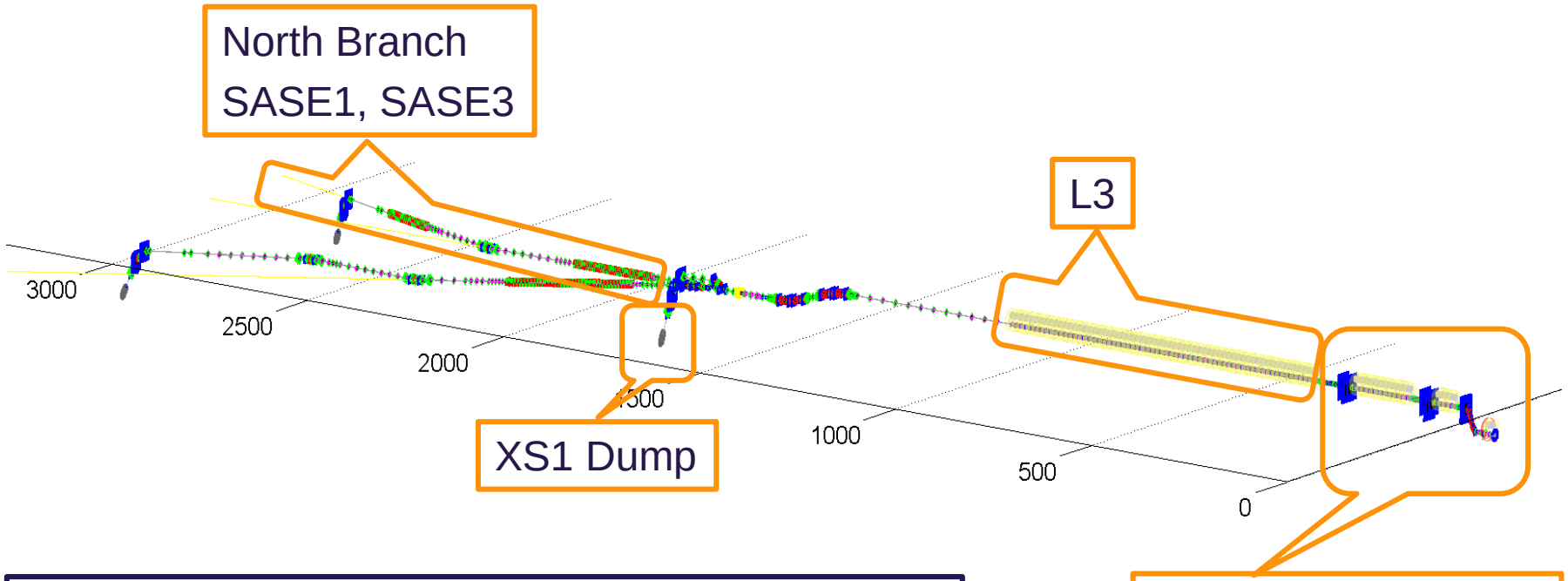
European XFEL Commissioning Plans

Winni Decking for the European XFEL Commissioning Team

Hard X-Ray FEL Collaboration Meeting

24.10.2016

Facility Overview - Nomenclature

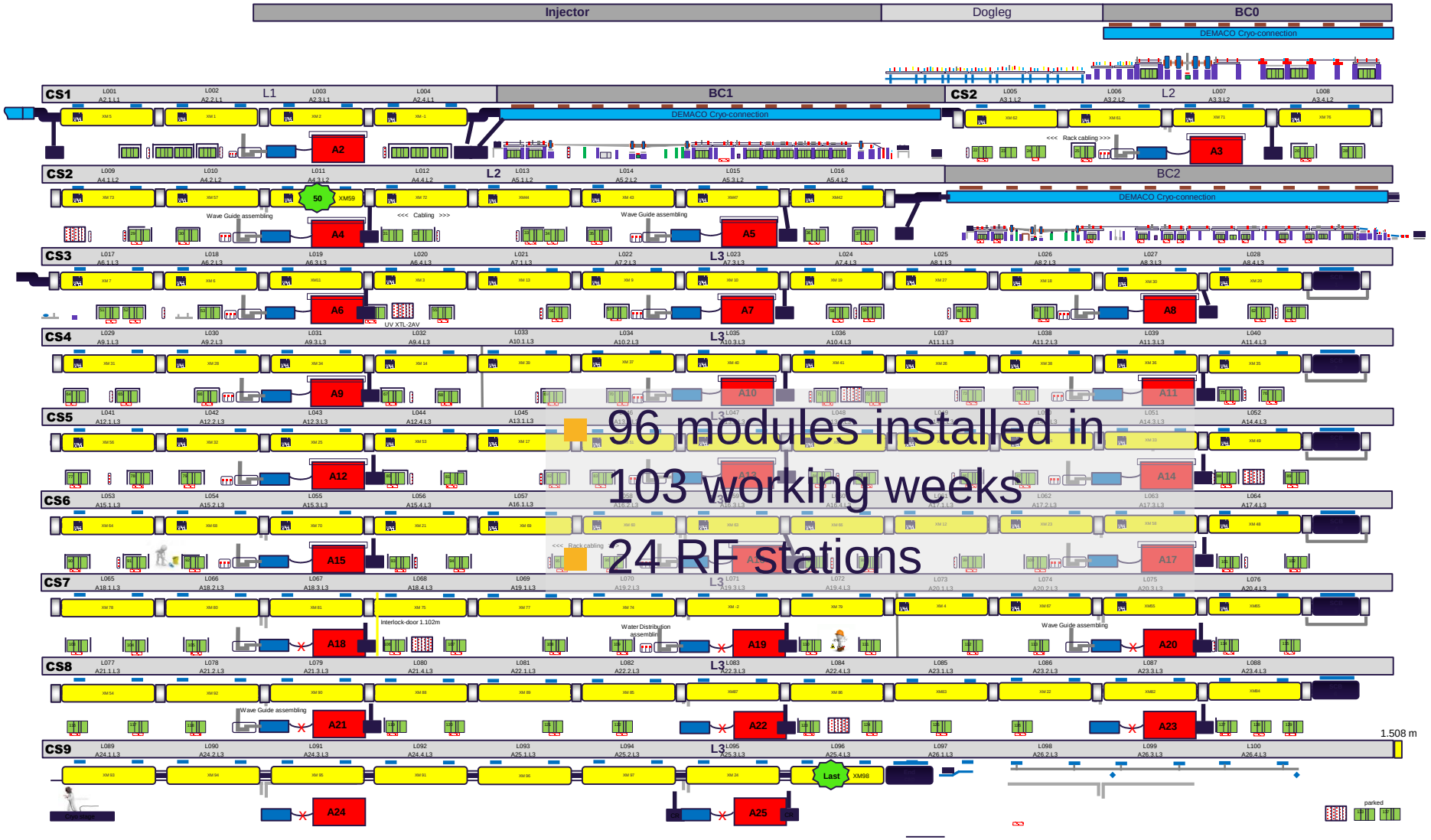


- 1 km of superconducting linac
- 3.3 km warm electron beam line
- 450 m undulator
- 6 photon beam lines
- …..

