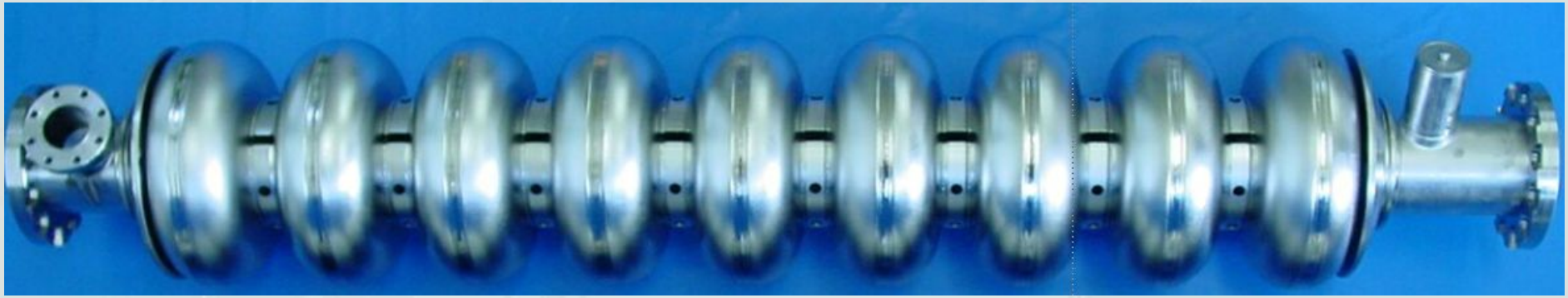
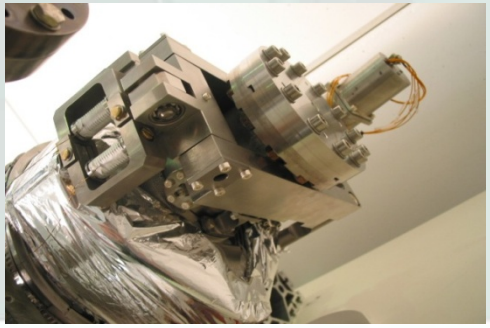
BESSY

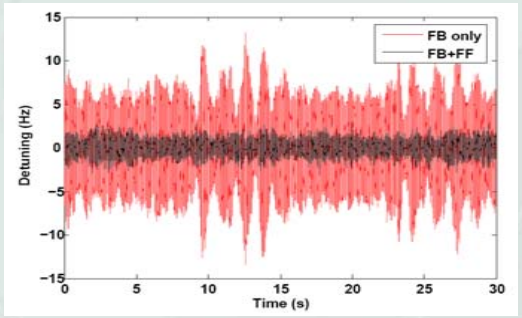
Berliner Elektronenspeicherring-Gesellschaft
für Synchrotronstrahlung m.b.H.

