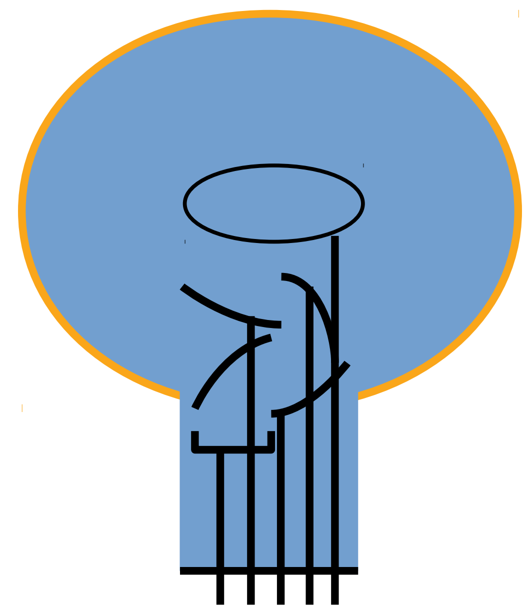
Simulation of PMT charge response

Source: Hamamatsu



Tim Kuhlbusch

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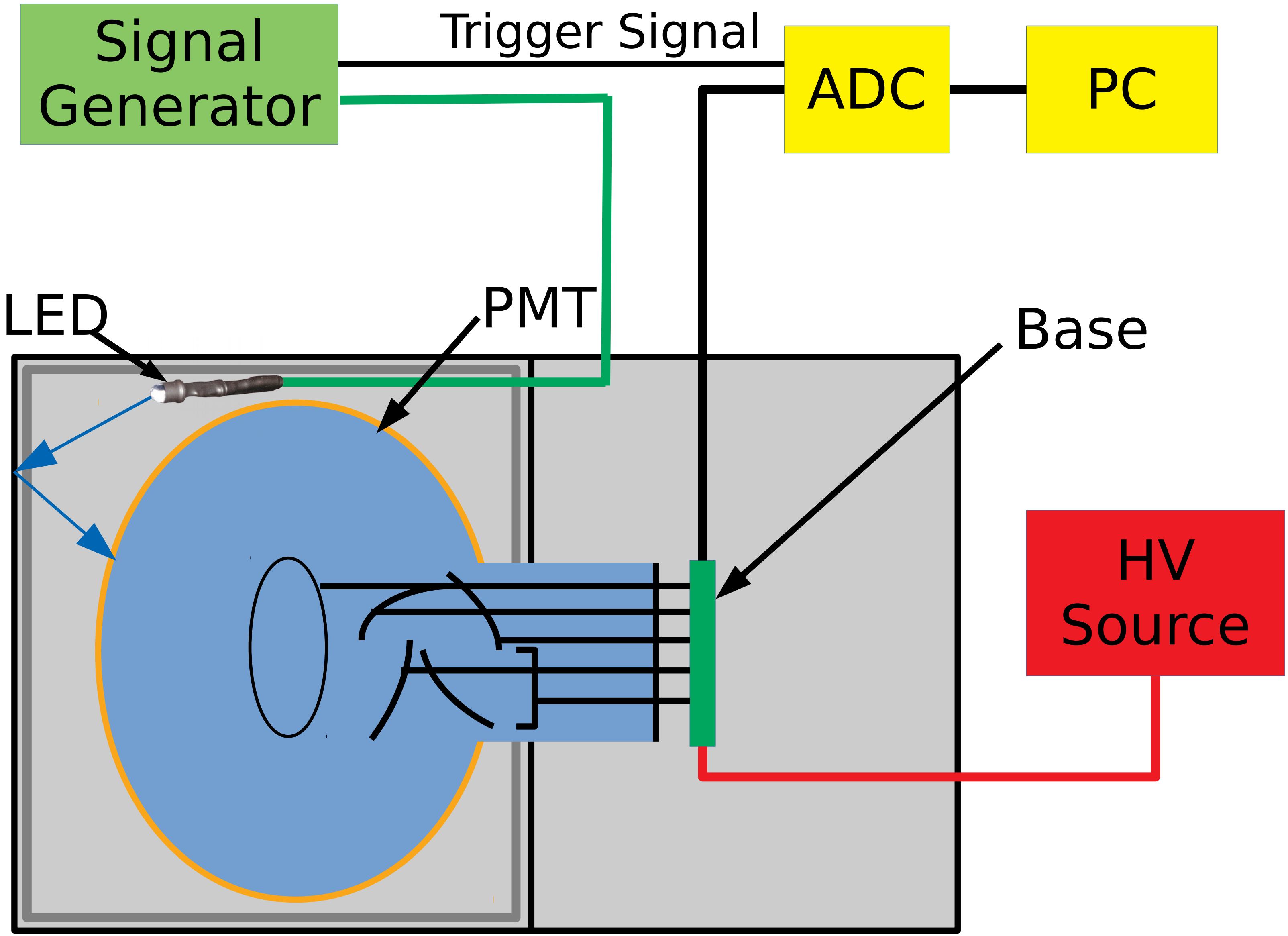
JUNO Forschergruppentreffen Hamburg

Motivation

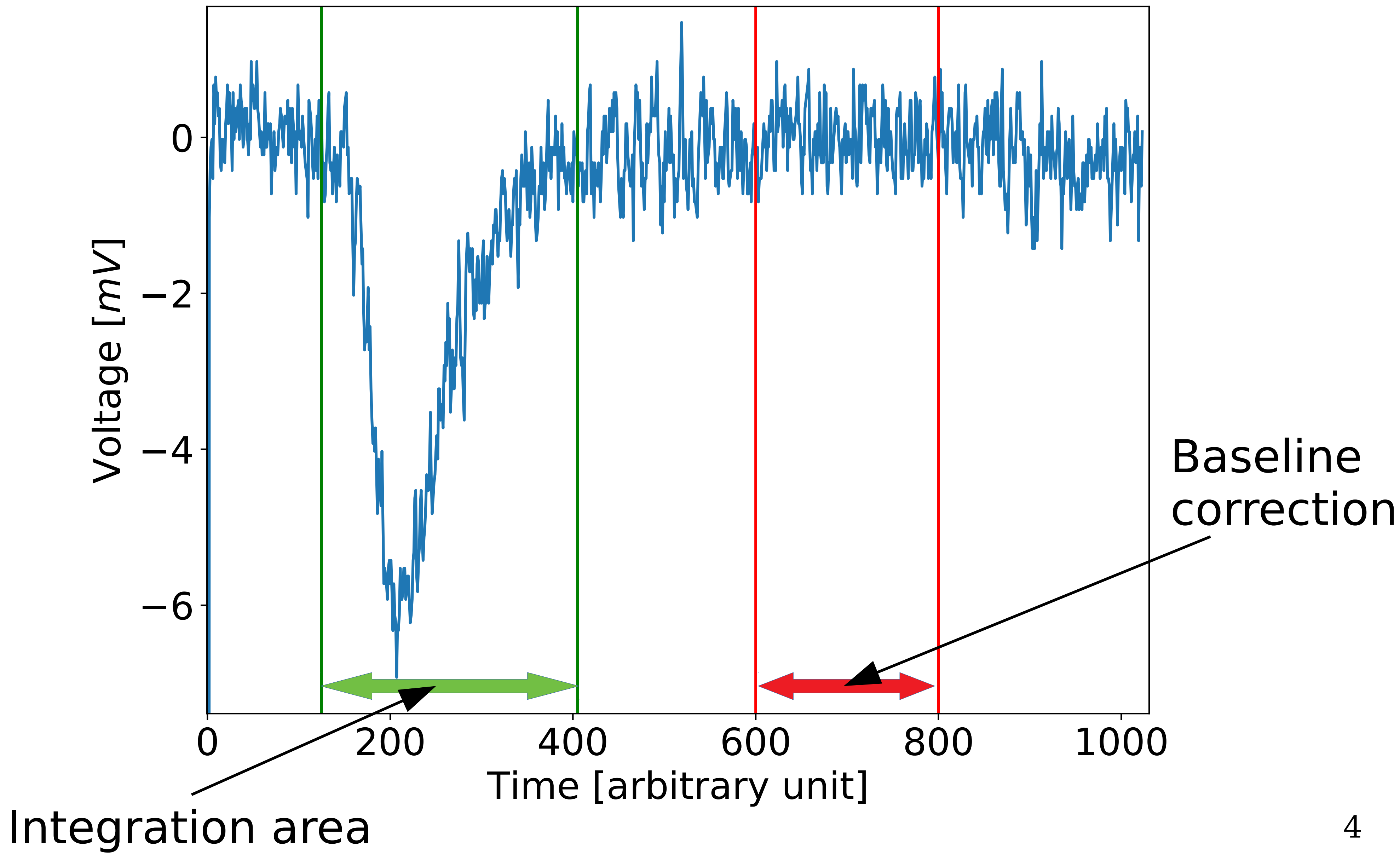
- Goal: determine trigger efficiency for >0 PE
  - For 20” Hamamatsu PMT
  - Important for the energy resolution

