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+ SwissFEL

Status of the SwissFEL and its Injector Test Facility

Bolko Beutner
on behalf of the SwissFEL Team

Joint DESY and University of Hamburg Accelerator Physics Seminar
19.2.2013

Contents

- SwissFEL
  - Overview
  - SwissFEL Injector Test Facility
- Operation modes
  - Standard operation modes
  - Large bandwidth mode
- Bunch Compressor
  - Movable girder system
- Optics and Emittance Measurements
  - Multi- and single-quad scans vs. FODO
  - Slice emittance
  - Experience at the Injector Test Facility

Overview

SwissFEL at PSI between Basel and Zürich in northern Switzerland

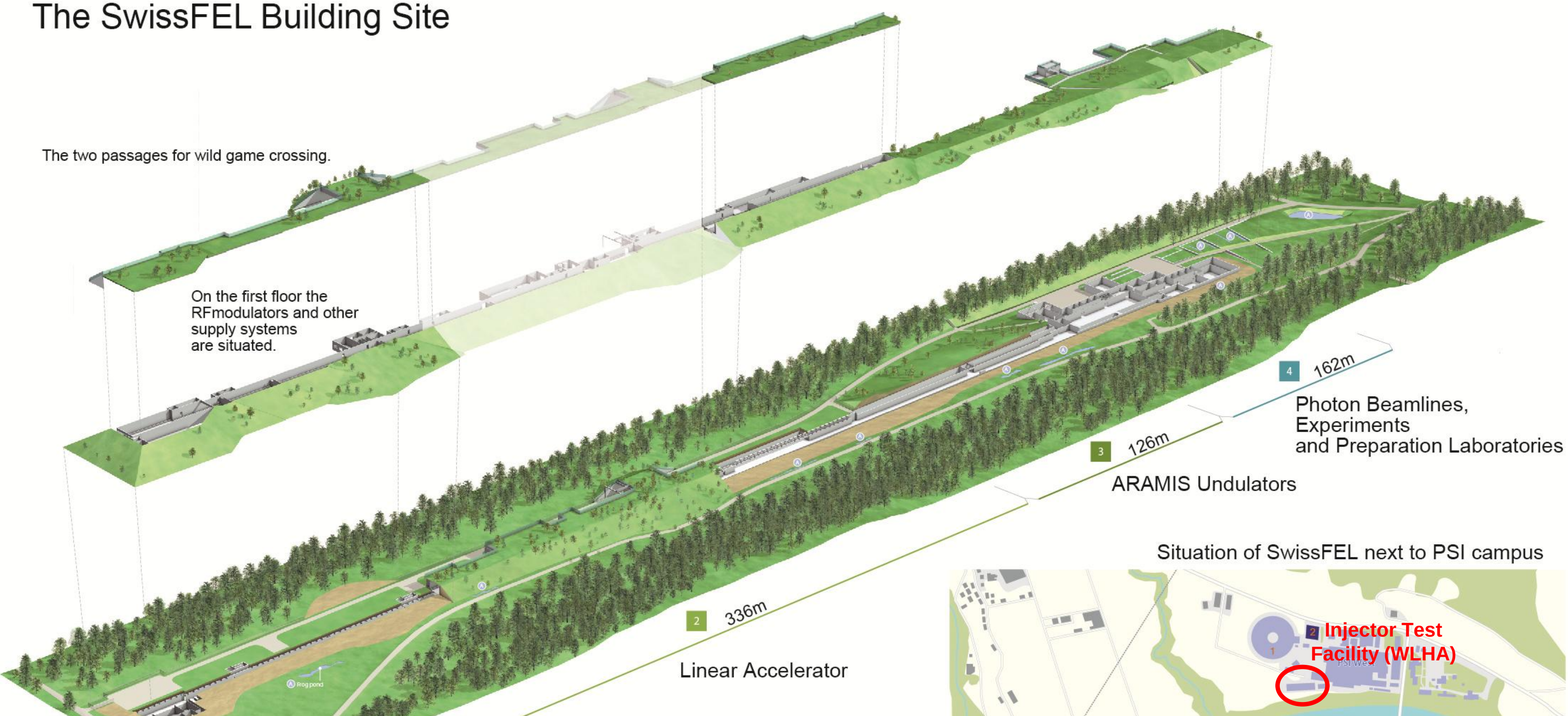
- Phase I:
  Hard X-ray SASE line (Aramis) down to 0.1 nm at 5.8 GeV
  (planar in-vacuum undulator U15)
- Phase II:
  Soft X-ray seeded FEL line (Athos) about 0.7-7 nm at 2.6-3.4 GeV
  (Apple II type undulator UE40)

- Swiss Parliament approved funding in late 2012

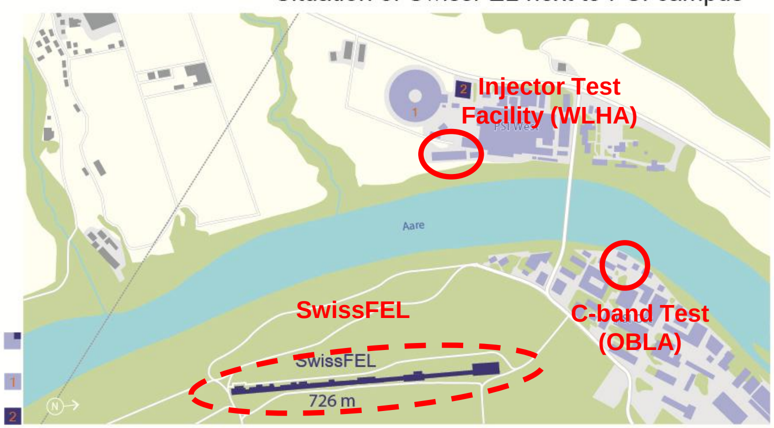
- SwissFEL design reports can be found at
  www.psi.ch/swissfel/swissfel-facility

SwissFEL Building

The SwissFEL Building Site



Situation of SwissFEL next to PSI campus



SwissFEL Building

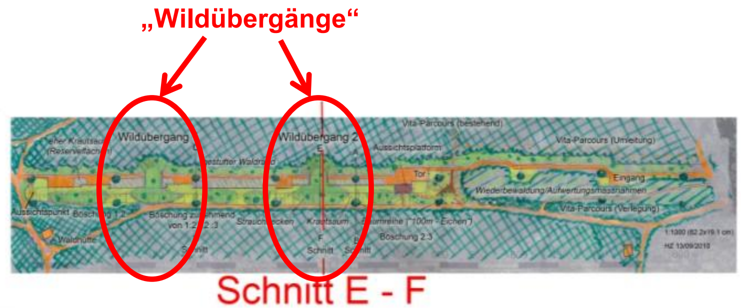
- Ground breaking April 2013
- Preparatory work already ongoing

Wildlife and Nature

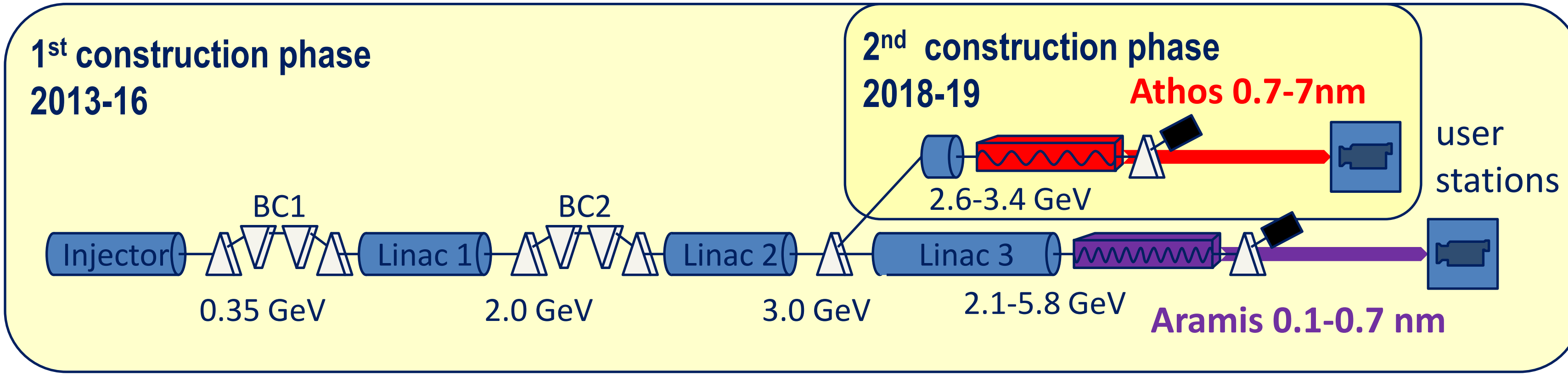
SwissFEL will build in the forest, with some issues for nature protection.

After the construction of the bunker the machine is covered by the original ground. Bridges („Wildübergänge“) for wildlife crossing are included in the building design.

The area is accessible for the public with implications for radiation shielding and interlock systems.



SwissFEL Overview



Advanced project funding from government and economic stimulus package

Swiss government finance period

Next finance period

<table>
<tr><th colspan="2">2012</th><th colspan="2">2013</th><th colspan="2">2014</th><th colspan="2">2015</th><th colspan="2">2016</th><th colspan="2">2017</th></tr>
<tr><td colspan="9">component procurement accelerator and ARAMIS FEL</td><td colspan="3">preparation ATHOS FEL</td></tr>
<tr><td colspan="2">prepatory work</td><td colspan="4">building construction</td><td colspan="3">Accelerator and ARAMIS FEL installation interleaved with injector commissioning</td><td colspan="2">Linac and ARAMIS commissioning</td><td colspan="1">friendly users</td></tr>
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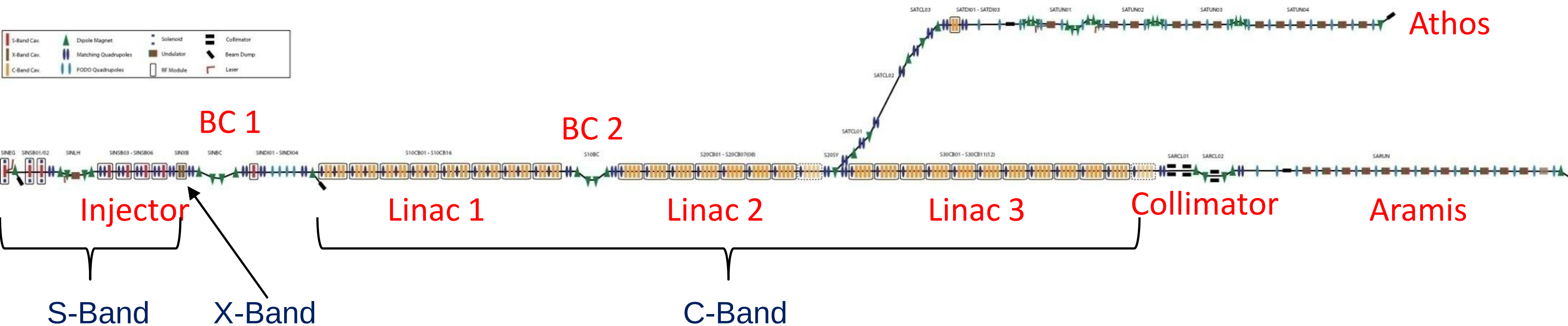
H. Braun

Accelerator Overview

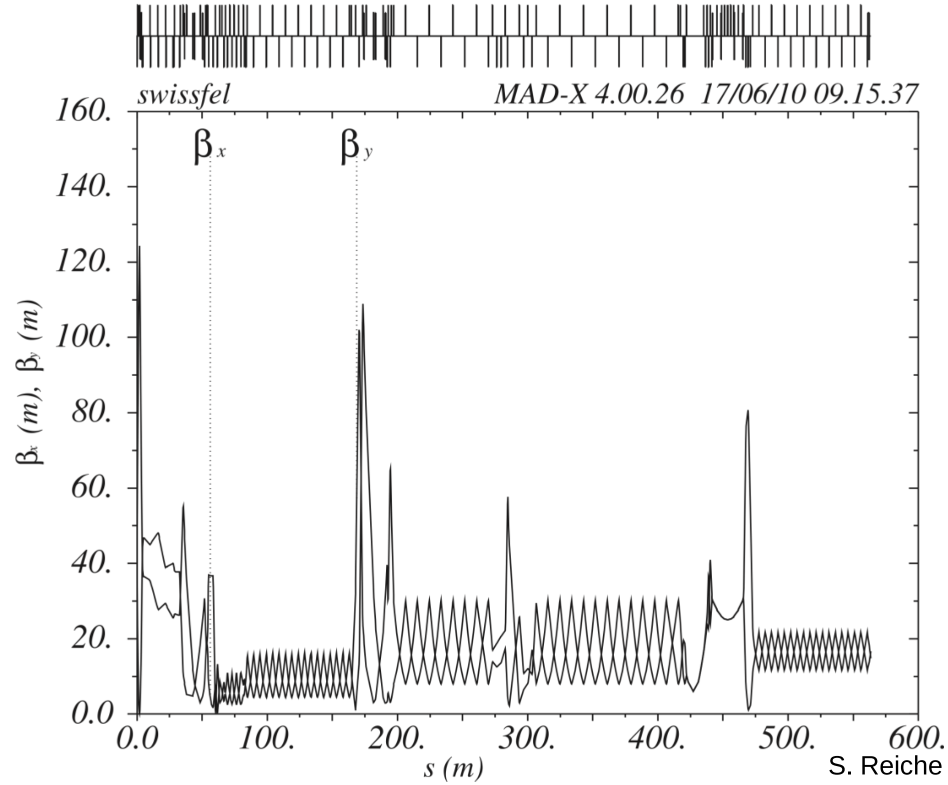
+ SwissFEL



- S-Band 2.5 cell RF gun (100 MV/m)
- S-Band Booster (14-16 MV/m)
- X-Band Linearizer (20 MV/m)
- C-Band Main Linac (26-28.5 MV/m)

- Bunch Charge: 10pC – 200pC
- Design Emittance: 0.18 to 0.43 mm mrad
- 100Hz Operation with option for two bunches per pulse to be kicked to the separate undulator lines (28ns spacing)

- Bunch Compressors with movable girder system 0 – 5 deg
  with R_{56} of -55mm at 3.8deg in BC1
  and -20mm at 2.1 deg in BC2



