Machine commissioning and studies of instabilities in the MAX IV 3 GeV ring

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on behalf of MAX IV Commissioning team

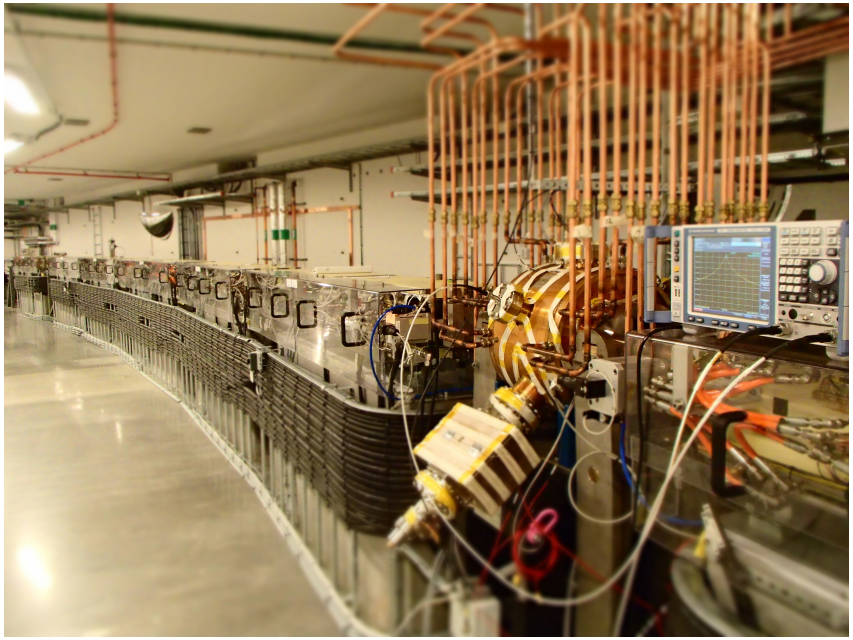
February 9, 2016

Outline

- MAX IV commissioning status
- Scope of instabilities project
- Harmonic cavities commissioning
- First results
  - single bunch
  - multibunch
  - emittance measurements
- Summary and Outlook

MAX IV 3 GeV storage ring

Energy	E_0	3.0	GeV
Current	I	500	mA
Circumference	L	528.0	m
Harmonic number	h	176	
RMS bunch length w/o HC	σ_τ	40	ps
RMS bunch length at 500 mA	σ_τ	195	ps
Peak rf-voltage w/o IDs	V_{rf}	1.02	MV
rf-frequency	f_{rf}	99.931	MHz
Energy loss per turn w/o IDs	U_{rad}	360	keV
Higher harmonic of HC	n	3	
Quality factor of HC	Q_f	21600	
HC detuning	Δf	48.1227	kHz
Total shunt impedance HC	R_s	2.36441	MΩ



- Multibend achromat lattice
- Ultra-low hor. emittance: 0.2 - 0.3 nm rad
- Round beam pipe, small radius: 11 mm
- High beam intensity: 500 mA
- Passive harmonic cavities:
  - relax the Touschek life-time and intra-beam scattering
  - fight collective beam instabilities

Ongoing activities

Beam commissioning:

- Optics characterization
- Tune adjustments
- Harmonic cavities tuning

Diagnostics commissioning:

- Diagnostics beamline
  - bunch length
  - emittance
- Bunch-by-bunch feedback system tests

Vacuum conditioning

Beam stability studies

Started

- PWD bunch lengthening
  - diagnostic beamline for bunch profile measurements
- TMCI threshold
- Transverse tune shifts
- Multibunch threshold current
- Multibunch spectrum at different HC settings
- Time domain mode characterization (with BBB)

Planned

- Microwave threshold
  - diagnostic beamline for energy spread measurements
- Local transverse impedance measurements from bumps

Bunch length

- Single bunch operation
- Assuming only PWD, effective impedance is 0.6 Ω (0.5 Ω predicted)

