

HOW TO PRODUCE 100 SUPERCONDUCTING MODULES FOR THE EUROPEAN XFEL IN COLLABORATION AND WITH INDUSTRY

Hans Weise, for the Accelerator Consortium



Courtesy: with many pictures from

D. Noelle / DESY & others

incl. E. Zanon & Research Instruments

The European XFEL

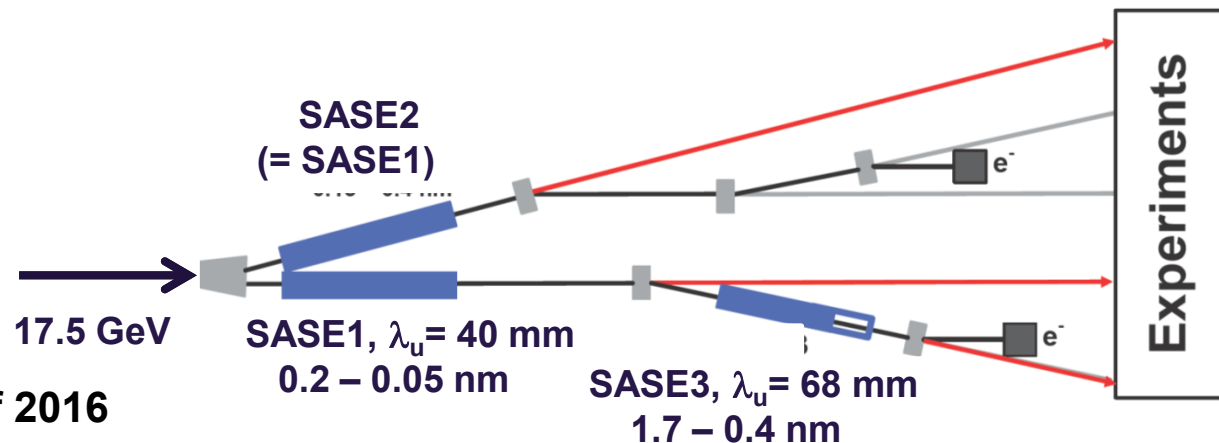
Built by Research Institutes from 12 European Nations

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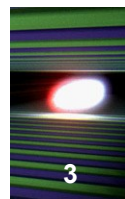
Some specifications

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

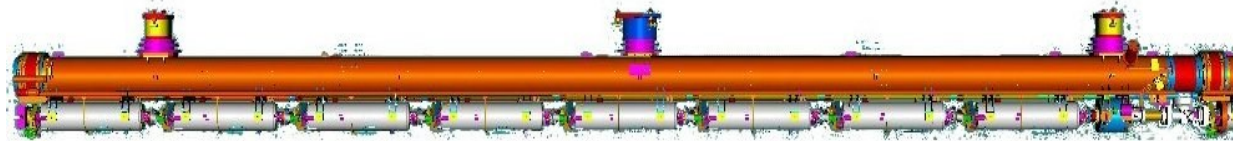
First electron beam 2nd half of 2016



An Accelerator Complex for 17.5 GeV



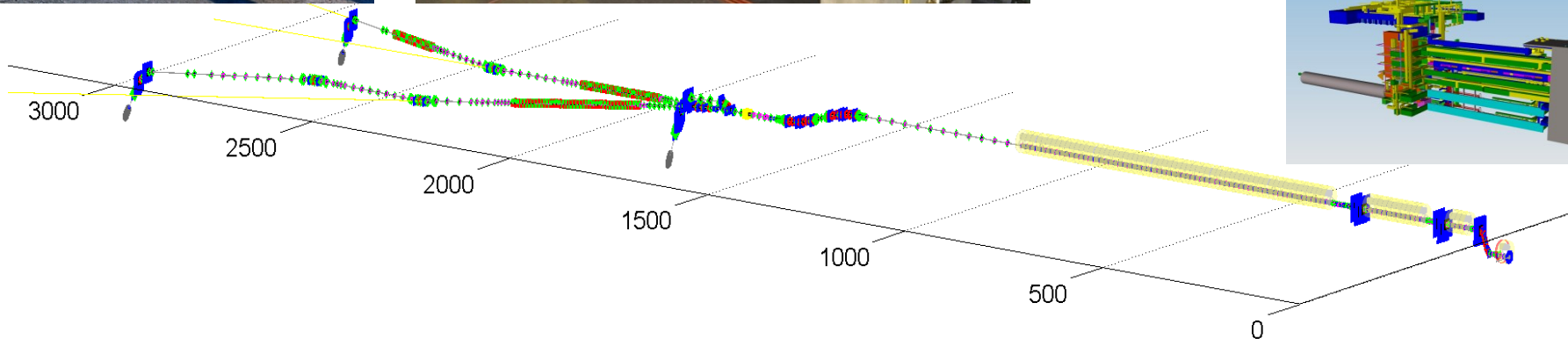
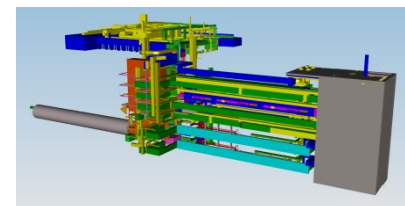
100 accelerator modules



