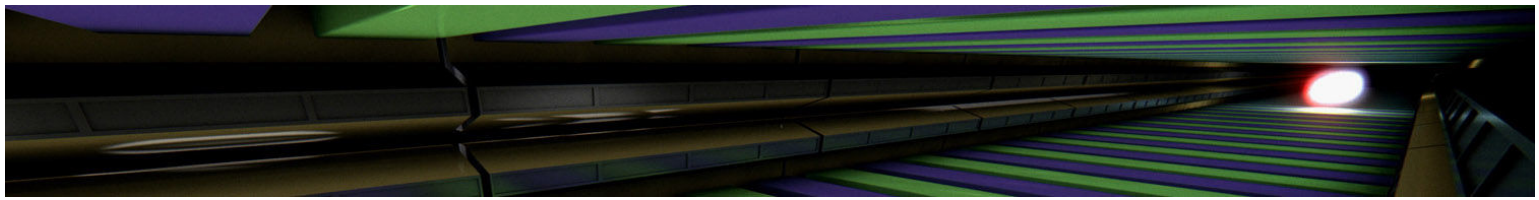


The European XFEL

Accelerator Consortium's Activities

Hans Weise / DESY

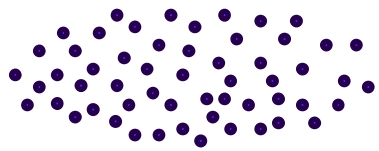
Abstract

- With main emphasis on the XFEL's cold linac a summary of the work done by the Accelerator Consortium will be given. Final prototyping of components and the preparation of large call for tenders are the main issues in 2009. The civil construction was started. Most of the possible in-kind contributions are identified.

Introduction
Free-Electron Laser - ingredients

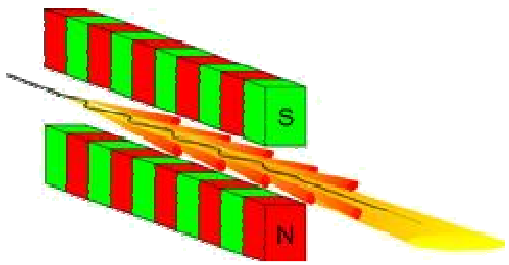
A **Free-Electron Laser** is a light source exploiting the spontaneous and/or induced emission of a relativistic electron beam "guided" by the periodic and static magnetic field generated by an undulator (typ. 0.5 – 1 T).

Electron beam at relativistic energy



Energy	(γ)
Current	(I)
Emittance	(ε)
Energy spread	($\delta\gamma$)
Dimensions	(σ)

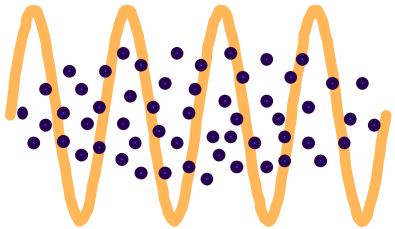
Undulator



Magnetic period	(λ_u)
Magnetic strength	(K)
Undulator length	(L)

Electromagnetic field

co-propagating with the electron beam and **getting amplified** to the detriment of the electrons' kinetic energy



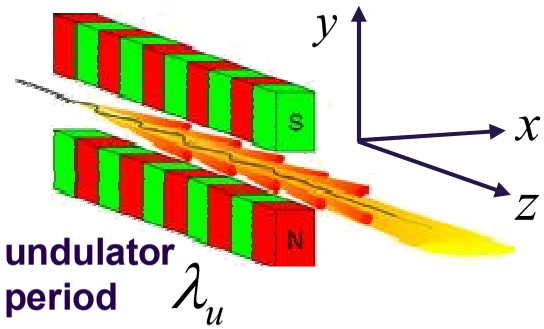
Wavelength	(λ)
Power	(P)

The Electron in a planar undulator …

$$\vec{B} = \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix} = B_0 \begin{pmatrix} 0 \\ \sin(k_u z)\cosh(k_u y) \\ \cos(k_u z)\sinh(k_u y) \end{pmatrix}$$

undulator field

$$k_u = 2\pi / \lambda_u$$



$$\frac{d\vec{p}}{dt} = q\ \vec{v} \times \vec{B}$$

equation of motion

$$\ddot{x} = \frac{eB_0}{\gamma m_0}\left(\dot{y}\cos(k_u z)\sinh(k_u y) - \dot{z}\sin(k_u z)\cosh(k_u y)\right)$$

$$\ddot{y} = \frac{eB_0}{\gamma m_0}\left(-\dot{x}\cos(k_u z)\sinh(k_u y)\right)$$

$$\gamma = E / m_0 c^2$$

… undergoes a periodic motion

$$x \approx x_m \sin(k_u z) + x_0' z + x_0$$

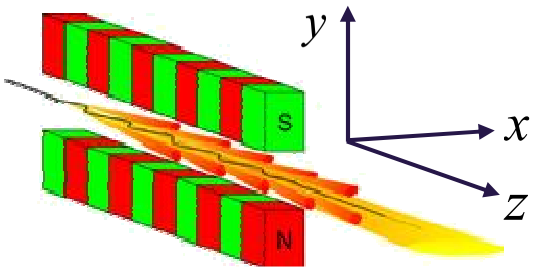
$$y \approx y_m \cos(k_\beta z + \Phi_\beta)$$

periodic motion

$$x_m = \frac{K}{k_u \gamma}$$

$$K = \frac{e}{2\pi m_0 c} \cdot \lambda_u B_0$$

$$k_\beta = k_u \frac{K}{\sqrt{2}\gamma}$$

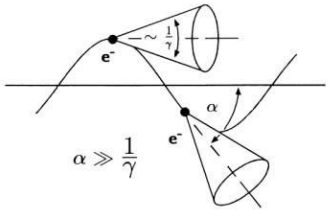


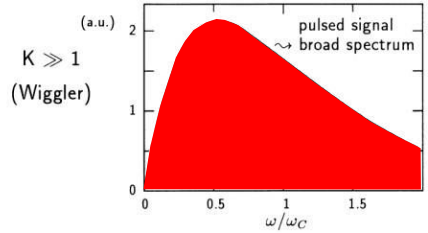
$x_0, x_0', y_m, \Phi_\beta$ depending on electron injection

$$\frac{d\vec{p}}{dt} = q\ \vec{v} \times \vec{B}$$

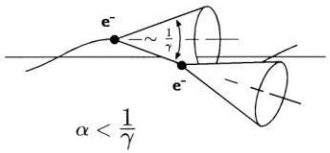
equation of motion

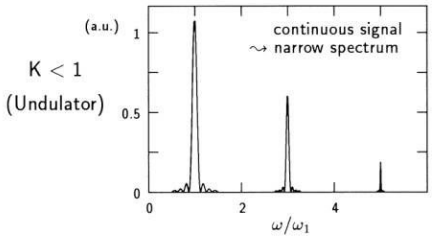
$K >> 1$
wiggler





$K < 1$
undulator





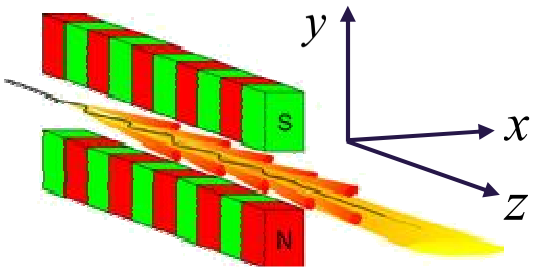
The electron's position and velocity

$$x \approx x_m \sin(k_u z) + x_0' z + x_0$$

ignore uniform motion

$$y \approx y_m \cos(k_\beta z + \Phi_\beta)$$

ignore slowly varying motion



periodic motion

$$\frac{d\vec{p}}{dt} = q\ \vec{v} \times \vec{B}$$

equation of motion

$$\vec{r}(t) = \begin{pmatrix} \frac{K}{k_u \gamma} \sin(k_u \beta_z t) \\ 0 \\ \beta_z t \end{pmatrix}$$

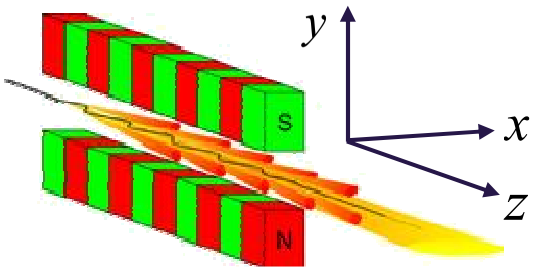
position vector

$$\vec{\beta}(t) = \begin{pmatrix} \frac{K}{\gamma} \cos(k_u \beta_z t) \\ 0 \\ \left(\left|\vec{\beta}\right|^2 - \frac{K}{\gamma} \cos^2(k_u \beta_z t) \right)^{1/2} \end{pmatrix}$$

velocity vector

Average electron velocity parallel to undulator axis

$$\beta_z(t) = \left(1 - \frac{2+K^2}{4\gamma^2}\right)$$



average electron velocity parallel to undulator axis

$$\beta_z(t) = \left(\beta^2 - \left\langle \beta_x^2 \right\rangle\right)^{1/2}$$

$$= \left(\beta^2 - \frac{K^2}{\gamma^2}\left\langle \cos^2(k_u \beta_z t)\right\rangle\right)^{1/2}$$

$$= \left(1 - \frac{1}{\gamma^2}\left(1 + K^2 \frac{1}{2}\right)\right)^{1/2}$$

$$\beta_z(t) \approx \left(1 - \frac{1}{4\gamma^2}\left(2 + K^2\right)\right)$$

$$\vec{\beta}(t) = \begin{pmatrix} \frac{K}{\gamma}\cos(k_u \beta_z t) \\ 0 \\ \left(\left|\vec{\beta}\right|^2 - \frac{K}{\gamma}\cos^2(k_u \beta_z t)\right)^{1/2} \end{pmatrix}$$

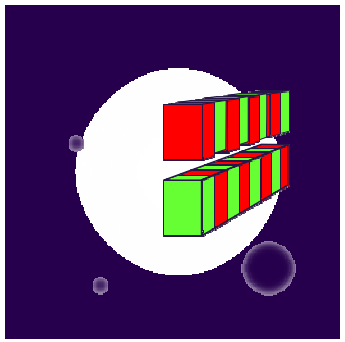
$$\frac{d\vec{p}}{dt} = q\ \vec{v} \times \vec{B}$$

equation of motion

Undulator radiation in forward direction

$$\beta_z(t) = \left(1 - \frac{2 + K^2}{4\gamma^2}\right)$$

average electron velocity parallel to undulator axis

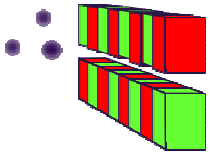


$$\lambda_e = \lambda_u \sqrt{1 - \beta_z^2}$$

the electron sees the Lorentz contracted undulator period

$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{K^2}{2}\right)$$

undulator radiation in forward direction



$$\lambda = \lambda_e \frac{1 - \beta_z}{\sqrt{1 - \beta_z^2}}$$

the FEL users sees and uses the Doppler shifted light

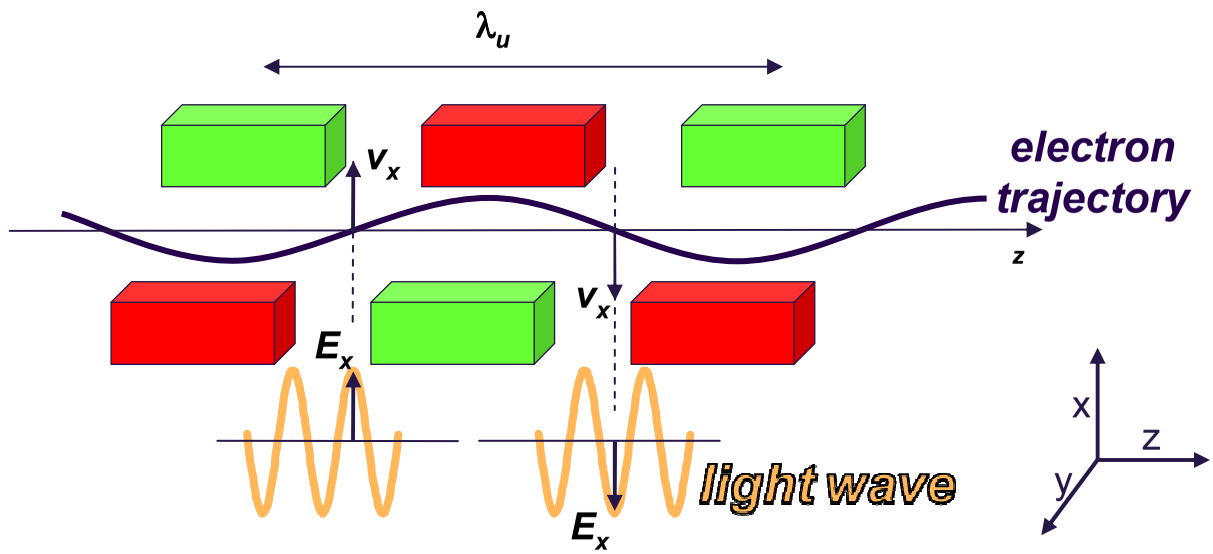
Sustained energy transfer

light wave

the transversally accelerated electrons emit synchrotron radiation

slippage

electrons move slower than the co-propagating electromagnetic light wave

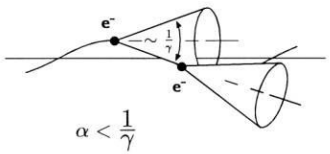


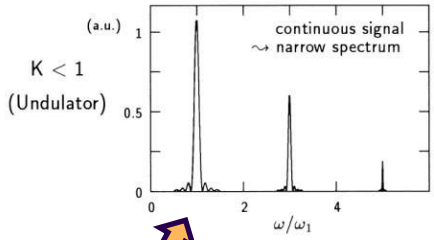
$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1+\frac{K^2}{2}\right)$$

Condition for sustained energy transfer leads to exactly the same wavelength as in undulator radiation

- sustained energy transfer from the electron to the light wave is guaranteed if **the light wave slips** forward by $\lambda/2$ per half period of the electron trajectory, i.e. per half period of the undulator ($\lambda_u/2$)
- this leads to **constructive interference** since the relative phase between the synchrotron radiation emitted by the electron and the co-propagating field remains constant

Electrons in the co-propagating light wave





fundamental mode

$$\omega_1 = \frac{2\gamma^2 k_u c}{1 + K^2/2 + \gamma^2\Theta^2}; \quad \Theta = 0°$$

$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{K^2}{2}\right)$$

Condition for sustained energy transfer leads to exactly the same wavelength as in undulator radiation

$$\frac{d^2W}{d\Omega d\omega} = const.\sum_n 4\xi \cdot F_J(n\xi)\cdot(nN)^2 \frac{\sin^2 x}{x^2}$$

intensity distribution of synchrotron radiation

$$\vec{E} = \hat{x}\cdot E_0 \cos(\omega t - kz + \Phi)$$

co-propagating light wave

$$\dot{\gamma} = -\left(\frac{e}{m_0 c^2}\right)^2 \frac{\lambda_u}{4\pi\gamma} B_0 E_0 \sin\psi$$

$$\ddot{\psi} = -\left(\frac{e}{m_0 c^2}\right)^2 B_0 E_0 \sin\psi$$

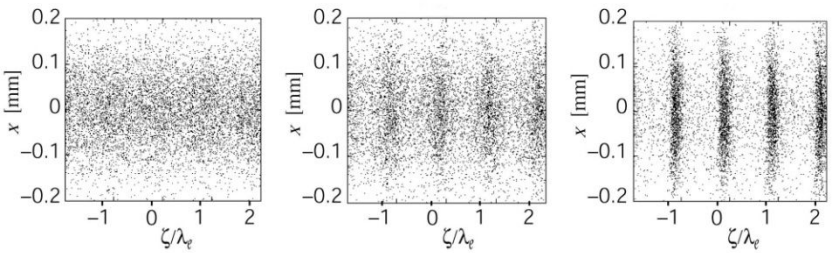
ponderomotive potential
(non-linearized pendulum equation)

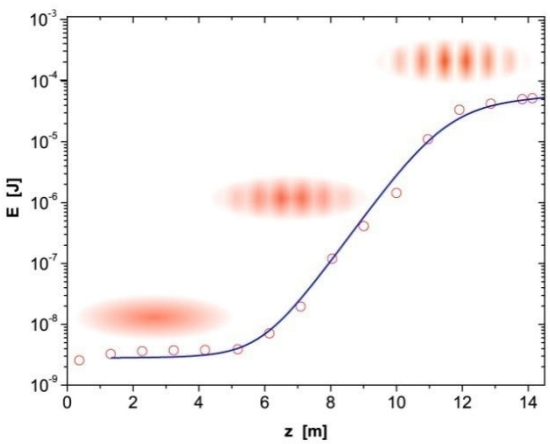
Bunching in the ponderomotive potential

electrons are micro-bunched in the periodic potential and groups of electrons become **point-like radiation sources**

the intensity of the light wave becomes **proportional to N^2** , N being the number of electrons

the FEL photon pulse energy is growing exponentially





$$\dot{\gamma} = -\left(\frac{e}{m_0 c^2}\right)^2 \frac{\lambda_u}{4\pi\gamma} B_0 E_0 \sin\psi$$

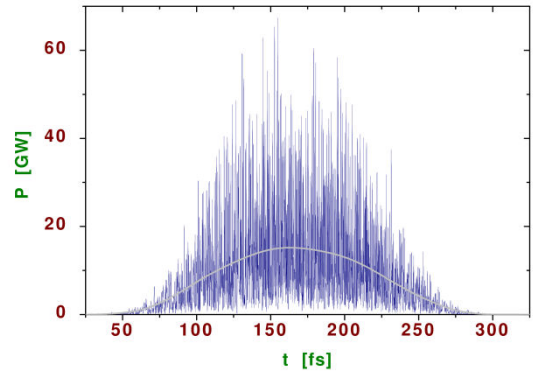
$$\ddot{\psi} = -\left(\frac{e}{m_0 c^2}\right)^2 B_0 E_0 \sin\psi$$

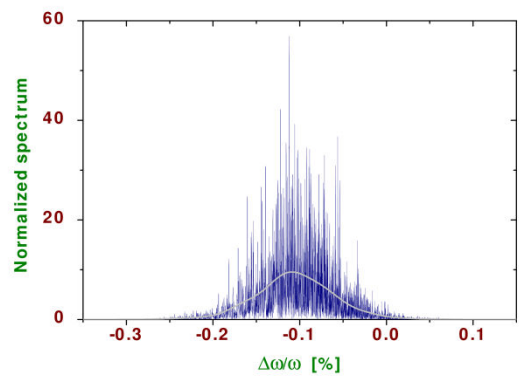
ponderomotive potential
(non-linearized pendulum equation)

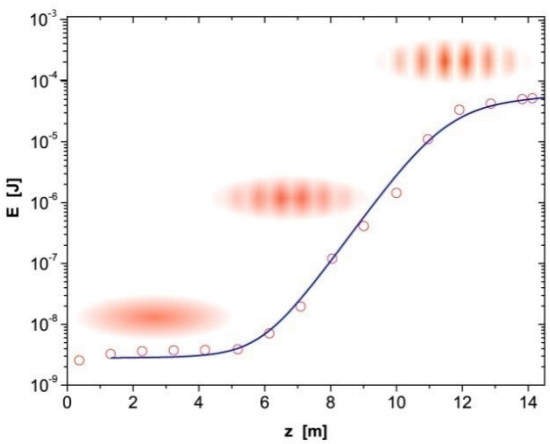
Self Amplified Spontaneous Emission (SASE)

Without seeding the process is initiated by shot noise and both temporal and spectral properties are affected.

Nevertheless, **Self Amplified Spontaneous Emission** can be used to produce brilliant light in the very short wavelength region down to 1 Å.







