PAUL SCHERRER INSTITUT

PSI

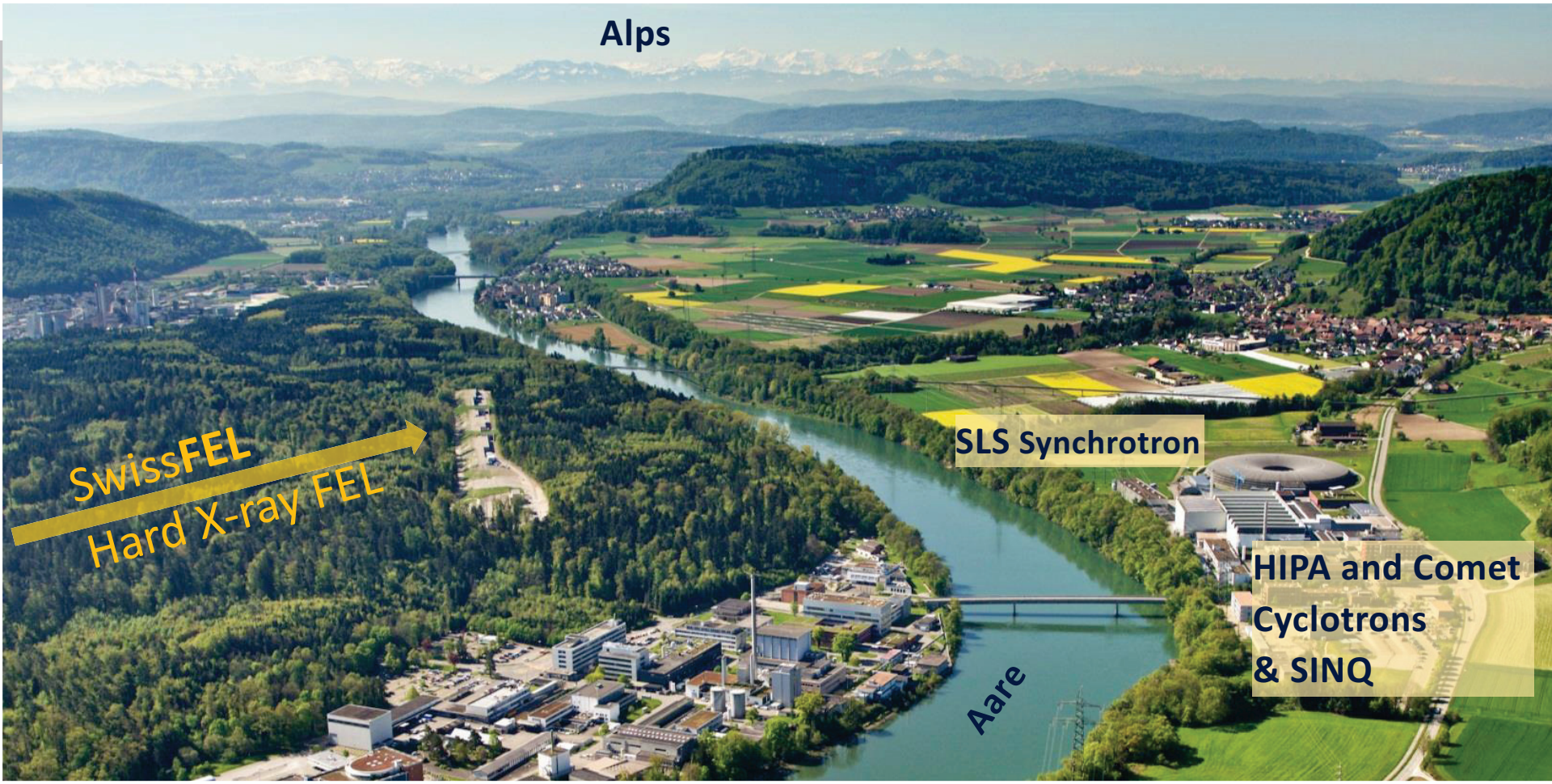
SwissFEL

Hans-H. Braun for SwissFEL Team :: Paul Scherrer Institut

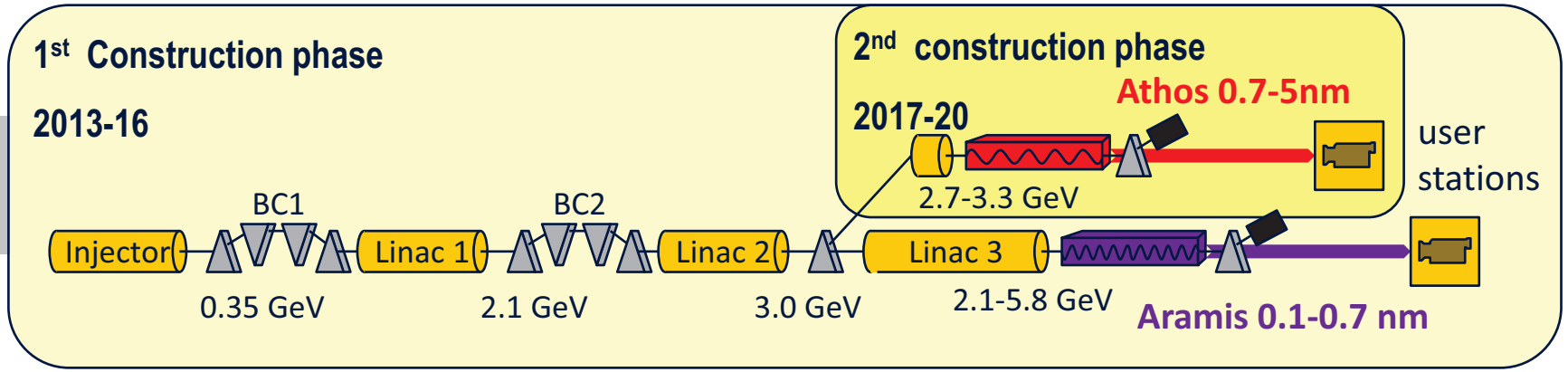
Commissioning of SwissFEL

8th International Particle Accelerator Conference, Copenhagen, 2017 May 14-19

PSI with accelerators, Aare river and Alps



SwissFEL in a nutshell



Aramis

Hard X-ray FEL, λ=0.1-0.7 nm

Linear polarization, variable gap, in-vacuum Undulators

First users 2018

Athos

Soft X-ray FEL, λ=0.65-5.0 nm

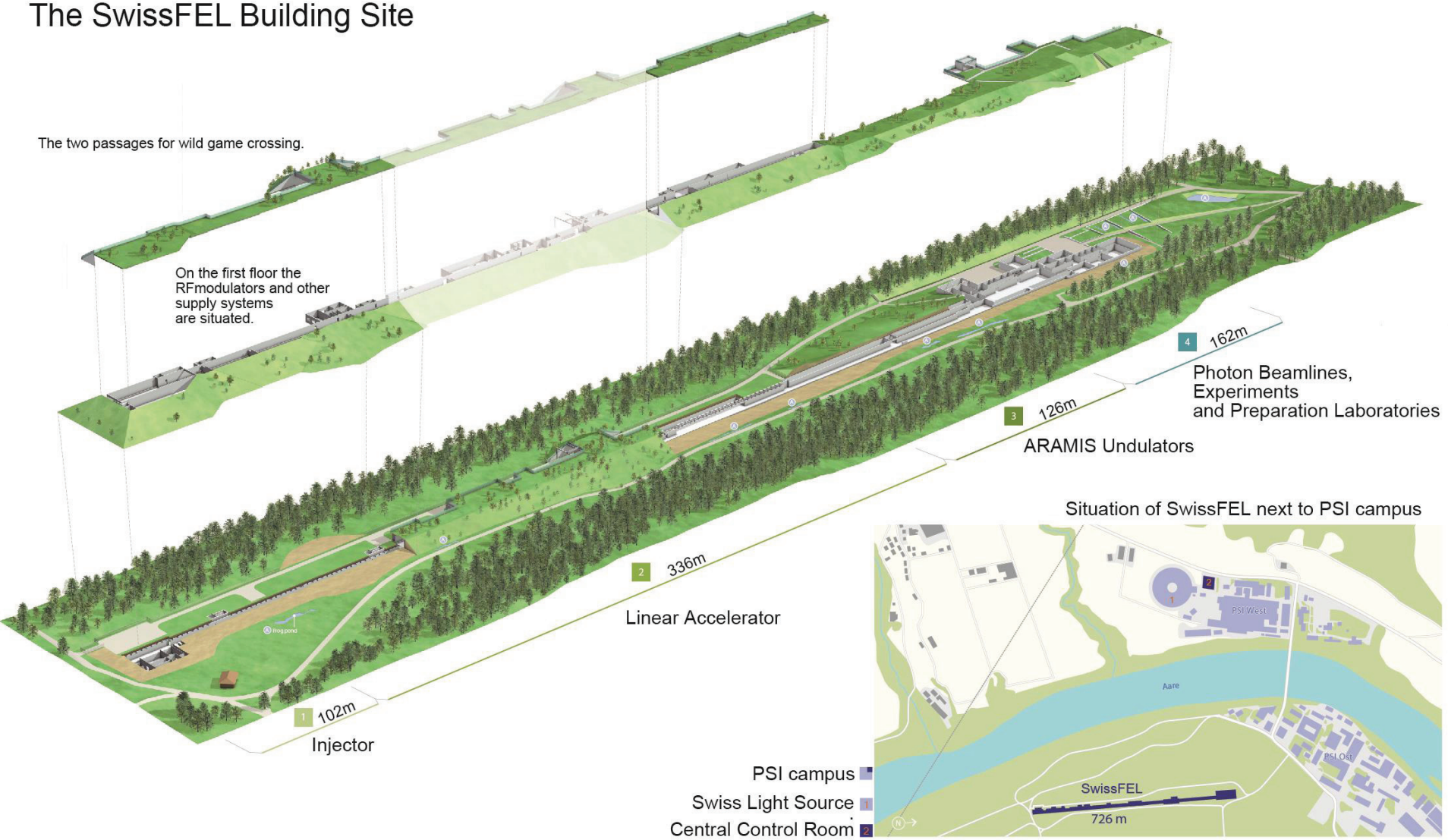
Variable polarization, Apple-X undulators

First users 2021

Main parameters

Wavelength from	1 Å - 50 Å
Photon energy	0.2-12 keV
Pulse duration	1 fs - 20 fs
e^- Energy	5.8 GeV
e^- Bunch charge	10-200 pC
Repetition rate	100 Hz

