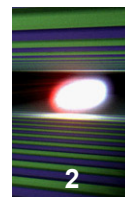


Status of the 10MW MBKs during commissioning of the European XFEL in DESY.

*Vladimir Vogel, Lukasz Butkowski, Andrey Cherepenko,
Stefan Choroba and Jens Hartung*

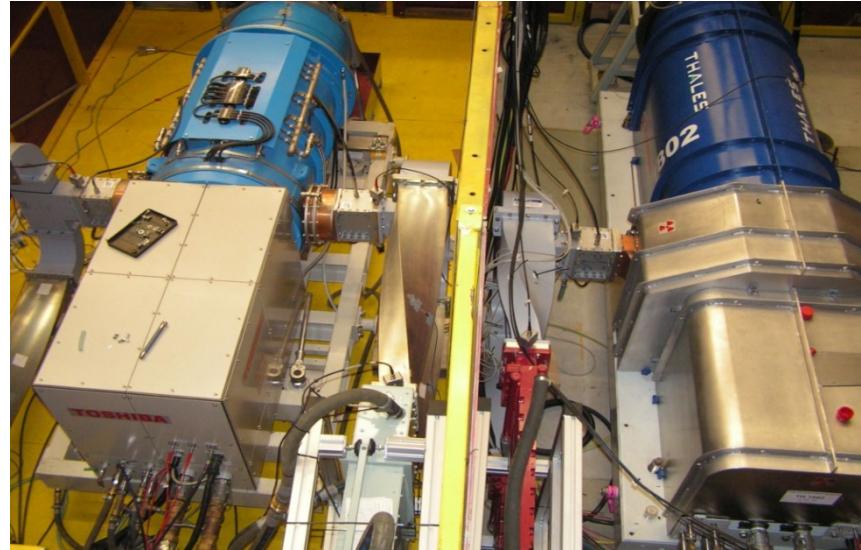




- Klystrons preparation and test results
- Installation in the tunnel
- Protection system for the MBK (KLM)
- Operation statistics
- Conclusion



VKL-8301B, 1 prototype

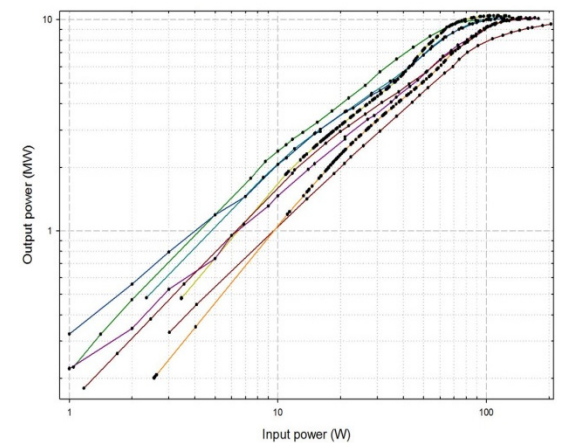
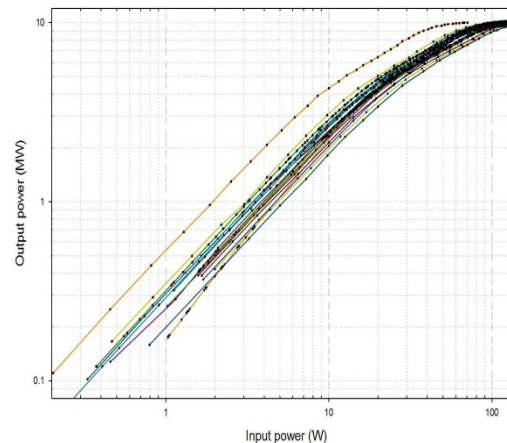


E3736H, 1 prototype +7 series tubes

TH1802, 1 prototype+22 series tubes

XFEL MBK main parameters

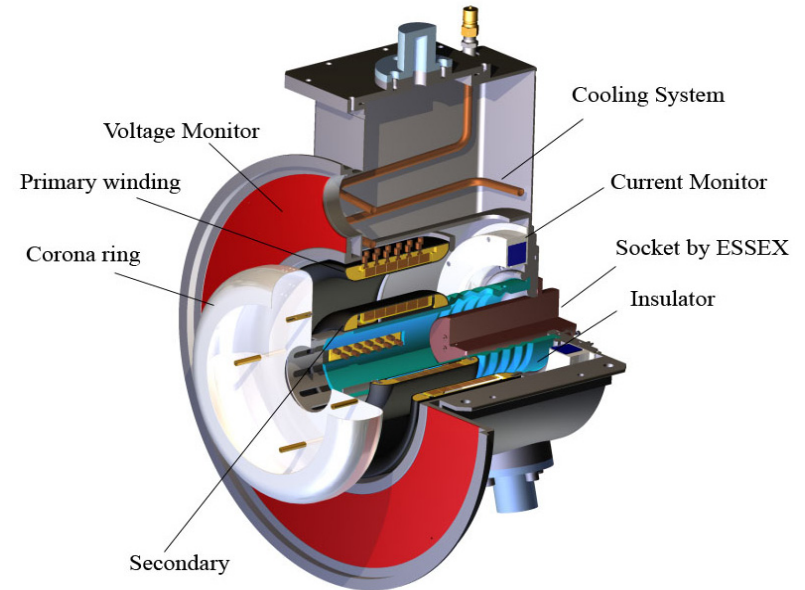
1. Central frequency 1300 MHz
2. Output Power 10 MW
3. Efficiency > 63%
4. RF pulse length 1500 μ S
5. Bandwidth > 3 MHz
6. Average RF power 150 kW





