The ASTRID2 3rd Harmonic Cavity

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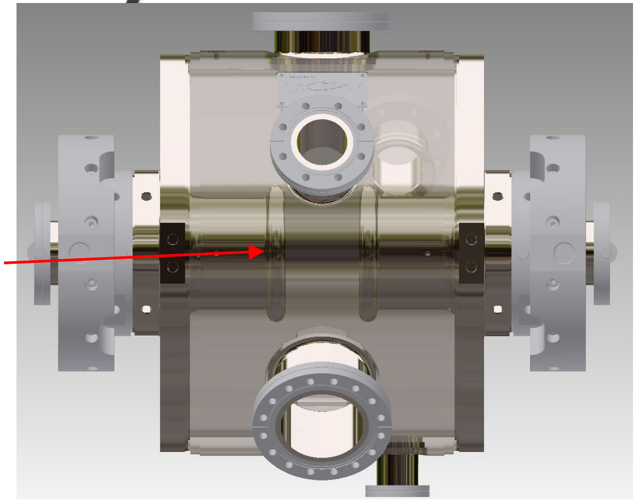
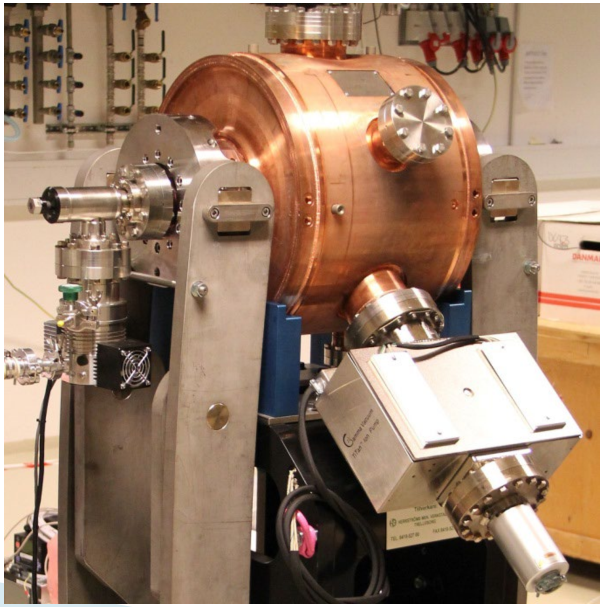
ISA

ASTRID2 3rd harm. cavity

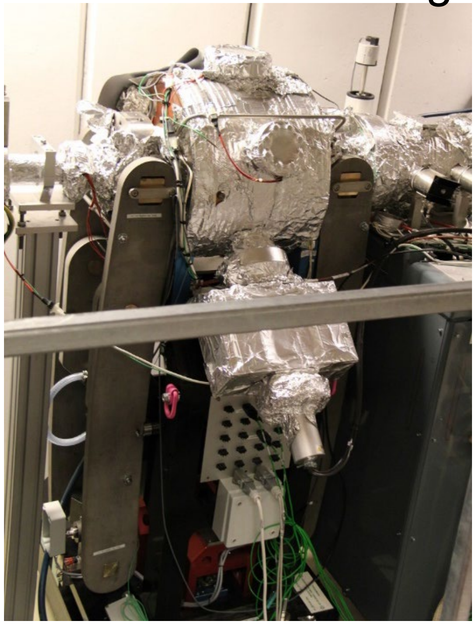
- Copy of MAX IV cavity, except 315 MHz
  - Cavity stub end diameter changed
  - Thanks to Åke and MaxLab
- Installed March 2015
  - Fixed cooling water temperature of ~20°C (at the time)



Before installation



Installed in the ring



Benefits (at installation time)

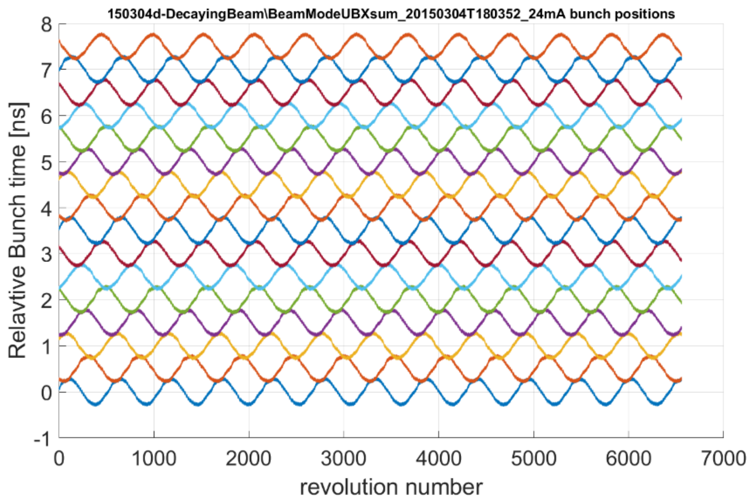
- Better lifetime
  - Before: 1.4 h @ 80 mA and 1.0 h @ 120 mA
  - After: 2.0 h @ 80 mA and 1.85 h @ 120 mA
- More stable beam
  - Moved instabilities to higher frequencies
  - SR diagnostic camera (in control room) showed a more stable beam (and happy users)
- Good tuning range is limited
  - Was for long using a detuning of around +400 kHz (possible tuning range is ±500 kHz).
    - "Theoretical optimum" (flat potential) should be +160 kHz
  - Drop in cavity voltage and outgassing 250–300 kHz

LCBI

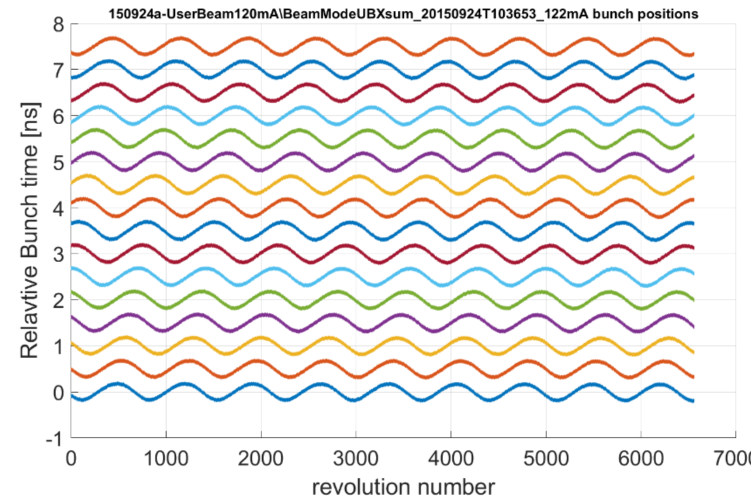
- After installation of 3rd cavity Longitudinal Coupled Bunch Instability (LCBI) mode spectra changed

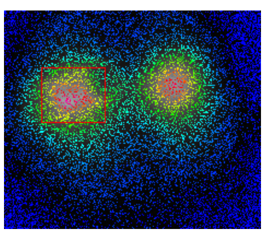
Relative bunch time [ns]
measured with fast oscilloscope

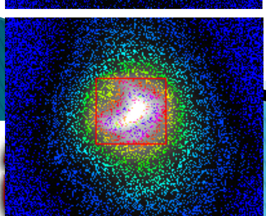
Before Landau cavity (24 mA)
Dominant mode: 9

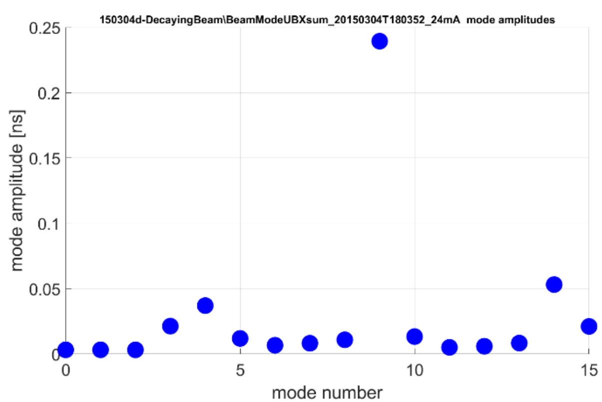


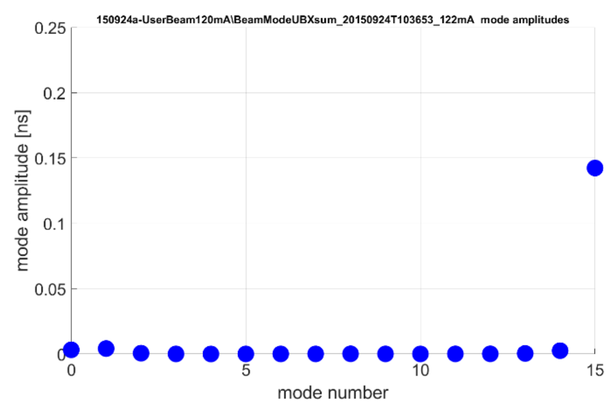
With Landau cavity (120 mA)
Dominant mode: 15

