

Longitudinal Bunch-by-Bunch Feedback at DLS

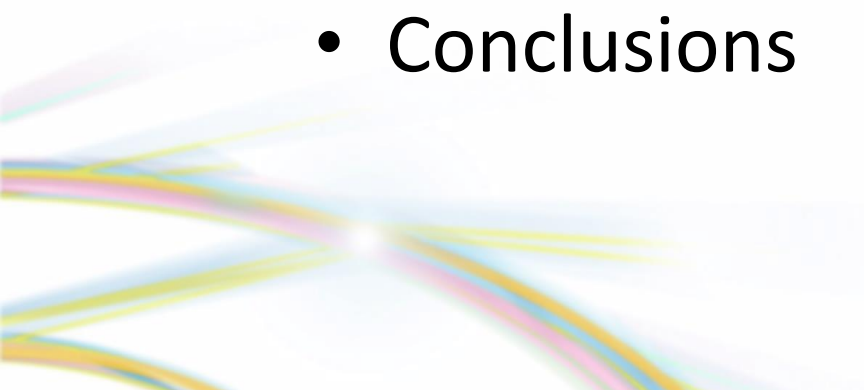
Guenther Rehm

Diamond Light Source

TWIICE2, 9 Feb 2016

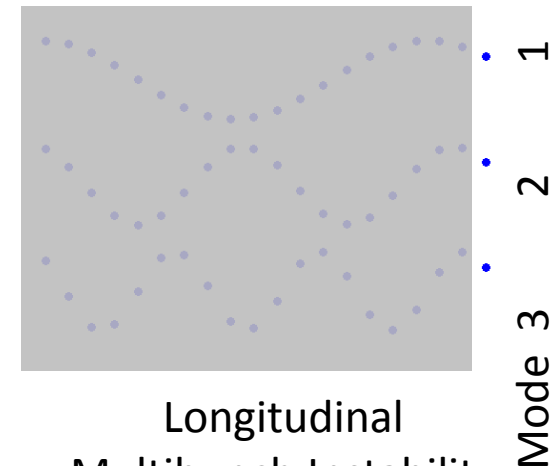


- Motivation
- System overview
- Kicker cavity
- Hardware
- Firmware / Software
- First results
- Conclusions

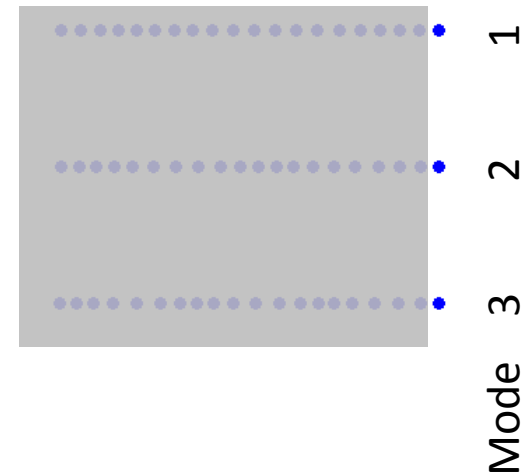


- A BbB feedback will add negative feedback at **betatron** or **synchrotron** oscillation frequency of each individual bunch.
- By doing so, it suppresses oscillations of **each** individual **bunch** and as a consequence also of **any mode** of oscillation of many or all bunches
- It is used to suppress **transverse** or **longitudinal** multi-bunch instabilities, which can be caused by wakefields or ion trapping

