

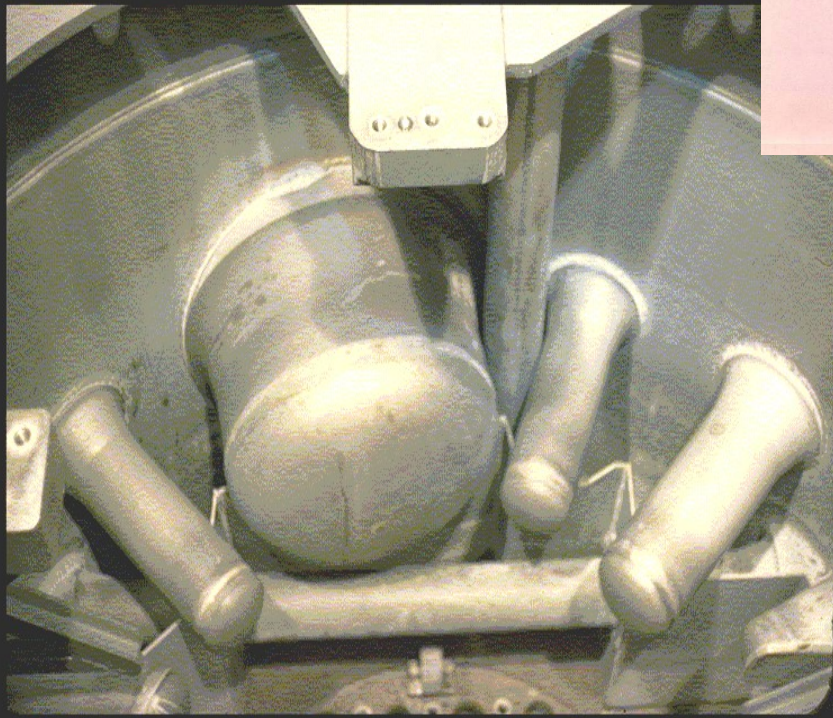
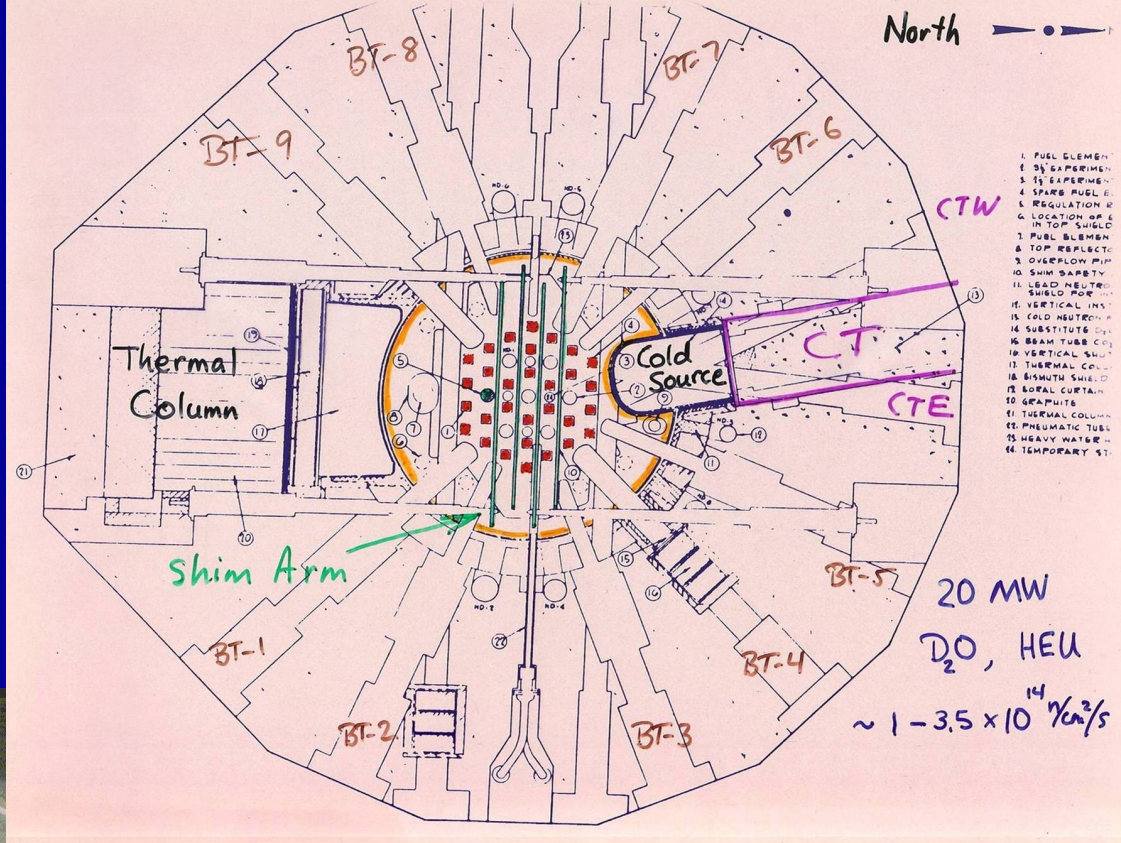
# **A Liquid Deuterium Cold Neutron Source for the NIST Research Reactor**

