



Detuning calculations, Detuning compensation studies

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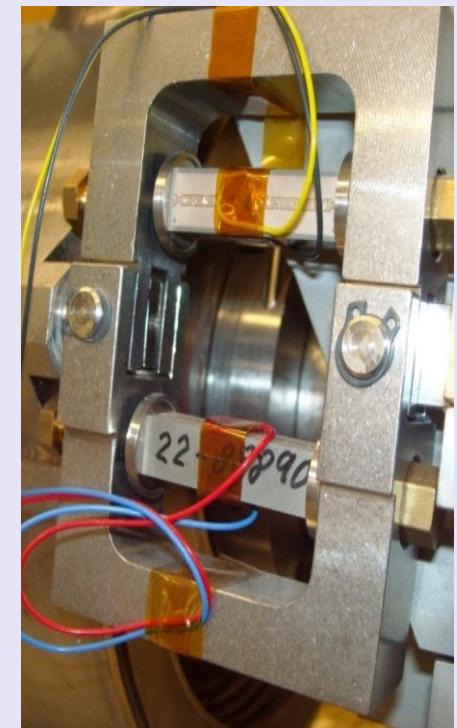
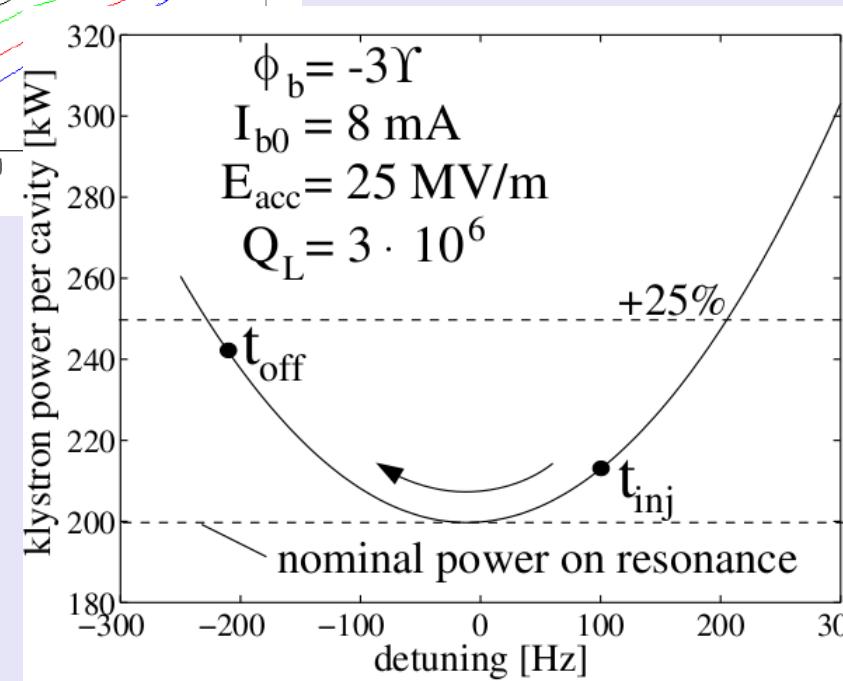
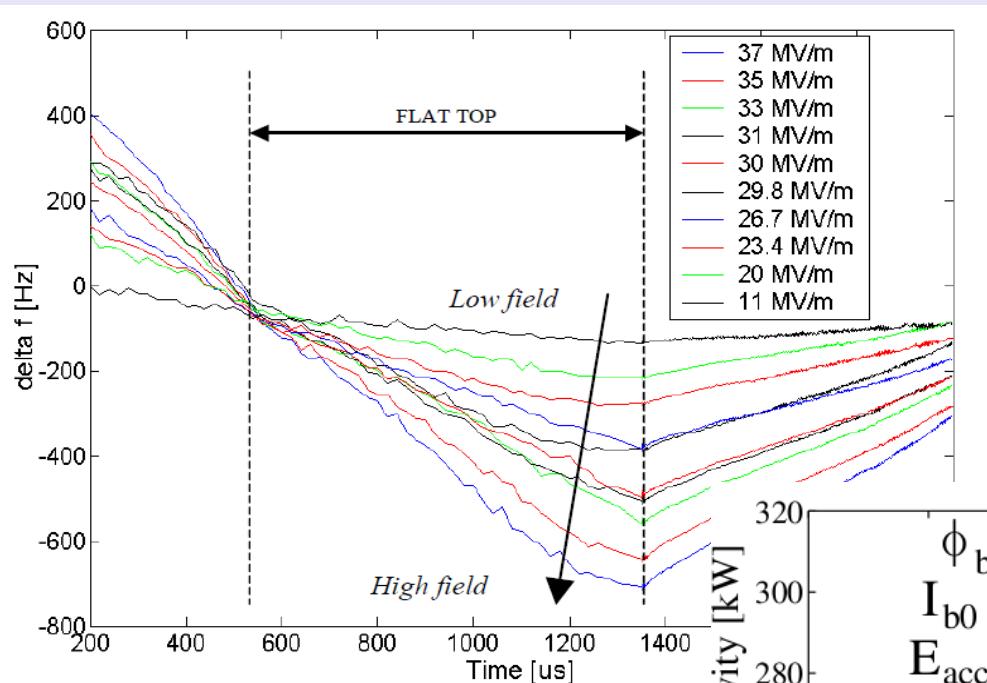


Agenda

- Lorentz Force Detuning and its compensation
- Piezo Control System at FLASH
- Detuning measurements and calculation
- Automatic procedure for cavity tuning
- Future plans
- Conclusion

