Status of the ASTRID2 RF systems

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ASTRID2

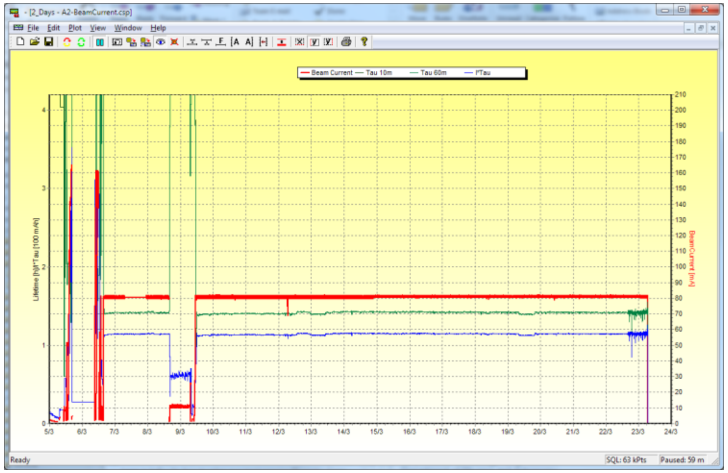
- ASTRID2 is the new synchrotron light source in Aarhus, Denmark, since 2013
- ASTRID2 main parameters
  - Electron energy: 580 MeV
  - Emittance: 12 nm
  - Beam Current: 200 mA
  - Circumference: 45.7 m
  - 6-fold symmetry
    - lattice: DBA with 12 combined function dipole magnets
      - Integrated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

ASTRID2 Layout

ASTRID2 Status

- Normal operation
  - 120 mA continuous TopUp
    - Beam line request
  - 5 beam lines in operation
  - 2 beam lines being installed
- 200 mA TopUp is possible
  - Bumper problem is solved
  - But 30% increase in vertical beam size
- The ASTRID2 ring is quite stable, but we are fighting a little with the ASTRID ring

14 days of continues beam



200 mA during (the nights of) 3 days

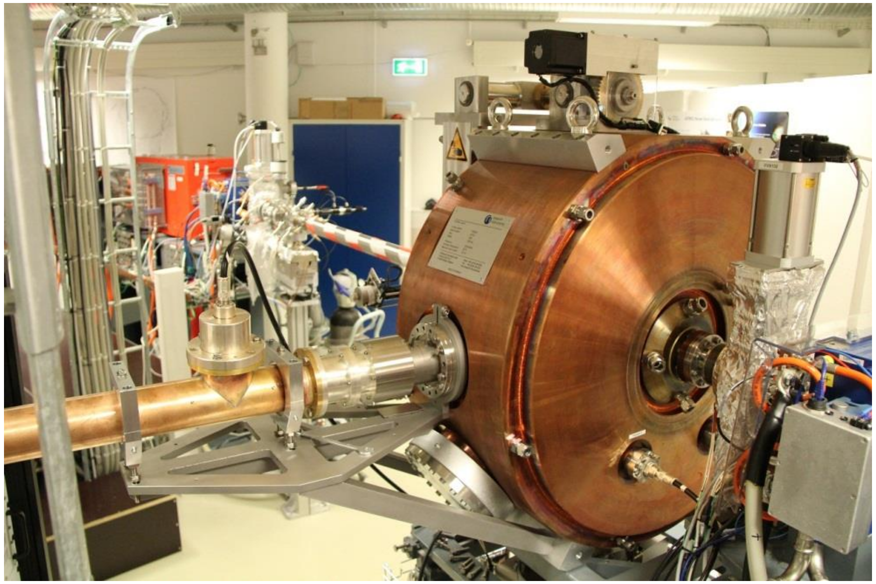
ASTRID2 RF

- 105 MHz (like ASTRID)
- Main RF parameters
  - Harmonic: 16
  - RF voltage: 50-150 kV
  - Synchrotron frequency: 10-20 kHz
  - Synchrotron radiation power: ~1.4 kW
  - Cavity power: 0.5-7 kW
- 8 kW solid state amplifier from Tomco Technologies (Australia)
  - Has been running exceptional well, except for two humidity sensor boards which failed in a way so an internal 5V supply was overloaded, preventing operation

ASTRID2 Cavity

- Basically the same as MAX IV cavities
  - Built by RI (RF design by MaxLab)
- Has been conditioned to ~150 kV (~4 kW)
  - No problems seen, but there is outgassing
- Usual operate at 80 kV (~900 W)

- Have a 315 MHz Landau cavity (also from RI and based on MaxLab design).
  - Installed March 2015



New developments

- Installed 3rd harmonic (Landau) cavity
  - March 2015
- Solved the bumper problem
  - Allows 200 mA continues TopUp
    - But we still have an beam current depended increase in vertical beam size for beam currents above ~150 mA
      - We believe the reason is (poor) vacuum (needs conditioning)
- New RF power amplifier for ASTRID
  - 1 kW (105 MHz) from Raditek Inc.
  - Solid state (one power amplifier power module)
  - Includes a circulator in a separate box

New ASTRID RF power amp.

