

# Magnetic field stabilization in superconducting magnets



## for high-precision Penning trap experiments

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# Why do we need an extremely stable magnetic field?

We are measuring:

the g-factor of a single H-like ion stored in a Penning trap by determination of the spin flip resonance in a magnetic field

J. Verdu et al.

the masses of short-lived radionuclides by determination of the cyclotron frequency of stored ions in a Penning trap

K. Blaum et al.

The line shape and precision of both measurements depend directly on the magnetic field stability.

(K. Blaum *et al.* PRL **91**, 260801, 2003

J. Verdú *et al.* PRL **92**, 093002, 2004)

# Sources of magnetic field instabilities

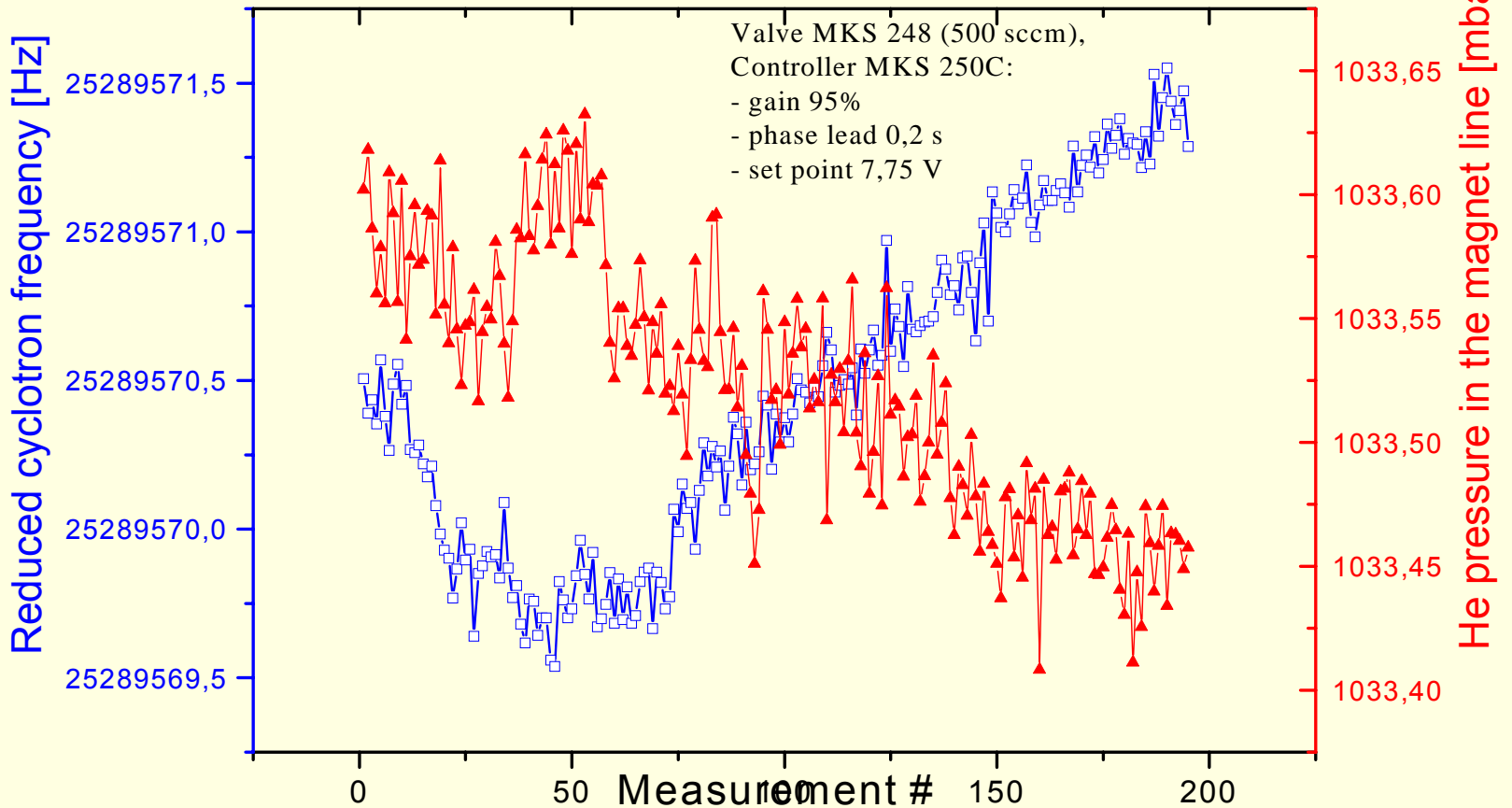
1. External
  - Movement of magnetic objects
  - Magnetic field fluctuations
2. Natural decay of the magnet's field
3. Internal
  - Pressure instabilities in the recovery lines
  - Temperature fluctuations
    - Environmental
    - Magnet's surface or magnet's bore

