NEUTRON SOURCES

- Types of Sources
- U.S. Sources Available for Users
- Plans for the Future
- The Neutron Scattering Society of America (NSSA)

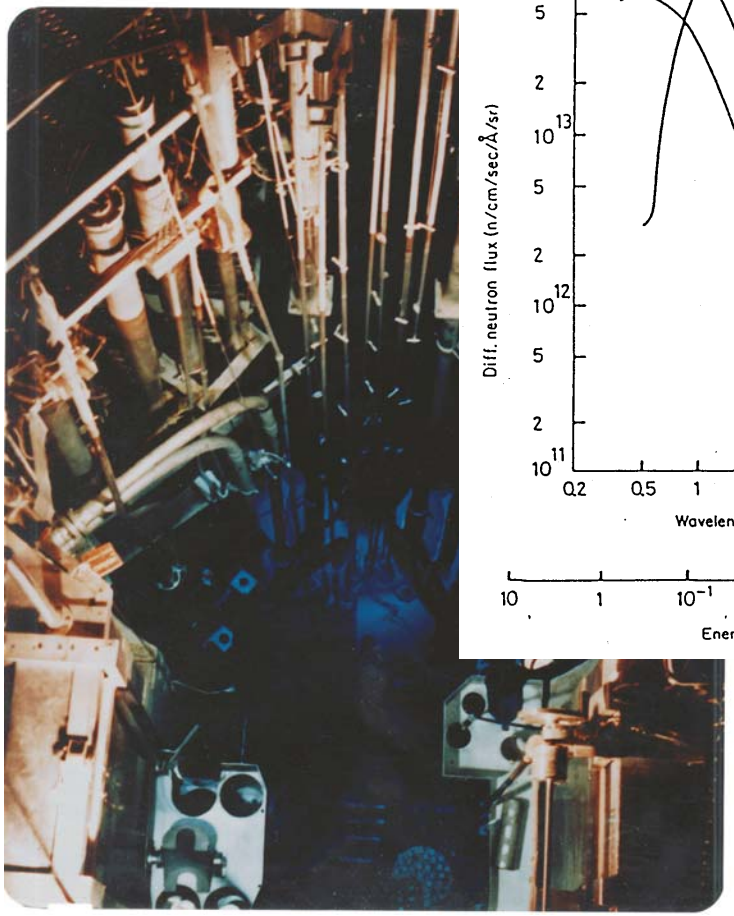
Jim Rhyne
Lujan Neutron Scattering Center
Los Alamos National Lab.

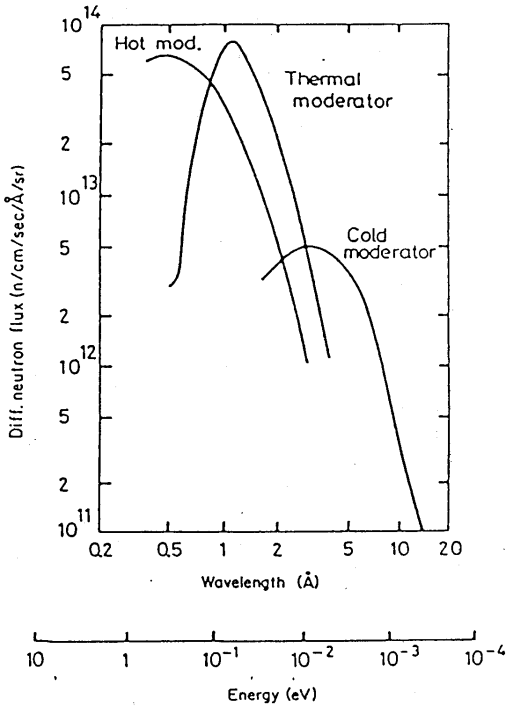
What do we need to do neutron scattering?

- **Neutron Source – produces neutrons**
- **Diffractometer or Spectrometer**
  - Allows neutrons to interact with sample
  - Sorts out discrete wavelengths by monochromator (reactor) or by time of flight (pulse source)
  - Detectors pick up neutrons scattered from sample
- **Analysis methods to determine material properties**
- **Brain power to interpret results**

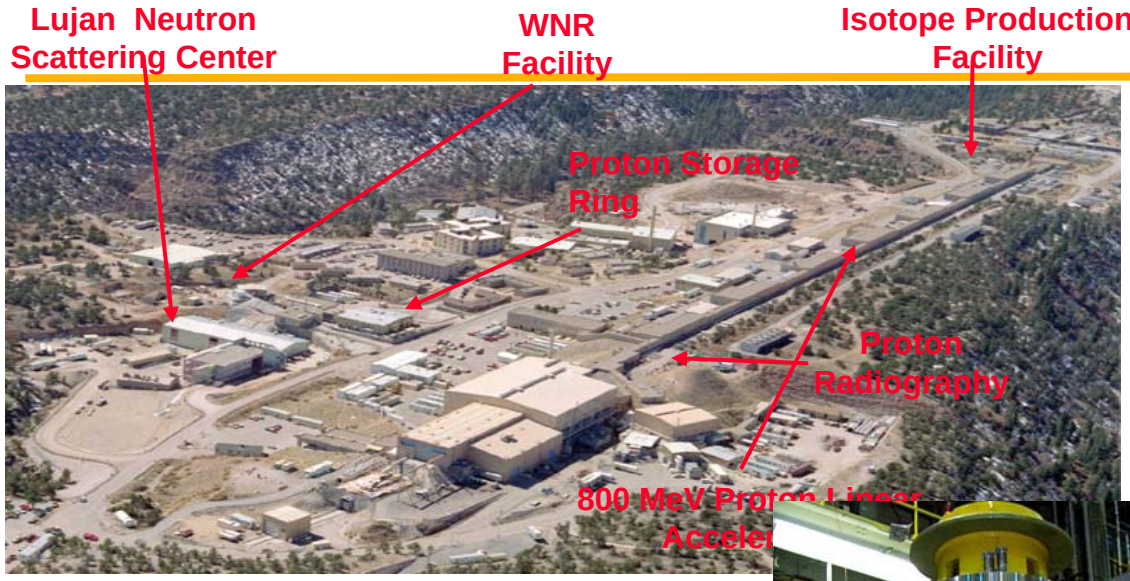
Sources of neutrons for scattering

- **Nuclear Reactor**
  - Neutrons produced from fission of ^{235}U
  - Fission spectrum neutrons moderated to thermal energies (e.g. with D_20)
  - Continuous source – no time structure
  - Common neutron energies -- 3.5 meV < E < 200 meV

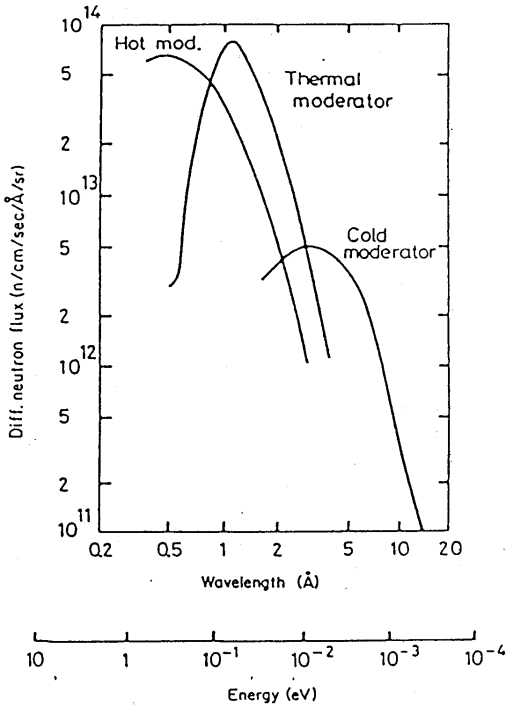


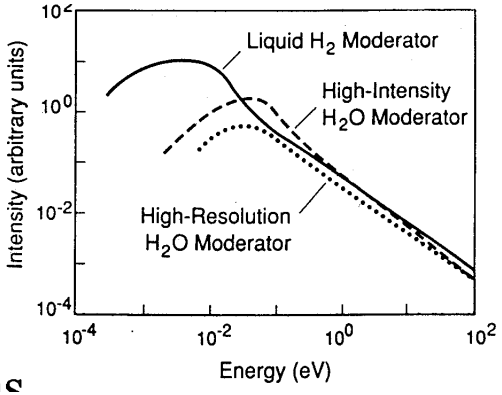


Pulse sources – time structure and wide energy spectrum



- **Proton accelerator and heavy metal target (e.g., W or U)**
  - Neutrons produced by spallation
  - Higher energy neutrons moderated to thermal energies
  - Neutrons come in pulses (e.g. 20 Hz at LANSCE)
  - Wider range of incident neutron energies





Neutron scattering machines

- **Spectrometers or diffractometers**
  - typically live in a beam room or guide hall
  - are heavily shielded to keep background low and protect us
  - Receive the neutrons from the target (or reactor)
  - Correlate data with specific neutron wavelengths by time of flight
  - Accommodate sample environments (high/low temperature, magnetic fields, pressure apparatus)

