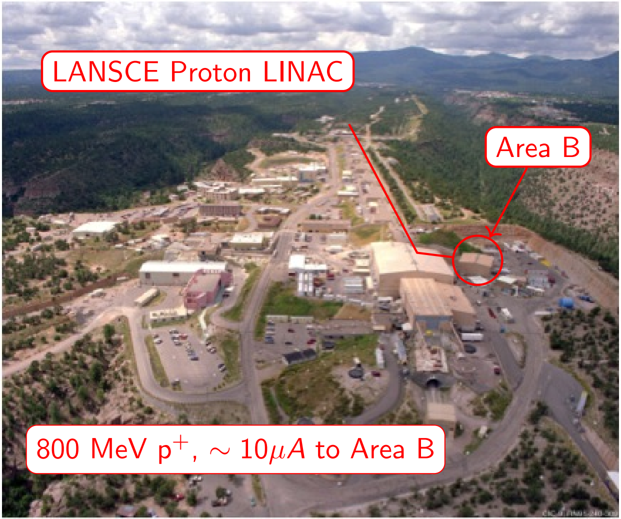
Commissioning of the upgraded Los Alamos Ultracold neutron source (LA-UR-17-29581)

R.W. Pattie Jr (for the LANL Neutron Team)

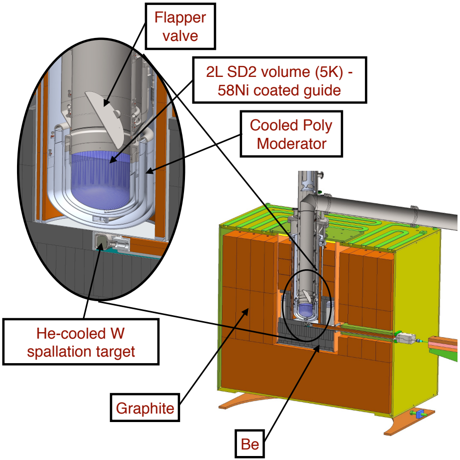
LANL P-25

October 17, 2017

The Los Alamos Neutron Science Center



Spallation Source



Spallation Neutrons from W target ∼2 MeV

↓

Thermal Neutrons in Be & Graphite Moderator ∼25 meV

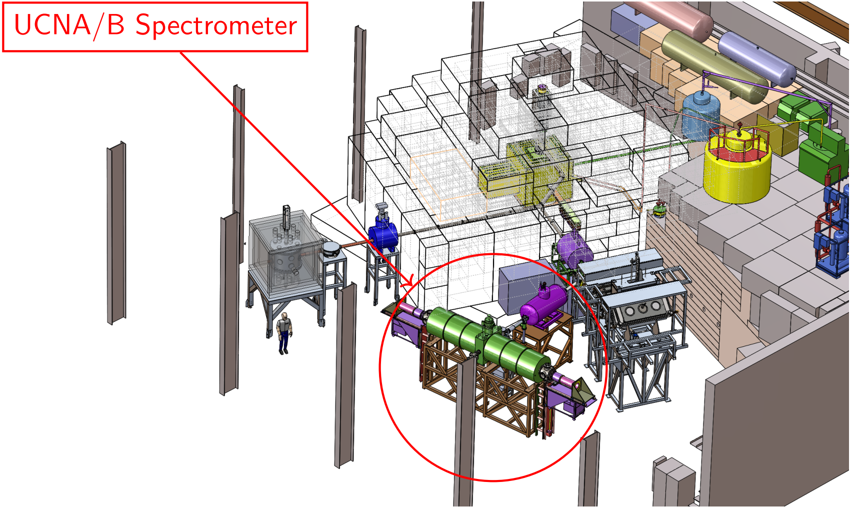
↓