The SwissFEL Building Site



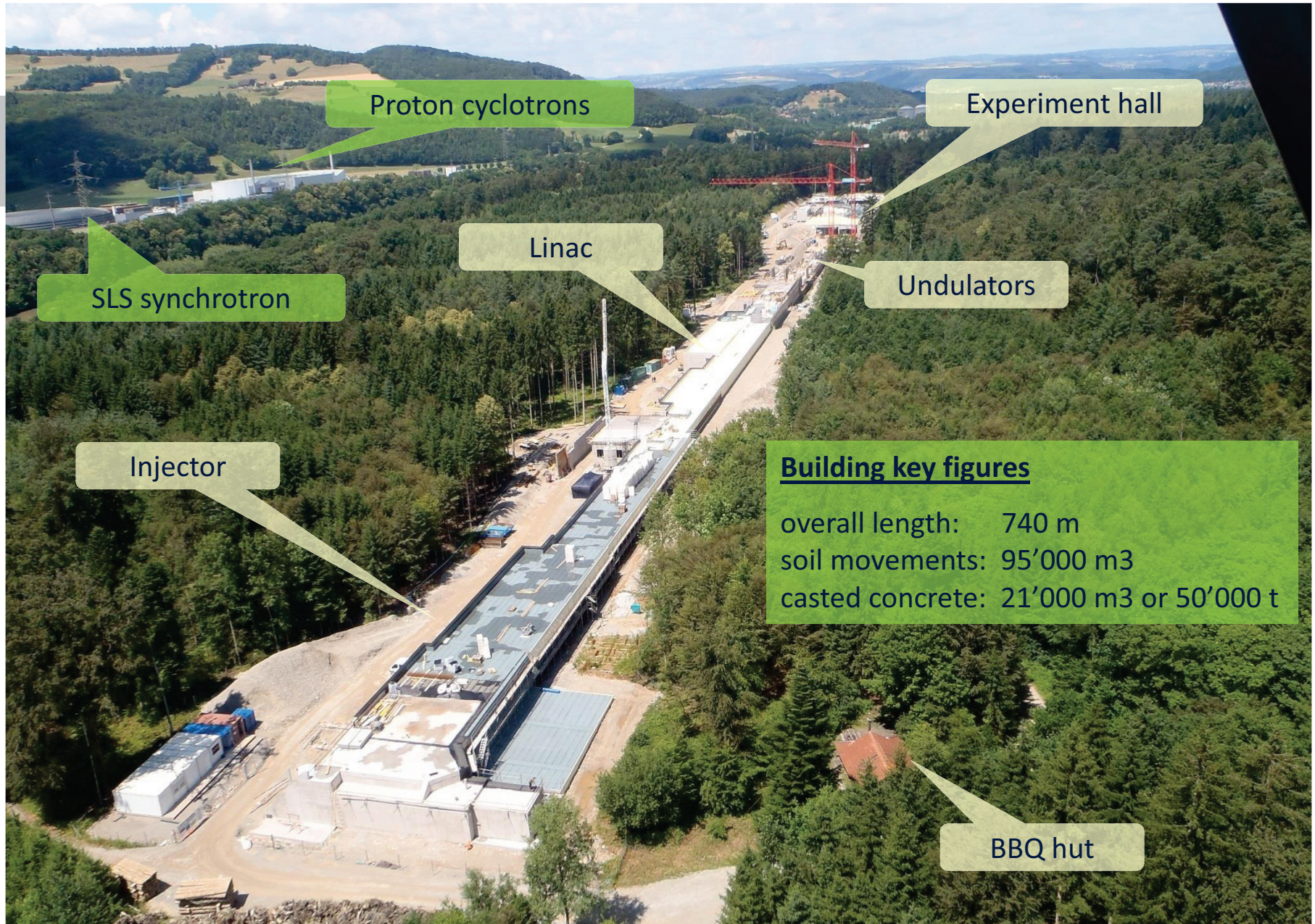
Situation of SwissFEL next to PSI campus

PSI campus
Swiss Light Source 1
Central Control Room 2

SwissFEL building evolution I

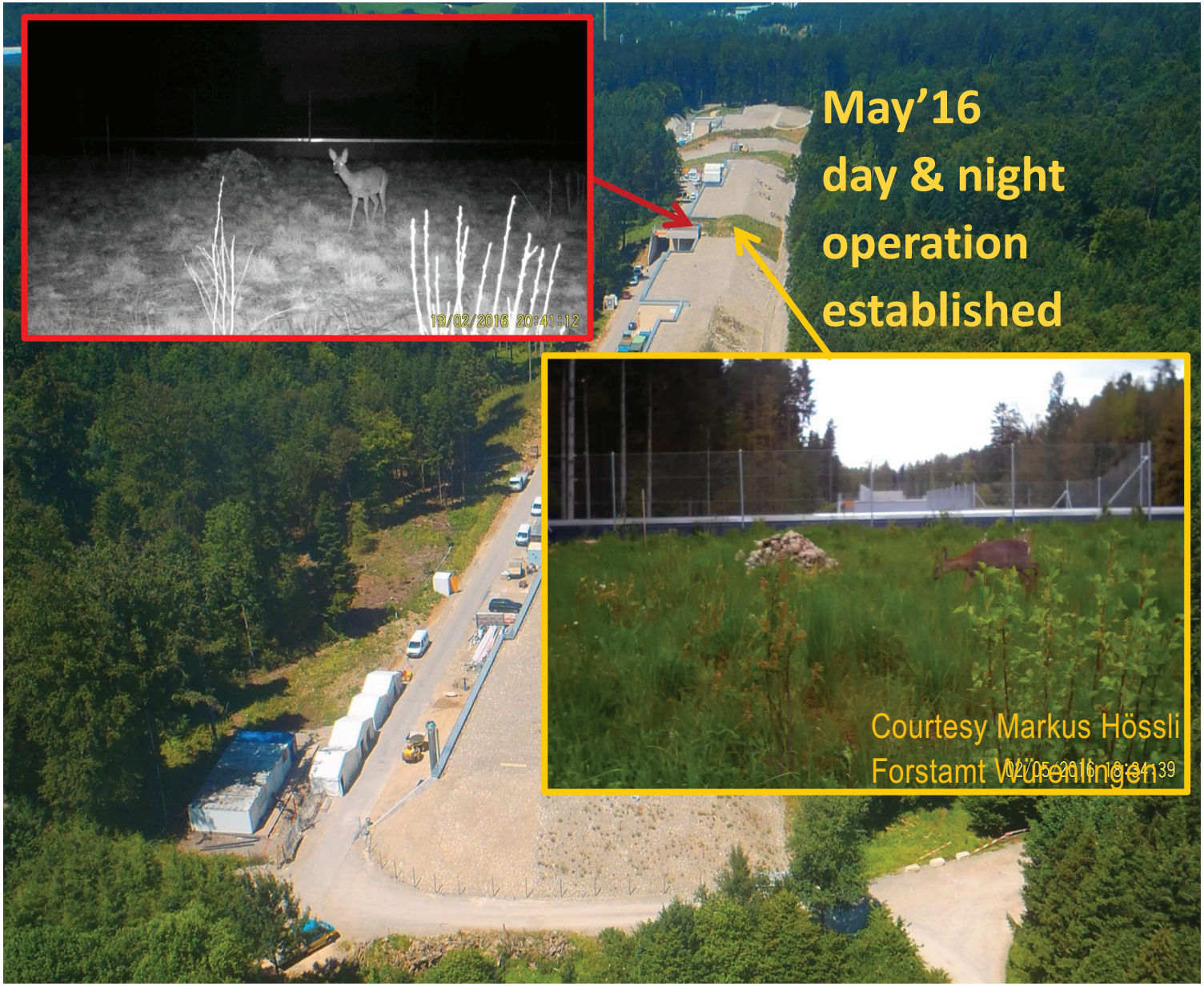
May 2013
Construction site after forest clearance

SwissFEL building evolution II
construction site, July 2014



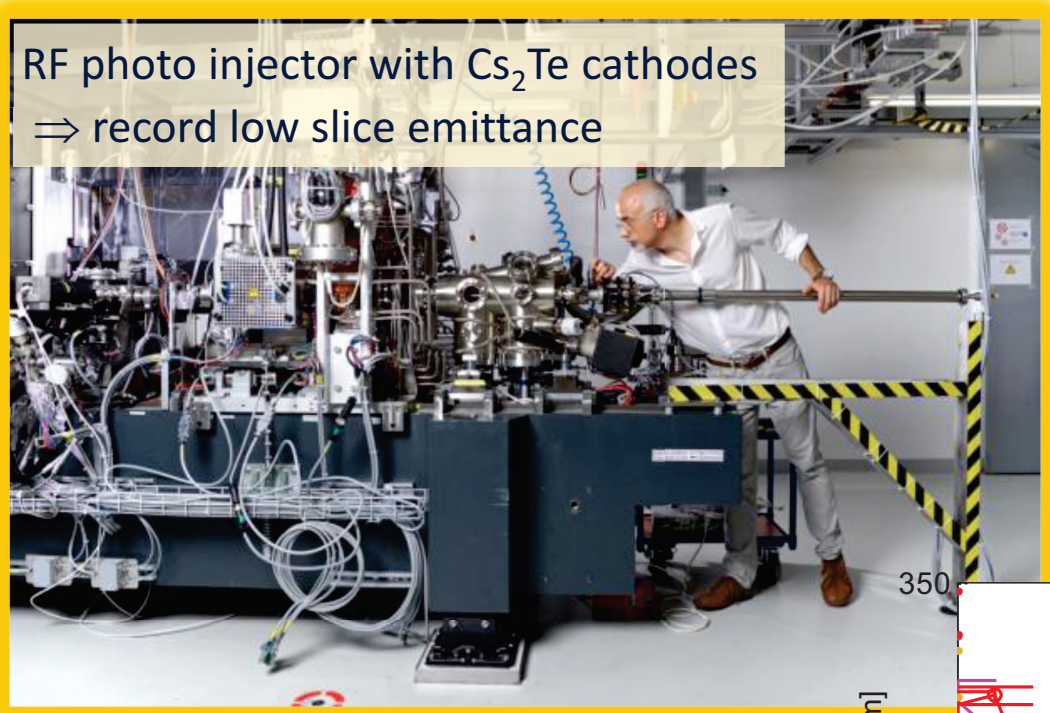
SwissFEL building evolution III
completed building, Jan'16

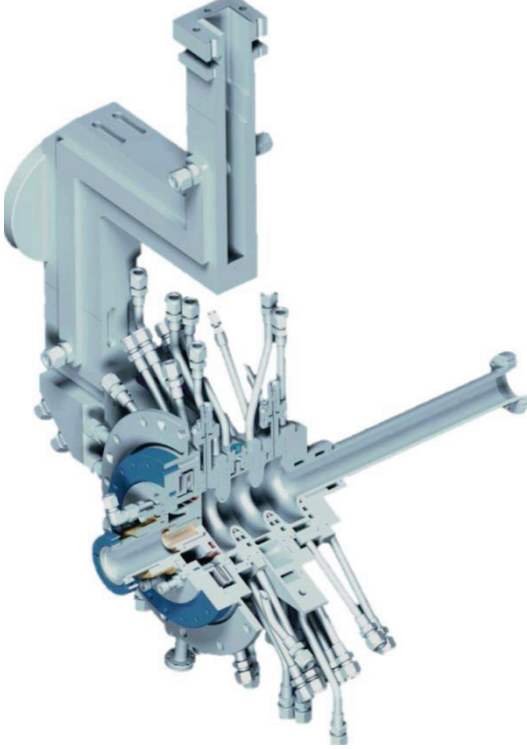
Jan'16, wild game crossing commissioned with first users



SwissFEL technical highlights I

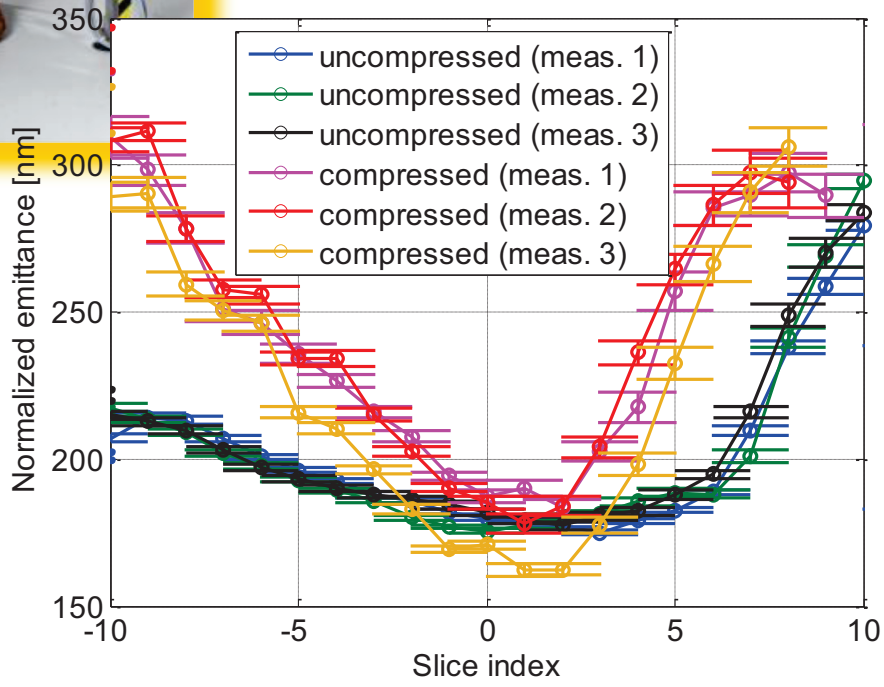
RF photo injector with Cs_2Te cathodes
⇒ record low slice emittance



