Argonne NATIONAL LABORATORY

… for a brighter future

U.S. Department of Energy

UChicago ▶ Argonne LLC

Office of Science U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

APS Renewal

J.M. Gibson

Presented at the Three Way Meeting

March 18th 2008

Much in common, but vive la difference!

APS

ESRF

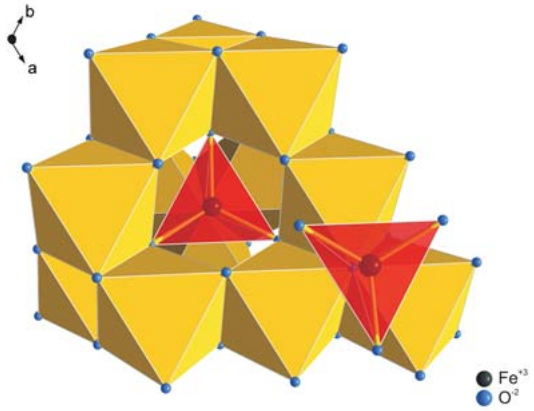
Spring-8

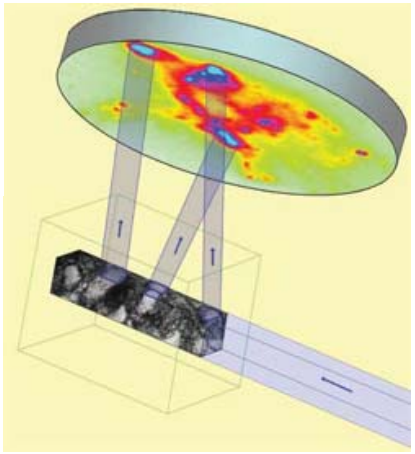
New ~3GeV "3 ½ generation" sources are flourishing

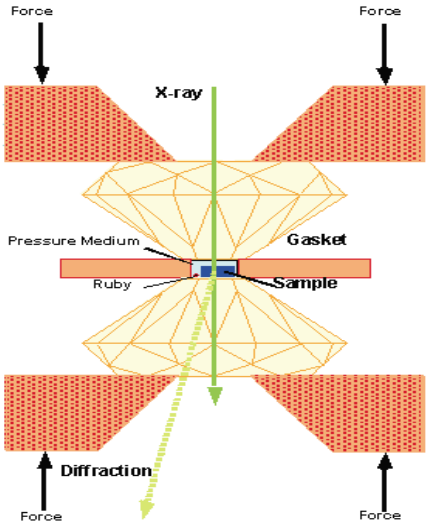
Existing or planned x-ray synchrotron light sources

I believe that the future for the big three is secure even with growing beamports at "3½ generation" sources nearby

- They will be uniquely suited for applications needing ~15keV or higher



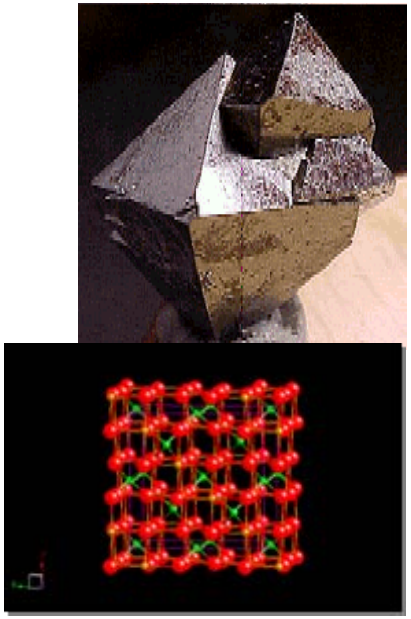




ESRF, APS and Spring-8 planning major upgrades

APS in 2008 enters its 12th year of operation

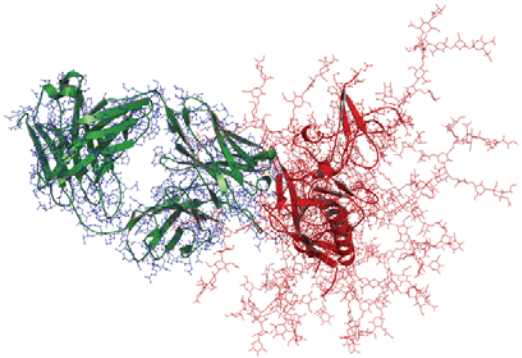
Exciting science in 2008 from APS



Lodestone holds surprises under high pressure

DNA guides nanoparticle assembly

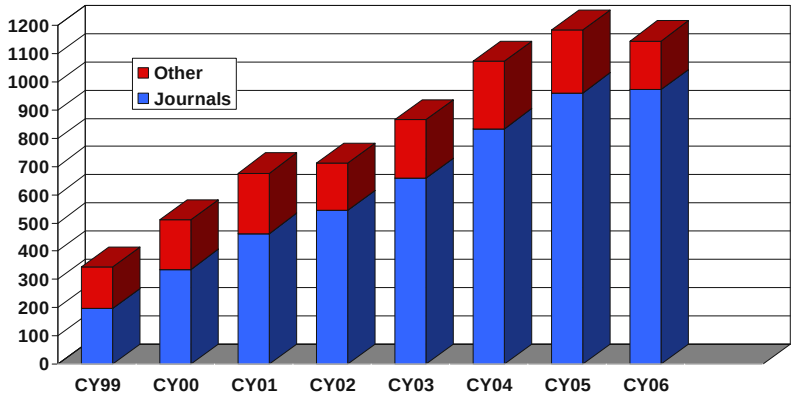
How muscle works under stress



AIDS virus vulnerability

APS scientific impact increasing (by the numbers)

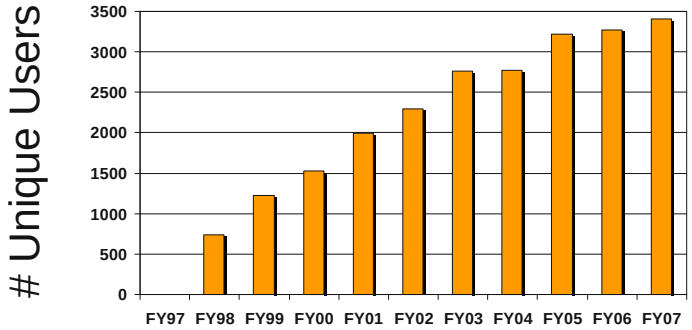
Refereed publications



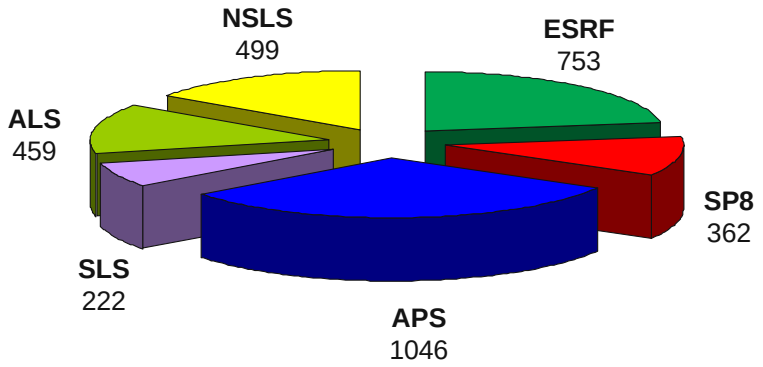
Selected high-impact stats

	2004	2005	2006
Cell	7	6	14
All *Nature*	32	37	37
PRL	21	27	37
Science	11	9	20
PNAS	33	44	43

58% journal papers with impact factor >3.5 (2006)

