

The European XFEL

Superconducting RF Technology at Large Scale

ACADEMIA-INDUSTRY MATCHING EVENT
Fostering Collaborations in Superconductivity

27-28 May 2013
CIEMAT

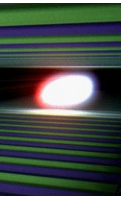
Presented by Hans Weise / DESY



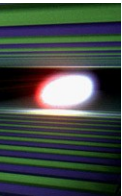
Courtesy: with many pictures from

D. Noelle / DESY & others
incl. E. Zanon & Research Instruments

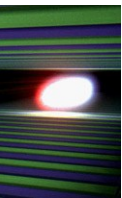
XFEL Cavities Ready for Testing at DESY



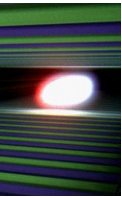
Vertical Test Cryostat at DESY



Cavity Arrival from Zanon and Research Instr.



Superconducting Cavities



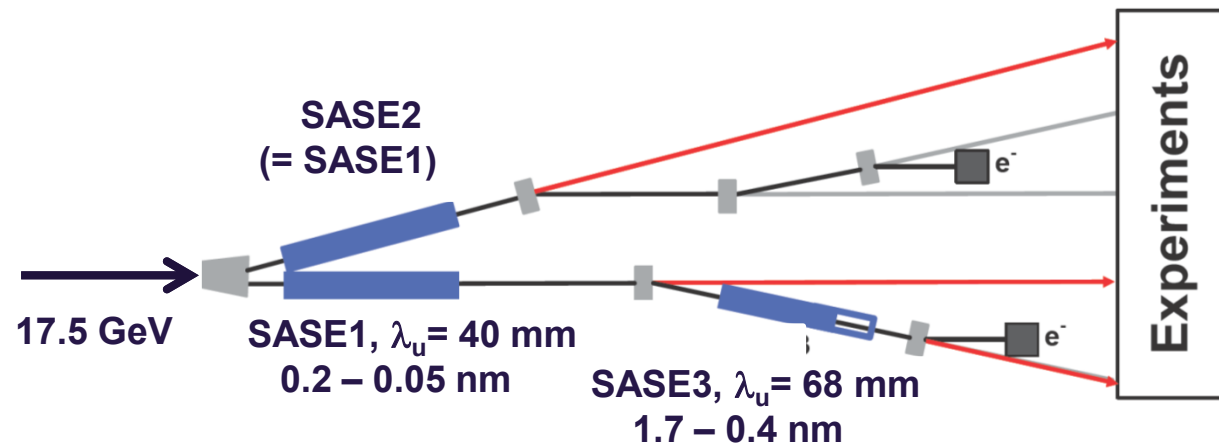
The European XFEL

Built by Research Institutes from 12 European Nations

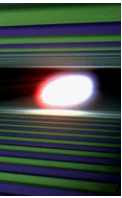
Some specifications

- Photon energy 0.3-24 keV
- Pulse duration ~ 10-100 fs
- Pulse energy few mJ
- Superconducting linac. 17.5 GeV
- 10 Hz (27 000 b/s)
- 5 beamlines / 10 instruments
 - Start version with 3 beamlines and 6 instruments
- Several extensions possible:
 - More undulators
 - More instruments
 -
 - Variable polarization
 - Self-Seeding
 - CW operation

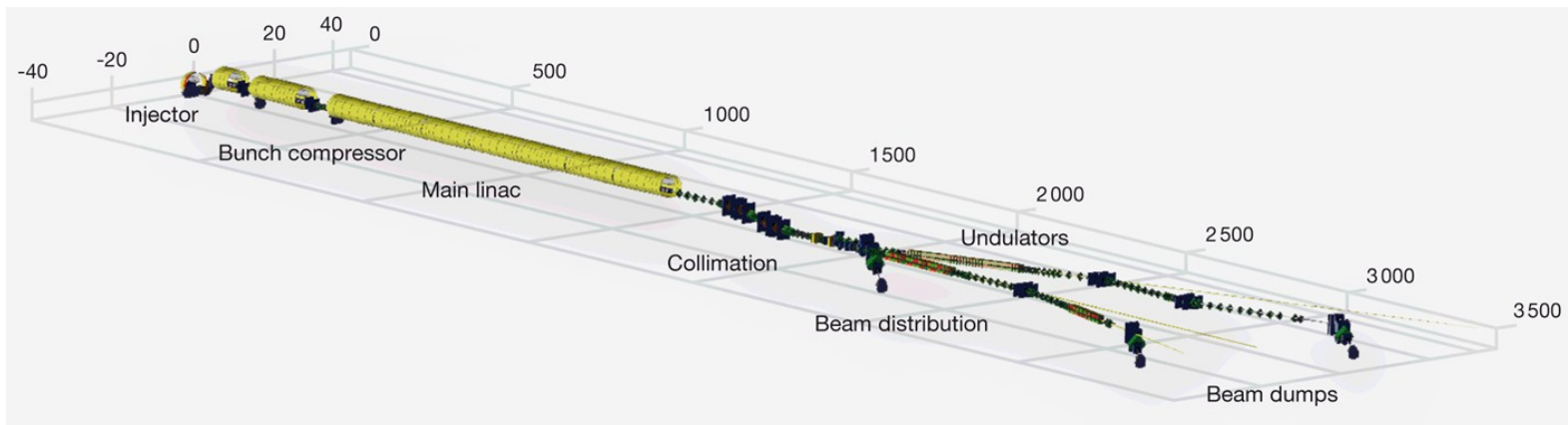
First beam late 2015



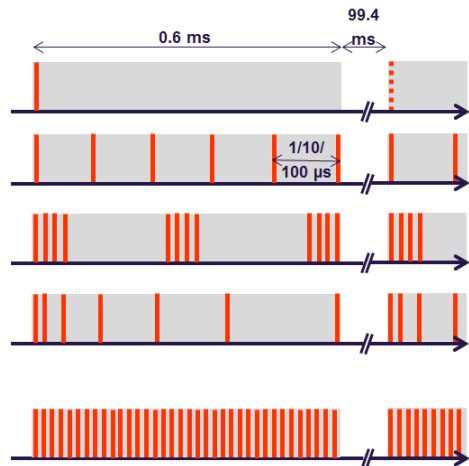
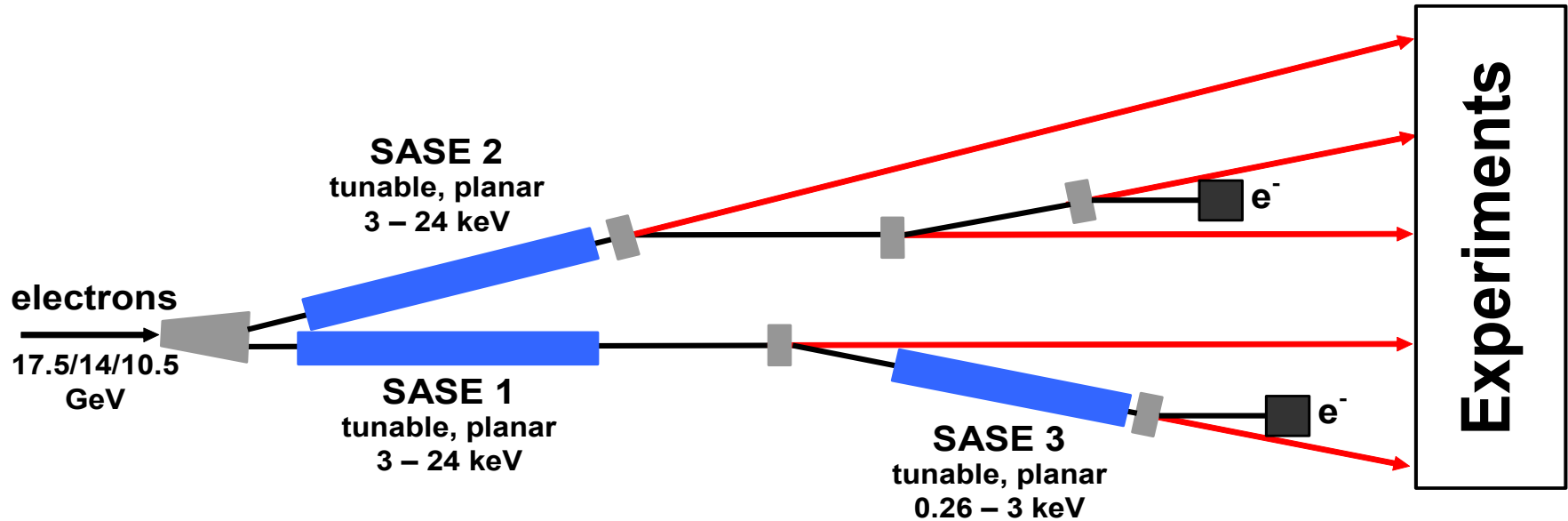
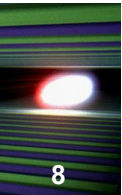
Accelerator Complex with Challenging Parameter Set



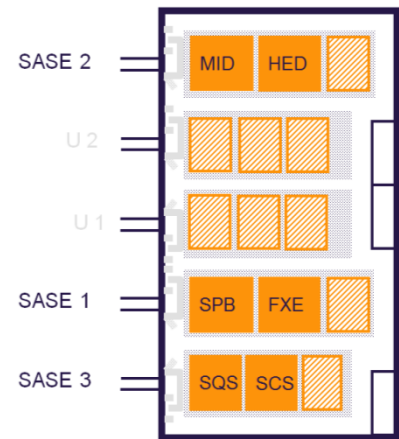
| | |
|--------------------------|--------------------------|
| Electron beam energy | 17.5 GeV |
| Bunch charge | 0.02 - 1 nC |
| Peak current | 2 - 5 kA |
| Slice emittance | 0.4 - 1.0 mm mrad |
| Slice energy spread | 4 - 2 MeV |
| Shortest SASE wavelength | 0.05 nm |
| Pulse repetition rate | 10 Hz |
| Bunches per pulse | 2700 |
| Pulse length | 600 μ s |



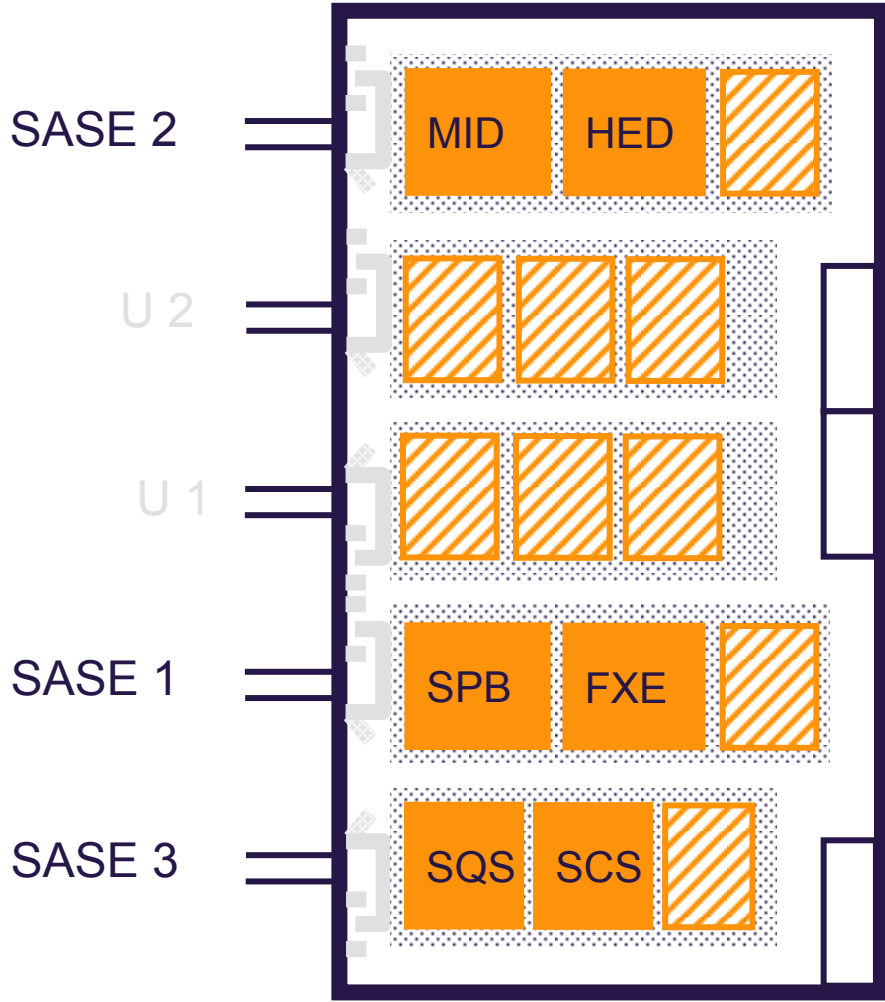
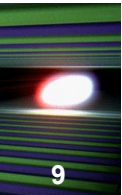
X-ray Beamlines for Different Wavelengths with Different Time Structures



