Florian Löhl :: Paul Scherrer Institut

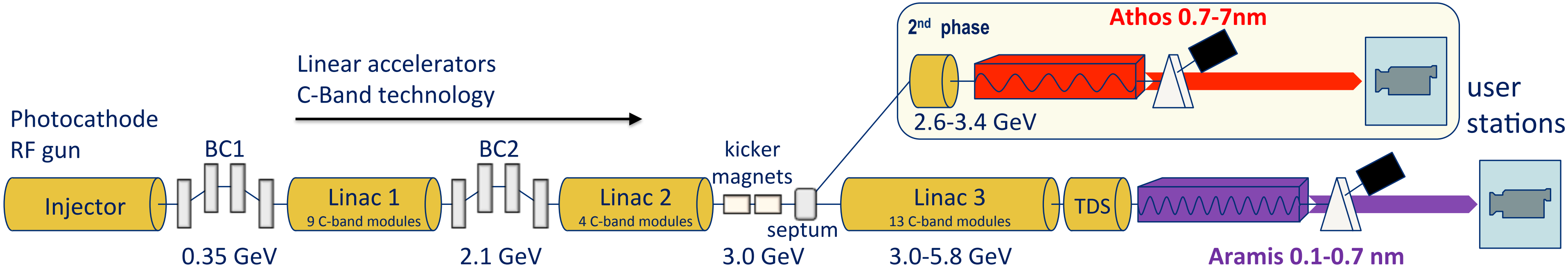
Status of SwissFEL

European Synchrotron Light Source Workshop - November 25, 2015

Outline

- Overview
- Building
- Machine
- Photon beamlines / end stations

SwissFEL in a nutshell



ARAMIS

- Hard X-ray FEL, λ=0.1-0.7 nm
- Linear polarization, variable gap, in-vacuum undulators
- First users 2017
- Operation modes: SASE & self seeded

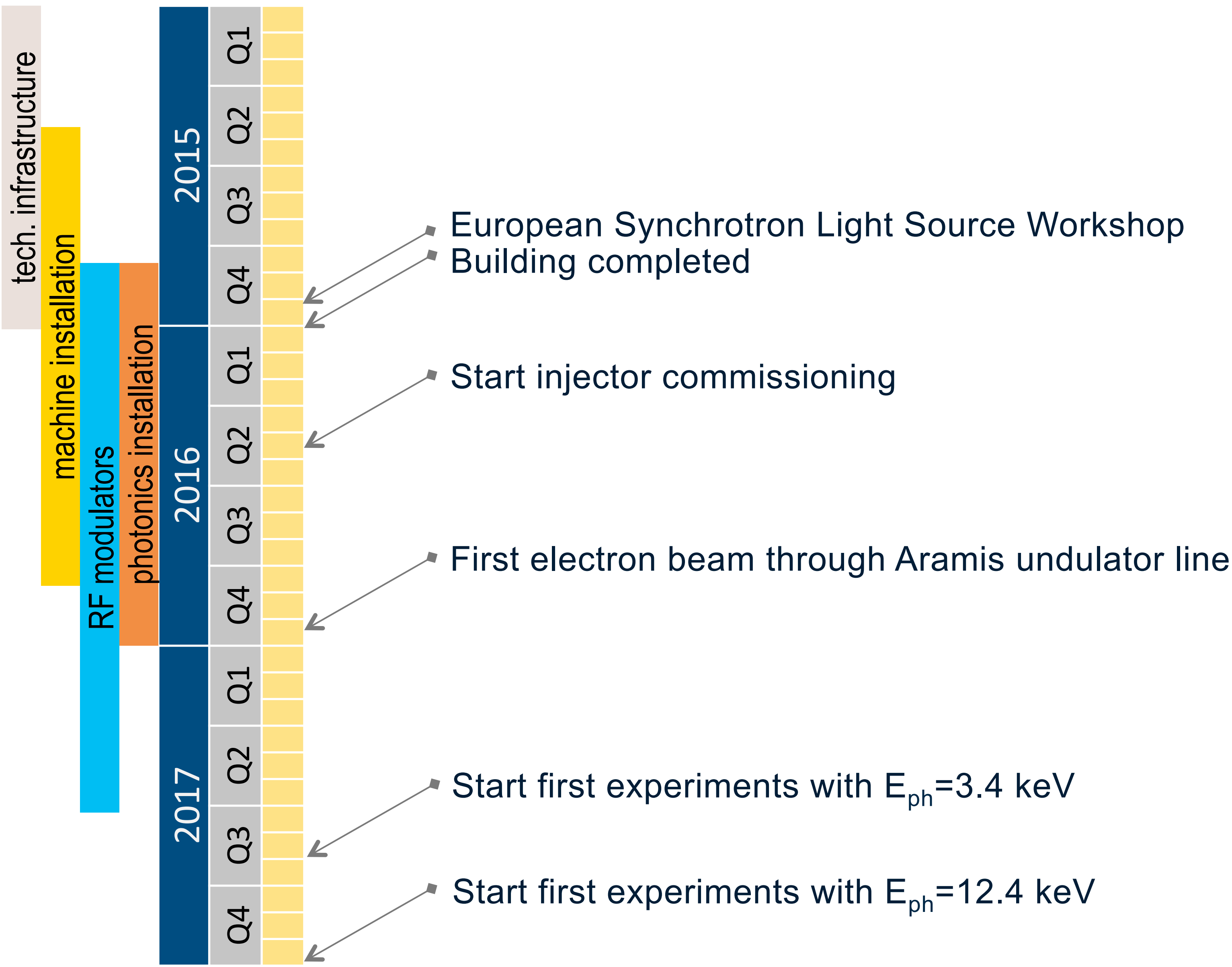
ATHOS

- Soft X-ray FEL, λ=0.7-7.0 nm
- Variable polarization, Apple III (Apple-X?) undulators
- First users 2019, 2020?
- Operation modes: SASE & self seeded

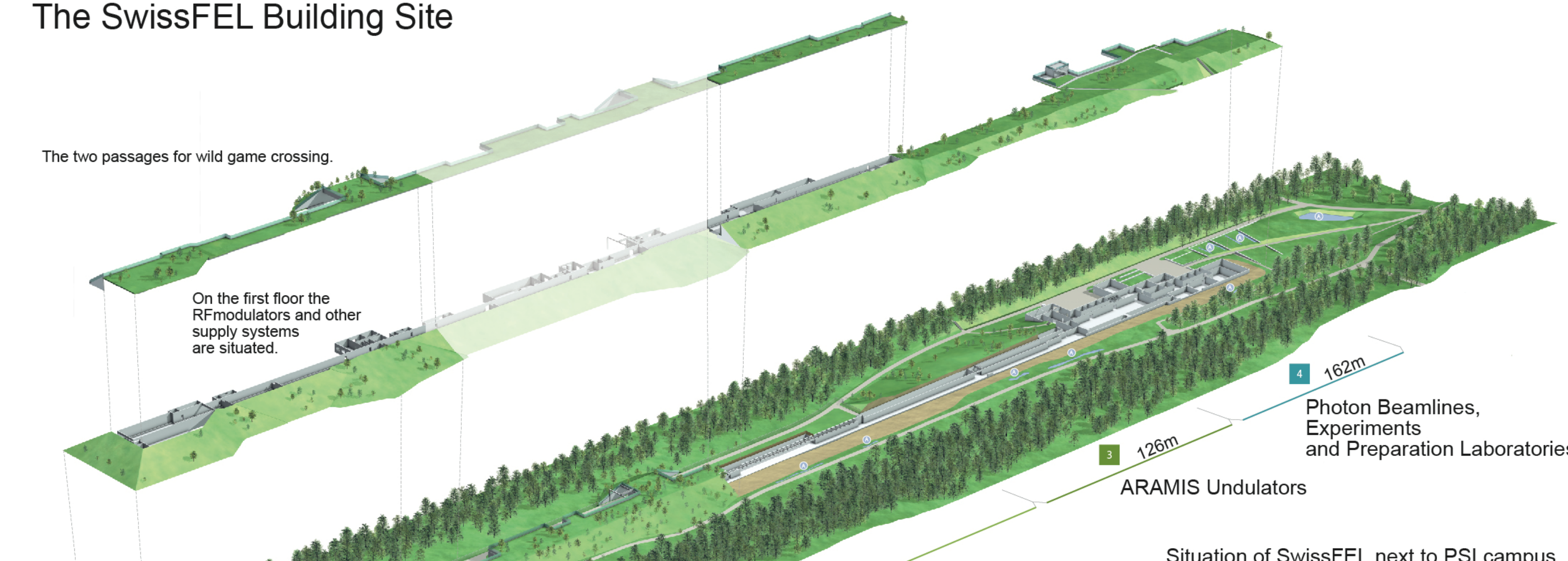
Main parameters

Wavelength from	0.1nm–7nm
Photon energy	0.2-12 keV
Pulse duration	1 fs - 20 fs
e^- Energy (0.1 nm)	5.8 GeV
e^- Bunch charge	10-200 pC
Repetition rate	100 Hz

Next milestones

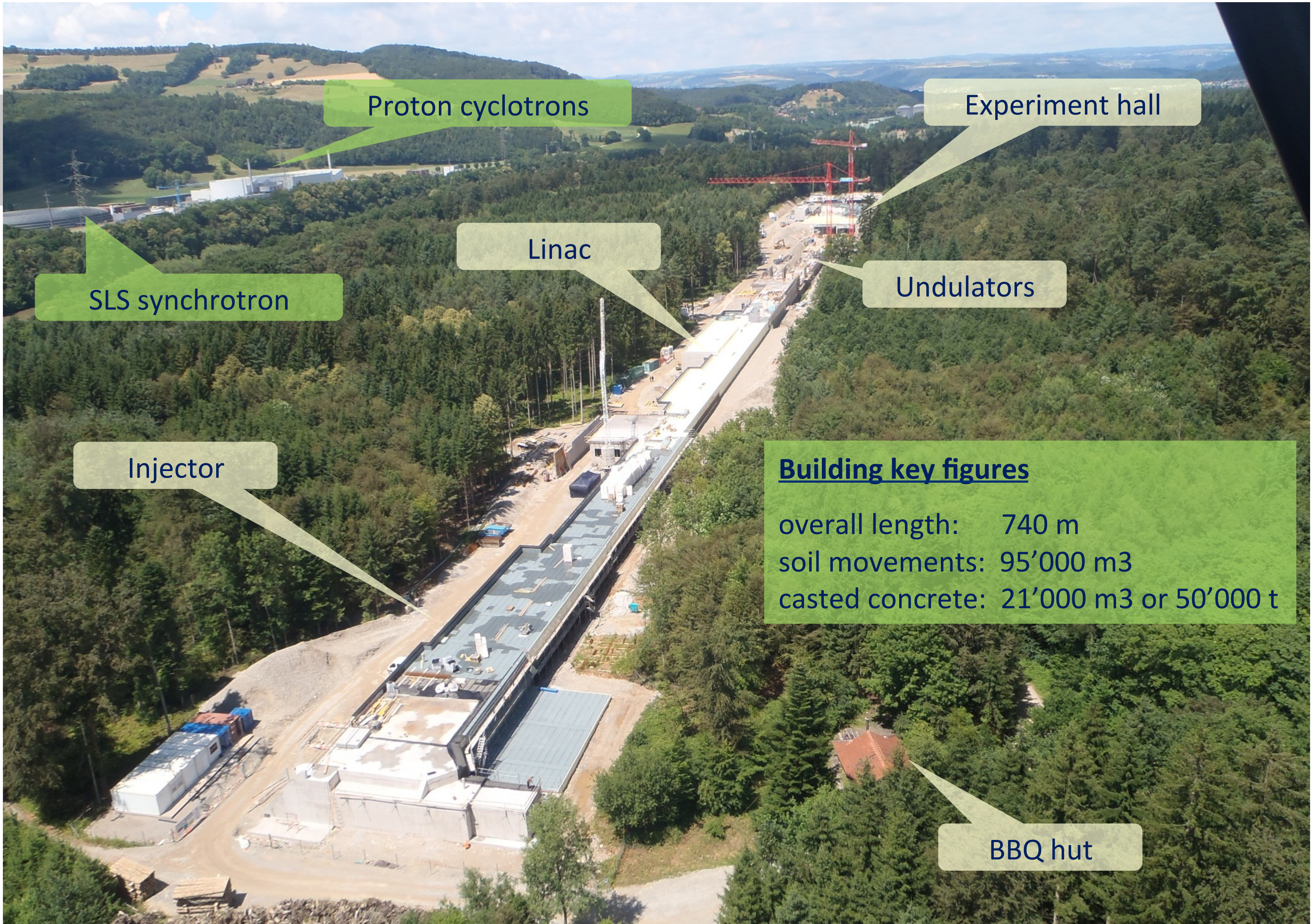


The SwissFEL Building Site



Situation of SwissFEL next to PSI campus

SwissFEL construction site, (picture July 2014)



