

# The Ultracold Neutron Source at LANSCE

---

*Presented By: Mark Makela, P-25, LANL*

*For the UCNA Collaboration:*

*California Institute of Technology:* R. Carr, B. Filippone, K. Hickerson, J. Liu, B. Plaster, R. Schmid, B. Tipton, J. Yuan

*Institute Lau-Langevin:* P. Geltenbort

*Idaho State University:* R. Rios, E. Tatar

*Los Alamos National Laboratory:* J. Anaya, T. J. Bowles (co-spokesperson), R. Hill, G. Hogan, T. Ito, K. Kirch, S. Lamoreaux, M. Makela, R. Mortenson, C. L. Morris, A. Pichlmaier, A. Saunders, S. Seestrom

*North Carolina State University/TUNL:* H. O. Back, L. Broussard, A. T. Holley, R. K. Jain, C.-Y. Liu, R. W. Pattie, K. Sabourov, D. Smith, A. R. Young (co-spokesperson), Y.-P. Xu

*Petersburg Nuclear Physics Institute:* A. Aldushenkov, A. Kharitonov, I. Krasnoshekova, M. Lasakov, A. P. Serebrov, A. Vasiliev

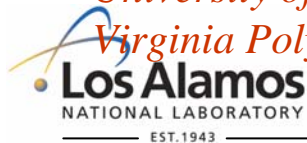
*Tohoku University:* S. Kitagaki

*University of Kyoto:* M. Hino, T. Kawai, M. Utsuro

*University of Washington:* A. Garcia, S. Hoedl, D. Melconian, A. Sallaska, S. Sjue

*University of Winnipeg:* J. Martin

*Virginia Polytechnic Institute and State University:* R. R. Mammei, M. Pitt, R. B. Vogelaar



# Talk Outline

---

- Motivation for the LANSCE UCN source
- Brief history of UCN at LANSCE
- The UCN source at LANSCE
- UCN Production in 2006
- UCN experiments at the LANSCE
- Future UCN experiments at LANSCE

# Motivation for the LANSCE UCN Source

---

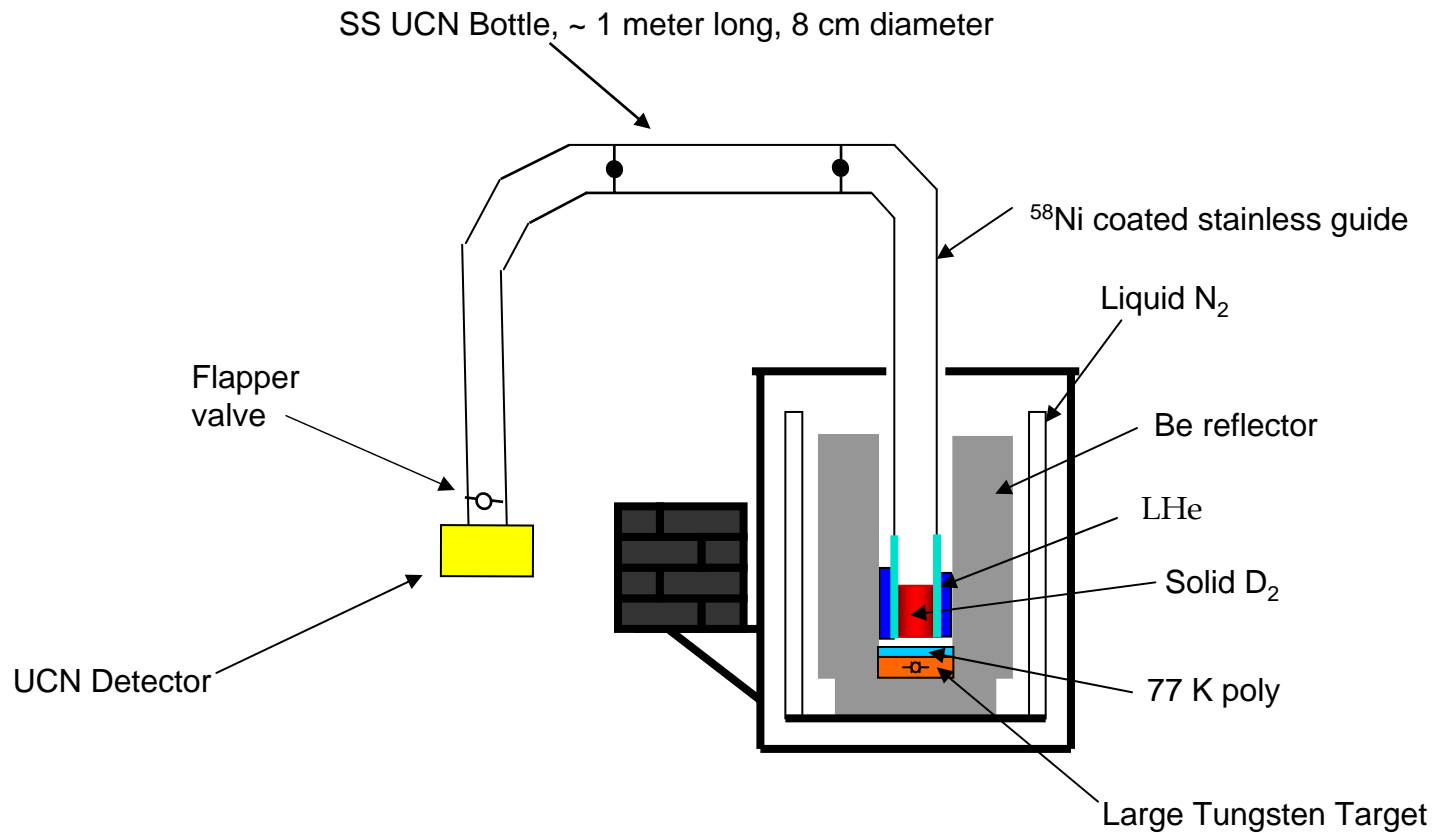
- Studying weak interaction physics with neutrons:
- Precision measurements of polarized Beta decay – New
- Neutron Lifetime

