The technical interlock for Gun, Booster and TDS at DESY Zeuthen

A gun/ booster IL system is designed to protect the accelerator from damage.
The klystrons must quick stop low level forward power, to prevent dangerous conditions.
The IL system must be clearly structured, to identify the source of problems.
All electronic components in the tunnel must be radiation robust,
An as fast as reasonable reset time is recommended, to have stable conditions during operation or quick progress during conditioning.

The interlock consists of the interlock 3 crate with Altera processor, 8- channel DAC/ADC cards, windows comparator cards, light I/O interface and digi I/O cards.
For fast signals as photomultiplier, photodiode sensors and e- detector there are additional 4 channel analogue input cards with integrating amplifier, fast comparator and light out and ADC out interface.
Some PT100 temperature sensors and the most important vacuum signals go direct to the interlock 3 crate. Full signal description list you can find in
N:\4groups\zn_electronics\Projects\Intlk3_PITZ_GUN\Signal_description\Gun_Booster
_CTS_Interlock_yyyymmdd.xlsm
All analogue outputs of the getter pumps and vacuum gages are connected to a SPS, which closes the neighbor valves automatically, when the vacuum is bad. These signals can be masked from the SPS panel. The SPS delivers a combined signal to the interlock crate.

Several bimetal temperature sensors observe the magnet temperatures and switch off the magnet power supplies in case of overheating via polarized electronic relays. When we upgrade the system to interlock 4, this function will be removed from the Gun/Booster/TDS interlock.

Each photo and e- detector signal is split at the input of the comparator to the ADC. With ADC polyparameter the magnitude is set to the real values, offset can be compensated.
The comparator is stretching short pulses in case of switching with positive feedback RC to several 100 ns. Since we use 1 nF capacitors in feedback of the preamplifier, pulses at the comparator input signals has decay times of several µs. This is important to see the signals in the ADC spectrum, which have a sampling rate of 1 µs. Furthermore oscillating pick up is suppressed.

Interlock cards for PMs, PDs and e- detector:

Preamplifier LMH6655 (bandwith 250 MHz)
comparator TL 3016 (7 ns)
analog output to ADC and optical output
detail schematic in appendix

Events detection:

Photo-detection of breakdowns, arcing and sparking near the incoupler and RF window are important.
Photo multipliers without internal HV supply are used for fast light detecting from 0,1 …200 lux. With the external HV the sensitivity is controlled during operation and radiation hardness is realized.
Photo diode detectors are additional used for light detecting from 1… 40 lux with rise times of ca. 2 µs or for gamma shower detection in connection with scintillating sticks.
Fast response time and light cables to the klystrons make it possible, to switch off the RF power within ca. 5 µs. With adapting the firmware the number of disabled pulses can be defined depending of the interlock type. In cases of not critical events the RF is recovered fast and the the cavity resonance is not lost.
All photo detectors are calibrated using a light meter LM-100 (permanent light).
All photo sensors are calibrated the same way with light pulses from 10 …1000 µs. PM HV should not be changed after finding the working point, because tracing back the HV values is difficult.

E-detector:
A rising flow of particles due to a multipactor or residual gas ionization can be detected. The sensor itself is a vacuum pick-up with an applied voltage of 10…30 V.
The IL response is simulated with current of 0,3 mA. reasonable threshold of the interlock system is between 1 … 10 mA, it depends of the antennas and the distance to the RF source.

Temperature:
The RF window frame temperature is monitored with PT100s and the ceramics is observed with an IR sensor, if the window makes this possible. The critical point is a temperature gradient not temperature itself. But even quarz windows are only transparent at wavelengths between 160…3500 µm (thermal infrared 3…50 µm).

Bad vacuum:
Rising pressure due to outgasing in the cavity volume is an indicator of some surface processes like multipacting or breakdown. Long exposure to bad vacuum conditions leads to degradation of the Cs2Te cathode quantum efficiency (oxidation and ion back bombardment).
The measurement is based on the read-out of the ion getter pump currents, which is known to be precise only for relatively bad vacuum.