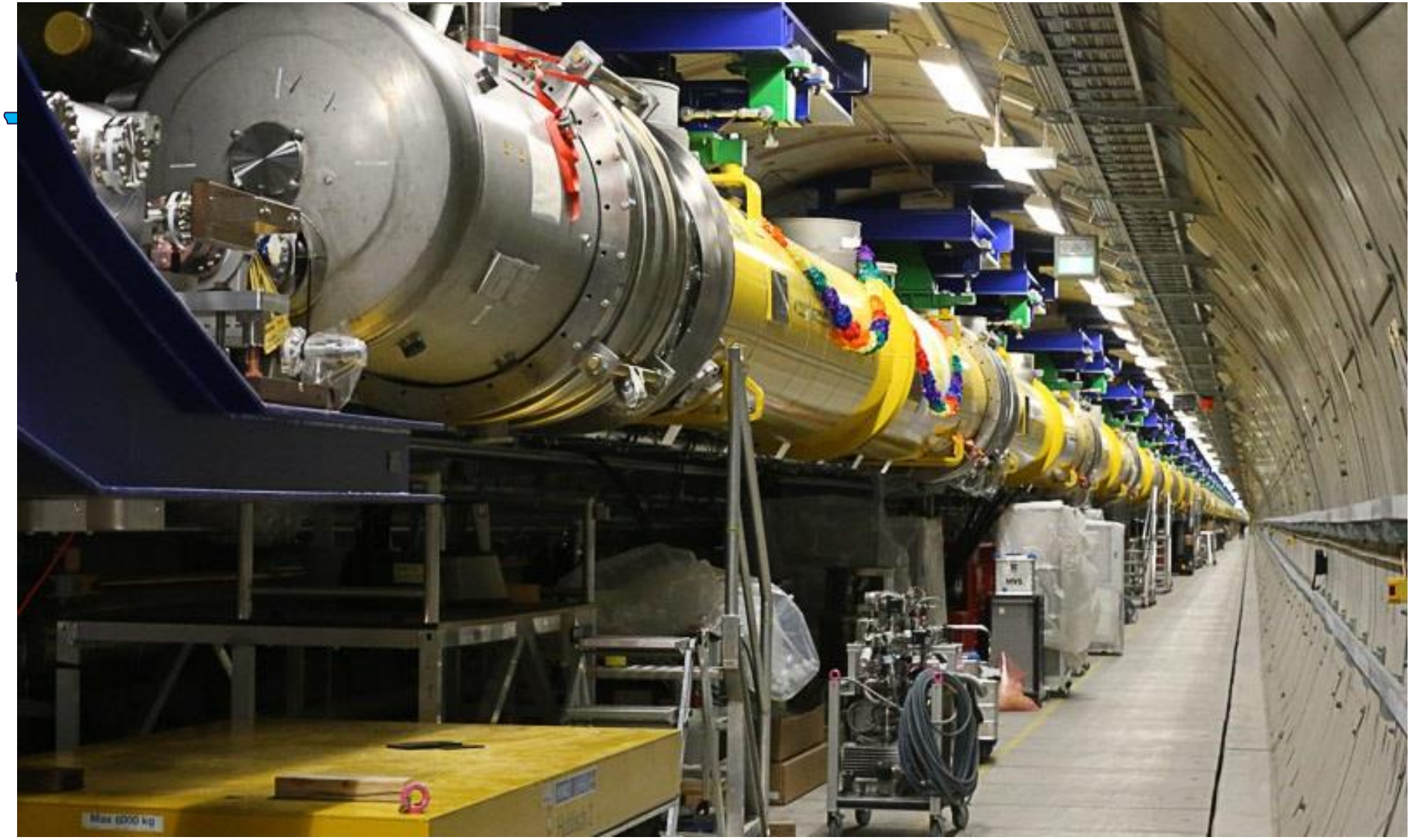
Injector in Operation

- First beam in 12/2105
- Fully commissioned up to 7/2016
