

Operation of a Fluorescence Light Based Burn Through Monitor System at the European XFEL



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Outline

- European XFEL
- Requirement for a Burn Through Monitor System
- Fluorescence Light Based BTM System
 - Fluorescence Light
 - Detectors
 - Safety Related Diagnostic
- Test Measurements
- Operation of the BTM System

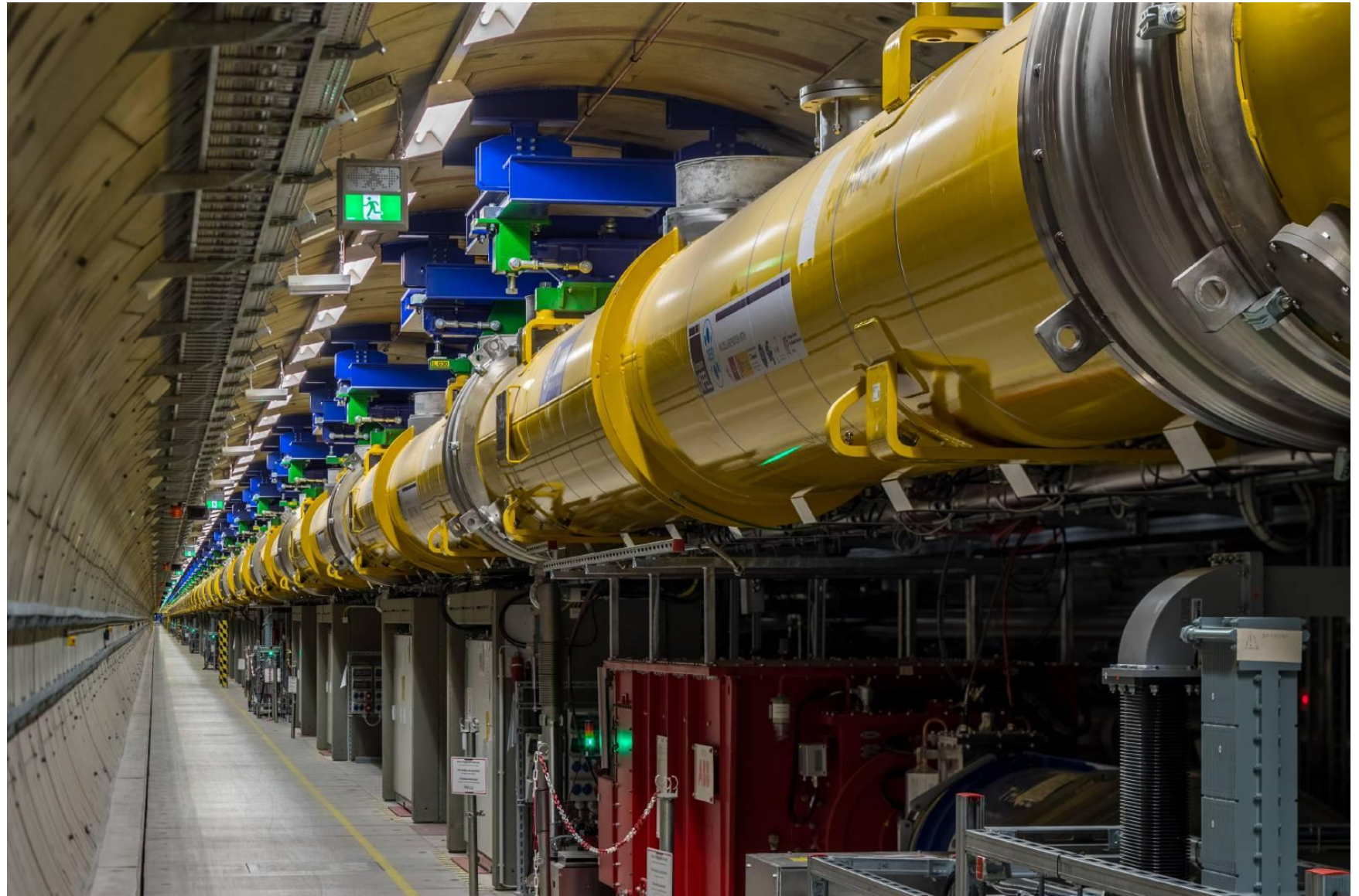
*Update on this talk
from 2019 in Lund*



European XFEL Site

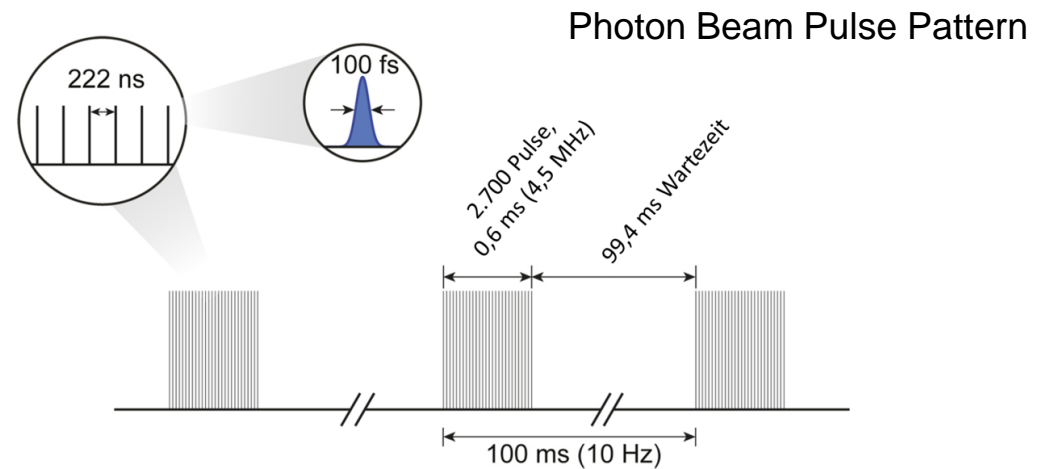
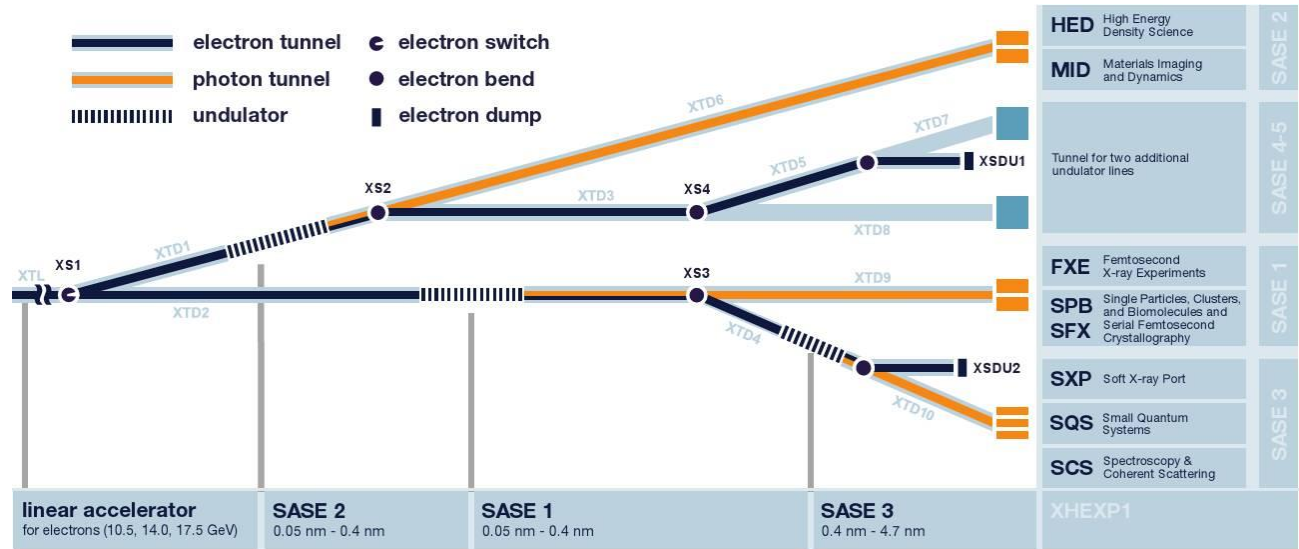