Transverse
Multibunch Instability

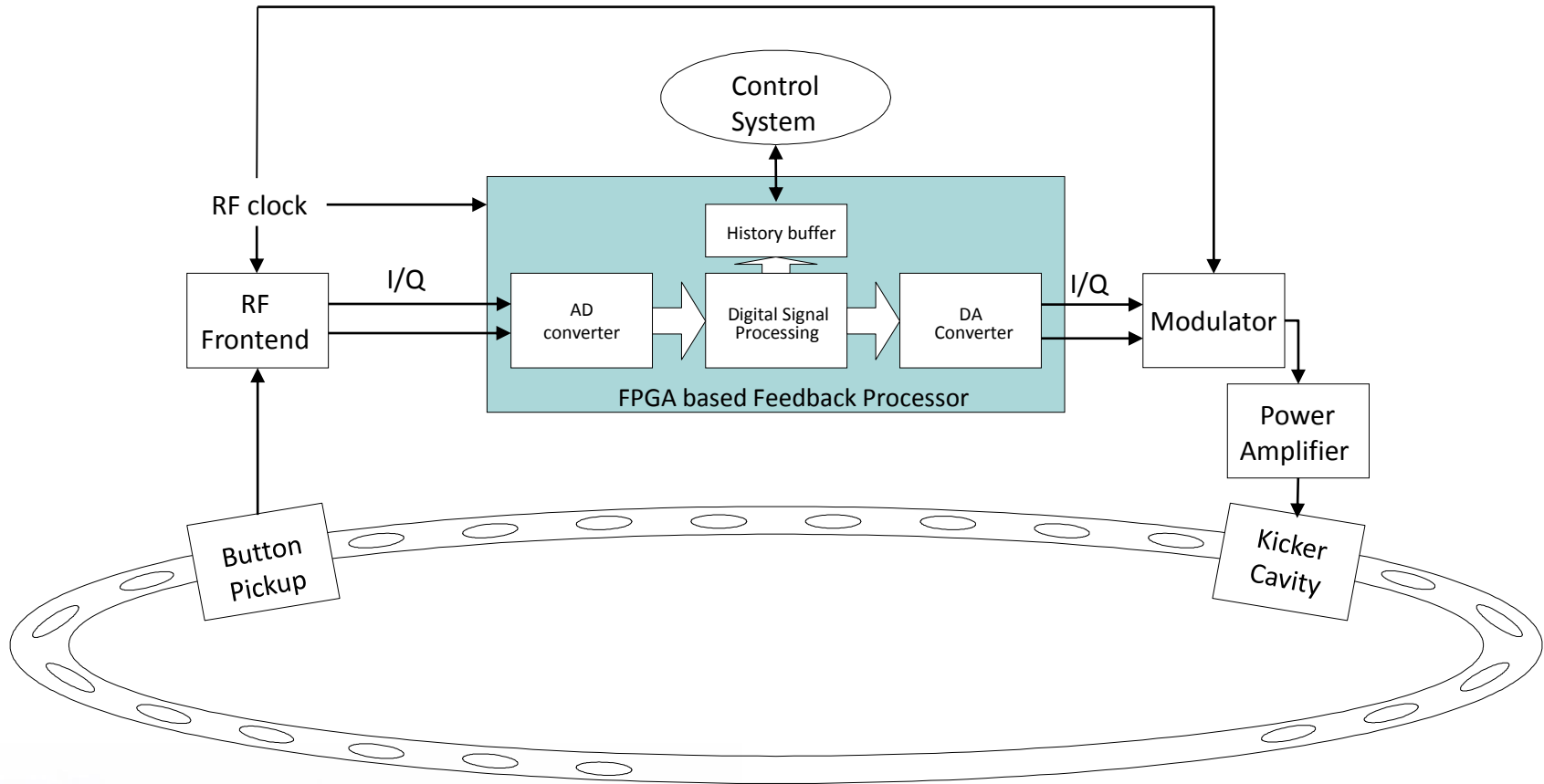


Longitudinal
Multibunch Instability



- Currently two SC cavities installed (Cornell type)
- Will add two NC cavities (HOM damped design) in Summer 2017
- BESSY 2, MLS, DELTA have these HOM damped NC cavities, still need longitudinal FB
- **Diamond needs longitudinal FB ready to operate before NC cavity installation to ensure operation at 300mA**

