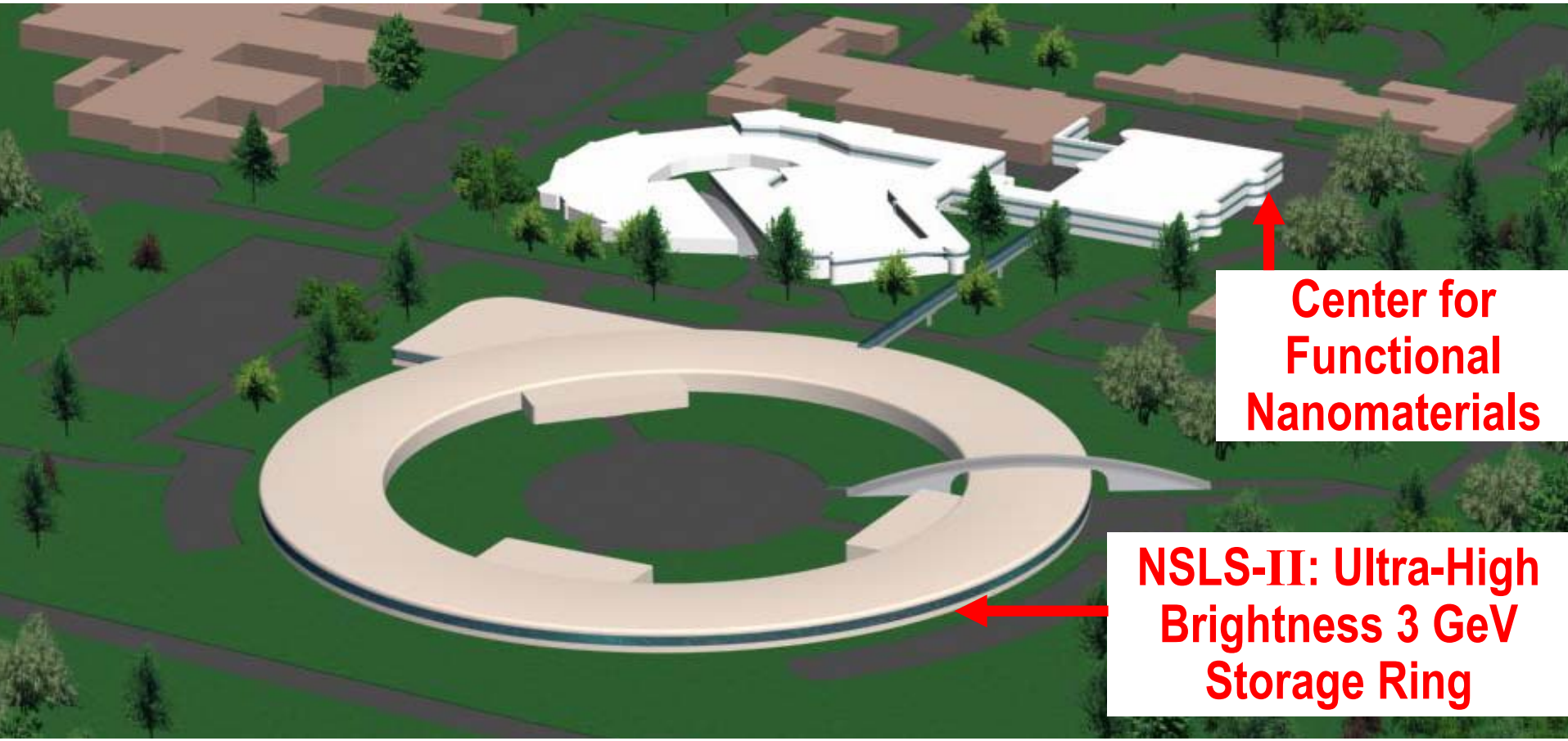
NSLS Facility Upgrade: NSLS-II

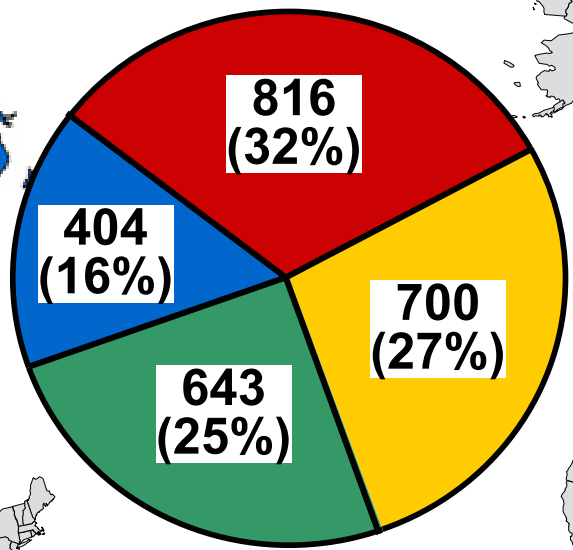


Steve Dierker
Associate Laboratory Director for Light Sources and Chairman, NSLS
September 22, 2003