Accelerator



European XFEL Key Parameters

Superconducting LINAC, 10 Hz		
Length	km	2.1
max. Electron Energy	GeV	17.5 (20.0)
max. Electron Power	MW	1.2
FEL beam		
Flashes per second	1/s	27.000
Photon Energy	keV	0.3 ... 24
max. Pulse Energy	mJ	3.6 ... 11
Pulse Duration	fs	< 100
max. Photons/Pulse		10 ¹²



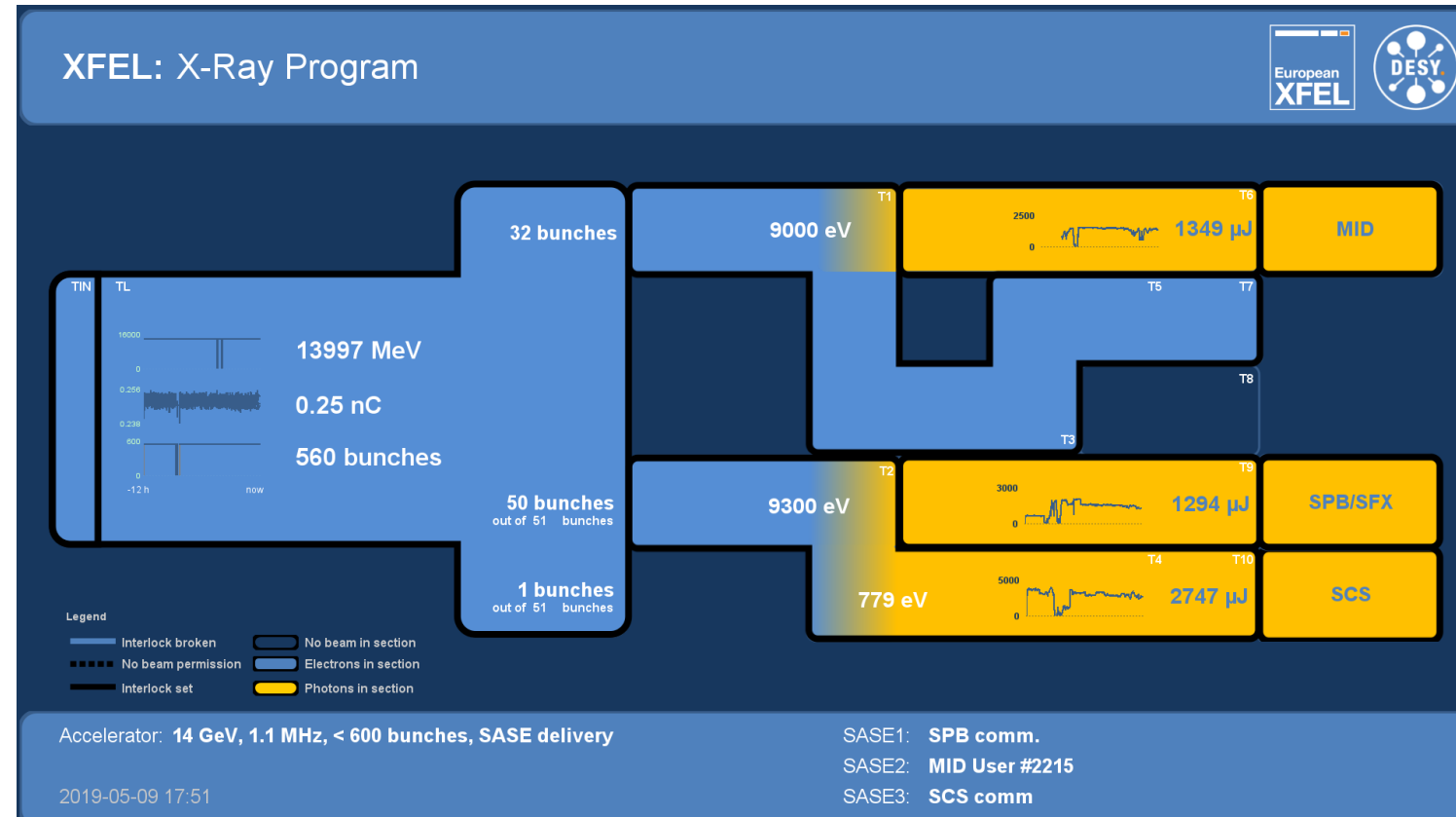
Status Quo

History

- Start commissioning: Oct. 2016
 - ▶ First lasing: May 2017
 - ▶ First users: Sept. 2017
- 4 years operation with strongly limited beam parameters 3...9 W („operation constraints“)