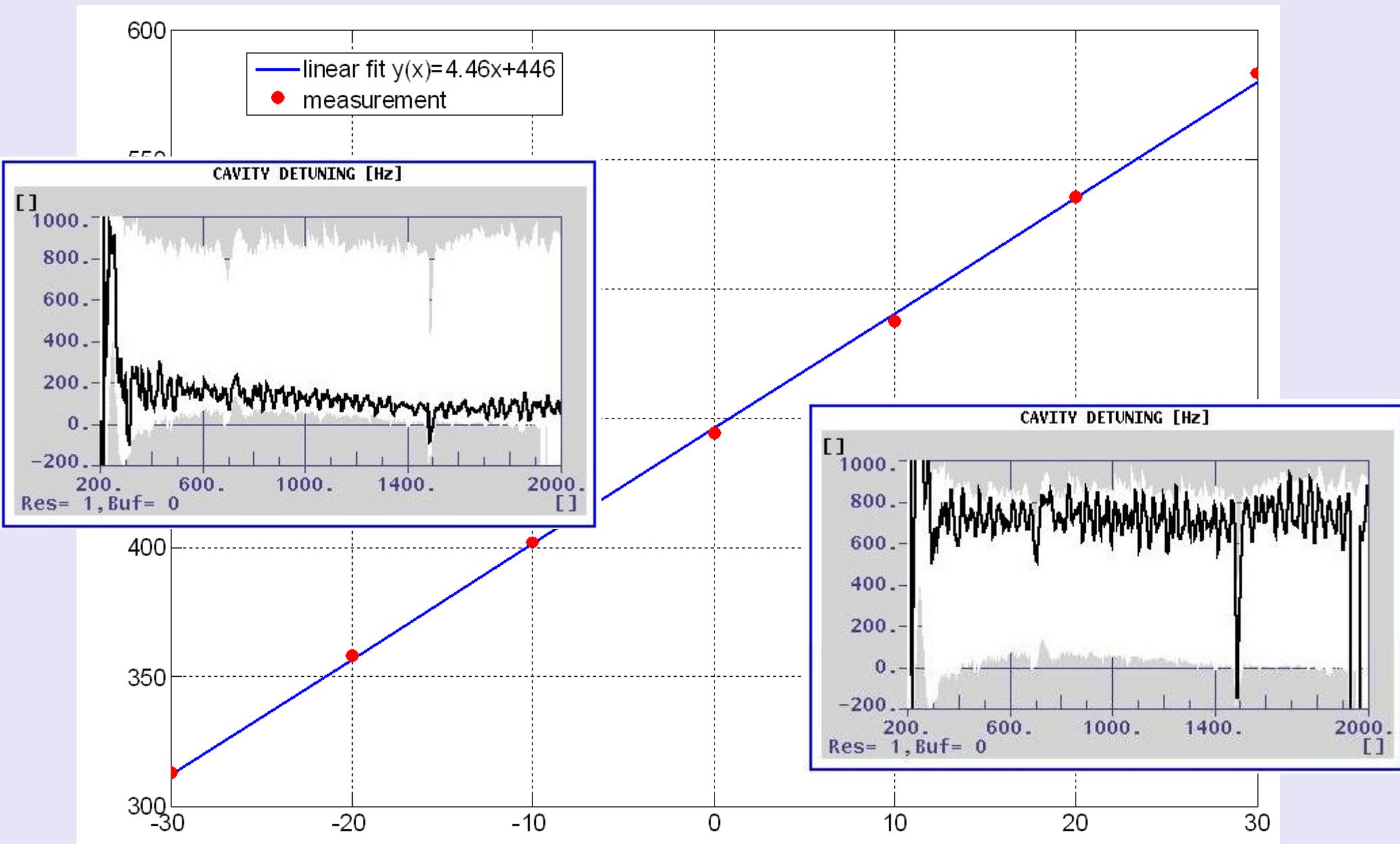


Lorentz Force Detuning

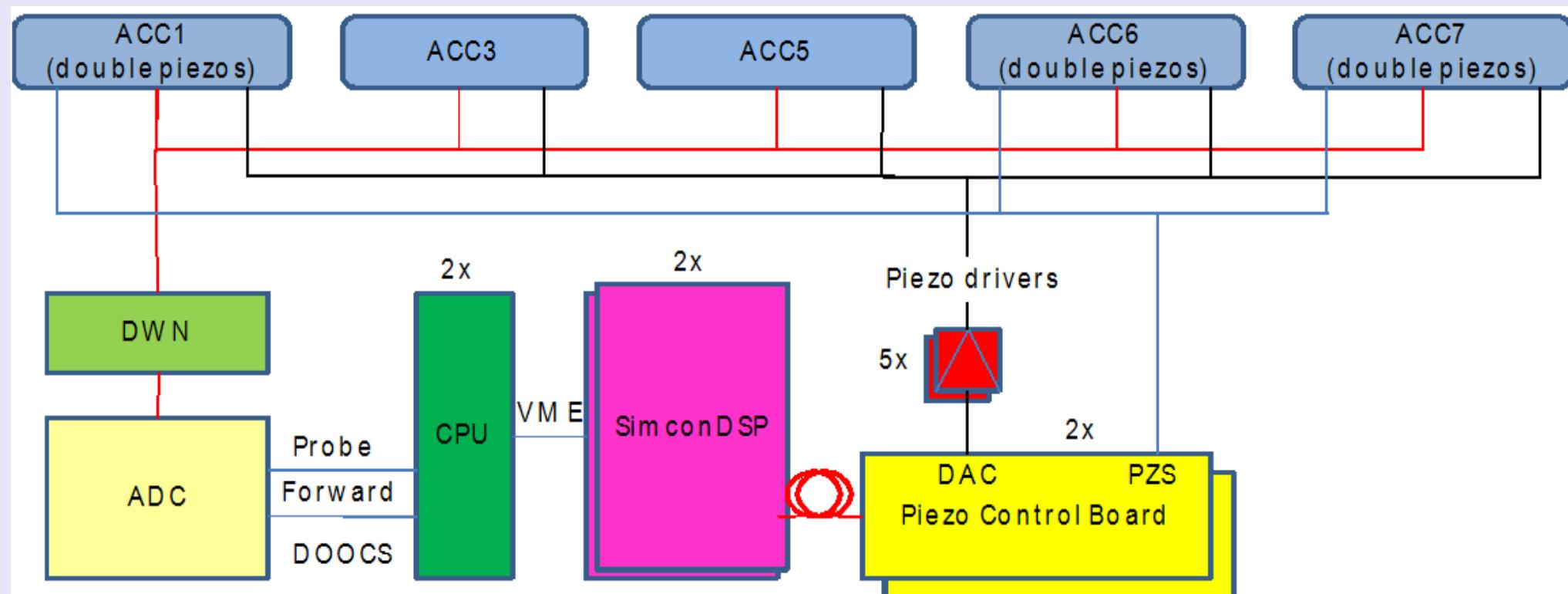
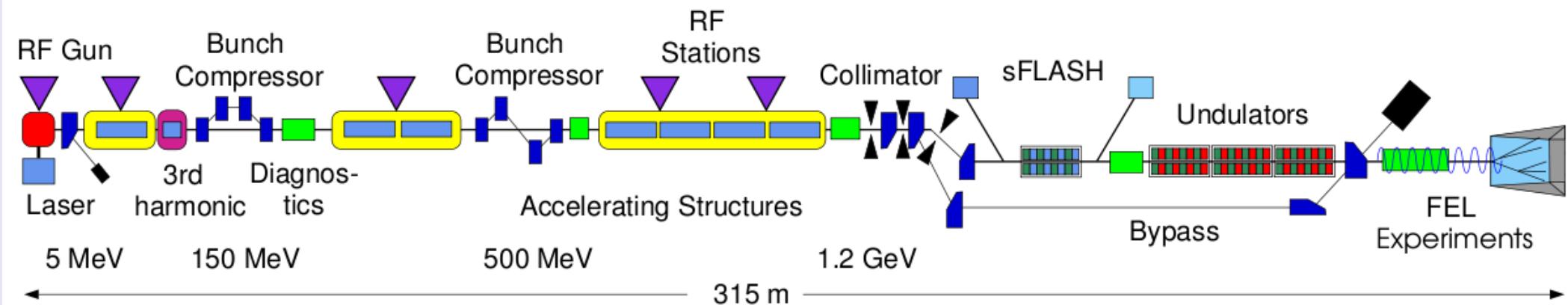


