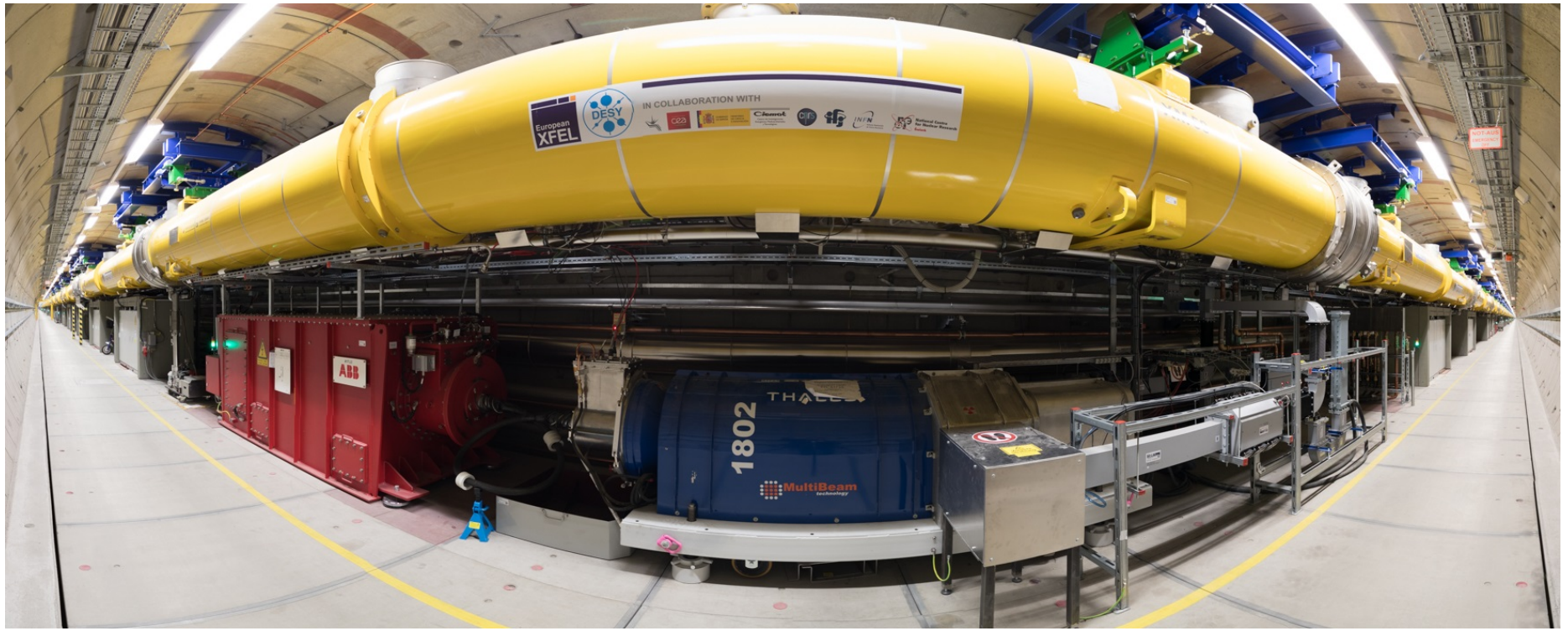
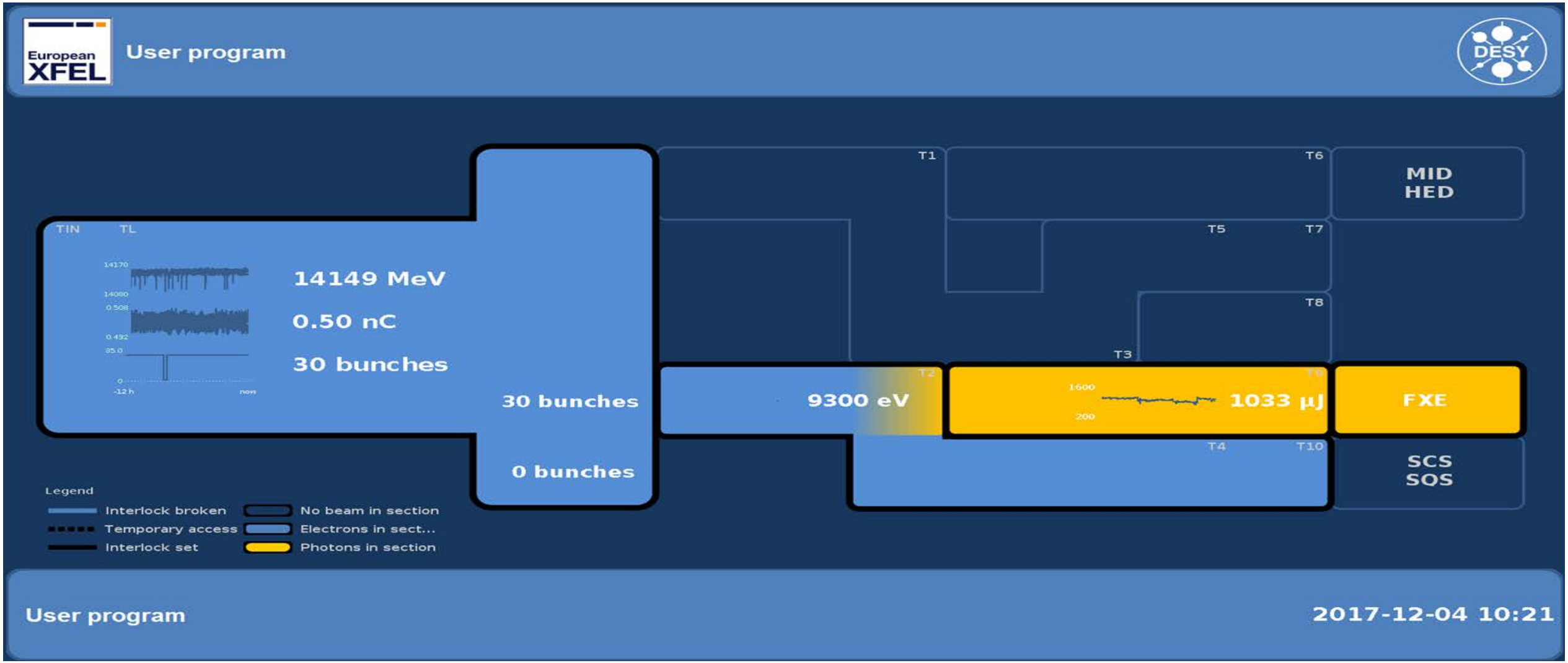
Electron Accelerator – Commissioning Experience and Plans for 2018