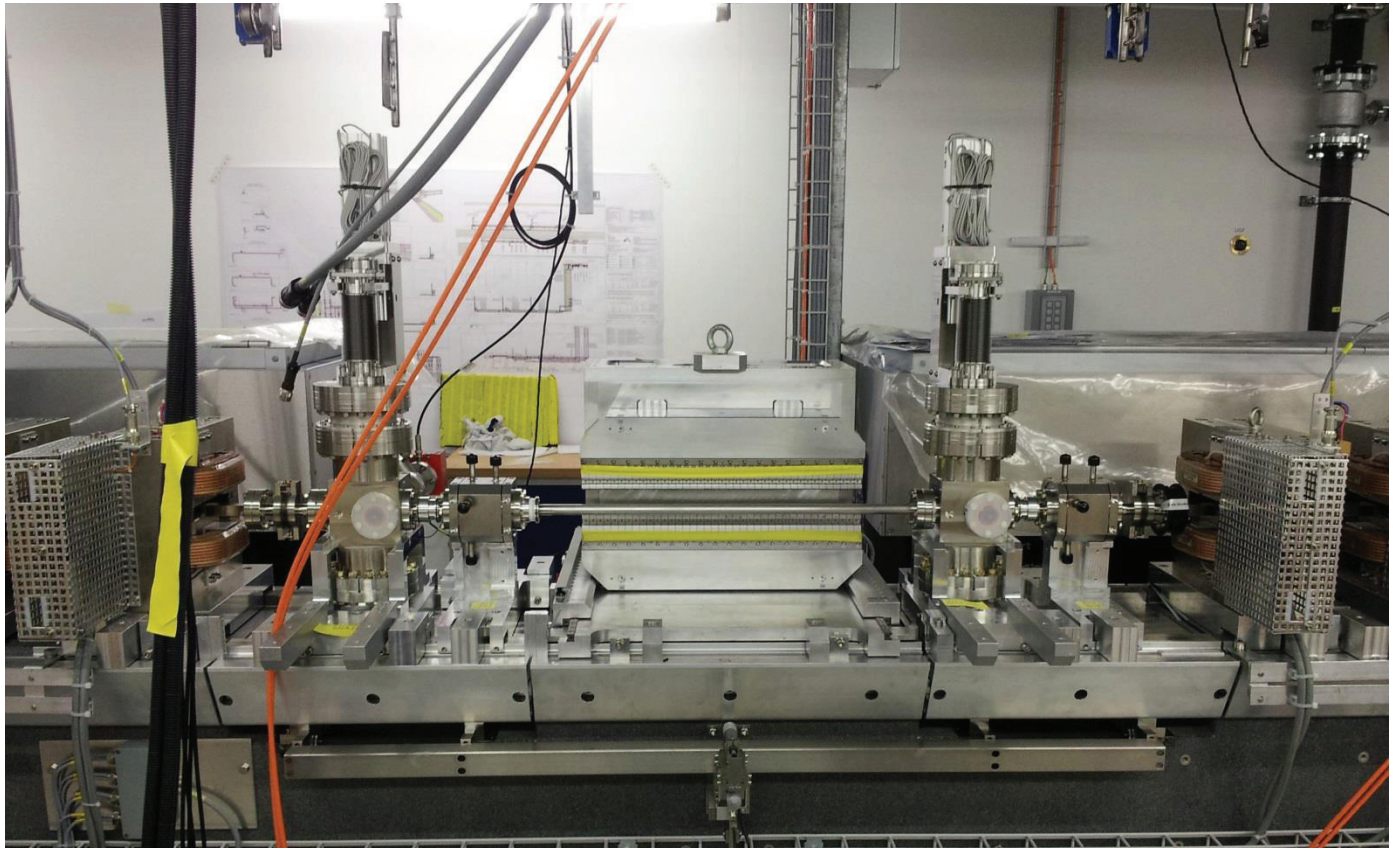


For Q_B= 200pC (SwissFEL nominal)

- Core slice emittance smaller than 200 nm (design value for SwissFEL is 430 nm)
- Slice emittance preserved in the core when compressing to 150 A



Laserheater provided by ASTeC/Daresbury



SwissFEL technical highlights II

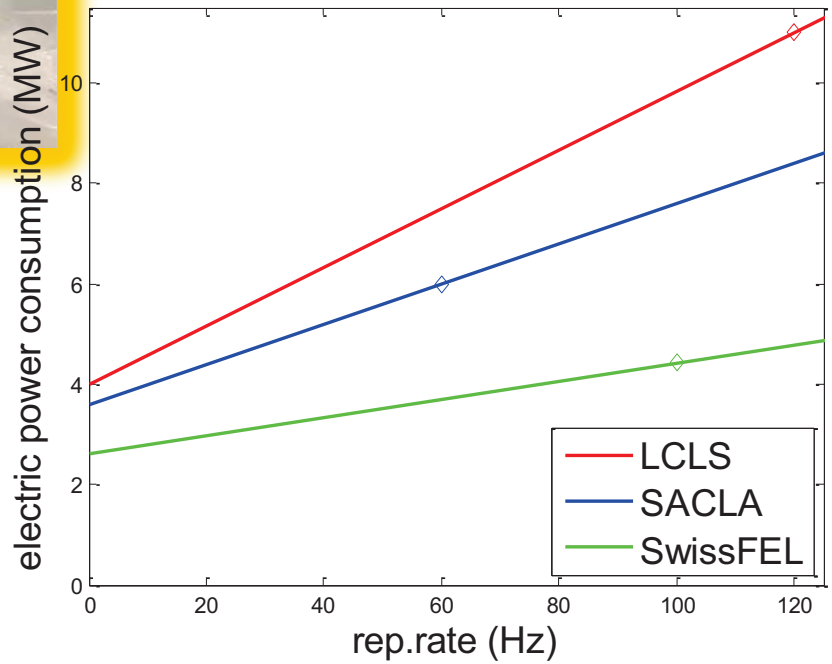
C-band Linac with IGBT switched klystrons
⇒ record low energy consumption per GeV

28 MV/m

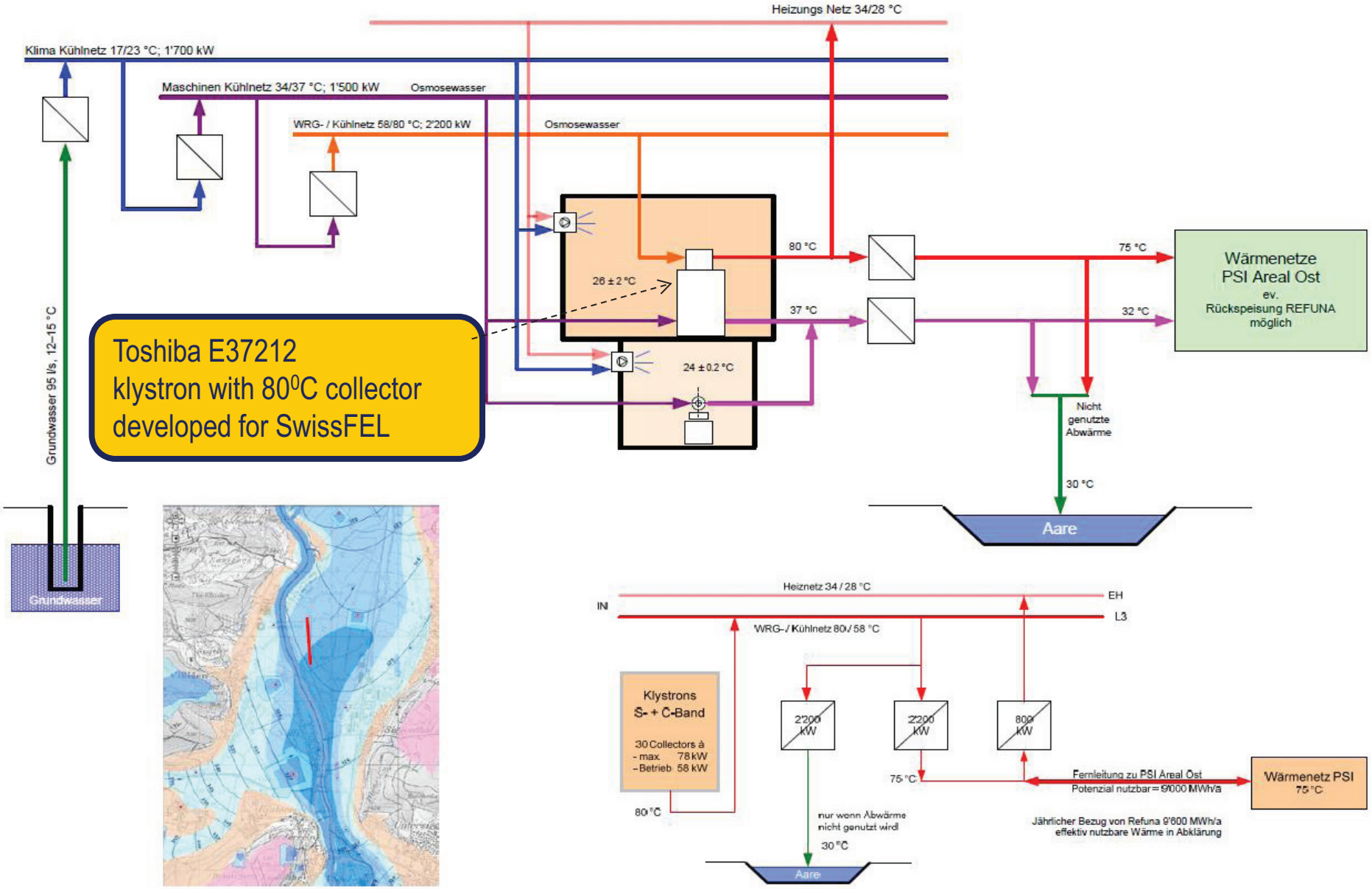
Beam energy
5.8 GeV

$$P_{HF} = \frac{V \cdot E}{R'}$$

Effective* Impedance
SwissFEL 168 MΩ/m



Energy recovery for SwissFEL



Grundwasserkarte

Wärmerückgewinnung

Solid-state modulators

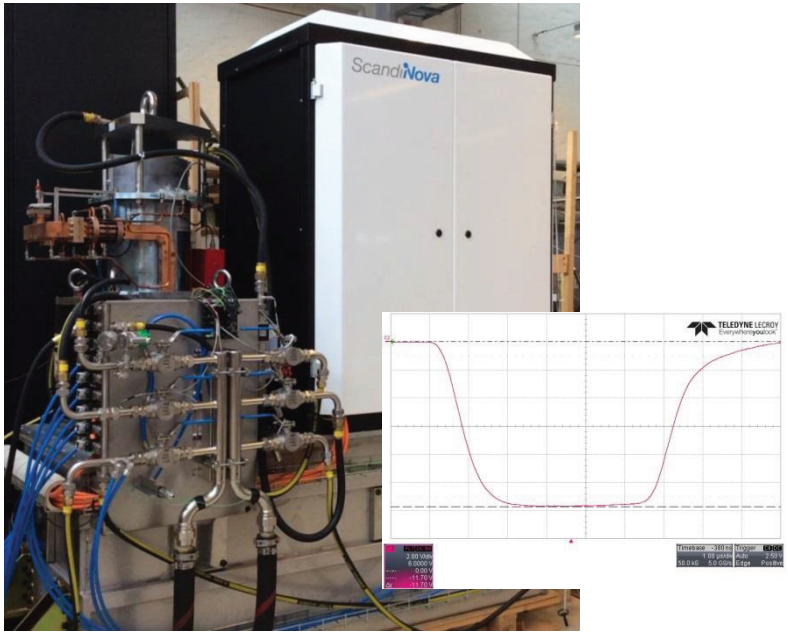
Two types were successfully qualified at PSI

