



RF related beam measurements

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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

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in der Helmholtz-Gemeinschaft**



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

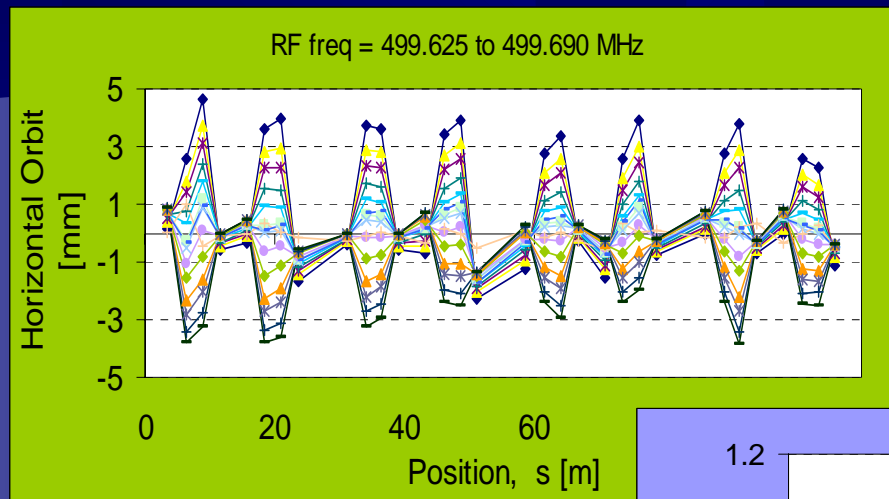


DISPERSION FUNCTION

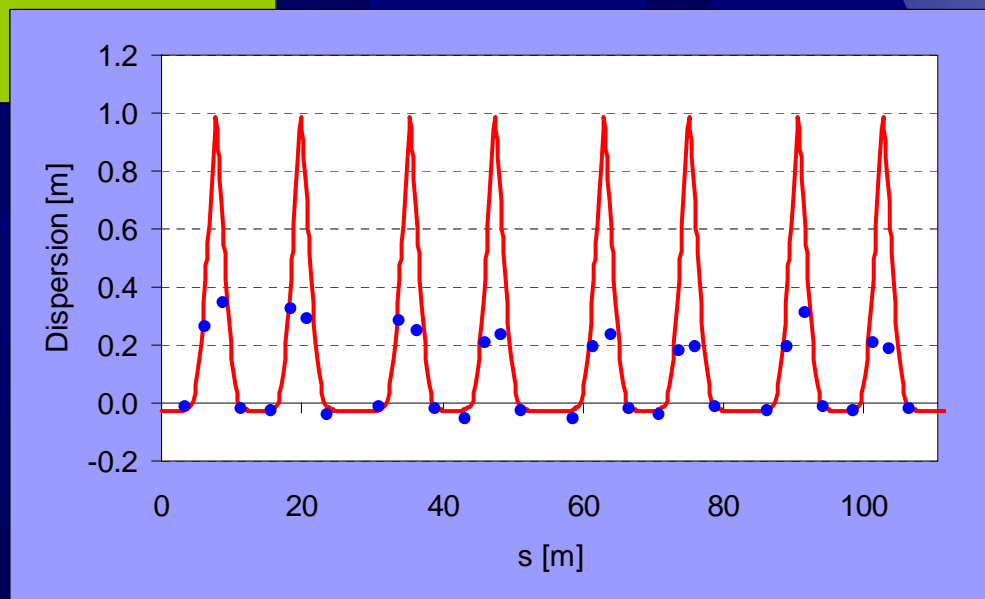
$$x(s) = x_D(s) + x_\beta(s) = D(s) \frac{\Delta p}{p} + x_\beta(s)$$