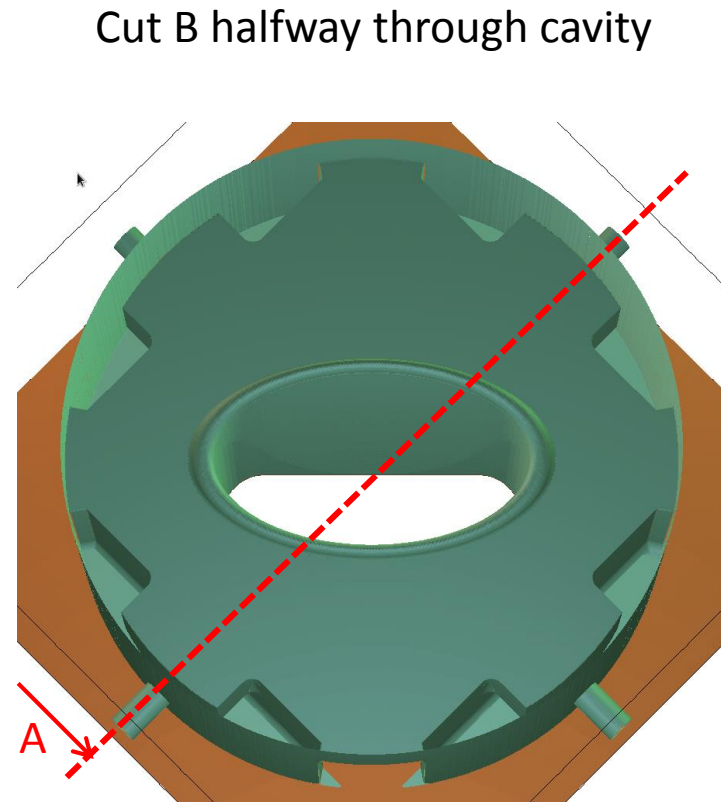
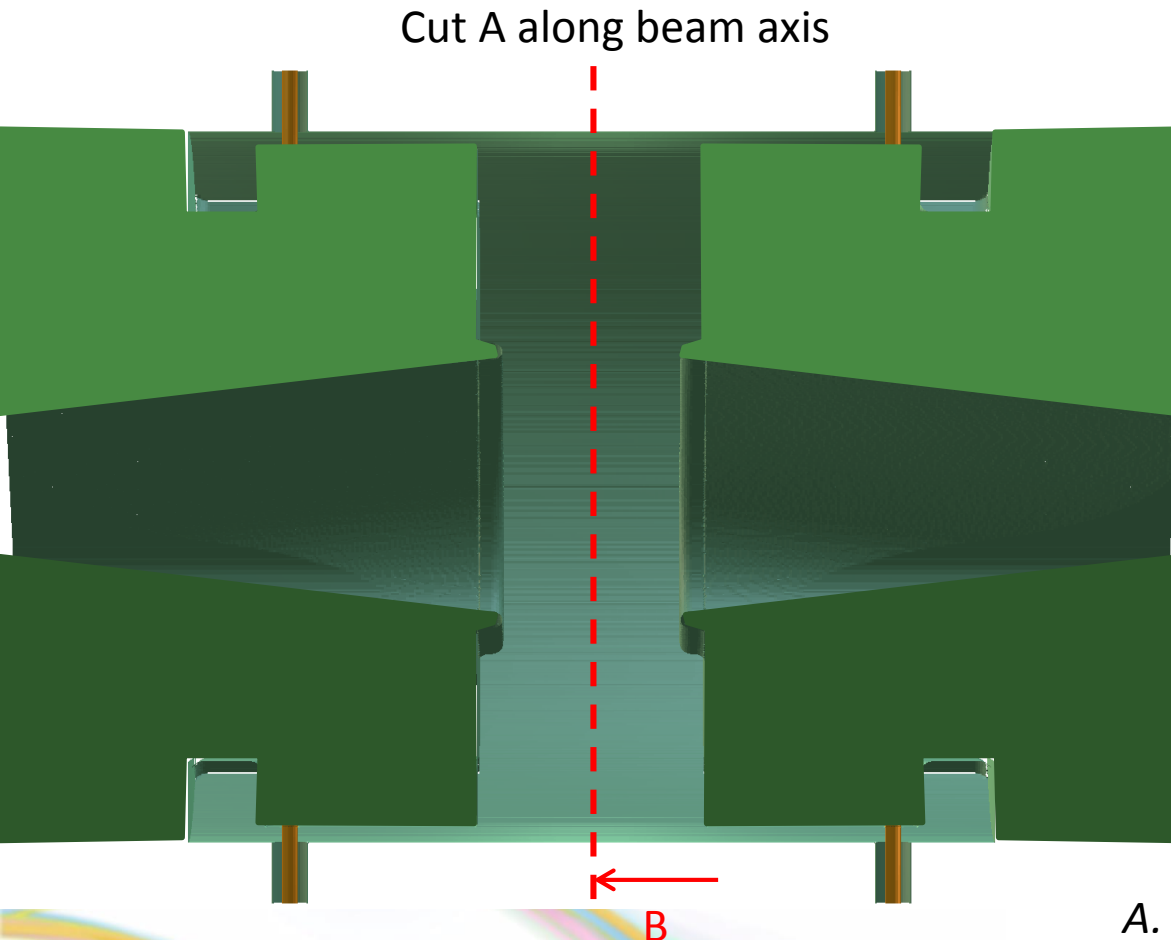