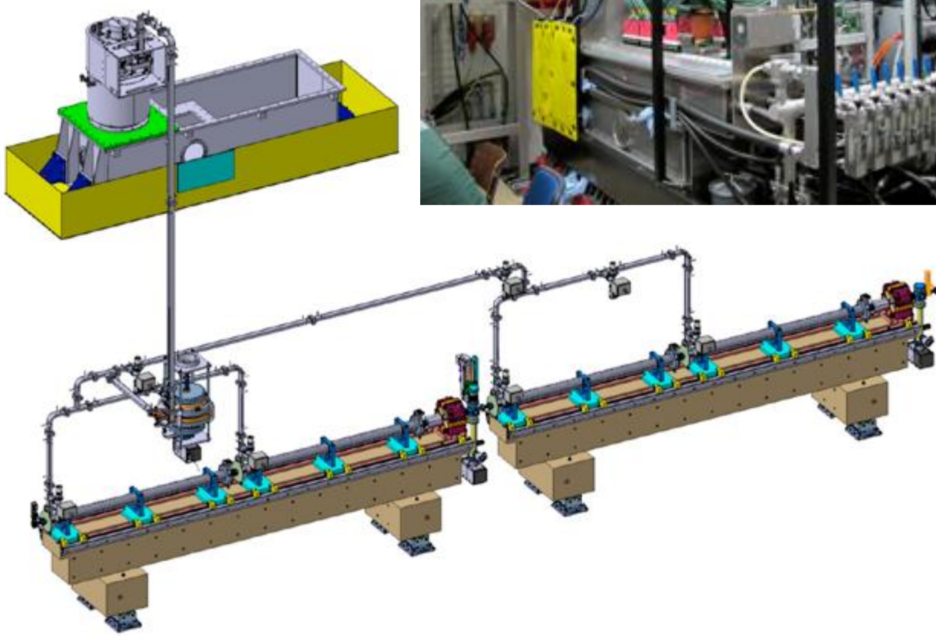
S. Reiche

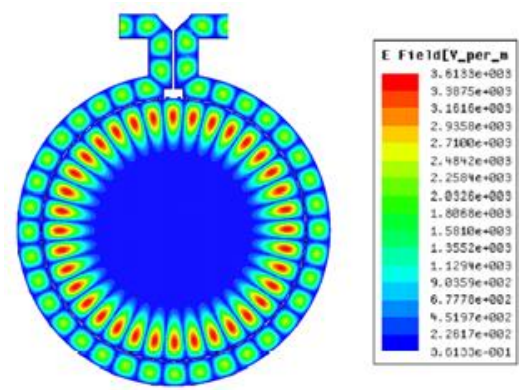
RF Overview

	Unit	S-band photogun	S-band cavities (injector)	X-band cavities (injector)	C-band cavities (Linacs 1)	C-band cavities (Linacs 2)	C-band cavities (Linacs 3)	C-band cavities (Athos linac)
Frequency (MHz) – f_b=142.8 MHz		2998.8 (21 x f_b)	2998.8 (21 x f_b)	11995.2 (84 x f_b)	5712 (40 X f_b)			
Phase Advance		π	2π/3	5π/6	2π/3			
Active Length	mm	162	4070	750	1978			
Total Length	mm		4150	965	2050			
Number of Cells		2.5	122	72	113			
Operating Temperature	°C	40	40	31	40			
Maximum Gradient	MV/m	120	25	34	28	28	30	30
Operating Gradient	MV/m	100	14.8	25	27	27.5	28.5	28.5
Required Input Peak Power per structure		19 MW for 100 MV/m	24 MW for 16 MV/m	7 MW for 20 MV/m	27.2 MW for 27.5 MV/m			
Klystron maximum performance		35 MW – 4.5 μs	45 MW – 4.5 μs	50 MW – 1.5 μs	50 MW – 2.5 μs 40 MW – 3 μs			
Filling Time	ns	490	1000	105	322			
Number of structures		1	6	2	36	16	52	8
Number of structures per klystron		1	1 or 2	2	4			

C-band

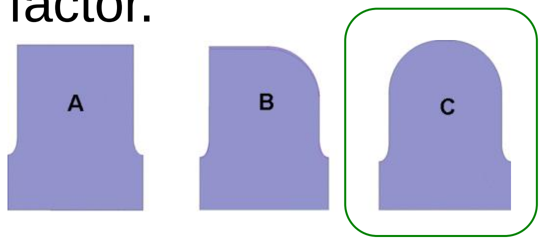
- C-band accelerating structures are grouped into 28 RF modules, each module being composed of four accelerating structures, one pulse compressor, one 50 MW klystron and one solid-state modulator

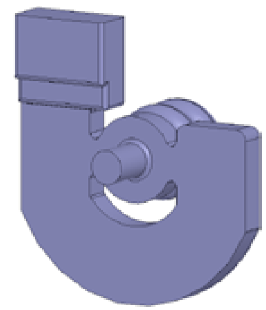




C-band structures

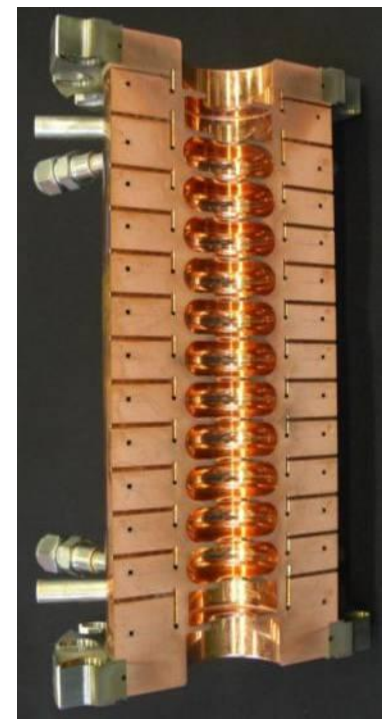
- C-band accelerating structure has 113 cells, including two coupler cells of the J-type
- The length of each cell is 17.495 mm and the active length of each structure is 1.978 m. Each cell has rounded walls to increase the quality factor.





- Short C-band structures are tested at the OBLA test facility:

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	$8\cdot10^{-7}$	68
2	11	14.6	no	50	36.0	1.0	100	$3\cdot10^{-6}$	68
3	11	11.2	no	49	57.0	0.8	100	$1\cdot10^{-6}$	45
4 (J-coupler)	11	11.2	no	49	57.0	0.5	100	$\approx10^{-7}$	45
SwissFEL nominal	113	14.6→11.2	no	28	28.0	0.35	100	$1\cdot10^{-8}$	



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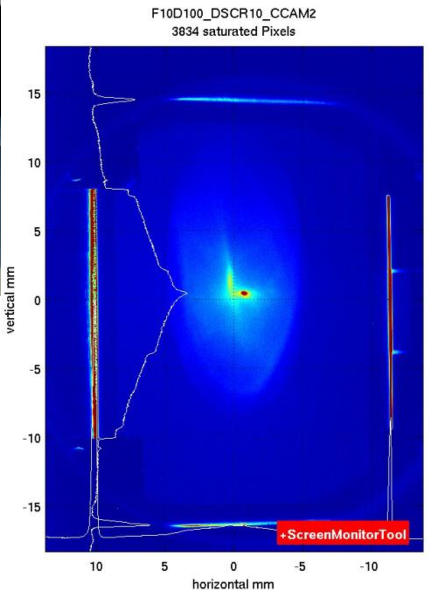
SwissFEL Injector Test Facility

- Injector Test Facility was build to
  - demonstrate design beam parameters
  - R&D of machine components (RF, diagnostics, ...)
  - Application and procedure development
  - Building in-house experience for operation

- S-band RF-gun
  - 7.1MeV at the nominal working point
  - Present gun on loan from CERN (so called "CTF3 Gun")
  - PSI gun will be installed mid 2013
- Four S-band accelerating structures
  - Design energy 250MeV, typically operated at 230MeV for compression studies
- 10-200pC design charge
- Two laser systems "Jaguar" (Nd:YLF) and "Pulsar" (Ti:Saphire)

First Beam

- Inauguration readiness 9. August 2010
- First beam 24. August 2010



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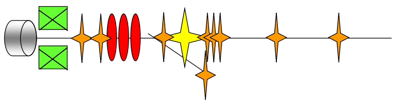
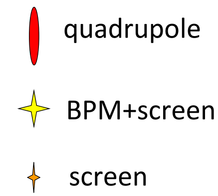
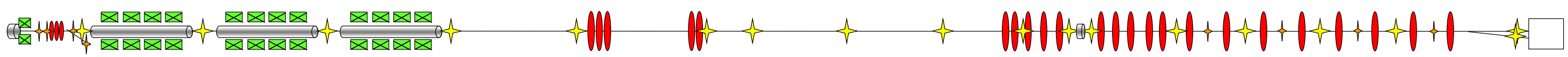
Phase 1: Electron source and diagnostics





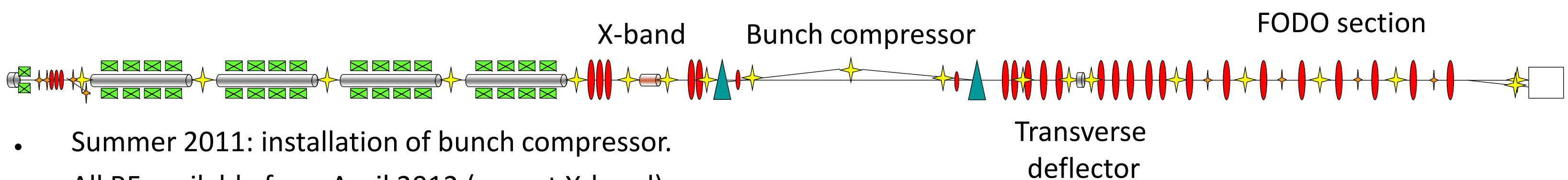
- March 2010 to June 2010
- Characterization of the electron source

Phase 2: Phase 1 + (some) S-band acceleration



- August 2010: inauguration phase
- October 2010 to Summer 2011
- Emittance damping in S-band booster (invariant envelope)

Phase 3: The full machine



- Summer 2011: installation of bunch compressor.
- All RF available from April 2012 (expect X-band)
- Begin 2013: installation X-band cavity

Phase 4: Installation of new PSI gun + undulator experiment

- April/May 2013 (tentative)

T. Schietinger

Aramis Operation Modes

- Bunch charges between 10 and 200pC are forseen
- Emittance is kept under control by adjustment of laser pulse length and spot size

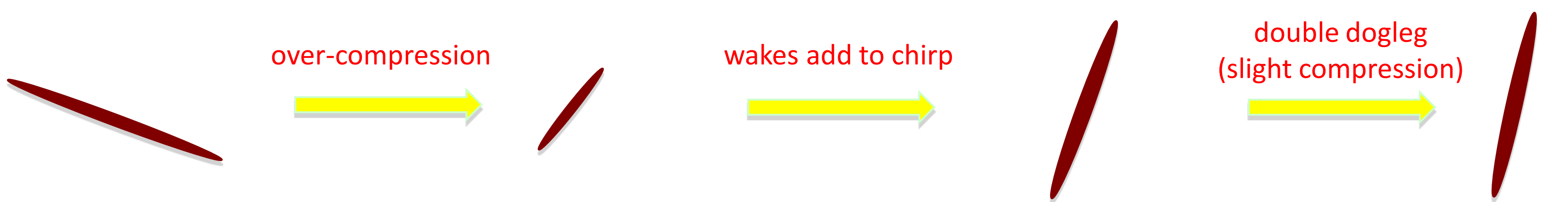
Charge (pC)	Laser pulse FWHM (ps)	$I_{peak, cathode}$ (A)	Laser $\sigma_{x,y}$ (µm	$\varepsilon_{intrinsic}$ (µm. rad)	$\varepsilon_{slice}/\varepsilon_{projected}$ (µm.rad)
200	**9.9**	**22**	**270**	**0.195**	**0.320/0.350**
150	9.0	18	245	0.177	0.272/0.283
100	7.9	14	214	0.155	0.220/0.233
50	6.2	8.7	170	0.123	0.160/0.174
20	4.6	4.7	125	0.091	0.108/0.122
10	**3.7**	**3**	**100**	**0.072**	**0.080/0.096**

- In **standard operation** the user can choose the charge to allow for an trade-off between photon number and pulse length
- For special user requirements a 200pC **large bandwidth** mode delivers a bandwidth on the order of percent
- In a special mode the energy collimator upstream of Aramis is used as a compressor to fully compress the beam for a short **“attosecond“** mode

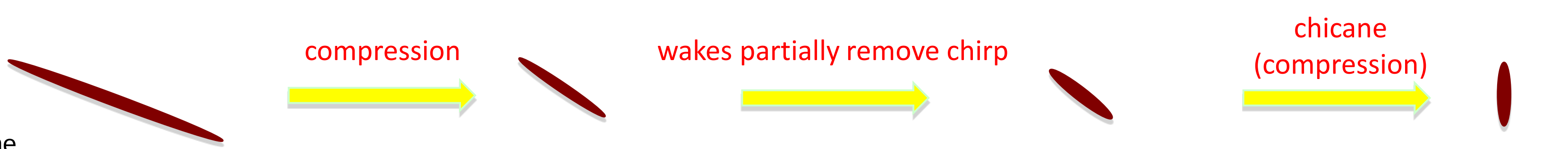
Operation Modes

Standard modes (200pC – 10pC):

Large Bandwidth mode (200pC):



Attosecond mode (10pC):



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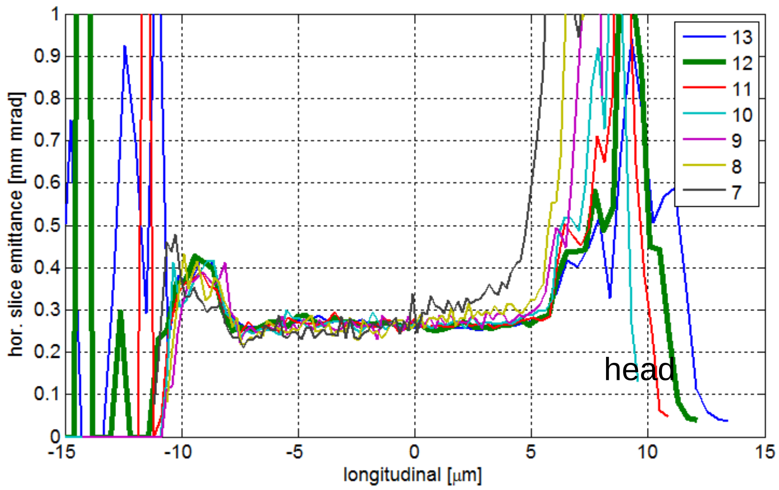
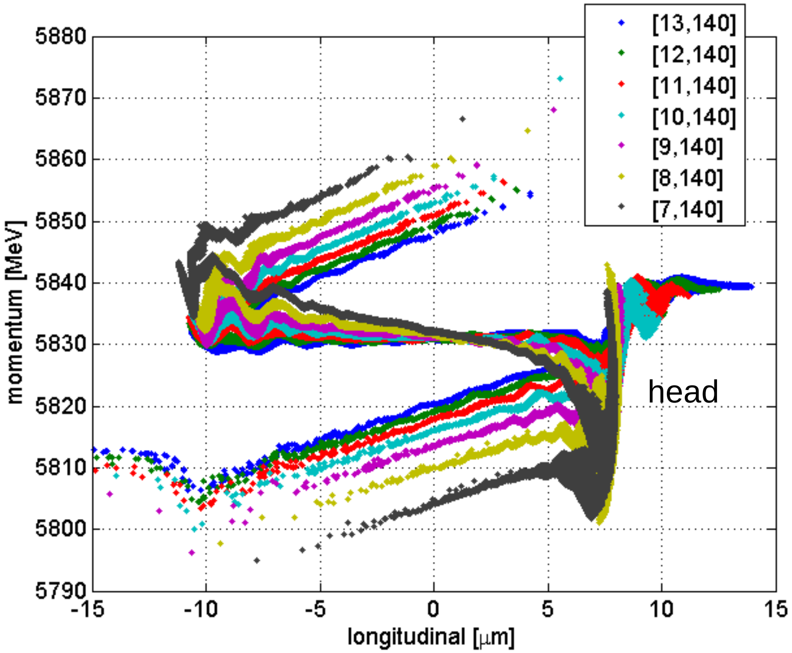
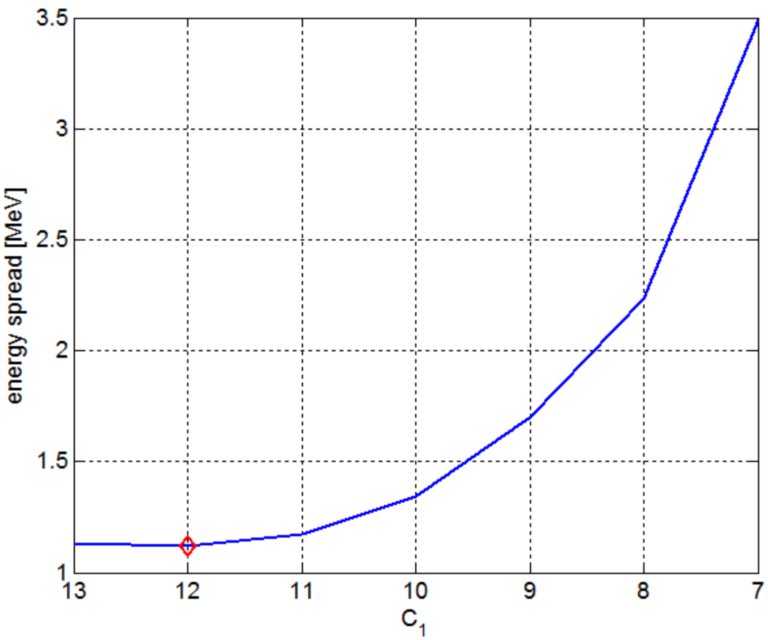
Chirp Removal

Compression factor of 12 in the first chicane minimizes energy spread while keeping the slice emittance is stable.







