Piezo tuner options for the next module

Lutz Lilje
MPY
21.1.2004

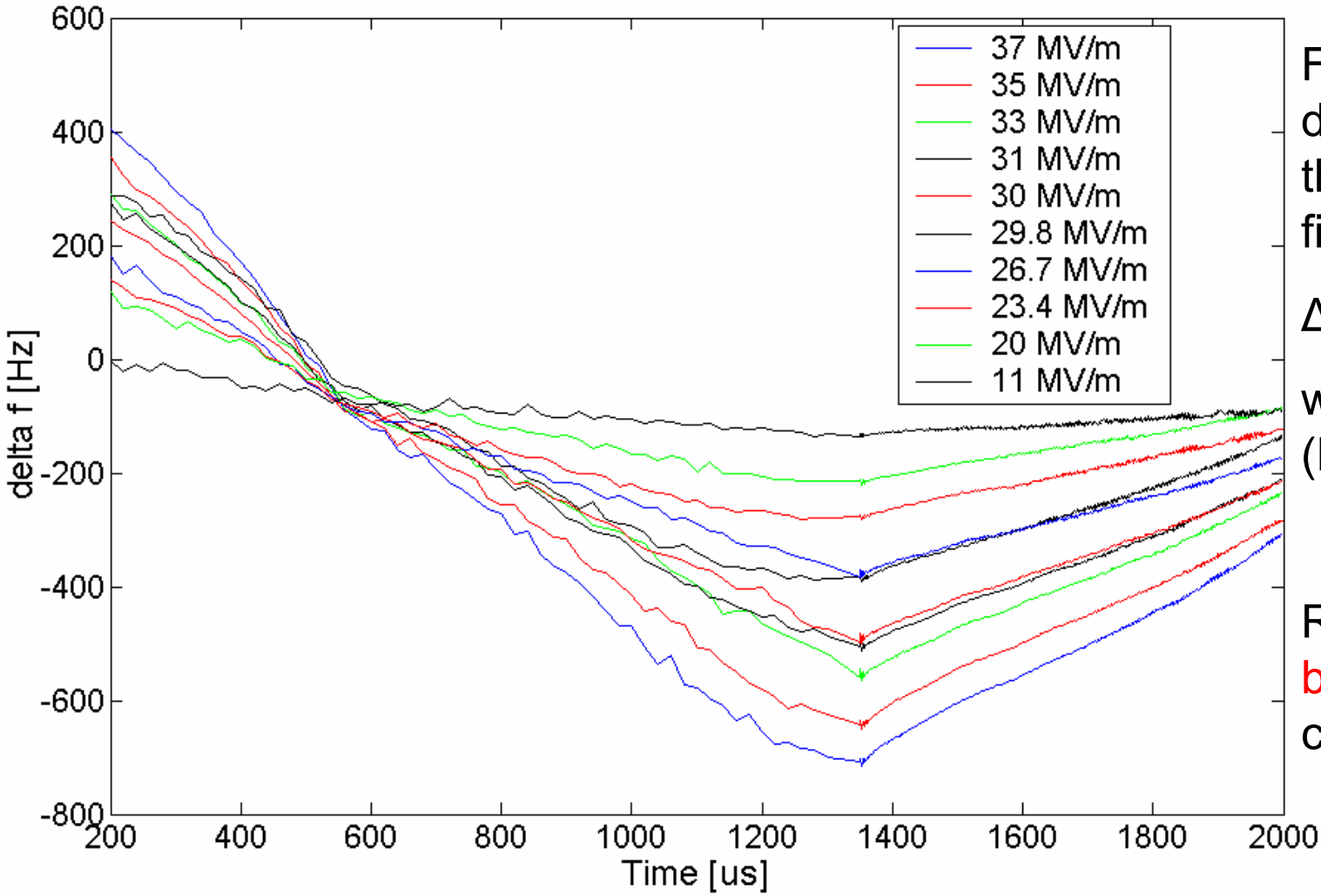
- Principle
- Proof-of-principle experiments
- Preliminary test setups
- Problems in the CHECHIA tests
- Tentative new designs

Active Lorentz force compensation

- Idea:
  - Actively compensate the detuning of the cavity during the RF pulse -> Reduce the RF power bill
- History:
  - Demonstrated the compensation of 200 Hz detuning at 23,5 MV/m with an piezo-electric element (S. Simrock et al.)
  - Has shown to some degree radiation hardness also in cryogenic environment and under pulsed conditions

Frequency detuning during RF pulse

Beam on



Frequency detuning due Lorentz forces of the electromagnetic field in the cavities:

$\Delta f = K \cdot E_{acc}^{2}$

where $K \approx 1\ Hz / (MV/m)^2$

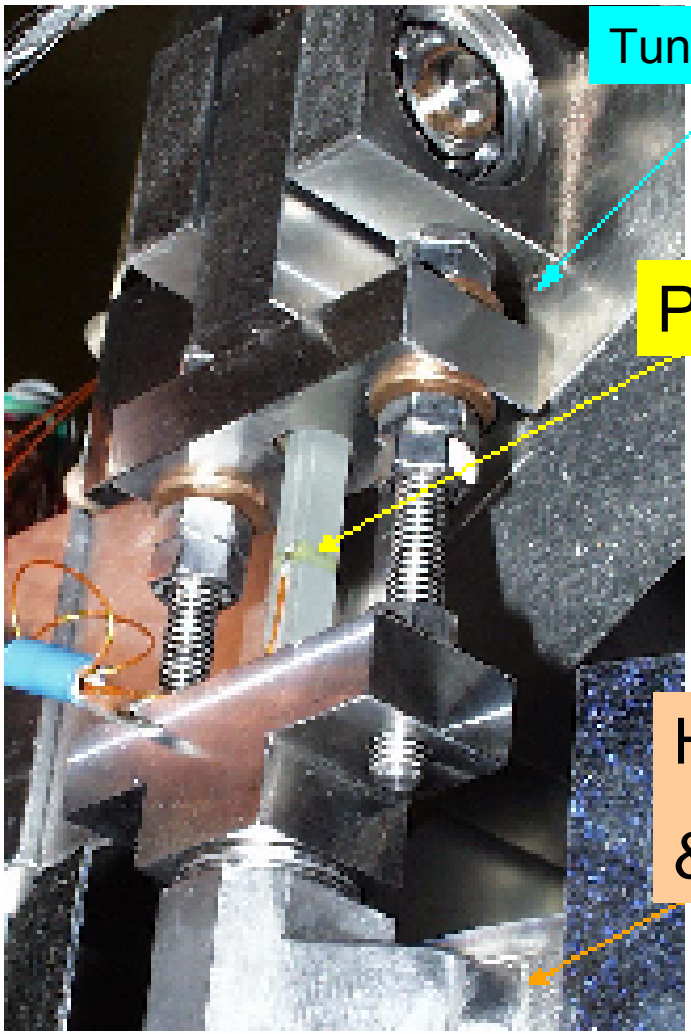
Remember: Cavity bandwidth with main coupler is ≈ 300 Hz

