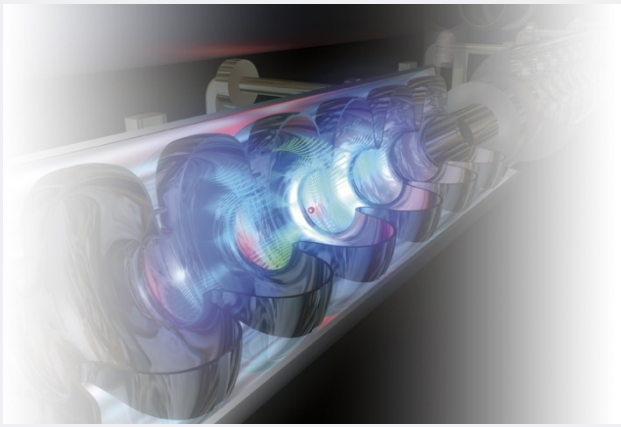
Government of India
Department of Atomic Energy
BHABHA ATOMIC RESEARCH CENTRE

भारत सरकार
परमाणु ऊर्जा विभाग
राजा रामन्ना प्रगत प्रौद्योगिकी केन्द्र, इंदौर

Government of India
Department of Atomic Energy
Raja Ramanna Centre for Advanced Technology, Indore

Status XFEL

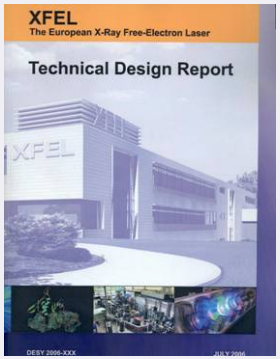
Hans Weise



TESLA Technology Collaboration Meeting
New Delhi, October 20th – 23th, 2008

DESY HELMHOLTZ GEMEINSCHAFT

Introduction / History



Oct 2002: XFEL supplement to TESLA TDR → Feb 2003 approval by German government to realize the XFEL as European project with at least 40% funding contributions from partners ***→ intense preparation work on technical design, industrialization of components, evaluation of cost/schedule, international project organization***

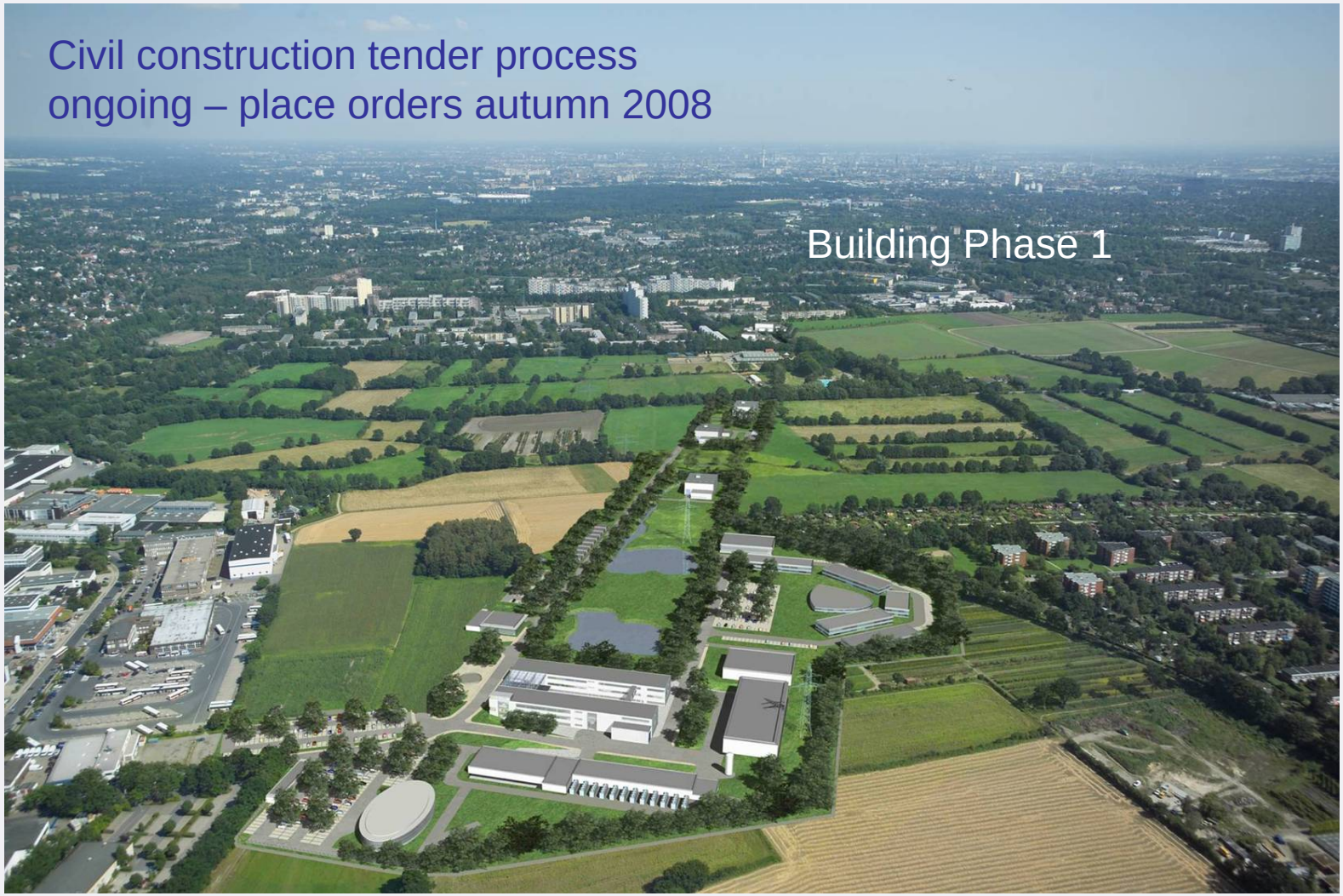
July 2006: completion of XFEL TDR, submitted to and approved by International Steering Committee ***→ 986M€/y2005 construction cost (+preparation & commissioning cost), negotiations of funding contributions continuing***

June 5, 2007: Official project start announced on basis of initially de-scoped start version at 850M€/y2005 construction cost ***→ launch tender process for civil construction, finalization of legal documents & prep of XFEL GmbH foundation, negotiations of in-kind contributions***

Overall layout of the European XFEL

XFEL site in Hamburg/Schenefeld

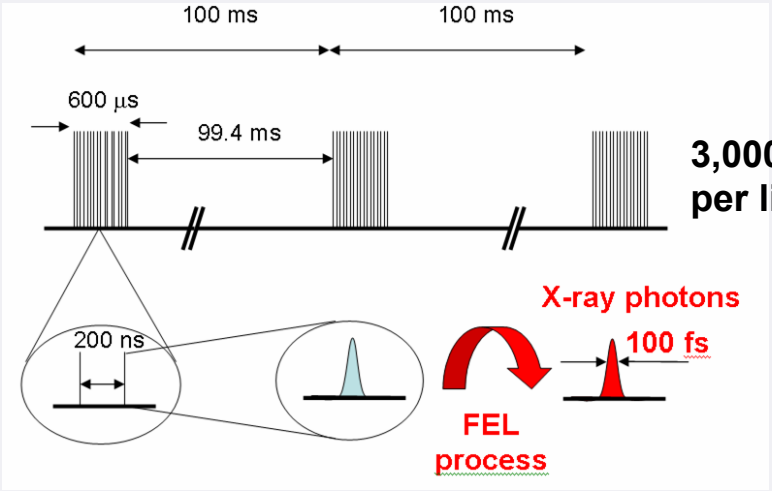
… after construction *(computer simulation)*



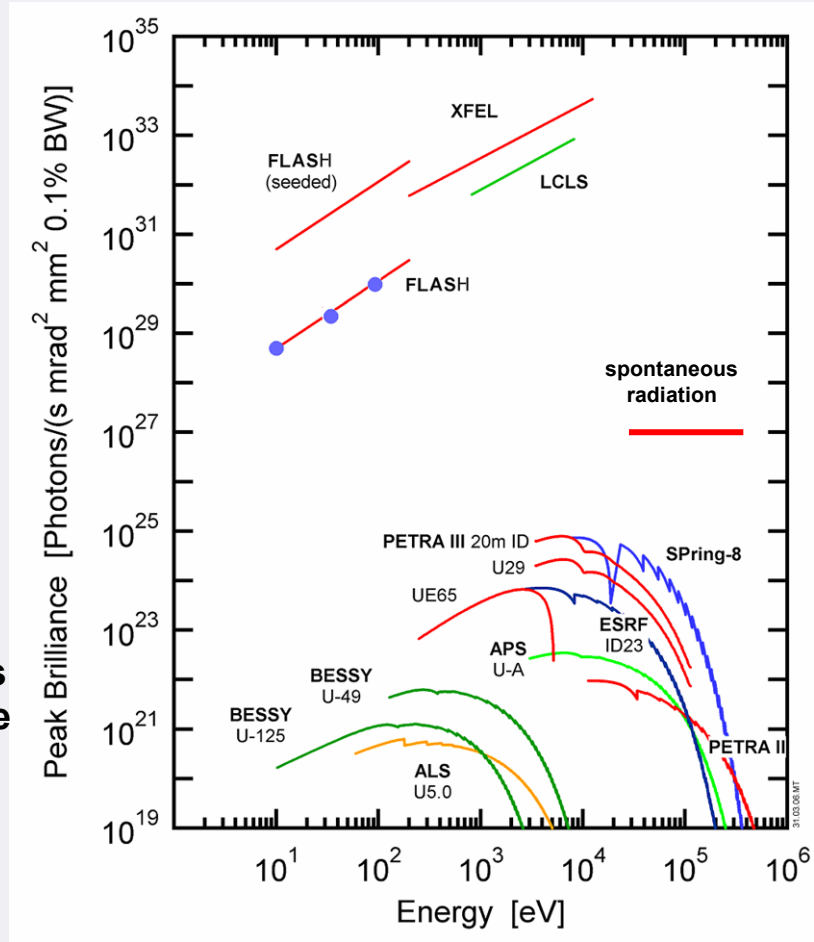
Properties of XFEL radiation

X-ray FEL radiation (0.2 - 12.4 keV)
- ultrashort pulse duration <100 fs (rms)
- extreme pulse intensities 10^{12}-10^{14} ph
- coherent radiation x10^{9}
- average brilliance x10^{4}

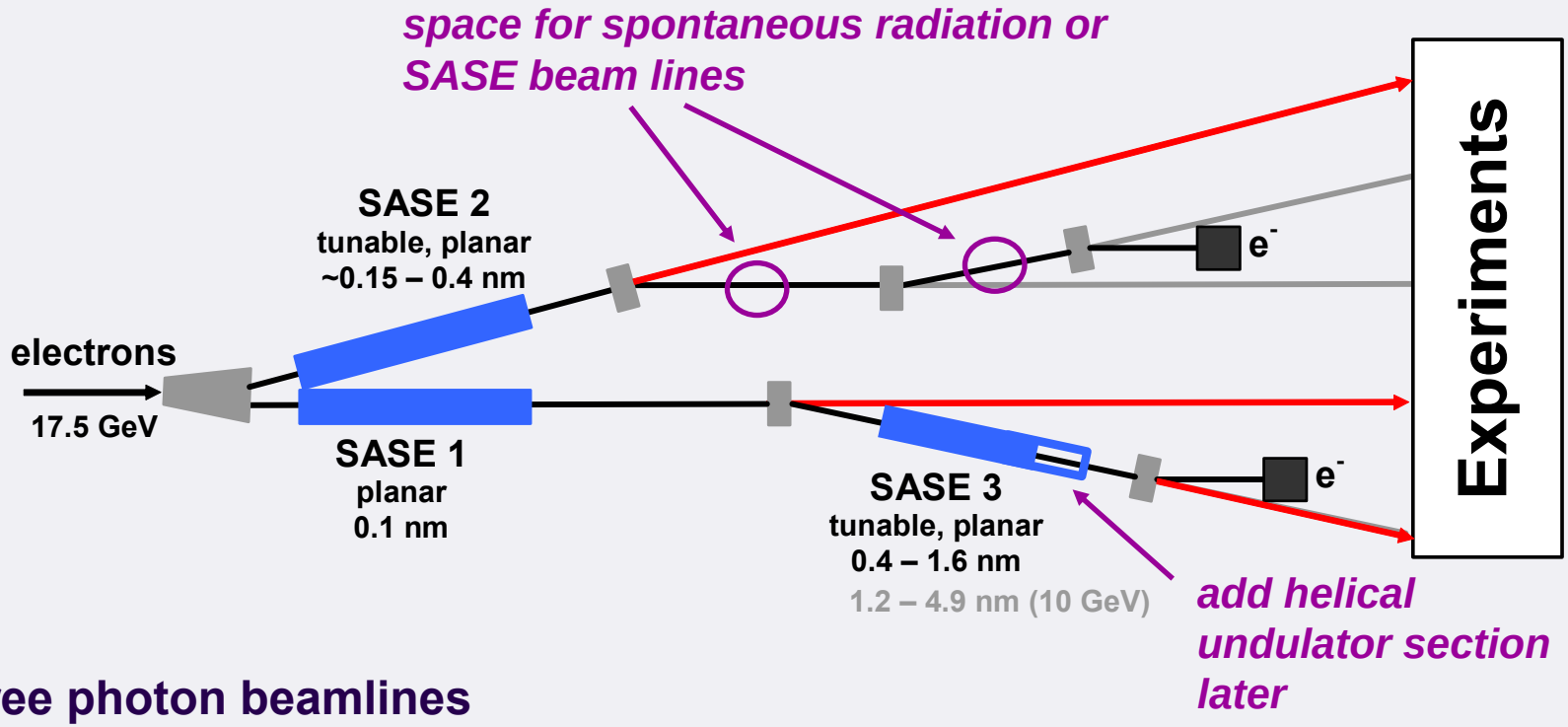
Spontaneous radiation (20-100 keV)
- ultrashort pulse duration <100 fs (rms)
- high brilliance



3,000 bunches per linac pulse



Beam lines in start version



three photon beamlines

superconducting linac: 17.5 GeV

→ Photon wavelengths below 0.1 nm design value require a linac gradient above 23.6 MV/m (design value)

