Plasma Simulations for an MBEC Cooler for the EIC

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Microbunched Electron Cooling (MBEC)

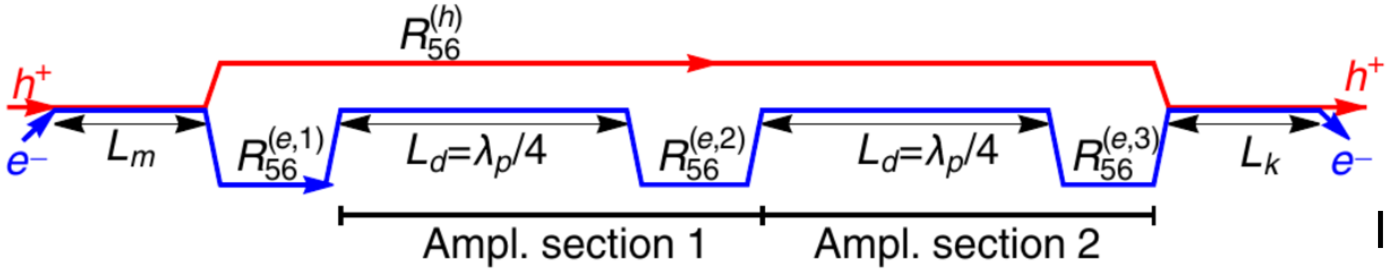
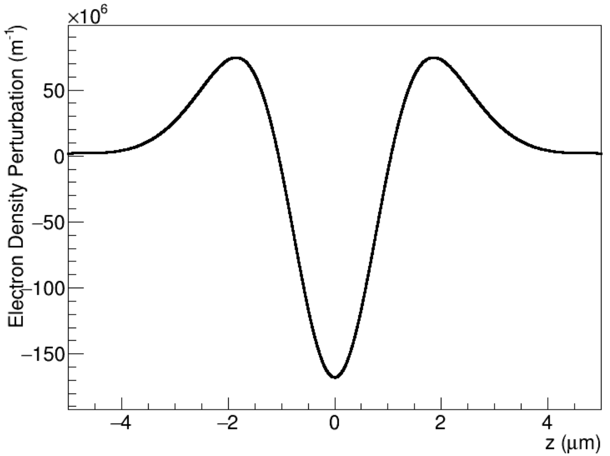
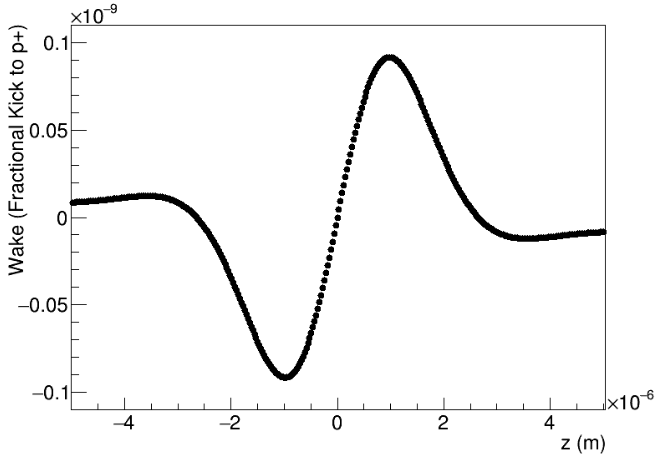


Image from [4].

More details in my TUPAB179 poster





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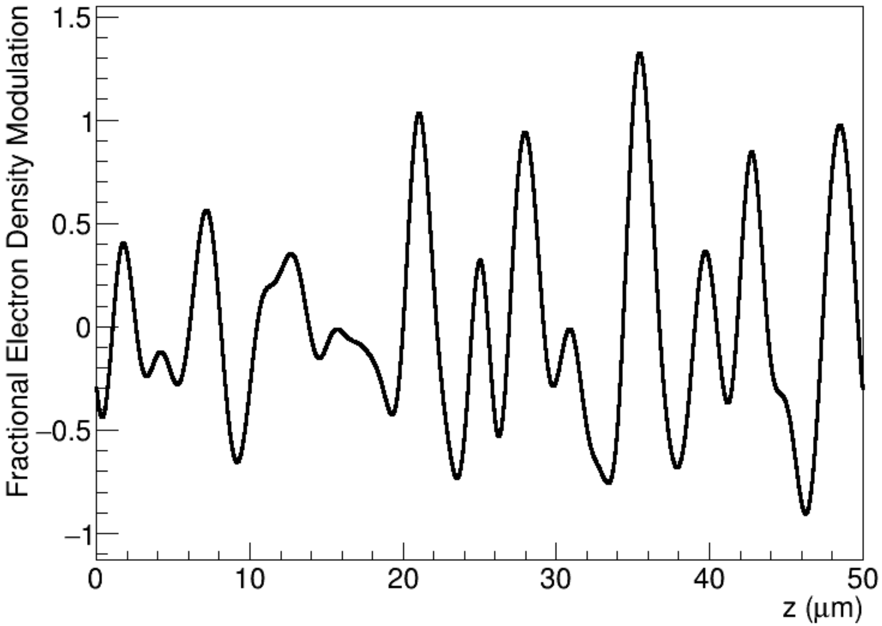
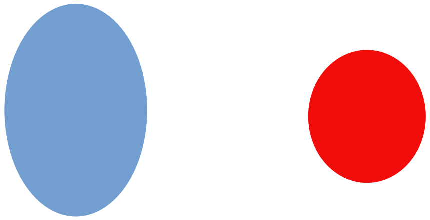
Saturation


Fractional Electron Density Modulation
1.5
1
0.5
0
−0.5
−1
0
10
20
30
40
50
z (μm)

