RF related beam measurements

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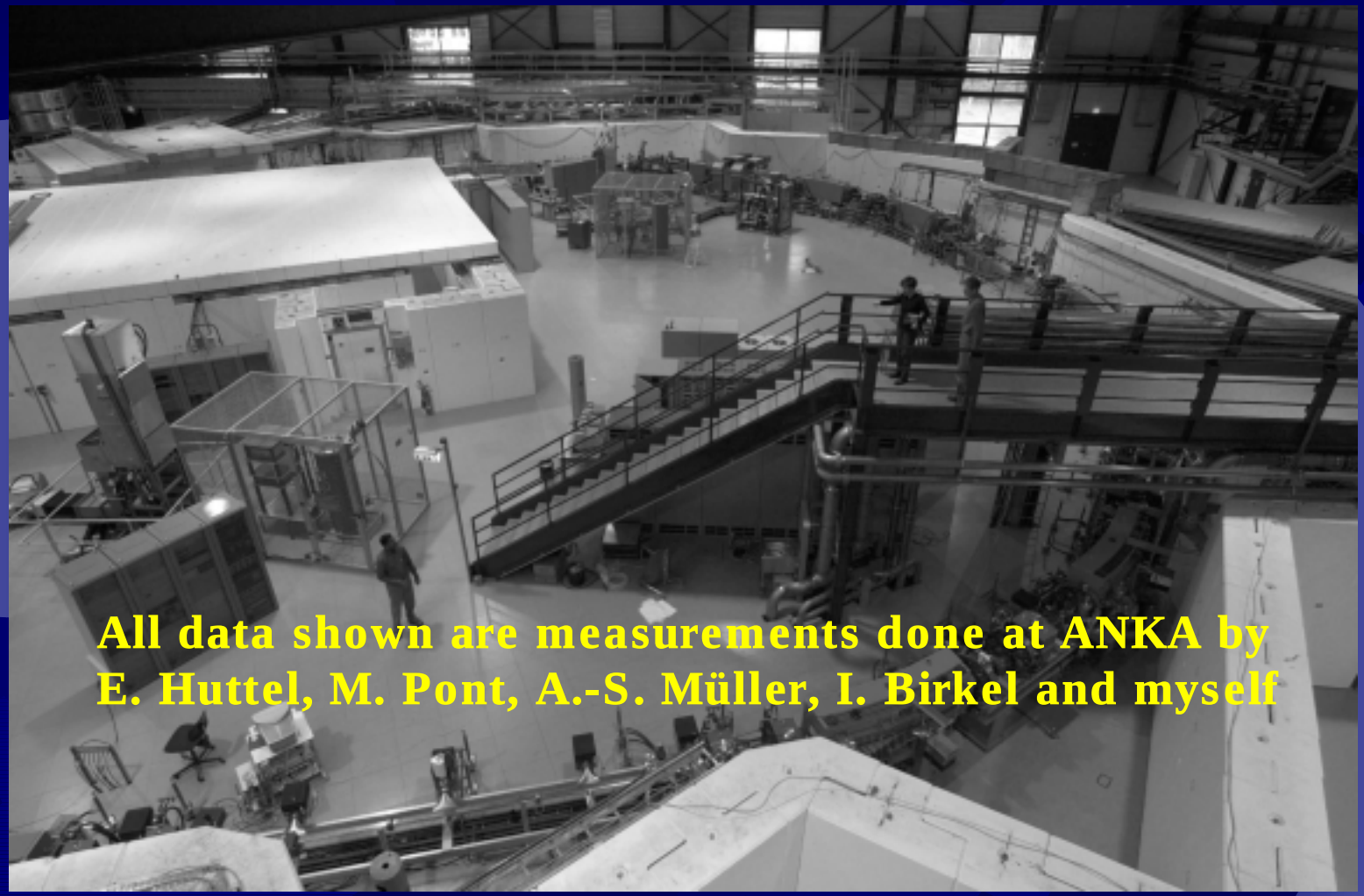
ISS - ANKA

How to obtain machine parameters using the **RF voltage and frequency** as a tool

- Dispersion function
- Chromaticity
- Momentum Compaction Factor
- Quantum lifetime
- Touschek lifetime
- Energy Acceptance

