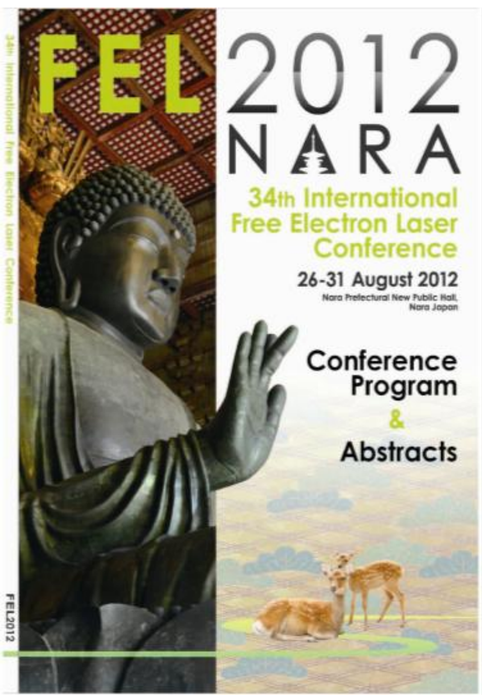
PAUL SCHERRER INSTITUT

SWISSFEL, The X-ray Free Electron Laser at PSI

Hans-H. Braun on behalf of the SwissFEL team



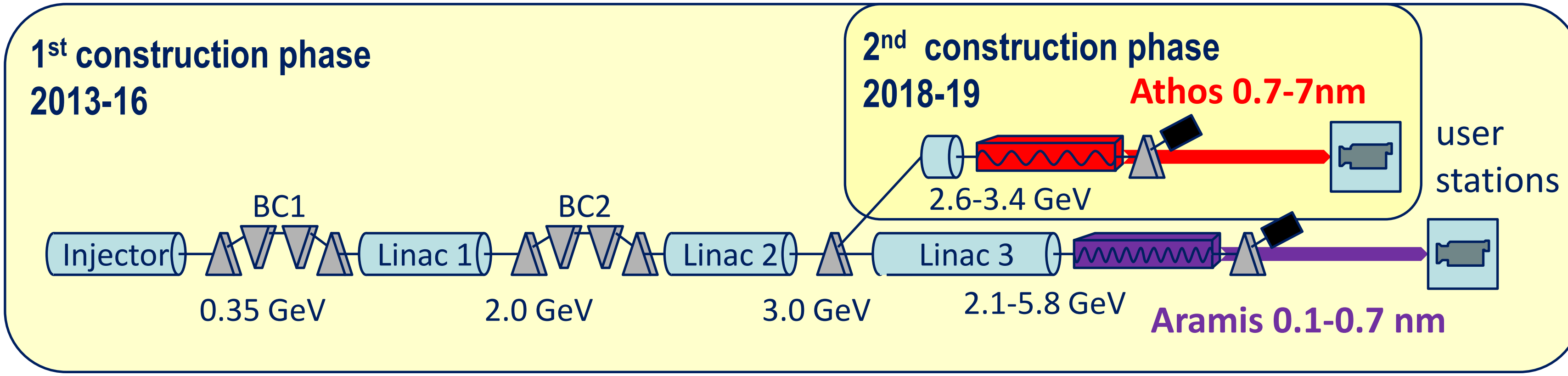
34th International Free Electron Laser Conference

Nara, August 26-31, 2012

Outline

- Overview
- Injector Test Facility
- Progress with C-band main Linac
- Undulators

SwissFEL



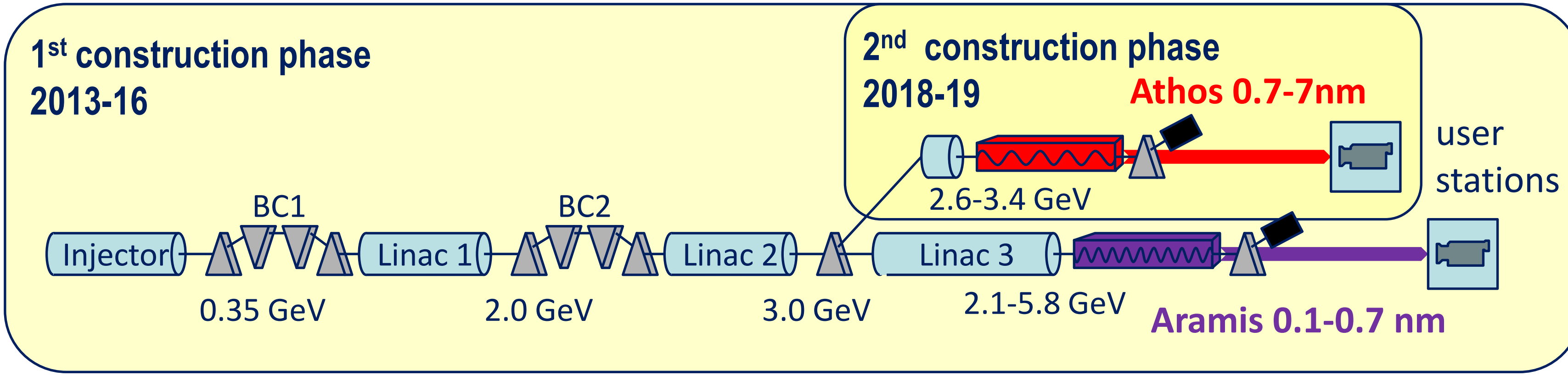
Aramis

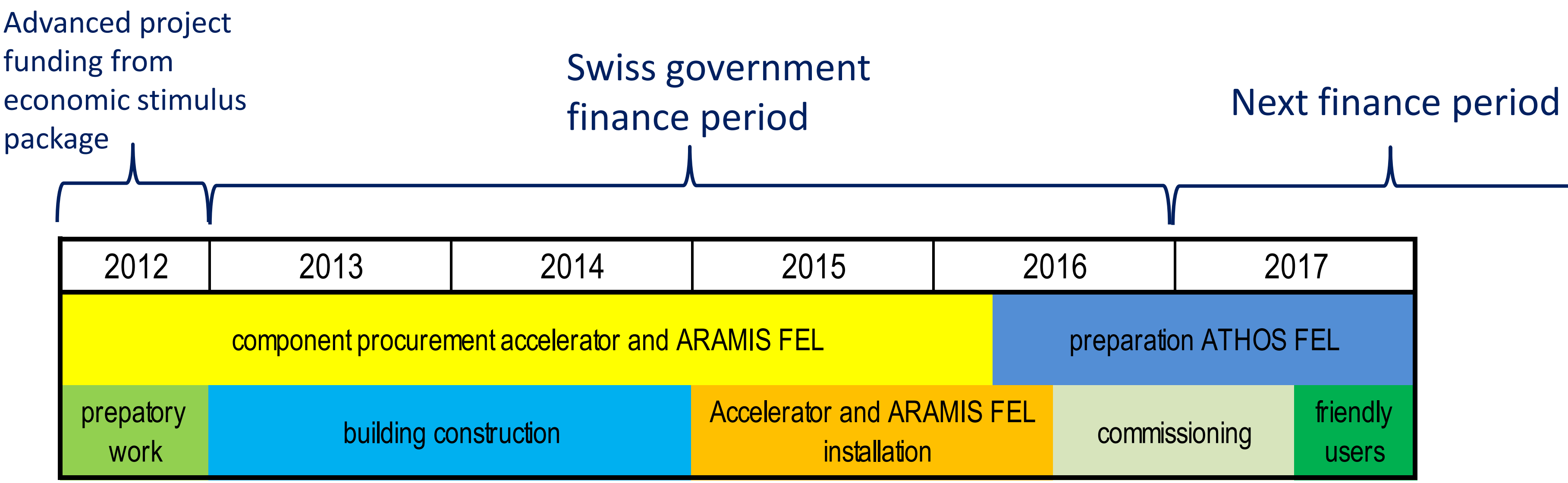
1-7 Å hard X-ray FEL for **SASE with reservations for self seeded** operation,
In-vacuum, planar undulators with variable gap.
User operation from 2017

Athos

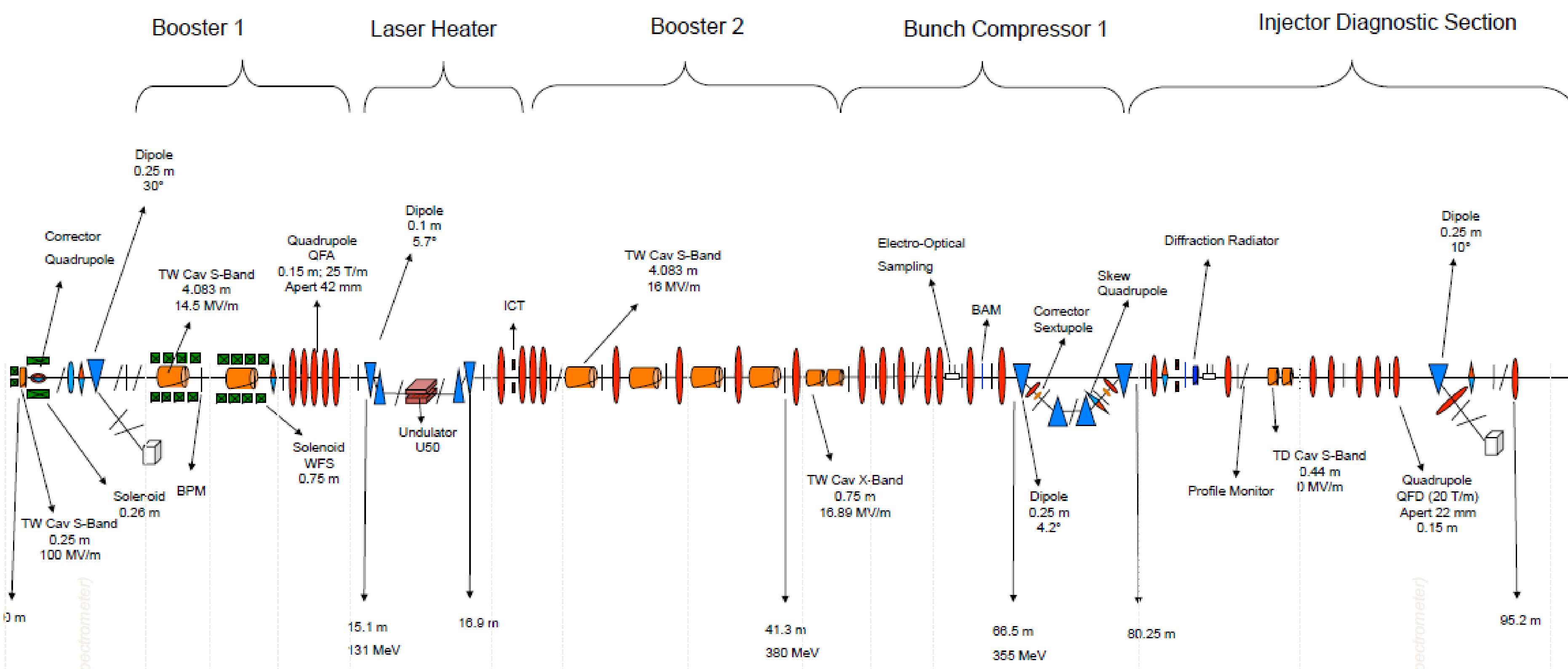
7-70 Å soft X-ray FEL for **SASE & self seeded** operation .
APPLE II undulators with variable gap and full polarization control.
User operation from 2019