- 1 kW Solid State from Raditek Inc.
  - Replaces the ~25 year old 8 kW tetrode amplifier
- Saves electrical power
  - Idle power consumption:
    - Tetrode: ~7 kW
    - Raditek: ~150 W

Old amplifier

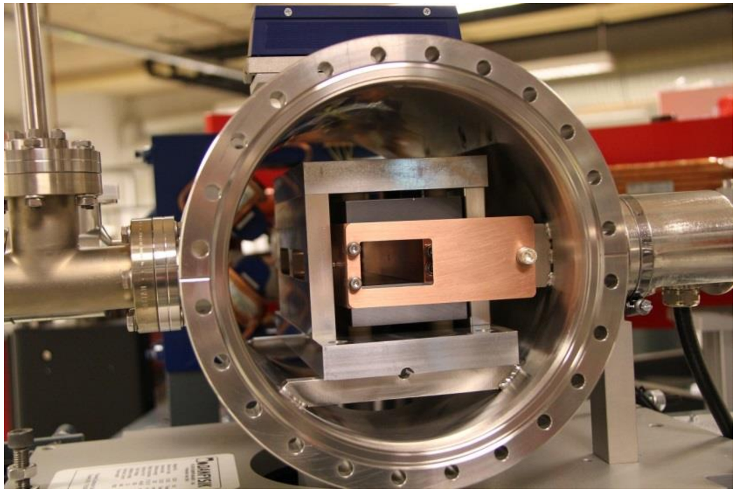
Amplifier

Circulator

Injection bumpers

- Simple design (in-vacuum ferrite)
- First version: Beam current limited to 60 mA
- We believe the problem was due to absorption of beam induced RF fields in the ferrites, causing them to heat above the Curie temperature of 130°C

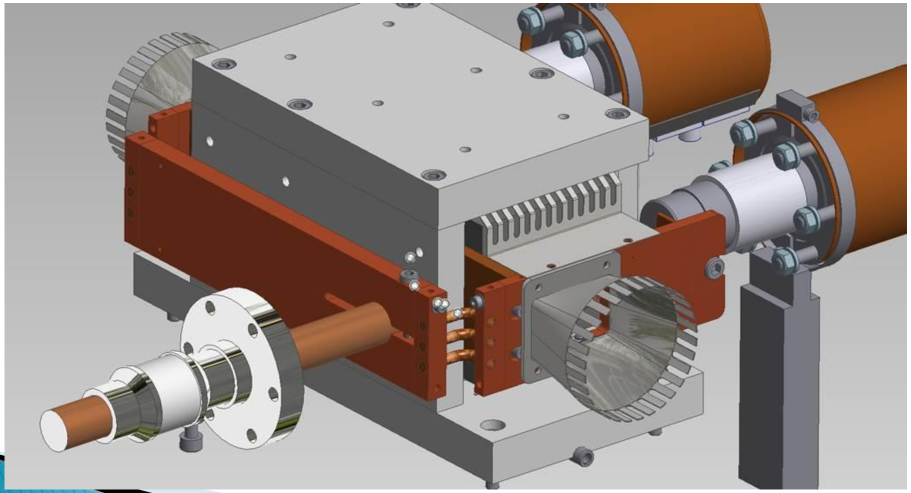
First version

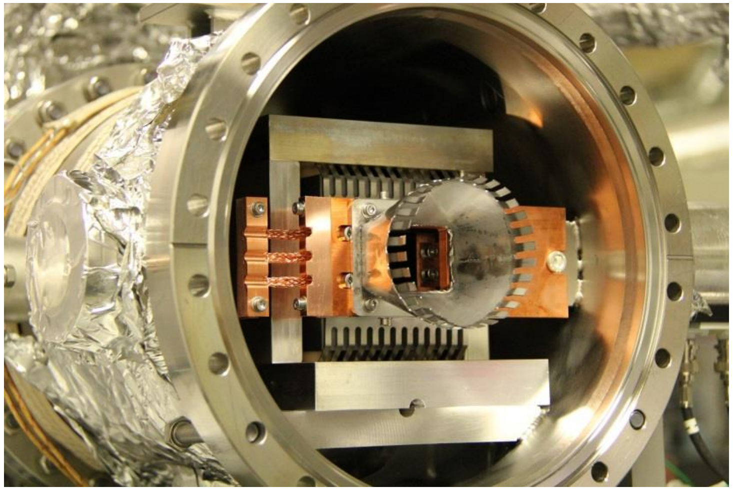


Injection bumpers 2

- Second version:
  - Added shields at the ends and cooling of ground conductor
- Beam current limited to 90 mA !
  - With no cooling water we could achieve 85 mA !