User instruments span general purpose and specialized categories

- **Diffraction instruments**
  - Atomic and magnetic structures – polycrystalline and single crystal form
- **Inelastic instruments**
  - Dispersive and non-dispersive excitations
  - Magnetic modes (magnons or crystal field excitations)
  - Phonon modes and density of states
- **Special purpose instruments**
  - Neutron reflectivity (depth profile of order parameters)
  - Small angle scattering (bridge between atomic and macro-dimensional structures)
  - Neutron applications to engineering problems
- **Sample environments enable science**

Sample environments – key to modern experiments

- **Extremes of temperature**
  - Low (cryostats)
    - » conventional closed cycle refrigerators [Joule expansion cycles] (4K and up)
    - » He cryostats (1.2 K [pumped] and up)
    - » He^3-He^4 dilution refrigerators (20 mK and up)
  - High (furnaces)
    - » Conventional (up to 1200 C)
    - » Special purpose (up to 3000 C)
- **Magnetic fields on samples**
  - Fe-core magnets (up to about 3T)
  - Superconducting magnets (typical – 9T; special [finicky] – 18T)
- **High Pressure**
  - Fluid cells (He or liquid) [up to 1.4 GPA (14 kbar)
  - Anvil presses (up to 40 GPa)
- **Other specialized environments – sheer cells, Langmuir troughs, etc.**

National User Facilities

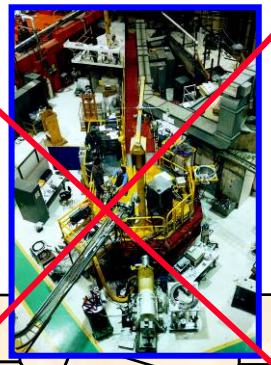
Have sample, will travel

Where do I go to get neutrons?

There are ~~five~~ four National User Facilities for neutron scattering in the US

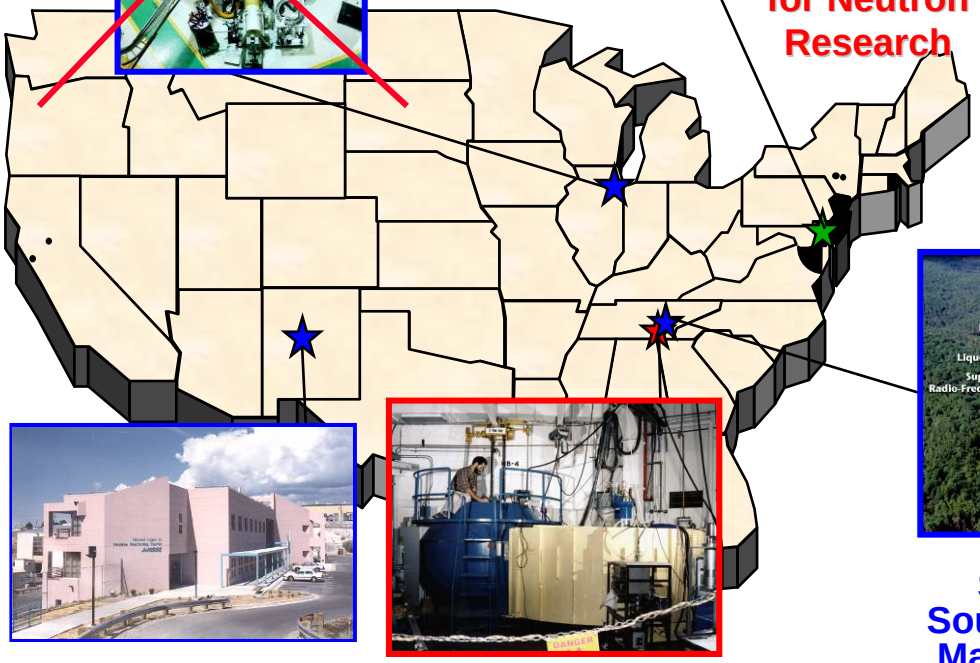
National User Facilities
HFIR 1966
NCNR 1969
IPNS 1981-2008
Lujan 1985
SNS 2006

Local/Regional Facilities (University Reactors)
MIT
Missouri
…



Intense Pulsed Neutron Source (7 kw)

NIST Center for Neutron Research



Manuel Lujan Jr. Neutron Scattering Center (100 kW)

High-Flux Isotope Reactor

Spallation Neutron Source (first neutrons in May 2006 -- operational instruments in 2007) (1400 kW)

US Neutron Source Support

- DOE operates 3 out of 4 of the Major Neutron Sources (and supports fuel for university reactors)
- DOC/NIST operates the only fully internationally competitive neutron facility (NCNR) with the largest user base (cold neutrons)
- NSF, NIH, and DOD support current neutron beam research mostly by supporting university research
  - EXCEPTIONS: NSF funds the Center for High Resolution Neutron Scattering (CHRNS) at NIST, and has supported some construction of instruments at LANSCE, HFIR, IPNS and MURR) NIH has funded a reflectometer at NCNR.

World View of Neutron Scattering Facilities

Facility	Start Operation	Cease Operation	Country	Type	Time structure	Peak Flux x 10-14	Power	Instruments Total	Diffraction	Low Q	Inelastic
NRU	1957	2005	Canada	Reactor	Continuous	3	120MW	5	2	1	2
R-2	1960		Sweden	Reactor	Continuous	1	50MW	6	5	0	1
IBR-2	1961		Russia	Reactor	Pulsed		2MW	13	5	4	4
FRJ-2	1962	2006	Germany	Reactor	Continuous	2	23MW	15	5	5	5
DR3	1963	2000	Denmark	Reactor	Continuous	1.5	10MW	7	2	3	2
HFBR	1965	1999	US	Reactor	Continuous	4	30MW	13	7	2	4
HFIR	1966		US	Reactor	Continuous	12	85MW	10	3.7	3	3.3
NCNR	1969		US	Reactor	Continuous	2	20MW	17	2	6	9
ILL	1972		France	Reactor	Continuous	12	58MW	34	15	4	15
BER-2	1973		Germany	Reactor	Continuous	2	10MW	15	10	2	3
Orphee	1980		France	Reactor	Continuous	3	14MW	25	12	6	7
KENS	1980		Japan	Spallation	Pulsed	3	3kW	15	5	4	6
IPNS	1981		US	Spallation	Pulsed	5	7kW	12	5	4	3
ISIS	1985		England	Spallation	Pulsed	20-100	160kW	19	9	3	7
LANSCE	1988		US	Spallation	Pulsed	30	56kW	7	3	2	2
JRR-3M	1990		Japan	Reactor	Continuous	2	20MW	23	7	5	11
SINQ	1996		Switzerland	Spallation	Continuous	2	1MW	10	5	2	3
Under development											
FRM-II	2002		Germany	Reactor	Continuous	7	20MW	17			
RR	2005		Australia	Reactor	Continuous	4	20MW	18			
SNS	2006		US	Spallation	Pulsed	200	2MW	24			
JSNS	2006		Japan	Spallation	Pulsed	100	1MW	24			
ESS†	2010		Europe	Spallation	Pulsed	2000	5MW	40			

The number of neutron scattering instruments available in the U.S. now and in the future will be less than half that available in Western Europe and less than available in Japan. On a per capita basis the United States has half the neutron scattering capacity of either Western Europe or Japan – and this shortfall is unlikely to change for the forseeable future

---- Ref. ***Report on the Status and Needs of Major Neutron Scattering Facilities and Instruments in the United States,*** June 2002