Status of the active tuner R&D

- There exist 2 designs
  - Single Piezo fixture
    - Old, simple design
    - Demonstrated 300-400 Hz compensation at 1,3GHz
  - Double Piezo fixture
    - Offers sensor-actuator coniguration
    - Has been operated for 700 hours
    - Demonstration of more than 500 Hz being compensated
- Evaluation of different piezo manufacturers in Vertical cryostat 3 (DESY) and Milano
- Discussion started on magnetostrictive materials
  - First actuator available

Piezoelectric tuner

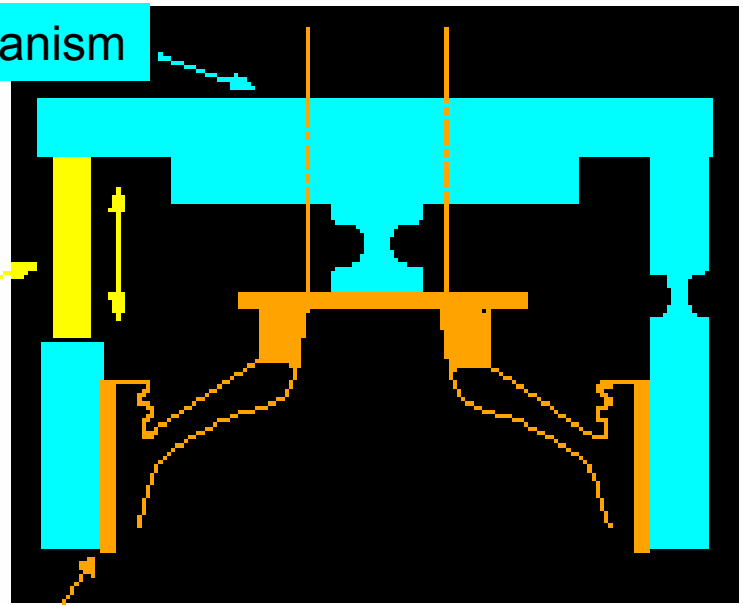
M. Liepe, S. Simrock, W.D.-Moeller



Tuning mechanism

Piezo

He-Tank & Cavity



Piezo-Actuator:

l=39mm

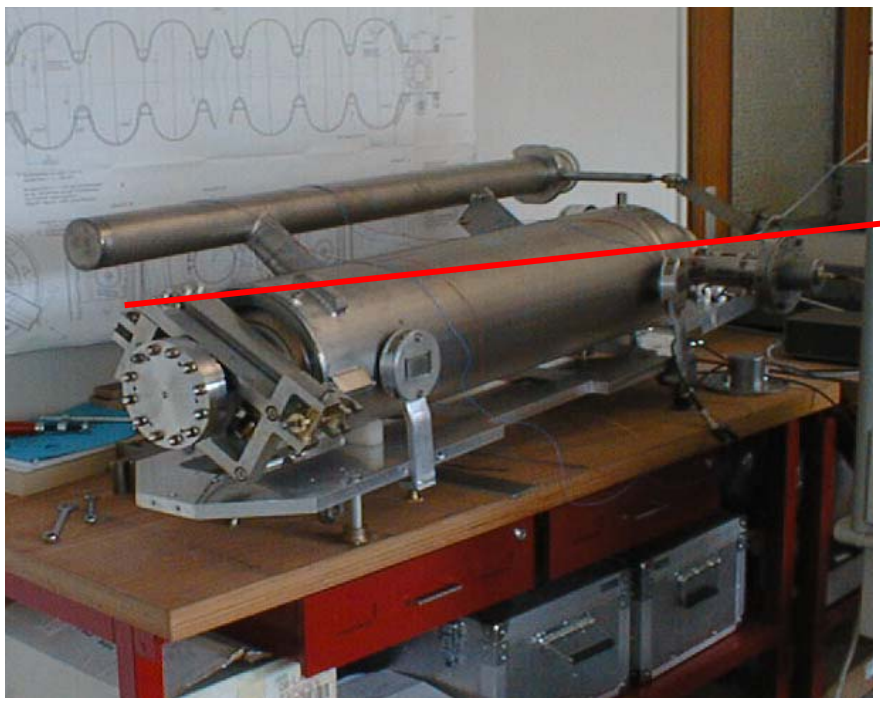
U_{max}=150V

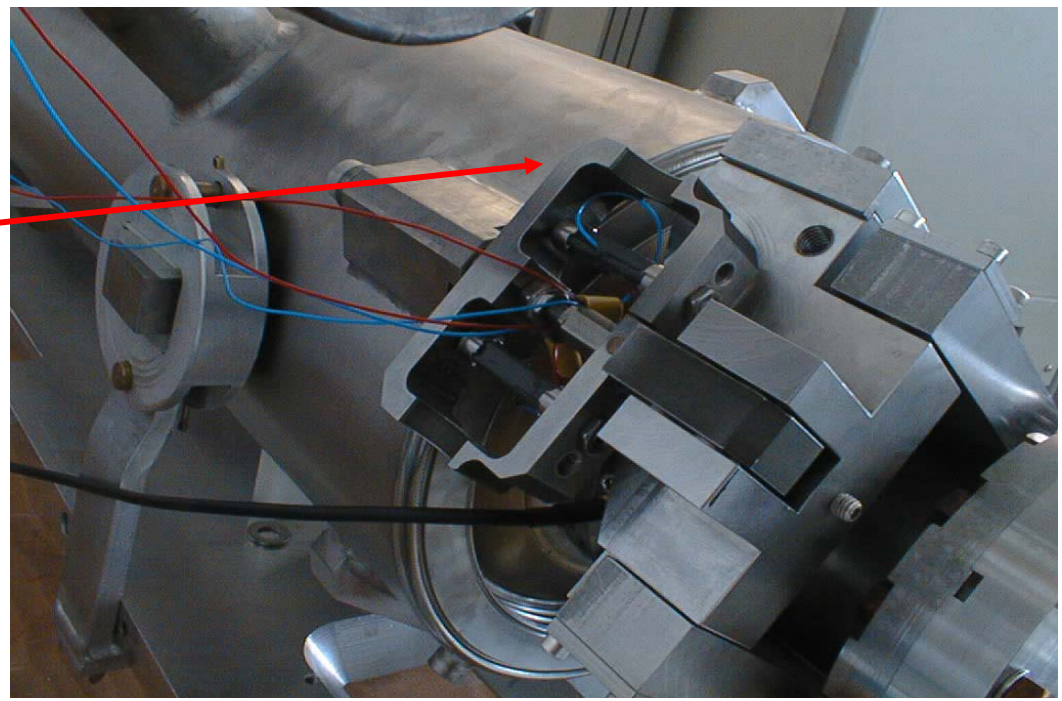
Δ l=3μm at 2K

$\Delta f_{max,static}$=500Hz

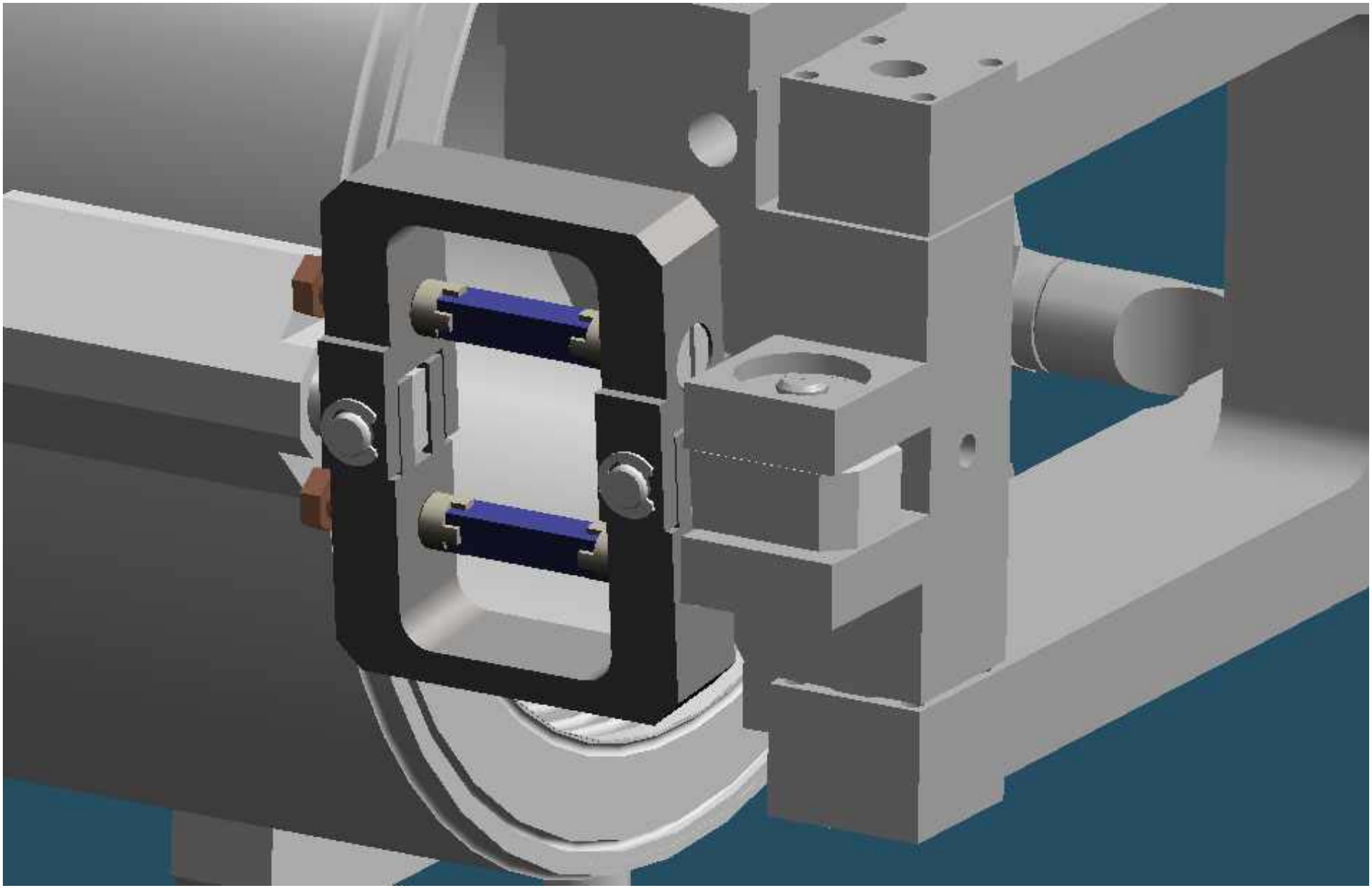
New Piezo-assisted Tuner setup

- Sensor-Actuator configuration
- To compensate for Lorentz force detuning during the 1 ms RF pulse
  Feed-Forward
- To counteract mechanical noise, “microphonics”
  Feed-Back

