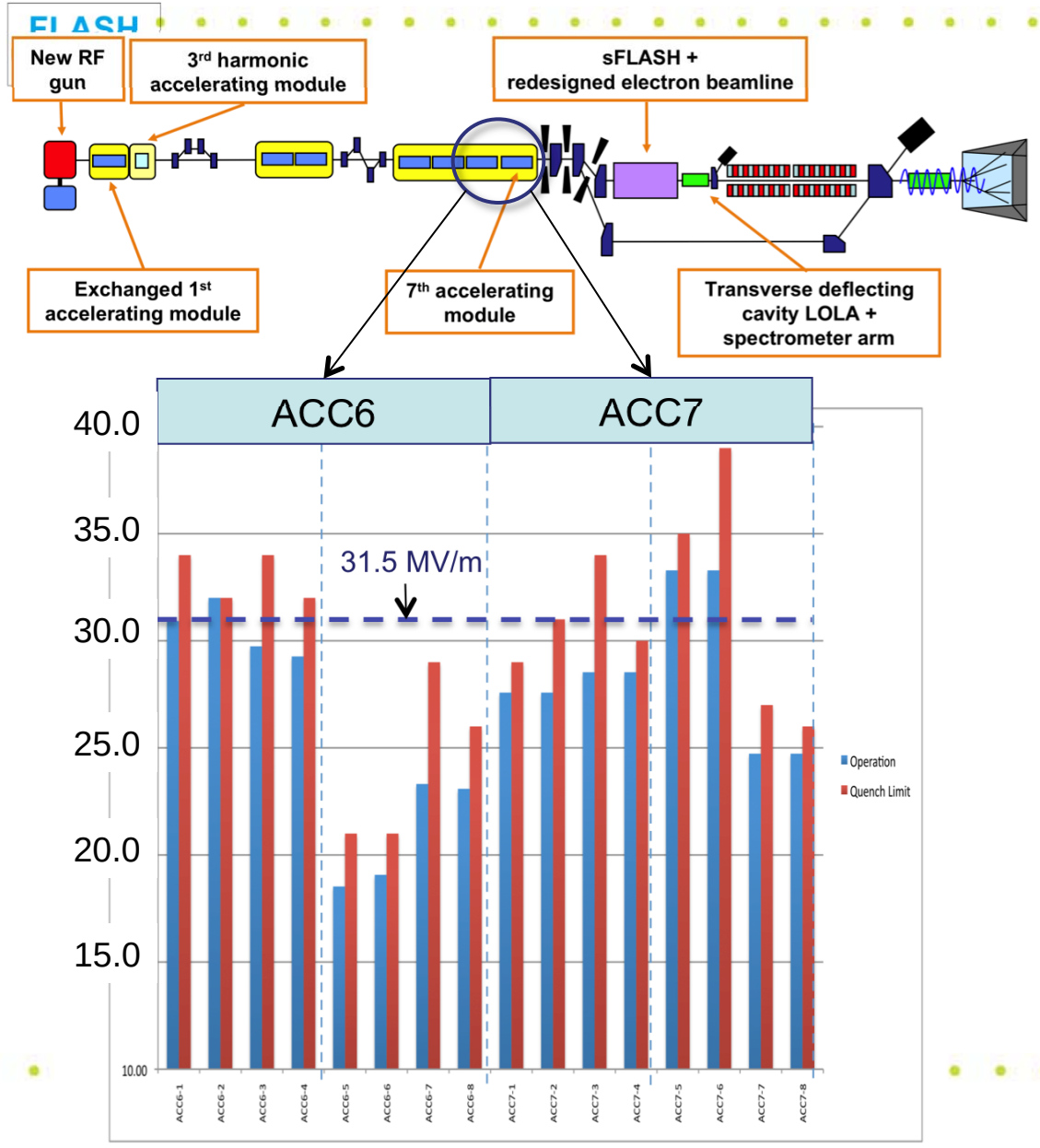
9mA studies report

John Carwardine

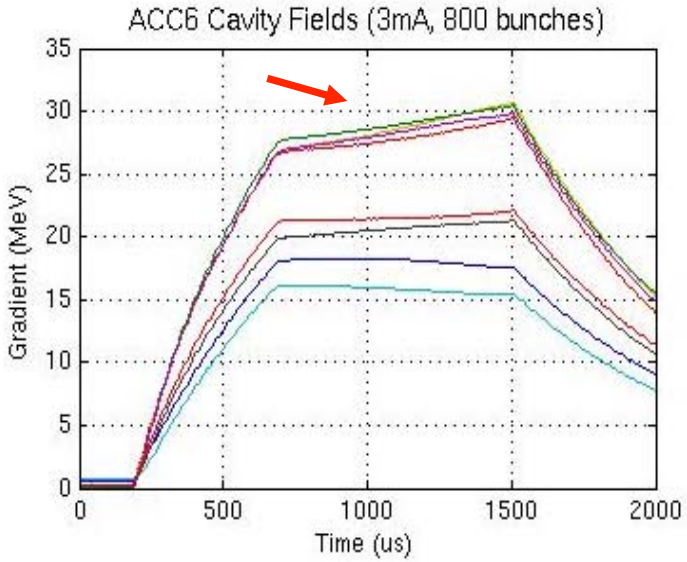
25 February 2011

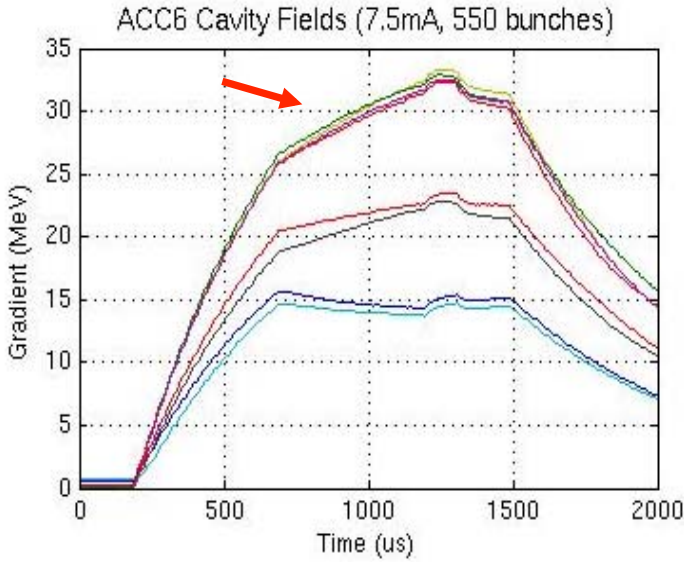
Recent FLASH Results



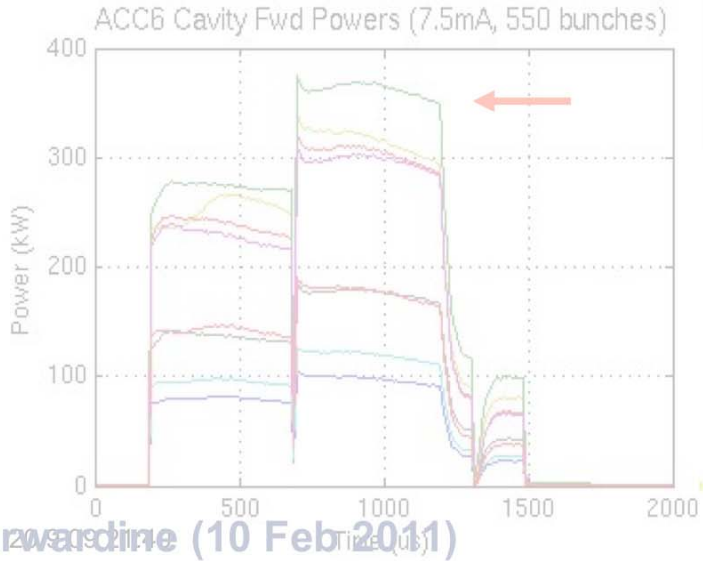
- **Operation with <u>Gradient Spread</u>**
  - From single RF source
  - now baseline
- **Specifically: achieving constant gradients <u>for each individual cavity</u> during beam pulse**
  - to within few percent
  - close to gradient limits

Comparison of ACC6 cavity gradients and forward powers for 3mA and 7.5mA





Substantial increase in gradient 'tilts' with 7.5mA (would have quenched with 800us flat-top)



Power during flat-top is higher than the fill power for the 7.5mA case

Gradient had been lowered in 7.5mA case to reduce peak power and prevent klystron trips

Adaptive feed-forward was ON for the 3mA case

Successful studies!!

- ***Can we actually operate the machine with all cavities within 3% of their quench limits?***

- **15 Shifts: 4th – 8th February**
  - 'Parallel' tasks: machine tuning; Pk/Ql studies; Piezo studies