# UCN Source History at LANSCE

---

- 1996-7: Started UCN rotor and solid deuterium source work
- 1998: First prototype source runs: no UCNs
- 1999: Investigation of UCN lifetime in SD2
- 2000: Highest UCN density with prototype
- 2001: Investigation of UCN transport at LANSCE and ILL
  - Area B D&D
- 2002: Area B construction begins, major component procurement
  - AFP and SCS magnets tested
- 2003: Area B construction, cryogenics installation
- 2004: Brief test run of Area B source, lab shutdown
- 2005: Source and experiment commissioning
- 2006: Source exit guide replaced, new insert tested, beta decay
- 2007: More moderator added to the source, new insert being tested, UCNA data runs

# LANSCCE UCN Prototype Source Layout

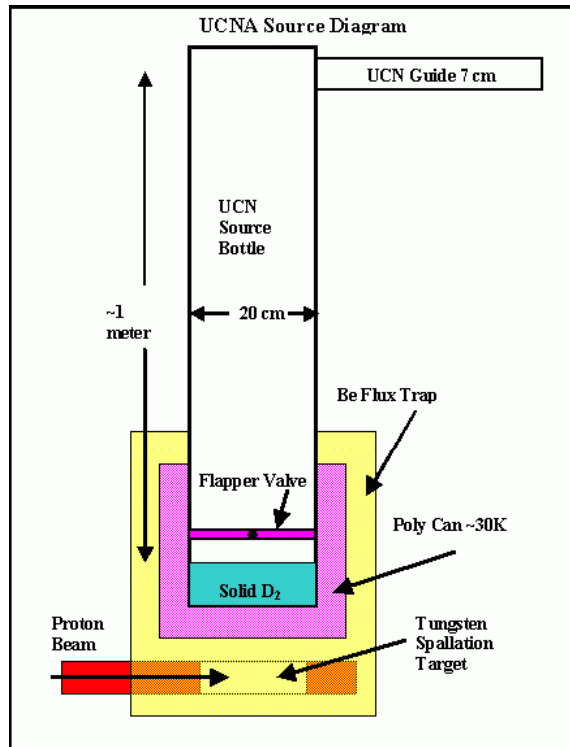


# Monte Carlo -> Design

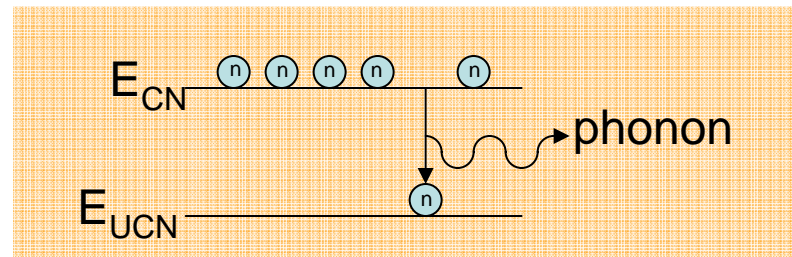
---

- With a large Monte Carlo effort the Area-B source was designed.
- This source was had a smaller W target and no warm poly moderator.
- The as built source was not the optimal one due to engineering issues.

# LANSCCE Area-B UCN Source



- 800 MeV proton beam hits a tungsten target.
- Spallation neutrons interact with various parts of the source.
- >2 MeV neutrons undergo 2-2n reactions in Be.
- Neutron thermalize in Graphite, Be, poly and solid deuterium.
- Cold neutrons scatter in the solid deuterium to ultracold state.
- UCN valve to increase bottle lifetime

