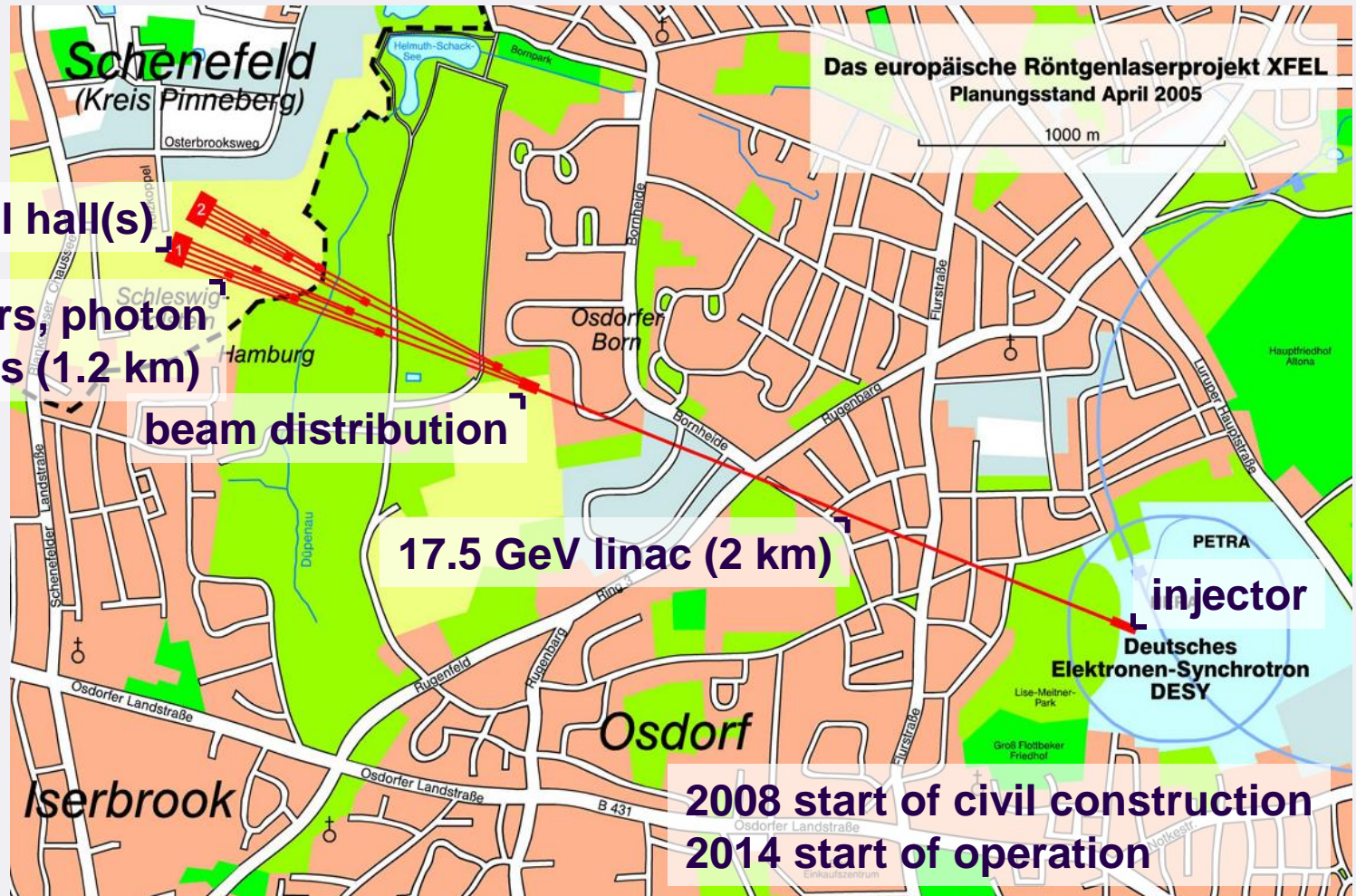


# Machine Protection for the European XFEL

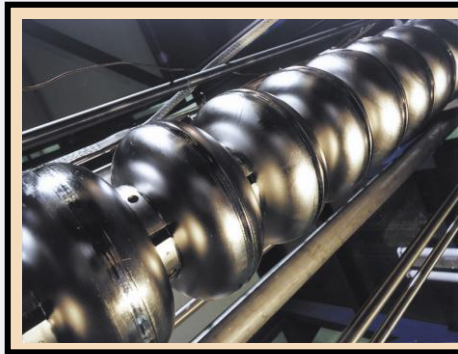
- XFEL overview
- Basic considerations
- Machine protection system architecture

