The 3rd harmonic Landau cavity in MAX III

Jonas Breunlin
Åke Andersson, Anders Hansson

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Introduction

Some information about MAX III

- 3rd gen. light source, 8-fold periodicity, $E = 700\ \mathrm{MeV}$, $\alpha_c = 0.0329$
- compact due to combined function magnets, $C = 36\mathrm{m}$
- Tripple rf system, two passive cavities (3rd and 5th harmonic)

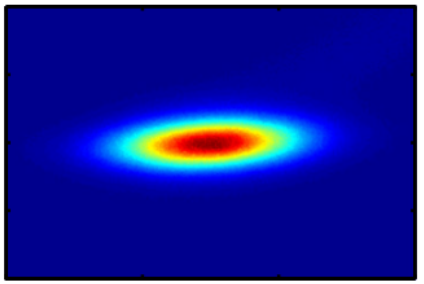
  3rd harmonic: $R_{sh} = 5.36\ \mathrm{M\Omega}$; $Q = 20400$

  5th harmonic: $R_{sh} = 3.14\ \mathrm{M\Omega}$; $Q = 21700$
- 3rd harmonic cavity is a prototype for MAX IV

Motivation: Why a harmonic cavity?

- Causes bunch lengthening → reduces electron density in the bunch
- Increases lifetime by reducing Touschek scattering
- Provides “Landau damping” against beam instabilities

The MAX III diagnostics beamline

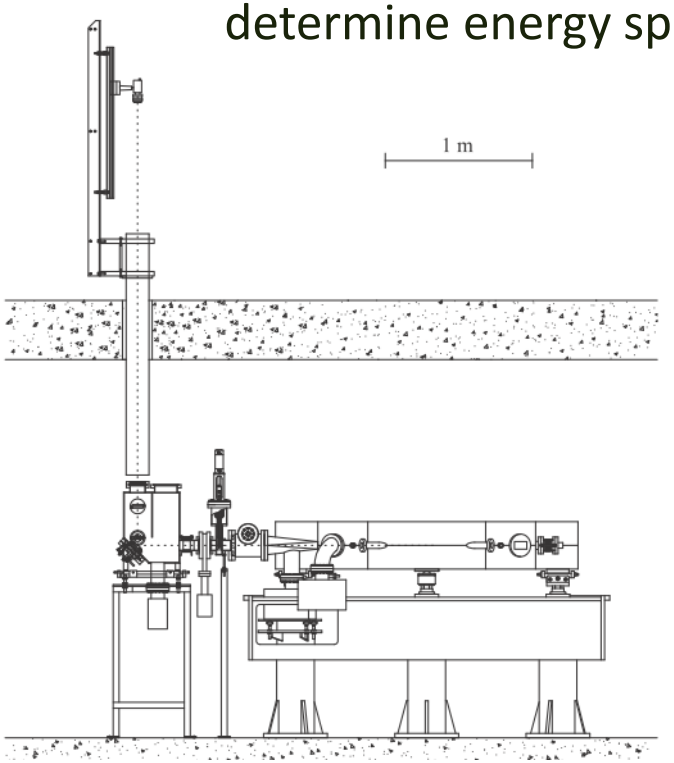


Visible to UV light from dipole magnet

- Transverse:

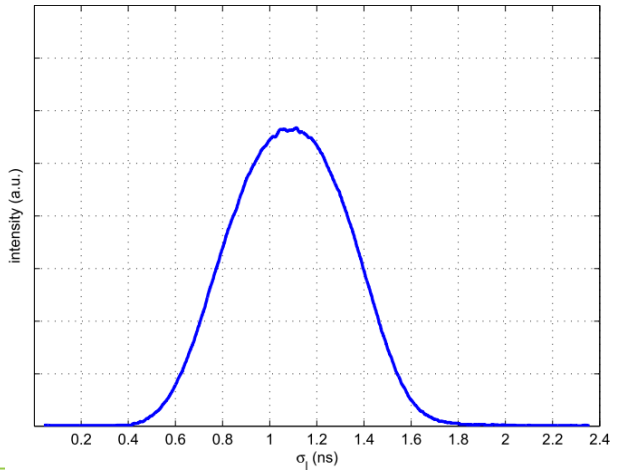
  measure transverse beam size

  determine energy spread (indirectly trough dispersion)



