MBEC / PCA
Cooling Time Comparison

- Fit current PCA and MBEC wakes to sine function with decaying exponential

- Extract cooling times

Caveats

- Parameters taken from current 275 GeV MBEC design and the PCA design slides of May 7, 2021 – both should be decently optimized, but changes practically guaranteed going forward
- Wake fits will not be perfect, but good enough to get decent estimates of cooling rates
- Cooling rate calculation assumes cooling rate falls as the square of electron beam current, as is the case for MBEC – unsure of the correct factor for PCA, but only O(1) correction factor
- Only initial longitudinal cooling rate examined
- Nonlinear effects, saturation, diffusion, 3D effects, etc. not included

Key Equations of https://arxiv.org/pdf/2102.10239.pdf

$$w(z) = -V_0 \sin\left(2\pi \frac{z}{z_0}\right) \exp\left(-\frac{z^2}{{\sigma_0}^2}\right)$$

$$\frac{1}{\tau_c} = \frac{\pi f_0 V_0}{\delta_p n E_0} \frac{\sigma_{ez}}{\sqrt{2}\sigma_{pz}} \left(1 + \frac{{z_0}^2}{2n^2{\sigma_0}^2}\right)^{-3/2} \exp\left(-\frac{\pi^2}{2n^2 + {z_0}^2/{\sigma_0}^2}\right)$$

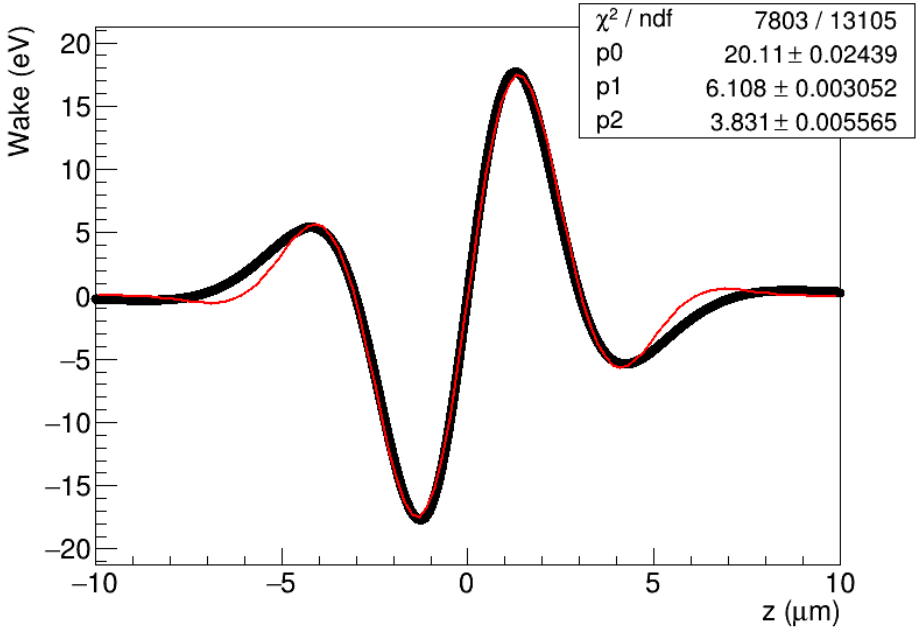
f_0: revolution frequency
σ_{ez}, σ_{pz}: electron and proton bunch lengths
δ_p: proton RMS fractional energy spread
n: cooling range

Selected Relevant Beam Parameters

	MBEC	PCA
Revolution Frequency (kHz)	78	78
Proton Bunch Length (cm)	6	6
Proton RMS Energy Spread	6.8e-4	6.8e-4
Electron Bunch Charge (nC)	1	12.5
Electron Bunch Length (mm)	7	15
Electron Slice Energy Spread	1e-4	1e-4
Minimum Electron Beam Size (mm)	0.1	0.1

