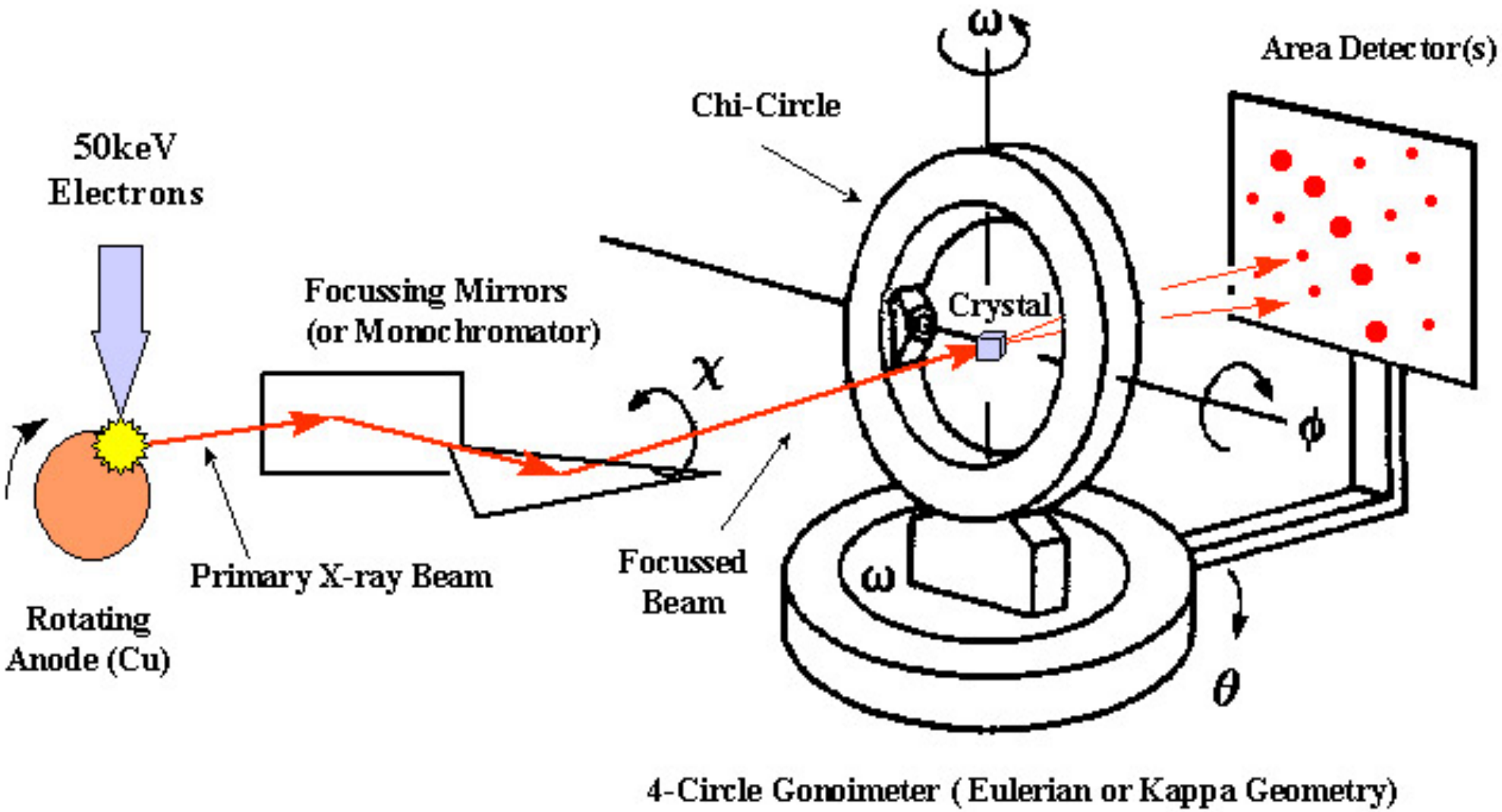
Physics of Life

PHYS-468

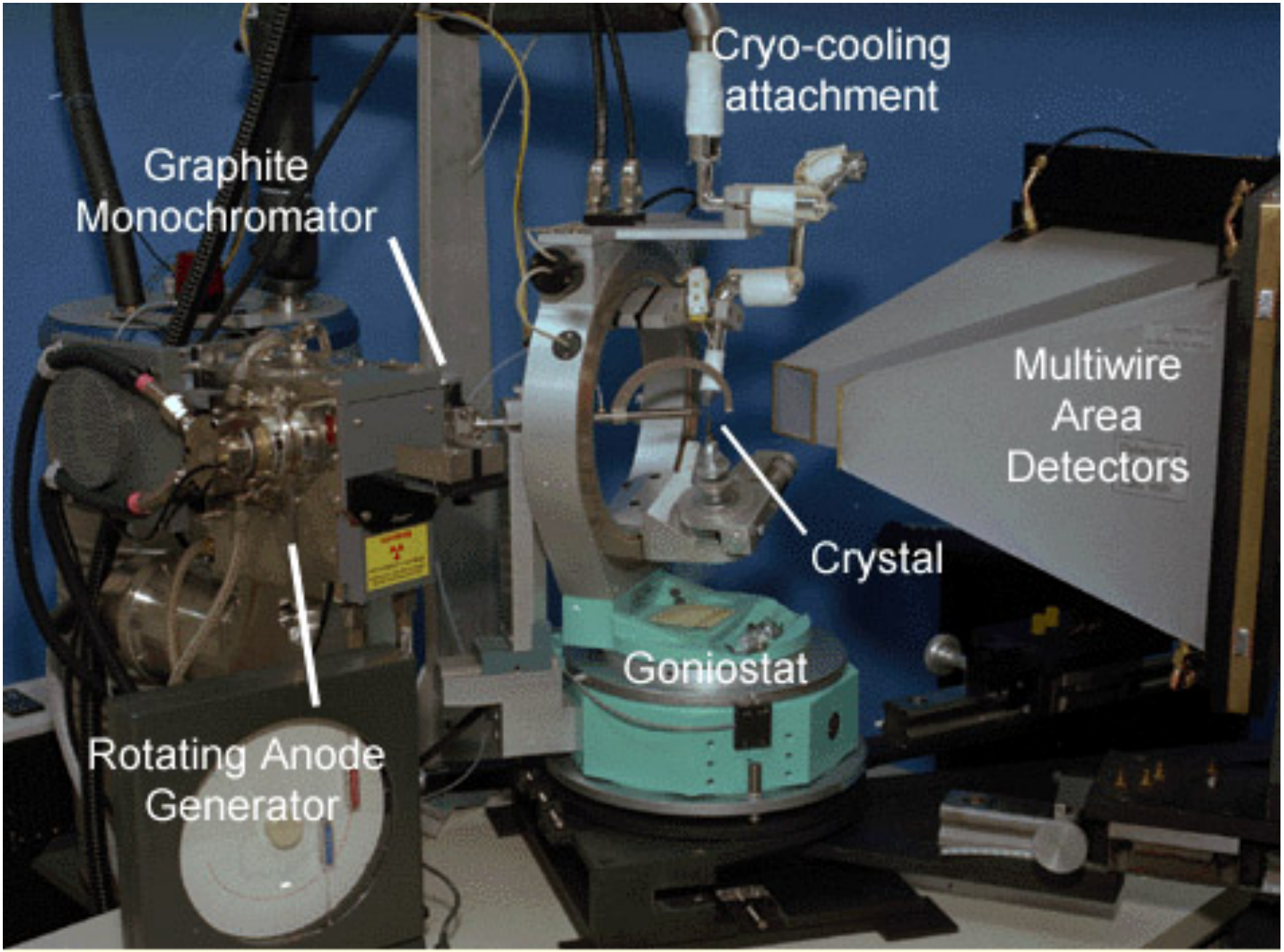
SwissFEL
The Swiss Free Electron Laser

Henning Stahlberg,
LBEM, IPHYS, SB, EPFL

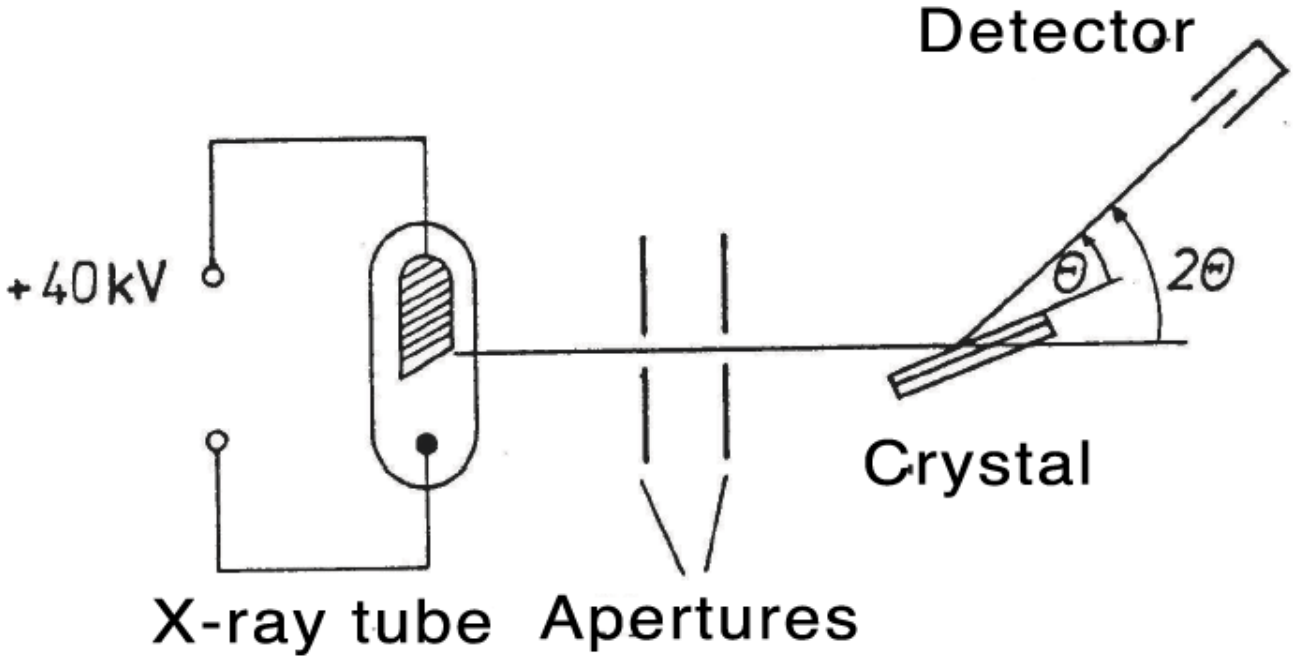
XRD Scheme

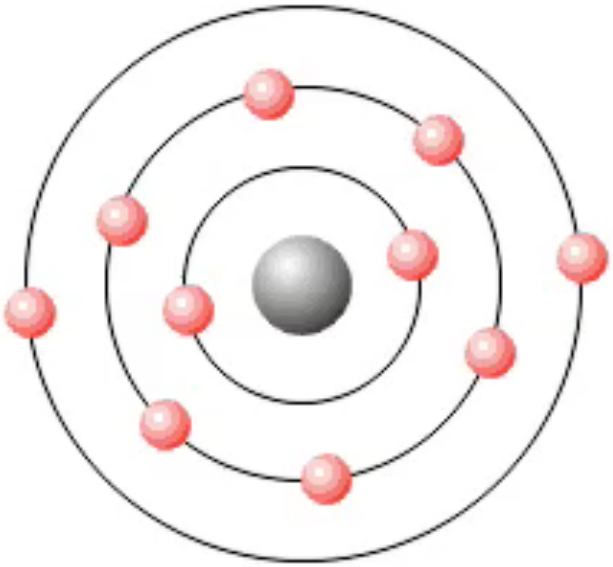

ω
Area Detector(s)
Chi-Circle
50keV
Electrons
