Electron Beam Diagnostics for the European XFEL

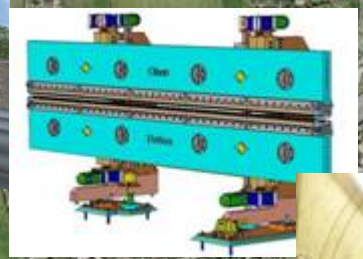
D. Nölle on behalf of the XFEL Team

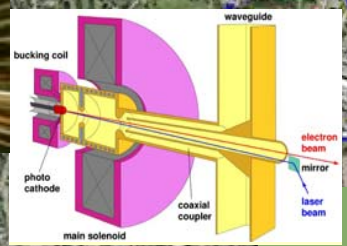
DIPAC'09, Basel

DESY

HELMHOLTZ ASSOCIATION

The European XFEL





3.3 km

HERA

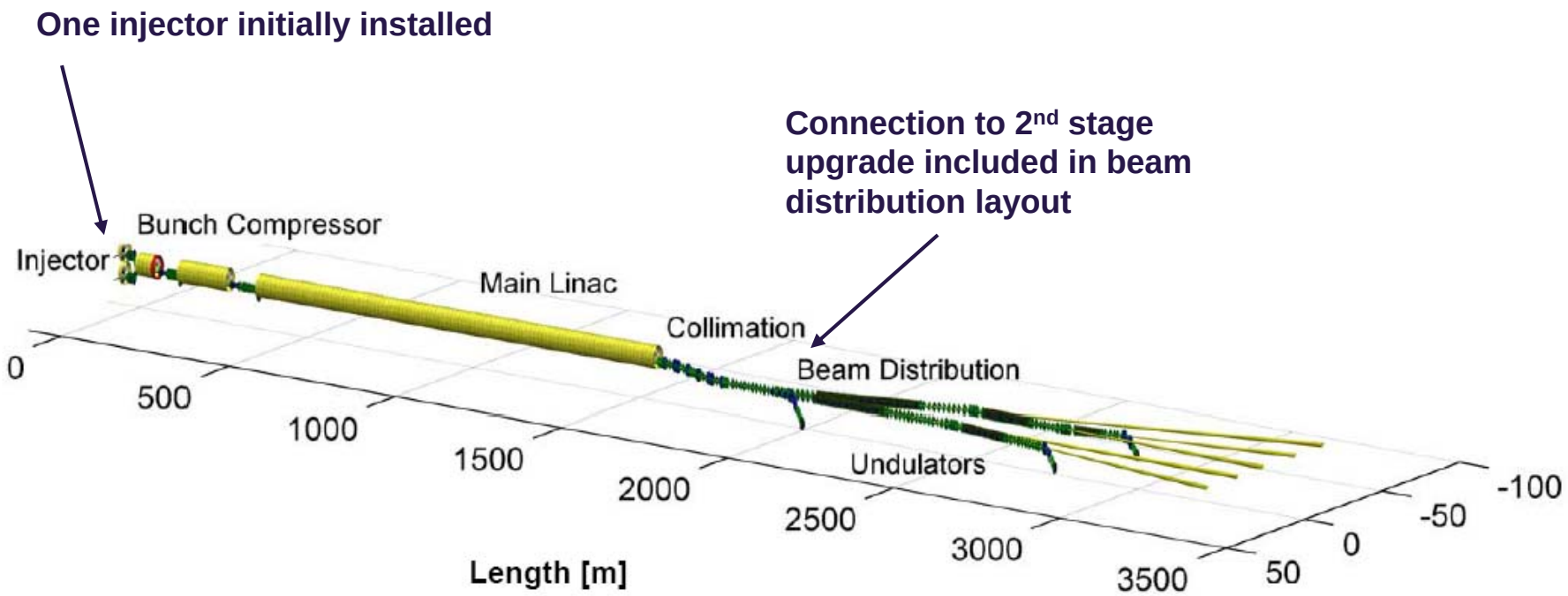
FLASH

PETRA III

DESY

Hamburg
City Centre (7 km)

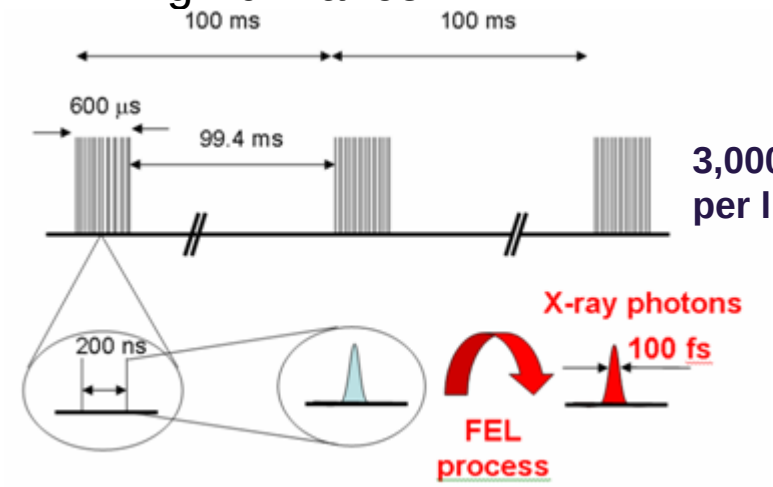
Accelerator Layout



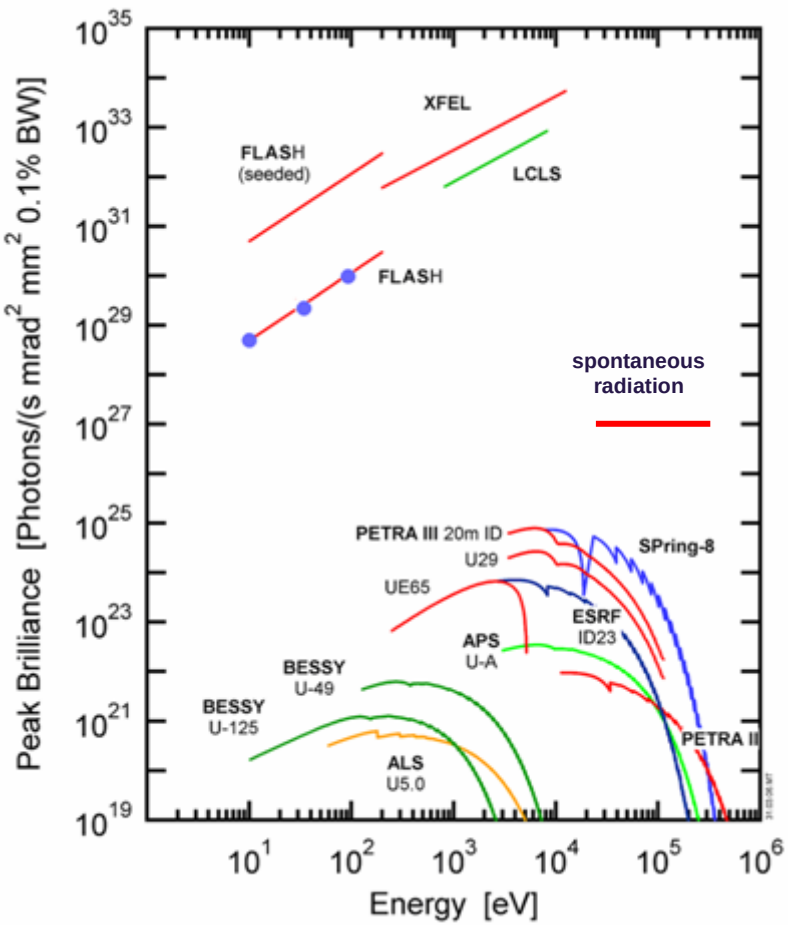
- 17.5 GeV superconducting LINAC
- RF photoinjector, two bunch compression stages
- 3 SASE undulators plus 1 spontaneous source, extension possible
- 5 experimental stations
- potential extension with a second experimental hall