SwissFEL Construction Site, June 2015

Some infrastructure around SwissFEL

PSI, November 30, 2015

2.5 cell S-band RF gun

Machined “on tune” according to HFSS

No tuning plungers

No tuning step during machining

Best design features from

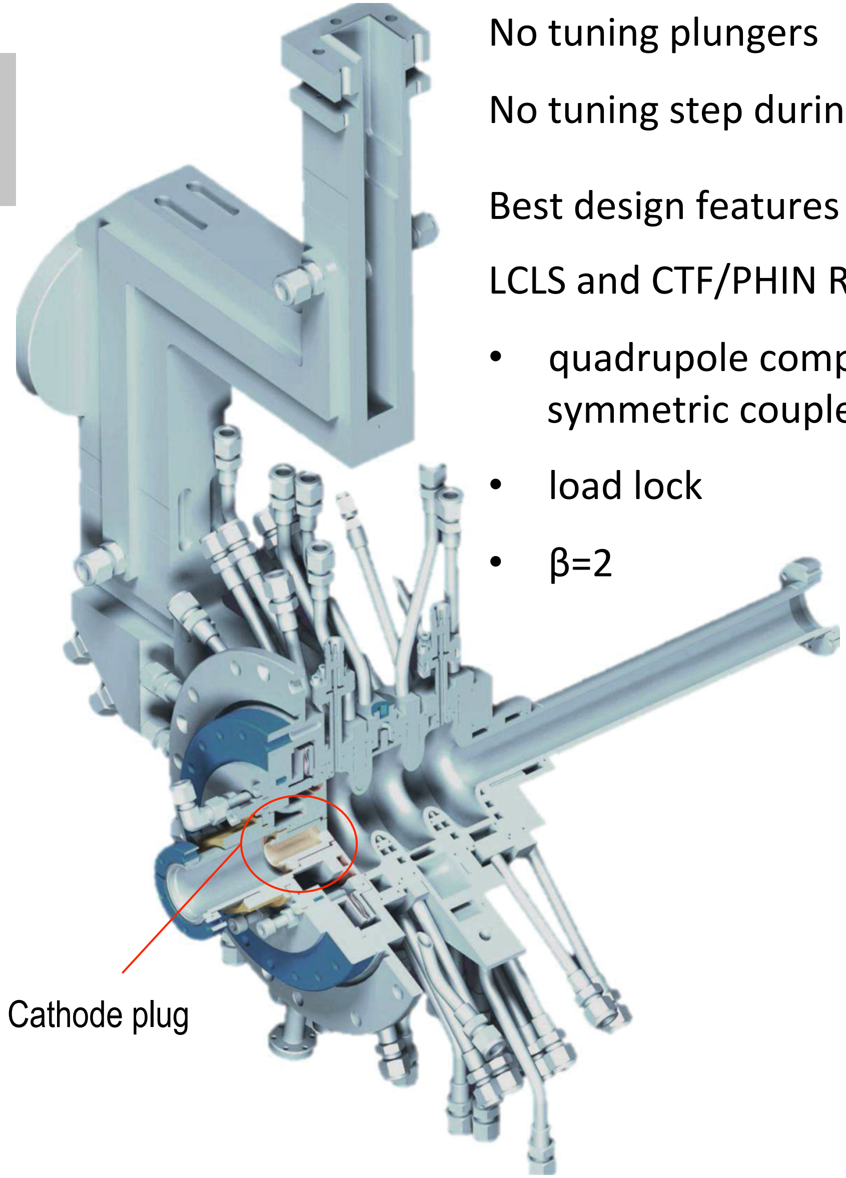
LCLS and CTF/PHIN RF guns adopted

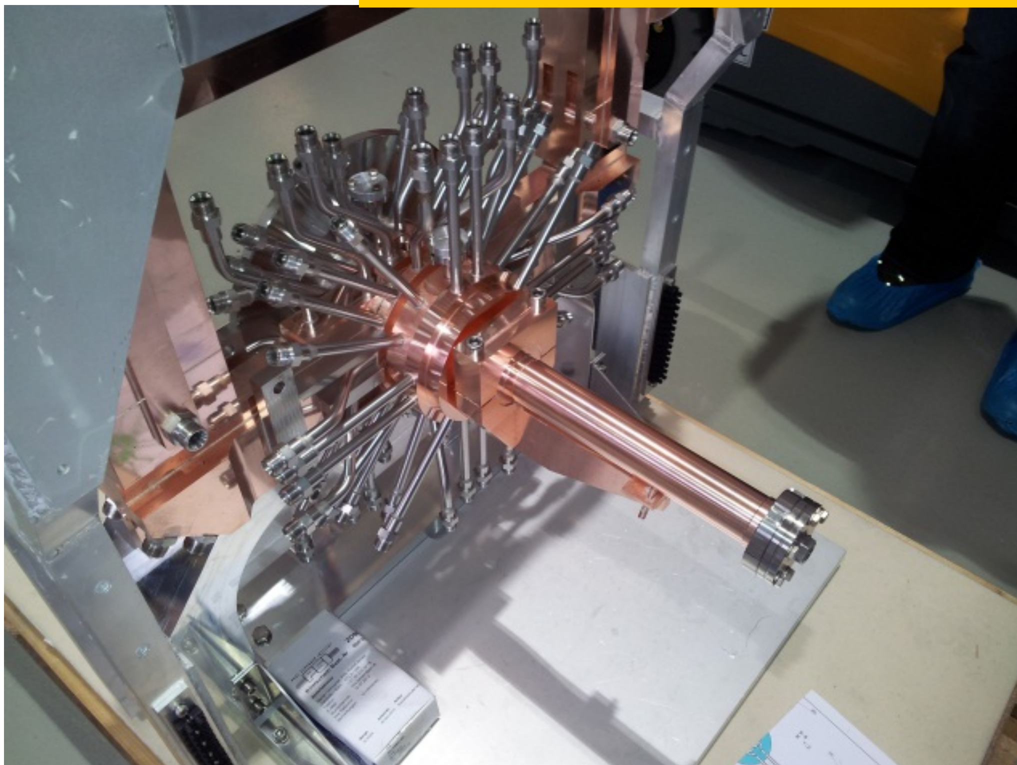
- quadrupole compensated symmetric coupler
- load lock
- β=2

