The European XFEL Beam Loss Monitor System

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Desy, Hamburg

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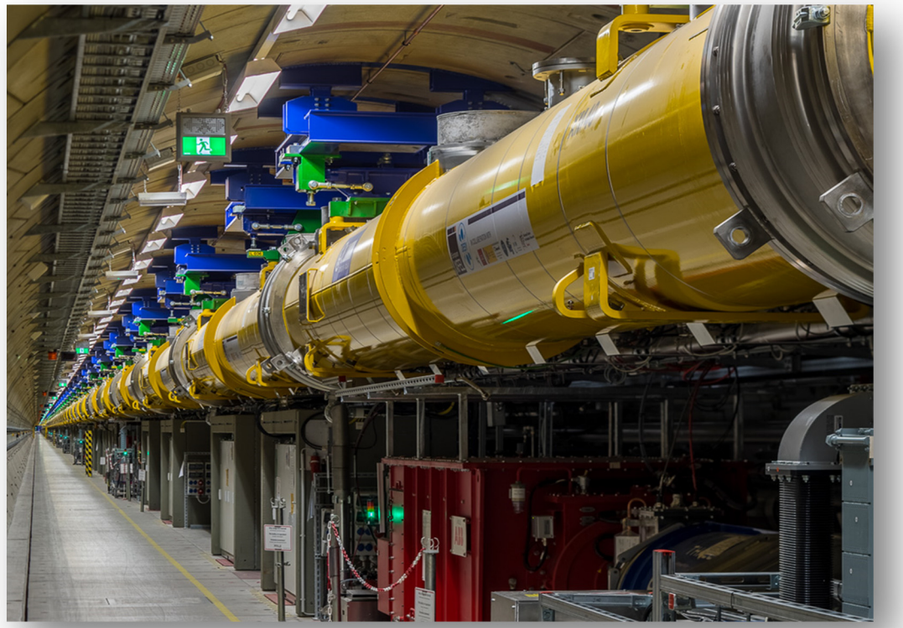
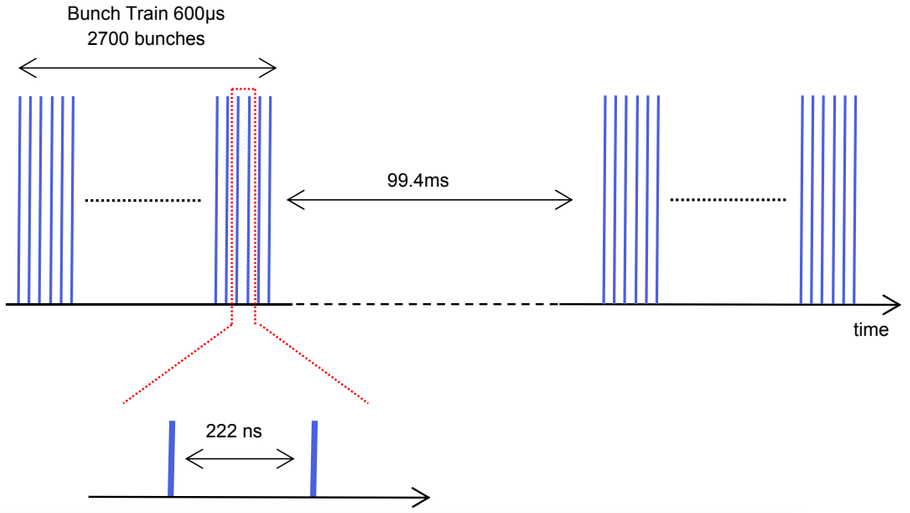


Outline

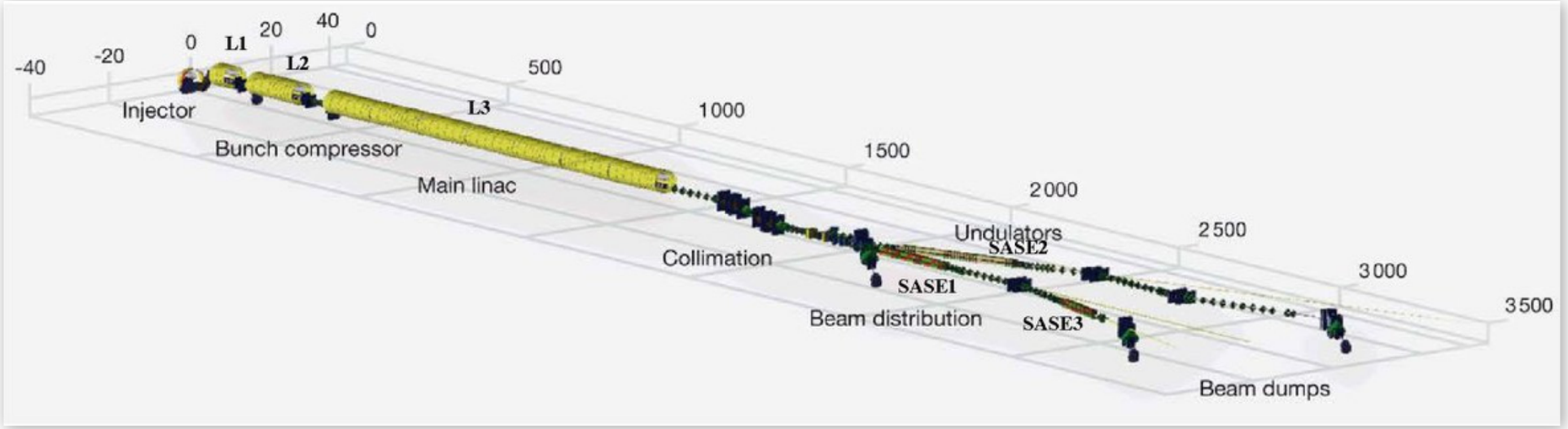
- European XFEL Goal Parameters
- BLM System Setup
  - Integration Examples
  - GUIs
  - Alarm Generation
    - Beam Based Alarms
    - Device Alarms
  - Alarm masking
- Conclusion

European XFEL Parameters

- Electron beam energy: ≤17.5 GeV
- Bunch charge: 0.02 – 1 nC
- Pulse repetition rate: 10 Hz
- Pulse length: 600 us
- Bunches per pulse: up to 2700
- Bunch repetition rate: up to 4.5 MHz

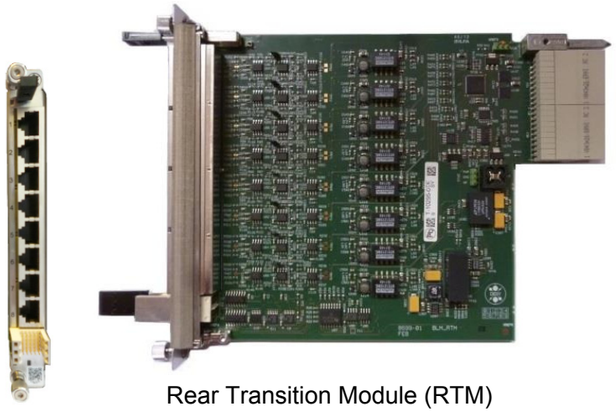


- Most electronics located in the tunnel

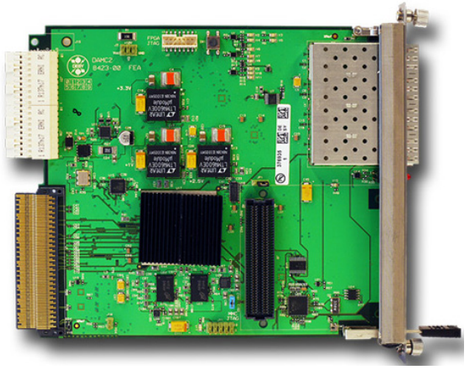


- Since there are up to 2700 bunches/train in the machine, the main goal of the BLM system is to cut the bunchtrain as fast as possible to protect the machine from damage

BLM System Setup



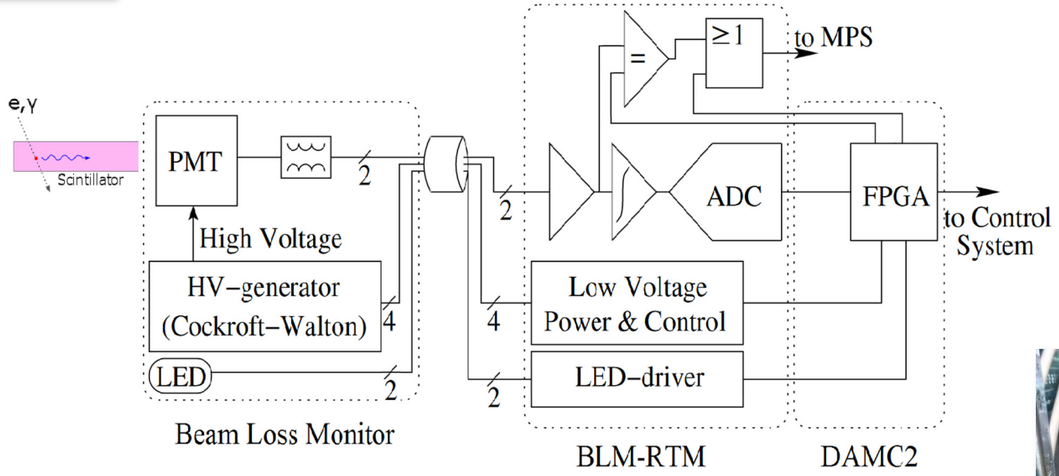
Rear Transition Module (RTM)

