A Second Liquid Hydrogen Cold Source for the NIST Research Reactor

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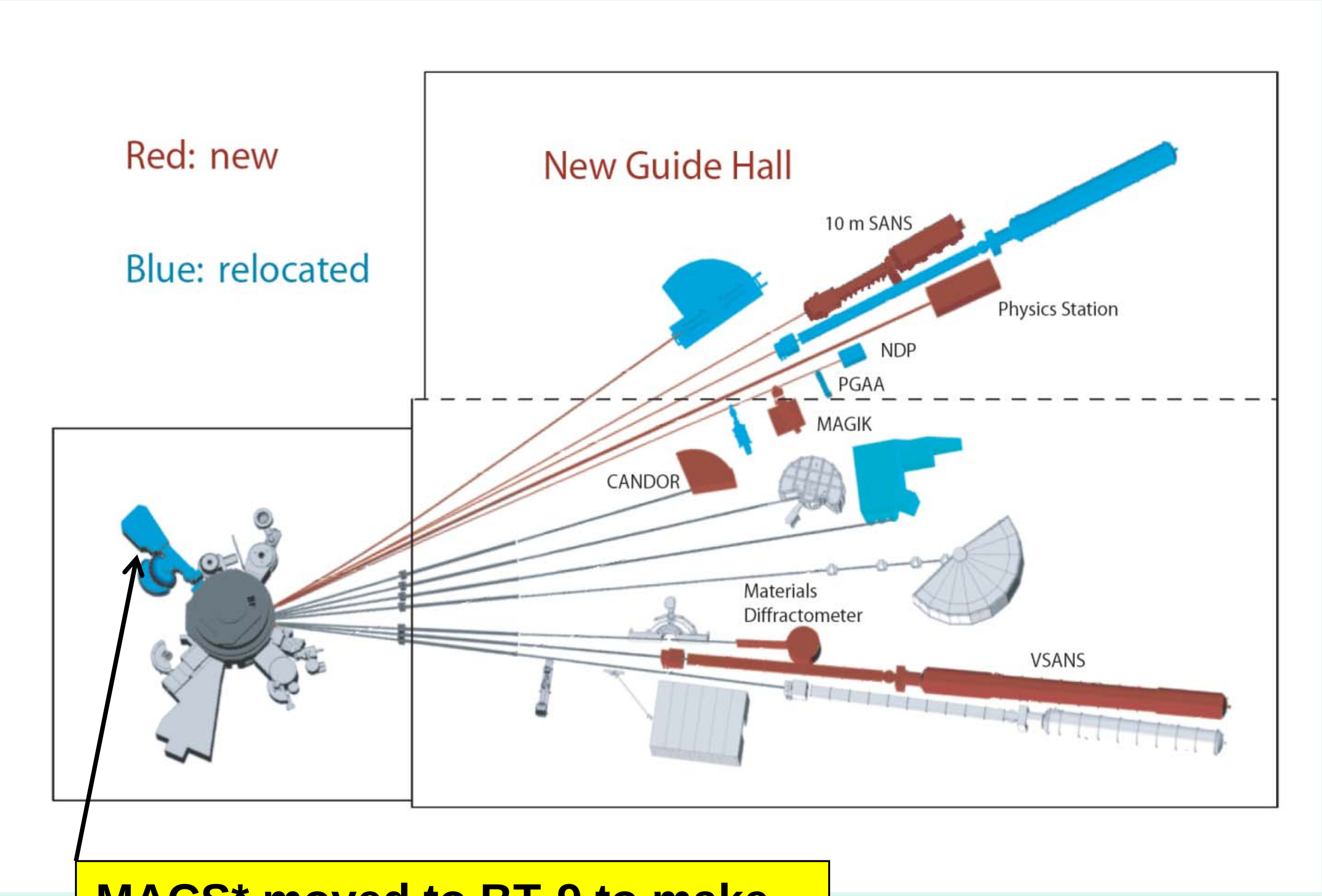
The Nuclear Regulatory Commission has renewed the NBSR operating license for 20 years!

- NCNR Expansion Project: 2007 – 2012
- A second liquid hydrogen cold source is needed.
  - Design Calculations
  - Thermal-Hydraulic Tests
  - Safety / Operation
- Conclusion

Expansion of Cold Neutron Facilities



MACS* moved to BT-9 to make room for new guides.