Cold Neutrons in 70K Polyethylene Moderator ∼6 meV

↓

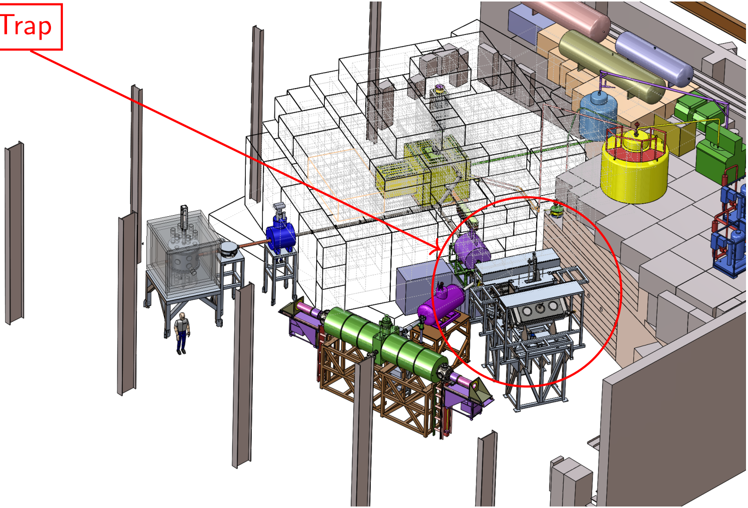
UCN in SD_2 Converter $<$350 neV

The LANSCE Area B Experimental Floor



The LANSCE Area B Experimental Floor

UCNτ Trap



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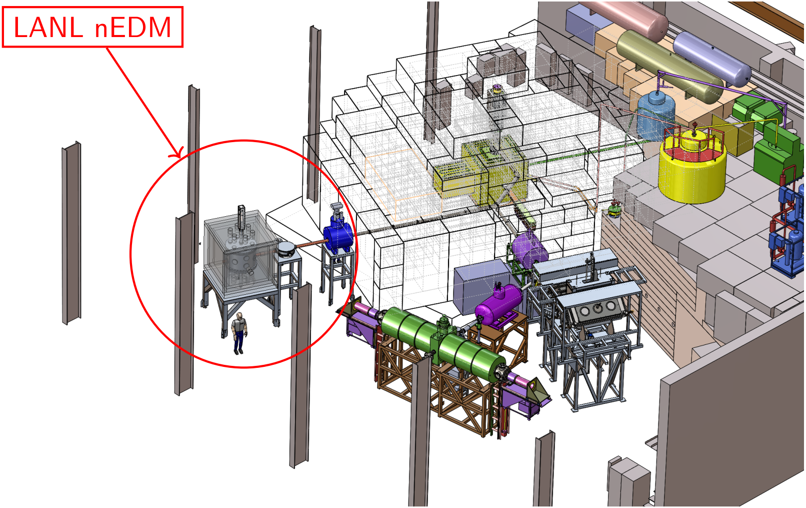

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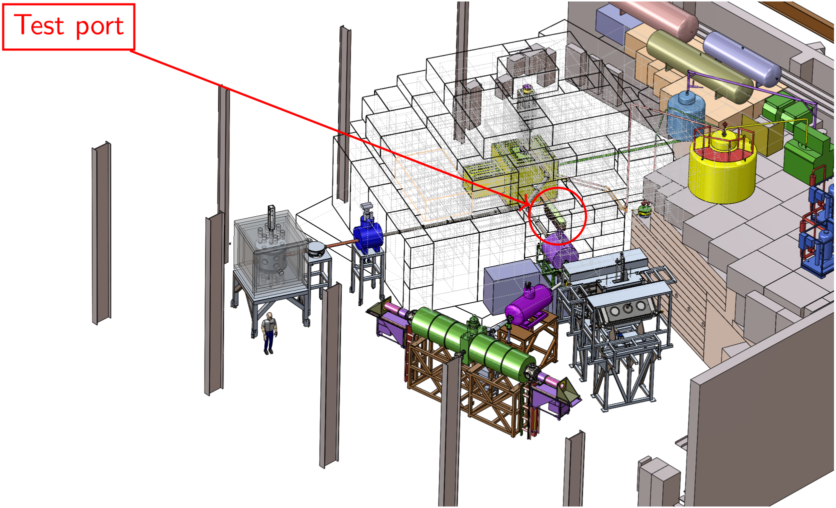
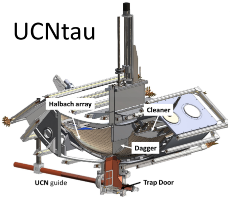
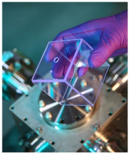


