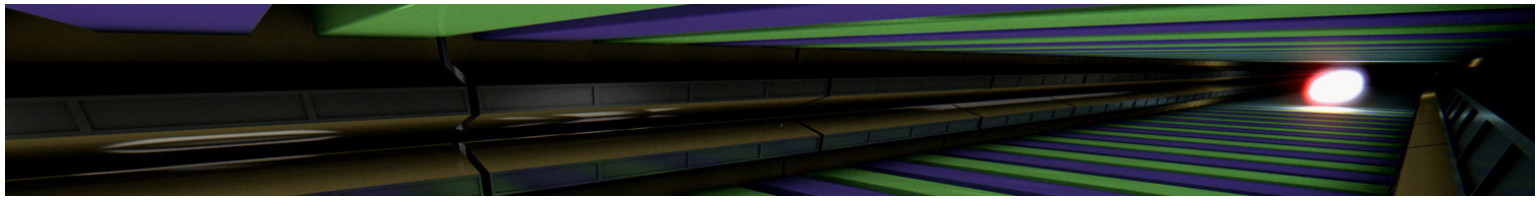
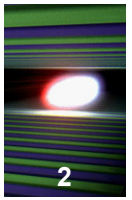


Report Commissioning Group

T. Limberg

Commissioning Group

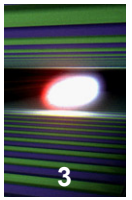


- (Core) Participants:

J. Pflüger	Undulators (WP 71)
J. Grünert	X-ray Photon Diagnostic (WP-74)
H. Sinn	X-ray Optics & Beam Transport (WP-73)
R. Treusch	FLASH Photon Coordination
Th. Tschentscher	Photon Experiments
W. Decking, T. Limberg	Machine Layout Coordination
E. Shneydmiller, M. Yurkov	FEL Concepts (WP-21), FLASH SASE Tuning
H. Schlarb	LLRF (WP-02)
S. Schreiber	FLASH Coordination

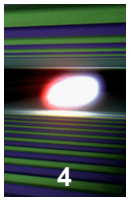
- Mandate:
  - The European XFEL Project board calls for a working group to plan the commissioning of the facility
  - This group will work out the commissioning strategy, the initial operating envelope, the high level goals and their sequence

LCLS Experience and Plans



- LCLS: **20.000 hours** of pre-beam check-out and commissioning time
- LCLS-II: **4.000 hours planned**, mainly pre-beam verification, actual beam commissioning time expected to be short
  - Beam commissioning of LCLS-II should be faster then LCLS-I
    - Hardware is very similar to that operating in LCLS-I
    - Beamline physics is well understood from LCLS-I
    - Controls and high-level apps are same as LCLS-I
      - Much of LCLS-I effort was writing apps to assist commissioning
    - Experienced team is in place

Example: Injector Pre-beam Verification Checklist



- First ½ of a 40 page document for the injector
- Every LCLS beamline component was verified in detail before turning on beam
- Will adopt similar procedure for LCLS-II

LCLS

Stanford Linear Accelerator Center
Stanford Synchrotron Radiation Laboratory

Pre-Beam Tunnel Check List for 2007 *LCLS* Commissioning

Nov. 27, 2006

(all *Z*-locations are measured from the cathode along the beam path)

Gun & GTL Beam Line:

SOL1BK (solenoid bucking coil):
SOLN: IN20:111

- O Z-location = 0 _____, Initials:_____, Date:_____
- O SLAC bar-code ? (ser. #?) _____, Initials:_____, Date:_____
- O beam-direction arrow OK _____, Initials:_____, Date:_____
- O polarity OK (Fig. 11) _____, Initials:_____, Date:_____
- O name-label visible on or near device _____, Initials:_____, Date:_____
- O field responds to controls _____, Initials:_____, Date:_____
- O power connections tight and clear _____, Initials:_____, Date:_____
- O power cables labeled for polarity _____, Initials:_____, Date:_____

