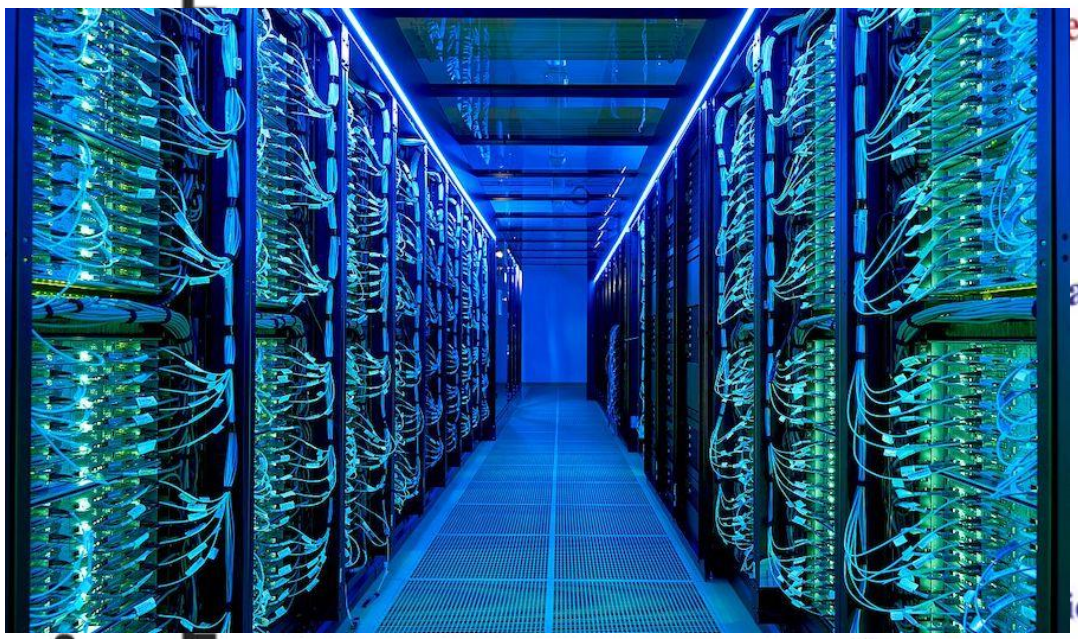
Vision of accelerator physics? (introduction to discussion)

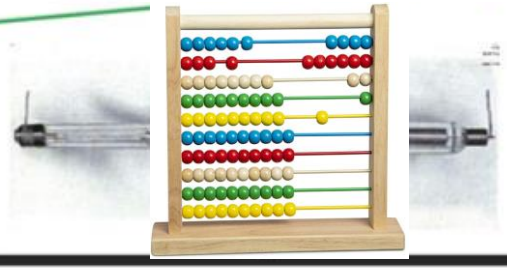
Vitaliy Goryashko

2025-11-12, UU

I: Some Thoughts on X-ray Photon Sources From the Technological Perspective

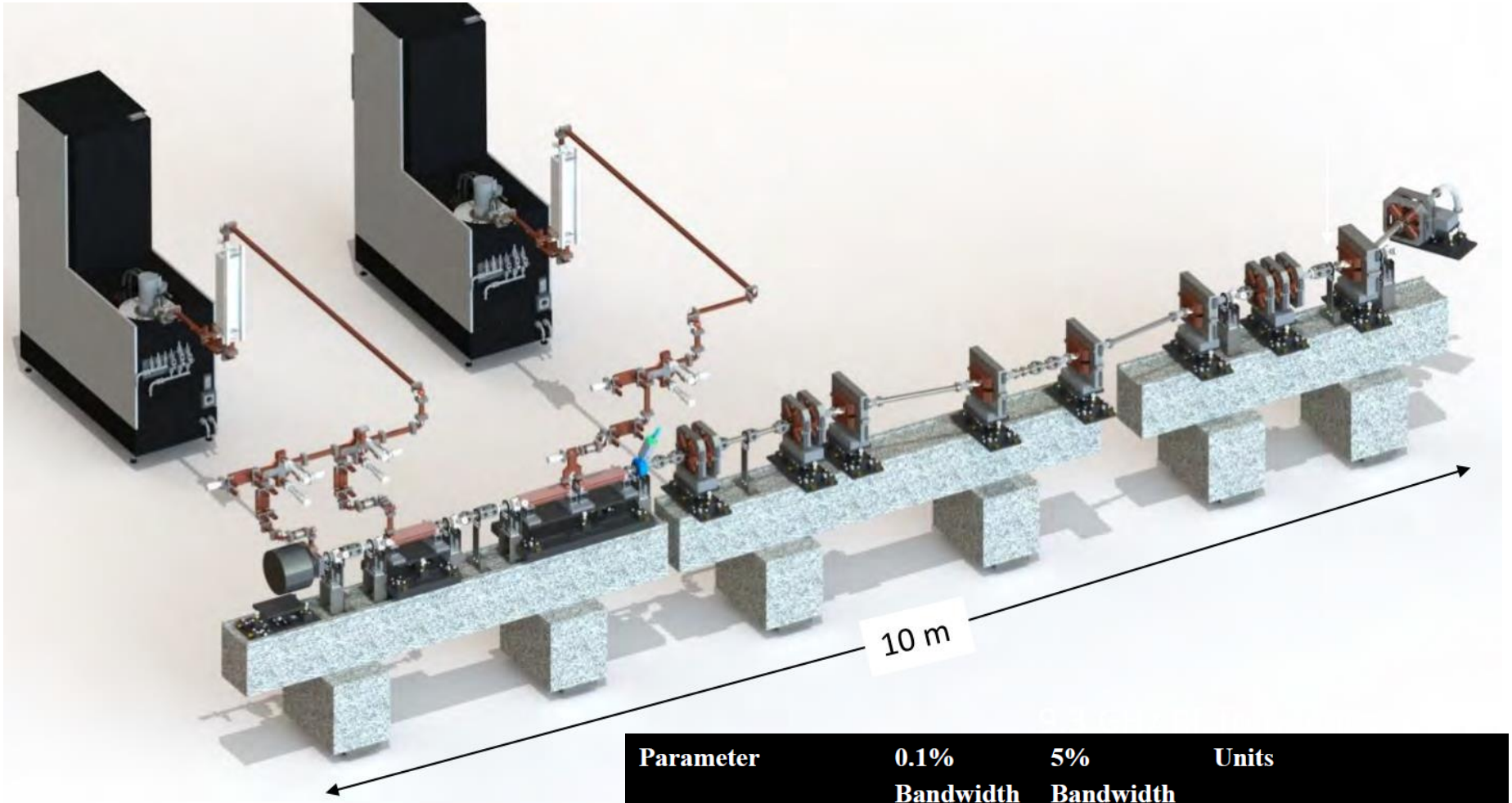
Technological evolution of X-ray generation





Valerio Cerantola et al 2021 J. Phys.: Condens. Matter 33 274003

Project at Arizona State University



Parameter	0.1% Bandwidth	5% Bandwidth	Units
Average flux	$5x10^{9}$	$1x10^{11}$	photons/s
Average brilliance	$2x10^{12}$	$5x10^{12}$	photons/(s .1% mm^2mrad^2)
Peak brilliance	$3x10^{19}$	$9x10^{18}$	photons/(s .1% mm^2mrad^2)
Photons per pulse	$5x10^{6}$	$1x10^{8}$	
RMS pulse length	<500	<500	fs
Repetition rate	1	1	kHz

ASU's instrument makes its first X-rays

ASU Arizona State University

ASU News

Explore | Expert Q&A | Video series | Magazine | Books and essays

Discoveries

First-of-its-kind instrument officially ushers in new era of X-ray science

Tempe campus

February 3, 2023

ASU's compact coherent FEL

ASU Arizona State University

ASU News

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The stakes are sky rocketing as the project is extremely challenging!