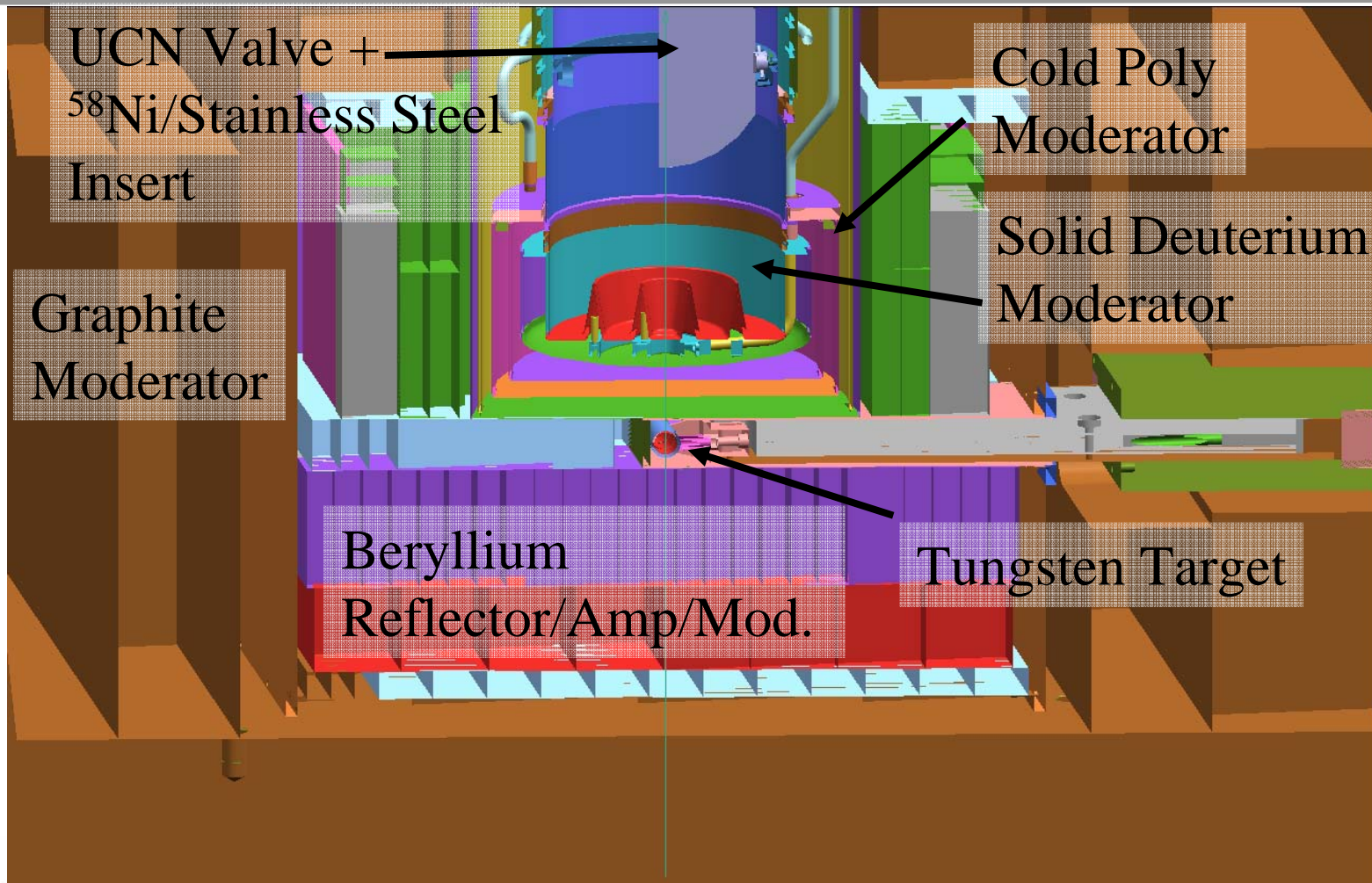


# Some Numbers

---

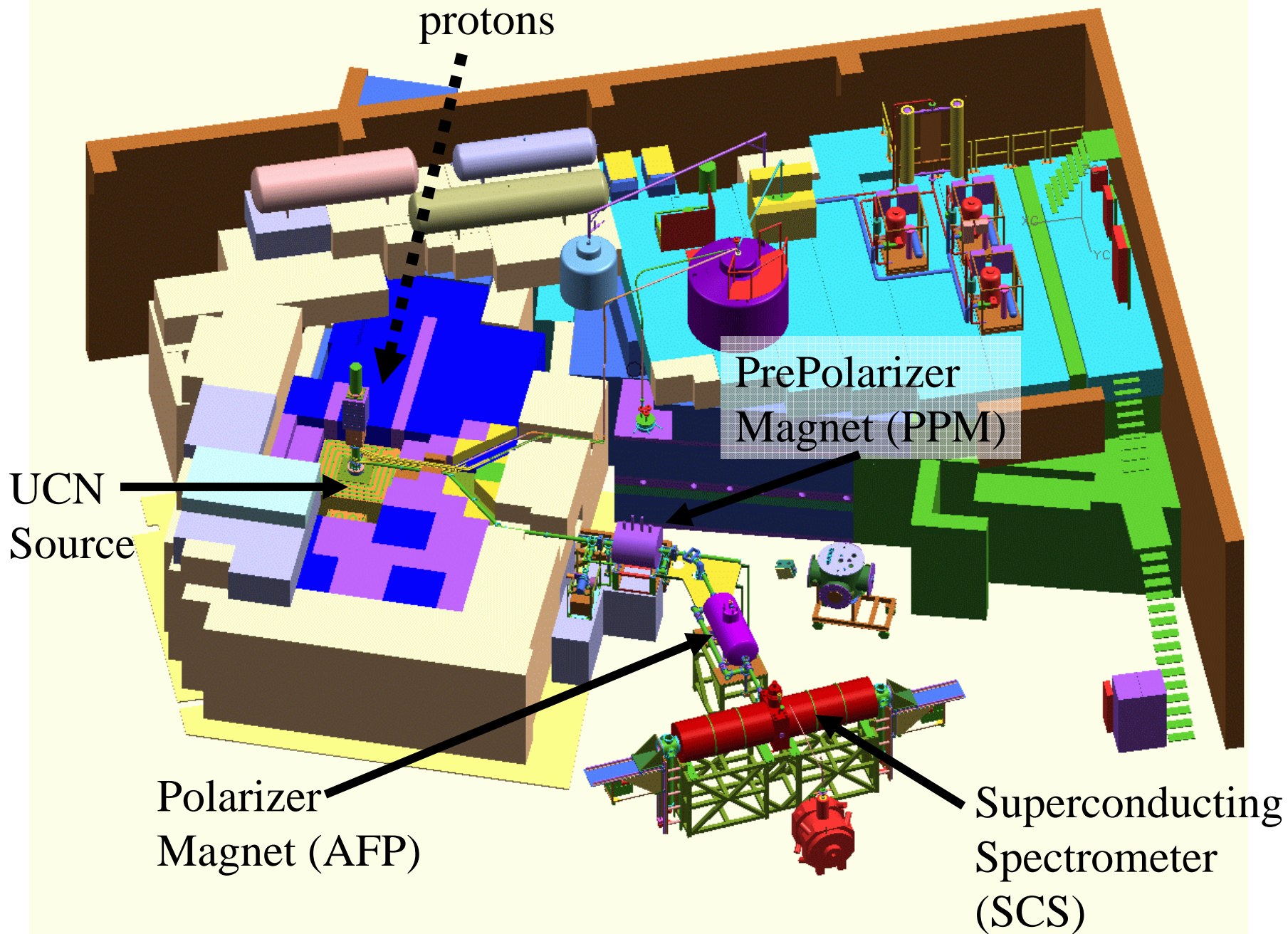
- Designed for 10 uA running, limited to 2 uA today.
- Typical beam structure, 10-30 uC (<1 sec.) every 15 seconds.
- 1-2 liters of solid deuterium
- Using ~ 20 liters of liquid helium per hour
- ~17 n per 800 MeV proton
- Cold (<110 K) neutrons, 30000 per cc per uC (average, 1 liter source)
- ~1000 UCN created per cc per uC of protons
- We have seen ~1-3 UCN per cc per uC in experimental hall.