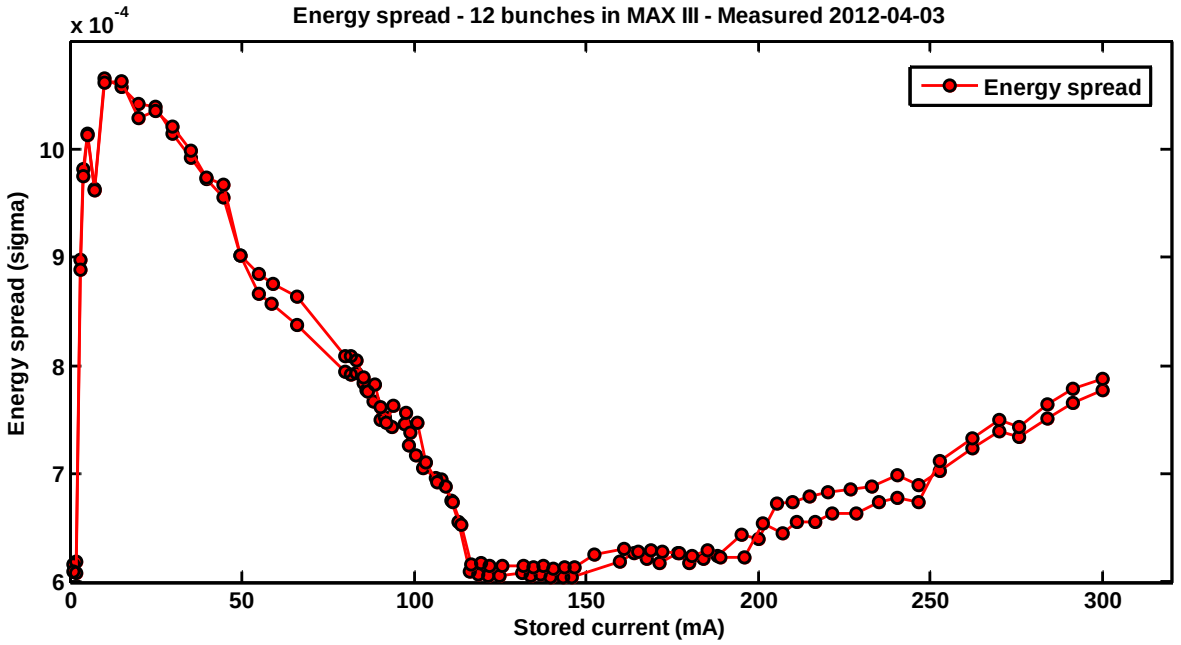
- Longitudinal:

determine bunch length with OSO (Optical Sampling Oscilloscope)



Energy spread and bunch length

- Determine energy spread σ_δ assuming $\sigma_x^2 = \varepsilon_x \beta_x + \eta_x^2 \, \sigma_\delta^2$



- Increased energy spread at I < 120 mA is caused by longitudinal instabilities
- Bunch length: $\sigma_l = \dfrac{\alpha_c \, c}{2\pi \, f_s} \, \sigma_\delta$ only in a single rf system (lin. approx.) !!

Landau cavity beam interaction

Total voltage seen by an electron

$$V(\phi) = V_{rf}\ \sin(\phi + \varphi_s) + V_L \sin(n\phi + \varphi_L)$$

For a passive Landau cavity

- Harmonic cavity voltage: $V_L = I\ R_{sh}\ F\ \cos(\psi)$ (R_{sh} in "linac def.")
- Tuning angle: $\psi = arctan\left(2\ Q\ \frac{f_{res} - n\, f_{rf}}{f_{res}}\right)$
- Harmonic phase: $\varphi_L = \psi - \frac{\pi}{2} - \theta$

- Constant parameters, determined before hand: $V_{rf},\ R_{sh},\ Q,\ f_{res},\ f_{rf}$
- Fourier amplitude F and Fourier phase θ derived from bunch shape