Selection of first instruments was made

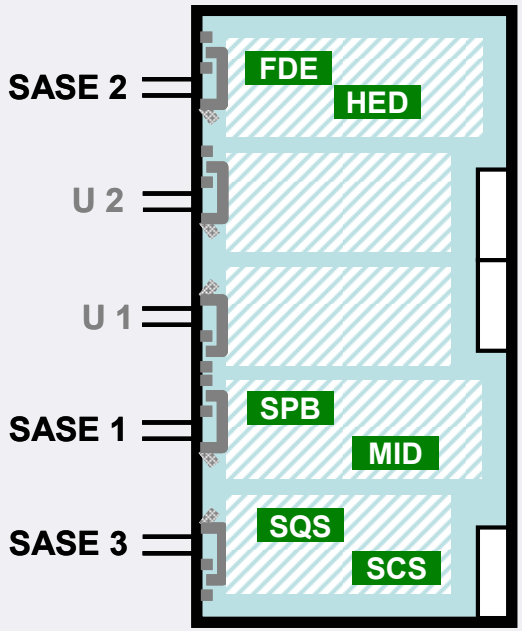
Hard X-rays

Soft X-rays

Instrument	Brief description of the instrument
SPB	Ultrafast Coherent Diffraction Imaging of **S**ingle **P**articles, Clusters, and **B**iomolecules – **Structure determination of single particles: atomic clusters, bio-molecules, virus particles, cells.**
MID	**M**aterials **I**maging & **D**ynamics **–Structure determination of nano- devices and dynamics at the nanoscale.**
FDE	**F**emtosecond **D**iffraction **E**xperiments – **Time-resolved investigations of the dynamics of solids, liquids, gases**
HED	**H**igh **E**nergy **D**ensity Matter – **Investigation of matter under extreme conditions using hard x-ray FEL radiation, e.g. probing dense plasmas.**
SQS	**S**mall **Q**uantum **S**ystems – **Investigation of atoms, ions, molecules and clusters in intense fields and non-linear phenomena.**
SCS	**S**oft x-ray **C**oherent **S**cattering **–Structure and dynamics of nano-systems and of non-reproducible biological objects using soft X-rays.**

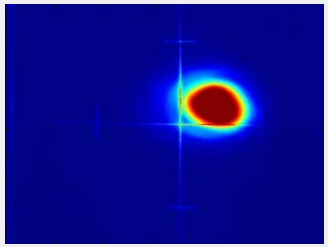
Distribution of first instruments

Source	Photon beam line characeristics
SASE 1	FEL radiation ~12 keV High coherence Spontaneous radiation (3rd, 5th harmonics)
SASE 2	FEL radiation 3-12 keV High time-resolution Spontaneous radiation (3rd, 5th harmonics)
SASE 3	FEL radiation 0.25 – 3 keV; High flux
	FEL radiation 0.25 – 3 keV; High resolution

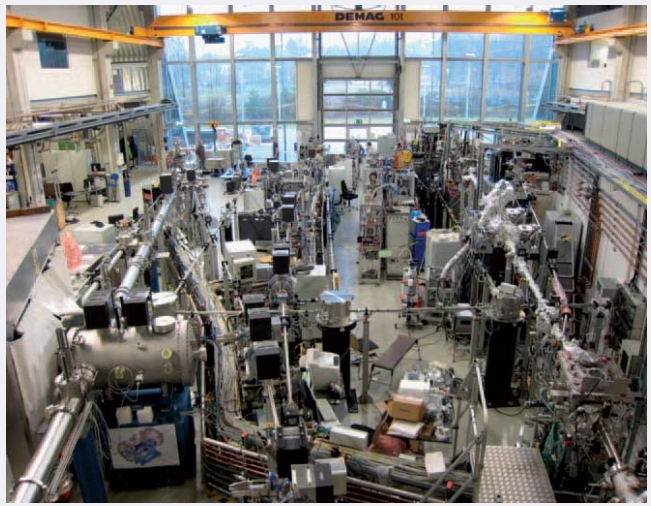


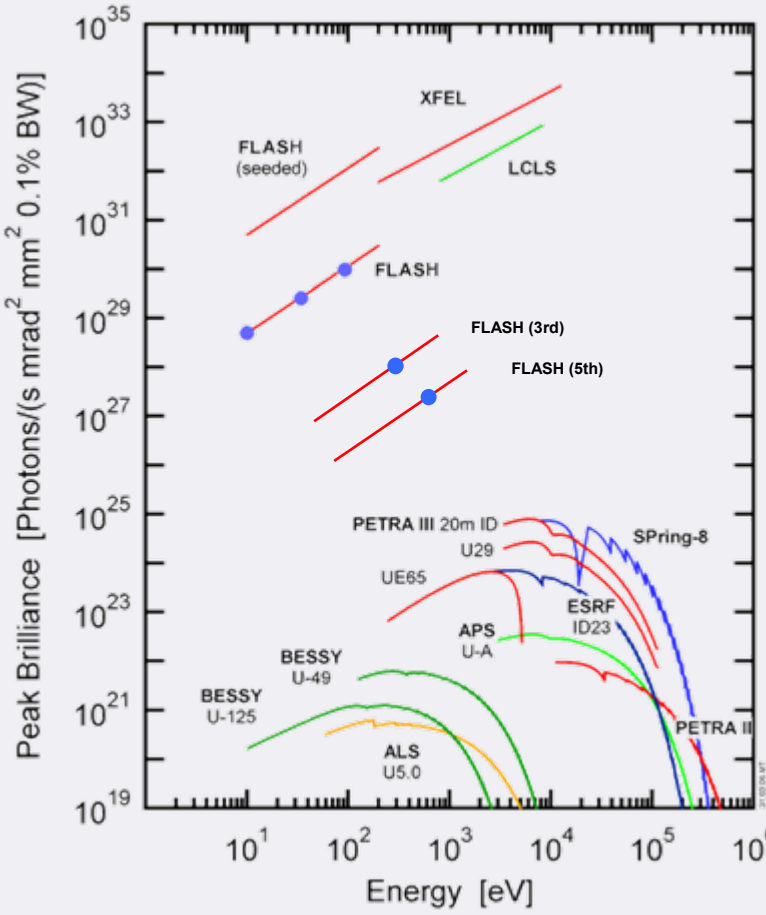
FLASH – Free-Electron Laser in Hamburg

Wavelength (fundamental)	**47 – 6.5**	**nm**	**(tunable!!!)**
FEL range (harmonics)	**→ 2.7**	**nm**	
Average energy per pulse	up to 100	µJ	
Maximum energy per pulse	200	µJ	
Radiation pulse duration	10 – 50	fs	
Peak power (calc. from average)	~ 3 – 4	GW	
Spectral width (FWHM)	**0.5 – 1**	**%**	
Angular divergence (FWHM)	160	µrad	
Peak brilliance (calc. from max)	**5-10×10²⁹**	ph/s/mrad²/mm²/(0.1% bw)	

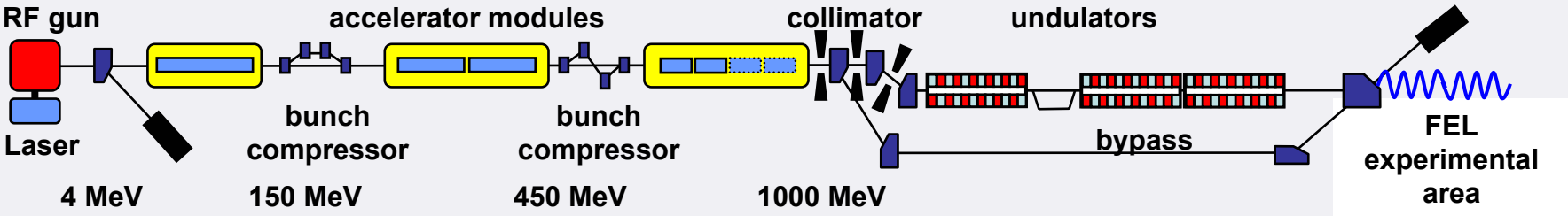


<E> = 70 µJ





The FLASH VUV-FEL facility at DESY



→ **6 accelerator modules** routinely in operation; design beam energy & photon wavelength (6.5 nm) since Oct. 2007

→ **pilot facility** regarding practically all aspects (accelerator technology, beam physics, FEL process, user operation) of the XFEL

FLASH and XFEL

Time to explore the femtosecond dynamics of nature

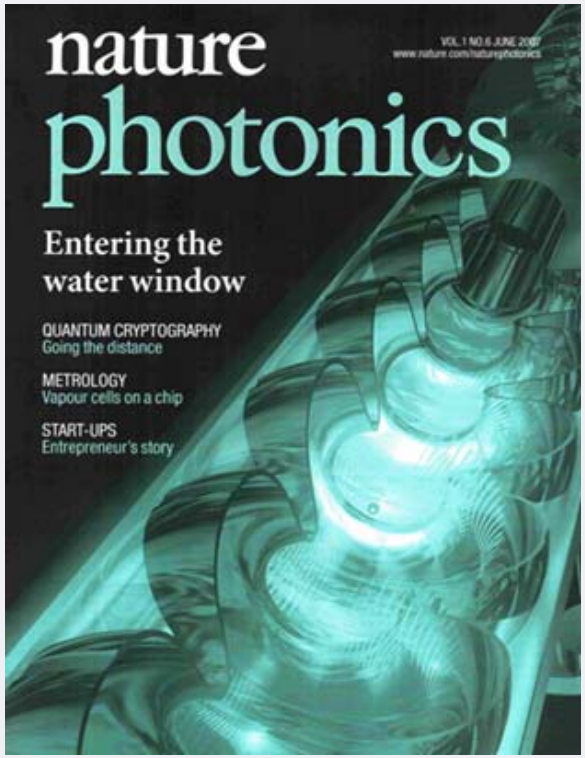
- ***Ever seen the machinery of a living cell at work at atomic resolution?***

- ***Observed how molecules change shape in femtoseconds during chemical or biochemical reactions?***

- ***Watched a drug molecule enter a protein receptor in real time?***

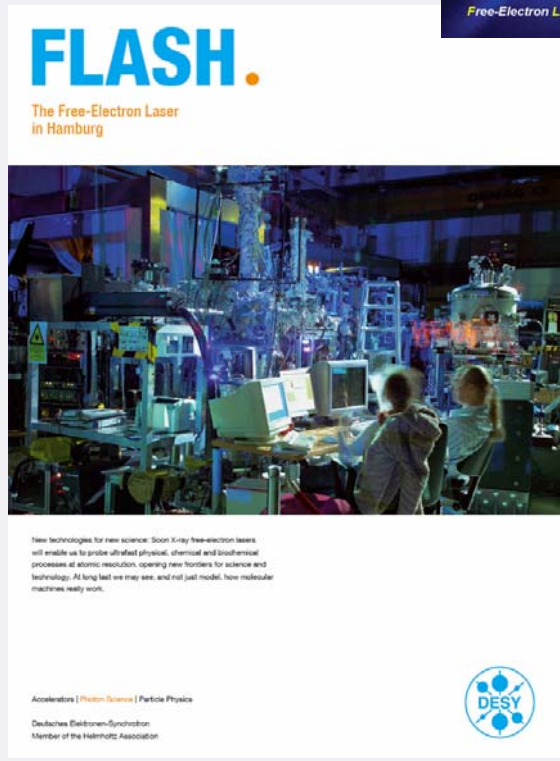
Soon X-ray free-electron lasers will enable us to probe ultra fast physical, chemical and biochemical processes at atomic resolution, opening new frontiers for science and technology.
At long last we may see, and not just model, how molecular machines really work.

FLASH References



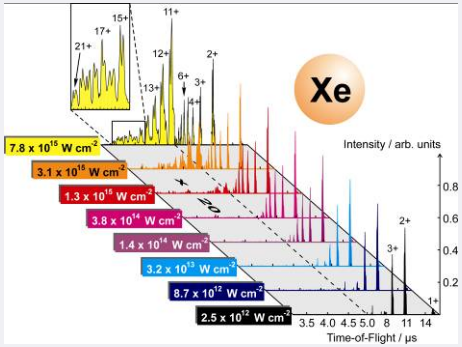
Operation of a free-electron laser from the extreme ultraviolet to the water window

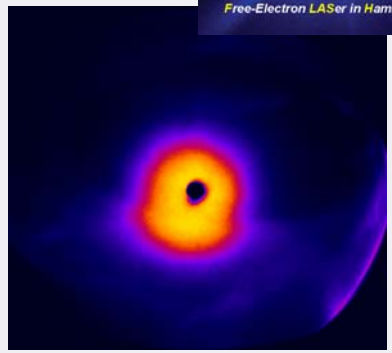
nature photonics | VOL 1 | JUNE 2007 | www.nature.com/naturephotonics

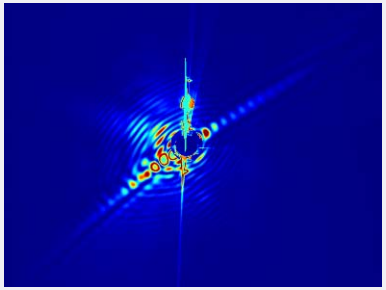


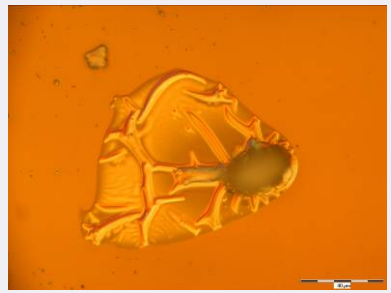
http://flash.desy.de/

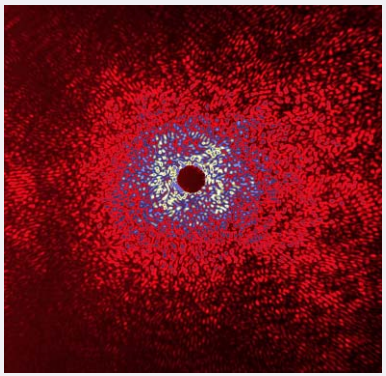
Experiments with the FEL Beam



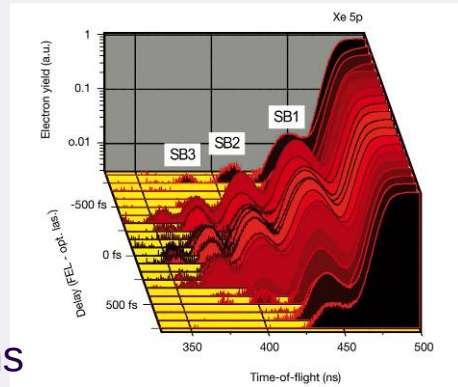






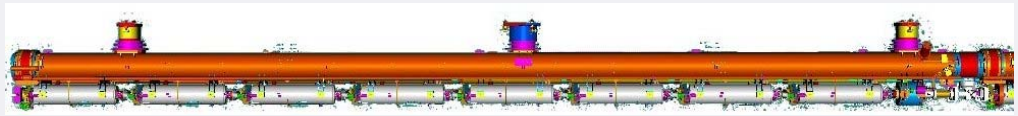


about 30 publications already,
many more to come
11 PRL
6 APL
1 Nature,
1 Nature Physics
4 Nature Photonics
...
See, e.g.,
http://hasylab.desy.de/facilities/flash/publications



