The National Lab Perspective: A Tale of Two National User Facilities

Peter M. Gehring
National Institute of Standards and Technology
NIST Center for Neutron Research
Gaithersburg, MD USA

The High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory

The NIST Center for Neutron Research (NCNR) at the National Institute of Standards and Technology
Overview

Some Statistics …

My Story – Getting from Here to There

National Laboratories – Pros and Cons

What Staff Scientists Do – Neutron Scattering

Classic Examples of Neutron Science

Some Tips …
Some Statistics …

Initial Employment of Physics PhDs, Classes of 2007 & 2008.

- Postdoc: 56%
- Potentially Permanent Position: 33%
- Unemployed: 4%
- Other Temporary Position: 7%

Note: Data only include US-trained physics PhDs who remained in the US after receiving their degrees.

http://www.aip.org/statistics
Some Statistics …

<table>
<thead>
<tr>
<th>Initial Employment Sectors of Physics PhDs by Type of Position Accepted, Classes of 2007 &amp; 2008.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Academic*</td>
</tr>
<tr>
<td>Private sector</td>
</tr>
<tr>
<td>Government</td>
</tr>
<tr>
<td>Nonprofit</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

Note: Data only include US-trained physics PhDs who remained in the US after receiving their degrees.

*Includes university affiliated research institutes.

http://www.aip.org/statistics
Some Statistics …

Initial Employment of Physics PhDs, Classes of 2007 & 2008.

Note: Employment in physics means an individual’s primary or secondary employment field was in physics. Data only include US-trained PhDs who remained in the US after receiving their degrees.

http://www.aip.org/statistics
Some Statistics …

**PhD Starting Salaries, Classes of 2007 & 2008.**

<table>
<thead>
<tr>
<th>Potentially Permanent Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Sector</td>
</tr>
<tr>
<td>University &amp; 4-year College</td>
</tr>
<tr>
<td>Postdocs</td>
</tr>
<tr>
<td>Government</td>
</tr>
<tr>
<td>University &amp; UARI</td>
</tr>
</tbody>
</table>

Typical Salaries in Thousands of Dollars

**Note:** Typical salaries are the middle 50%, i.e. between the 25th and 75th percentiles. Government includes Federally Funded Research and Development Centers, e.g. Los Alamos. UARI: University Affiliated Research Institute. Data only include US-trained PhDs who remained in the US after receiving their degrees.

http://www.aip.org/statistics
Getting from Here to There

Statistically, I was in the largest category – postdoc.

To be honest, I was utterly naïve and uncertain about what I wanted.

A year before graduating I had two awkward industry interviews.

Buckshot approach – I sent out a large number of letters inquiring about postdoctoral positions.

I was lucky: postdoctoral positions were relatively plentiful that year.

I interviewed at two places:
UC Santa Barbara and Brookhaven National Lab
Both interviews went well ....
Getting from Here to There

Pros and Cons:

**UC Santa Barbara:**
- Great scientist (Vincent Jaccarino)
- Used many techniques
- × Studied mainly Mn_{1-x}Zn_xF_2
- Gorgeous location
- × Salary - $25K/year

**Brookhaven National Lab:**
- Great scientist (Gen Shirane)
- × Used one technique (neutron scattering)
- Studied many systems
- × OK location
- Salary - $35K/year

Had a very hard time deciding (I waited until the last day).
Getting from Here to There

I made my decision.

Letter from Gen Shirane ...

The High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory

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Mr. Peter M. Gehring
Leomis Laboratory
Department of Physics
University of Illinois
Urbana, Illinois 61801

Dear Peter:

I am delighted to learn that you are coming to Brookhaven. I am looking forward to a fruitful scientific collaboration with you in the near future. As for your actual starting date, you should keep John Tranquada informed. John will be acting as your “host” when you arrive this fall.

See you soon.

G. Shirane

cc: J. Tranquada
Getting from Here to There

The rest, as they say, is history ...

I have worked (happily) at national labs ever since.

I spent almost four years at Brookhaven National Lab before accepting an offer at NIST to work as an instrument scientist.

Come September I will have finished 20 years at NIST.

Time flies! (This is not an empty cliché.)
National Laboratories – Pros and Cons

Not all national laboratories are the same.