  => Measure PMT response

Measurement setup



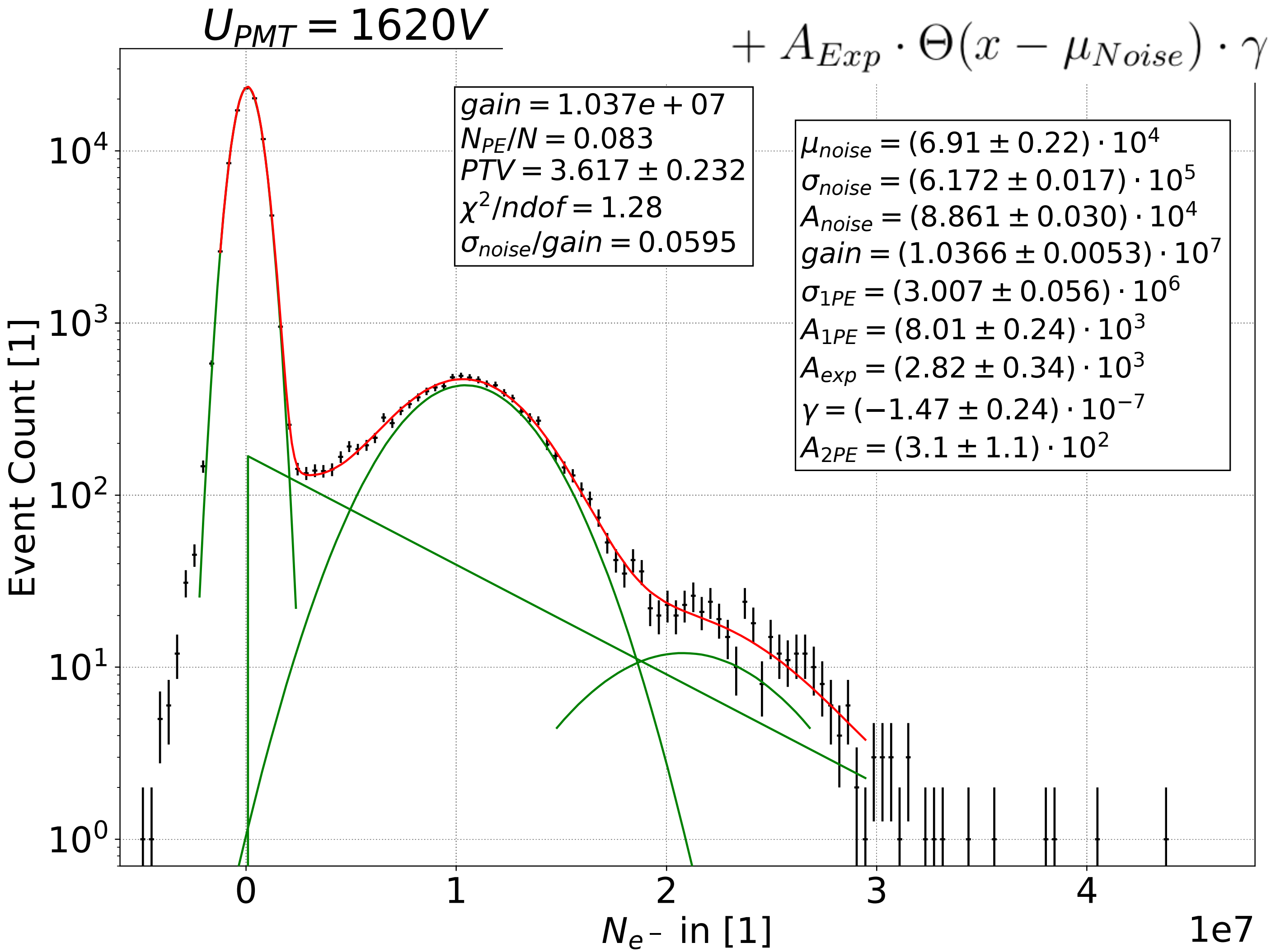
PMT Signal



Voltage [mV]
0
−2
−4
−6
0
200
400
600
800
1000
Time [arbitrary unit]
Baseline correction
Integration area

Histogram of e- counts

$$R_{Ges}(x) = A_{Noise} \cdot N(\mu_{Noise}, \sigma_{Noise}, x)$$
$$+ A_{1PE} \cdot N(\mu_{Noise} + \text{Gain}, \sigma_{1PE}, x)$$
$$+ A_{2PE} \cdot N(\mu_{Noise} + 2 \cdot \text{Gain}, \sqrt{2} \cdot \sigma_{1PE}, x)$$
$$+ A_{Exp} \cdot \Theta(x - \mu_{Noise}) \cdot \gamma \cdot \exp(-\gamma \cdot (x - \mu_{Noise}))$$

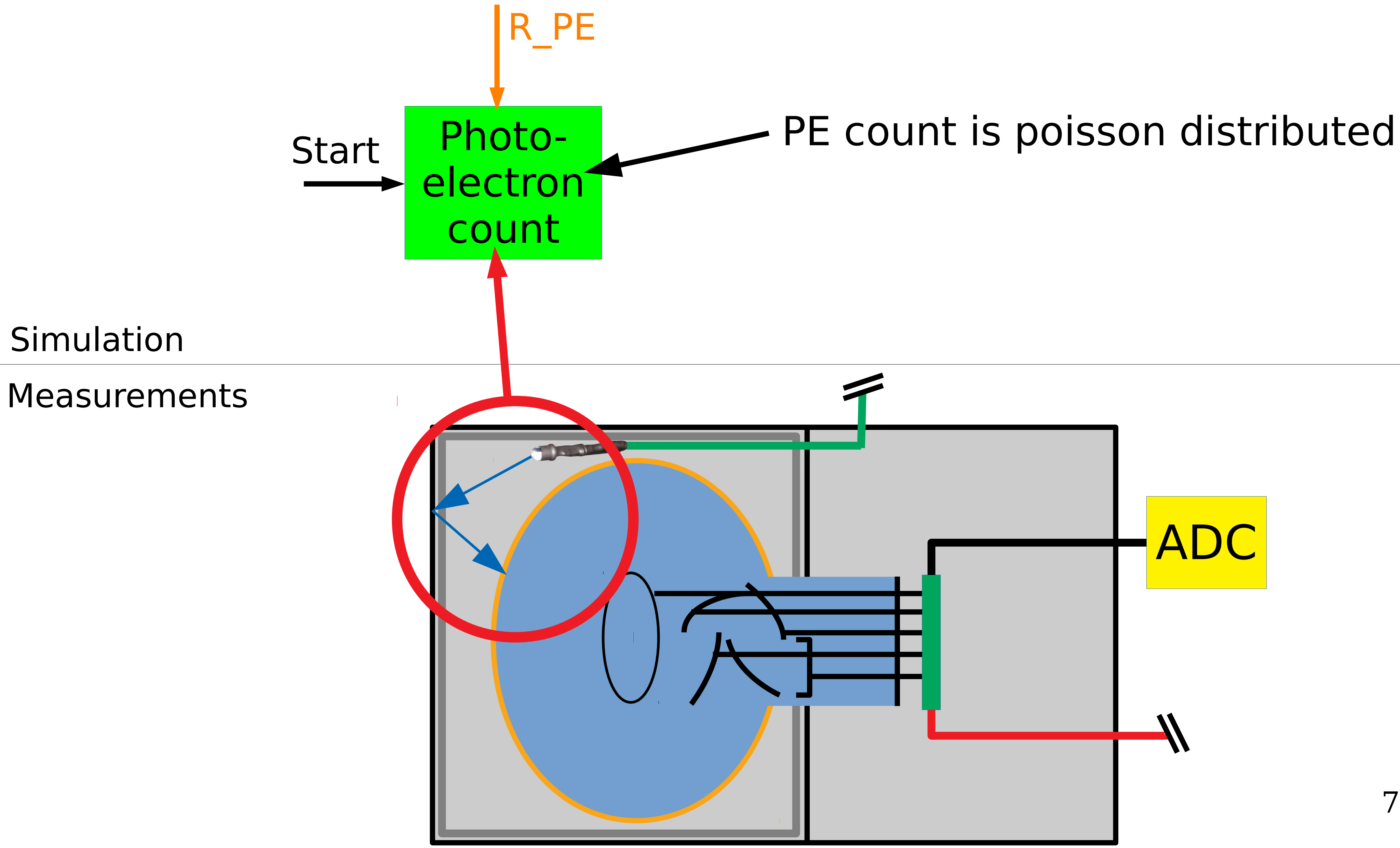


Why simulate the PMT?

