Adaptive Lorentz Force Detuning Compensation in the ILC S1-G Cryomodule at KEK

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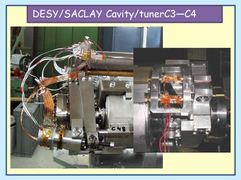
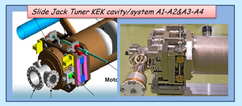
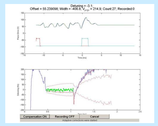
Abstract

The recent tests of the S1-Global cryomodule at KEK provided a unique opportunity to compare the performance of four different styles of 1.3 GHz SRF cavities and tuners under similar operating conditions. Results of adaptive LFD compensation at gradients of up to 35 MV/m for DESY/Saclay,FNAL/INFN and KEK cavity/tuner designs are compared.



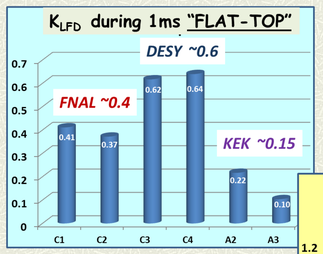


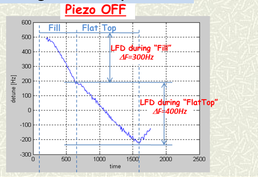


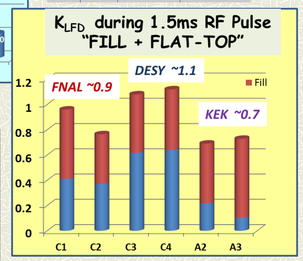
Cavity/Tuner LFD sensitivity

Blade(FNAL/INFN) vs. DESY/SACLAY vs. KEK(Slide Jack)

$\Delta F = -K_{LFD} * E_{ACC}^2$ → K_{LFD} – Cavity/Tuner Detuning Sensitivity to LFD



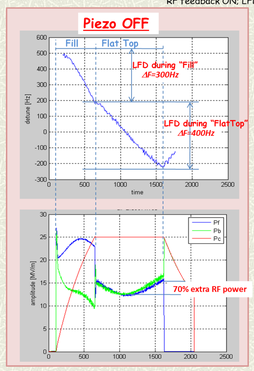


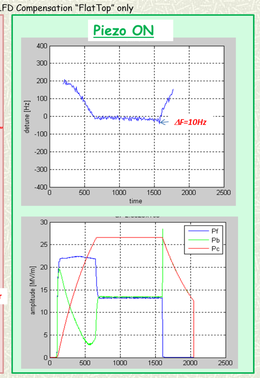


	FNAL/INFN	DESY/Saclay	KEK
K_{LFD} (1ms FLAT-TOP)	0,4	0,6	0,15
K_{LFD} (1.5ms FILL+FLAT-TOP)	0,85	1,1	0,7

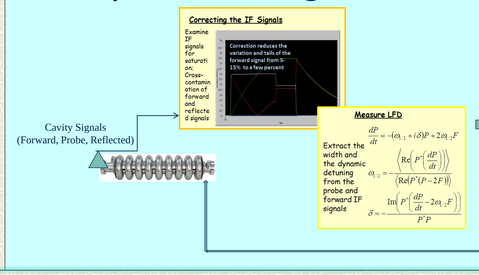
C4-DESY Cavity/Tuner System LFD at Eacc=25MV/m

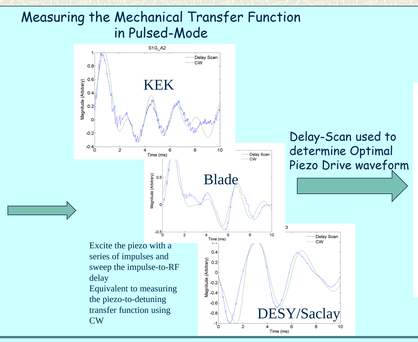
RF feedback ON; LFD Compensation "FlatTop" only