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

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



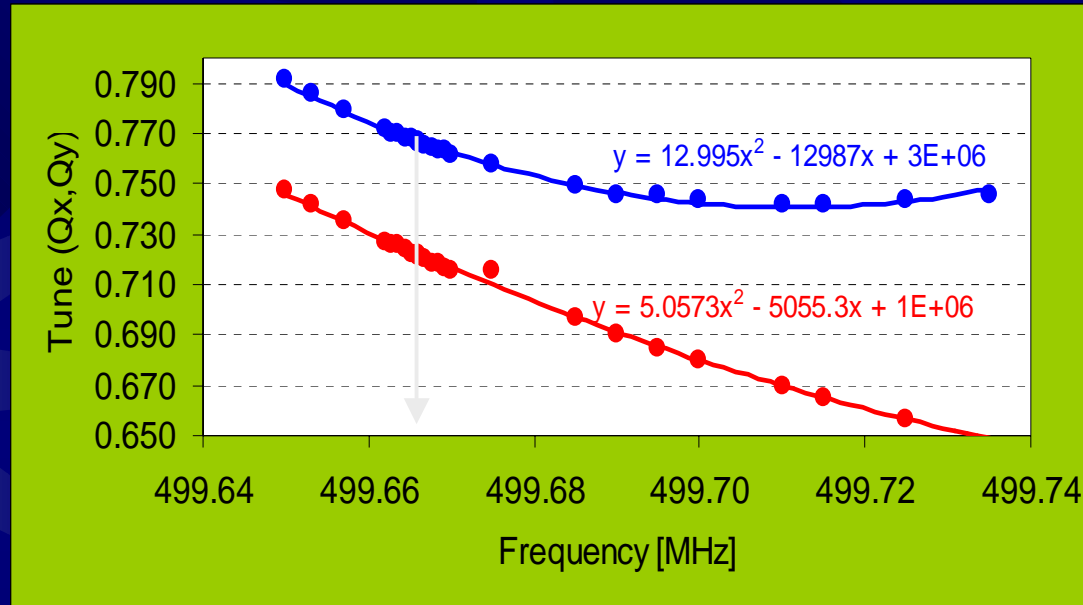
CHROMATICITY

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

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

$$\Delta Q = \xi \left(\frac{\Delta p}{p} \right)$$

$$\frac{\Delta C}{C} = \alpha \left(\frac{\Delta p}{p} \right) = - \left(\frac{\Delta f}{f} \right)$$



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

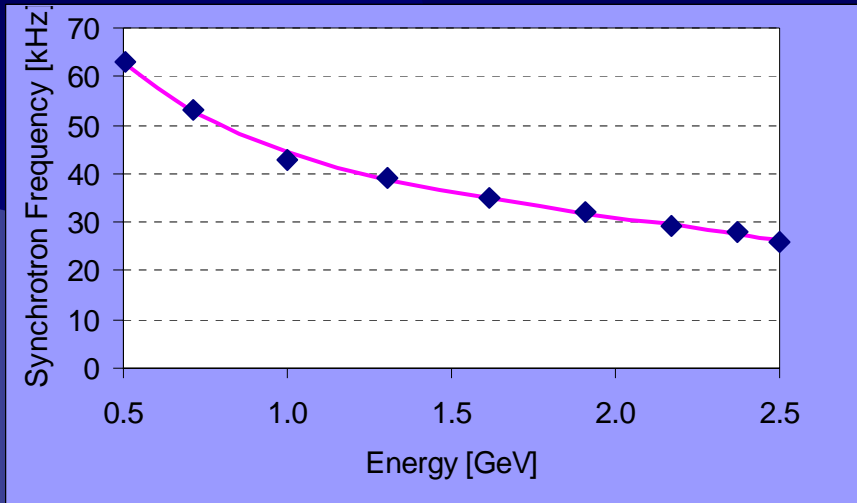
$$\xi_x = 4.2 \quad \xi_y = 5.1$$



MOMENTUM COMPACTION FACTOR

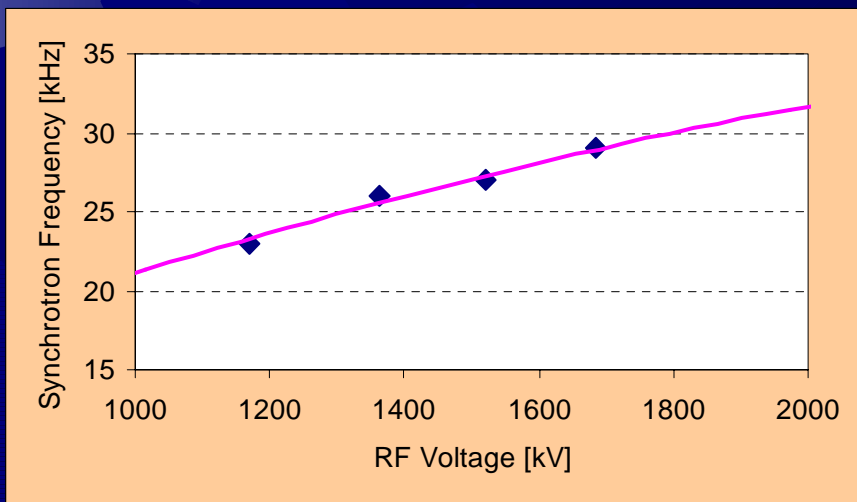
$$f_s = \sqrt{\alpha} \frac{eV_{RF}}{E} \frac{h \cos \phi_s}{2\pi} f_0$$

