Eigenmode Computations for Transverse Modes

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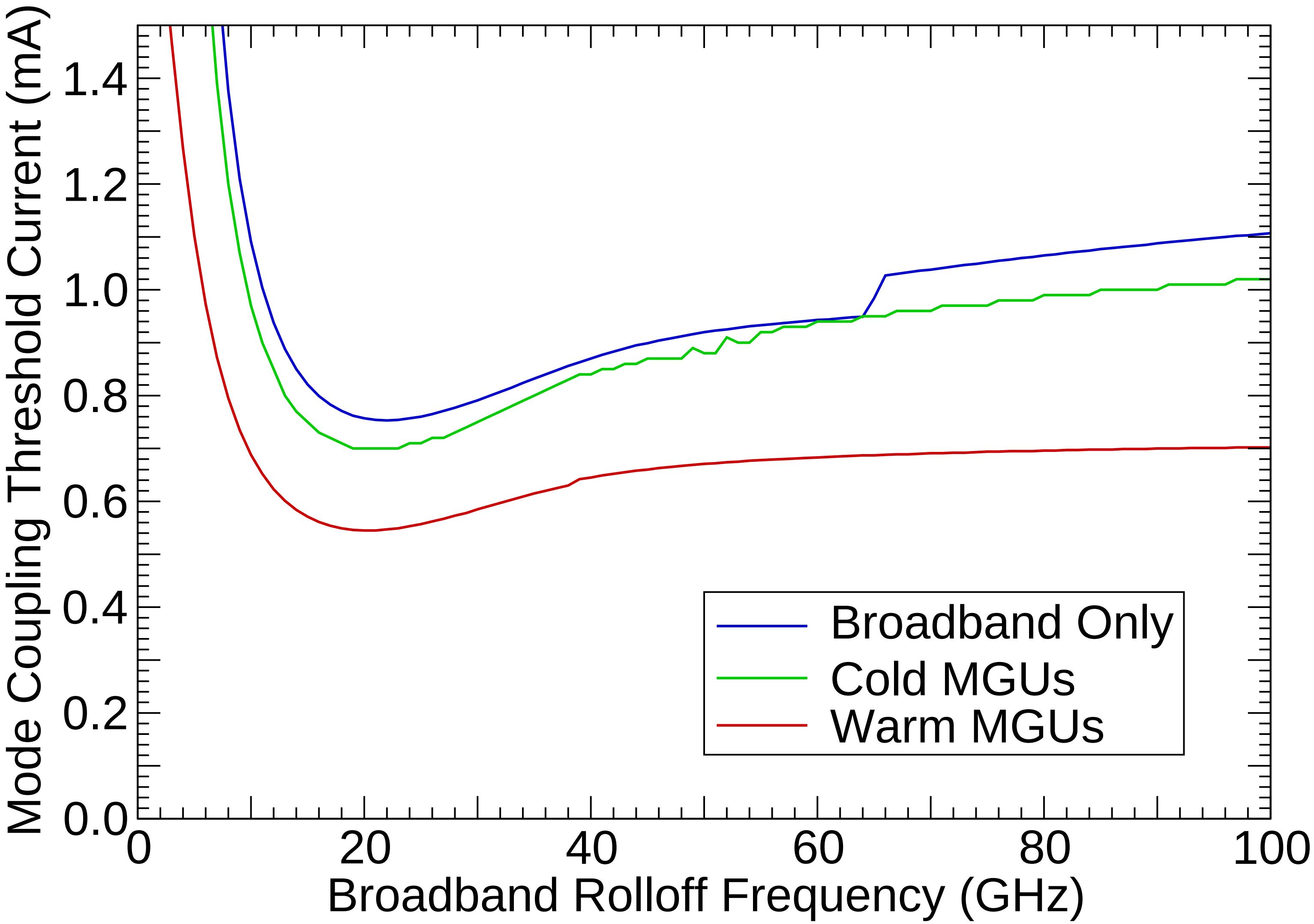
Code

- Using some custom code that I wrote years ago
- Computes multibunch eigenmodes with full mode coupling
- Can handle an arbitrary impedance (does a dumb sum)
- I've made some improvements to handle NSLS-II problems better (described soon)

Single Bunch Computations

- Used broadband impedance model from Krinsky
  - 1 MΩ/m, $Q = 1$, variable rolloff ("resonant") frequency
- Add resistive wall one of two ways
  - Warm MGUs: standard resistive wall
  - Cold MGUs: anomalous skin effect
  - Always include resistive wall from rest of ring
- Can find TMCI threshold and plot