Experiments hosted

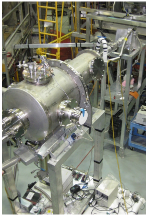
UCNtau



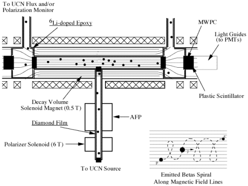


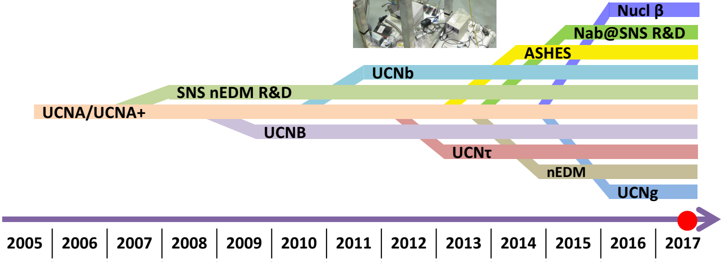
UCNb

SNS nEDM Test Cell

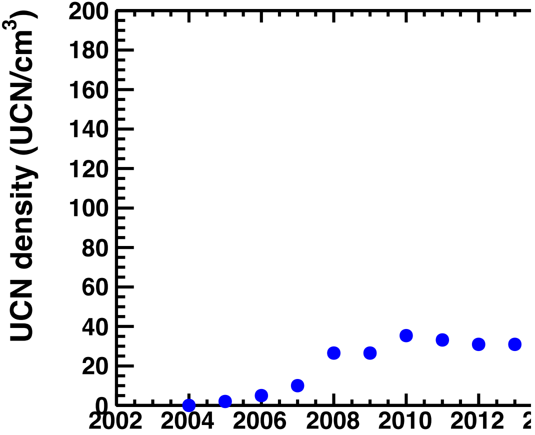


UCNA(B)





LANSCE UCN Production over the years



[1]

[1]internal guide density determine by Vanadium activation

Time for an Upgrade

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  3. Redesign of the UCN converter and moderator insert.
- The LANL LDRD office provided funding to start this upgrade in 2014.

Details of the Upgrade

Performance of the upgraded ultracold neutron source at Los Alamos National Laboratory and its implication for a possible neutron electric dipole moment experiment

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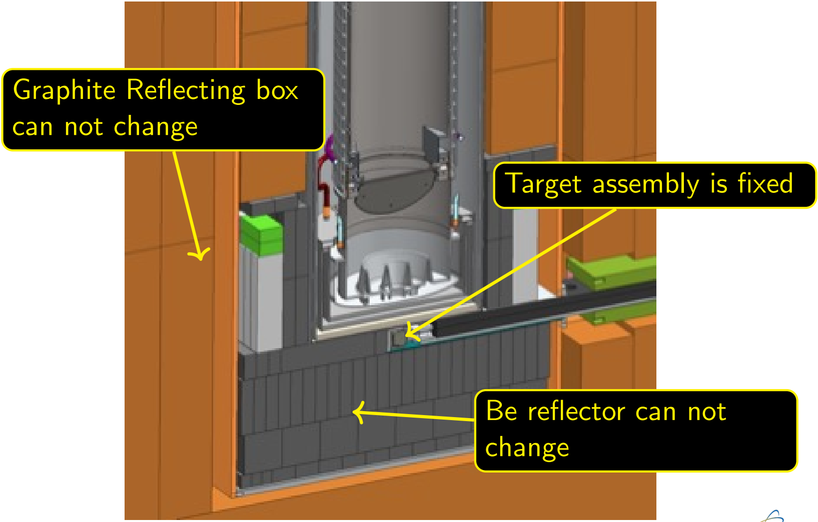
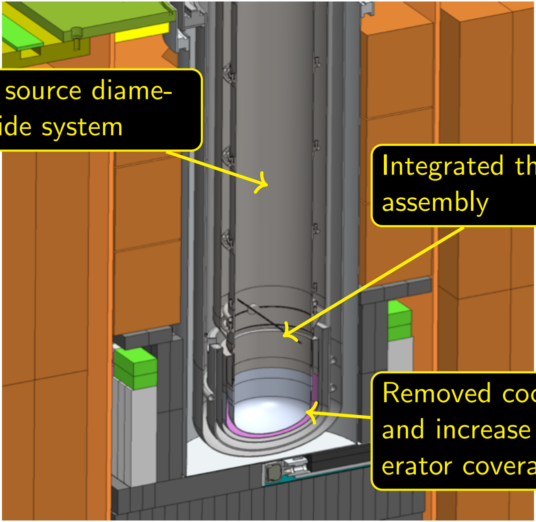
(Dated: October 17, 2017)

