ERL Wake Fields and One Possible Recovery Technique

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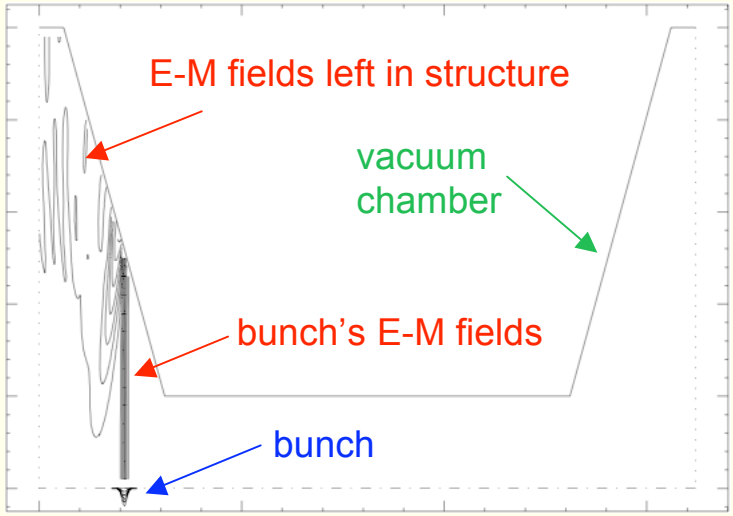
Electromagnetic Self-Interaction of Beam: Wake Function

- Self-Wake Field
  - Direct interaction of the bunch with vacuum chamber
    - E-M fields of bunch couple to stationary E-M modes in the vacuum chamber structure. These are associated with discontinuities in the chamber's cross-section
    - In a smooth chamber, E-M fields travel unperturbed with the bunch, but when the chamber shape changes some field-lines get "disconnected" from the charges in the bunch
    - Strongest fields occur within the bunch since all of the different modes of the structure are excited "in phase"

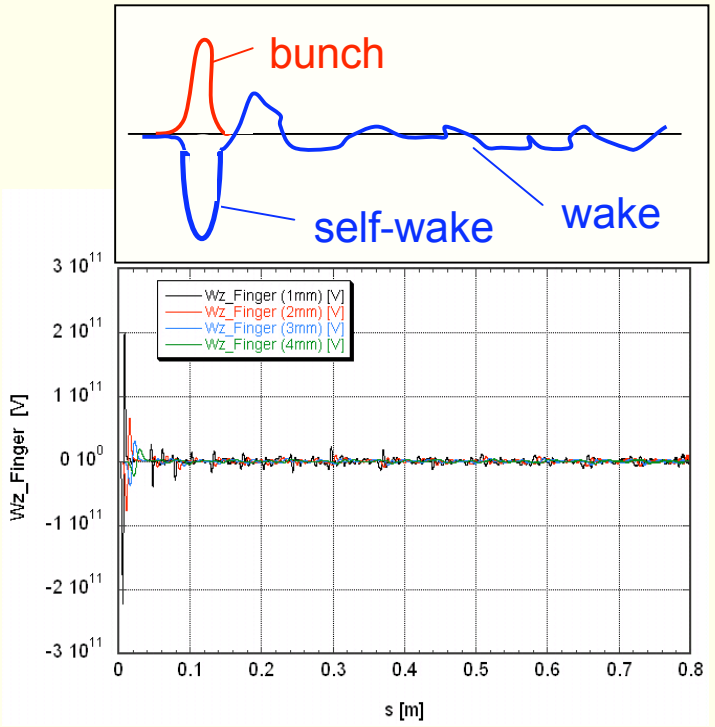


Wake Voltage

- Beam-Chamber Interaction Can Written as an Induced Wake Voltage
  - Voltage for particle following charge, q depends on its longitudinal position, s, within the bunch - due to the effect of all vacuum chamber components in ERL

$$V_{\parallel}(s)\Big|_{\text{entire ERL}} = q\ W_{\parallel}(s)\Big|_{\text{entire ERL}}$$