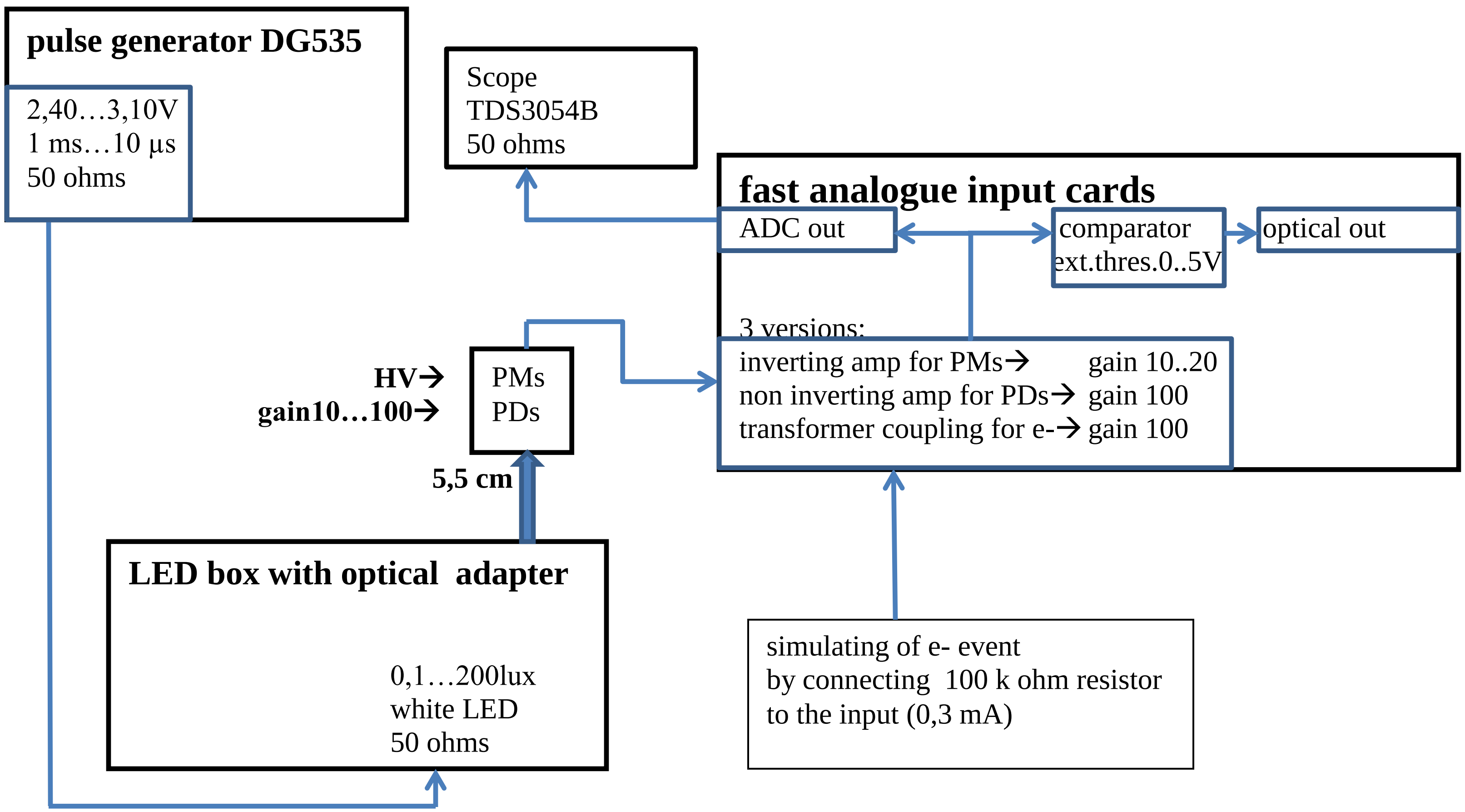
The reflected power measurement is only implemented in the klystron interlock, but could be integrated for the gun interlock as well.

Potential extension:

Acoustic positioning system:
- piezo detectors. Reconstructing the 3D position of the breakdown are under investigation at the moment.

Cathode contact detector
- measurement of the contact resistivity, capacity, inductivity

Testsetup for PMs, PDs and e- detector

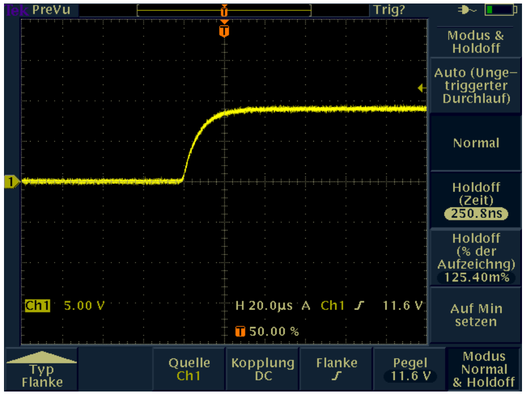


Photomultiplier:

PM type Hamamatsu RU 5600 U, base E5780, HV supply max. 800 V with CAEN crate,
RS 232 control via GUI (diagnostic→HV power supply)
PM current is observed

