Design of an MBEC Cooler for the EIC

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Microbunched Electron Cooling (MBEC)

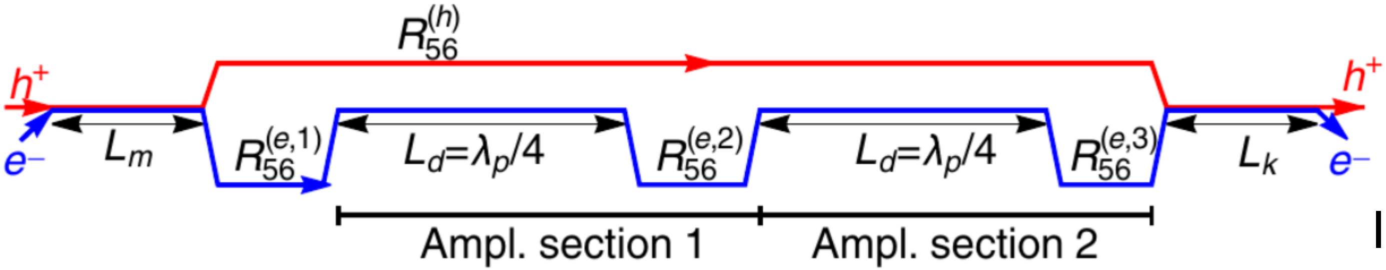

Image from [4].

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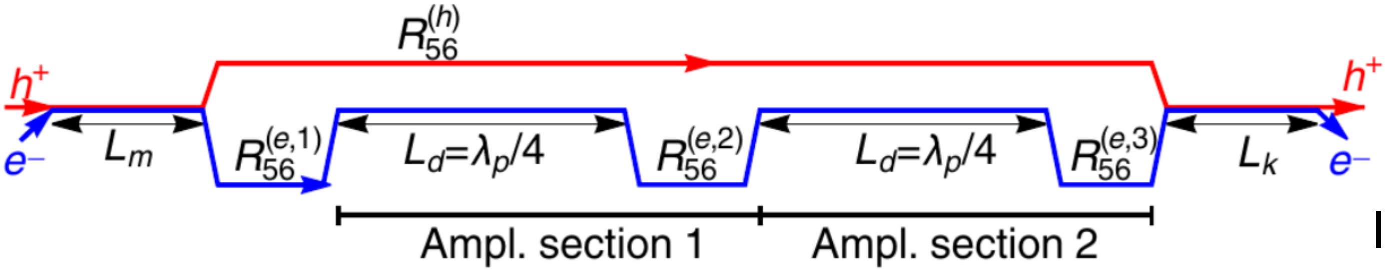

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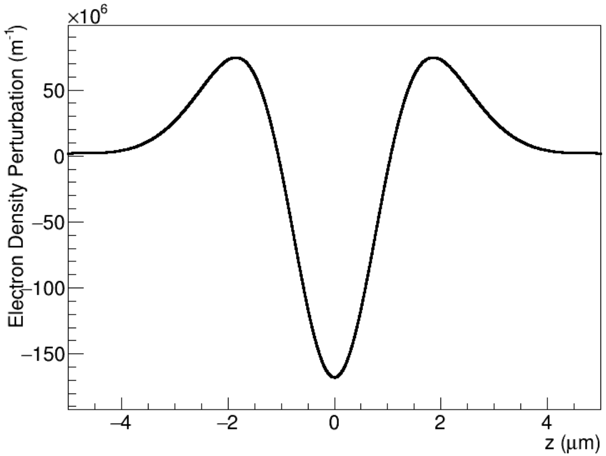

