The LANL nEDM Experiment

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On behalf of the LANL nEDM collaboration

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The LANL nEDM collaboration

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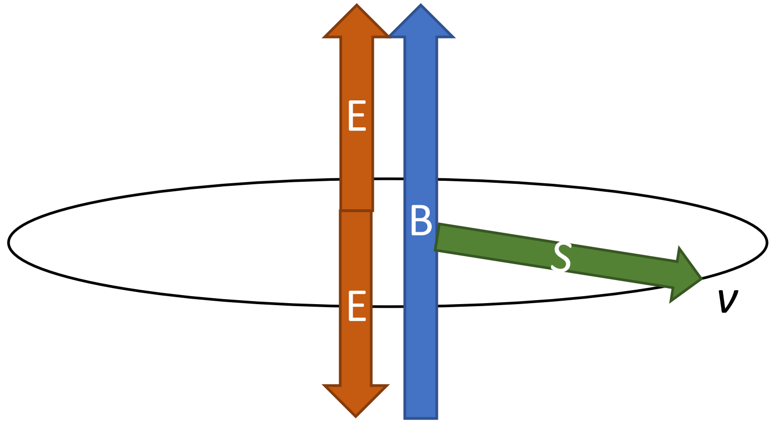
Outline

- Measurement overview
- Experimental overview
  - UCN source
  - Neutron storage and measurement
  - Magnetically shielded room
  - Magnets and magnetometry
- Status and plans

Measurement overview

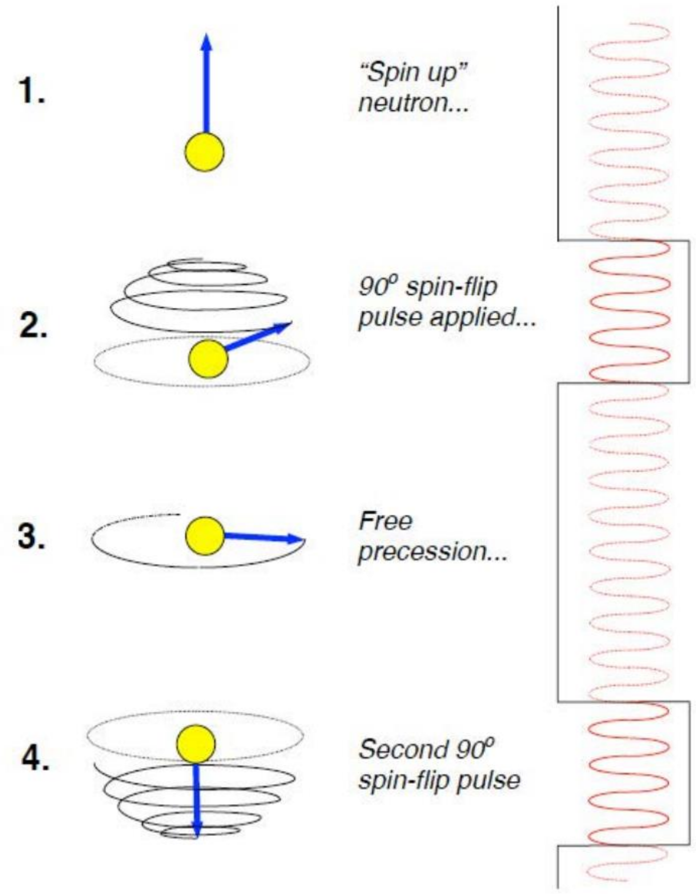
- Two cells with equal magnetic field but opposite electric field
- Difference between spin precession of cells is proportional to EDM
- For realistic values (B = 1 uT, ν = 30 Hz, E = 10 kV/cm, d = $3x10^{27}$ e-cm), $\Delta\nu$ = 30 nHz



$$\nu = (2\mu B \pm 2dE)/h$$
$$\Delta\nu = 4dE/h$$

Measurement overview

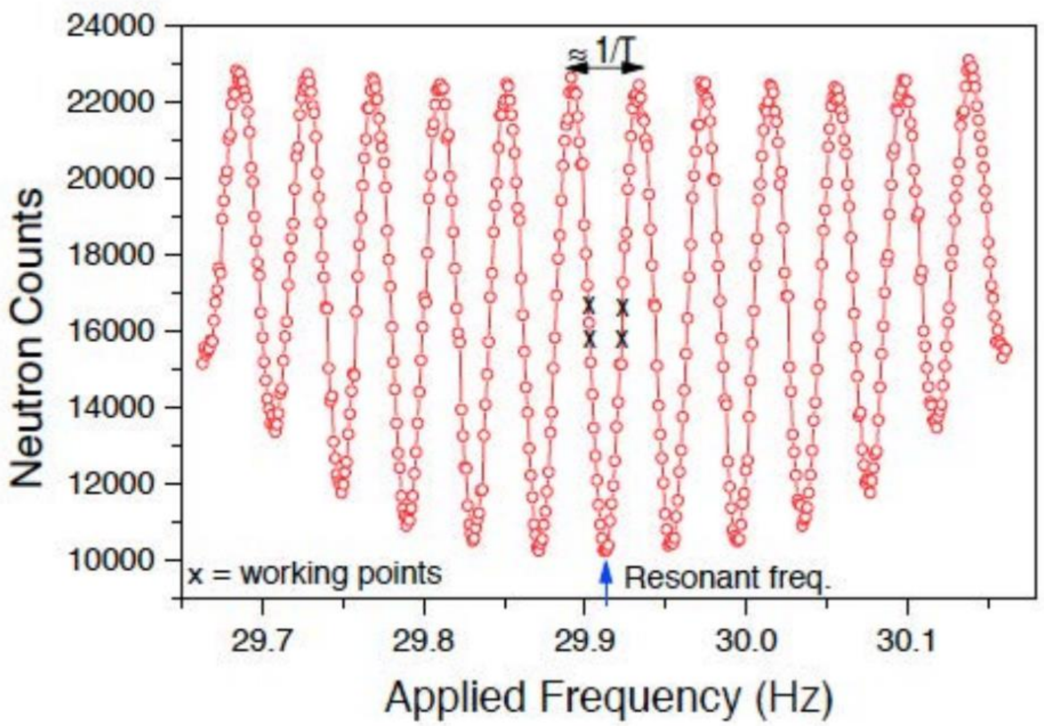
- Use Ramsey's method of separated oscillatory fields
- π/2 pulse is applied to neutrons
- Neutron spins precess in the magnetic and electric fields
- Time T later, another π/2 is applied to the neutrons



Baker *et al.*, NIMA 736, 184 (2014)

Measurement overview

- Use Ramsey's method of separated oscillatory fields
- π/2 pulse is applied to neutrons
- Neutron spins precess in the magnetic and electric fields
- Time T later, another π/2 is applied to the neutrons
- Neutron precession frequency encoded in Ramsey fringes



Baker *et al.*, NIMA 736, 184 (2014)