Accelerator complex & TESLA Technology

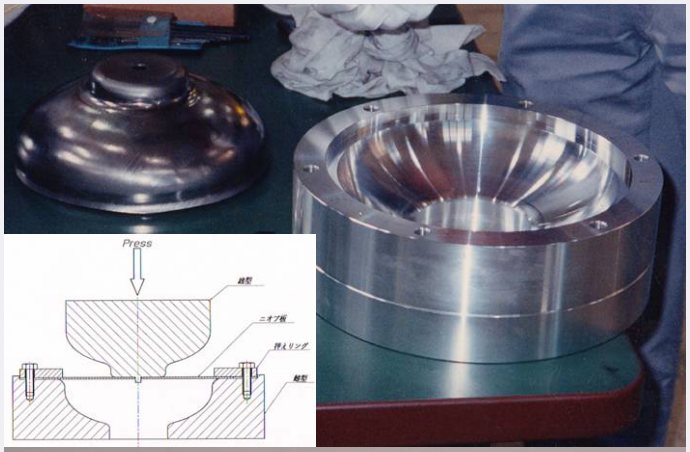
100 accelerator modules

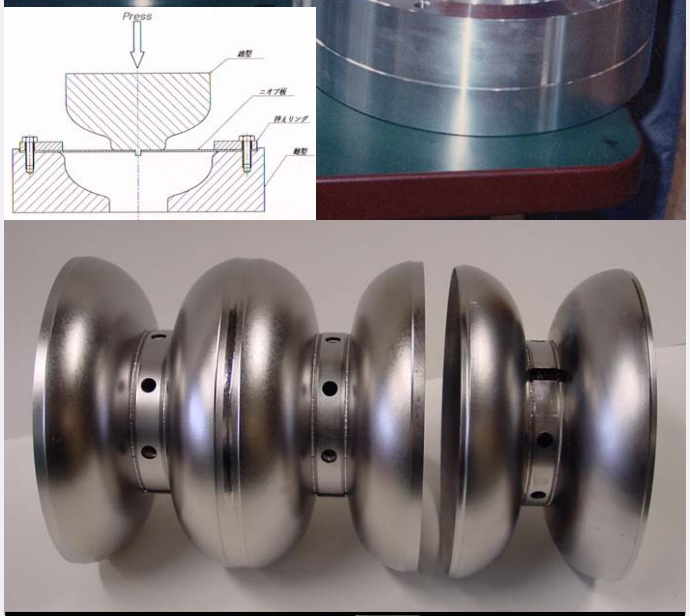


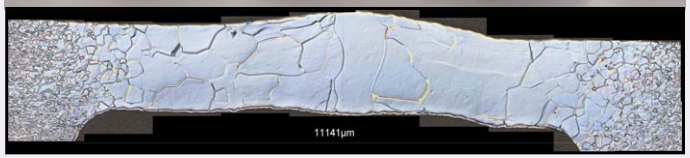
800 accelerating cavities
1.3 GHz / 23.6 MV/m

25 RF stations
5.2 MW each

XFEL cavity fabrication





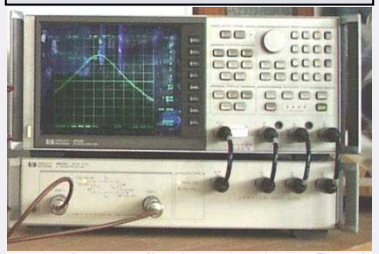


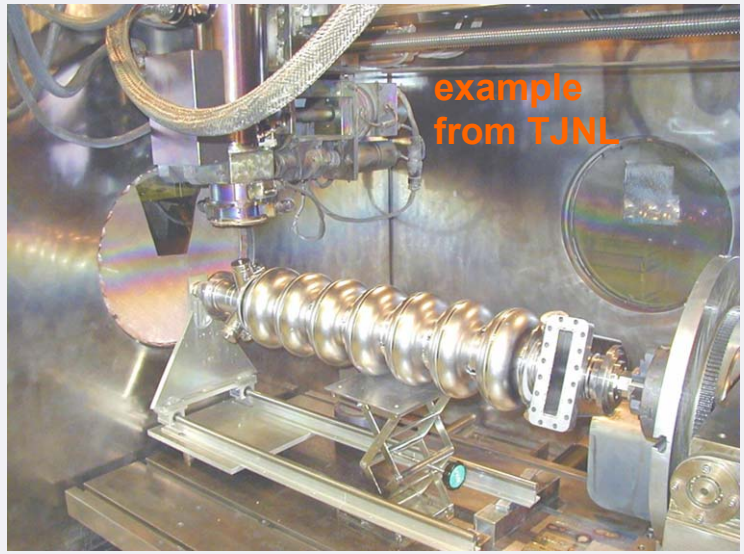
Half cells are produced by **deep drawing**.

Annealing is next to achieve complete re-crystalisation.

Dumb bells are formed by **electron beam welding**.

RF measurements support visual **inspection**.





After proper **cleaning** eight dumb bells and two end group sections are assembled in a precise fixture.

All **equator welds** can be done in one production step.

Engineering Data Management Systems (EDMS) is used for the **documentation of the cavity fabrication process**.

XFEL cavity preparation test cycle

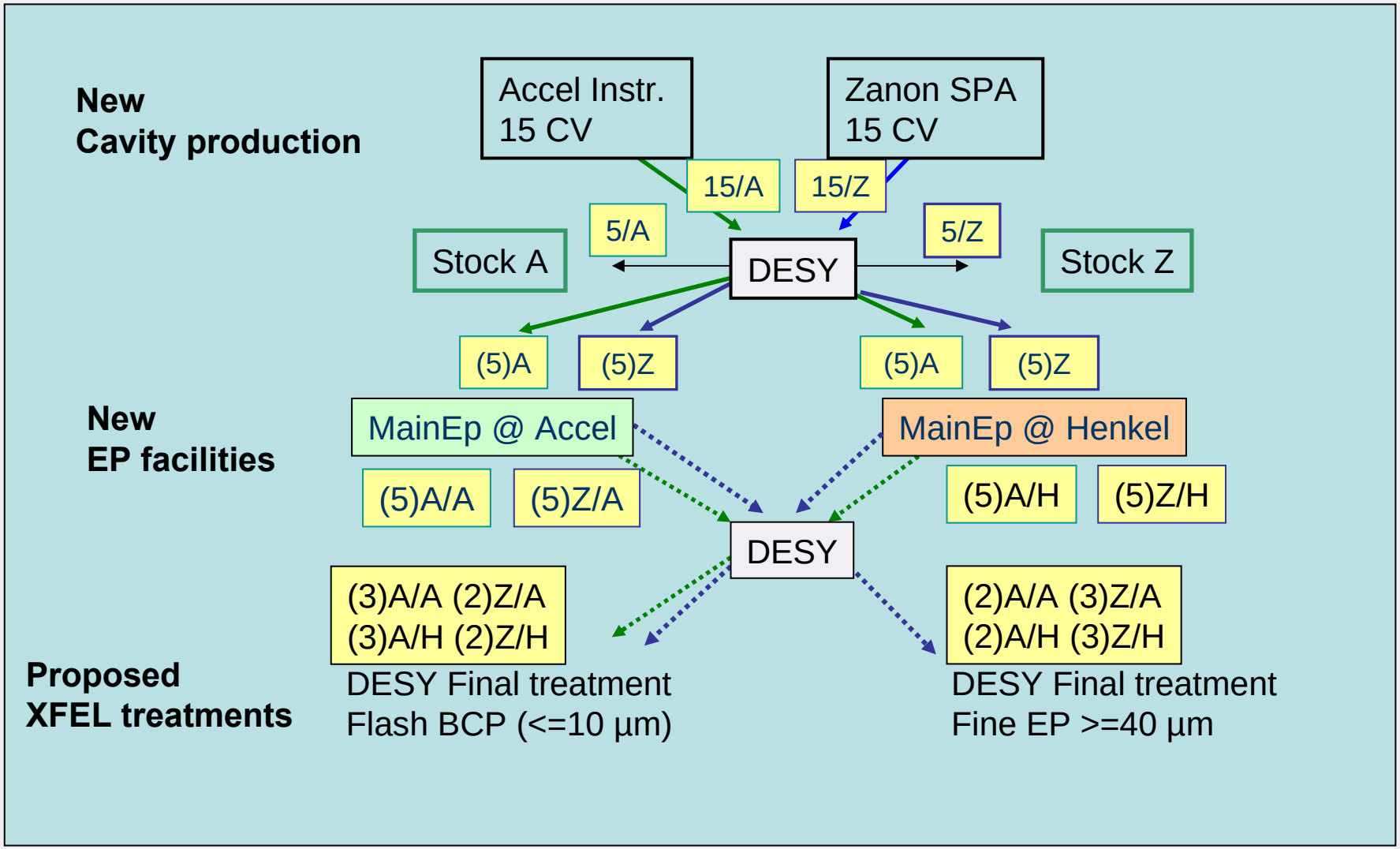
Proposal for minimum cost: One RF Test @ 2K only
Minimum manipulations on CV after 2K test (ready for module assembly)

Final EP:
Tuning
Final EP (40 µm)
HPR
Installation of FMS
TI-cone rings welding
FM control/ tuning
Tank welding
Removal of FMS
Installation of probes
(HOM /Pick Up)
HQ Antenna (Fixed coupling)
HPR
120 C bake
Acceptance test @ 2K
Ready for module

Flash BCP:
Tuning
Installation of FMS
TI-cone rings welding
FM control/ tuning
Tank welding
Removal of FMS
Flash BCP (10 µm)
Installation of probes
HOM /Pick Up
HQ Antenna (Fixed coupling)
HPR
120 C bake
Acceptance test @ 2K
Ready for module

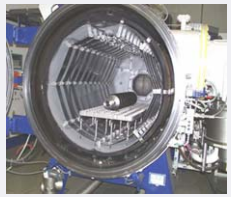
** FMS= field profile measurement system

Cavity preparation at DESY



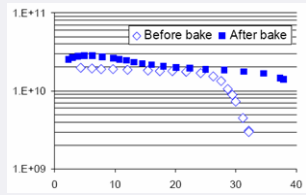
Cavity preparation cont'd

EP 150 µm (inside)



UHV 800°C annealing

"flash" BCP ~10 µm
Or: final EP ~40 µm

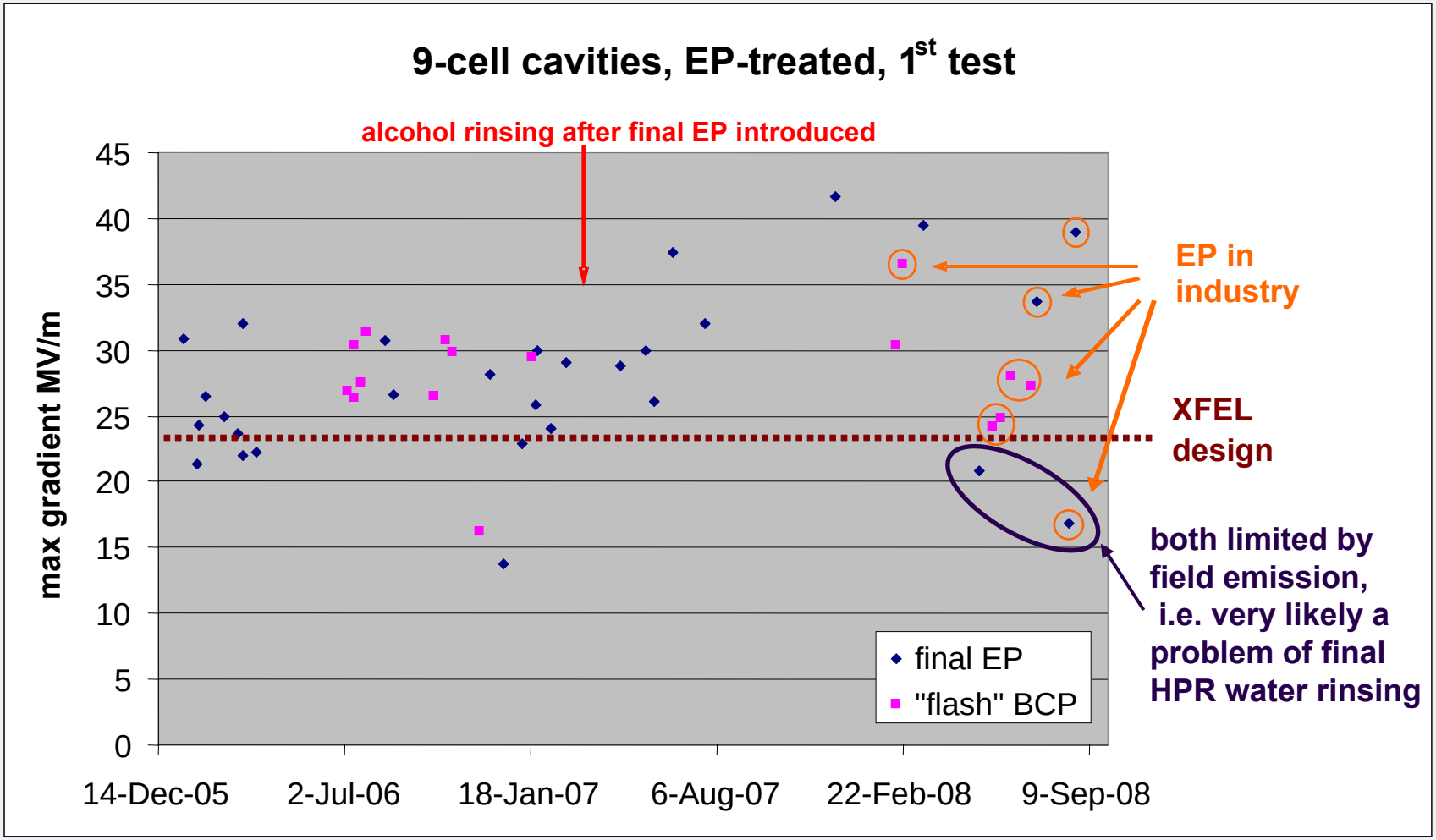


UHV 120°C baking

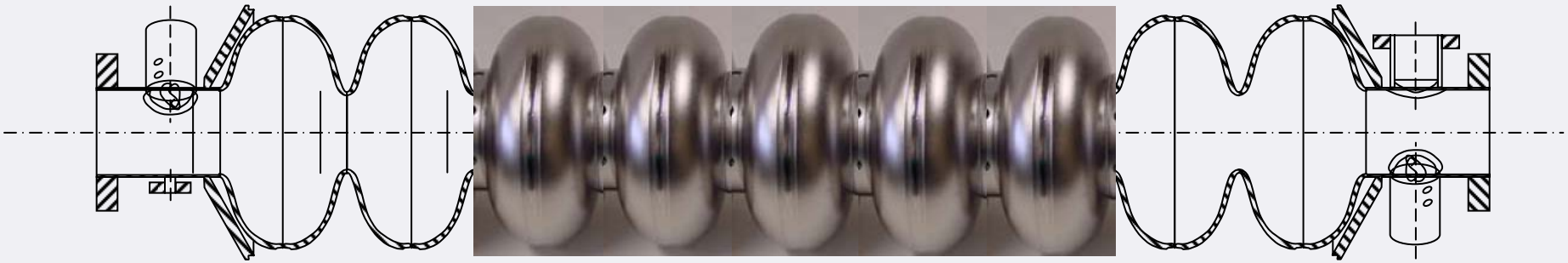
100 bar HPR (6 ×)

