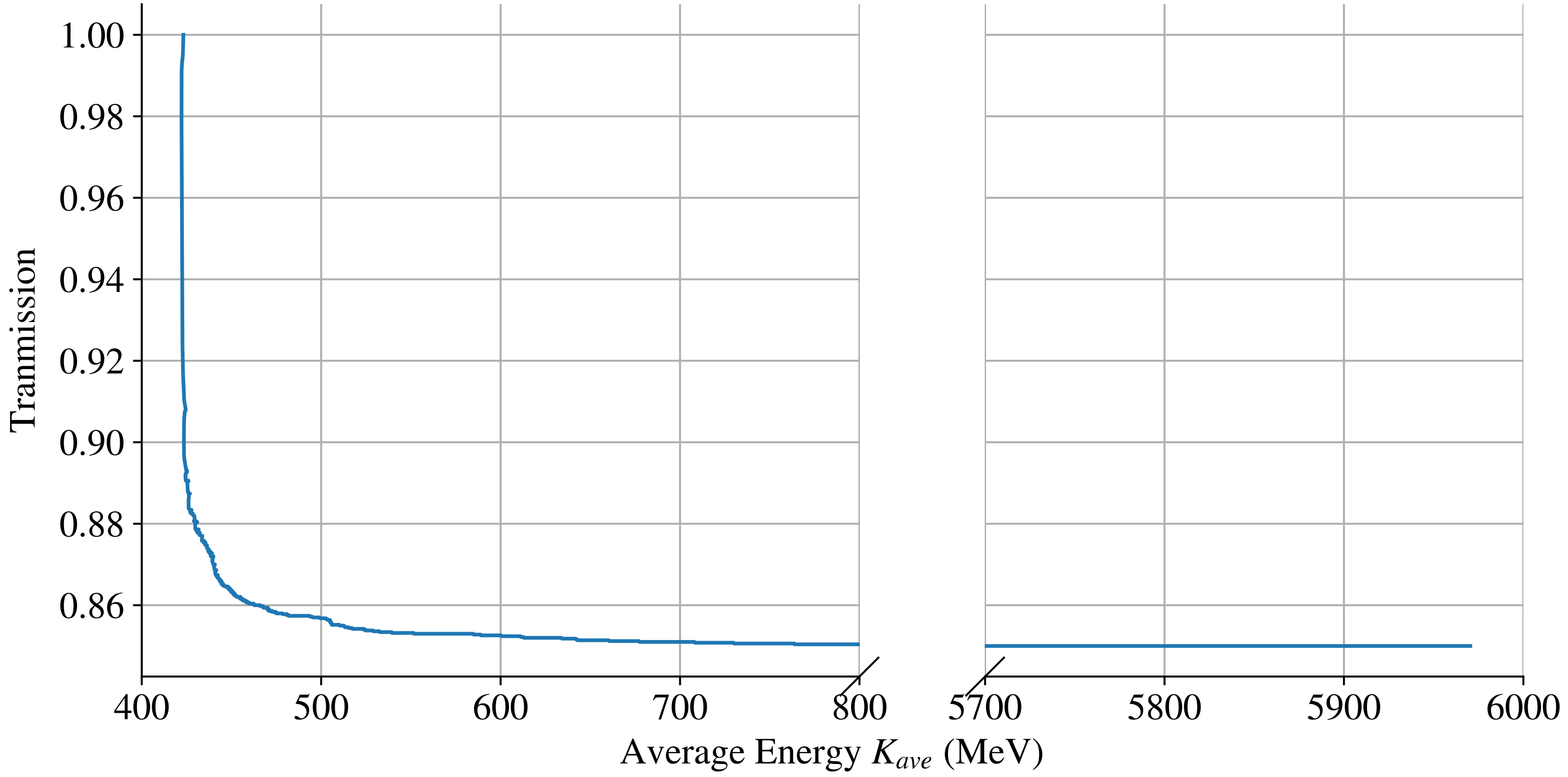
- Energy gain from RF cavity:

$$\Delta U_{RF} = V \sin\psi_s$$

- Ramp $V = \boldsymbol{V_0} + b \cdot E^4$ as well to compensate for synchrotron losses