800 accelerating cavities
1.3 GHz / 23.6 MV/m



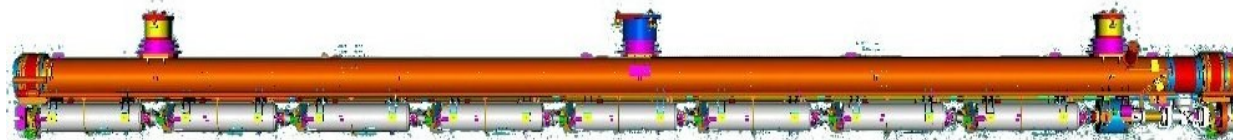
25 RF stations
5.2 MW each



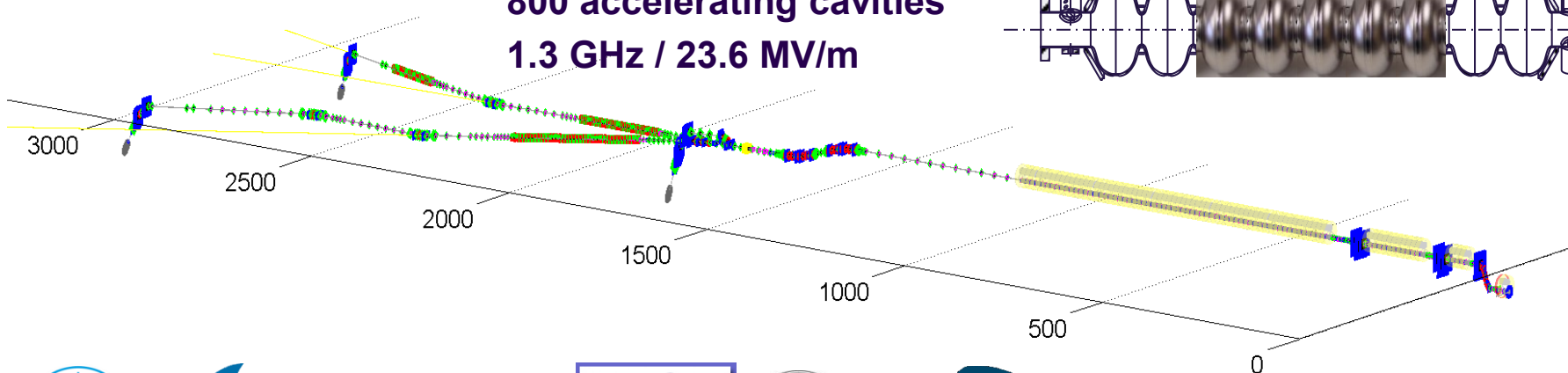
Contributors to the XFEL Accelerator

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100 accelerator modules



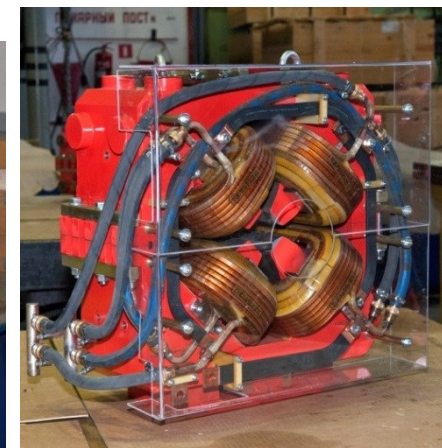
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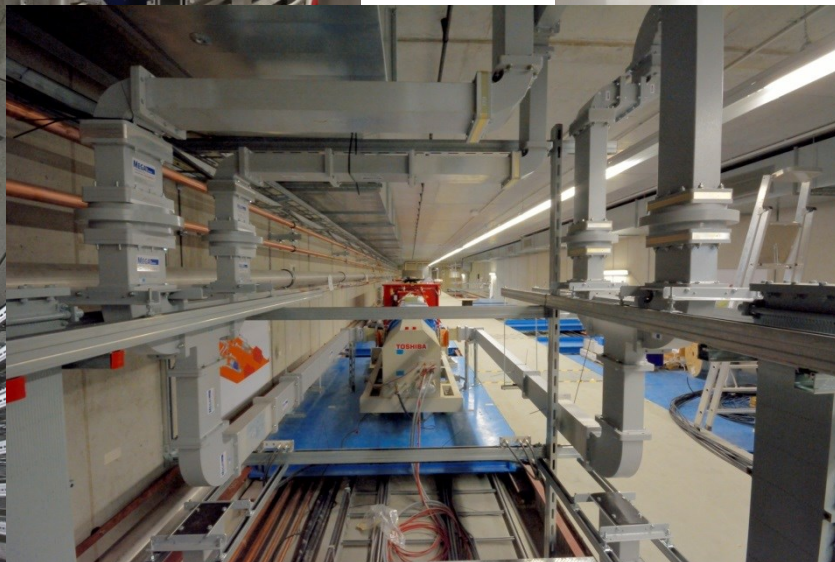
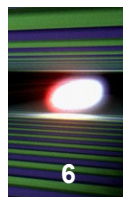