- 2 hard x-ray undulators and beam transport with 4 instruments
- 1 soft x-ray undulators and beam transport with 2 instruments



The Suite of Instruments



FXE Femtosecond X-ray Experiments

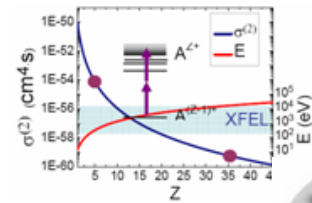
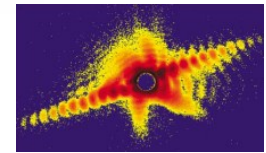
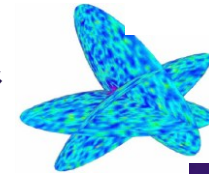
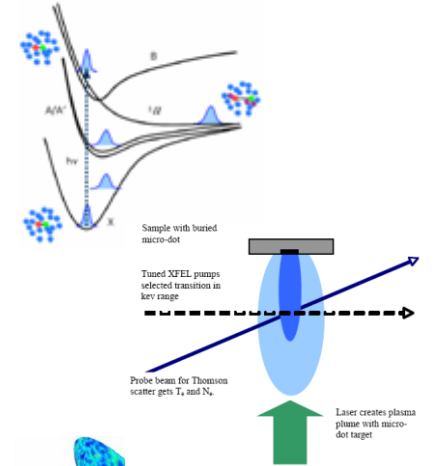
HED High Energy Density Science

SPB Single Particle & Biomolecules

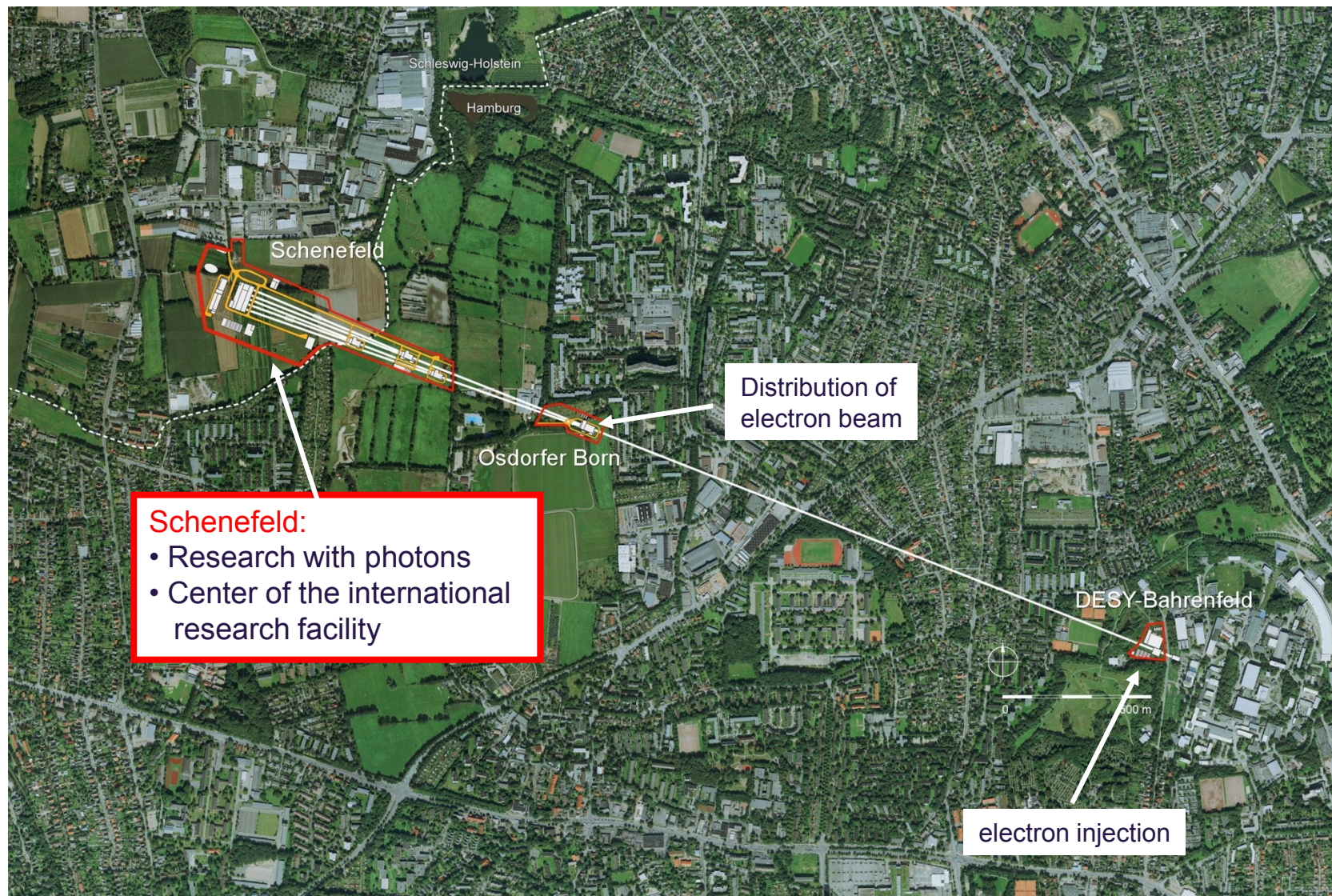
MID Materials Imaging & Dynamics

SQS Small Quantum Systems

SCS Spectroscopy & Coherent Scattering



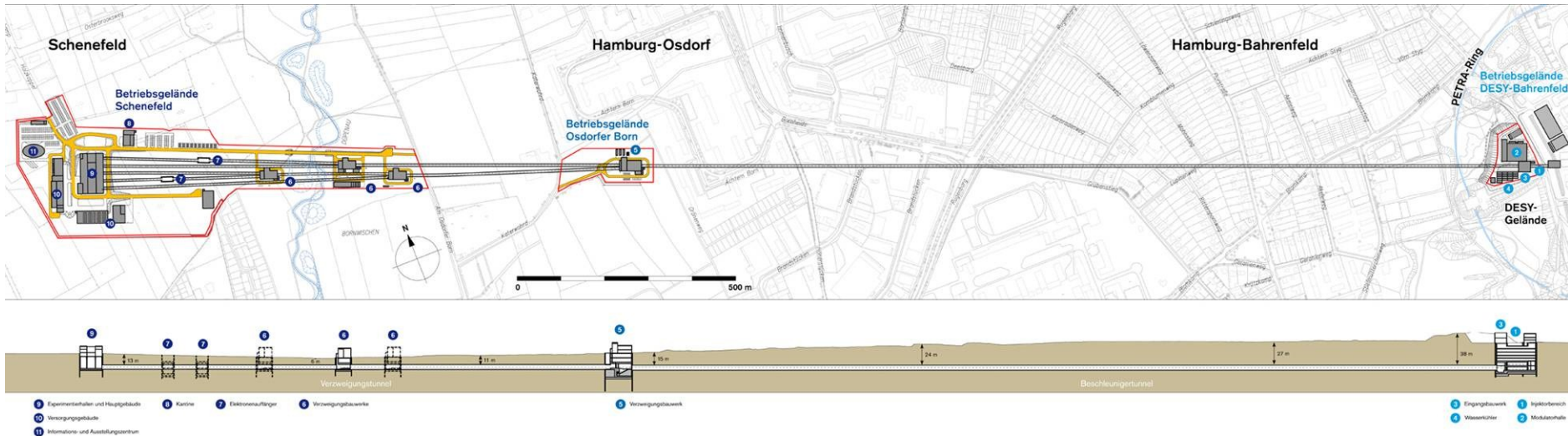
Overall Layout: **Three** Above Ground Sites



Schenefeld

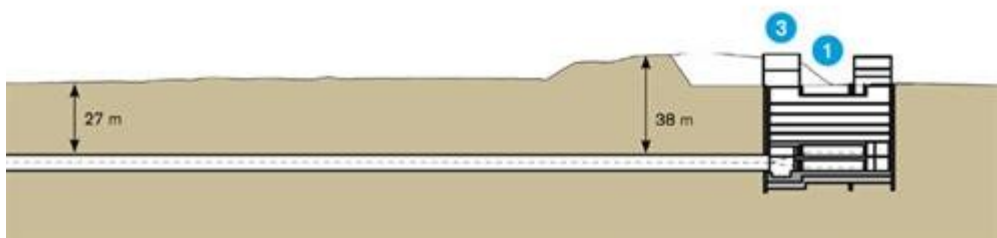
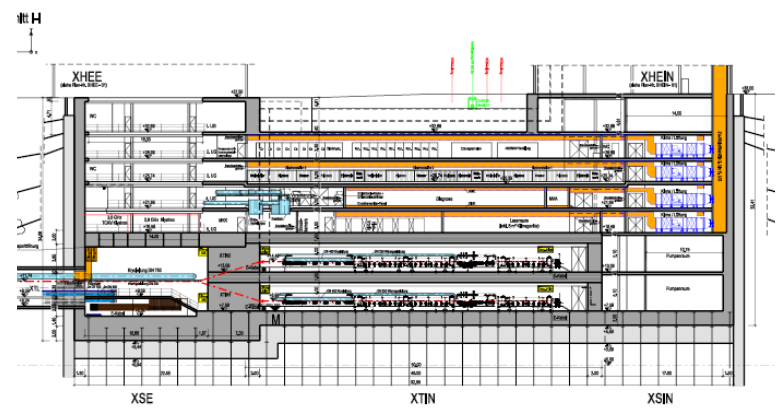
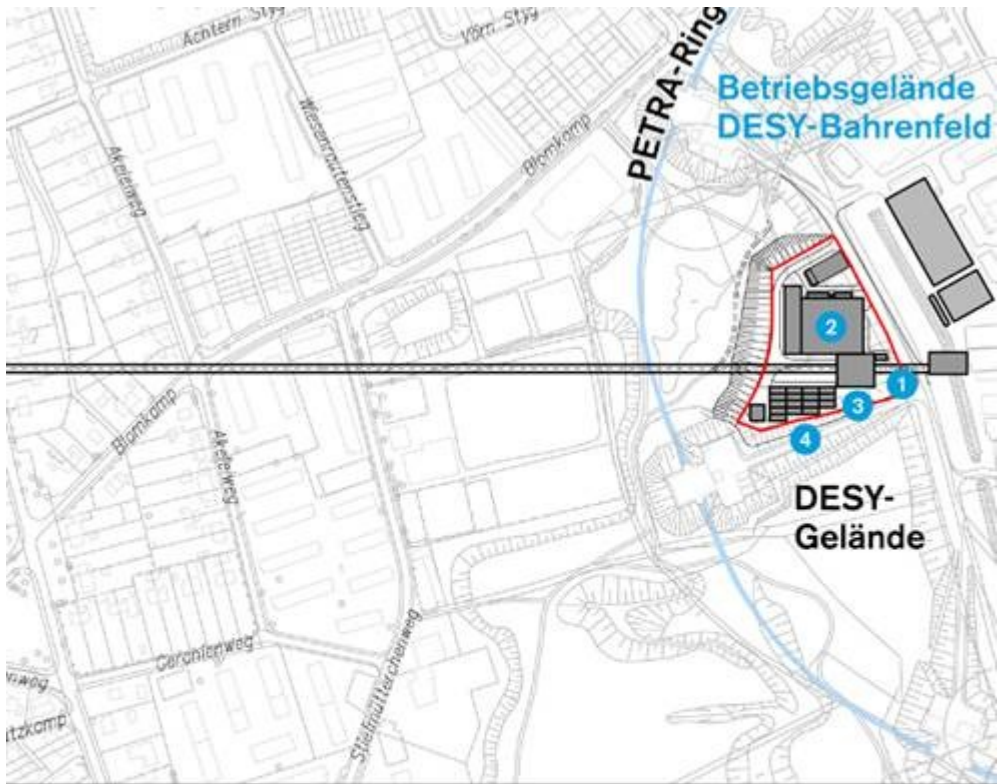
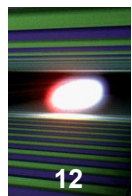
Osdorfer Born