50 MW / 3µs RF, 370kV / 344A / < 15 ppm voltage stability pulse to pulse @ 100 Hz

AMPEGON

13 modulators (Linac 1, Linac 2)
3 in operation, 3 under commissioning
7 expected May - October

ScandiNova



6 K2 type in operation (injector)
13 K2-3 type (Linac 3) expected June – November

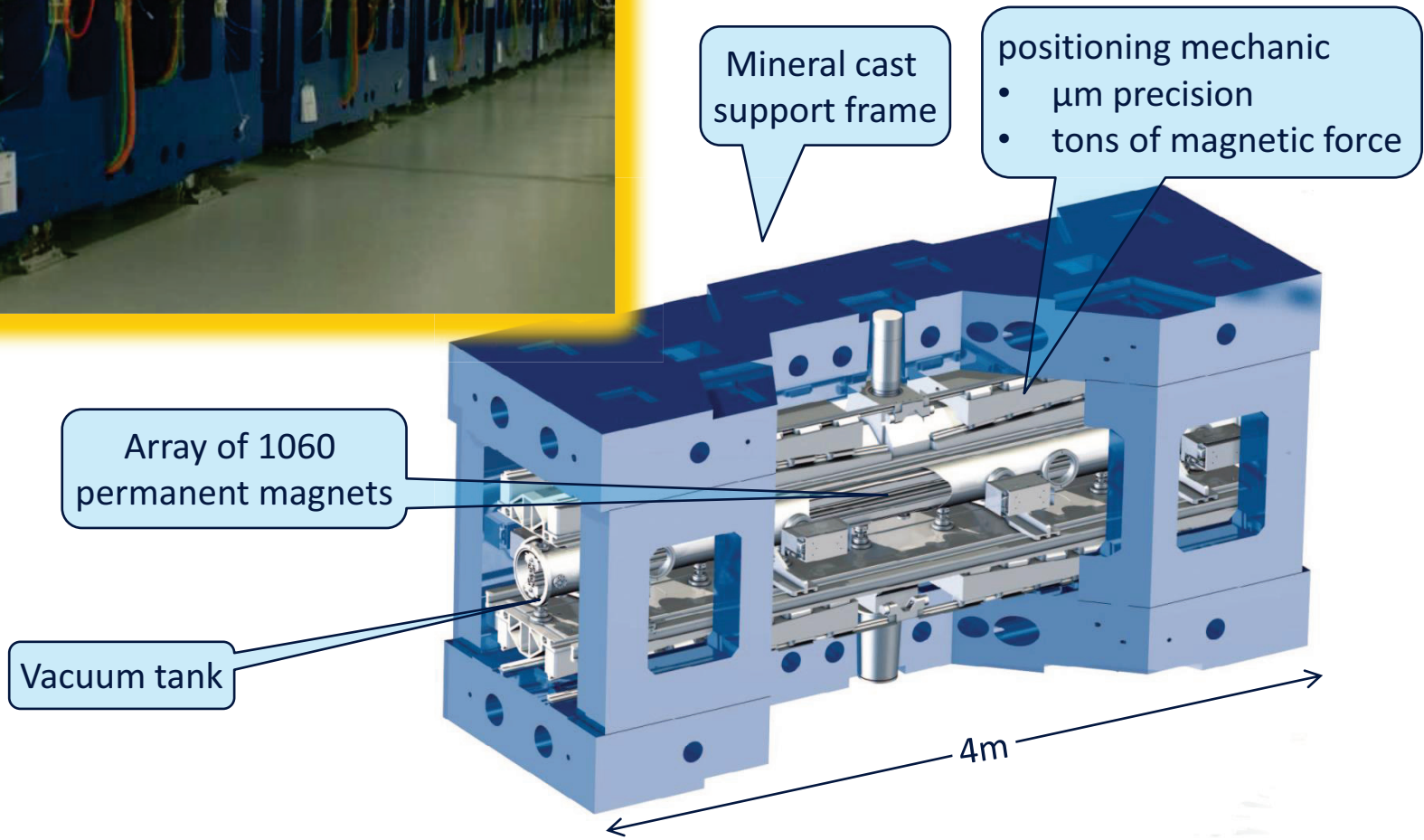
⇒ delivery schedule drives commissioning schedule