National & Regional Resource

2500 Users/year
(Largest number of users - 40% of all DOE sync users)

International

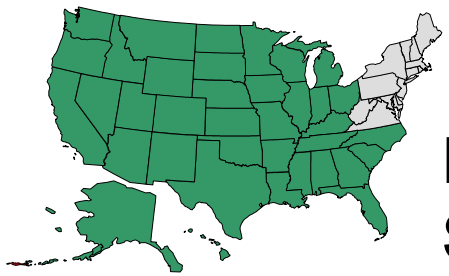


New York

Central to BNL programs

Other Northeast States

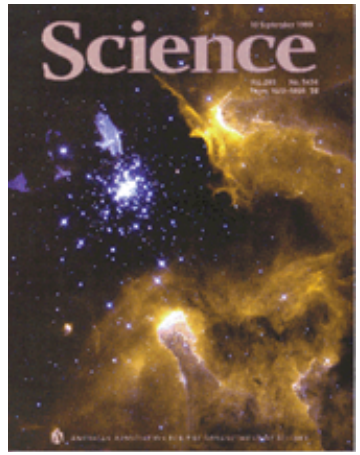
Industry: IBM, ExxonMobil, Lucent, pharmaceuticals



Non-Northeast States

Provides Essential Scientific Tools

- BNL Center for Functional Nanomaterials
- NIH NCRR, NIGMS Research Resources
- Ctr. for Environmental Molecular Science
- Real Time Materials Growth and Charact.
- COMPRES (Geosciences)
- DOE Core Research Programs



Highly Productive & High Impact

- 650 publications per year
- 150 publications/year in premier journals

(PRL, Science, Nature, Cell, EMBO J., Nature Str. Bio., Proc. Nat. Acad. Sci, Structure, APL)

Upgrading the NSLS

- ***User science needs higher average brightness and shorter pulses for "grand challenge" problems***
- Goals for the Upgrade
  - Highest Average Brightness in 5-20 keV energy range

    10,000-fold increase in average brightness over NSLS X25 beamline
  - More Straight Sections

    ~ 21 Insertion Device Straight Sections (Currently only 5 on X-ray)
  - Shorter Pulses w/ Higher Peak Brightness

    ~ 30 psec pulse length (FWHM) (Currently 400 psec)
  - Highest Average Flux

    10x increase over current NSLS flux

DOE Planning Background

- Summer 2002 – Ray Orbach requests that each Associate Director (AD) of the Office of Science (SC) develop a 20-year plan for facilities using input from Advisory Committees, NRC studies, community workshops, etc
- November 2002 – The five SC ADs present a total of 53 upgrades and new facilities to Ray Orbach
- December 2002 – Ray Orbach charges each Advisory Committee with assessing these plans by March 2003
- December 2002 – A BESAC Subcommittee is formed in response to the charge to BESAC. The Subcommittee is co-chaired by Geri Richmond and Sunil Sinha.

Basic Energy Sciences Subcommittee for 20-year Facilities Roadmap

February 22-24, 2003

Washington, D.C.

BESAC Recommendation: NSLS Upgrade

The NSLS is one of the world's most productive synchrotron facilities. Having led the way for dedicated X-ray sources, it continues to be a world leader in the output of synchrotron-based science with an impressive 650 publications per year. It is critical that the NSLS continue to deliver the highest quality synchrotron radiation and support its scientifically diverse user community, which is predominantly in the northeastern sector of the nation.

To maintain their prodigious scientific output in the near future will require continued beamline innovation and development, and, for instance, instrumentation for higher energy and spatial resolution. These enhancements will best be achieved through increased and sustained AIP support.