Focussing Mirrors
(or Monochromator)
Crystal
χ
ϕ
ω
Primary X-ray Beam
Focussed
Beam
Rotating
Anode (Cu)
θ
4-Circle Goniometer (Eulerian or Kappa Geometry)

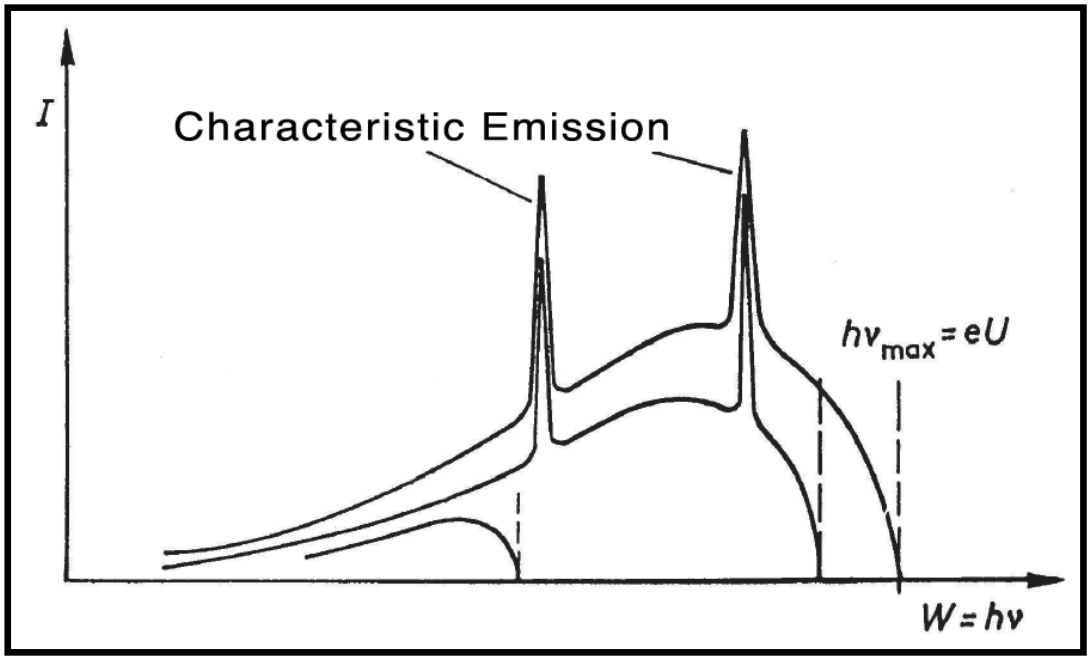
XRD Setup


Cryo-cooling attachment
Graphite Monochromator
Multiwire Area Detectors
Crystal
Goniostat
Rotating Anode Generator