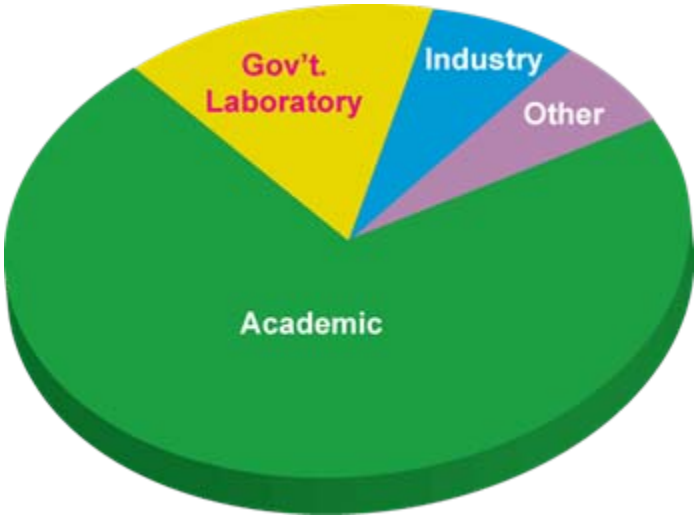


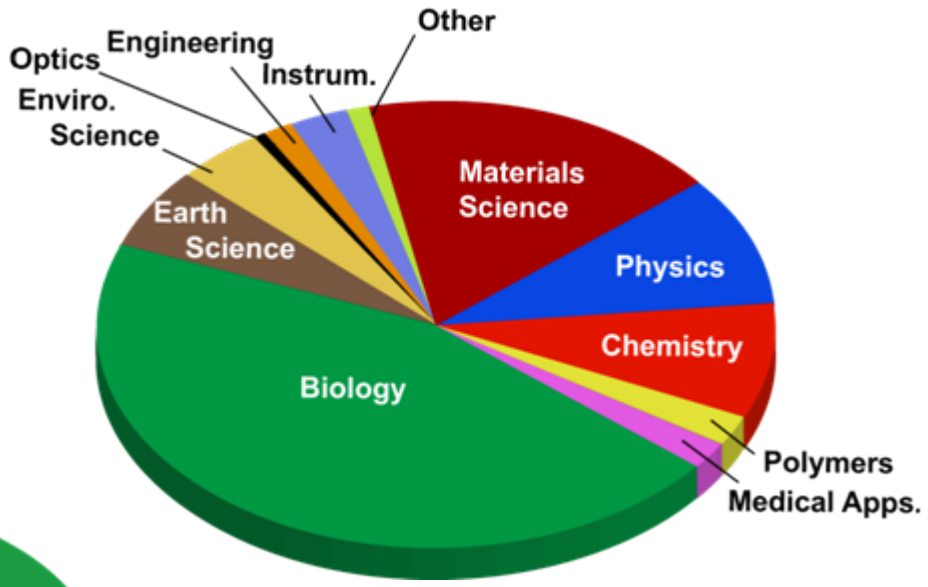
3411 unique users in 2007

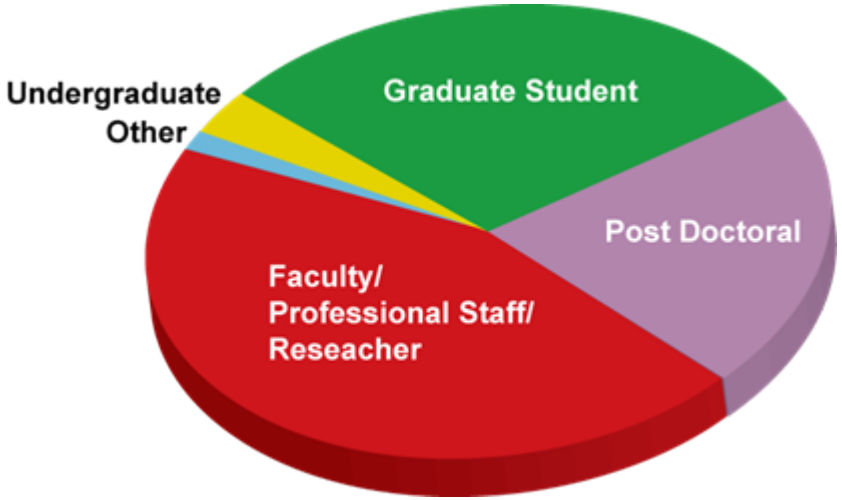


2006 Protein Data Bank deposits

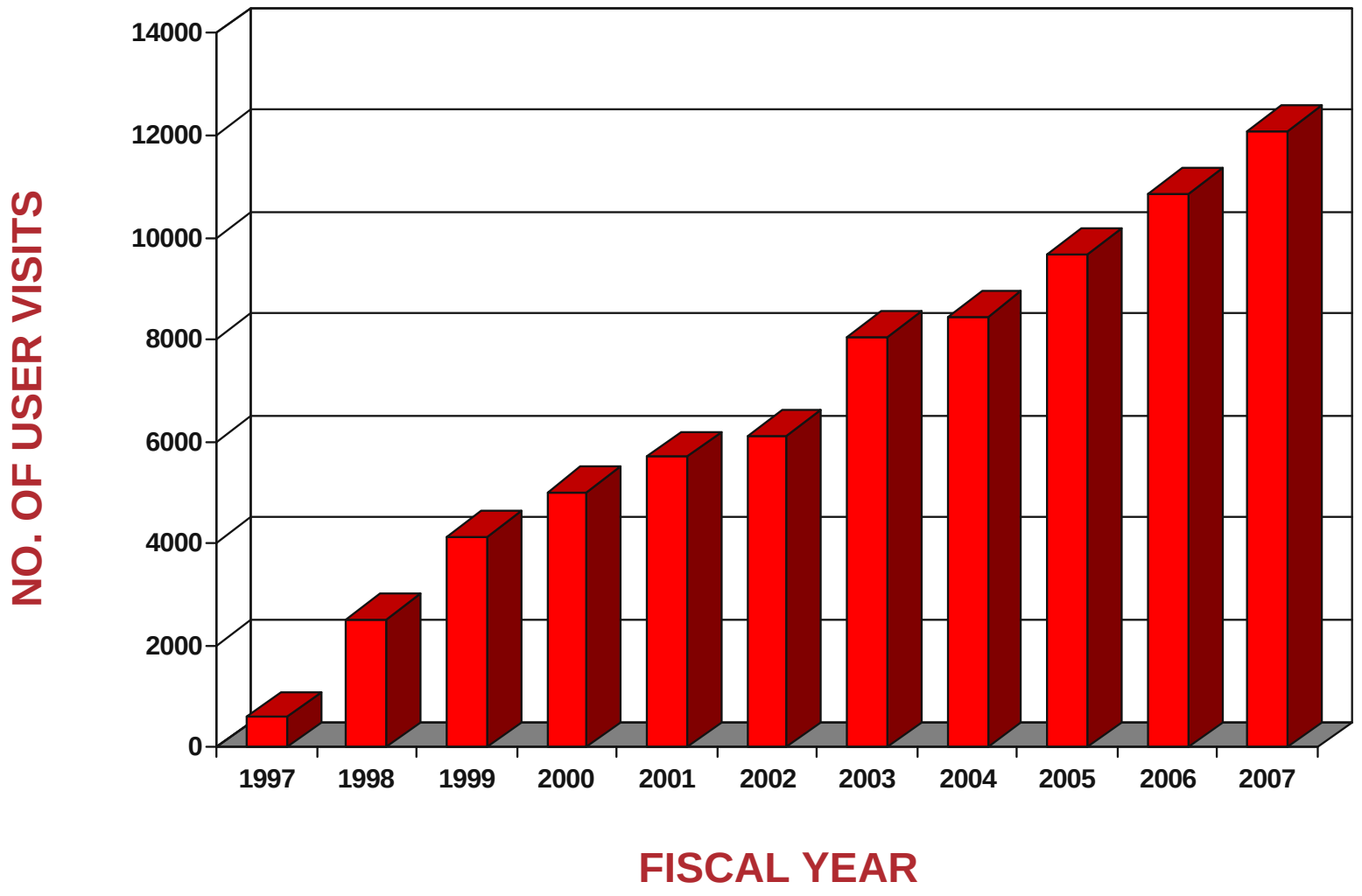
Demographics of APS Users





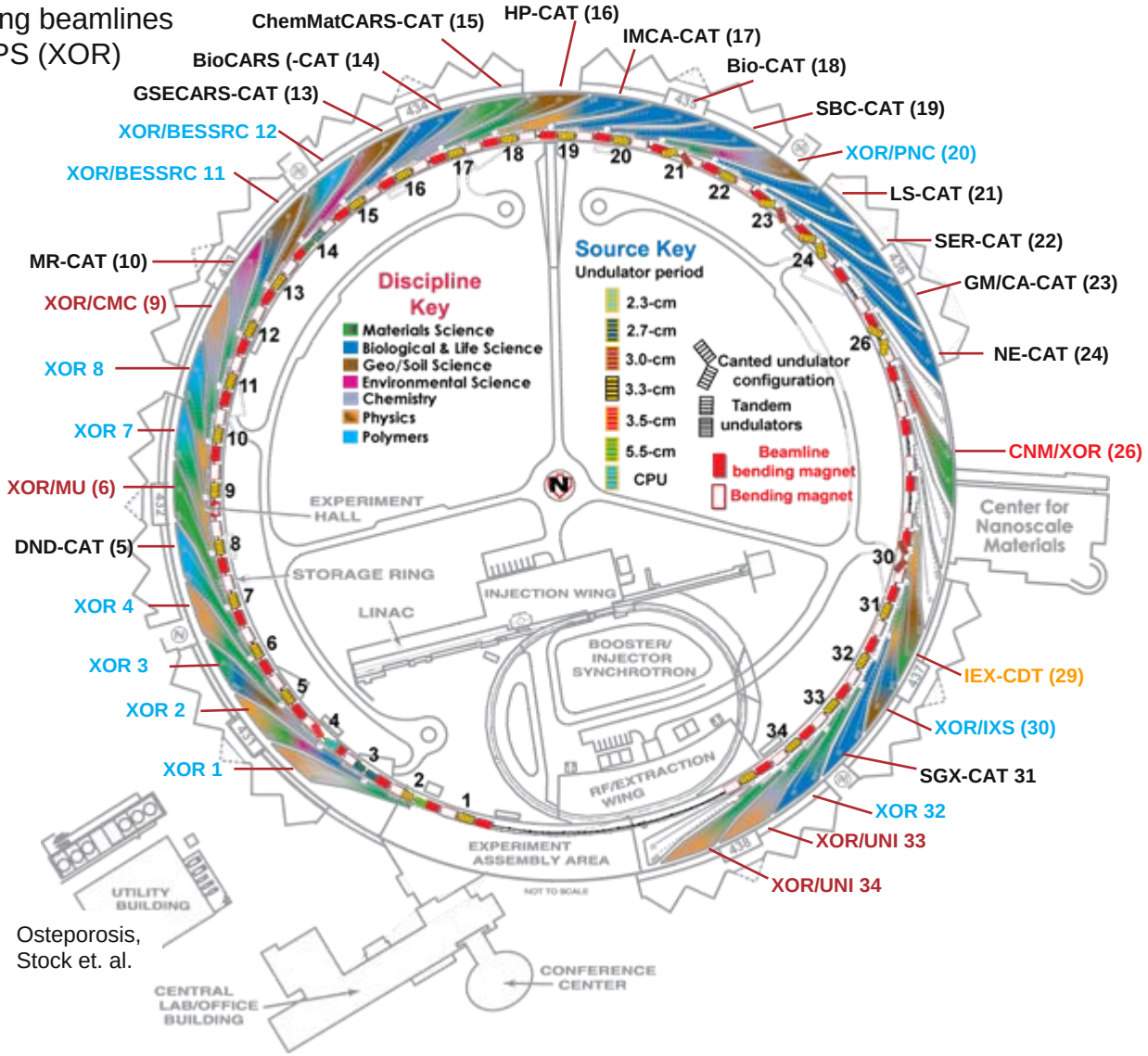


User Visits by Fiscal Year



Beamline map of APS today

FY '08: 54 operating beamlines
30 operated by APS (XOR)



Osteporosis,
Stock et. al.