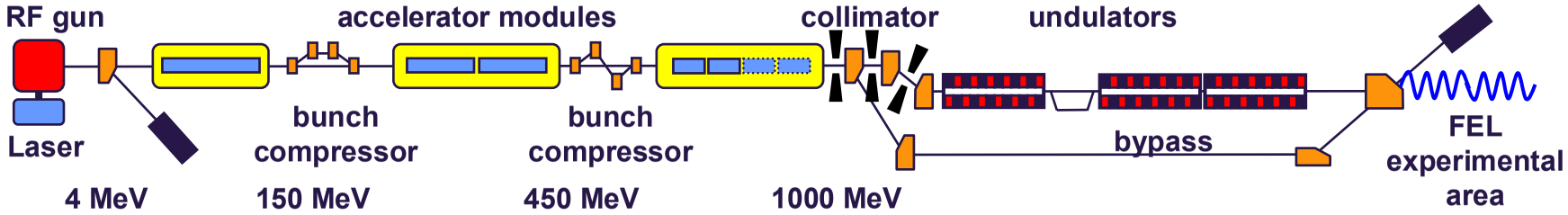
gain length

$$L_g = C\left(\frac{\gamma\varepsilon\beta}{I_{peak}}\right)^{1/3}$$

$$C = \frac{1}{\sqrt{3}}\left(\frac{2m_0 c\lambda_u}{\mu_0 e K^2}\right)^{1/3}$$

XFEL simulation for 12.4 keV (0.1 nm) at 17.5 GeV electron beam energy

The FLASH VUV-FEL facility at DESY

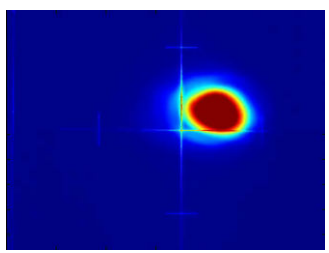


→ **6 accelerator modules** routinely in operation; design beam energy & photon wavelength (6.5 nm) since Oct. 2007

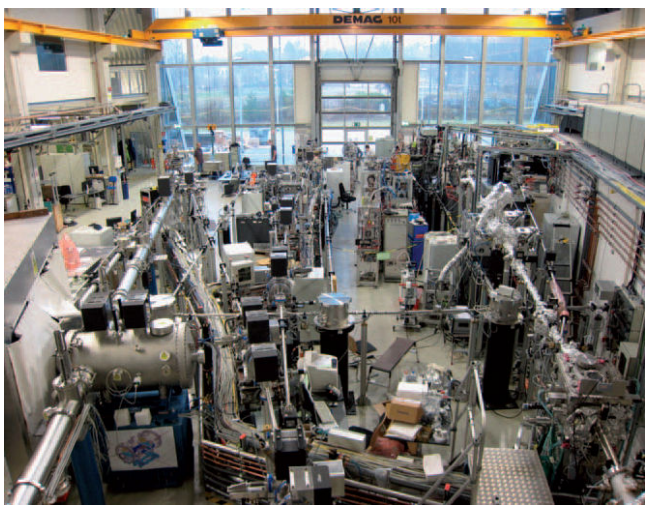
→ **pilot facility** regarding practically all aspects (accelerator technology, beam physics, FEL process, user operation) of the XFEL

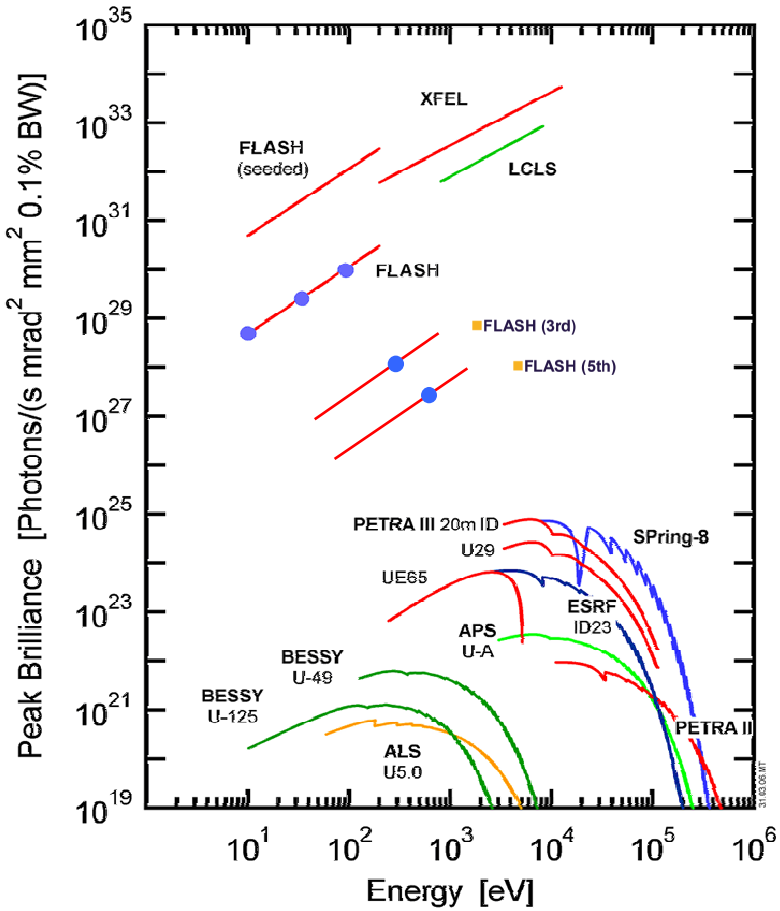
FLASH – Free-Electron Laser in Hamburg

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)	**5-10×10^{29}**	ph/s/mrad^2/mm^2/(0.1% bw)	

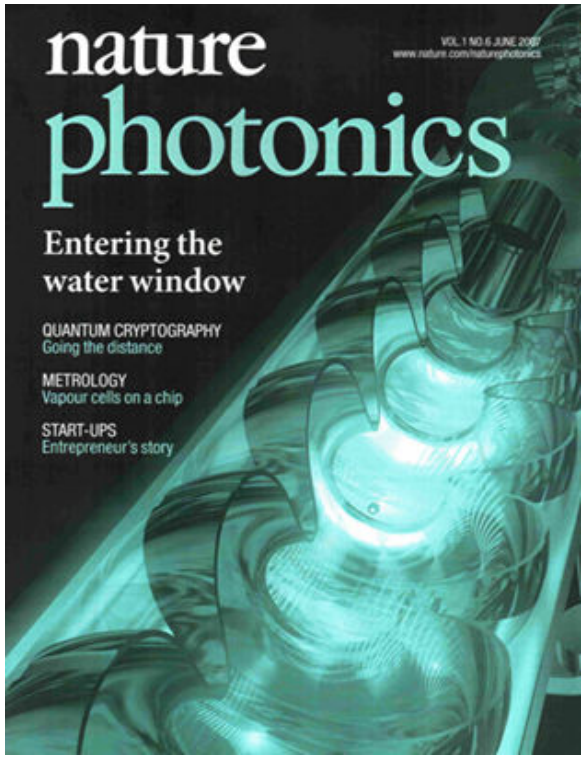


<E> = 70 µJ





FLASH References



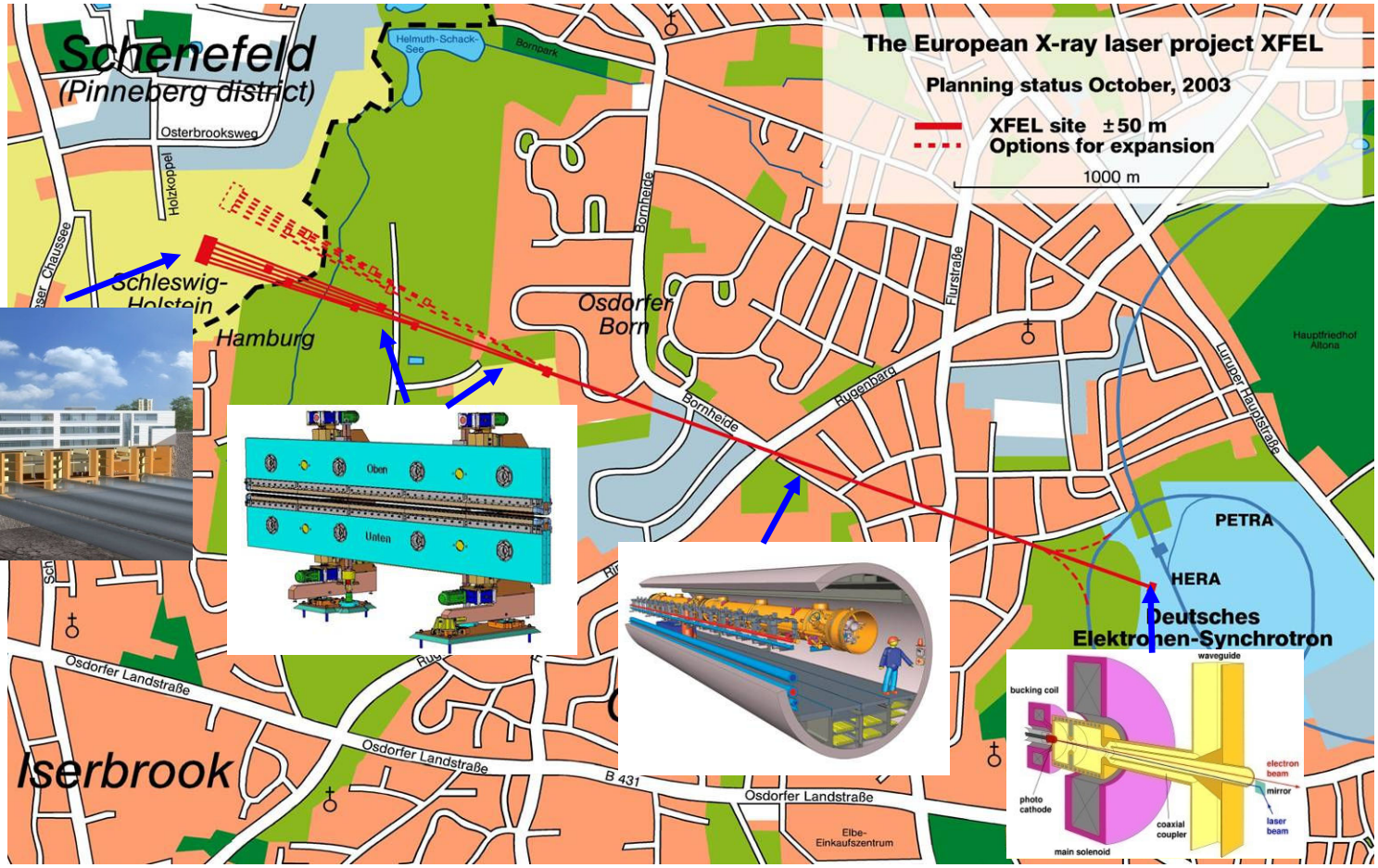
Operation of a free-electron laser from the extreme ultraviolet to the water window

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

- http://flash.desy.de/

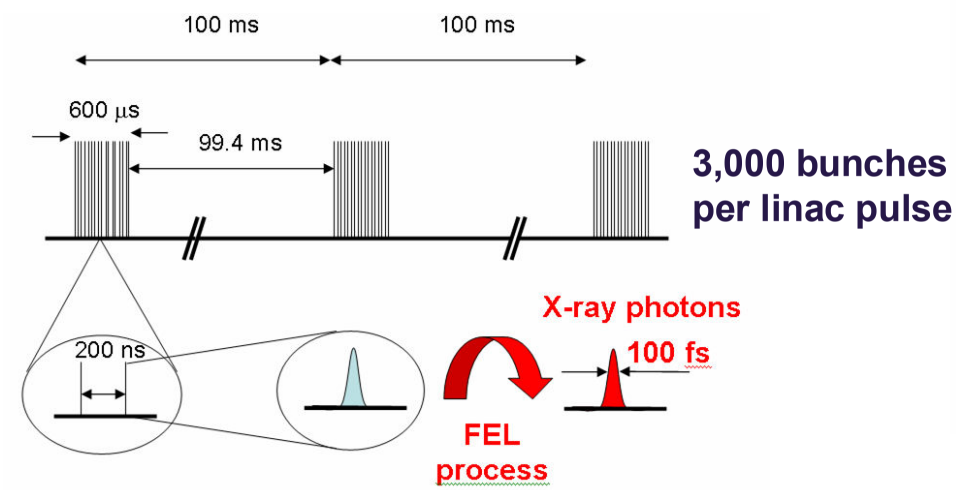
Overall layout of the European XFEL

3.4km

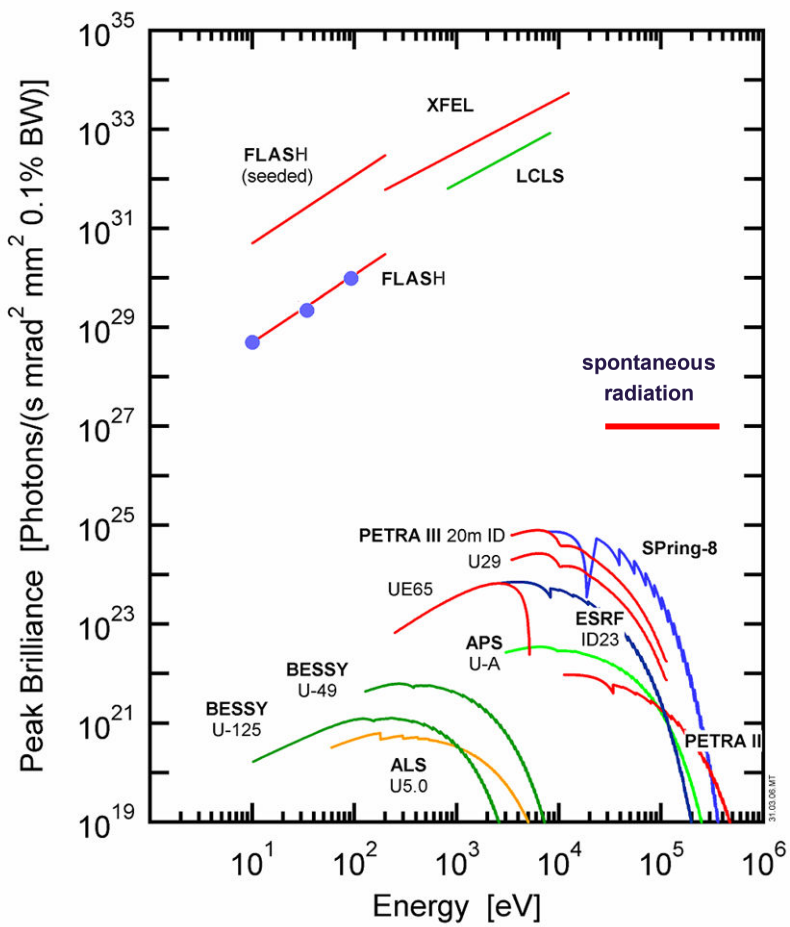


Properties of XFEL radiation

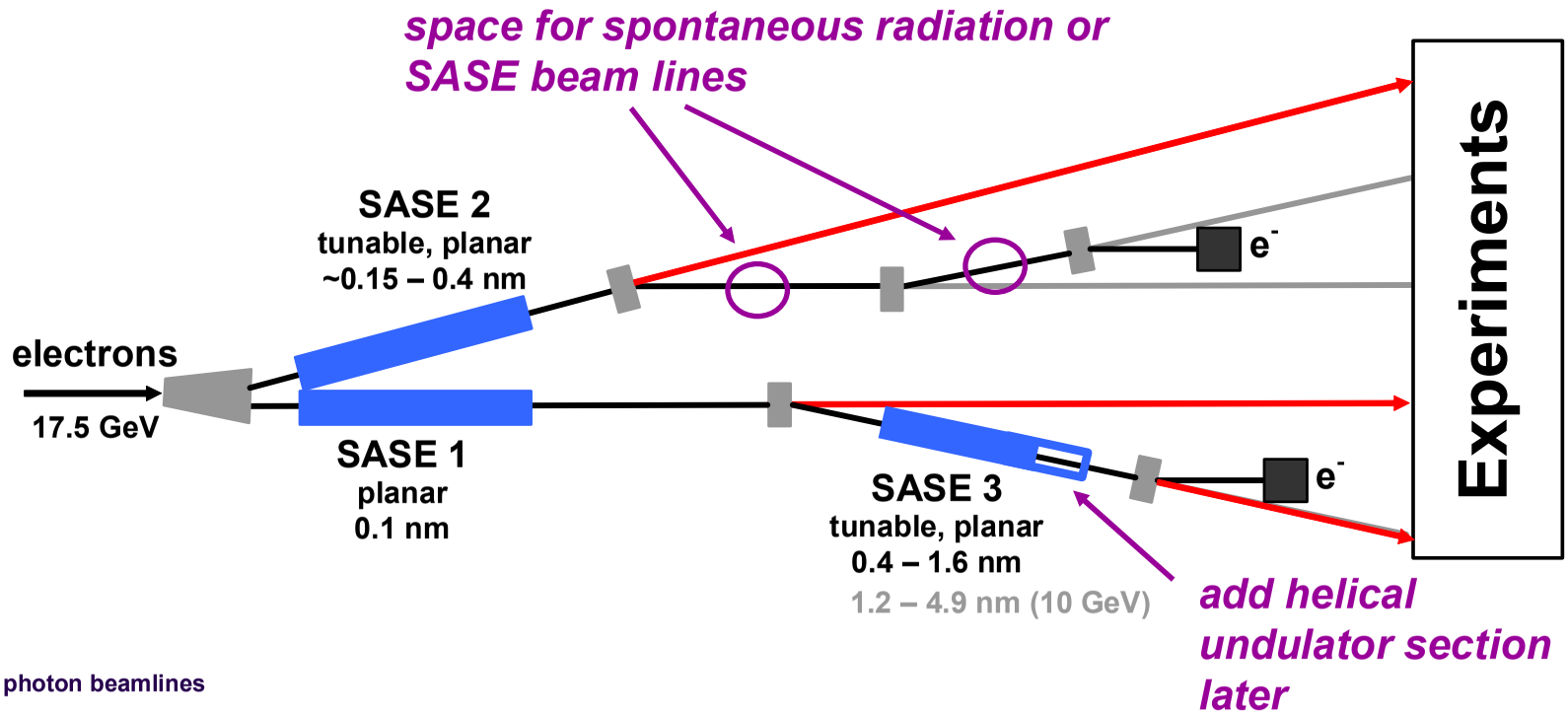
- X-ray FEL radiation (0.2 - 12.4 keV)
  - ultrashort pulse duration <100 fs (rms)
  - extreme pulse intensities 10^{12}-10^{14} ph
  - coherent radiation x10^9
  - average brilliance x10^4
- Spontaneous radiation (20-100 keV)
  - ultrashort pulse duration <100 fs (rms)
  - high brilliance



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)

