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LEPP REU
ERL Wake Fields (Wakefields?) and Methods for Their Reduction

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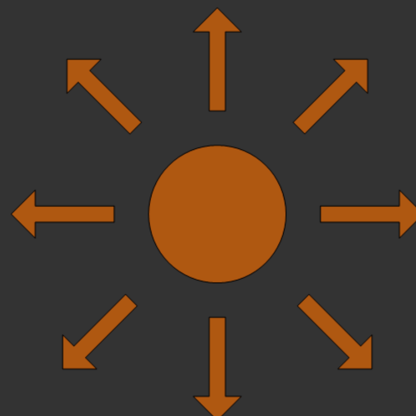
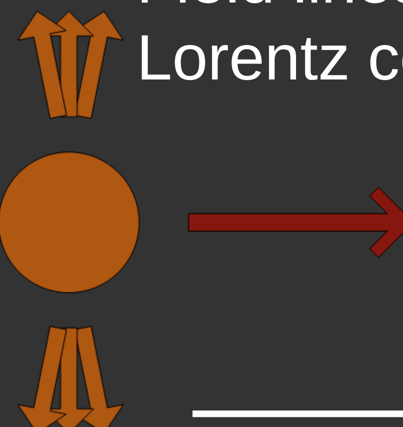
Overview of Wake Dynamics

Stationary charge:

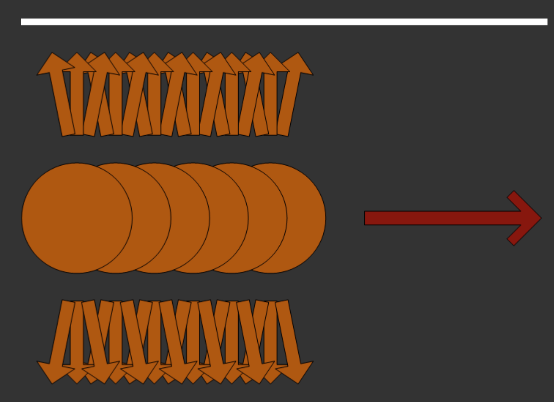


Field lines experience Lorentz contraction

Moving charge:



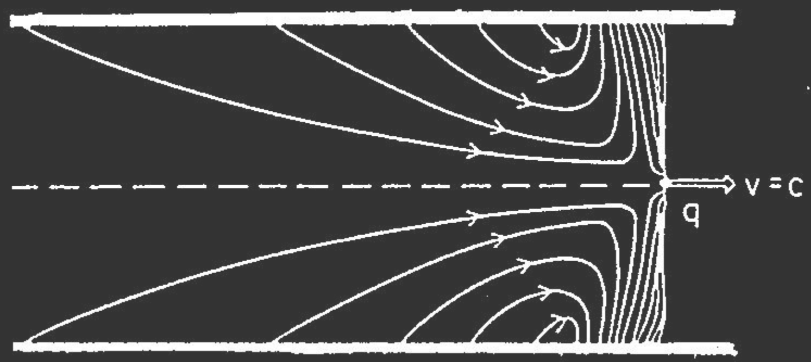
Charges (bunch) in a pipe:

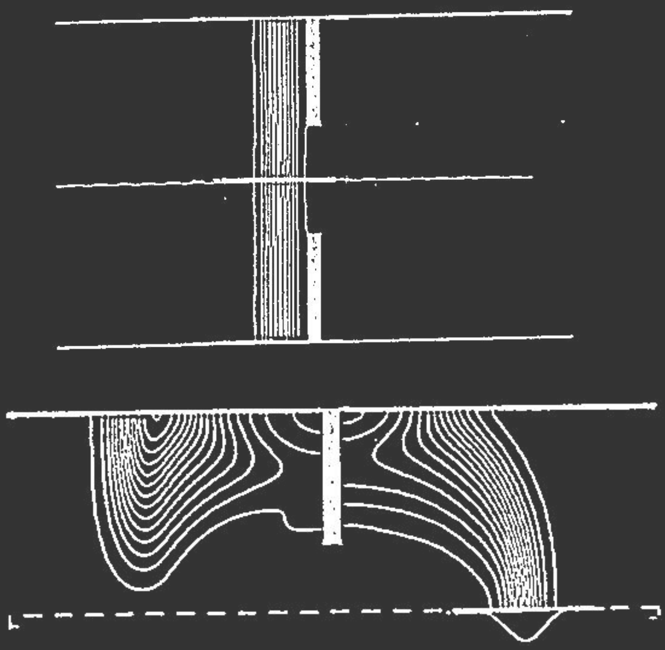


Currents induced in pipe wall

Where do wakes come from?