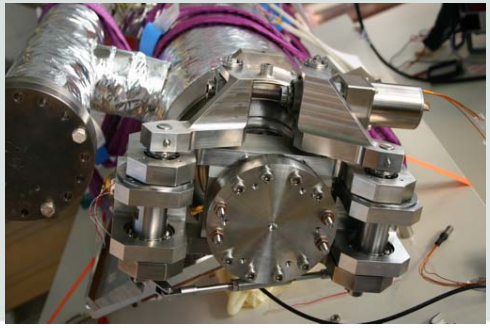
EURO FEL

Microphonics in CW TESLA cavities and their compensation with fast tuners

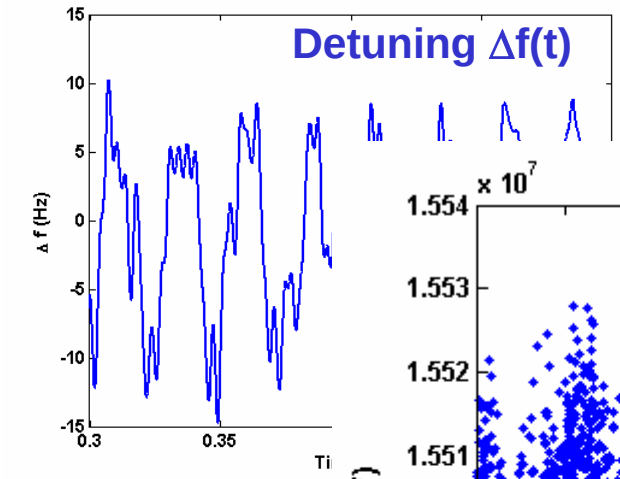




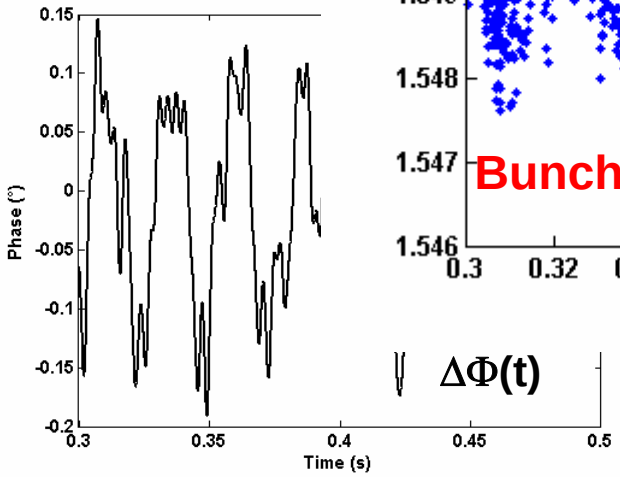




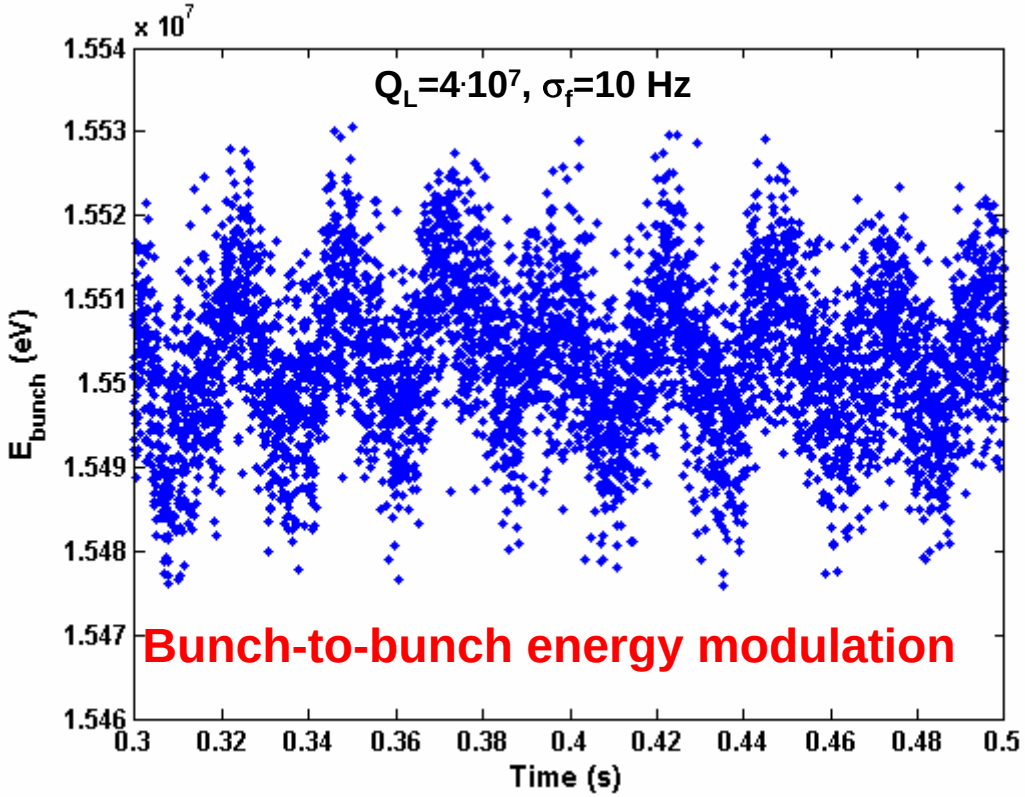
Motivation for microphonics detuning control

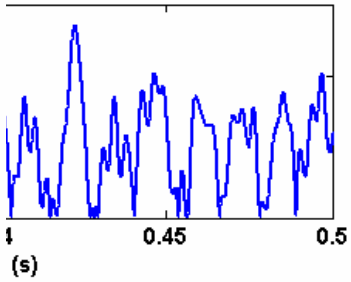


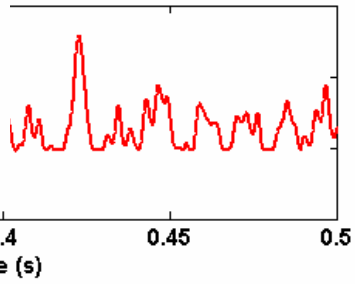
CW Pha
detunir

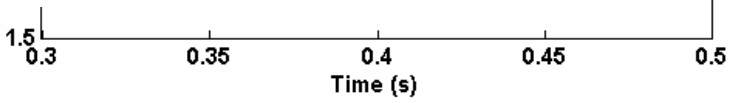


Superconducting CW Cavity operational aspects:
(from LLRF control simulations)









ΔΦ(t)

Phase stability ~ 0.02° achievable without further means?