Kick/Drift Model



$$\Delta\delta = \frac{F}{\gamma m c^2} dL$$

$$F = \frac{4Q_1 Q_2 \gamma z}{4\pi\epsilon_0\sqrt{\pi}} \int_0^\infty d\lambda \lambda^2$$

$$\times \frac{\exp(-\lambda^2\gamma^2 z^2)}{\sqrt{1+2\lambda^2(\Sigma_{x,1}^2+\Sigma_{x,2}^2)}\sqrt{1+2\lambda^2(\Sigma_{y,1}^2+\Sigma_{y,2}^2)}}$$

$$\Delta z = R_{56}\delta$$

(Model from [3-5])

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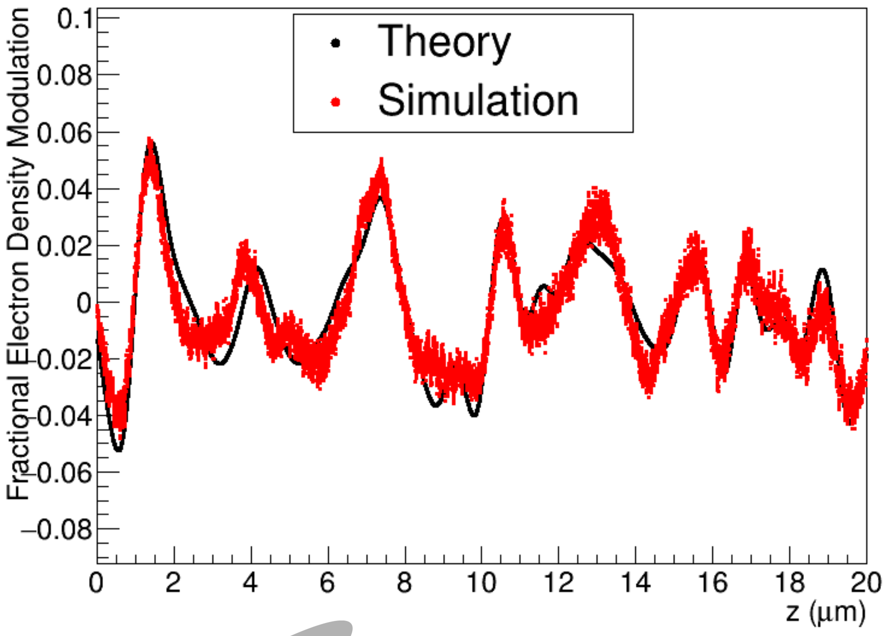
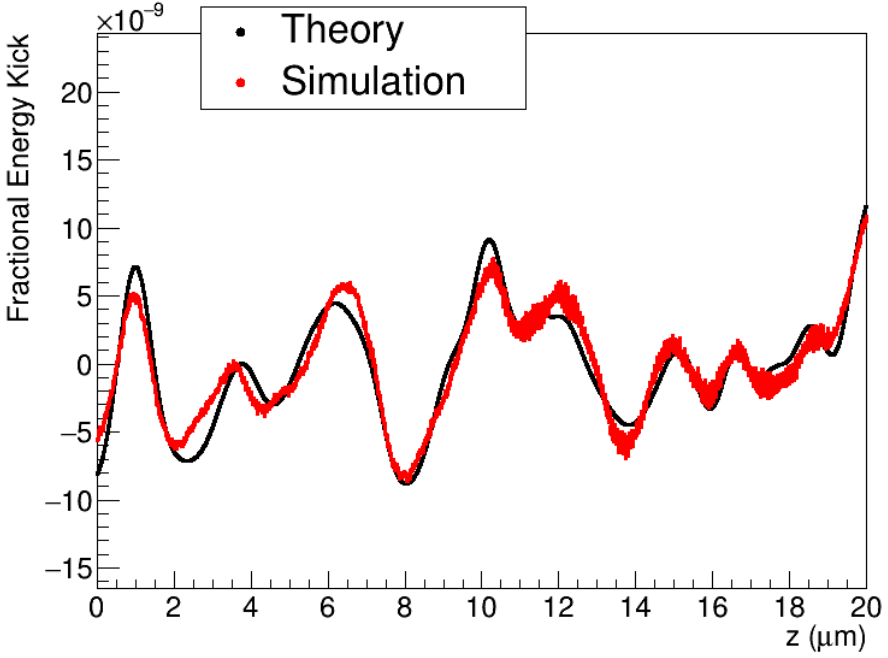
One Amplifier