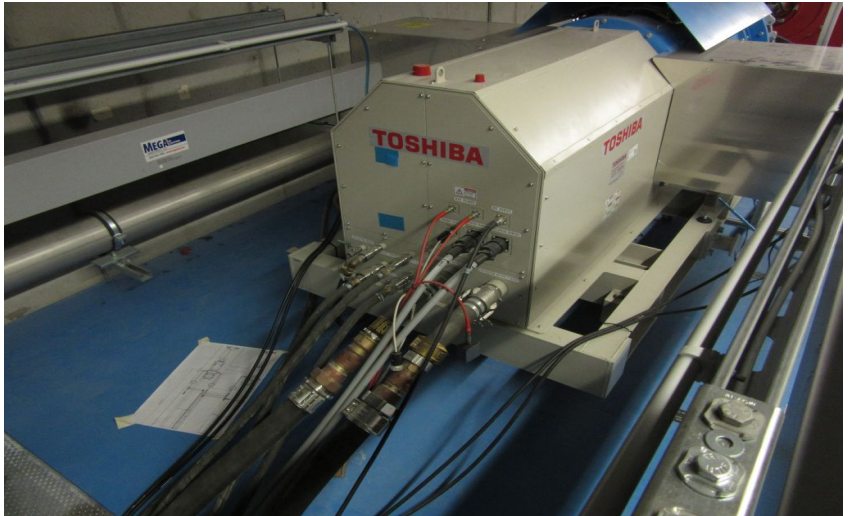
From several types of HV cables and connectors were tested, for the tunnel installation we have chosen connector “PFISTERER 3S” with “NEXANS” 54 kV AC cable. After about 440 days of operation, one of HV cable (RF station A19, U_{hv}=104 kV) was sent back to factory to measure the level of partial discharges.

Pd = 0.9 pC, no difference compare to the initial value.

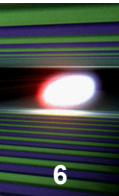


Mains parameters of CM and HFPS

- | | | |
|----|----------------------------------|-------------|
| 1. | Working frequency | 1.6 kHz |
| 2. | Power | up to 840 W |
| 3. | Stability of power | +/- 0.3% |
| 4. | Oil volume in CM | < 30 litres |
| 5. | Max electrical field strength | < 35 kV/cm |
| 6. | Accuracy for current measurement | +/-0.1% |



Klystron Life time Management system (KLM) protection and measurement functions



Main goal: to have the lifetime of each klystron not less than 40000 hours

■ Protection functions:

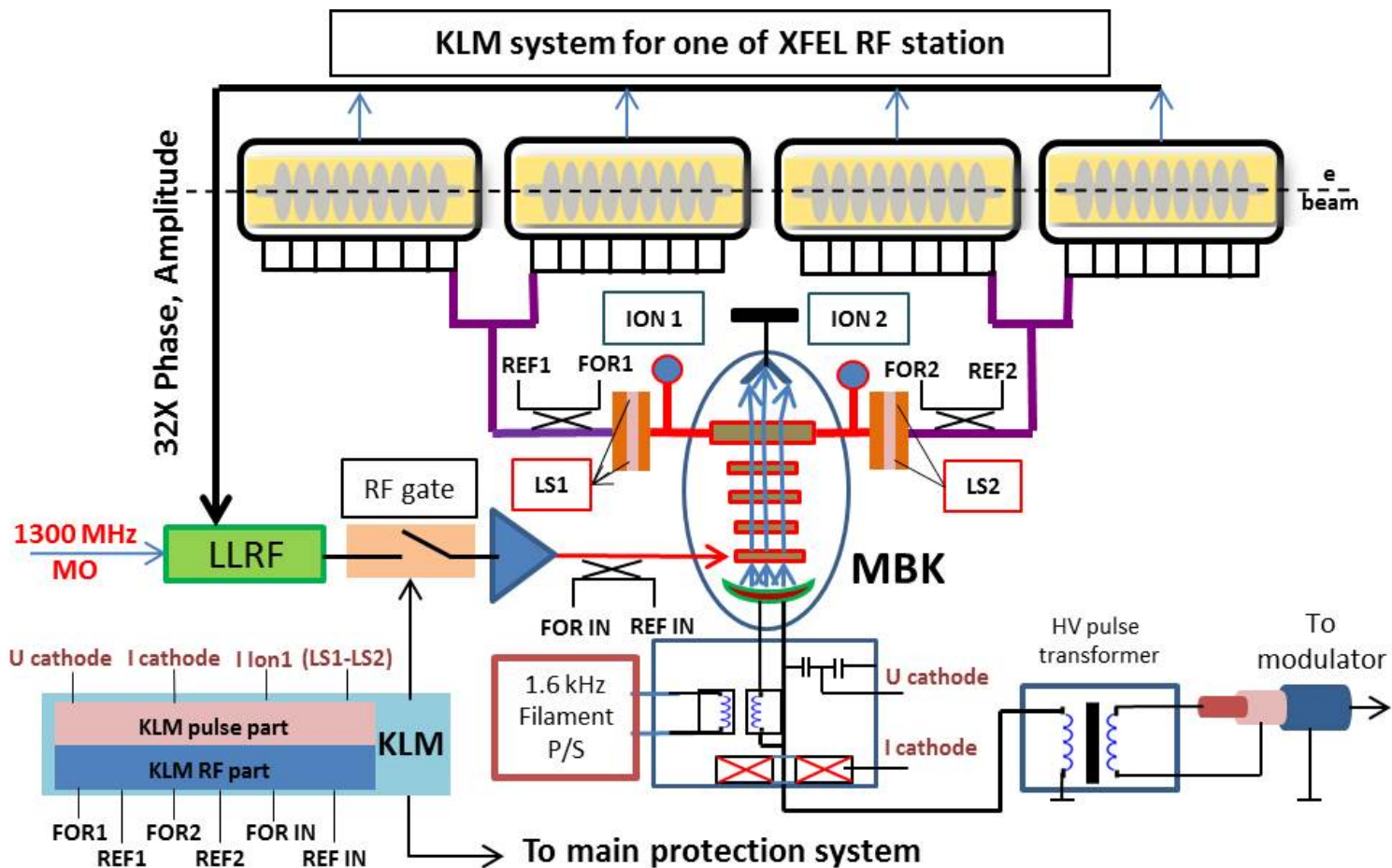
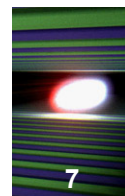
- RF breakdown inside tube detection;
- Arcs in WG system detection;
- Limitation of input power to the saturation level;
- Arcs near output windows detection;
- Bad vacuum in the tube detection;
- Gun HV arc detection;