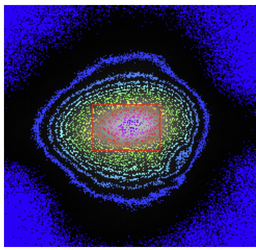






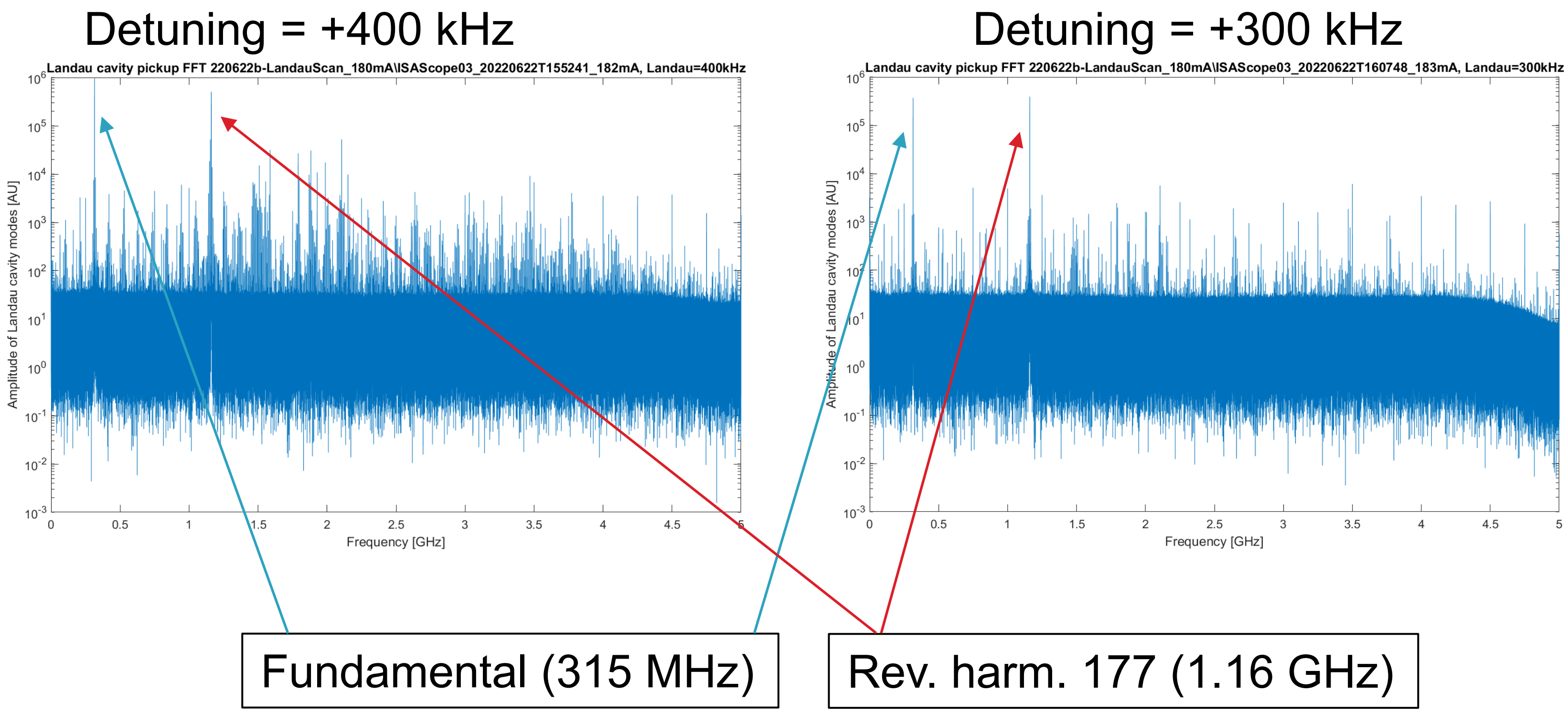






Strong HOM at rev. harm. 177

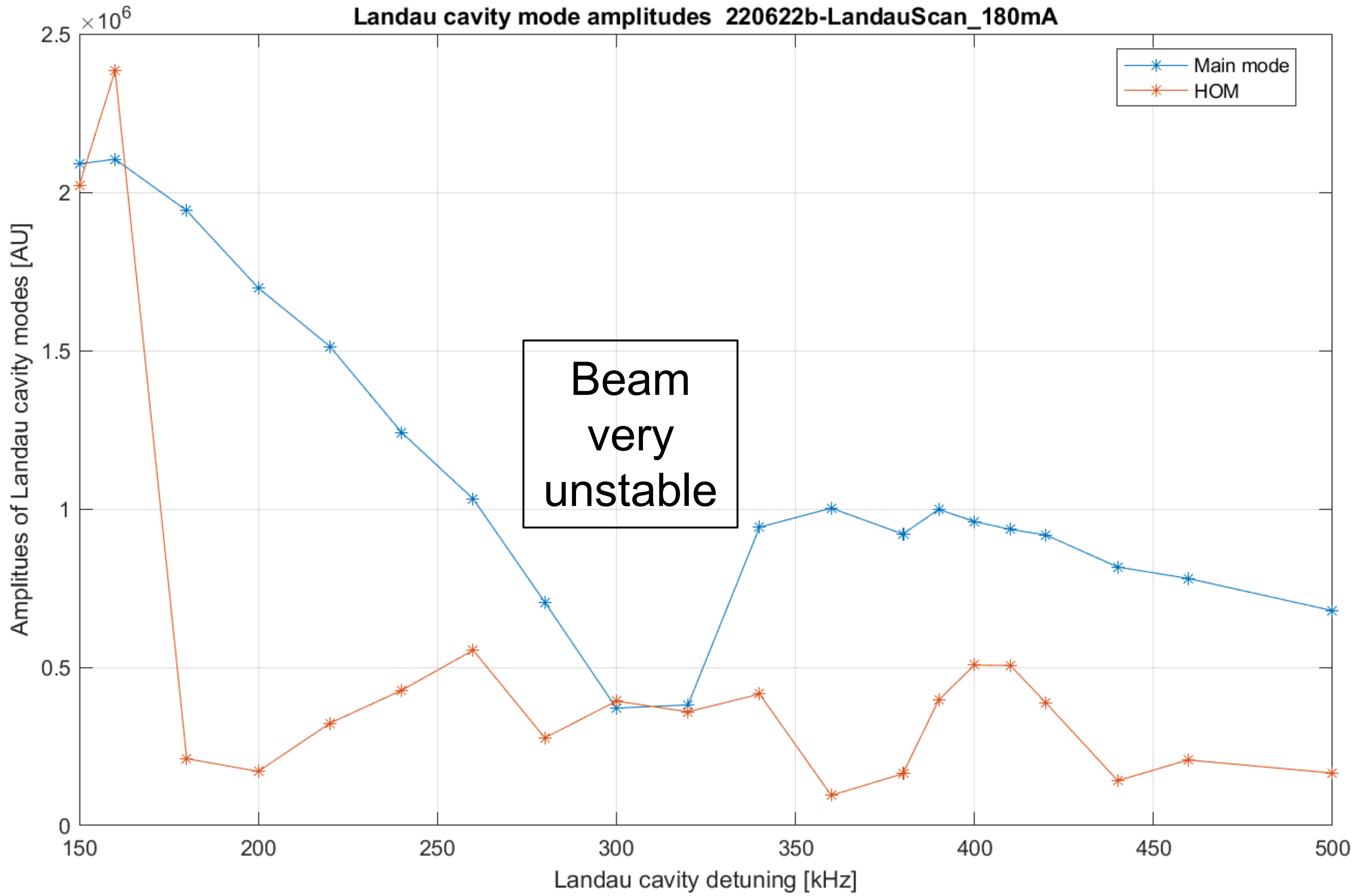
- Direct sampling of Landau cavity pickup signal with (fast) scope and then FFT



Beam has been accumulated at a cavity detuning of +400 kHz and a cavity temperature of ~20°C