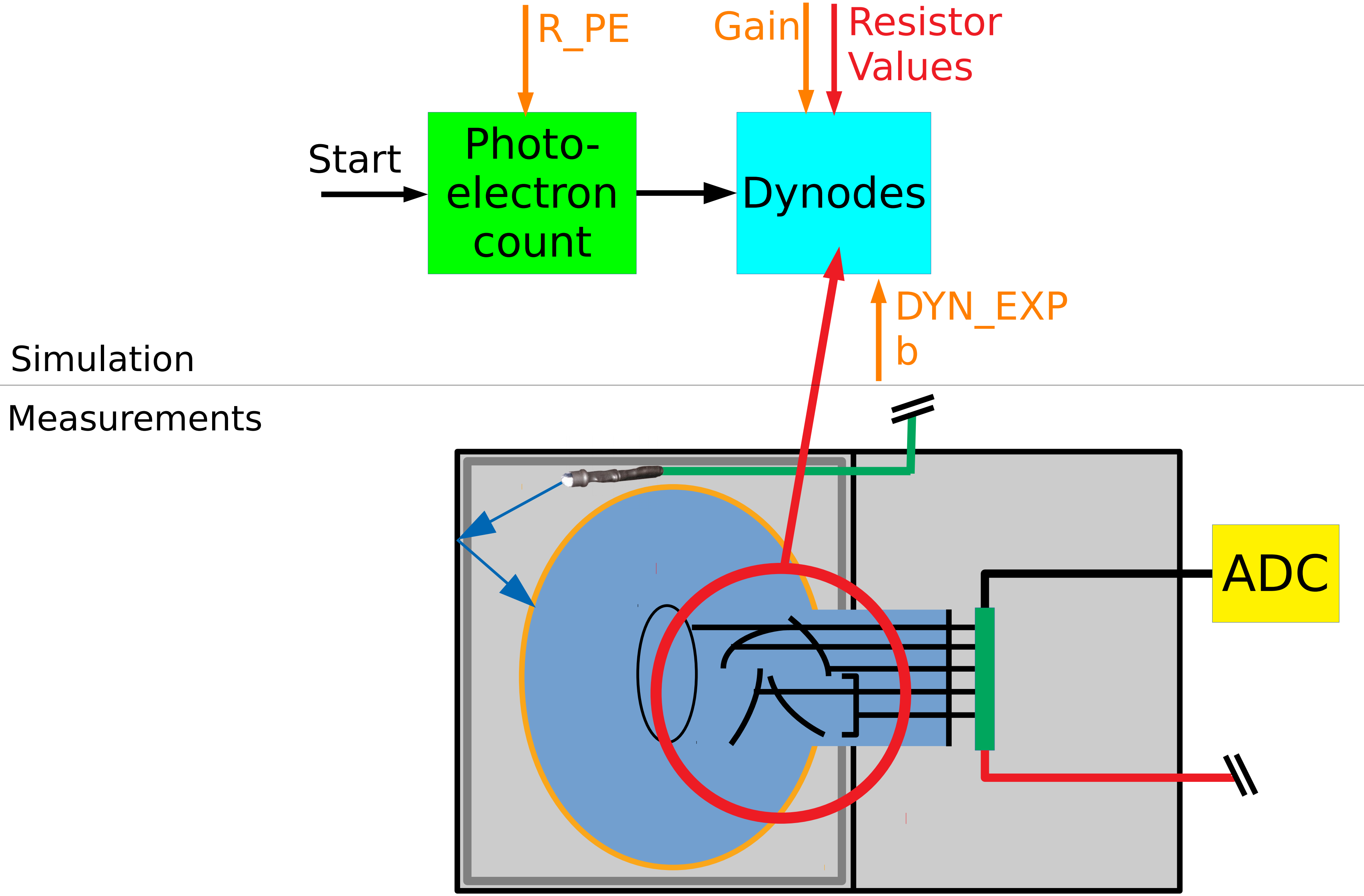
- Using fit
  - Exponential modell is not a correct description
- Subtracting the noise peak
  - Big errors => requires very long measurements
  - False values from offset-correction