How bad is the real world? → Measure microphonics

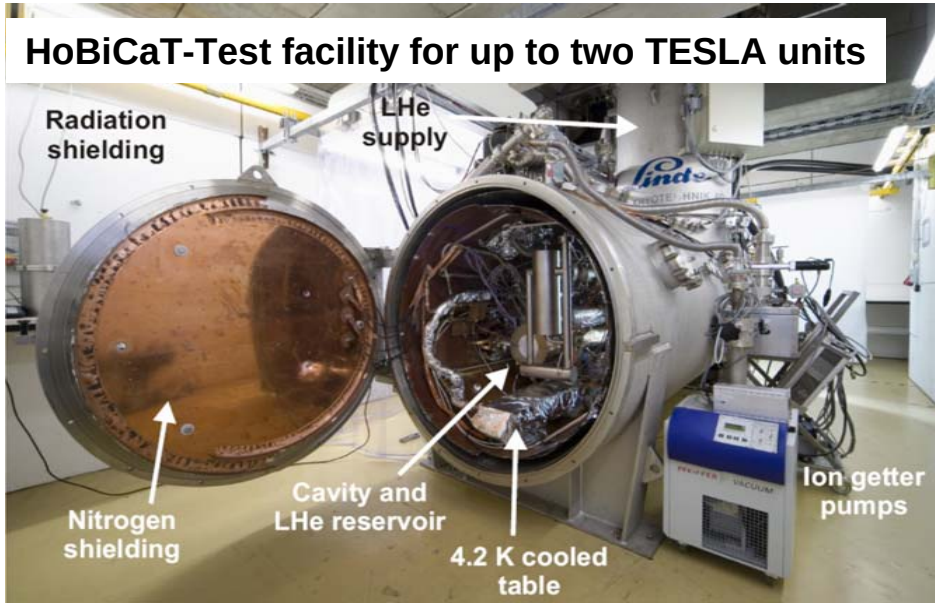
What are the mechanics of my system?→

Tuner-cavity characterization, Transfer function

Combine information of detuning and transfer function →

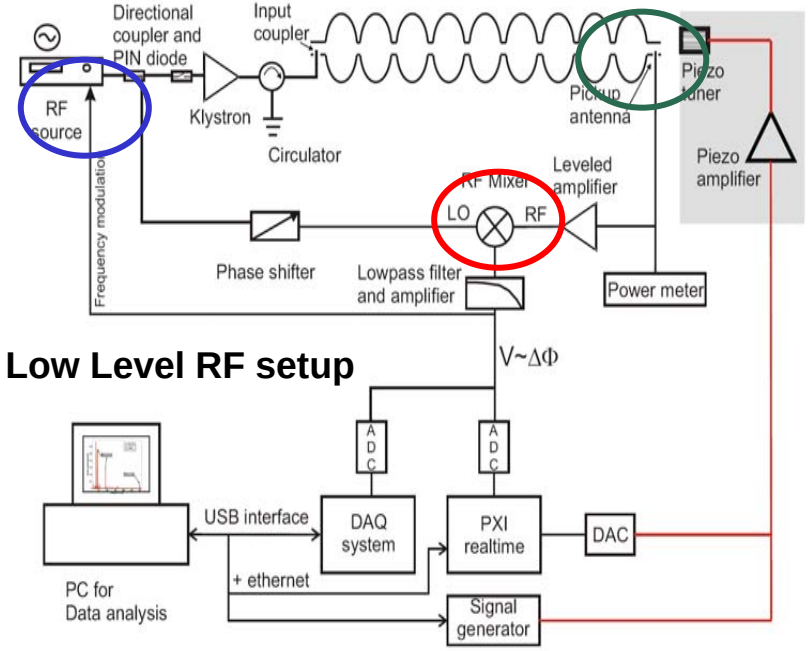
Implement compensation scheme

HoBiCaT-Test facility for up to two TESLA units



- T_{LHe}= 1.8 Kelvin
- **Bandwidths ~20-40 Hz**
- **Measurement accuracy by mixer and RF source: 0.2 Hz at 1.3 GHz**

Open loop detuning detection by comparing phase between RF source and measured field



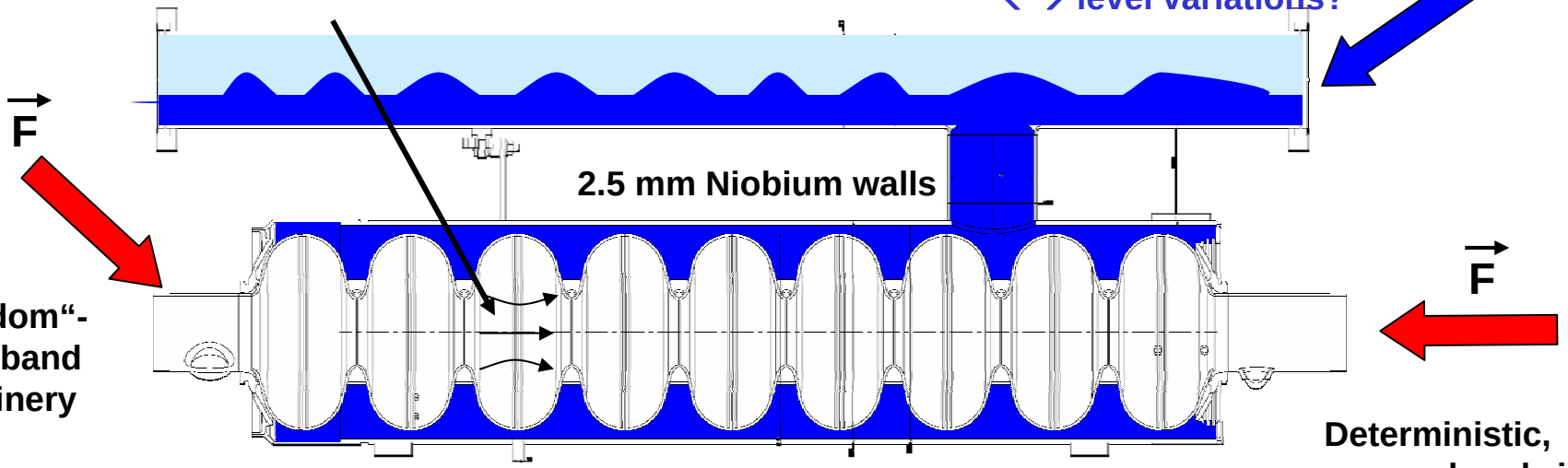
Low Level RF setup

Possible detuning sources

Field strength variations:
Dynamic Lorentz forces

Helium pressure fluctuations
20-50 Hz/mbar
←→ level variations?

