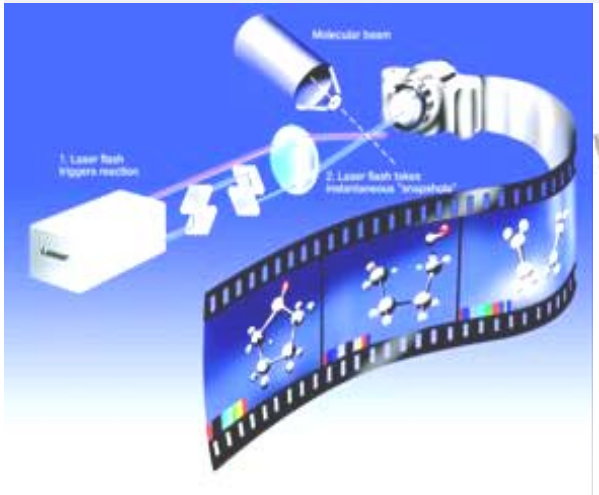
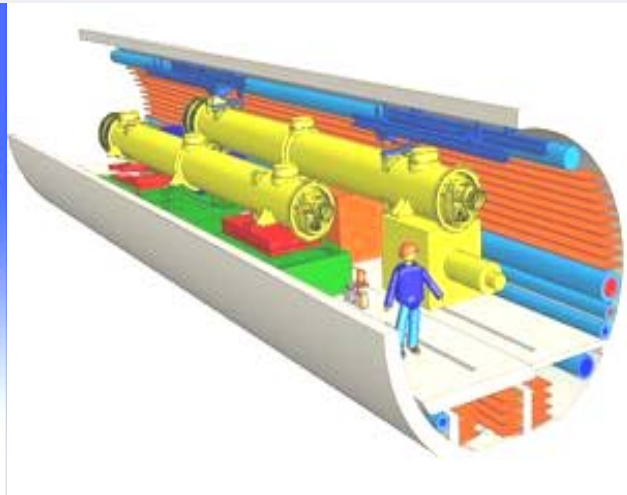
# XFEL:
# Plans for 101 Accelerator Modules

Lutz Lilje, DESY
for the XFEL team



# Outline

- Overview
- XFEL Project - Current status
  - Project approval
  - Schedule
- Test facilities: Existing and planned
  - FLASH
    - **F**ree-Electron-**Las**er in **H**amburg
  - Tunnel Mockup
  - CMTB
    - Cryomodule Test Bench
  - AMTF
    - Accelerator Module Test Facility
- Industrialization examples
  - Cavity
  - Coupler
  - Module
- Distribution of Workload
  - Common In-Kind Proposal

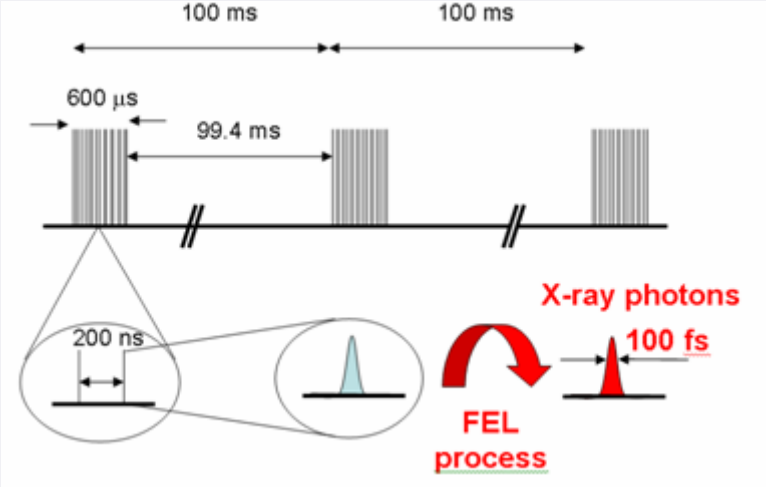
# Properties of XFEL radiation

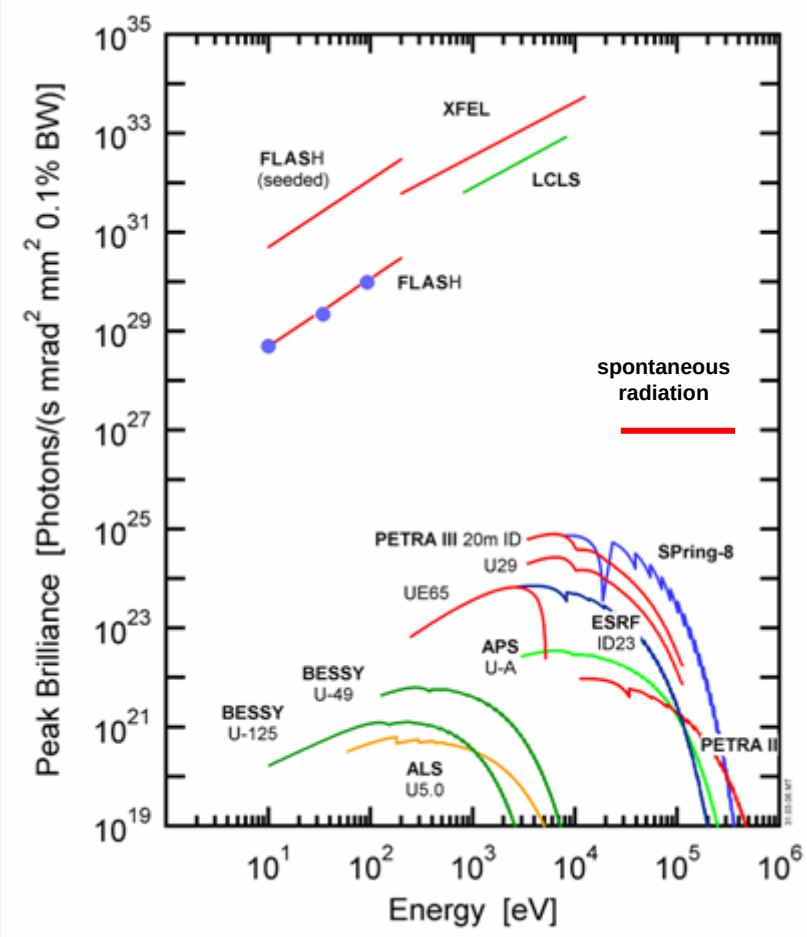
X-ray FEL radiation (0.2 - 14.4 keV)

- ultrashort pulse duration <100 fs (rms)
- extreme pulse intensities $10^{12}$-$10^{14}$ ph
- coherent radiation x$10^{9}$
- average brilliance x$10^{4}$

Spontaneous radiation (20-100 keV)

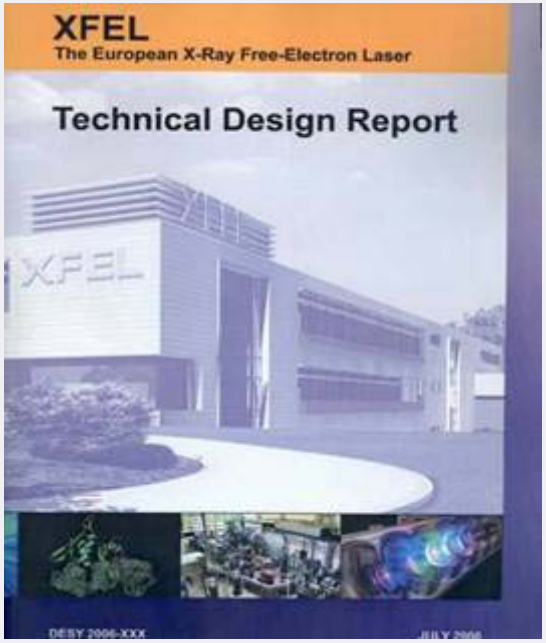
- ultrashort pulse duration <100 fs (rms)
- high brilliance



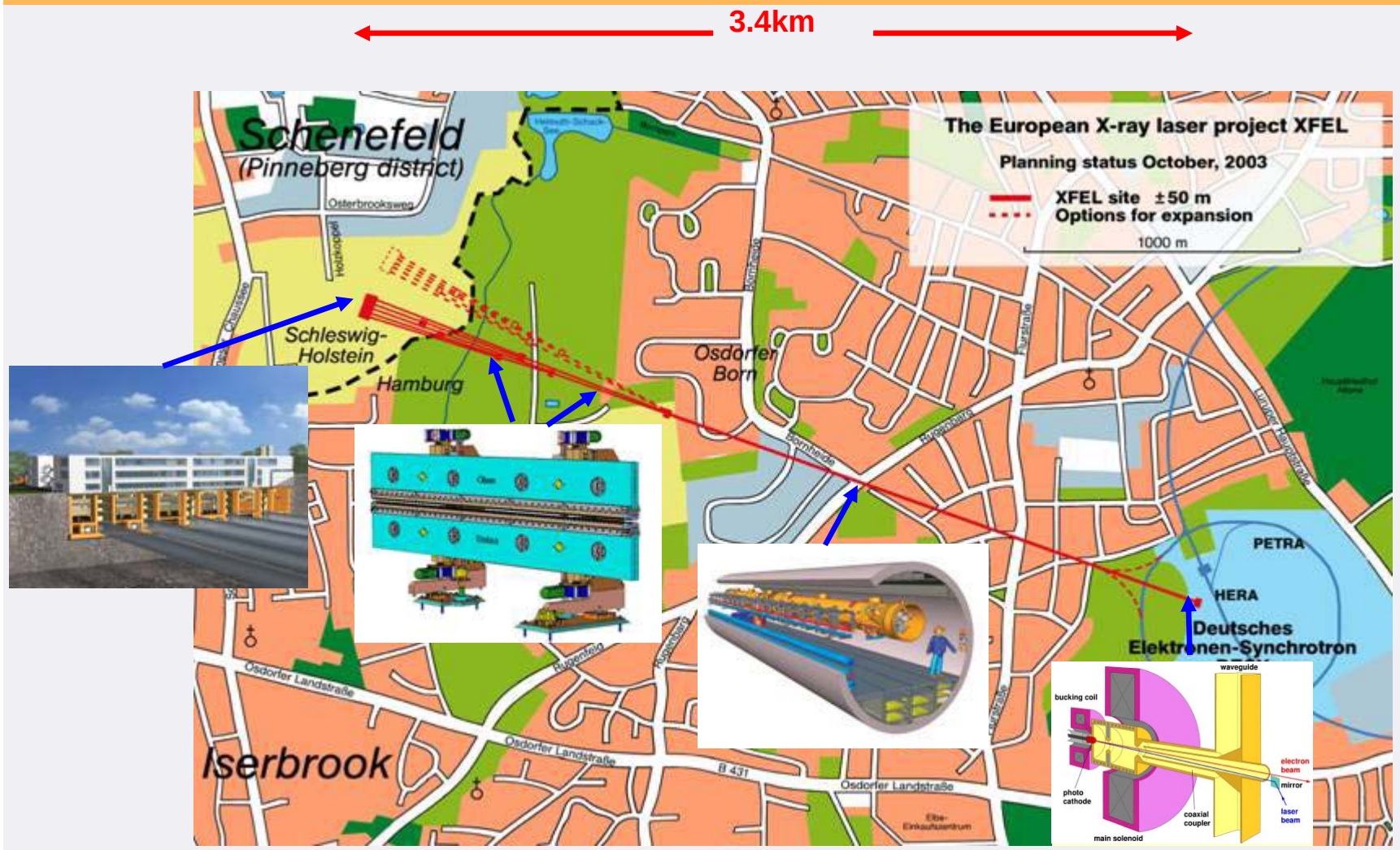



# XFEL Documentation

- Technical Design Report
  - Report by over 300 Authors from 17 countries and 71 institutions
  - Has been reviewed internationally
  - Is available at:
  - http://xfel.desy.de/tdr/tdr/index_eng.html
  - Completed July 2006
    - Minor edits: Final version available now
- In parallel finished the 'Planfeststellungsverfahren'
  - Legal procedure to get plan approval
  - Includes ecological impact studies etc.
  - July 2006: Plan approval announced by authority in charge