TMCI Threshold vs. Rolloff Frequency



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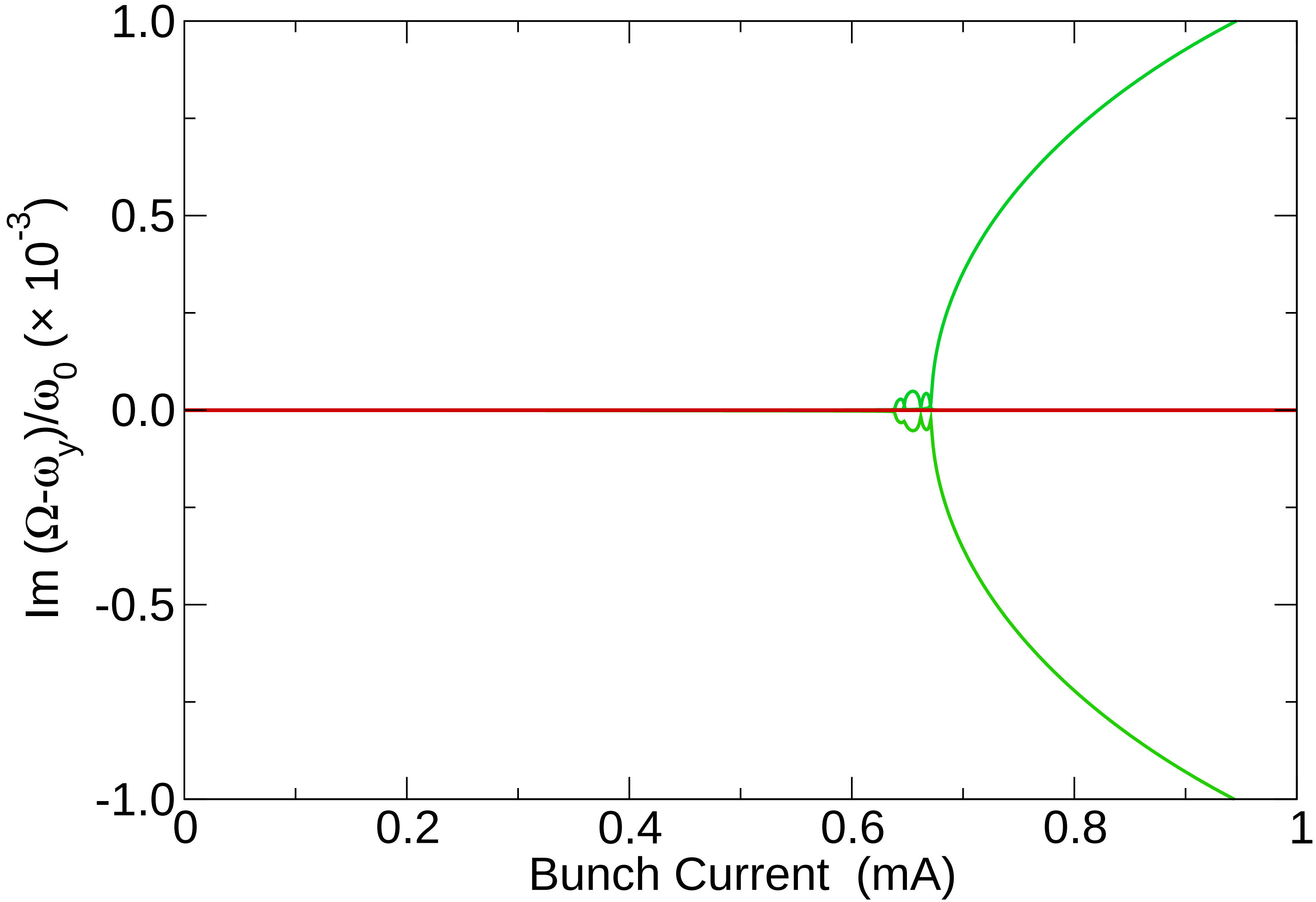
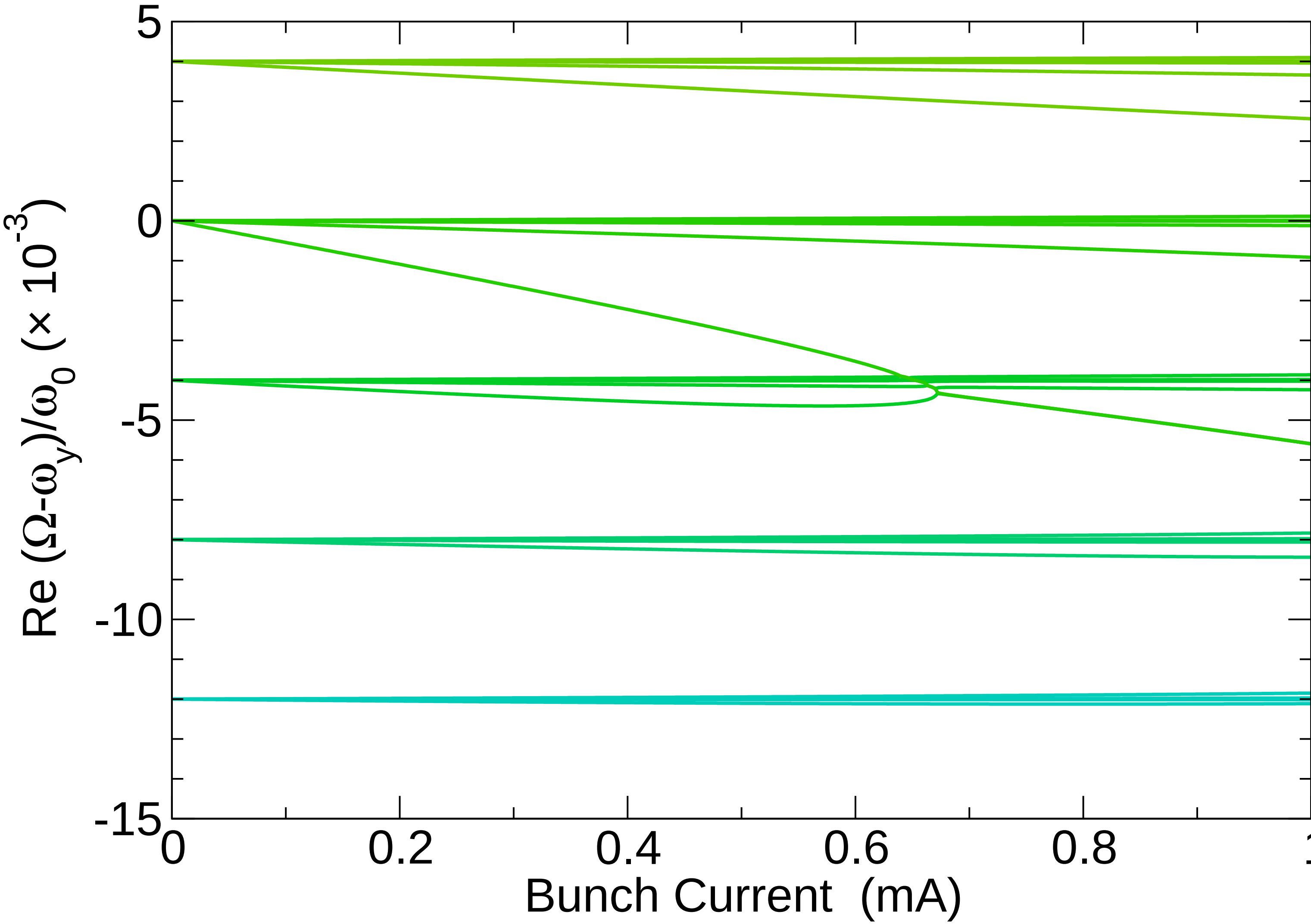
Observations

