Nikhef testing on PMTs for the KM3NeT

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KM3NeT General Meeting
20-23 February 2012
LNS Catania

NIKHEF

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- Photomultipliers and specifications
- Set-up at Nikhef
- Measured characteristics
- Test Results
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Introduction

- KM3NeT design: single 17" DOMs of 31 3" PMTs
- 100 PMTs delivered at Nikhef (ETEL)
- Their performance currently being tested in the lab
- Nikhef-lab results presented here

Photomultipliers

ET Enterprises Ltd

Hamamatsu

PMT Specifications

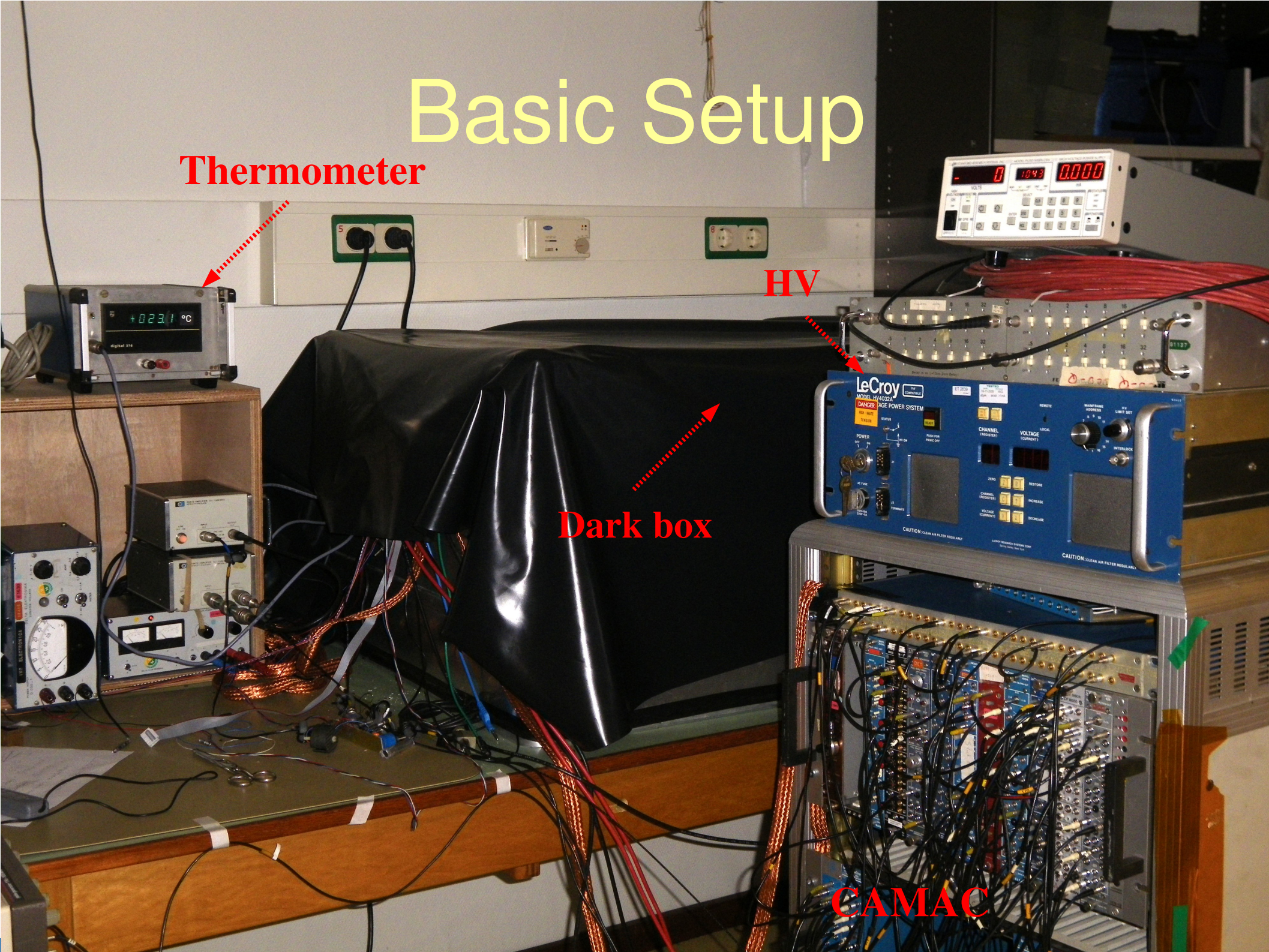
- QE @470nm >20%
- Supply voltage <1400V
- Gain 5×10^6

