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Transverse magnetic field measurements with scalar cesium magnetometers at the nEDM experiment

E. Wursten

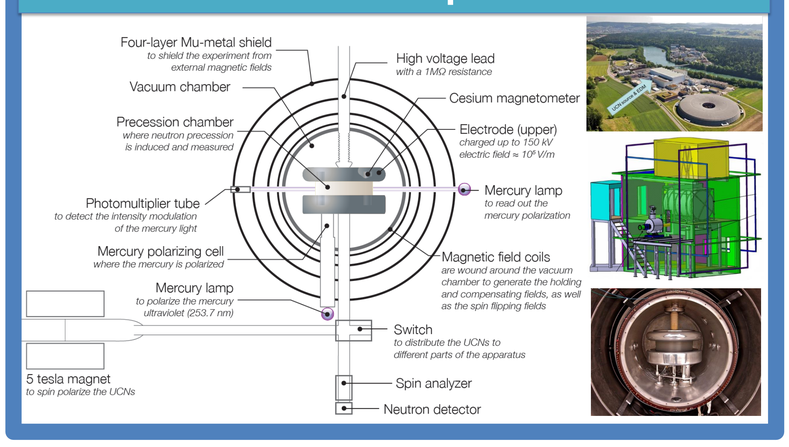
Instituut voor kern- en stralingsfysica, KU Leuven, Celestijnenlaan 200D, B-3001 Heverlee, Belgium

1. Motivation & Goal

Goal:
- Improving instantaneous knowledge of the magnetic field
- Homogenising the magnetic field

Why do we need a homogeneous field:
- Inhomogeneous field reduces neutron T2 time
- Geometric phase effect
- Ultra Cold Neutrons probe a different part of the volume than the cohabiting Hg magnetometer due to gravity
  => If the field is inhomogeneous, Hg and UCNs see a slightly different field
  => No full compensation of field drifts

2. nEDM setup at PSI



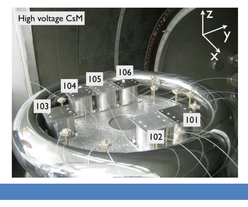
3. Magnetometers

There are 3 types of magnetometers in the setup:

HgM
- Average over precession chamber
- Nonadiabatic
- Gas at room temperature

CsM
- Local
- Measures magnitude
- 16 sensors around the precession chamber

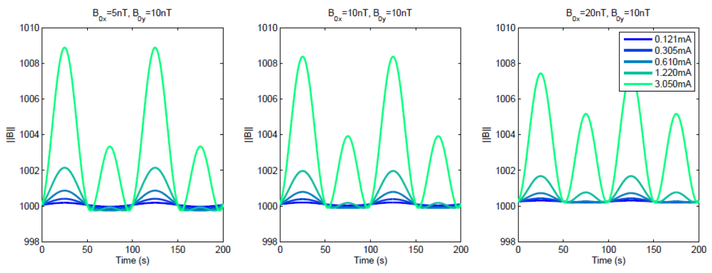
UCNs
- Average over precession chamber
- Adiabatic
- Density profile due to gravity



4. Method

How to measure vector components?

1. Measure the magnitude of the field
2. Apply alternating current to a coil that produces a transverse field:
   $\vec{B}_{AC} = (B_{ACx}, B_{ACy}, B_{ACz}) \cdot \sin(\omega t + \phi)$
3. Measure time evolution of the field with the CsMs



$$\|B\| = \sqrt{\|B_0\|^2 + 2(\vec{B}_0 \cdot \vec{B}_{AC})\,\sin(\omega t + \phi) + \|B_{AC}\|^2 \sin^2(\omega t + \phi)}$$

4. Extract transverse components

$$\approx \|B_0\| + \left(\frac{\|B_{AC}\|^2}{4\|B_0\|} - \frac{(\vec{B}_0 \cdot \vec{B}_{AC})^2}{4\|B_0\|^3}\right) + \frac{\vec{B}_0 \cdot \vec{B}_{AC}}{\|B_0\|}\sin(\omega t + \phi) - \left(\frac{\|B_{AC}\|^2}{4\|B_0\|} - \frac{(\vec{B}_0 \cdot \vec{B}_{AC})^2}{4\|B_0\|^3}\right)\cos(2\omega t + 2\phi)$$