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## **Outline:**

- 1. Existing LH<sub>2</sub> Cold Source**
- 2. Feasibility of Liquid Deuterium**
- 3. Work Required for Unit 3**

The NBSR was designed with a 55-cm diameter cryogenic beam port for a D<sub>2</sub>O-ice CNS.



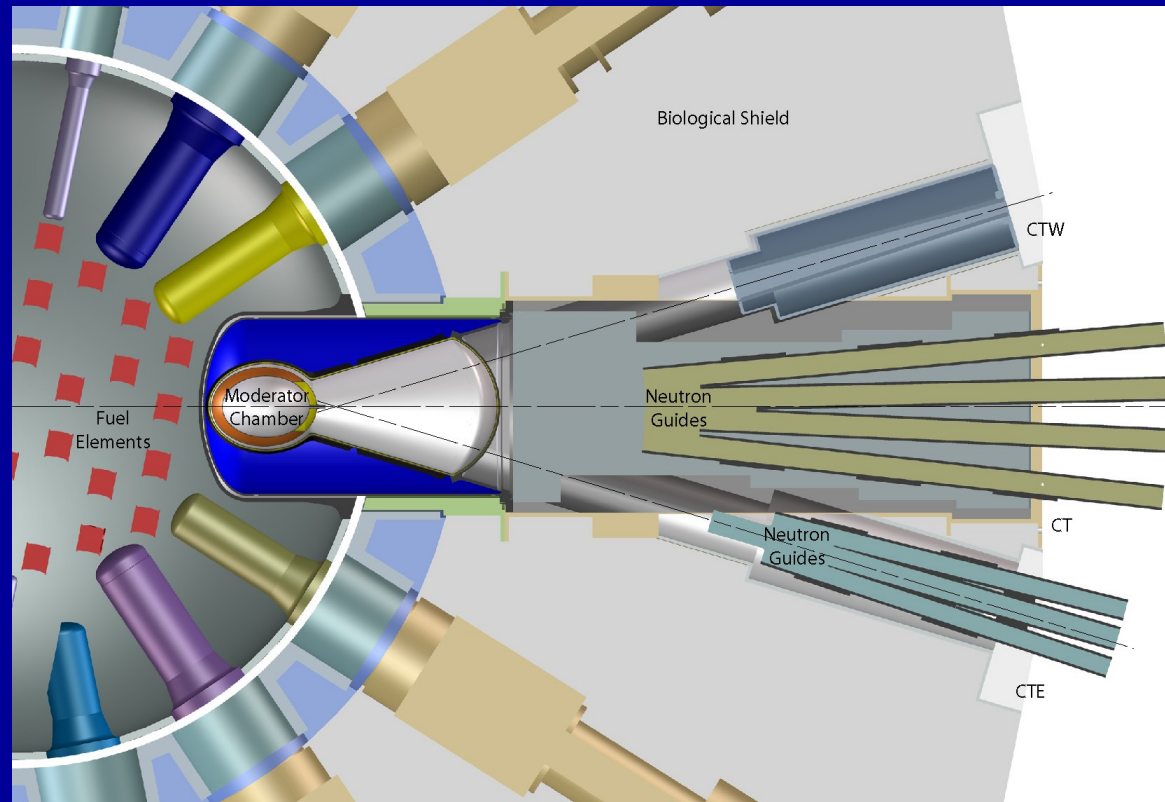
1967-1987: No Cold Source

1987-1994: D<sub>2</sub>O cold source, gain=3

1995-2001: Liquid Hydrogen, gain=6  
(Unit 1)