- Geometrical non-uniformities (dominant effect: thousands of kV/m)
- Dielectric coatings on pipe wall (~ 500 kV/m)
- Finite conductivity in pipe wall (~ 1 kV/m)





Weiland and Wanzenberg. *Wake Fields and Impedances*. 1990 Joint US-Cern Accelerator Course

Numerical Wake Field Solvers

- URMEL – computes resonant modes in cavities and cut-off frequencies of longitudinally homogeneous fields in waveguides.
- ABCI – solves Maxwell's equations directly in the time domain when a bunched beam passes through a structure.

Why care?

- N.B.: The longitudinal component of wake field is the more important component (cylindrically symmetry).
- Particles within a bunch experience Lorentz forces.
- Fields left behind = energy loss
- BUT: the energy loss can be recycled

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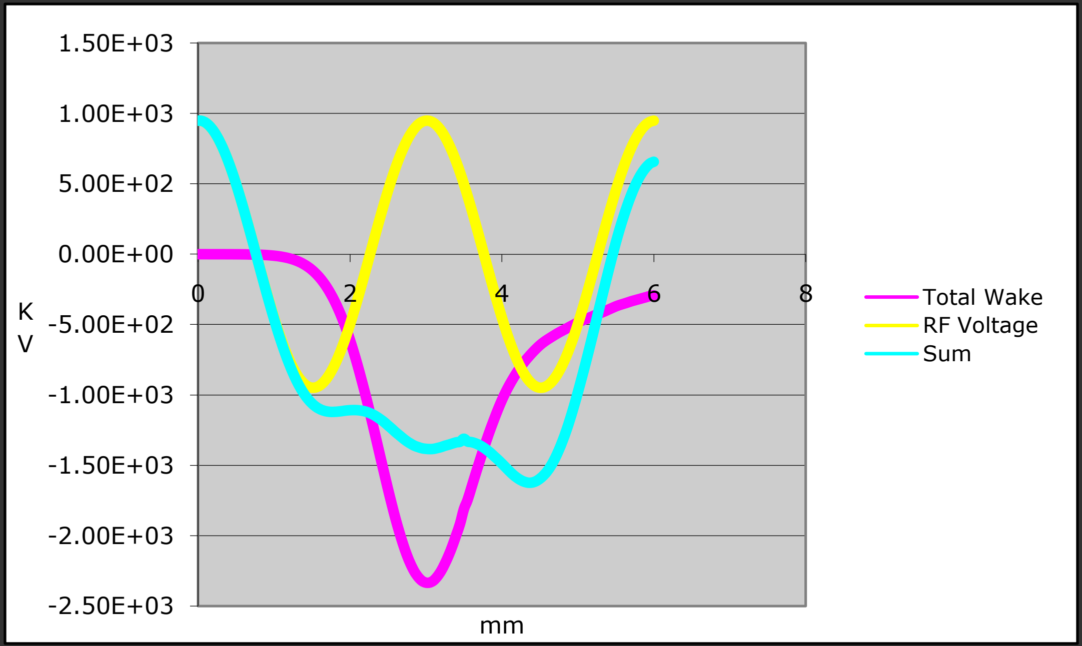
Recipe for a Possible Solution (in a nutshell)

1. Extract RF power from the wake of a short driving bunch (dielectric loading)
2. Inject RF power in a longer bunch (correctional superposition)
3. Apply sloping and DC corrections



Courtesy Mike Billing

Pipe with Dielectric Layer (E-fields at Phi=0)

- Calculated using URMEL-T (triangular mesh)
- Partially trapped mode
- Tapering models infinite length

What I’ve been doing

- Extrapolating from data calculated for a 0.6 mm bunch (explained briefly in next couple of slides)
- Writing some convenience-motivated scripts to parse URMEL/ABCI output files
- Familiarizing myself with the literature and existing software
- Running simulations to gain intuition