Sensitivity considerations

EDM statistical sensitivity

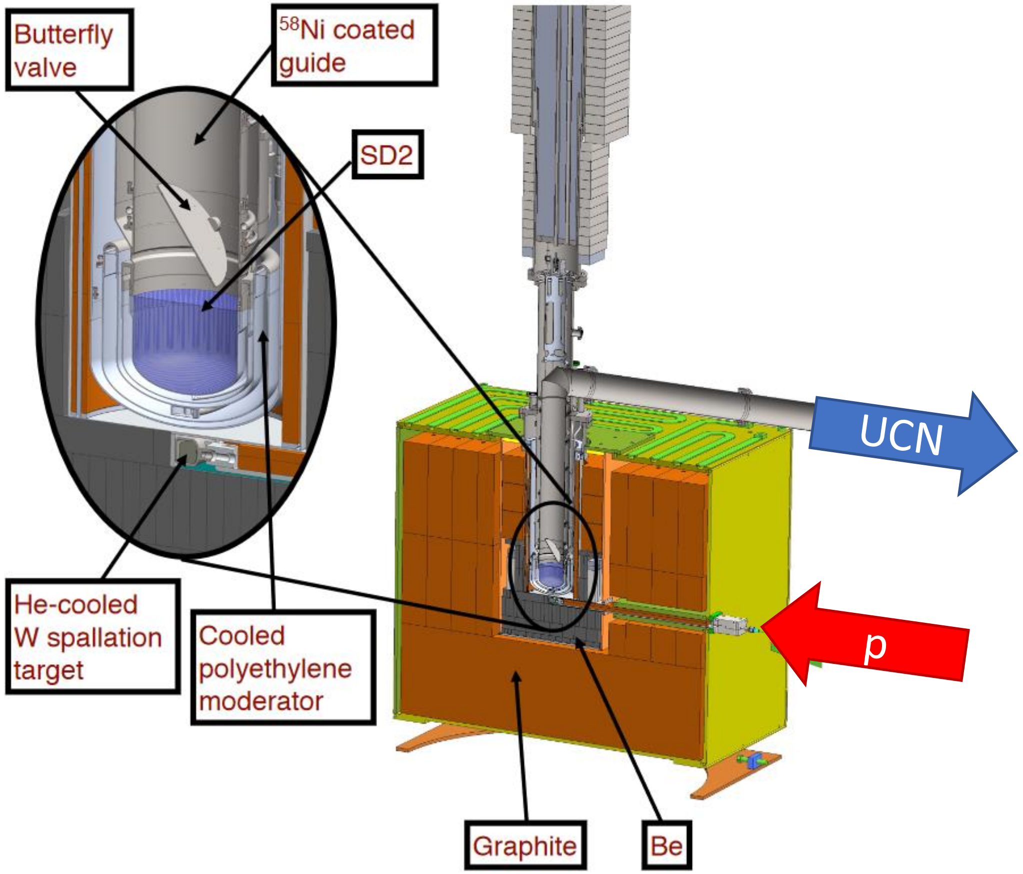
- α is the combined polarization and analyzer power
- Estimates of E, T, and α based on what's been achieved by others
- Estimate of N based on data from UCN source
- T_{duty} ~ 300 sec
- 1 year of data expected to take 5 calendar years

$$\delta d_n = \frac{\hbar}{2\alpha E T \sqrt{N}}$$

Quantity	Value
E (kV/cm)	12.0
N (neutrons per cell)	39,100 x num fills
T (sec)	180
α	0.8
σ/day/cell (10^{-26} e-cm)	5.7
σ/year (10^{-27} e-cm)	2.1

The LANL UCN source

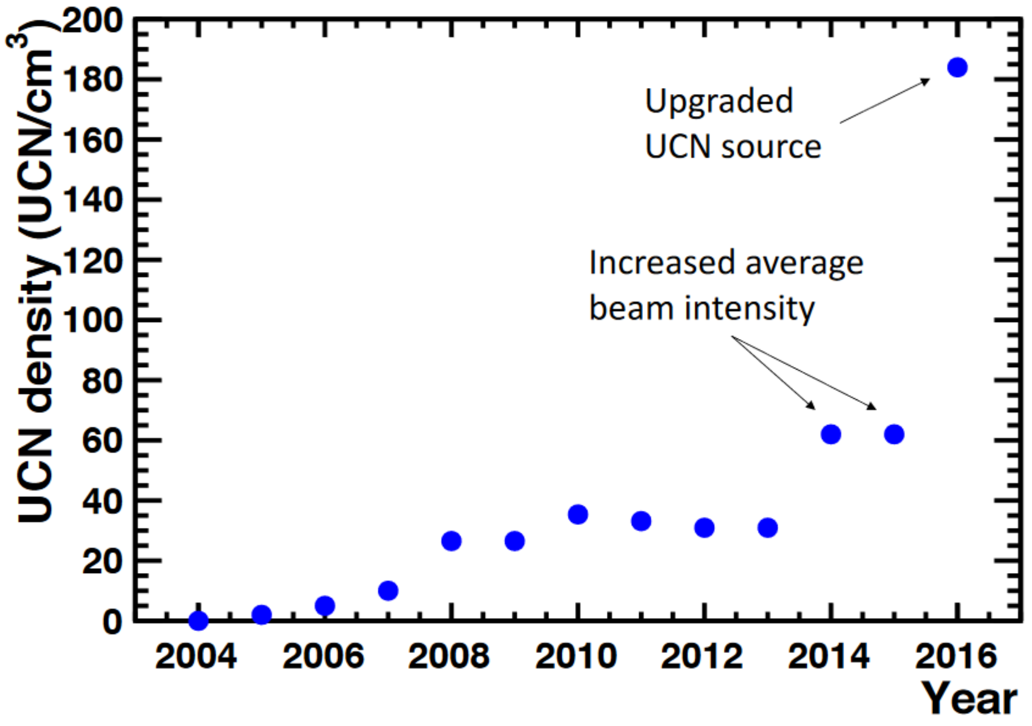
- Spallation neutrons produced at tungsten target @ ~2 MeV
- Neutrons come to room temp in beryllium and graphite moderators @ ~25 meV, 300 K
- Cold neutrons in cold polyethylene @ ~6 meV, 70 K
- UCNs in solid deuterium converter @ ~100 neV, 1 mK



Ito *et. al.* PRC 97, 012501(R) (2018)