Center for Neutron Research

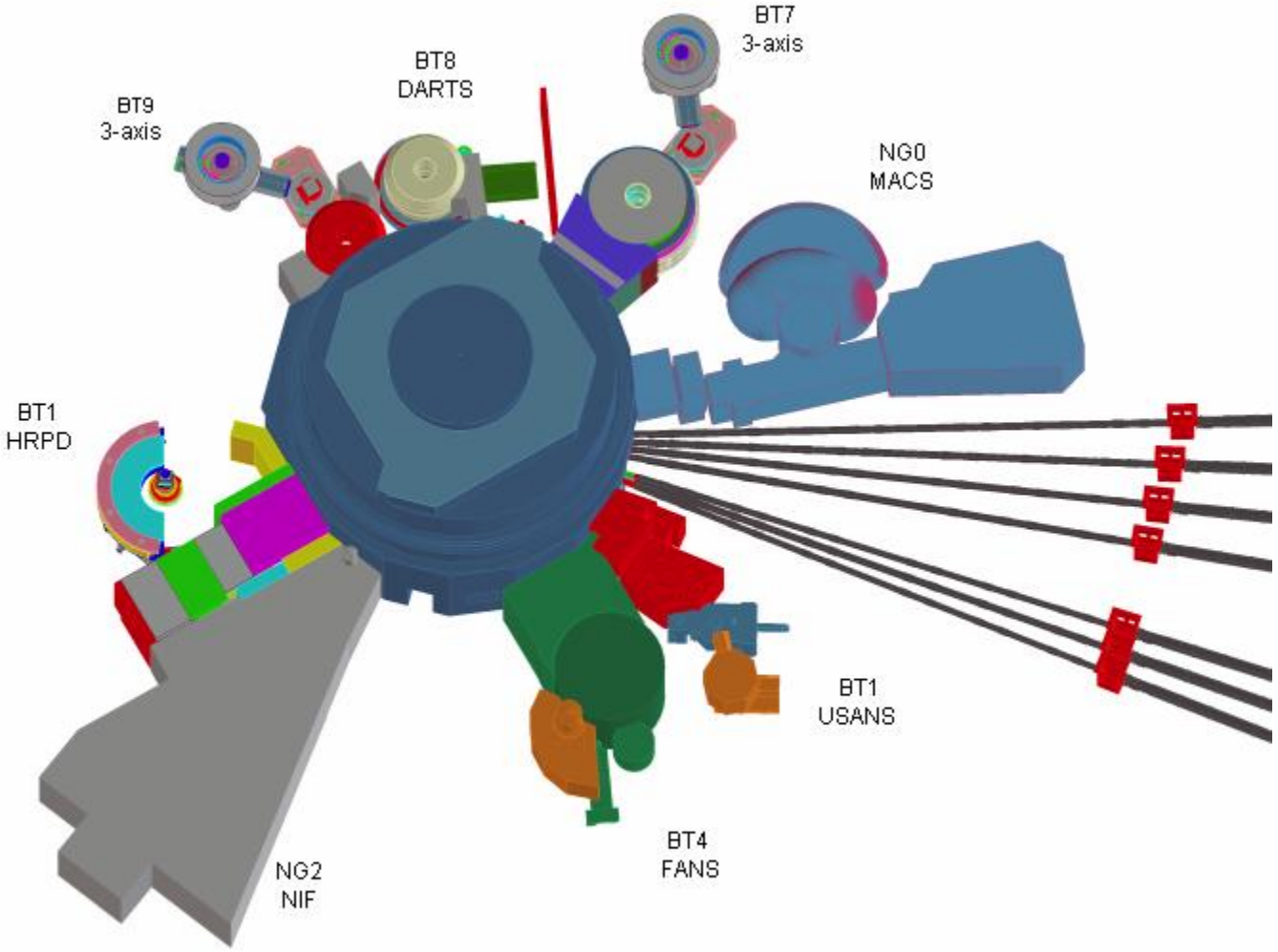
NIST Center for Neutron Research (NCNR)

A Comprehensive Neutron User Facility

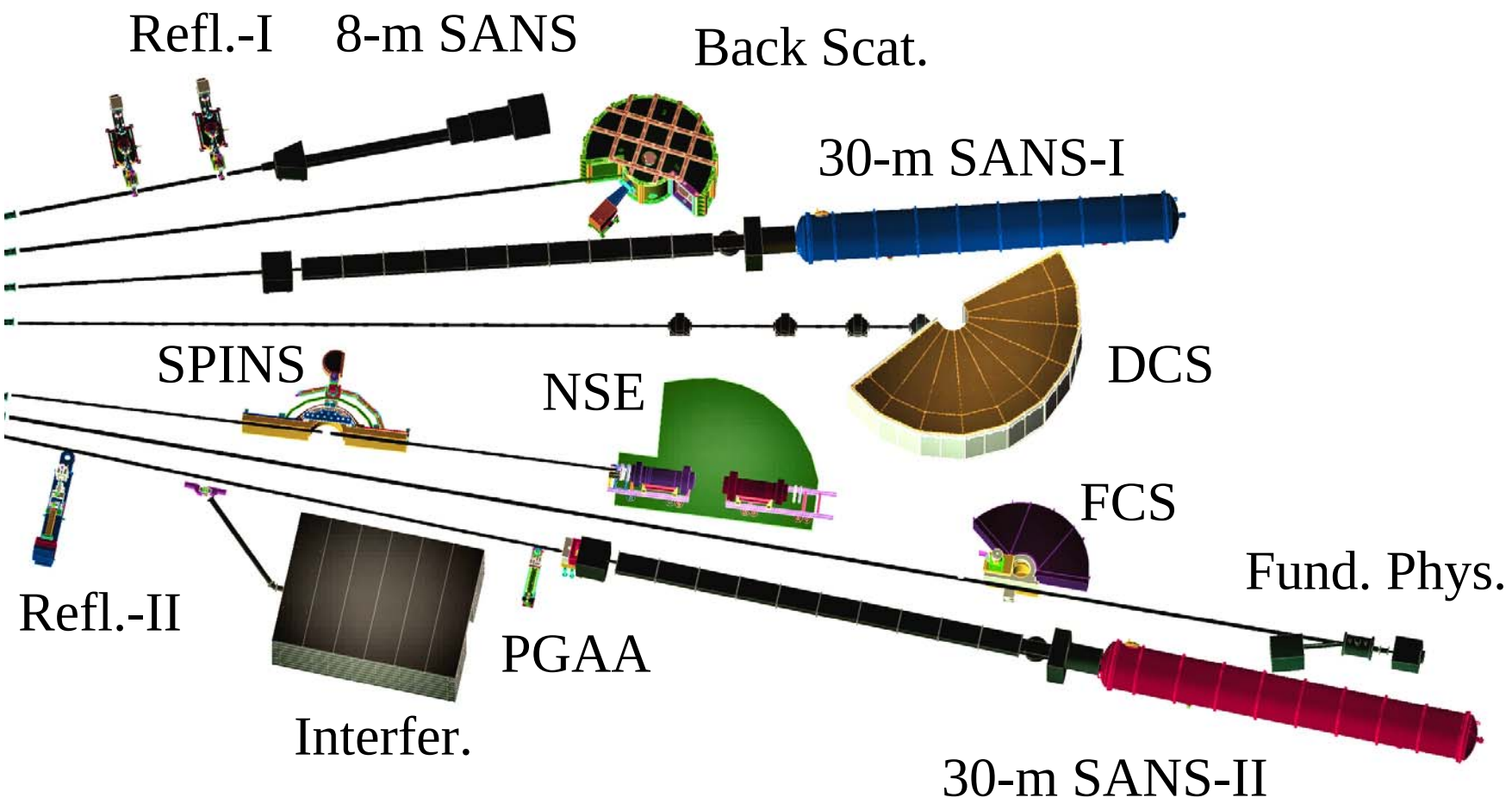
- 20 MW Heavy-Water-Moderated REACTOR
- A Cold Neutron Source and Guide Hall
- Current Total -- 17 Thermal and Cold Neutron Instruments
- Developing 2nd guide hall – Amer. Competes Act