# Influence of He pressure on cyclotron frequency

16.02.2002

—▲— He pressure in the magnet

—□— Reduced cyclotron frequency

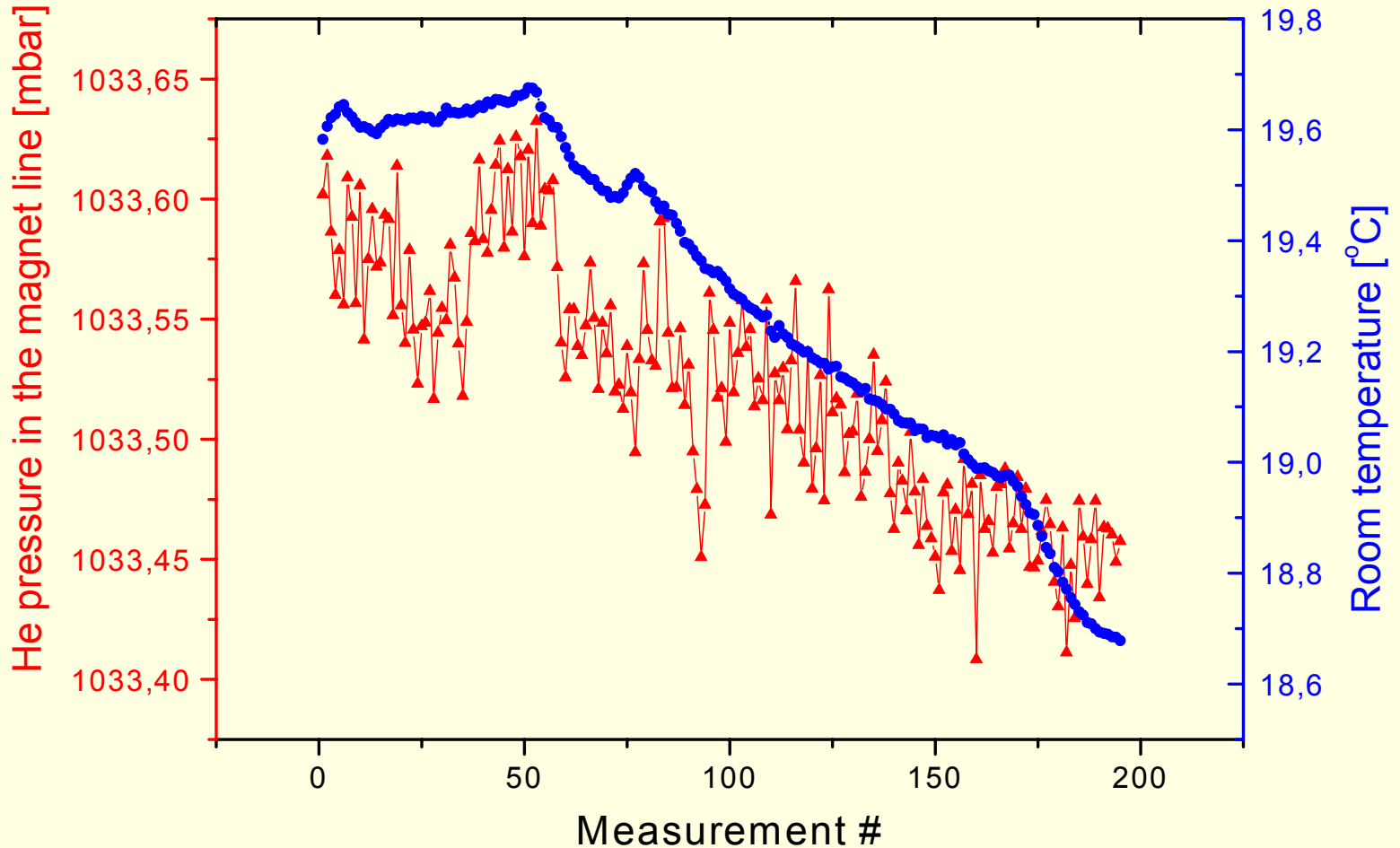


# Linear correlation between He pressure and