  - Increases the energy spread, ΔE, of the bunch



- Limitation:
  - ERL accelerates beam to 5 GeV & the energy spread is usually not serious,
  - BUT as the beam decelerates to 10 MeV, the effect is magnified x 500
  - Maximum acceptable beam energy spread at the dump places a limit on the maximum wake field, i.e.

$$\max\left\{eV_{\parallel}(s)\Big|_{\text{entire ERL}}\right\} \le \kappa\ \max\left\{\Delta E\Big|_{\text{dump}}\right\}$$

where $0 \le \kappa \le 1$ (e.g. $\kappa \sim 0.5$)

Peak Wake Function Limit

- Estimating maximum energy spread at the dump
  - Decelerated beam at the Dump:
    - Average Beam Energy at the Dump: E = 10 MeV
    - Acceptable Maximum Energy Spread at the Dump: $\Delta E = 5$ MeV
- Cast limit in terms of wake field $W_{||}$
- Limit depends on operating charge:
  - ERL operation (77 pC & $\sigma_z = 0.6$ mm):

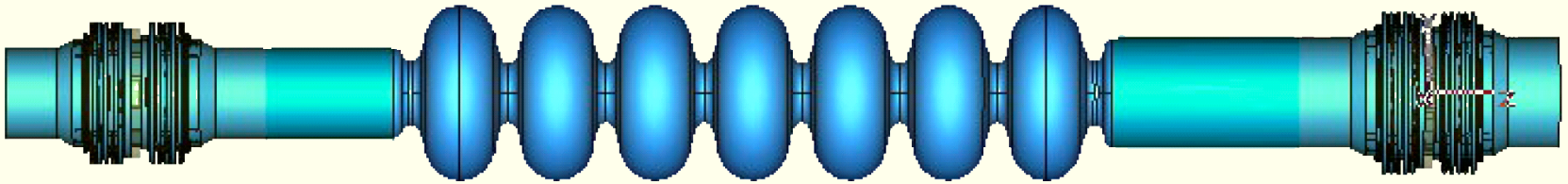
$$\max\left\{W_{||}(s)\Big|_{\text{entire ERL}}\right\} = \frac{1}{q}\max\left\{eV_{||}(s)\Big|_{\text{entire ERL}}\right\}$$

$$\leq 0.5\ \frac{1}{q}\max\left\{\Delta E\Big|_{\text{dump}}\right\} \approx (0.5)\frac{5\ \text{MeV}}{77\text{pC}}$$