Conventional X-ray Source







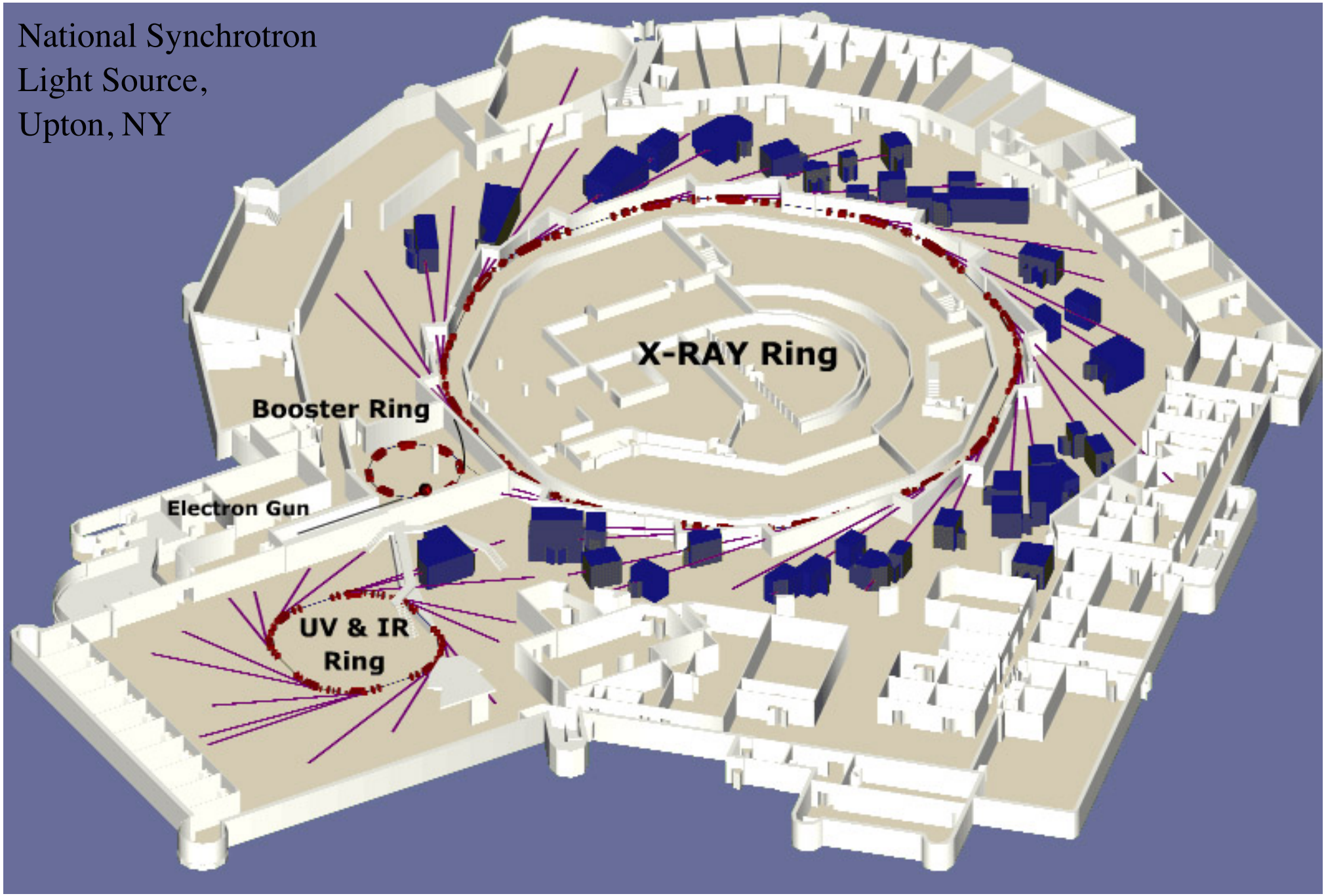
Synchrotron X-ray Source

National Synchrotron
Light Source,
Upton, NY

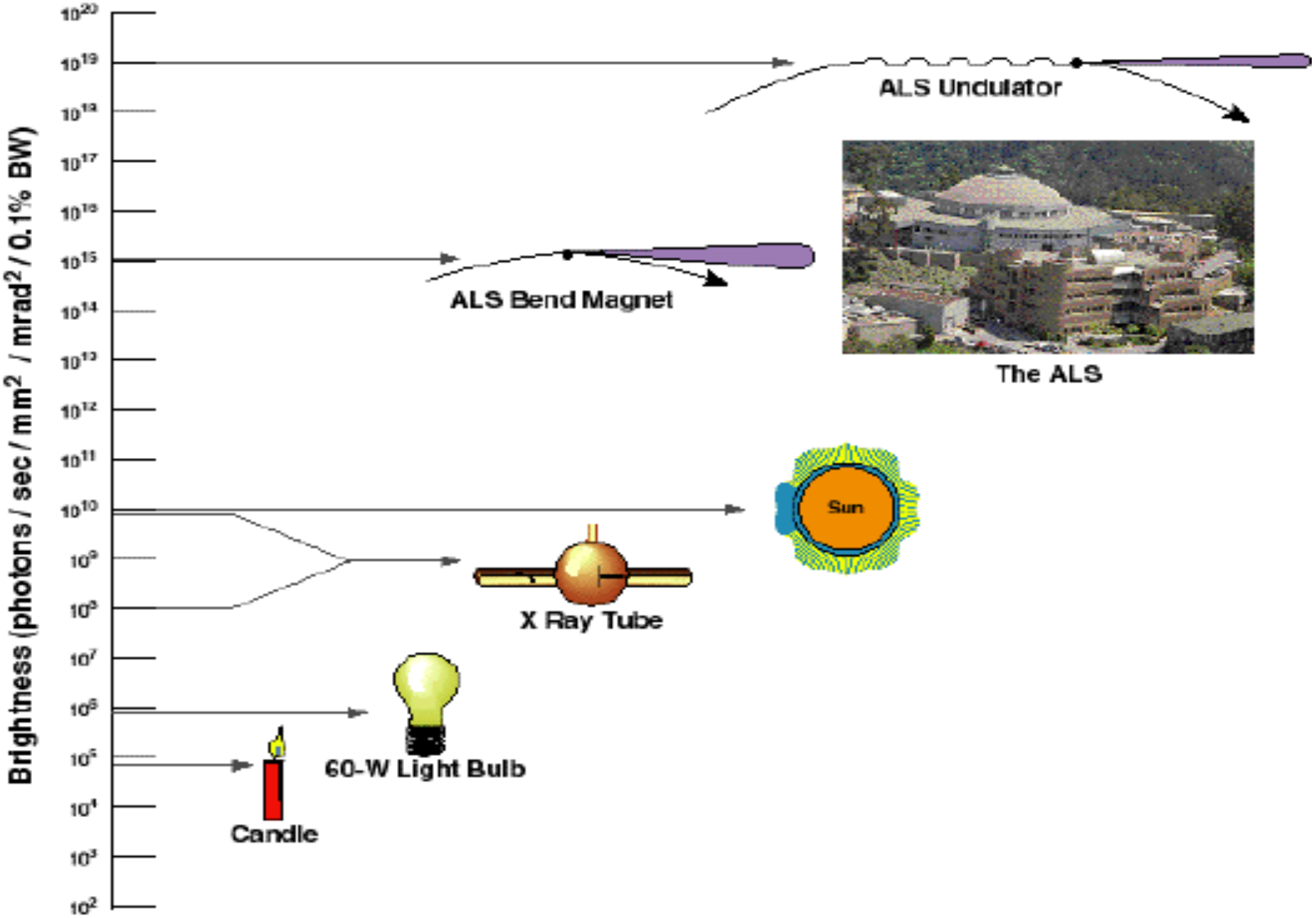
ESRF, Grenoble, France

Advanced Light Source, LBNL