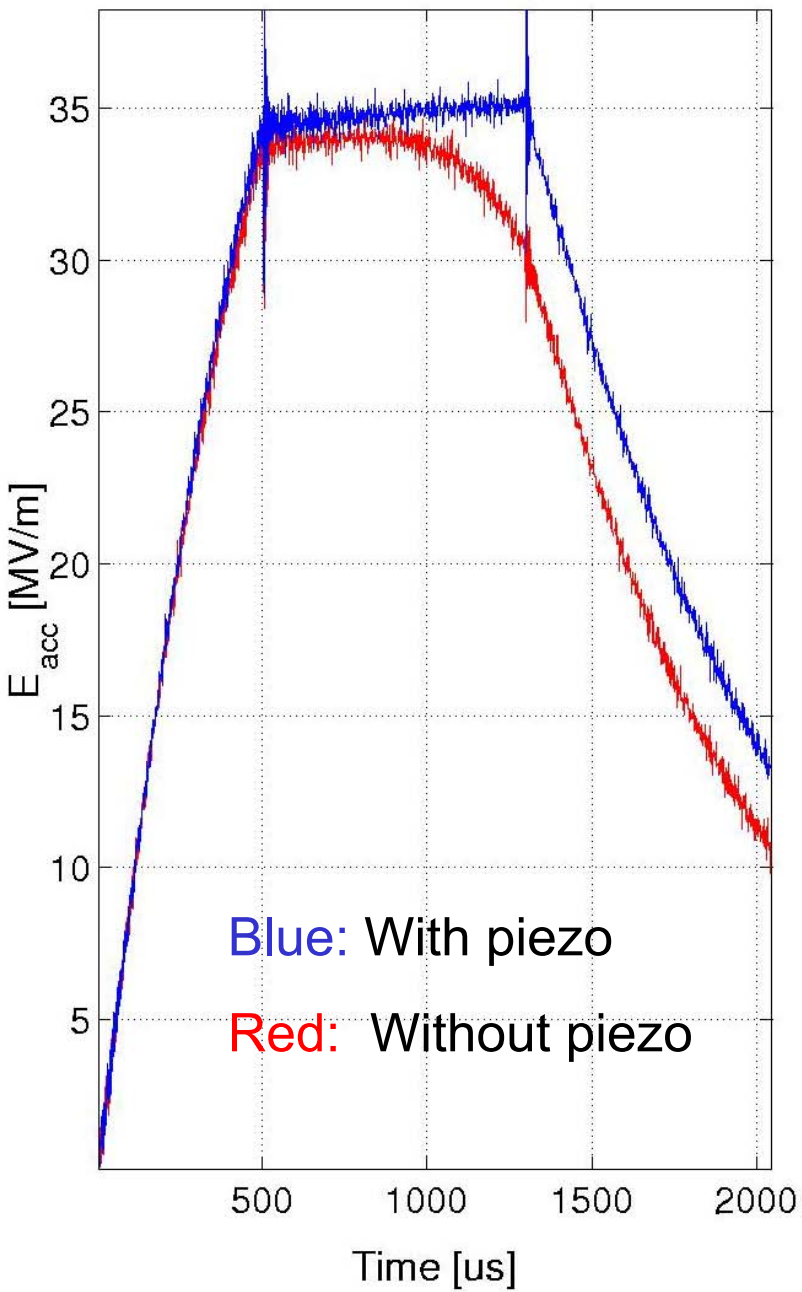


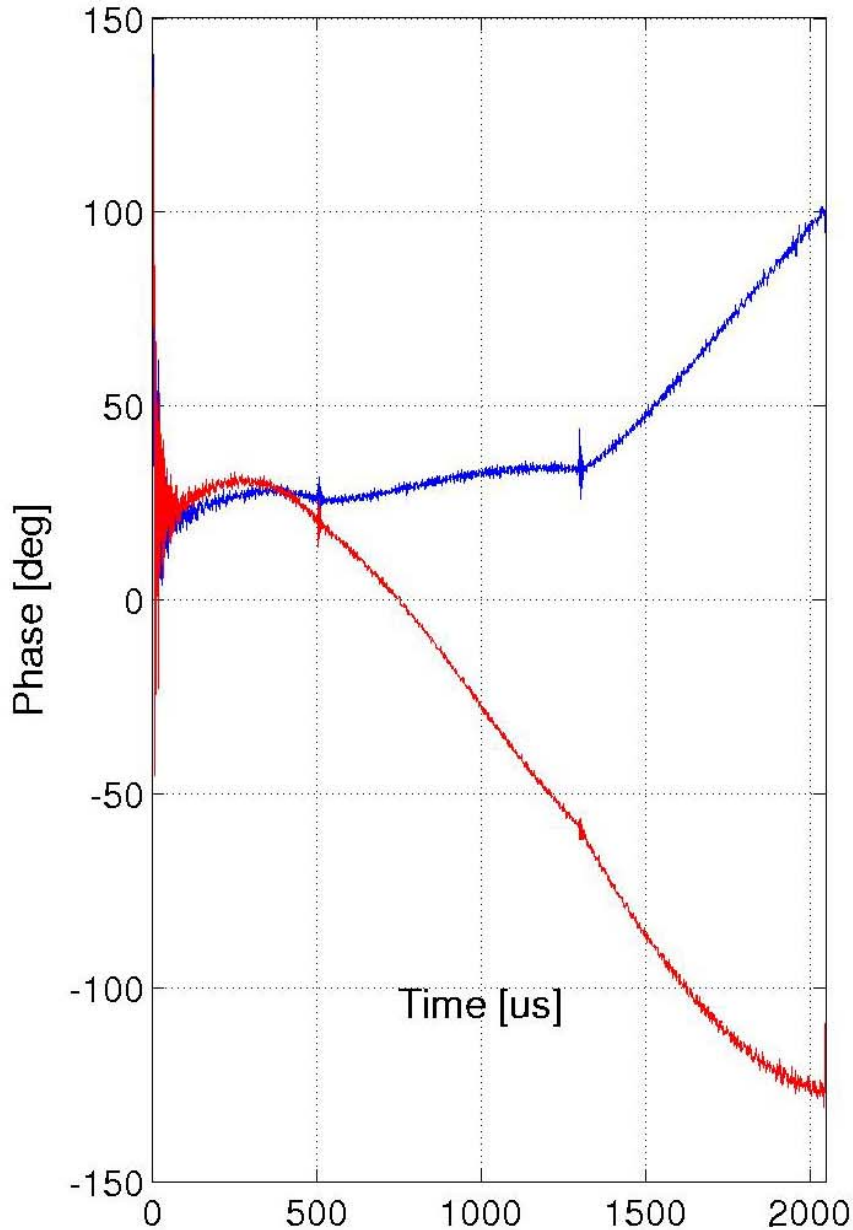


Drawing of current setup (H.-B. Peters)