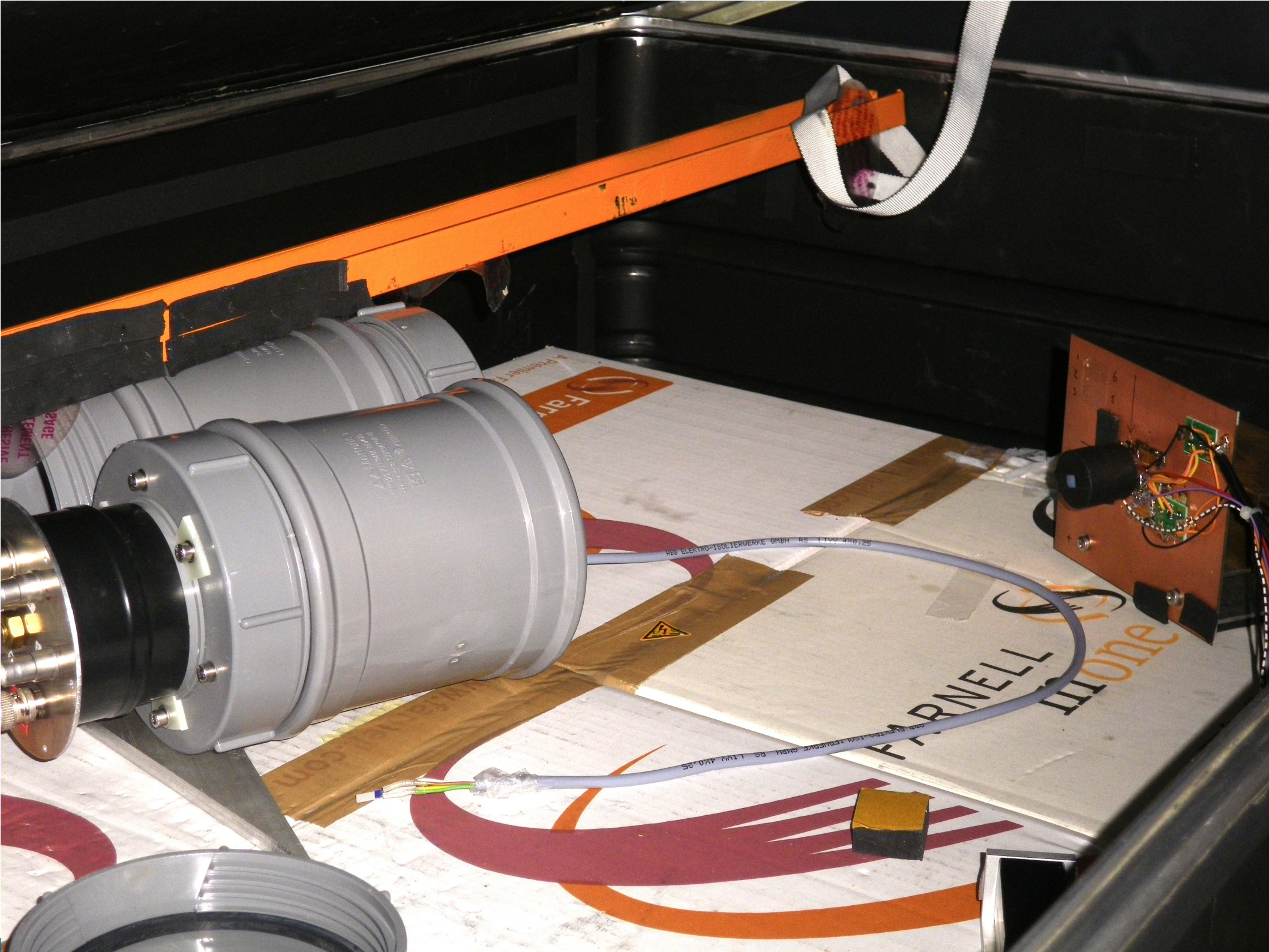
Anode characteristics

- Dark count rate <3000 Hz
  (at 15°C and for signals above threshold of 0.3 spe)
- Transit Time Spread <2ns (σ)
- Peak to valley ratio >3

Environment

- Storage 0-60°C
- Operation 10-25°C


Basic Setup
Thermometer
HV
Dark box
CAMAC
LeCroy
MODEL HV4032A
HIGH VOLTAGE POWER SYSTEM
DANGER


FARNELL
ABB ELEKTRO-ISOLIERWERKE GMBH

Technical characteristics

- Dark count
- Gain
- Afterpulse
- Transit Time Spread (TTS)

