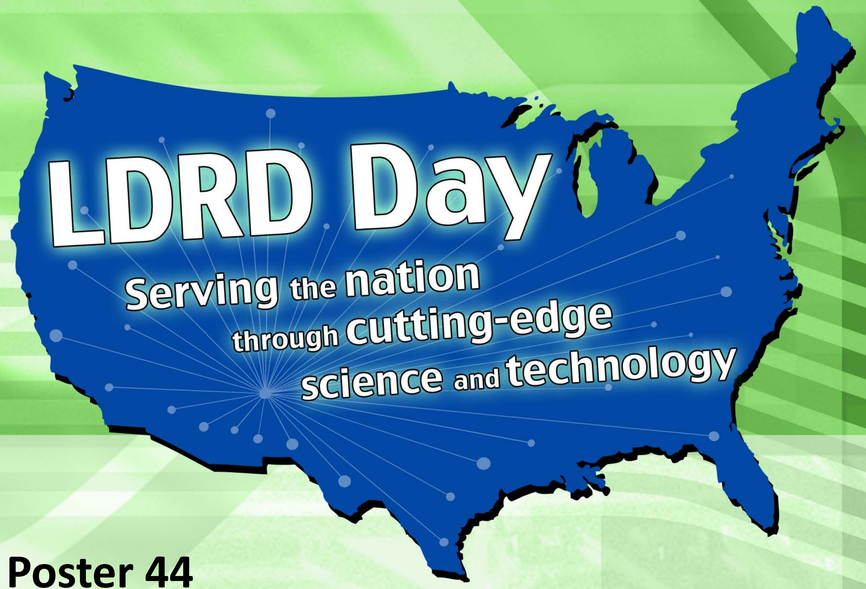


Poster 44

Development of Precise Measurement of the Neutron Lifetime

Neutrons are some of the basic building blocks of matter, yet there are many things about the neutron that remain a mystery. A better understanding of these basic building blocks will help us understand, utilize, and interact with the universe around us.

Andy Saunders (Principal Investigator)

Los Alamos NATIONAL LABORATORY EST. 1943

LDRD innovation for our nation

What is the challenge?

The CKM matrix describes mixing between the weak and mass quark eigenstates. Unitarity, (or lack thereof) of the CKM matrix tests **existence of further quark generations** and possible new physics (eg. Supersymmetry). The unitarity can be tested using neutron beta decay, either using **correlations between decay particles** or by using the **lifetime of the neutron**. As of now, both methods have been plagued by substantial discrepancies between existing experiments. **New techniques are needed to resolve the discrepancies between the previous results.**

Neutron Decay and CKM Unitarity

Weak eigenstates **Mass eigenstates**

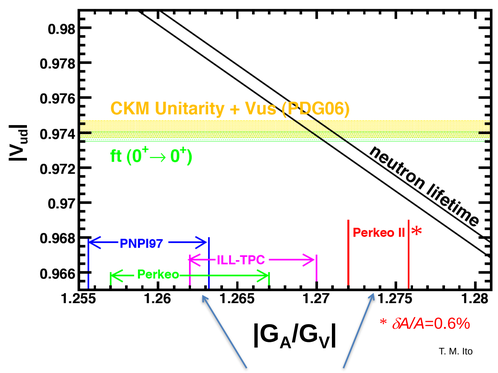
$$\begin{pmatrix} d_w \\ s_w \\ b_w \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$\begin{pmatrix} d_w \\ s_w \\ b_w \end{pmatrix} = \begin{pmatrix} 0.975 & 0.22 & 0.005 \\ 0.22 & 0.97 & 0.04 \\ 0.005 & 0.04 & 0.99 \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