Beam Loss

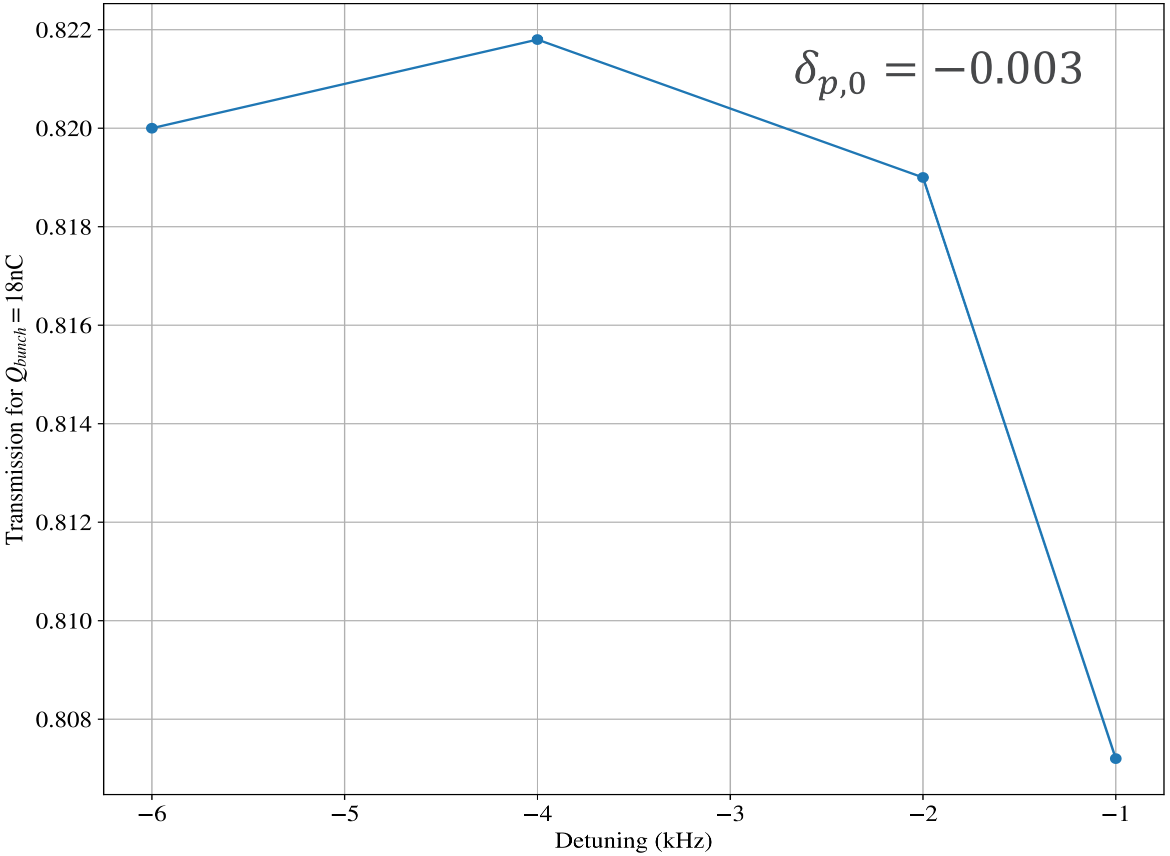
- Most (>95%) losses occur at low end of ramp: *initial bunch length is too long*
  - Consider benefits of bunch shortening (reduce to 80%) achievable with increased longitudinal focusing in the PAR



