NLC - The Next Linear Collider Project

# Damping Rings Impedance and Collective Effects

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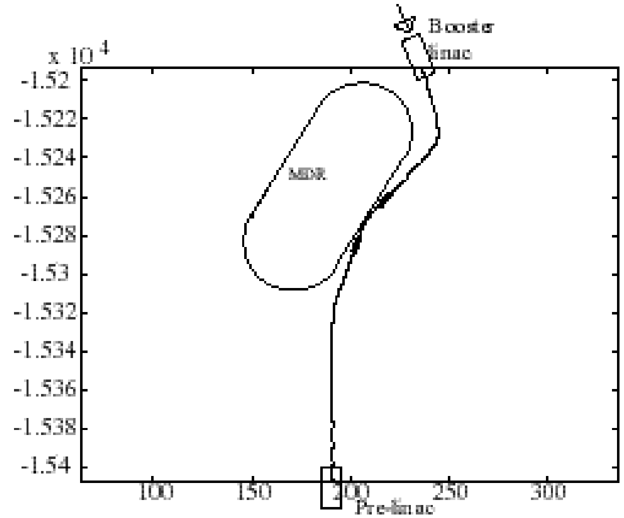
# Damping Rings Parameters

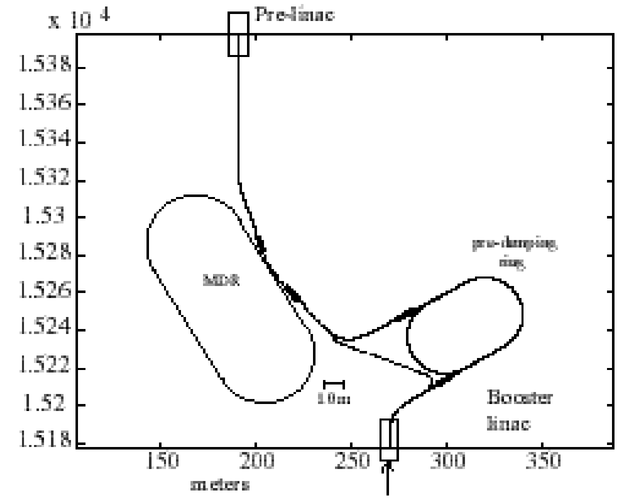
- 2 main rings for generating low emittance $e^+/e^-$
- 1 pre-ring for capturing $e^+$
- Similar to 3rd generation synchrotron light sources except
  - Injection and extraction at 120 Hz
  - Three bunch trains 95 bunches each
    - 800 mA, $1.9 \times 10^{10}$ particles/bunch
    - Typical beam size 60 x 6 μm (x,y)
    - Bunch length ≈ 4 mm
    - Vacuum chamber radius ≈ 1.6 cm
- Collective effects less severe for pre-damping ring
  - Larger beampipe, larger emittance, longer bunch, larger momentum compaction

# Damping Rings

- Must provide stable injection into linac
  - Similar to 3rd generation light sources

