The PULSTAR systematics test apparatus of the SNS nEDM experiment

Kent Leung on behalf of the collaboration

The SNS nEDM experiment

• Will be installed at the Spallation Neutron Source, Oak Ridge National Lab., USA with planned sensitivity $d_n < 5 \times 10^{-28}\,\mathrm{e \cdot cm}$

• Polarized UCNs produced via super-thermal down-conversion of a polarized CN beam in superfluid helium inside two EDM cells.

• Use of superconducting magnetic shields for high field uniformity.

• HV electrode (350kV producing a 50kV/cm field) sandwiched in between two UCN cells, with ground electrodes outside (E-field opposite in the two cells).

• Novel use of polarized ^{3}He (~10^{-10}) in superfluid ^{4}He as co-magnetometer in Golub & Lamoreaux double-resonance scheme:

Apply π/2 pulse and measure scintillation light:

$$\propto \frac{\rho_{\mathrm{UCN}} V}{\tau_{^3\mathrm{He}}} \left(1 - P_3 P_n \cos[\theta_{n3}(t)]\right)$$

^{3}He(n,p)^{3}T (Q = 764keV) has:

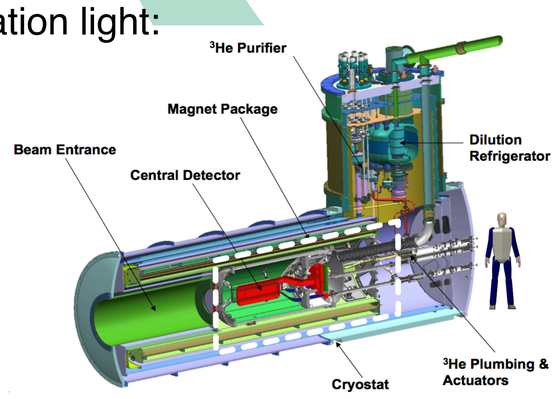
$$\sigma_{\uparrow\uparrow} = 59\,\mathrm{b} \quad \sigma_{\uparrow\downarrow} = 11\,\mathrm{kb}$$

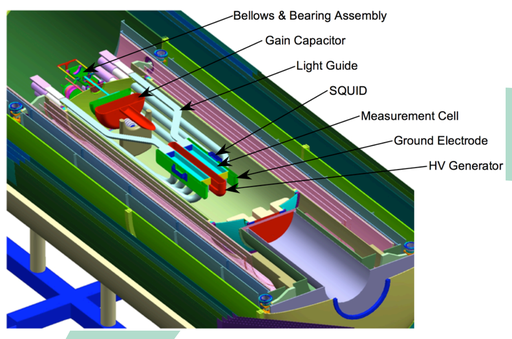
Gyromagnetic ratios: $\gamma_3 \approx 1.112\gamma_n$

Shift due to EDM: $\omega_E = \pm\frac{2d_N E}{\hbar}$

^{3}He has a negligible EDM. Can observe difference in precession frequencies between the 2 species for EDM signal.

Observe absolute ^{3}He precession with SQUIDs or can dress-spin so precession frequency the same.





PULSTAR apparatus: full-sized cell & no E-field

• Complexity and long cooling cycle of full nEDM apparatus makes these measurements difficult and time consuming

• Observe scintillation light from relative ^{3}He-UCN precession

• Study the geometric phase systematic, which comes from interaction between $\vec{v} \times \vec{E}$ field and B-field gradients and is linear in E.

• Different for ^{3}He and n due to difference in motion (ballistic vs diffusive regimes). Can vary effect on ^{3}He with temperature. Test analytic description: $\delta\omega = \frac{ab}{2}\int_0^\infty R(\tau)\cos(\omega_0\tau)d\tau \quad D_{^3\mathrm{He}} \approx 1.6\,T^{-7}\,\mathrm{cm^2\,s^{-1}}$

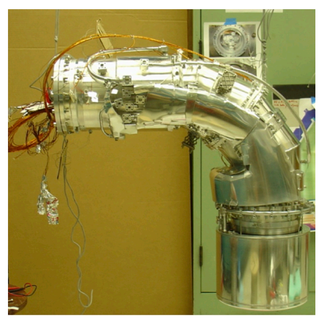
• Demonstrate the concept of dressing the spins with ~3kHz RF-field (minimizes systematic shifts from static fields and increases sensitivities): $\theta_{n3}(t) = 2ed_nEt/\hbar$

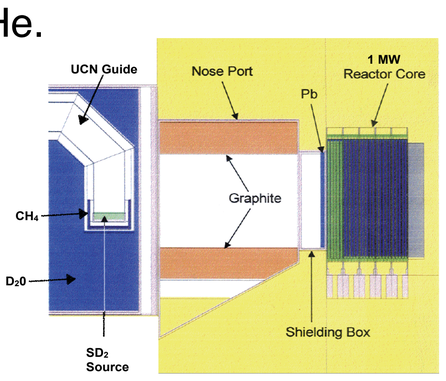
• Study the ^{3}He pseudo-magnetic field caused by scattering length difference: $b_{\uparrow\uparrow} = 4.29\,\mathrm{fm}$ & $b_{\uparrow\downarrow} = 10.07\,\mathrm{fm}$. Occurs when imperfect pi/2 pulse. Cancelled out by having 2-cells with opposing E-field.