SOL1 (gun solenoid magnet):
SOLN:IN20:121

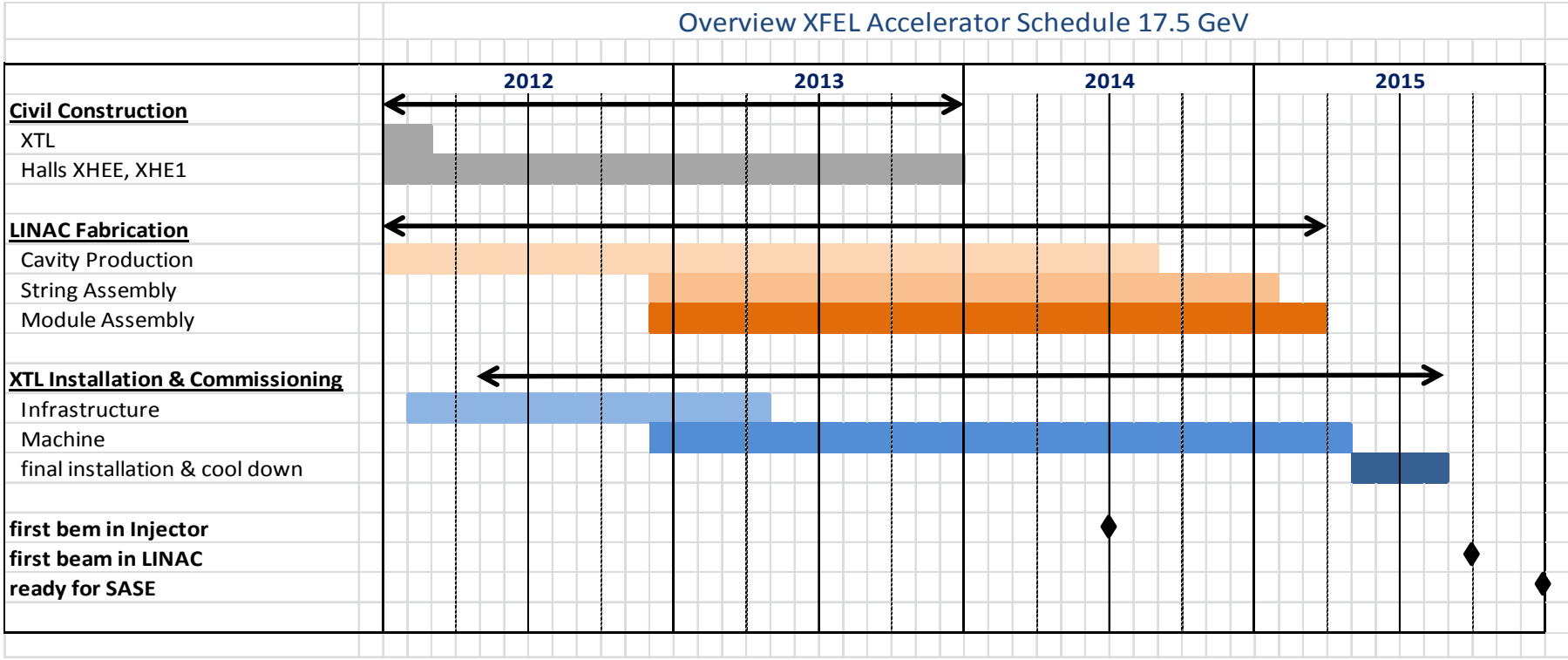
- O Z-location = 0.20 m _____, Initials:_____, Date:_____
- O SLAC bar-code 001099 (ser. #2) _____, Initials:_____, Date:_____
- O water connected _____, Initials:_____, Date:_____
- O beam-direction arrow OK _____, Initials:_____, Date:_____
- O polarity OK (Fig. 11) _____, Initials:_____, Date:_____
- O name-label visible on or near device _____, Initials:_____, Date:_____
- O field responds to controls _____, Initials:_____, Date:_____
- O power connections tight and clear _____, Initials:_____, Date:_____
- O power cables labeled for polarity _____, Initials:_____, Date:_____

CQ01 (gun solenoid quad trim):
QUAD:IN20:121

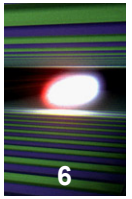
- O Z-location = 0.20 m (inside SOL1) _____, Initials:_____, Date:_____
- O polarity OK (Fig. 7) _____, Initials:_____, Date:_____
- O name-label visible on or near device _____, Initials:_____, Date:_____
- O field responds to controls _____, Initials:_____, Date:_____
- O power connections tight and clear _____, Initials:_____, Date:_____
- O power cables labeled for polarity _____, Initials:_____, Date:_____

European XFEL Accelerator Schedule

- start of injector commissioning mid 2014
- start of linac commissioning mid 2015
- observe first SASE by end of 2015



'Start of Operation' as defined in the European XFEL Convention

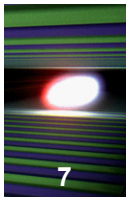


The accelerator complex and SASE1 start operation when on SASE1 a photon beam is obtained with the intermediate values of Table 4.1, and sufficient equipment is installed and commissioned to perform first scientific experiments.