E-XFEL Properties

- 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

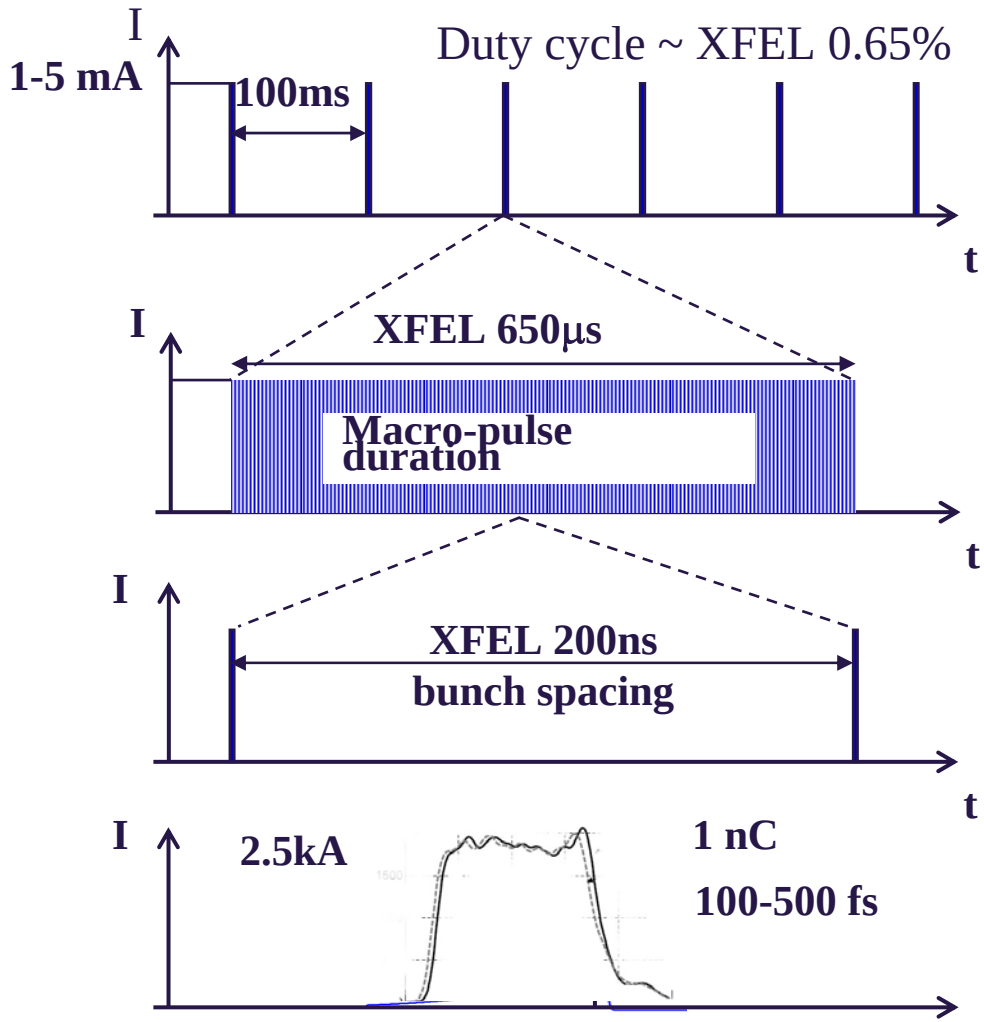


3,000 bunches per linac pulse

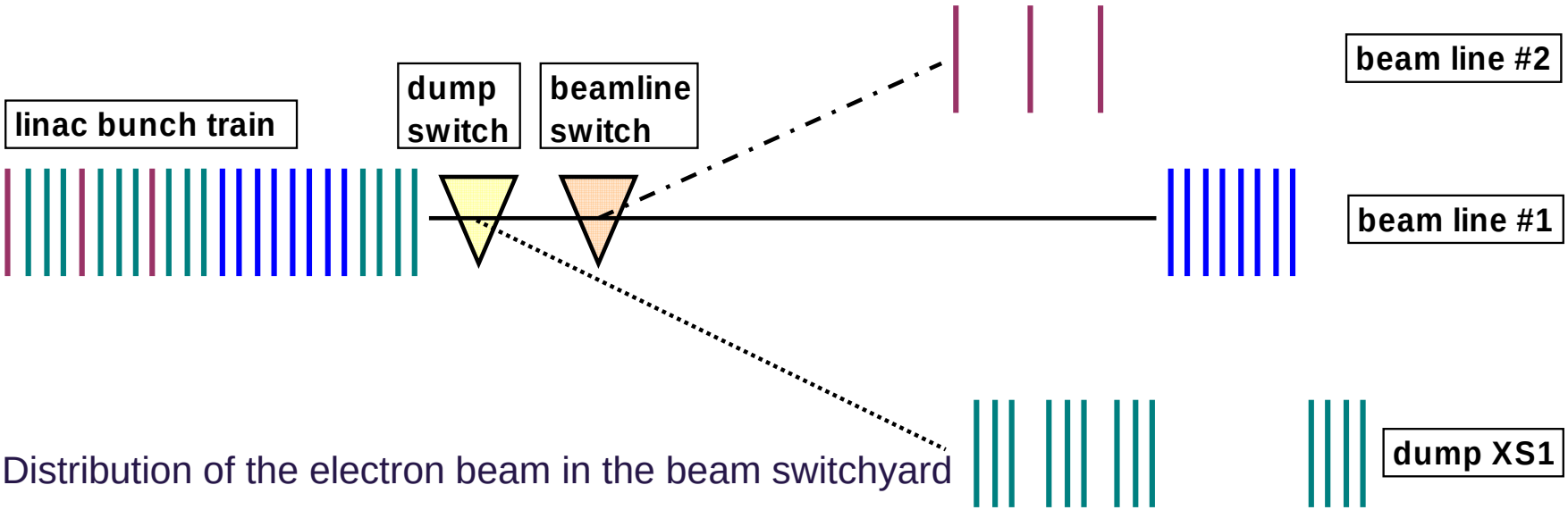


E-XFEL Time Structure

- Repetition rate
- Macro-pulse
- Bunch
- Slice



Time Structure of E-XFEL: Beam Distribution



- Distribution of the electron beam in the beam switchyard
- Kicker septum scheme with precision kicker and septum + knock out kicker
  - Machine operated with fixed beam loading (only length of the train is varied)
  - 3 way switch
    - SASE 1
    - SASE 2
    - Dump
  - First bunches send to the dump (used for looking of feedbacks)
  - First half train is send to SASE 1
  - Second half train is send to SASE 2
  - Not needed bunches can be knocked out to the dump

XFEL-Milestones

- **Oct 2002:** XFEL supplement to TESLA TDR
- **Feb 2003:** approval by German government as European project with at least 40% funding contributions from partners
- **July 2006:** completion of XFEL TDR, submitted to and approved by International Steering Committee
- **June 2007:** Official project start announced on basis of initially de-scoped start version at 850M€/y2005 construction cost
- November 2008: Contracts for the construction of the underground buildings (tunnels, shafts, halls) awarded
- Early 2009: Start of construction. Duration: 5.5 years
- **2009:** Involved countries sign international state treaty which provides the basis for the foundation of the European XFEL GmbH in charge of the construction and operation of the XFEL facility. The research centre will be coordinated and financed on the European level.