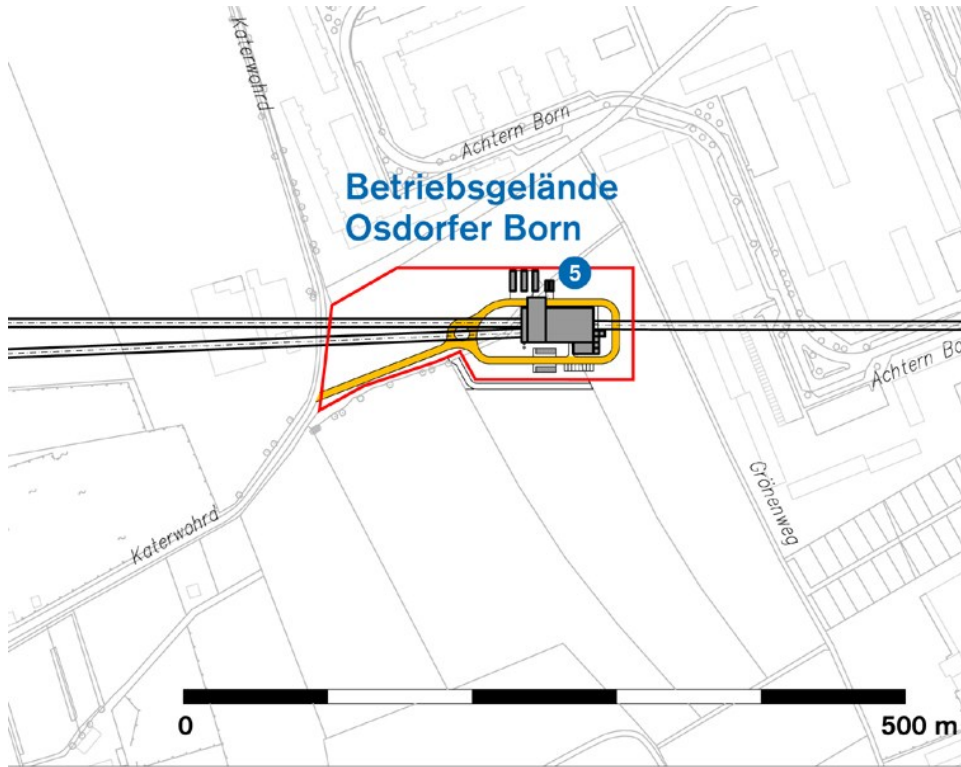
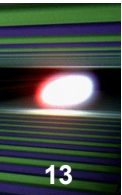
Bahrenfeld



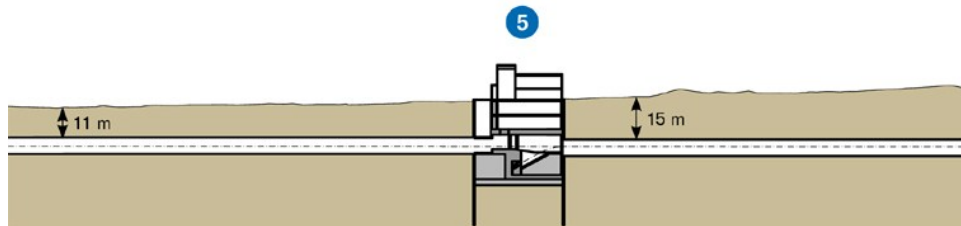
- Three construction sites
- 5.8 km tunnels
- 12,000 m² surface are buildings
- 150,000 m³ of underground building volume

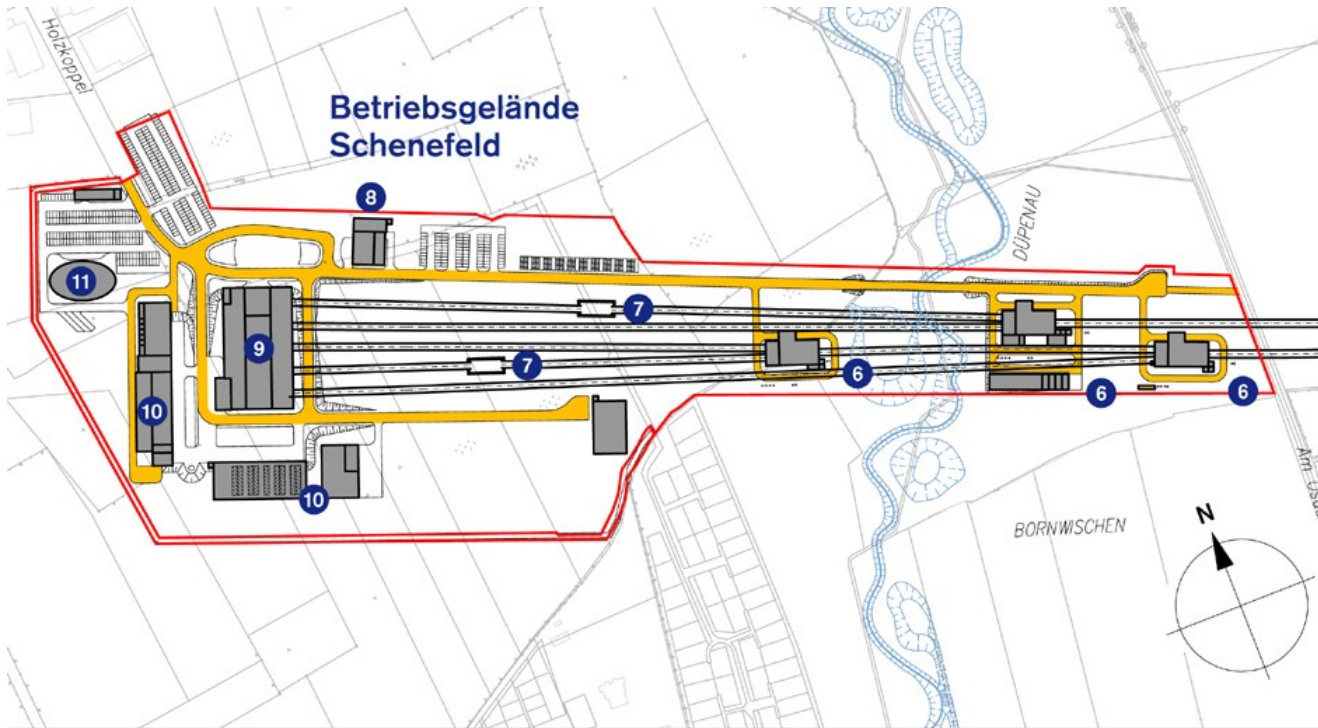
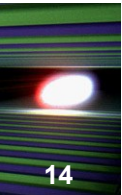
DESY Bahrenfeld – Injector Complex





Distribution shaft from linac tunnel to undulator tunnels



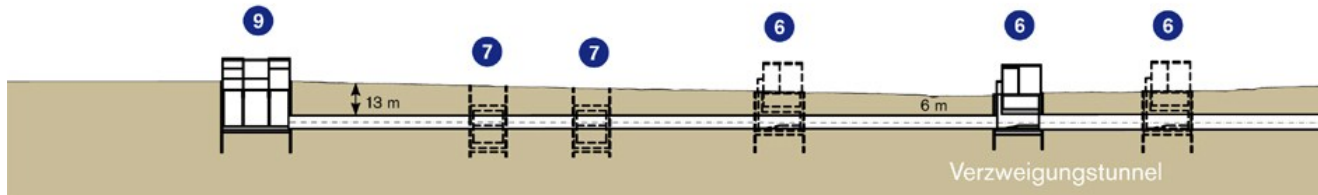


Distribution Shafts

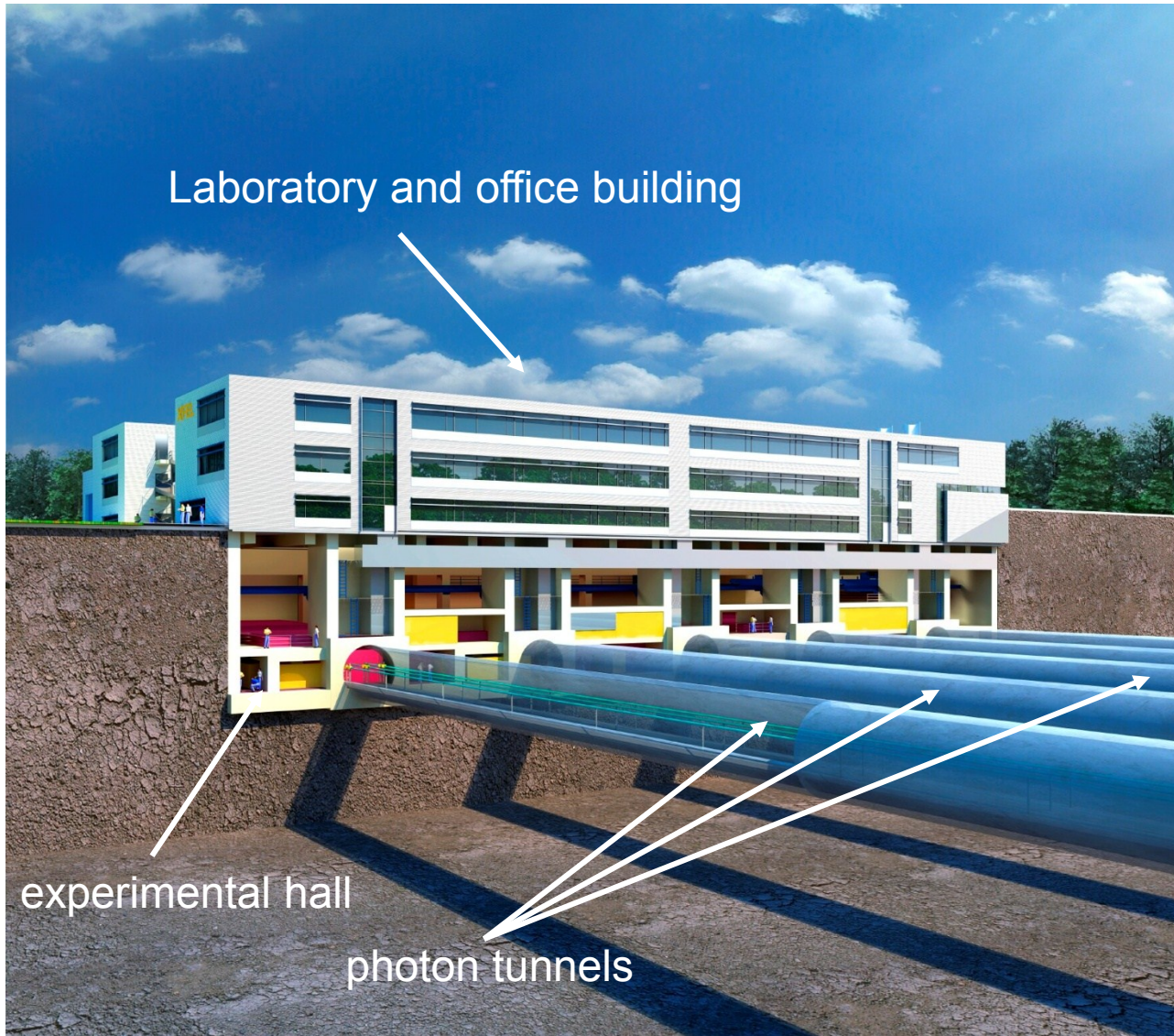
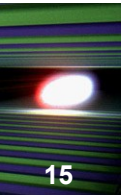
Power, Water,
Cooling Supplies