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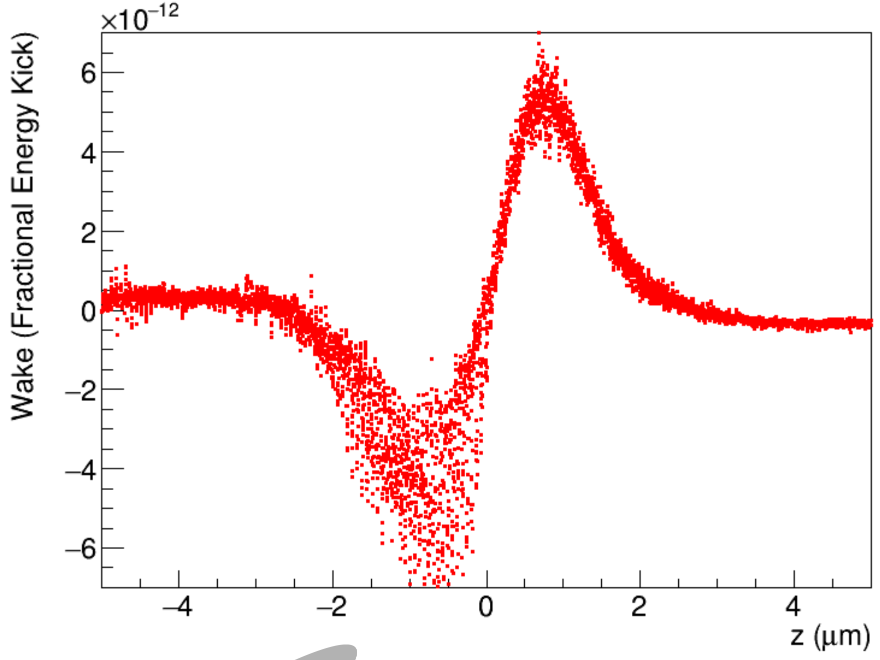
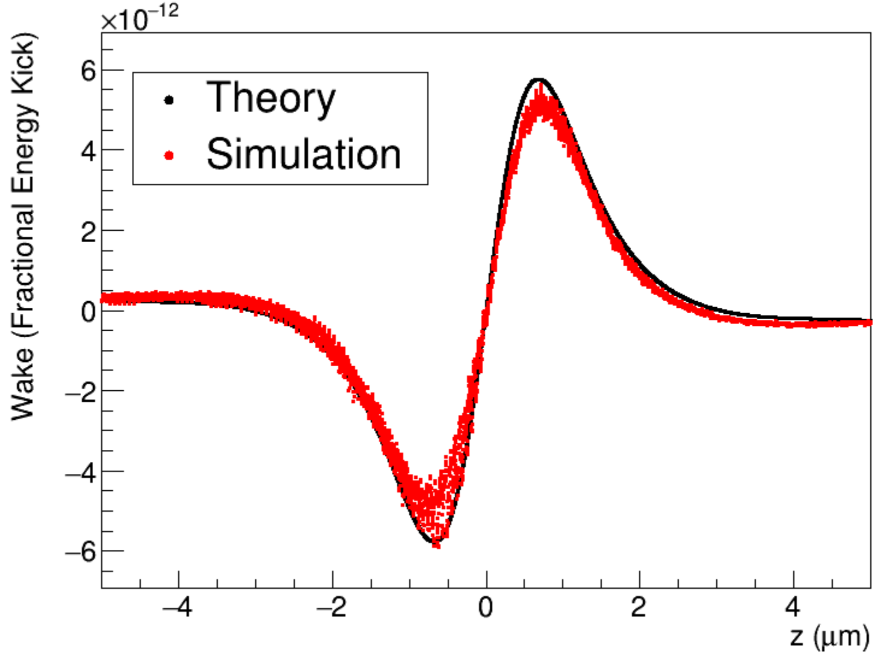
One Amplifier (Wake)





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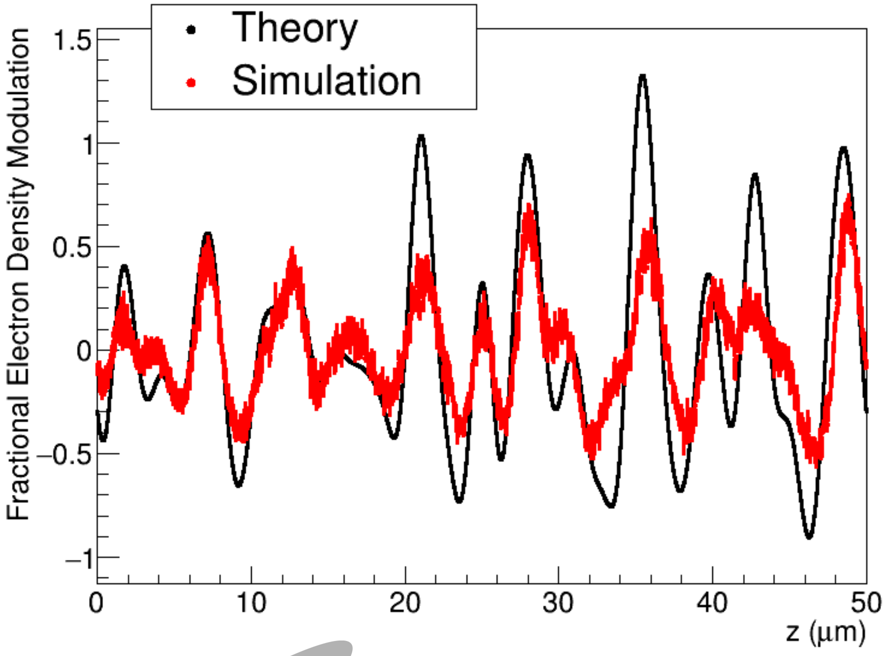
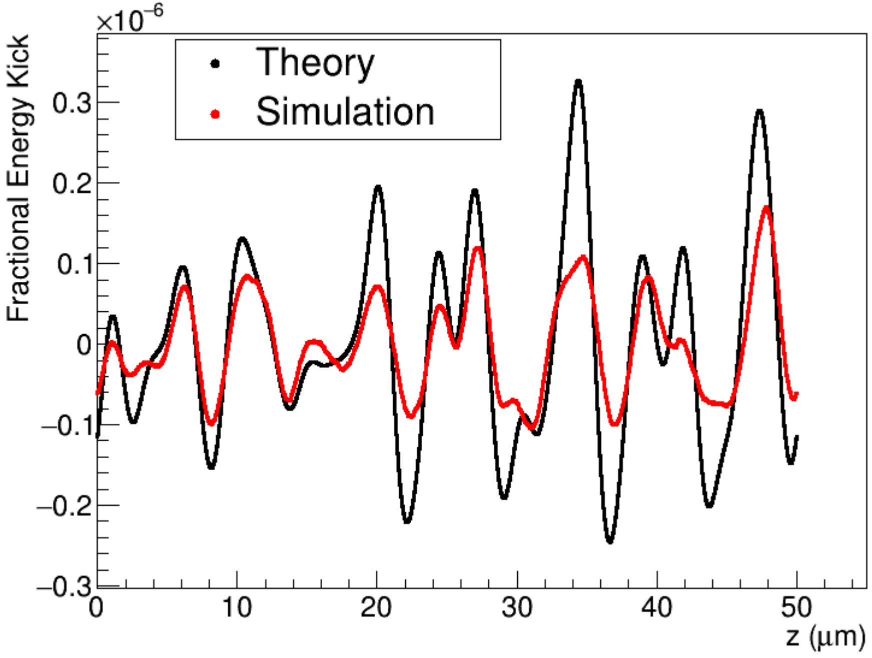
Two Amplifiers (Current Design)