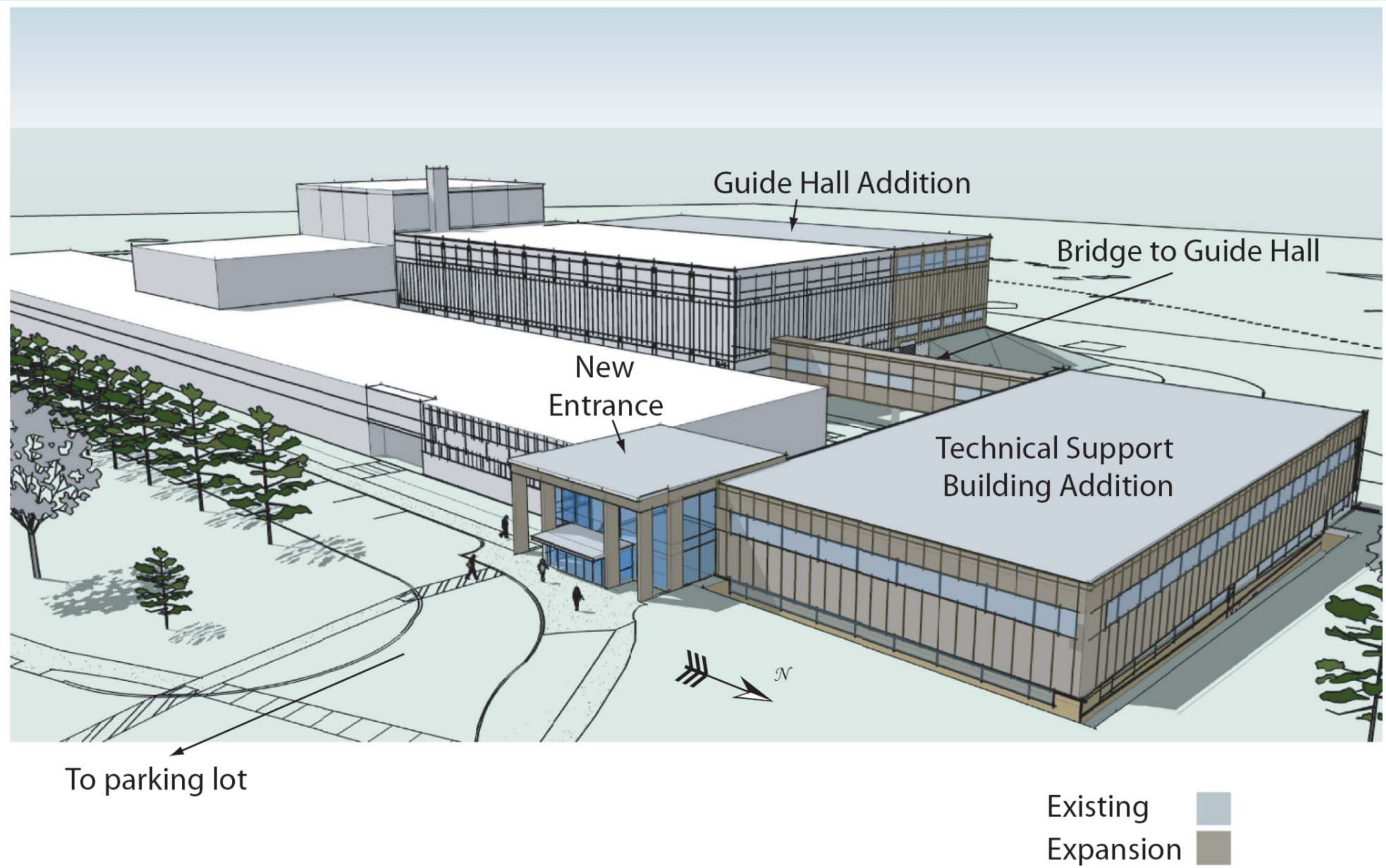
***Multi-Axis Crystal Spectrometer**

Five-year plan funded by American Competitive Initiative ~$100 M

5 new guides, at least 6 instruments

New guide hall nearly doubles space

Technical Support Building for sample environment, machine shop, conference room and offices.


Guide Hall Addition
Bridge to Guide Hall
New Entrance
Technical Support Building Addition
N
To parking lot
Existing
Expansion

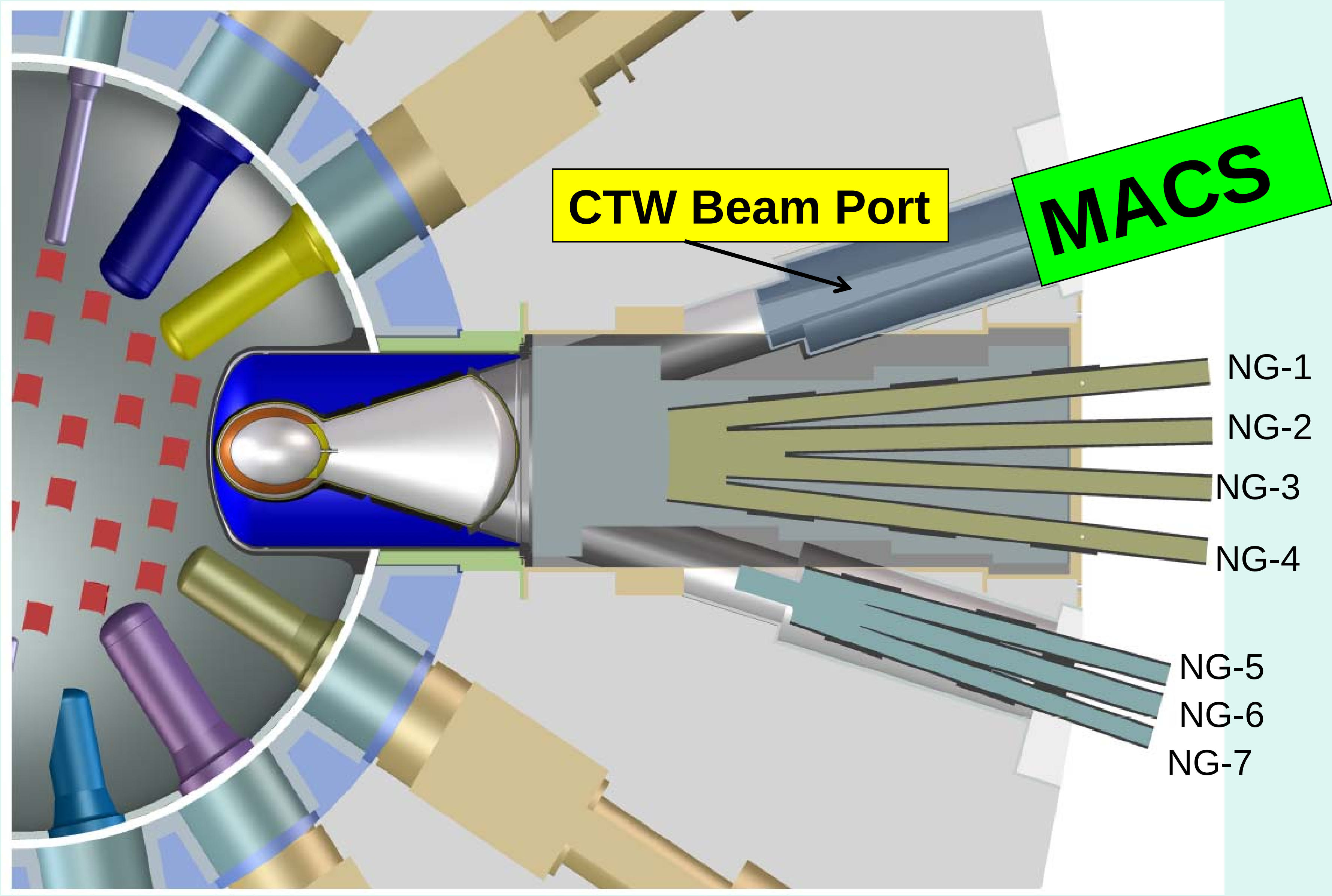
New NCRN Guide Hall Construction:
Looking East from Cooling Tower (October 19, 2009)

Inside the New Guide Hall Structure (October 19, 2009)