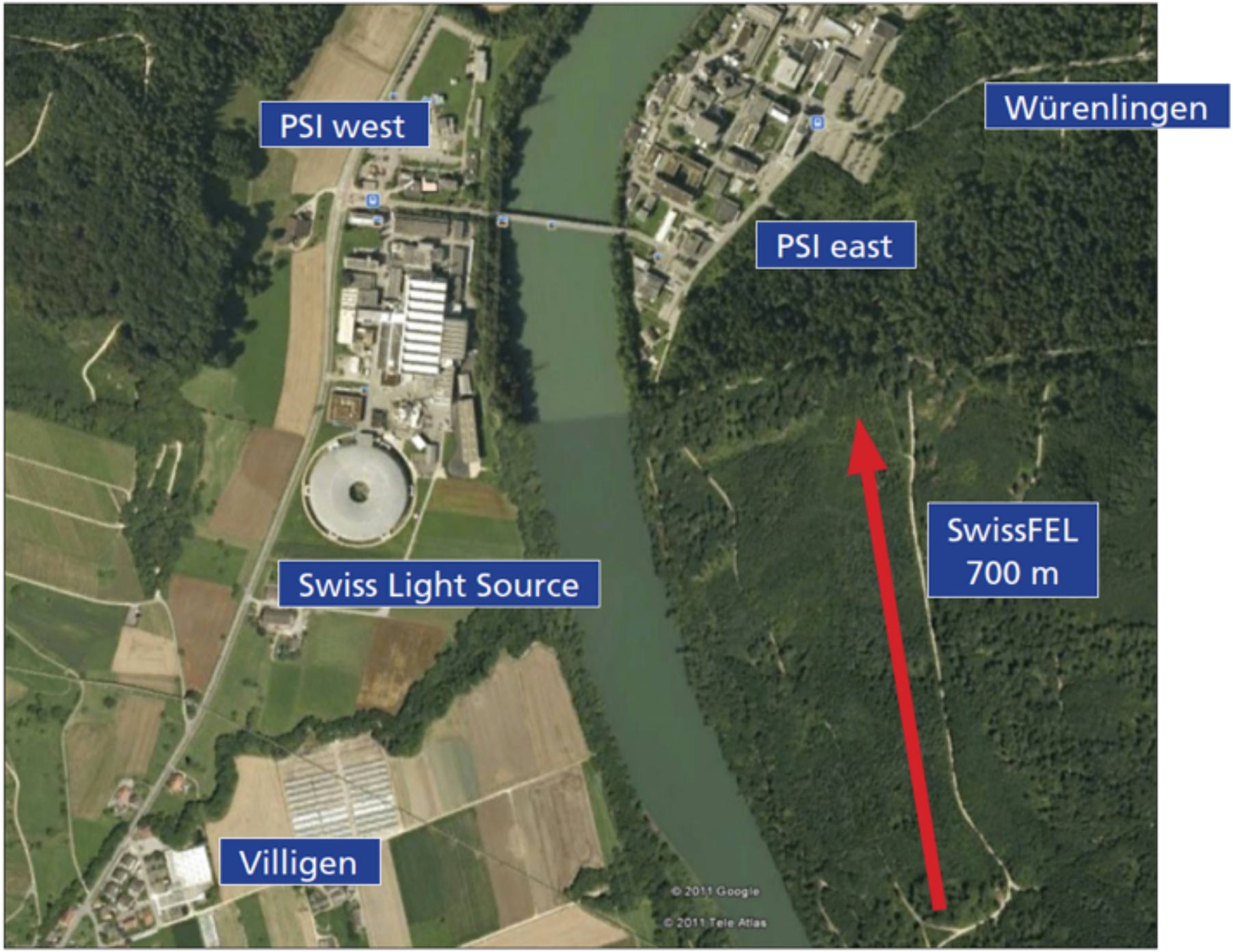
Synchrotron X-ray Source: NSLS



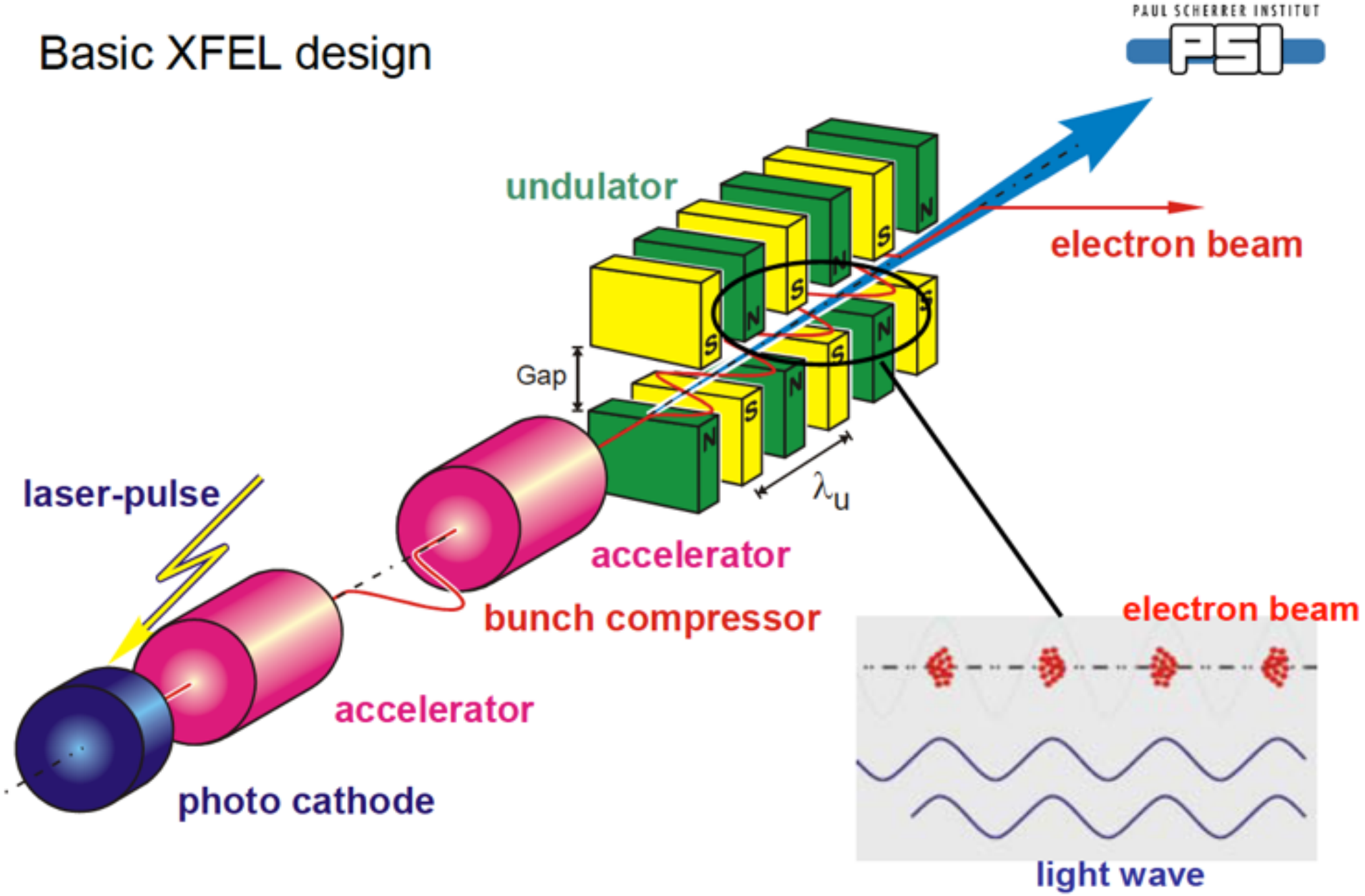
X-ray Intensity



SwissFEL


PSI west
Würenlingen
PSI east
SwissFEL
700 m
Swiss Light Source
Villigen
© 2011 Google
© 2011 Tele Atlas