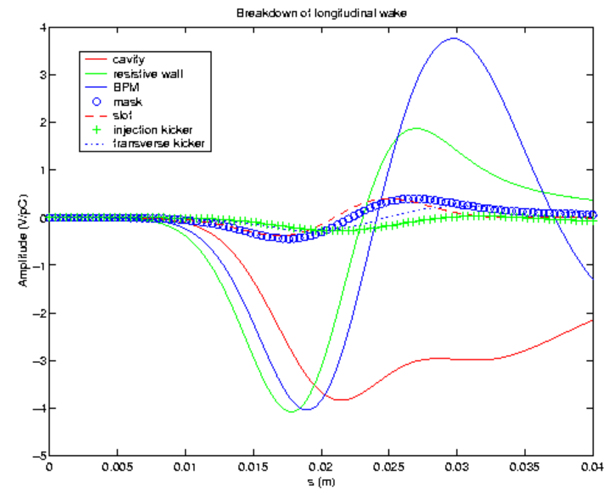
| | Pre-damping ring | Main damping rings |
|---|---|---|
| Energy (GeV) | 1.9 – 2.1 | 1.9 – 2.1 |
| Circumference (m) | 214 | 297 |
| Bunch spacing (ns) | 2.8 | 2.8 |
| Fill pattern | 2 trains 95 bunches<br>2 gaps 100 ns | 3 trains 95 bunches<br>3 gaps 68 ns |
| Damping time (ms) | < 5.21 | < 5.21 |
| $N_{max}$/bunch | $1.9\times10^{10}$ | $1.6\times10^{10}$ |
| Current (mA) | 800 | 750 |
| Injected emittance X/Y (m-rad) | $< 9\times10^{-2}$ (edge) | $< 150\times10^{-6}$ (rms) |
| Extracted emittance X/Y (m-rad) | $< 1\times10^{-4}$ | $< 3\times10^{-6} / 0.03\times10^{-6}$ |
| RF voltage (MV) | 2 | 1.5 |
| Momentum compaction | 0.0051 | 0.00066 |
| Energy spread (%) | 0.09 | 0.09 |
| Bunch length (mm) | 8.4 | 3.8 |
| Vacuum pressure (Torr) | $1\times10^{-9}$ | $1\times10^{-9}$ |
| Maximum rep. Rate (Hz) | 120 | 120 |

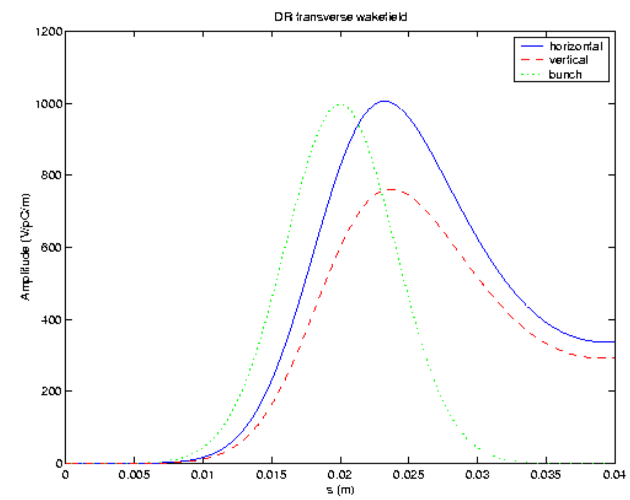


# Impedance Model

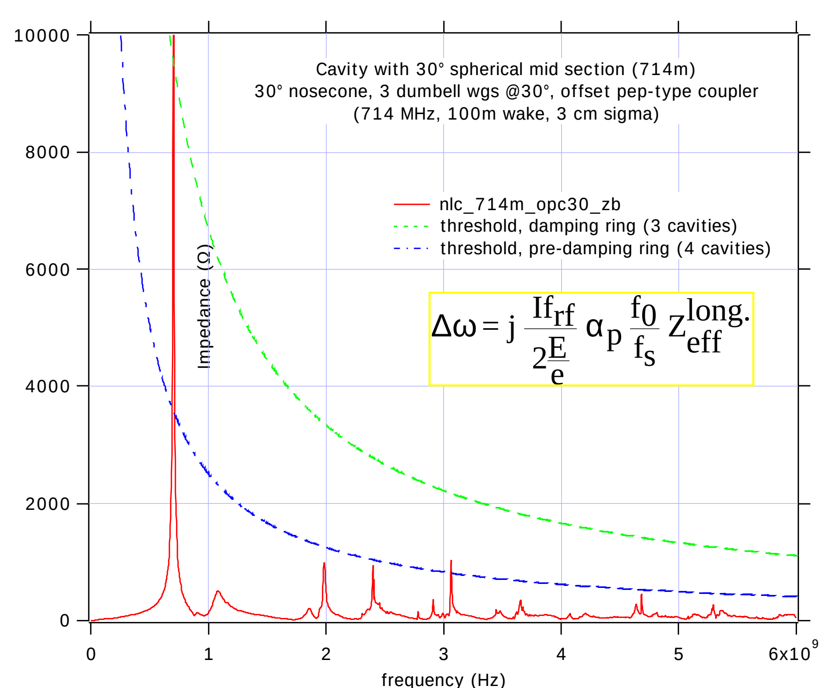
- Longitudinal wake
  - Major vacuum chamber components
    - RF cavities
    - Resistive wall
    - Ante-chamber slots
    - Bellows shields
    - BPM's
    - Injection and extraction magnets
  - Z/n ≈ 0.03 Ω
- Similar impedance model for transverse wake
- Single bunch thresholds > design currents