RF signals at 35 MV/m



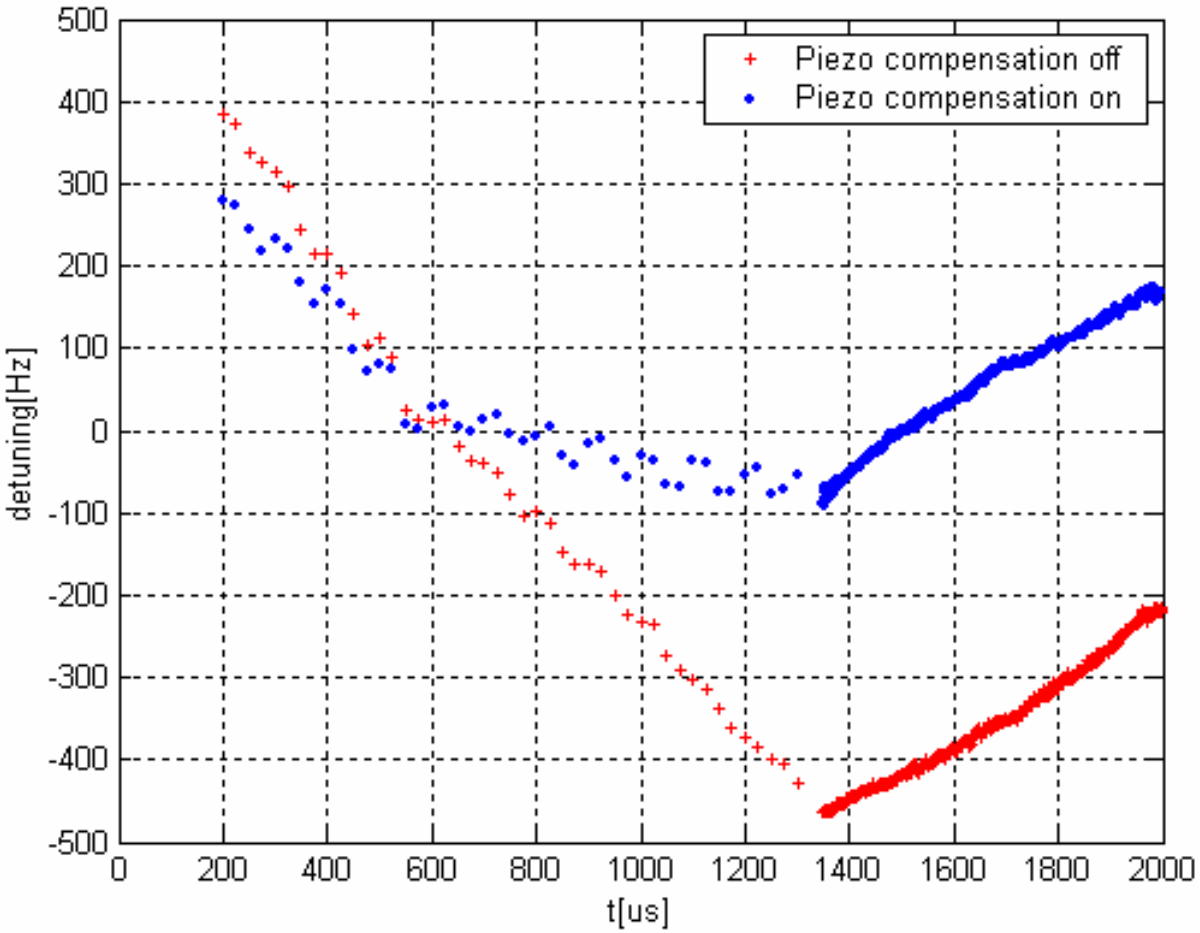


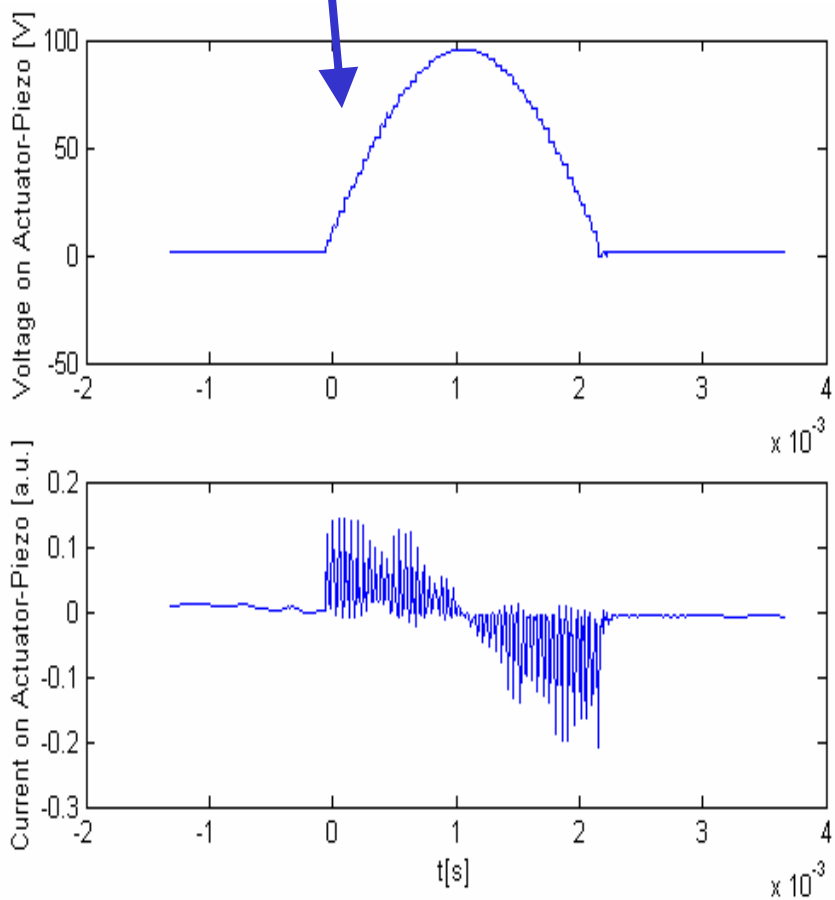
Frequency stabilization during RF pulse using a piezoelectric tuner