Federally Operated Labs (incomplete)  Contractor Operated Labs (mainly DoE)

AFRL (Air Force)                              USGS (US Gov)
ARL (Army)                                    NASA (US Gov)
NIH (DHHS)                                    NRL (Navy)
NIST (DoC)                                    USGS (US Gov)
National Laboratories – Pros and Cons

Many support large, national, user facilities, which attract leading scientists worldwide and provide unique research opportunities.

One of the best examples is Brookhaven National Lab

AGS and RHIC

NSLS

HFBR

AGS researchers won three Nobel Prizes in Physics:
1976: Ting for the J/ψ part of the J/ψ and charm quark.
1980: Cronin and Fitch for CP violation.

NSLS researchers won one Nobel Prize in Chemistry:
2009: Ramakrishnan and Steitz for ribosome.

HFBR researchers won two APS Buckley Prizes:
1973: Shirane for studies of soft modes.
1987: Birgeneau for low-dimensional magnetism.
National Laboratories – Pros and Cons

Exposure to a broad variety of interesting science.

Do not have to write grant proposals for funding (federal labs).

No teaching requirements and comparatively few committee requirements.

You can get more research done, and it is often of higher impact.

Freer evenings compared to academics.

It is illegal to ask or pressure someone to retire at a federal lab.

NIST staff possess tremendous expertise about physics and measurement science – if you have a question, it’s likely that someone at NIST can answer it.

People freely share thoughts when you’re thinking of trying a new experiment. They offer suggestions on how to measure it better and warnings about what you might find difficult.
National Laboratories – Pros and Cons

Slightly less job security than for a tenured professor. (But much better than the private sector/industry.)

Needless bureaucracy.

Tend to have a focused “mission.” Your work needs to be “relevant.”

NIST is a very applied place, and we sometimes have to educate management about how the work we do fits within the NIST mission.

No teaching requirements. (For those who enjoy teaching …)

You won’t be able to “build an empire;” get two or three postdocs at most.

Slightly less autonomy than in academia, but more than in industry.
NIST Center for Neutron Research (NCNR)
What Staff Scientists Do
What Staff Scientists Do

They get to interact/collaborate with many world-class scientists.

They are reasonably well-paid.

They publish papers and are well-positioned to strike first on hot-topics in science, e.g. iron-based, high-$T_c$ superconductors.

They don’t have to write grant proposals (a few exceptions).

They serve as local contacts for external users who run experiments on a variety of different neutron instruments.

They get to “teach” external users (mainly graduate students and postdocs).

They often have to work long hours/night/weekends. (Industrial researchers typically work 9-5.)
What Staff Scientists Do

- 43 companies
- 146 academic institutions
- 36 gov agencies

Research Participants

Publications
Different Career Paths

Sample Environment Team

Data Acquisition Team

IT Support

Management

Univ. of Illinois PhDs

Instrument Scientist
What Staff Scientists Do

Primarily, they schedule and run experiments on, as well as maintain our many neutron scattering instruments.

So let’s discuss neutron scattering a bit …
“If the neutron did not exist, it would need to be invented.”

Bertram Brockhouse – 1994 Nobel Laureate in Physics
Neutron Scattering in the World

Western Europe dominates in terms of...

- number of users
- capacity/throughput
- scientific productivity
Neutron Production by Spallation

New Spallation Neutron Source (SNS) located in Oak Ridge Nat. Lab, USA.

Uses a cascade effect that results from the collision of a proton on a heavy target nucleus.

Delivers an intense beam of neutrons with a pulsed time structure.
Nuclear fission is used in power and research reactors.

\[ ^{235}_{92}U_{143} + n \rightarrow \left[^{236}_{92}U_{144}\right]^* \rightarrow X + Y + 2.44n \]

A liquid medium (D₂O, or heavy water) is used to moderate the fast fission neutrons to room temperature (2 MeV → 50 meV).

The fission process and moderator are confined by a large containment vessel.
Maxwellian Distribution

\[ \Phi \sim \nu^3 e^{-\frac{\nu^2}{2k_B T}} \]

Neutron Moderation

“Fast” neutrons: \( \nu = 20,000 \text{ km/sec} \)

Liquid Hydrogen

Heavy Water (D₂O)

Hot Graphite

[Graph showing neutron velocity distribution with temperatures 25 K, 300 K, and 2000 K]
Wave - Particle Duality

**de Broglie Relation** \( \lambda = \frac{h}{m_v} \)

- **Fast Neutron**, \( V \sim 20,000,000 \text{ m/sec} \)
  - \( \sim 0.00002 \text{ nm} \)