Key

CAT sectors

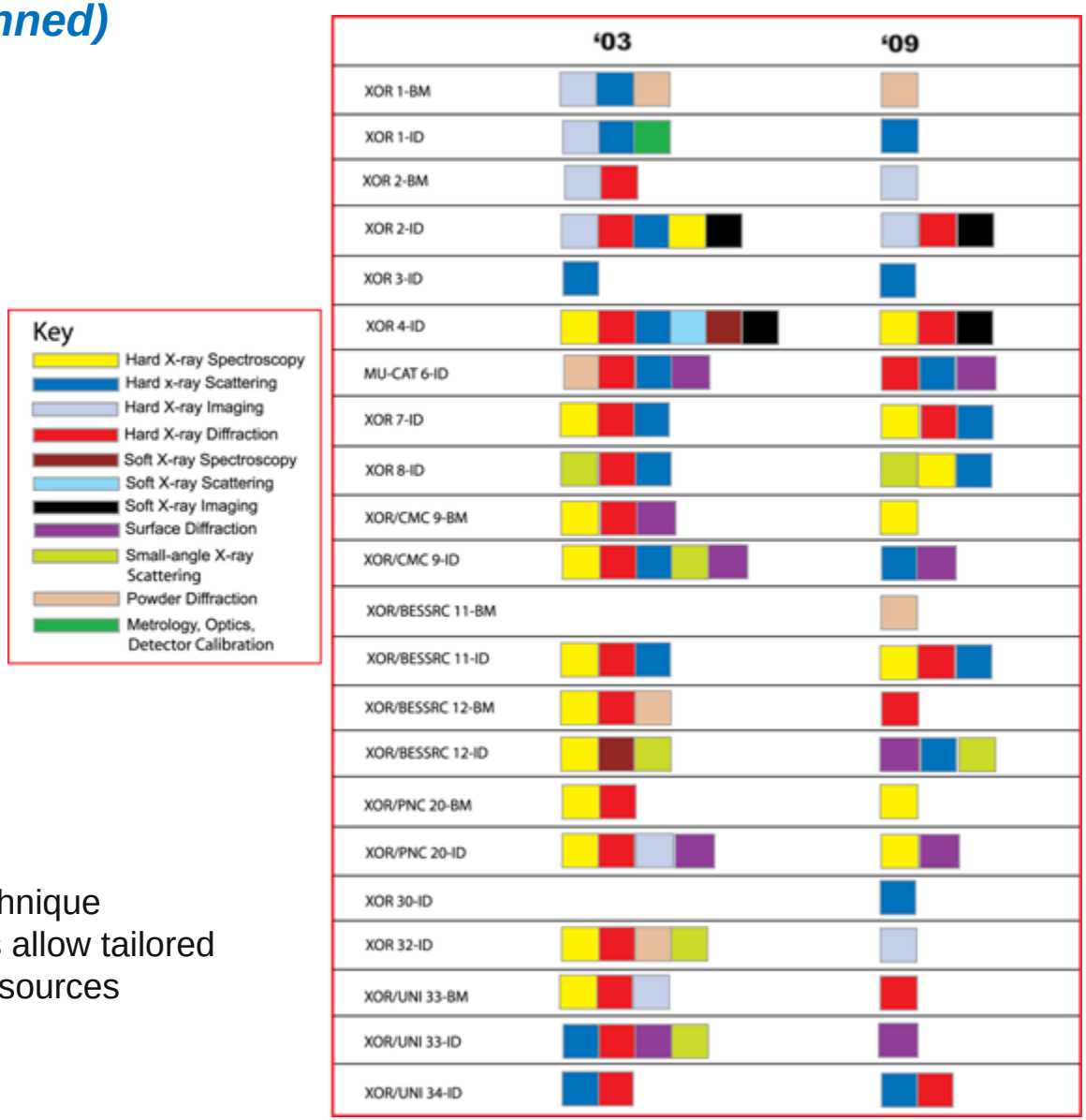
Current XOR sectors

Transitioning to XOR sector

CDT sector

Operated jointly (APS, CNM)

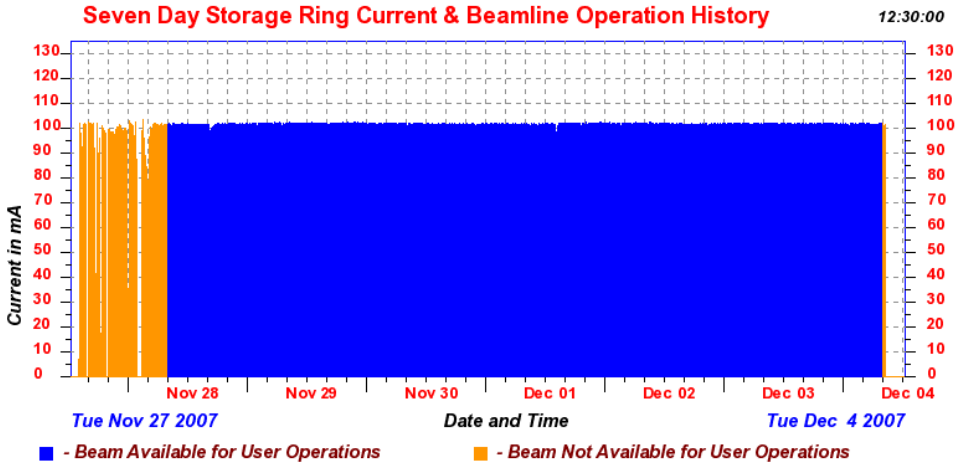
Increasingly optimized XOR beamlines - techniques at the APS – 2003 vs. 2009 (planned)



Single technique beamlines allow tailored undulator sources

Science possible by a highly performing machine

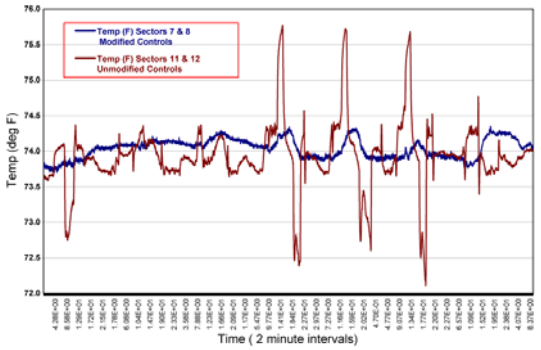
- Over the last three years the average availability has been > 98%
  - And the mean time between faults (MTBF) has been over 90 hours
- These are outstanding metrics
  - The result of many years of a sustained QA approach to faults
    - *Combined with a well-built machine!*
- Our goal has become 97% availability and 70 hours MTBF



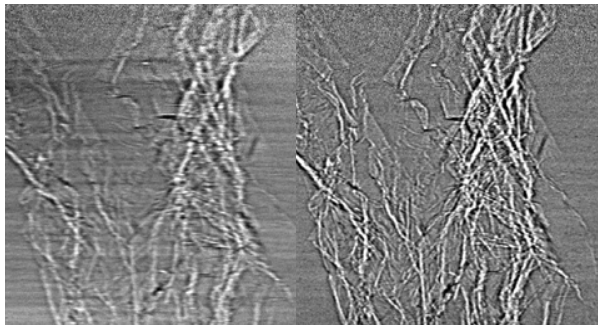
- *We are concerned that our resources have not been adequate to deal with obsolescence, without which sustaining our goals will be a challenge*

Some examples of machine innovation in last three years

a. Improved beam stability



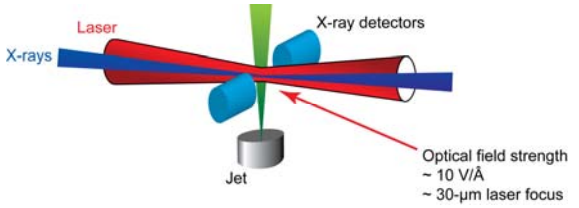
b. Local beta functions



pays off for a dedicated imaging sector (32ID)

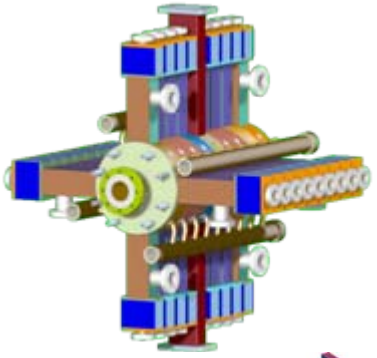
c. Single bunch charge increased by ~2 times to 16 mA

L. Young et al., “X-Ray Microprobe of Orbital Alignment in Strong-Field Ionized Atoms,” Phys. Rev. Lett **97**, 083601 (2006).

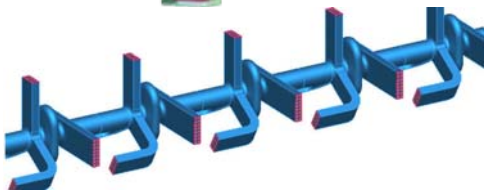


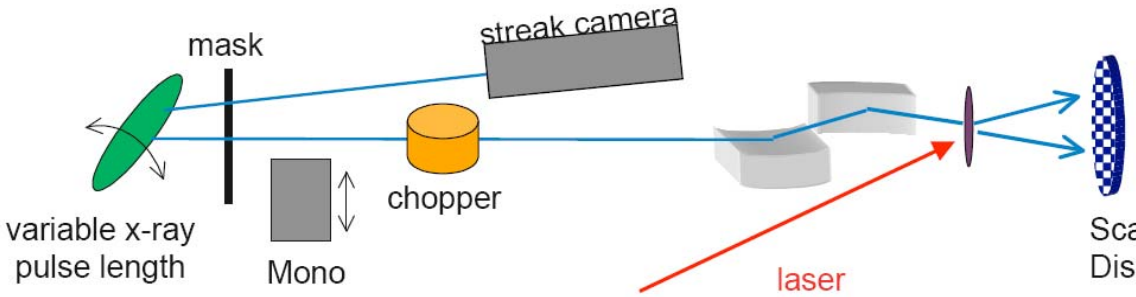
…driven by x-ray science

Some medium-term accelerator innovations



- Short Pulse X-Ray Project – ps pulses with CW SRF
  - Tunable, high rep rate ps pulse source





- Responsibility as LCLS partner for undulators in world's first x-ray laser

New beamline proposals which emerged from strategic planning since 2004 (more than a dozen workshops held..)

1. Transition of several multi-purpose to dedicated APS beamlines:

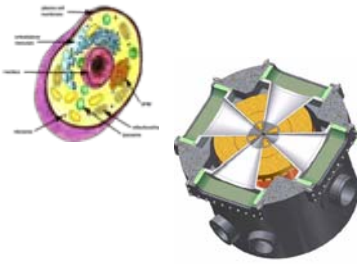
- High-energy (E>50 keV) beamline: 1-ID ☑
- Imaging beamline: 32-ID ☑
- Small/wide angle x-ray scattering: 12-ID-B
- *Time-resolved picosecond scattering: 7-ID-C* ***(NEW)*** ☑

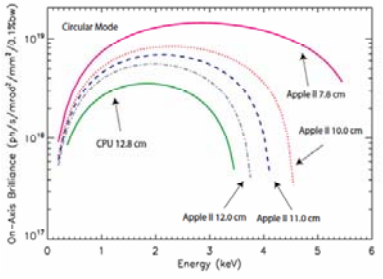
2. Several groups formed partnerships to develop new beamlines:

HP-Sync – a virtual beamline for high-pressure studies ☑

- Intermediate X-ray Energy Spectroscopy and Scattering ☑
- BioNanoprobe
- Diffraction in High Field

