Teachers Day at the Particle Accelerator Conference in 2005

The Spallation Neutron Source

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Mai 18th, 2005

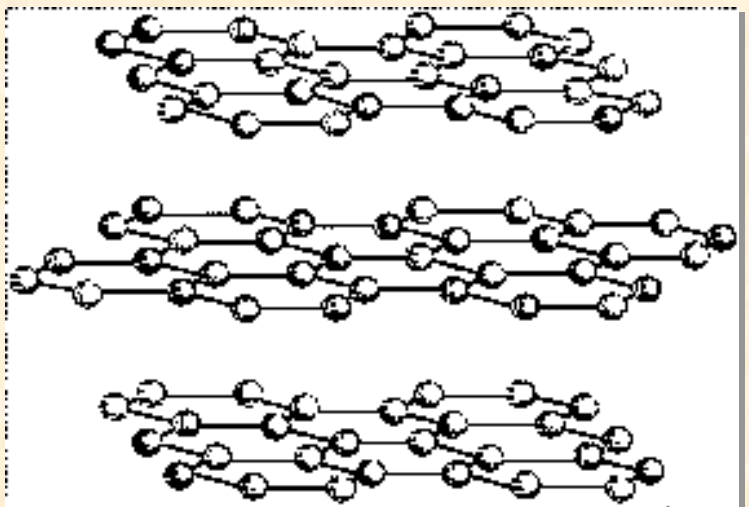
Knoxville, TN

Materials define the ages of civilization

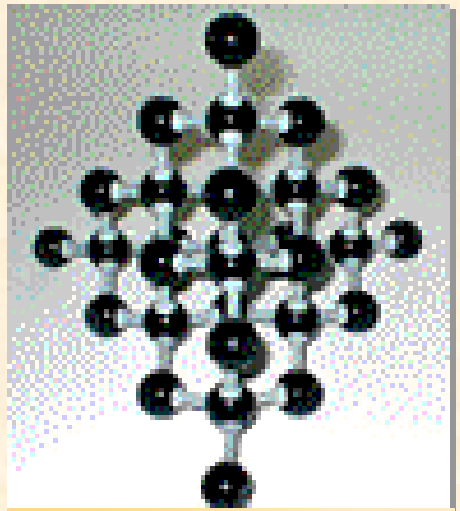
- Stone Age – Bronze Age – Iron Age
- The modern era has seen iron advance to steel
  - Achieved by trial and error starting with Excalibur
- More recently we've moved to silicon
- All of these are actually relatively "simple" materials
  - Increasingly we are trying to master very complex materials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

Structure determines properties

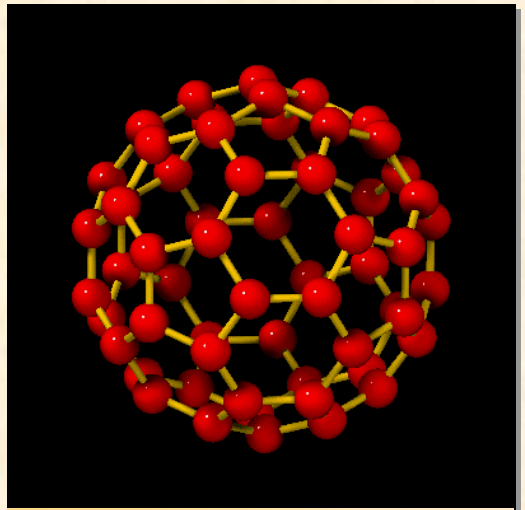
Three forms of carbon – very different materials



Graphite



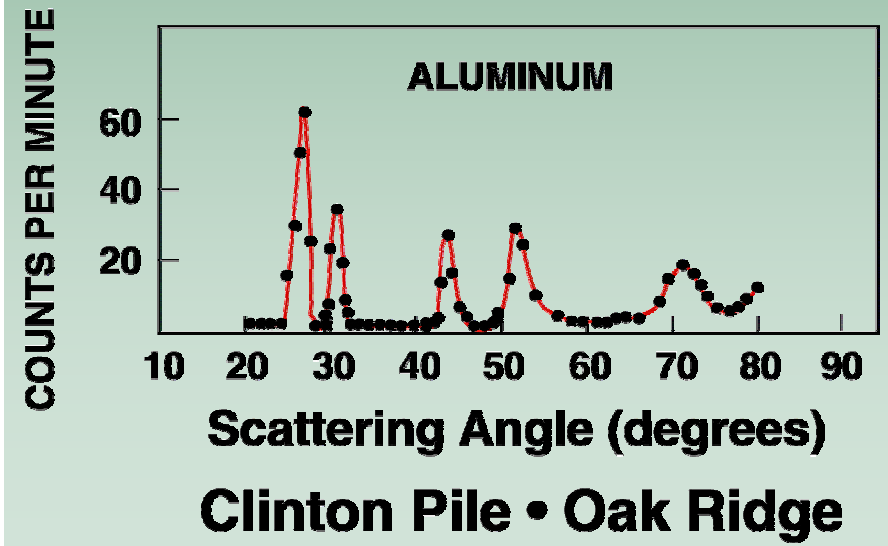
Diamond



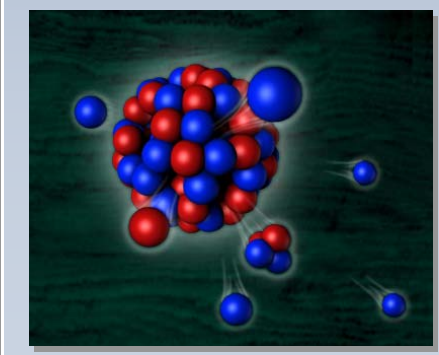
Buckyballs

Neutrons and neutron sources *Continued*

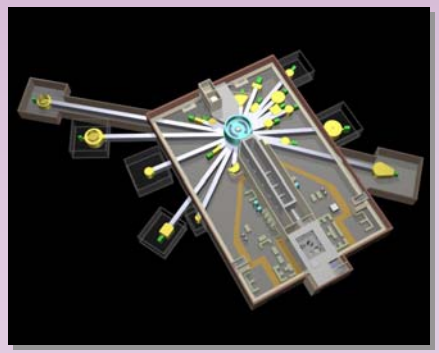
The application of slow neutron scattering to the study of condensed matter had its birth in the work of Wollan and Shull (1948) on neutron powder diffraction



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

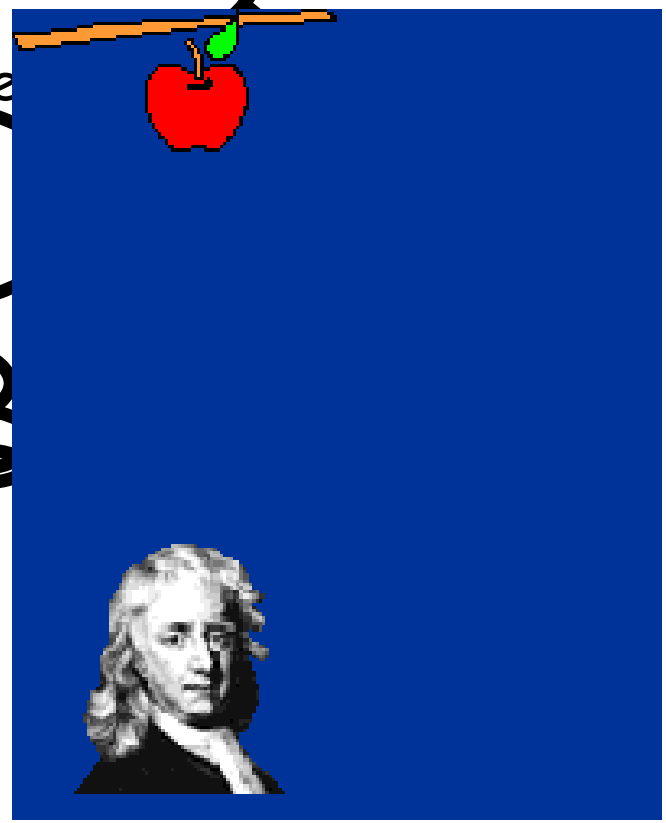


The scattering experiment tells you about the sample, not the probe



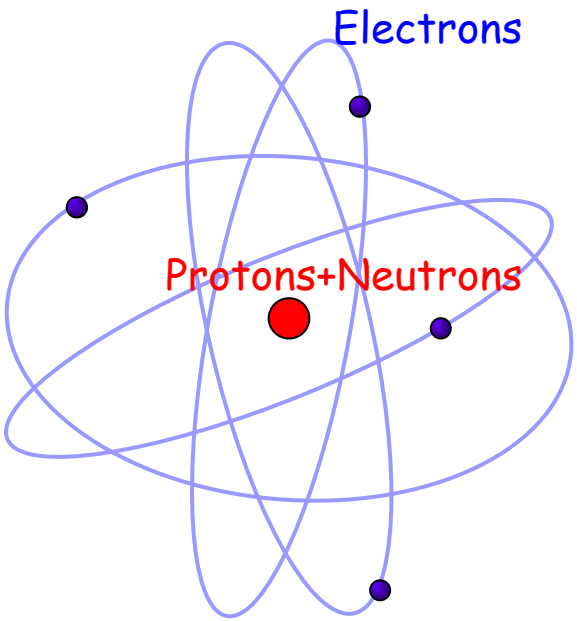
Newton's First Law and the concept of force!

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

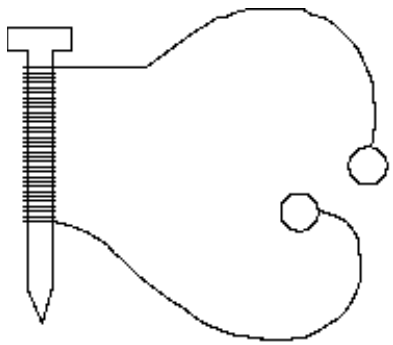
Moving charges, currents, and electromagnets

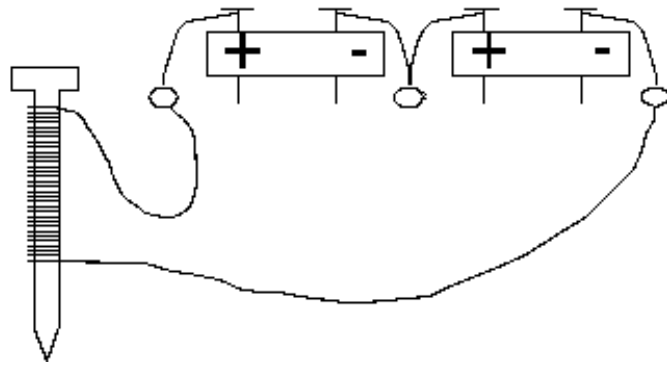
- If charges move they represent a current
- Currents can transport energy

- Currents can produce magnetic fields
- Magnetic fields can change the direction of moving charges

What happens if

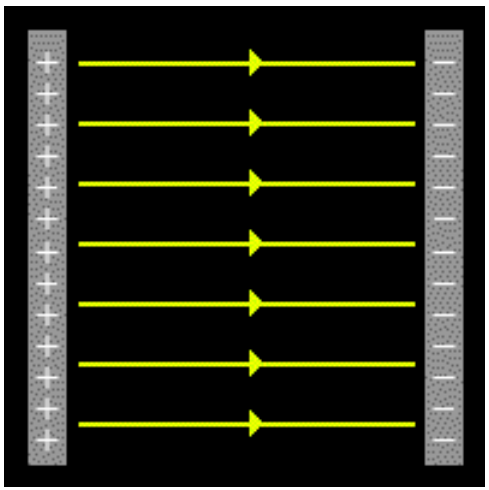
a compass comes close?

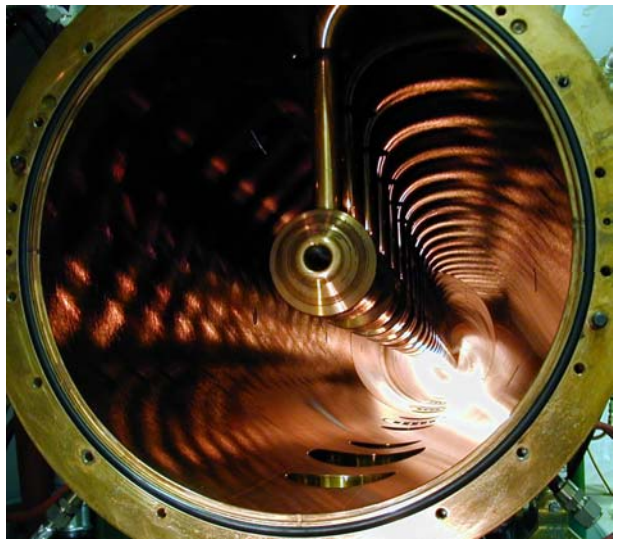


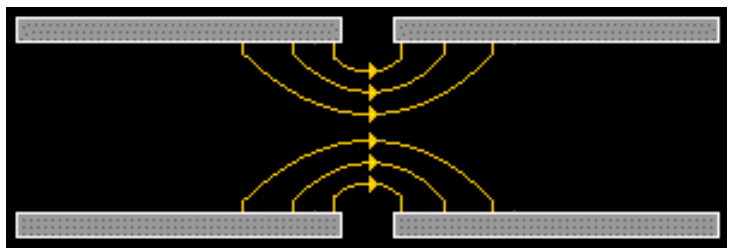


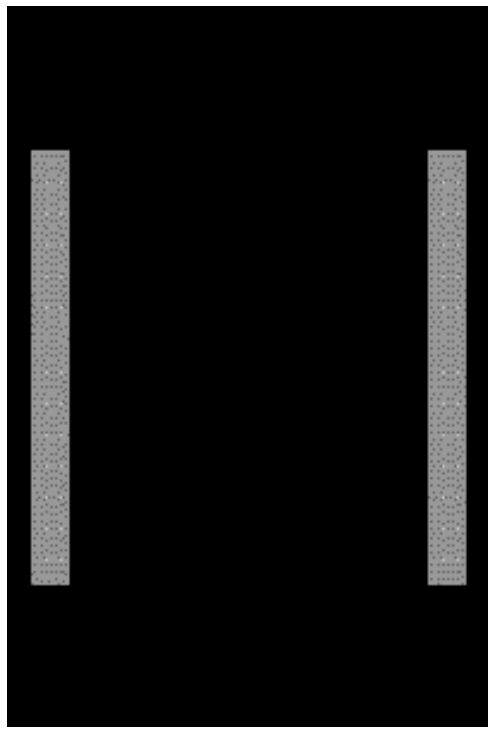
Force and Acceleration: Electric Fields

- An electric field will impose a force on charge, and the charge will be accelerated along the direction of the force !!!