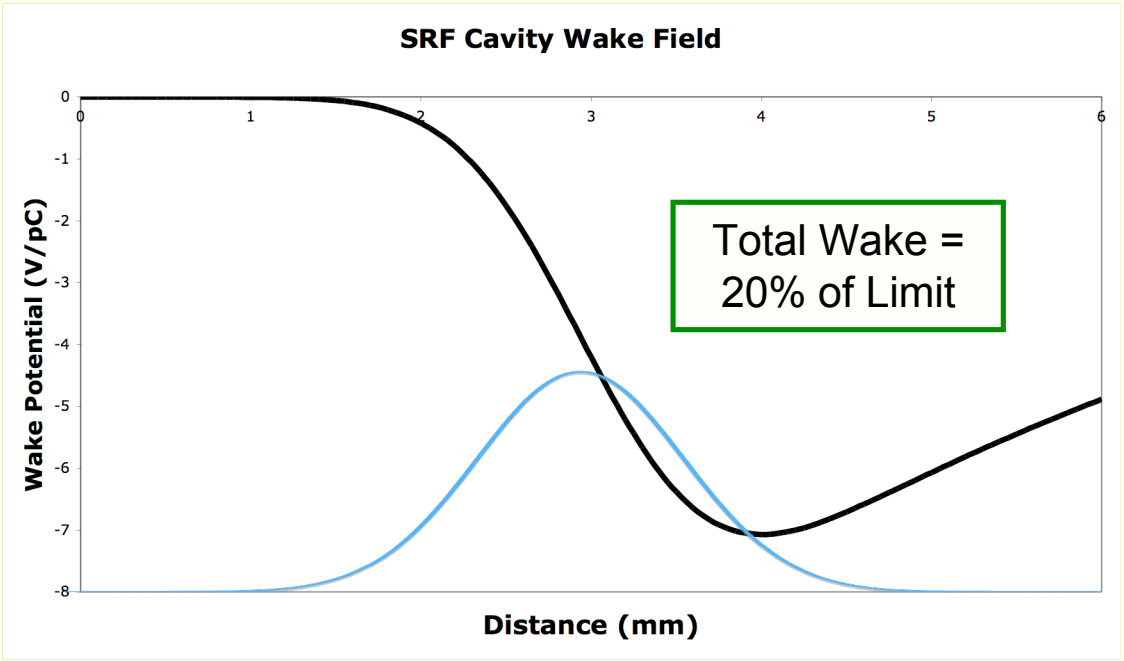
$$\approx \boxed{32\ \text{kV/pC}}$$

One Example of Self-Wake Functions

- Linac accelerator RF cavities
  - 7 cells (scaled from the 9 cell Tesla cavities)
  - Min, Max $\{W_{||}\}$ = -8.1, 0.0 V/pC k_{HOM} = 7.3 V/pC
  - Quantity = 400 (x 2 for the two passes thru the RF)