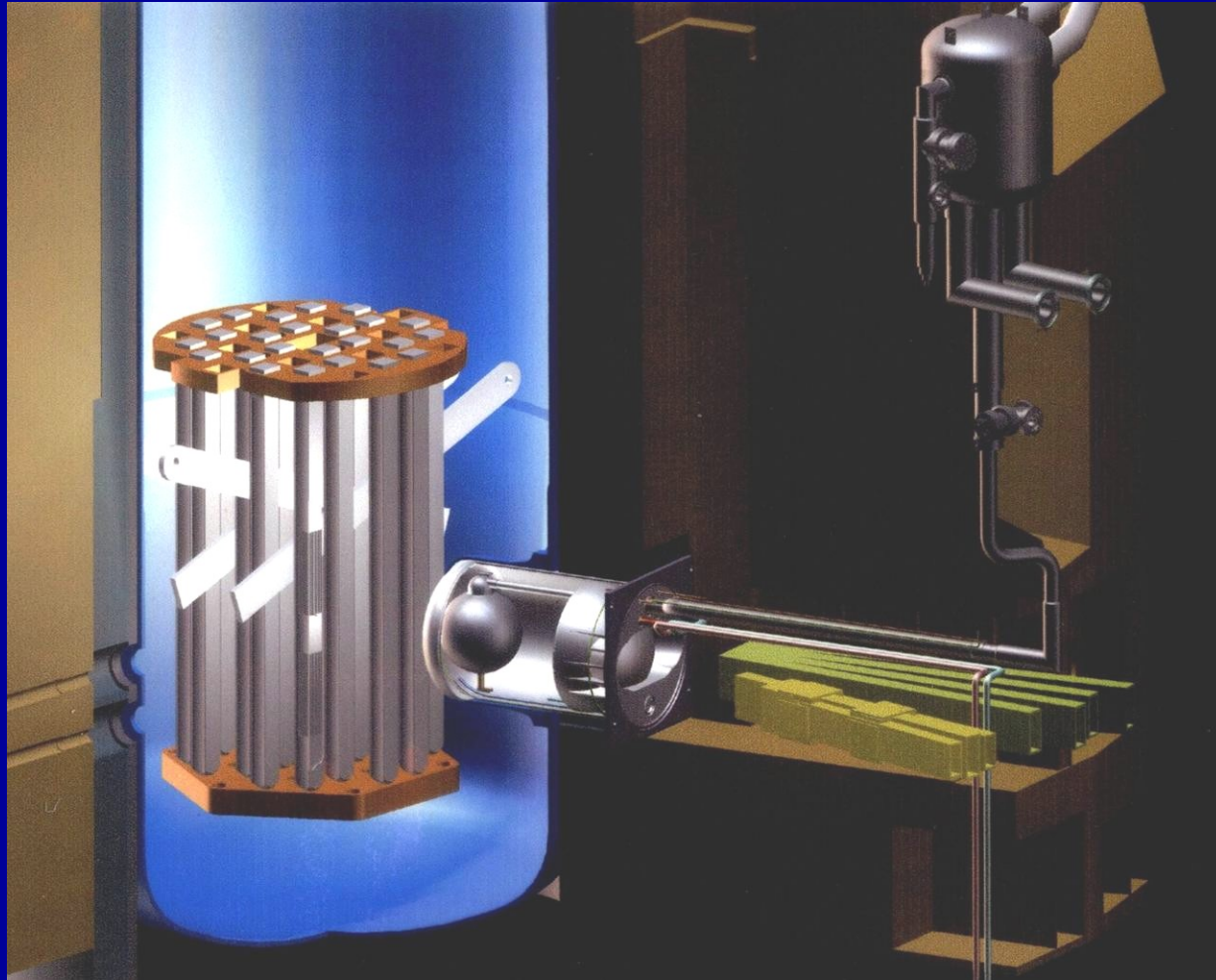
## Unit 2: The Advanced LH<sub>2</sub> CNS, installed in 2002, nearly doubled the brightness of Unit 1

- 5 liters of LH<sub>2</sub> partially surrounded with D<sub>2</sub>O.
- Heat load is 1150 watts.
- Refrigerator, H<sub>2</sub> system and condenser unchanged from Unit 1.