Standard Mode 200pC

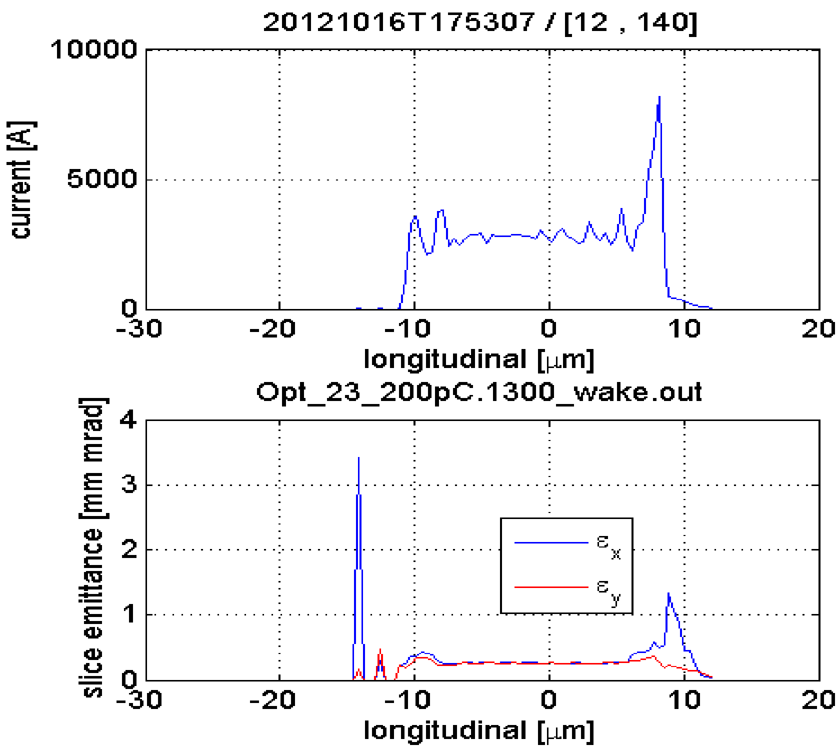
sbgrad: 15.320MV/m
sbphase: 23.5816

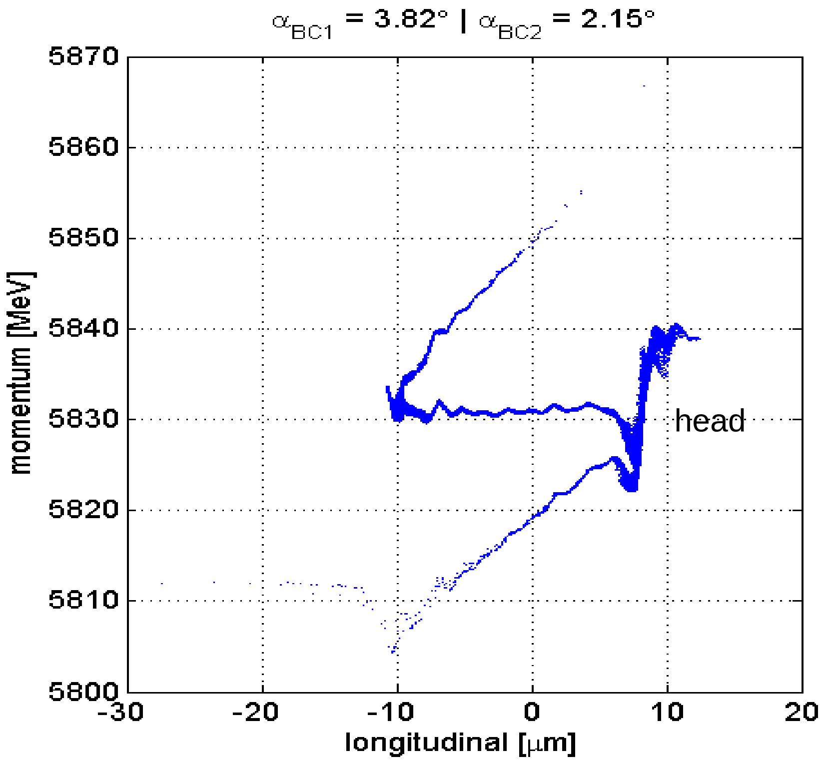
xbgrad: 15.958MV/m
xbphase: -175.9386

cbgrad: 26.160MV/m
cbphase: 17.4486

- Ipeak0 = 2644.59A
- esx0 = 0.26771mm mrad
- esy0 = 0.25935mm mrad
- I/sqrt(ex ey) = 10036.535
- RMS s = 5.939\mum
- RMS delta = 0.040205%

- Perfect chirp removal
- leading “spike” in current profile





Standard Mode 10pC

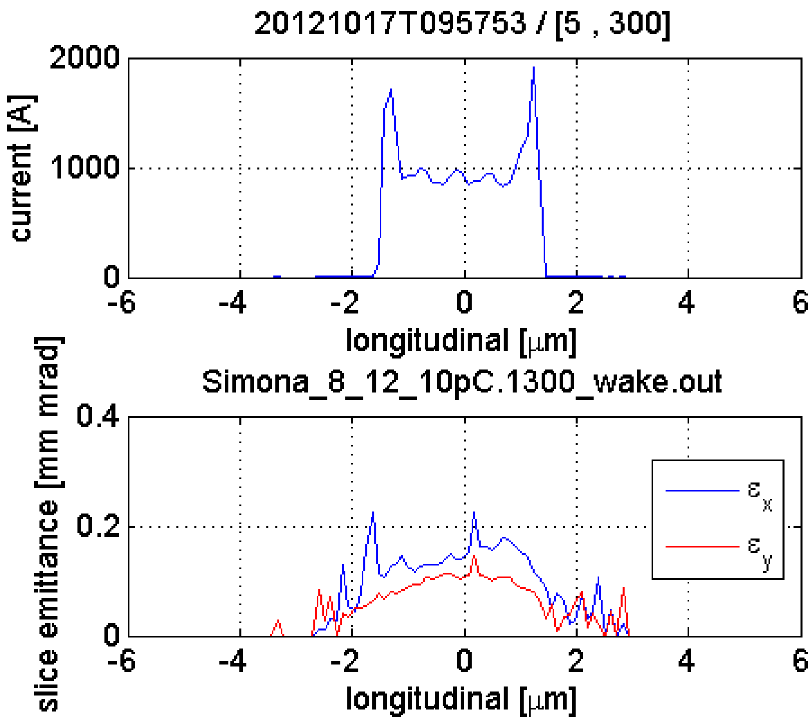
sbgrad: 15.774MV/m
sbphase: 24.1055deg

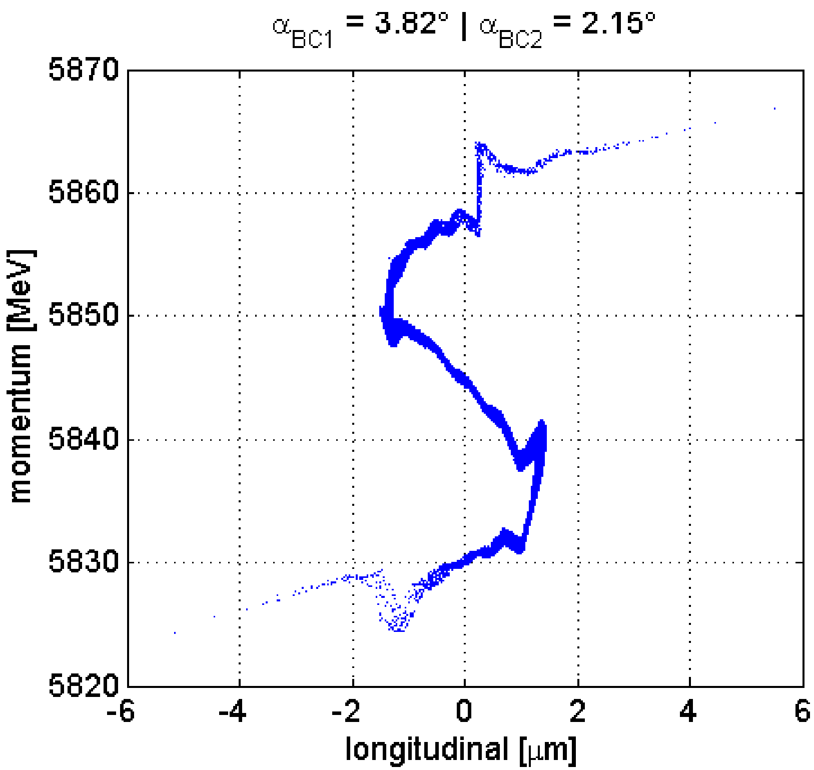
xbgrad: 20.662MV/m
xbphase: -166.9433deg

cbgrad: 26.400MV/m
cbphase: 19.5376deg

Ipeak0 = 917.5792A
esx0 = 0.14362mm mrad
esy0 = 0.10615mm mrad
I/sqrt(ex ey) = 7431.5037
RMS s = 0.90069\mum
RMS delta = 0.084784%

- chirp removal not complete
- More compression is possible on the expense of more chirp
- “spikes” in the current profile





Large Bandwidth Mode

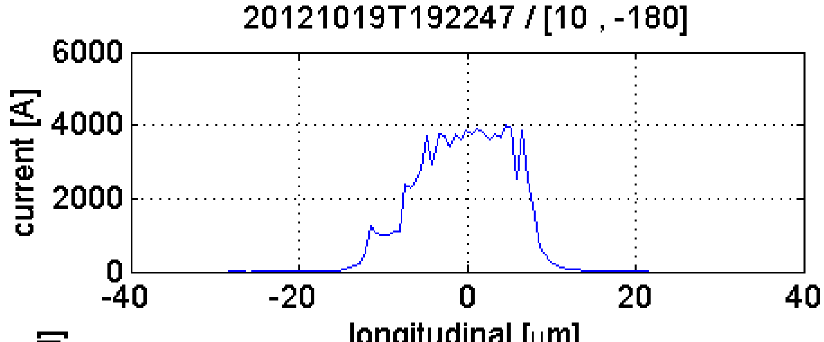
sbgrad: 15.062MV/m
sbphase: 21.5029deg

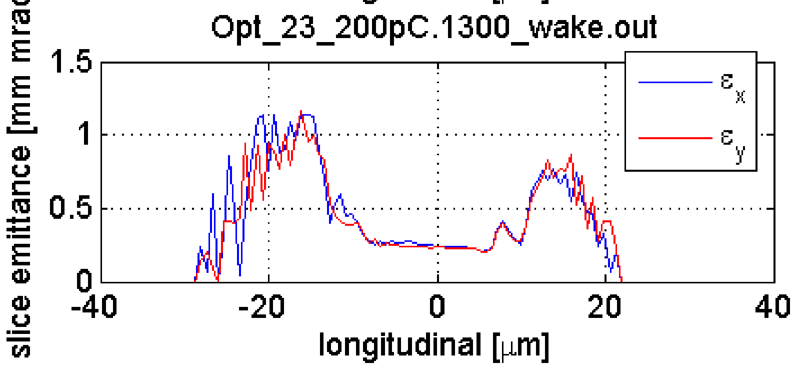
xbgrad: 15.603MV/m
xbphase: 179.0207deg

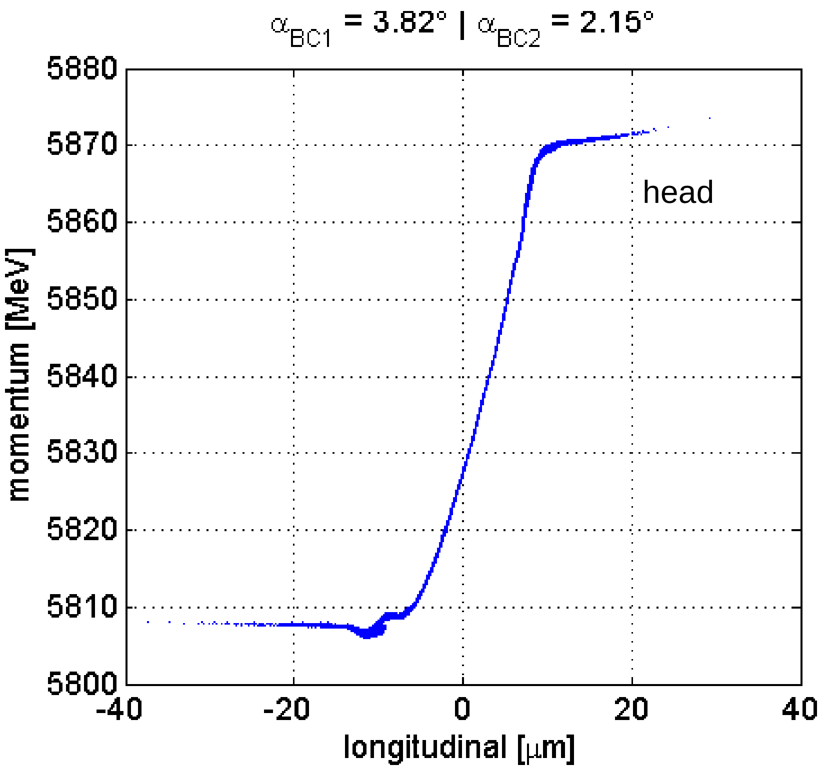
cbgrad: 26.860MV/m
cbphase: 21.7018deg

- Ipeak0 = 3856.3099A
- esx0 = 0.24378mm mrad
- esy0 = 0.23421mm mrad
- I/sqrt(ex ey) = 16138.7261
- RMS s = 5.3817\mum
- RMS delta = 0.30925%

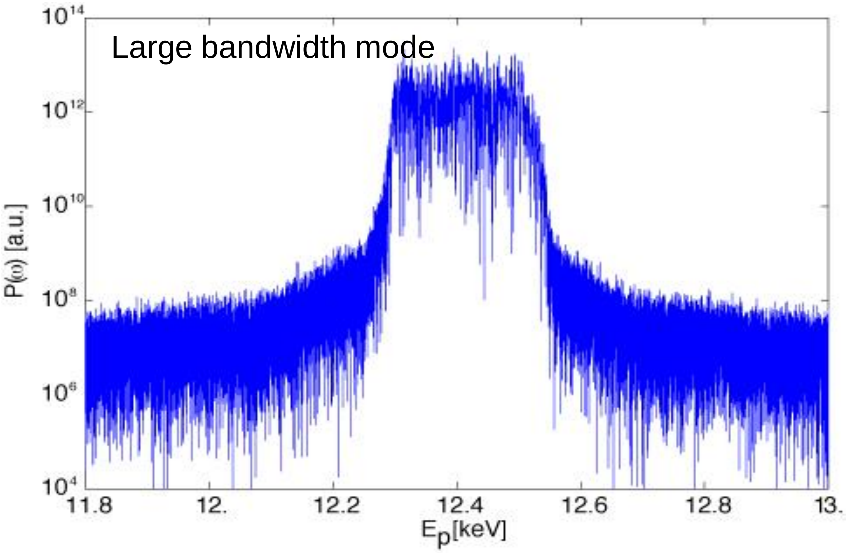
- Stronger compression than in the 200pC standard case
- less compression is possible – depends on user requirements

