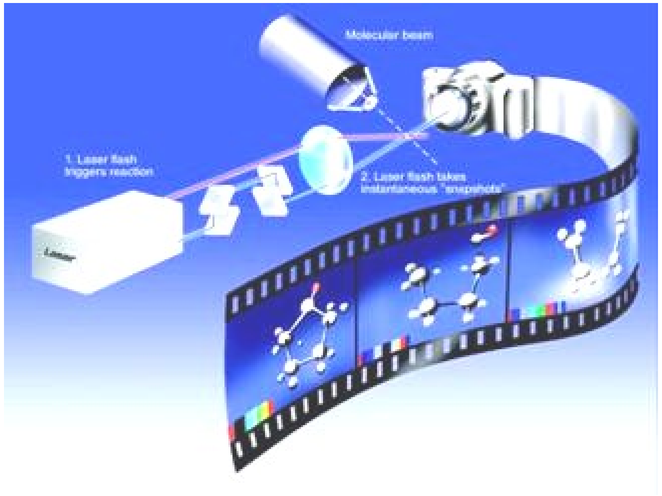
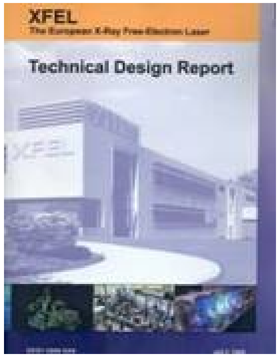
European XFEL Project

R. Brinkmann, DESY
For the XFEL Team



Introduction

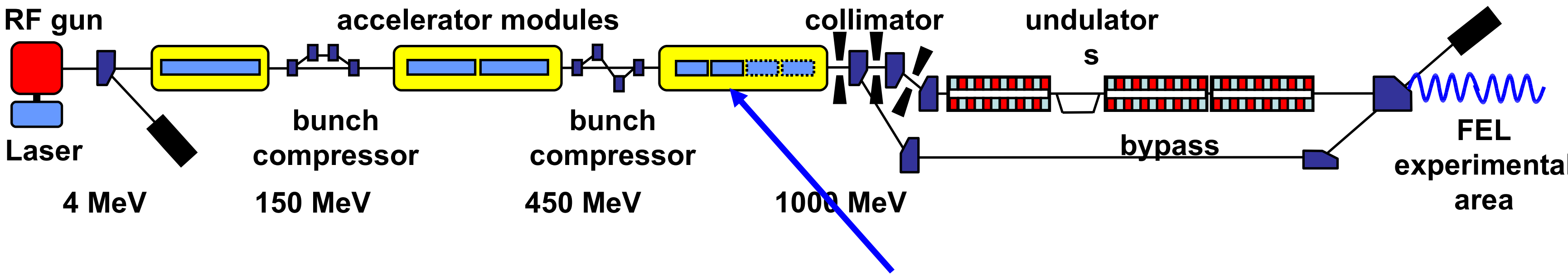
Oct 2002 : XFEL supplement to TESLA TDR → Feb 2003 approval by German government to realize the XFEL as European project with at least 40% funding contributions from partners → ***intense preparation work on technical design, industrialization of components, evaluation of cost/schedule, international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

The FLASH VUV-FEL facility at DESY

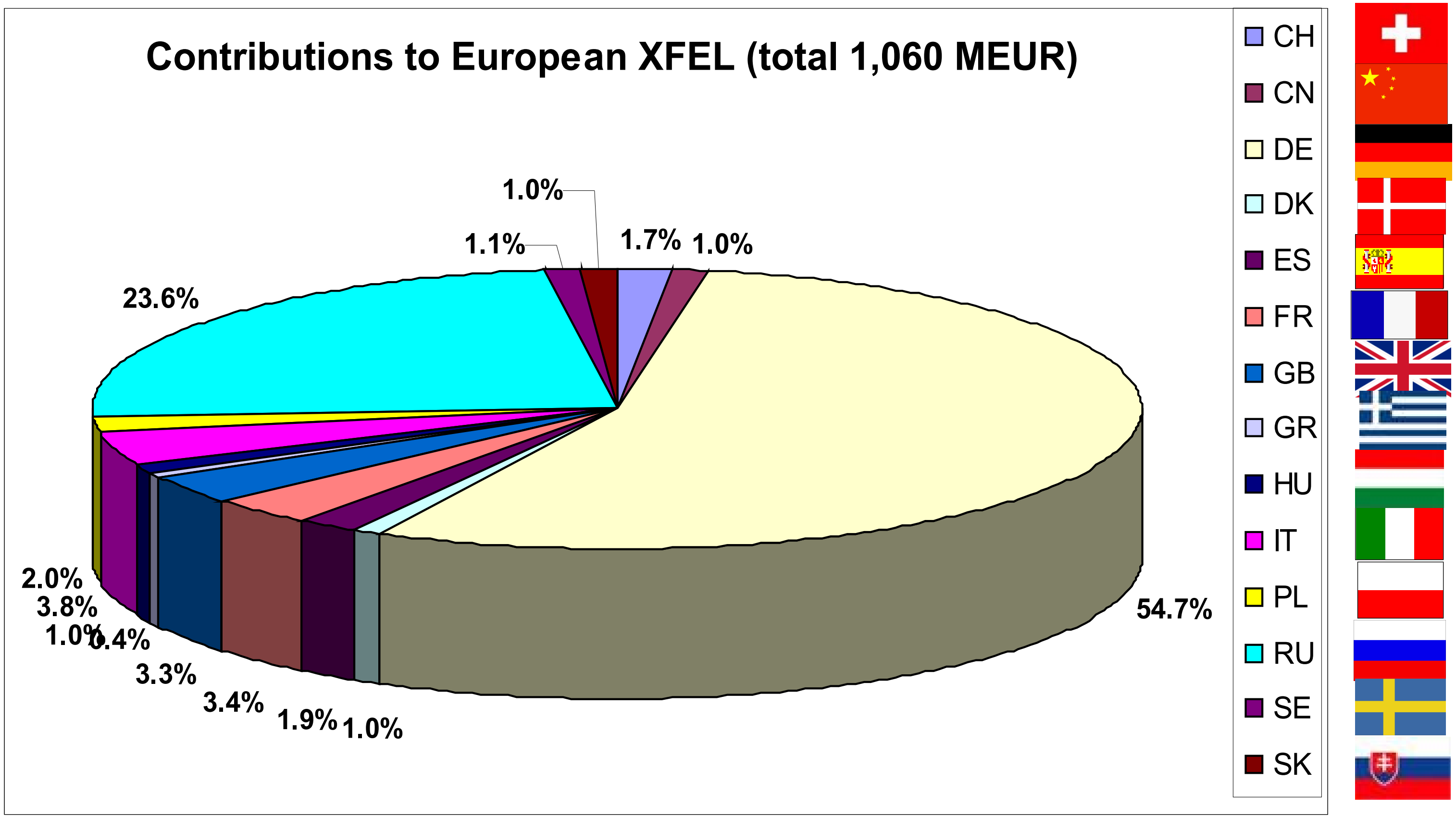


→ 6 accelerator modules routinely in operation; design beam energy & photon wavelength (6.5 nm) reached Oct. 2007

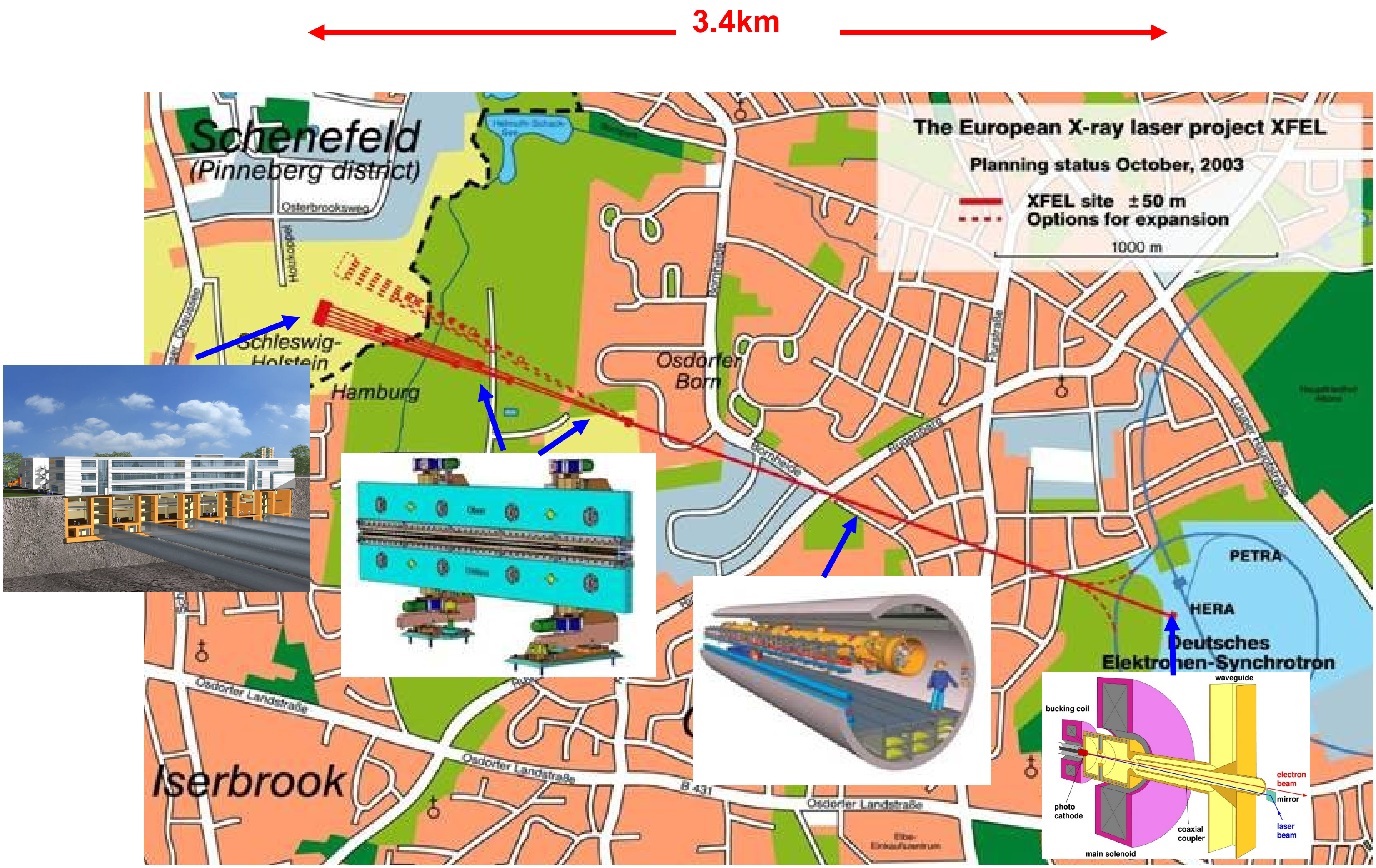
→ Pilot facility regarding practically all aspects (accelerator technology, beam physics, FEL process, user operation) of the XFEL