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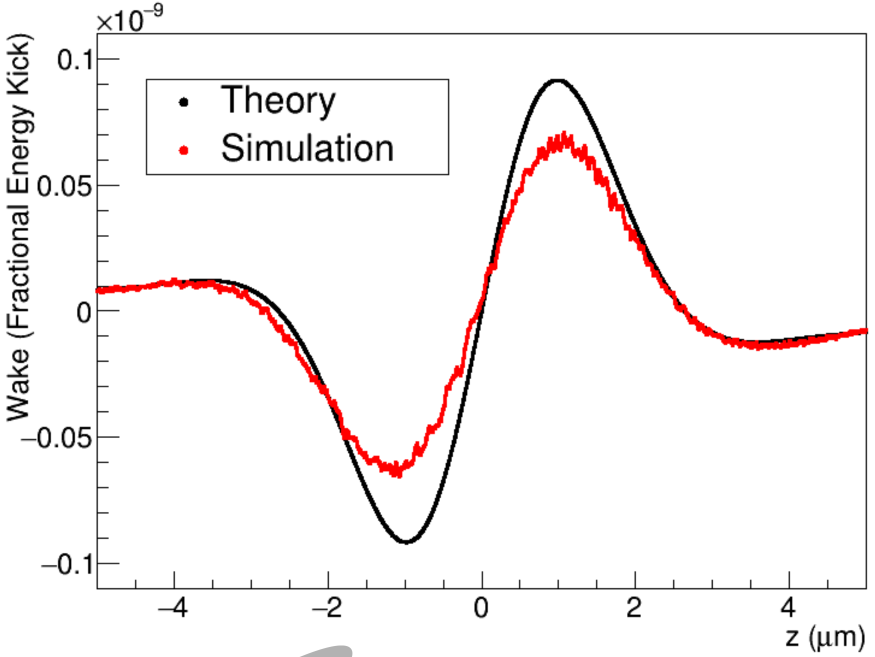
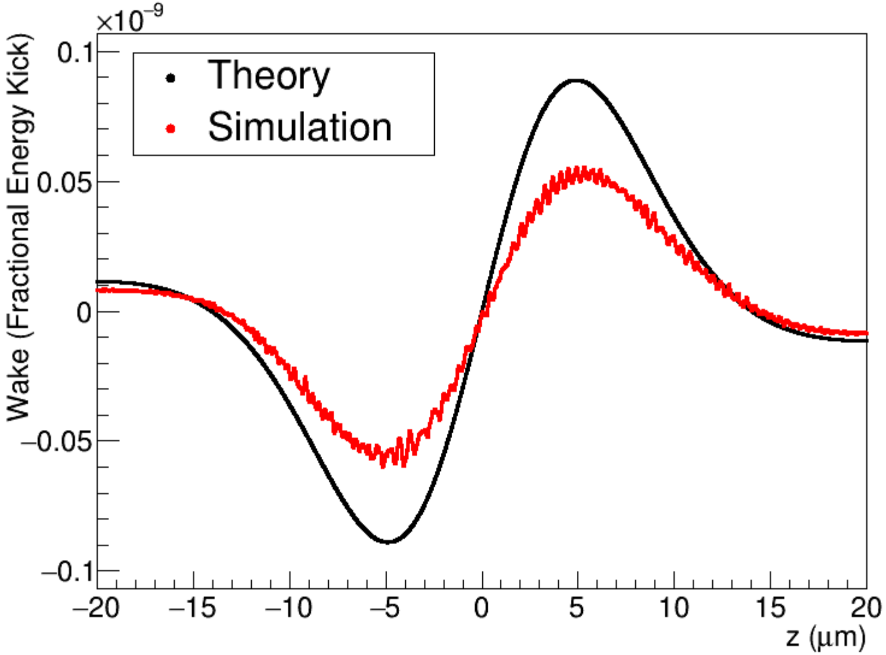
Wake Function
(275 GeV and 100 GeV)





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63% (275 GeV) and 59% (100 GeV) of cooling rate as in theory

64% (275 GeV) and 43% (100 GeV) of diffusion as in theory

Conclusions

- Theory and simulation agree well at low saturation
- Can input reductions in cooling and diffusion rates into cooling theory

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References

[1] Electron-ion collider at Brookhaven National Laboratory, conceptual design report 2021, `https://www.bnl.gov/EC/files/EIC_CDR_Final.pdf`

[2] D. Ratner, "Microbunched electron cooling for high-energy hadron beams", *Phys. Rev. Lett.*, vol. 111, p. 084802, Aug. 2013.

[3] G. Stupakov, "Cooling rate for microbunched electron cooling without amplification", *Phys. Rev. Accel. Beams*, vol. 21, p. 114402, Nov. 2018.

[4] G. Stupakov and P. Baxevanis, "Microbunched electron cooling with amplification cascades", *Phys. Rev. Accel. Beams*, vol. 22, p. 034401, Mar. 2019.

[5] P. Baxevanis and G. Stupakov, "Transverse dynamics considerations for microbunched electron cooling", *Phys. Rev. Accel. Beams*, vol. 22, p. 081003, Aug. 2019.

[6] P. Baxevanis and G. Stupakov, "Hadron beam evolution in microbunched electron cooling", *Phys. Rev. Accel. Beams*, vol. 23, p. 111001, Nov. 2020.

[7] W. F. Bergan, P. Baxevanis, M. Blaskiewicz, E. Wang, and G. Stupakov, "Design of an MBEC cooler for the EIC", presented at IPAC'21, Campinas, Brazil, May 2021, paper TUPAB179, this conference.

