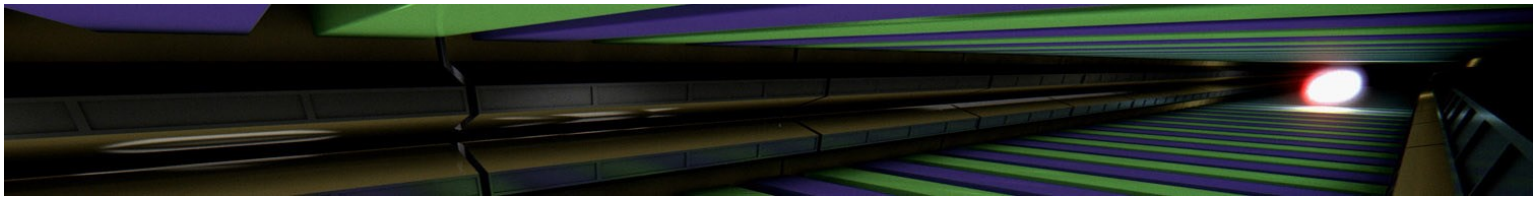


European XFEL
Status of the Accelerator

Presented at the
2015 European XFEL Users' Meeting
January 28, 2015

Hans Weise, for the Accelerator Consortium

Courtesy: with many pictures from D. Noelle / DESY & others

European XFEL

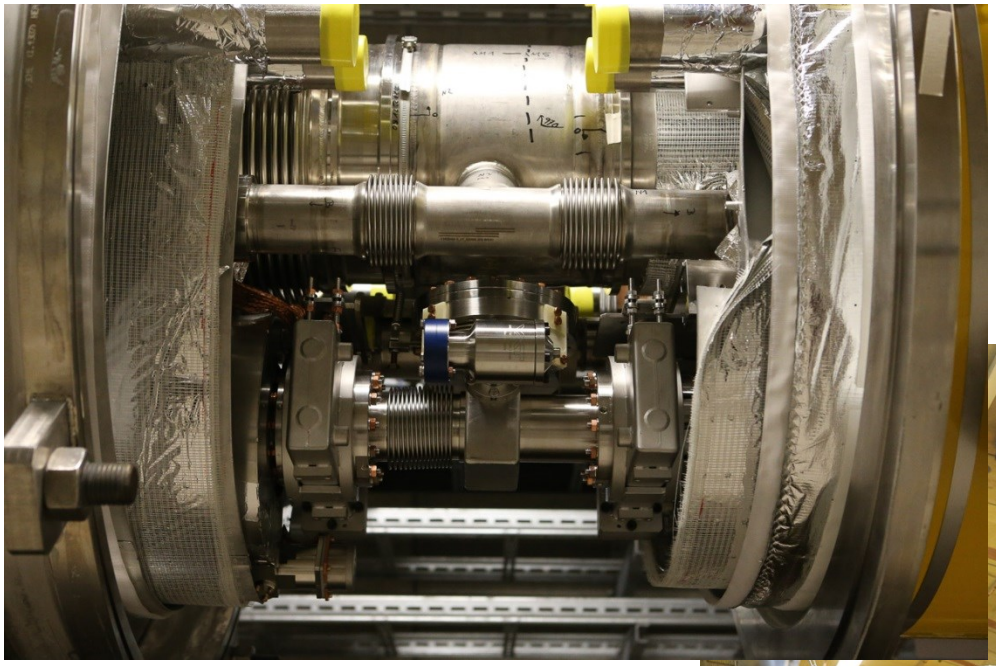
First Linac Section (L1)