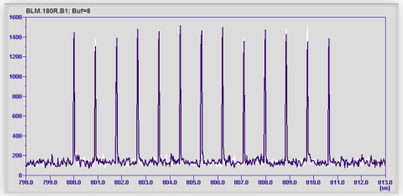


DAMC2, DESY Advanced Mezzanine Card

- Plastic scintillators
- HV: 0V – 900V
- 8 channels/RTM
- ADC: 14 bit @ 45MHz
- RJ-45 connectors

- Bunch by bunch resolution

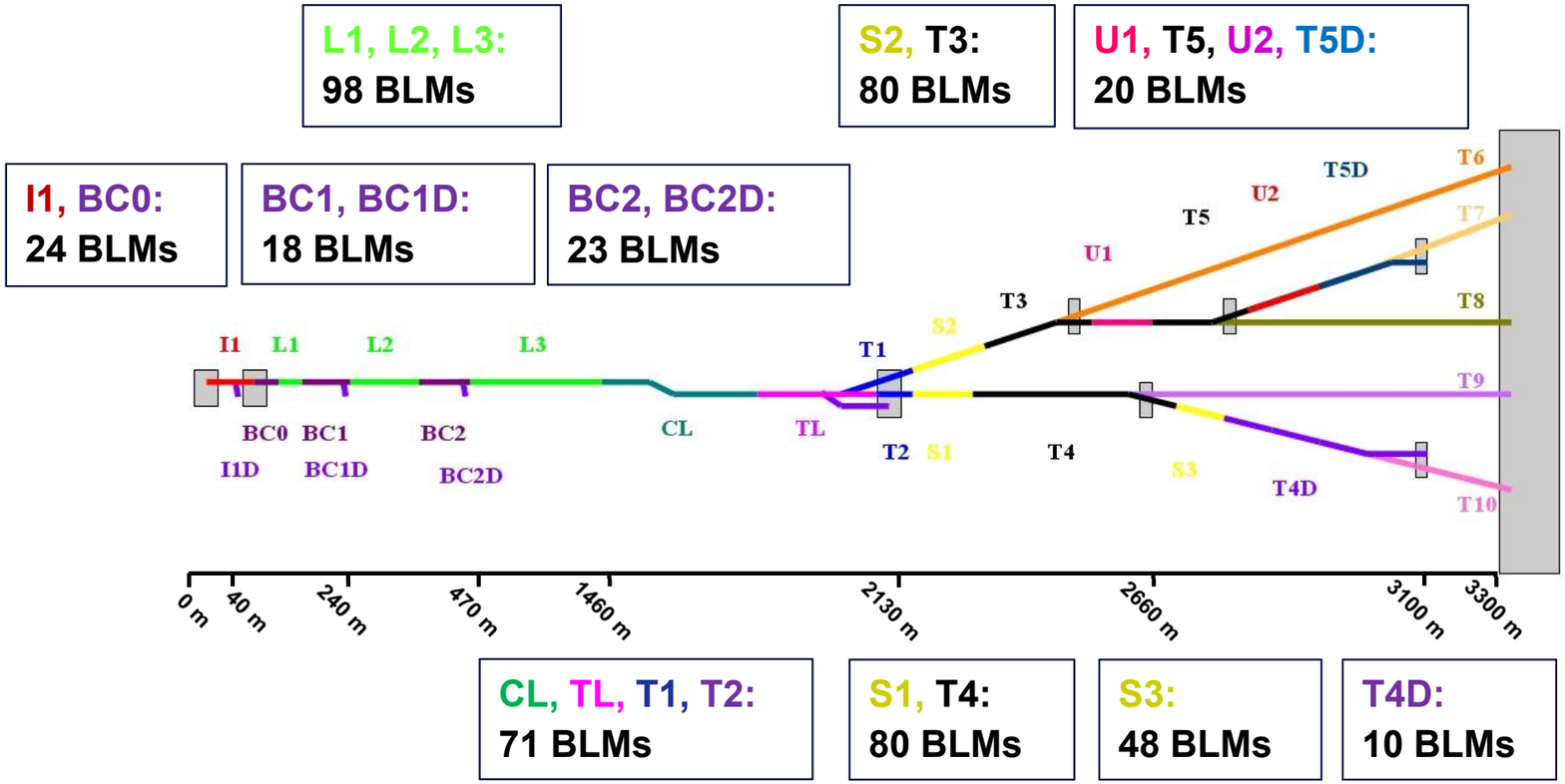




13 bunches @ 1.13MHz rep. rate

µTCA crate

BLM System Setup

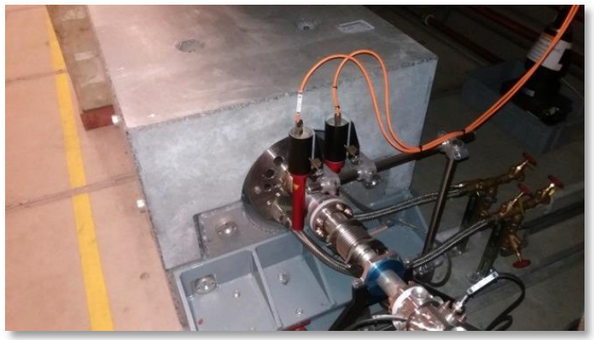


Explanation:

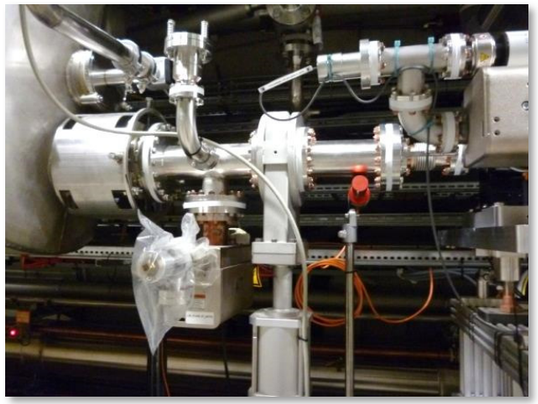
I1 - Injector 1
I1D - Injector Dump
L1 - Linac 1
BC1 - Bunch Compressor 1
BC1D - Bunch Compressor 1 Dump(Line)
L2 - Linac 2
BC2 - Bunch Compressor 2
BC2D - Bunch Compressor 2 Dump(Line)
L3 - Main Linac
CL - Collimation Section
SA1-3 - SASE Undulator Sections
UN1-2 - Spontaneous Radiation Undulator Sections (not equipped yet)
T5D - Main Dump(Line) in XTD5/XSDU1
T4D - Main Dump(Line) in XTD4/XSDU2
T1 - (straight) e-beam line
T2 - (straight) e-beam line
T3 - (straight) e-beam line
T4 - (straight) e-beam line
T5 - (straight) e-beam line
T6 - SASE-2 photon beam line
T7 - UN2 photon beam line
T8 - UN1 photon beam line
T9 - SASE-1 photon beam line
T10 - SASE-3 photon beam line

- Most BLMs in undulator area, each undulator intersection equipped with two BLMs
- A total of 472 BLMs are installed
- Cable-connected to 78 RTMs in 58 µTCA crates located in the tunnel
- All BLMs connected to the Machine Protection System (MPS)
  - Stops beam production at the photoinjector gun