Status of financial commitments to European XFEL project

Includes ~90 M€ project preparation phase & commissioning costs



Overall layout of the European XFEL



XFEL site in Hamburg/Schenefeld

… after construction *(computer simulation)*

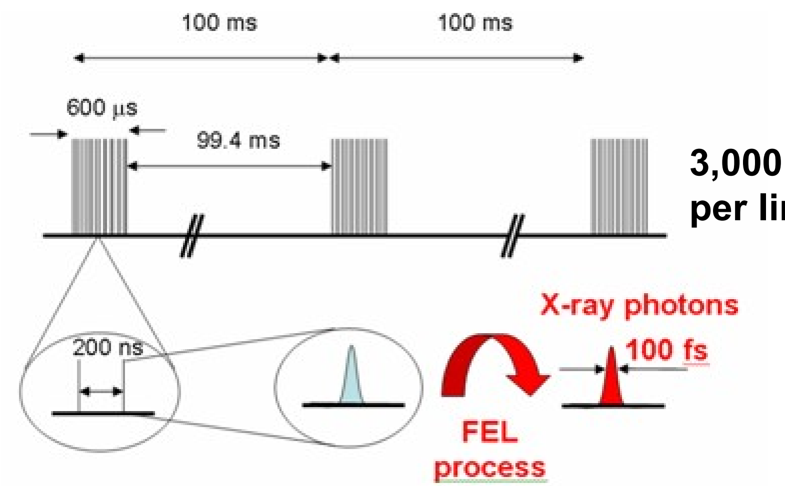
Properties of XFEL radiation

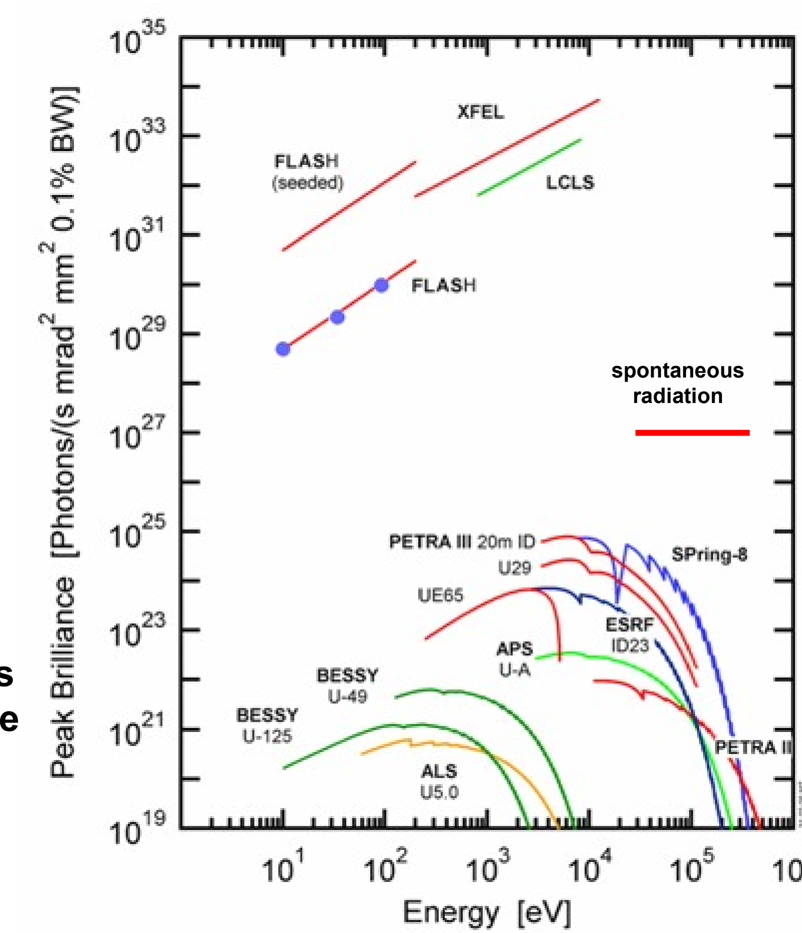
X-ray FEL radiation (0.2 - 12.4 keV)

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

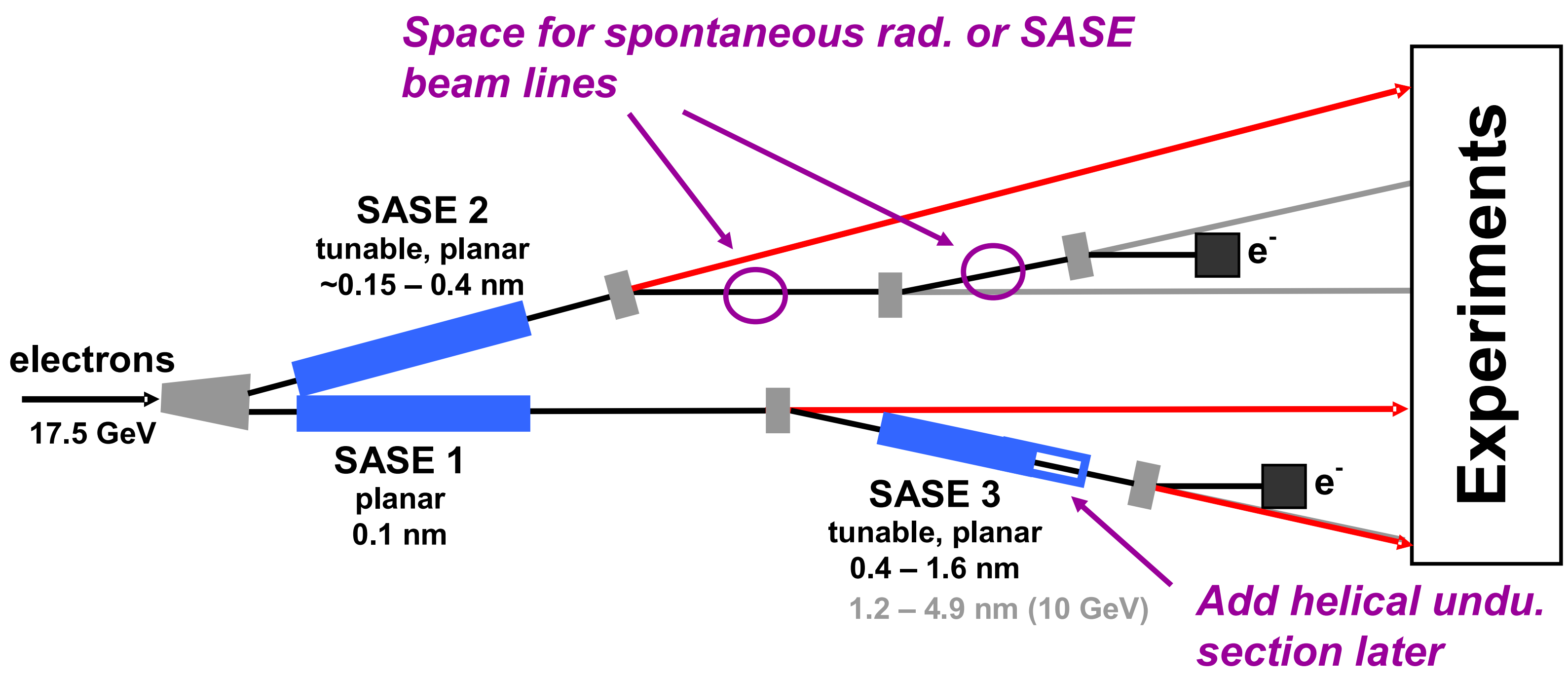
Spontaneous radiation (20-100 keV)

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





Beam lines in start version



Additional initial cost saving by shortening s.c. linac 20 → 17.5 GeV

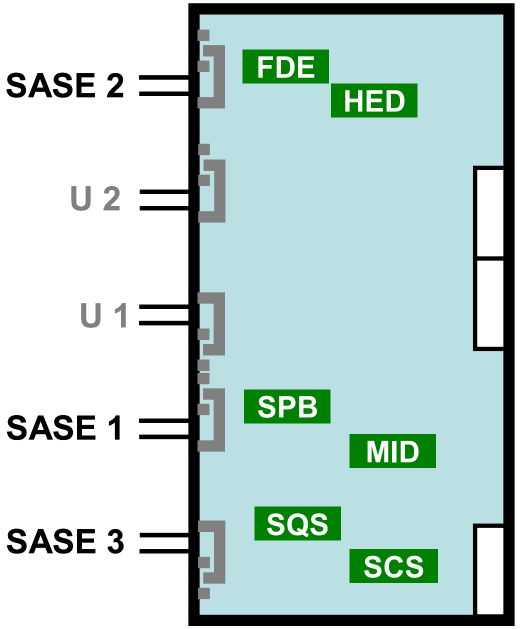
→ Photon wavelengths below 0.1nm design value require linac gradient above 23.6 MV/m design value

Selection of first instruments

	Instrument	Brief description of the instrument
Hard X-rays	SPB	Ultrafast Coherent Diffraction Imaging of Single Particles, Clusters, and Biomolecules – **Structure determination of single particles: atomic clusters, bio-molecules, virus particles, cells.**
	MID	Materials Imaging & Dynamics –**Structure determination of nano- devices and dynamics at the nanoscale.**
	FDE	Femtosecond Diffraction Experiments – **Time-resolved investigations of the dynamics of solids, liquids, gases**
	HED	High Energy Density Matter – **Investigation of matter under extreme conditions using hard x-ray FEL radiation, e.g. probing dense plasmas.**
Soft X-rays	SQS	Small Quantum Systems – **Investigation of atoms, ions, molecules and clusters in intense fields and non-linear phenomena.**
	SCS	Soft x-ray Coherent Scattering –**Structure and dynamics of nano-systems and of non-reproducible biological objects using soft X-rays.**

Distribution of first instruments

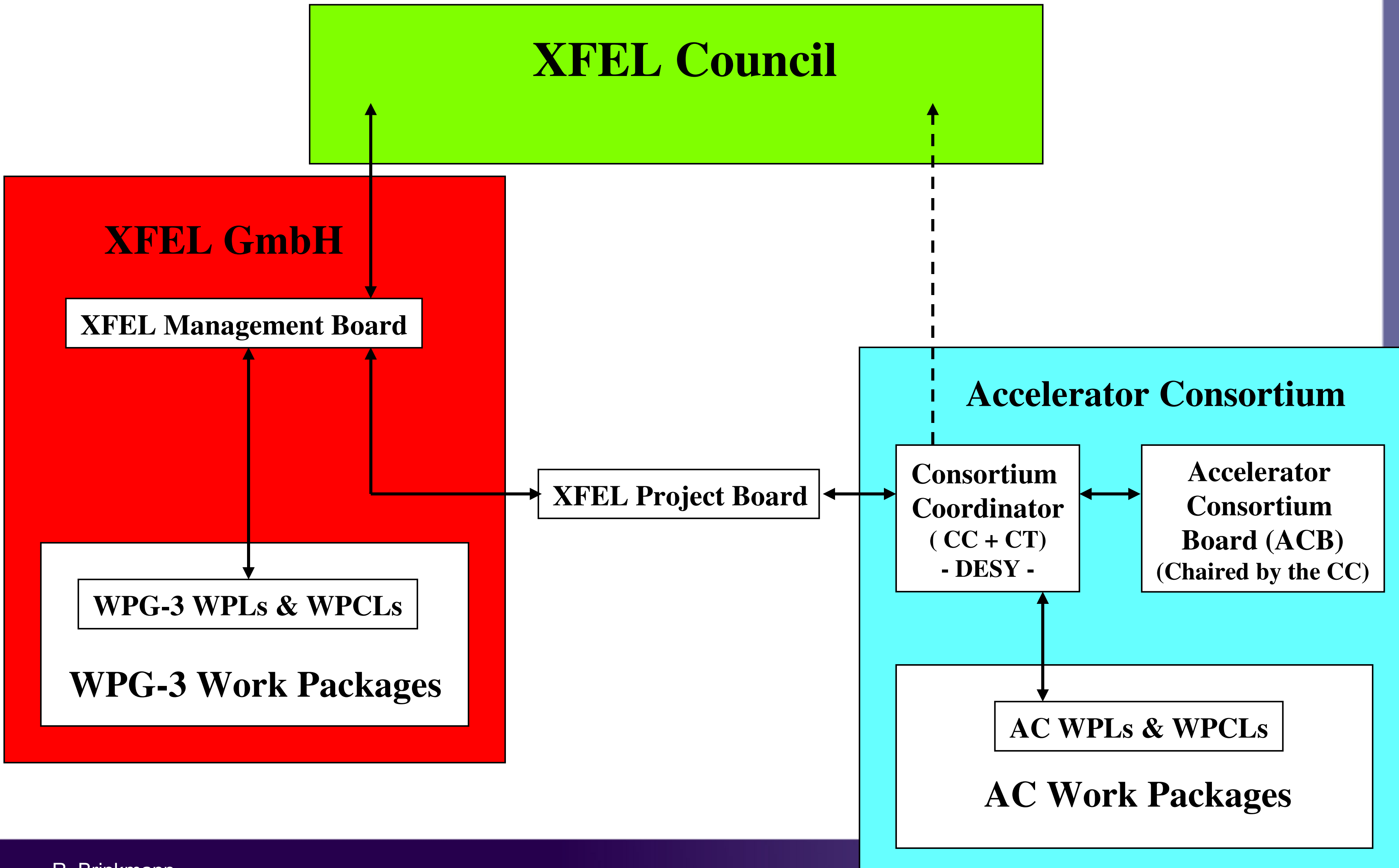
Source	Photon beam line characteristics
SASE 1	**FEL radiation ~12 keV High coherence Spontaneous radiation (3 , 5 harmonics)**
SASE 2	**FEL radiation 3-12 keV High time-resolution Spontaneous radiation (3 , 5 harmonics)**
SASE 3	**FEL radiation 0.25 – 3 keV; High flux**
	FEL radiation 0.25 – 3 keV;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



