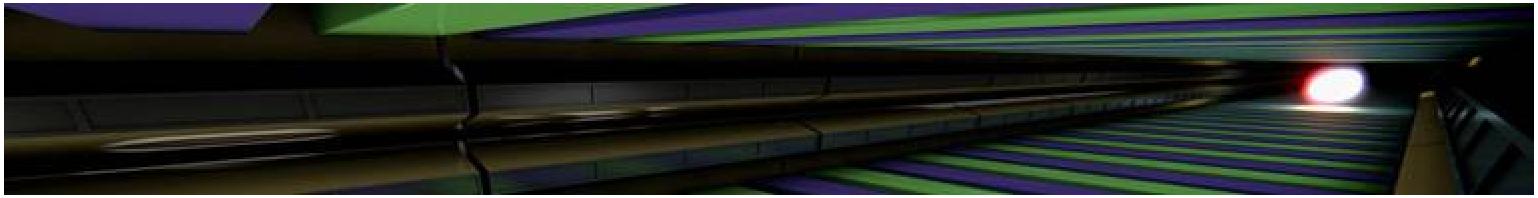
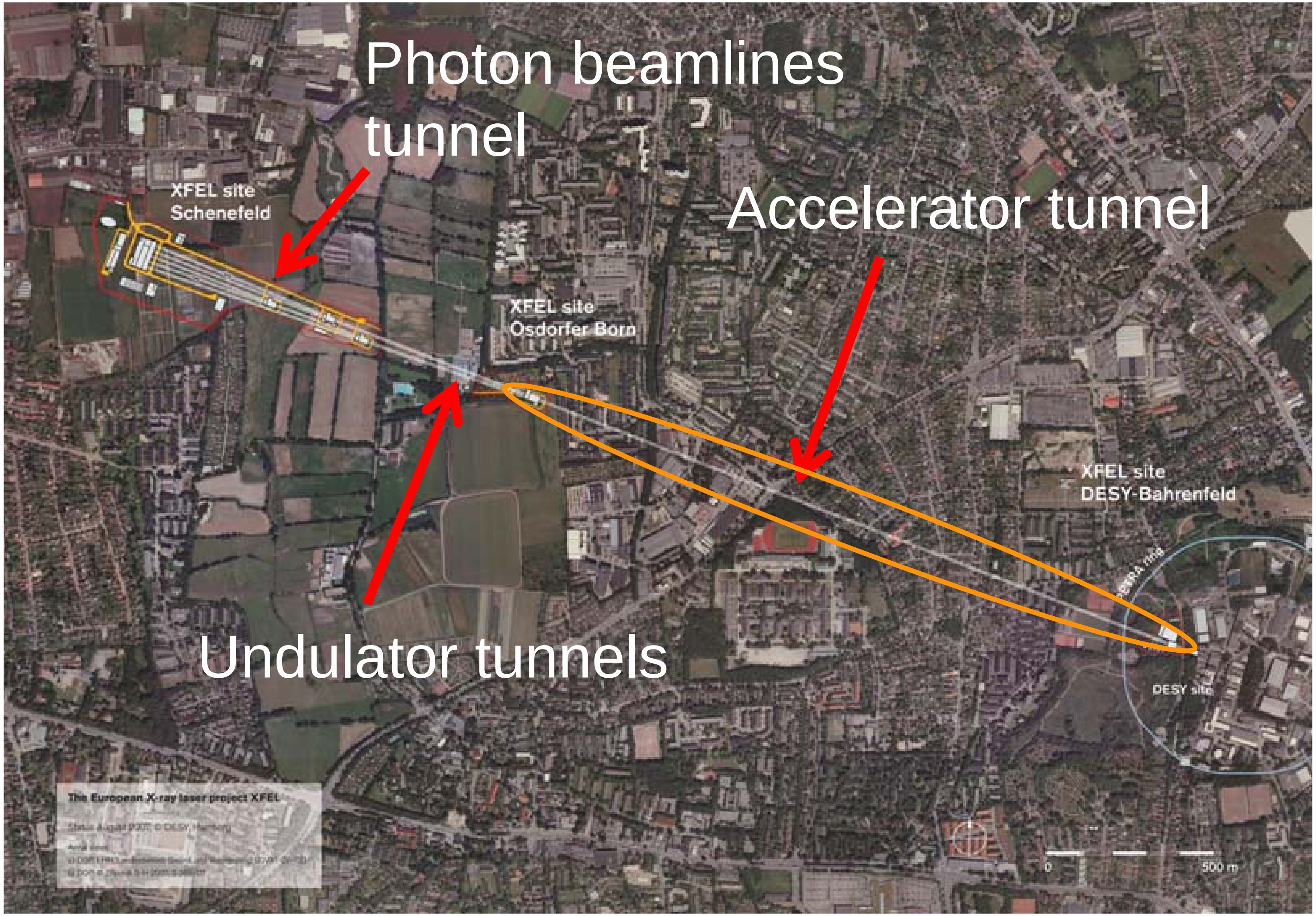


# Accelerator achievements and strategy

R. Brinkmann

# Facility layout – 2.1 km linear accelerator





European XFEL

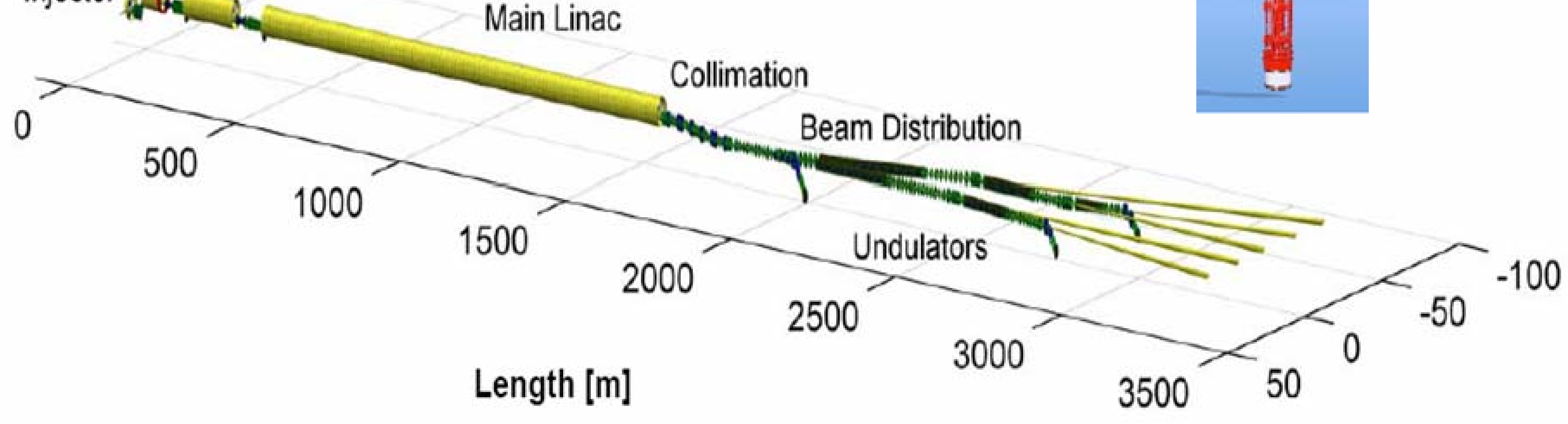
# Sub-systems of the accelerator complex



