Mode 1 Instabilities in Fourth Generation Storage Rings

Francis Cullinan, Åke Andersson, Jonas Breunlin, Miriam Brosi,
Pedro Fernandes Tavares
(MAX IV Laboratory, Lund, Sweden)

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Overview

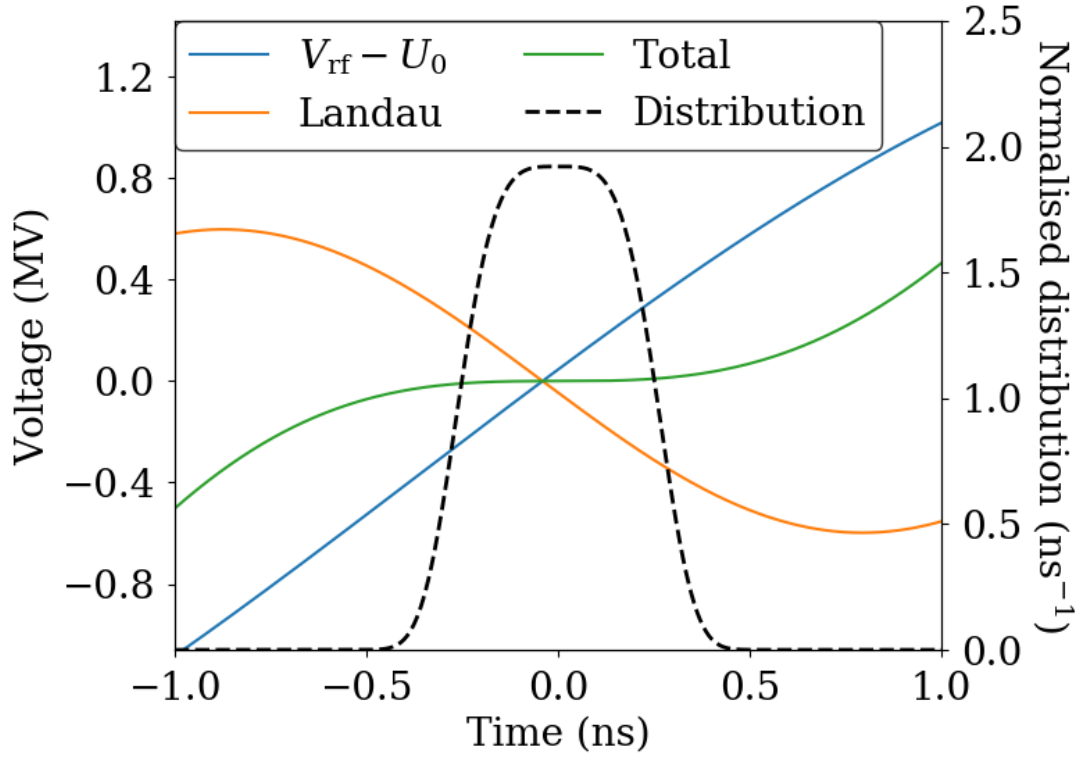
- MAX IV 3 GeV ring
- Landau cavities
- Mode 1 instability
- Measurements
- Parked main cavities

MAX IV 3 GeV Ring

Parameter	Value
RF frequency (MHz)	100
Landau-cavity (LC) harmonic	3
Shunt impedance per HC (MΩ)	2.75
HC quality factor	20800
Delivery beam current (mA)	400
RF voltage (MV)	1.0
Natural RMS bunch duration (ps)	40.4
…with ideal HC lengthening (ps)	199
Harmonic number	176
Number of main (landau) cavities	5 (2)

Landau (harmonic) Cavities

- Landau cavities used to flatten the RF potential to lengthen the bunches
  - Longer Touschek lifetime
  - Less intrabeam scattering
  - Reduced heating of vacuum components

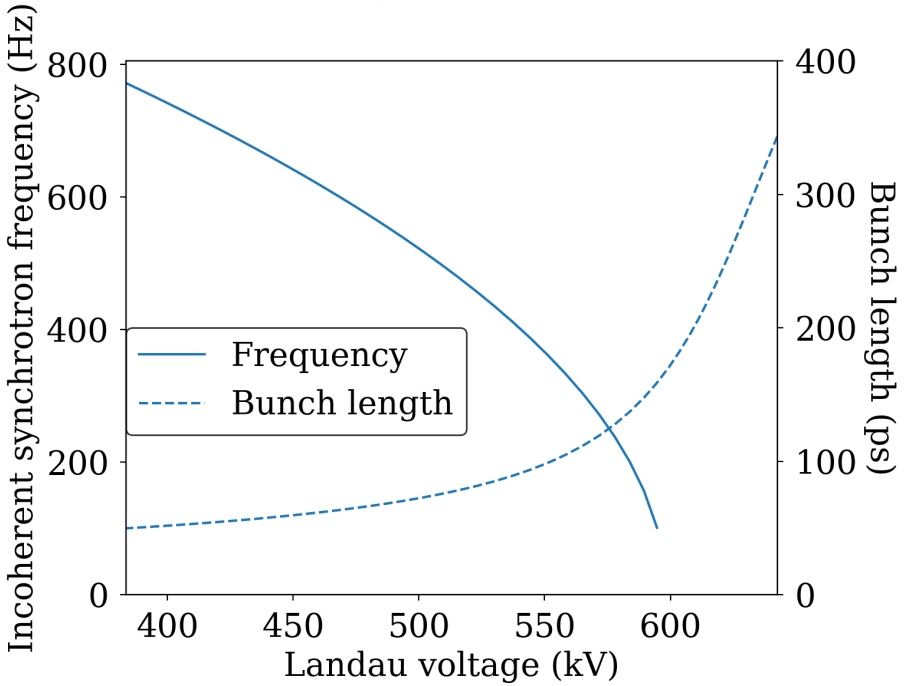


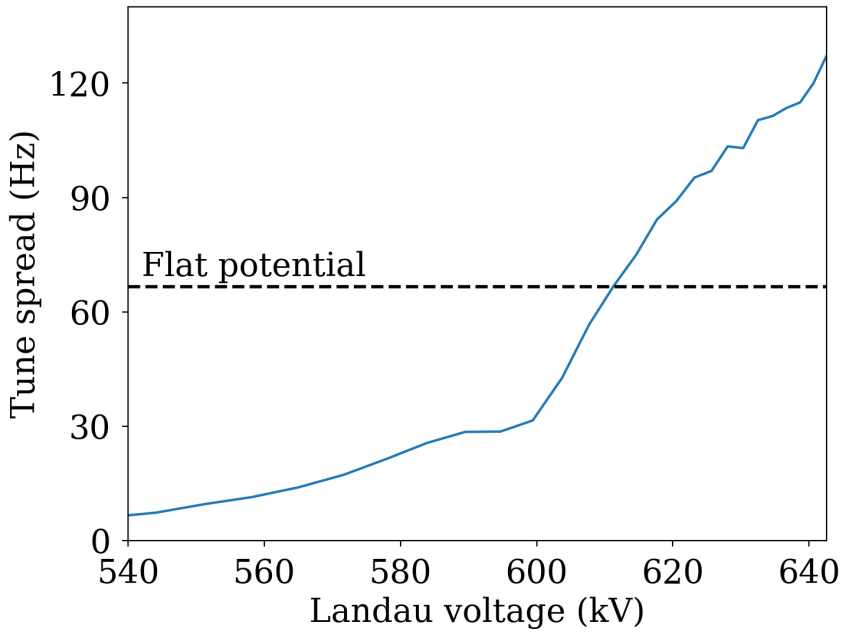
J. M. Byrd & M. Georgsson, PRSTAB 4 030701 (2001)