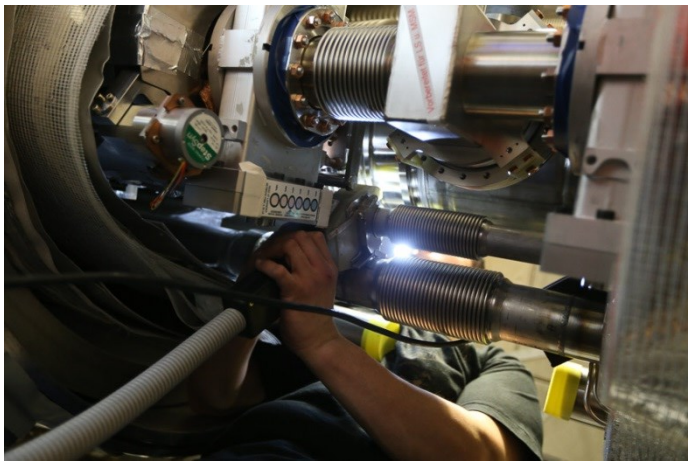
European XFEL

L1 Accelerator Modules in the XTL

European XFEL

Module to Module Connection

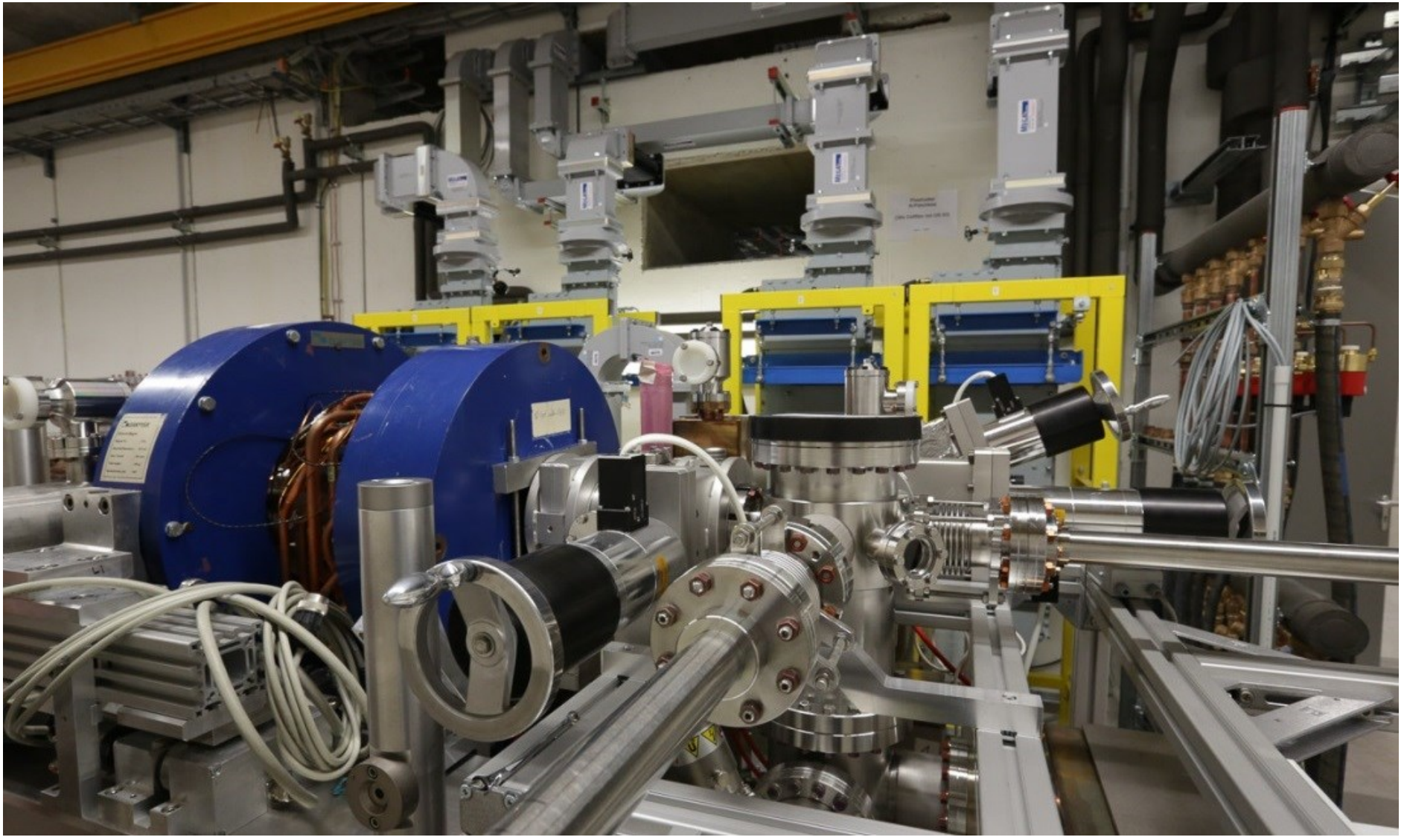




DESY HELMHOLTZ ASSOCIATION

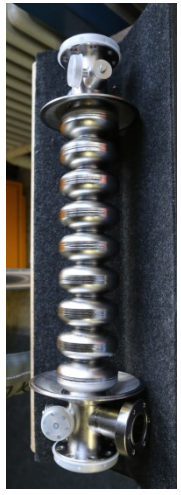
European XFEL

XFEL RF Gun Commissioning



European XFEL

XFEL Injector Installation and Commissioning

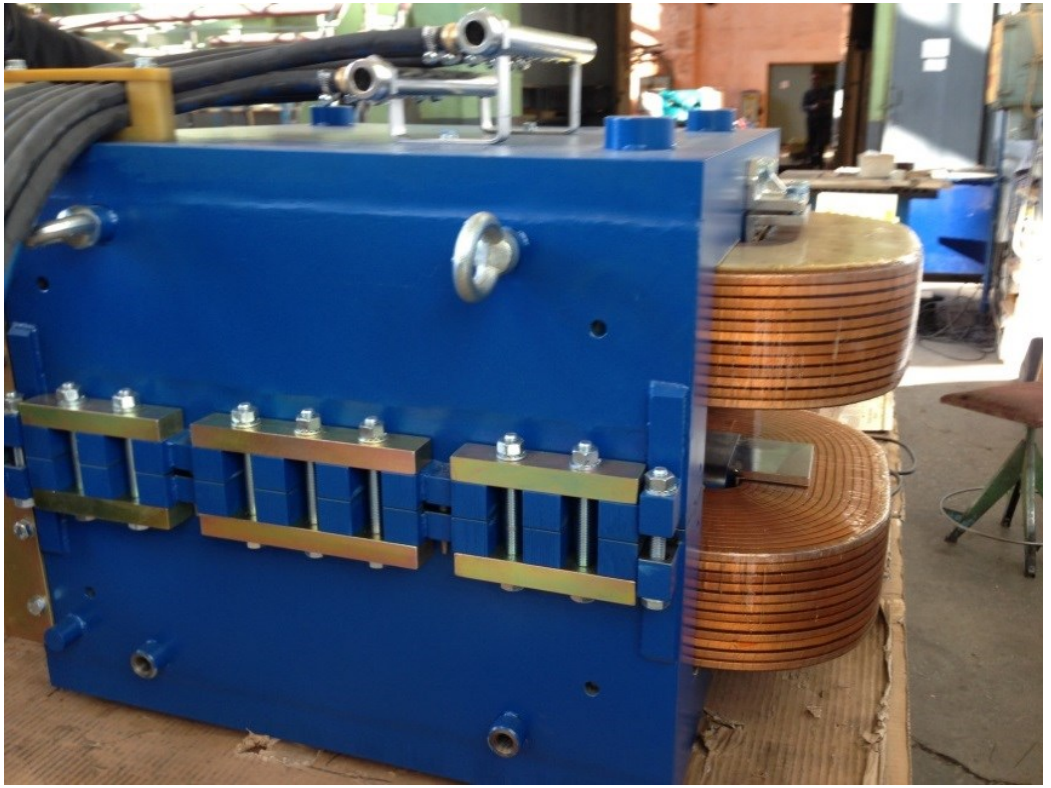


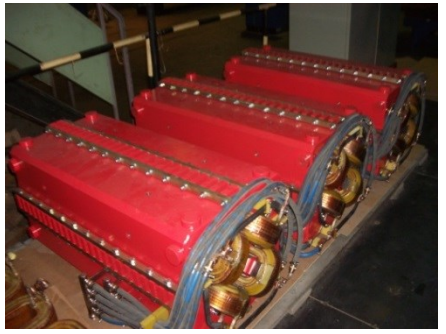
European XFEL

Beamline Girder Assembly at DESY

European XFEL

Some of the almost 800 Delivered Magnets





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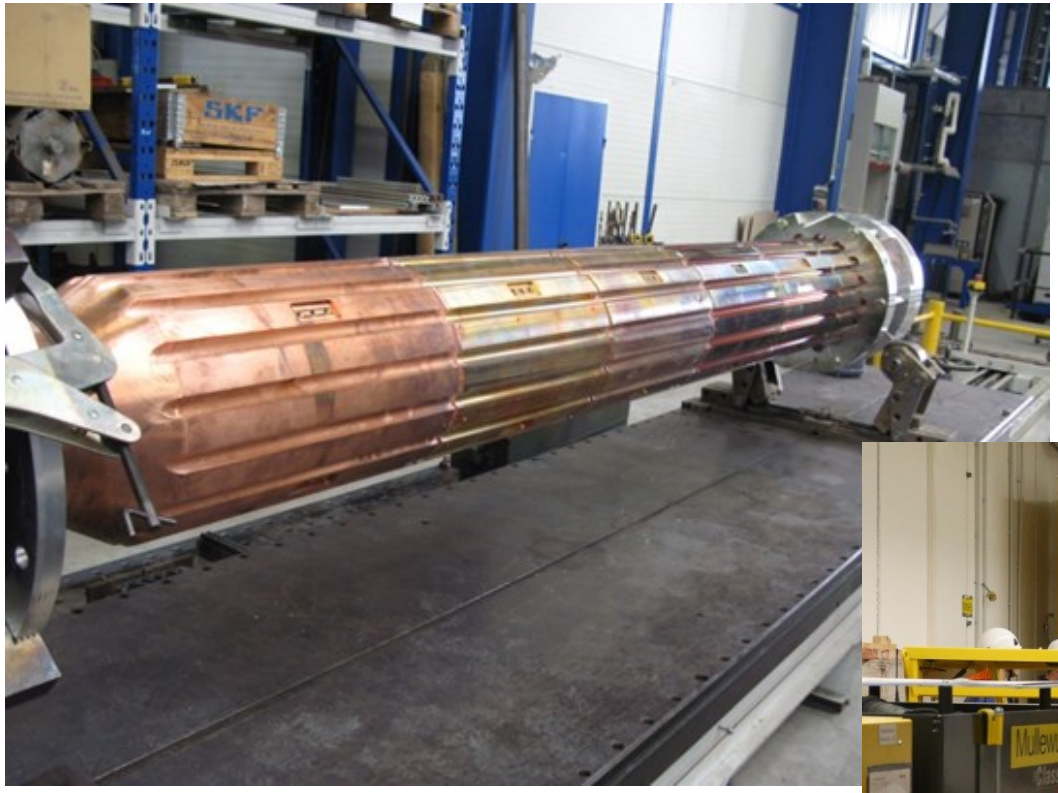
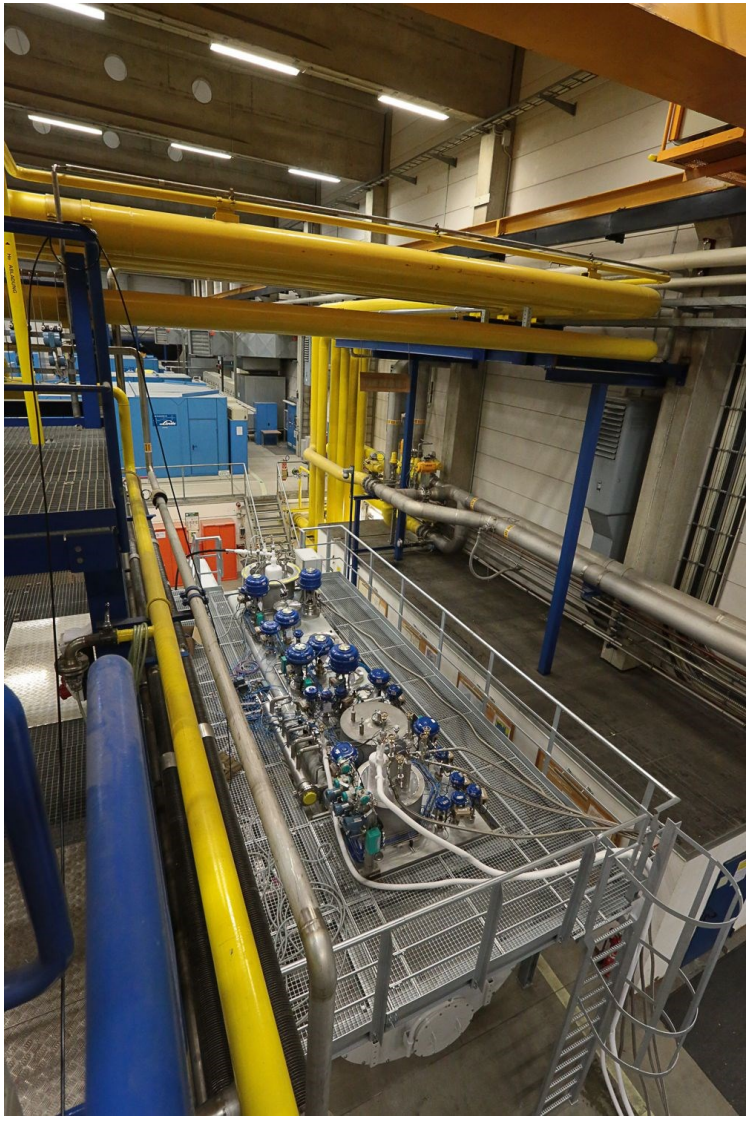
Dump Fabrication and Installation