Today

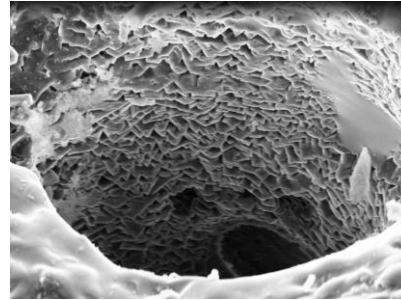
- 7 experimental stations in operation
- Operation with 40 W max. photon power



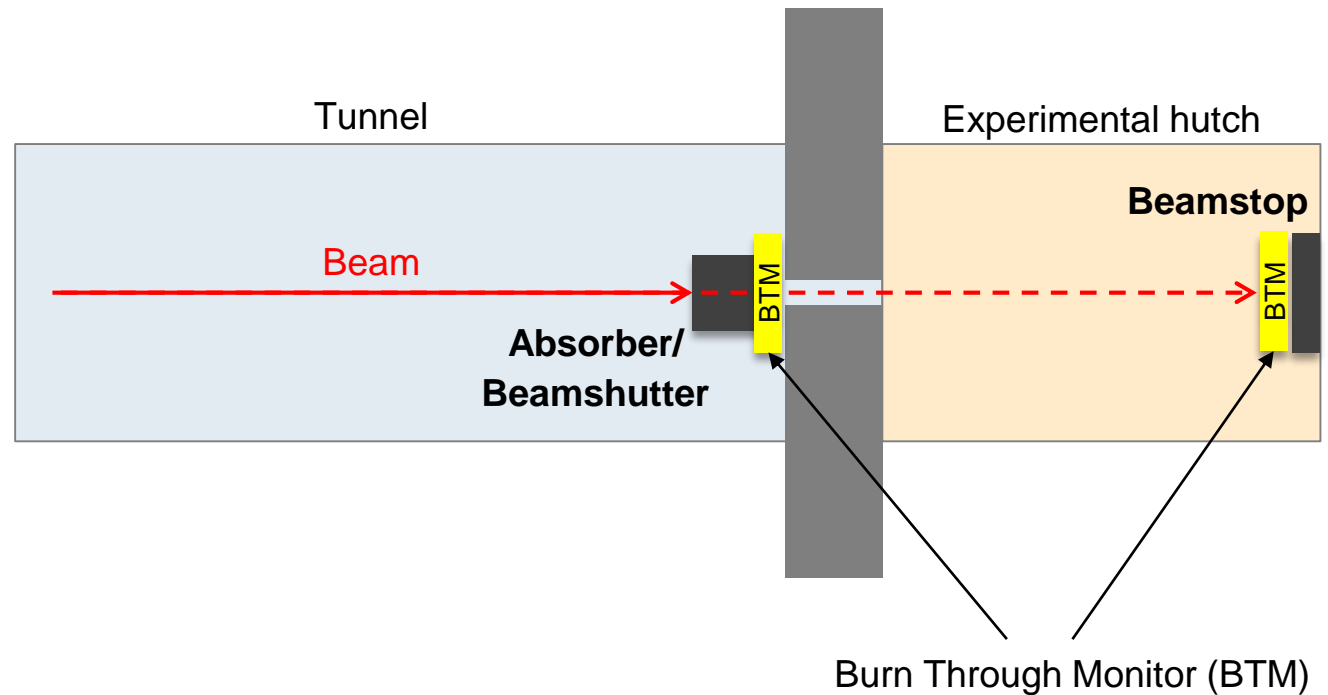
Screenshot XFEL Status Info System, May 9, 2019

The FEL beam must be stopped ...and be detected if stopping fails

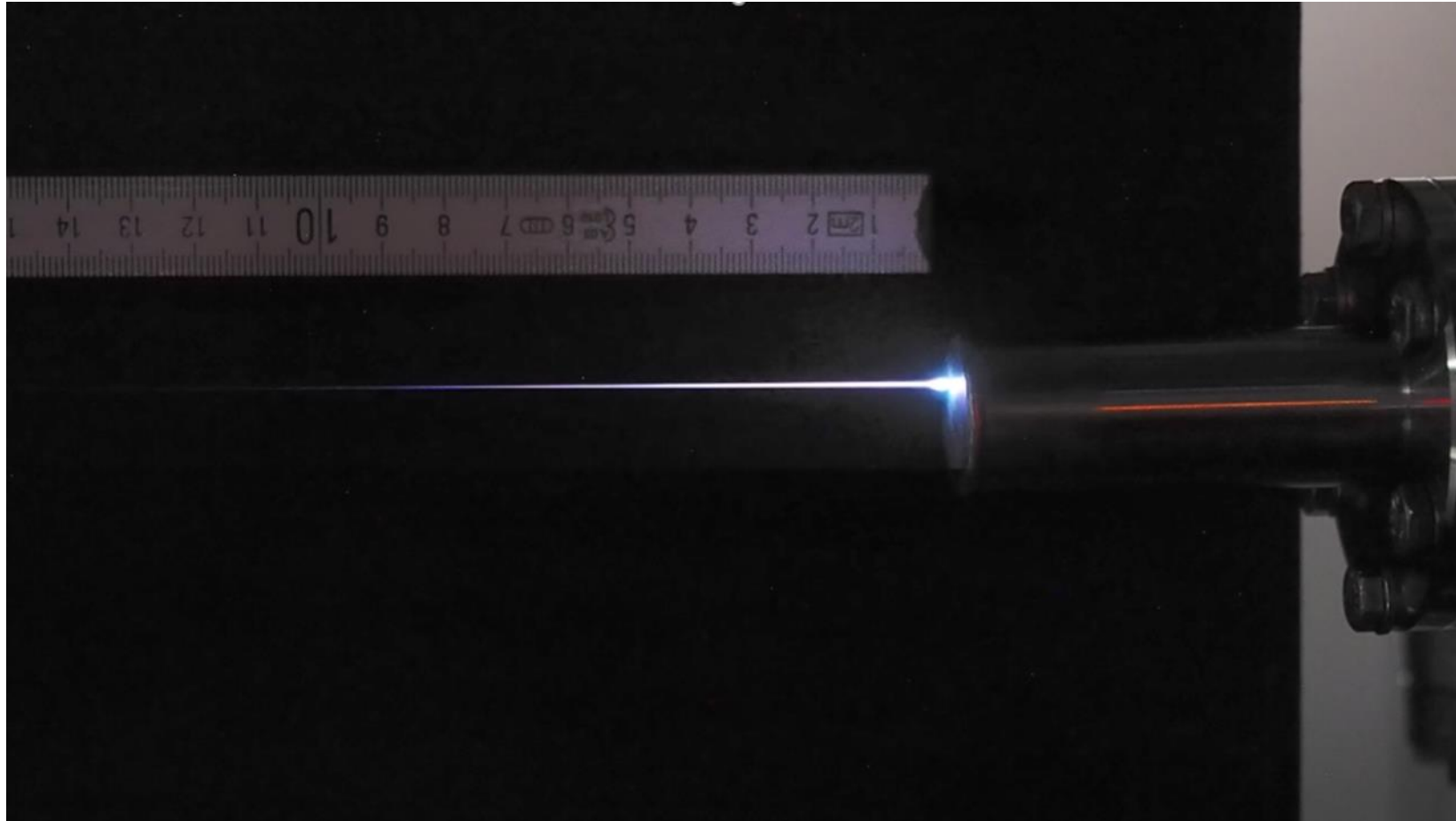
- Material tests proof capability of focused FEL beam to **drill through any solid material** (see Ted's talk)
- Stopping the beam safely is crucial to protect personnel
- What can be done?
 - Avoid critical beam conditions at safety components (see Zunaira's talk)
 - Monitor positions where the beam mustn't be and switch off beam immediately if beam burnt through (this talk)