DESY coordinates the accelerator consortium.

2014: Start of commissioning

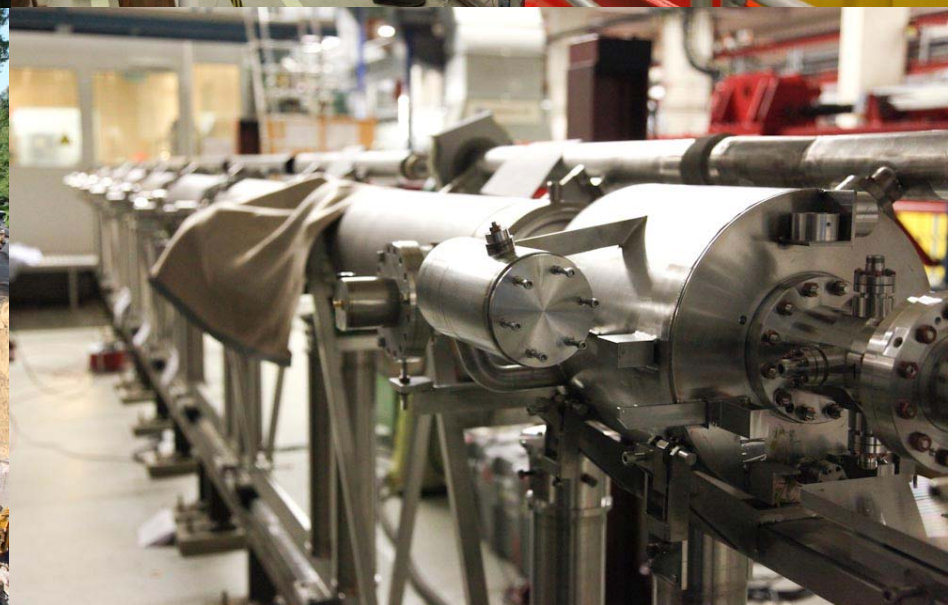
... there is really something happening ...

Civil Construction

- Start in Jan 09
- 3 Sites
  - DESY
  - Osdorfer Born (Switchyard)
  - Schenefeld (Exp. Hall)

European XFEL

... recent views:



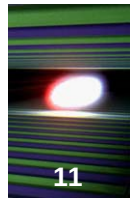
Standard Beam Diagnostics

Disclaimer: This talk is not about the special, thrilling stuff!

But will cover the large systems of bread and butter diagnostics.

- BPM
  - Cold
  - Warm Cavity
  - Electronics Concept
- Beam Size Measurements
  - OTR
- Charge and Transmission
- Machine Protection and Beam Loss Monitoring

BPMs for E-XFEL



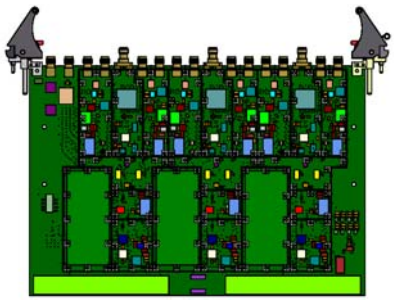
BPM Type	Number	Diameter	Single Bunch Resolution
Standard Button BPM	228	40 mm	50 µm
"cold" BPM (Button, 30% Re-entrant Cavity)	104	78 mm	50 µm
Precision BPM (Cavity)	117	10 mm	1 µm
Precision BPM (Cavity)	12	40 mm	1 µm

- Collaboration between PSI, CEA and DESY
  - PSI will provide Electronics, except RF front-end of the Reentrant Cavity BPM
  - DESY will provide Mechanics, except Reentrant Cavity BPM
  - CEA will provide Reentrant Cavity BPM, incl. RF front-end

Cavity & Button BPM Electronics (PSI Designs)

Undulator RFFE

- 3.3GHz (cavity BPM)
- IQ demodulation
- Requirements: Sub-↗m resolution & drift



ADC Mezzanine

- Six 16-bit ADCs
- 160Msps

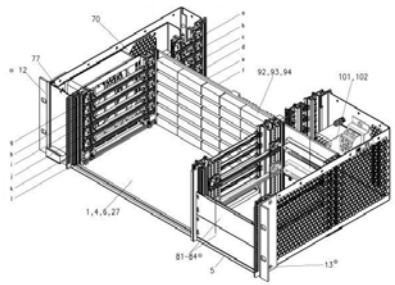
FPGA Carrier Board

- Virtex-5 FPGAs
- Flexible interfaces: 1-5Gbit Rocket IO, VME, VXS, Ethernet
- Two mezzanines: 500-pin connectors