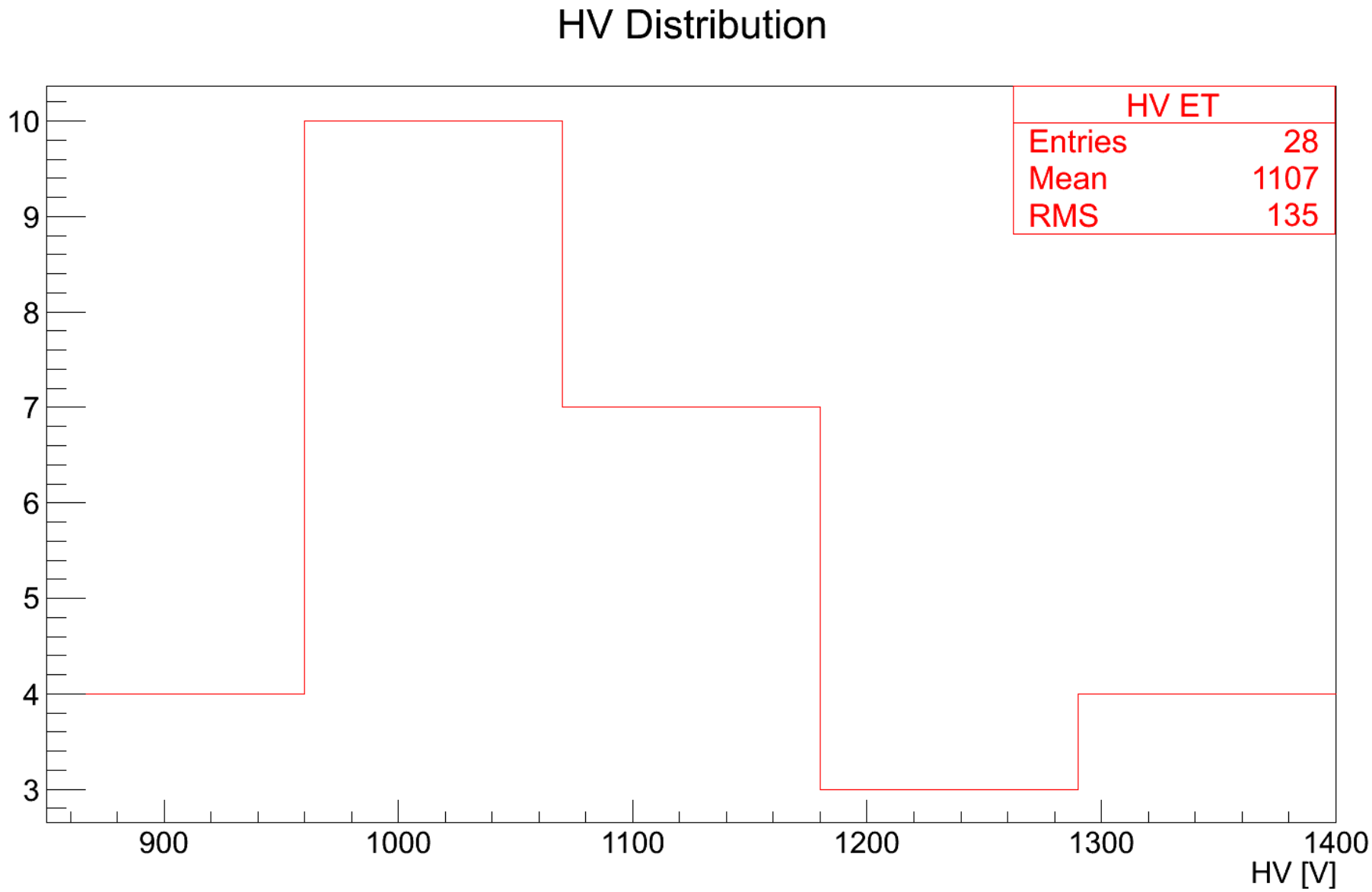
Tests performed

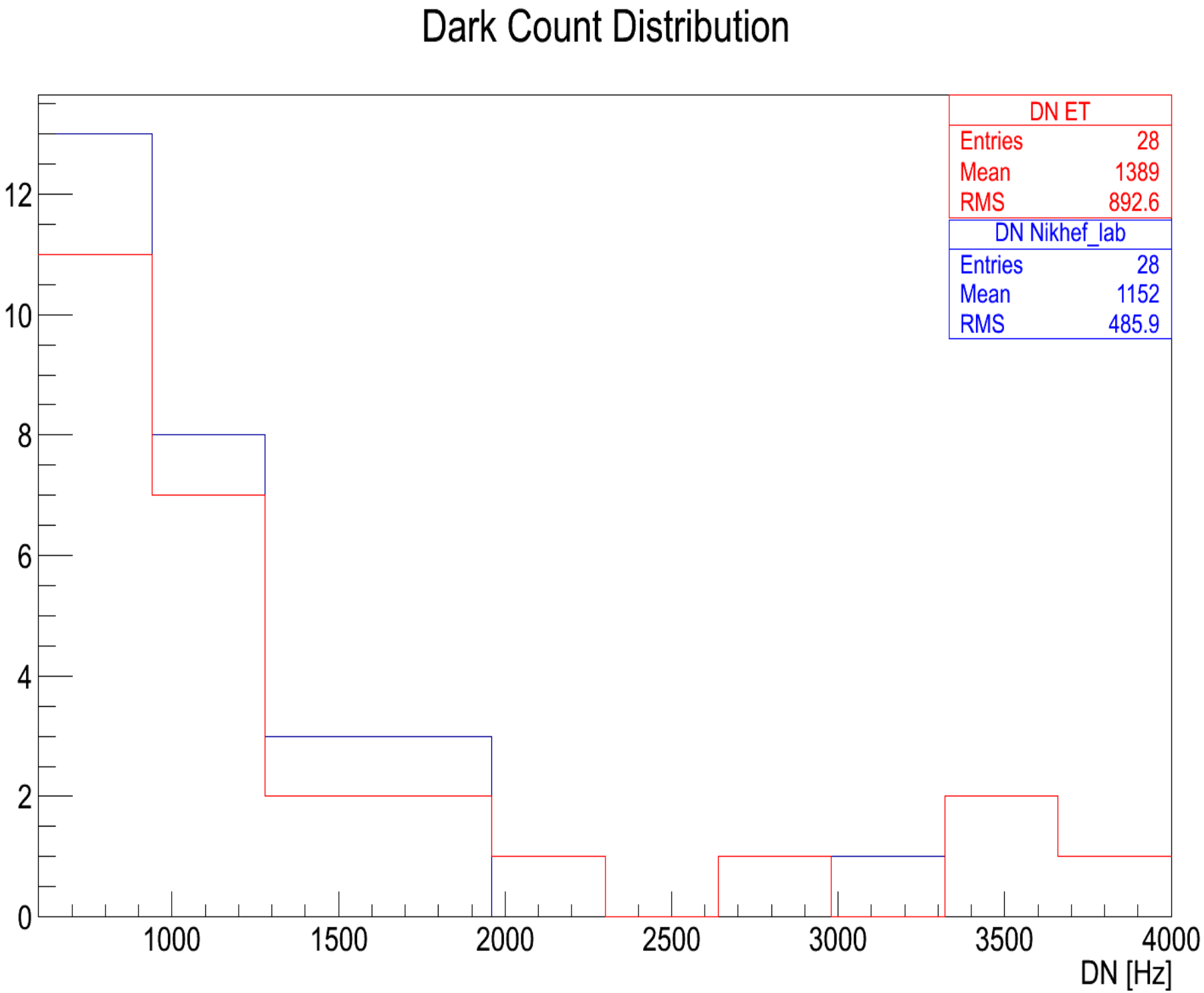
- Dark count was measured at the nominal HV
- Illumination by a blue LED of ~2ns pulse width
- For the Gain, three measurements took place: for the nominal voltage, for 50V lower and for 50V higher than the HVnom.