Reactor Shutdown for Expansion: March 2011 – January 2012

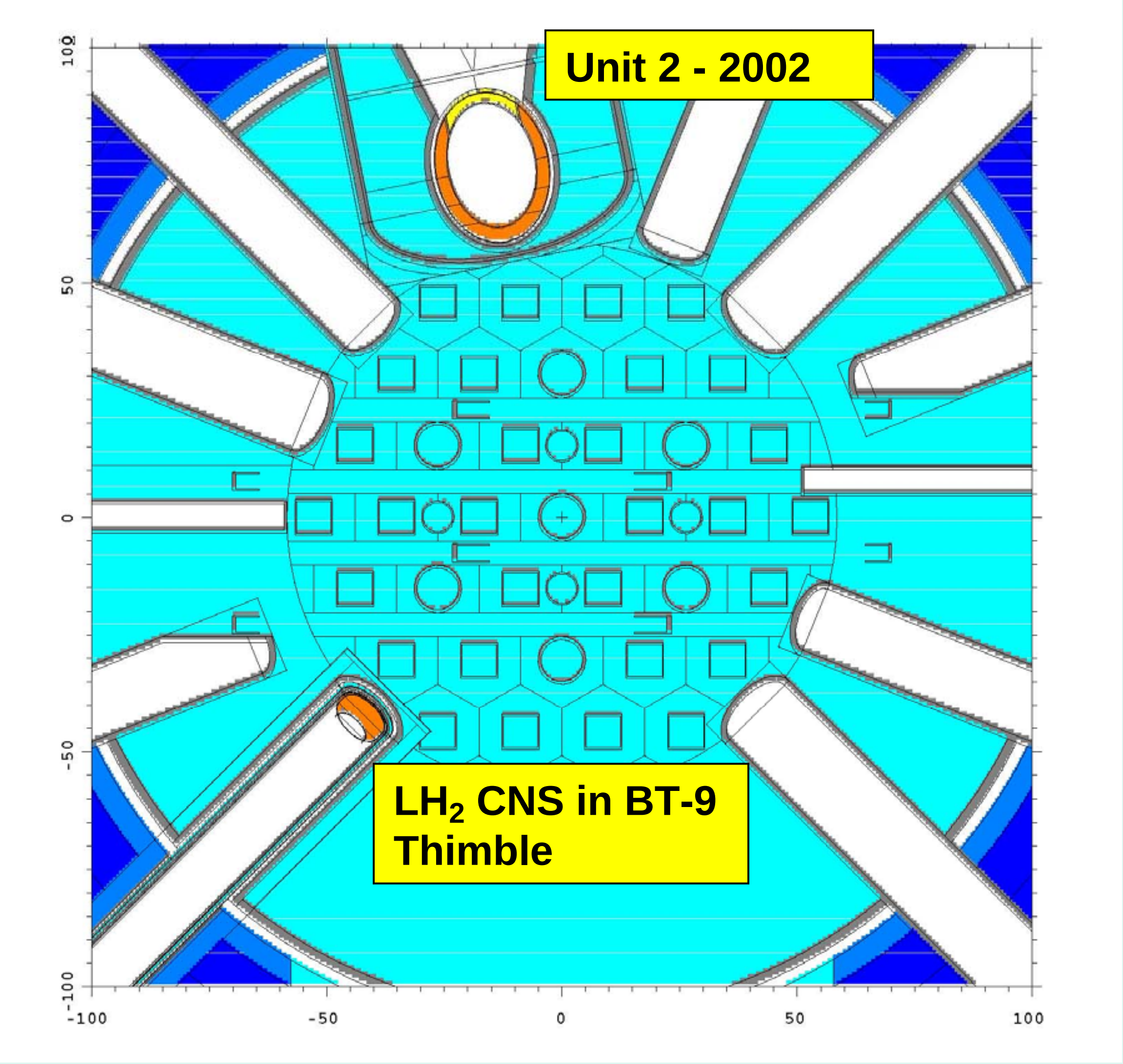
1. Install BT-9 CNS and move MACS.
2. Relocate Secondary Cooling System pipes and pumps to new pump house.
3. Drill holes in confinement and install guides, shields, and instruments.
4. Replace control room console with digital control console.
5. Modify Thermal Shield Cooling System.

Existing LH_2 Cold Source, In-pile Neutron Guides



A second LH_2 source is being developed as part of the NCNR Expansion Initiative

- **MCNP calculations used to estimate neutron performance and heat load.**
- **"Pee Wee" has an 11-cm ID, and a 0.5-L volume, 4.5-cm thick.**
- **Gain in brightness of about 1.7 compared to Unit 2.**
- **Flux perturbations lower near BT-9 compared to large CT**
  - **BT-9 ~ 1.5×10^{14}**
  - **CT ~ 1.0×10^{14}**