European XFEL

Cryogenics – Cold Box and Transfer Lines



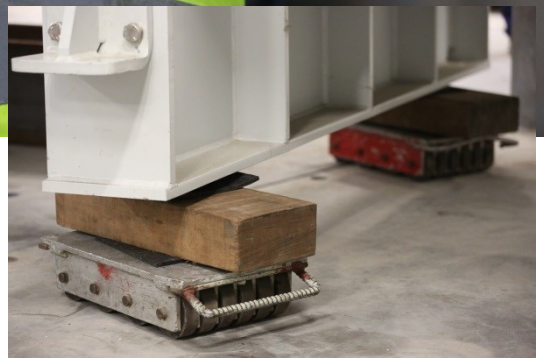
European XFEL

Cold Box in XSE Shaft Building

DESY HELMHOLTZ ASSOCIATION

European XFEL

The Right People and the Right Tools



European XFEL

Cold Box CB44 in Front of DESY Cryo Hall

DESY

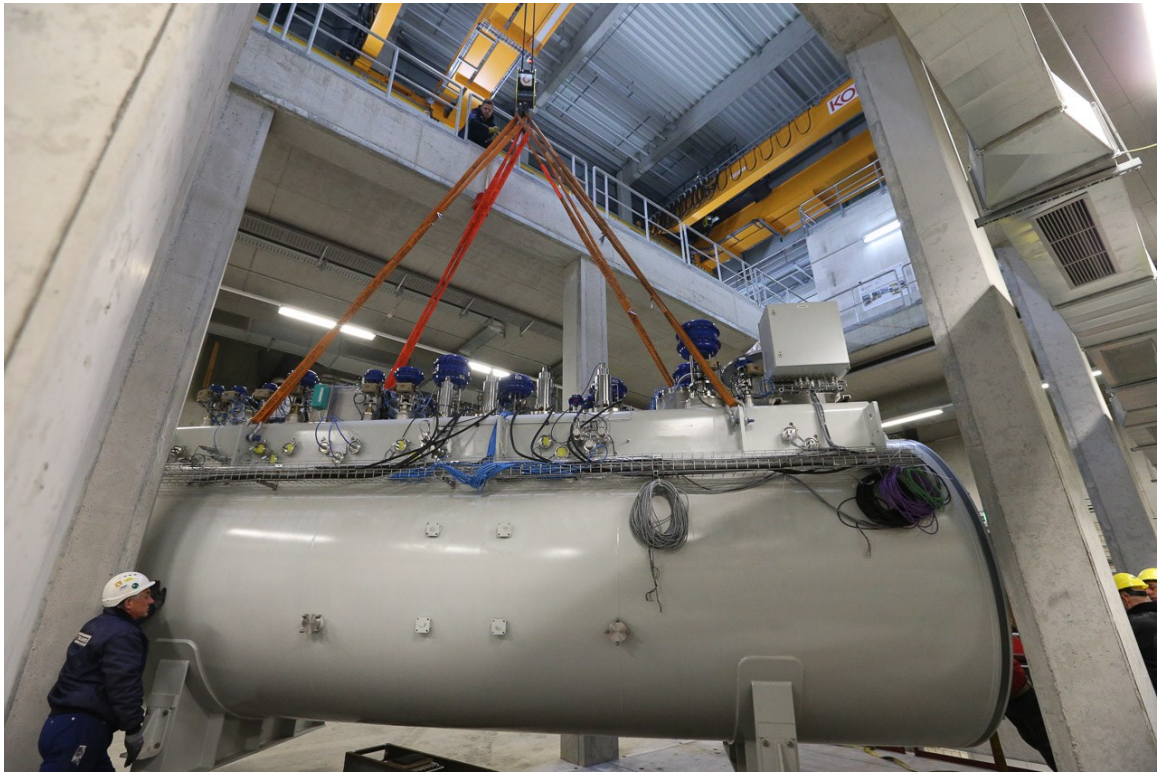
HELMHOLTZ ASSOCIATION

European XFEL

Cold Box 44 on its Way to the XSE Shaft

European XFEL

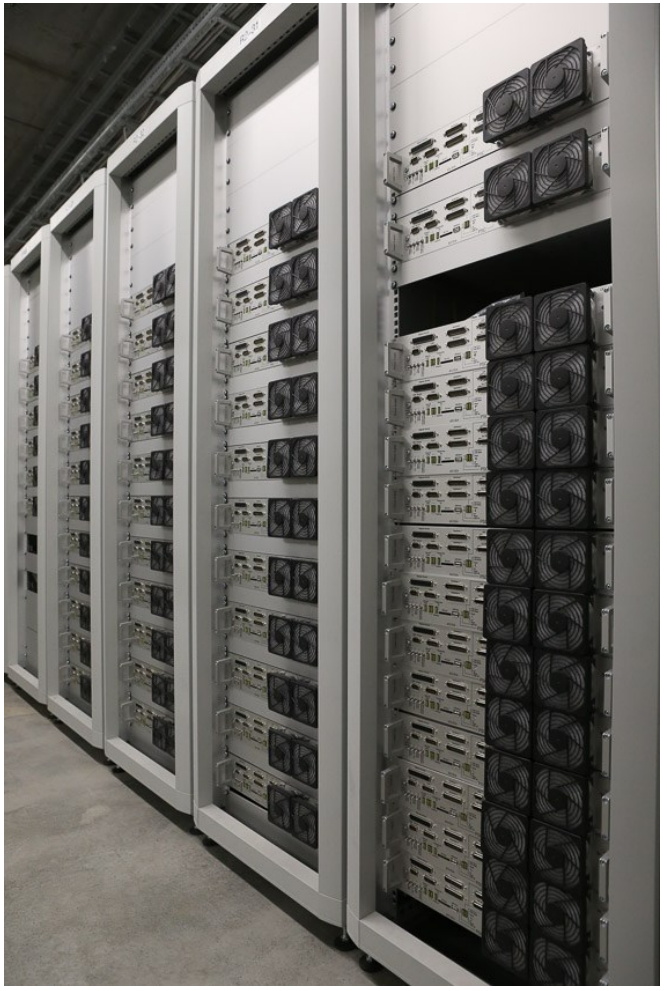
Oooooops …



DESY HELMHOLTZ ASSOCIATION

XFEL Tunnel Tours Usually Go to UG7 / XTL

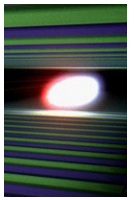
UG2
Magnet Power Supplies



UG3
Multi Beam Klystron in the Injector Building

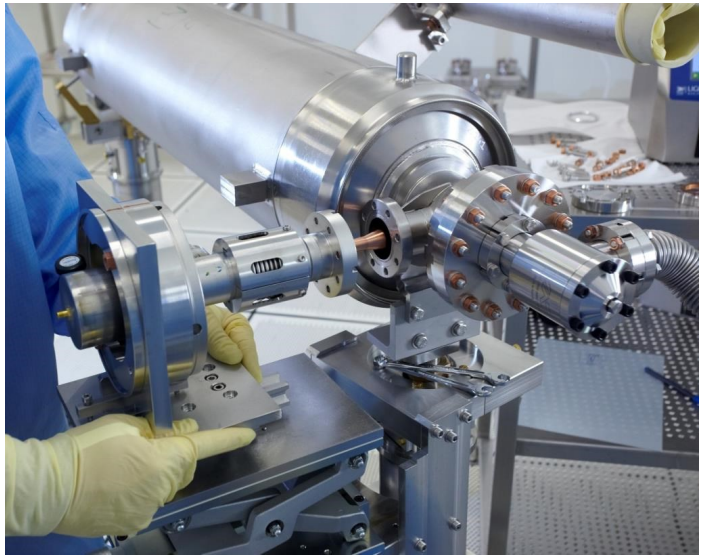
UG5
Setting-up of XFEL Injector Laser

Reference to last Users' Meeting
Production of Accelerator Components in Full Swing



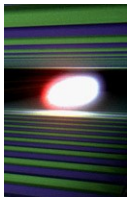
- many challenging tasks were solved
- today mostly (but not only) logistics challenges
  - **Guaranteed delivery dates**
    - Can we keep the *delivery rate* constant?
    - How to cope with *varying delivery rates*?
    - How to deal with *slight deviations from the specification*?
  - Quick but **reliable quality control(QC)**
    - QC requires *sufficiently high test rates*. Do we achieve it at AMTF? How about other test stands? In general: is the incoming inspection sufficiently well established?
  - Storage place; a daily asked question…
  - **Component integration** is the on-going challenge
    - Accelerator module assembly started
    - Integration of electronics in combined racks to be done
    - Integration of warm beam line sections

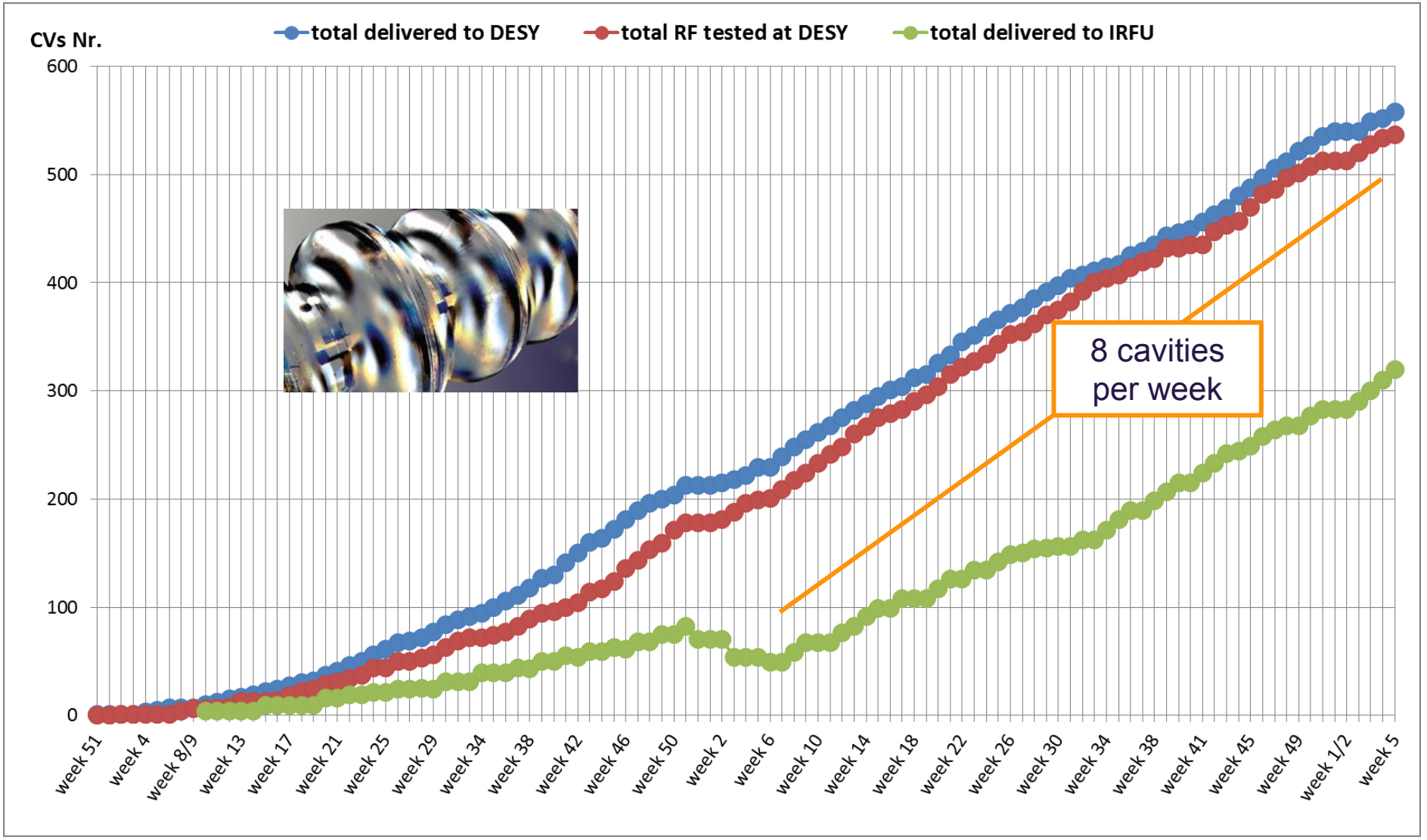
Cold Linac
Module Assembly is Based on Sub-Components



- string and module assembly relies on sufficiently filled buffers for all parts
  - **Cavities**
  - **Couplers**
  - **BQU (beam pos.monitor & quadrupole**
  - **Vacuum parts (bellows / gate valves)**
  - **Cryostats**
  - **Magnetic shielding**
  - **Tuner**
- transportation boxes and parts-in-circulation are an issue; good logistics is required

Cold Linac
Cavity Delivery Status as of 1/2015

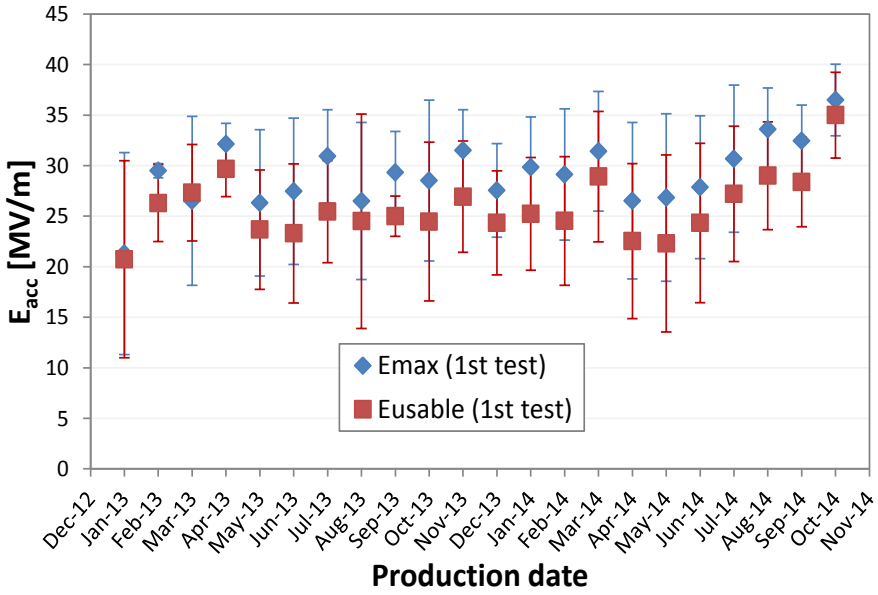


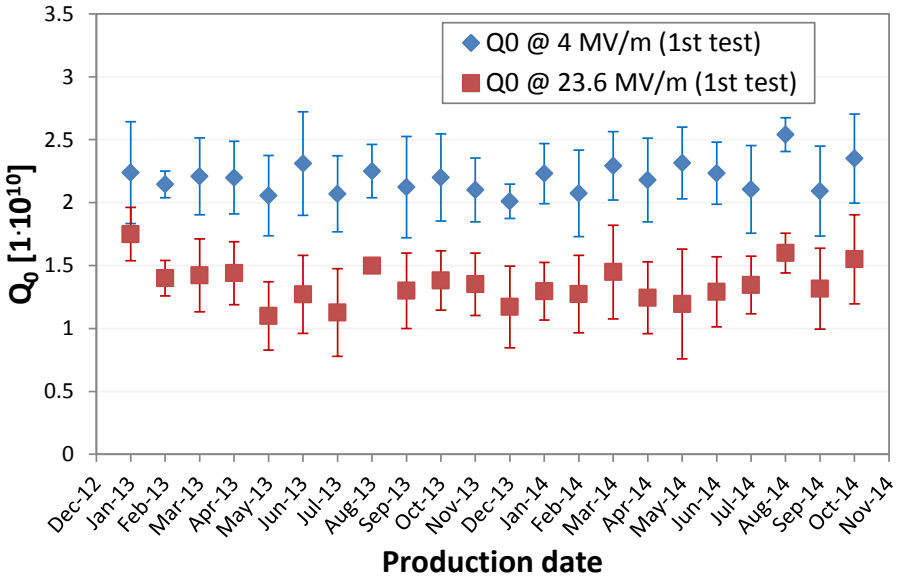


European XFEL

Vertical RF Test on as Delivered E. Zanon Cavities

Accelerating gradient E_{acc} and unloaded quality factor Q_0.
Average value per month (226 tests).