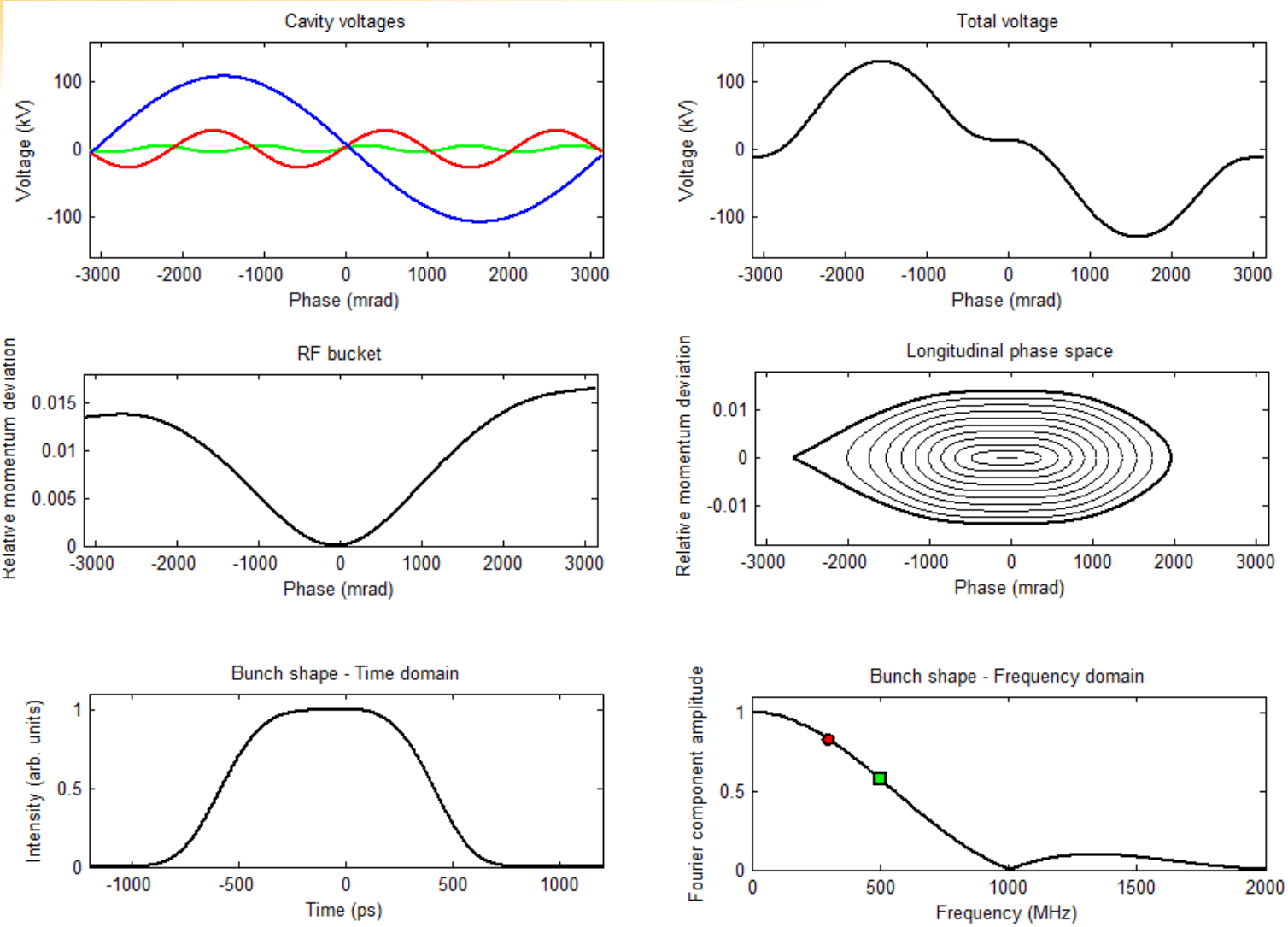
A. Hofmann, S. Myers, Beam dynamics in a double RF system, 1980, CERN-ISR-TH-RF-80-26, 728.
L. H. Chang et al., Effects of the Landau cavity on the electron beam, Proceedings of PAC 1997, 1691.
J. M. Byrd, M. Georgsson, Lifetime increase using passive harmonic cavities in synchrotron light sources, Phys. Rev. Special Topics – Acc. and Beams, vol. 4, Iss. 3, 030701.