Dimensions: 10x10x36mm
Manufacturer: PI

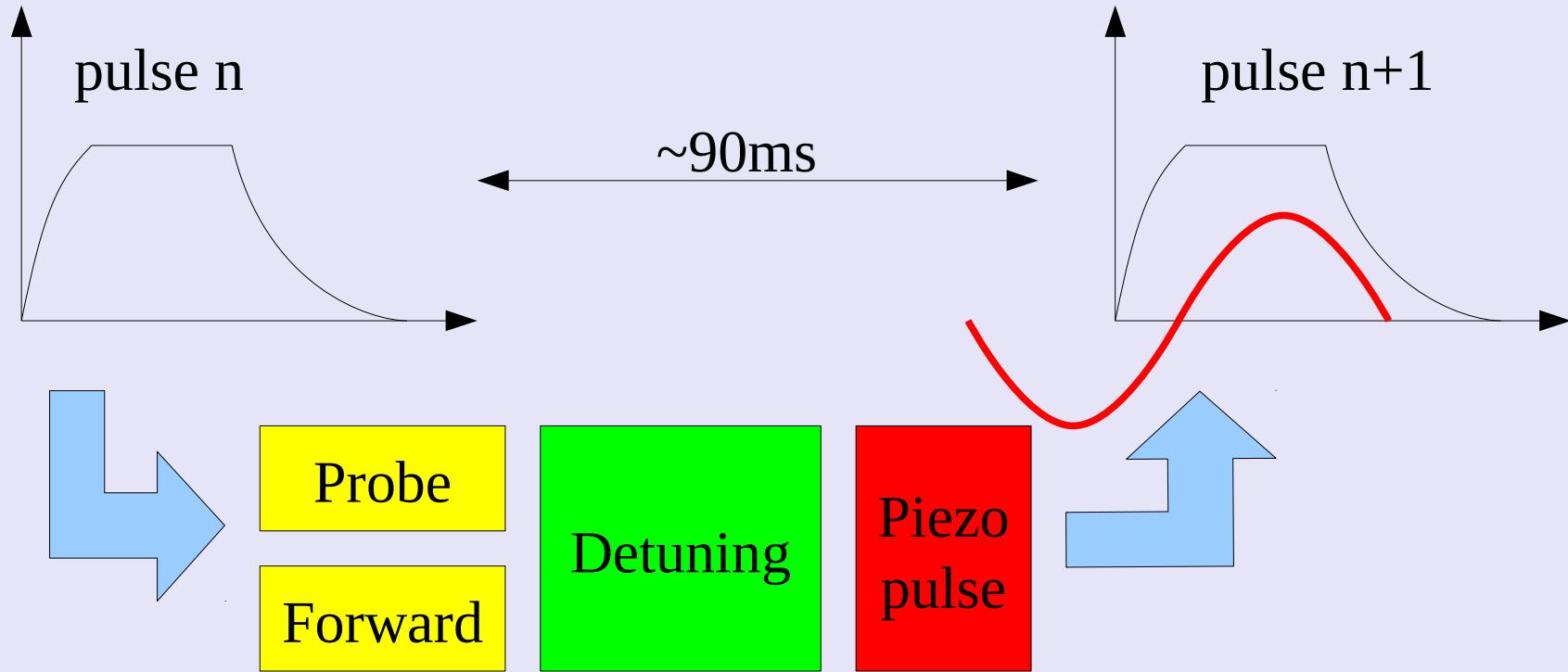
Transfer function (ACC5 cav. 8)