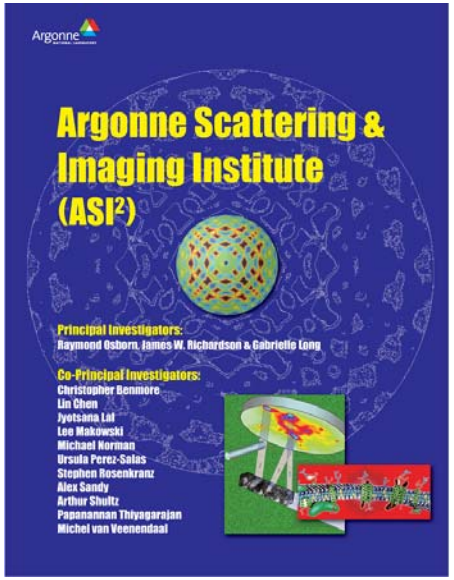
others under development





Software and instrumentation

Software is a critical "weak link" in accessibility to APS



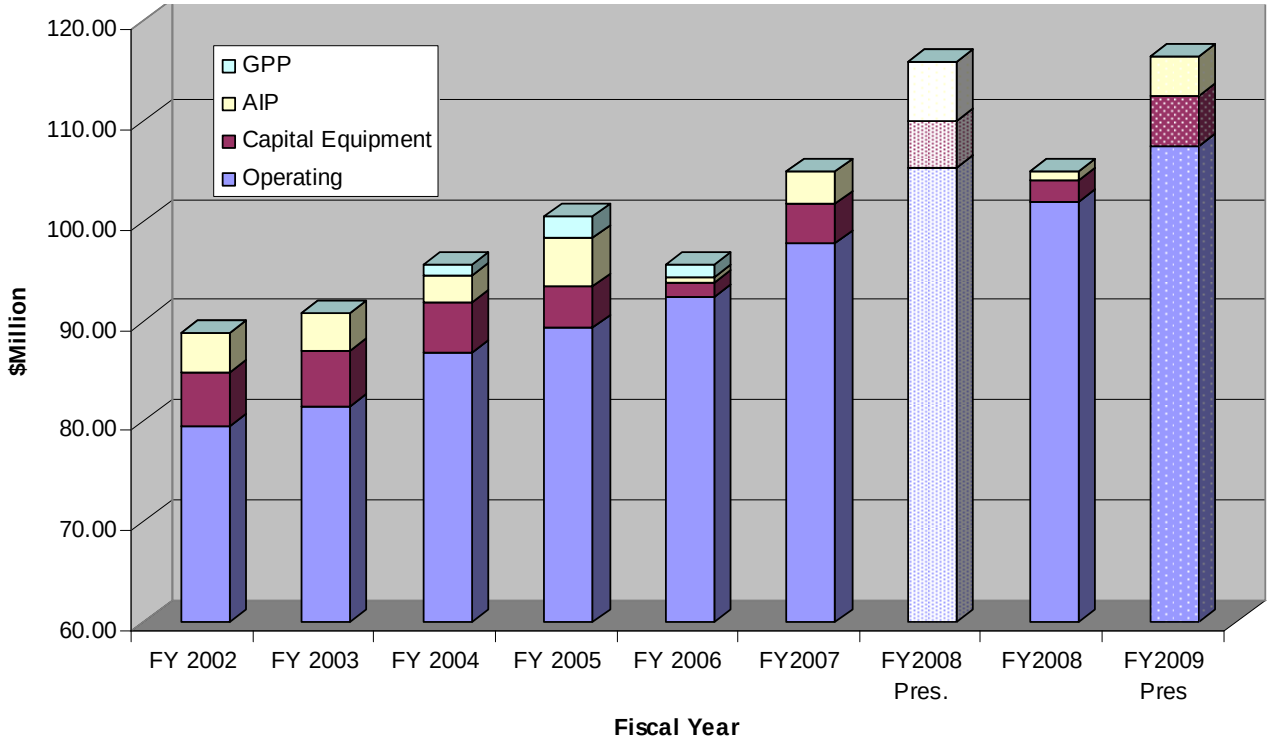
BEAMLINE TECHNICAL SUPPORT
P. FERNANDEZ
GROUP LEADER

J. BALDWIN
K. BEYER
L. GADES
H. LEE
T. LUTES
T. MADDEN
A. MICELI
D. MORGAN (6)
C. PIATAK
S. ROSS
R. SPENCE
J. WEIZEORICK

Detector development supported by ANL laboratory strategic LDRD in 2007

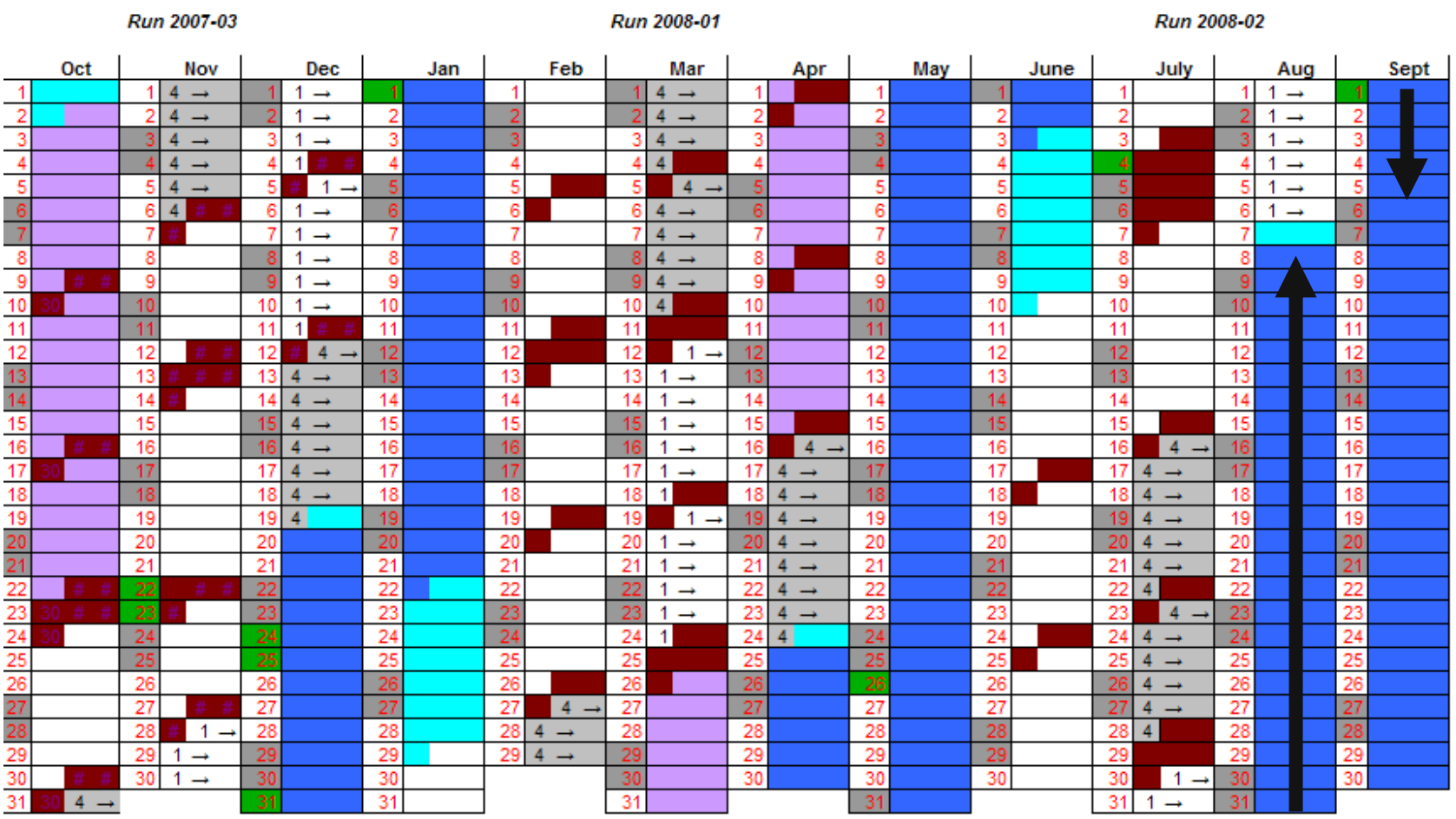
and ASI^2 would make this a national asset for x-ray and neutron grand challenge science (*follows on from NSF funded DANSCE*)

Challenges: The crisis created by the 2008 US Congress Omnibus Funding Bill



Particularly discouraging given broad support for physical science increases
All science research in the US faces similar problems, many worse (e.g. HEP)
Funding shortfalls forced sudden closure of IPNS

APS FY 2008
Long Range Operations Schedule



~1 Month Reduced Operating Time

User Operation in standard lattice
User Operation in Reduced Horizontal Beam Lattice (RHB)

SOM Periods
1 Hybrid Fill - (singlet)
4 324 Singlets - Non Top-Up

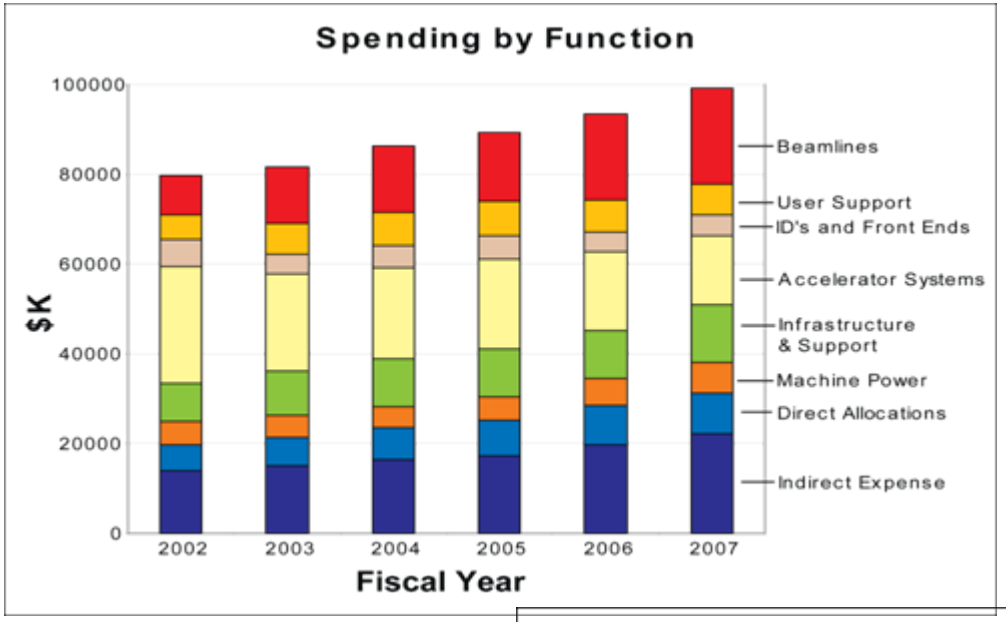
Machine Studies
Maintenance
Shifts set aside for Studies/ Machine Intervention as Needed

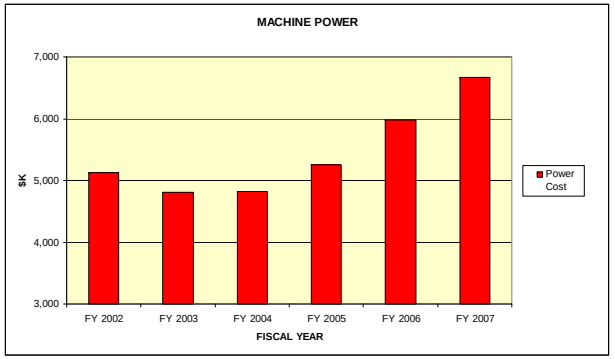
Weekends
Lab Holidays

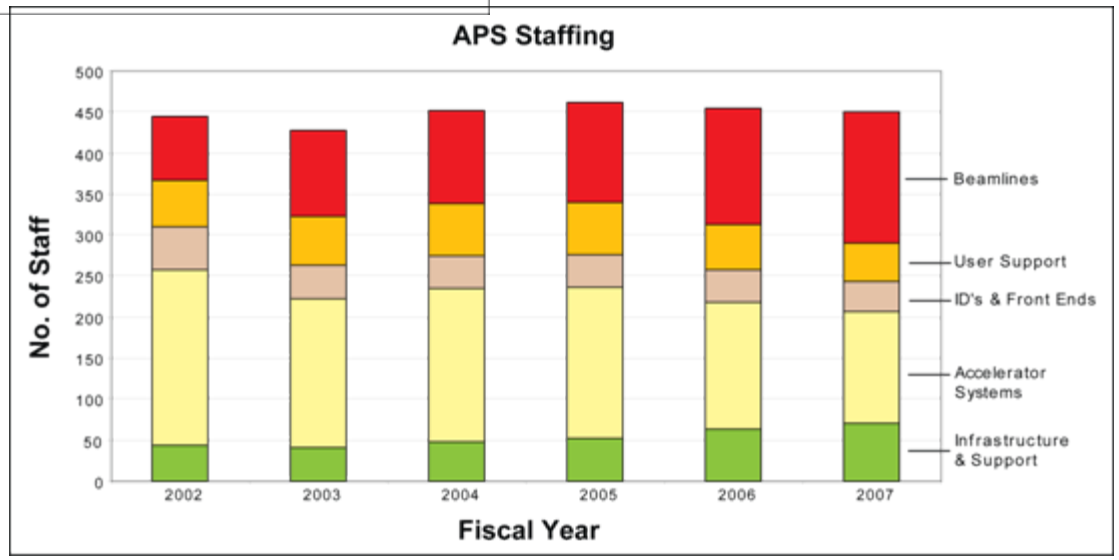
Top-Up Operations is standard unless indicated in fill pattern