**100 accelerator modules**

**800 1.3 GHZ cavities g=23.6 MV/m**

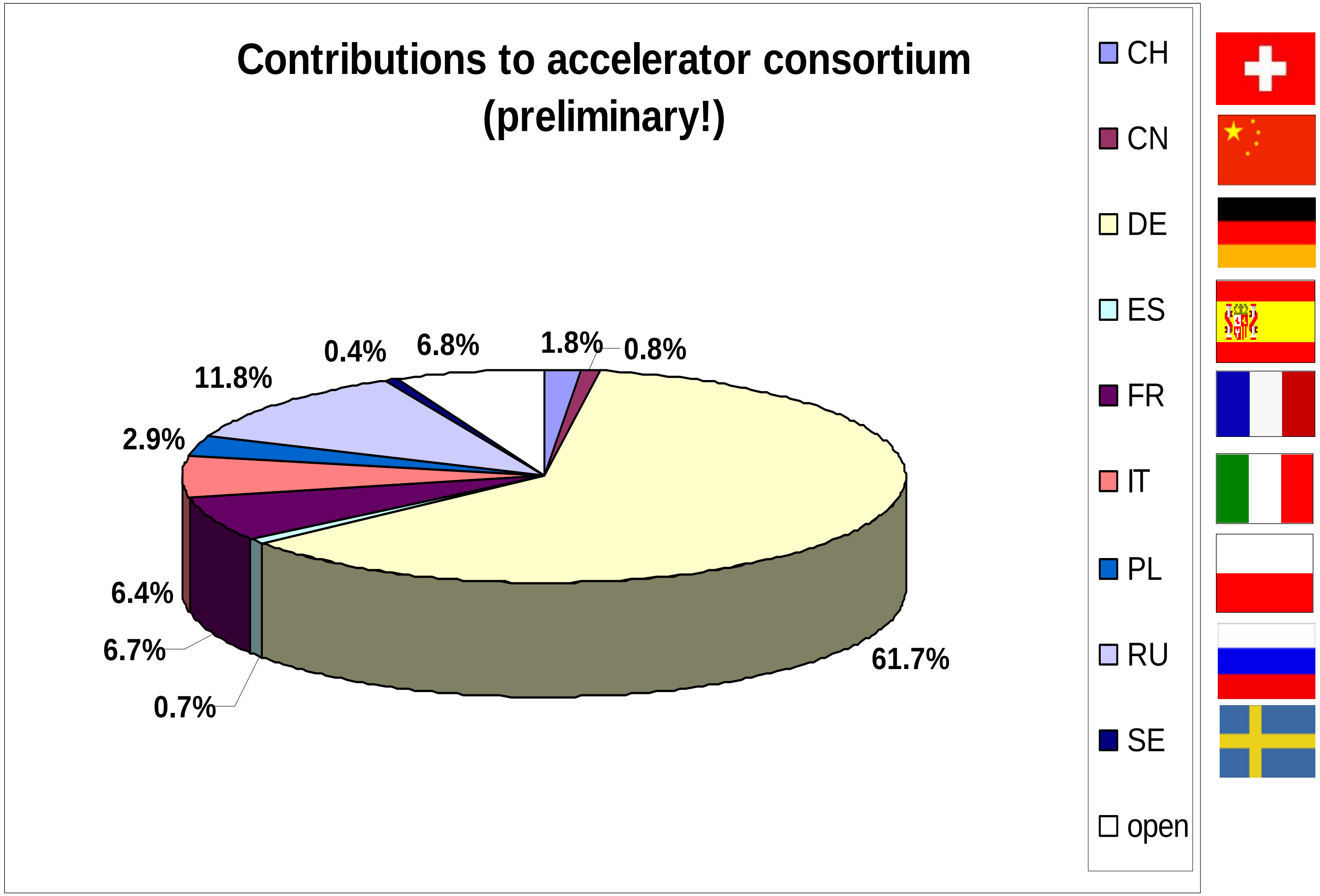
**25 RF stations P=5.2 MW**



# Consortium participation – total volume ~500 MEUR

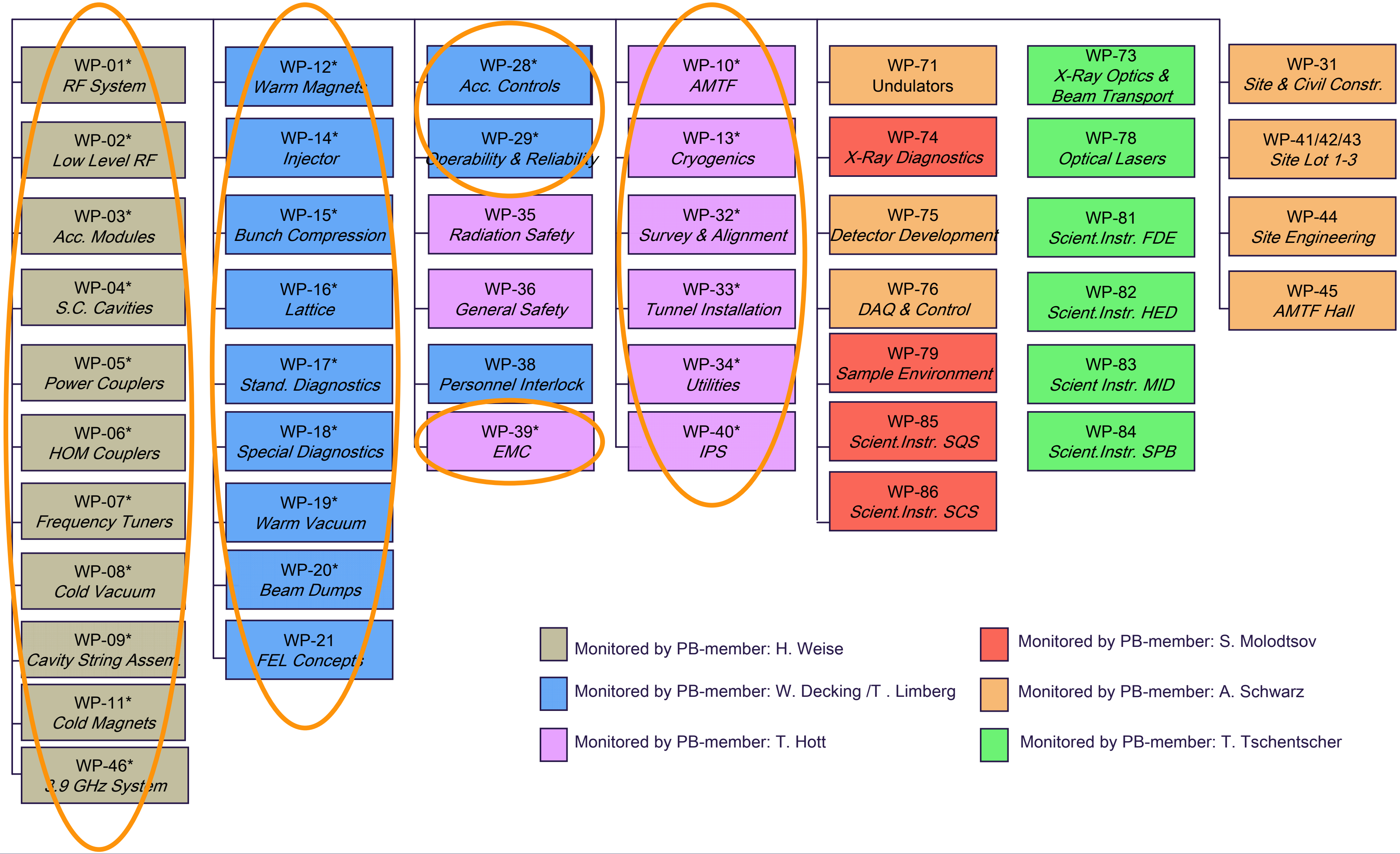


**17 institutes from 9 countries**



# Work package structure – accelerator complex



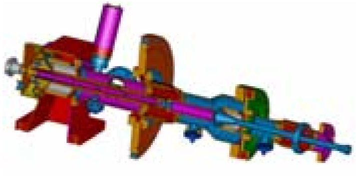


# Accelerator modules – collaborative effort

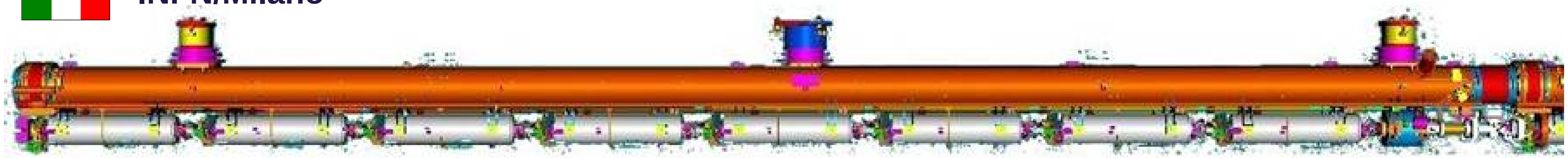


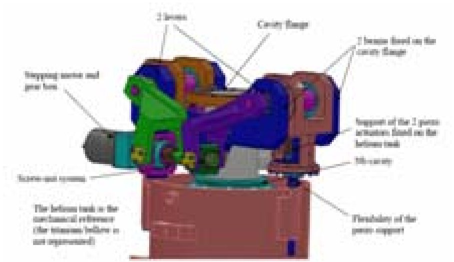
## Vessel & cryostat
IHEP/Beijing
DESY
CEA/Saclay
INFN/Milano