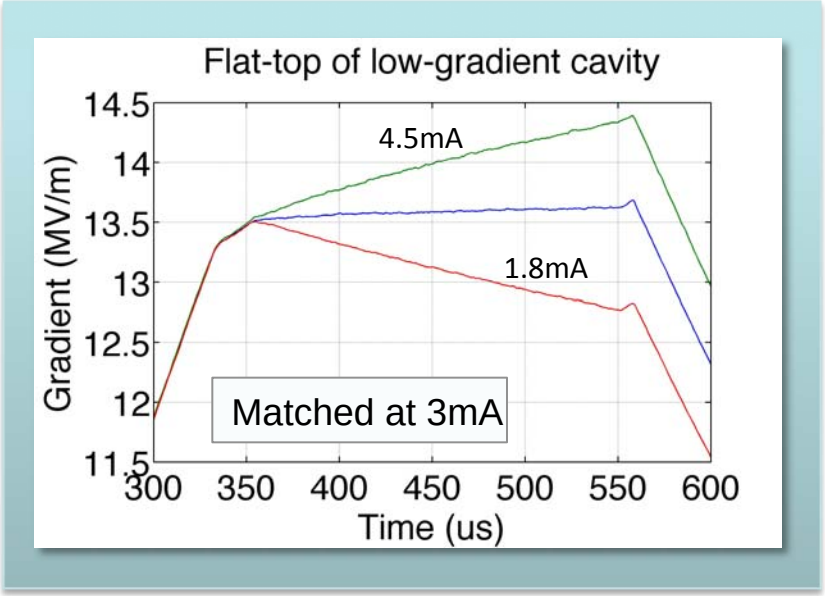
- **The accelerator ran flawlessly**
  - 1GeV, 400us bunch-trains, beam current from 1.5mA to 4.5mA
  - 400us bunch-trains were available within 10mins, always!
  - Energy stability with beam loading over periods of hours: ~0.02%

- **A lot of progress with the 9mA experiments + good results**
  - Achieved flat gradients within few % at 1.5mA, 3mA, 4.5mA

And of course…we have a lot of data ☺

FLASH: Goal of Feb. Studies

- **Understanding RF parameter solutions**
  - RF power to cavities
  - Adjustment of loaded Q
- **Compensation of Lorentz-Force Detuning via fast piezo-tuners**
  - LFD is proportional to g^2
- **Calibration (benchmarking) of simulation model(s)**
- **Better characterisation of errors, calibration and tuning precision**
- **Establishing best-approach tuning algorithms close to gradient limits**
  - with a view to automation
  - without quenching cavities



cavity field over 400us bunch train with different beam loading

*note: 400μs beam pulse limited by RF gun

Tuesday 2/8 afternoon shift – highlights:

- 4.2mA beam, 360 MeV
- Lorentz force detuning compensation
- Use calculator to predict QL → very accurate prediction
- Flatten ACC6/7 gradients tilts to ~ 1.5% (tuned for 4.2mA)
- beam current scan to 4.5 mA

J. Branlard

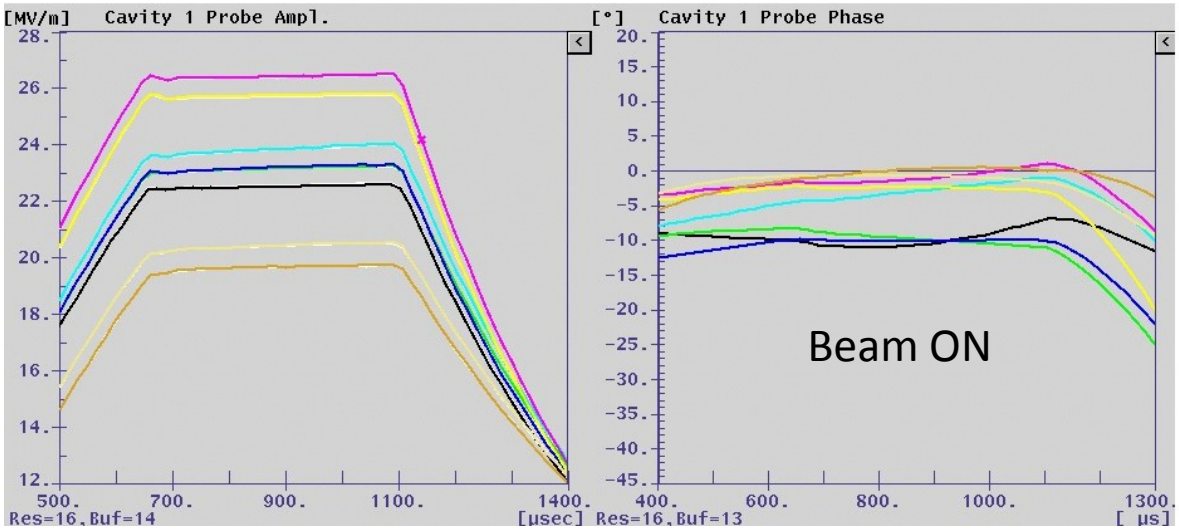
ACC7 Q_L values

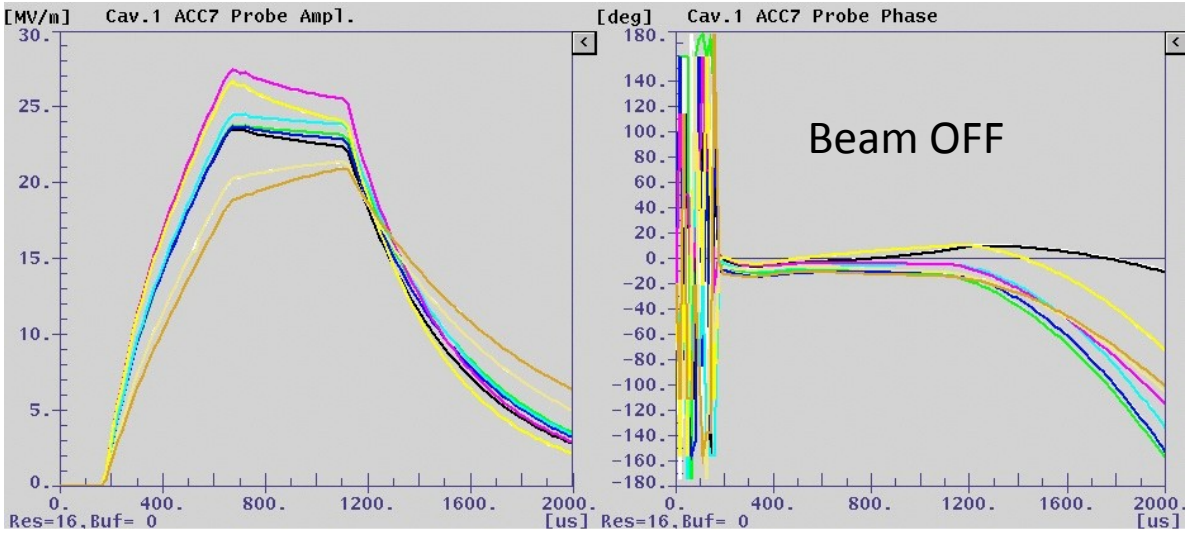
Predicted

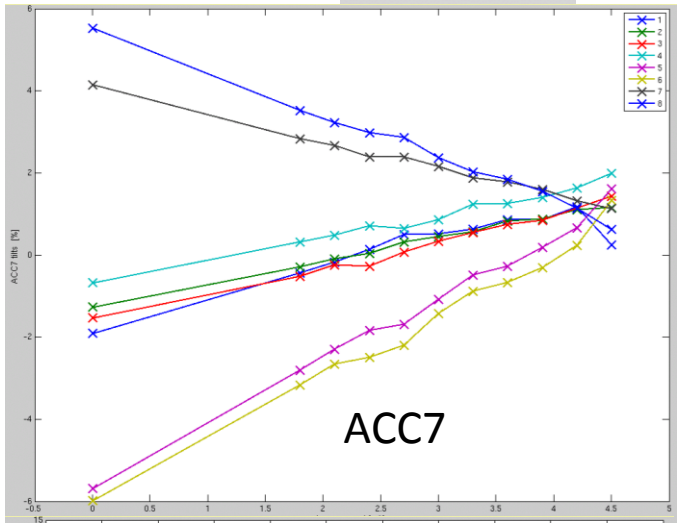
cav1. 1.78 e6
cav2. 1.74 e6
cav3. 1.85 e6
cav4. 1.88 e6
cav5. 3.25 e6
cav6. 3.12 e6
cav7. 2.37 e6
cav8. 2.40 e6