Basic XFEL design



SwissFEL

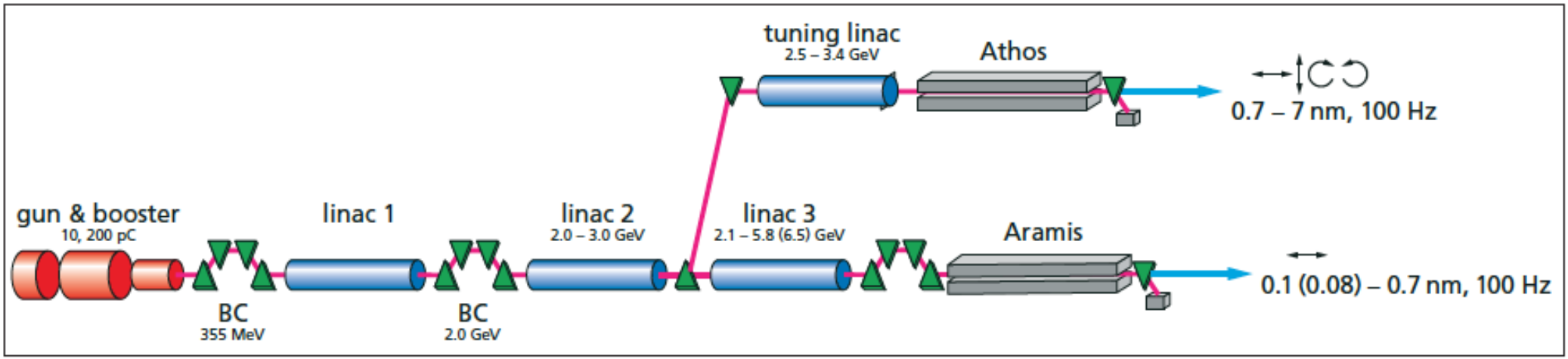


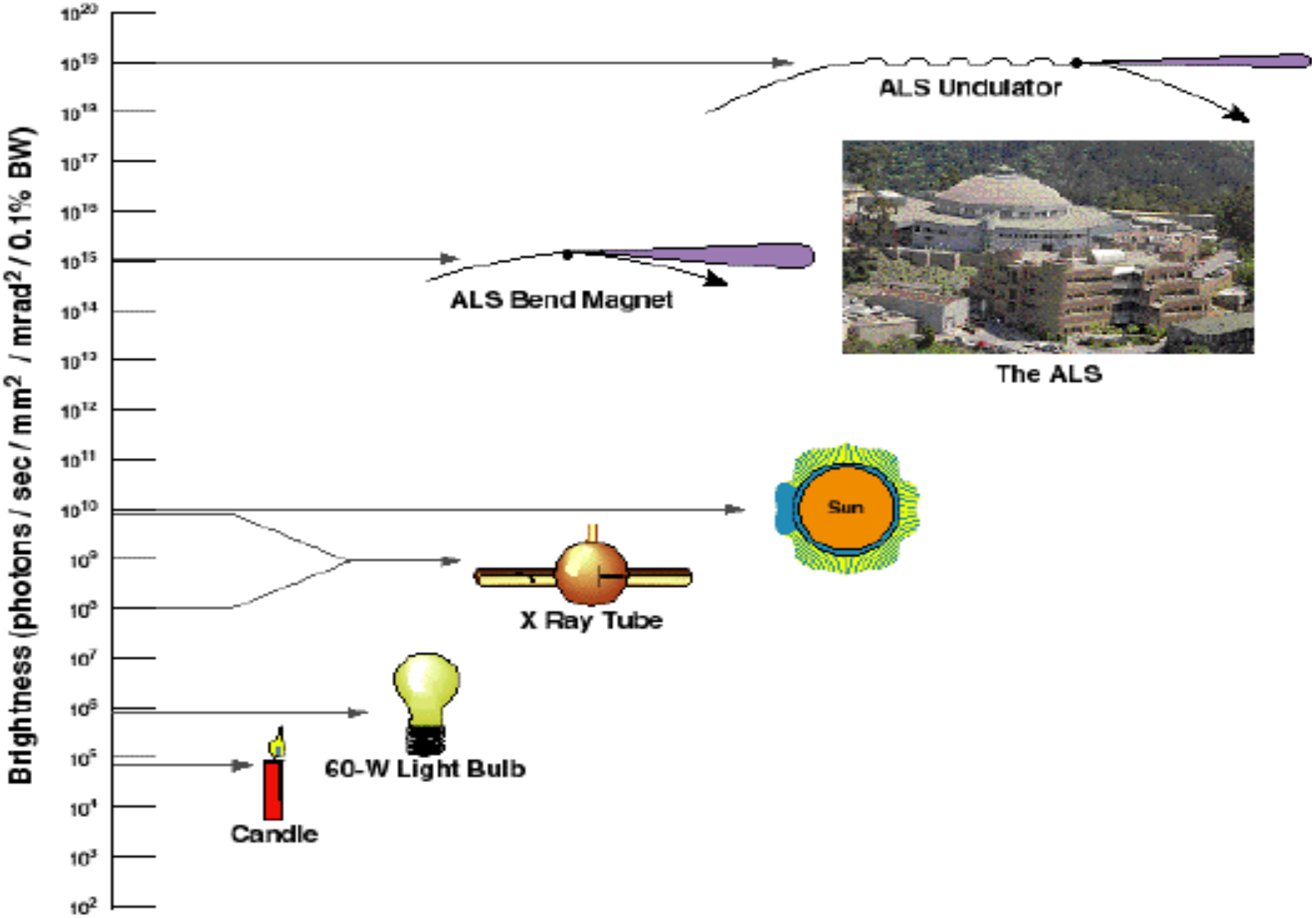
Figure 1. (a) Map of the planned location for the SwissFEL, in the forest close to the present PSI-east facilities. (b) Schematic view of the planned SwissFEL machine, which includes the injector, three accelerator sections and the two X-ray undulators ARAMIS and ATHOS.

SwissFEL

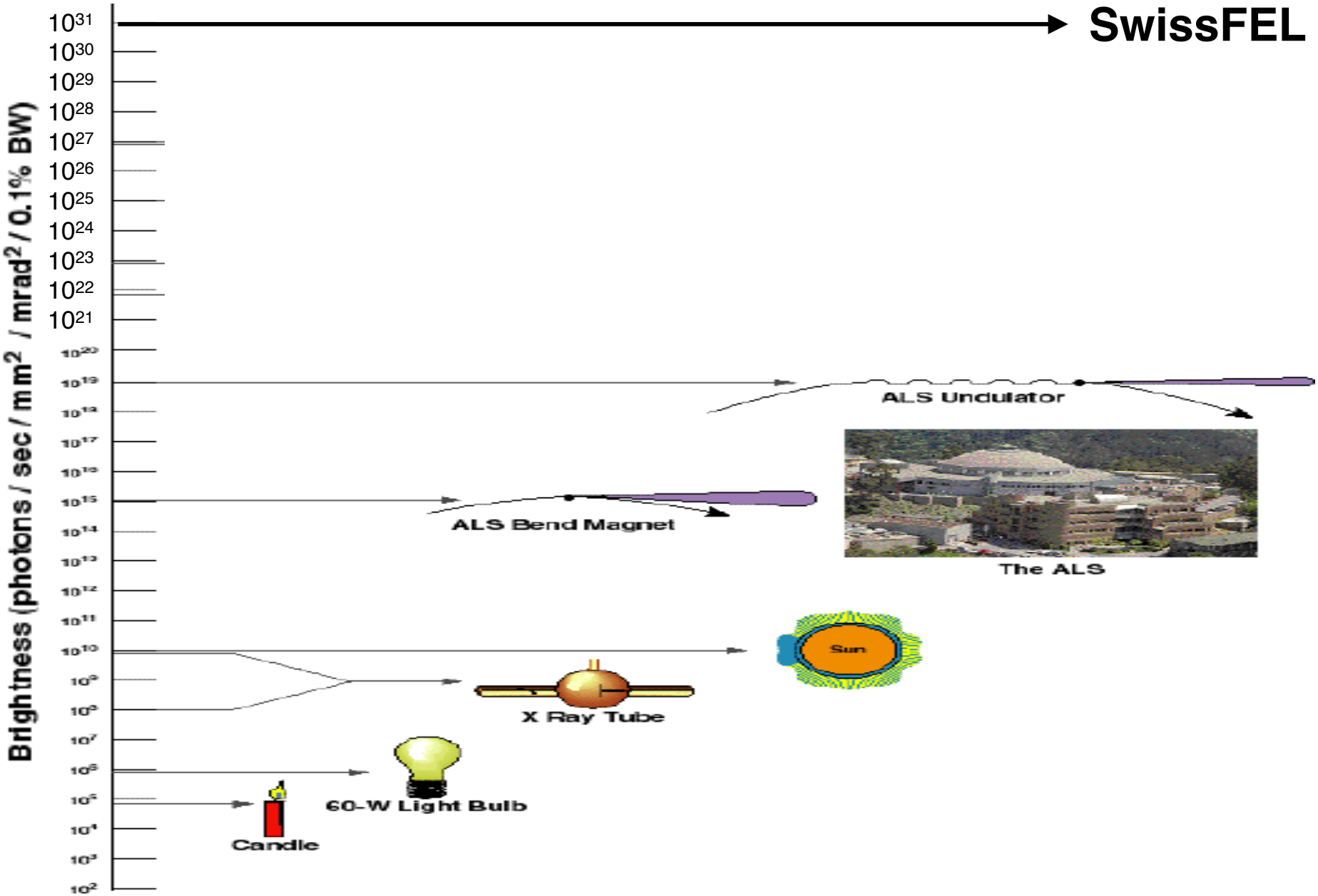
Parameter	Unit	λ = 0.1 nm	λ = 0.7 nm
Photon energy	keV	12.39	1.770
Pulse energy	mJ	0.0724	0.143
Photons per pulse	#ph/pulse	$3.6 \cdot 10^{10}$	$5.1 \cdot 10^{11}$
Effective peak power	GW	2.2	3.3
Pulse length, RMS	fs	13.1	15.7
Beam radius, RMS	μm	24.5	43.0
Beam divergence, RMS	μrad	1.5	5.3
Bandwidth, RMS	%	0.044	0.096
Peak spectral flux	#ph/pulse/0.1%bw	$8.2 \cdot 10^{10}$	$5.3 \cdot 10^{11}$
Peak spectral brightness	#ph/pulse/μm2mrad2/0.1%bw	$7.4 \cdot 10^{31}$	$1.0 \cdot 10^{31}$
Average brightness per pulse	#ph/pulse/μm2mrad2/0.1%bw	$2.4 \cdot 10^{18}$	$4.1 \cdot 10^{17}$
Weight of first coherent mode	%	82	

Table 1. X-ray beam parameters at the ARAMIS undulator exit, extracted from numerical simulations at different photon wavelengths. The electron bunch charge is 200 pC.