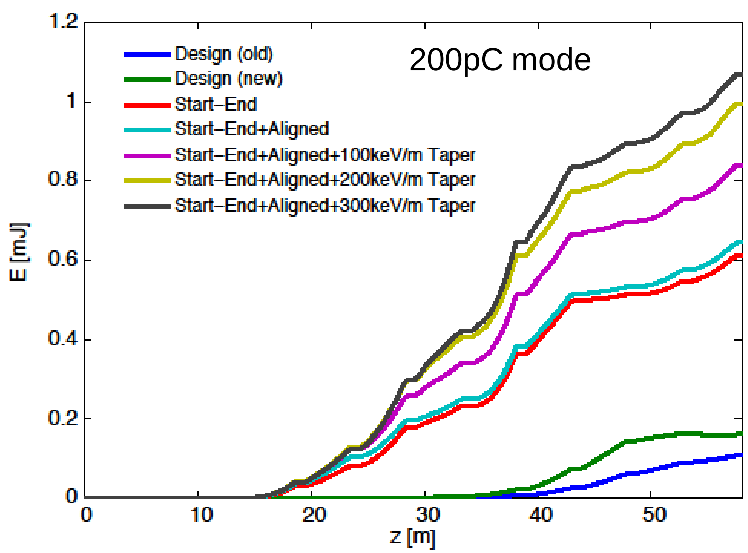






FEL Performance





Beam energy	5.8 GeV	2.2 GeV
Peak current	2.7 kA	2.7 kA
Charge	200 pC	200 pC
Central Slice Energy spread	350 keV	350 keV
Central Slice Emittance	0.43 mm.mrad	0.43 mm.mrad
Undulator period	15 mm	15 mm
Undulator parameter	1.2	1.2
Undulator module length	4.00 m	4.00 m
Undulator section length	4.9 m	4.9 m
Average β-function	15 m	15 m
Wavelength	1 Å	7 Å
Saturation length	48 m	33 m
Saturation pulse energy	0.15 mJ (*)	0.20 mJ
Effective saturation power	2.8 GW	5.5 GW
Photons at saturation	$7.3\ 10^{10}$	$9.84.10^{11}$
Bandwidth (rms)	0.05 %	0.2 %
Pulse length (rms)	21 fs	20 fs
Beam radius	26.1 μm	77.9 μm
Beam divergence	1.9 μrad	7.4 μrad

(*) Simulated values obtained with Gaussian approximation but up to 1 mJ has been reached after simulation optimisation.

S. Reiche

How does the machine behave on RF failure?

- In the S- and X-band system we don't have much reserve if one klystron/modulator is not operational

- C-band Linac 2 and 3 need some readjustment of optics (e.g. LEM at LCLS) but in continued operation is possible at a lower photon energy

- C-band Linac 1 affects both energy and compression
  - Energy loss is treated as in Linac 2 and 3
  - Readjustment of RF setup to maintain longitudinal profile at Aramis

  - Beam optimisation for varying beam energies at BC2
  - 2100MeV, 1768MeV, 1436MeV
    for about 0, 1, 2 and klystron systems out of operation in linac 1

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Energy Variation 200pC

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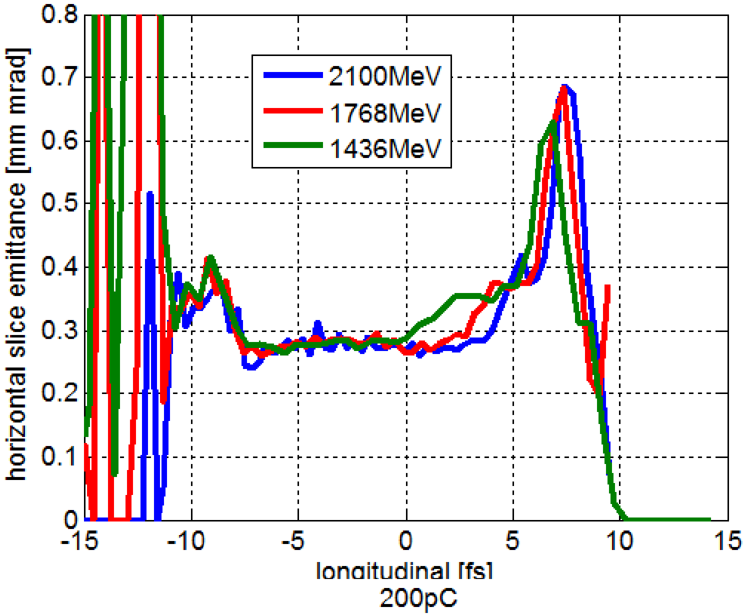
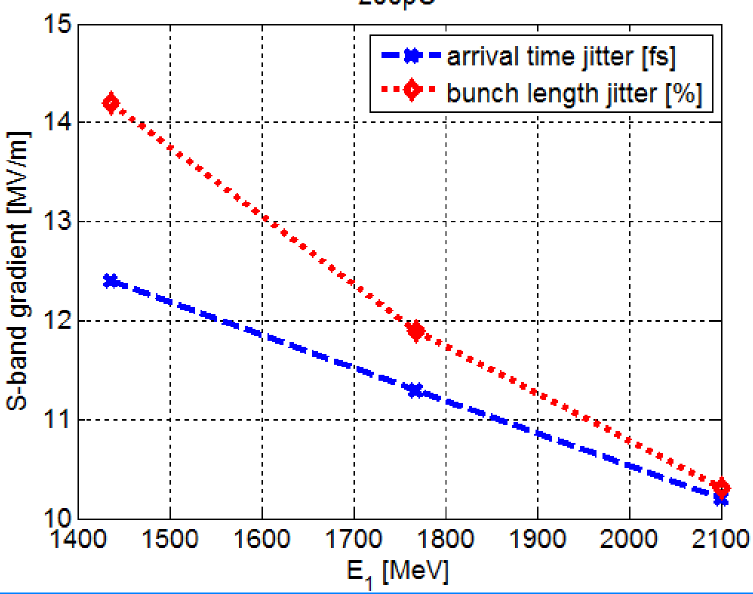
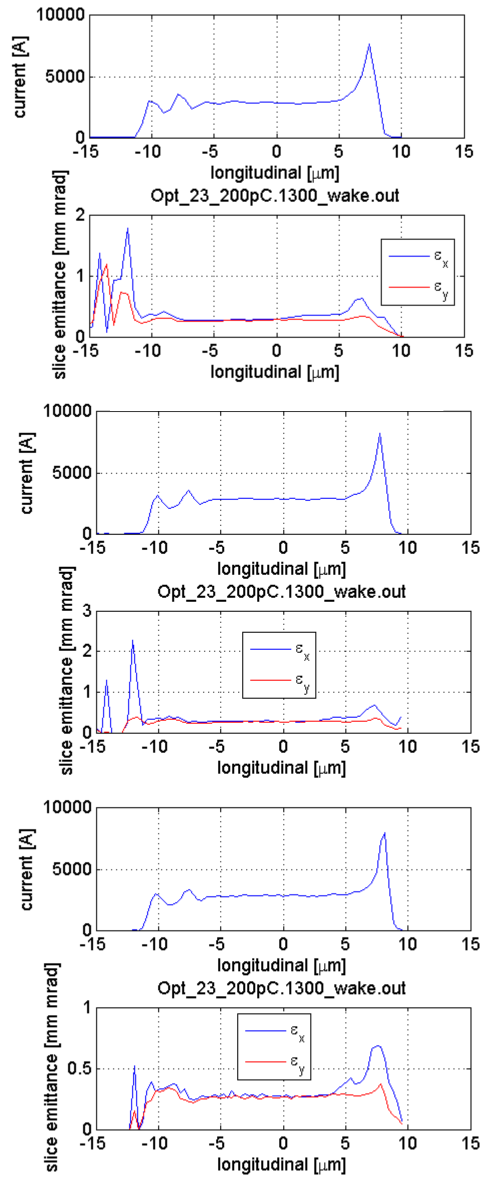
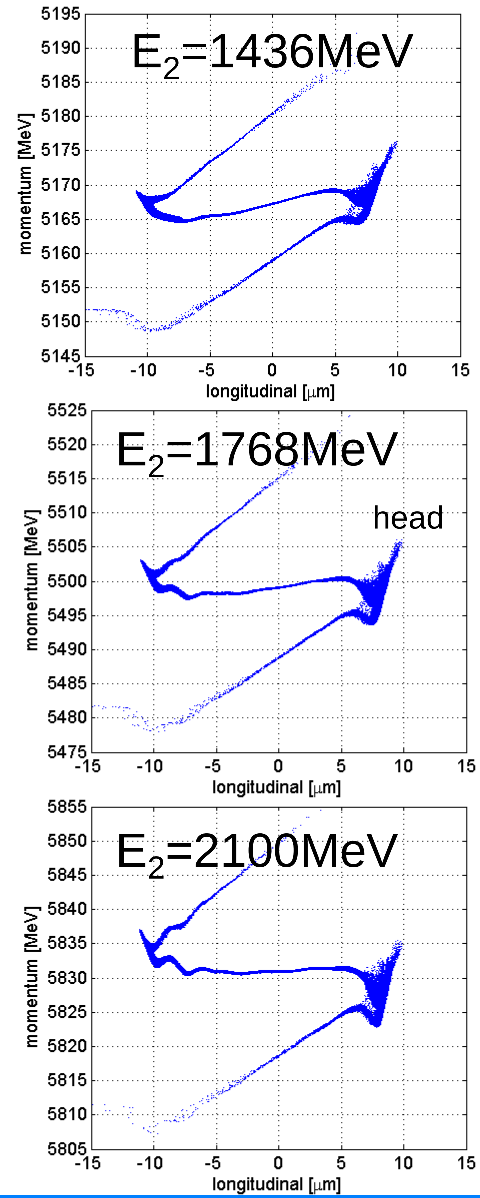




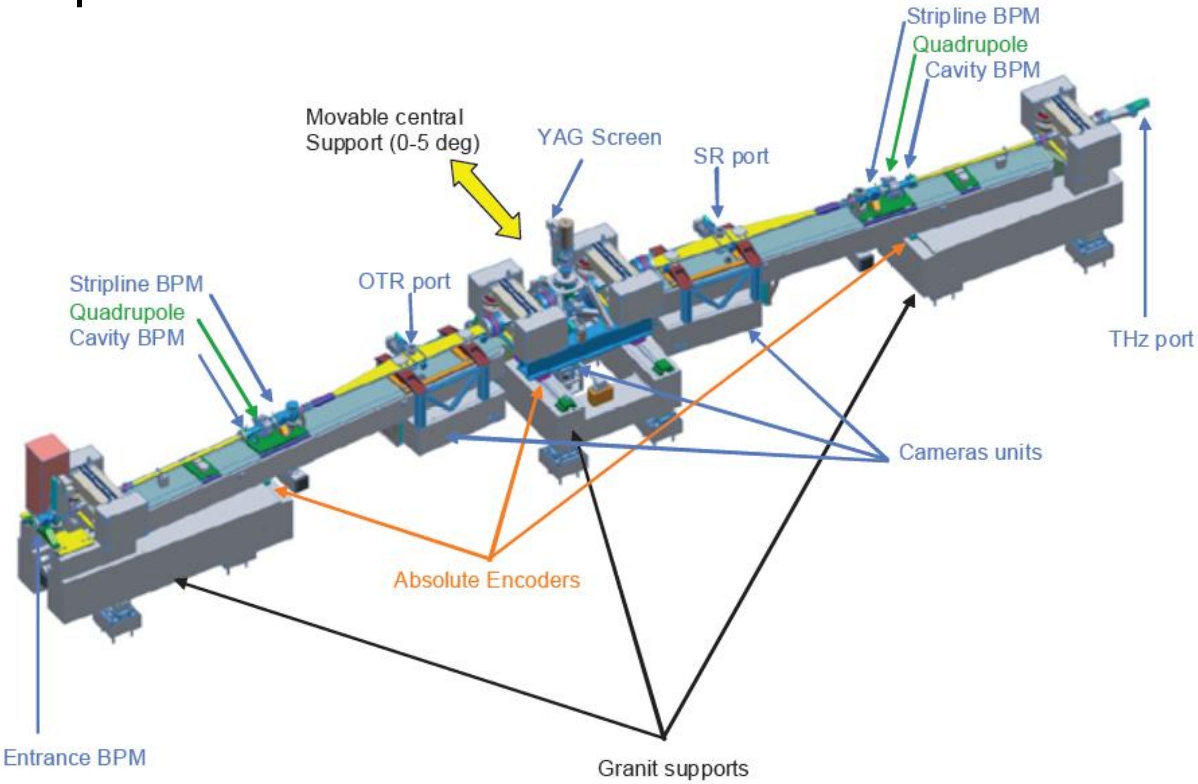




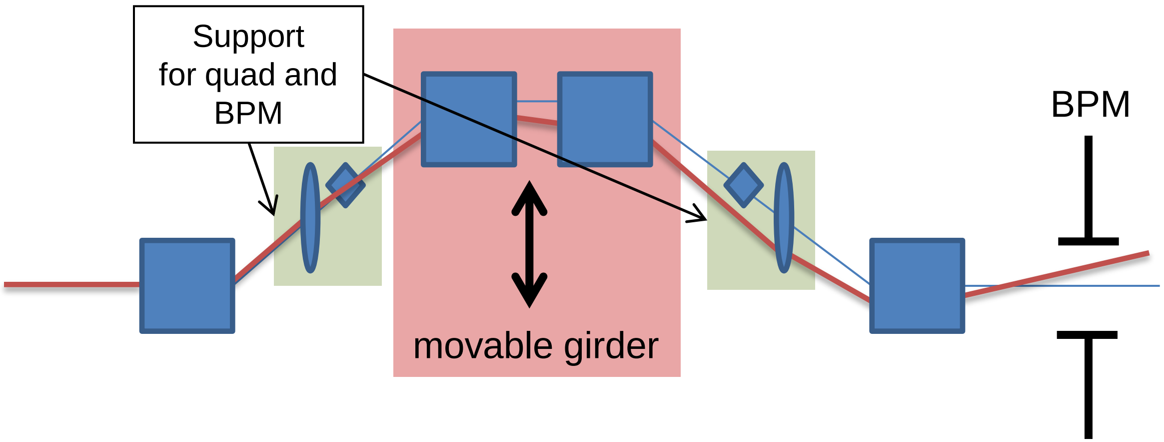
Bunch Compressor

- Movable girder system
- Quadrupoles, Sextupoles and standard BPMs in dispersive section

- Online energy measurements
- Corrector quads can be used to correct for beam tilts



Bunch Compressor Alignment



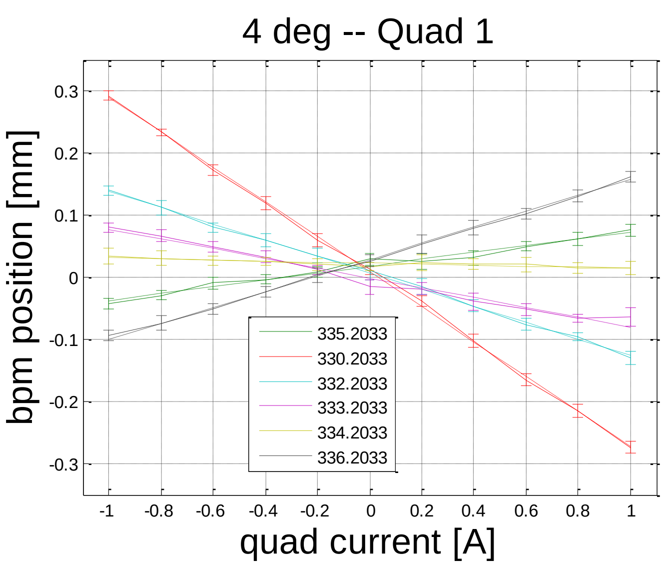
Overall movable girder position has to be matched to the orbit bend from the magnets
Alignment of the corrector quadrupoles with respect to the BC BPMs has to be verified

Alignment Procedure:
For each girder position the quadrupole strength is varied and the BPM response is recorded. The girder position which minimises these orbit variations is the correct one

Alignment results at 4 deg.
Quad 1: 334.3mm / Quad 2: 335.9mm →
Girder is moved from 325.2mm to 335.1mm

This procedure works well for all bending angles (0 to 5 deg.).