- Industrialization of EP ongoing: 10 cavities received from each of two companies
- **Decision on final treatment before end of 2008**
- If final EP then large overlap with ILC interest

Cavities since Jan 2006, 1st test



Cavities since Jan 2006, 1st test

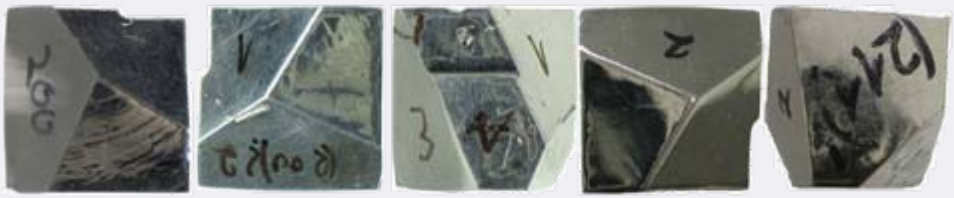


more on cavity results later this morning
and in WG 3
by Detlef Reschke

Large Grain Cavities

Results of the DESY / W.C. Heraeus Collaboration on large grain material

- **Positive experience**
  several large grain ingots were produced
  large grain crystals are growing in axial direction
- **Disappointing**
  transition phase from start crystal to continuously growing crystal is critical
  quite a few of the well prepared start crystals were destroyed

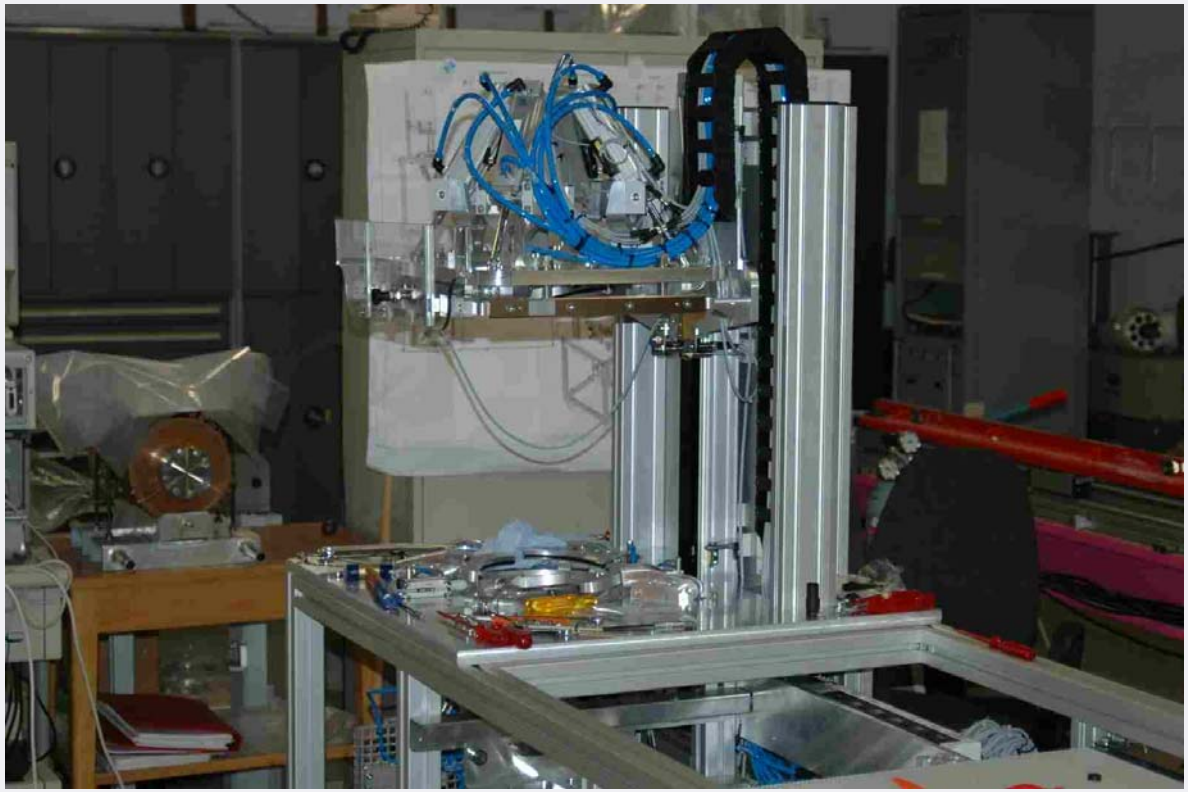


different start crystals produced by W.C. Heraeus

the goal and the problem

not a stable process
no reproducible growth of the required 150 mm diameter central grain
→ **the XFEL unfortunately can no longer support this interesting program**

HAZEMEMA (machine RF measurement of dumb bells etc.)



Equipments for RF measurement of half cells, dumb bells and end groups

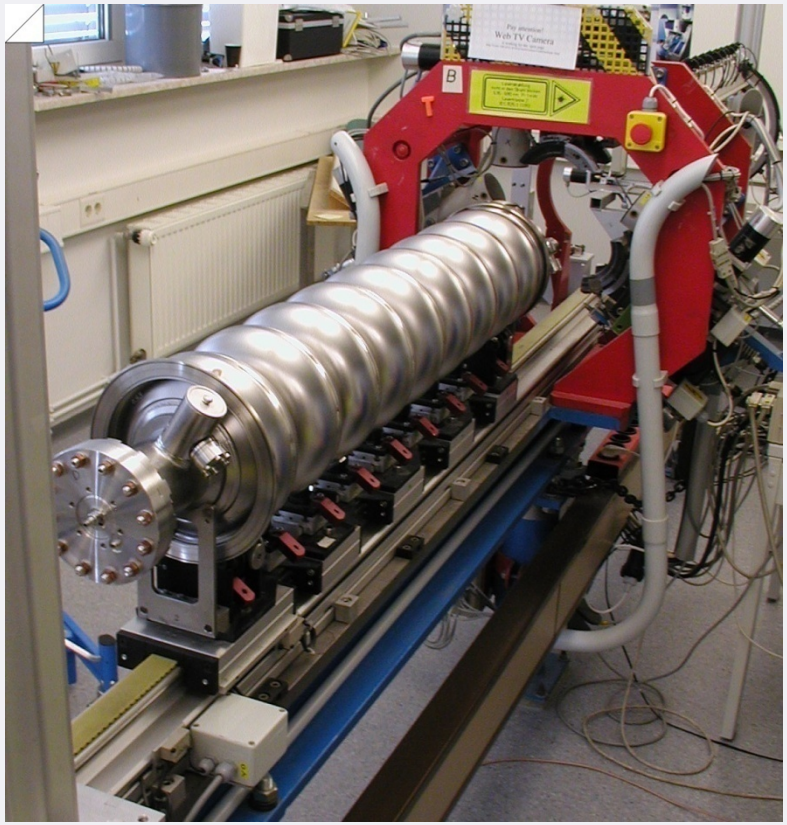
- prototype has been tested at ACCEL and ZANON during fabrication of last 30 cavities
- some improvements in design were done
- main parts for two equipments are ordered
- final assembly to be done at DESY
- ready end of 2008

Niobium Scanning

DESY eddy current apparatus

- Niobium for the pre-series (ca. 30 cavities) will be scanned on the existing prototype equipment at DESY
- equipment will be renovated for that purpose
- order of a new equipment is not critical in time and will be shifted to 2009

Niobium Scanning



actually existing tuning machine at DESY

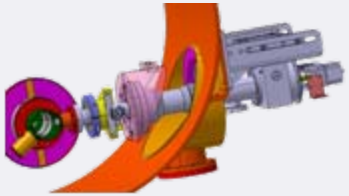
- 4 tuners are going to be built in collaboration with FNAL and KEK, two of them for XFEL
- final assembly and commissioning as well as certification at DESY
- main parts are ordered
- project should be completed in Q2 2009

Cavity string & module assembly

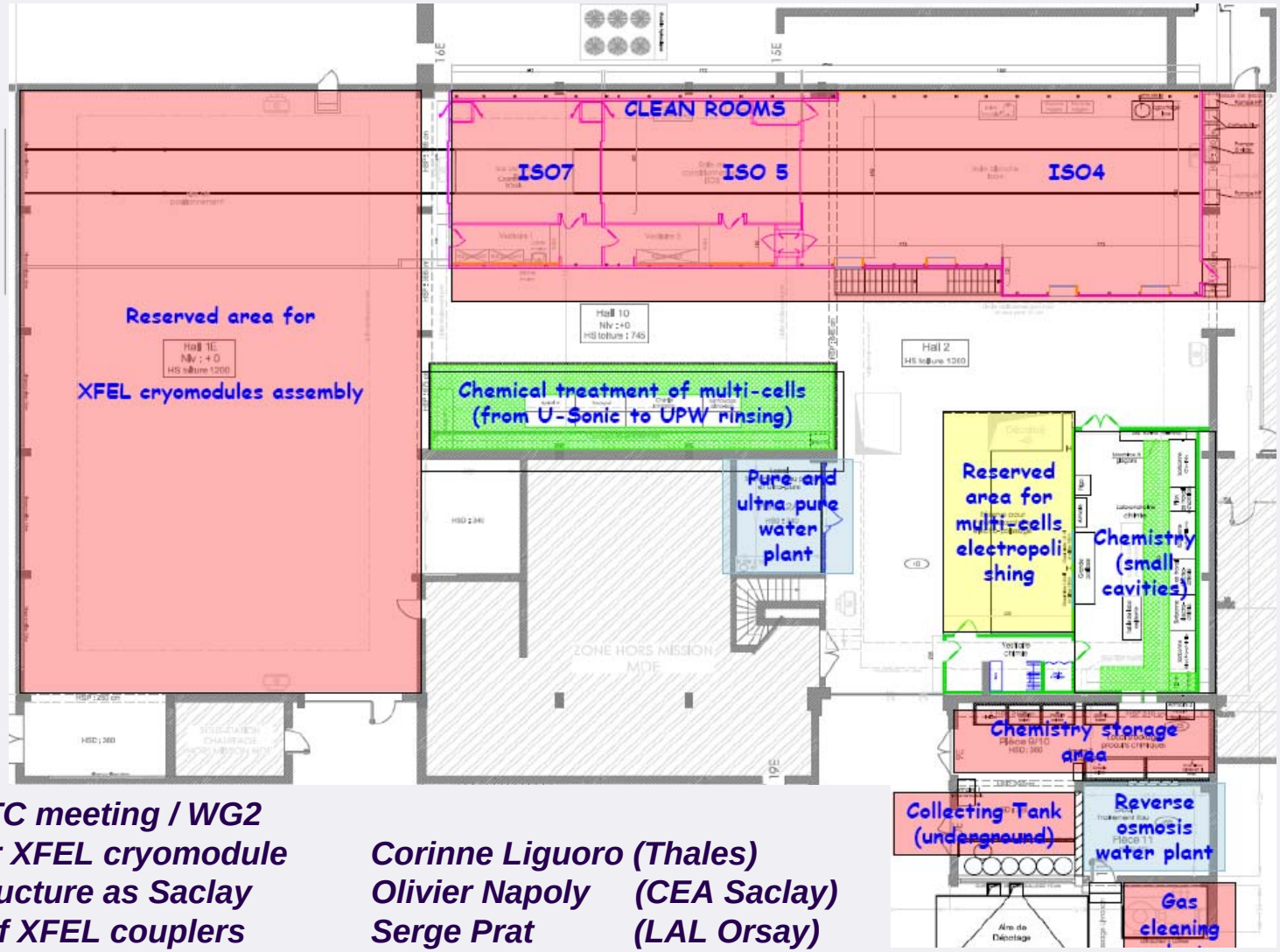
Using experience gained at DESY and results of industrial studies, the assembly facility for all 100 XFEL modules will be set up at the CEA-Saclay site.

CEA (IRFU), CIEMAT, DESY, INFN-Milano, LAL Orsay, Swierk take the responsibility for the cold linac.

Assembly facility at CEA Saclay – industrial study near completion



RF coupler processing facility under preparation at LAL Orsay



More during this TTC meeting / WG2

- *Assembly plan for XFEL cryomodule* — *Corinne Liguoro (Thales)*
- *Assembly infrastructure as Saclay* — *Olivier Napoly (CEA Saclay)*
- *Industrialization of XFEL couplers* — *Serge Prat (LAL Orsay)*

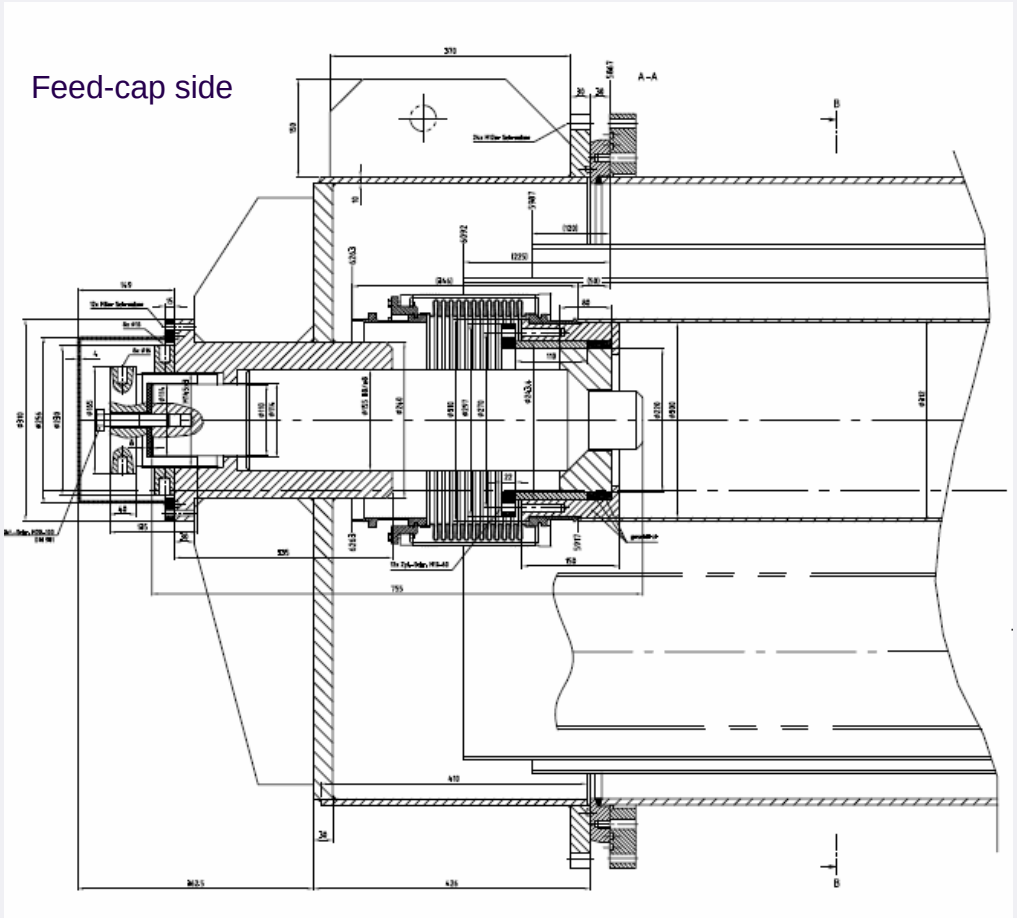
Module Transport Frame

- The Frame is equipped with two **Data Loggers** EnDal Curve 1111
- INFN equipped the Frame and the Module with **additional sensors and** uses **3 geophones** inside of the module (2 on the magnet and 1 on the coldmass' center)
- The INFN electronic will also **readout the vacuum gages** on the beam pipe and coupler pump line and the is permanently checking all RF main input couplers with respect to a short circuit.