Reduction in fundamental

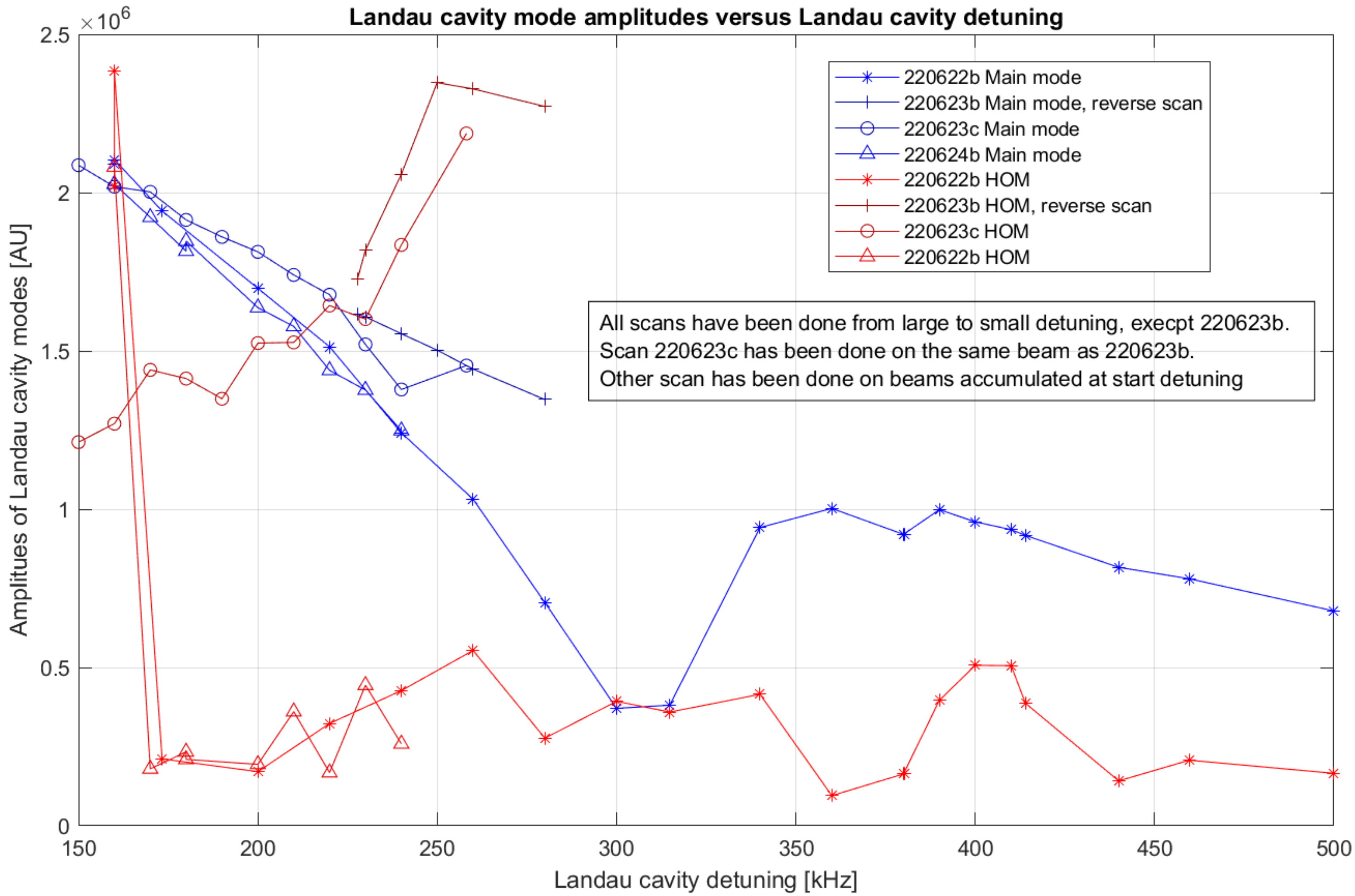
- Scanning the cavity detuning yields a dip in amplitude of the fundamental



Beam has been accumulated at a cavity detuning of +400 kHz

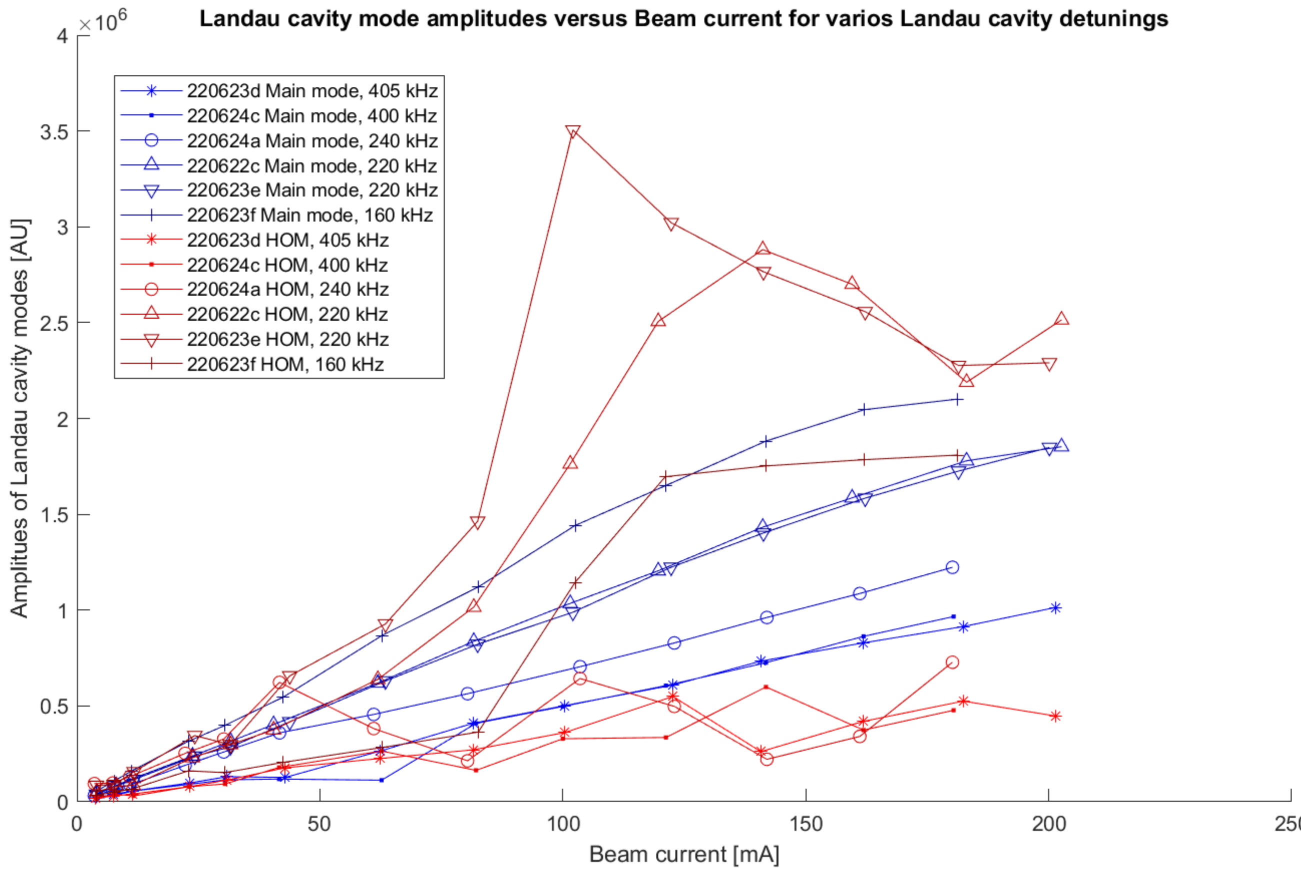
Accumulate at various detuning's

- Cavity behavior depends on "history"