Schedule

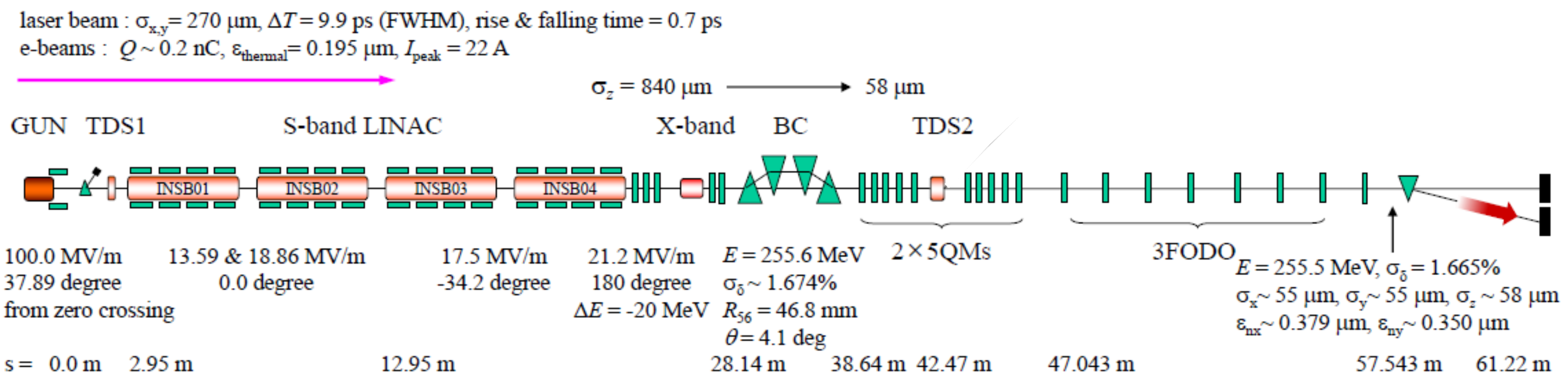

1st construction phase
2013-16
2nd construction phase
2018-19
Athos 0.7-7nm
user
stations
2.6-3.4 GeV
BC1
BC2
Injector
Linac 1
Linac 2
Linac 3
0.35 GeV
2.0 GeV
3.0 GeV
2.1-5.8 GeV
Aramis 0.1-0.7 nm


Advanced project funding from economic stimulus package
Swiss government finance period
Next finance period
2012
2013
2014
2015
2016
2017
component procurement accelerator and ARAMIS FEL
preparation ATHOS FEL
prepatory work
building construction
Accelerator and ARAMIS FEL installation
commissioning
friendly users

Injector


Booster 1
Laser Heater
Booster 2
Bunch Compressor 1
Injector Diagnostic Section
Dipole
0.25 m
30°
Corrector
Quadrupole
TW Cav S-Band
4.083 m
14.5 MV/m
Quadrupole
QFA
0.15 m; 25 T/m
Apert 42 mm
Dipole
0.1 m
5.7°
ICT
TW Cav S-Band
4.083 m
16 MV/m
Electro-Optical
Sampling
BAM
Corrector
Sextupole
Skew
Quadrupole
Diffraction Radiator
Dipole
0.25 m
10°
Solenoid
WFS
0.75 m
Undulator
U50
Solenoid
0.26 m
BPM
TW Cav S-Band
0.25 m
100 MV/m
TW Cav X-Band
0.75 m
16.89 MV/m
Dipole
0.25 m
4.2°
Profile Monitor
TD Cav S-Band
0.44 m
Quadrupole
QFD (20 T/m)
Apert 22 mm
0.15 m
15.1 m
16.9 m
41.3 m
380 MeV
66.5 m
355 MeV
80.25 m
95.2 m

SwissFEL inector Tesf facility

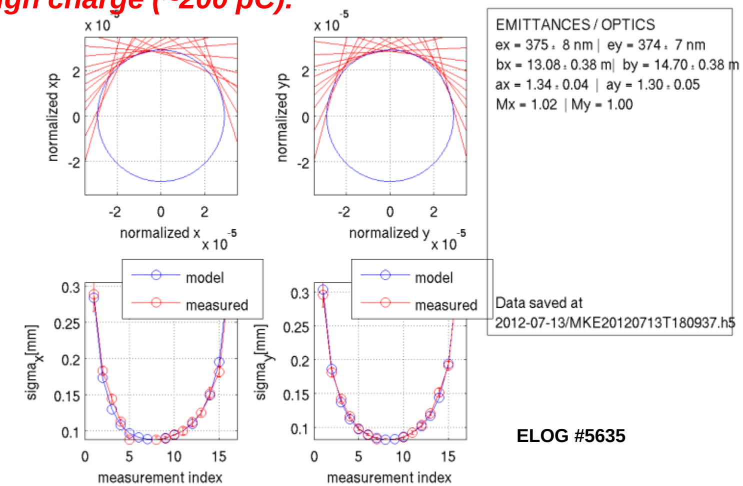


SwissFEL Injector Test Facility

Emittance optimization (uncompressed beam)

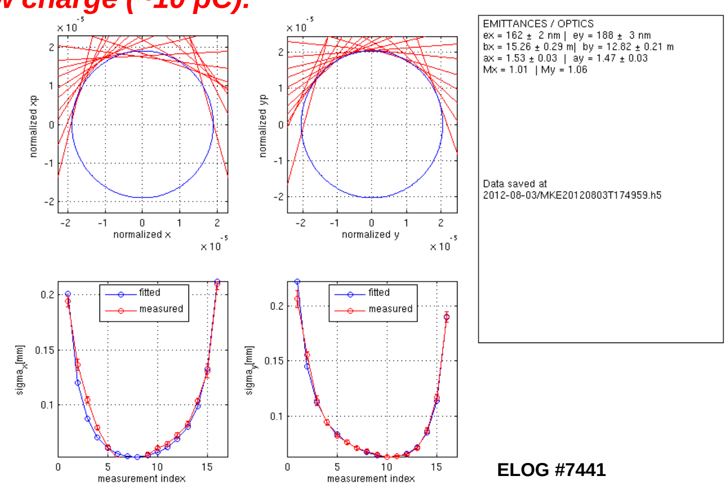
Example measurements projected emittance (symmetrized single-quad scan)

High charge (~200 pC):



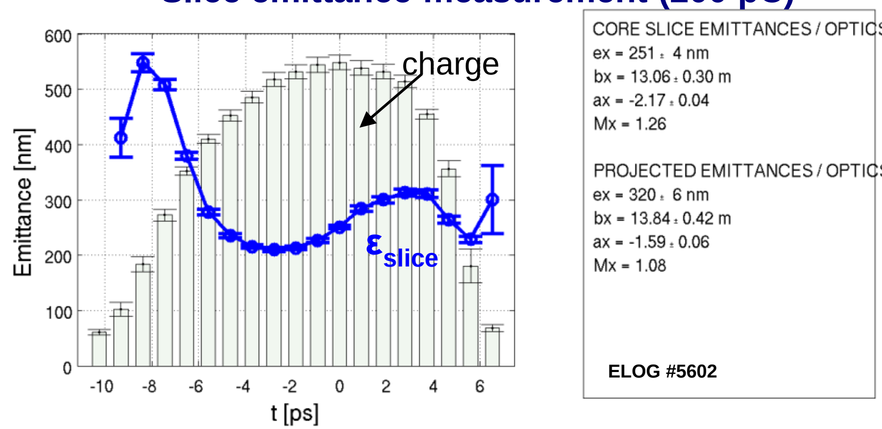
ELOG #5635

Low charge (~10 pC):



ELOG #7441

Slice emittance measurement (200 pC)



Key steps for optimization:

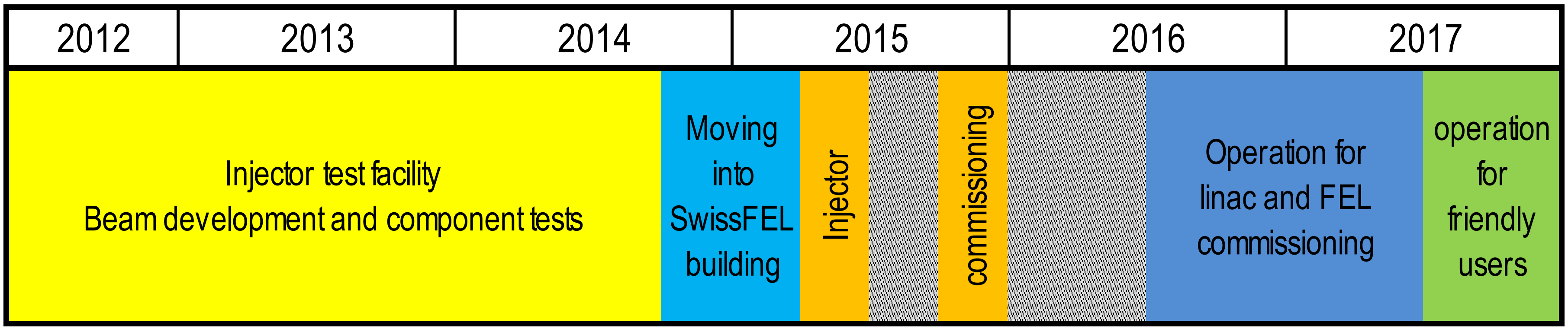
- Optimization gun solenoid (incl. corrector quads)
- Orbit correction in S-band structures (wakefields)
- Local correction of dispersion at observation point

Summary emittance measurements (uncompressed beam):