After moving the girder the orbit offsets in the BC BPMs are mitigated →
good quad/BPM alignment

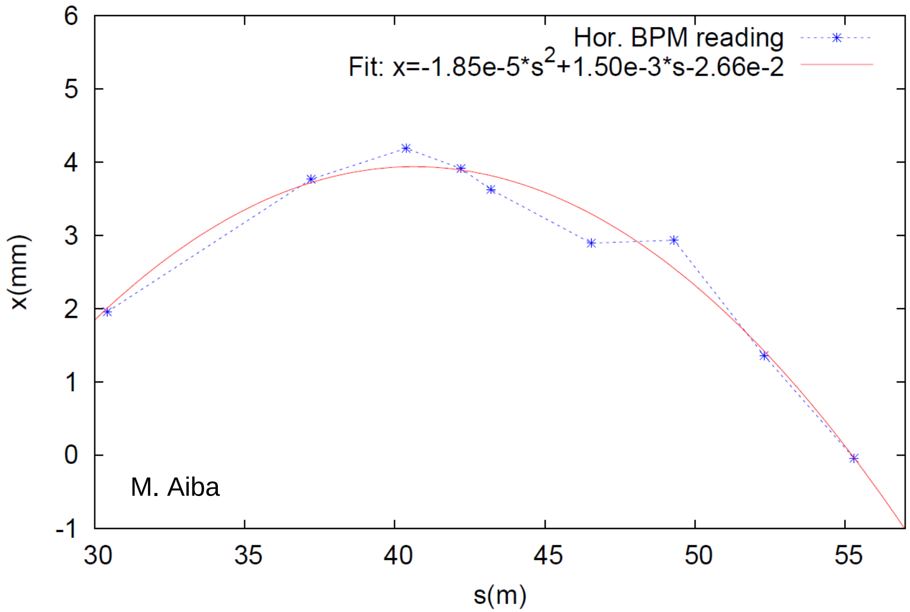


BC Setup

Geomagnetism measurement

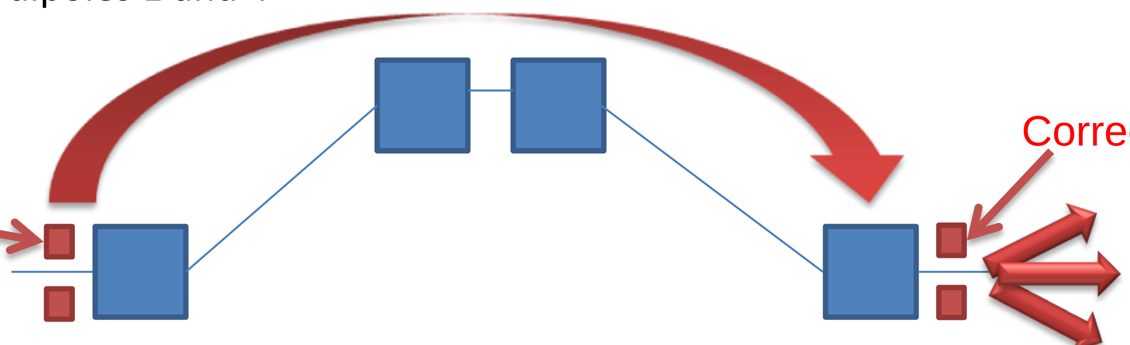
0) Measure the beam momentum
1) Turn off all the magnets of BC and downstream
2) Measure beam orbit at BPMs
3) Apply quadratic fit and find the geomagnetism

Average geomagnetism is 28.4 µT



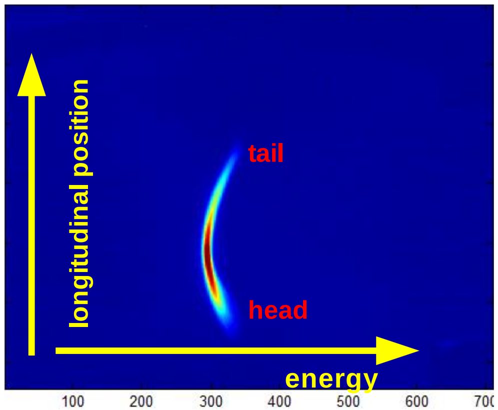
Bunch compressor set-up

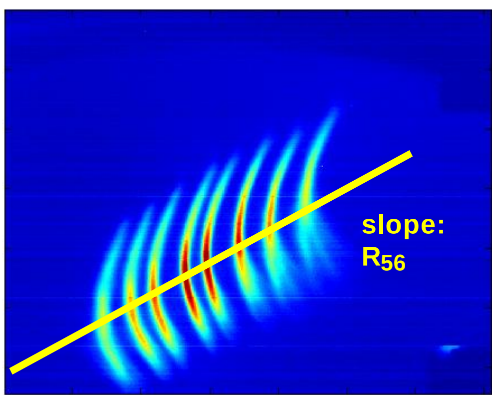
1. Set BC dipoles to the current corresponding to the requested R_{56} (lookup tables, to be measured soon)
2. Set all trim-coils to correct geomagnetism
3. Minimize BPM offset with BC mover
4. Correct residual dispersion using the horizontal correctors next to dipoles 1 and 4



R_{56} Measurement

$R_{56} = \Delta s/\delta$
$\delta = \Delta p/p$



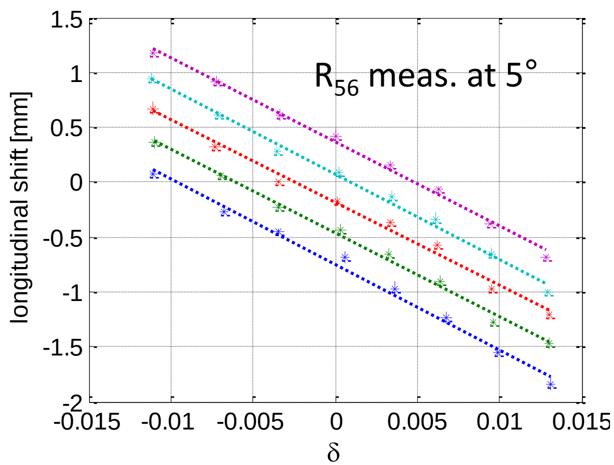


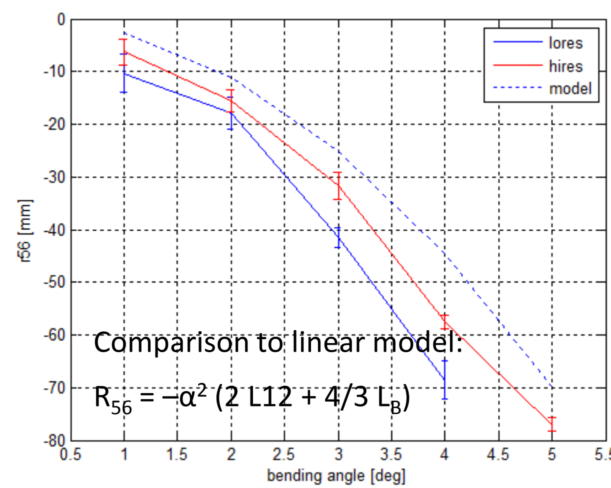
Correlation between horizontal and vertical position gives R_{56}

Measurement of longitudinal dispersion

arrival time measurements with TDC since the BAMs are not operational yet

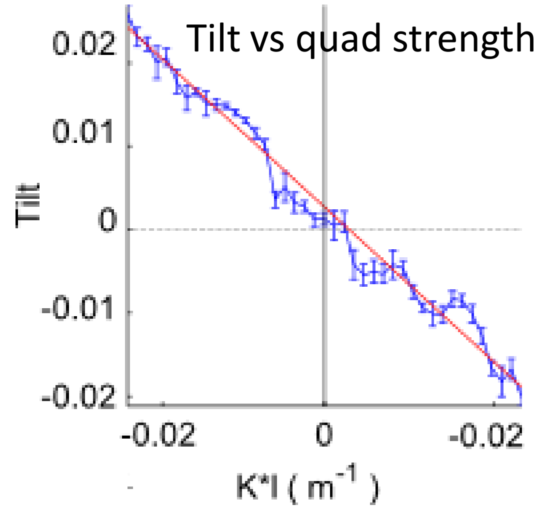
- Measurement of the longitudinal phase-space for different energies
- The energy is changed varying the power in s-band structures 3-4
- TDC calibration is done for each point

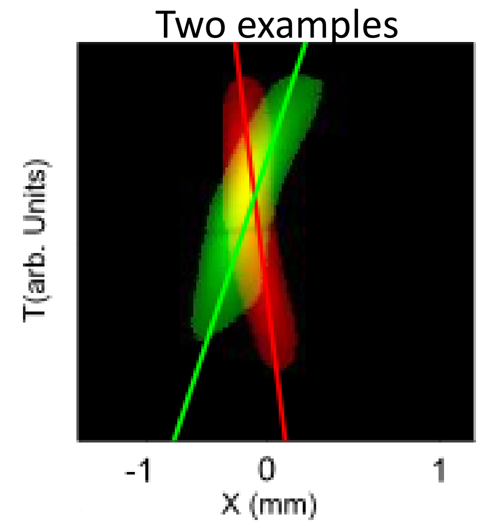




Beam Tilt Correction

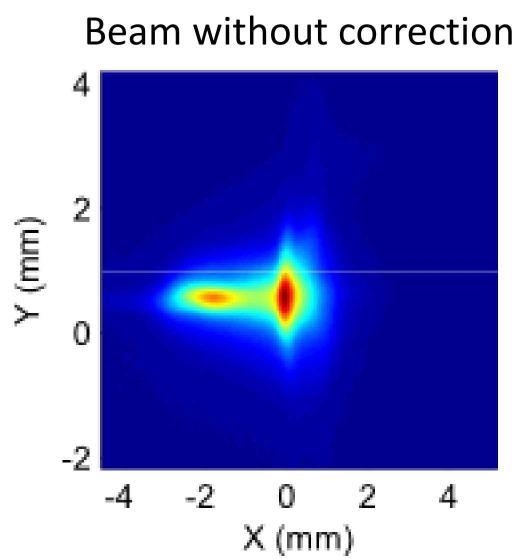
For SwissFEL:
- ➢Quadrupoles and sextupoles in the bunch compressors will be used to correct the x-t tilt generated due to CSR and other sources
- ➢Skew quadrupoles could be used to correct y-t tilts.



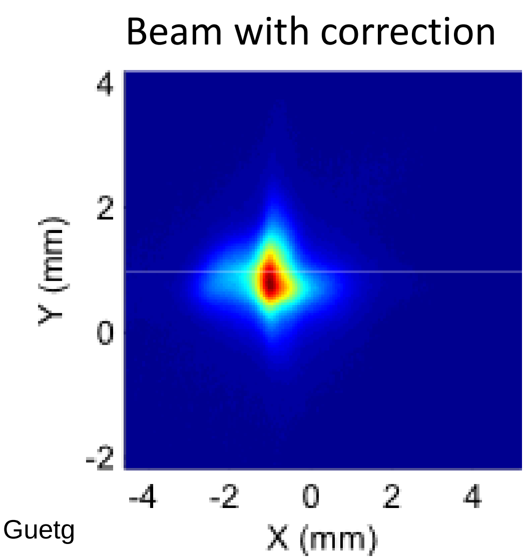


Proof-of-principle measurement

- ➢Beam strongly over-compressed at 200 MeV, BC at 5 degrees.
- ➢Beam tilt was manipulated using the corrector quads in BC.
- ➢Clear effect on projected emittance
- ➢Comparison with simulations and detailed analysis is in progress

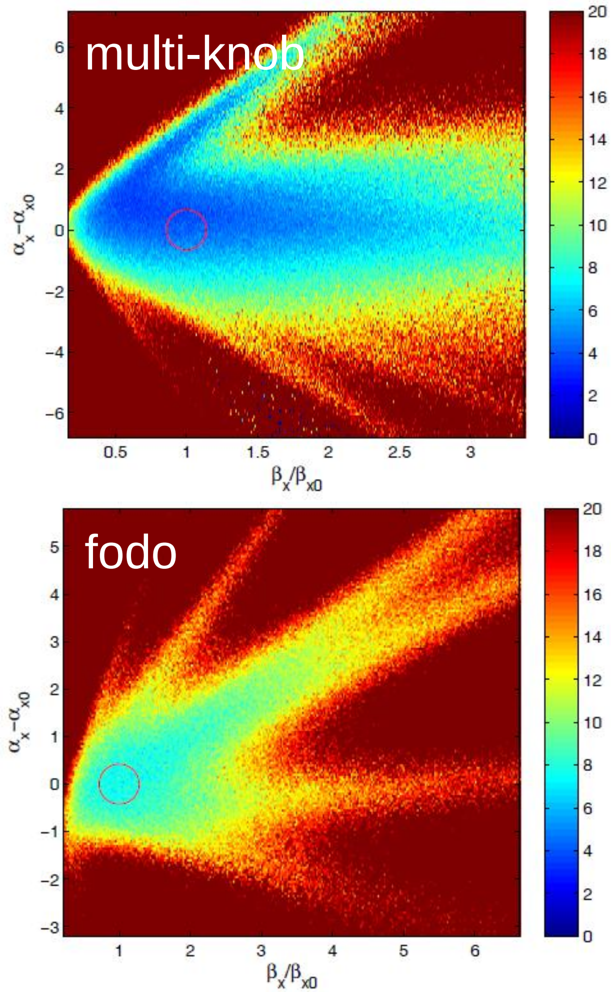


M. Guetg



Optics and Emittance Measurements

- Multi-, and symmetric single quadrupole scans are used for phase space measurements
- Advantages over FODO section:
  - Higher number of measurements points
  - Arbitrary beta function at screen to adapt spot size to diagnostics capabilities
  - Less space required
  - any matching section in lattice can be used for measurements
  - Measurements of x-y coupling are possible
- Disadvantages:
  - Non parasitic
  - Hysteresis effects need to be corrected

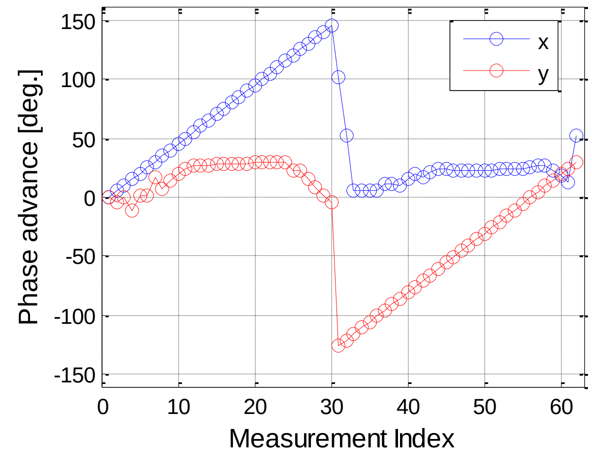


B. Beutner, E. Prat, "Considerations about Optics-Based Phase-Space Measurements at Linac-Based FEL Facilities", Proceedings of FEL 2011, Shanghai