I. Cheviakov, L. Fröhlich, S. Karstensen, T. Lensch, F. Schmidt-Föhre,  
M. Staack, J. Thomas, P. Vetrov, M. Werner

# The European X-Ray Free Electron Laser



# The European X-Ray Free Electron Laser

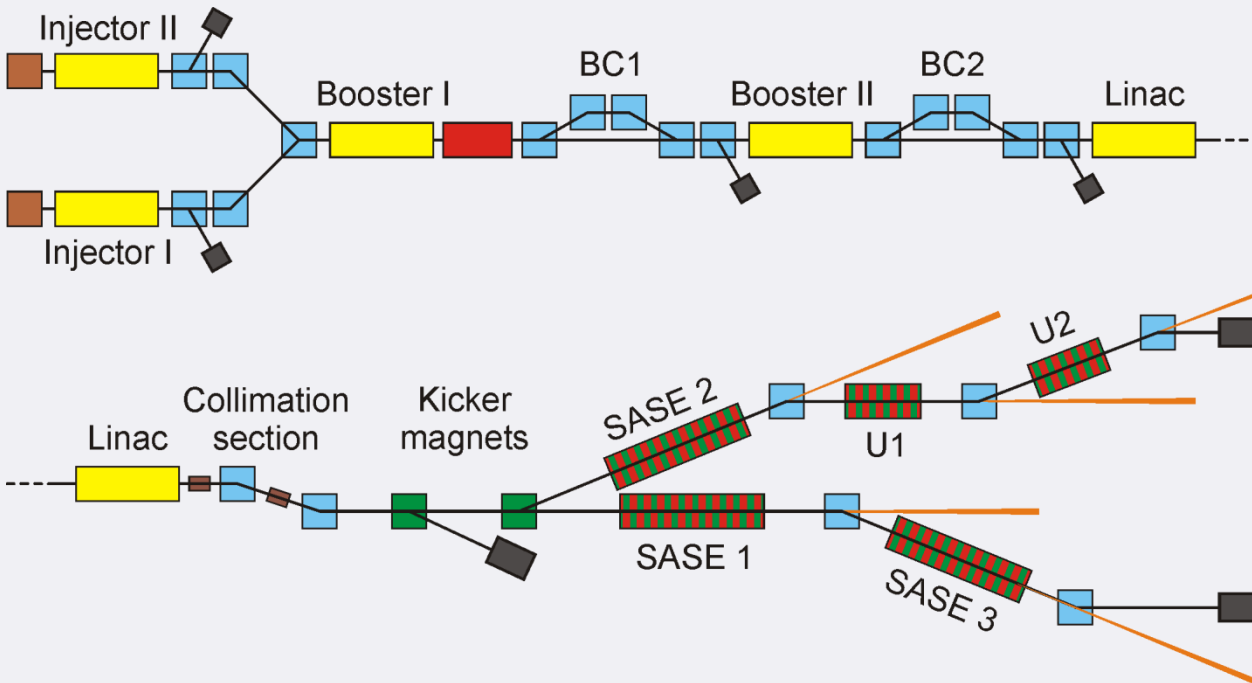


**Superconducting  
TESLA cavities**

23.6 MV/m  
total: 17.5 GeV

**Permanent magnet  
undulators**

FEL wavelength  
down to 0.1 nm

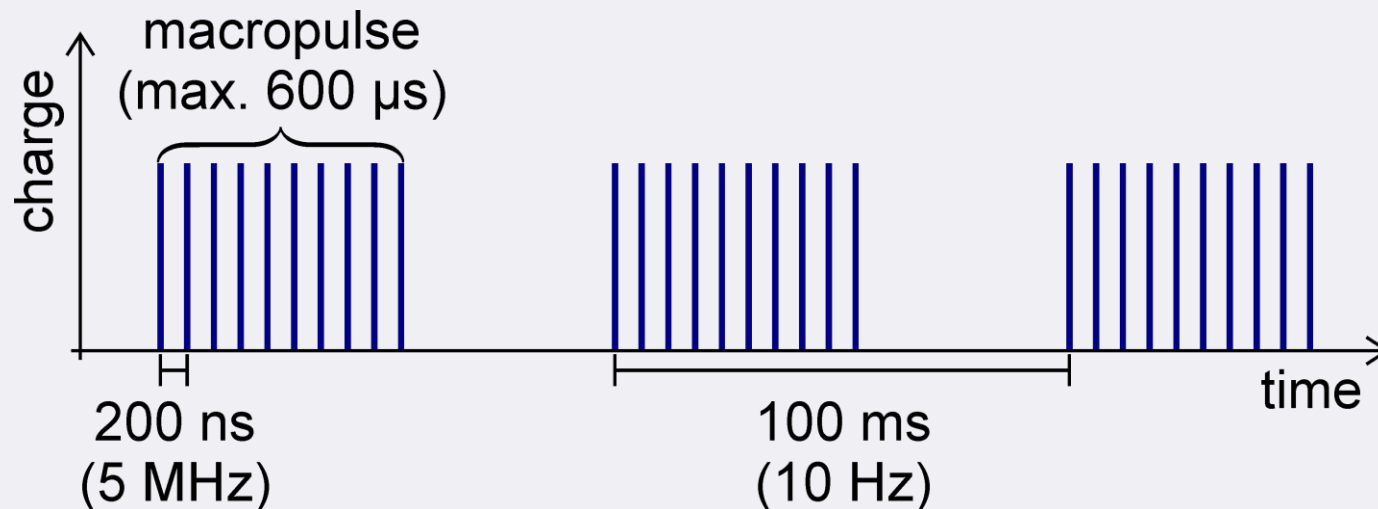


# Beam structure

- RF system pulsed at 10 Hz
- Electron bunches (1 nC) grouped in macropulses
- Up to 3000 bunches/macropulse in arbitrary pattern
- Average beam power at 17.5 GeV: **525 kW**
- Power density at spot size 10  $\mu\text{m}$  (rms): **80 GW/cm<sup>2</sup>**

**1 macropulse  
melts 125 g  
of copper**

**Arc welding:  
10 kW/cm<sup>2</sup>**



# Machine Protection Goals

- 1. protect accelerator components from the beam**  