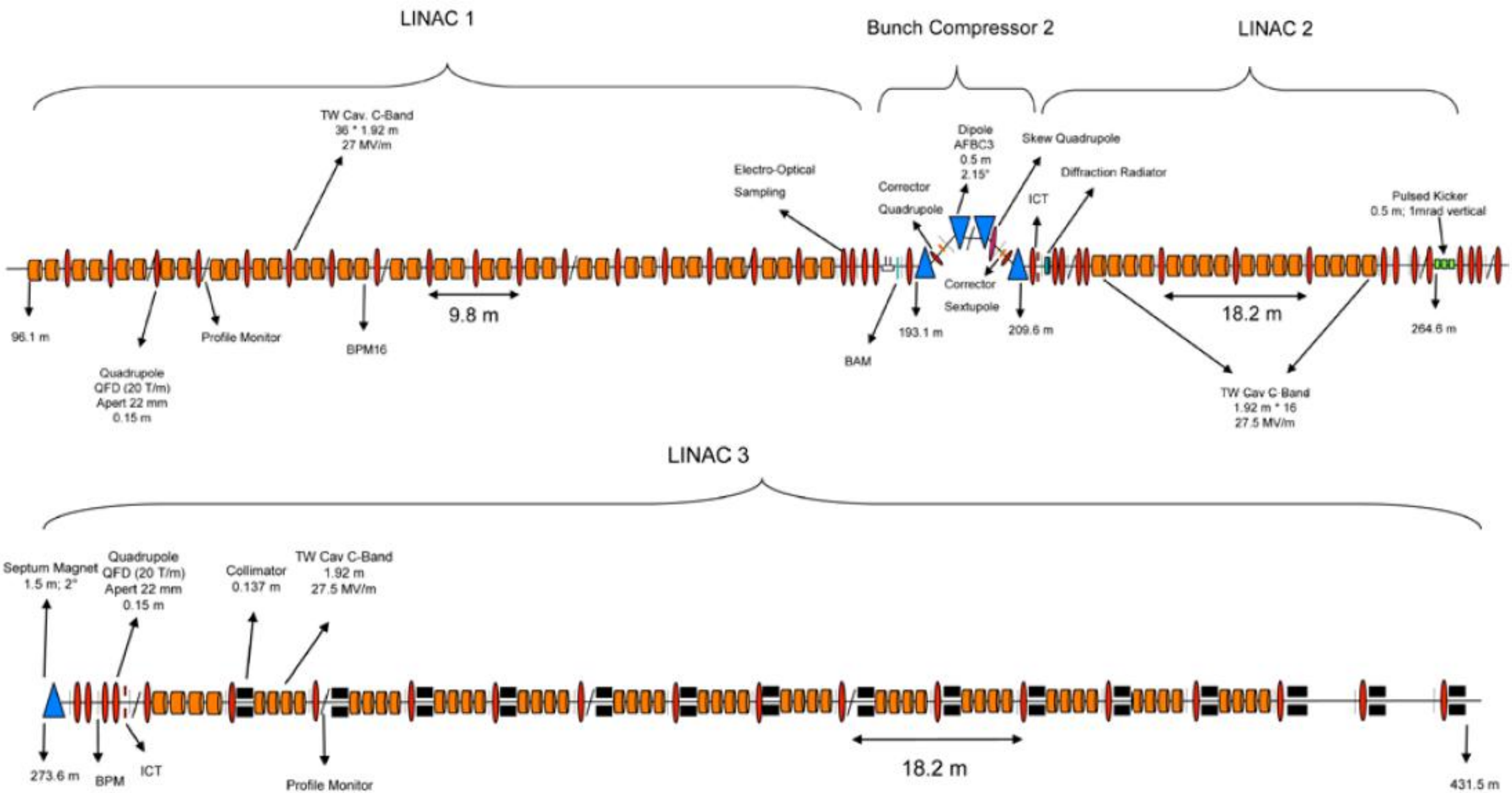
Measurement	σ_{laser} [mm]	$\varepsilon_{n,x}$ [µm]	$\varepsilon_{n,y}$ [µm]	$\varepsilon_{n,simulated}$ [µm]	$\varepsilon_{n,required}$ @undulator [µm]
High-charge mode (~200 pC):					
projected:	0.21	0.38	0.37	0.350	0.65
core slice:	0.21	0.25	–	0.330	0.43
Low-charge mode (~10 pC):					
projected:	0.10	0.16	0.18	0.096	0.25
core slice:	0.10	≤ 0.15*	–	0.080	0.18

*measurement limited by signal-to-noise ratio

Injector schedule



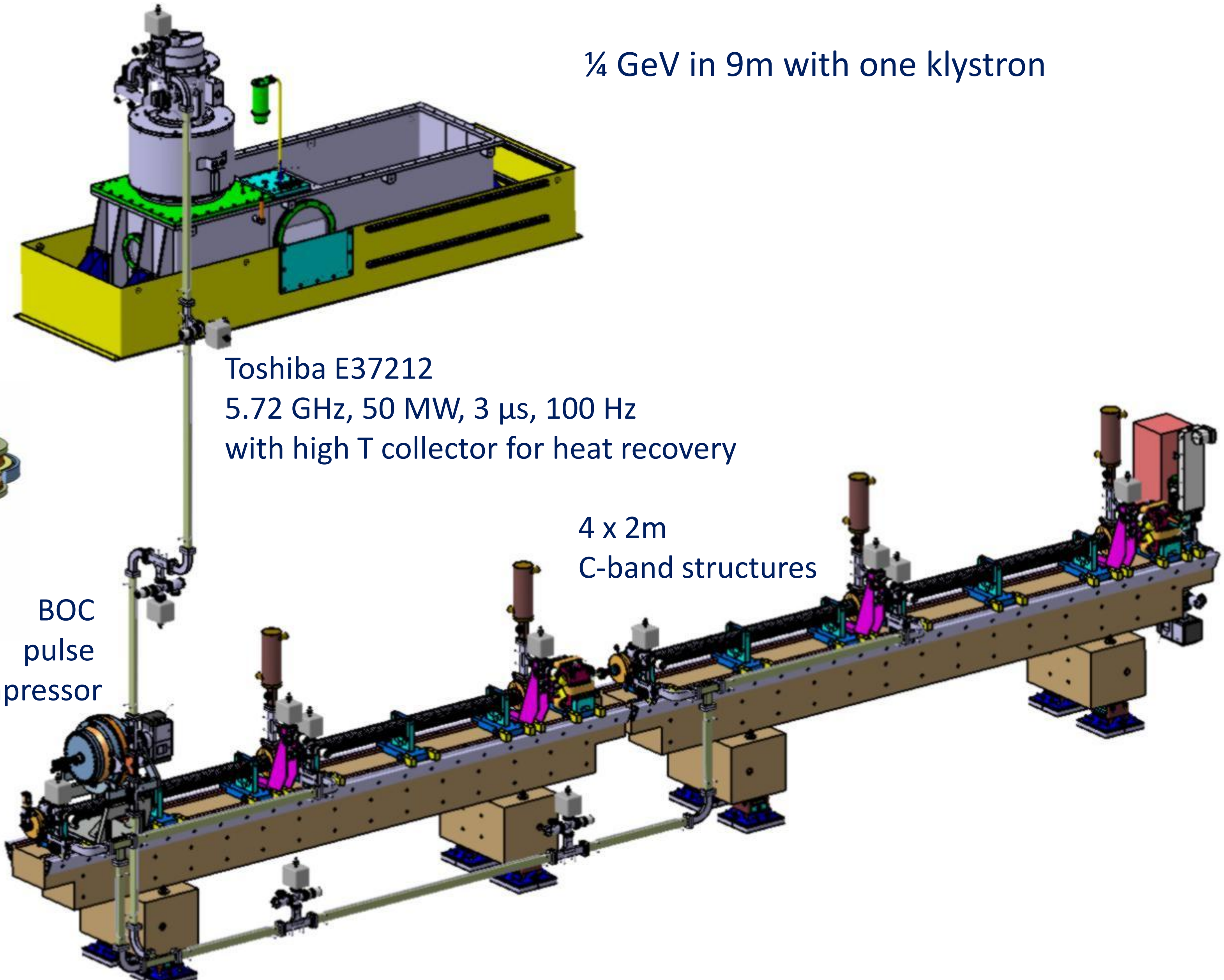
Linac



LINAC 1
Bunch Compressor 2
LINAC 2
TW Cav. C-Band
36 * 1.92 m
27 MV/m
Electro-Optical
Sampling
Corrector
Quadrupole
Dipole
AFBC3
0.5 m
2.15°
Skew Quadrupole
Diffraction Radiator
ICT
Pulsed Kicker
0.5 m; 1mrad vertical
96.1 m
Quadrupole
QFD (20 T/m)
Apert 22 mm
0.15 m
Profile Monitor
BPM16
9.8 m
BAM
193.1 m
Corrector
Sextupole
209.6 m
18.2 m
264.6 m
TW Cav C-Band
1.92 m * 16
27.5 MV/m
LINAC 3
Septum Magnet
1.5 m; 2°
Quadrupole
QFD (20 T/m)
Apert 22 mm
0.15 m
Collimator
0.137 m
TW Cav C-Band
1.92 m
27.5 MV/m
273.6 m
BPM
ICT
Profile Monitor
18.2 m
431.5 m