[8] R.W Hockney and J.W Eastwood, *Computer simulation using particles*. New York, NY, USA: Taylor & Francis, 1988.

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Backup Slides

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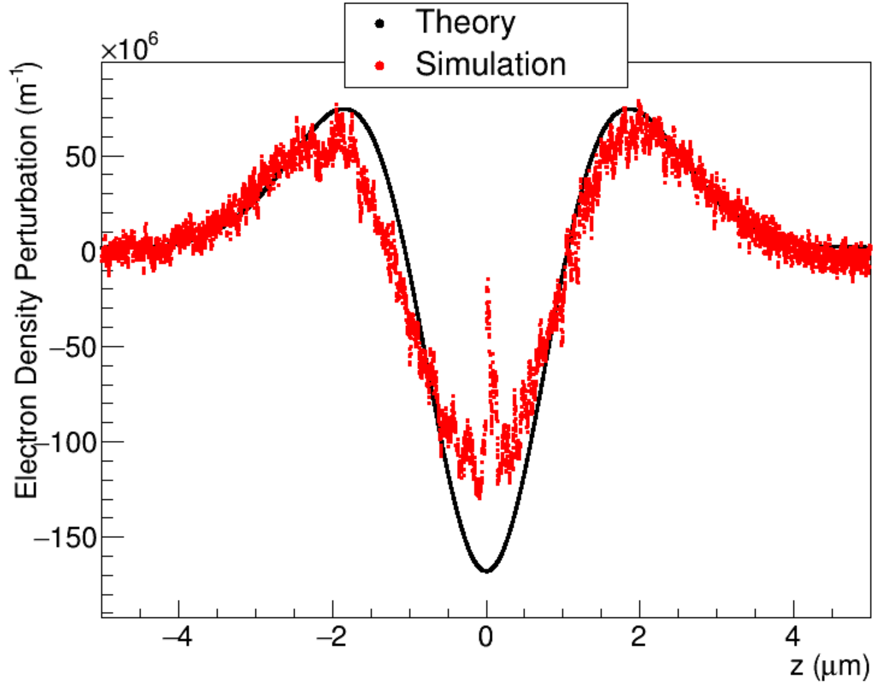
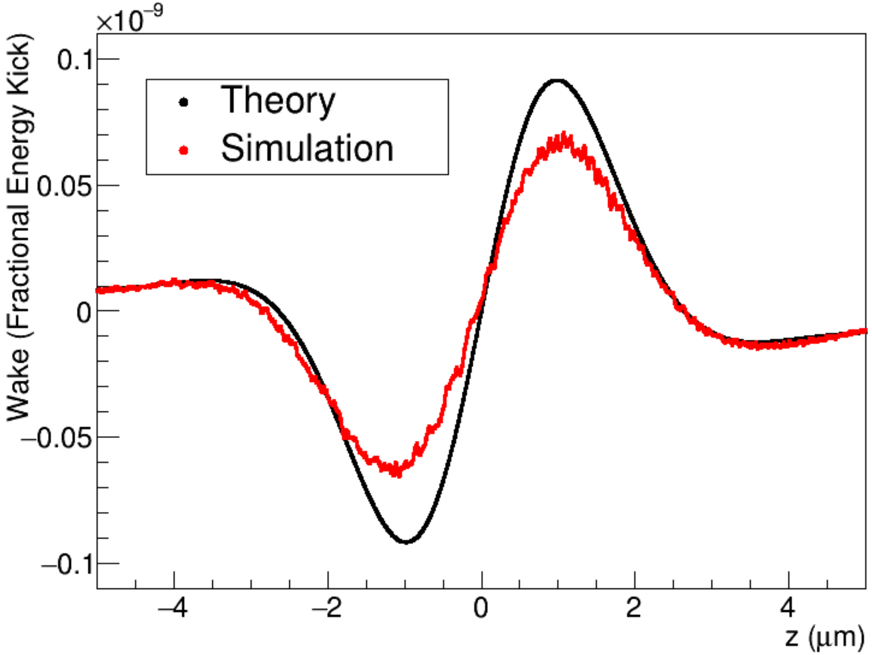
Induced Wake (275 GeV)