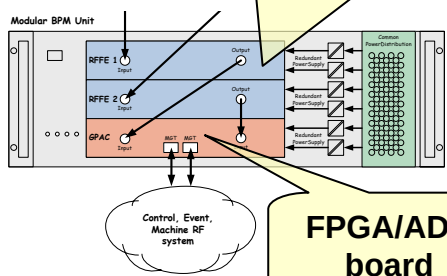
Low-cost version of IBFB carrier board (no DSPs, …), used for all E-XFEL BPMs

Modular BPM Unit

Crate: customized power, backplane & cooling: low noise, high temp. stability



2 cavity BPM or 4 button BPM RFFEs

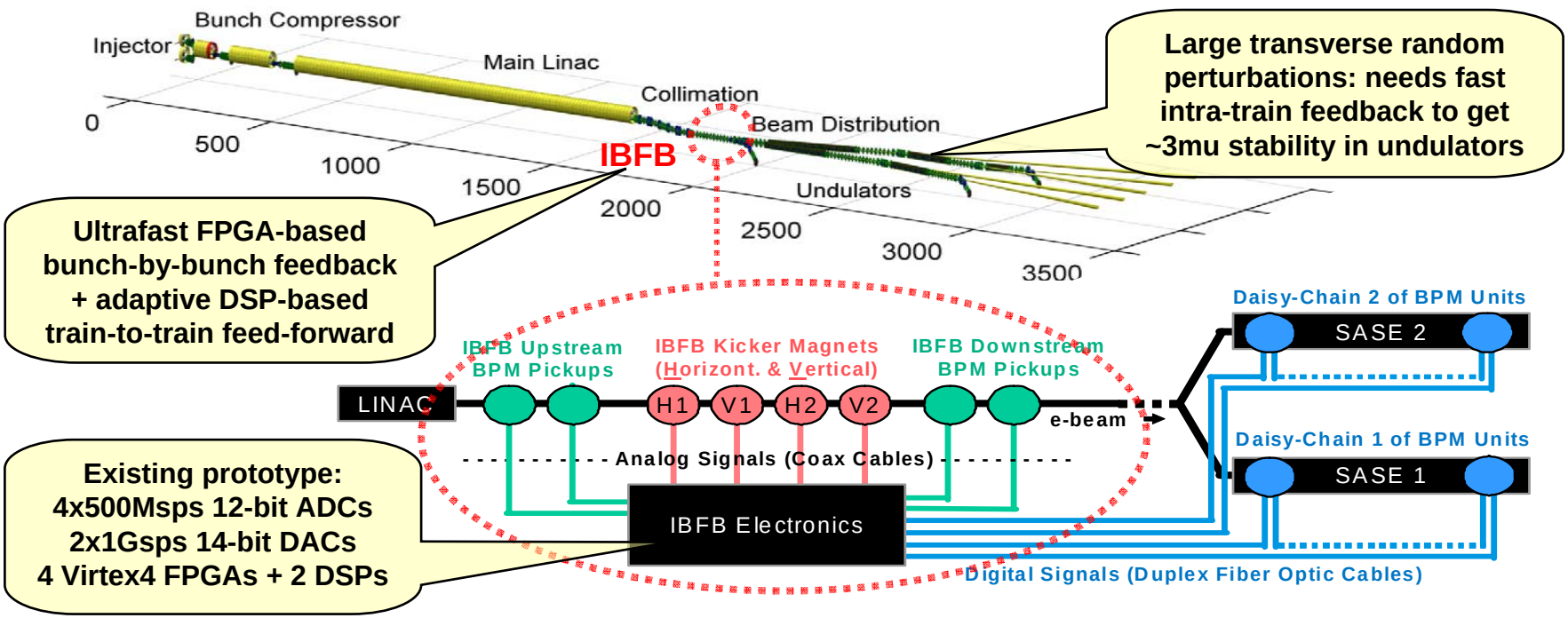


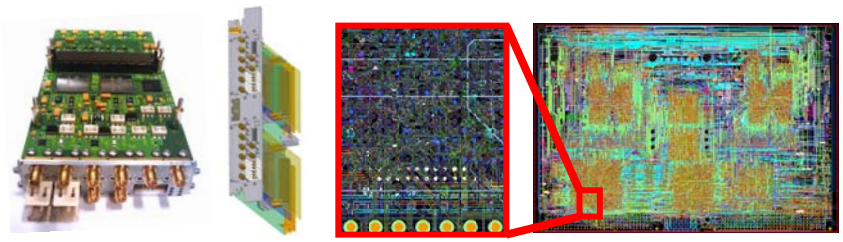
FPGA/ADC board

by Courtesy of B. Keil, PSI

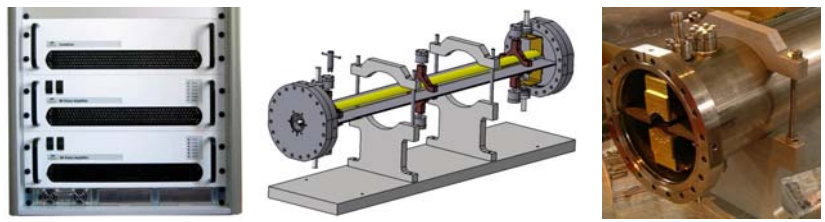
Intra-Bunchtrain Feedback (PSI Contribution)

PAUL SCHERRER INSTITUT





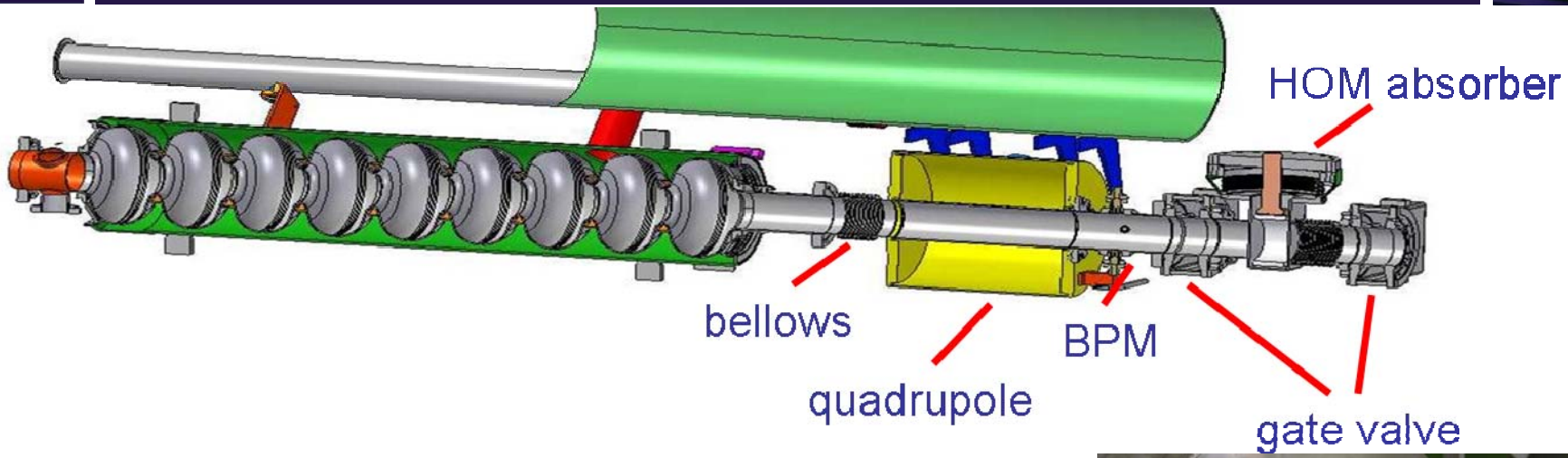
Low-Latency BPM & Signal Processing Electronics