arXiv:1710.05182v1 [physics.ins-det] 14 Oct 2017

Design Constraints



Insert Redesign



Matched source diameter to guide system

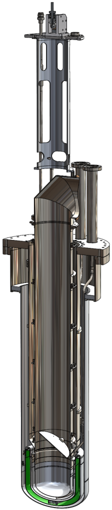
Integrated the flapper assembly

Removed cooling fins and increase cold moderator coverage

The new source insert

Improvements

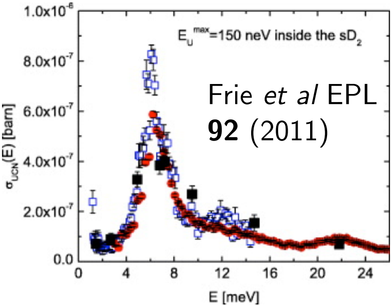
- Fully integrated flapper valve
- Mitered elbow coupling source volume to UCN guides
- Moderator volume is detachable
- ^{58}Ni coated about the flapper valve
- Entirely new cryogenic system for maintaining the moderator temperature

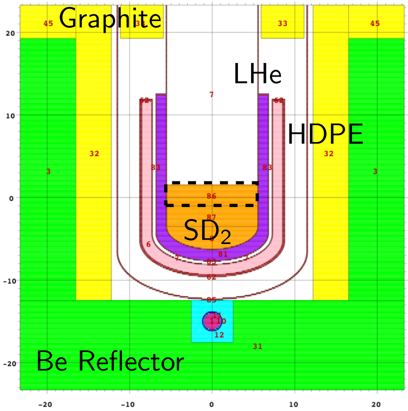


Simulation Framework

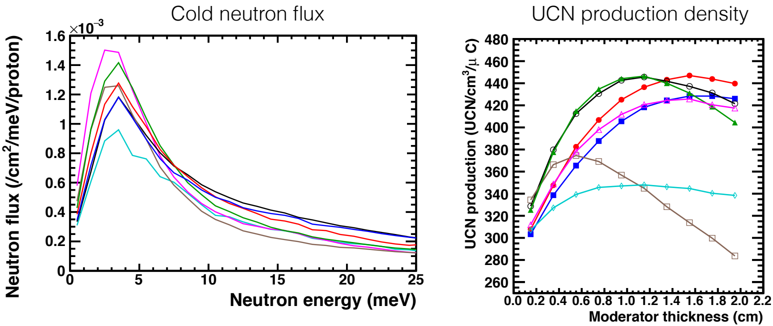
$$P_{ucn} = \rho_{SD_2} n_p \int_0^{E_{ucn}} \Phi_n(E)\sigma(E)\mathrm{d}E$$

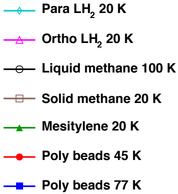
- $\Phi_n(E)$- neutron flux
- $\sigma(E)$ - production xs
- ρ_{SD_2} - density of SD_2
- n_p - protons on target





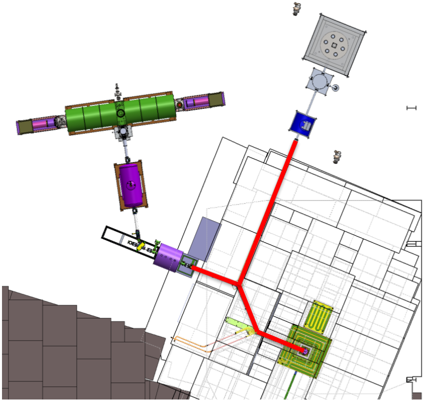
Moderator Optimization





We chose to use cold polyethylene beads at 45 K, cooled by cold helium gas.

