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ACAS Australian Collaboration for Accelerator Science

Closing the Bunch-by-bunch Feedback Loop

The path to a long and stable life

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On behalf of
Martin Spencer & Karl Zingre – design and commissioning
David Peake & Mark Boland – development, characterisation and operation

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Where are we?

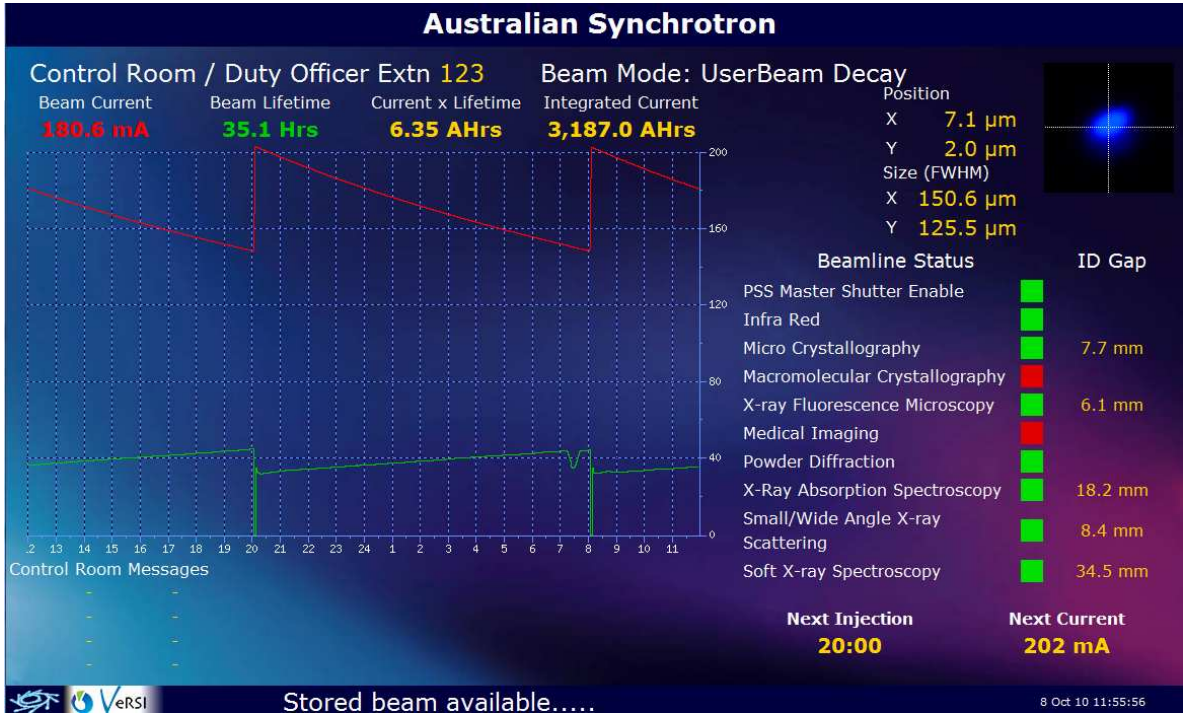
Storage Ring Overview

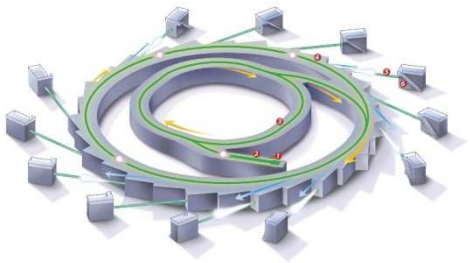
Operations:

- Operational since April 2007
- 9 beamlines
- 1000+ users
- 5000+ hr user beamtime per year

Machine:

- 3 GeV storage ring
- Full energy injection
- 200 mA
- 35 hr lifetime
- f_{RF} =500 MHz
- Circ. 216 m
- f_{rev} =1.39 MHz
- Harmonic # 360





In the beginning…

Vertical Instability

Threshold depends on:

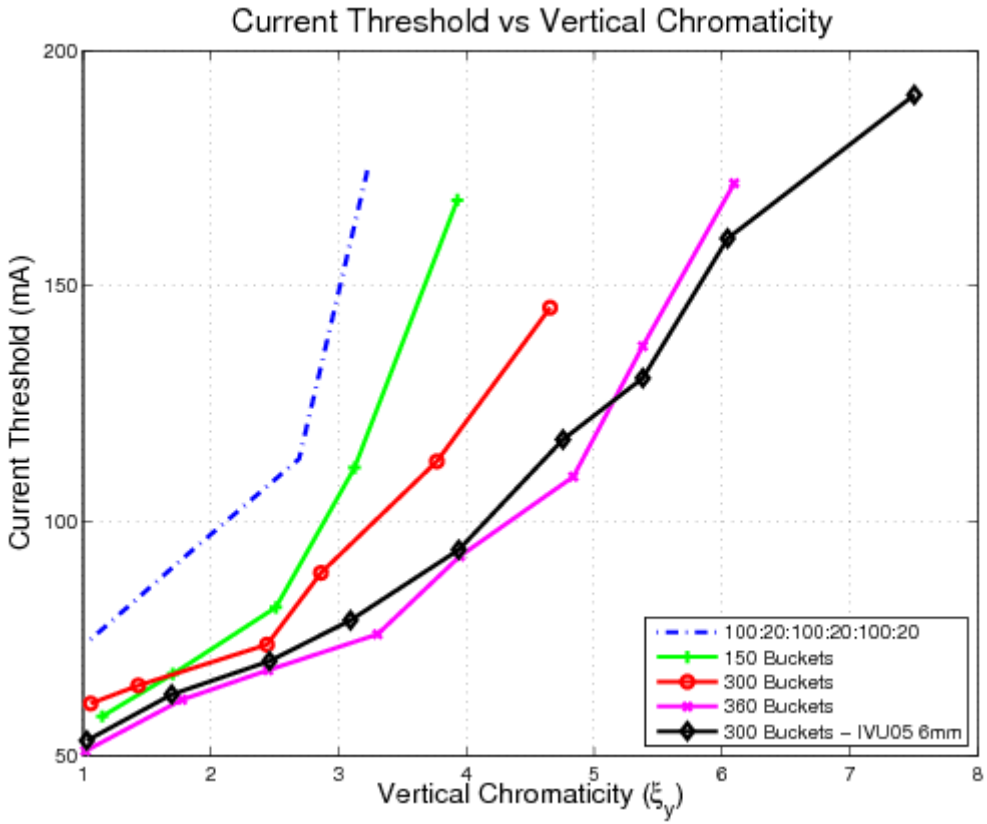
- Total beam current
- Bunch current
- Beam fill pattern
- ID gap
- Chromaticity

Problems:

- Vertical instability
- Limited by sextupole PSU max current output

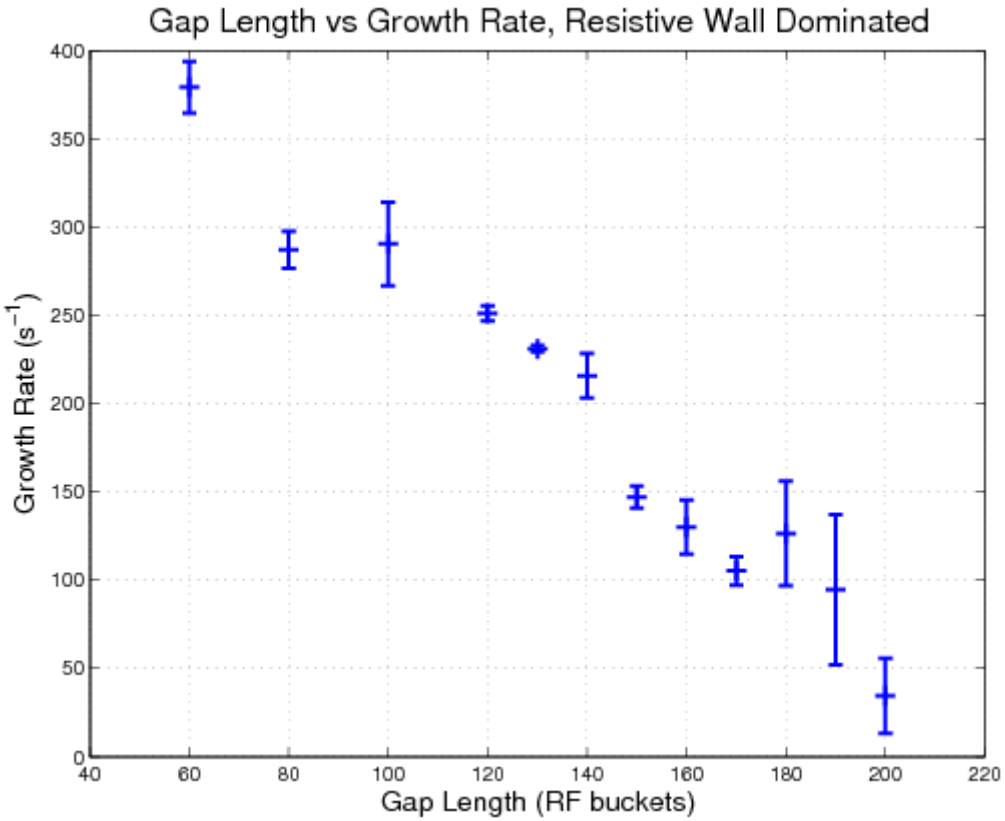
Challenge to:

- Understand physics
- Design feedback requirements
- Build feedback system
- Commission system



NB: Threshold defined as current at which tune lines appeared on spectrum analyser

