FLASH Future studies

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28 September 2011

LCWS 2011 - Granada

Wrap-up slide from Tuesday's talk…

- **Should be in good shape with respect to TD Phase Goals**

- **One or two blocks of studies in 2012 (for 'filling the gaps')**
  – Almost certainly we will not have reached operation with every one of the criteria being met at the same time
  – Develop a risk register of key TDP issues requiring beam studies
  – Any gaps remaining at the end of 2012 will be addressed for the TDR through simulations and extrapolation of results
- **The urgent-most items for studies blocks in 2012**
  1. Establish a 'boot-strapping' methodology for high gradient operation
  2. Operation close to quench with progressively higher beam loading
  3. Operation with different bunch lengths for absorber studies

- **The System Tests program will continue beyond 2012**

Short term (2012): Facility access

- **FLASH (dedicated 9mA studies time)**
  - Request to FLASH mgmt: 1wk in Spring + 1wk in Autumn
- **FLASH (participate in FEL studies)**
  - FEL studies blocks for FEL user setup and machine development are scheduled every ~2 months
- **NML (RF only studies)**
  - Studies access on CM1 is possible now till end of 2011
  - Studies access on CM2 starting around mid 2012…

Longer term…

- **FLASH will remain the focus of the beam test program**
  - The only facility capable of beam tests until after the end of 2012
  - The only facility capable of beam tests with >1 RF unit until ~2014
- **Beam tests will begin at NML, STF, and EU-XFEL as they become available for beam studies (2012-2014)**
- **Fundamentally, the aim of the beam test program will be to establish routine operation of an RF Unit at ILC-like design parameters and to mitigate associated risk**
- **Key issue (Main Linac cost driver): effective usable gradient**

Short-term (2012): Studies focus and priorities

- **FLASH (dedicated studies – initially at 6mA)**
  - Boot-strapping methodology to reach high gradient/current
  - Operation close to quench with heavy beam loading
  - Operation with different bunch lengths for absorber studies
  - (Maybe) operation at 9mA (must be done in 'bypass' mode)

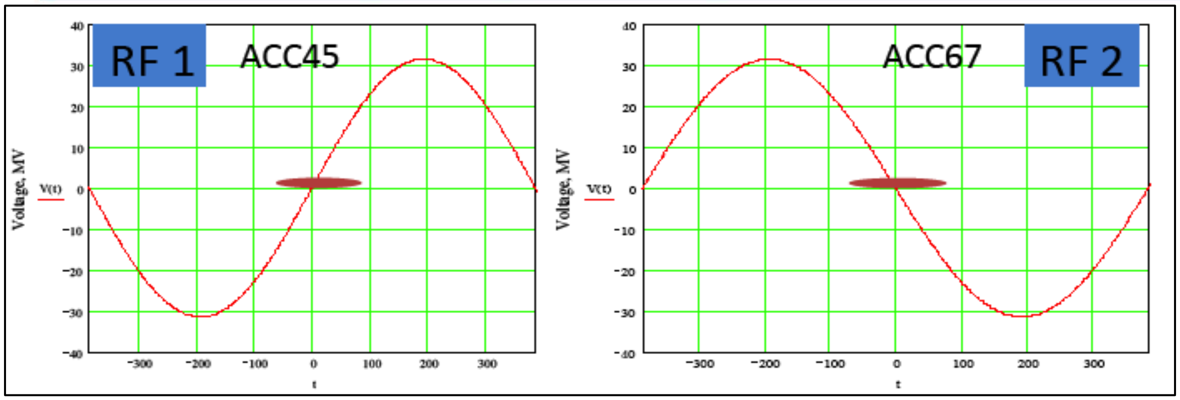
- **FLASH (FEL studies)**
  - Several overlapping interests between ILC/TDP and FEL studies, eg back-phasing ACC45 / ACC67 and long bunch-train setup/optimization

- **NML (RF only studies to complement FLASH beam studies)**
  - Develop procedures for automated Pseudo-Pk/Ql optimization
  - Develop bootstrap methodologies for reaching full current / gradient
  - Piezo tuner studies for optimizing gradient flatness

Proposal to test zero-crossing stability for RTML (Also interesting for fast energy changes for FEL)

Two RF systems

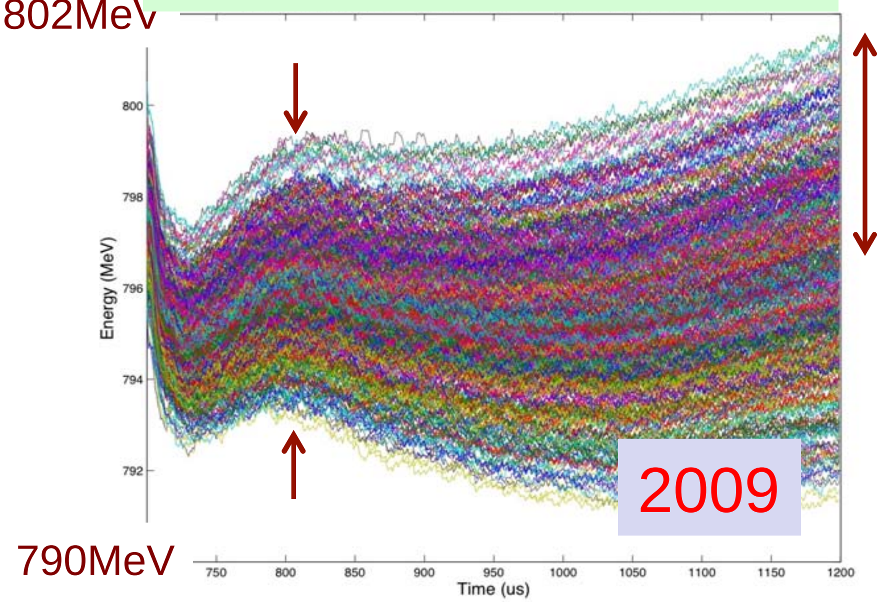
Schematic of the bunch jitter compensation. The two RF modules RF1 and RF2 are operating in counter-phase near the zero crossing.