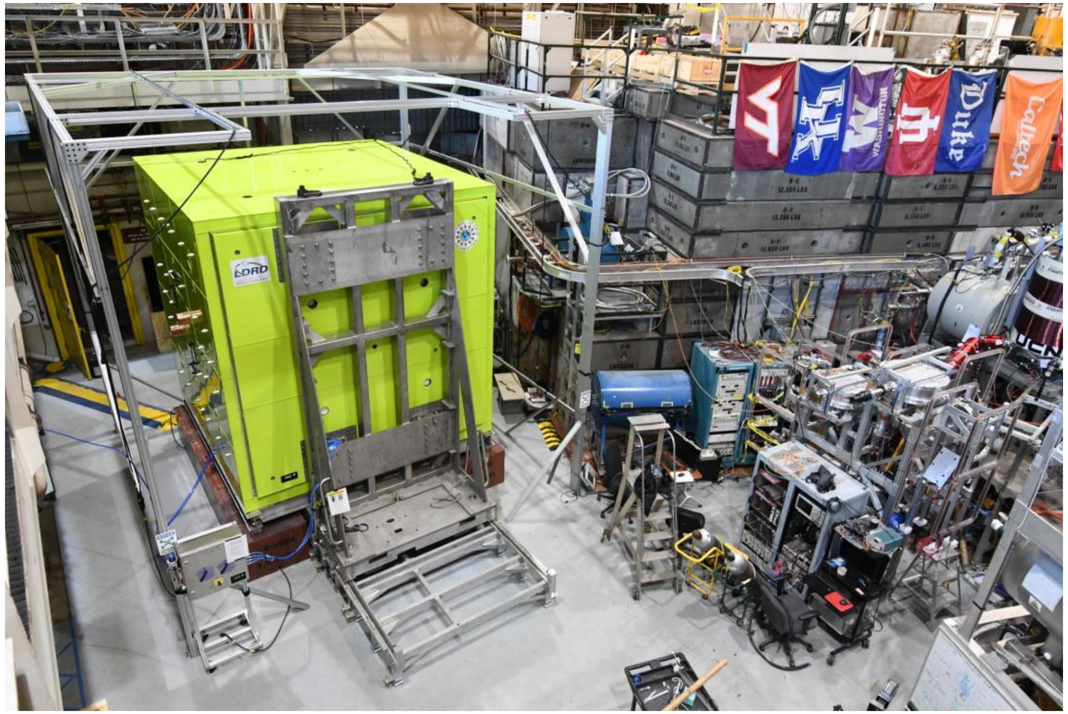
The LANL UCN source

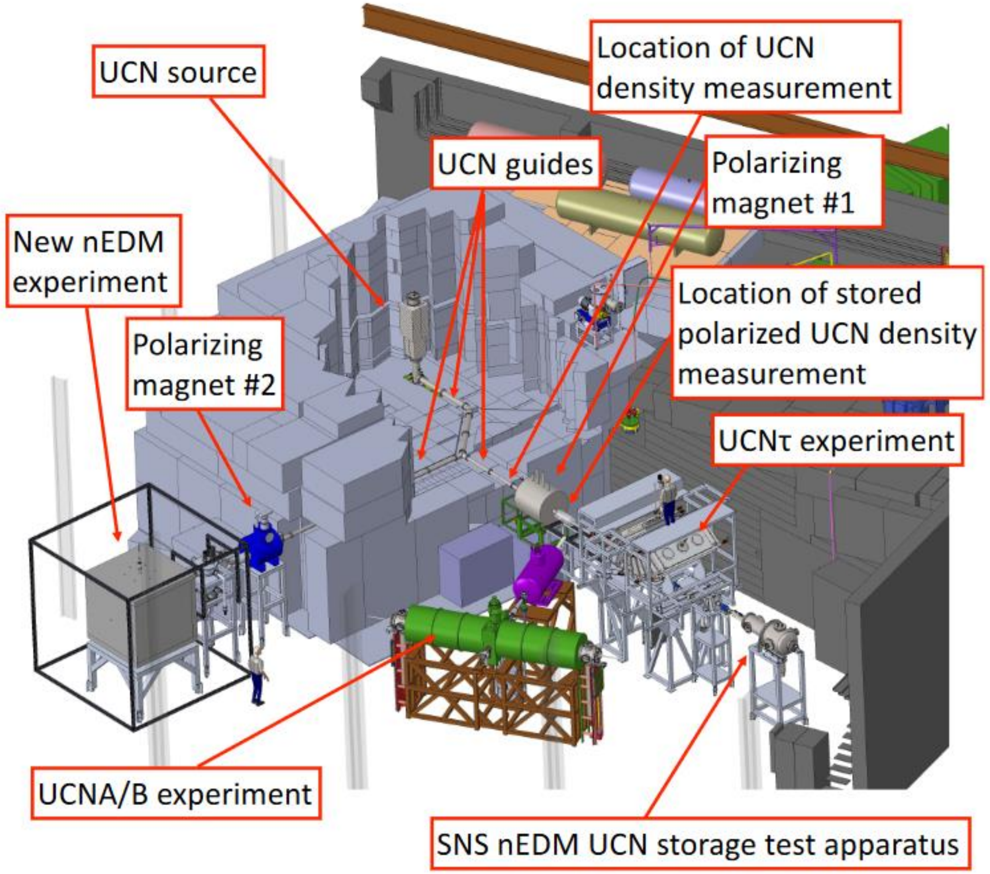
- Recent upgrades to UCN source have made LANL nEDM possible
- Upgrades in 2014 — 2017 quadrupled UCN output
- Increased the beam current
- Upgraded UCN source insert



Ito *et. al.* PRC 97, 012501(R) (2018)