Resistive Wall



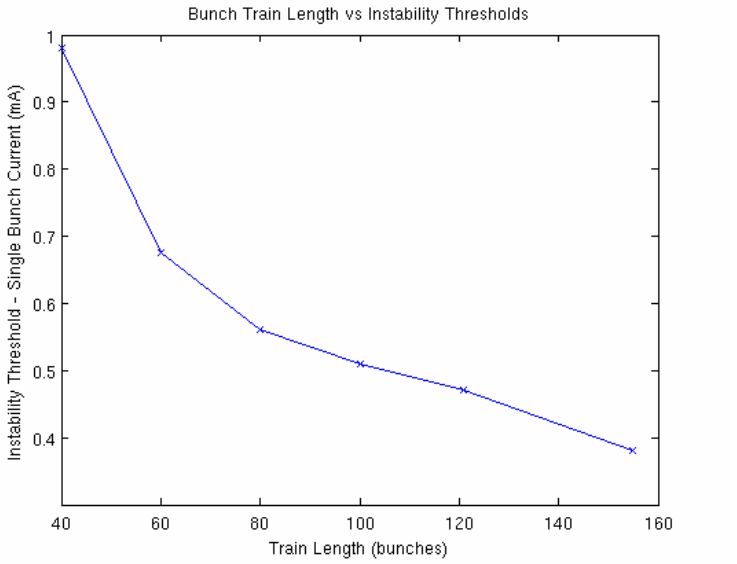
Coupled Bunch Instability

Instability growth rate for the *i*-th coupled bunch mode

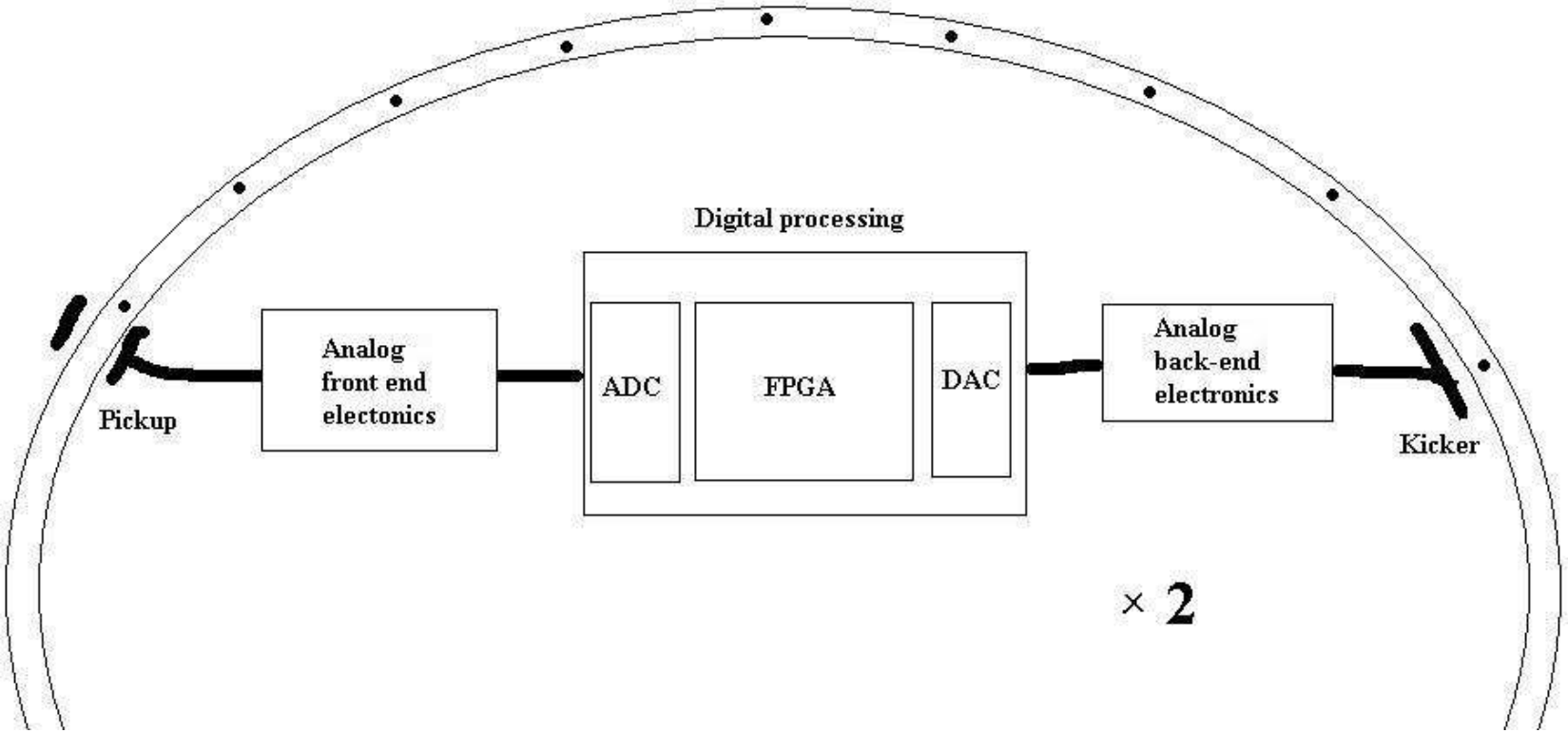
$$\frac{1}{\tau_{mi}} \propto \frac{eMI_b\omega_0}{4\pi\beta E_0}\left[\text{Imedance and other terms}\right]$$

Control I_b and M and measure $\tau_{m\mu}$

Obtained good repeatable control over inducing the instability!