# Overall layout of the European XFEL



# XFEL site in Hamburg/Schenefeld

# … after construction *(computer simulation)*

# XFEL International Project Organization

**XFEL Steering Committee ISC** (Chair: J. Wood, UK)

- Representatives of all countries intending to contribute to the XFEL facility
- ***13 countries have signed MoU (project preparation phase) in 2004***

**CH CN DE DK ES FR GB GR HU IT PL RU SE**

- ***Nomination of European Project Team (Leader:* Massimo Altarelli)**

**WG on Scientific and Technical issues STI** (chair: F. Sette, ESRF)

**WG on Administrative and Funding issues AFI** (chair: H.F. Wagner, Germany)

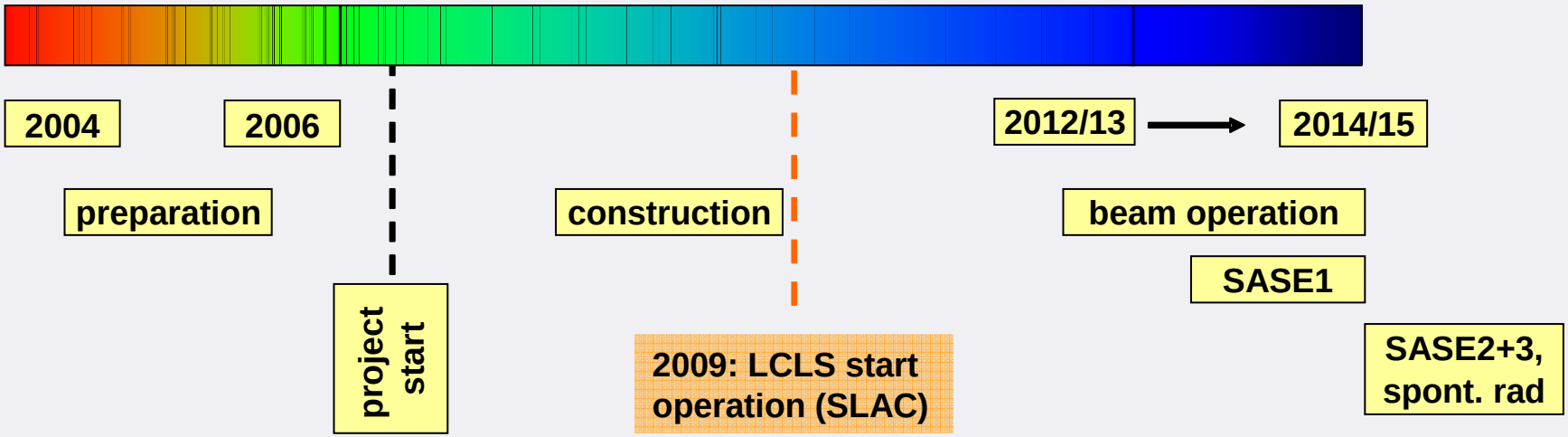
**Bi-lateral negotiations between Germany and signature countries on funding contributions are ongoing**

# XFEL Project start

– On 5th of June 2007
  - Official start of the project

– On 6th of June
  - Start of tendering process for civil contruction

# XFEL Principle Schedule




industrialization of all Linac sub-systems

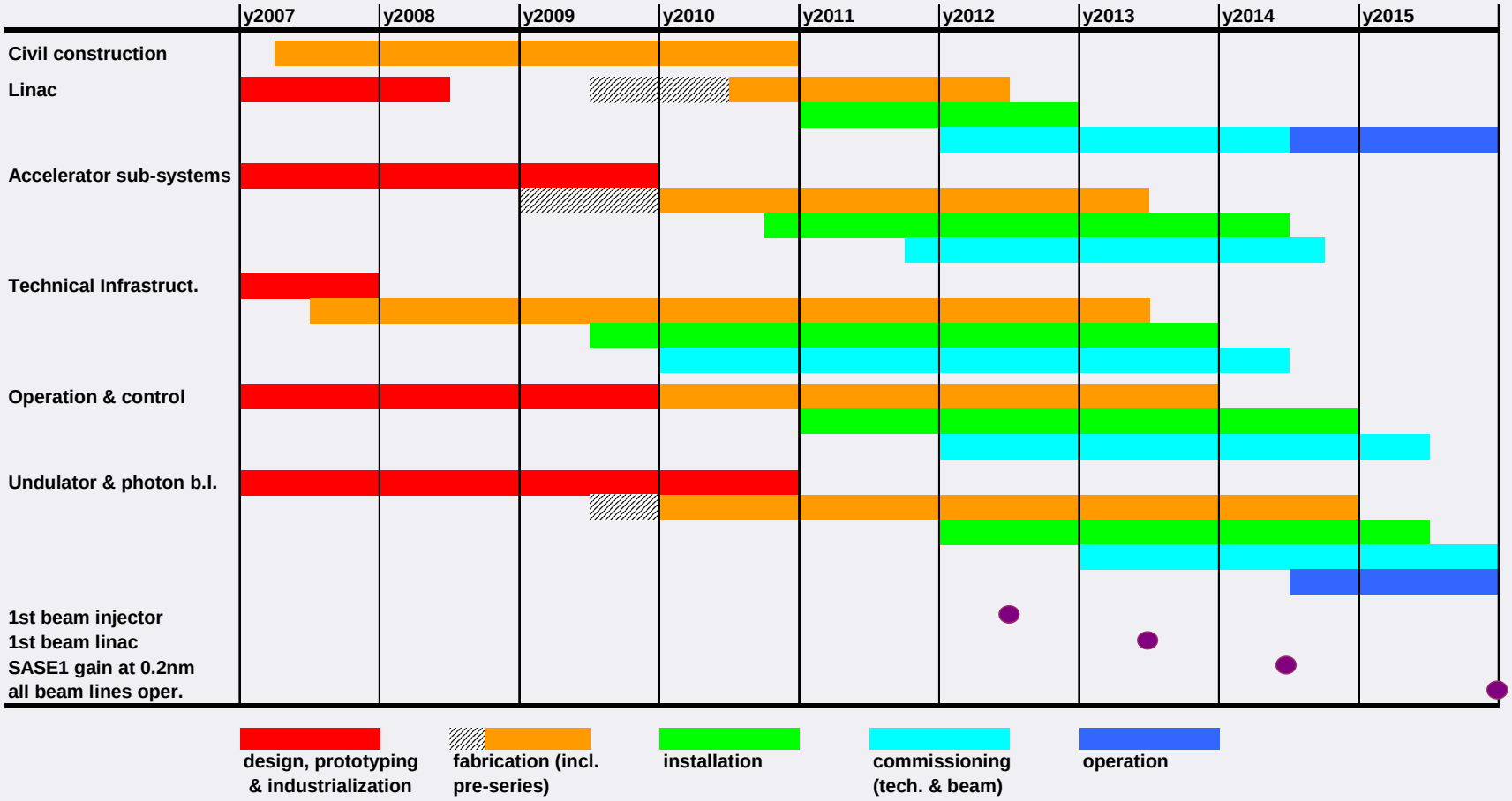
production

commissioning

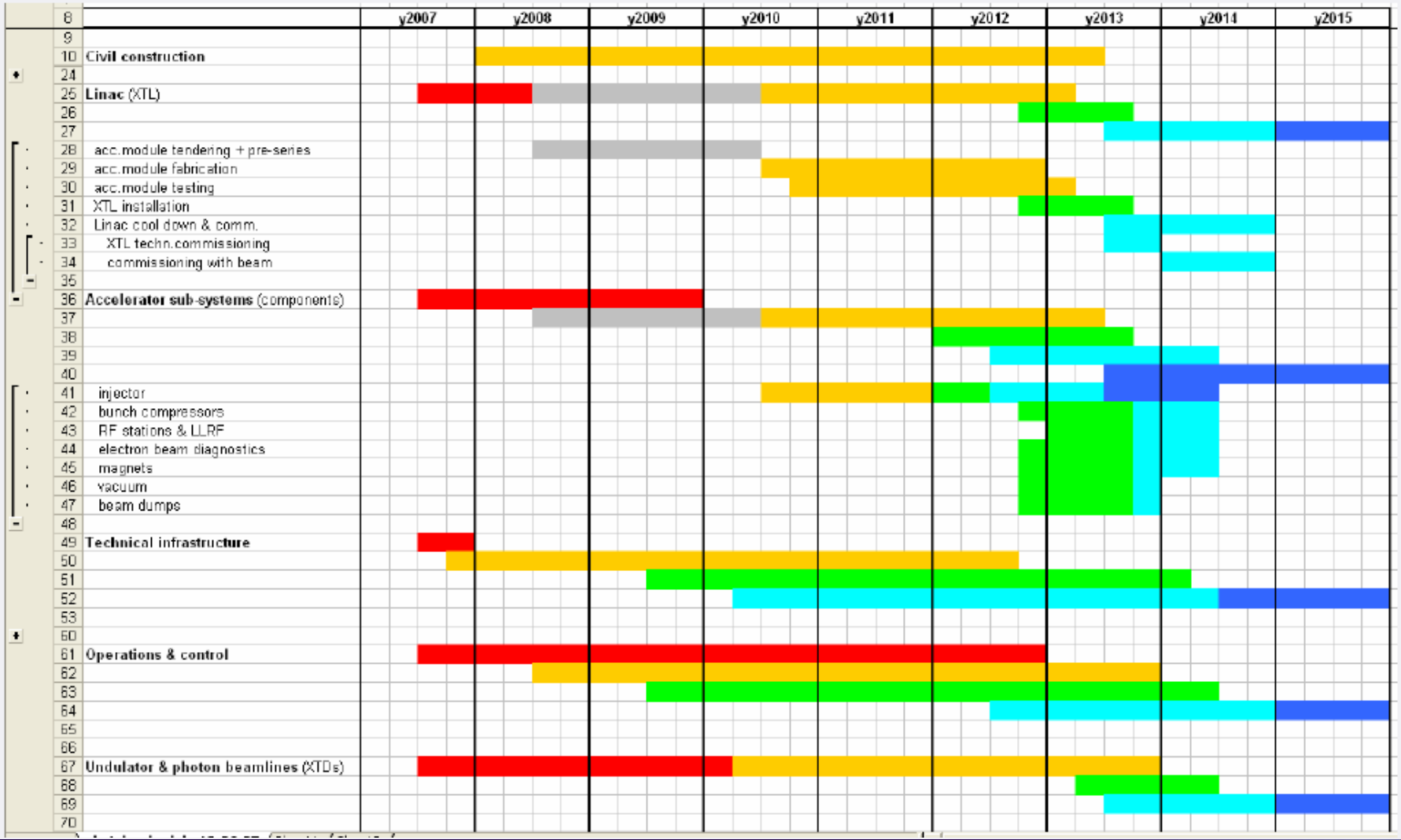
acceptance test and installation

FLASH FLASH FLASH operation experience XFEL XFEL XFEL

# XFEL Schedule



# Tentative XFEL Schedule (more details)

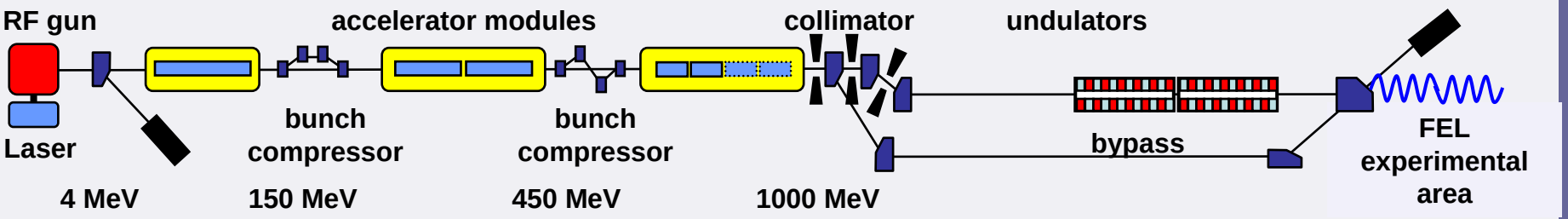


# XFEL Test facilities at DESY: Existing and planned

- FLASH
  - **Free**-Electron-**Las**er in **H**amburg
  - Verify overall concept
- Tunnel Mockup
  - Verify installation concept
- CMTB
  - Cryomodule Test Bench
- AMTF
  - Accelerator Module Test Facility for series Production