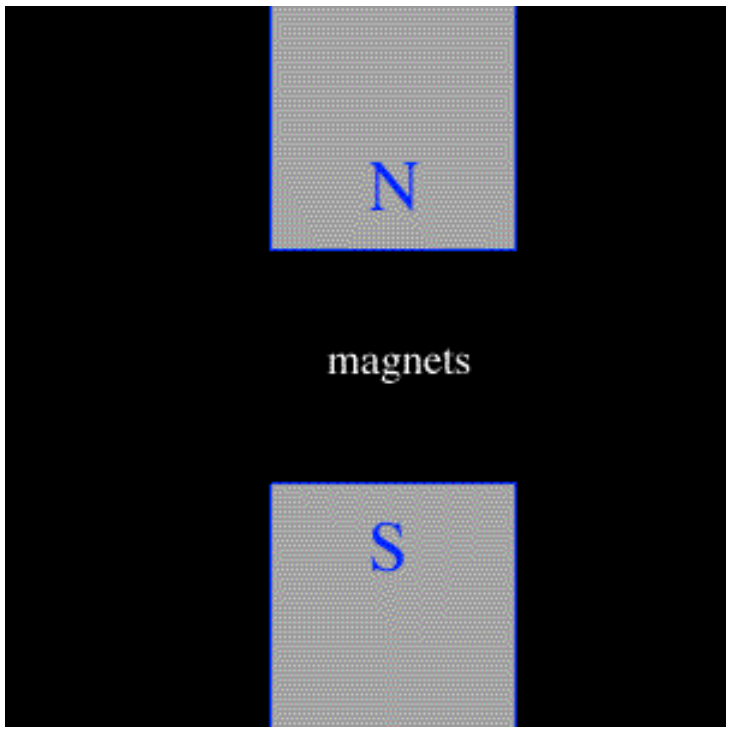






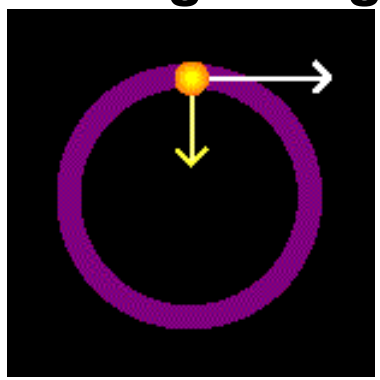
Force and Acceleration: Magnetic Fields

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

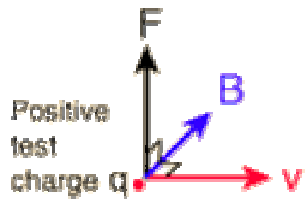


TOP VIEW

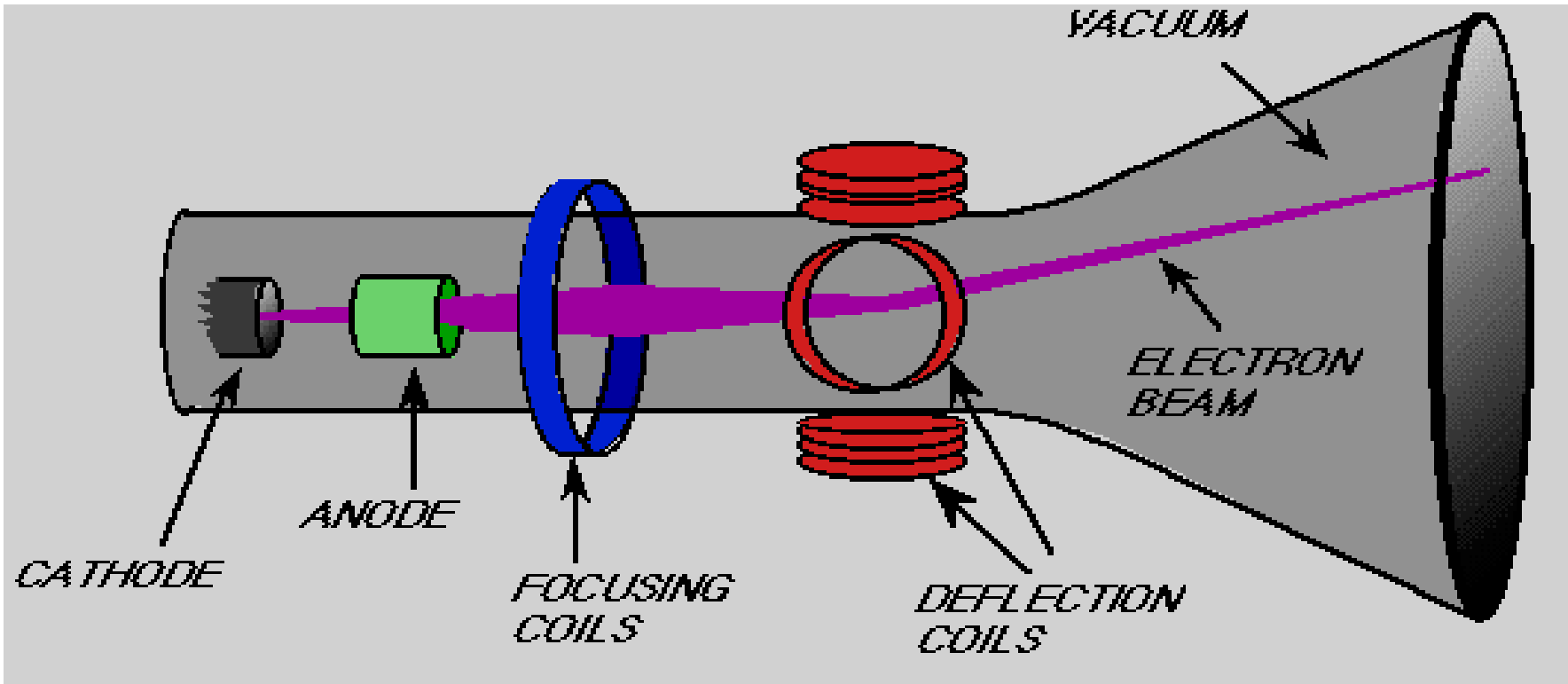
Charged Particle Storage Ring

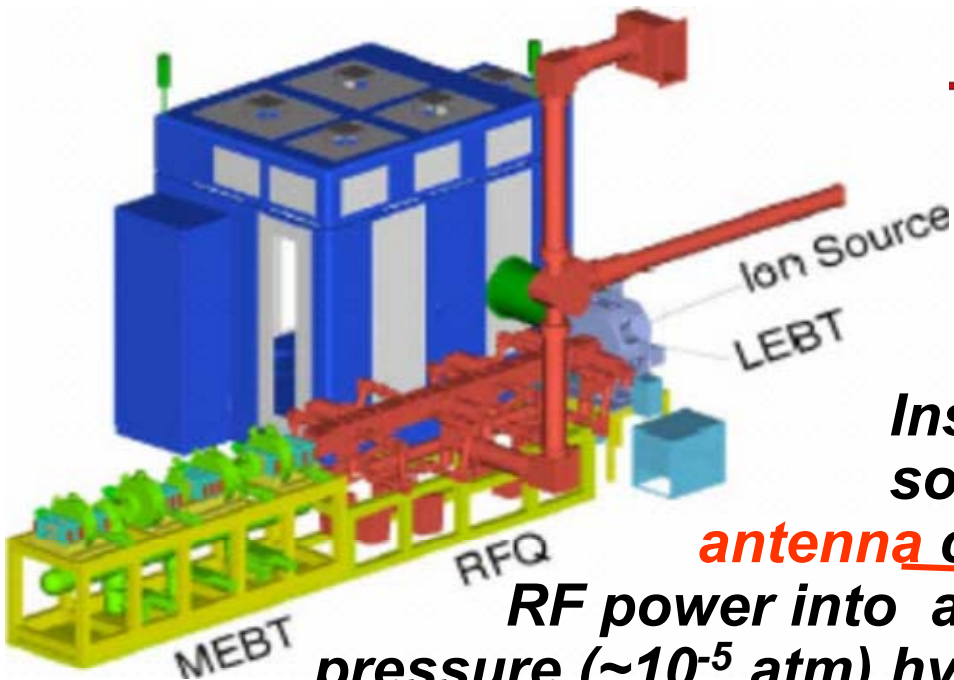


$$\vec{F} = q\vec{v} \times \vec{B}$$

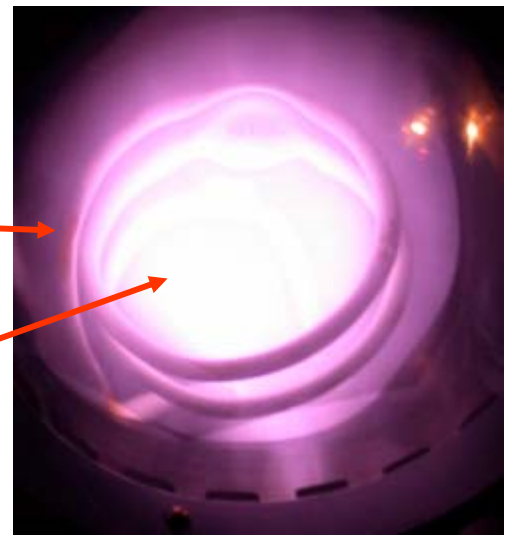


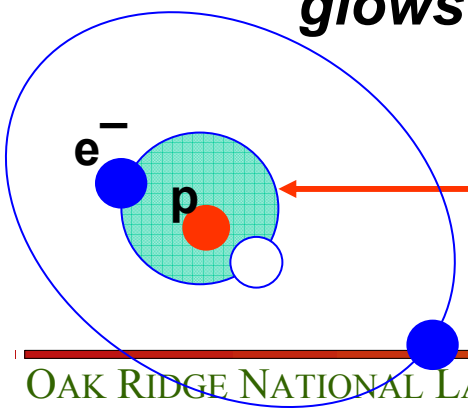
The Simplest DC Electron Accelerator at Home





Inside the ion source the antenna couples RF power into a low pressure (~10^{-5} atm) hydrogen gas. The partially ionized gas (plasma) glows like a fluorescence light.

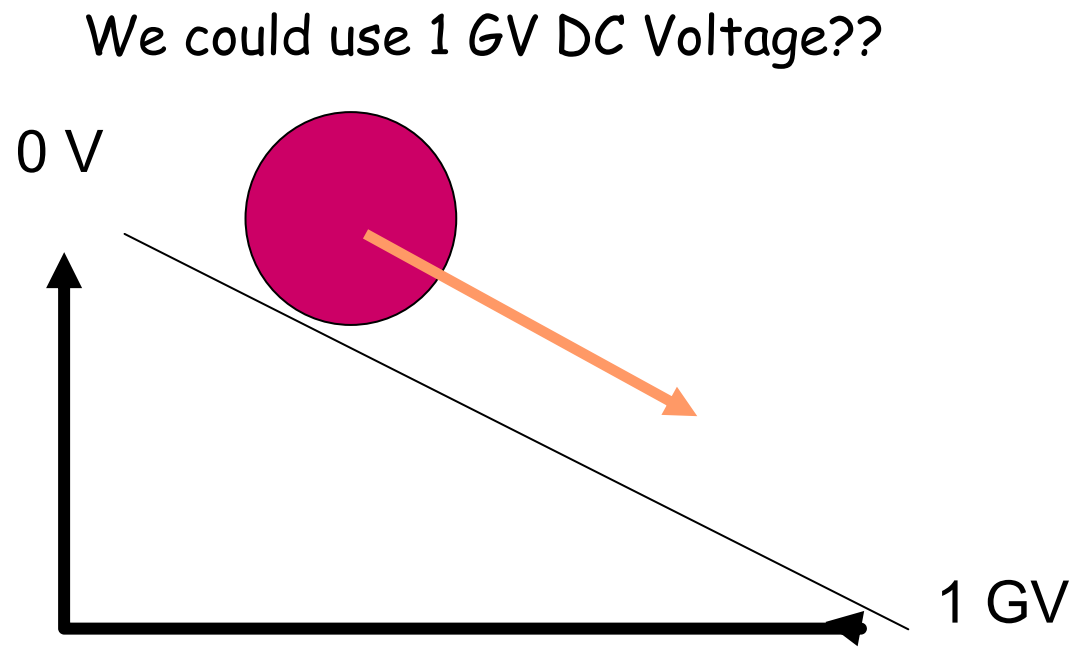




Low energy ions, electrons, atoms, and exited molecules drift through a magnetic field towards the exit aperture where some of them form negative Hydrogen ions.