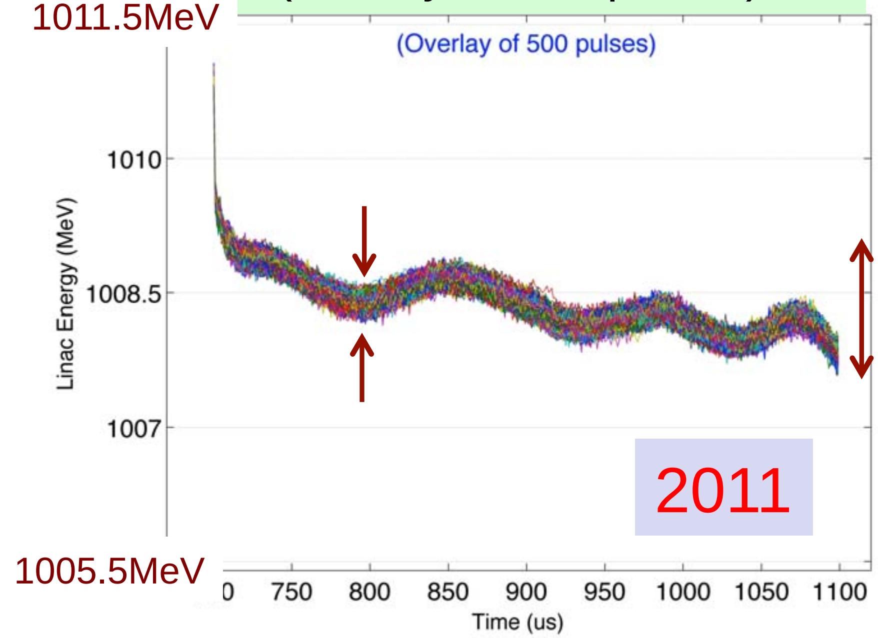
- Allows to evaluate two systems with respect to each other – just like we need for the electron and positron BC's
- If two RF systems are running at equal amplitudes and 180° apart, the correlated energy spread and bunch arrival jitter are mostly canceled
- The phase jitter of one system with respect to another will show up as energy jitter in the beam.
- Use energy spectrometer to measure the beam energy jitter.

Improved energy stability for 9mA studies: Sept 2009 to Feb 2011

Linac energy (3mA, 500us)
(overlay of 200 pulses)



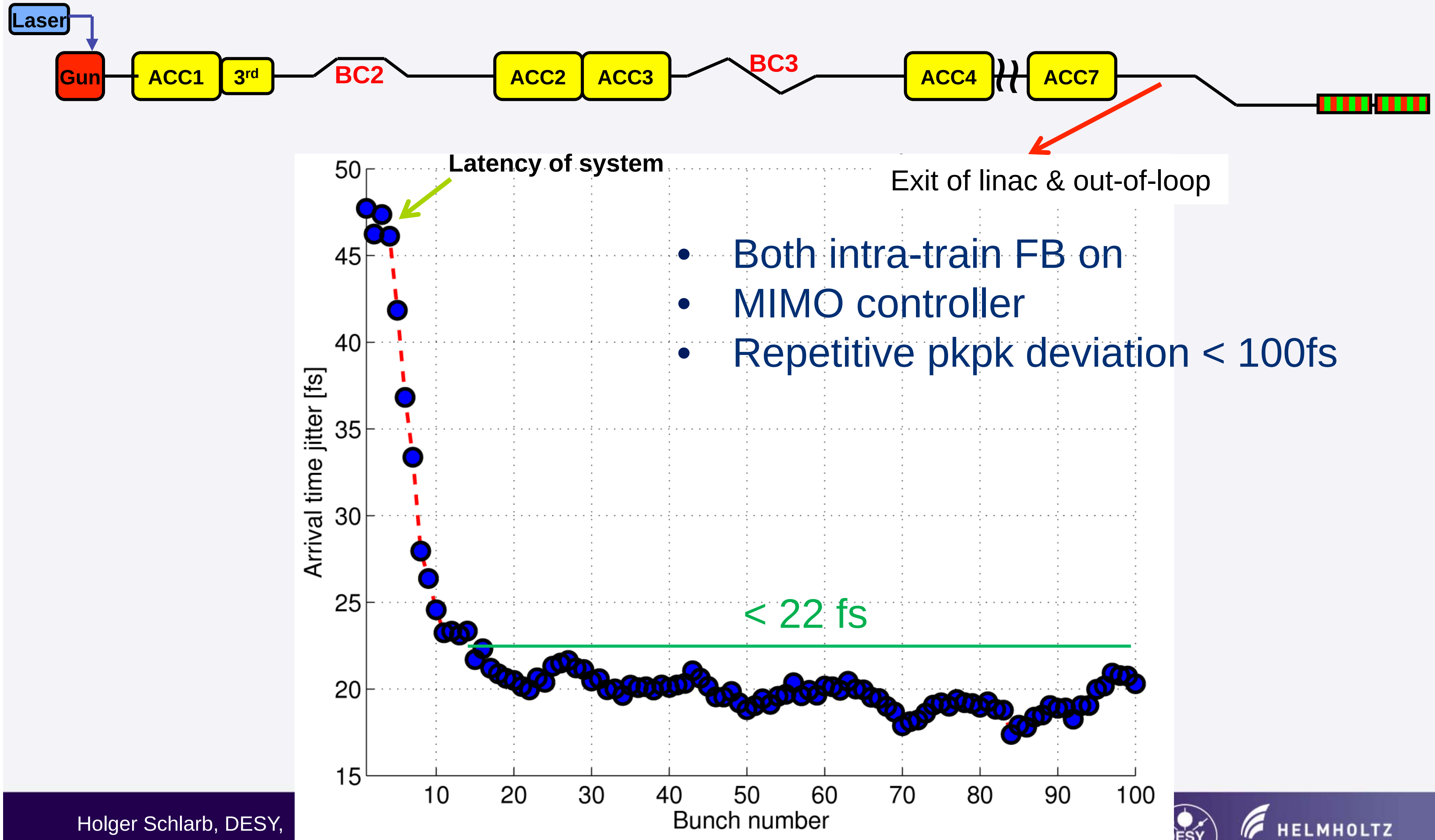
Linac energy (4.3mA, 400us)
(overlay of 500 pulses)