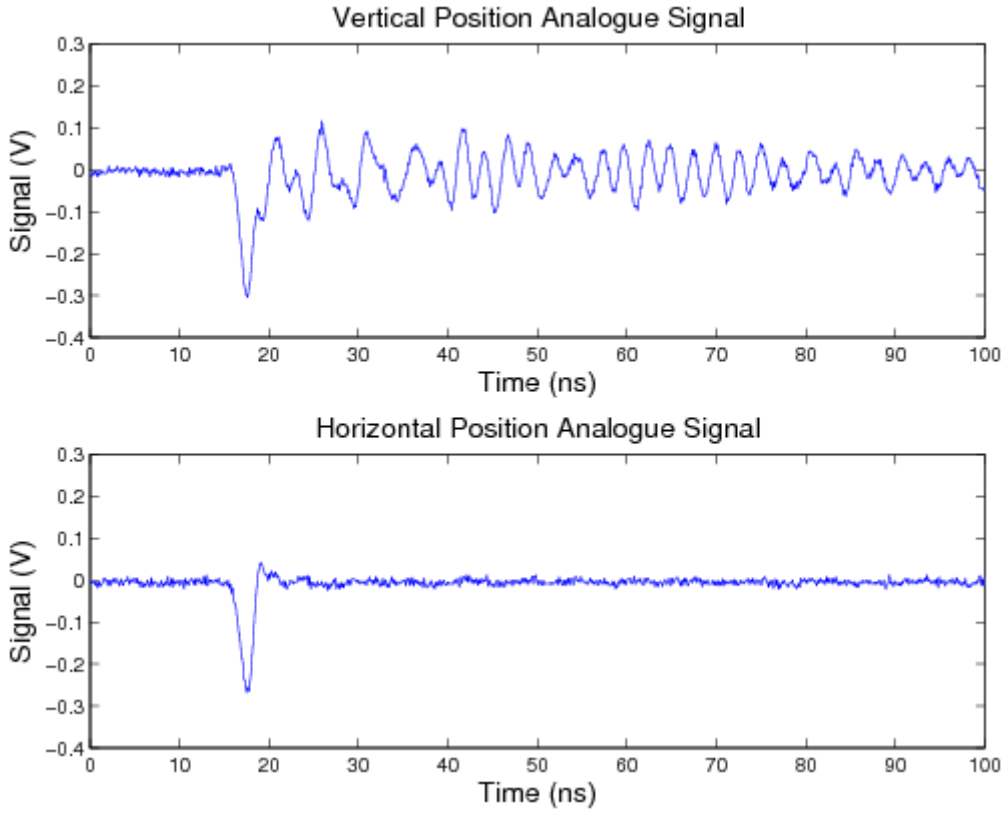


Feedback System Design



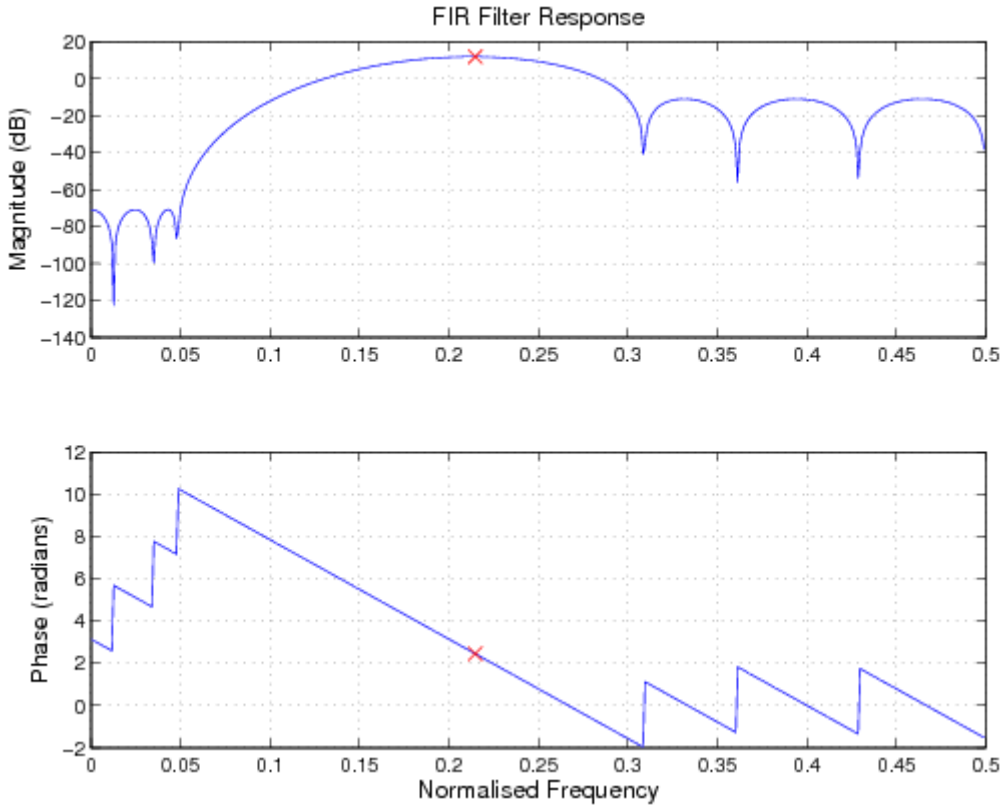
Single Bunch Pick-up Response

- Raw BPM pick-up response with a single bunch in the ring



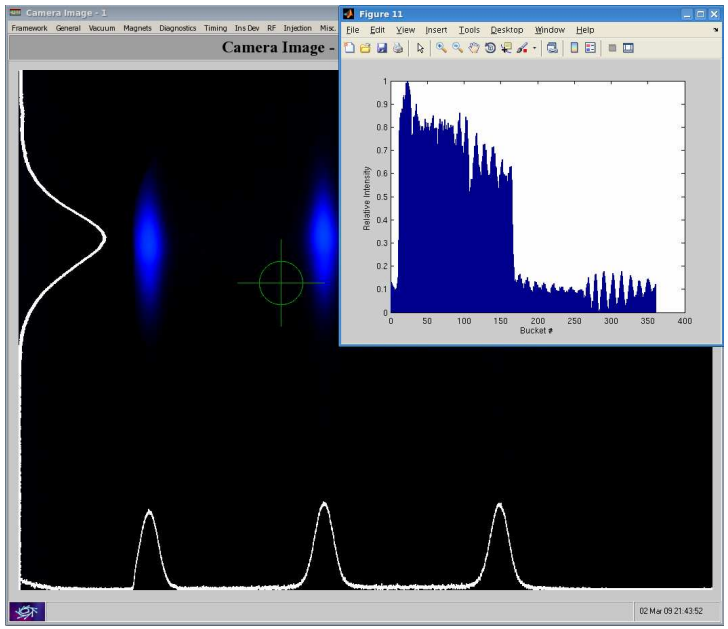
Filter Response

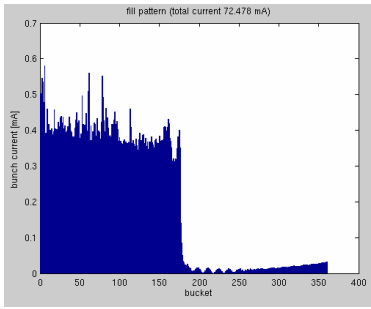
- Calculated filter for vertical tune of 0.216

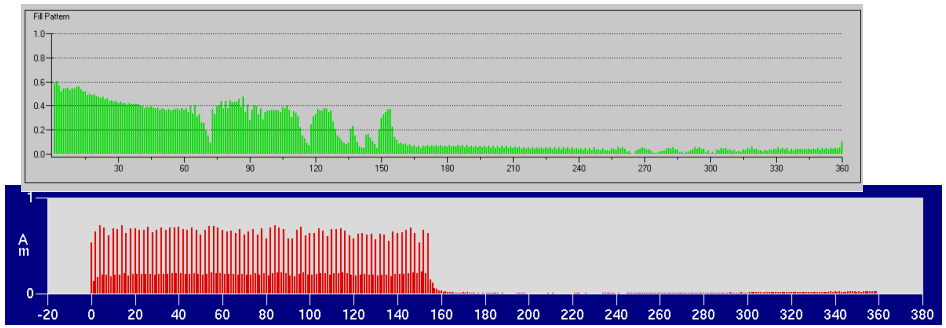


Method to study the instability

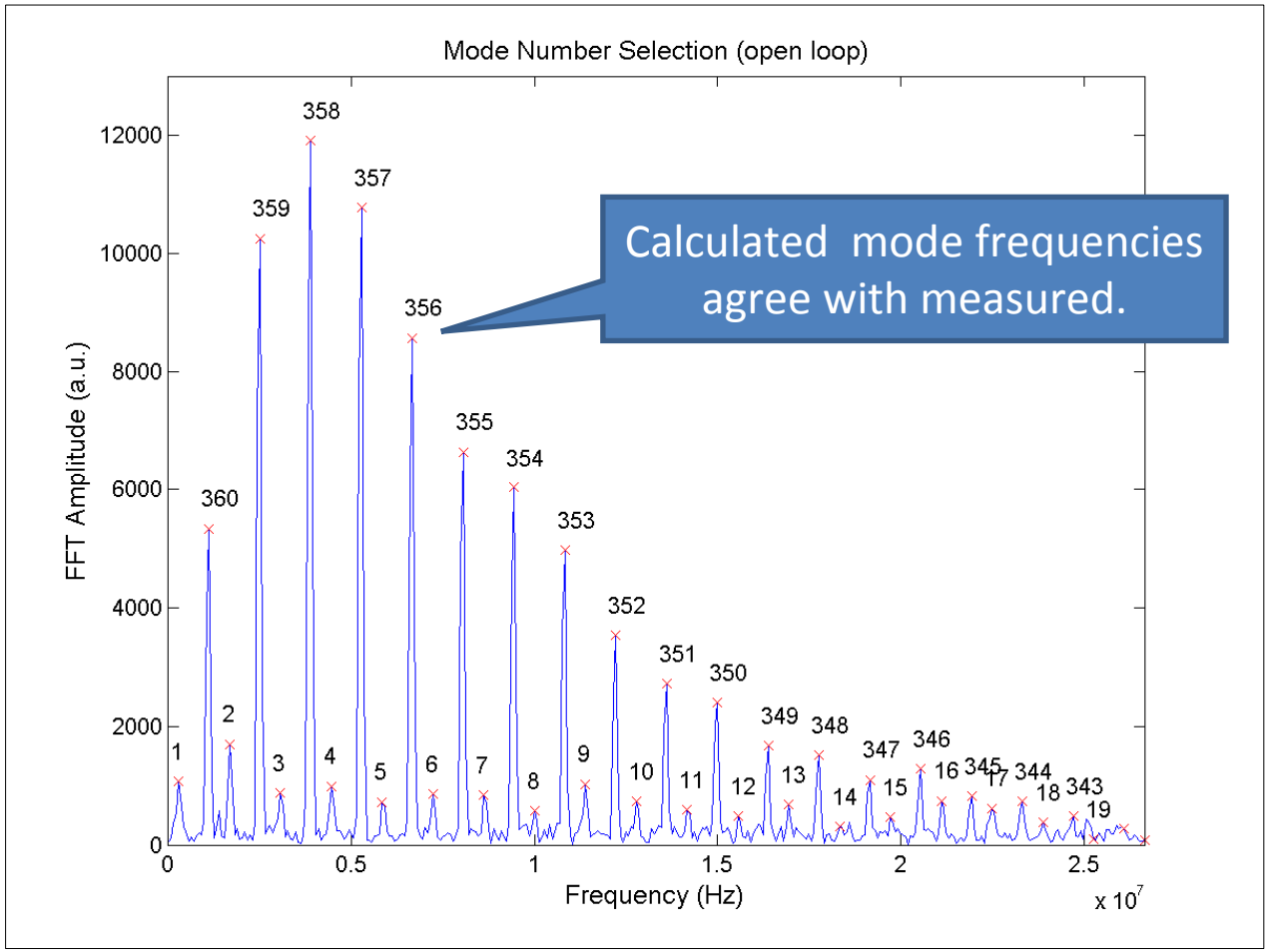
- Need Stably unstable beam
- 100 mA in 150 bunches.