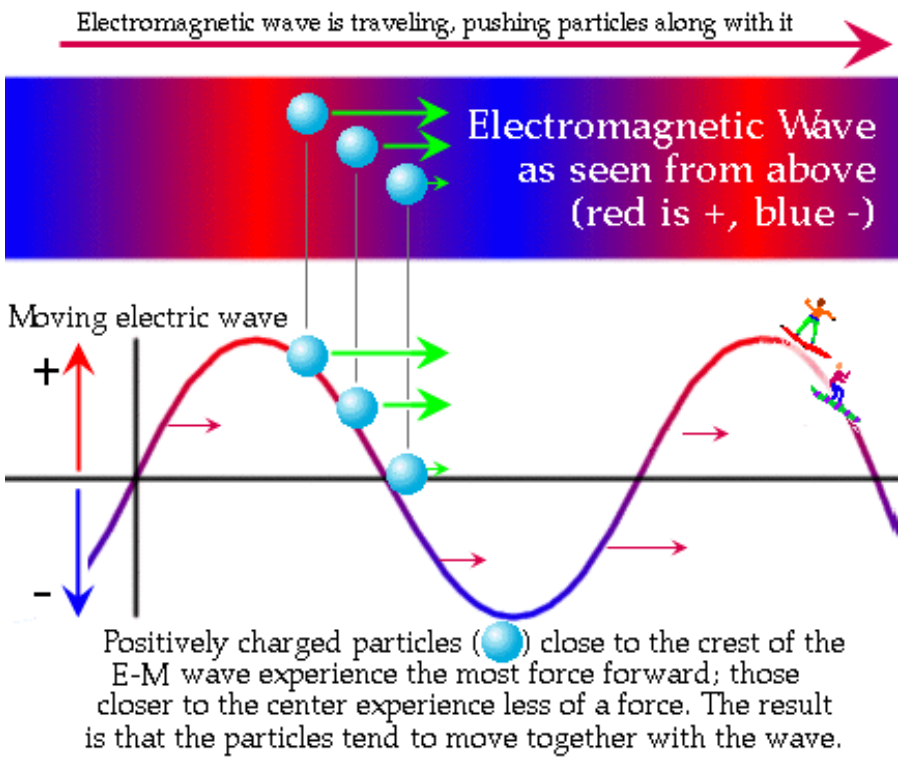
How do we accelerate many charged particles???

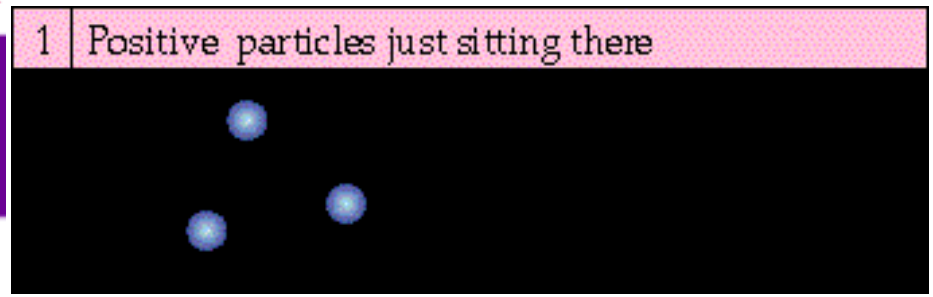
- SNS:
  - 1000 x 1000 x 10 x 100 V = 1000 x 1Million Volt (MV)
  - 1 Giga Volt



Or we could be smarter

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



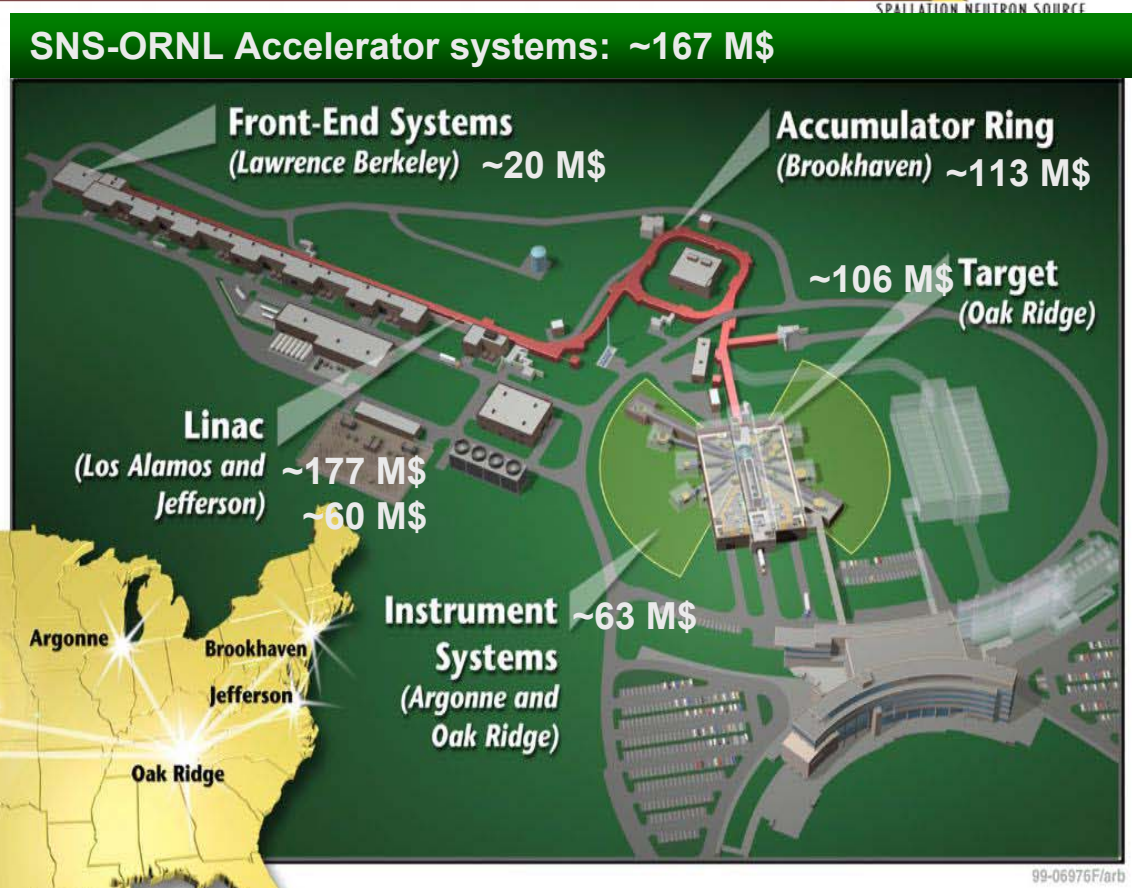


SNS has a 300 meter long evacuated tube where we do this !!!!

The Spallation Neutron Source Partnership

Description		Accelerator
Project Support	75.6	
Front-End Systems	20.0	20.0
Linac Systems	315.9	315.9
Ring & Transfer System	142.0	142.0
Target Systems	108.2	
Instrument Systems	63.3	
Conventional Facilities	378.9	
Integrated Control Syst	59.7	59.7
BAC	1,164.4	
Contingency	28.3	
TEC	1,192.7	
R&D	100.0	80.0
Pre-Operations	119.0	95.2
TPC	1,411.7	713.6

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 2001

Spring 2002

Spring 2003

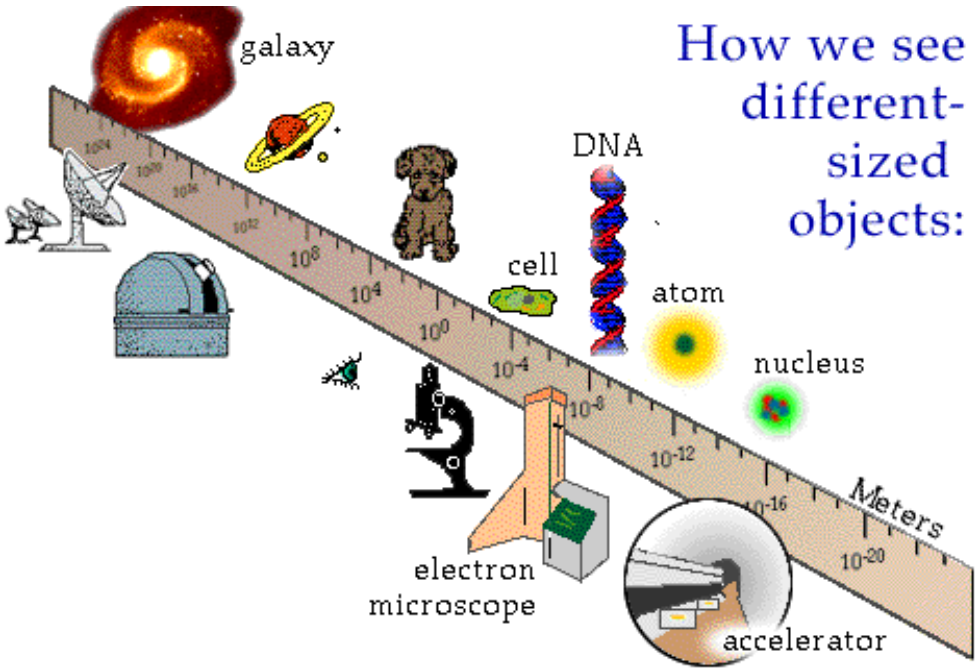
Spring 2004

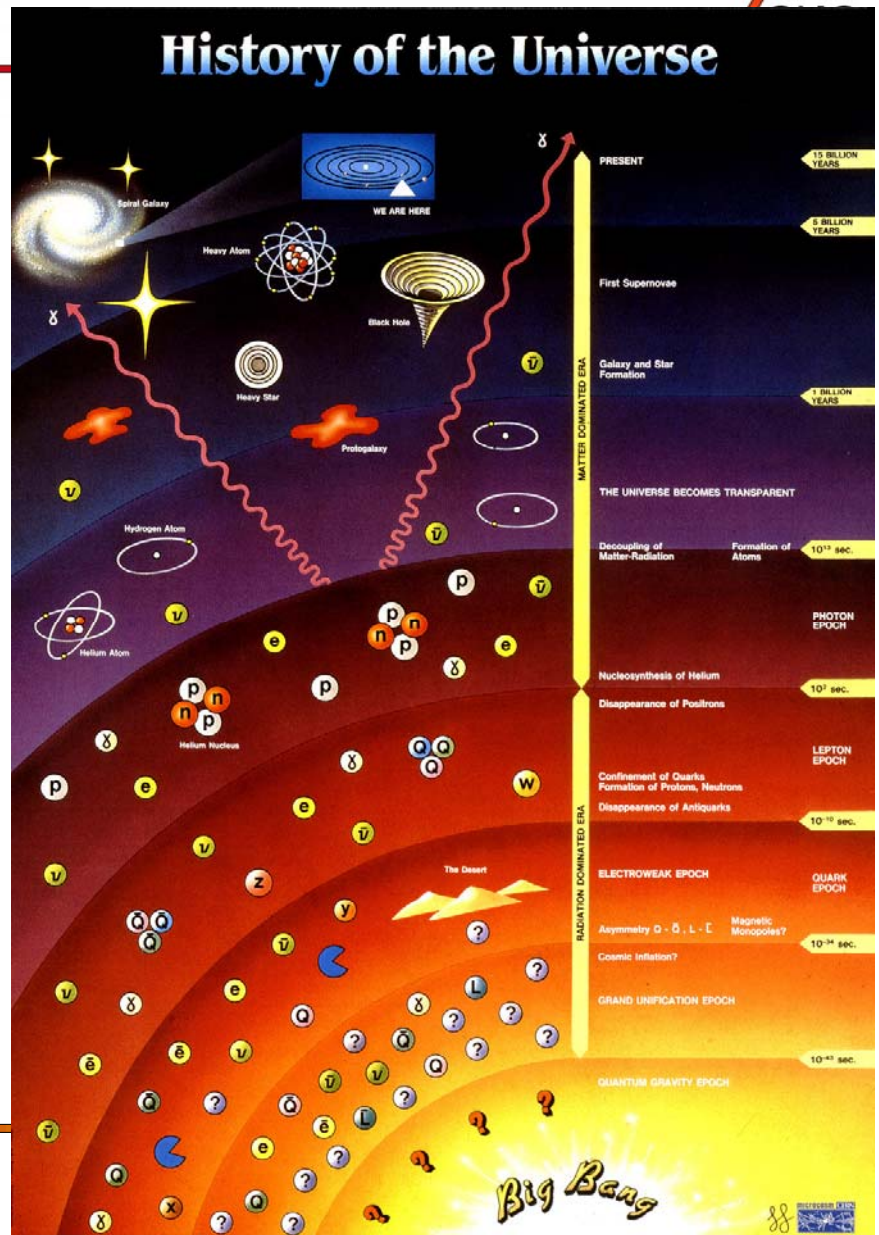
Spring 2005


Front-End Building
Central Helium Liquefaction Building
Klystron Building
Linac Tunnel
Ring
Radio-Frequency Facility
Target
Support Buildings
Central Laboratory and Office Complex
Center for Nanophase Materials Sciences
04-06610/arm