Parameter	SASE1 Intermediate Values	SASE1 Final Project Values	Units
Wavelength	< 0.2	0.1	nm
Peak Brilliance	10^{30}	5×10^{33}	Photons/s/mm^2/ mrad^2/0.1%BW
Dimension at sample (no optics)	< 1.0	~ 0.6	mm^2, FWHM
Positional Stability	50	10	% of beam size, rms
Photon Energy Stability	~ 0.1	~ 0.1	%
Shot-to-Shot Intensity Fluctuations	Up to a factor 10	0.3 – 0.5	Dimensionless, Peak-to-Peak

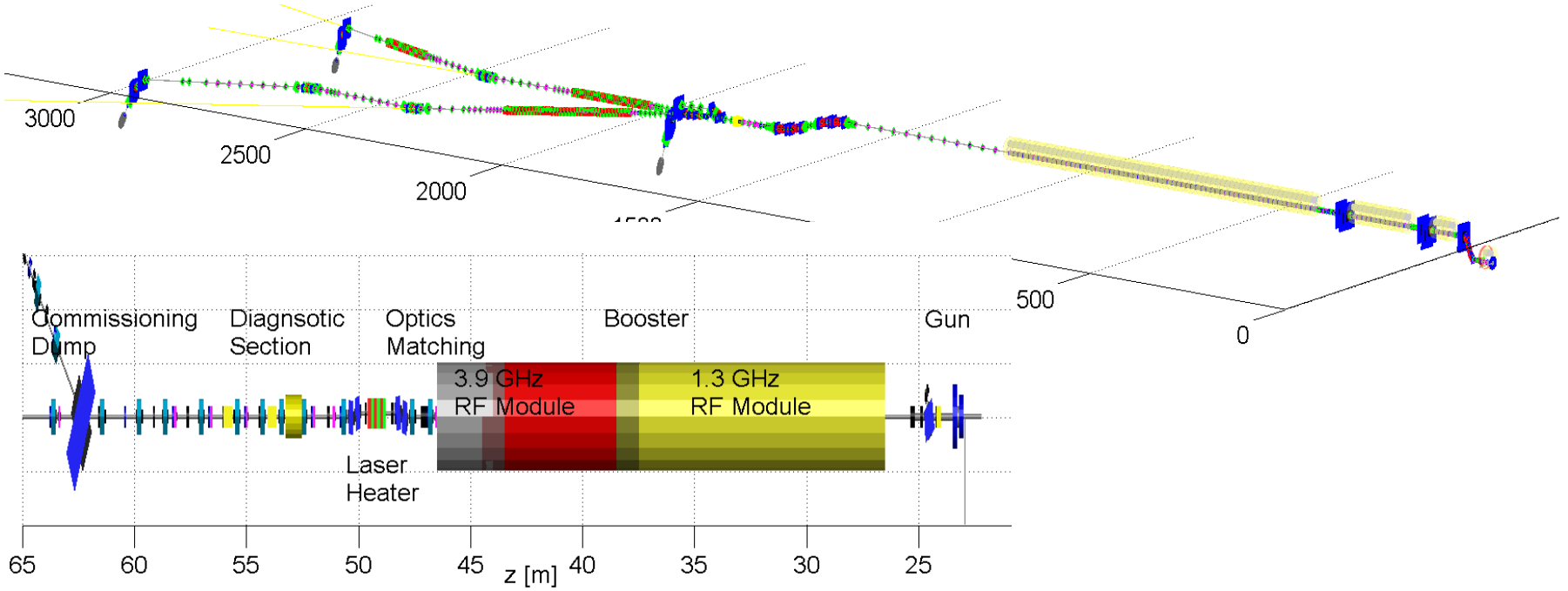
Technical Document 1
attached to the European XFEL Convention

E-beam parameters



- A first set of e-beam parameters:
  - Beam energy will be 17.5 GeV
  - Linac will be operated with several tens of bunches (not single bunch) as fast as possible
    - single bunch operation is useless for LLRF diagnostics and studies
  - beam charge around 0.5 to 1 nC
    - General Diagnostics and LLRF