RF and mechanical design: PSI

Fine machining cavities : VDL

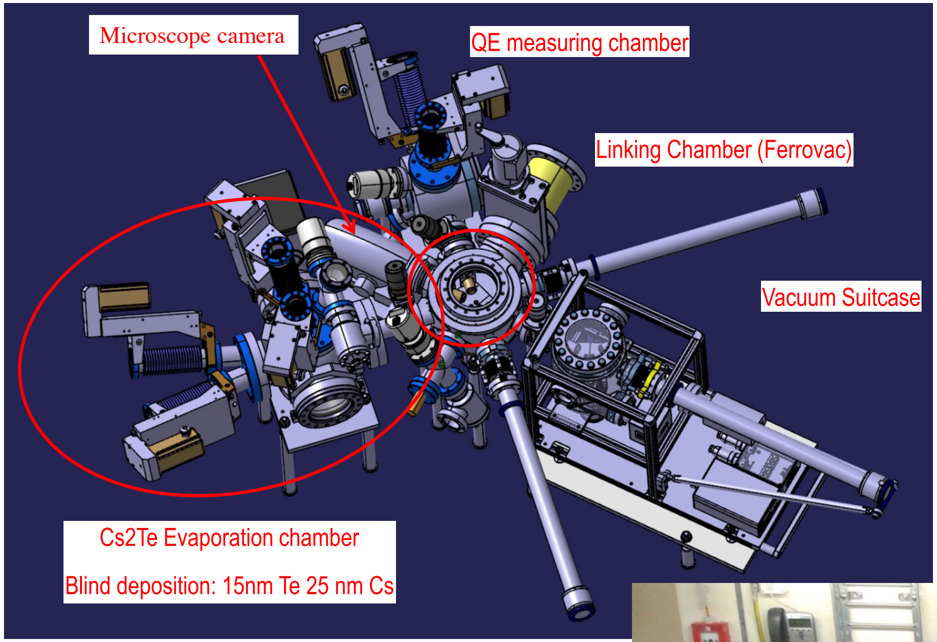
Pre-machining & brazing: PSI workshop

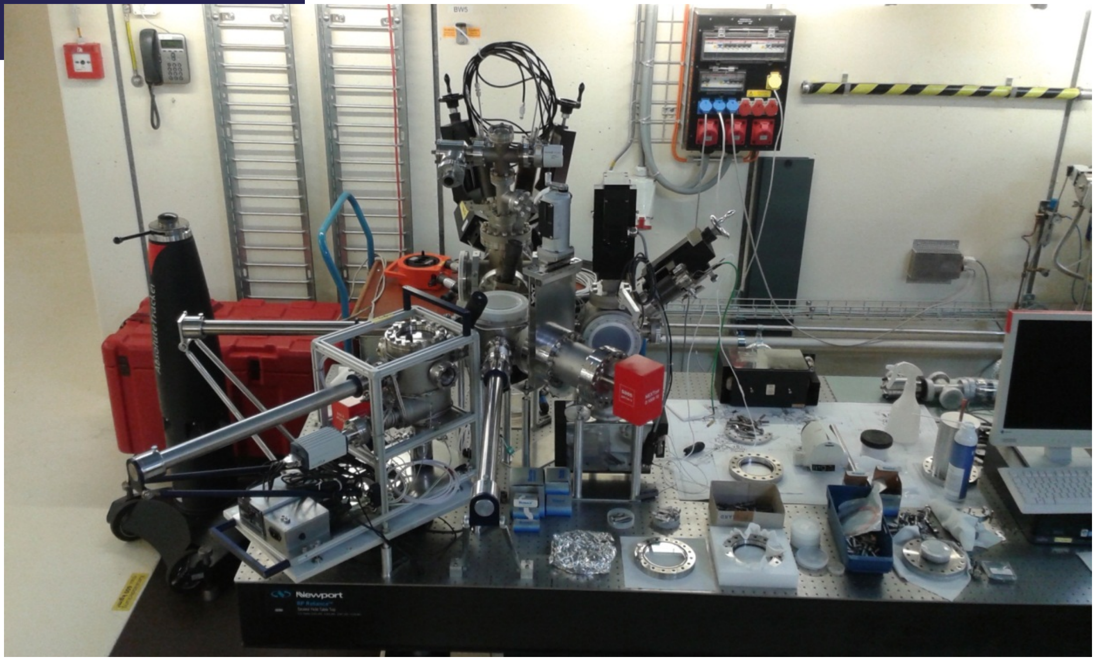




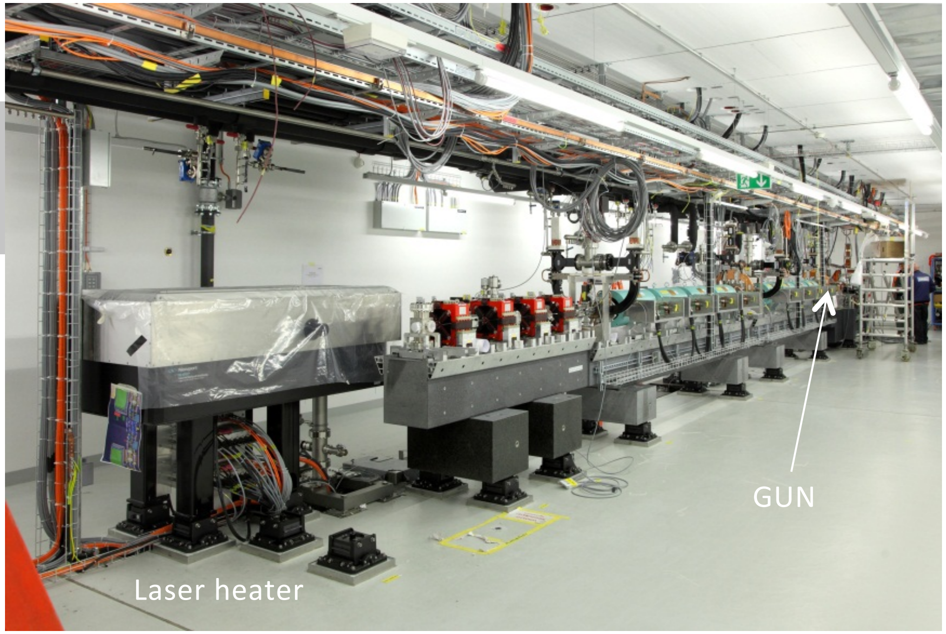
Cs_2Te cathode preparation & load lock system

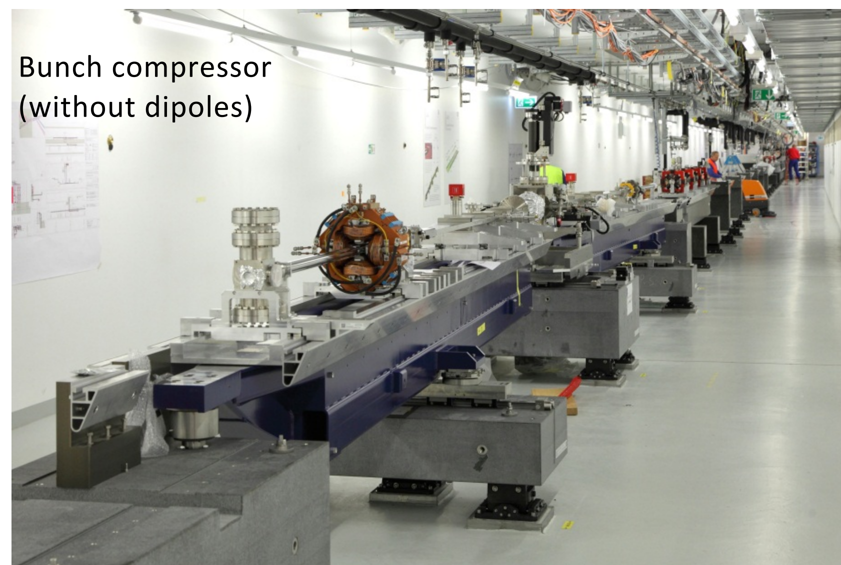
courtesy Romain Ganter





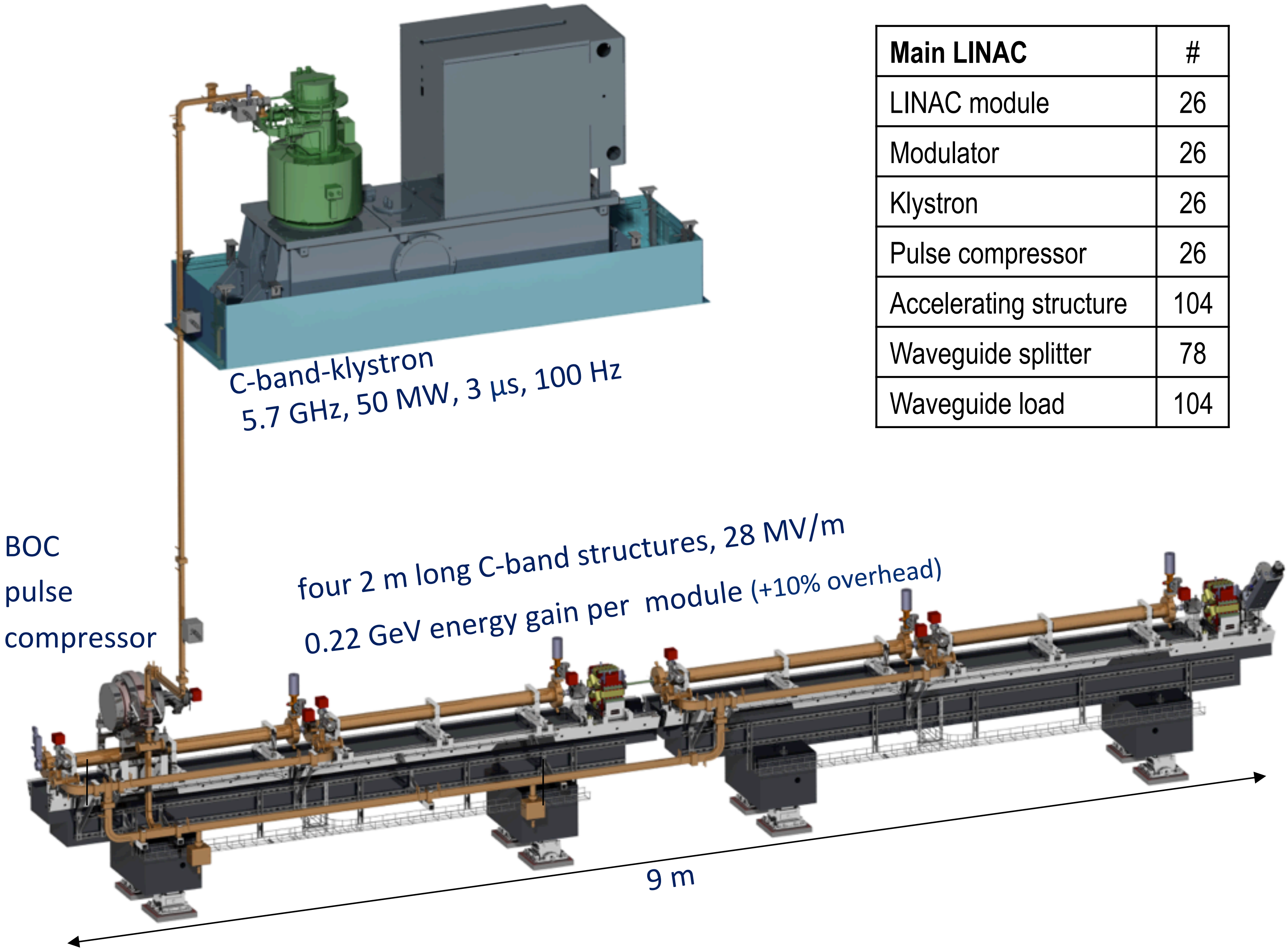
Status Injector Installation
courtesy Marco Pedrozzi





C-band linac modules

Main LINAC	#
LINAC module	26
Modulator	26
Klystron	26
Pulse compressor	26
Accelerating structure	104
Waveguide splitter	78
Waveguide load	104



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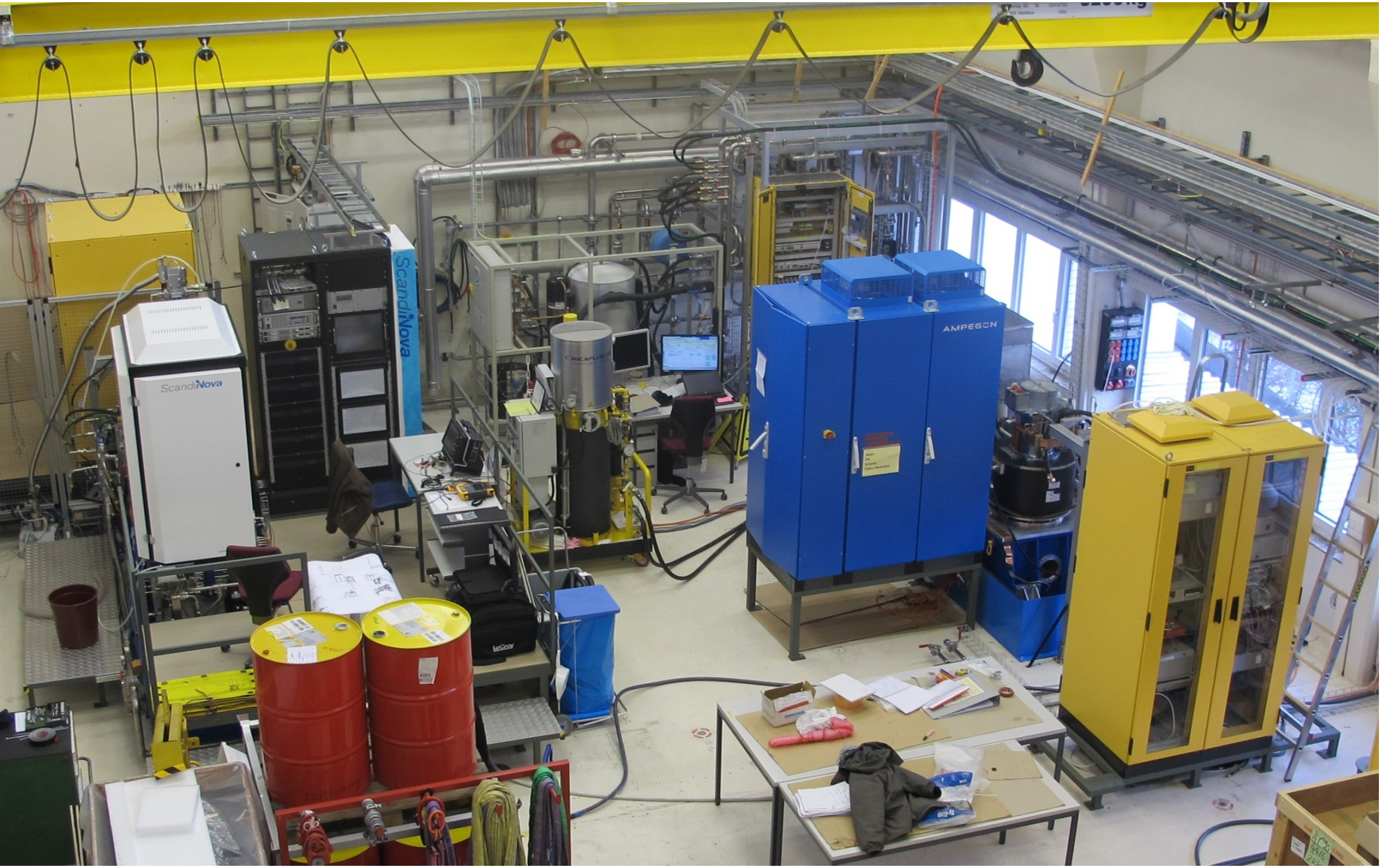
Modulator prototypes in C-band test area