An iterative algorithm

Bunch shape is determined by a potential derived from total cavity voltage $V(\phi)$

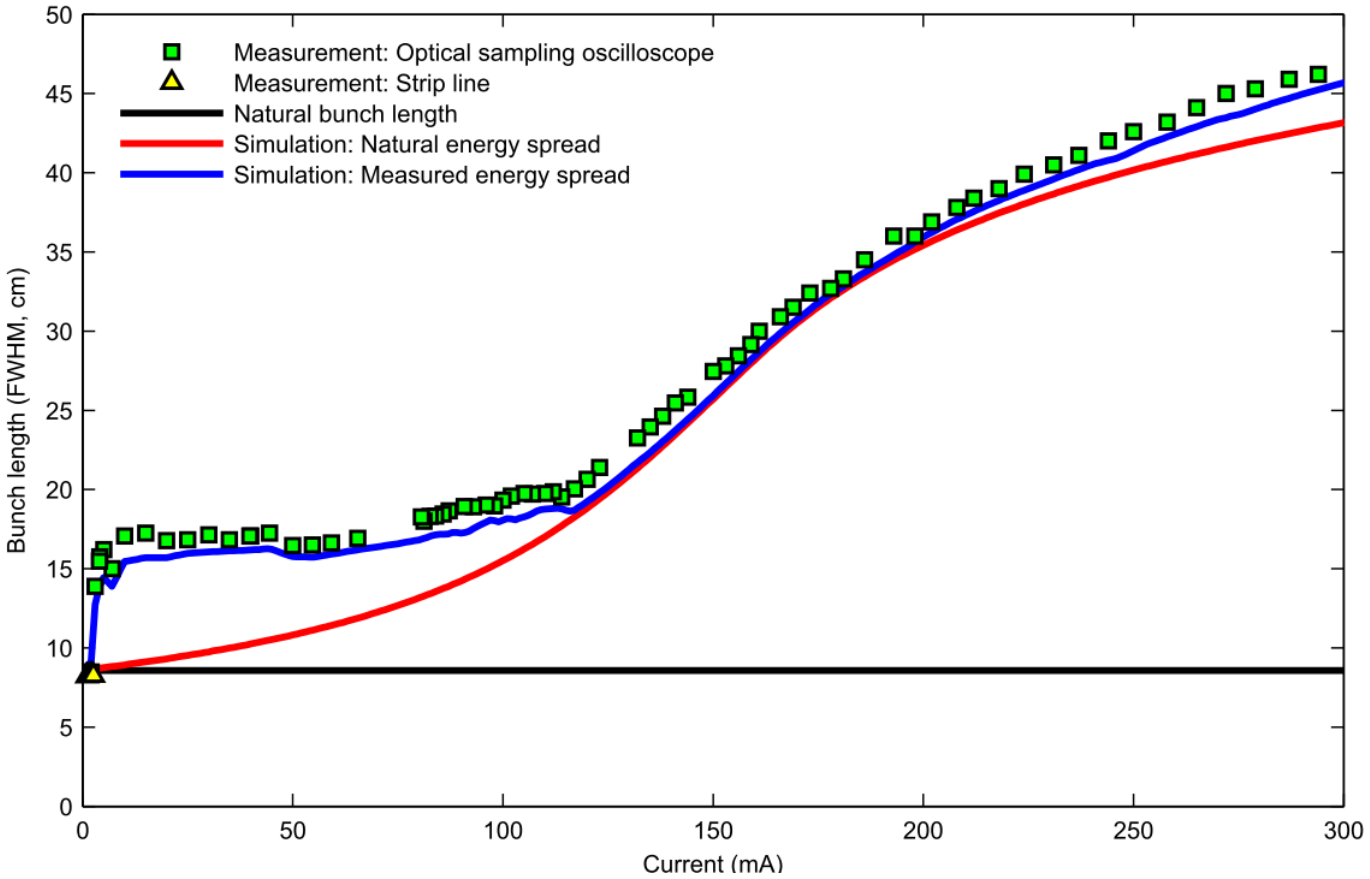
Excitation of passive harmonic cavity (cavities) depends on bunch shape (F and θ)

- Iteration starts from a guess for F and θ
- Finds a stable, self consistent solution
- Code works for triple RF system (3rd and 5th harmonic in Max III)



Example: 166mA stored current in Max III (3rd and 5th harmonic cavity)

Comparison: bunch length (FWHM)



Simulated bunch lengths based on the measured energy spread agree well with OSO measurements.

A. Hansson, E. Wallén, Å. Andersson, J. Breunlin, G. Skripka; Electron beam stability and lifetime at the MAX III synchrotron light source. Submitted to Nucl. Instr. and Meth. A.