=> Monte carlo simulation

Simulated noise



Simulated noise



Dynodes

Secondary Emission

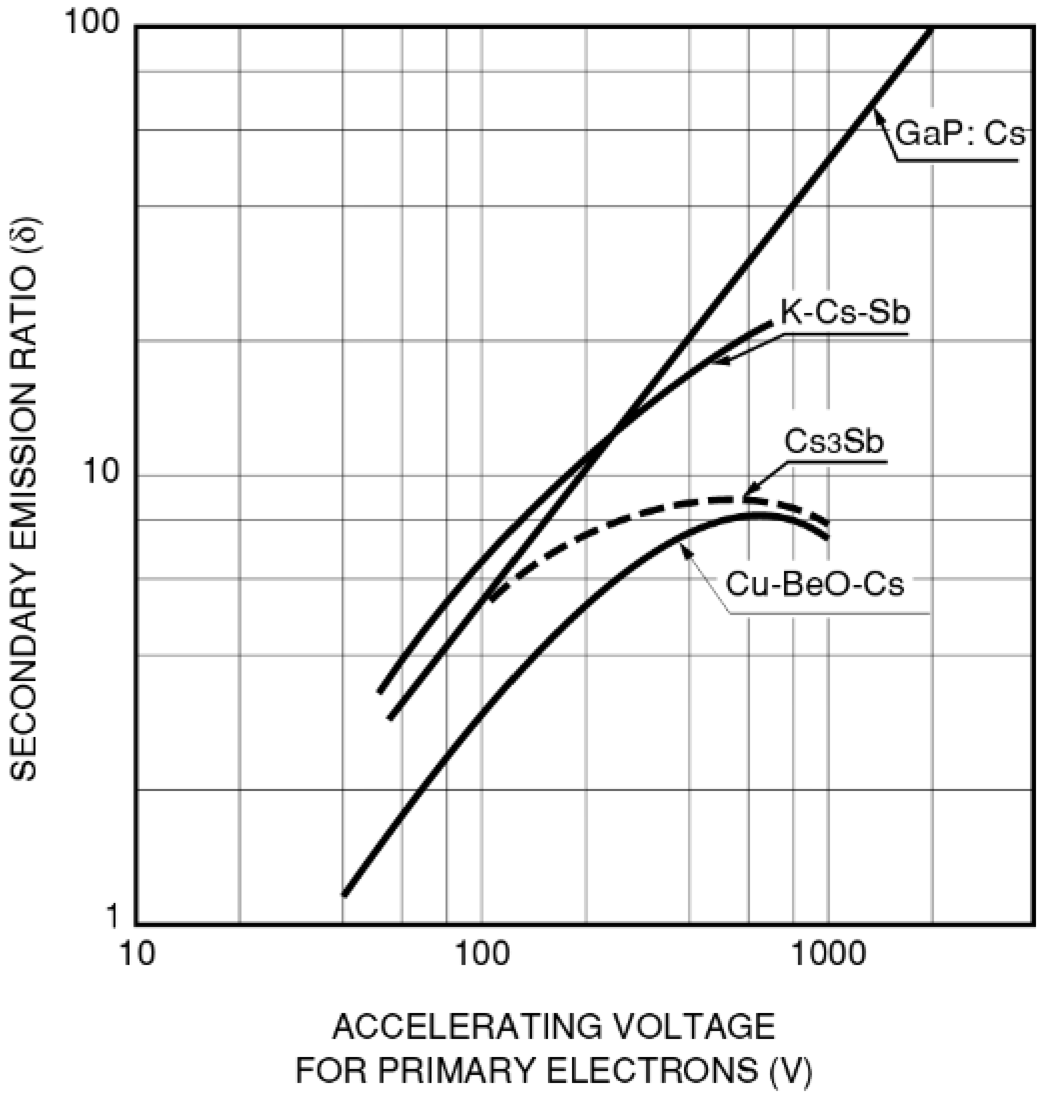


Image: Hamamatsu

$$\bar{\delta}_i \approx a' \cdot {U_i}^b$$
$$= a \cdot {R_i}^b$$

$$\text{Gain} \approx \prod_i \bar{\delta}_i \approx \prod_i a \cdot {R_i}^b$$

$$\Rightarrow a = \frac{\text{Gain}}{\prod_i {R_i}^b}$$

Dynode calculation

Dynodes

δ is poisson-distributed

$$\bar{\delta}(R) = a \cdot R^b$$

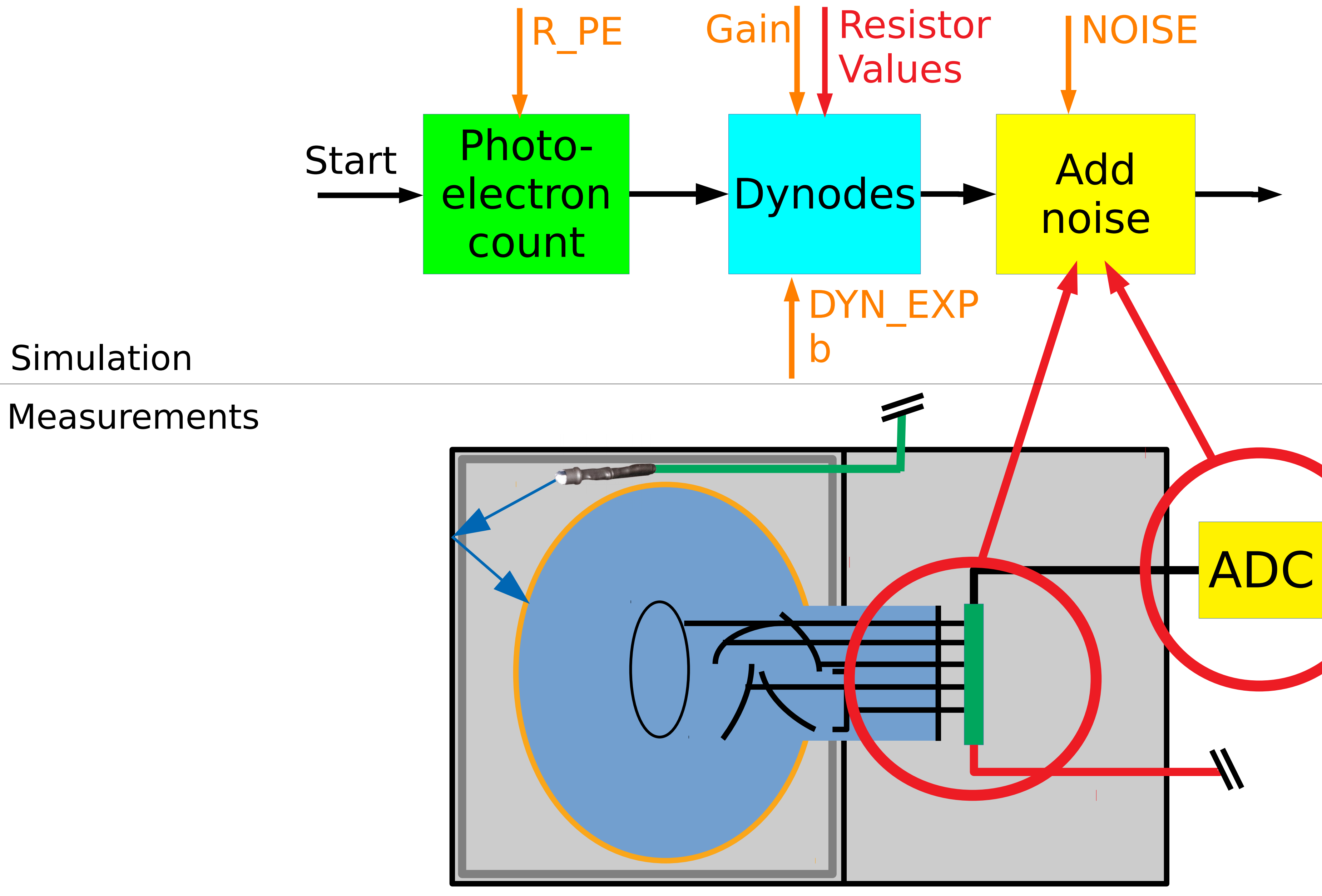
$$P(\delta(E) = k) = \frac{\bar{\delta}(E)^k}{k!} e^{-\bar{\delta}(E)}$$

Calculation of secondary electron count

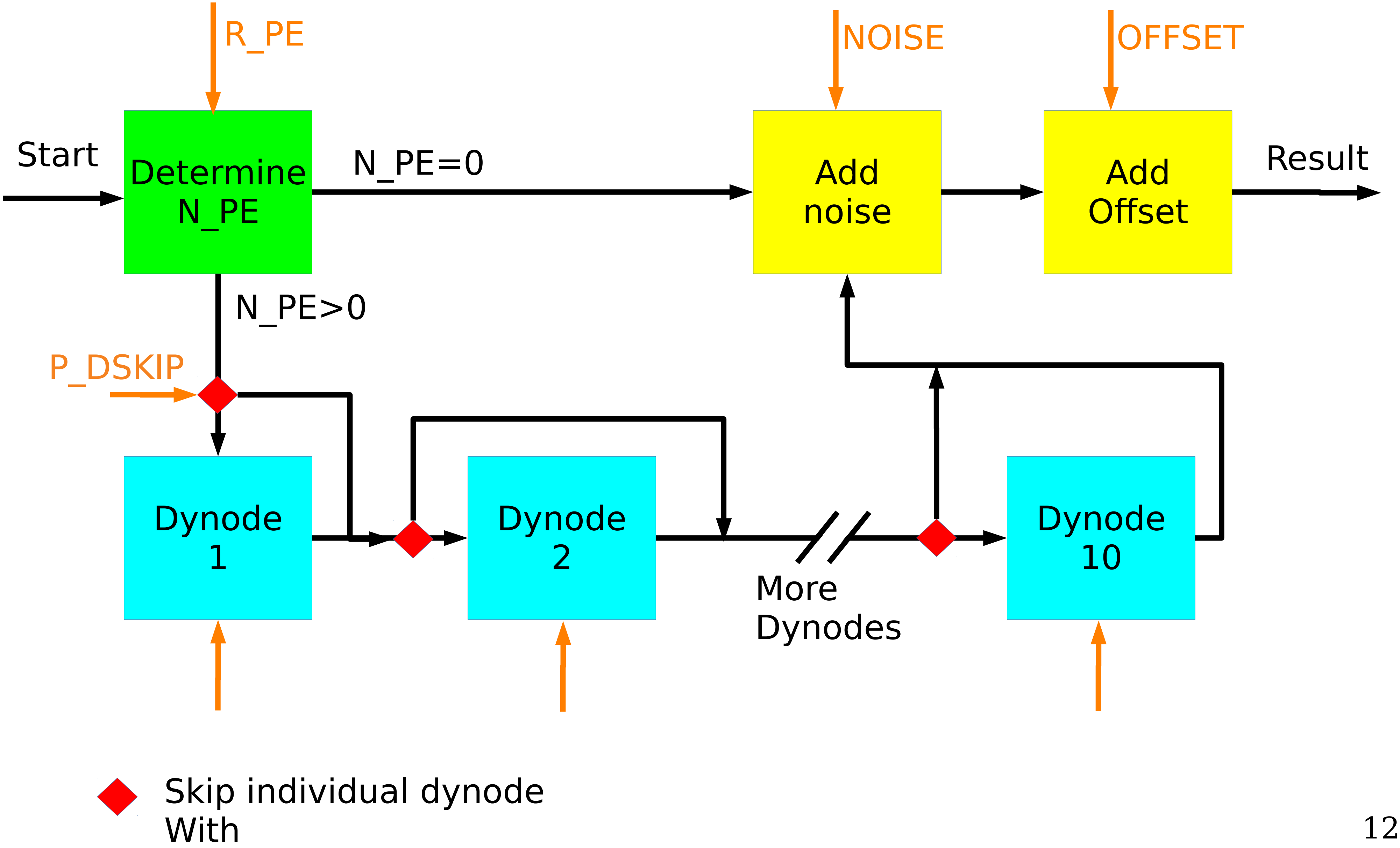
$$N_{\text{sek}} = \sum_{N_{\text{prim}}} \delta(E)$$