- **Thermal Neutron**, \( V \sim 2,000 \text{ m/sec} \)
  - \( \sim 0.2 \text{ nm} \)

- **Cold Neutron**, \( V \sim 200 \text{ m/sec} \)
  - \( \sim 2 \text{ nm} \)
Nuclear Interaction

- strong but short-ranged (s-wave scattering)
- varies from isotope to isotope ("isotopic labeling")
- light elements and heavy elements comparable
- nuclear spin-dependent (coherent and incoherent scattering)

\[ V_{\text{nuc}}(\vec{r}) = \sum_j \frac{2\pi \hbar^2}{m} b_j \delta(\vec{r} - \vec{r}_j) \]
Basics of Neutron Scattering Methods

Elements of all scattering experiments

A source

A method to specify the incident wave vector $\mathbf{k}_i$

Detector(s)

A well chosen sample + good idea

A method to specify the final wave vector $\mathbf{k}_f$
(1) Neutron scattering experiments measure the flux of neutrons scattered by a sample into a detector as a function of the change in neutron wave vector ($Q$) and energy ($\hbar \omega$).

\[
\begin{align*}
\text{Momentum} & : & \hbar k_n &= \hbar (2\pi/\lambda_n) \\
& & \hbar Q &= \hbar k_i - \hbar k_f \\
\text{Energy} & : & \hbar \omega_n &= \hbar^2 k_n^2 / 2m \\
& & \hbar \omega &= \hbar \omega_i - \hbar \omega_f
\end{align*}
\]

(2) The expressions for the scattered neutron flux $\Phi$ involve the positions and motions of atomic nuclei or unpaired electron spins.

\[
\Phi = F\{\mathbf{r}_i(t), \mathbf{r}_j(t), \mathbf{S}_i(t), \mathbf{S}_j(t)\}
\]

$\Phi$ provides information about all of these quantities!
(3) The scattered neutron flux $\Phi(\vec{Q}, \hbar \omega)$ is proportional to the space ($\vec{r}$) and time ($t$) Fourier transform of the probability $G(\vec{r}, t)$ of finding one or two atoms separated by a particular distance at a particular time.

$$\Phi \propto \frac{\partial^2 \sigma}{\partial \Omega \partial \omega} \propto \int \int e^{i(\vec{Q} \cdot \vec{r} - \omega t)} G(\vec{r}, t) d^3 \vec{r} dt$$

**The Neutron Scattering Cross Section**

- **Real space**
  - Neutron scattering on a lattice of atoms
- **Q-space**
  - Wave vector $Q$
  - Width $\xi$
  - Relation $2\pi/d$
- **Time space**
  - Time $T$
  - Frequency $\Gamma$
- **ω-space**
  - Frequency $\omega$
  - Width $1/\Gamma$
Why so Many Different Spectrometers?

Because neutron scattering is an intensity-limited technique. Thus detector coverage and resolution MUST be tailored to the science.

Uncertainties in the neutron wavelength and direction imply $Q$ and $\hbar\omega$ can only be defined with a finite precision.

The total signal in a scattering experiment is proportional to the resolution volume $\rightarrow$ better resolution leads to lower count rates! Choose carefully …

Courtesy of R. Pynn
There are two main ways of measuring the neutron scattering cross section $S(Q,\omega)$.

**Constant-E scans:**
vary $Q$ at fixed $h\omega$.

**Constant-Q scans:**
vary $h\omega$ at fixed $Q$.

Phonon and Magnon Dispersions
Nobel Prize in Physics 1994

The Fathers of Neutron Scattering
“For pioneering contributions to the development of neutron scattering techniques for studies of condensed matter”

“For the development of the neutron diffraction technique”

Clifford G Shull
MIT, USA
(1915 – 2001)

Ernest O Wollan
ORNL, USA
(1910 – 1984)

Bertram N Brockhouse
McMaster University, Canada
(1918 – 2003)