FLASH and Piezo Control



Piezo control - signal flow



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

$$pp = f(\Delta\omega_d, \Delta\omega_s, curvature)$$

Detuning measurements w/o beam

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

$\Delta\omega$ – detuning ,

V_c, φ_c – field amplitude and phase ,

$\omega_{1/2}$ – cavity bandwidth

V_{for}, φ_{for} – forward power amplitude and phase

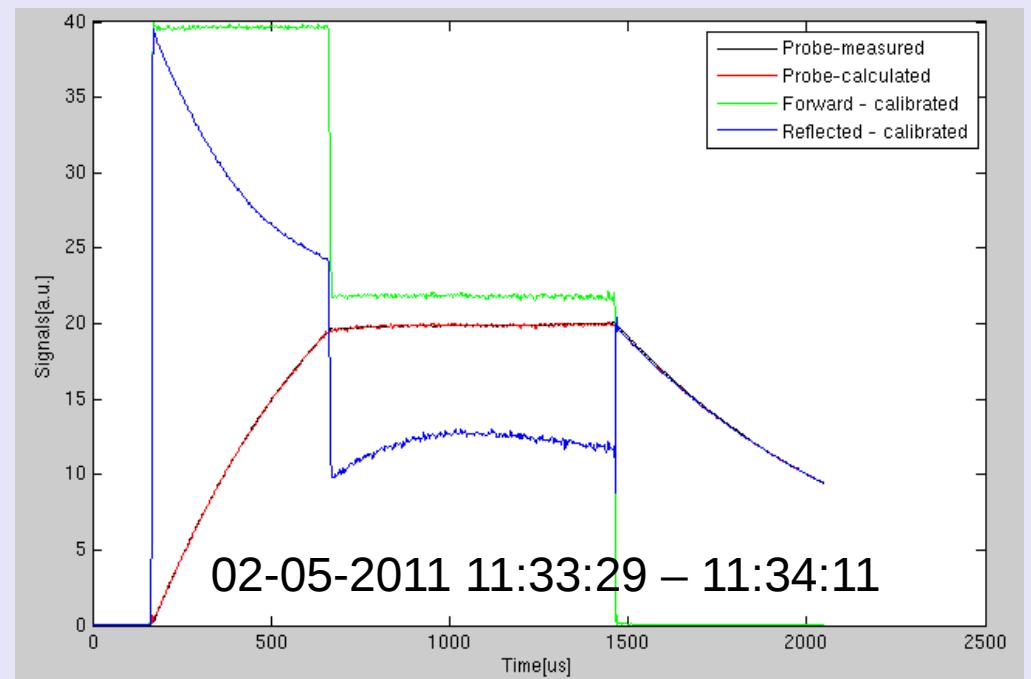
$$V_c = V_{for} + V_{ref}$$

$$V_{for} = a V_{form} + b V_{refm}$$