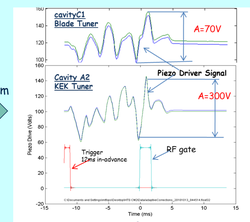




FNAL's Adaptive LS LFD Compensation Algorithm

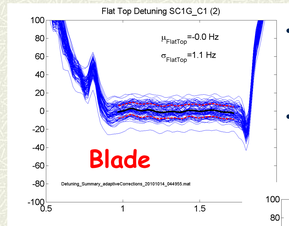




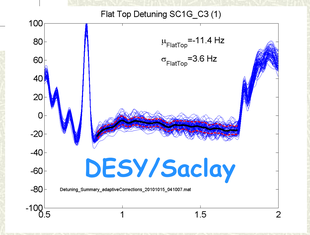


LFD Compensation during "FLAT-TOP"

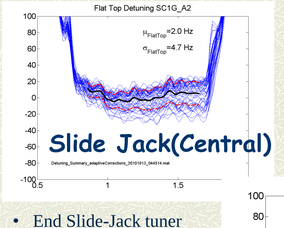
Average multiple pulses (black line) and calculate mean and standard deviation of average over the flat top



- Uncompensated Blade tuner has LFD (up to 700 Hz @ 35 MV/m)
- Able to compensate to several Hz

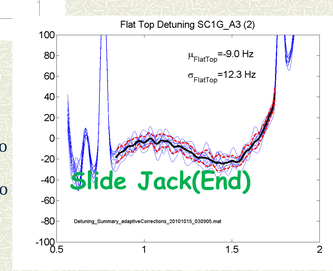


- DESY/Saclay tuner has slower response and longer time constants (large residual vibration at high rep. rate) than Slide-Jack or Blade
- Still able limit LFD to several Hz
- Spikes are filtering artifacts

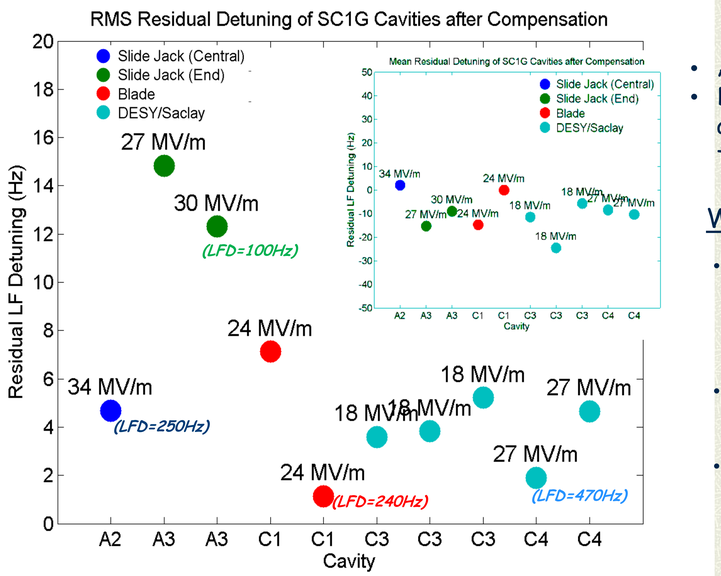


- End Slide-Jack tuner shows very little LFD (~100 Hz at 34MV/m)
- Concerned that stiffness might make it difficult to compensate

-12Hz offset is likely due to limitations of adaptive bias correction stability



BACK-TO-BACK COMPARISON



- All tuners respond very well
- Detuning control limited by adaptive bias correction rather than cavity/tuner design

Why Are the Results So Similar?

- Major differences between cavity/tuner types in
  - ✓ Stiffness
  - ✓ Fast Tuning Range
  - ✓ Etc.
- 1 ms RF pulse not able to resolve details of mechanical spectrum to better than 1kHz
- Also explains why simple half-sine pulse works so well
  - ✓ Half-sine would probably not work well for pulse-lengths comparable to or longer than the period of the dominant mechanical oscillation

Summary

- **Adaptive LFD compensation system used to evaluate performance of SC1G cavities**
- **Optimal piezo drive waveform provides a rigorous basis for back-to-back cavity performance comparisons**
- **Four cavity/tuner types tested represent four distinctly different design philosophies**
- **Residual LFD could be limited to better than 16 Hz in all four cavity types tested**
- **LFD control limits for ILC will likely depend more on controller and quality of the input signals than the mechanical details of cavity/tuner**