PM calibration at PITZ to reach 1 V output after amp with gain 20, HH LED

name	HV for 1 Lux	HV for 10 Lux	HV for 100 Lux	HV 1 Lux corr to ref	HV 10 Lux corr to ref	HV 100 Lux corr to ref	frame
PM Gun coup	675	499	365	94	74	54	old
PM Gun wind	566	415	304	-15	-10	-7	new
PM Boo cell 1	582	420	300	1	-5	-11	old
PM Boo cell 14	576	426	312	-5	1	1	old
PM Boo WG 1	643	472	340	62	47	29	new
PM Boo WG2	627	462	336	46	37	25	new
reference PM	581	425	311	0	0	0	new
PM G win2mm	925	666	475	344	241	164	new
ref. PM 2mm			456				



PM reference to DESY Hamburg, 1 lux, same LED

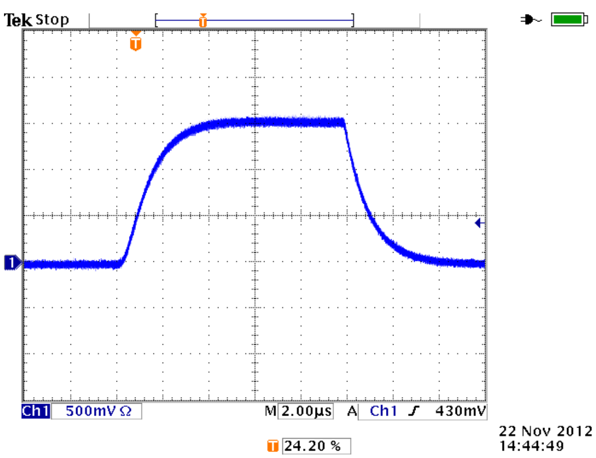
PM calibration at DESY Hamburg

adjusting with potentiometer the internal HV supply to 10 V output signal of amplifier at 1 lux