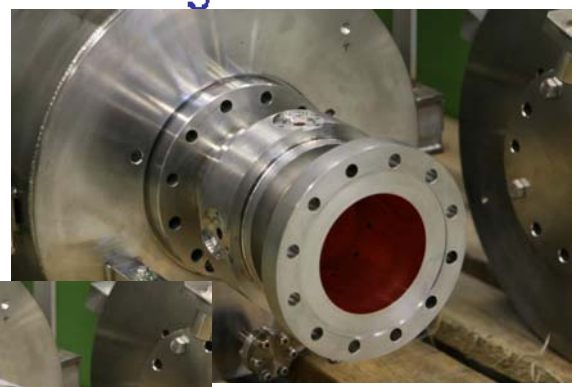
High-BW Stripline Kicker Magnets & Power Amps

by Courtesy of B. Keil, PSI

BPMs: Module or Cold BPMs



- One Cold BPM at the end of each module
- Button or Reentrant Type
- 78 mm beam pipe, 170 mm long
- Operation at 4 k level



Button + Quad

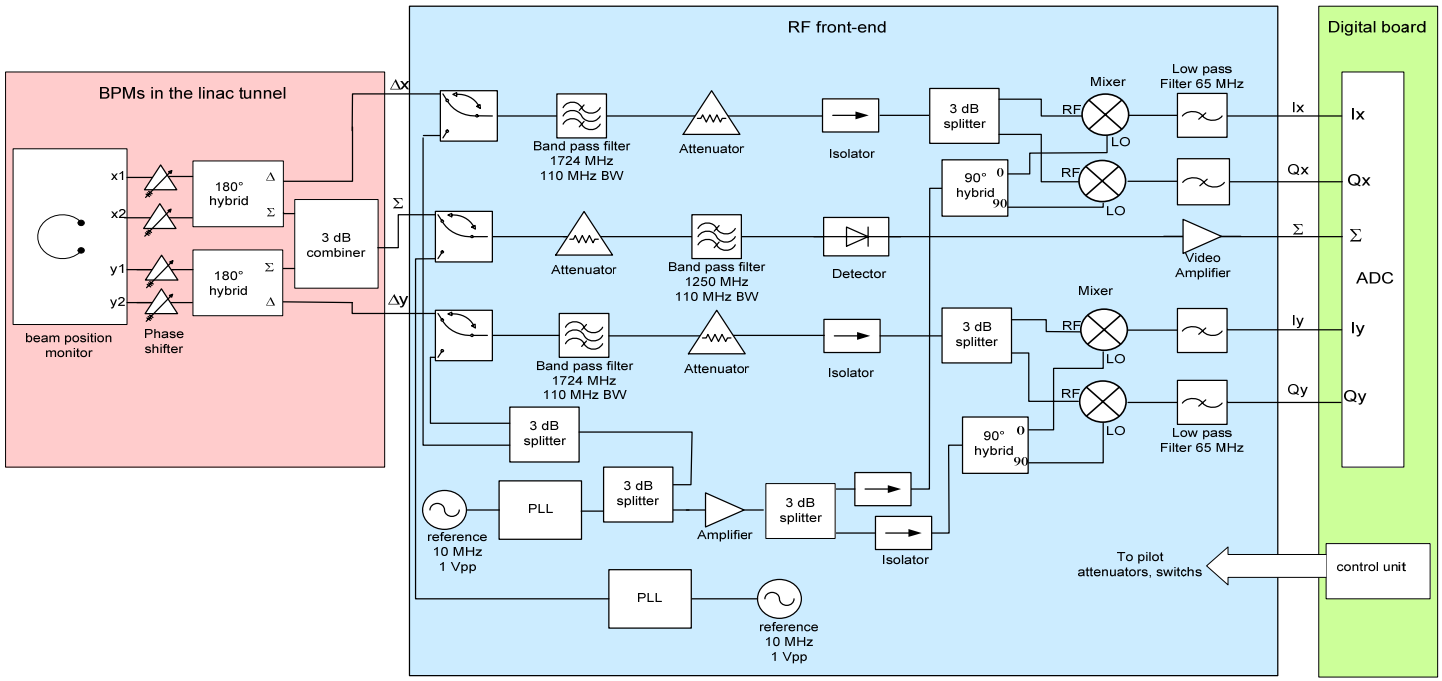
Reentrant + Quad

20 mm button

Cold Reentrant Cavity BPM

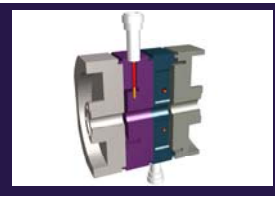
- 30 reentrant cavity BPMs will be installed in XFEL cryomodules
- Feedthroughs passed cryogenic tests
- Cavity has an effective cleaning