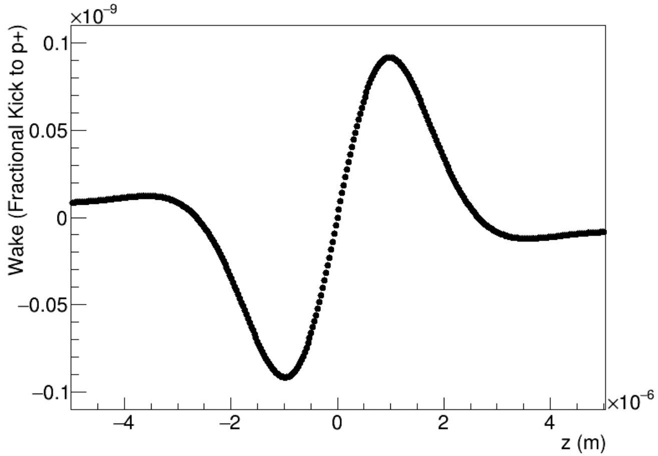

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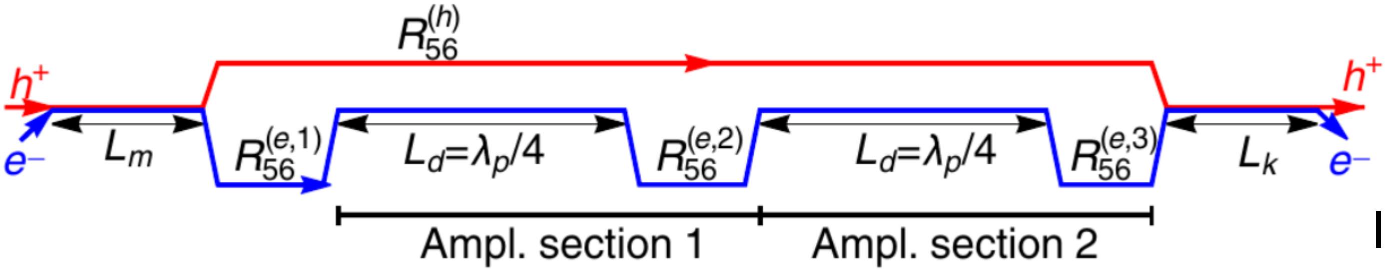

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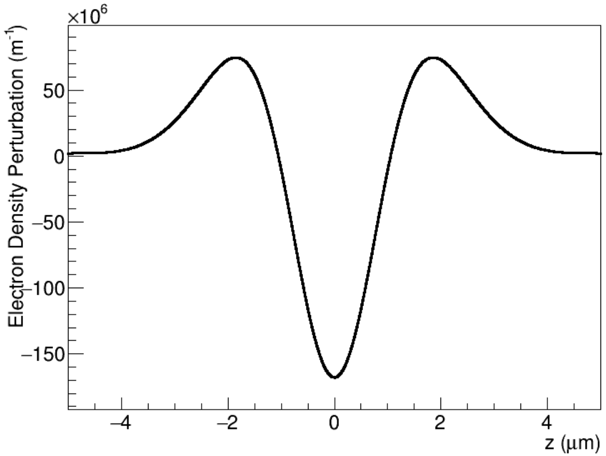