A Sense of Scale

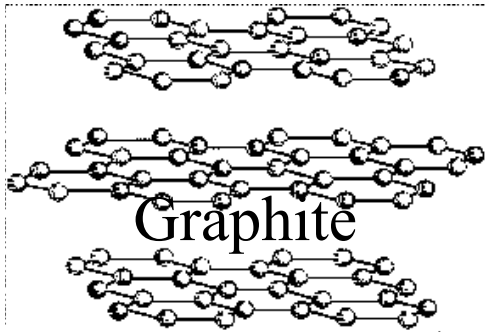
- Next thing: Get a feeling for **time** or **scale** or is it the **same**?: Or why do we built SNS

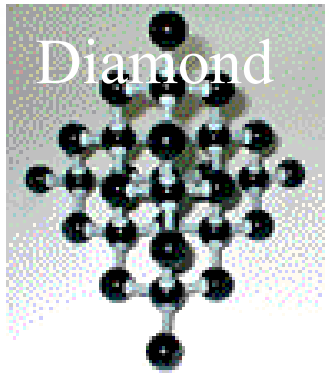


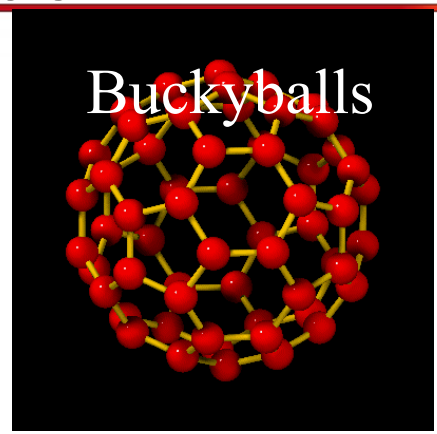


Structure Determines Properties

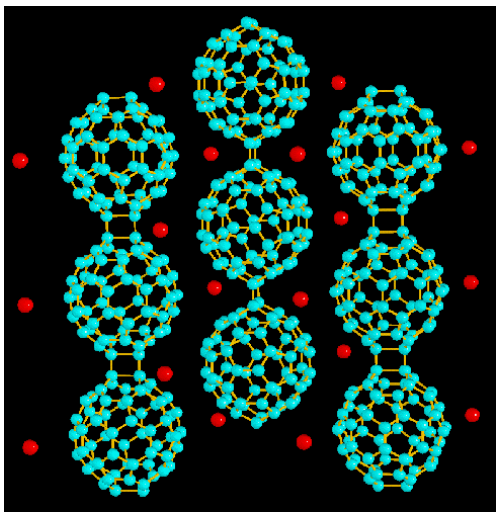
3 forms of Carbon - very different materials

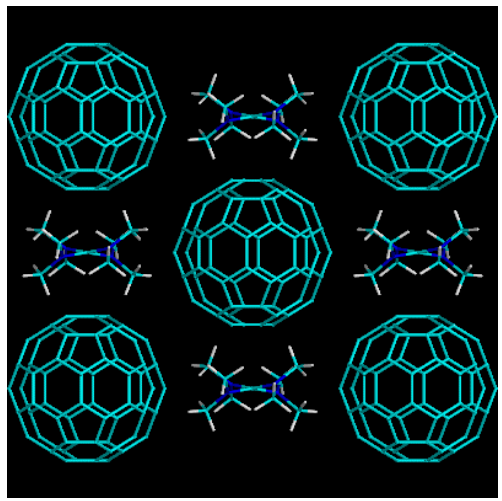




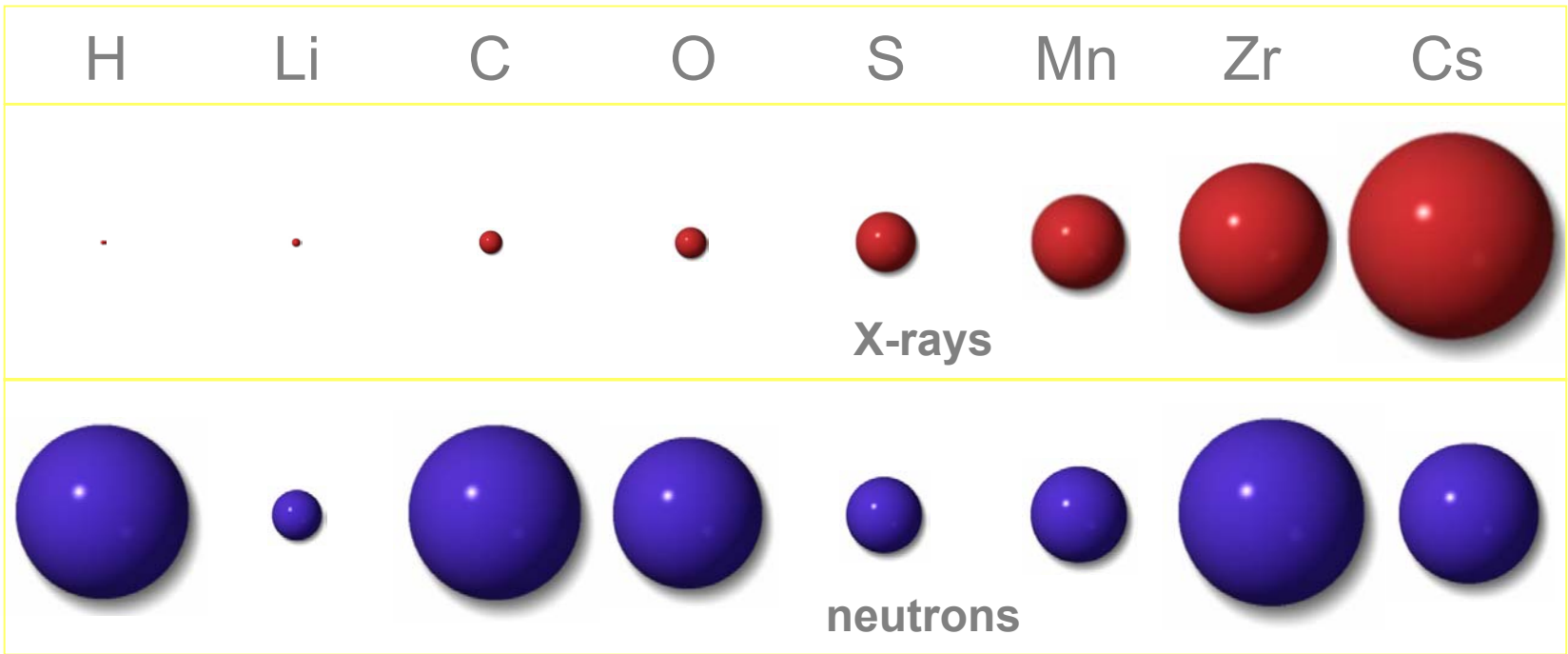


- Superconductors or organic ferromagnets





Neutrons see the Nuclei

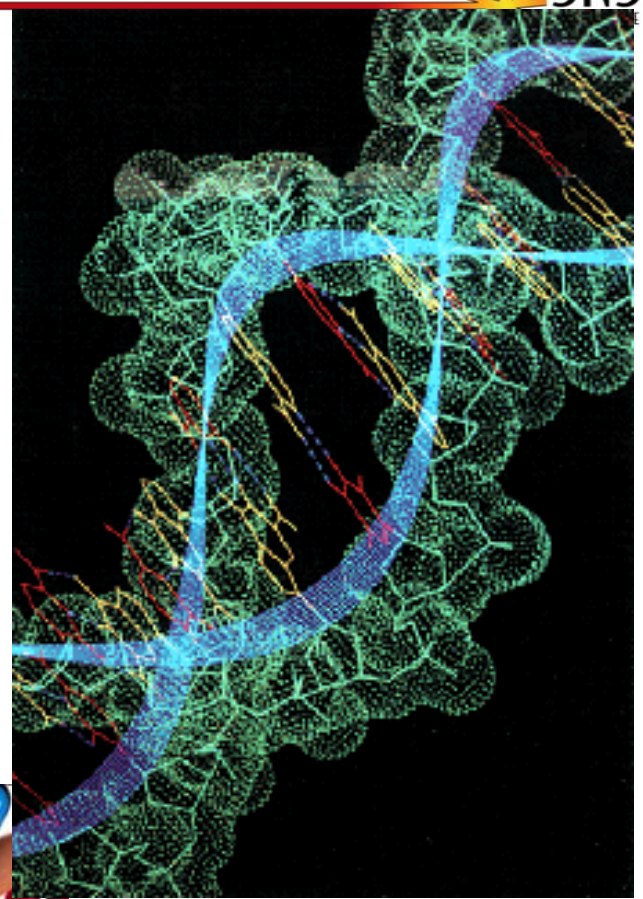


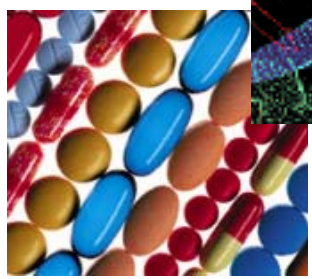
Neutrons see the Nuclei

Better performance of complex fluids.

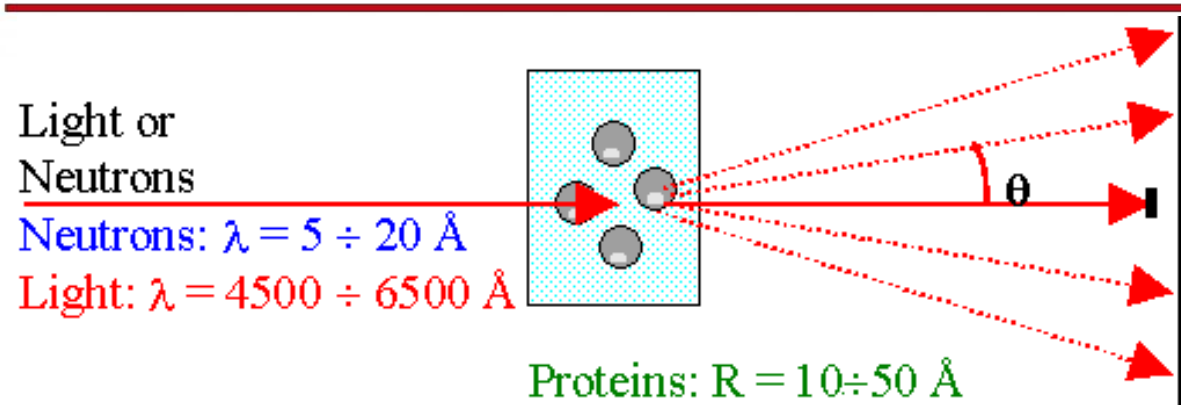
Biology and Neutron Scattering: >95 % of the Body is Water!

- 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?