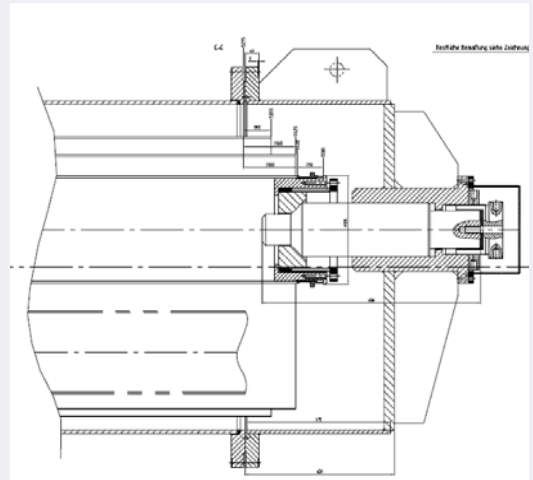
More during this TTC meeting / WG2 by Rolf Lange
• DESY – CEA Saclay – DESY transport scheduled for week 45
• re-test at CMTB in end of November '08

Coldmass vs. Vacuum Vessel Caps

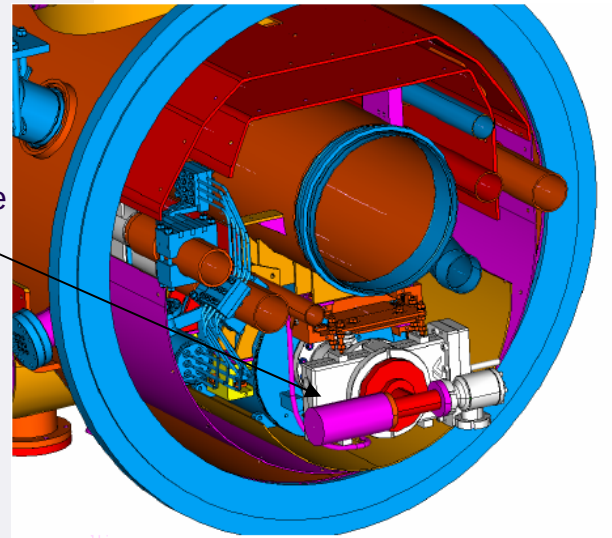
Feed-cap side



End-cap side



Beam pipe
Vacuum gage
End-cap



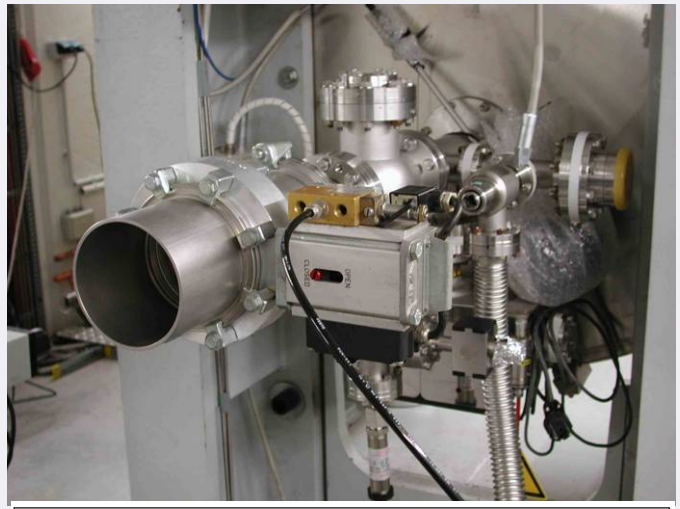
Operation of CMTB at DESY *(cryo module test bench)*

- **Four modules tested** on CMTB → 3 installed at FLASH, 1 in 2009
- **Positive experience** for later series tests:
  - Fast conditioning of RF-power coupler
  - little additional conditioning in FLASH Linac necessary
- **Good performance** of the modules → design beam energy reached in FLASH
- **"crash test"** of fault conditions (using old module M3* from FLASH)

M3* "crash test" – *worst case* vacuum faults

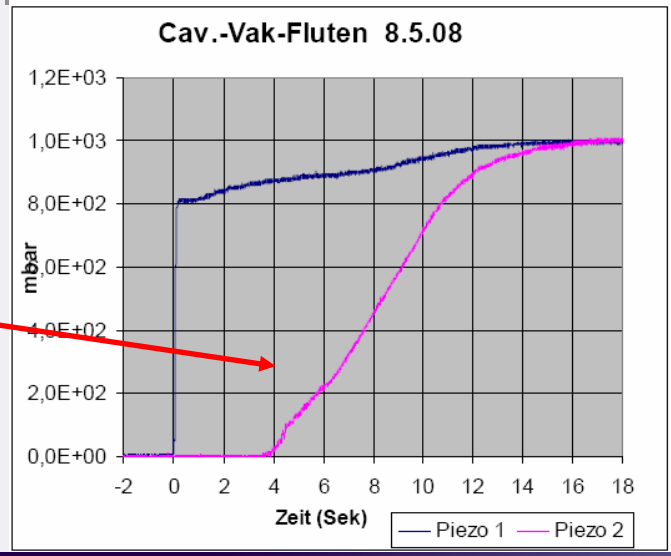
Venting system Iso.-vac DN 100

Venting system beam-pipe-vac DN 100



After recovery from **iso-vac "accident"**, module could be operated with unchanged performance (16 – 20 MV/m)

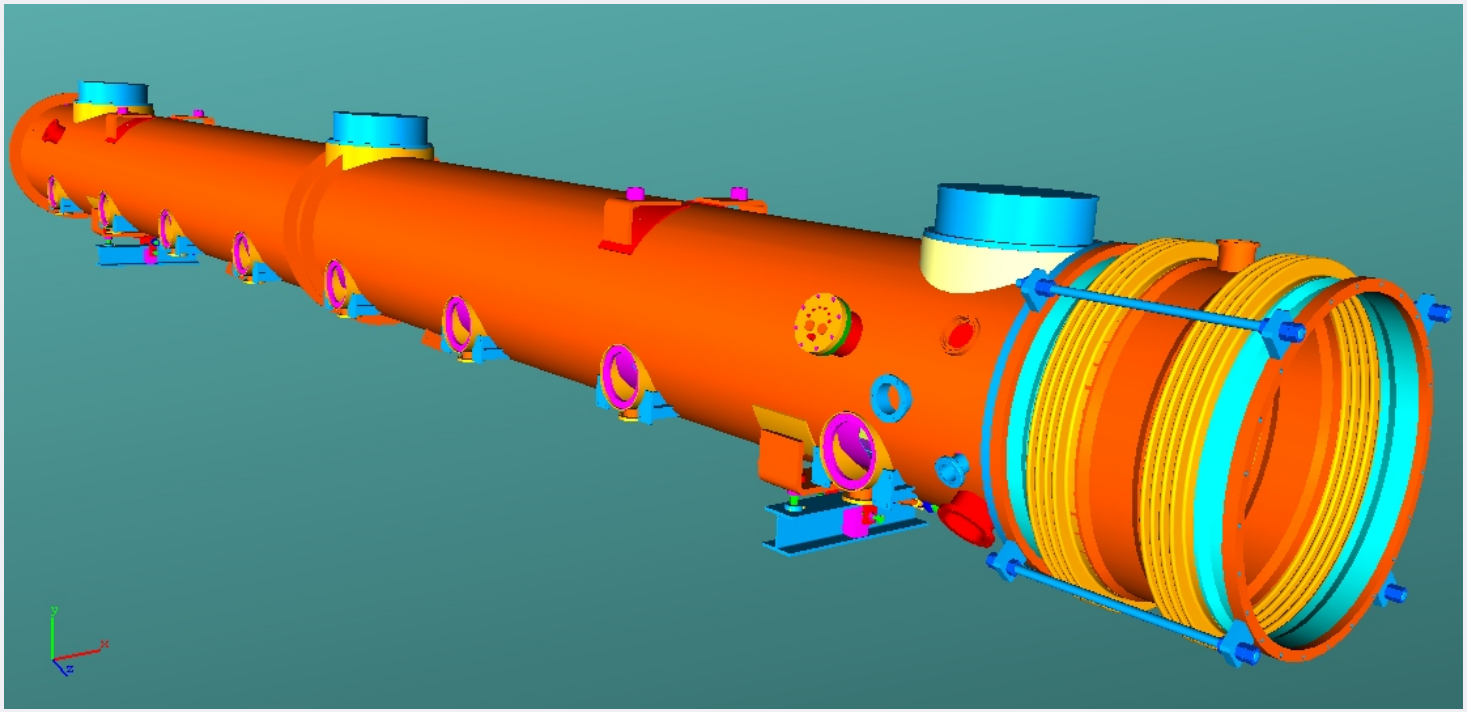
Pressure front in beam-vac takes ~4s(!) through module length



More during this TTC meeting / later this morning by Rolf Lange

- ***High pressure vessel code: Test of module 3****

XFEL Prototype Cryogenic Modules



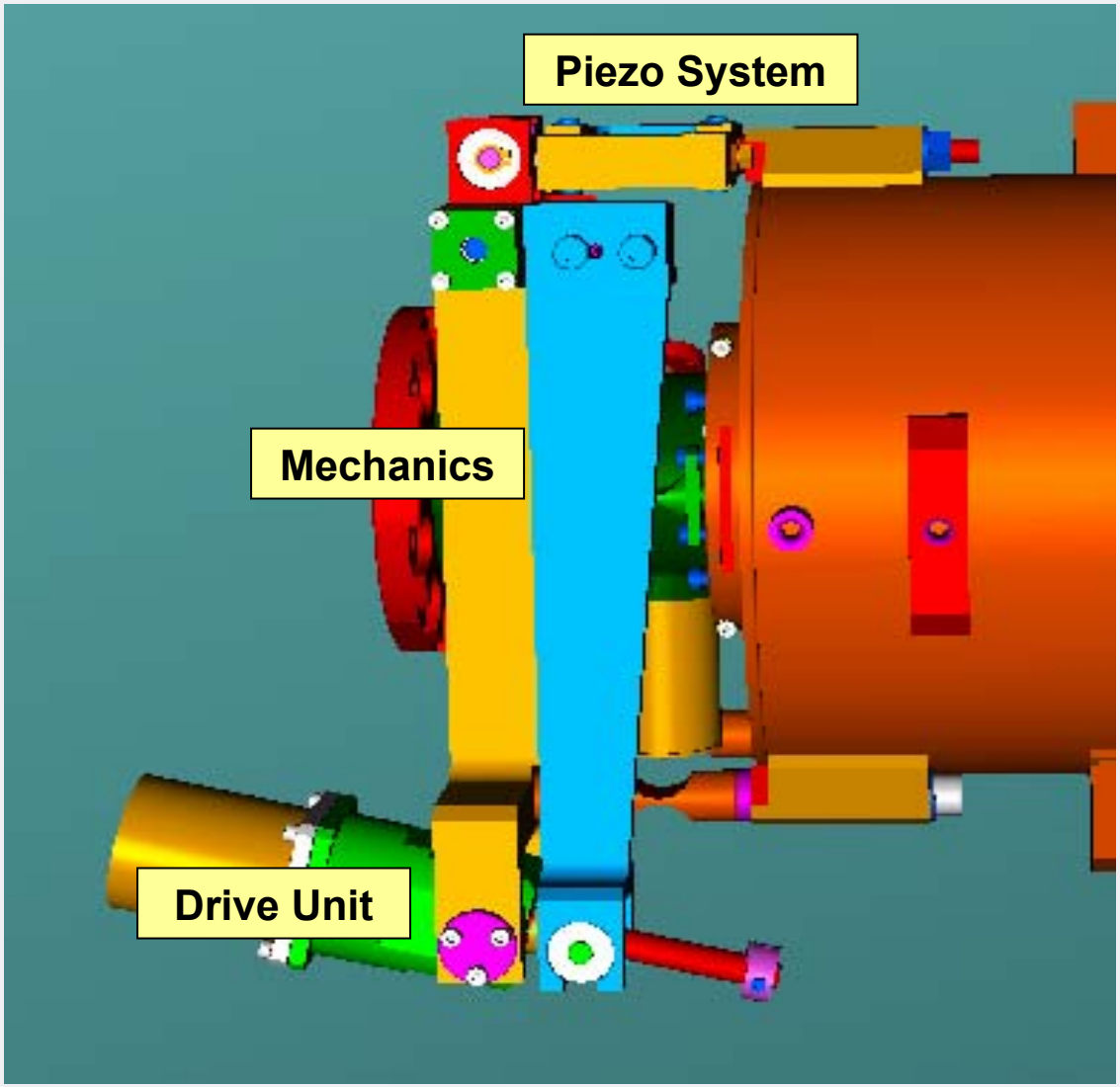
One cryomodule each from …

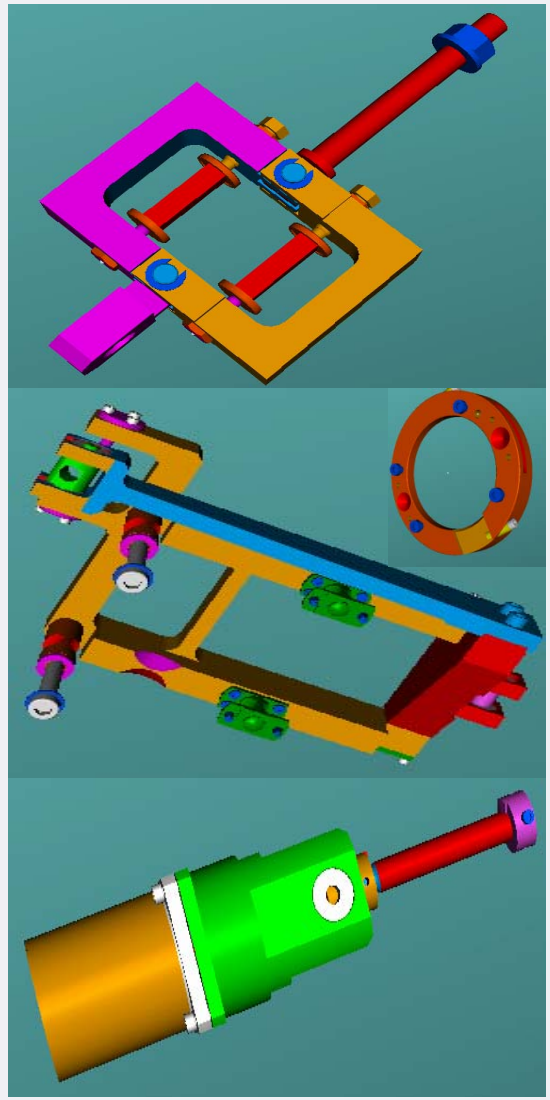
- **Thales / Phoebe (France) — delivery expected for December 2008**
- **FCM (Spain) — delivery expected for January 2009**
- **IHEP / Aerosun (China) — delivery expected for February 2009 (?)**