X-ray Intensity

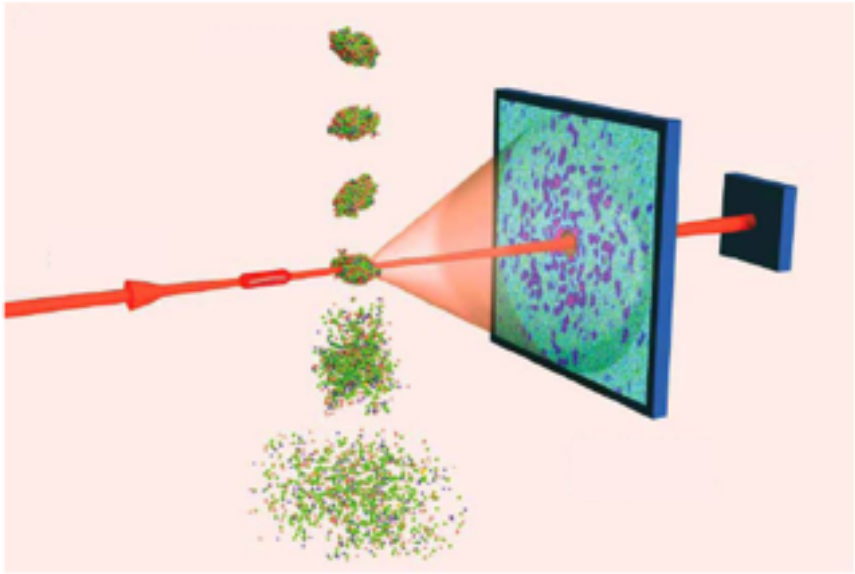


X-ray Intensity



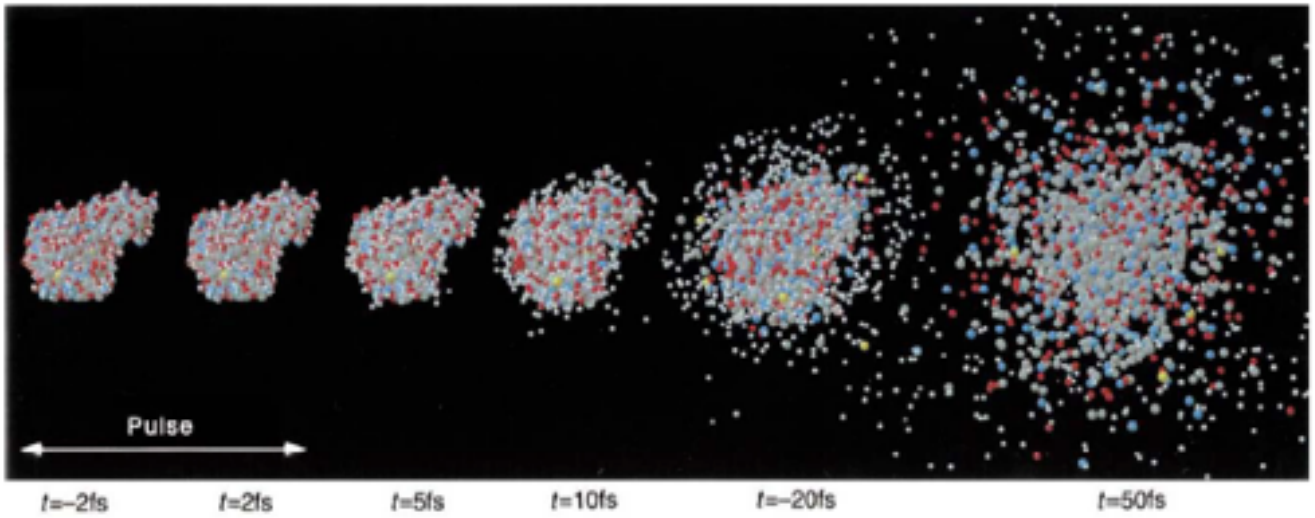
Single-molecule diffraction?

⇒ avoid need for crystals



Gaffney, et al.

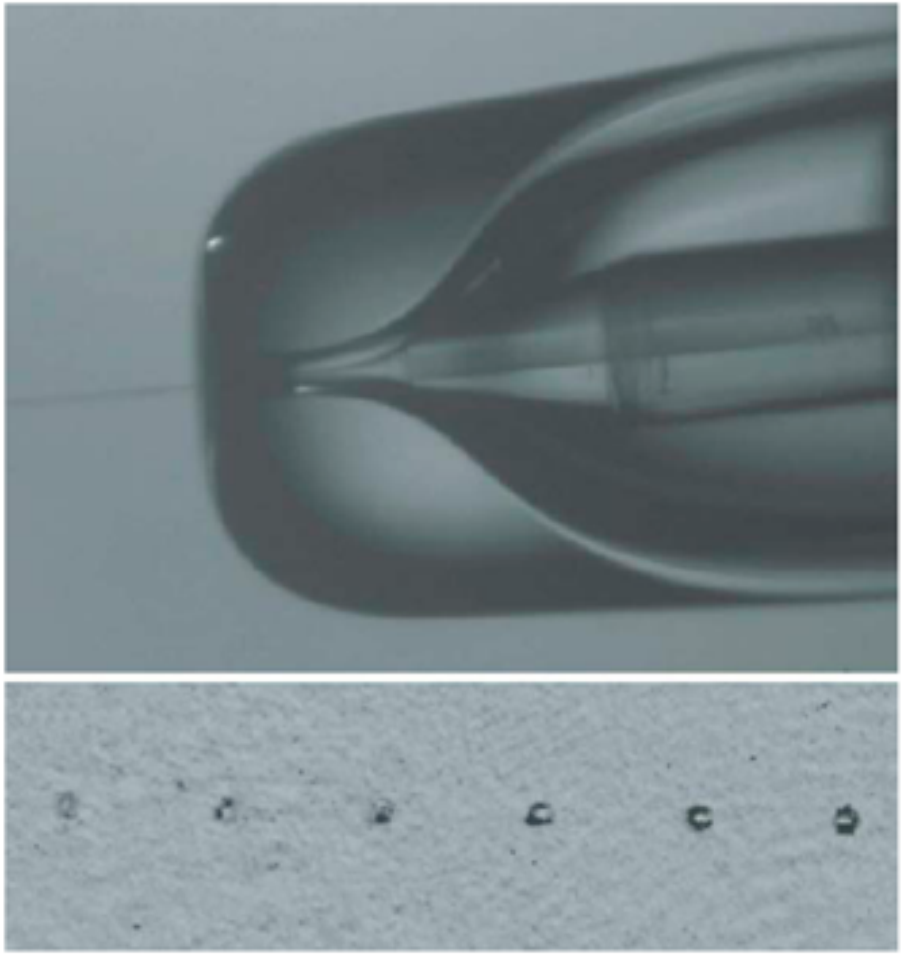
⇒ and avoid radiation damage



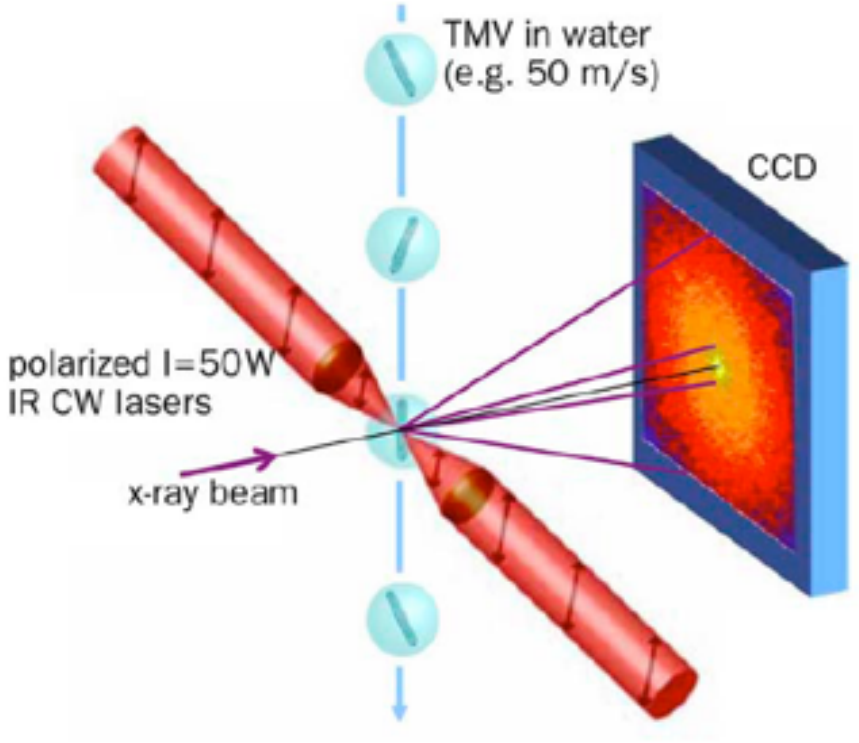
Neutze, et al.