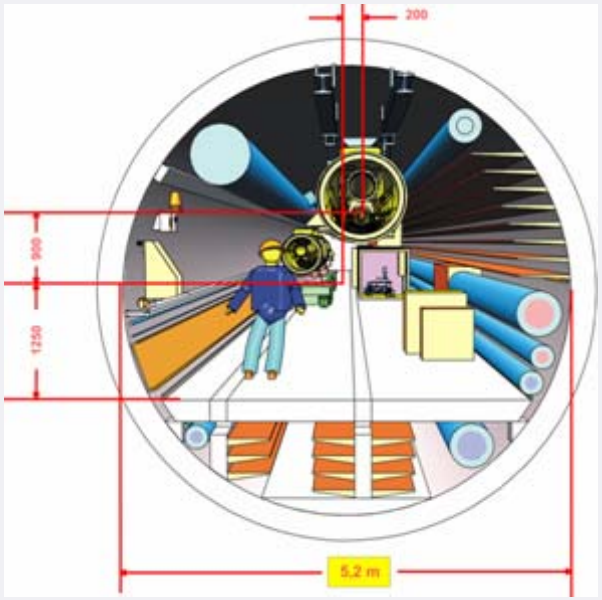
# XFEL Test Facilities: TESLA Test Facility and FLASH

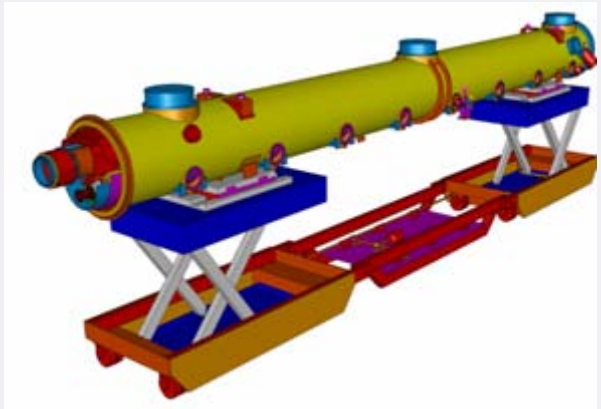
E. Vogel, MO204




- Pilot facility regarding practically all aspects (accelerator technology, beam physics, FEL process, user operation) of the XFEL
- Test bed for technical developments specifically required for the XFEL
- Injector development at PITZ, DESY-Zeuthen
- Recently: 1 GeV maximum energy and lasing at 6.5 nm!

# XFEL Tunnel

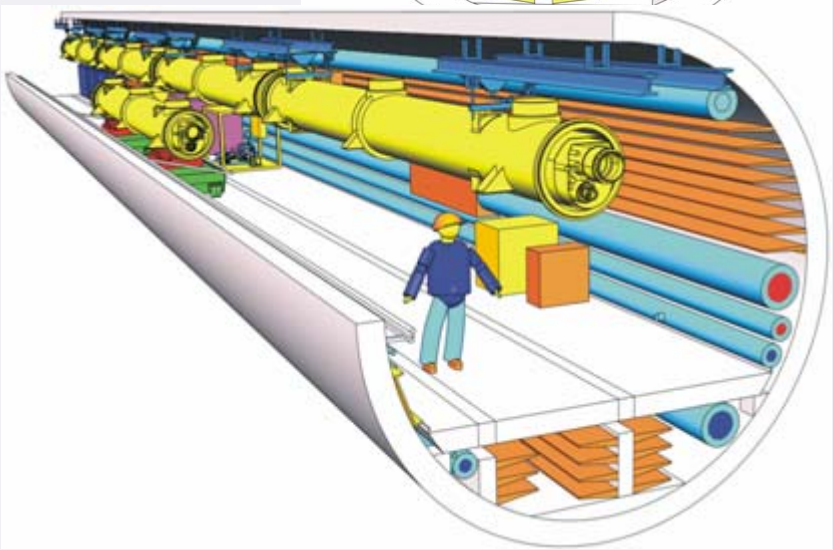


The **XFEL tunnel layout** was developed in several iterations.

A **mockup** is currently under construction.

**Installation procedures are under study.**



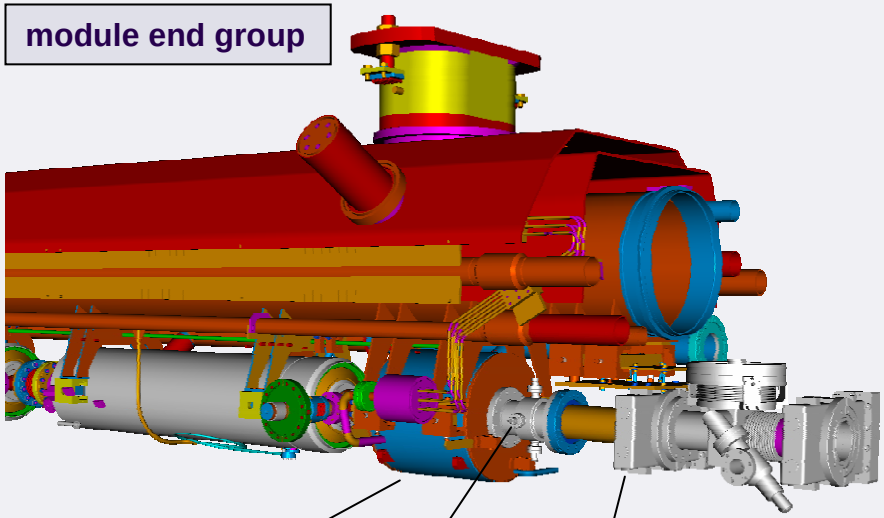
# XFEL Test Facilities: Tunnel Mockup

# XFEL Test Facilities: Cryomodule test bench (CMTB)

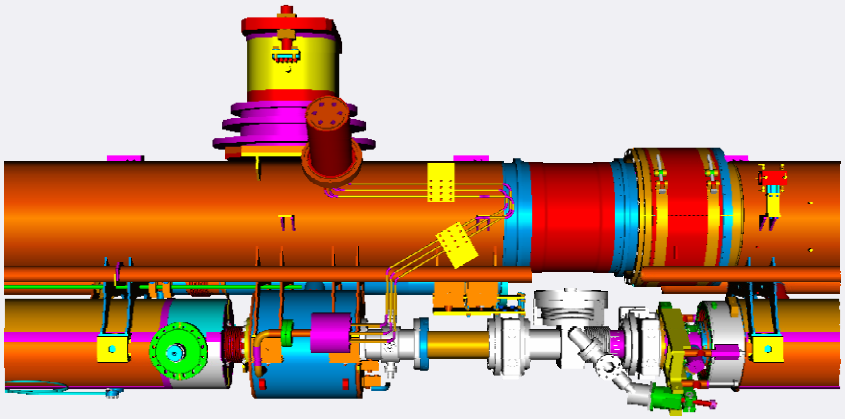
- CMTB permits test of modules (prototypes & pre-series) without the need to install them in the FLASH linac
  - Construction & commissioning completed autumn 2006
- Modul #6, 7, 5 (FLASH) tests completed
  - coupler processing,
  - cav performance,
  - cryo load,
  - cold-warm cycles,
  - piezo-compensation,
  - LLRF, …
- Gain important experience for the later larger scale series test facility

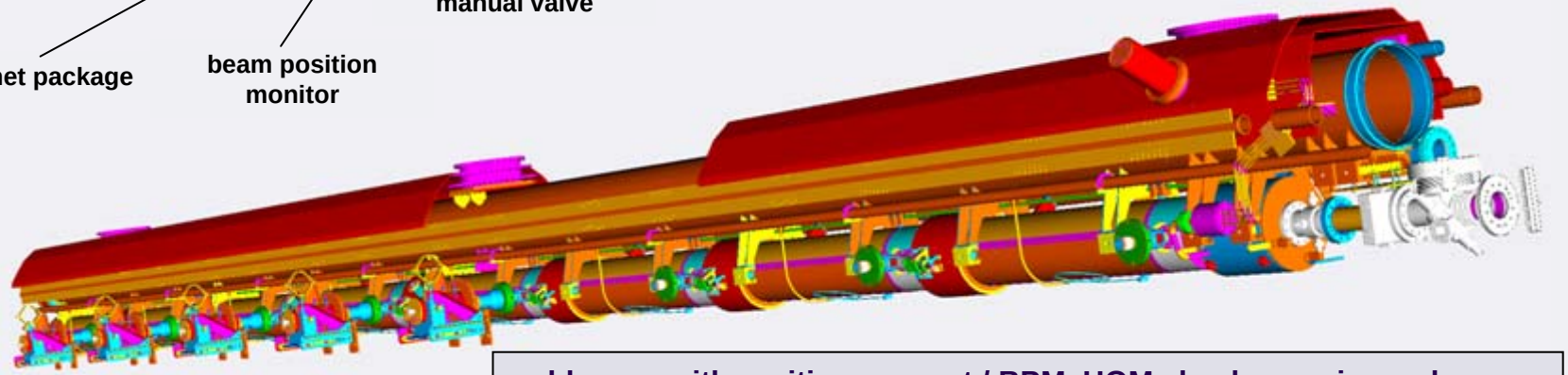
# XFEL Accelerator Module (Cryomodule)