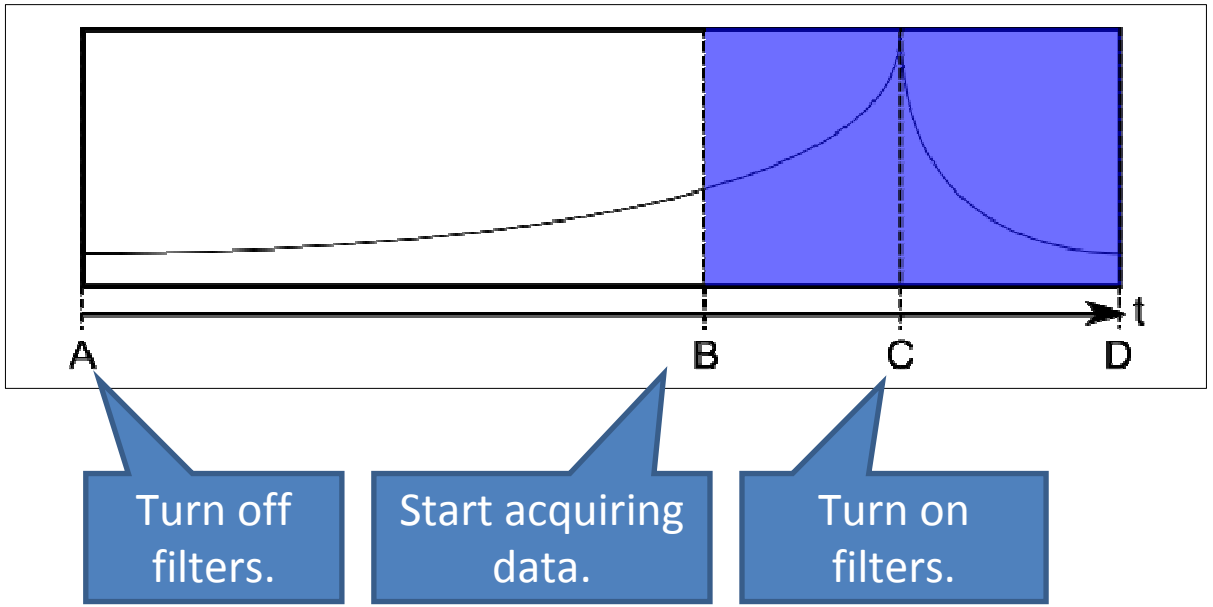


Measured vs Model Modes



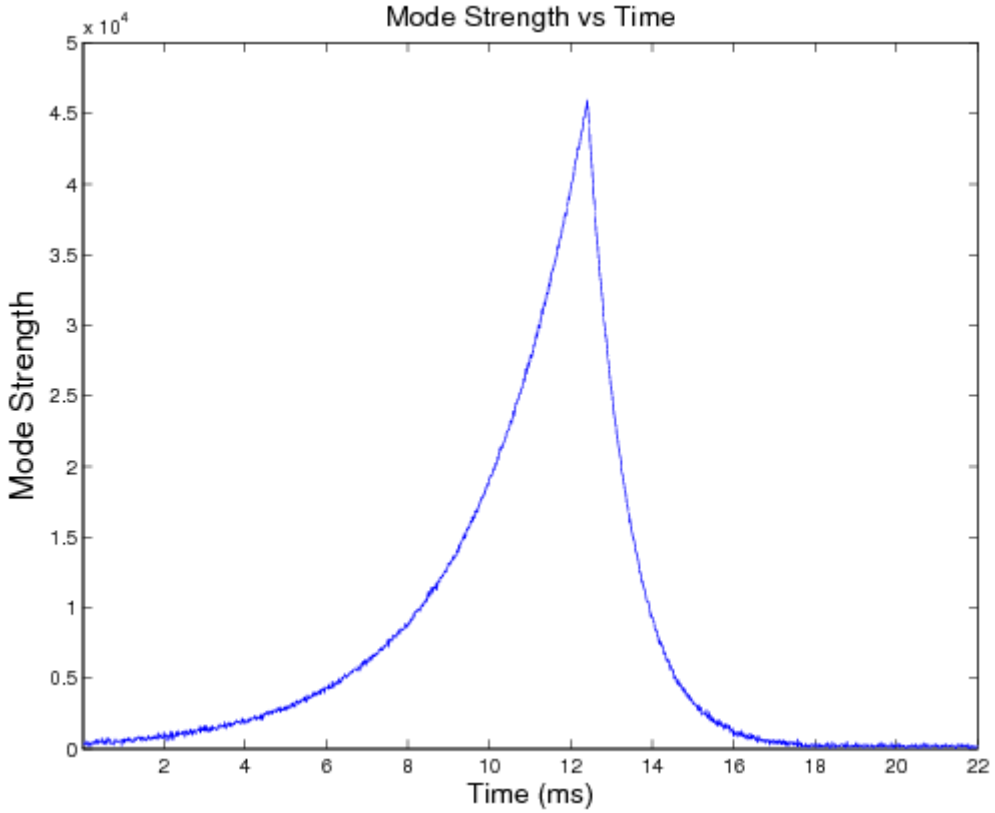
Grow/Damp Diagnostics

- In house C-code using Itech API
- Triggers from Event System
- NFS cross mount for data transfer is a speed bottle neck
- “passive” diagnostic, relies on natural instability modes to get data



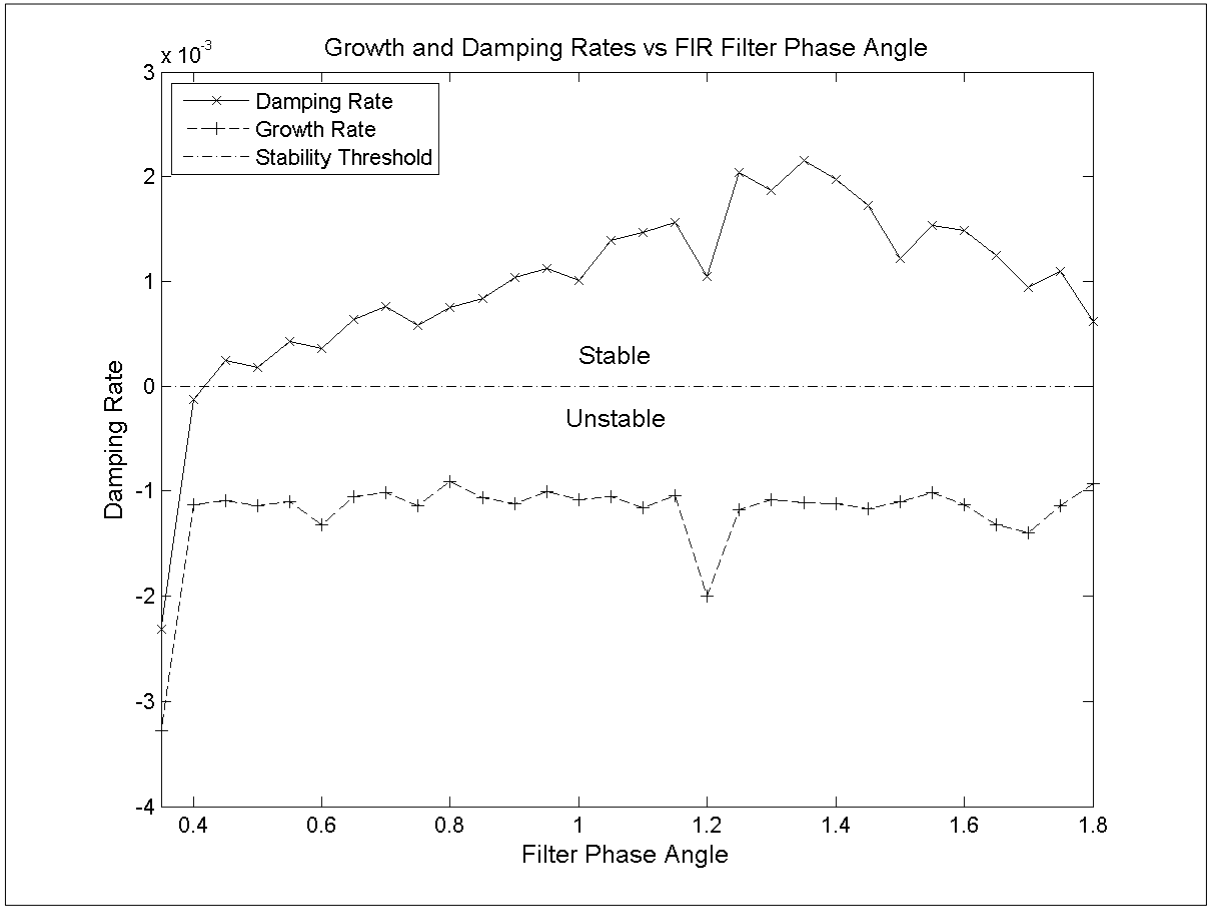
Grow/Damp Data

- Adjust disable / enable FIR time and acquisition time to capture grow/damp
- Fit rising and falling edges of mode strength data to obtain grow/damp rates