New Guide System

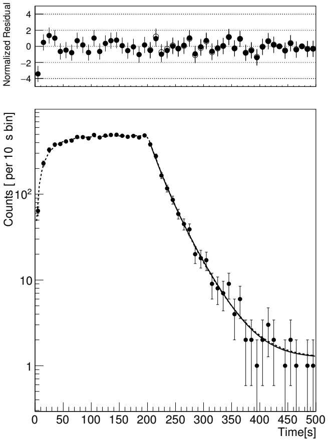


- First 4 m of guide 15 cm diameter to match the source
- After the "Y" guides reduce to 10 cm.
- New UCN-line adds 7 m of 10 cm inside the biological shielding

Guide Upgrades (Potential and loss factor)

- Commercial Electroless nickel phosphorus coating
- Loss factor measured at LANL and ILL using pinhole bottling
- $f = 1.4(1) \times 10^{-4}$
- Fermi Potential measured by Asterix at the Lujan Center
- $V_F = 212(5)$ neV

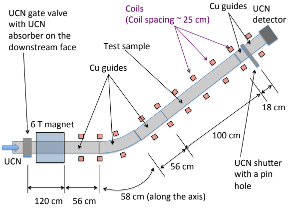
R.W. Pattie Jr *et al* NIMA **872** (2017)

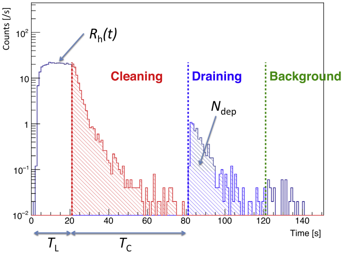


Guide Upgrades (Depolarization)

- UCN were polarized by a 6 T magnet
- Coils maintained a ∼2 mT holding field along the test guides
- Wrong spin UCN were bottled between a shutter and magnet
- Right spin UCN could pass through the magnet to absorber
- $\beta_{NiP} = \left(3.3^{+1.8}_{-5.6}\right) \times 10^{-6}$

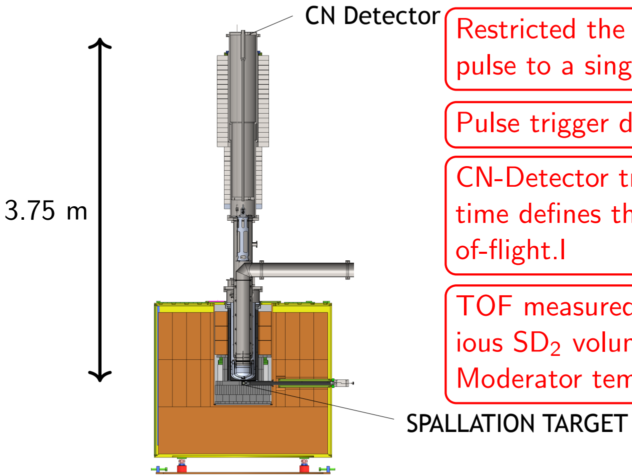
Z. Tang *et al*, NIMA **827** (2016)





Los Alamos NATIONAL LABORATORY EST. 1943

Cold Neutron Flux Benchmarking



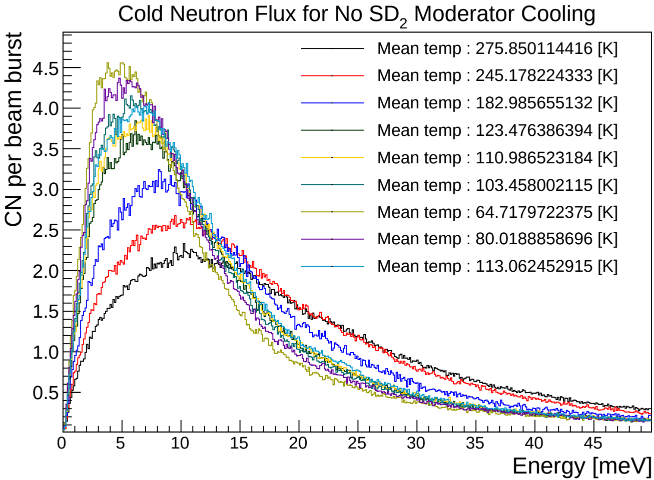
Restricted the proton pulse to a single bucket.

