Teachers Day at the Particle Accelerator Conference in 2005

The Spallation Neutron Source

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Accelerator Systems Division Director for the SNS

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Knoxville, TN
Materials define the ages of civilization

- Stone Age – Bronze Age – Iron Age
- The modern era has seen iron advance to steel
  - Achieved by trial and error starting with Excalibur
- More recently we’ve moved to silicon
- All of these are actually relatively “simple” materials
  - Increasingly we are trying to master very complex materials
    - Polymers
    - Proteins
    - Nanomaterials
    - Superconductors
- Understanding complicated materials requires sophisticated scientific tools
Structure determines properties

Three forms of carbon – very different materials

- Graphite
- Diamond
- Buckyballs
The application of slow neutron scattering to the study of condensed matter had its birth in the work of Wollan and Shull (1948) on neutron powder diffraction.

The neutron is a weakly interacting, non-perturbing probe with simple, well-understood coupling to atoms and spins.

The scattering experiment tells you about the sample, not the probe.
Newton’s First Law and the concept of force!

Every object continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.
Electricity and Magnetism

- Electrons have a negative charge
- Protons have a positive charge
- Neutrons have no charge

• Opposite charges attract
• Like charges repel

Rutherford, 1912
Moving charges, currents, and electromagnets

- If charges move they represent a current
- Currents can transport energy
- Currents can produce magnetic fields
- Magnetic fields can change the direction of moving charges

What happens if a compass comes close?
Force and Acceleration: Electric Fields

- An electric field will impose a force on charge, and the charge will be accelerated along the direction of the force!!!
Force and Acceleration: Magnetic Fields

- In a magnetic field a moving charge will be accelerated perpendicular:
  - To the direction of motion
  - To the direction of the magnetic field

\[ \vec{F} = q\vec{v} \times \vec{B} \]
The Simplest DC Electron Accelerator at Home
Low energy ions, electrons, atoms, and exited molecules drift through a magnetic field towards the exit aperture where some of them form negative Hydrogen ions.
How do we accelerate many charged particles??

• SNS:
  – 1000 x 1000 x 10 x 100 V = 1000 x 1 Million Volt (MV)
  – 1 Giga Volt

We could use 1 GV DC Voltage??
Or we could be smarter

- Riding on a wave is acceleration ....
- Will show later how we do that !!!

SNS has a 300 meter long evacuated tube where we do this !!!!
The Spallation Neutron Source Partnership

<table>
<thead>
<tr>
<th>Description</th>
<th>Accelerator</th>
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<tbody>
<tr>
<td>Project Support</td>
<td>75.6</td>
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<tr>
<td>Front End Systems</td>
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<td>Linac Systems</td>
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<td>Ring &amp; Transfer Systems</td>
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<td>TEC</td>
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<td>R&amp;D</td>
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<td>Pre-Operations</td>
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<td>TPC</td>
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</table>

At peak: ~500 People worked on the construction of the SNS accelerator.

Oak Ridge, TN
35° 49' N, 83° 59' W
Spring 1999
Spring 2000
Spring 2002
Spring 2004
A Sense of Scale

- Next thing: Get a feeling for **time** or **scale** or is it the **same**?: Or why do we built SNS
Structure Determines Properties

3 forms of Carbon - very different materials

- Graphite
- Diamond
- Buckyballs

- Superconductors or organic ferromagnets
Neutrons see the Nuclei

<table>
<thead>
<tr>
<th>H</th>
<th>Li</th>
<th>C</th>
<th>O</th>
<th>S</th>
<th>Mn</th>
<th>Zr</th>
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X-rays

neutrons
Neutrons see the Nuclei

Better performance of complex fluids.
Biology and Neutron Scattering:

>95 % of the Body is Water!

- The Human genome project will tell you what sequence the DNA’s represent

- Neutron and X-Ray scattering will tell how they function

- Neutrons are very good, because they are sensitive to hydrogen

- New medicine will be developed
How does it work?

Light or Neutrons

Neutrons: $\lambda = 5 \div 20 \, \text{Å}$
Light: $\lambda = 4500 \div 6500 \, \text{Å}$

Proteins: $R = 10 \div 50 \, \text{Å}$

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{(2m_N*E)}}$  

De Broglie

Detector measures intensity $I(q)$

$|q| = \frac{4\pi}{\lambda} \sin \left( \frac{\theta}{2} \right)$

Measure size of struck objects (Rutherford 1912)
Spallation-Evaporation Production of Neutrons and Why to use heavy metal target

**Fission**
- chain reaction
- continuous flow
- 1 neutron/fission

**Spallation**
- no chain reaction
- pulsed operation
- 30 neutrons/proton
Why a pulsed source?

- Arrival time of neutrons at a sample is directly related to the energy (and wavelength) of the neutrons
  - Can either use this information to get spectral information, or filter out most of the signal to gather data at a particular wavelength
- Create separation in arrival time, i.e. energy or wavelength resolution, by extending length of neutron beam line
SNS will be World-Class! (being the best...)
RF Acceleration for the SNS

- How to efficiently accelerate H⁻ ions/charged particles?
Drift Tube Linac
Coupled-Cavity Linac

Bridge Coupler 44 final machining

Installation Complete August 2004
Major Components of the SNS High Power RF System

• Radio frequency is the heart of the accelerator
• So how do we make it (or: what happens in a microwave oven?)
High-Power RF Installation

- High-Power RF System (klystrons, waveguide, power supplies, ...) supplied by LANL
Superconductivity

Absolute Zero
Thermometers compare Fahrenheit, Celsius and Kelvin scales.

Water Boils
- 212 °F
- 100 °C
- 373 K

Water Freezes
- 32 °F
- 0 °C
- 273 K

Absolute Zero
-459 °F
-273 °C
0 K

Current 0

Current on,
Resistance is high

Current on,
Resistance very low,
After cooled down
Cavity Preparation

BCP 1:1:1 or 1:1:2
~120µm removed

Assembly in clean room (class 100)

Dewar insertion
Medium Beta Cryomodule Internal Structure

Magnetic shield  2.1-4.2 K He liquid

Magnetic shield

Thermal shield at 50 K
Cryomodules H1, H3, & H5 thru H8     Sep 04
Status of Superconducting Linac

- SCL accelerates beam from 187 to 1000 MeV
- Jefferson Lab is building 23 cryomodules with 81 SC cavities
The SNS Storage Ring

ACCELERATING CAVITY

COLLISIONS

VACUUM CHAMBER

FOCUSING MAGNET

BENDING MAGNET

INJECTION

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY
RTBT Installation Progress
RTBT/Target Interface

Section through RTBT/Target Flight-tube Interface
Target Region Within Core Vessel

- Target Module with jumpers
- Outer Reflector Plug
- Core Vessel water cooled shielding
- Moderators
- Core Vessel Multi-channel flange
Target Service Bay Installation

- Target is transitioning from civil construction to installation

- GC installation of target systems in Target Service Bay completed in Jan. 05

- Outer Reflector Plug in place – Jan. 05
Seventeen instruments now formally approved
SNS Contact

• For more information about the Spallation Neutron Source Project,
  – Use the SNS public web-site address:  http://www.sns.gov/
  – Email:  snsprojectoffice@sns.gov