Discoveries

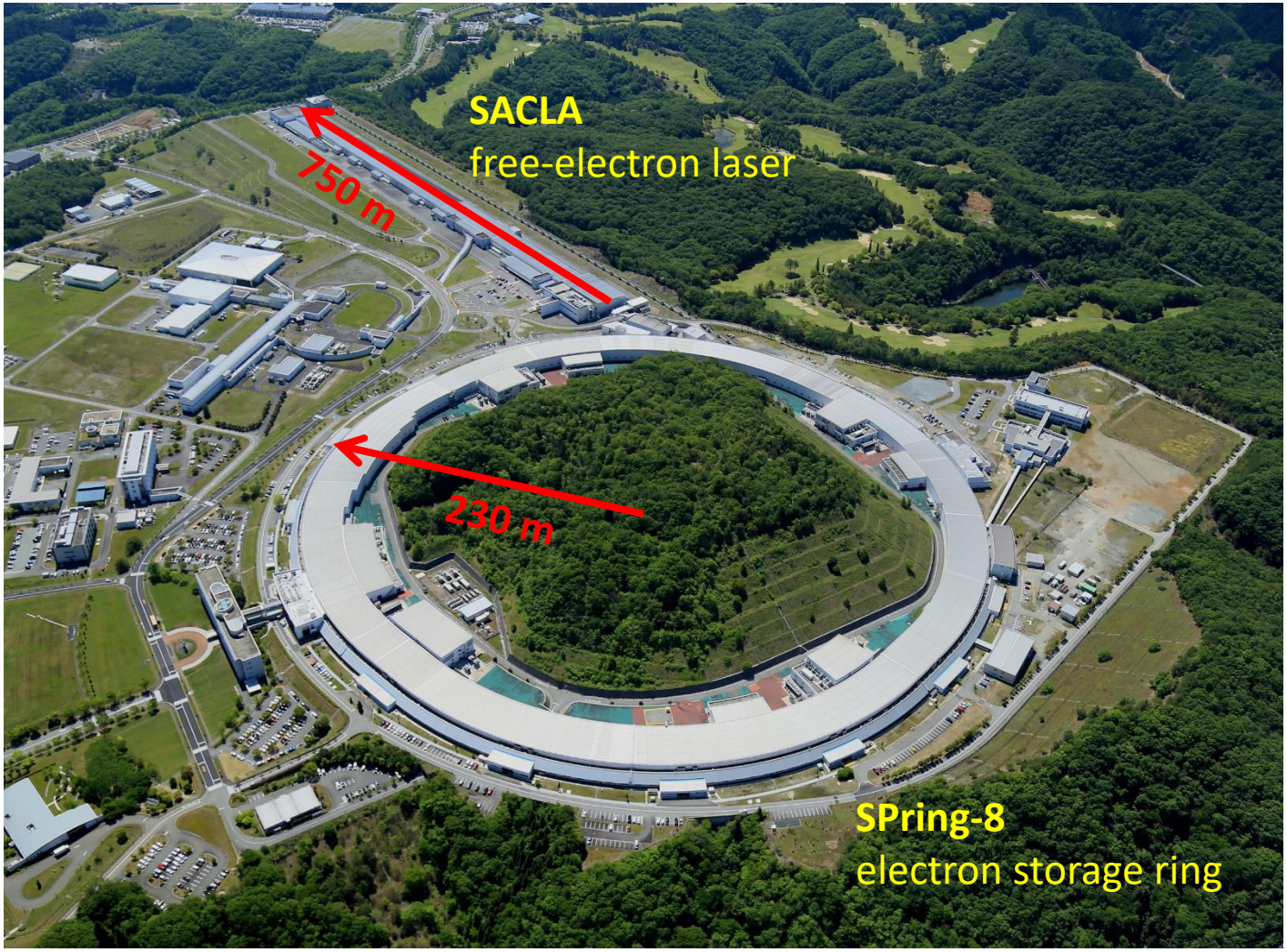
National Science Foundation awards $90.8M to ASU to advance X-ray science

Tempe campus

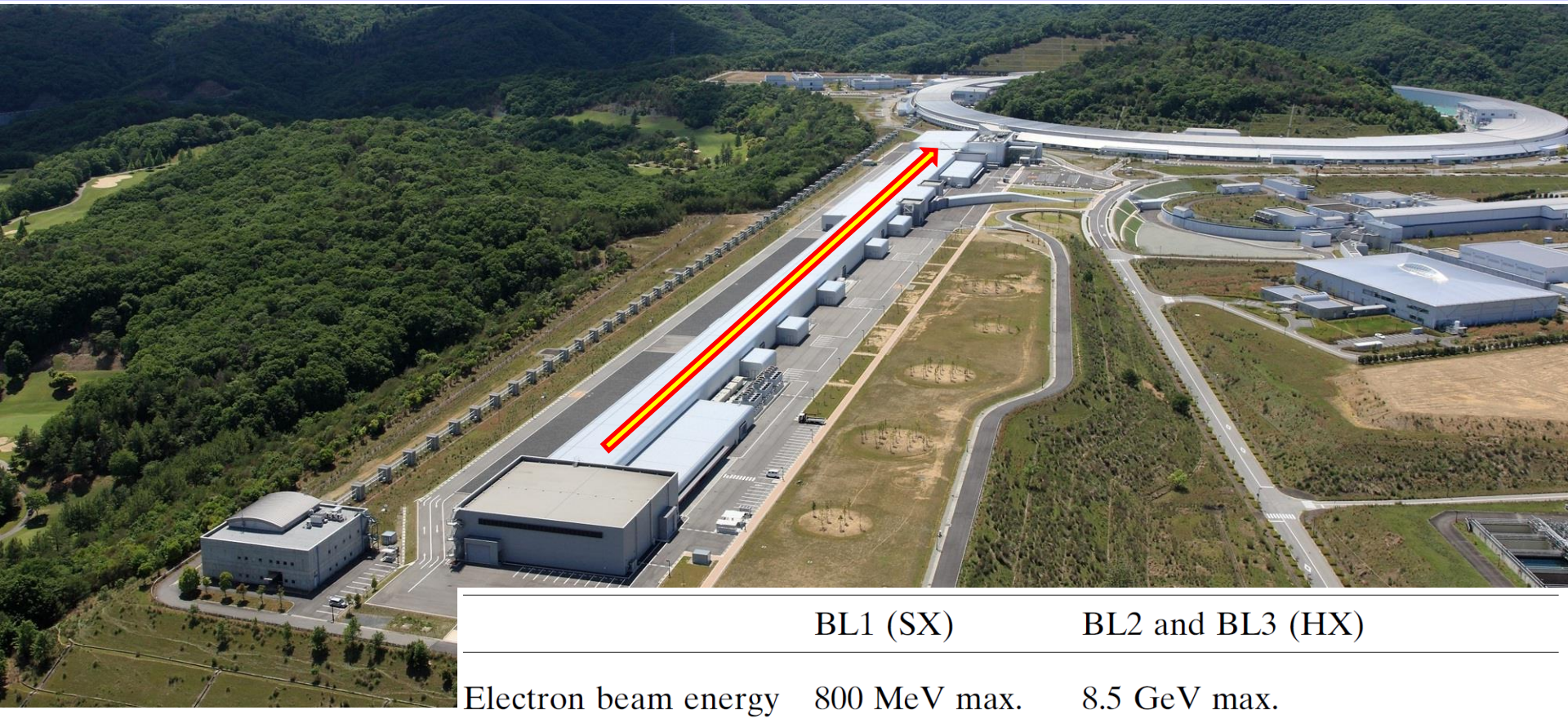
March 8, 2023

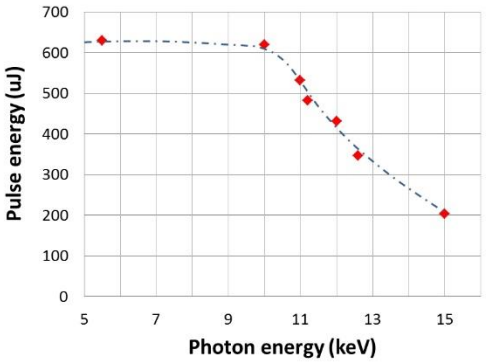
Lab-scale X-ray Sources that can partly replace synchrotrons and FELs is an Active Area of Research