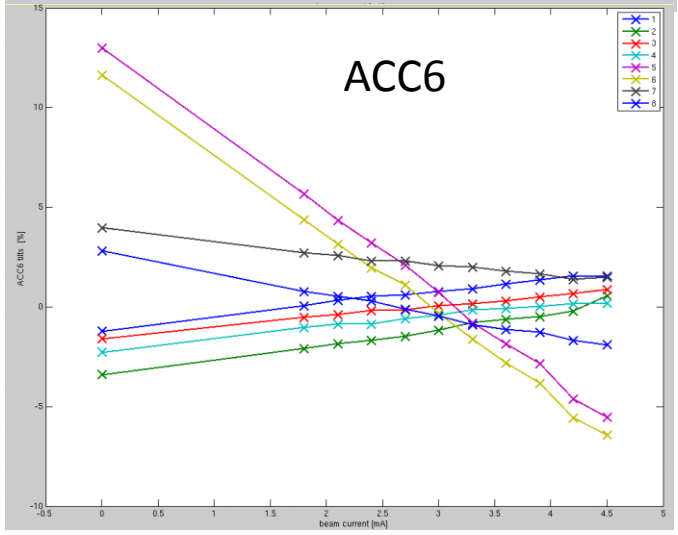
Implemented

Cavity#	Loaded Q
1	1.79e+06
2	1.77e+06
3	1.84e+06
4	1.91e+06
5	3.28e+06
6	3.10e+06
7	2.37e+06
8	2.28e+06