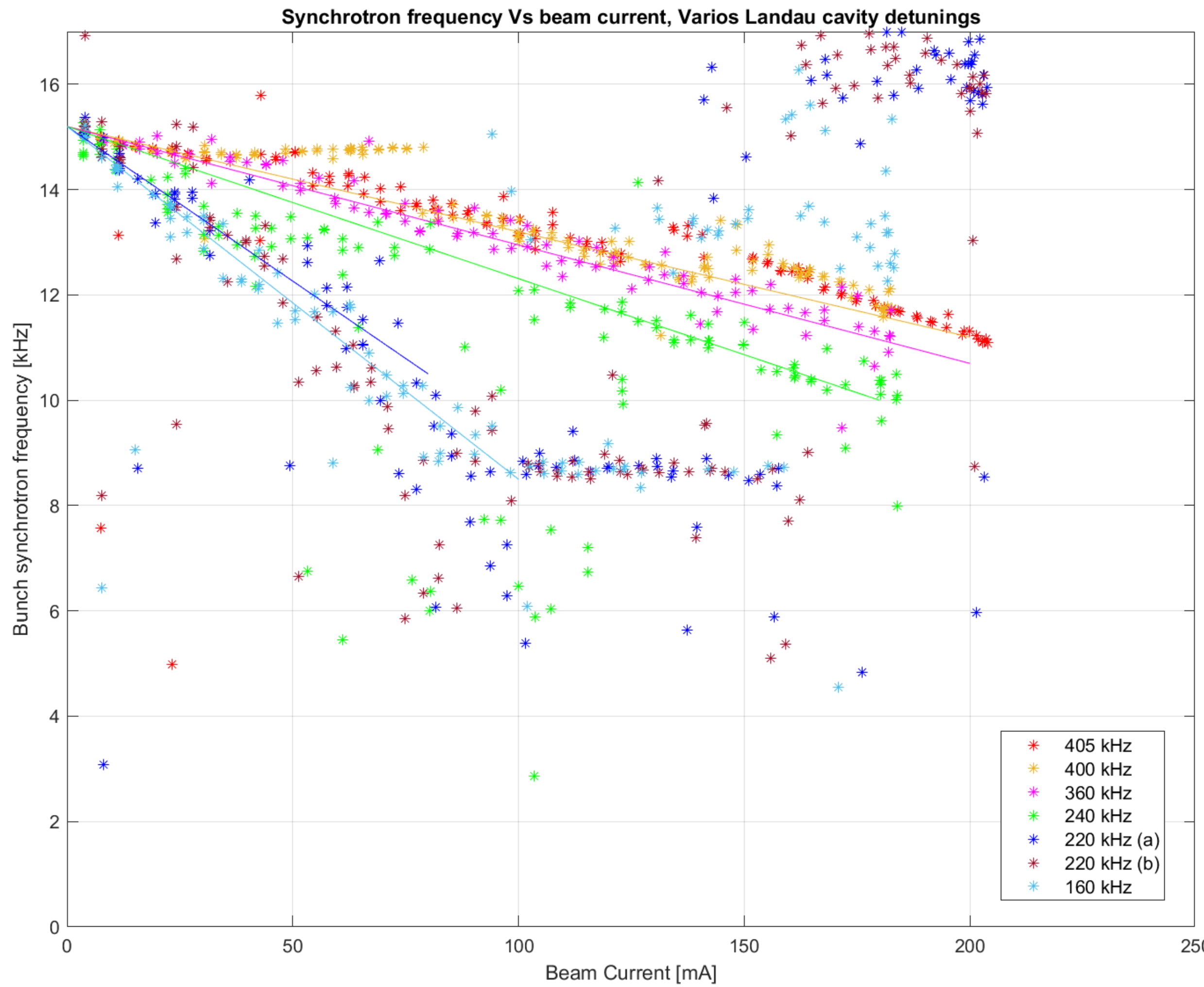
Beam accumulation

- Cavity amplitudes as function of beam current
  - Amplitude of fundamental (blue) increases as detuning is lowered
  - But amplitude of RevHarm177 (red) are more irregular, but with a tendency that smaller detuning give much more amplitude of harmonic



Synchrotron frequency

- Synchrotron frequency gives a measure of total voltage seen by the beam (or rather slope around synchronous point)

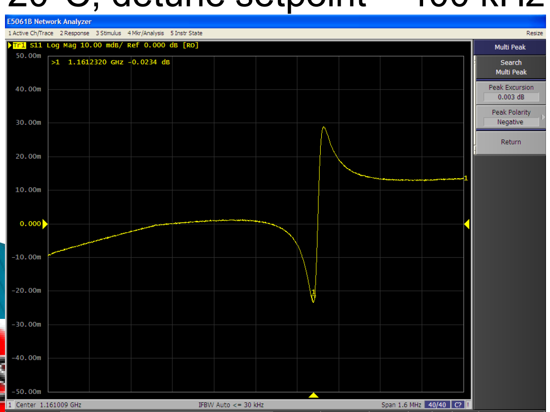


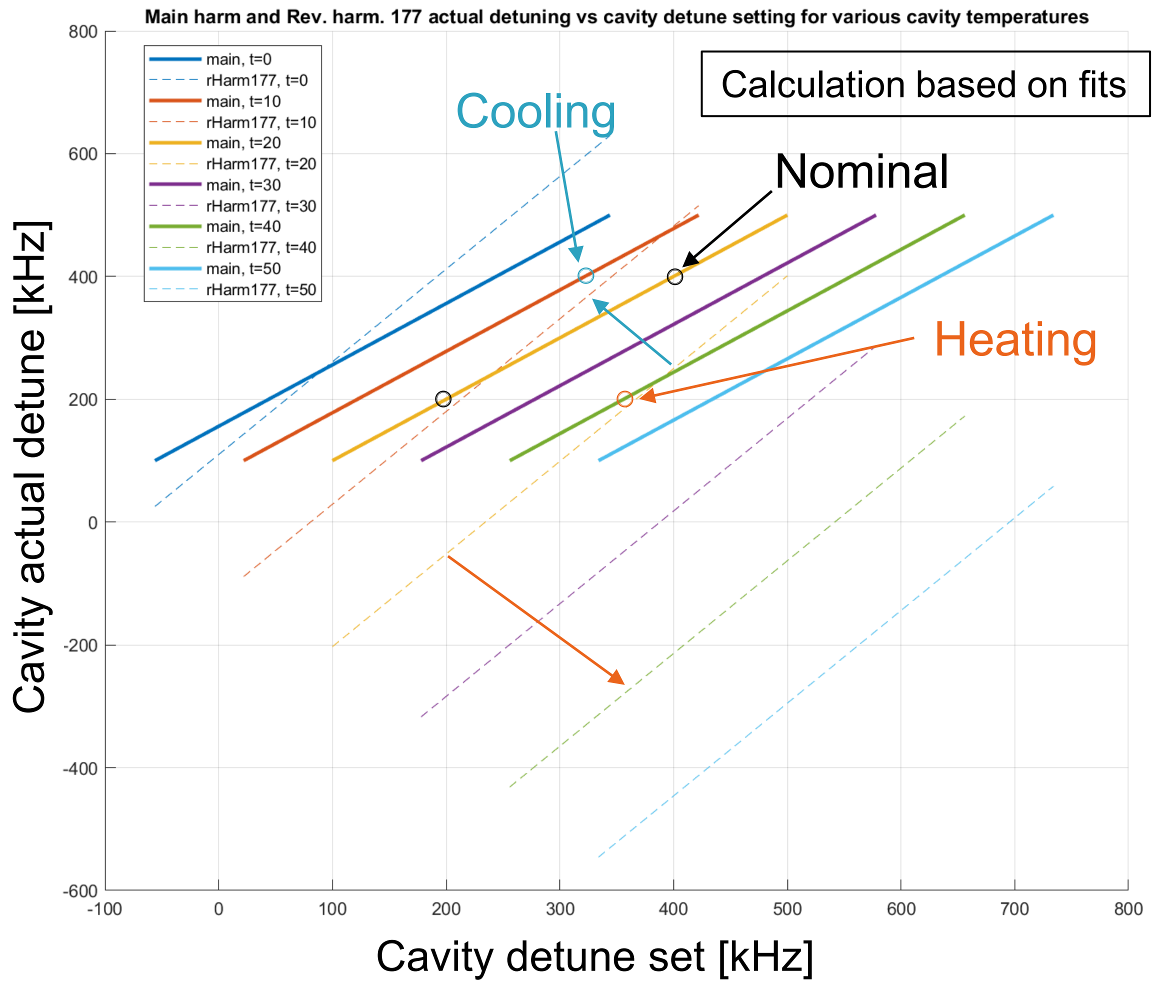
Temperature dependance

- Have recorded all resonances with a network analyzer for various cavity temperatures (baking the cavity)

Main resonance
20°C, detune setpoint = 400 kHz

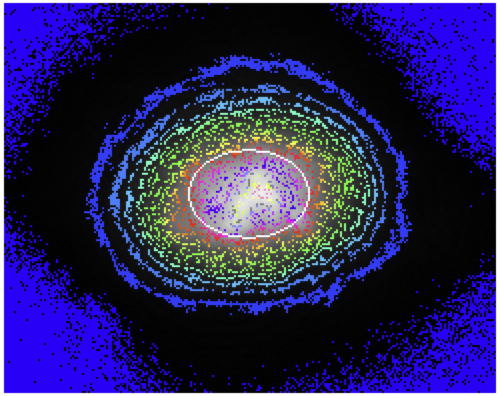
Rev. Harm. 177
20°C, detune setpoint = 400 kHz