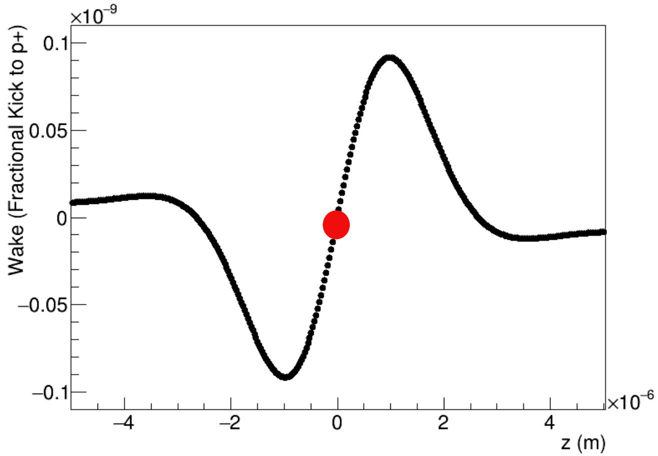

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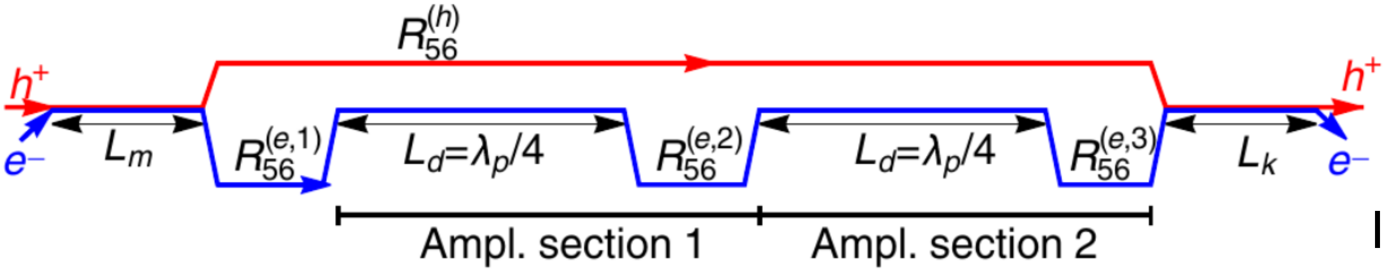

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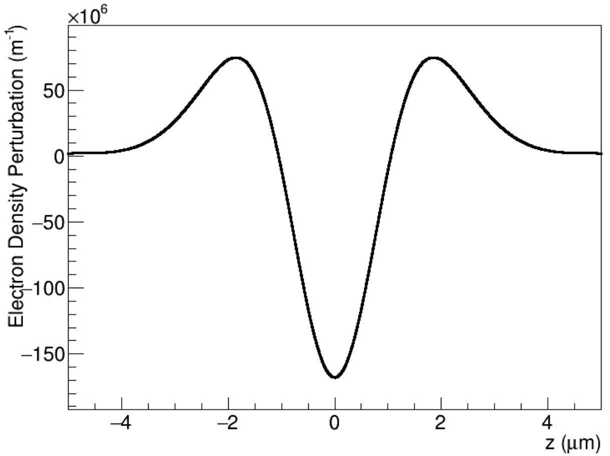
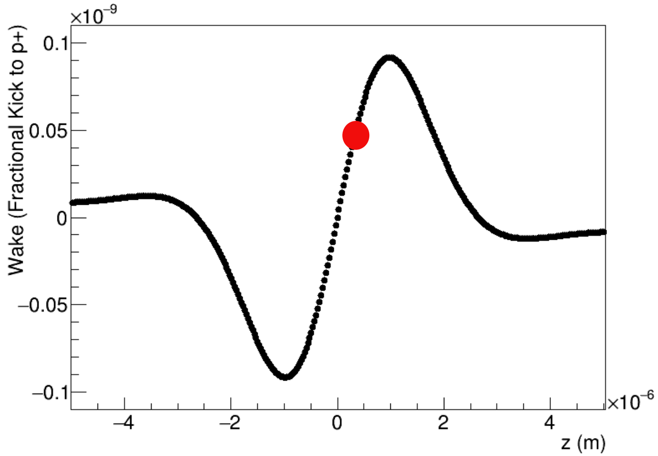
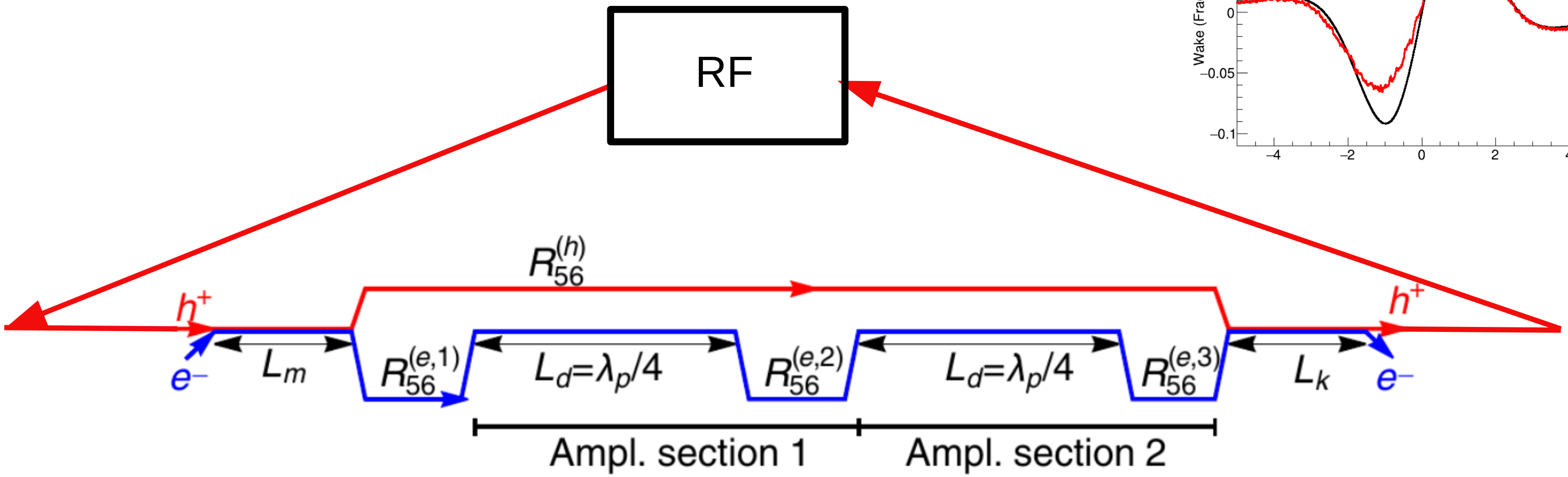
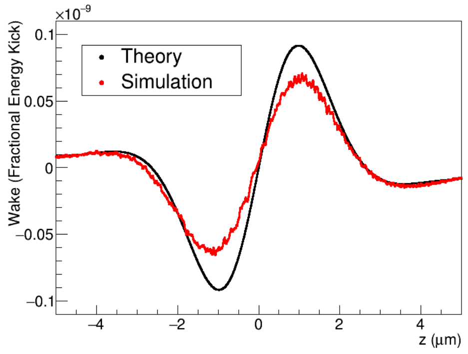