Rescaling wake data

$W(s) \equiv Wake\ of\ a\ 0.6\ mm\ bunch$

$W^{'}(s) \equiv Wake\ of\ a\ bunch\ with\ variable\ length$

$\rho \equiv Charge\ density\ (gaussian)\ of\ a\ 0.6\ mm\ bunch$

$\rho^{'} \equiv Charge\ density\ (gaussian)\ of\ a\ variable\ length\ bunch$

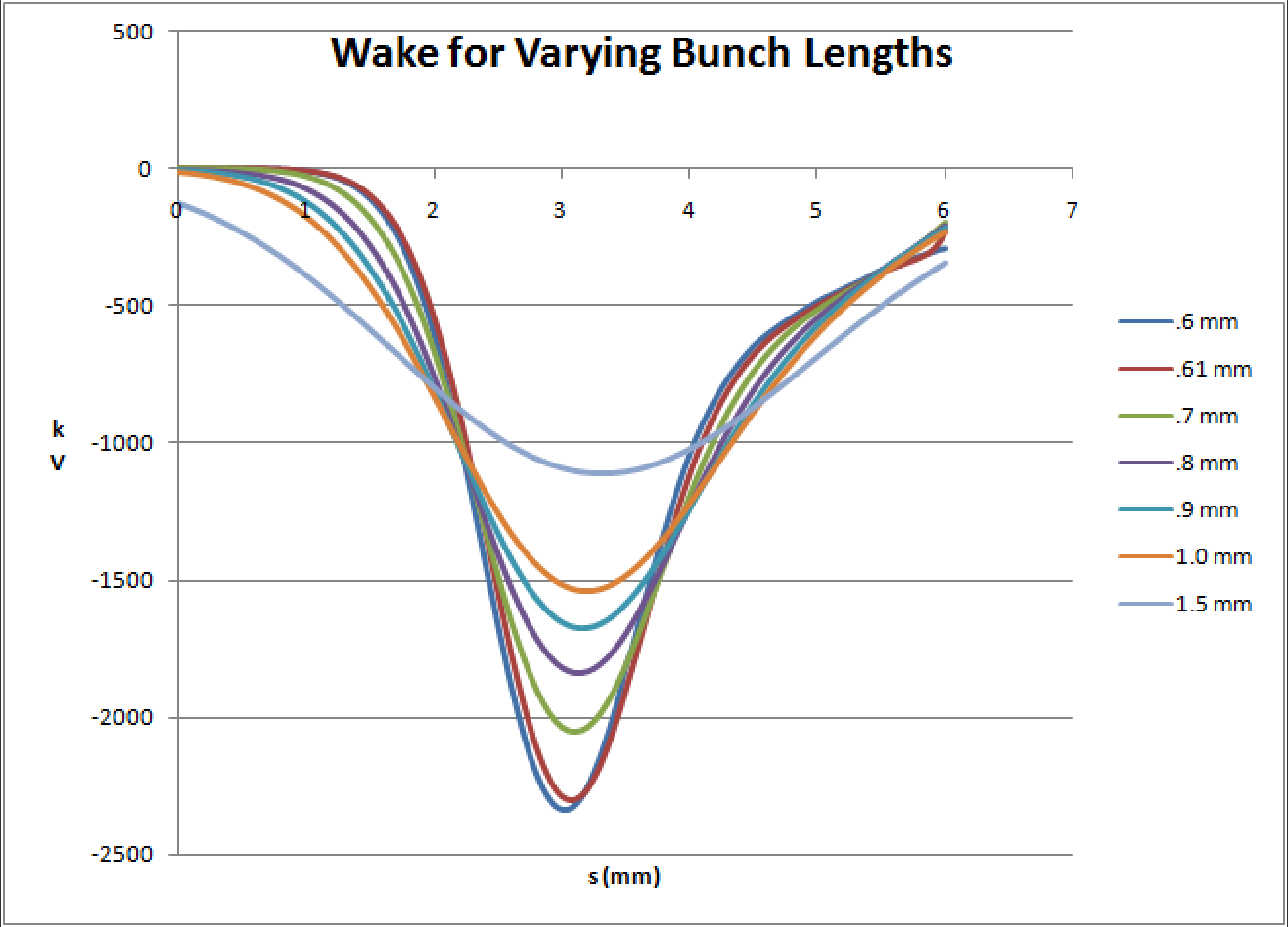
$$W(s) = \rho \otimes W_{\delta}$$

$$\mathcal{F}\{W(s)\} = \mathcal{F}\{p\}\mathcal{F}\{W_{\delta}\}$$

$$\mathcal{F}\{W'(s)\} = \mathcal{F}\{p'\}\mathcal{F}\{W_{\delta}\}$$

$$\mathcal{F}\{W^{'}(s)\} = \frac{\mathcal{F}\{p^{'}\}}{\mathcal{F}\{\rho\}} \cdot \mathcal{F}\{W(s)\}$$

$$W^{'}(s) = W \otimes \mathcal{F}^{-1}\left\{\frac{\mathcal{F}\{\rho^{'}\}}{\mathcal{F}\{\rho\}}\right\}$$


Wake for Varying Bunch Lengths
500
0
-500
-1000
-1500
-2000
-2500
kV
0
1
2
3
4
5
6
7
s (mm)
.6 mm
.61 mm
.7 mm
.8 mm
.9 mm
1.0 mm
1.5 mm

What's next

- Design: optimize dielectric resonator and coupler
- Verification: analyze existing wake data (which may need correction)
- More reading