Experimental Hall

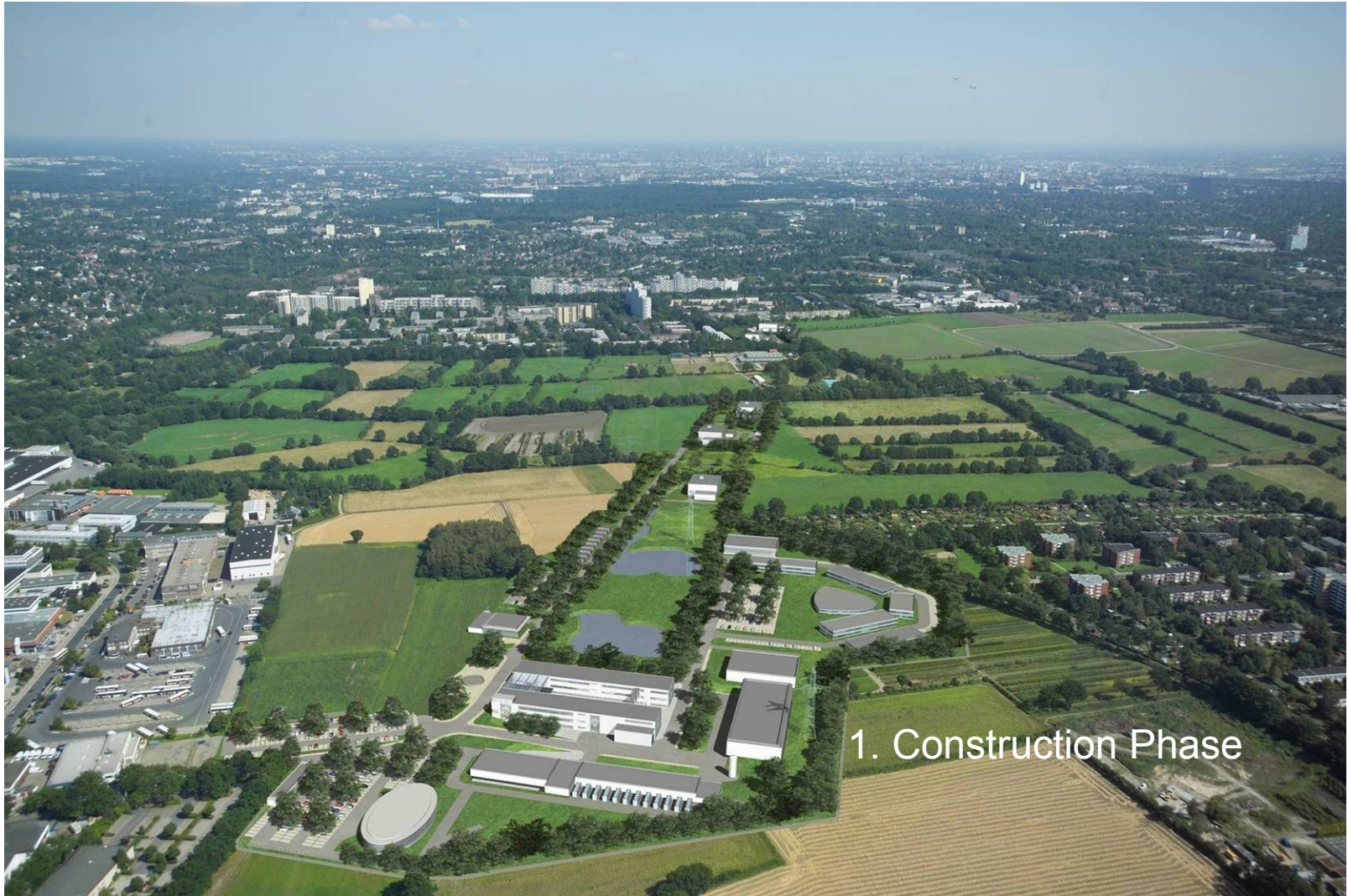
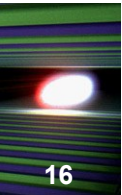
Office Building



Schenefeld Site – Experiment Complex

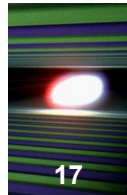


Schenefeld Site – Computer Simulation

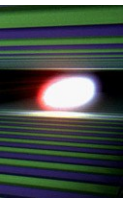


1. Construction Phase

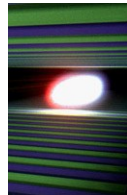
LINAC Tunnel February 2013



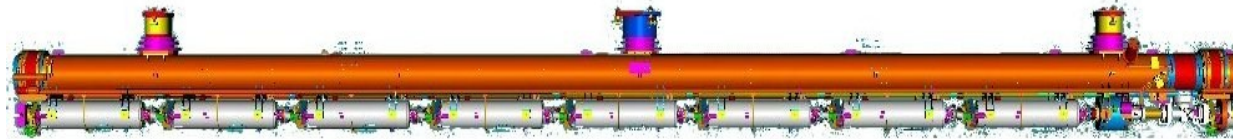
Experimental Hall European XFEL



An Accelerator Complex for 17.5 GeV



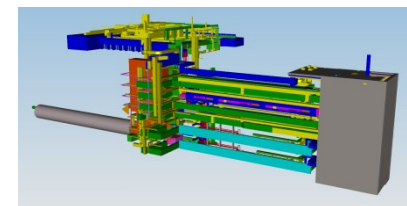
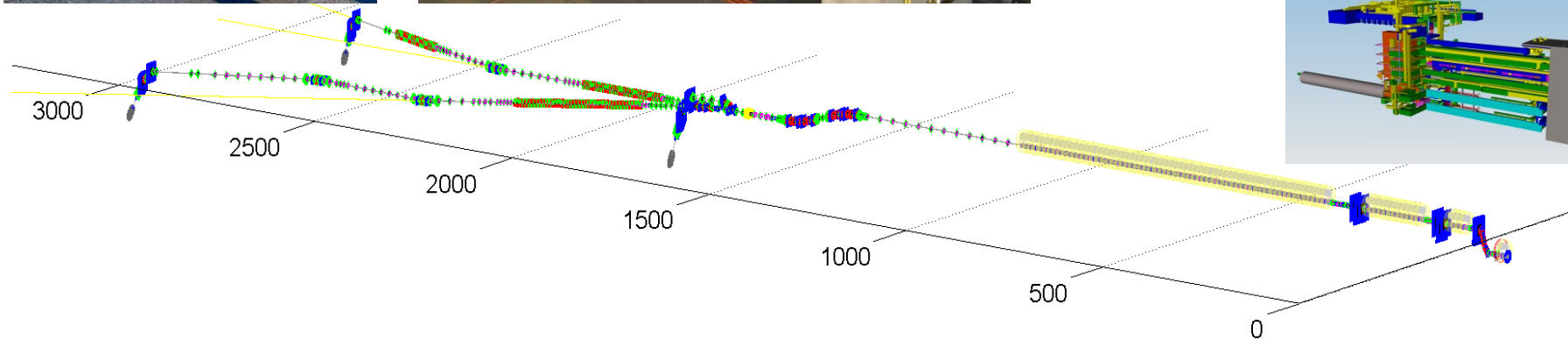
100 accelerator modules



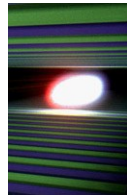
800 accelerating cavities
1.3 GHz / 23.6 MV/m



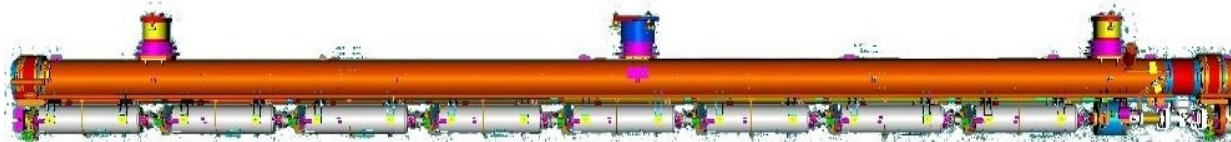
25 RF stations
5.2 MW each



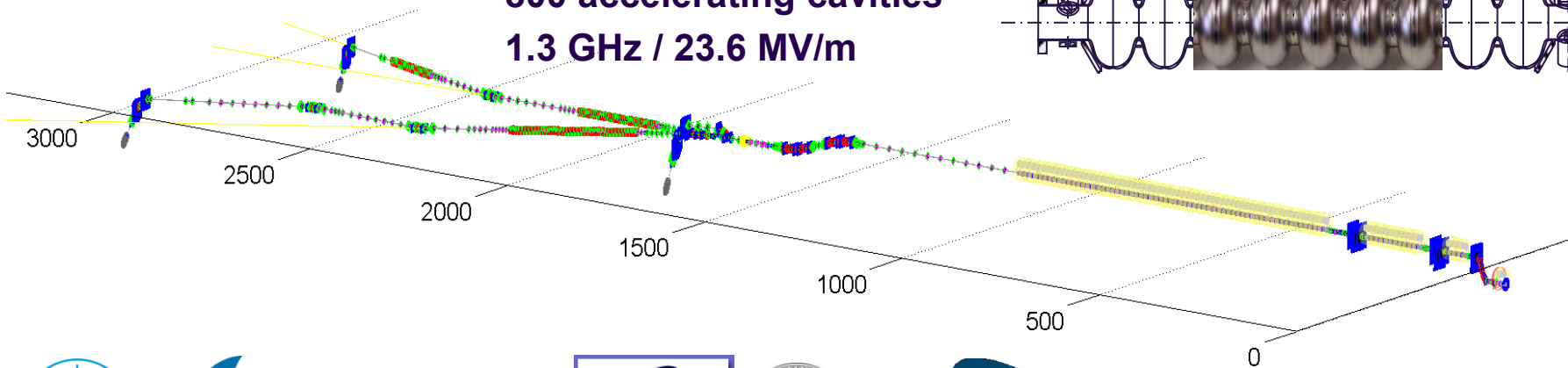
Contributors to the XFEL Accelerator



100 accelerator modules



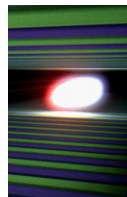
800 accelerating cavities
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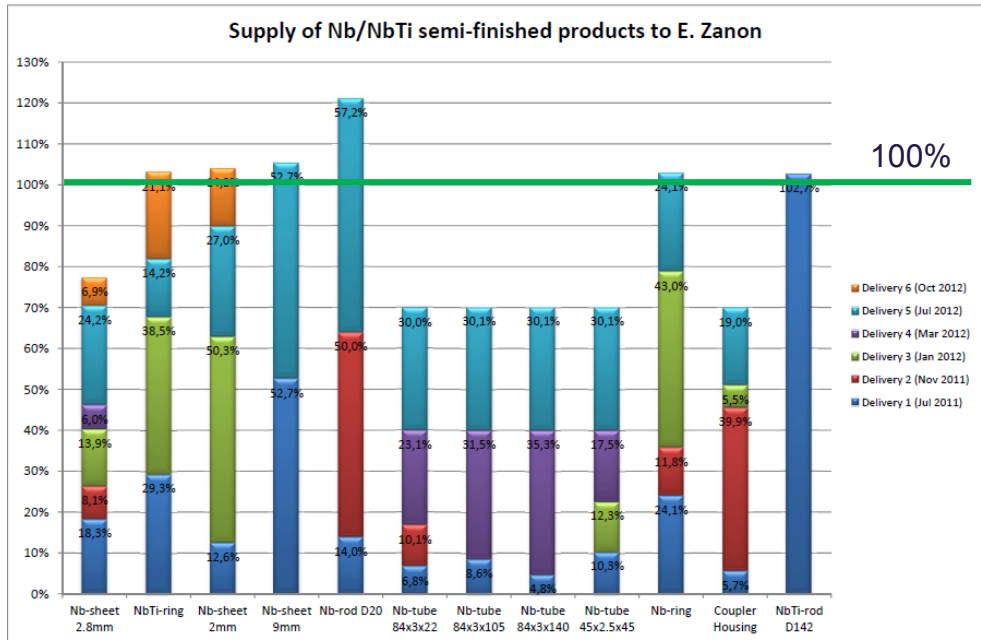
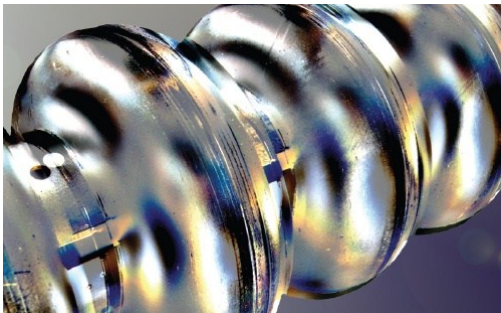
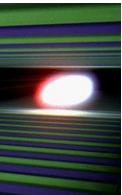
Wrocław University of Technology