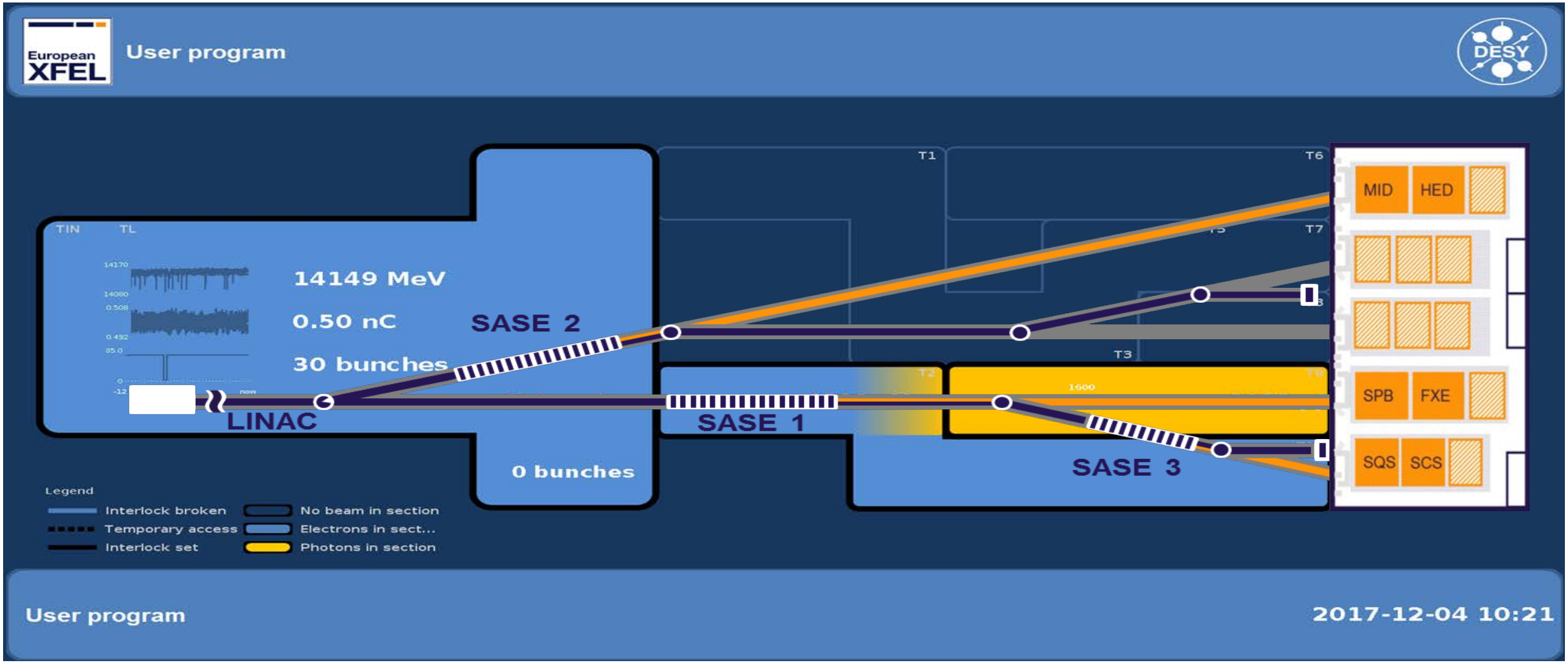


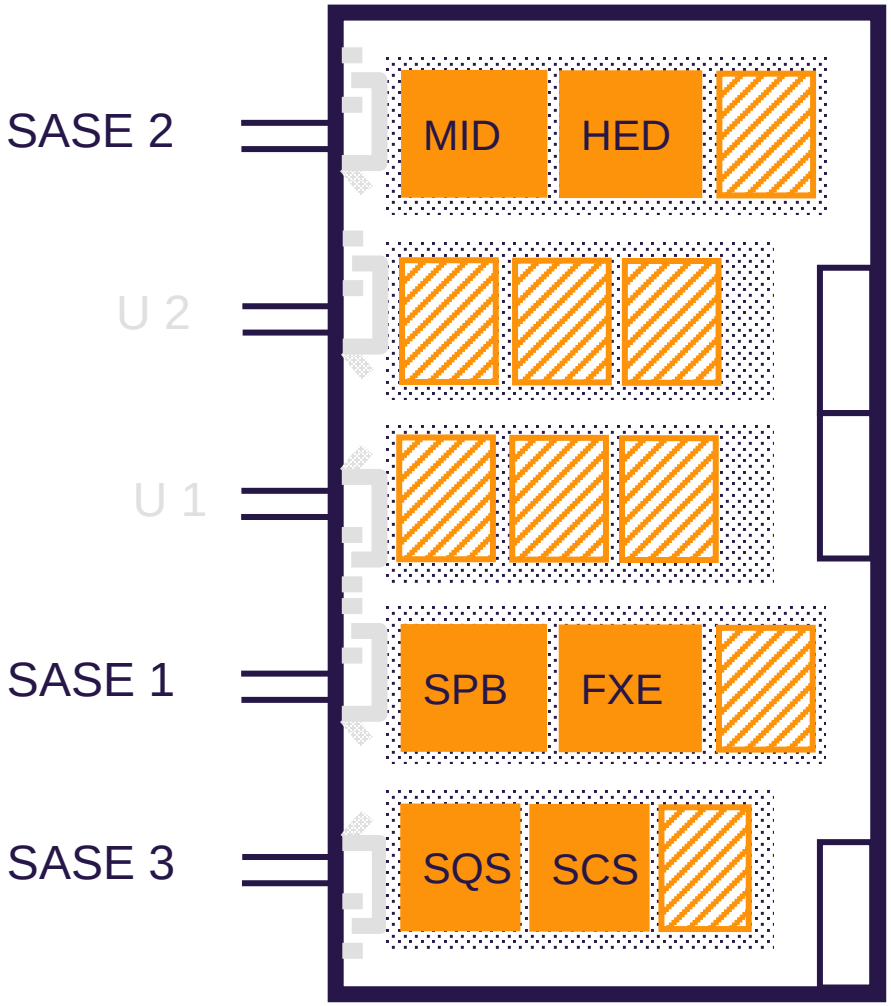
Winni Decking & Hans Weise, DESY 01.2018

User Program Started

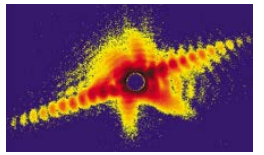


Who is getting the First Photons?