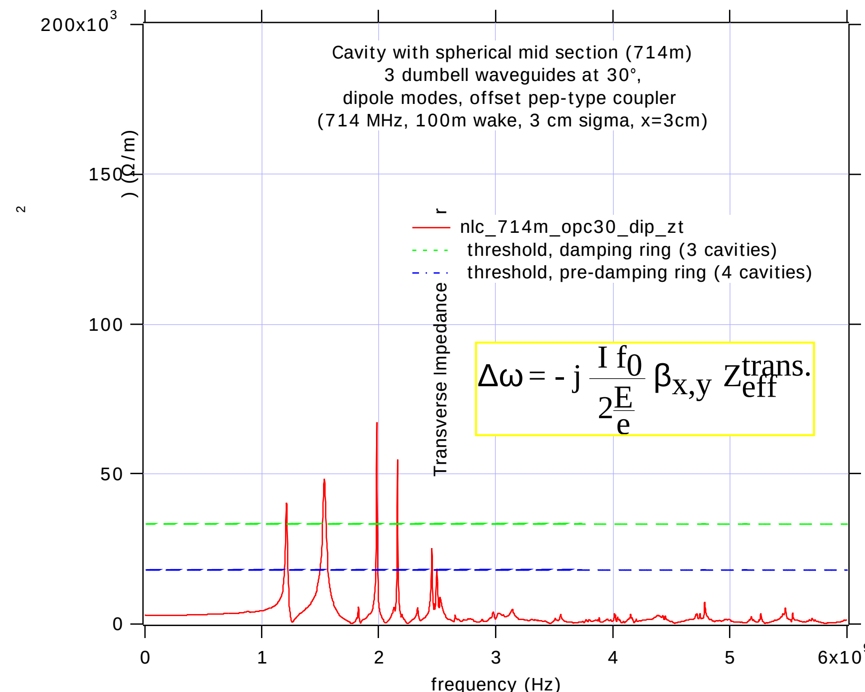


# Impedance model

- Longitudinal modes
- Transverse modes

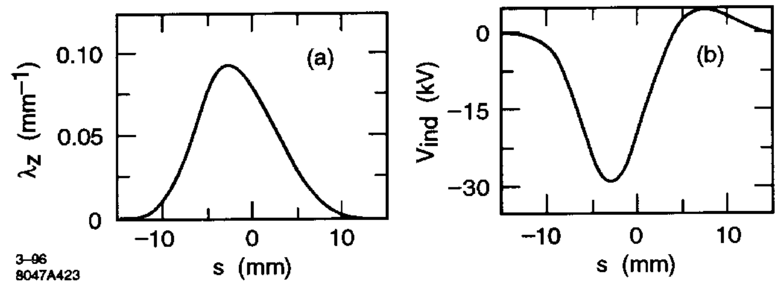



- Damp higher-order modes
  - *Transverse feedback system required*
    - » *HOM's, two-beam instabilities, and resistive wall*