## RF power coupler
DESY
LAL/Orsay

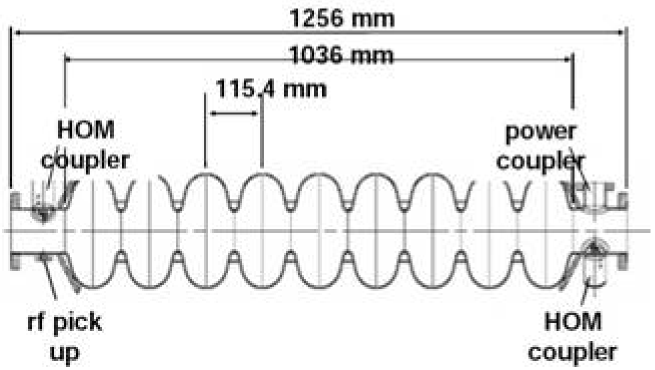


## Superferric magnet
DESY
CIEMAT/Madrid





## Freq. tuner
DESY
INFN/Milano



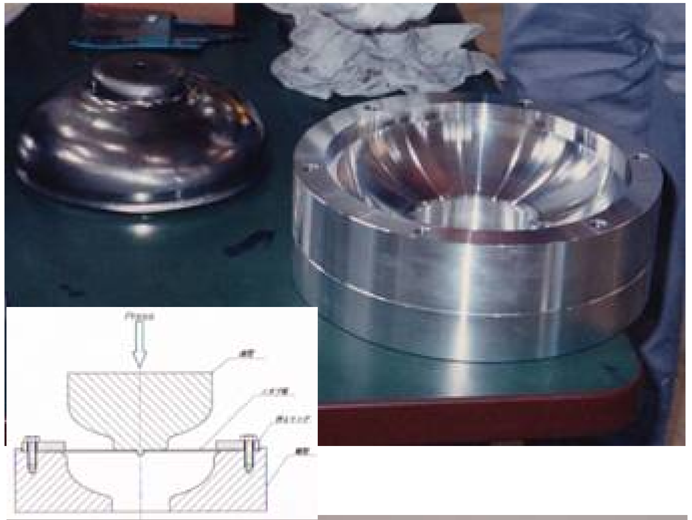

## s.c. cavities
DESY
INFN/Milano

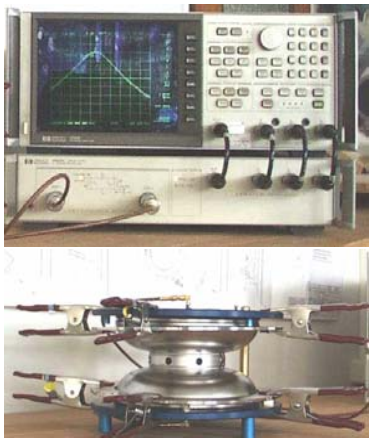
## BPM
DESY
CEA/Saclay
PSI/Villigen

## HOM absorber
Soltan Inst/Swierk

# Cavity production: offers received, negotiations ongoing







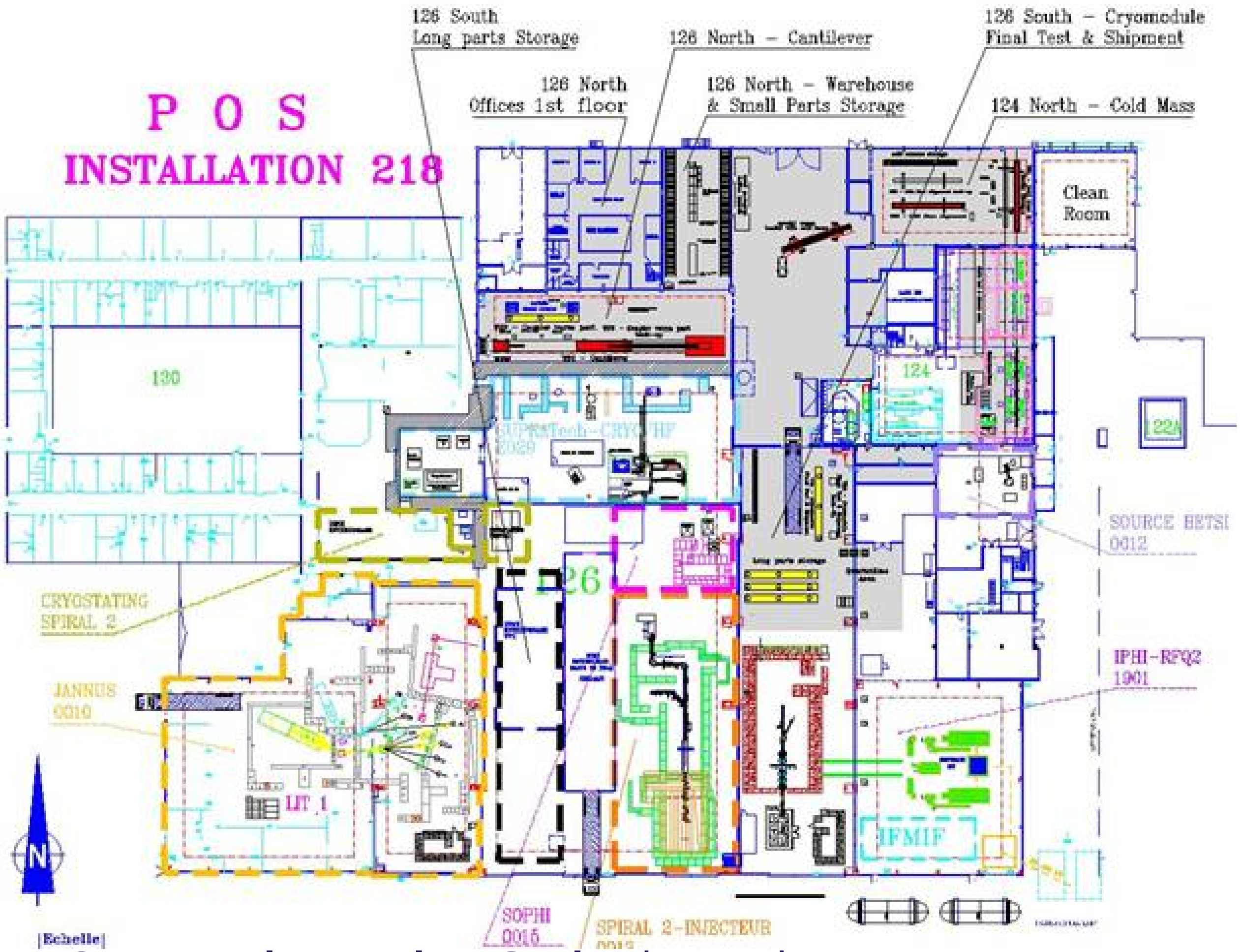
# RF-coupler procurement & processing at IN2P3-LAL/Orsay




LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE


- Conditioning rate of **8 couplers per week**.
- Schedule integrated in overall project schedule.
- Direct delivery to assembly site at CE Saclay.

# String & module assembly at IRFU-CEA/Saclay




- **Construction work at Saclay** is ongoing;
  cranes, cantilever, all big assembly tools are ordered
- **clean room infrastructure inauguration Nov 2009**

# Module transport test Hamburg-Saclay-Hamburg




- Vibration/shock-damped transport frame developed in industry
- After truck transport to Saclay, back on CMTB for RF test:
  - No mechanical damage, no vacuum leaks
  - Cool-down and RF-powering without problems

European XFEL

# Refurbished DESY Clean Room



- Increased ISO4 assembly area
- Chemistry and ultra sound infrastructure now in ISO6/5 instead of ISO7/6
- New rotational clean room airlock
- Reduced power consumption

- DESY will be able to handle (few exceptional) performance “problem cases” of cavities and modules from series production

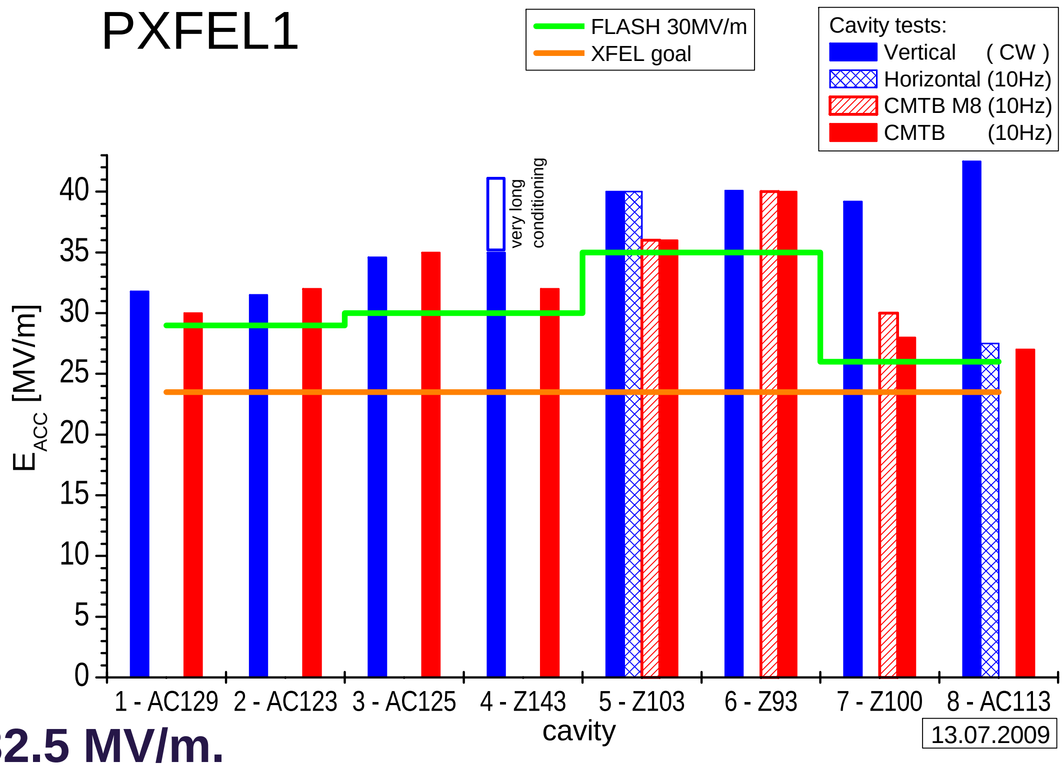
# XFEL Accelerator Module Prototypes


Institute of High Energy Physics
Chinese Academy of Sciences

duro felguera, s.a.