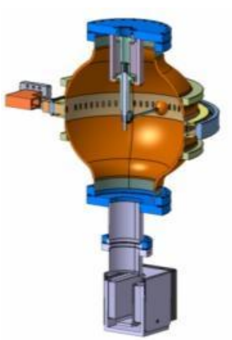
SwissFEL C-Band Linac Module

¼ GeV in 9m with one klystron



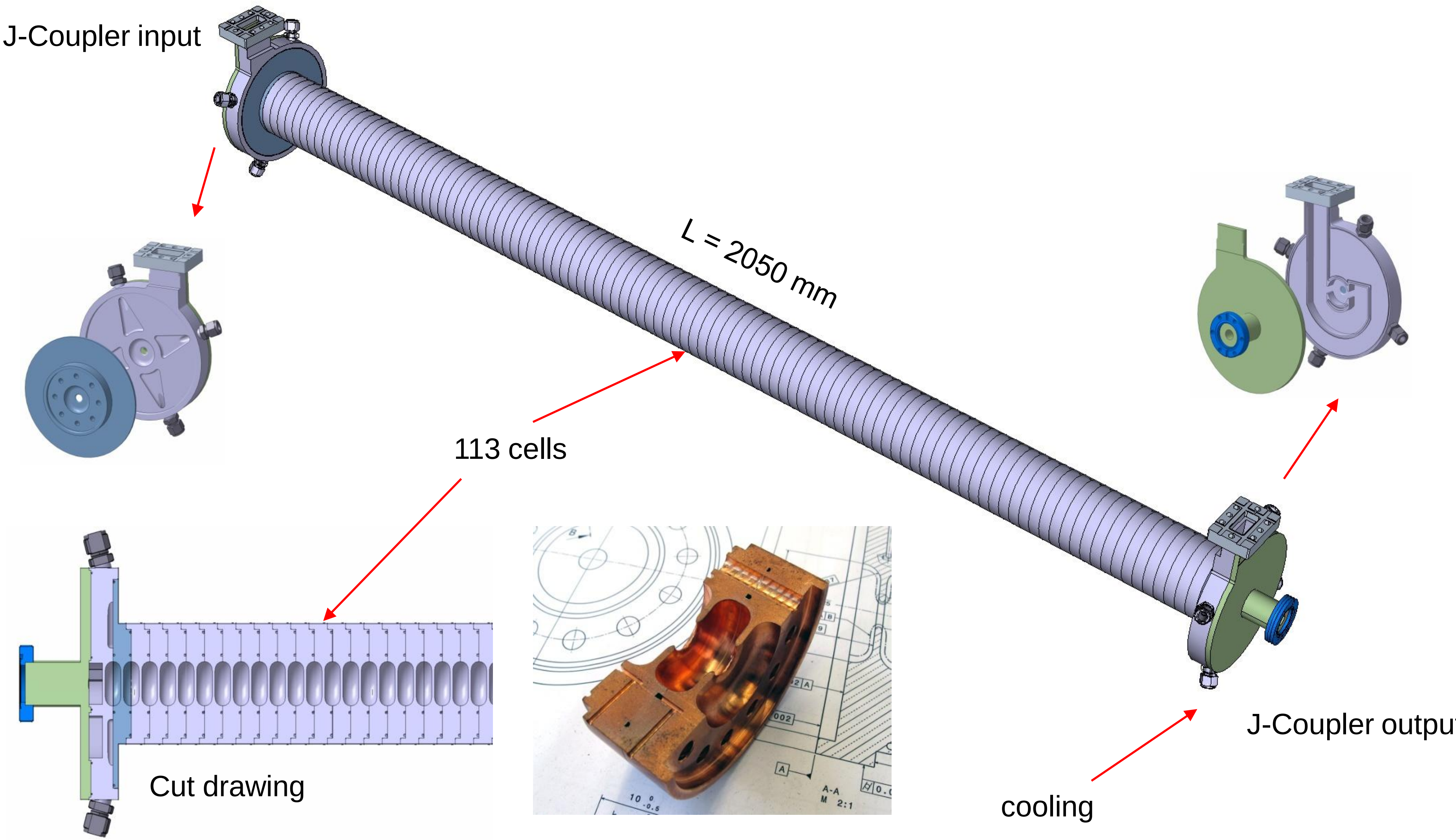
Toshiba E37212
5.72 GHz, 50 MW, 3 µs, 100 Hz
with high T collector for heat recovery

4 x 2m
C-band structures



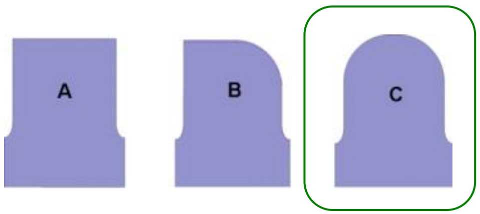
BOC
pulse
compressor

C-Band Structure

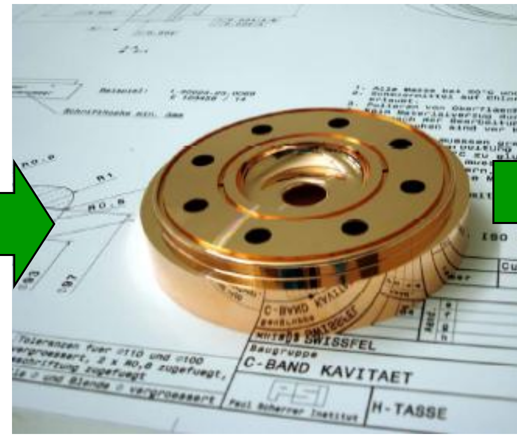


First SwissFEL C-band cavity prototype successfully tested

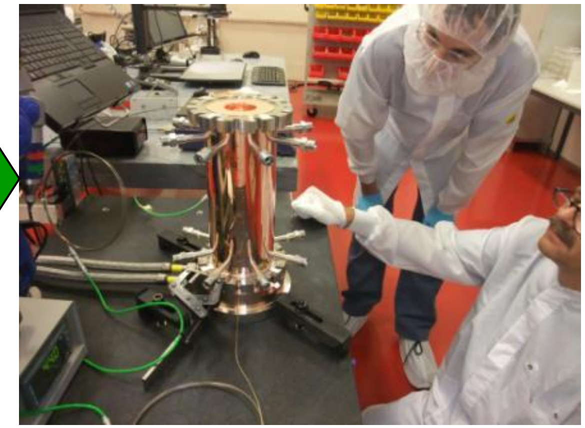
RF designs

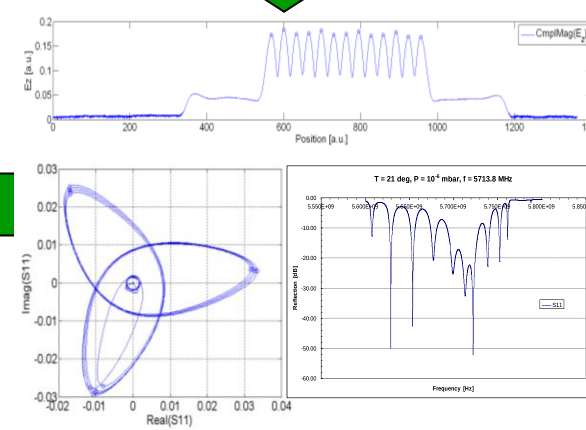


mech. design & UP machining

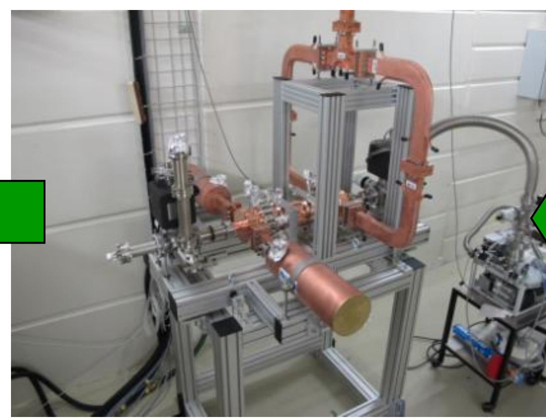


Assembly & brazing

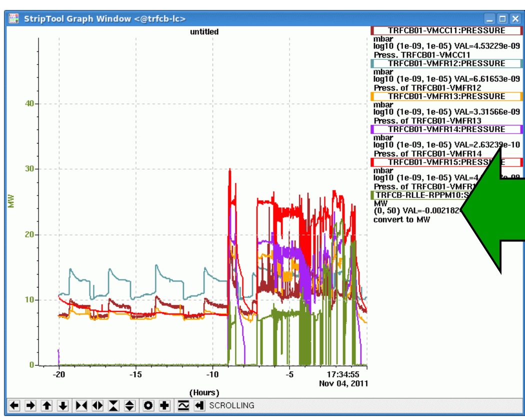




LL RF measurements



HP RF set-up

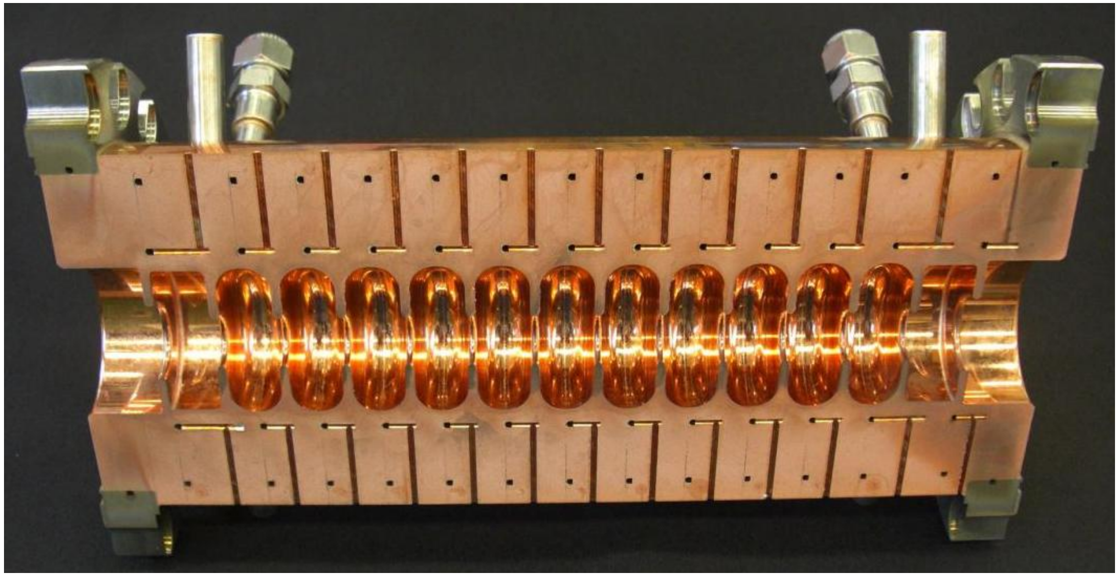


HP RF processing

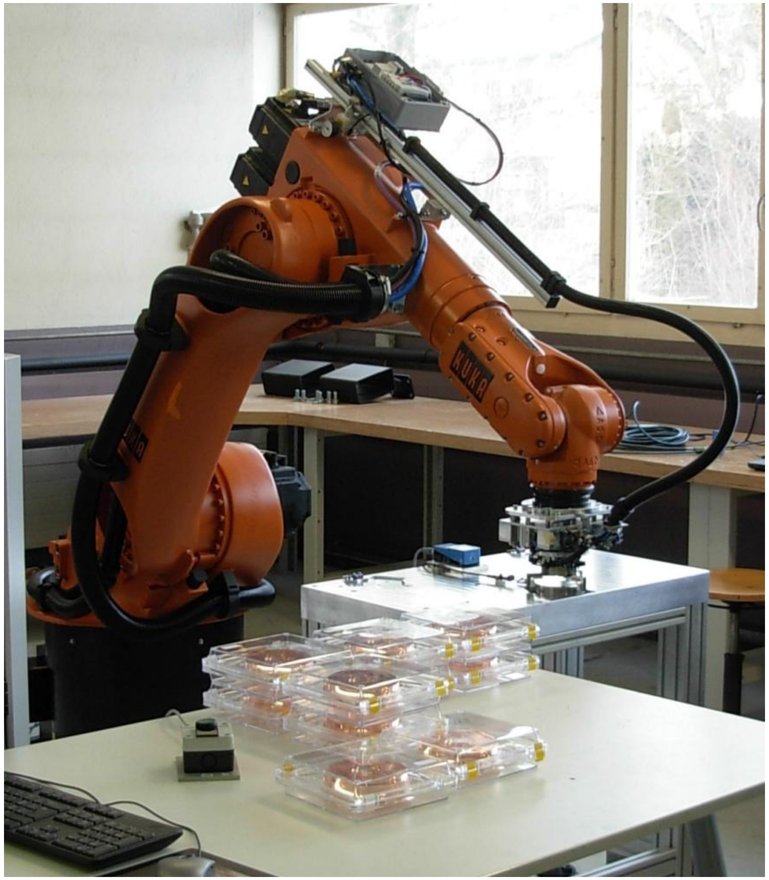
Results C-band short prototype structure high power tests