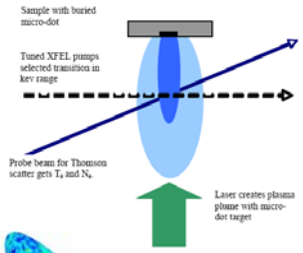




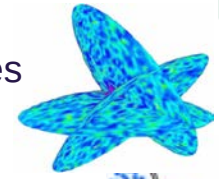
MID Materials Imaging & Dynamics



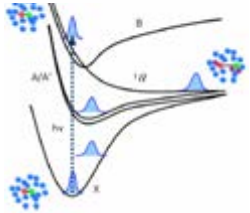
HED High Energy Density Science



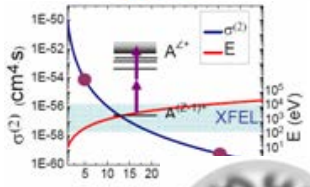
SPB Single Particle & Biomolecules



FXE Femtosecond X-ray Experiments

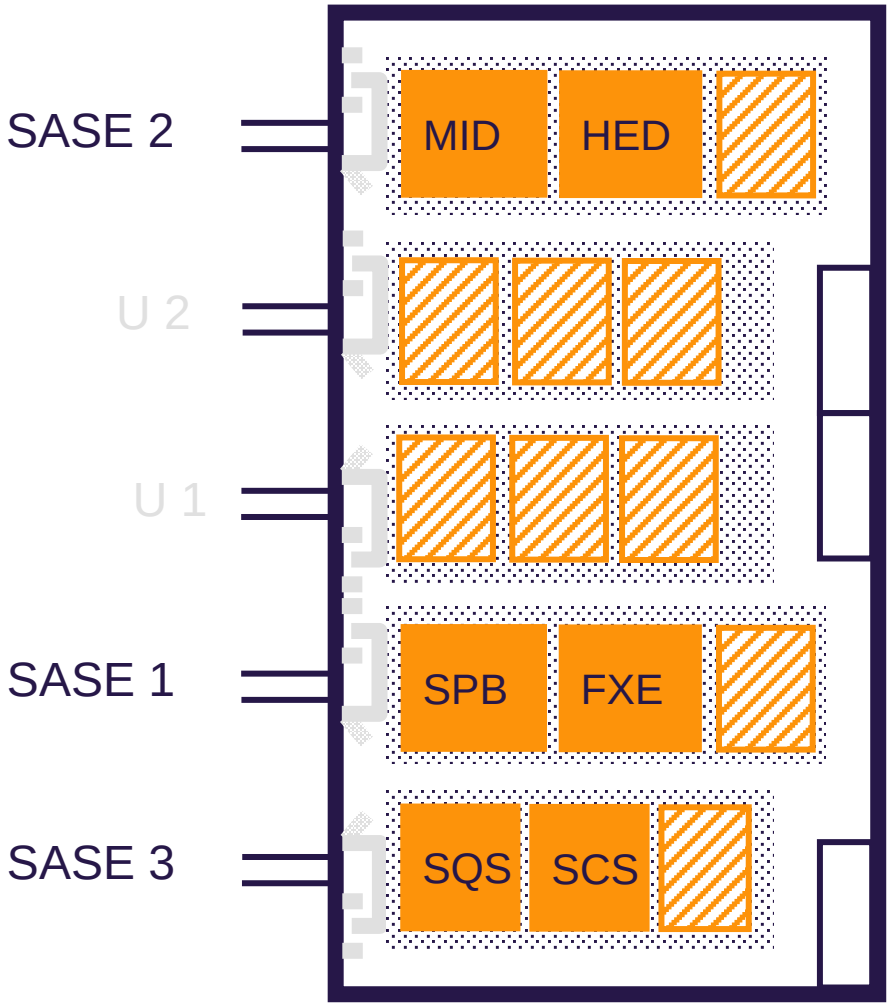


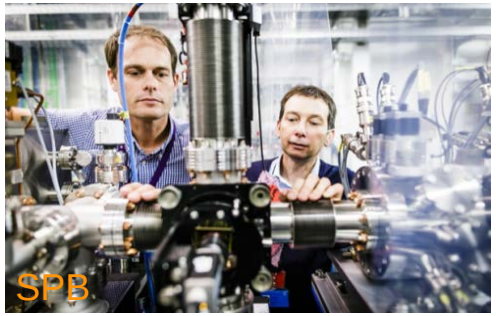
SQS Small Quantum Systems



SCS Spectroscopy & Coherent Scattering

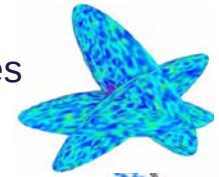
More about experiments: http://www.xfel.eu

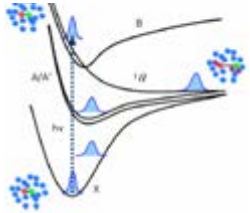




- study of molecule structure and functions

SPB Single Particle & Biomolecules





FXE Femtosecond X-ray Experiments

- molecular movies and chemical reactions

More about experiments: http://www.xfel.eu

European XFEL History

2000:

First laser light (109 nm) at the Tesla Test Facility (TTF);
today known as FLASH

2001 / 2002 / 2006:

TESLA Linear Collider TDR with XFEL Appendix (2001)
TESLA TDR Supplement with stand-alone XFEL (2002)
European XFEL TDR (2006)

2009:

Foundation of the European XFEL GmbH
Start civil construction

2010:

Foundation of the **Accelerator Consortium**
16 institutes coordinated by DESY

2012:

Tunnel finished
Start infrastructure installation

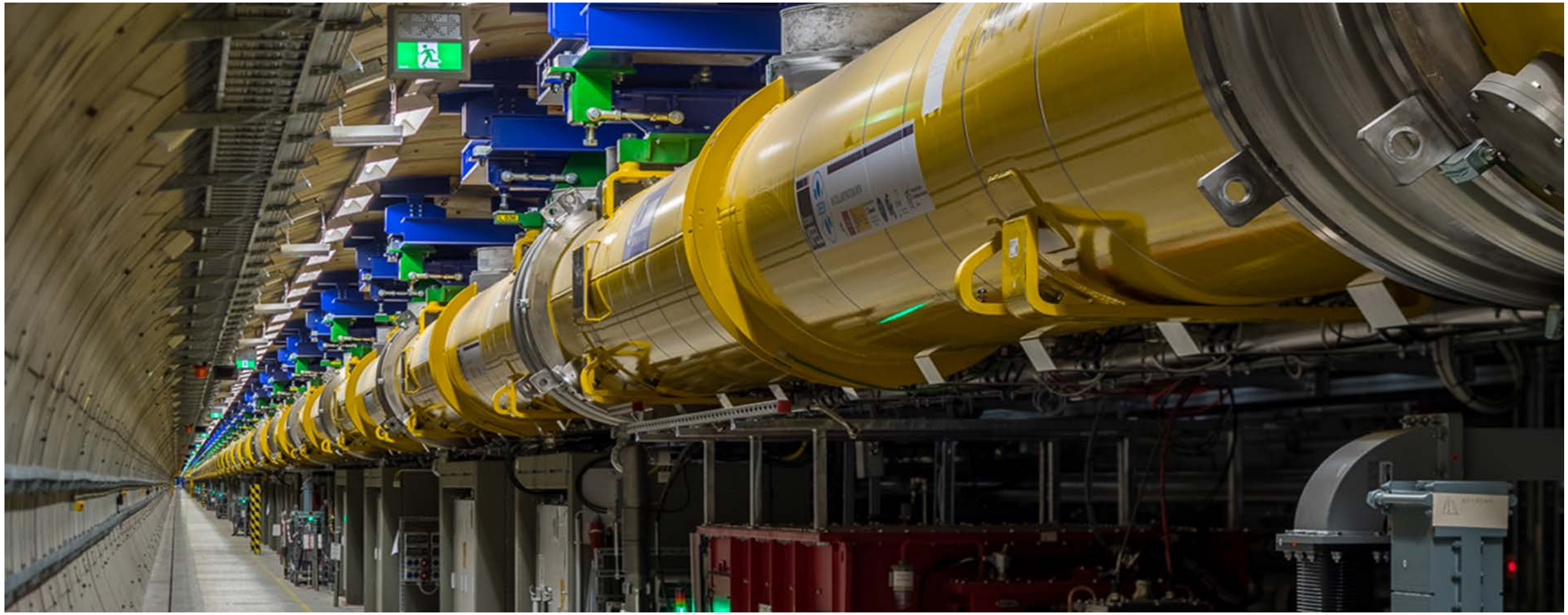
2016:

Accelerator finished
Start commissioning with cool down

Special Thanks to all Colleagues and Friends

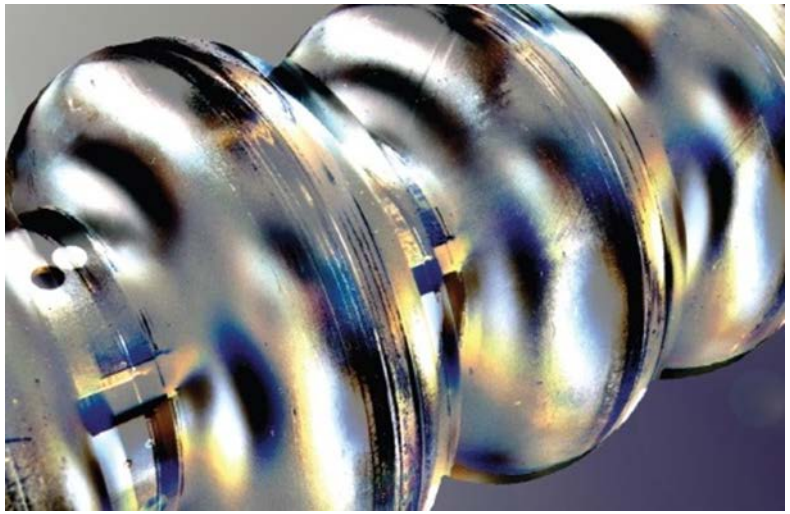
European XFEL
DESY
European XFEL
Ciemat
cea SACLAY
cnrs IN2P3 Les deux infinis
INFN LASA
Elettra Sincrotrone Trieste
CANDLE
PAUL SCHERRER INSTITUT PSI
Stockholm University
SLAC NATIONAL ACCELERATOR LABORATORY
PAUL SCHERRER INSTITUT PSI
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES
DESY

The European XFEL uses the by far Longest Superconducting Linac Worldwide

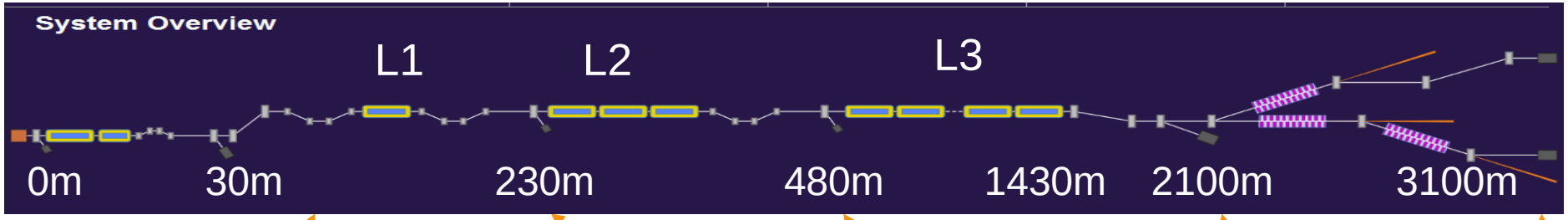


Superconducting Technology

- The successful construction and commissioning of the European XFEL was the result of excellent cooperation within the DESY coordinated **Accelerator Consortium** consisting of 16 institutes.
- The used **TESLA technology** was developed since the early 90ies. **FLASH** is the first result of this R&D and can be seen as the prototype.
- With the European XFEL the **fully successful technology transfer to industry** reached an important point:
  - Other worldwide projects (LCLS-II, ESS, new SRF based FELs at e.g. SINAP, China) are profiting greatly from our efforts.