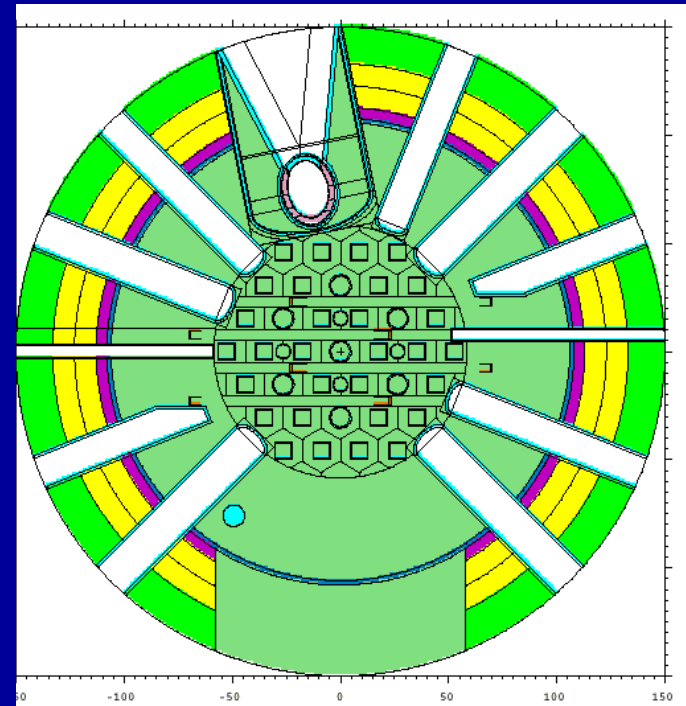
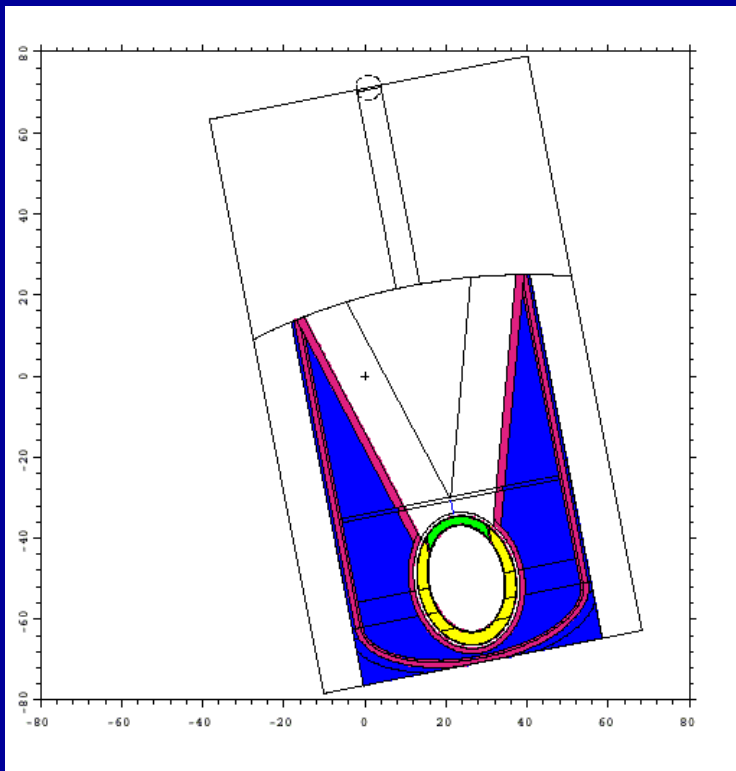


**The condenser is located outside the reactor, 2 meters above the source**



The MCNP model of the NBSR was created for CNS development.

The code has generalized geometry and scattering kernels for cold moderators, and **powerful variance reduction techniques** to tally low-probability events ( $10^{-6}$ ).



A surface source was generated from the whole-core criticality calculation for CNS performance calculations.

This source preserves the normalization.