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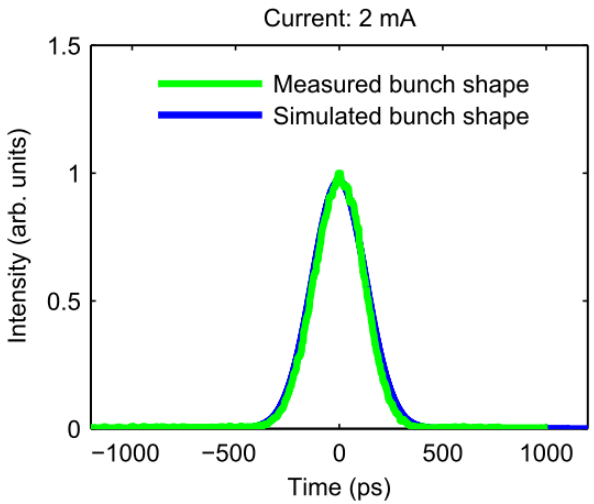
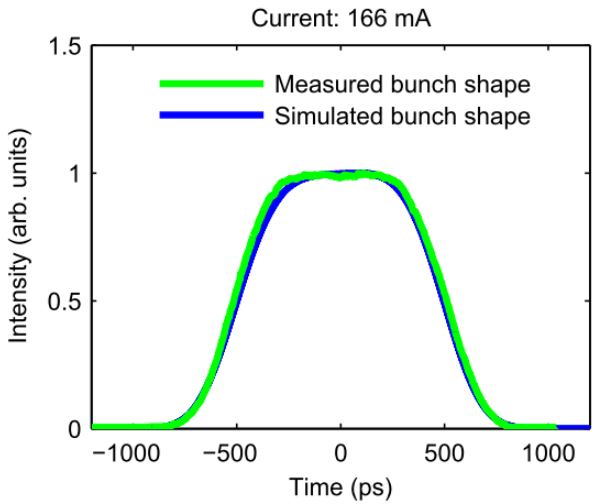
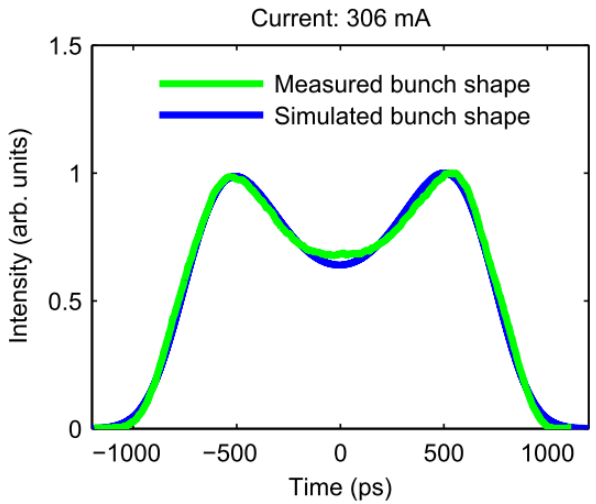
Comparison: bunch shapes

Electron distributions at different currents

- Gaussian bunch shape at low currents
- Bunch lengthening due to increasing Landau cavity fields
- Over-stretched bunch shape (verified by single-shot PD measurement)







- Simulations based on measured energy spread
- Bunch shape is not an input parameter for simulation