SwissFEL technical highlights III

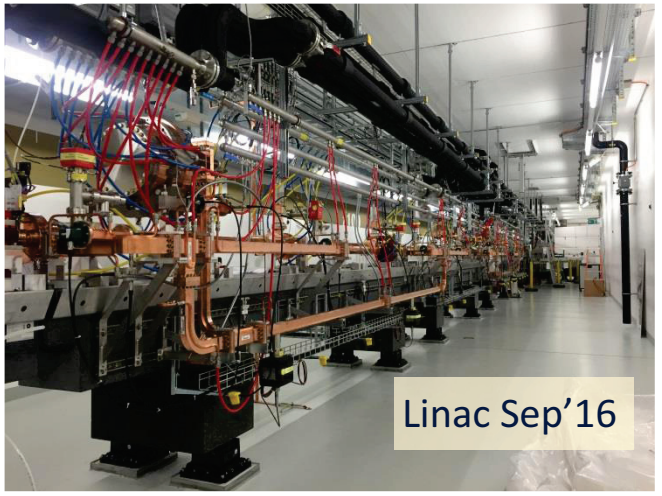
U15 undulator

nominal working point
- λ_U=15 mm
- K=1.2
- g=4.5mm

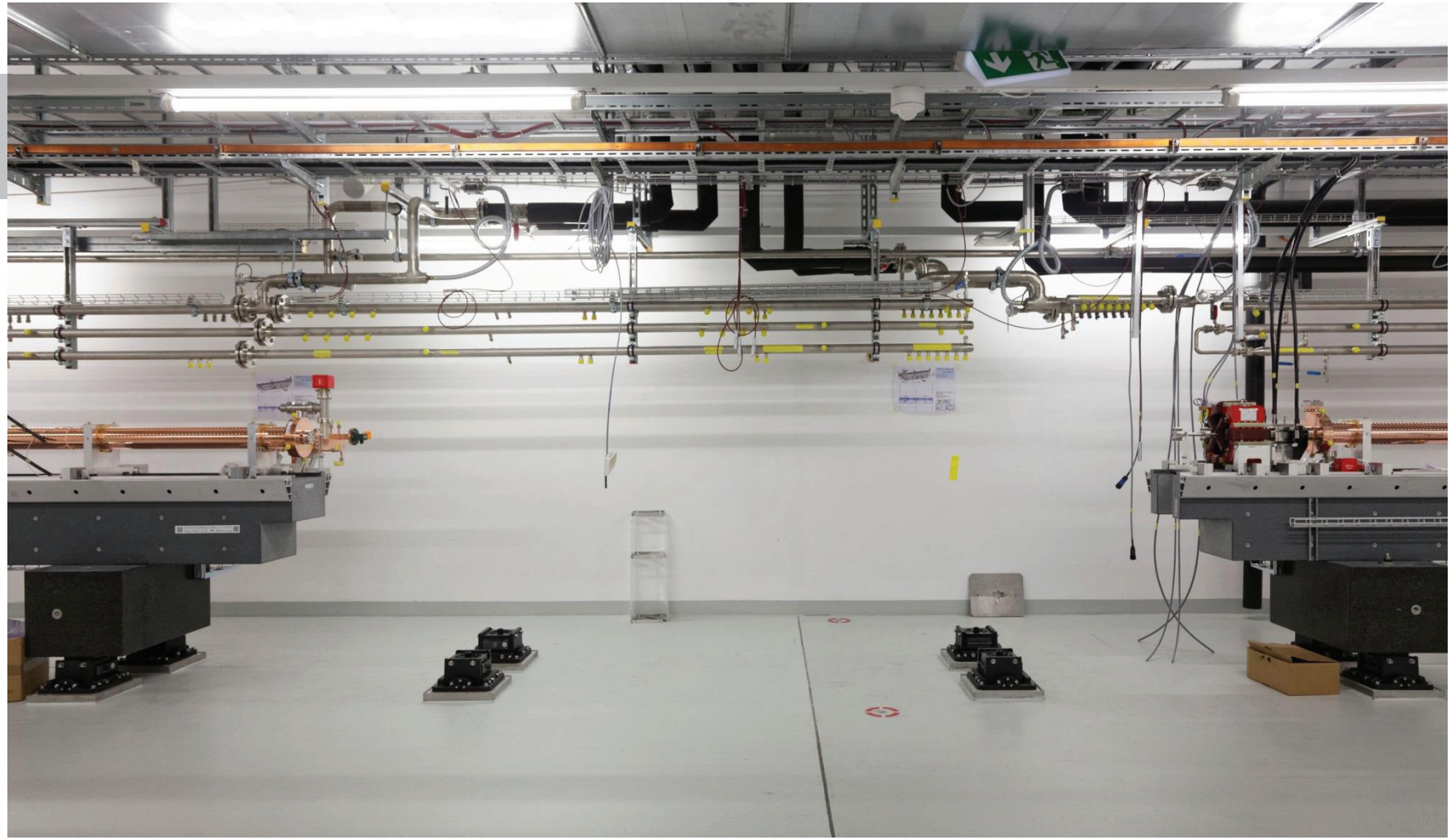
ARAMIS FEL consists of 13 x U15



SwissFEL installation progress



Installation of last Linac girder: Sept. 13, 2016



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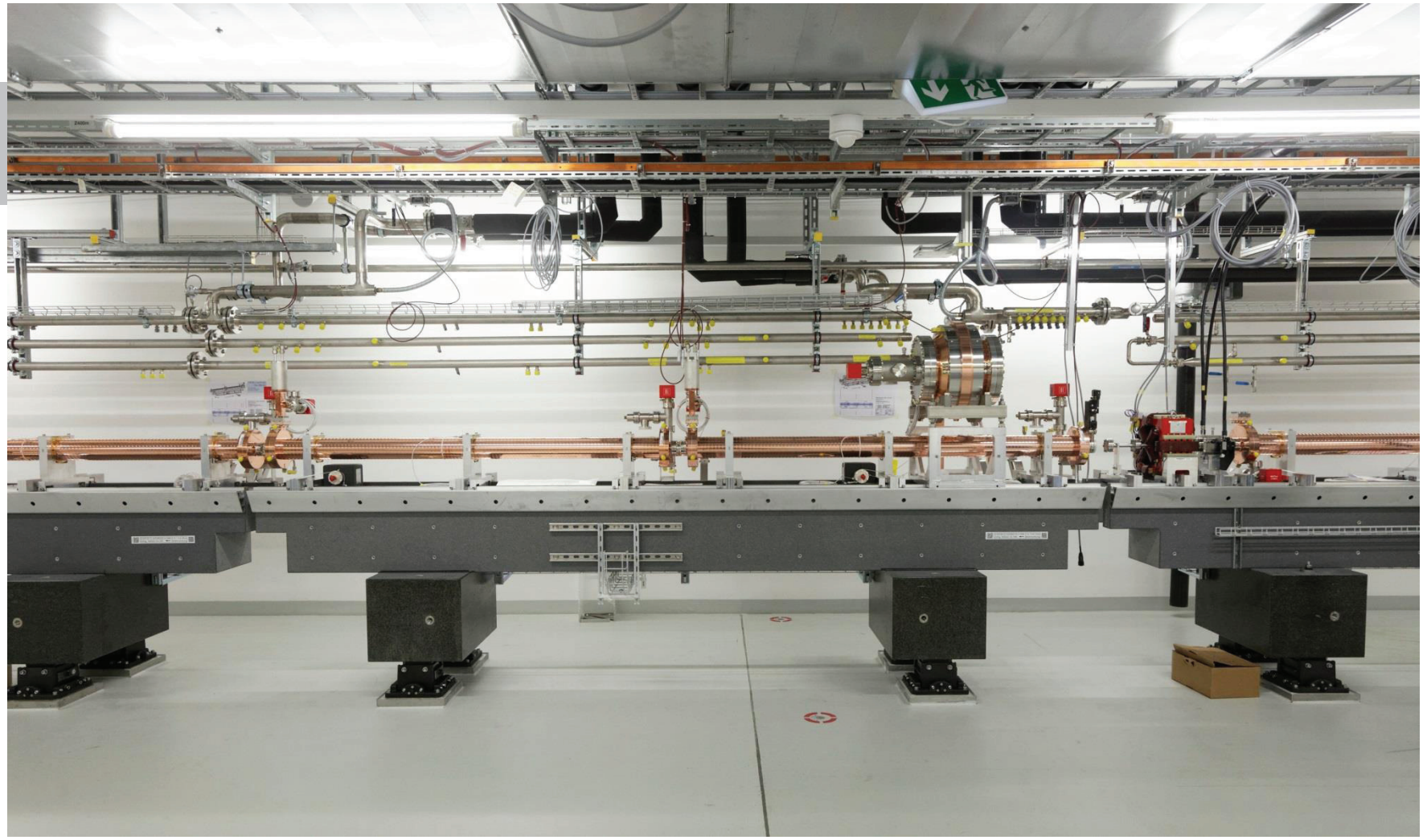

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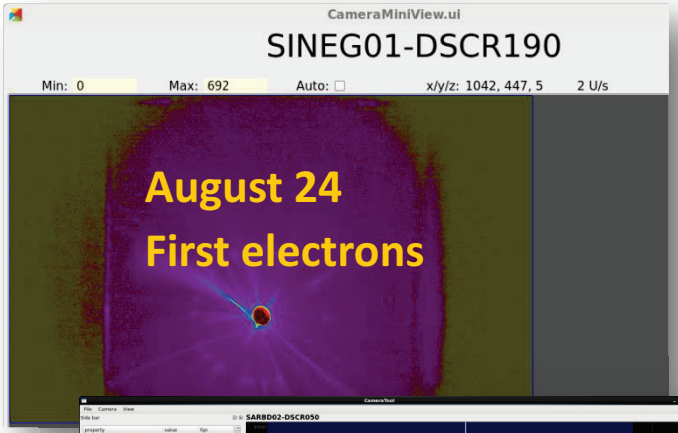
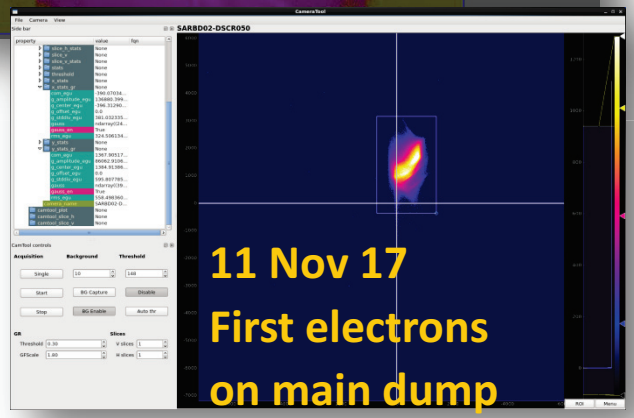
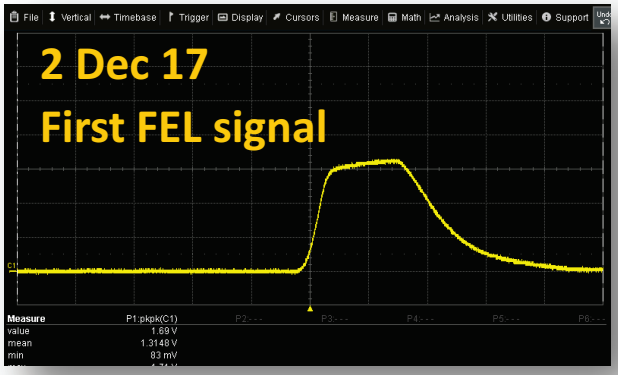
2016, October 7
Beamline complete from Photo-injector to beam dump

Commissioning Progress in 2016

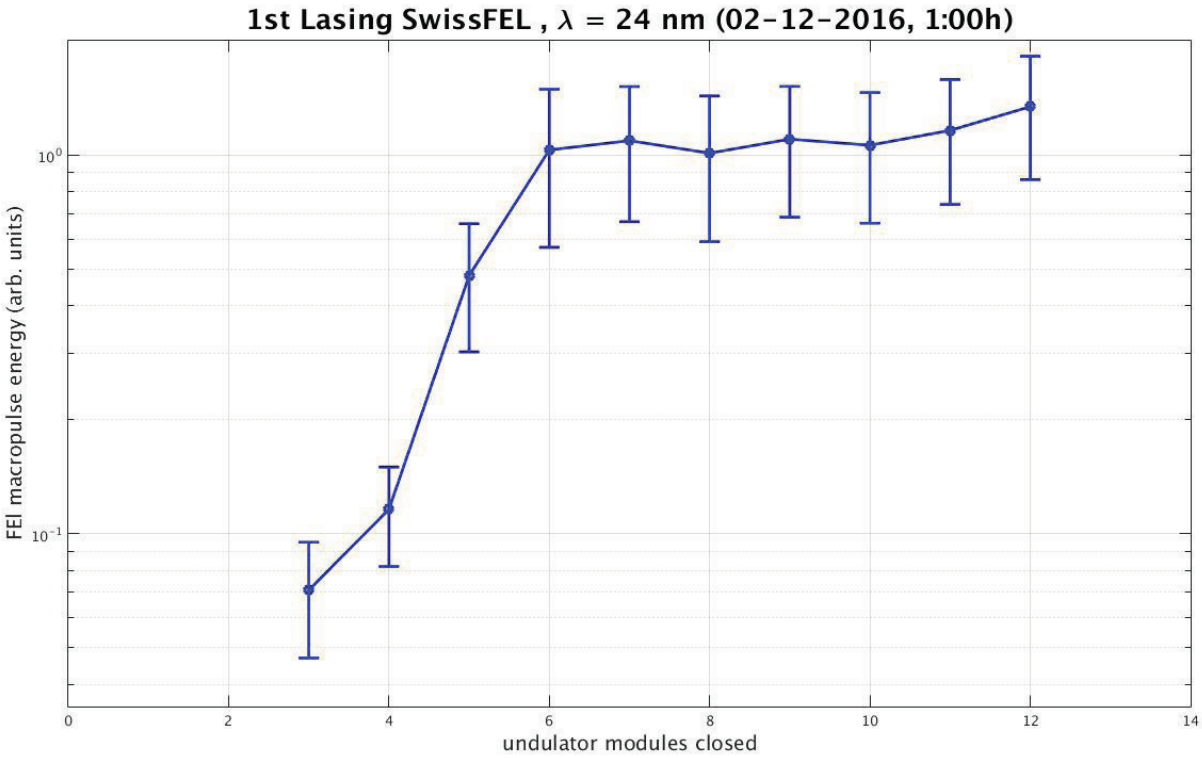
Date	achievement
August 24	First free electrons from gun with 7.9MeV
September 7	First electrons to injector beam dump
September 8	First acceleration with one C-band module
October 7	Beam line injector to main dump completed and under vacuum
November 11	First beam transport through undulators to main dump
December 2	First lasing at 345 MeV, 24 nm
December 5	Inauguration ceremony & party







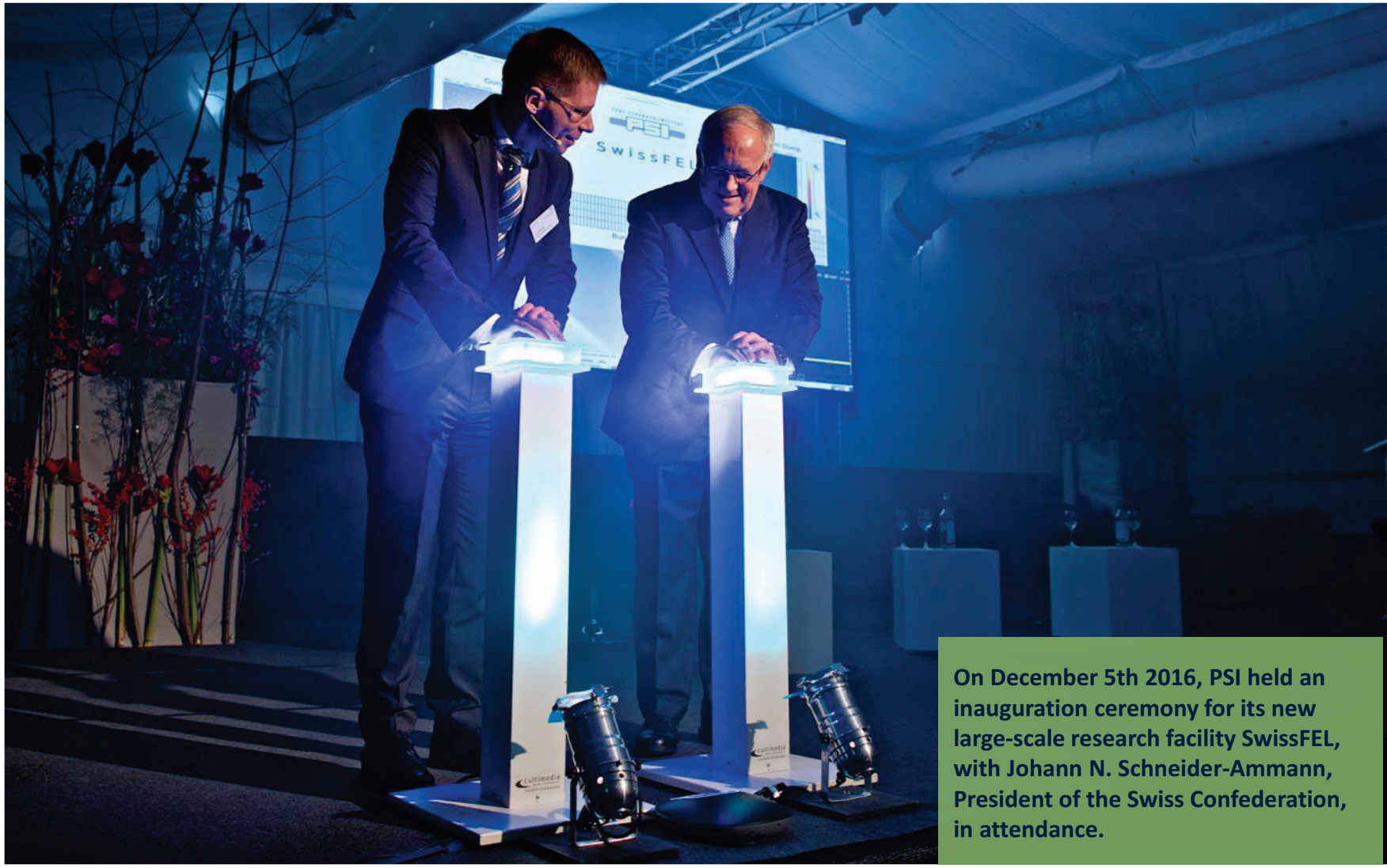
First lasing at moderate wavelength on 2.12.2016



Obtained with only 345 MeV beam energy, signal measured with Si-Diode (half the injector RF + 1 main linac C-band RF station)

Mainly a systems test!