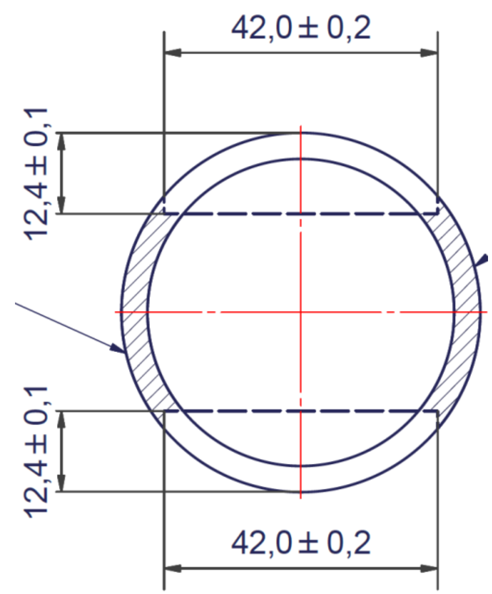
Second version



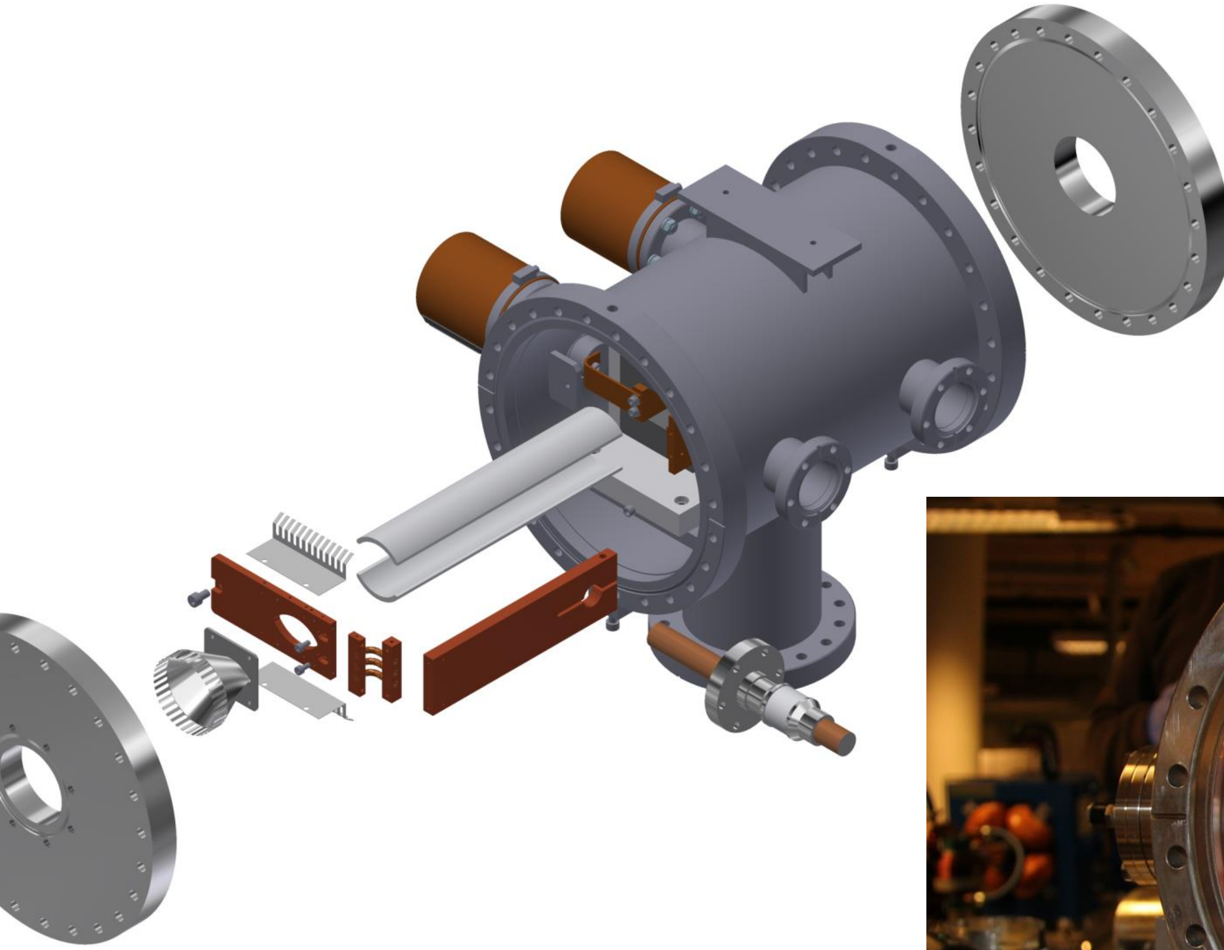


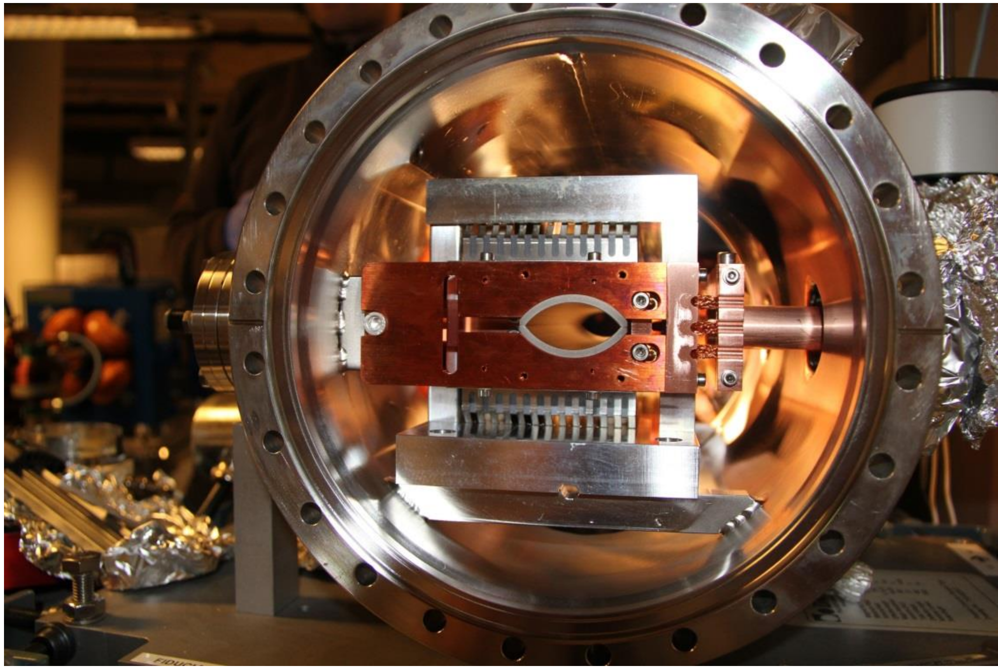
Injection bumpers 3

- Third version:
  - Added Ti-coated ceramic shells inside bumper to shield the ferrites from the beam
  - Allows us to run 200 mA indefinitely
  - Install dates: Aug. 2014, Oct. 2014, March 2015
  - Price: ~4000 € (for the three bumpers)
    - Much cheaper than a system with out-of-vacuum ferrites