THALES


# PXFEL1 - The *Chinese* Module at CMTB




- The accelerator module PXFEL1 was conditioned and tested at the Cryo-Module Test Bench (CMTB).
- The average maximum gradient is **32.5 MV/m.**
- After string and module installation we have seen a **gradient reduction of only 5%.**
- PXFEL1 will be installed at FLASH and **can be operated** there with an average gradient of **30 MV/m.**
- The **XFEL waveguide distribution** will be used.

# RF system R&D and industrialization


Test stand @ DESY, Zeuthen

- Modulator and interlock system developments in Zeuthen
- Very good test results for prototype from industry
- Klystron prototype tests in Hamburg
- Three companies qualified for series production

# Installation tests in the mock-up tunnel



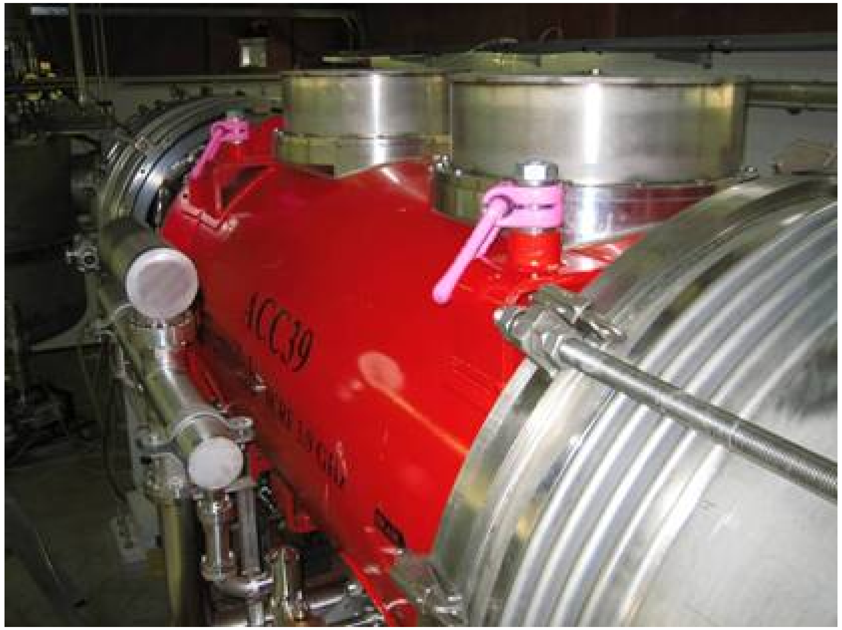
# 3rd harmonic accelerator module

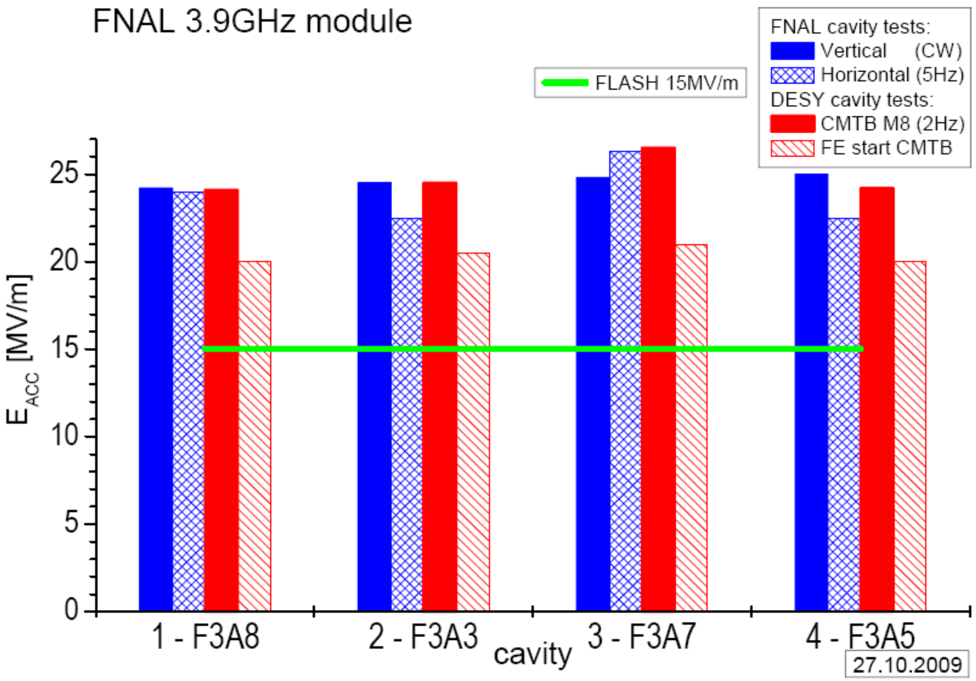
**DESY**

**INFN/Milano**

- Contribute 8-cavity 3.9 GHz module for XFEL

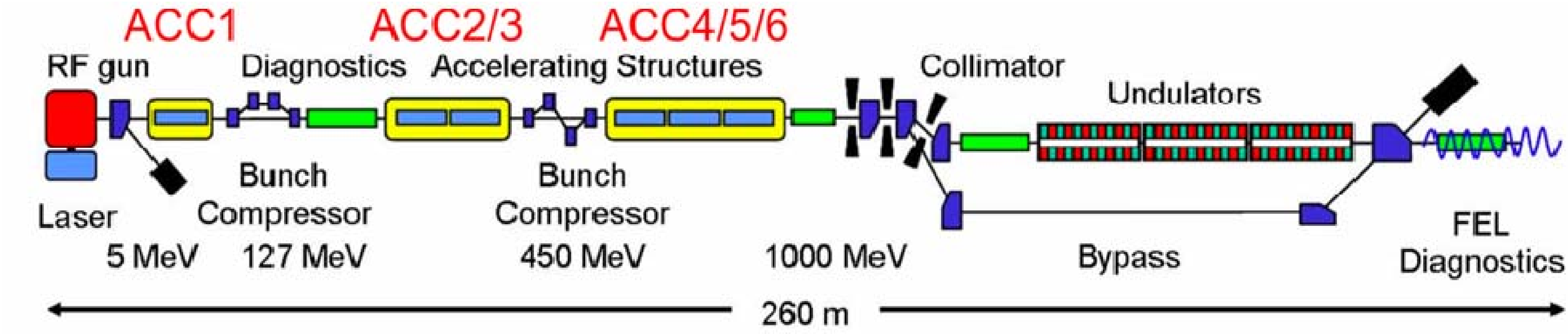
- Smaller version with 4 cavities built at FNAL in collaboration with DESY
- Installed at FLASH after successful test with RF
- Invaluable experience for XFEL