Injector



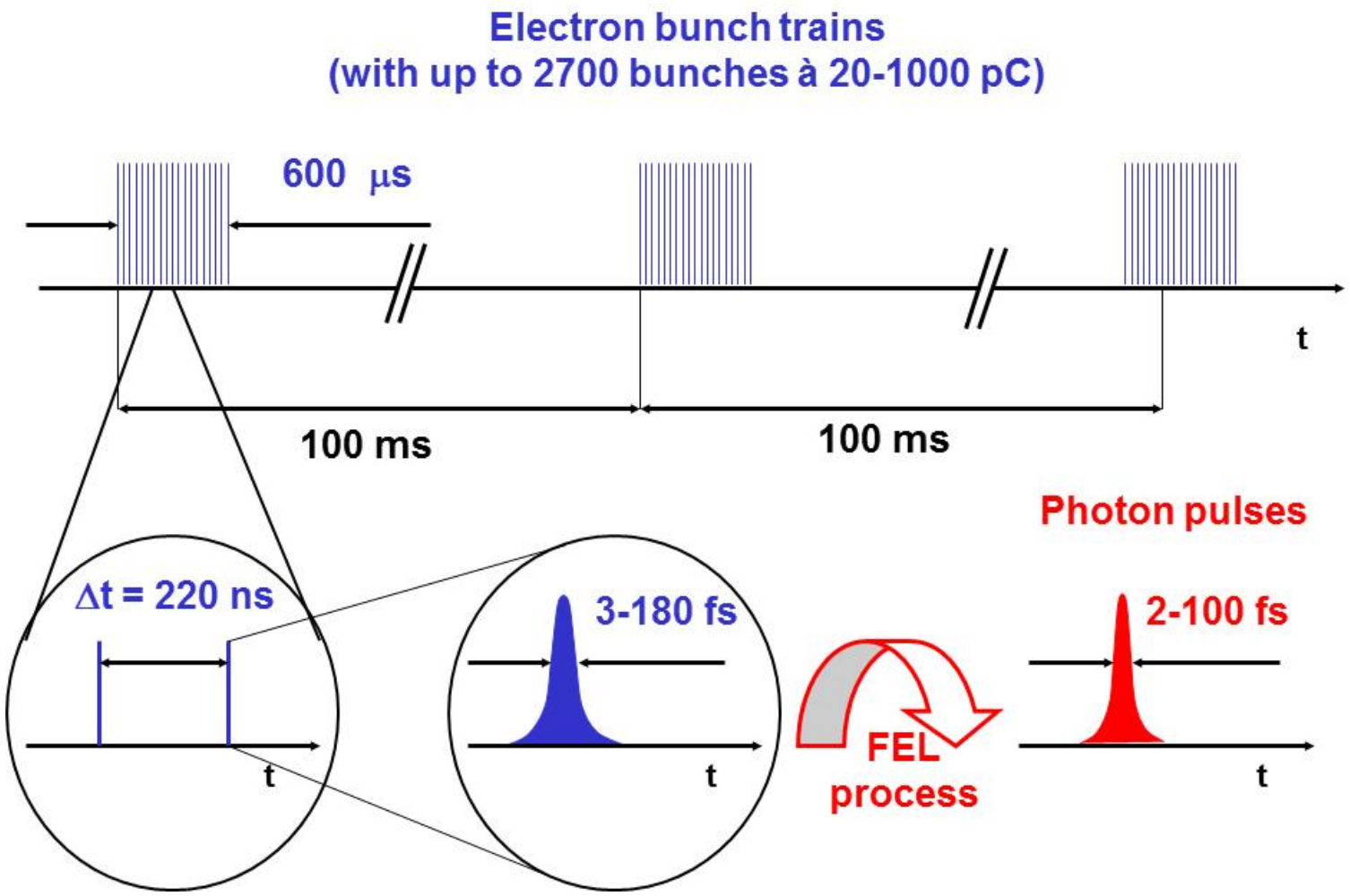
Ready for beam July 2014

Commissioning July 2014 – June 2015 (12 month)

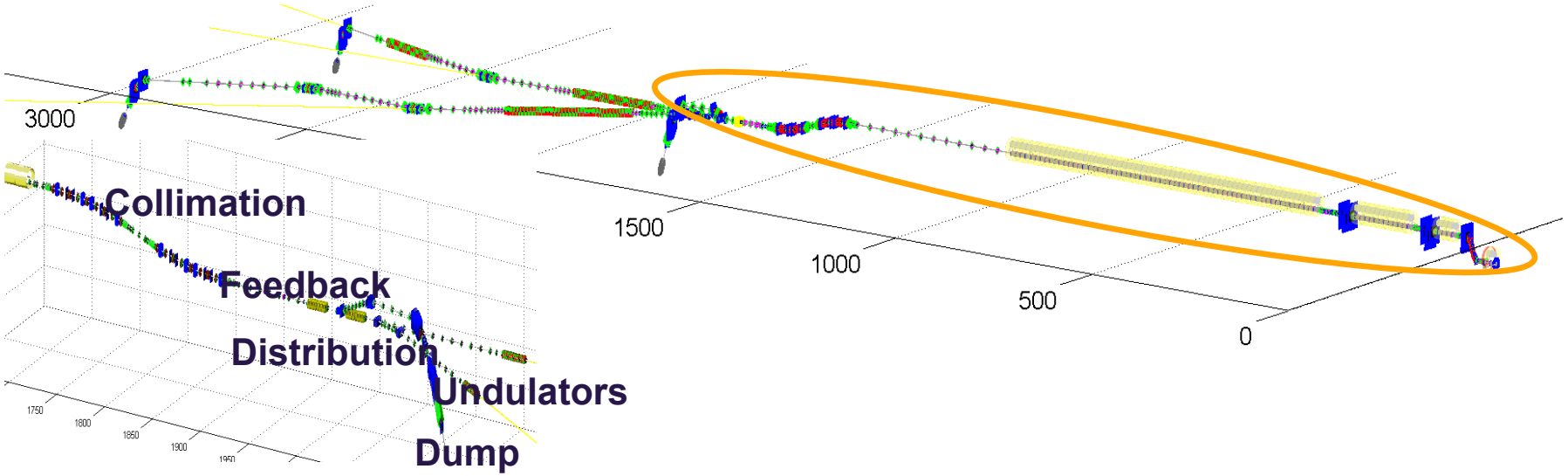
Goal: Stable operation with XFEL parameters

