# CeC cooling decrement with painting

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Consideration for FEL-based CeC were described in*: Effects of e-beam Parameters on Coherent Electron Cooling*, S.D. Webb, V. Litvinenko, G. Wang, Proceedings of 2011 Particle Accelerator Conference, New York, NY, USA, March 25-April 1, 2011, p.232

# Simple 1D model

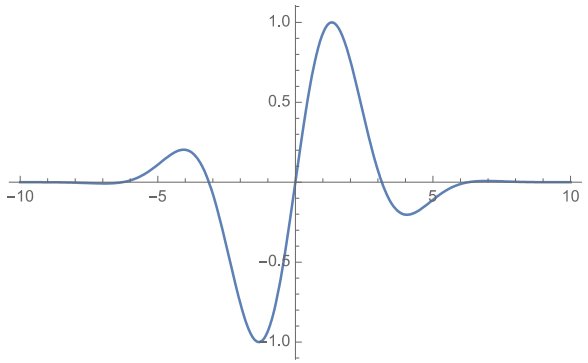
- Real 3D model is replaced by a trivial longitudinal kick with shape described by dimensionless parameter *r* repressing the relative bandwidth of the amplifier

$$dg = \mathrm{D}g \cdot \sin w_o t \cdot e^{-\frac{t^2}{2t_o^2}} \equiv \mathrm{D}g \cdot \sin k_o z \cdot e^{-\frac{z^2}{2V_o^2}} =; z = vt = R_{56}d; d = \frac{g - g_o}{g_o};$$

$$\frac{dd}{dn} = \frac{dg}{g_o} = \frac{\mathrm{D}g}{g_o} \cdot \sin k_o z \cdot e^{-\frac{z^2}{2V_o^2}} = x_o \cdot \sin k_o z \cdot e^{-\frac{z^2}{2V_o^2}};$$

$$g\left(A,B\right) = \overline{g}\left(A,r\right) = \sin A \cdot e^{-\frac{B^2}{2}} = \sin A \cdot e^{-r^2\frac{A^2}{2}}; \; r = \frac{1}{w_o t_o}$$