Calculated Nuclear Heat Load (MCNP) of the BT-9 Cold Source

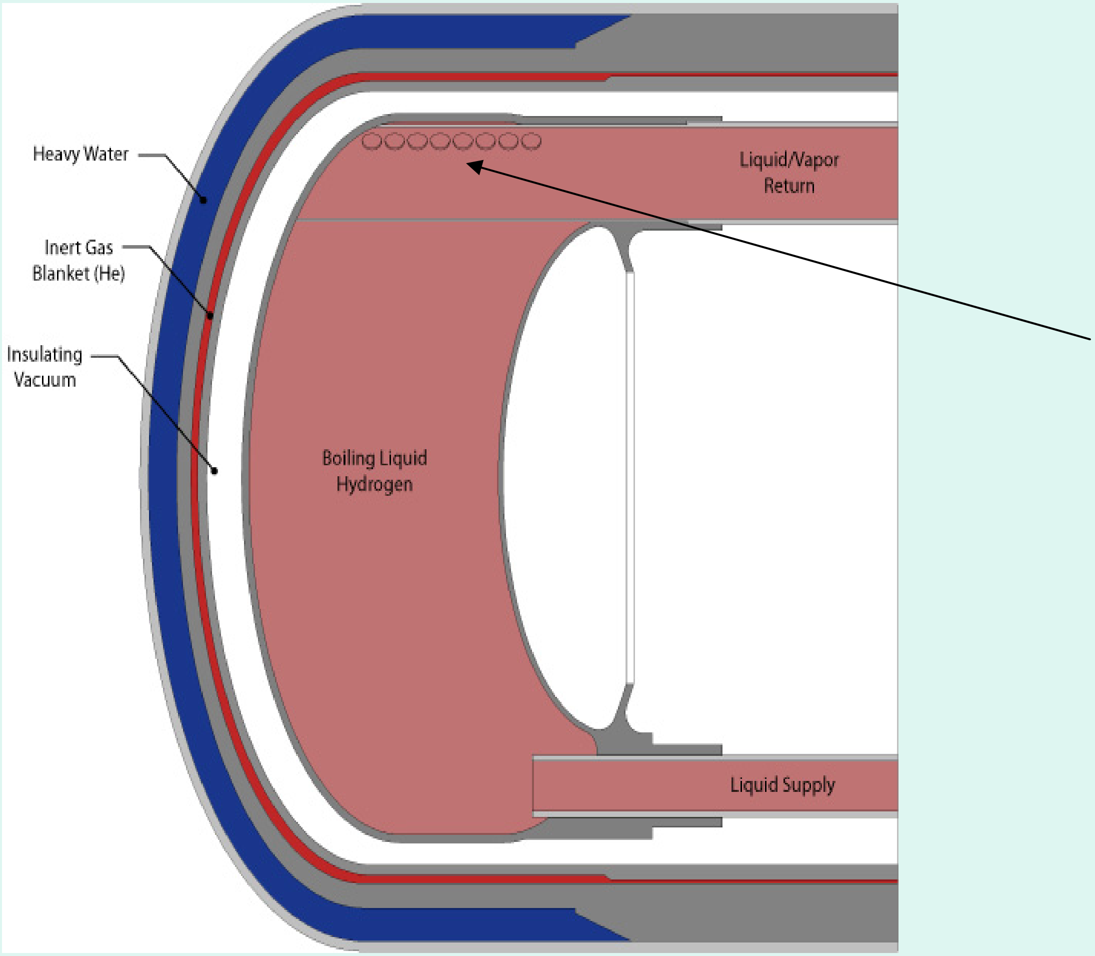
(Watts)	LH_2 (27 g)	Al (141 g)
Neutrons	33	1
Beta Particles	-	29
Gamma Rays*	26	74
Totals	**59**	**104**

163 Watts

BT-9 source can be added to the existing refrigerator load of 1200 W.

* Used ^{235}U cross sections with enhanced gamma-ray production to simulate f.p.

Side View of BT-9 Cold Source



Pee Wee:

14.6-cm OD water jacket

It will have its own H_2 tank.

Control independent of Unit 2.

“Piccolo” phase separator

Status:

T-H tests complete

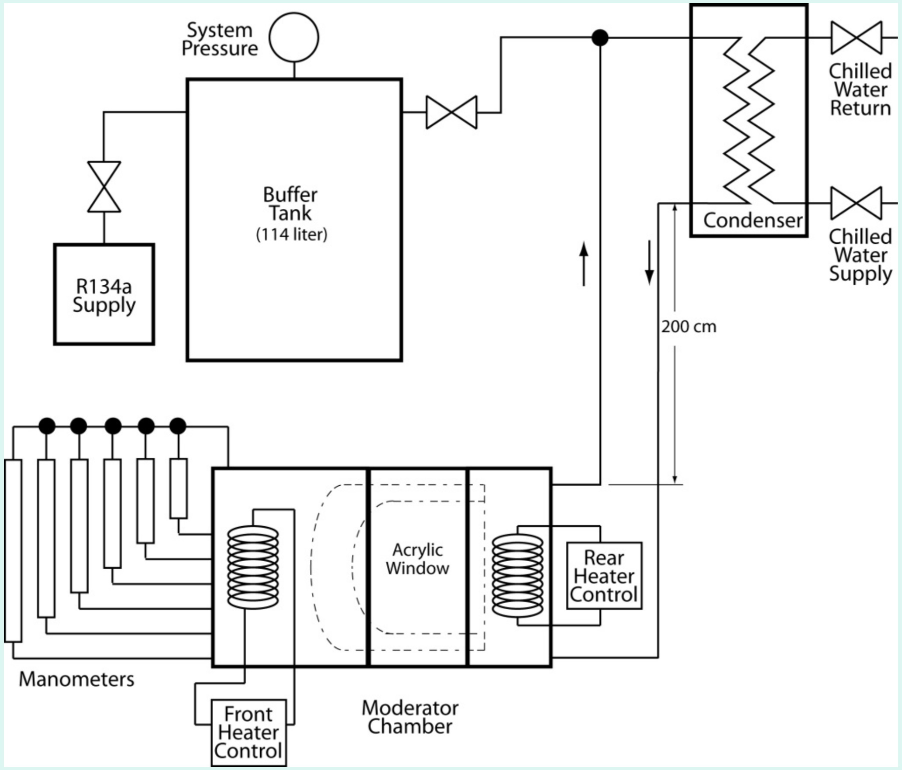
Cooling water flow tests complete

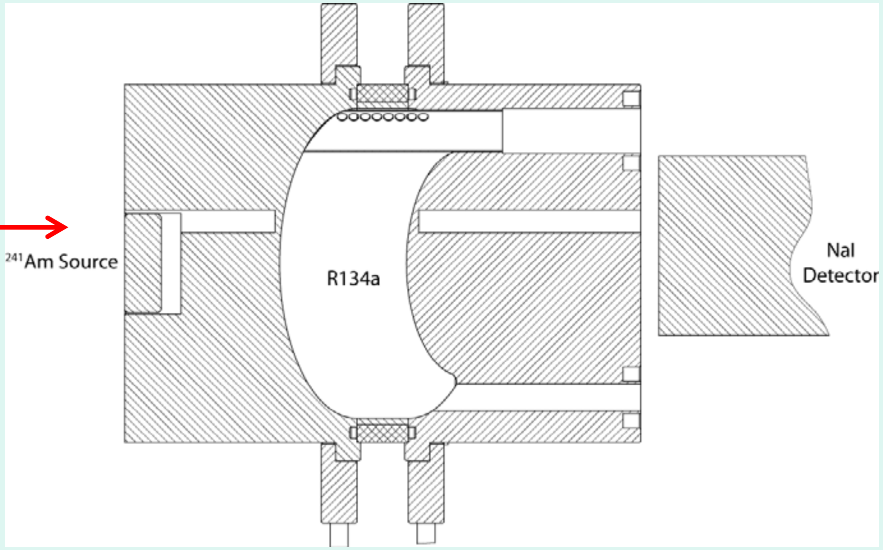
Pressure tests of moderator chamber and He containment complete

Cryostat Assembly being fabricated

Thermal-Hydraulic Tests

- Small vessel very unlike Unit 2.
- **Same geometry, but used R-134a at 287 K and 0.48 MPa.**
- Same ratio of liquid-to-vapor densities expected in CNS.
- **1200 W to get same volume flow rate expected in CNS.**
- Demonstrated stable operation at 3600 W! Never emptied.
- **Void fraction determined using 60-keV gamma-ray transmission measurements: voids ~ 13%**
- Piccolo-type phase separator brings liquid level to the top of the vessel.