SACLA - a lab lost in the mountains



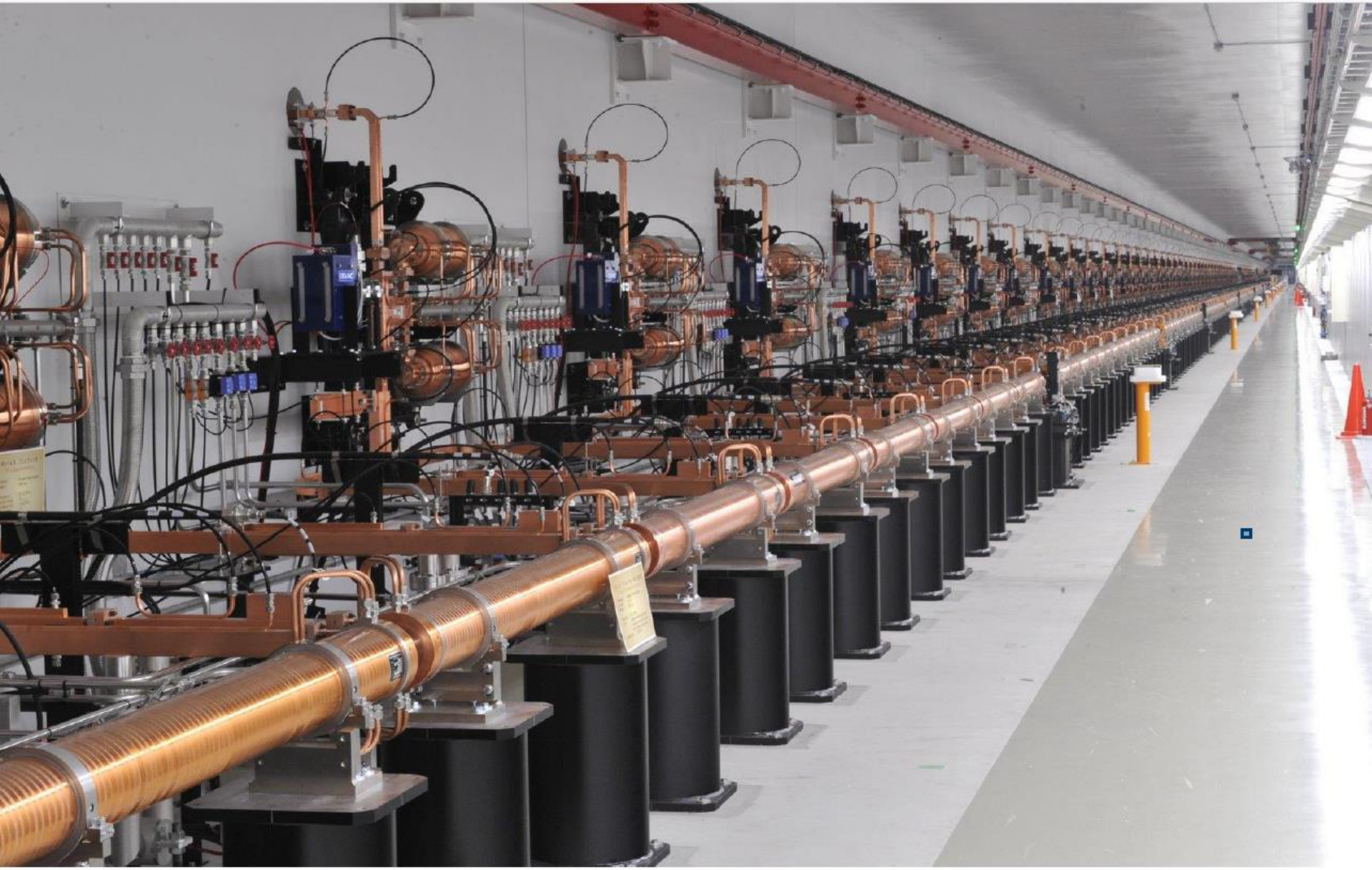
High-level overview



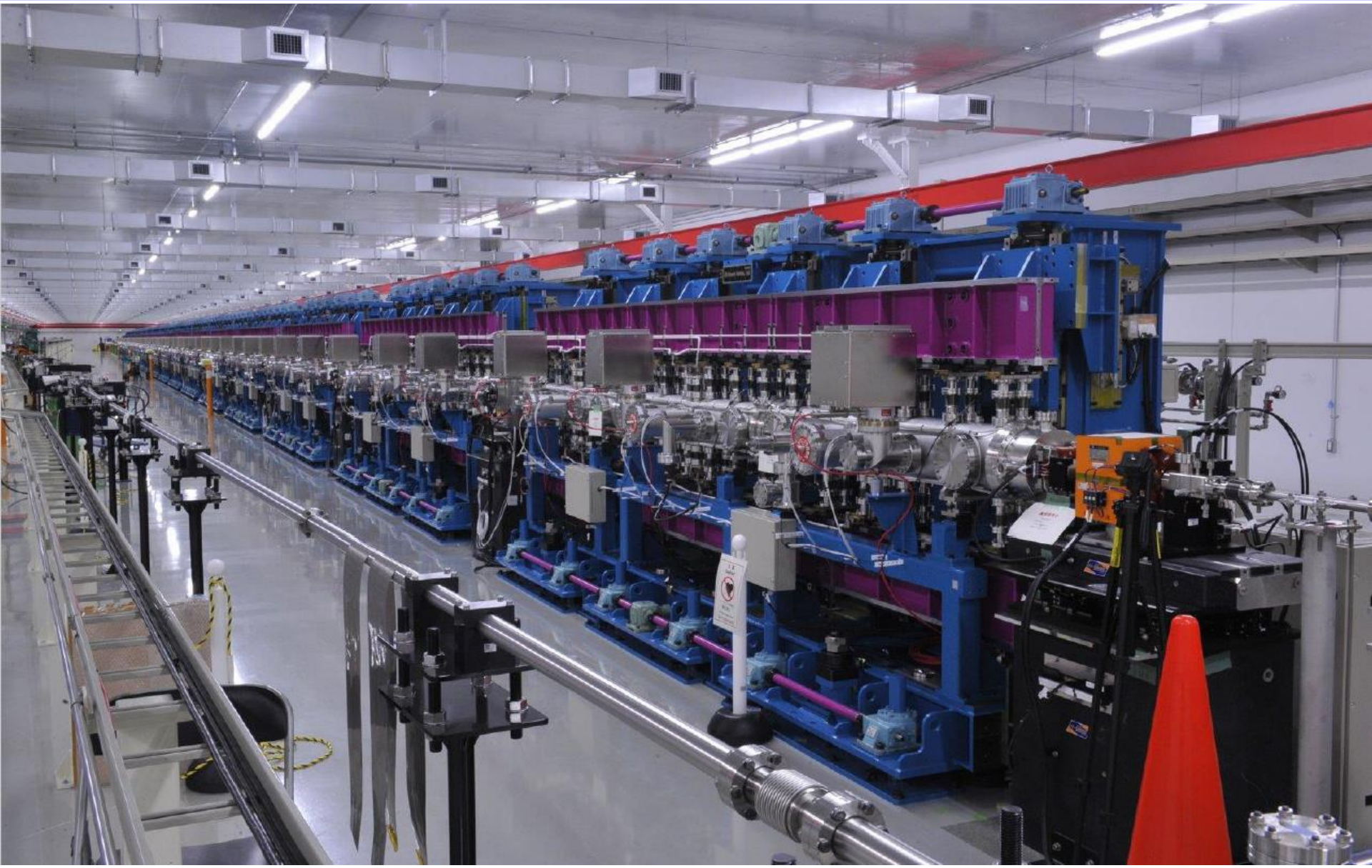


	BL1 (SX)	BL2 and BL3 (HX)
Electron beam energy	800 MeV max.	8.5 GeV max.
Bunch charge	0.2–0.3 nC	0.2–0.3 nC
Peak current	0.3 kA	>10 kA
Bunch length	<1 ps (FWHM)	<20 fs (FWHM)
Repetition	60 Hz max.	60 Hz max.
Undulator period	18 mm	18 mm
Undulator K value	2.1 max.	2.7 max.
