Magnetic Field Environment for the CryoEDM Experiment

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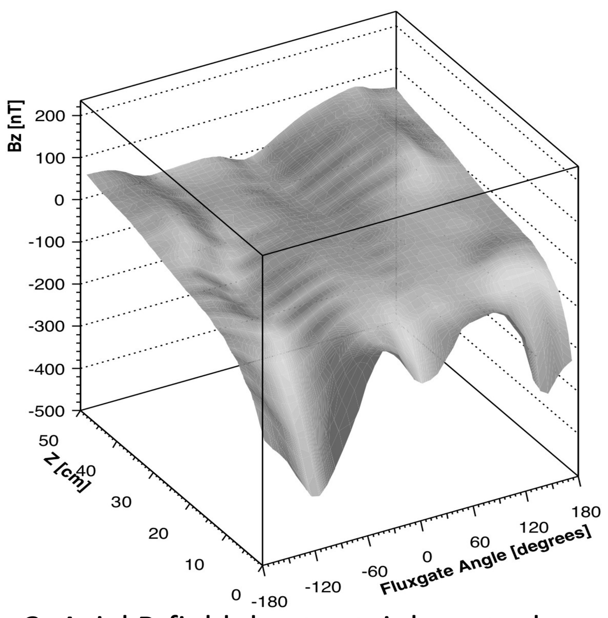
B-field homogeneity in the Ramsey cells

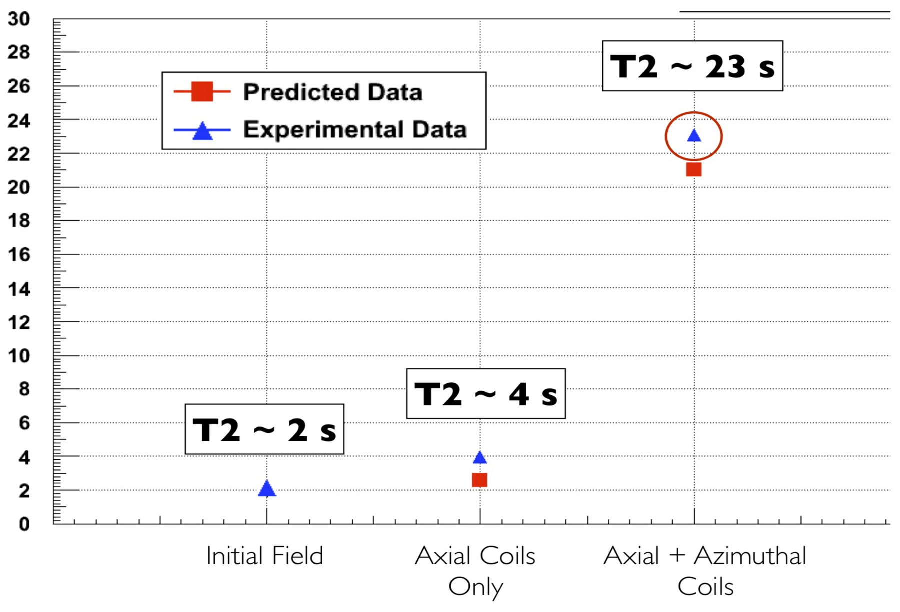
A Ramsey resonance is carried out on stored UCN under a high electric field. A non-zero electric dipole moment (EDM) will result in a shifted Larmor precession frequency, detected by spin analysis of detected UCN. The statistical uncertainty of this EDM measurement is limited by UCN numbers, polarisation, storage time and applied electric field (see box 1).

$$\sigma(d_n) = \frac{\hbar}{2\alpha E T \sqrt{N}}$$

1. Statistical uncertainty in EDM measurement with stored UCN; ***E***, applied electric field, ***T***, Ramsey cells storage time, ***N***, number of detected neutrons.