“Advanced” Quadrupole Scans

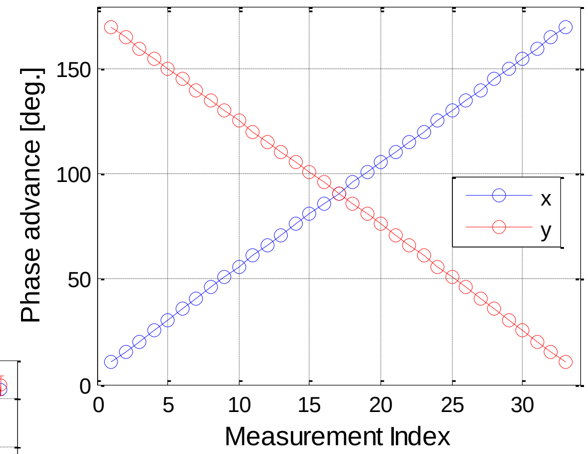
Multi-quad scan (mainly used for coupling measurements)

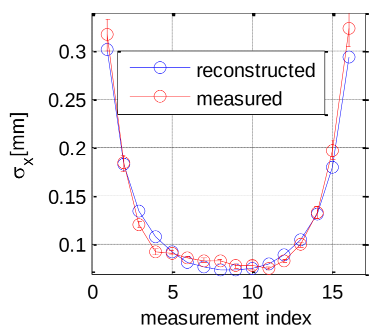
- 3 quads are used to generate the phase-advance (first in x, then in y), while keeping the beam size under control
- Beam size measurement at one screen
- It allows measuring coupling terms and intrinsic emittances

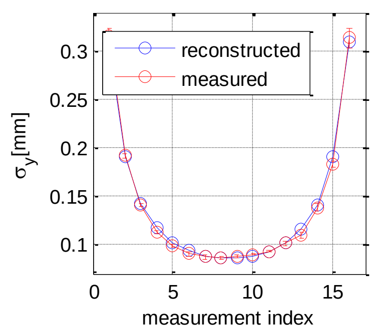


Single-quad scan (main method)

- One quadrupole is used to generate the phase-advance simultaneously in x and y
- It needs special optics at the quad position
- Beam size measurement at one screen
- If beam is matched beam stays round during the scan
- Fastest method







E. Prat

Emittance Optimisation

- Strategy: optimize projected emittance in both planes, then measure slice emittance (in x)
- So far only optimization with uncompressed bunches (it's not relevant to optimize compressed bunches without x-band cavity) for 10pc and 200pC
- Main used knobs:

Knob	What influences?	Comments
Laser longitudinal profile	(Projected) emittance compensation	Flat top (pulsar) gives better emittance
Laser transverse profile	Emittance and x/y asymmetry	Set as homogeneous and symmetric as possible
Laser alignment	Orbit, dispersion	Alignment done
Laser radius (aperture)	Emittance compensation	Set aperture to simulations optimum
Gun solenoid field	Emittance compensation	Scanned empirically
Gun solenoid alignment	Orbit (wakes), dispersion	Alignment done
Corrector quads in solenoid	x/y coupling	Empirically optimized
Gun gradient and phase	Emittance compensation	Set to design in spectrometer (7.1 MeV, δ_{min})
FINSB01 gradient	Emittance compensation	Set to design
FINSB solenoids	x/y coupling	Empirically optimized
Orbit through FINSB1-4	Projected emittance (wakes)	Empirically optimized at FINSB01
Orbit after S-band	Dispersion	Empirically optimized

- New profile monitor (YAG + OTR) to be used for SwissFEL was recently installed. Beam size resolution is ~14 μm and signal to noise ratio is good enough to measure slice emittance down to few pC.

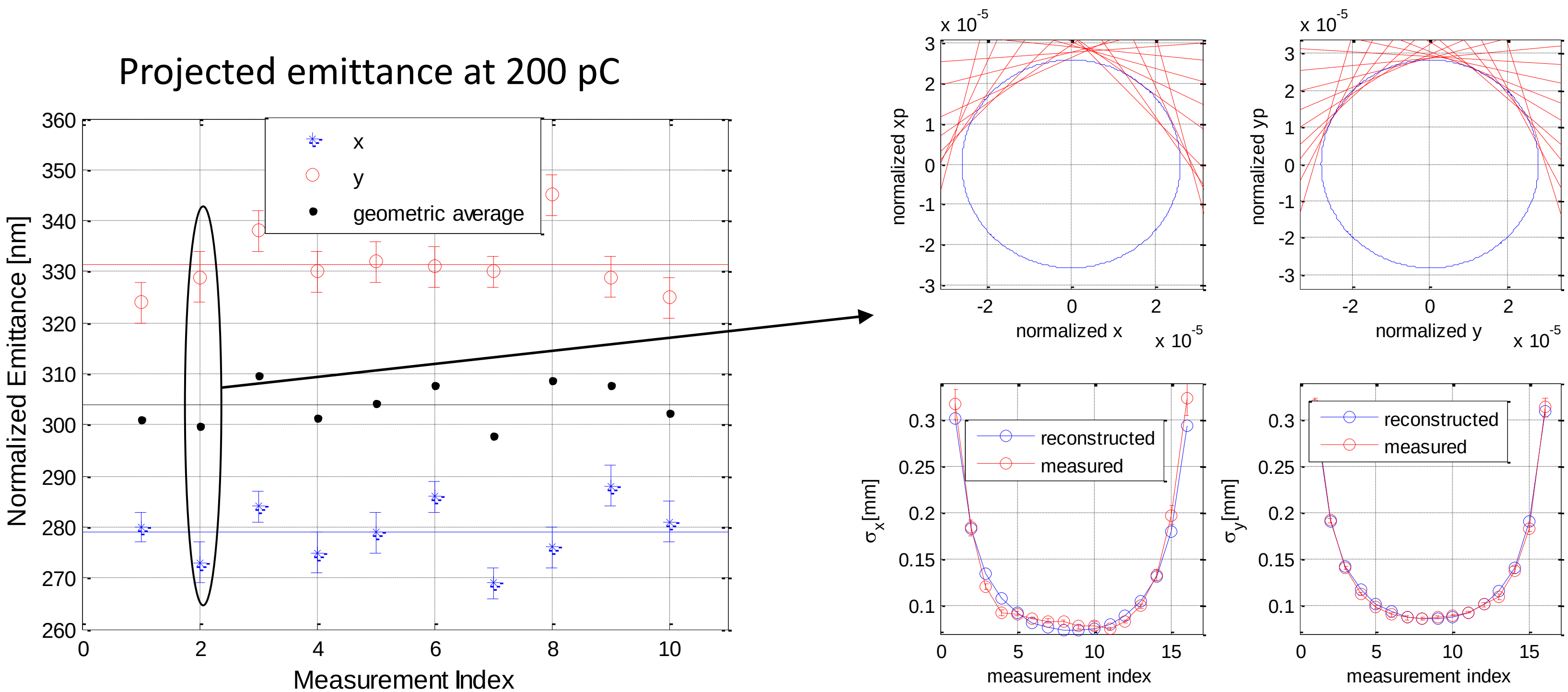
E. Prat

Emittance Results

- By doing a full optimization we have achieved the following emittance values

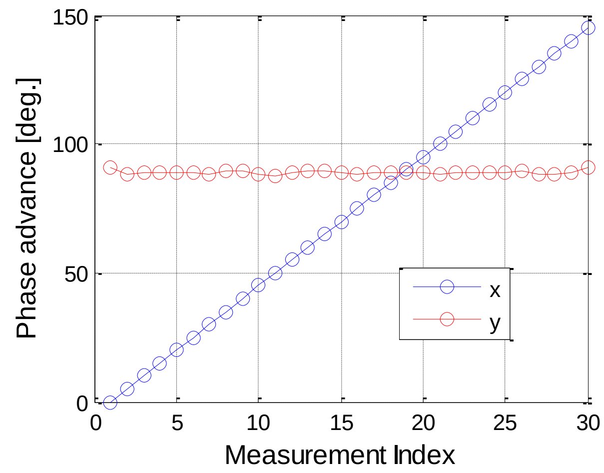
	200 pC	10 pC
Projected emittance	~0.30 µm	~0.15 µm
Slice emittance	~0.20 µm	~0.10 µm

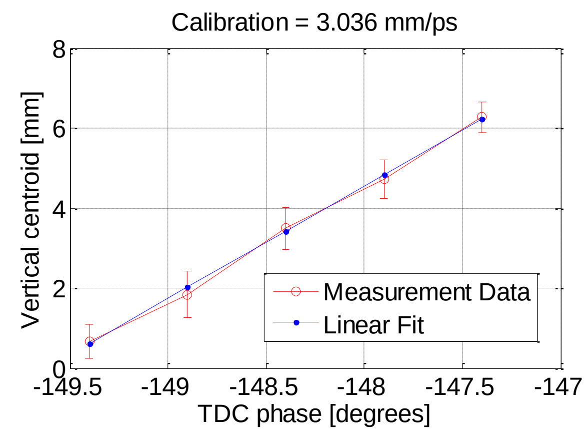
- These emittances fulfill the SwissFEL requirements (but not compression yet!)
- Emittance values are stable in short-term and optimum settings are reproducible

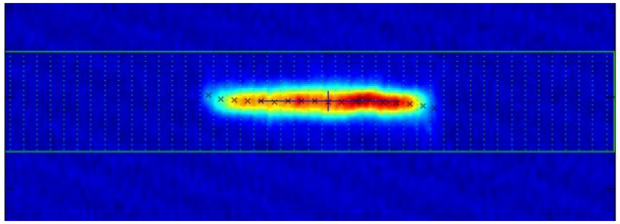


Slice Emittance

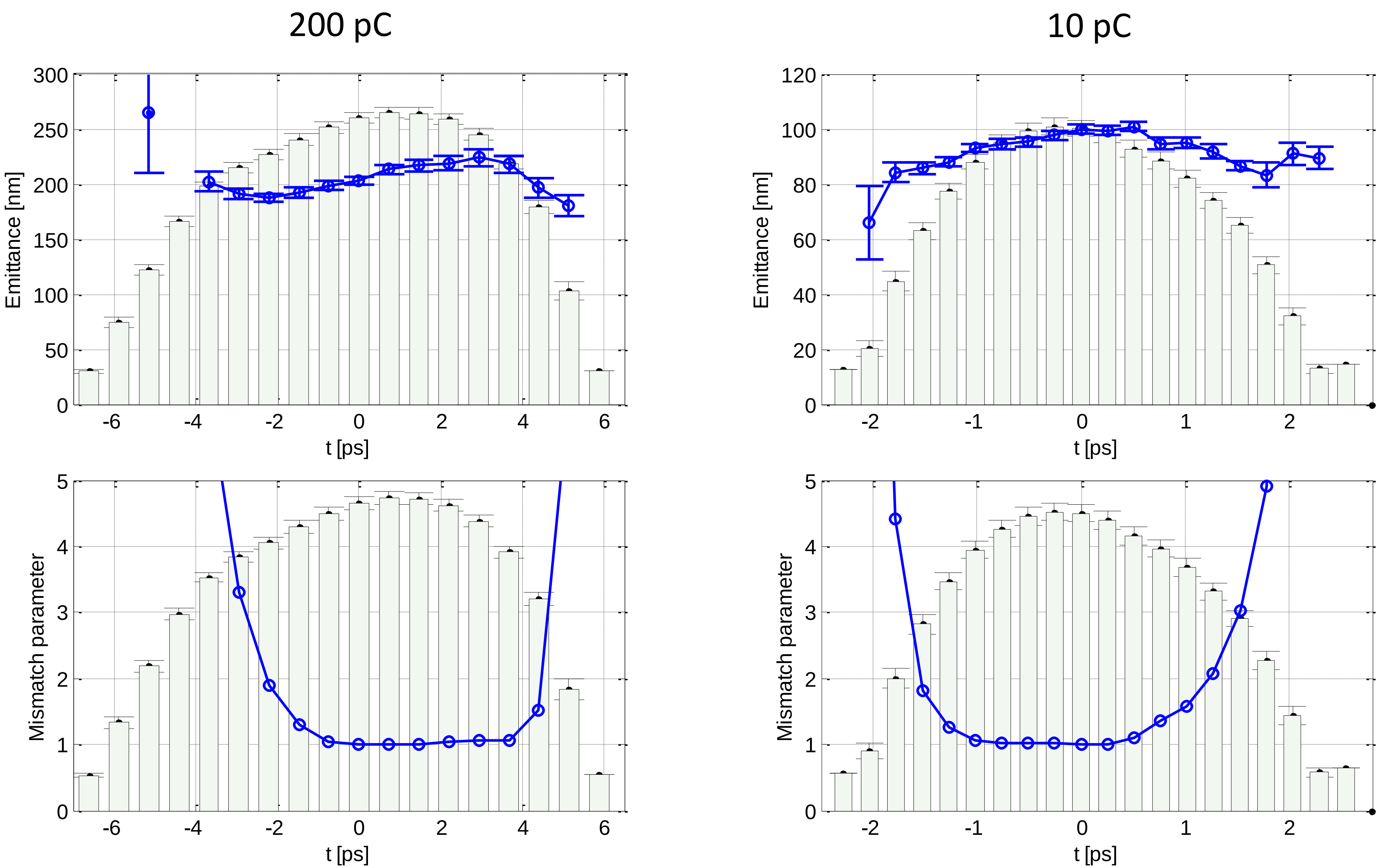
- Transverse deflection (streaking)
- Optics. The optics are scanned using 5 quads between transverse deflector and observation point (end of FODO) to:
  - Generate regular phase-advance in x:
  - $\mu_x = [0:5:150]$
  - Keep beam size under control:
  - $35m < \beta_x < 40m$
  - Keep longitudinal resolution constant:
  - $\sin(\mu_y) \sim 1$
- Transverse deflector calibration. At each optics the phase of the deflector is changed to obtain individual mm-ps calibration for each optics
- Slice analysis. The beam is split into slices, using the centroid from Gauss fit as a reference. Per each slice the beam size from Gauss fit is obtained
- Emittance/mismatch determination. From the beam sizes per each optics the emittance and optics are obtained per each slice.
- Projected parameters are also obtained







Slice Emittance Results




Thank You
for Your Attention!