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

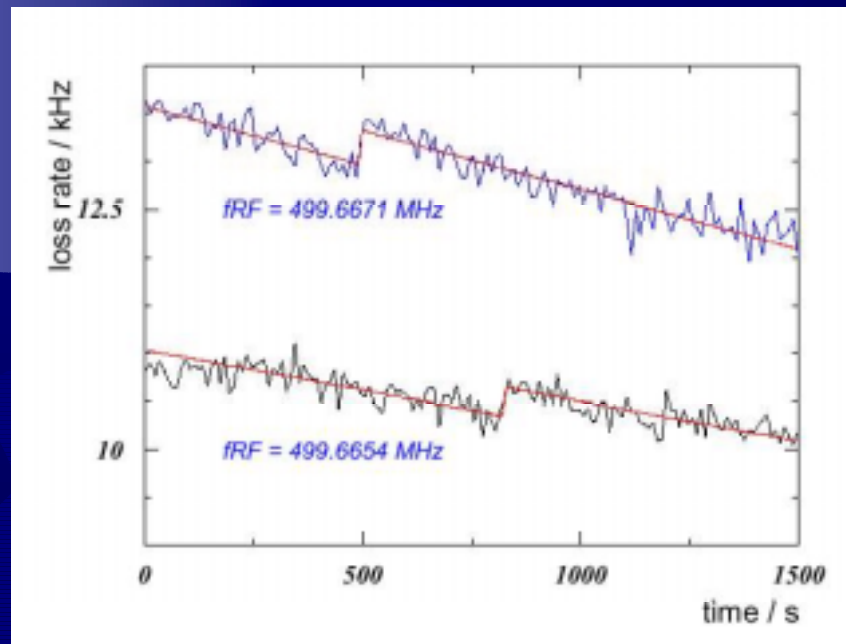
$$\alpha = 0.0063$$

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:



$$\Delta f_{RF} = 1.70 \text{ kHz}$$
$$\Delta E = 1.19 \text{ MeV}$$

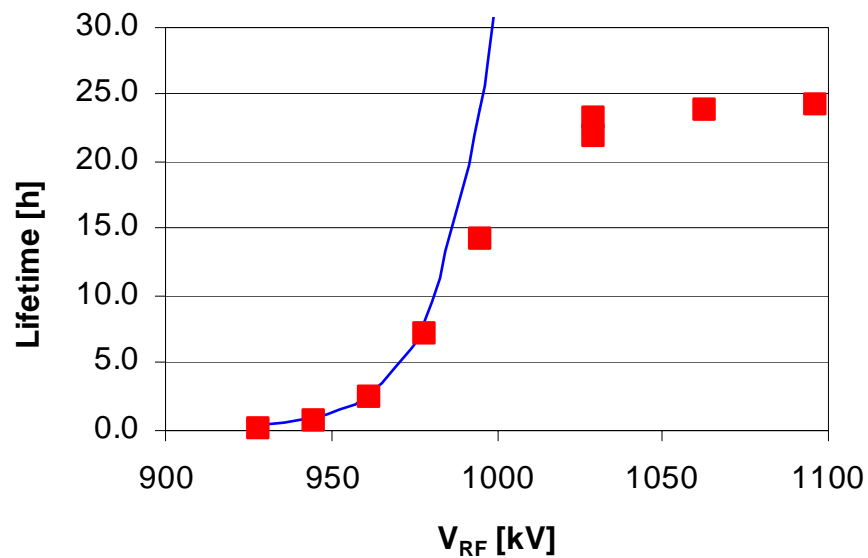


$$\alpha = 0.0071$$



QUANTUM LIFETIME

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



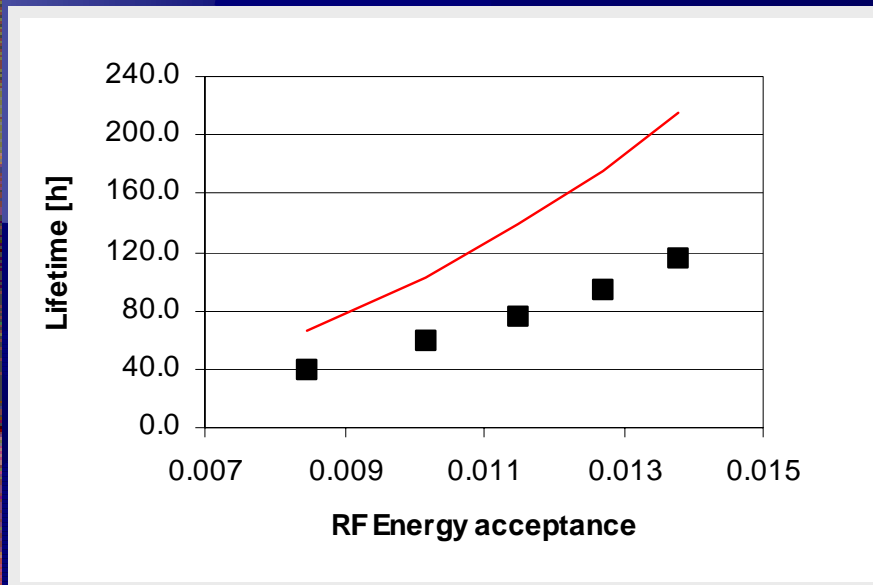
A calibration
factor for the
RF voltage
could be
determined:
0.93