room temperature

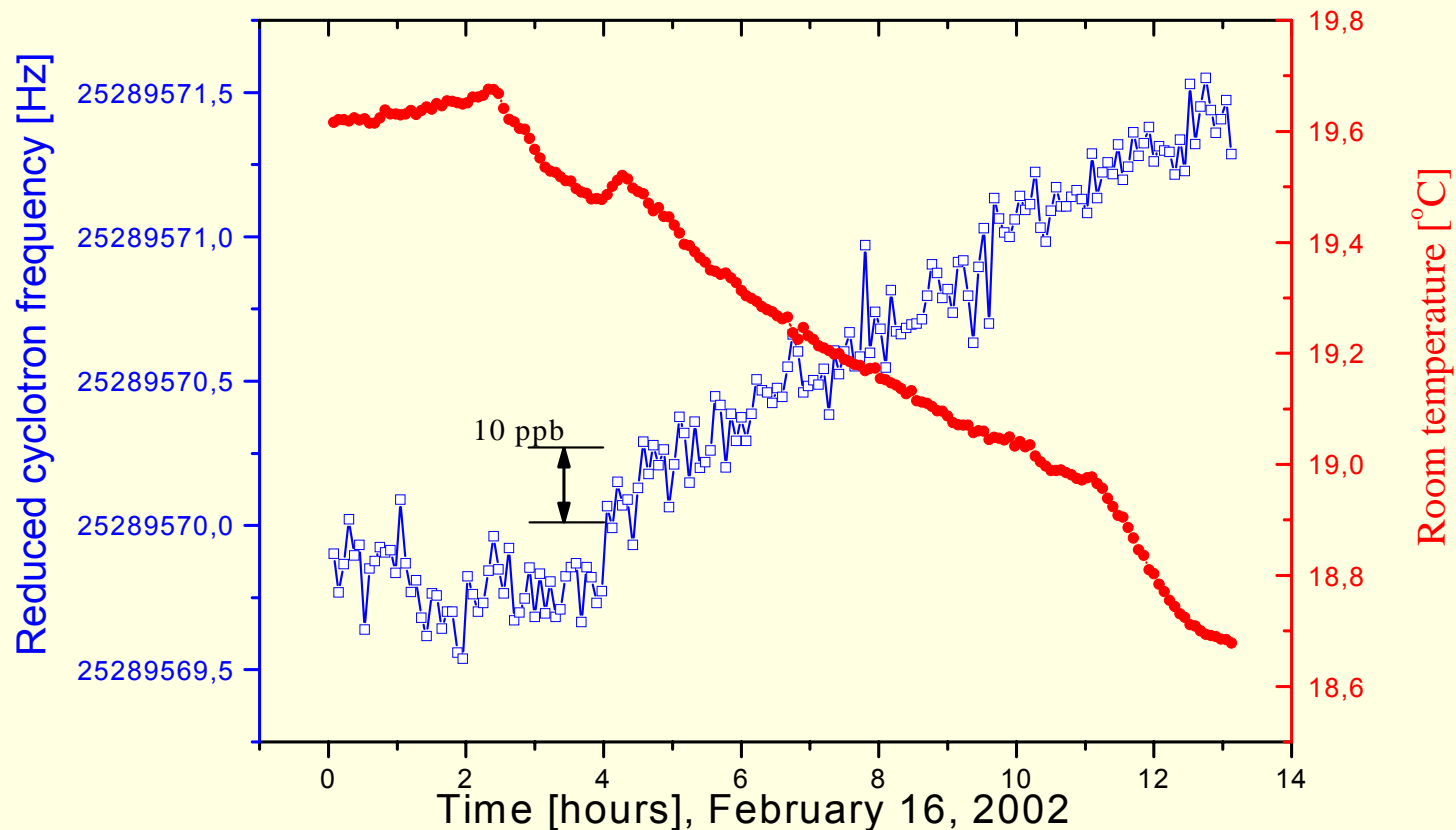
16.02.2002

—●— Room Temperature

—▲— He pressure in the magnet

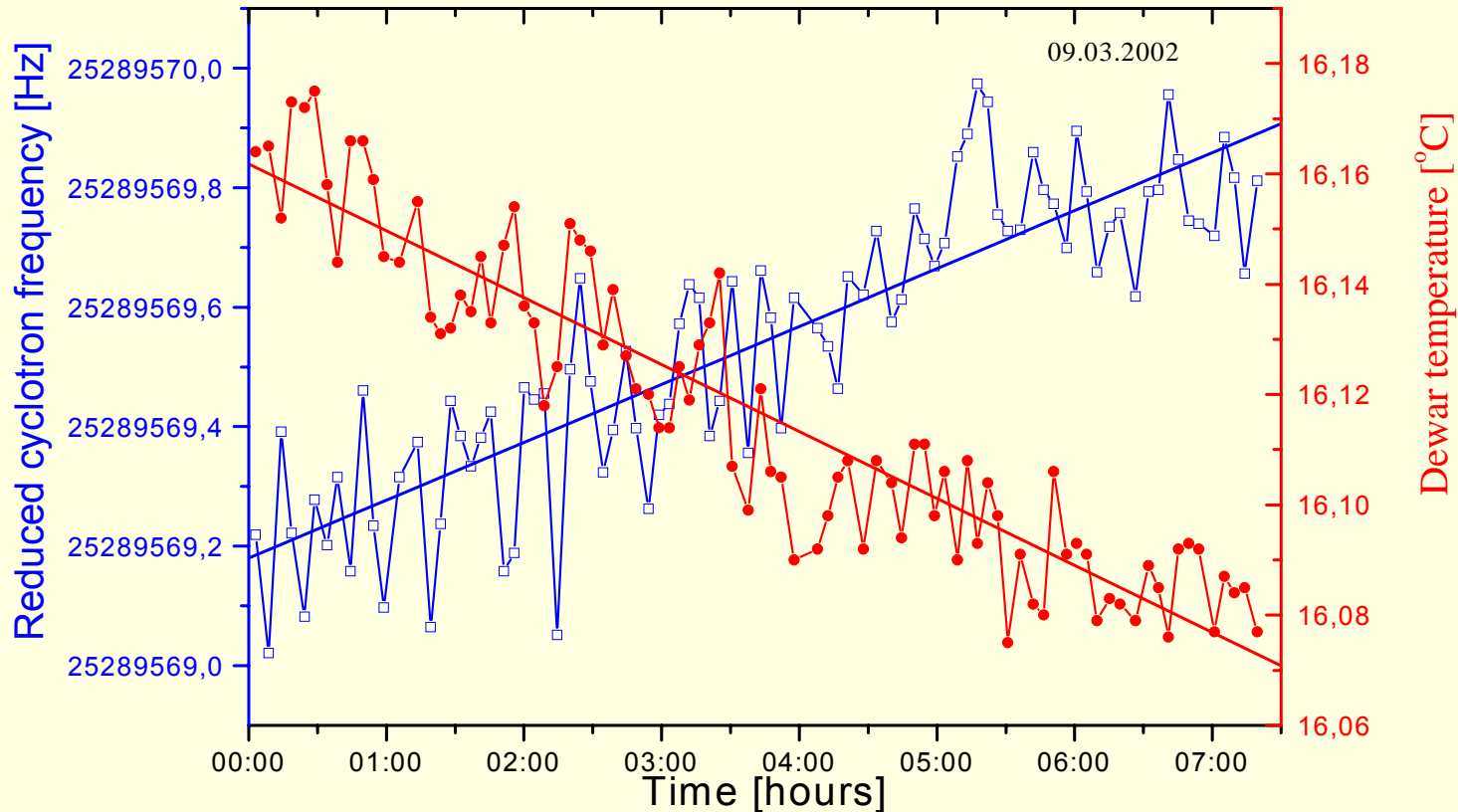


# Anticorrelation between the frequency and room