M. Georgsson, Å. Andersson & M. Eriksson, NIM A 416 2-3 pp 465-474 (1998)

Synchrotron tune

- MAX IV parameters, 500 mA current
- Main RF voltage, 1.8 MV (flat potential with 3 LCs)

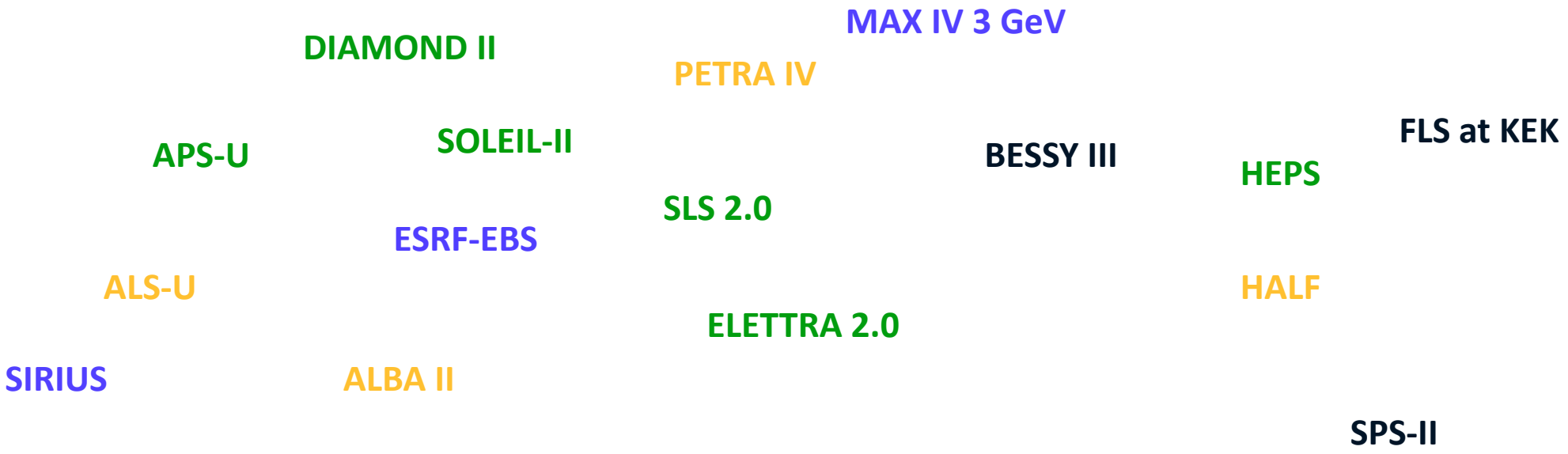




T. Olsson, F. Cullinan & Å. Andersson, PRAB **21** 120701 (2018)
P. F. Tavares, Å. Andersson, A. Hansson & J. Breunlin, PRSTAB **17** 064401 (2014)

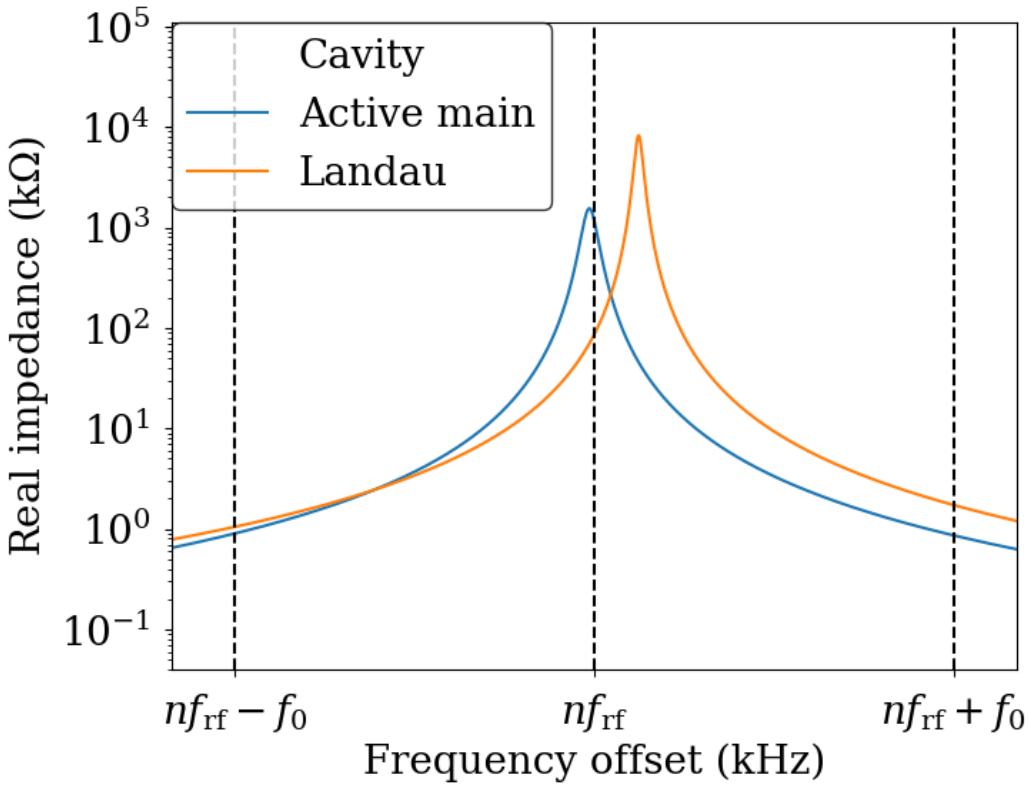
Harmonic Cavities in Fourth Generation Light-Source Synchrotrons

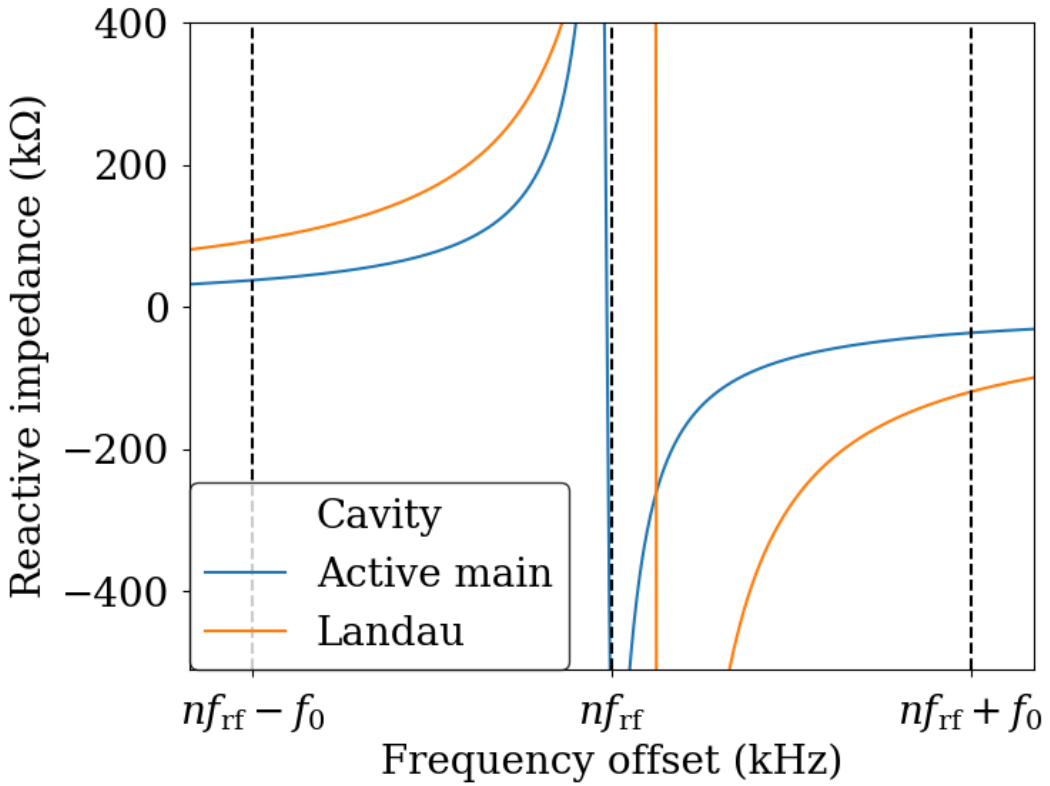
- Survey of harmonic cavity systems carried out for discussion at FLS 2023