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C-band structures

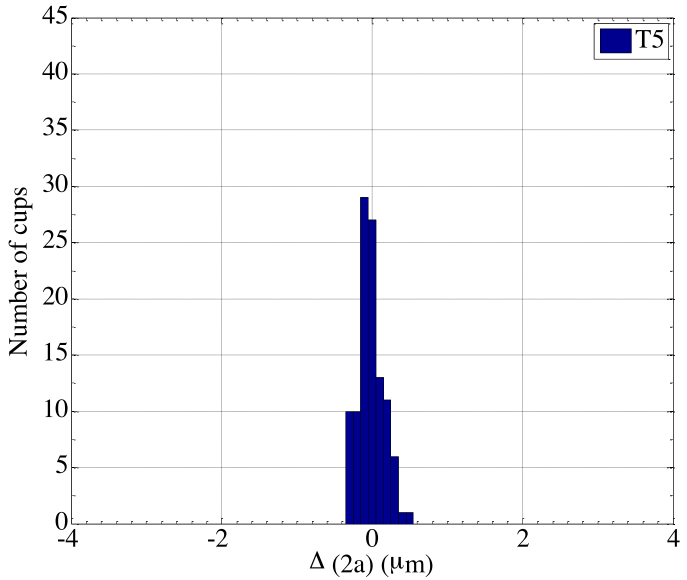
- Structures are machined “on tune”, no provisions for dimple tuning!
- Stacked by robot
- Vacuum-brazed
- Production rate: 1-2 / week

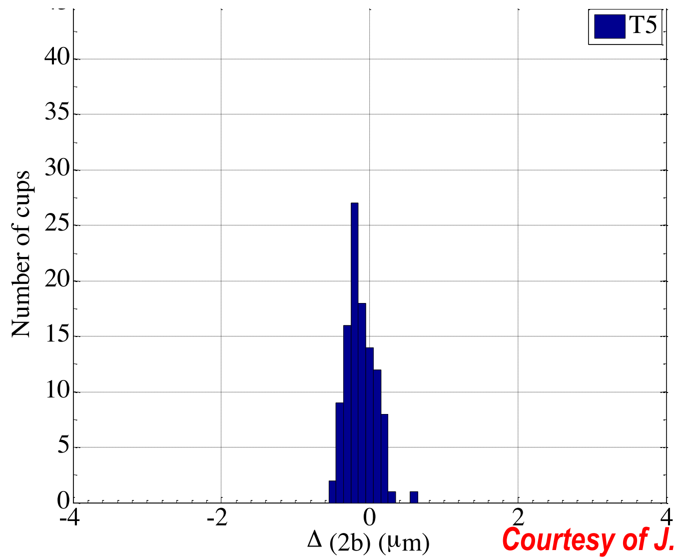
- **High power results for first structure:**
  - → Conditioned to 52 MV / m
  - → Break-down rate at 52 MV / m ≈ 2 x 10^{-6}
  - → At nominal 28MV/m, break-down rate negligible (well below the specified threshold of 10^{-8})

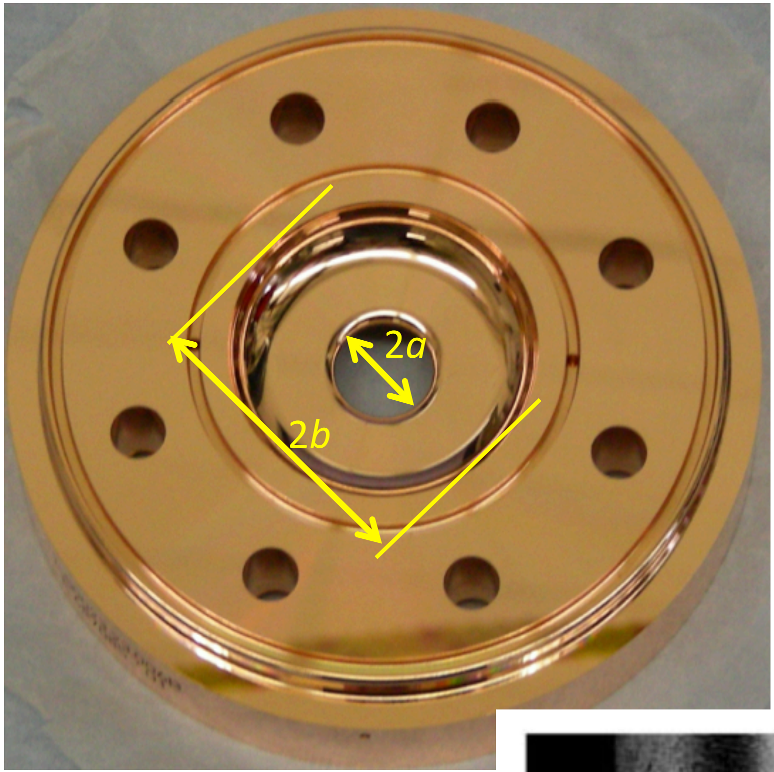
R. Zennaro et al.,

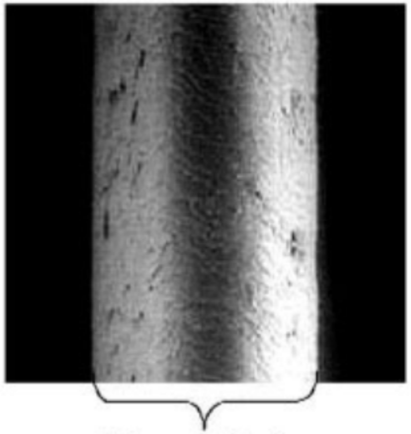
“Measurement and High Power Test of the First C-Band Accelerating Structure for SwissFEL”, Proceedings of LINAC2014, Geneva, Switzerland

Achieved precision at VDL-ETG-Switzerland







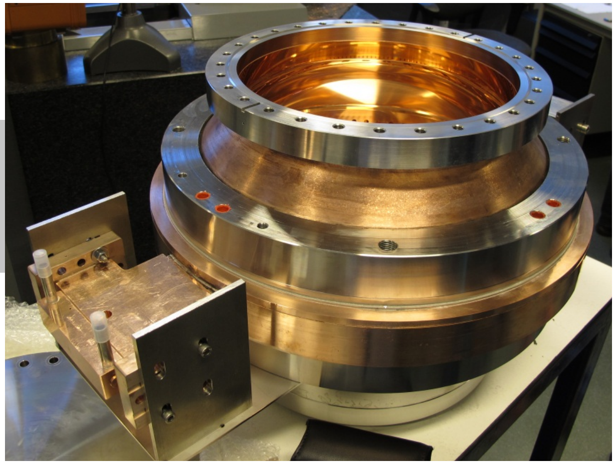


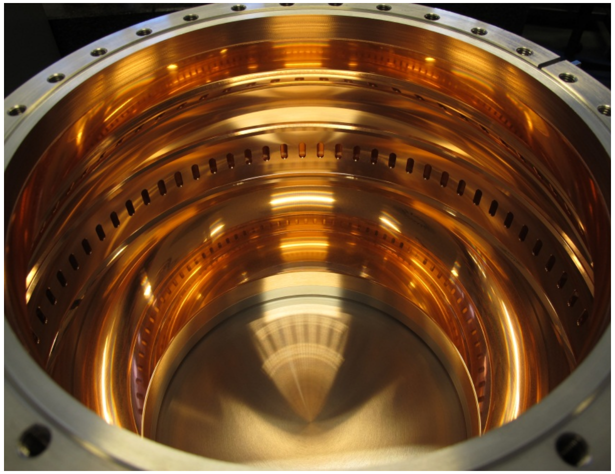
Human Hair
(60 μm diameter)

Courtesy of J.Y. Raguin

Typical examples of metrology on a structure: on top histogram iris diameter ,
on bottom histogram iris cell diameter

RF pulse compressor





RF design:

✓ Single cavity

✓ Whispering gallery mode with analytical solution

✓ intrinsic high Q>200000

Adapted from the original design for S-Band of I. Syratchev (CERN).

Mechanical design:

Simple and robust design:

✓ Inner body from a single piece

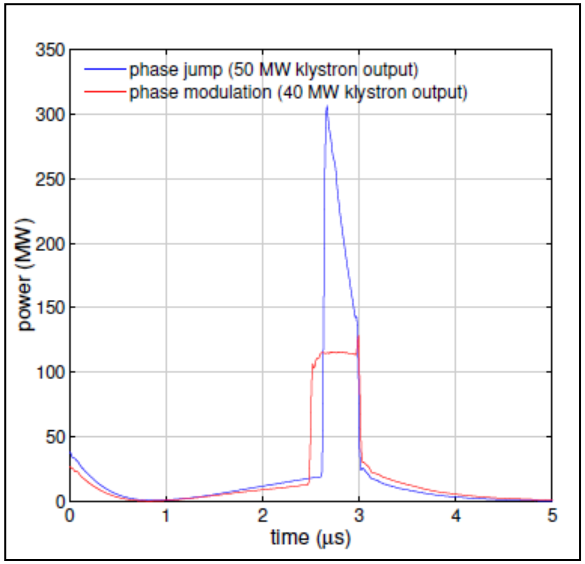
✓ Two brazing steps

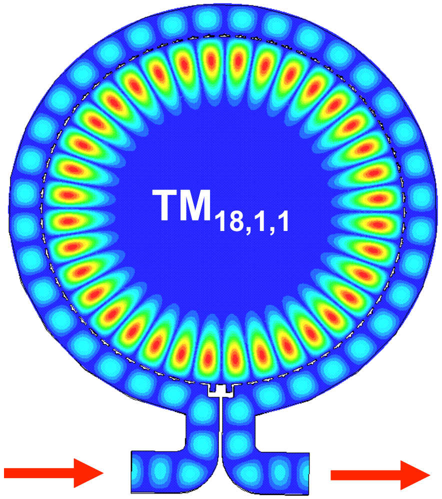
✓ Machined on tune

Production:

✓ 100% in house

✓ 20/26 BOCs ready, no rejections





- R. Zennaro et al., "C-band RF pulse compressor for the SwissFEL", Proc. IPAC 2013, Shanghai
- U. Ellenberger et al., "The SwissFEL C-Band RF Pulse Compressor: Manufacturing and Proof of Precision by RF Measurements", FEL 2014, Basel
- A. Citterio et al., “C-band Load Development for the High Power Test of the SwissFEL RF Pulse Compressor”, LINAC 2014, Geneva
- I. V. Syratchev, “RF pulse compressor systems for CTF3”, Proc. 5-th MDK Workshop, Geneva, June 2001.