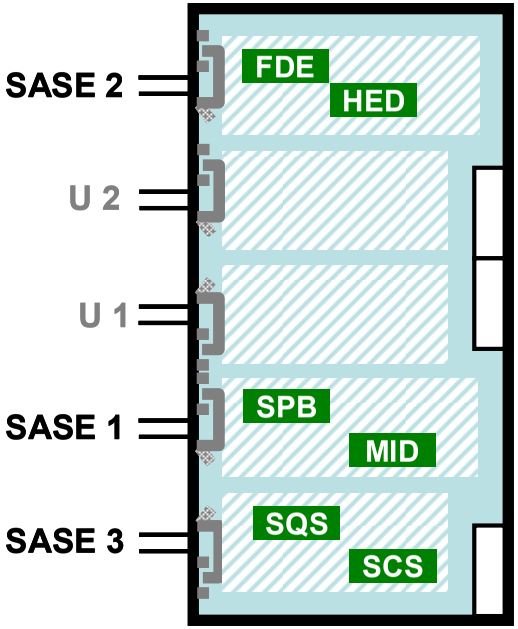
Selection of first instruments was made

Soft X-rays — Hard X-rays

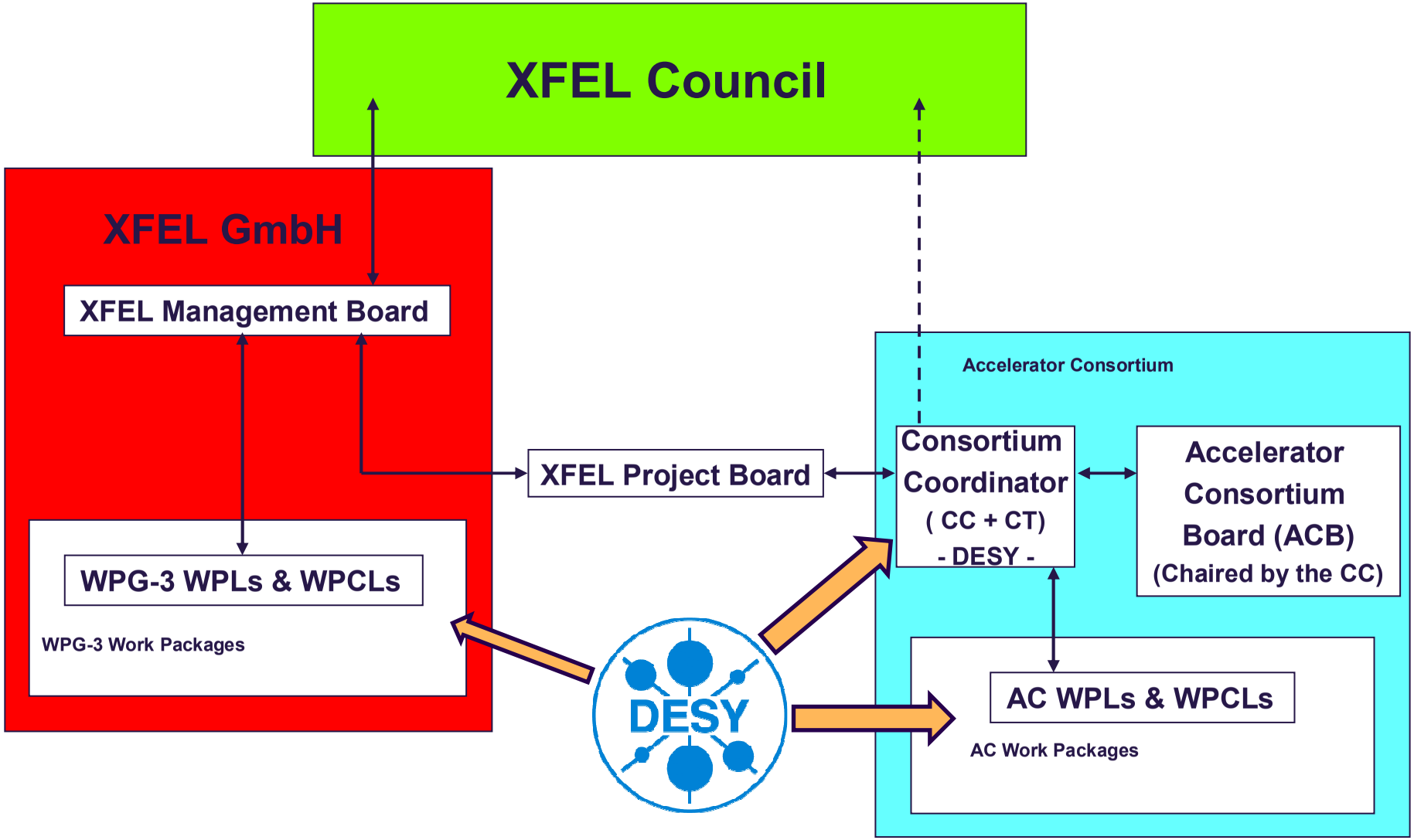
Instrument	Brief description of the instrument
SPB	Ultrafast Coherent Diffraction Imaging of Single Particles, Clusters, and Biomolecules – Structure determination of single particles: atomic clusters, bio-molecules, virus particles, cells.
MID	Materials Imaging & Dynamics –Structure determination of 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.
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 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

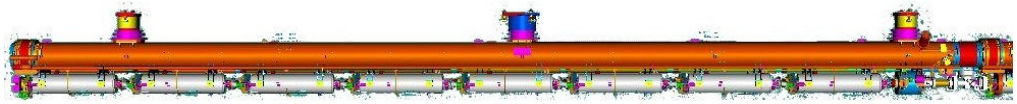


XFEL Company and Accelerator Consortium



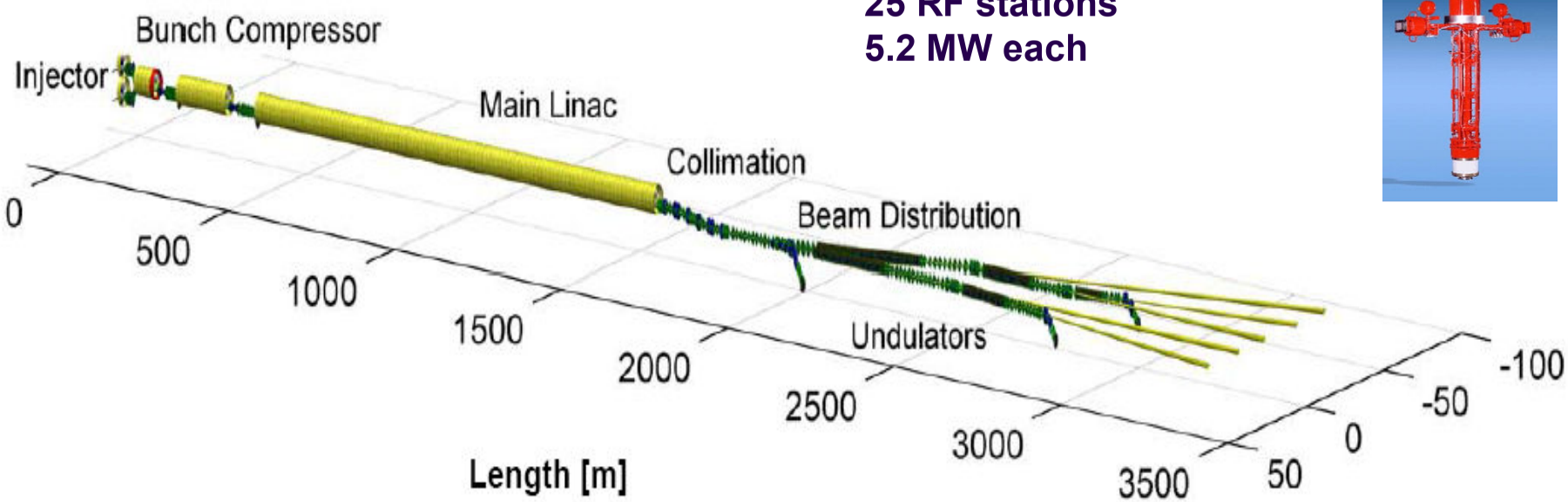
Accelerator complex

100 accelerator modules

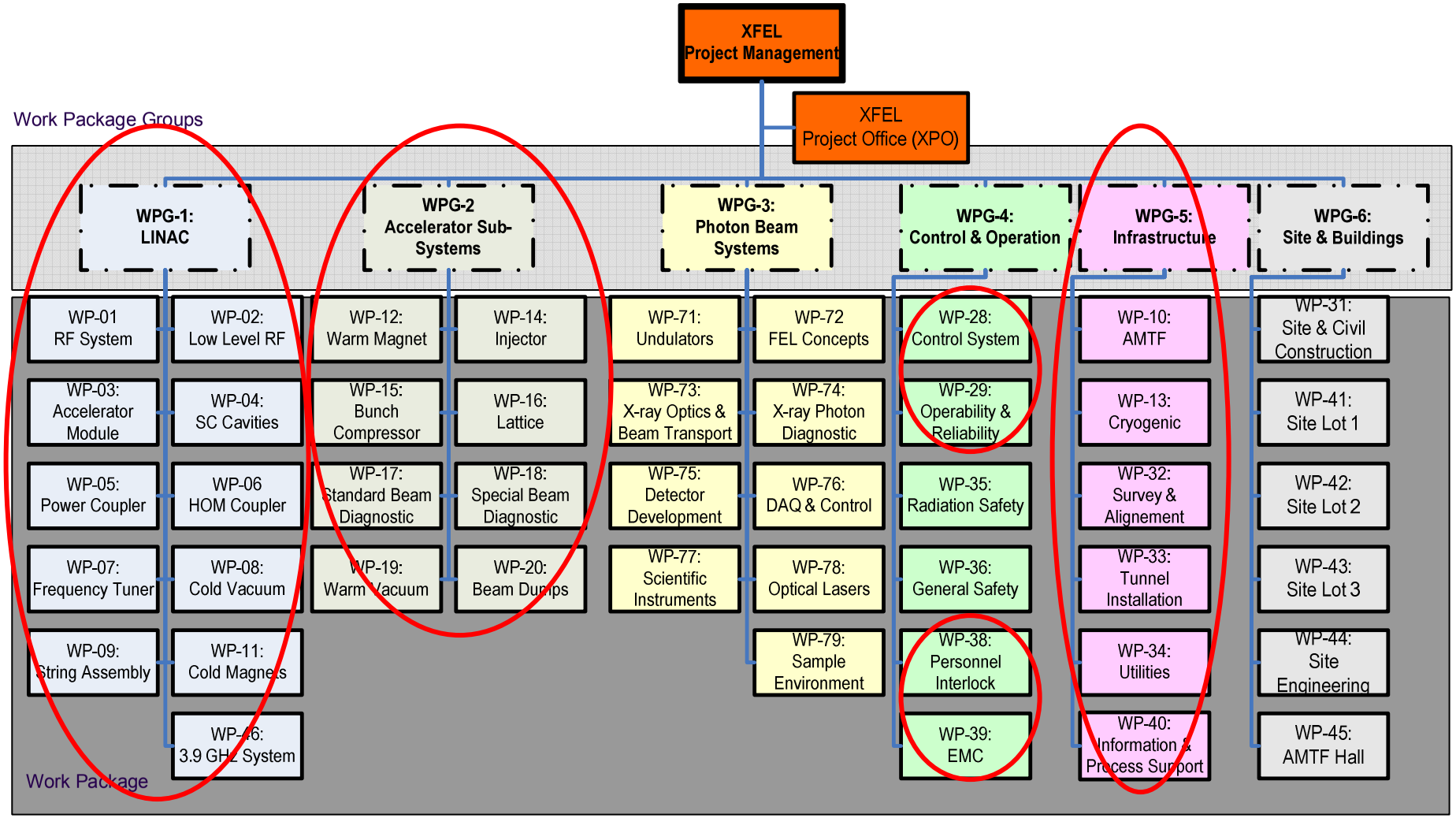


800 accelerating cavities
1.3 GHz / 23.6 MV/m

25 RF stations
5.2 MW each

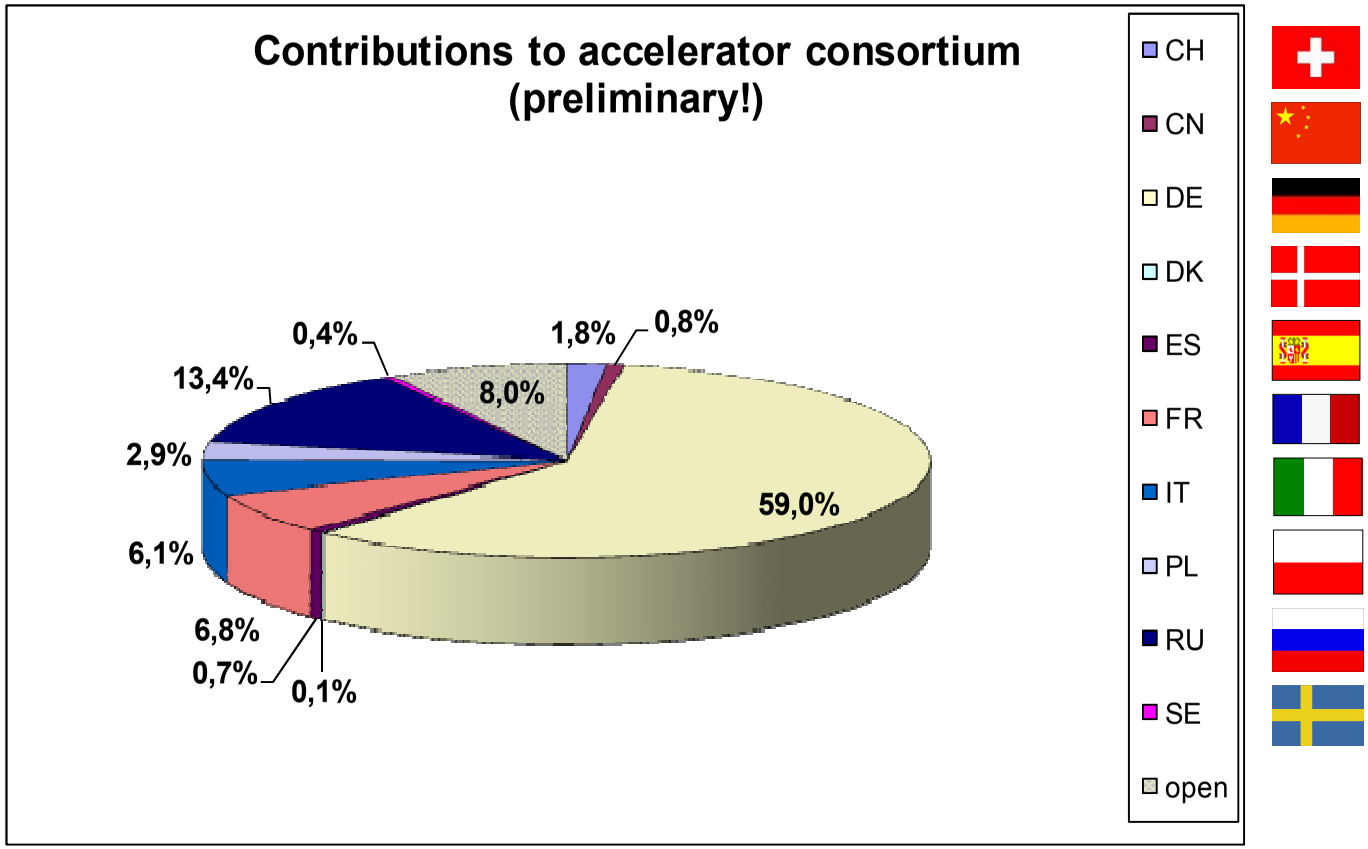


Accelerator Consortium Work Packages



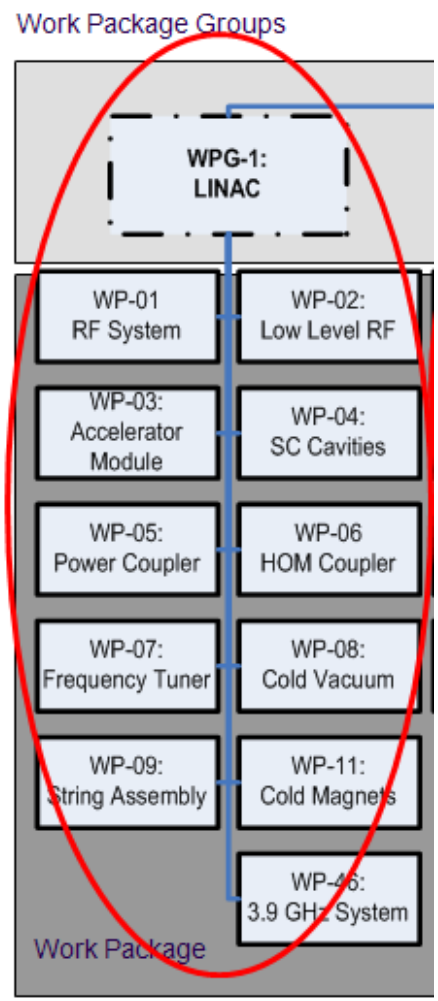
Accelerator In-kind Contributions (total value ~500 M€)

Figures will change in detail – negotiations ongoing!

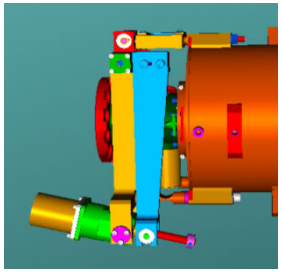


Many institutes from TESLA collaboration & some new partners

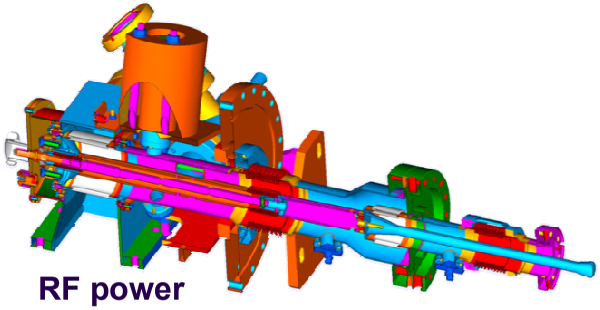
The Cold Linac



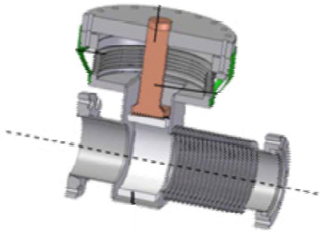
- s.c. accelerating cavities
- RF power coupler
- frequency tuners
- vacuum components
- cold magnets



frequency tuner



RF power coupler



HOM coupler

cavities

Accelerator Modules – Transportation

Schedule:

- **03 Nov. 2008 departure from DESY**
- **04 Nov. 09 at CEA** (~24h trip):

8:25	Arrival at CEA
10:00 – 10:45	Uploading the frame from the trailer
11:05	Disconnecting of the cables
13:45 – 13:50	Lift M8 out of the frame down to concrete stand

- **05 Nov. 2008 departure from CEA**

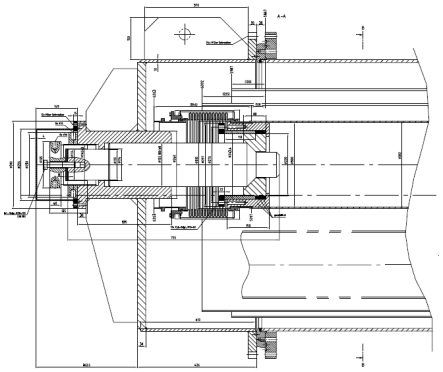
  About 150km north of Paris the truck has a technical incident and need to be towed away from the highway with the trailer. At night the truck-company sent a new truck from Hamburg to Paris to pickup the trailer with M8. Truck change operations were smooth and did not produce critical impacts on the module.
- **07 Nov. 2008** : because of the incident M8 arrived one day later at Desy.
- **05 Dec. 2008: Start cool down of M8 on CMTB**
- **09 Dec. 2008: M8 RF-tests, test and measuring on the cold magnet**
- **Week 3, 2009 : removal of M8 from CMTB scheduled**