Impedances

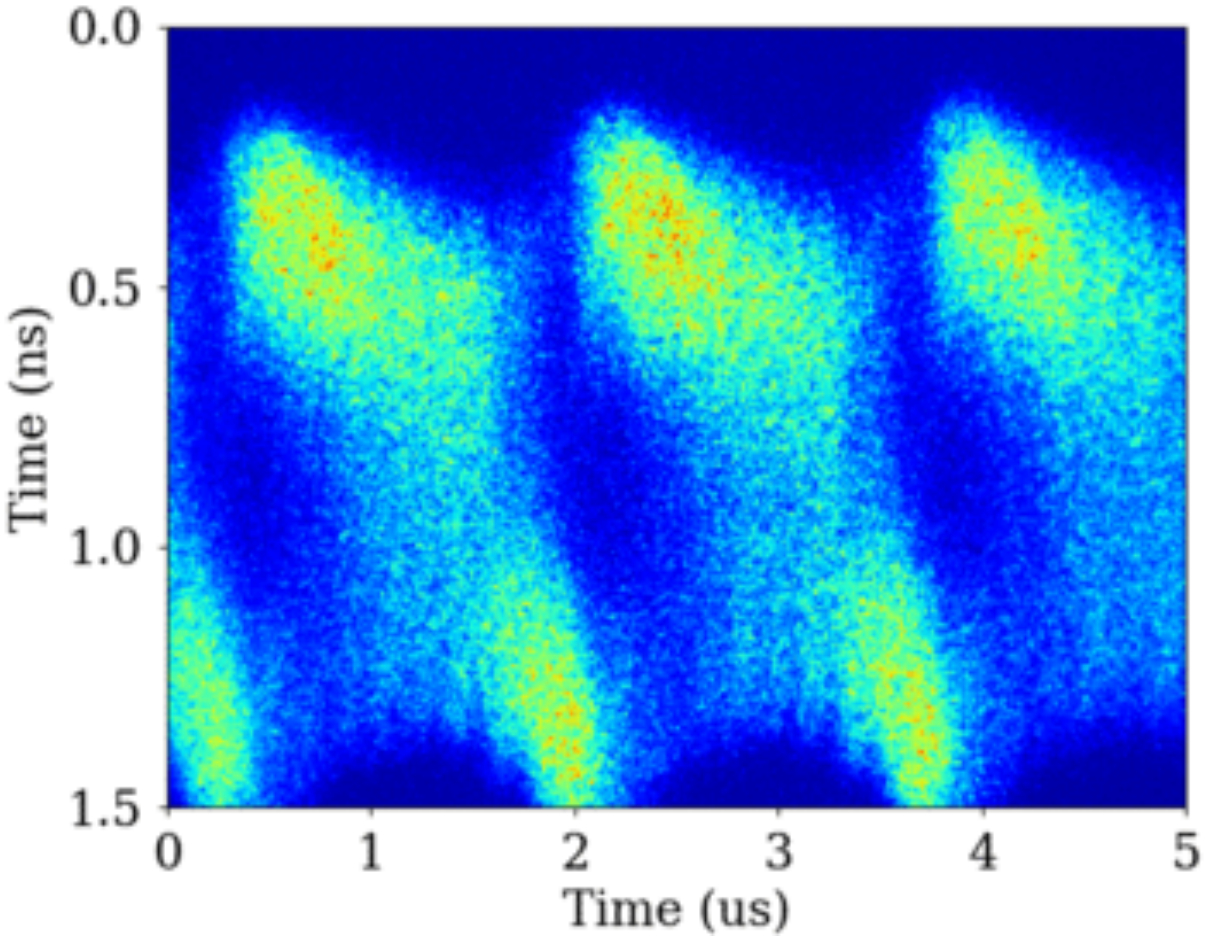
- 3 Landau cavities, flat potential at 200 mA with RF voltage of 1 MV





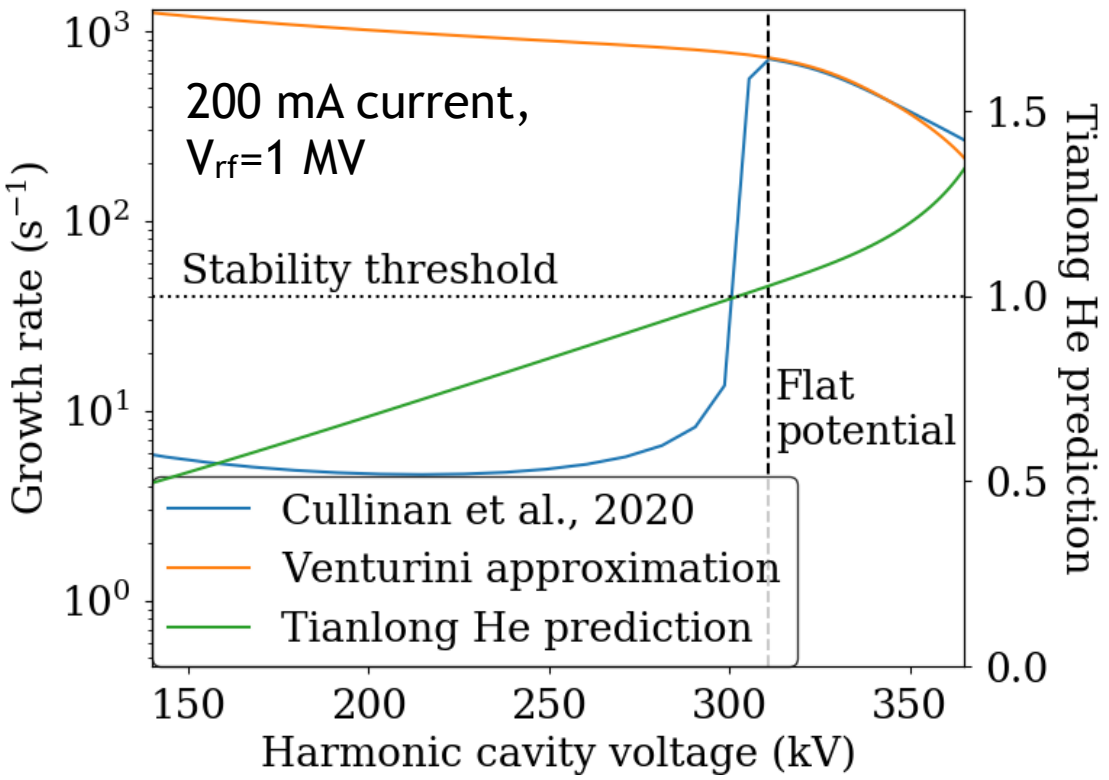
Mode 1 Instability

- Characterised by low coherent frequency
- Sometimes referred to as ‘periodic transient beam loading’*



R. A. Bosch, K. J. Kleman & J. J. Bisognano, PRSTAB **4** 074401 (2001).
M. Venturini, PRAB 21, 114404 (2018).
*T. He, PRAB **25** 024401 (2022).