Gauss approximation if $\bar{N}_{sek} > 50$
to reduce calculation times

Simulated noise



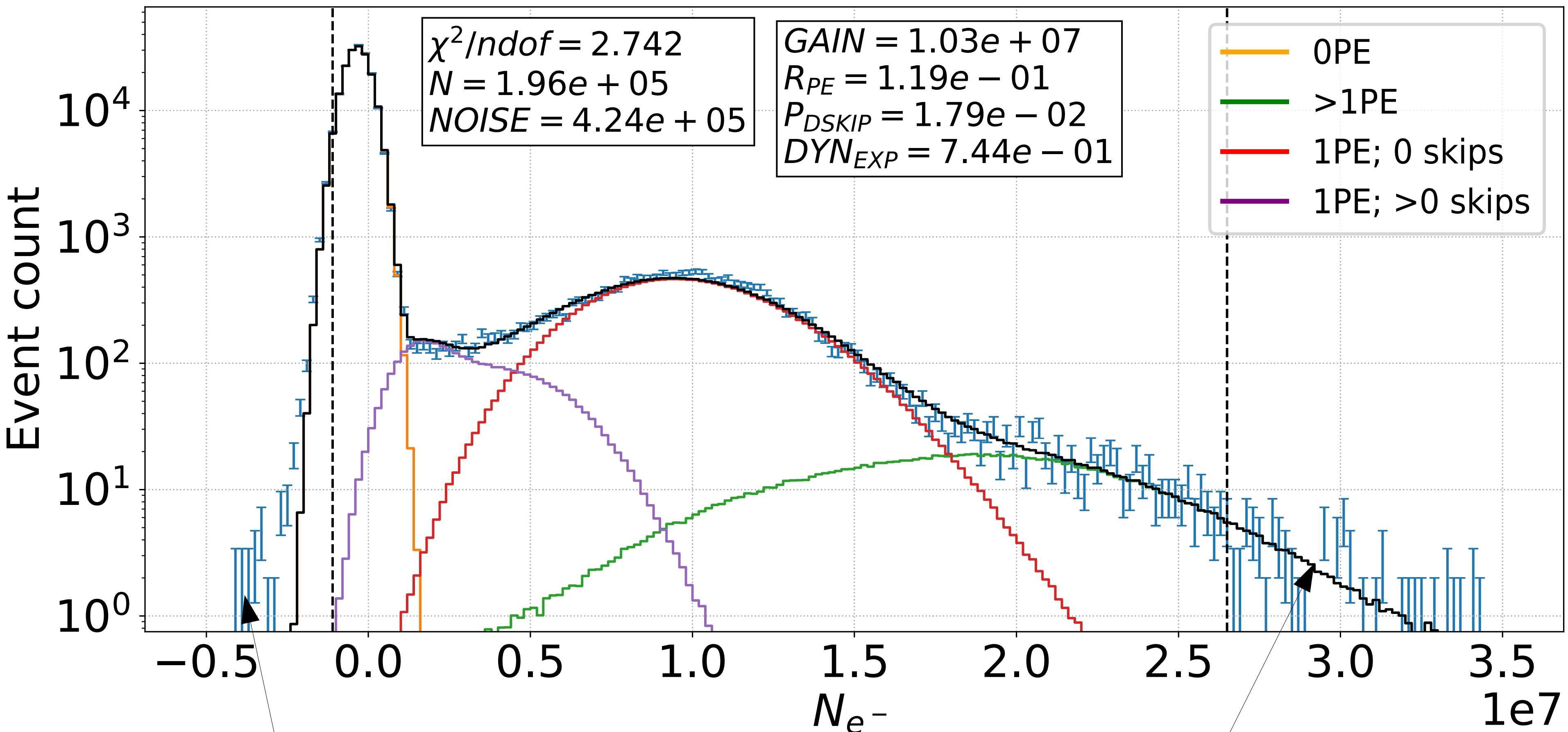
Skipping of dynodes



Simulation parameters

Parameter	Value	Meaning	Main dependency
N	~2*10^5	Amount of neasured/simulated events	
Resistors	-	Resistors of the Voltage divider for the PMT	Base
GAIN	~10^7	Average PMT gain	Base and HV
NOISE	4.2*10^5	Noise width	ADC
R_PE	0.19	Average photoelectron count per event	Signal generator / LED
P_DSKIP	0.018	Propability of skipping a single dynode	PMT
DYN_EXP	0.74	Powerlaw exponent b for secondary emission yield calculations	PMT