Accelerator Modules - Transportation Tools

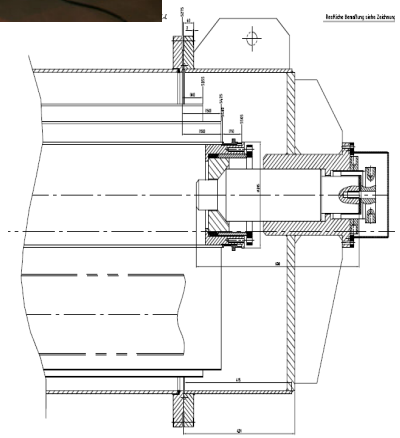
irfu

cea

saclay



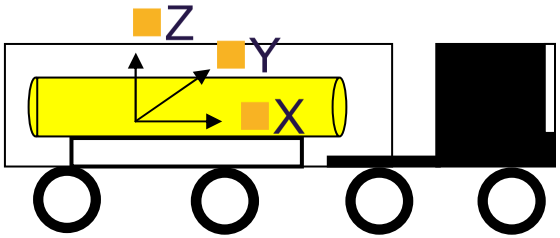
Feed-cap side



End-cap side

The First Accelerator Module at CEA Saclay

A "Return-Ticket" to Paris

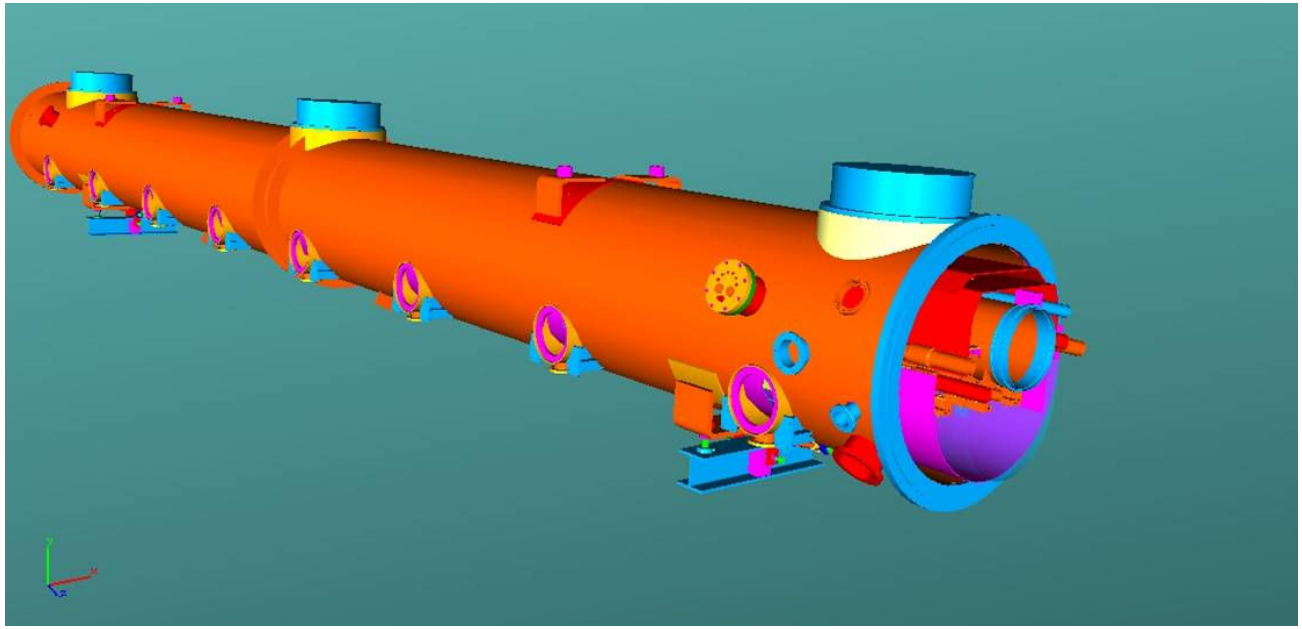


- Saclay to Hamburg
- Zmax= 1,424 g
- ACCEL, inside frame

- Hamburg to Saclay
- Zmax= 1,11g
- ACCEL, inside frame

- From Hamburg to Saclay the tour was observed over the whole time of 24h

Prototype XFEL Accelerator Modules



- **Fabrication** of XFEL prototype cold masses (incl. outer vessel)
  (based on TESLA / ILC / DESY / INFN / TTF / FLASH experience)
- **module assembly** to verify the work of three additional vendors
- **cold test** all thee modules before ordering the final XFEL series
- use the modules for **assembly training / further transportation checks** / XFEL injector

A First Cryostat Being Produced in France

irfu

cea

saclay

- Status 28.11.2008

- Vacuum vessel final welds and machining
- Cold mass final welds and machining, welds done by a additional subcontractor

A First Cryostat Being Produced in Spain

irfu

cea

saclay

- Status 27.11.2008

A First Cryostat Being Produced in China

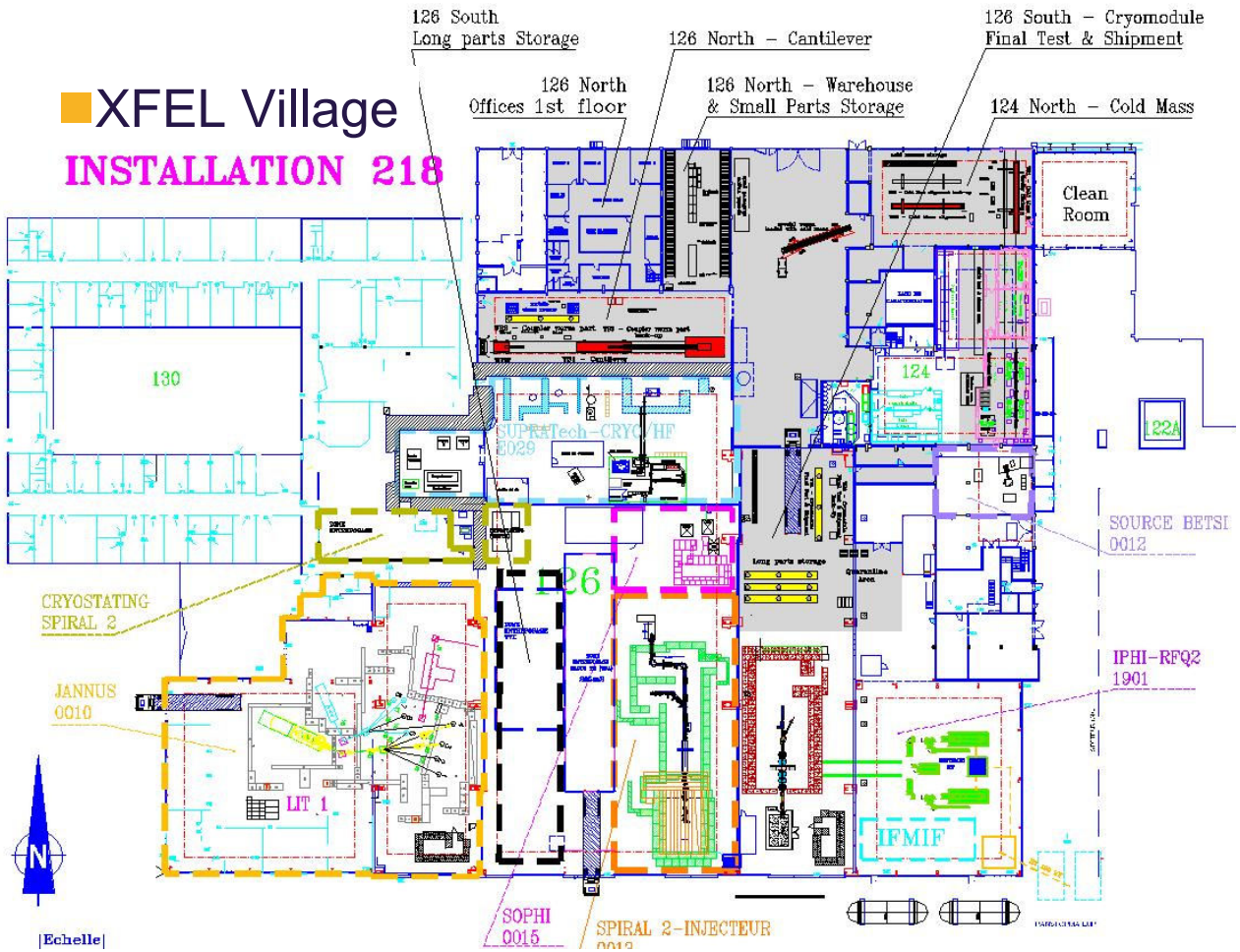
irfu

cea

saclay

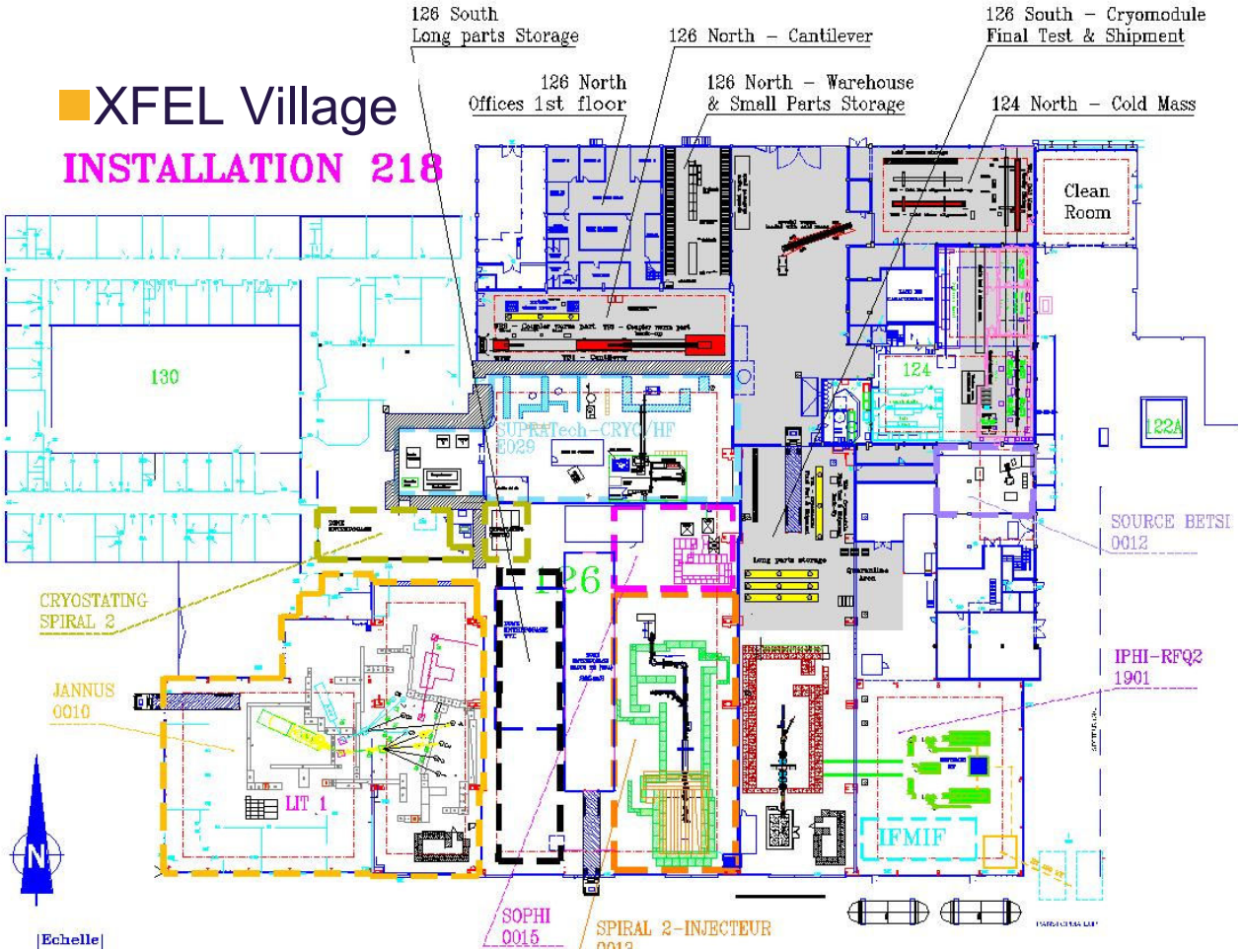
- Status 28.11.2008

String and Module Assembly Site at CEA Saclay



- Preliminary Industrialization Study (EPI) done by industry and handed over to CEA Saclay.

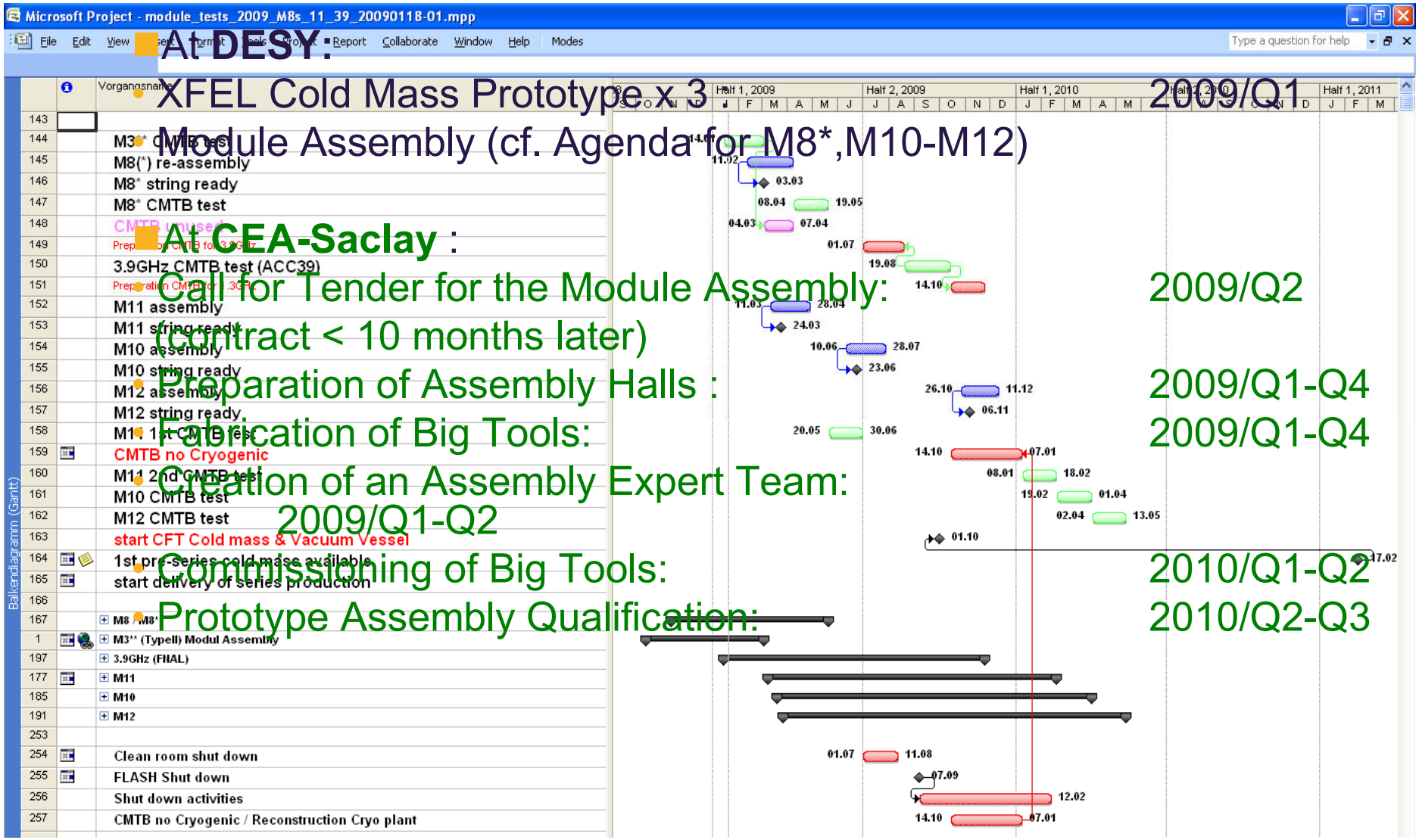
Building and Infrastructure



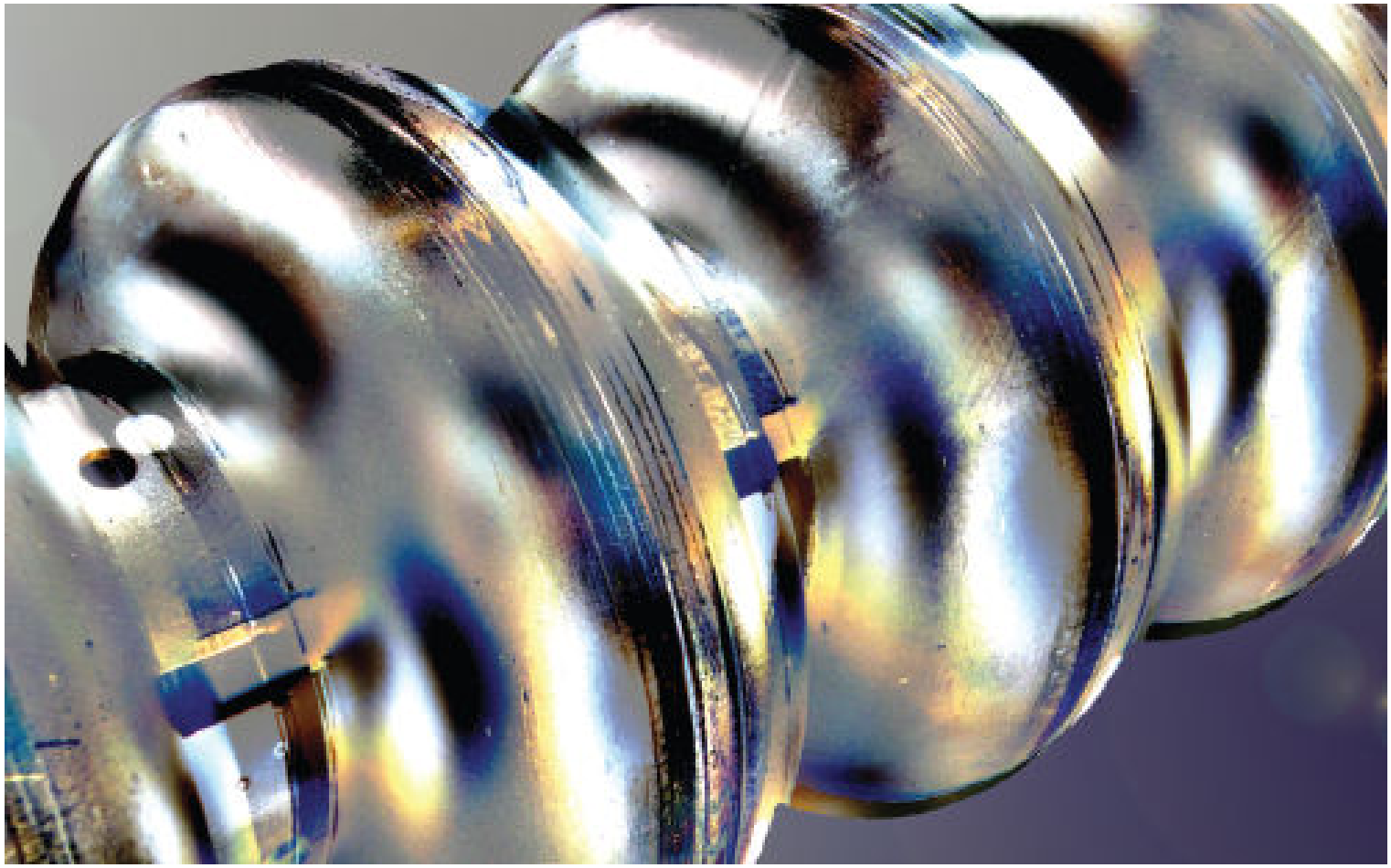
- A complete design and cost estimate for the civil engineering and general equipments is now available; construction starts now.