The first months after the last Users' Meeting



13/01* → 15/01 @ 130 MeV
19/01 @ 600 MeV

02/02 @ 600 MeV
22/02 @ 2.5 GeV

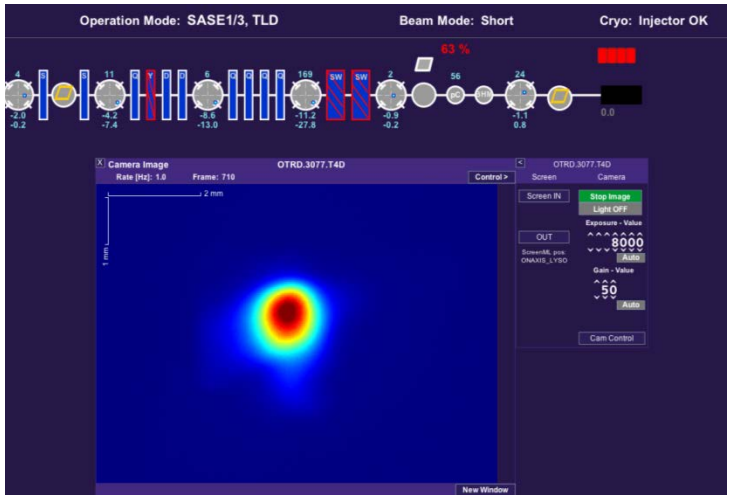
25/02 @ 2.5 GeV
19/03 @ 6 GeV
08/04 @ 12 GeV

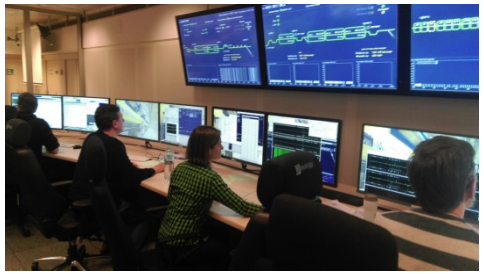
27/04*

* *Beam permission on 13/01*

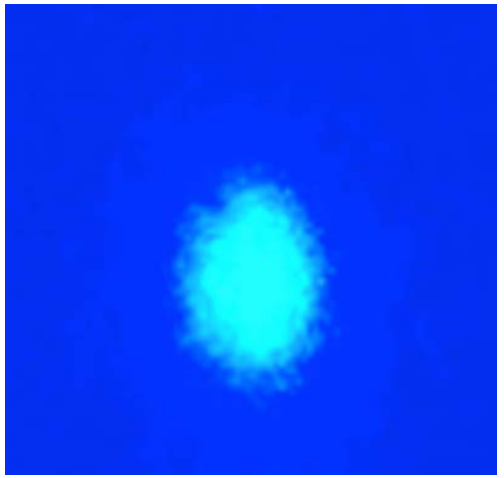
* *Beam permission on 26/04*

27/04 Beam spot before dump





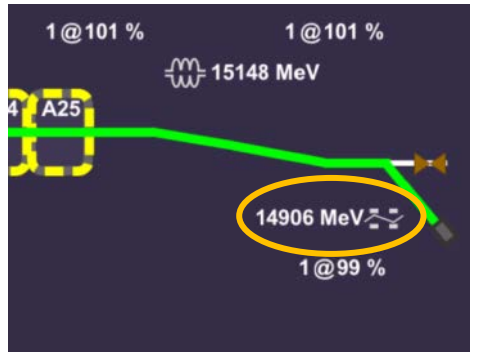
"keen on lasing…"

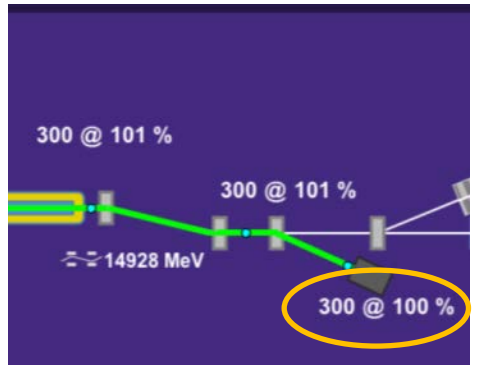


First lasing (0.9 nm) reached on May 2nd/3rd

Accelerator Status as of today

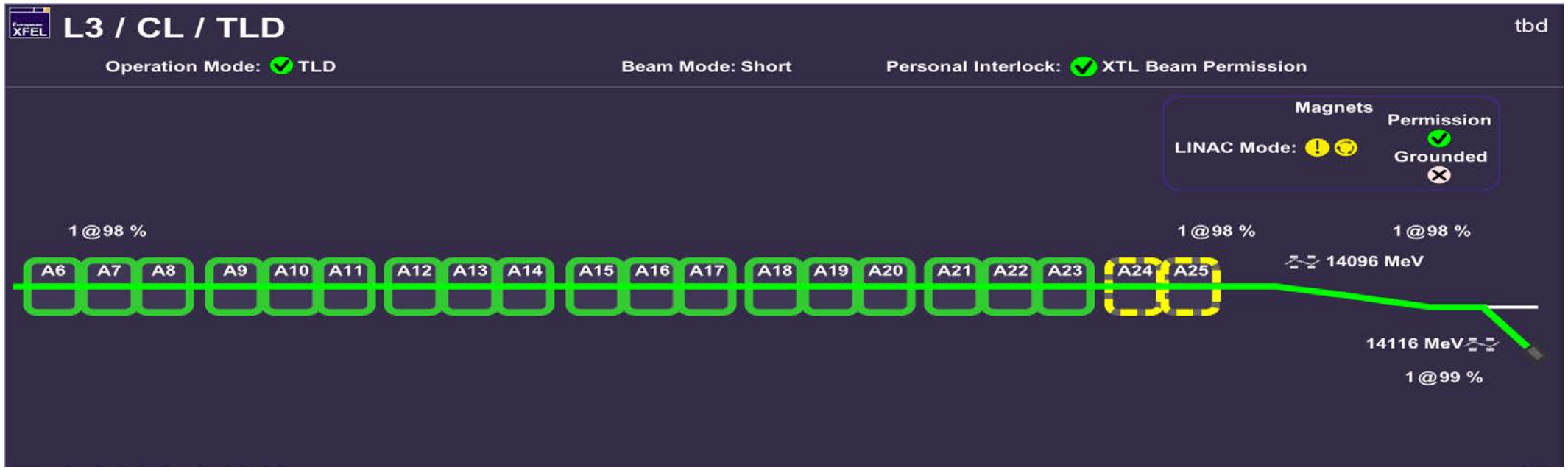
- Accelerator has been commissioned according to schedule and towards expected parameters, about 6400 h of scheduled beam time, always being very close to the commissioning schedule
- **23 out of 25 RF** stations commissioned (last two in CS9, will be ready in Q2/2018)
- Maximum potential final energy obtained during dedicated LLRF studies: **16.1 GeV**
- Maximum beam energy **14.9 GeV**, user operation with **14.0 GeV**
- Routine operation with **300 bunches/second** in user mode
- Test operation in linac mode with **3000 bunches/second** (≈ 18 kW beam power)