# Long bunch train experiment @FLASH Sep2009



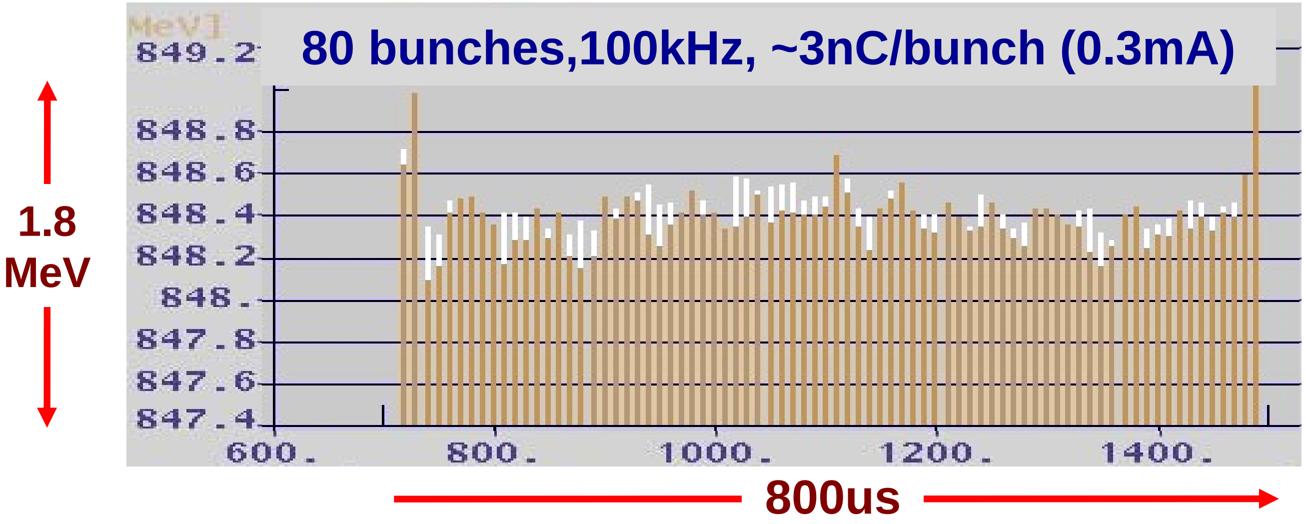



## Comparison of machine parameters

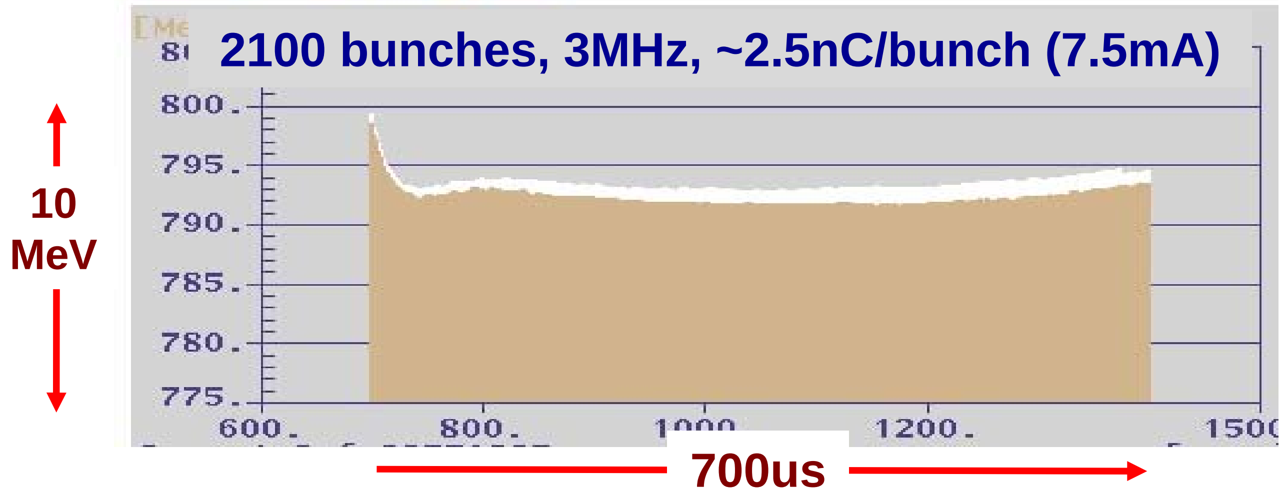
| | | XFEL | ILC | FLASH design | 9mA studies |
|---|---|---|---|---|---|
| Bunch charge | nC | 1 | 3.2 | 1 | 3 |
| Bunch rate | MHz | 5 | 2.7 | 9 | 3 |
| # bunches | | 3250 | 2625 | 7200 | 2400 |
| Pulse length | µs | 650 | 970 | 800 | 800 |
| Current | mA | 5 | 9 | 9 | 9 |

## Nominal experiment setup

- 3nC/bunch
- Bunch rates: 40kHz – 3MHz
- RF systems operating ‘on crest’
- BC magnets on, but no compression
- Beam through Bypass line to dump
- RF gun: 1.5 cell warm PC gun
- ACC1: 8 SC cavities
- ACC23: 2x 8 SC cavities
- ACC456: 3x 8 SC cavities
- LLRF: digital I/Q control of VS
- Piezo tuners: ACC3, ACC5, ACC6



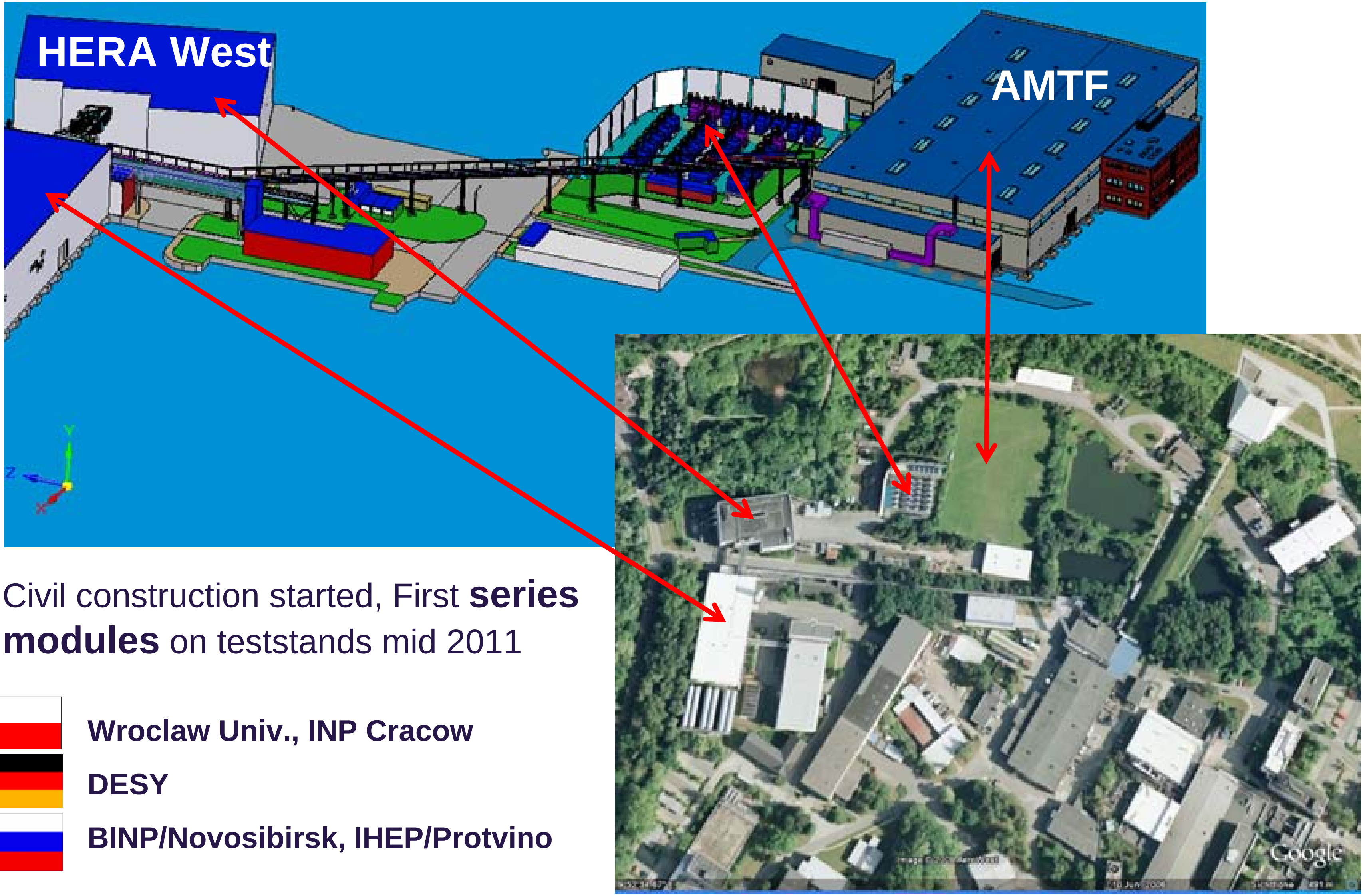

Along pulse: 0.035% p-p




Along pulse: 0.5% p-p
Pulse-pulse: 0.13% RMS

# Accelerator Module Test Facility (AMTF)






- Civil construction started, First **series modules** on teststands mid 2011

**Wroclaw Univ., INP Cracow**

**DESY**

**BINP/Novosibirsk, IHEP/Protvino**

# AMTF civil construction



- Laying of foundation stone July 21, 2009

- Start of construction work

- The hall a few weeks ago

# S.c. magnets



- Cryostat etc. completed and ready for testing the 100 s.c. quads for the XFEL linac
- 3 quad prototypes delivered by CIEMAT and test programme has started