(from direct and indirect damage)
- 2. facilitate handling of the machine**  
(impair operation only if necessary)
- 3. limit activation of accelerator components**  
(to preserve their maintainability)

# Inputs for the Machine Protection System

## Beam loss monitoring

- Beam Loss Monitors (BLMs): mainly photomultipliers + plastic scintillators
- Bunch charge difference between several measurement positions (toroids)

## Precautionary monitoring

- Magnet power supplies
- LLRF exceptions, quench detection
- Valves, screens, temperatures, water flow, ...
- Beam position



**>> 1000 digital signals**

# Functionality

## Operation modes

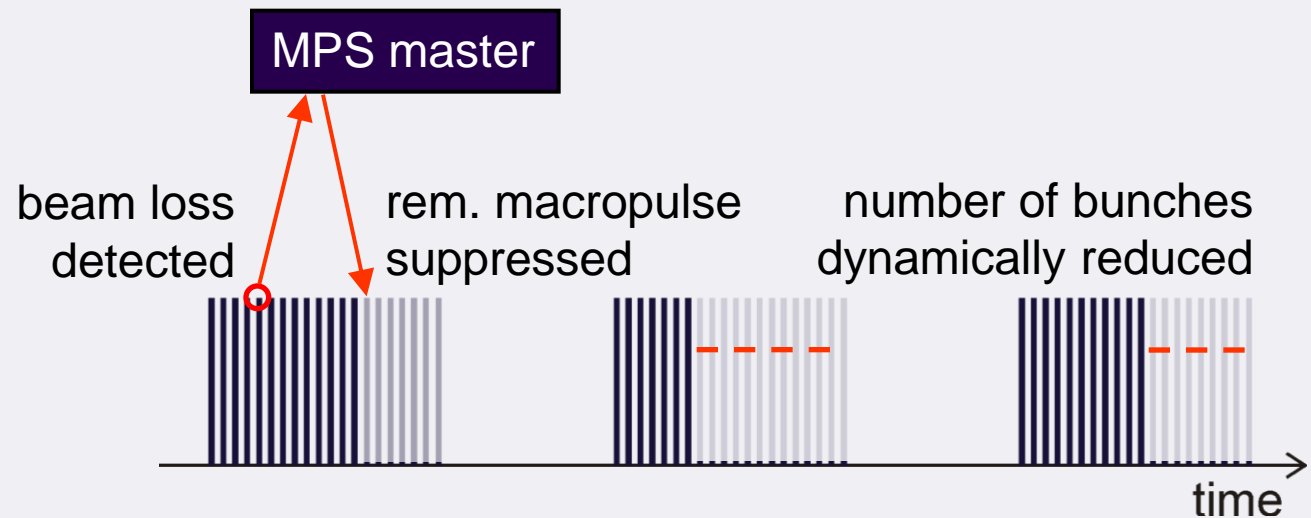
- Valves and dipoles are set right to guide the beam to a dump

## Power limits

- Limit the number of bunches for startup, to protect screens, ...