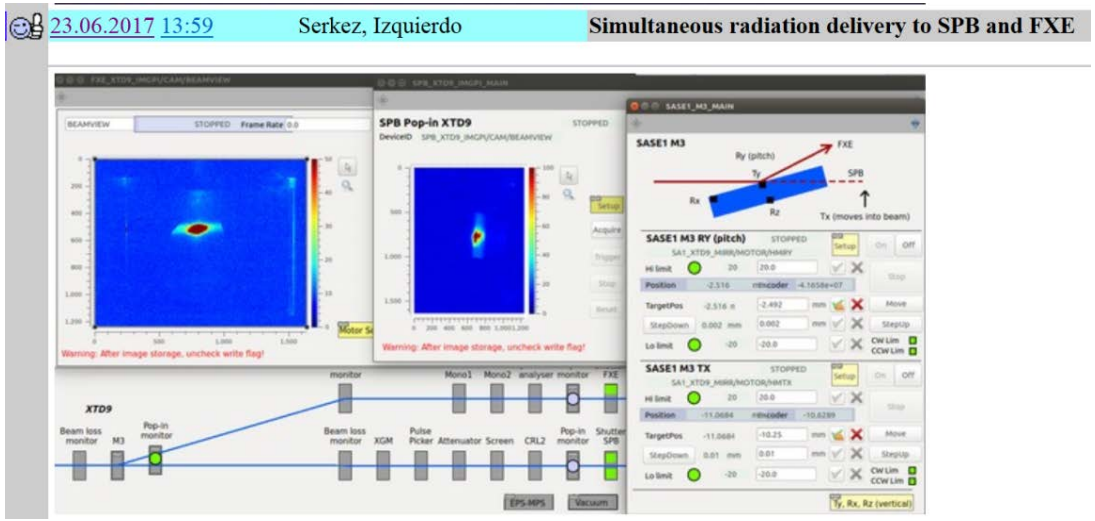
RF Commissioning: process and results

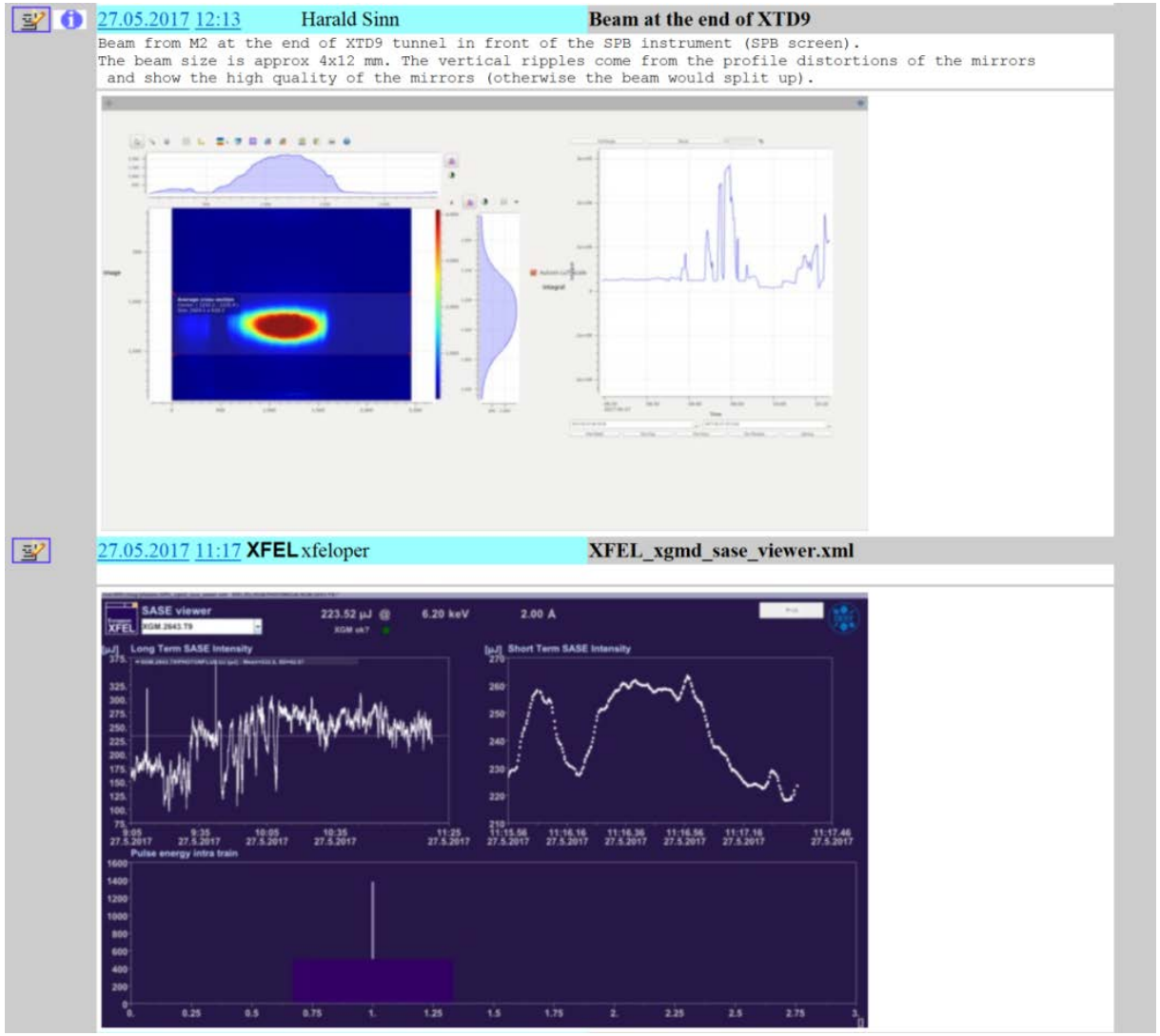
- About 3.5 month total commissioning time with up to 3 teams in parallel
- Without and with electron beam in parallel to other beam commissioning
- 23 out of 25 RF stations initially commissioned
- Operation automated; energy goal for 2017/2018 reached with 1-2 stations in reserve
- Reserve stations can be and are used for further studies / gradient increase