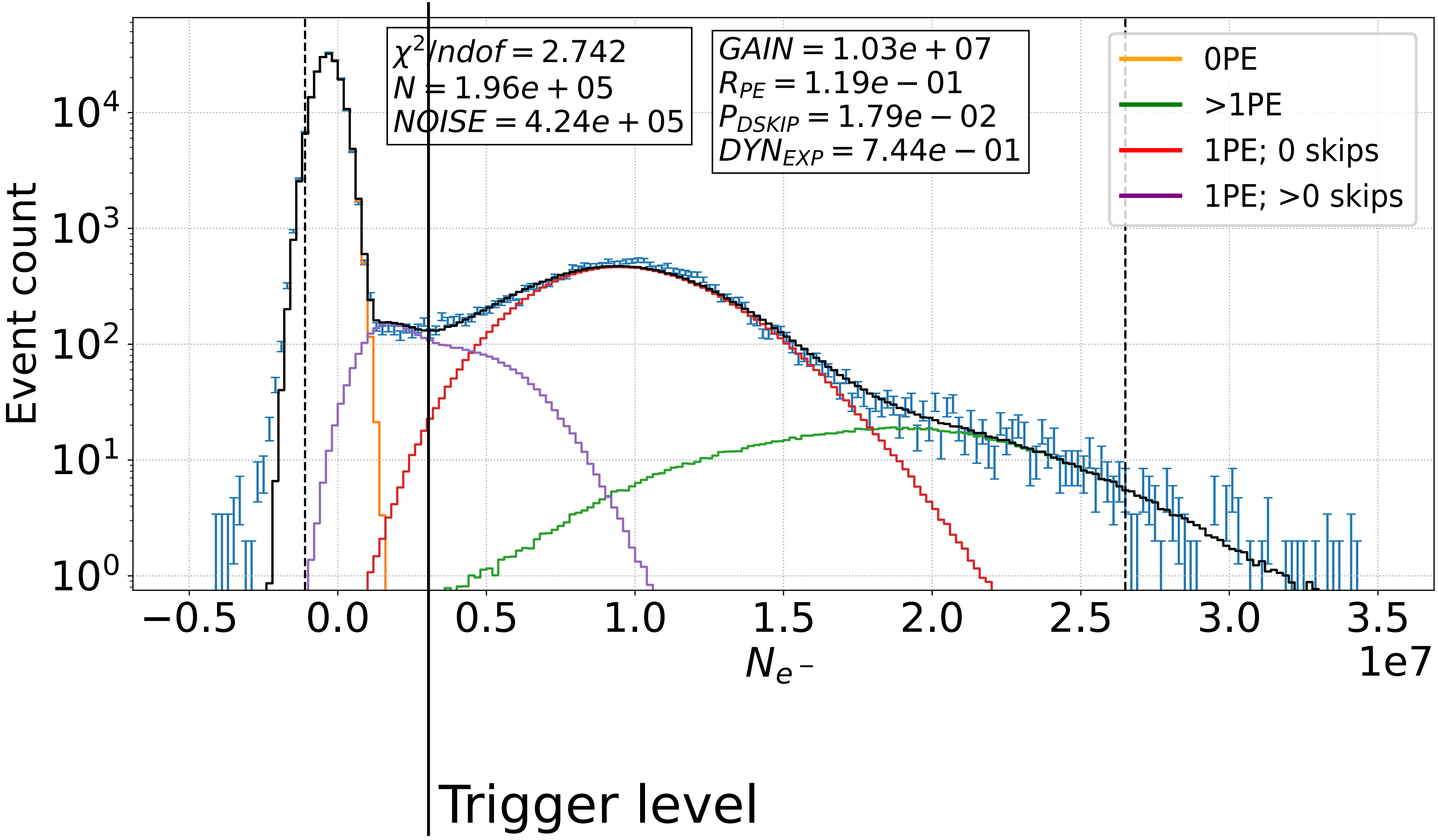
Simulation result



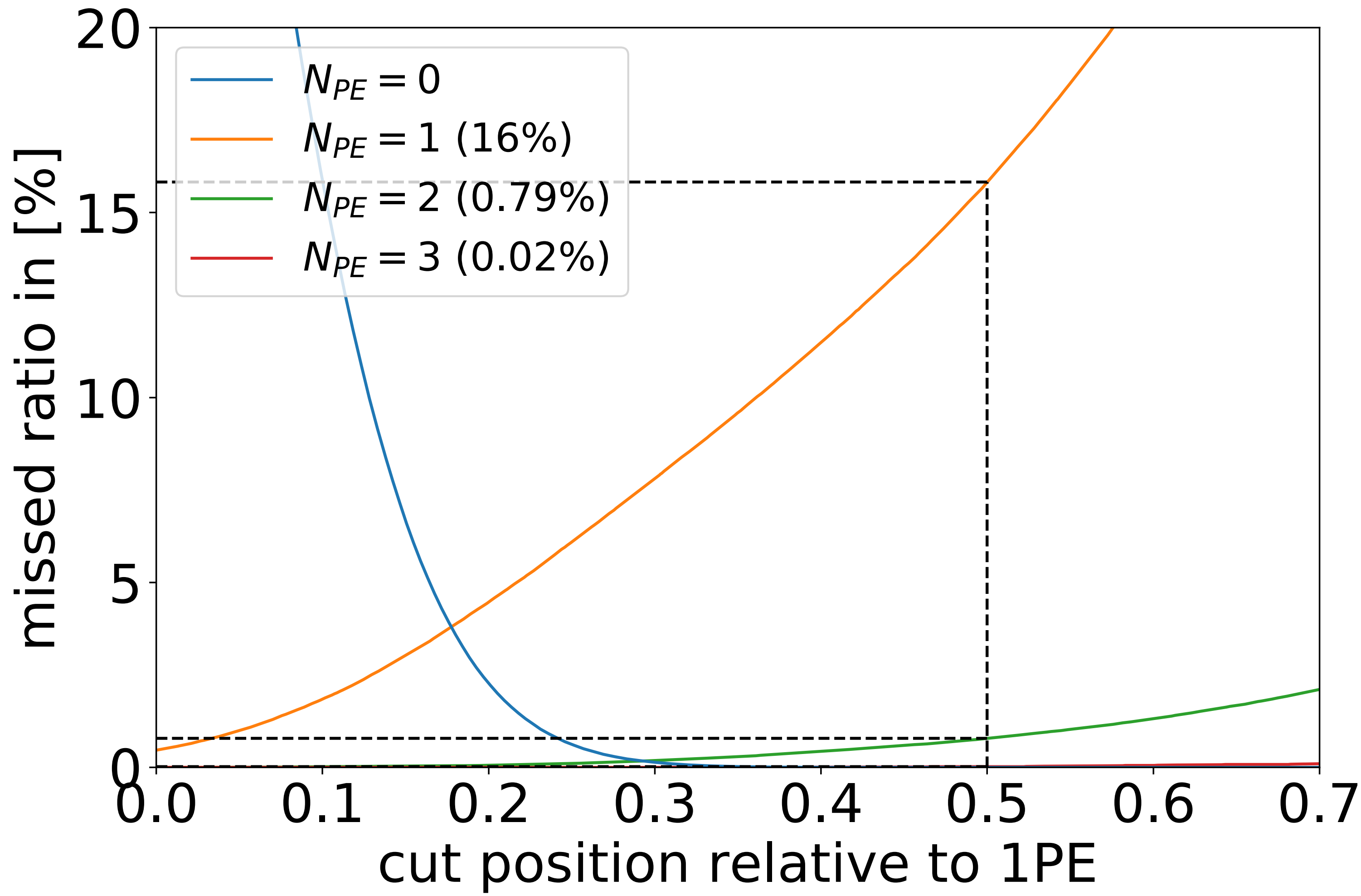
Errorbars: Measurement

Black: Simulation total

Simulation result



Trigger efficiency



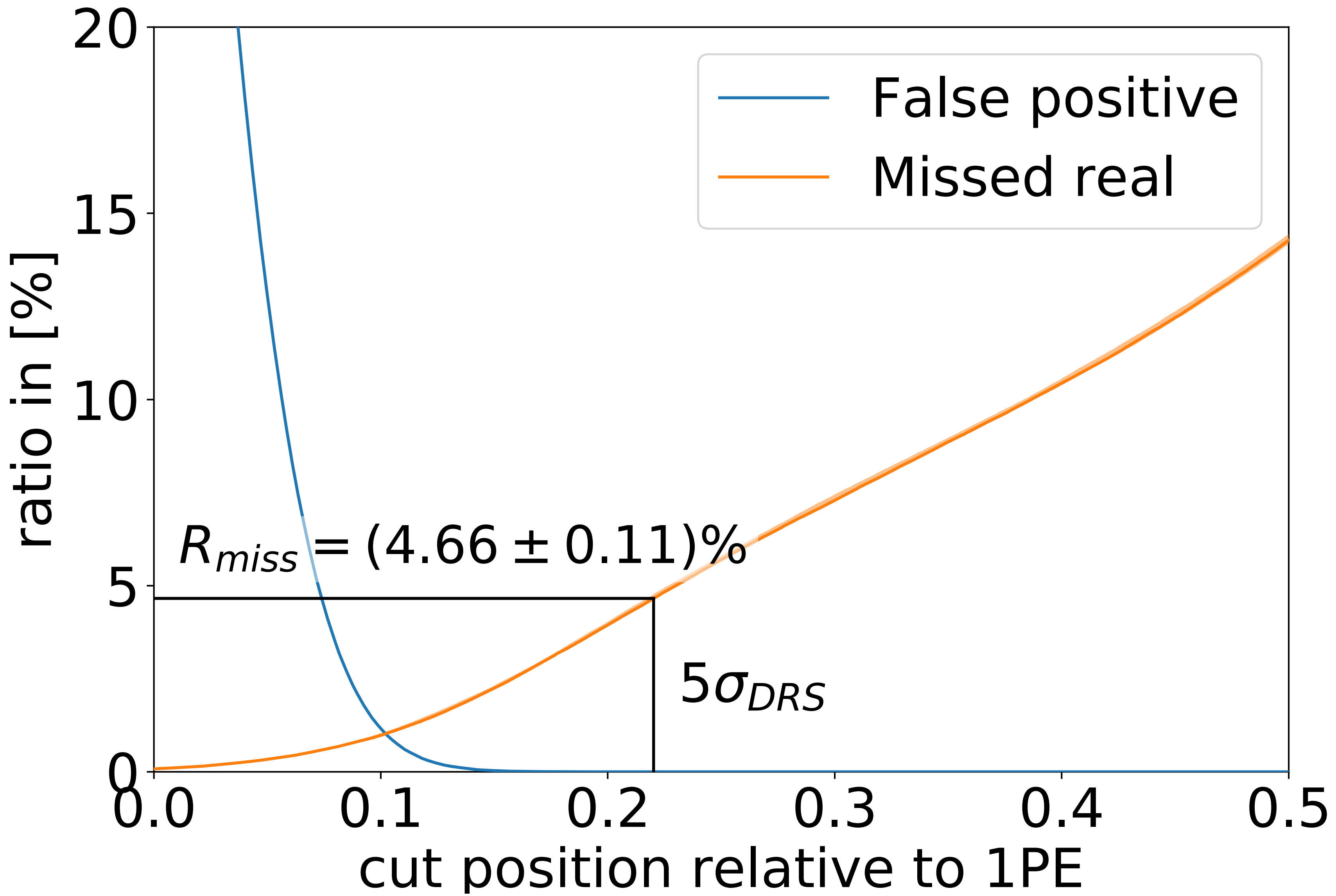
Trigger efficiency <16% for 0.5 PE trigger level