$\vec{F}$



$\vec{F}$

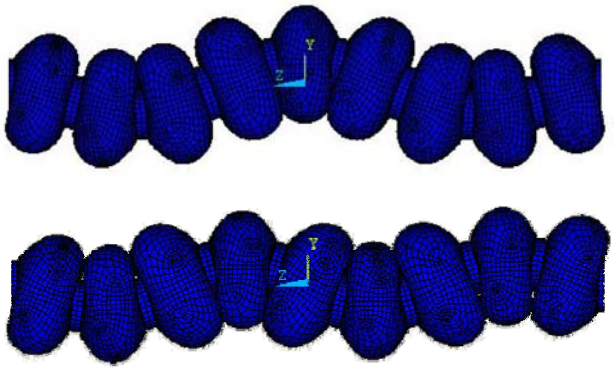
$\vec{F}$

"Random"-broadband machinery noise

Deterministic, narrow bandwidth sources:
Vacuum pumps, water cooling pumps

nm-movements→Δf ~ Hz

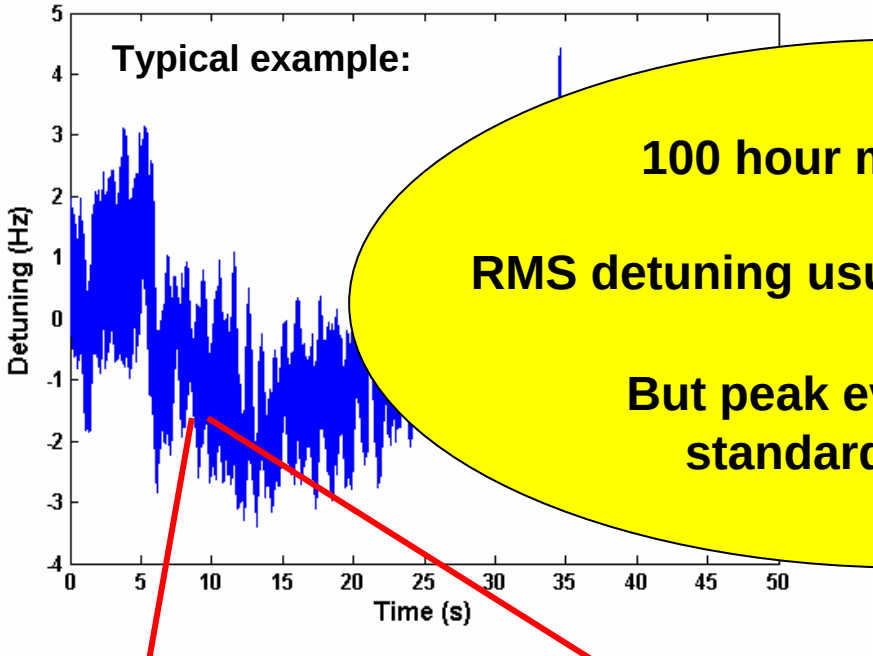
Possible system response of cavity-tank-tuner system predicted by FEM simulations, see e.g.
Devanz et al. EPAC 2002
Bisoffi, BESSY-report, 2003



222 Hz

151 Hz

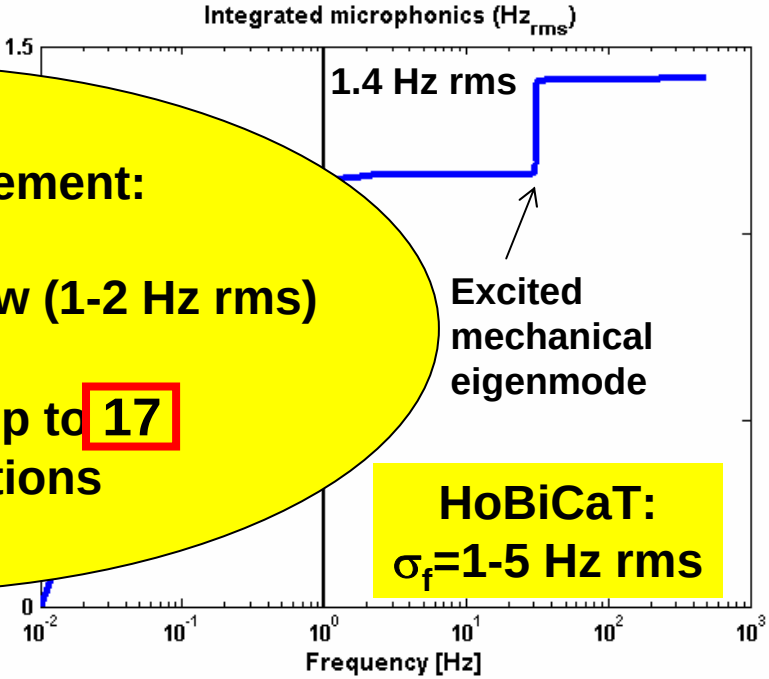
Piezo-to-RF Transfer function



100 hour measurement:

RMS detuning usually low (1-2 Hz rms)