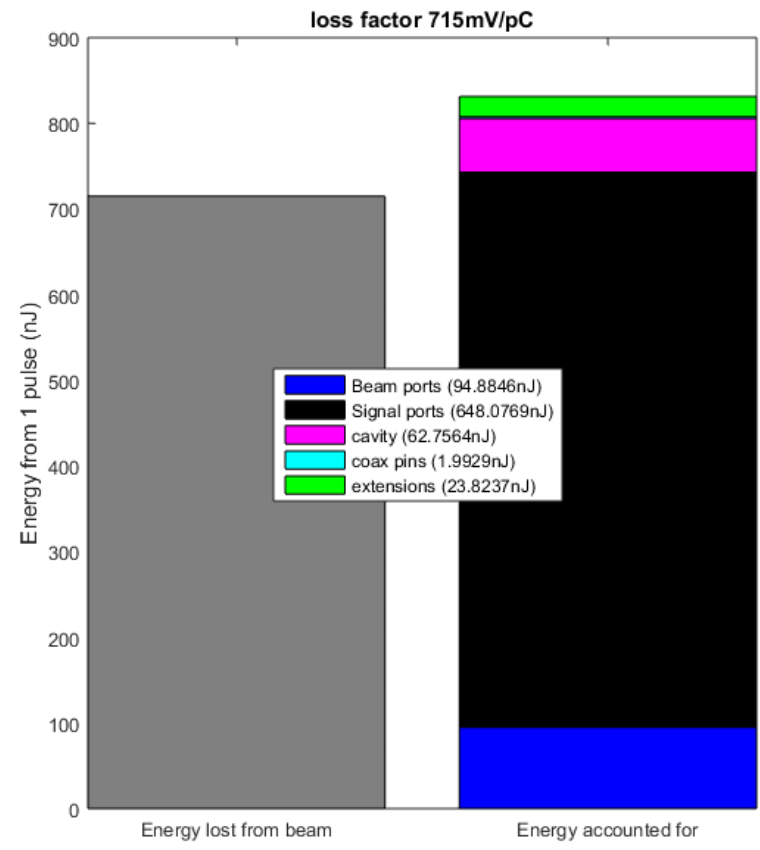
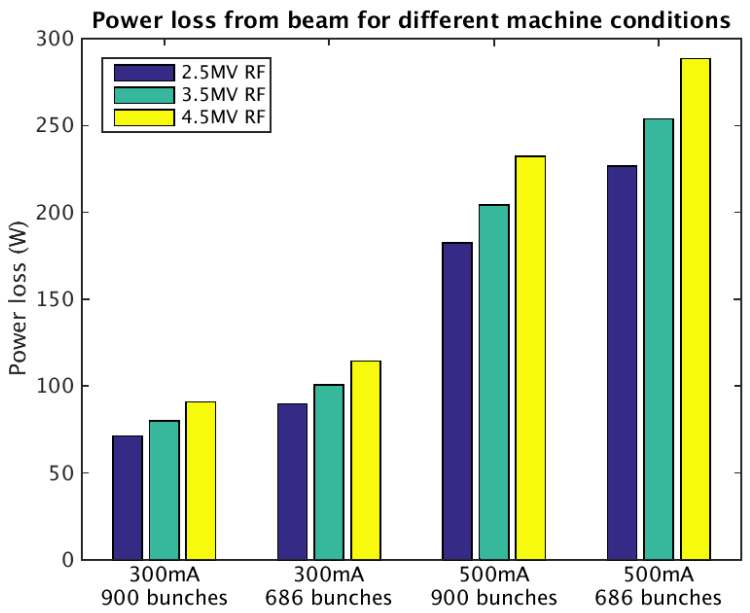
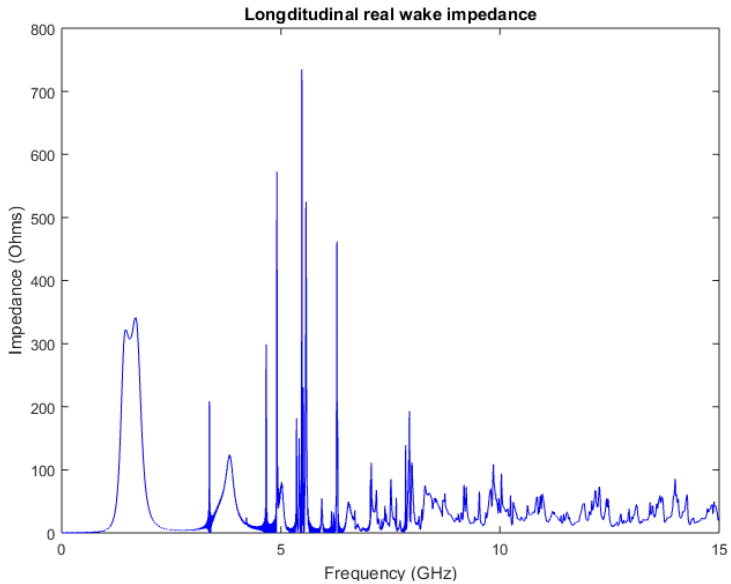
- A/D and D/A run synchronous to bunches, every bunch measured
- RF frontend can be shared with transverse feedback
- Different feedback parameters/actions for individual bunches possible

- Each bunch needs acting upon, typically only 2ns between bunches
- Each oscillation mode is associated with a frequency, these span **0-250 MHz bandwidth**
- All modes need to receive negative feedback:
 - **Phase response** of the whole loop over the whole bandwidth needs to be **flat to a few 10 degree**, otherwise driving some modes instead of damping
 - **Amplitude response** should be **flat to within 3dB**, otherwise very little damping for some modes

- Pillbox cavity with 8 ridged waveguide couplers following DAPHNE, SLS/Elletra, BESSY, LCLS tradition
- Need to taper to race track cross section of adjacent vessels



A. Morgan, Proc. of IBIC15, MOPB064



A. Morgan, Proc. of IBIC15, MOPB065

- Hybrids for ABCD to XY processing:
 - ABCD digitisation as in EBPMs would just be a burden
 - Scaling of X/Y with bunch charge is not an issue, in fact it provides automatically more gain at higher stored current
 - Handling of large ABCD to look at the differences is not good for S/N
- Keep RF frontend:
 - 250 MHz bandwidth requires this as undersampling would deteriorate S/N too much
- Use I/Q mixing rather than synchronous mixer
 - Process I/Q all the way through digital processor to I/Q modulator

Embedded	Modular
Extremely compact (1/2 size 1U)	Compact 2U
Fixed ADC/DAC	Choice of ADC/DAC through FMC
Fixed FPGA size	Choice of FPGA through carrier
Fixed CPU	Choice of CPU through crate / module
Standalone	Crate could house several channels
One specific use	Adaptable use
All built for one purpose with system performance in mind	Combination of modules with reliance on standardised interfaces
<u>Significant</u> development cost/time	Available 'off the shelf'



- Innovative Integration FMC-500
- Two A/D, 500MS/s, 14 bit, DC coupled
- Two D/A, 1230MS/s, 16 bit, DC coupled
- External sample clock
- Timing chip for sample alignment