More during this TTC meeting / WG2

- ***Cold mass prototyping and industrialization — Rolf Lange (DESY)***

Frequency Tuner Parts: Overview





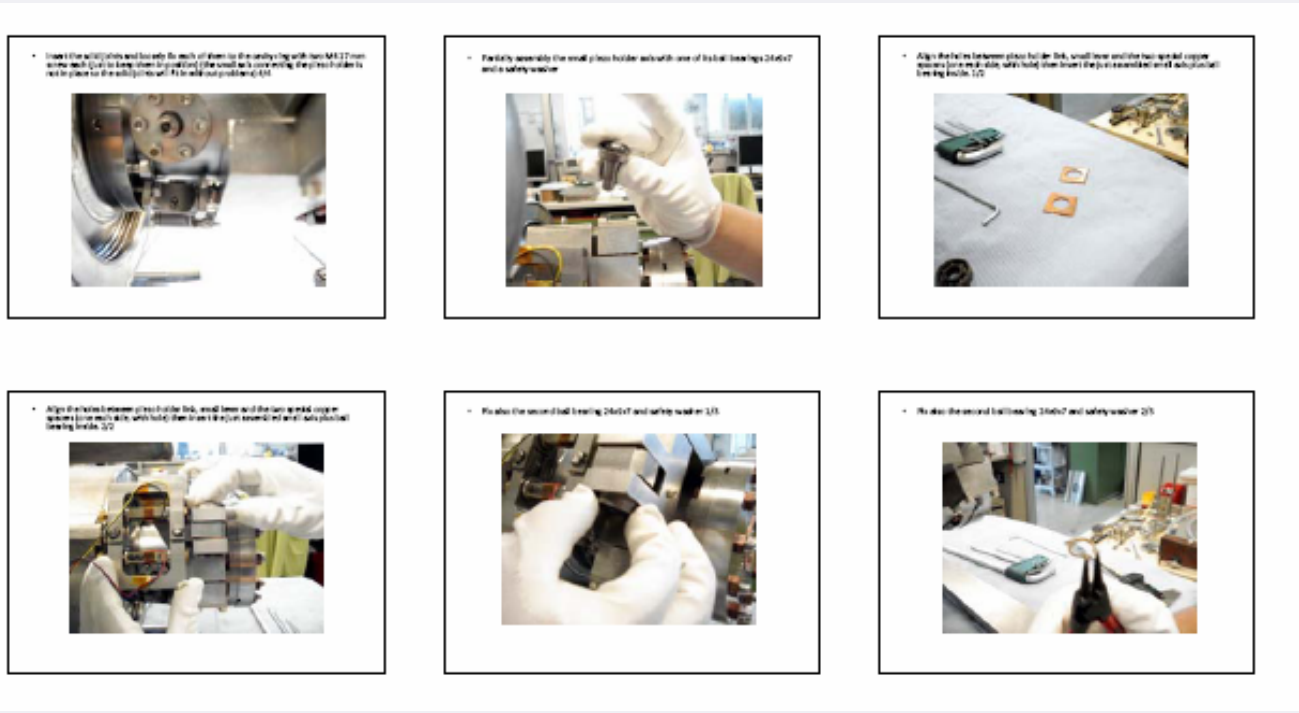
Tuner WP-07: Ongoing Work

- **Tests**
  - M3*: Motors survived crash test
  - M8: Is done, final acceptance of piezo fixture and choice of pre-tuning
- **Mechanics**
  - Qualification of vendors
    - Need 24 prototypes for M10-M12
- **Drive unit**
  - Found vendors to deliver full drive unit
  - Vendor qualification is underway
- **Piezo system**
  - Beginning installation of permanent FLASH setup
  - Tested piezo for breakdown under He atmosphere (INFN)
- **Work on specifications and procedures**
  - Detailed assembly steps are available (INFN, DESY)
  - Development of a semi-automatic test system for verification during installation

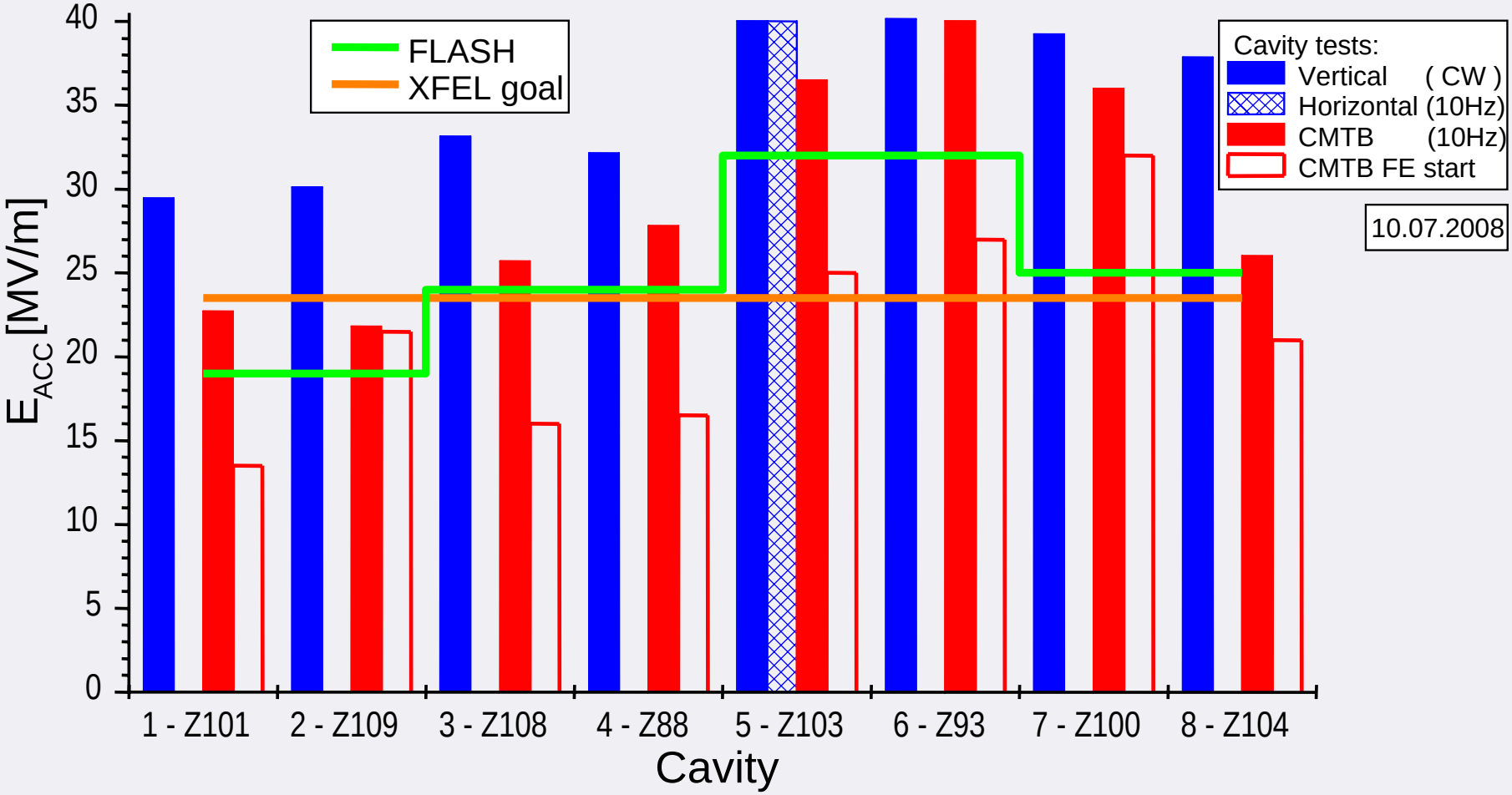
Detailed tuner assembly steps

Goal:

- Verification of current procedure
- Very detailed description, e.g. for training purposes
- for both, the piezo and the mechanical system



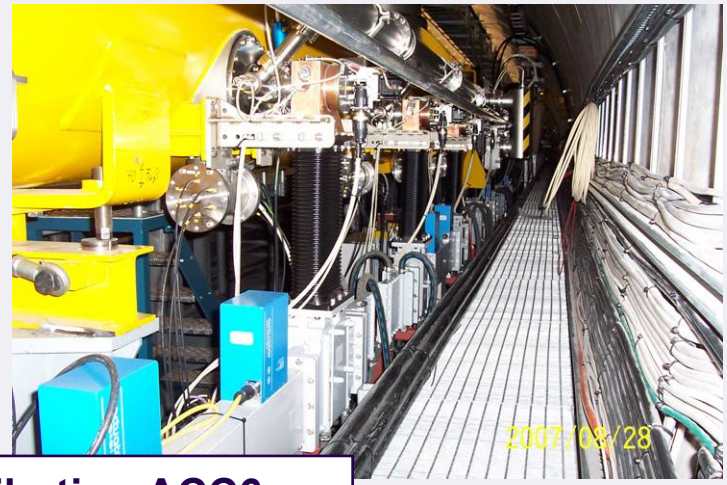
Module #8 test results

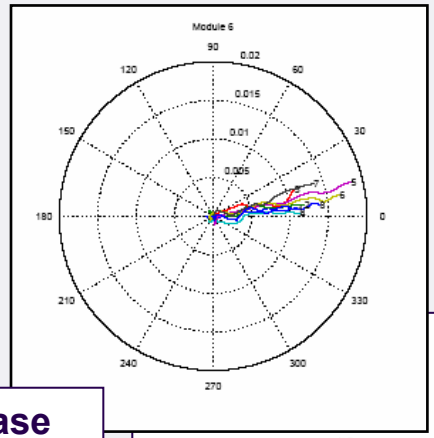


More during this TTC meeting / WG3 by Hans Weise

New pre-adjusted waveguide distribution system for ACC6

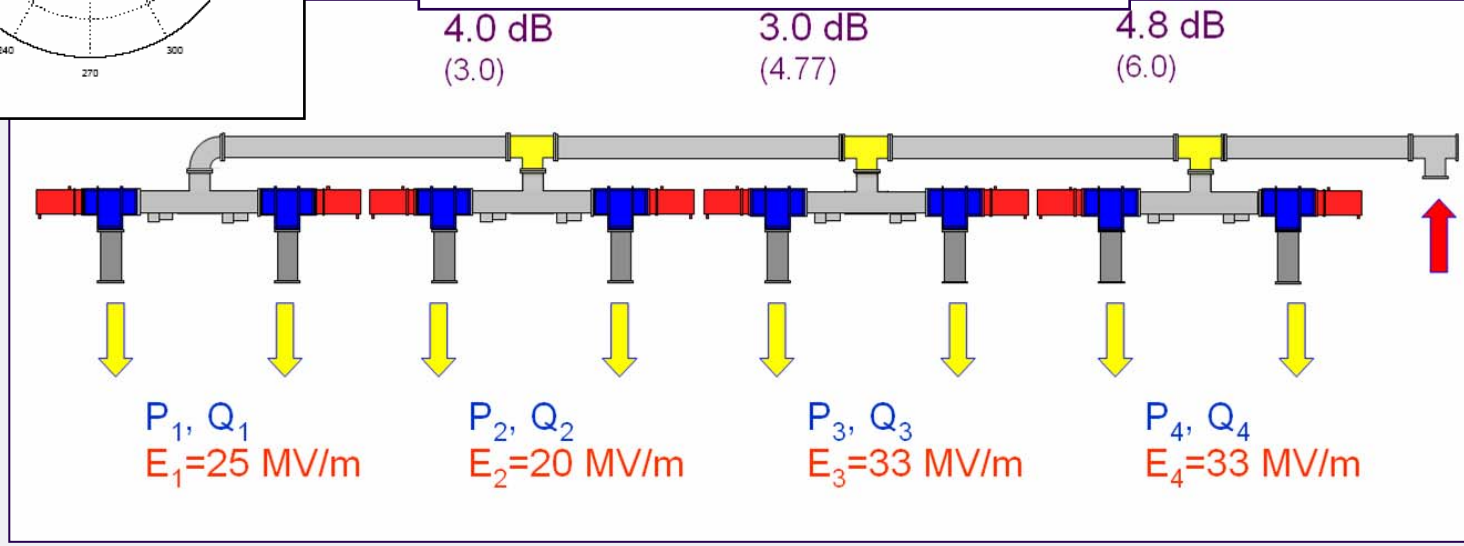
Power distribution and phase distribution for the individual cavities almost perfect





Initial phase distribution

Waveguide distribution ACC6



Klystron and modulator prototyping

Toshiba E3736H at Toshiba, Japan

- Factory Acceptance Test in Nasu successfull on August 22/23, 2007
- Klystron arrived at DESY on 18th Sept.
- **Site Acceptance Test at DESY successfull!**