Mode 1 approximations



F. J. Cullinan, Å. Andersson & P. F. Tavares, PRAB **23** 074402, (2020).
M. Venturini, PRAB, **21** 114404, (2018).
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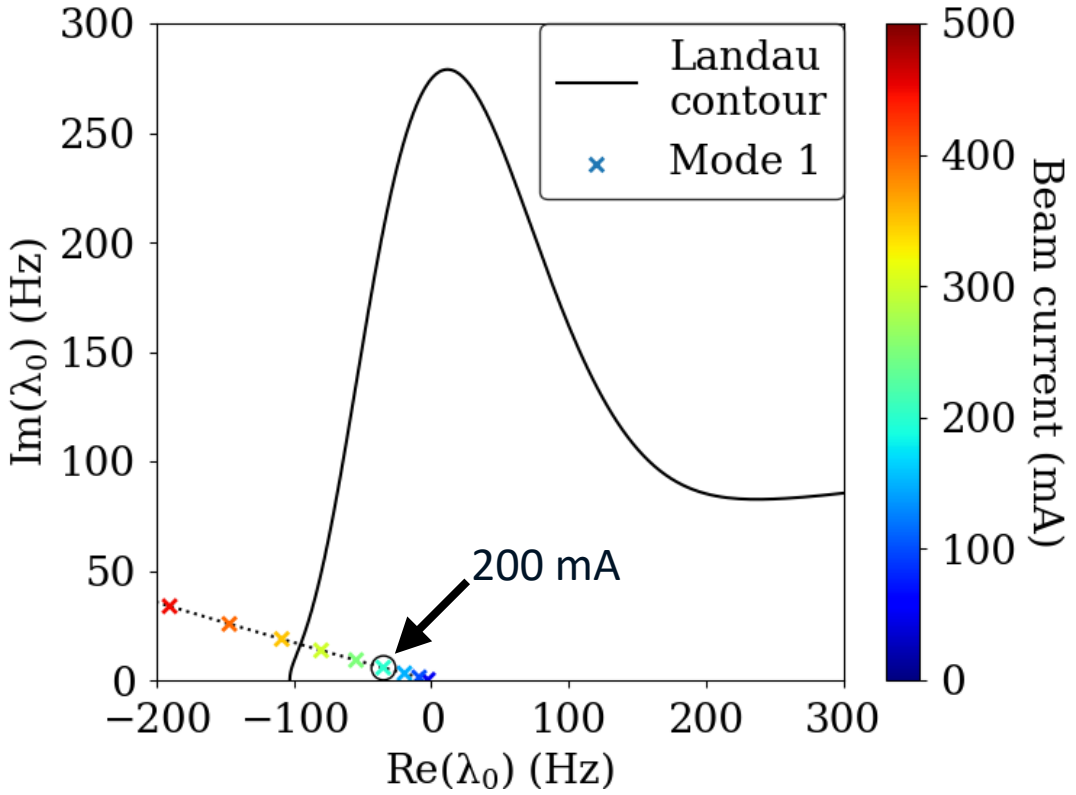
Landau damping



S. Krinsky & J. M. Wang, Part. Accel. **17** 109 (1985)
R. R. Lindberg, PRAB **21** 124402 (2023).

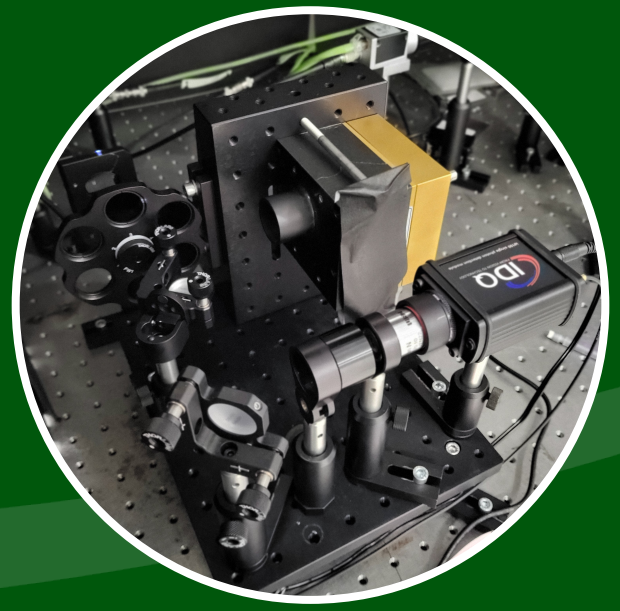
Diagnostics

STREAK CAMERA

Hamamatsu

BUNCH BY BUNCH PHASE DETECTION

Dimtel Inc.