Delta-E over bunch-train: ~5MeV
Pulse-to-pulse jitter (p-p): ~4MeV

Delta-E over bunch-train: ~1.5MeV
Pulse-to-pulse jitter (p-p): ~0.4MeV

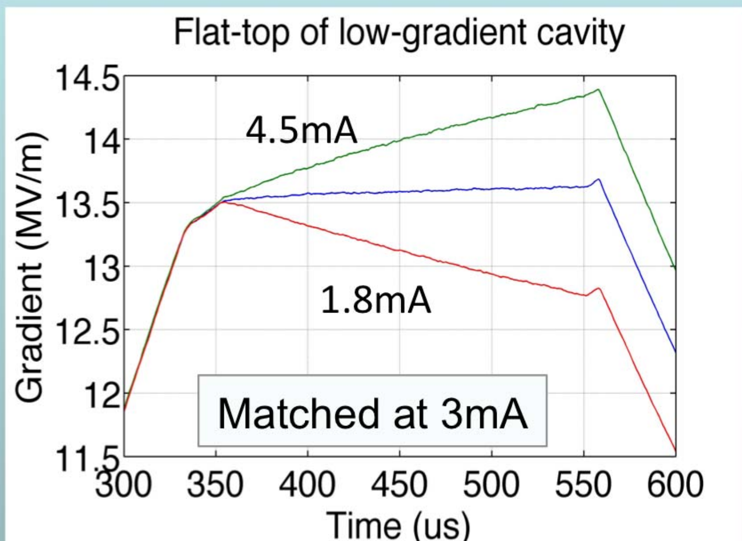
FLASH results: Beam base FB (with MIMO & LFF)



- Both intra-train FB on
- MIMO controller
- Repetitive pkpk deviation < 100fs

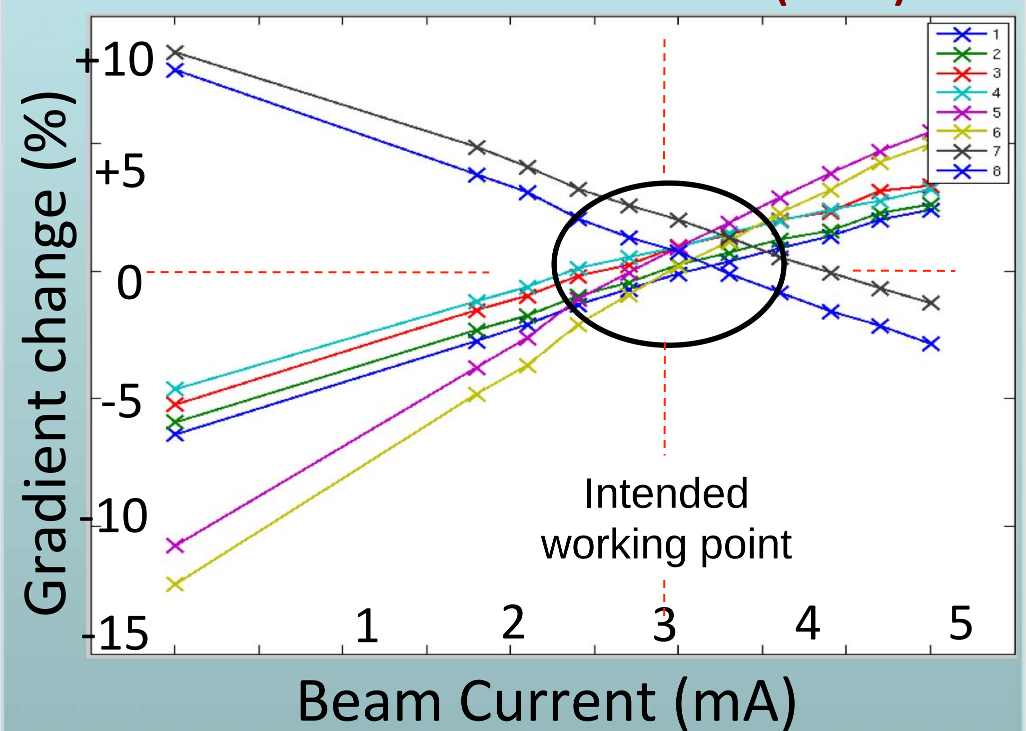
Bounding sources of errors from beam current scans (Example of match at 3mA)

As the beam current is scanned, the tilt changes from negative to positive. At some current, the cavity tilt is zero