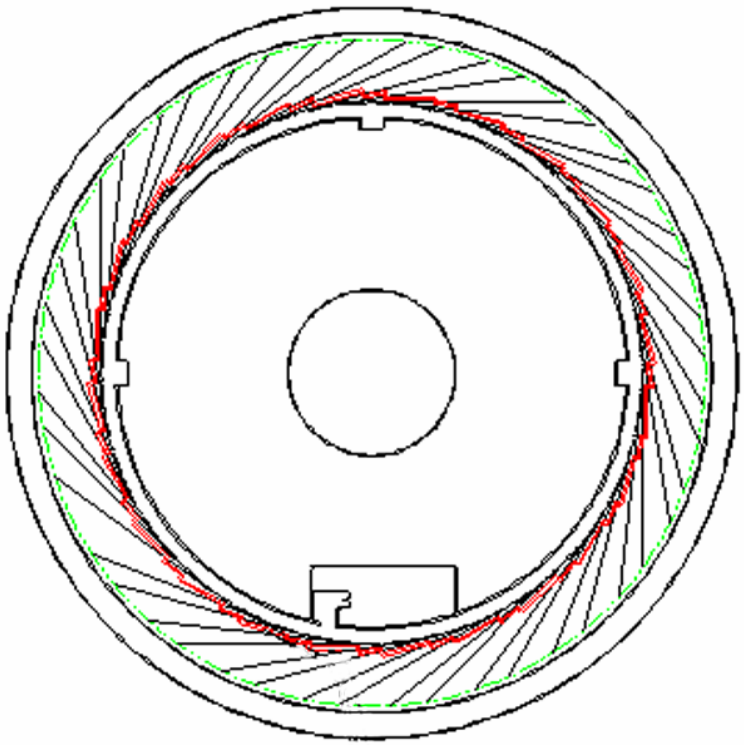
BESAC Recommendation: NSLS-II

- One of the world's most scientifically productive x-ray sources with ~ 4000 users.
- Proposed - 3rd generation ring, SC LINAC, HGHG FEL and upgraded VUV ring.

Recognizing the continued need for 3rd generation x-ray sources, we recommend that NSLS and BES formulate a plan for a 3rd gen. ring.