# Los Alamos Solid Deuterium, UCN Source

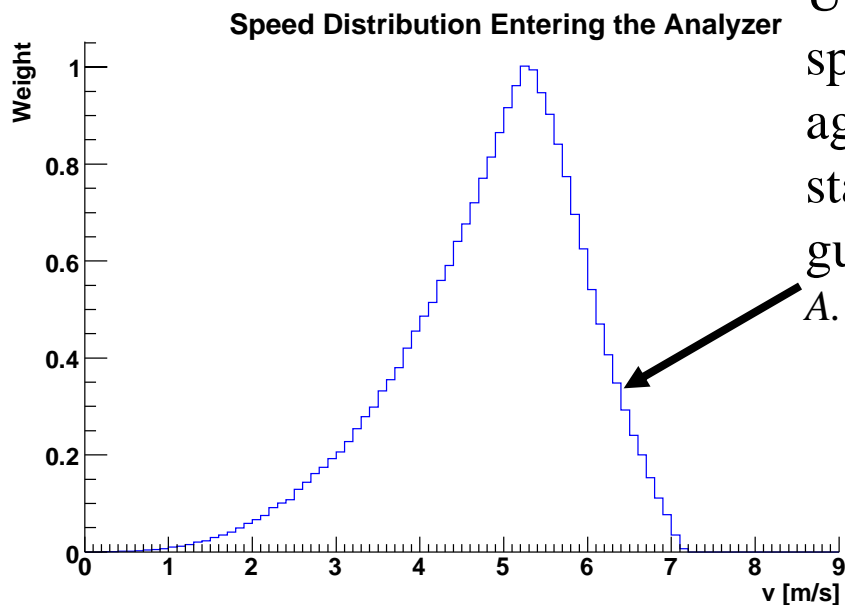


800 MeV  
protons

# Layout in Area B



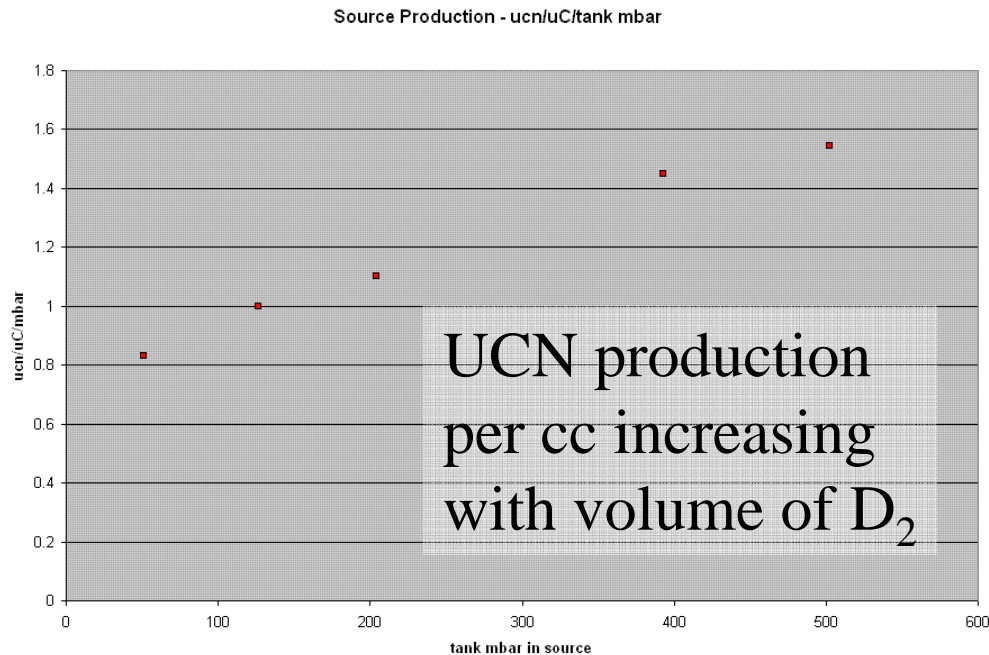
# UCN Transport Out of Shield Wall



Using a magnetic field and Monte Carlo to determine the UCN speed distribution.

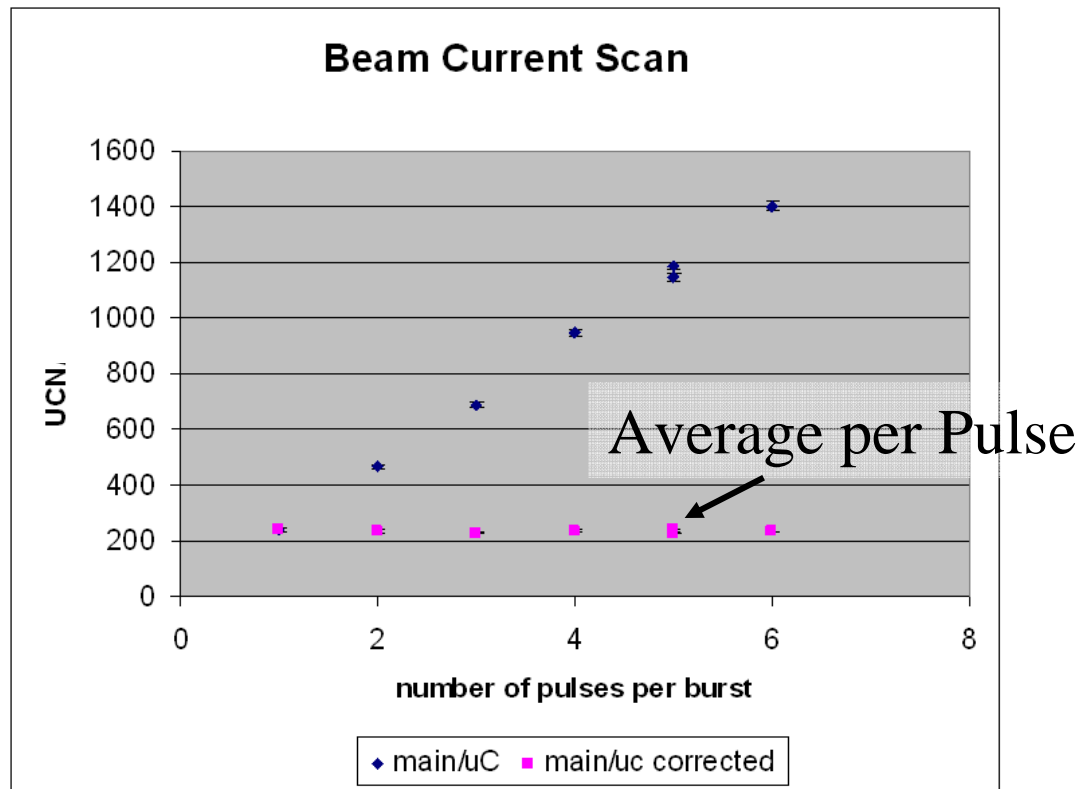
- 7 meters of guide
- 2x 45 degree bends
- Guide diameter increased, **2.5"-3.8"**
- Guide material changed from **DLC coated quartz to electropolished stainless steel.**
- Specularity: Decreased
- No tunneling
- More UCN