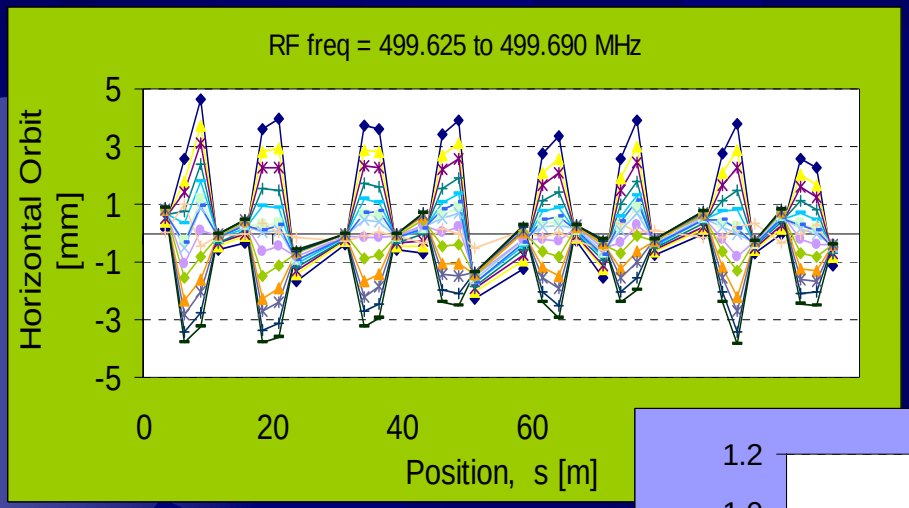

All data shown are measurements done at ANKA by
E. Huttel, M. Pont, A.-S. Müller, I. Birkel and myself

DISPERSION FUNCTION

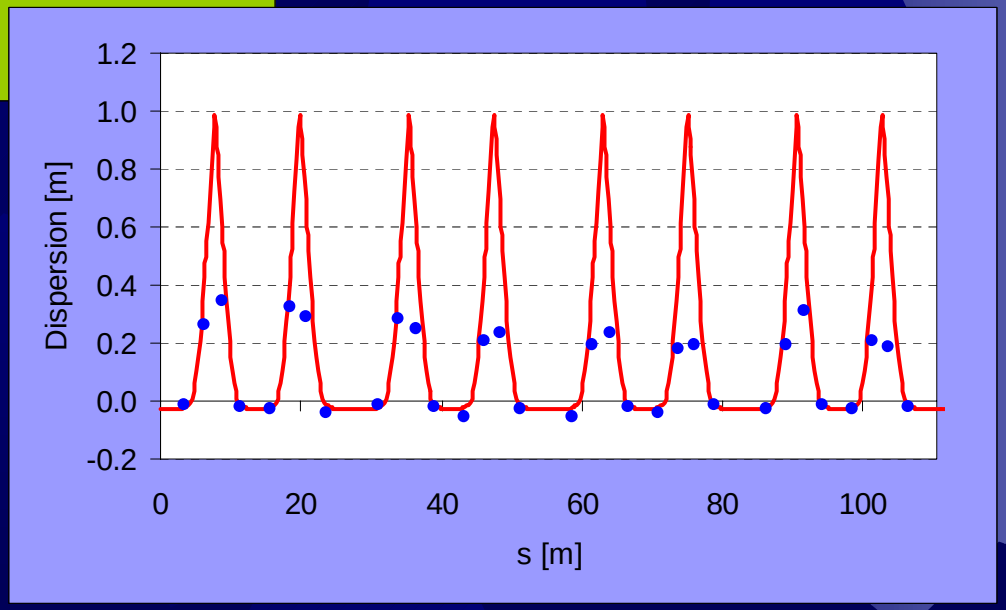
$$x(s) = x_D(s) + x_\beta(s) = D(s)\frac{\Delta p}{p} + x_\beta(s)$$

$$\frac{\Delta C}{C} = \alpha\frac{\Delta p}{p} = -\frac{\Delta f}{f}$$

Changing the **frequency** and measuring the **orbit**, the **Dispersion Function** can be obtained, assuming that the momentum compaction factor is known.