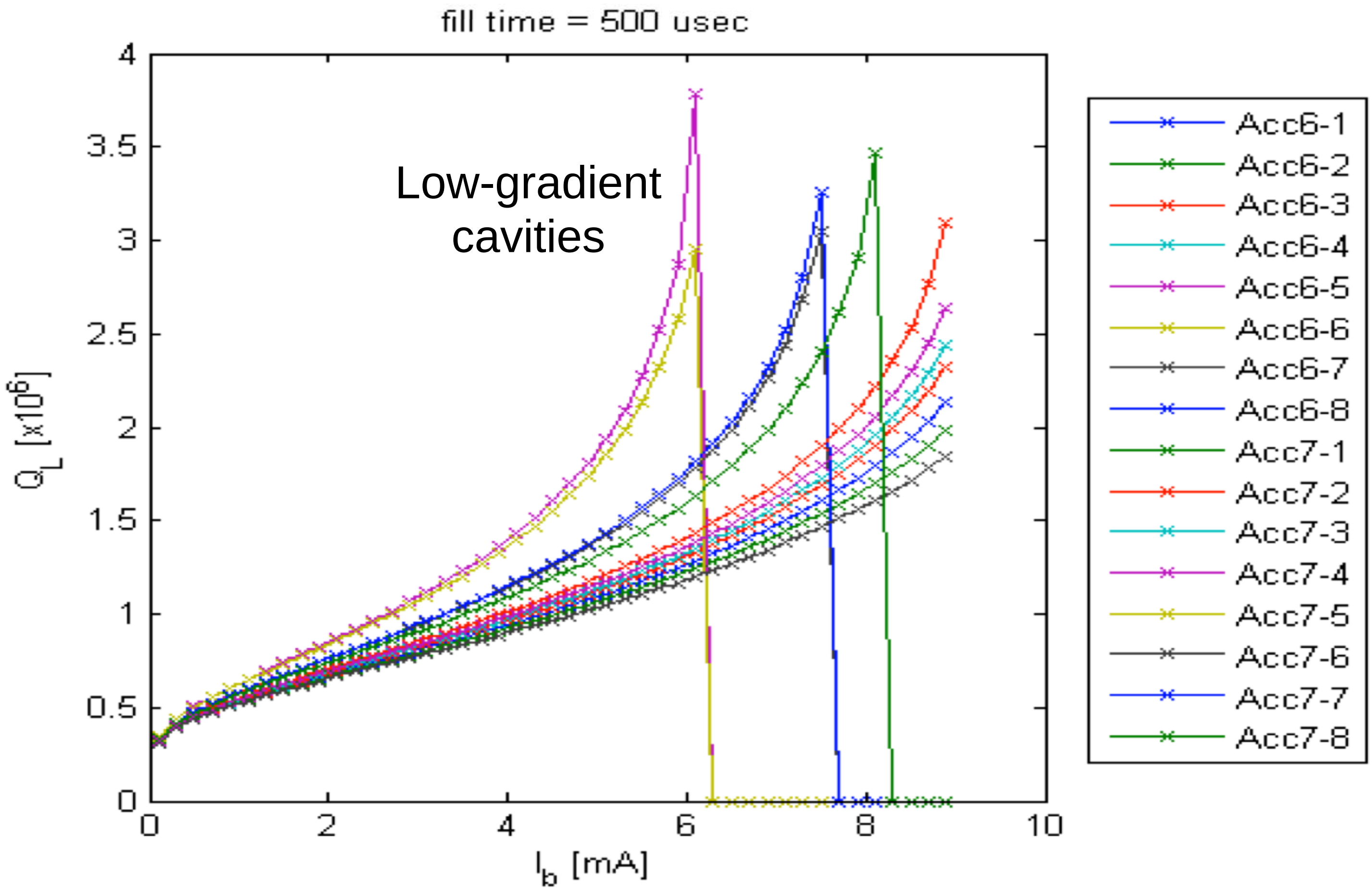


Should get insight into sources of error from the discrepancies in the currents where cavity gradient tilts were zero

Gradient Tilts vs Beam Current (ACC7)

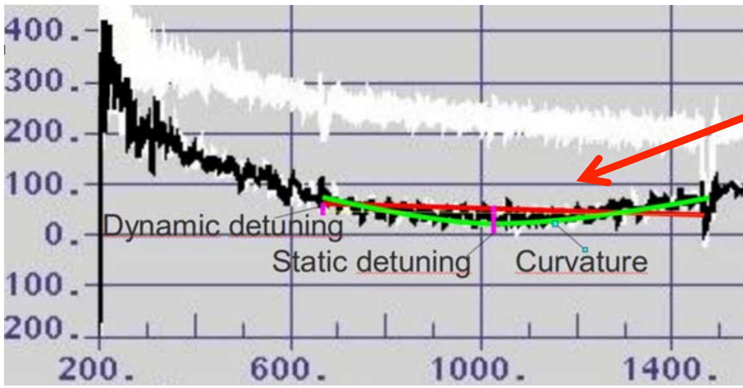


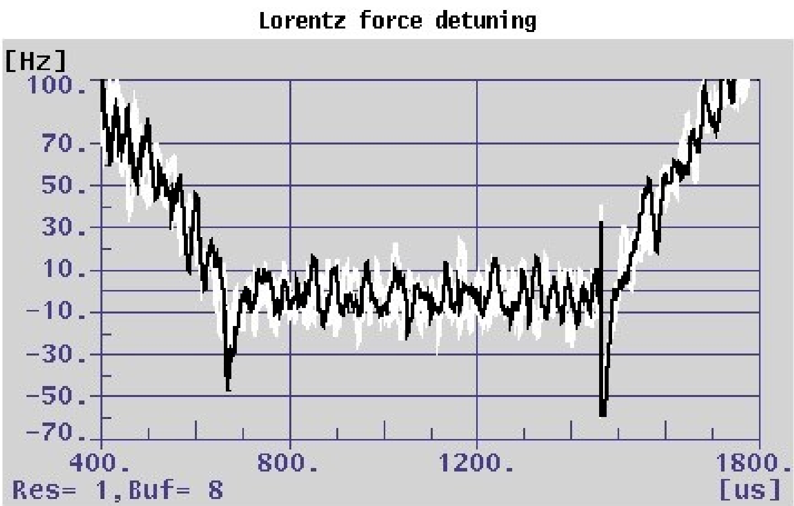
Limited range of Loaded-Q 'solution sets' to achieve flat gradients