No. of undulator units	4.5 m × 3	5 m × 18 (BL2), 5 m × 21 (BL3)
Photon energy	40–150 eV	4–15 keV
FEL pulse energy	0.1 mJ at 100 eV	0.7 mJ at 10 keV

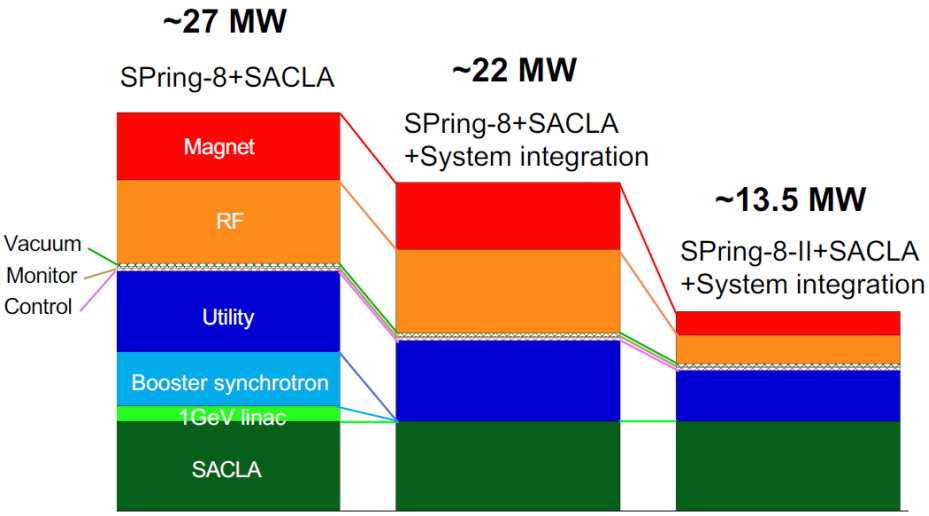
SACLA linac: 8 GeV, 400 m C-band technology

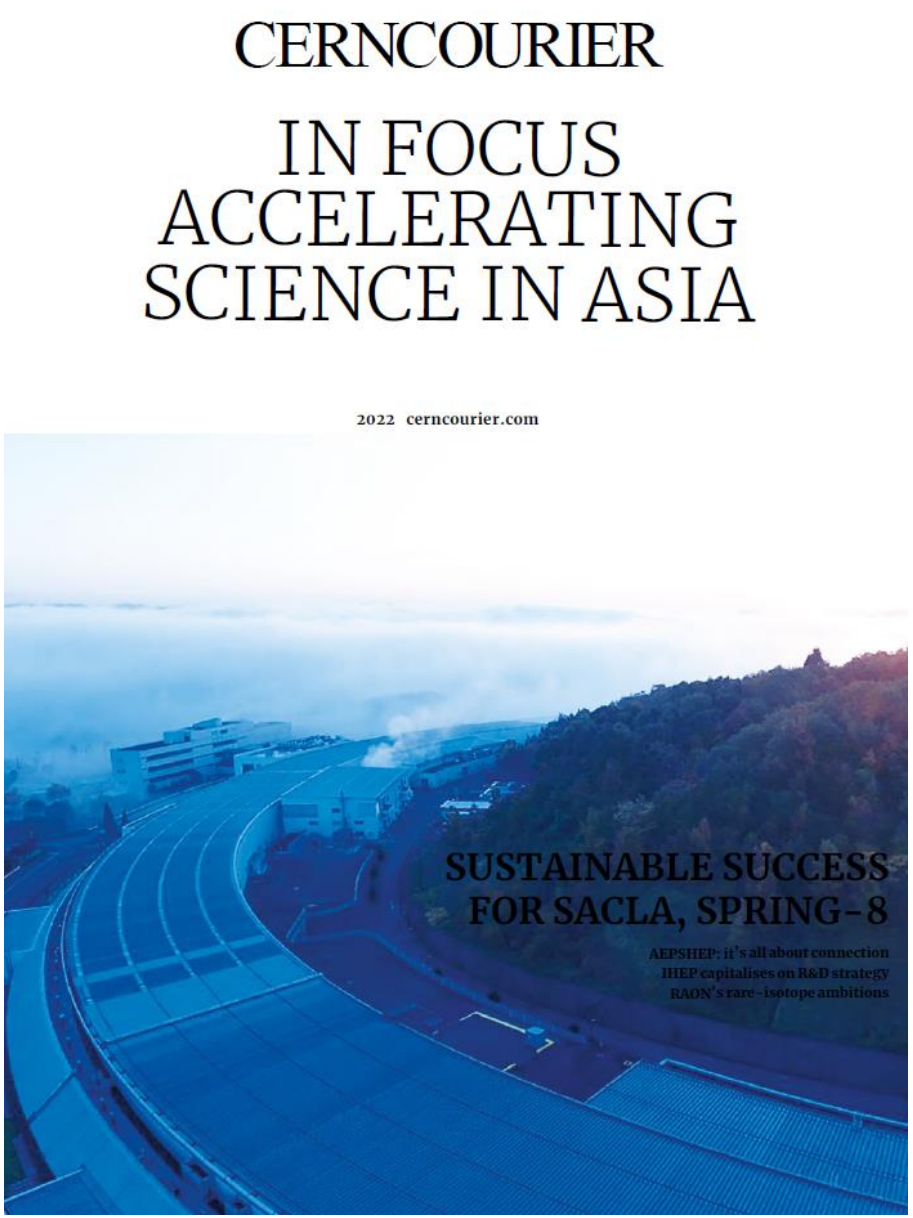


90-m in-vacuum undulator



Next generation ‘green’ accelerator technology





Green technology is a must in Japan!