Center for Neutron Research

Reactor Hall Instruments

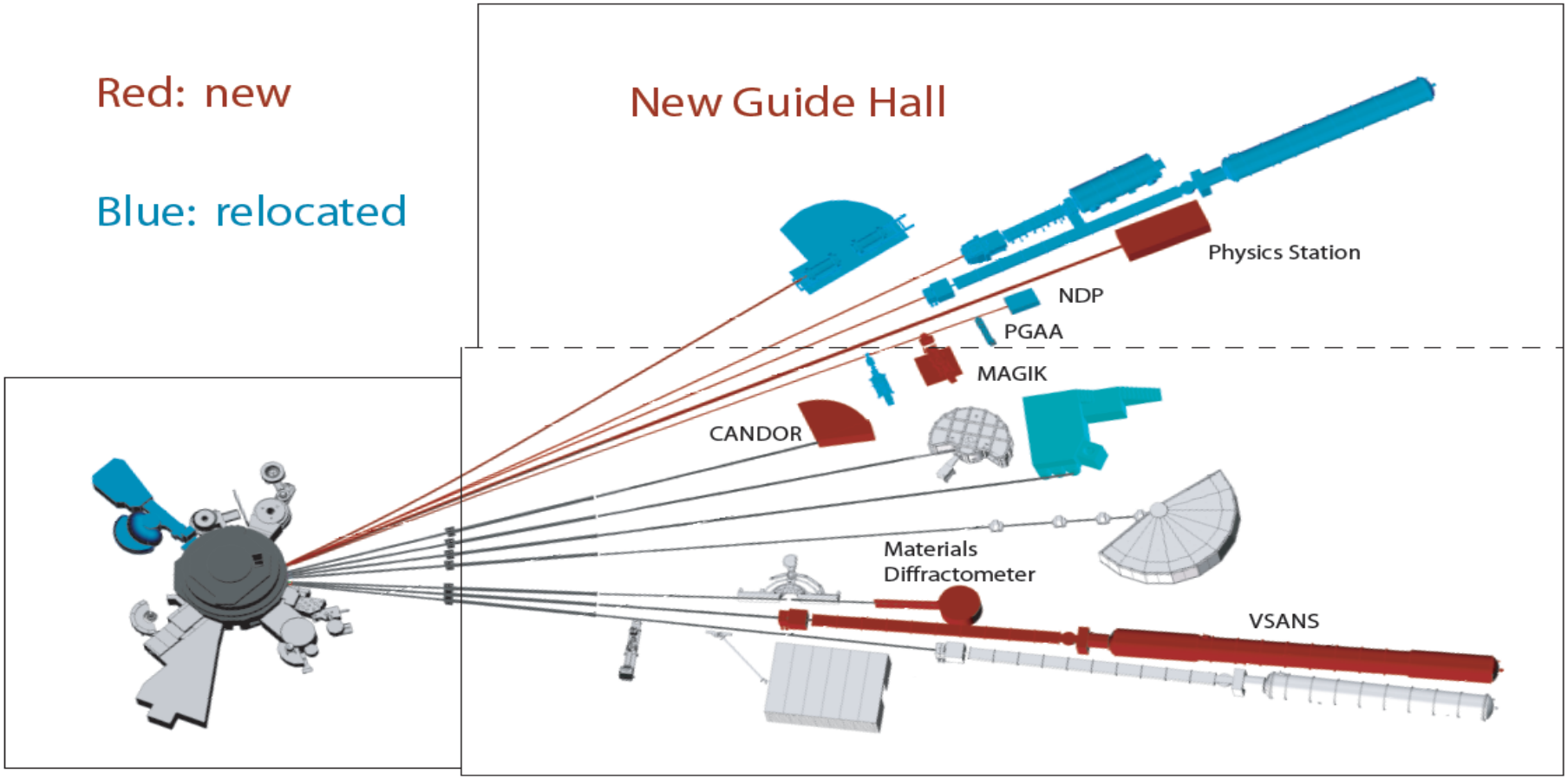


NCNR Guide Hall Instruments

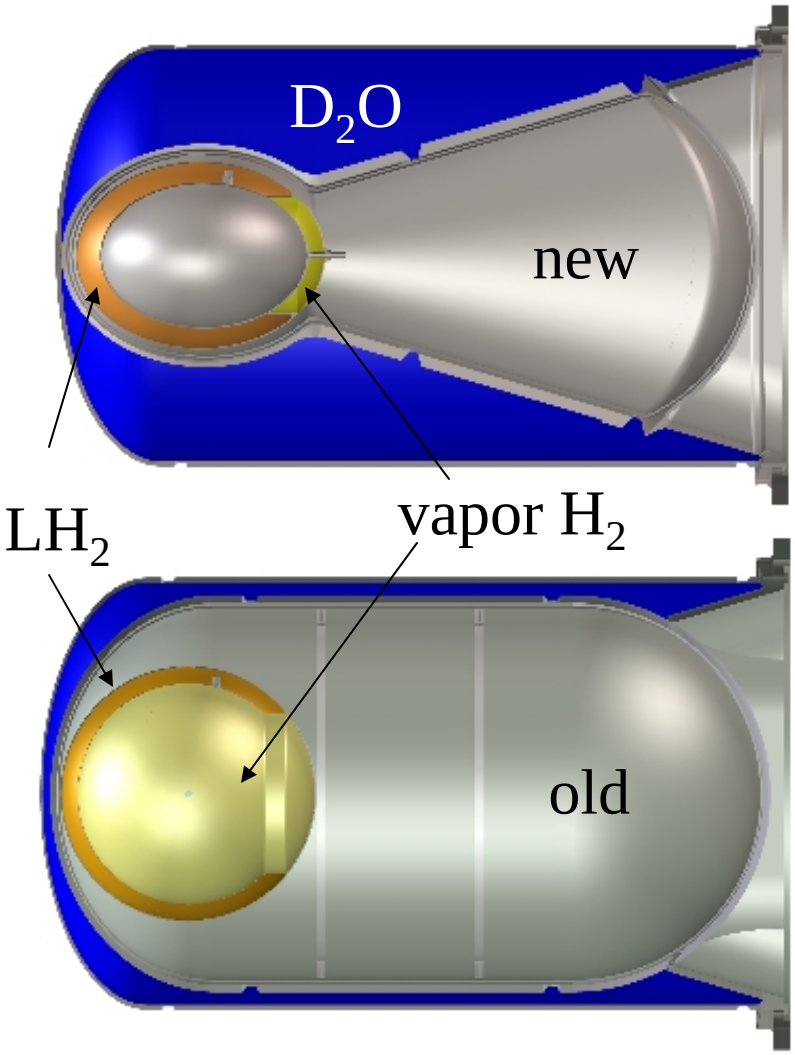


10 Cold-Neutron Scattering Instruments

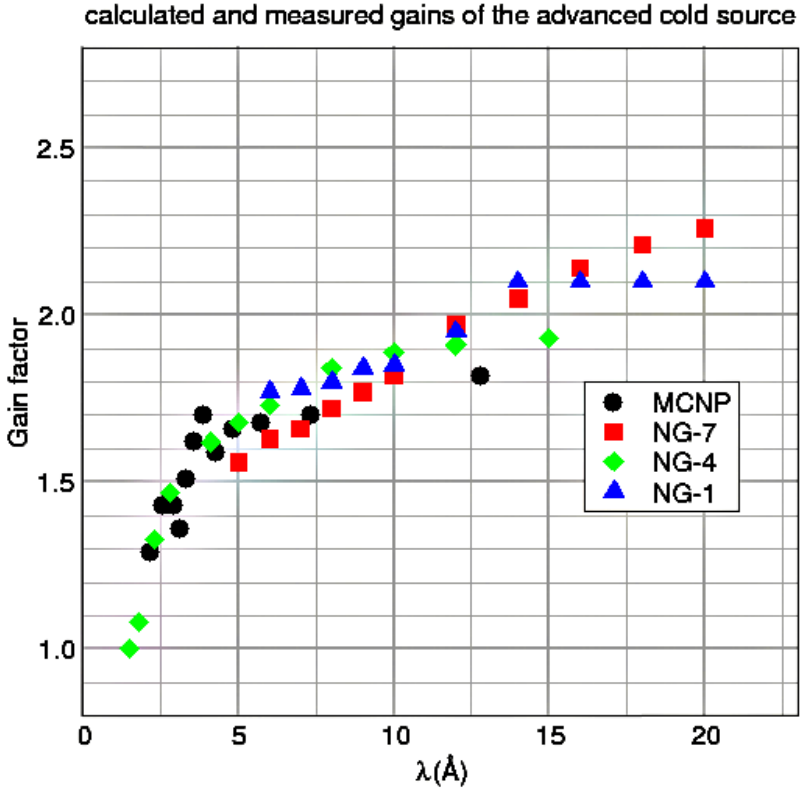
New Guide Hall Initiative
5 additional instruments



The NCNR Advanced Cold Neutron Source



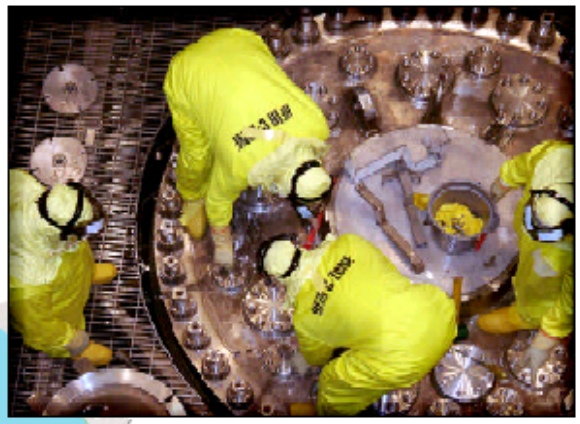
New source: additional D_2O acts as a neutron reflector. LH_2 thicker near source. Inner ellipsoid evacuated.



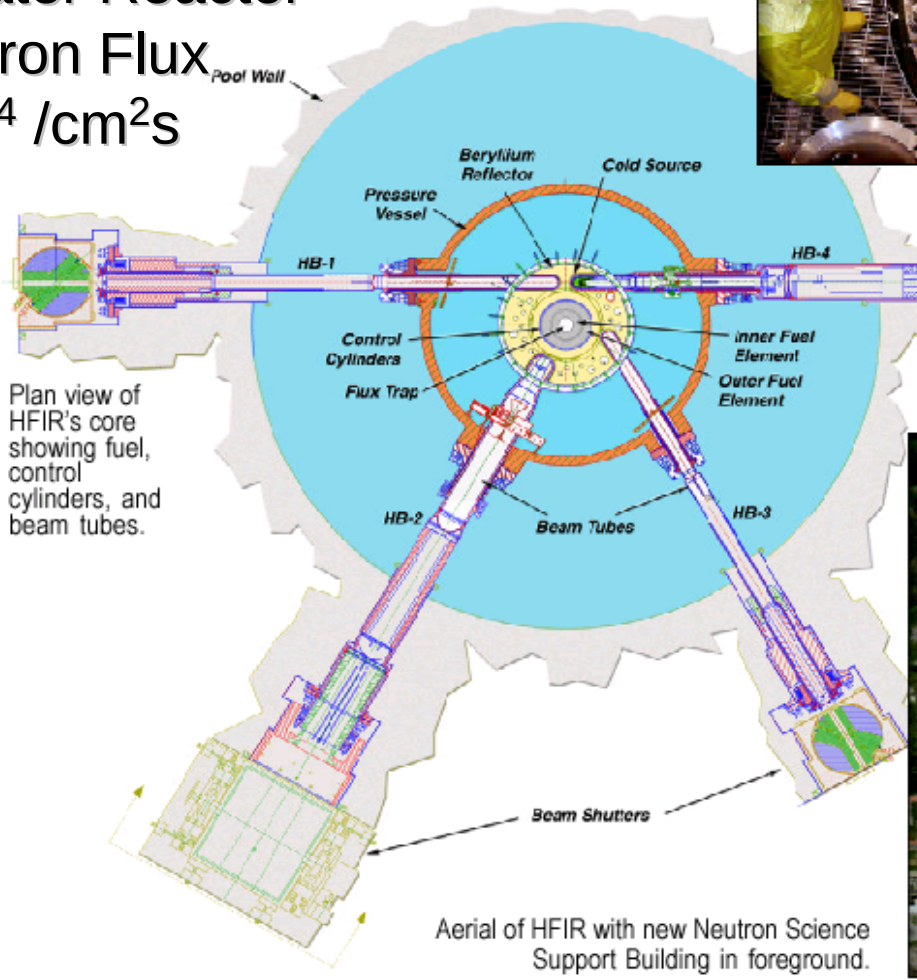
Overall gain: 40 % at 2.4 Å to slightly more than 100 % for $\lambda > 15$ Å. Excellent agreement with MCNP.