SEM picture of B4C hole with 20 μm beam @ FXE, 9 keV, 1 mJ

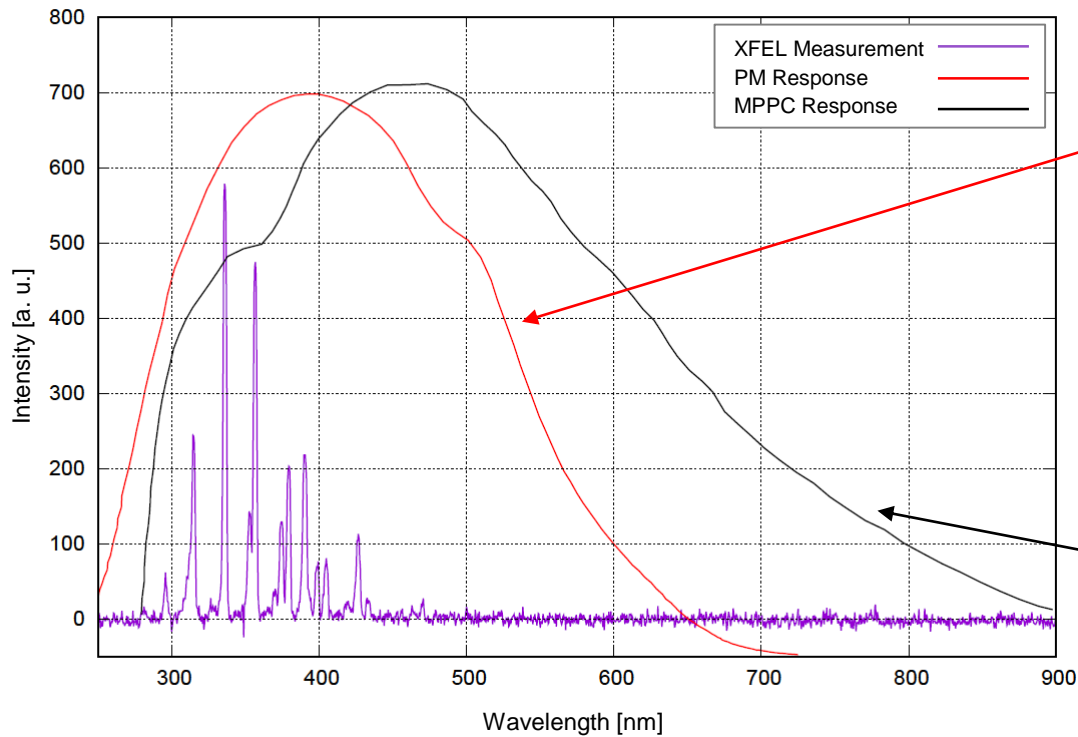


Burn Through @SQS, 0.7 keV, 50 bunches/pulstrain, 10 Hz

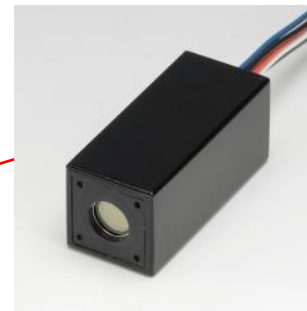


Detectors for a Burn Through Monitor System

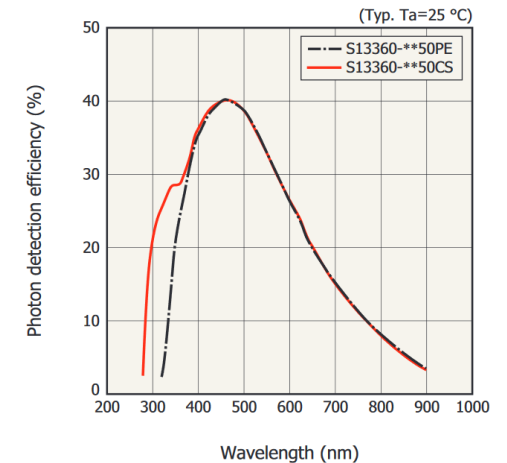
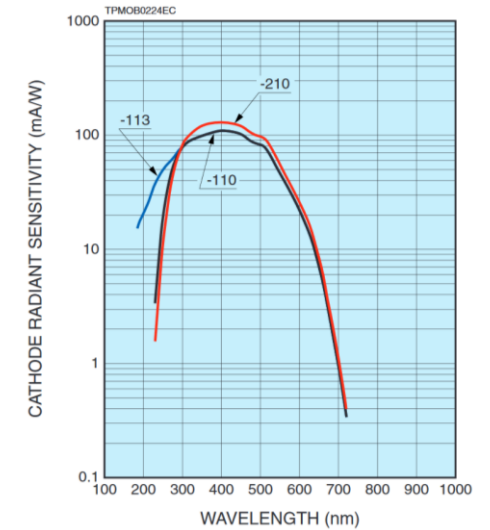
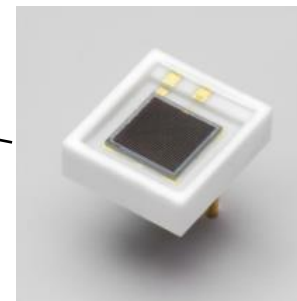
Fluorescence spectrum @ 6.1 keV overlaid with PM and MPPC response