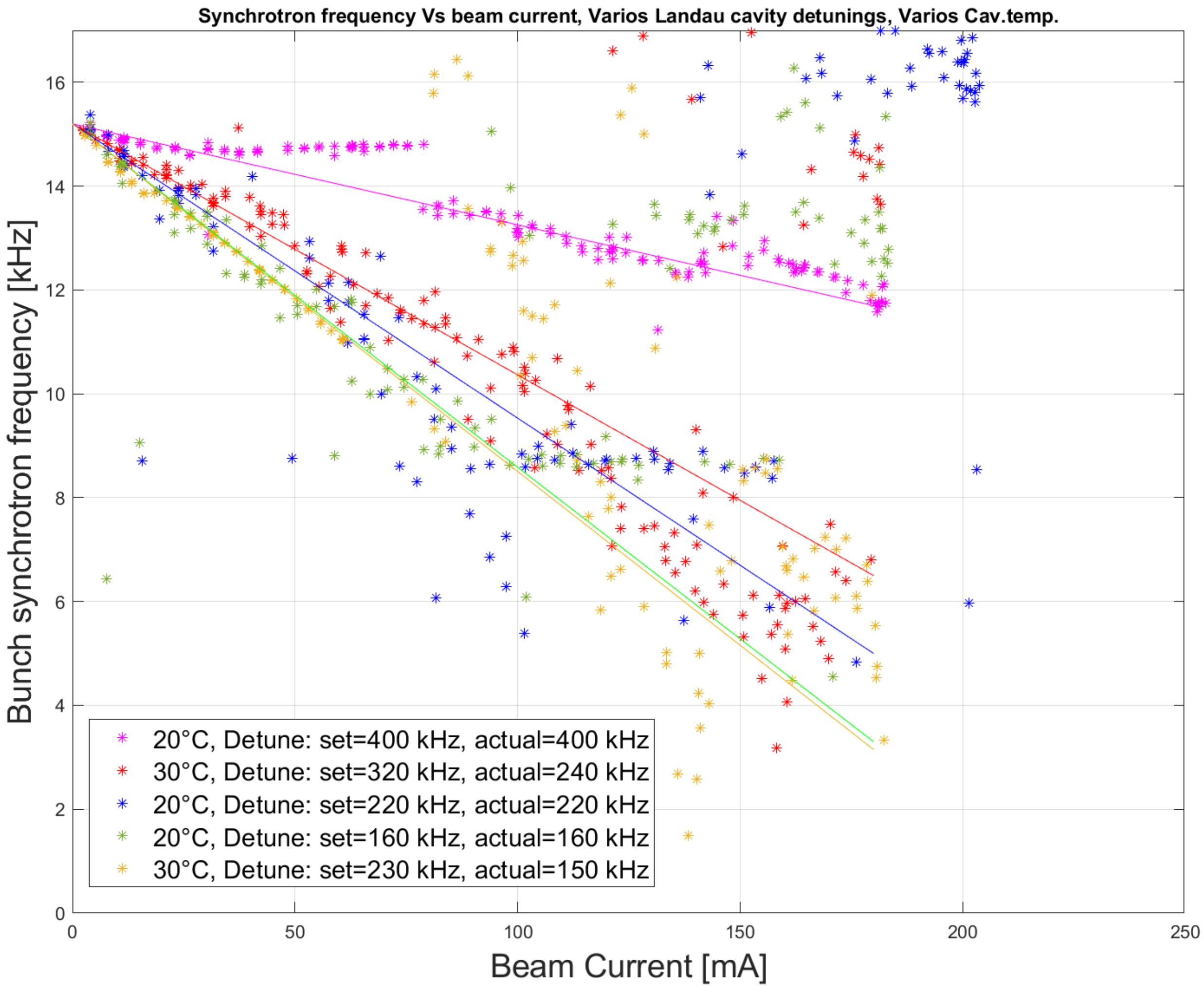
Increased cavity temperature

- In August 2022, a small (borrowed) cooler/heater (10–40°C) was installed for our 3rd harm. cavity
- By raising the 3rd harm. cavity temperature (30–35°C) we can operate stable at smaller main resonance detuning ("jumping" below the RevHarm177 resonance)
  - Beam lifetime is better (~2.3 h @180 mA versus ~2.0 h earlier)
    - with a smaller and more stable horizontal beam size
  - The range with stable beam is (still) rather narrow
  - Unless careful with temperature, we see an increase in vertical beam size
  - It seems that LCBI modes are damped even more, but measurements are uncertain
    - Bunches are not always nice gaussians, so (automatically) finding the bunch crossing time is not always easy



Sync. freq. vary cav. temperature

- Synchrotron frequency measurements are consistent for various cavity temperatures



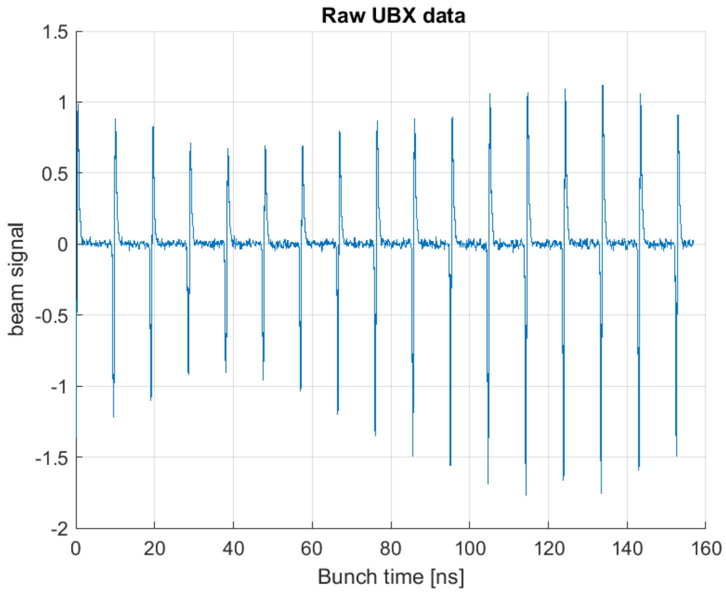
Summary

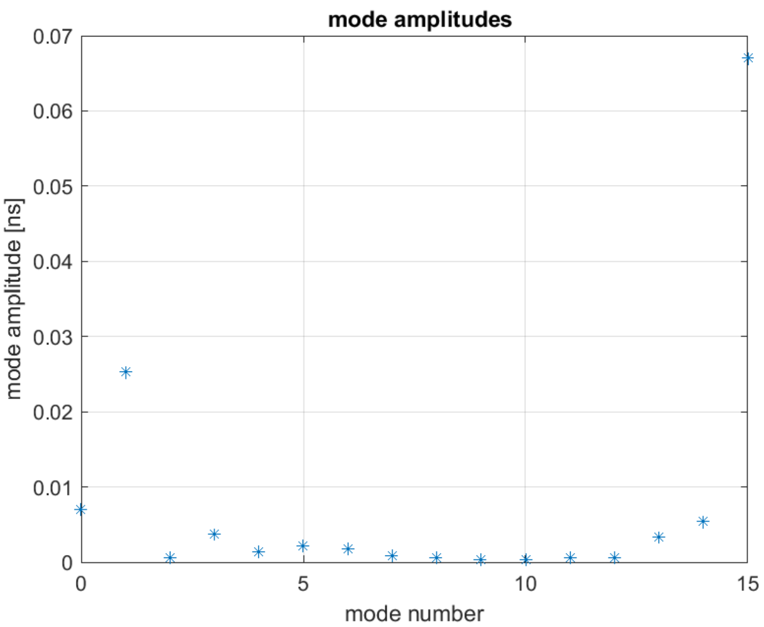
- At a Landau cavity temperature of 20°C beam parameters (lifetime, beam sizes, ...) are only stable in a rather narrow range around a cavity detuning of 400 kHz
  - With a beam lifetime of ~2.0 h, and some jitter in horizontal beam size
- At elevated temperatures (30-35°C) parameters can be found which give better beam lifetime and more stable beam
  - Presently beam lifetime is ~2.3 h, with a smaller and more stable horizontal beam
    - Vertically beam size is as earlier (at the right settings)
- We will have to build a dedicated cooler/heater system, which can go higher up in temperature (20-70°C)
  - We should expect some need for conditioning