SwissFEL

Single-particle injection

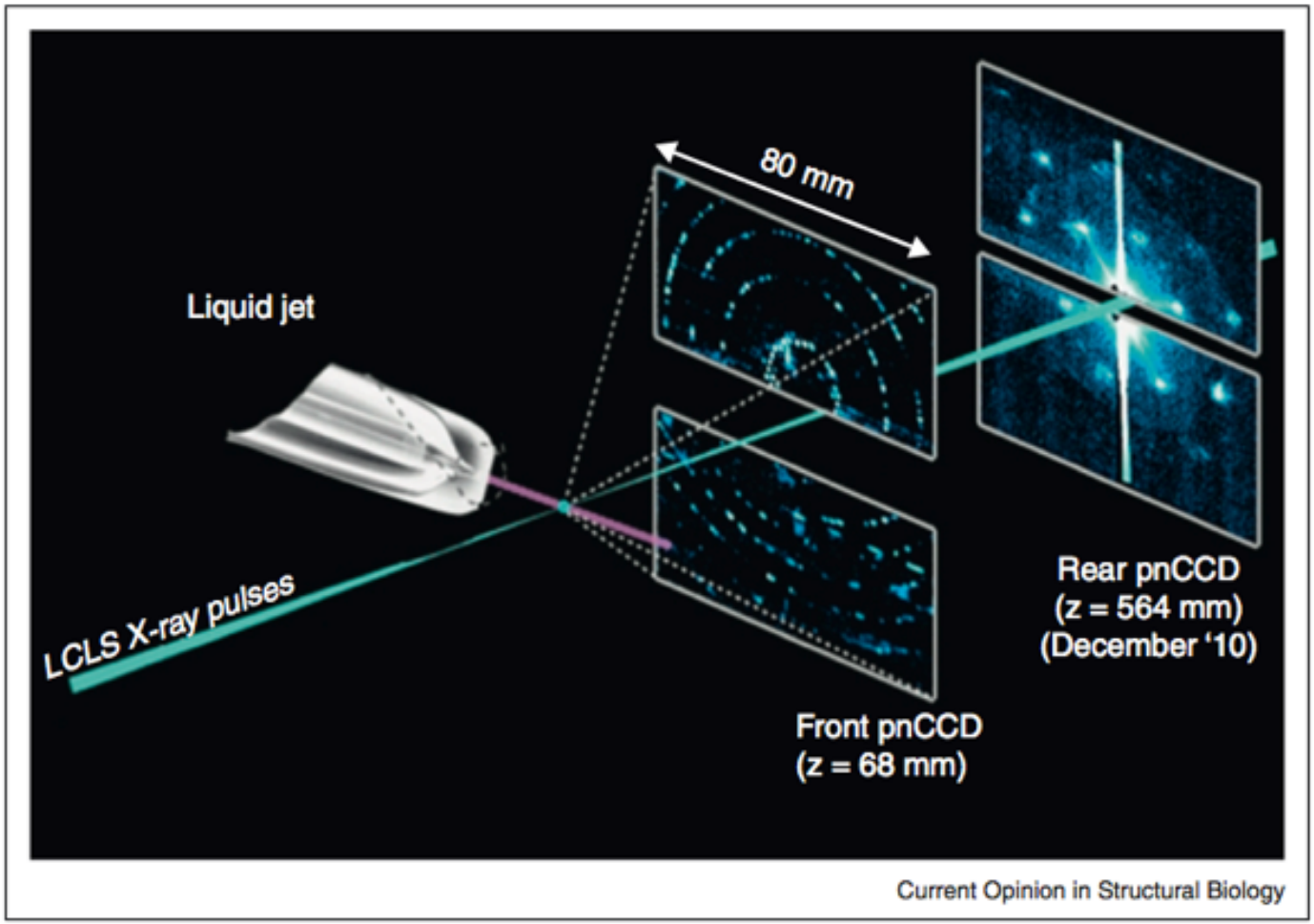


Aerosol spraying
(Shapiro, 2008)



Laser alignment?

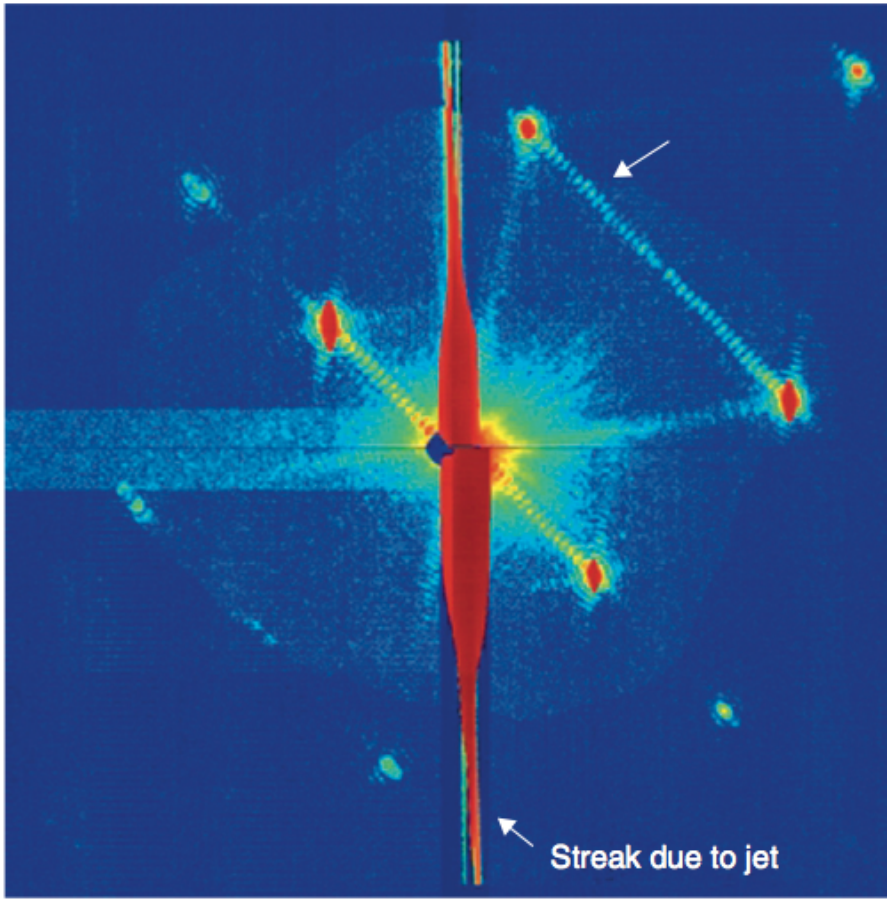
(Hau-Riege)