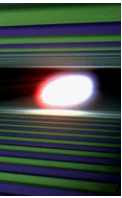
Well Established SRF Technology



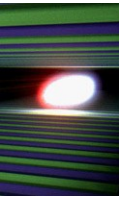
Accelerator Components for the Superconducting Linac - a *non-exhaustive* tour



Superconducting Cavities



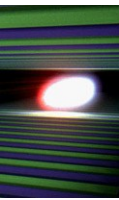
A Total of 800 s.c. Cavities Ordered in Industry



Based on DESY's **long time experience** the two companies Research Instruments and E. Zanon were contracted to produce each

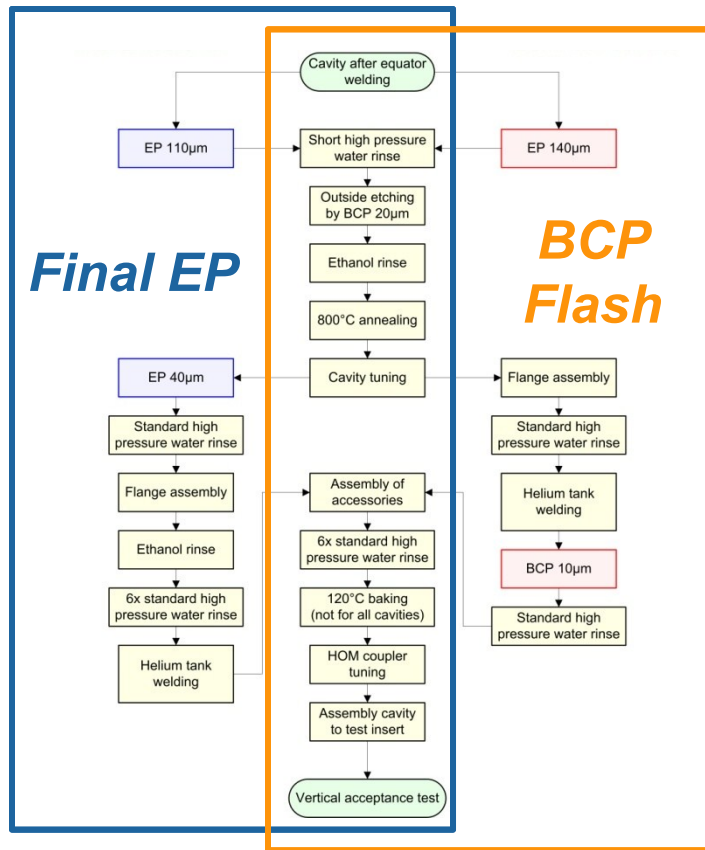
- **4+4 pre-series cavities**
- **280 XFEL type series cavities**
- **12 HiGrade cavities**, first used for quality assurance, later available for further investigations & treatments (high gradient R&D towards ILC)
- **Additional 120 cavities each** were ordered as an option to be placed after the evaluation of the successful start of the series production
- **No performance guaranty given by the two vendors**, i.e. the risk of unexpected low gradient or field emission is with DESY
- **Production precisely following the specifications** which also include the exact definition of infrastructure to be used
- **Nb / NbTi to be supplied by DESY**

Cavity Surface Treatment – Based on DESY Experience



Two schemes for the final surface treatment (*Final EP* and *BCP Flash*) were studied with cavities from two different vendors.

The preparation strategy to go for a final treatment with the cavity already welded into the He-vessel was investigated.



Results were:

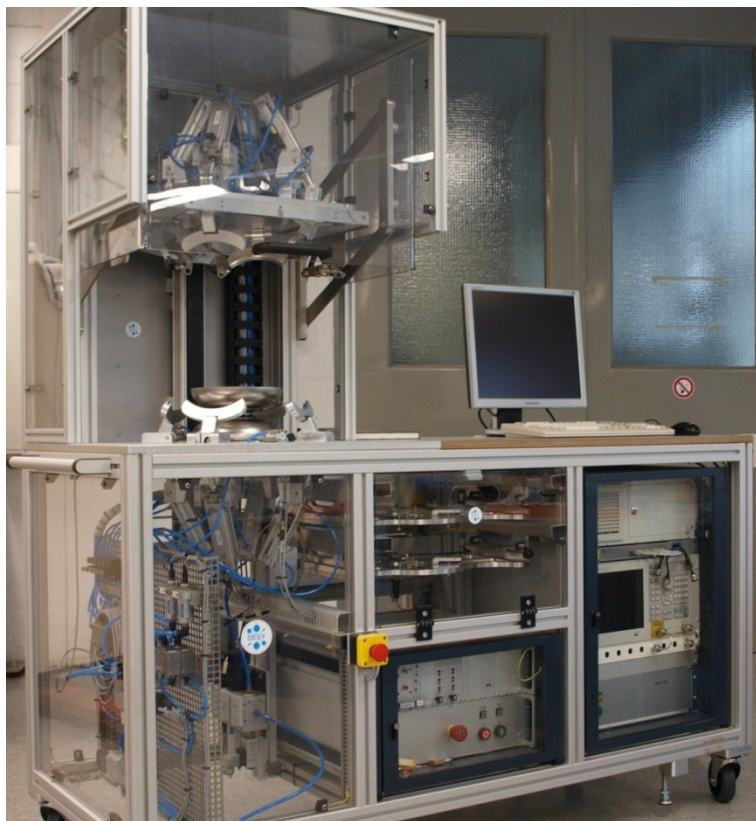
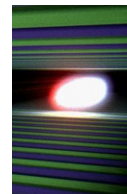
- yield curves for the different schemes
- yield curves for the different vendors
- a preparation strategy allowing two different final treatments

Some **tooling** provided by DESY

DESY procedures and experience described very much in detail in the CFT

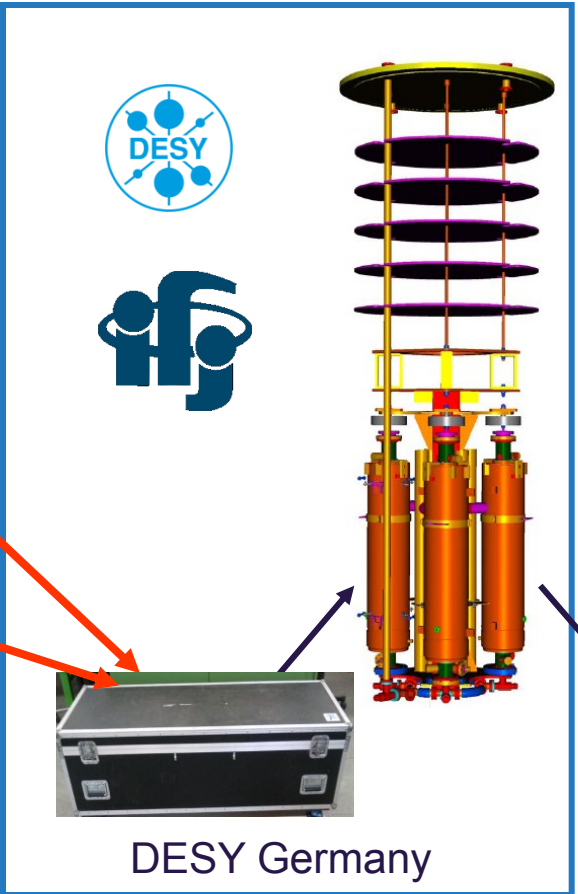
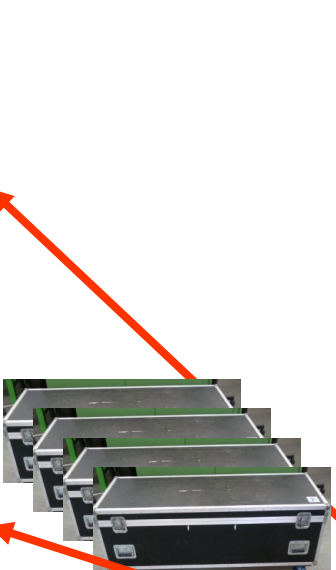
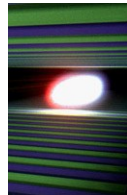
Specification was **made available** to the SRF community after contract placing.

RF Measurement and Field Flatness Tuning using DESY-provided Tools



- Both machines in operation at the cavity vendors (CE certified).
- Machines can be operated by Non-RF-Experts.
- Considerably shorter measurement / tuning time.
- Automation and documentation supported.

XFEL Cavities Travel through Europe

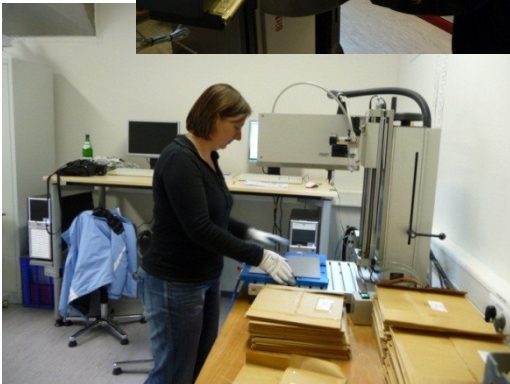
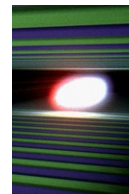