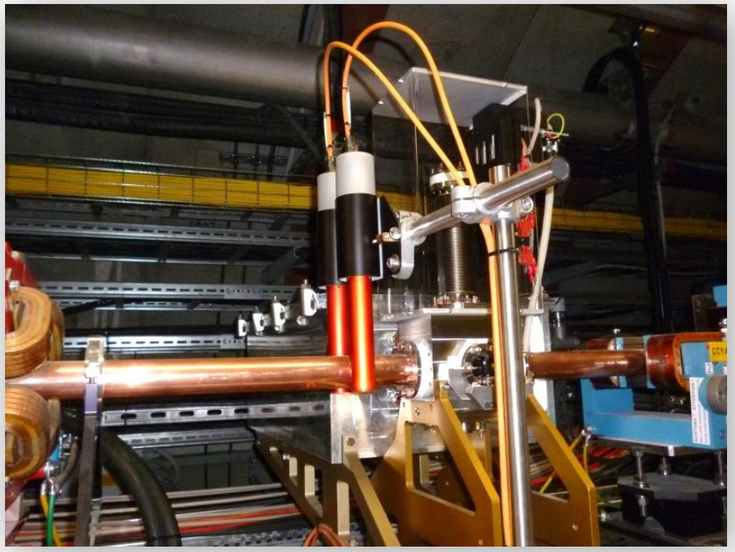
BLM Integration Examples



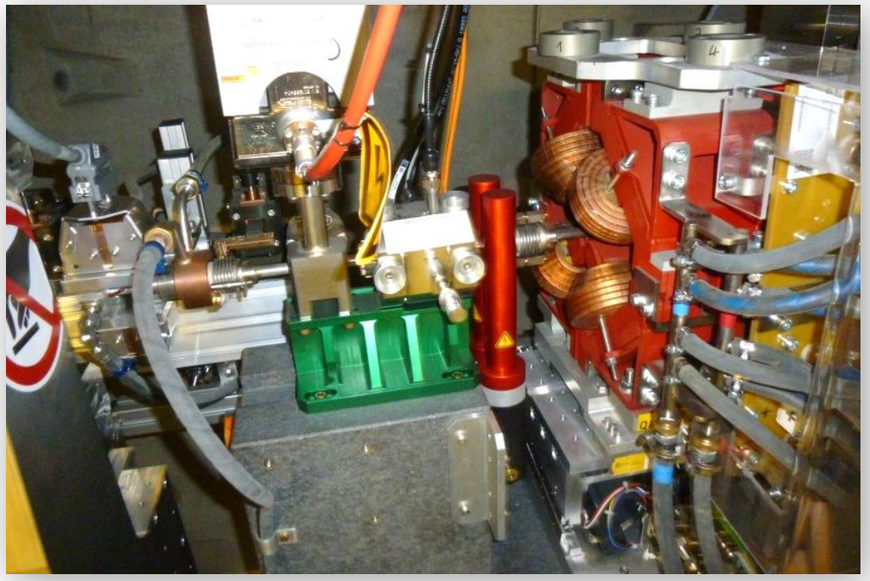
In front of BC1 dump



In front of linac 3



BC2 line



Undulator intersection

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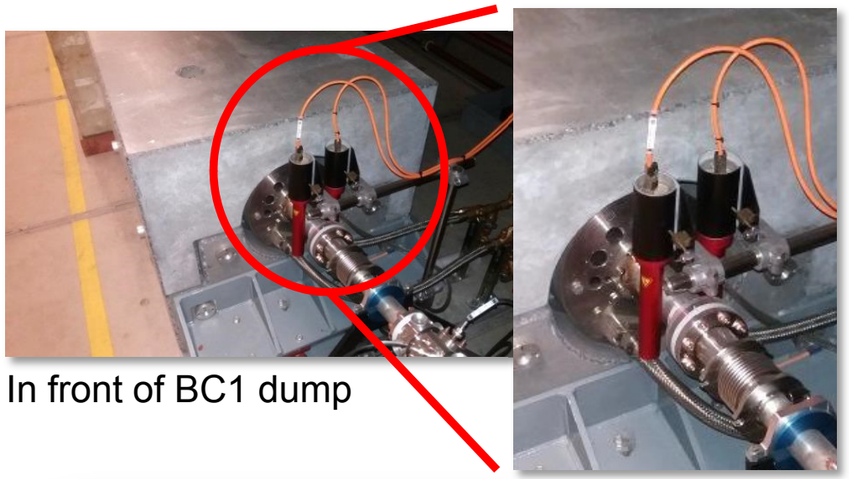

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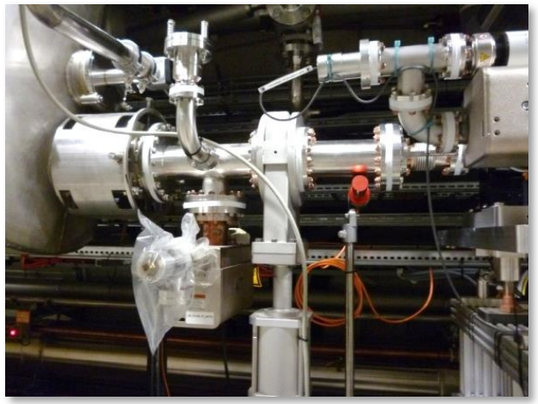

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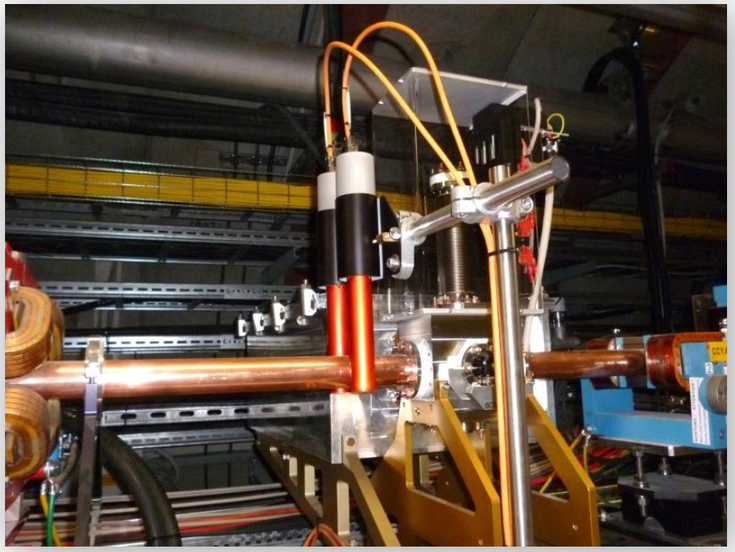

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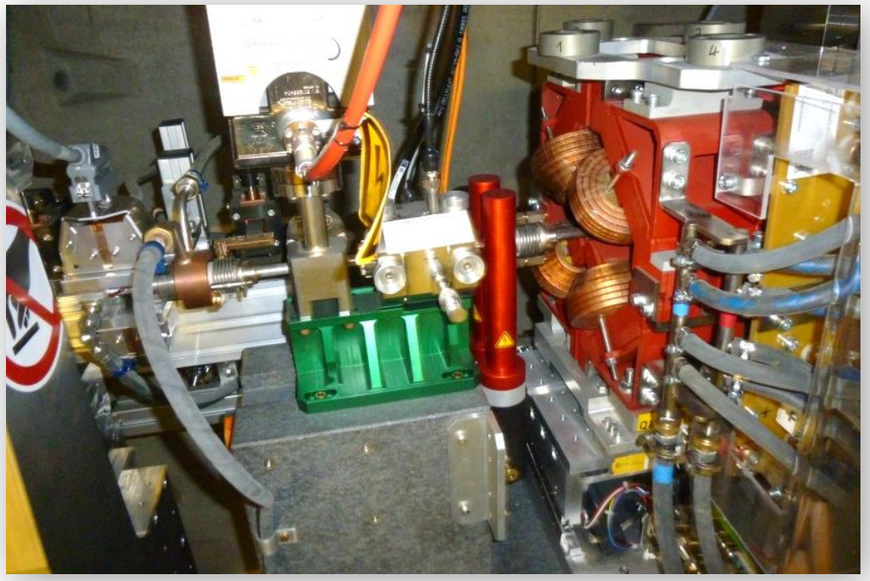

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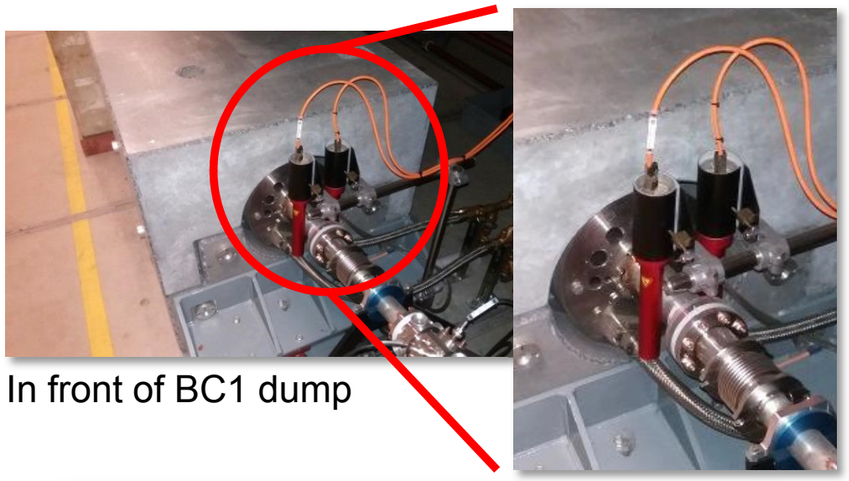