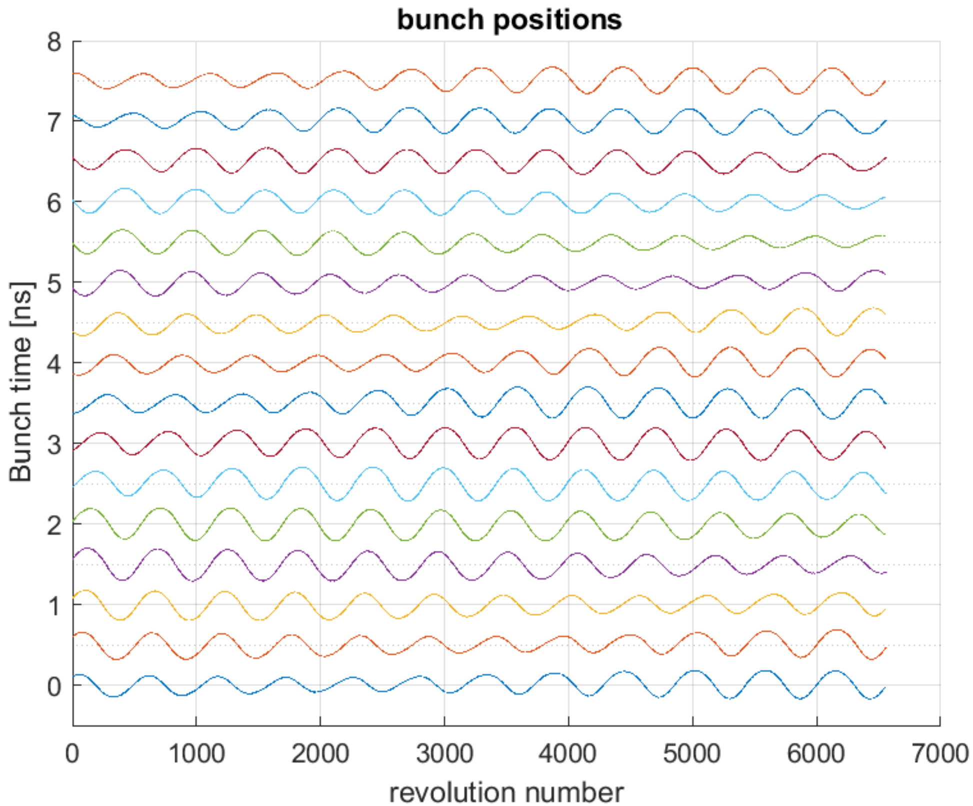
Thank you for your attention

Extra/spare slides

LCBI, 180 mA, Landau cav. at 20°C, detune 400 kHz

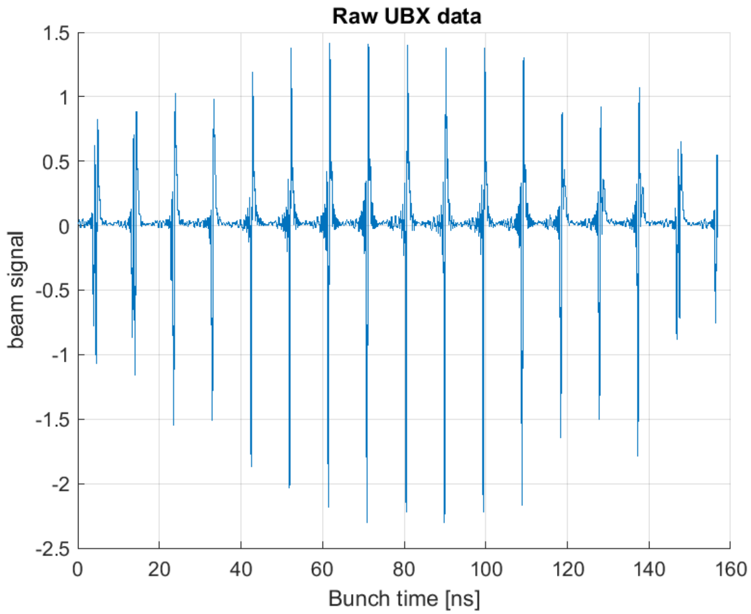


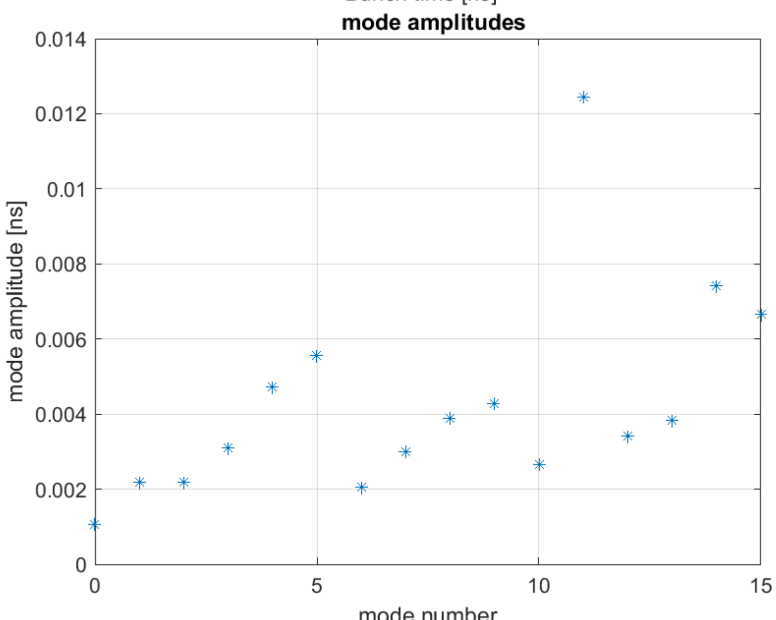


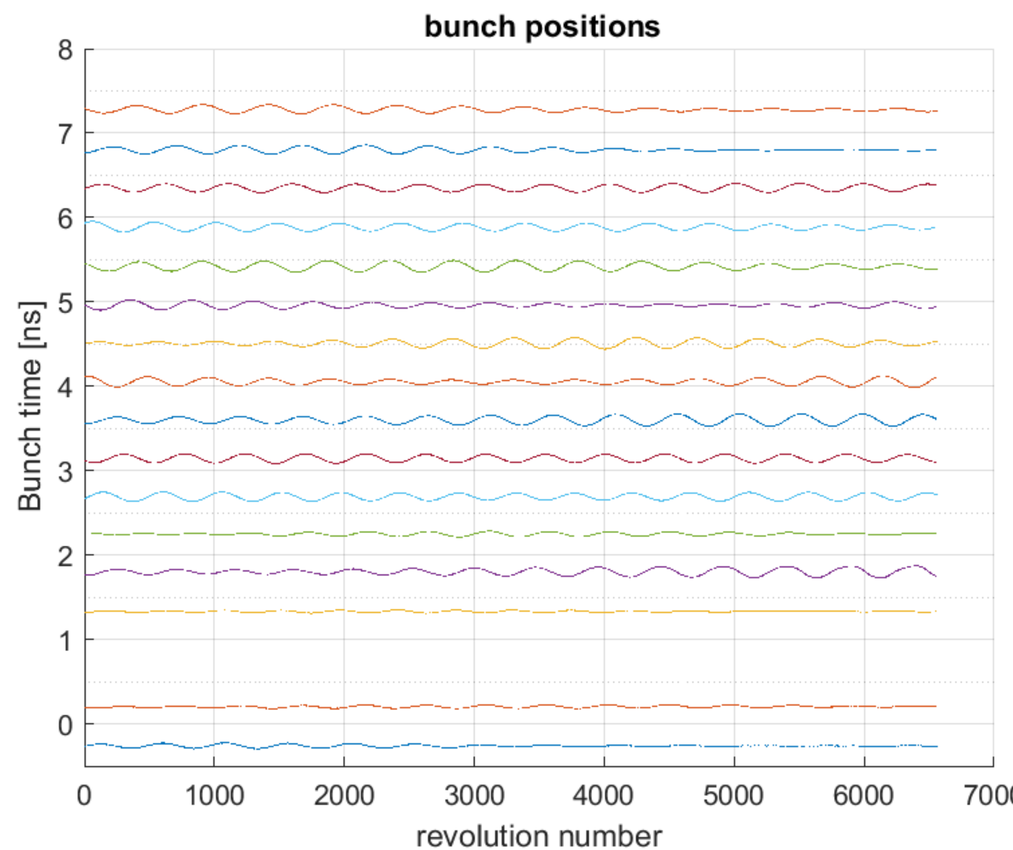


220624c-BeamAccumAtLandau400kHz

LCBI, 180 mA, Landau cav. at 30°C, detune set 320 kHz (actual 240 kHz)