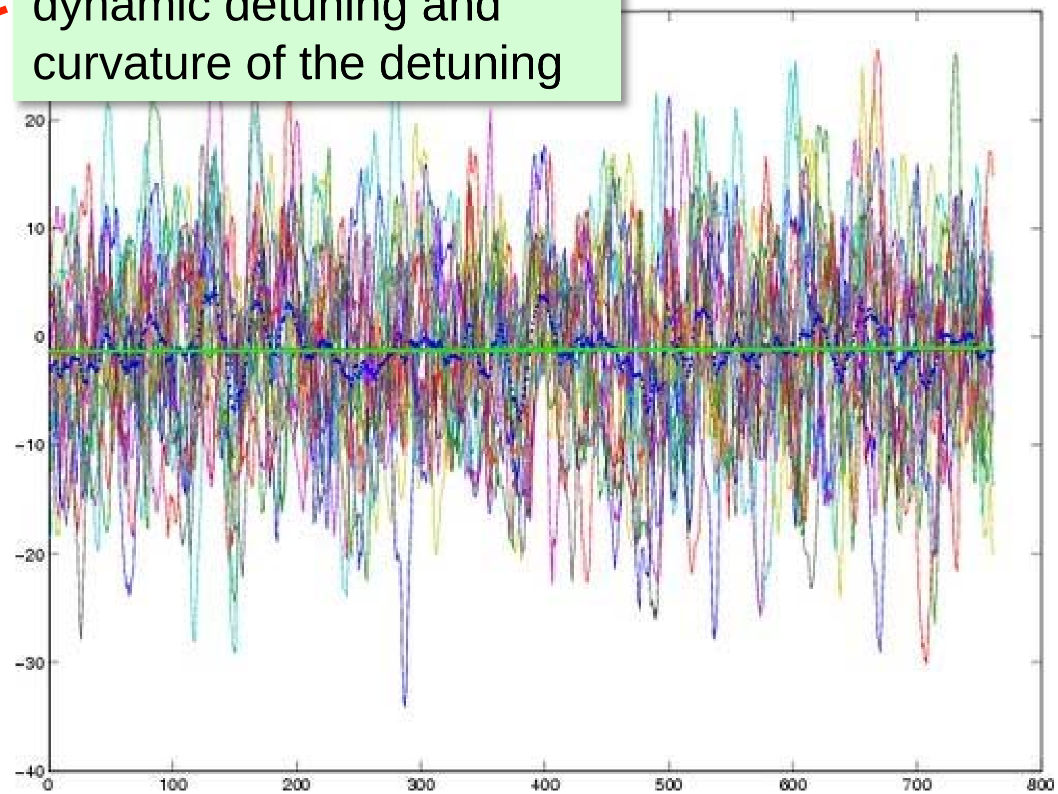
- **Because of the wide gradient spread and fixed Pks, there are no 'flat-gradient' solutions above 6mA for all cavities**

Detuning compensation result





Optimization of static & dynamic detuning and curvature of the detuning



c1@acc6: measured over 20 pulses. The achieved parameters: dynamic detuning 0.3190Hz static detuning: -1.1760Hz, curvature: 0.1774 a.u. (linear and quadratic approximation covers in the picture). Settings for the piezo: 200Hz, 1 pulse, 19.12ms after A2, amp=-23.06V, DC off=-36.62V

Detuning measurements with beam

$$\Delta\omega = \frac{d}{dt}\varphi_c + 2\omega_{1/2}\frac{|V_{for}|}{V_c}\sin(\varphi_{for} - \varphi_c) + 2\omega_{1/2}\frac{|V_b|}{V_c}\cos(\varphi_b - \varphi_c)$$

$\Delta\omega - detuning$,

$V_c, \varphi_c -$ *field amplitude and phase* ,

$\omega_{1/2} -$ *cavity bandwidth*

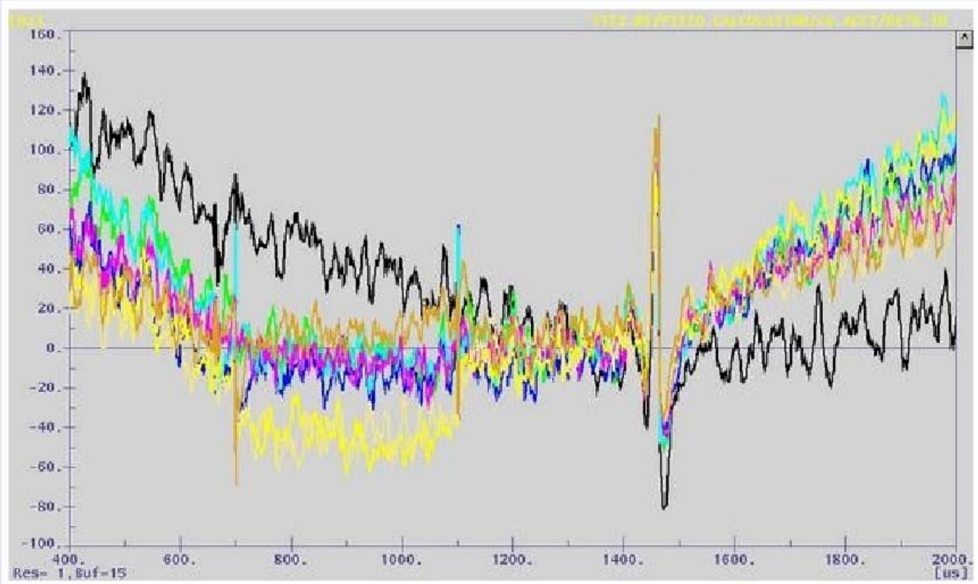
$V_b, \varphi_b -$ *beam induced voltage amplitude and phase*