TOUSCHEK LIFETIME

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

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



The machine does not want to fit with the model ☹



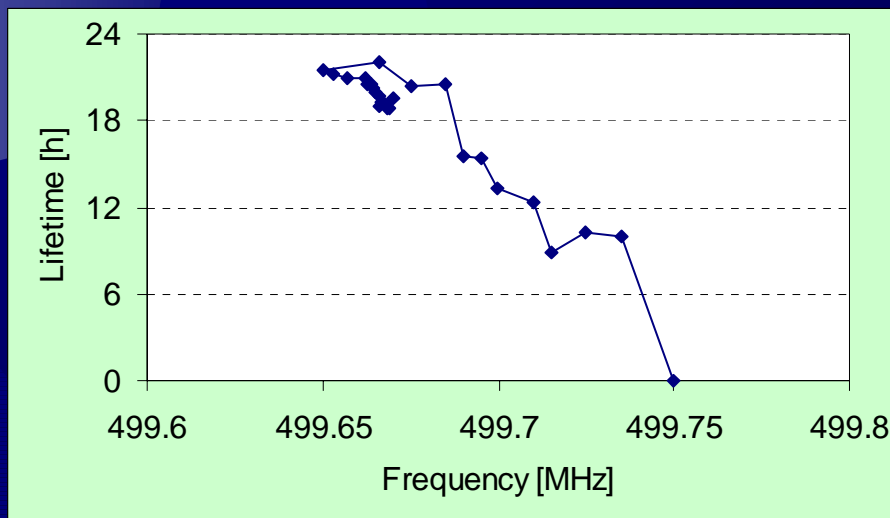
RF acceptance may not be the limiting effect ...



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%



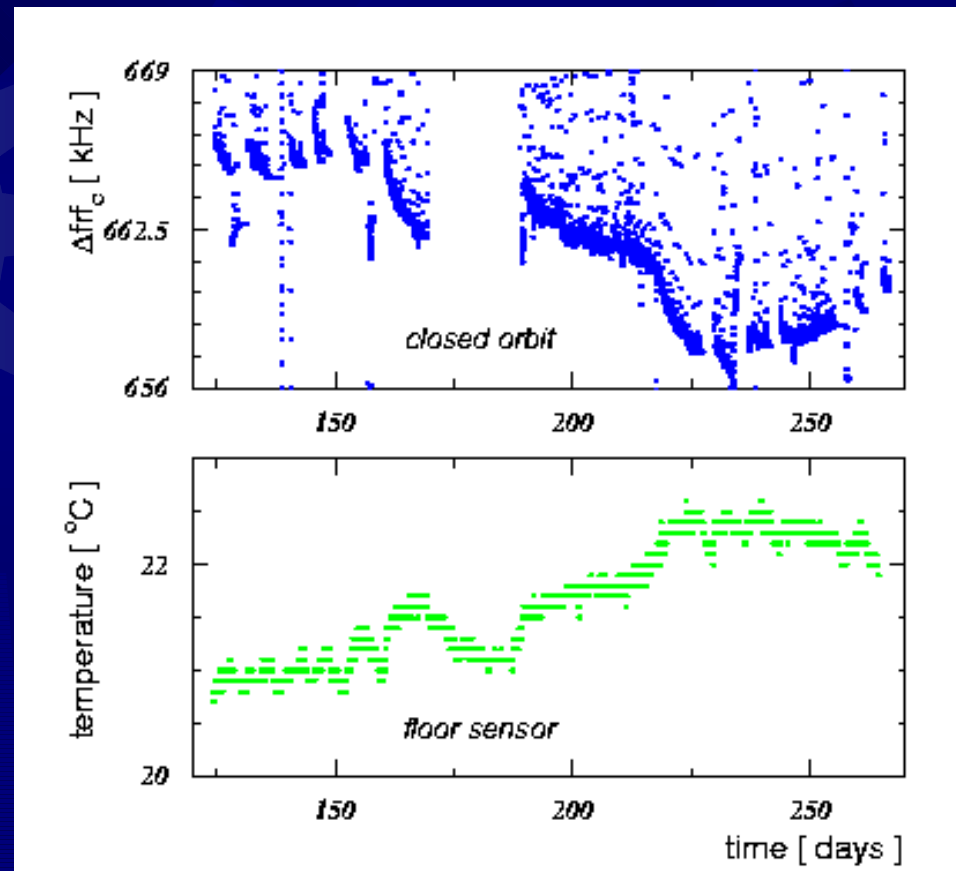
SUMMARY

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 !