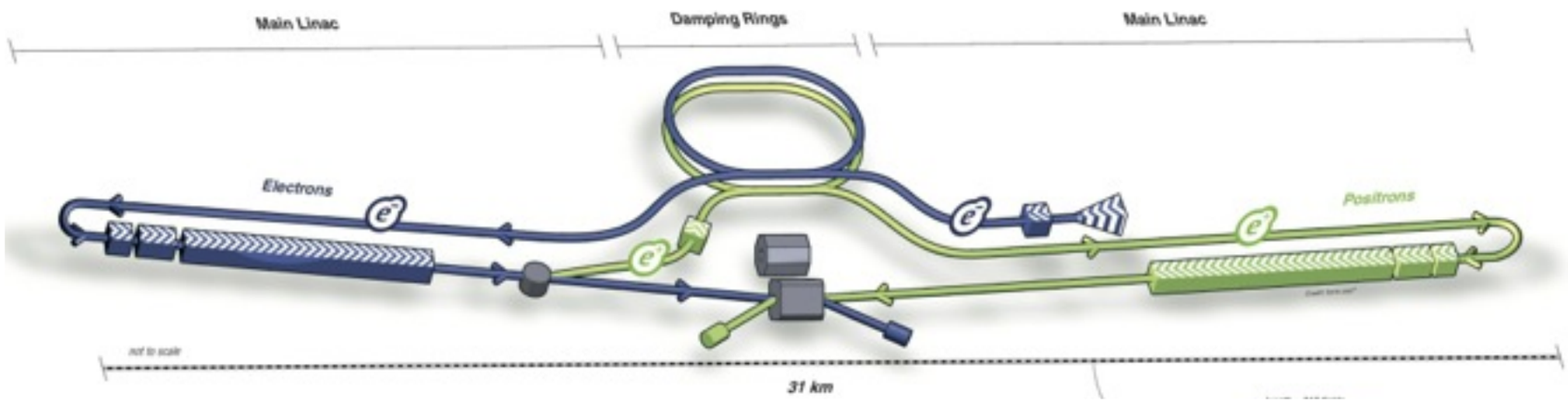
# Accelerator R&D in Germany

Eckhard Elsen

Report on the LC related activities at DESY (and beyond)



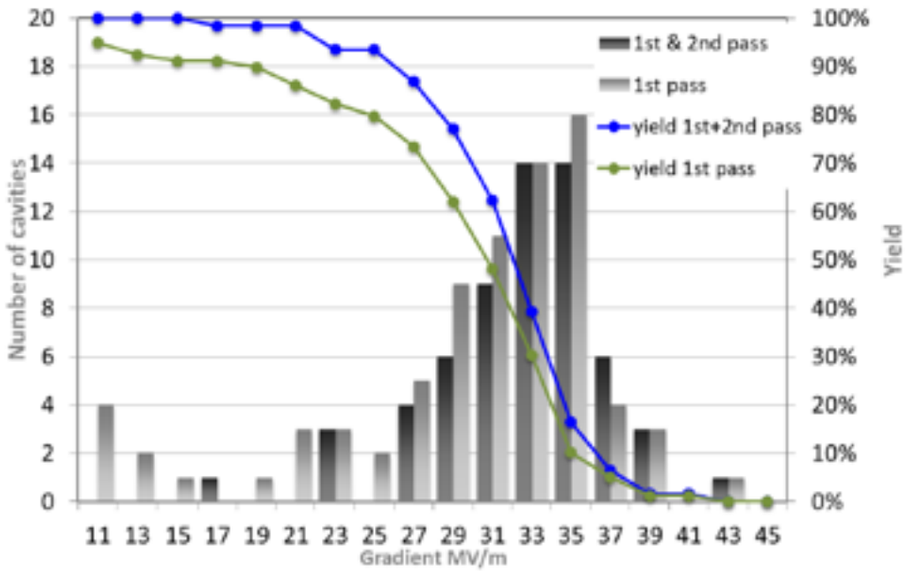

French IRFU Linear Collider Days, CEA Saclay, Nov 27-29, 2013

# Overview of R&D activities

- High-performance cavities
  - as part of the large-scale industrial production for the European XFEL and ILC-HiGrade and CRISP (DESY) and bmbf for U Hamburg (U Göttingen)
  - fundamental surface studies and shape optimization (U Wuppertal, U Darmstadt). Generic studies, which will not be further detailed today
- Cost studies for cavities, couplers and cryomodules (DESY)
  - following initial attempts during the TDR programme
- Positron yield and polarization studies
  - joint effort with CLIC for high yield and efficiency
- ILC-like beam tests at FLASH (DESY and international collaborators)
  - long-pulse, high current, maximum gradient operation: 9 mA experiments

# Towards high-performance cavities

- Industrial production recipe of cavities for the European XFEL yields gradients well above the required 23.6 MV/m.