Test structure #	# cells	Ø iris mm	bake-out	P_{in} MW	E_{acc} MV/m	T_{pulse} µs	rep. rate Hz	break-down prob.	β_{FN}
1	11	14.6	yes	43	33.5	0.35	10	$8 \cdot 10^{-7}$	68
2	11	14.6	no	50	36.0	1.0	100	$3 \cdot 10^{-6}$	68
3*	11	11.2	no	49	57.0	0.8	100	$1 \cdot 10^{-6}$	45
SwissFEL nominal	113	14.6→11.2	no	28	28.0	0.35	100	$1 \cdot 10^{-8}$	

*Test in progress

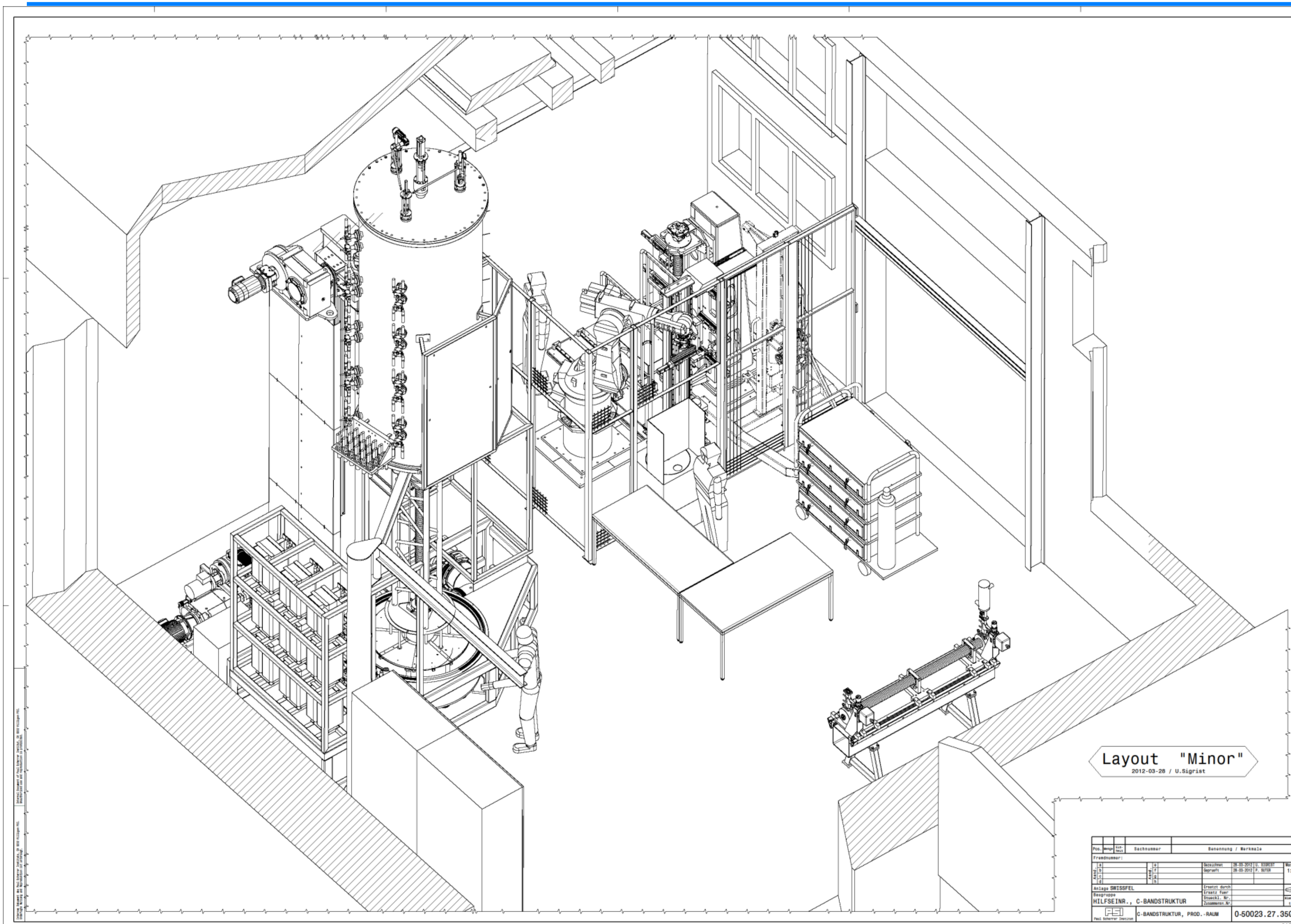


RF structure assembly robot



New brazing furnace for 2m linac structures

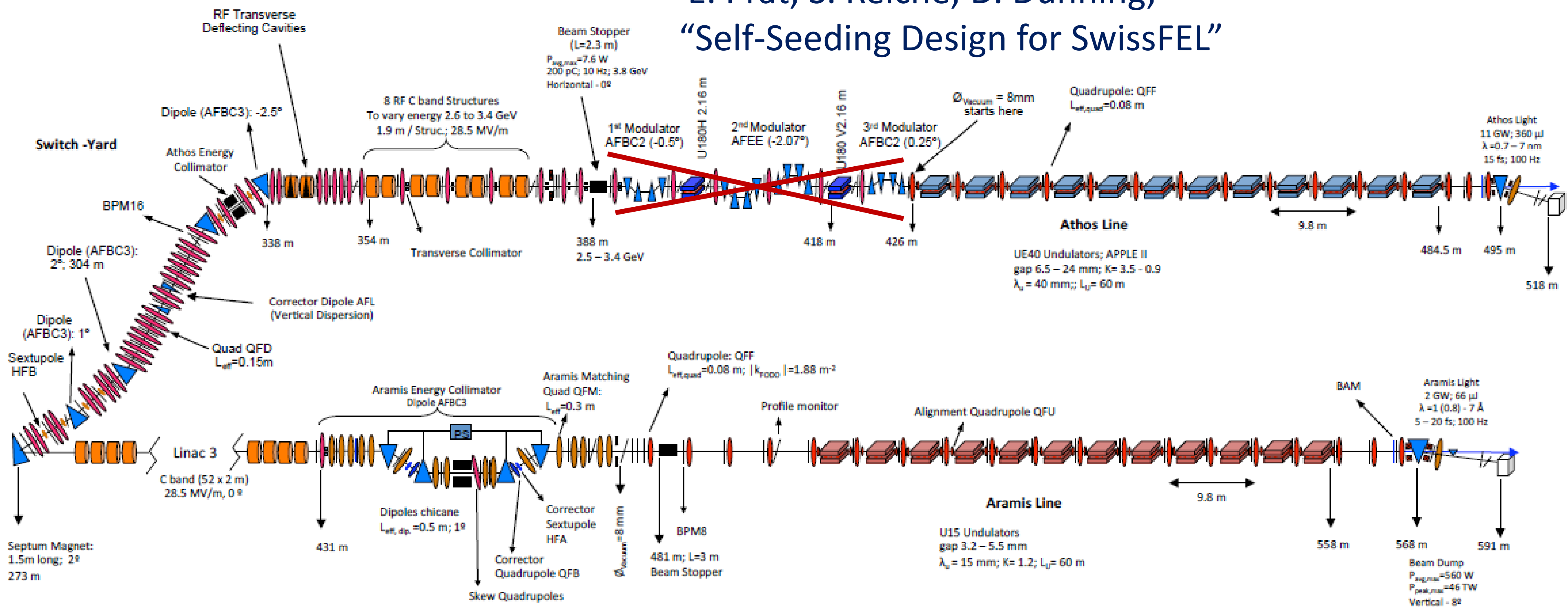
Assembly & brazing set-up for series production