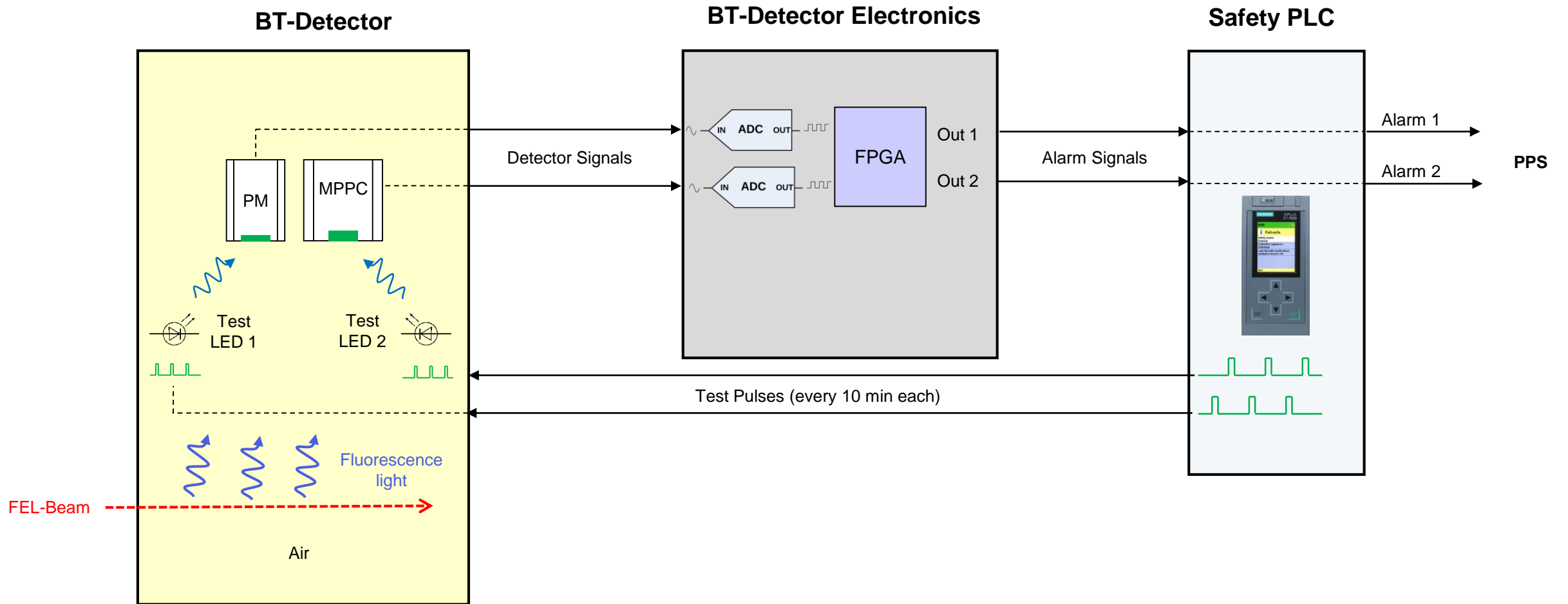
Photomultiplier (PM)
Hamamatsu H11901-110