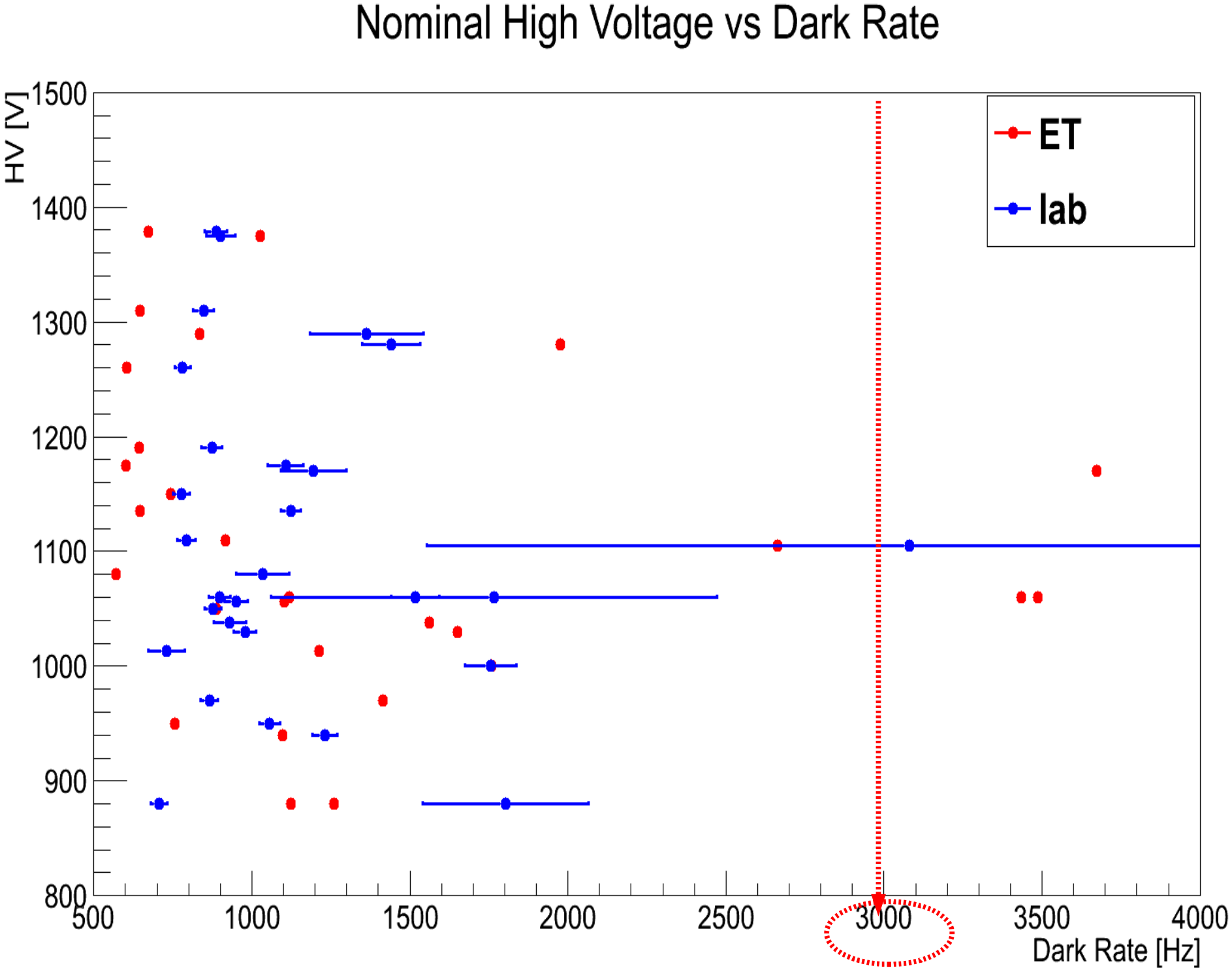
Nikhef Lab Results

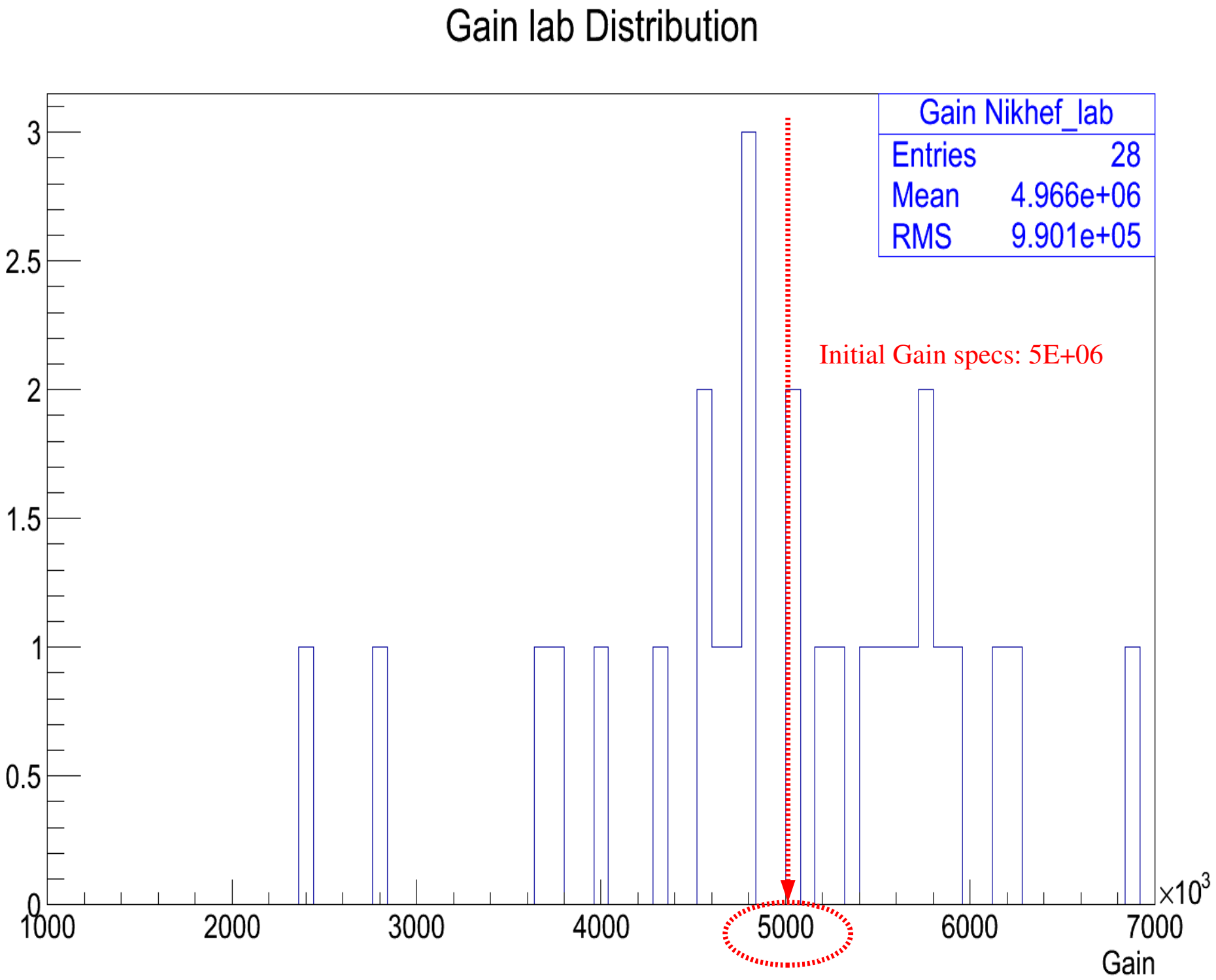
Characteristics	*Specifications*	*Range*	*Mean Values*
High voltage:	<1400 V	880-1400 V	1107 V
Dark rate_data sheets:	<3000 Hz	600-3675 Hz	1389 Hz
Dark rate_lab:		700-3080 Hz	1152 Hz
Gain_data sheets:	5E+06	5E+06	5.00E+06
Gain_lab:		2.4-6.90 E+06	4.97E+06
Afterpulse_data sheet:		1.6-3.8 %	2.70%
Afterpulse_lab:		0.1-9.55 %	3.15%
Transit Time Spread:	<2 ns	2.4-4.2 ns	3.36 ns