Photon beam systems developments

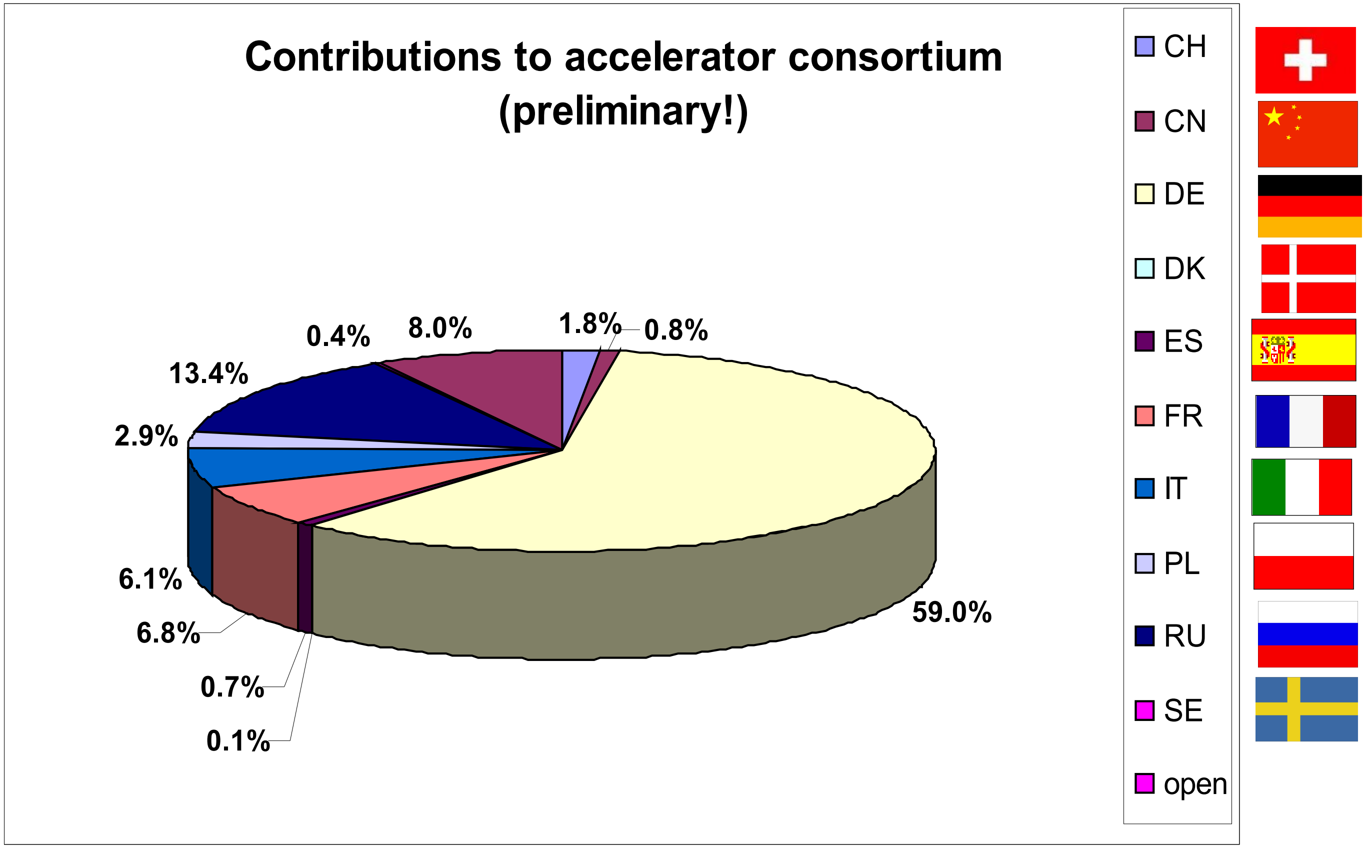
- Undulators: prototyping ongoing (synergy with PETRA-III), studies of mech. Tolerances, temperature stabilization, …
- Photon diagnostics: conceptual design & tests of beam diagnostics, photon beam based alignment for undulator sections, …
- Investigations of photon beam transport systems
- 2D-Detectors: major challenge e-beam time structure, R&D program launched in two consortia (HPAD, LPD), 3 under discussion (DEPFET)
- DAQ work package recently established & active

XFEL Company & Accelerator Consortium



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

Figures will change in detail – negotiations ongoing!



Many institutes from TESLA collaboration & new partners

R. Brinkmann	M. Altarelli, K. Witte

WPG-1: LINAC
- WP-01* RF System
- WP-02* Low Level RF
- WP-03* Accelerator Modules
- WP-04* S.C. Cavities
- WP-05* Power Couplers
- WP-06* HOM Couplers
- WP-07* Frequency Tuners
- WP-08* Cold Vacuum
- WP-09* Cavity String Assembly
- WP-1* Cold Magnets
- WP-46* 3.9 GHz System

WPG-2: Accelerator Sub-Systems
- WP-12* Warm Magnets
- WP-14* Injector
- WP-15* Bunch Compression
- WP-16* Lattice
- WP-17* Standard e--Beam Diagnostics
- WP-18* Special e--Beam Diagnostics
- WP-19* Warm Vacuum
- WP-20* Beam Dumps

WPG-4: Control and Operation
- WP-28* Accelerator Control System
- WP-29* Operability & Reliability
- WP-35 Radiation Safety
- WP-36 General Safety
- WP-38 Personnel Interlock
- WP-39* EMC

WPG-5: Infrastructure
- WP-10* AMTF
- WP-13* Cryogenics
- WP-32* Survey & Alignment
- WP-33* Tunnel Installation
- WP-34* Utilities
- WP-40* Information & Process Support

WPG-3: Photon Beam Systems
- WP-71 Undulators
- WP-72 FEL Concepts
- WP-74 X-Ray Diagnostics
- WP-75 Detector Development
- WP-76 DAQ & Control Systems
- WP-79 Sample Environment
- WP-85 Scient. Instrument SQS
- WP-86 Scient. Instrument SCS
- WP-73 X-Ray Optics & Beam Transport
- WP-78 Optical Lasers
- WP-81 Scient. Instrument FDE
- WP-82 Scient. Instrument HED
- WP-83 Scient. Instrument MID
- WP-84 Scient. Instrument SPB

WPG-6: Sites and Buildings
- WP-31 Site & Civil Construction
- WP-41/42/43 Site Lot 1-3
- WP-44 Site Engineering
- WP-45 AMTF Hall

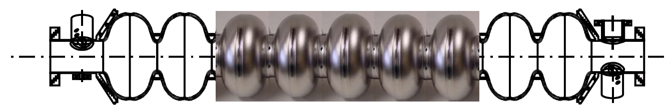
WP	Cold Linac Coordinator, H. Weise
WP	Machine Layout Coordinators, W. Decking/T. Limbe
WP	Technical Coordinator, T. Hott
WP	Scientific Director S. Molodtsov
WP	Scientific Director A. Schwarz
WP	Scientific Director T. Tschentscher

* Work Packages, which are covered by the Accelerator Construction Consortium

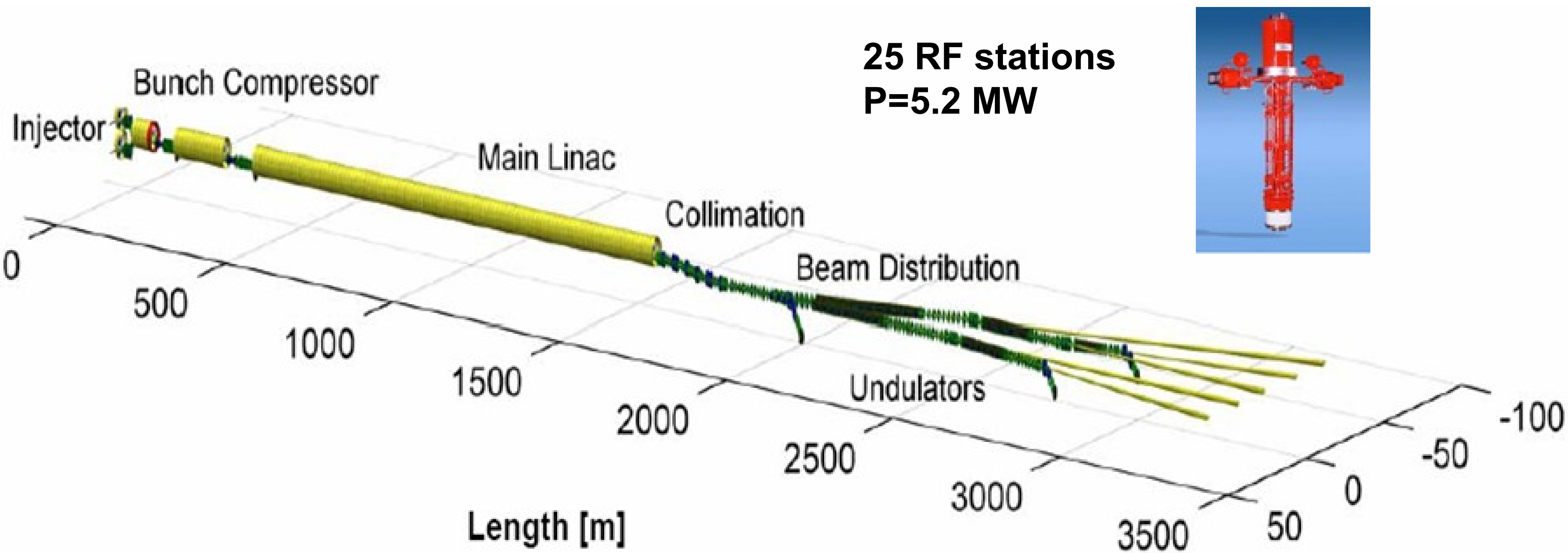
Accelerator complex

100 accelerator modules

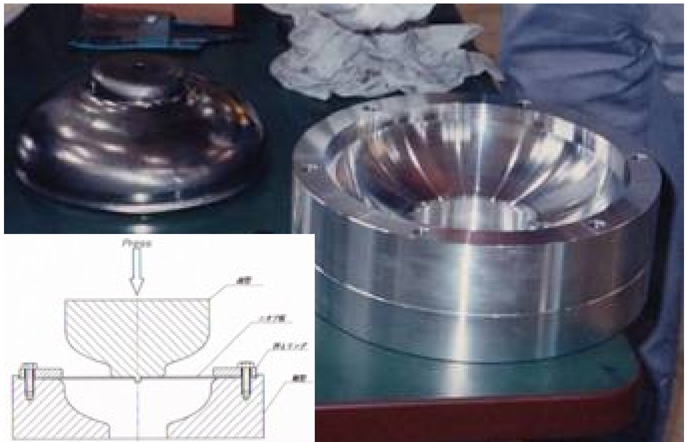
800 1.3 GHZ cavities
g=23.6 MV/m



25 RF stations
P=5.2 MW



Cavity Fabrication

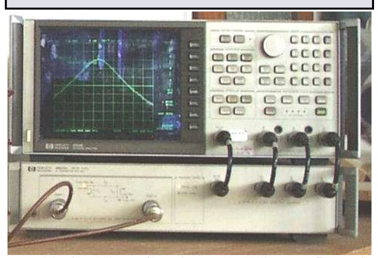


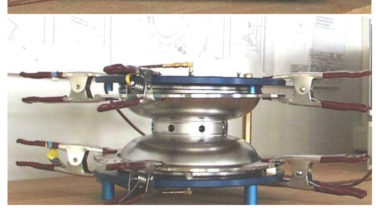
Half cells are produced by deep drawing.