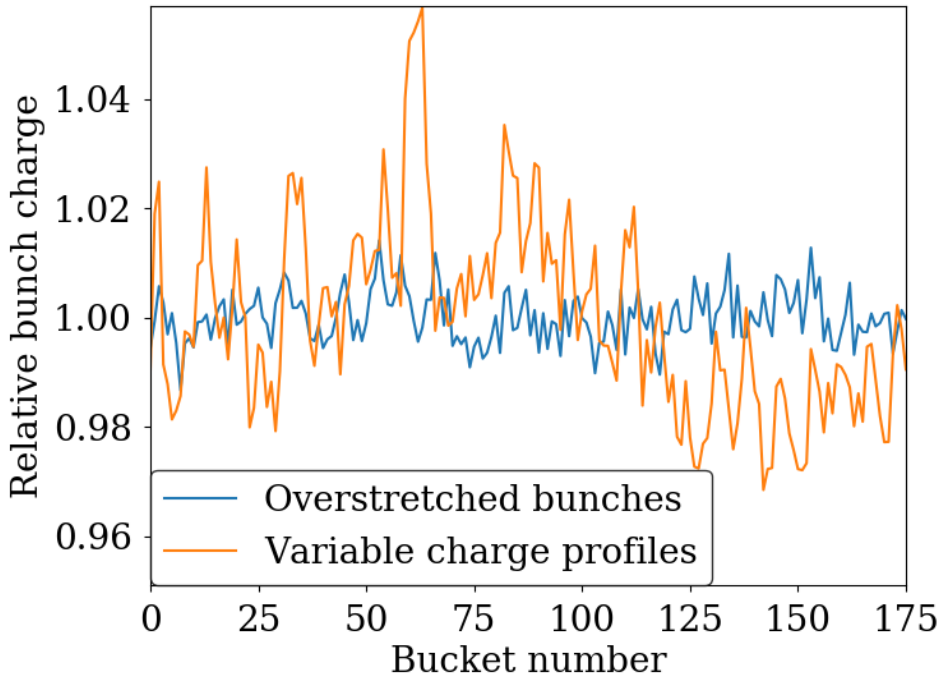
FILL-PATTERN MONITOR

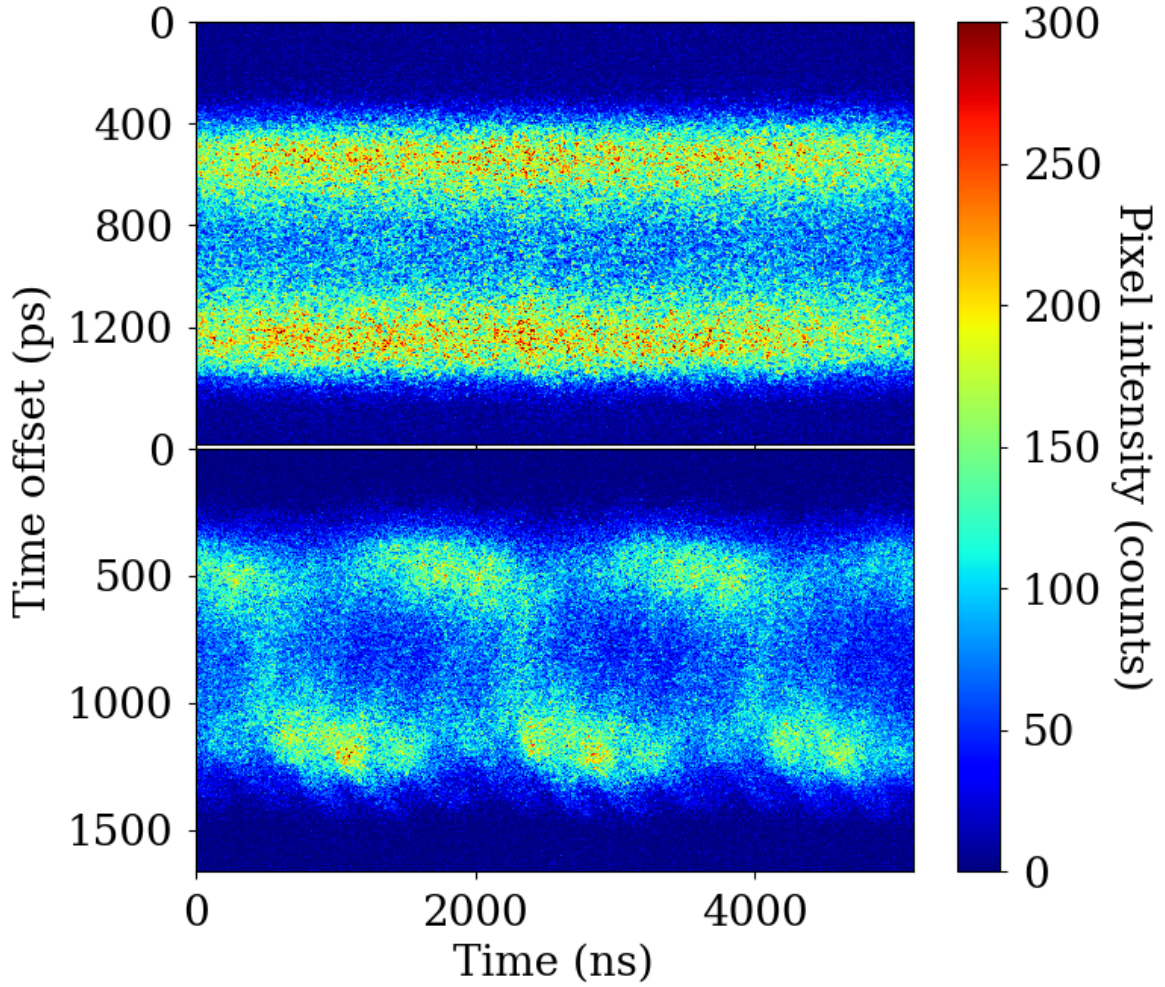
PicoQuant

Fill Pattern Considerations

2 Landau cavities,
RF voltage of 1.13 MV,
300 mA

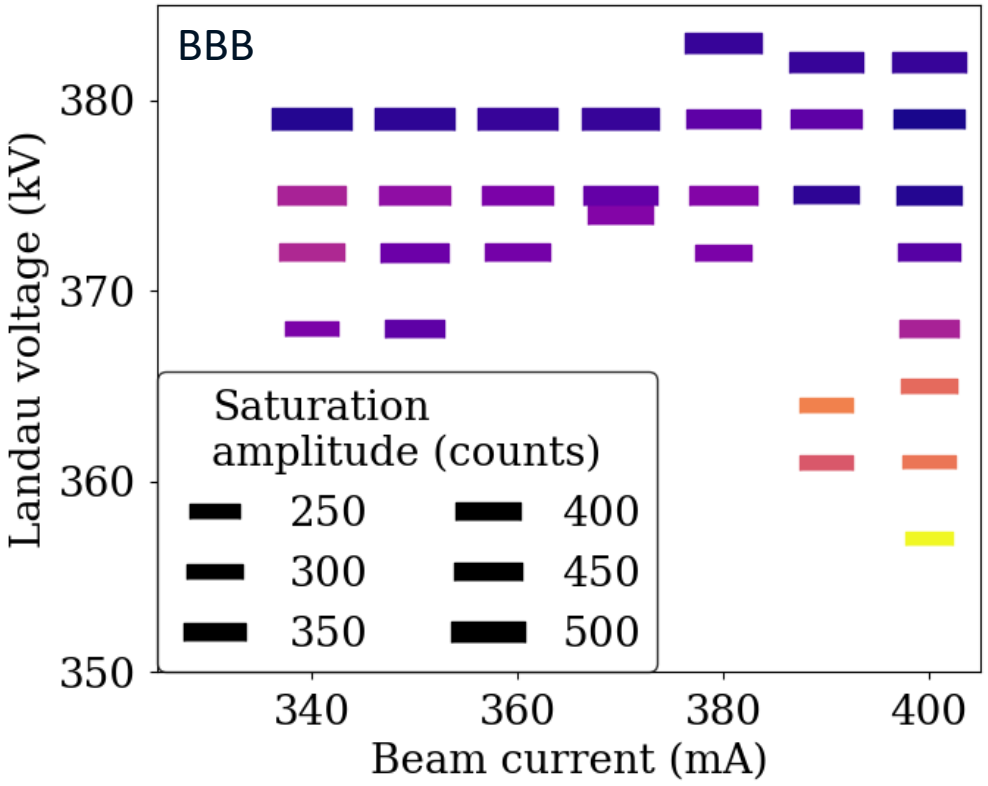
- Inhomogeneous beam loading can look like Mode 1 instability and alter threshold