Pulse trigger defined t_0

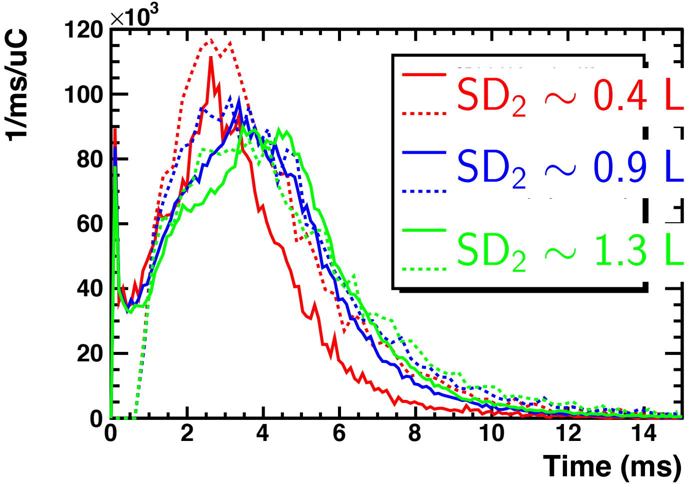
CN-Detector trigger time defines the time-of-flight.I

TOF measured at various SD_2 volumes and Moderator temperatures

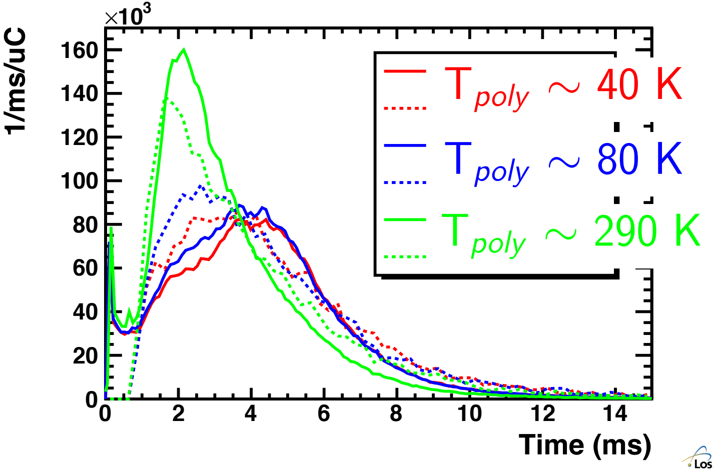
Cold Neutron Flux SD_2



Cold Neutron Flux Benchmarking (SD_2 Volume)



Cold Neutron Flux Benchmarking (Moderator Temperature)

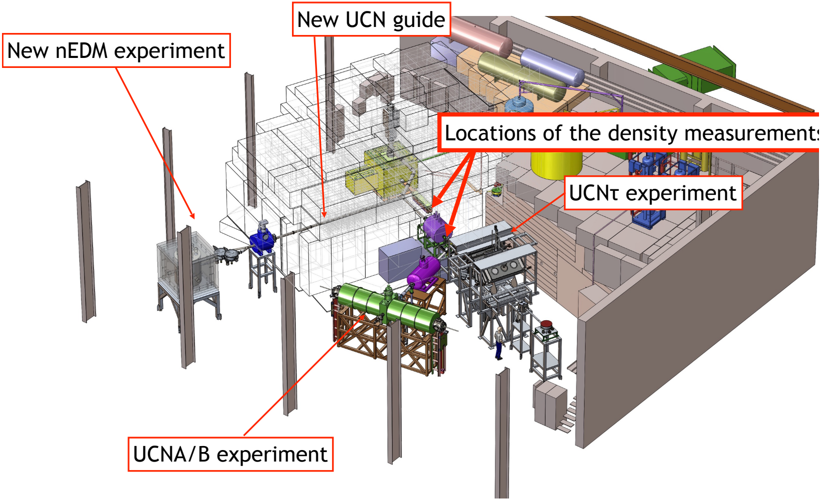


Density Measurements by V-activation

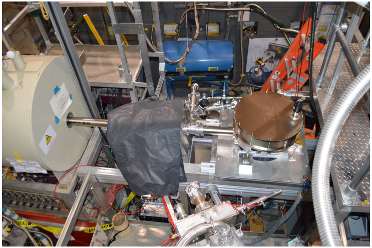
$$^{51}\mathrm{V} + n \rightarrow \, ^{52}\mathrm{V} \rightarrow \, ^{52}Cr + \gamma + \beta$$