**CIEMAT fabrication** | **DESY test facility** | **INP Cracow manpower test**

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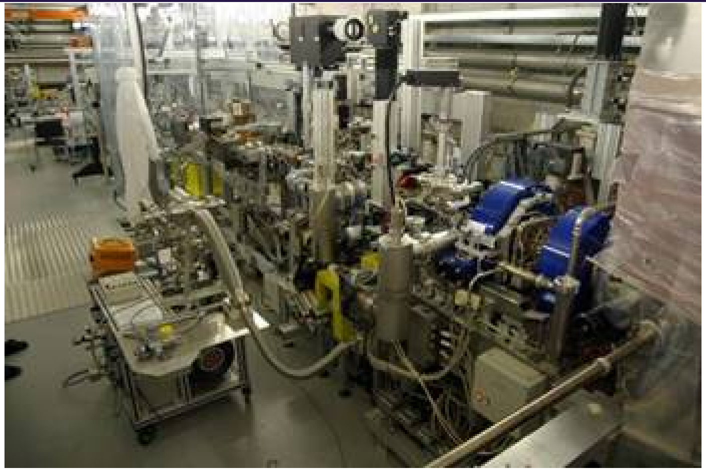
# Injector R&D: PITZ at DESY in Zeuthen





**August 2007:**

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

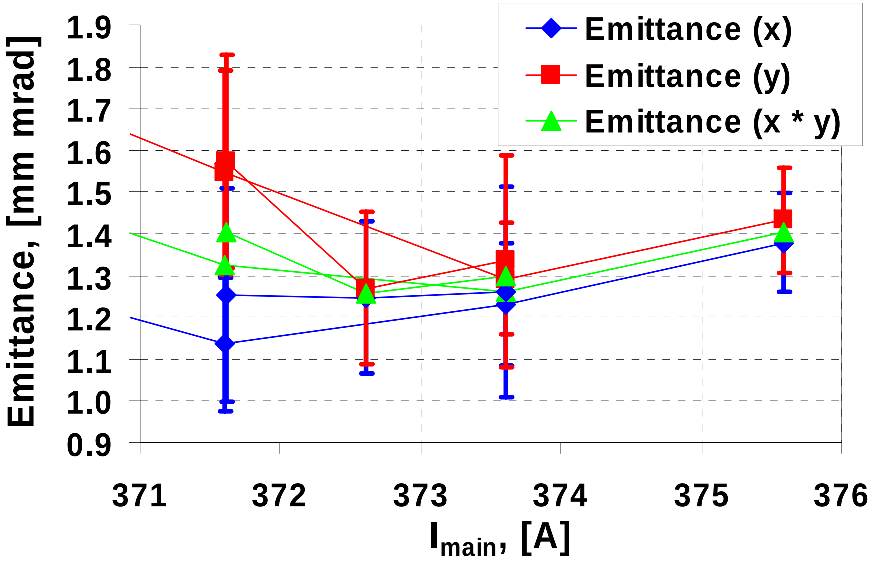
**@1nC**

**for 100 % RMS emittance !**

Cut of large-amplitude tails:

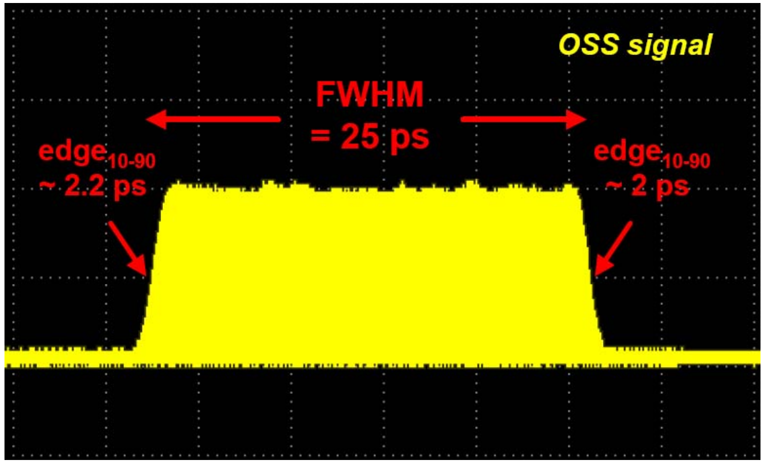
**For 90% RMS ➔**

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

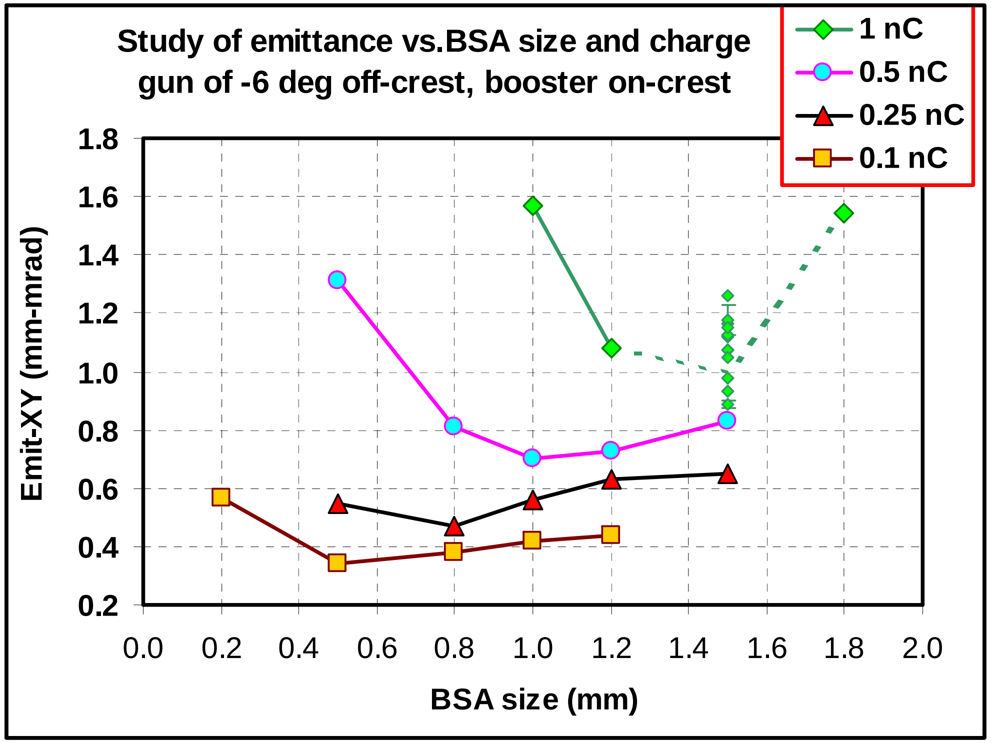


# Continued R&D at PITZ: new laser, low charge, …






- Laser pulse “synthesizer”: 13 pulses with 2ps rise/fall time overlapped, individually adjustable (built by MBI, Berlin)

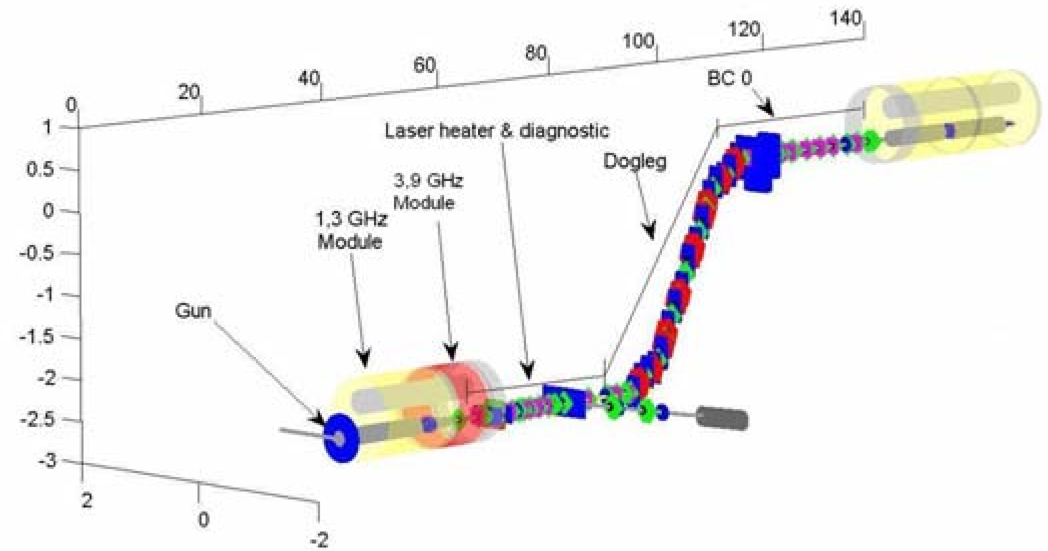



- Emittance at 0.25nC comparable to LCLS

# Injector section



- 3rd compression stage at low energy (BC-0) added and 3rd harmonic system moved to position after injector module (at 150 instead of 500 MeV)




- Space for two injectors in separate shielded enclosures – can be installed & operated independently