3. Axial B-field due to stainless steel superfluid vessel. ***ΔB*** < 10 μT/m.



4. Improved storage polarisation time T_2 after correction coil (7 axial, 12 azimuthal) current optimisation.

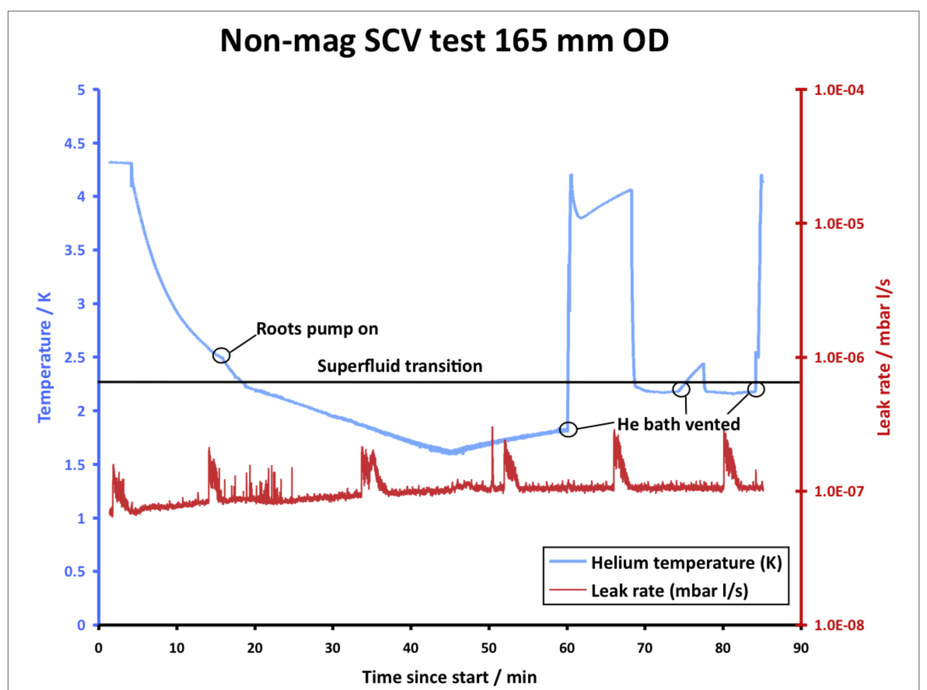
Development of non-magnetic cryogenic components is required for improved experimental performance. Stainless steel components may be used if carefully scanned, selected and machined. Tests for integrity of G10 GRP-to-stainless large-diameter seals under superfluid He-II filling indicate that a new superfluid vessel may be fabricated using this technique (see box 5). Use of G10 GRP insulator in new HV feed designs is also under investigation.

UCN stored in the resonance cells (Ramsey cells) are subject to depolarisation due to inhomogeneous B-fields[1]. Additionally, the net motion of stored UCN under gravity in an inhomogeneous B-field introduces an EDM-like Larmor frequency shift, proportional to ***E***, which is a significant systematic error (see box 2). B-field gradients of 10 nT/m at the Ramsey cells would produce systematic errors at 10^{-27} e cm level[2]. For these reasons the homogeneity of the B-field at the Ramsey cells must be optimised.

$$d_{af} = -\frac{J\hbar}{2}\left(\frac{\partial B_{0z}/\partial z}{B_{0z}^2}\right)\frac{v_{xy}^2}{c^2}$$

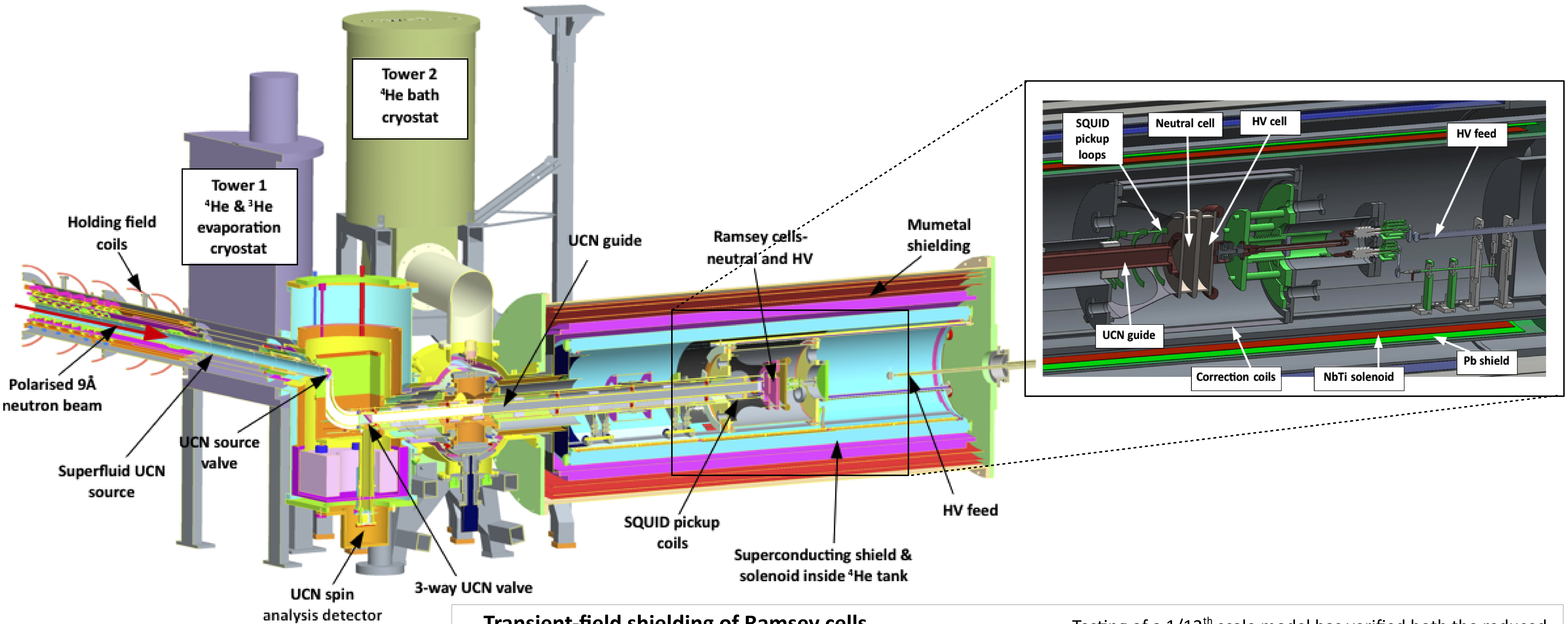
2. False EDM due to ***v x E*** effect; $\partial B_{0z}/\partial z$ field gradient in axial direction, v_{xy} net motion of UCN CoM.