Showed us where the atoms are …

Did first neutron diffraction expts …

Showed us how the atoms move …
## Awards for or Influenced by Neutrons

<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Award</th>
<th>Research Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>Clifford Shall (MIT)</td>
<td>APS Buckley Prize</td>
<td>Neutron diffraction, magnetic structure</td>
</tr>
<tr>
<td>1963</td>
<td>Bertram Brockhouse (AECL)</td>
<td>APS Buckley Prize</td>
<td>Phonons, magnons</td>
</tr>
<tr>
<td>1973</td>
<td>John Axe, Gen Shirane (BNL)</td>
<td>ACA Warren Diffraction Award</td>
<td>Soft modes, phase transitions</td>
</tr>
<tr>
<td>1973</td>
<td>Gen Shirane (BNL)</td>
<td>APS Buckley Prize</td>
<td>Phonons, soft modes</td>
</tr>
<tr>
<td>1974</td>
<td>Paul Flory (Cal Tech)</td>
<td>Nobel Prize, Chemistry</td>
<td>Polymer structure</td>
</tr>
<tr>
<td>1978</td>
<td>Henri Benoit (Strasbourg)</td>
<td>APS High Polymer Prize</td>
<td>Neutrons, polymer structure</td>
</tr>
<tr>
<td>1982</td>
<td>Edwards (Cambridge) and Pierre de Gennes (Col. Paris)</td>
<td>APS High Polymer Prize</td>
<td>Reptation theory</td>
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<tr>
<td>1984</td>
<td>Charles Han (NIST)</td>
<td>APS Dillon Medal</td>
<td>Polymer structure and dynamics</td>
</tr>
<tr>
<td>1986</td>
<td>Muthu Kumar (U. Mass.)</td>
<td>APS Dillon Medal</td>
<td>Theory of polymer structure</td>
</tr>
<tr>
<td>1987</td>
<td>Robert Birgeneau (MIT)</td>
<td>APS Buckley Prize</td>
<td>Magnetism</td>
</tr>
<tr>
<td>1988</td>
<td>Robert Birgeneau (MIT), Paul Horn (IBM)</td>
<td>ACA Warren Diffraction Award</td>
<td>Low-dimensional systems</td>
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<tr>
<td>1988</td>
<td>Jean Gomet (Saclay)</td>
<td>APS Dillon Medal</td>
<td>Gel formation</td>
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<tr>
<td>1990</td>
<td>Ewald Bates (A.T.&amp;T)</td>
<td>APS Dillon Medal</td>
<td>Block copolymers</td>
</tr>
<tr>
<td>1990</td>
<td>James Jorgensen (ANL)</td>
<td>ACA Warren Diffraction Award</td>
<td>Structure of ceramic superconductors</td>
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<tr>
<td>1990</td>
<td>Dieter Richter (KFA) and John Huang (Exxon)</td>
<td>Max Planck Research Prize</td>
<td>Dynamics of polymers and microemulsions</td>
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<tr>
<td>1991</td>
<td>Ken Schweizer (Sandia)</td>
<td>APS Dillon Medal</td>
<td>Polymer RISM theory</td>
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<td>1992</td>
<td>Glenn Frederickson (UCSB)</td>
<td>APS Dillon Medal</td>
<td>Theory of microsphere polymer structure</td>
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<tr>
<td>1992</td>
<td>Phil Pincus (UCSB)</td>
<td>APS High Polymer Prize</td>
<td>Theory of complex fluids</td>
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<td>1992</td>
<td>Alice Gast (Stanford)</td>
<td>Colburn Award (American Institute of Chemical Engineering)</td>
<td>Colloids and polymers</td>
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<tr>
<td>1994</td>
<td>Schull and Brockhouse</td>
<td>Nobel Prize, Physics</td>
<td>Neutron-scattering methods for structures</td>
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<tr>
<td>1996</td>
<td>Frank Bates (U. Minn.)</td>
<td>APS High Polymer Prize</td>
<td>Structure of copolymers</td>
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<tr>
<td>1996</td>
<td>Nitash Balsara (N.Y. Polytech)</td>
<td>APS Dillon Prize</td>
<td>Properties of polymer blocks</td>
</tr>
<tr>
<td>1997</td>
<td>David Price (ANL)</td>
<td>ACA Warren Prize</td>
<td>Structure of disordered systems</td>
</tr>
</tbody>
</table>

Classic Examples of Neutron Science
Antiferromagnetism

Confirmed magnetic sublattice model of Louis Neel (Nobel – 1970)

Fig. 4. Neutron diffraction patterns for MnO taken at liquid nitrogen and room temperatures. The patterns have been corrected for the various forms of extraneous, diffuse scattering mentioned in the text. Four extra antiferromagnetic reflections are to be noticed in the low temperature pattern.

Fig. 5. Antiferromagnetic structure existing in MnO below its Curie temperature of 120°K. The magnetic unit cell has twice the linear dimensions of the chemical unit cell. Only Mn ions are shown in the diagram.