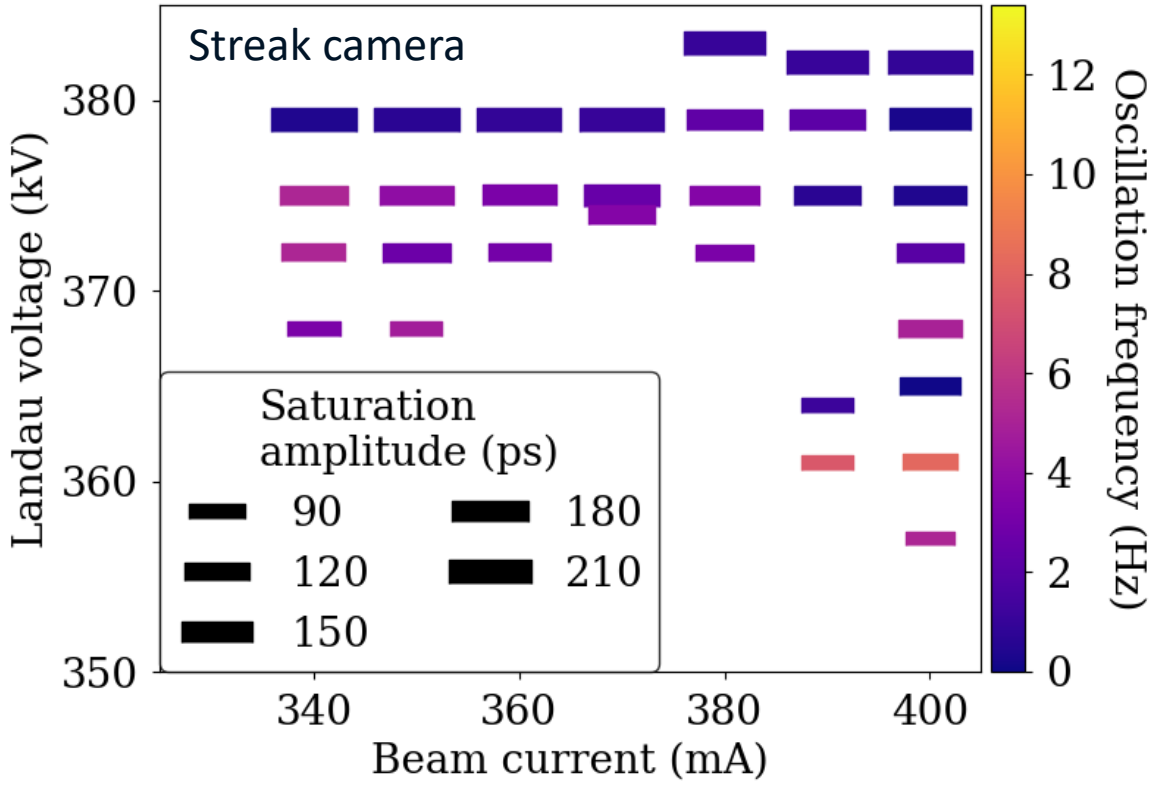




Overstretched Conditions

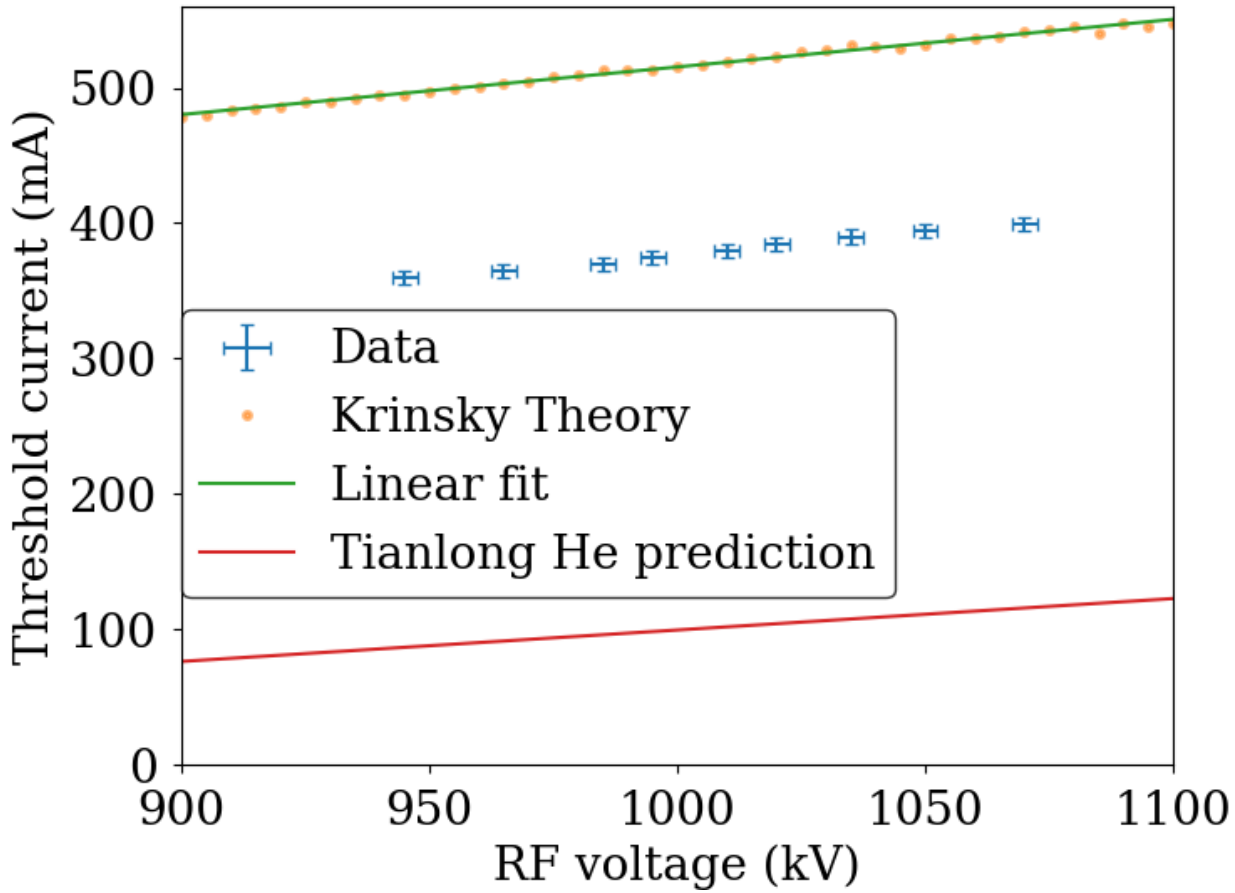
- 2 Landau cavities and an RF voltage of 1.13 MV