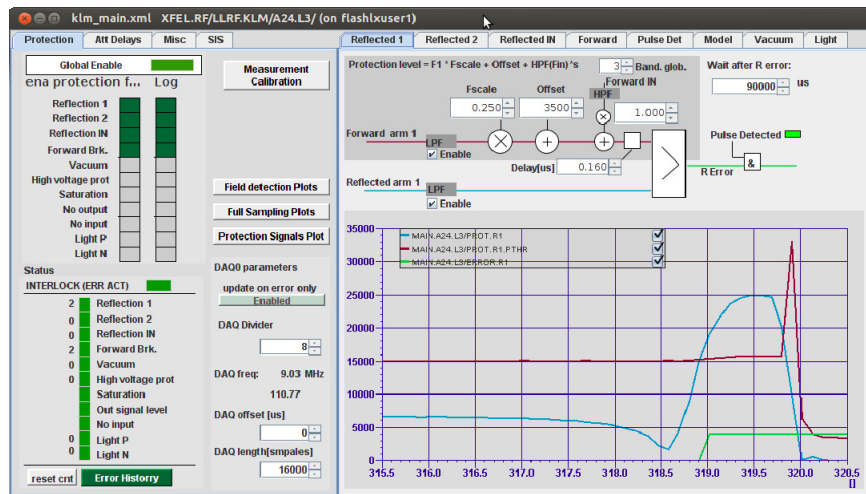
In case of event:

1. RF driving signal will be stop, if necessary then stop signal to the modulator will be send.
2. Start one of recovery modes, in accordance with the kind of event happened.

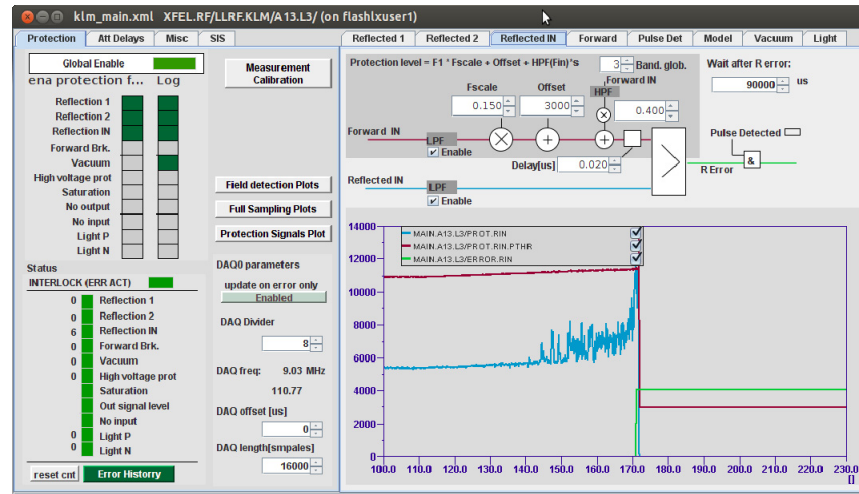
■ Measurement functions:

- Power and phase at klystron outputs and input;
- Levels of high voltage and klystron current;
- Level of partial discharges in HV systems;
- Tube vacuum measurement.