Turn-by-Turn Beam Simulation





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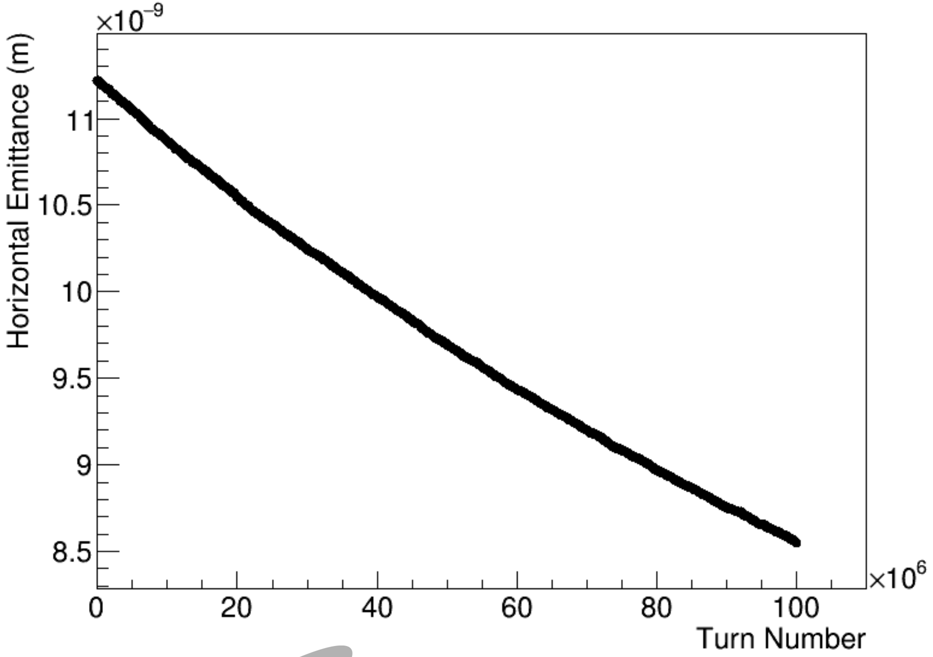
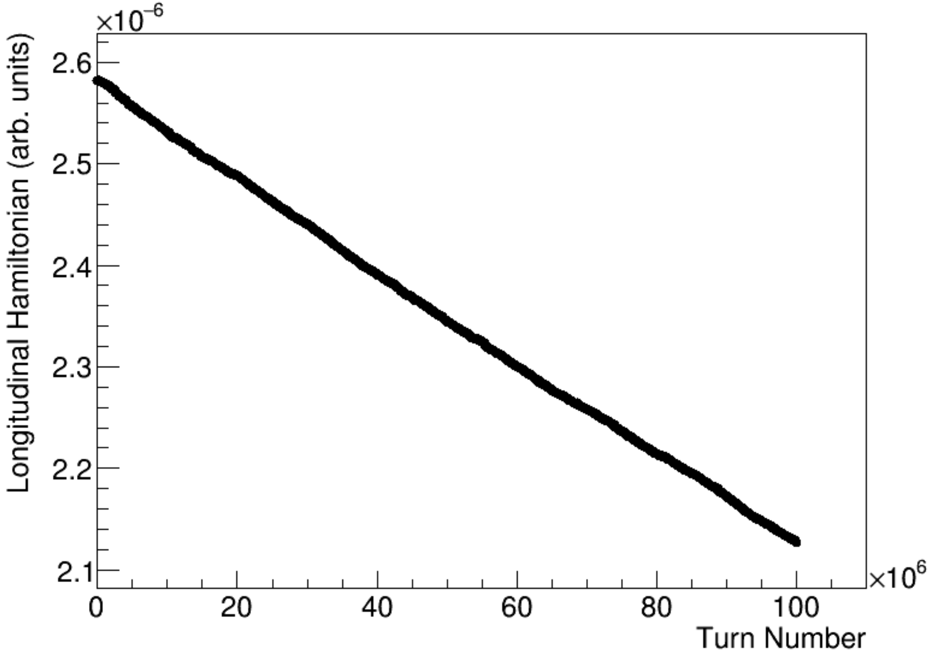
Cooling Rates