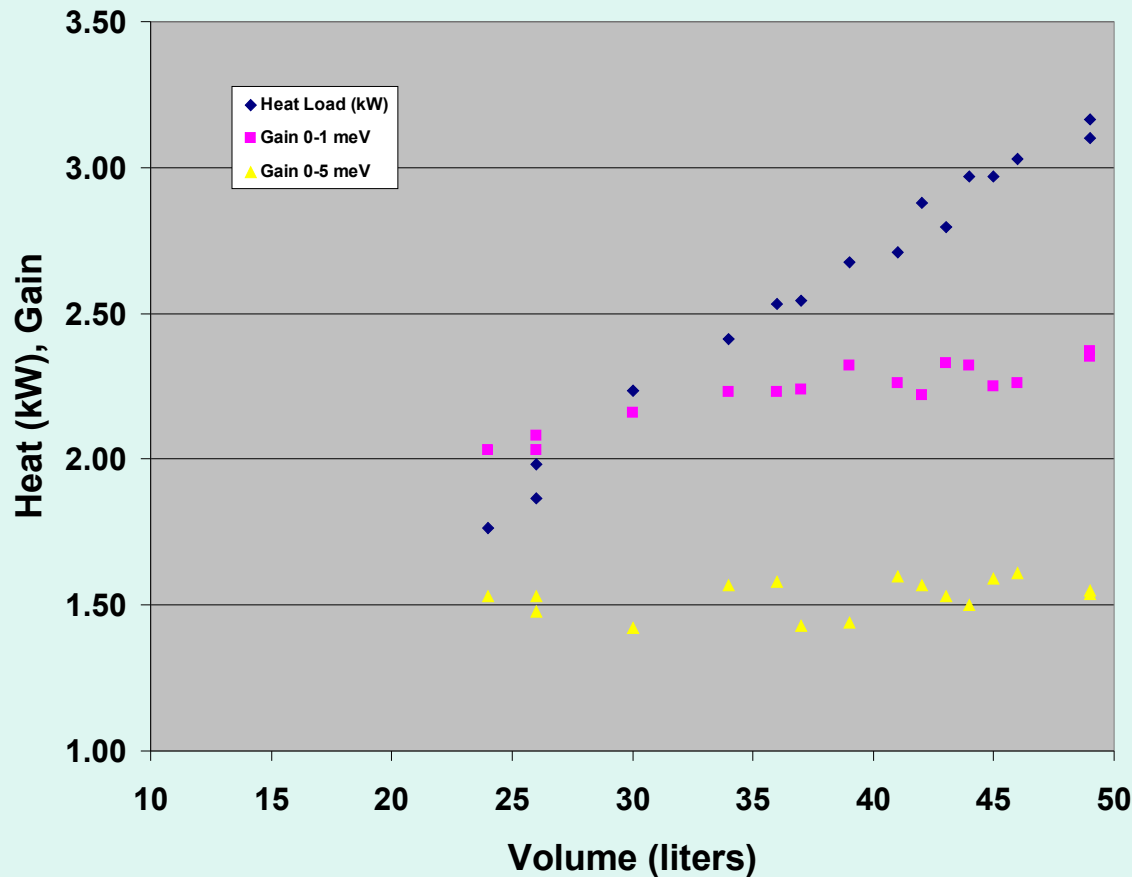
The DXTRAN feature was used to force “pseudo” particles to a current tally plane at the neutron guide entrance.

# Can a liquid deuterium source give us another gain over Unit 2?

- There is plenty of room in the CT thimble for a large volume LD<sub>2</sub> source.
- Many parameters can be varied to optimize its performance: diameter, length, reentrant hole depth, hydrogen content.
- Varied vessel diameter from 32 to 46 cm; volumes from 20 to 50 liters.
- Goals:
  - Gain factors of 1.5,  $\lambda \geq 4 \text{ \AA}$ , and 2 at 9-10  $\text{\AA}$ .
  - Heat load small enough for refrigerator.
  - Use thermosiphon and existing condenser piping.
  - Keep it simple and passively safe.

Since the heat load increases linearly with the volume, there is little to gain in performance above 35 liters.

Unit 3 Heat Load, Gains vs. LD2 Volume



In the 25-30 liter range, a few atom percent of hydrogen enhances the overall brightness, but NOT at the longest  $\lambda$ .

The best choice appears now to be 38x38 cm, with a 20-cm reentrant hole and 1-2% H<sub>2</sub>.

Still need more detailed calculations on smaller volumes.