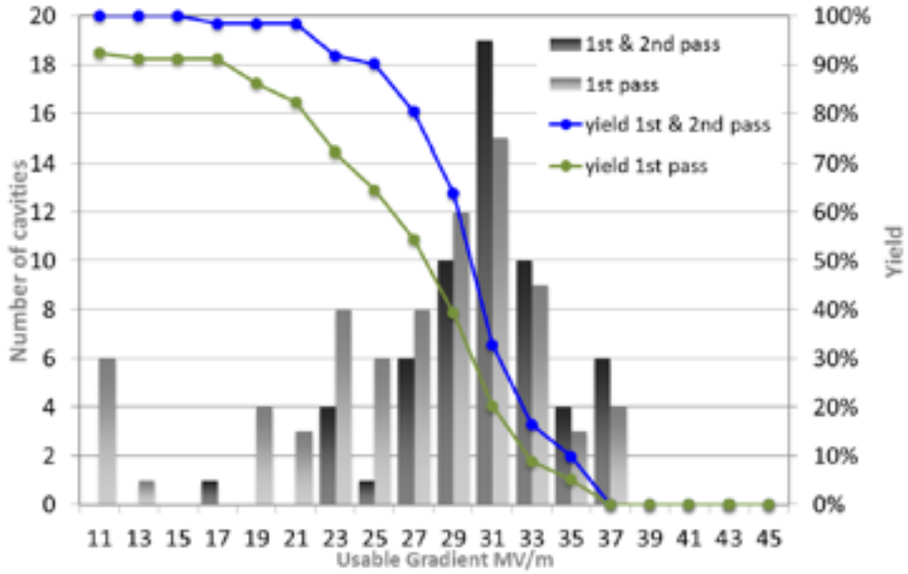



Average **maximum** gradient:

**(30.9 ± 4.4) MV/m**

EZ: (30.4 ± 4.5) MV/m

RI: (32.3 ± 4.1) MV/m




Average **usable** gradient:

**(29.0 ± 3.9) MV/m**

EZ: (28.4 ± 4.0) MV/m

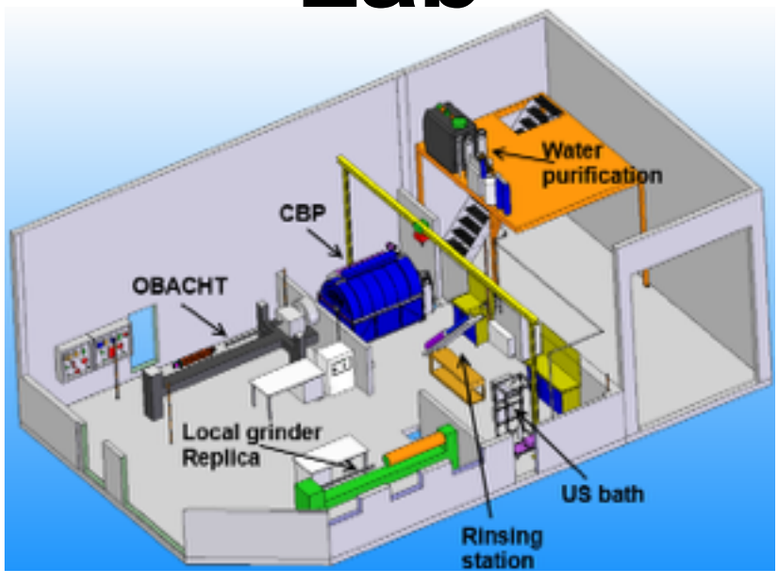
RI: (30.6 ± 3.1) MV/m

- Yield for high-gradient cavities is limited by local defects in individual cells, by quench of cavity or eventually field emission at large gradients
- ILC-HiGrade tries to localize and eliminate such local defects

# High performance cavities

- 800 cavities for the European XFEL will provide unique statistical sample for the properties of mass-produced cavities
- 24 ILC-HiGrade cavities added to the mass production will allow for detailed studies of the performance limitations of these cavities and allow for post-processing
  - thorough optical inspection of defects
  - quench localization via 2nd sound technique
  - analysis and removal of local defects
  - development of additional and optimized post-processing methods to improve maximum field
- Eventually provide 3 cryomodules of maximum performance