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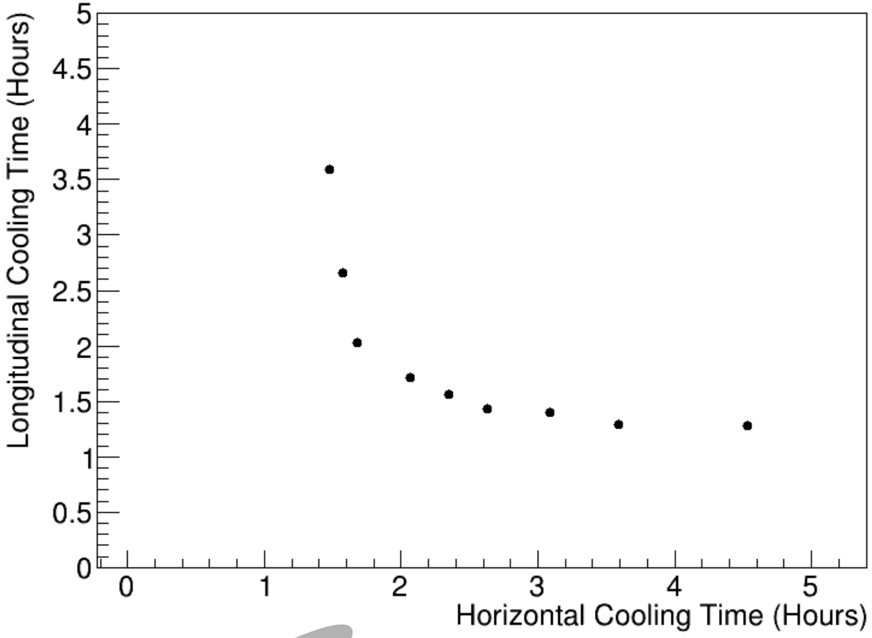
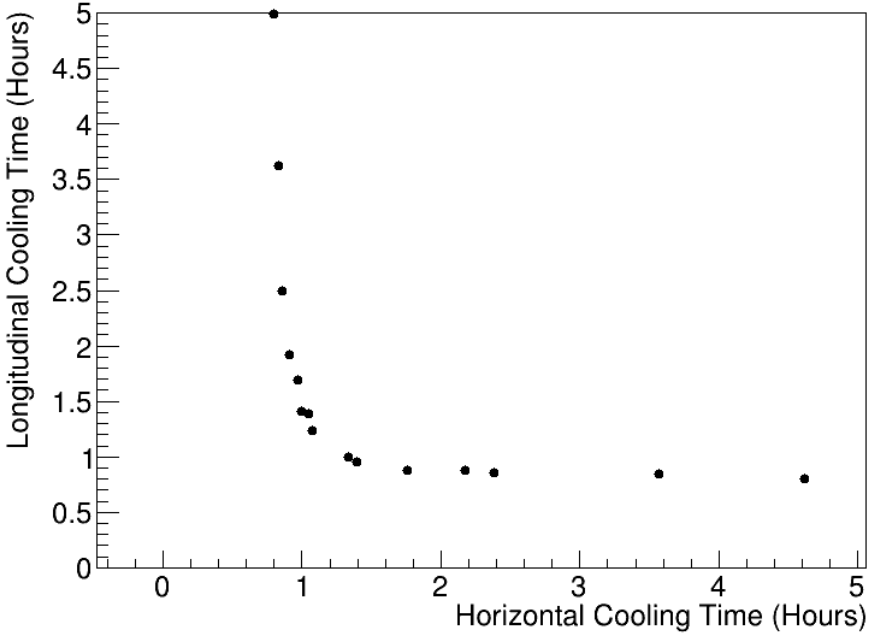
Genetic Algorithm