First Lasing Results

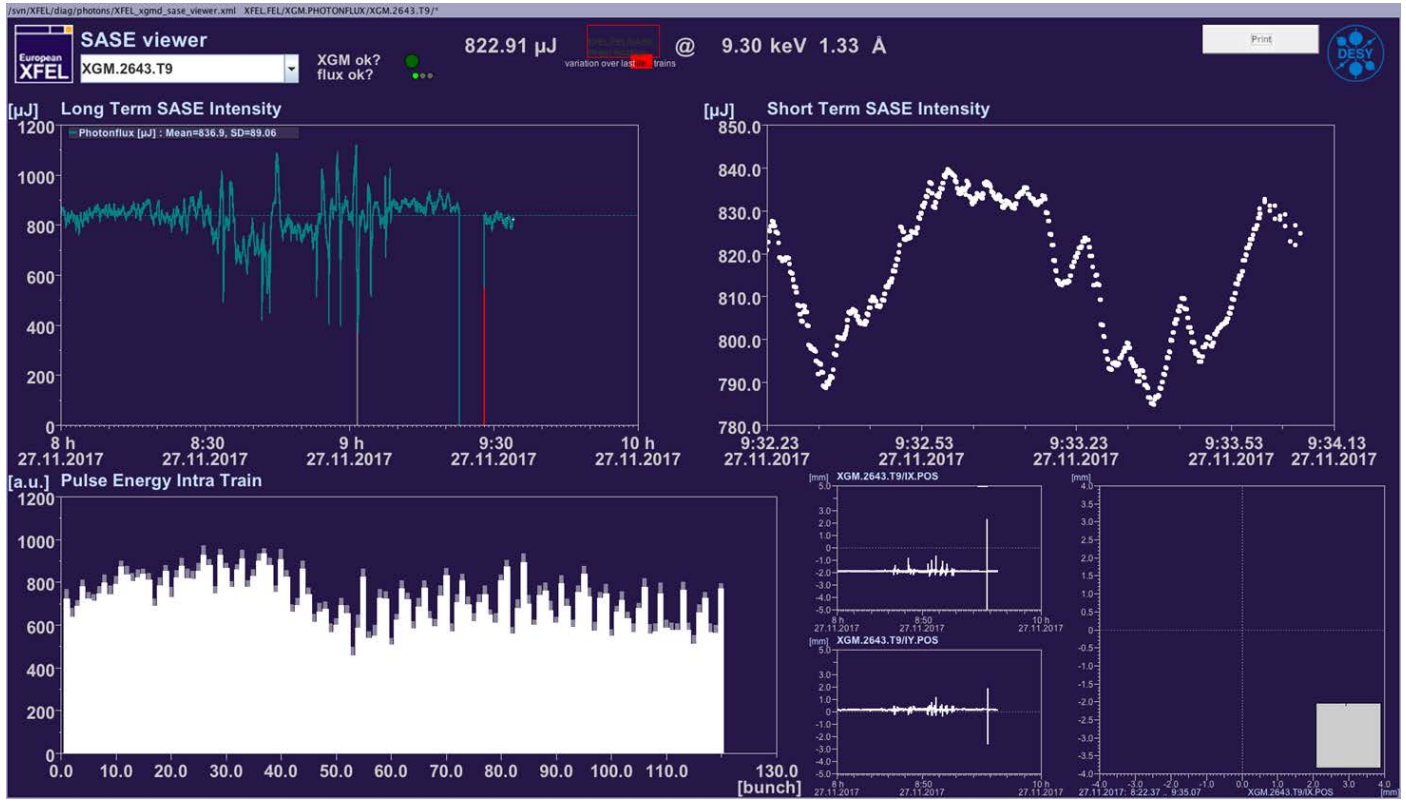
- 1st lasing at about 1.6 keV (02/05)
- Undulator trajectory alignment (23/05)
- 1st lasing at about 6.2 keV (24/05)
- Photon beam transport (26/05)
- First photons in hutches (26/06)





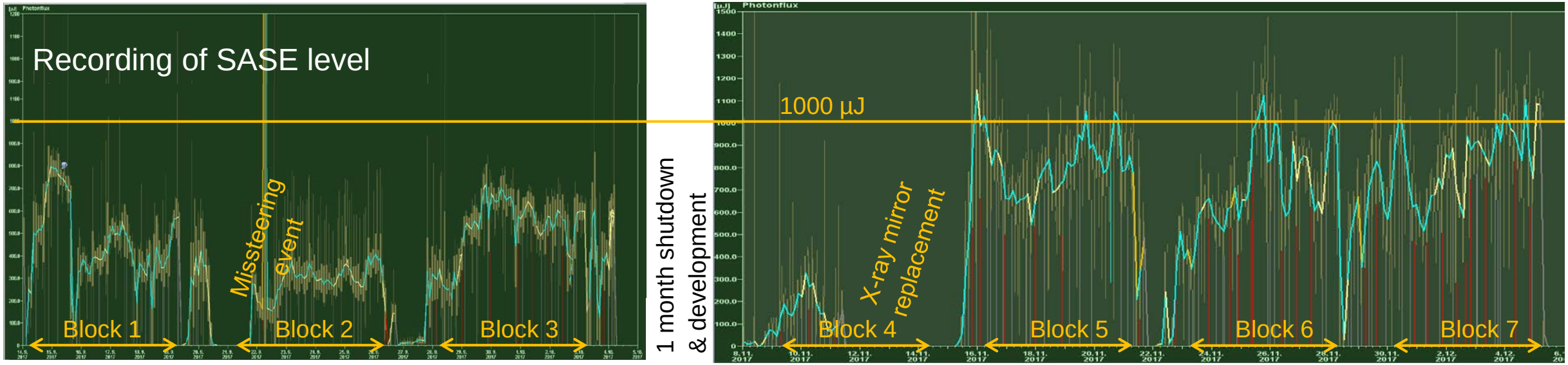
First Lasing Results

- 1st lasing at about 1.6 keV (02/05)
- Undulator trajectory alignment (23/05)
- 1st lasing at about 6.2 keV (24/05)
- Photon beam transport (26/05)
- First photons in hutches (26/06)
- Photon systems / experiment commissioning
- First user run (14/09)
- 1200 X-Ray pulses / s (27/11)



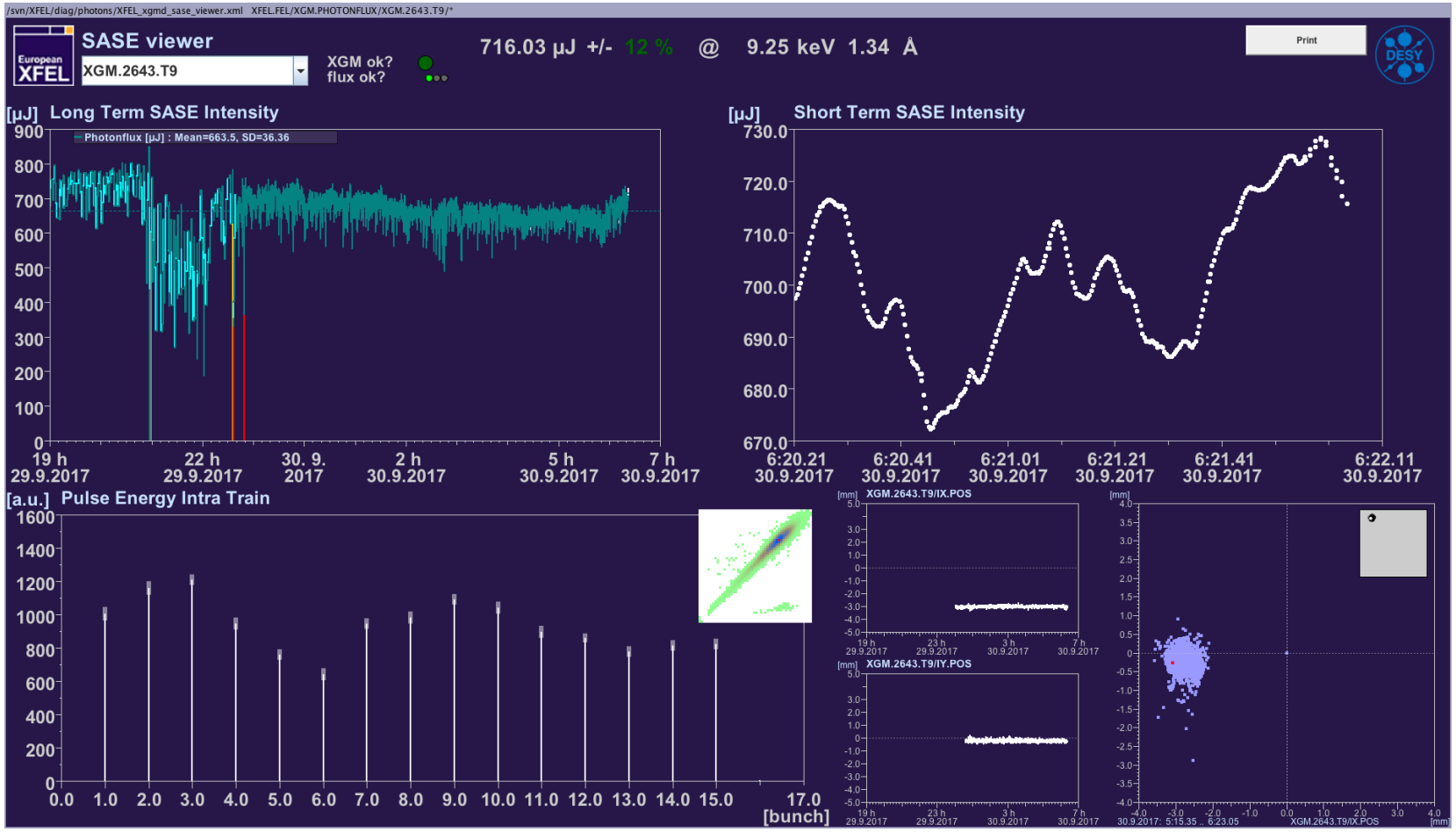
1200 bunches/s lasing – during radiation protection tests

Facility performance during user run



- 7 user blocks, 5 days each, with 2 days in between for set-up & tuning
- 14 GeV, 1-30 bunches, 9.2 - 9.3 keV
- Availability (= SASE delivery above threshold) between 10% (Block 4) and 97% (Block 6&7)
- Little tuning needed (because of limited flexibility offered), but frequent small wavelength changes and variation of bunch number (1-30)
- Prominent error sources: X-ray mirror, operation & controls, RF trips (speedy recovery), magnets

Good User Day (30.09.)