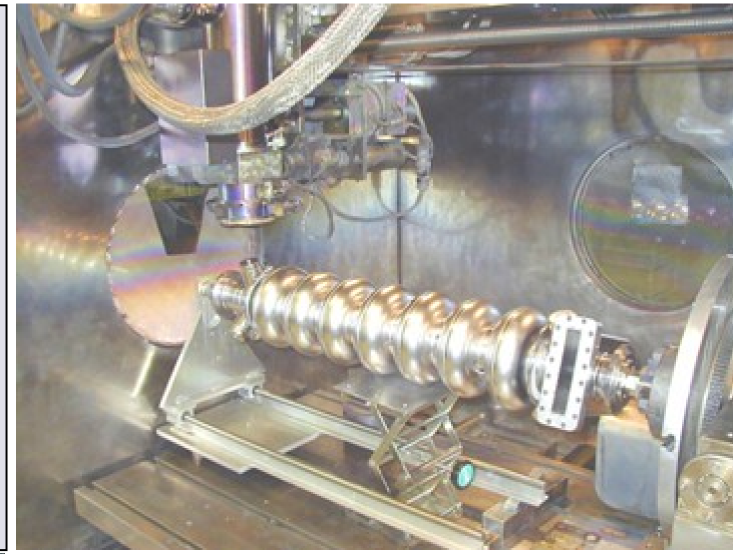
Annealing is next to achieve complete re-crystalisation.

Dumb bells are formed by electron beam welding.

RF measurements support visual inspection.





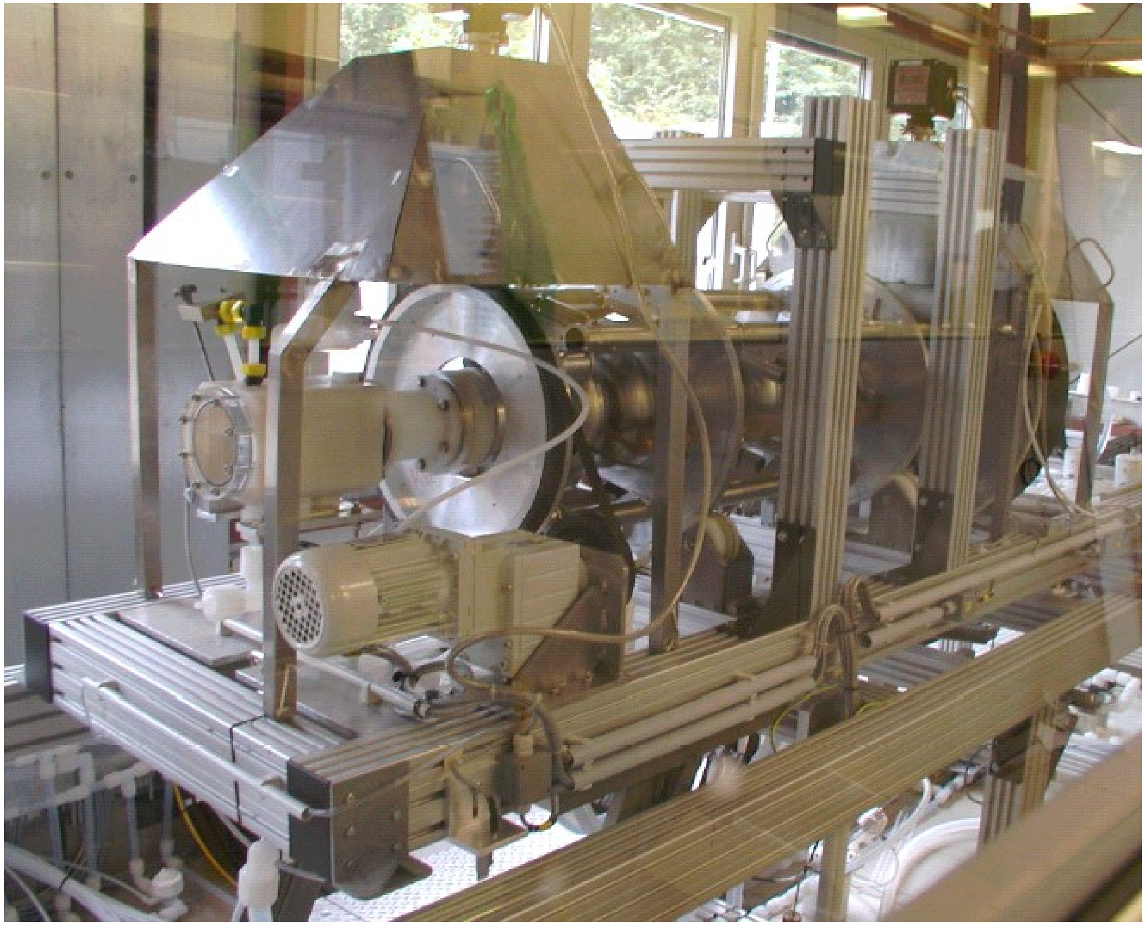


After proper cleaning eight dumb bells and two end group sections are assembled in a precise fixture.

All equator welds can be done in one production step.

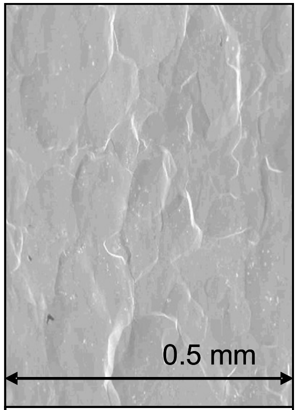
Engineering Data Management Systems (EDMS) is used for the documentation of the cavity fabrication process.

Cavity Preparation (Electrolytical Polishing)

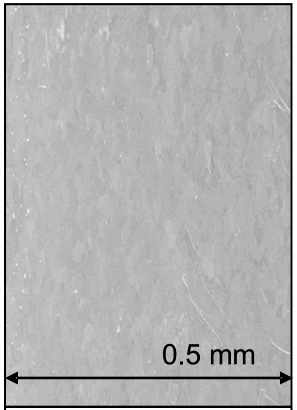


Electro-polishing (EP) instead of the standard chemical polishing (BCP) eliminates grain boundary steps.

Gradients above 40 MV/m at Q values above 10^{10} have been achieved.

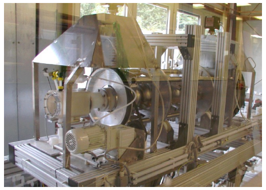


BCP Surface
(1µm roughness)



EP Surface
(0.1µm roughness)

Cavity preparation cont'd

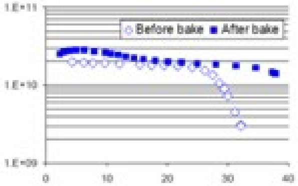


EP 150 µm (inside)