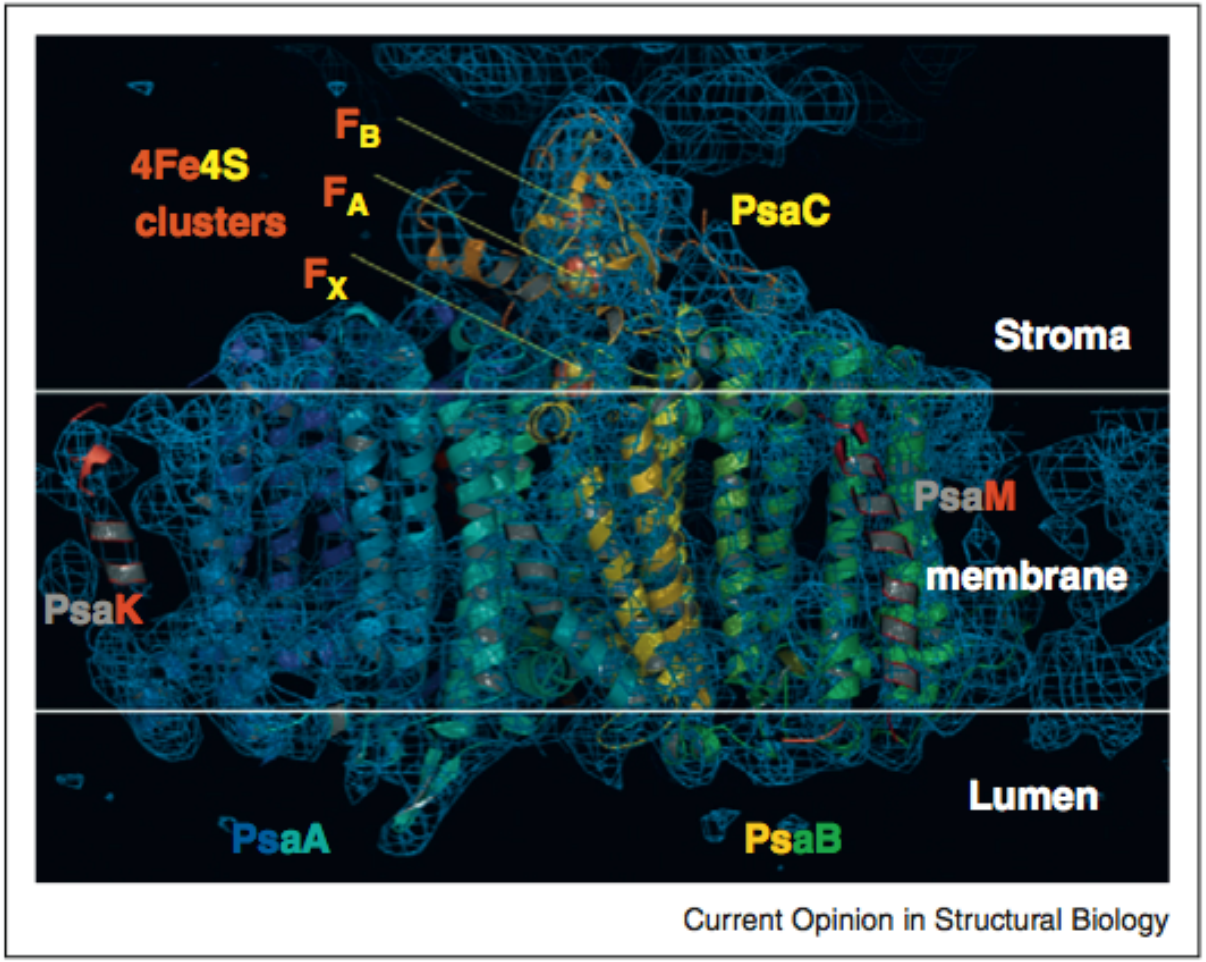


Principle of the experimental setup used for femtosecond crystallography. The stream of crystals is provided by the injector with the gas focusing nozzle. The femtosecond X-ray beam intersect with the continuous crystal stream; diffraction patterns are recorded with the frequency of the Free Electron Laser at LCLS (60 or 120 Hz) using either a one or two CCD detector setup. In the two detector setup, which was used in the CAMP camber at the AMO beamline at LCLS for the first fs crystallography experiments reported in [24••], the high order reflections are detected on the front detector. The back detector, which records the low order reflections, allows the resolution of the shape transforms of the reflections. The figure has been modified after [24••].

Fromme & Spence, Curr. Op. Struct. Biol. (2011)

SwissFEL





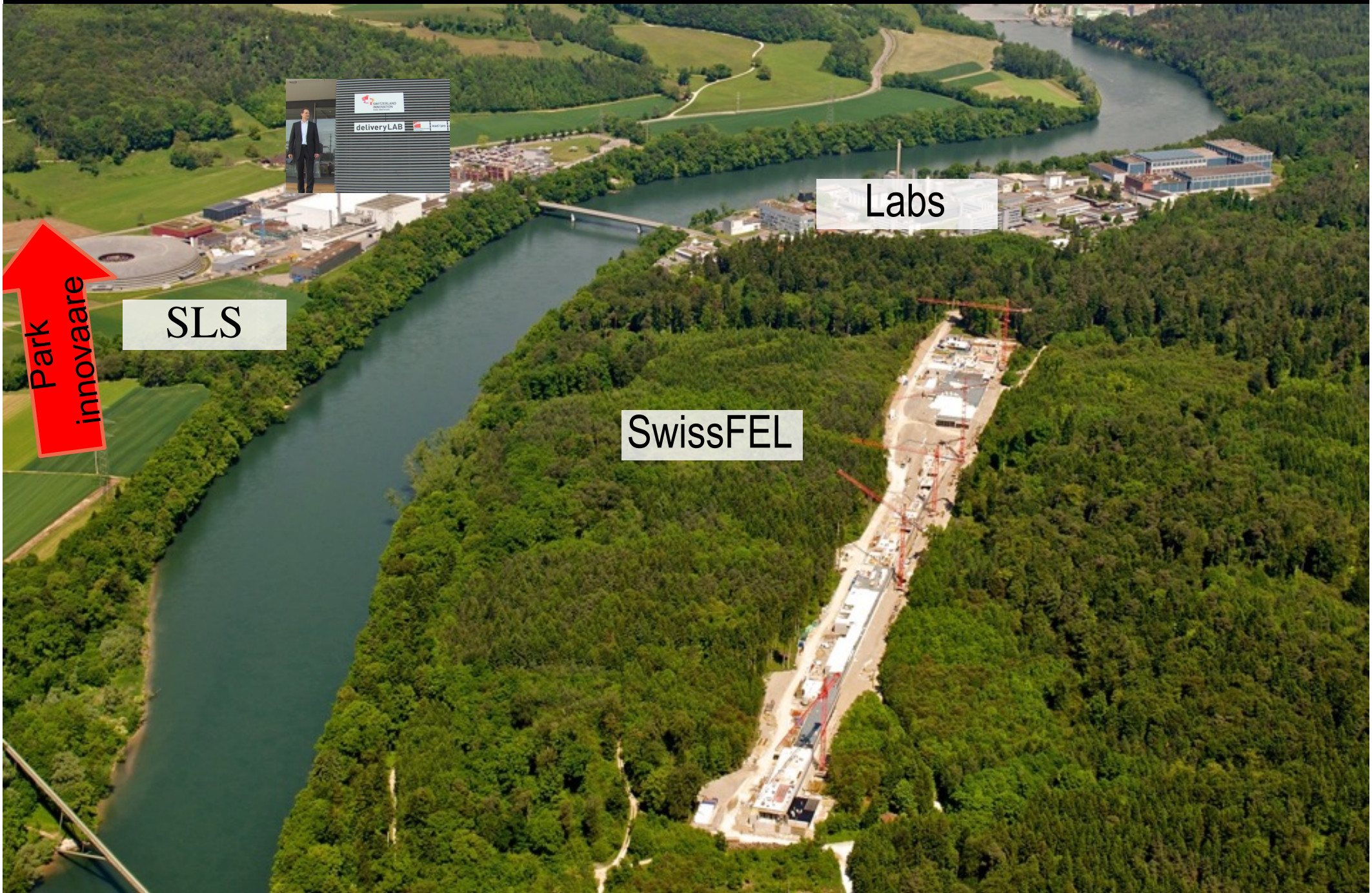
Electron density map of Photosystem I at 8 Å resolution, derived by fs crystallography. The phases were obtained using molecular replacement as described in [24••]. The section of the electron density in this picture shows transmembrane helices of the large PSI subunits PsaA, PsaB as well as helices of PsaK and PsaF. This figure has been modified after [25••].

Fromme & Spence, Curr. Op. Struct. Biol. (2011)

SwissFEL

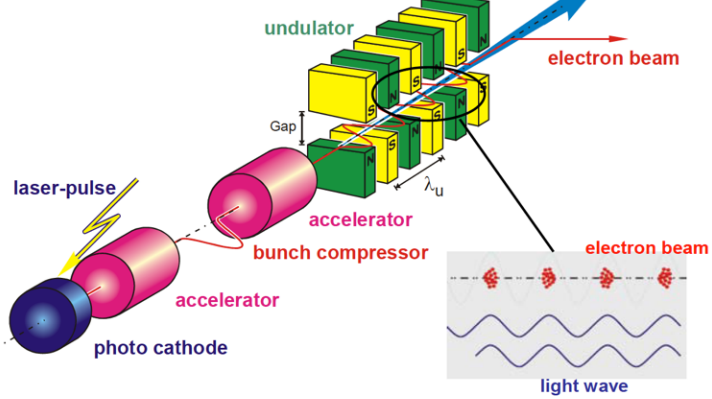
http://www.psi.ch/info/film-swissfel

SWISS FEL under construction – first beam Q2/2017



SwissFEL

Total electric power consumption	3.8 MW
Electron beam energy	5.8 GeV
Charge per electron pulse	0.2 nC
Normalized beam emittance	0.4 mm·mrad
Number of X-ray pulses per second	200 (100 at each photon beamline)
X-ray pulse duration	24 fs
X-ray brilliance	$1.3 \cdot 10^{33}$ photons/·(s·0.1%·b.w.·mm^2·mrad^2)
Shortest lasing wavelength	0.1 nm



PAUL SCHERRER INSTITUT

PSI

https://www.psi.ch/en/media/camera-ride-swissfel

Arizona University LCP injector