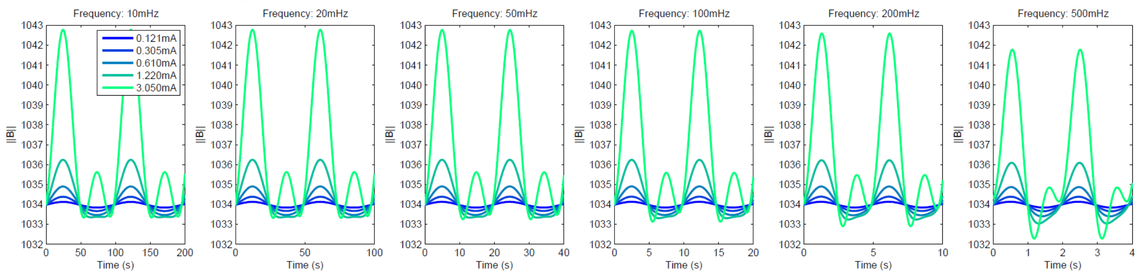
Fit function:

$$\|B\|(t) = a + b\sin(\omega t + \theta_1) - c\cos(2\omega t + 2\theta_1)$$

with $b = \frac{\vec{B}_0 \cdot \vec{B}_{AC}}{\|B_0\|} = \frac{B_{0x}B_{ACx} + B_{0y}B_{ACy} + B_{0z}B_{ACz}}{\|B_0\|}$ so $B_{0x,y} \approx \frac{\|B_0\|\,b - \|B_0\|B_{ACz}}{B_{ACx,y}}$

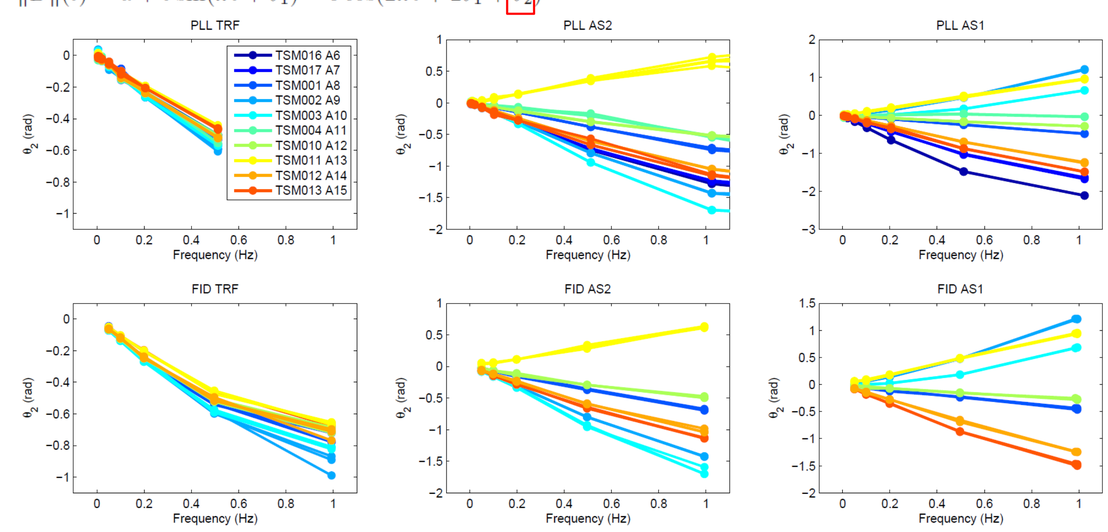
5. Results

The measured signal seems distorted!