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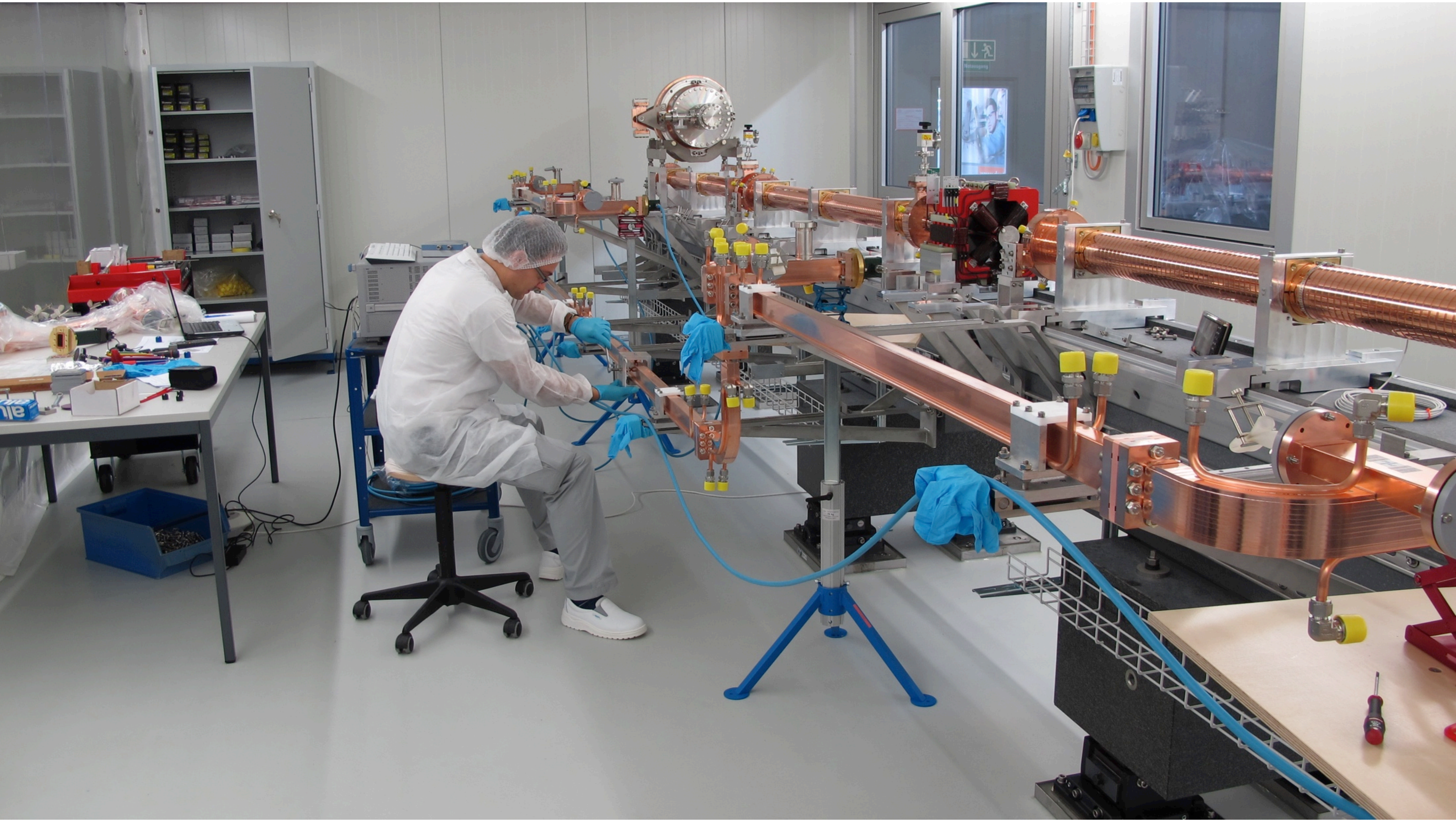
PSI

Waveguide tuning



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Transport of girders in tunnel

First C-band linac modules in SwissFEL tunnel

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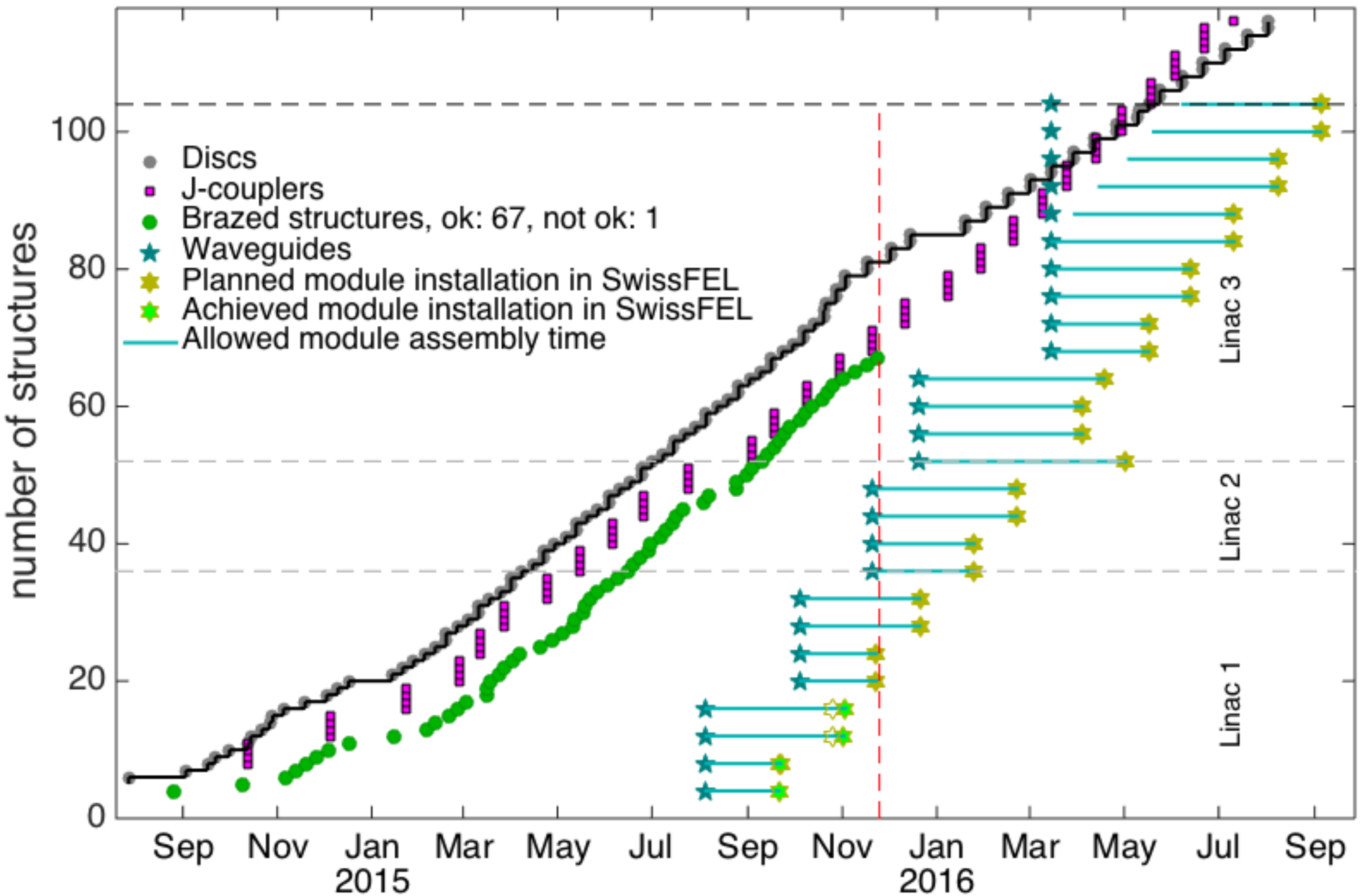
Production plan linac modules

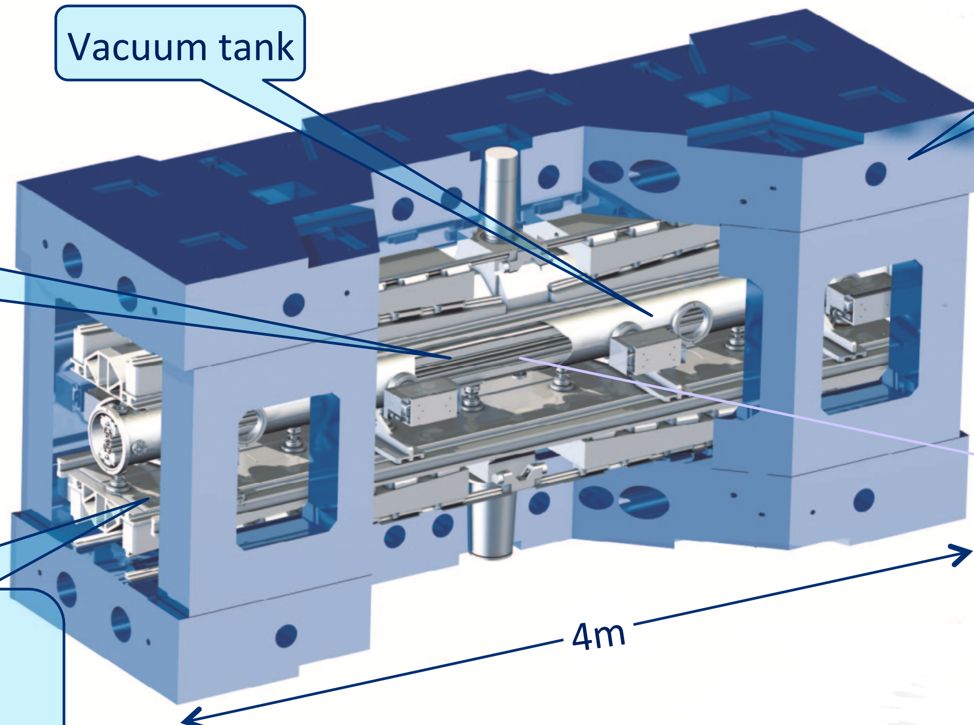


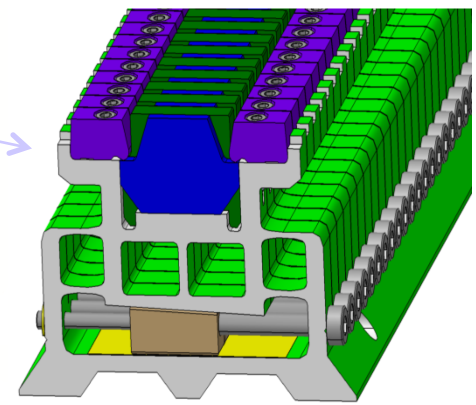
Aramis undulators

courtesy Romain Ganter

m = 17t

12 x U15 for ARAMIS





Magnetic Length	3990 mm
Period λ_u	**15 mm** (266 periods)
Gap	3.2 4.2 4.7 5.5 mm
Undulator K value	1.8 1.4 1.2 1.0
Magnetic field Bz on axis	1.3 1.0 0.9 0.7 T
Magnetic material	NdFeB-Dy
Pole Material	Permendur (CoFeVa)

Design & engineering + final assembly and mag. meas.: PSI

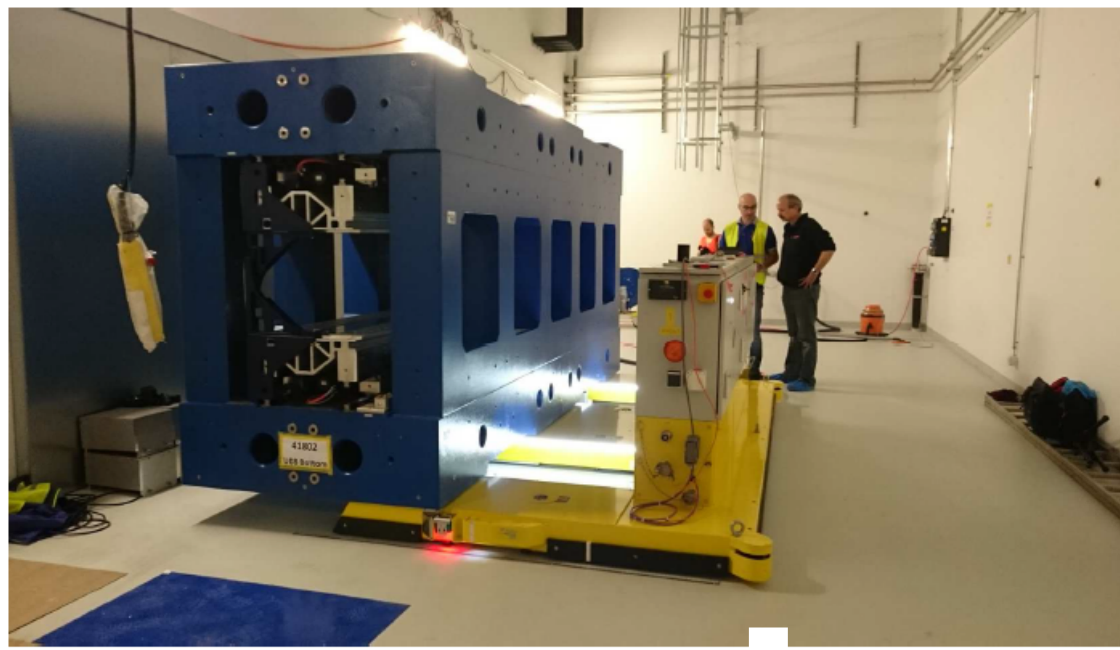
Key industry partners:

- MDC Daetwyler Industries (CH) - frame, gap mechanics
- RI (D) - Assembly magnets on beams
- Hitachi (Jp) - Permanent magnets (series)

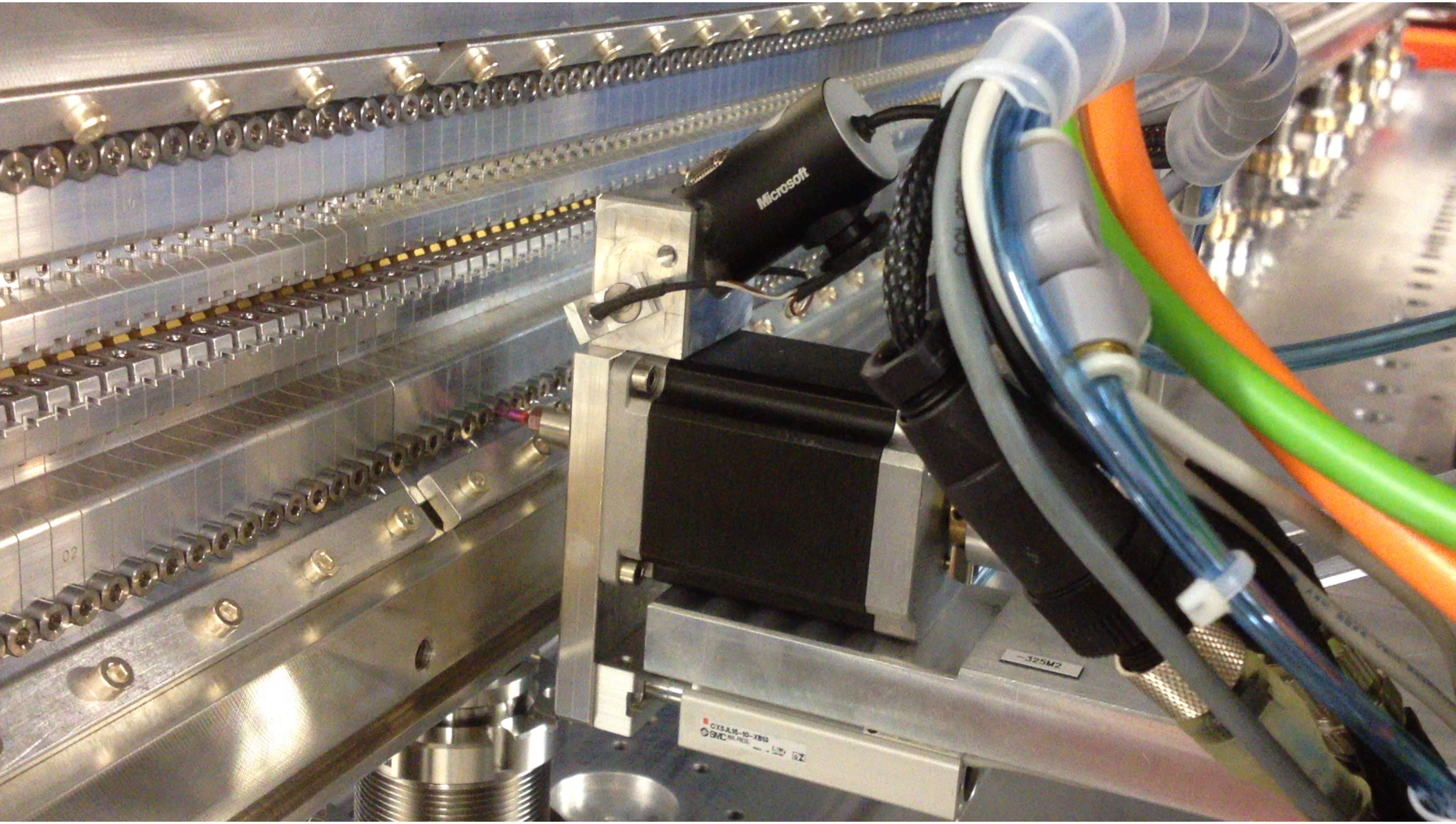
April ‘15, first undulator frames arrive in new SwissFEL building

courtesy Romain Ganter

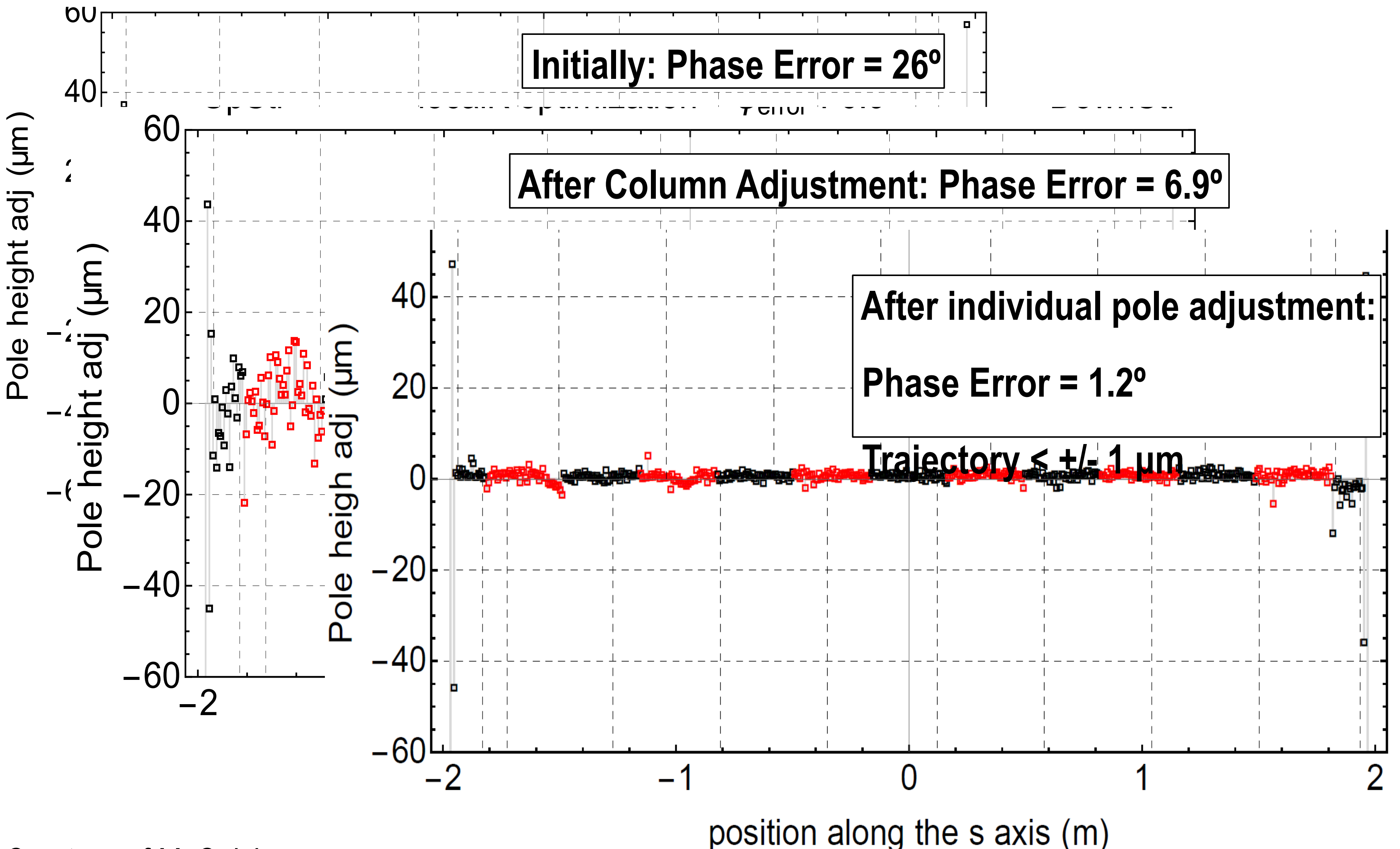
Transport in SwissFEL building with air-cushion vehicle