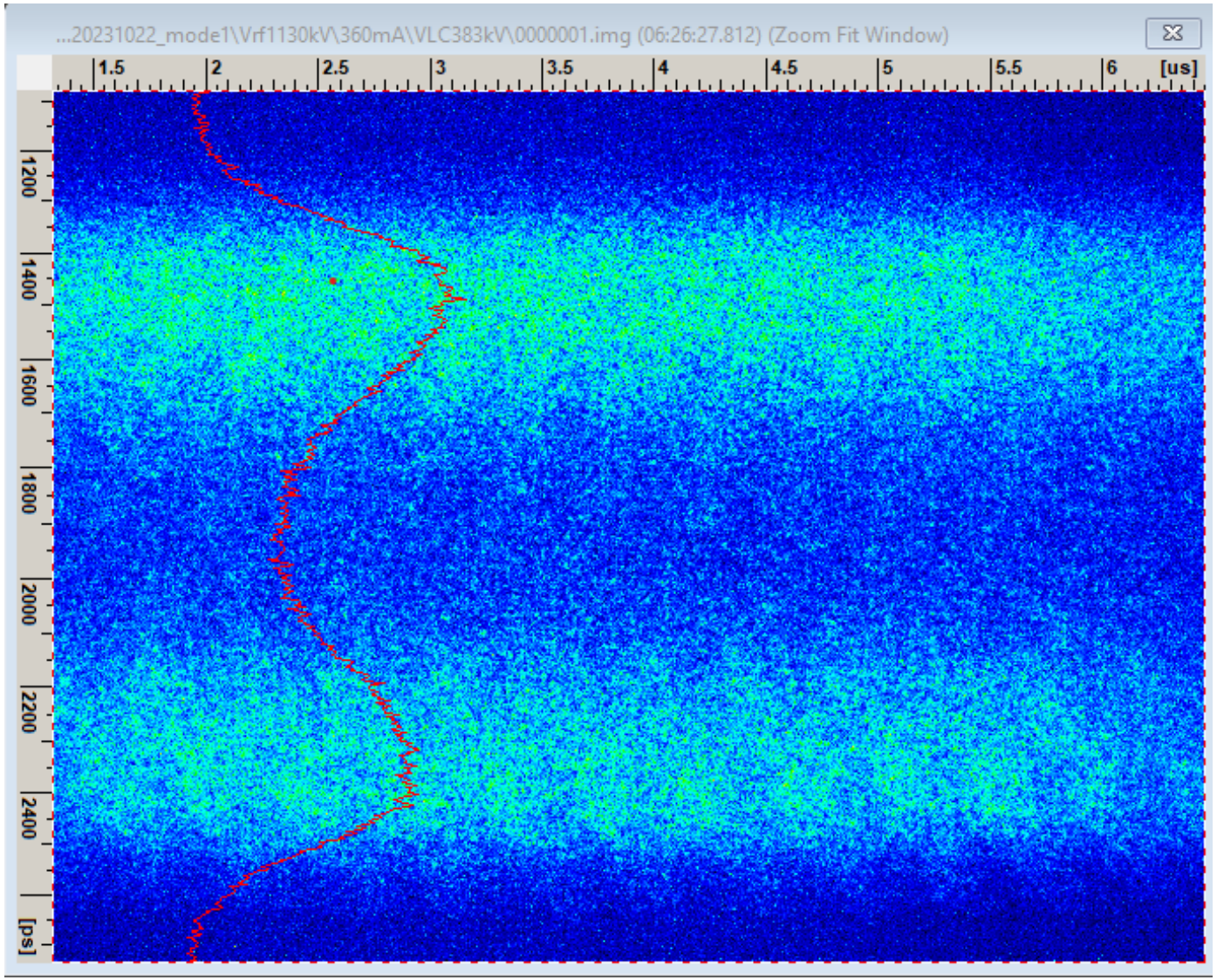
Flat potential conditions

- 2 Landau cavities, 1.13 MV RF voltage



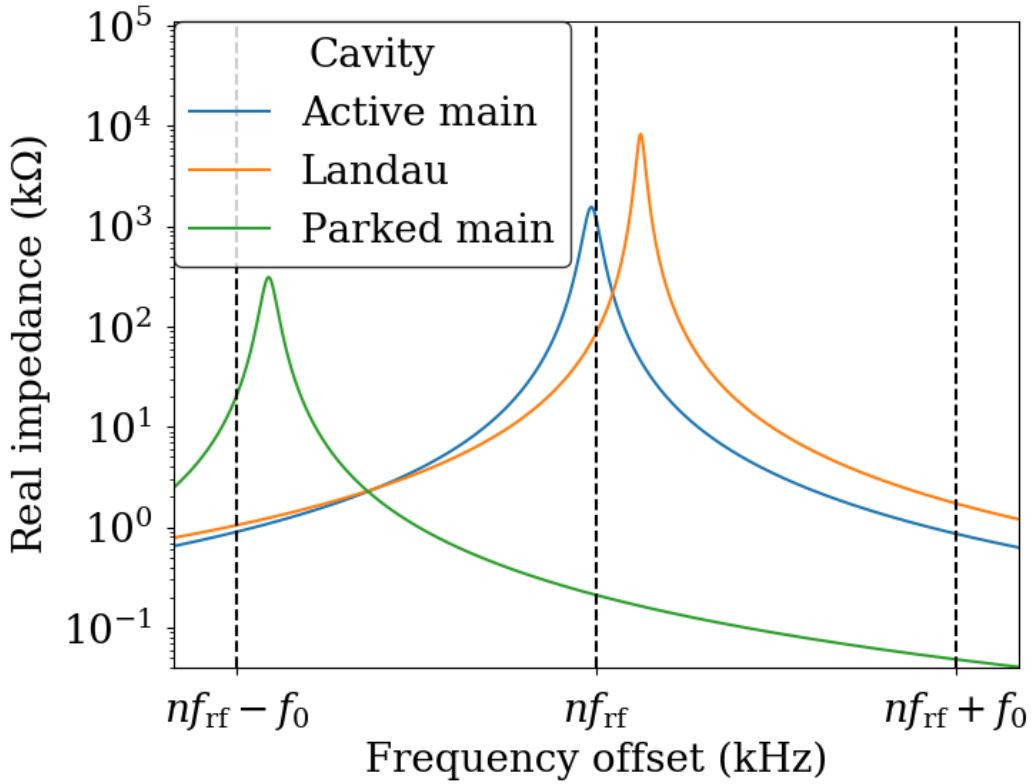
Beyond Mode 1

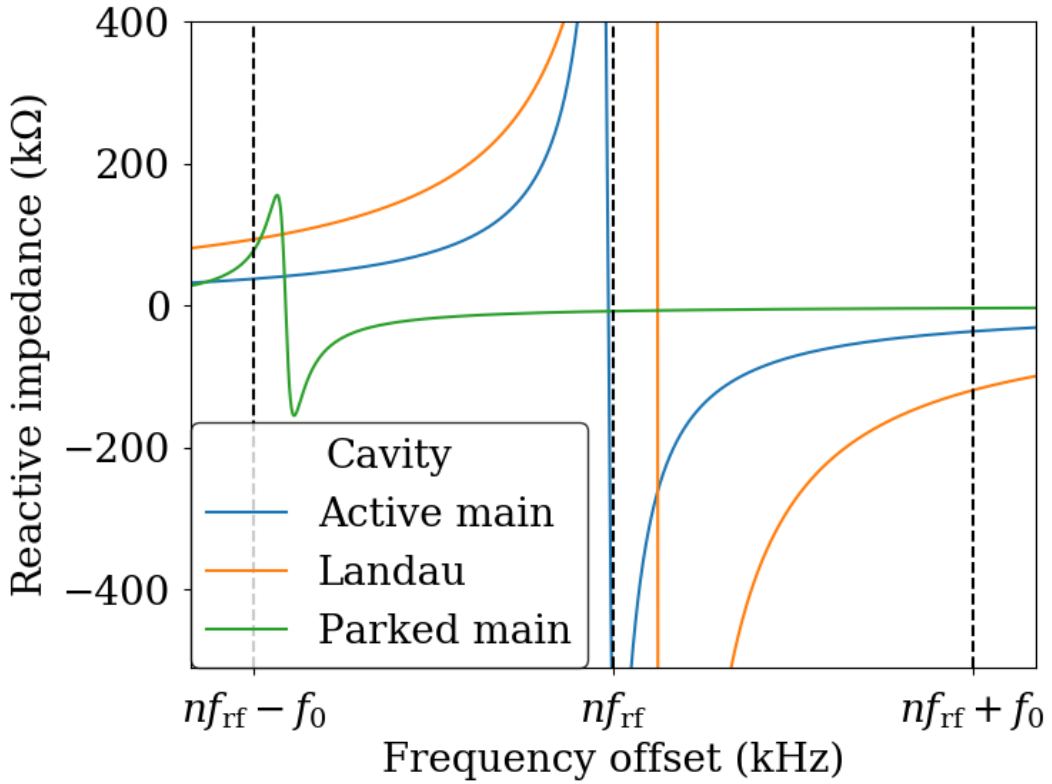
- At a certain Landau voltage, mode 1 goes stable and overstretched bunches are reestablished