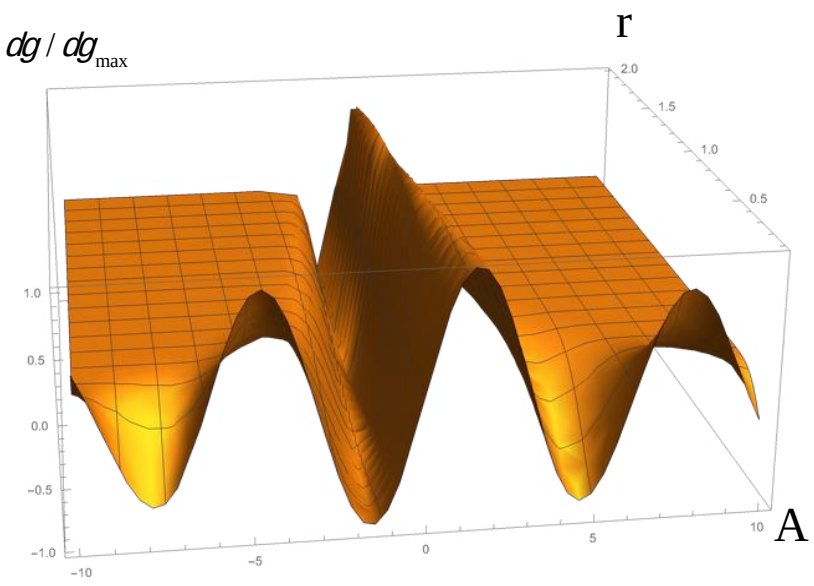
$dg / dg_{\max}$

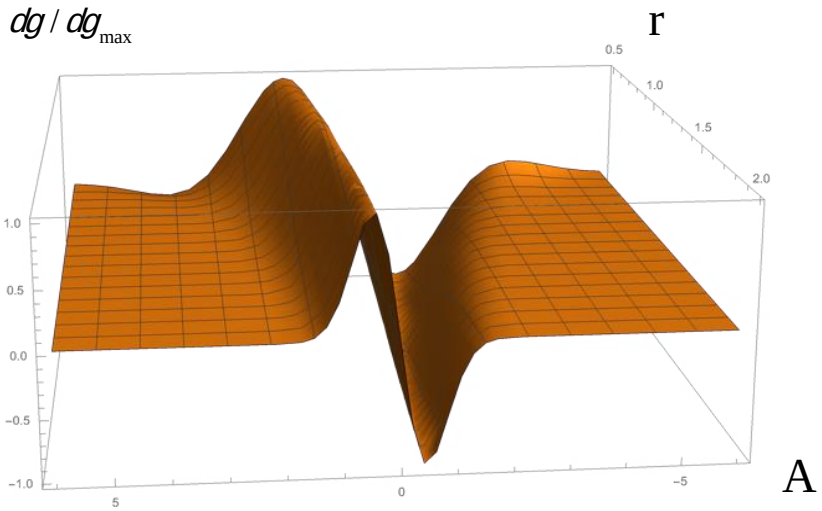



A

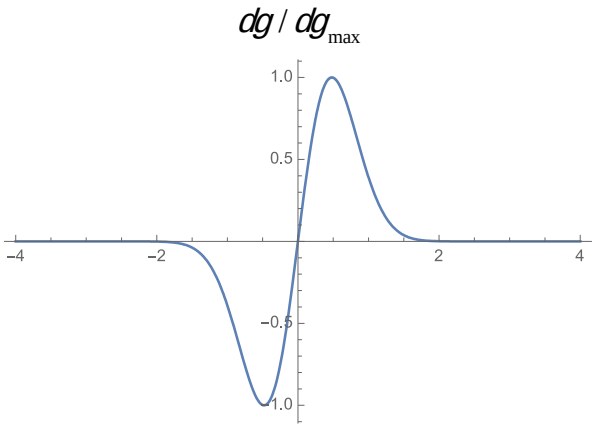
$$dg(w) \quad e^{-\frac{(w-w_o)^2 t_o^2}{2}} - e^{-\frac{(w+w_o)^2 t_o^2}{2}} = e^{-\frac{\left(\frac{w}{w_o}-1\right)^2}{2r^2}} - e^{-\frac{\left(\frac{w}{w_o}+1\right)^2}{2r^2}}$$