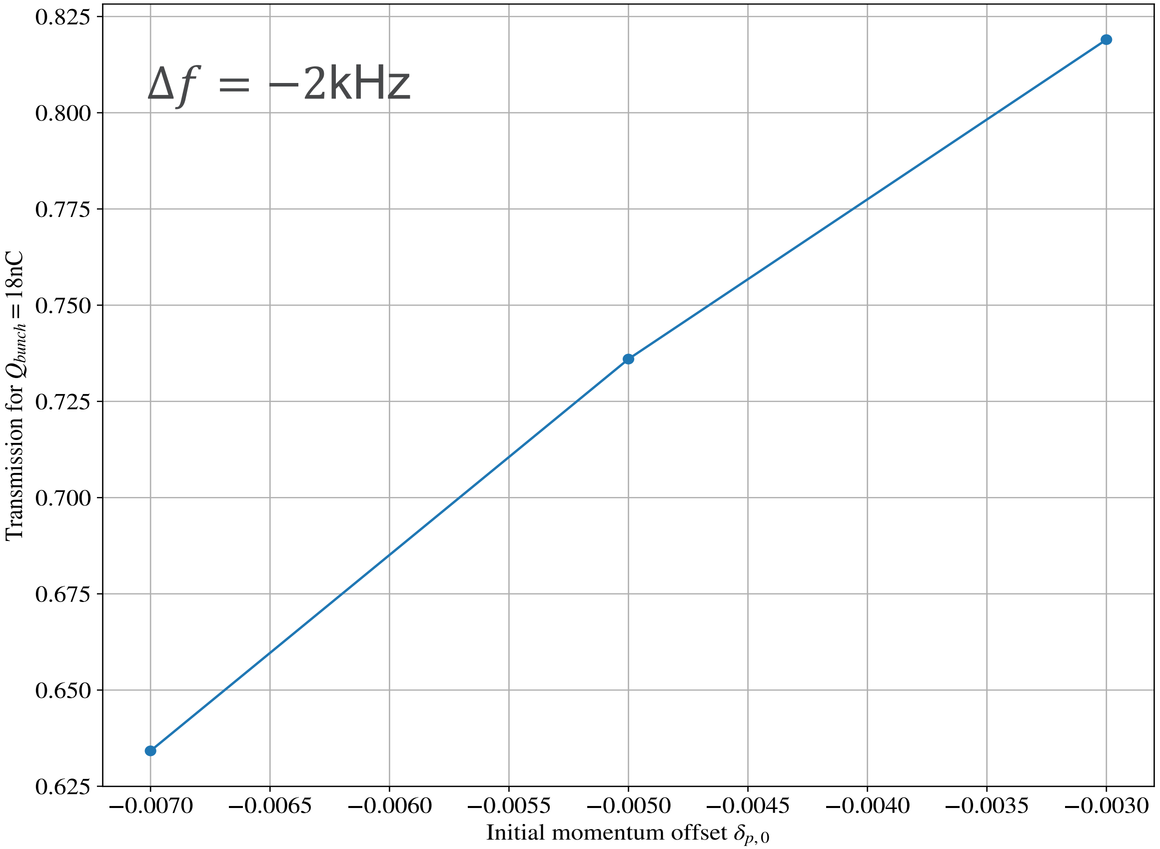
Detuning and Initial Momentum Offset

- Bunch charge $Q_{bunch} = 18$nC, initial voltage $V_0 = 1.5$MV

- Detuning has little effect ($\beta = 3$)