5.12.2016 SwissFEL, the Inauguration



On December 5th 2016, PSI held an inauguration ceremony for its new large-scale research facility SwissFEL, with Johann N. Schneider-Ammann, President of the Swiss Confederation, in attendance.

Program 2017 & 2018

2017

Winter: Shutdown for installations

Spring: Ramp up beam energy to 3GeV

Summer: Lasing at 3 keV

Autumn: First pilot experiments at 3 keV

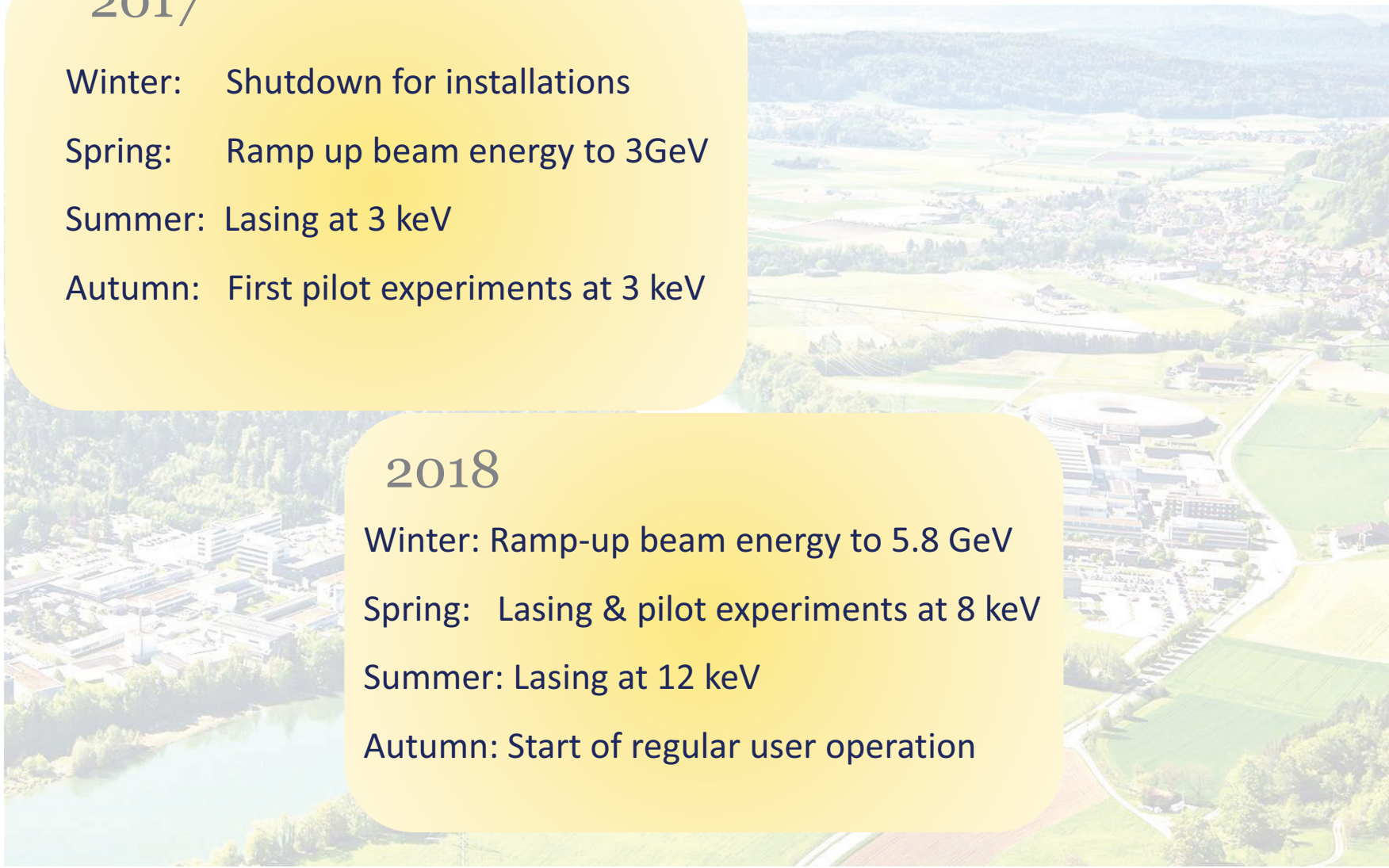
2018

Winter: Ramp-up beam energy to 5.8 GeV

Spring: Lasing & pilot experiments at 8 keV

Summer: Lasing at 12 keV

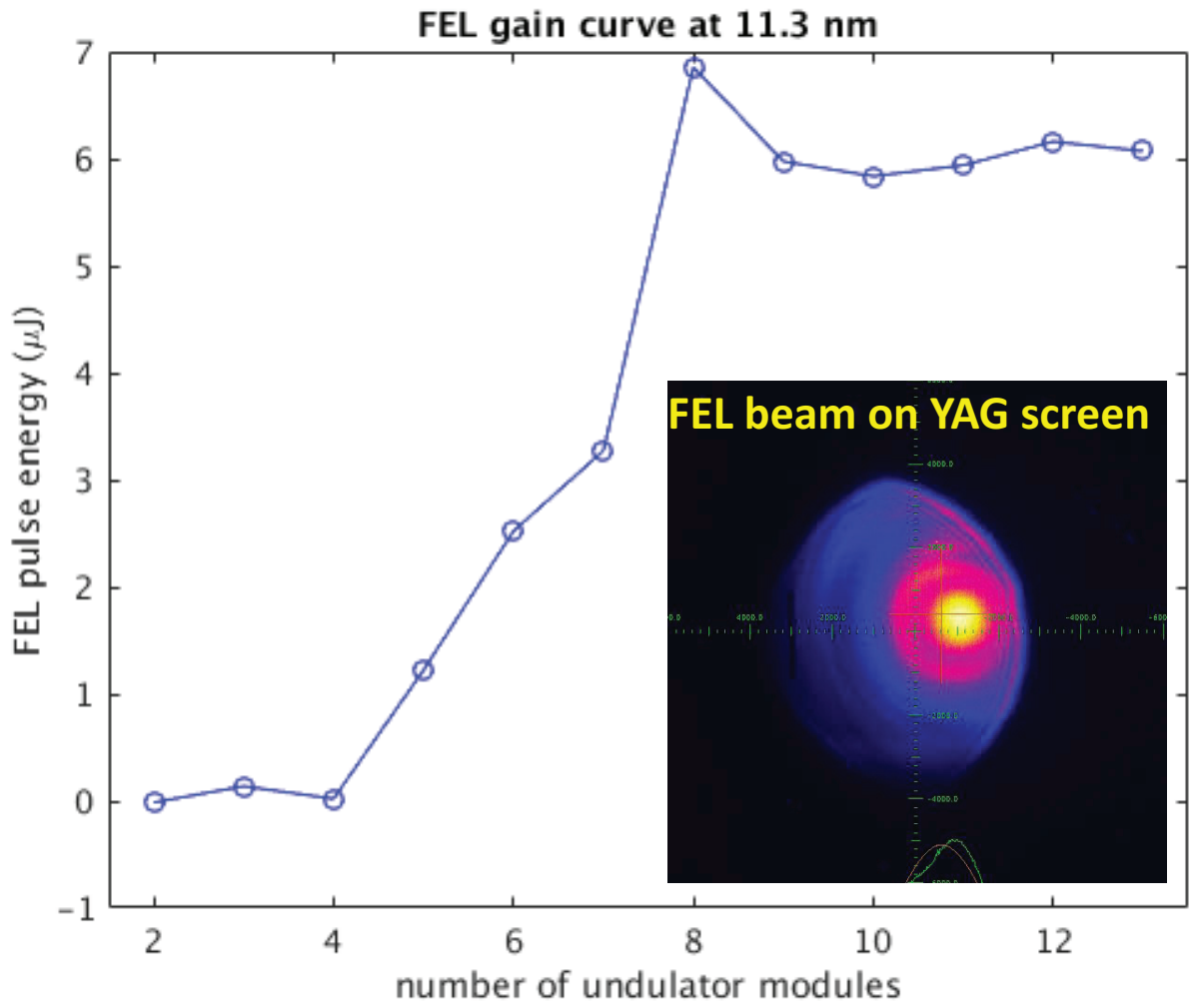
Autumn: Start of regular user operation



Commissioning progress May 14, 2017

Gain curve measured with Neon Gas intensity monitor

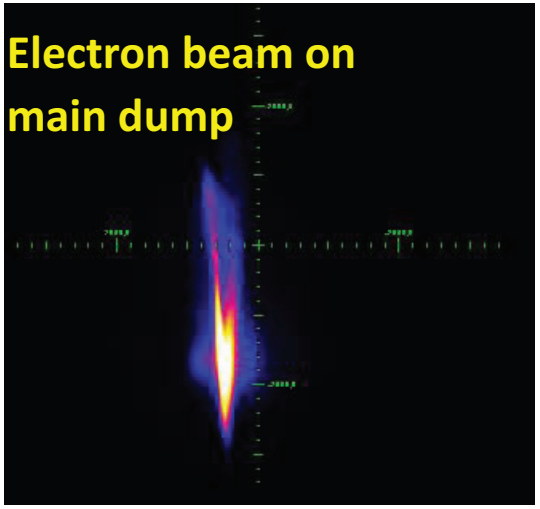
E_e-	0.545	GeV
q_B	145	pC
b.l. (rms)	≈0.4	ps
K	1.2	
λ_{FEL}	11.3	nm
$W_{FEL\ (g.m.)}$	≈7	µJ