Orbit measurements at different frequencies



Dispersion function measured vs. calculated

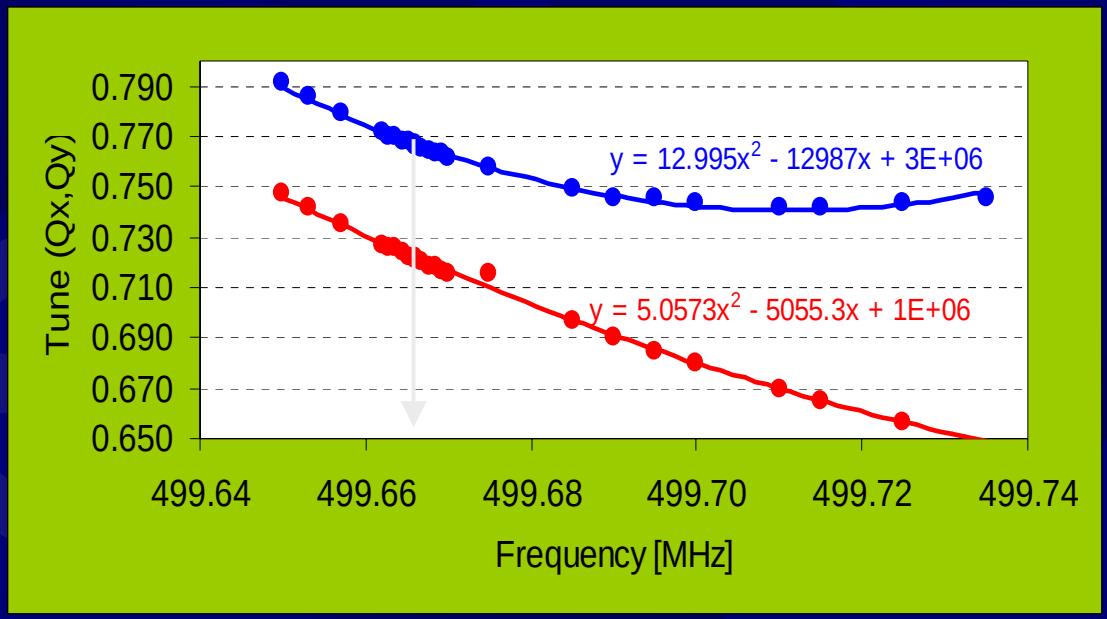
CHROMATICITY

Particles with $dp \neq 0$ are differently focused.

This lead to a tune shift, the amount of **tune shift** with respect to the **energy** difference is the **chromaticity**.

$$\Delta Q = \xi \frac{\Delta p}{p}$$

$$\frac{\Delta C}{C} = \alpha \frac{\Delta p}{p} = -\frac{\Delta f}{f}$$



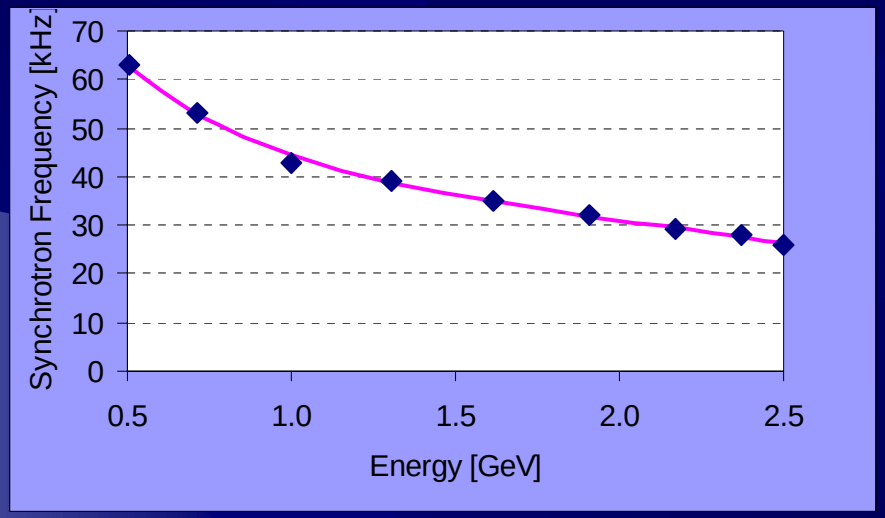
The slope of the curve around the central frequency is the **lineal chromaticity:**