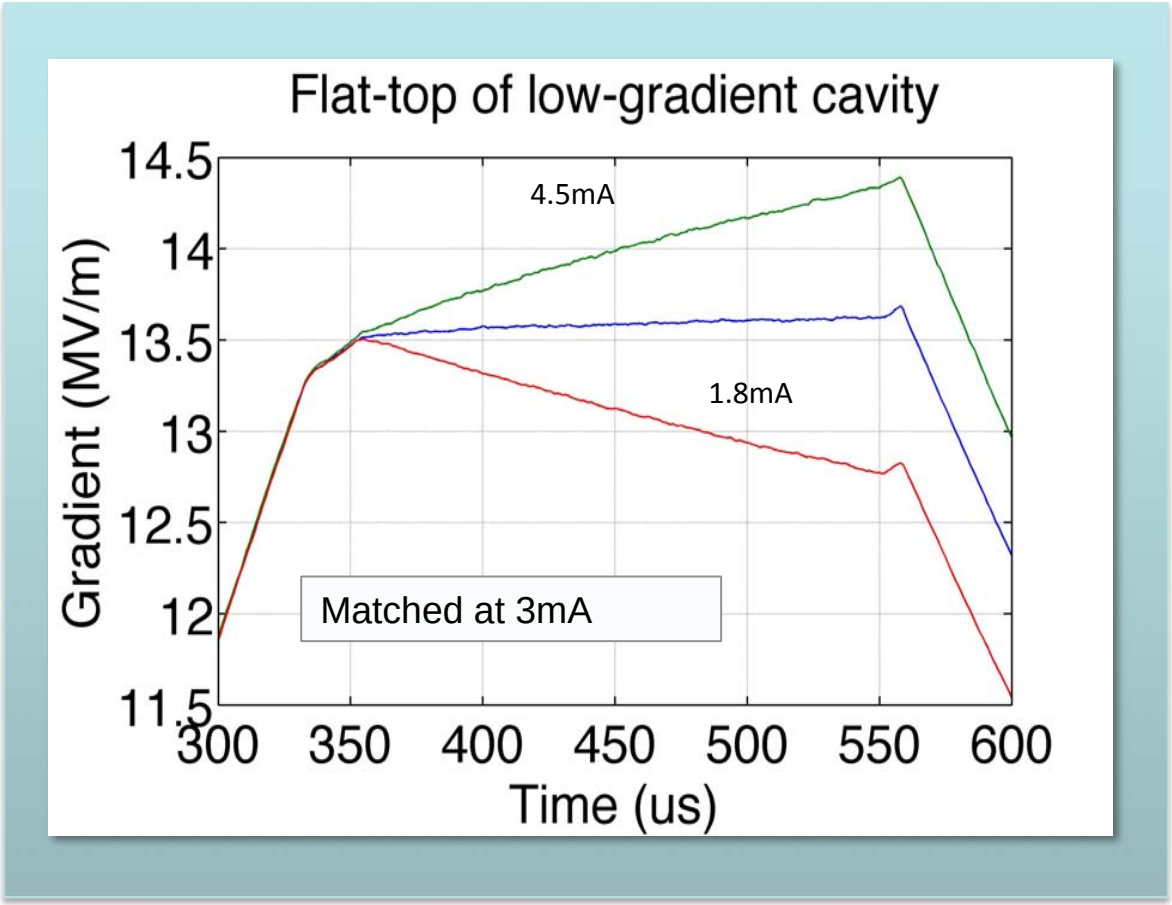








Cavity field over 400us bunch train with different beam loadings

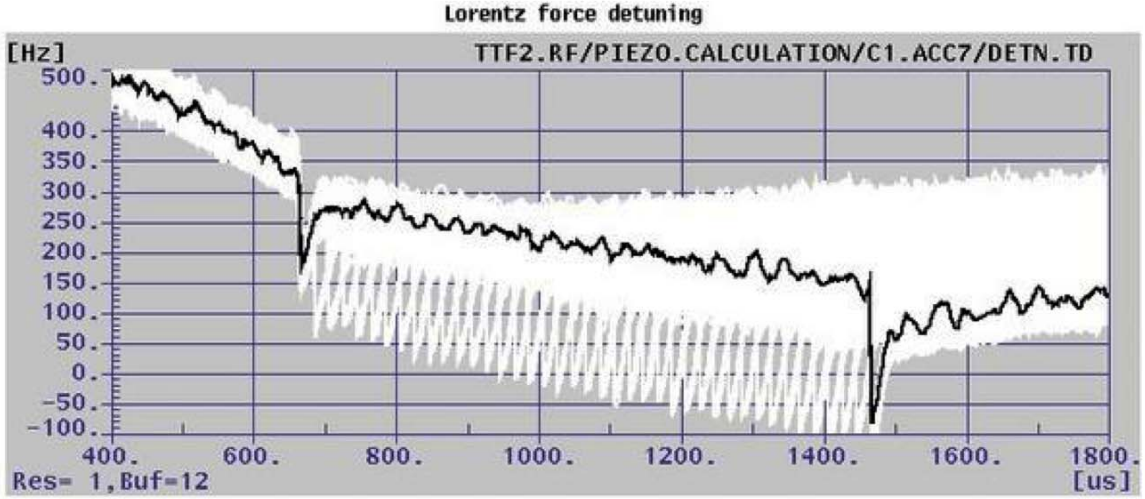


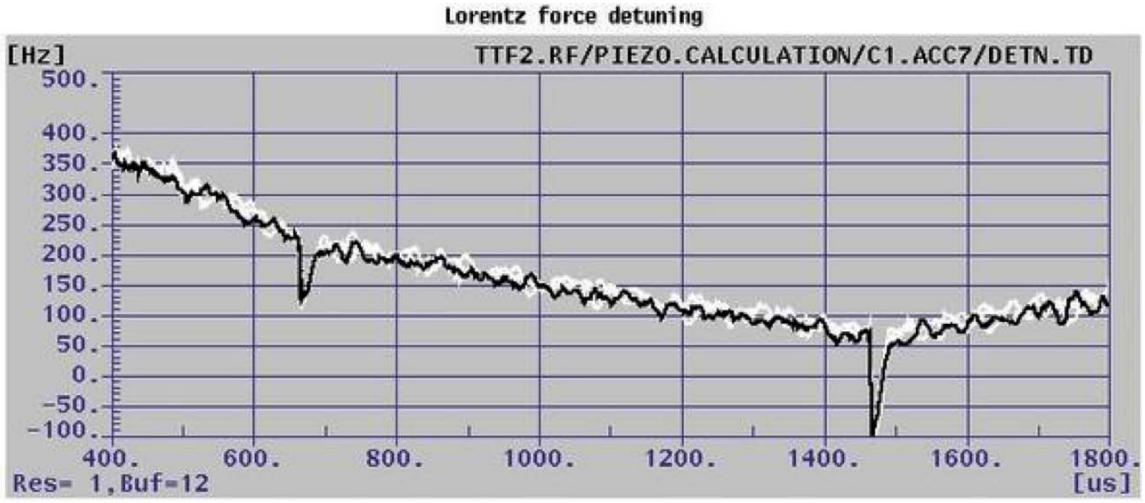
Ql adjustment procedure during Pk/Ql studies: obervations

- **Since the beamloding is only 1.5mA over 400us, sometimes it was hard to see the improvement until the cavity was slightly retuned**
- **The approach was validated and seems viable for flattening individual cavities under heavier beamloadings up to something like 6mA**
- **Maintaining tilts below 1% will depend on how much cavities detuned over time and other drifts**

- **Preliminary tests were also performed with automated fine tuning to be used once we were close to the optimum from the model-based setup**

Calibration of detuning computations



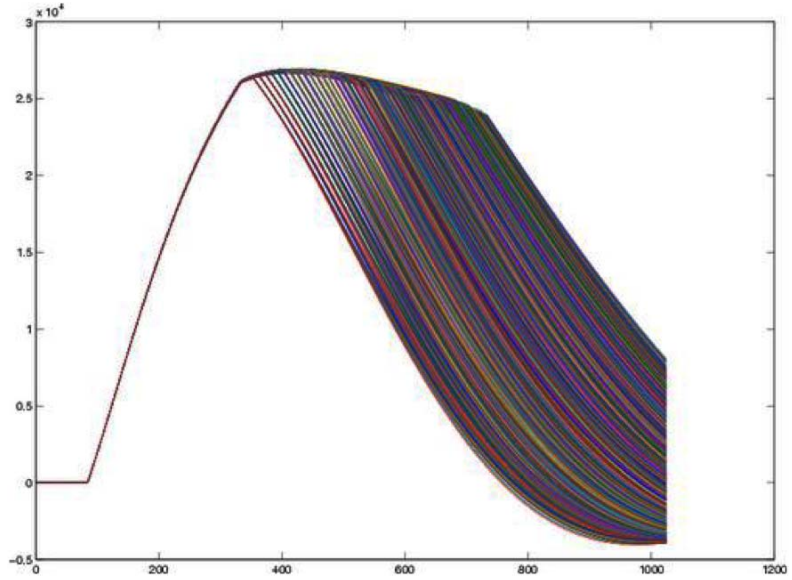


Detuning over the rf pulse as computed online by piezo controller

There was a lot of discussion on the validity of the calibration

Measurement of detuning over the flat-top by scanning the length of the flat-top

ACC67 Vector Sum (overlay of may pulses)