Multi Pixel Photon Counter
(MPPC) Hamamatsu S13360



Detection System and Continuous Self-Test



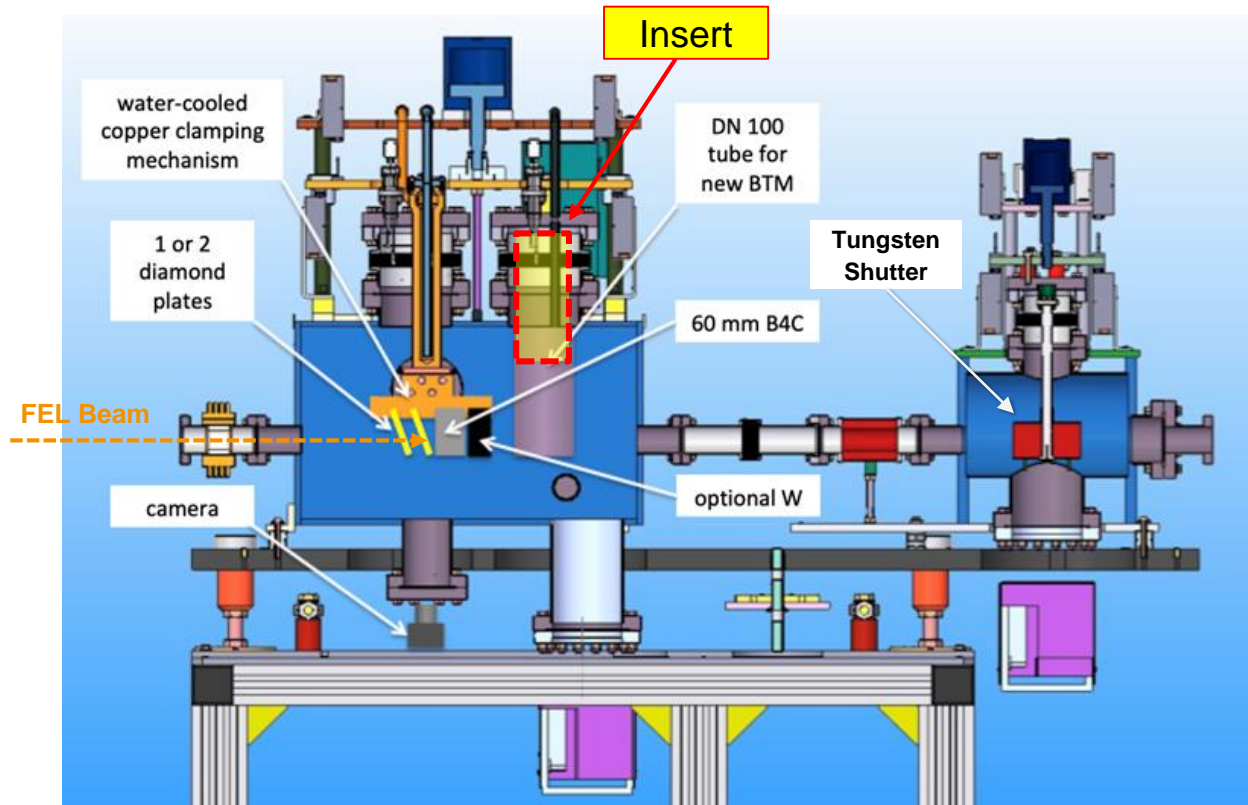
Safety Related Diagnostic Function

- The safety function of the BTM system must be **extremely reliable**
- Complex detectors and electronics make it **nearly impossible** to build up a **safety related** BTM system
 - Two separated alarm systems
 - Two different detectors for the purpose of **diversity**
- Continuous self test with LED light ensures a **completely independent** diagnostic function
- As the LED trigger and the evaluation of the response signal is done by a safety PLC (**SIL 3**) the diagnostic function itself is **safety related**



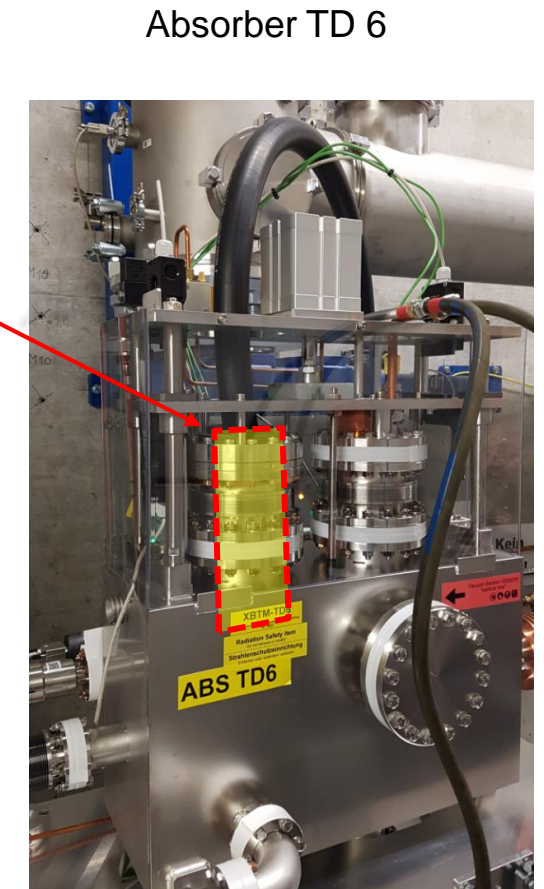
BTM Detector I: Insert

“**Inserts**” behind absorbers but in front of the beamshutters detect fluorescence light in case of a **burn through** of the absorber



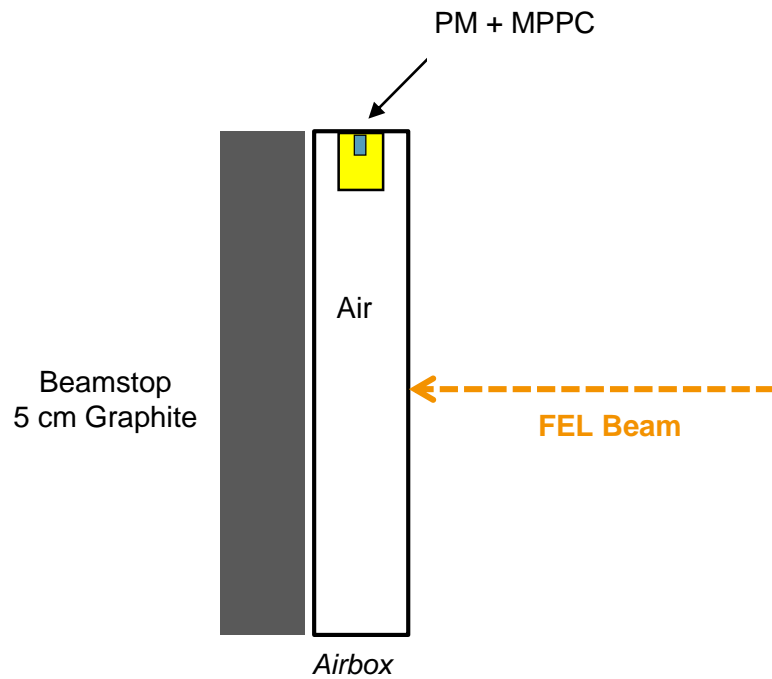
Absorber and beamshutter (by Fan Yang, EXFEL and Reuter company)

European XFEL

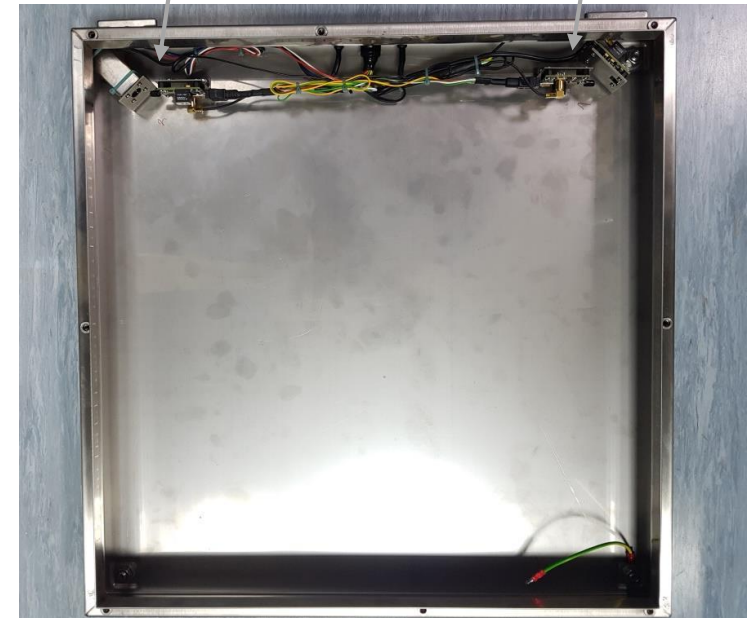
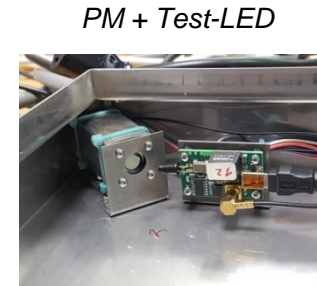


BTM Detector II: Airbox

“Airboxes” in front of the graphite beamstops at the end of experimental hutches detect fluorescence light in case of a **burn through** of the technical beamstop.