Wrocław University of Technology

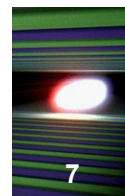


Production of Accelerator Components

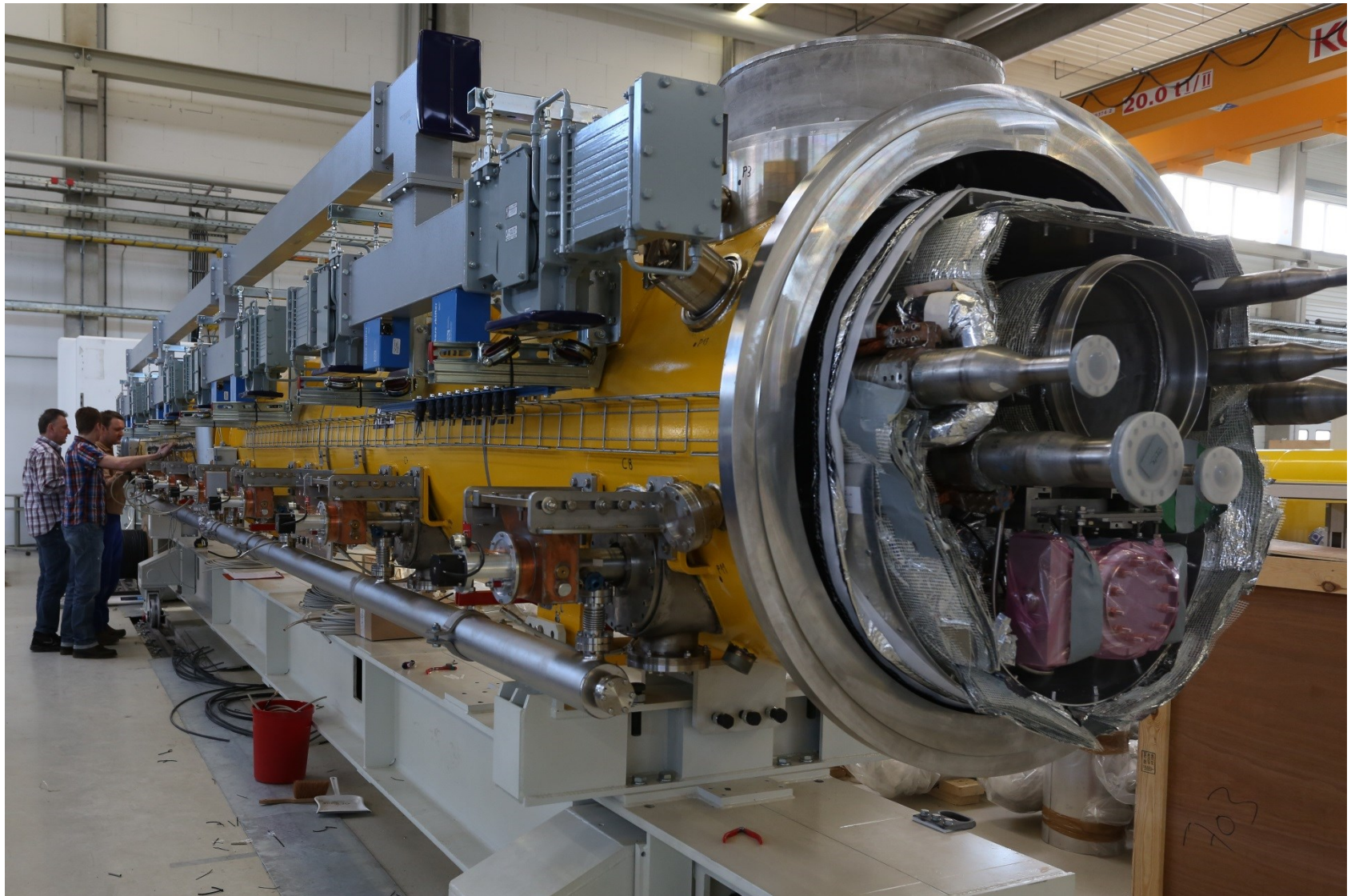




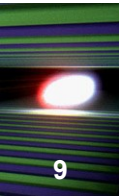
Installation Test



XFEL Accelerator Module with Tailored Waveguide System



Contributions to the European XFEL Modules



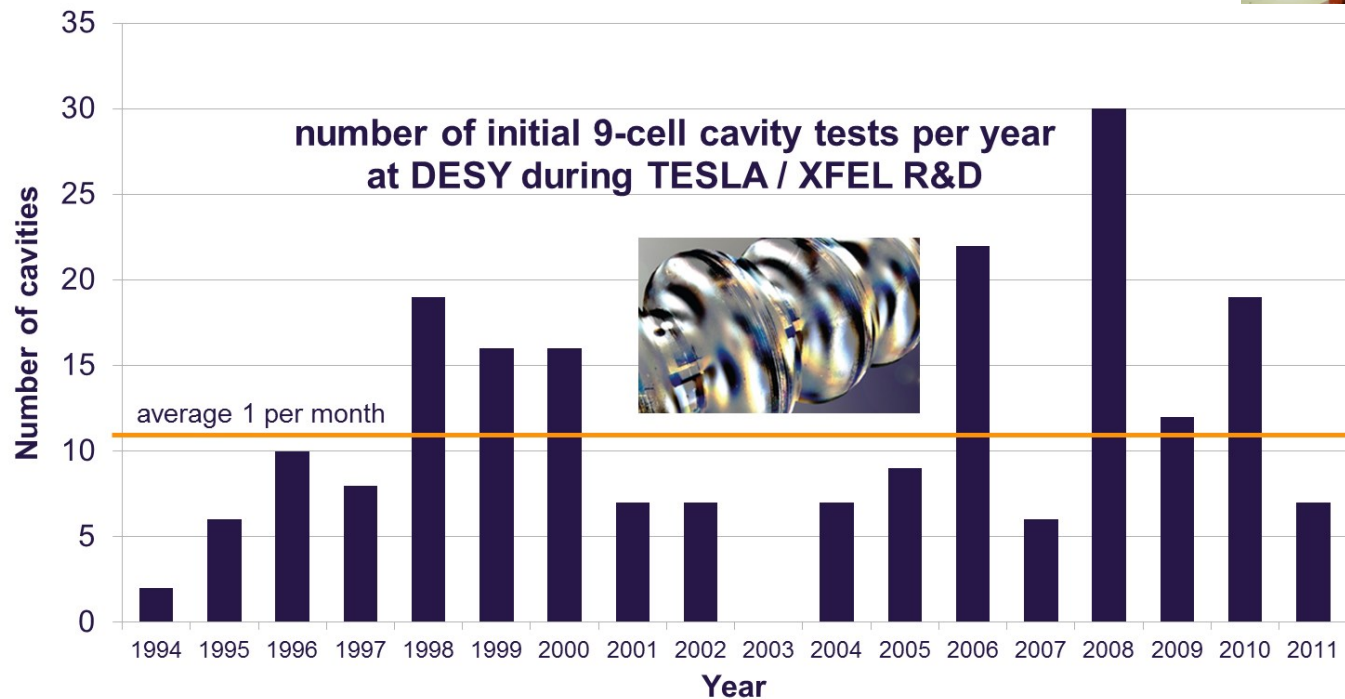
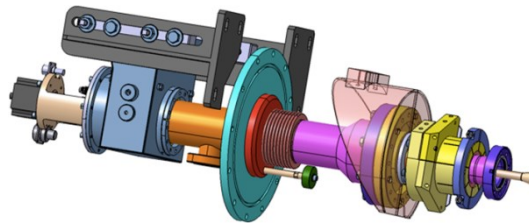
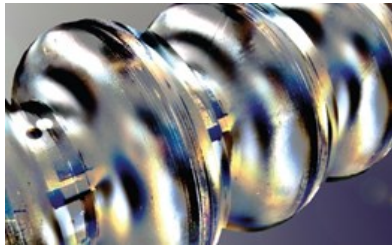
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BINP Novosibirsk, Russia	<ul style="list-style-type: none"> • cold vacuum bellows • coupler vacuum line
CEA Saclay / Irfu, France	<ul style="list-style-type: none"> • cavity string and module assembly • cold beam position monitors • magnetic shields, superinsulation blankets
CIEMAT, Spain	<ul style="list-style-type: none"> • Superconducting magnets
CNRS / LAL Orsay, France	<ul style="list-style-type: none"> • RF main input coupler incl. RF conditioning
DESY, Germany	<ul style="list-style-type: none"> • cavities & cryostats • contributions to string & module assembly • coupler interlock • frequency tuner • cold vacuum system • integration of superconducting magnets / current leads • cold beam position monitors
INFN Milano, Italy	<ul style="list-style-type: none"> • cavities & cryostats • contributions to frequency tuners
Soltan Institute, Poland	<ul style="list-style-type: none"> • Higher Order Mode coupler & absorber

Production Rate of Key Components

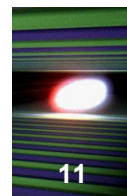
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European XFEL requires **8 cavities & couplers** to build **1 module per week**



monthly average
was to increased
by approximately
x 30

Cavity Production (here at Company RI)



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all pictures courtesy Research Instruments

Cavity Production (here at Company E. Zanon)



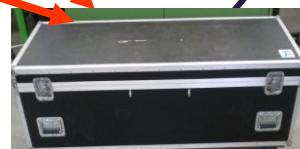
800 XFEL Cavities Travel Through Europe



research
instruments



E. ZANON



DESY Germany



CEA / Ifru France



i r f u
cea
sacalay



- two cavity vendors were contracted to produce 400 cavities each

- slight variation in final surface treatment

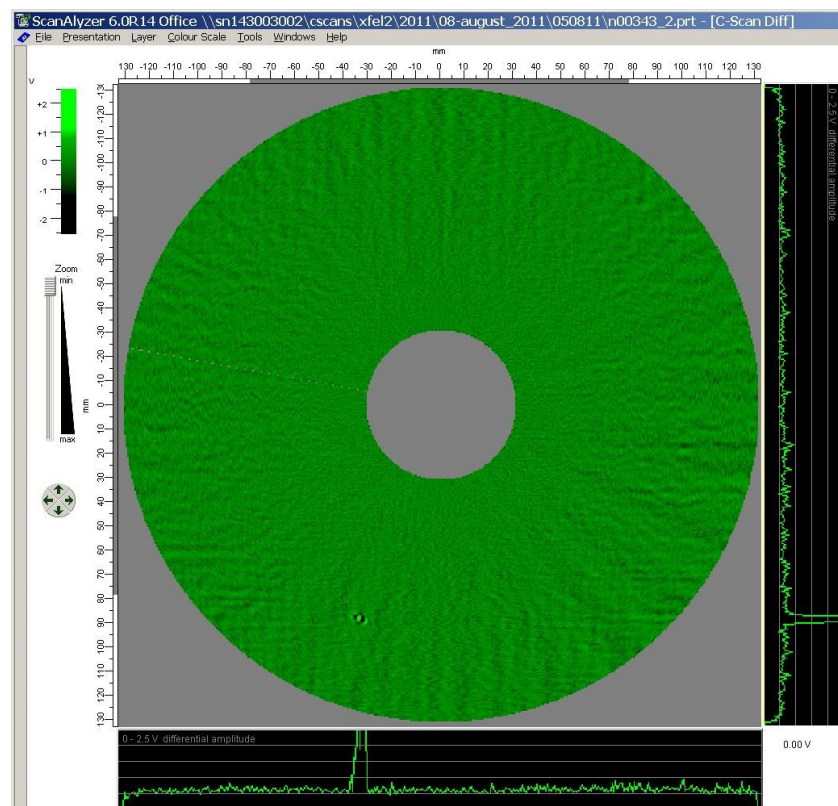
- all cavities are tested and partly re-treated / re-tested in collaboration of IFJ / DESY

- further assembly takes place at CEA Saclay / Ifru

Niobium Material Bought and QC-ed by DESY

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- All Nb / NbTi material (24,420 single parts!) was procured by DESY.
- Detailed quality inspection was developed and carried out.
- All material available to cavity vendors.



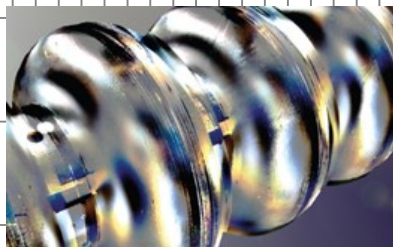
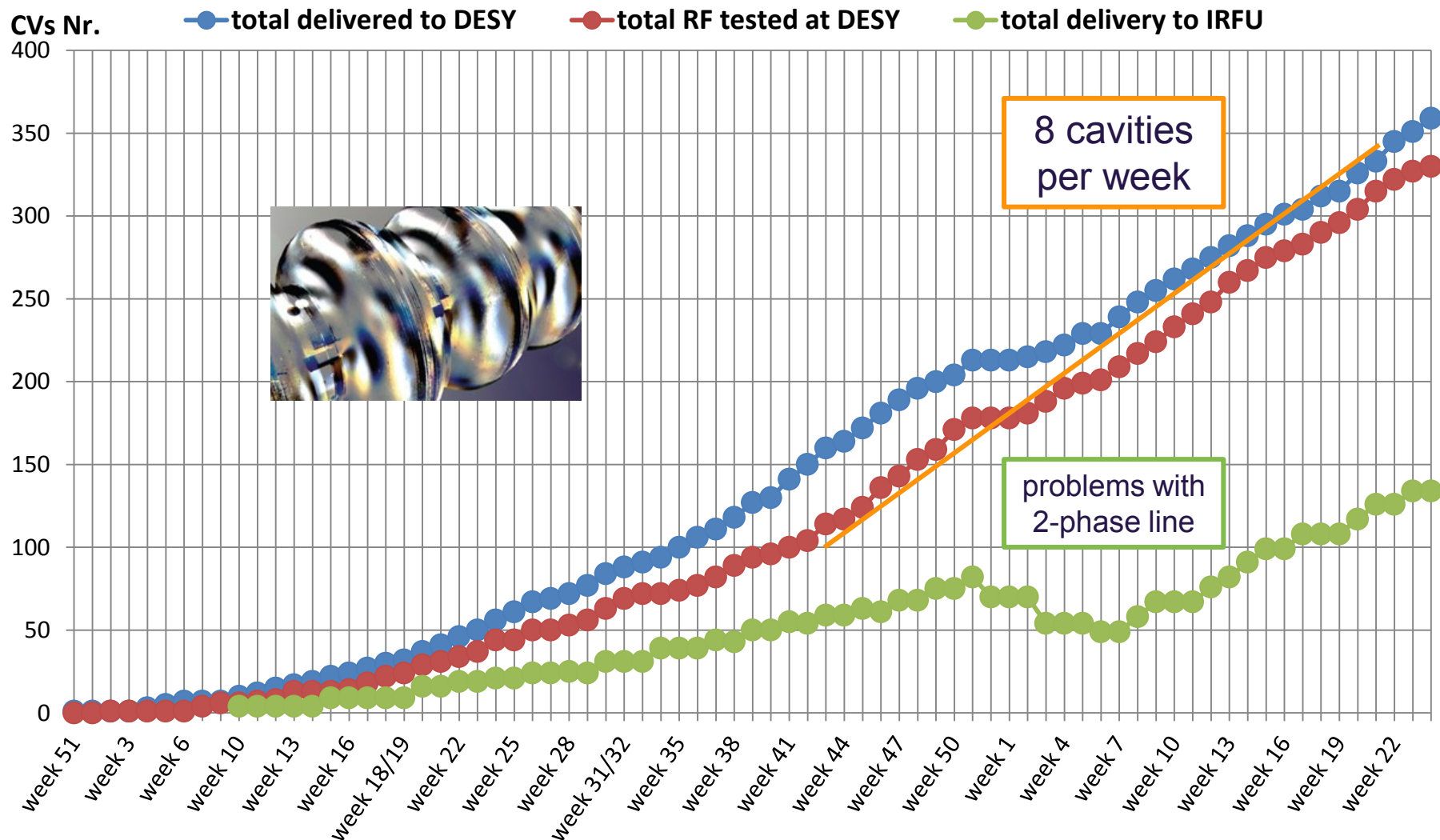
Industrial Cavity Production Relies on DESY & INFN Supervision