Fill pattern is 24 singlets unless otherwise indicated by number

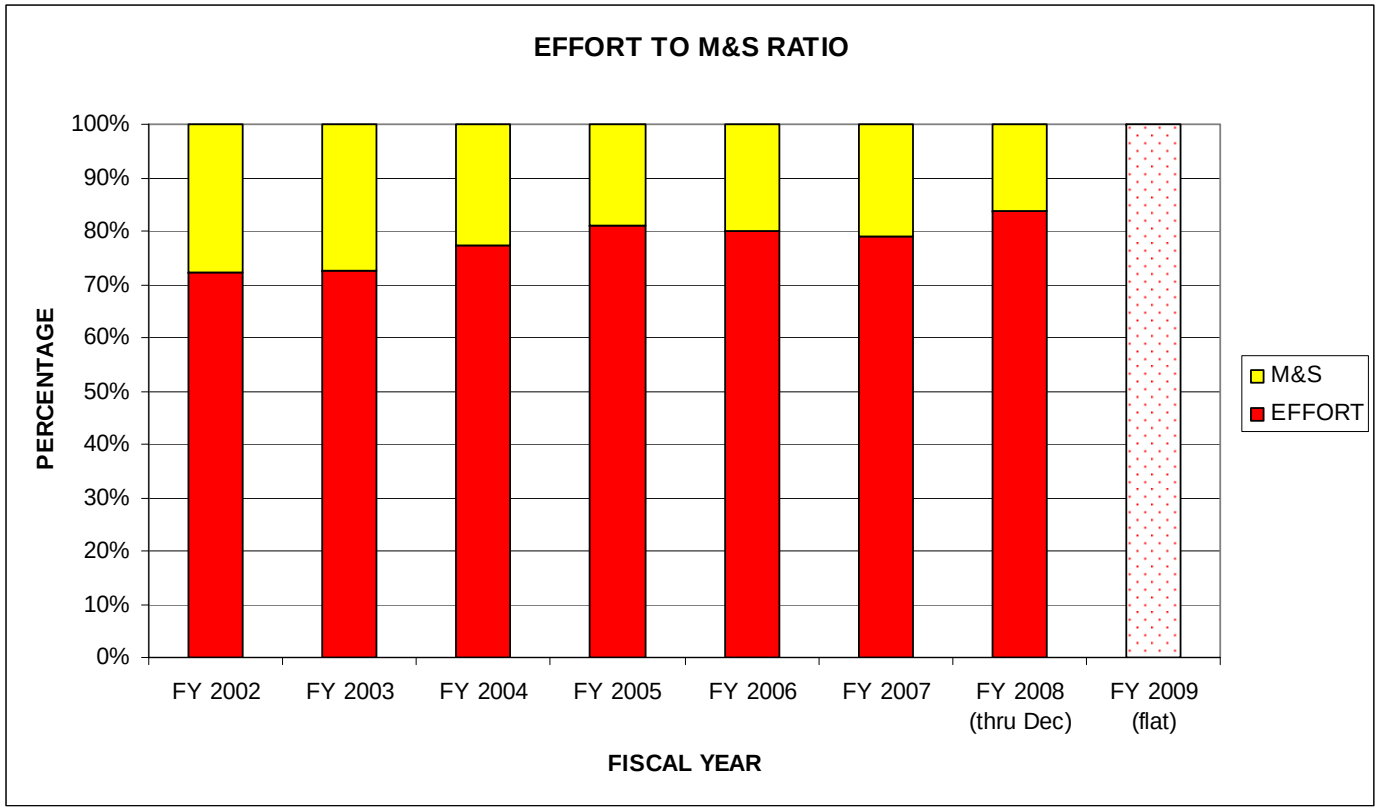
Functional analysis of APS DOE operating budget and staffing







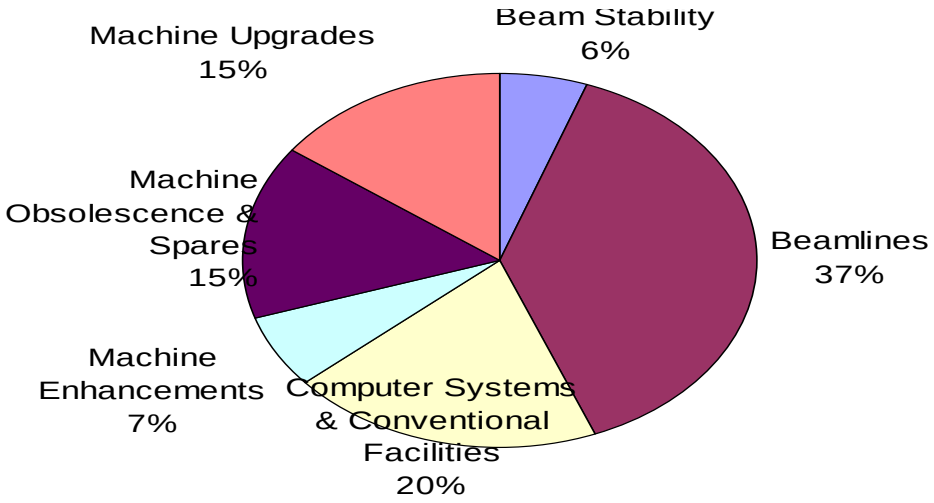
Effort ratio as a fraction of total budget for APS divisions



Some amelioration from external income (~5% annually)

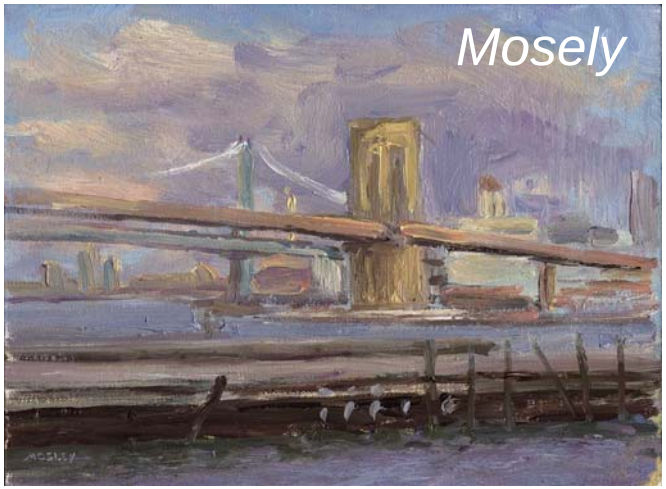
We cannot continue to defer machine and beamline maintenance

- Allocation of resources to accelerator and beamline improvements, repairs:



For 2006,7,8 we have allocated only $12M capital and accelerator improvements (4% ops). Normal capital budget is ~10% ops, is still insufficient

- "painting the bridge"



Some science areas where we see great growth potential

Biology outside protein crystallography
Magnetism
Inelastic x-ray scattering for Condensed Matter Physics, Geophysics, Biophysics
Nanoscience
Intermediate energy x-ray scattering
Catalysis…

Status of Facilities for the Future: 20-Year Outlook – By the End of FY 2008

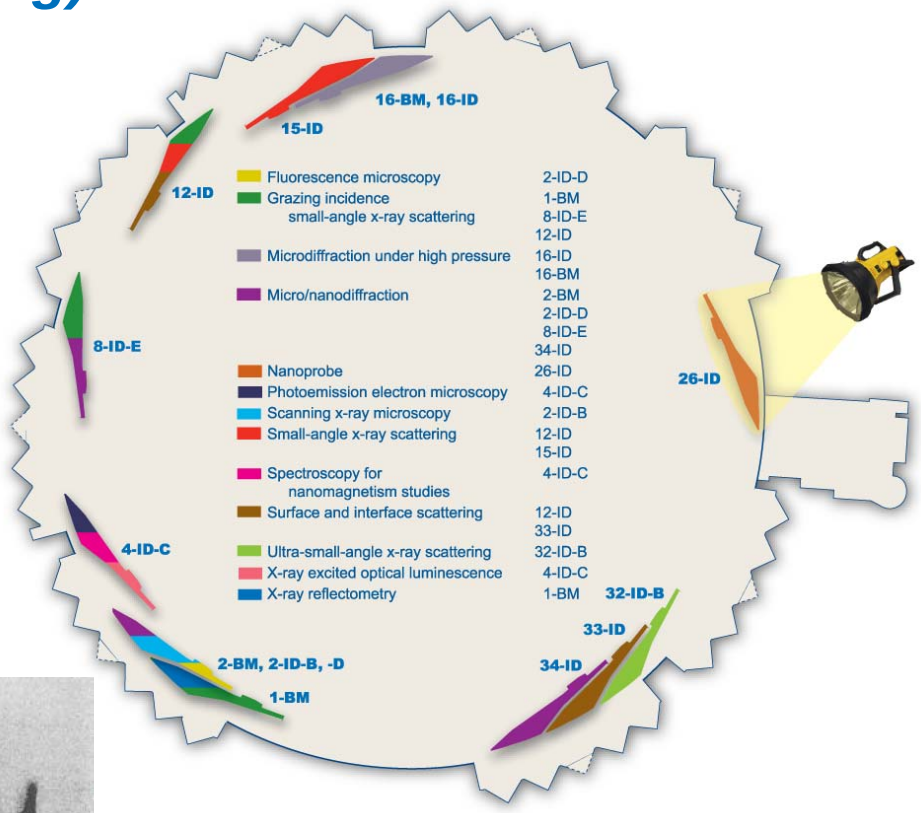
	Priority	Program	Facility	R&D	Conceptual Design	Engineering Design	Construction	Operation
Near-Term	1	FES	ITER					
	2	ASCR	UltraScale Scientific Computing Capability					
	Tie for 3	HEP	Joint Dark Energy Mission					
		BES	Linac Coherent Light Source					
		BER	Protein Production and Tags → Bioenergy Research Centers*					
		NP	Rare Isotope Beam Facility (previously RIA) #					
	Tie for 7	BER	Characterization and Imaging → Bioenergy Research Centers*					
		NP	CEBAF Upgrade					
		ASCR	ESnet Upgrade					
		ASCR	NERSC Upgrade					
		BES	Transmission Electron Aberration Corrected Microscope					
	12	HEP	BTeV #	Terminated				
	13	HEP	International Linear Collider					
Mid-Term	Tie for 14	BER	Analysis/Modeling of Cellular Systems → Bioenergy Research Centers*					
		BES	SNS 2-4 MW Upgrade					
		BES	SNS Second Target Station					
		BER	Whole Proteome Analysis → Bioenergy Research Centers*					
	Tie for 18	NP/HEP	Double Beta Decay Underground Detector					
		FES	Next-Step Spherical Torus					
		NP	RHIC II					
	Tie for 21	BES	National Synchrotron Light Source Upgrade*					
		HEP	Super Neutrino Beam					
Far-Term	Tie for 23	BES	Advanced Light Source Upgrade					
		BES	Advanced Photon Source Upgrade					
		NP	eRHIC or eLIC or Electron Ion Collider					
		FES	Fusion Energy Contingency					
		BES	HFIR Second Cold Source and Guide Hall					
		FES	Integrated Beam-High Energy Density Physics Experiment					