High Flux Isotope Reactor

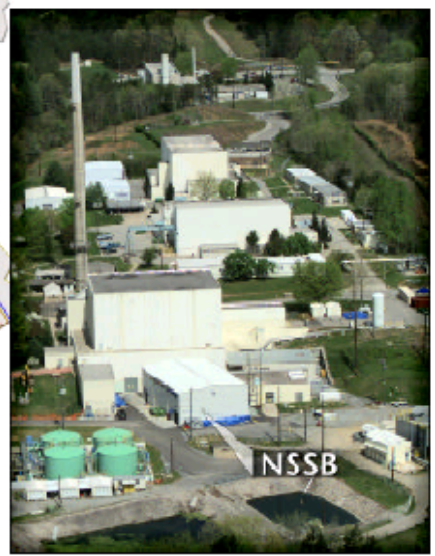
- Oak Ridge, Tennessee
- BES, Department of Energy
- Started Operation:1966
- 85 MW Light Water Reactor
- Peak Core Neutron Flux
  - 12×10^{14} /cm^{2}s



The reactor was disassembled and the beryllium reflector replaced.



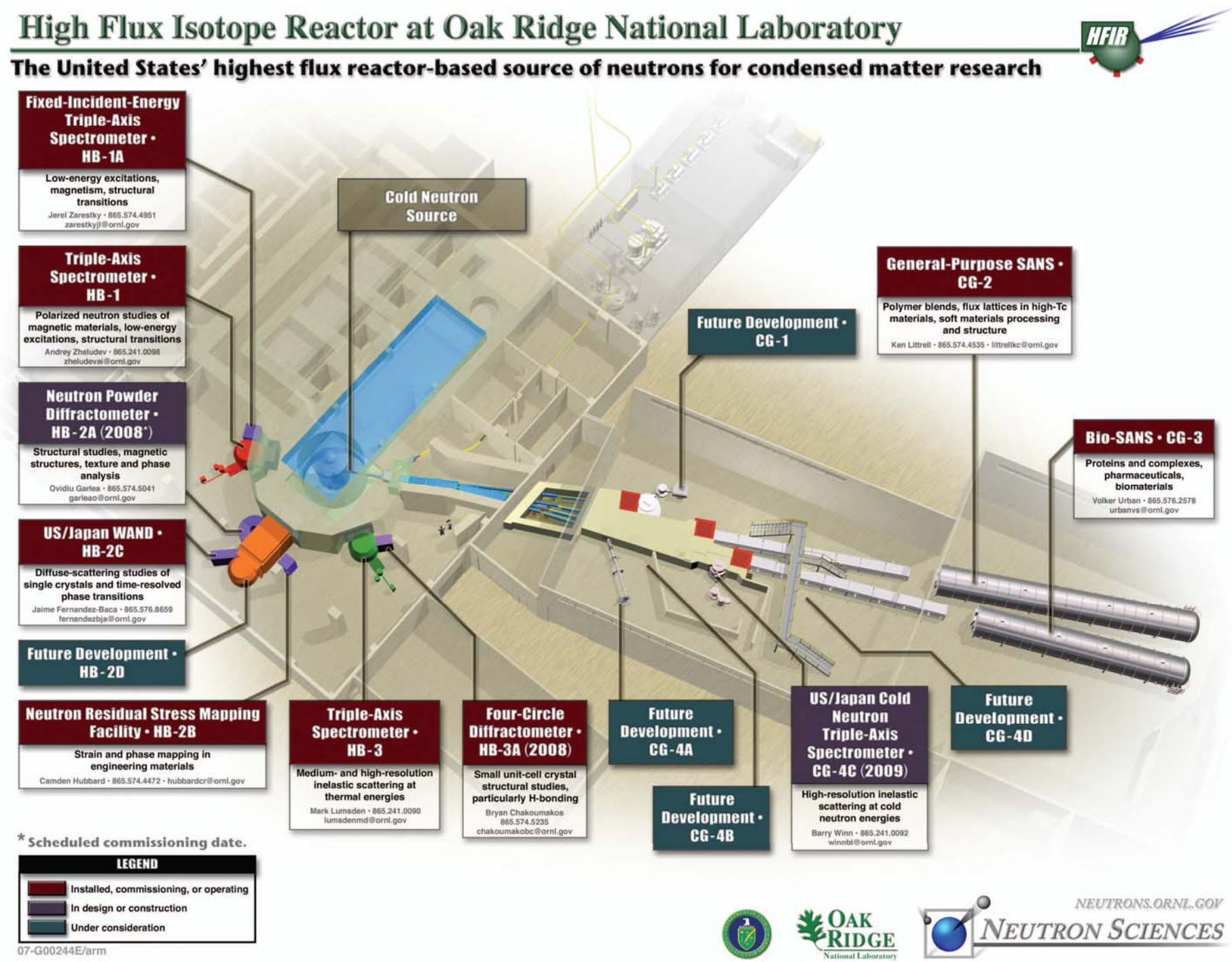
Plan view of HFIR's core showing fuel, control cylinders, and beam tubes.



Aerial of HFIR with new Neutron Science Support Building in foreground.

High Flux Isotope Reactor at Oak Ridge National Laboratory

The United States' highest flux reactor-based source of neutrons for condensed matter research



* Scheduled commissioning date.

LEGEND

- Installed, commissioning, or operating
- In design or construction
- Under consideration