**module end group**



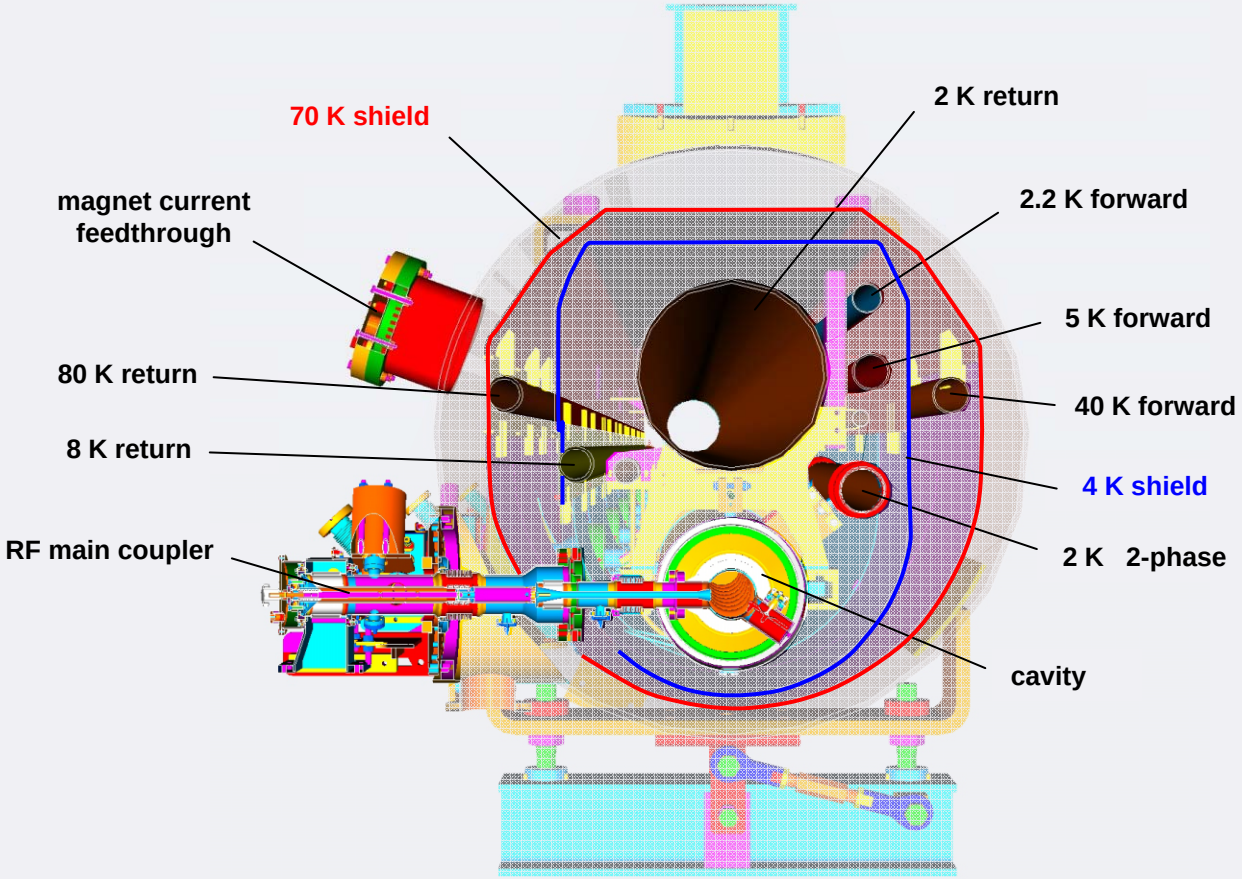

**module to module connection**





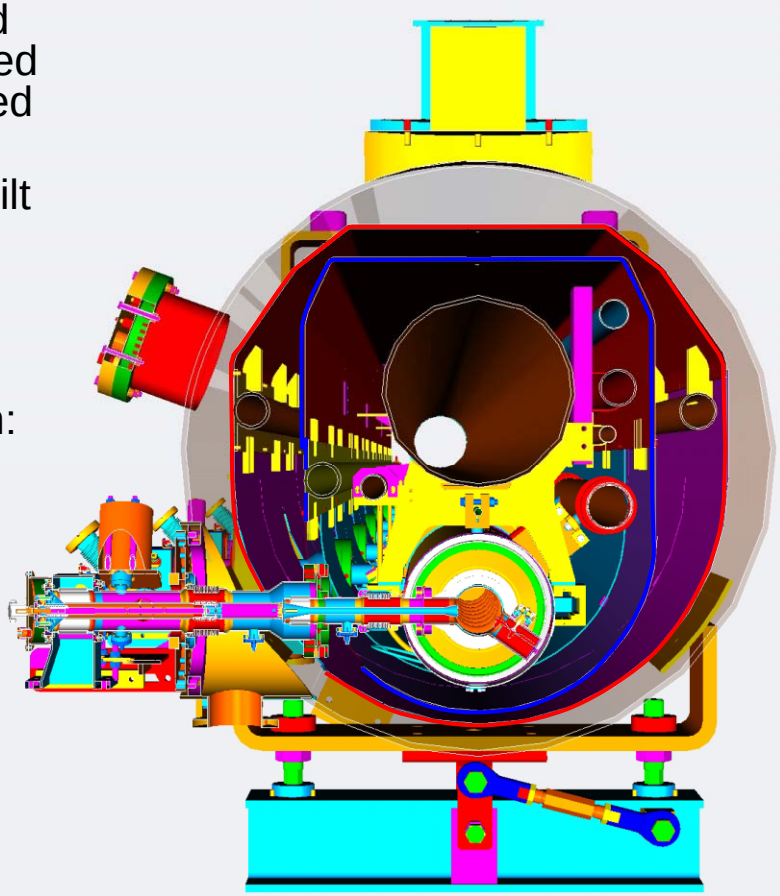
**cold mass with cavities, magnet / BPM, HOM abs. beam pipe, valve**

# XFEL Accelerator Module (Cryomodule)



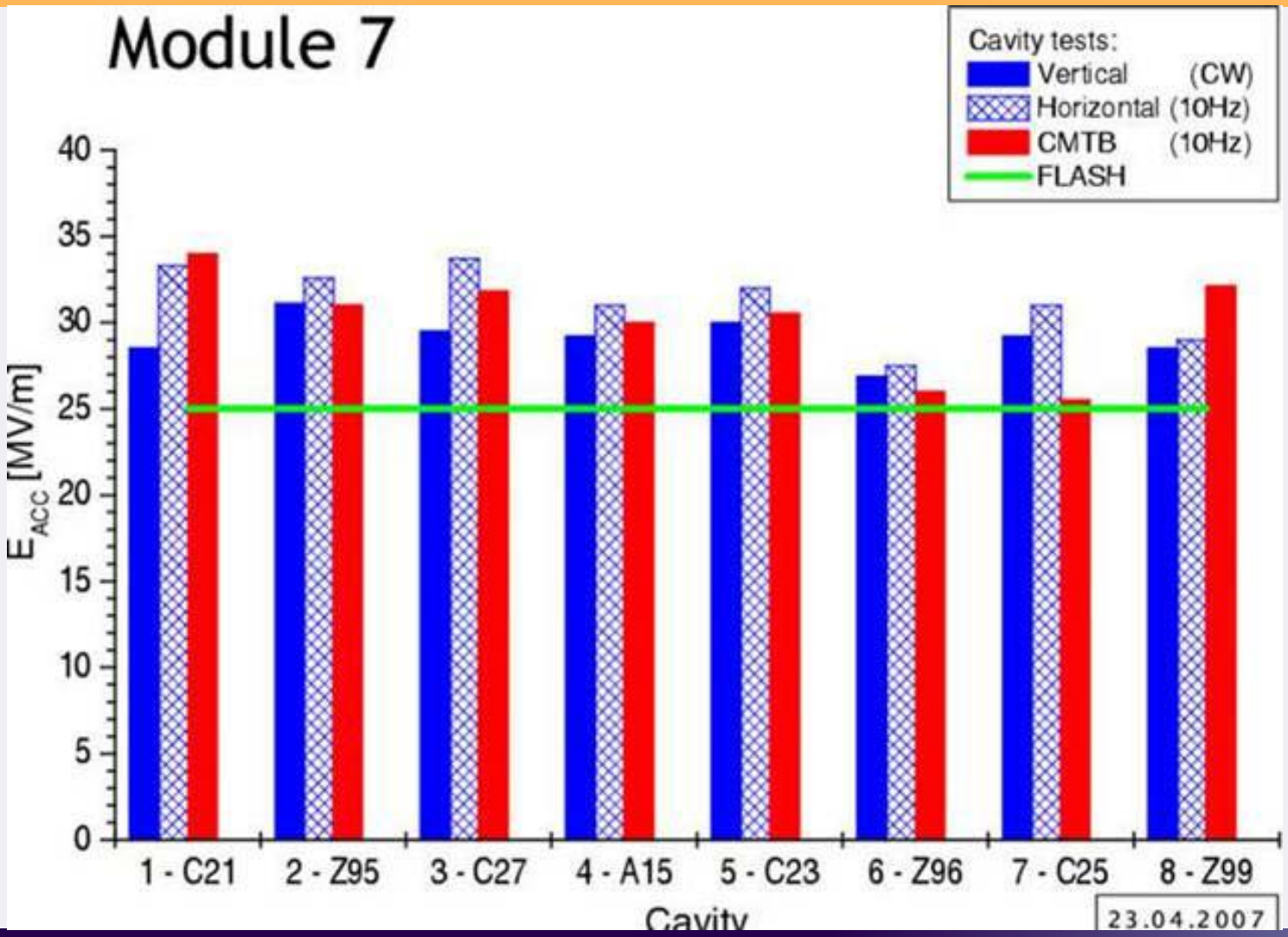
# XFEL Accelerator Module (Cryomodule)

- The XFEL accelerator module is based on the 3rd cryomodule generation tested at the TESLA Test Facility and designed by INFN.
- Already 10 cryomodules have been built and commissioned for the TTF Linac.
- Module 6 and Module 7 (repl. ACC3) were just recently installed at TTF/FLASH.
- Additional cryostats under construction:
  - Module 8
    - most likely ACC7
  - Module 9
    - FNAL ass. kit
  - Module 3**
    - spare ACC1, sched. 2008
  - 2-3 cryostats in 2008 with XFEL layout
    - Tendering process on-going