75-100% 50-75% 25-50% > 0% complete

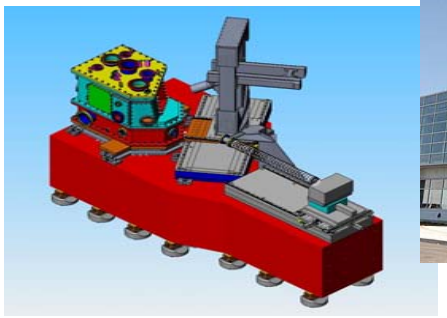
Ray Orbach
9/21 update to
BESAC

*Technology readiness changed
Changed due to planned facility abroad

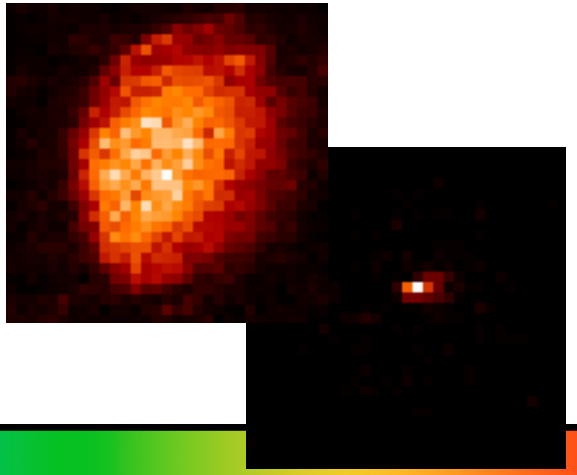
APS science at the nanoscale (predominantly imaging or focusing) will benefit from increase source brilliance



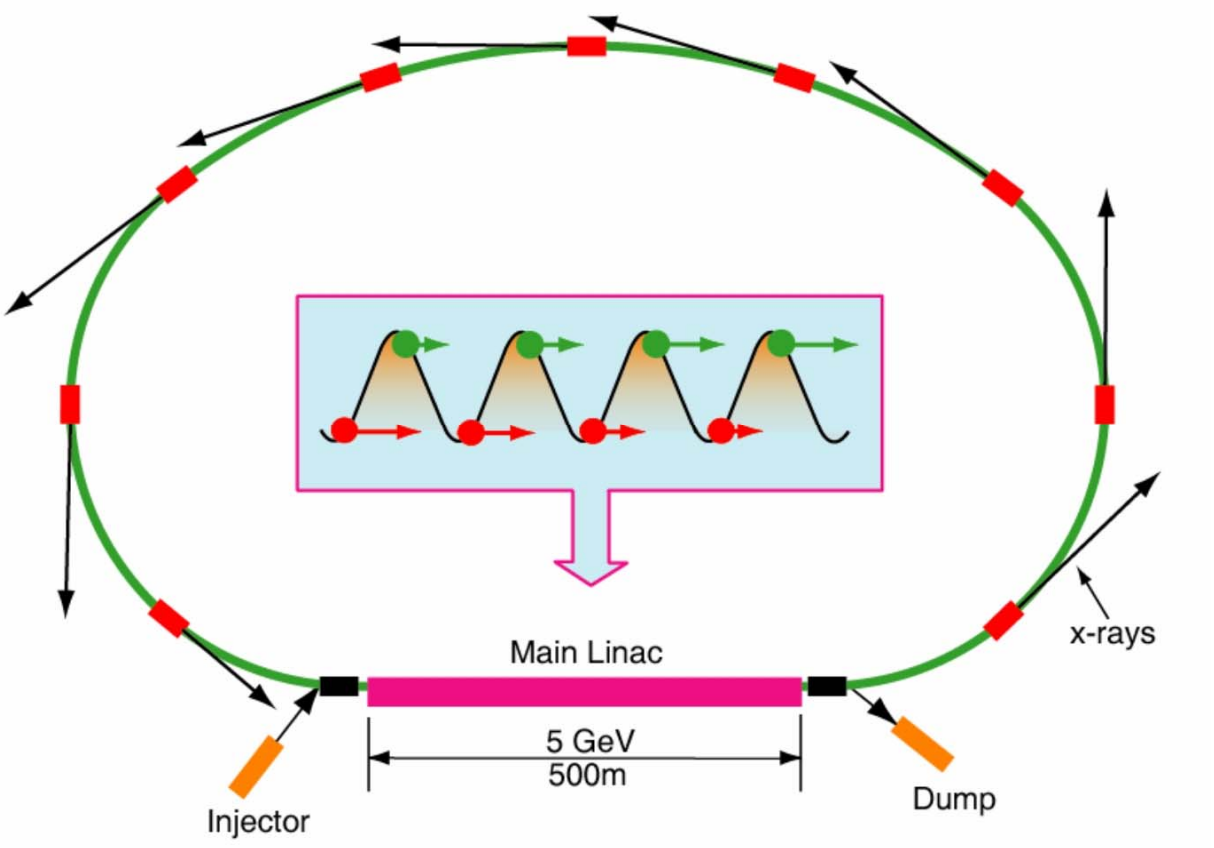
New nanoprobe jointly with Center for Nanoscale Materials
~10nm resolution aim in hard x-ray region



110 years



Energy Recovery Linac

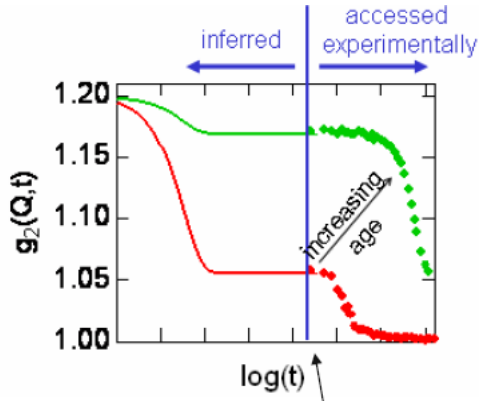


- *Accelerating bunch*
- *Returning bunch*

A superconducting LINAC is <u>required</u> for high energy recovery efficiency

An ERL would produce almost fully-coherent illumination (transversely) => probing complex materials dynamics by x-ray photon correlation spectroscopy (XPCS)

e.g. Photon correlation spectroscopy becomes 4 orders of magnitude faster

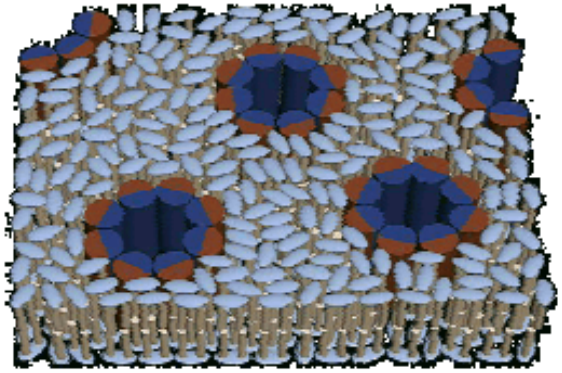


Courtesy B. Leheny, JHU

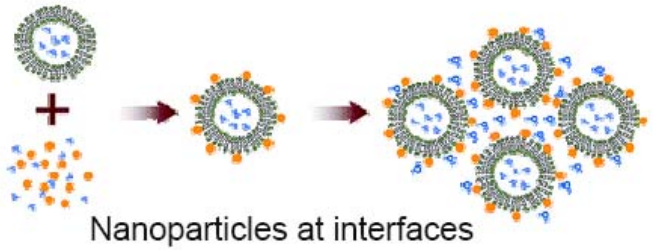
Glassy dynamics

$$S / N \propto I\sqrt{t}$$

EXAMPLE



Dynamics of membranes

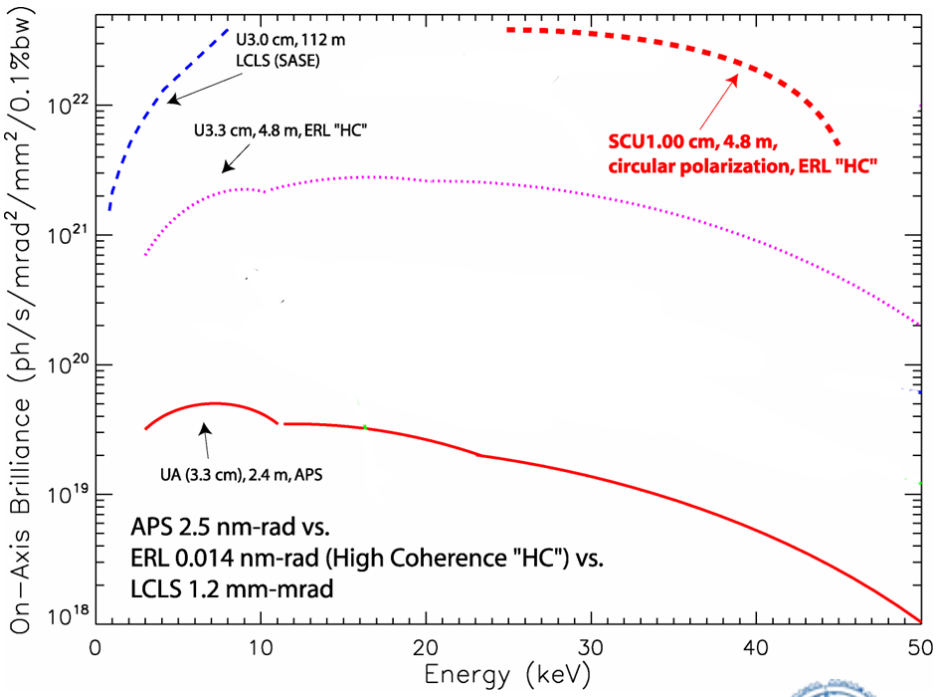


Nanoparticles at interfaces

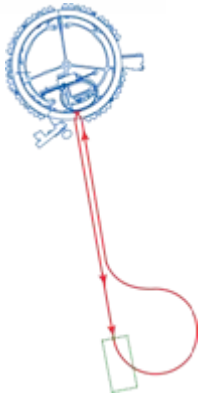
[L. Zhang and S. Granick, Nano Lett. **6**, 694 (2006)]

Better detectors will reach sub-μs

What would an ERL offer?