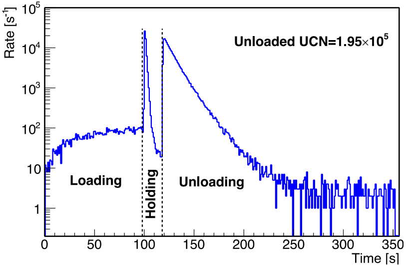
- We want to measure the UCN density in the guide system.
- 1 cm diameter V foil fixed to the inside of guide
- We use a HPGe Detector to measure the 1.4 MeV γ's
- ^{60}Co source used to determine solid angle
- $R = \frac{1}{4} v A \rho_{ucn}$

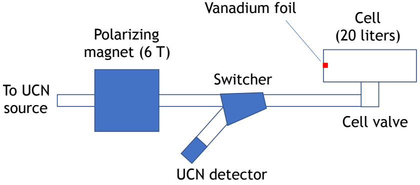
Density Measurements in the Original configuration



Fill and Dump density measurements







Polarized UCN density (E < 170 neV) at t=0

- 12 UCN/cc from the fill and dump measurement (was 2.5 UCN/cc before the source upgrade)
- 36 UCN/cc from vanadium foil activation measurement

The difference can be attributed to loss in the switcher and the finite detection efficiency.

Coupling productions and transport simulations

Use MCNP6 to generate CN-Flux

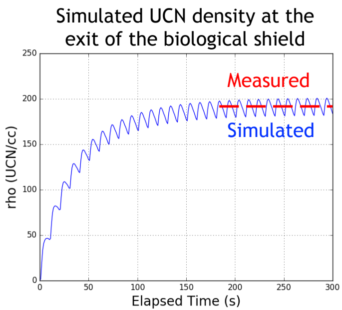
Fold CN-Flux with UCN prod. XS.

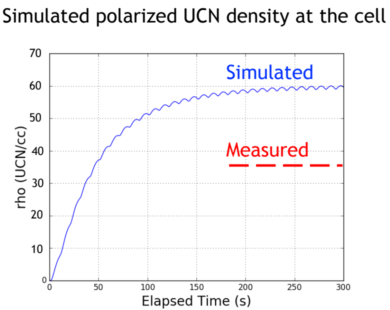
Input production into a transport model.

Compare to data.

- Model assumptions : non-spec=0.06, $f = 1.5 \times 10^{-4}$, $\tau_{SD_2} = 49$ ms, $\lambda_{SD_2} = 4$ cm.

Comparison to Transport Monte Carlo

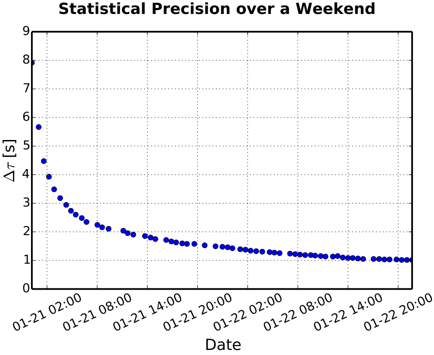




- Measured upstream of polarizer magnet
- Consistent with transport and production simulation

- Measured density about 60% of MC prediction
- Can be explained by transmission through the switcher