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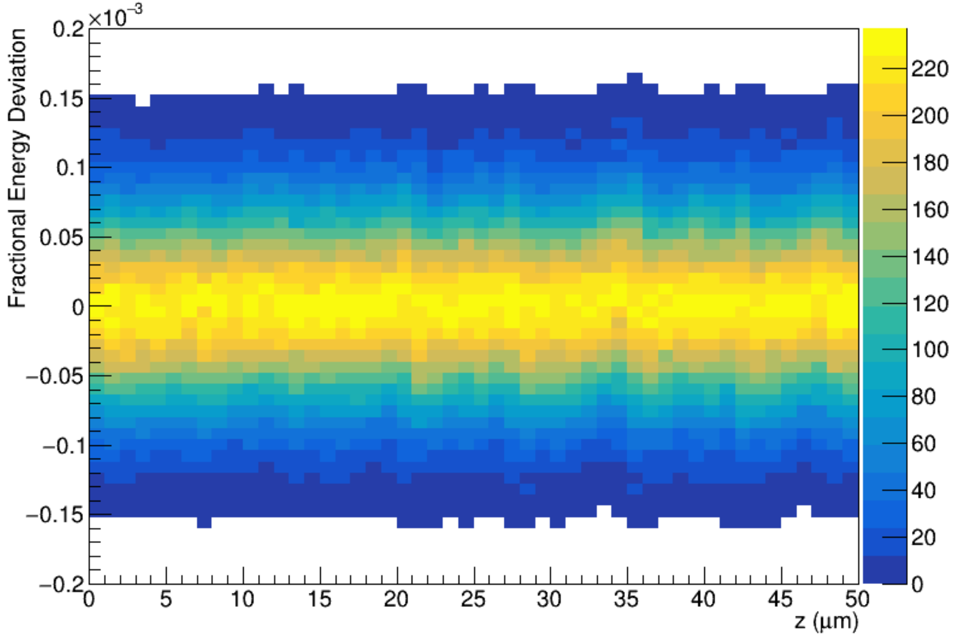
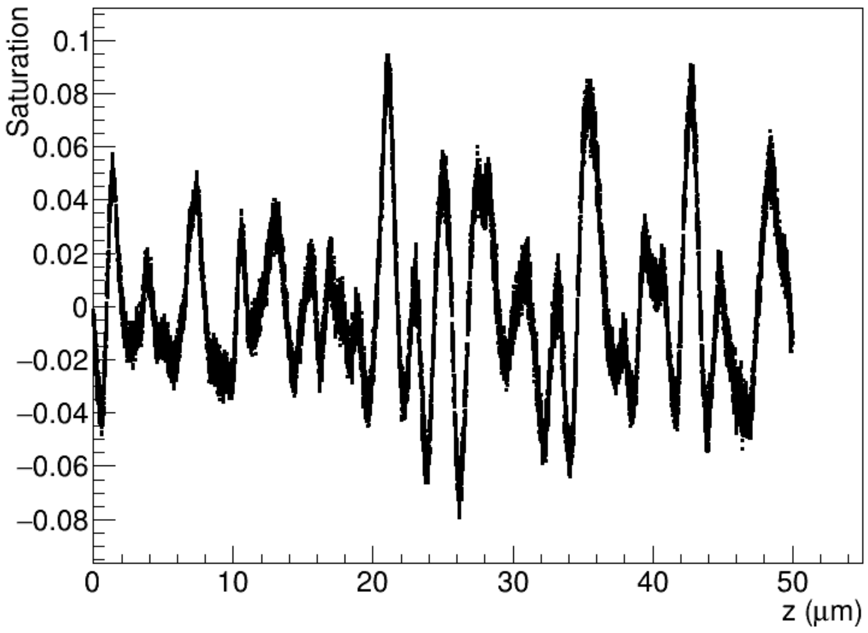
Start of 2nd Amplifier





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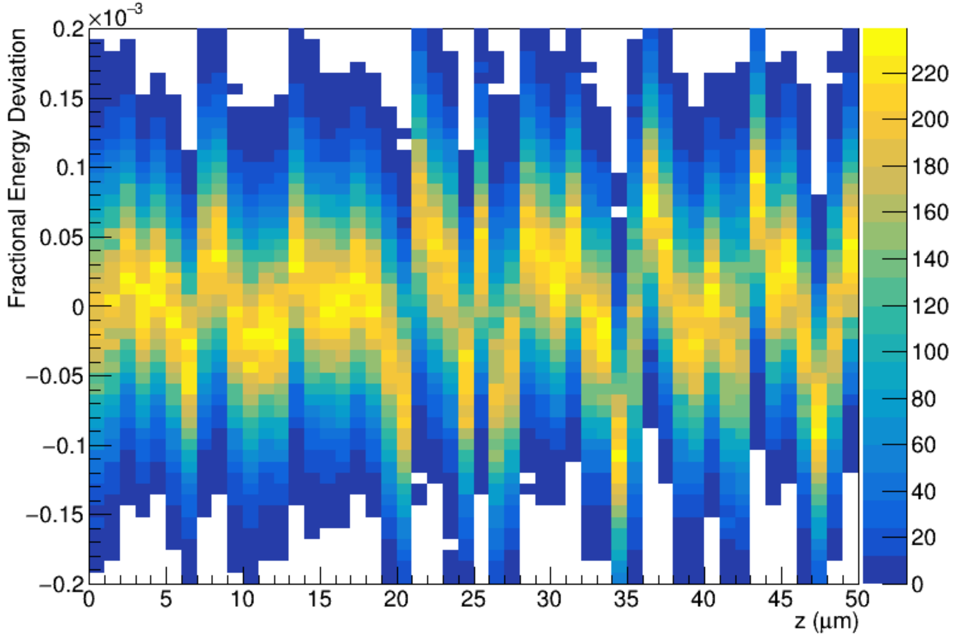
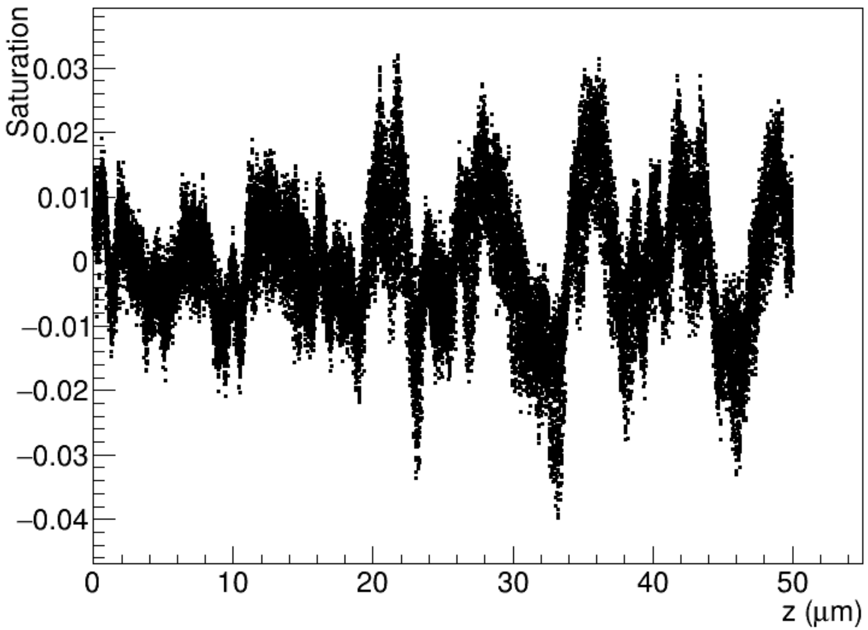
End of 2nd Amplifier