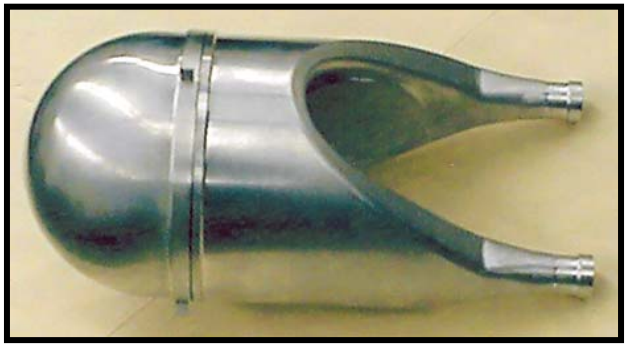
07-G00244E/arm

OAK RIDGE National Laboratory

NEUTRONS.ORNL.GOV
NEUTRON SCIENCES

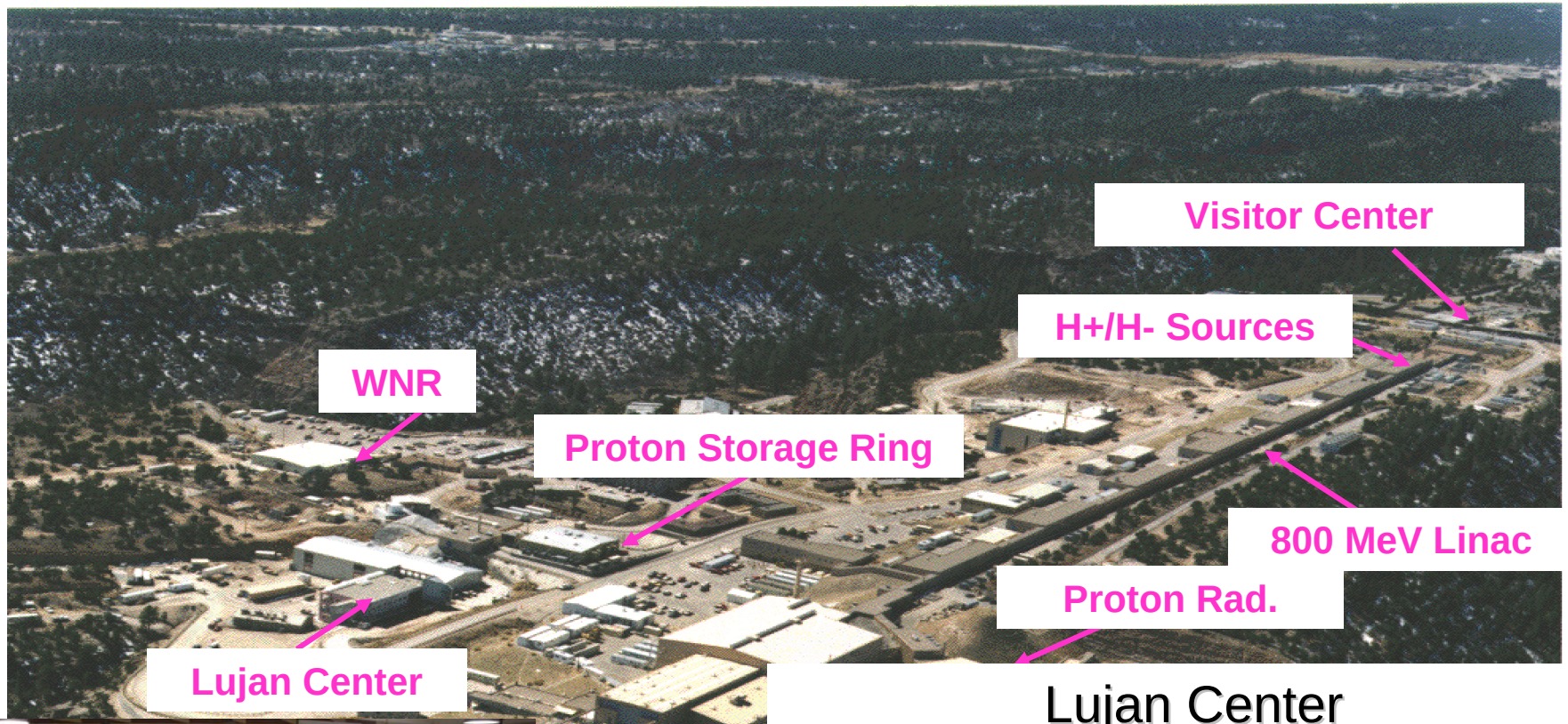
HFIR Neutron Scattering Upgrade

- Beam tubes enlarged to 6”
  - New monochromator dums
  - Focussing optics
- Cluster of 4 instruments at HB-2
  - Powder diffractometer
  - Triple axis spectrometer
  - Wide angle diffractometer
  - Residual stress spectrometer
- High-brightness cold source installed at HB-4 (guide hall)
  - 2 SANS (40m, 35m; flux gain x 100)
  - Cold triple axis spectrometer



- Schedule
  - Rx restarted May 2007 following cold source installation
  - Cold guide hall instruments – currently being completed

User Facilities at LANSCE: Los Alamos Neutron Science Center



Lujan Center

- BES/NNSA, Department of Energy
- Started Operation:1985
- 85 kW Spallation Source (LANSCE)
- Peak Flux – 30 x 10^{14} /cm^2s
- Cold Source
- 11 Instruments

Lujan has has 17 flight paths, 11 of which have neutron scattering instruments

Moderators (FPs)

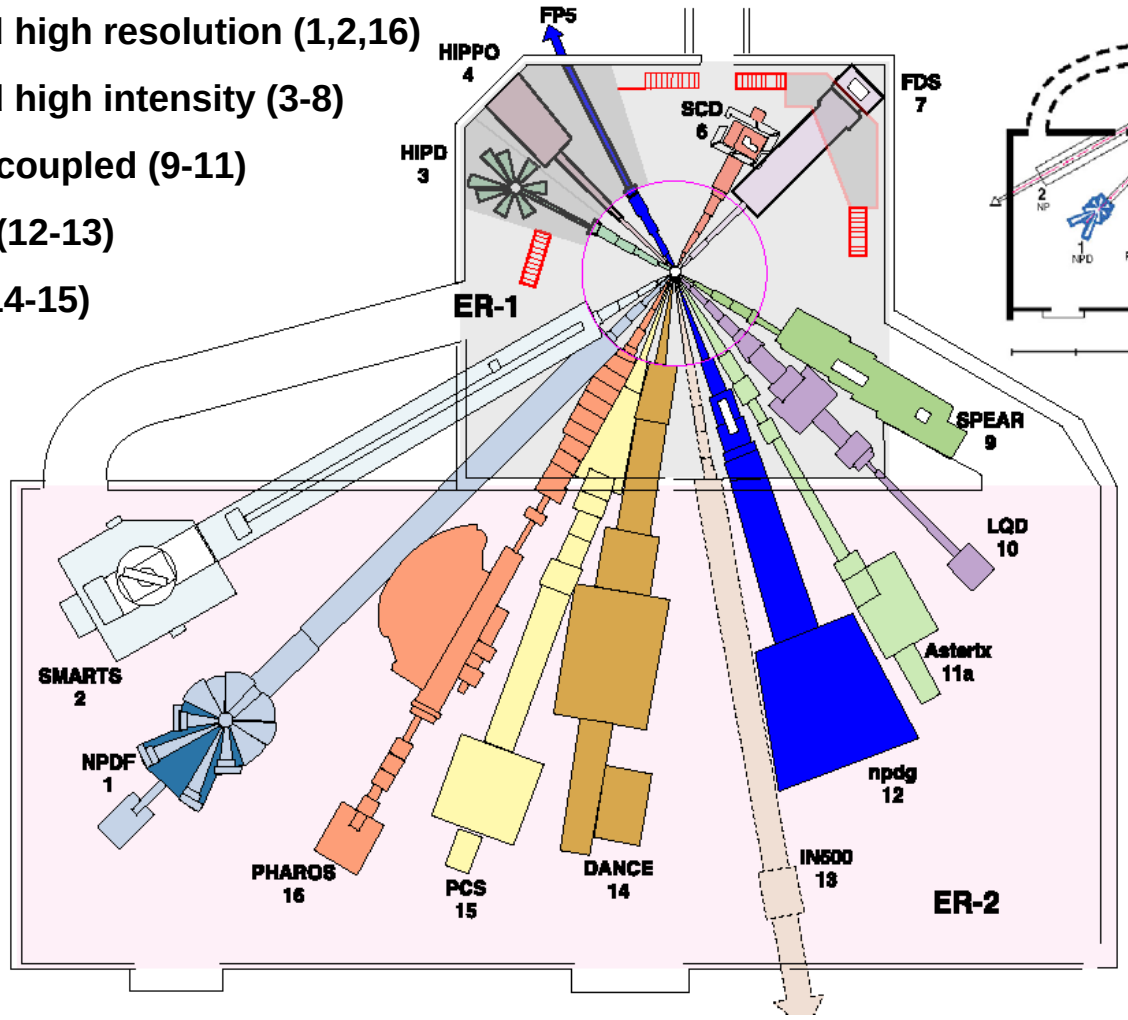
H_2O decoupled high resolution (1,2,16)

H_2O decoupled high intensity (3-8)

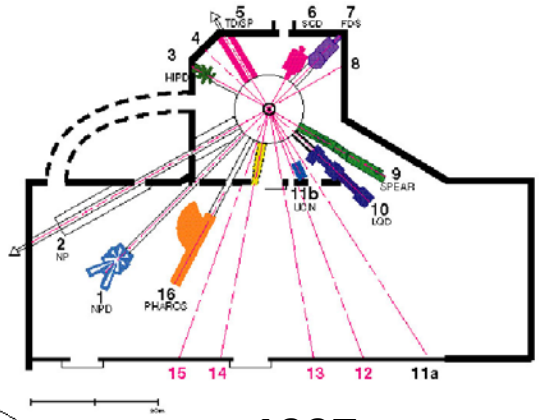
liq-H_2 partially coupled (9-11)

liq-H_2 coupled (12-13)

H_2O coupled (14-15)