- Full bunch train and repetition rate
- Various bunch charges (1, 0.5, 0.25, 0.1, 0.02 nC)
- Basic commissioning for many sub-systems

European XFEL Time Structure



Main Linac, Collimation Section & Beam Distribution, Dumps



Ready for beam July 2015

Initial commissioning July 2015 – September 2015

Goal: Stable operation to establish initial lasing

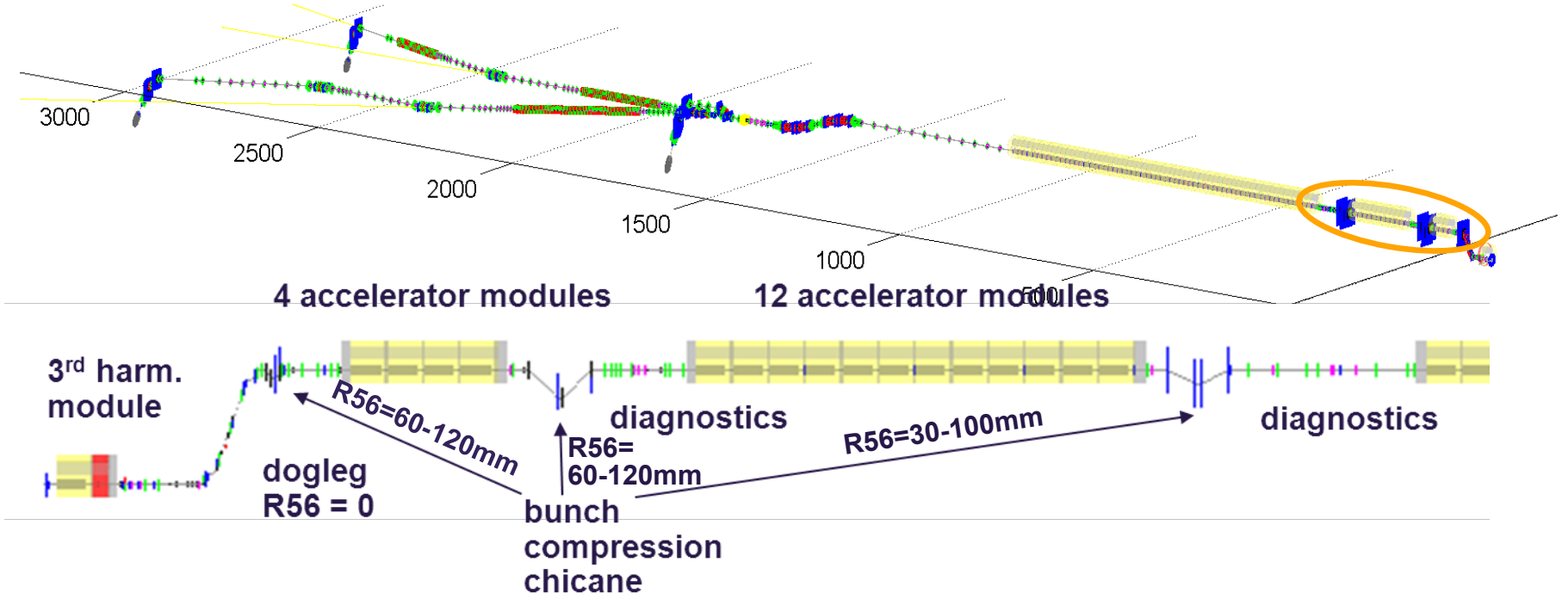
- Single to few (~100) bunches at 17.5 GeV
- One bunch charge (0.5 nC)
- Slow feedbacks for final energy & trajectory

Challenges: Linac: Commissioning of cold linac (cryo, high power RF, LLRF, …)