no HV breakdown for 1,3 ms light pulses visible

threshold usually set to 50 %

at the accelerator modules 3 mm aperture is inserted after the calibration

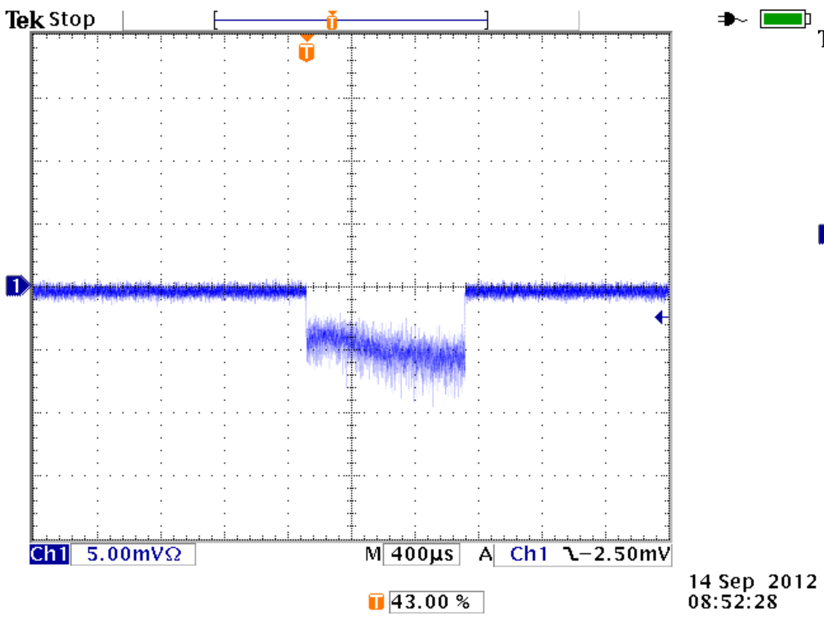


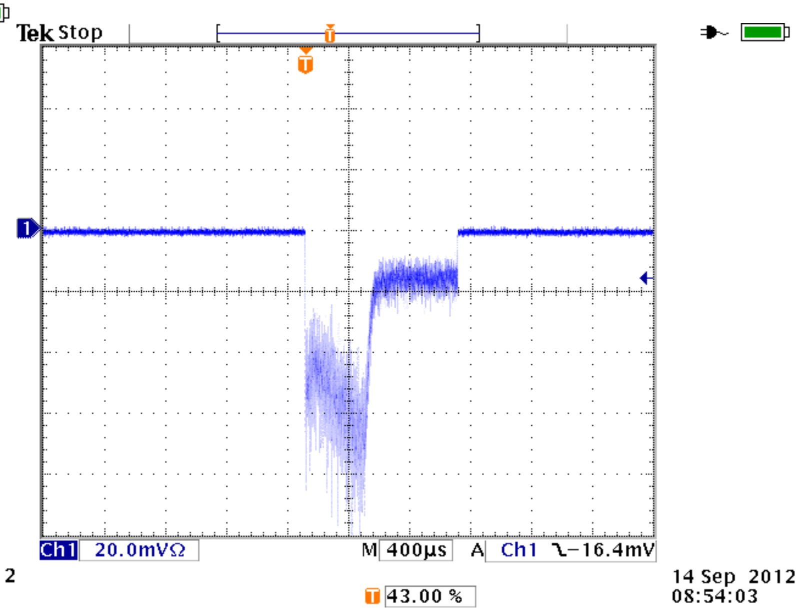
PM calibration at DESY Zeuthen

adjusting with external HV supply to defined output signal of amplifier for 1, 10, 100 lux

amplifier gain 20, integrating capacitance of 1 nF in feedback

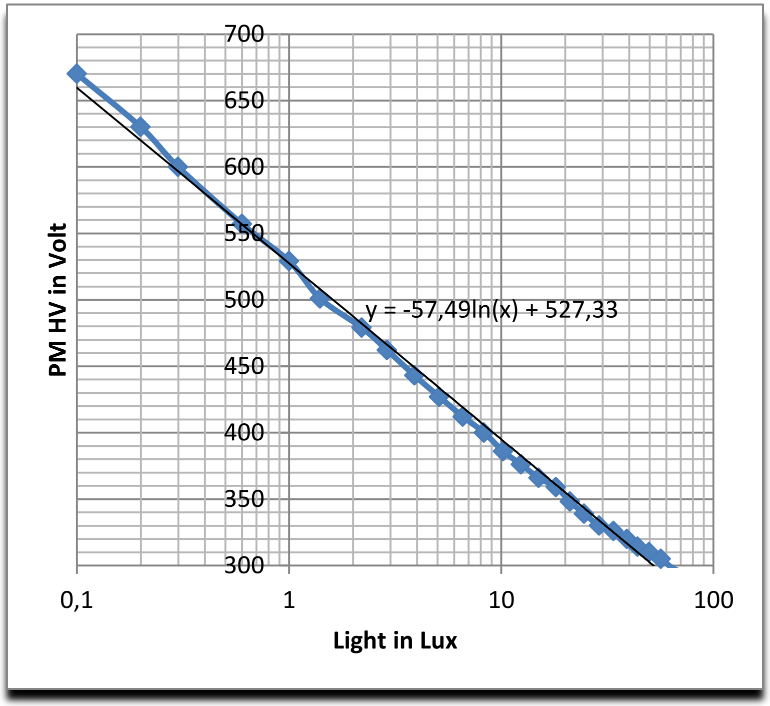
here 1 lux, 614 V, reference PM

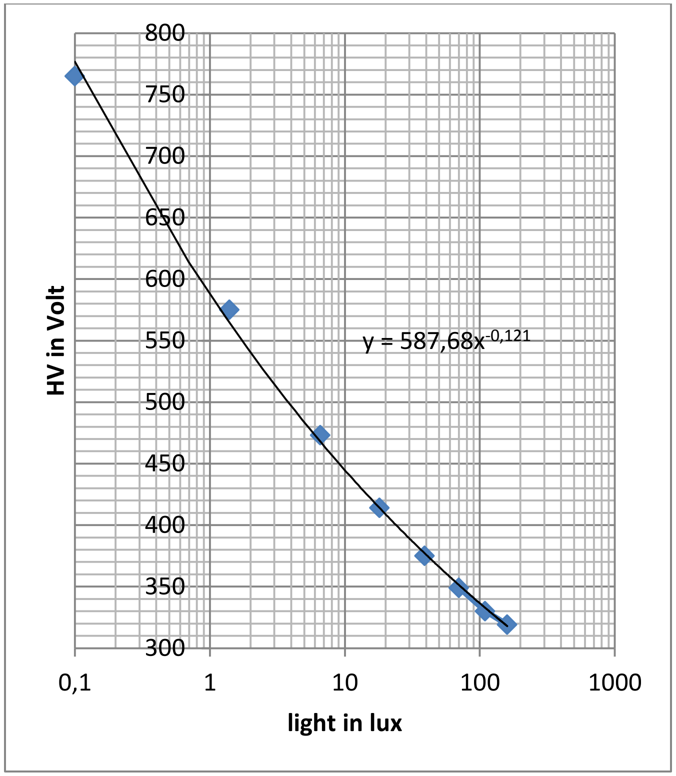




500 V **700 V**

PM response for 1 ms light pulses of 1 lux, white LED, with HV breakdown





HV versus light for 500 mV output signals

HV versus light for 1,5 V output signals

Photodiode sensors:

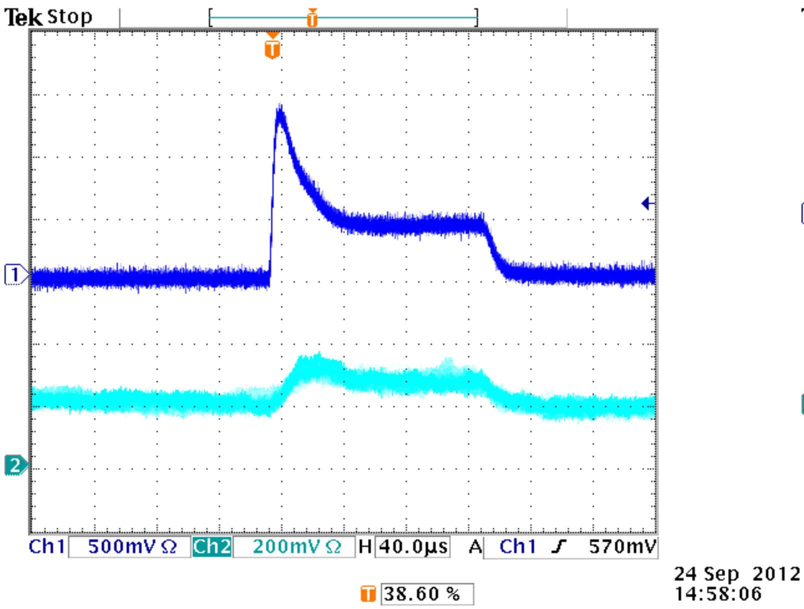
Photodiodes S3072 and S3399 (3 mm circle diameter, fast and sensitive)
current feedback post amplifier EL2260 (bandwith180 MHz, quite radiation hard)
gain 10 for IL components, gain 100 for gamma sensors with scintillators (direct to ADC)
with offset compensation

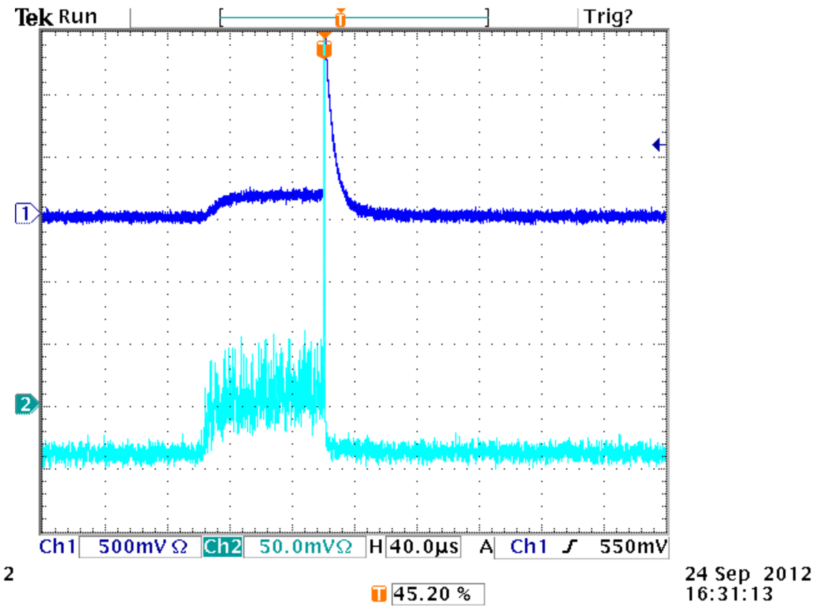
PD scintillator gamma sensors don`t belong to the interlock, but could be used
They are simple to mount, and show in case of light interlocks mostly gamma showers

PD reference table for different sensors at 1 lux

	PD sensor calibration	
name	output in mV	1 Lux, 1 ms
PD Gun WG1	100	low gain PDs
PD Gun WG2	85	
PD Boo WG1	100	
PD Boo WG2	100	
PD Com WG1	100	
PD Com WG2	50	
PD Com WGL	100	
PD Szi G1	1000	high gain PDs
PD Szi G2	1000	gamma
PD Szi G3	1100	sensors
PD Szi G4	1000	with
PD Szi G5	1000	scintillator
PD3399-3	85	
PD3399-4	85	