Prototypes from two more manufacturers in near future

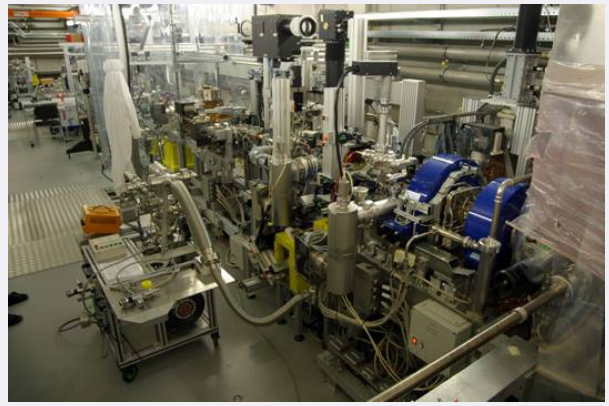
Test stand @ DESY, Zeuthen

Prototype from 1st of two companies recently arrived – test program started

Tunnel mock-up completed and installations ongoing

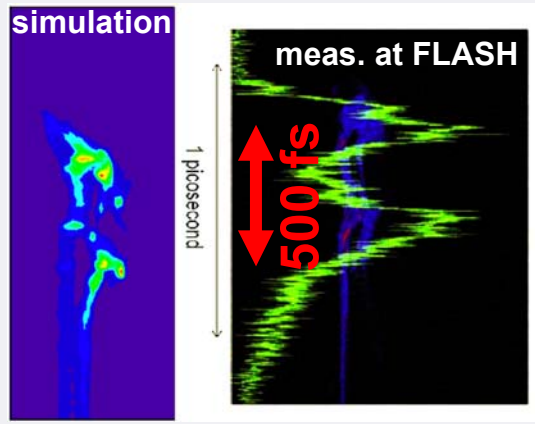
Other important XFEL R&D at DESY

- **Injector R&D at PITZ**
  → small emittance, dark current reduction
- **Extensive S2E simulations**
  → Slice emittance at undulators < 1 mm*mrad
- **FEL simulations**
  → SASE1: 0.1nm with wakefields
- **Slice emittance diagnostics**
  → different methods tested at FLASH
- **Timing / synchronisation**
  → diagnostics in fs-regime
- **Beam distribution**
  → Fast intra-train feedback system
  (DESY & PSI cooperation)



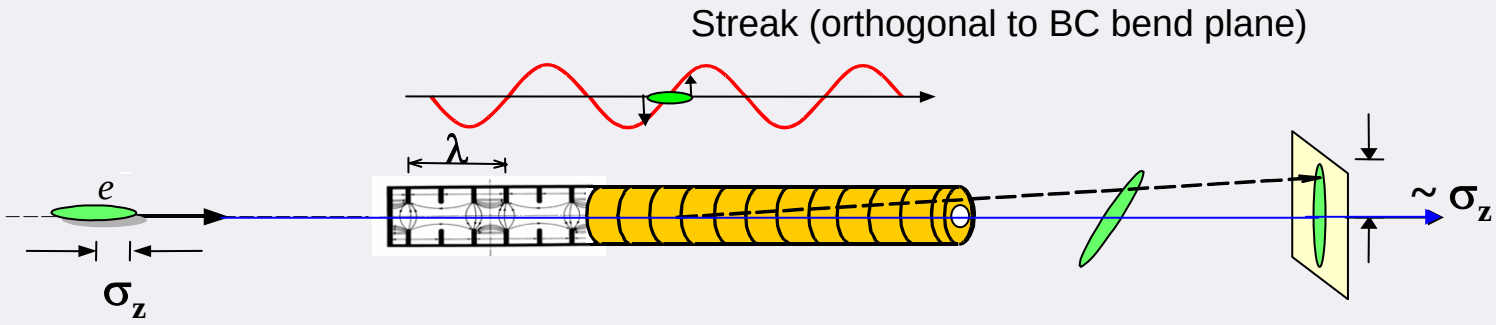
Injector R&D at PITZ

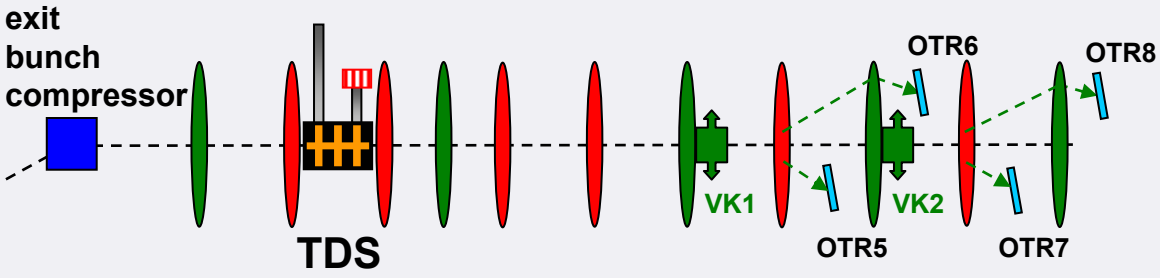
Most of the R&D is done in collaboration between DESY & PhD students from different universities



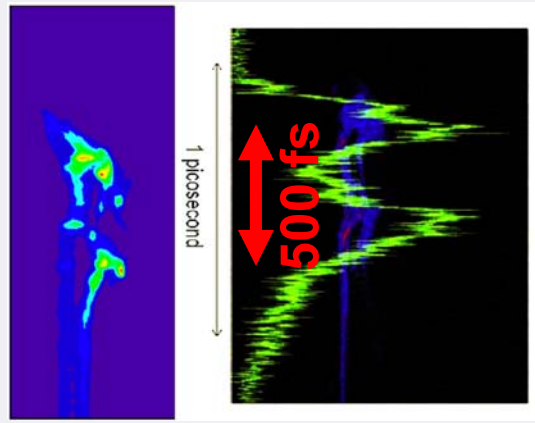
Slice emittance diagnostics

Slice emittance diagnostics *(method developed @SLAC)*





XFEL layout: Single bunches can be extracted from bunch train → continuous monitoring of bunch slice parameters



simulation

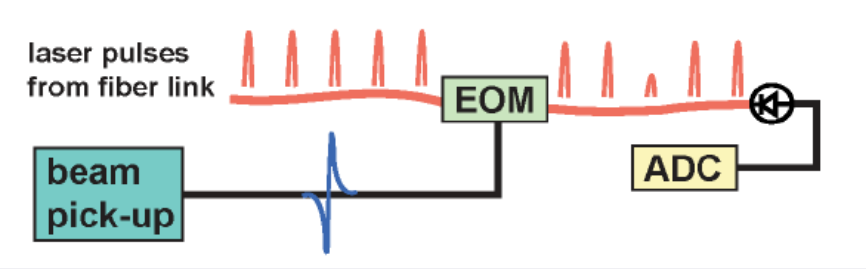
Example of measurement at FLASH ("LOLA")

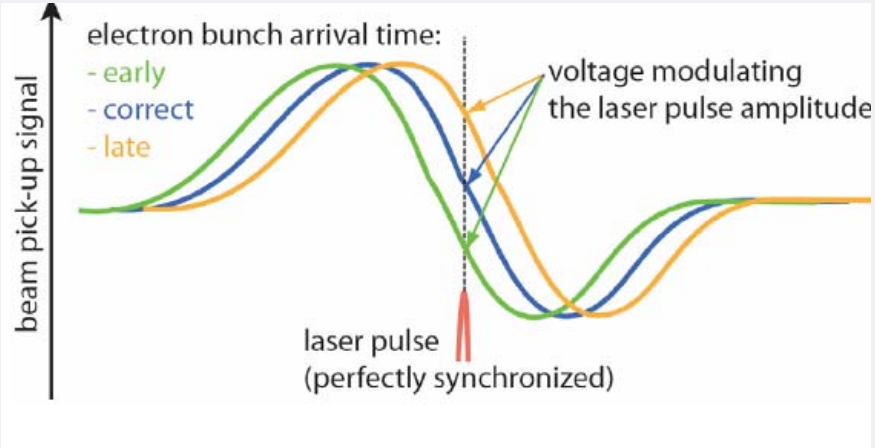
M. Roehrs / DESY & Hamburg Univ.

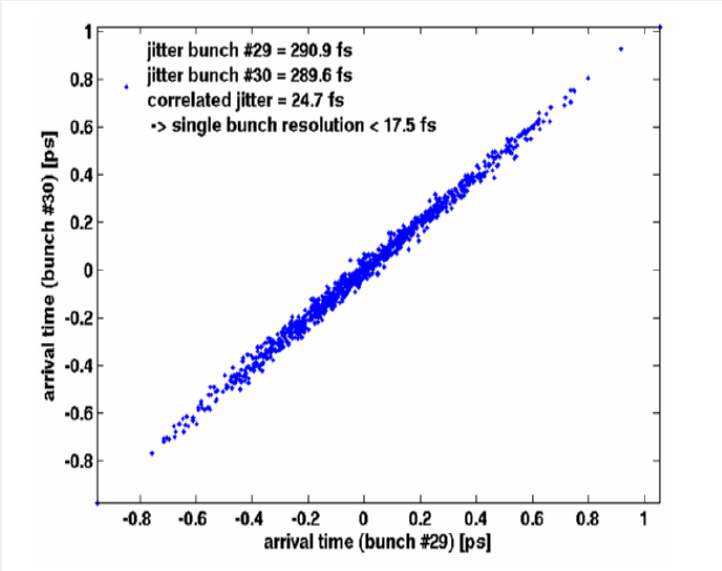
Timing/synchronisation diagnostics in fs-regime

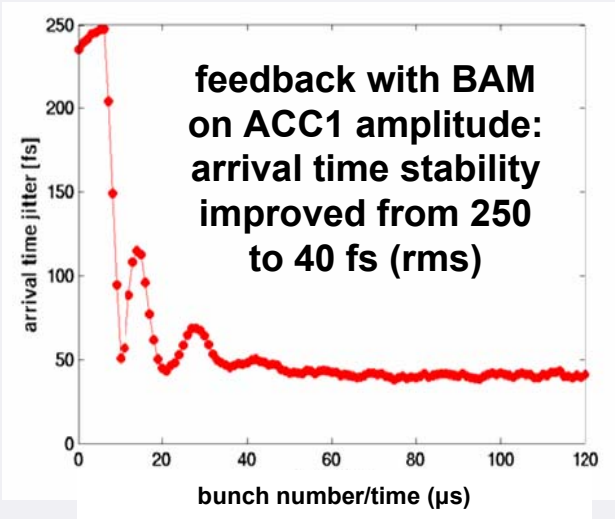
Arrival time monitor installed and tested at FLASH

Timing information of electron bunch is transferred into a laser amplitude modulation.