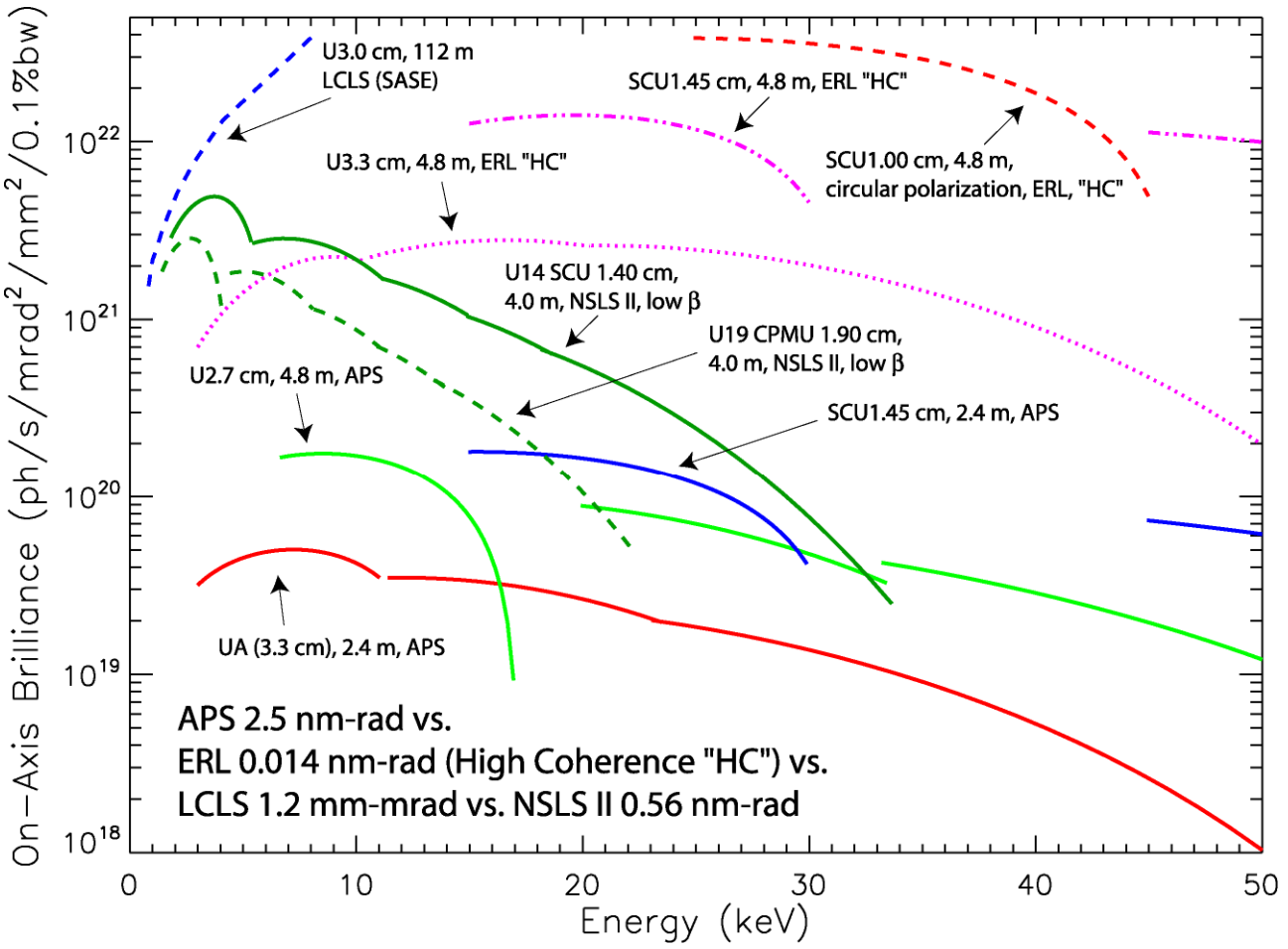


We continue to consider other options, but are now targeted on the ERL



- Substantially spatially-coherent source ("like a laser")
  - It can put >100 times more flux into a <10nm probe and improve phase contrast compared with a storage ring
  - And deliver to many users
- It offers pulses 100 times shorter or less (in the sub-ps regime)
  - Does not rival FEL for peak brilliance
  - But compatible with FEL upgrade as well
- Natural upgrade path for storage ring such as APS
  - Could be done without compromise or major disruption

On-axis Brilliance Tuning Curves for Current APS Lattice vs. ERL High-coherence Mode vs. LCLS vs. NSLS II

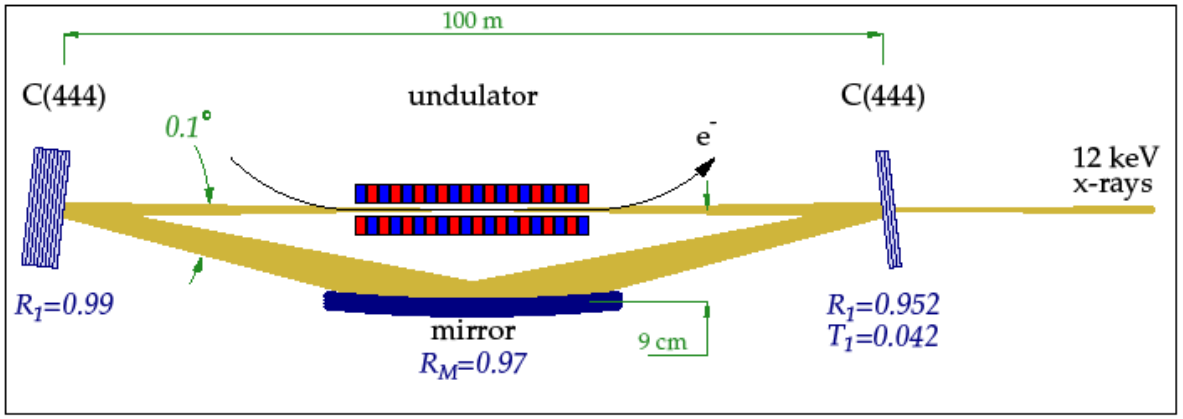


- Beam energy: 7.0 GeV (APS), 4.3 – 13.6 GeV (LCLS), 3.0 GeV (NSLS II)
- Beam current: 100 mA (APS), 25 mA (ERL High Coherence “HC”), 500 mA (NSLS II)

R&D Hilite: Cavity laser might become possible with ERL beam

K.J. Kim and Y. Shvydko

Diamond cavity for the X-FEL Oscillator

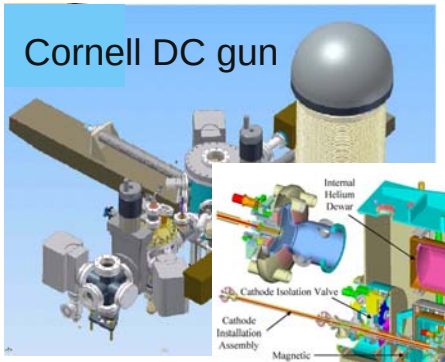


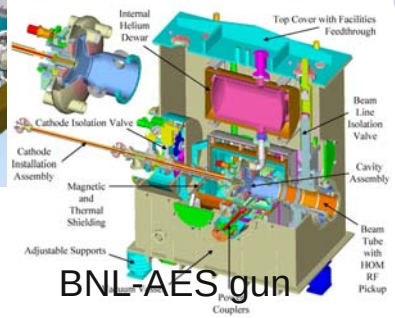
$$R_1 \times R_2 \times R_M = 0.91 \qquad T_1 \simeq 0.042$$

Fully coherent (temporal and spatial) x-ray laser source!

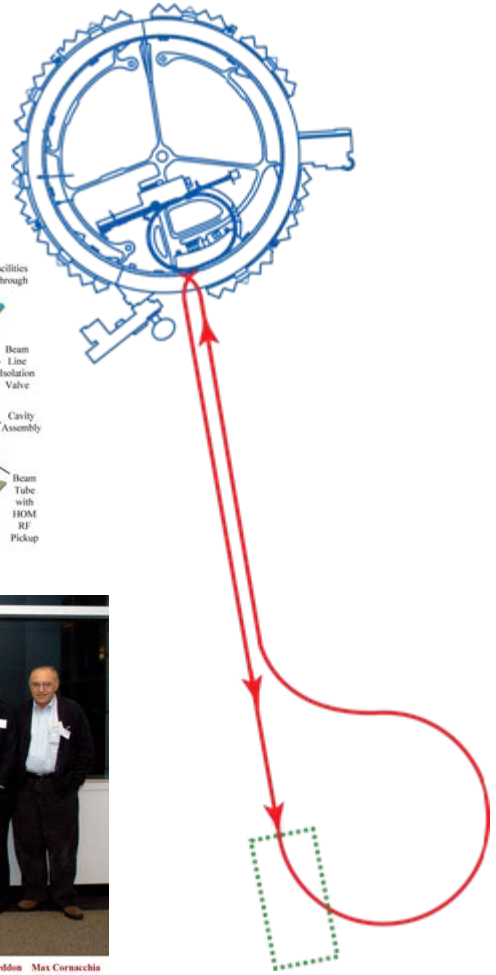
Where are we now on upgrade planning?