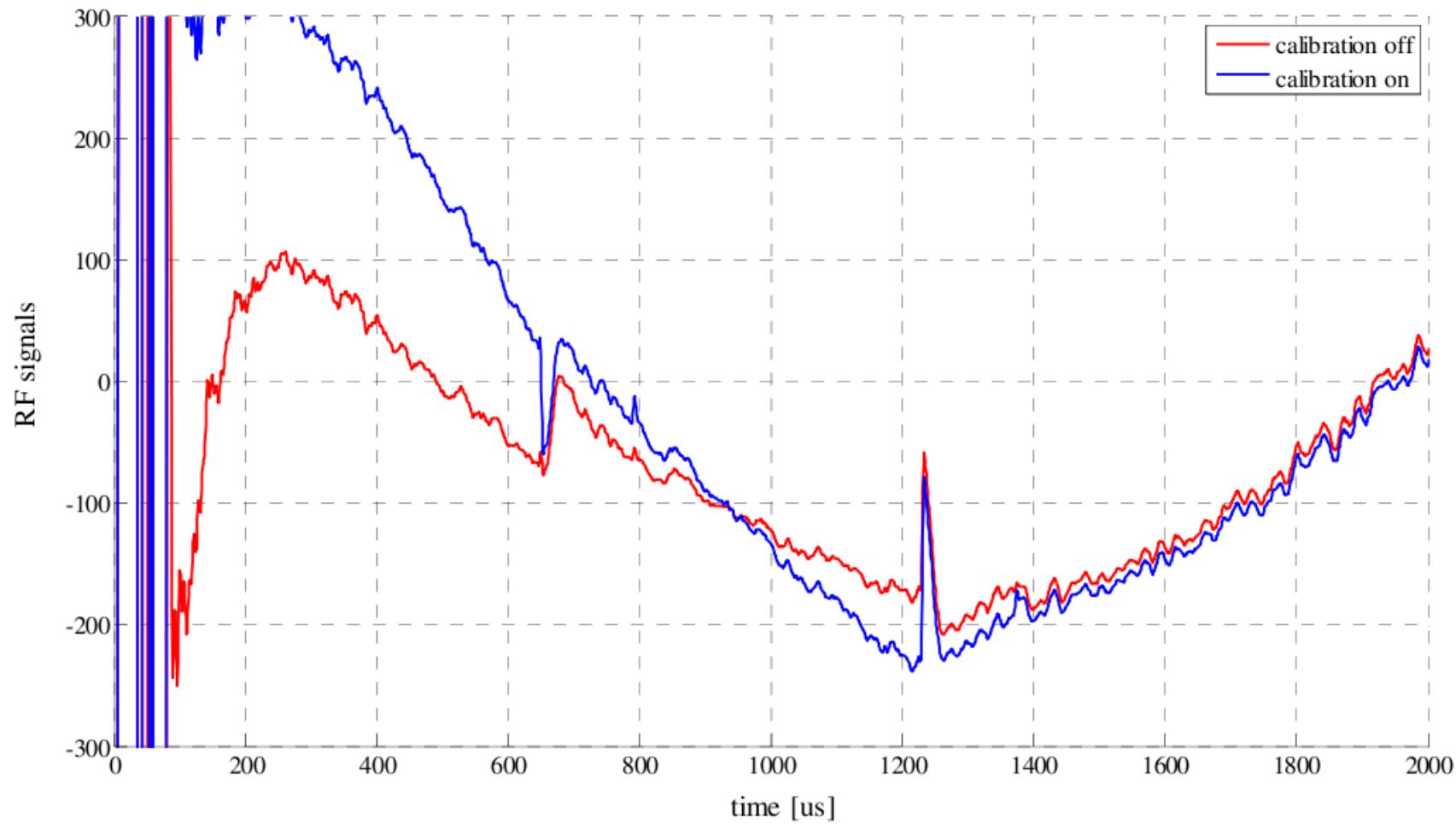
$$V_{ref} = c V_{form} + d V_{refm}$$

V_{form} – measured forward power

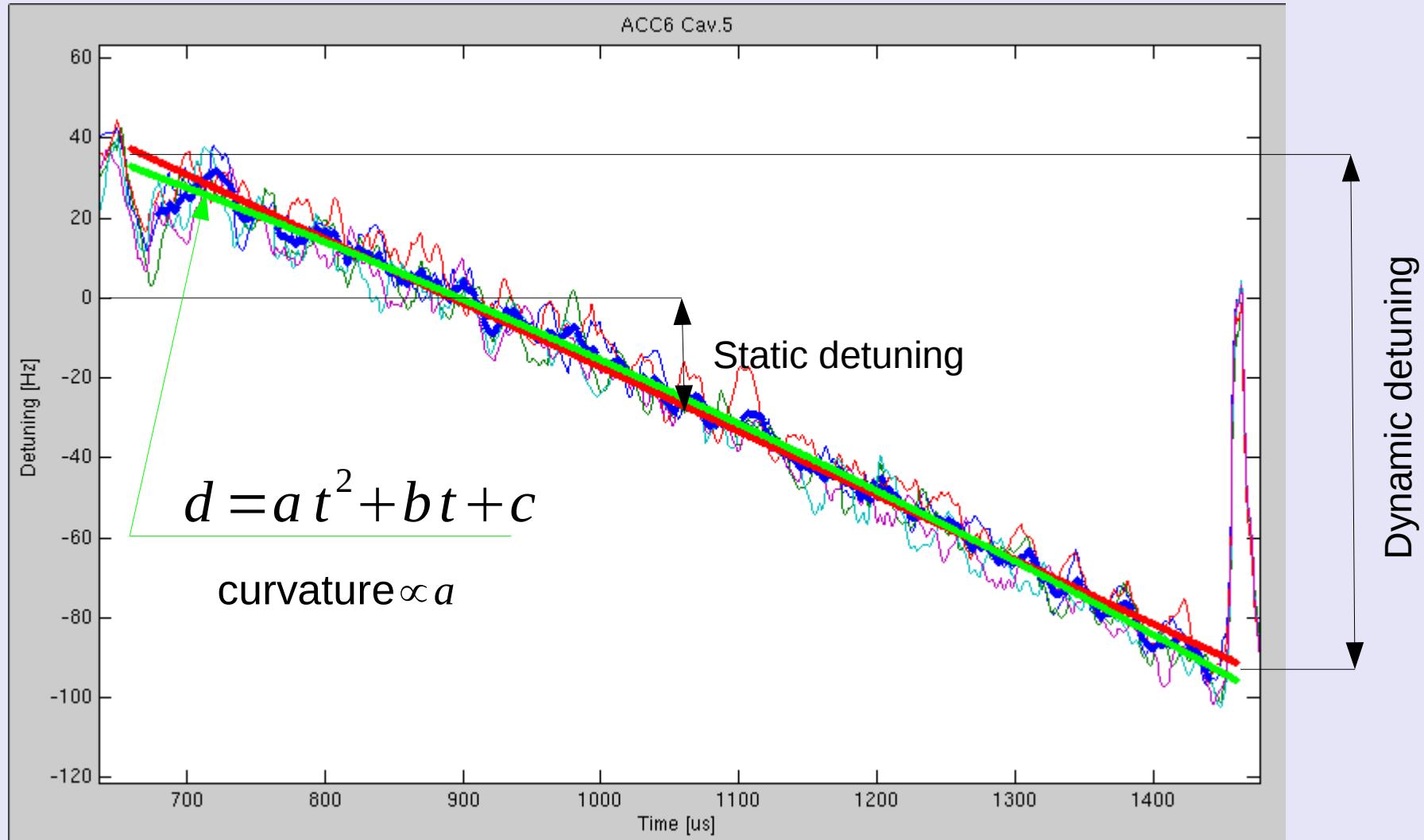
V_{refm} – measured reflected power



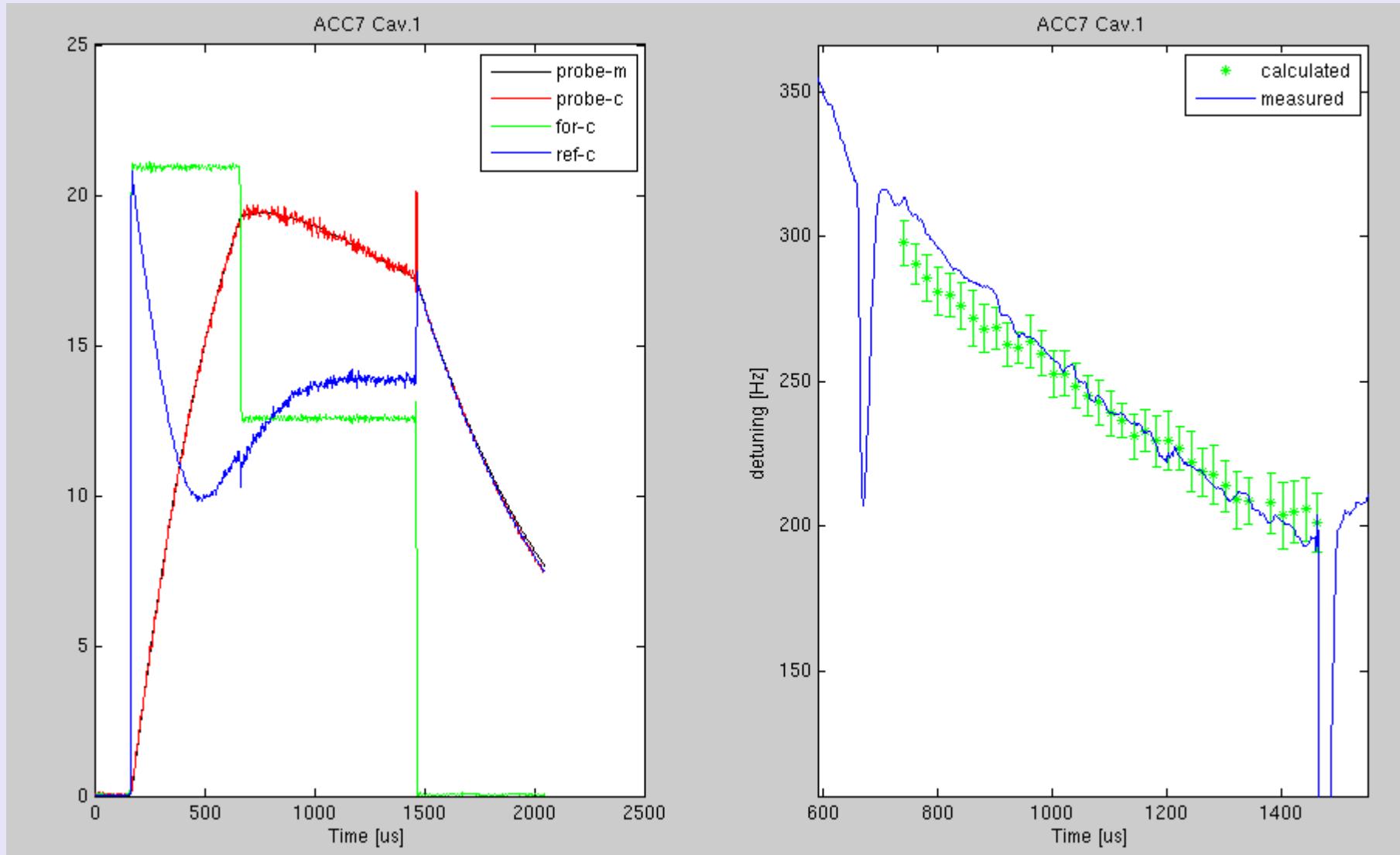
Detuning measurements (2)



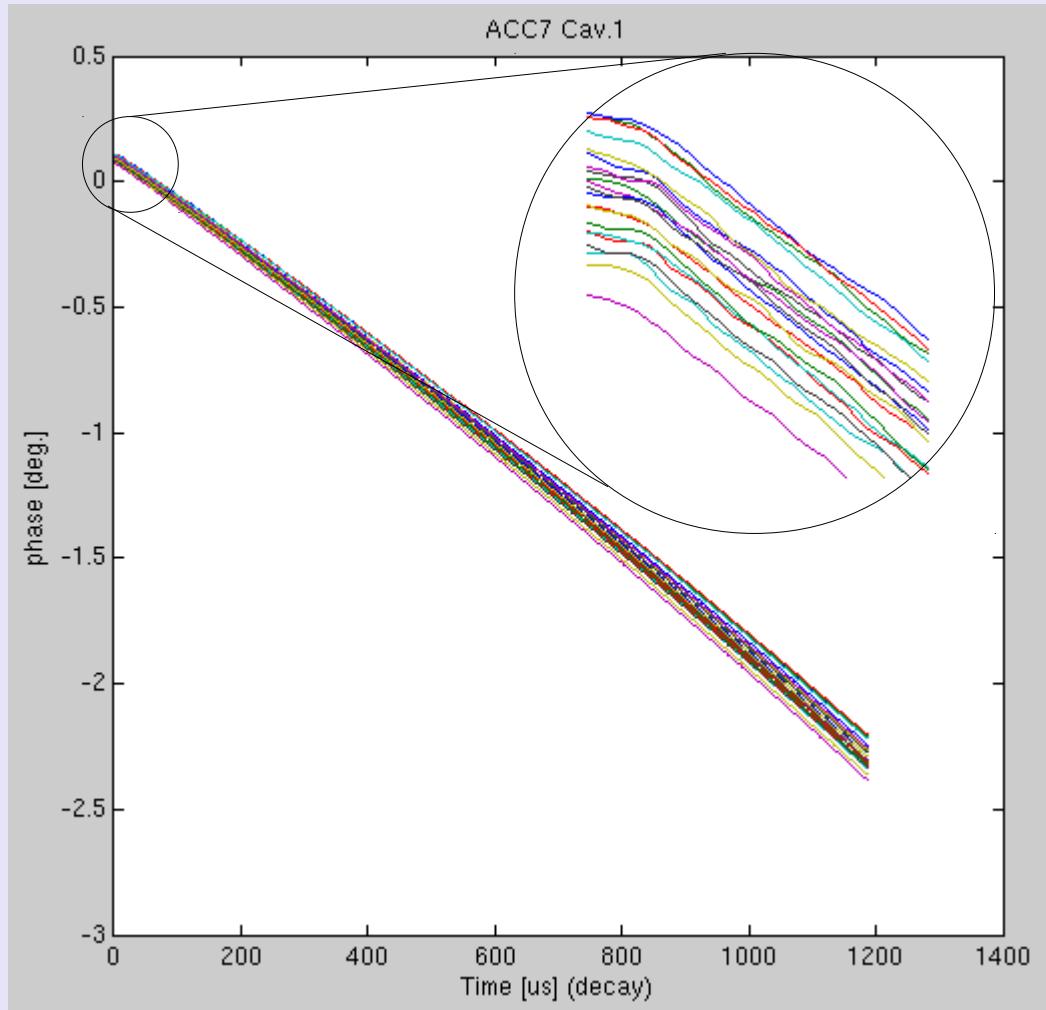
Definition of detunings



Comparison of detuning measurements



Probe phase during decay



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, φ_c – field amplitude and phase ,