**A 38 x 38 cm liquid deuterium source, with a 20-cm reentrant hole, in the CT thimble:**

**Large volume: 30 liters**

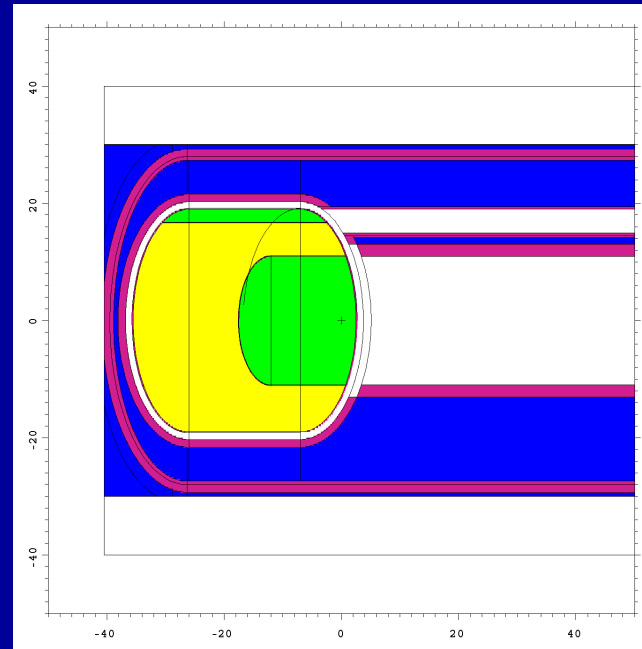
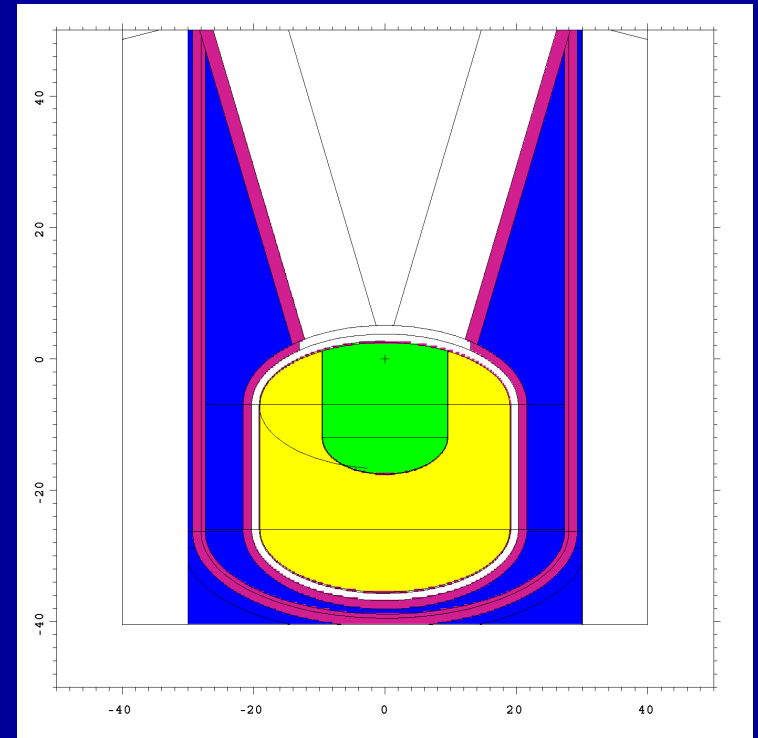
**7 kg @ 300 kPa will have an expansion volume of nearly 15 m<sup>3</sup> (7.5 times our ballast tank)**

**Calculated heat load of 2200 watts (1.6-mm thick Al wall) will tax our refrigerator.**

**Boils 6.7 g/s, producing 3.3 liters of D<sub>2</sub> vapor per second, close to Unit 2 value.**

**(It might be possible to cut 400 watts by building a 6-mm Bi shield into the D<sub>2</sub>O jacket.) (Side)**

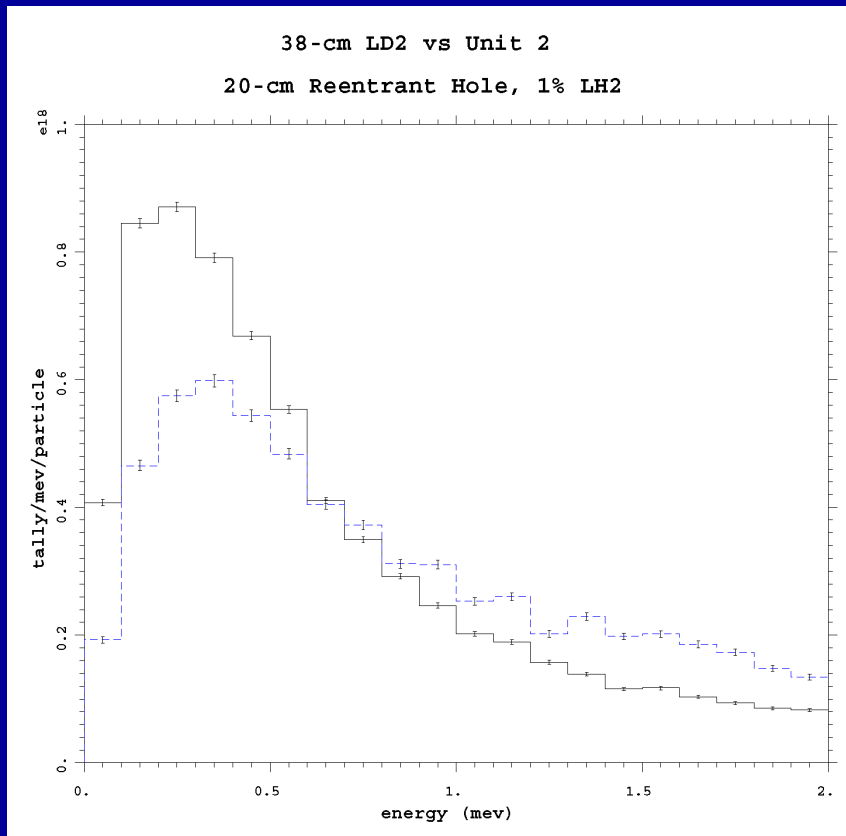
(Top)