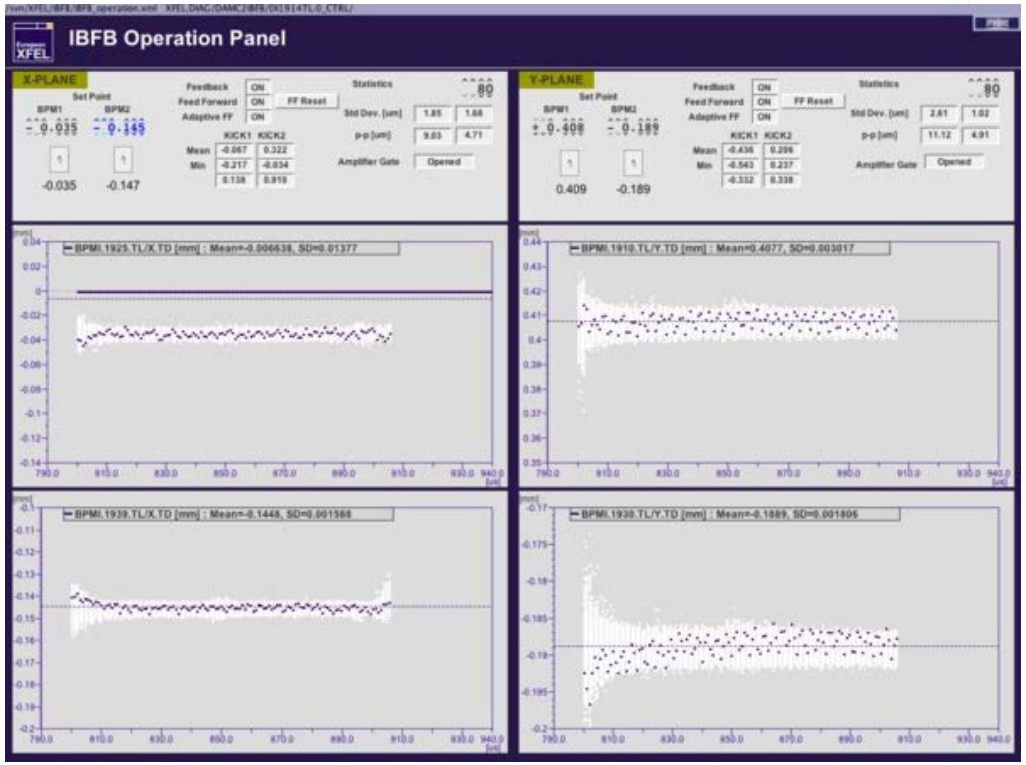


- 14 GeV, 500 pC, 1 to 30 bunches
- Photon energies: 9.2 – 9.3 keV
- fine tuning: Gap & number of bunches on user demand

- Challenging:
  - Easy control of photon wavelength
  - Missing possibility to look for correlation between electron and photon signals
  - Global undulator controls

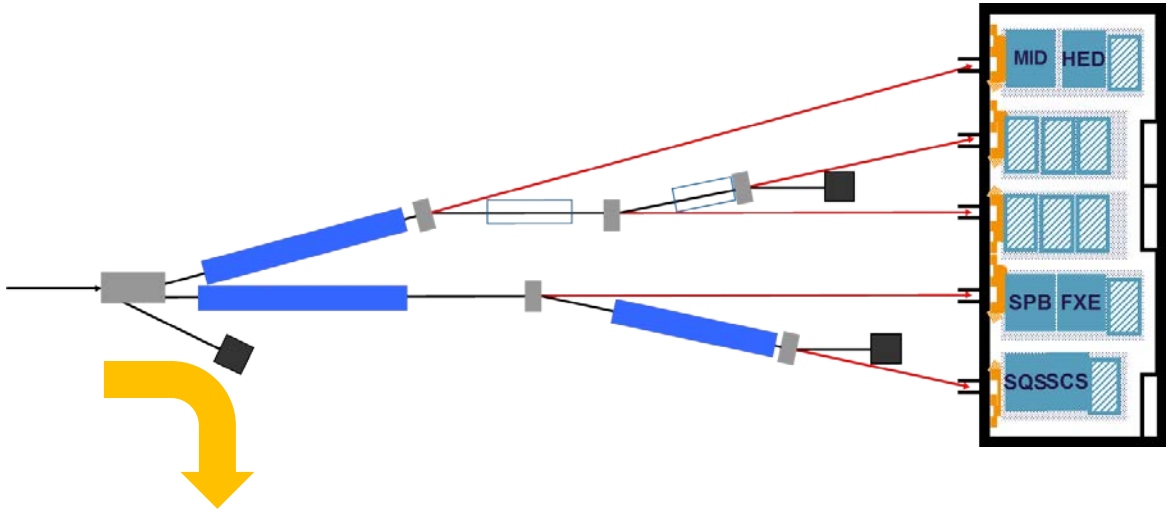
Stability & Feedbacks

- Stability will be greatly improved by feedback systems (needs bunch trains)
- Continue to find – and hunt for – jitter and drift sources
- Need more on-line correlation with photon based signals from photon diagnostics and experiments
- Electron beam measured jitter
  - Transverse jitter about 0.1 σ for bunches 5 – 30
  - Energy jitter about 1e-4
  - Arrival time jitter about 30-40 fs, potential for 10 fs