Ultra-high Brightness Medium Energy 3rd Generation Storage Ring

Highly Optimized X-ray Storage Ring

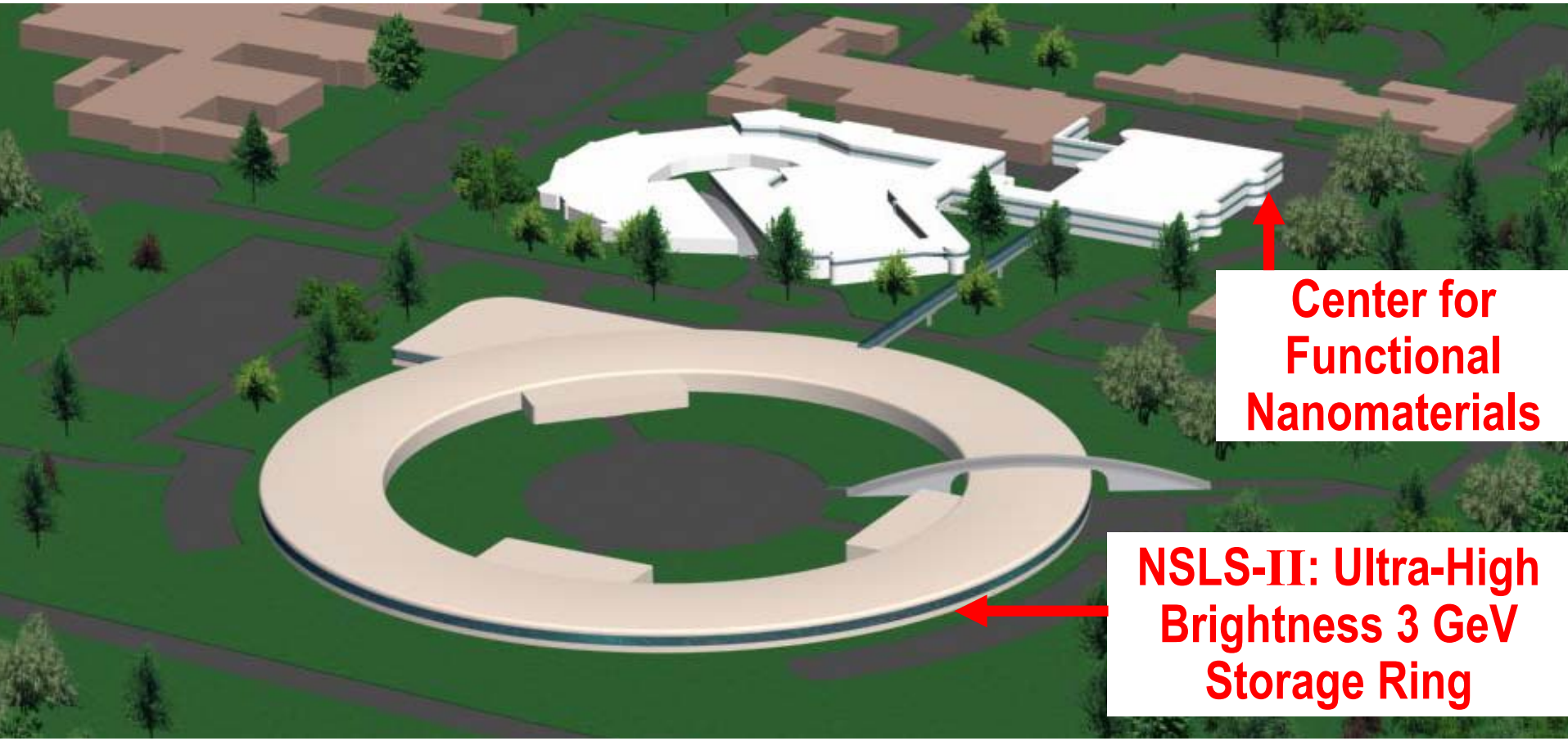


523 m Circumference

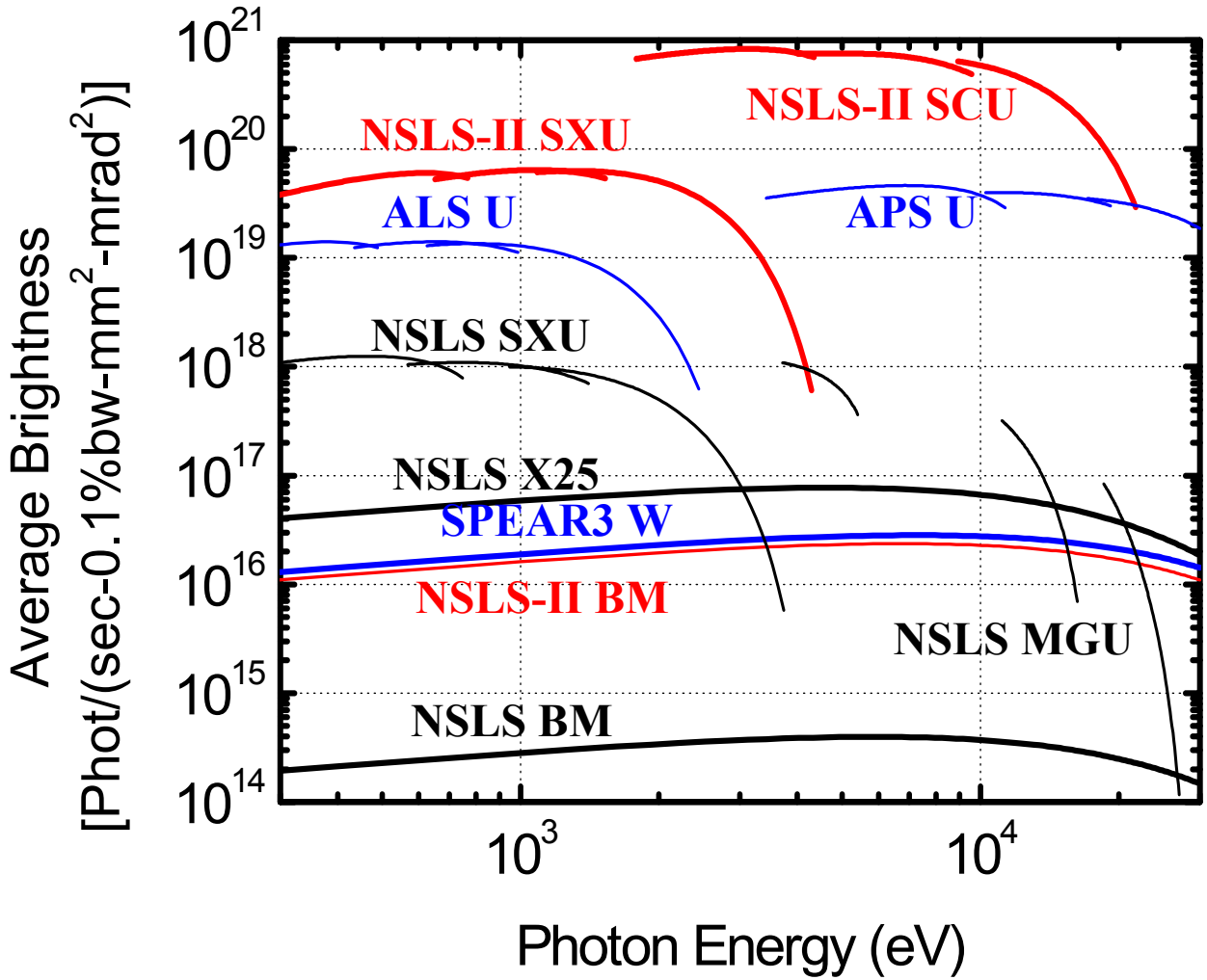
NSLS-II: Initial Parameters

- 3 GeV, 500 mA, Top-off Injection
- 24 Cell, Triple Bend Achromat
- 21 Insertion Device Straight Sections (4 m)
- 24 Bending Magnet Ports
- Ultra-Low Emittance (1.5 nm horiz, 0.5% coupling - Diffraction limited in vertical @ 1 Å)
- Brightness ~ 10^{21} (p/s/0.1%bw/mm^2/mrad^2)
- Beam Size (σ_x, σ_y) – 54.5, 2.8 μm
- Beam Divergence (σ_x', σ_y') – 27.3, 2.8 μm
- Bunch length ~ 30 psec (FWHM)