- See talk by Matthias Scholz

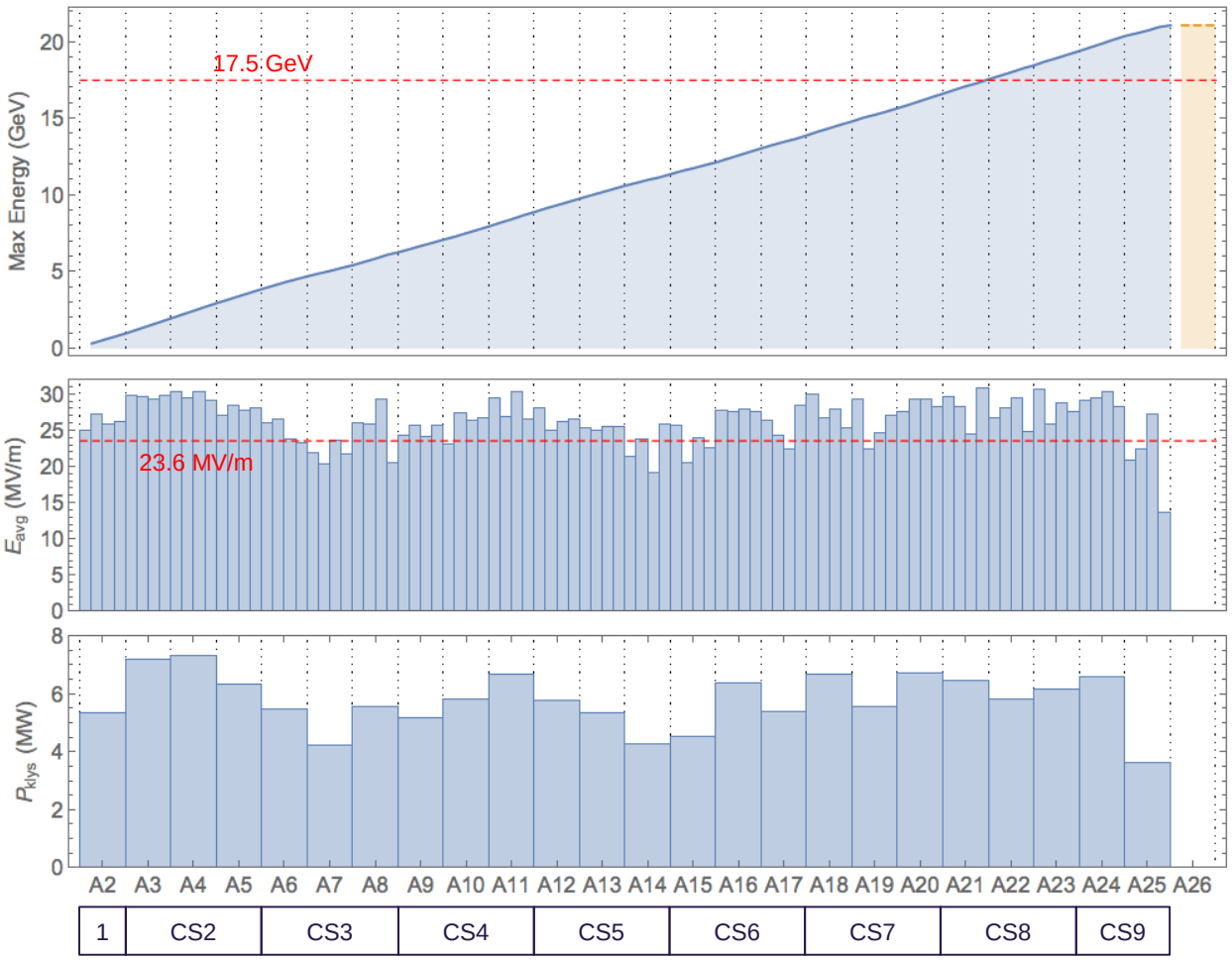
Superconducting Accelerator – All Modules Installed