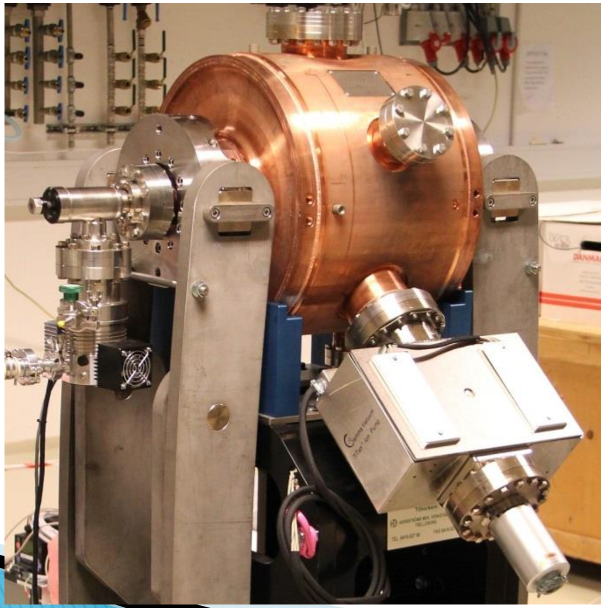
Injection bumpers 3



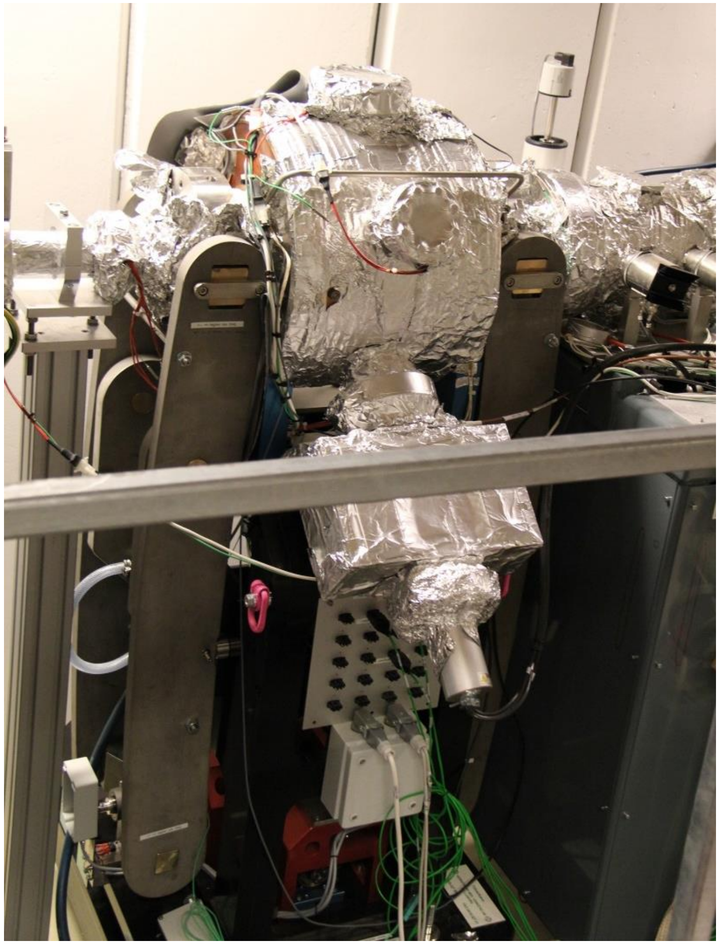


Landau cavity

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



Installed in the ring



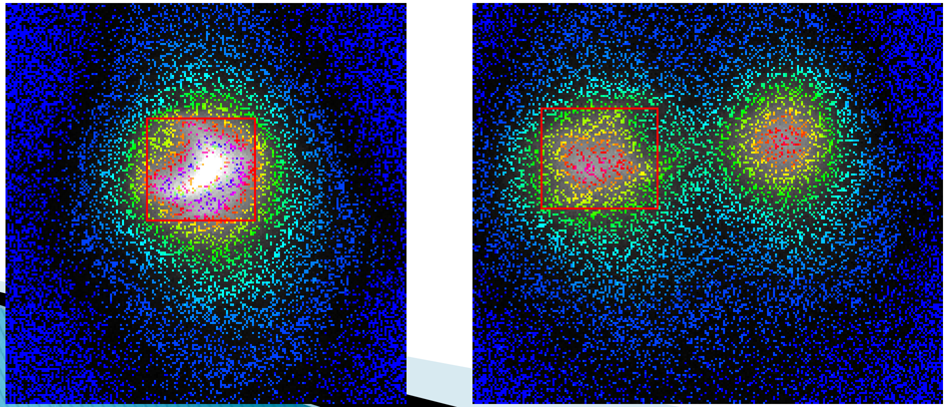
Landau cavity

Preliminary:
5.5 h @ 120 mA
(Detuned +150 kHz)

- Better lifetime
  - Before: 1.4 h @ 80 mA and 1.0 h @ 120 mA
  - Now: 2.0 h @ 80 mA and 1.85 h @ 120 mA
- More stable beam
  - Moved instabilities to frequencies in the (many) MHz range
  - SR diagnostic camera (in control room) now shows a stable beam (and happy users)
- Good tuning range is limited
  - Pt. use a detuning of +400 kHz (tuning range is ±500 kHz).