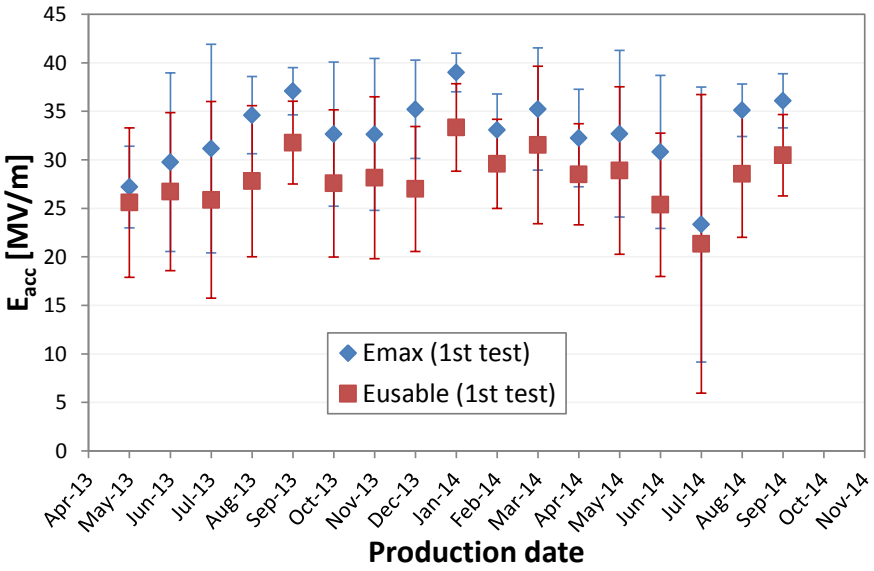


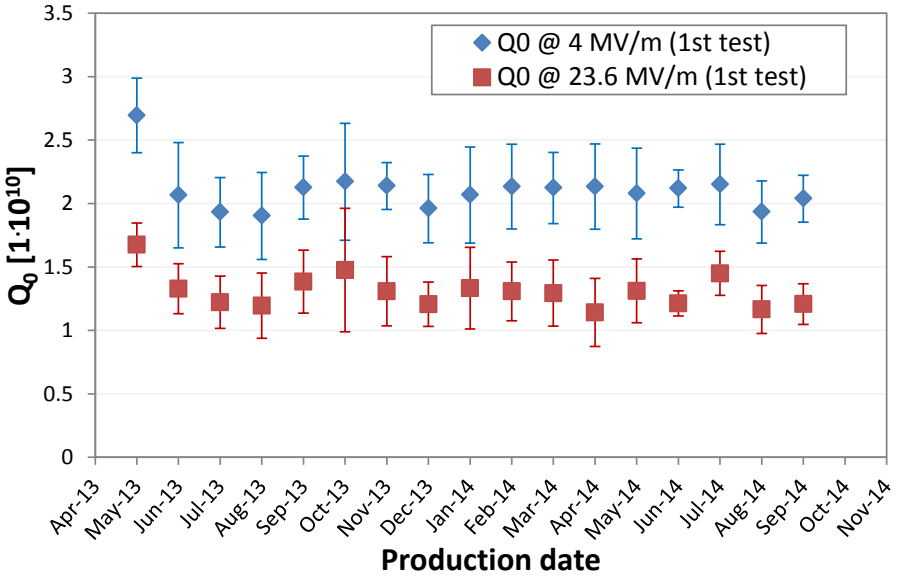
Summarized by L. Monaco
Preliminary results, not yet published

HELMHOLTZ ASSOCIATION

Vertical RF Test on as Delivered RI Cavities

Accelerating gradient E_{acc} and unloaded quality factor Q_0.
Average value per month (177 tests).





Summarized by L. Monaco
Preliminary results, not yet published

Cold Linac
Cavity Results and Cavity Summary

- **Mechanical production + surface treatment** in full + standard operation
- **Vertical cavity testing** and all work flows at AMTF are well established

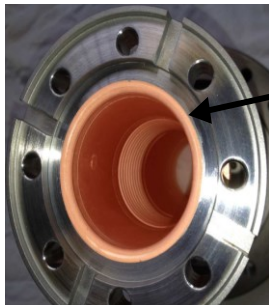
- **Gradients** in average above specification (almost 550 cavities tested)
  - Average usable gradient after delivery (26.8 ± 7.1) MV/m
  - 2/3 of cavities can be used w/o further treatment
  - 1/3 is getting additional treatm. -> usable grad. increased to (29.6 ± 5.1) MV/m
- **Re-treatment gives significant improvement**
  ~100 additional treatments / tests for initial gradients < 20MV/m give a projected **energy gain of approx. 1300 MeV**

- More than 300 Cavities (up to **XM39)** are made available for module assembly at CEA Saclay
- **Cavity production ends in autumn 2015**

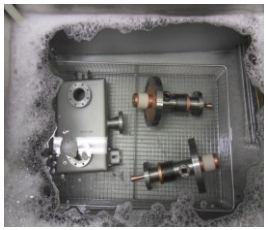
Cold Linac
Coupler Fabrication at Thales / RI

Brazing

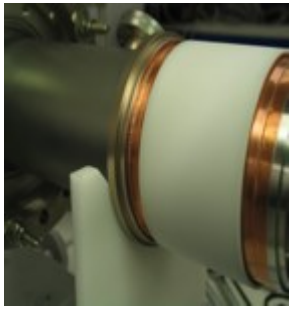
Copper plating



Inspection, then Shipment to RI



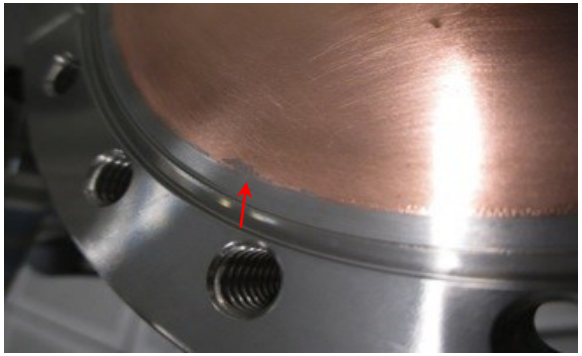
Cleaning, drying, particle counting

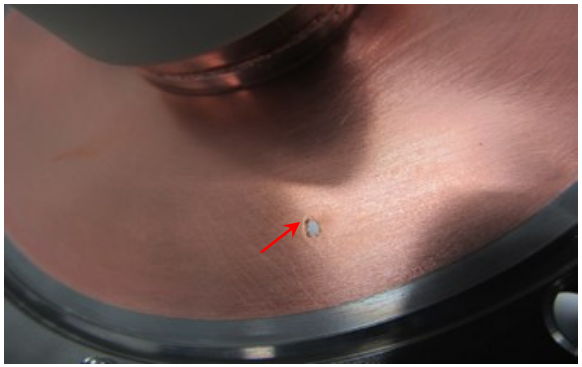


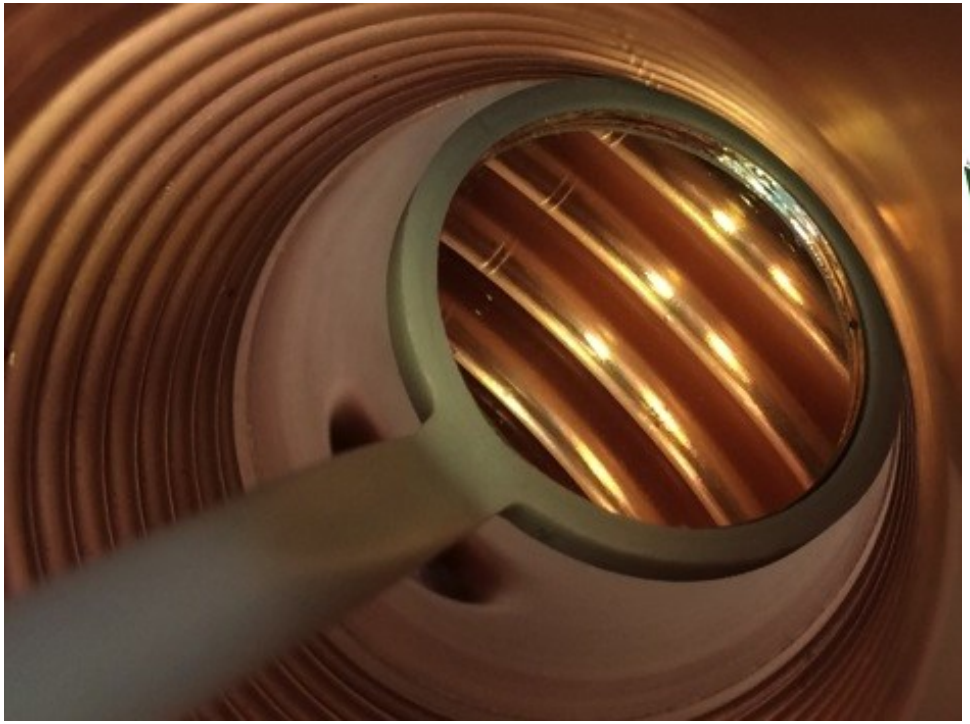
Ceramics TiN coating
Ceramics EB welding