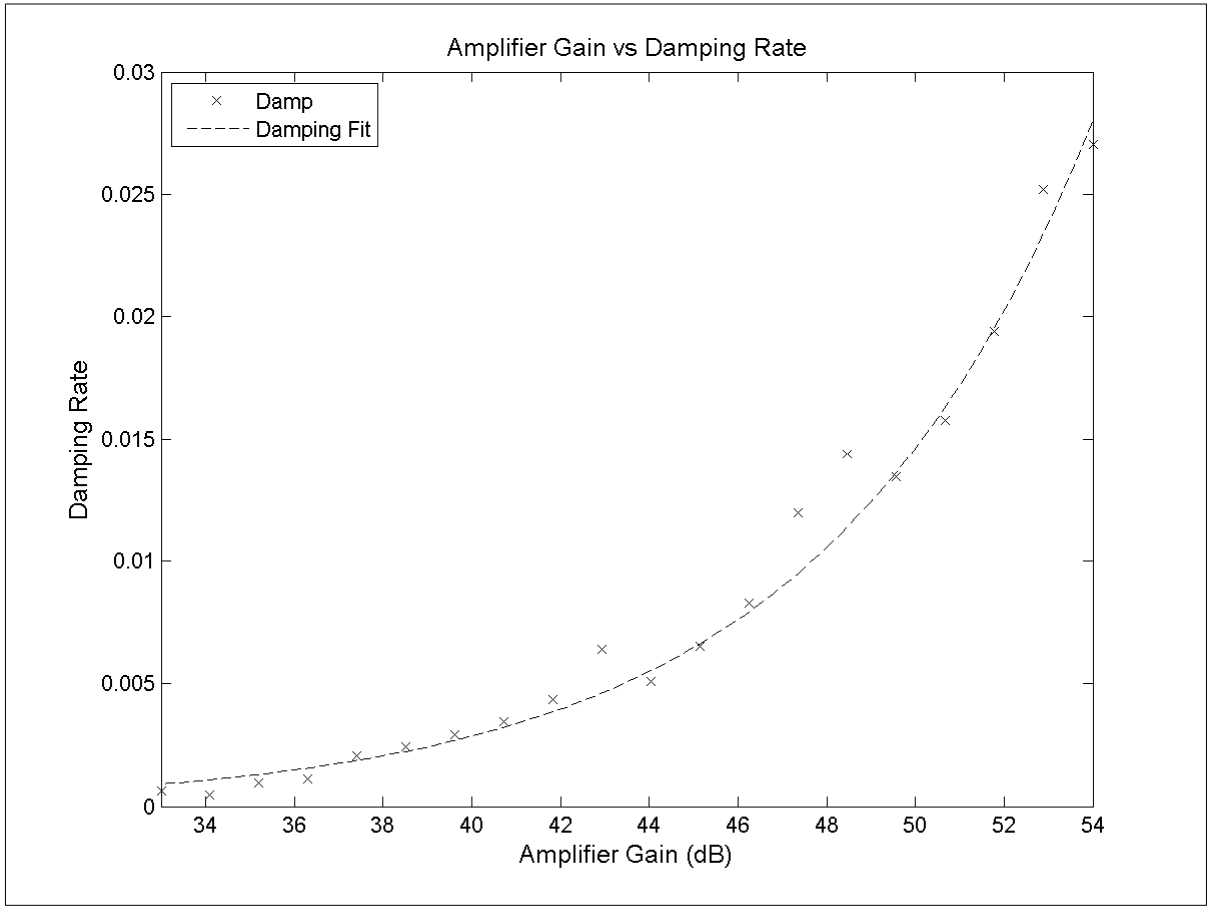
FIR Filter Tuning

- Measure grow/damp rates for unstable mode

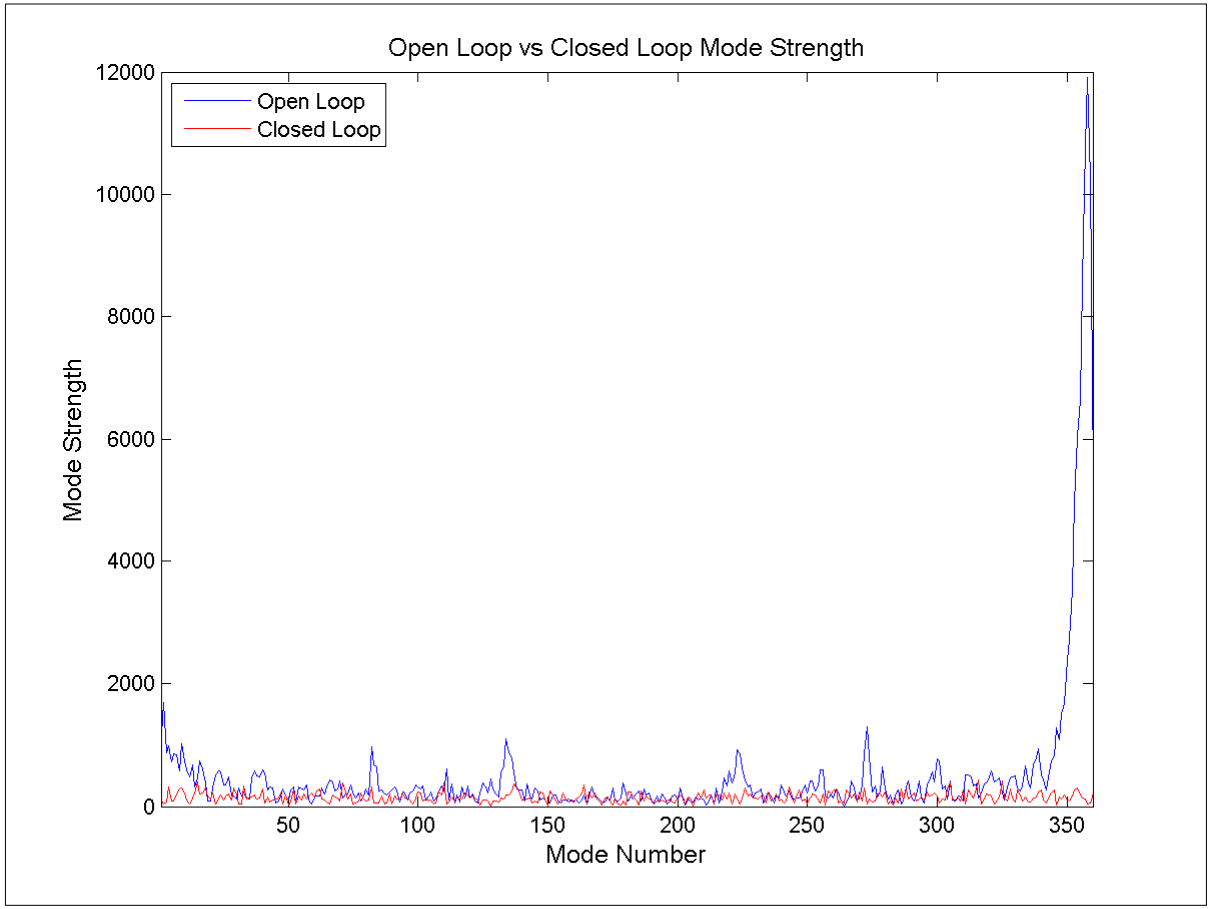


Amplifier Tuning with Grow/Damp

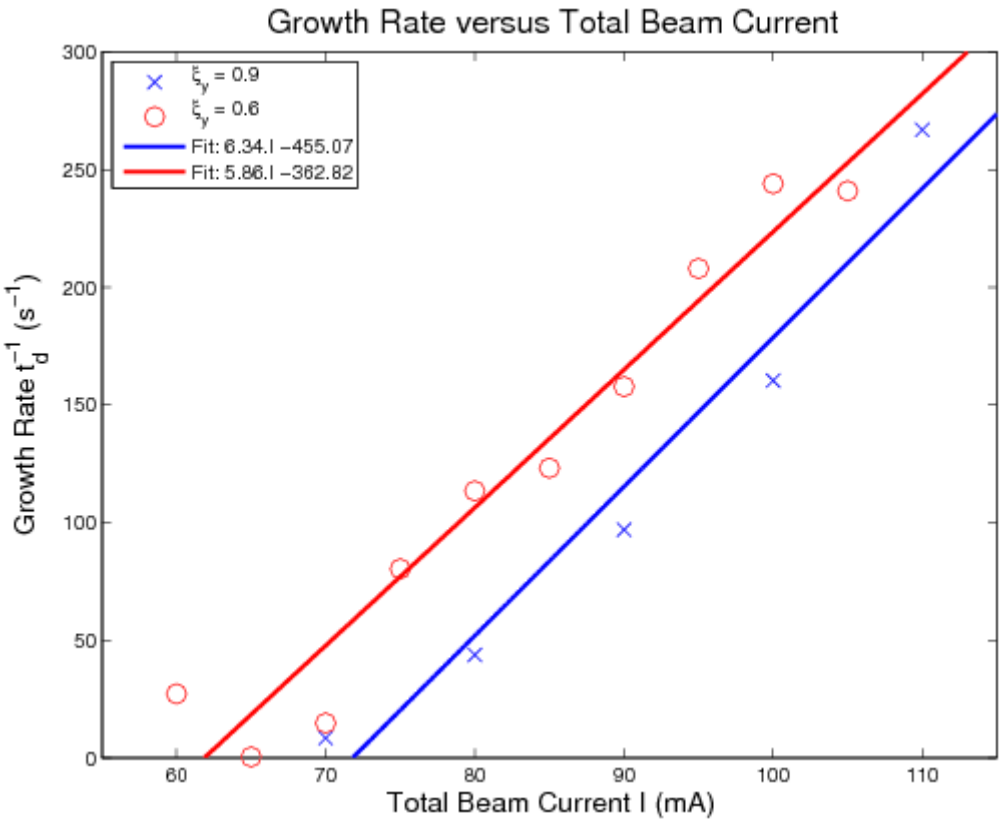
- Check effectiveness of amplifier at different gains
- Can be used for benchmarking of amplifier