(Note Saturation Only Estimated)



100 GeV



275 GeV

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Parameters

Proton Energy (GeV)	100	275
Protons per Bunch	6.9e10	6.9e10
Proton Bunch Length (cm)	7	6
Proton Emittance (x/y) (nm)	30 / 2.7	11.3 / 1
Proton Fractional Energy Spread	9.7e-4	6.8e-4
Electron Normalized Emittance (x/y) (mm-mrad)	2.8 / 2.8	2.8 / 2.8
Electron Bunch Charge (nC)	1	1
Electron Bunch Length (mm)	14	7
Electron Peak Current (A)	8.5	17
Electron Fractional Energy Spread	7e-5	5e-5
Electron/Proton Betas in Modulator (m)	30 / 39	100 / 39
Electron/Proton Betas in Kicker (m)	10 / 39	8 / 39
Modulator Length (m)	39	39
Number of Amplifier Drifts	2	2
Amplifier Drift Lengths (m)	48.5	48.5
Kicker Length (m)	39	39
R56 in First Two Electron Chicanes (cm)	2.0	0.68
R56 in Third Electron Chicane (cm)	-5.20	-1.52
R56 in Proton Chicane (cm)	-0.52	-0.22
Proton Horizontal Phase Advance (rad)	4.46	4.79
Proton Horizontal Dispersion in Modulator / Kicker (m)	0.76	1
Proton Horizontal Dispersion Derivative in Modulator/Kicker	-0.023 / 0.023	-0.023 / 0.023
Electron Betas in Amplifiers (m)	11.2	2.5
Horizontal / Longitudinal IBS Times (hours)	2.0 / 2.5	2.0 / 2.9
Horizontal / Longitudinal Cooling Times (hours)	1.7 / 1.9	1.3 / 1.8