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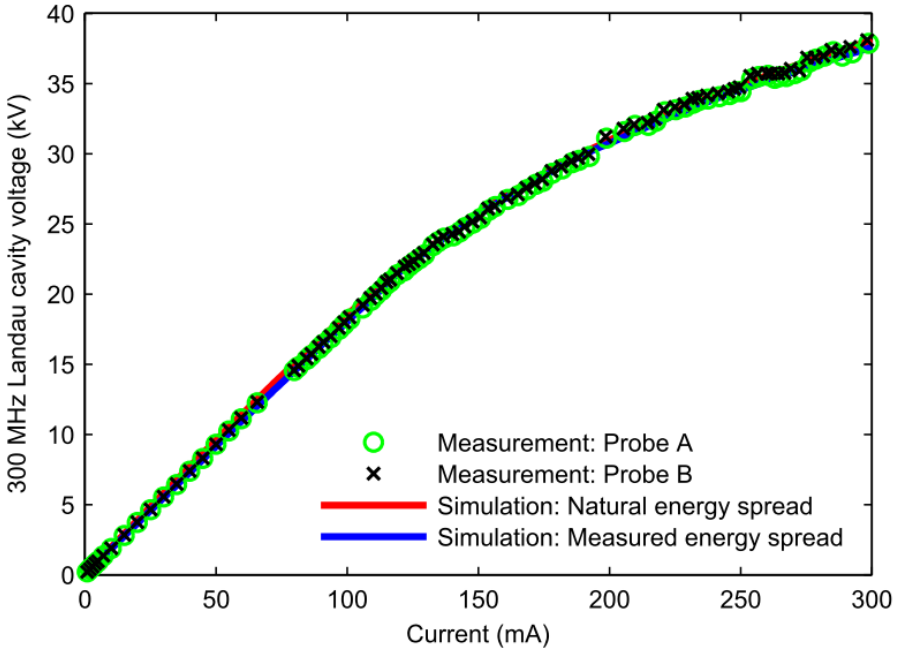
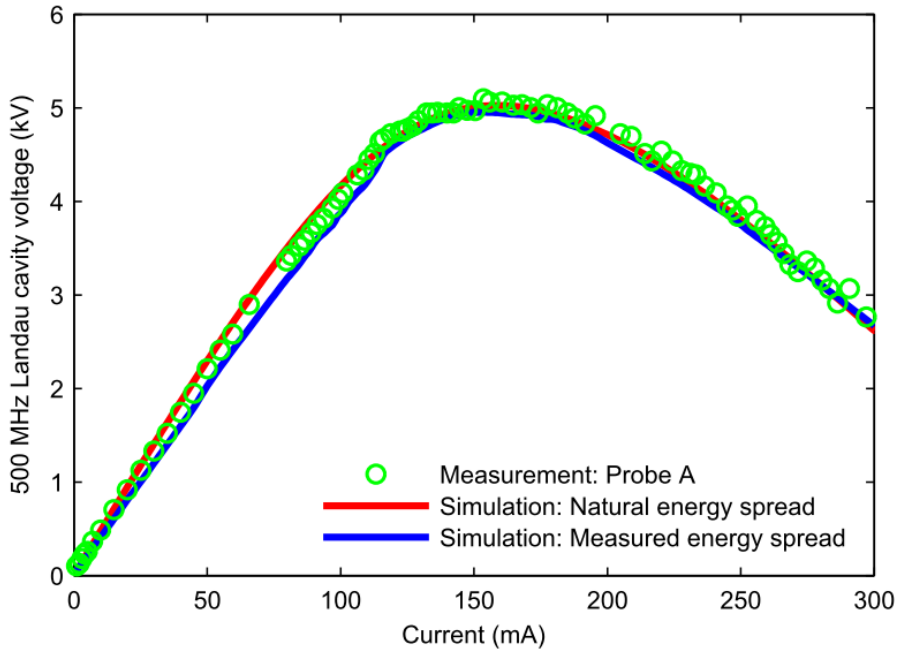
Harmonic cavity voltage