- Serious R&D is required for APS upgrade (esp. gun and RF)
- R&D proposal submitted to DOE strengthens international effort
  - Leveraged by ANL LDRD and accelerator institute
- During R&D phase there is time to consider all options
- *Major workshop with users planned for October 20-21 2008*
- Meanwhile, BESAC plans to evaluate user community needs which will drive DOE-BES plans
- Of equal priority to us is development of new and dedicated beamlines, instrumentation, detectors and software to expand imaging and ultrafast capabilities





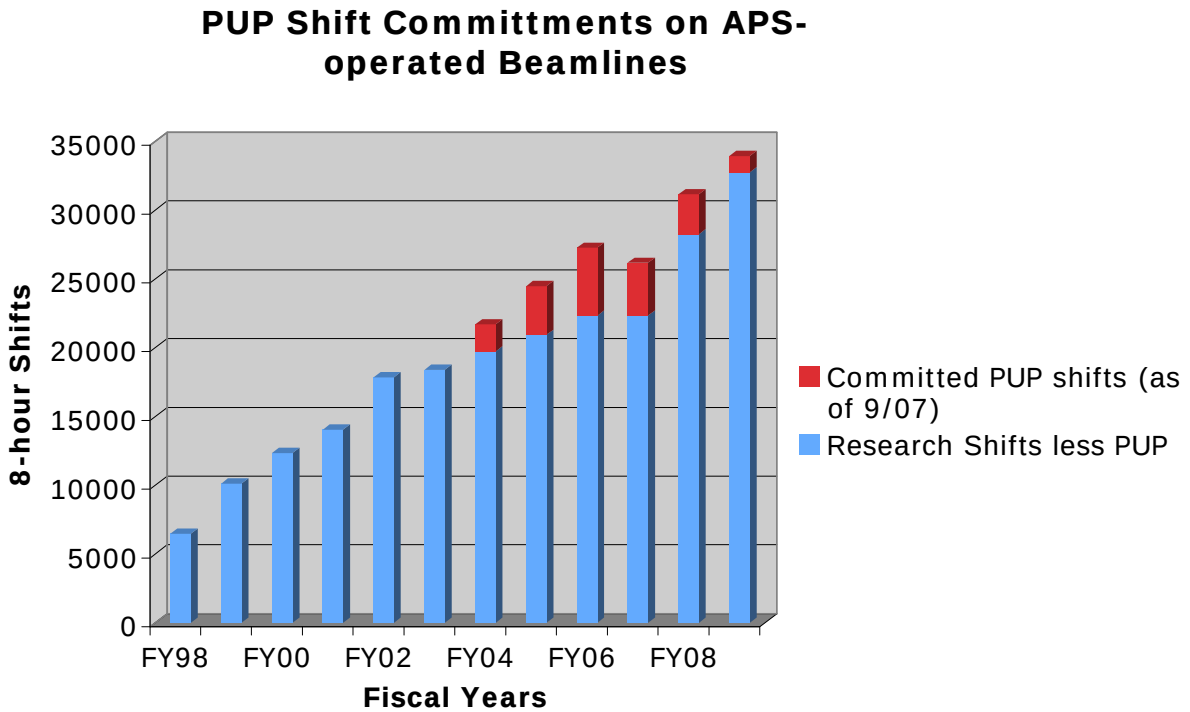
BNL-AES gun

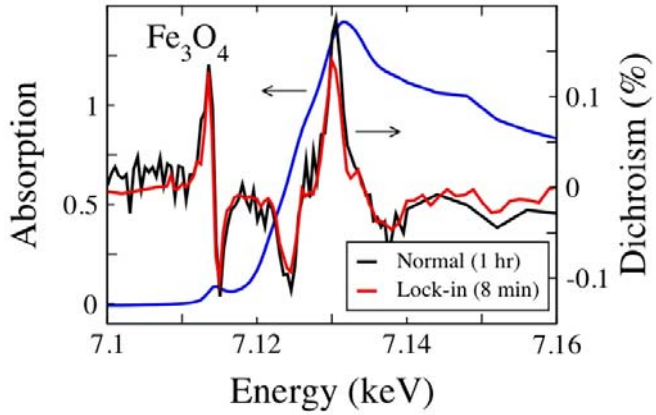


→ APS RENEWAL 5-Year Plan

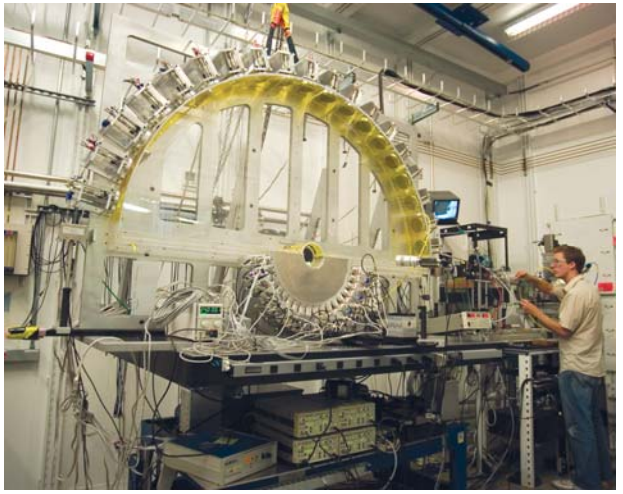
Extra material on APS user program and internal reviews

Limited scope Partner User Proposals bear fruit

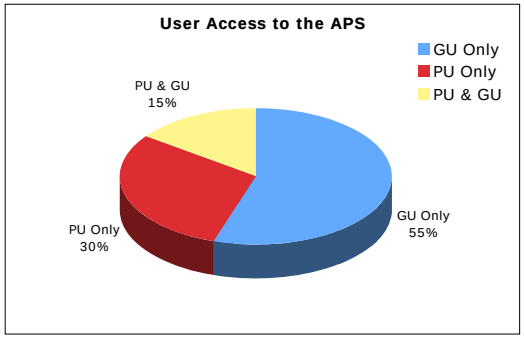




(~10^{-5} sensitivity)



General user (GU)
Partner user (PU)



Scientific Advisory Committee (SAC) Members

SAC Committee Members: Jens Als-Nielsen, Michelle Buchanan, Slade Cargill, Howard Einspahr, Miles Klein, Richard Leapman, Dan Neumann, Piero Pianetta, Michael Wasielewski, Soichi Wakatsuki, Glenn Waychunas, Donald Weidner, Pierre Wiltzius, Wei Yan, Tim Graber and Denis Keane

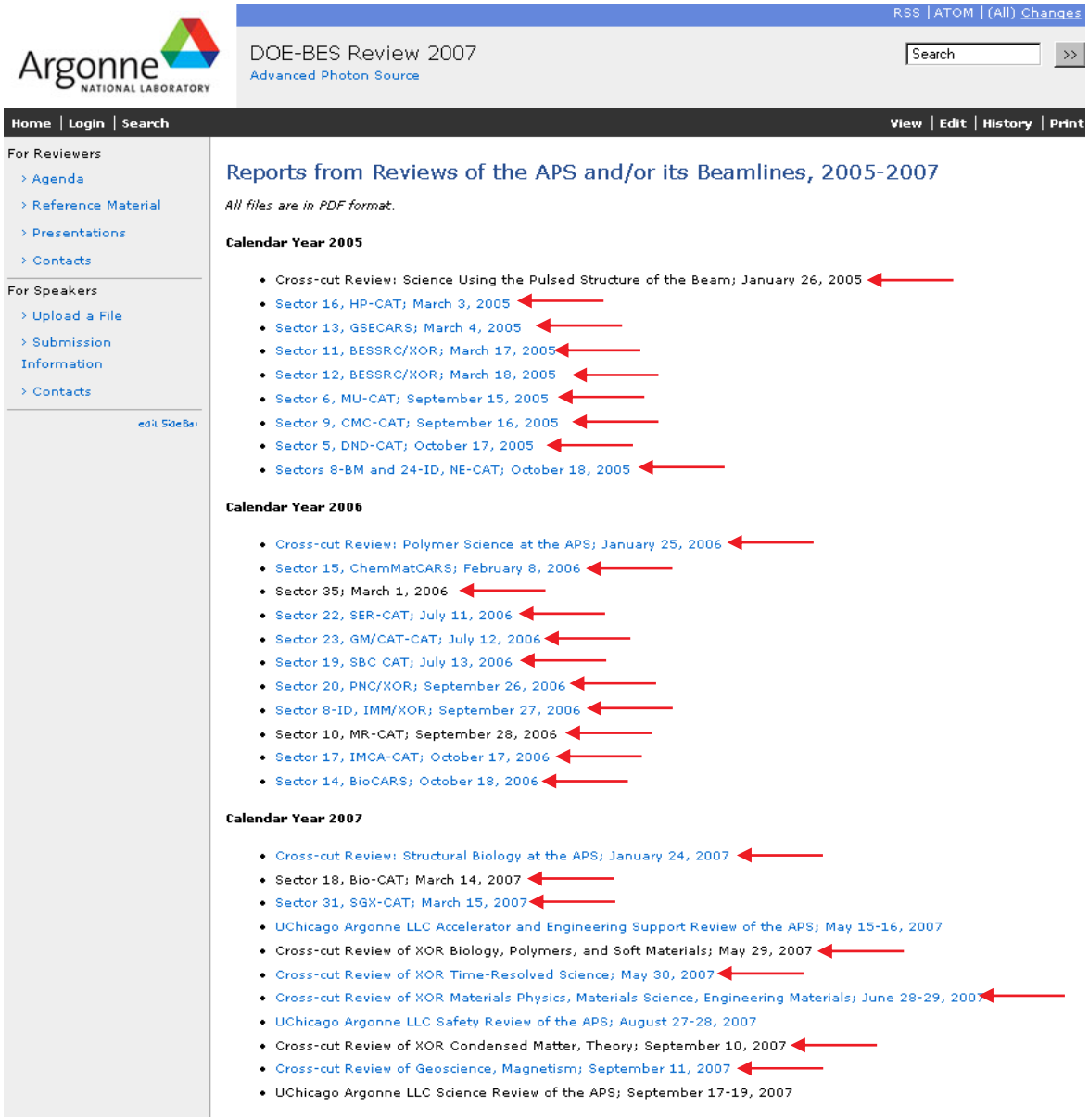
APS Reviews

Internal

and

External

Red arrows ← indicate internal reviews in which SAC members participated.



New Internal SAC Review Process: Eight subject areas proposed for cross-cut reviews

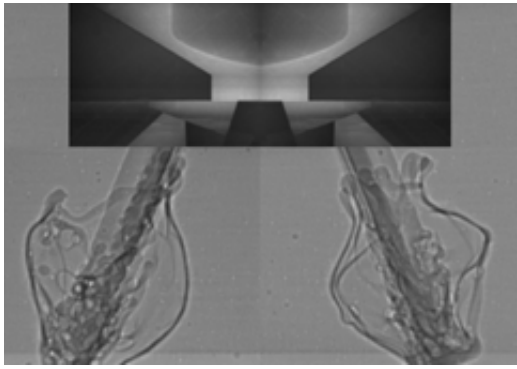
Proposed 2009 reviews

- *Atomic, Optical, Molecular, and Chemical Science*
- Condensed Matter and Materials Physics
  - (includes magnetism, superconductivity, and emergent materials)
- Engineering Applications/Applied Physics
  - (includes deformation, cements and mortars, shape memory alloys, superalloys, liquid sprays)
- *Geological, Environmental, and Planetary Sciences*
- Macromolecular Crystallography (MX)
- Materials Science and Technology
  - (includes photonics, semiconductors, nanomaterials, and liquid crystals)
- Polymers, Soft Materials, and Biology (excluding MX)
- Surfaces, Interfaces, and Thin Films

Combined with short sector management reviews

Conclusions

- Despite short-term difficult national budget picture, APS is growing and developing renewal plans for the short-term, medium-term and long-term including a major upgrade
- Science drivers towards the ultra-small (~1nm) and ultrafast (~1ps)
- The Energy-Recovery LINAC, developed by Cornell and also planned by KEK, seems the most promising upgrade path for APS
  - R&D is ongoing
  - Major user workshop planned for this fall
- The big three facilities will retain their niche in high energy x-rays
  - And we benefit from working together
    - *At the least through sharing information*
    - *But co-operative projects are of high value*
      - e.g. Scientific software?



Vive La Difference!