    - "Theoretical optimum" (flat potential) is +160 kHz
  - Drop in cavity voltage and outgassing 250–300 kHz
    - Needs more conditioning ?

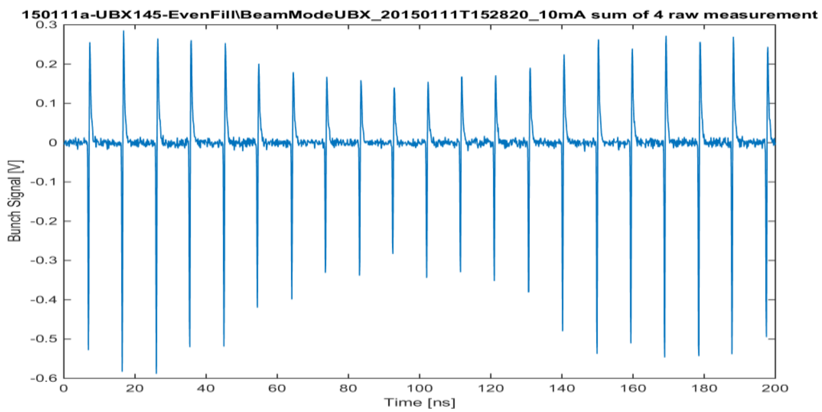
Longitudinal coupled bunch instability

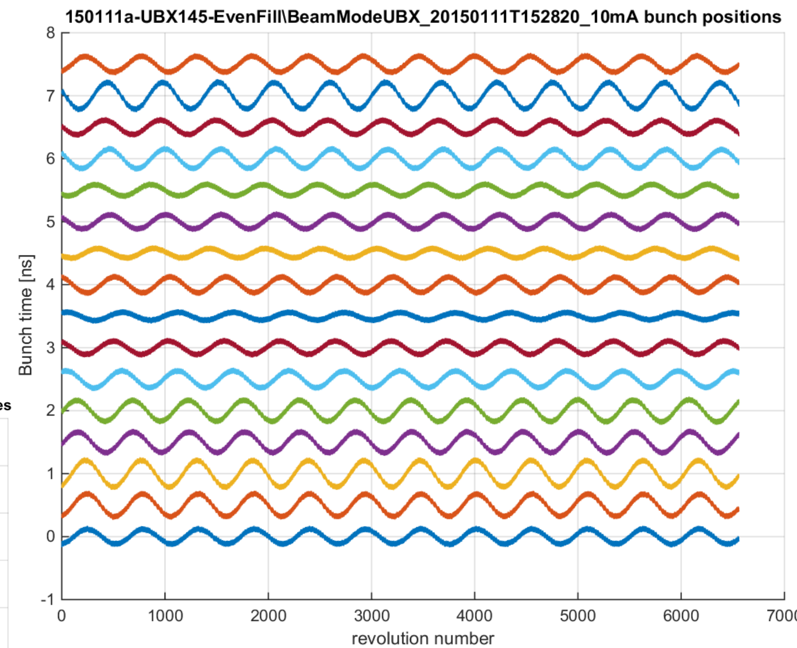
- We have strong longitudinal coupled instability
- Mode amplitudes are up to ~0.1 ns
  - 10 ns bunch separation
- Threshold (beam current) is low (a few mA)
- Through dispersion it gives strong horizontal oscillations
  - Clearly visible on our SR diagnostic camera (with short exposure time)
    - Dispersion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