- High frequencies required LARGE number of modes (100s)
  - Eigenvalue computation was dominating time for computation (usually effective impedance calculation dominates)
  - Modified code to be "smart" about choosing modes to include
  - Included many radial modes but fewer azimuthal modes
  - Simulations should be aware of this: need enough particles to produce high order radial (in longitudinal phase space) modes
- TMCI thresholds are a bit deceptive, especially without resistive wall
  - At lower currents, start with weakly coupled modes
    - These may or may not be a problem in real life
  - For even higher rolloff frequencies, coupling is extremely weak

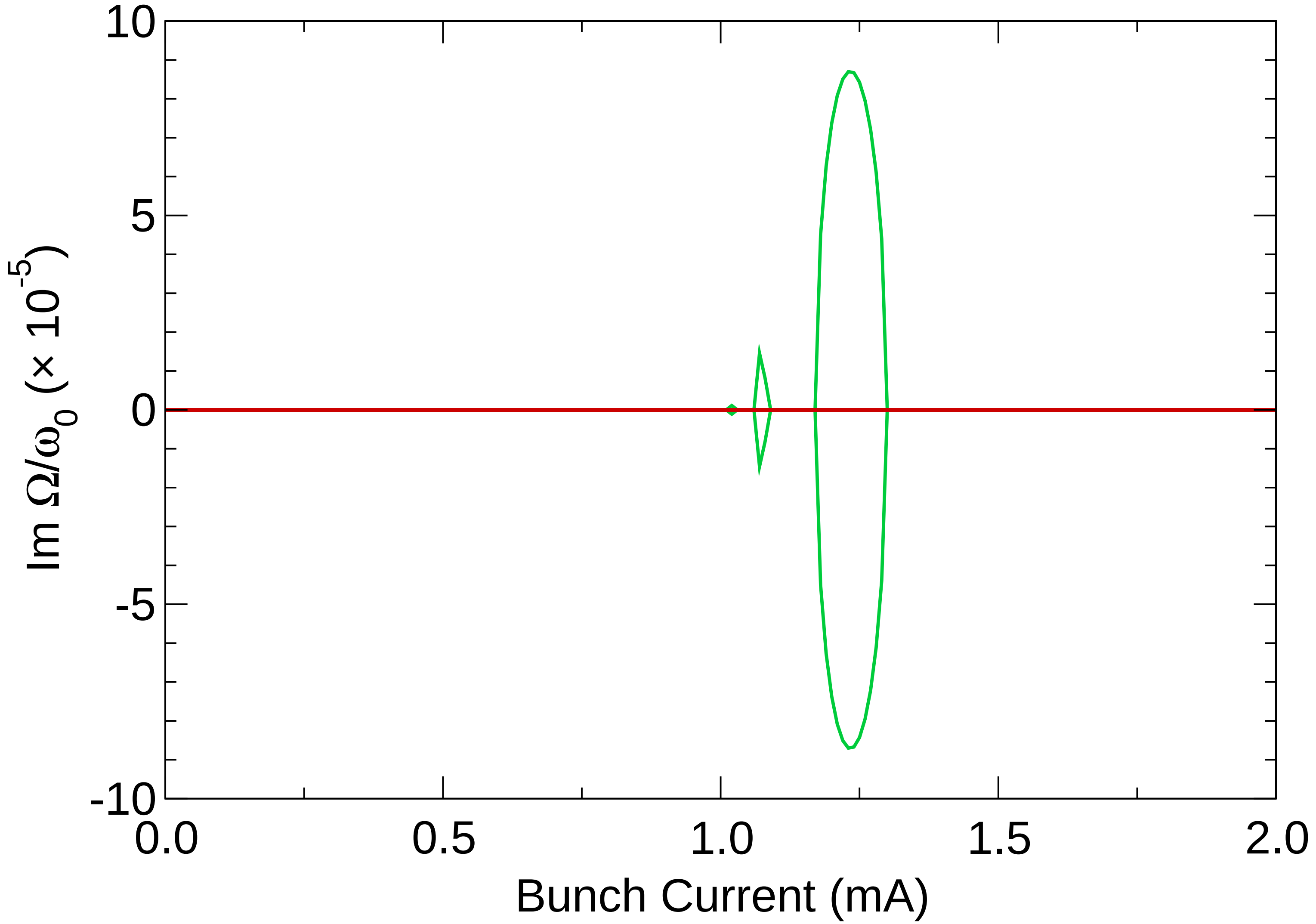
40 GHz Rolloff TMCI



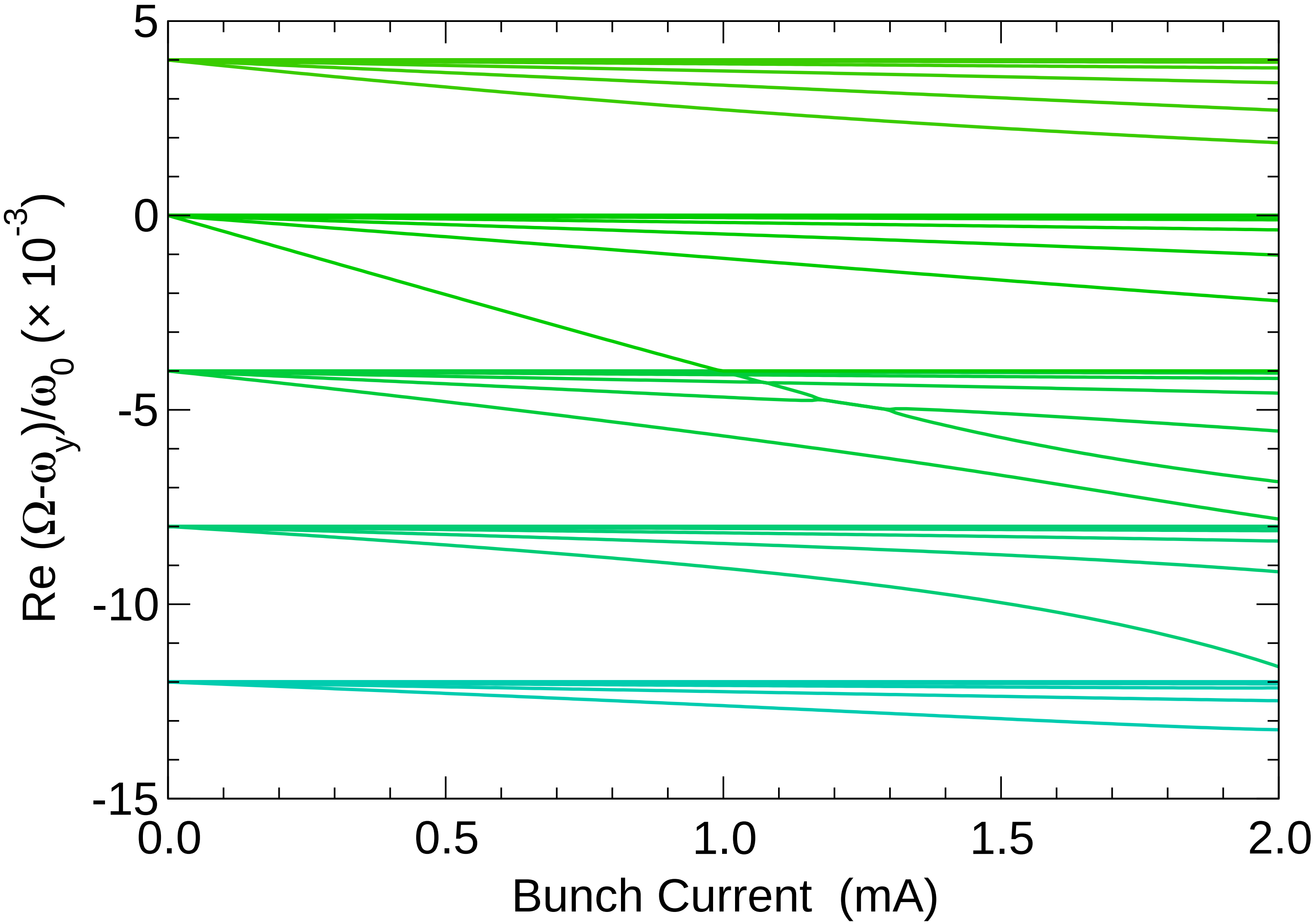
40 GHz Rolloff TMCI



80 GHz Rolloff TMCI



80 GHz Rolloff TMCI



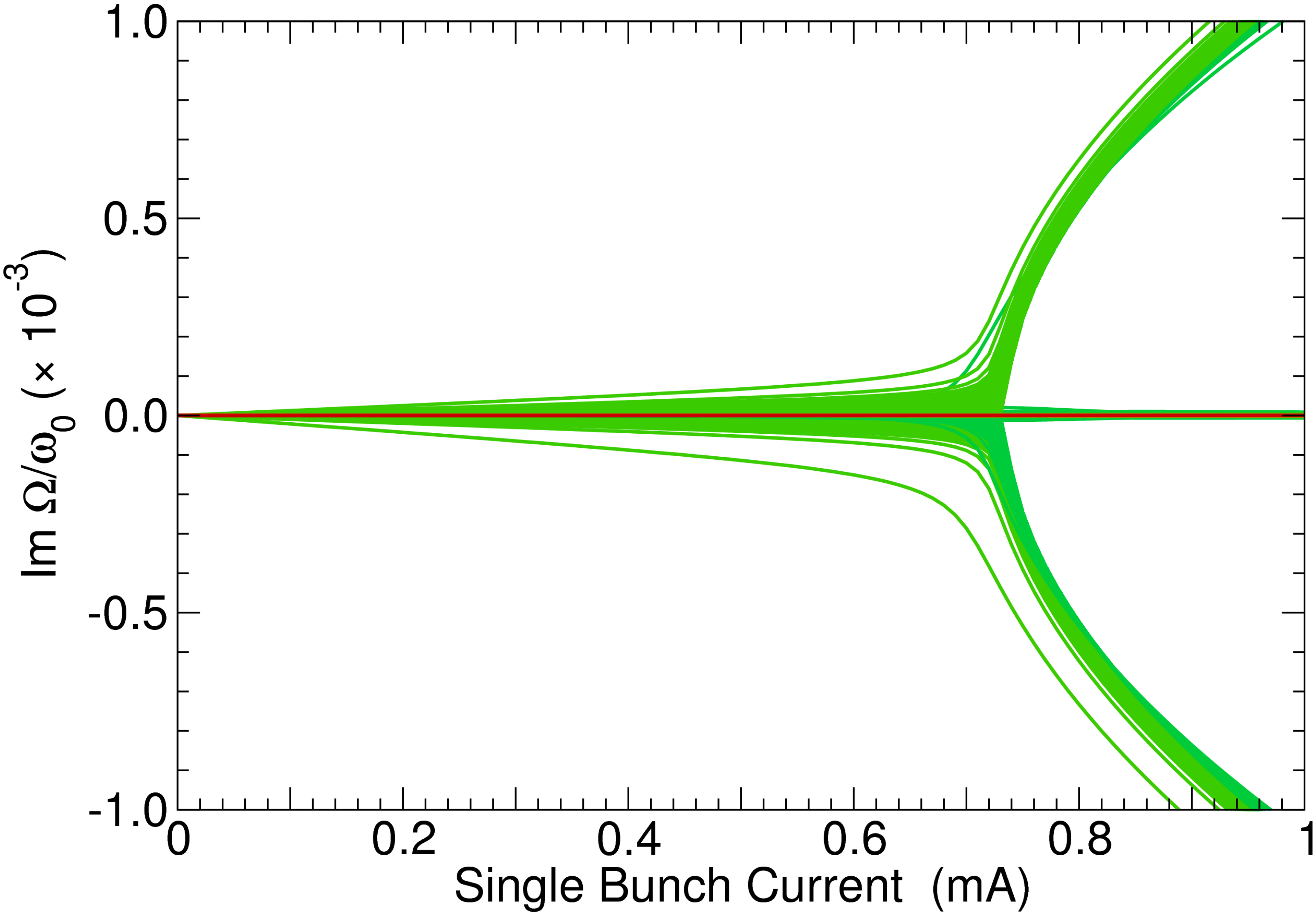
More Observations

- There is virtually no resistive impedance in these calculations
- Resistive wall significantly reduced threshold
  - Required significantly fewer modes to compute accurately: lower order modes couple more stringly
  - Shifts were also higher, of course
- There are definitely missing resistive sources
  - Kickers
  - BPMs
  - Cavities