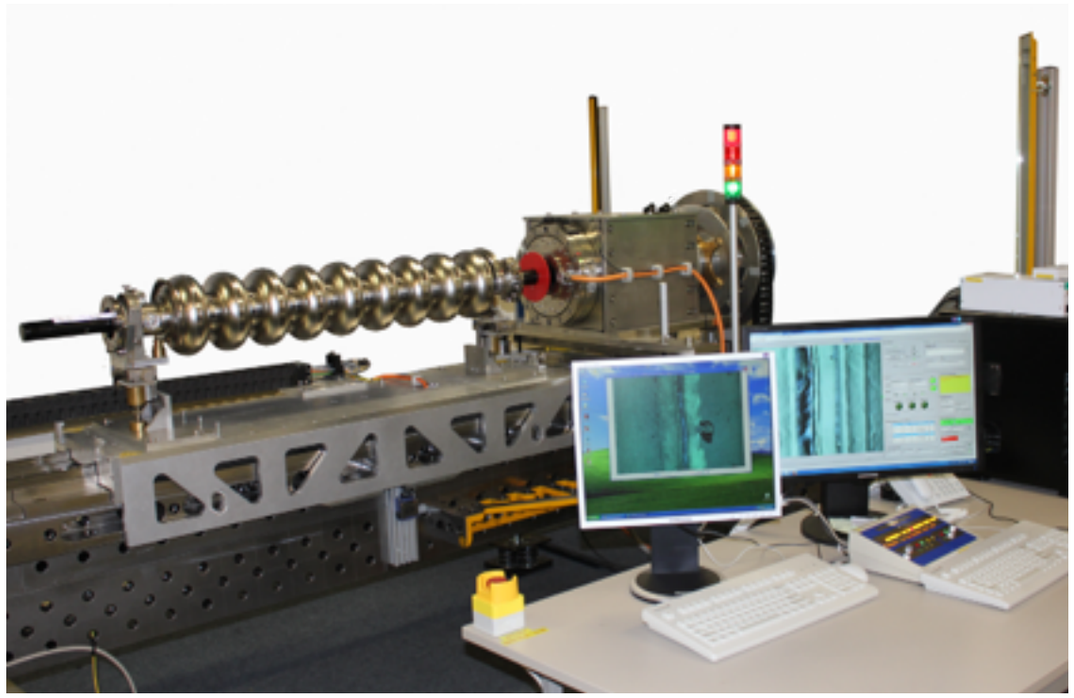
**ILC-HiGrade Lab**

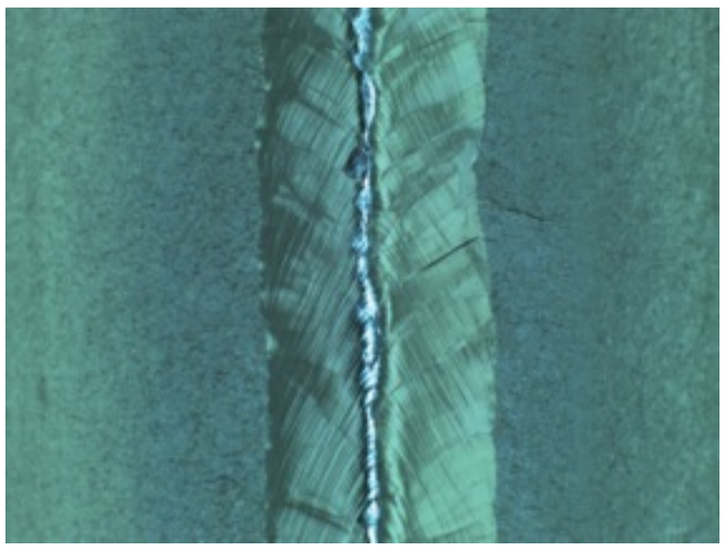



~150 $m^2$
2 laboratory rooms
1 storage/technical room

# OBACHT – Optical inspection tool of cavities

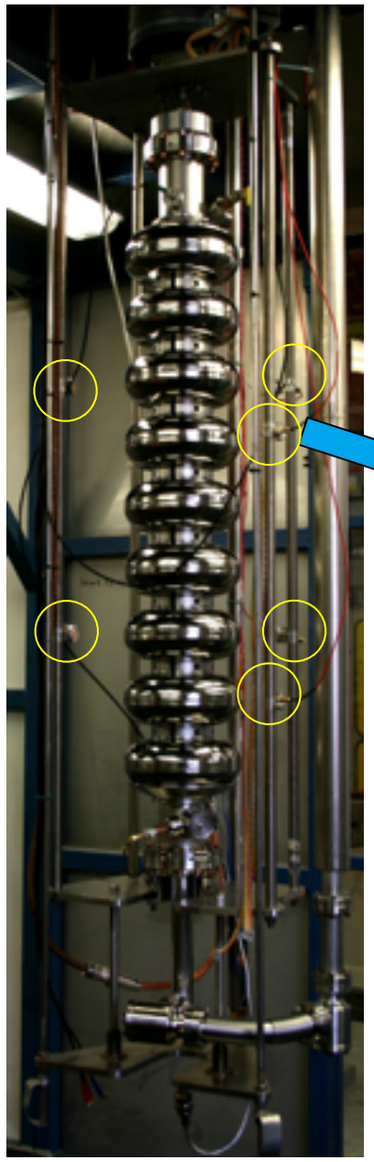
- Optical inspection of bare and dressed cavities
- Cavity camera with 10 µm and 0.01° resolution
- Automated cavity inspection with Kyoto Camera System
- Collision free movements assured by optical tests (planned)
- Fully automatic cavity positioning, illumination, and image recording
- Automatic image processing and possibly defect recognition