PM and PD signals during booster operation





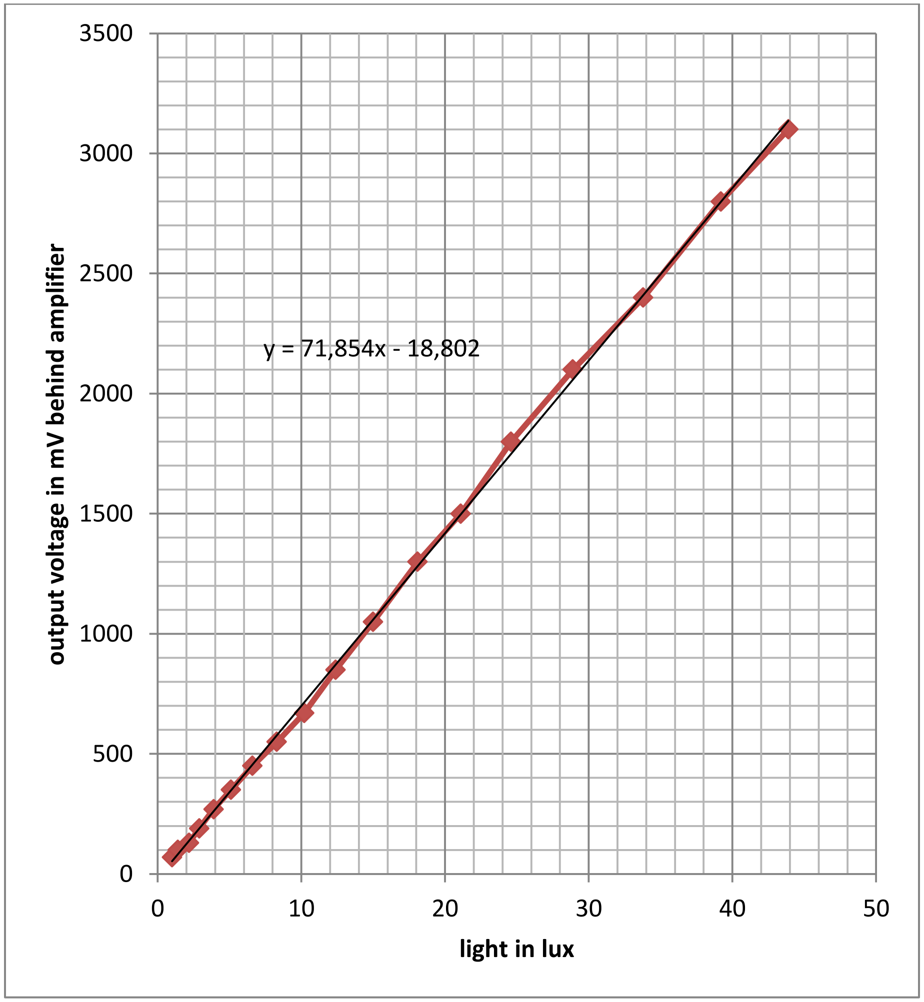
up: Boo_PM_WG1 VAC (saturation effects)

down: Boo_PD_WG2

up: Interlock: Boo_PM_cell1

down: Gun PD_WG2 (crosstalk due to gamma shower)

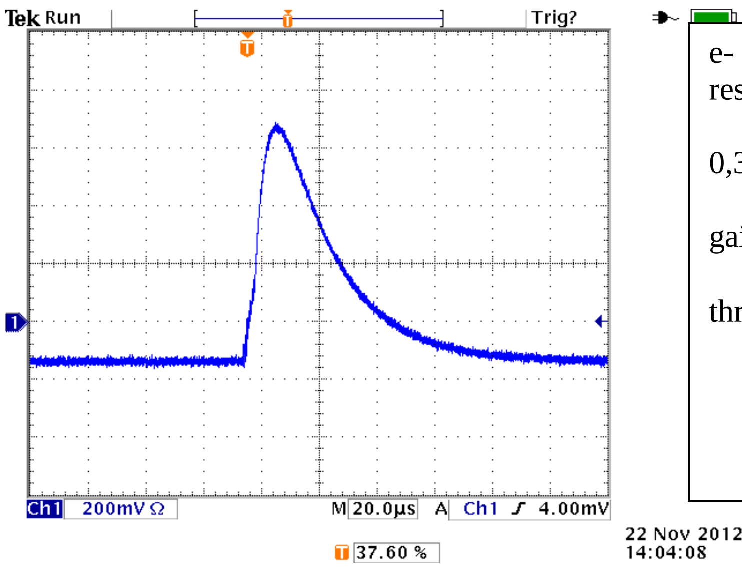
PD output signal versus light 1…50 lux



e- detector:

with mini transformers 1TT16KK81 suction voltage of 10…30 V is applied to the antennas