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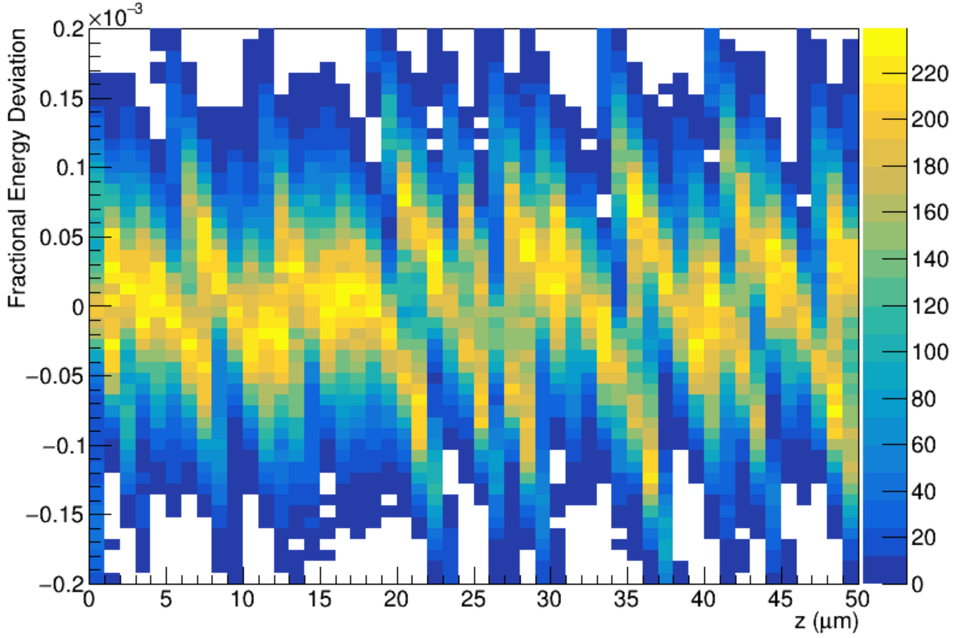
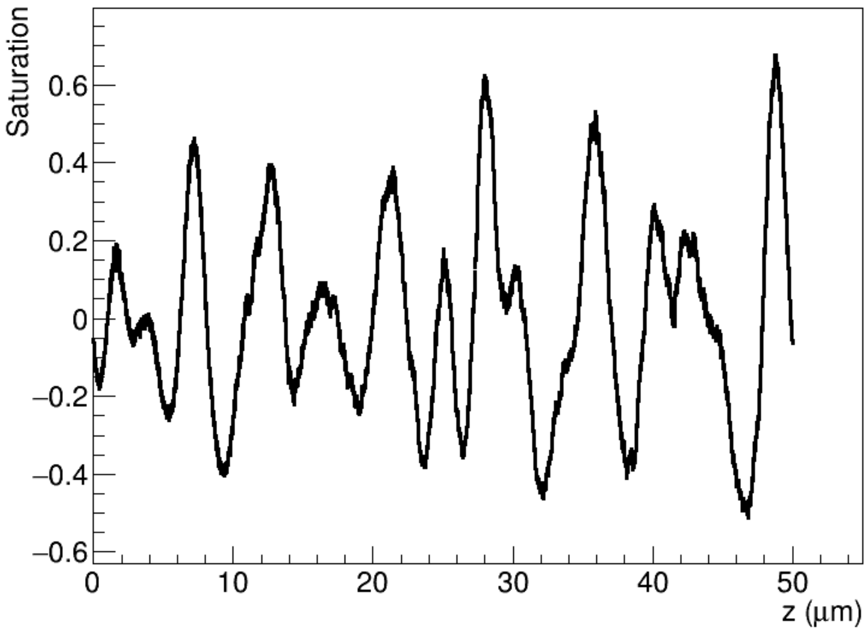
Start of Kicker