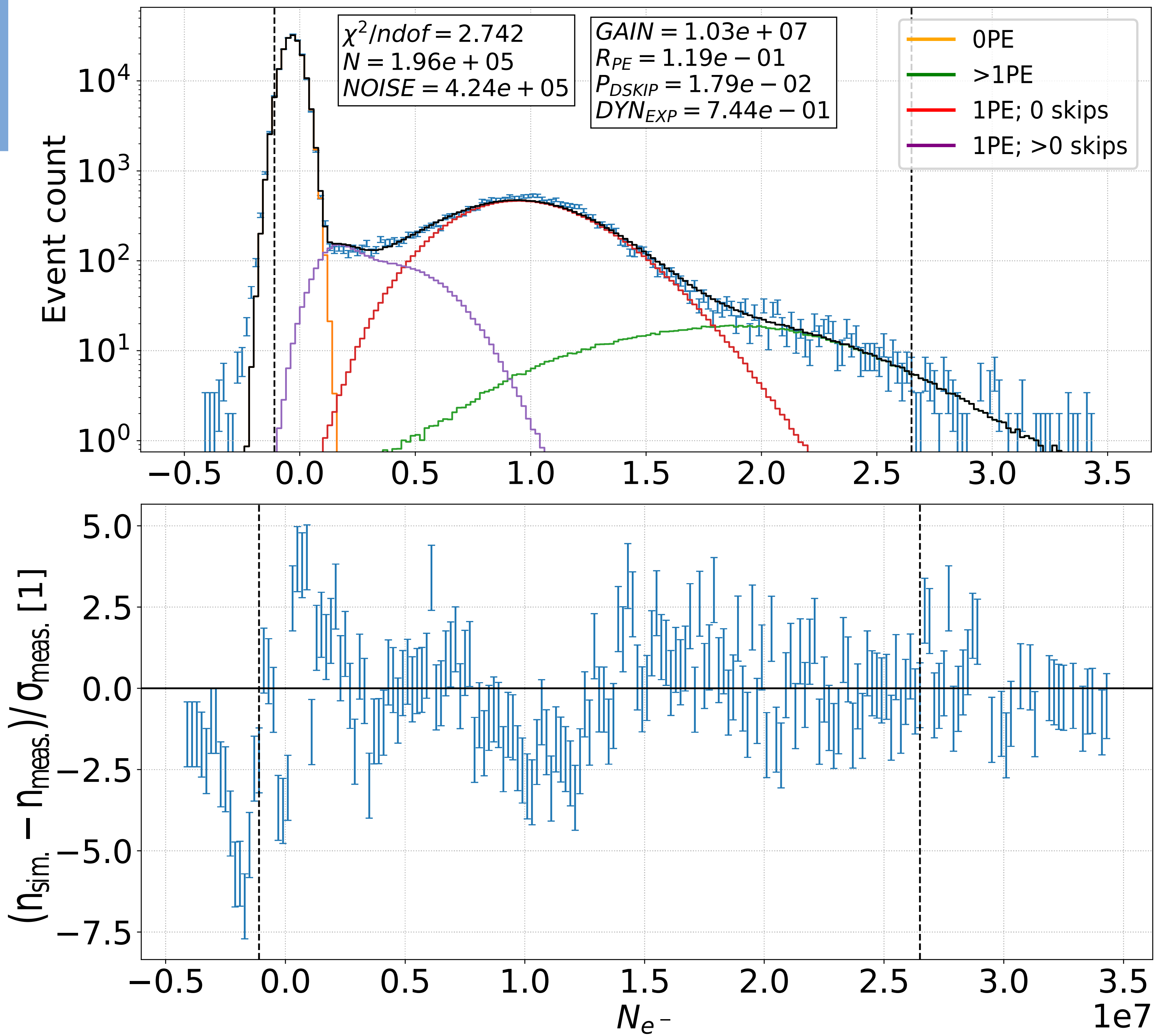
Thank you for your attention

Gefördert durch
DFG Deutsche Forschungsgemeinschaft

Contact:
tim.kuhlbusch@rwth-aachen.de

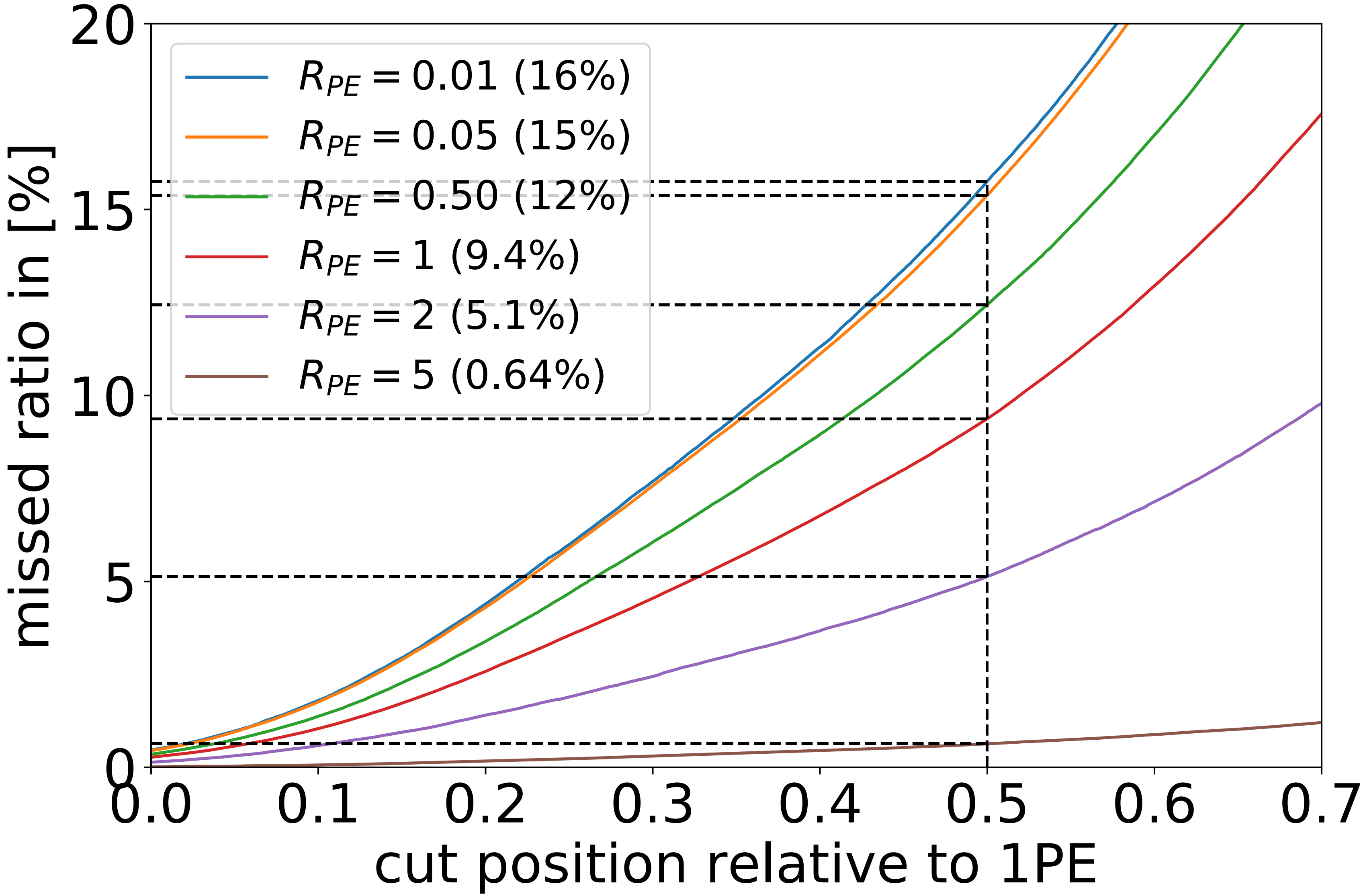
False positive rate





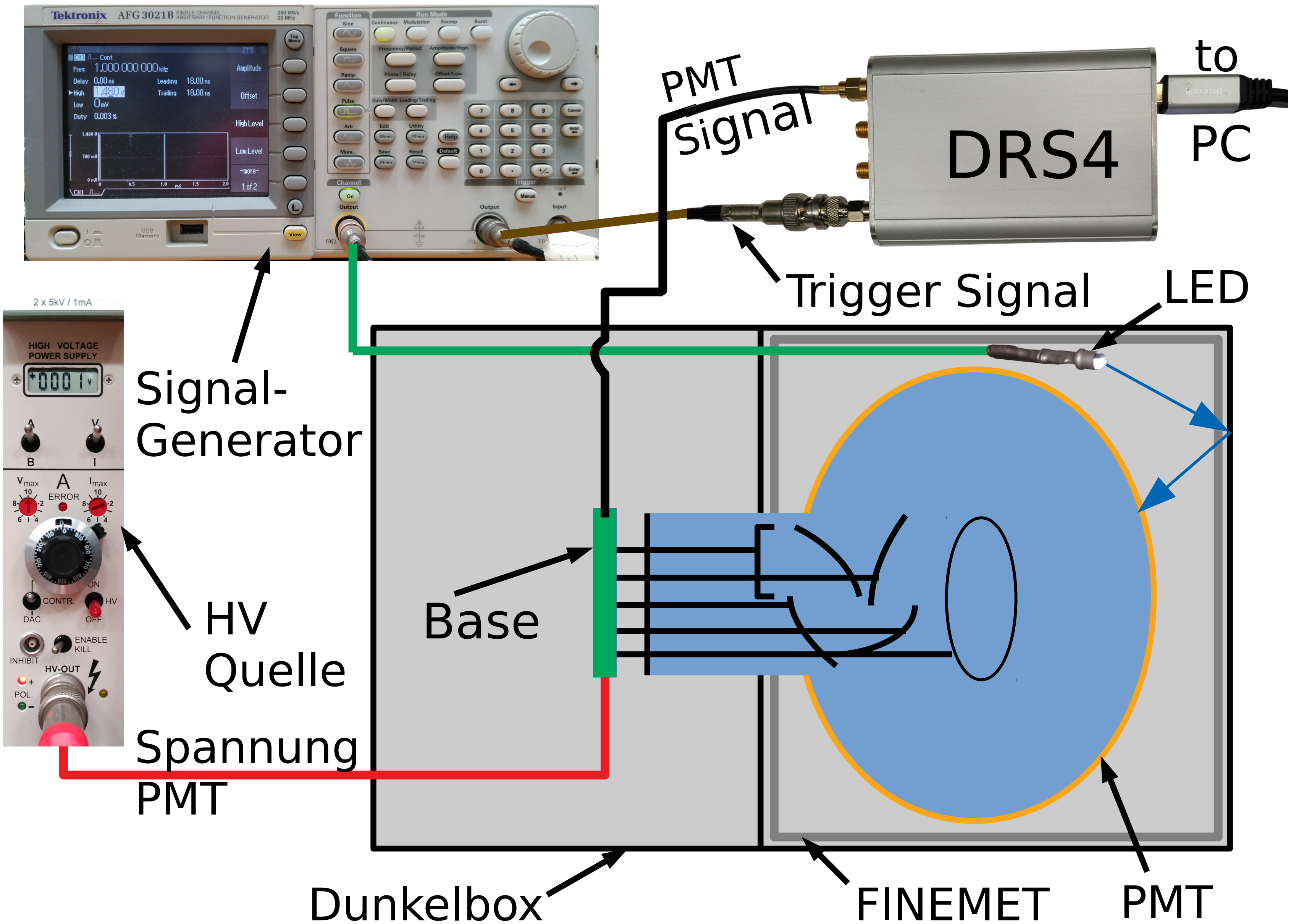
$\chi^2/ndof = 2.742$
$N = 1.96e+05$
$NOISE = 4.24e+05$
$GAIN = 1.03e+07$
$R_{PE} = 1.19e-01$
$P_{DSKIP} = 1.79e-02$
$DYN_{EXP} = 7.44e-01$
0PE
>1PE
1PE; 0 skips
1PE; >0 skips
Event count
$(n_{sim.} - n_{meas.})/\sigma_{meas.}$ [1]
N_{e^-}
1e7

TE for Poisson distributed PE count