$$\xi x = 4.2 \qquad \xi y = 5.1$$

MOMENTUM COMPACTION FACTOR

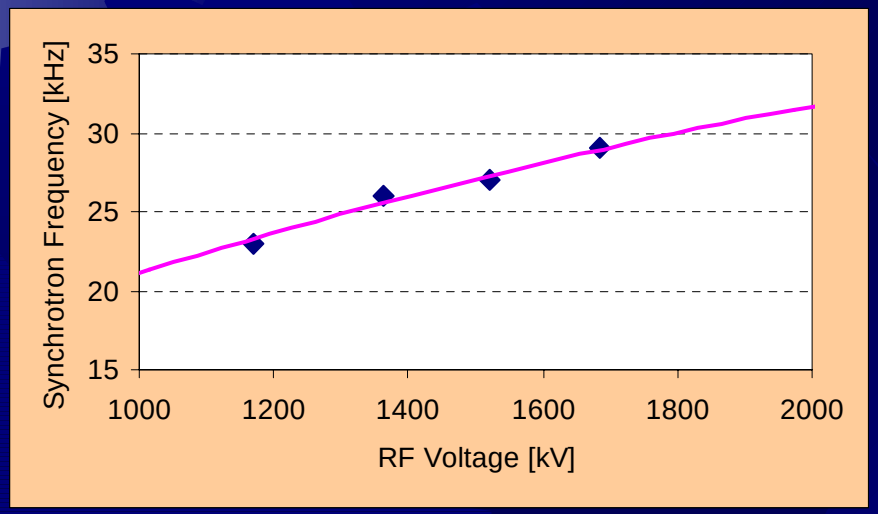
$$f_s = \sqrt{\alpha \frac{eV_{RF}}{E} \frac{h \cos\phi_s}{2\pi}} f_0$$

By measuring the **synchrotron frequency** while changing the **energy** of the machine or the **RF voltage**, the **momentum compaction factor** can be determined.



Constant RF Voltage

$\alpha = 0.0074$



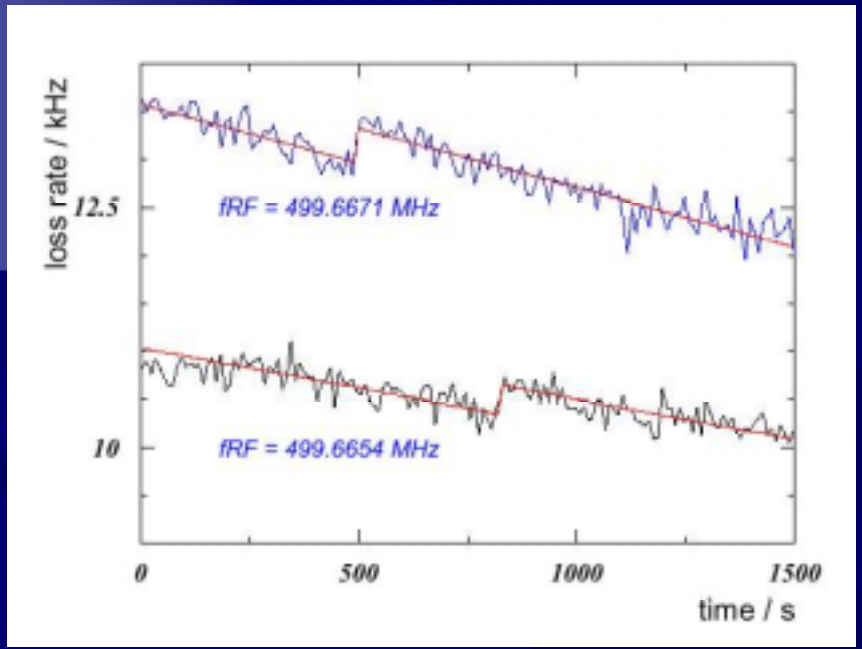
Constant Energy

$\alpha = 0.0063$

15% difference

$$\frac{\Delta C}{C} = \alpha \frac{\Delta p}{p} = -\frac{\Delta f}{f}$$

Change the **frequency** and determine the **energy** by electron spin depolarization:



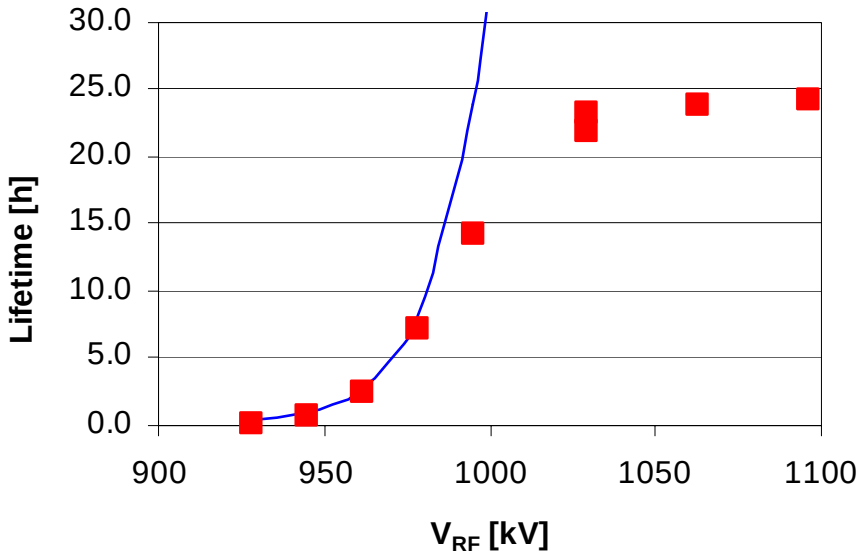
Δf_{RF} = 1.70 kHz

ΔE = 1.19 MeV

α = 0.0071

QUANTUM LIFETIME

$$\tau_q = \frac{\tau_\varepsilon}{n^2} \exp\left(\frac{n^2}{2}\right) \qquad n = \frac{\Delta E_{accep}}{\sigma_\varepsilon}$$

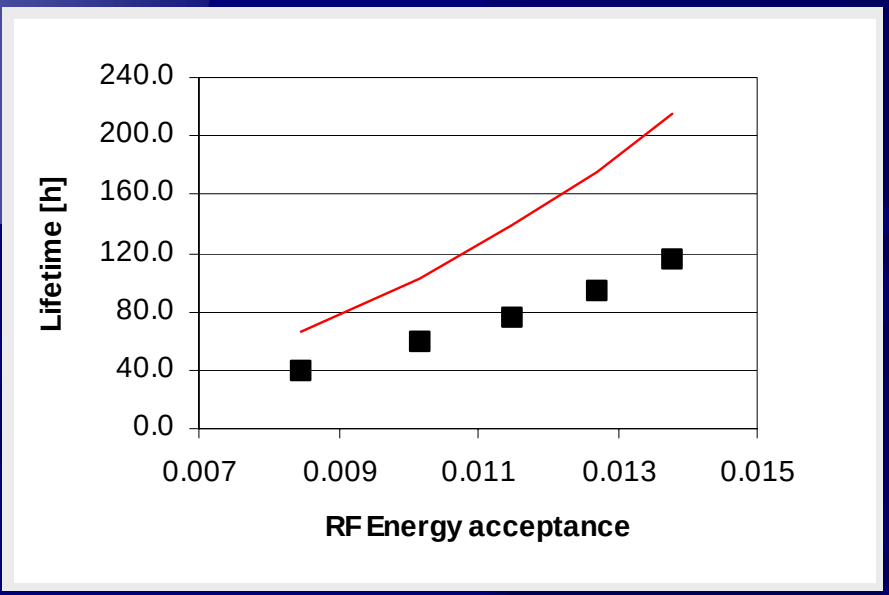


A calibration factor for the RF voltage could be determined:
0.93

TOUSCHEK LIFETIME

$$\frac{1}{\tau_{total}} = \frac{1}{\tau_e^N} + \frac{1}{\tau_i^N} + \frac{1}{\tau_e^e} + \frac{1}{\tau_i^e} + \frac{1}{\tau_T}$$

$$\frac{1}{\tau_T} = \frac{r_e^2 c n_e D(\varsigma)}{8\pi\,\gamma^2 (\sigma_x \sigma_y \sigma_z)\,(\Delta p / p)^3}$$