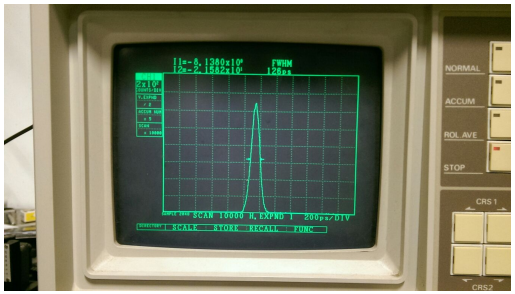
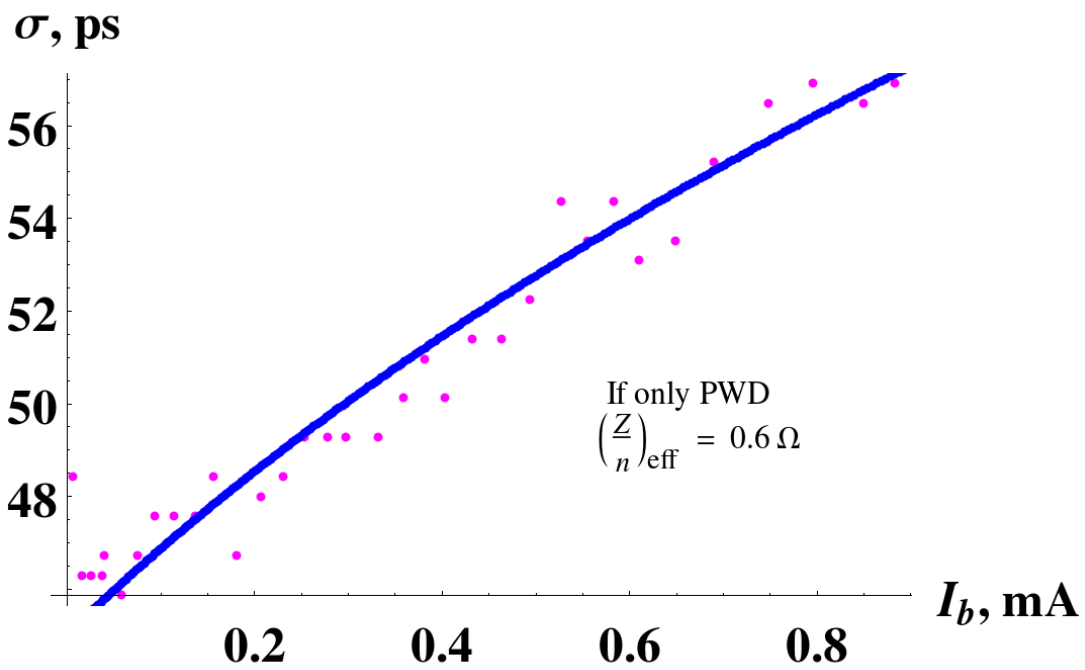
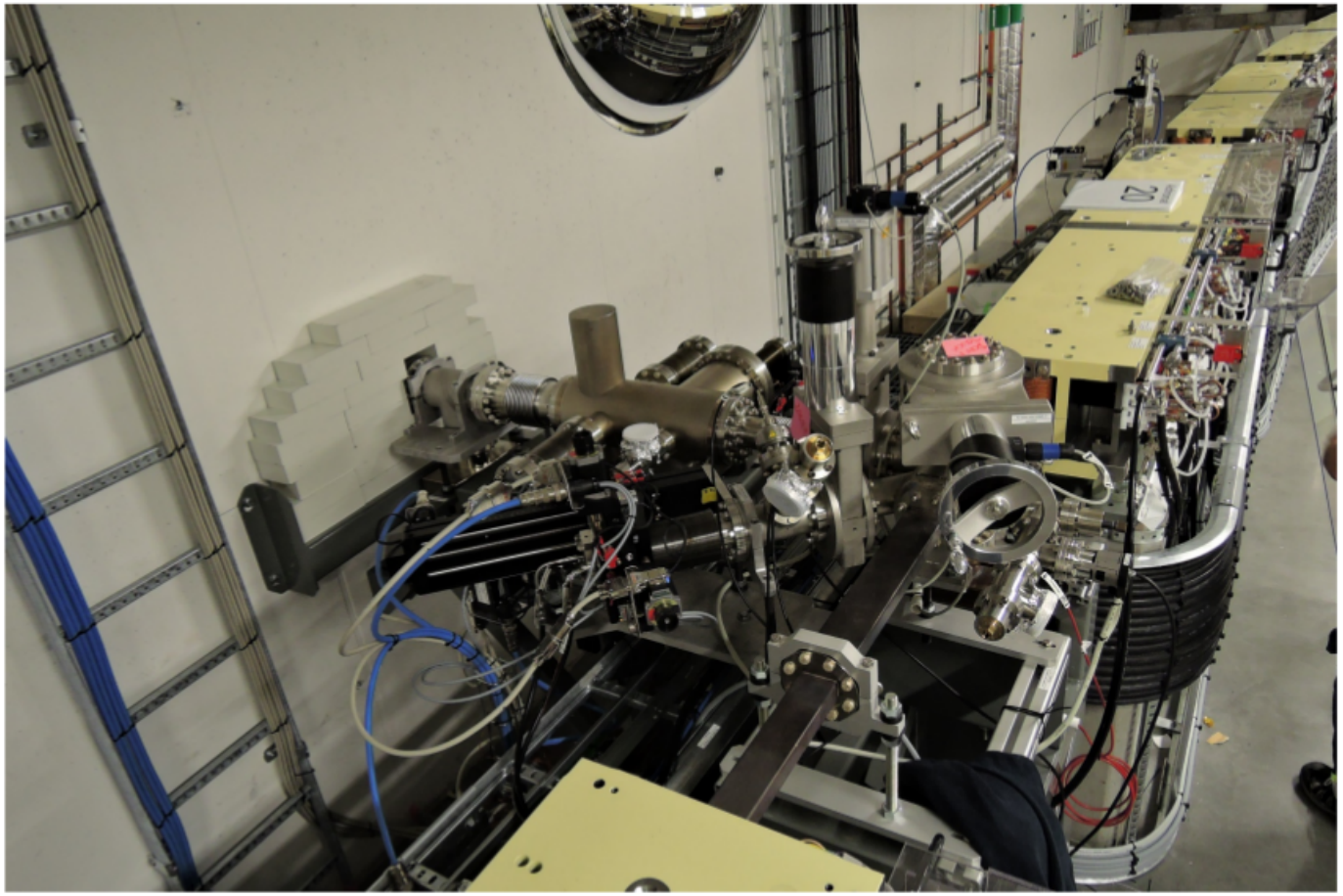