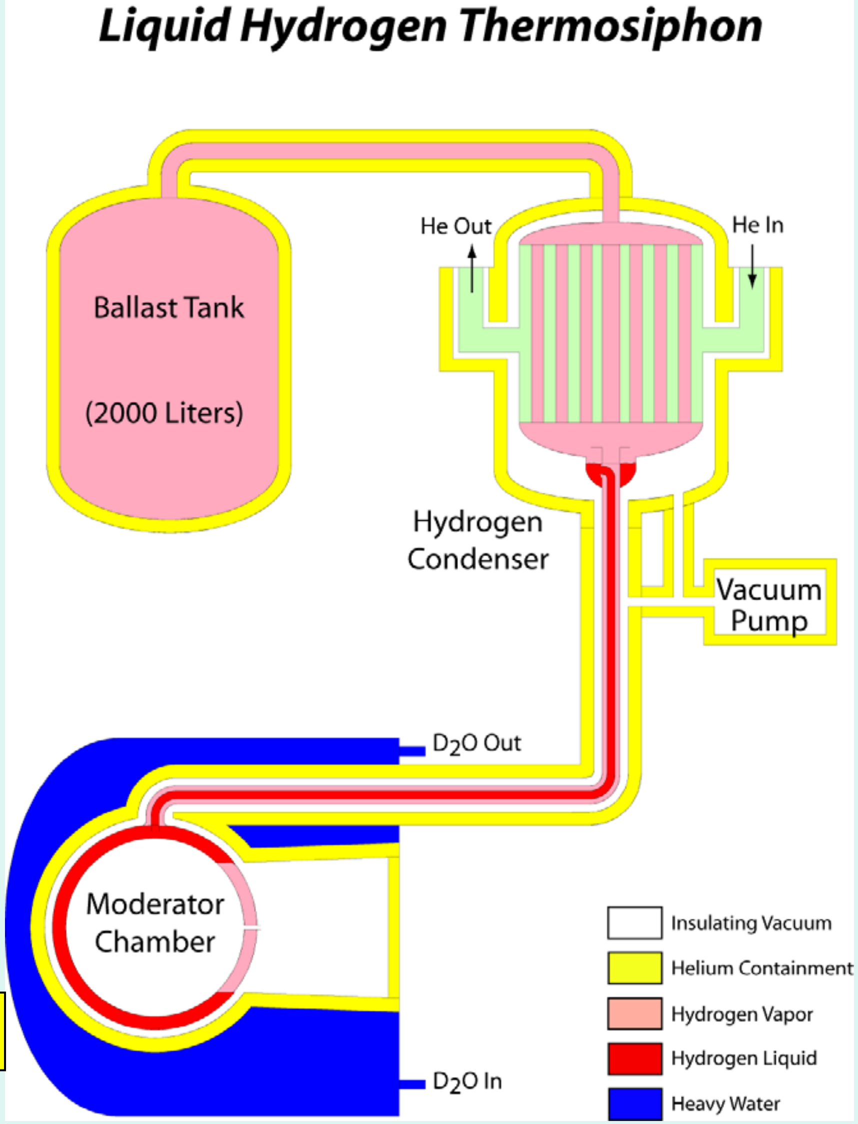




Unit 2 is passively safe, simple, and reliable. Same safety philosophy for Pee Wee.

- A thermosiphon is the simplest way to supply the source with LH_2.
  - Cold helium gas cools the condenser below 20 K.
  - Hydrogen liquefies and flows by gravity to the moderator chamber.
  - Vapor rises to the condenser and a naturally circulating system is established.
- Thermal hydraulic tests showed a thermosiphon could safely remove at least 2200 watts.
- ***The system is closed to minimize hydrogen gas handling.***
- All system components are surrounded by He containments.