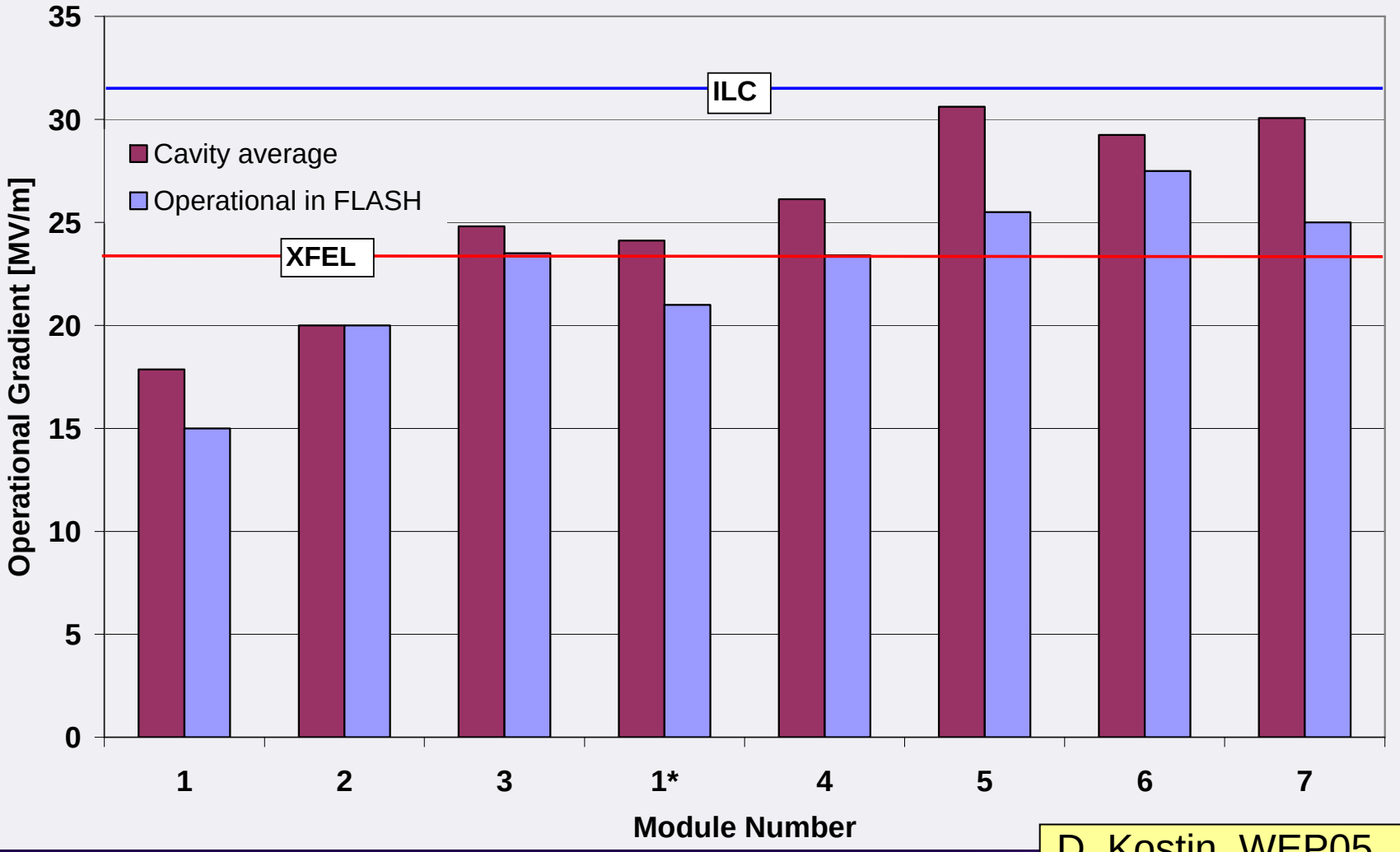


# Module #7 test results at CMTB

D. Kostin, WEP05



# Performance of Accelerator Modules



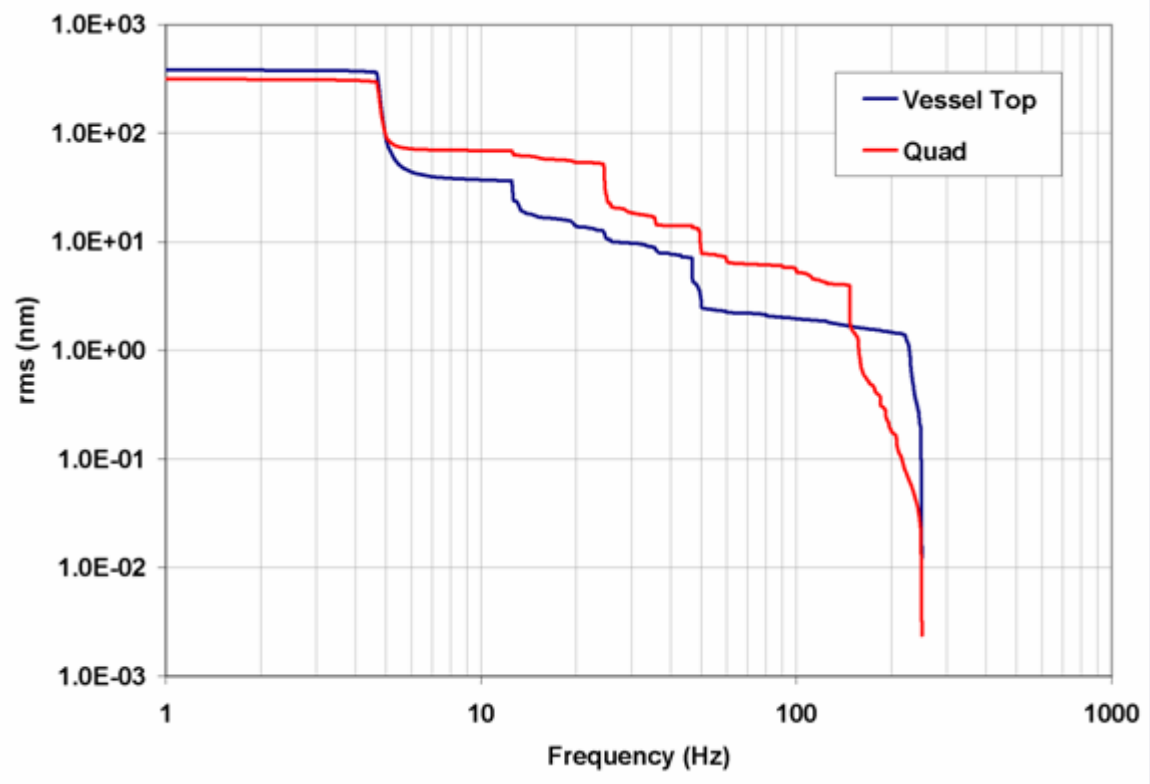

D. Kostin, WEP05

# Vibration studies – stability within module

Work done within ILC/EUROTEV programme

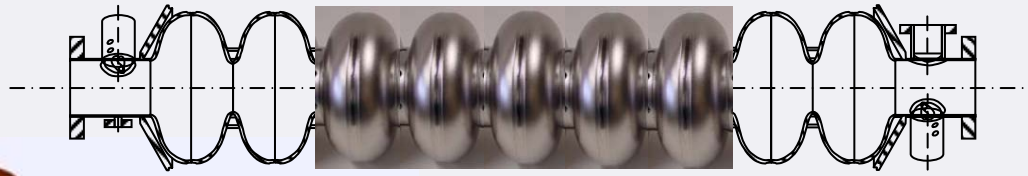
→Overall amplification of quad vibration vs. external vibration of module vessel is small

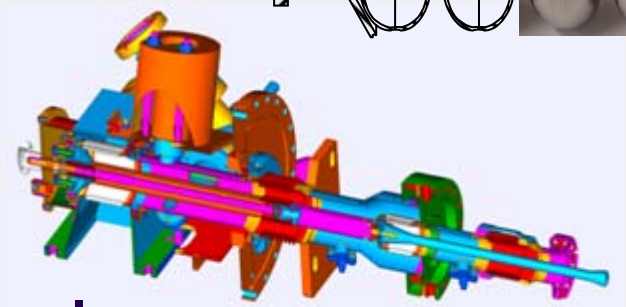
"Vibration Stability Studies of a Superconducting Accelerating Module at Room Temperature and at 4.5 K", R. Amerikas, A. Bertolini, LCWS07, DESY



# XFEL Accelerator Components

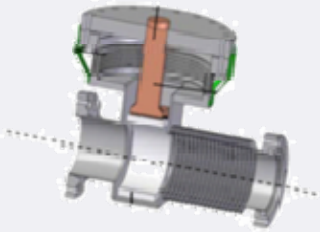
**cavities**





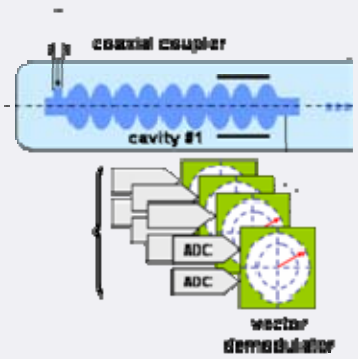
**coupler**

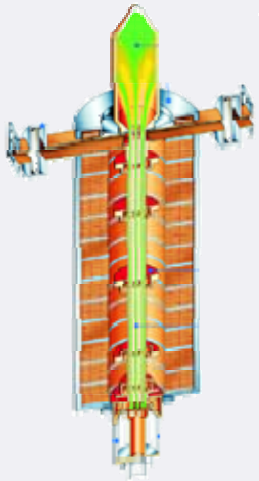
**TESLA Technology**



**HOMs**

**LLRF**

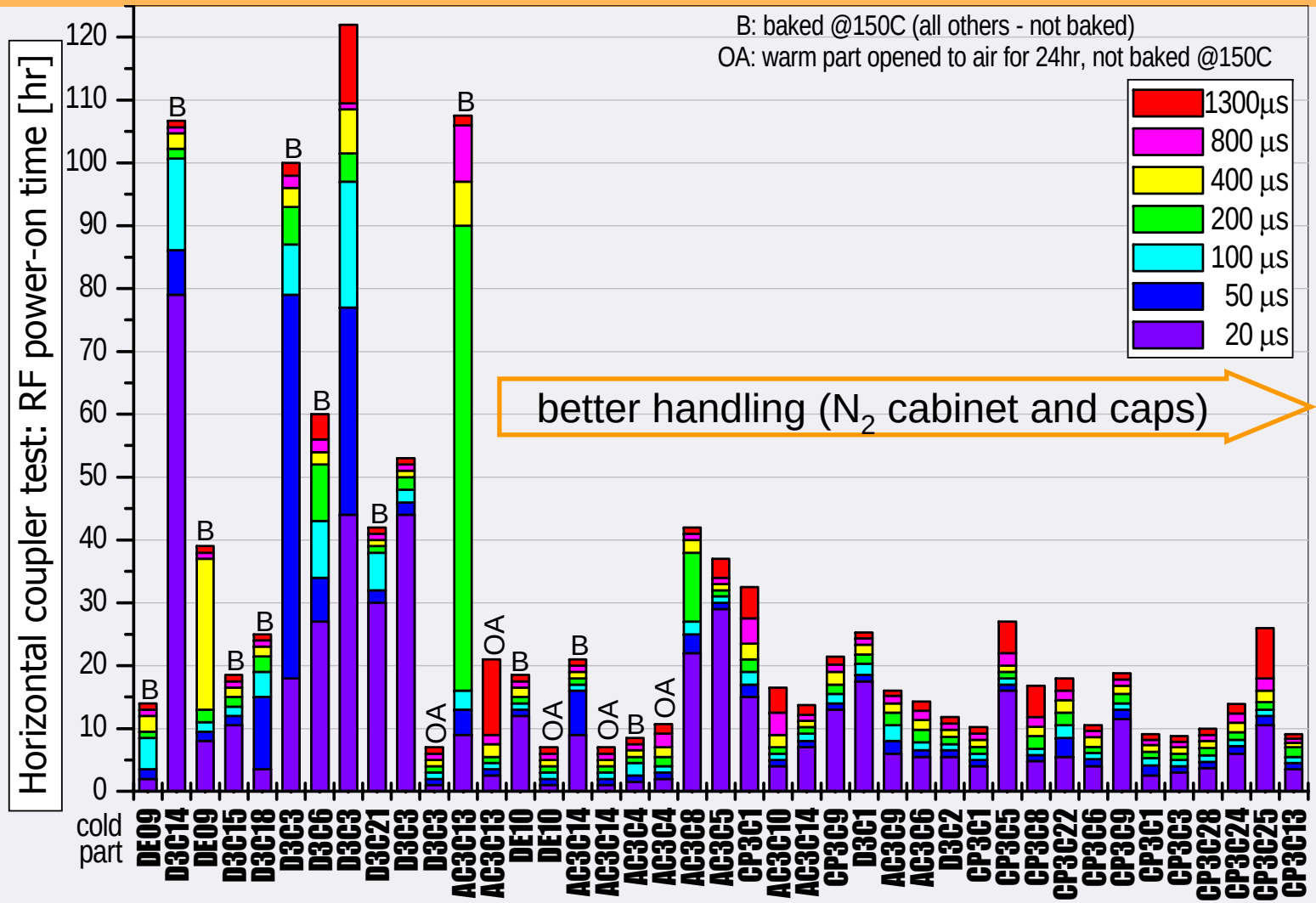


**RF**

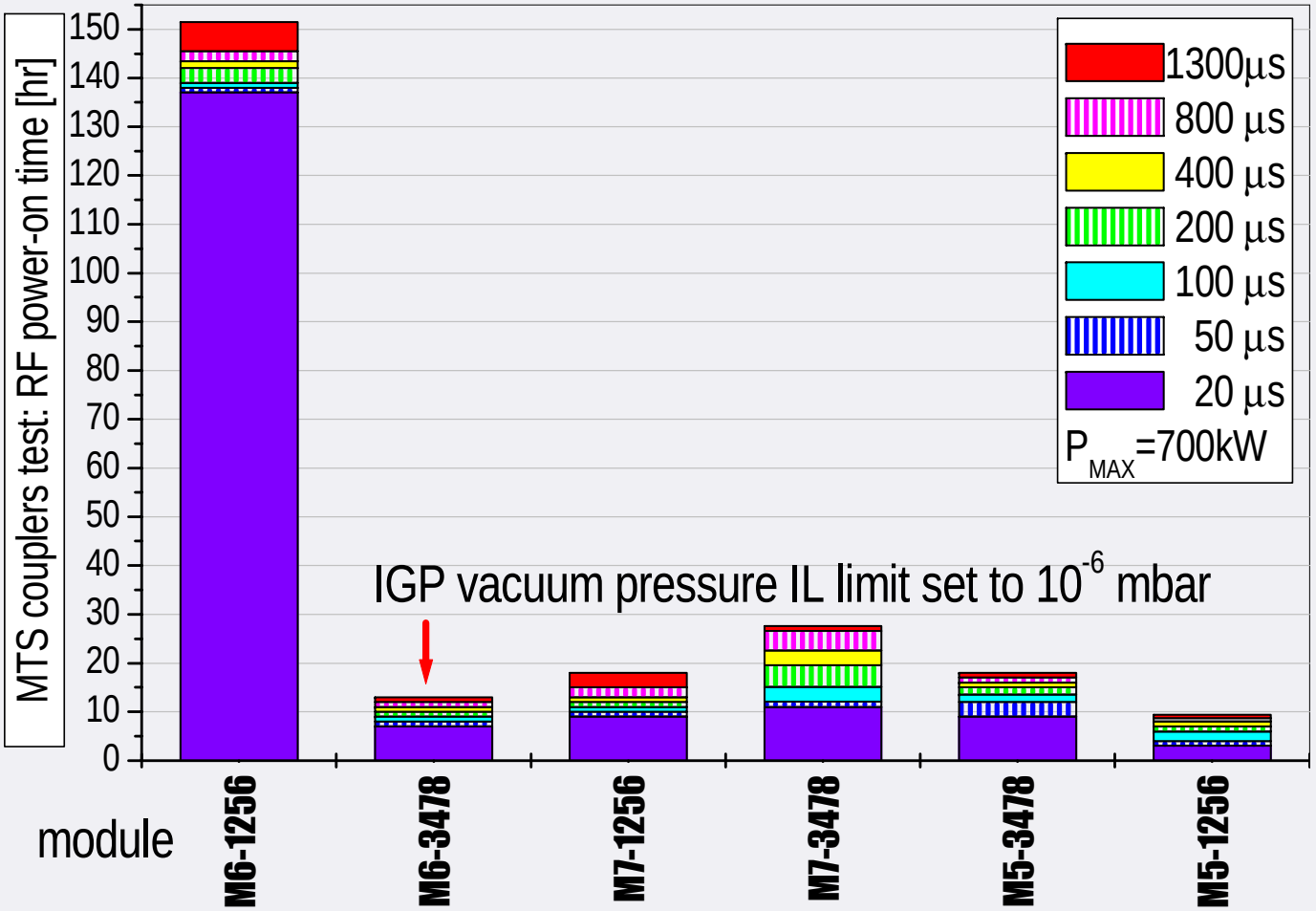
# Fast coupler processing (in CHECHIA)