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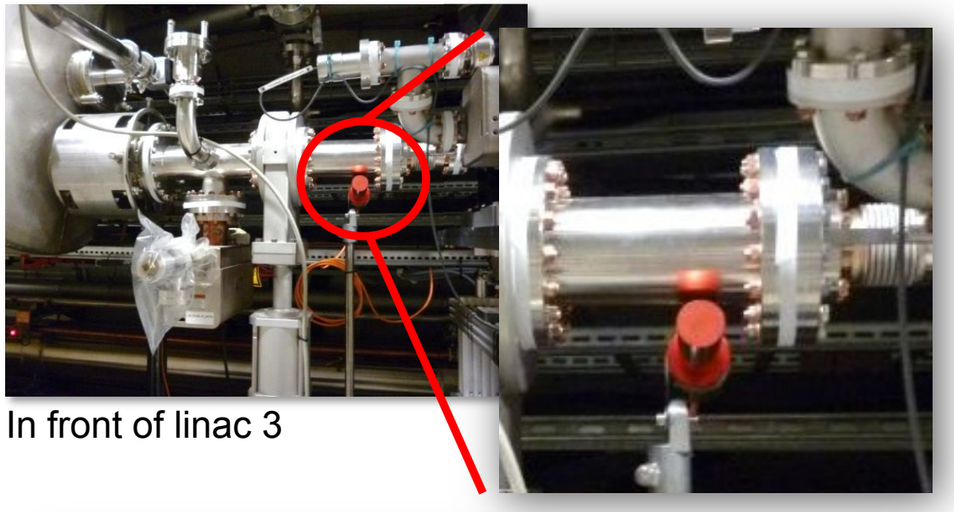

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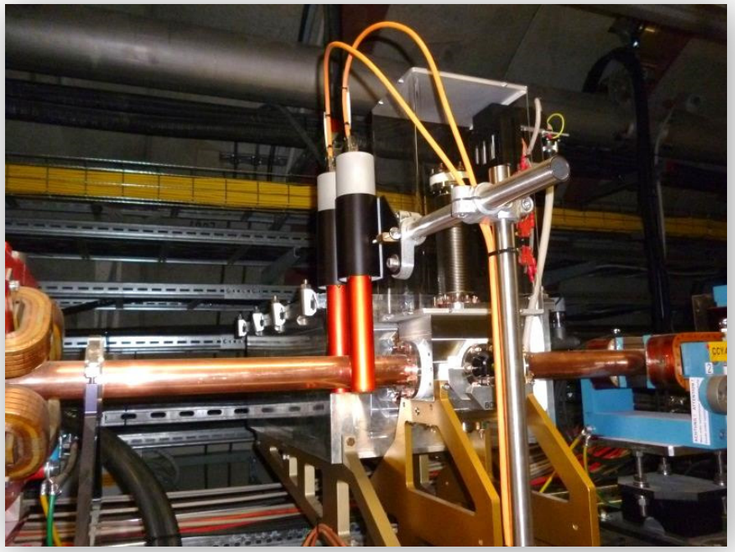

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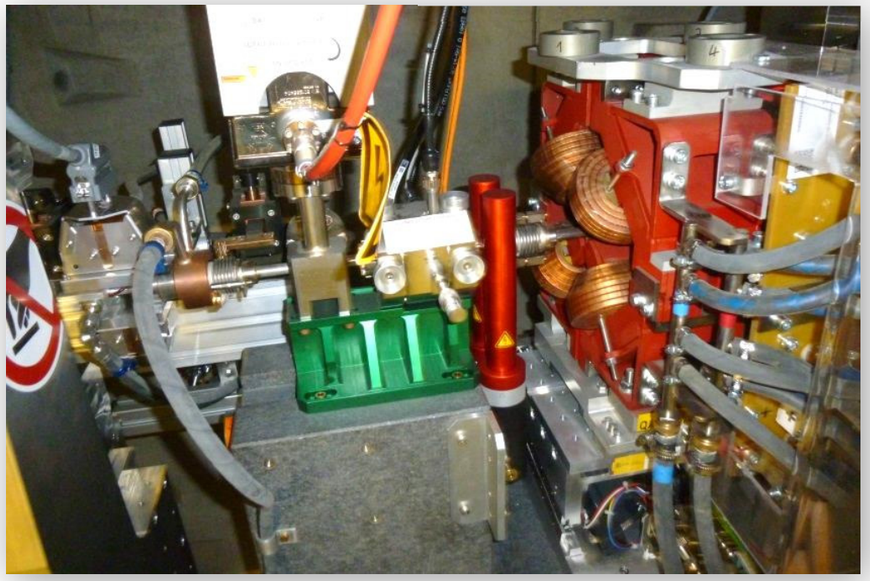
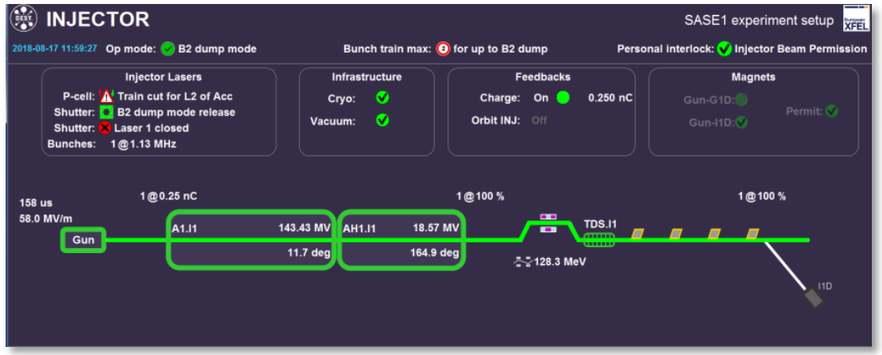


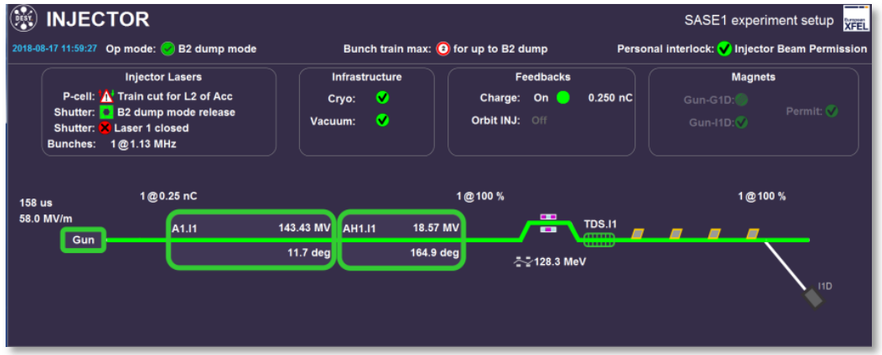
Undulator intersection

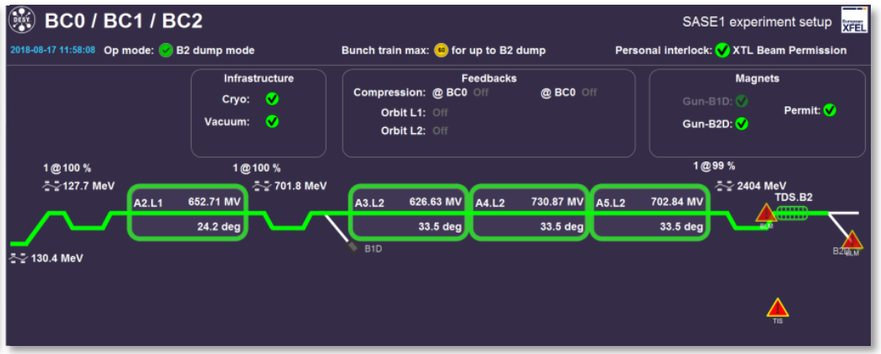
BLM GUIs



- Main Overview Panels
  - Alarms shown by section

BLM GUIs





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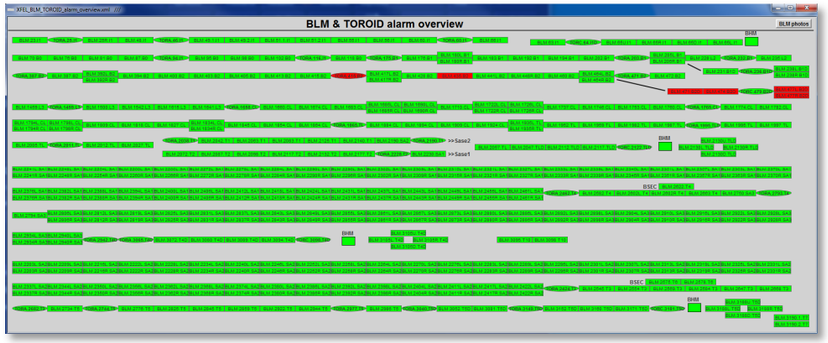

- BLM & toroid Alarm Overview
  - Shows alarms from all BLMs and toroid (bunch charge monitor) based transmission Interlock
  - Each BLM selectable from this panel