Unit 2



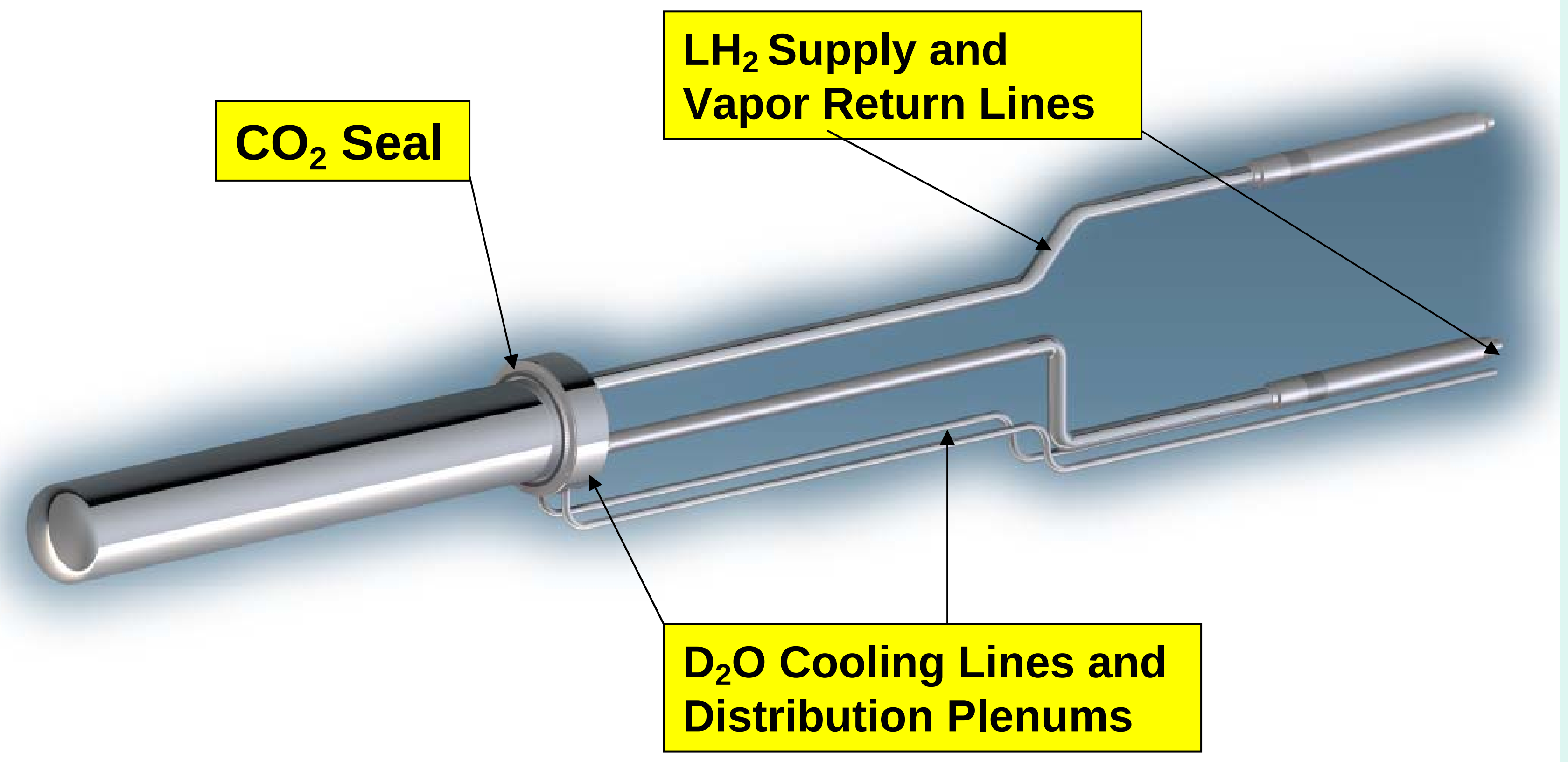
Safety Analysis: BT-9 Accidents Bounded by Existing Source

- Unit 2 accident scenarios analyzed for BT-9 source (NISTIR-7352, Chapter 8):
  - Loss of Insulating Vacuum
  - Leak of air and H_2 into vacuum vessel
  - Release of H_2 into Confinement building
  - Detonation of a stoichiometric mixture of air and H_2 in the moderator chamber.
  - **Maximum Hypothetical Accident** – Severed vacuum line, LH_2 reaction with solid O_2 (bounded by measurements of Ward, et al.)

CNS Tests and Quality Assurance

- Hydrostatic pressure tests to failure on prototype vessels.
  - Moderator Vessel ~ 5 MPa
  - He Containment Vessel ~ 9.8 MPa
- Thermal hydraulic tests of the thermosiphon using R-134a as the working fluid
- Leak test vessels, piping $< 10^{-9}$ cc-He/sec.
- H_2 system entirely welded. Welds within the biological shield are radiographed.
- Final pressure tests at 125% of working pressure (as per ASME Code).