Superconducting Accelerator – Last Module Installed



Energy Reach of European XFEL Modules



maximum energy reach

- after tunnel installation *and*
- according to accelerator module test

	Installed (GeV)	Module (GeV)
CS1	1.	1.05
CS2	3.89	4.06
CS3	6.29	6.72
CS4	8.91	9.49
CS5	11.38	12.09
CS6	13.92	14.76
CS7	16.63	17.62
CS8	19.42	20.44
CS9	21.09	22.23

the maximum energy during FEL operation needs to respect the bunch compressor (BC) working points

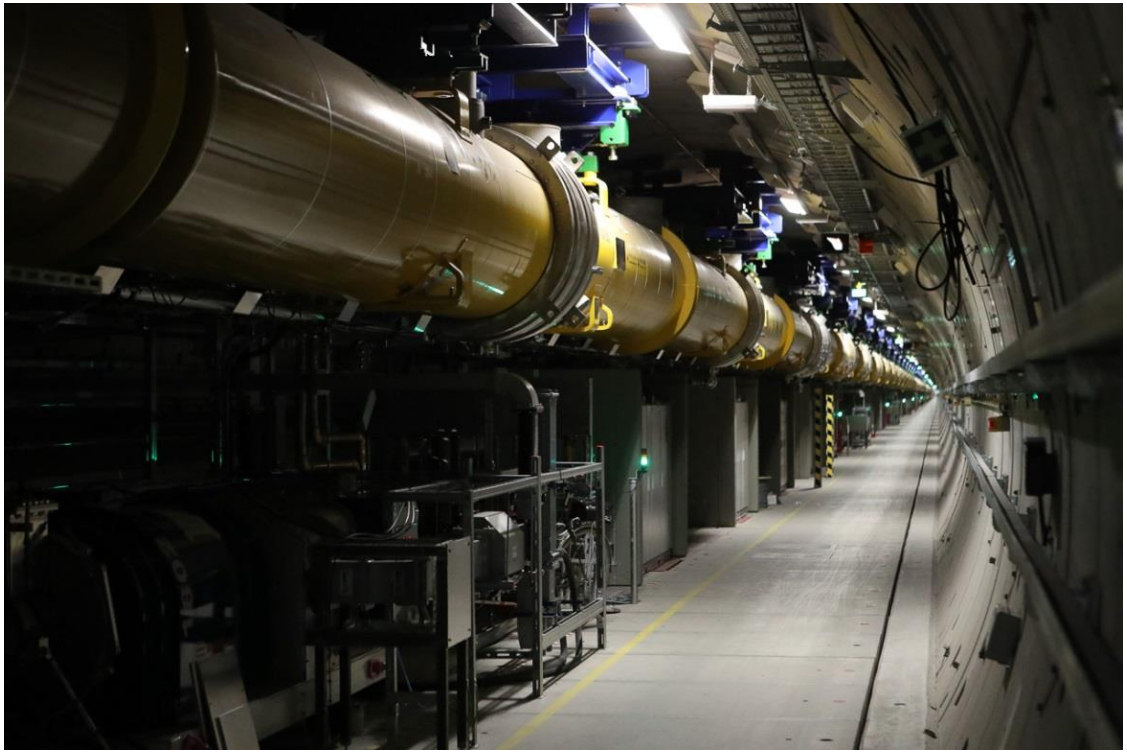
- 2.4 GeV nominal BC2 energy leads to approx. 19.5 GeV
- higher BC2 energy (e.g. 3.3 GeV) allows for > 20 GeV

increased max. energy assures higher availability

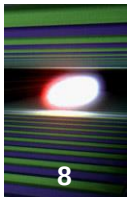
Linac Commissioning – ‚Warm‘

‘Warm’ technical commissioning of RF stations - in parallel with ongoing tunnel installation (1 week/station)

- Making RF in the tunnel for the first time
- First full system integration (personnel protection, timing, MPS, RF reference, servers, communication)
- Warm conditioning of couplers
- Exercise components, calibrate signals
- Operation of RF station from control room