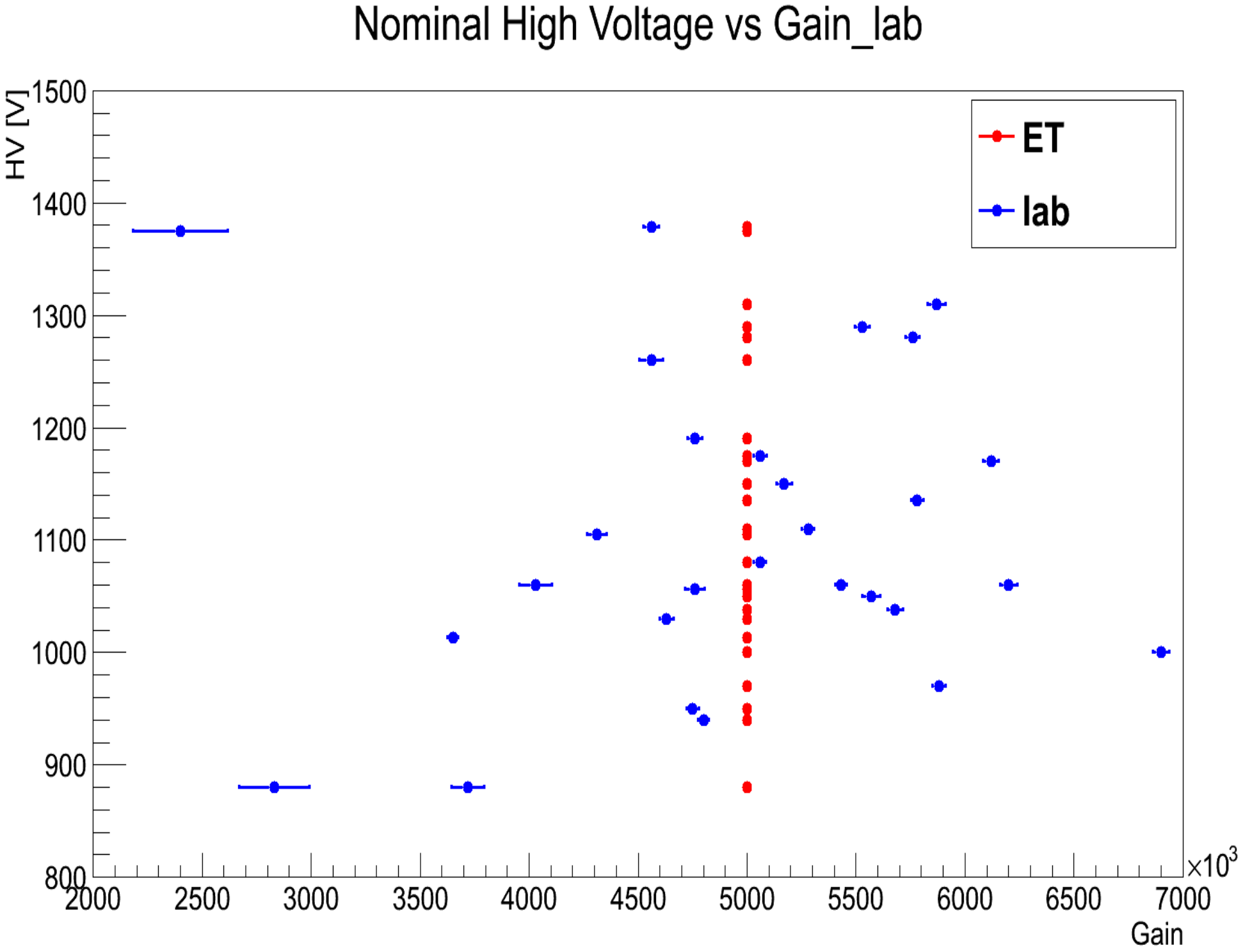
Results


HV Distribution
HV ET
Entries 28
Mean 1107
RMS 135
10
9
8
7
6
5
4
3
900
1000
1100
1200
1300
1400
HV [V]

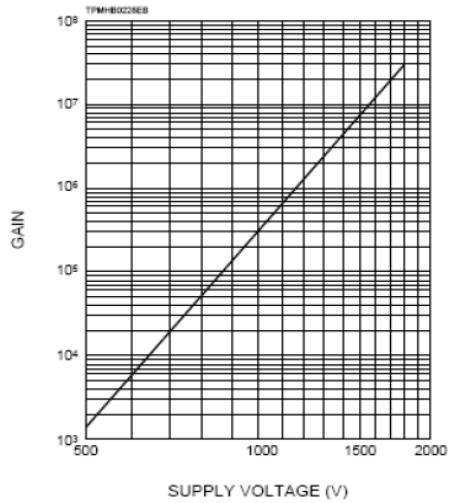

Dark Count Distribution
DN ET
Entries 28
Mean 1389
RMS 892.6
DN Nikhef_lab
Entries 28
Mean 1152
RMS 485.9
0
2
4
6
8
10
12
1000
1500
2000
2500
3000
3500
4000
DN [Hz]


Nominal High Voltage vs Dark Rate
HV [V]
1500
1400
1300
1200
1100
1000
900
800
500
1000
1500
2000
2500
3000
3500
4000
Dark Rate [Hz]
ET
lab


Gain lab Distribution
Gain Nikhef_lab
Entries 28
Mean 4.966e+06
RMS 9.901e+05
Initial Gain specs: 5E+06
3
2.5
2
1.5
1
0.5
0
1000
2000
3000
4000
5000
6000
7000
×10^3
Gain


Nominal High Voltage vs Gain_lab
HV [V]
1500
1400
1300
1200
1100
1000
900
800
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
×10^3
Gain
ET
lab