Components for the superfluid vessel, HV supply and Ramsey cells must be carefully selected for magnetic homogeneity. Currently a vessel of 316LN stainless steel is used for superfluid containment, commercial ceramic HV feeds, and a Be/BeO Ramsey cell. Detailed magnetic profiling was carried out in 2010 and 2012 (see box 3), revealing gradients of up to 1 μT/m. Application of fields from 19 correction coils can increase storage polarisation time T_2 from 2 s to 23 s (see box 4).



5. Superfluid testing of non-magnetic seal; (blue) He-II temperature, (red) leak rate.

6. 150 kV low-mag HV feedthrough for He-II vessel.



CryoEDM upgrade

The CryoEDM experiment is now ready to be moved to a new dedicated cold neutron beamline at ILL. The final commissioning run at H53 was completed in July 2013 and reinstallation will begin in 2015. A polarised 9 Å beam with an intensity of 1.2 x 10^8 n cm^{-2} s^{-1} will be available, a fourfold increase on the old cold neutron beam intensity.

During 2013/14, off-line upgrade work will be undertaken. A superconducting inner shield will be installed and evaluated *(right)* and further non-magnetic components produced for the Ramsey cells volume *(top)*. The development of a new HV feed to allow simultaneous ± ***E*** measurements in the Ramsey cells is planned in order to allow further control of systematic effects. Cryogenic performance of the horizontal shield cryostat will be improved through the reduction of heatload and installation of additional pre-cooling, with the aim of reducing overall system cooldown times. Additional modifications may be made to allow pressurisation of the He-II with the aim of suppressing HV breakdown initiated by bubble formation.

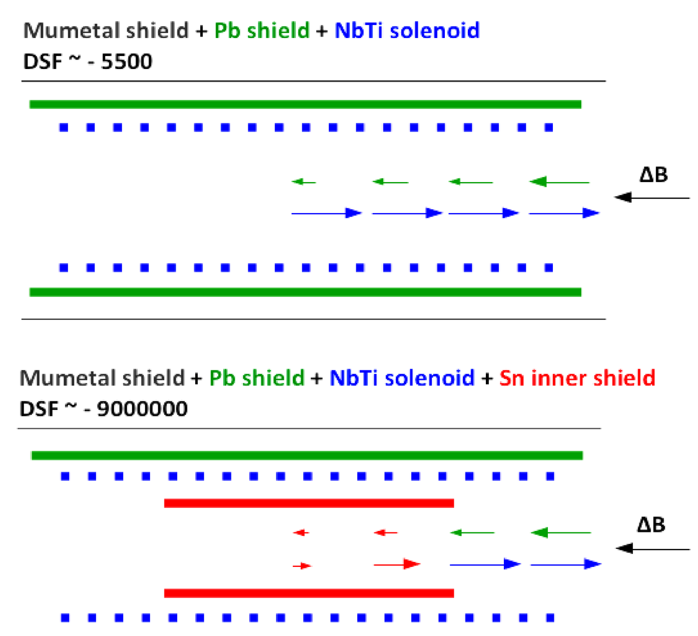
Transient-field shielding of Ramsey cells