Accelerator Modules – The Plan for 2009

- At **DESY**:
  - XFEL Cold Mass Prototype x 3 2009/Q1
  - Module Assembly (cf. Agenda for M8*,M10-M12)
- At **CEA-Saclay** :
  - Call for Tender for the Module Assembly: 2009/Q2 (contract < 10 months later)
  - Preparation of Assembly Halls : 2009/Q1-Q4
  - Fabrication of Big Tools: 2009/Q1-Q4
  - Creation of an Assembly Expert Team: 2009/Q1-Q2
  - Commissioning of Big Tools: 2010/Q1-Q2
  - Prototype Assembly Qualification: 2010/Q2-Q3



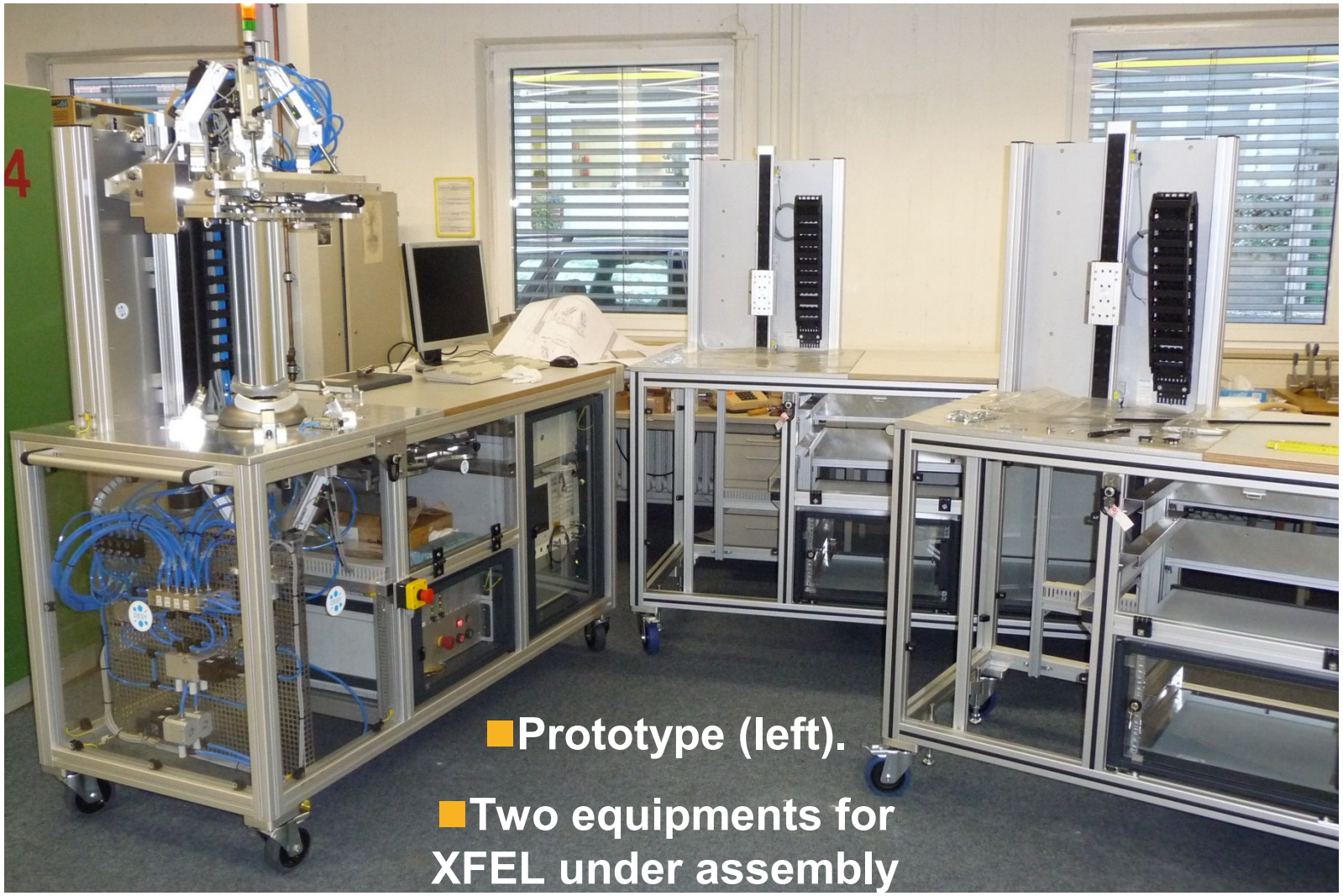
Cavities



Cavities - Activities Scheduled for Q1-Q4 2009

- **final specification** for cavity mechanical fabrication with He vessel (deadline Q1 2009)
- **final specification** for cavity treatment with He vessel (deadline Q1 2009)
- **update overall plan** (cavity schedule as part of the cold linac plan)
- **Allocation of contract for cavity production (Q4 2009)**
- Fabrication of **2 equipments** for RF measurement of half cells, dumb bells and end groups HAZEMEMA (deadline Q2 2009)
- Fabrication of **2 equipments** for warm tuning (deadline Q4 2009)
- Fabrication of **2 equipments** for scanning of Nb (deadline Q4 2009)
- Equipment for optical control of inside surface (rented at KEK and installed at DESY)

Equipment for RF Measurement of Dumb Bells and End Groups: HAZEMEMA



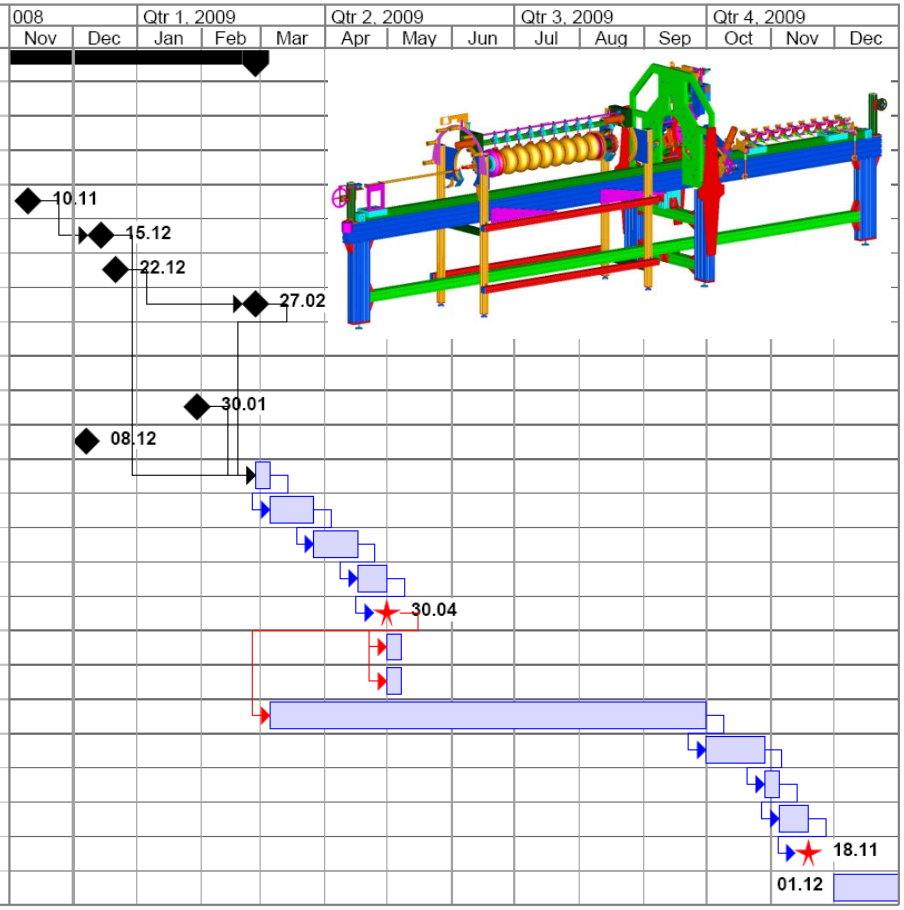
- Prototype (left).
- Two equipments for XFEL under assembly

Cavities – Field Flatness Tuning

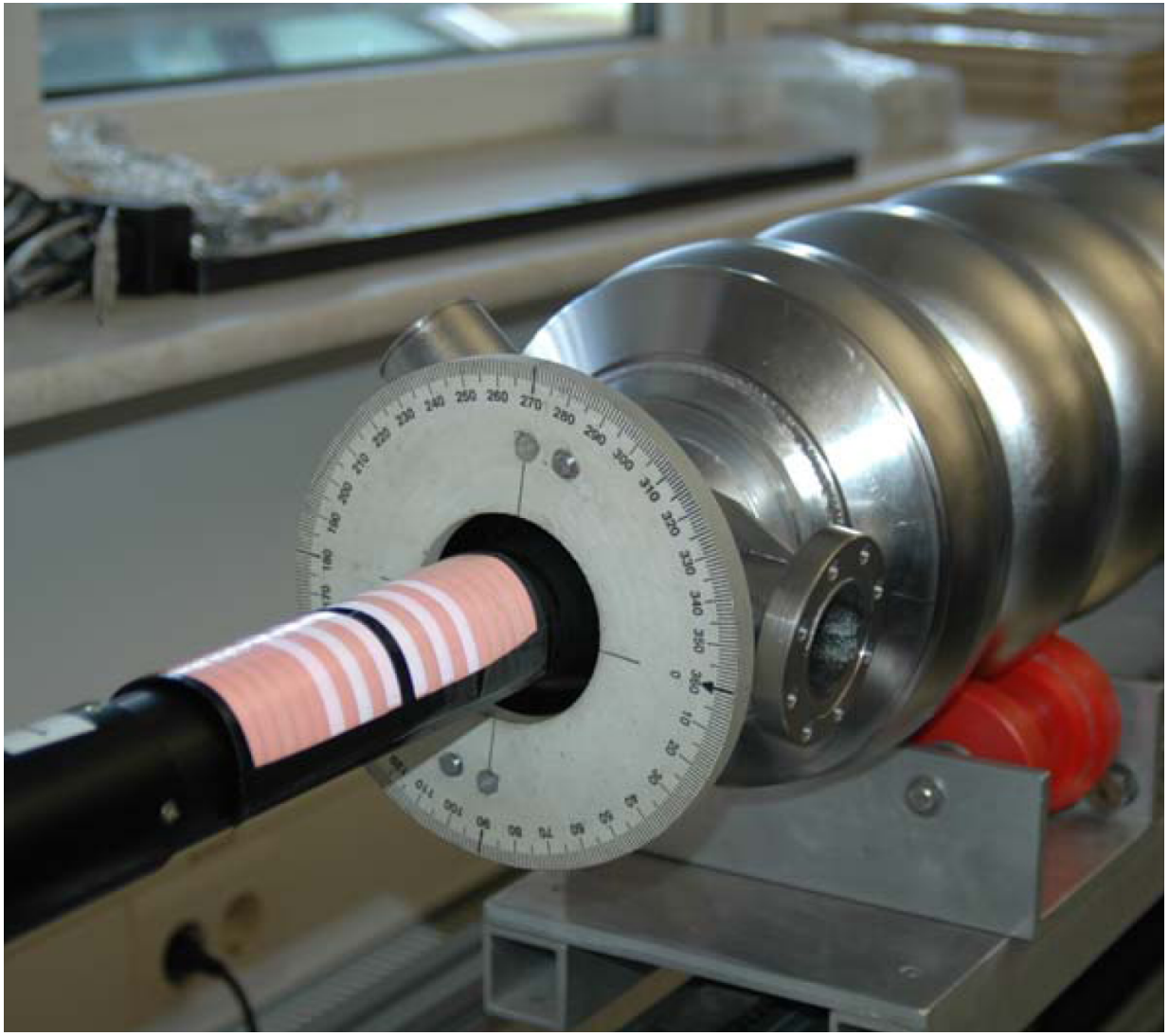
Tuning Machine - Fabrication Milestones

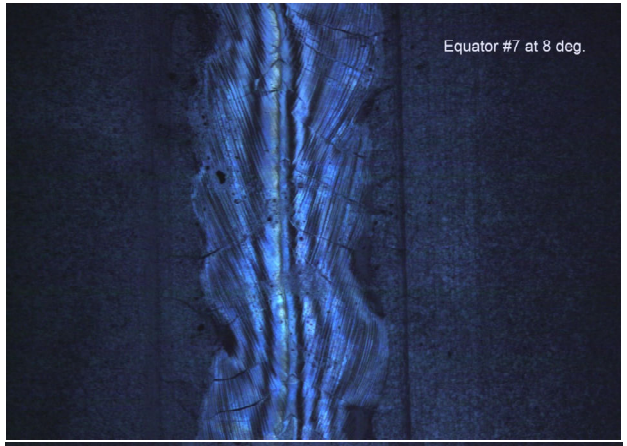
2008 April, 23rd
1. update 2008 July, 22nd
2. update 2008 December, 01st

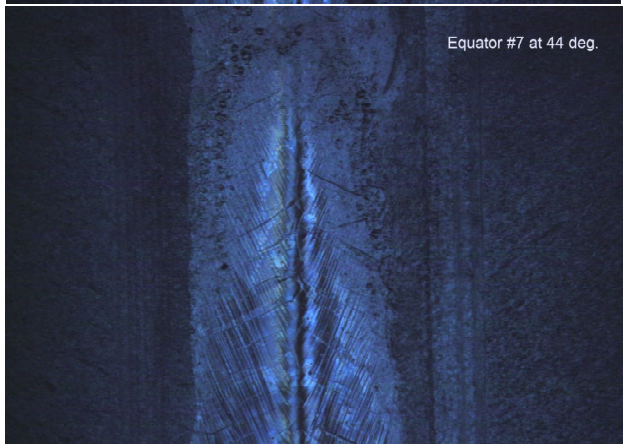
ID	Vorgangsname
1	**Tuning Machine - Fabrication Milestones**
2	tuning frame finished
3	base frame finished
4	linear slide system finished
5	Redesign of the cavity train finished
6	Fabrication of redesigned CT parts completed
7	Redesign of tuning jaw, protective shields, connection end rings finished
8	Fabrication tuning jaw, protective shields, connection end rings finished
9	bead pull system finished
10	wire input tooling finished
11	DELAYED / eccentricity measurement device finished
12	machine housing delivery
13	**Final mechanical checks and adjustments**
14	**Wiring of the entire machines**
15	**Final electrical checks**
16	**Packing and shipping of #1 and #2 to FNAL**
17	**Machine #1 and #2 at FNAL**
18	**Assembly of CTM #1 at FNAL**
19	**Shipment of sluice #1 to DESY**
20	**Remainder of controls**
21	**Comissioning of control system on CTM #1**
22	**Shipment of control system #3 and #4 to DESY**
23	**Commisioning of control system at DESY**
24	**Machine #3 and #4 ready for XFEL**
25	**XFEL - pre series cavity tuning at DESY (expected !)**



High Resolution Kyoto -Camera of KEK Adapted to Optical Entrance Control at DESY

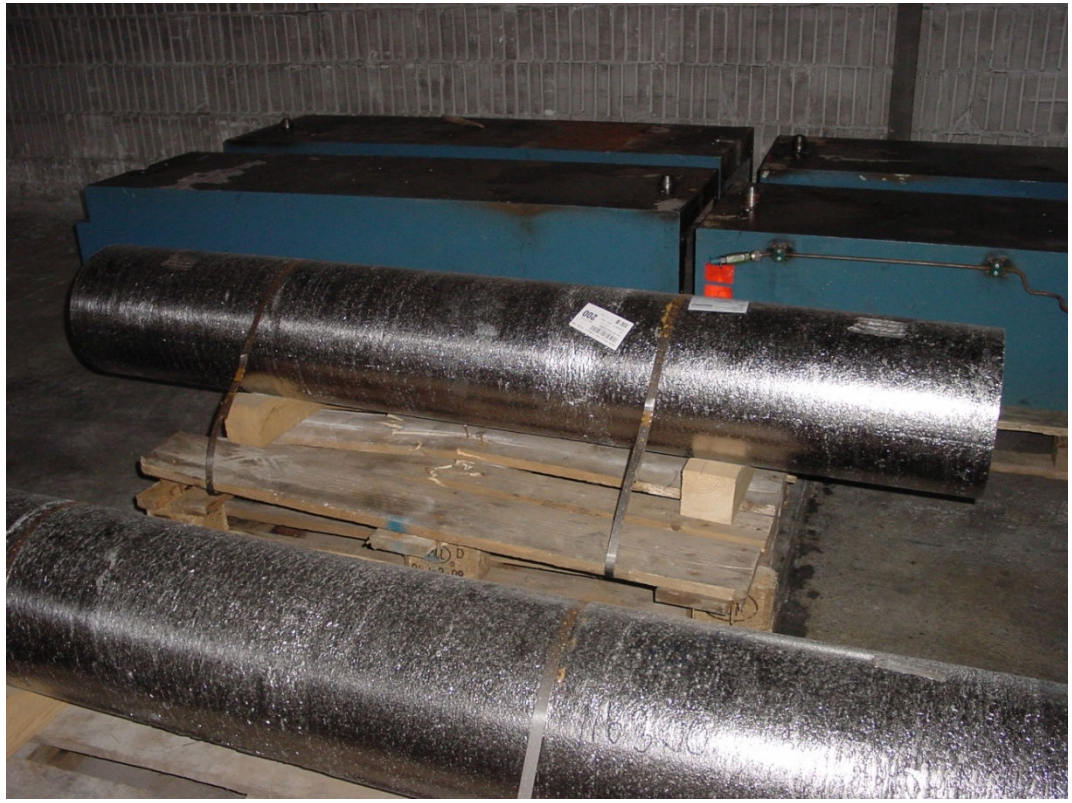






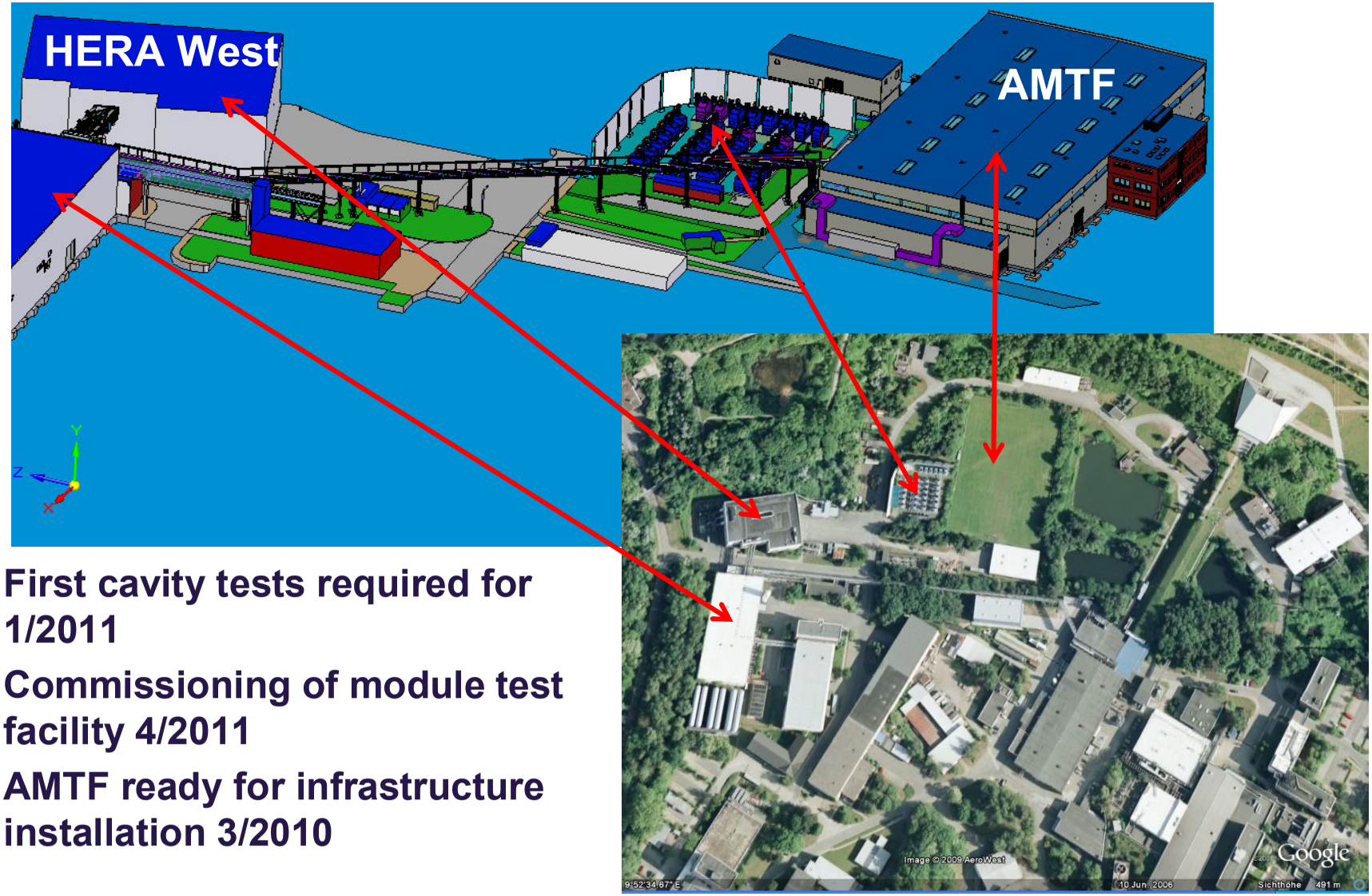
- Under preparation:
  - automation
  - set up for cavity inspection with He vessel