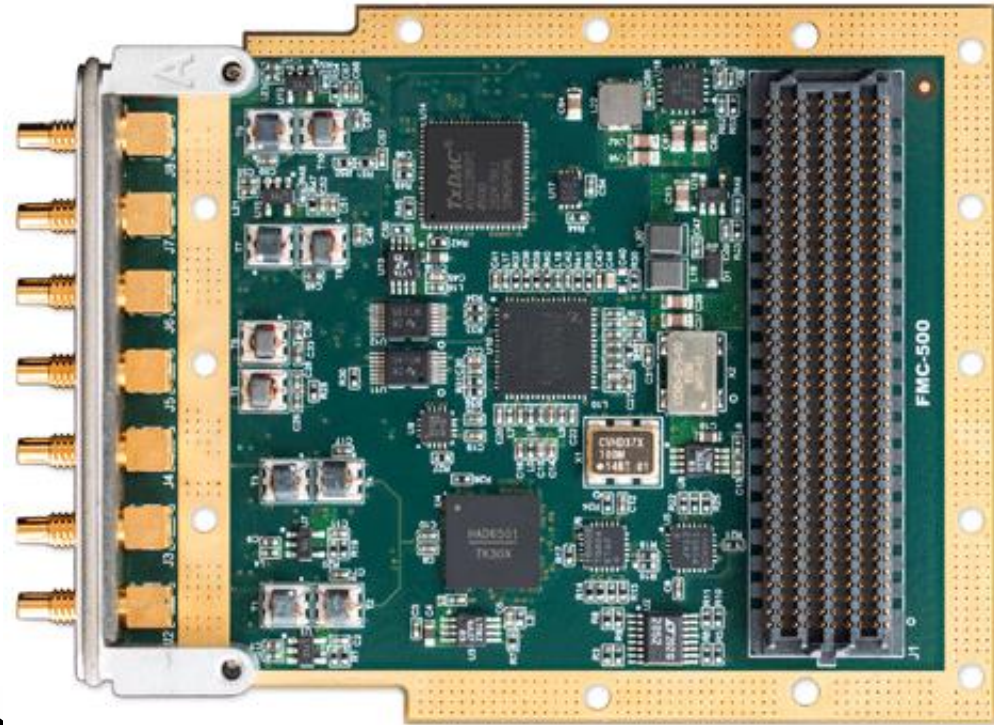


Image courtesy of Innovative Integration

- Vadatech AMC 525
- Xilinx Virtex-7 690T
3600 DSP blocks
- Quad-core 1.2GHz CPU
- 2GB DDR3 RAM
- Dual High Pin Count
FMC sites