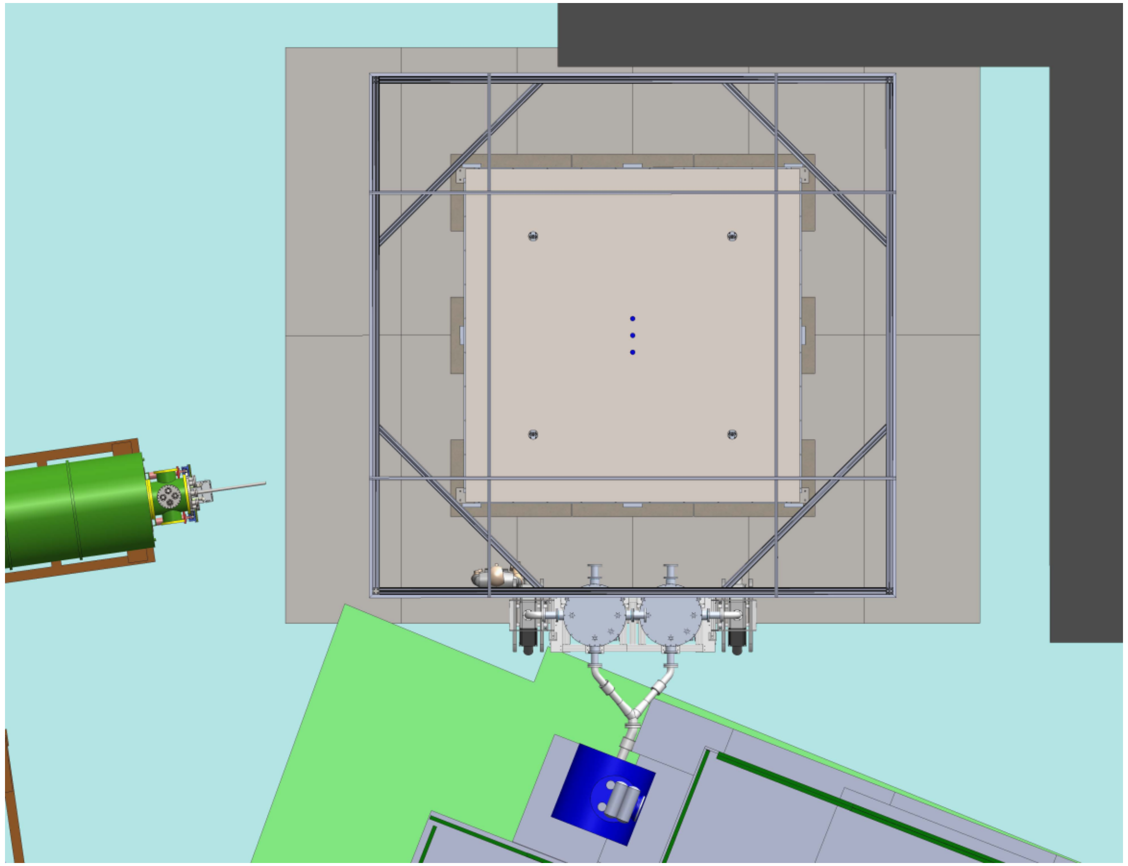
The experimental setup at LANSCE



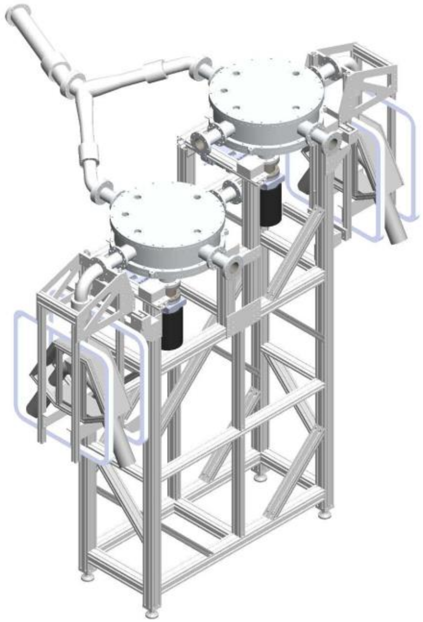


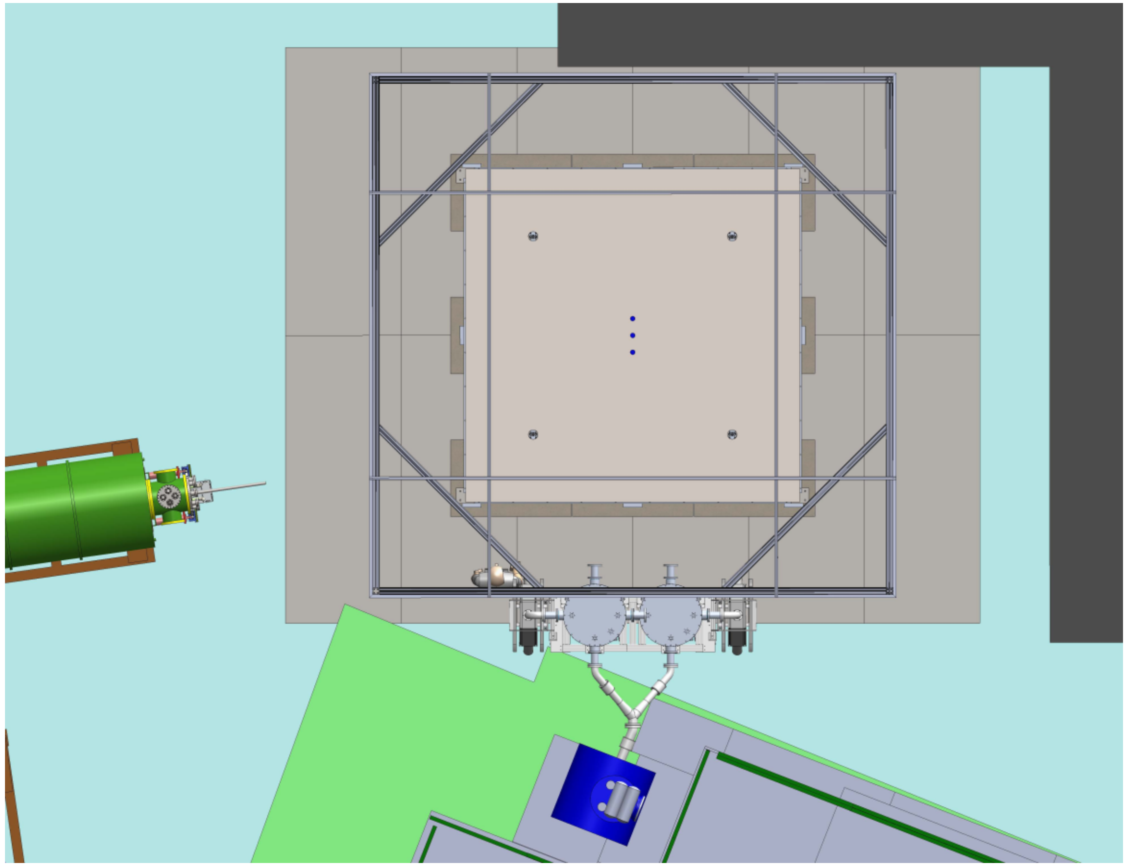
UCN transport and storage

- UCNs pass through polarizer to splitter
- Splitter fills both top and bottom cells through spin transport coils
- After free precession time, valves allow neutrons out to spin analyzers



UCN transport and storage





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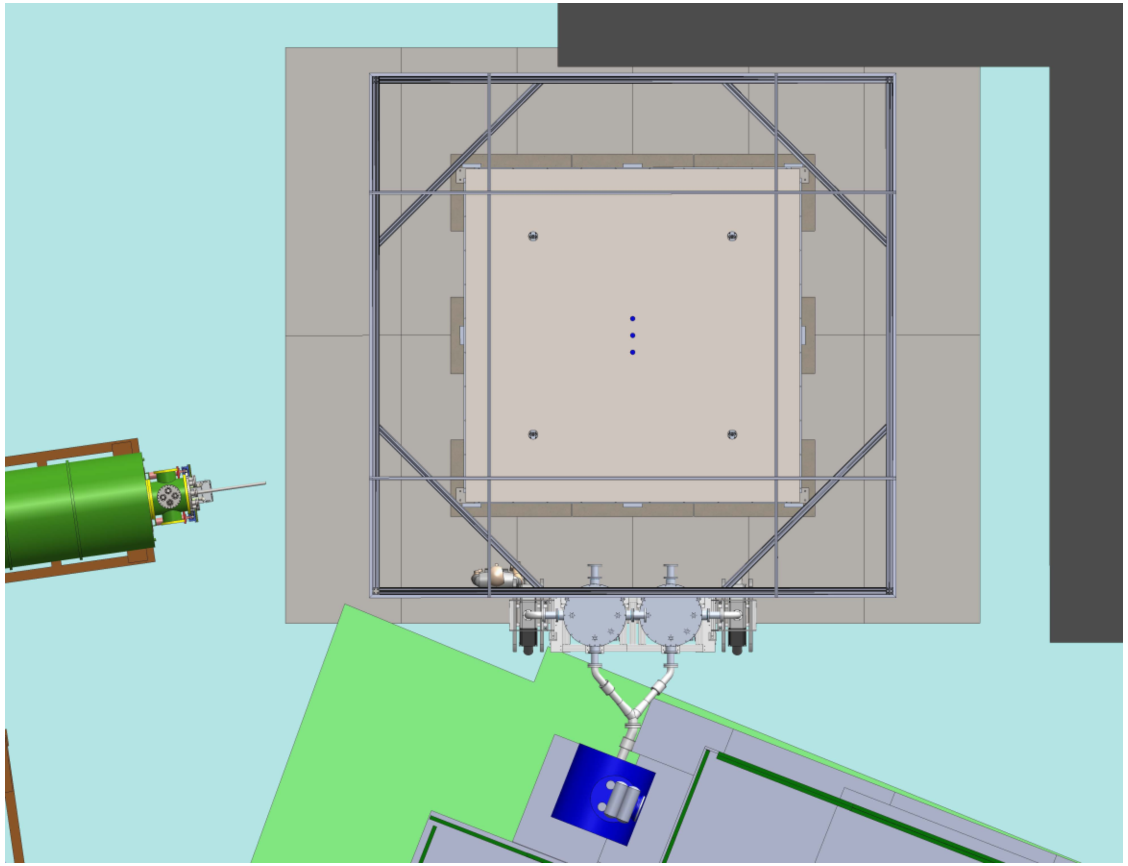