Linac Commissioning – ‚Cold‘



‘Cold’ technical commissioning without beam - in parallel with upstream beam commissioning

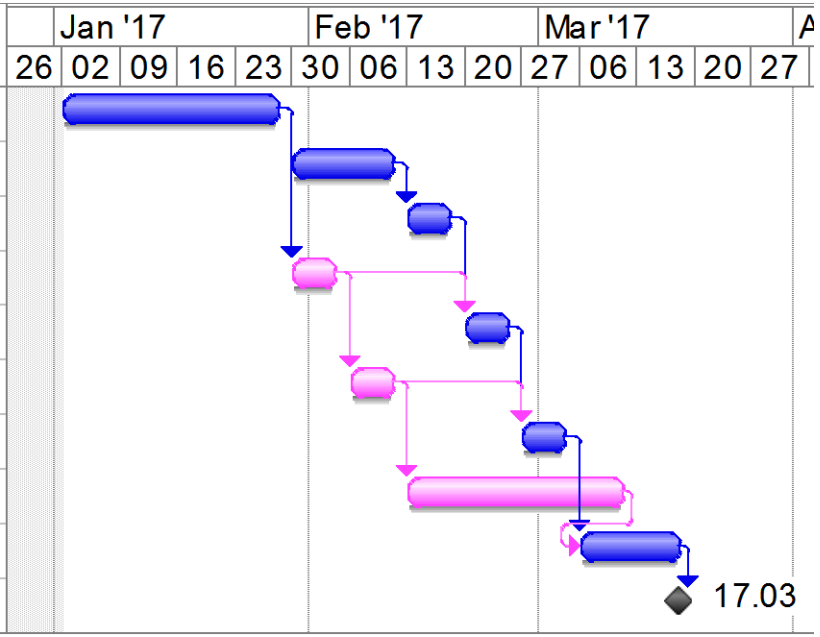
- Adjust magnet PS parameters and interlock limits Tune cavities on resonance (1 day/station)
- LLRF (3 shifts/station):
  - Low gradient operation to adjust signal levels, gradient pre-calibration, cavity fine-tuning
  - Controller configuration and basic operation
  - Middle and high level server commissioning

Beam commissioning - in parallel with ‘cold’ commissioning downstream

- Short bunch trains to do beam based calibration, basic functionality of beam-based feed back, … (1 shift/station)
- Measurement campaign for whole linac (1 week) for high beam current operation

Linac Commissioning Schedule

ID	Task Name
41	Cool down
58	commissioning of injector after cooldown
66	Beam commissionig of dogleg
69	L1 commissioning no beam (Cav. Tuning, PS, LLRF)
70	L1 & BC1 beam commissioning
71	L2 commissioning no beam (Cav. Tuning, PS, LLRF)
72	L2 & BC2 beam commissioning
73	L3 commissioning no beam (Cav. Tuning, PS, LLRF)
74	L3 & CL, TLD beam commissioning
75	Beam in XS1 dump