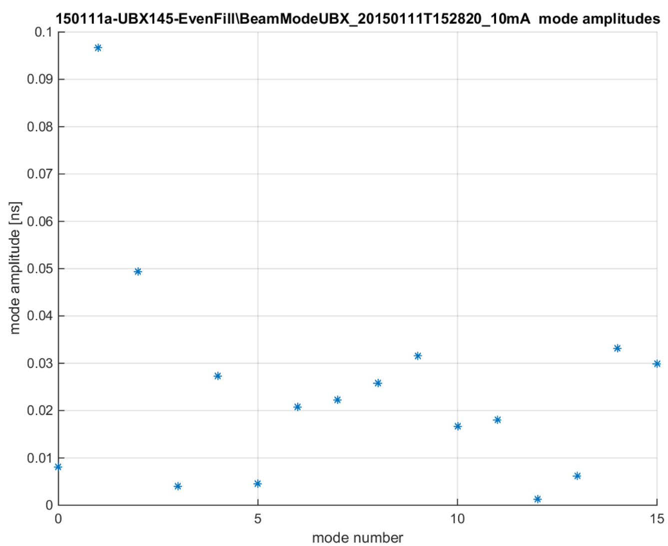


Longitudinal coupled bunch instability

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





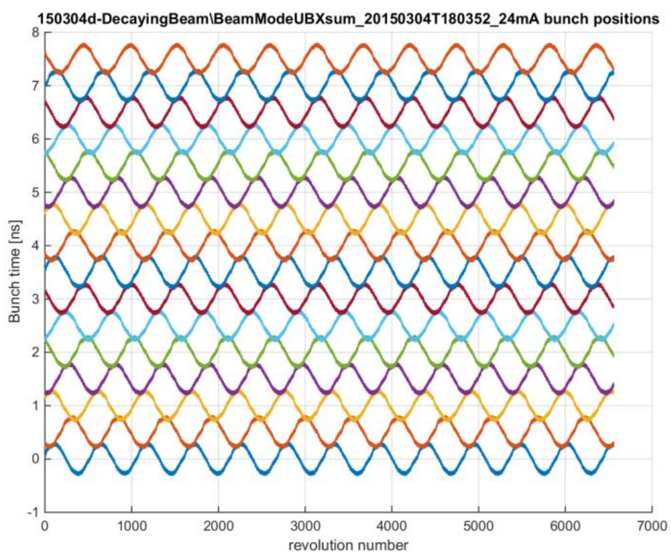


Before Landau cavity
10 mA

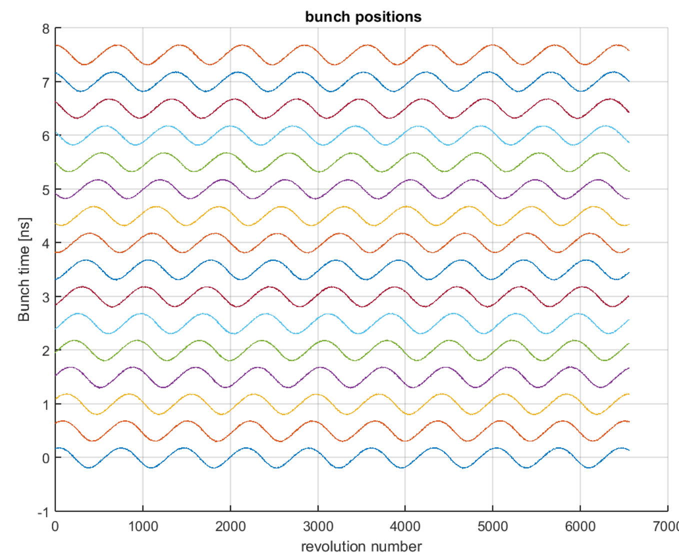
Longitudinal coupled bunch instability

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