irfu
cea
saclay

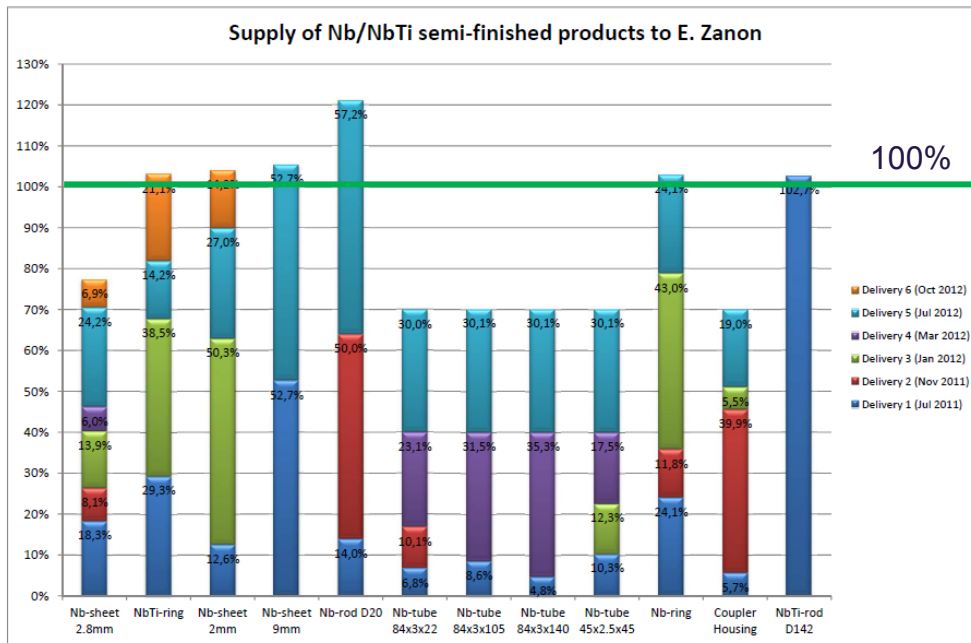
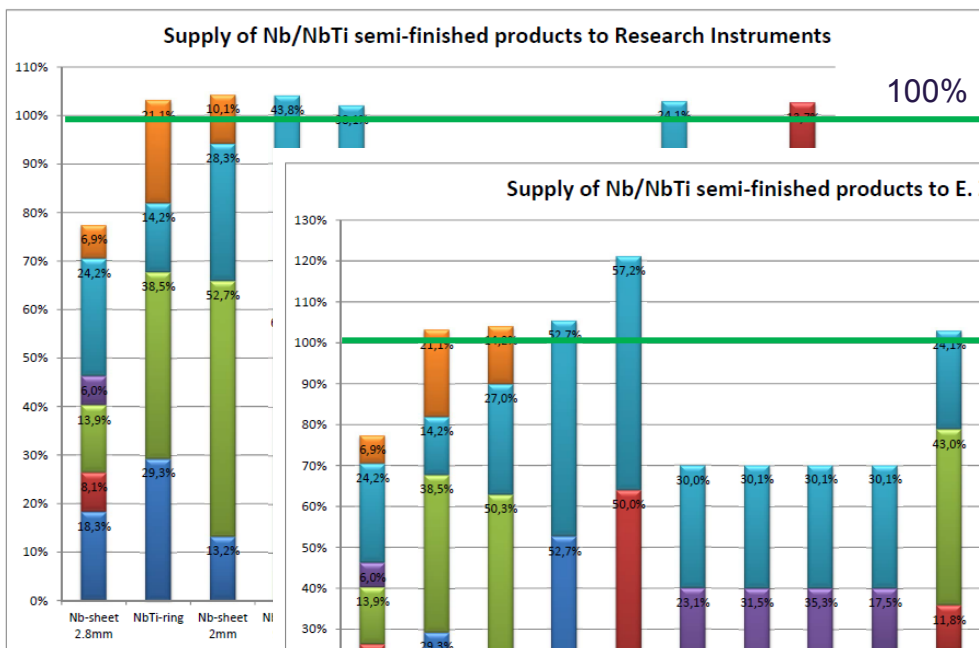


- DESY takes care of installation / dismounting of cavities into / from test insert
- Transport to IRFU / CEA

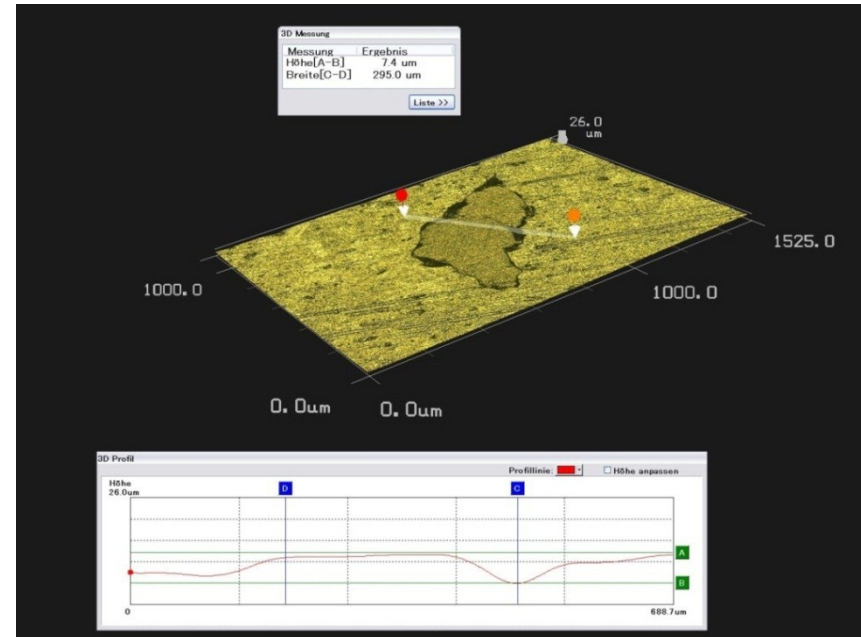
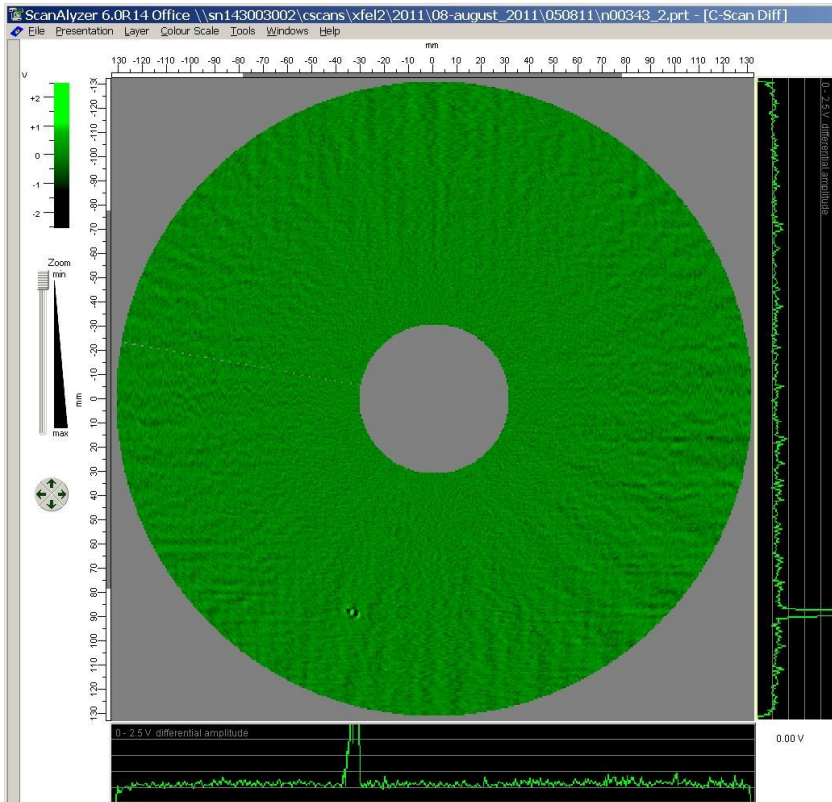
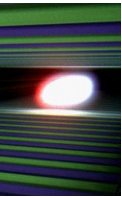
Niobium / Cavities



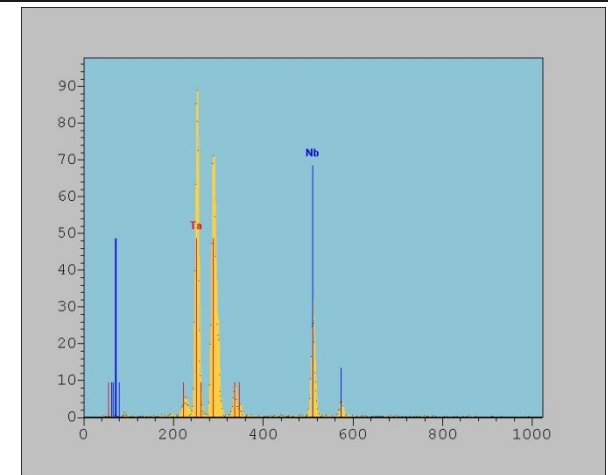
- 94% of Nb / NbTi material (24,420 pieces) arrived at DESY
- well established quality control at DESY for the almost 15,000 niobium sheets as well as for all other parts
- Last material delivery to vendors in fall 2013.



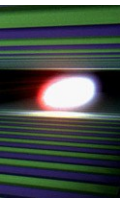
Example for Foreign Material Inclusion Tantalum Detected in a Niobium Sheet



- eddy current scan
- 3D -microscope image
- nondestructive element analysis



Cavity Delivery until 5/2013



| Cavity tracing | | | | | | | | | | | | | | |
|-------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|-------|--|
| week 21 | | | | | | | | | | | | | | |
| year | 2013 | | | | | | | | | | | | | |
| month | March | | | April | | | | | May | | | | | |
| calendar week | week 11 | week 12 | week 13 | week 14 | week 15 | week 16 | week 17 | week 18 | week 18/19 | week 20 | week 21 | week 22 | we | |
| EZ CVs Nr./ date | 520 / 14.03. | 523 / 21.03. | 527 / 28.03. | 531 / 04.04. | 529 / 11.04. | 537 / 18.04. | 539 / 25.04. | 543 / 02.05. | 545 / 07.05. | 518 / 16.05. | 508 / 23.05. | 548 | | |
| | 522 / 14.03. | 525 / 21.03. | 530 / 28.03. | 532 / 04.04. | 534 / 11.04. | 538 / 18.04. | 540 / 25.04. | 544 / 02.05. | | 524 / 16.05. | 528 / 23.05. | 549 | | |
| | | 526 / 21.03. | | | 535 / 11.04. | 500 / 18.04. | 541 / 25.04. | | | 547 / 16.05. | 546 / 23.05. | 556 | | |
| | | | | | 522 / 11.04. | | | | | 551 / 16.05. | 558 / 23.05. | 560 | | |
| | | | | | | | | | | 552 / 16.05. | | | | |
| RI CVs Nr./ date | 009 / 12.03. | 012 / 20.03. | | 004 / 03.04. | | | | 009 / 03.05. | 011 / 08.05. | 014 / 17.05. | 013 / 23.05. | 012 / 28.05. | 016 / | |
| | | | | | | | | | | 002 / 17.05. | | 010 / 28.05. | 018 / | |
| | | | | | | | | | | | | 017 / 28.05. | 022 / | |
| | | | | | | | | | | | | | 023 / | |
| delivered to DESY | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 5 | 4 | 7 | | |
| total delivered to DESY | 12 | 15 | 17 | 19 | 22 | 24 | 27 | 30 | 32 | 37 | 41 | 48 | | |
| tested at DESY | 1 | 1 | 5 | | | 1 | 4 | 4 | 2 | 3 | | | | |
| total tested at DESY | 7 | 8 | 13 | 13 | 13 | 14 | 18 | 22 | 24 | 27 | 27 | 27 | | |
| delivery to IRFU | | | | | 5 | | | | | | | | | |
| total delivery to IRFU | 4 | 4 | 4 | 4 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | |

- approx. **50 cavities** expected until end May 2013

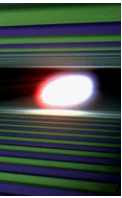
- approx. 3 cavities per week per company

- final ramp-up to 4 cavities per week required

Some additional infrastructure at cavity vendors to be commissioned

- number of non-conformities still to be decreased

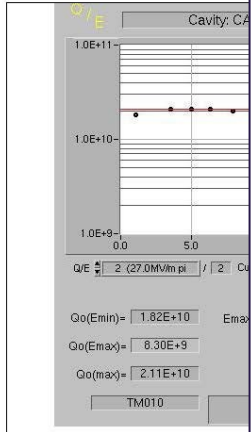
Several Cavity Tests per Week



Short Report on vertical test of CAV_FEM00526, test 1

| | |
|-------------------------------------|--|
| CAVITY ID | |
| RF test date | |
| test # | |
| # of runs | |
| max Eacc | |
| Limitation | |
| Q0 @ Eacc = 23.5 MV/m | |
| x-rays @ Eacc = 23.5 MV/m [mGy/min] | |
| Acceptance criteria met | |

Comment 1: Activation of radiation in
 Comment 2: Stronger radiation at bott

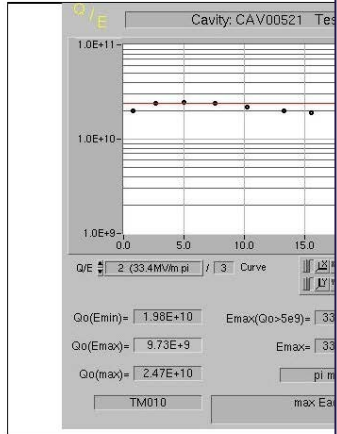


28.03.2013

Short Report on vertical test of CAV_FEM00526, test 1

| | |
|-------------------------------------|--|
| CAVITY ID | |
| RF test date | |
| test # | |
| # of runs | |
| max Eacc | |
| Limitation | |
| Q0 @ Eacc = 23.5 MV/m | |
| x-rays @ Eacc = 23.5 MV/m [mGy/min] | |
| Acceptance criteria met | |