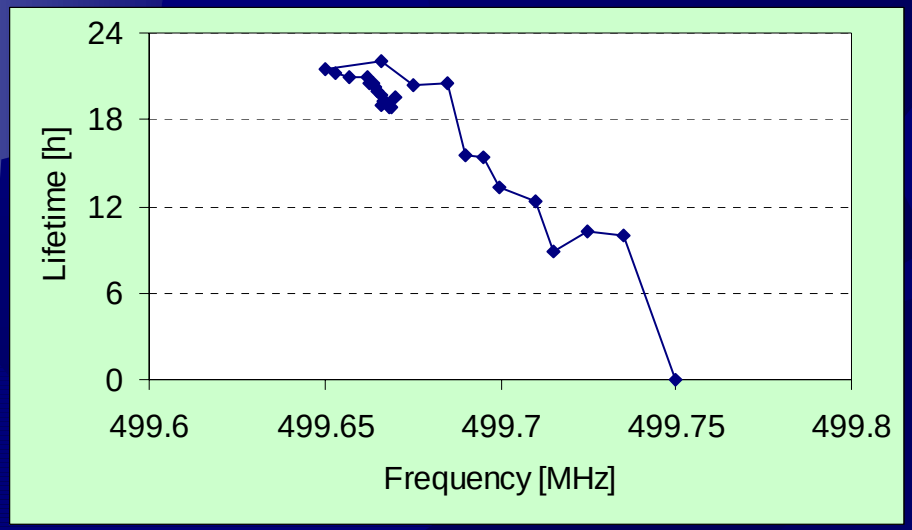
The machine does not want to fit with the model ☹

RF acceptance may not be the limiting effect ...

DYNAMIC APERTURE

$$\frac{\Delta C}{C} = \alpha \frac{\Delta p}{p} = -\frac{\Delta f}{f}$$

Change the energy of the beam and measure the lifetime:



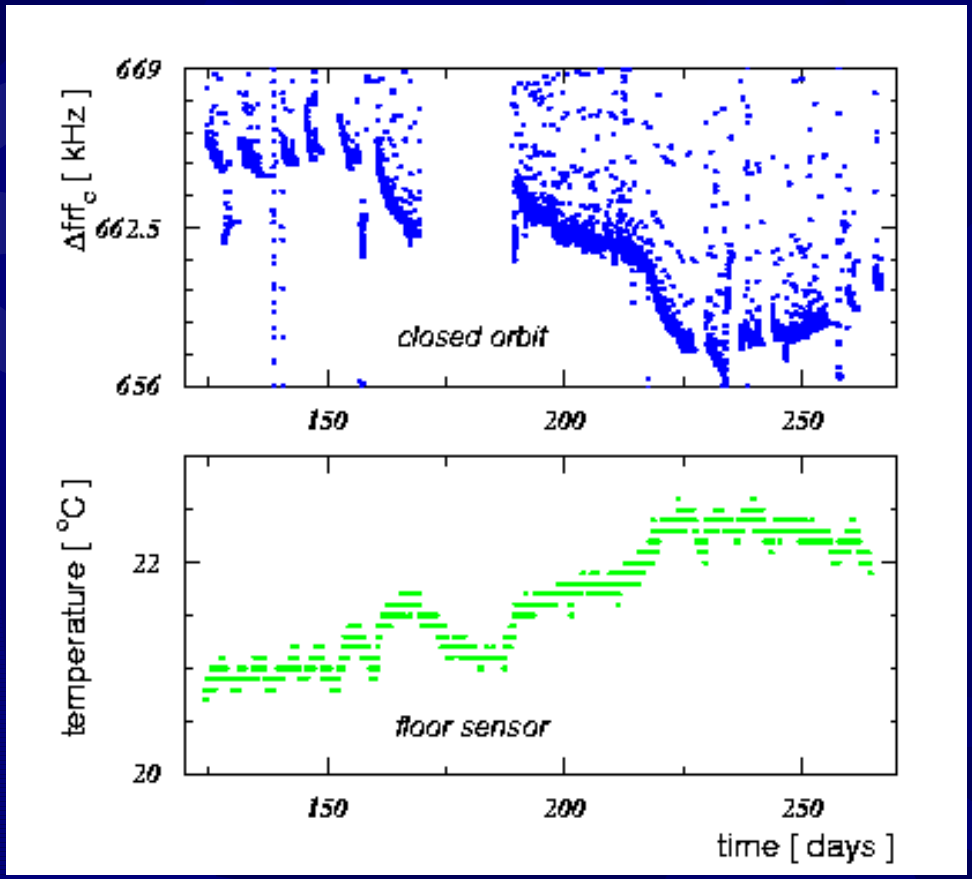
-2% to > 0.5%

SUMMARY

Lot of machine parameters depend on
the RF voltage and frequency,
in order to properly measure them
it is important to have

A GOOD CALIBRATED RF SYSTEM

Remember, you can always use your central frequency as a THERMOMETER !



THANKS !