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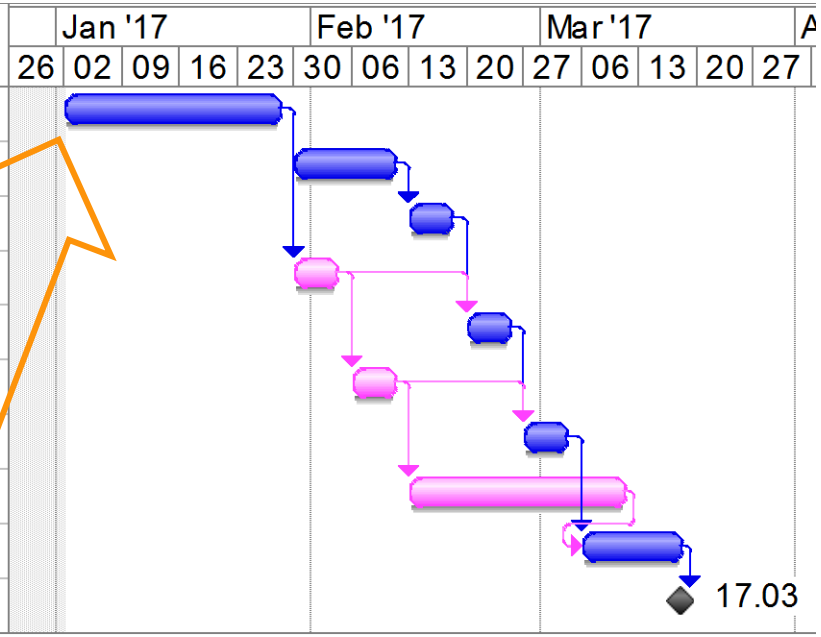
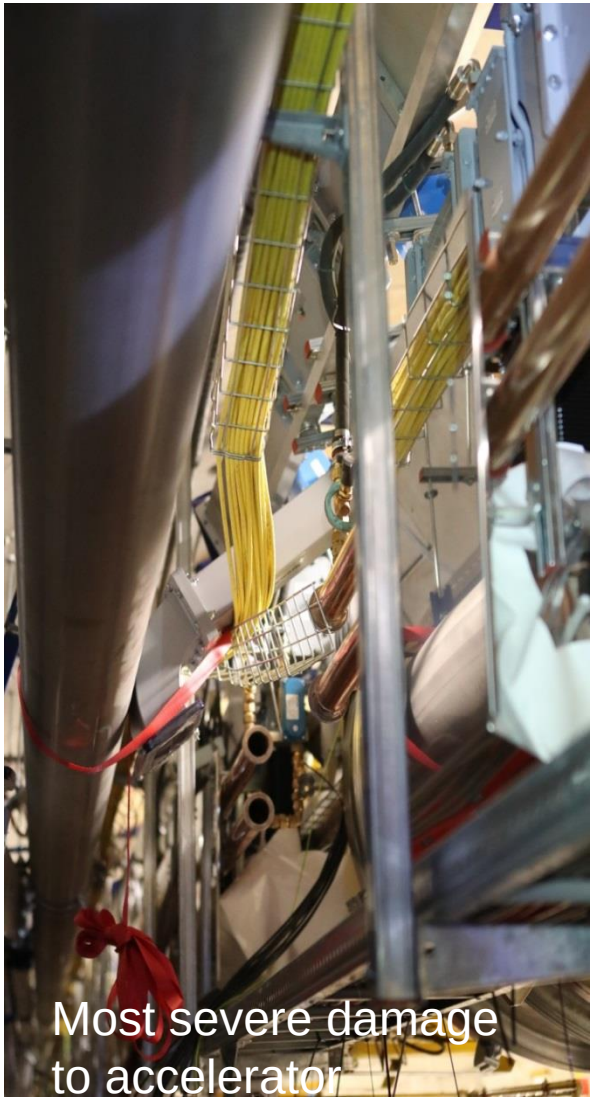


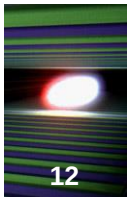
- All dates are tied to start of cool down
- Was scheduled for today
- During preparatory pressure tests support of an auxiliary He pipe broke
- Start of coold down delayed by up to three month

Damage to accelerator infrastrucuture

- Along CS9 and CS8 the line came to a halt on some of the wave guide sections which are 0.5 m below the original position of the pipe.
- At the cryo end box and also at the string connection box connecting CS8 to CS9 all connections to the DN200 pipe broke.

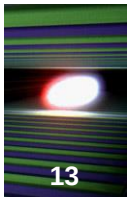


E-beam parameters



Quantity	Value
electron energy	8/12.5/14/17.5 GeV
macro pulse repetition rate	10 Hz
RF pulse length (flat top)	600 μs
bunch train length	600 μs
bunch repetition frequency within pulse	4.5 MHz
bunch charge	0.02 – 1 nC
electron bunch length after compression (FWHM)	2 – 180 fs
Slice emittance	0.4 - 1.0 mm mrad
beam power	500 kW
Variable undulator gap	10-20 mm
Simultaneously operated SASE undulators	3