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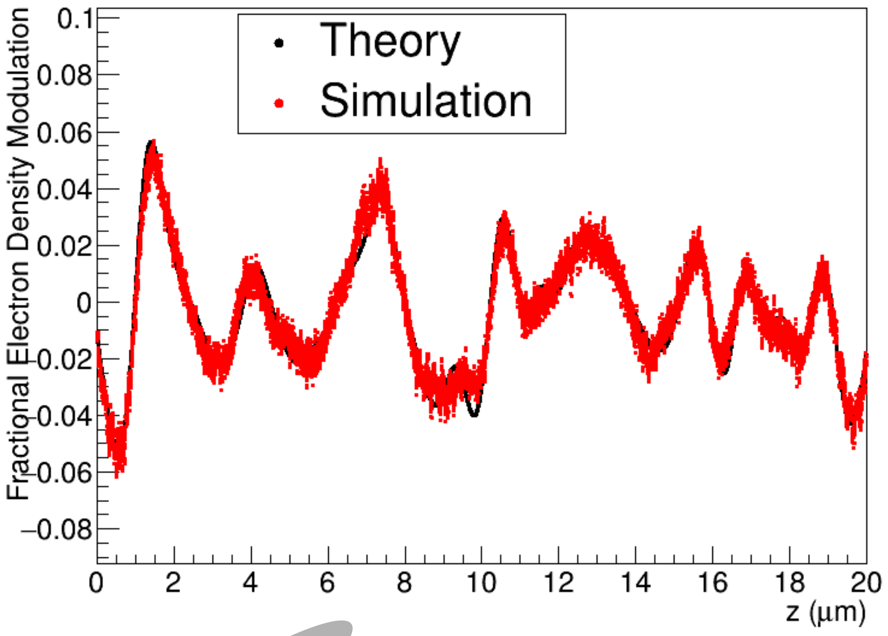
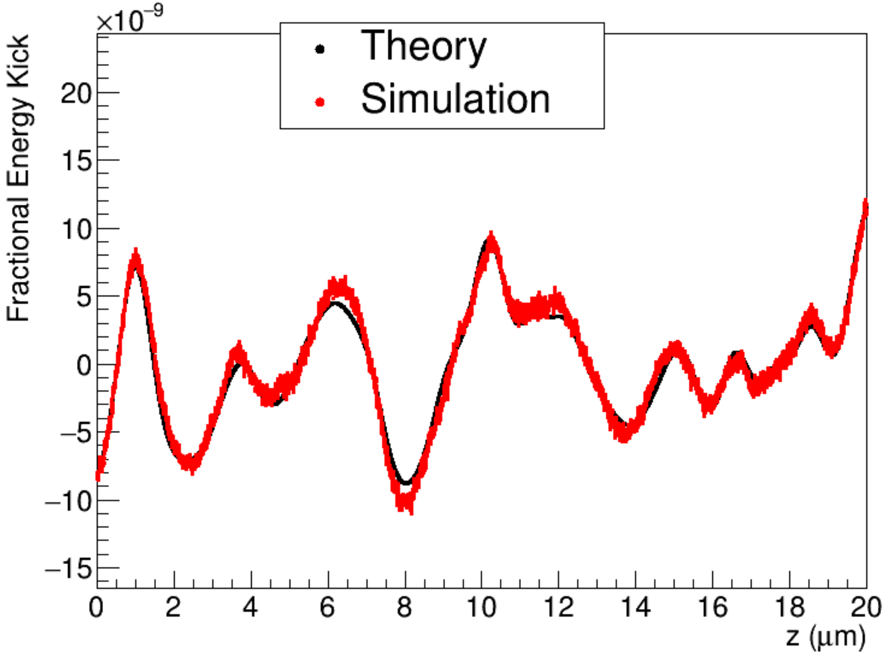
One Amplifier w/o Modulator/Kicker Plasma Oscillations





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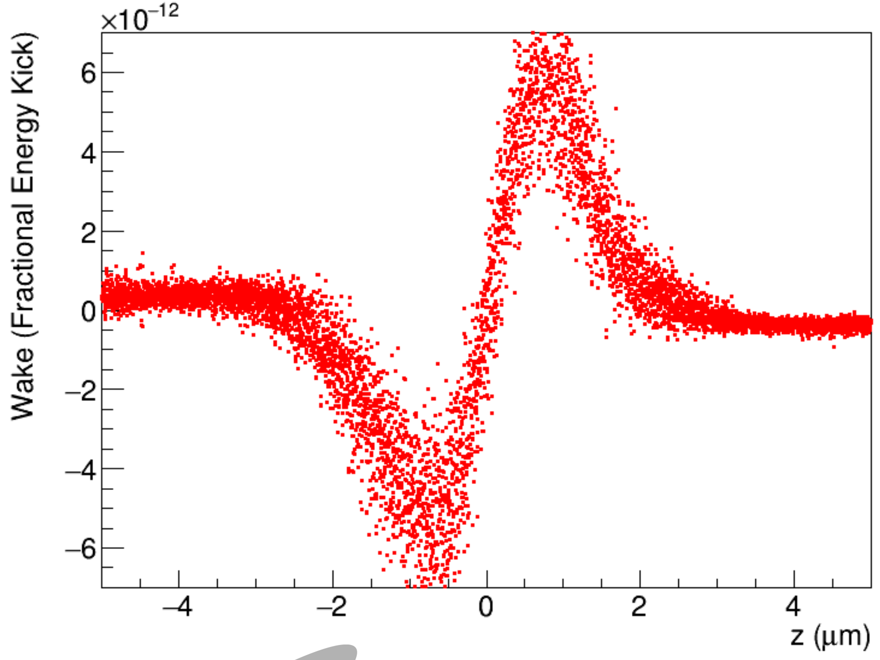
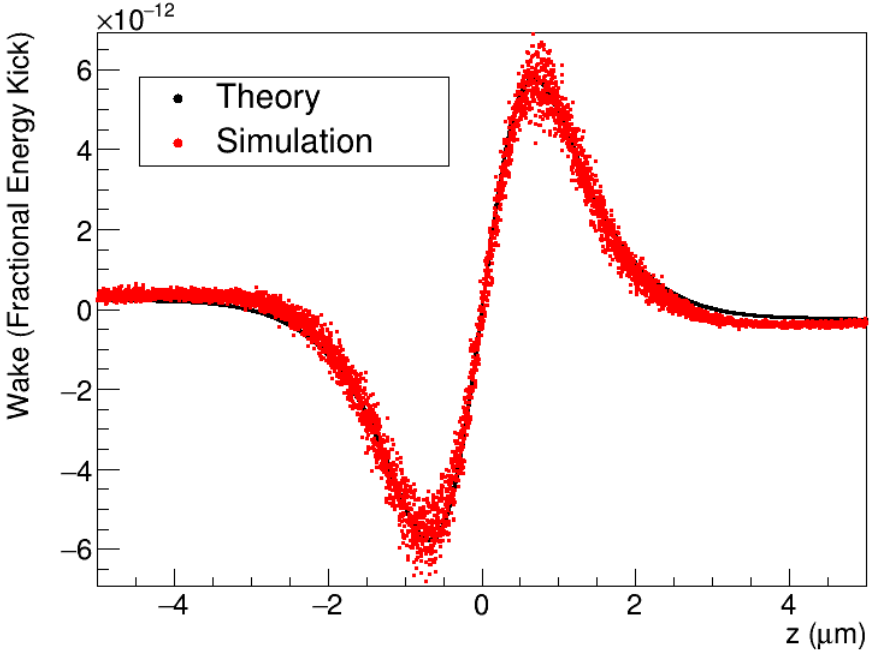
One Amplifier w/o Modulator/Kicker Plasma Oscillations (Wake)





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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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