# UCN Production 2006 – no UCN Valve



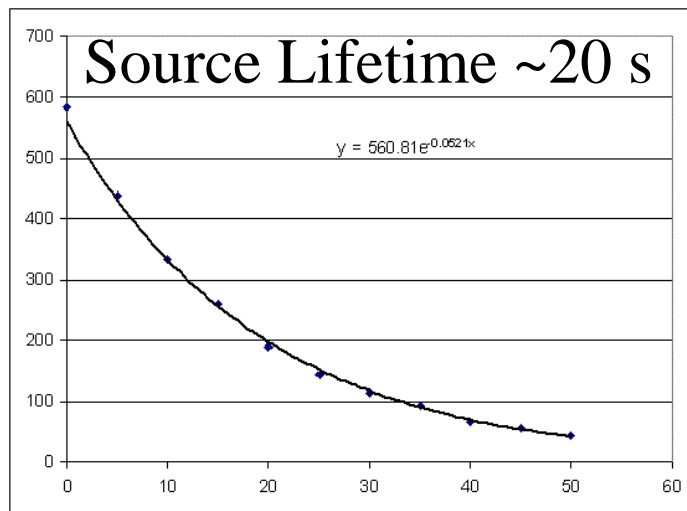
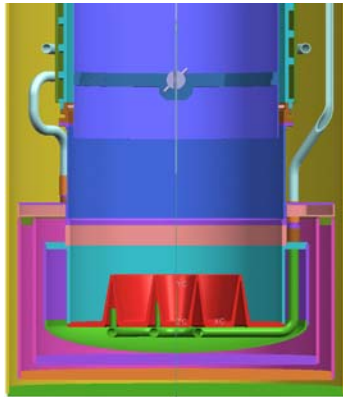
- Max. production /uC/(Tank mbar) of D<sub>2</sub>, 1.6, ~1.2/cc/uC
- Without SS insert or UCN valve → short lifetime.
- Detector is ~50% efficient.
- Scaling, 1000 mbar, ~2l, source ~3200 ucn/uC
- No direct measurement of this due to PPM installation.

# UCN Production with Increased Proton Current



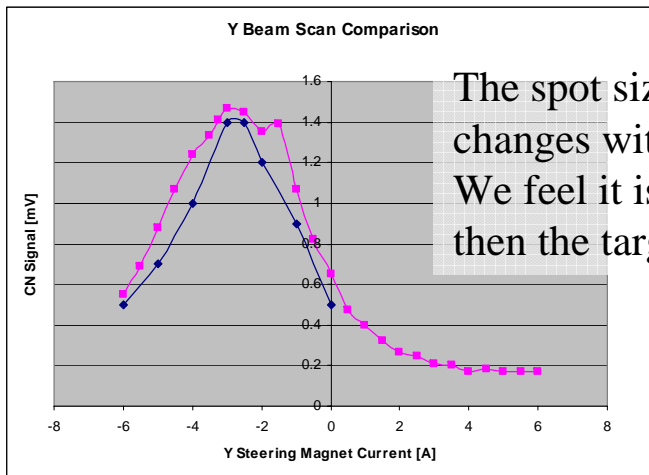
- No decrease in production up to ~30 uC/burst
- Measured beyond the PPM
- Scaling,  $30 \times 3200 = 96000$  ucn/burst at guide exit
- Current limit  $< 2 \mu\text{A}$ ,  $30 \mu\text{C}/15\text{s}$

# Production Increase with 2006 $^{58}\text{Ni}$ /Stainless Steel Insert and UCN Valve

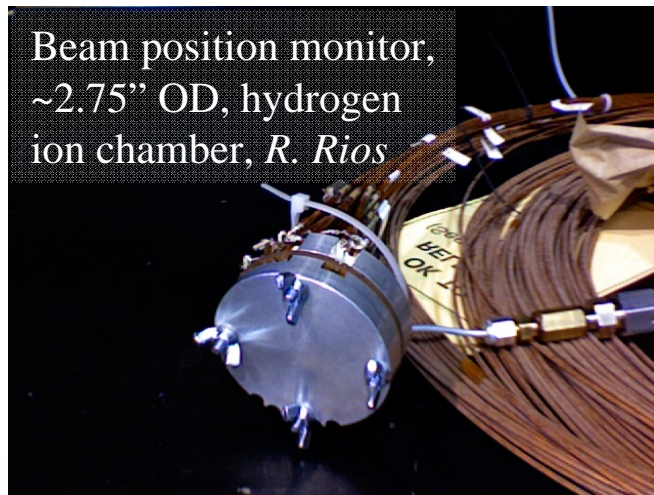


- Valve and insert increased the number of **UCN 2-3 times**.
- Scaling,  $\sim 200000$  ucn/30 uC and **2 ucn/cm<sup>3</sup>** average in the guide system assuming 100 l source UCN volume.
- The source lifetime increased from  $\sim 7$  seconds to  $\sim 20$  seconds.
- The lifetime was short due to a **large gap** at the top of the insert.
- Increasing the lifetime will increase production.

# Proton Beam Tuning

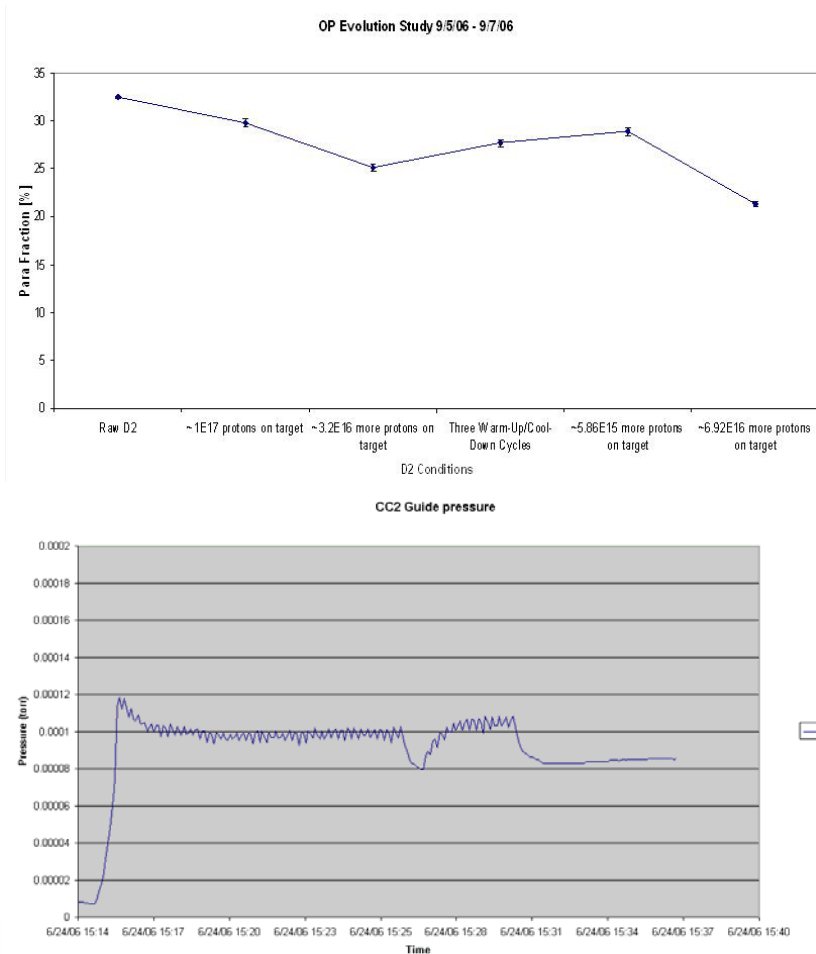


The spot size on the target changes with upstream tune. We feel it is generally larger then the target.



