1. Goal
Optimise the magnetic field to:
- improve nEDM sensitivity
- reduce systematic effects
Combining both offline and online magnetic field information

2. Sensitivity
Statistical uncertainty:
\[ \sigma_B = \frac{B}{2E_B T \sqrt{N}} \]
Ramsey visibility \( \alpha \):
- depends on the transverse depolarisation time \( T_2 \) of the neutrons
- increases with homogeneity of the longitudinal magnetic field component \( B_z \)

3. Systematic effects
Using a co-habiting Hg magnetometer introduces systematic effects:
- Density & velocity
  - Vertical gradients are sampled differently
  - Transverse fields are sampled differently due to difference in adiabaticity
- Geometric phase effect
  - HgM frequency shift due to interplay of motional magnetic fields \( \mathbf{v} \times \mathbf{E} \) and magnetic field gradients
  - False nEDM proportional to vertical gradient \( B_z \)

4. Field mapping - offline
Mapping device:
- Vector fluxgate sensor mounted on trolley that can move radially on arm
- Arm that can rotate around the vertical axis, and move up and down
Field maps:
- Scan magnetic field at set of positions
- Maps of main field \( B \)
- Maps of all 30 trimcoils installed around the vacuum tank

5. CsM variometer mode - online
Cs magnetometers:
- 16 CsM around the precession chamber \([1]\)
- Probe the magnitude of the field locally
- Vector information in variometer mode
Variometer mode:
1. Measure the magnitude of the main field \( |\mathbf{B}| \)
2. Apply a set of known currents \( I \) to a mapped transverse coil that generates field \( \mathbf{B}_{\perp} \)
3. Monitor the change in magnitude of the field
   \[ |\mathbf{B}| + |\mathbf{B}_{\perp}| = |\mathbf{B}_{\perp}|^2 + 2 \mathbf{B}_{\perp} \cdot \mathbf{B} + 2 \mathbf{B}^2 \]
4. Repeat with a second coil transverse to both \( B_z \) and the first transverse coil
5. The transverse components of \( B_z \) can be extracted from the scalar products

6. Optimisation procedure
Ingredients
- Transverse components of \( B_z \) and all trimcoils from field maps
- Online longitudinal components of \( B_z \) generated by each trimcoil from the CsMs variometer results
Procedure
Minimise the following function:
\[ f(I) = a |S_{\text{longitudinal}}| + b |S_{\text{transverse}}| + c |S_{\text{current}}| \]
where \( a, b \) and \( c \) are used to balance the different influences:
- \( S_{\text{longitudinal}} \) pushes all CsM readings to a certain goal value
- \( S_{\text{transverse}} \) pushes the volume average \( \langle B_z^2 \rangle \) to 0
- \( S_{\text{current}} \) pushes the generated trimcoil fields to 0

7. Results
Before 2015, the typical visibility was 50% - 65%, corresponding to a neutron \( T_2 \) time of around 500s. There was a significant difference in visibility for the two \( B_z \) directions.

Since 2015, we successfully reach visibilities of 75% - 80% for both \( B_z \) directions (compared to 86% extrapolated to 0s storage time), corresponding to a neutron \( T_2 \) time of a few thousand seconds.

This gain in visibility effectively increased the sensitivity of our experiment by 30%, enabling us to cross the \( 1 \times 10^{-9} \pm 1 \) cm (1σ) mark in 2016, while at the same time keeping systematic effects related to transverse components in check.

8. References
[2] Afach et al., Measurement of a false electric dipole moment signal from \( ^{199}\text{Hg} \) atoms exposed to an inhomogeneous magnetic field. EPJ D 69 (10), 1
[3] See poster of M. Kasprzak