UHV 800°C annealing

"flash" BCP ~10 µm

Or: final EP ~40 µm

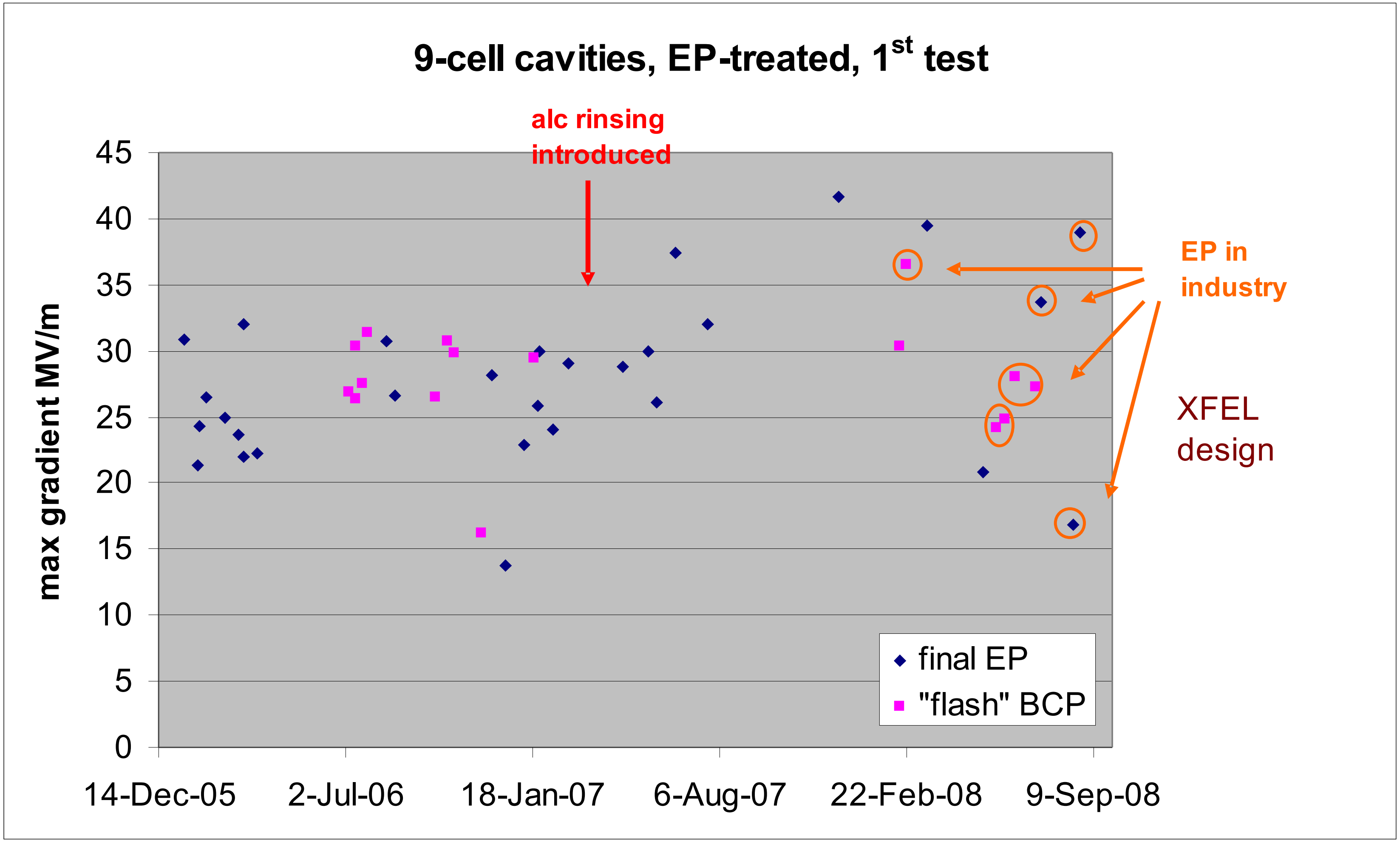


UHV 120°C baking

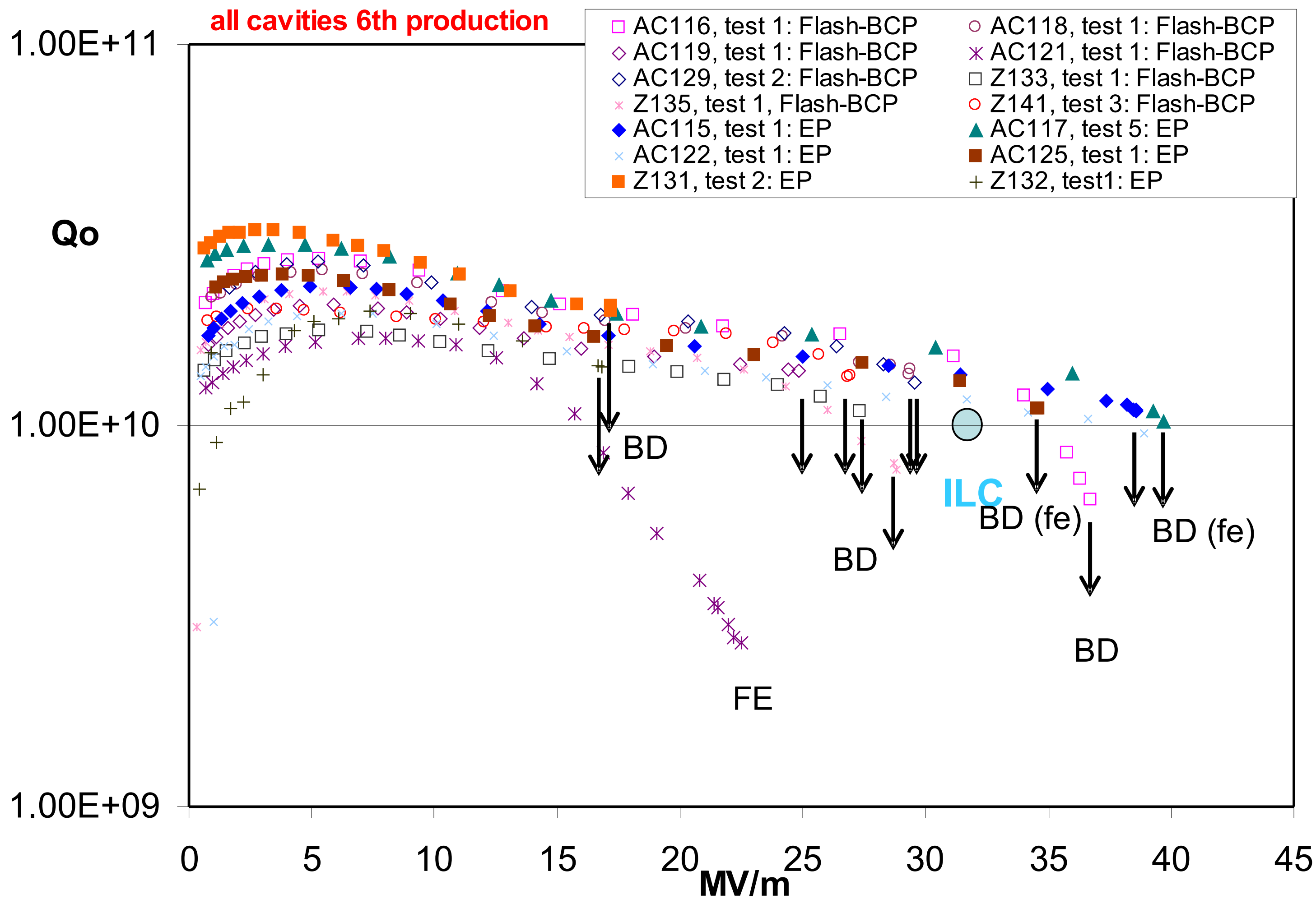
100 bar HPR (6 ×)

- Industrialization of EP ongoing: 10 cavities received from each of two companies

Cavities since Jan 2006, 1st test



Q_0 vs gradient: best results with final ep

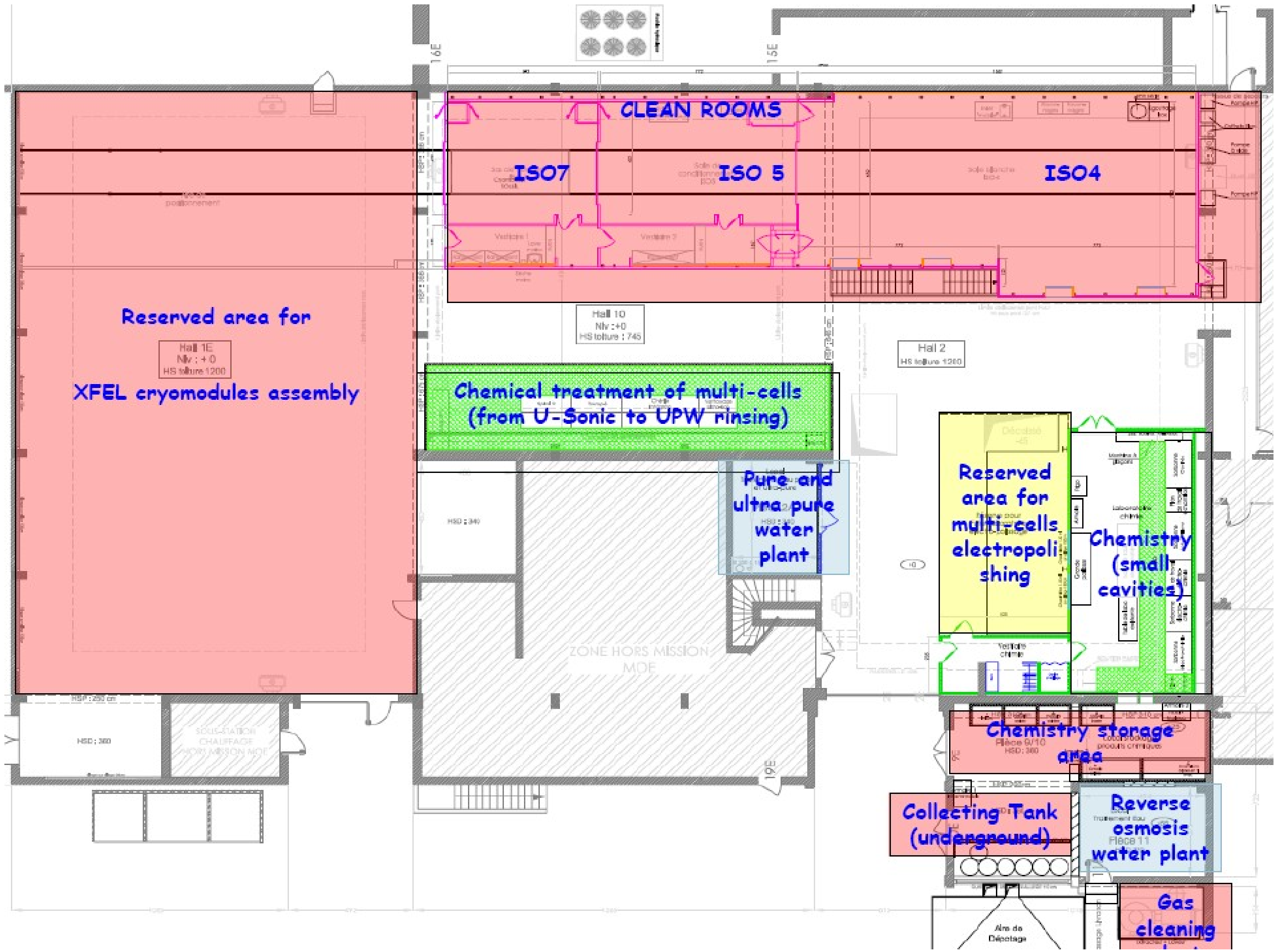


Cavity string & module assembly

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

Assembly facility at CEA/Saclay – industrial study near completion

RF coupler processing facility under preparation at LAL/Orsay

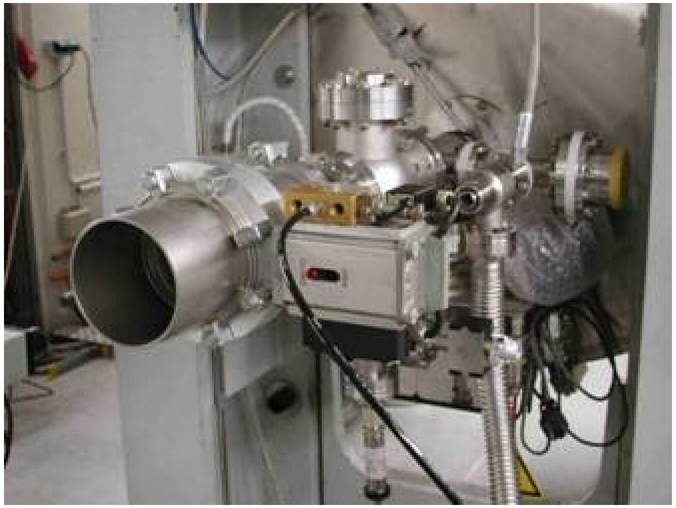


Operation of CMTB at DESY *(cryo module test bench)*

- Four modules tested on CMTB → 3 installed @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