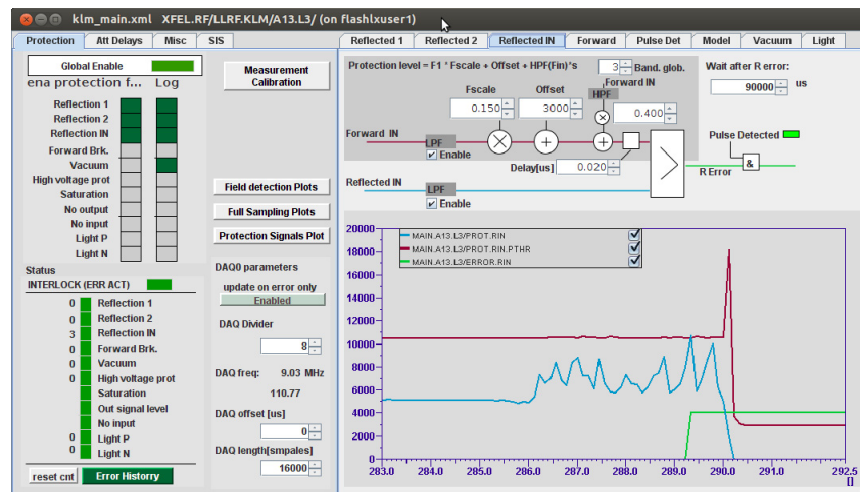




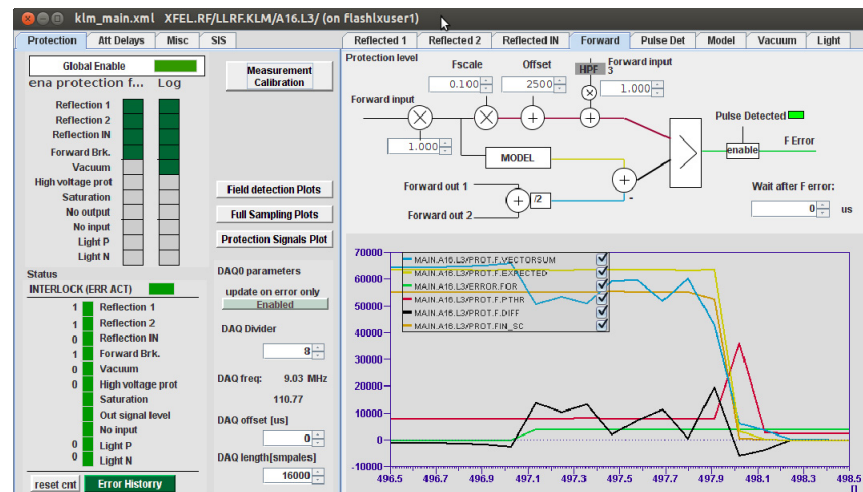
RF breakdown in WG system of ARM1, RF station A24.L3



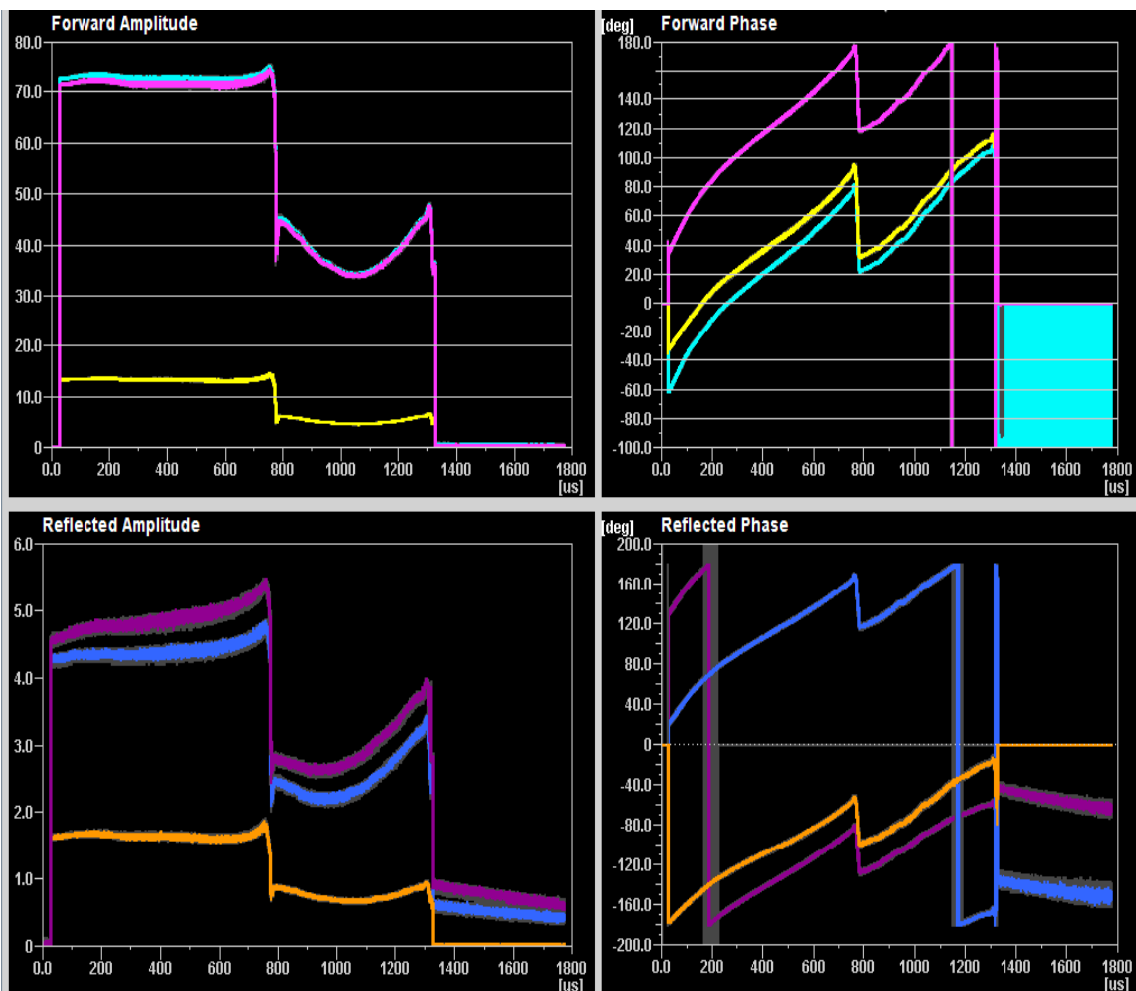
RF breakdown inside klystron, RF station A13.L3