SlopeHisto

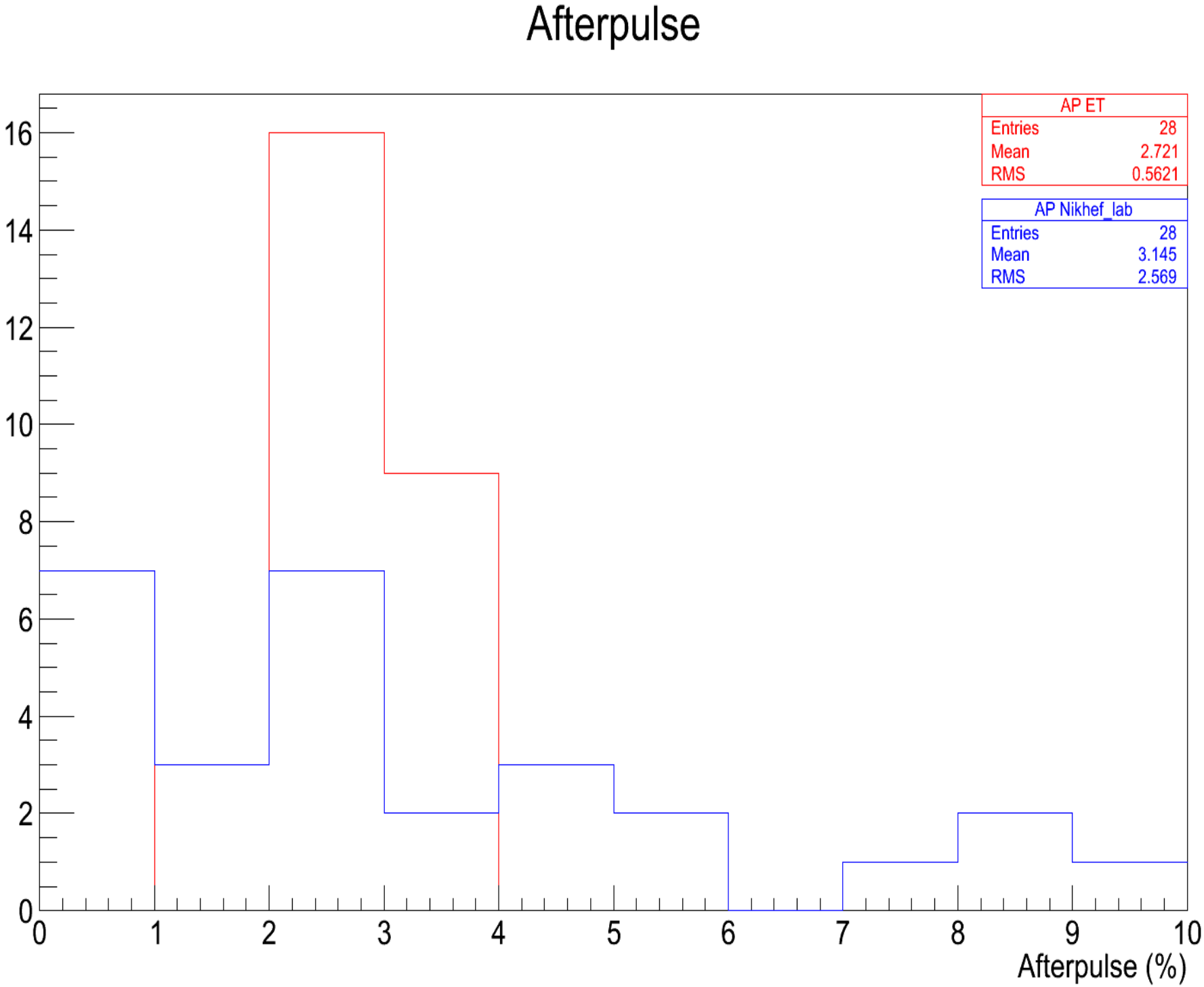


SlopeHisto	
Entries	28
Mean	7.295
RMS	1.108

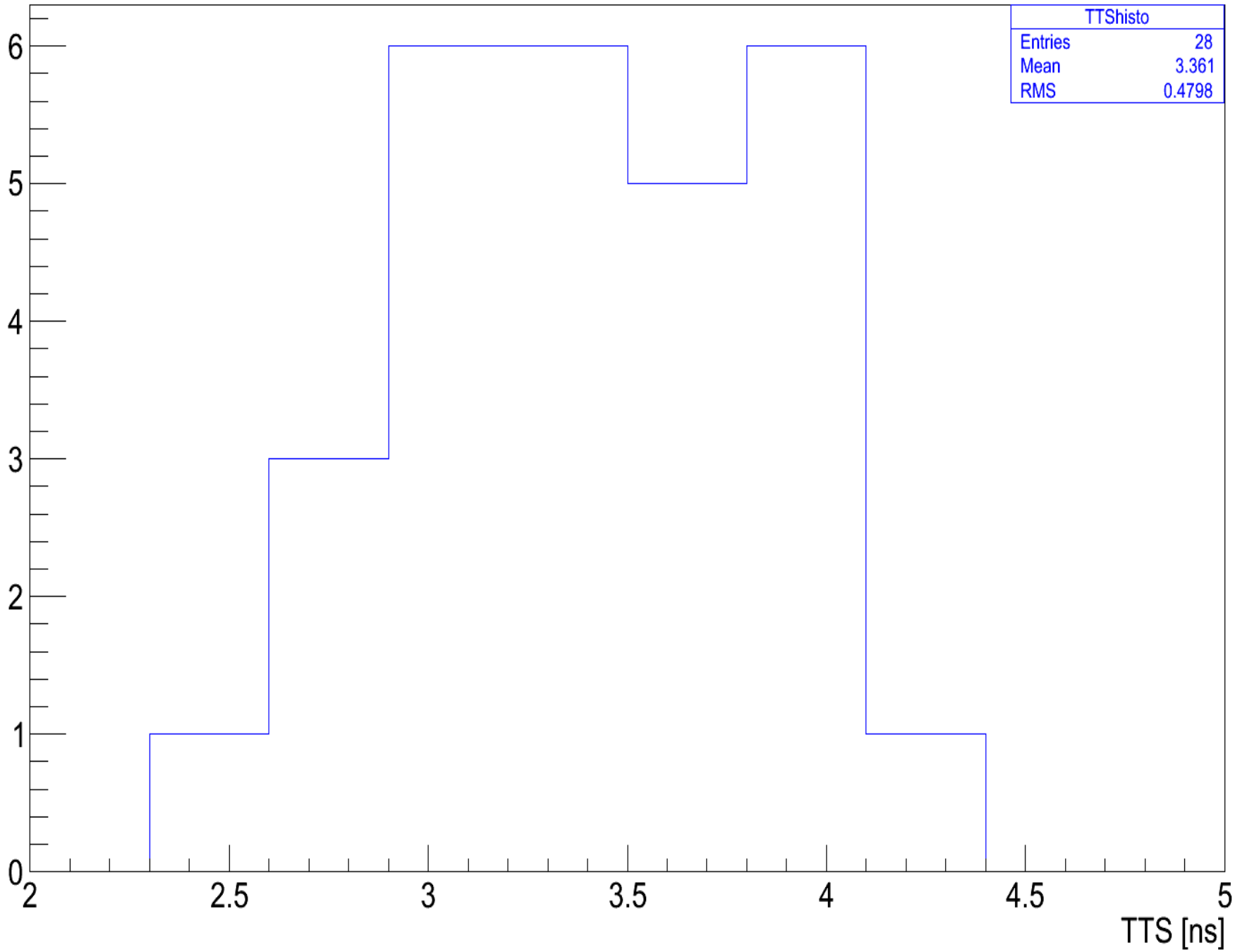
0 1 2 3 4 5 6 7 8 9 10

0 2 4 6 8 10

logG-logV slope


Afterpulse
AP ET
Entries 28
Mean 2.721
RMS 0.5621
AP Nikhef_lab
Entries 28
Mean 3.145
RMS 2.569
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5
6
7
8
9
10
Afterpulse (%)

Transit Time Spread



PMT Specifications (v2)

- QE @470nm >20%
- Supply voltage <1400V
- Gain 5×10^6

Anode characteristics

- Dark count rate <3000 Hz
  (at 15°C and for signals above threshold of 0.3 spe)
- Transit Time spread <2ns (σ)
- Peak to valley ratio >3

Environment