NSLS-II Location



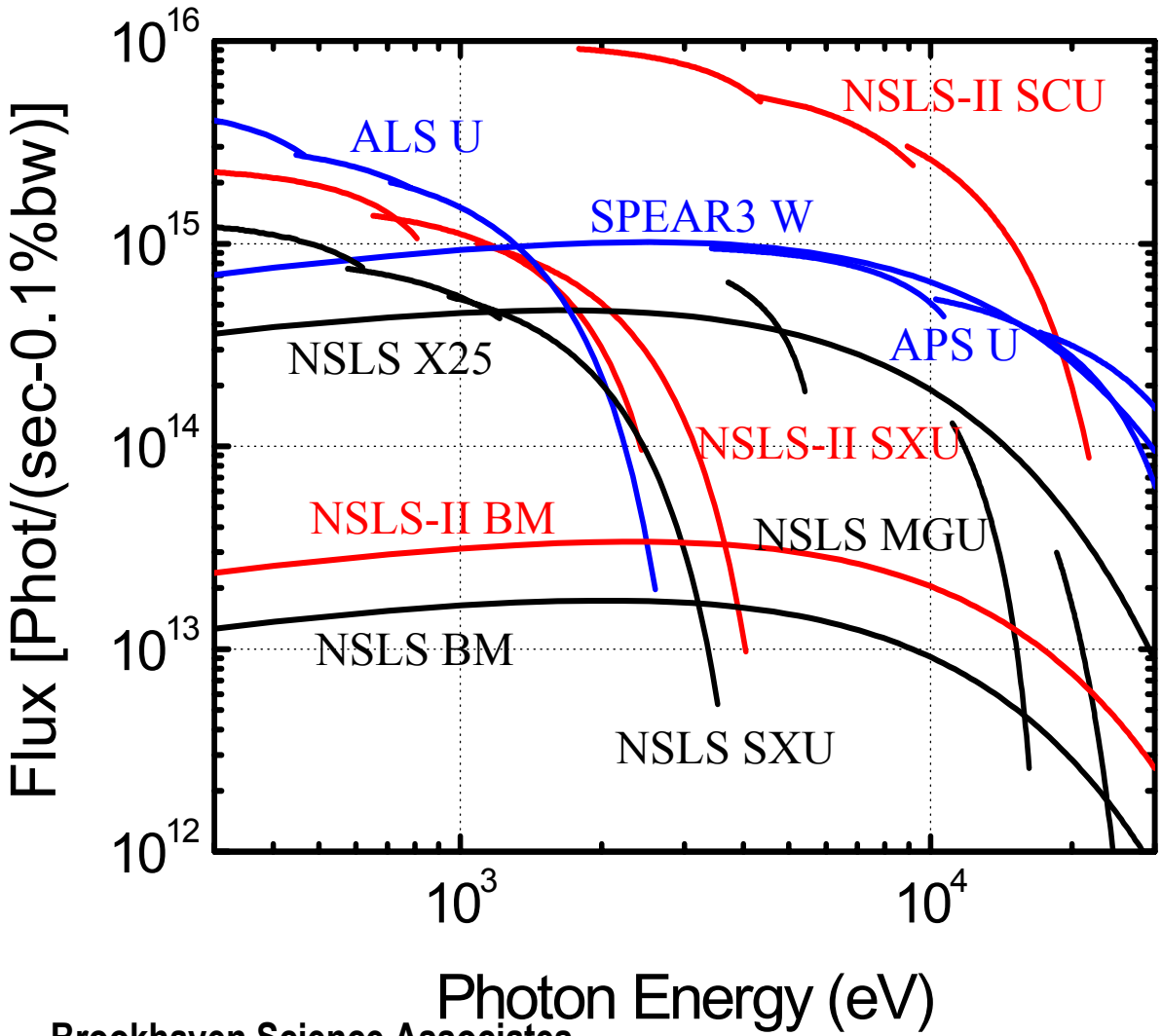
Average X-ray Brightness



NSLS	NSLS-II	Gain
X25	SCU	10^4
BM	SCU	$5x10^6$
BM	BM	10^2
SXU	SXU	50

	NSLS	NSLS-II
# Und	5	21
# BM	30	24

Average X-ray Flux

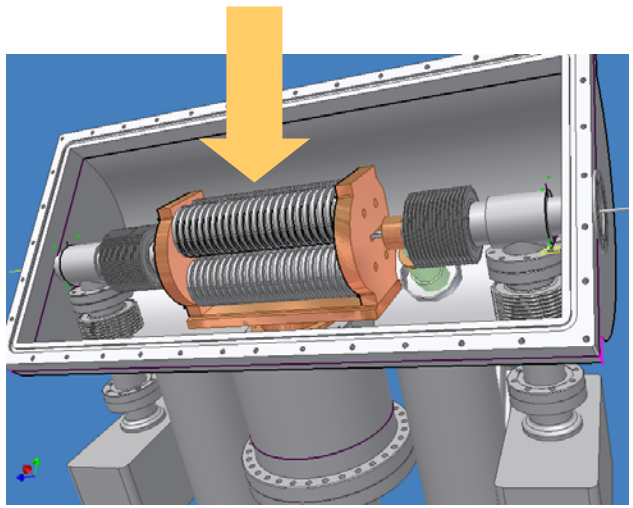


NSLS	NSLS-II	Gain
X25	SCU	20
BM	SCU	300
BM	BM	2
SXU	SXU	2

Superconducting Mini Gap Undulators

Why SCU?