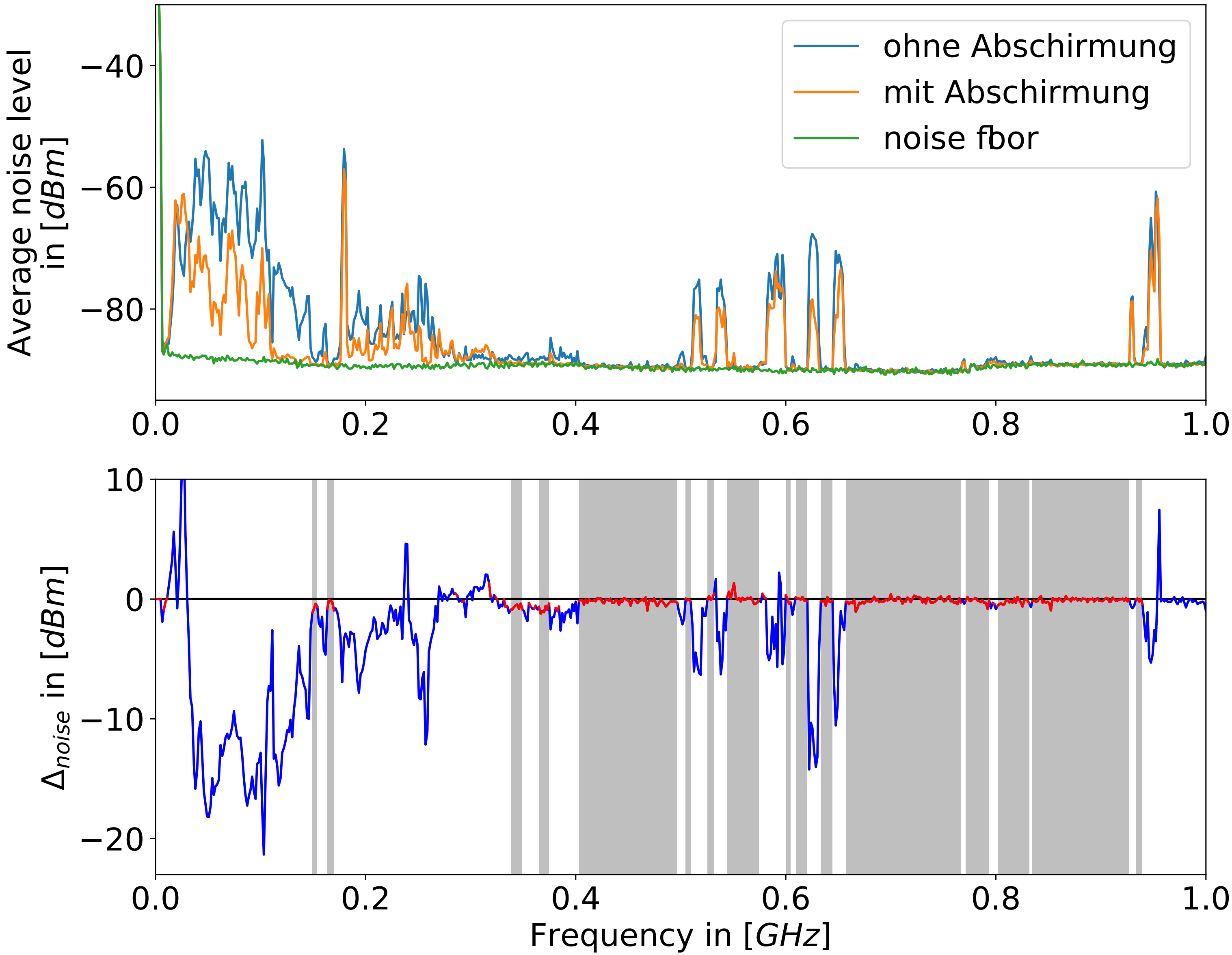


Poisson distributed PE counts

N_{PE} \ R_{PE}	$P(N)$ wenn $N > 0$: 1	2	≥ 3
0.01	99.5%	0.5%	< 0.1%
0.05	97.5%	2.4%	< 0.1%
0.50	77.1%	19.3%	3.7%
1.00	58.2%	29.1%	12.7%
2.00	31.3%	31.3%	37.4%
5.00	3.4%	8.5%	88.1%



PMT
Signal
to
PC
DRS4
Trigger Signal
LED
Signal-
Generator
HV
Quelle
Base
Spannung
PMT
Dunkelbox
FINEMET
PMT


ohne Abschirmung
mit Abschirmung
noise floor
Average noise level
in [dBm]
−40
−60
−80
0.0
0.2
0.4
0.6
0.8
1.0
10
0
−10
−20
Δ_{noise} in [dBm]
Frequency in [GHz]