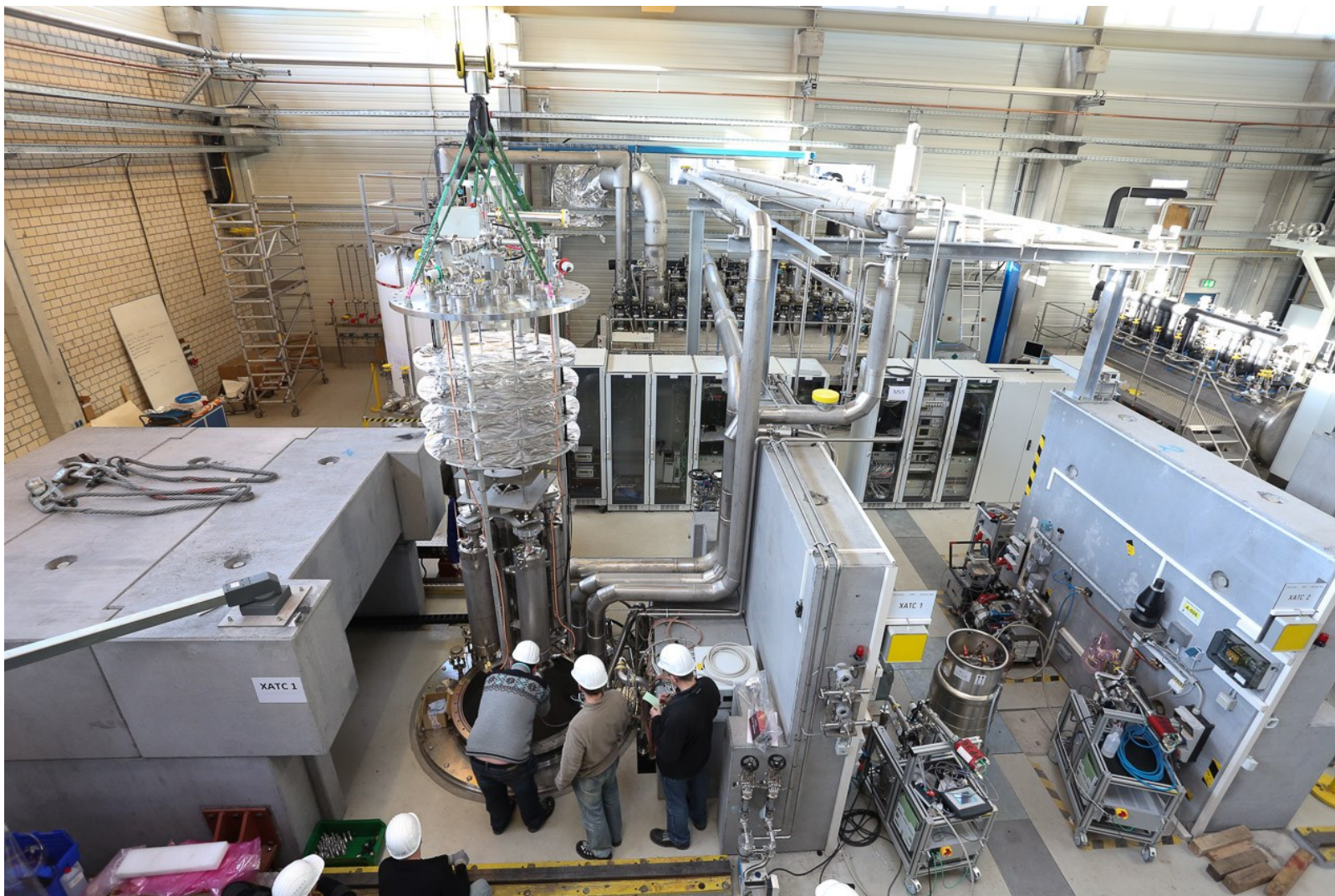
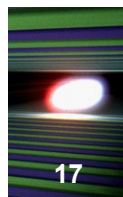
- Special CE certified machines were developed and given to industry.
- Since accelerator cavities are delivered without performance guarantee, very detailed specifications are used.
- Many productions steps are supported and partly supervised by DESY & INFN.
- Several QC steps are established. Very detailed documentation.

Cavity Delivery Status as of 6/2014

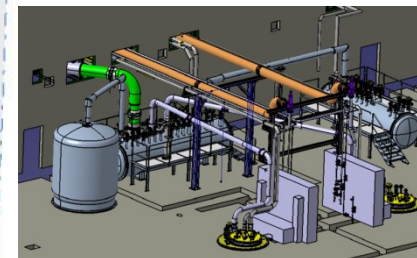
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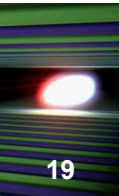
Vertical Cavity Testing at DESY