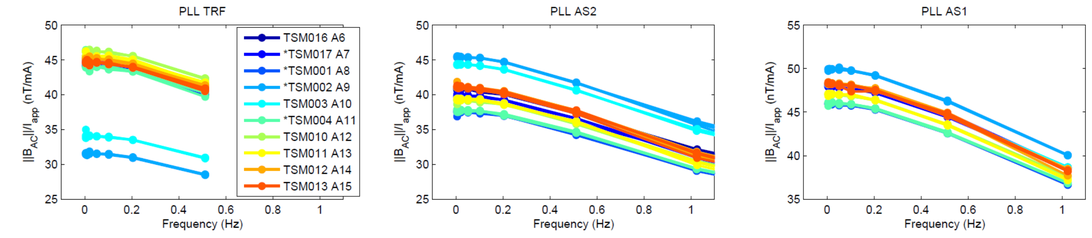


One has to add an extra phase to the fit function:

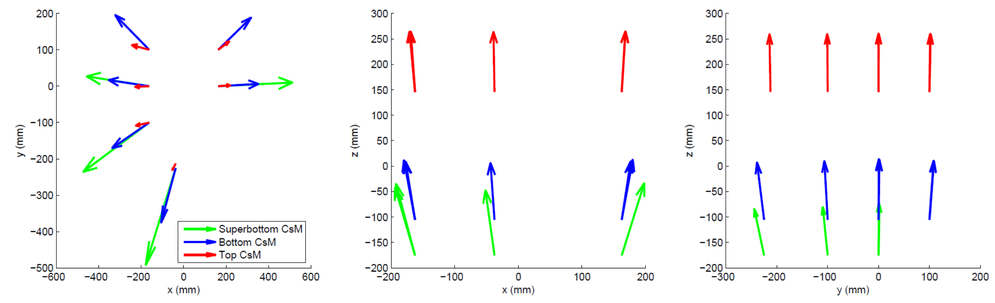
$$\|B\|(t) = a + b\sin(\omega t + \theta_1) - c\cos(2\omega t + 2\theta_1 + \theta_2)$$



Distortion is independent of CsM mode of operation (Phase Locked Loop vs Free Induction Decay). Maybe it is caused by elliptical eddy currents in the CsM housing?



Measured vector components for B_0 field + high current in closest guiding coil:

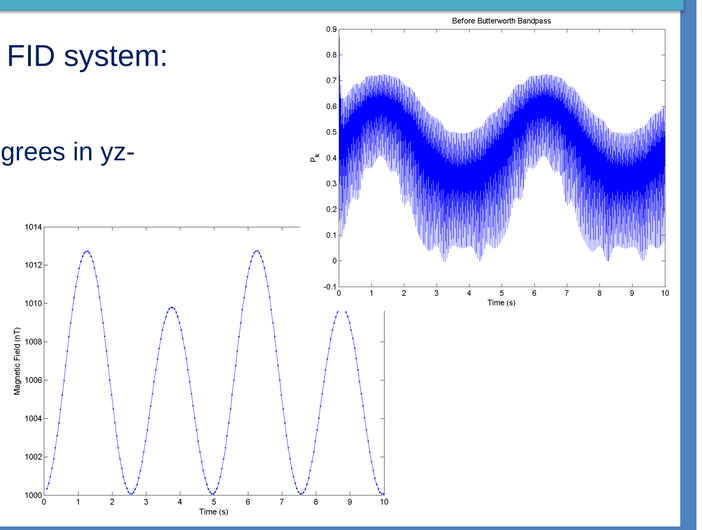


6. Simulations

Simulation of Bloch equations for FID system:
- B_0 field
- Transverse oscillating field
- 10ms of RF pulse at 3.5kHz , 45 degrees in yz-plane, 10nT, repeated every 50ms
- Optical pumping
- Spin relaxation

Steps
1. Get polarization in function of time
2. Project on laser axis
3. Send through band pass filter
4. Fit FID signal

Cannot reproduce asymmetry!



7. Conclusion & Outlook

1. We have developed a procedure to measure transverse magnetic field components using the scalar cesium magnetometers that are placed around the precession chamber. The precision we can reach is order 10nT, and is limited by the knowledge of B_{AC} from field maps.
2. There is an unexpected distortion of the CsM signal. FID simulations cannot reproduce this effect. A possible explanation is elliptical eddy currents.
3. The optimisation procedure still has to be tested.