- high-gradient X-band linac
- short-pulse klystron modulator
- 1 kHz repetition rate
- permanent magnets

There is a Public Expectation for Green Technologies: Example: Green SPring-8/SACLA-II in Japan

II: Some Thoughts on X-ray Photon Sources From the User Perspective

X-ray Light Sources around the world

SYNCHROTRON FACILITIES AROUND THE WORLD

Over 35 major synchrotron facilities world-wide

Over 40,000 scientists use these facilities each year.
Five are large-circumference high-energy (>5 GeV) high-brilliance (<3nm-rad) storage rings

UChicago Argonne, LLC | U.S. DEPARTMENT OF ENERGY | Argonne NATIONAL LABORATORY

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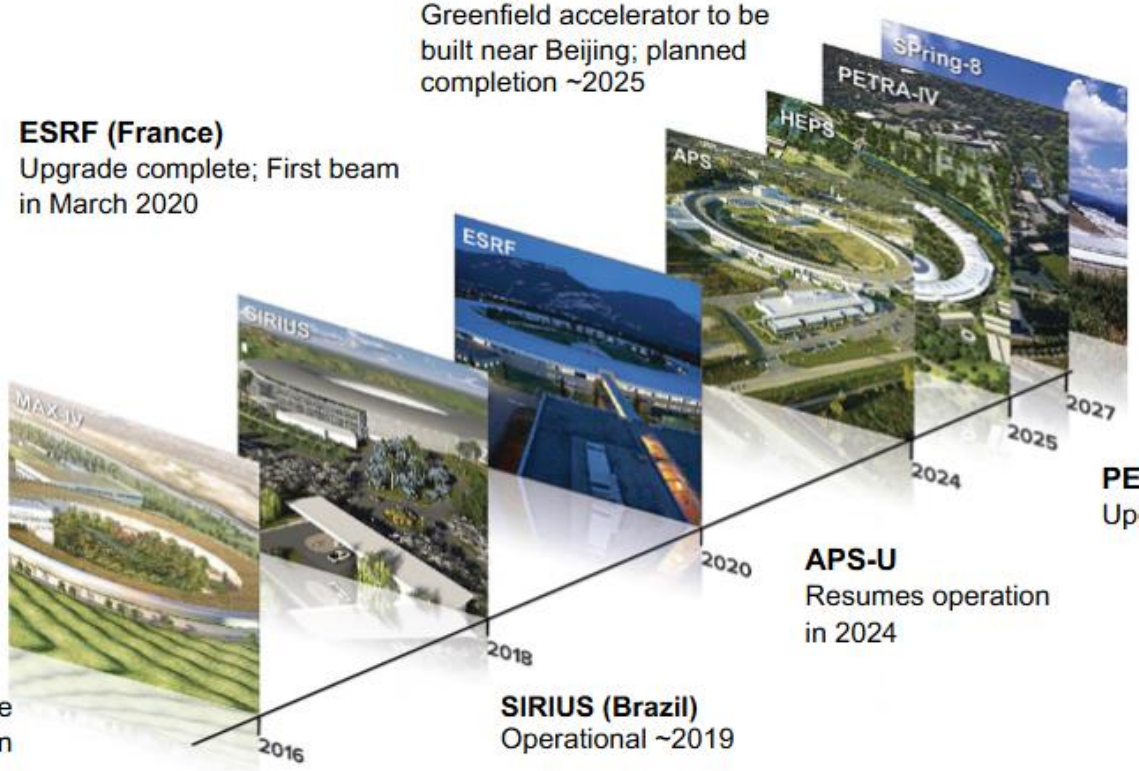
Courtesy of Dr. Jonathan Lang, Neutron X-ray Summer School, July 18, 2022

World-Wide Light Source Upgrades



MAX-IV (Sweden)
Inauguration June 2016; in operation

SIRIUS (Brazil)
Operational ~2019

ESRF (France)
Upgrade complete; First beam in March 2020

APS-U
Resumes operation in 2024

HEPS (China)
Greenfield accelerator to be built near Beijing; planned completion ~2025

PETRA-IV (Germany)
Upgrading 2027

SPring-8 (Japan)
Upgrading >2027

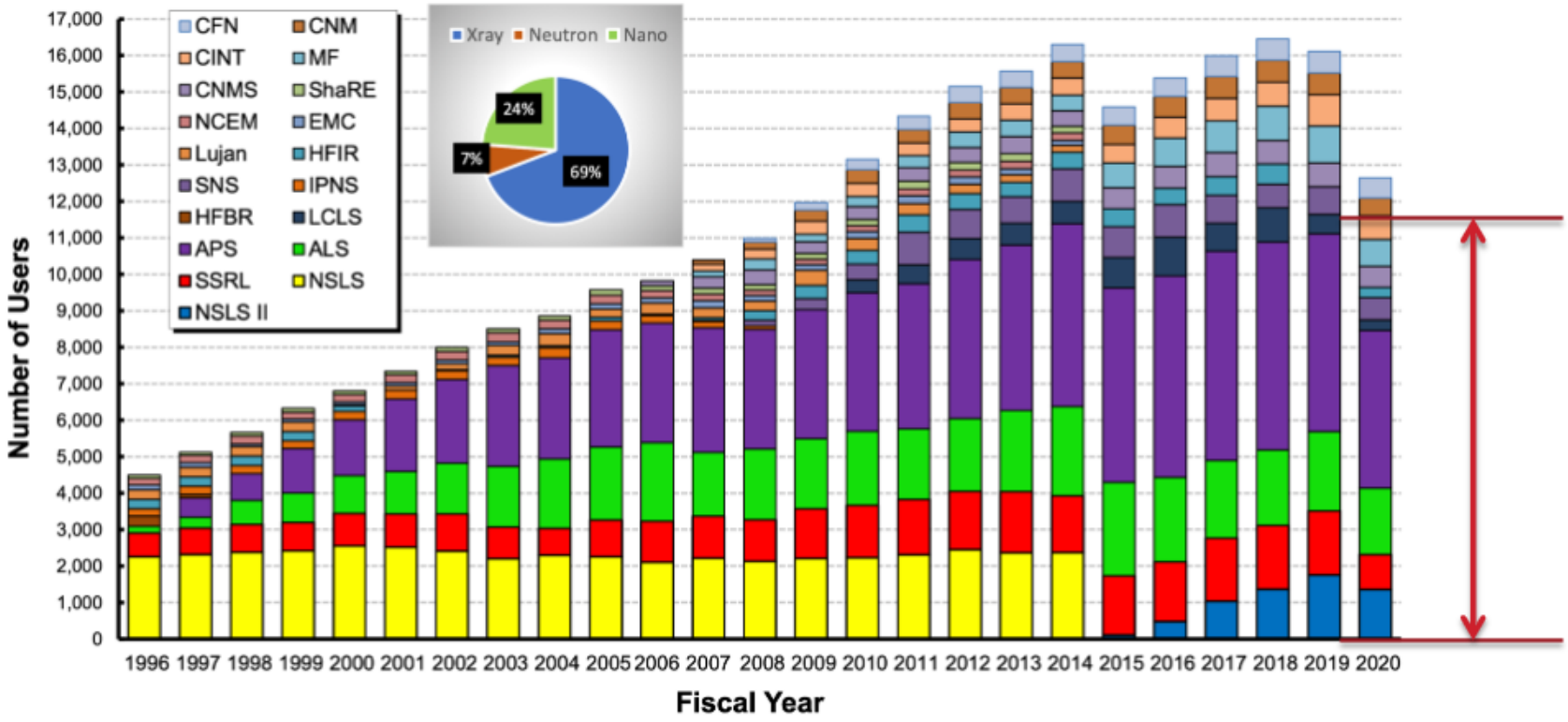
UChicago Argonne, LLC U.S. DEPARTMENT OF ENERGY