• UCN storage and depolarization (^{3}He and UCN) for studies to optimize cell fabrication.

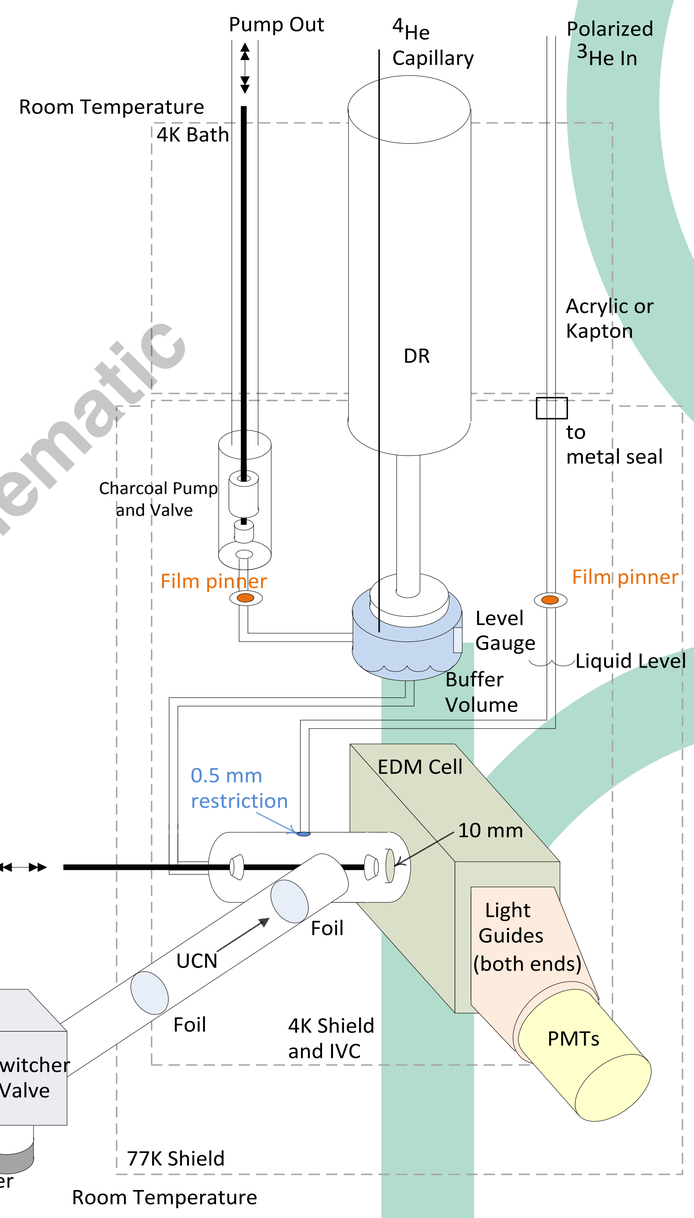
• Develop techniques for NMR imaging of ^{3}He.

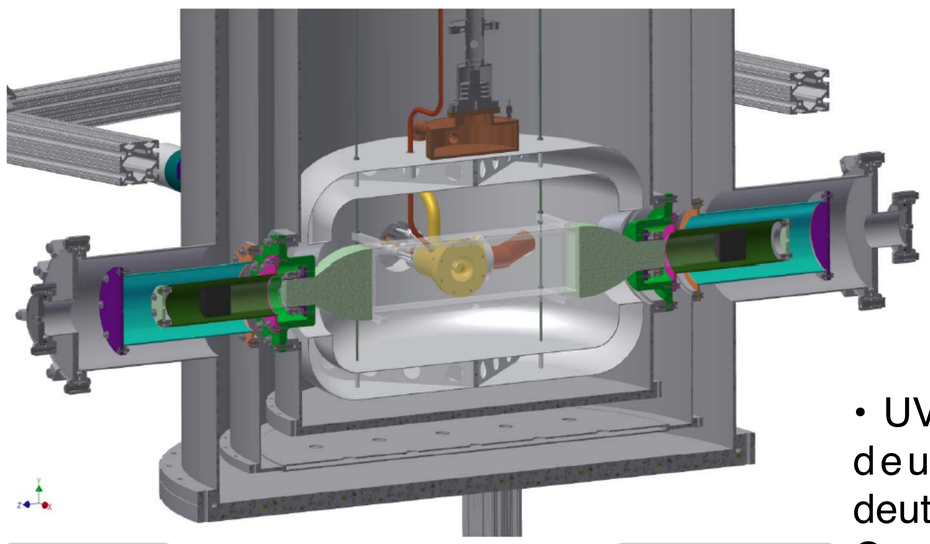
• Will use the *sD$_2$* UCN source at the recently upgraded 2 MW PULSTAR reactor at North Carolina State University, Raleigh, NC, USA.