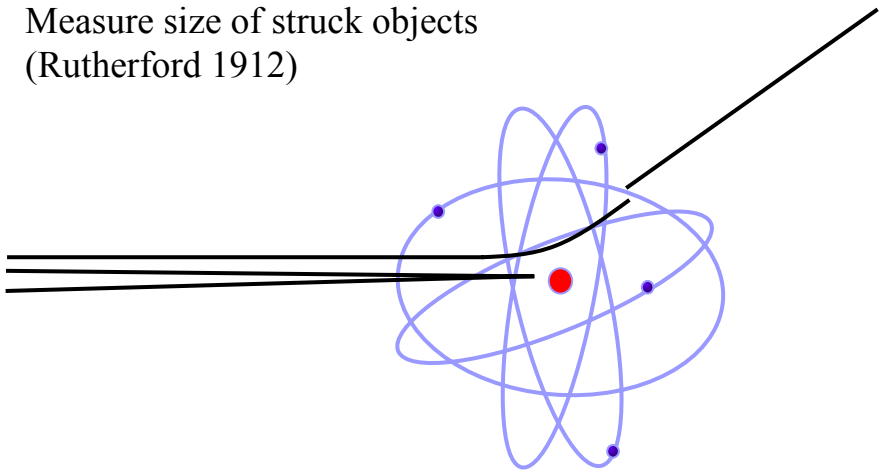


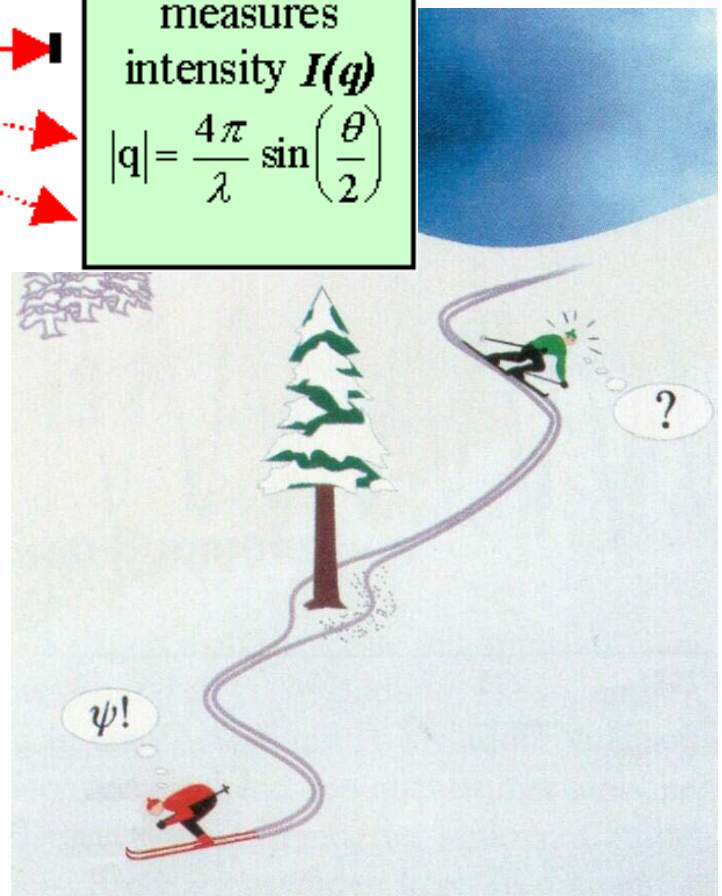
Detector measures intensity $I(q)$

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

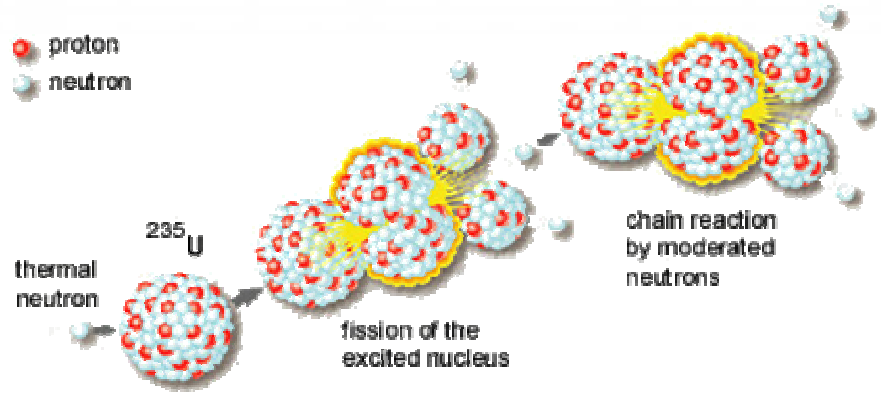
$\lambda = h/p = h/\sqrt{(2*m_N*E)}$ De Broglie

Measure size of struck objects
(Rutherford 1912)



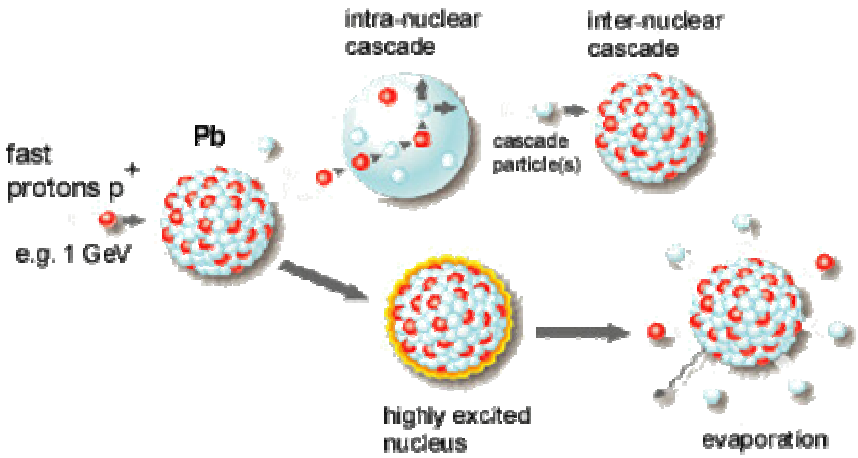


Spallation-Evaporation Production of Neutrons and Why to use heavy metal target



Fission

- chain reaction
- continuous flow
- 1 neutron/fission

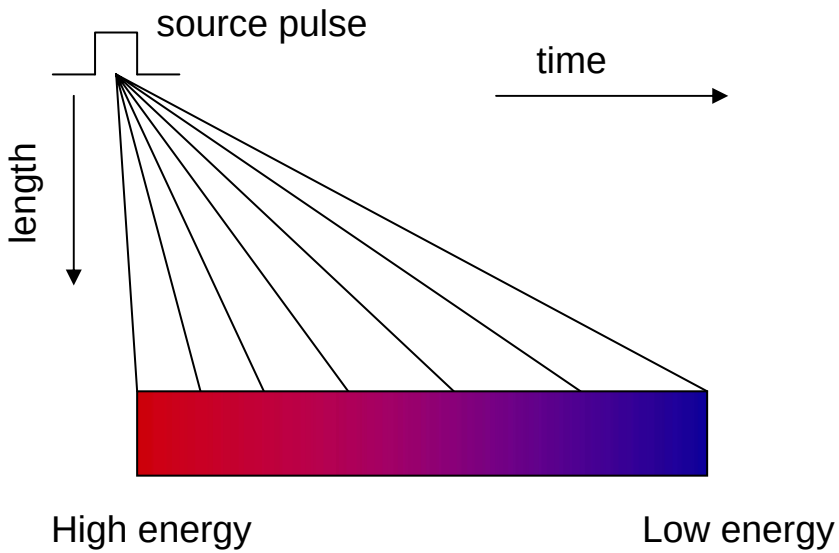


Spallation

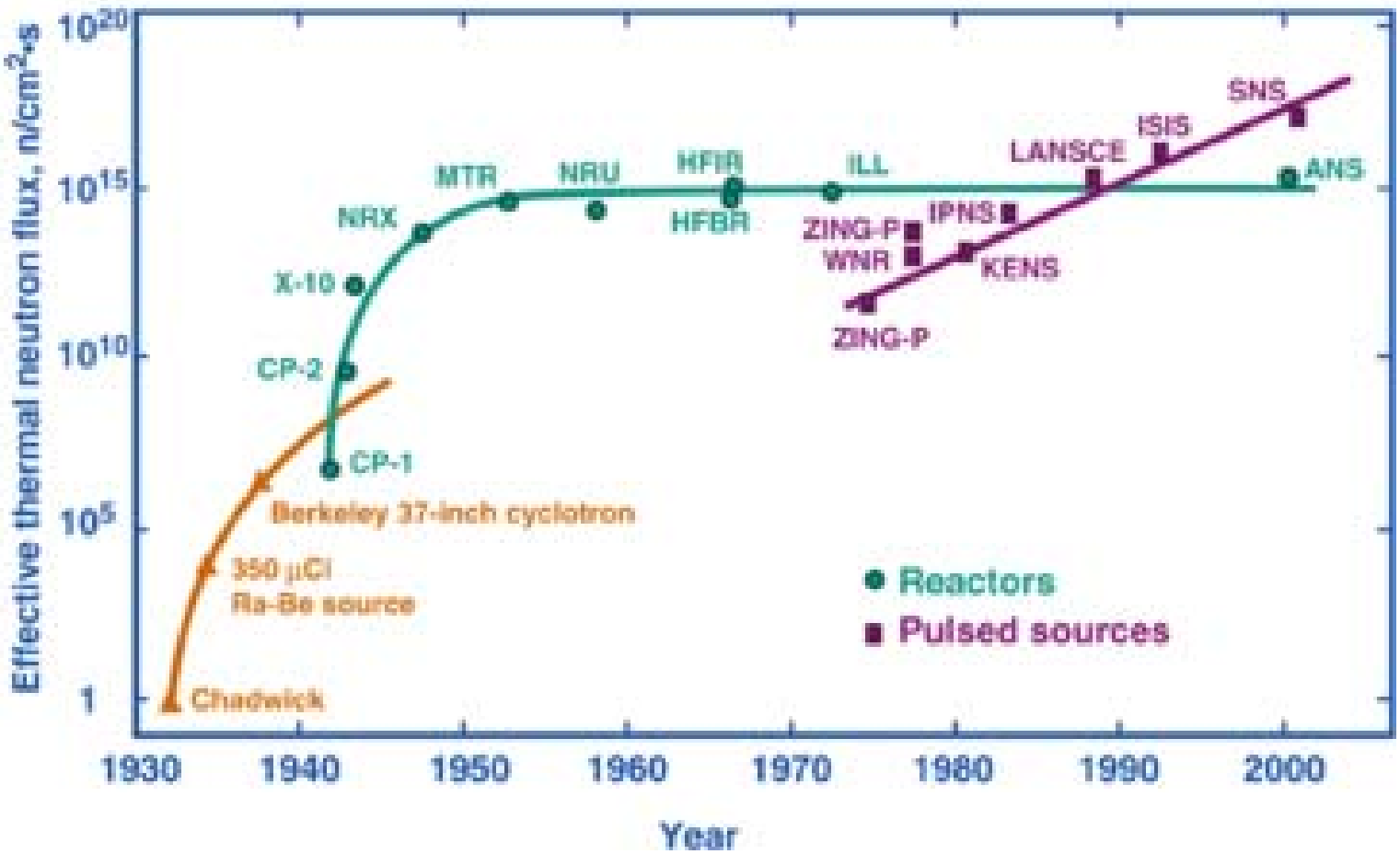
- no chain reaction
- pulsed operation
- 30 neutrons/proton

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



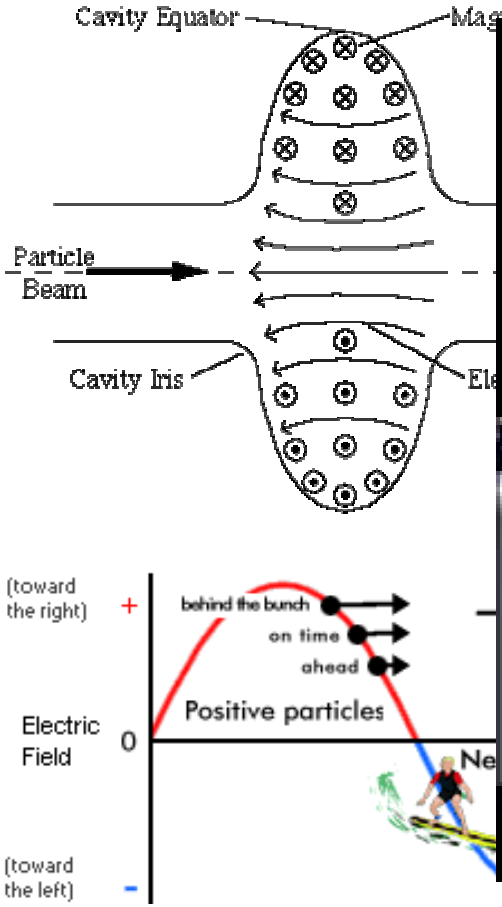
SNS will be World-Class! (being the best…)