Blue: With piezo

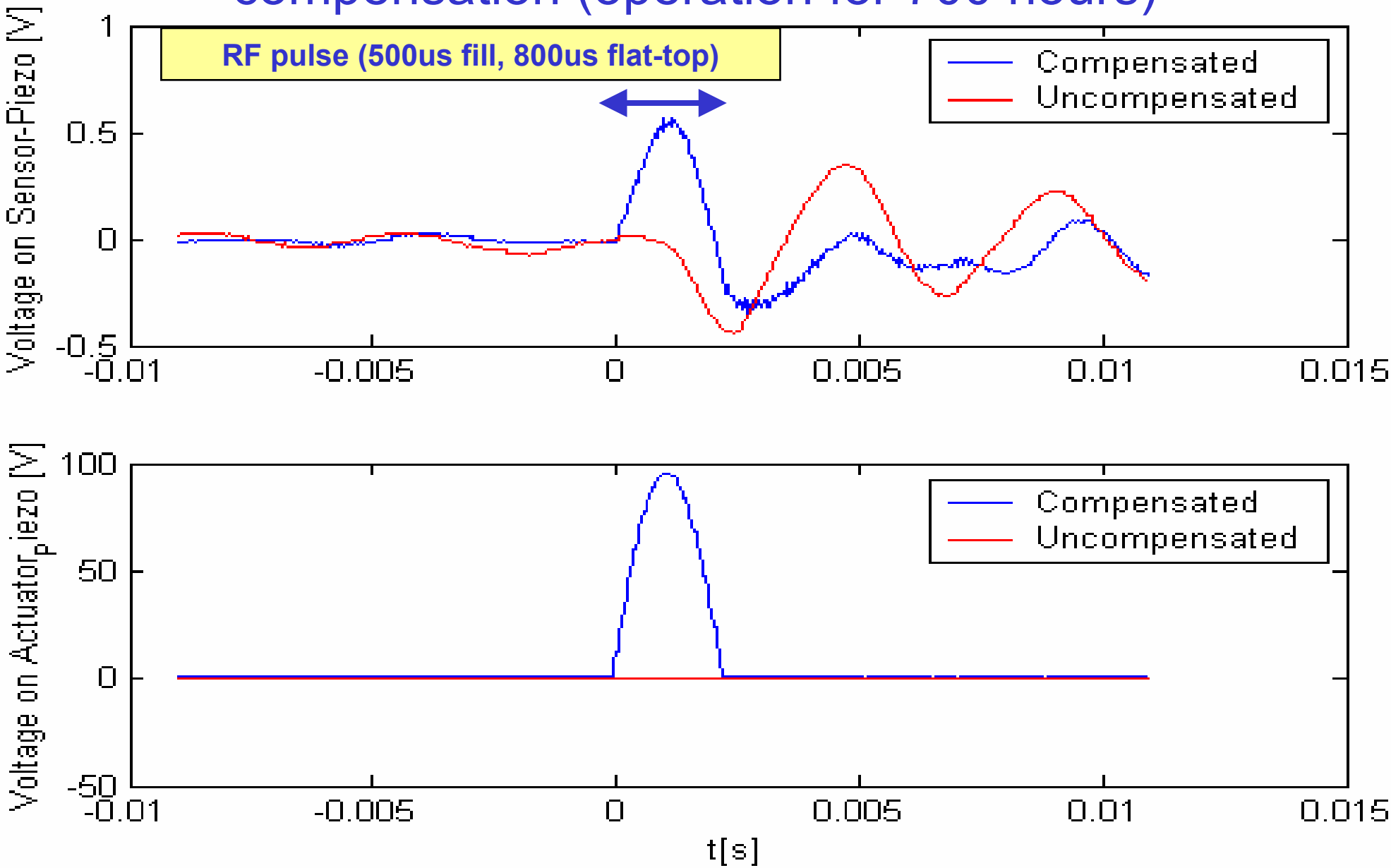
Red: Without piezo

Frequency detuning of 500 Hz compensated voltage pulse (~100 V) on the piezo. No resonant compensation

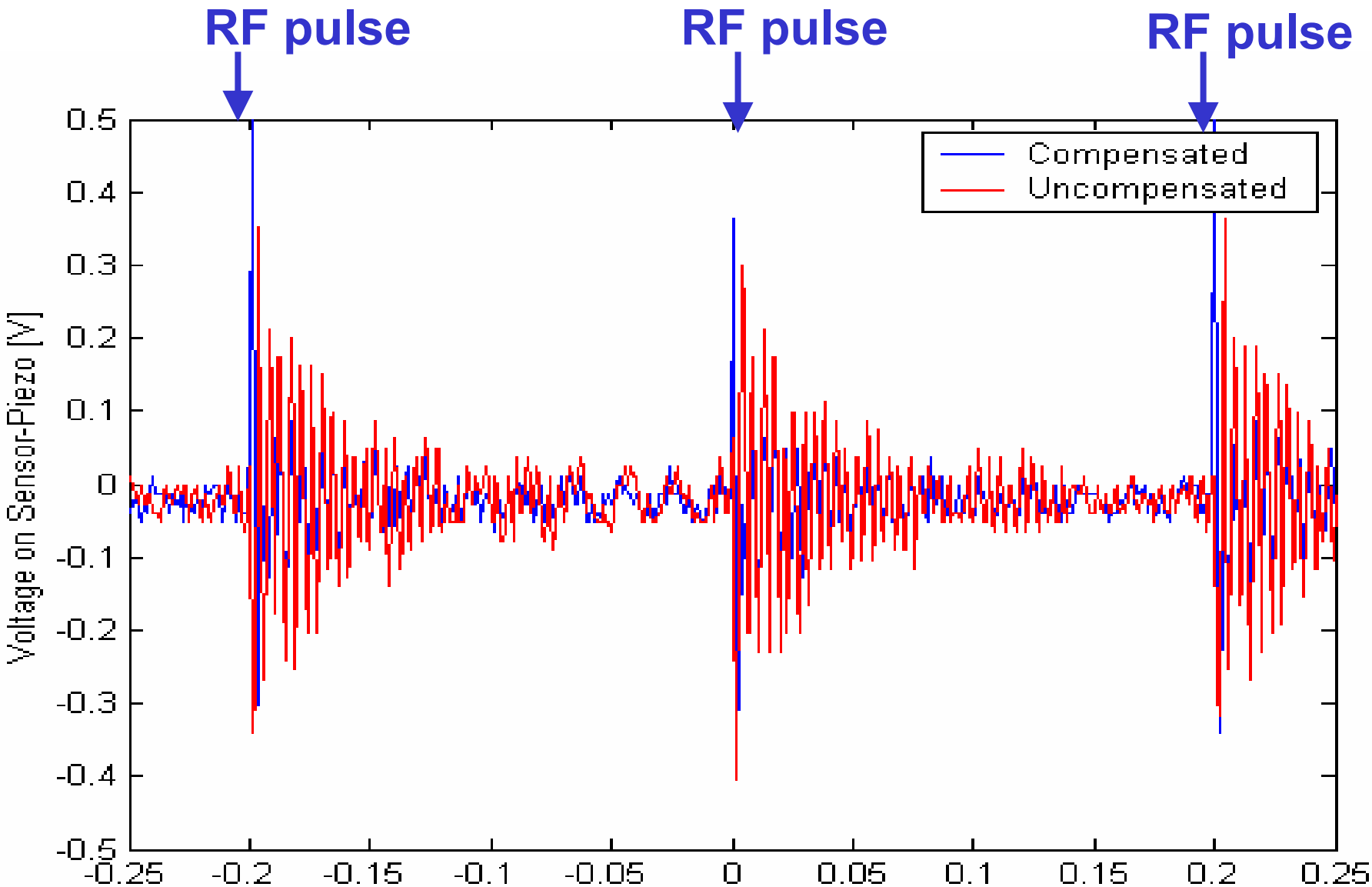




Piezo excitation of the cavity for frequency compensation (operation for 700 hours)