- Target 2 cm diameter, ~12 cm long.
- 30 feet of drift to target.
- Tune checked by scanning the beam and looking at neutron production.
- No idea how many protons are hitting the target.
- Beam position monitor near the target should help.
- New monitor tested at TUNL – works well!

# Ortho-Para Ratio and Beam Heating



- To have an efficient UCN source the solid deuterium must be in the ground (ortho) state. Otherwise ucn can be upscattered when it relaxes.
- The ortho-fraction of the solid deuterium does not decrease during running and may increase.
- Beam heating of the source has not decreased ucn production. Although it can be seen via temperature sensors and vacuum pressure.

# 2007 UCN Source Upgrades



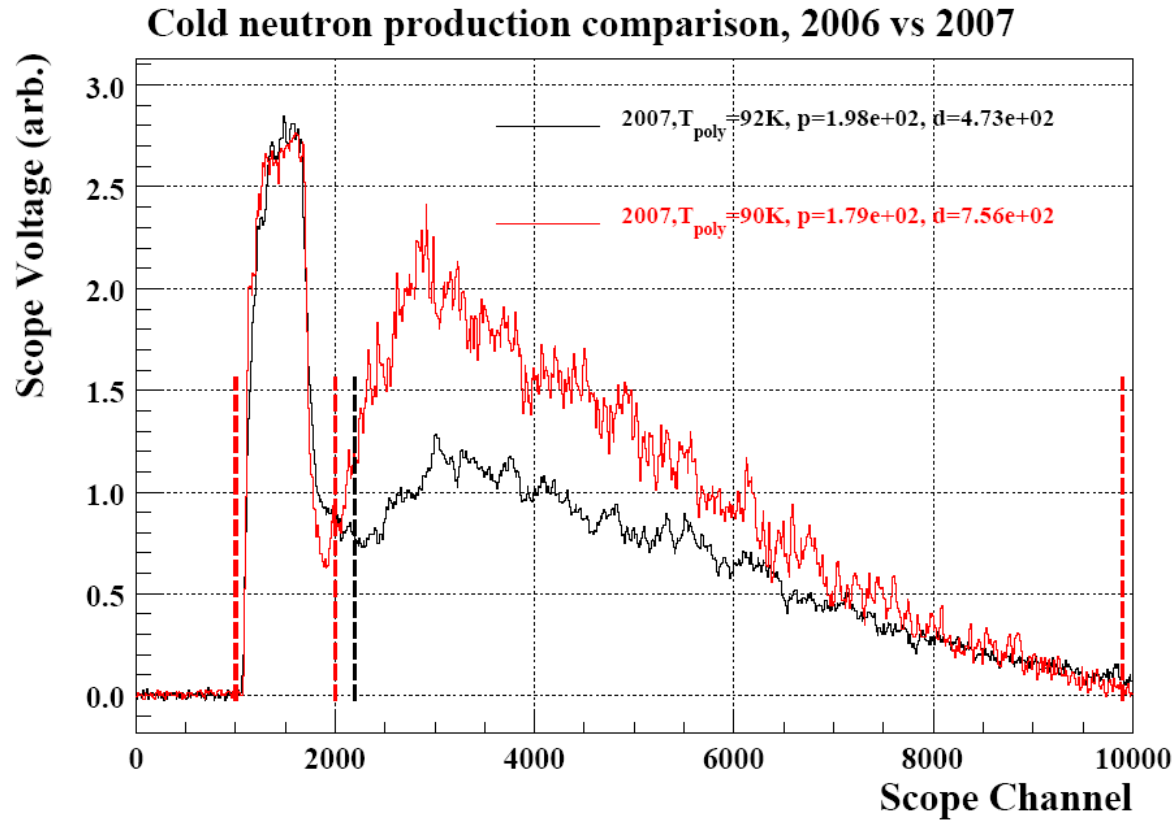
- A new  $^{58}\text{Ni}$  coated stainless steel insert and ucn valve will be installed. The new design will **eliminate several gap**, this should increase the source lifetime.
- Some additional warm **polyethylene** will be added under the source, this should increase thermal, cold and ultracold neutron production.
- More proton **beamline diagnostics** and a beam position monitor should result in more protons on the Tungsten target.