**LD<sub>2</sub>**  
**Vapor**  
**D<sub>2</sub>O**



# Relative Brightness of a 30-liter LD<sub>2</sub> CNS vs. Unit 2, 0 – 20 meV

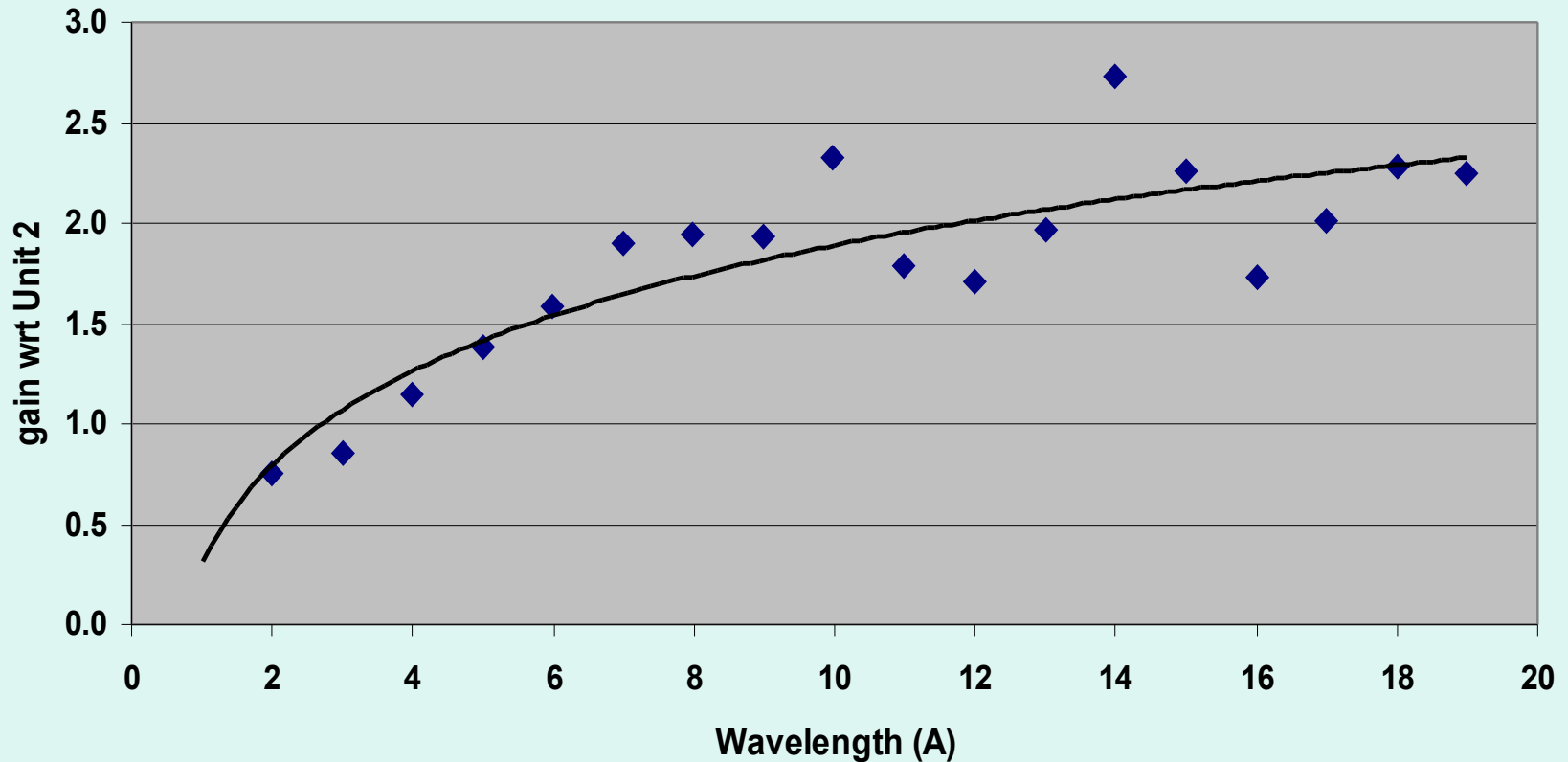


(LD<sub>2</sub> – solid line)

- Spectrum shifts to lower energies.
- Gain = 1.5 for  $E < 5$  meV.
- Gain  $> 2$  for the longest wavelengths
- Maxwell-Boltzmann temperature drops from 38 K to 28 K
- 25% loss at 15 meV (2.5 Angstroms)