Neutron scattering and diffraction studies on a series of paramagnetic and antiferromagnetic substances are reported in the present paper. The paramagnetic diffuse scattering predicted by Halpern and Johnson has been studied, resulting in the determination of the magnetic form factor for Mn²⁺ ions. From the form factor, the radial distribution of the electrons in the 3d-shell of Mn²⁺ has been determined, and this is compared with a theoretical distribution of Duncalf. Antiferromagnetic substances are shown to produce strong, coherent scattering effects in the diffraction pattern. The antiferromagnetic reflections have been used to determine the magnetic structure of the material below the antiferromagnetic Curie temperature. For some substances the magnetic unit cell is found to be larger than the chemical unit cell. The temperature dependence of the antiferromagnetic intensities has been studied, and the directional effects which characterize neutron scattering by aligned atomic moments have been used to determine the moment alignment with respect to crystallographic axes. From studies with magnetic ions possessing both orbital and spin moments, it is found that the antiferromagnetic intensities contain partial orbital moment components along with the spin moment component. The degree of orbital moment contribution agrees satisfactorily with that predicted by models of lattice quenching.
Phonons and Magnons

Scattering of Neutrons by Phonons in an Aluminum Single Crystal

B. N. Brockhouse and A. T. Stewart
Physics Division, Atomic Energy of Canada, Limited,
Chalk River, Ontario, Canada
(Received August 29, 1955)

Fig. 1. Typical energy distributions of neutrons inelastically scattered by an aluminum single crystal and approximate resolution functions. The incident neutron energy $E$ is indicated by the arrows.

Fig. 3. Relation between $\omega$ and $q$ for observed phonon groups, with estimated errors.
Superconductivity

Inelastic-Neutron-Scattering Study of Acoustic Phonons in Nb$_3$Sn

J. D. Axe and G. Shirane
Brookhaven National Laboratory, Upton, New York 11973
(Received 21 February 1973)

Transverse-acoustic-phonon frequencies and line shapes have been studied as a function of temperature in Nb$_3$Sn. There is a substantial (~10%) reduction in all of the mode frequencies studied between 300$^\circ$K and the cubic-tetragonal transformation temperature $T_u = 45$K. Even more pronounced elastic softening is observed for [$110$]$_T$ phonons with $q \gtrsim \frac{1}{2} a_{\text{c},\text{h}}$. As $T \rightarrow T_u$ from above, phonons in this latter group acquire an unusual quasielastic "central" component in addition to the phonon-like sidebands. The evolution of this central component is adequately described by a phenomenological theory which assumes an additional low-frequency relaxation mechanism for the acoustic phonons. Finally, abrupt changes in certain phonon lifetimes are detected near the superconducting transformation temperature $T_c = 18.0$K. This behavior is traced to the the inability of phonons with energies less than that of the superconducting gap $2\Delta(T)$ to decay by creation of excited electron-phonon-pair states. These measurements give an estimate of $2\Delta(0) = (4.4 \pm 0.6)k_B T_c$ and reveal a strong anisotropy in the electron-transverse-phonon interaction.

FIG. 13. Widths of low energy [110]$T_1$ acoustic phonons broaden appreciably at temperatures near $T_c$, the superconducting transformation temperature. This figure shows the same phonon profile above and below $T_c = 18.0$ K.

Measures of the electron-phonon interaction in Nb by inelastic neutron scattering

S. M. Shapiro, G. Shirane, and J. D. Axe
Brookhaven National Laboratory, Upton, New York 11973
(Received 1 April 1975)

Precise linewidth and frequency measurements of transverse acoustic modes propagating along the [001] and [110] directions were performed on single crystals of niobium in the normal and superconducting phases $(T_c = 9.3$K). For transverse phonons propagating along the [110] direction changes in linewidth are observed when the superconducting gap $2\Delta(T)$ equals the phonon frequency. This behavior agrees with Bolognesi's calculation for the attenuation of high-frequency sound waves in superconductors and the magnitude of the change enables us to calculate the electron-phonon interaction. In addition to linewidth changes,
Polymers

Confirmed De Gennes’ model of polymer reptation

TABLE I. Fit results for the entanglement distance $d$ for various models. The reduced $\chi^2$ is also indicated.