- Short-period (~ 1 cm) is a must to generate tunable, multi-keV photons in medium-energy rings
- Higher fields, higher K (>2.2), full tuning range (3:1) attainable only with SC technology



NSLS SCU cryo-cooler design
Brookhaven Science Associates
U.S. Department of Energy

R&D

- NSLS pioneered PM MGUs.
- NSLS and BNL SC Magnet Division are setting up a SCU testing facility.
- NSLS joined SLAC, ALS & APS in collaboration in SCU R&D.
- Parallel R&D efforts in Europe (ANKA, ACCEL) may lead to commercial sources of SCUs.
- $\Rightarrow$ Confidence in availability of SCU in time for NSLS-II

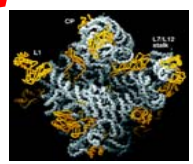
NSLS-II SCU

g=5 mm, λ_u=15 mm
K~2.2, n=1-11

Protein Crystallography Demands Higher Brightness

Bending Magnet
B ~ 10^{15}

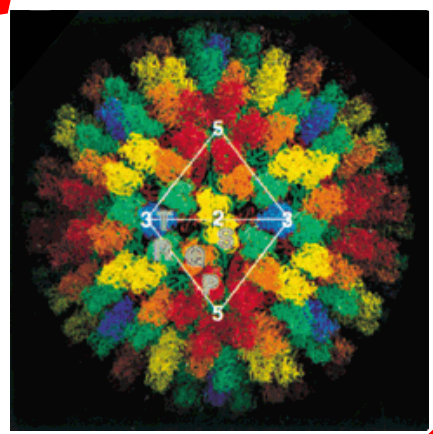
Protein (~100 Å)



Ribosome (~250 Å)

Wiggler
B ~ 10^{17}

Increased Brightness



Virus (~750 Å)

NSLS-II Undulator
B ~ 10^{21}

Molecular Machinery

High brightness is essential for projects with small crystals and large unit cells, such as large asymmetric complexes, particles like ribosomes, and membrane proteins.

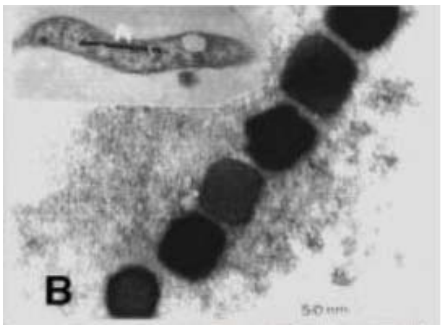
X-ray Storage Ring will enable:

- **Large unit cells (> 1000 Å)**
- **Small crystals (~10 μm)**
- **High resolution (< 1.0 Å)**

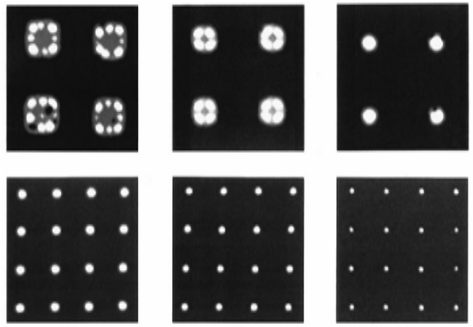
Nanoscience

High brightness: < 10 nm focused x-rays for characterization

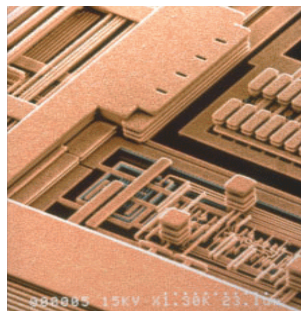
High coherent flux: brighter focused beams, time-resolved speckle analysis and improved contrast