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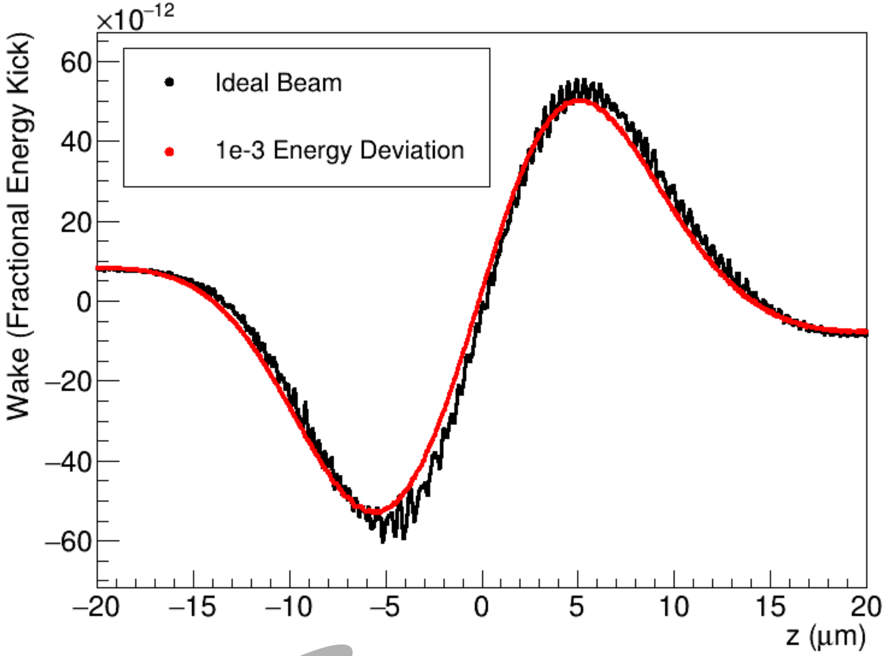
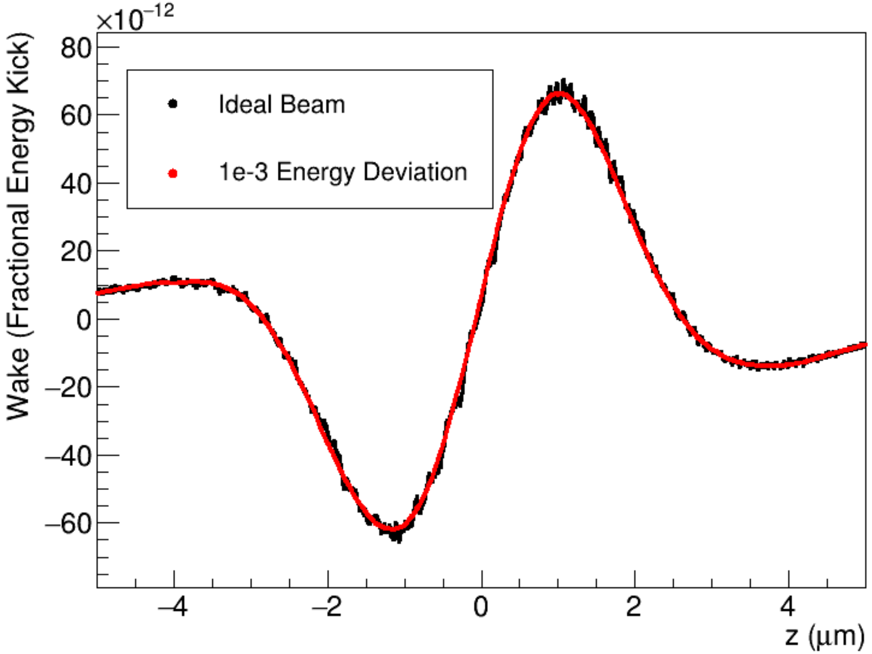
Electron Energy Error



100 GeV



275 GeV

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Conclusions

- Have MBEC design to adequately cool proton beam at 275 and 100 GeV
- Largely insensitive to off-energy electron beam
- Work is ongoing to make a realistic lattice

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Theoretical Impedance and Wake

$$Z(k) = G_1 G_2 \frac{4iI_e L_m L_k}{c\Sigma^2\gamma^3 I_A \sigma_e} q_1 \varkappa e^{-\varkappa^2 q_1^2/2} H_{ep,m}(\varkappa) H_{ep,k}(\varkappa)$$

$$w(z) = -\frac{cr_h}{2\pi\gamma}\int_{-\infty}^{\infty} Z(k) e^{ikz} dk$$

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Electron Noise

$$Z_{e,1}(k) = G_1 G_2 \frac{4iI_e L_m L_k}{c\Sigma^2\gamma^3 I_A \sigma_e} q_1 \varkappa e^{-\varkappa^2 q_1^2/2} H_{ee,m}(\varkappa) H_{ep,k}(\varkappa)$$

(Electrons induce kick analogous to protons)

$$Z_{e,2}(k) = G_1 G_2 \frac{-2ieL_k}{r_e \Sigma \gamma I_A} H_{ep,k}(\varkappa)$$

(Electron density modulations carried through directly)

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Electron Noise

$$\frac{d\sigma_h^2}{dt} = \frac{n}{T}\int_{-\infty}^{\infty} w^2(z)dz$$

$$\frac{d\sigma_h^2}{dt} = \frac{n}{T}\int_{-\infty}^{\infty} \left[w_{e,1}^2(z) + w_{e,2}^2(z)\right] dz +$$

$$\frac{2n}{T}\int_{-\infty}^{\infty} dz \int_{-\infty}^{\infty} d\delta \frac{1}{\sqrt{2\pi}\sigma_e} e^{-\delta^2/2\sigma_e^2} w_{e,1}(z) w_{e,2}(z + R_{56}\delta)$$