# Longitudinal single-bunch (ZDR)

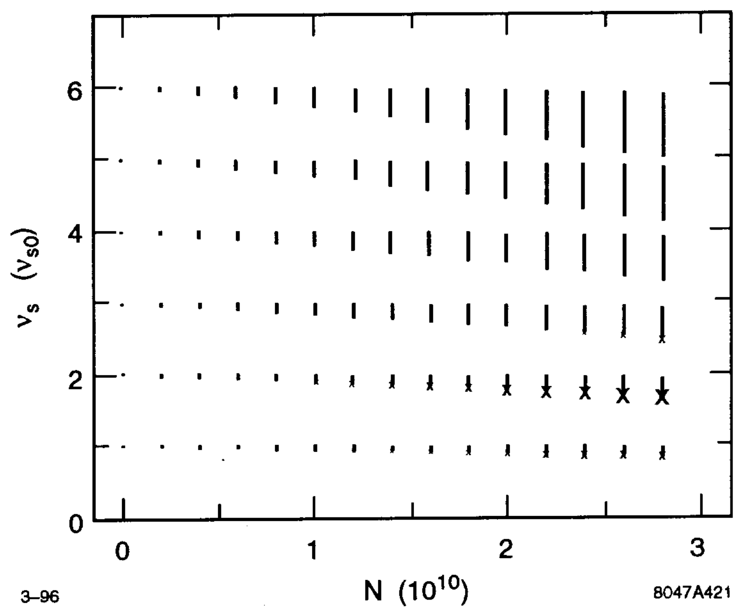
- Potential well distortion




- Microwave instabilities
  - $Z/n \approx 0.03\ \Omega$
  - Strong threshold estimate

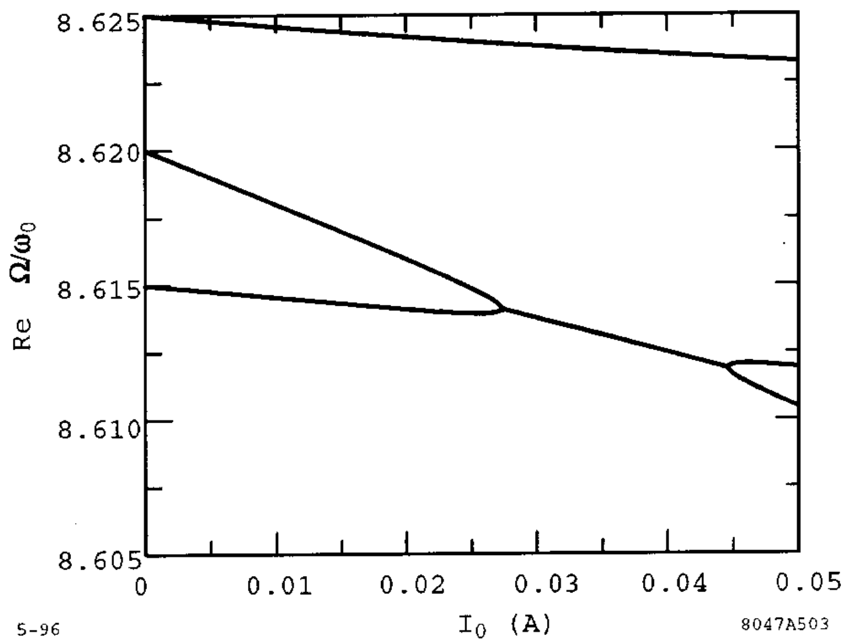
$$I_p = \frac{2\pi|\eta|\left(\frac{E}{e}\right)(\beta\sigma_p)^2}{\left|\frac{Z_{\parallel}}{n}\right|_{eff}}$$

    - Threshold ≈ 2 x operating current
  - Simulations
    - Threshold ≈ 4 x operating current