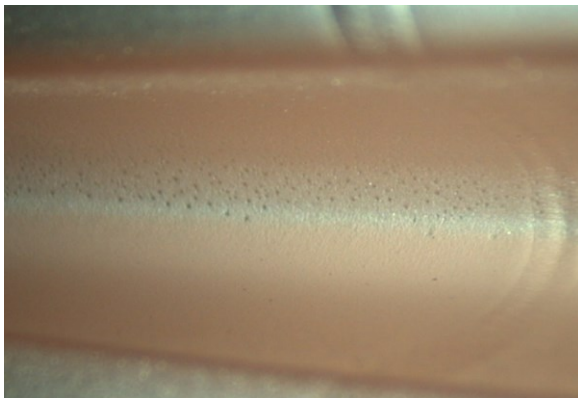
Assembly by pair

Cold Linac
Current status of coupler production



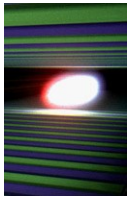


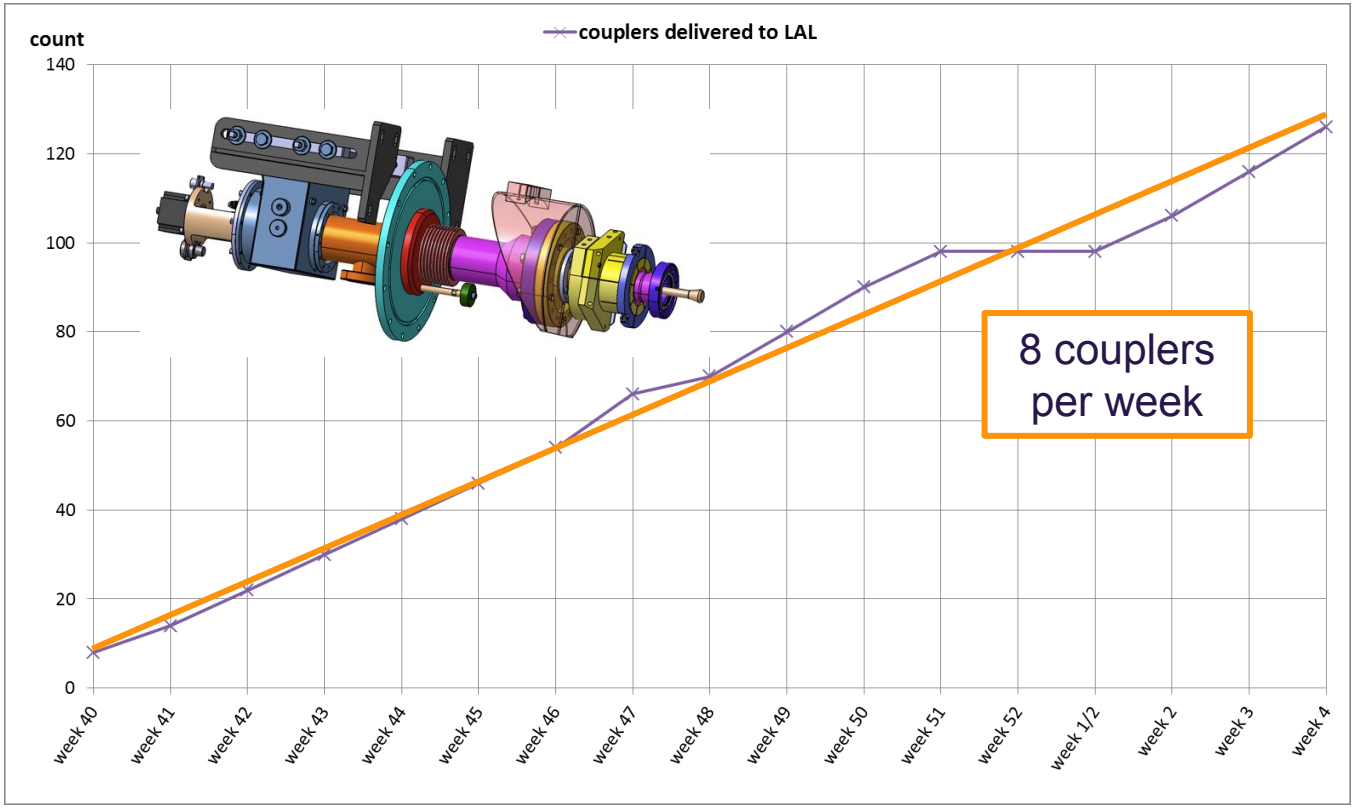




- copper plating clearly improved and common understanding on acceptance criteria exists (based on all available expertise)
- XFEL initiated a copper plating review held together with Thales, LAL, DESY, and CERN experts
- production of parts for 8 couplers per week since autumn
- strongest attempt to fulfill needs but **still no buffer!**

Cold Linac
Couplers Delivered from Vendor During Q4/2014



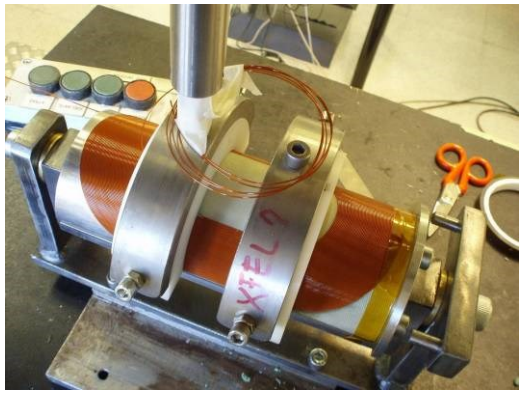


- rejection rate after RF power conditioning became small (here 3 out of 92)
- delayed ramp-up in accelerator module production asks for an **average of 10 couplers per week** to support an accelerated module assembly

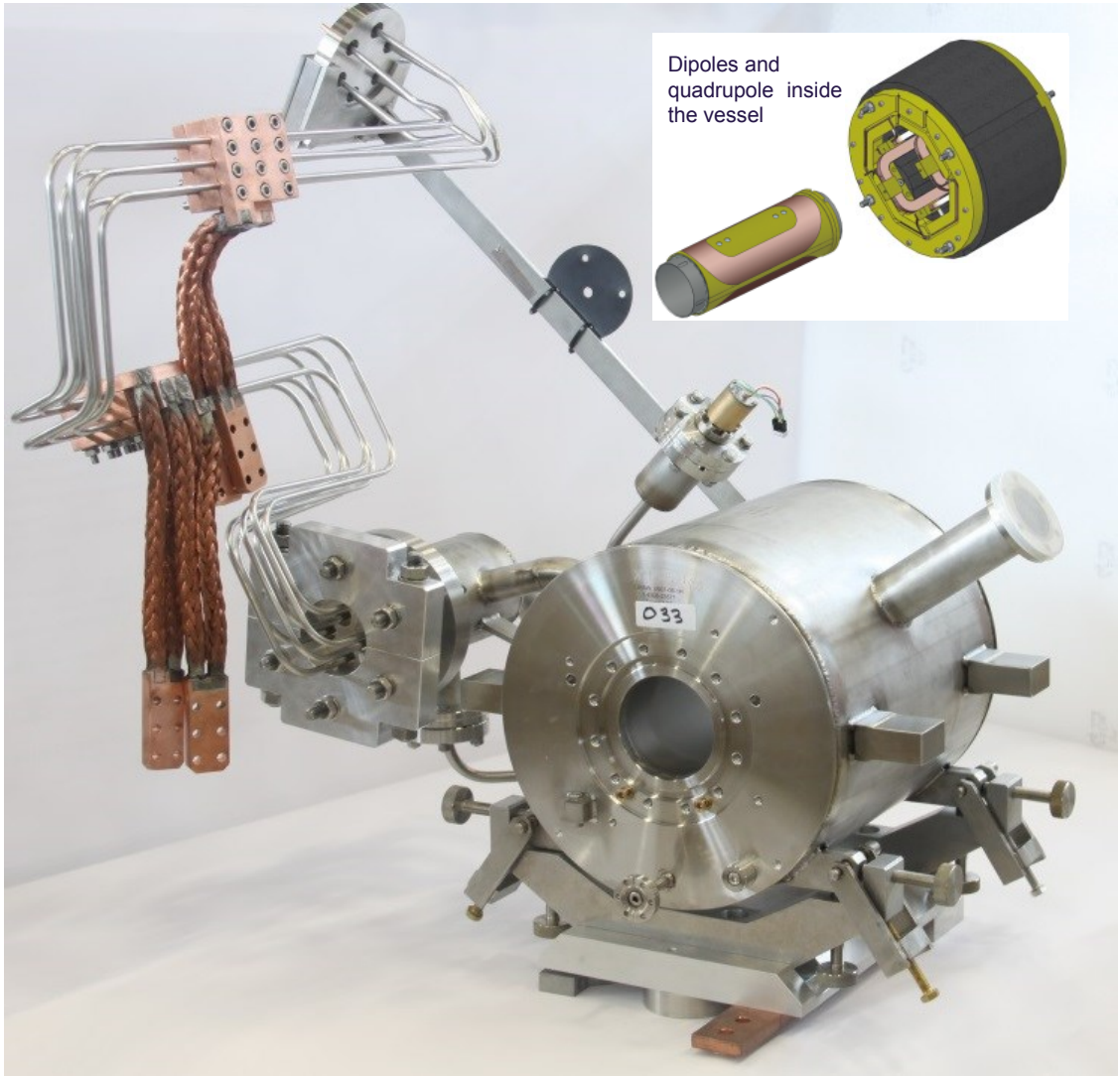
- based on XFEL Council decision XFEL contracted the production of 150 couplers at a second vendor
- DESY expertise for contract supervision / LAL expertise for RF conditioning
- first 8 pre-series couplers delivered for module assembly
- series couplers expected at rate of 4 per week starting with Q2/2015

Cold Linac
RF Conditioning at LAL Runs Smoothly at 8+ per Week

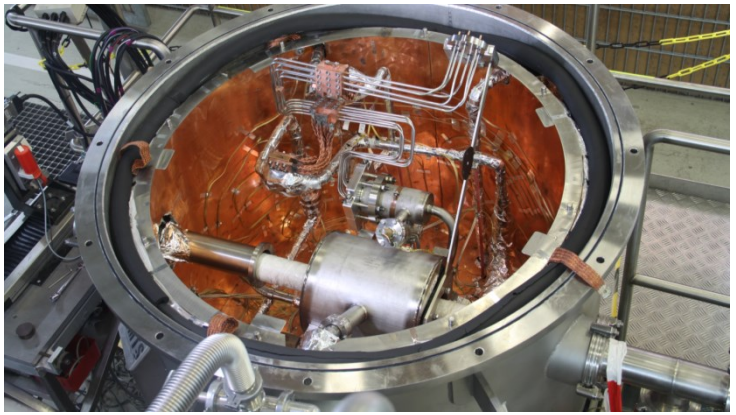
Cold Linac
Magnet Production is Finished by now



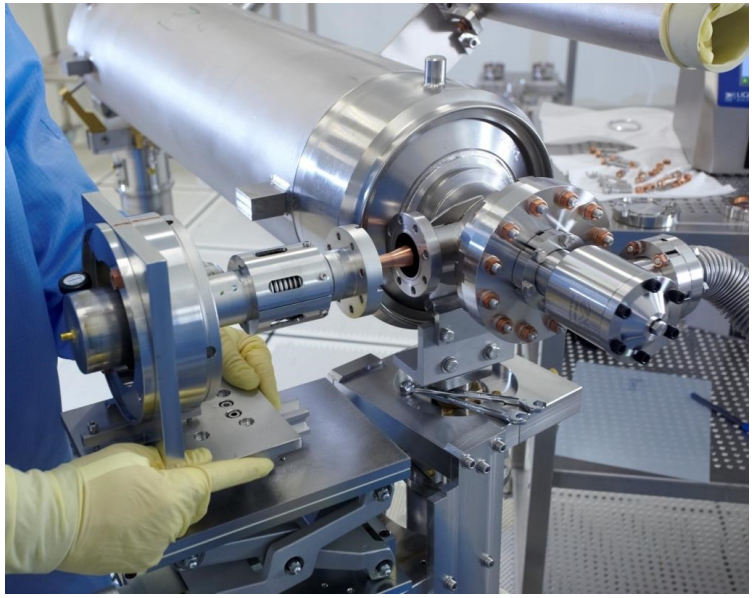
Cold Linac
Cold Magnets and Current Leads