$$V_b = 2\omega_{1/2} q_b R_L = C_b I_b$$

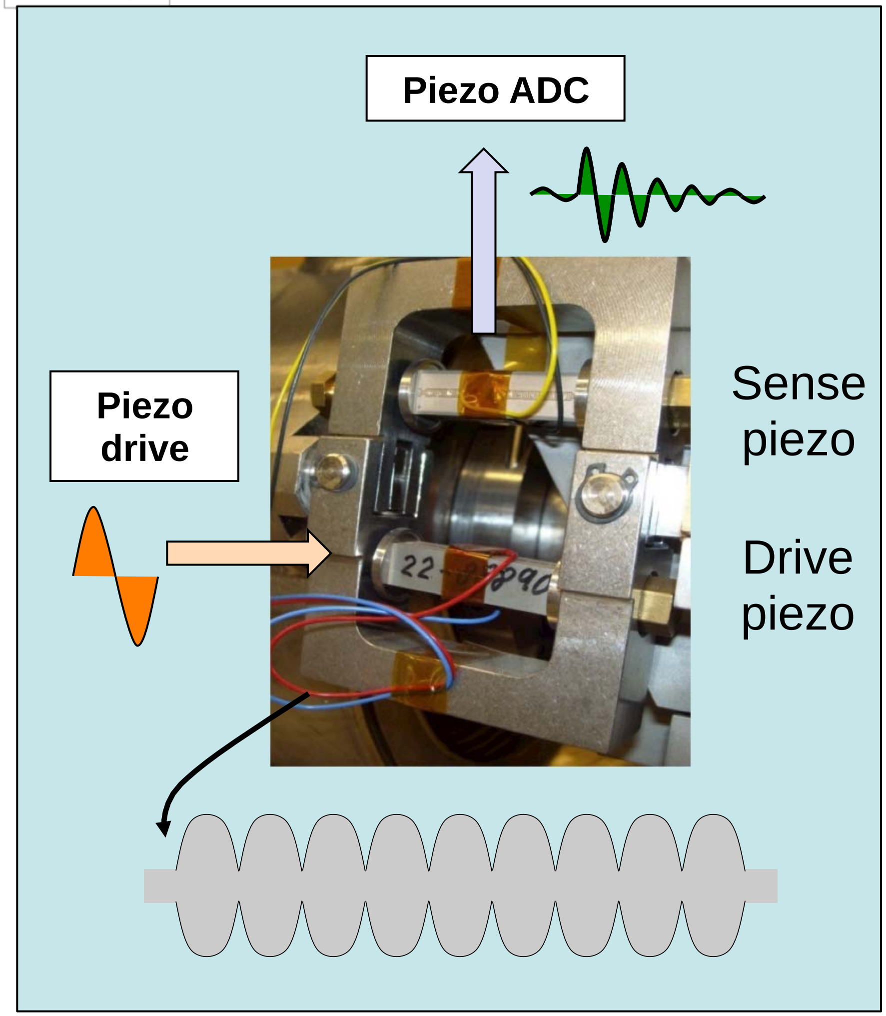
$C_b -$ *calibration factor*

$I_b -$ *beam current*

(*measured at toroid*)