Undulator lines

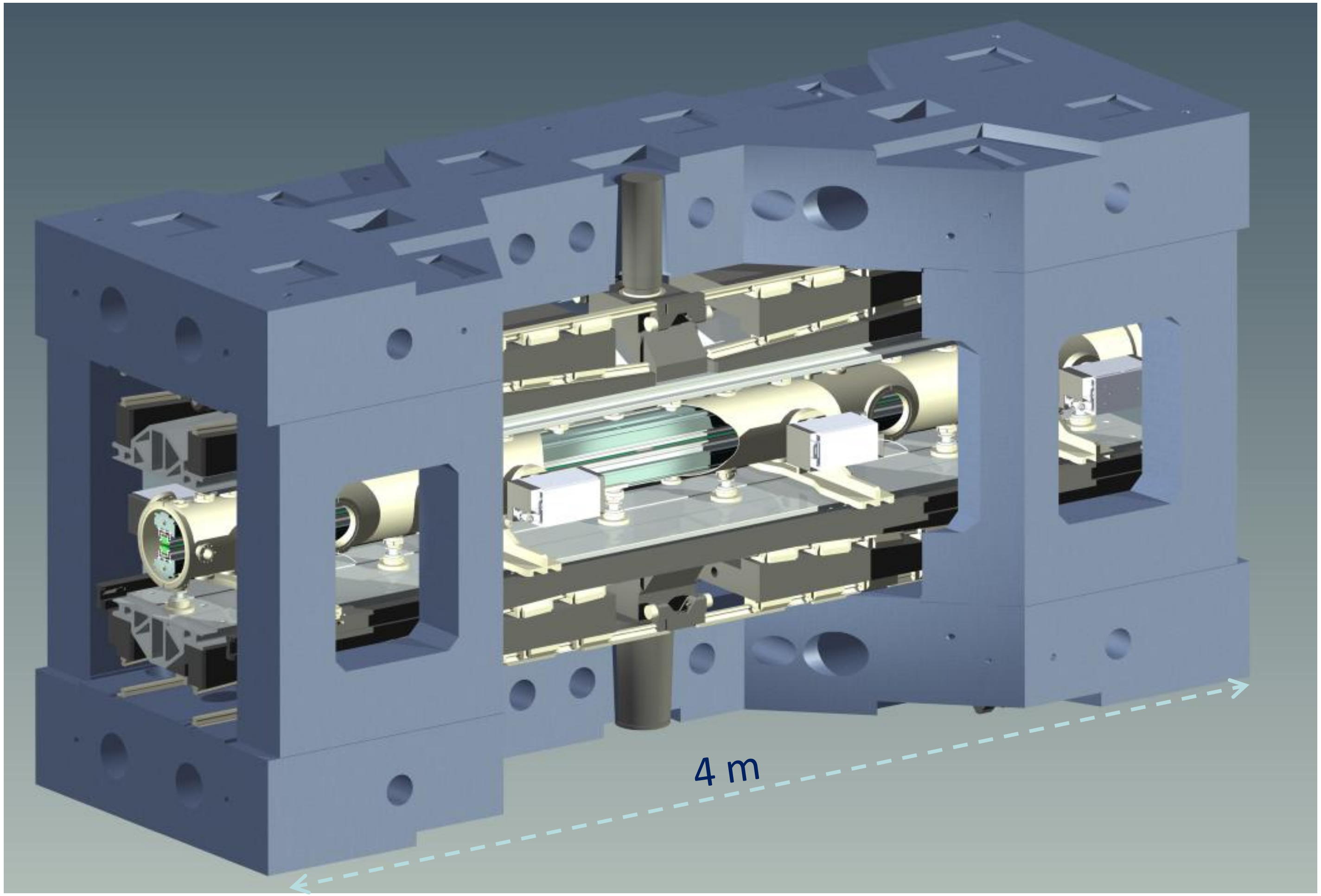
MOPD37,
N. Milas, S. Reiche,
“Switchyard Design: Athos”

TUPD21
E. Prat, S. Reiche, D. Dunning,
“Self-Seeding Design for SwissFEL”



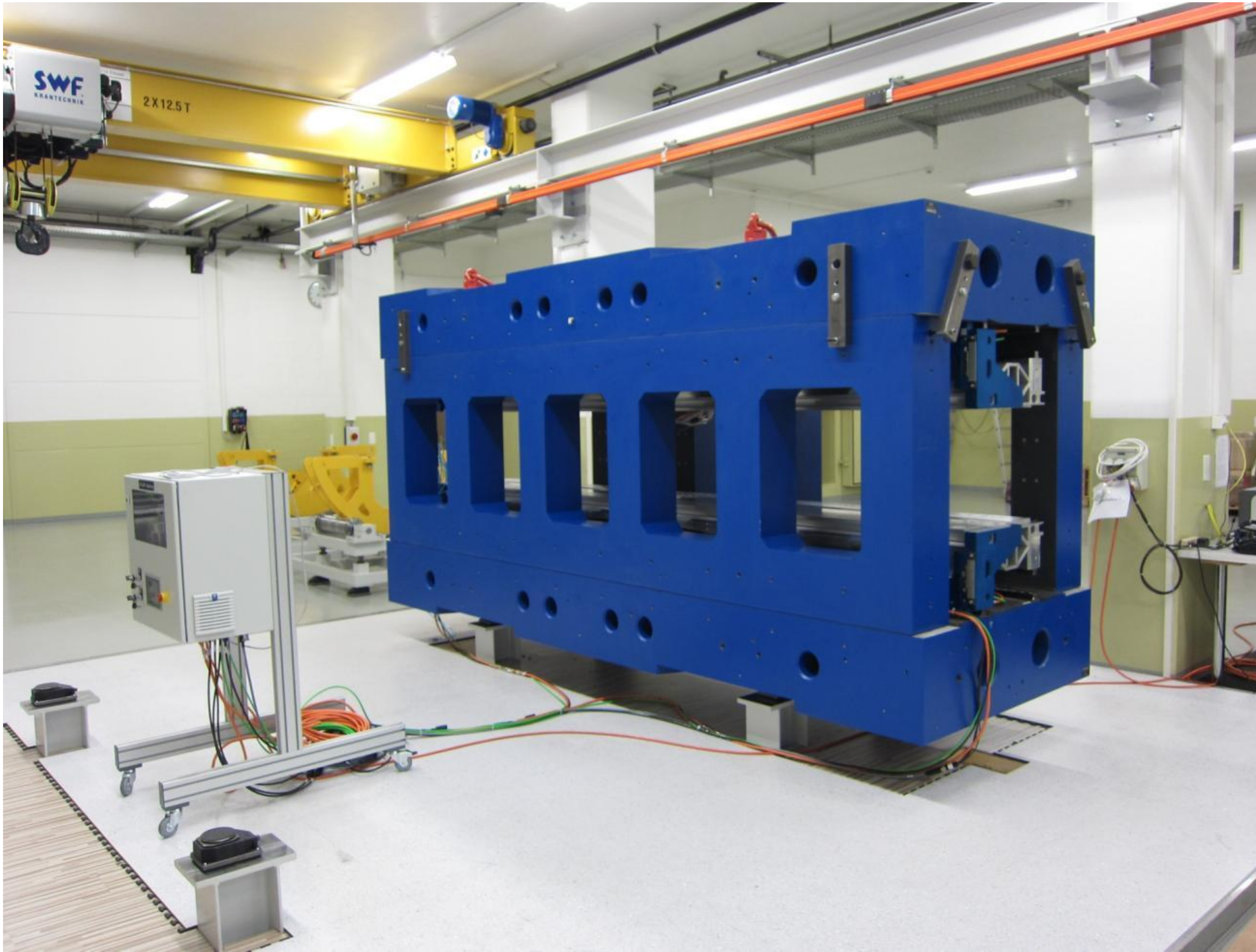
THPD19,
R. Ganter , M. Aiba, H. Braun, M. Calvi, A. Fuchs, E. Hohmann, R. Ischebeck, H. Joehri, B. Keil, N. Milas, M. Negrazus, S. Reiche, S. Sanfilippo, T. Schmidt, P. Wiegand,
“Technical Overview of SwissFEL Undulator Section”

U15 in-vacuum undulator for SwissFEL



THPD64,
T. Schmidt, M. Calvi,
“SwissFEL U15 Prototype Design and First Results”

Undulator frame at Daetwyler facilities



Magnet array

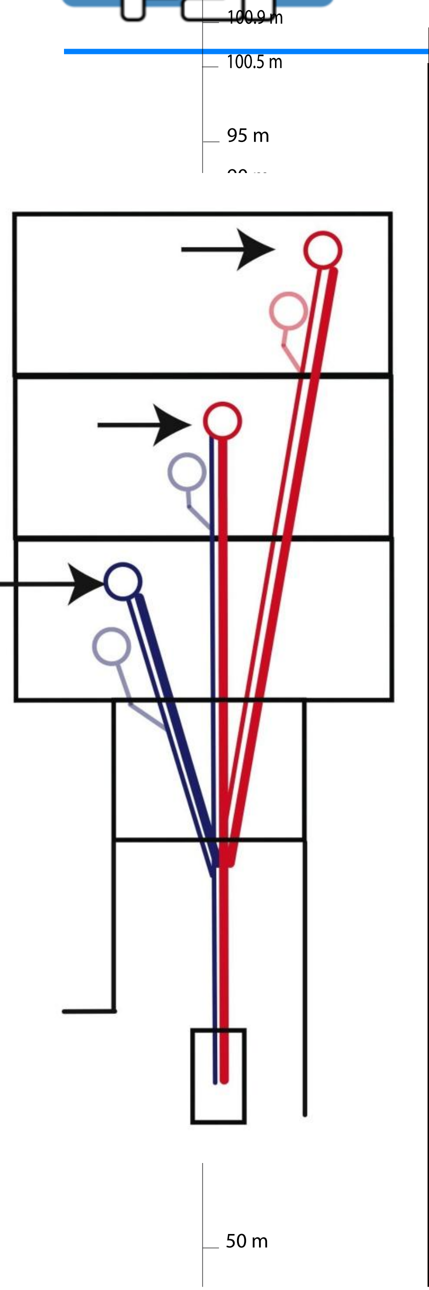
short prototype

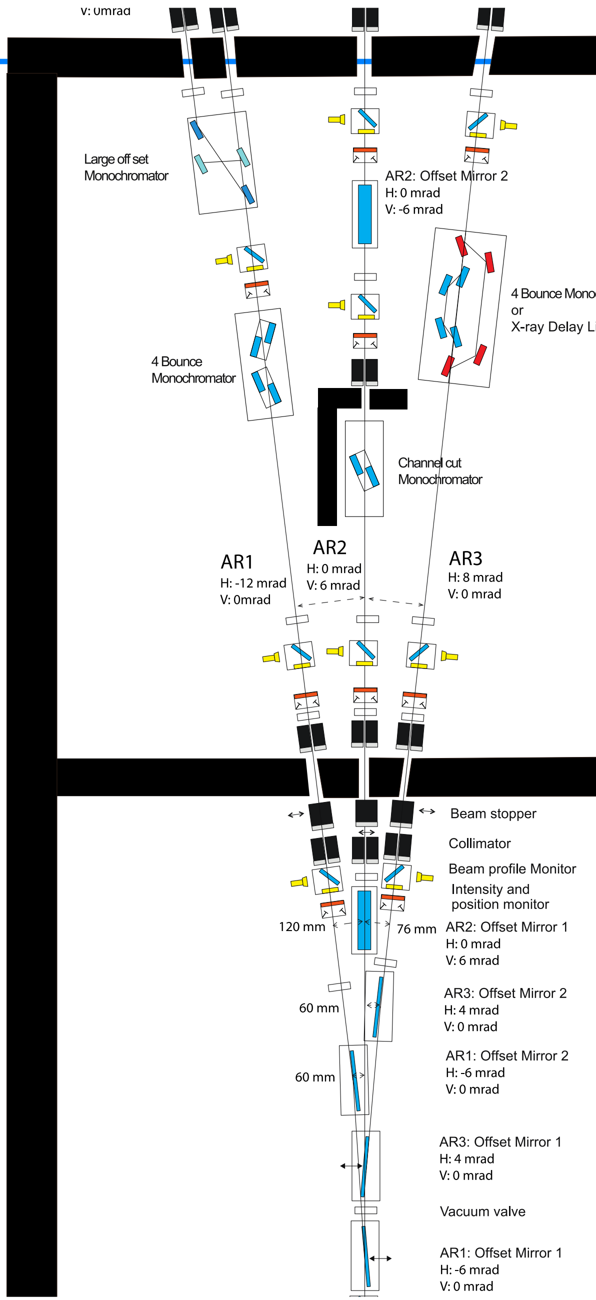
THPD63

M. Calvi, T. Schmidt,

"SwissFEL U15 Magnet Assembly: First Experimental Results"