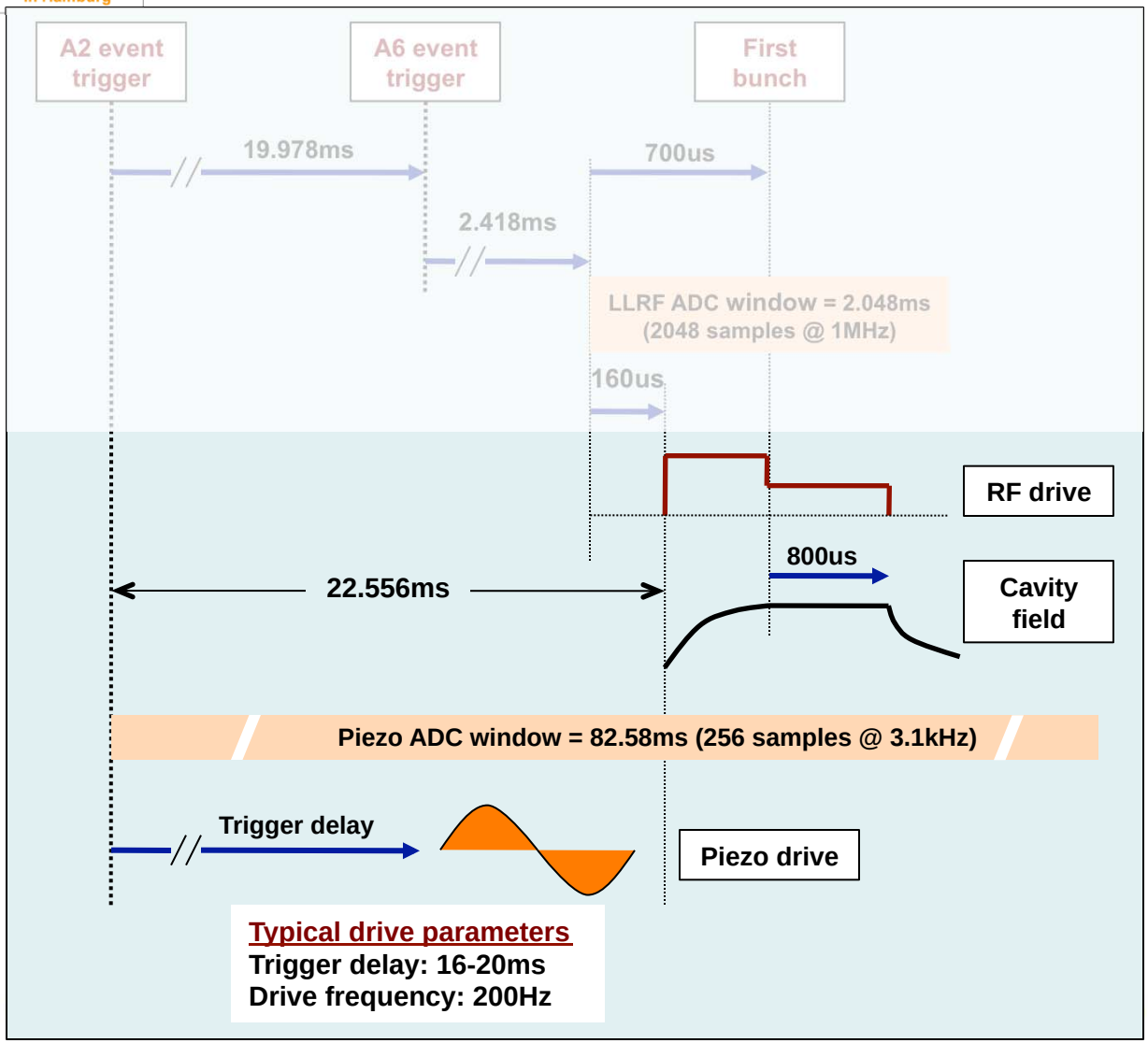


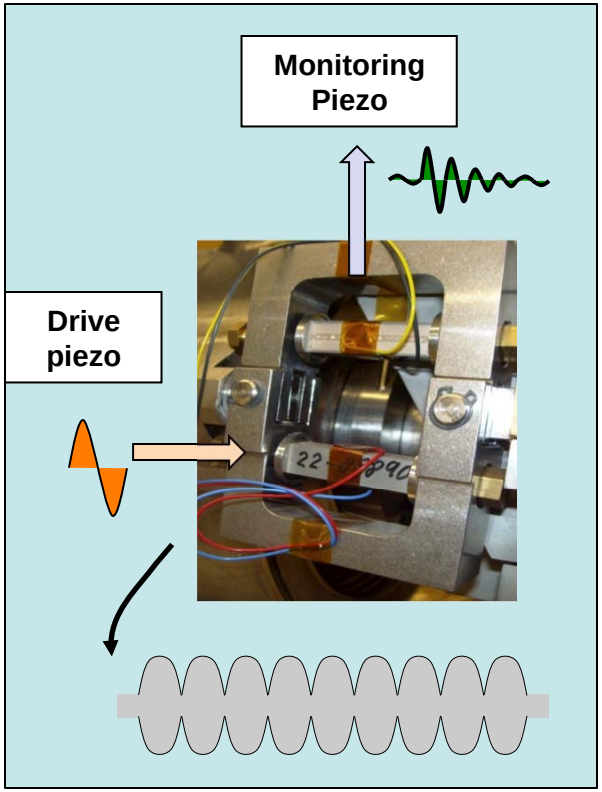
Length of flat-top reduced in 20us steps from 800us to 20us

- **Performed scans on ACC67 at different gradients: VS from ~100MeV to 380MeV**
- **Scan with ~4.5mA beam loading**