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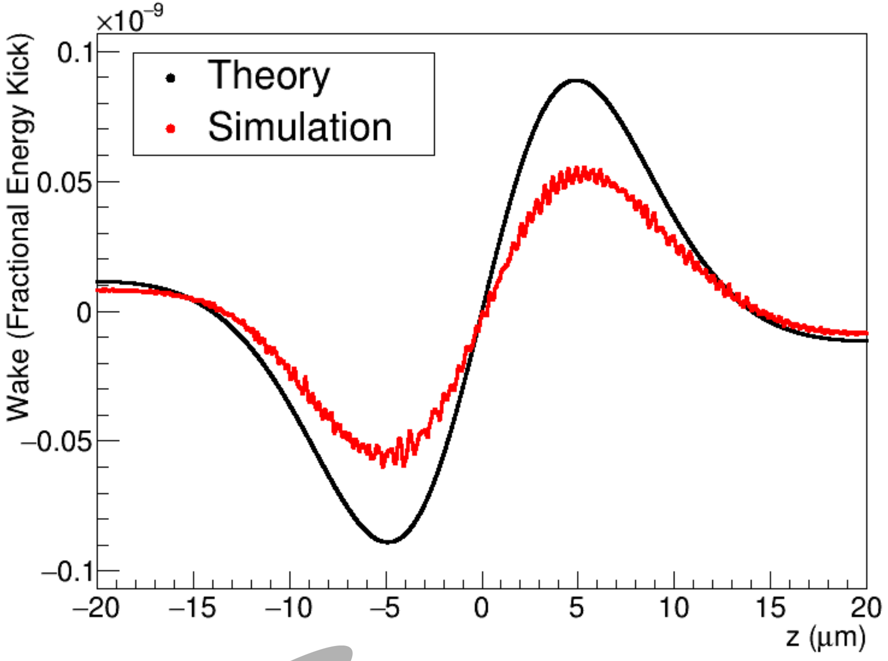
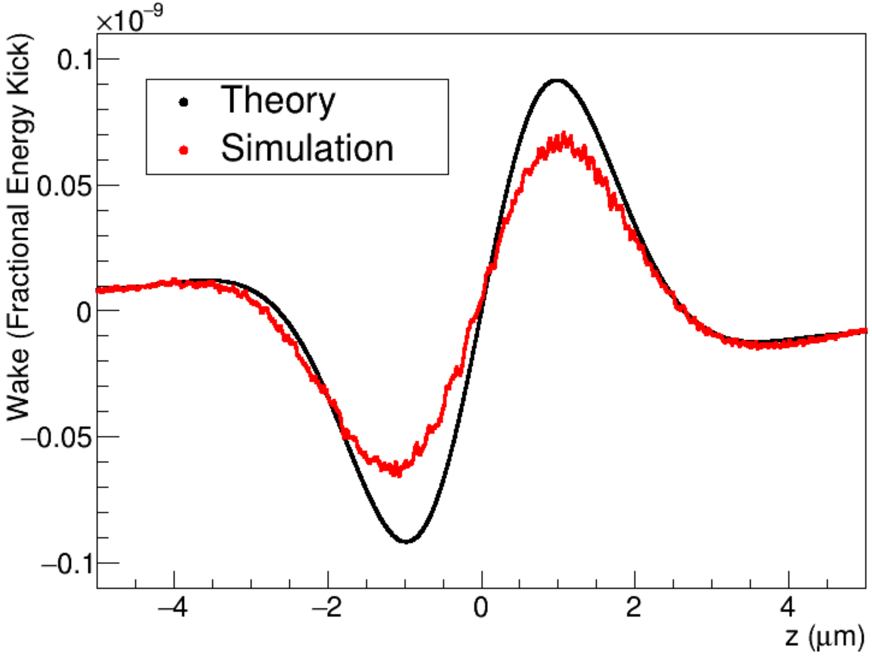
Wake Function



100 GeV



275 GeV

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