Photo: J. Breunlin



- Measurement of energy spread is needed

Beam line inside ring tunnel



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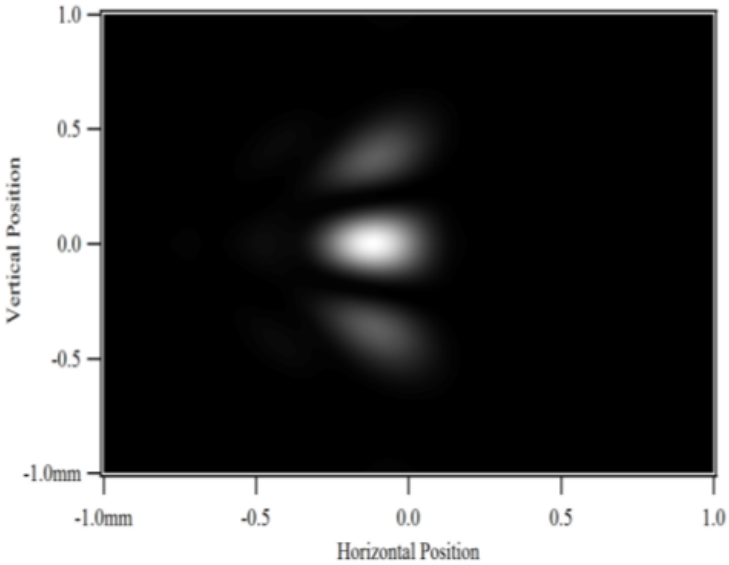
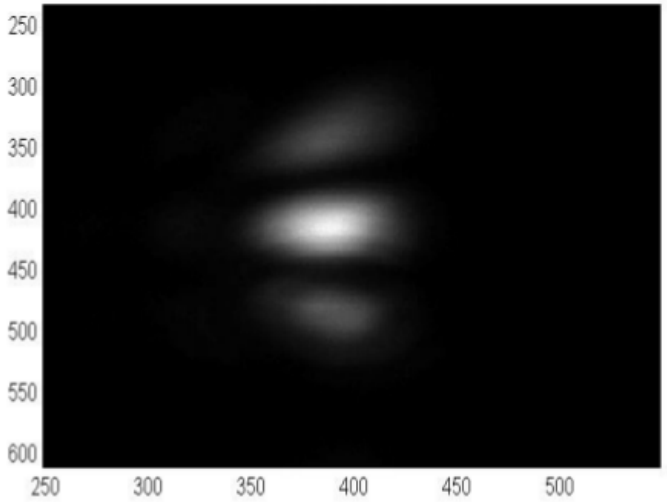
by J. Breunlin