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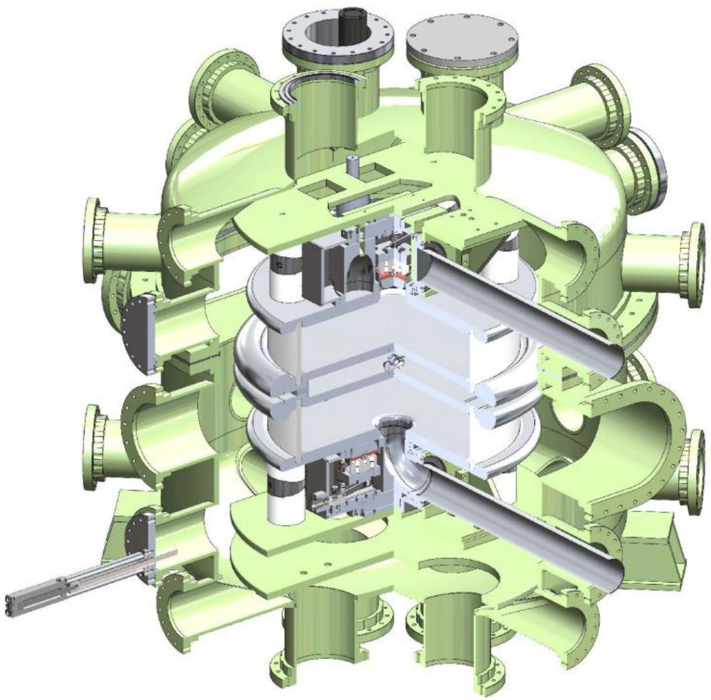