Robot adjusting position of magnets



Results from first field correction of undulator in new SwissFEL building

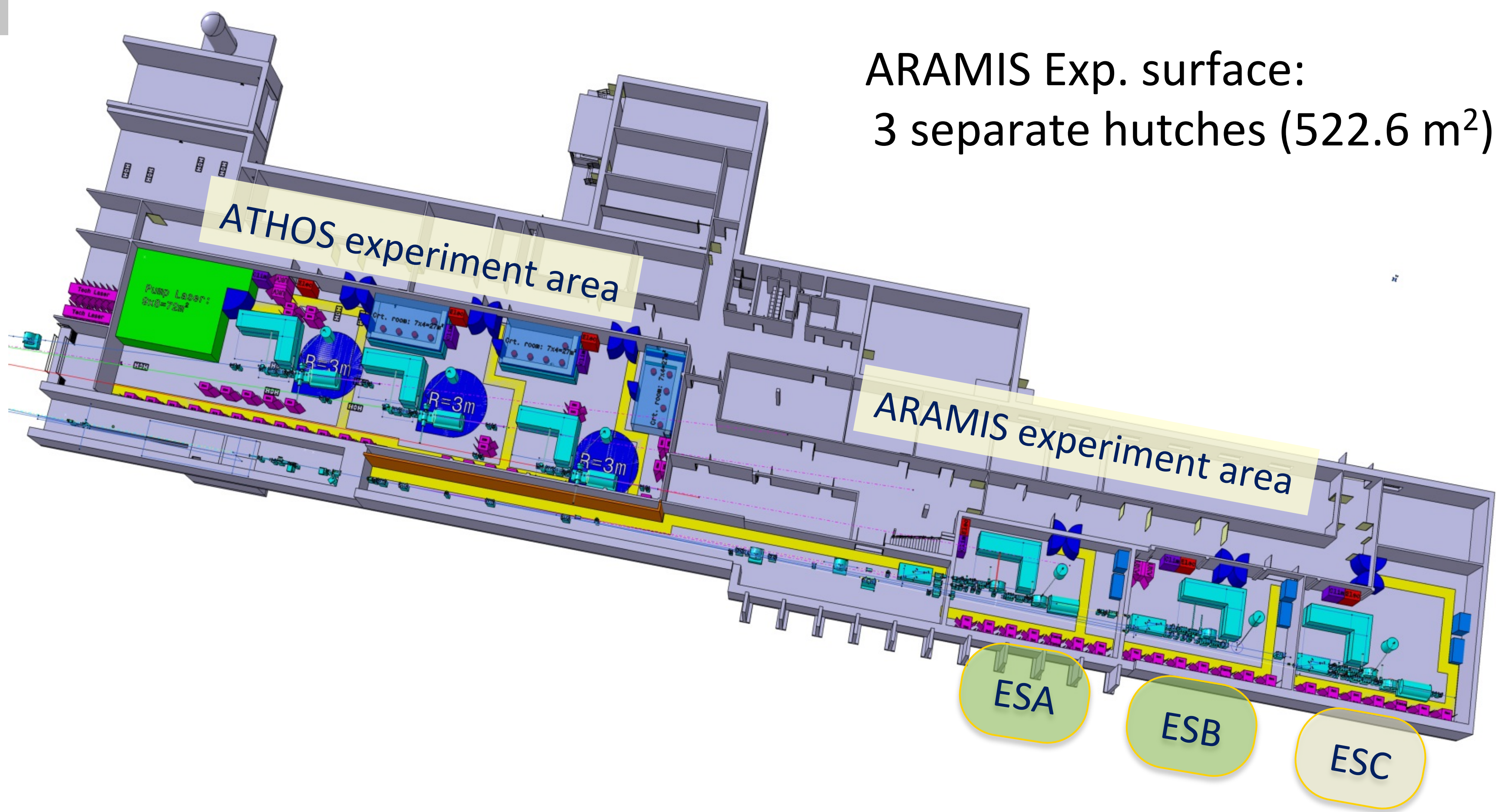


Courtesy of M. Calvi

Experiments

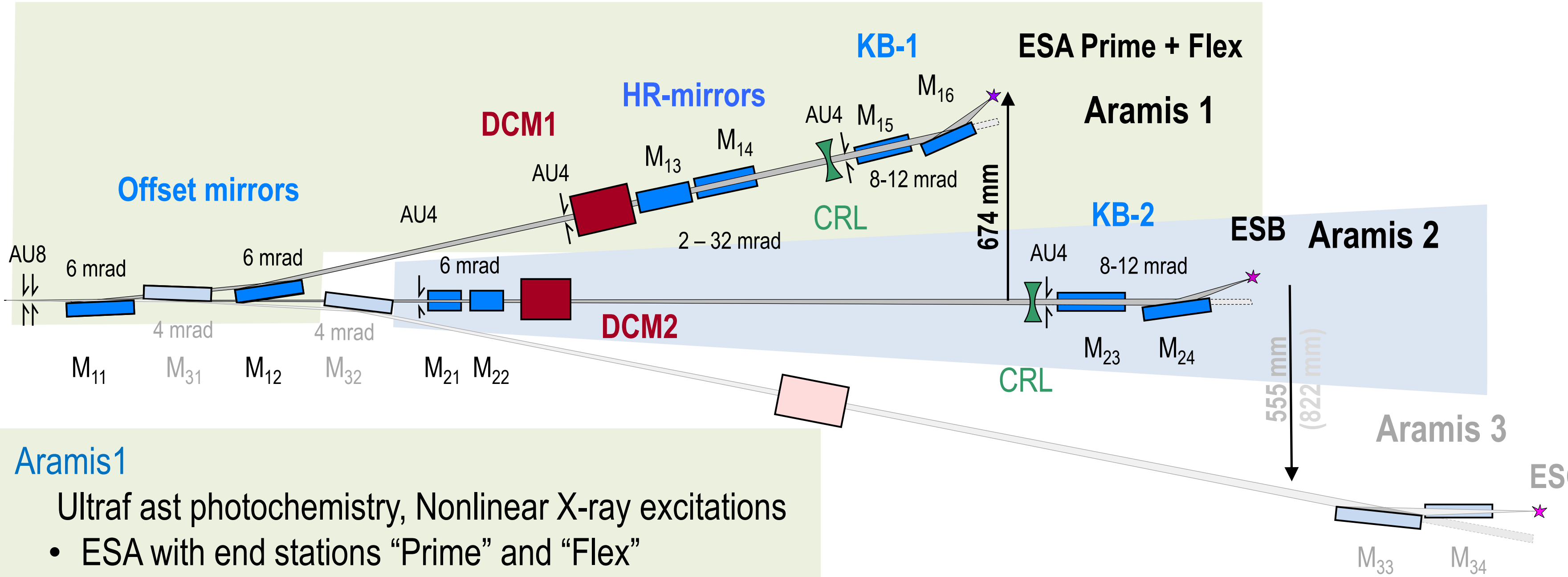
ATHOS Exp. surface:
1 single hutch (692 m²)

ARAMIS Exp. surface:
3 separate hutches (522.6 m²)



ARAMIS photon beamline layout

courtesy Rolf Follath



Aramis1

Ultraf ast photochemistry, Nonlinear X-ray excitations

- ESA with end stations “Prime” and “Flex”
- Harmonic rejection < 10^{-5}
- 1.5 m / 4 m working distance
- Prime focus : <1 µm (ideal optics @12.4 keV)
  Flex focus : 1.5 µm (ideal optics @12.4 keV)

Aramis 2

Pump Probe Diffraction and Scattering

- Grazing incidence (resonant) X-ray diffraction
- 2.5 m working distance
- 2-200 µm spot size
- 1 µm focus size (Ideal optics @ 12.4 keV)

Photon energy range

1.7 – 12.4 keV (1- 7 Å)

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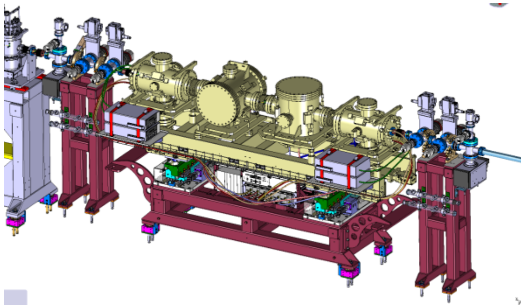
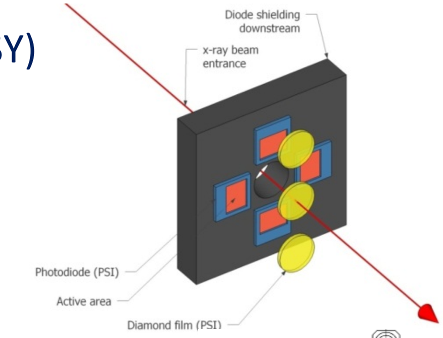
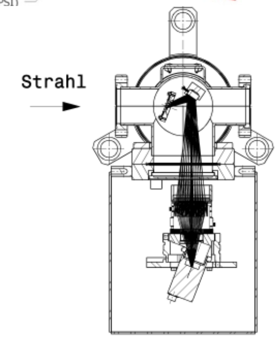
Photon beam diagnostics

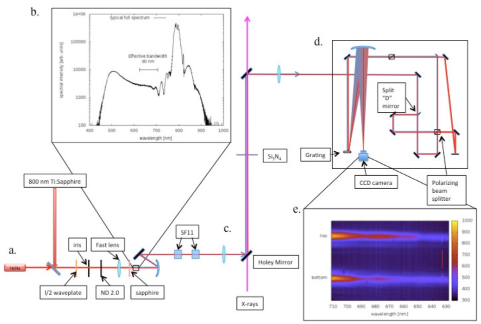
courtesy Pavle Juranic

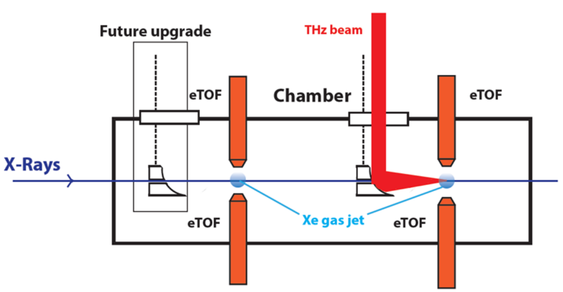


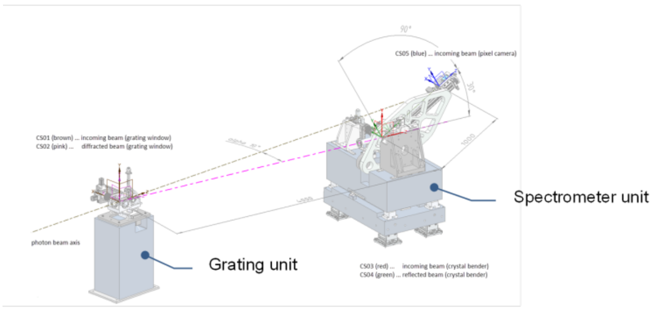
- Gas Beam Position Monitor (PBPG, from DESY)
- Gas Beam Intensity Monitor (PBIM , from DESY)
- Solid Beam Position Monitor (PBPS)
- Profile Monitor (PPRM)
- SR Detector (PSRD)
- Photo-diode Intensity Monitor (PDIM)
- Photon Single Shot Spectrometer (PSSS)
- Photon Arrival and Length Monitor (PALM)
- Photon Spectral Encoding Monitor (PSEN)

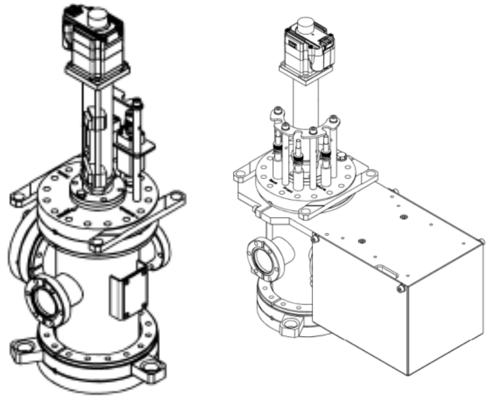






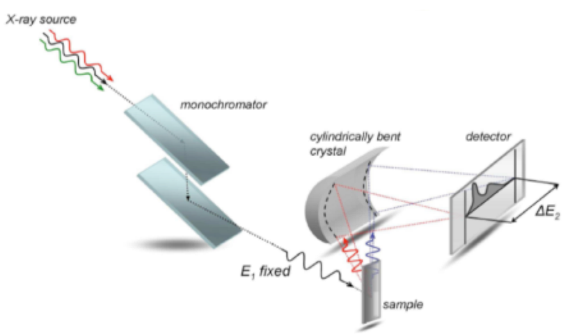






SwissFEL Aramis experimental stations

ESA:
Ultrafast photochemistry and photobiology



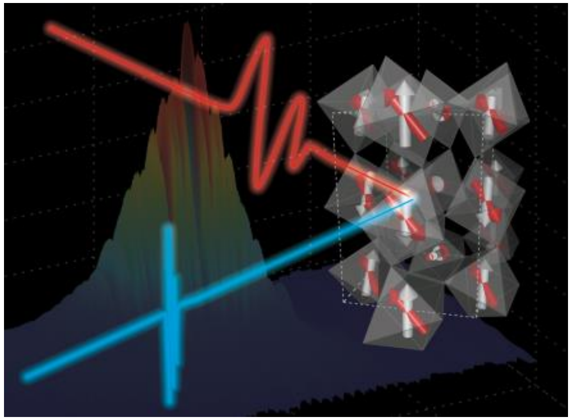
- XAS & XES
- WAXS & SAXS
- SFX

- liquid samples

ESA review January 2014

Phase I (2017)

ESB:
Ultrafast dynamics in solid matter, strongly correlated electron systems

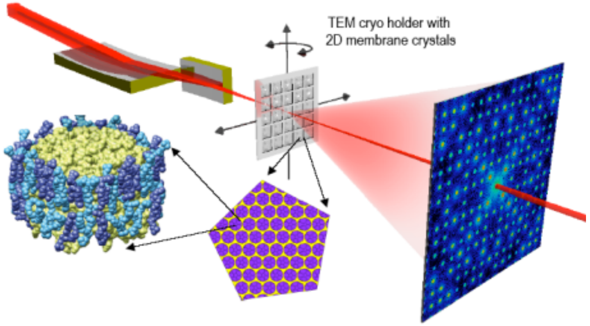


- (resonant) x-ray diffraction
- x-ray scattering: diffuse, inelastic …
- RIXS (phase II)

- Solid matter

Phase I (2017)

ESC:
Coherent diffraction and nanocrystallography



Phase II (>2018)