# Transverse single-bunch (ZDR)

- Transverse mode coupling instability (TMCI)
  - Simulations

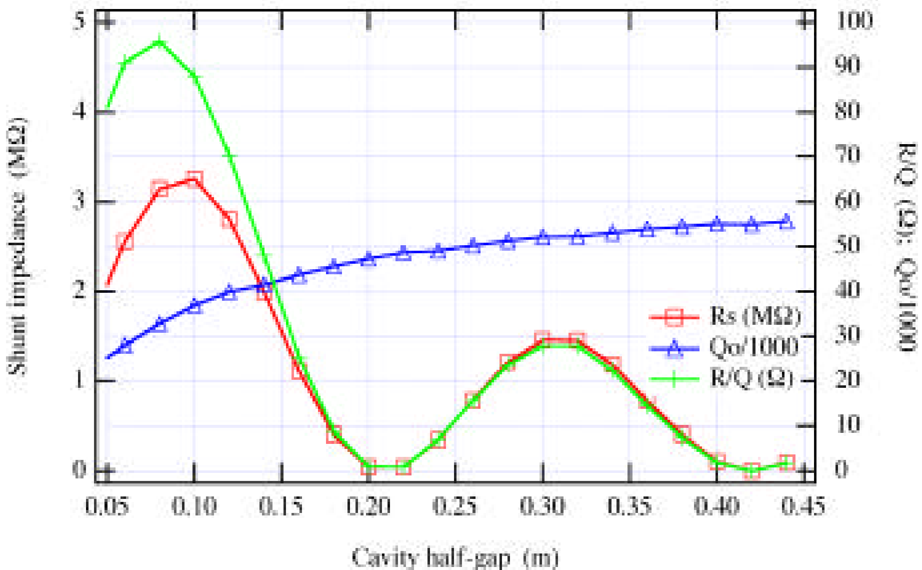



- Threshold ≈ 10 x operating current

# Gap transient effects

$$\Delta\varphi \approx -\frac{2kI_oT_{gap}}{V_{cavity}\sin\varphi_{synch}}$$

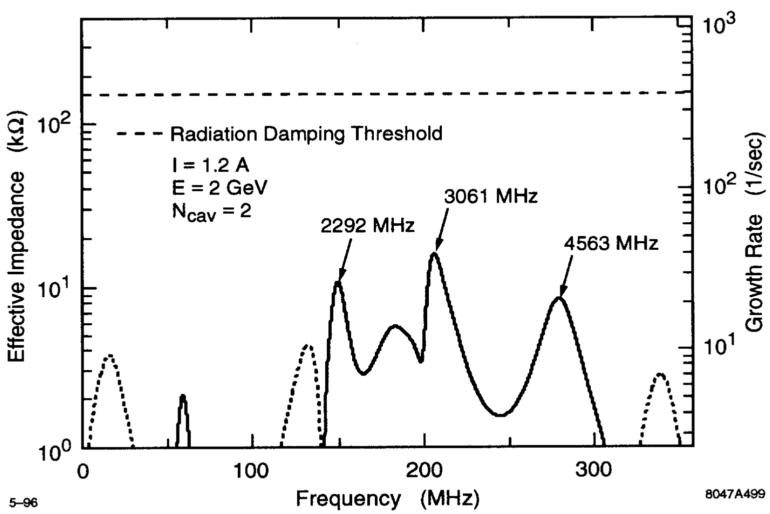
- Bunch-to-bunch synchronous phase variation
  - Leads to energy variation after bunch compression
  - 4° / 30 ps
- Compensation techniques
  - Adaptive-inverse feedforward with broadband klystron (Δf ≈ 10 MHz)
  - Harmonic cavities
  - Ring off-frequency (∂f ≈ 40 kHz)
  - High-stored-energy cavities



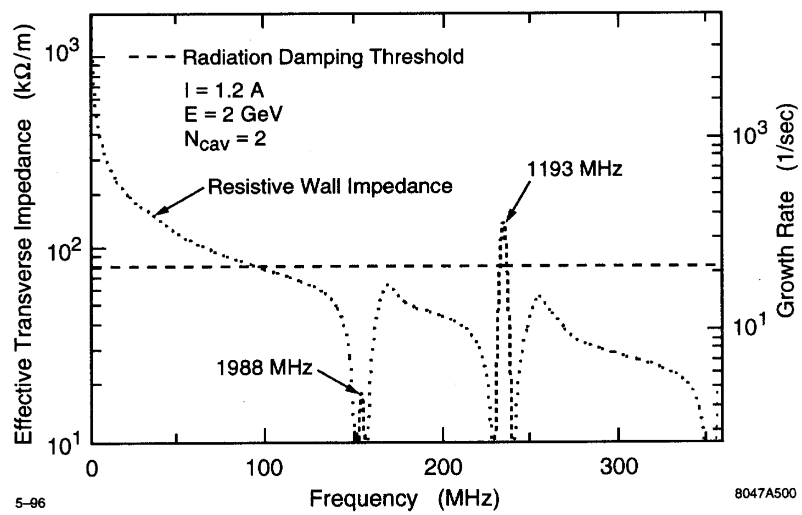
# Coupled-bunch instabilities (ZDR)