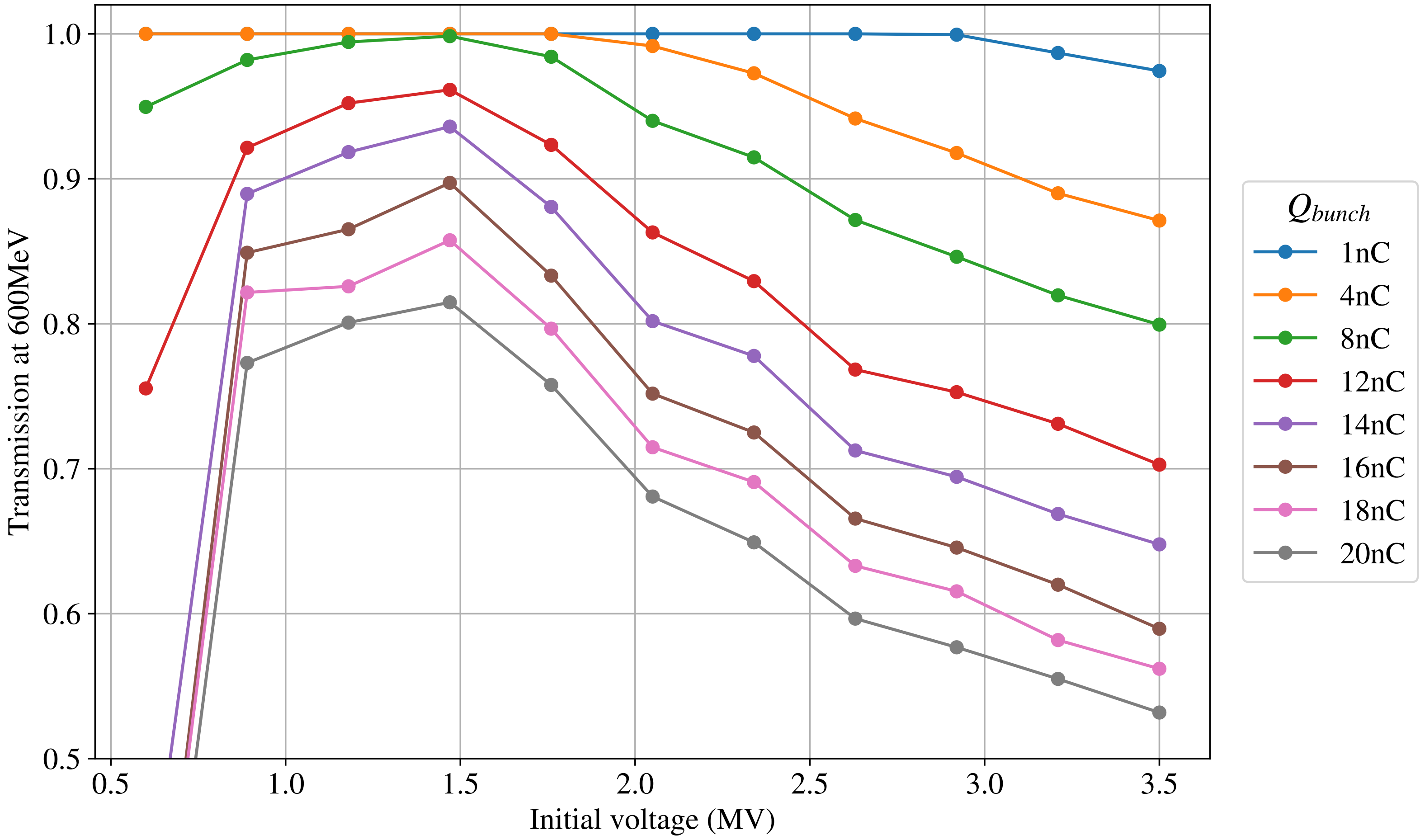


- Initial momentum offset can have large effects

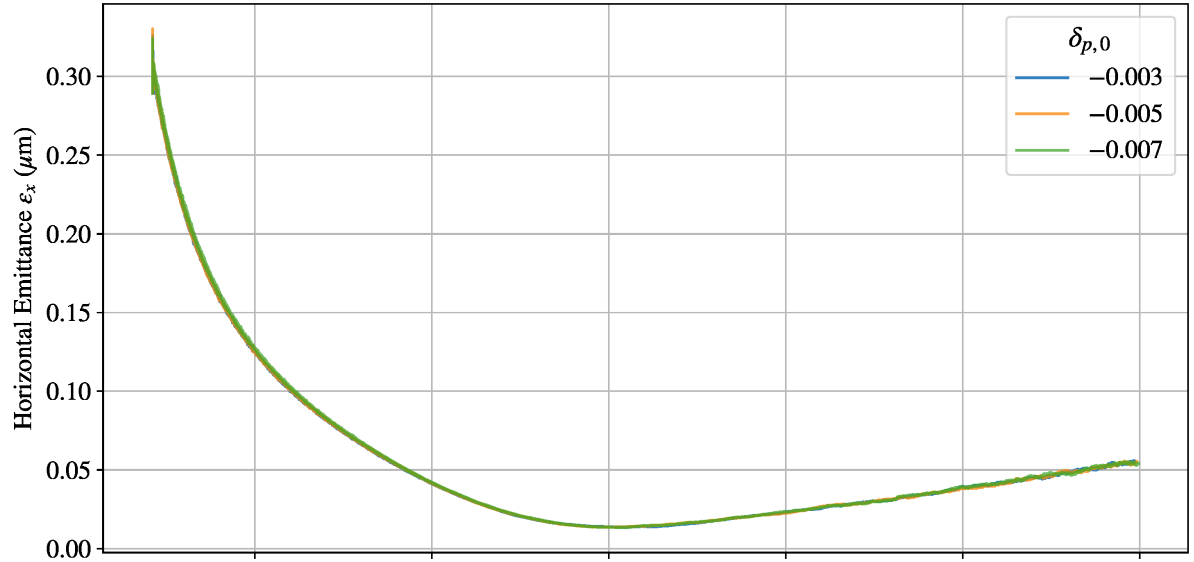


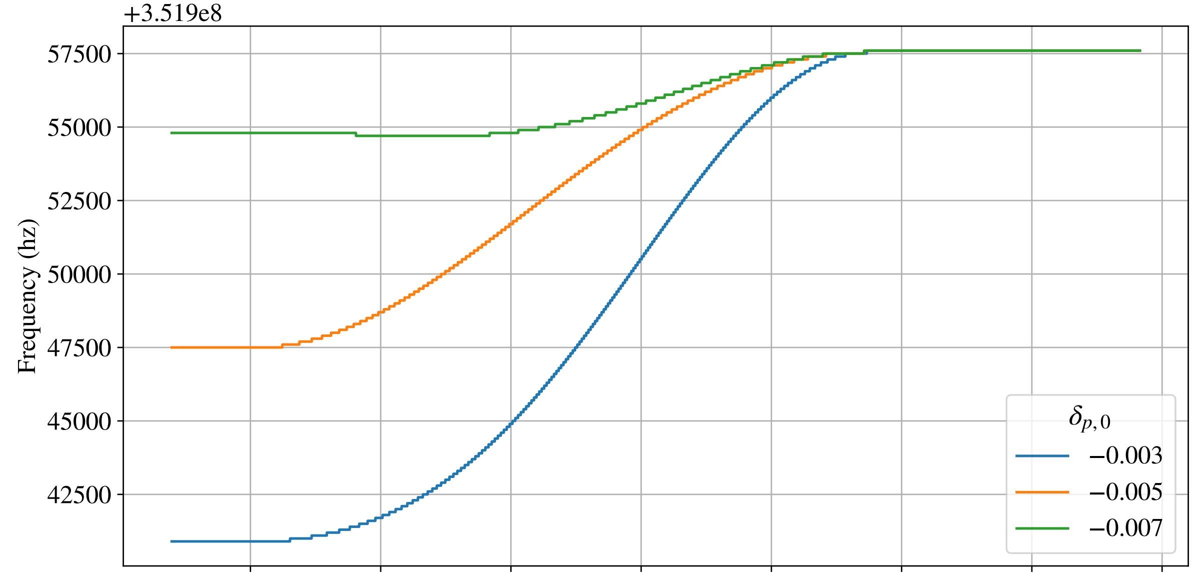
Voltage

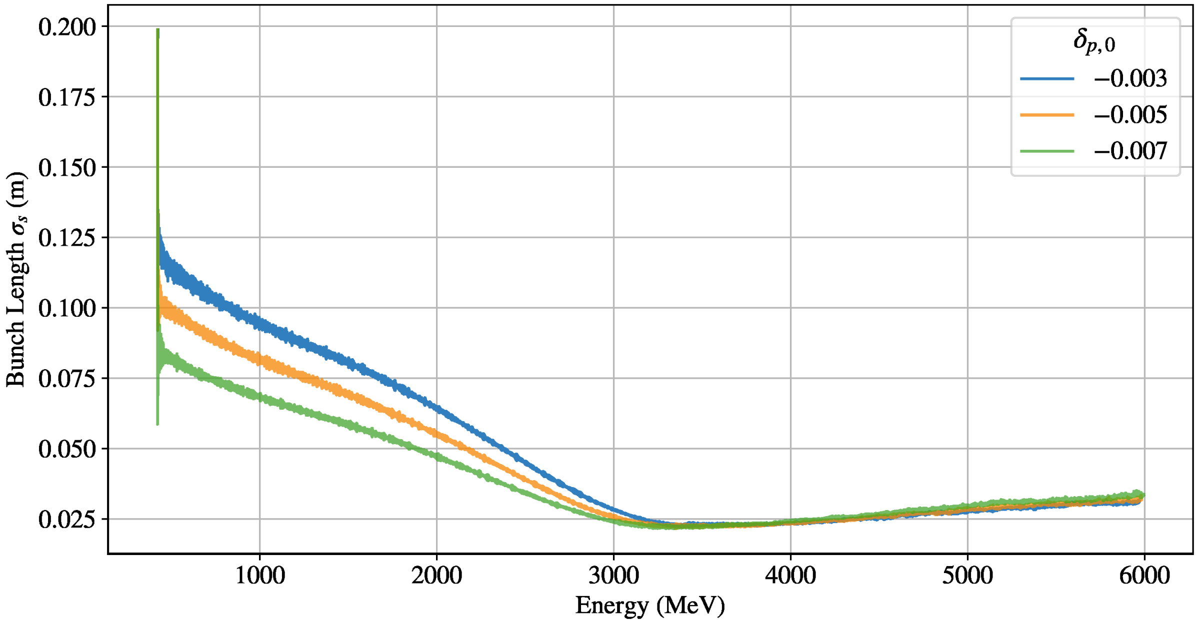