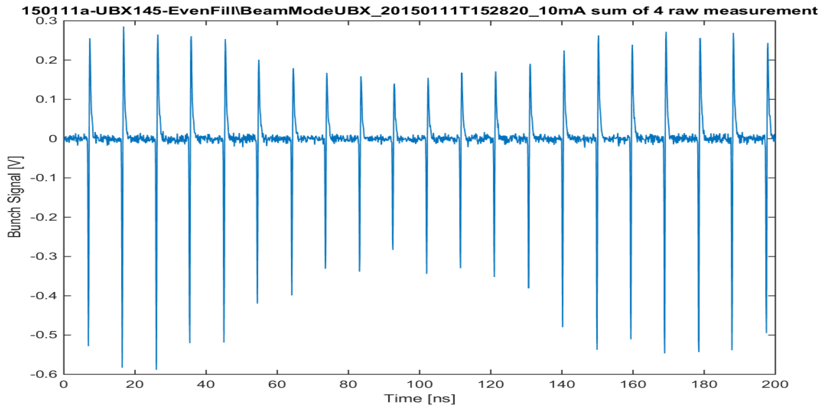


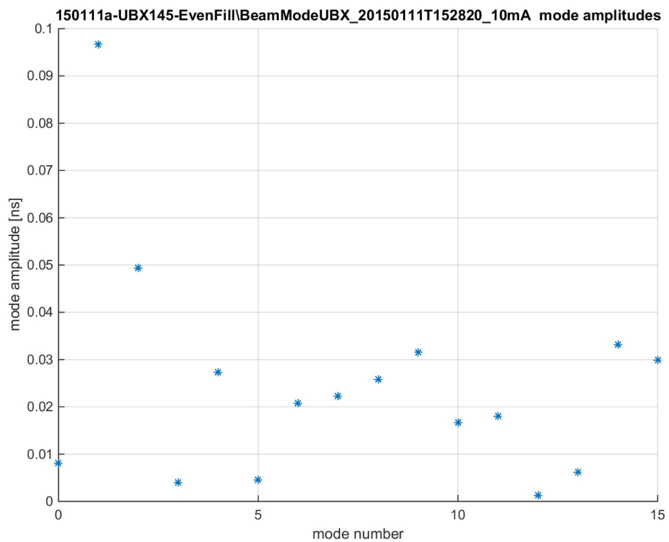


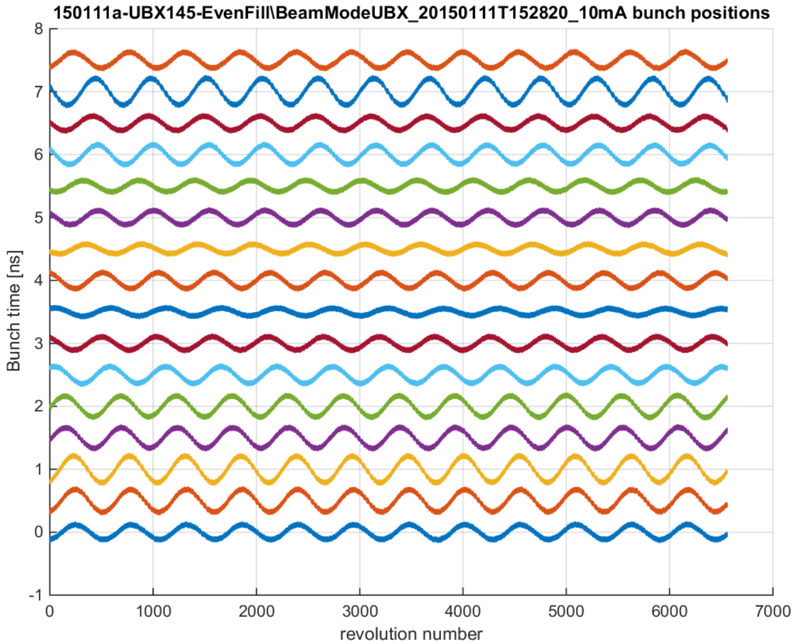
220925d-BeamAccumAtLandau320kHz30degC

Longitudinal coupled bunch instability

- All bunch positions can be found by finding all zero crossings
  - We can follow the oscillation of each bunch



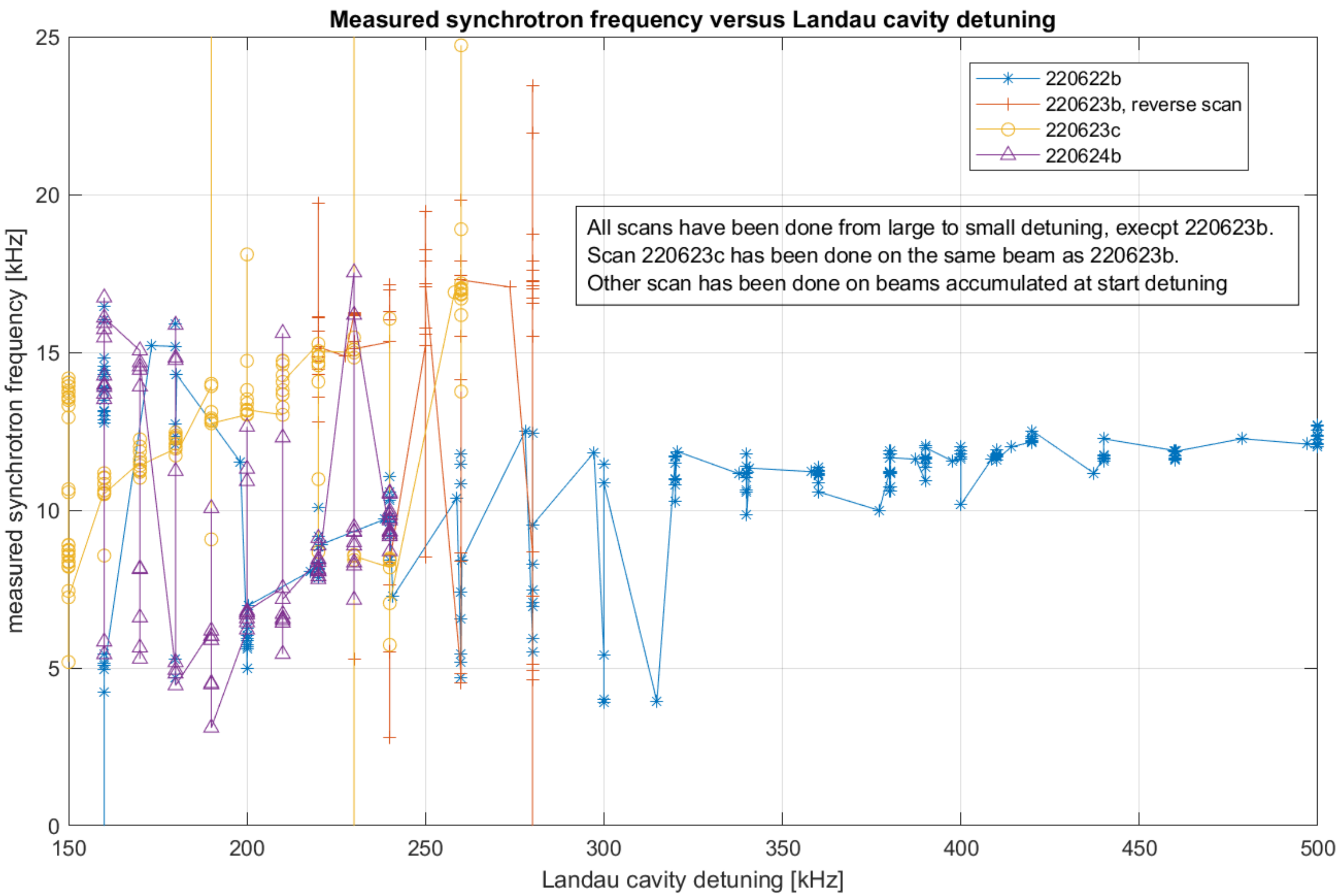




Before Landau cavity
10 mA

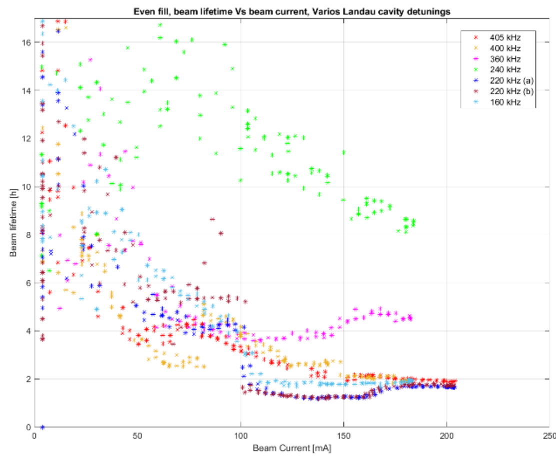
Synch. Freq. Vs cavity detuning

- General trend is lower sync. freq. for lower detuning, but with other effects also taking place

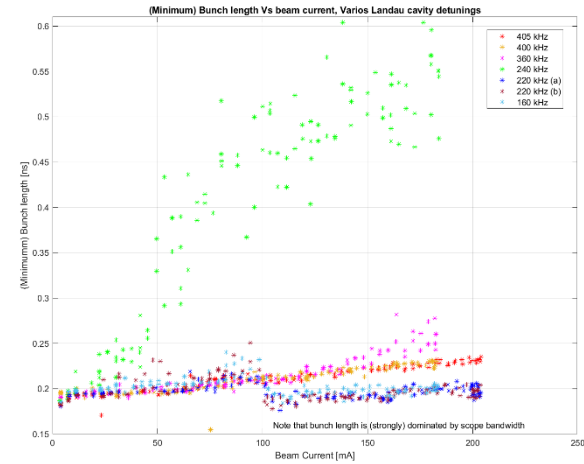


Other parameters (cav. at 20°C)