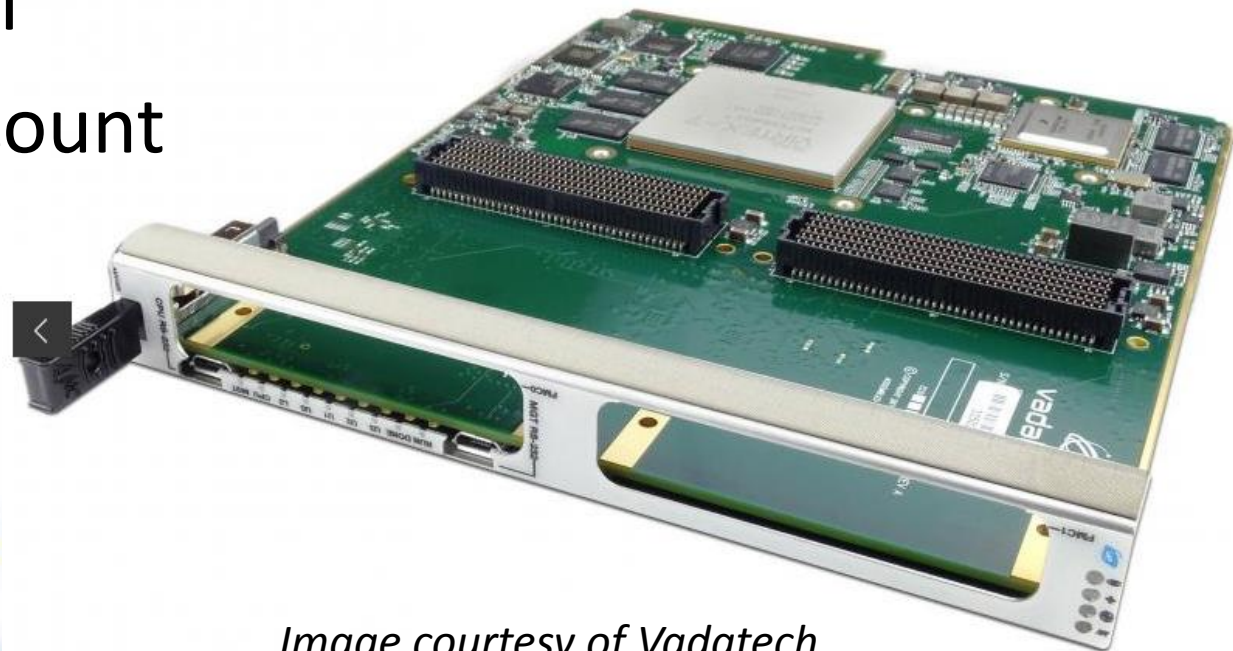
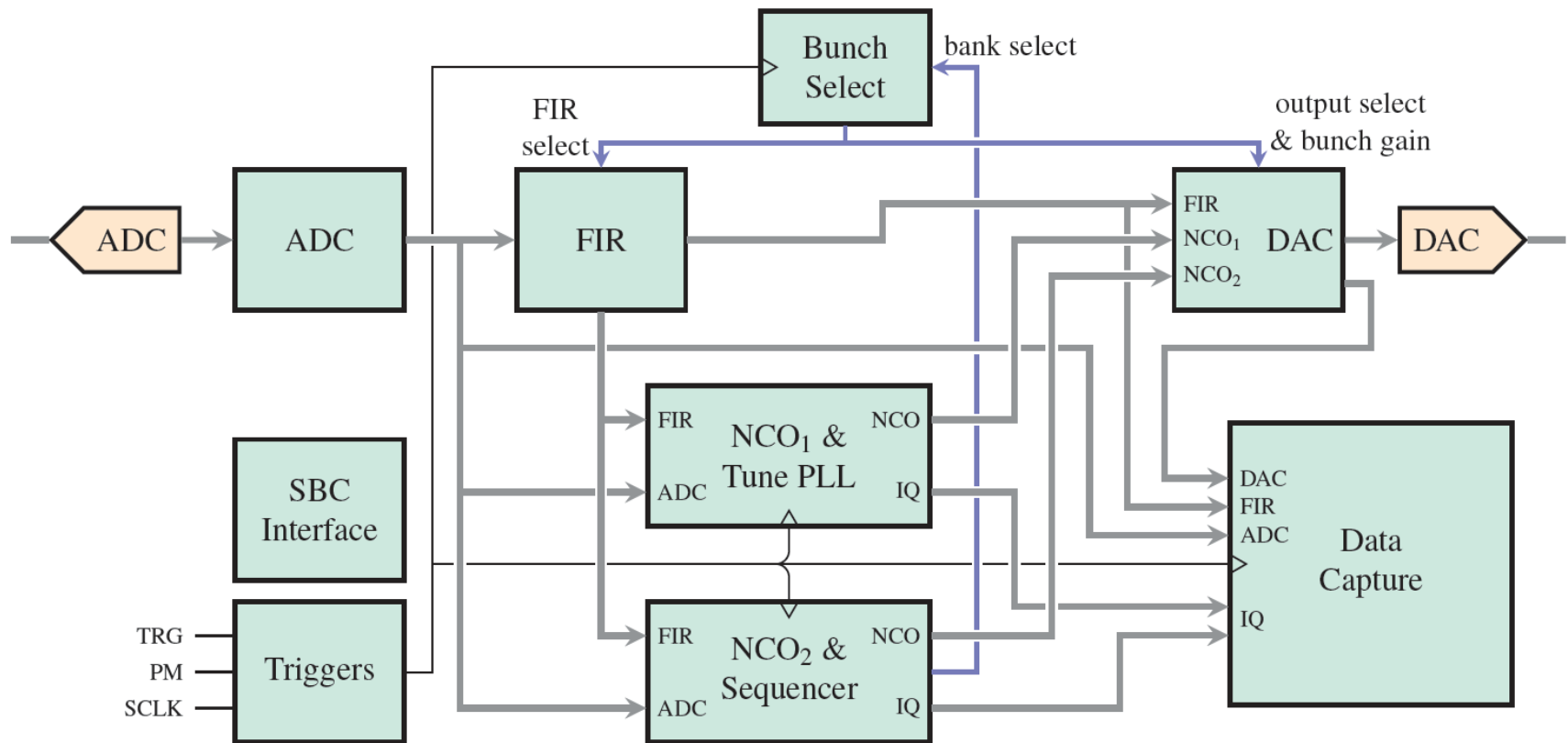


Image courtesy of Vadatech

- Vadatech VT814
- Redundant power supplies, fans
- PCIe and GBE on backplane
- Room for 5 FPGA carriers
- CPU card AMC720
4 core Xeon 2 GHz, 32GB RAM