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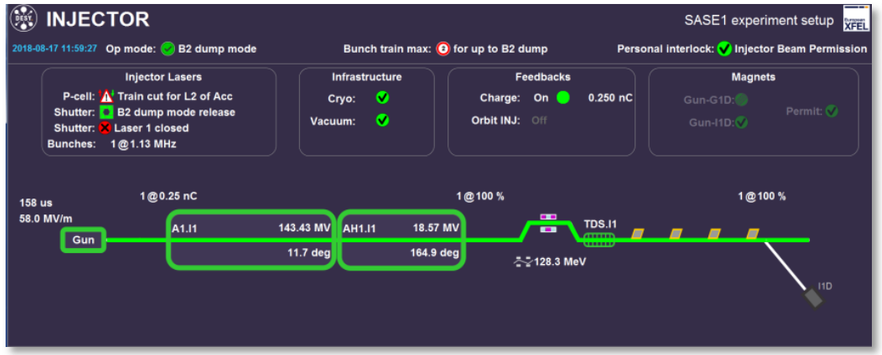

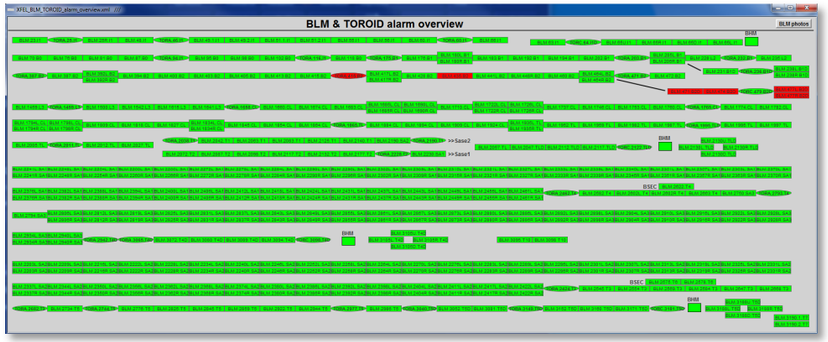

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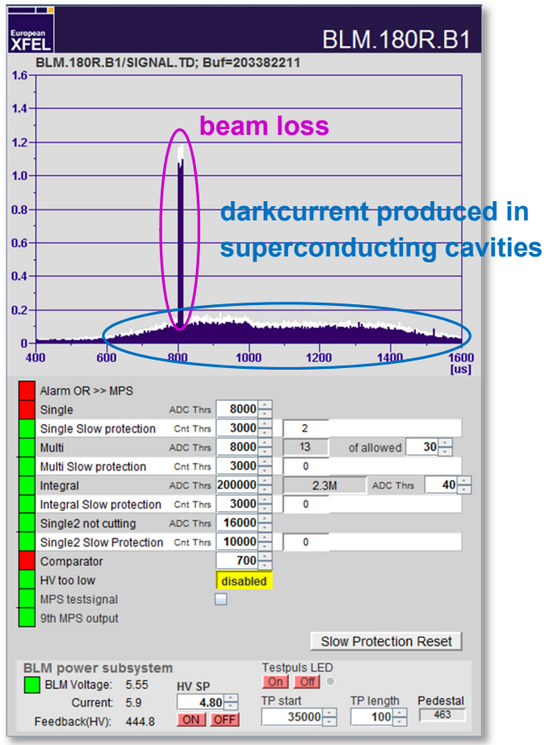

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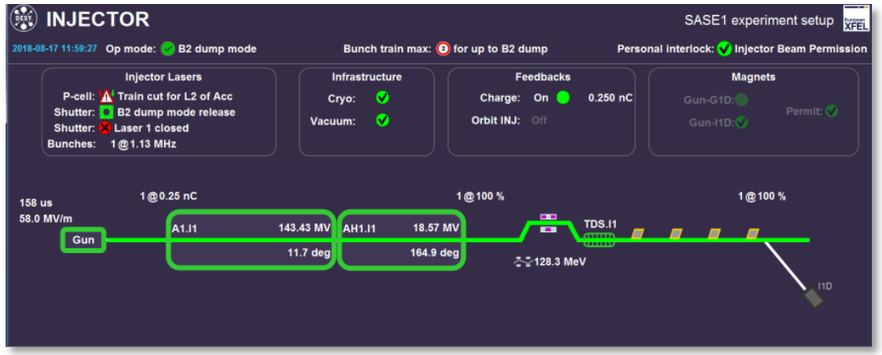

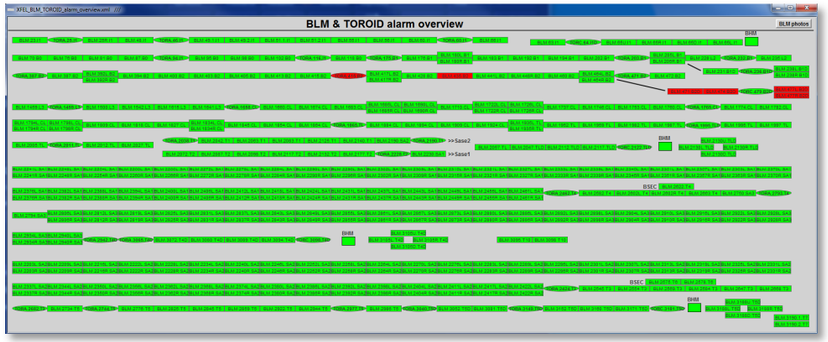

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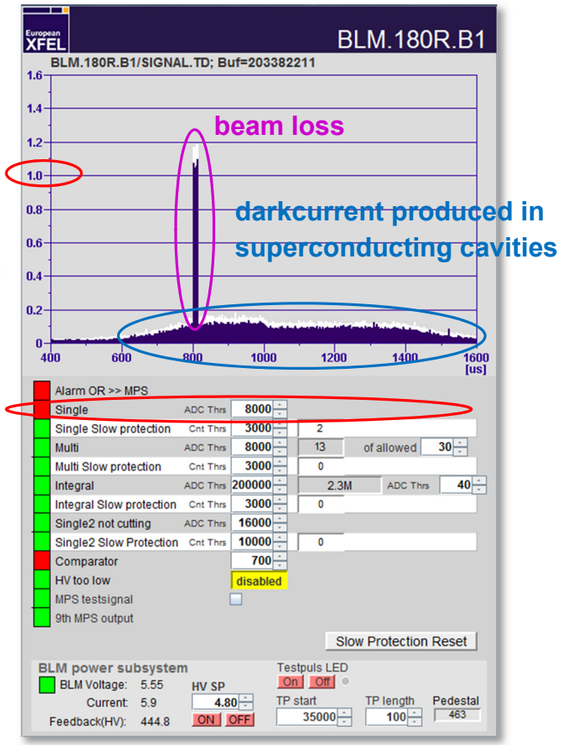

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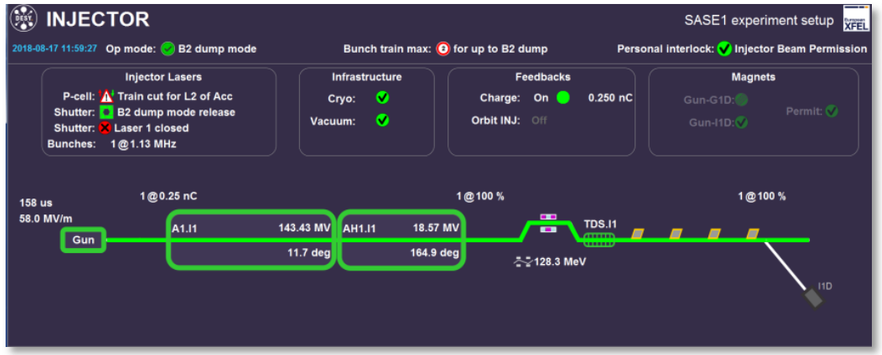

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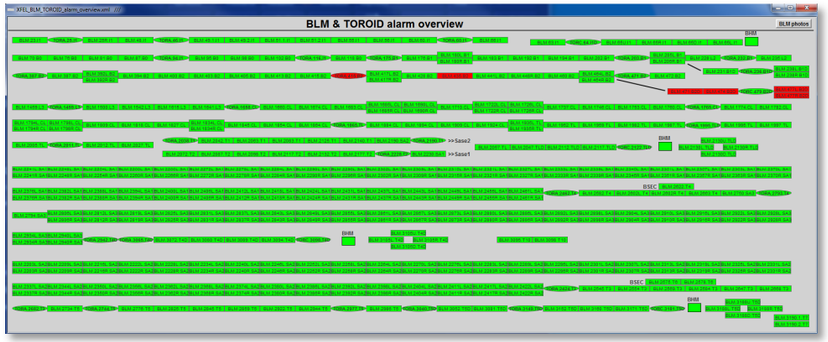