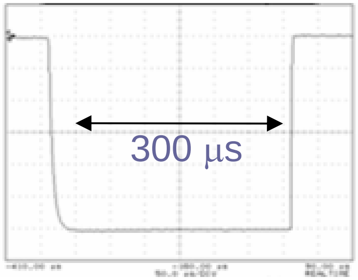
# Electron beam lines & distribution

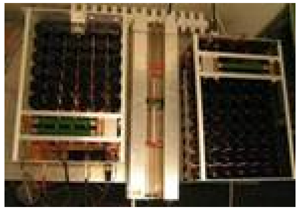


## Beamline magnets

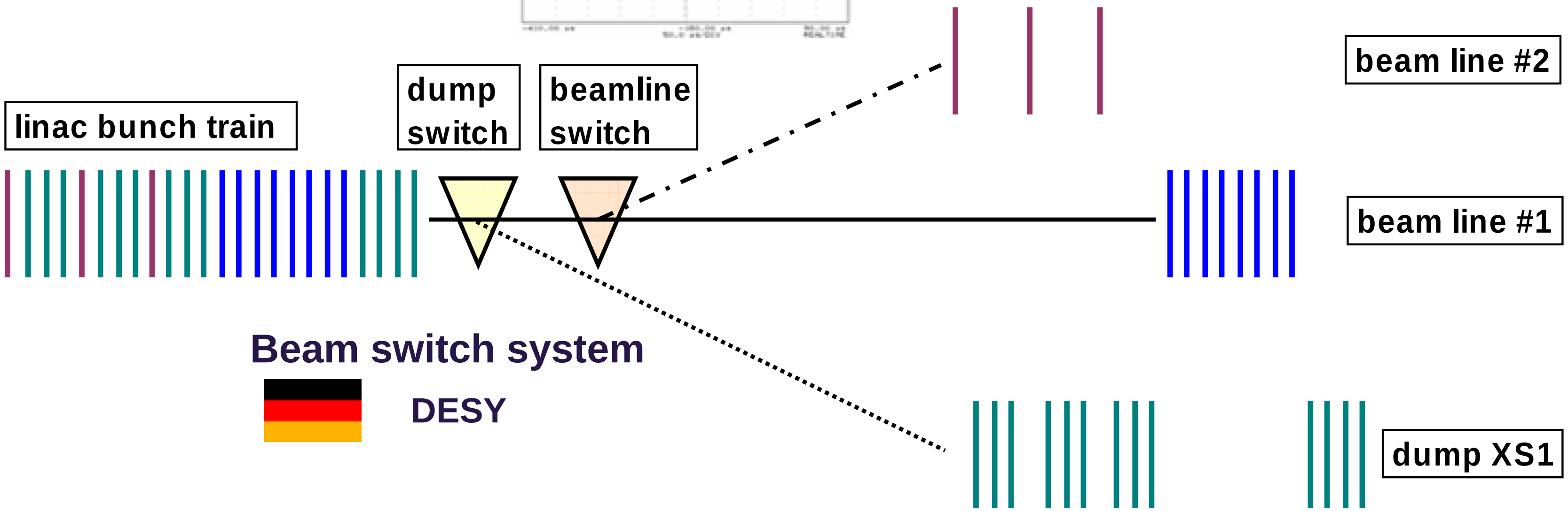
NIIEFA/St. Petersburg

MSL/Stockholm



- high accuracy (< 0.01 %)
- 10 Hz operation




## Beam switch system

DESY

## Vacuum system

BINP/Novosibirsk

DESY

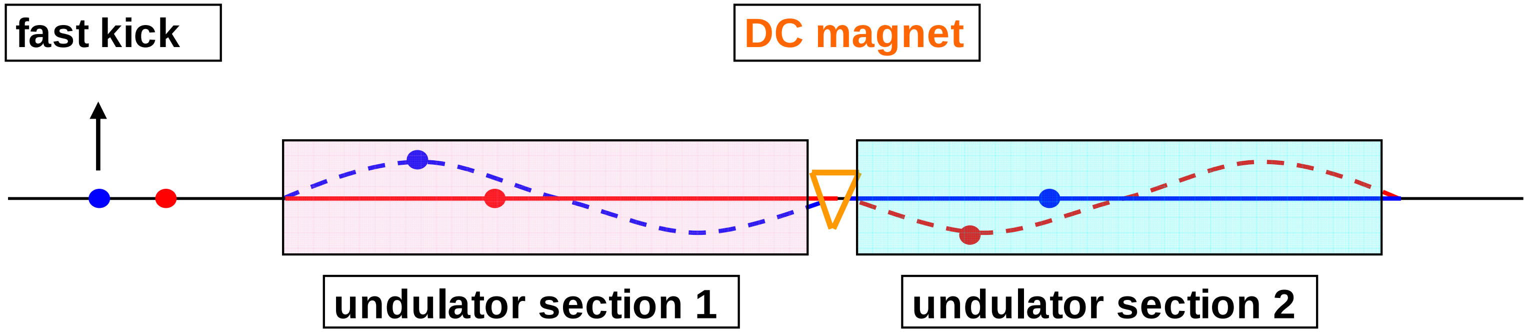
## Bm. Position measurement & stabilisation

DESY

PSI/Villigen

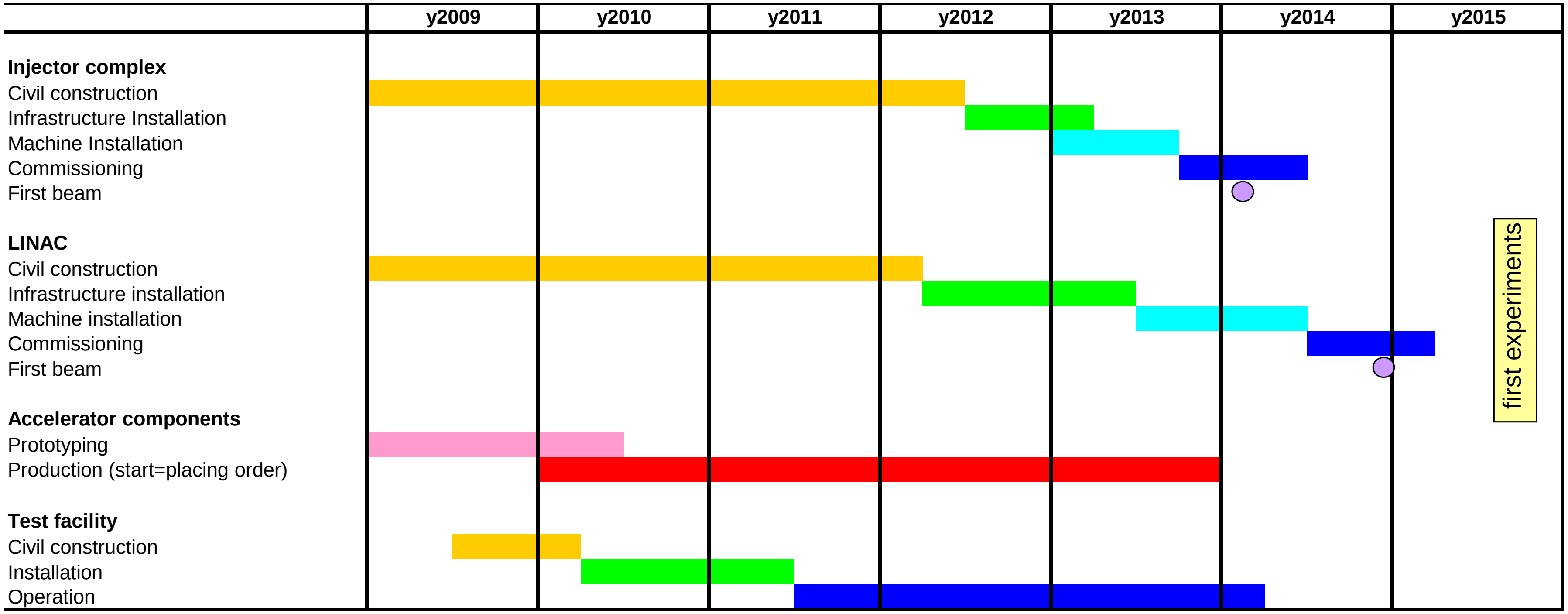
# Example for operational flexibility






- FEL gain can be suppressed if bunch is kicked from axis (e.g. using fast feedback kicker)
- Fast kicker + DC magnet can select which bunches “lase” in which undulator section *ad libitum*
- can be used for subsequent undulator beam lines or within one undulator (e.g. 1st and 2nd half of SASE2) → two (or more) –color schemes with adjustable delay
- ***Many more*** ideas for beyond-baseline options of the XFEL facility!