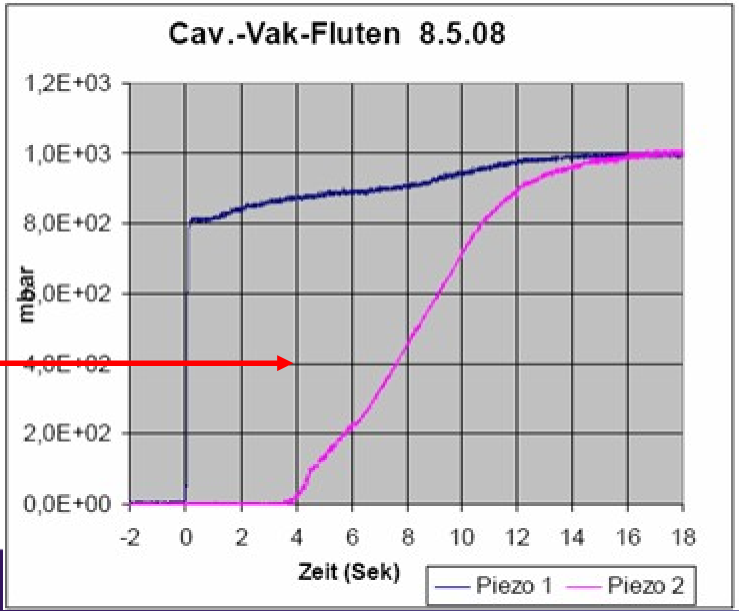
Venting system beam-pipe-vac DN 100



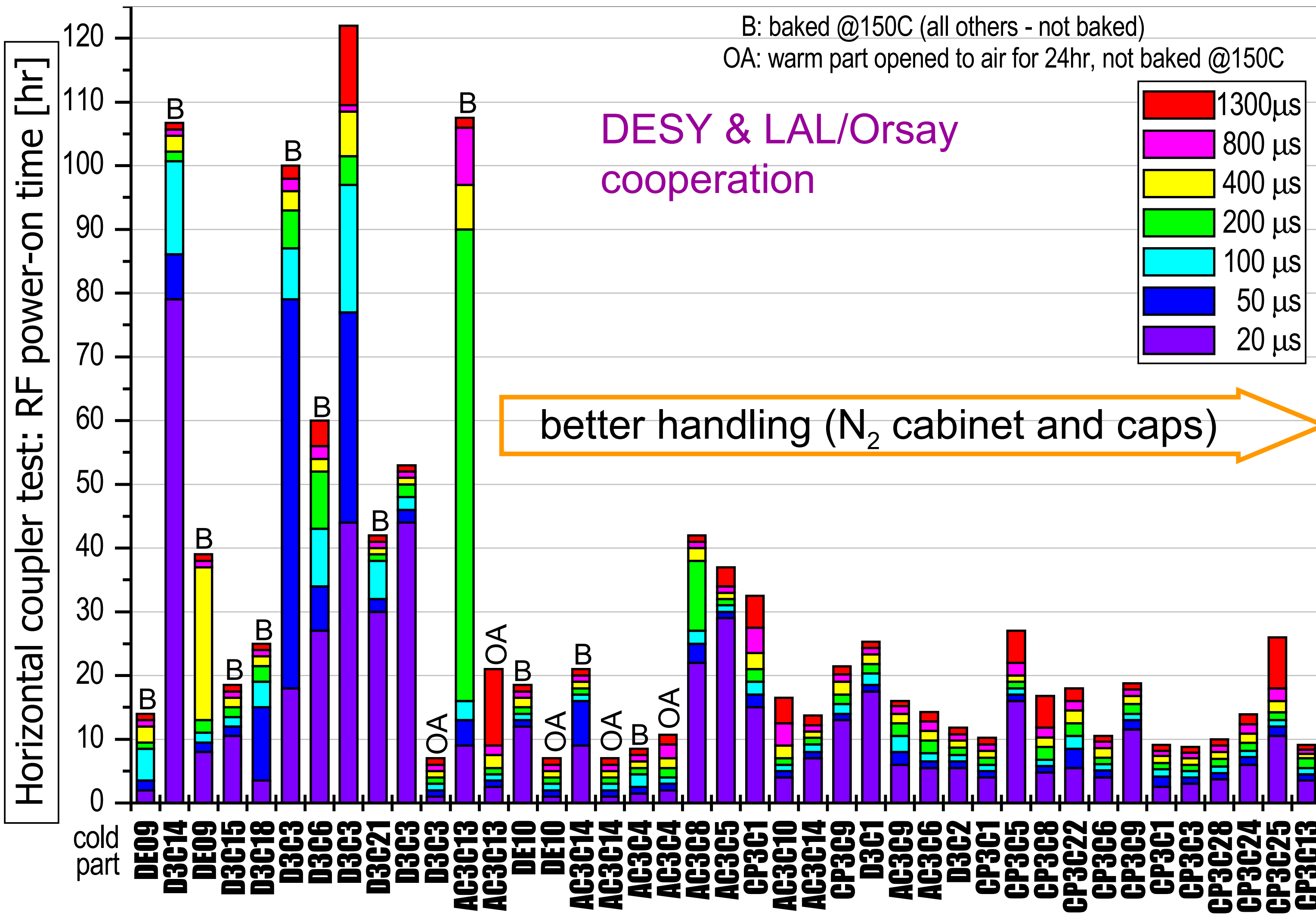
Venting system Iso.-vac DN 100

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

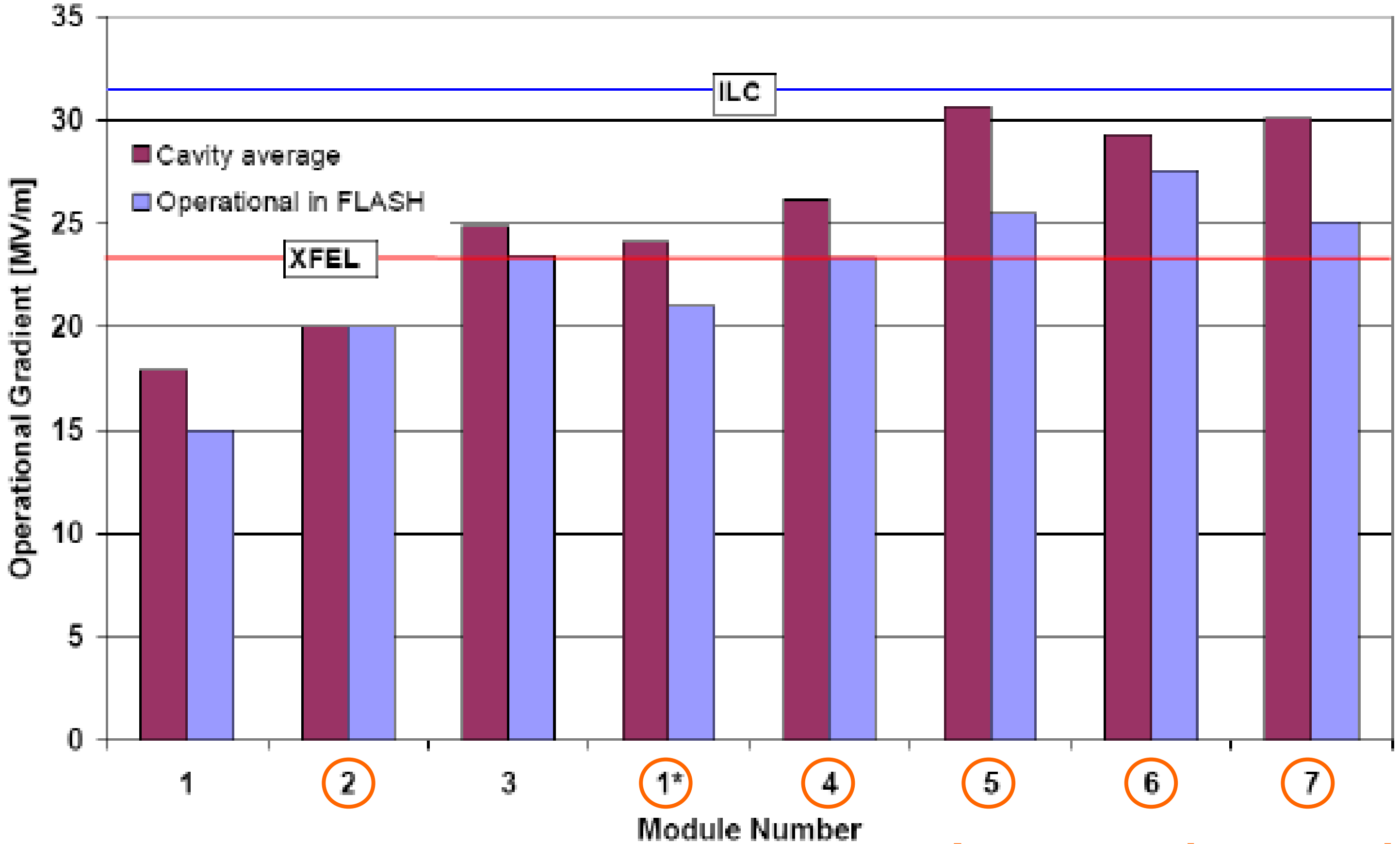
Pressure front in beam-vac takes ~4s(!) through module length



Fast coupler processing (in CHECHIA → in M6,7,8)

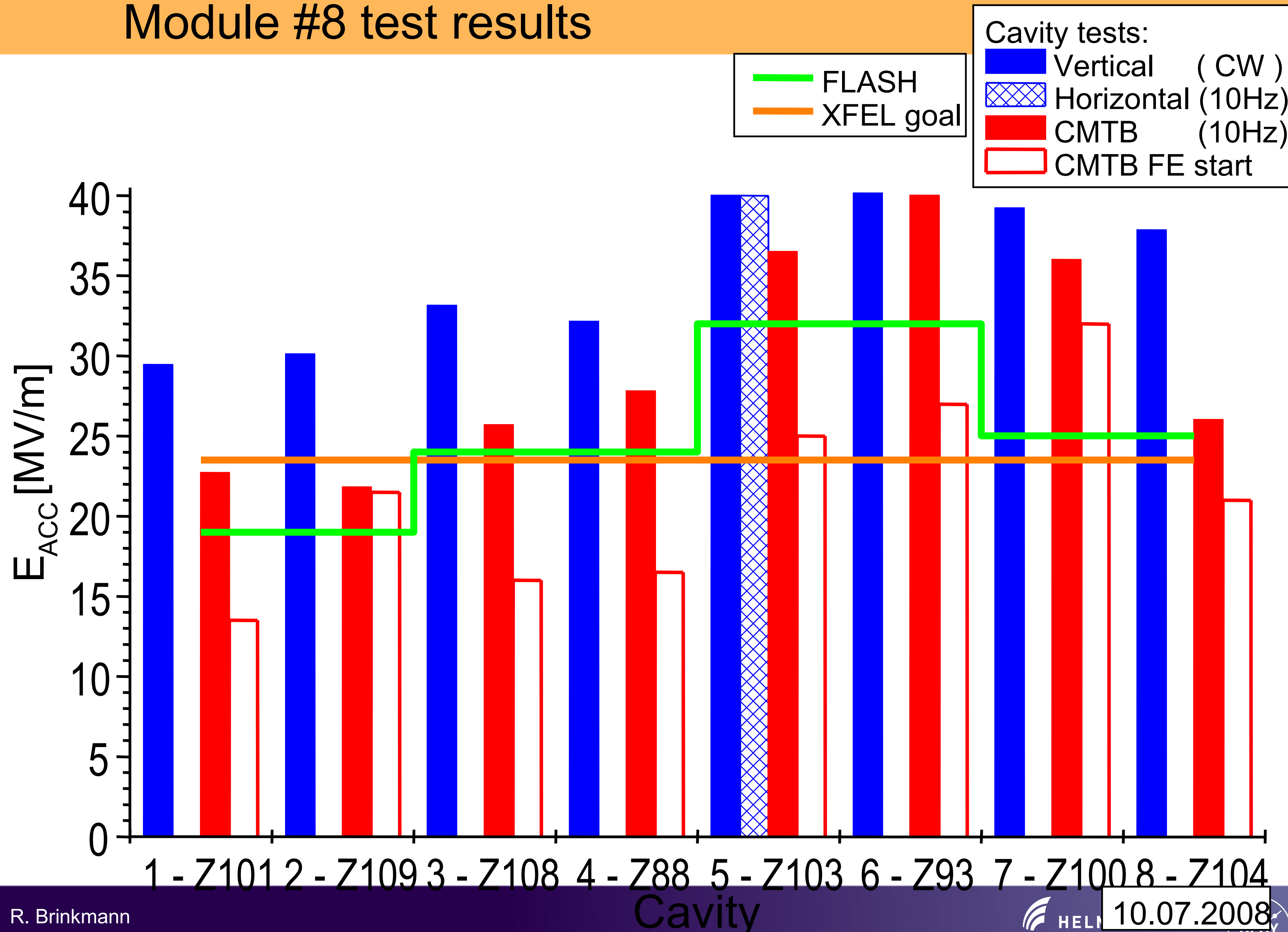


Module performance in FLASH linac



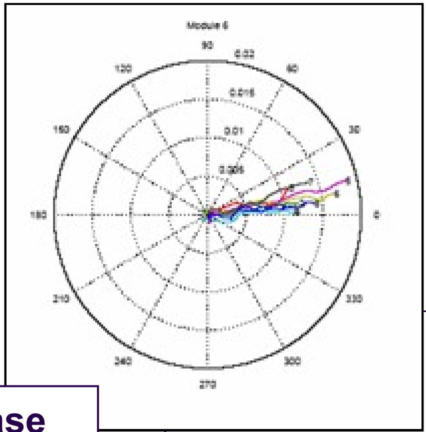
At present in operation @ FLASH

Module #8 test results



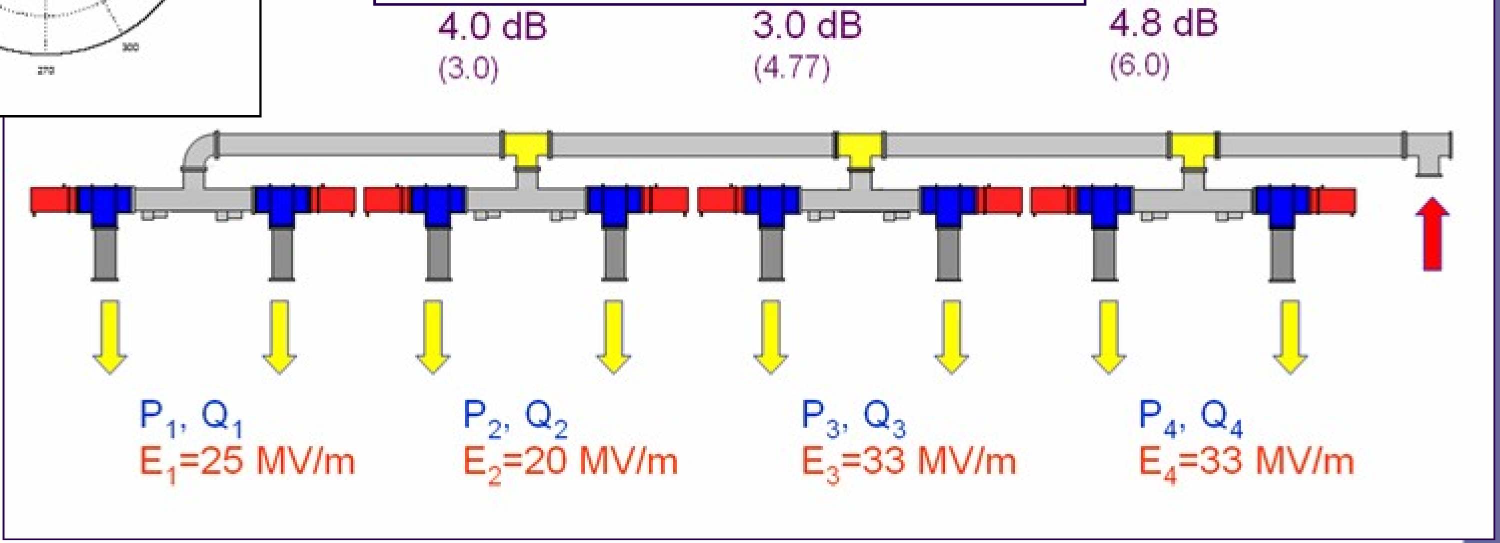
New pre-adjusted waveguide system tested at FLASH/ACC6