Voltage in Landau cavity: $V_L = I\, R_{sh}\, F\, \cos(\psi)$

Form factor F decreases as bunch lengthens





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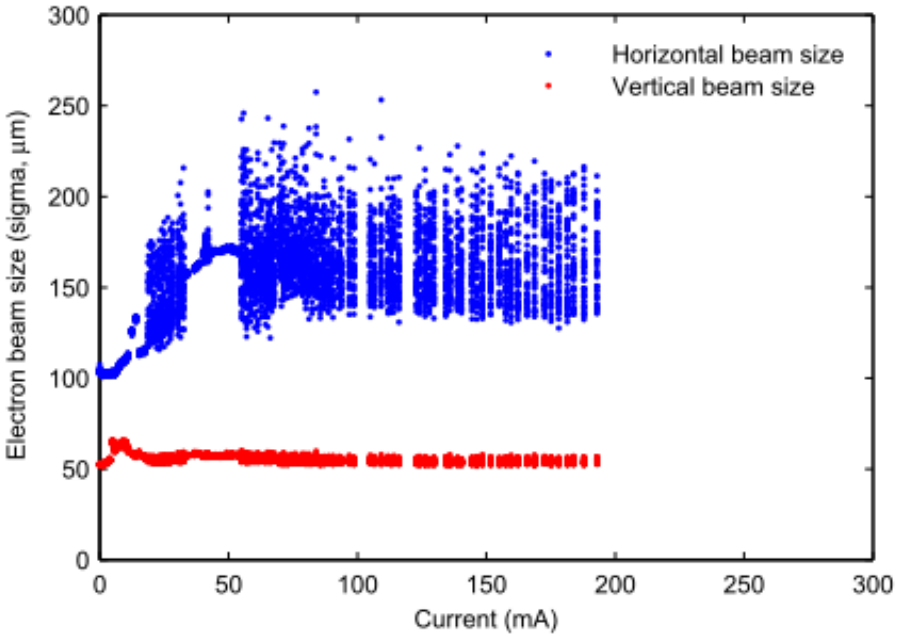
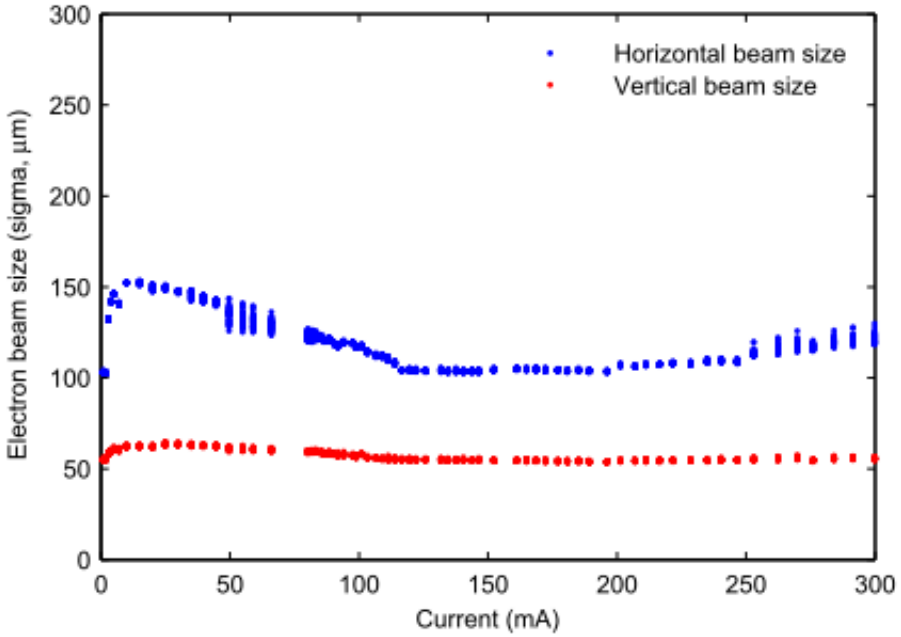
Landau damping

- 3rd harmonic Landau cavity effectively dampens long. bunch instabilities
- Improved camera shot-to-shot stability
- Increased maximum stored current



without 3rd harm. cavity



with 3rd harm. cavity

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Conclusion and outlook

MAX III

Done

- Good understanding of bunch lengthening in the triple rf system
- Damping of instabilities in the user operation current range