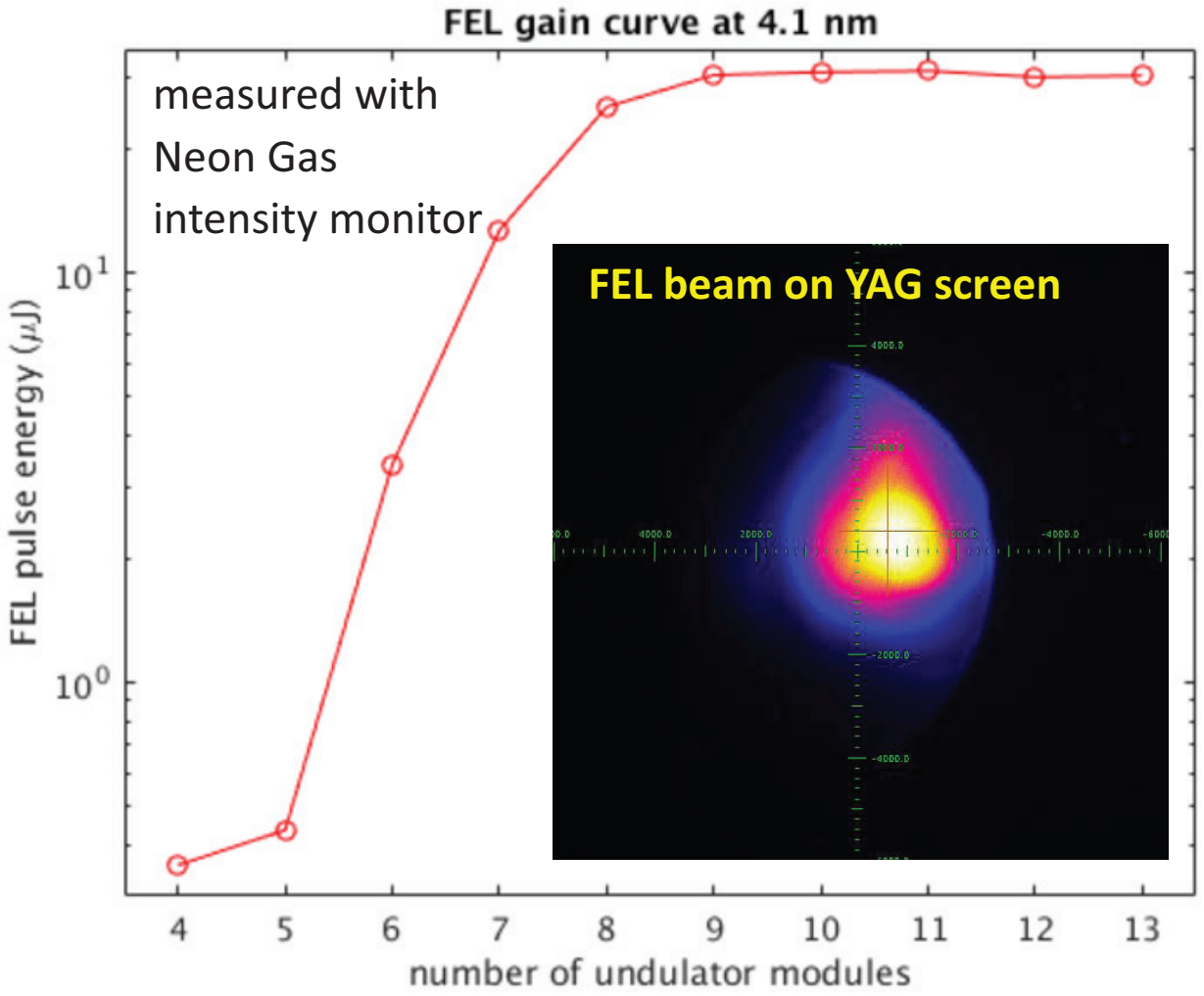


Commissioning progress May 15, 2017

First Lasing in nominal SwissFEL wavelength range (0.1-5.0 nm)!

E_e-	0.91	GeV
q_B	145	pC
b.l. (rms)	≈0.4	ps
K	1.2	
λ_{FEL}	4.1	nm
W_{FEL}	≈30	µJ





Establishing SASE at 4.1nm

- careful set-up of gun and cathode laser
- careful transverse optics measurement and matching in injector region
- computed optics in linac and undulators
- set-up of bunch compression in BC1 with deflecting cavity
- steering according to BPM centers
- so far no special alignment procedures were required in undulator region
- measured pulse energy is consistent with theoretical expectations

$\Rightarrow$ We are positive that with the addition of more RF stations
we can proceed to shorter wavelength