CS&BD: Transport through collimation section and beam distribution into dump

Dumps: Guarantee beam spot size on dump window

Bunch Compression System



Ready for beam July 2015

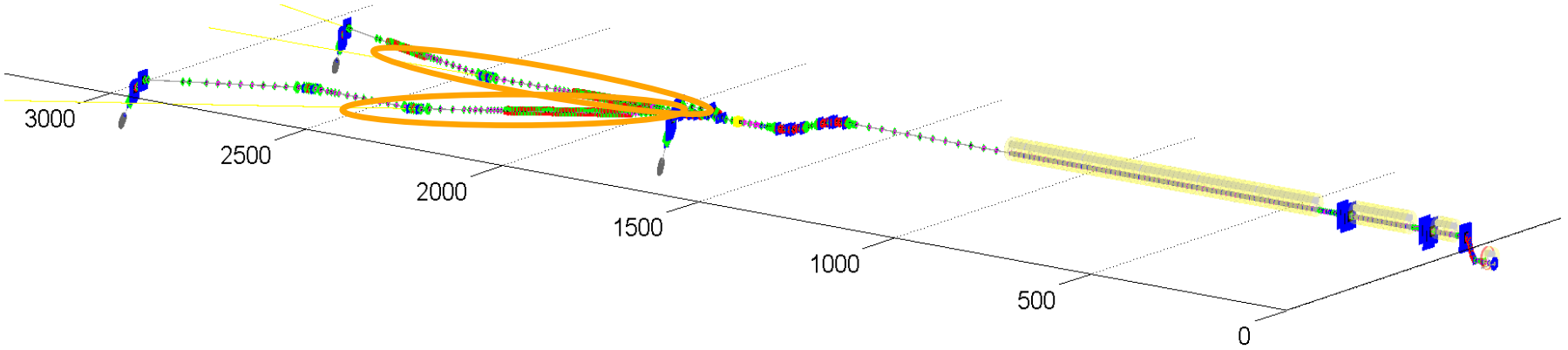
Initial commissioning September – October 2015

Goal: Establish first lasing working point

- Single to few (~100) bunches at 17.5 GeV
- One bunch charge (0.5 nC)

Challenge: Commissioning of longitudinal diagnostics

European XFEL - Undulators



Ready for beam September 2015

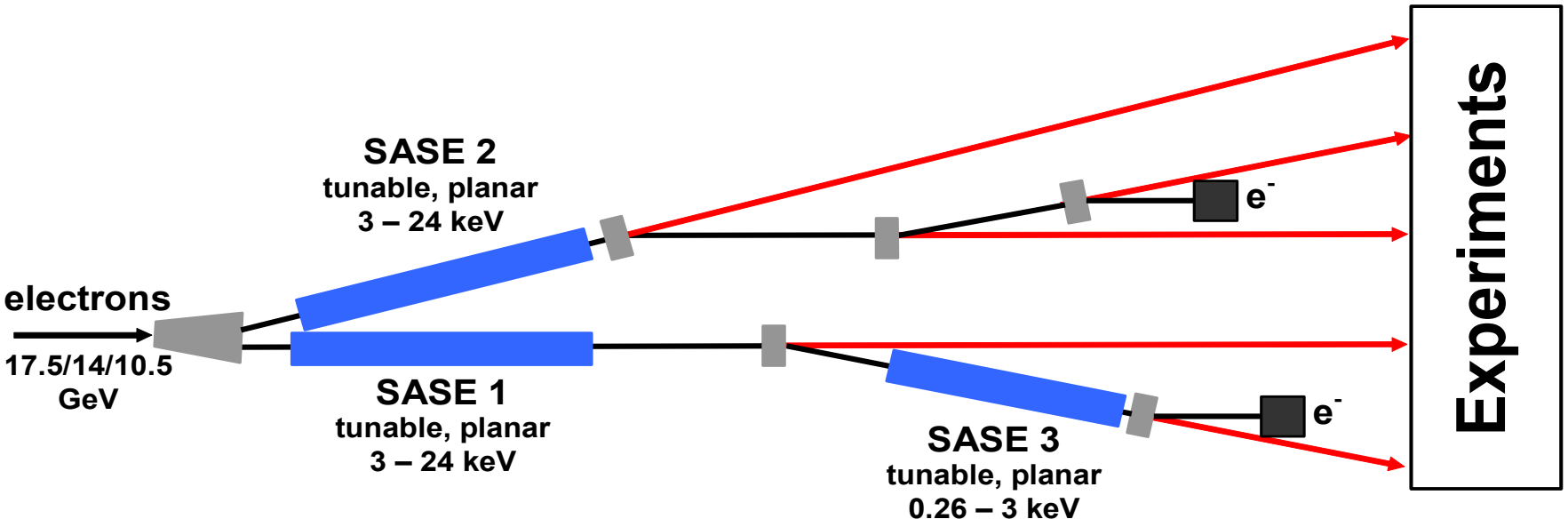
Initial commissioning SASE1/SASE3 September – November 2015