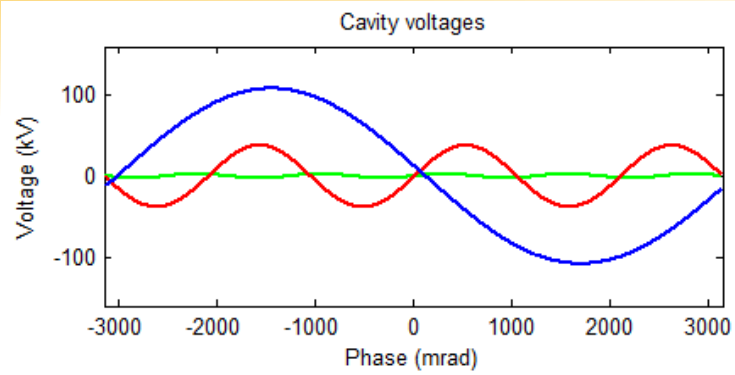
To do

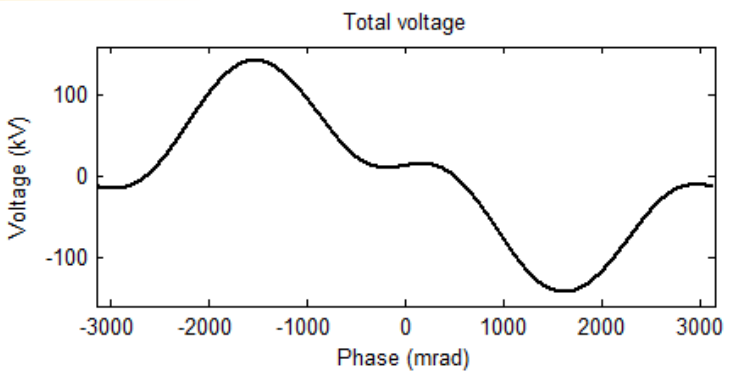
- Install automatic cavity tuning
- Run with constant (or predefined) bunch length

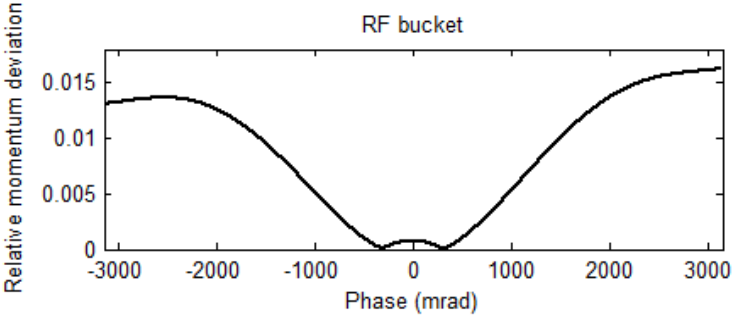
Max IV

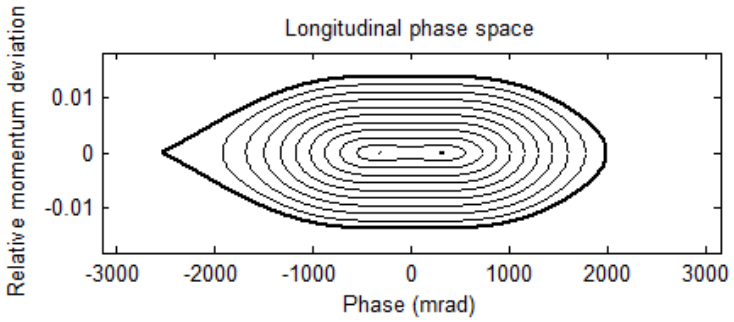
- Already started: Use of simulation code for both 1.5 GeV and 3 GeV storage rings

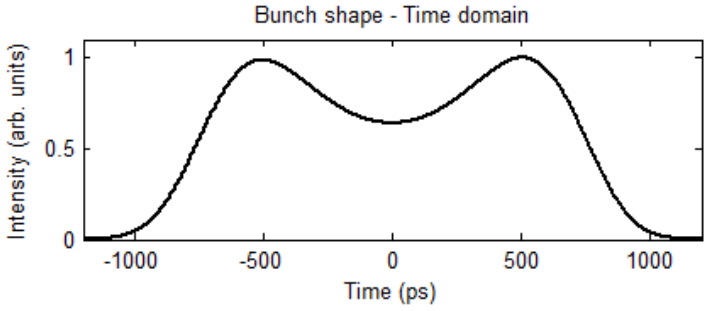
Thank you for your attention
Do you have questions?

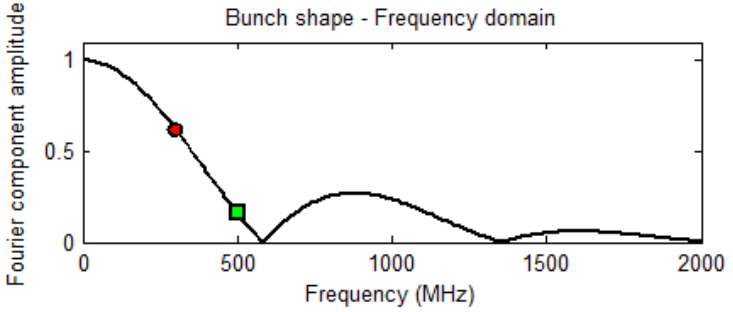












Example: 166mA stored current in Max III (3rd and 5th harmonic cavity)