Cavities – Let's Start with the Pre-series



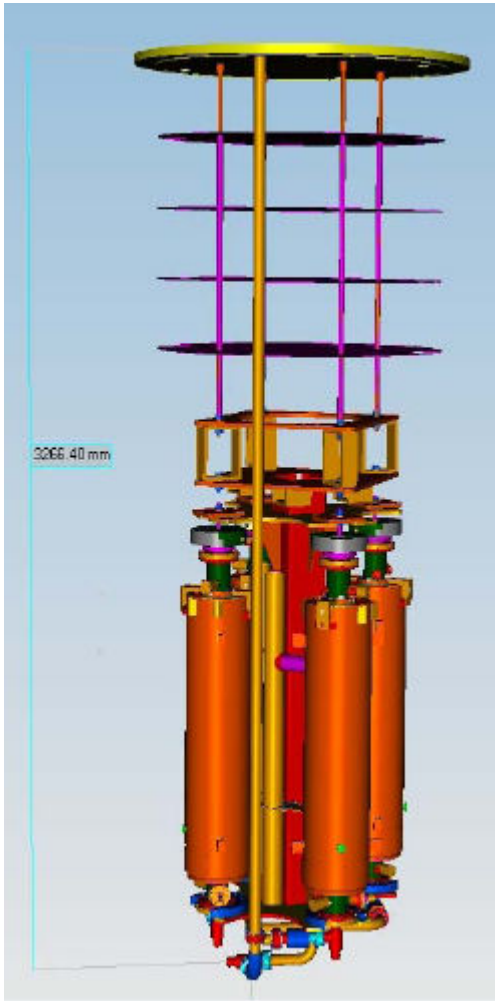
- Purchase niobium and flange material (not sheets) for 30 pre-series cavities ordered
- ingots delivered, cutting of sheets under way
- Scanning of the Nb sheets for 30 pre-series cavities is next

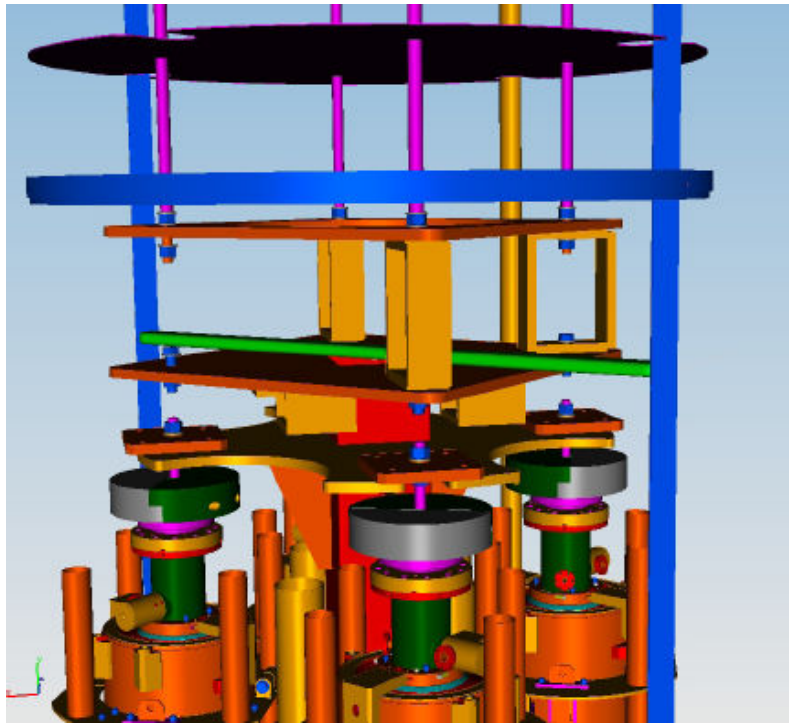
Accelerator Module Test Facility (AMTF) Including single Cavity tests



- First cavity tests required for 1/2011
- Commissioning of module test facility 4/2011
- AMTF ready for infrastructure installation 3/2010

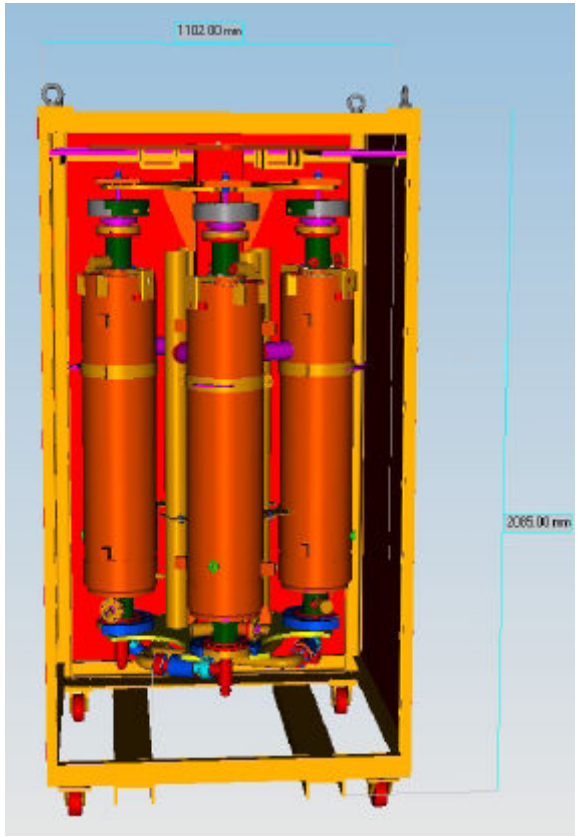
Cavity Tests at AMTF Starting in 2011





- 4-cavity insert for AMTF test cryostats; design ready, construction a.s.a.p.

- Transportation frame; actual design, tests with single cavities on-going



European XFEL

RF Power Coupler – LAL Orsay Contribution

WP 1 – Waveguide
1.1 Waveguide flange, bolts and nuts
1.2 Kapton window

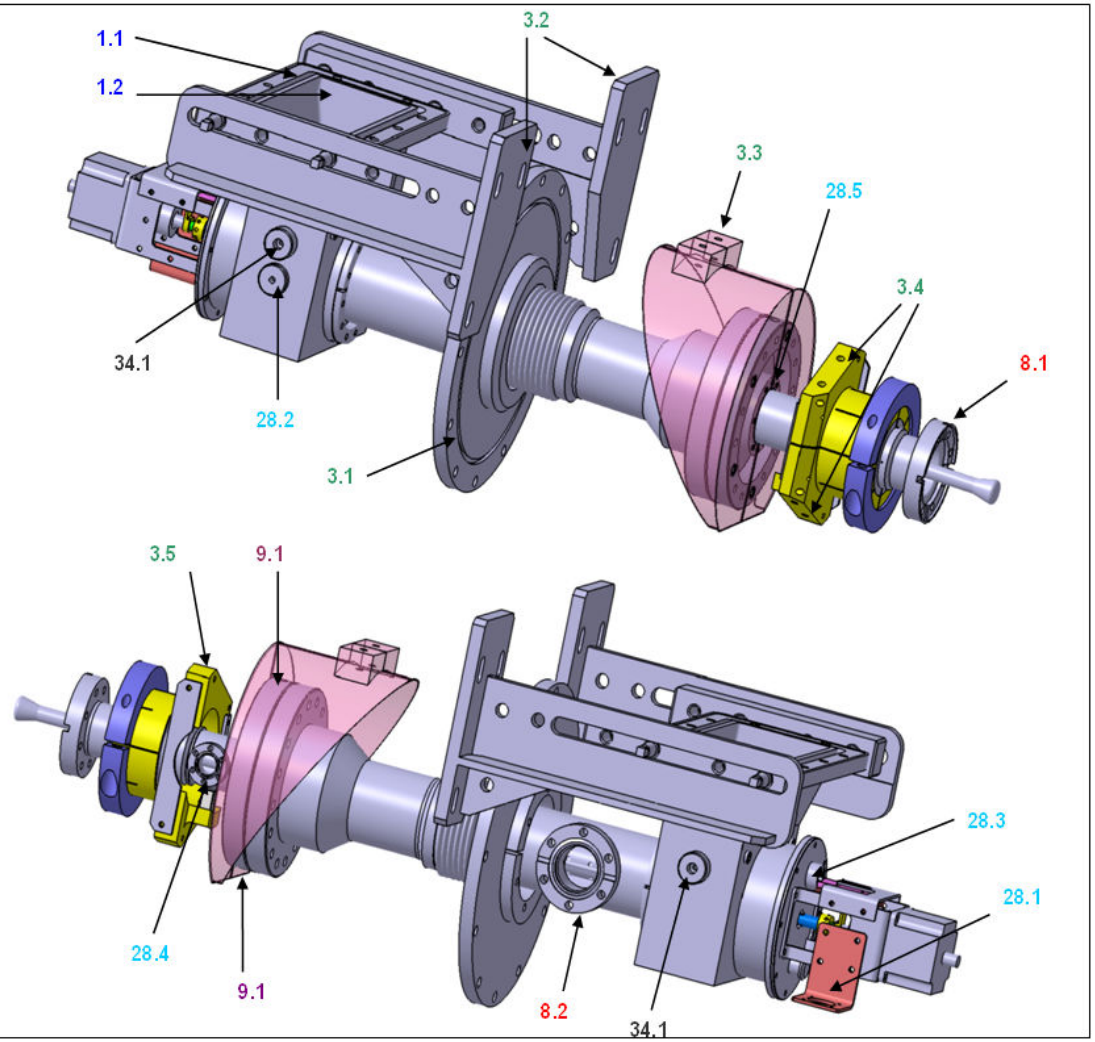
WP 3 – Cryomodule
3.1 Flange on vacuum vessel, gasket, bolts
3.2 Coupler supports (left & right), bolts
3.3 Connection of Cu braids from 80K thermal shield, bolts
3.4 Connection of Cu braids from 4K thermal shield, bolts
3.5 4 holes in 4K interface for assembly rods
3.6 Super insulation

WP 8 – Cavity & vacuum
8.1 Cavity flange, gasket, bolts & nuts
8.2 Coupler vacuum pumping port, gasket, bolts & nuts

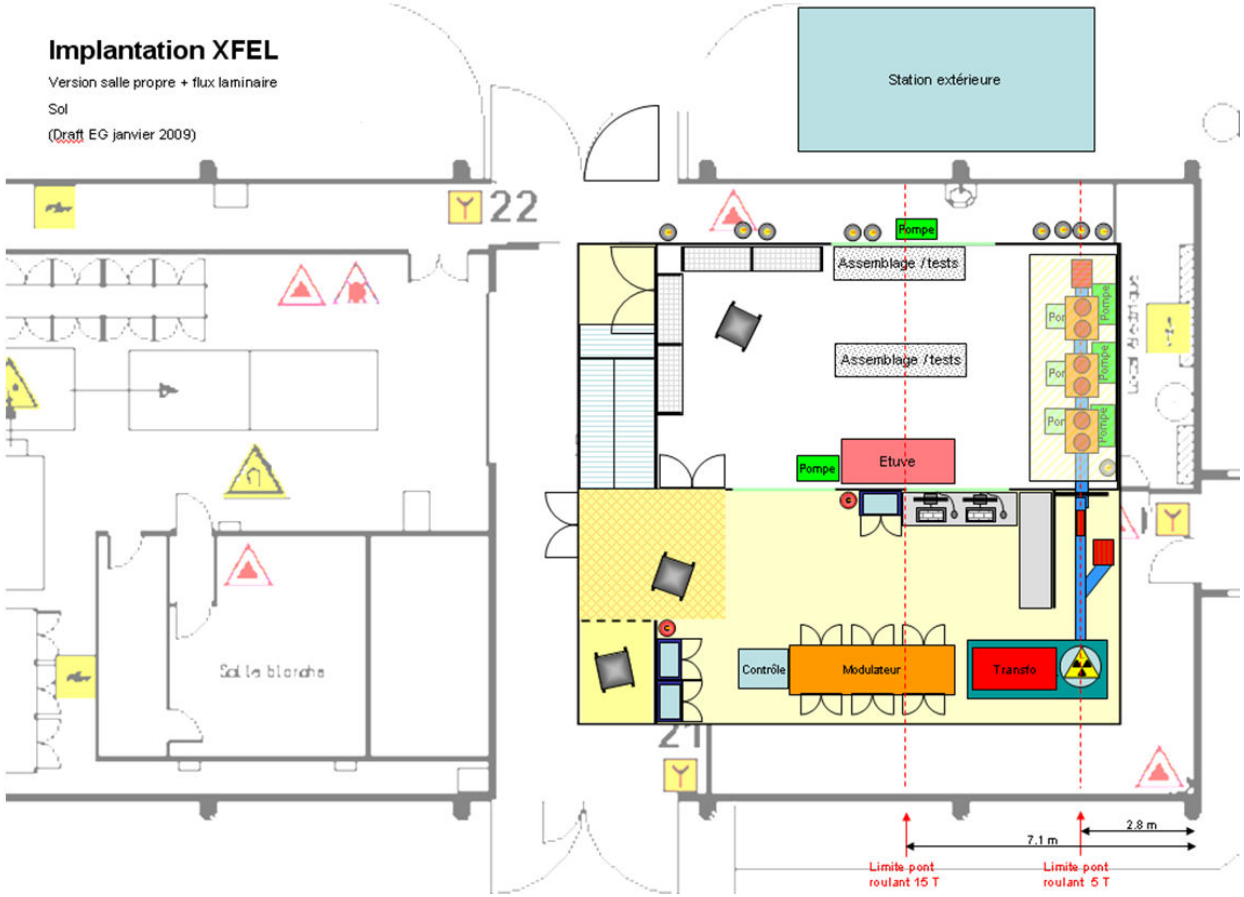
WP 9 – Cavity string assembly
9.1 Two holes in big cold flange
9.2 Clamp for cold bellows

WP 28 – Control system
28.1 Connector for motor, end switches, PT100
28.2 Arc detector
28.3 HV connector
28.4 e- pickup
28.5 2 sensors PT100 in 80K zone

WP 34 – Utilities
34.1 Two N2 cooling ports
34.2 Environmental conditions: T, P, H, radiations



Future LAL RF Station for XFEL Coupler Conditioning



Call for Tenders

800 Coupler

Contracts award

Pre-series

{12 units/tender}

160 (8x20)

240 (8x30)

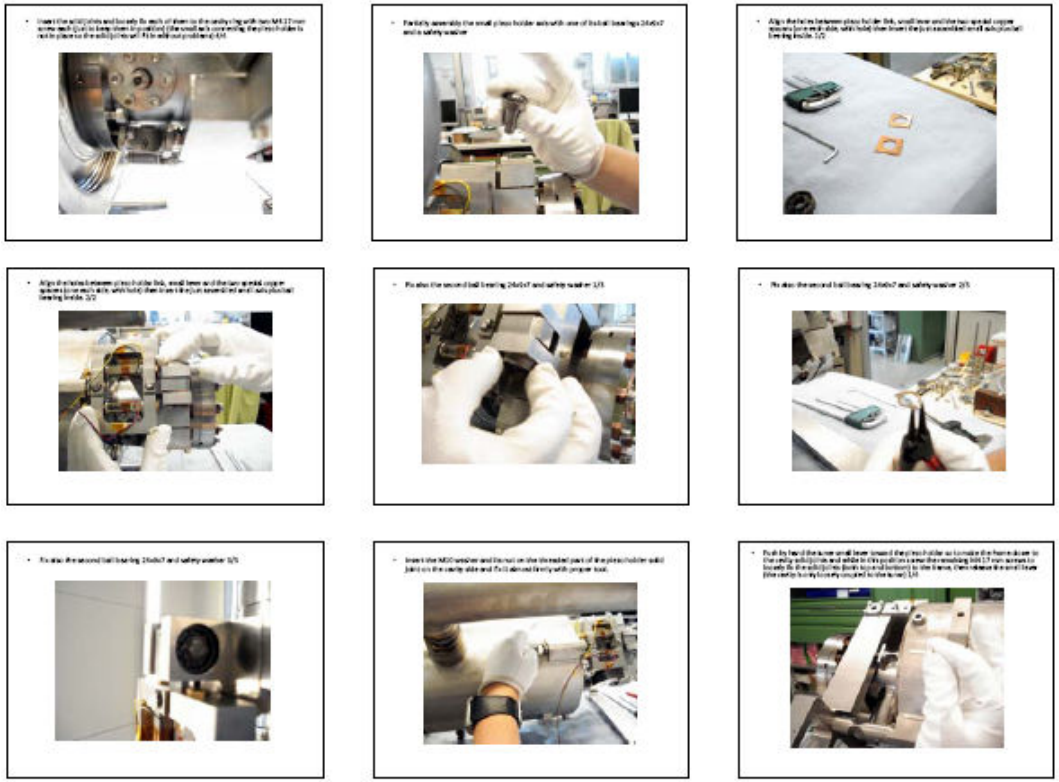
384 (8x48)

End of procurement

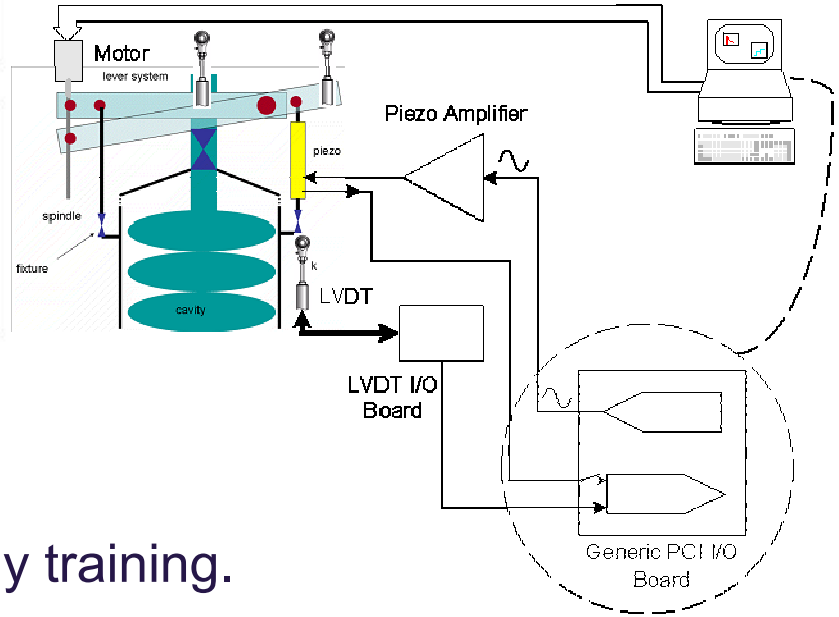
2009 | 2010 | 2011 | 2012

- RF station ready for commissioning beginning of 2010.