But peak events up to 17 standard deviations

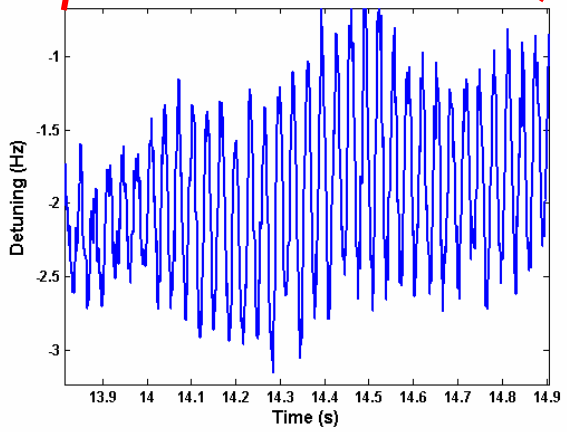


Excited mechanical eigenmode

HoBiCaT: σ_f=1-5 Hz rms

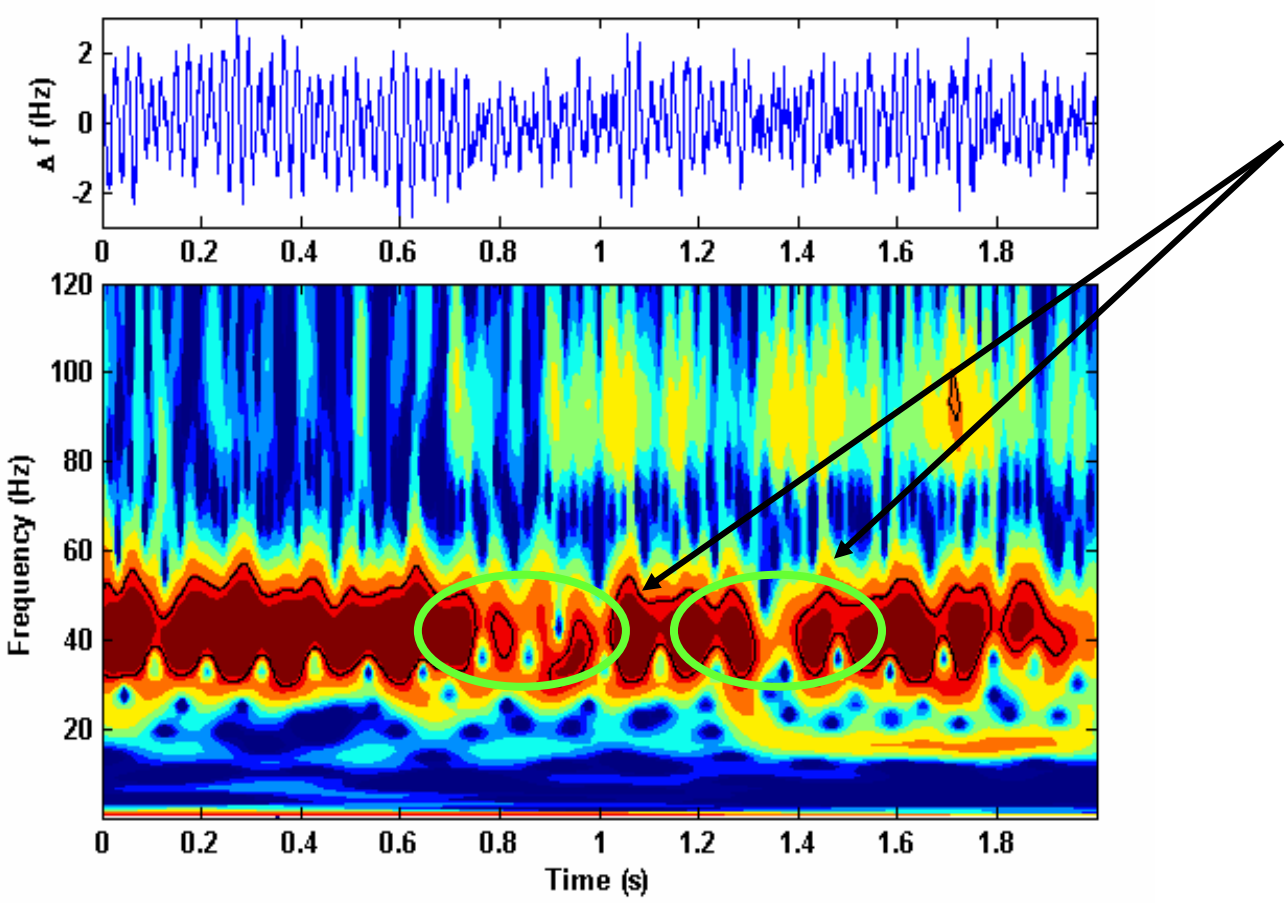
Spectrum time invariant?

Zoom



Time-frequency analysis of detuning data

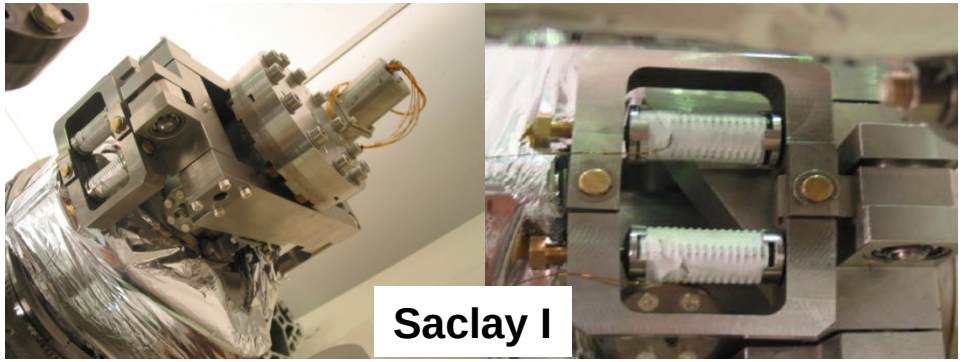
Microphonics spectrum visualized with WAVELETS

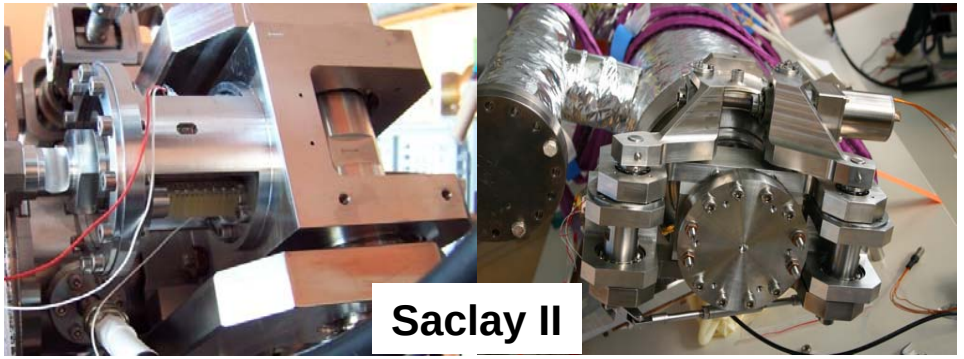


- **Eigenmode contribution: Strong variation with time**
- **Cannot be controlled by simple feedforward**
- **Adaptive/Learning system needed**