D. Kostin



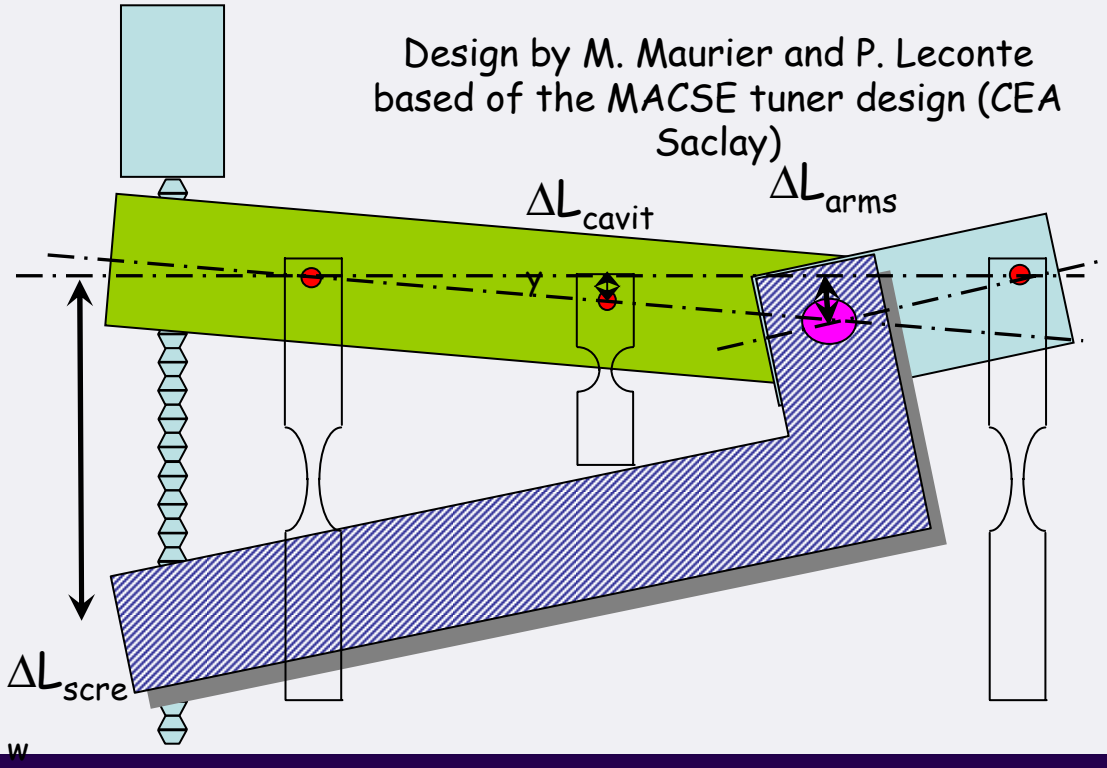
# Fast coupler processing (on CMTB)

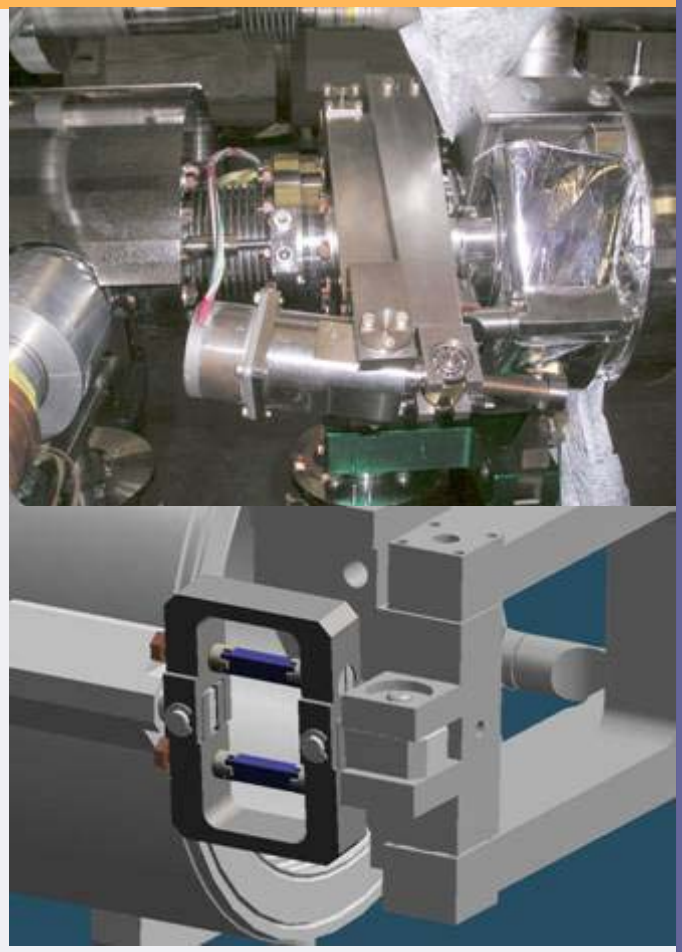
D. Kostin



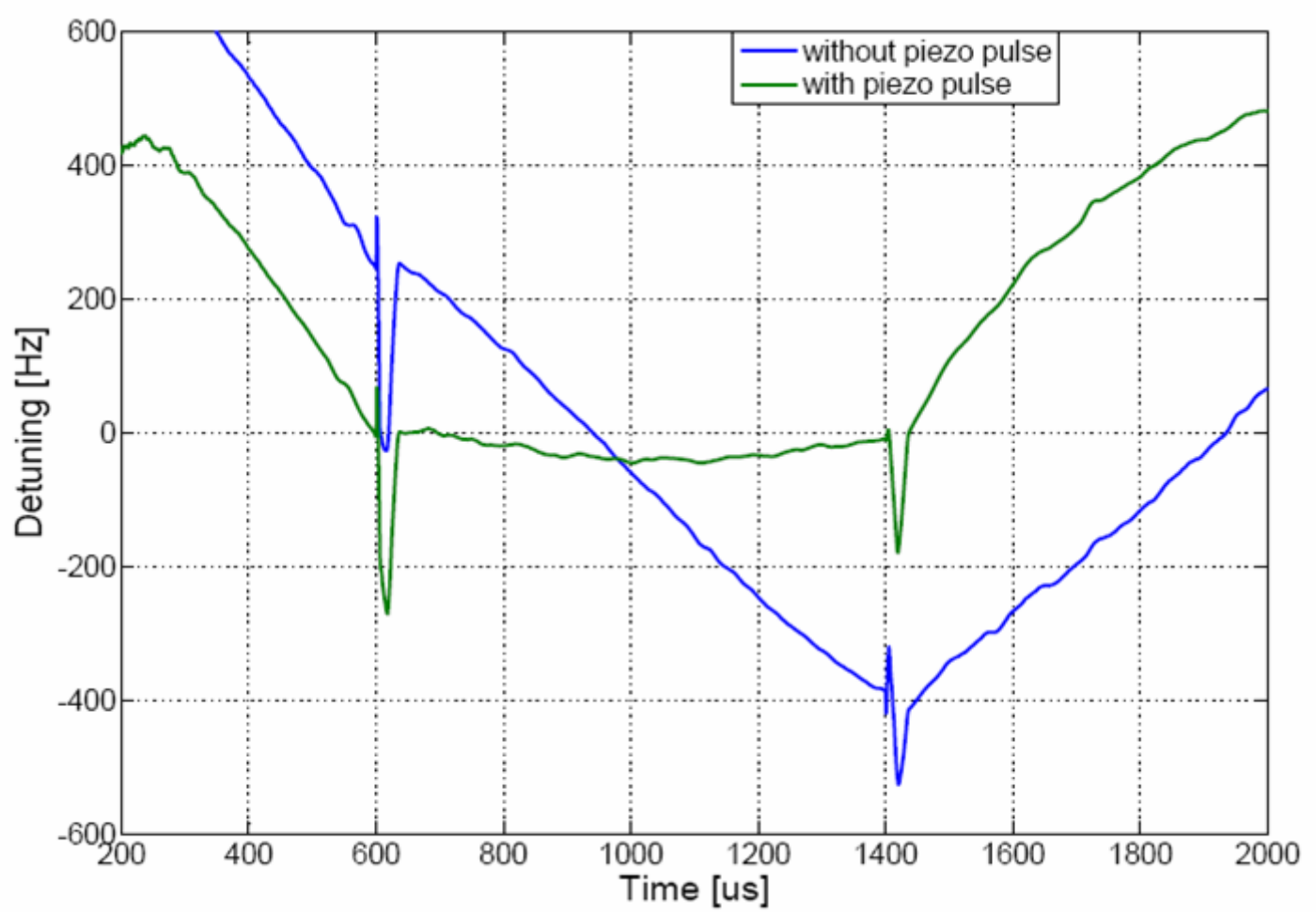
# XFEL Tuner

- Current design in use at FLASH
  - Design by CEA
  - Fast piezo detuning introduced not from beginning
  - Is the solution for XFEL so far



# XFEL Tuner: Compensation at 35 MV/m

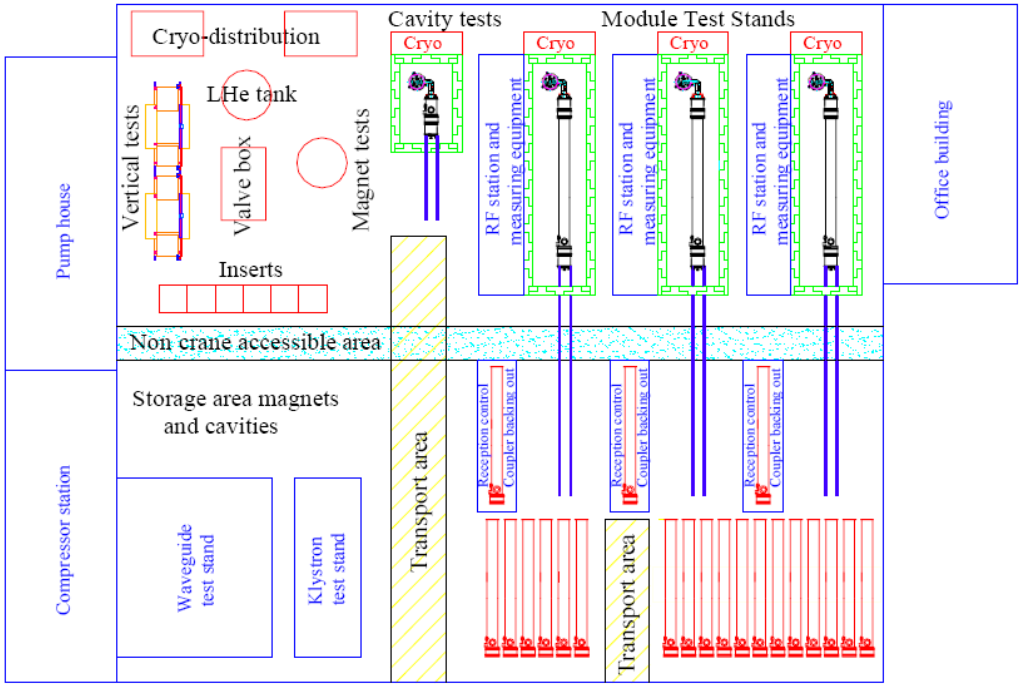


# XFEL Accelerator Modules: Delivery and Testing

- Number of components
  - Injector
    - RF Gun + 1 single accelerator module
  - Main Linac
    - 25 units (4 acc. modules each)
  - Energy reach
    - (1 ) x 4 x 8 x 23.6 = 500 MeV
    - (2+1) x 4 x 8 x 23.6 = 1.5 + spare -> 2 GeV
    - (20+1) x 4 x 8 x 23.6 = 15.1 + spare -> 17.5 GeV