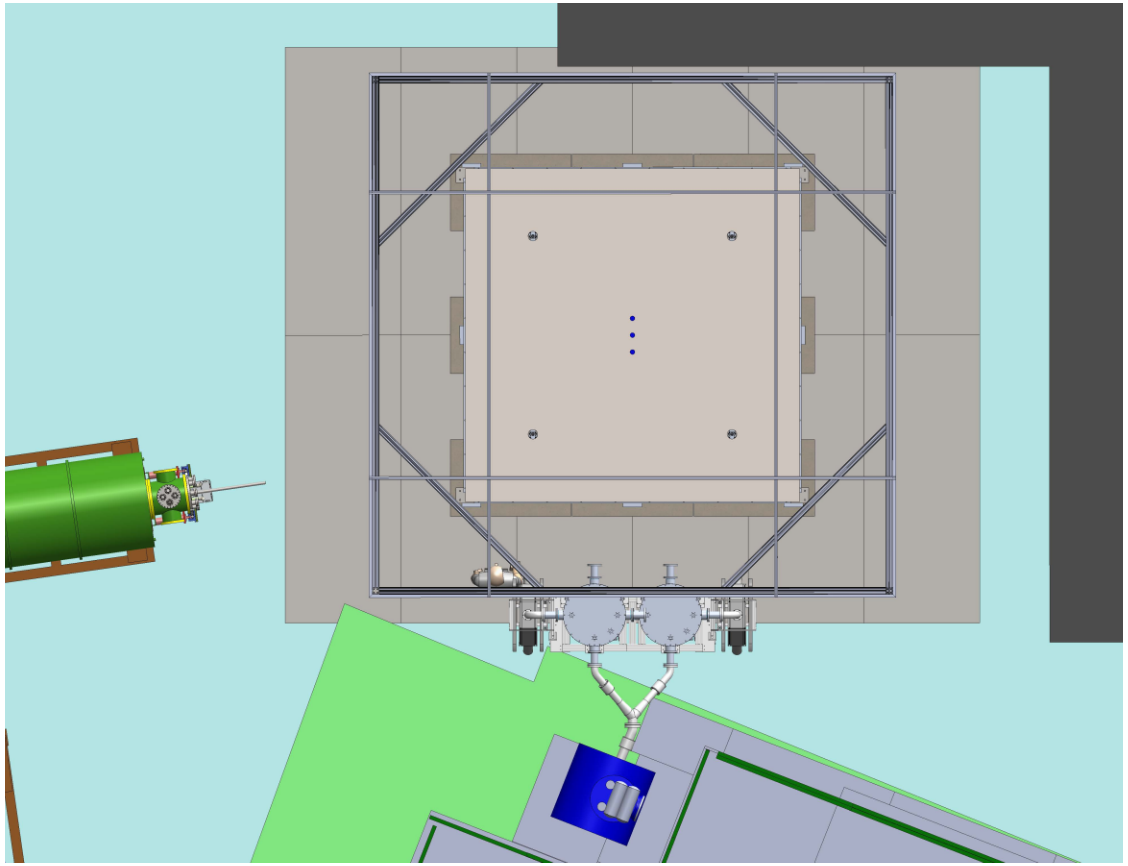

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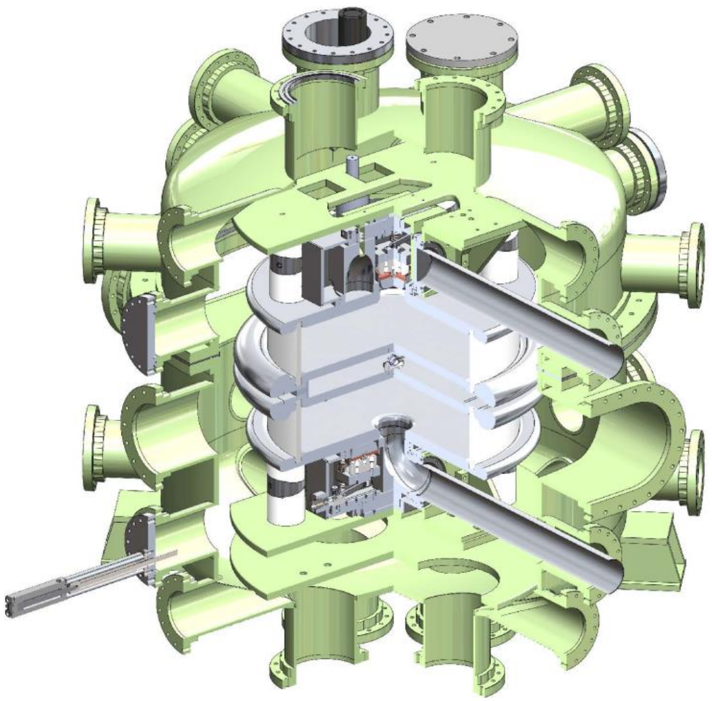
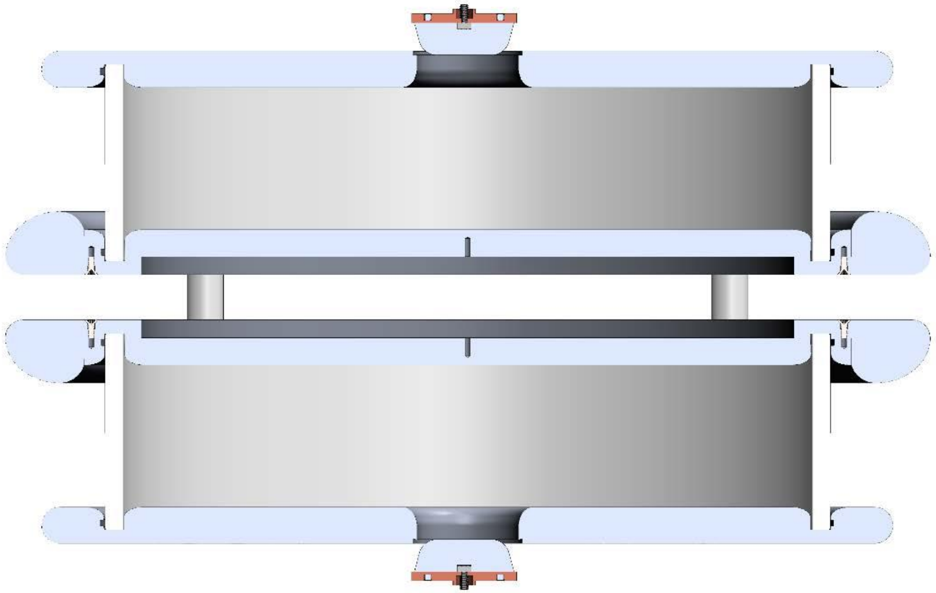
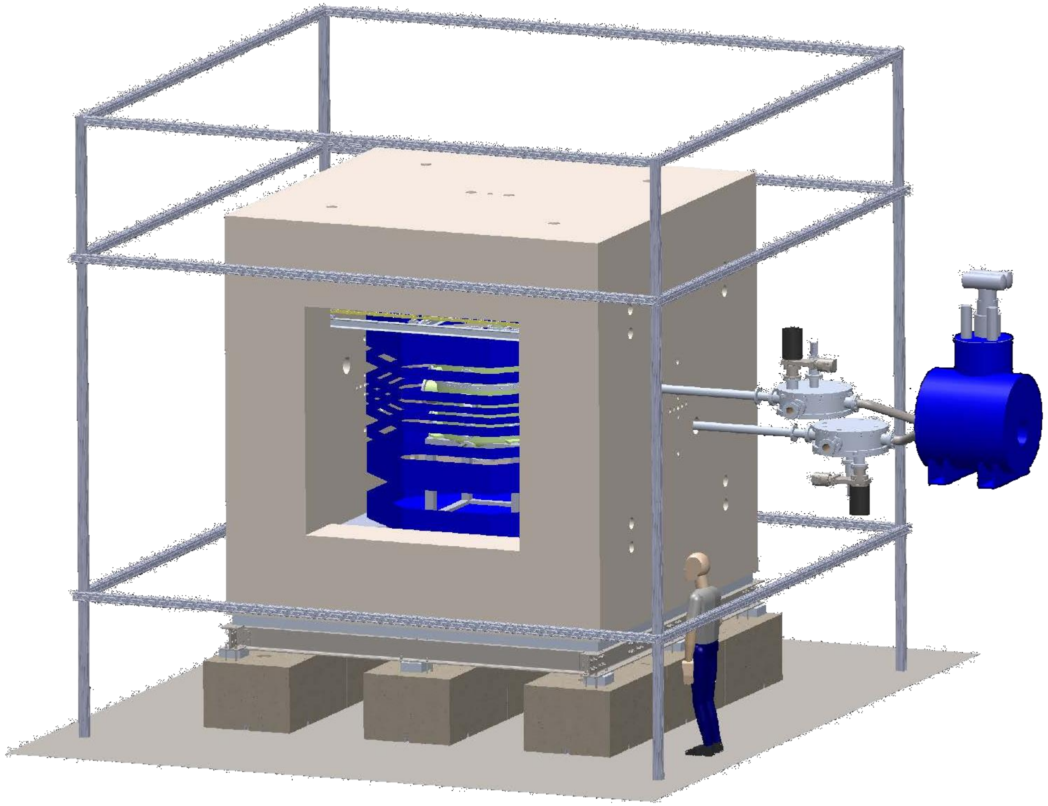




Each cell: 50 cm diameter, 10 cm height

Magnetically shielded room (MSR)

- MSR provides shielding against external fields and drift
- External coils cancel local field, plan to use fluxgates to feedback on external coils to optimize field cancelation



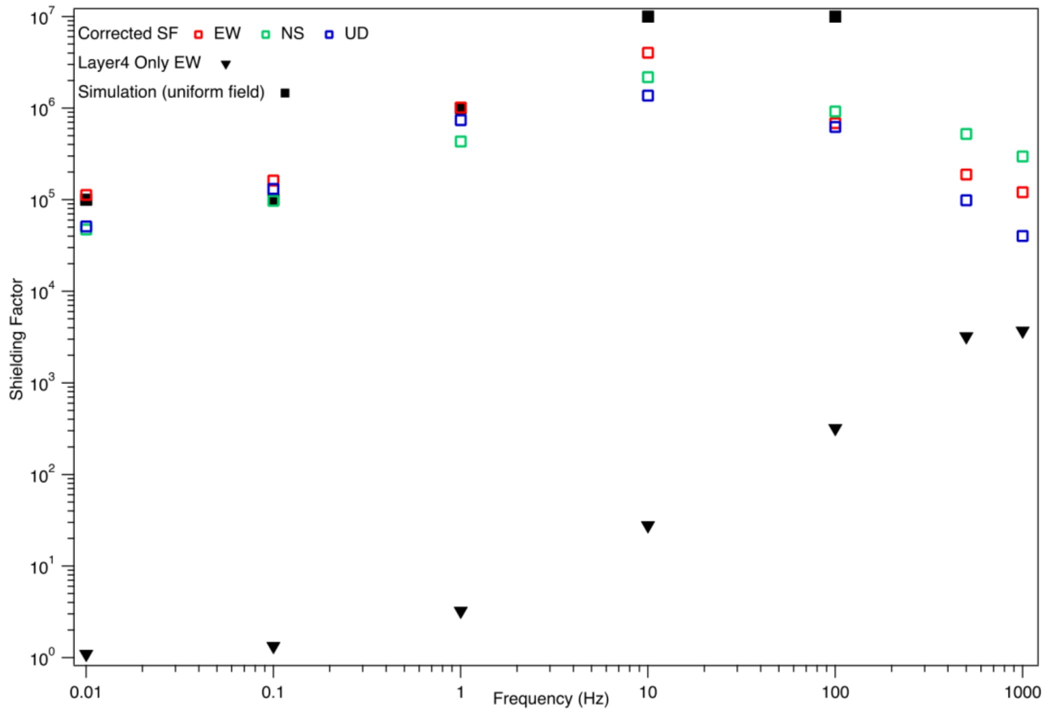
Magnetically shielded room (MSR)

- MSR provides shielding against external fields and drift
- External coils cancel local field, plan to use fluxgates to feedback on external coils to optimize field cancelation
- Shielding factor of mu metal shielding predicted to be high