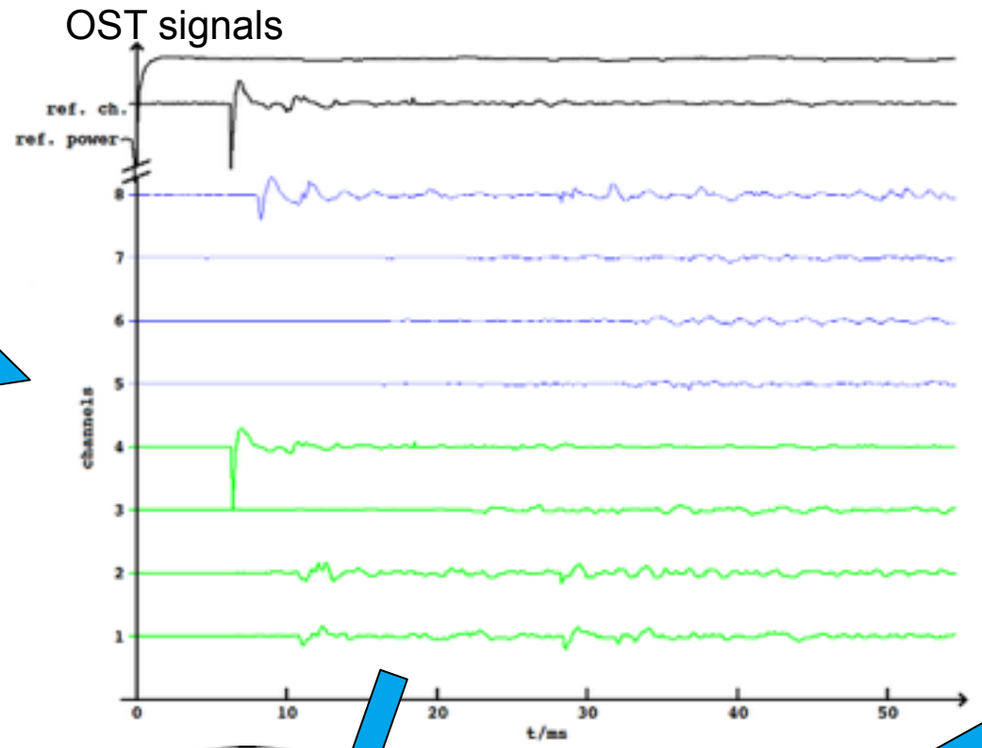




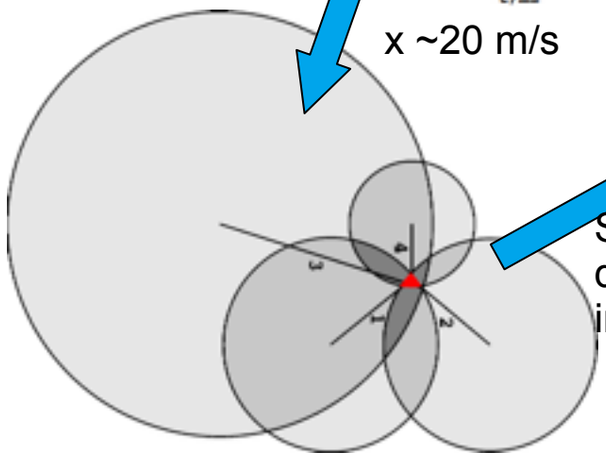
*Welding seam*

# Quench localization using 2nd sound

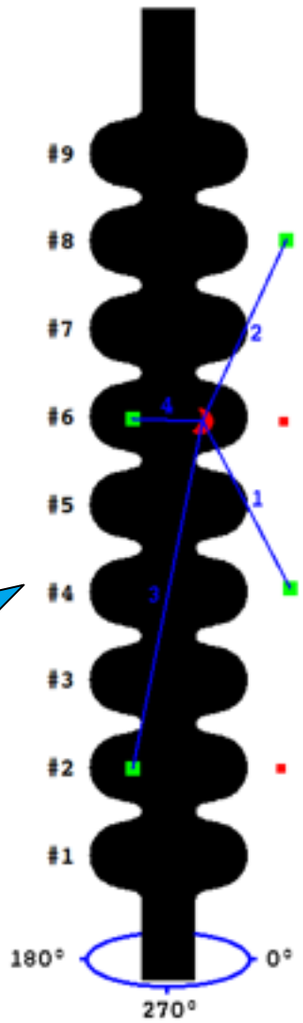





x ~20 m/s



Schematic drawing of determination of the intersecting volume

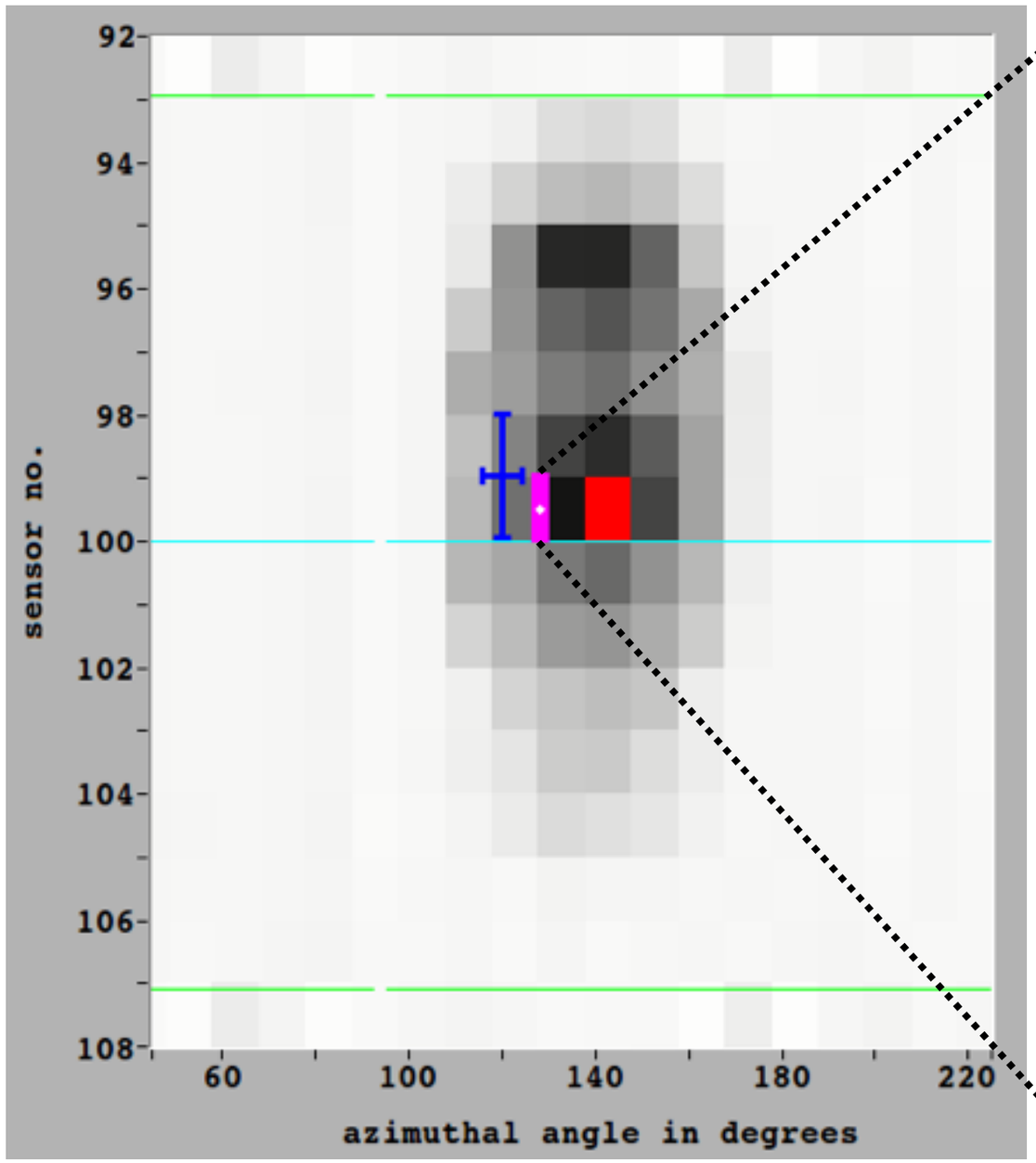


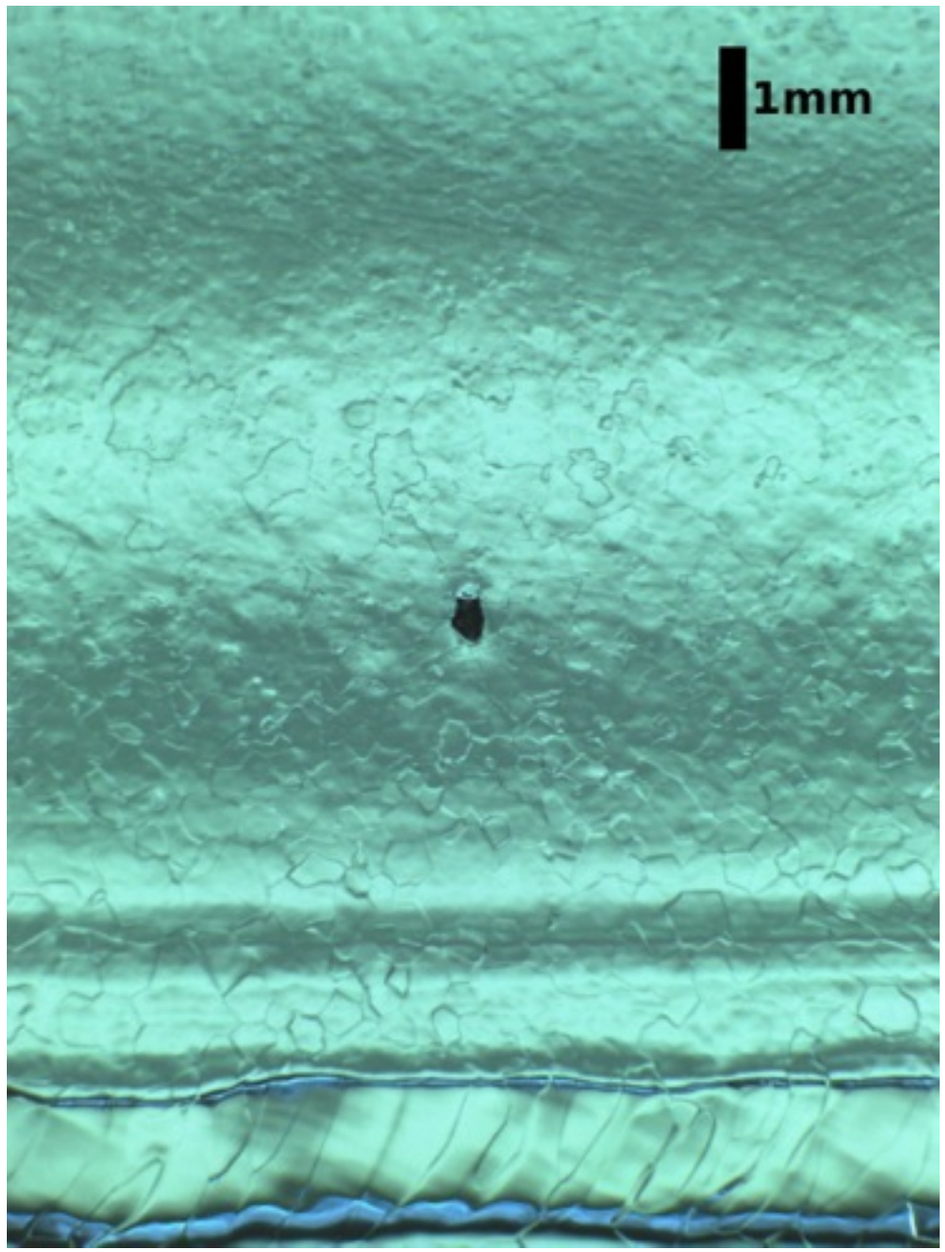

Calculation result

# Example of quench localization

Z161, Cell 2
π-mode test

Consistent result of **2nd sound**, **OBACHT** and **T-map**