Design Parameters

+ SwissFEL

Electron Beam Design Parameters	Nominal Operation Mode		Special Operation Mode	
	Long Pulses	Short pulses	Large Bandwidth	Ultra-Short Pulses
Charge per bunch (pC)	**200**	**10**	200	10
Beam energy for 1 Å (GeV)	5.8	5.8	5.8	5.8
Core slice emittance (mm.mrad)	0.43	0.18		0.25
Projected emittance (mm.mrad)	0.65	0.25		0.45
Slice energy spread (keV, rms)	350	250		1000
Relative energy spread (%)	0.006	0.004		0.02
Peak current at undulator (kA)	2.7	0.7	3.7	14
Bunch length (fs, rms)	30	6		< 0.6
Bunch compression factor	125	240		636
Repetition rate (Hz)	100	100		100
Number of bunches / RF pulse	2	2		2
Bunch spacing (ns)	28	28		28

FEL Beam Design Parameters	Nominal Operation Mode		Special Operation Mode	
	Long Pulses	Short Pulses	Large Bandwidth	Ultra-Short Pulses
Undulator period (mm)	15	15		15
Undulator parameter	1.2	1.2		1.2
Energy spread (keV)	350	250		1000
Saturation length (m)	50	50		50
Saturation pulse energy (μJ)	60	3		15
Effective saturation power (GW)	2	0.6		50
Photon pulse length (fs, rms)	13	2.1		0.06
Number of photons ($\times 10^9$)	31	1.7		7.5
Spectral Bandwidth, rms (%)	0.03	0.04	0.8	0.05
Peak brightness (# photon/mm^2.mrad^2.s^1.0.1% bandwidth)	3.10^{32}	1.10^{32}		$1,3.10^{33}$
Average brightness (# photon/mm^2.mrad^2.s^1.0.1% bandwidth)	1.10^{21}	$5,7.10^{18}$		$7,5.10^{18}$

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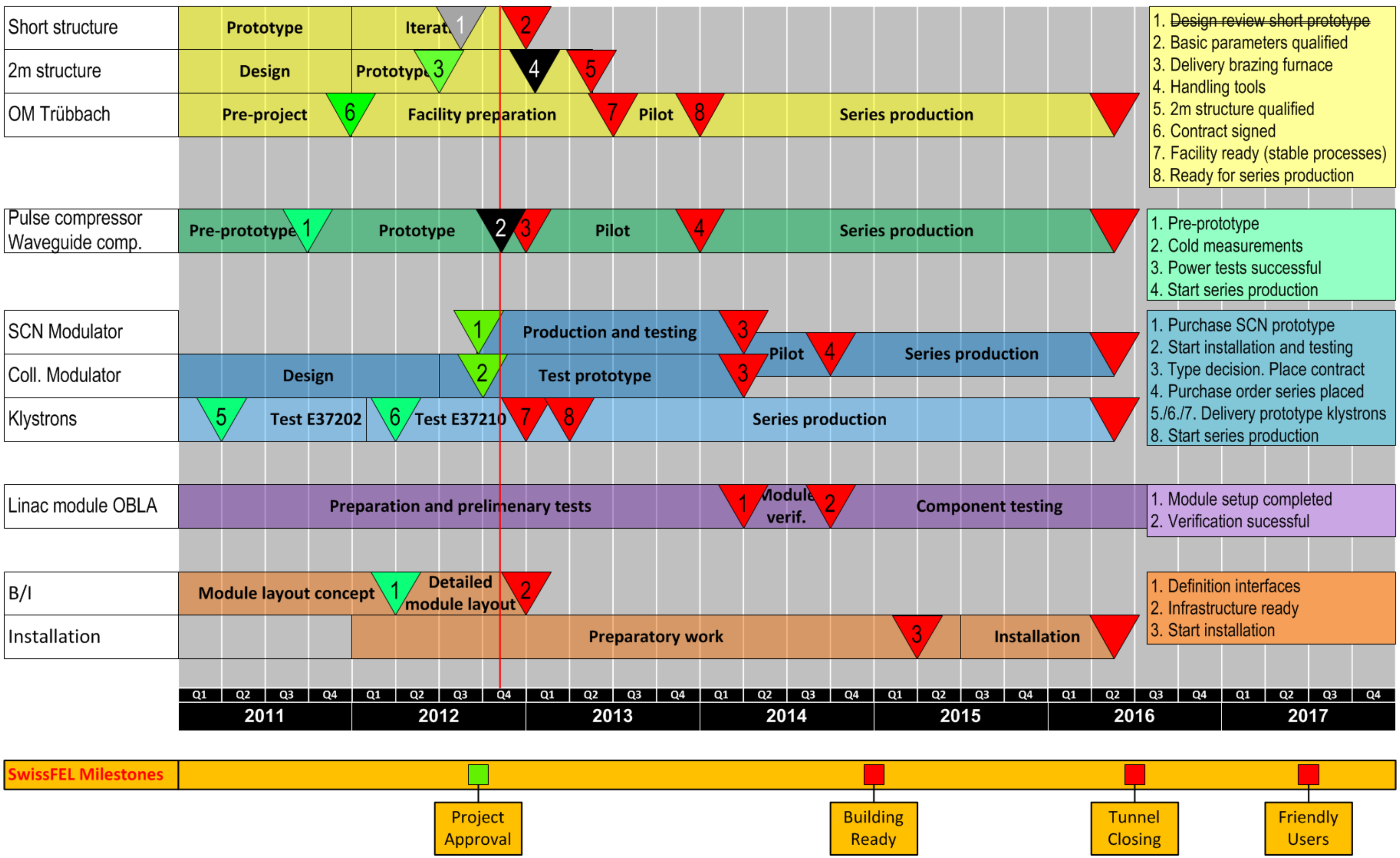
+ SwissFEL



Introduction

The SwissFEL facility will produce coherent, bright, and short photon pulses covering a wavelength range down to an angstrom, requiring an emittance between 0.18 to 0.43 mm mrad at bunch charges between 10 pC and 200 pC. The facility consists of a S-band RF-gun, booster, and a C-band main linac, which accelerates the beam up to 5.8 GeV.

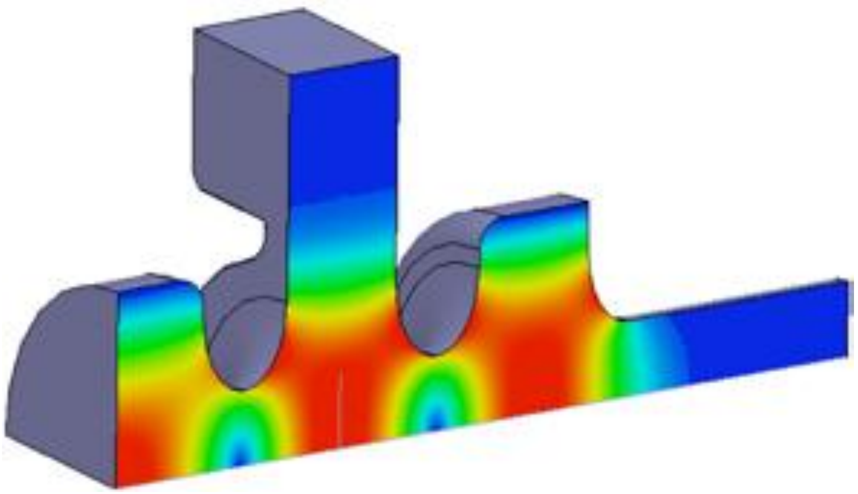
Two compression chicanes will provide a nominal peak current of about 1 to 3 kA depending on the charge.

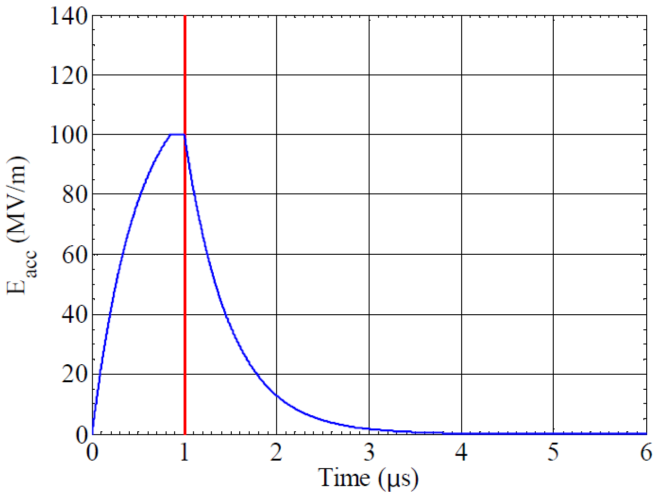
Since 2010 the SwissFEL Injector Test Facility is in operation to demonstrate the required beam parameters.

In this talk an overview of the SwissFEL project is presented as well as recent results from the test accelerator.

S-band

- PSI Gun:
  - RF gun for Swiss FEL consists of 2.5 cells operating in the π mode.
  - second cell is coupled to two waveguides symmetrically arranged to cancel the dipolar filed component
  - a racetrack profile is used to minimize the quadruple field component.





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S-band

+ SwissFEL

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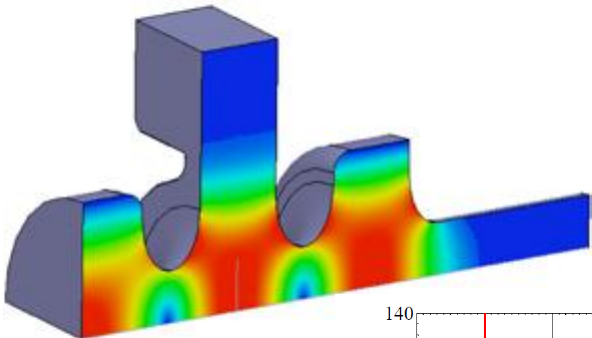
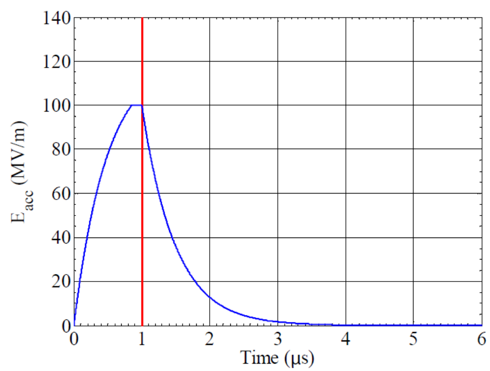
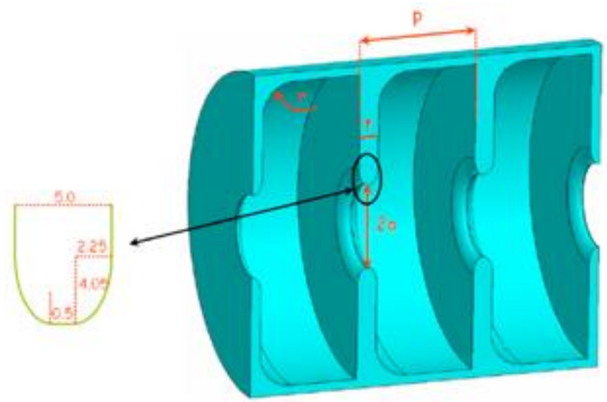


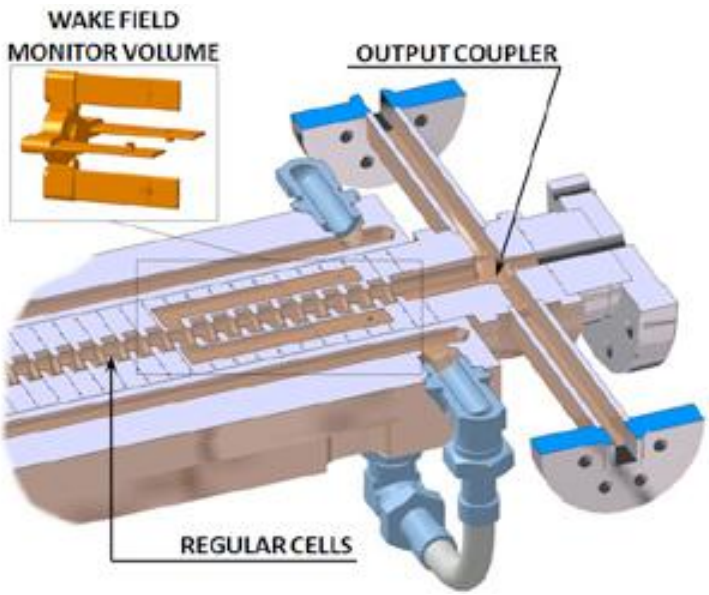


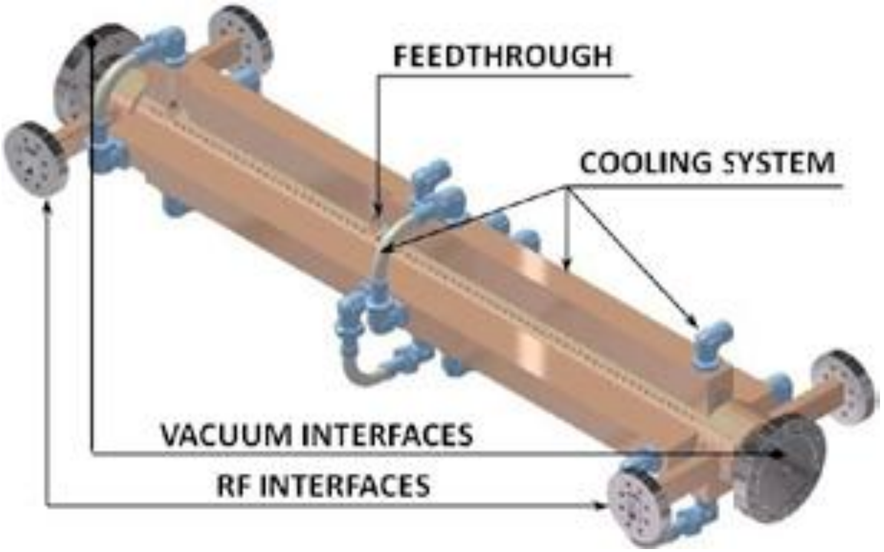


- Booster
  - constant-gradient 2π/3 travelling-wave accelerating structures
  - RF structure design derives from the Linac II DESY structures and was optimized to decrease the power requirement.
  - 122 cells, including the coupler cells.

X-band

- X-band harmonic structure is a modification of the SLAC H75 structure, developed in collaboration with CERN.
- Two structures have been manufactured for PSI in an frame of a CERN, PSI, ELETTRA collaboration.