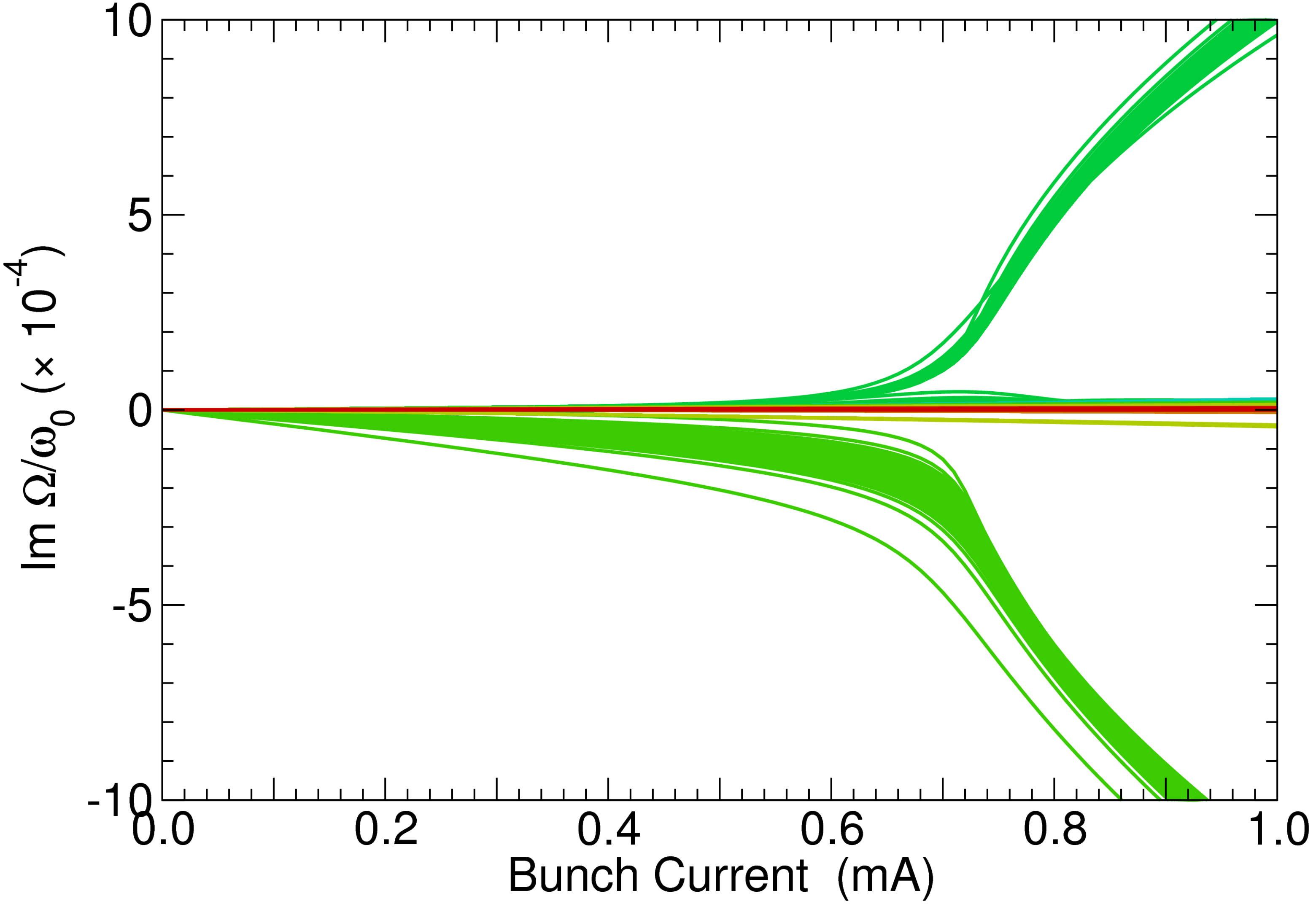
Multibunch Modes

- Do the same calculations as before, but for symmetric multibunch modes
  - The magnitude of the symmetric mode shift is always larger than the magnitude of the real ones
  - Magnitude is not always relevant, though (Landau damping)
  - Can include full coupling between modes
- Add chromaticity to correct $m = 0$ growth
- Examples are all 22 GHz rolloff (most pessimistic), cold MGUs