AMTF Test Stand Infrastructure

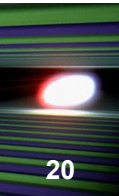


Cavity Results

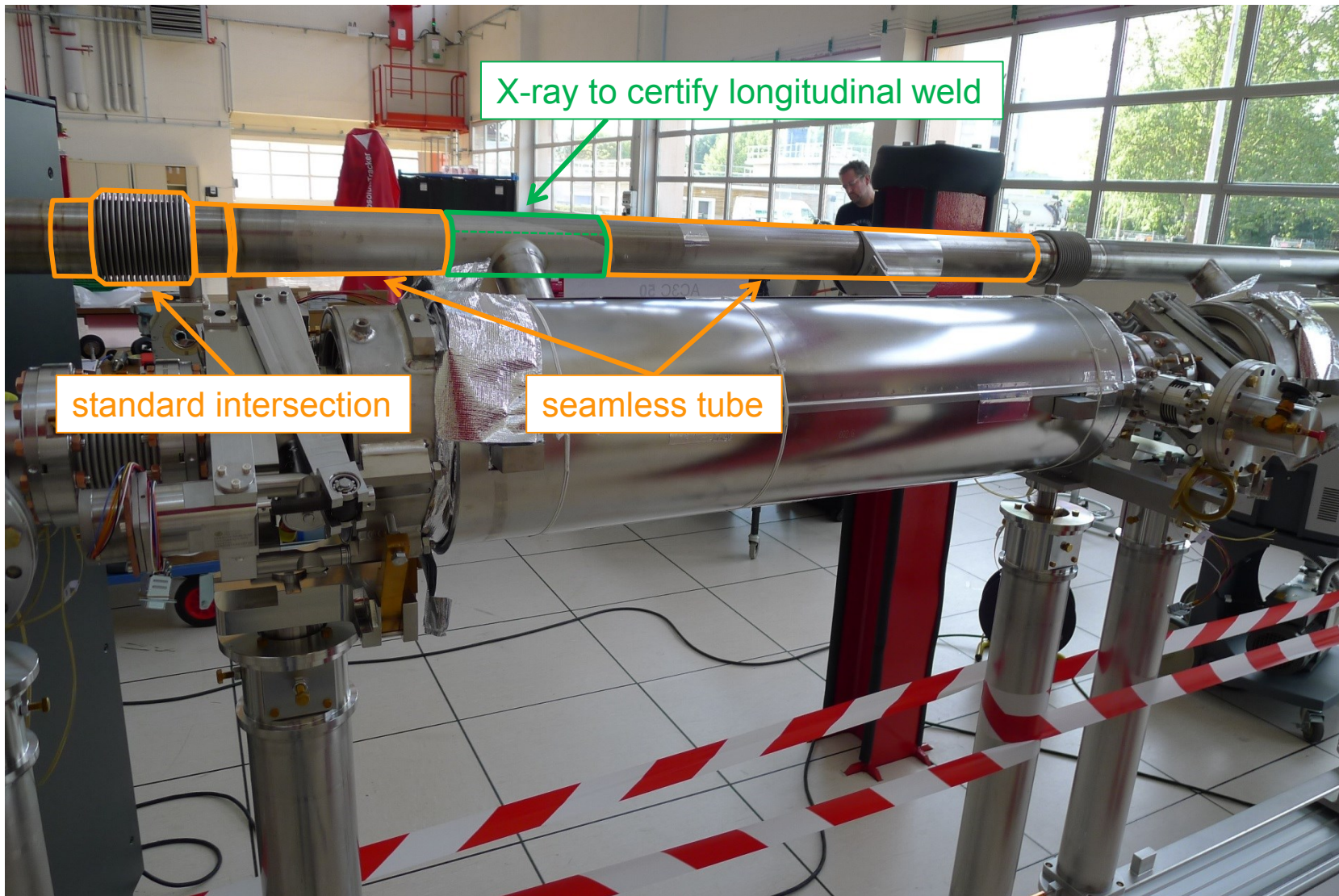


- **Mechanical production + surface treatment** in full + standard operation
- **Vertical cavity testing** and all work flows at AMTF are well established
- **Gradients** in average above specification (almost 300 cavities tested)
 - Average usable gradient after delivery (26.8 ± 7.1) MV/m
 - 2/3 of 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**
since ~100 additional treatments / tests for initial gradients < 20MV/m give a projected **energy gain of approx. 1300 MeV**
- Vertical testing incl. re-treatment & re-testing can be finished in time with realistic assumptions based on experience gained so far
- Cavities up to **XM14** are available for module assembly at CEA Saclay

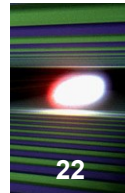
Cavities (Ready for Transport to IRFU)



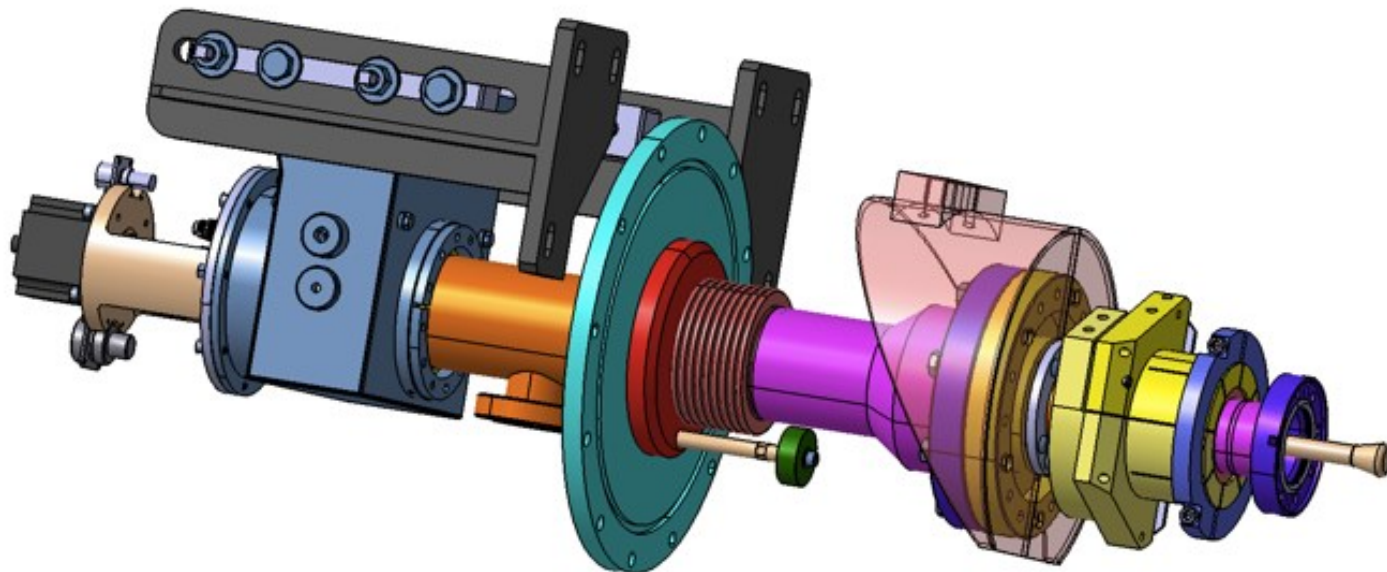
2-Phase Line (Service Pipe) Needs and Gets Systematic Repair Work



RF Power Couplers



- Ramp-up of RF power coupler production at Thales / RI needed more time than assumed.
- The problem was the copper plating which requires perfect cleanliness of stainless steel surfaces.
- Reproducibility of copper plating remains challenging.
- In general excellent quality control is required to reject bad parts early during production.



Coupler Fabrication

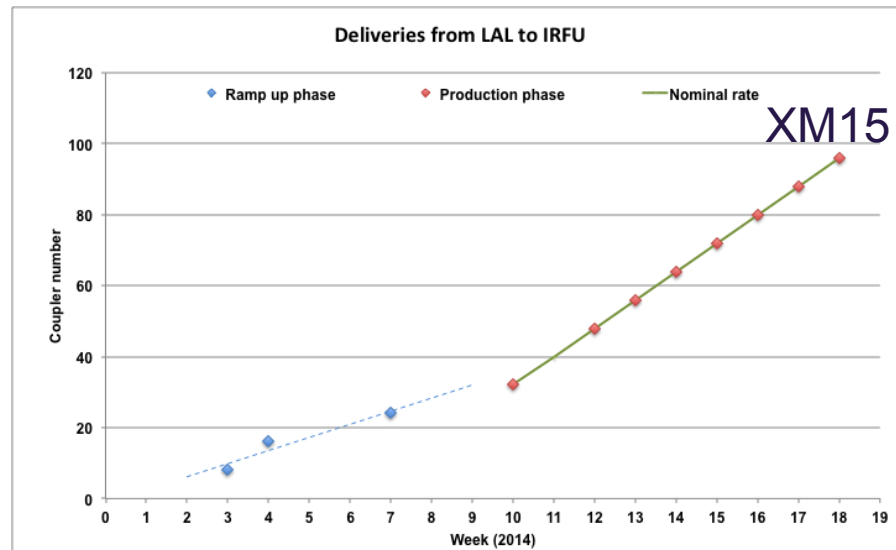
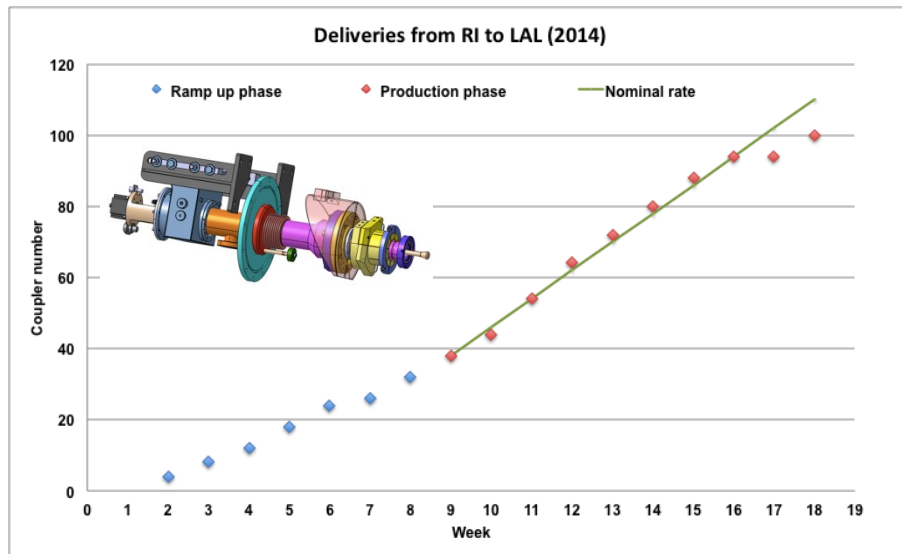