Two-piezo configuration in ACC67



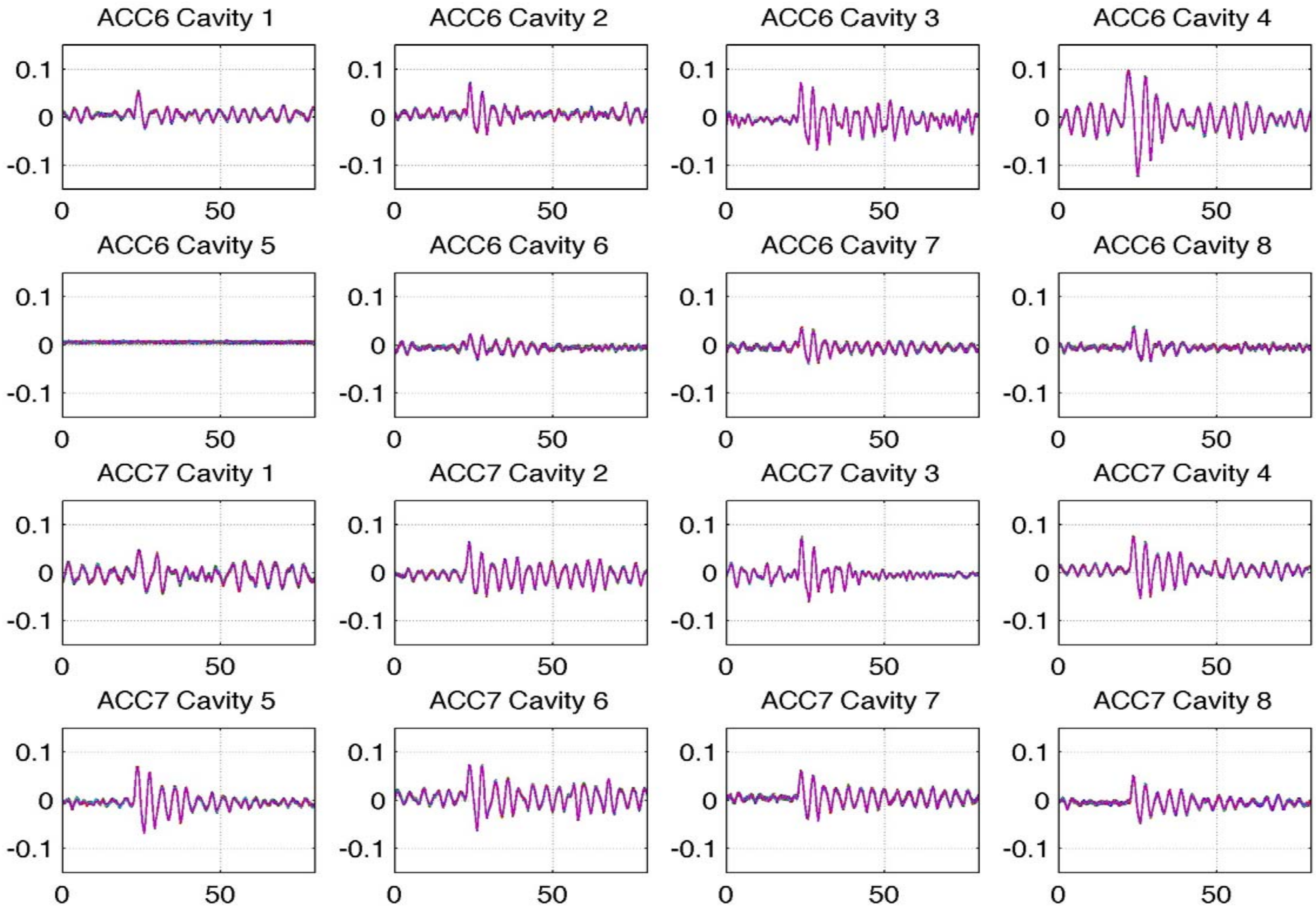
Hypothesis:

- The sense piezo is like a strain gauge, so the readback signal in some way is a representation of mechanical deflection of the cavity

If this is correct…

- Can we deduce anything about detuning from the signal?
- In part, it depends on the transfer functions between cavity, drive piezo, and sense piezo

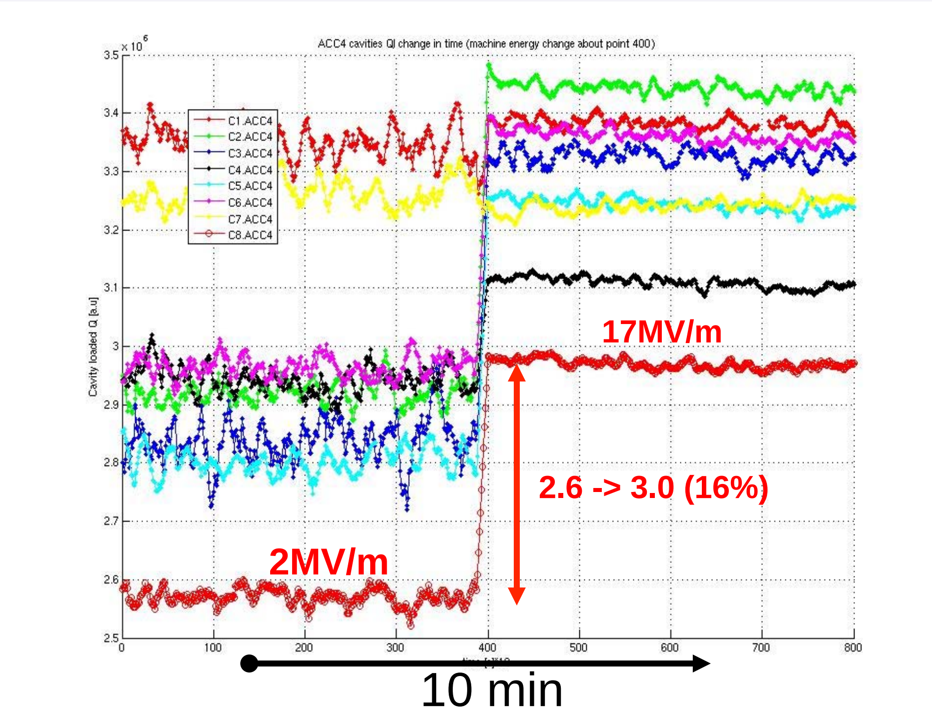
Quick look at the signals from all 16 cavities
(piezo drives are off - except on ACC6 Cavity 4)