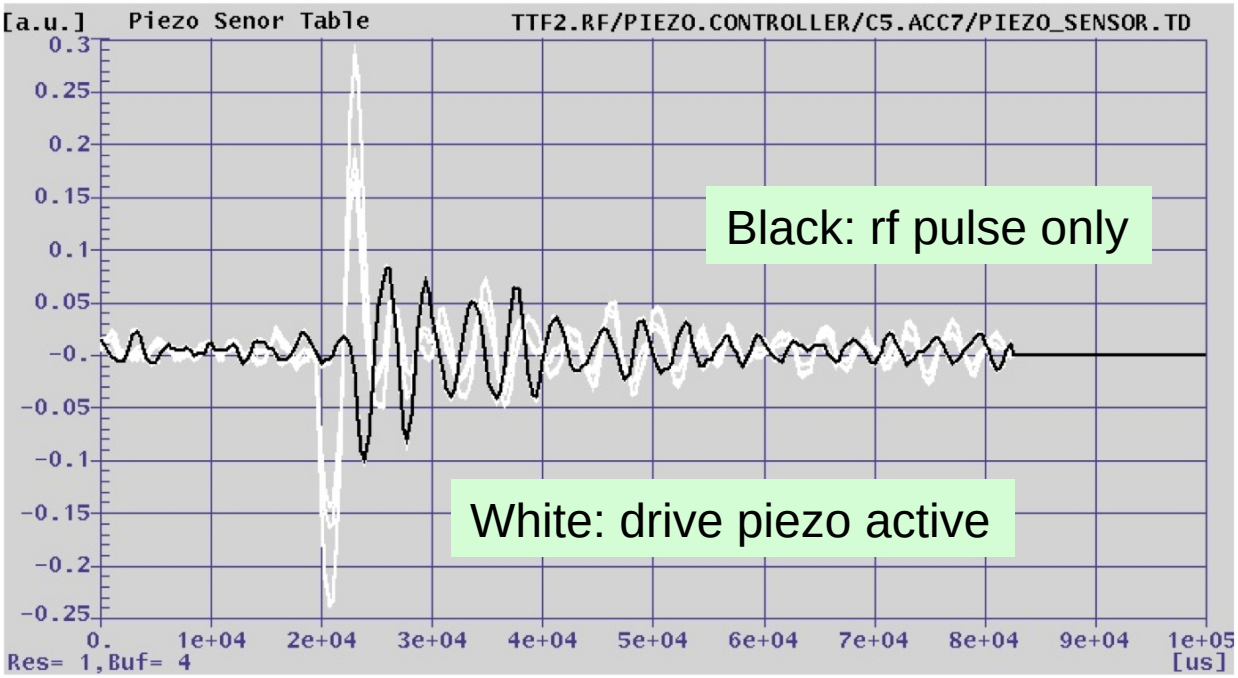
Detuning computed from decay at the end of each pulse

Trigger timing for the piezo tuners
(nominal setup)





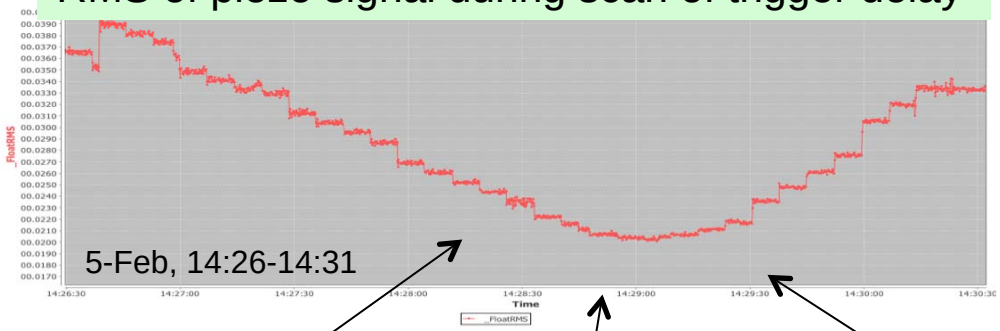
Comparison of piezo signal from rf pulse ping only and ping from drive piezo