Argonne

Courtesy of Dr. Jonathan Lang, Neutron X-ray Summer School, July 18, 2022

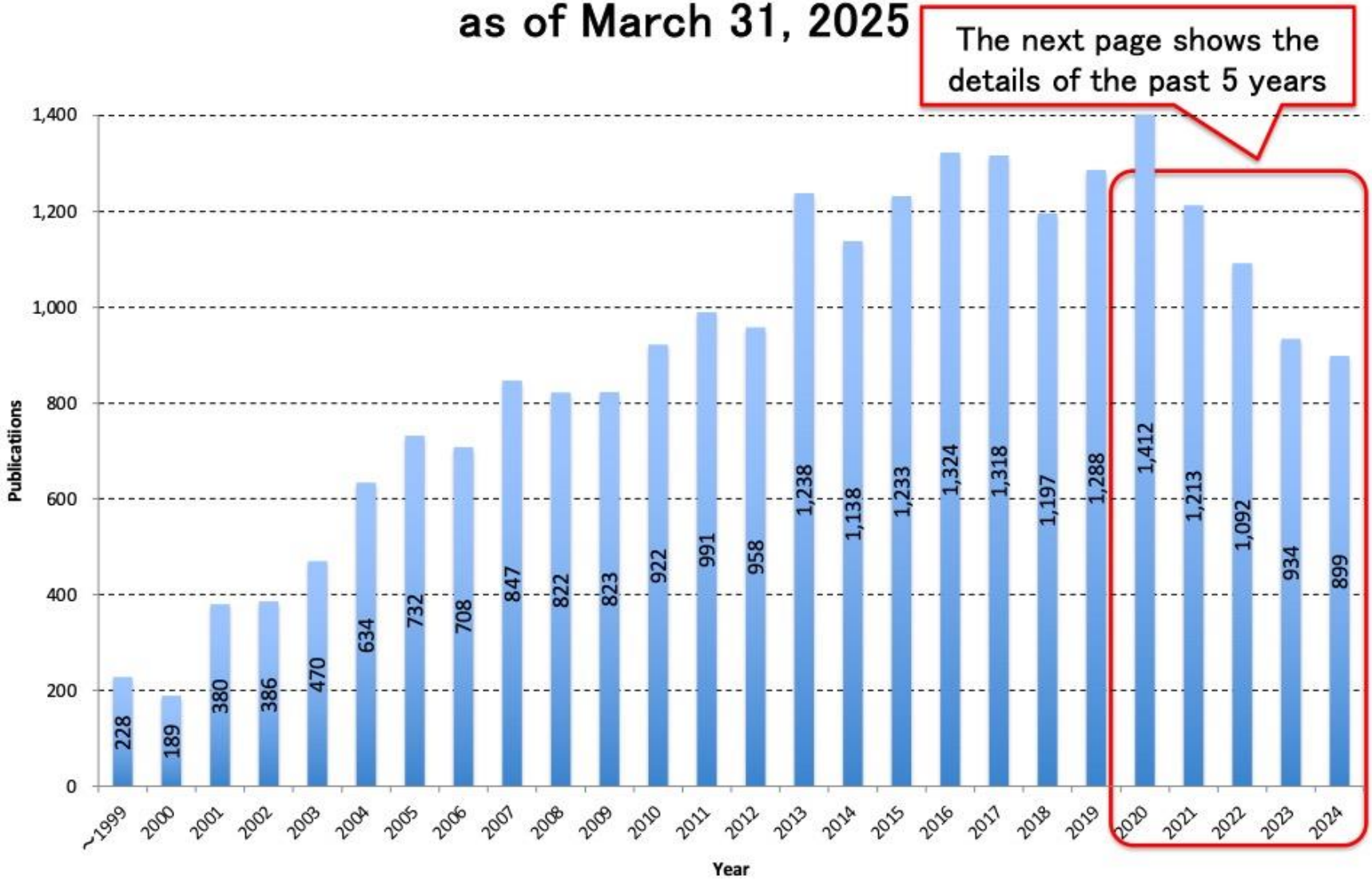
DOE SCIENTIFIC USER FACILITIES

More than 11,000 unique users use one of the DOE light sources each year; Canadian Light Source ~1000; CHESS ~1000