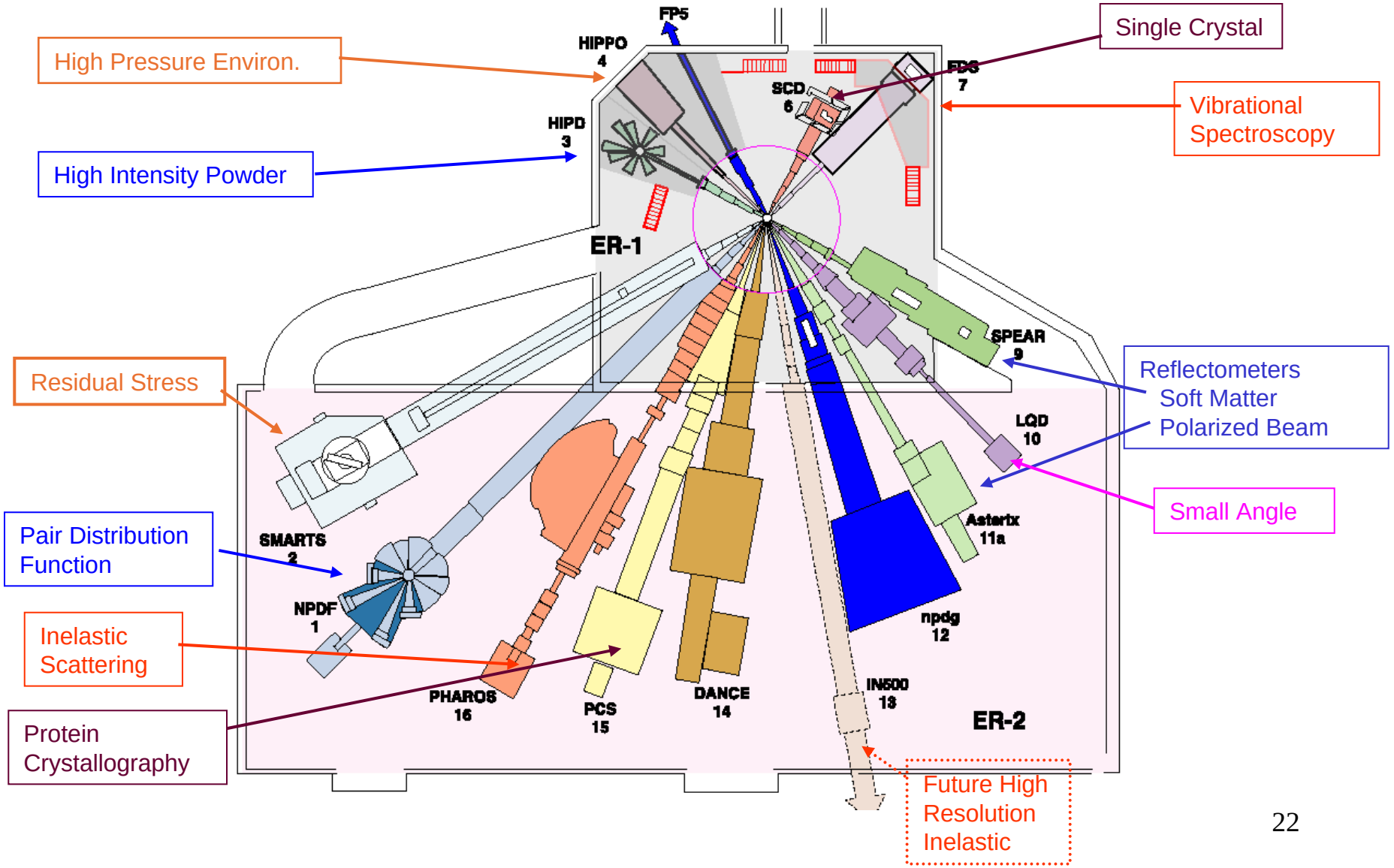
2004



1997

Rapid growth in number and versatility of instruments has occurred in the last decade

Instruments by functional categories

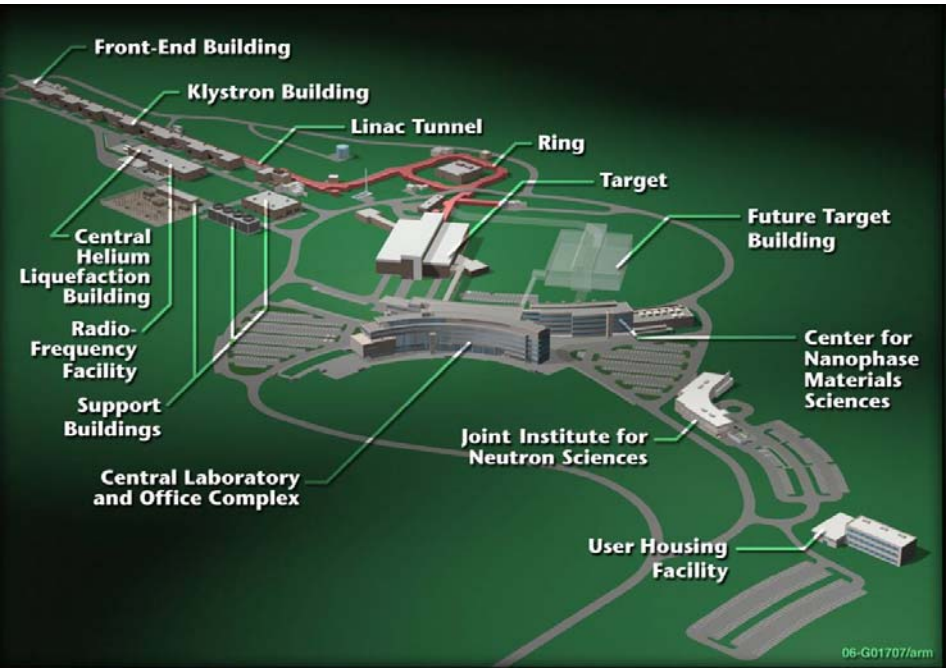


NRU Reactor – Chalk River, CA

- 125 MW heavy water reactor – Large Core, peak thermal flux of $3x10^{14}$, initial operation in 1957
- Seven beam tubes dedicated to neutron instruments
  - DualSpec
    - C2, High Resolution Powder Diffractometer
    - C5, Polarized Beam Triple-Axis Spectrometer /Reflectometer
  - D3 – Reflectometer
  - E3 – Materials Science Diffractometer
  - L3 – Strain-Scanning Spectrometer
  - N5 – Triple-axis Spectrometer
  - T3 – Bioscience Diffractometer

- Neutron Scattering Program Funded/Operated by National Research Council of Canada

SPALLATION NEUTRON SOURCE



- First neutron production ~~scheduled for~~ June 2006
  April 28, 2006
  2:04 p.m.
- Started with 3 (soon to be 8) instruments
- Capacity for a total of 24 instruments – plan for second target
- Accommodate 2000 users/year at full operation

Procedure for Obtaining Time on Spectrometers

- Make contact with and discuss proposed experiments with instrument scientist at facility
- Go to facility web site and access proposal form – complete by deadline (caution: usually only 2 per year!)
- Approval (declination) received within about 6 weeks
- Fine tune schedule with instrument scientist (if necessary)
- Complete radiation training module and access approvals in advance of visit (each lab has different procedures).
- If using ancillary equipment, make sure sample dimensions are correct, etc.
- Arrange travel and housing for visit (partial travel assistance may be available for fist-time visitors or students.)
- Arrive at facility in advance of allocated time to set up experiment
- Apply for more time for next series of experiments (max. about 2 – 3 visits/year)

Reports

- *Neutron Source Upgrades and Specifications for SNS* (1996)
  - Research Reactor Upgrades, Robert Birgeneau, Chair
  - Spallation Neutron Source Upgrades, Gabriel Aeppli, Chair
  - Technical Specifications for the Next Generation Spallation Source, Thomas Russell, Chair
- *Review of the High Flux Isotope Reactor Upgrade and User Program* (October, 1998; Jack Crow, Chair)
- *Neutron Scattering* (February, 2000; Martin Blume, Chair) http://www.sc.doe.gov/production/bes/BESAC/neutronrpt.pdf
- *Review of IPNS/LANSCE* (March, 2001; Ward Plummer, Chair)
- ***Report on the Status and Needs of Major Neutron Scattering Facilities and Instruments in the United States*** (June 2002; Patrick Gallagher, Chair) http://www.ostp.gov/html/NeutronIWGReport.pdf

Information on North American National Neutron Scattering Facilities

- ***Neutron Scattering Society of America (NSSA)*** [on-line or mail-in membership form]
  - http://www.neutronscattering.org
  - Announcements of meetings, workshops, etc.
  - Links to major neutron facilities
- ***Oak Ridge Spallation Neutron Source (SNS) and High Flux Isotope Reactor (HFIR)***
  - http://neutrons.ornl.gov/
- ***NIST Center for Neutron Research (NCNR)***
  - http://www.ncnr.nist.gov/
- ***Los Alamos Lujan Neutron Scattering Center (LANSCE)***
  - **http://lansce.lanl.gov/**
- ***NRU Chalk River***
  - ***http://neutron.nrc.ca/intro.html***

Neutron Scattering Society of America (NSSA)

Purpose and New Initiatives

NSSA www site: www.neutronscattering.org

SNS/ANL School on Neutron and X-Ray Scattering
May-June 2009

What is the NSSA?

- NSSA is an organization of scientists and engineers with a common interest in using neutron scattering for research.
- Formed in 1992, NSSA now has almost 1500 members from 26 countries
- Became a non-profit corporation in 2002
- Sister organizations in Europe, Japan and Canada
- NSSA is an advocacy group for YOUR CONCERNS about neutron sources, instruments, and user policies

NSSA GOALS AND PURPOSE

- To identify and provide a focal point for the neutron scattering community in the USA
- To identify the needs of the neutron community (present and future source and instrumentation requirements) and to bring these needs to the neutron facility management and funding sources.
- To foster educational activities associated with neutron scattering including conferences, workshops, and neutron scattering schools.

From the Members

- We ask our members to freely communicate to NSSA their successes, problems, and concerns about present-day issues and longer-term concerns about new sources and instruments.
- We call on our members (hopefully not too frequently!) to write to the Federal Funding Agencies and to the Congress on issues affecting the future of our careers.
- In short, **WE WANT AND NEED TO HEAR FROM YOU:**
  - www.neutronscattering.org
  - fernandezbja@ornl.gov

NSSA Executive Committee Elected 2009

- **President: *Bruce Gaulin***, Dept. of Physics, McMaster Univ.
- **Vice-President: *Simon Billinge*,** Dept. of Physics, Columbia University
- **Secretary: *Suzanne G.E. te Velthuis*,** Matls. Science Division, Argonne National Lab.
- **Treasurer: *John Tranquada*,** Physics Dept., Brookhaven National Lab
- **Membership Secretary: *Jaime Fernandez-Baca*,** Neutron Sciences Division, Oak Ridge National Laboratory
- **Communications Secretary: *Thomas Proffen*,** Lujan Center, Los Alamos National Laboratory
- **3 Members at Large (to be nominated by Executive Committee)**

Current NSSA Concerns

- Building an enthusiastic young group of neutron scattering investigators who will be the core users and support of the SNS and upgraded facilities at other sources.
- Reassuring graduate students* that neutrons have a bright future in the US

(* i.e., can I get a job and do research if I get a Ph.D. in neutron scattering?)