# Gain vs. Wavelength, 2 – 20 Å

Gain: 38-cm LD2, 1% LH2, 20-cm hole

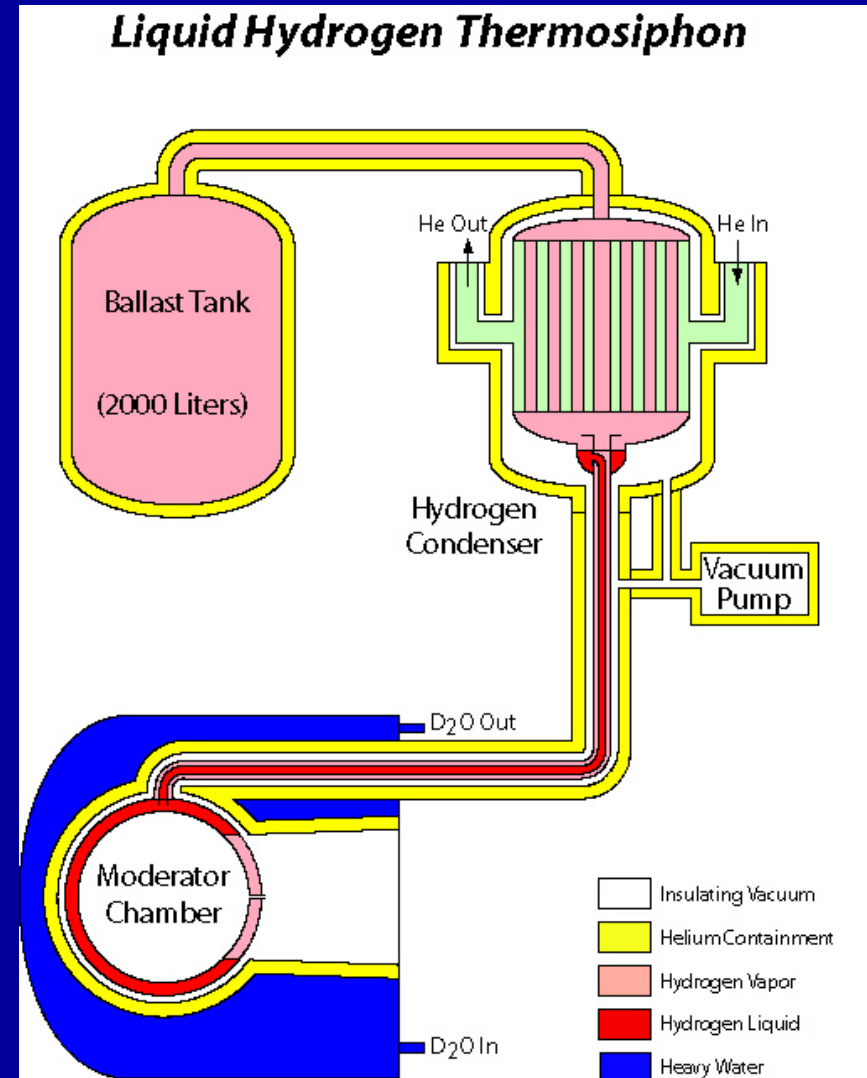


Most work with cold neutrons uses 4 to 10 Å neutrons.  
There will be a 25 to 100 percent increase over this range.

# The LD<sub>2</sub> source must also be passively safe, simple and reliable

- A thermosiphon is the simplest way to supply the source with LD<sub>2</sub>.
  - Cold helium gas cools the condenser below 20 K.
  - Deuterium liquefies and flows by gravity to the moderator chamber.
  - Vapor rises to the condenser and a naturally circulating system is established.
- The system is closed to minimize gas handling (No vents or pressure relief).
- Low pressures: 3 bar warm, 1 bar operating
- All system components are surrounded by He containments.
- Rigorous quality assurance.

(Unit 2 CNS)



## Required Work:

- Finalize performance and heat load calculations incorporating “engineering constraints”, such as the minimum wall thickness, and the actual dimensions of the vacuum and He jackets.
- Build and test prototype vessels to check FEA stress analysis.
- Thermal-hydraulic tests of the moisture separator at the top of the moderator chamber.
- Modify the refrigerator for higher temperatures.
- Install a BIG ballast tank (room in C-100?).
- Amend the cold source SAR for a higher inventory.
- Control tritium with hydride storage or recombiner.

**Cost: \$1 Million**

**Target Date: 2008-2009**

# Conclusion

- 2005 marks 20 years since the work began on the D<sub>2</sub>O cold source.
  - 10<sup>th</sup> anniversary of the first LH<sub>2</sub> source
- Cold source development continues to better serve the neutron scattering community.
- MCNP is a critically important tool in the effort.



# Neutron Flux Gains