- Schedule for modules (tentatively)
  - Module installation from 9/2012 until 3/2013 at a rate of 1 unit / day
    - Commissioning and cooldown in summer, beam by end of 2013
  - all modules to be tested at AMTF between mid 2010 and end 2012
  - Sub-components
    - cold-mass delivery at a rate of 1/week; 1st cold-mass delivered Q3/2009
    - 1st cavity string components Q3/2009
    - 1st module spring 2010
  - i.e. all accelerator components ready to order end of 2008;
    - actual R&D status supports this

# XFEL Test Facilities: Accelerator Module Test Facility




TDR version of the AMTF. After some iterations (costs, practicability) the final version to be built until 2009 will look slightly different.

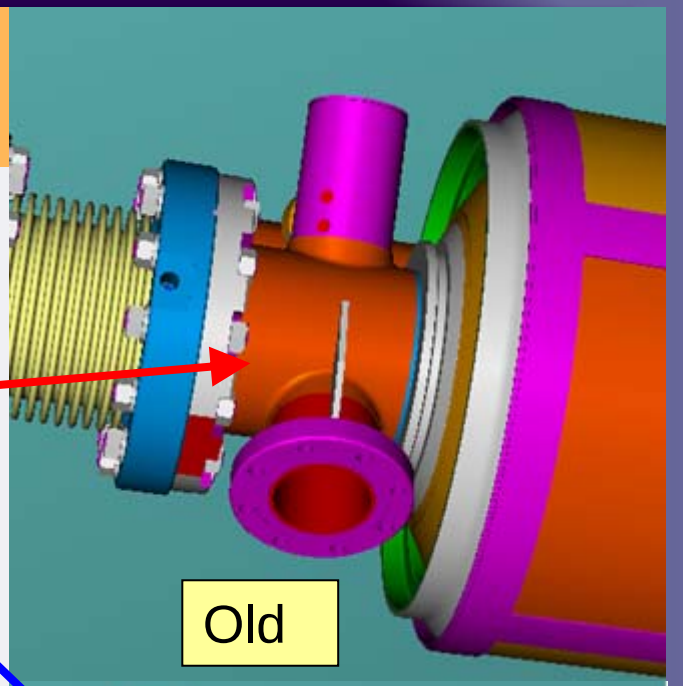
- The XFEL requires an **Accelerator Module Test** of all 101 individual modules.
  - The test rate is 1 module/week corresponding to the envisaged assembly rate.
- In order to be most efficient, the **vertical test** of bunches of cavities is integrated.
- Other issues are **waveguides and cold magnets**.

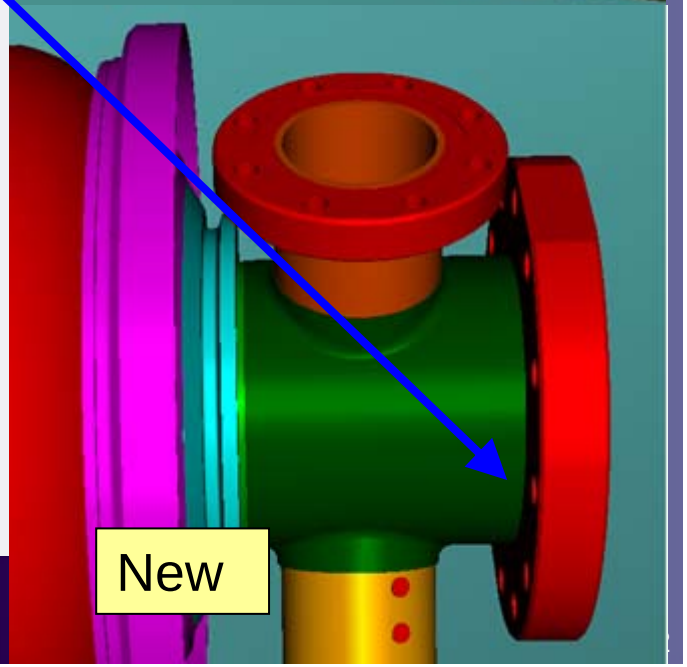
# XFEL Industrialization: Examples

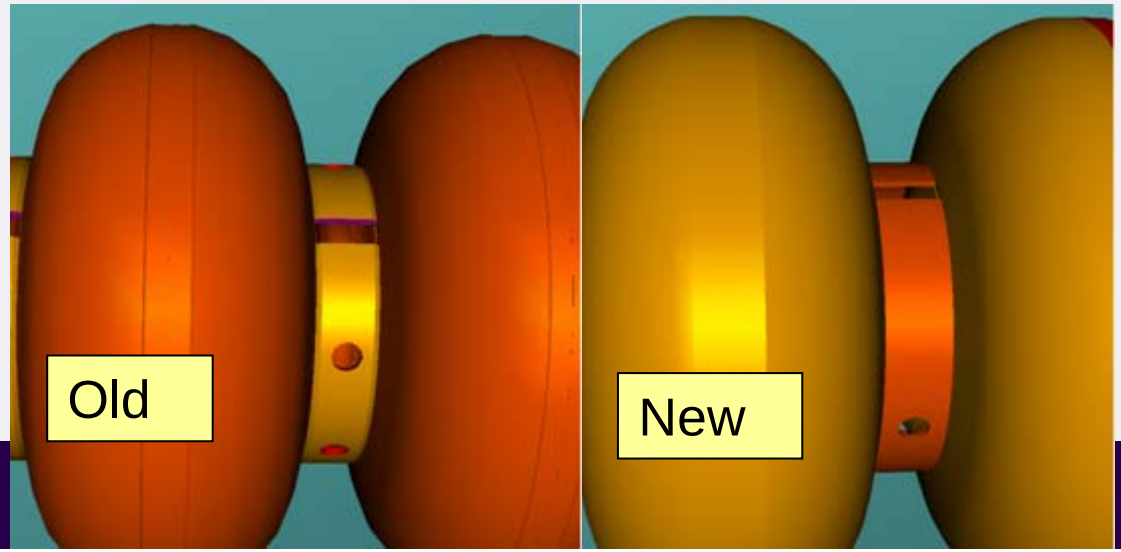
- Cavity
  - Re-design for simpler manufacturing
  - Train EP process in industry
- Coupler
  - Study at LAL Orsay
- Module
  - Study on module assembly

# TTF Cavity Today and XFEL Cavity

- Only minor design changes to reduce cost/simplify manufacturing will be done e.g.
  - Removal of coupler port stiffener
  - Removal of ‘pockets’ short side
  - Removal of outside recess
  - Less holes in stiffener ring
  - Thinner stiffener ring
- Review tolerances
  - Loosen where possible e.g. stiffeners rings



# XFEL Cavities

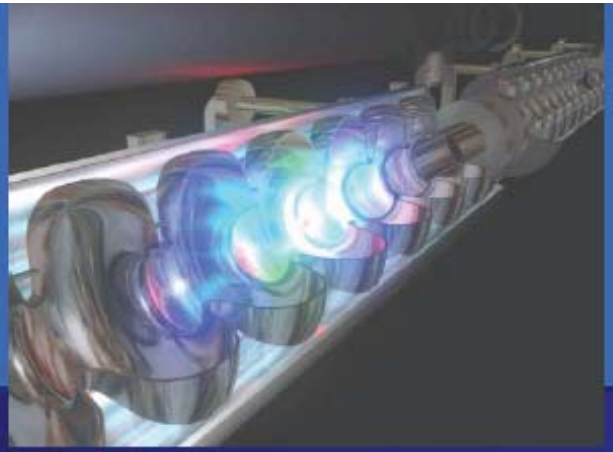
## The XFEL will use 808 accelerating cavities (rapid start-up scenario)

There are at least two well established ‘sources’ for an **industrial cavity production** guaranteeing the required rate of 8 to 10 cavities per week over two years. **At the companies, new infrastructure is required** but the effort is well understood.

**Cavity treatment will be done in industry.** In order to prepare this, two companies will do the first electro-polishing of 15  9-cell cavities each in 2007.

The **quality check** will be done in terms of a vertical test on the XFEL/DESY site. The **tested cavities will be given to industry** for string/module assembly.

Several Posters: A. Matheisen TUP30, A. Schmidt TUP28, N. Krupka TUP32, M. Schmökel TUP31, B.v.d. Horst, N. Steinhau-Kühl TUP33, D. Reschke TUP74 TUP77 , P. Gall TUP02

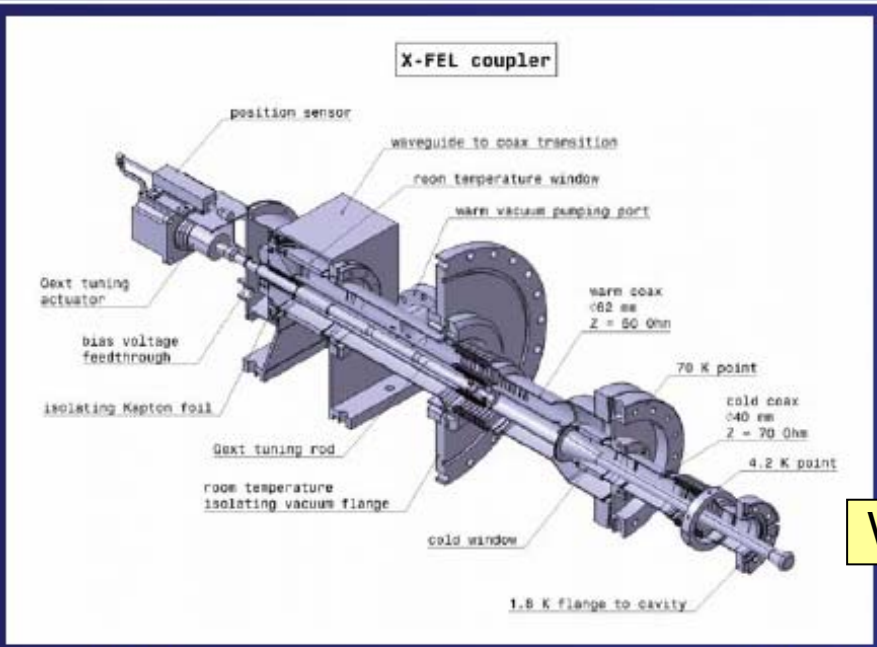


XFEL
X-Ray Free-Electron Laser

# Industrialization process for XFEL Power couplers and Volume manufacturing

TTC meeting at Fermi lab, April 2007

Serge Prat / LAL - Orsay

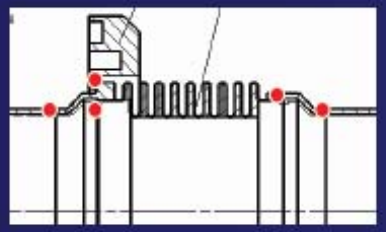



W.-D. Möller, TH202

# Some results

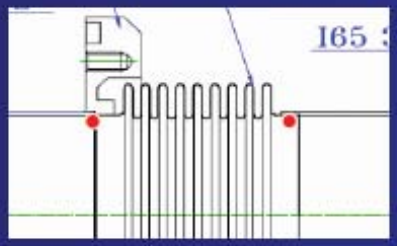
- Functional analysis
  - Small thermal emissivity coefficient → Polish the antenna (gain in radiative thermal power)
  - Thermal model → Cu rings at 4K point can be attached on thicker tube instead of bellows, brazed or glued
  - Big flange on vacuum vessel: 12 holes are enough instead of 24
  - Change some materials in actuator for radiation resistance
  - Choose PPS for connectors and Kapton for cable insulation
  - Floating big flanges must be supported