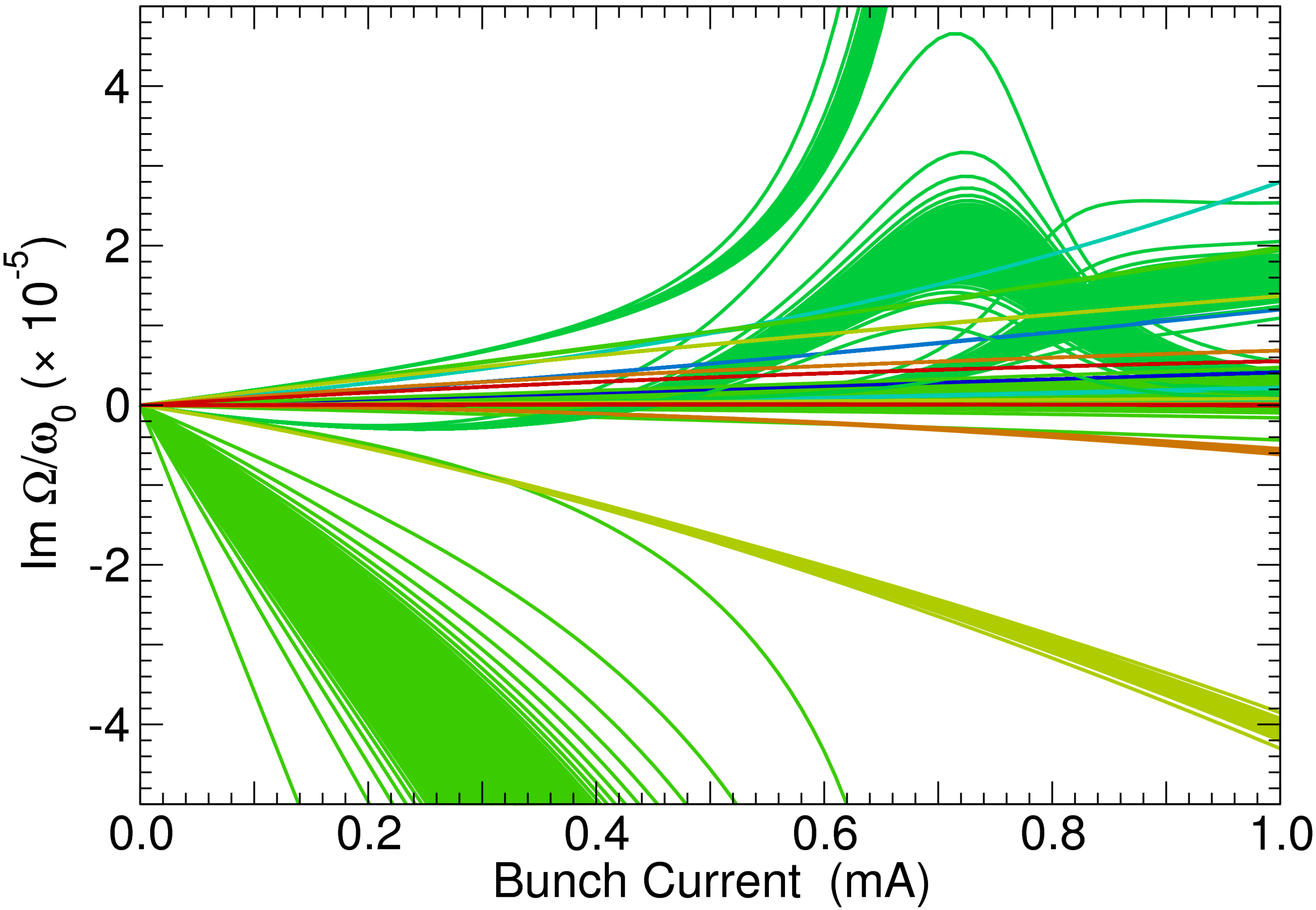
Multibunch Mode Growth Rates



Multibunch Mode Growth Rates with Chromaticity Correction