temperature (measured with a single $O^{7+}$ ion)



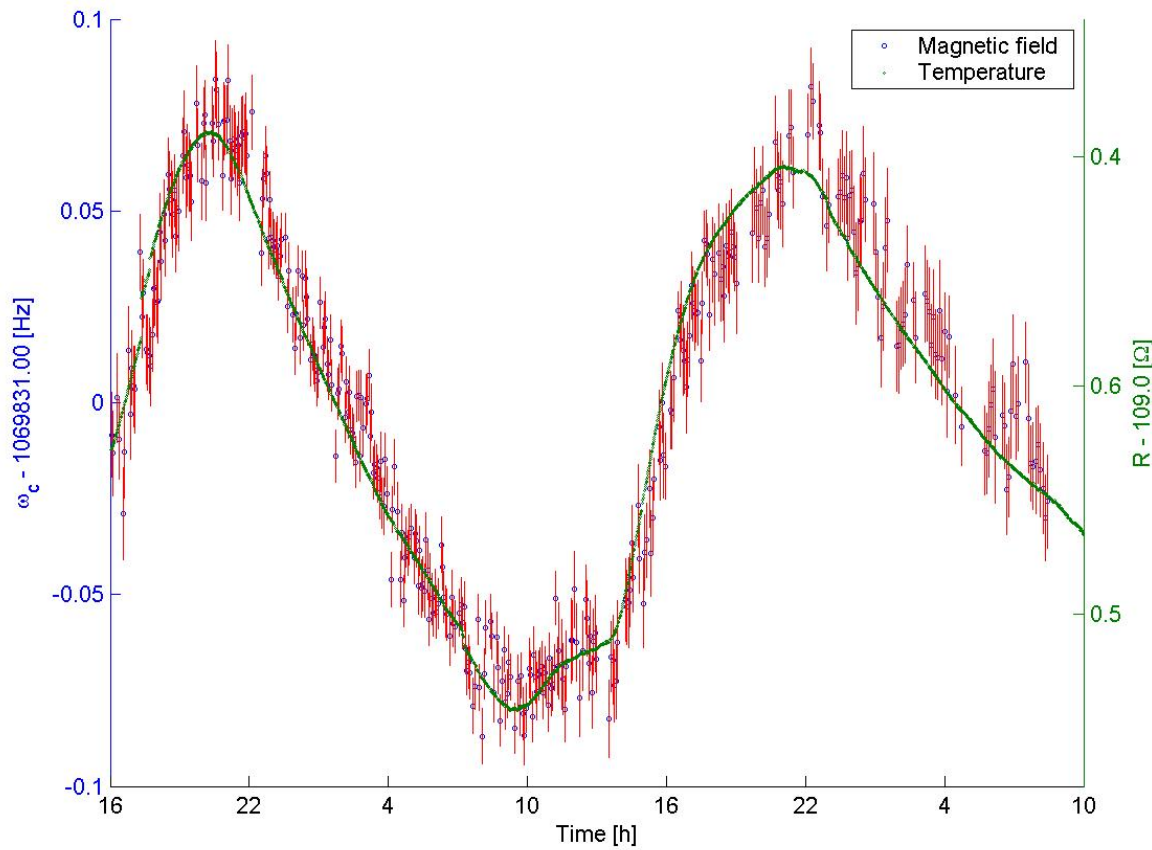
- Room temperature decrease with rate 0.1 K/h induce increase of reduced cyclotron frequency with rate 0.2 Hz/h (8 ppb/h)