Cavity Frequency Tuner – Assembly and Test Procedures



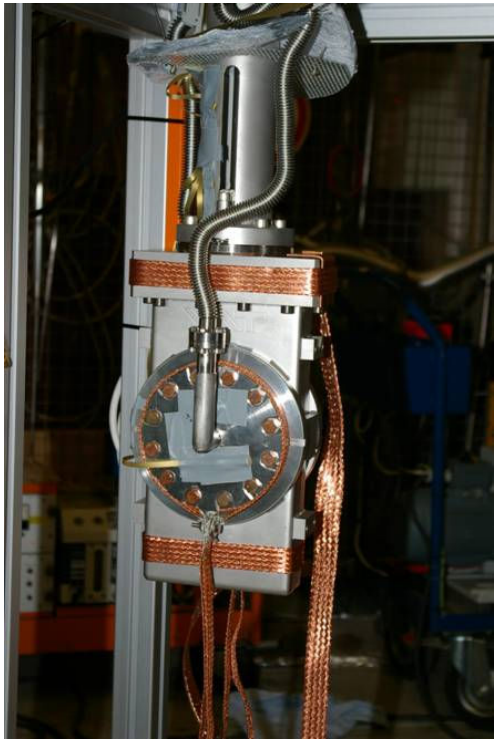
- An **automated test procedure** proposed by INFN is under preparation for AMTF tests.



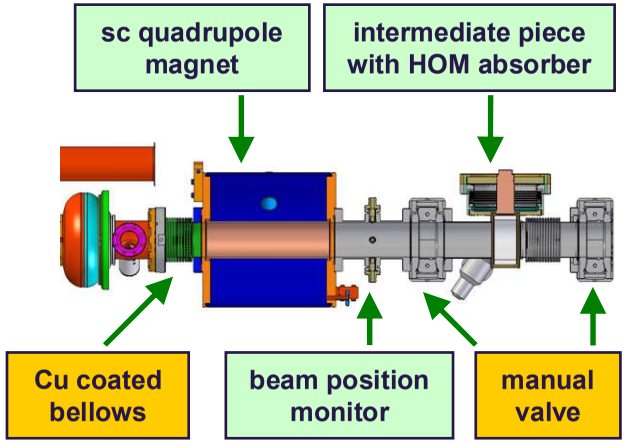
- Detailed **assembly procedures** are prepared for string and module assembly training.

Cold Vacuum Requires Special Attention

- An automated slow **venting system** is under preparation for all kind of cavity / string / module interventions.

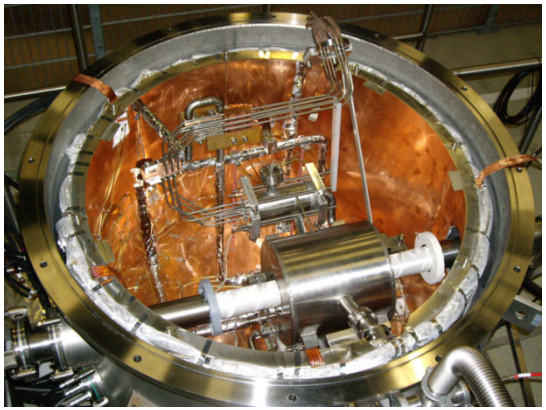


- A **cold valve** to separate beam vacuum at string connection boxes in case of catastrophic events.

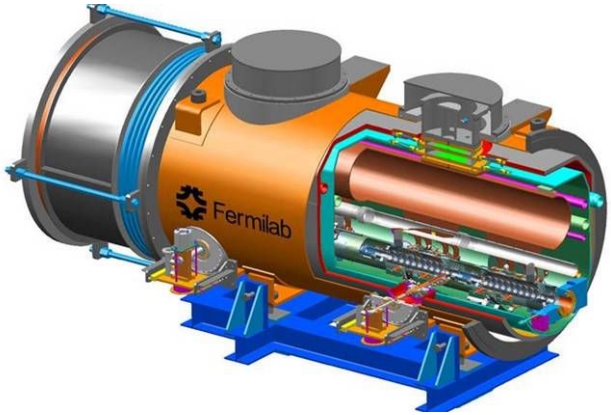


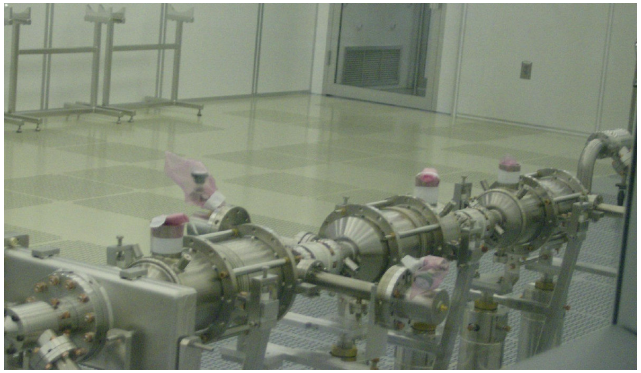
- **High Order Mode absorbers** at the end of the accelerator modules.

Many More Components, e.g. Cold Magnets, 3.9 GHz Acceleration, RF Systems …



- The first **cold magnet** in the test cryostat.



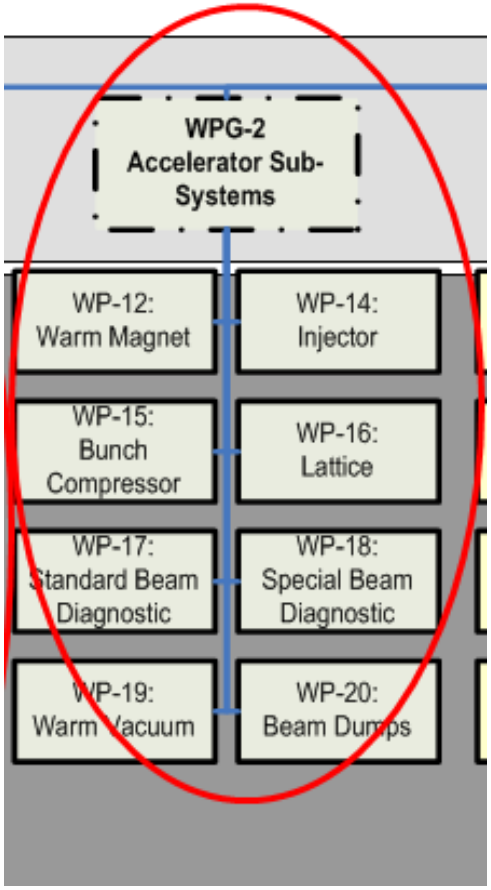


- The **3.9 GHz** accelerator module to be delivered in spring 2009.


Test stand @ DESY, Zeuthen

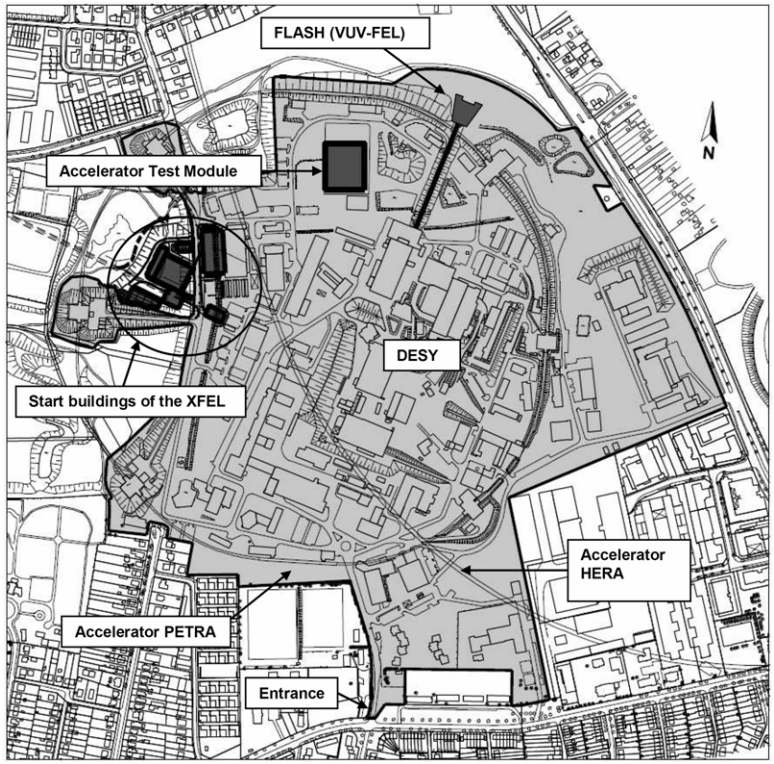
- **RF system** R&D at DESY.

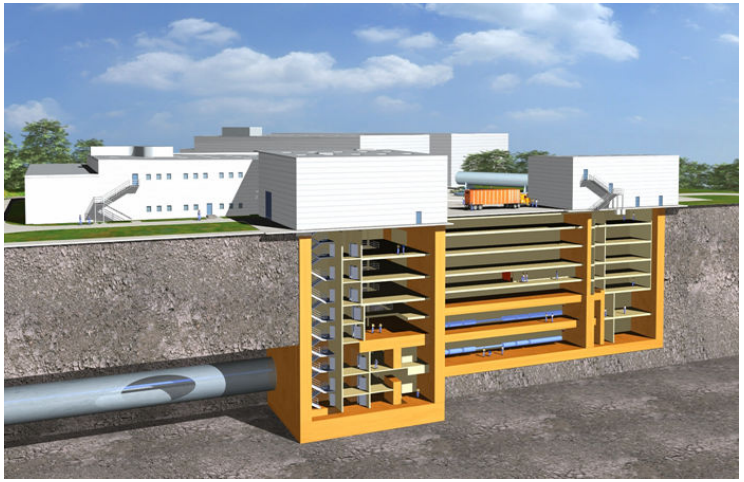
The Warm "Linac"



- warm magnets
- bunch compressors
- beam diagnostics
- warm vacuum
- injector
- lattice
- beam dumps

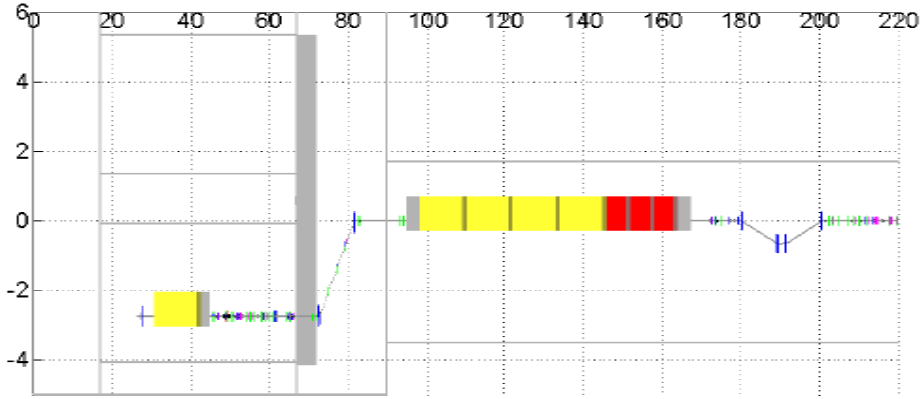
XFEL Injector





- **Construction work** has started.
- The XFEL injector is to quite some extent a copy of the TTF/FLASH Linac.

New Layout of the XFEL Injector

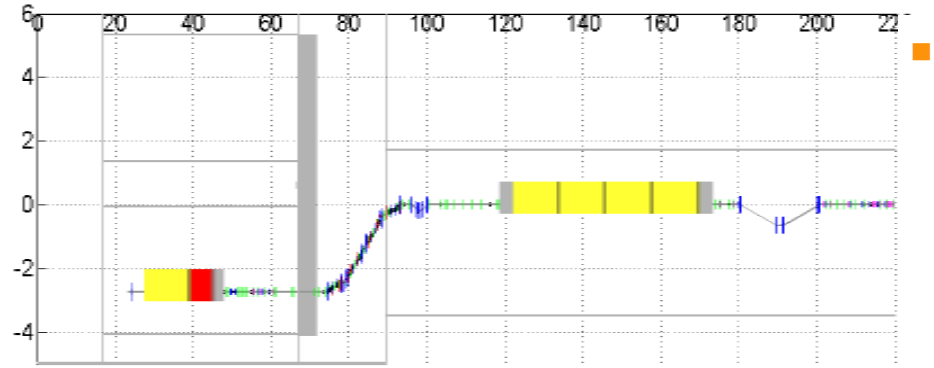


- old layout

The **new system** provides:

- More compression stability
  (lower charge / shorter bunches)
- Lower Costs
- Commissioning of 3rd harmonic (3.9 GHz) in injector mode

- new layout



accelerator modules | 3.9 GHz acceleration

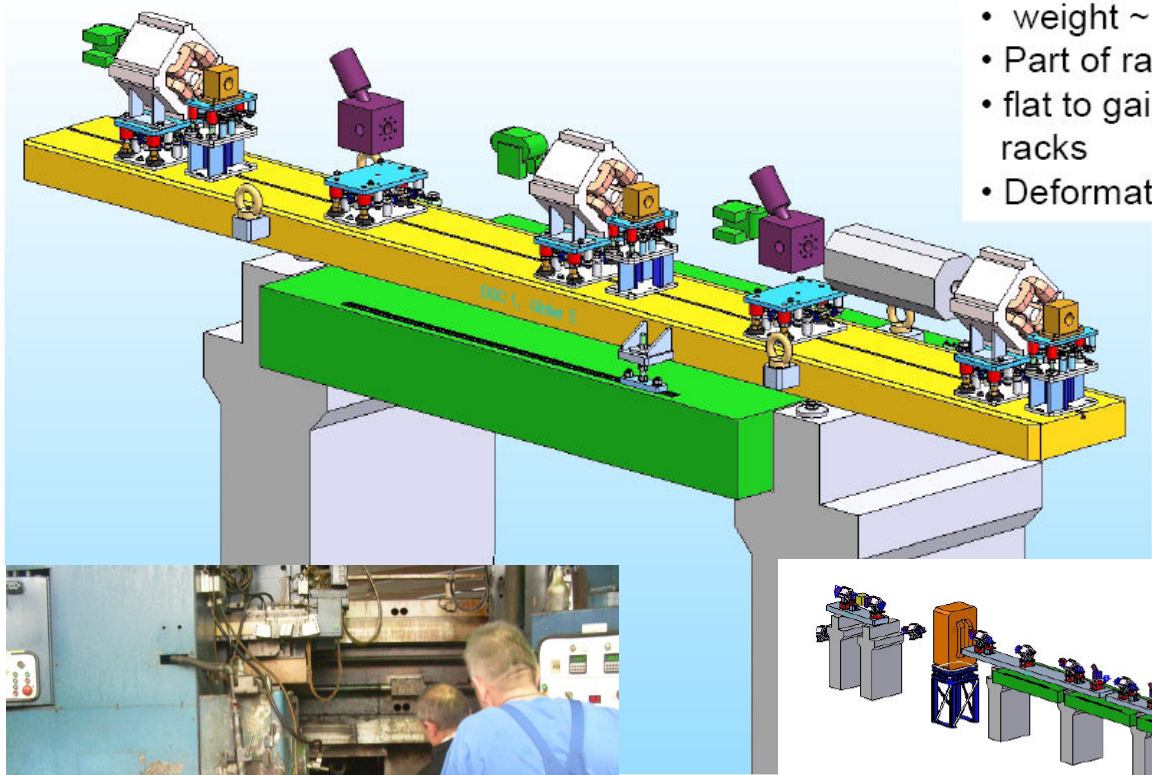
- Potential Problems:
  - More complex (esp. dogleg), can probably be somewhat simplified (at least at the cost of avoiding extreme energy chirps)
  - Laser heater needs higher power (up to 20 μJ if we adopt the LCLS scheme)
  - Might need re-scheduling of some components (3rd harmonic rf) to meet commissioning schedule

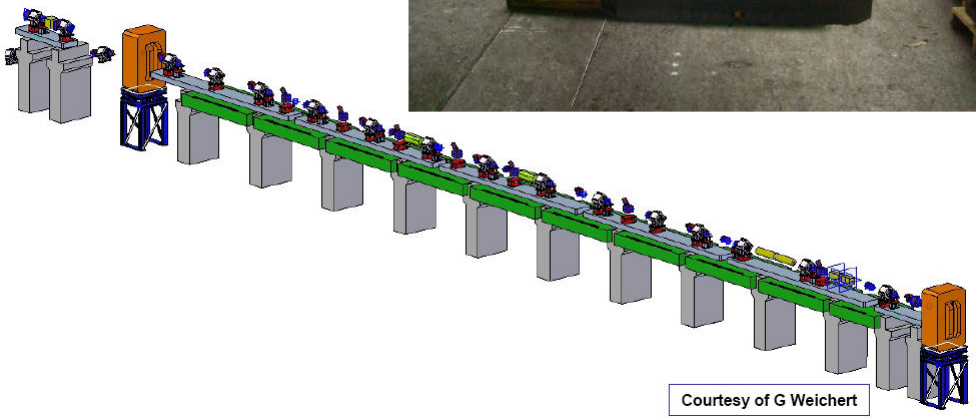
European XFEL

Solid Steel Girder in Warm Linac Sections

Solid Steel Girder:

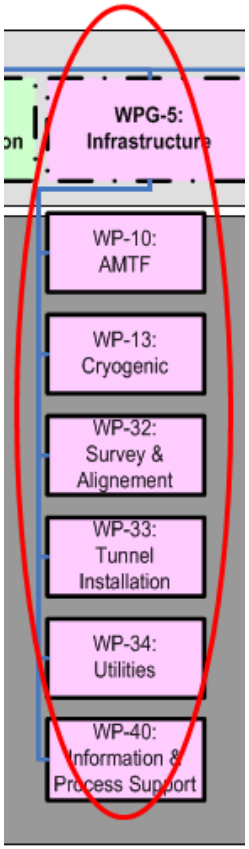
- 4600mm x 450mm x 120mm
- weight ~ 2 t
- Part of radiation shielding
- flat to gain space for electronic racks
- Deformation: < 0.15 mm





Courtesy of G Weichert

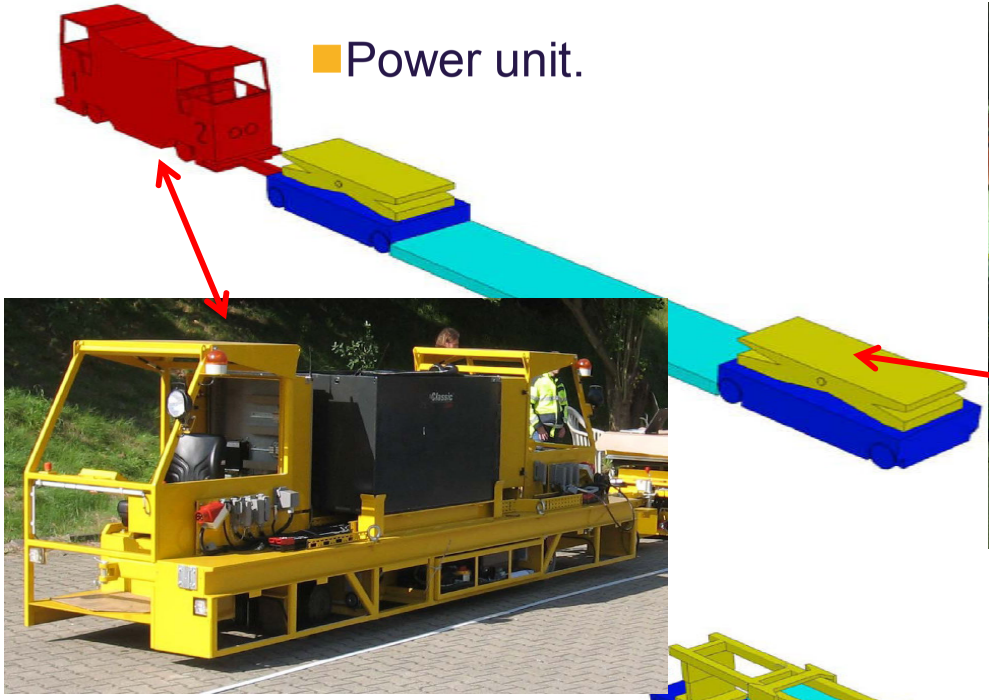
Infrastructure



- Accelerator Module Test Facility
- cryogenics
- survey and alignment
- tunnel installation
- utilities
- information & process support

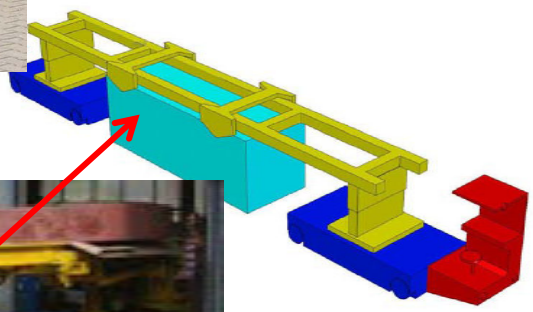
Tunnel Mock-up Completed and Installations Ongoing & to be Continued

Transportation in the Tunnel

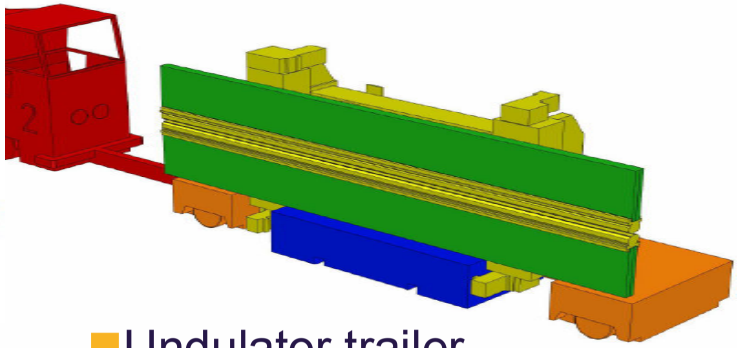


- Power unit.