Transient magnetic fields during Ramsey resonance cycles must be limited to below 10 fT to reduce the systematic error due to ***B*** drift to 10^{-27} ecm (see box 7). Transient fields in the laboratory have been measured at the 10 nT level, necessitating a total shielding factor of 10^6 or more for the Ramsey cells.

$$d \simeq \frac{\Delta B(t).\mu_n}{2E}$$

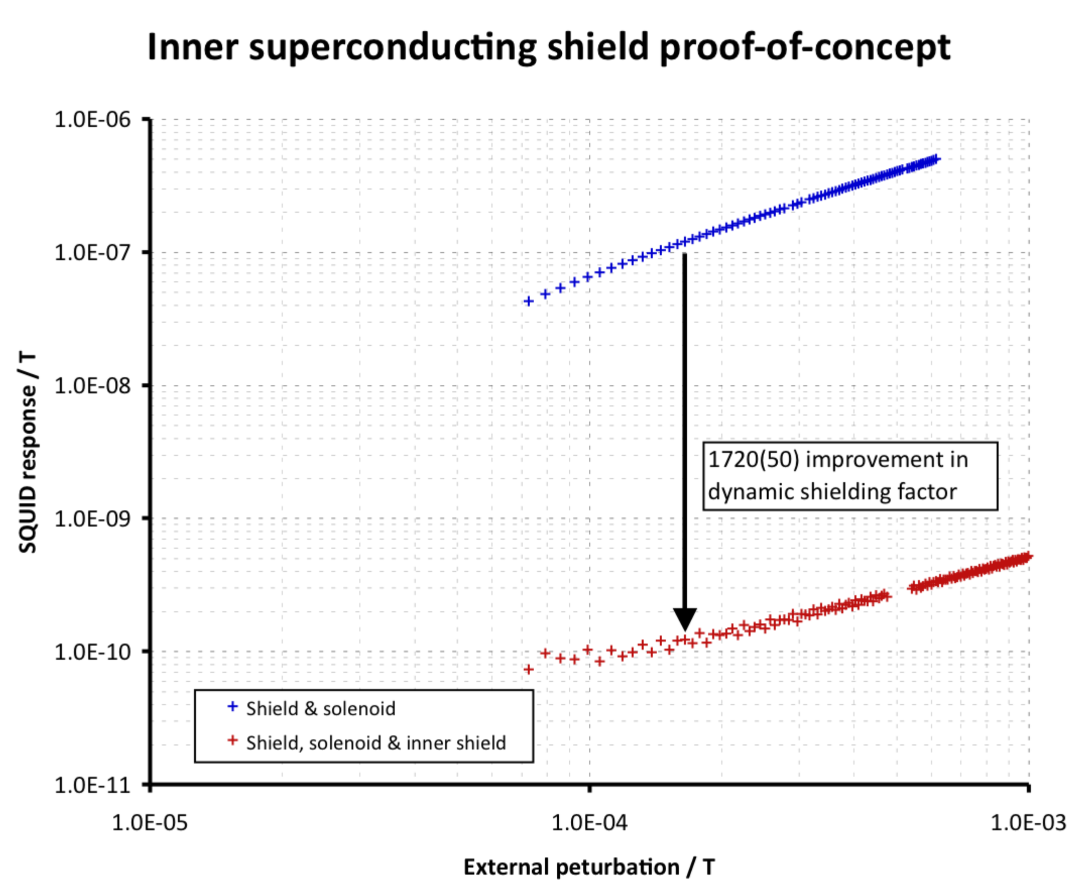
7. False EDM signal ***d*** due to fluctuation in axial field ***ΔB(t)*** during resonance cycle.

The existing shielding, consisting of coaxial mumetal and cryogenic lead cylinders, is compromised by a persistent-mode niobium-titanium solenoid (providing B_0) inside the lead shield, reducing the overall shielding factor to 5500 (see box 8). A proposed repair is to insert an inner superconducting shield to attenuate the field inside the solenoid.



8. Shielding the CryoEDM Ramsey cells from transient B-fields; *(top)* current configuration, *(below)* proposed ISS.

Testing of a 1/12th scale model has verified both the reduced shielding factor of the shield-solenoid system and the increased shielding factor of a tin inner shield. The installation of a full-sized inner tin shield is under way. We expect that the resulting shielding factor will be increased by around 1720, to a value in excess of 9 x 10^6.



9. Measured response to external field perturbation in 1/12th scale model; *(blue)* current configuration, *(red)* proposed ISS.

[1] Harris, Pendlebury, Devenish. ArXiv:1306.1252 (2013) [2] Pendlebury et al. Phys Rev A 70 032102 (2004)