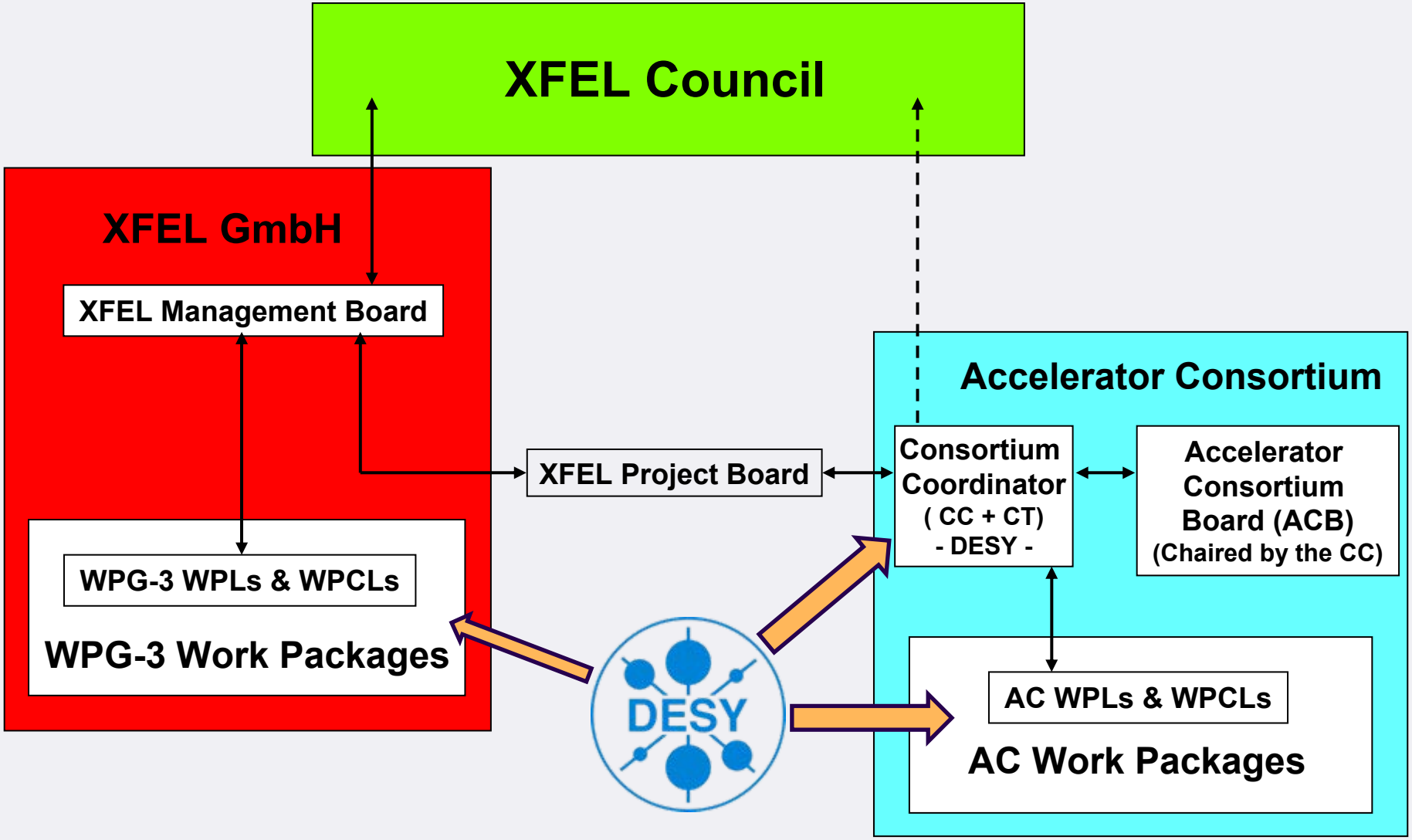




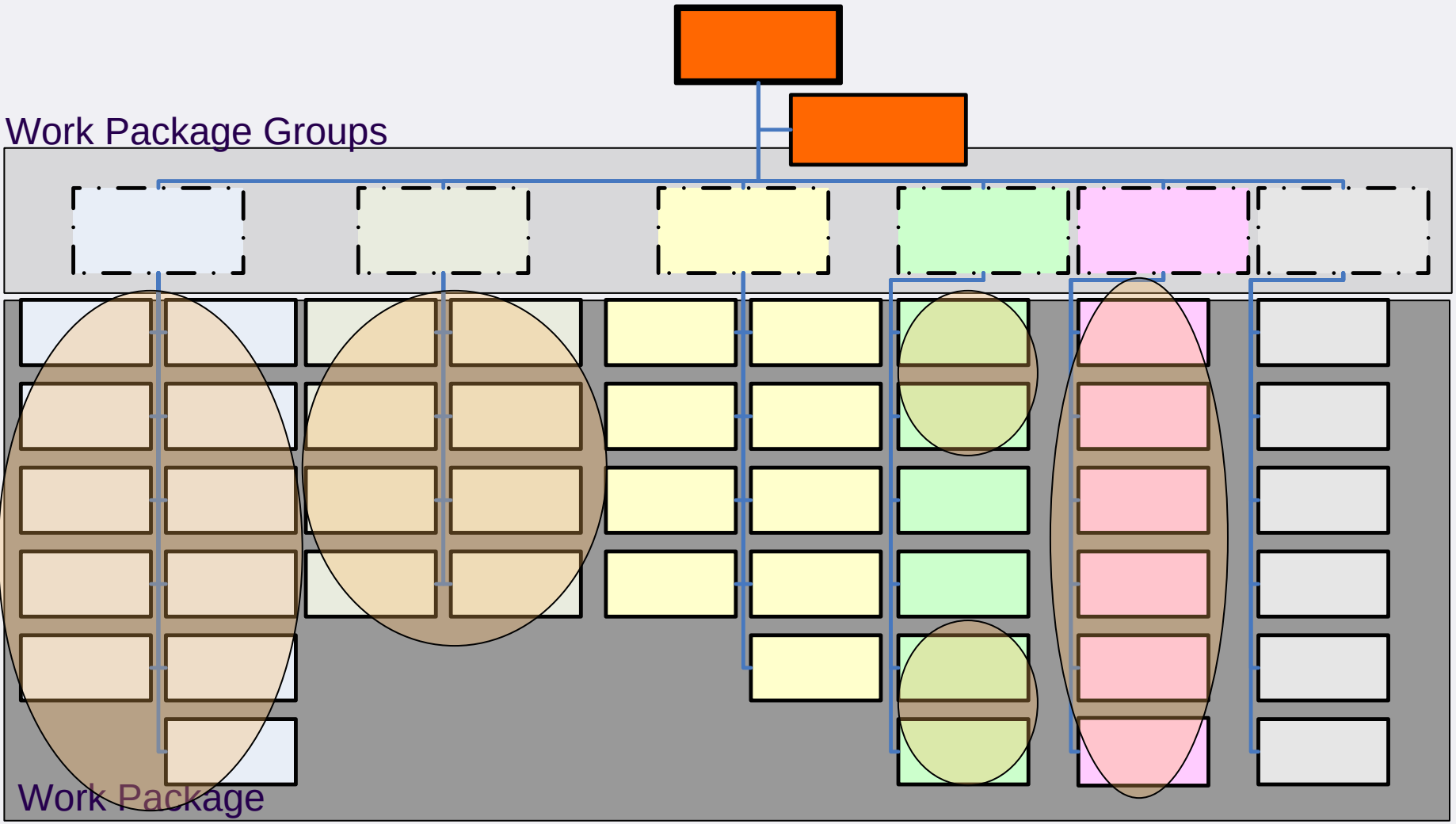


F. Loehl / DESY & Hamburg Univ.

XFEL Company and Accelerator Consortium

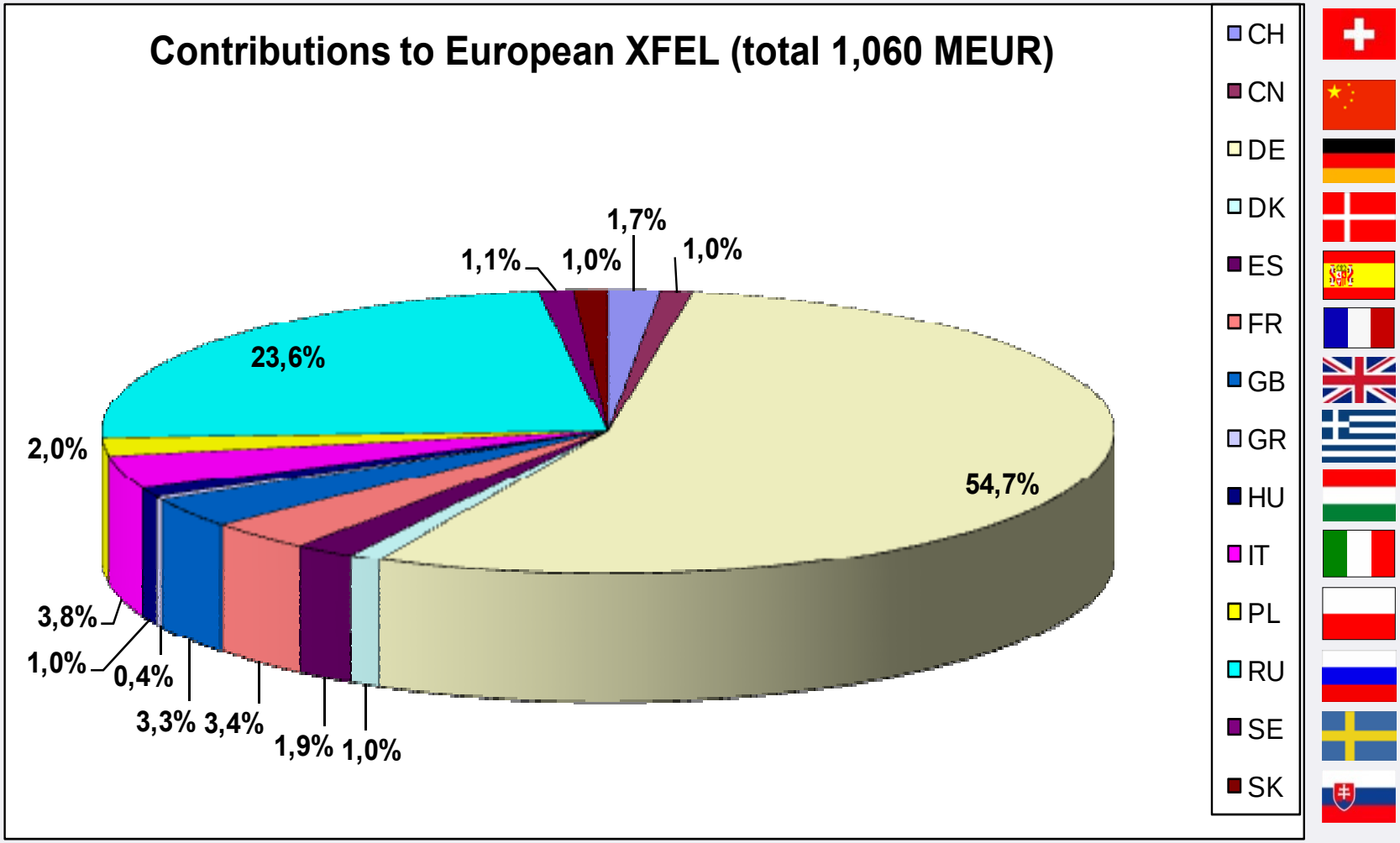


Accelerator Consortium work packages



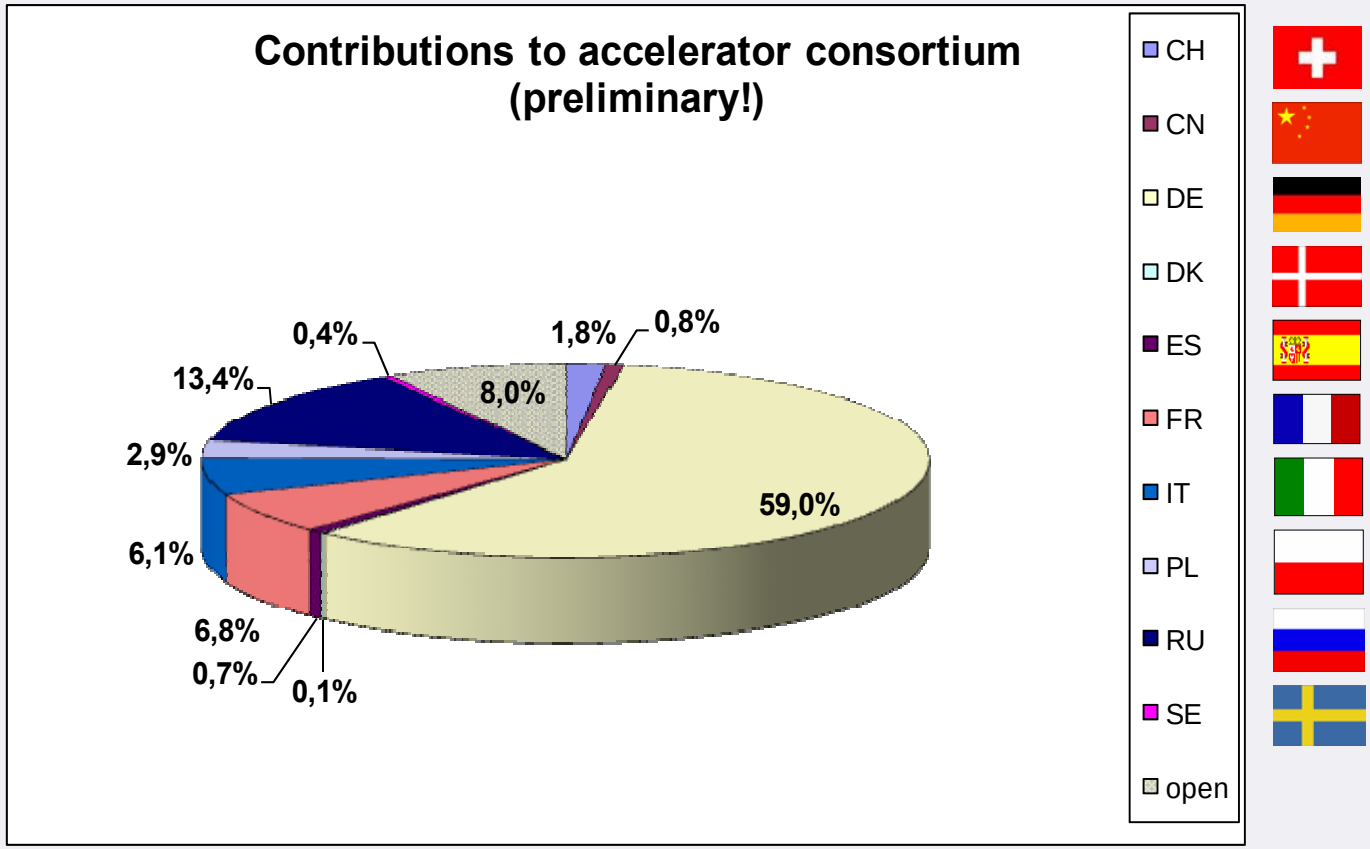
Financial commitments to the European XFEL project

Includes ~90 M€ project preparation phase & commissioning costs



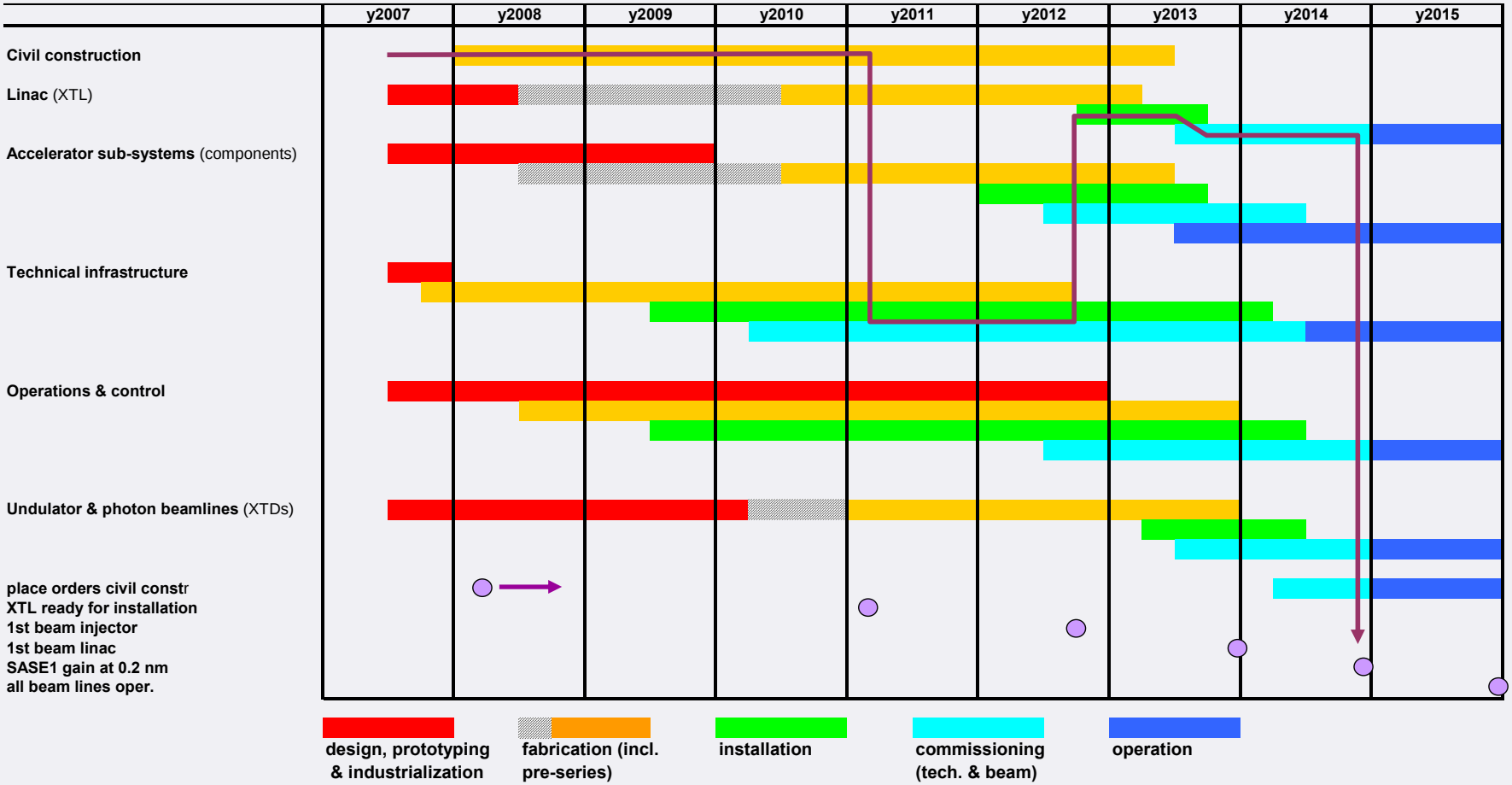
Accelerator in-kind contributions *(total value ~500 M€)*

Figures will change in detail – negotiations ongoing!



Many institutes from TESLA collaboration & some new partners

Schedule *(as of July 2007)*



Estimated delay ~ 10 months

(tender process underground construction)

The end