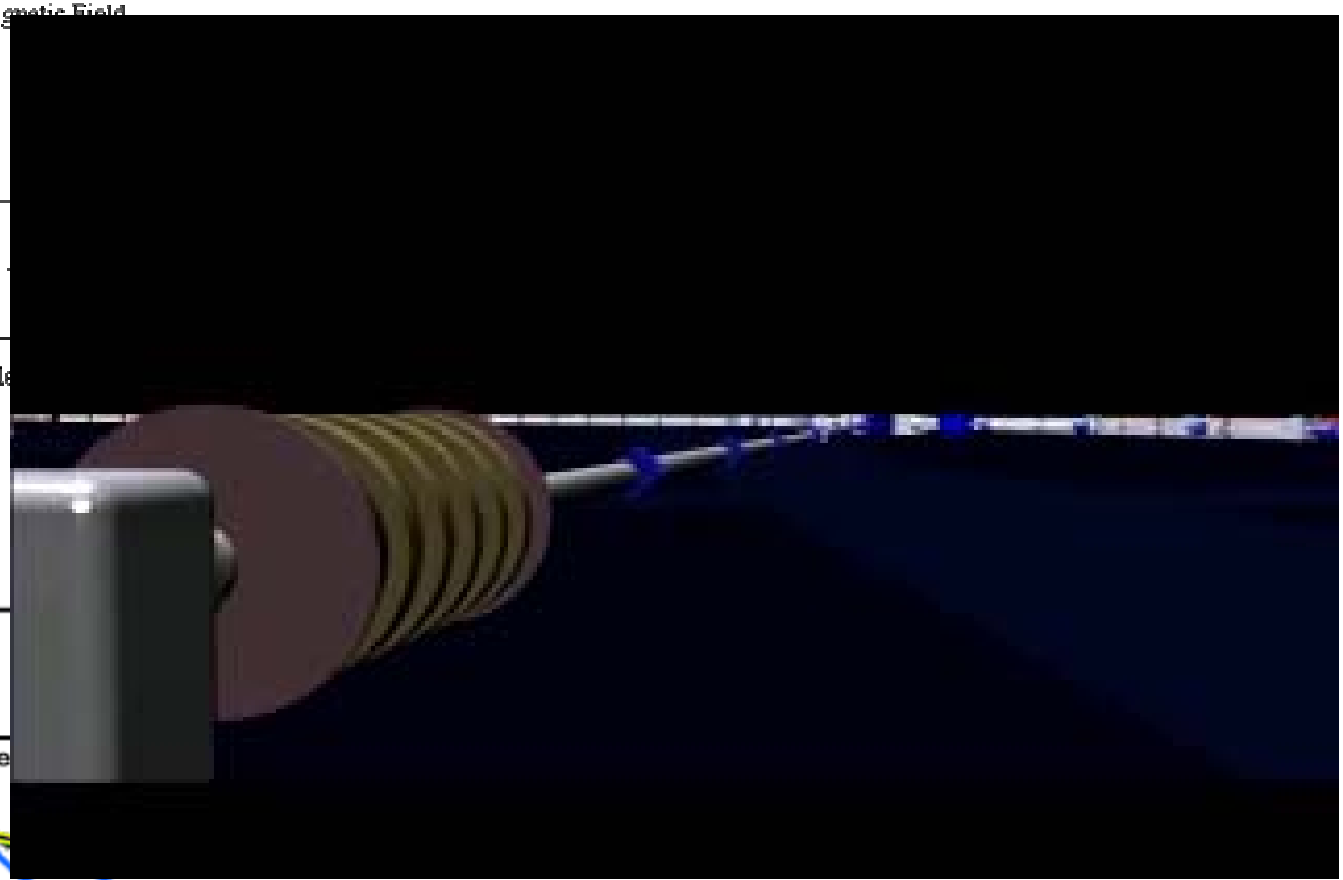


97-3924E uc/djr

RF Acceleration for the SNS

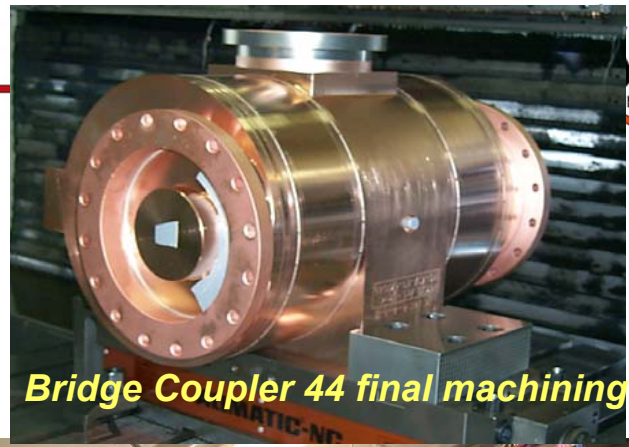
- How to efficiently accelerator H^- ions / charged particles?





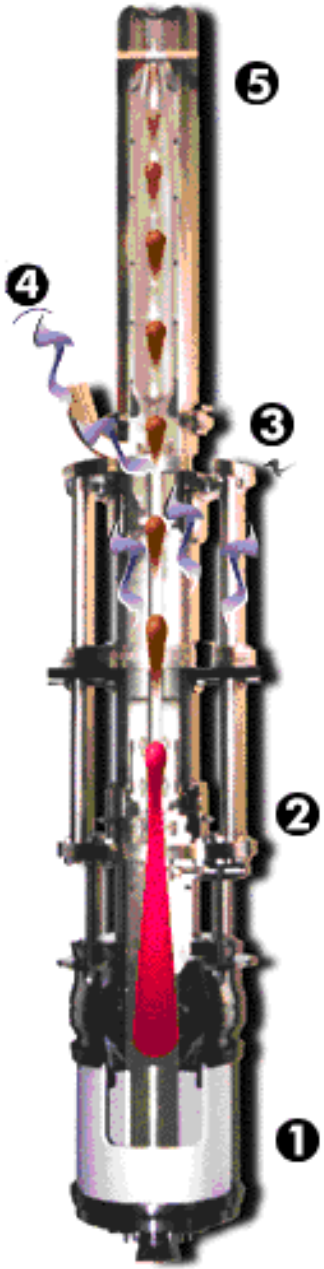
Drift Tube Linac

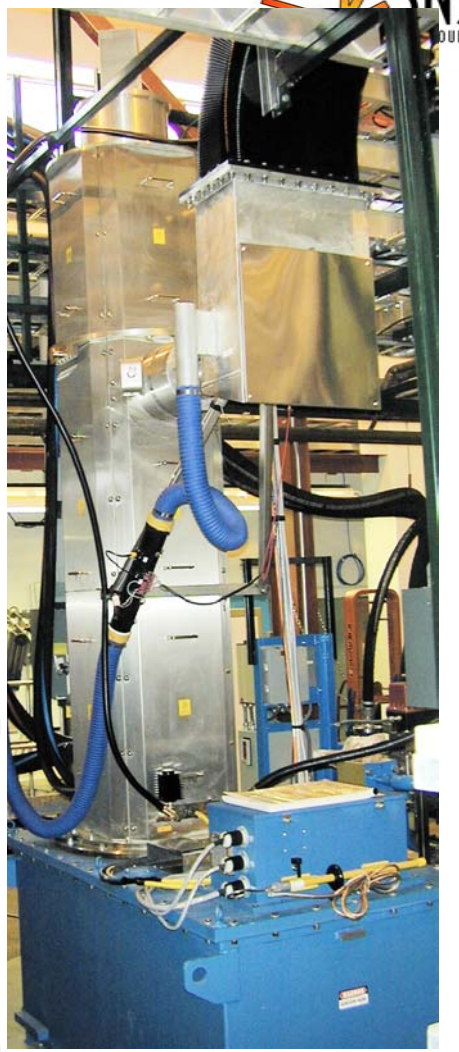
Coupled-Cavity Linac



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?)

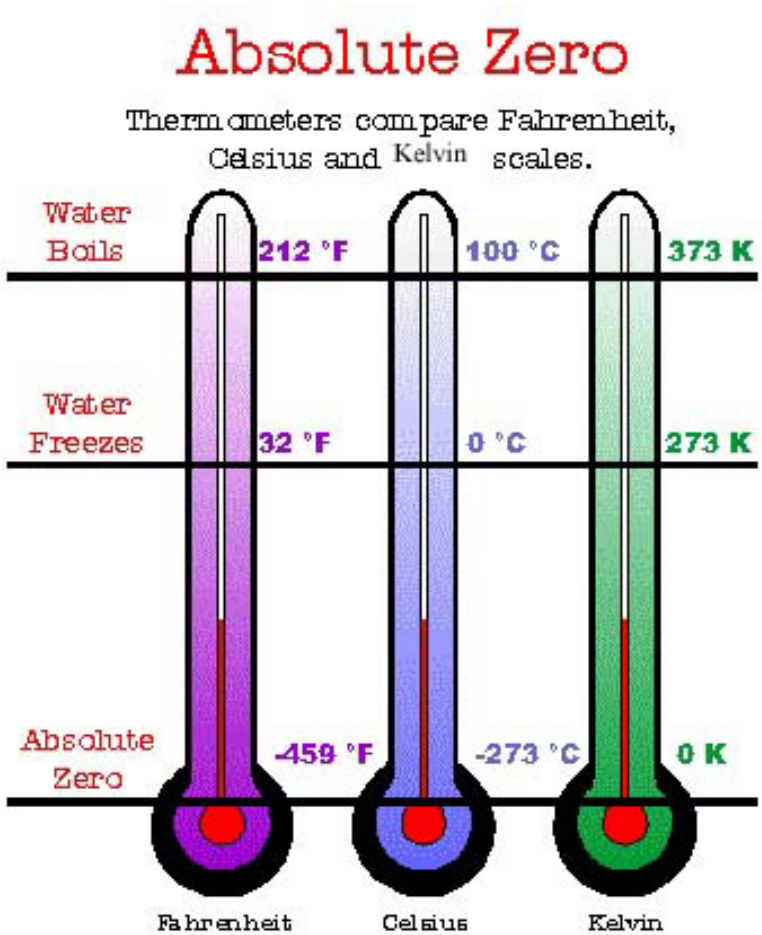


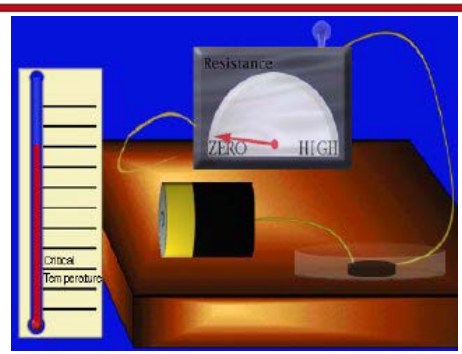


High-Power RF Installation

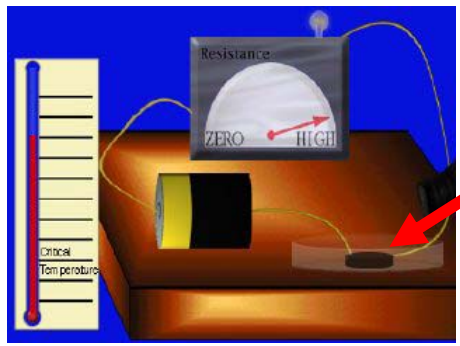
- **High-Power RF System (klystrons, waveguide, power supplies, …) supplied by LANL**