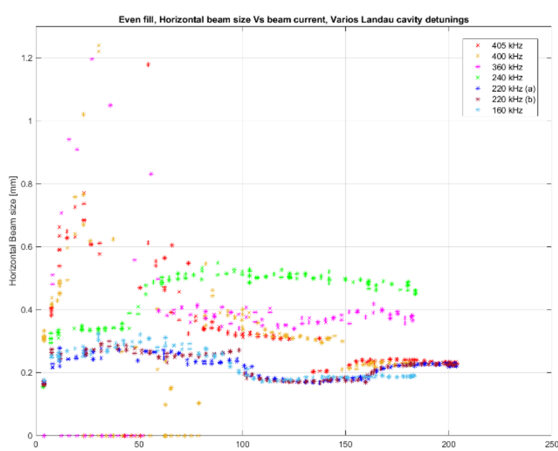
Beam lifetime



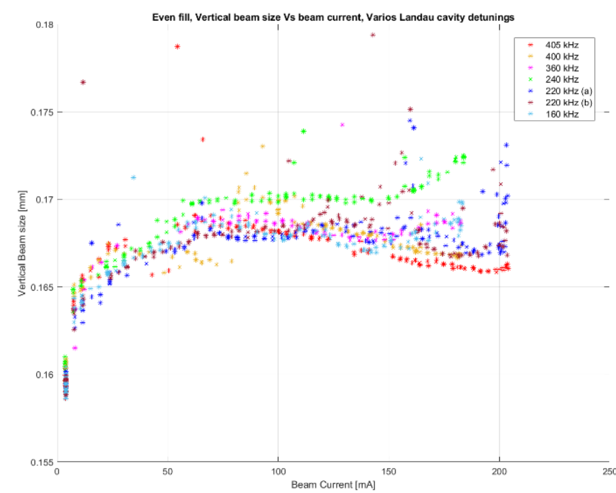
(minimum) Bunch length



Horizontal beam size



Vertical beam size



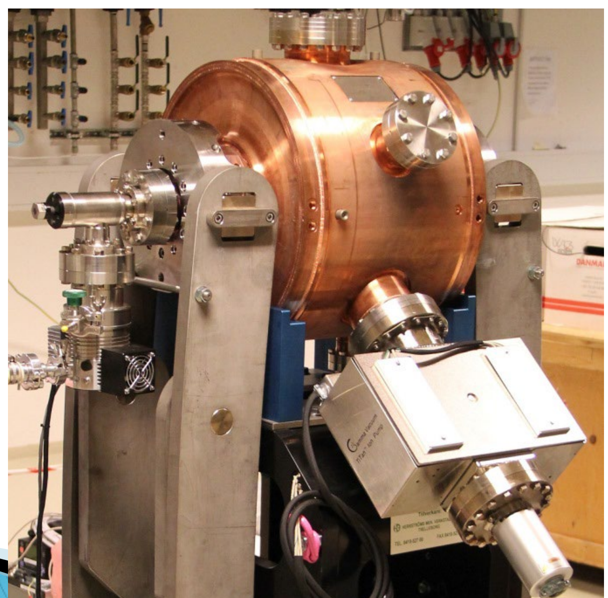
ASTRID2

- ASTRID2 is since 2013 the new synchrotron light source in Aarhus, Denmark
- ASTRID2 main parameters
  - Electron energy: 580 MeV
  - Emittance: 12 nm
  - Beam Current: 200 mA
  - Circumference: 45.7 m
  - 6-fold symmetry
    - lattice: DBA with 12 combined function dipole magnets
      - Integrated quadrupole gradient
  - 4 straight sections for insertion devices
  - Using ASTRID as booster (full energy injection)
      - Allows top-up operation

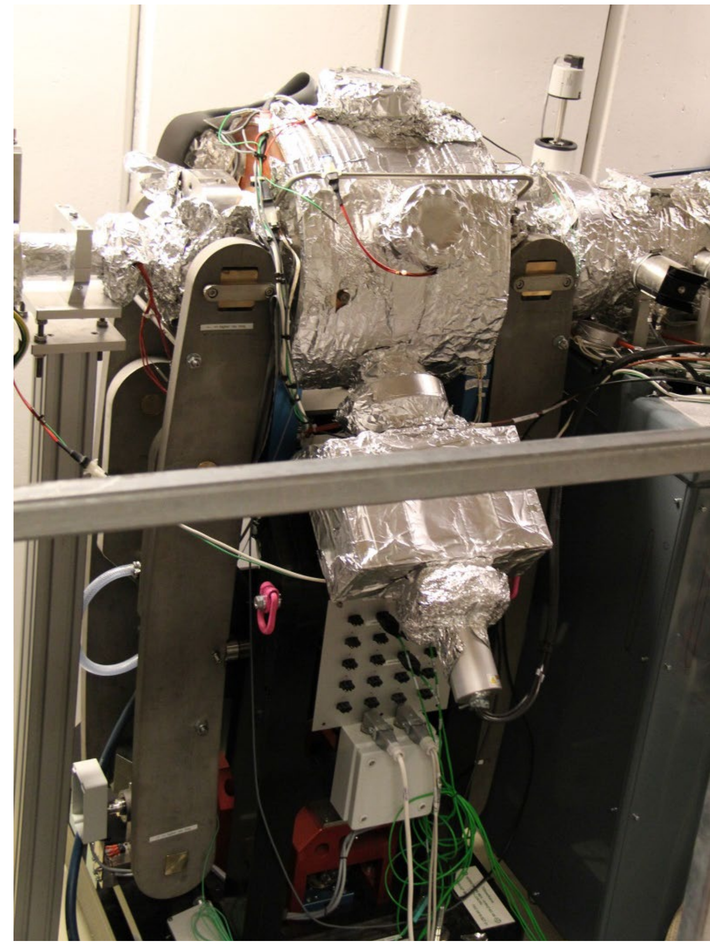
ASTRID2 Layout

Landau cavity

- Installed March 2015
- Prebaked (130°C)
- Preconditioned with 100 W (~20 kV)
  - Multipactoring around 10 W (200 V)

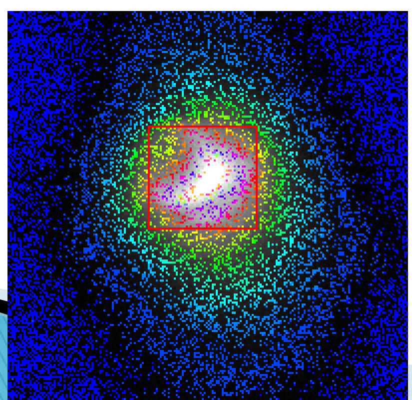


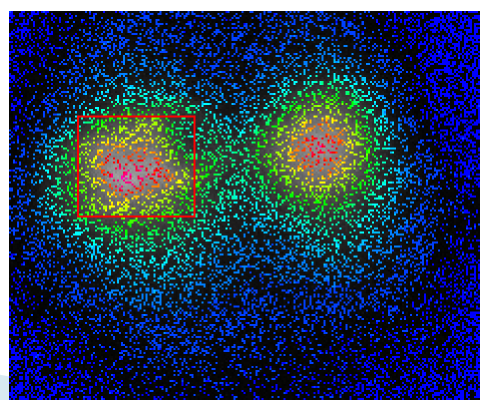
Installed in the ring



Longitudinal coupled bunch instability

- We have strong longitudinal coupled instability
- Mode amplitudes are up to ~0.1 ns
  - 10 ns bunch separation
- Threshold (beam current) is low (a few mA)
- Through dispersion it gives strong horizontal oscillations
  - Clearly visible on our SR diagnostic camera (with short exposure time)
    - Dispersion = 0.18 m

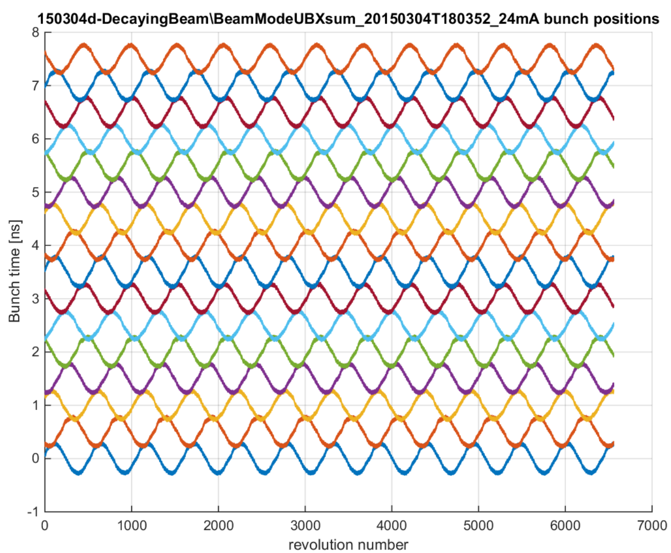




Longitudinal coupled bunch instability

- Landau cavity is damping the instability a little, and it changes which modes are the strongest
  - We can find a Landau detuning where the beam appears stable on our diagnostic camera
    - We are moving the oscillations higher up in frequency (where they are less apparent)

Before Landau cavity (24 mA)
Dominant mode: 9



With Landau cavity (120 mA)
Dominant mode: 15