- Tuning initial voltage V_0 can have non-trivial improvements for transmission

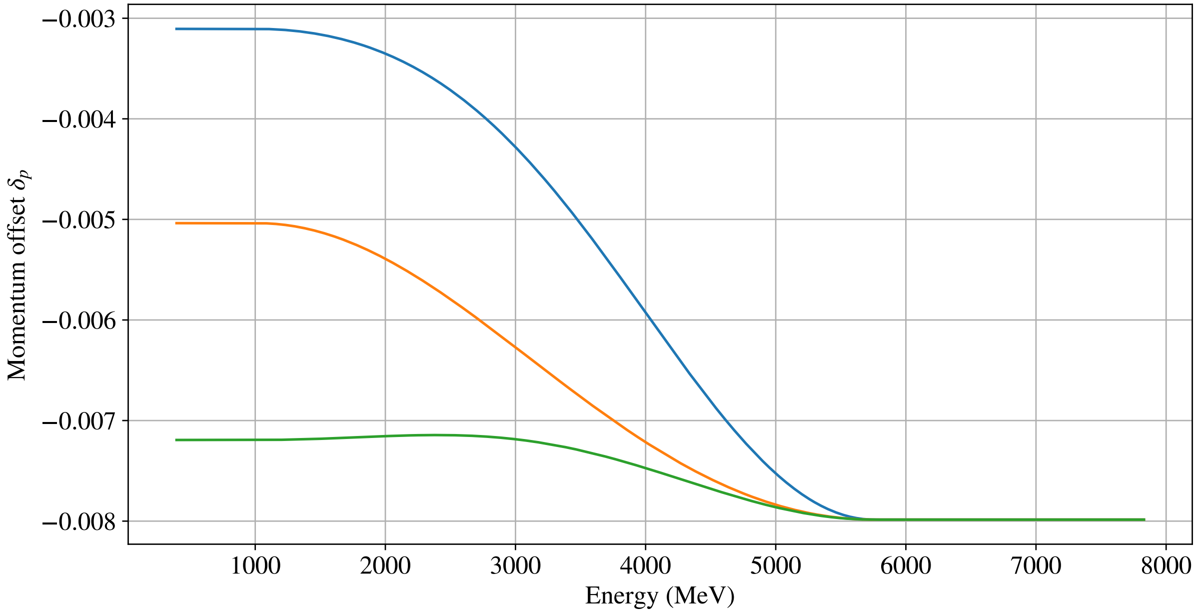


Emittance and Bunch Length









Next Steps

- Limitations of the ILMATRIX model
  - Some physical apertures may not be accurately modeled
  - Assumptions about momentum acceptance = 0.025
- Element by element tracking

Acknowledgements

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