First measurements (J. Breunlin)





Sigma polarized SR, 632.8 nm, SRW calculation (left) and measured image (right). The simulation is done for ε_x = 320 pm rad, β_y = 1.5 m.
Both figures show a 2 x 2 mm^2 area of the image plane.
The fringe pattern is too weak to be visible.

Optical magnification of m=-2.28 is taken into account in the SRW model
Horizontal opening angle: 6 mrad
Vertical opening angle: 8 mrad
Exposure time: 2.9 ms

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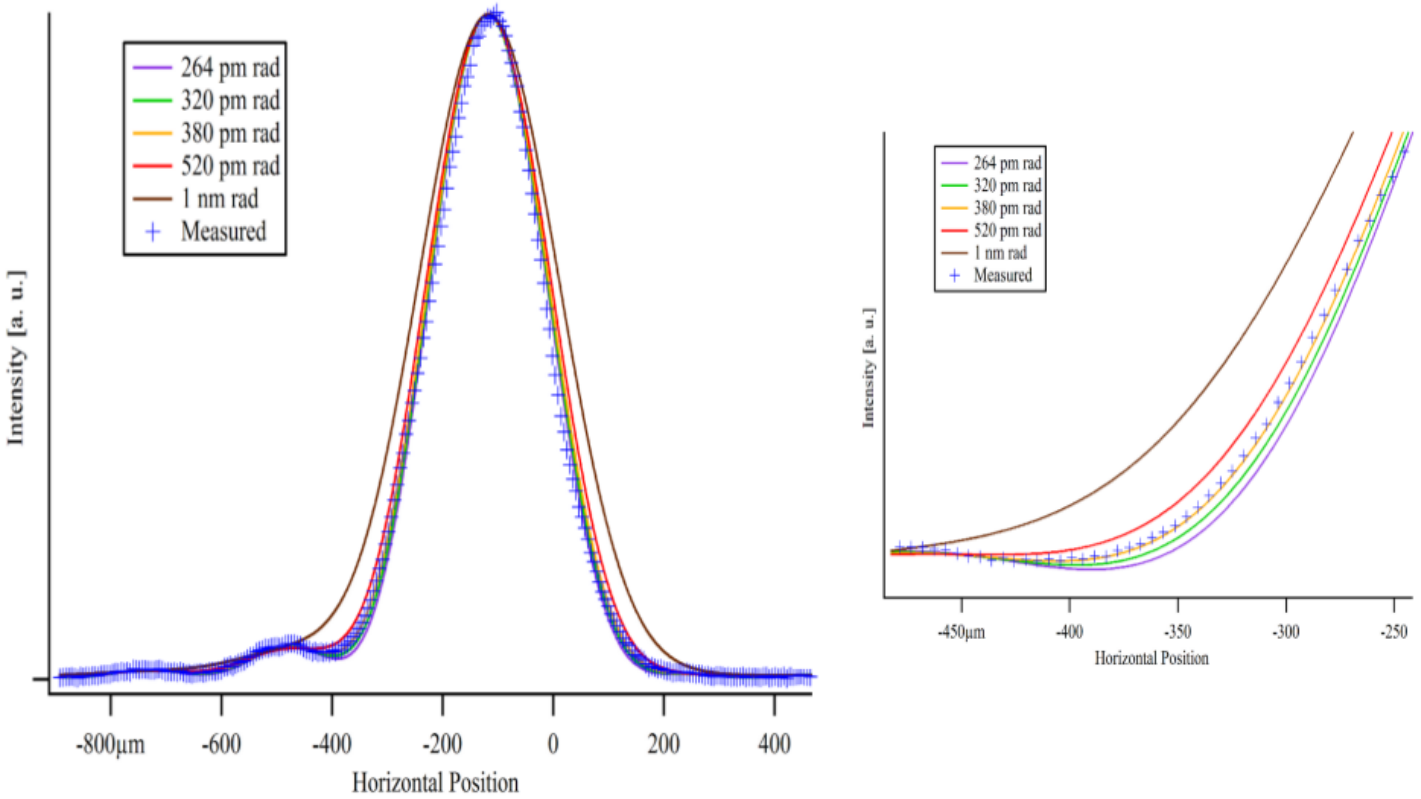
Emittance measurements