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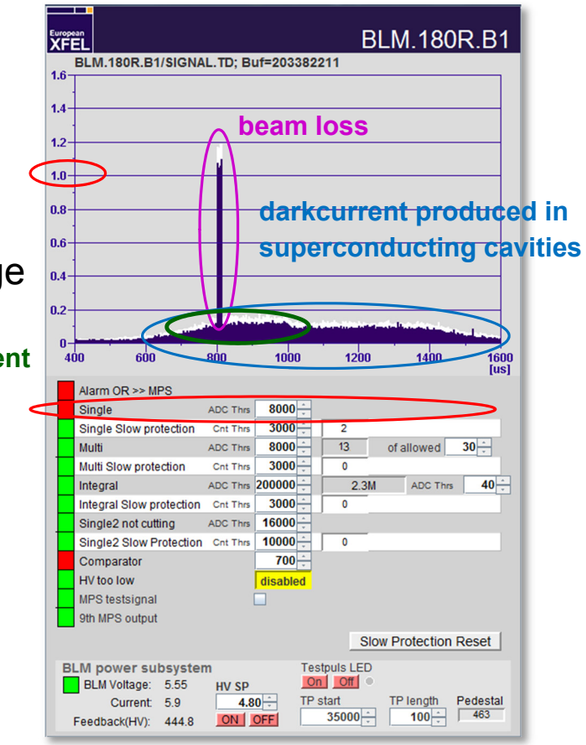

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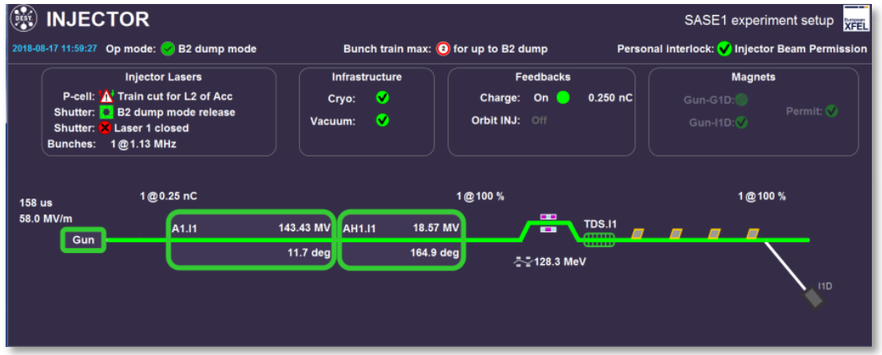

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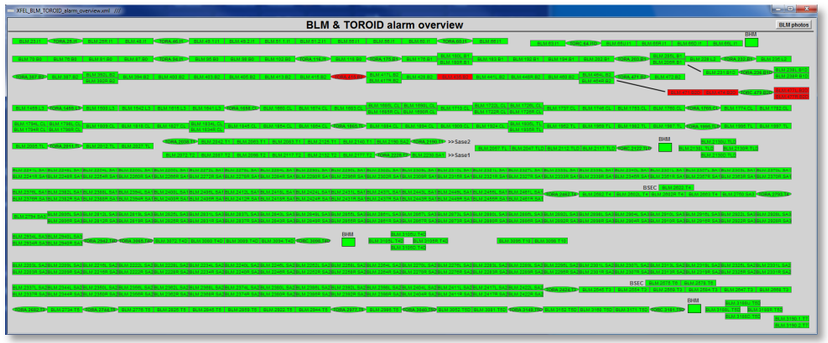

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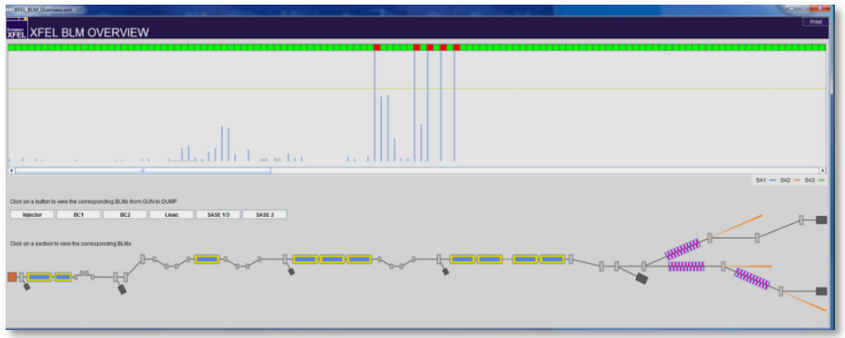

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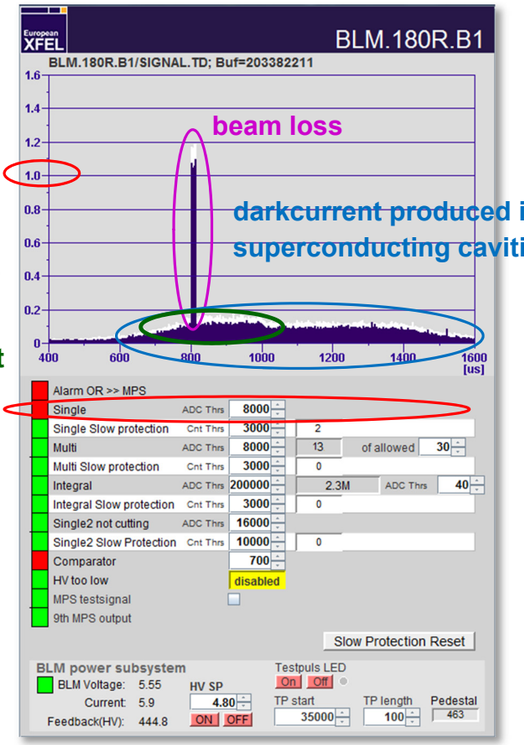
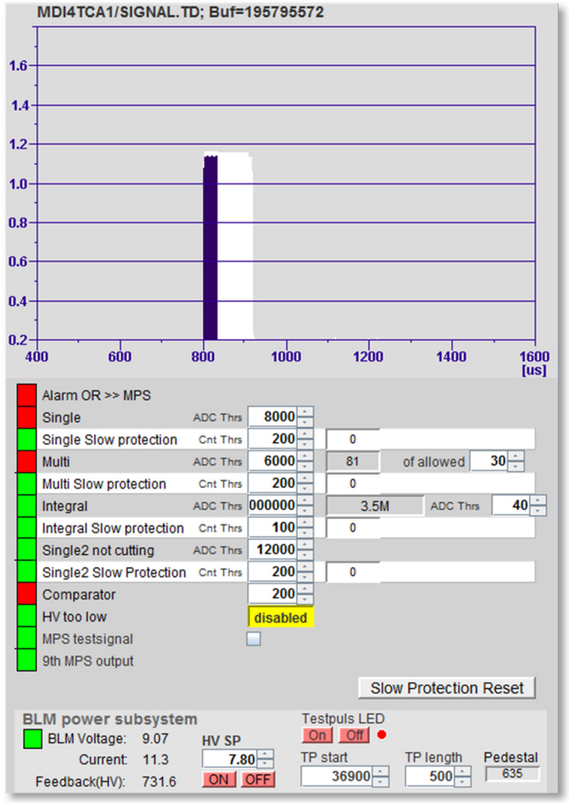
- XFEL BLM Overview
  - Shows maximum amplitude from each BLM
  - Fast overview of losses along the machine



BLM Alarm Generation: Beam Based Alarms



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  - comparator alarm triggers additionally
- Latency: up to 28us → ~130 bunches @ 4.5 MHz run through

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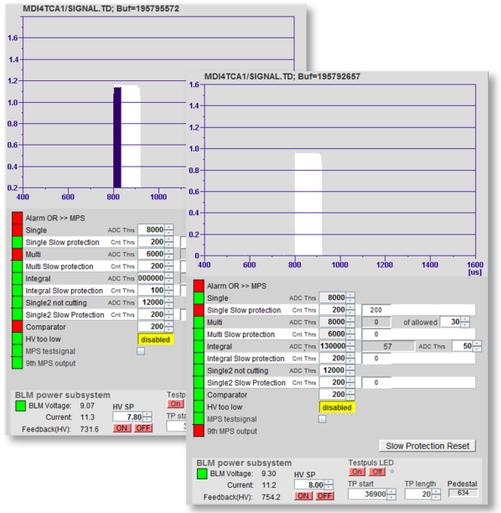

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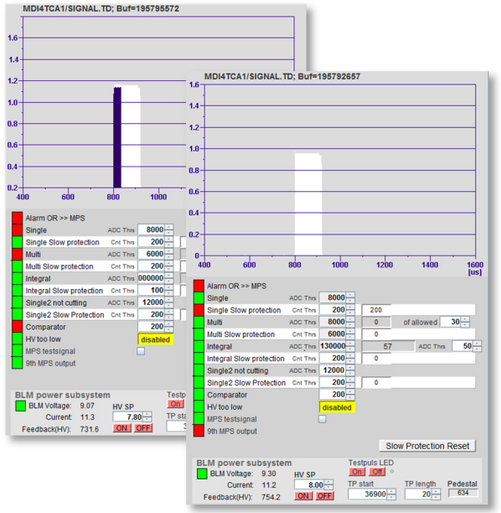