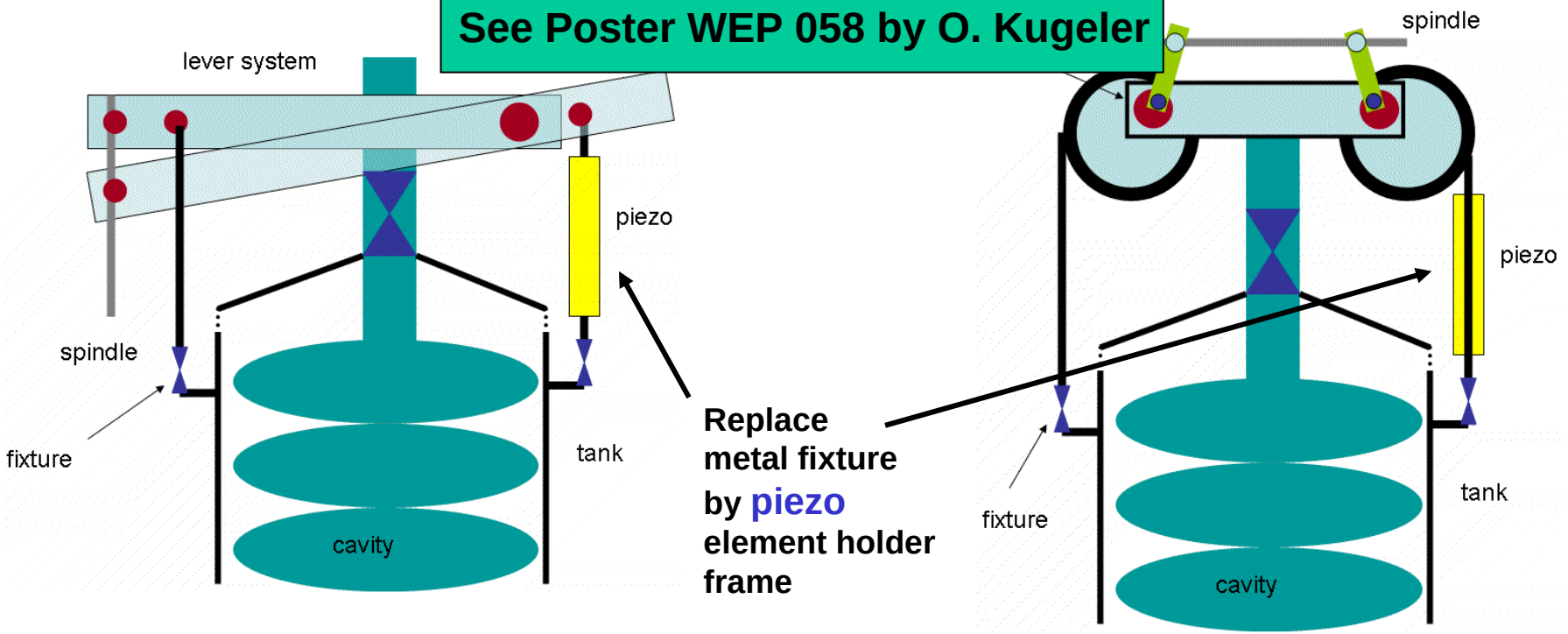
Countermeasure: Fast tuning systems

Characteristics



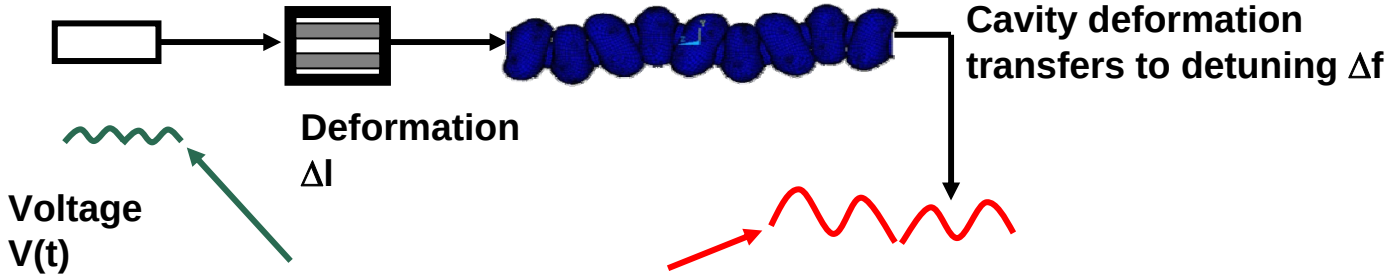


See Poster WEP 058 by O. Kugeler



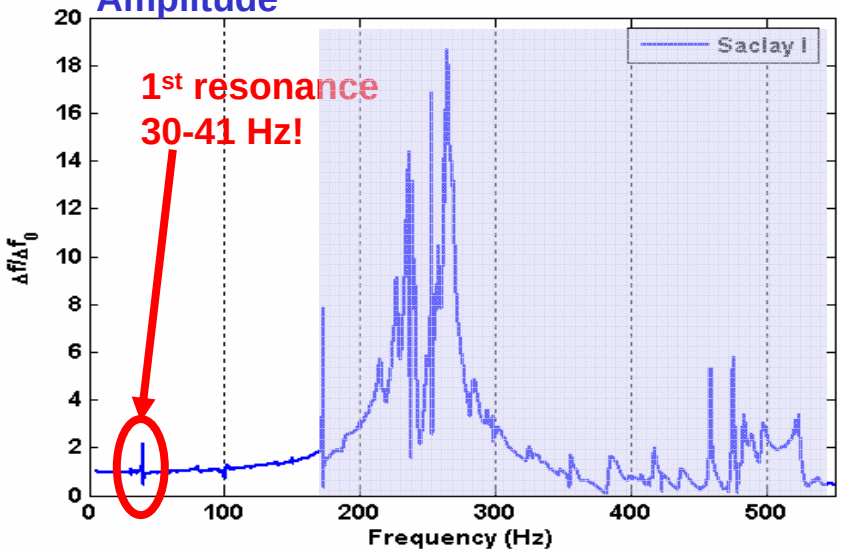
Tested Saclay I and Saclay II tuning system