Coupler Pairs Installation in the RF Test Stands

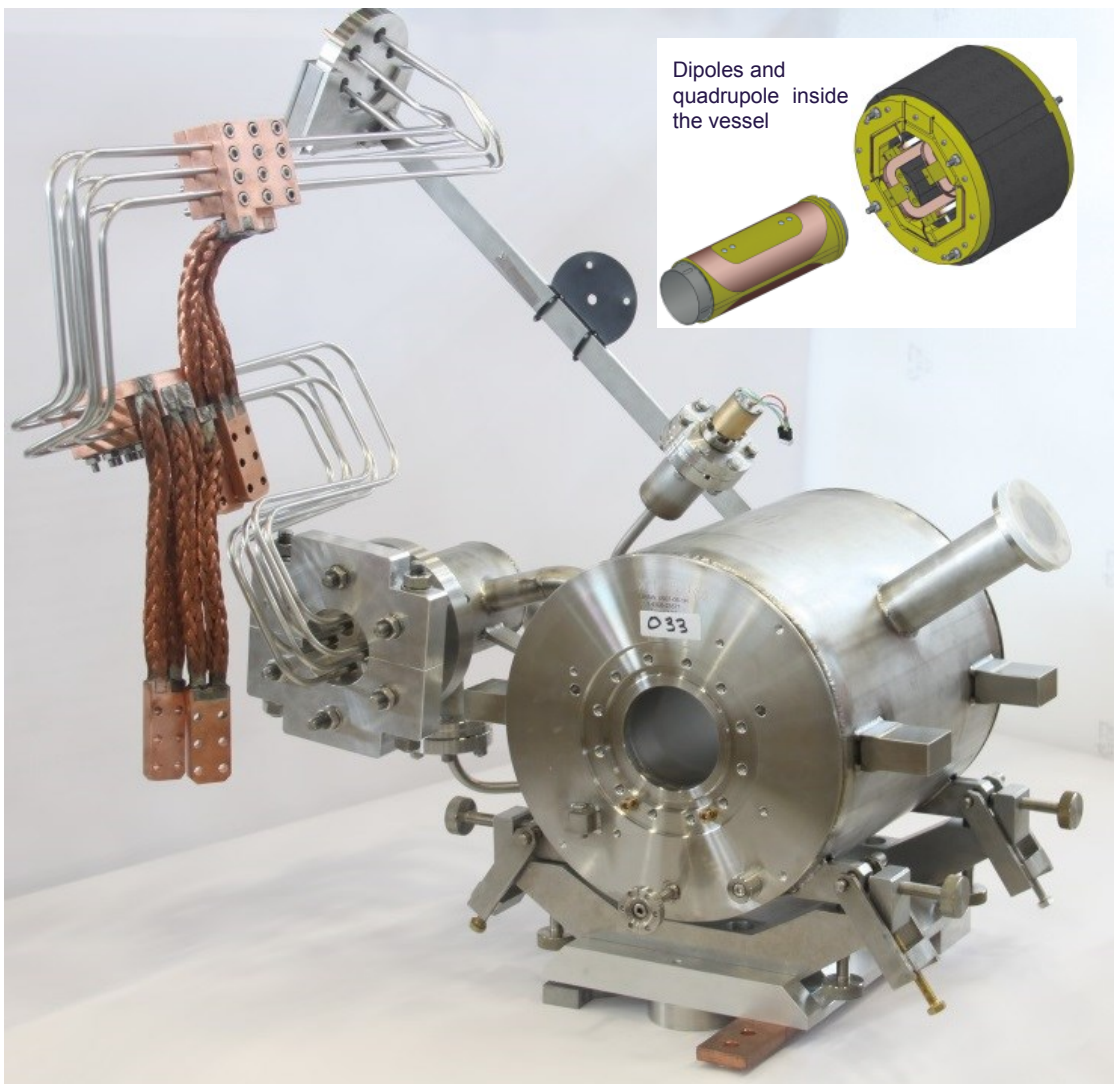


RF Power Coupler Delivery Status as of 4/2014

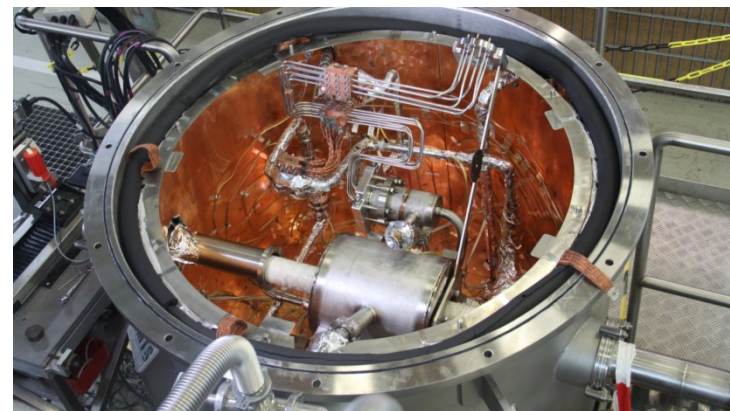
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Cold Magnets



- 80 (of 100) magnets at DESY
- 67 cold tested
- 48 copper plated
- 20 BQU assembled
- 10 BQU's shipped

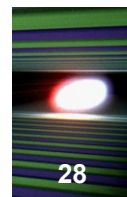


Cavity String Assembly at CEA Saclay / Iffu

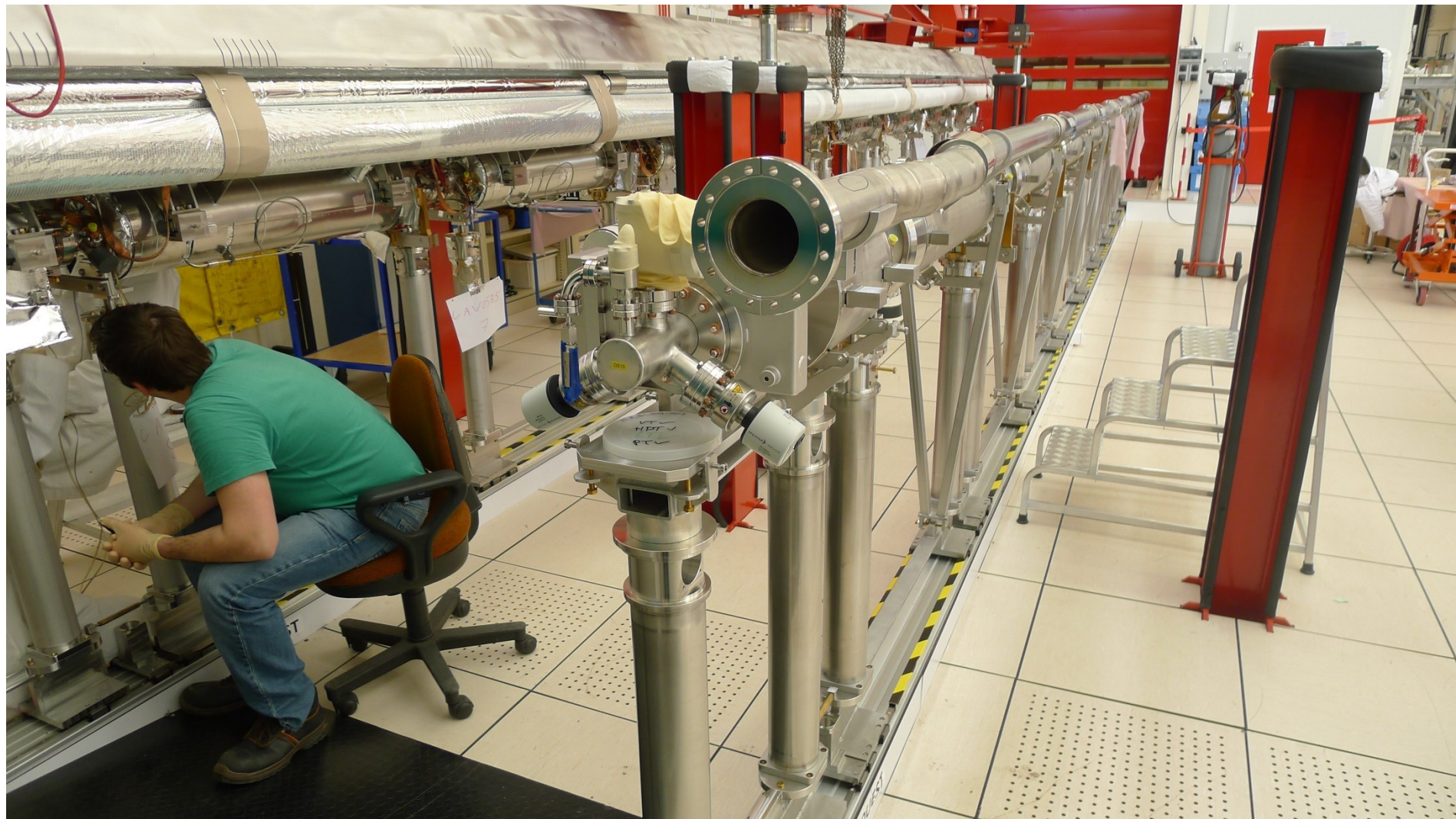
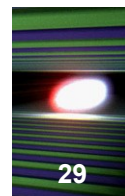
■ see also next presentation WEIB04 given by F. Chastel (ALSYOM)