Goal: Beam transport and alignment

- Single to few (~100) bunches at 17.5 GeV
- One bunch charge (0.5 nC)

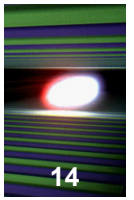
Challenge: Trajectory alignment in undulator

Electron Bunch Distribution



- 27.000 bunches/sec to (up to) 5 beamlines

Undulator Sequence and SASE Wavelength



- Commissioning should start with SASE1 and continue with SASE3:
  - eases initial e-beam operation
  - allows parallel commissioning of SA1 and SA3 photon beam lines
  - if no SASE is reached in SASE1, SASE3 could be put into operation with much looser tolerances to diagnose e-beam parameters
  - if availability of components prevents installation of SASE3 and SASE1 the decision to install SASE2 first should be made as early as possible
  - it is recommended from FLASH experience to focus activities on one beam line and commission this fully to benefit from the lessons learned and not double errors
- SASE search should be performed with fully closed gaps

  (i.e., 0.19 nm wavelength at SASE1)

High Level Milestones

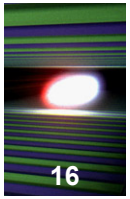
1. First Beam through Linac

- A 17.5 GeV beam is transported through the linac to the TLD dump.
- Pattern: 10-100 Hz, single bunch, 0.5nC, C=100 (total longitudinal bunch compression factor)
- Control: Charge, peak current, energy and trajectory are controlled by slow feedbacks.

2. First Beam to TD4 (SASE1 and SASE3)

- A 17.5 GeV beam is transported through the linac to the T4D dump.
- Pattern: 10-100 Hz, single bunch, 0.5nC, C=100
- Control: Charge, peak current, energy and trajectory are controlled by slow feedbacks.
- Electron beam based trajectory alignment in undulator

High Level Milestones continued



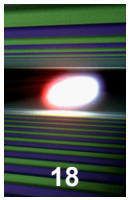
3. **First Lasing in SASE1**
   - First lasing is observed at 0.19 nm
   - Commissioning of photon diagnostics & beam line with spontaneous radiation
   - Photon based alignment of undulator gap and phase shifter setting (if nec.)
   - SASE search
4. **Lasing in SASE 3**

High Level Milestones continued

From here on parallel operation photon/electron development appears possible.

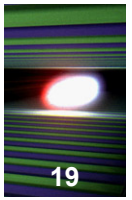
5. **Multi-bunch operation**
   - Pattern: 10 Hz, 600 bunches, 0.5nC, C=100
   - Control: Charge, peak current, energy, trajectory and arrival time are controlled by slow and fast feedbacks.
6. **Quasi-simultaneous operation of SASE1 and SASE2 beam line**
   - Pattern: 10 Hz, 600 bunches, 0.5nC, C=100
   - Control: Charge, peak current, energy, trajectory and arrival time are controlled by slow and fast feedbacks.
   - Tasks:
     - Bunch pattern control by fast switching elements
7. **First lasing in SASE 2**
8. **Flexibility in wavelength and bunch length**
   - Pattern: 10 Hz, 2700 bunches, 0.02-1nC, C=2000-50
   - Control: Charge, peak current, energy, trajectory and arrival time are controlled by slow and fast feedbacks.
   - Tasks:
     - establish procedures to change bunch length/bunch charges
     - establish procedures to change photon wavelength by changing energy/undulator gap

High Level Milestones: an Attempt to Sort



High Level Milestone			Beam where	Energy [GeV]	Repetition Rate [Hz]	# of Bunches	Bunch Charge [nC]	Peak Current [kA]	SASE Wavelength [nm]	Time [Months]
	1	First Beam in Injector	I1D	0,13	10	1-2700	0,5	0,05	-	12
	2	First Beam in BC2	B2D	2	10	1-100	0,5	5	-	0,5
1	3	First Beam in TLD	TLD	17.5	10	1-100	0,5	0,5	-	1,5
	4	Bunch compression	TLD	17.5	11	1-100	0,5	0,5	-	1
2	5	First Beam in T4D	T4D	17.5	10	1-100	0,5	0,5	-	0,5
3	6	Lasing in SASE 1	T4D	17.5	10	1-100	0,5	5	0.19	0,5
	7	First Beam in T5D	T5D	17.5	10	1-100	0,5	0,5	-	0,5
4	8	Lasing in SASE 3	T4D	17.5	10	1-100	0,5	5	4	0,5
7	9	Lasing in SASE 2	T5D	17.5	10	1-100	0,5	5	0.19	0,5
	10	1 MHz Operation	TLD	17.6	11	600	0,5	5	0.19	1,5
5	11	Lasing with 1 MHz bunch trains	T4D	17.5	10	600	0,5	5	0.19	1
	12	Parasitic lasing SASE1 and SASE 3	T4D	17.5	10	600	0,5	5	0.19/4	0,25
6	13	Slow 10 Hz switch between 1 & 2	T4D/T5D	17.5	10	600	0,5	0,5	-	0,25
	14	Fast switching and arbitrary bunch patterns	T4D/T5D	17.5	10	600	0,5	0,5	-	0,25
	15	Compression at various bunch charges	TLD	17.5	10	1-100	0.05-0.5	5	-	1
	16	Lasing with short pulses	T4D	17.5	10	1-100	0.05-0.5	5	0.19	1
8	17	Wavelength variation	T4D/T5D	10.5-17.5	10	600	0,5	5	<0.1	0,5
	18	Multi Bunch operation	TLD	17.5	10	2700	0,5	0,5	-	1