- Storage 0-60°C
- Operation 10-25°C

- QE @470nm 18%min, 20%typ
- QE @404nm 27%min, 39%typ
- Supply voltage 900-1250V
- Gain 2×10^6

Anode characteristics

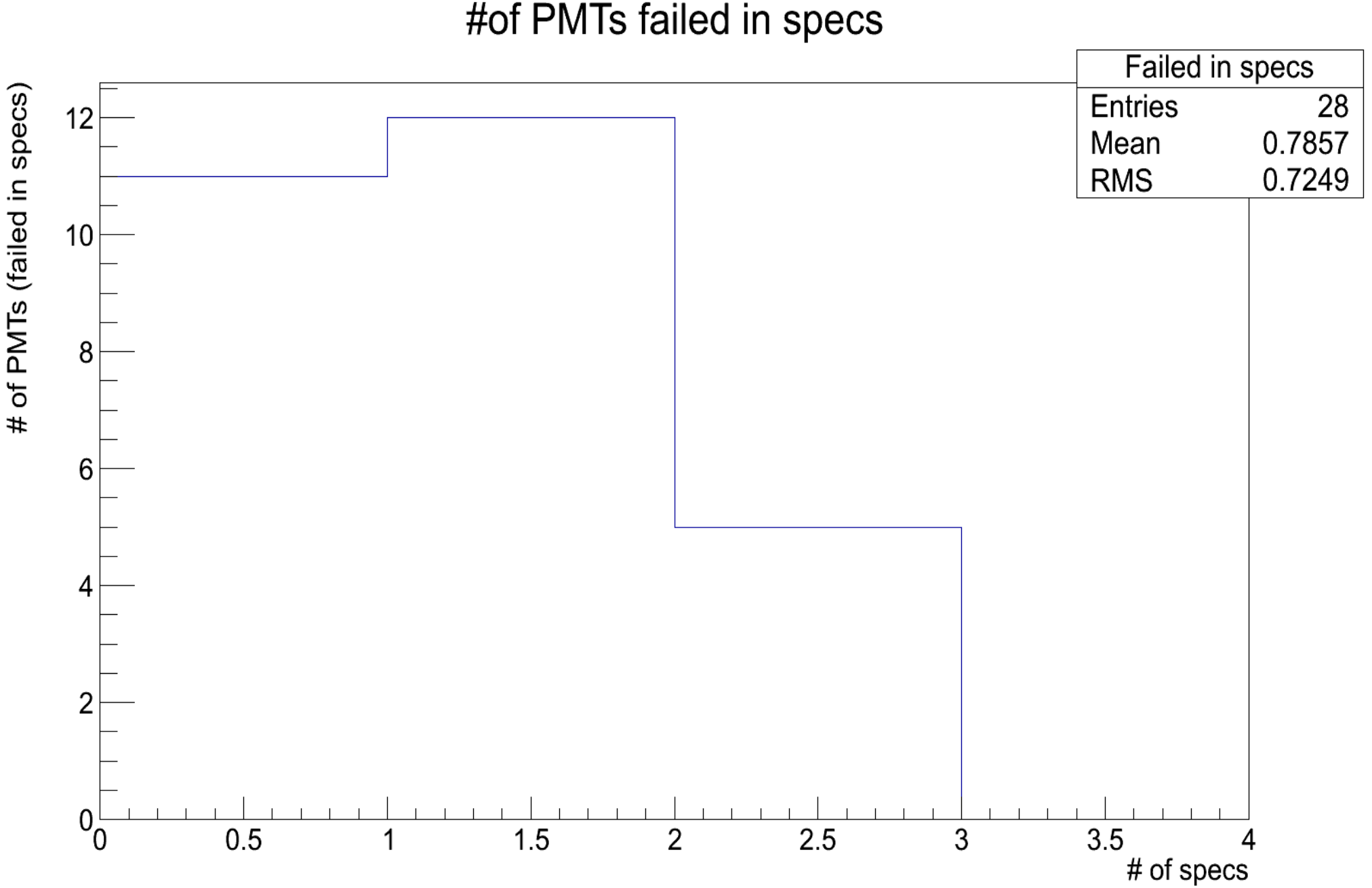
- Dark count rate <1500 Hz
  (at 20°C and for signals above threshold of 0.3 spe)
- Transit Time spread <2.4ns (σ)
- Peak to valley ratio >2

Environment

- Storage -25°C - 75°C
- Operation 10-25°C

min/max: no delivered PMT may fail the spec

typical: 80% of each batch of 1000PMT must pass the spec


#of PMTs failed in specs
Failed in specs
Entries 28
Mean 0.7857
RMS 0.7249
# of PMTs (failed in specs)
# of specs
0
2
4
6
8
10
12
0
0.5
1
1.5
2
2.5
3
3.5
4