$\omega_{1/2}$ – cavity bandwidth

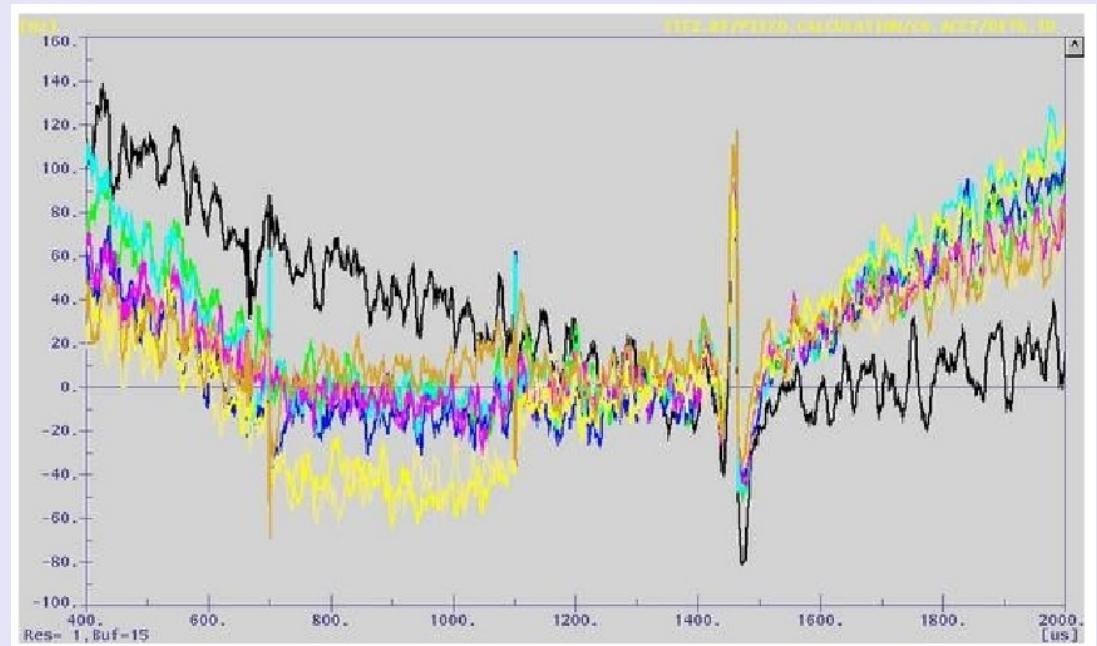
V_b, φ_b – beam induced voltage amplitude and phase

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

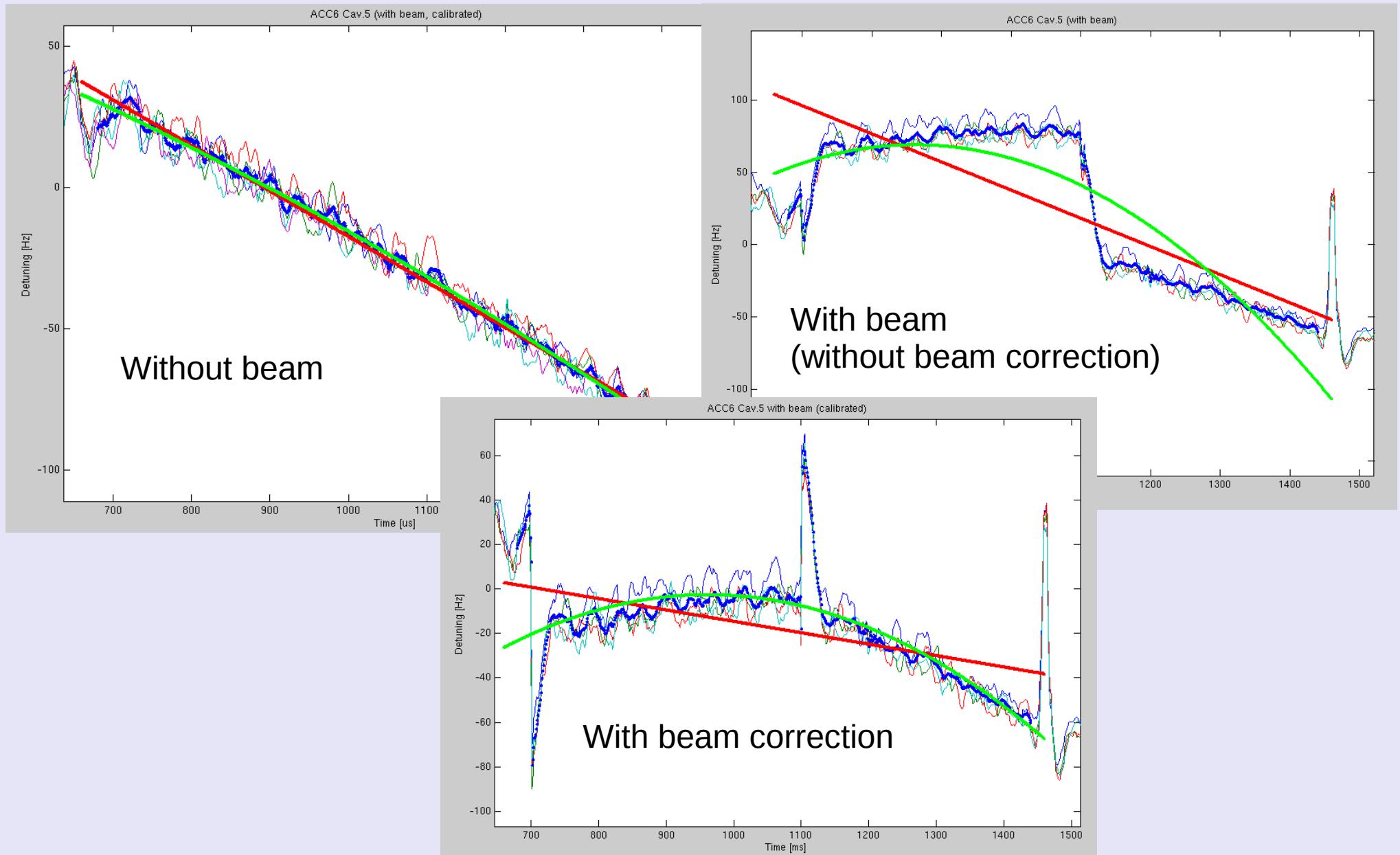
C_b – calibration factor

I_b – beam current

(measured at toroid)