Comment 1: Vertical test without problems ; little de



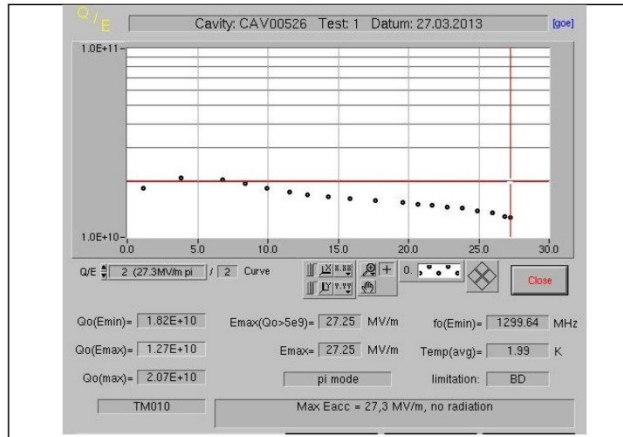
Final Q(E) of CAV00521, test 1

28.03.2013

Short Report on vertical test of CAV_FEM00526, test 1

| | |
|-------------------------------------|----------------------|
| CAVITY ID | CAV00526 |
| RF test date | 27.03.13 |
| test # | 1 |
| # of runs | 2 |
| max Eacc | 27 MV/m |
| Limitation | Quench (bd) |
| Q0 @ Eacc = 23.5 MV/m | $1,4 \times 10^{10}$ |
| x-rays @ Eacc = 23.5 MV/m [mGy/min] | none |
| Acceptance criteria met | Yes |

Comment 1: Vertical test without problems
 Comment 2: **Filling line bend** => tbd, if cavity is usable



Final Q(E) of CAV00526, test 1

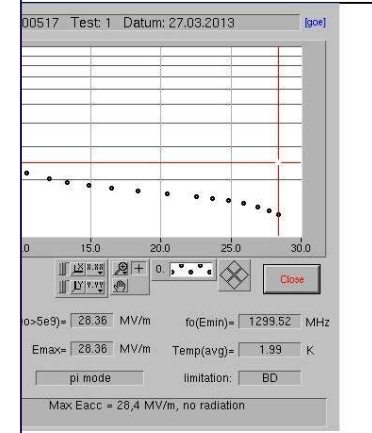
28.03.2013

Page 1 of 1

Short Report on vertical test of CAV_FEM00517, test 1

| | |
|-------------------------------------|----------------------|
| CAVITY ID | CAV00517 |
| RF test date | 27.03.13 |
| test # | 1 |
| # of runs | 2 |
| max Eacc | 28 MV/m |
| Limitation | Quench (bd) |
| Q0 @ Eacc = 23.5 MV/m | $1,6 \times 10^{10}$ |
| x-rays @ Eacc = 23.5 MV/m [mGy/min] | none |
| Acceptance criteria met | Yes |

Comment 1: Vertical test without problems ; little de

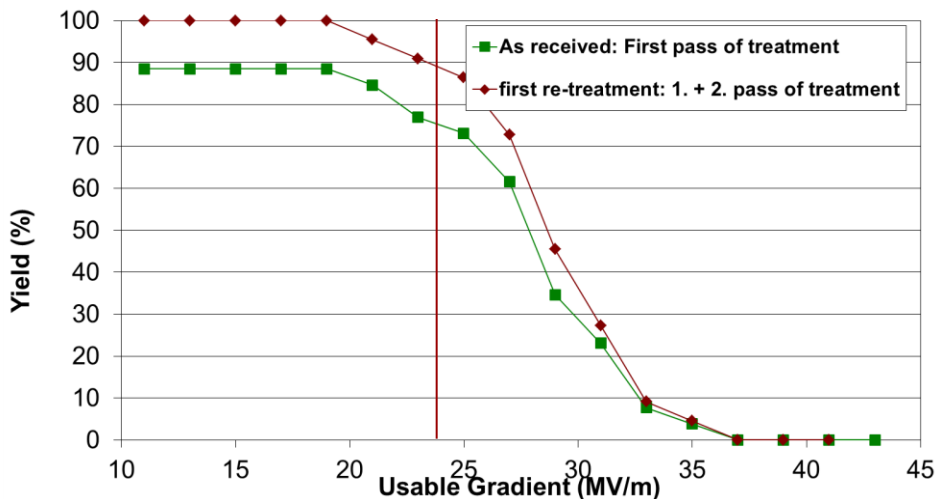
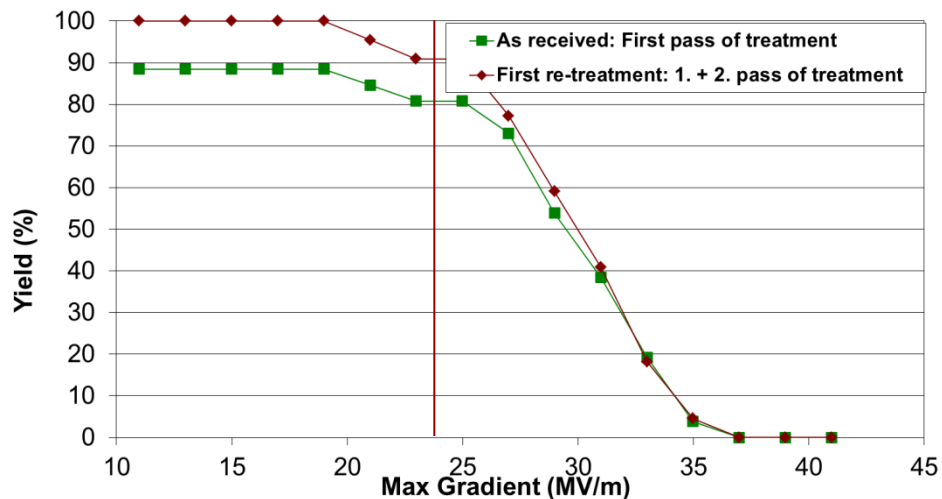


Final Q(E) of CAV00517, test 1

Page 1 of 1

First Results of XFEL Cavities: Vertical Acceptance Tests of EZ cavities (mid 5/2013)

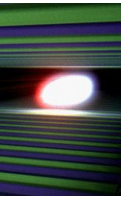
- Vertical acceptance test done on 25 cavities equipped with He-tank and HOM feedthroughs + 1 HiGrade Cavity w/o He-tank, but with HOM feedthroughs
 - 17 cavities meet specification w/o re-treatment
- Re-treatment by High Pressure Ultra-Pure Water (HPR) rinsing =>
 - 3 cavities successful done at DESY
 - 1 cavity in preparation; 3 cavities under discussion
- 2 cavities with quench at 19 MV/m and 22 MV/m, resp.



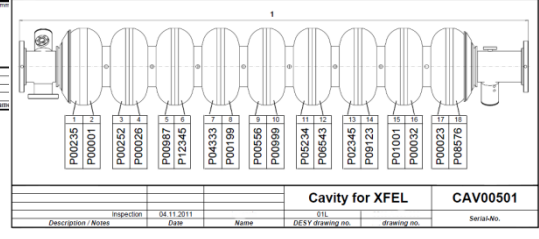
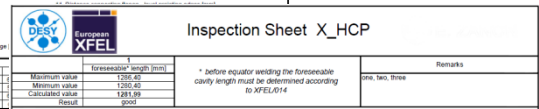
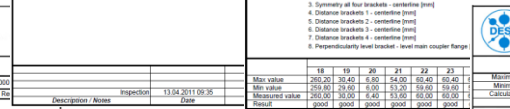
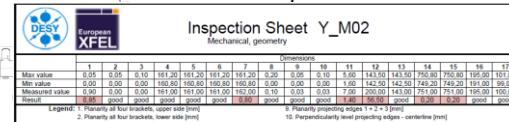
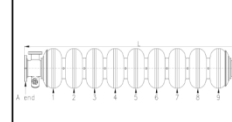
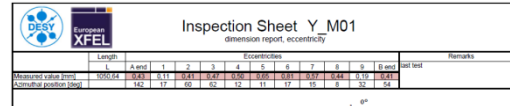
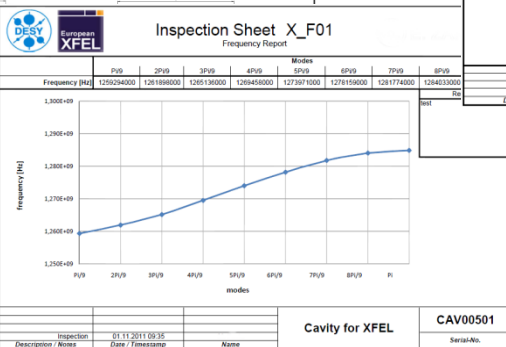
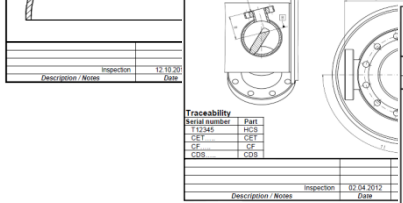
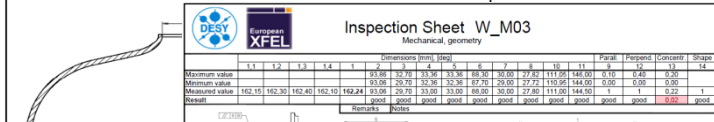
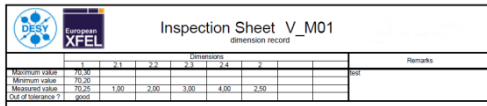
Yield of max. and usable gradient based on
26 cav. for first pass of treatment; 22 cav. for 1.+2. pass of treatment

Preliminary data; results are not published

Quality Assurance of Cavity Fabrication and Surface Treatment

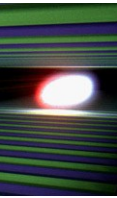


- QA done at companies
- Transfer of key documents related to
 - a) PED => traceability of components and material
 - b) RF properties (dimensions, eccentricity, frequencies)
 - c) surface treatment
 to **DESY EDM System** and **“Cavity Data Base”**



Cold Mass and Vacuum Vessel

First out of 58 Delivery from IHEP Beijing



Hamburg Harbour

- 12 units already delivered to DESY
- some smaller non-conformities require corrections
- some first modules suffered from transport within China; re-work required
- delivery at an average rate of 2/month
- date for last delivery uncritical



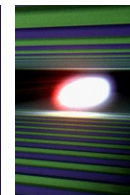
Unpacking at DESY



QC at DESY hall 3

Cold Mass and Vacuum Vessel

First out of 45 Delivery from Zanon



Arrival at CEA shipping hall

- 16 already delivered to DESY or CEA-Saclay; one used for the first pre-series module
- only minor non-conformities
- average rate of 2/month achieved
- overall schedule uncritical.