# 2007 Running

---

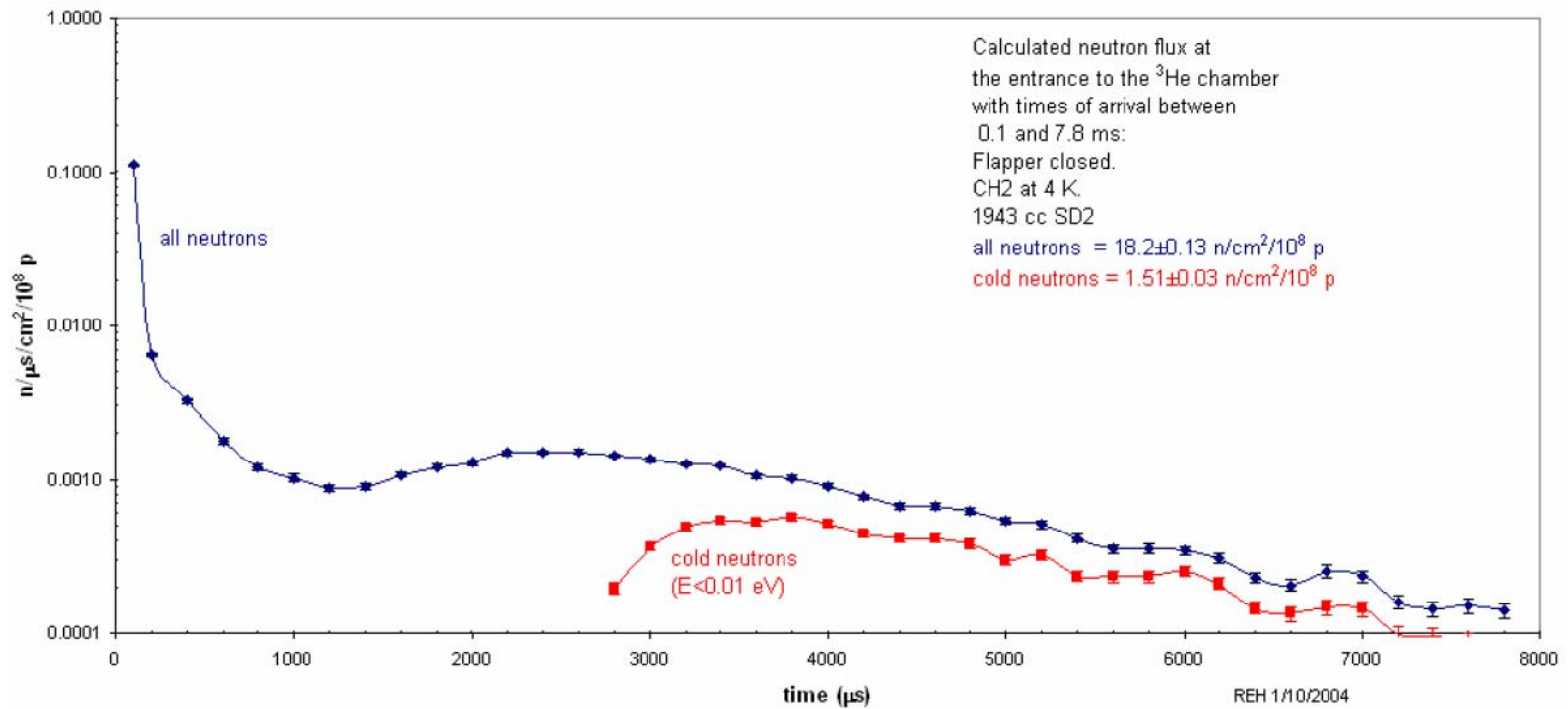
- The proton beam diagnostics have confirmed that the beam spot is larger than the target.
- Additional warm poly has increased UCN production, ~2x
- New guide test setup is running well, no new guides to test.
- Currently testing polarizing and spin-flipping efficiencies.
- New source insert is being warm tested, preparing for cold testing and installation. This should address all known problems with the prototype of 2006.
- Beta decay runs will be starting soon.