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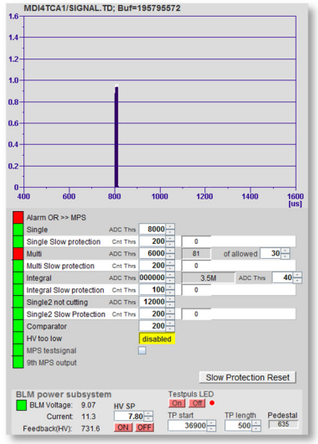

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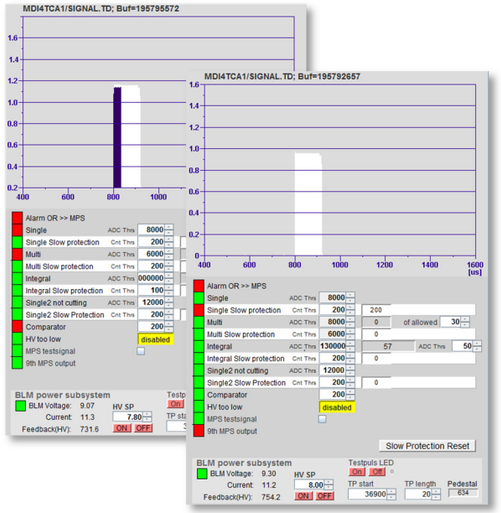

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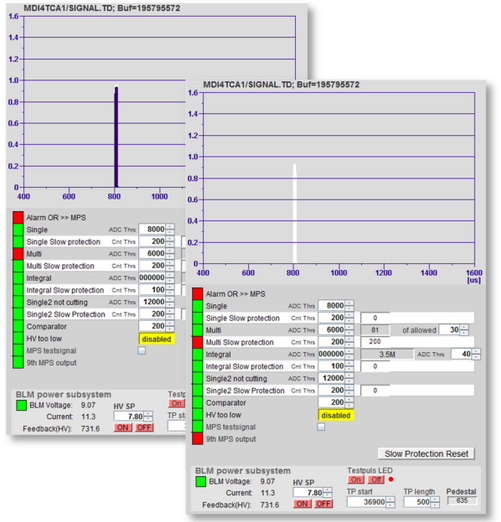

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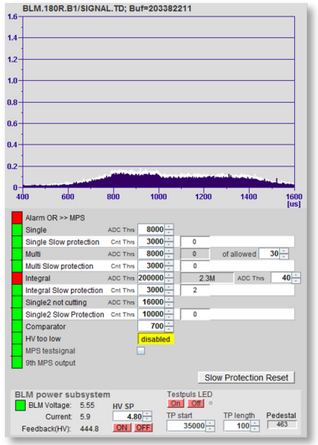

- Integral alarm due to darkcurrent, alarm threshold exceeded
  - Slow protection counter increments

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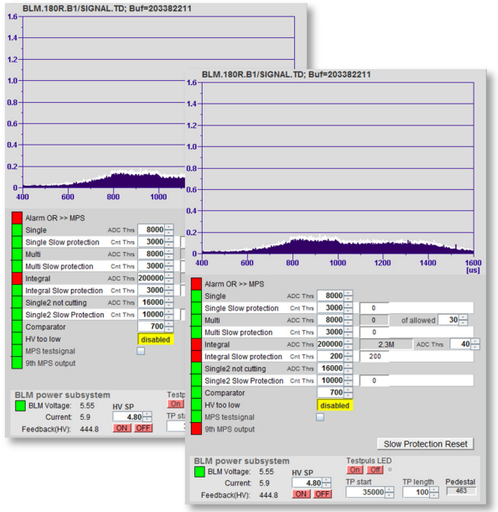

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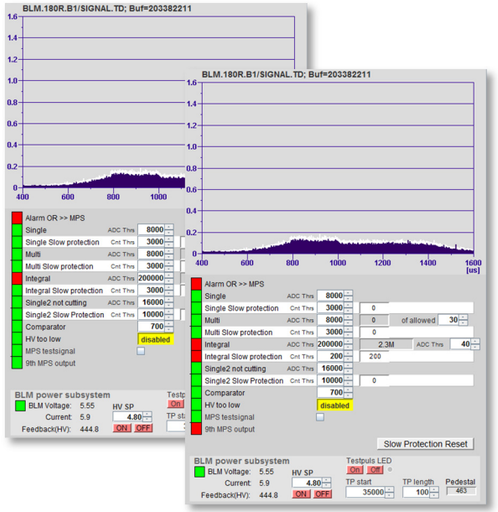

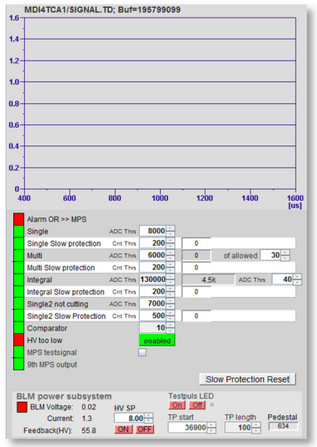

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  - Slow protection counter increments
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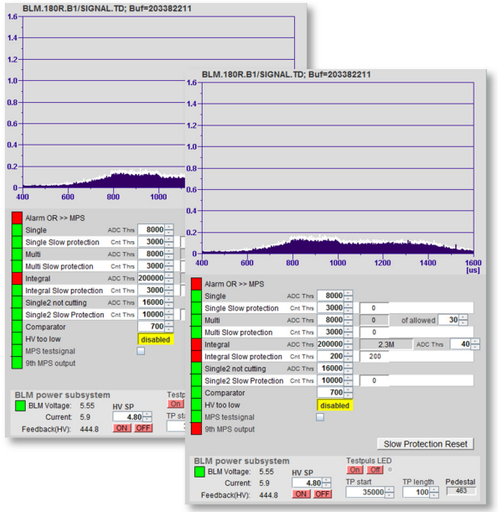
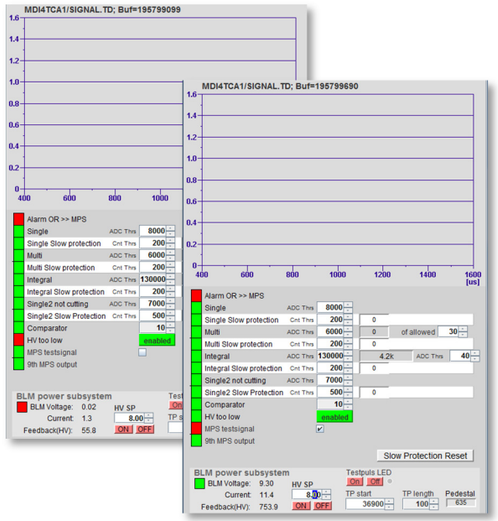
  - Alarm still there since it is not a beam based loss
  - Reset necessary
- High Voltage (HV) alarm, PMT cannot work, BLM not functional
  - No beam possible
  - Can be disabled

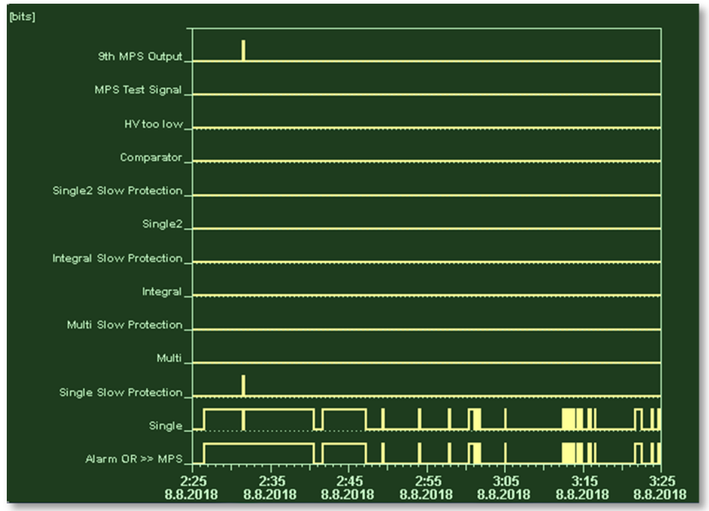
BLM Alarm Generation: Darkcurrent Alarms, Device Alarms