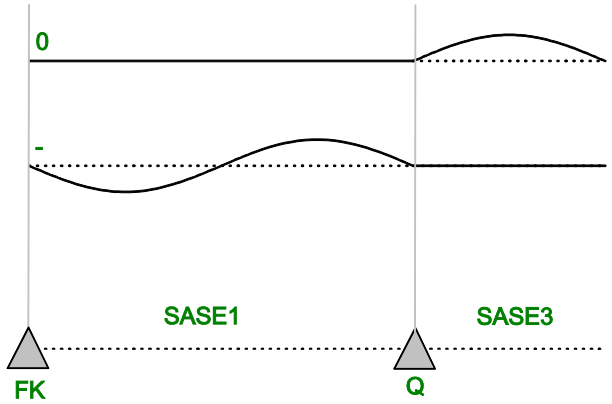


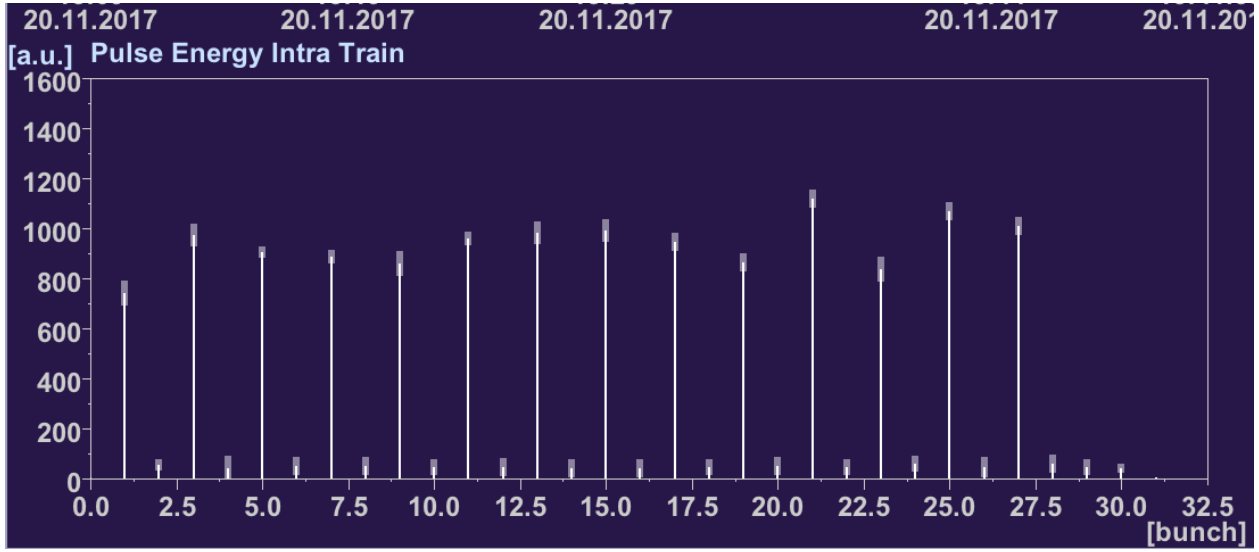
Individual Bunch Pattern

- Kick bunches into dump after linac

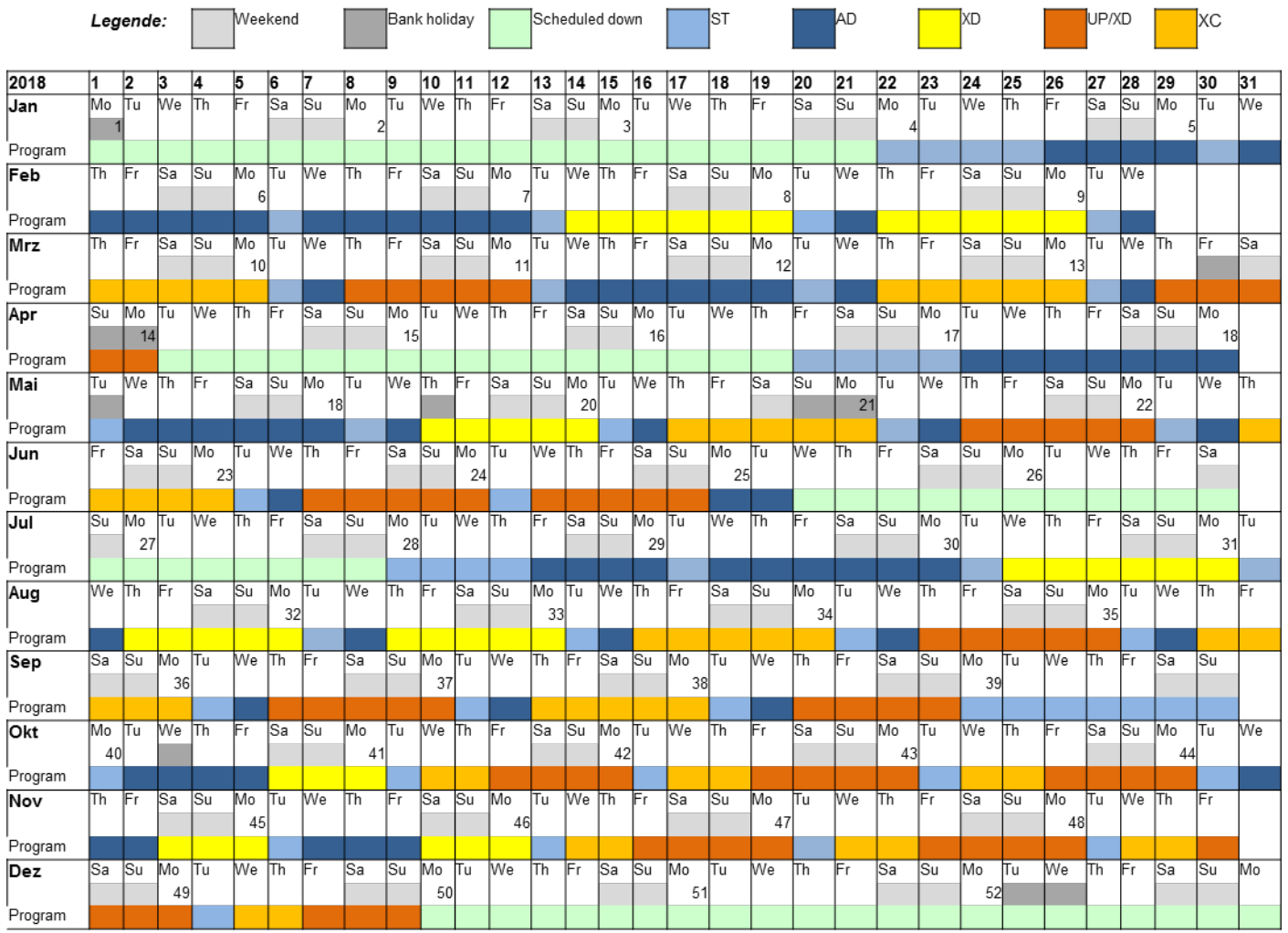


- Operate SASE3: Suppress lasing in SASE1





Schedule 2018



2018	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We
	1							2							3							4							5		
Program																															
Feb	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We			
					6							7							8							9					
Program																															
Mrz	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa
					10							11							12							13					
Program																															
Apr	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	
		14							15							16							17							18	
Program																															
Mai	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th
							18							20							21							22			
Program																															
Jun	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa		
				23							24							25							26						
Program																															
Jul	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	
		27							28							29							30							31	
Program																															
Aug	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	
						32							33							34							35					
Program																															
Sep	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su		
			36							37							38							39								
Program																															
Okt	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We
	40							41							42							43							44		
Program																															
Nov	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr		
					45							46							47							48					
Program																															
Dez	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	
			49							50							51							52								
Program																															

SD		Scheduled down			
ST		Access, Setup, Tuning			
AD		Accelerator Development			
XD		X-ray Development			
XC		Experiment Development			
UP		User Program			

- About 6800 hours of operation
- Shutdowns:
  - January & April for CS9
  - June/July for IL and MKK work
  - December for SASE2 self-seeding

Accelerator R&D – Different Categories

IMP:

Improvement of operational stability and efficiency

Continuous R&D to improve operational stability and efficiency of the existing facility. The direction of these activities might alter during operation.

CW:

Continuous Wave (CW) operation of XFEL (common interest with ARD-ST1 program)

R&D with the goal for a credible proposal for an upgrade of the European XFEL towards CW operation.

EXT:

Extension of the facilities' parameters and performance range (common interest with ARD-ST3 program)

Electron source, electron bunch manipulation, novel diagnostics, novel radiation schemes.

OPEN:

Open short term R&D

Goals for 2018

- SASE1: About 1,600 h user operation
- SASE2: First e-beam in March, first lasing in May
  - Commission laser and photon systems parallel to user runs
  - Installation of Self-Seeding Chicanes (December)
- SASE3: First lasing in February
  - photon systems commissioning influences SASE1 operation
- Accelerator:
  - 17.5 GeV by July (continue high gradient task force & CS9 installation and commissioning)
  - 3,000 bunches/second lasing in SASE1 by mid of the year (Possible limitation: dose rate in undulators)
  - 27,000 bunches in XTL by December

2018 E-beam Parameters

Quantity		Project Goal	Achieved	Routine	2018 Goal
electron energy	GeV	8/12.5/14/17.5	6-14.9	14	8/12.5/14/17.5
bunch repetition frequency within pulse	MHz	Up to 4.5	1.1, 4.5	1.1	1.1
bunch charge	pC	20 – 1000	100, 500	500	200, 500
electron bunch length after compression	fs (FWHM)	2 – 180	20, 90	90	40, 90
beam power	kW	500 kW	18 kW	1.8 kW	50 kW
undulators in operation (lasing)		SASE1-3	SASE1	SASE1	SASE1-3
photon energy (SASE1)	keV	0.25 - 25	1,6,9	9-9.5	6-15
photon pulses / s / undulator		27000	1200	300	3000
saturation power (@ 14 GeV, 500 pC, 9 keV)	mJ	1	1	0.4	1