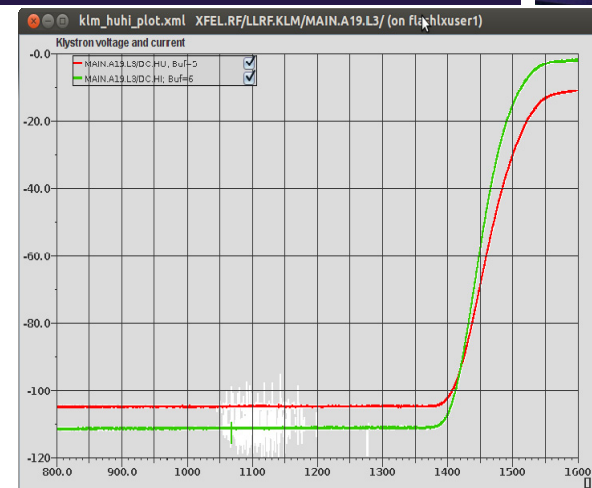
HV breakdown in klystron gun area, RF station A23.L3



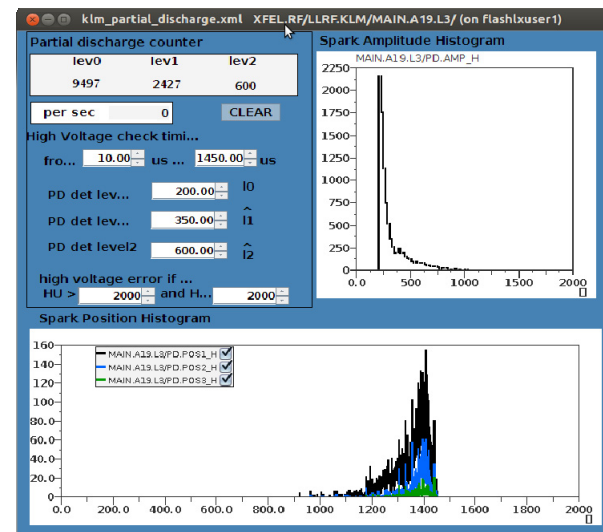
~800 ns between detection and RF stopping, RF station A16.L3



Output forward and reflection amplitudes and phases in case of using the phase modulation, RF station A6.L3 Gradient 760 MV