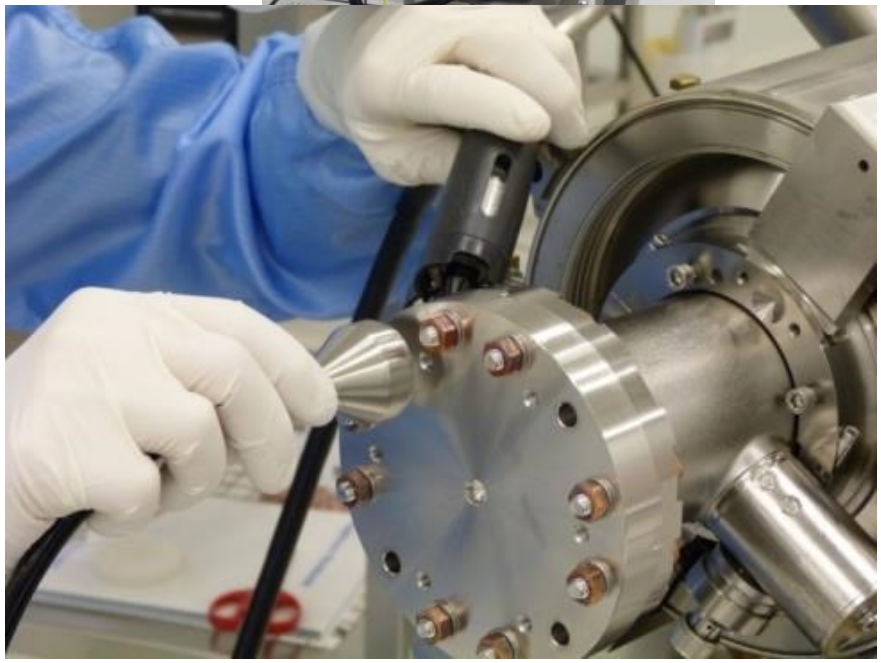


- all magnets at DESY
- >95 successfully cold tested
- approx. 75 copper plated
- approx. 40 BQUs assembled
- 35 BQUs shipped
- all current leads received / most of them tested / regular delivery to IRFU

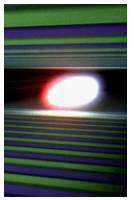


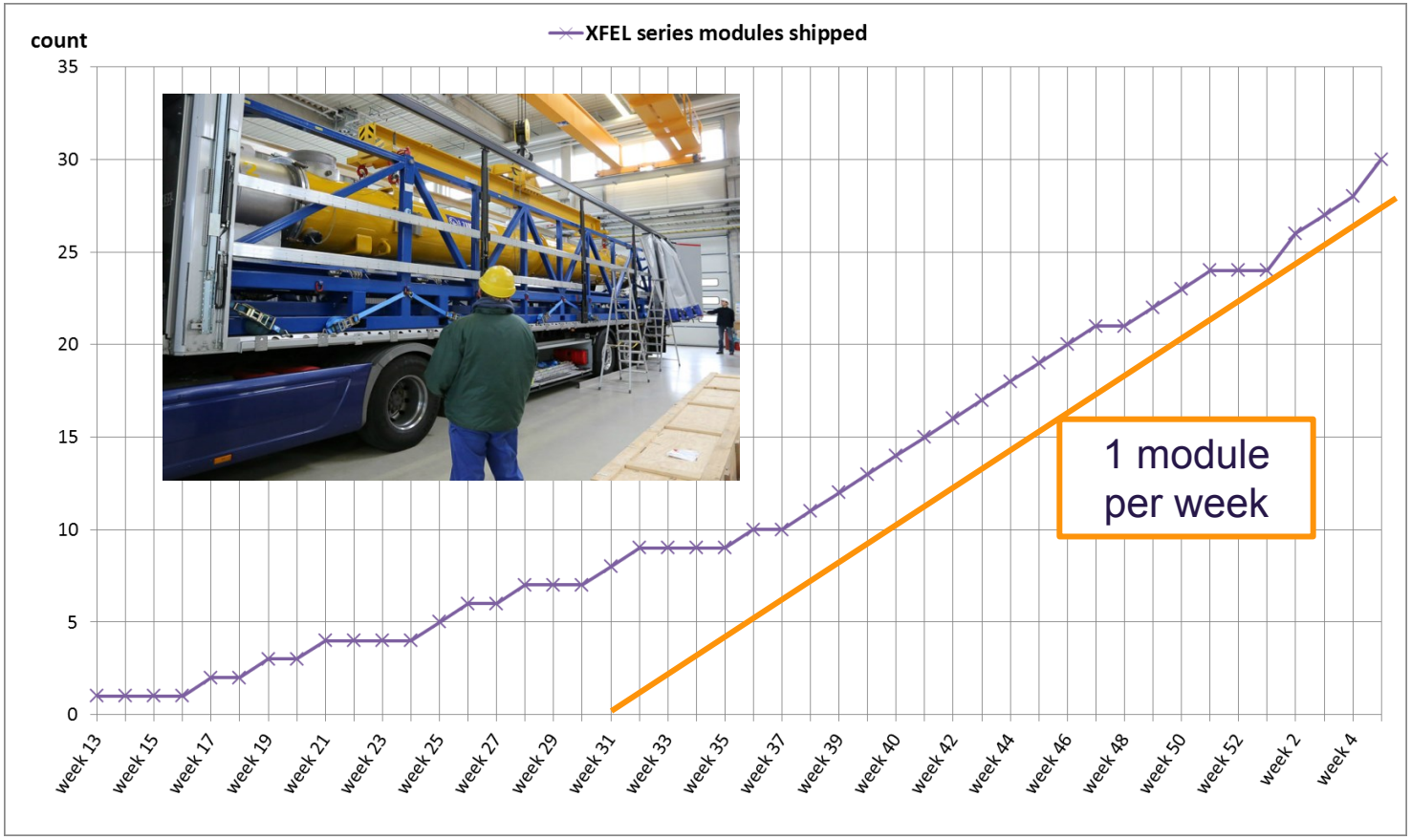
Cold Linac
Cavity String and Module Assembly at CEA / Irfu





Cold Linac
Accelerator Modules Shipped to Hamburg



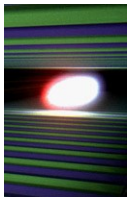


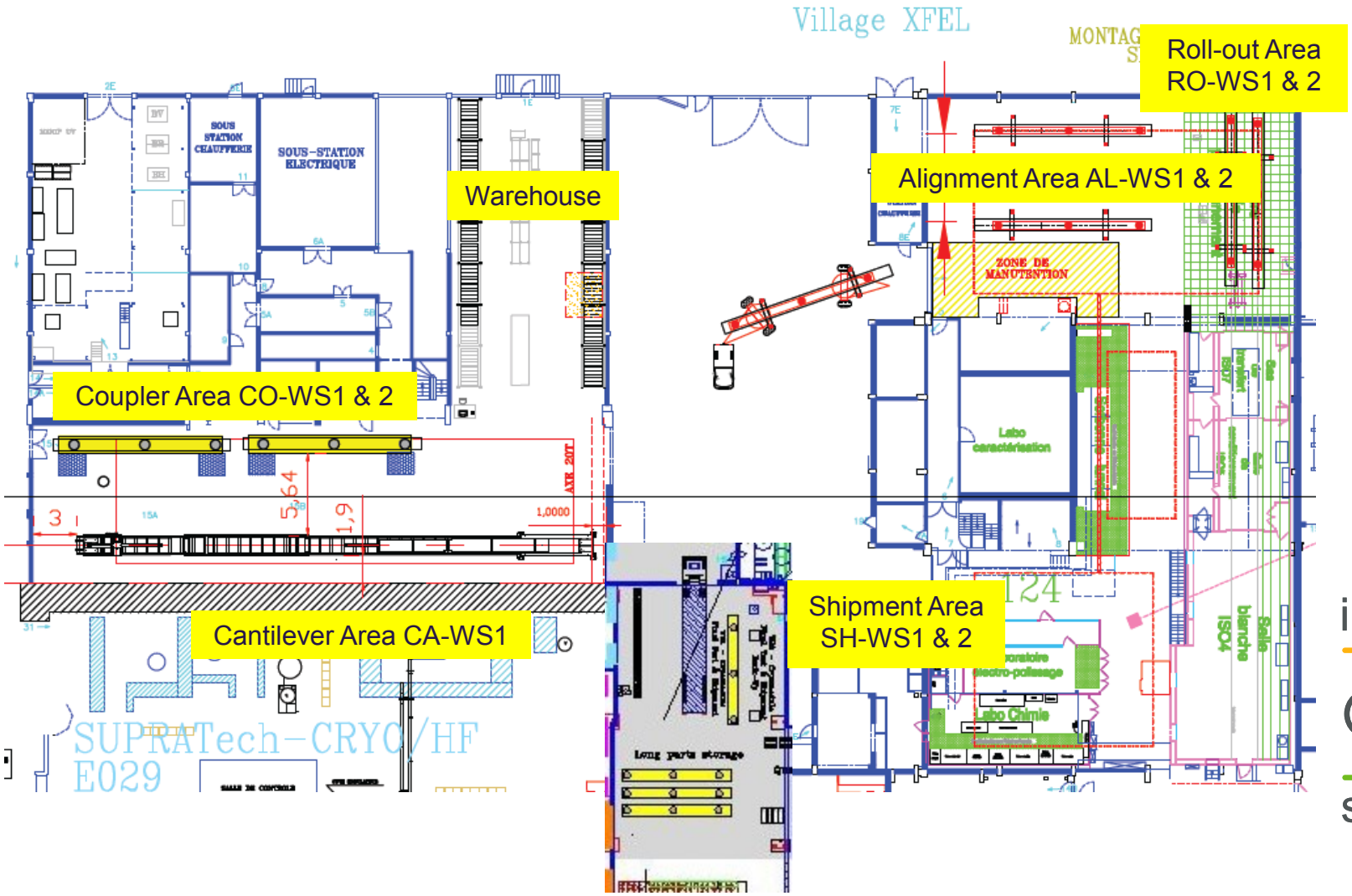
The nominal rate of 1 module per week has been reached with XM12 (24/09/2104).

Assuming 1 CM/week from now on: XM100 shipped 2nd August 2016 (w30).