Before Landau cavity (24 mA)
Dominant mode: 9

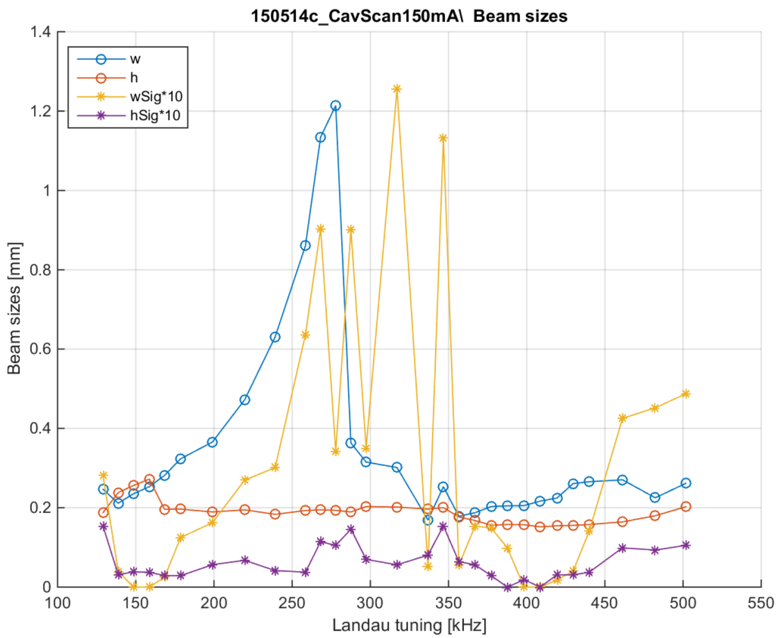


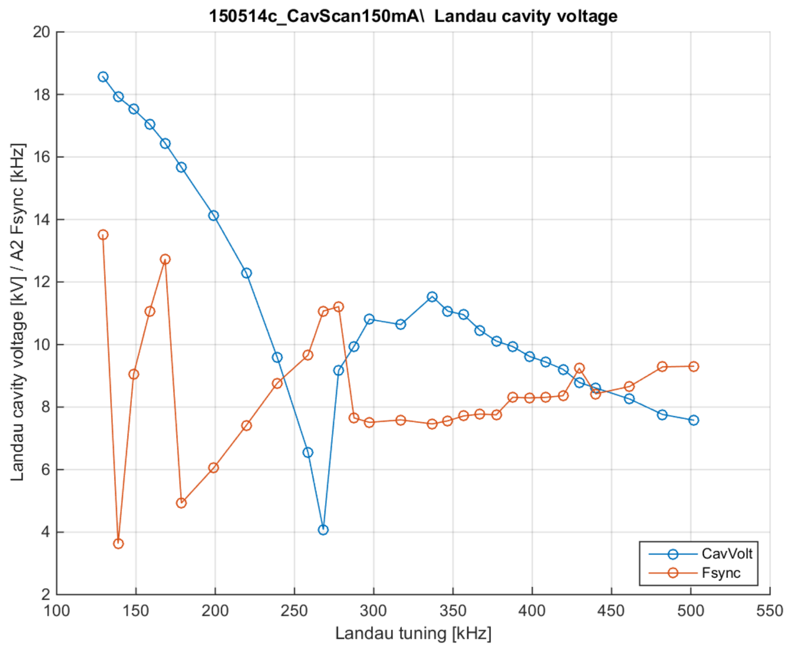
With Landau cavity (120 mA)
Dominant mode: 15

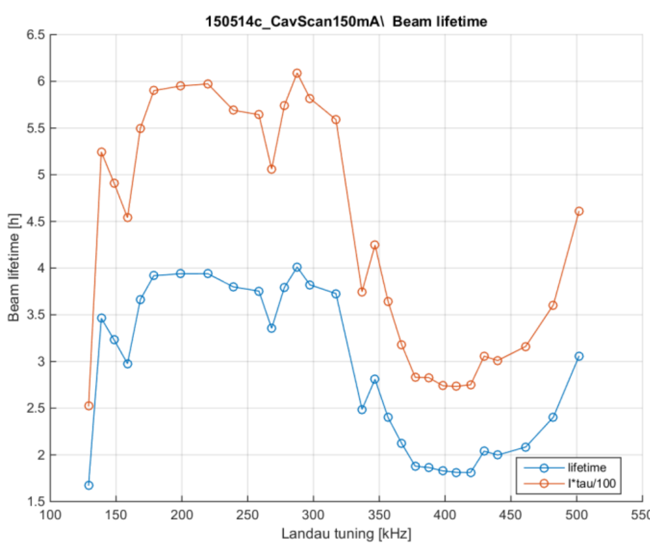


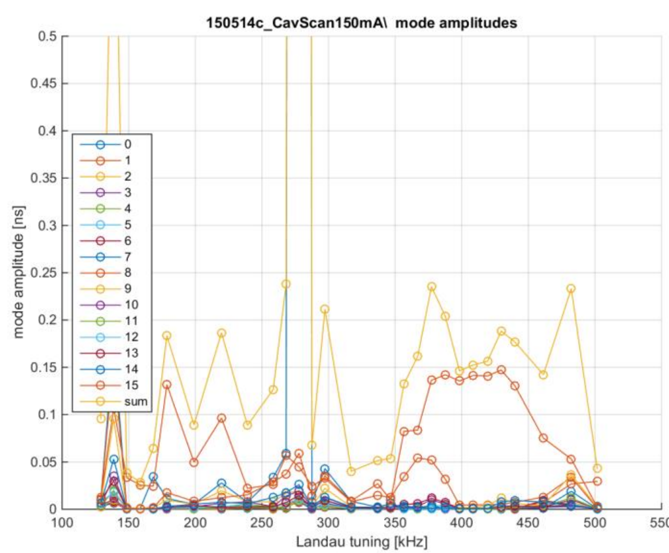
Thank you for your attention

Landau cavity scan (@150 mA)