HOM Load HOM Load

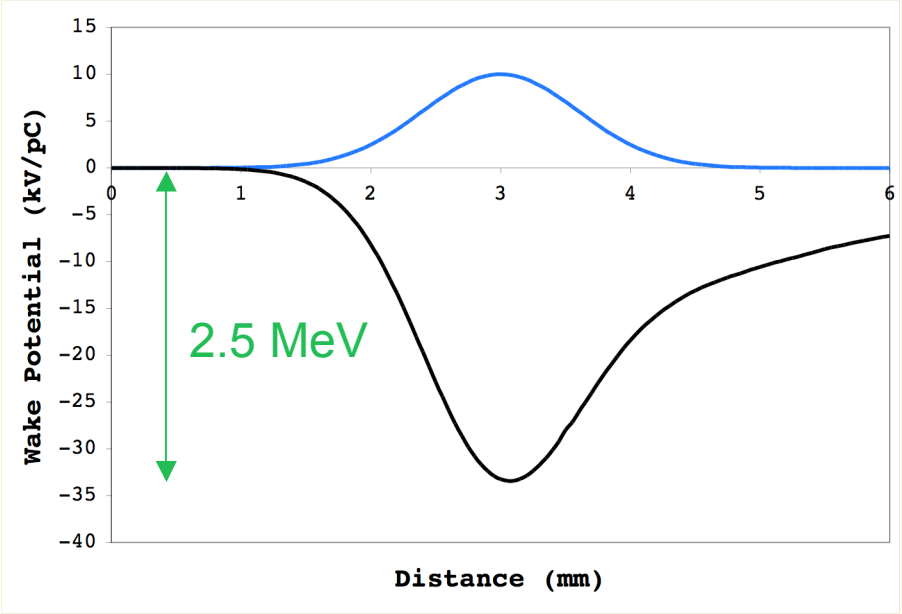


Estimated Total Self-Wake

- Peak Wake

$$\max\left\{W_{\parallel}(t)\Big|_{ERL}\right\} = 33 \text{ kV/pC}$$

Same as 32 kV/pC Limit



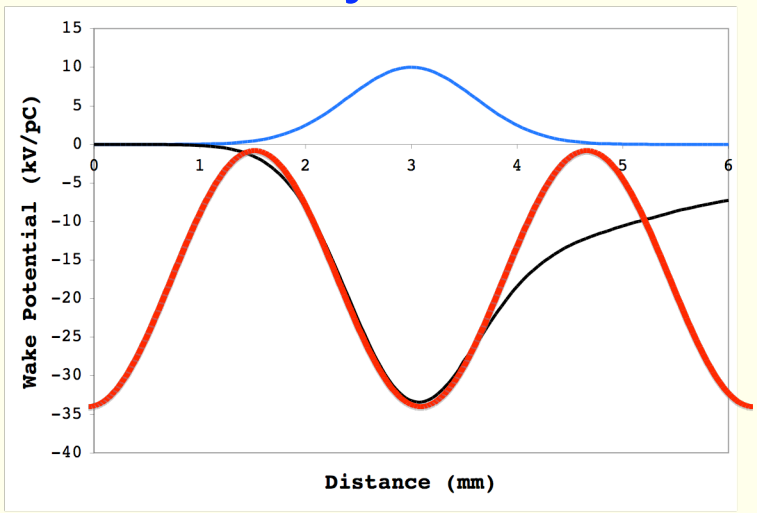
Component	Number	Total -Wake (KV/pC)	Total +Wake (KV/pC)	Total k (KV/pC)
7 Cell RF Cavity	800	-5.66	0	5.81
HOM Load (78 mm)	400	-0.89	0	0.64
HOM Load (106 mm)	400	-0.50	0	0.36
Expansion Joint	356	-0.74	0.10	0.53
BPM (Button)	664	-0.35	0	0.24
BPM (Stripline)	20	-0.01	0	0.01
Flange Joint	356	-0.90	0	0.64
Clearing Electrode	150	-0.18	0.14	0.04
Gate Valve	68	-0.71	0.69	0.42
Resistive Wall (12.7 mm)	2500	-4.00	0	2.75
Roughness (12.7 mm)	2500	-14.00	0.50	8.75
Undulator Taper (3 mm)	18	-0.61	0.37	0.36
Resistive Wall (3 mm)	144	-0.98	0	0.69
Roughness (3 mm)	144	-3.60	0.12	2.52

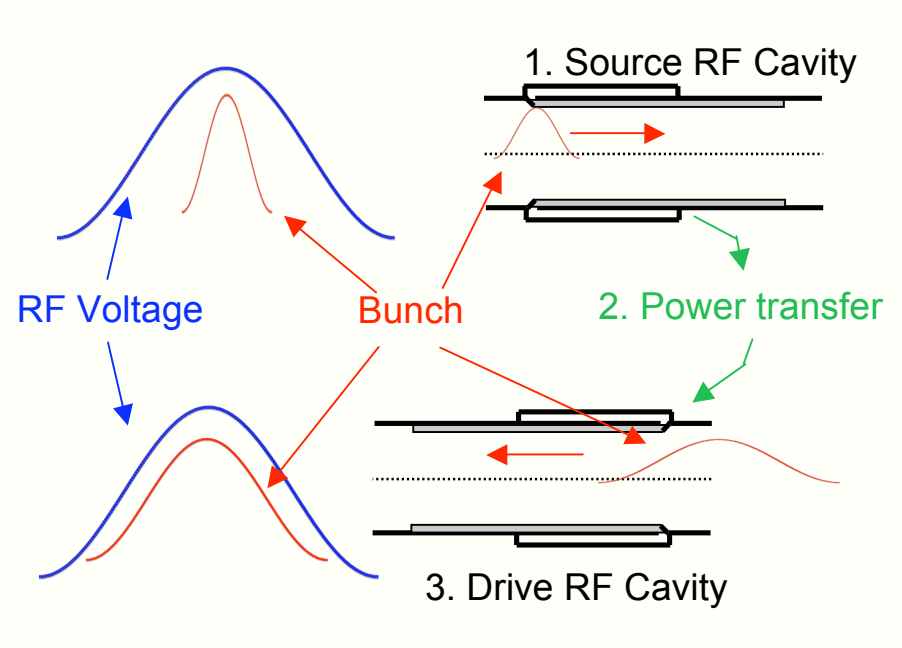
Total k
= 23.8KV/pC

Total HOM Power
= 183 KW

Possible Wake Field Correction

- Correcting curvature is hardest - use very High Frequency RF system
  - Good idea, but no large power sources are available
  - Use beam as the power source





1. Use a short bunch to resonantly excite the Source RF Cavity (less curvature)
2. Extract RF power to
3. Excite the Drive RF Cavity, which re-accelerates a longer bunch (more curvature)

Tasks for the Summer

- Recalculate the Wake Fields
  - The bunch length has increased

    σ_z= 0.6 mm ==> σ_z= 1 mm

    This changes (largely reduces) the Wake Field shape

- Test Different RF Structure Designs
  - Model the cavities
  - Look into technical details