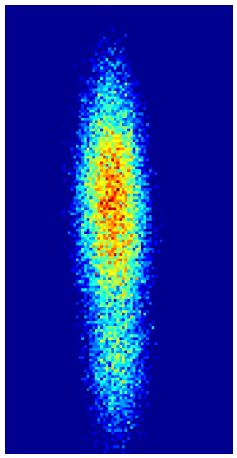
Open vs Closed Loop



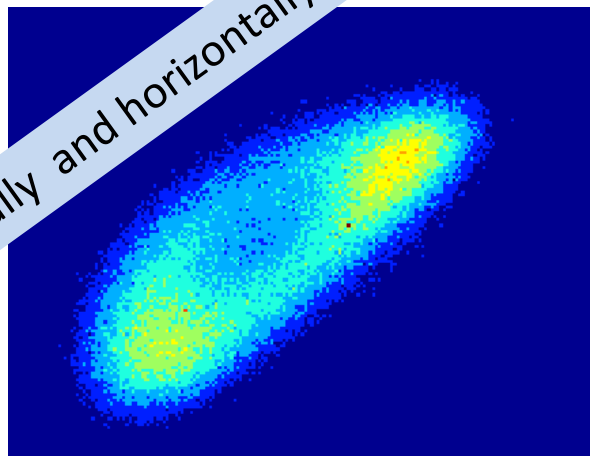
Beam Current vs Growth Rate



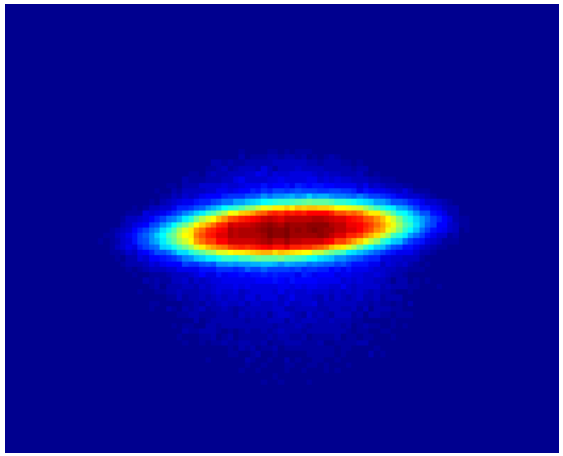
X-ray Pinhole Beam Spot



Vertically unstable



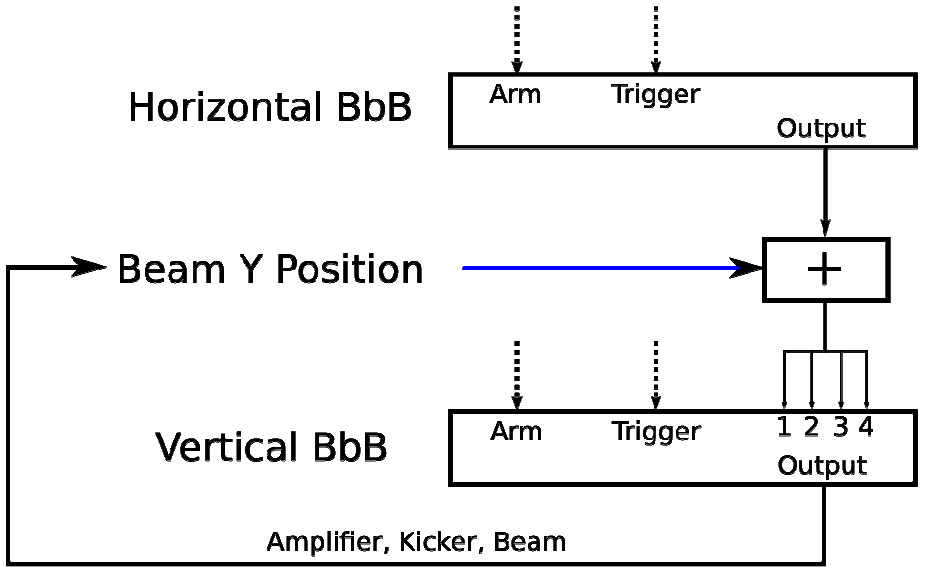
Vertically and horizontally unstable



Stable with feedback loops closed

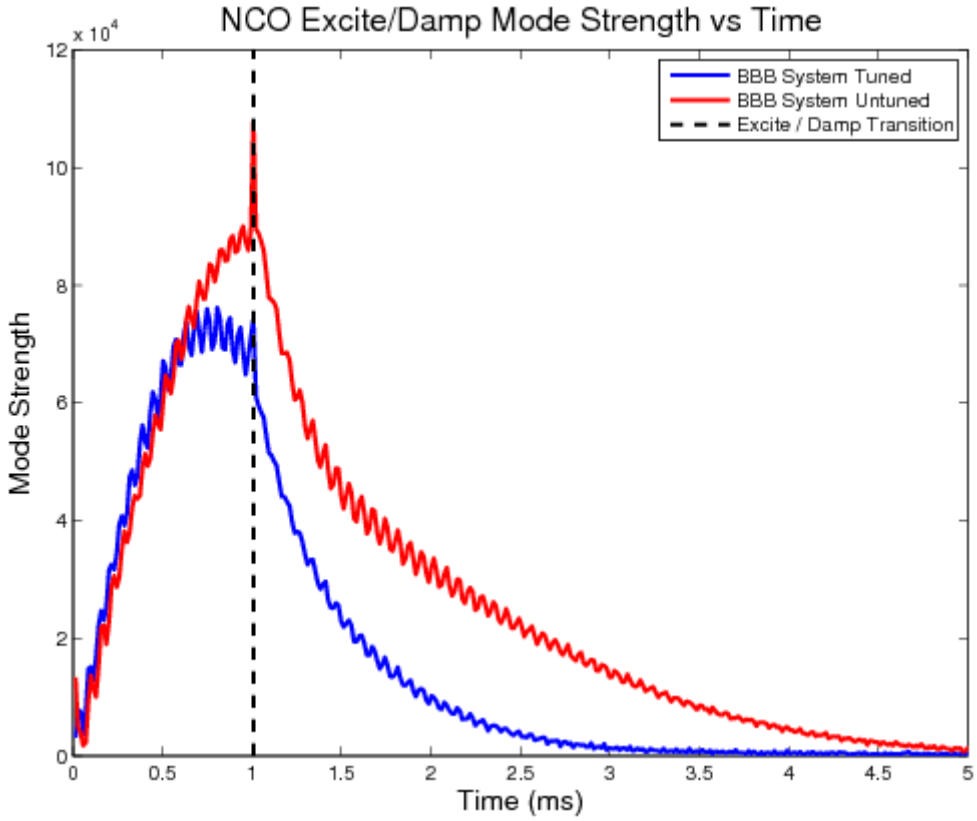
Excite Damp with NCO Circuit

- Use Hor. NCO to excite in Ver.
- Synchronise through Event System triggers



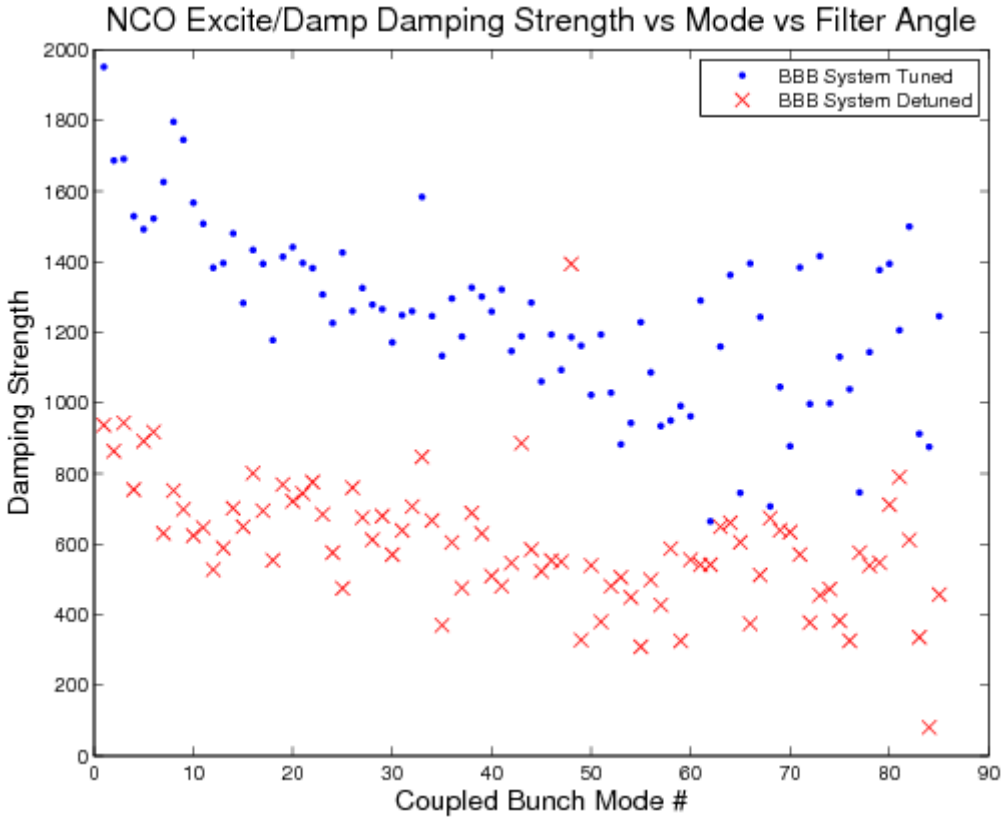
Excite Damp with NCO Data

- "Active" diagnostic, can measure modes that the machine does not at present excite naturally
- Change parameters (e.g. filter phase) and measure damping rate after turning off excitation
- Diagnostic for system performance over time and with new IDs or machine changes