- In-house developed firmware in VHDL will be ported from TMBF to new hardware

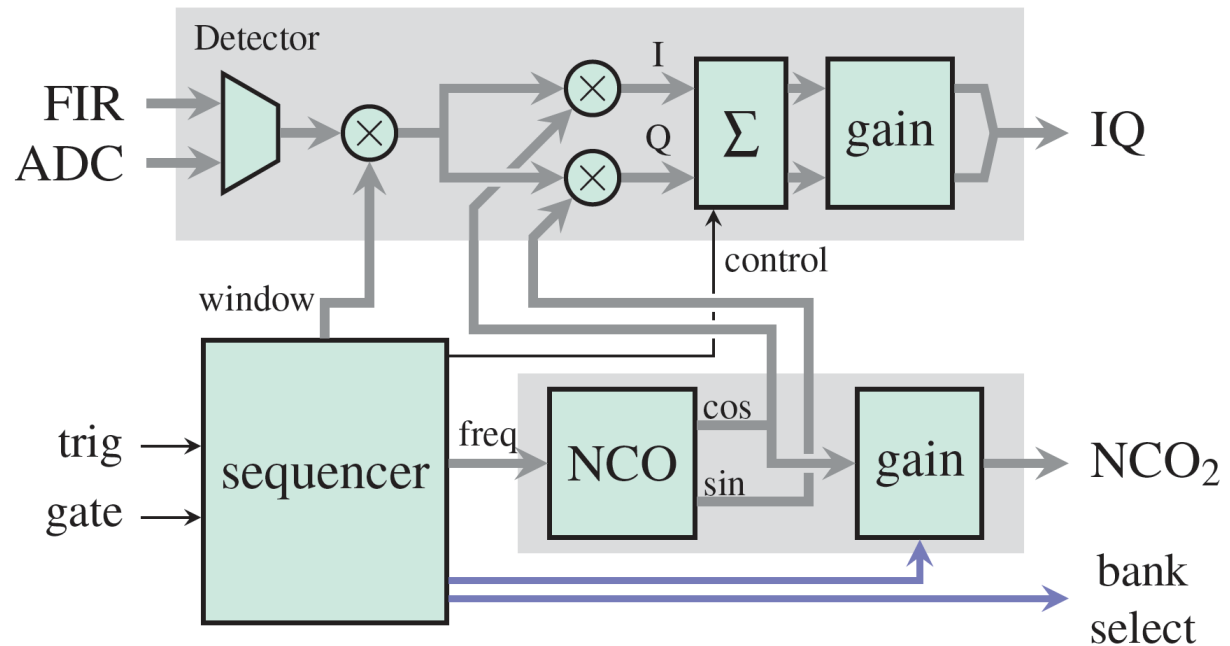


M. Abbott, Proc. of ICALEPCS15, MOPGF097

- Besides the fundamental task of B-b-B feedback the power for the FPGA offers lots of other opportunities:
 - BbB observation to assess motion in any mode (250 MHz instantaneous bandwidth spectrum analyser)
 - BbB manipulation:
 - Exciting bunch with small oscillation for measurement of tunes
 - Exciting bunches with large oscillation for bunch clearing
 - Different feedbacks / actions for different bunches at different times
 - Mode by Mode manipulation:
 - Excite individual modes and observe natural and forced damping
 - Different feedback for different modes (idea for future!)
- All this requires FPGA/memory/network resources