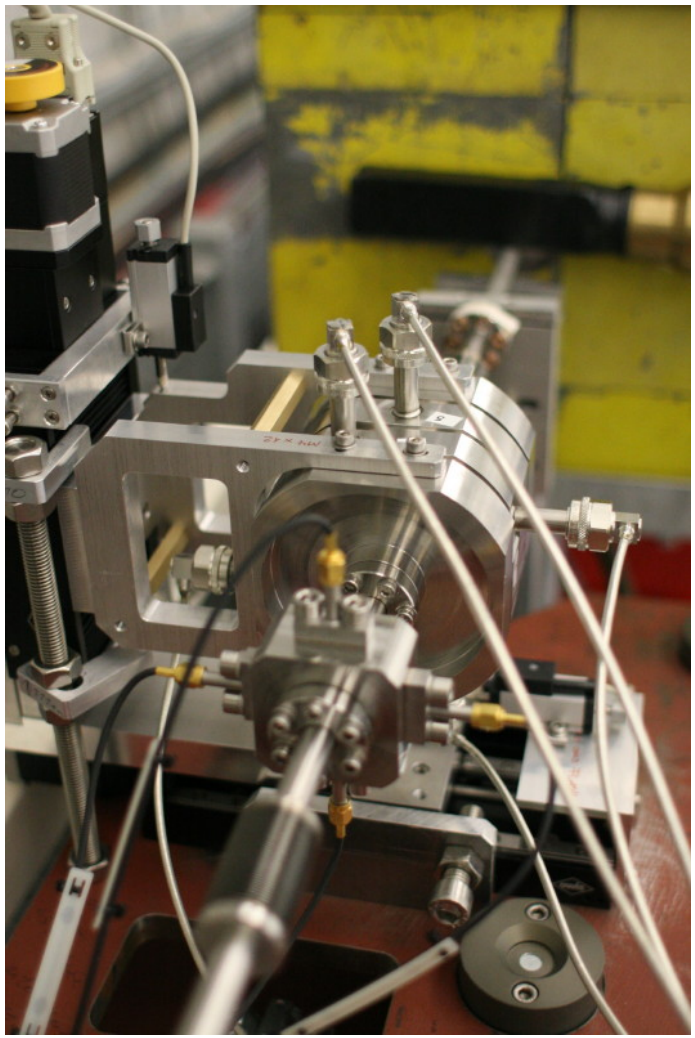
- **Signal processing electronics** uses a **single stage down conversion**
- **RF front-end electronics** based on an Printed Circuit board
- **Digital electronics** designed by **PSI**