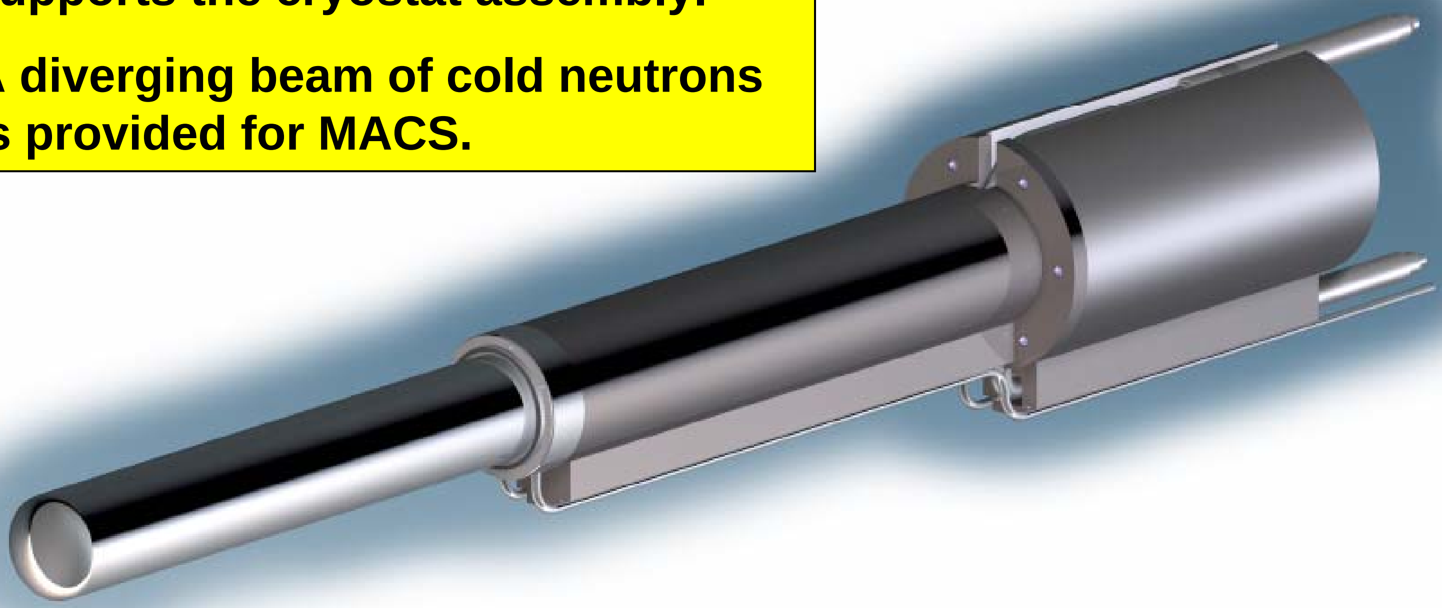
Cryostat Assembly



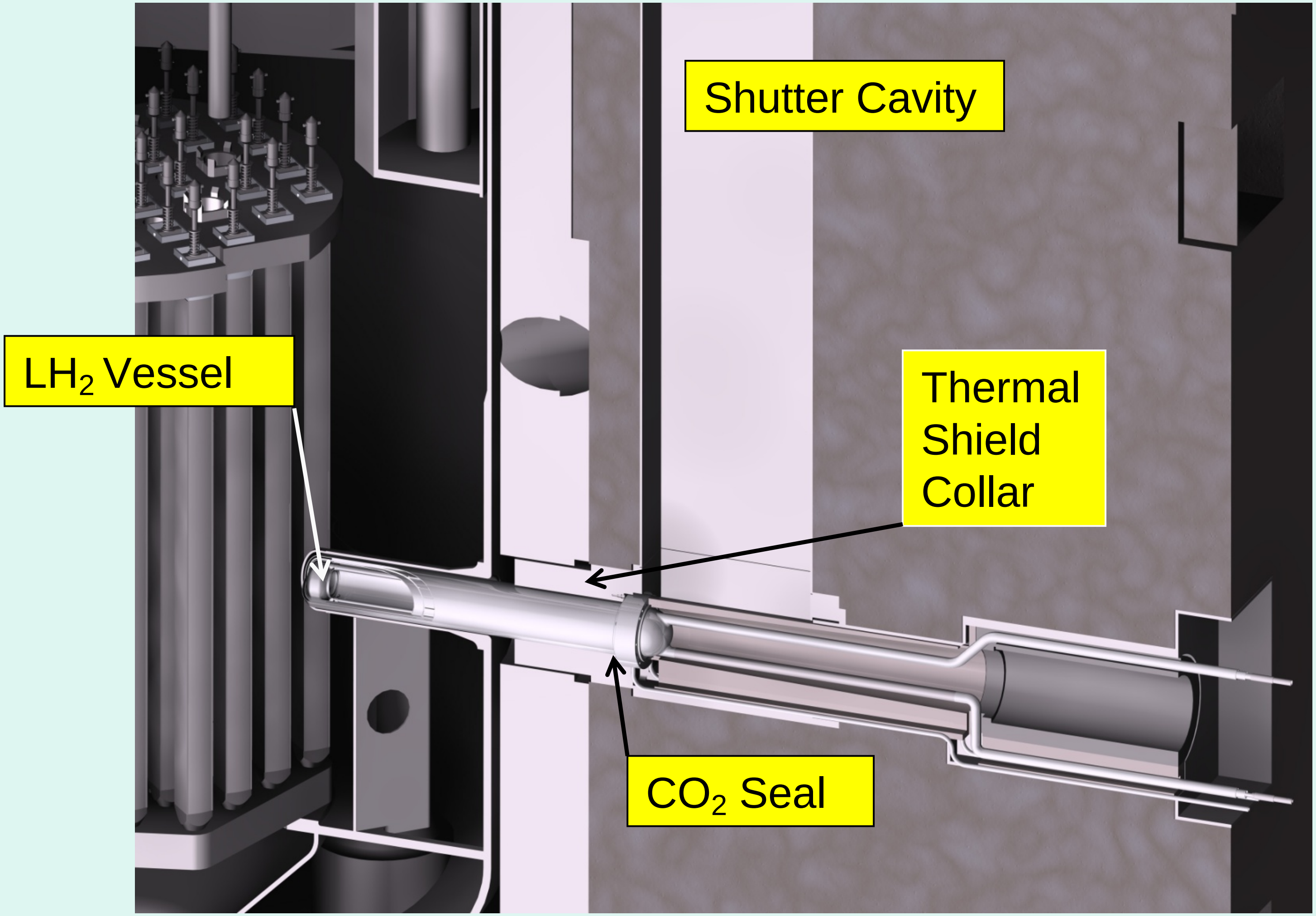
Inpile Assembly

The plug provides shielding and supports the cryostat assembly.

A diverging beam of cold neutrons is provided for MACS.