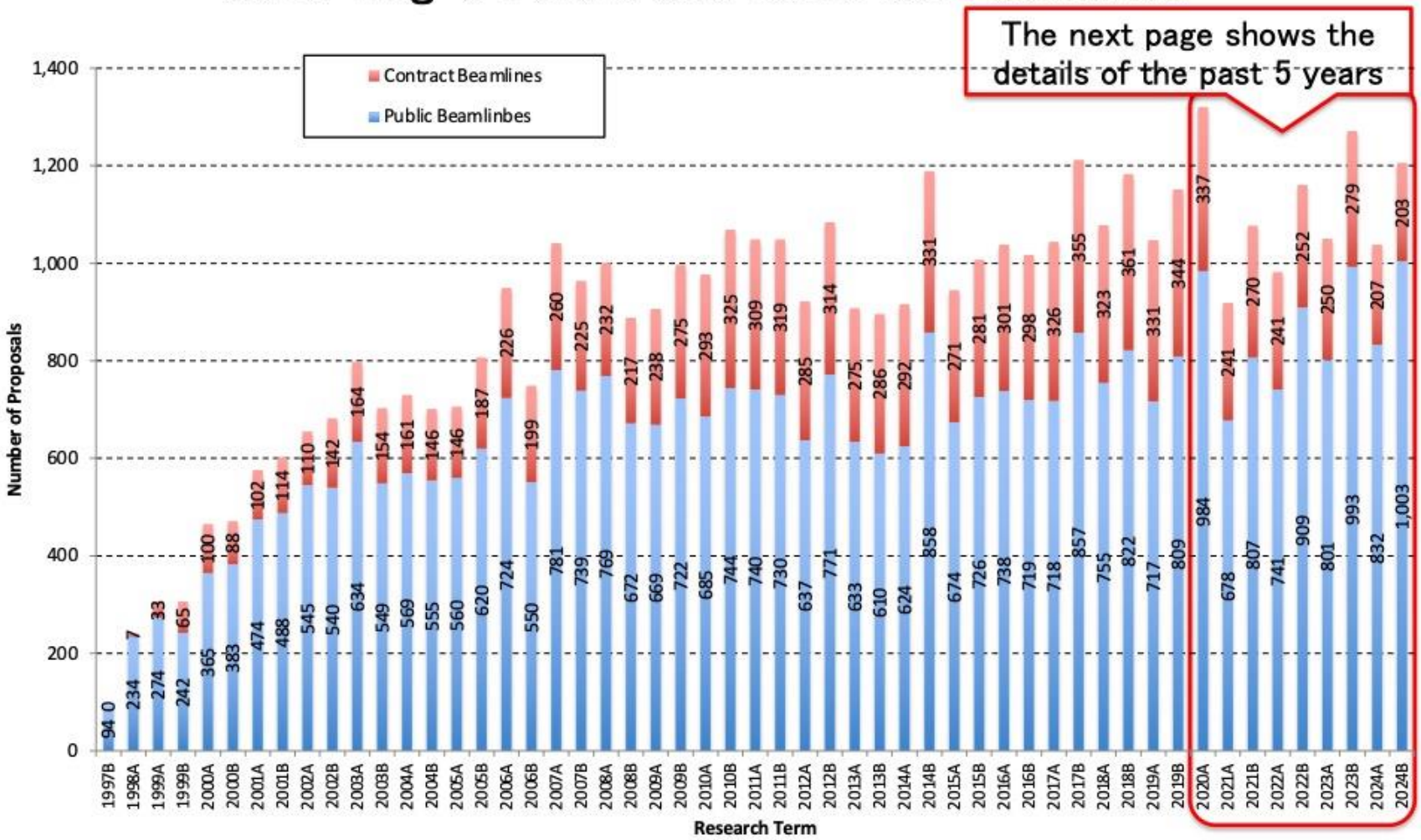


Courtesy of Dr. Jonathan Lang, Neutron X-ray Summer School, July 18, 2022

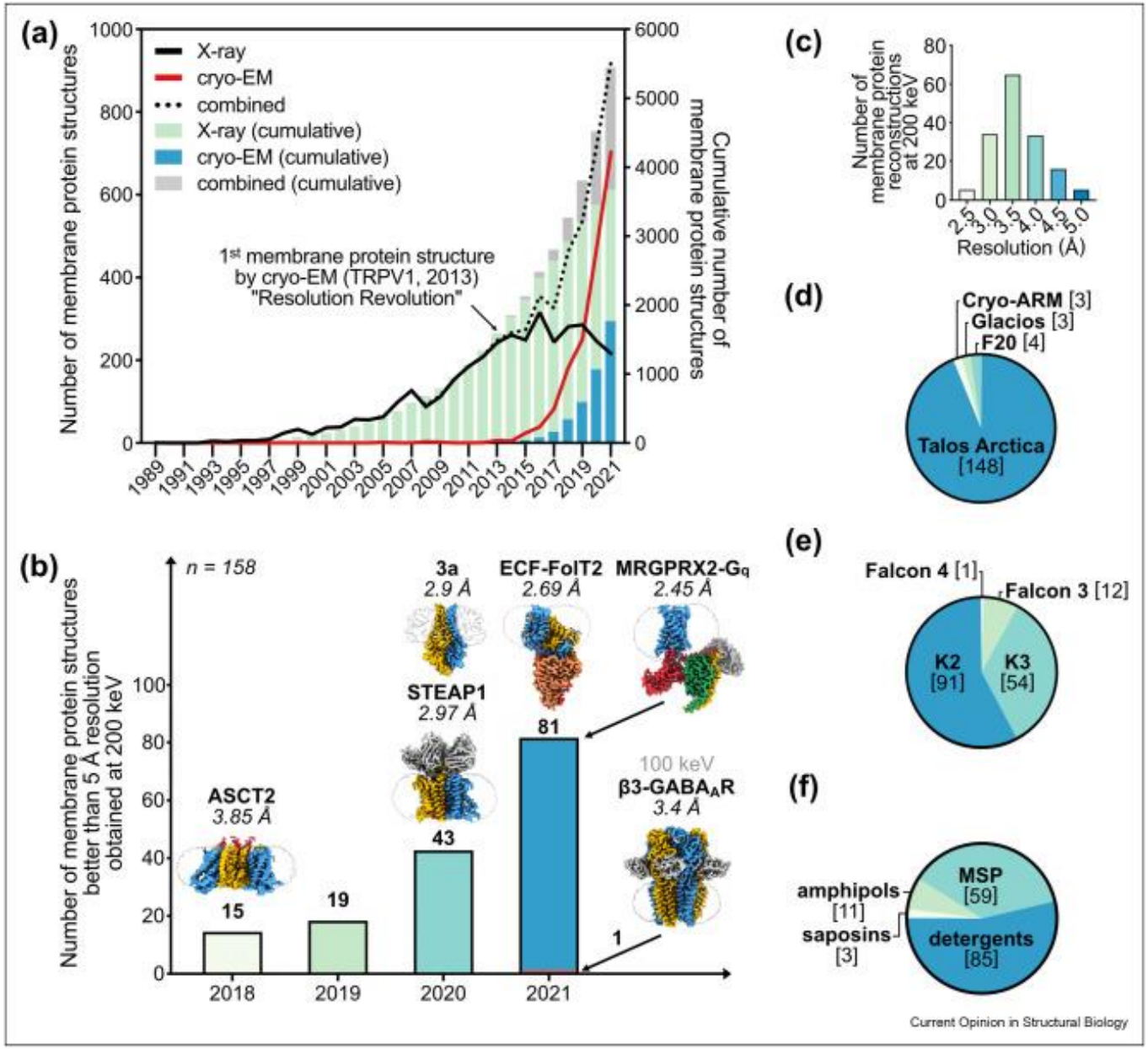
Number of Refereed Publications at SPring-8 as of March 31, 2025