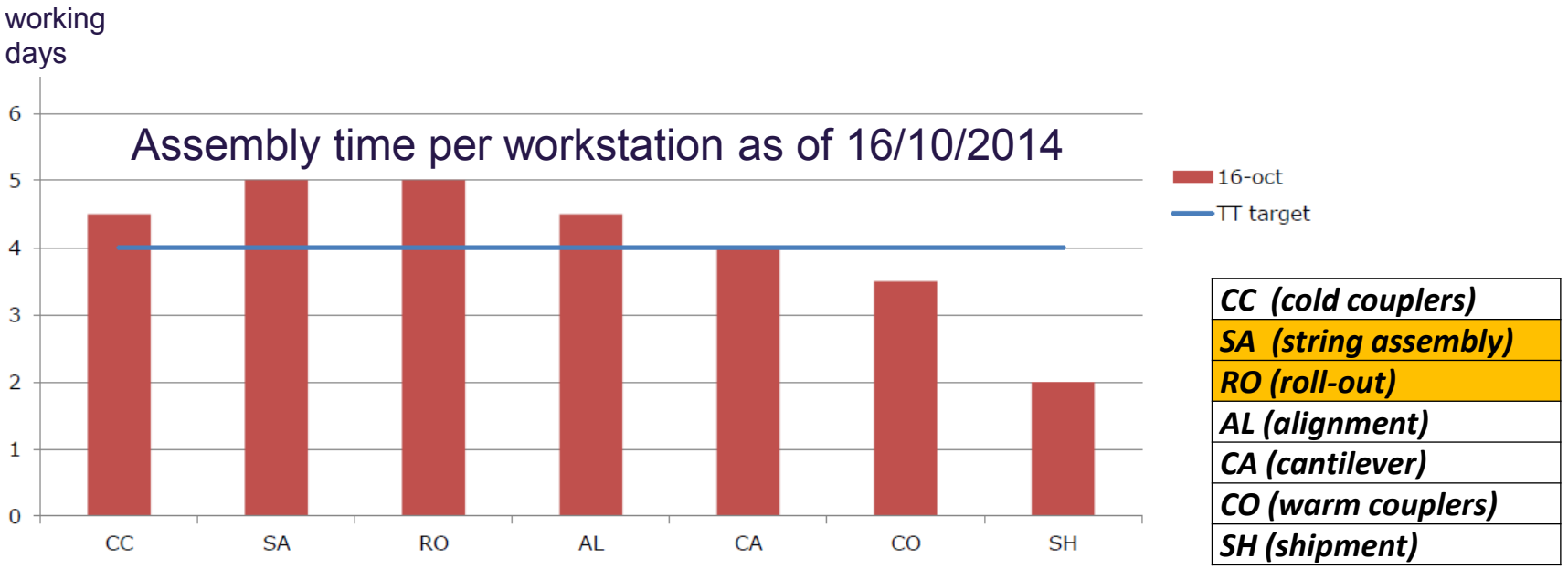
Thus **acceleration to 1.25 modules per week** was discussed and attempts were started to continue from now on with the increased rate.

Cold Linac
Module Assembly - Workstations





Cold Linac
Optimization of Accelerator Module Assembly



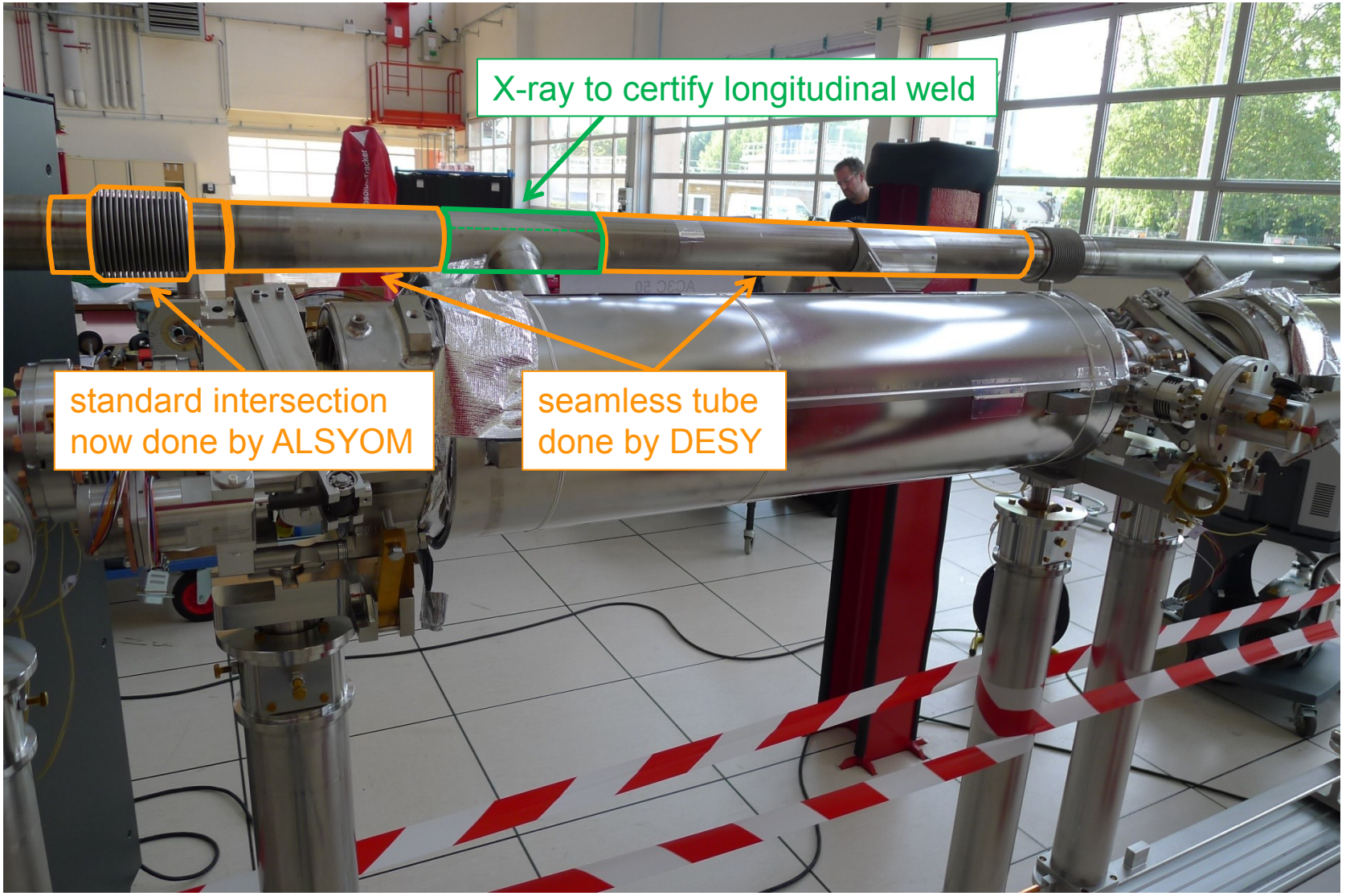
CC (cold couplers)
SA (string assembly)
RO (roll-out)
AL (alignment)
CA (cantilever)
CO (warm couplers)
SH (shipment)

Assuming 1.25 CM/week from now on (throughput of 1 Module / 4 days) brings XM100 back to early Q2/2016.

All initiatives wrt. an accelerated scheme are urgently required and thus useful.

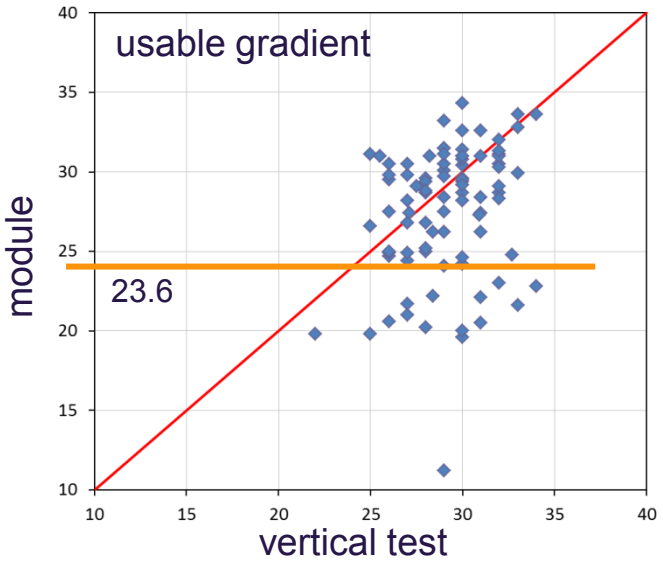
Consequence of CEA Saclay / Irfu activities to speed up the assembly: we also need to increase the module testing, wave guide system and tunnel installation rate.

Cold Linac
2-Phase Line Welding done in Routine Operation



Cold Linac
AMTF Accelerator Module Results

- all measured **modules can be operated above the XFEL design gradient** of 23.6 MV/m but an optimized / tailored RF power distribution is required
- too often we are disappointed by a **decreased gradient of single cavities**; further investigation is needed to profit from the high usable gradient meas. in the vertical test
- for some of the first modules the connection of the warm inner conductor to the respective cold part was not done properly; this **non-conformity** required changes in the assembly procedure and **repair at several modules**
- module XM8 shows a leak in the 2K area and needs further investigation



- **we lose in usable gradient between vertical and module test**
- **the average usable gradient in the module test is above design**

Cold Linac
Risks and Challenges – Module Testing

- testing accelerator modules reached quasi routine operation
- all three module test stands at AMTF in operation
- until the end of 2014 we have learned enough to optimize throughput
- the testing schedule is based on high quality modules
- **what is the path** to match the testing with an increased production rate at CEA/Irfu?

Cold Linac
RF Power – Waveguide Distribution

- ca. 85% of waveguides delivered
- approx. 10 series module distributions incl. cooling and cables are assembled, tested and connected
- modules are transported to the XTL
- WG assembly rate seems to be ok

European XFEL

Accelerator Modules at AMTF

Key Components
RF Power – Klystrons and Modulators

- 20 of 29 Multi-beam Klystrons delivered,
  14 of 22 Thales TH1802,
  6 of 7 Toshiba E3736H

- All 27 modulators manufactured and installed

Key Components
Low Level RF Control

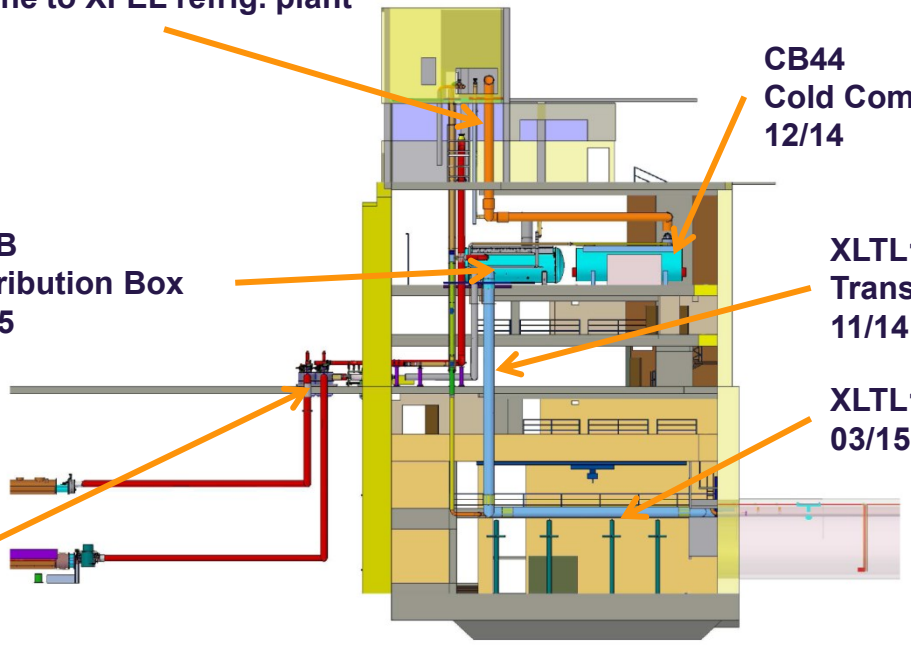
- One year of FLASH **operation with prototype** of XFEL LLRF system
  - more work to analyze impact of radiation on FPGA and memory (hard disks, RAM)
- **Master oscillator and RF distribution**
  - PRR accepted & MO installation started
- **Rack Assembly and Test Area**
  - ready for LLRF racks preparation