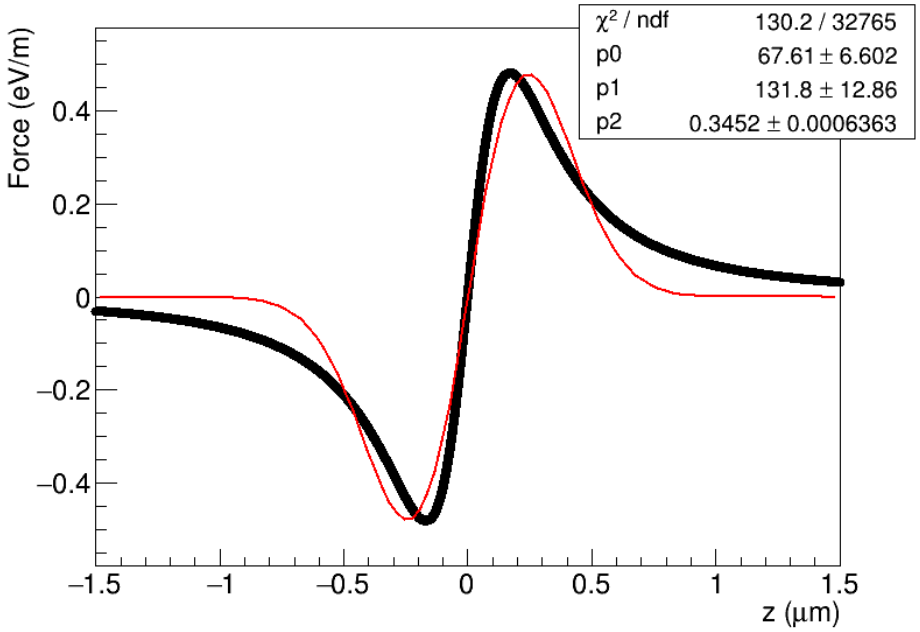
MBEC Wake

V_0 (eV)	20.1
z_0 (μm)	6.11
σ_0 (μm)	3.83
n	3.5
Cooling Time (min.)	45



PCA Wake

V_0 (eV)	1352 (20m x 67.6eV/m)
z_0 (μm)	131.8
σ_0 (μm)	0.345
n	380
Cooling Time (min.)	37



(Wake of form $E_{fit}(z) = E_0 \frac{z}{\sigma_c} \cdot \left(1 + \frac{z^2}{\sigma_c^2}\right)^{-3/2}$ with parameters chosen to give peak of 0.48 V/m at 0.17 μm)

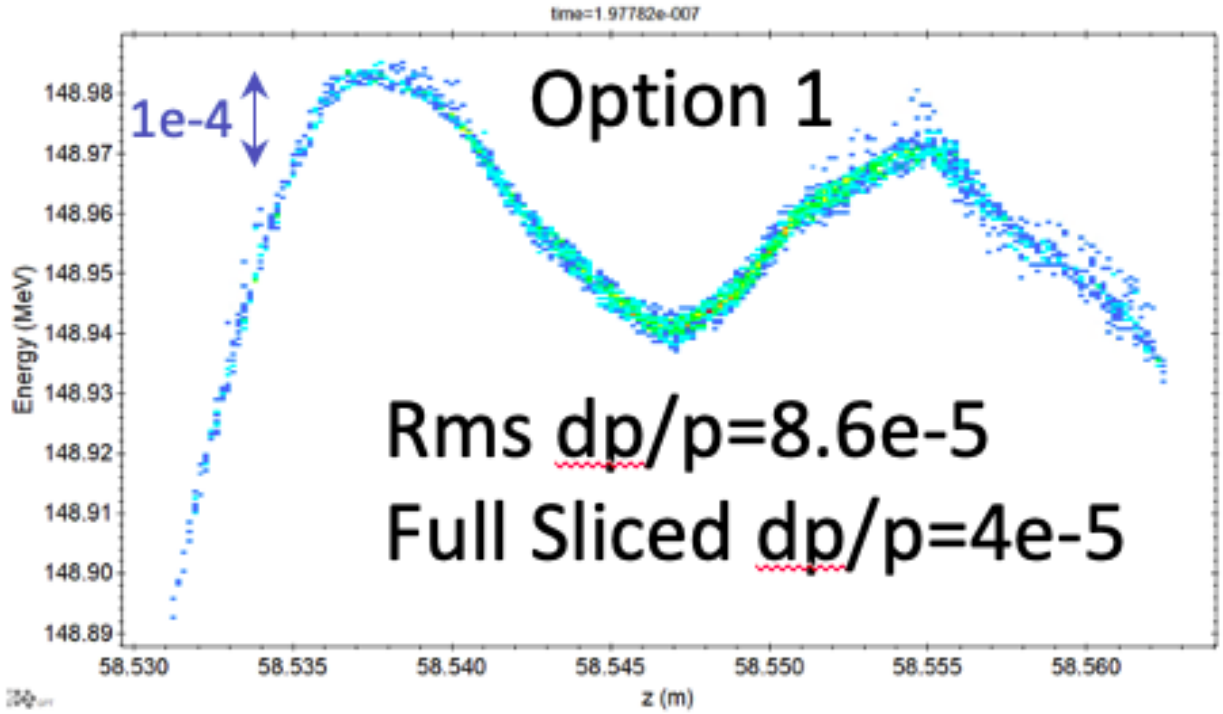
Conclusions

- Current MBEC and PCA designs give comparable cooling times
- Any differences in this estimate likely minor compared to future reoptimizations, impositions of reality, etc.

Backup Slides

- Electron distribution
- IPAC MBEC wake

Electron Energy Spread



Optimistic e- Energy Spread

	IPAC MBEC	MBEC	PCA
Revolution Frequency (kHz)	78	78	78
Proton Bunch Length (cm)	6	6	6
Proton RMS Energy Spread	6.8e-4	6.8e-4	6.8e-4
Electron Bunch Charge (nC)	1	1	12.5
Electron Bunch Length (mm)	7	7	15
Electron Slice Energy Spread	0.5e-4	1e-4	1e-4
Minimum Electron Beam Size (mm)	0.15	0.1	0.1

IPAC MBEC Wake

V_0 (eV)	32.0
z_0 (μm)	5.16
σ_0 (μm)	2.32
n	3.5
Cooling Time (min.)	31