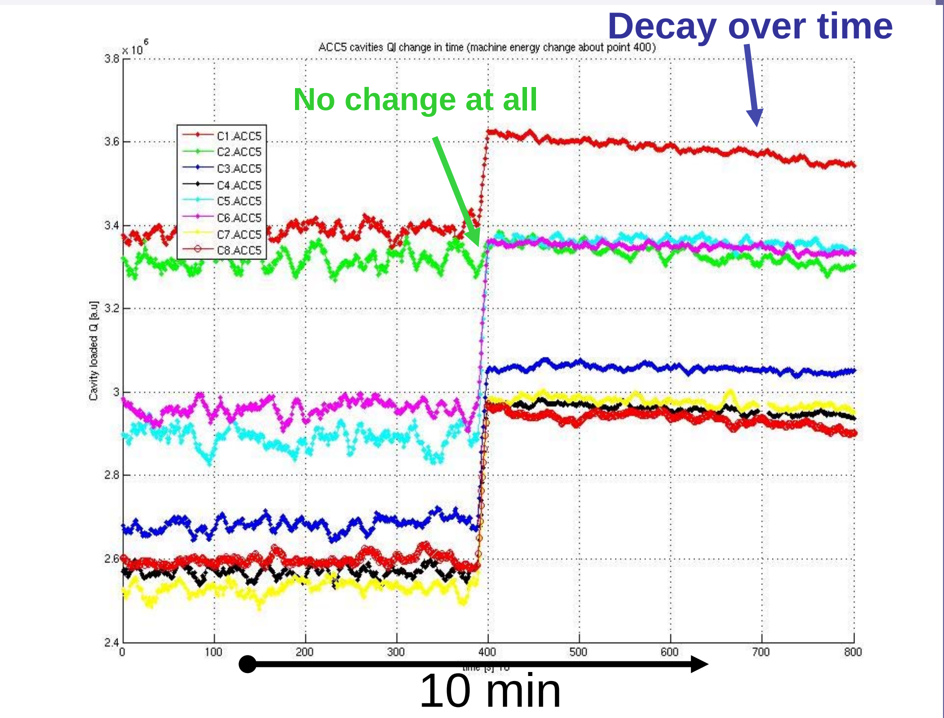
Open issues: observation Q_L changes

- Voltage change ACC45 from 67MV to 255MV (~4MV/m -> ~15MV/m)

ACC4

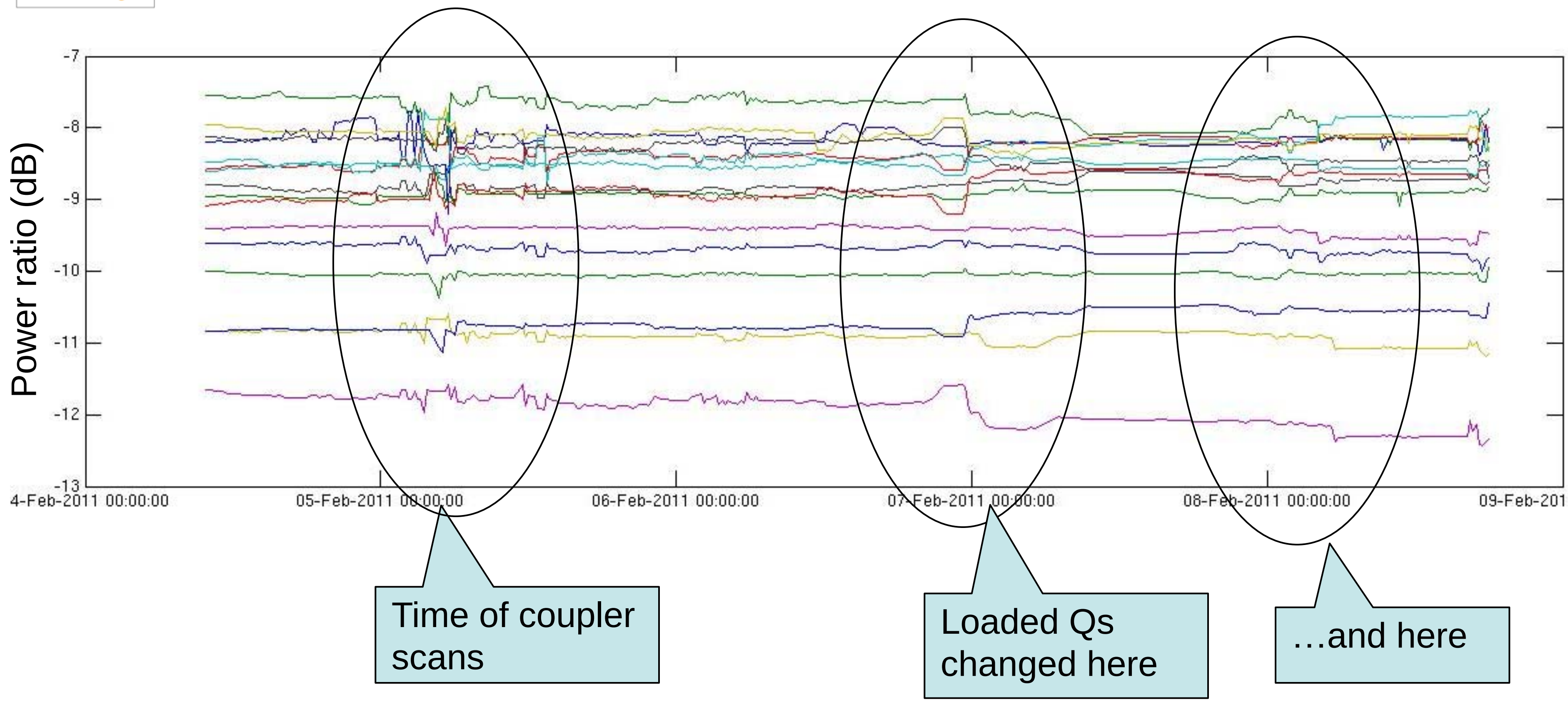


ACC5



- Cause need to be investigated (likely main coupler antenna position change due to thermal expansion)

ACC67 Forward Power Ratios during 9mA study: 4th to 8th February



Longer term: Study topics

- **Effective usable gradient (gradient margins)**
  - Trade-studies: effective usable gradient vs stability vs gradient spread vs beam current vs …
- **Develop automation methodologies and strategies**
  - Operate the linac ‘as if there were 16,000 cavities’
  - FLASH – ‘scale-model’ of EU-XFEL operations
  - EU-XFEL – scale-model of ILC operations
- **Exception handling**
  - Fault detection and recovery
- **Address ‘devil in the details’ practical issues, eg**
  - Measurement and calibration
  - Resolution of control of parameters (Loaded-Q, tuning,...)
  - Thermal stability, repeatability, robustness