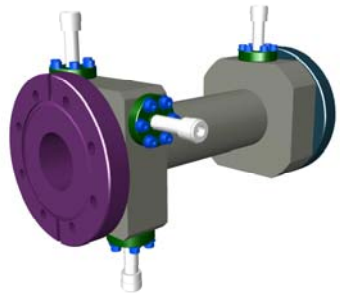


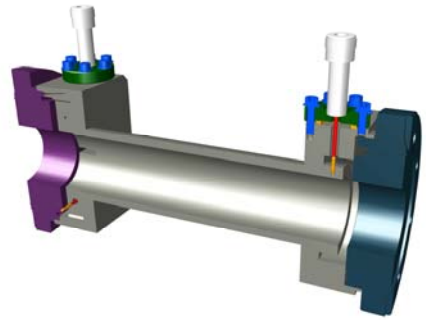
by Courtesy of C. Simon, CEA

Cavity BPMs



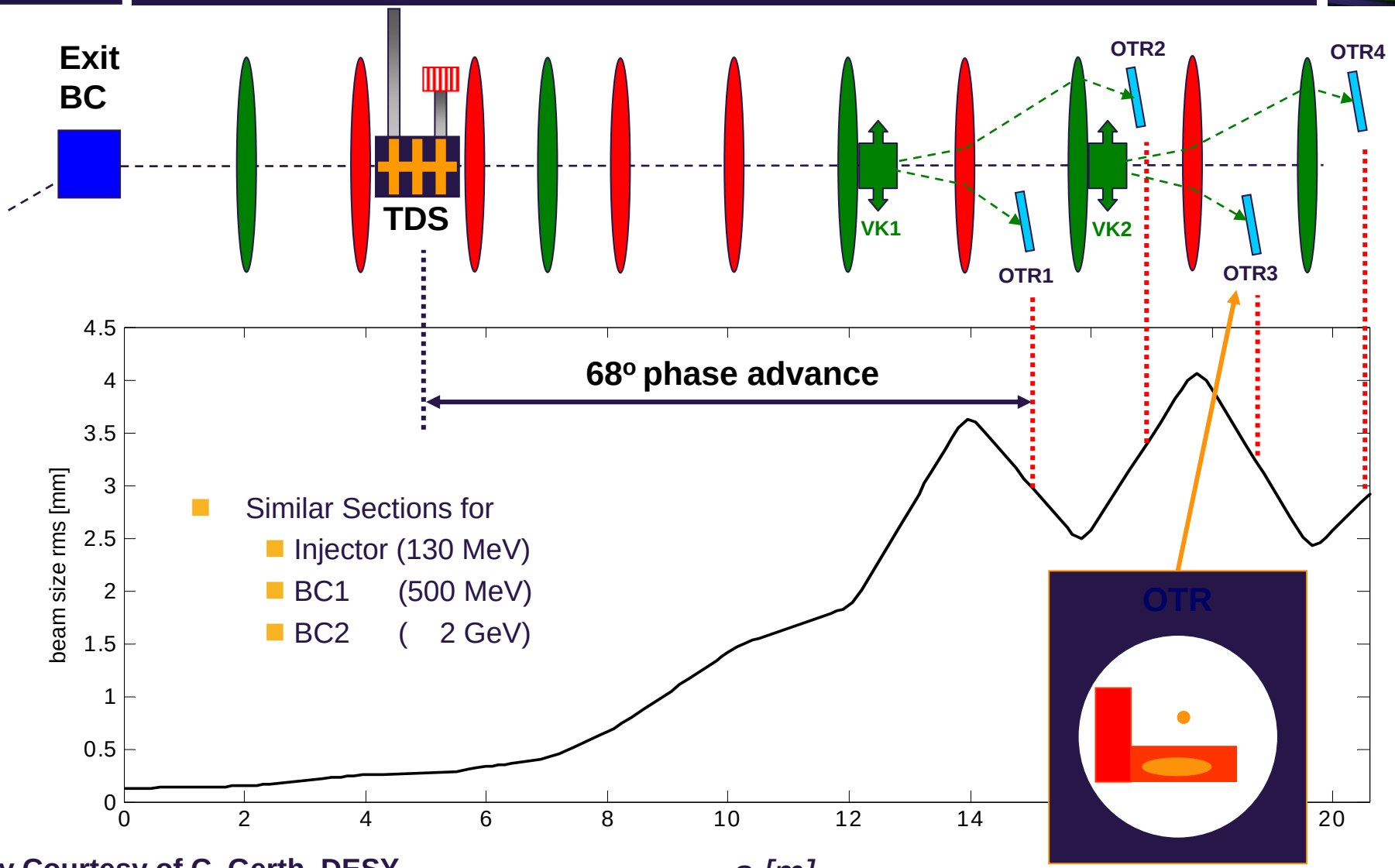






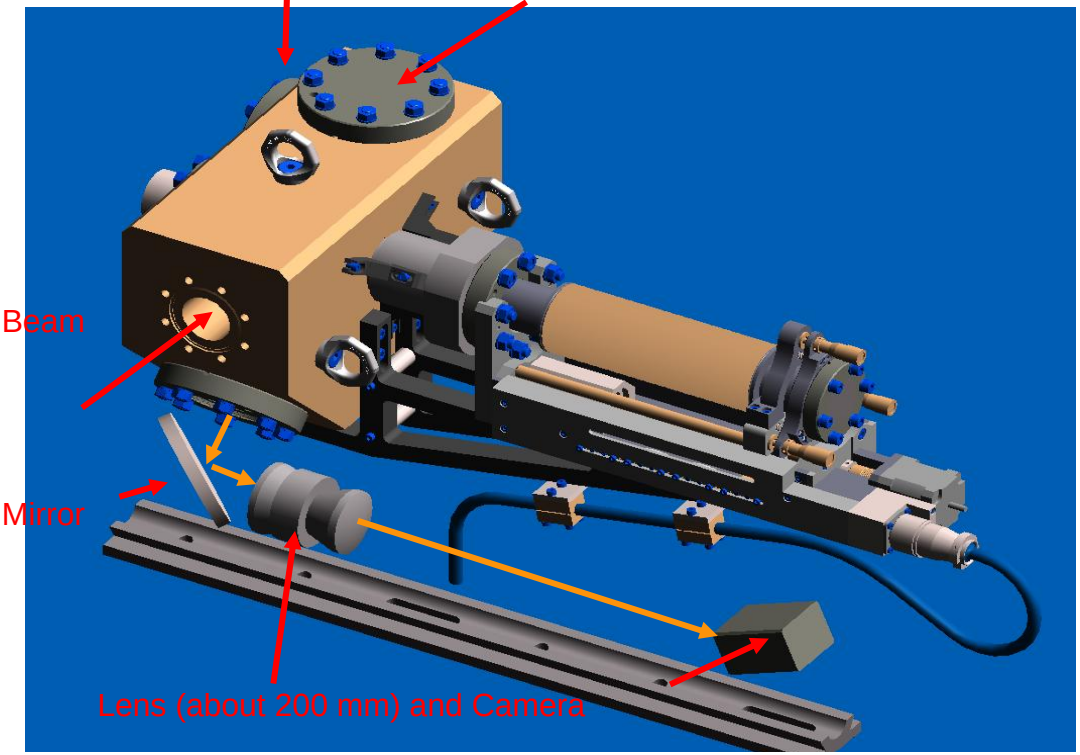
- Cavity BPMs with 3.3 GHz and Q about 70
- Single Bunch Measurements with 5 MHz Rep Rate
- Goal: 1 µm Resolution, low Drift (0.1 µm/Train)
- Stainless Steel Design based on Shintake's Work
- Two Types
  - 10 mm beam-pipe: Undulator
    - Prototypes ready, good agreement bet. Simulation and Measurement
    - Test in FLASH ongoing
  - 40.5 mm beam-pipe: Warm Beamlines/Feedback
    - Ordering of Prototypes currently prepared

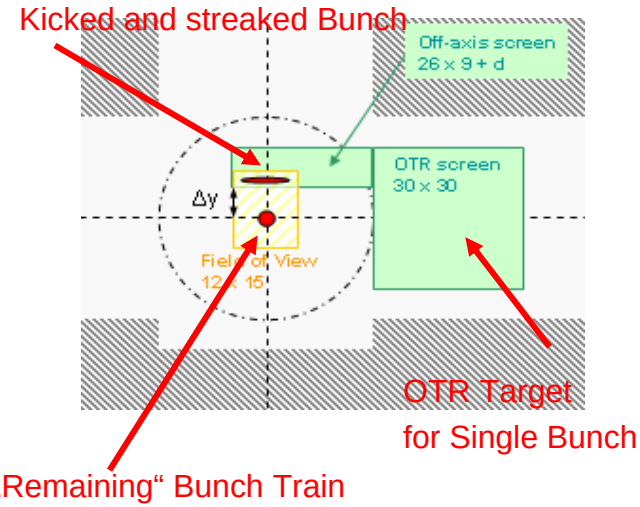
Beam Size Measurement: TDS + Kicker

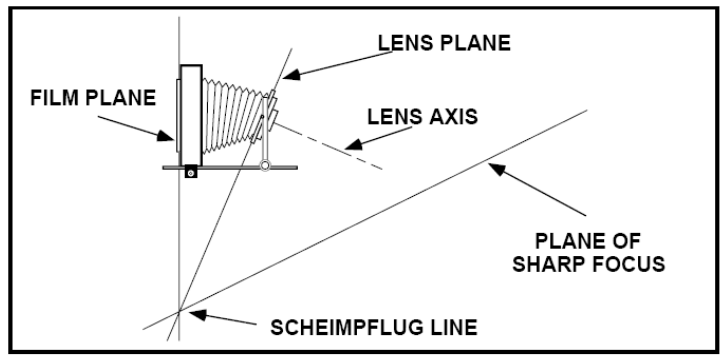


by Courtesy of C. Gerth, DESY

OTR Stations

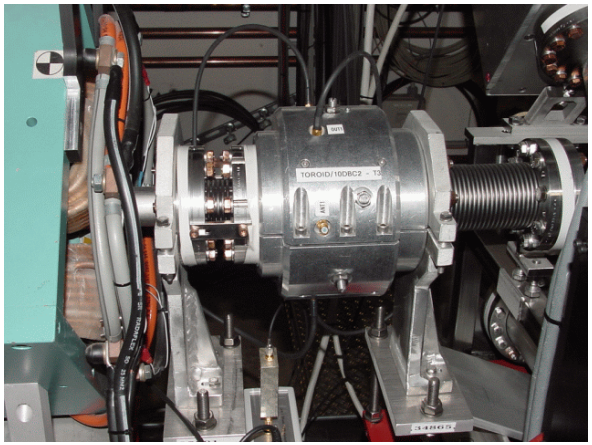






- Screen with 67.5 deg. with respect to beam direction
- OTR out coupling under 45 deg.
- camera tilted by 22.5 deg. to use „Scheimpflug‘s principle to extend depth of field
- 1 : 1 reproduction scale
- Resolution requirement 10 – 30 µm (depending on section)
- Wire scanner ports for optional wire scanners
- Prototype test at FLASH scheduled
- Collaboration with IHEP, Protvino