Power distribution and phase distribution for the individual cavities almost perfect



Initial phase distribution

Waveguide distribution ACC6



RF system – hor. Klystron

Toshiba E3736H at test stand in August 2007 at Toshiba in Nasu, Japan

Prototypes from two more manufacturers in near future

Test Results (Toshiba)

Test Results (Toshiba)		*(design)*
Peak Output Power at 117kV (MW)	10.3	*(10)*
Efficiency (%)	~67	*(65)*
Beam Pulse Length (ms)	1.7	
RF Pulse length (ms)	1.5	*(1.5)*
Repetition Rate (pps)	10	*(10)*
Saturation Gain (dB)	50	

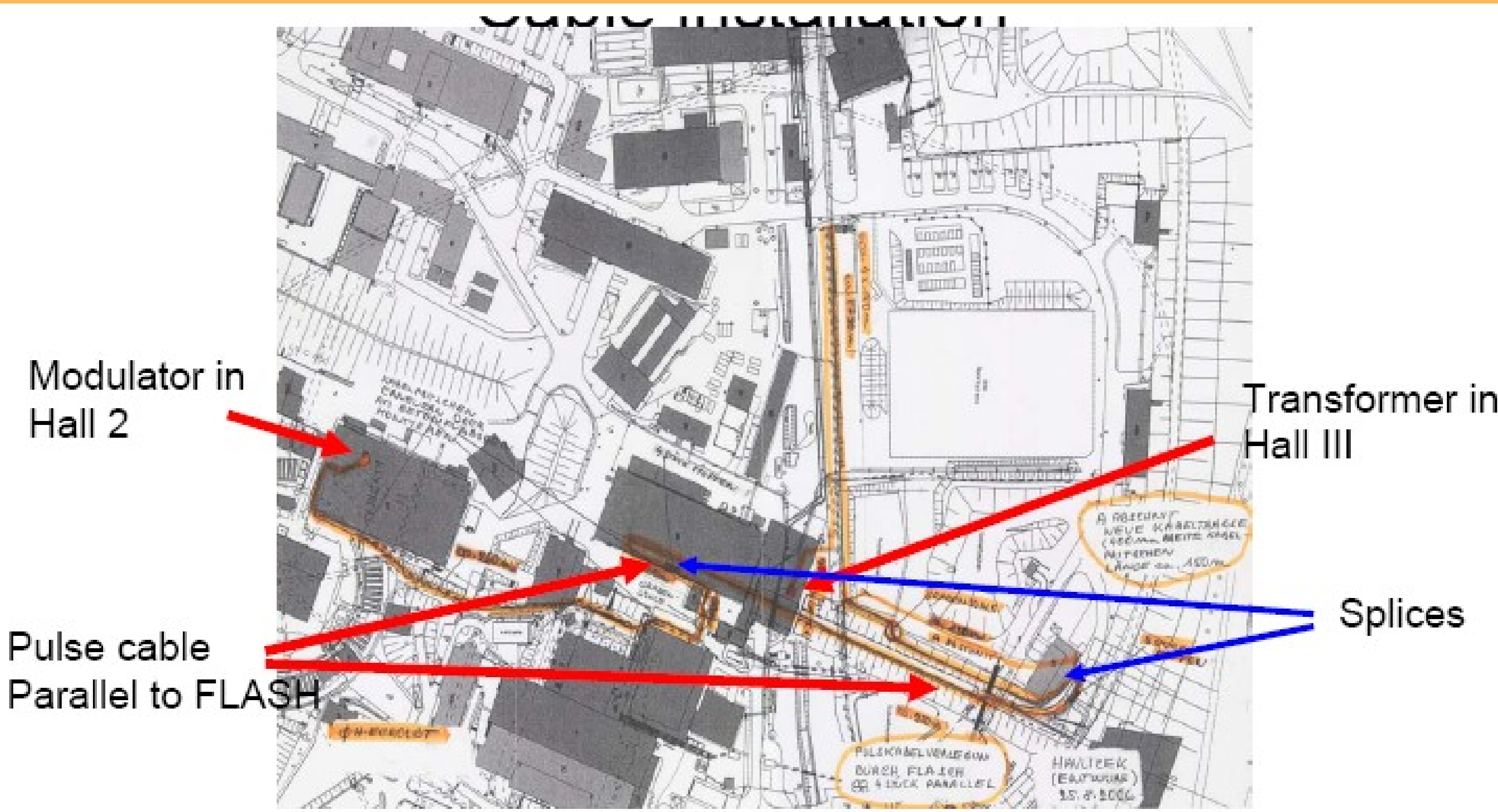
- Factory Acceptance Test in Nasu successfull on August 22/23, 2007
- Klystron arrived at DESY on 18th Sept.
- Site Acceptance Test at DESY

Modulator prototyping

Test stand @ DESY-Zeuthen

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

Pulse cable test in FLASH



→ No perturbation of FLASH operation due to EMI from pulse cables

Tunnel mock-up completed and installations ongoing

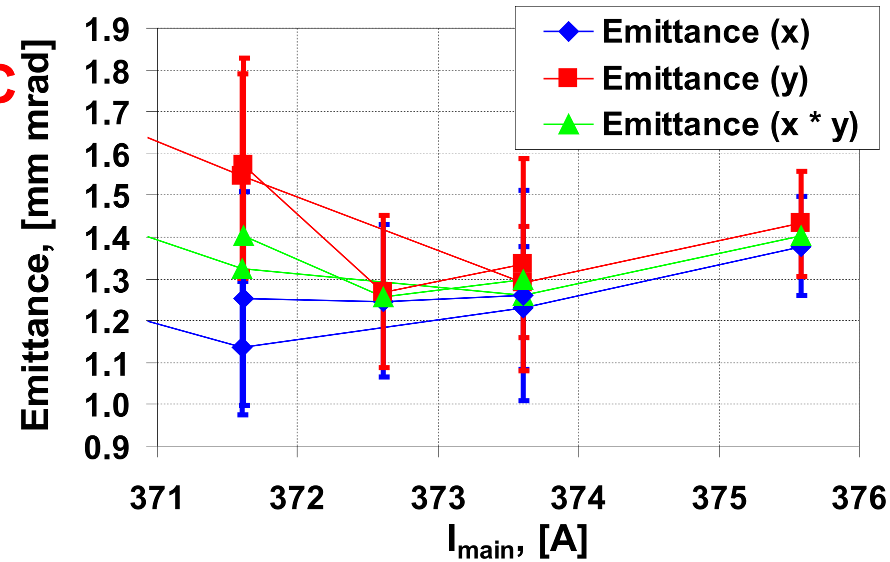
Injector R&D - PITZ

August 2007:

$$\varepsilon_{x,n} = 1.25 \pm 0.19 \text{ mm mrad}$$
$$\varepsilon_{y,n} = 1.27 \pm 0.18 \text{ mm mrad}$$

@1nC

for 100 % RMS emittance !



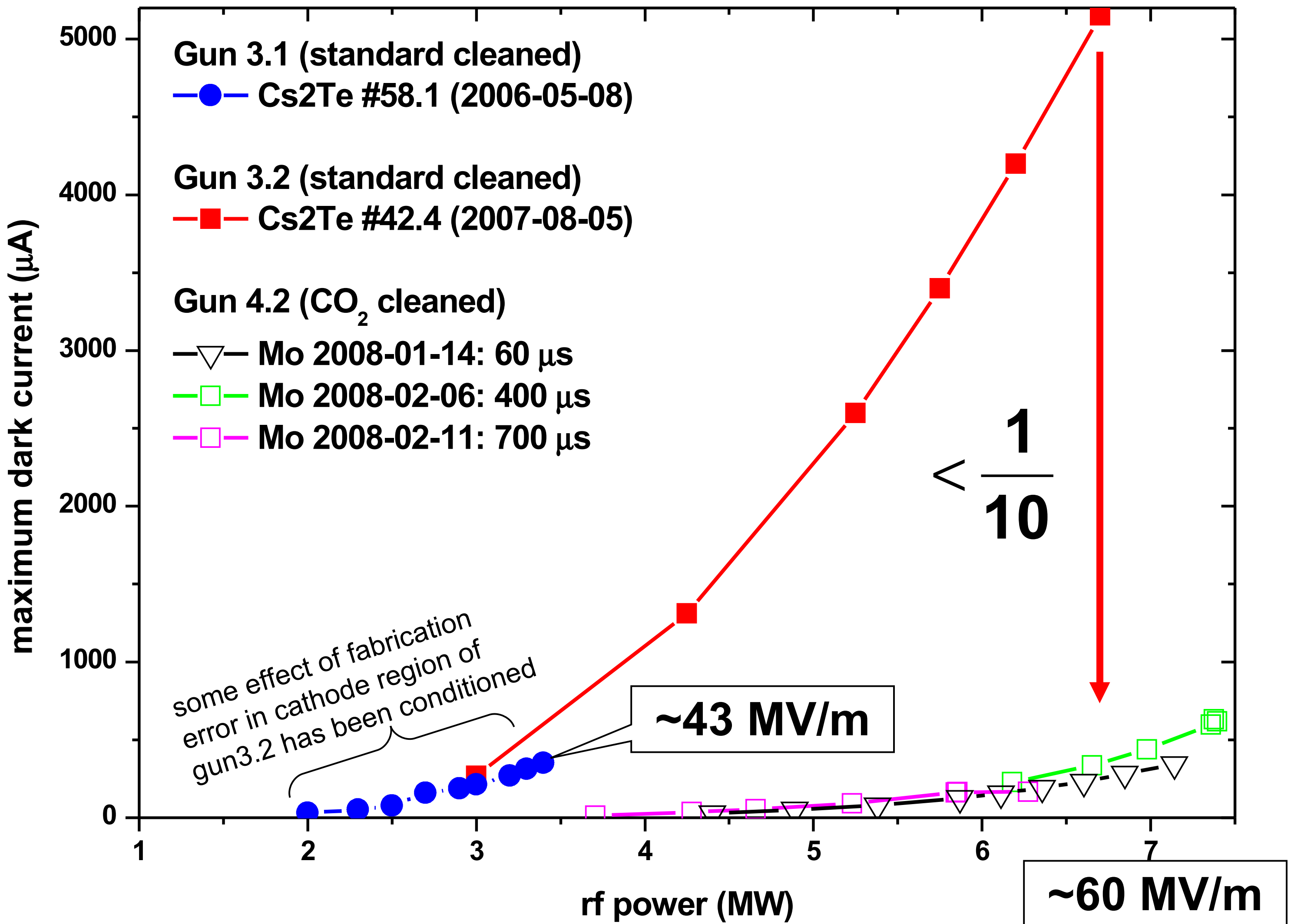
With 10% charge cut:

$$\varepsilon_{x,y,n} \approx 0.9 \text{ mm mrad}$$

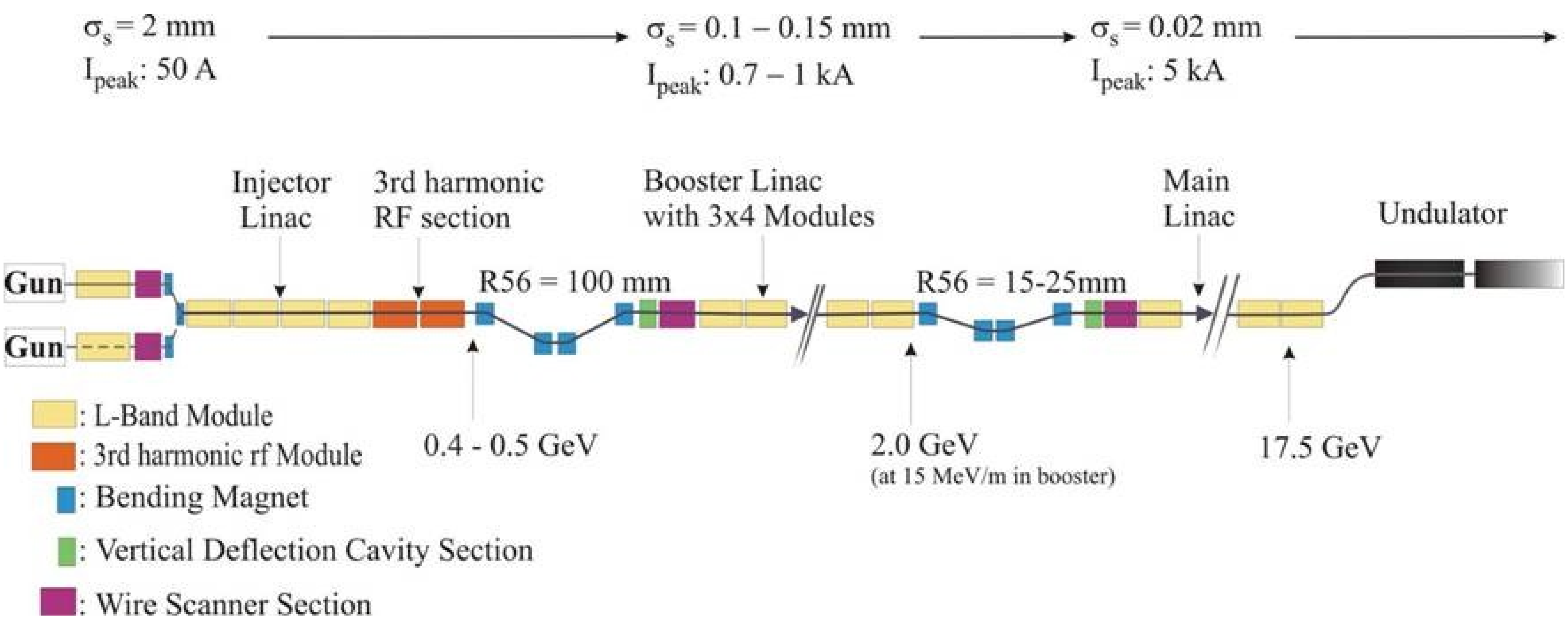
XFEL design values is 0.9 mm mrad from the gun and 1.4 mm mrad in the undulators for FEL saturation at 0.1nm wavelength

Further improvement of projected emittance with laser upgrade

Reduced dark current with new CO_2 cleaned gun 4.2



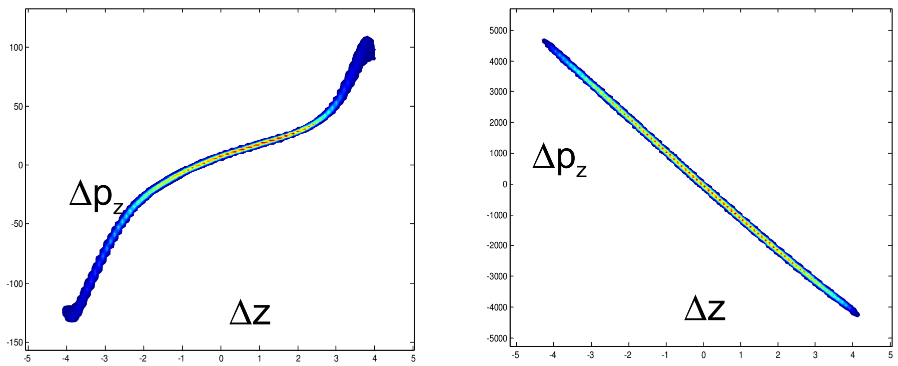
Bunch compressor & diagnostics stations



Extensive S2E studies of beam dynamics

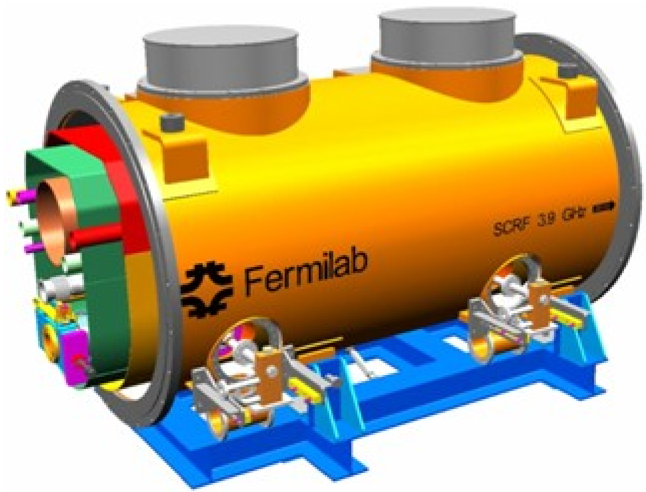
→ Slice emittance at undulators < 1 mm*mrad

3rd harmonic RF-system → FLASH



Will gain invaluable experience for XFEL!

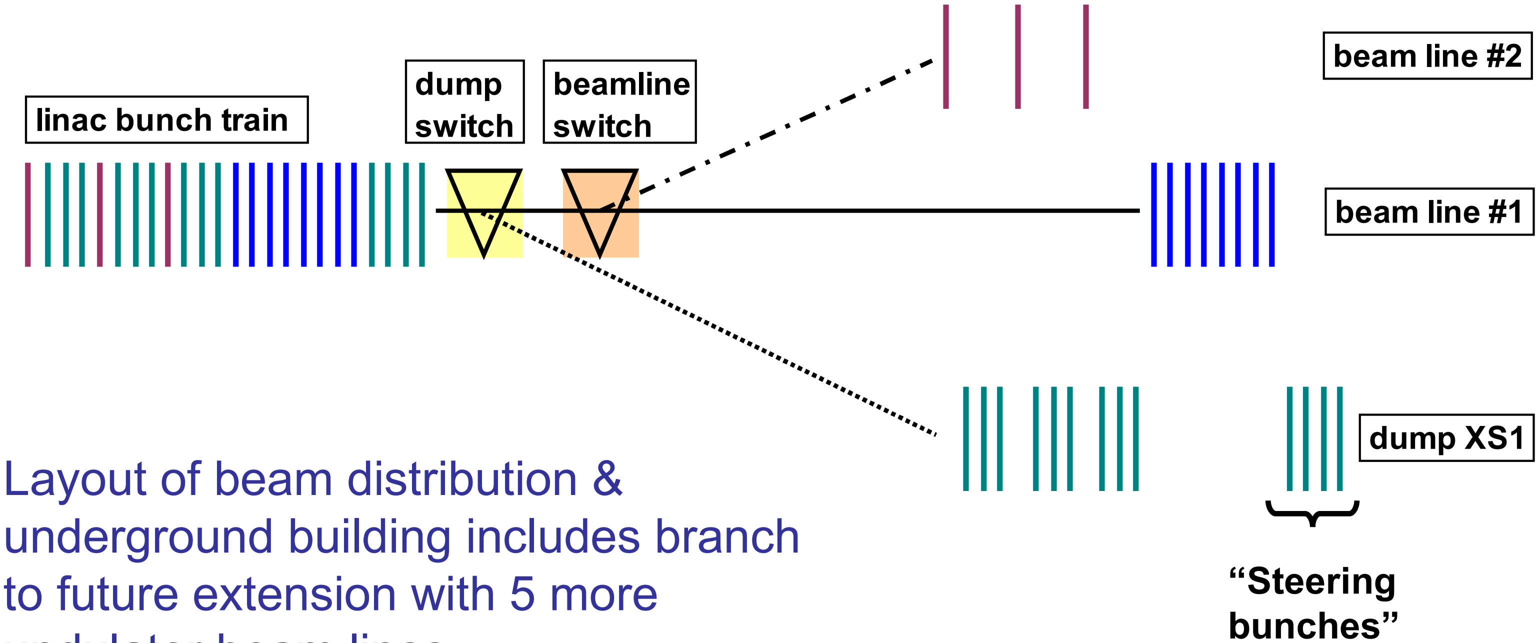
- Complete cryomodule delivered by FNAL
- Installation after ACC1 scheduled for 2009



- module with four nine cell cavities
- fits type 2 TESLA module
- XFEL will use three 6m modules/8 cavities (DESY & INFN coop.)

Beam distribution

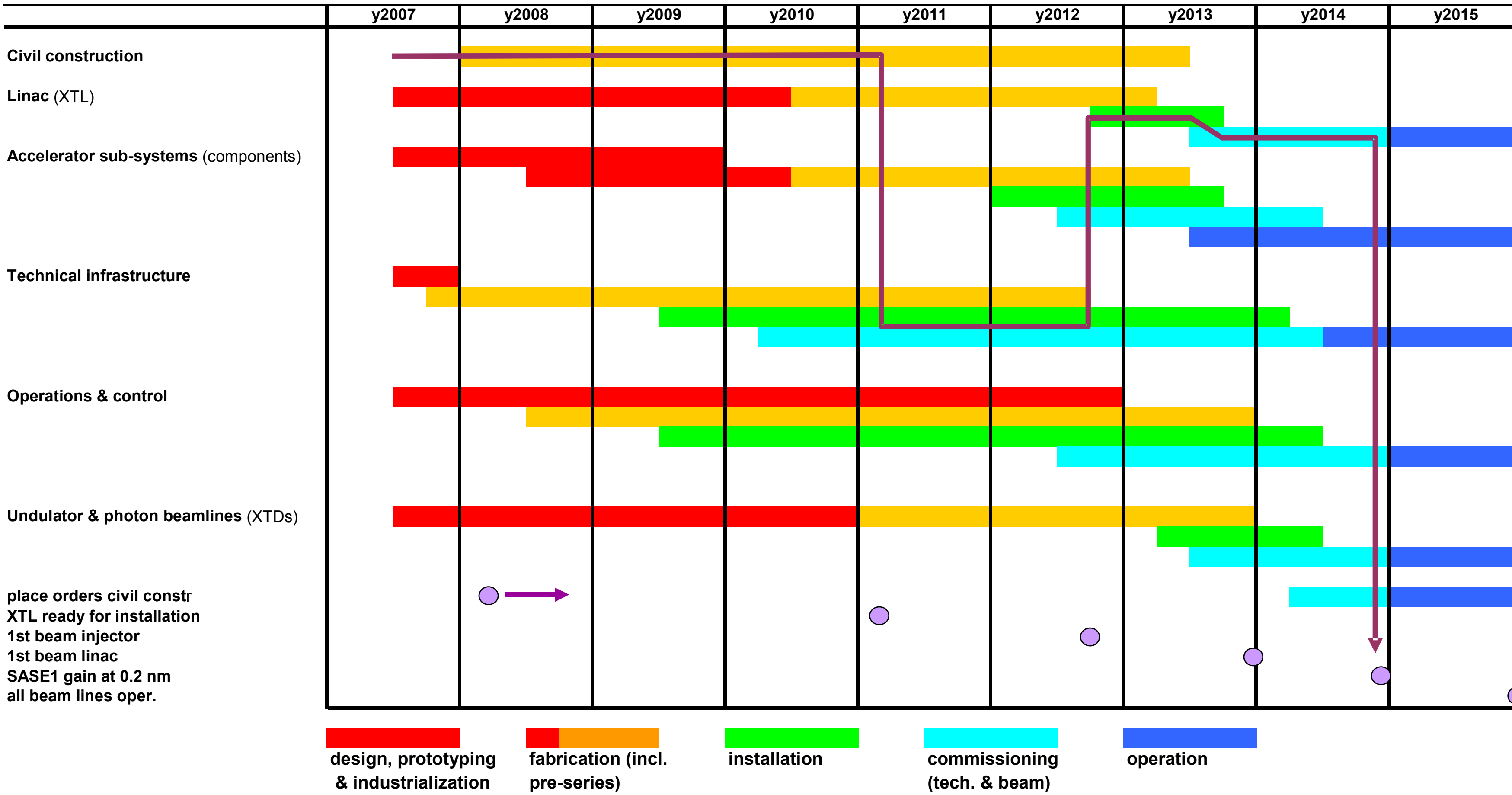
Different beam time structure to different experiments – concept using kicker devices permits large flexibility without having to change the (preferably homogenous) bunch train structure in the linac



Layout of beam distribution & underground building includes branch to future extension with 5 more undulator beam lines

Fast intra-train feedback system (DESY & PSI cooperation)

Schedule *(as of July 2007)*



Estimated delay ~ 10 months *(tender process underground construction)*

The end