Horizontal intensity profile of imaged sigma polarized SR. Due to the 6 mrad horizontal opening angle the fringe pattern is not as pronounced as it could be, but easier to understand and to calculate.
We will try to measure more accurately with larger hor. opening angle and at longer wavelengths.

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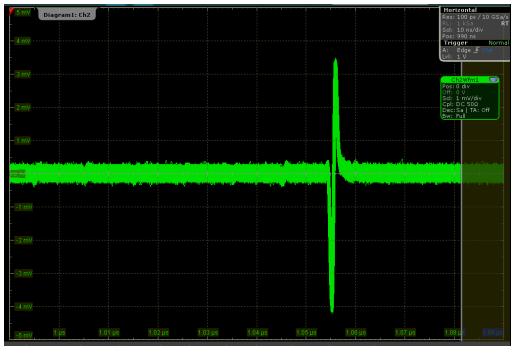
Measured emittance is below 500 pm rad

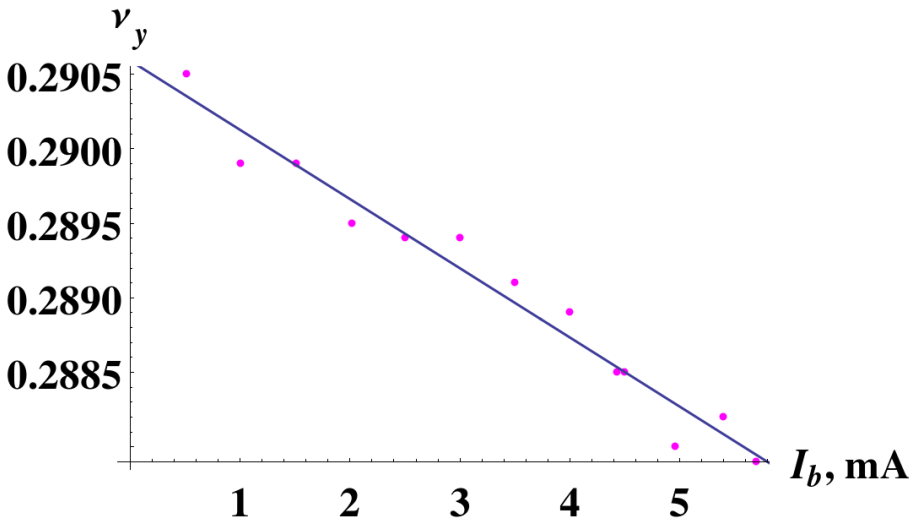
by J. Breunlin

Single bunch, TMCI threshold

- Single bunch operation: cleaning with BBB
- No sign of TMCI up to 8.5 mA in single bunch (design current per bunch is 2.84 mA/bunch)