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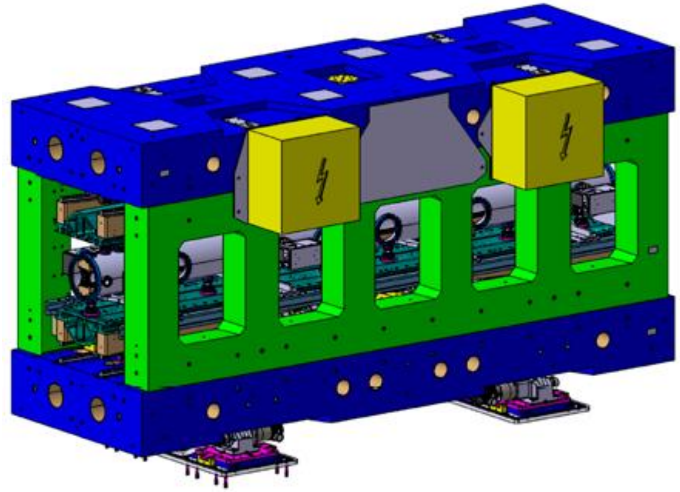
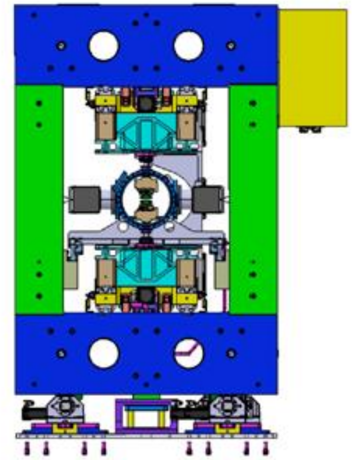
Undulator Systems

+ SwissFEL

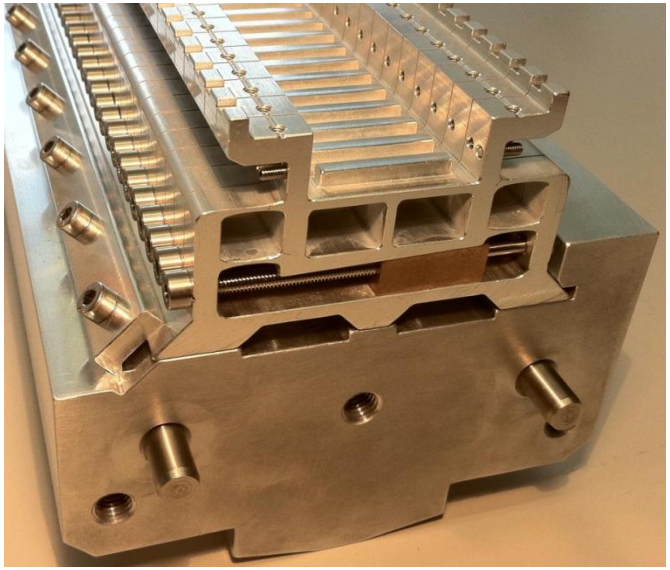


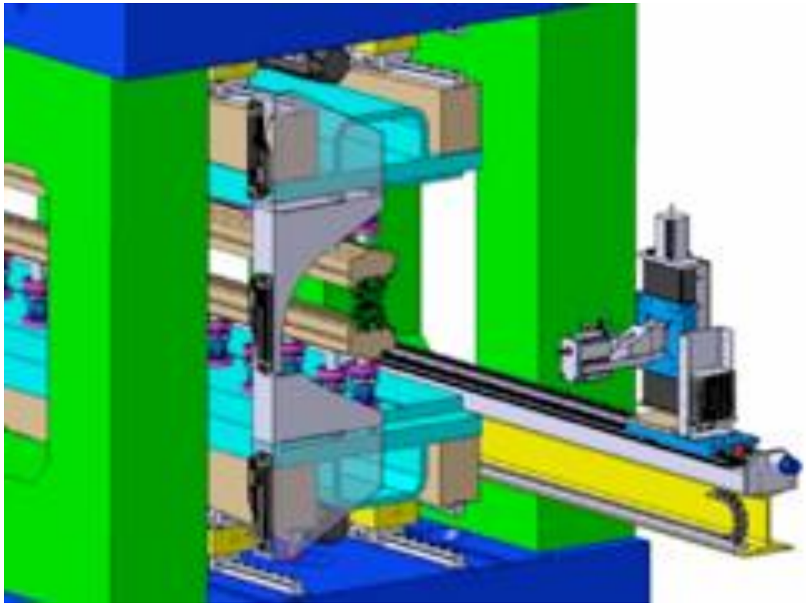


	Aramis (U15)	Athos (UE40)
Wavelength	0.1-0.7 nm	0.7-7.0 nm
Photon energy	1.71-12keV	0.17-1.71keV
Tuning	Electron energy	Undulator
Type	Planar, in-vacuum	APPLE II
Magnetic Length	3990 mm	3920 mm
K-Value	**1.2** (1.8—1.0)	3.5—0.9
Period	15 mm	40mm
Gap	**4.7 mm** (3.2—5.5)	6.5—24 mm

Undulator Support System

T. Schmidt / M. Calvi





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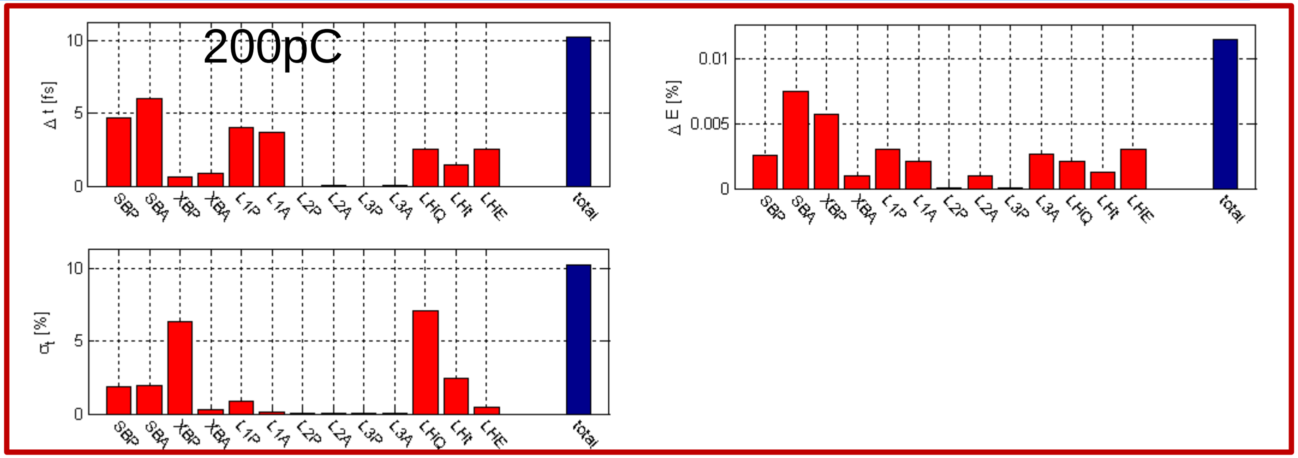
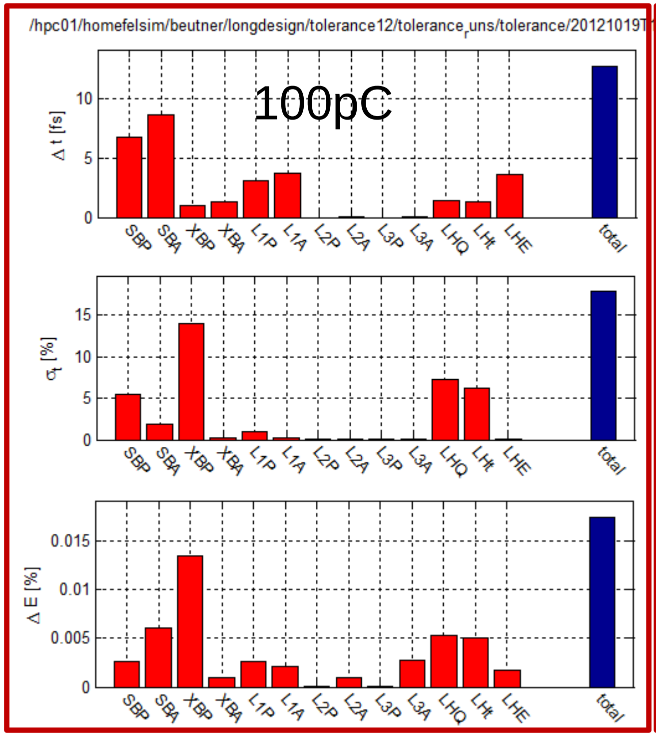
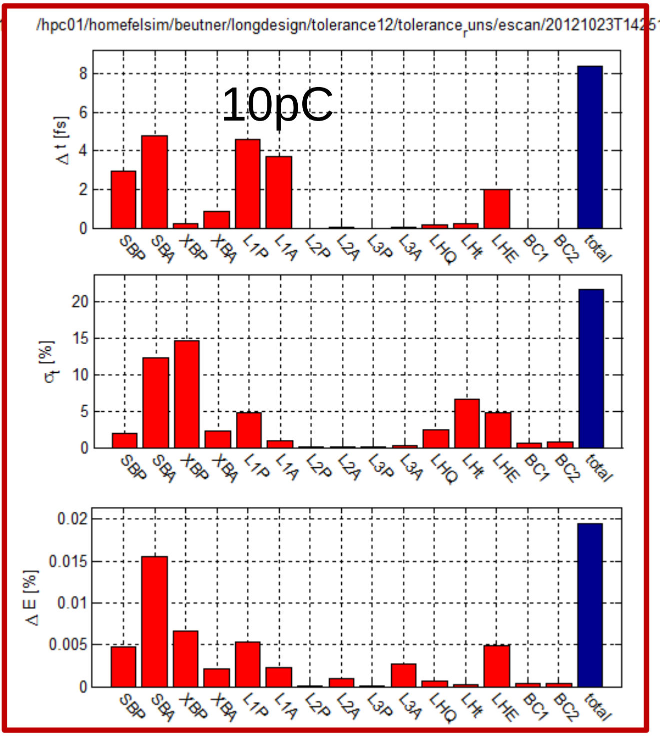
Energy spread (keV, rms)	350	250	25000	1000
Relative energy spread (%, rms)	0.006	0.004	0.3	0.02
Peak current at undulator (kA)	2.7	1.6	3	15
Bunch length (fs, rms)	25	2	22	0.3
Bunch compression factor	125	533	136	5000
Repetition rate (Hz)	100	100	100	100
Number of bunches / RF pulse	2	2	2	2
Bunch spacing (ns)	28	28	28	28

Stability Summary

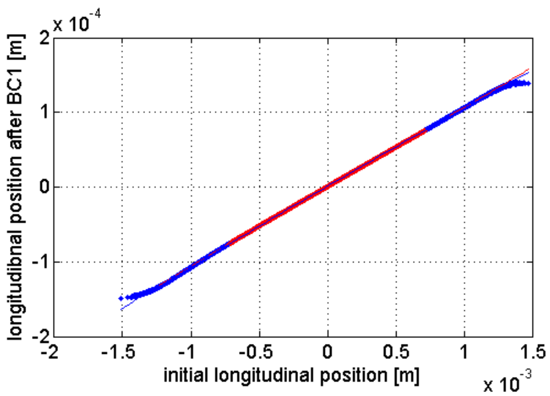
	Expected Performance
S-Band Phase [deg]	0.018
S-Band Voltage [rel]	1.8 * 1e-004
X-Band Phase [deg]	0.072
X-Band Voltage [rel]	1.8 * 1e-004
Linac 1 Phase [deg]	0.036
Linac 1 Voltage [rel]	1.8 * 1e-004
Linac 2 Phase [deg]	0.0360
Linac 2 Voltage [rel]	1.8 * 1e-004
Linac 3 Phase [deg]	0.0360
Linac 3 Voltage [rel]	1.8 * 1e-004
Charge	1%
initial arrival time [fs]	30
Initial Energy [rel]	1e-004
BC1 angle [rel]	5 * 1e-005
BC2 angle [rel]	5 * 1e-005

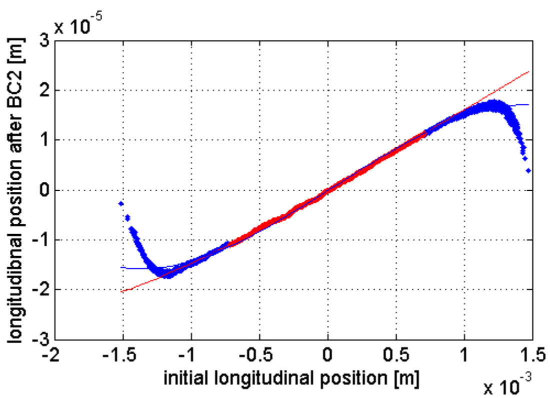






- A semi-analytically iterative procedure is used to setup the bunch compression to produce a required longitudinal bunch profile





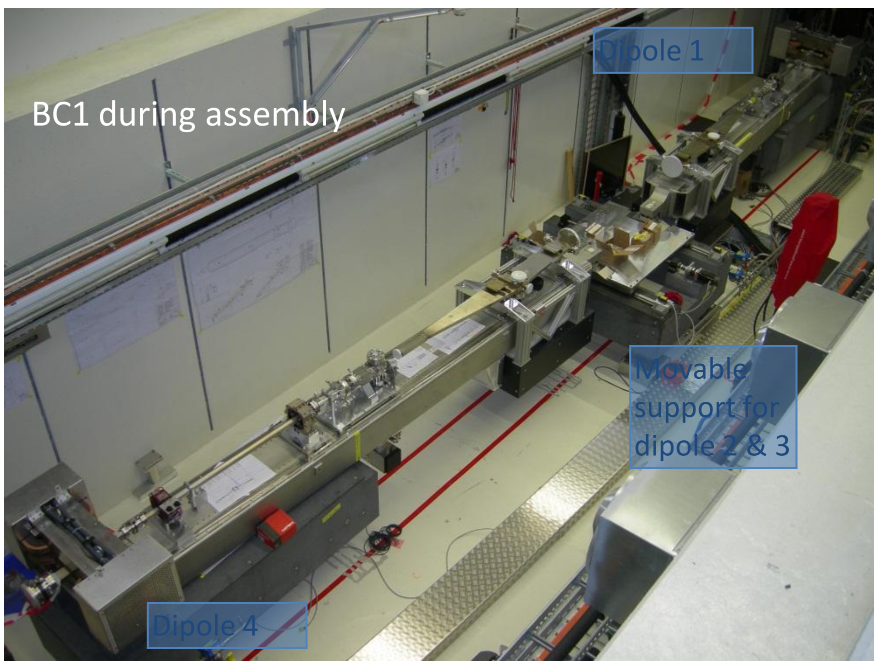
- Input:
  - Compression factors for each chicane
  - R56, … at each chicane
  - Energy at each chicane
  - Longitudinal shape parameters for desired final beam
    - Second and third order of a polynomial fit characterise the longitudinal bunch shape
- Output:
  - Voltages and phases of all RF stations downstream of the Laser Heater

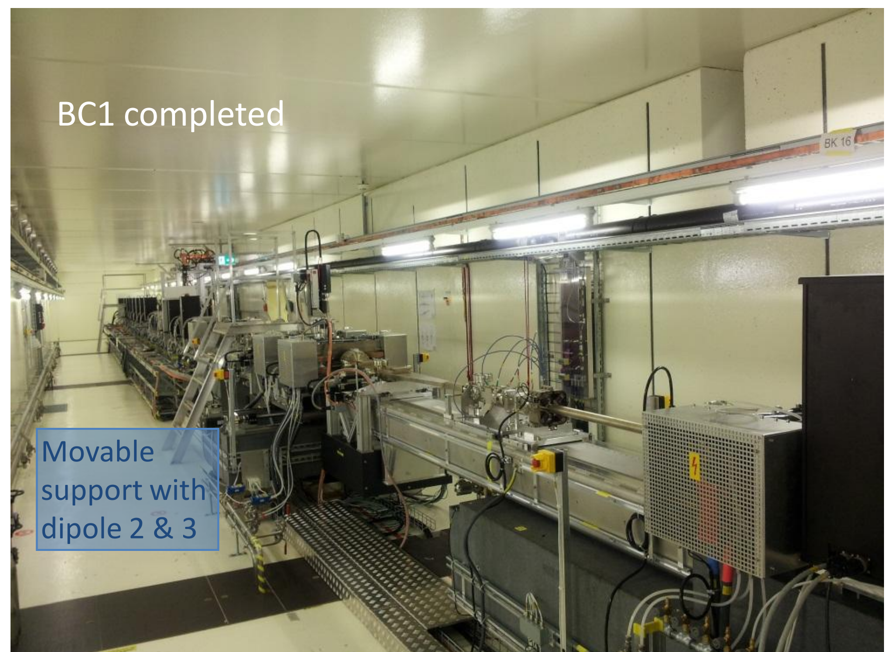
I. Zagorodnov and M. Dohlus, “A Semi-Analytical Modeling of Multistage Bunch Compression with Collective Effects” PRSTAB **14**, 014403 (2011)

WLHA Bunch Compressor

- Bunch Compressor with Movable Girder for the inner Dipoles
    - alpha[deg] = 0.0123 * x[mm]
- Dipole Projected Length: LB = 250mm
- Projected length of Drift Arm: L12 = 4375mm

alpha [deg]	B[T] 200MeV	R56[mm]
0	0	0
1	0.0466	-2.767
2	0.0931	-11.07
3	0.1397	-24.90
4	0.1861	-44.27
5	0.2326	-69.17





M. Pedrozzi / P. Wiegand