Superconductivty



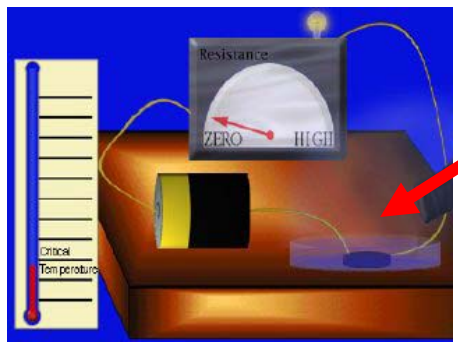


Current 0



Current on,

Resistance is high



Current on,

Resistance very low,

After cooled down

Cavity Preparation

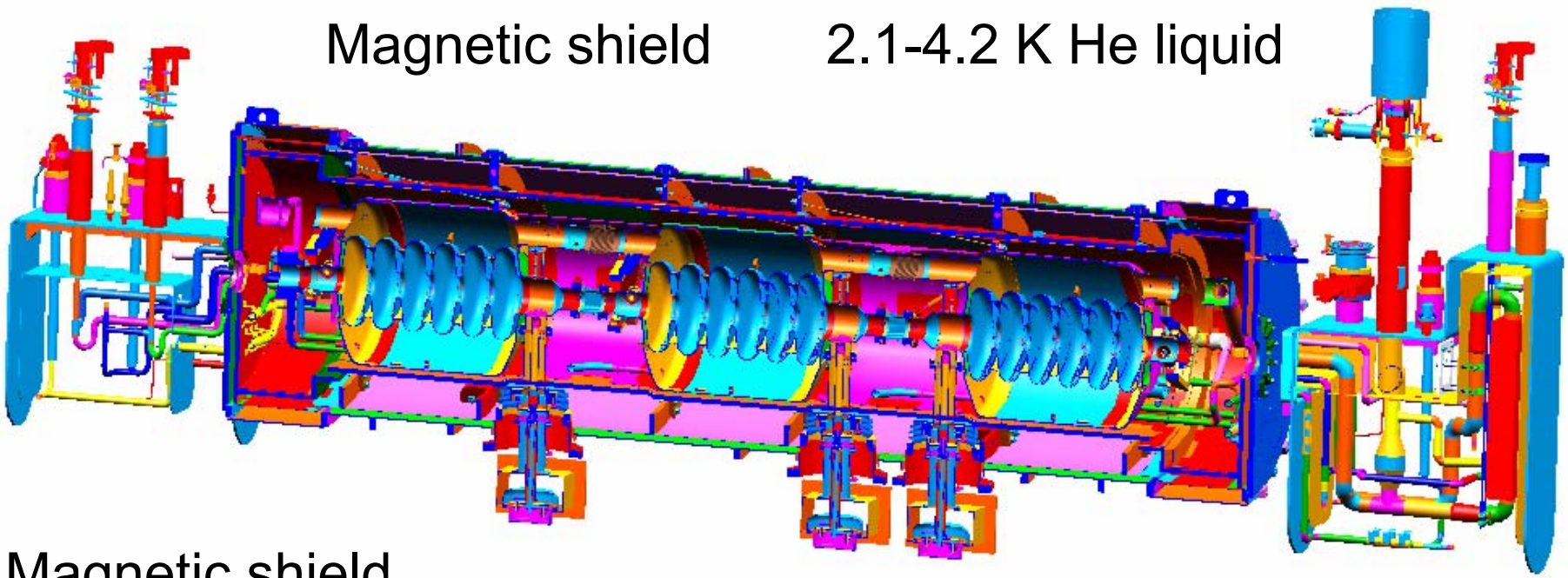
BCP 1:1:1 or 1:1:2
~120μm removed

~1hr HPR

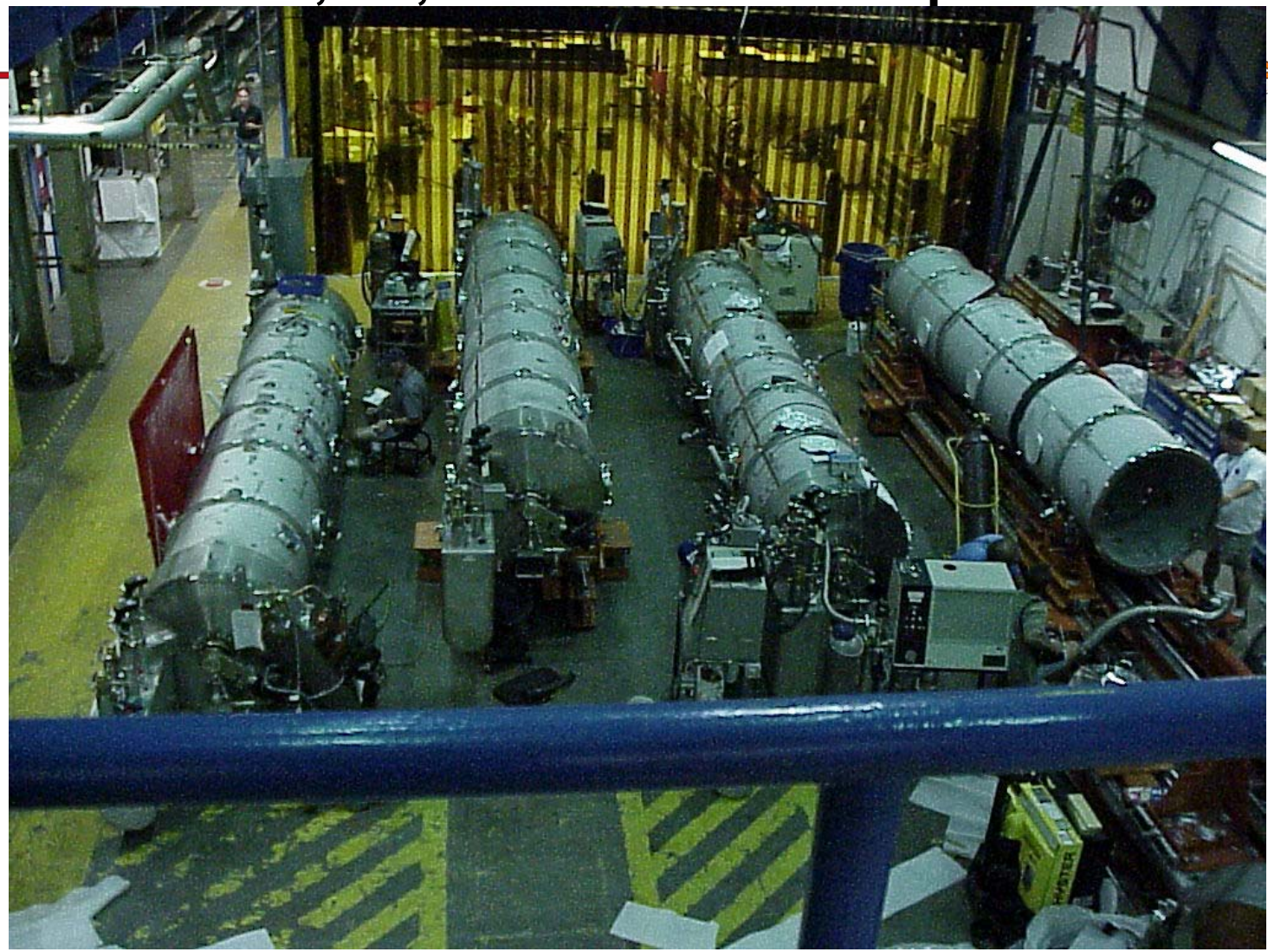
Assembly in clean room
(class 100)