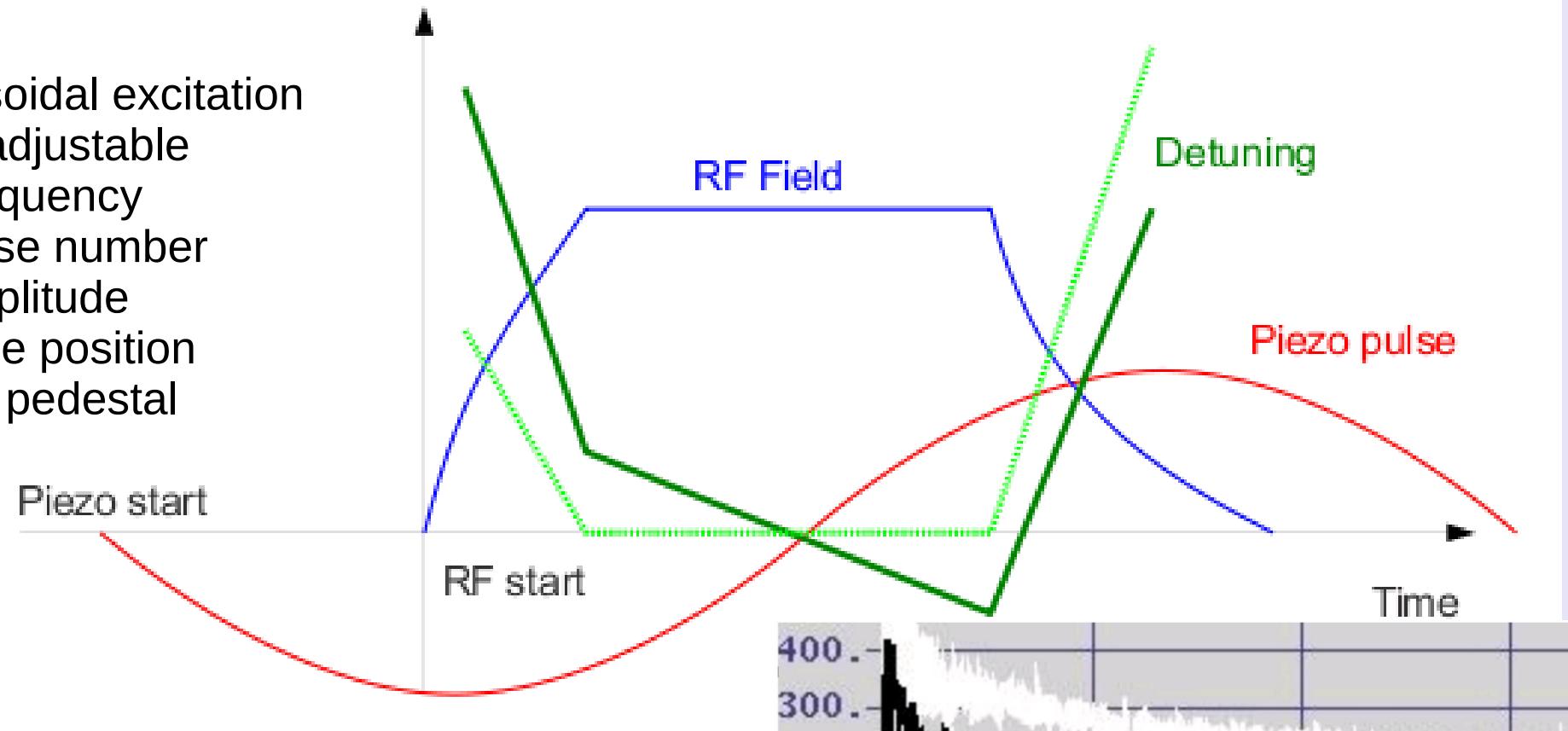
Detuning in ACC6 Cav.5



Piezo control for LFD compensation

Sinusoidal excitation
with adjustable

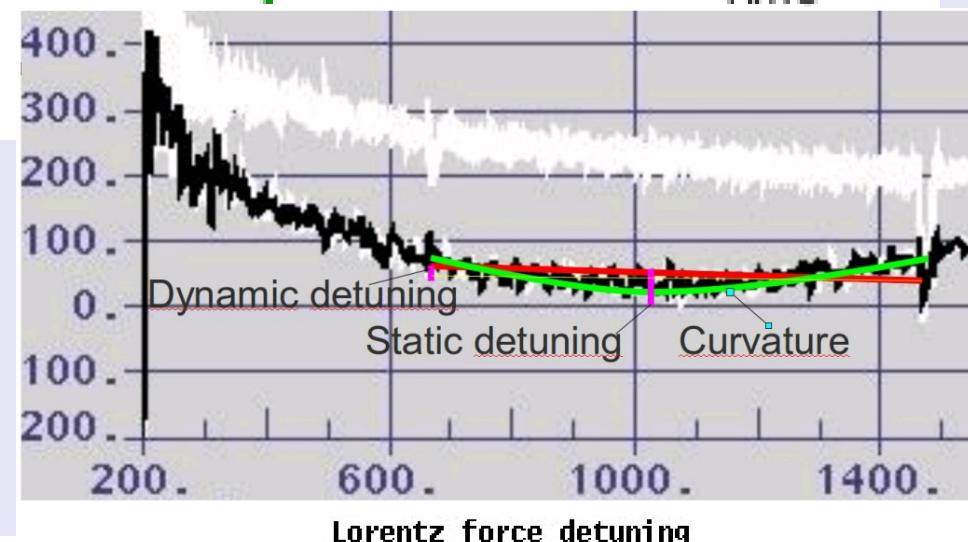
- Frequency
- Pulse number
- Amplitude
- Time position
- DC pedestal



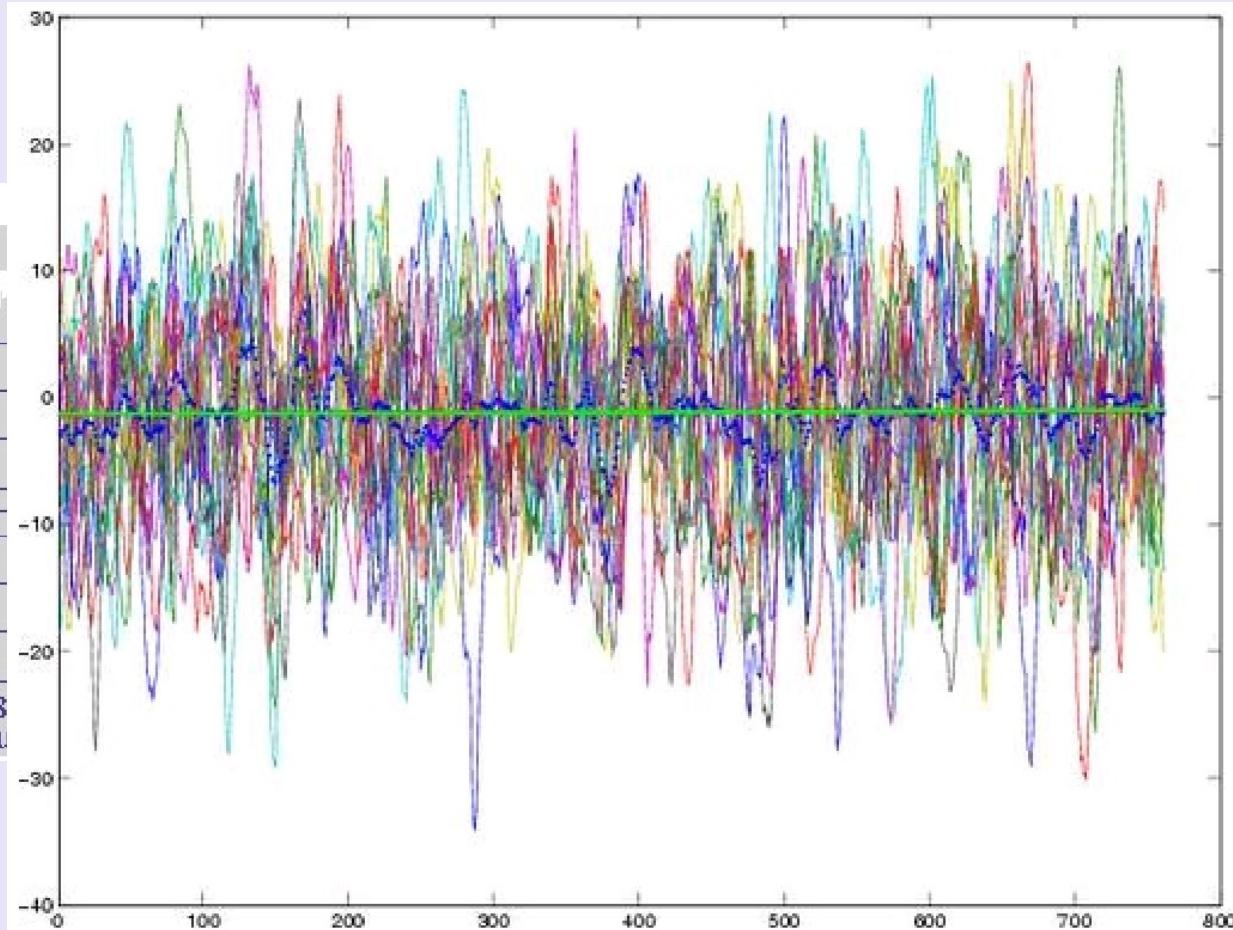
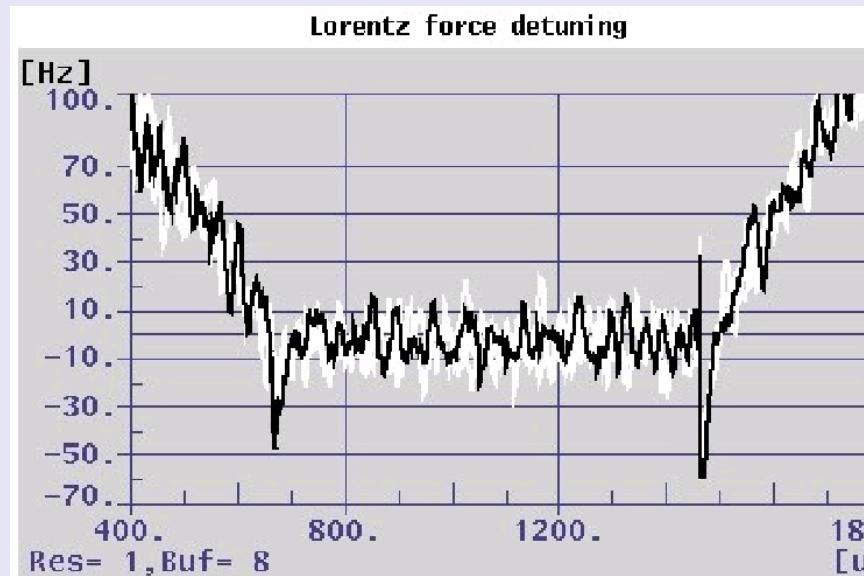
Amplitude → dynamic detuning