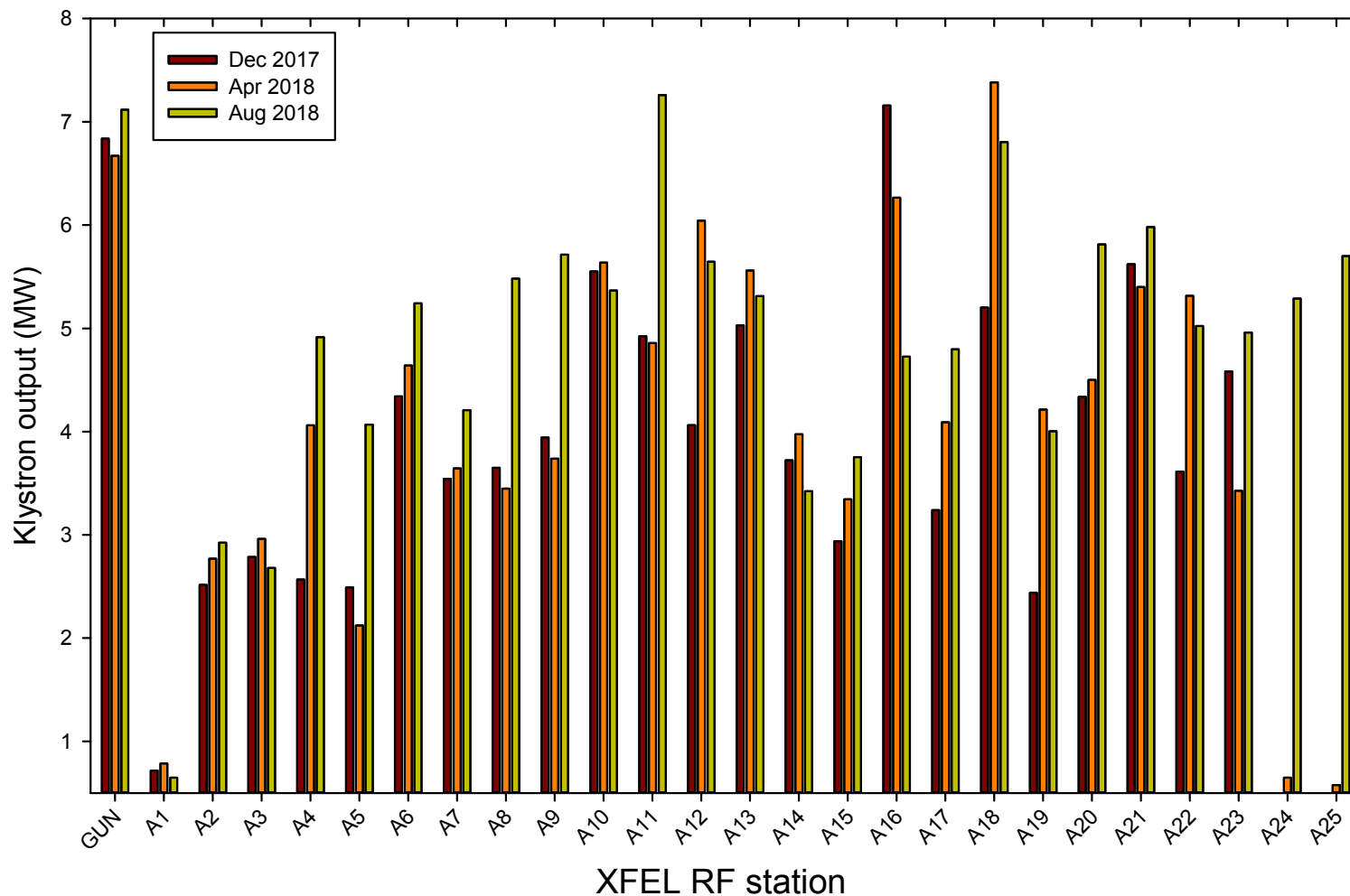
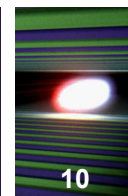


Partial discharges on HV waveform, A19.L3

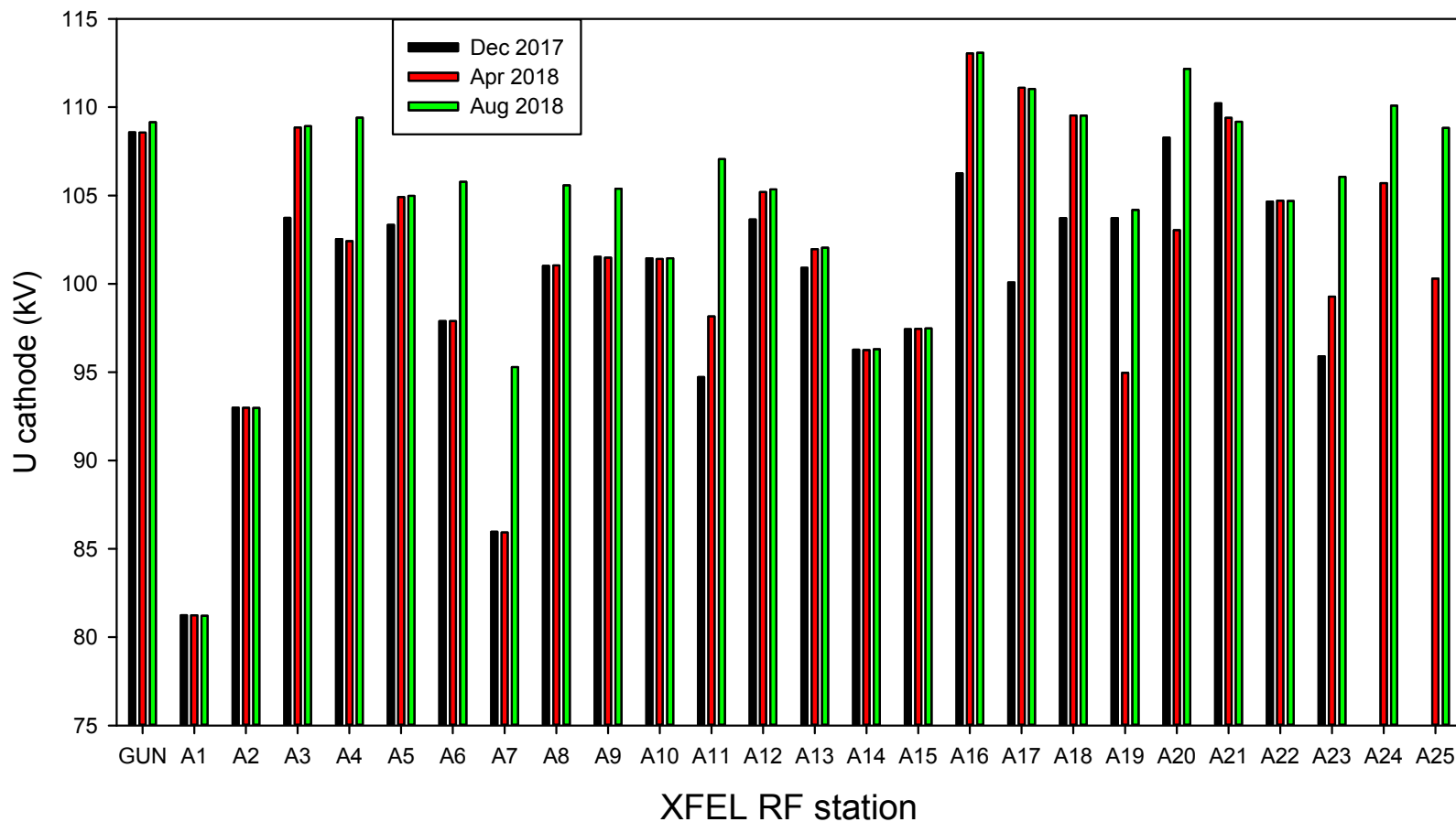
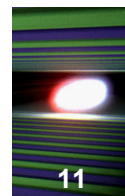