eg. $|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$

B. W. Filippone

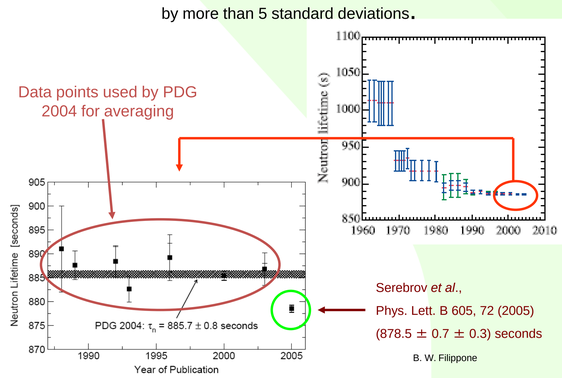
V_{ud} Experimental Status



Discrepancy in correlation results

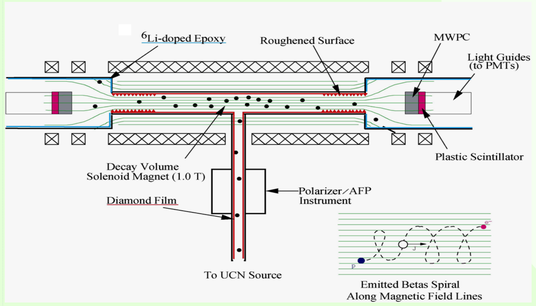
Neutron Lifetime versus Year

A recent measurement of the lifetime disagrees with the accepted value by more than 5 standard deviations.

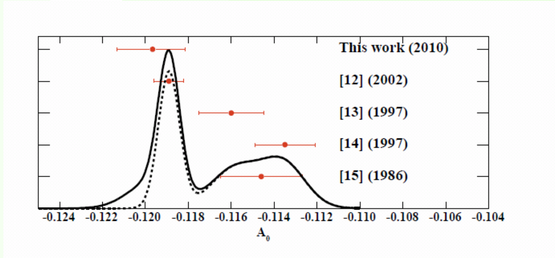


What have we learned so far?

The UCNA experiment has begun to resolve the discrepancy in G_A/G_V

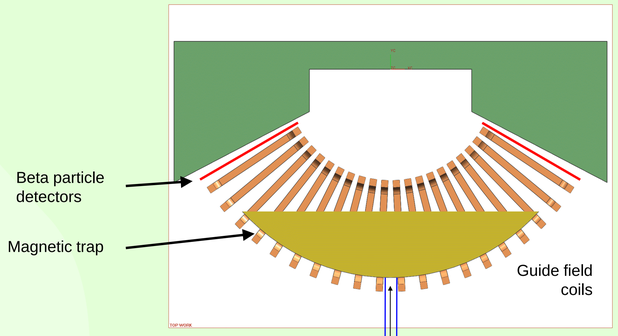


Top view schematic of UCNA experiment. UCNs from source enter from bottom of page, are polarized by SC magnet, then decay in 1 T field decay trap. Decay betas spiral along field lines and are counted at each end.



Interim results of the UCNA experiment, compared with previous measurements of the neutron beta decay asymmetry. The two-peaked probability distribution hints at unrevealed systematic uncertainties in the previous experiments.

LANL Neutron Lifetime Experiment



UCNs from source enter vertically.

Our neutron lifetime experiment, now under construction, is expected to resolve the discrepancy in the neutron lifetime. It uses polarized neutrons in a magnetic trap to reach smaller systematic uncertainties than existing experiments. First data are expected in 2010.

What is our innovation?

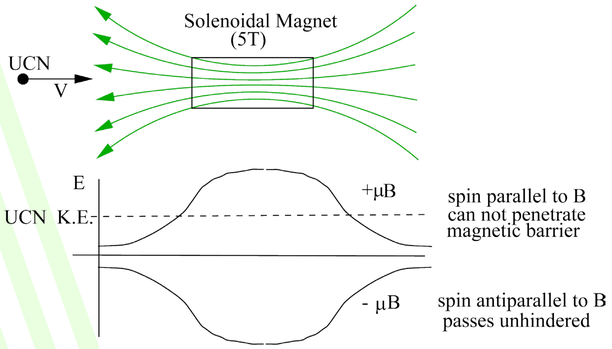
Ultra-cold neutrons (UCN) : a unique tool for improved searches for physics Beyond the Standard Model

What are UCN?