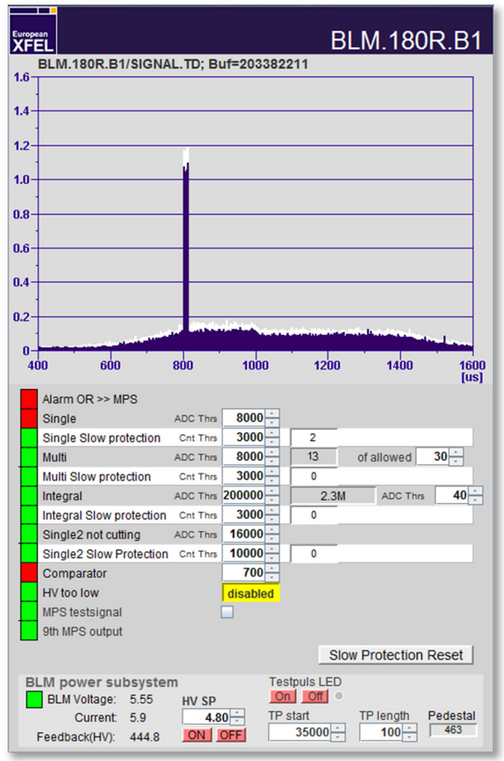




- Integral alarm due to darkcurrent, alarm threshold exceeded
  - Slow protection counter increments
- Slow protection counter reached threshold
  - Alarm still there since it is not a beam based loss
  - Reset necessary
- High Voltage (HV) alarm, PMT cannot work, BLM not functional
  - No beam possible
  - Can be disabled
- MPS testsignal, can be switched on to check BLM alarm response

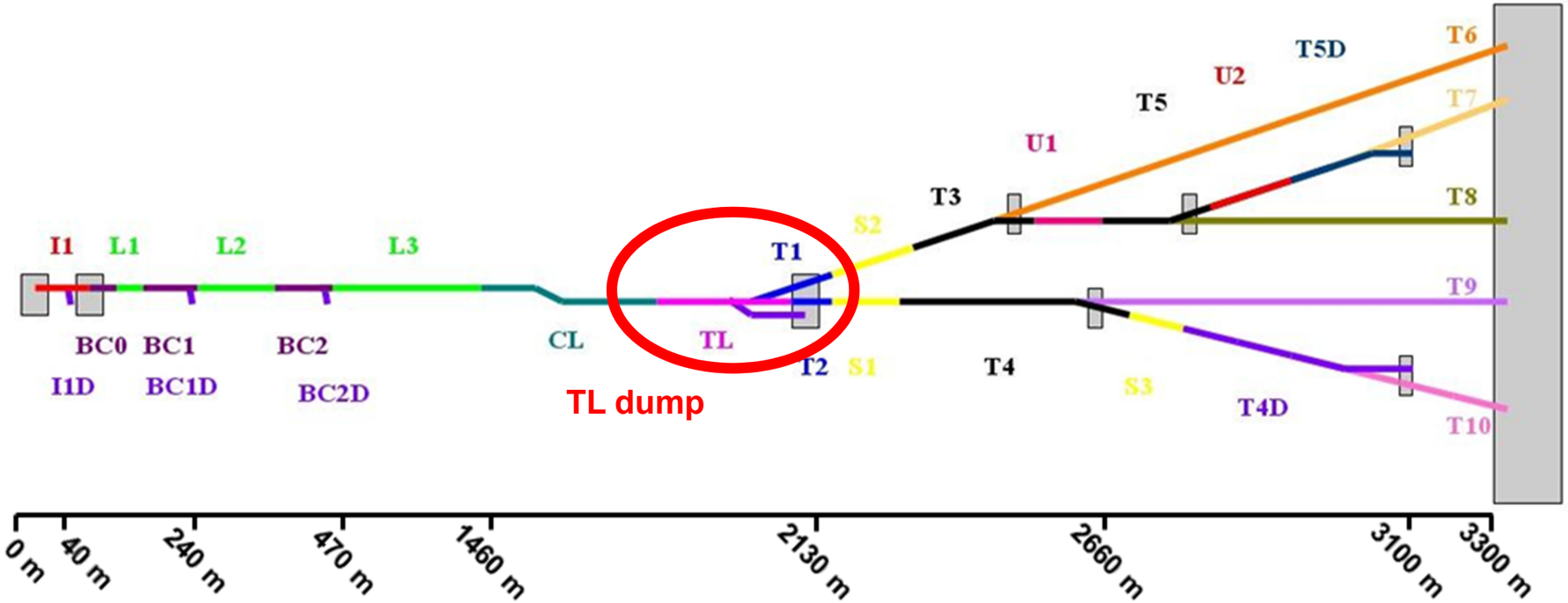
BLM Alarm History Plot





- Alarm history plot for each BLM
  - Kind of alarms traceable
- Complete traces stored for two weeks in DAQ system (reduced data from ADC sample rate of 45 MHz to 4.5 MHz)
  → For all BLMs roughly 1TB/day

BLM Alarm Latency Decrease

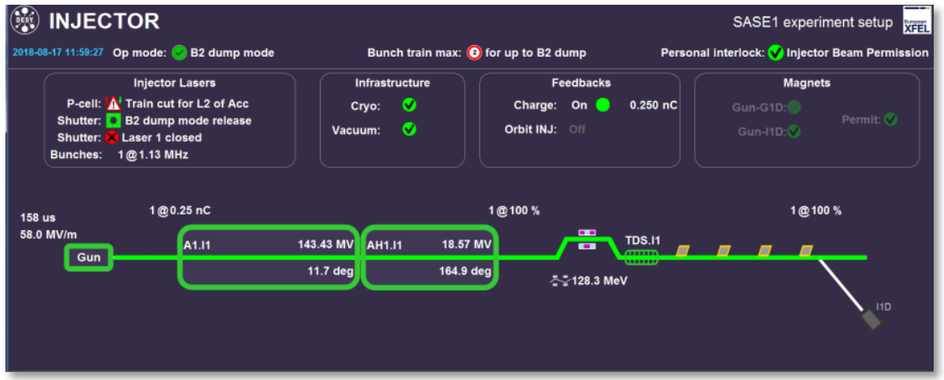


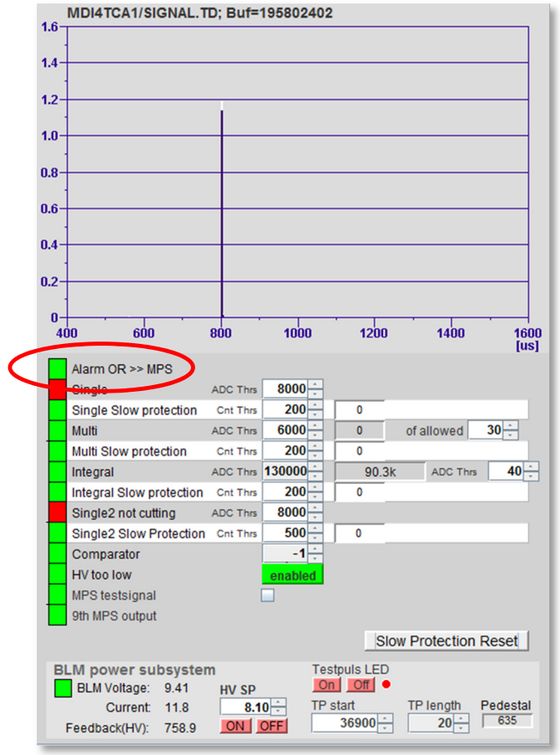
- Max latency for the hole machine 28us
- BLM Alarm in one of the SASE branch
  - Bunchtrain redirected to TL dump
  - Decreases cut latency to 7us for branches

BLM Alarm Masking of Dedicated Losses

- Streaked bunch by TDS and kicked to off axis screen (in Injector or in BC2 section)
- Fast Wire scan (Scan of complete train with up to 2700 bunches, masking necessary not to cut the bunch train during measurement)
  See also WEPHA086 *„A Fast Wire Scanner System for the European XFEL and its Impact to Safety Systems"*
- Alarms get not masked when
  - Screen inserted (only single bunch possible)
  - Slow wire scan (single bunch), in case wire gets stuck

→ Slow protection will stop beam after 5 minutes at the latest





Alarm not redirected to MPS

BLM Calibration Concept

- No absolute calibration

- Get activation results from
  - Measurements from radiation department:
    Activation profile of the machine
  - Additional information from RadFet dosimetry system
  - Thermoluminescent dosimeter (TLDs)

- Strategy for the warm beamline
  - Use activation profile, look for non tolerable increase and tighten BLM threshold or step up PMT voltage at these positions

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However:
Main goal of the BLM system is <u>not</u> to keep activation low but to switch off as fast as possible within a bunchtrain to prevent machine from substantial damage (within seconds at max. bunch number and charge)

Conclusion

- 472 BLMs installed
- 78 RTMs in 58 MTCA Crates
- Different independent configurable alarm thresholds
- Automatic masking of dedicated losses
- Slow protection prevents permanent high losses
- Dump kicker decreases bunchtrain cut latency
- Fast reaction to losses within max. 28us

Thank you for your attention