Airbox SPB hatch



Opened airbox

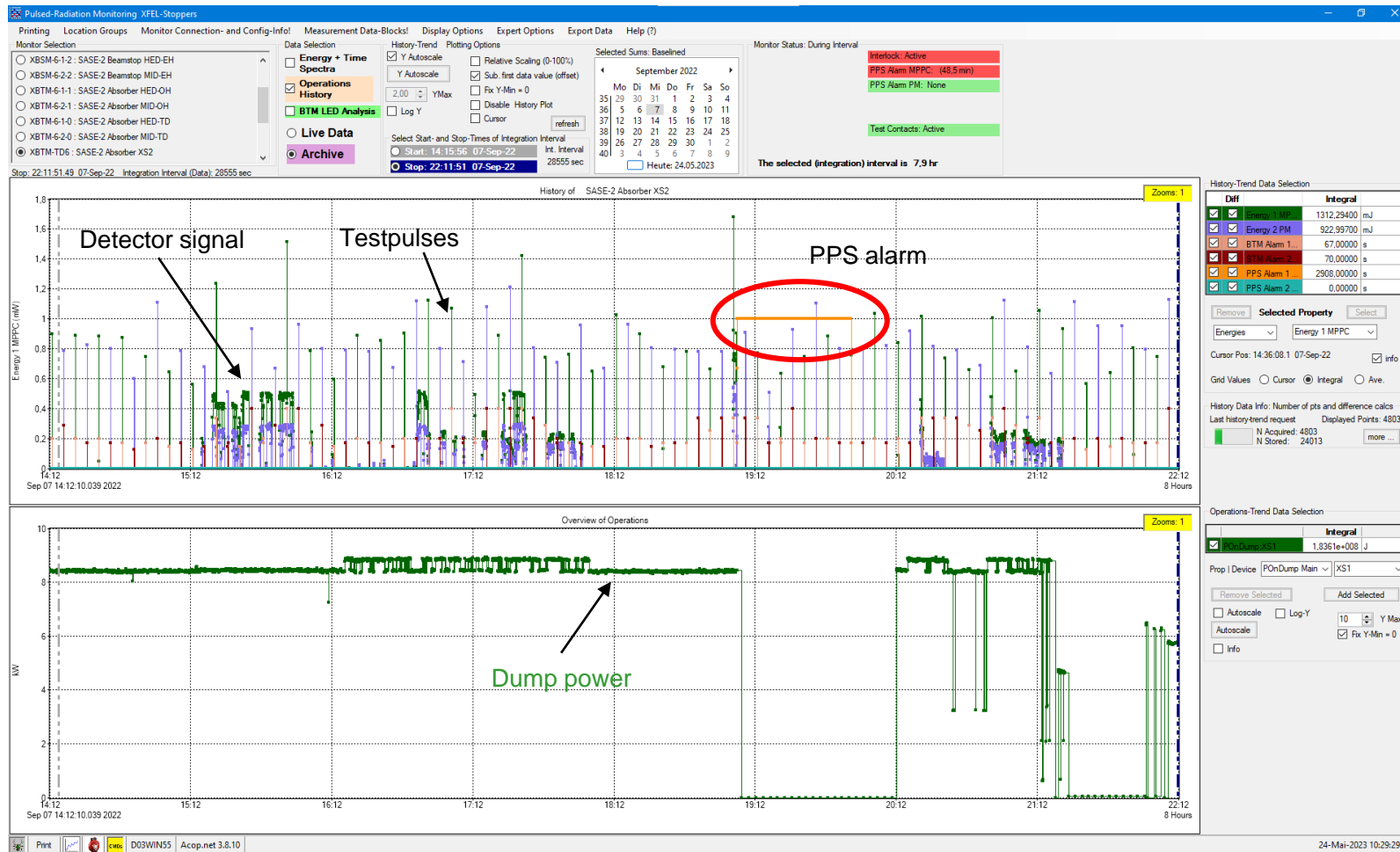
Executed test measurements with BTM detectors: Overview

Measurement	Values	Result
Fluorescence spectra	0.77 keV - 14 keV	Spectra look similar
Response unfocused/focused beam	1 mm \rightarrow 20 μ m	Decrease of signal unfocused/focused by a factor of 2-3
Response as function of photon energy	0.77 keV - 20 keV	Corresponds to mass attenuation coefficient in dry air
Response as function of pulse energy	< 0.1 ... 10 mJ/pulse	Signal scales linearly as long as detectors are not saturated
Response as function of # of pulses	1 ... 400 pulses/bunch train	Signal scales linearly as long detectors are not saturated