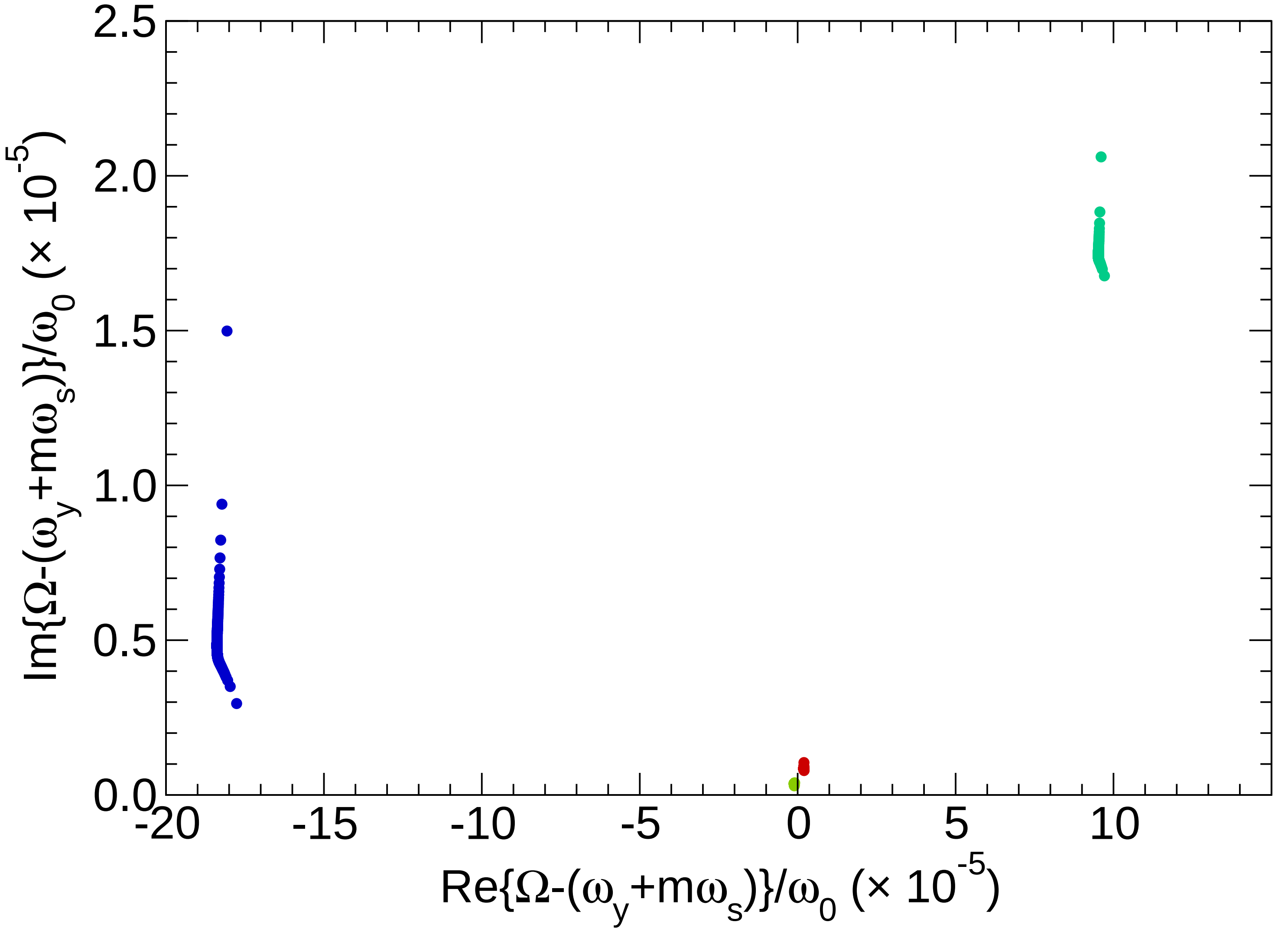
Multibunch Mode Growth Rates with Chromaticity Correction