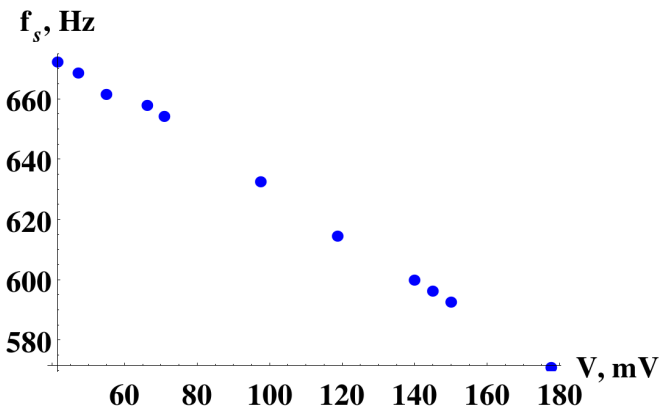


- $\xi_x = 0.4$ and $\xi_y = 0.03$
- Synchrotron tune $\nu_s = 0.00134$
- Vertical tune shift by more than ν_s
- MOSES shows modes 0 and -1 detuning in the same direction

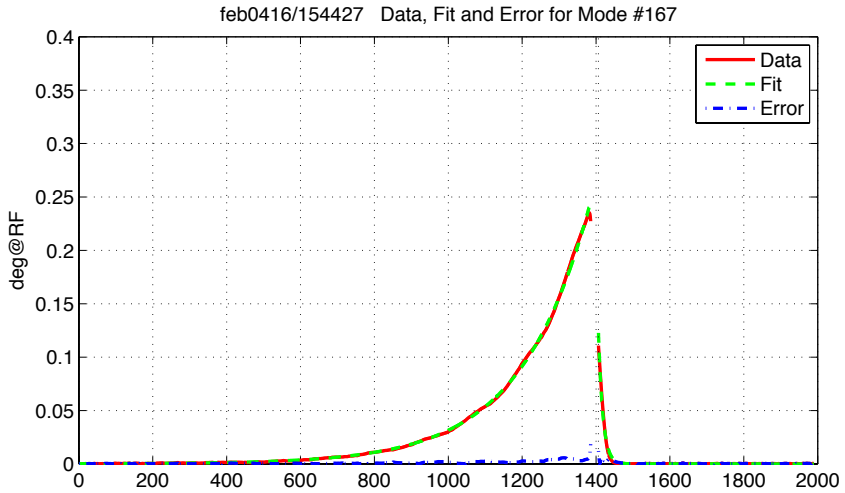


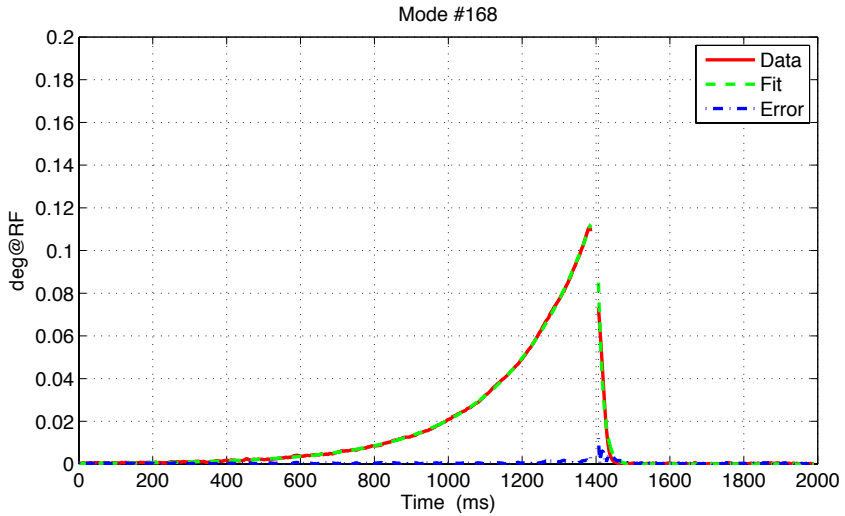
Multibunch, HC effect

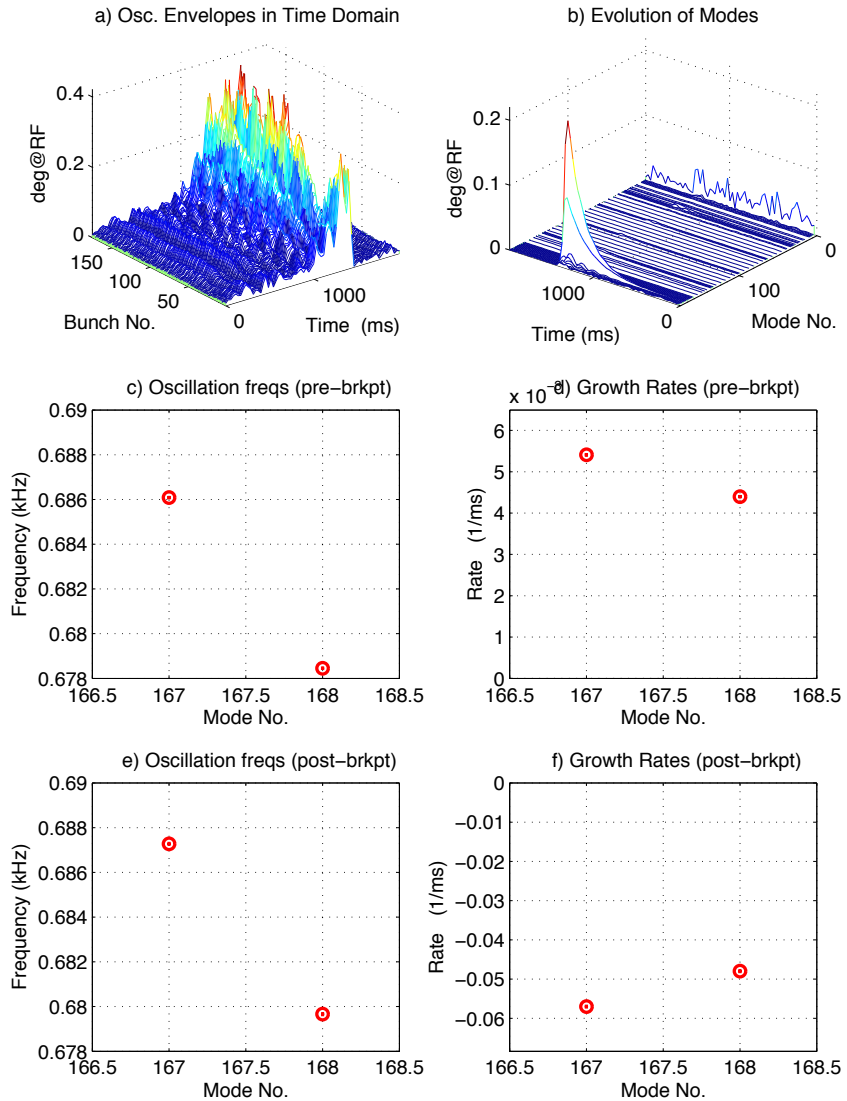
- Beam is longitudinally unstable at >3 mA current (even fill)
  - bunch profile shows dipole oscillations
  - BBB diagnostics and Spectrum analyser show longitudinal CBI
- Maximum current reached today is 121 mA (vacuum trip) with no HC tuned in, 61 mA with zero chromaticity
  - particle tracking showed 40 mA RW threshold (zero chrom)
  - possible explanation for increased threshold is longitudinally unstable beam
- With HCs tuned in
  - Tune shift is observed
  - Significant stabilisation



BBB Measurements (D. Teytelman)







MAX IV 3 GeV:feb0416/154427: Io= 3.5462mA, Dsamp= 16, ShifGain= 3, Nbun= 176,
At Fs: G1= 71.4142, G2= 0, Ph1= 8.0654, Ph2= 0, Brkpt= 49450, Calib= 5090.594.

Main issues

- Vacuum trips in RF
  - Typically run with 3 cavities of 6
- Tuning of all HCs
  - Voltage feedback to be commissioned
- Conditioning is required

Outlook

After shutdown (Week 14):

- use BBB for diagnostics and spectrum analysis
- Detailed studies of HC role in beam stabilization: multibunch spectrum as a function of harmonic cavity settings
- Experiment vs simulation

NB: 2 IDs and 30 cm 4-electrode stripline kicker will be installed so impedance will change

Thank you