Number of Conducted Proposals at SPring-8 Public and Contract Beamlines

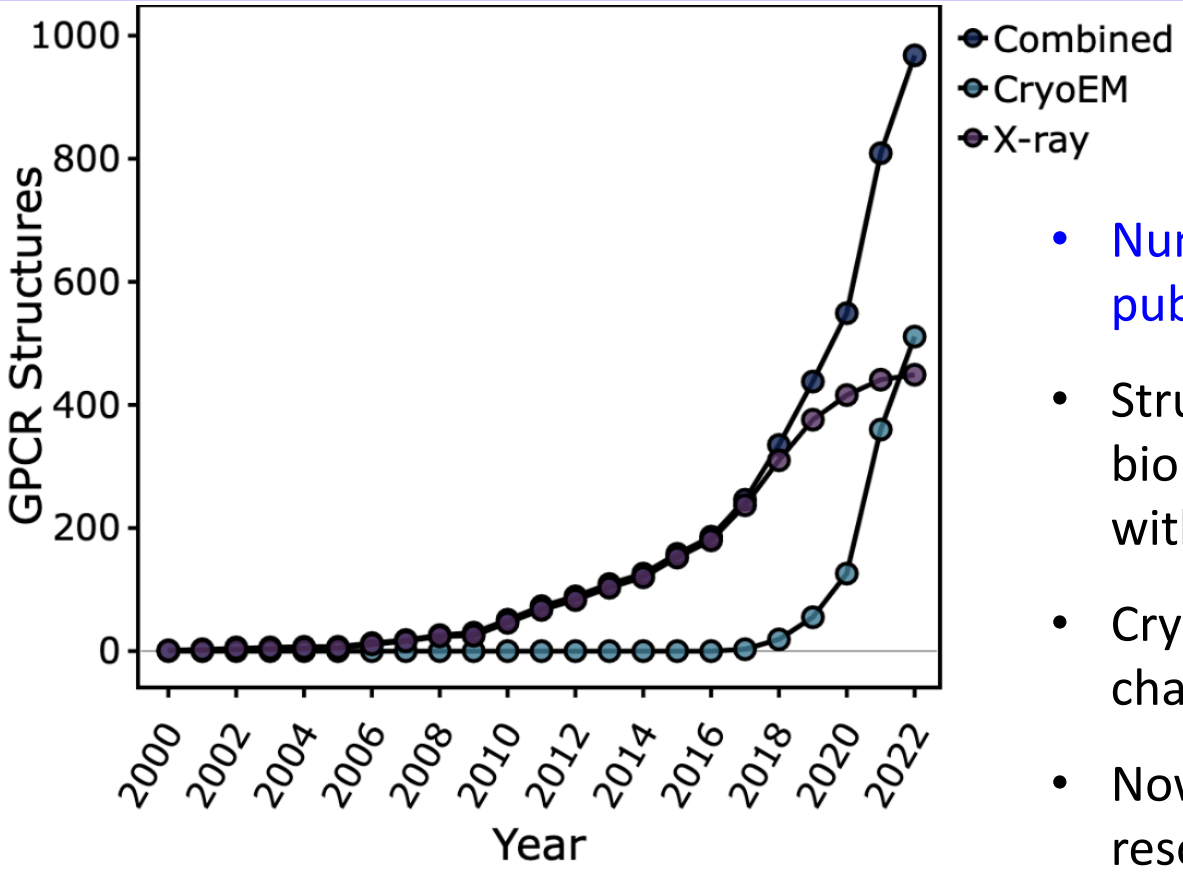


Revolution in cryo-EM and Structural Biology



https://www.sciencedirect.com/science/article/pii/S0959440X22001191

Potential reshaping of the user landscape

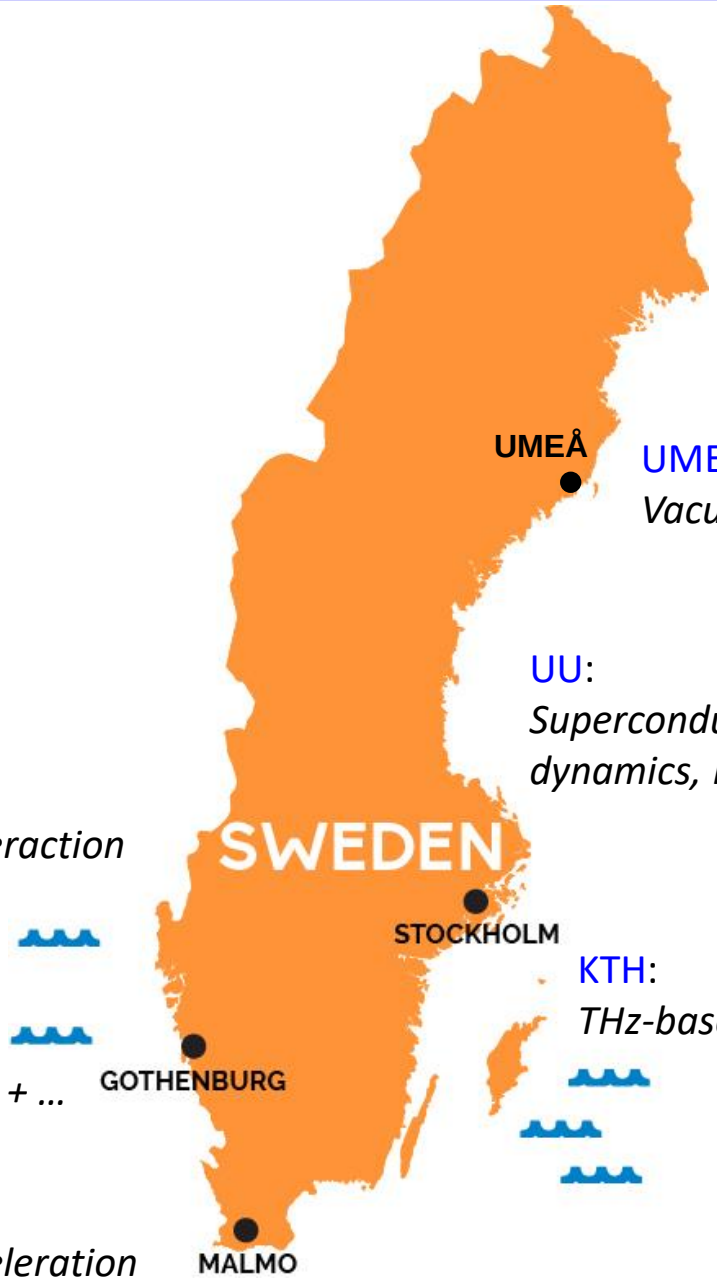


https://peakproteins.com/cryo-em-at-peak-proteins

- Number of synchrotron users and publications has saturated.
- Structures of proteins and biomolecules have been studied with X-ray crystallography
- Cryo-electron microscope challenges X-ray monopoly
- Now, the majority of proteins is resolved with cryo-EM.
- It is natural to expect the reduction in crystallography synchrotron users.
- But increased demand for time-resolved studies at FELs.

III: Strength of Accelerator Physics in Sweden

Accelerator physics/technologies in Sweden



UMEÅ:
Vacuum laser acceleration

UU:
Superconducting RF & magnets, beam dynamics, FELs

KTH:
THz-based acceleration

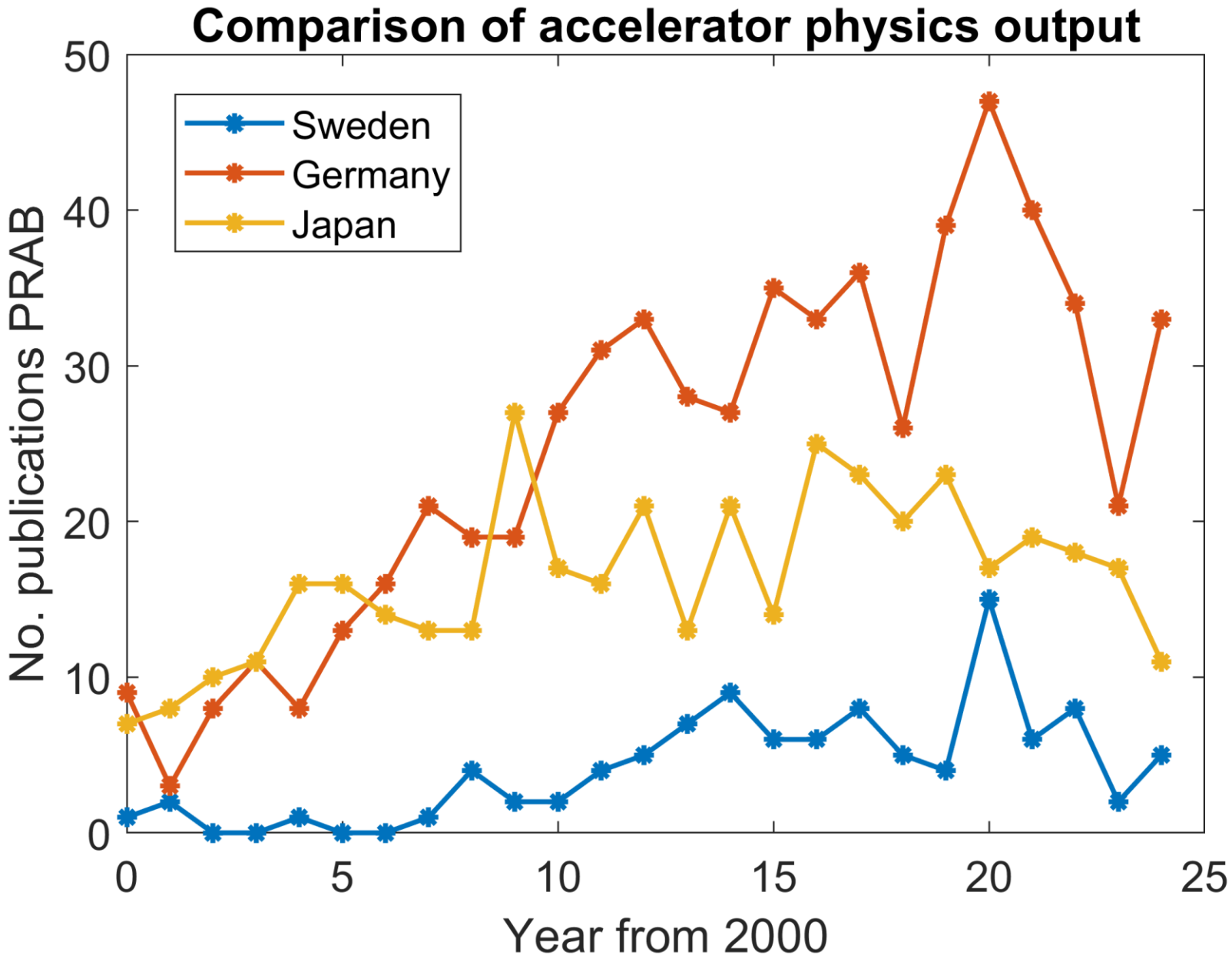
Chalmers:
High-intensity laser-particle interaction

MAX IV:
synchrotron technology

ESS:
Proton accelerator, SRF + …

LU:
FELs, beams dynamics

LU:
Plasma-based acceleration


Comparison of accelerator physics output
Sweden
Germany
Japan
No. publications PRAB
Year from 2000
0
10
20
30
40
50
0
5
10
15
20
25

IV: Challenges

SWOT analysis

Strength	Weakness	Opportunities	Threats
Accelerator physics is represented at national facilities and academia	No platform for R&D like DESY in Germany, IFNF in Italy, KEK in Japan	Critical mass of competence	4-year funding cycle of VR; contacts with CERN are K-contracts.
Tradition of accelerator physics	No national funding schemes to bridge basic and applied science	Diverse research program	All major projects were planned before the 2008 economic crisis
Successful start-ups that have grown into world-recognized leaders: Scandinova, Excillum, Scienta	No exchange of good practice via long-term visits of junior researchers or joint appointments	X-ray photon community is world leading; high-energy community is proactive at CERN	Accelerator projects come once in two decades and then not much R&D in between.

We shall establish a national R&D platform and play a key role in the next European or international project like the Muon Collider or FCC!