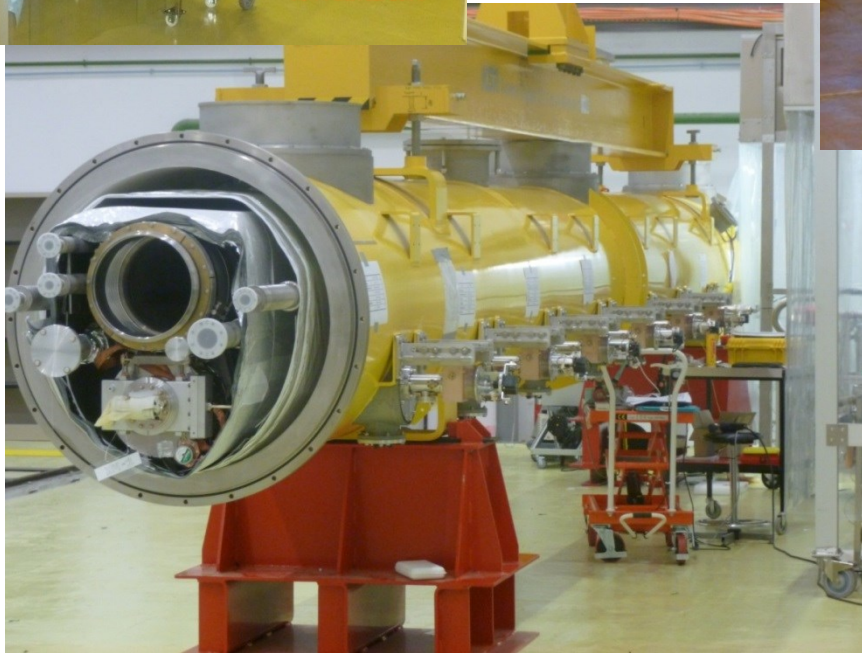
Accelerator Cavity String Assembly at Iffu (XM4)



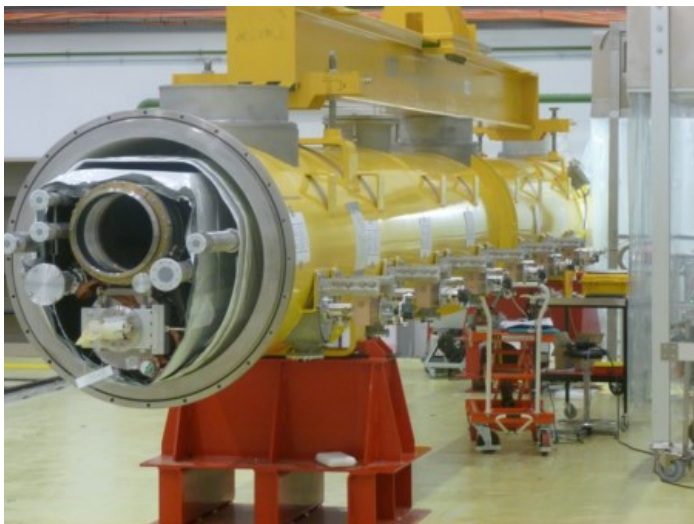
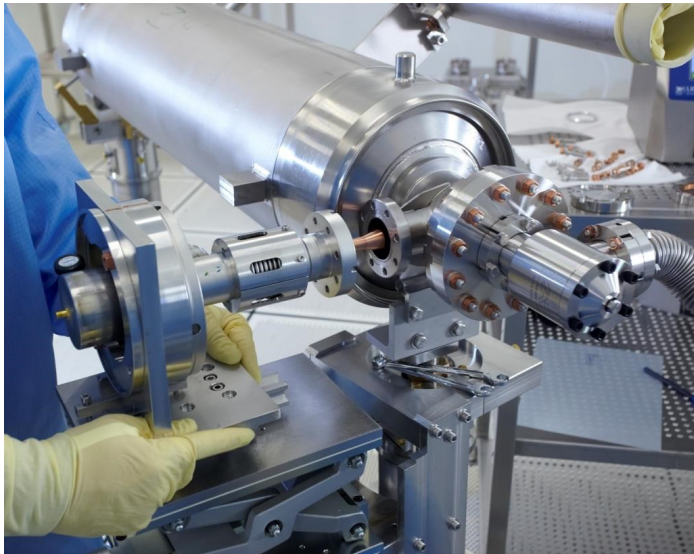
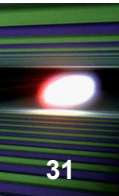
String / Cold Mass Marriage (XM3 & XM4)