- **LLRF racks installed for injector**
- LLRF racks ready for L1
- LLRF components for L2, L3
  - call for tender awarded (MTCA crates, power supplies, CPUs, down converters, digitizers)

Injector Cool Down Mid 2015
Critical Path XLVB: LINAC Valve Box

- Fabrication of valve box XLVB (BINP) delayed due to late delivery of large cryogenic valves (sub contractor)
- as a consequence cryo supply of injector delayed by 2-3 months to June 2015

FAT of XIVB 10/14 at BINP



Finishing of Injector Installation
Continued RF Gun Commissioning / Accelerator Modules

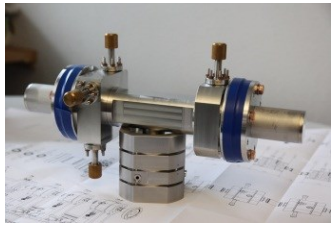
- RF Gun Commissioning with emphasis of RF window
- aim for long pulse operation even before official start of injector commissioning
- prepare for module installation

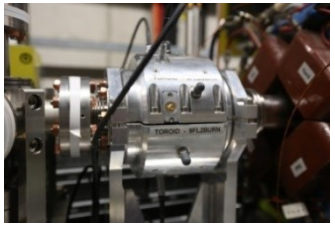
- one standard accelerator module will be made available
- the 3.9 GHz module is on the critical path but clear progress is visible
  - cavities tested and integrated
  - assembly starts soon

Cathode laser alignment and commissioning	January 21st – mid of March
Gun commissioning with beam	End of January – March 9th
Window conditioning (test stand)	Until end of January
Exchange of RF window	March (3 weeks shutdown)
Installation of electronic racks	"
Cabling work	"
Preparation for module installation	"
Vacuum conditioning of gun	End of March – mid of April
Long pulse commissioning of gun	Mid of April – mid of May
Shutdown for module installation and finalizing the injector	Mid of may – end of June

Warm Beamlines
Beam Diagnostics

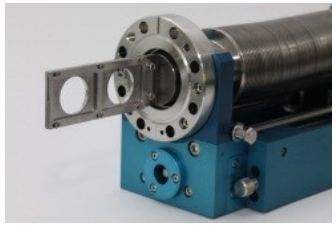

cold BPM

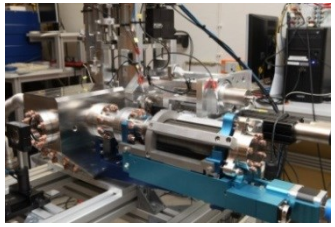

warm BPM

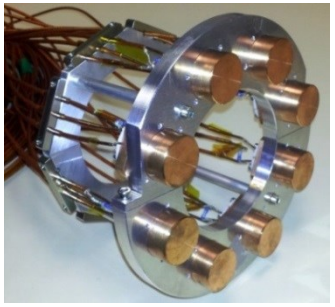

toroid


dark current


beam loss


screens


wire scanners


beam halo


dosimetry

- work on the **large variety of beam diagnostics** is progressing very well
- sufficient number of components in house to work on girder integration
- problems with vacuum chambers for screens are addressed
  - used steel was too soft and windows were corroding

Warm Beamlines
Vacuum System

- 95% of commercial products (pumps, valves, …) in house
- **Injector:** >90% installed
- **BC1&BC2:**

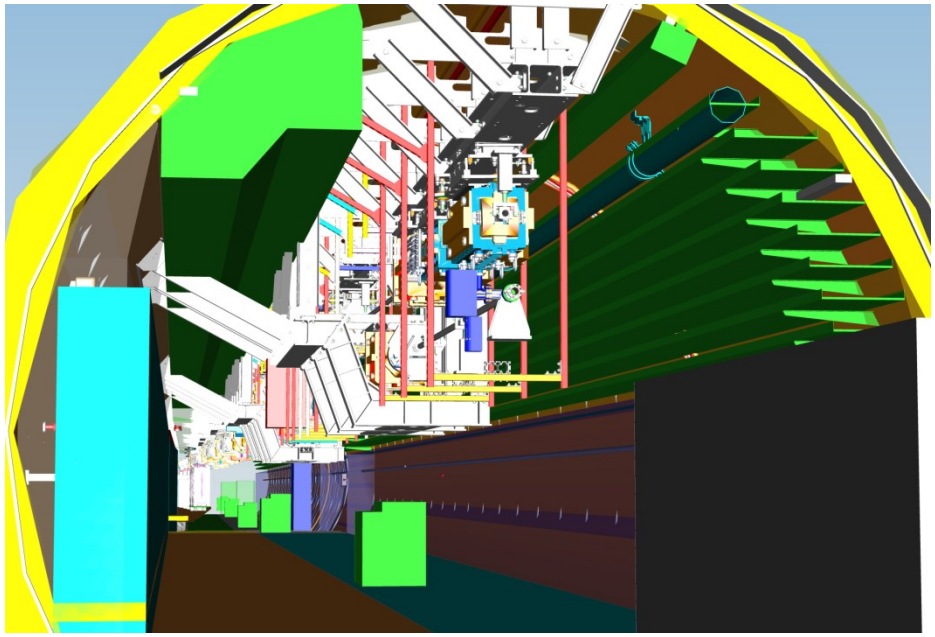
  Girder installation started, tunnel installation asap; delivery of chicane vacuum system (BINP) needed Q1/2015
- **XTL:**

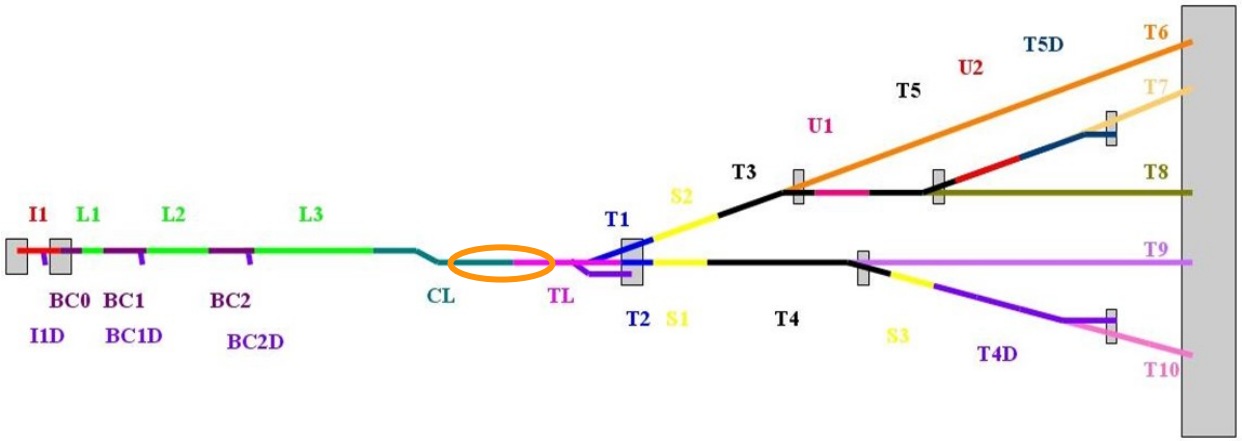
  Installation starts Q3/2015; 'hanging' solution engineering ongoing; fabrication start (BINP, DESY) needed in Q1/2015
- **Undulator:**

  Installation start Q1/2015; 50% of undulator chamber rfi; delivery of vacuum chamber supports and intersection vacuum needed (BINP) now
- **Beam distribution system:**

  Beamline reviews ongoing; component delivery start Q1/2015 (BINP) needed

Warm Beamlines
Suspended Sections at End of XTL





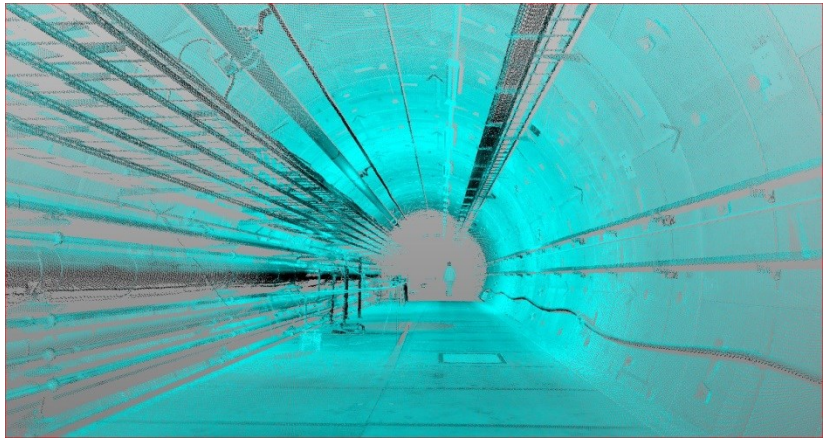
- Installation of steel structures and frames starts in Q1/2015
- vacuum systems follow with the goal to finish all warm beamlines until end of 2015

Warm Beamlines
Work on XTD2 Section

- In the Undulator section XTD2 **all vacuum columns** installed, grouting done
- **Floor mounts** for SASE section and photon beamline completed; the mounts for (electron) transport line follow now after final beamline review
- **Undulator racks** are mounted

- Straight line reference system pending
- After completion and closing of final walls a general cleaning is scheduled for Mid March 2015
- **Undulators are waiting; roll-in should follow asap**
- XTD4 follows with a shift of a few months

Survey and Alignment
Intake Control / Fiducialization / Alignment



- **Survey Work** carried out:
  - reference grid survey in all tunnels and all shafts done
  - 3D laser scan of all tunnels and all shafts done
  - XTL has been scanned in a second run

- **Alignments:**
  - Main dump area XS1, but also XSDU1 and XSDU2
  - Linac L1: 4 modules installed and aligned
  - Injector: RF gun / 5 Girders / feed- and end cap of modules / dump installed and aligned
- **Fiducialization** of components
  - warm magnets: 80% done
  - Beam Position Monitors: partly done (BPMD & BPME)
- **Intake Control** measurements
  - Cold masses measured for Chinese Cryomodules (26 out of 58)
  - Control survey of reference points after transport done for all delivered modules (16)

European XFEL

Risks and Challenges

- the accelerator module assembly reached the **end of the ramp-up phase**
- there is quite some **experience with the three module test stands** at AMTF; nevertheless, the through-put is still to be demonstrated; optimization?
- an accelerated module assembly seems to be achievable but requires more discussions
- one question remains: **do we get the RF power couplers in time?**
- with the end of the ramp-up we can put main **emphasis on installation** procedures
- linac L1 in XTL is currently be used for further optimization
- if necessary, resources needed for installation are to be adopted

Outlook

- there is still **hard work ahead**
- the industrialization of cold linac technology is mostly done
- stable series production with further optimized throughput is required
- the project still needs great effort

- **we have a realistic chance to close the tunnel around mid 2016**
- **we must avoid any additional delay**

Thank you to all XFEL Contributors