e- signals with simulated 0,3 mA current



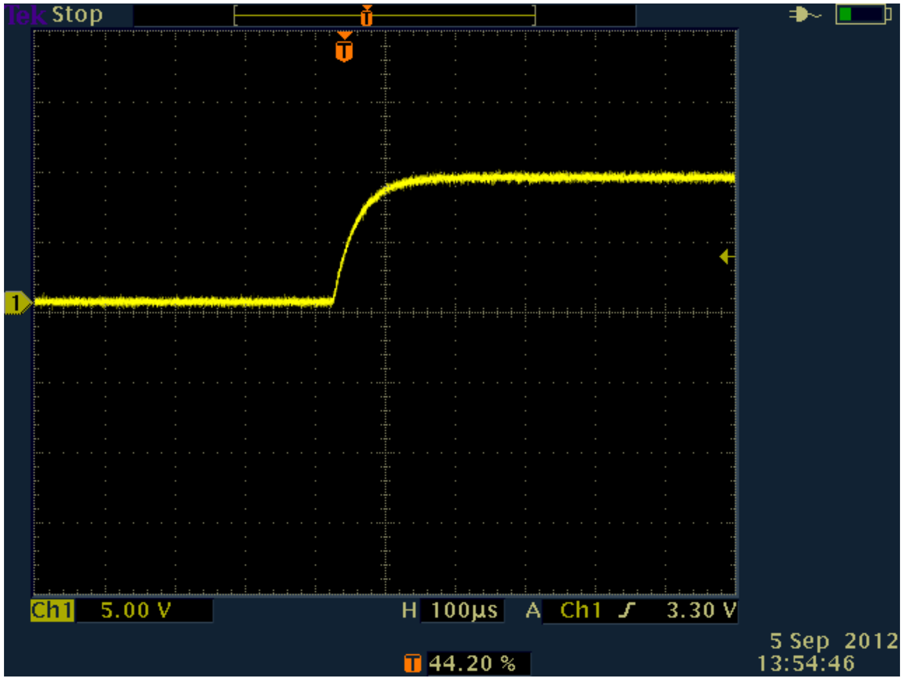
e- event simulated with 100 k ohms resistor (30 V suction voltage)