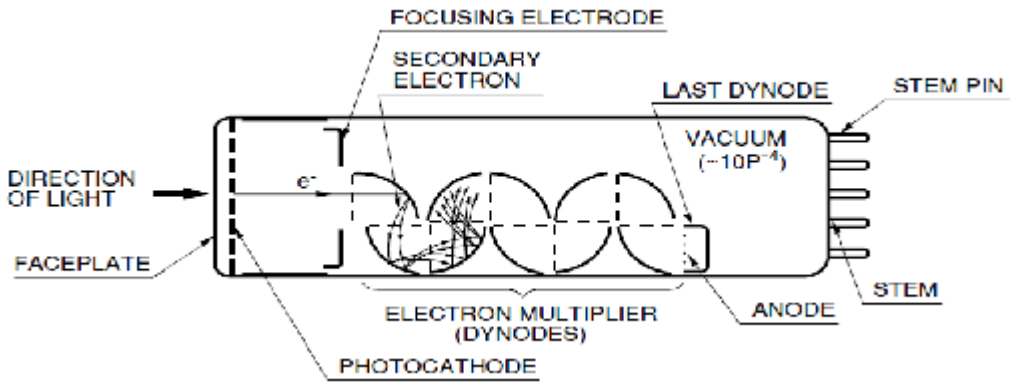
Conclusions

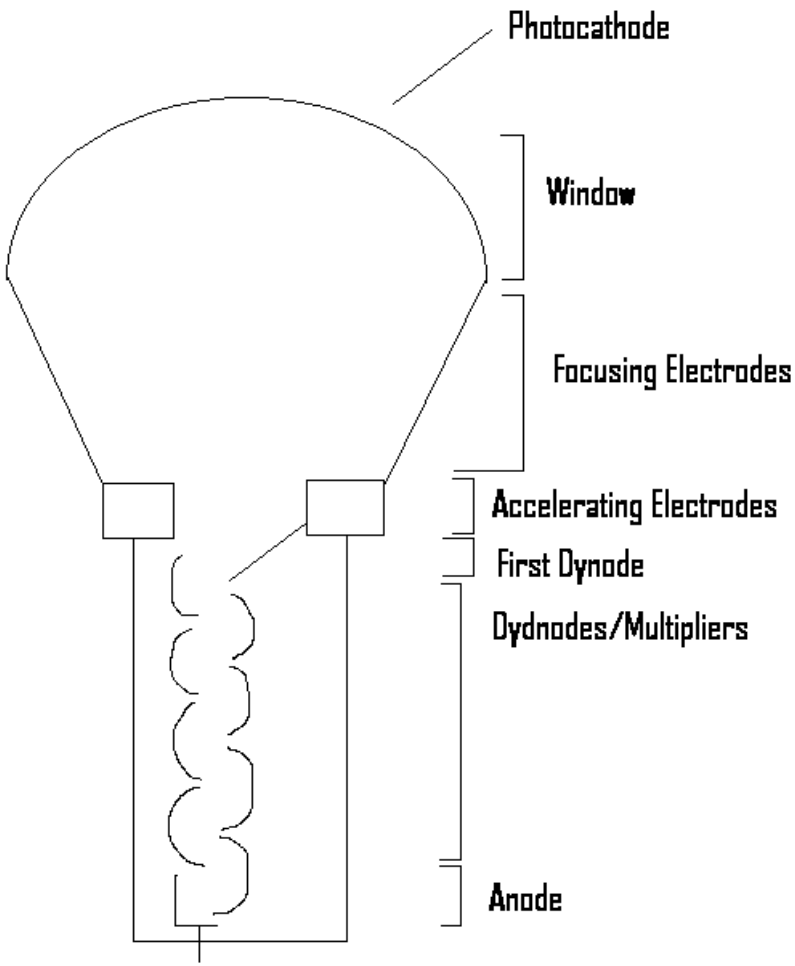
- 28+ PMTs tested at Nikhef-lab
- Continue taking measurements for all the phototubes received at Nikhef
- PMTs with high dark count need to be sent back
- Lower dark count (<1500Hz) seems possible for this photo cathode
- New specifications are required - although still at *development* phase

Thank you!

Back Up slides

PMTs: Principles and General characteristics





Dark Rate measurement

-The analog output signal of the PMT is led to the module where the charge is estimated by the integration of the area covered by the pulse waveform

-The digital output signal, after being discriminated, is led to another Channel of the same module.

Whenever the pulse crosses a certain preset threshold, the resulted output is recorded

-The amount of counts over threshold is recorded by the electronics every 10 seconds

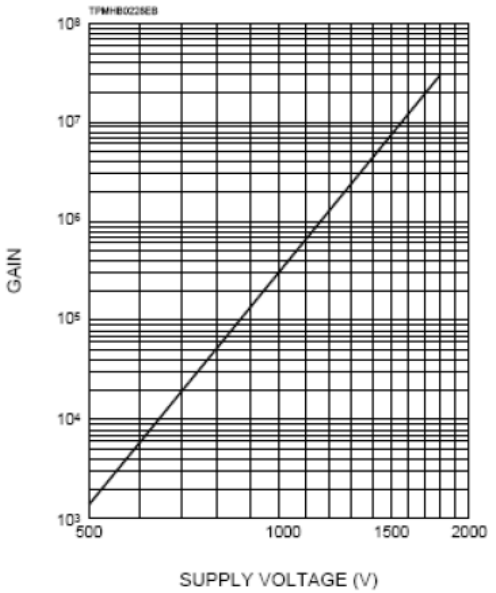
Gain measurement

- The PMT is illuminated by the LED of 3 ns pulse width
- Coincidence trigger assures that (should LED is on) only the PMT output is read by the electronics
- Three different values are examined: for the exact operating value provided by the manufacture company (for each PMT), for 50V higher than this value and for 50V lower than this.

  This is to assure that the measurements of the ETEL are accurate and that the obtained three values result in a linear relation between the gain and the voltage(both in logarithmic scale)

Technical characteristics measured at Nikhef lab

- **Dark noise:** Photoelectrons produced even when there are no incident photons (due to thermionic emission, leakage, cosmic rays...)
- **Gain**: the ratio of the number of electrons collected on the anode to the number of the emitted photoelectrons.



Technical characteristics measured at Nikhef lab

- **Afterpulse**: Pulse created due to an electron created at the 1st dynode that is not collected on the 2nd dynode
- **Transit Time Spread (TTS)**: the time from the absorption of a photon at the photocathode to the corresponding output signal at the anode (dependence on the emission at the photocathode, multiplication procedure...)