RF Power Coupler Assembly Transport Caps / Final Checks / Shipment

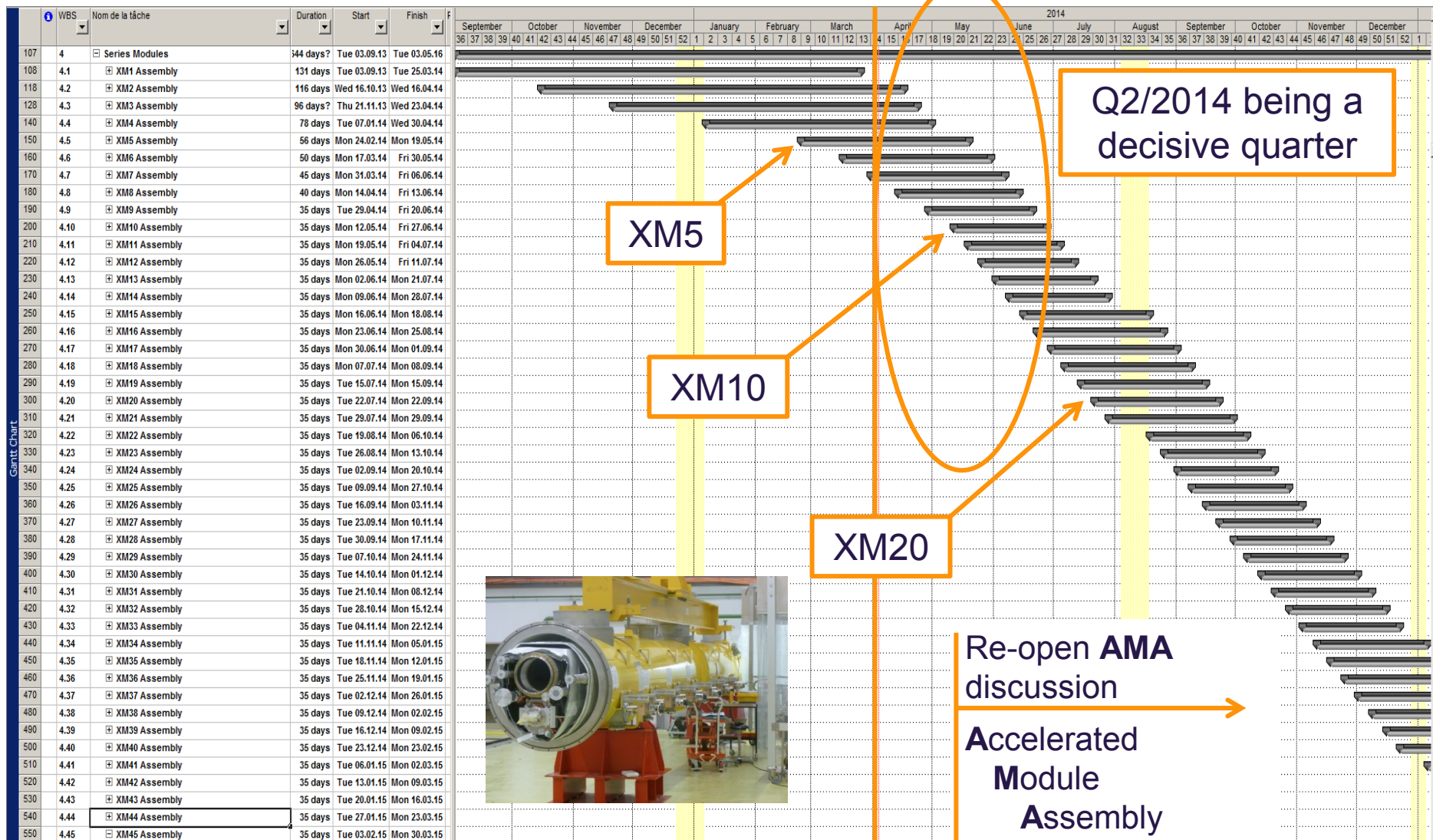


Module Assembly – Buffers are Filled



- string and module assembly relies on sufficiently filled buffers for all parts
- at present parts available at CEA for at least the next 4 modules
 - Cavities
 - Couplers
 - BQU
 - Vacuum parts (bellows / gate valves)
 - Cryostats
 - Magnetic shielding
- transportation boxes and parts-in-circulation are an issue; quick return is a must

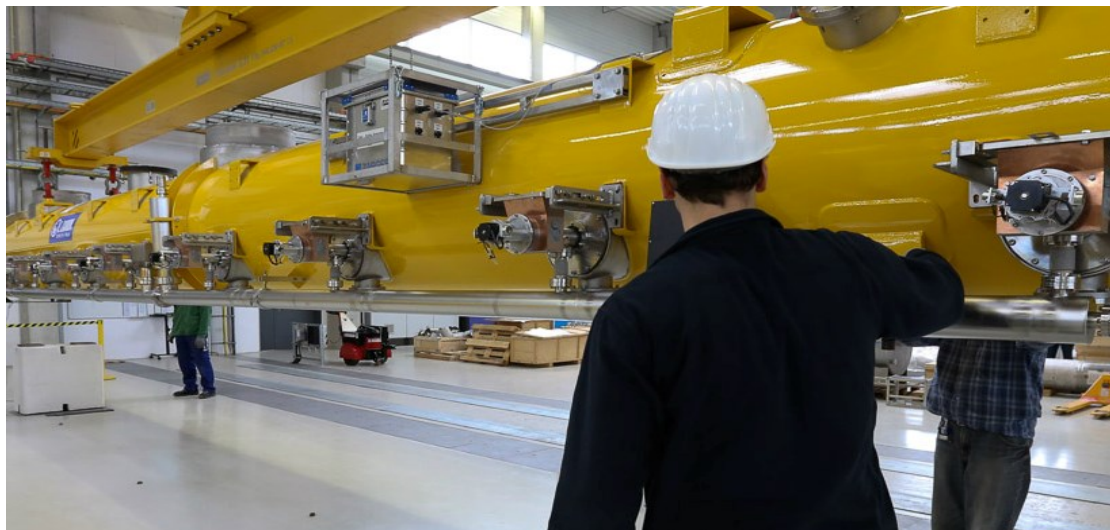
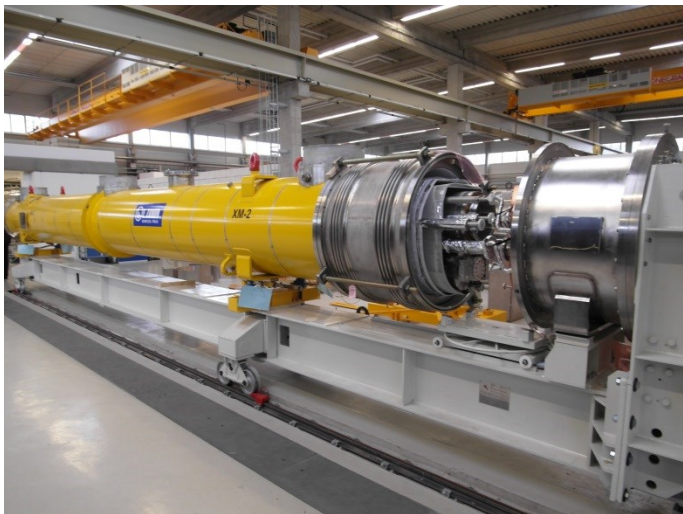
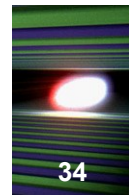
Accelerator Module Assembly Chart



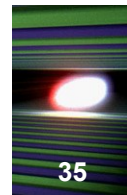
Module Transport (XM1 arriving at DESY)



XM-2, XM-1, XM1, XM2, XM3 and XM4 at AMTF

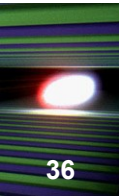


Accelerator Module Testing at DESY

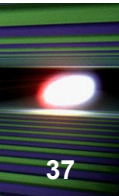


- first results: XM-2, XM-1 and XM1 are all above XFEL specs. of 23.6 MV/m
- some non-conformities exist but lead to final improvements of series production; feedback to CEA / Ifu



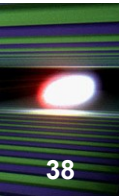


- Major key-player already working together in the TESLA linear collider R&D phase joined the European XFEL in an early phase.
- DESY has the role as coordinator of the accelerator complex including the superconducting linac. At the same time large in-kind contributions in the field of SRF technology are coming from DESY.
- Work packages contributing to the cold linac are in all cases co-led by a DESY expert and a team leader from the institutes contributing. Integration into the linac installation and infrastructure is a DESY task.
- The European XFEL clearly profits from the long-time experience of DESY in SRF technology, and from the history in building and operating large scale accelerator facilities.



- Large series production in industry requires pre-qualification.
- While in some cases vendors were qualified already during the TESLA R&D phase, in some other areas a careful multistep qualification was done.
- There was a strong effort to always have at least two qualified vendors, and where possible the overall production was split accordingly.
- After contract award a continuous close cooperation with vendors is needed. Many of the used components remain challenging, and non-conformities can be reduced only in fruitful discussions. SRF technology does not allow real compromises, i.e. problems have to be smoothed out in a common effort.

In-kind Contributions



- The European XFEL is built based on in-kind contributions. The project includes technology transfer between the different institutes and also industry. In such a model the coordination effort should not be underestimated. The original budget estimate needs to take care of this.
- Difficult to handle are also the duties defined by dependencies, e.g. in the supply chain. In a technically ambitious project the responsibilities in terms of work sharing may be clear but in case of sudden and unexpected technical problems the collaborative spirit is needed and of utmost importance. Discussion of legal constraints is often of no avail, even if necessary.
- Coordination and integration of in-kind contributions requires not only additional resources but also relies on the possibilities of a strong laboratory. Expecting turn-key systems is an incorrect approach. Both partner, the receiving party but also the in-kind contributor need expertise and excellent communication skills. A well-developed team spirit is of large benefit.

- The superconducting linac of the European XFEL can only be built due to the great collaborative effort accompanied by an immense team spirit of the involved partners.

Thank you!!!