Frequency (Hz)	Shielding Factor
0.01	10^5
0.1	10^6
1	10^6
10	10^7
100	10^7

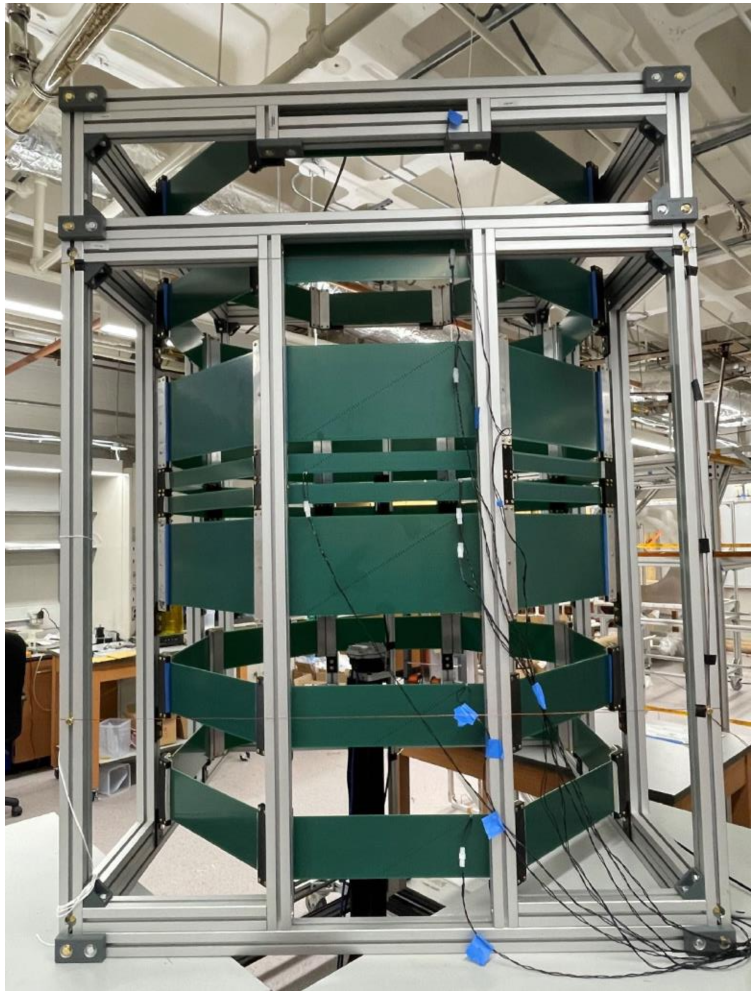
Magnetically shielded room (MSR)

- MSR provides shielding against external fields and drift
- External coils cancel local field, plan to use fluxgates to feedback on external coils to optimize field cancelation
- Shielding factor of mu metal shielding predicted to be high
- MSR performance closely matches spec



B0 coil

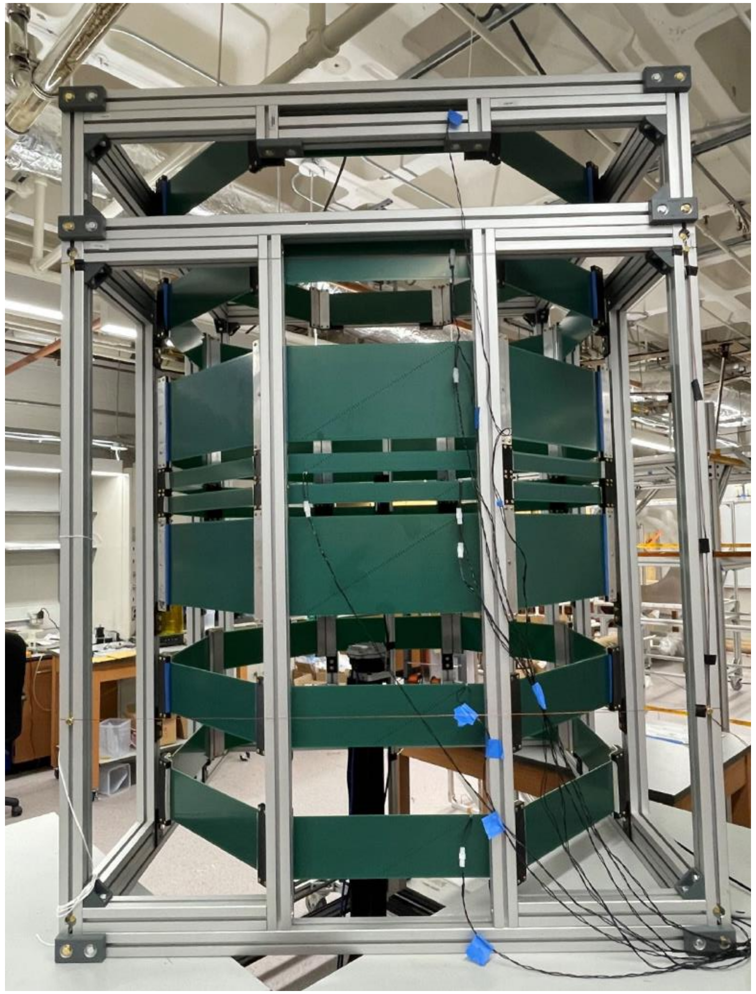
- Eight octagonal coil sections wired into two effective coils
- Tuning the relative currents between the inner and outer coils allows us to tune the field gradients
- Coils are installed and awaiting full characterization
- First round of coil upgrades already planned



Half-scale model of B0 coils

B0 coil

- Coils are installed and awaiting full characterization
- Goal: 1 uT field with gradients under 0.3 nT/m in the measurement region



Half-scale model of B0 coils

Magnetometry

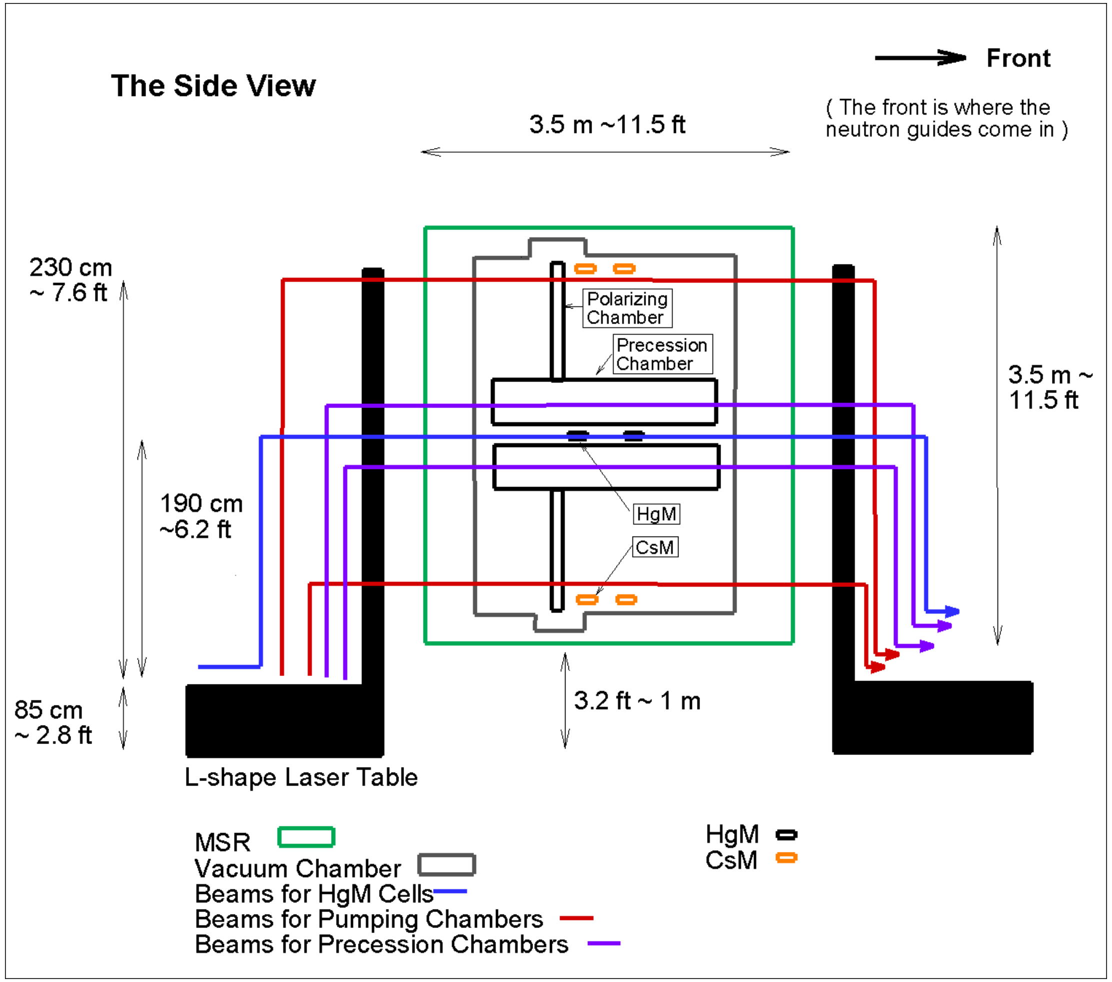
- External-to-cell magnetometers in vacuum chamber
  - Optically pumped magnetometers
  - Nuclear spin magnetometers
- Magnetometers measure time evolution of magnetic field and gradients