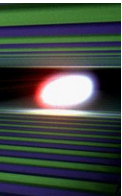


Unpacking CEA shipping hall

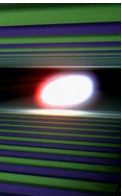


CEA assembly hall

Many Cryostats and Cold Masses Available

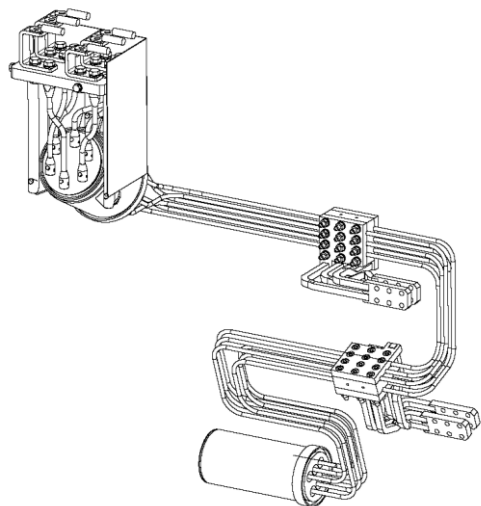
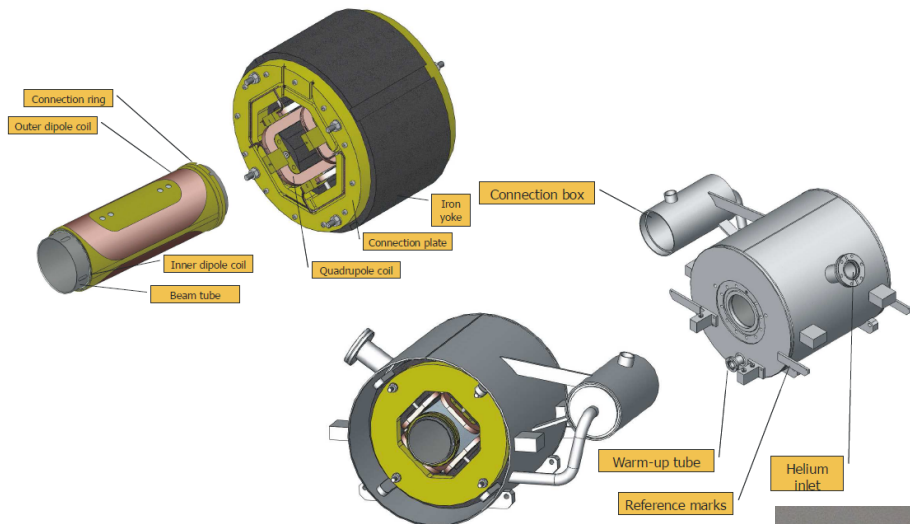
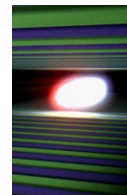


15:46 17/APR/2013



15:35 17/APR/2013

Cold Magnets and Current Leads

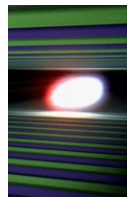


- 25 magnets (CIEMAT IKC) measured at DESY (IFJ-PAN IKC)
- current leads (DESY IKC) for first modules available

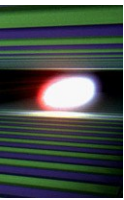


- assembly of quad packages stopped after 8 units due to buffer overflow

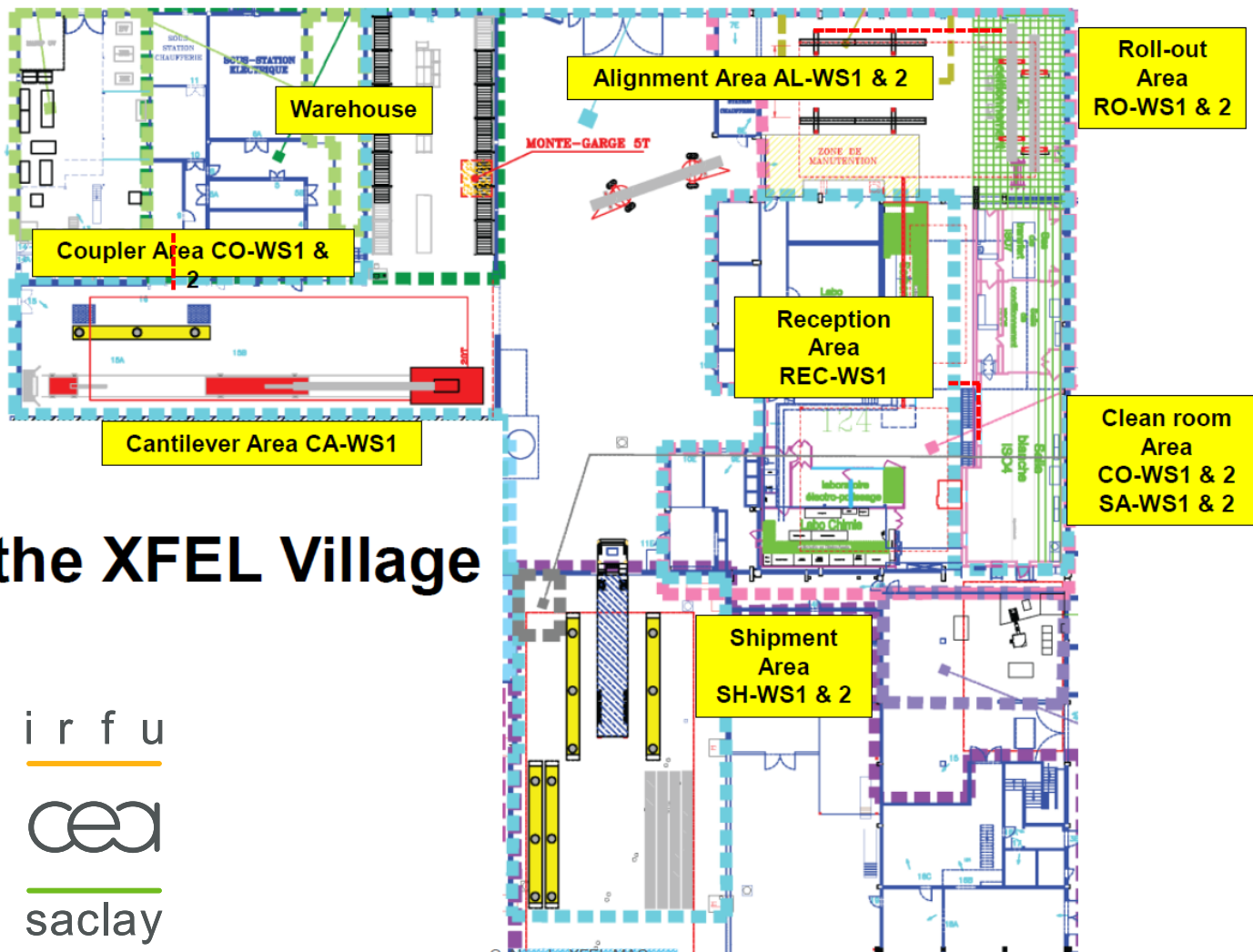
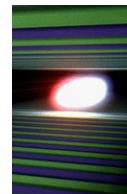
Cold Coupler Assembly



ISO4 Clean Room Assembly of a Cavity String



The XFEL Village at IRFU / CEA Saclay



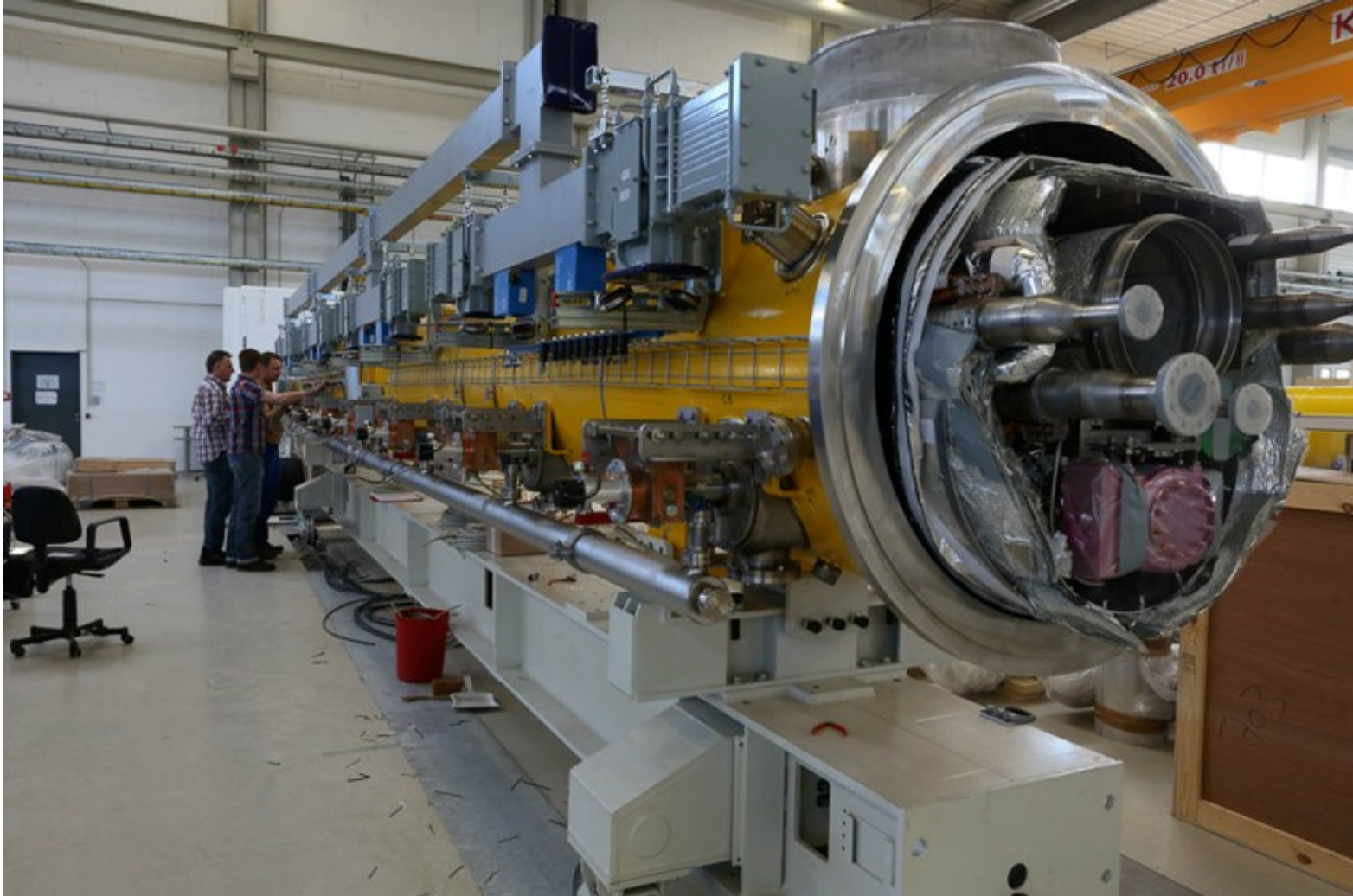
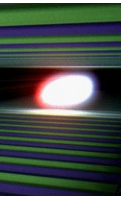
the XFEL Village

irfu

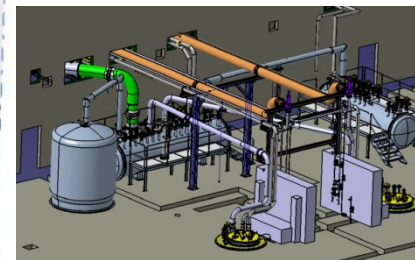
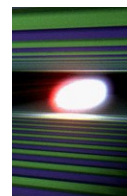
cea

saclay

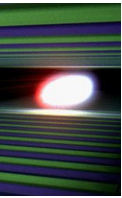
Each Module Gets a Tailored Waveguide System



AMTF Test Stand Infrastructure



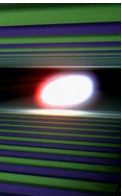
Risks and Challenges



- do we get the RF power couplers in time?
- timely production of beam dumps unclear
- part of the production of cryogenic components



- Sophisticated interplay between work packages requires careful steering in order to minimize cost impact



Firefox

Construction Picture Gallery | DESY, XFEL; Baustelle Schenefeld | AMTFellog e-Logbook | European XFEL

<https://www.xfel.eu> CRISP FP7 logo

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European XFEL ENLIGHTENING SCIENCE

[Overview](#) [Research](#) [Organization](#) [Construction project](#) [News, events, ...](#) [Information for ...](#)

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ENLIGHTENING SCIENCE
The European XFEL is a research facility currently under construction in the Hamburg area, Germany. From 2015 on, it will generate extremely intense X-ray flashes to be used by researchers from all over the world.

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Constructive destruction

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First technical design reports for

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CORPES 13 International Workshop

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Deadline: 30 Jun 2013
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Deadline: 14 Jun 2013
Laser Engineer or Physicist (f/m)

WEBCAMS

STRONG PARTNERS

The European XFEL and DESY collaborate on the construction, commissioning and operation of the facility. [More](#)