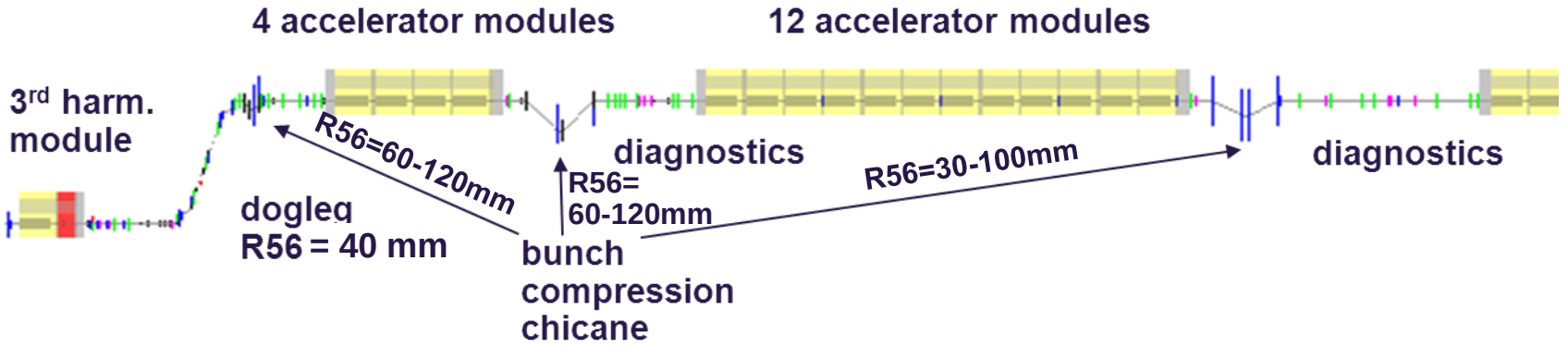
Initial E-beam parameters



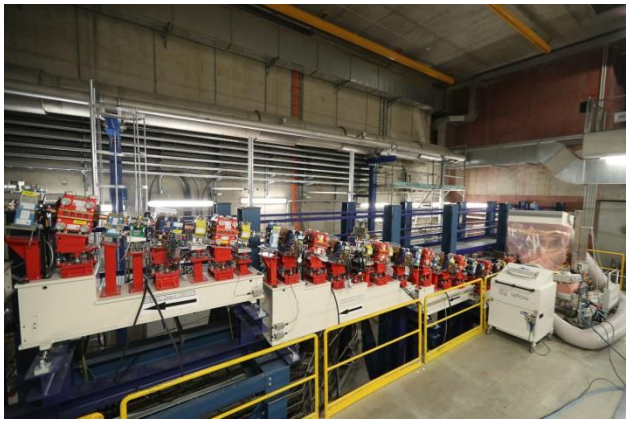
Quantity	Value
electron energy	~~8/12.5/14/17.5~~ GeV
macro pulse repetition rate	10 Hz
RF pulse length (flat top)	600 μs
bunch train length	70 μs
bunch repetition frequency within pulse	~~4.5 MHz~~ 1.1 MHz
bunch charge	~~0.02 – 1 nC~~ 0.5 nC
electron bunch length after compression (FWHM)	~~2 – 180 fs~~ 90 fs
Slice emittance	~~0.4 -~~ 1.0 mm mrad
beam power	~~500 kW~~ 5 kW
Variable undulator gap	~~10-20 mm~~ 14 mm
Simultaneously operated SASE undulators	~~3~~ 1

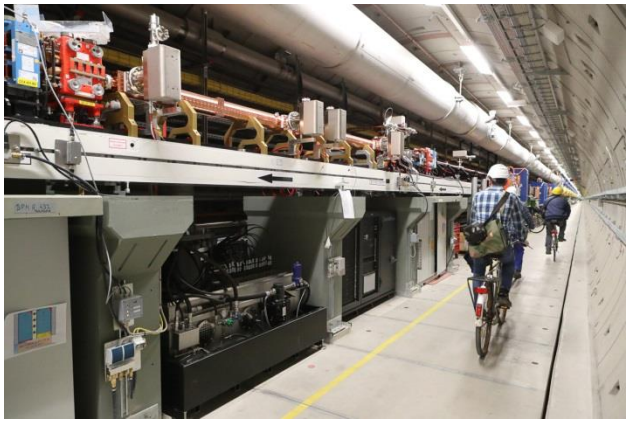
3 Stage Bunch Compression

3 stage bunch compression: flexible and less sensitive to noise from RF system



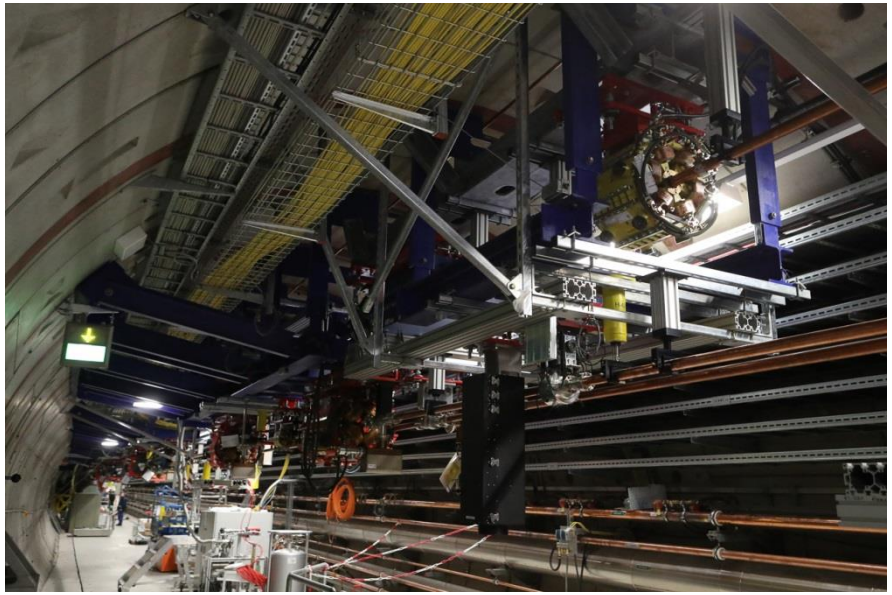
σ_σ = 2 mm	σ_σ = 1 mm	σ_σ = 0.1 mm	σ_σ = 0.02 mm
I_{peak}= 50 A	I_{peak}= 100 A	I_{peak}= 1 kA	I_{peak}= 5 kA
σ_E = 0 %	σ_E = 1.5 %	σ_E = 1 %	σ_E = 0.3 %
E = 130 MeV	E = 130 MeV	E = 600 MeV	E = 2400 MeV