# Anticorrelation between the frequency and dewar temperature



- dewar temperature decrease with rate 0.01 K/h induce increase of reduced cyclotron frequency with rate 0.1 Hz/h (4 ppb/h)

# Correlation between cyclotron frequency and temperature at ISOLTRAP



Magnetic field drift

**-2.7 ppb/h**

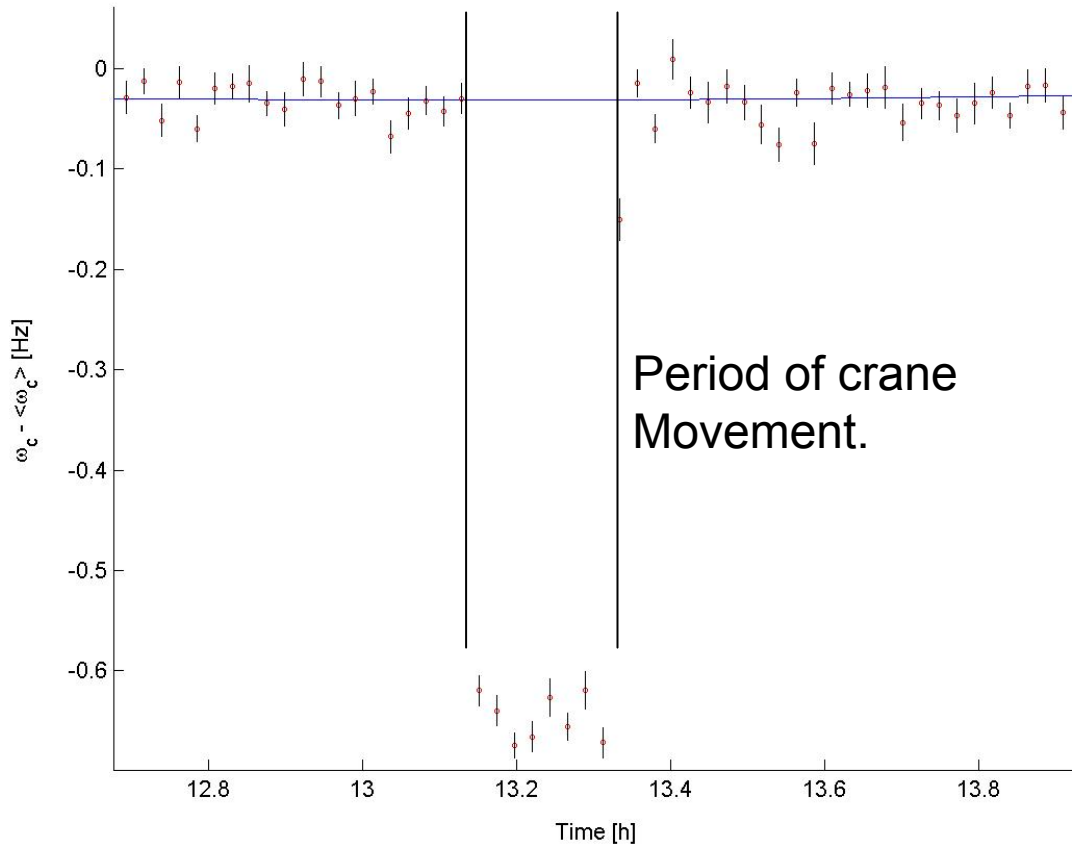
Linear drift in the magnetic field already corrected for.