# Kick shapes


dg / dg_max
r
A
2.0
1.5
1.0
0.5
1.0
0.5
0.0
−0.5
−1.0
−10
−5
0
5
10

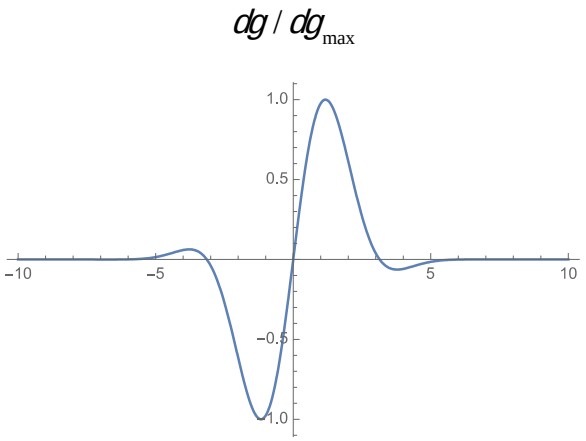

dg / dg_max
r
A
0.5
1.0
1.5
2.0
1.0
0.5
0.0
−0.5
−1.0
5
0
−5

# Kick shapes



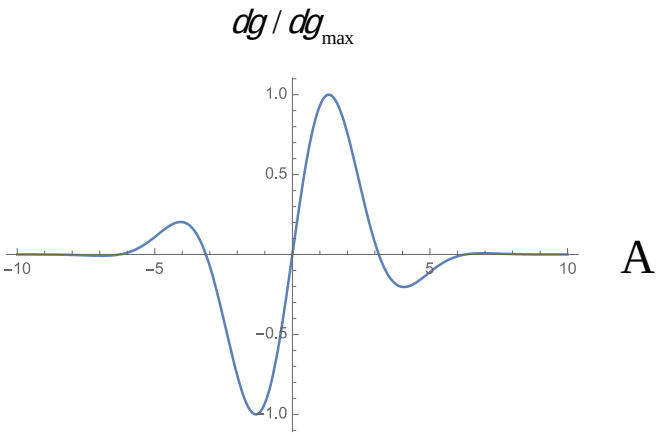

A

r=2



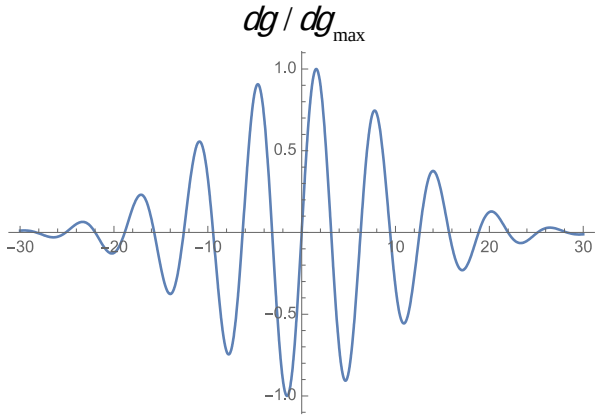

A

r=0.6




A

r=0.435




A

r=0.1

# Painting

- Distribution $f = f(s); \int_{-\infty}^{\infty} f(s)\,ds = 1$

- Synchrotron oscillations

$$d = d_o \cdot \sin \Omega_s n;\ s = s_o \cdot \cos \Omega_s n;$$

$$\Omega_s = \sqrt{2\pi h h_{RF} \frac{ZeV_{RF}}{A \cdot g_o mc^2}};\ s_o = \frac{hC}{\Omega_s} d_o.$$

- Average reduction of the amplitude of energy oscillations

$$\langle \Delta d_o \rangle = \frac{\chi_o}{2\pi} \int_0^{2\pi} d\varphi\ \sin\varphi \cdot \sin\left(kR_{56} d_o \sin\varphi\right) \cdot e^{-\frac{\left(kR_{56} d_o \sin\varphi\right)^2}{2}} \int_{-\infty}^{\infty} f(z)\,\delta\left(z - s_o \cdot \cos\varphi\right) dz =$$

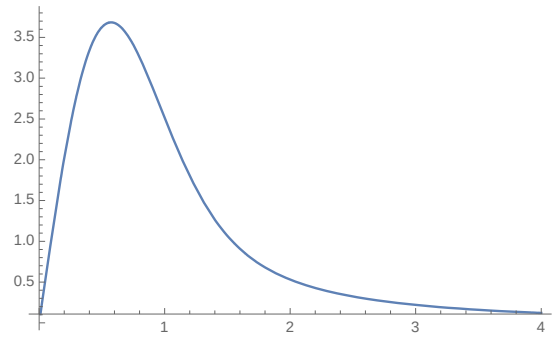
$$\frac{\chi_o}{2\pi} \int_0^{2\pi} f\left(s_o \cos\varphi\right) \sin\varphi \cdot \sin\left(kR_{56} d_o \sin\varphi\right) \cdot e^{-\frac{\left(kR_{56} d_o \sin\varphi\right)^2}{2}} d\varphi\ ;\ k = 1/V$$

# Uniform Painting

$$f(s) = f_o \propto \frac{s_e}{s_h}; a = kR_{56}d_o; b = kR_{56}d_o$$

$$\langle Dd_o \rangle = -\frac{x_o f_o}{2p}\int_0^{2p} \sin j \cdot \sin(a\sin j)\cdot e^{-\frac{(b\sin j)^2}{2}} dj$$