<table>
<thead>
<tr>
<th>Model</th>
<th>Ref.</th>
<th>$d$ (Å)</th>
<th>Reduced $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reptation</td>
<td>[10]</td>
<td>46.0 ± 0.1</td>
<td>3.03</td>
</tr>
<tr>
<td>Local Reptation</td>
<td>[10]</td>
<td>46.5 ± 0.1</td>
<td>3.21</td>
</tr>
<tr>
<td>des Cloizeaux</td>
<td>[18]</td>
<td>59.8 ± 0.2</td>
<td>7.19</td>
</tr>
<tr>
<td>Ronca</td>
<td>[19]</td>
<td>47.4 ± 0.1</td>
<td>12.2</td>
</tr>
</tbody>
</table>

FIG. 3. Semilog plot of $S(q, t)$ vs $t$ for various $q$. The solid lines are the fit of the reptation model [Eq. (1)]. The dashed lines are a fit using the model of des Cloizeaux [Eq. (27) of Ref. [18]].
Neutron Imaging
Viewing Operational Fuel Cells in Real-Time

Problem: Water management in fuel cell; metal cell components; scattering from hydrogen

Solution: Neutron imaging
Formation of HIV-1 is mediated by the viral Gag polyprotein. Expressed in the cellular cytoplasm, Gag eventually targets the inner surface of the cellular membrane of the infected host cell where viral assembly occurs. Molecular insight from early cryo-electron microscopy data showed Gag in the immature spherical virus as elongated rods radiating from the membrane with one end tightly bound to the viral genome [1]. However, in a recent study using small angle neutron scattering as well as other techniques, it was found that the properties of monomeric Gag in solution are incompatible with an extended structure [2]. Rather, Gag likely exists in several compact conformations in solution, most likely due to the presence of several unstructured, flexible domains in the protein. These results imply that the protein must undergo a large conformational change when it assembles into a virus particle. Understanding the mechanism of this conformational change would give important insights into retroviral assembly.

FIGURE 3: (a) nSLD profile of full-length HIV-1 Gag protein on a tBLM. Neat lipid bilayer (black), bound Gag protein (red), Gag + TGx7 DNA strand (blue), Gag:TGx7 500 mmol/L NaCl salt rinse (green). The inset cartoon illustrates how the charged ends of the Gag cause it to fold toward the surface, and then how the viral strands attach to NC, extending and crosslinking the Gag molecules. (b) Illustrative models of folded and extended conformations of Gag on a membrane surface.
Magnetic Trapping of Neutrons

Neutrons lose energy in liquid Helium

Electrons from decay excite Helium

Demagnetized helium gives off photons

Light is detected by outside PMTs

Superconducting Ioffe Trap containing a helium filled cell

3.1 Tesla trap depth

∼ 9 Liter volume

Expected Sensitivity : 2 s
Some Tips

Things to consider the following when choosing your next job ...

- Do you like research?  
  *Personality matters.*
- Do you like to teach?  
  *Communication skills matter.*
- Career path potential
- Quality of management
- Location (US or abroad?)
- Your boss
- Salary/benefits
- Stability
- Tenure
- Retirement
More Tips

Many federal labs offer NRC postdoc positions.

RAP/NRC Postdocs earn $65K at NIST.

Many open only to US Citizens …

BEFORE you apply, contact a mentor.

They can help you to write a solid proposal.

http://sites.nationalacademies.org/PGA/RAP/index.htm
In 1996, the routine maintenance of the reactor was being conducted when tests indicated a slightly increased level of tritium in ground water monitoring wells on the perimeter of the reactor. A thorough inspection of the reactor found no leaks in the reactor itself but a small leak in the water system of a pool where spent fuel was being stored. This turned out to be the only source of the tritium and was easily fixed. Unfortunately, the disclosure of the tritium leak lead to a political effort that would prevent the reactor from reopening. Scientists and laboratory personnel fought to keep the reactor alive for the next three years, but in 1999, the Secretary of Energy Bill Richardson ordered that the reactor be decommissioned.
The NCNR Expansion Project

Part of the America Competes Act

A multi-year plan to meet strong U.S. demand for cold neutron measurement capability by creating new beamlines and instruments at the NCNR.

- Five-year project (started in 2007)
- Four new state-of-the-art neutron guides
- Five new cold neutron instruments
- 500 additional research participants/year
December 2012

- 10 m SANS
- Physics
- PGAA
- MAGik
- MACS II
- NG D REFL
Thank-You!

Questions?