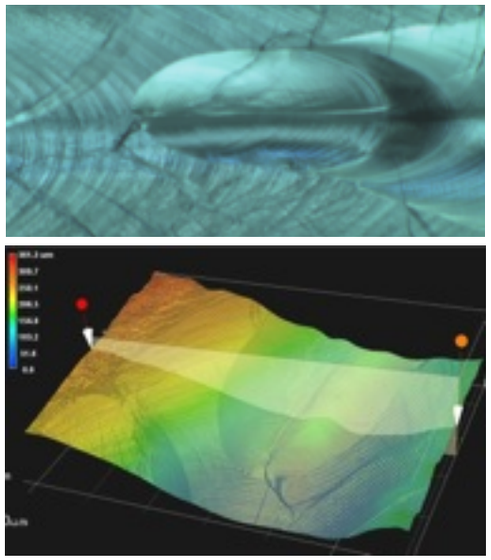


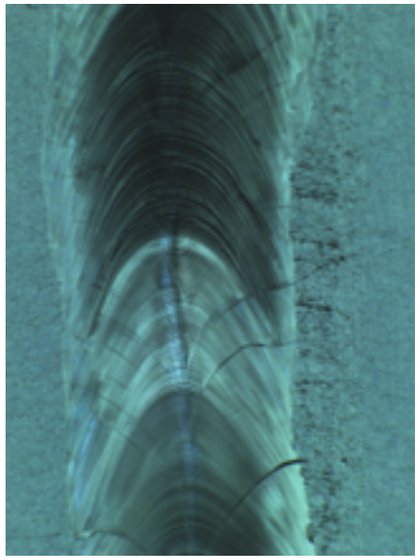



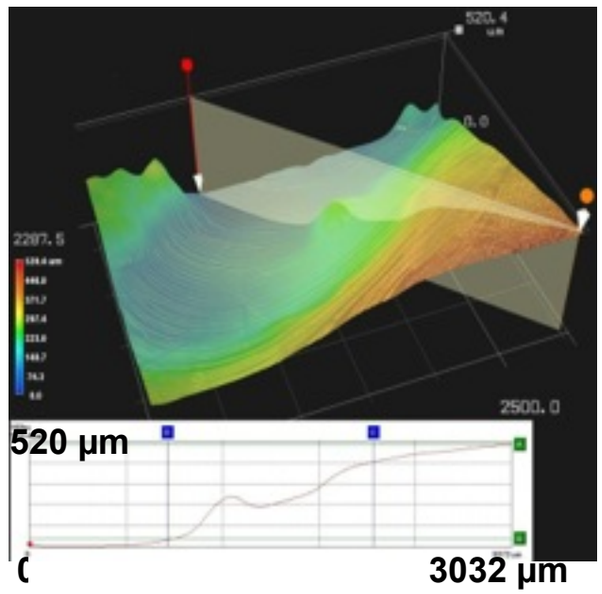
# Surface replica

- Silicon replica of surface structure can be used to resolve effects down to ~1 µm size without affecting cavity performance (after HPR)

- Helps to resolve ambiguities of surface inspection
  - Example shows the detailed surface structure on the welding seam, which appears to be particular exposed from the surface analysis

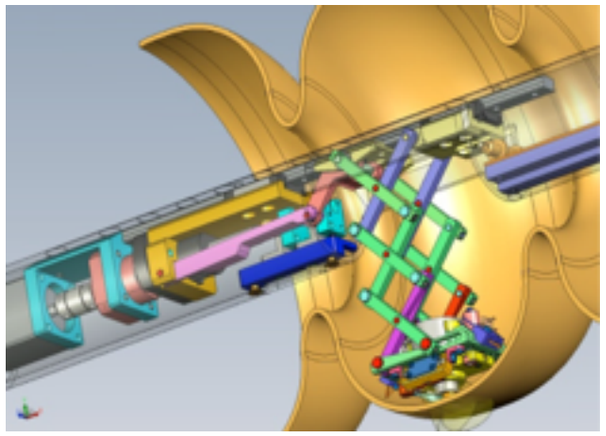


