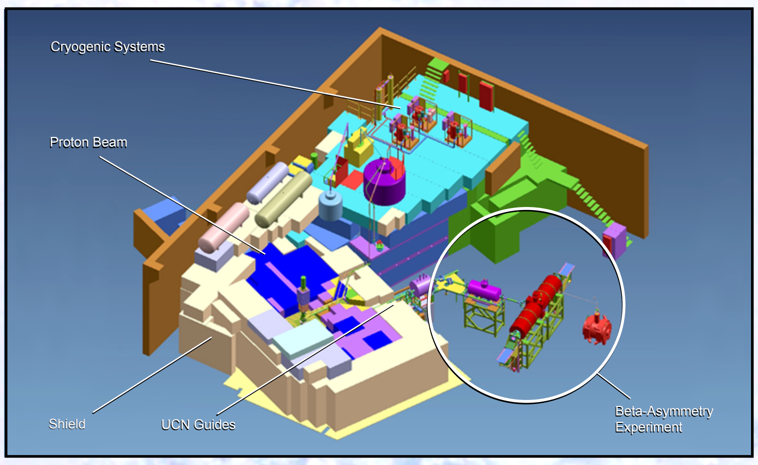
PHYSICS

Ultra-Cold Neutrons

Properties of Ultra-Cold Neutrons

Ultra-Cold Neutrons (UCNs) have the remarkable property that they can be confined in material or magnetic bottles for periods comparable to the neutron lifetime (~ 10 minutes). UCNs are neutrons whose energies are so small (≤ 8 m/s neutron velocity) that they can undergo total external reflection at all angles from the surfaces of a variety of materials and are reflected back from a strong magnetic field (> 6 T). Thus, UCNs can provide a compact source of stored neutrons for use in measurements of fundamental physics.

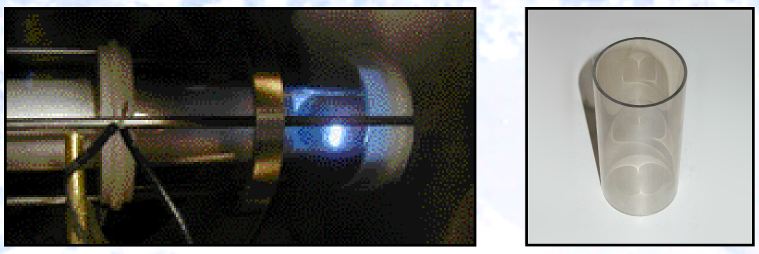
UCN production at reactors has been limited in intensity—a problem that can be addressed at spallation neutron sources. Spallation UCN sources also offer the advantage of lower backgrounds: the UCN can be produced by a short beam pulse of protons and then stored for use in experiments, thus eliminating beam-associated backgrounds.



This drawing shows the UCN facility at LANSCE. Experiments (such as the beta-asymmetry experiment shown) can be carried out in the experimental hall.

UCN Production at the Los Alamos Neutron Science Center (LANSCE)

At Los Alamos, we developed (with LDRD funding) a prototype UCN source that achieved a world-record density (120 UCNs/cm^3) of UCNs in a storage bottle. Based on this success, we have constructed a dedicated UCN source in Area B at LANSCE that was brought on-line this spring. This intense superthermal UCN source uses solid deuterium at 5 K driven by the LANSCE proton accelerator on a tungsten spallation target that is coupled to a set of graphite/beryllium and cold polyethylene moderators. The UCNs are transported to the experimental area through diamond-coated guide tubes. These novel non-depolarizing guides provide high efficiency for polarized UCN transport. The initial measurements of the source performance indicate that we will achieve our goal of producing the most intense UCN source in the world when we move to full intensity operation next fall.

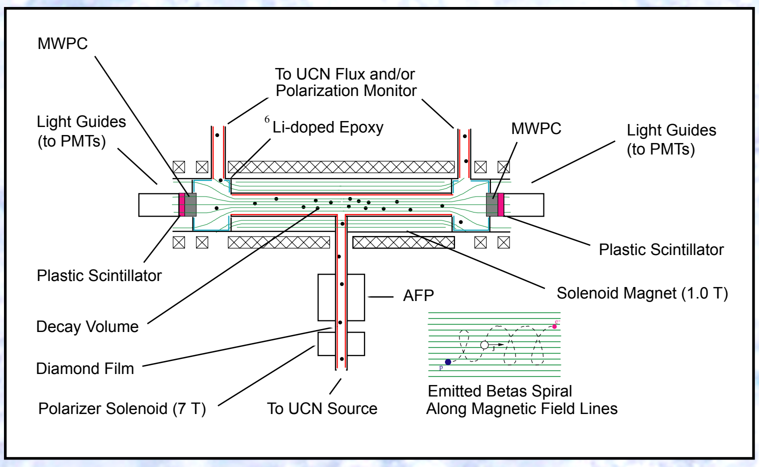


Production of diamond-coated guides. The photo on the left shows a laser beam evaporating a graphite target. The laser is so powerful that the evaporated graphite forms diamond bonds on the inner surface of the quartz guide (right image). This process produces guides with highly uniform surfaces—a feature critical for UCN transport.

Fundamental Physics with UCNs

Neutrons provide the simplest baryonic system in which the weak force between the lightest quarks and leptons can be studied. A wide range of experiments are feasible, including angular correlation measurements, neutron lifetime, searches for the electric dipole moment of the neutron, and a search for neutron-antineutron oscillations. All of these types of experiments aim at making highly precise measurements that can be compared to the predictions of the Standard Electroweak Model. A deviation between experiment and the Standard Model would indicate the existence of the new physics that is predicted to exist due to the unification of the four known forces at very-high-energy scales. Different theories predict different evolutions of the forces at low energies. Thus, precision measurements can potentially determine which path Nature followed as the four known forces evolved from one primal force.

Combining the advantages of UCNs with the intensity possible at a spallation UCN source will allow us to carry out a number of fundamental nuclear-physics measurements with UCNs, the first of which will be a very precise measurement of the beta asymmetry in polarized UCN beta decay (see figure to the right). Ultimately, we are working to establish a national UCN user facility at LANSCE that will carry out a wide range of research with applications that also extend to other research areas, such as neutron scattering from surfaces and large biological molecules.



A schematic of the UCN beta asymmetry experiment. UCNs enter through the guide tube and are polarized by the 7-T magnet. The betas from UCN decay in the decay volume are detected at the ends of the spectrometer in Multi-Wire Proportional Chambers (MWPC) and scintillators.

UNC is a collaborative effort involving the following institutes:

California Institute of Technology
Idaho State University
Institut Laue-Langevin
Kyoto University
Los Alamos National Laboratory
North Carolina State University
Petersburg Nuclear Physics Institute
University of Washington
Virginia Polytechnic and State University

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