- Residual cavity HOM's
- Resistive wall

- Longitudinal




- Transverse



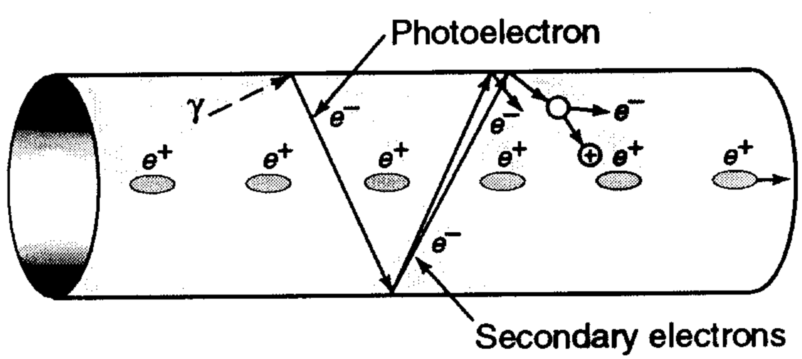

- Control residual motion with broadband feedback systems
  - Extend and develop ALS and PEP-II B-factory designs

# Fast ion instability

- Interaction between intense electron beam and ions gives rise to fast transverse instability
- Growth time <≈ 1 ms
- Experimental evidence from ALS and PLS
  - Maintain average pressure < 1 nTorr
  - Bunch-by-bunch feedback system
  - Additional gaps in bunch trains

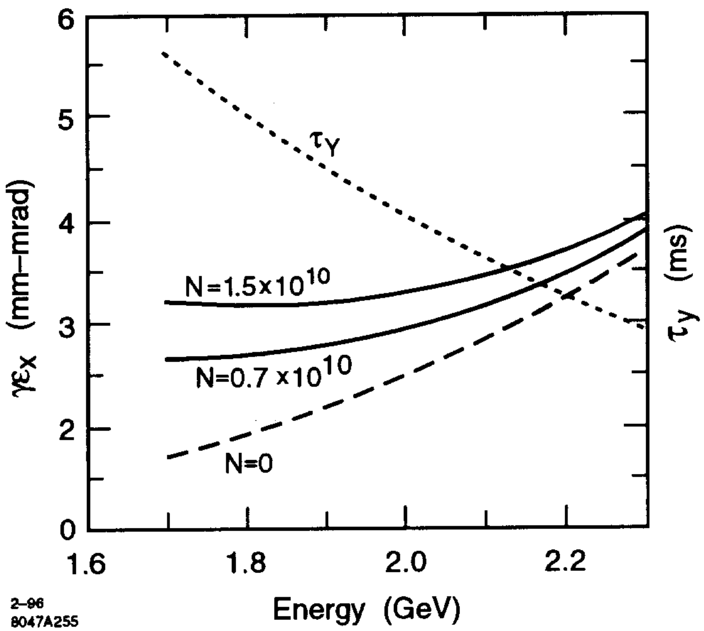
# Electron cloud instability

- Intense positron beam produces cloud of photoelectrons and secondary electrons
- Experimental evidence at BEPC
- Desorbs gas from surfaces
- Interaction between positron beam and electron cloud gives rise to fast transverse instability
  - Low secondary emission coatings
  - Bunch-by-bunch feedback system
  - Solenoidal magnetic fields



# Lifetime and intrabeam scattering

- Gas-scattering lifetime several hours
- Touschek lifetime few minutes
  - Increase bunch volume for commissioning studies
- Intra beam scattering (IBS)
  - significant at lower energies



# Conclusions

- Impedance model and analysis for ZDR (1996)
  - no show-stoppers
- Updated impedance model
  - SLAC workshop, Feb. 2000
- Collective effects to be re-calculated