Night day temperature variation

**0.61 °C**

Linear correlation of magnetic field and temperature of 220 ppb/K

# External magnetic field disturbances at ISOLTRAP

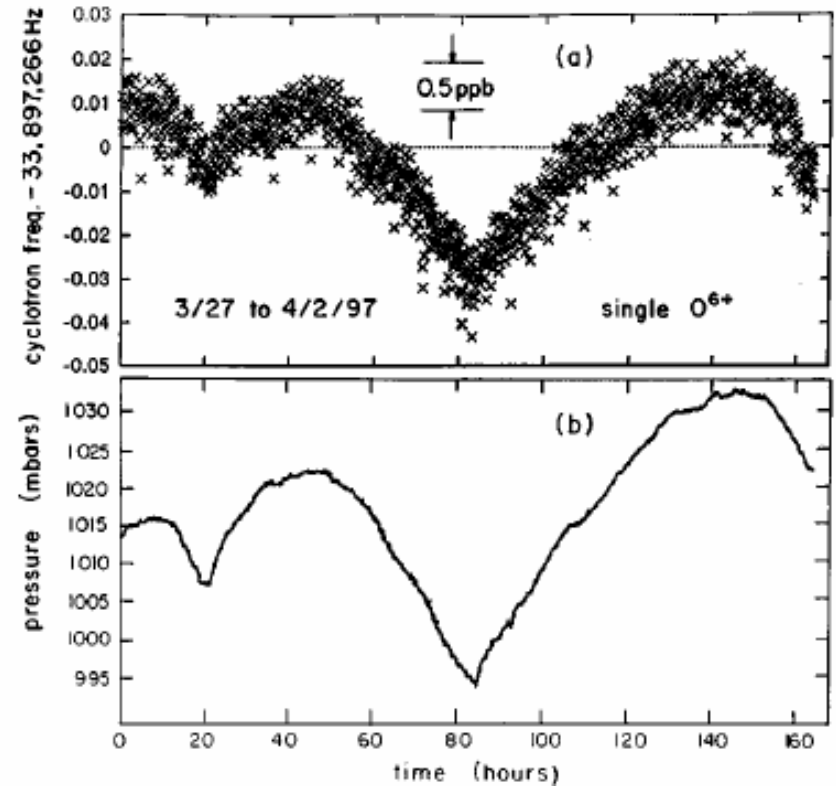
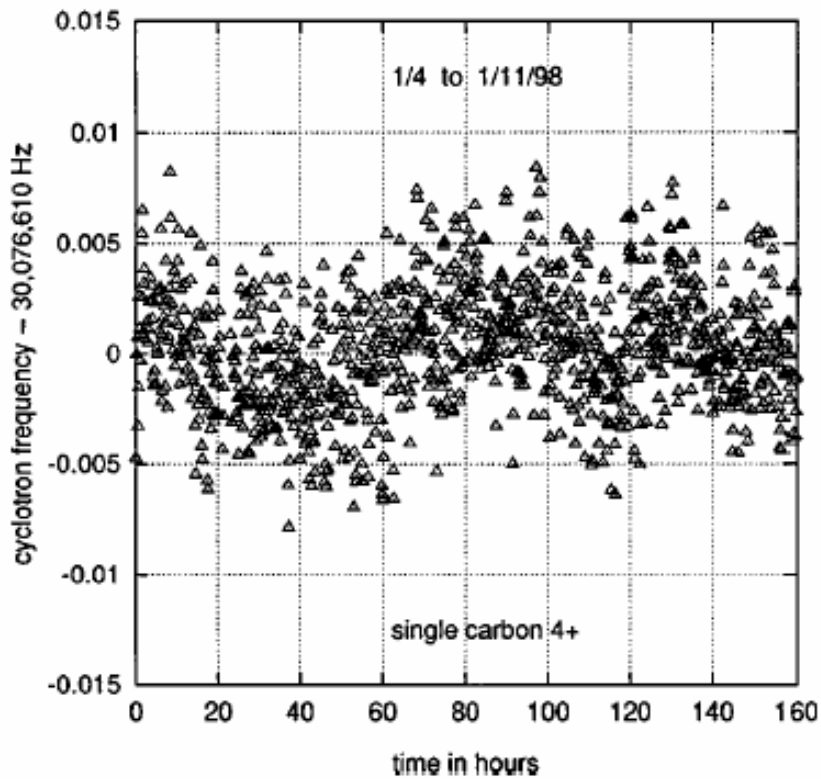


Crane movement  
in the ISOLDE hall:

Impossible to measure

# Ultrastable superconducting magnet system

R. S. Van Dyck, et.al; RSI 70, 1665(1999)



Residual structure is believed to be associated with temperature effects of electronic parts in various control systems.

The cyclotron resonances for a single O<sup>6+</sup> with a linear drift of -52 ppt/h removed.

# Results from the other labs

## ■ Gabrielse and collaborators:

- Linear correlation of magnetic field and pressure of 1.1 ppb/mbar
- To keep drifts below 1 ppb/h
  1. Flow regulated to 0.1 %/h
  2. Pressure drifts less than 0.01 mbar/h
  3. Ambient temperature regulated to 0.1 K

## ■ Fritioff and collaborators:

- Linear correlation of magnetic field and temperature of 300 ppb/K
- To keep drifts below 1 ppb/h
  1. Pressure stabilize to  $\pm 0.02$  mbar
  2. Ambient temperature regulated to  $\pm 0.5$  K
  3. Air temperature in the magnet bore  $\pm 0.03$  K