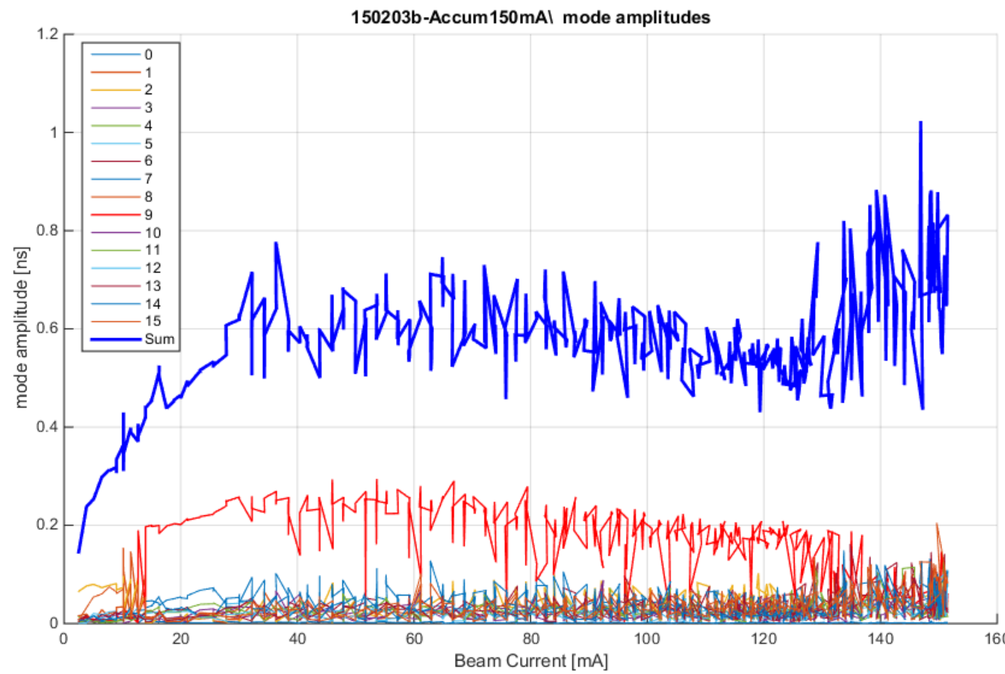


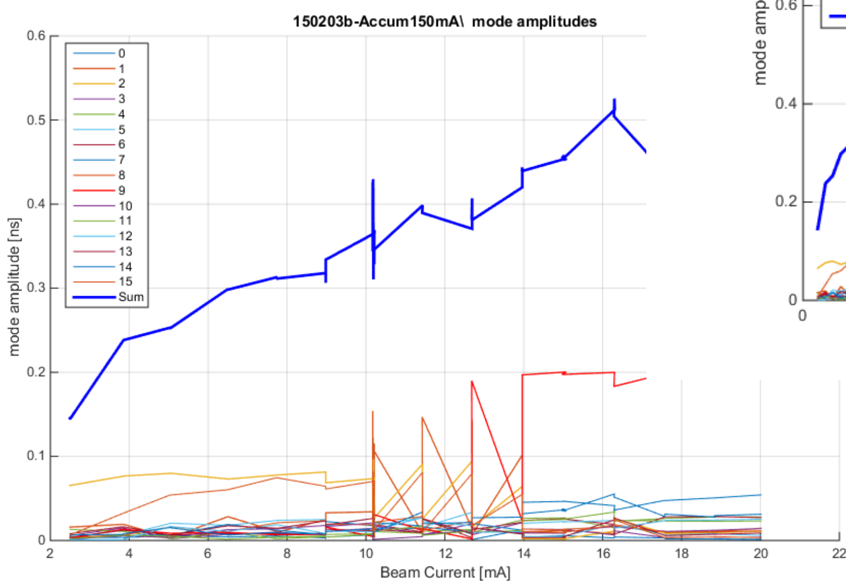
ASTRIDx LLRF

- Since January 2011: New LLRF in operation at ASTRID
  - Same system for ASTRID and ASTRID2
    (except for different tuning control)
- Digital control of baseband signals
  - A computer (PC) running LabVIEW Real-Time with FPGA equipped multifunction card to measure and control the baseband signals
    - NI PCIe-7852R:
      - Virtex 5 FPGA, 8 AI, 750 kS/s/ch, 8 AO, 1 MS/s/ch, 16 bit
  - Detection: IQ demodulators with low pass filter
      - $\pm$180° phase detection
  - Control: Amplitude and Phase (voltage controlled)
- FPGA (Amplitude Loop): No problems at all
- Real-time (Tuning Loop and Phase Loop): A few restarts have been necessary (data acquisition loop stops)
- Very happy with the systems

Coupled bunch instability 3

- The oscillations can be decomposed into modes
  - Dominant modes
  - 1, 2, 9





Before Landau cavity