Observations

- Strong mode coupling effect still observed with multibunch modes
- Chromaticity effectively damps low order $m = 0$ modes
- Higher order mdoes still have significant growth
  - Chromaticity creates growth in higher order modes (sum of all growth rates is zero)
  - Mode coupling exacerbates the growth rates
  - Plot real and imaginary parts of tune shift
    - Landau damping: need both real and imaginary parts
    - Mode sets have different signs for real frequency shift
    - Plot against “stability diagram”
- Effectiveness of chromaticity depends on broadband impedance
  - Worse mode coupling, better chromaticity dapming

Mode Shifts in Complex Plane



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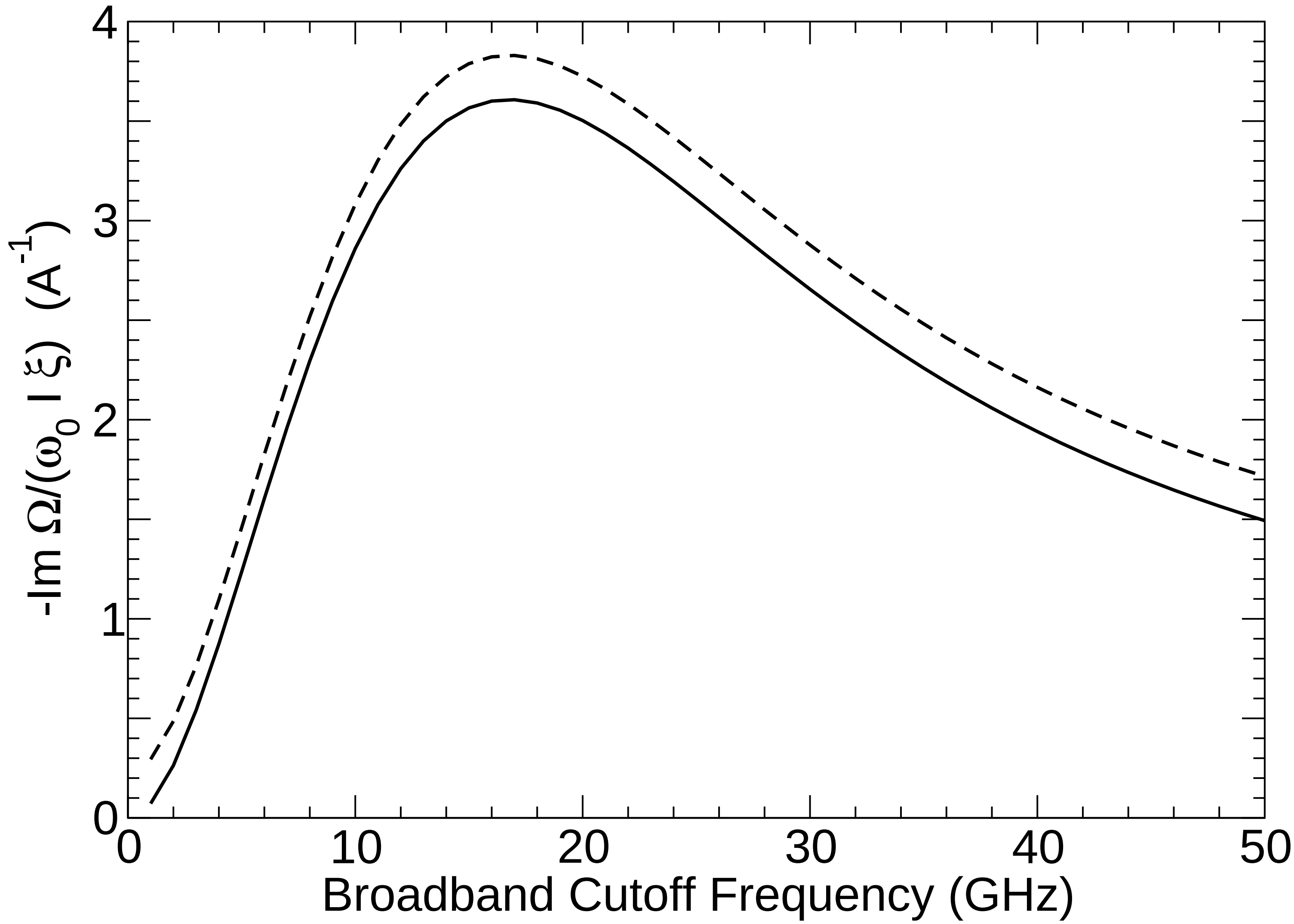
Chromaticity Damping vs. Broadband Rolloff



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Conclusion

- Have tools to perform eigenvalue analysis of transverse collective modes
- Useful for gaining qualitative and quantitative understanding of machine performance
- Need to get the “correct” impedance in there
    - The code can put anything in