Beam Collimation and Distribution

- Beam distribution after main collimation system runs three beam lines in parallel (Dump, North – SASE1&SASE3, South – SASE2)
- Kicker-Septa combinations allow flexible distribution to all beam lines

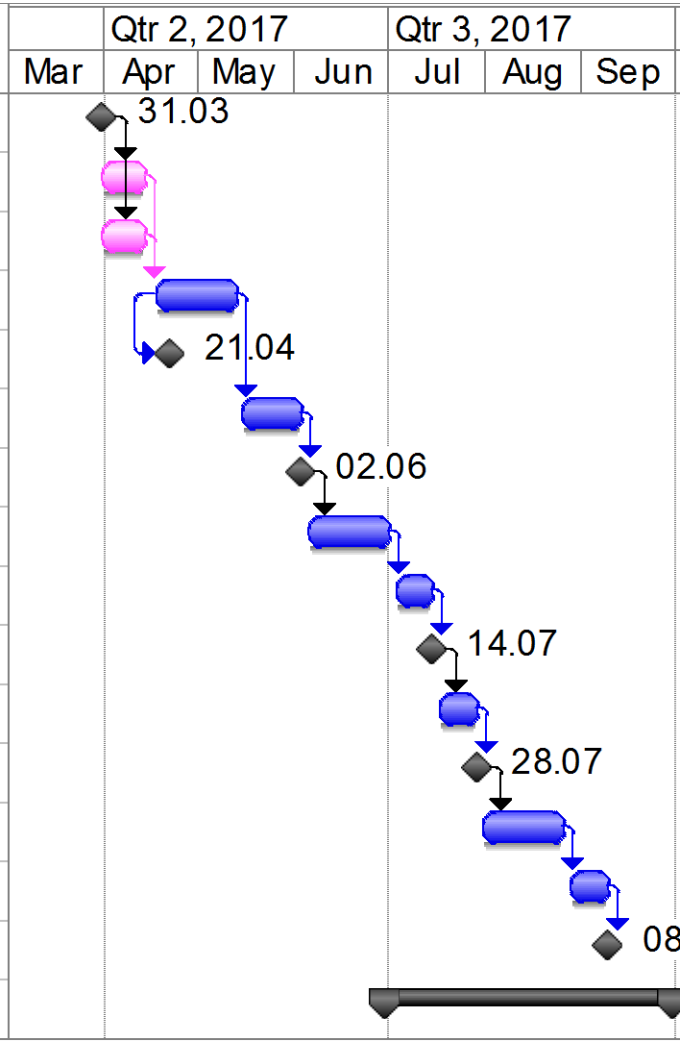


Undulator System Commissioning

- Undulator final technical commissioning after final alignment to straight line reference
- First lasing:
  - Electron BBA based on dispersion-free steering (‘LCLS method’)
  - Undulator and phase shifter settings based on magnetic measurements

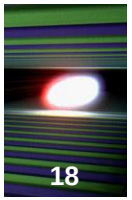
North Branch Commissioning Plan

ID	Task Name
78	North branch ready / Tunnels closed
79	Commissioning of North branch magnets
80	Technical commissioning of north branch components
81	North branch beam commissioning
82	First Spont. Radiation from SASE1
83	Commission for lasing SASE1
84	First lasing possible SASE1
85	Commissioning SASE1 beam line
86	Commissioning SASE1 experiment
87	First experiment in SASE1
88	Commission for lasing SASE3
89	First lasing possible SASE3
90	Commissioning SASE3 beam line
91	Commissioning SASE3 experiment
92	First experiment in SASE3
93	South branch commissioning



See also talk by Harald Sinn

South Branch Commissioning Plan



- South branch commissioning follows after SASE1 and SASE3 lasing with first lasing also in 2017
- Self seeding set-up for SASE2 prepared (see talk by Shan Liu)

Summary & Outlook

- Injector commissioned
- Exciting time of accelerator production/testing/installation comes to an end
- Based on injector experience and accelerator module performance we are looking forward to reaching all design parameters
- Linac & SASE commissioning plans detailed, controls and software prepared (see talk by Raimund Kammering)
- First lasing possible about 6 month after tunnel closure (with no margin) with user operation to start in 2017
- Full performance is expected approx. 1.5 years after first lasing