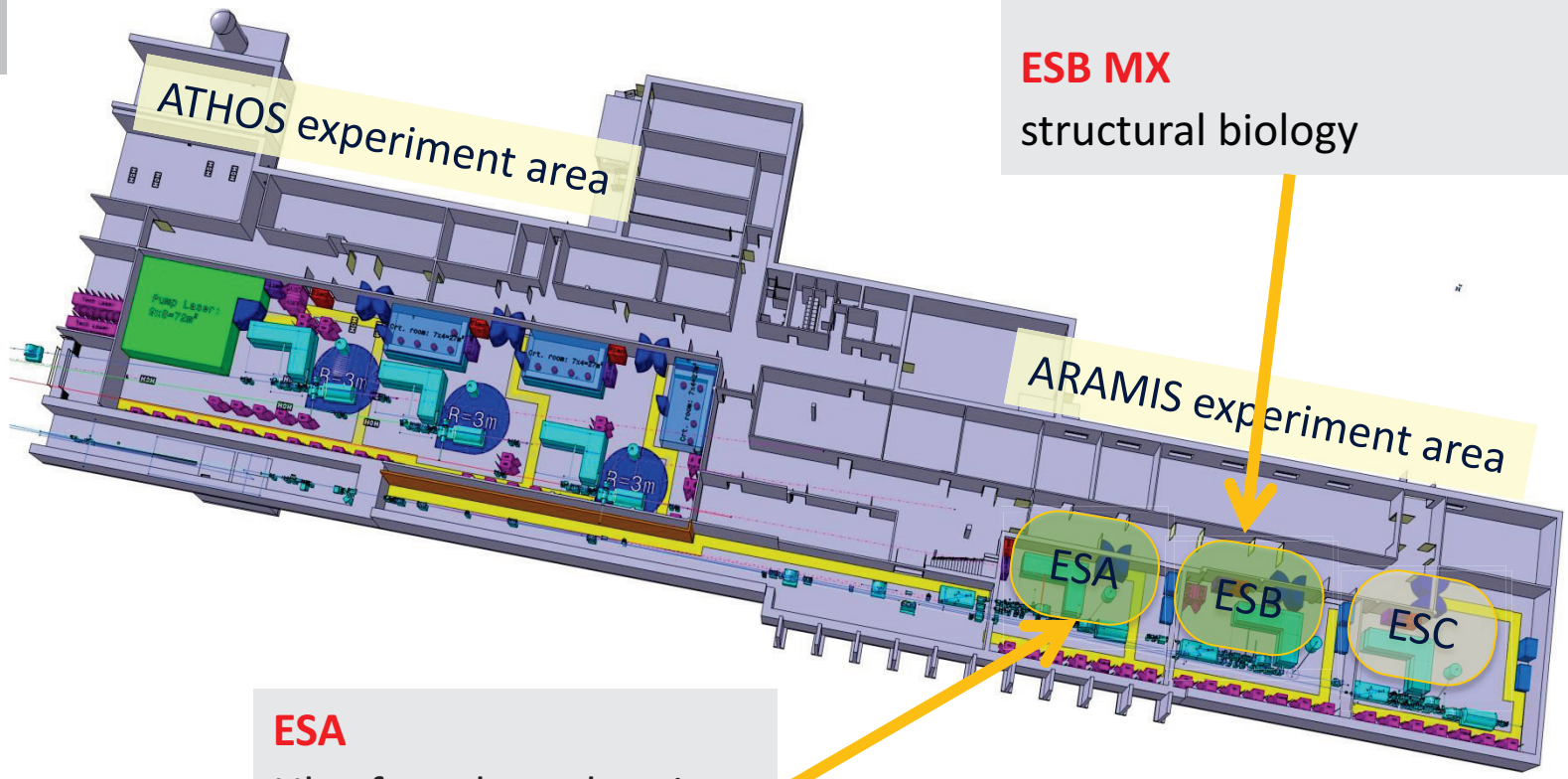
Photon Beamlines and Experiments

ESB

Ultrafast dynamics in solid matter, strongly correlated electron systems

ESB MX

structural biology



ESA

Ultrafast photochemistry and photobiology

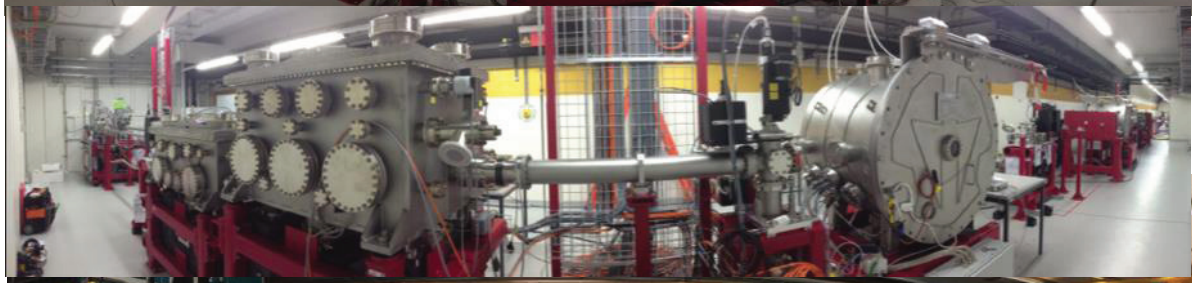
ARAMIS beamline

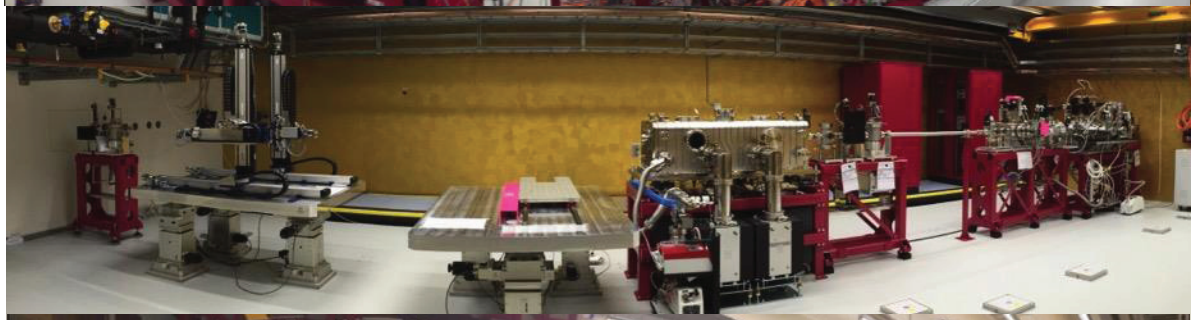
Front-End

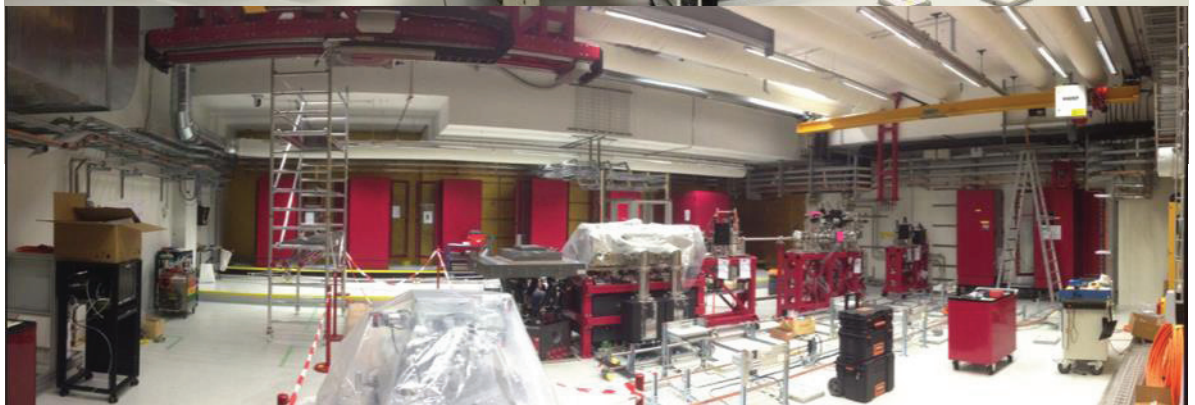
Optical hutch

ESA hutch

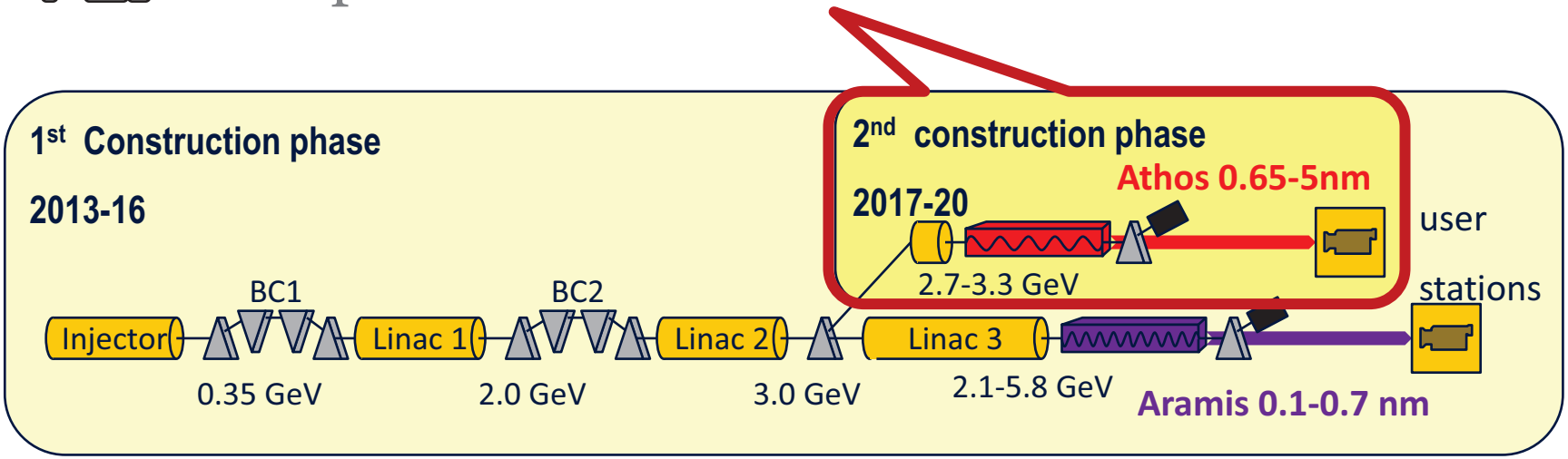
ESB hutch







Preparation for ATHOS



ATHOS

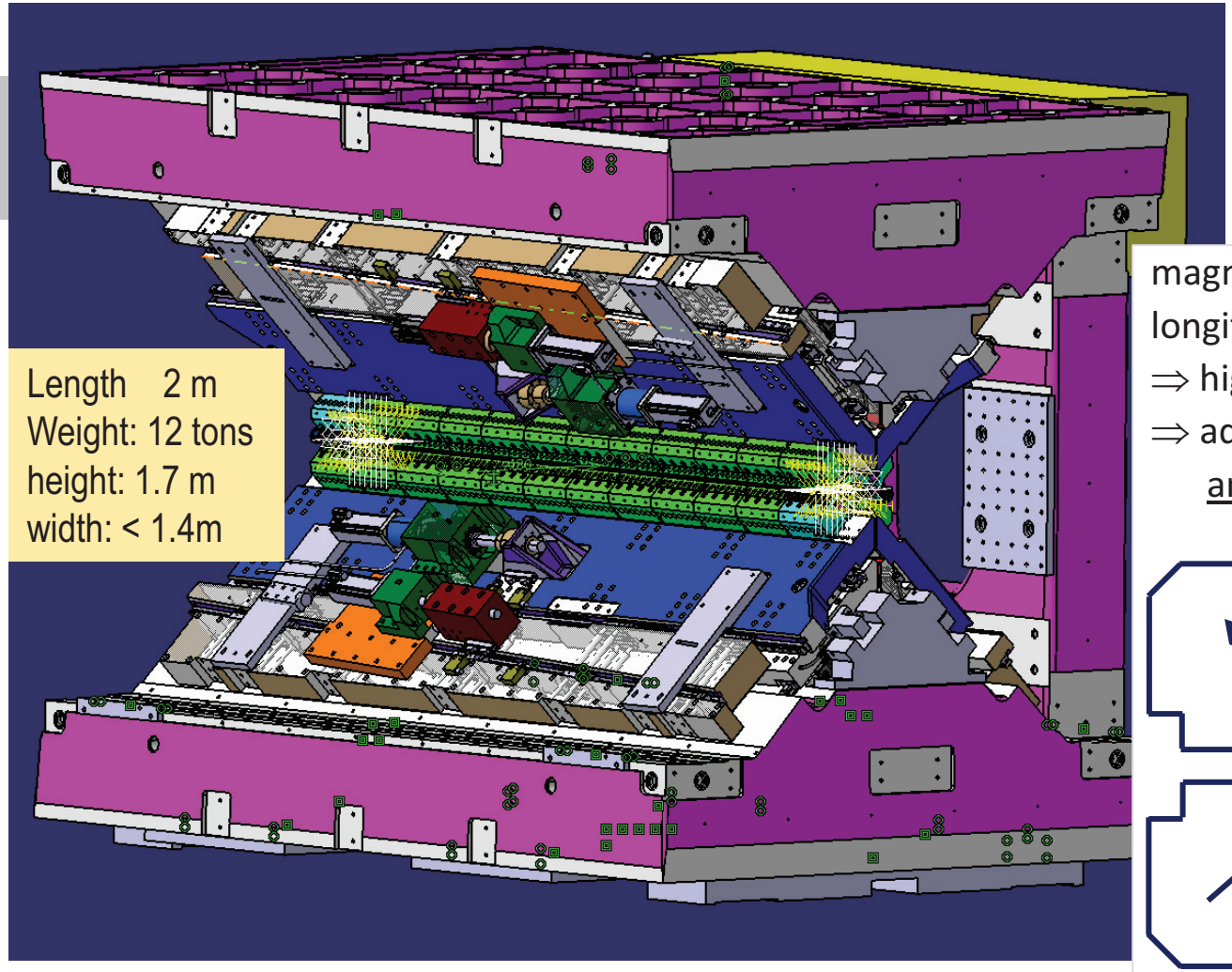
Soft X-ray FEL, λ=0.65-5.0 nm

full polarization control withU38 Apple-X Undulators

Switch Yard: already installed in phase 1

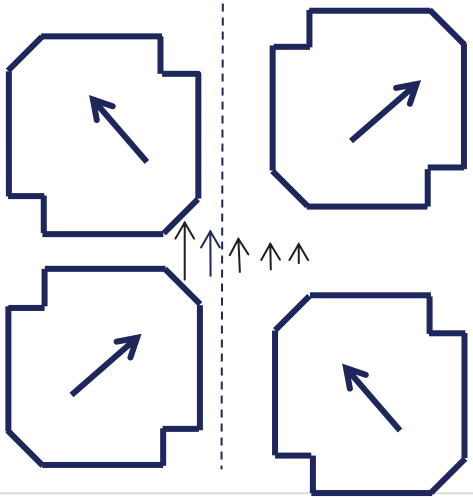
Extraction done at constant energy of 3 GeV

UE38 Apple X undulator for ATHOS, prototype construction has started



Length 2 m
Weight: 12 tons
height: 1.7 m
width: < 1.4m

magnet arrays with
longitudinal and radial shift
⇒ highest flexibility
⇒ adjustable polarization
and gradient



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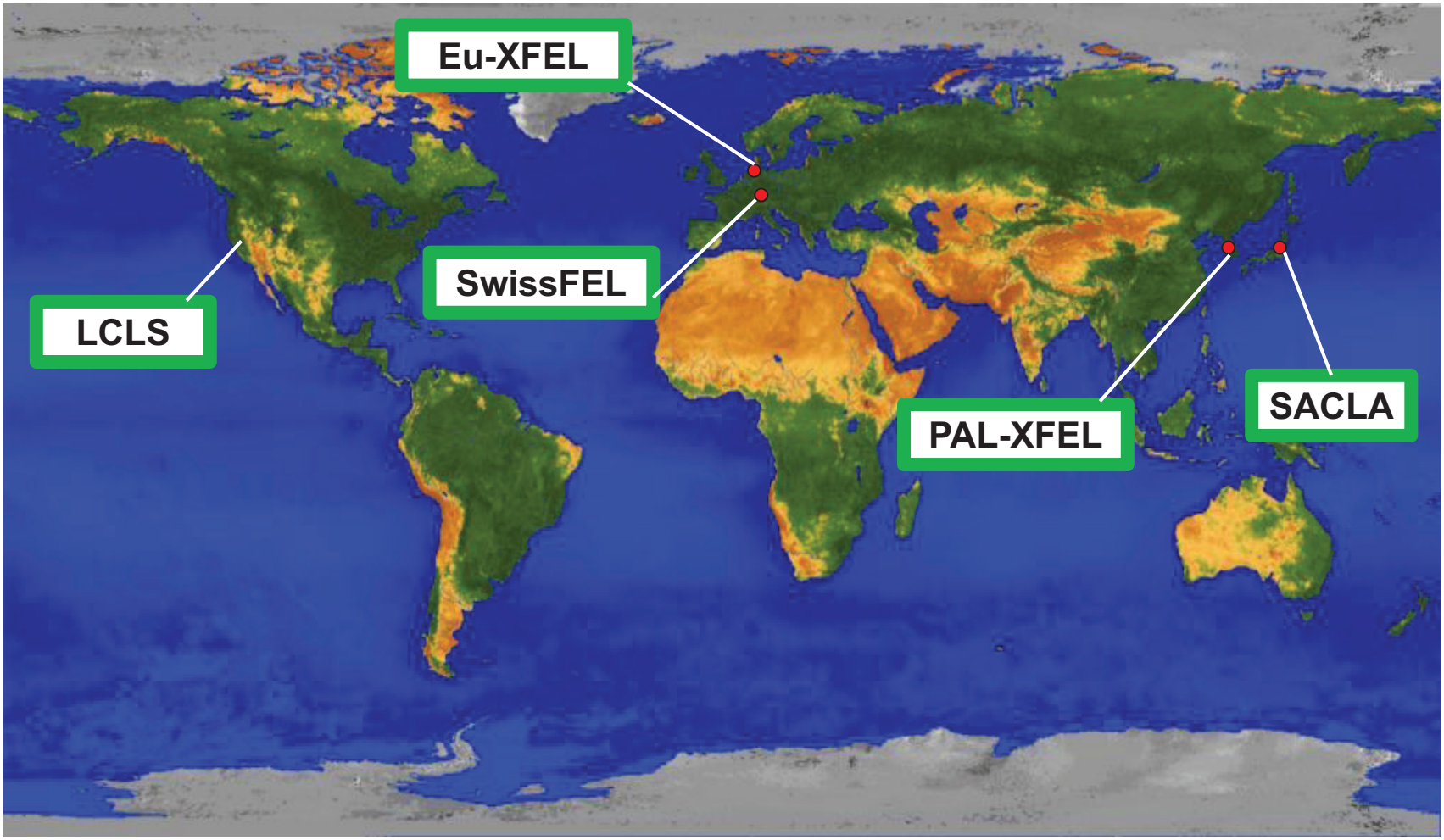
SwissFEL control room photo gallery (selection)

Hard X-ray FELs around the world communitiy with excellent collaboration and exchange + annual 5 way meeting



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Hard X-ray FELs around the world community with excellent collaboration + annual 5 way meeting + spontaneous collective actions

advanced acceleration experiment performed by SwissFEL, PAL-XFEL, Eu-XFEL and LCLS