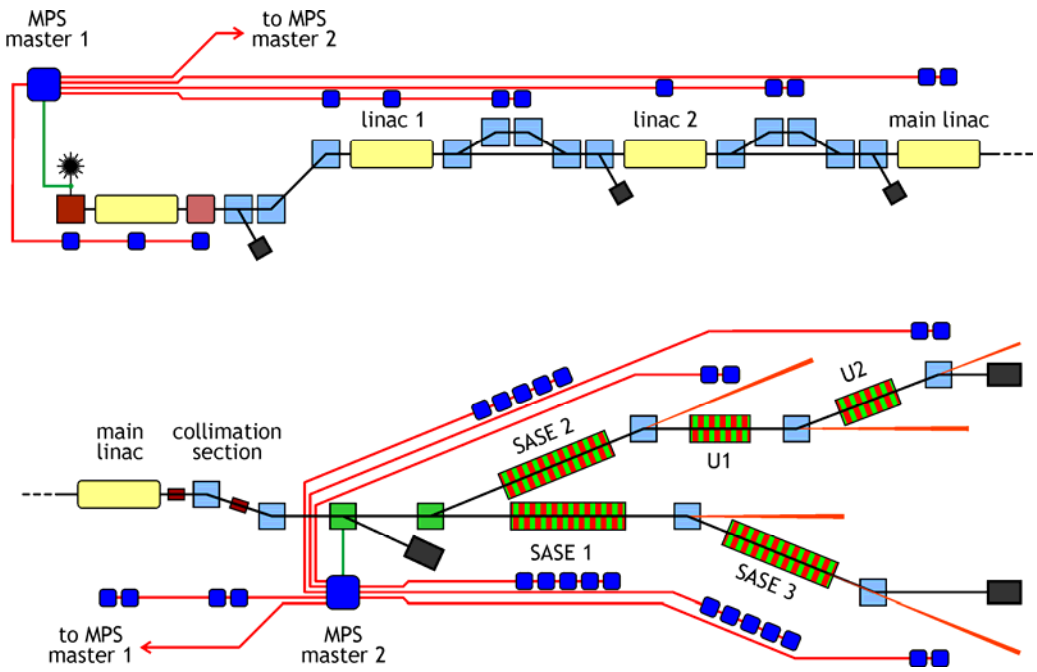
Charge and Transmission Monitoring



Prototype of an AMC Carrier Board and a 100 MHz ADC/DAC Board

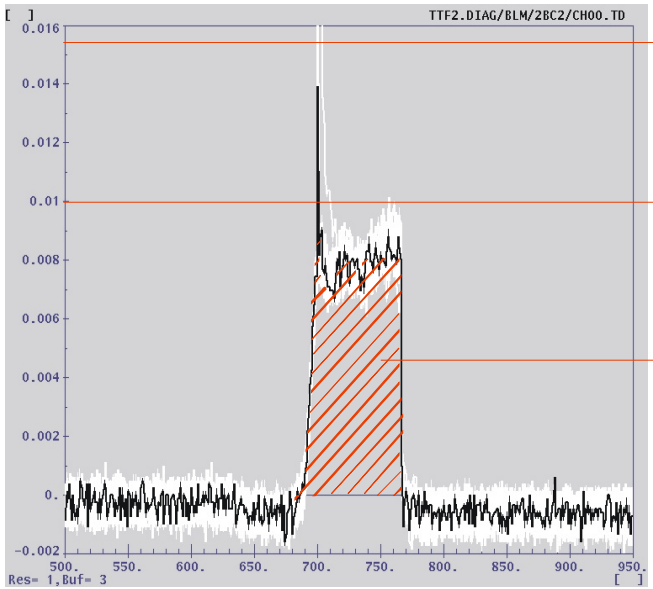
- Need to control charge and transmission along the LINAC
- Loss monitors show „Zero Losses“ when they are broken -> need transmission monitoring to make them save.
- Charge monitors (about 30)
  - at the gun
  - at entry and exit of each (warm) Section
  - at each branching point
- Monitor hardware: Reuse of FLASH or DESY type
- Readout: Go for a digital system fast ADC on µTCA
- Online FPGA processing and fast links to neighbor monitors will produce alarms for the machine protection system.

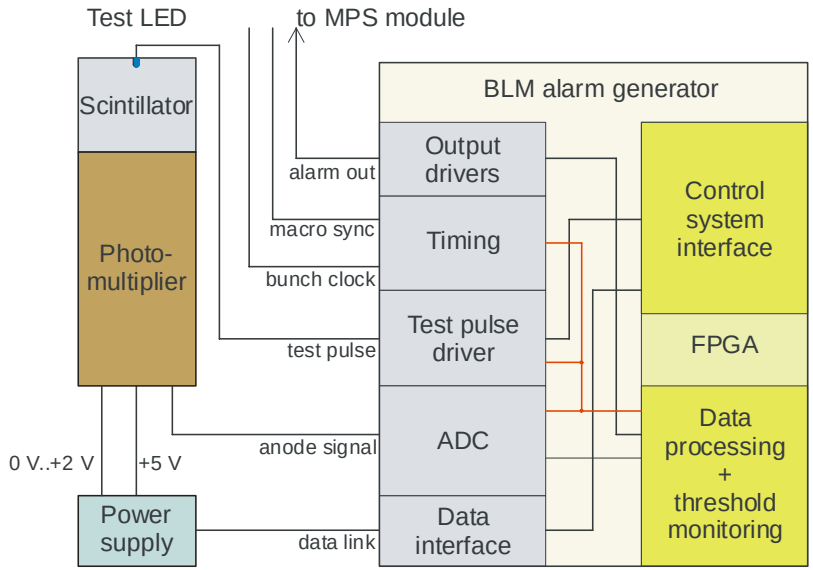
Machine Protection System



- Based on FLASH experience
- Distributed system
  - 100 nodes
  - 2 masters
  - Two “off buttons”
    - Laser
    - Dump kicker in distr. system
- Collecting fast and slow inputs
- Check machine integrity before RF pulse
- Cut bunch train in case of fast alarms
- Reaction time < 10 µs
- Based on digital electronics
  - Flexible
  - Customizable

Beam Loss Monitors





- Good experience with FLASH system
- Stay with plastic scintillators and photomultipliers
- about 250 channels distributed over the entire machine
- Reengineering of the FLASH system
  - go to a pure digital readout and FPGA processing
  - AMC, µTCA form factor
- Collaboration with IHEP, Protvino

Summary

- E-XFEL has entered the construction phase
  - even if the International Company is not founded till today
- Collaborations for E-XFEL diagnostics are established
  - even if formal contracts have to wait
- Conceptual designs for the main diagnostic systems are ready
- First prototypes are available or under construction
- Tests at FLASH going on

The End

Thanks to all colleagues for their help for the preparation of the talk, specially (arbitrary order):

- W. Decking
- C. Simon
- B. Keil
- C. Gerth
- M. Siemens
- S. Vilcins
- C. Wiebers