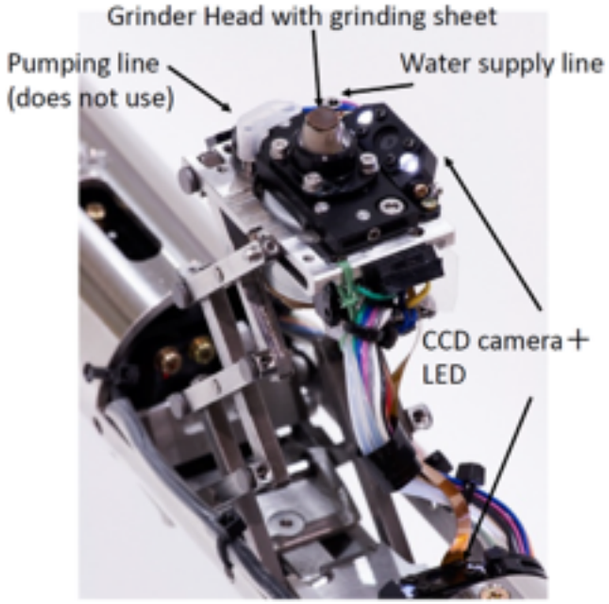


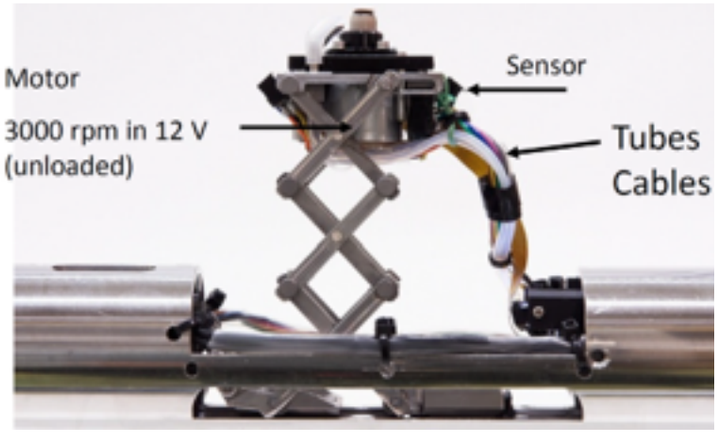


# Local defect removal (planned)

- Local grinder is a mechanical polishing technique used for local defects removal (K. Watanabe et.al, WEPEC033 , IPAC2010)
- Similar tool is being developed by University Hamburg / DESY and used at the ILC-HiGrade Lab for
  - serial tests of the repair procedure (partially with ILC-HiGrade cavities) as feasibility study for meeting the ILC performance goal
  - further optimization of the process