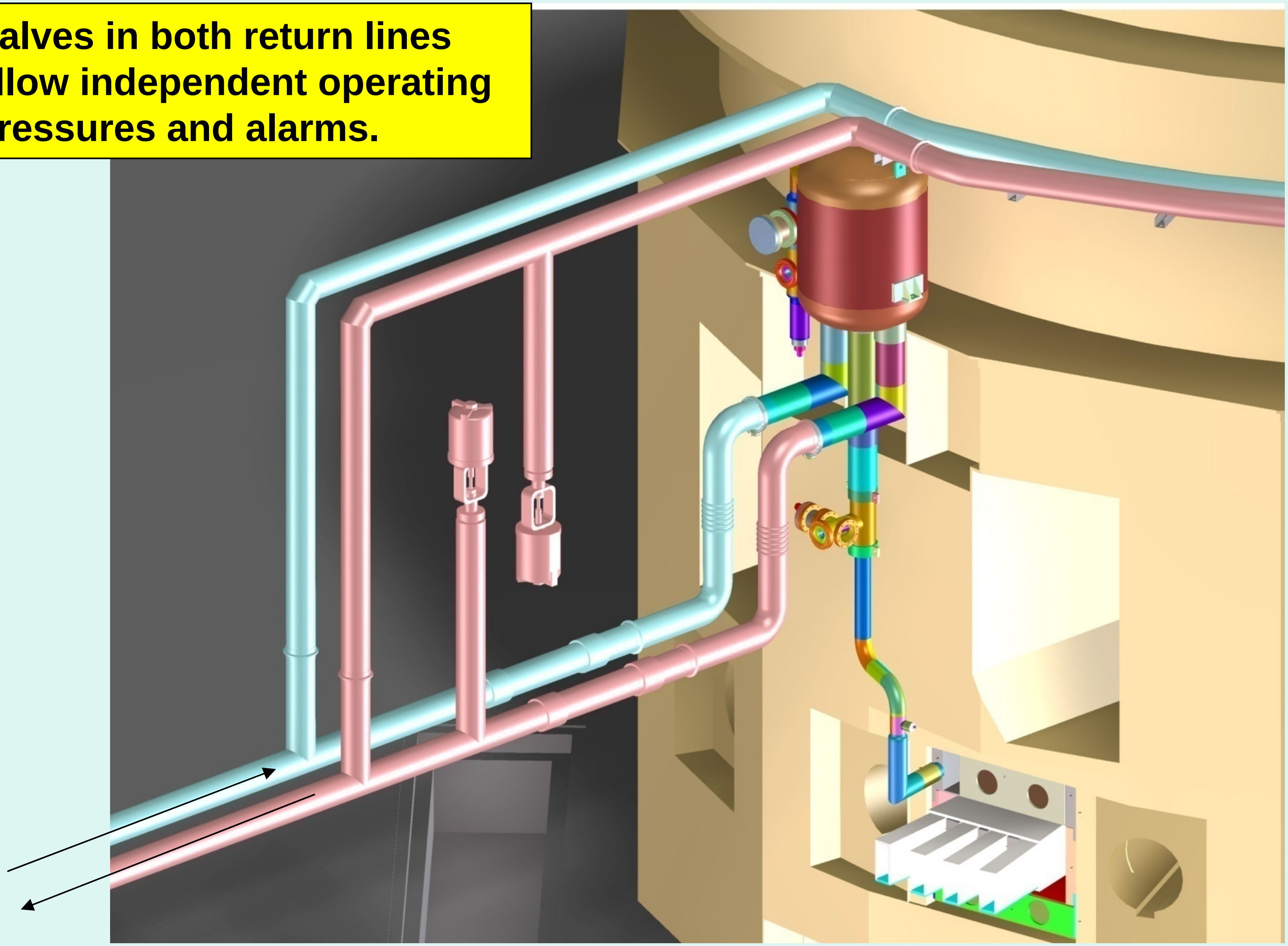


Installation of the Cryostat Assembly in the BT-9 Beam Port

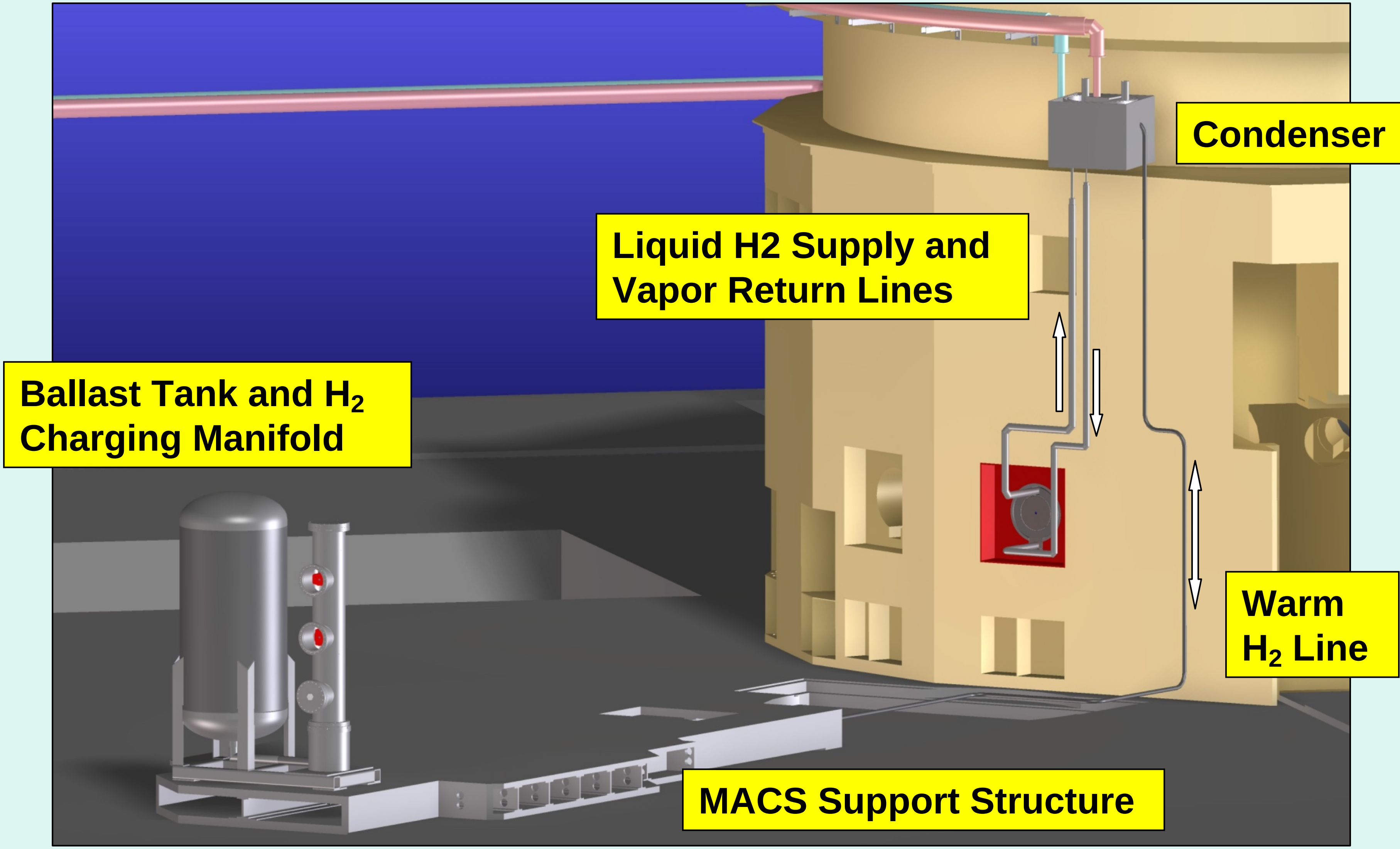


Refrigerator Load Lines for the Addition of Pee Wee

Valves in both return lines allow independent operating pressures and alarms.



Approximate Locations of Major Components of the BT-9 Cold Source



BT-9 CNS Moderator Chamber (11.3-cm OD)

BT-9 CNS Helium Containment Jacket (~1 meter long)

Cold Source Parameters

	Existing Source	BT-9 Source
	(Unit 2)	(Pee Wee)
Geometry	Elliptical Annulus	Disk
Diameter (cm)	32 x 24	11
Thickness (cm)	2 – 3	4.5
LH_2 Volume (L)	5.0	0.45
LH_2 Mass (g)	320	27
Al Mass (g)	2840	140
Ballast Tank Volume (m^3)	2.0	0.38
H_2 Inventory (g)	720	130

Like Unit 2, PeeWee will operate between 0.1 MPa (20.4 K) and 0.4 MPa (warm).

Conclusion

- A second cold source is being built for the spectrometer, MACS, displaced by the NCNR expansion project.
- Thermal-hydraulic tests have demonstrated the feasibility of operating it as a thermosiphon.
- Existing refrigerator and control system can accommodate the new source.
- Accident scenarios are bounded by Unit 2
- The source will be installed in 2011.

NCNR