Damping of the ringing between pulses (5Hz operation)



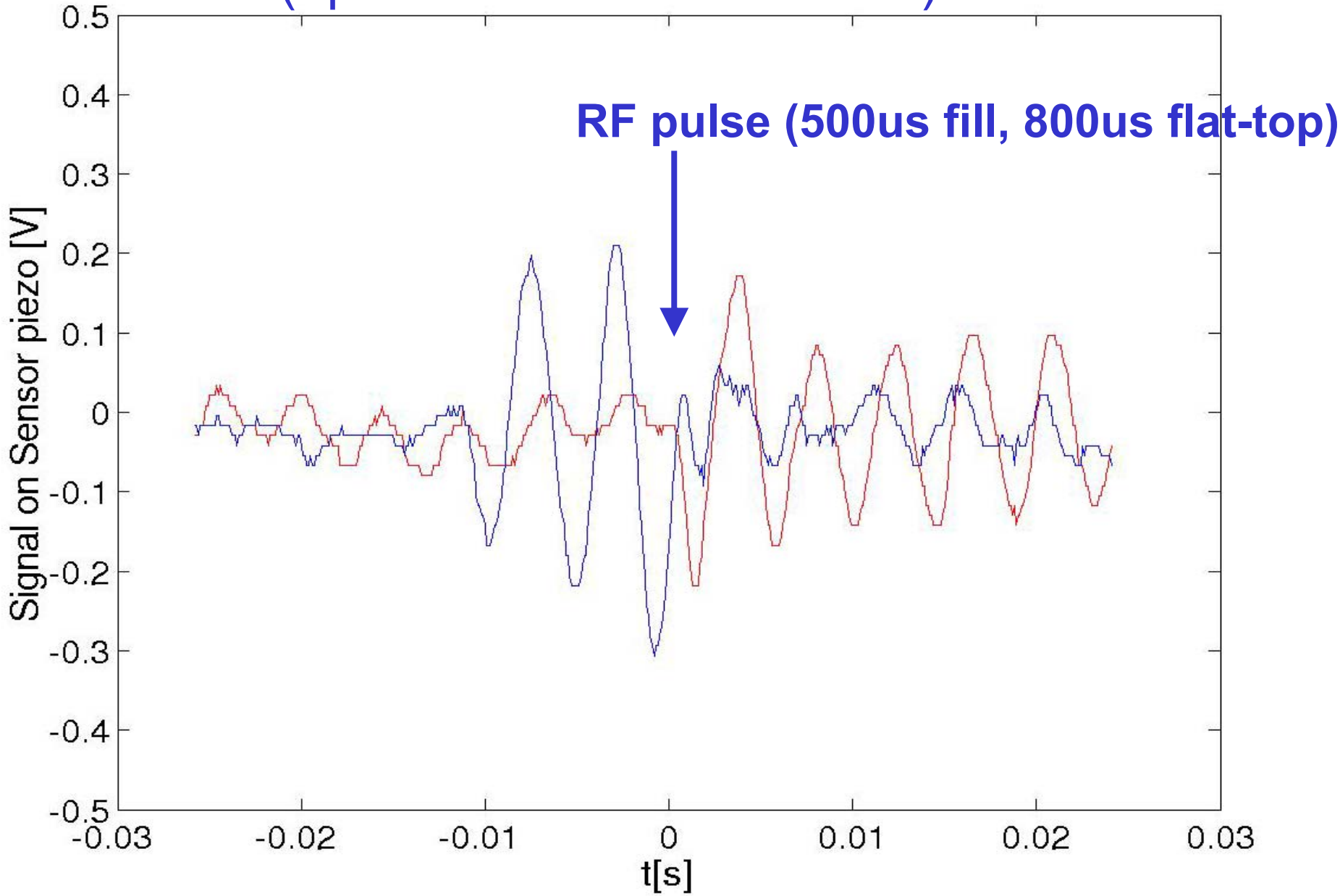
Problems with the active tuner

- Fundamental problem:
  - large tuning needed for AC72 (and AC73)
    - ´natural´ frequency after tank welding is 780 kHz above 1,3 GHz
    - Normally this is more like 200-300 kHz
  - this results in a very large force tearing on the piezo fixture
  - even the very rigid single piezo fixture cannot be used to operate at nominal frequency
- Single Piezo fixture
  - So far only 300-400 Hz compensated (no resonant excitation of the cavity)
  - Achieved compensation at 1,3 GHz
  - Alternative: Resonant mechanical excitation of the cavity
- Double Piezo fixture
  - Has only been operated at 1,3 GHz + 600kHz
  - Needs a stiffer design
  - Alternative: Put 2 single Piezo fixtures ?