# Accelerator schedule (very coarse!)



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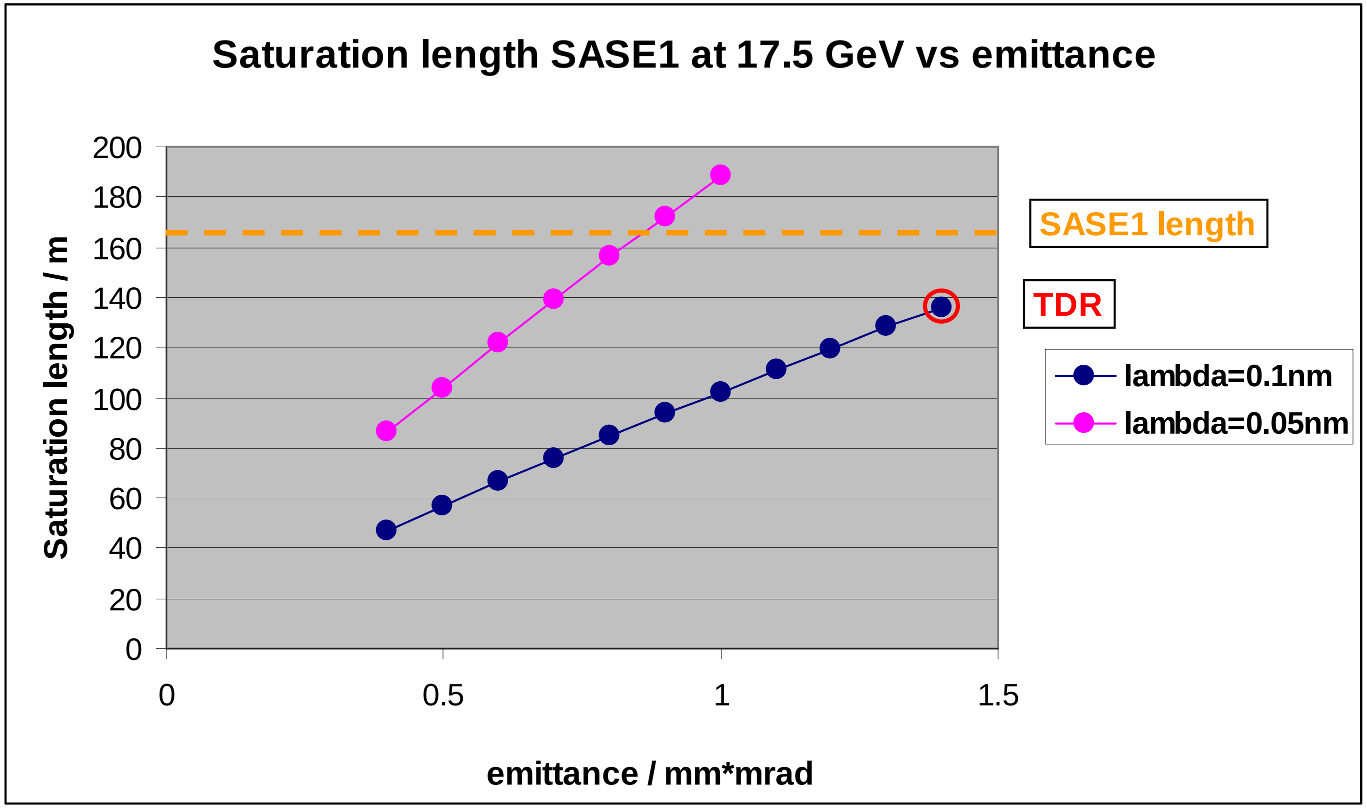
# Strategy



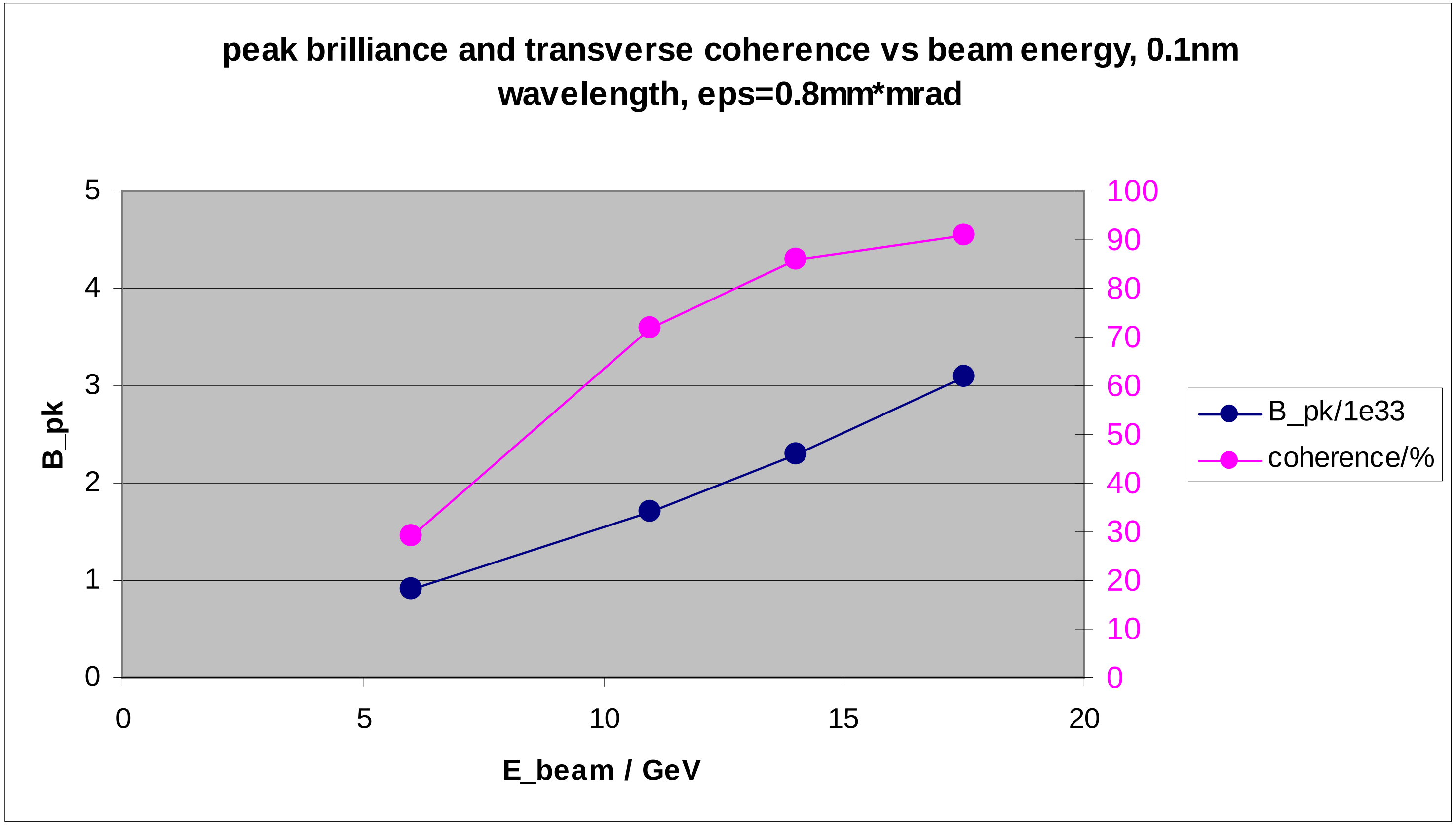
- Most remarkably fast & successful start-up of LCLS has triggered some discussions regarding European XFEL
  - Perhaps too conservative assumptions on beam quality/safety margins
  - Very low charge/short bunch options
  - Higher duty cycle (up to CW?)
- Flexibility has been built into XFEL design and options within certain range have been considered in the past – new ideas still emerge
- Lower emittance makes shorter wavelength immediately accessible ***without any changes*** to the machine (simply open SASE1 undulator gap) – two (or more) color modes become attractive as well
- Cost saving (shorter linac) is a possibility *(and perhaps necessity)* to some extent – ***without unacceptably compromising the scientific potential of the facility***

# Saturation length vs. beam emittance




- Wavelength well below 0.1nm (e.g. 0.05nm) accessible (just open undulator gap)
  → layout of photon beam transport!
- Undulators could be shorter, cost reduction or:
  - Two (or more) color modes possible + further options

# Peak brilliance & transverse coherence vs beam energy




- → significant loss of # coherent photons/pulse if beam energy is strongly reduced

*(calculation using parametrization of numerical studies by Saldin, Schneidmiller, Yurkov)*

European XFEL

# Strategy



- With realistic assumptions on lower beam emittance, linac energy reduction by 20% to 14 GeV appears as a reasonable compromise between cost aspects and scientific potential of the facility
- Many ideas for a most flexible use of the facility have already emerged and more will come – the layout has plenty of room to accommodate such options!

- CW mode remains an interesting future option, but:
  - Not technically ready yet (injector, CW tests of modules + RF system necessary, considerations of cryo upgrade/lower T,…)
  - Not the optimum for ***all*** experiments: more uniform time structure has to be traded against loss in coherent photons per pulse

- If CW mode is realized, should go along with re-establishing the full (TDR) linac length to permit ~7GeV

- The end