0,3 mA → 0,8 mA signal after amplifier

gain 100, 1 nF int. capacitance

threshold of 2,6 V means 1 mA

e- signals reference to DESY Hamburg

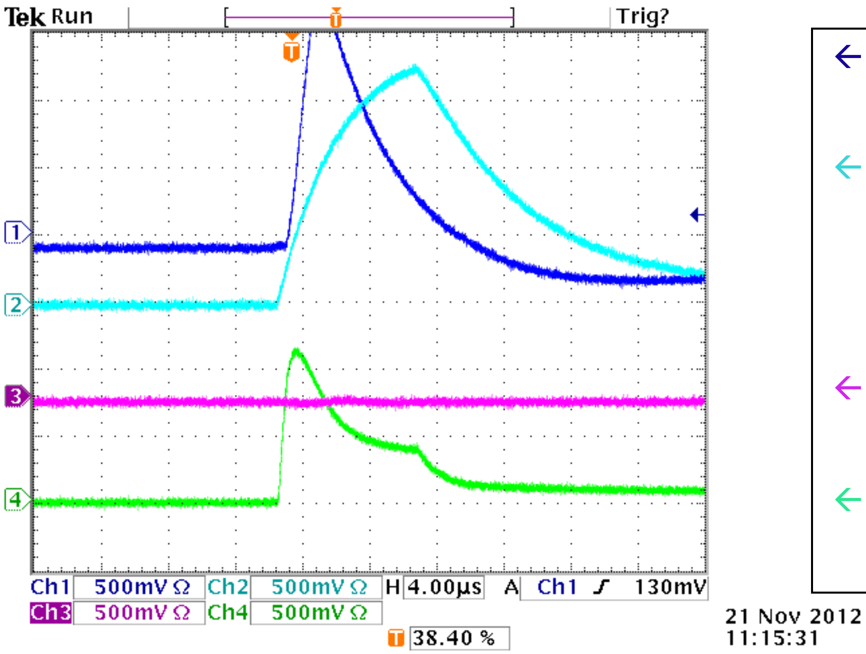


10 mA current corresponds to 10 V output signal

threshold is set to about 50 %

this means: e- IL current → 5 mA

e- and PM IL signals during Gun 3.2 operation from 21.11.12



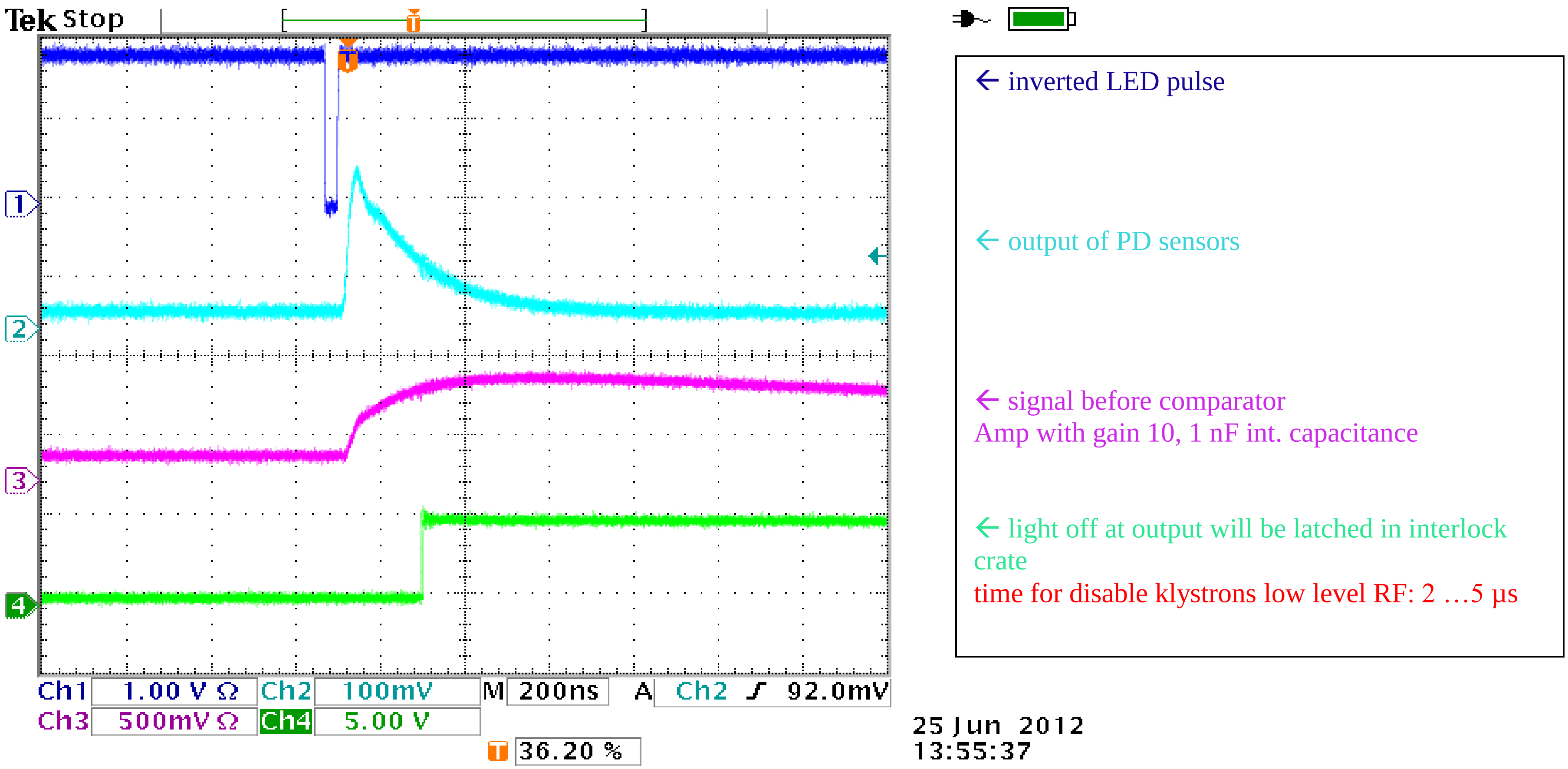
← e- event Gun coupler

← PM Gun coupler (12 lux)

← e- Gun window

← PM Gun window (120 lux)

Interlock timing:



Conclusion
of comparing interlock electronic at Zeuthen and Hamburg

we use now the same test light sources and can unify the thresholds, but it depends of the precise environment

main difference is the response time for switching off the klystrons in case of interlock (Zeuthen 2…5 µs)
at DESY Hamburg due to the slow relay outputs only the next RF pulse is disabled, this might be dangerous for the gun

Thresholds
of the interlock system depend on the environment. Even for normal operation the dark current light can vary from 1 … 200 lux. With the external HV control of the PMs or apertures, the output signal can be set to a reasonable value. In case of sparks this level is exceeded clearly, so that this events are easy to detect.
The e- detector thresholds depend of the antenna length and the distance to the RF source.
Thresholds of 1 … 10 mA should be fixed after watching the signals with inclusion of light and vacuum events.
If the level of light is known and stable, Photodiode sensors are a cheap alternative.
But crosstalk caused by gamma showers must be prevented with shielding or reasonable thresholds.
The latest list of included interlock signals with thresholds and HV for PMs you can find at:

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