# 2006 and 2007 Neutron Production

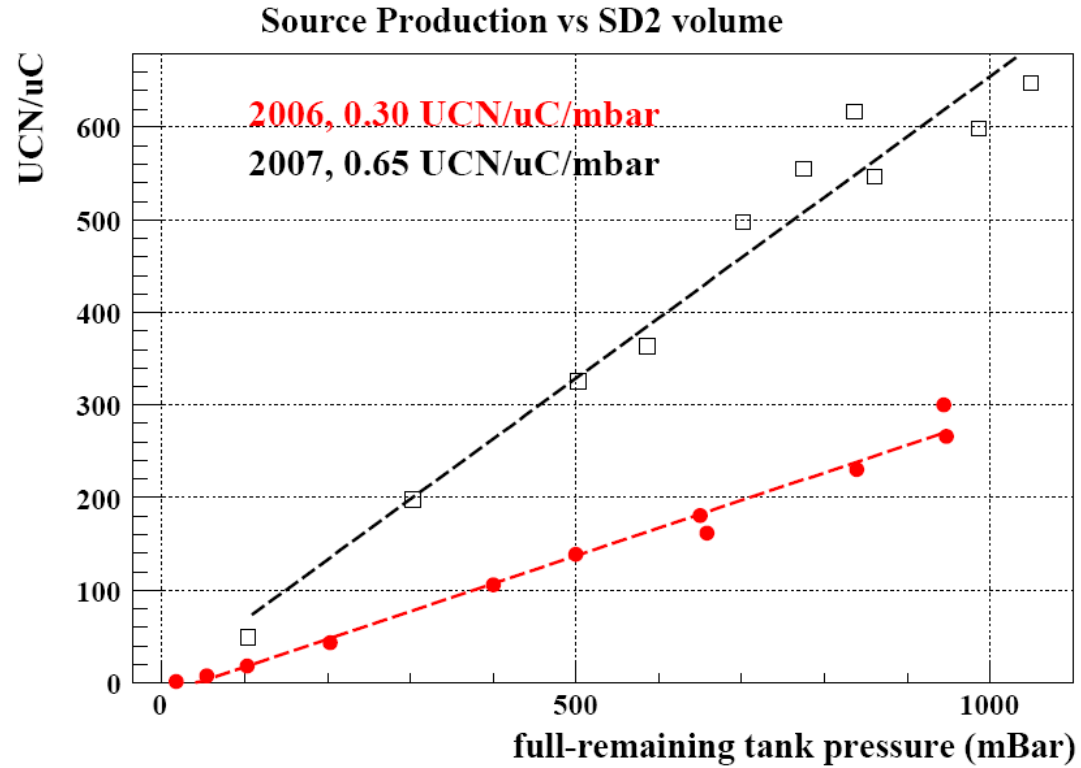


# 2004 Monte Carlo – Cold Neutrons

Neutron time-of-arrival



# 2006 and 2007 UCN Production

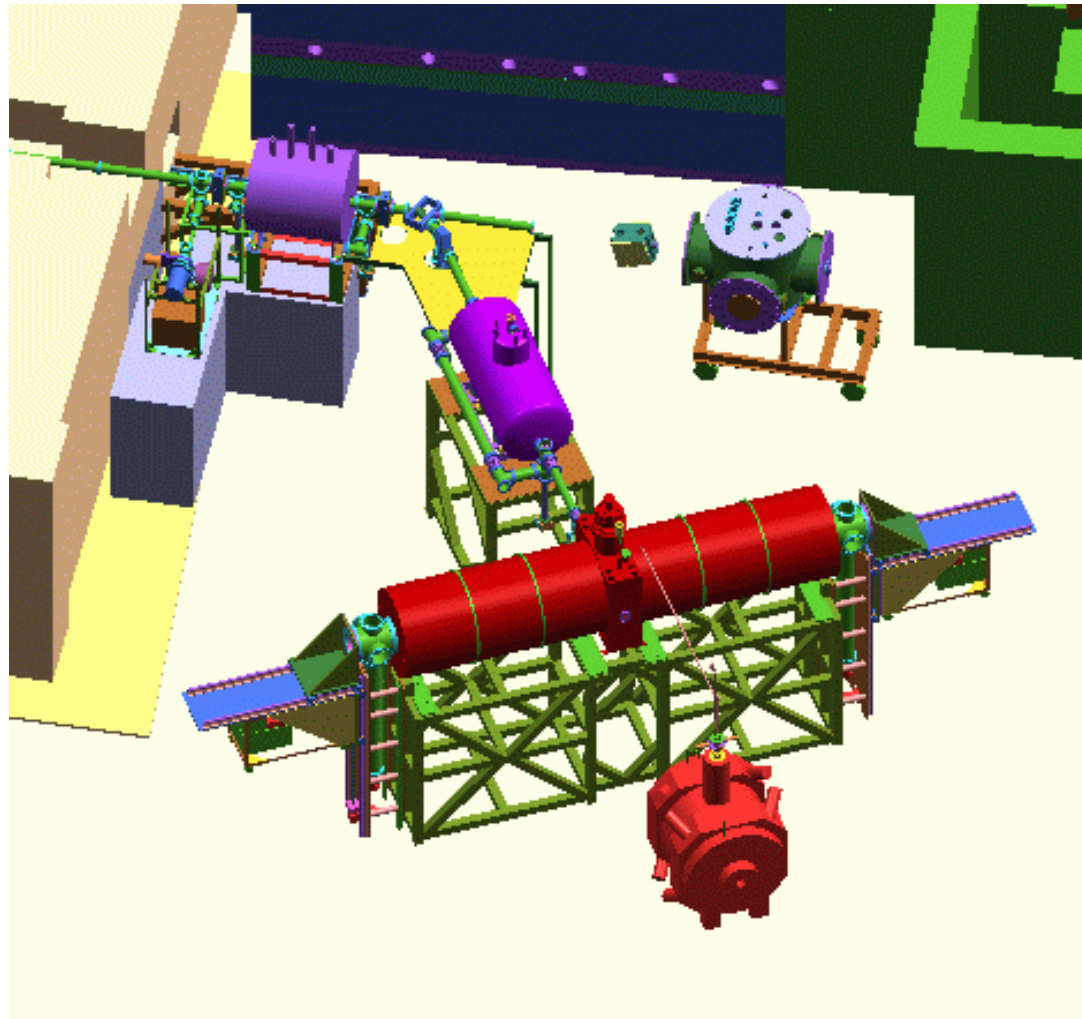


# Two Classes of UCN Experiments at LANSCE

---

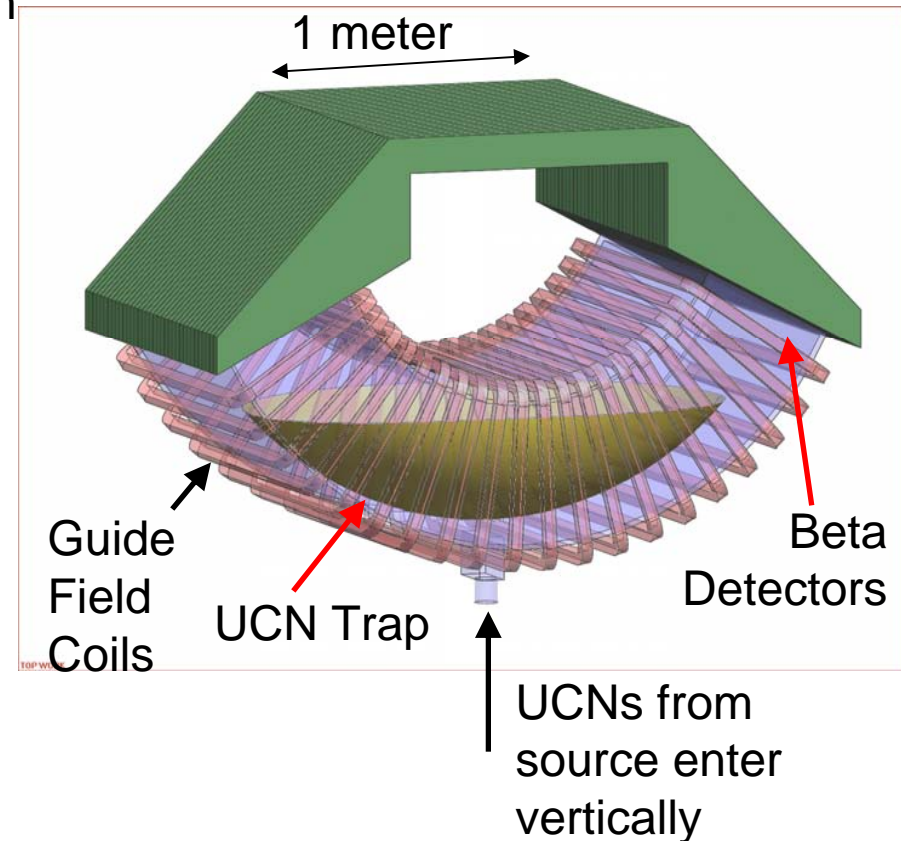
- Fundamental Physics Experiments
  - Precision measurements of polarized neutron decay – UCNA
  - Precision measurement of the neutron's lifetime
  - Neutron EDM – development, will run at the SNS
- UCN experiment development and prototyping
  - Guide and Source coating testing – UCNA
  - Testing of materials for future neutron lifetime experiment
  - Coating testing for UCN EDM experiment
  - UCN detector development

# UCNA Experiment and Test Beamline



# A New UCN Lifetime Experiment

- Recent measurement disagrees with accepted value by  $>6$  sigma
- Our Goal: independent 1 second measurement (0.1%)
- New experiment design eliminates leading error of previous experiments: material wall interactions
- Design and initial procurement supported by LANL LDRD-DR funding
- Now in detailed design and procurement phase



# Other UCN work in 2007

---

- Testing of polarization and spin-flipping efficiencies.
- Testing of new guides and other components for this years UCNA experiment.
- Continued testing of UCN EDM cryogenic test bottle.
- Testing of next generation UCN source guide.
- Thank you