- Platform trailer with scissor lifts for accelerator modules.



- Load train for e.g. pulse transformers.



- Undulator trailer (still under design).

European XFEL

Collaborative Design – A First Workshop

The European X-Ray Laser Project XFEL

What is Collaborative Design?

- complex facilities are developed via the interaction of many, sometimes thousands of participants, who are working concurrently on different elements of the design
- collaborative design aims to provide a systematic approach for integrating their design contributions
  - aiming to converge on a single design that is acceptable to all participants
- a complete product design includes the requirements on the product, the specification[1] of the product, and the processes[2] for mastering the product through its lifecycle
  - [1]specification includes geometry, materials, properties, behavior
  - [2]processes: e.g. manufacturing, operation, maintenance support

compiled from input of various sources of literature

T. Hott, L. Hagge: Report from the 1st Workshop on the XFEL Collaborative Design Effort
22.10.2008

DESY HELMHOLTZ GEMEINSCHAFT 24

- coordination issues
- standards
- project management
- use of centrally offered methods and tools

DESY HELMHOLTZ ASSOCIATION

Scheduling
From the CFTs to the installation

Microsoft Project - Cold_Linac_070109repaired.mpp

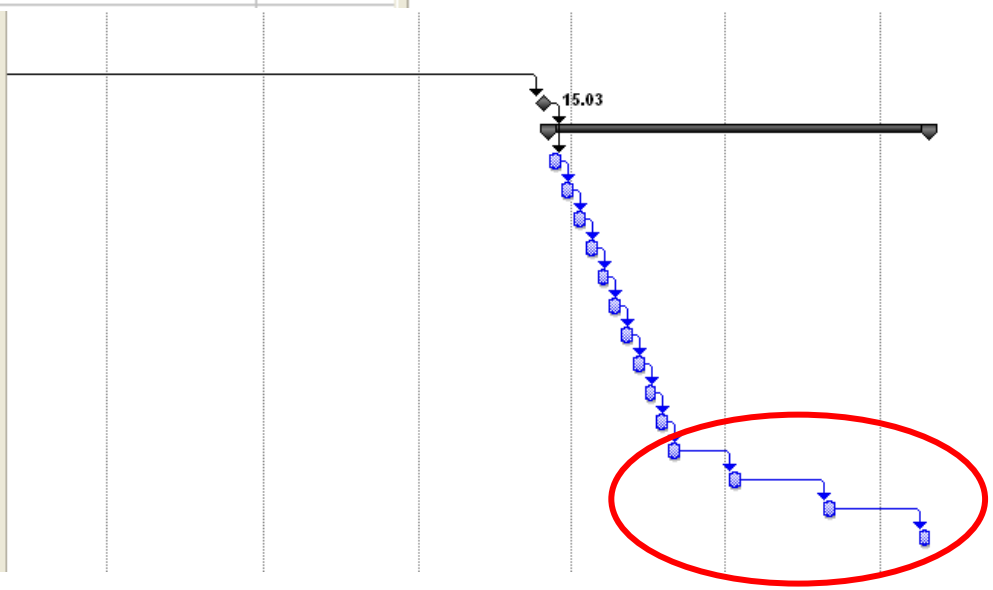
File Edit View Insert Format Tools Project Report Collaborate Window Help Modes

frequency tuner

	out / in / internal	Task Name	Duration
1	Input PM	PM AMTF handing over (WTM 18.11.0	0 dy
2	Input PM	PM XTL Handing over (WTM 18.11.08)	0 dy
3	Input PM	PM CFT cavities	0 dy
4	Input PM	PM CFT couplers	0 dy
5	Input PM	PM CFT vacuum	0 dy
6	Input PM	PM CFT frequency tuner	0 dy
7	Input PM	PM CFT Cold mass & Vacuum vessel	0 dy

Gantt Chart

15	WP4x WP33 in	XTL Handing over (WTM 18.11.08)	0 dy
16	WP33 out PM in	beginn primary installation (via XSIN?)	0 dy
17	WP33 out PM in	primary installation completed	0 dy
18		start module installation (week 12/2013)	161 dy
19	WP33 internal	install module #1 - #4	1 w
20	WP33 internal	install module #5 - #8	1 w
21	WP33 internal	install 8 modules (no. 9-16)	1 w
22	WP33 internal	install 8 modules (no. 17-24)	1 w
23	WP33 internal	install 8 modules (no. 25-32)	1 w
24	WP33 internal	install 8 modules (no. 33-40)	1 w
25	WP33 internal	install 8 modules (no. 41-48)	1 w
26	WP33 internal	install 8 modules (no. 49-56)	1 w
27	WP33 internal	install 8 modules (no. 57-64)	1 w
28	WP33 internal	install 8 modules (no. 65-72)	1 w
29	WP33 internal	install 8 modules (no.73-80)	1 w
30	WP33 internal	install 8 modules (no. 81-88)	1 w
31	WP33 internal	install 8 modules (no. 89-96)	1 w
32	WP33 internal	install 8 modules (no. 97-100)	1 w
33			

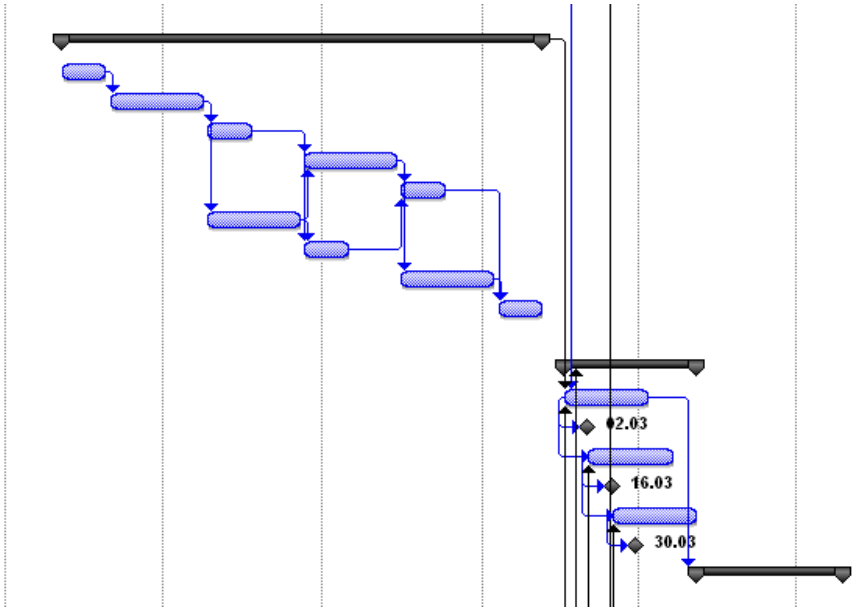


European XFEL

Assembly training and pre-series to be included

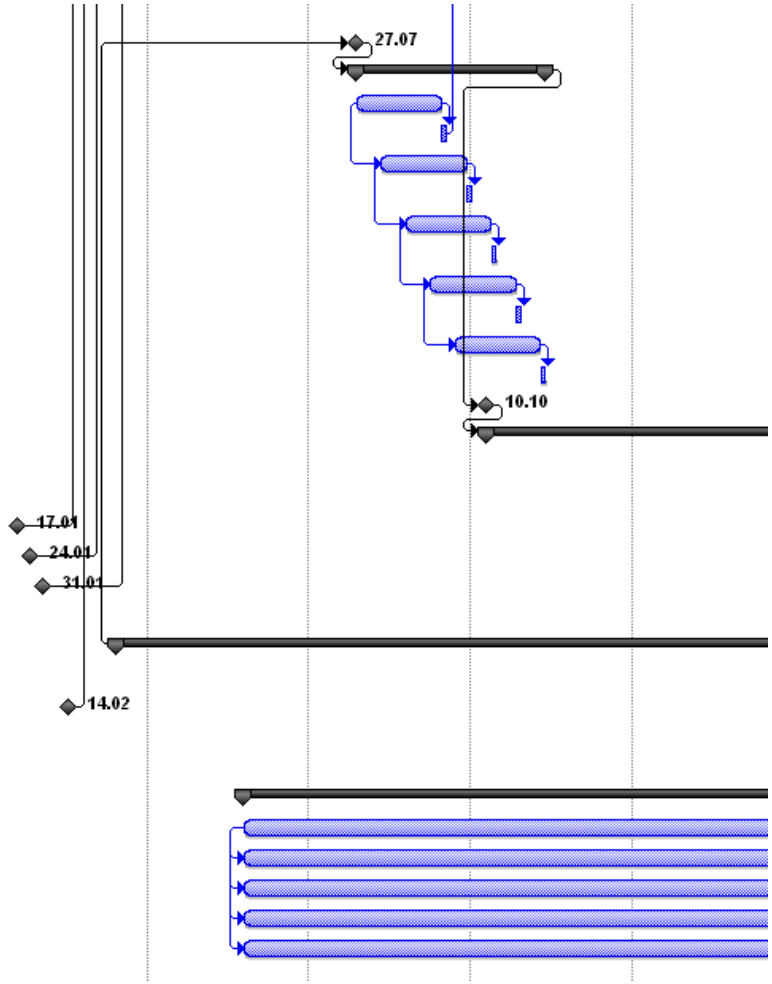
Gantt Chart

33				
34		WP3/9 out PM in	**string and module assembly training**	**200 dy**
35			initial training of new assembly teams	4 wk
36			1st dis- and re-assembly of prototype modu	8 wk
37			CMTB test of re-assembled prototype #1	4 wk
38			2nd dis- and re-assembly of prototype mod	8 wk
39			CMTB test of re-assembled prototype #1	4 wk
40			1st dis- and re-assembly of prototype modu	8 wk
41			CMTB test of re-assembled prototype #2	4 wk
42			2nd dis- and re-assembly of prototype mod	8 wk
43			CMTB test of re-assembled prototype #2	4 wk
44				
45			**pre-series module assembly**	**55 dy**
46		WP03 out PM in	pre-series module #1	7 wk
47		WP09 out WP03 in	first pre-series string ready	0 dy
48		WP03 out PM in	pre-series module #2	7 wk
49		WP09 out WP03 in	second pre-series string ready	0 dy
50		WP03 out PM in	pre-series module #3	7 wk
51		WP09 out WP03 in	third pre-series string ready	0 dy
52			**start CMTB module testing**	**60 dy**
56				

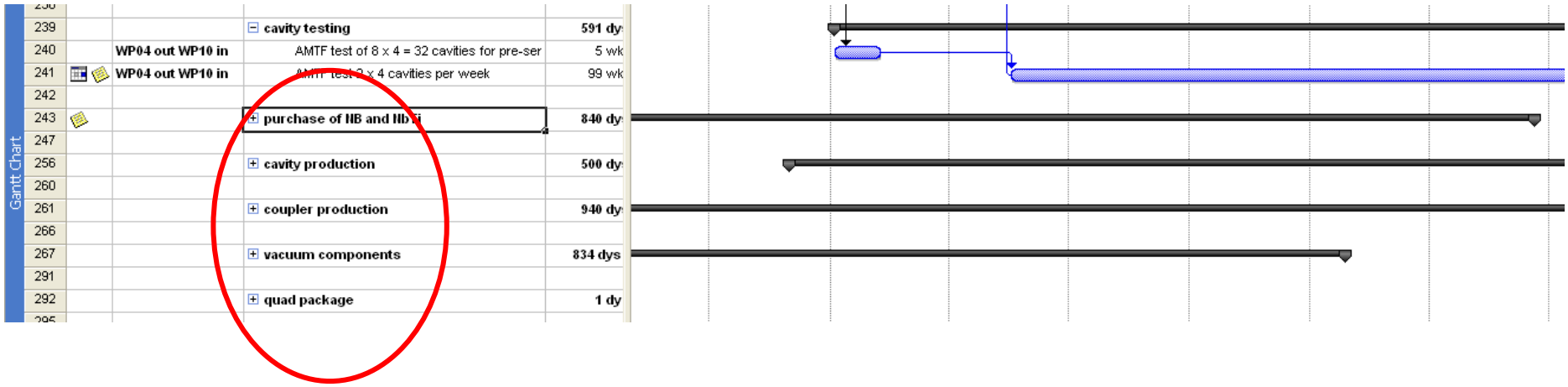


The first modules – ramping up

80				
81		WP03 out PM in	start module assembly with rate 0.5 modu	0 dy
82		WP03 internal	assemble modules 1-5	77 dy
83			assemble module #1	7 wk
84			transport module #1	2 dy
85			assemble module #2	7 wk
86			transport module #2	2 dy
87			assemble module #3	7 wk
88			transport module #3	2 dy
89			assemble module #4	7 wk
90			transport module #4	2 dy
91			assemble module #5	7 wk
92			transport module #5	2 dy
93			start module assembly with rate 1 module	0 dy
94			assemble module 6-100 (95 weeks + 35 day	507 dy
192			finish last module assembly	0 dy
193				
194			all components ready for pre-series modu	0 dy
201			all components ready for pre-series modu	0 dy
208			all components ready for pre-series modu	0 dy
215				
216			final production rate for all module compor	552 dy
223				
224			all components ready for pre-series assen	0 dy
230				
231				
232			all components available for series assem	495 dy
233		WP10 out WP09 in	8 tested cavities per week	99 wk
234		WP05 out WP09 in	8 conditioned cold coupler parts per week	99 wk
235		WP08 out WP09 in	8 bellows per week	99 wk
236		WP08 out WP09 in	2 gate valves per week	99 wk
237		WP11 out WP09 in	1 quad package per week	99 wk
238				



Individual components show up at some rate



European XFEL

The logic…. and the impact of changes

Gantt Chart

15	WP4x WP33 in	XTL Handing over (WTM 18.11.08)	0 dy
16	WP33 out PM in	beginn primary installation (via XSIN?)	0 dy
17	WP33 out PM in	primary installation completed	0 dy
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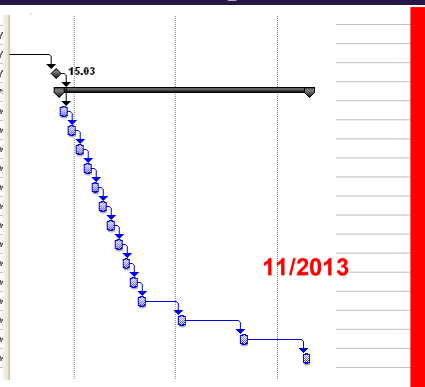
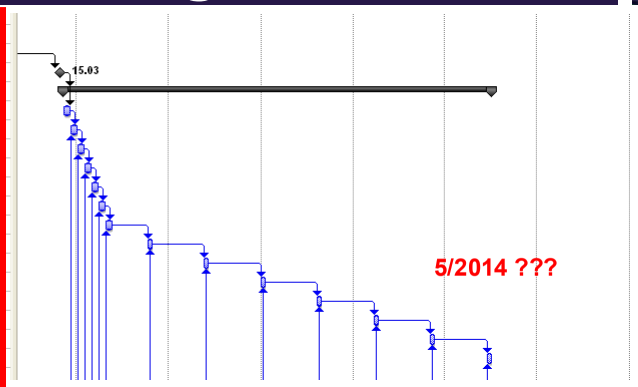
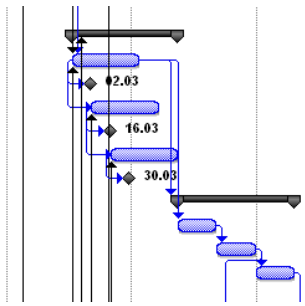
33			

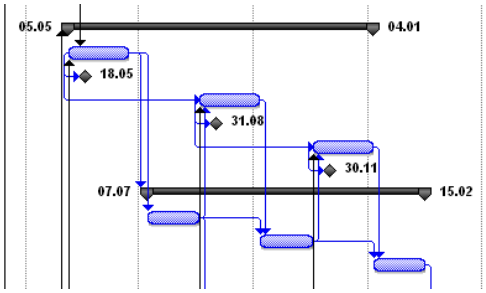




Gantt Chart

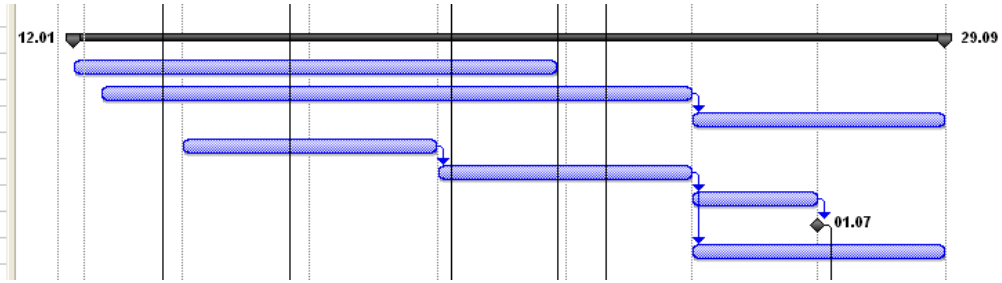
44			
45		pre-series module assembly	55 dy
46	WP03 out PM in	pre-series module #1	7 wk
47	WP09 out WP03 in	first pre-series string ready	0 dy
48	WP03 out PM in	pre-series module #2	7 wk
49	WP09 out WP03 in	second pre-series string ready	0 dy
50	WP03 out PM in	pre-series module #3	7 wk
51	WP09 out WP03 in	third pre-series string ready	0 dy
52		start CMTB module testing	60 dy
53		CMTB test pre-series module #1	4 wk
54		CMTB test pre-series module #2	4 wk
55		CMTB test pre-series module #3	4 wk
56			





logic for pre-series modules needs further discussion

32			
33	WP3/9 out PM in	CEA Assembly Facility	
34		Civil constrution assembly halls	
35		Ordering assembly "big tools" by CEA	
36		Commissining "big tools"	
37		Invitation CFT Module assembly for WP3 and 9	
38		CFT Module assembly WP3 and 9	
39		Allocation of assembly contract	
40		Assembly team available WP3 and 9	
41		Prototype assembly qualification WP3 and 9	
42			



infrastructure at other laboratories needs to be integrated

DESY HELMHOLTZ ASSOCIATION

Collaborative Effort

Thanks to:

- WP(C)Ls
- THE experts
- my colleagues in the coordination team

…. it really is a great experience!