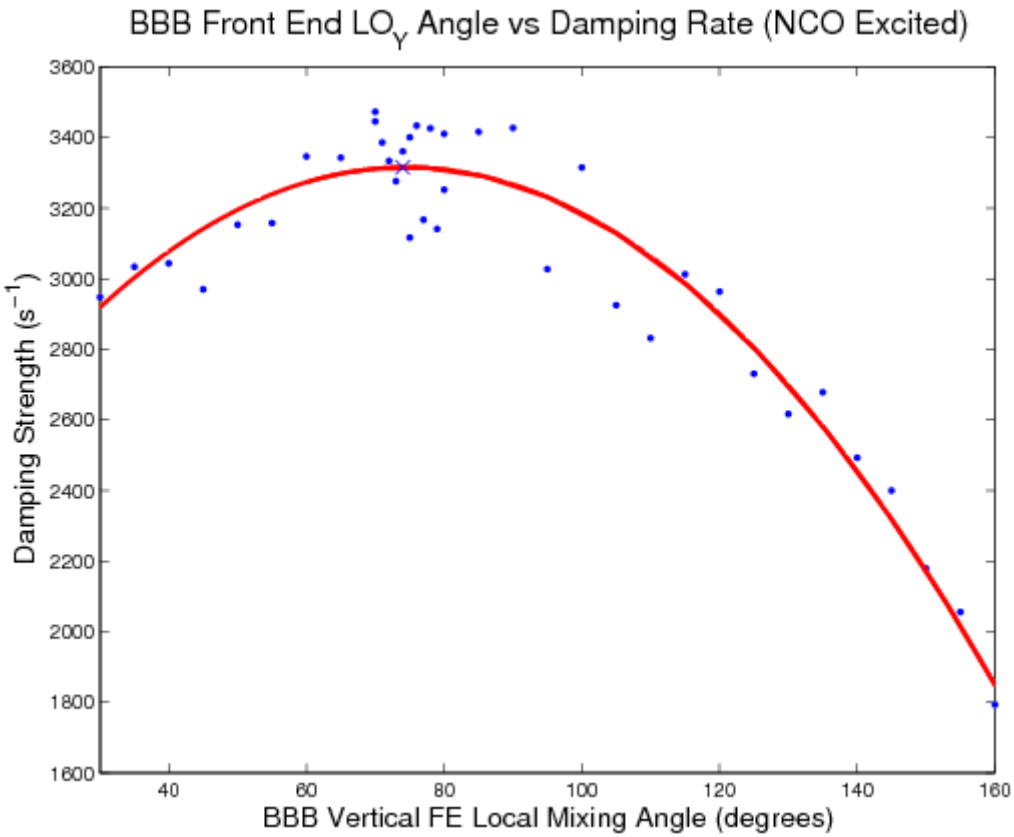


Excite Damp with NCO: Tuning Filter Angle

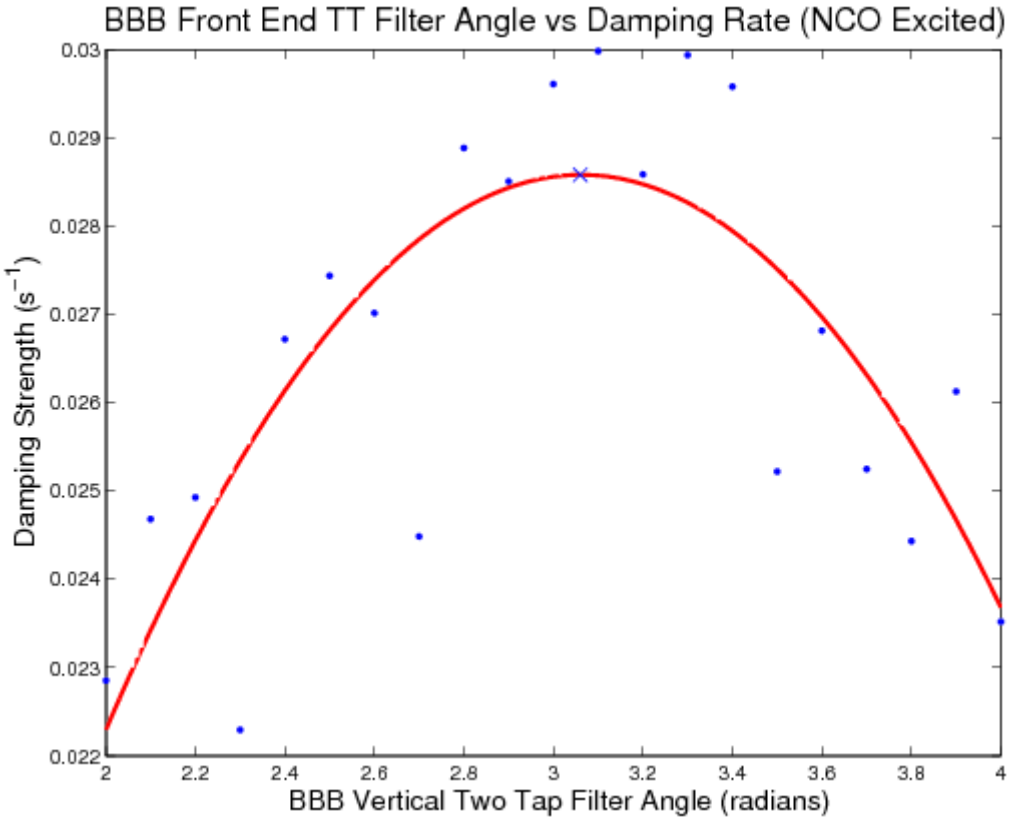
- Optimise damping strength across all modes
- Not just those excited by instabilities in the machine



Excite Damp with NCO: Tuning LO_Y Phase

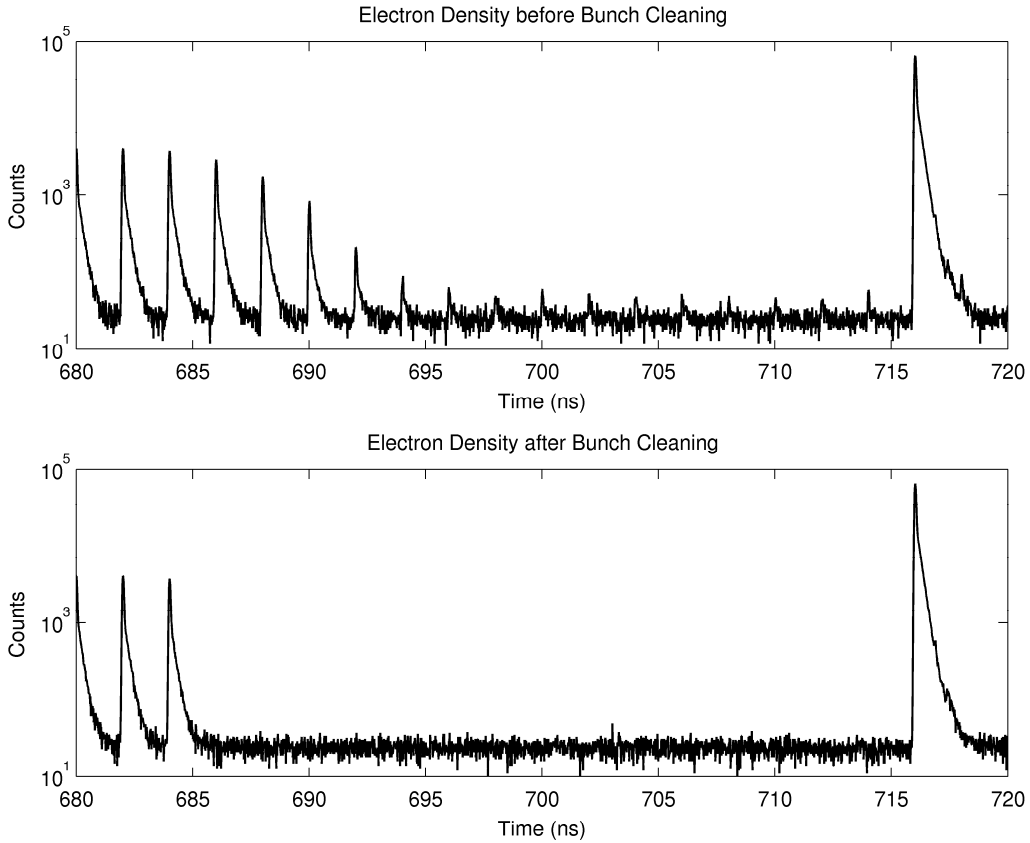


Excite Damp with NCO: Tuning Filter Angle

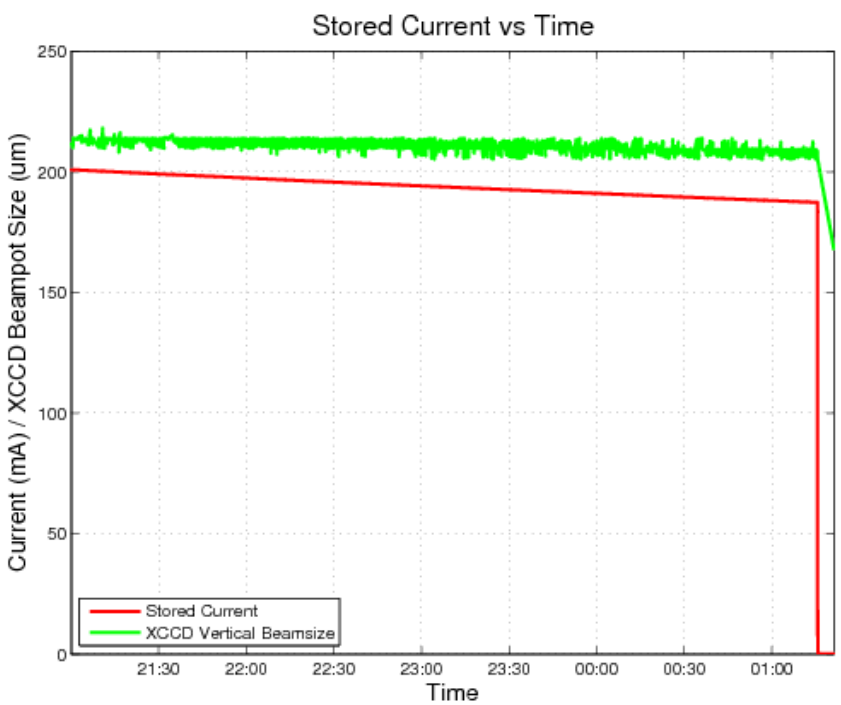


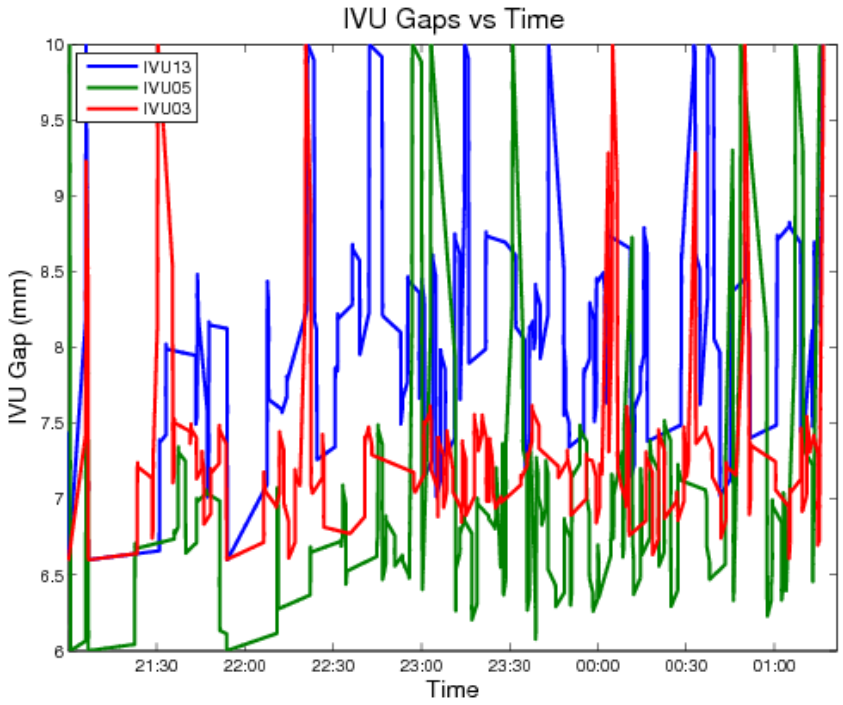
Bunch Cleaning with NCO

- Excite bunches around the fill gap with harmonic of vertical tune frequency
- Check result with optical diagnostic beamline bunch purity monitor