Current NSSA Initiatives

- Organizes the ***American Conference on Neutron Scattering.*** This meeting, held every two years, has a rotating venue among the national neutron centers. It is intended to serve as a national user meeting as well as showcase recent research results.
- Awards the Clifford G. Shull Prize in Neutron Science, the NSSA Sustained Research Prize, the NSSA Science Prize, and the Outstanding Student Research Prize
- Hosts information booths and displays at major national meetings (e.g., March 2000 – 2006 APS)

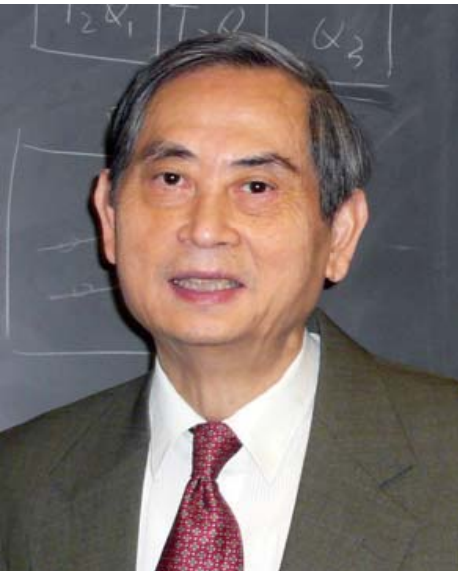
ACNS American Conference on Neutron Scattering

- 2008 Meeting held in Santa Fe, New Mexico May 11-15
- 400 in attendance
- > 300 papers including large number of invited/tutorial papers
- Third Shull Prize in Neutron Science awarded to Prof. Sow-Hsin Chen from MIT
- Several tutorial workshops were held on Sunday before conference
- Next conference 2010 – location TBD

Clifford G. Shull Prize

in Neutron Science

Prof. Sow-Hsin Chen from MIT
received the 2008 Clifford G. Shull Prize



"For seminal contributions to understanding the dynamical properties of supercooled and interfacial water using neutron scattering techniques, and for an exceptional record of training young scientists in the use of scattering techniques to solve topical interdisciplinary problems in complex fluids and soft matter."

NSSA Research Prizes

- ***Prof. Seung-Hun Lee***

  University of Virginia, received the 2008 Sustained Research Prize

  "For his innovative and insightful neutron scattering studies of frustrated magnetic systems"

- ***Prof. Frank Bates***

  University of Minnnesota received the 2008 Science Prize

  "For his pioneering SANS experiments that probe the structure and thermodynamics of polymeric fluids and block copolymers."

- **NSSA also awards an Outstanding Student Research Prize at each ACNS**

U.S. Neutron Scattering Schools

- National Neutron and x-ray Scattering Summer School
  - Introduction to neutron and x-ray scattering
  - Now 2 ½ weeks – Month varies
  - http://www.dep.anl.gov/nx/; Application deadline -- varies
- NCNR-NIST Summer School
  - Emphasizes alternately NCNR neutron spectroscopy and small angle scattering and reflectometry instruments
  - One week in June
  - http://www.ncnr.nist.gov/summerschool/index.html ; Application deadline -- April
- LANSCE School in Neutron Scattering
  - Topical focus (changes each year)
  - 9 days – Month varies depending on beam cycle
  - http://www.lansce.lanl.gov/neutronschool/ ; Application deadline -- varies
- All have a mixture of classroom lectures and hands-on experiments
- All have funds for travel and subsistence support for students accepted
- Students need not be US citizens, but must be affiliated with a US university, industry, or national laboratory

LANSCE Neutron Scattering School

PhaseTransformations Studied With Neutron Scattering

July 7-17, 2009

Los Alamos National Laboratory, Los Alamos, New Mexico USA

With the construction of the world's most powerful neutron source, the Spallation Neutron Source, the future for neutron scattering is bright in the U.S. Added to this is the importance of phase transformation in science and technology. Considering that one of the key strengths of neutron scattering is to probe materials under stress, pressure, magnetic fields, or elevated temperatures, an education in neutron scattering to study phase transformations has never been more timely.

For the LANSCE neutron school on phase transformations, lectures will be presented by world recognized experts in the field and will span all levels from introductory concepts (neutron scattering basics, thermodynamics and crystallography of phase transformations) to phase transformations specific to certain classes of materials (minerals, ceramics, metals, amorphous materials). Real-life applications of neutron scattering will be presented by leading researchers, illustrating how neutron scattering provides insight into phase transformations.

The lectures will be complemented by hands-on experiments using Lujan neutron instruments. Data involving high and low temperature, pressure, and stress-induced phase transformations will be analyzed and students will leave the school with the knowledge to identify phase transformation related problems that can be solved with neutron scattering.

The school is limited to 30 participants who will be selected from their application materials including reference letters and a statement of "why neutron scattering could be (is) relevant to my research." Applicants should be full time graduate students or postdocs. Early career industrial researchers and advanced undergraduate students are also invited to apply. Applicants need not be U.S. citizens; however, preference will be given to students attending U.S. universities.

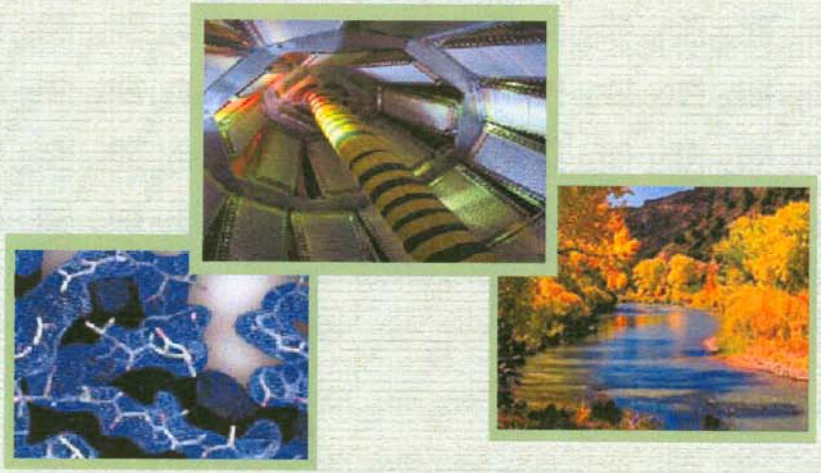
The LANSCE neutron scattering school is supported by the National Science Foundation and the Department of Energy-Office of Basic Energy Sciences. The school is tuition-free and assistance for travel, lodging and subsistence is available.

Confirmed Lecturers:

Chris Benmore, Argonne National Laboratory
Don Brown, Los Alamos Neutron Science Center
Michael Carpenter, University of Cambridge
Luke Daemen, Los Alamos Neutron Science Center
Bob Field, Los Alamos National Laboratory
Ken Herwig, Spallation Neutron Source
Rex Hjelm, Los Alamos Neutron Science Center
Kanani Lee, Yale University
Robert McQueeney, Ames Laboratory
Scott Misture, Alfred University
Alexandra Navrotsky, University of California, Davis
Thomas Proffen, Los Alamos Neutron Science Center
Simon Redfern, University of Cambridge
James Rhyne, Los Alamos Neutron Science Center
Art Schultz, Argonne National Laboratory
Stephen Shapiro, Brookhaven National Laboratory
Alexis Sitchler, University of Wyoming
Sven Vogel, Los Alamos Neutron Science Center
Bjoern Winkler, Goethe University Frankfurt/ Germany

Chair: SvenVogel sven@lanl.gov School Director: Jim Rhyne rhyne@lanl.gov Admin: Lisa Padilla ljp@lanl.gov

Apply on-line at: www.lansce.lanl.gov/neutronschool Application deadline: April 13, 2009



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Anyone Here Not a Member of NSSA?

We would like to have you join (it's free)!!

And we have membership forms!

Or you can use the on-line form at
www.neutronscattering.org

Purpose of the Society

The purpose of the Society shall be the advancement of neutron scattering research in the United States. Pursuant to this purpose, the Society shall undertake the following:

a. Identify and bring together the neutron scattering community of the USA.

b. Identify the needs of the neutron scattering community, including future requirements for instrumentation and sources, and to represent these needs to the neutron facilities and funding agencies.

c. To stimulate, promote, and broaden the use of neutron scattering in science and technology.

d. To carry out educational activities that support the above goals.

e. To engage in other activities deemed appropriate and necessary for attaining the objectives of the Society.

✂----------

Application for Membership

Note: If this is an address or other information change only, please check ☐

Name: _____ Title: _____

Department/Division: _____

Institution: _____

Mailing Address: _____

_____ FAX #: _____

Phone #: _____ e-mail: _____

Area of interest/expertise in neutron scattering: _____

_____

Suggestions for current issues NSSA should address _____

_____

_____

Signed: _____ Date: _____

Please return your completed application to:

Dr. Greg S. Smith *NSSA Corresponding Secretary*
HFIR Center for Neutron Scattering
ORNL PO Box 2008, MS6393 Oak Ridge, TN 37831-6393
(865) 241-1742 (voice) (865)574-6268 (FAX) e-mail: smithgs1@ornl.gov