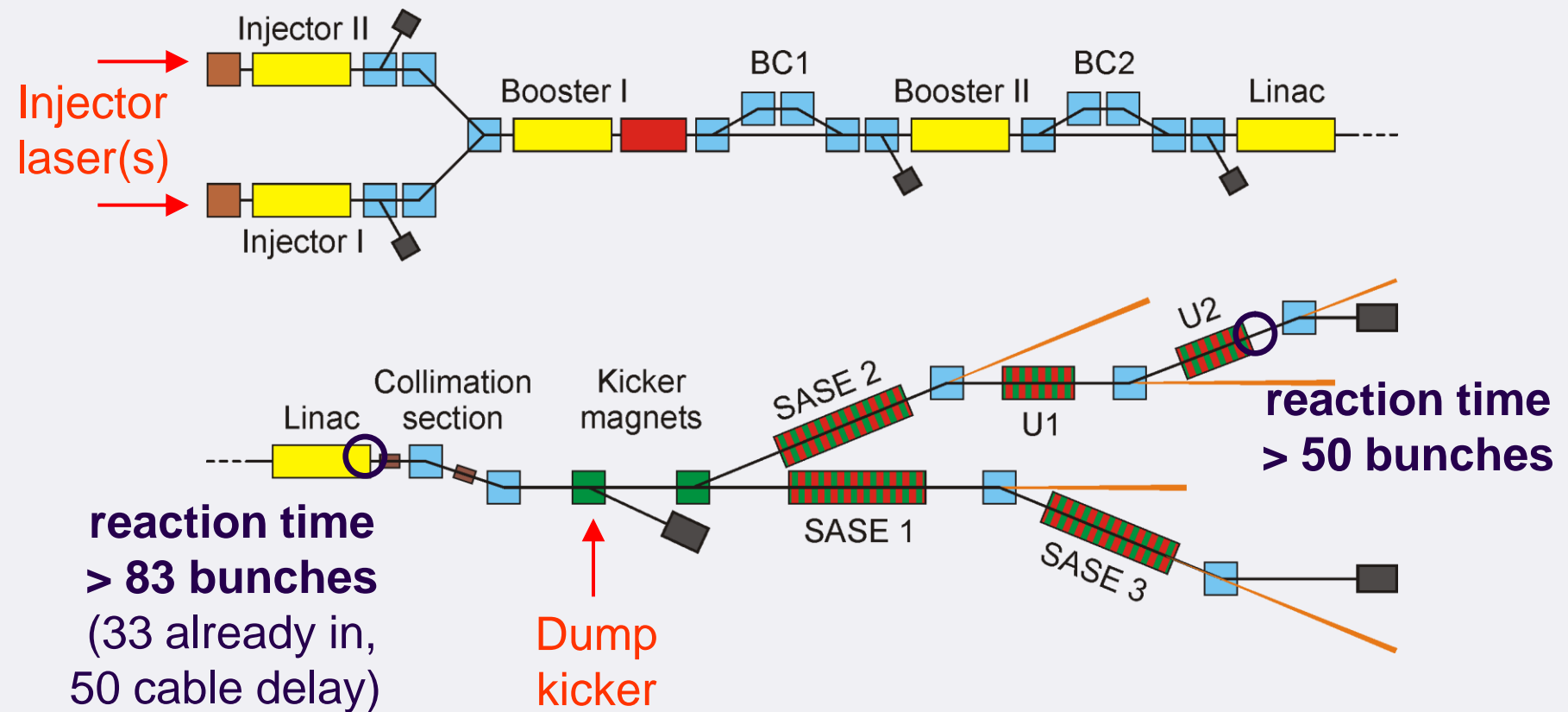
## Alarm cutoffs

- Immediate reaction in case of beam loss



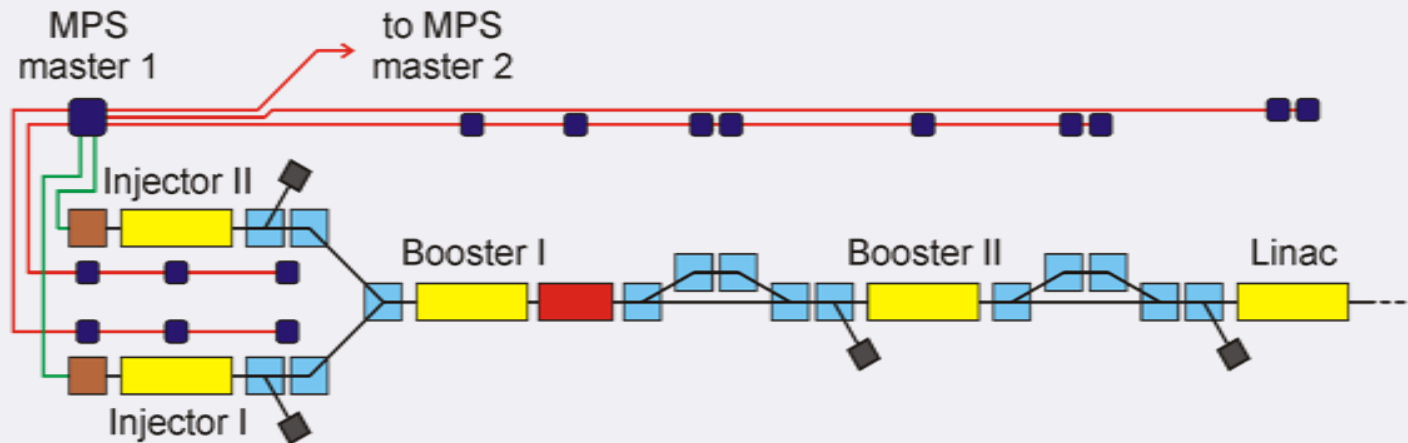
# Topology I

Only two points for intra-macropulse beam stops:

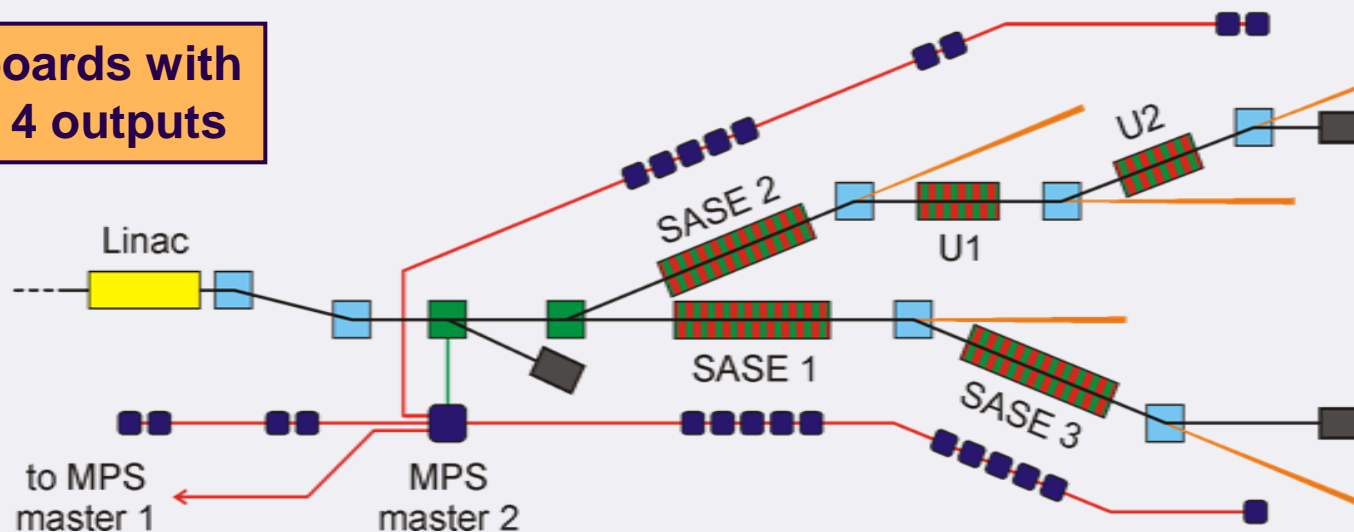




# Topology II



**~100 I/O boards with  
24 inputs, 4 outputs**



# Summary

- XFEL has very dangerous beam power
- XFEL is a long machine – *esp. when compared to its bunch spacing*
- Need to detect beam losses fast – *better: before they happen*
- >>1000 signals relevant for MPS
- Distributed system with ~100 MPS boards, 2 masters
- Guaranteed response time  
electronics: < 5 bunches  
with cables: ~90 bunches (collimators), ~60 bunches (last undulators)
- XFEL, ILC, LHC, ... will not work without proper machine protection