DC pedestal → static detuning

Time position → curvature

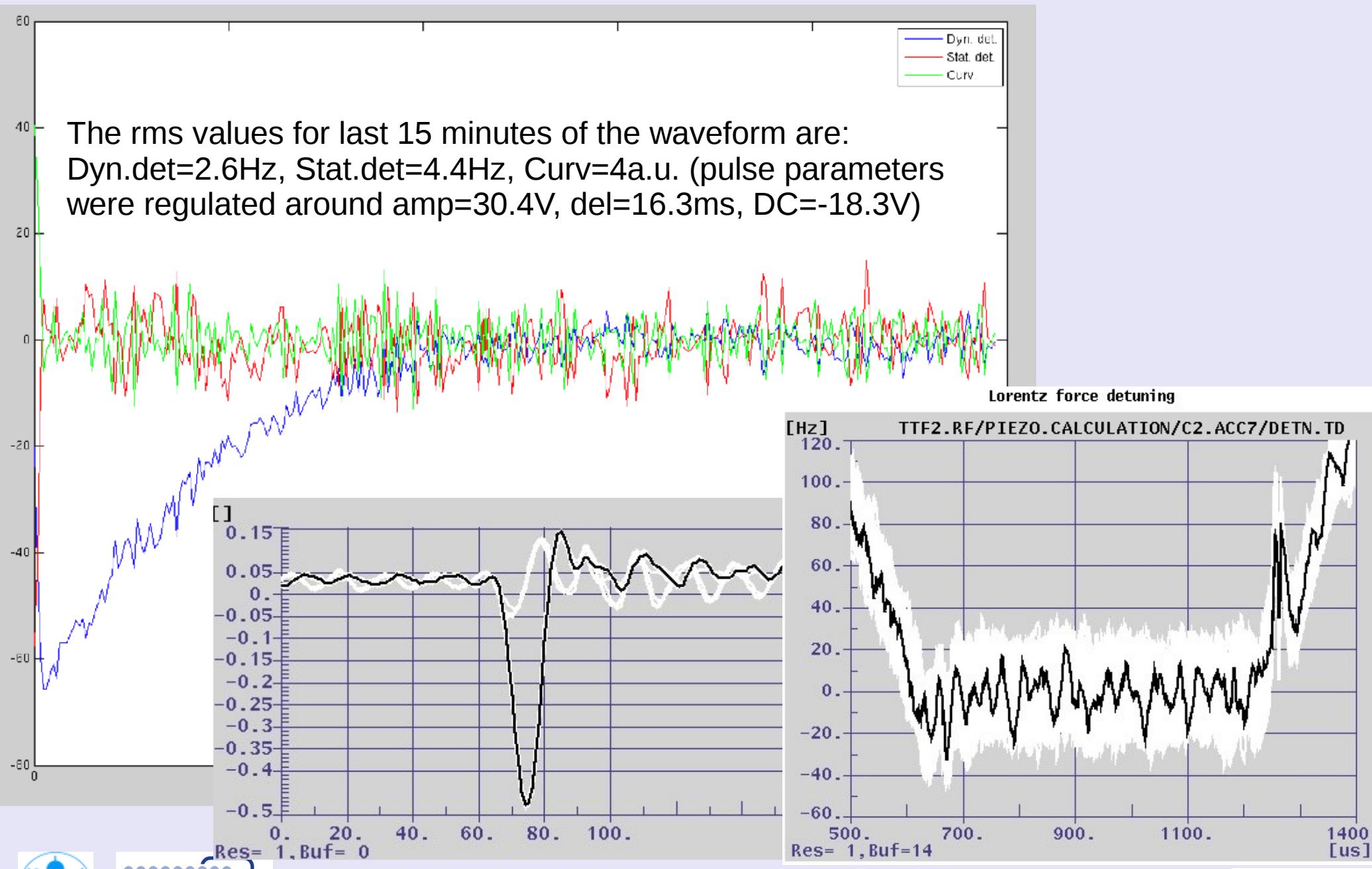


Tuning of cav. 1 at ACC6



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: bipolar mode, 200Hz, 1 pulse, 19.12ms after A2, amp=-23.06V, DC off=-36.62V

Automatic tuning of cav. 2 ACC7



Future plans

- Quantify the beam influence on detuning calculation
- Implementation of automatic cavity tuning using piezo in the DOOCS server for routine operation
- Microphonics compensation



Conclusion

- LFD is one of the limiting factor for high gradient cavities operation
- The measurement of cavity detuning is not a trivial task, in particular in heavy beam conditions, further studies are needed to evaluate the beam correction terms
- The automatic procedure for cavity tuning is worked out and will be implemented in the piezo control system