Aramis Beamline





ARAMIS Endstations

2017

ES-A

Multi-purpose Pump-Probe

2017

ES-B

Pump-Probe Crystallography

2018

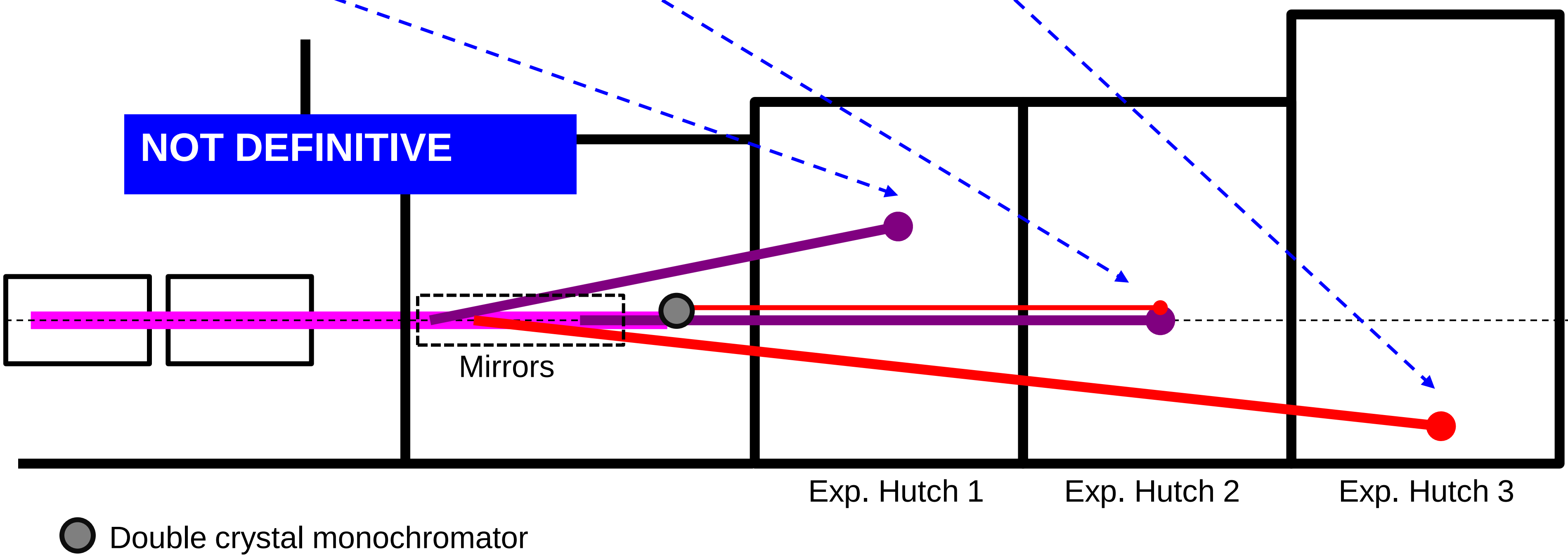
ES-C

Coherent Diffraction Imaging

201X

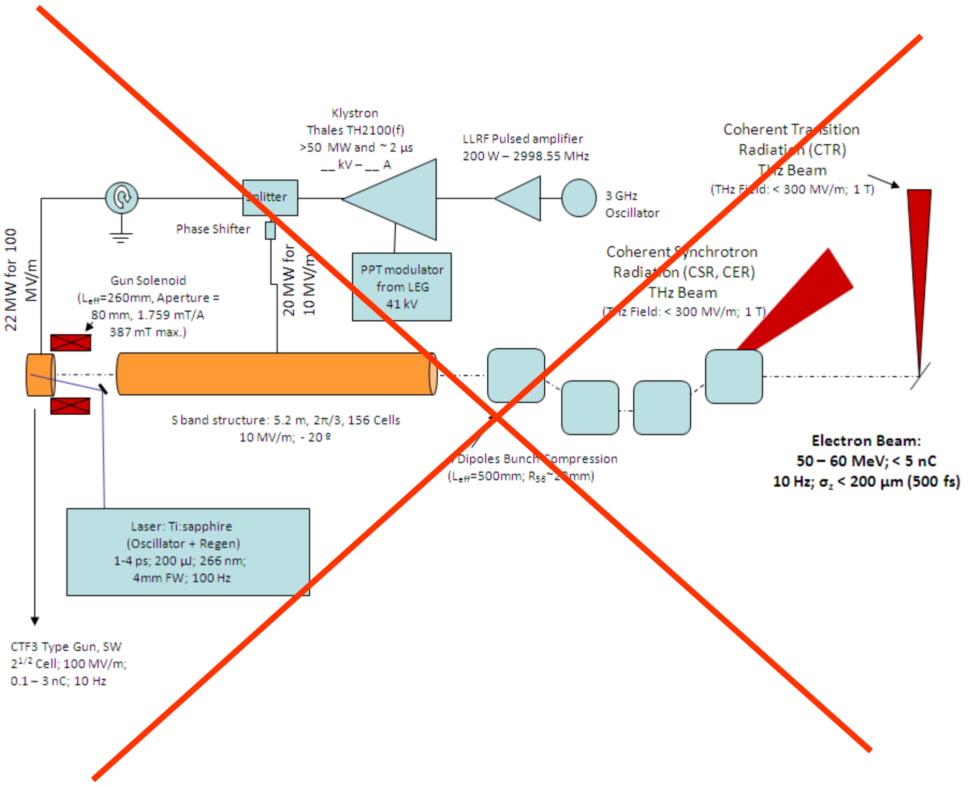
ES-O

“Others”



High power THz source for experiments

Laser based instead of accelerator based



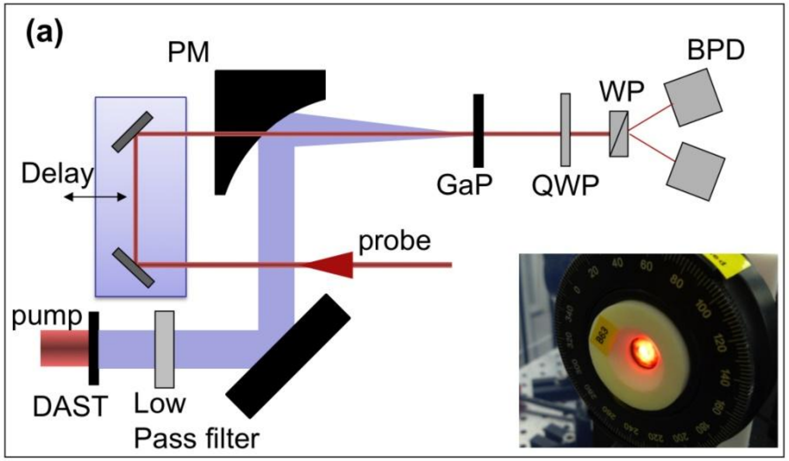
APPLIED PHYSICS LETTERS 99, 161116 (2011)

PAUL SCHERRER INSTITUT PSI

Strong-field single-cycle THz pulses generated in an organic crystal

Christoph P. Hauri,[1,2,a)] Clemens Ruchert,[1] Carlo Vicario,[1] and Fernando Ardana[1,2]
[1]*Paul Scherrer Institute, 5232 Villigen, Switzerland*
[2]*Physics Department, Ecole Polytechnique Federale de Lausanne, 1013 Lausanne, Switzerland*

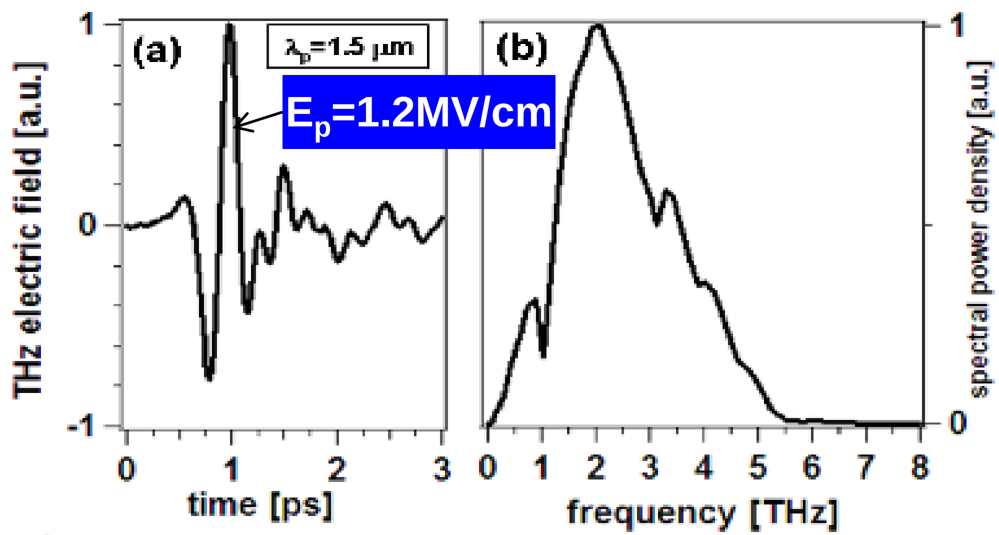
DAST : 4-N,N-dimethylamino-4’-N’methyl stilbazolium tosylate
strong optical nonlinearity, low absorption