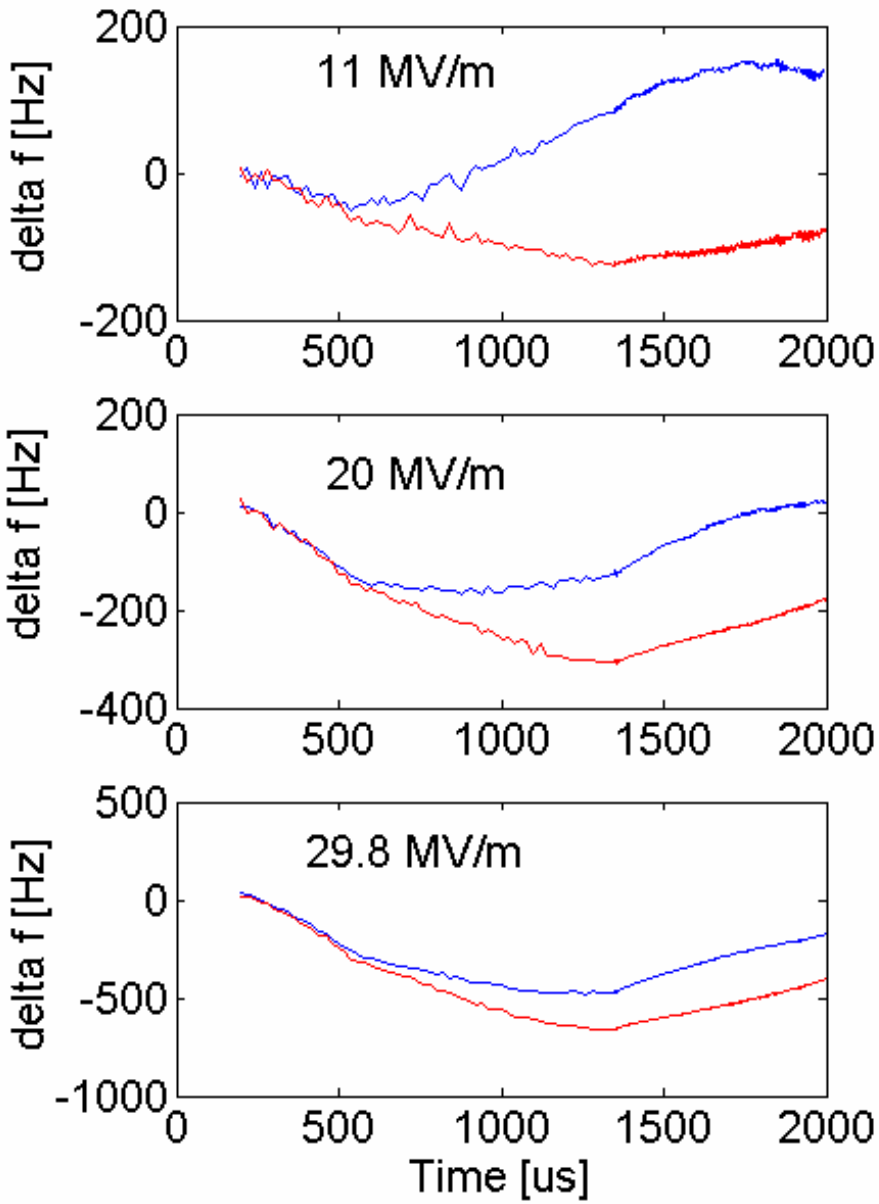
To be done

- Need a solution for Piezos by November this year for module 6
  - Tested in CHECHCIA
  - Produce fixture for 8 cavities
- Needs CHECHIA/Module tests with preferably very high gradient cavities
- Cold-warm cycling procedures of Piezos are delicate (water condensation)
- First test on magneostrictive material
- Design for X-FEL

Resonant excitation of the cavity for compensation (operation since 200 hours)



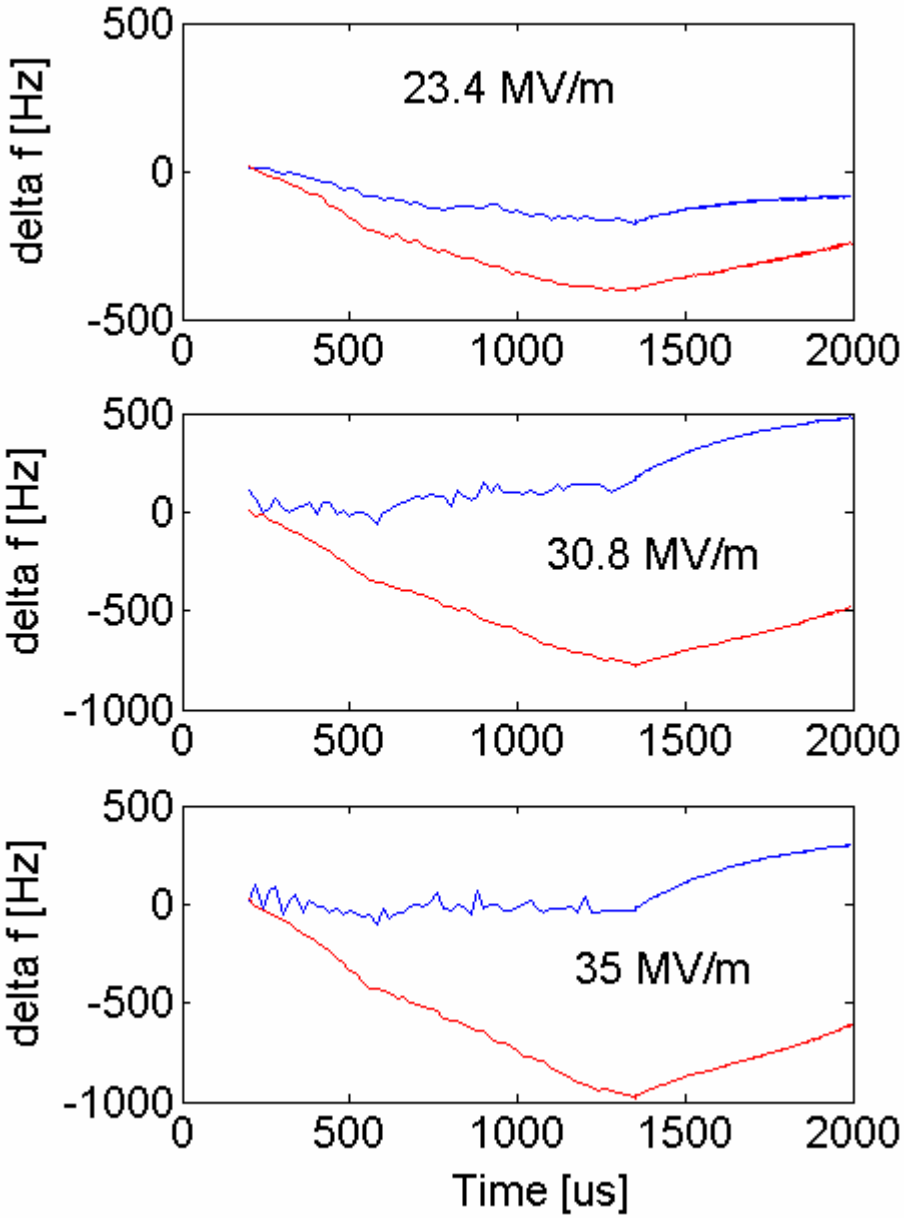
Frequency stabilization during RF pulse using a piezoelectric tuner



Blue: With piezo

Red: Without piezo

Frequency detuning of 200 - 250 Hz compensated with rectangular voltage pulse (~120 V) on the piezo.



NEW: Frequency stabilization at 35 MV/m

Blue: With piezo

Red: Without piezo

Frequency detuning of ~1000 Hz compensated with resonant excitation of a mechanical cavity resonance at 230 Hz.

NOTE: This is rather an demonstration of the capability of active tuning. Application in a real machine is probably difficult/impossible.