Dewar insertion

Medium Beta Cryomodule Internal Structure



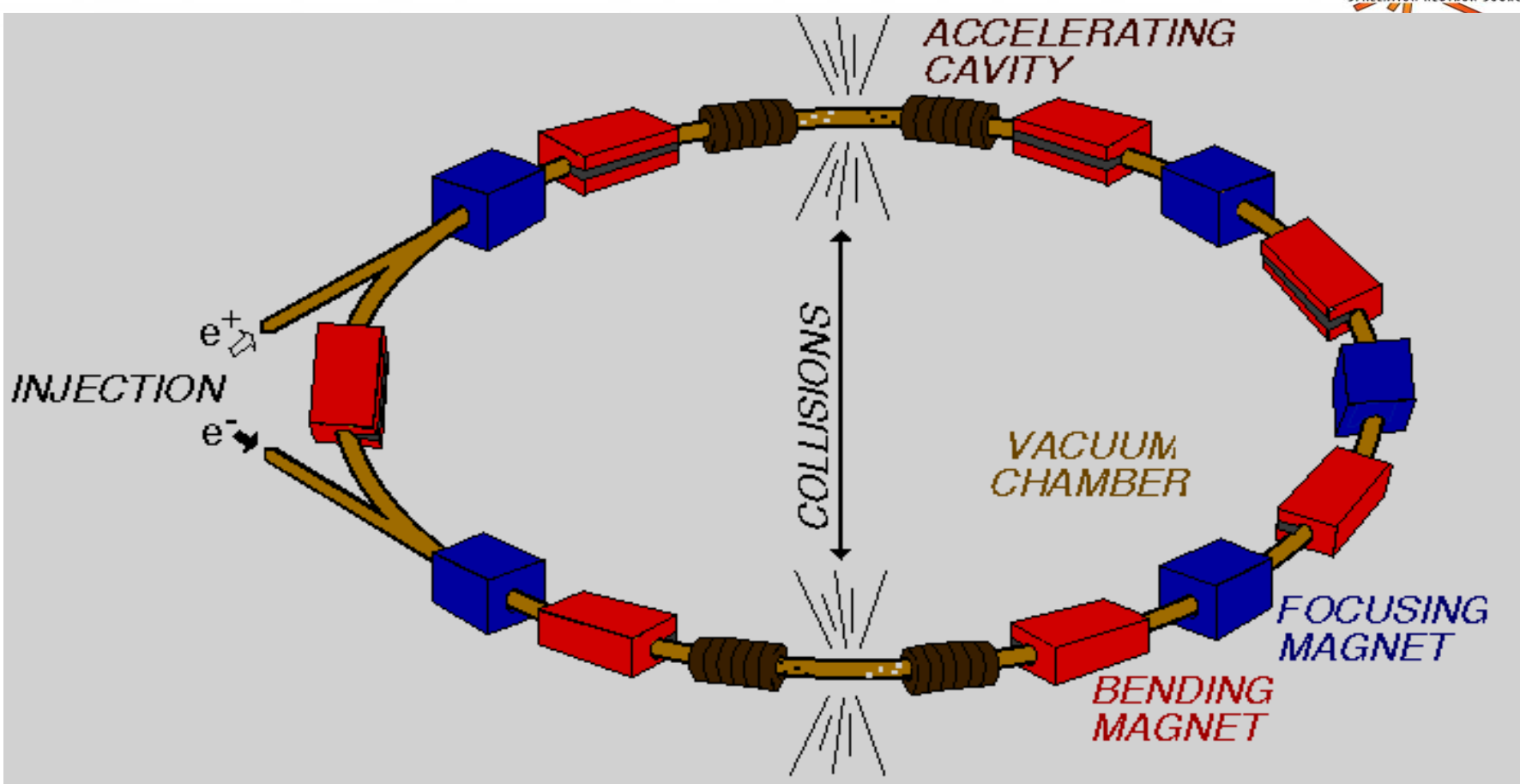
Cryomodules H1, H3, & H5 thru H8 Sep 04



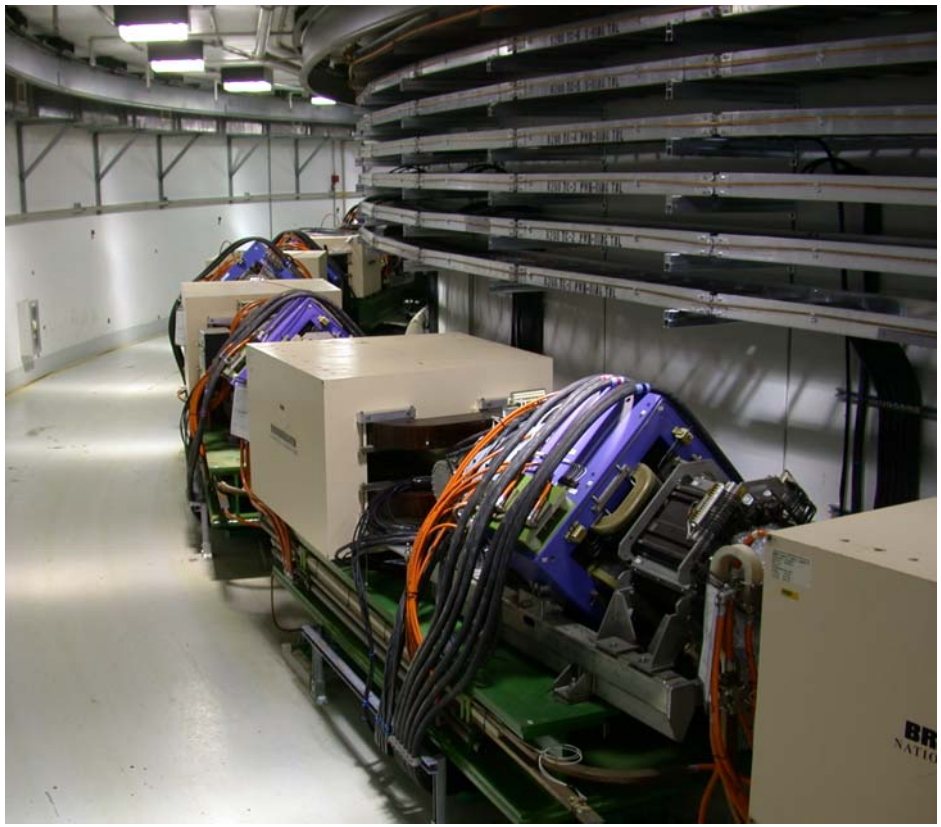
Status of Superconducting Linac

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

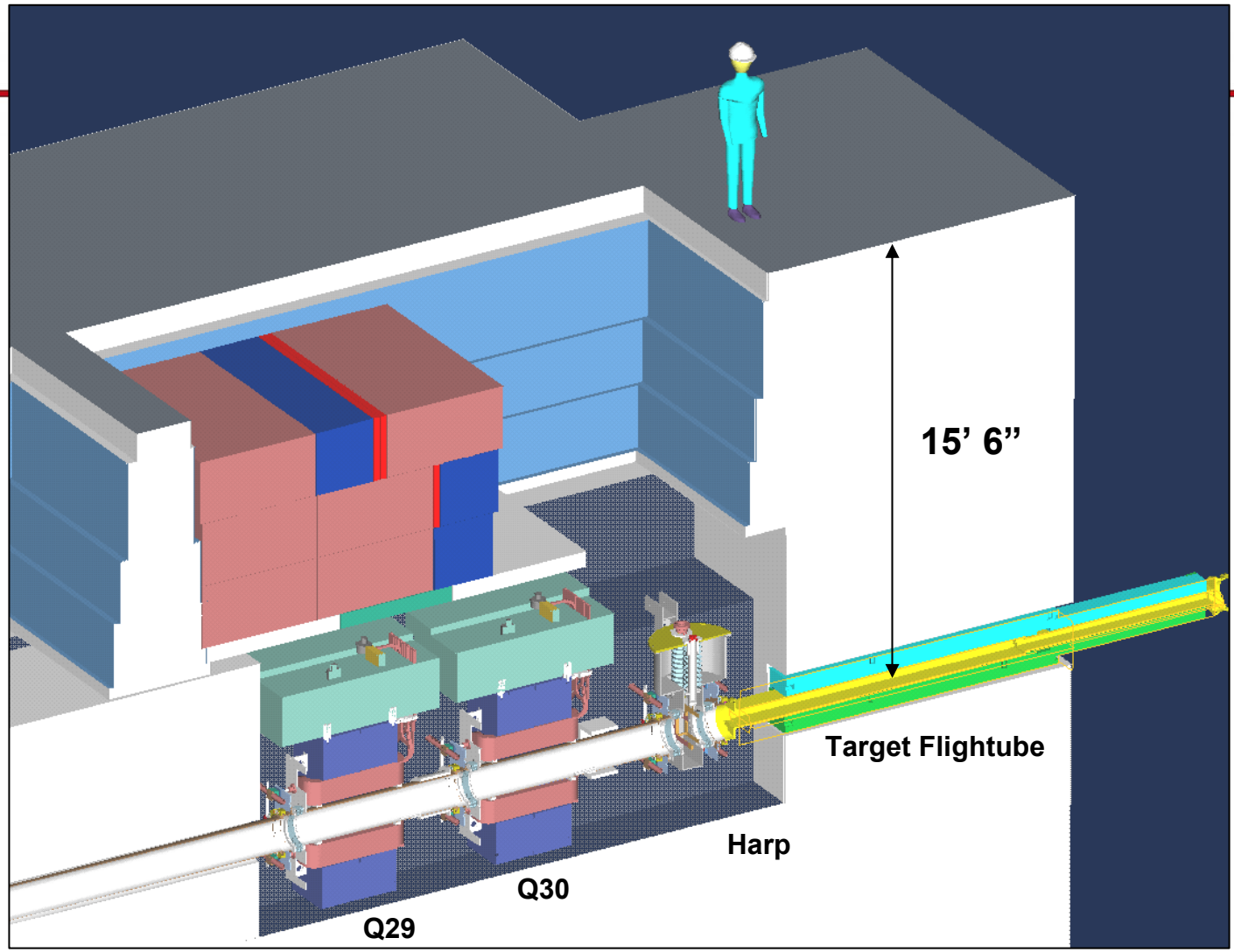
The SNS Storage Ring



RTBT Installation Progress

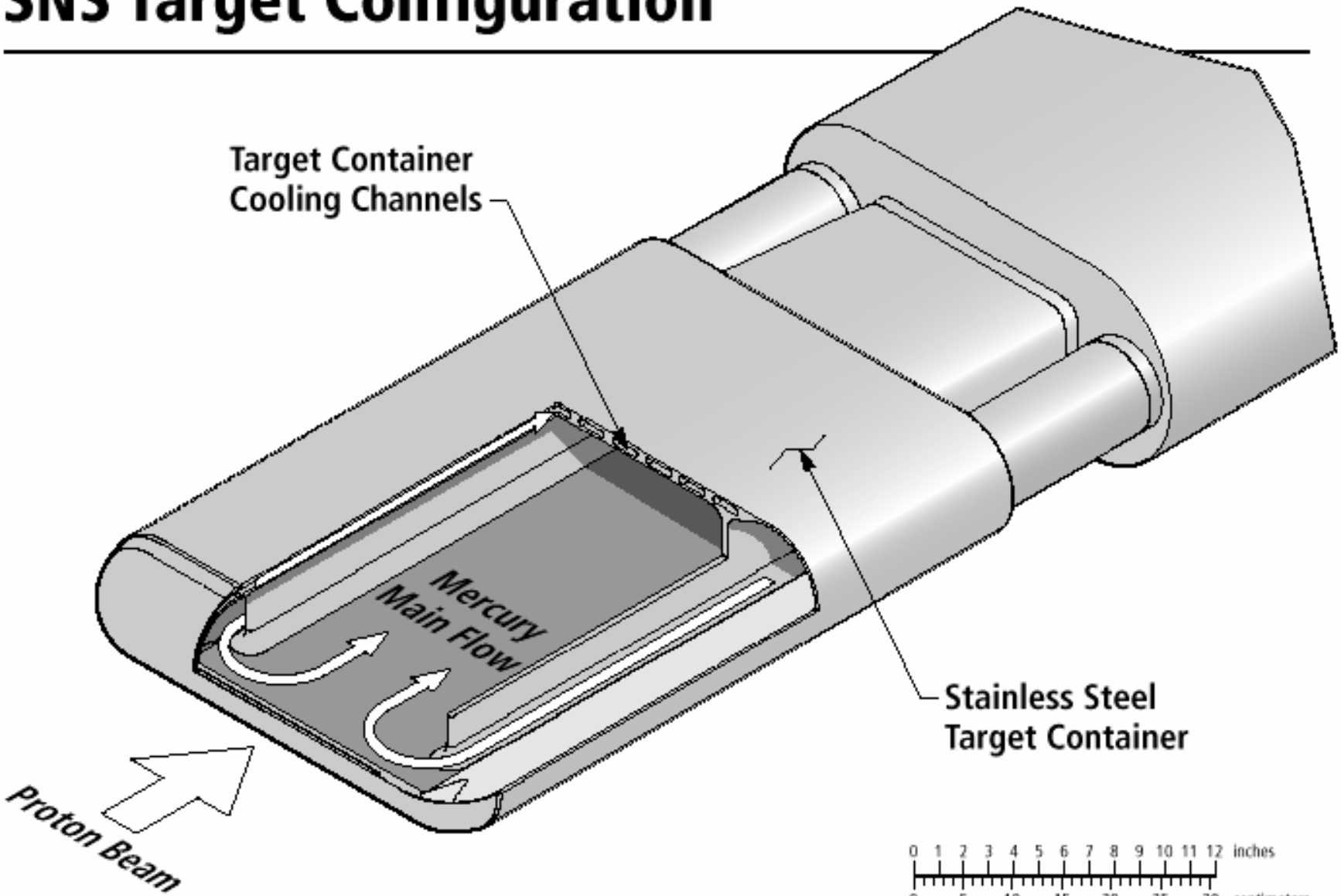


RTBT/Target Interface

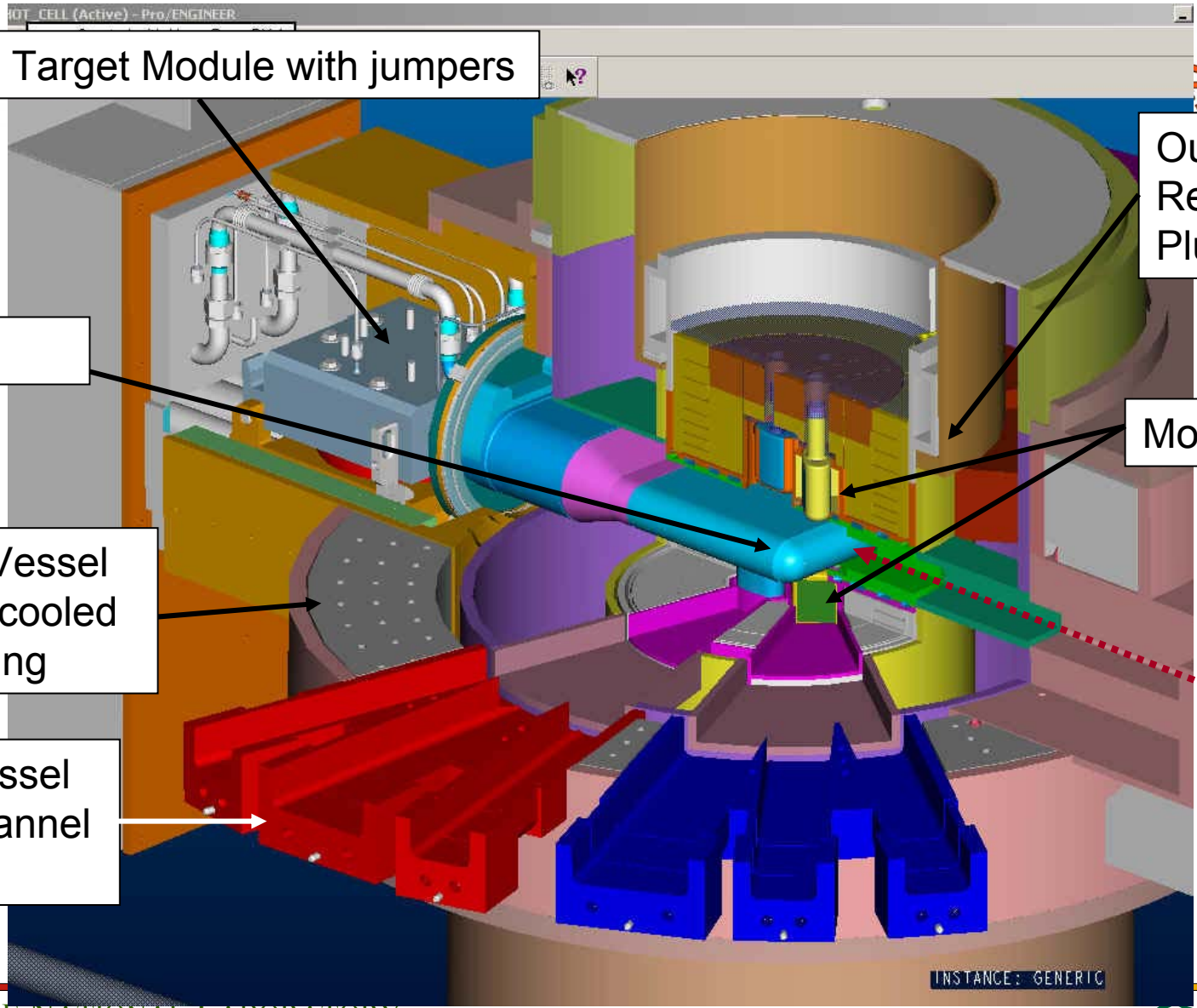


Section through RTBT/Target Flight-tube Interface

SNS Target Configuration

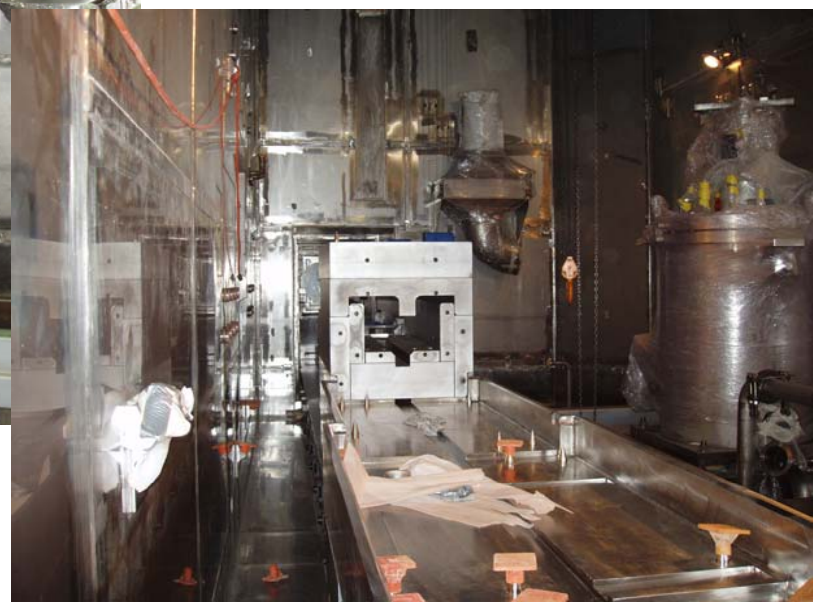


Target Region Within Core Vessel



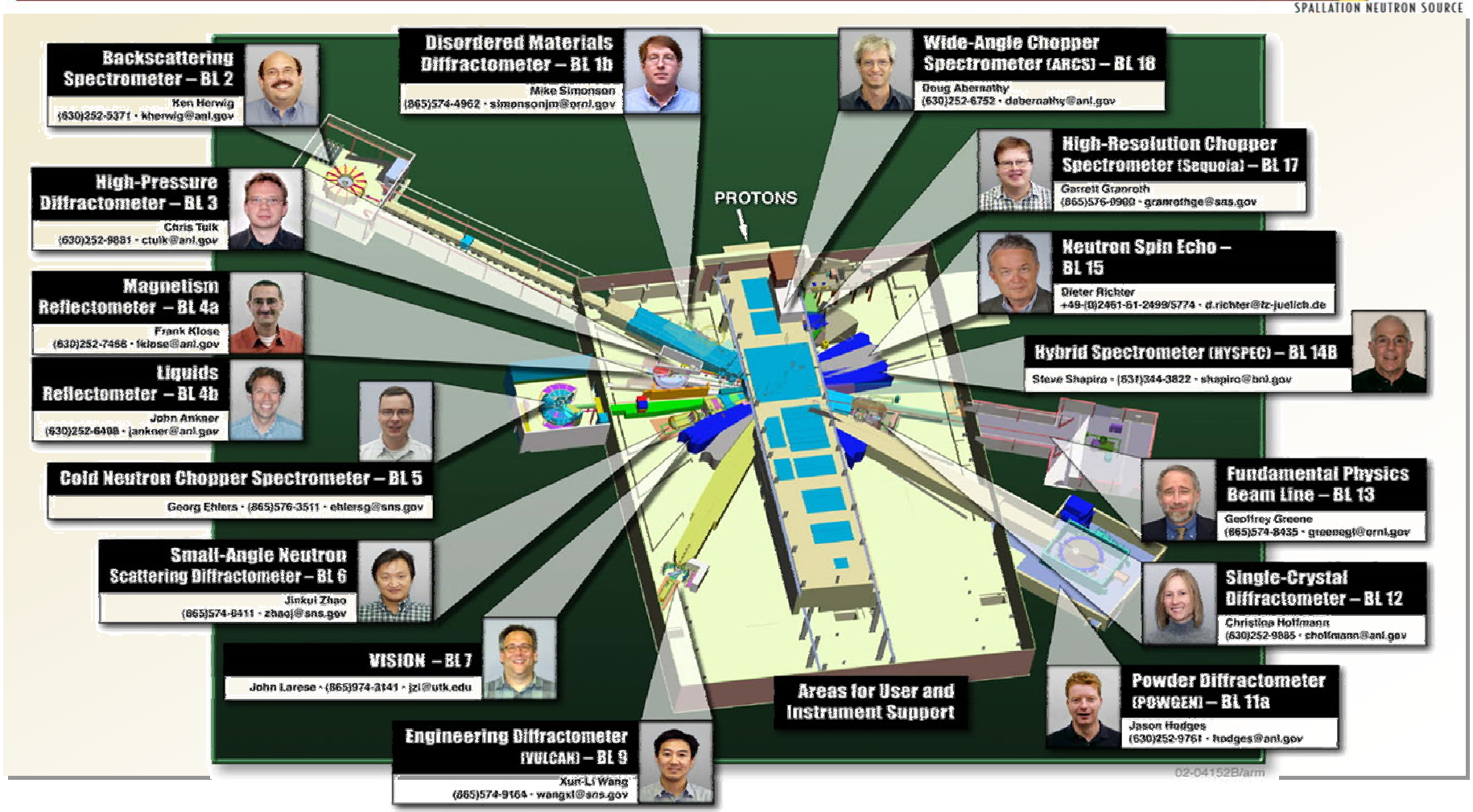
Target Service Bay Installation

- 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