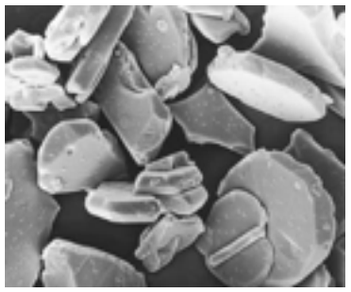


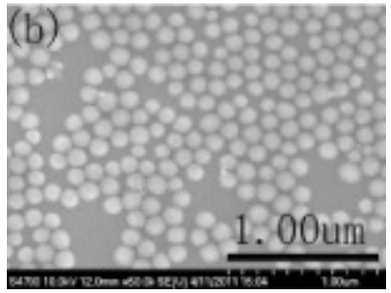




[1] K. Watanabe et.al, WEPEC033 , IPAC2010

# Centrifugal Barrel Polishing (CBP)

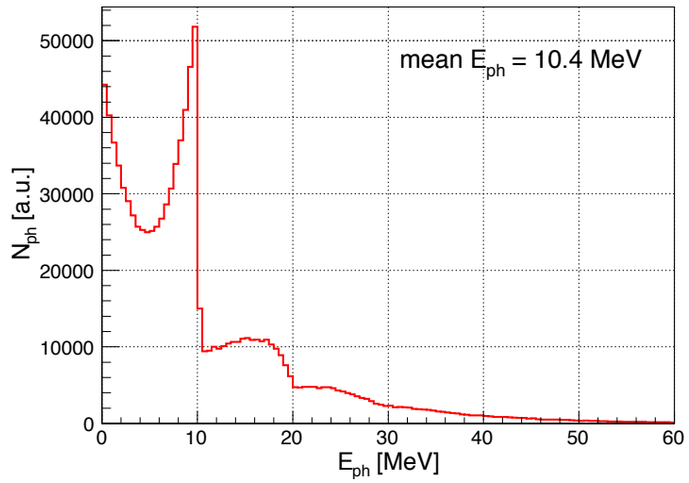
- CBP: purely mechanical polishing technique using abrasive media
  - no or only light electropolishing (EP) (~10 µm) required
  - ~10x smaller roughness (mirror-like surface) possibly yielding better $Q_0$ and $E_{acc}$
- CBP machine has been purchased by University of Hamburg and will be used in ILC-HiGrade Lab for:
  - serial tests of the polishing proc. (partially with ILC-HiGrade cavities)
  - further optimizations/understanding of the process (time, polishing recipes,etc.)
  - Study of CBP as cavity repair and standalone preparation technique



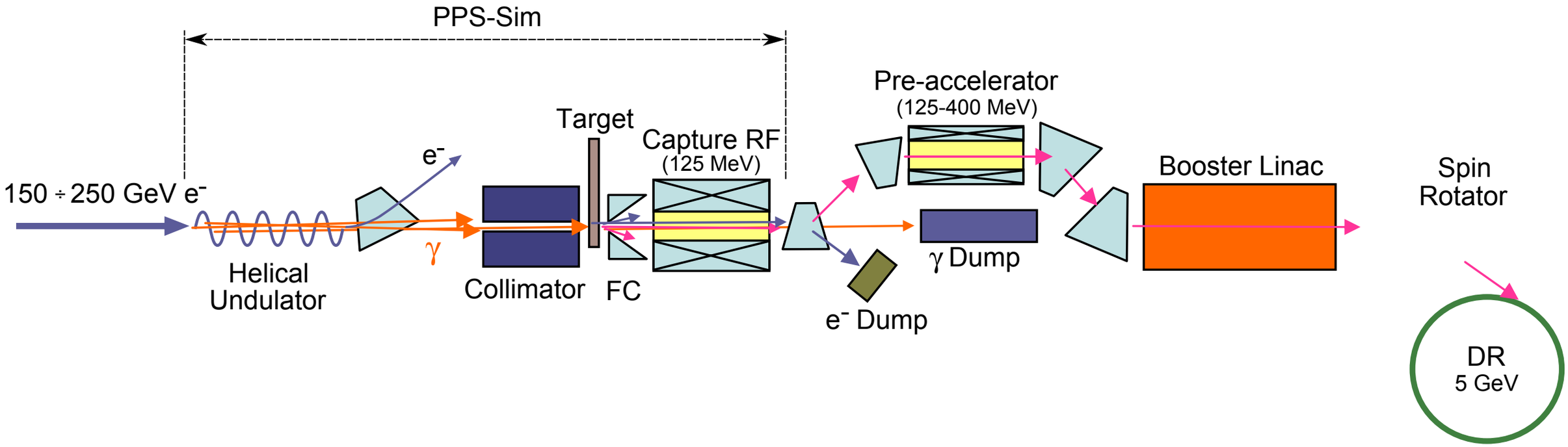


# Positron yield and polarization

- $e^-$ Beam Energy: 150 ÷ 250 GeV
- Helical Undulator: 11.5 mm period, max 0.86 T ⇒ max K = 0.92
- Target: solid Ti6Al4V, 0.4 $X_0$ ⇒ 1.4 cm




- Pulsed Flux Concentrator: tapered solenoid, 12 cm long, max 3.2 T on axis, 0.5 T at end
- Capture RF: 1.3 GHz cavities embedded into 0.5 T solenoid