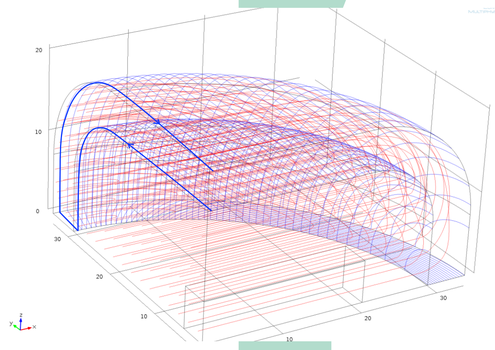
Experimental design (still in development)



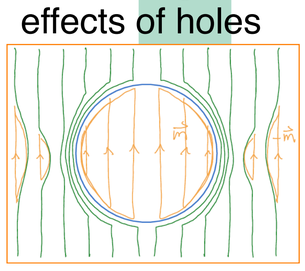


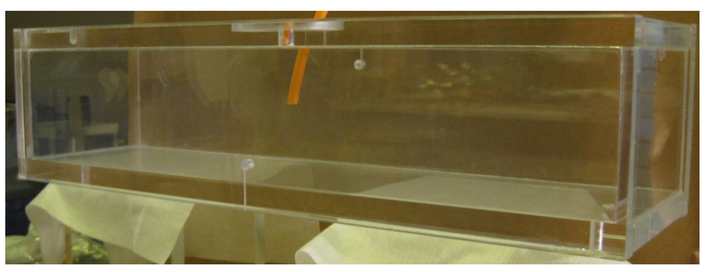
multi-layer magnetic shell: serves as cosθ B_0 coils, correction foils for field uniformity, and RF coil for dressed spins

exploring 3D printed ABS plastic, electrode less copper plating, laser etch away with robot arm



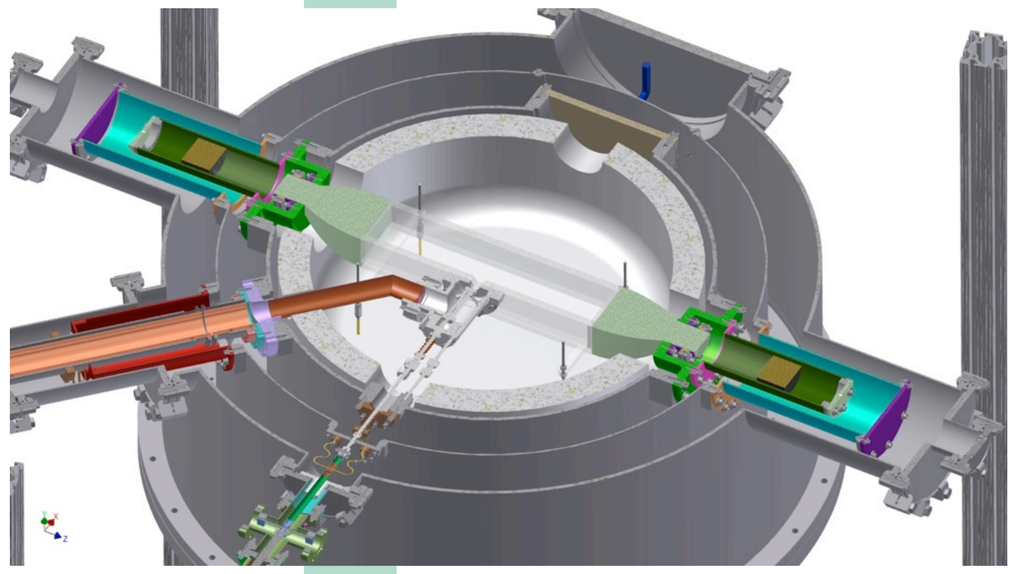
current rerouting to cancel effects of holes



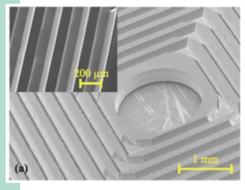


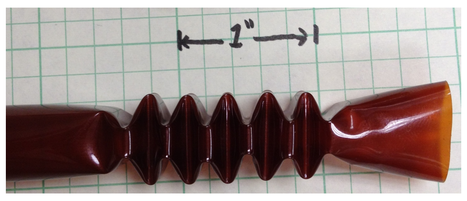
• UV transmitting acrylic plates coated with deuterated polystyrene (dPS) and deuterated tetraphenyl butadiene (dTPB). Coating shifts 80nm scintillatied light to 430nm for PMTs. Guiding along plates and light guides. Need to be superfluid tight.

• V_{opt} = 165neV, measured f~5x10^{-5} with UCNs. Aimed for storage time ~200s



Reduce heat load and saturation of charcoal pumps: superfluid film-cutters





Develop non-magnetic cryogenic components:
e.g. Kapton bellows