Test set-up @ SQS

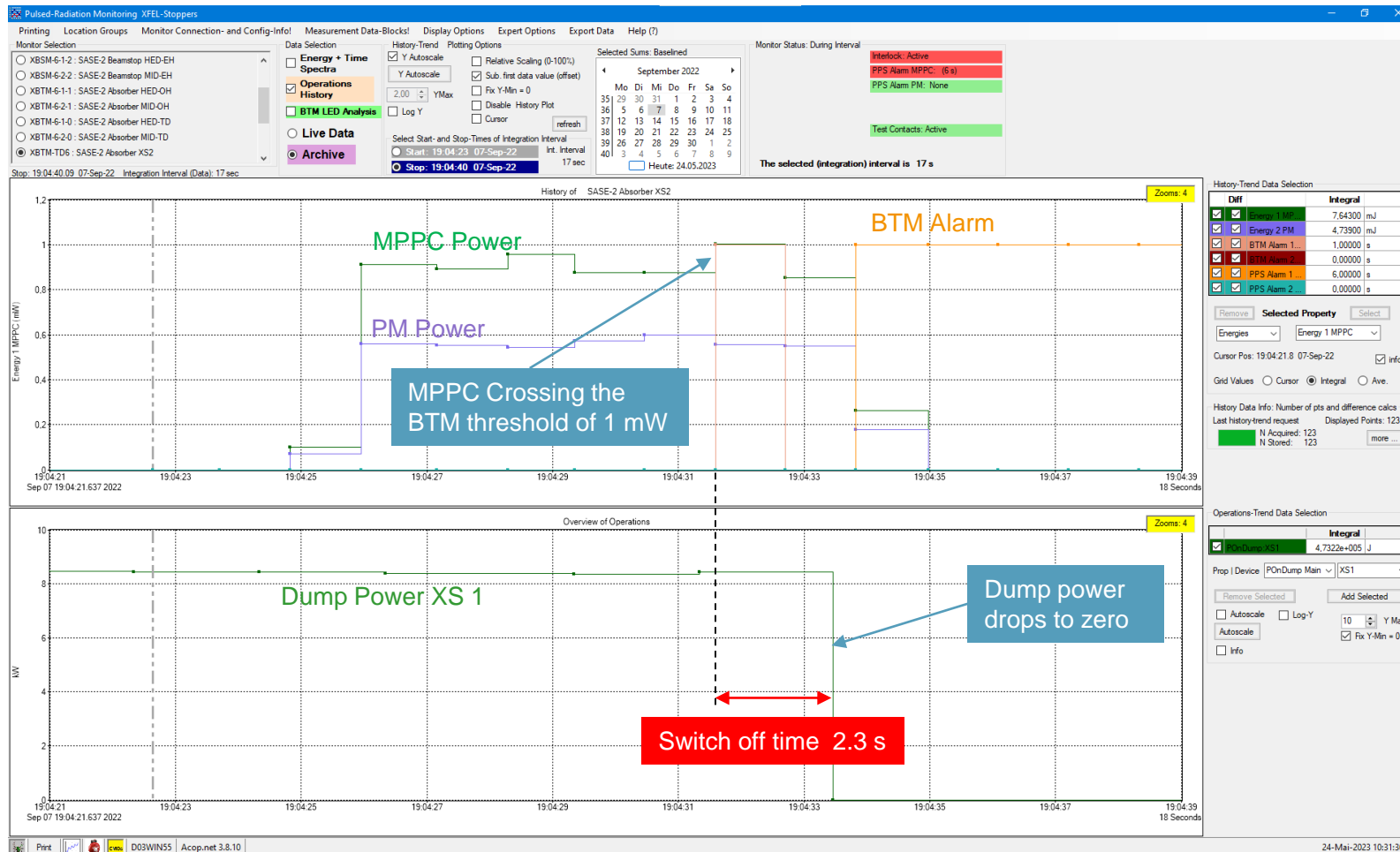
False Alarm by Bremsstrahlung in Front of BTM TD6



Screenshot of BTM GUI

- Use of screen in SASE 2 produces Bremsstrahlung
- BTM „TD6“ location at about 50 m distance
- Bremsstrahlung generates fluorescence light at BTM (absorber open)
- → PPS alarm occurred

Switch-off time

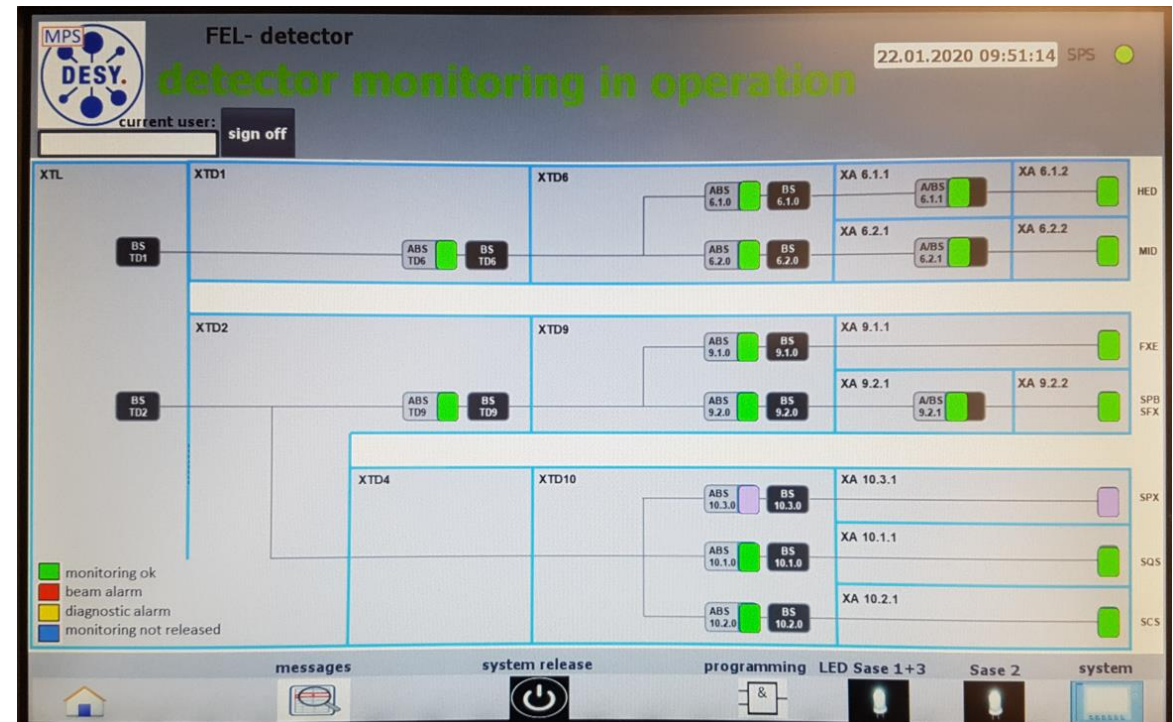


Screenshot of BTM GUI

- time delay between BTM signal and dump power drop = 2.3 s
- ~ 1 s integration time for safe determination of the detection threshold
- 1...2 s delay PPS relais chain and modulator switch off time

Three Years of XFEL Operation with BTMs

- Good news: No burn through yet!
- 19 BTMs in operation since 01/2020
 - ~ 5 Million test pulses so far
- About 20 false alarms
 - Diagnostic alarms
 - ▶ Decrease of detector response or LED light
 - ▶ Missing test pulses
 - Hardware failures
 - Bremsstrahlung
 - Last alarm in 10/2022 !
- Measures
 - Regular check of test pulse energy
 - Optimization of hardware
 - Some shielding added



Screenshot BTM System HMI

Thanks for attention!