# Simulations of Undulator-Based Positron Source with Tungsten-Alloy Target

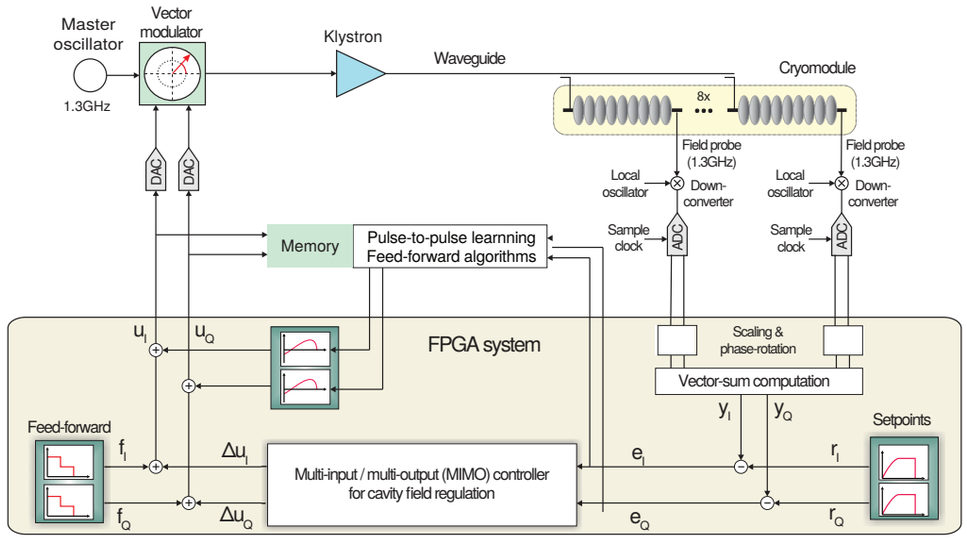
A Ushakov at LCWS 13

- 5 Hz $e^+$ production scheme well conceivable with 150 GeV $e^-$ beam
  - alternative 10 Hz scheme is not required
- Baseline source with solid tungsten target shows preferred $e^+$ yield: Y(W)/Y(Ti) = 1.34 at 150 GeV. Issues with target cooling and thermal stress have to be solved:
  - Can a target cooled by liquid Li (W25Re as an entry window of thin Li lens) be alternative to the fast rotating Ti-alloy target + pulsed Flux Concentrator?
  - Radiative cooling?
    Thin (pure) Li lens has approximately the same efficiency as pulsed
  - The heat load in the windows of the Flux Concentrator has to be studied. Energy of generated positrons in baseline source is too low for thick Li or W-doped Li lenses (low capture efficiency).

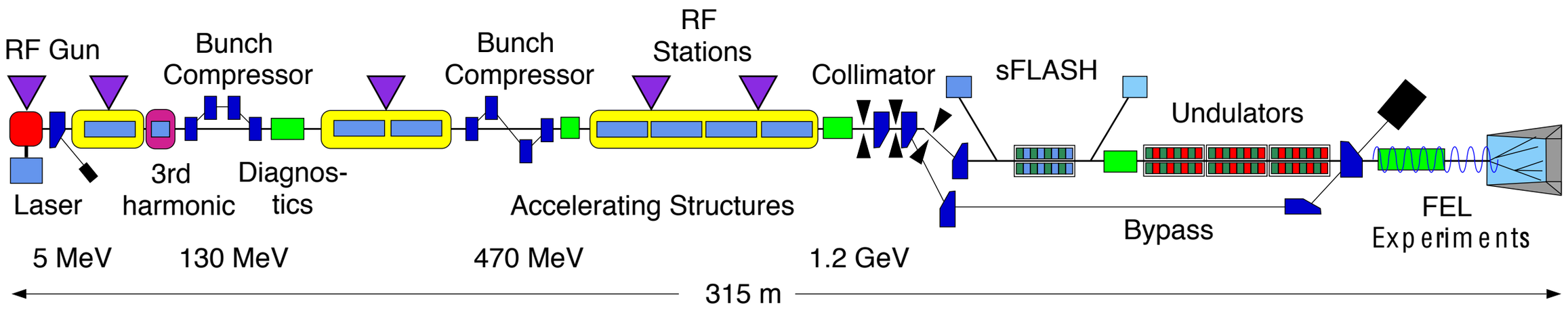
# Continuation of 9 mA runs at FLASH

- FLASH operating parameters very similar to those required for the ILC
- First beam test facility – soon to be complemented by STF (KEK) and NML test facility (Fermilab)
- Test of high-performance cryomodules?

| | units | TDR Baseline | TDR Upgrade | European XFEL | FLASH 9 mA Expt. |
|---|---|---|---|---|---|
| Number of bunches per pulse | | 1312 | 2625 | 3250 | 2400 |
| Bunch repetition rate | MHz | 1.8 | 2.73 | 5 | 3 |
| Beam pulse length | μs | 727 | 960 | 650 | 800 |
| Bunch Charge | nC | 1.9 | 3 | 1 | 3 |
| Beam current | mA | 5.8 | 9 | 5 | 9 |




FLASH digital LLRF control system



# Experience from construction of European XFEL

- European XFEL linac is a ~5% prototype of the ILC
- Electronic Data Management System (EDMS) has been used from the start and now accompanies all manufacturing and installation processes
- EDMS will also be used for inventory of components and tracking of component integrity
- Such a system could be a good start to conceive an internationally dispersed construction of ILC accelerator components that is interfaced to a Japanese based EDMS for explicit construction (Japanese companies)

# Summary

- DESY profits from the synergy with the European XFEL
  - Cavity mass production
    - R&D towards improving yield of high performance cavities jointly with Hamburg University and others
  - $e^+$ yield studies (DESY and UHH)
- DESY ready to engage further into R&D as the Japanese project gains momentum: ILC is a vital element of the next 5 year plan just submitted to Helmholtz Association