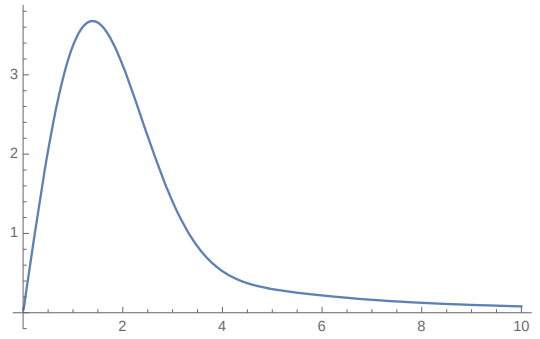
$\langle Dd_o \rangle$




a

r=2

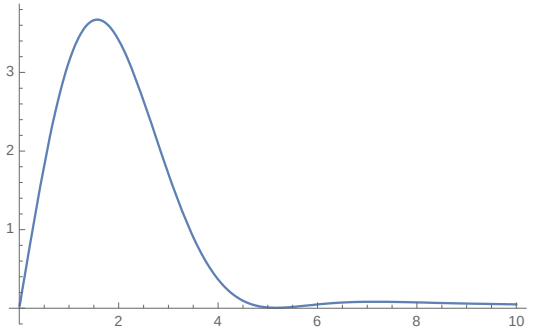
$\langle Dd_o \rangle$




a

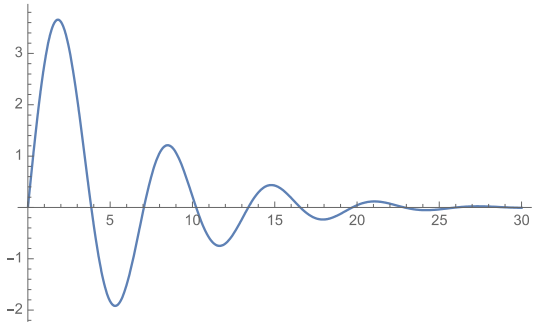
r=0.6

$\langle Dd_o \rangle$




a

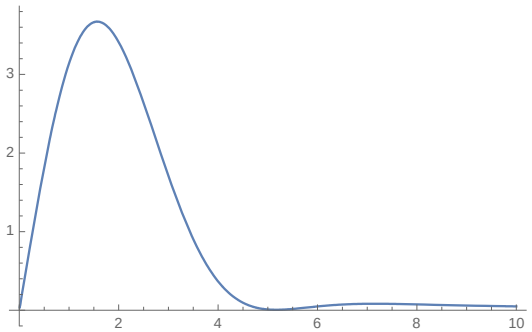
r=0.435




a

r=0.1

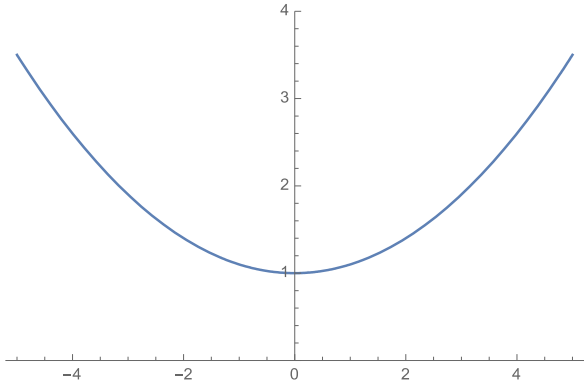
# Non -Uniform Painting

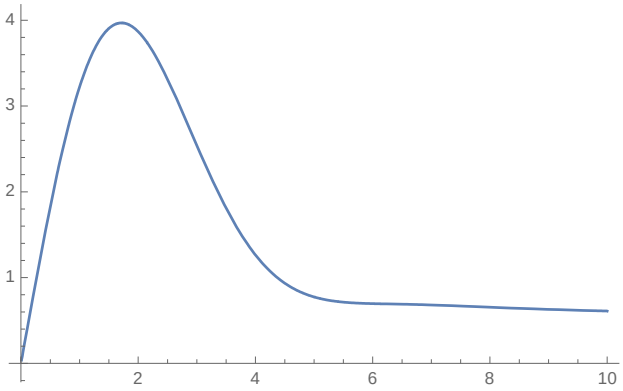



a

r=0.435

# Non -Uniform Painting




r=0.435

# Summary

- There is no antidumping for PCA-based CeC when painting is used.
- Using painting with longer time spent bunches head and tails can improve cooling of large amplitudes of synchrotron oscillations
- It also means that for effective cooling of the entire proton bunch in EIC we will need significant margin in strength of the CeC cooler – simple estimates can result in underestimation of the real challenge
- 3D simulations are the must – simple 1D theory and 1D models capture only basics, but not all very important details