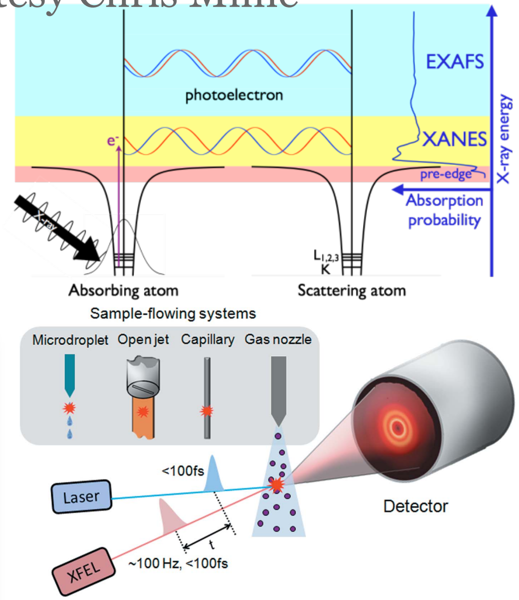
http://www.psi.ch/swissfel/

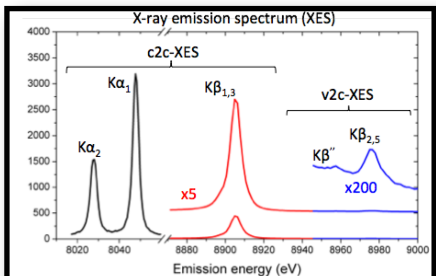
Experimental Station A at SwissFEL

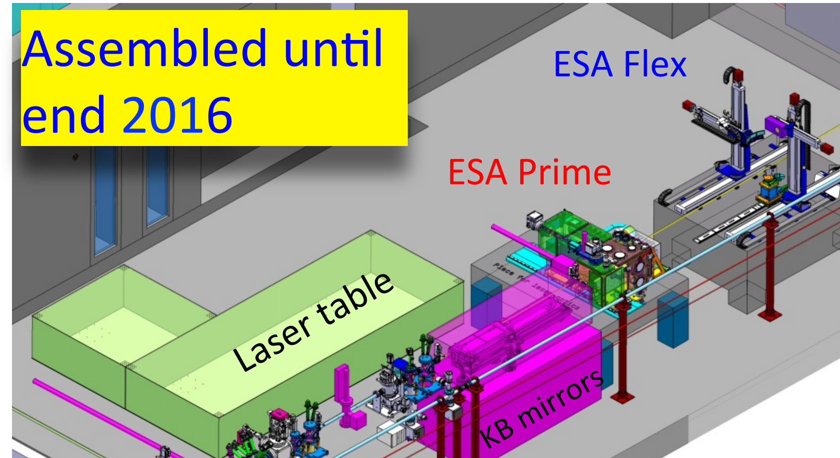
courtesy Chris Milne

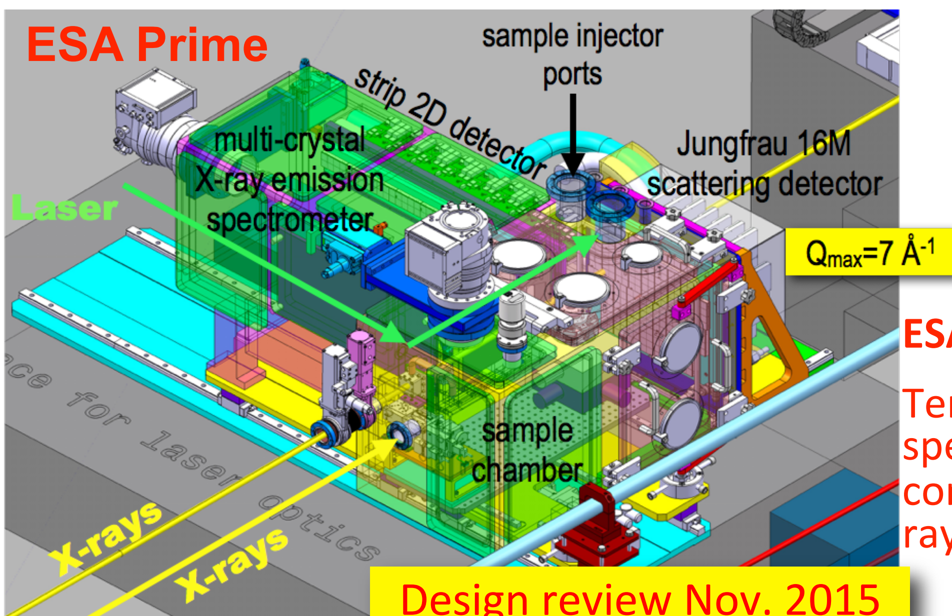
C. Milne,
J. Szlachetko
and G. Knopp

ESA: Ultrafast photochemistry and photobiology







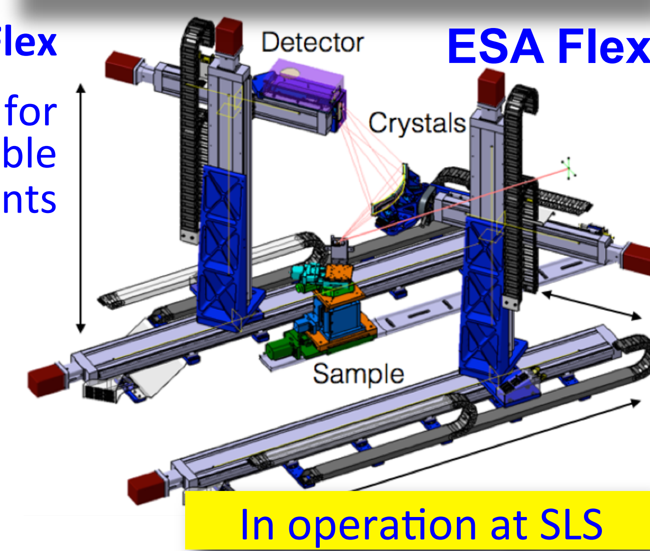


ESA Flex

Flexible station for user-configurable experiments

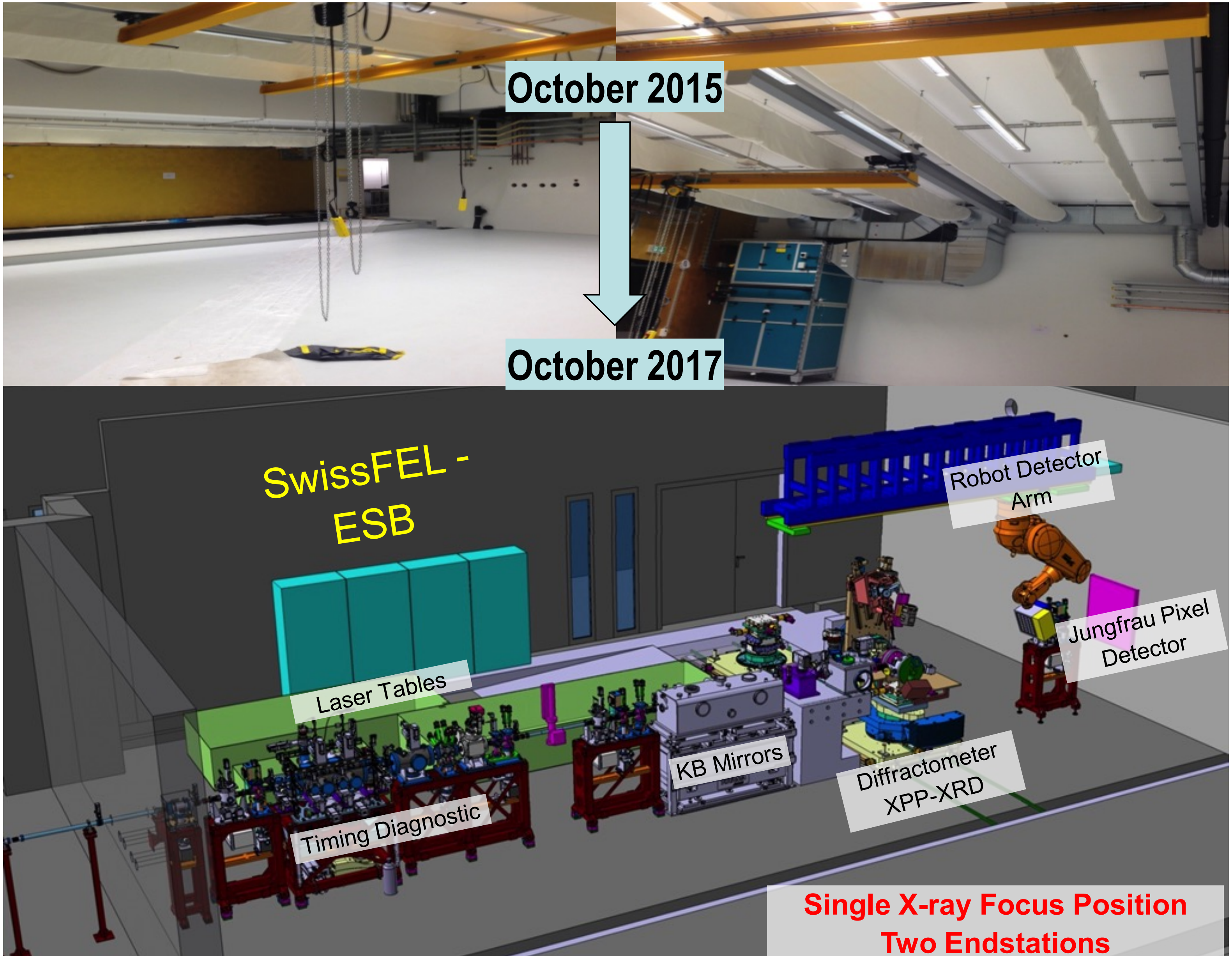
ESA Prime

Tender X-ray spectrometer combined with X-ray scattering



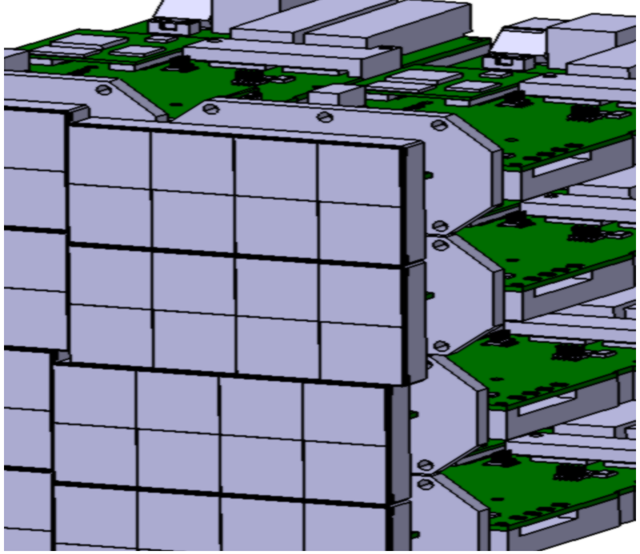
SwissFEL ESB: General Layout (Phase I)

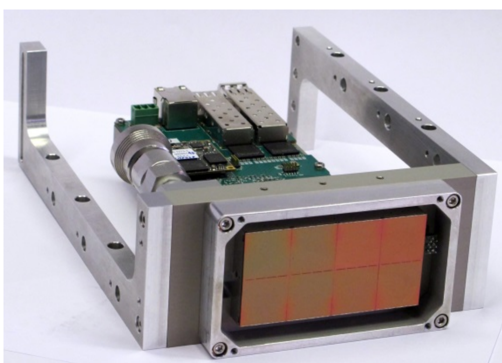
courtesy Gerhard Ingold



The Jungfrau 2D detector
courtesy Aldo Mozzanica

a 4M system drawing





Module in prototype mechanics

- Specifically developed for SwissFEL applications
- Charge integrating detector with dynamic gain switching, with:
  - Front-end electronics similar to AGIPD and GOTTHARD
  - Dimensions, sensor and mechanics similar to the EIGER project: 75x75 μm^2 pixel size, 4x8 cm^2 module area.

- 500k (one module), 1M (2 modules), 4M and 16M (ESA-ESB main instruments, 32 modules) systems are foreseen
- Horizontal gaps very small (8px)
- compact (20-25cm) in the Z direction
- Vacuum compatible option

jungfrau

JUNGFRAU 0.1: A. Mozzanica et al., JINST, 9, C05010, 2014

JUNGFRAU 0.2: J. H. Jungmann-Smith et al., JINST, 9, P12013, 2014

JUNGFRAU Technical Design Report, J.H. Smith et al.,SwissFEL website, 2015

Thank you for your attention