- Design for manufacturability
  - Choose deformation techniques instead of machining: *deep drawing, spinning, pull-out*
  - Optimize the process for vacuum brazing by use of special tooling: *adapt tolerances & thermal expansion*
  - Decrease number of parts and junctions:

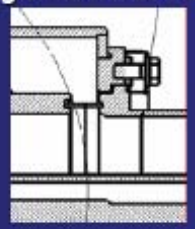


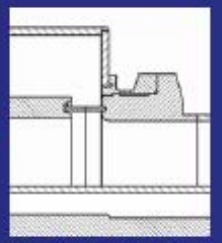
6 Parts 4

5 Junctions 2



- Lean manufacturing
  - Use RF seals for better electrical contact at waveguide interface box
  - Use chain clamp instead of screws for assembly





S. Prat, W.-D. Möller, TH202

A. Labanc WEP22

# Validation samples and tests

→ Manufacturing techniques:

- tube pull out for e- pickup and pumping ports
- deep drawing for conical part

→ TIG welding:

- Validate TIG welds from outside

→ Vacuum brazing:

- He leak test < $10^{-10}$ Pa $m^3/s$
- pull tests on window assembly

OK if

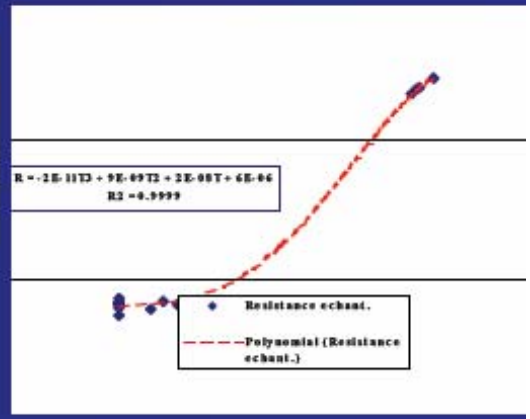
$\sigma_m$ > 100 MPa

→ Cu coating:

- adhesion test
- thickness uniformity measurements on bellows
- RRR measurements

→ TiN coating:

- layer thickness and stoichiometry
- $\varepsilon_R$ and tanδ measurements on ceramic



# XFEL Module Industrialization Study: E.g. Module Transportation

B. Petersen, TH201

ACCEL

**ACCEL Cryomodule Assembly Study I**

S. Bauer, B. Griep, M. Pekeler, H. Vogel, J. Zeutschel
ACCEL Instruments GmbH
Friedrich-Ebert-Str. 1
51429 Bergisch Gladbach

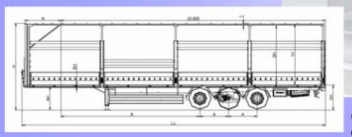
TTC meeting at FNAL, April 23-26, 2007

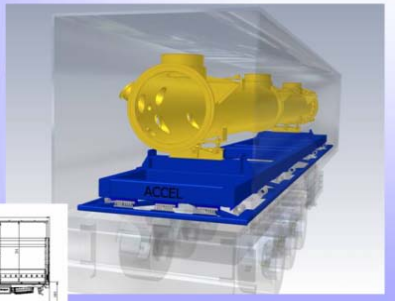


ACCEL

**possible solution for XFEL module transports**

- transport frame is mounted on truck
- truck can be loaded with crane from top
- truck travels between assembly site and XFEL site
- available length: 13.6 m
- available width 2.5 m
- available height: 2.5 m
- allowable weight: 12 t





Caution: top loaded road semi trailer hard to find outside EU. In US only hard cover or flat bed trucks (weather impact) available.



BILFINGER BERGER

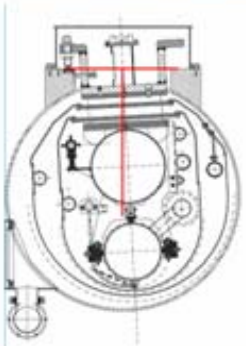
BABCOCK NOELL

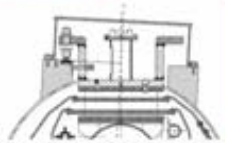
**Industry Study on the Series Production of XFEL Cryomodules**

C.Boffo, W. Gärtner, S. Sattler, G. Sikler, U.-M. Tai

**CM Transport Critical Components II**

BABCOCK NOELL





-A lift-off case has to be avoided.

-Bending of the post is still critical, even though distributed over three posts

-A fixture of the GRT at both ends will (widely) solve both problems (-stiffness of the GRT)

# Distribution of Workload

- Accelerator technology was and is a collaborative effort
  - Build on TESLA Collaboration
  - Some R&D support for from EU FP6 programs
    - E.g. CARE, EUROFEL, EUROTeV
- Common In-Kind Proposal for XFEL cold linac by several labs

# Accelerator Technology: Collaborative Effort

**Industrial study module assembly (M6 done, M8 autumn 2007)**

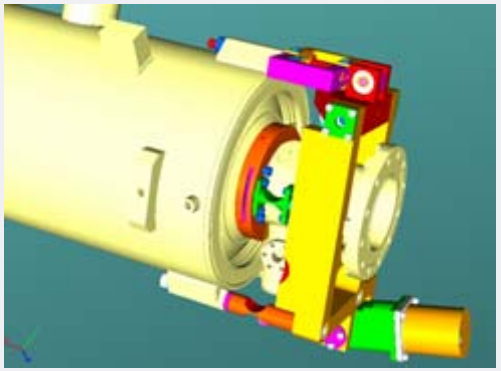
**2 more cryostats (TTF3/INFN) delivered**

**Superferric magnet (CIEMAT)**

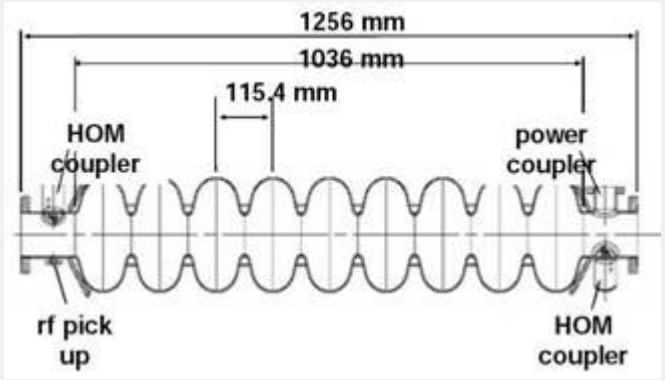
**BPM (Saclay)**

**Integrated HOM absorber**

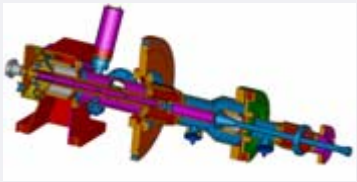
**Length quantized n·λ/2 (possibility of ERL)**



**Tuner w/piezo (Saclay)**




**LLRF development (collab. Warsaw/Lodz)**



**TTF3-type coupler**

**Industrialization launched (Orsay)**

In-kind Review Committee Meeting

# Common in-kind proposal for the superconducting linac of the XFEL WP3 – WP9 and WP11

presented by Hans Weise / DESY

for

CEA Saclay
CIEMAT
DESY
INFN
IPJ Swierk
LAL Orsay

# Approach to minimize the project risk for the XFEL cold linac

- With the goal to **define in-kind contributions to the superconducting linac of the XFEL**, a series of meetings was organized with the major players in the field.
- All meeting participants contributed with key components during the R&D effort of the TESLA Collaboration, i.e. can be seen as **experienced partners.**
- There might be additional interest by **'new-comers'** in the SCRF community. At this moment in time, the already identified interest of China is seen as a promising option but requires qualification of the institutes in terms of producing first prototypes of e.g. cold masses (the cryogenic unit of an accelerator module).
- Depending on the success and its timeline, new partners could either join the soon starting activities in the different laboratories, or, if the step from the current rapid start-up scenario with 100 modules to the final stage (116 modules) can be made, take some responsibility for additional accelerator sections.

# Laboratories involved and their fields of interest

The following laboratories were involved in the discussion of the cold linac and agreed on the delivery of a common proposal for the in-kind contributions. Besides clarification of a few still open questions, the final official in-kind proposal will also require approval of the individual funding agencies.

| Laboratory | Country | Fields of interest |
|---|---|---|
| CIEMAT | Spain | cold magnets, power supplies |
| LAL Orsay | France | main RF input coupler |
| DAPNIA Saclay | France | accelerator modules, cavities, cold beam position monitors (BPM), cold frequency tuners, 3.9 GHz harmonic accelerator section |
| INFN Milano | Italy | accelerator modules, cavities |
| DESY | Germany | accelerator modules, cavities, cold beam position monitors (BPM), cold frequency tuners, cold vacuum system |
| IPJ Swierk | Poland | HOM |

# Summary

| | | Laboratory | Country | Invest / M€ | FTE | FTE / M€ |
|---|---|---|---|---|---|---|
| Accelerator Modules | WP – 3 | CEA Saclay | France | 60% | | 43% |
| | | INFN | Italy | 19% | | 29% |
| | | DESY | Germany | 21% | | 29% |
| | *sum* | | | *100%* | | *100%* |
| Superconducting Cavities | WP – 4 | INFN | Italy | 50% | | 34% |
| | | DESY | Germany | 50% | | 66% |
| | *sum* | | | *100%* | | *100%* |
| | | Received from WP-9 | | | | |
| Power Couplers | WP – 5 | LAL Orsay | France | 73% | | 52% |
| | | DESY | Germany | 27% | | 48% |
| | | or | | | | |
| | | LAL Orsay | France | 99% | | 100% |
| | | DESY | Germany | 1% | | 0% |
| | *sum* | | | *100%* | | *100%* |
| HOM Coupler / Pick-up | WP – 6 | IPJ Swierk | Poland | 100% | | 100% |
| | *sum* | | | *100%* | | *100%* |
| Frequency Tuners | WP – 7 | DESY | Germany | 100% | | 100% |
| | *sum* | | | *100%* | | *100%* |
| Cold Vacuum | WP – 8 | DESY | Germany | 100% | | 100% |
| | *sum* | | | *100%* | | *100%* |
| Cavity String Assembly / Clean Room Quality Assurance | WP – 9 | CEA Saclay | France | 90% | | 51% |
| | | DESY | Germany | 10% | | 49% |
| | | Transferred to WP-4 | | | | |
| | *sum* | | | *100%* | | *100%* |
| Cold magnets | WP - 11 | CIEMAT | Spain | 56% | | 10% |
| | | DESY | Germany | 44% | | 90% |
| | *sum* | | | *100%* | | *100%* |

# Summary and Conclusions

- XFEL Project has started
  - Official opening ceremony on 5th of July 2007
  - Started to set up In-Kind contributions
- Modules design is mature
  - Several successful tests on CMTB and in FLASH
    - E.g. Coupler Processing, thermal cycling, fast tuner performance
- Industrialization for large series ongoing
  - Several studies concerning components on the way
    - E.g. EP in industry, high-power couplers, module assembly
  - Define/fix in-kind contributions
    - All experienced european labs participating
  - Goal:
    - Finish specifications so that tendering process can be started in fall 2008