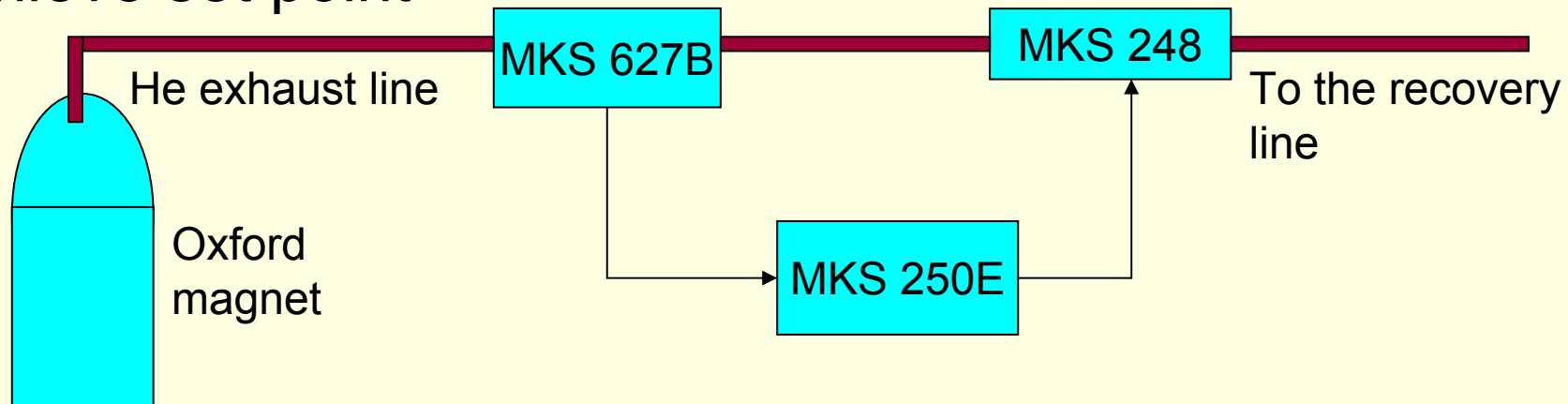
# Pressure control system at Mainz, planned for ISOLTRAP



- Consists of three basic parts

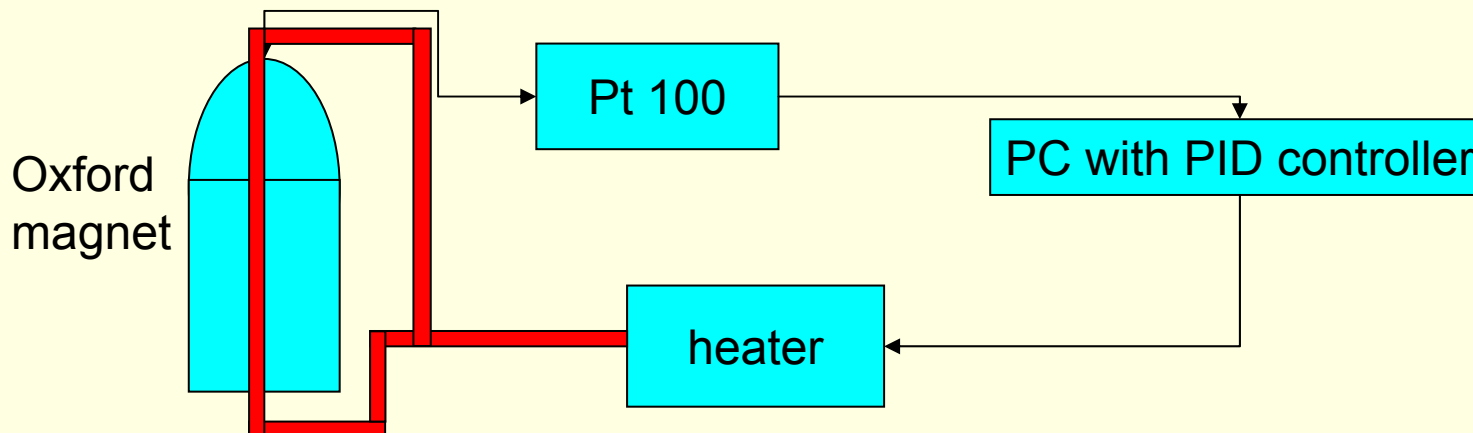
1. Process sensor: Baratron capacitance manometer (MKS 627B)
2. PID controller: Pressure control module (MKS 250E)
3. Control element: Compatible control valve (MKS 248)

- Controller compares measured pressure to the desired set point and adjust the gas flow control valve to reach achieve set point



# Planned temperature stabilization system for ISOLTRAP

- Consists of:
  1. Process sensor: Pt 100 temperature sensor with readout unit
  2. PID controller: Labview programed module with DAC card
  3. Control element: Standard 250 W heater
- Computer PID control module compares measured temperature to the desired set point and adjust the heat current in the heater to achieve set point