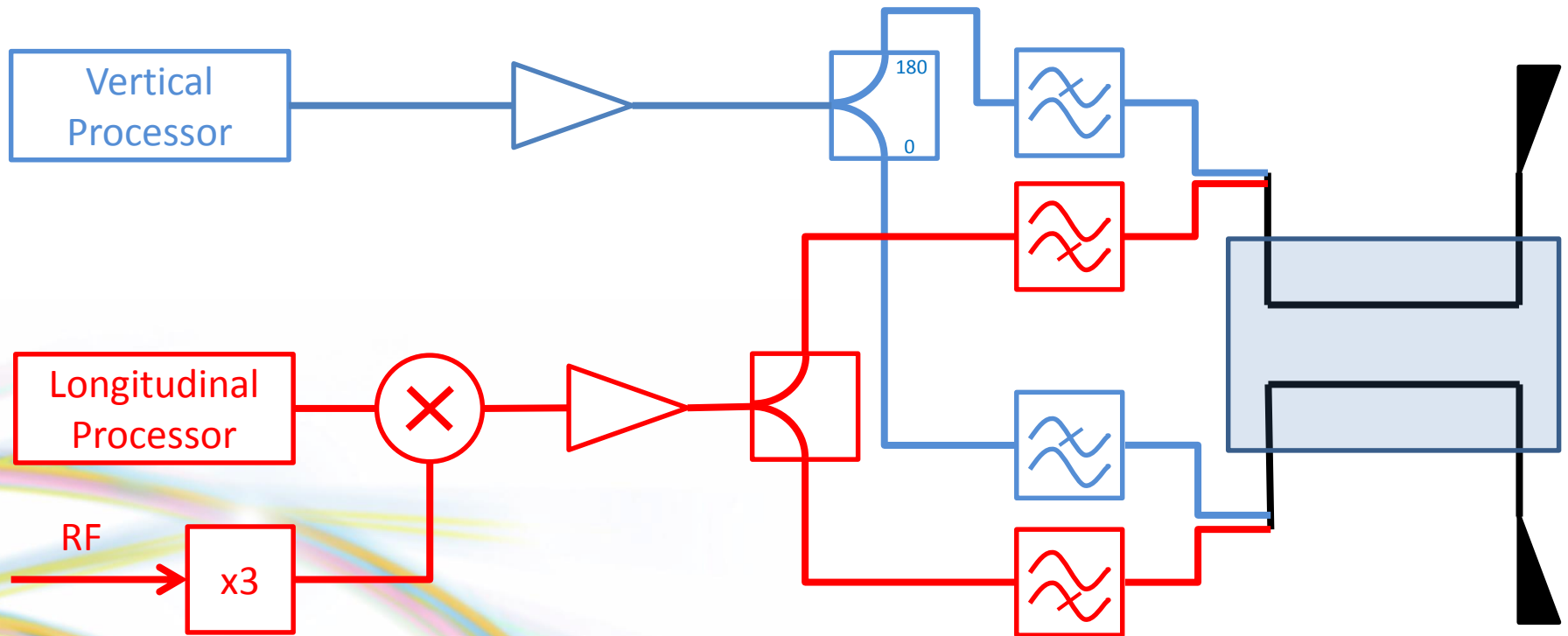
Detector and Sequencer

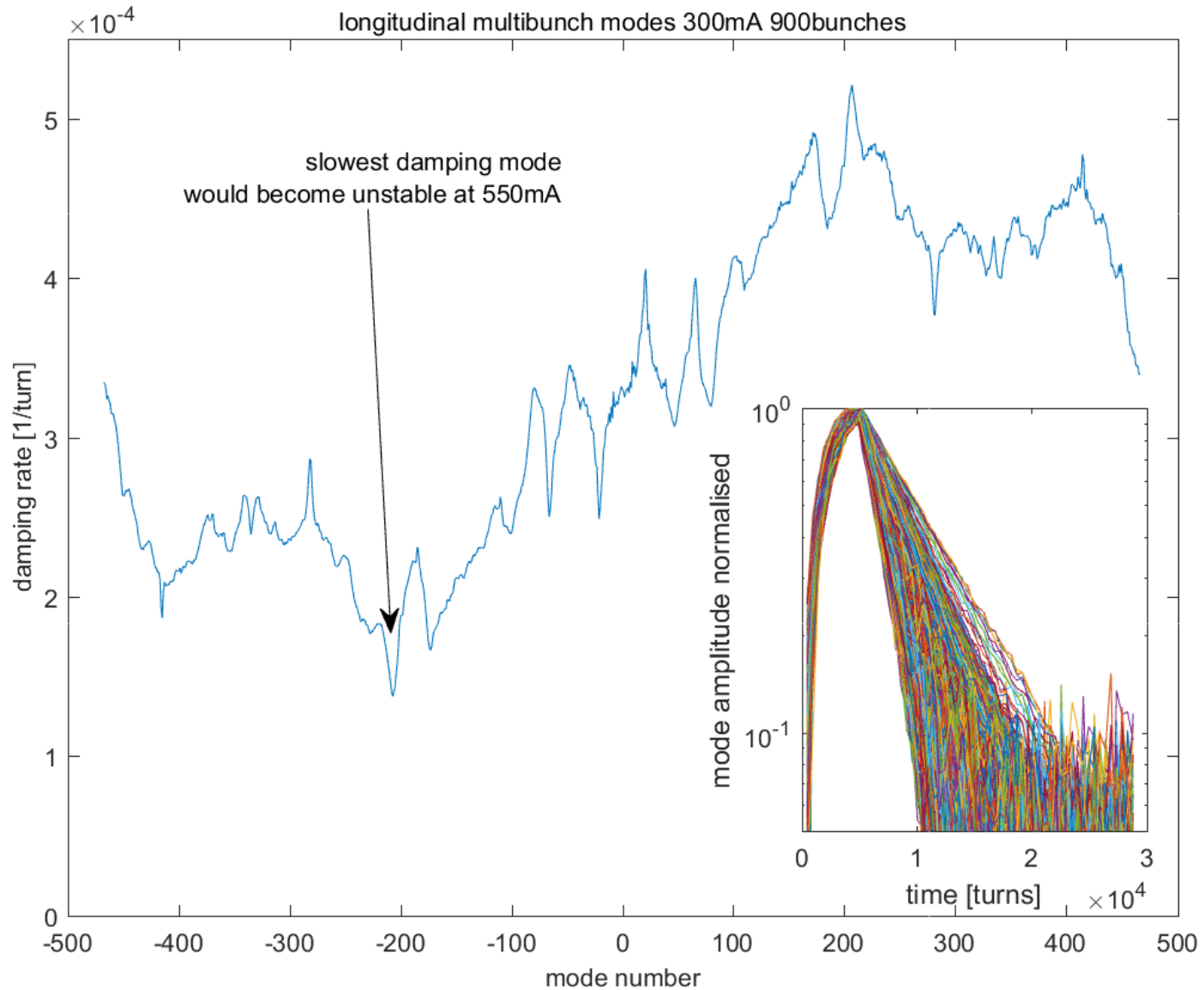
- Numerical oscillator is controlled by sequencer that can produce sweeps, drive/grow/damp, mode-by-mode
- Bunch data is analysed by Detector to reduce a configurable number of turns into mode amplitudes
- This allows measuring drive/grow/damp on all modes within seconds



M. Abbott, Proc. of ICALEPCS15, MOPGF097

- Transverse kicks at baseband (0-250MHz) in differential mode
- Longitudinal kicks upconverted to $3 \times \text{RF}$ in common mode
- Diplexers combine signals to allow concurrent use as vertical and longitudinal kicker





- Diamond will install a longitudinal BbB feedback by early 2017 to ensure continued operation at 300mA with NC cavities
- System will be based on MTCA technology with firmware/software ported from existing TMBF
- Preliminary investigations using vertical stripline as longitudinal kicker show clear impact of longitudinal impedance
- Mode-by-mode drive/damp experiments are key to characterising stability margin of all modes

- DLS: Alun Morgan, Michael Abbott, Isa Uzun
- Micha Dehler (SLS)
- Eric Plouviez (ESRF)
- Dmitry Teytelman (Dimtel)