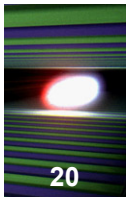
Photon Beam Line Commissioning (H. Sinn)



- Prerequisites, Steps and time needed to reach:
  - **Milestone #2** (beam through SASE1 and SASE3 beam lines)
  - and **Milestone #3** (first SASE)

- **Prerequisites:**
  - Photon beam line closed and evacuated
  - Technical commissioning finished
  - Beam Protection System tested (without beam, possible for limited bunch numbers)
  - Personal Interlock finished
  - Radiation Safety approval

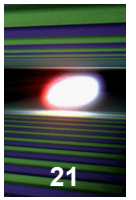
Photon Beam Line Commissioning Continued



- **Steps with (dedicated) beam:**
  - **each commissioning steps takes roughly 1-2 shifts**
  - **(not so sure about times needed for radiation tests)**

  - 1. Radiation safety measurements with spontaneous radiation (shutter tight?), Personal interlock (?)
  - 2. Beam on FS before mirrors
  - 3.Test of absorber system
  - 4.Test of gas monitor system
  - 5.Test of slit system
  - 6. Beam through double mirror system (beam on FS after mirrors)
  - 7. If beam needs to go to experimental hall:
    - Further radiation tests (interlock?) of shutters towards experimental hall
    - Beam in XTD9
  - 8. Beam through 600 m of pipe (min. 2 intermediate FS)
  - 9. Adjustment of focus of mirrors
  - 10.Test of beam protection system / test of beam absorbers (mass spectrometer)
  - 11.Test of BPM at beam line end
  - 12. Beam in experimental hall
- **total 12-18 dedicated shifts for X-ray beam commissioning**

Photon Diagnostic Items to Characterize SASE



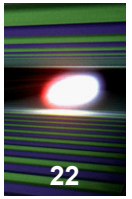
- Transmission & 2D Imagers (Screens)

- K-Mono Instrument
- Diode

- MCP
- XGMD
- (XBPM)

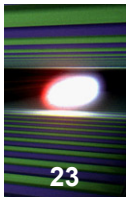
- Total instrument commissioning time: 5-10 shifts

Commissioning Sequence



- 2015 30 Jun - XTL tunnel closing
- 2015 30 Sep - beam through XTL
- 2015 30 Sep - XTD2, XTD4, XTD9, XTD10 tunnel closing
- 2015 15 Dec - First lasing SASE1 (FXE or SPB)
- 2016 15 Jan - Beam through 2nd electron branch
- 2016 30 Jan - First lasing SASE3 (SQS or SCS)
- 2016 31 Mar - 'First' user experiment at SASE 1 (SPB & FXE)
- 2016 30 Apr - 'First' user experiment at SASE 3 (SQS & SCS)
- 2016 31 May - First lasing SASE2 (MID or HED)
  - Hereafter commissioning of fast switching starts
- 2016 31 Jun - 'First' user experiment at SASE 2 (MID & HED)
  - From this moment onwards baseline (TDR) beam delivery specifications are considered to be reached
- 2017 31 Dec - Extended beam delivery specifications reached
  - End of extended accelerator and x-ray system commissioning
  - Start delivery of full number of hrs for user operation

'First Lasing' and 'First User Experiments'



- Conditions for 'First Lasing'
  - x-ray beam according to initials beam conditions as described in convention
  - up to 30 electron bunches per train
  - transport of x-ray beam to XHEXP
  - performance of 1st 'simple' experiment at one of the instruments at this BL

- Conditions for 'First User Experiments'
  - experiments can use x-ray beam at TDR performance, but with limited flexibility in terms of pulse pattern, pulse length and photon wavelength

Machine Time Distribution