The piezo-to-RF detuning transfer function

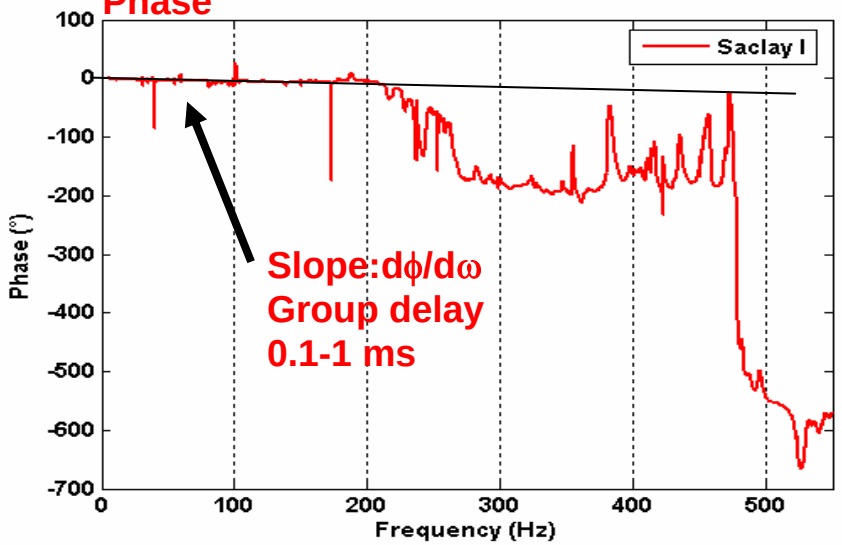


Compare Amplitude and Phase of excitation and RF response

Amplitude

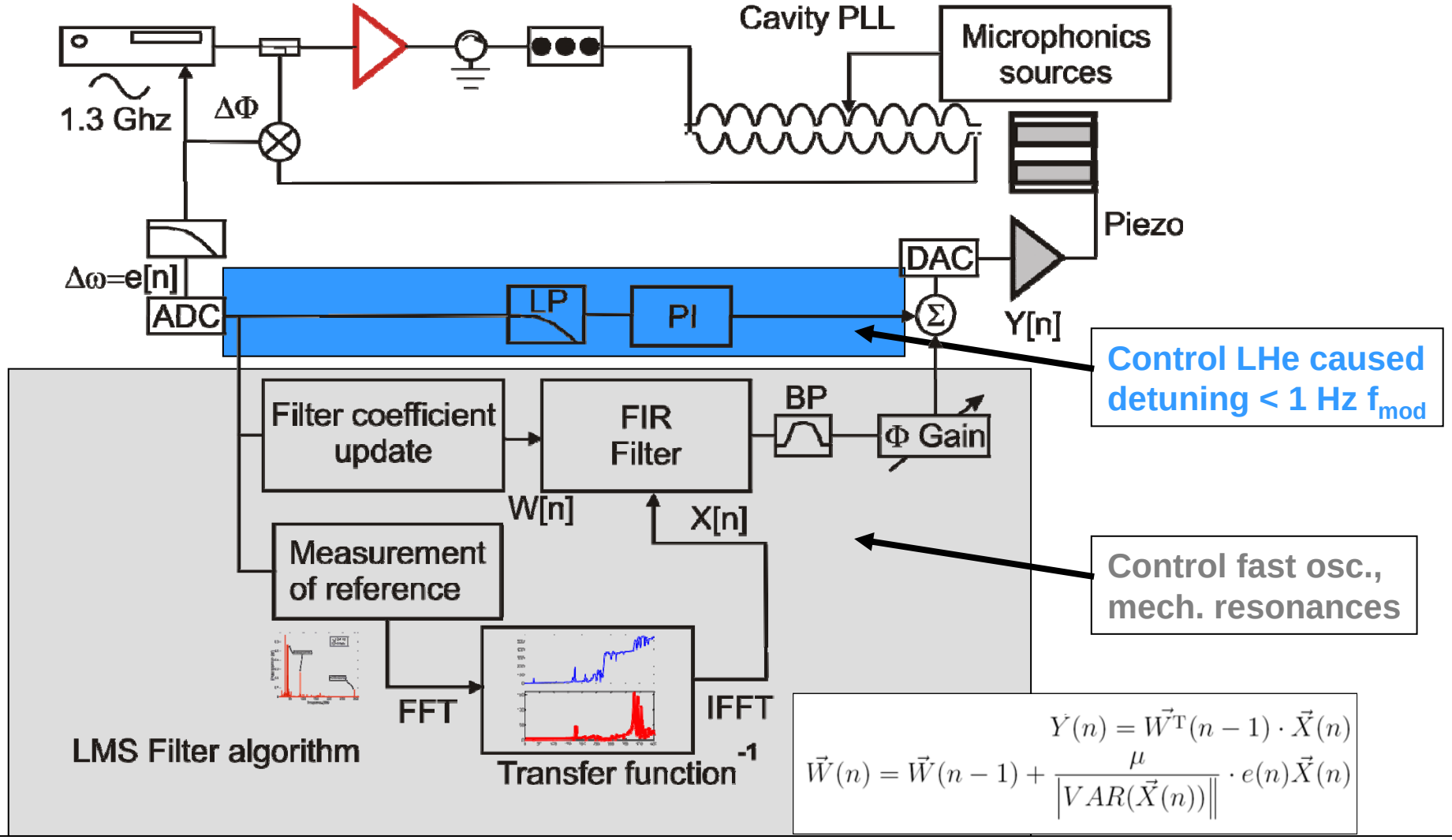


Phase

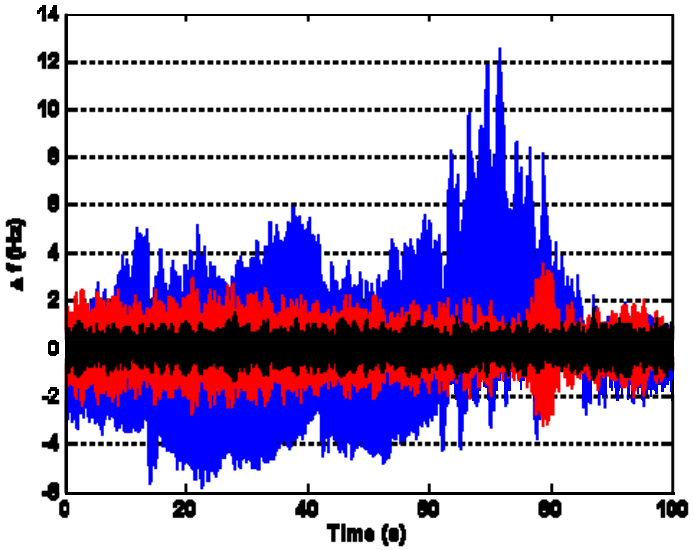


Nature of microphonics and transfer function set boundary conditions for controller design

Two-folded approach: Low frequency feedback and adaptive feedforward



Detuning compensation at a nine-cell TESLA cavity

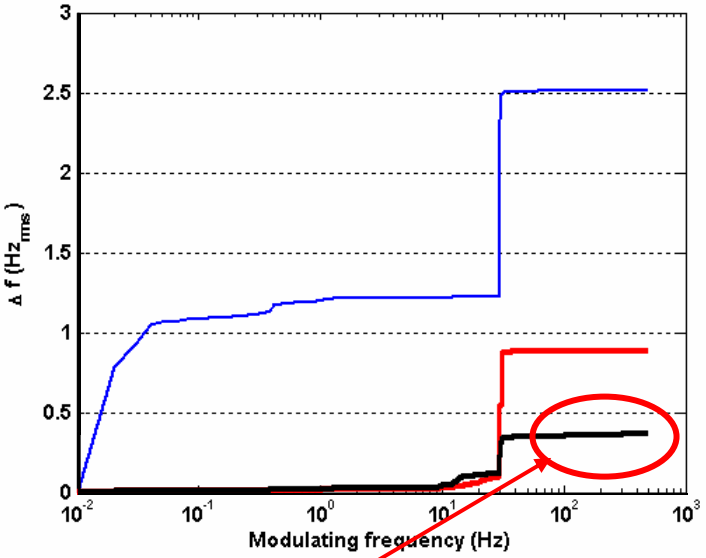


ΣFFT

Open loop

Feedback

FB+Feed forward

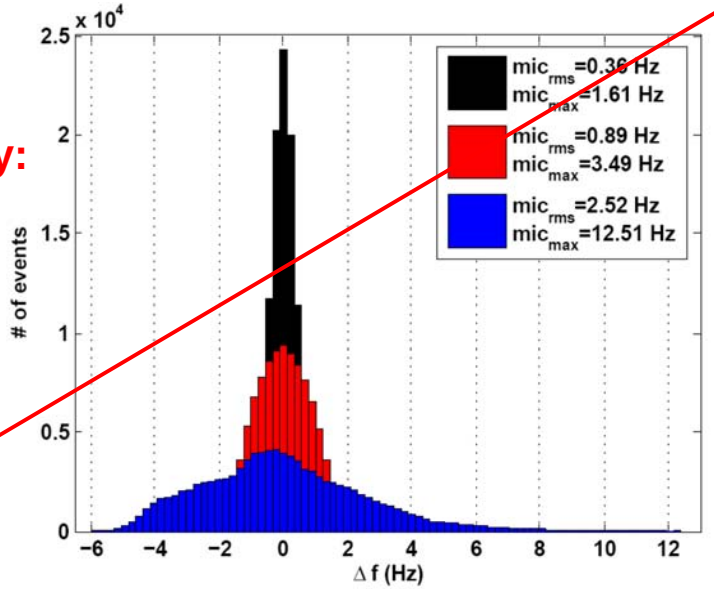


Factor 7.6 of compensation

Improved open loop phase stability:

13.2→ 2.0°

Limit by piezo-tuner resolution



Outlook

- **Microphonics : Pressure fluctuations of LHe bath, mechanical eigenmodes**
- **Need for a fast tuning system to save RF power and improve CW field stability**
- **Very stable cryogenic system important, 20-30 μbar**
- **Compensation by slow feedback and adaptive feedforward algorithm**
- **Reduction between a factor of two up to seven**
- **Open loop phase stability up to 1° for $f_{1/2}$~10-20 Hz**

<u>To do (at least):</u>

- **Show long-term stable, reliable operation, combine with LLRF control**
- **Improve tuner resolution**

Acknowledgements

Thanks to:

CEA-Saclay: Pierre Bosland, Guillaume Devanz, Eric Jacques, Michel Luong

BESSY: Wolfgang Anders, Jens Knobloch, Oliver Kugeler, Michael Schuster, Sascha Klauke, Dirk Pflückhahn, Stefan Rotterdam

DESY: Kai Jentsch, Clemens Albrecht, Lutz Lilje

**Work funded by the European Commission
in the Sixth Framework Program, contract no. 011935 EUROFEL**

Further questions? Meet me at WEP56