Partial discharges distribution for the time position and amplitude, A19.L3

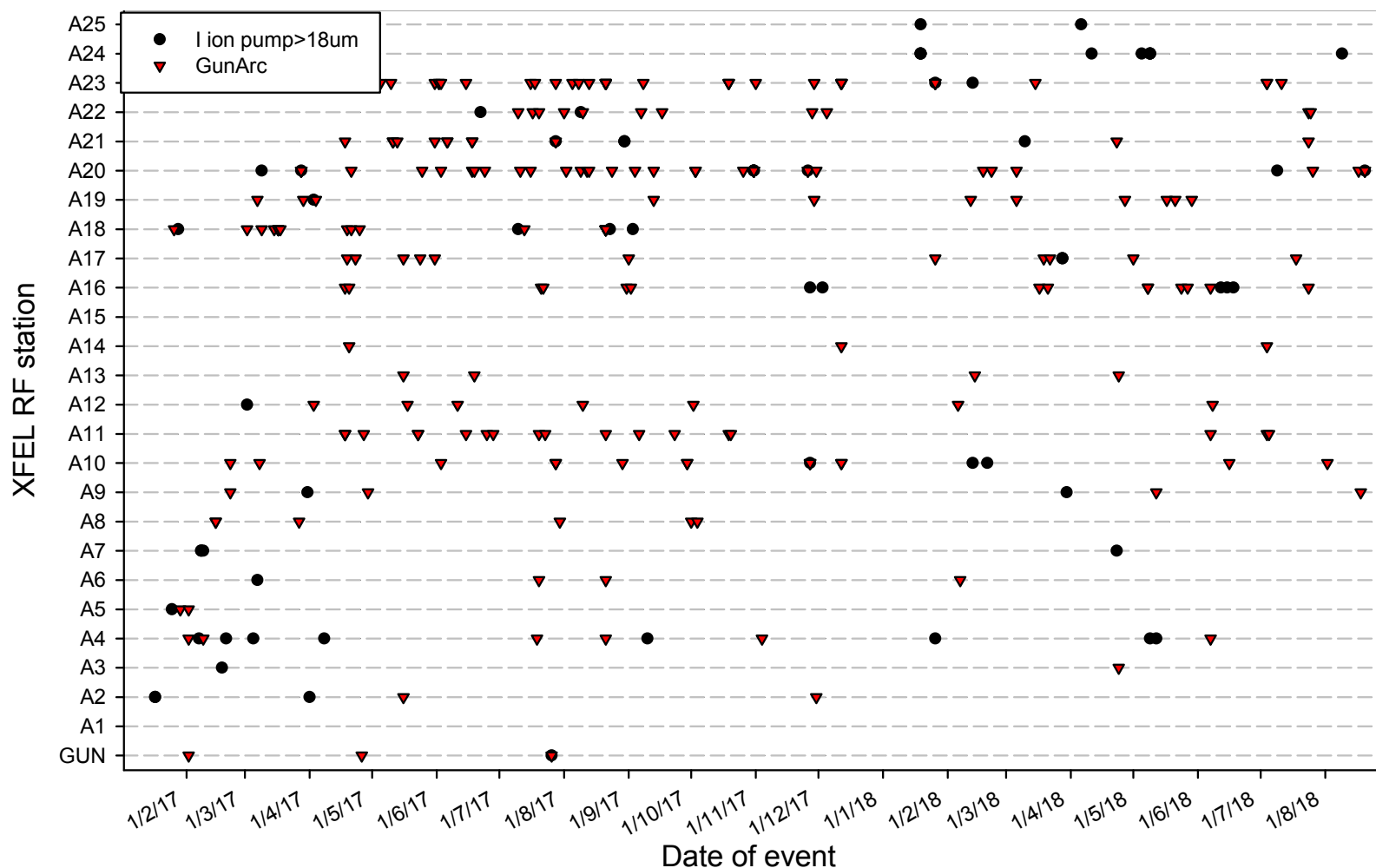
Klystron output power for each of XFEL RF stations, average is 4.87 MW, e-beam energy 17.5 GeV