TwinLeaf

QuSpin

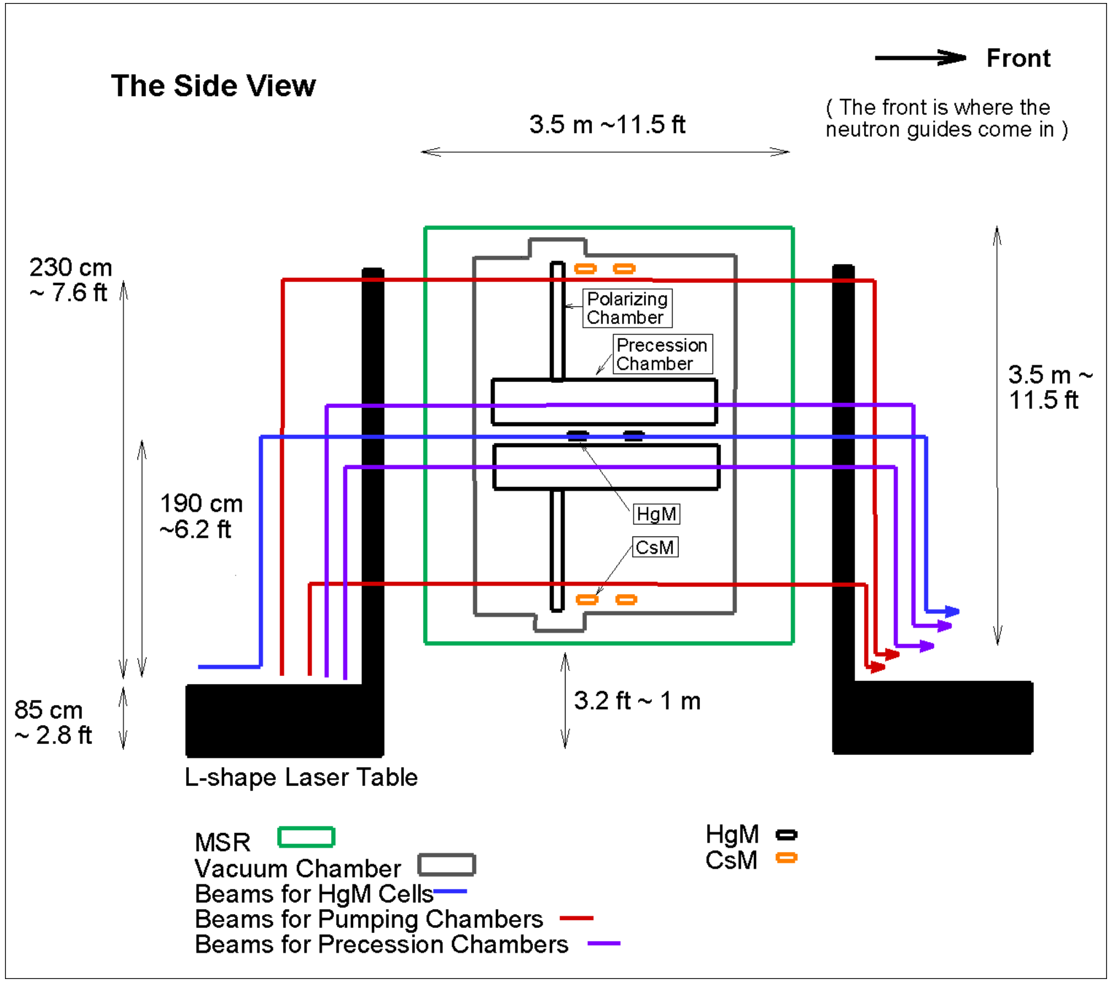
Magnetometry

- External-to-cell magnetometers in vacuum chamber
  - Optically pumped magnetometers
  - Nuclear spin magnetometers
- Magnetometers measure time evolution of magnetic field and gradients
- Mercury co-magnetometer under development



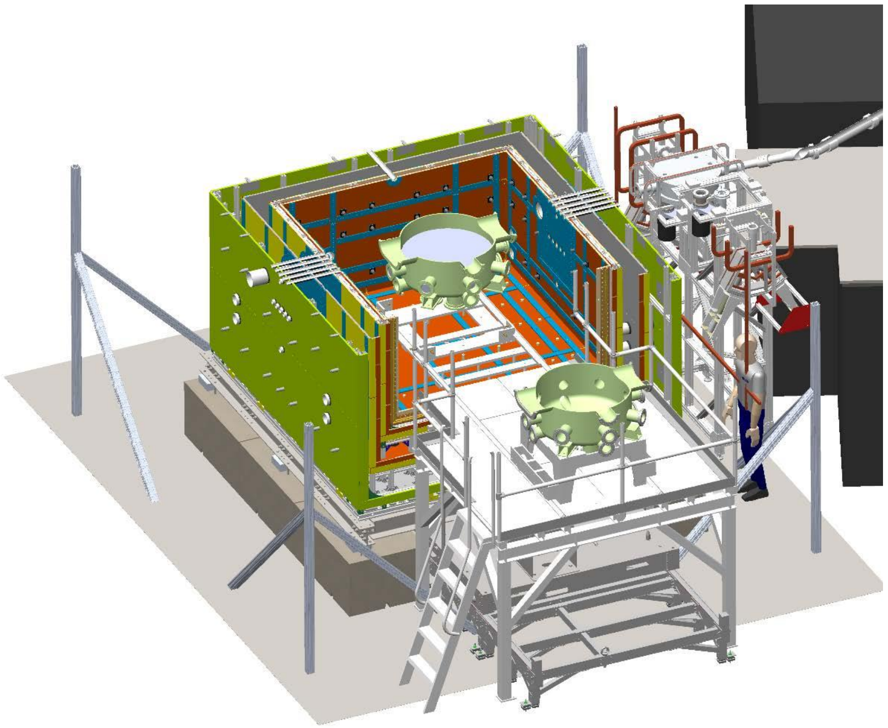
Magnetometry

- Mercury co-magnetometer under development
- Optically pumped Hg transferred into precession chambers, monitor average field
- Hg magnetometers (HgM) in HV electrode
- Pumps beam come from outside MSR



Status

- MSR installed, characterization ongoing
- Neutron transport and storage apparatus are being assembled
- Engineering runs planned for September, starting with UCN transport and storage



Acknowledgments

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Thanks to all the great collaborators on LANL nEDM.

Thanks to the organizers who made this conference happen.

And thanks to all of you for listening!

Backup Slides

Systematic Effects

- Quadrupole fields
- Earth's rotation
- Dipole fields
- Uncompensated B-field drift
- Gravitationally enhanced depolarization
- Mercury light shift
- Leakage currents