Parked main cavity

- 3 Landau cavities, flat potential at 200 mA with RF voltage of 1 MV

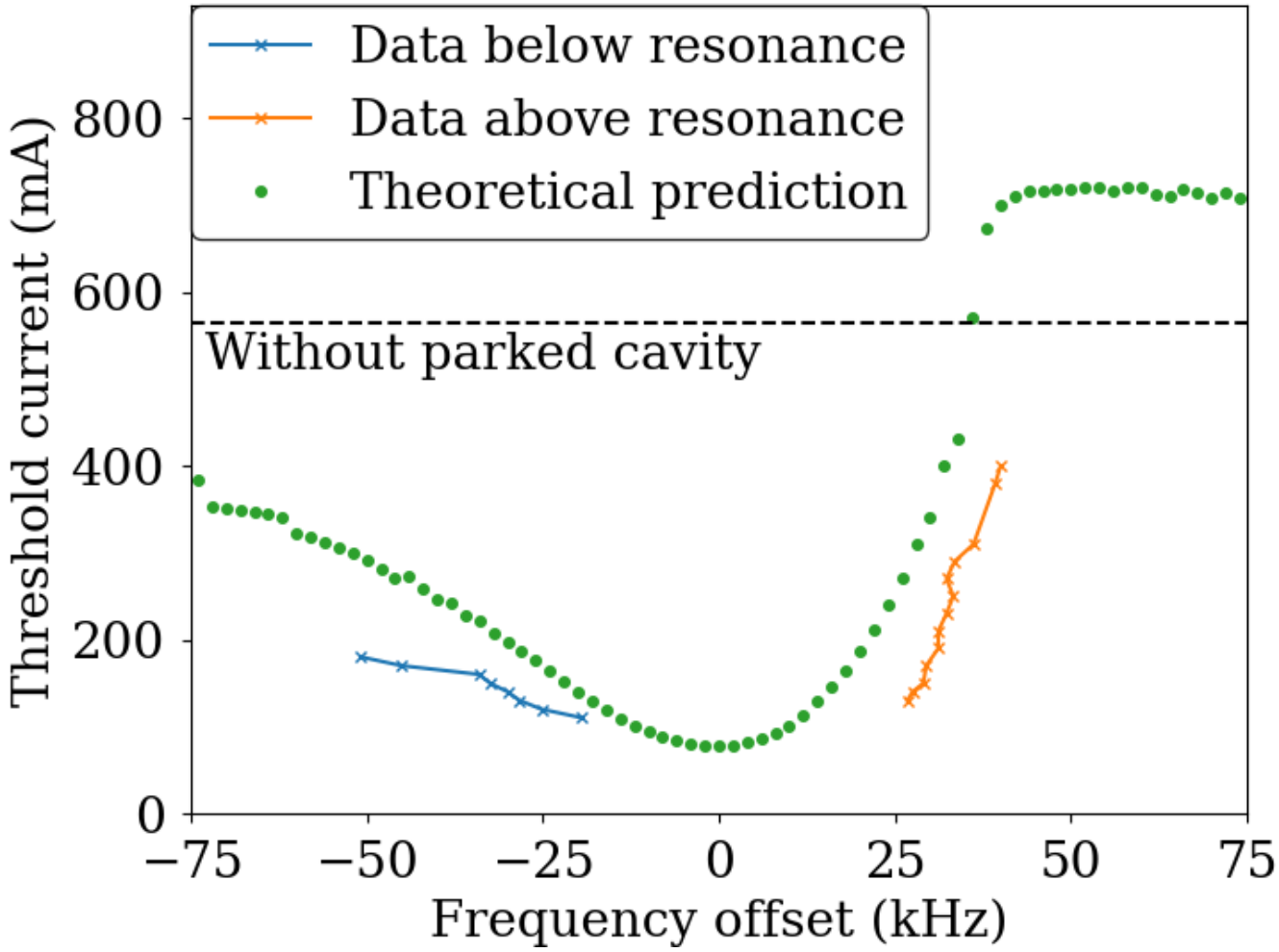




Parked Main Cavity

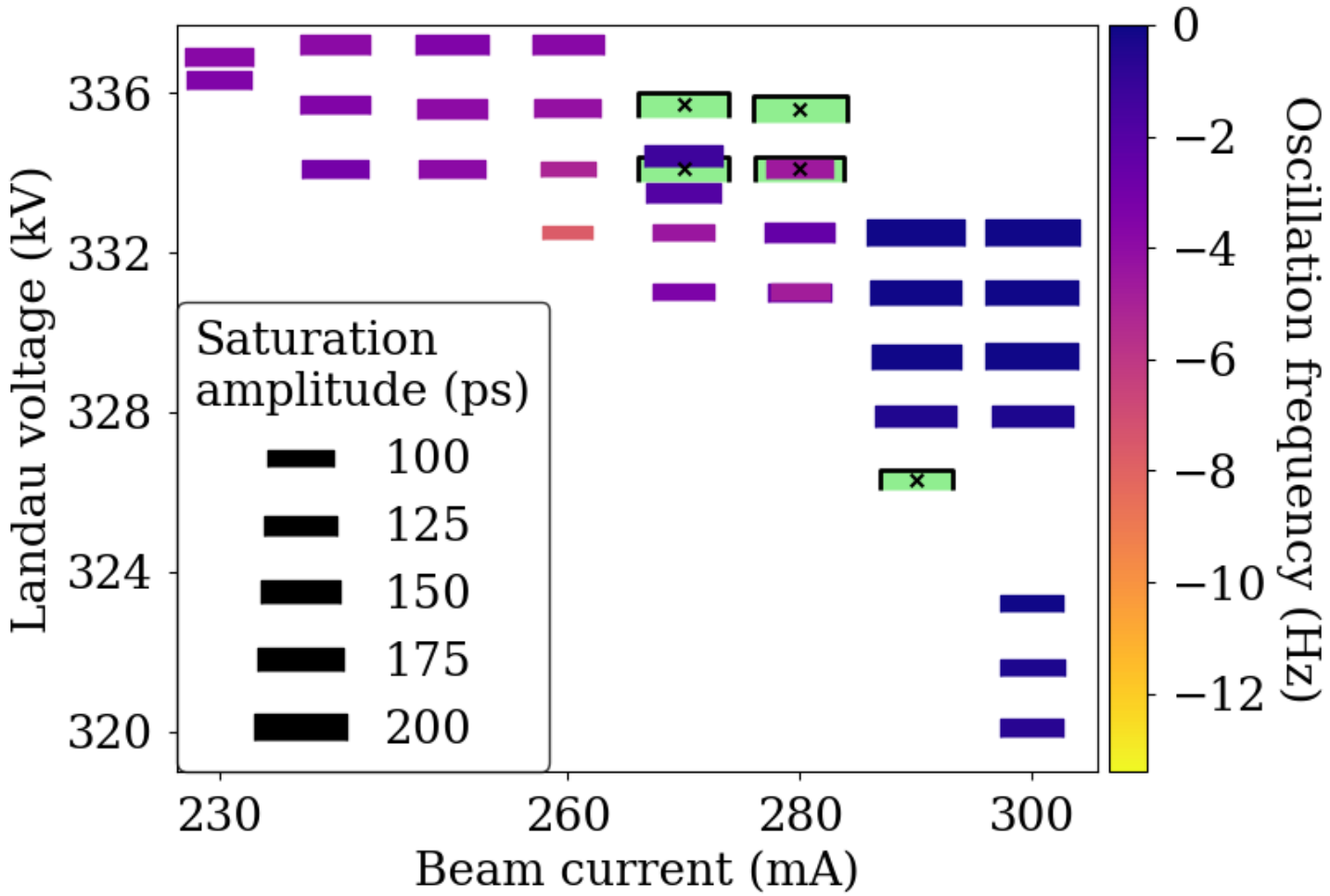
CAN BE BOTH HELPFUL AND A HINDRANCE

- 2 Landau cavities and an RF voltage of 1.13 MV



Three Landau Cavities

- 3 Landau cavities and an RF voltage of 1 MV



Conclusion

- Landau cavities are essential in 4th-generation storage rings
- Mode 1 stability is an important consideration
- Methods that neglect Landau damping are prone to underestimate the threshold current
- Extensive measurements of the mode-1 instability have been made at the MAX IV 3 GeV ring


MAX IV

Coherent Frequency (below threshold)

- 90 mA, 690 kV RF voltage