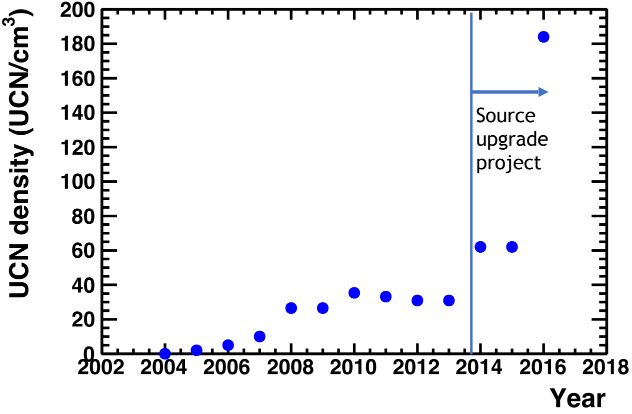
Impact on the UCNτ experiment



See R. W. Pattie Jr, *et al* arXiv:1707.01817

- Demonstrated $(\Delta\tau_n)_{stat} < 1$ s precision over a weekend (60 hrs)
- 5 such data sets collected to explore systematic effects
- trap depth $\approx$ 50 neV
- Maximum unload 90k UCN
- Typical unload 30k UCN
- $(\Delta\tau_n)_{stat} \approx 0.6$ s already achieved this run cycle with 3 months remaining.

Storage and Density Measurement

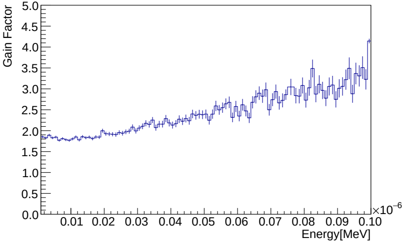


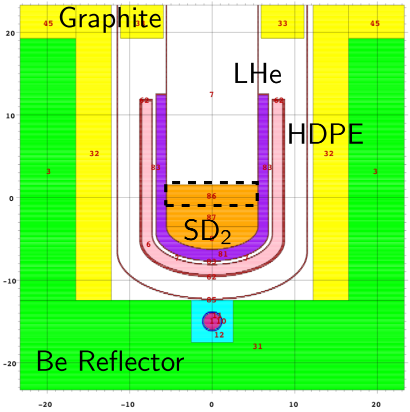
The North UCN-Line

- North UCN-Line open for business and 95% complete
- New rotatory switcher with minimal gaps installed
- Can operator simultaneously with UCNτ
- Initial storage time test of Nickel Phosphorus cell shows a density of ≈7 UCN/cc for a monitor rate of 350 UCN/s (typically rate is ≈ 1000 UCN/s).

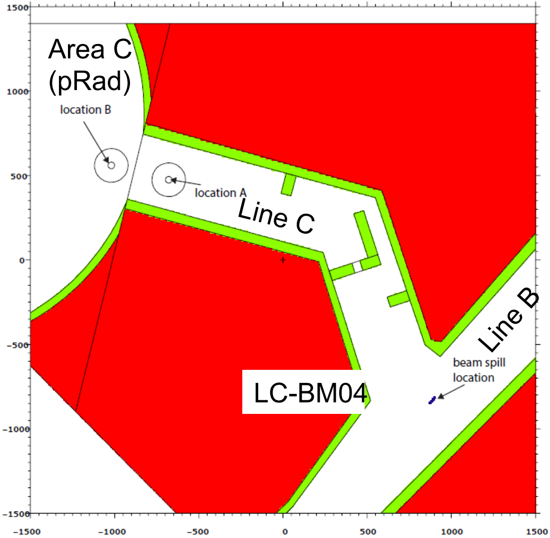
Light Enriched Uranium reflectors

- Replace Graphite shell with 19.5% Enriched Uranium
- Roughly factor of 2 increase in CN flux 0-10 meV
- LANL has the facilities to machine a Uranium shell





Ongoing Facility Upgrades



- Currently we can only run nights and weekends
- If people are working in the Proton Radiography facility, we can not run
- A few engineering solutions will allow almost 24 hour running:
  1. Beam plugs
  2. B/C Wall
  3. Steering solution

UCN Source Team

LANL	S. Clayton, S. Currie, D. E. Fellers,T. M. Ito, S. MacDonald, M. Makela, C. Morris, R. W. Pattie Jr, J. Ramsey, A. Saunders, C. O'Shaughnessy, S. Sjue, Z. Tang, F. Trouw,H. Weaver, B. Zeck
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ILL	P. Geltenbort
VPI&SU	X. Ding

Students

Conclusions

- We have completed a 3 year upgrade of the LANL UCN source (arXiv:1710.05182)
- The result was a $\times 4.5$ increase in the UCN density
- This a possibility of increasing the production by another factor of 1.8.
- Ongoing improvements to the accelerator complex will roughly double the UCN source up-time.
- New buffer volume will be install on the West beam line