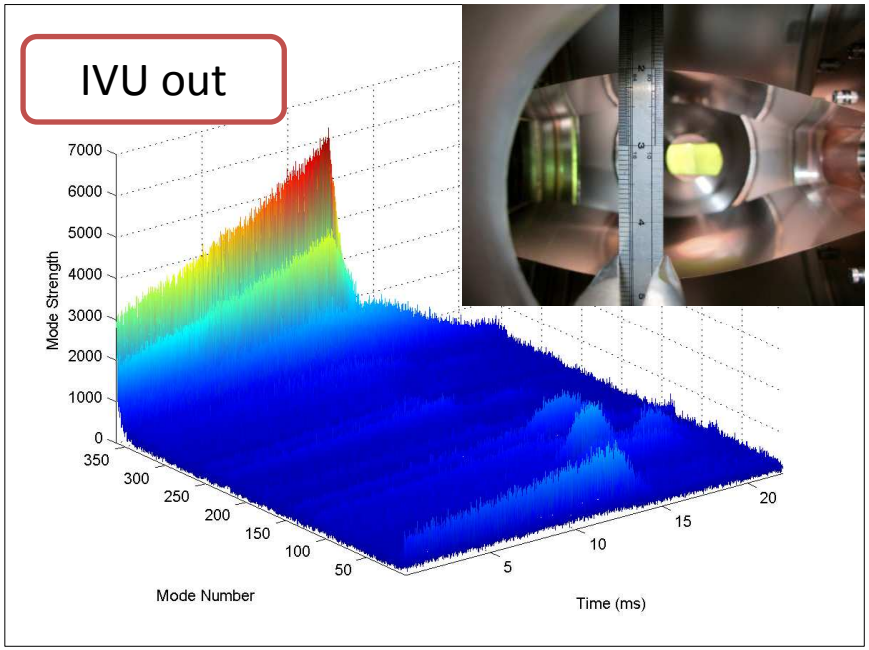
Machine Studies Shift Tests

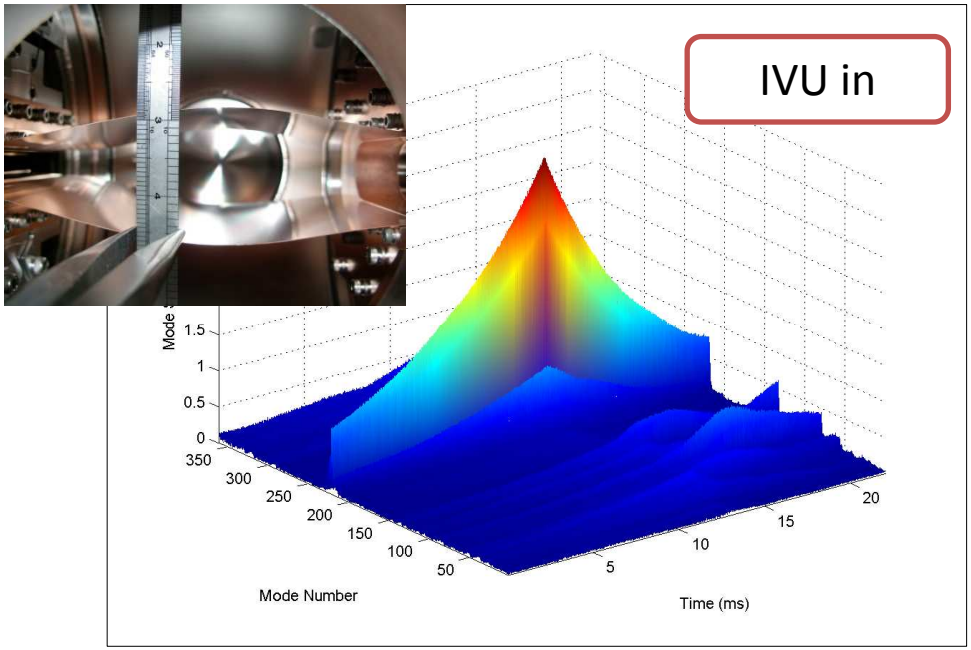




IVU Taper Problems?

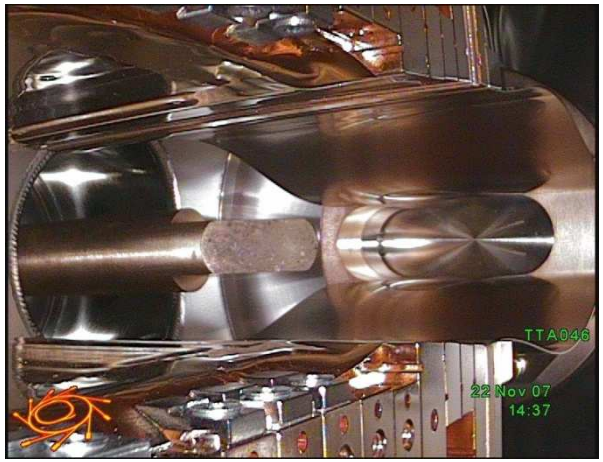
- Resistive wall low frequency mode
- Coupled bunch high frequency mode

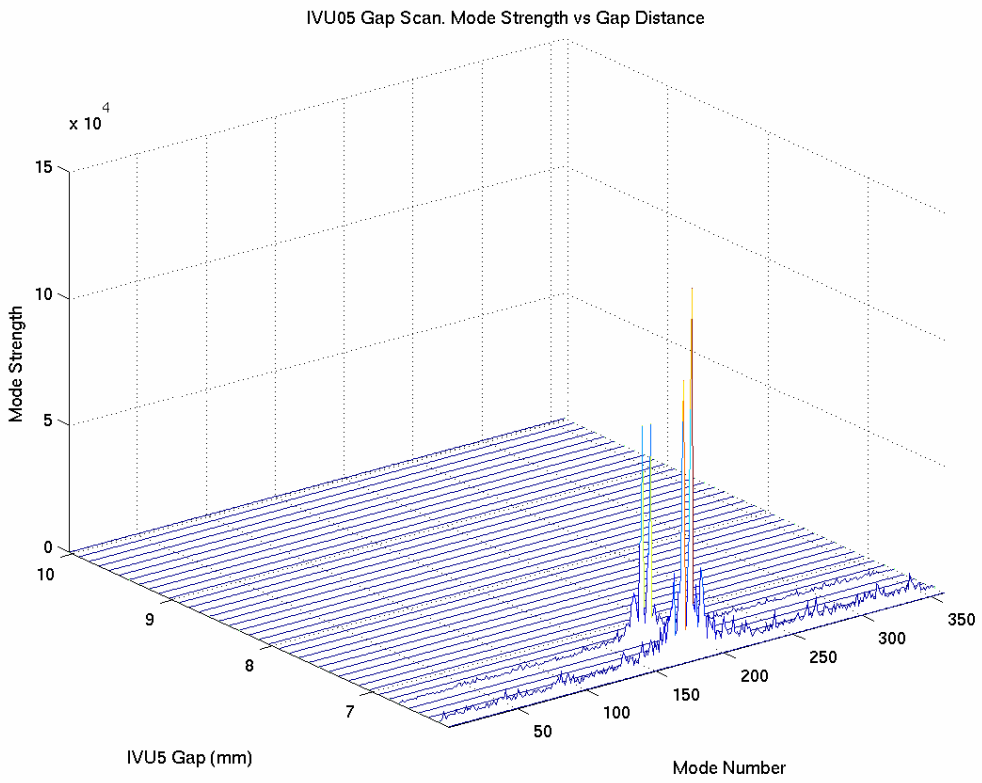




IVU Gap

- Min 6 mm full gap
- Very sensitive to In Vacuum Undulator gap
- +/- 10 μm gap can create instability
- High frequency resonator
- Trapped mode?





Summary

- Both loops closed during machine shifts.
- 100% lifetime increase (35 Hrs to 70 Hrs)
  - All IDs closed and low chromaticity (2/2)
  - >80% injection efficiency
- Bunch cleaning proof of principal (not currently required)

Further Work

- Change fill pattern to help damp narrow band instabilities generated by the IVUs.
- Harmonic sextupole optimisation.
- Single bunch tune measurement.
- Bunch cleaning.

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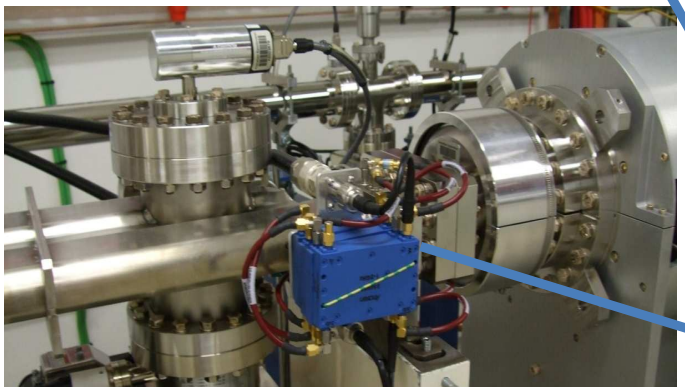

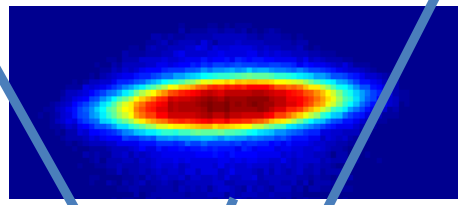

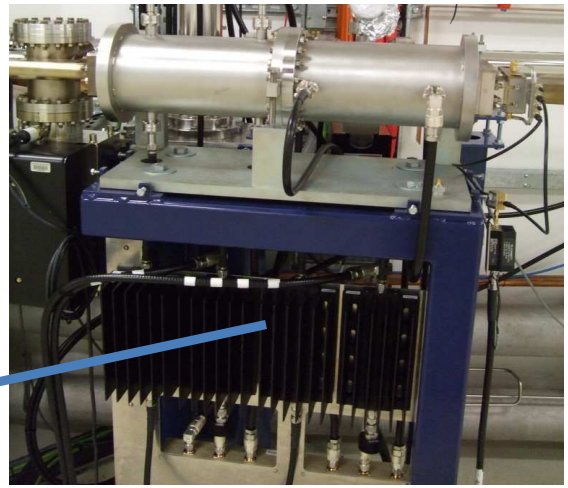

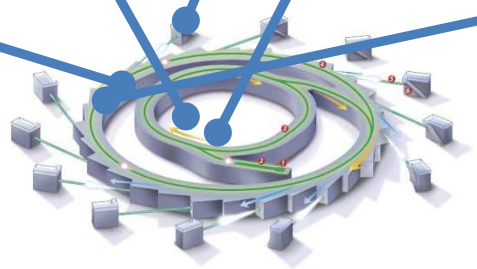

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Thank you