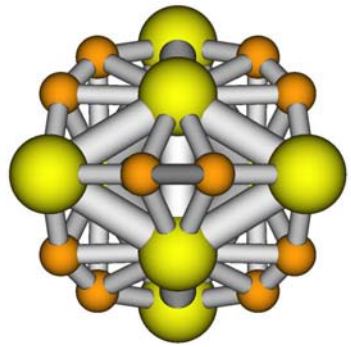
Biomaterials



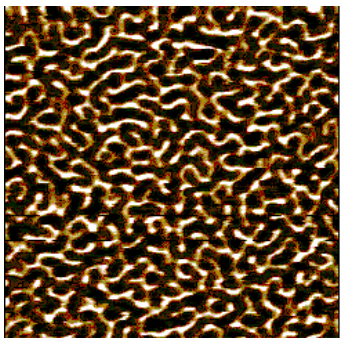
Quantum Dots



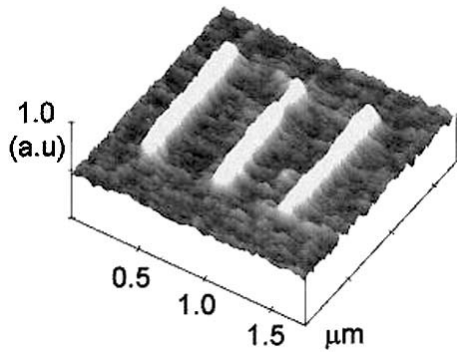
Electronic Devices



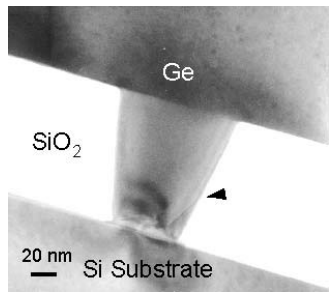
Chemical Catalysis



Magnetic Domains



Piezo-Electric Sensors

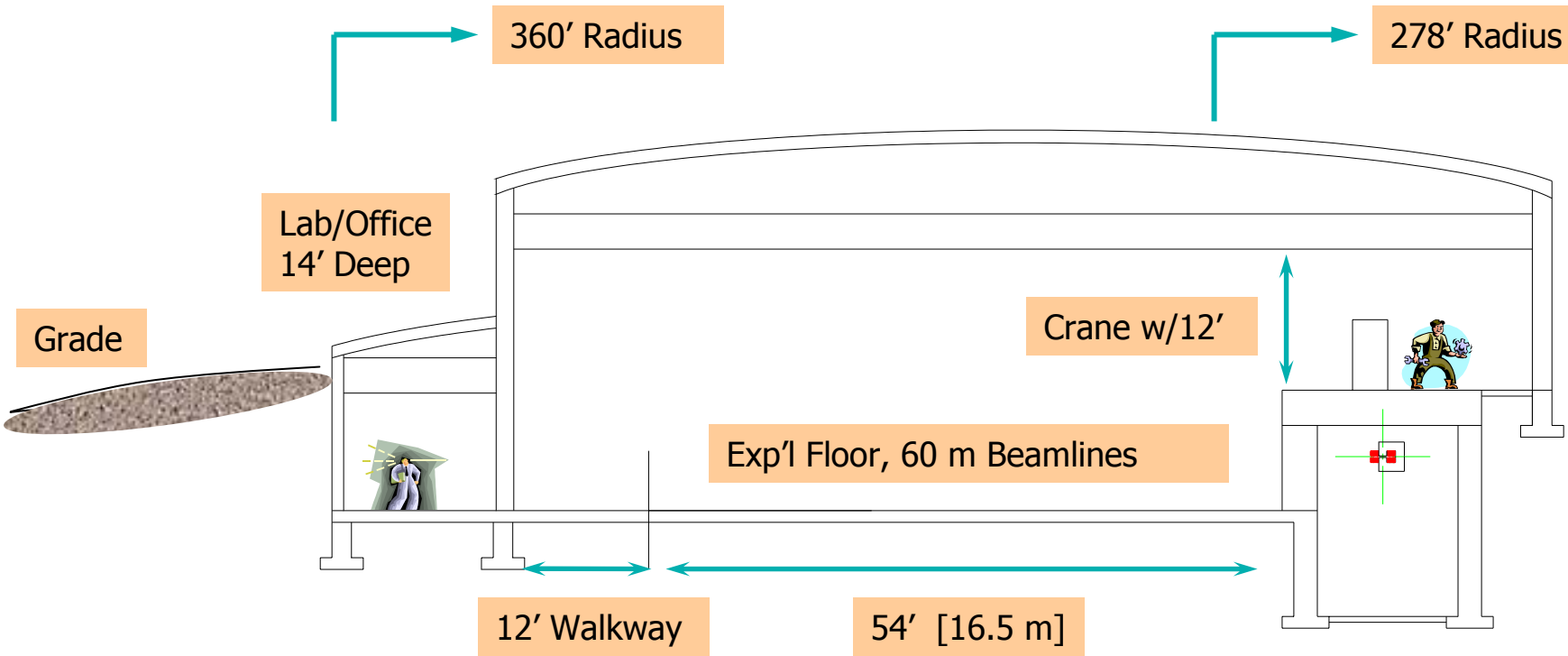


Seeded Film Growth

NSLS-II: Tentative Beamline Plan (21 ID)

Macromolecule Crystallography: 5
Coherent x-ray scattering: 1
Small angle x-ray scattering: 1
X-ray Micro-beam diffraction: 1
Resonant/Magnetic x-ray scattering: 1
Materials science/time-resolved: 1
Inelastic x-ray scattering: 1
Superconducting wiggler: 2 (three separate beamlines each)
Soft x-ray undulator beamlines: 4 (scattering, spectroscopy, and imaging)
To be determined: 4

Facility Layout



The ring building is sized for 60 m long beamlines with the sawtooth 25 m from the ID center