# Conclusion

## Solutions for the different sources of magnetic field instabilities

- **External B field changes**
  - Self shielding superconducting solenoid
  - Measurement stopped during crane movement
- **Natural decay** of the magnet should be taken into account (normally) only for the subppb level accuracy
- **Internal B field changes**
  - Pressure stabilization system with extreme stability  $\pm 0.02$  mbar
  - Environmental temperature regulated better than  $\pm 0.1$  K/h
  - Magnet surface or magnet bore temperature regulation system with accuracy  $\pm 0.01$  K/h

# THANKS to all colleagues

## MAINZ&GSI TEAM

- J. Alonso
- F. Galve
- W. Quint
- S. Stahl
- T. Valenzuela
- J. Verdú
- M. Vogel
- G. Werth

- K. Blaum
- H.-J. Kluge

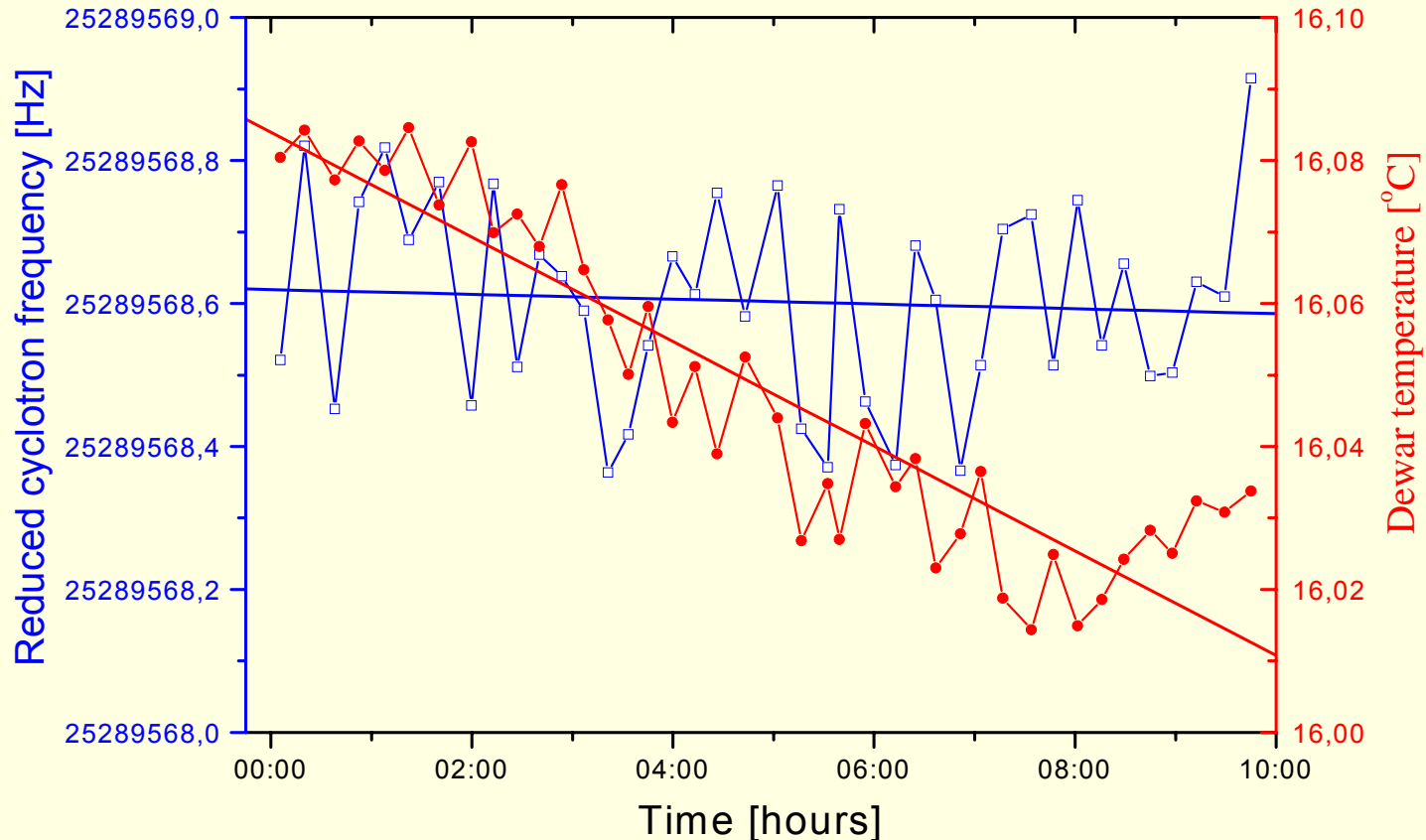
## ISOLTRAP TEAM

- M. Brodeur
- P. Delahaye
- J. Dilling
- S. George
- F. Herfurth
- A. Herlert
- L. Schweikhard
- C. Yazidjian

- And the ISOLTRAP collaboration

# Necessary stability of the dewar temperature

08.03.2002



- dewar temperature decrease with rate 0.006 K/h induce no increase in reduced cyclotron frequency only drift of 4 ppb remains