"Man is the Measure of All Things" Protagoras, 480-411 BC

300 neV = Potential Energy in wall	External reflection
= ½ $m_n v^2$ = ½ m_n (8 m/s)^2	Running speed
= m_n g h = m_n g (3 m)	Human scale equipment
= h^2/ (2 m_n λ^2) = h^2/ (2 m_n (50 nm)^2)	Ultraviolet
= μ_n B = μ_n (3.5 T)	100% polarization
= k T = k (3 mK)	Ultra-cold!

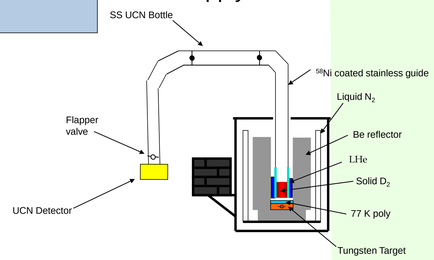
UCN can be 100 percent polarized by passing them through a magnetic field, eliminating the leading systematic in previous experiments



(note: neutron magnetic moment is negative)

R. B. Vogelaar

A special source, developed at LANL using LDRD funds, is needed to supply the UCNs



Schematic of Superthermal UCN Source

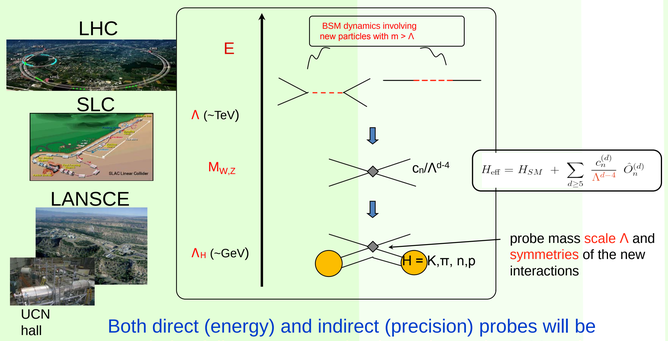
Protons from the LANSCE accelerator strike the tungsten target and produce spallation neutrons, which are reflected by Be and moderated by CH_2. 5K solid deuterium converts the cold neutrons to UCNs. The UCNs are guided away from the source to detectors or experiments by stainless steel guides.

- UCN Source operating since 2007
- Multiple experiments now operating
- UCNA experiment taking production data
- Lifetime experiment starts 2010
- UCNB and UCNb to follow

Why is this important for our nation?

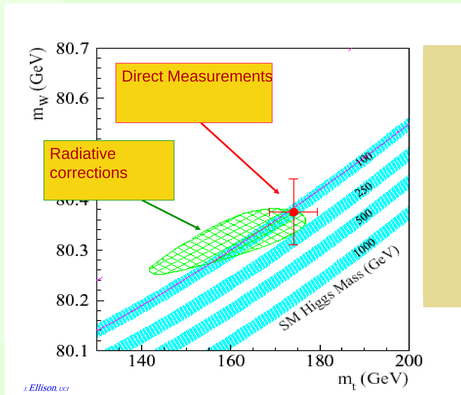
Precision physics measurements using UCN allow us to probe the same physics as the Large Hadron Collider, now coming online. Our measurements are directly complimentary to those at the LHC. The LHC will directly detect new particles, but precision measurements using UCNs will probe their masses and symmetries.

The big picture: energy vs precision frontier



Both direct (energy) and indirect (precision) probes will be needed to fully reconstruct the dynamics at the TeV scale

Precision Electroweak Measurements and Collider Searches are Complementary: They access the same energy regimes



In the past, precision low energy measurements determined the mass of the W boson and the top quark before they were directly detected.

M. J. Ramsey-Musolf

Saunders
LAUR-10-05785