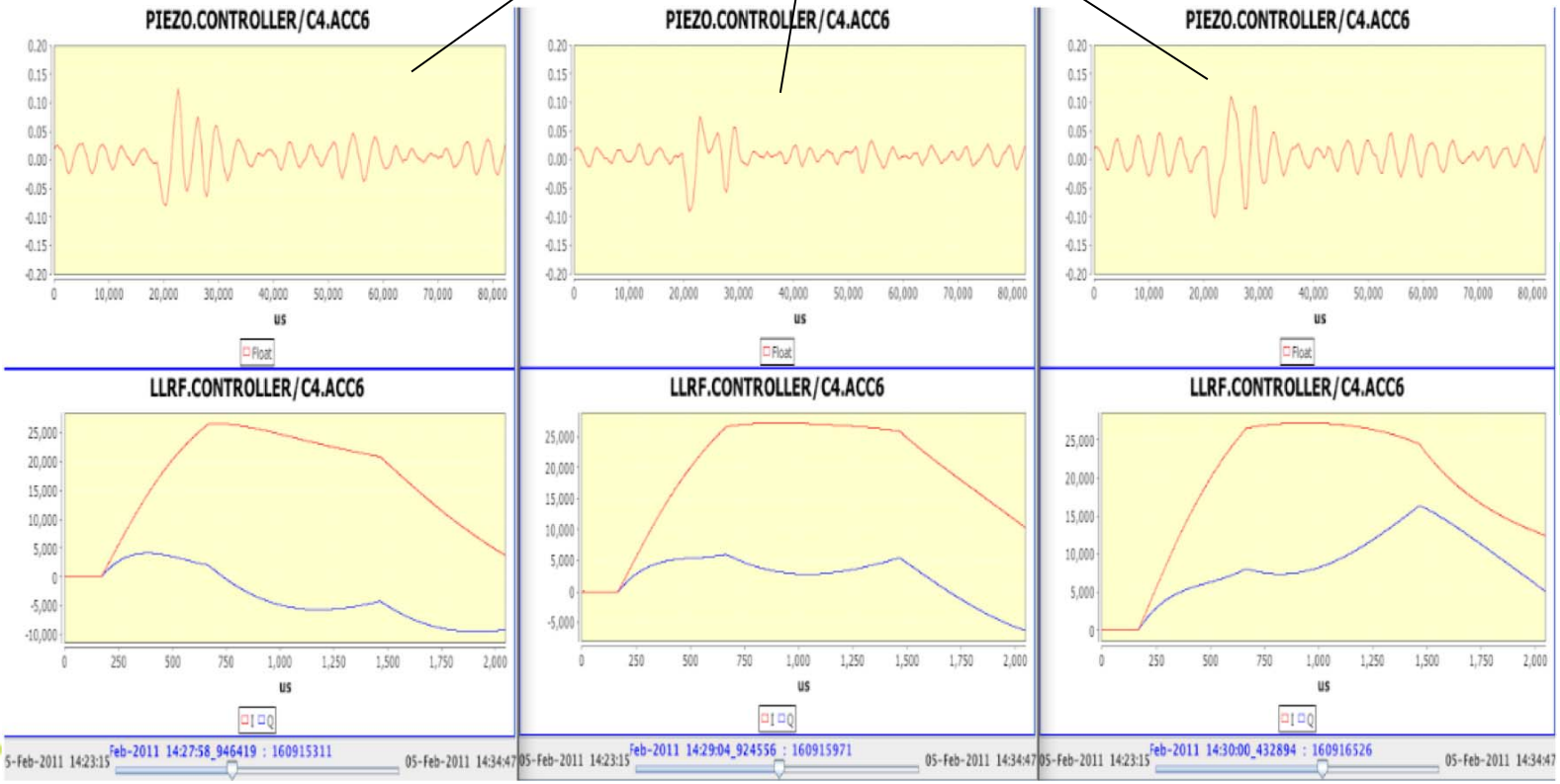


- **The ping used for Lorentz-force detuning compensation is quite large compared with the ping from the cavity itself**
- **But what's important for LFD compensation is the detail during the rf pulse itself**

ACC7 Cavity 5 piezo sensor waveforms during scan of piezo drive trigger delay

RMS of piezo signal during scan of trigger delay





monitoring piezo signal (80ms)

Cavity gradient I&Q (2ms)

These scans were made with drive voltage of 7.5v (not 20v)

Before memories fade…

http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=5022
(Access key: ttf9ma)

To collect / document – 9mA studiers

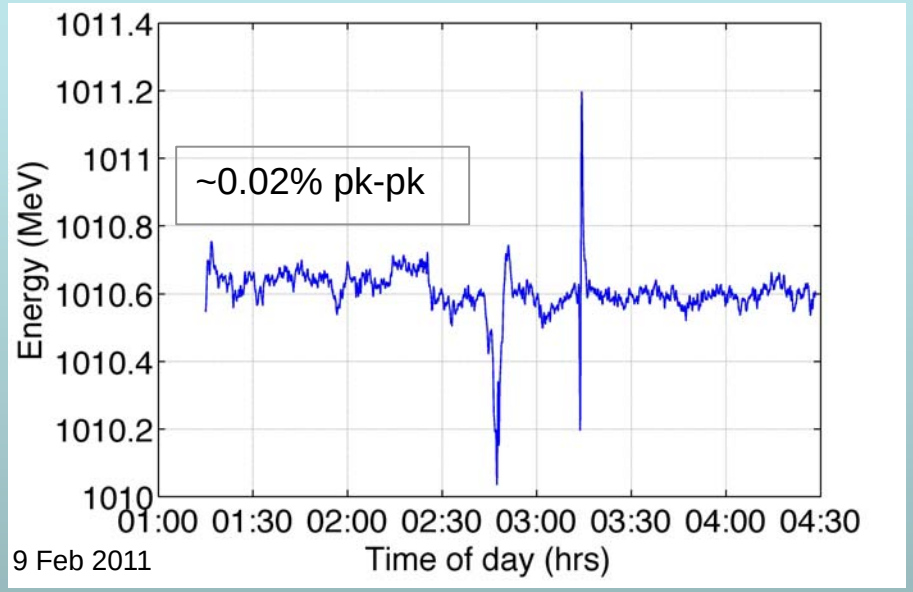
- **Shift-by-shift activity summaries**
  - Specific experiments and measurements
  - Other notable events for follow-up
  - Timestamps for DAQ data and eLog
  - Locations of any scripts, data files, …
  - Additional relevant information not in the eLog
  - Issues, questions,…
- ***Details of how to access & analyse DAQ data***

- ***Currently using Indico to collect information (to be moved to 9mA wiki):***
- ***http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=5022***
- ***(Access code: ttf9ma)***

- **Linear Collider Workshop (ALCPG)**
  - March 19-23 in Eugene, Oregon.
  - Parallel session on FLASH / 9mA experiment
- **Long Bunch Trains Workshop**
  - June 6-8 at DESY
- **FLASH seminar….**
  - TBD

FLASH: Stability

Energy stability over 3hrs with 4.5mA



Machine setup

1GeV nominal energy
400us bunch trains
1MHz and 1.6nC/bunch at 10Hz
3MHz and ~1.6nC/bunch at 5Hz

- **15 consecutive studies shifts (120hrs), and with no downtime**
- **Time to restore 400us bunch-trains after beam-off studies: ~10mins**
- **Energy stability with beam loading over periods of hours: ~0.02%**
- **Individual cavity "tilts" equally stable**