Experimental results

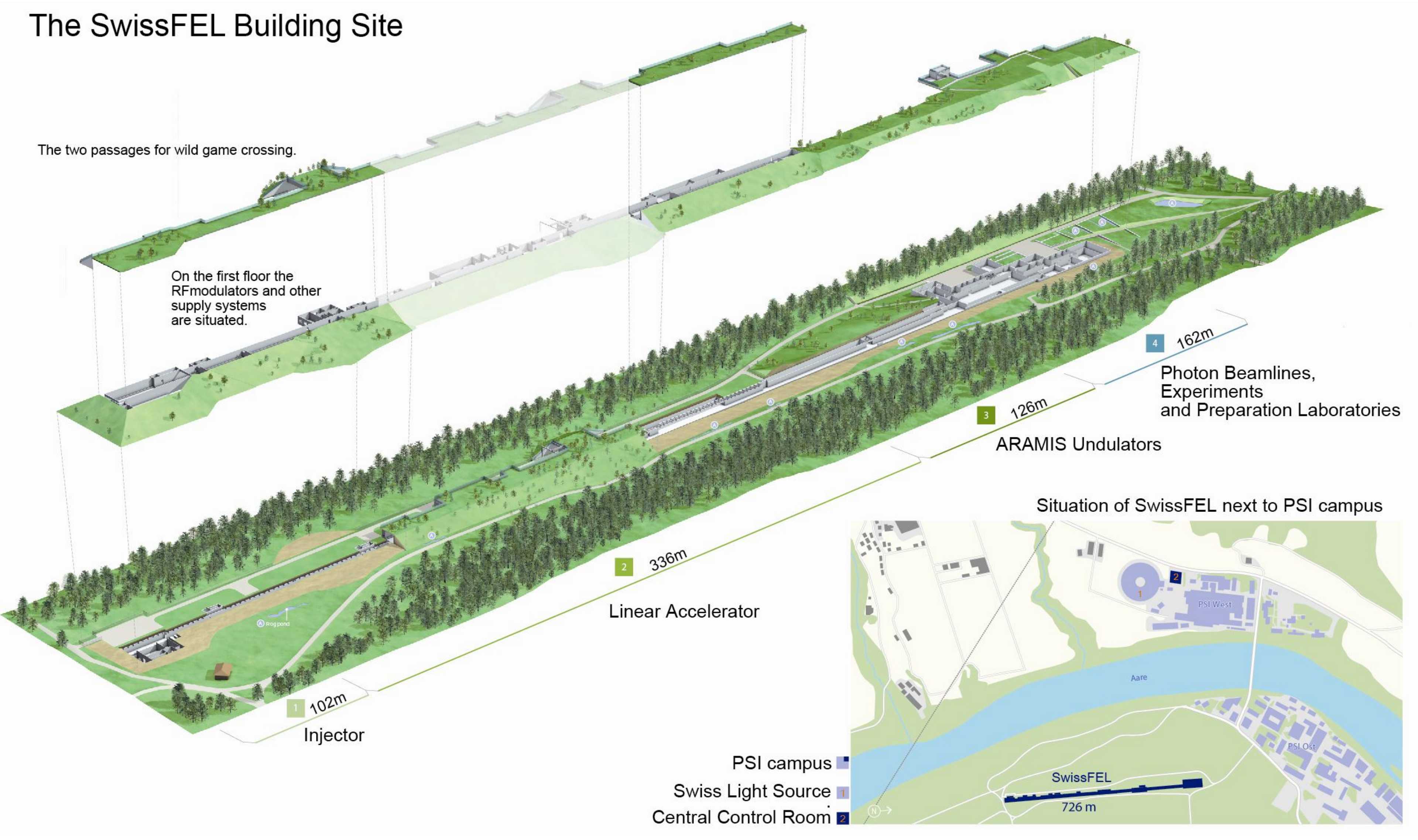
- Recorded peak E field >1.2 MV/cm, B > 0.35 T
- spectrum <5THz centered at ν_c= 2 THz
- close to single cycle
- THz pulse energy up to 45 uJ
- Good shot-to-shot energy stability (rms 1%)
- Energy up-scaling feasible
  (larger crystal, more pump energy)

IR-THz phase matching require
1.2-1.5 µm pump (OPA)



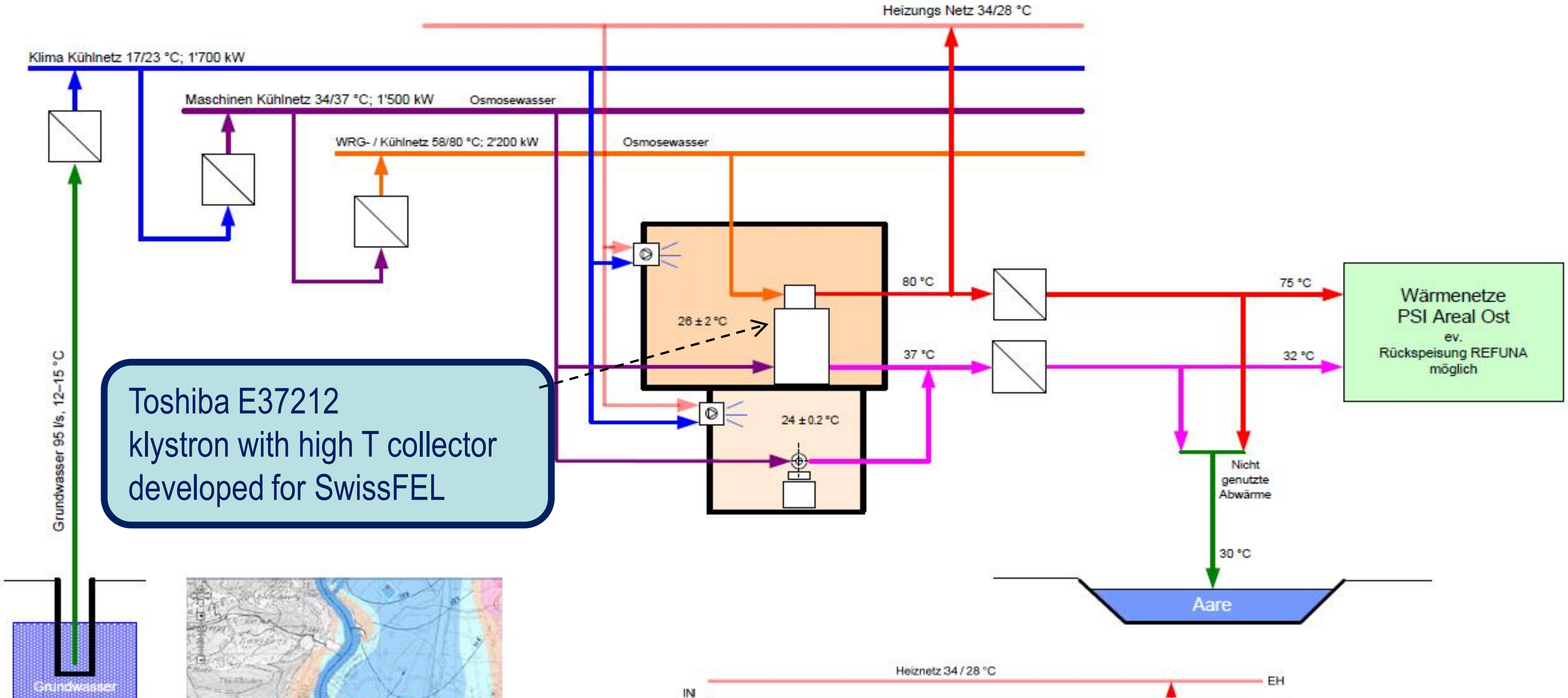
FROA04,
C. Hauri, F. Ardana-Lamas, M. Divall-Csatari,
A. Trisorio, C. Vicario, C. Ruchert
“New Laser Developments for
Pump-probe Experiments at SwissFEL”

SwissFEL building

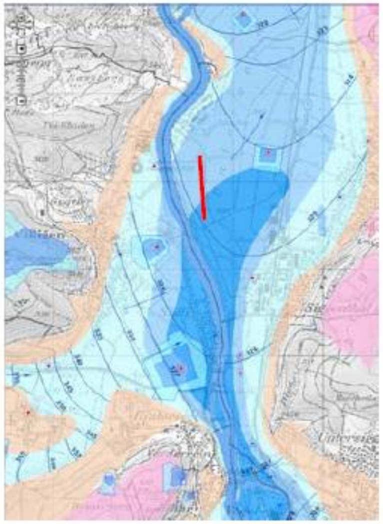


Ground water well for cooling water, first civil work for SwissFEL

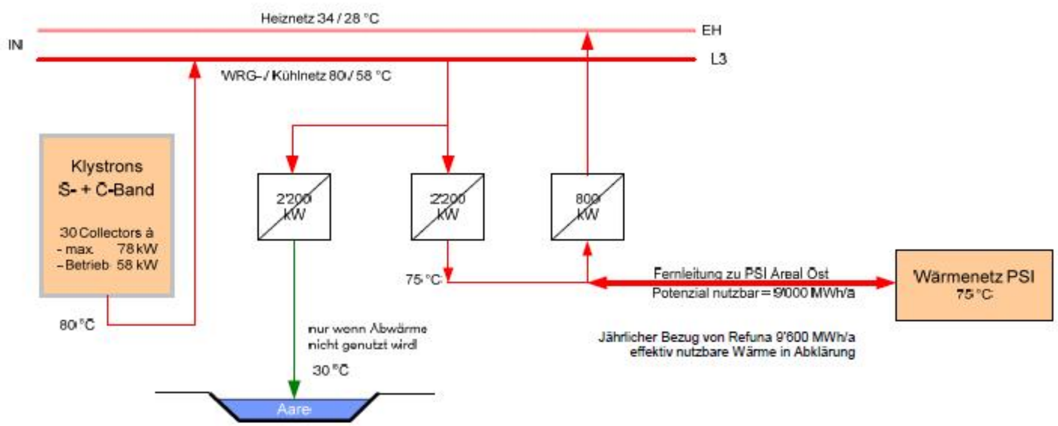
Energy recovery for SwissFEL



Toshiba E37212
klystron with high T collector
developed for SwissFEL



Grundwasserkarte



Wärmerückgewinnung

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SwissFEL papers & talks at FEL'12

MOOC02
S. Reiche, E.Prat, "Growth Rates and Coh. Properties of FODO-lattice based X-ray Free Electron Lasers"

MOPD36
F. Le Pimpec, A. Adelmann, S. Reiche, R. Zennaro, B. Grigoryan, "Dark Current Studies for SwissFEL "

MOPD37
N. Milas, S. Reiche, "Switchyard Design: Athos"

TUPD21
E. Prat, S. Reiche, D. Dunning, "-Seeding Design for SwissFEL"

TUPD27
M. Aiba, M.Böge, "Beam based Alignment of X-FEL Undulator Section Utilizing Corrector Pattern"

TUPD28,
B. Beutner, "Bunch Compression Layout and Longitudinal Operation Modes for the SwissFEL Aramis Line"

THPD19
R. Ganter et al., "Technical Overview of SwissFEL Undulator Section"

THPD63
M. Calvi, T. Schmidt, "SwissFEL U15 Magnet Assembly: First Experimental Results"

THPD64
T. Schmidt, M. Calvi, "SwissFEL U15 Prototype Design and First Results"

FROA04
C. Hauri, "New Laser Developments for Pump-probe Experiments at SwissFEL"

New release of design report, April 2012

PDF at

www.psi.ch/SwissFEL