Cathodes voltage for each RF station, average = 104.5 kV



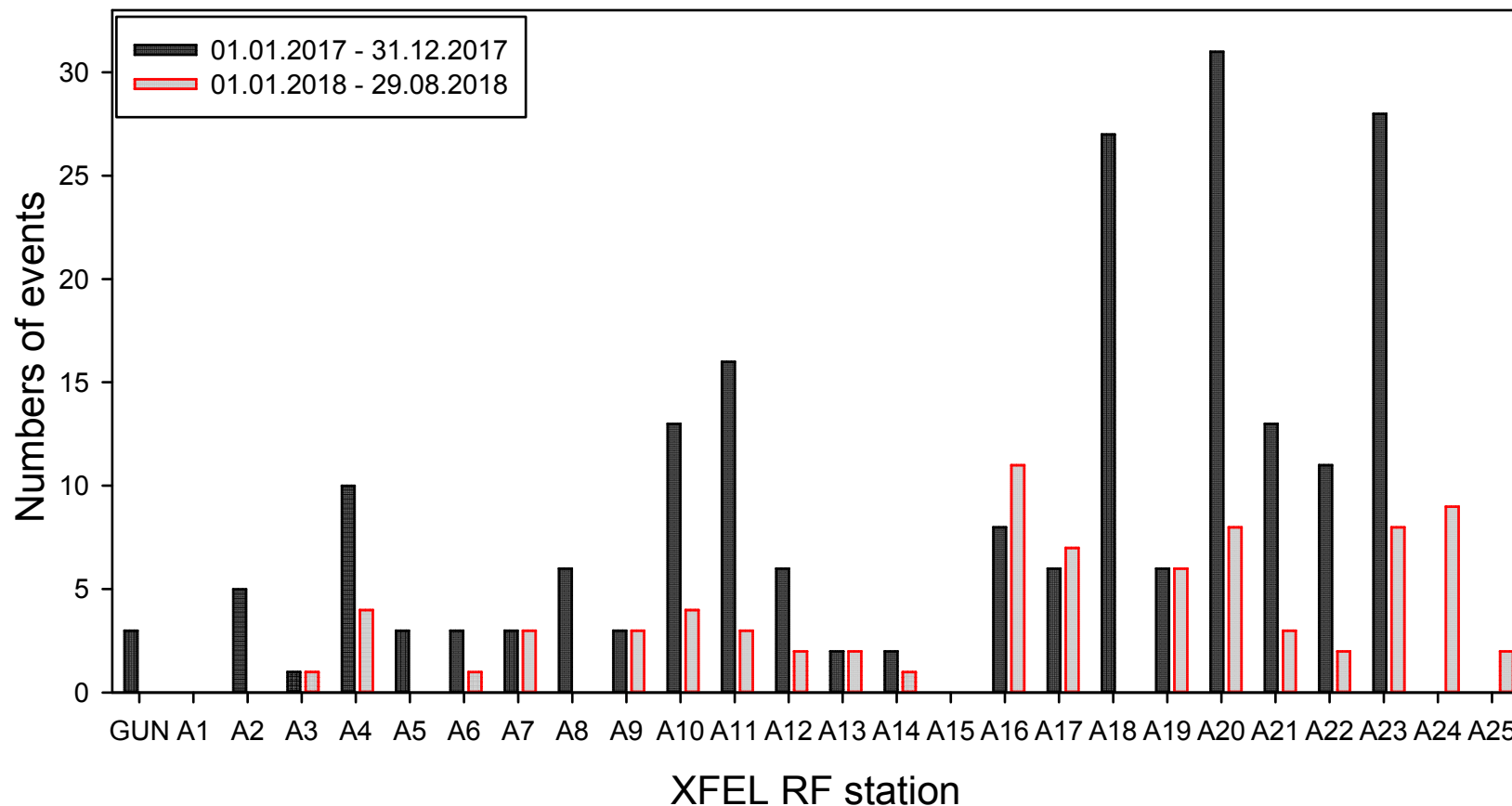
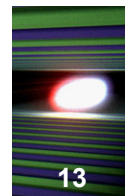
HV and RF breakdowns in XFEL klystrons



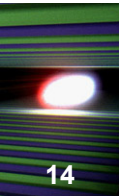
Up to 31/12/2017, total operation time = 7,670 days, klystrons breakdown rate = **0.644** per day for 24 RF stations

Up to 30/08/2018, total operation time = 12,370 days, klystrons breakdown rate = **0.601** per day for 26 RF stations

HV and RF breakdowns in XFEL klystrons



01/01/2018-30/08/2018, operation time = 4,7000 days, klystrons breakdown rate = **0.443** per day for 26 RF stations



In February 2008 the first prototype of MBK for XFEL had been installed on the MBK test stand DESY. Since August 2012 we have started a test and conditioning of the first one from 27th serial MBKs for XFEL. The klystrons were tested together with connection modules (CM) and with different types of HV cables. To increase the lifetime of klystron a special fast protection system (KLM) was designed and tested. In March 2015 we started the installation of MBK to the XFEL tunnel. In July 2018 XFEL reached the design energy of 17.5 GeV. For the moment 26 XFEL RF stations produced in total 124.6 MW impulse power, 4.87 MW in average, the average cathode voltage is 104.5 kV, RF and HV breakdown rate for the MBK during last 8 months is 0.443 breakdowns per day for all of XFEL klystrons.

*Thank you for your
attention!*