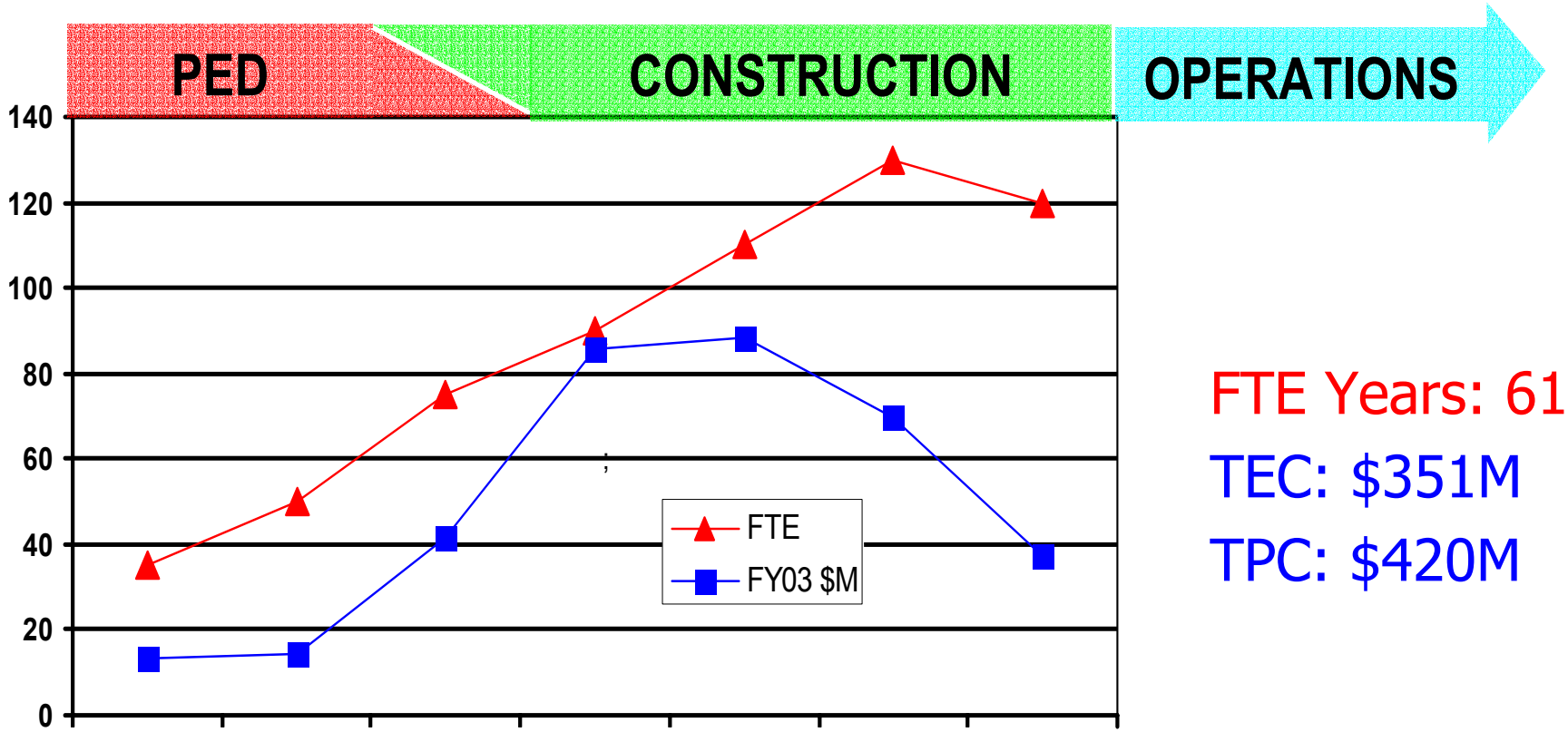
Readiness for Construction

- Storage Ring based on mature technology
  - Most components available commercially
  - Superconducting Undulators – Ongoing R&D, collaboration between BNL, APS, SLAC, and LBL

Pre-CD0 Strategic Activities

- Science Case / User Input
  - Holding focused user science workshops this summer
    - Structural Biology, Environmental Science, Strongly Correlated Materials, Soft Matter and Biomaterials, Imaging, Nanoscience
  - **Holding major user workshop on December 12**
- Formed a Machine Advisory Committee
- Conducting R&D on machine feasibility issues
- Submitting formal proposal in November ’03
  - CD0 in Feb ’03?

NSLS-II Preliminary Project Profile



FTE Years: 610

TEC: $351M

TPC: $420M

2006	2007	2008	2009	2010	2011	2012	Fiscal Year
13.5	14.2	41.6	85.7	88.5	69.6	37.2	FY03 $M
35	50	75	90	110	130	120	Full Time Equivalents

Summary

- User Science requires CW ultra-high average brightness source on East Coast
- Storage Ring will deliver best-in-class performance