

PMT Measurements at Nikhef

Dorothea Samtleben,
Leiden University / Nikhef

Tested PMTs:

30 Hamamatsu PMTs

94 ETL PMTs

7 HZC PMTs

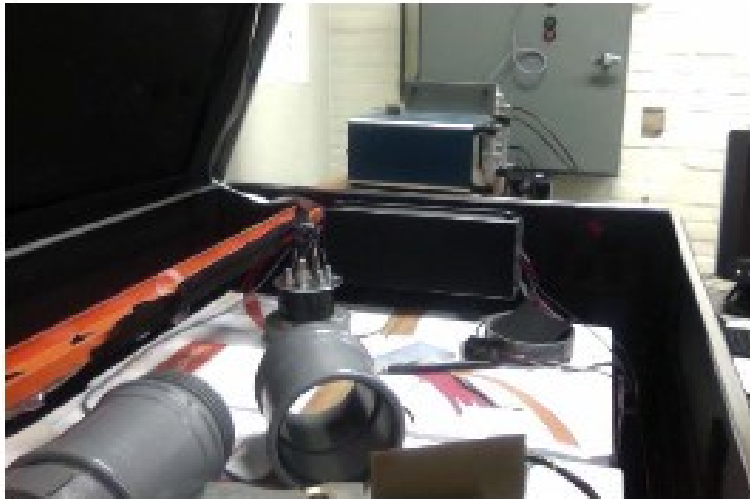
Measurements of:

Gain, Dark rate, TTS, Afterpulse fraction

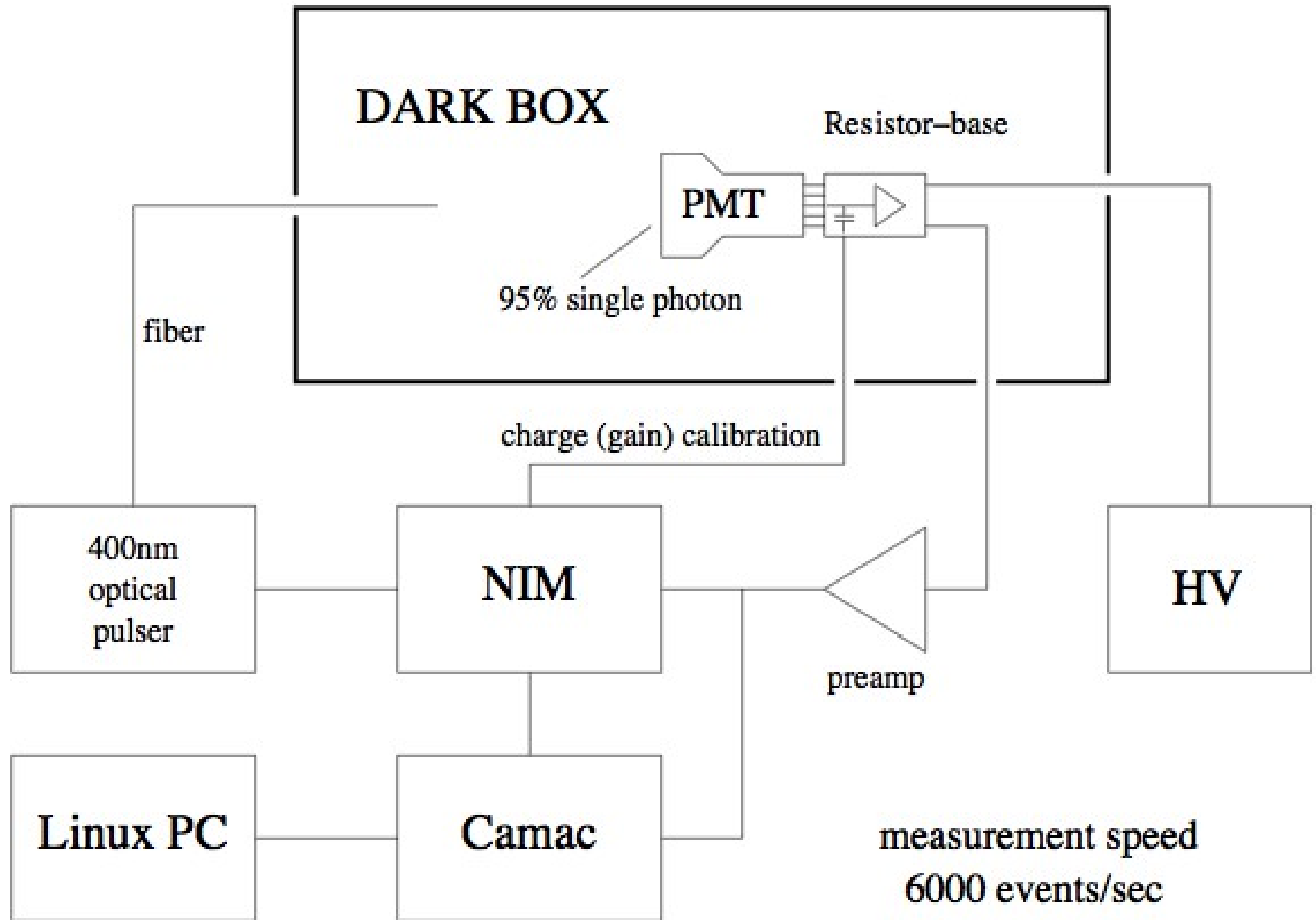
Engineers: Henk Peek, Jos Steiger

Students: Erwin Visser, Maria Tselengidou, Dimitris Paleosilitis,
Robert Bormuth

Setup

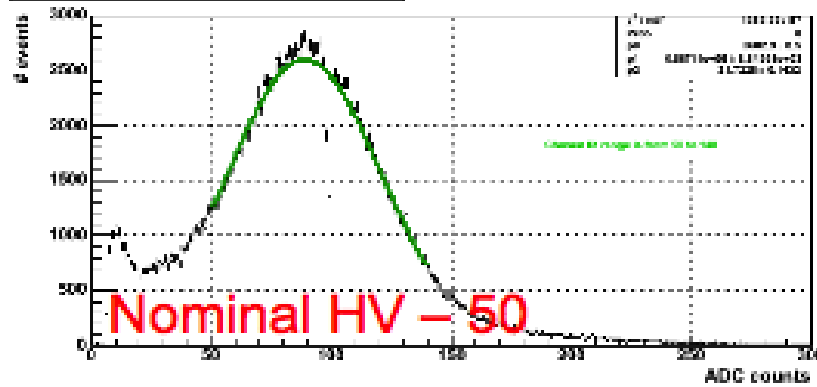


- Used for **Gain**, **dark rate** and **TTS** measurements
- For **Afterpulses** a different setup is used
- Preparing and inserting PMT takes most time
 - Preparing: ~ **5** minutes
 - Inserting: **5 – 10** minutes
 - Gain + TTS: ~**10** minutes
 - Dark Rate: ~**3** minutes

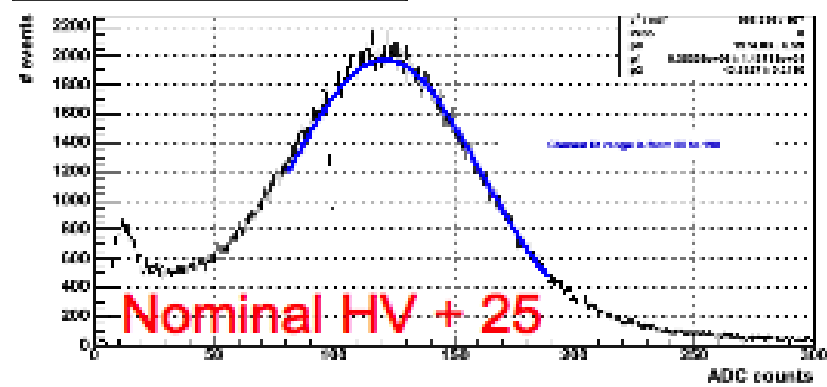


Gain

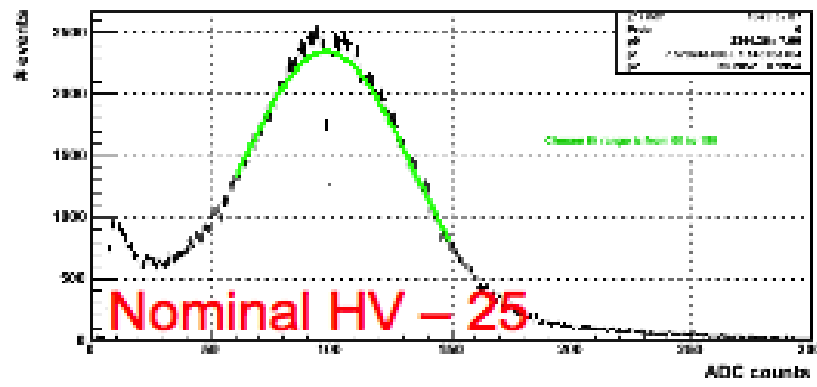
Gain measurement ZB 6092 (HV = 1400)



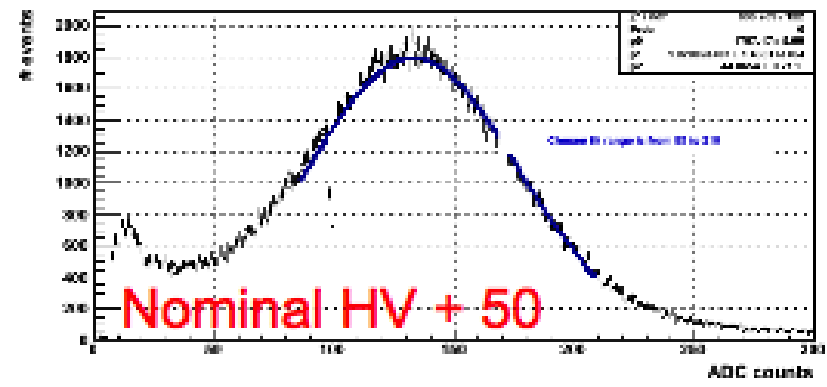
Gain measurement ZB 6092 (HV = 1475)



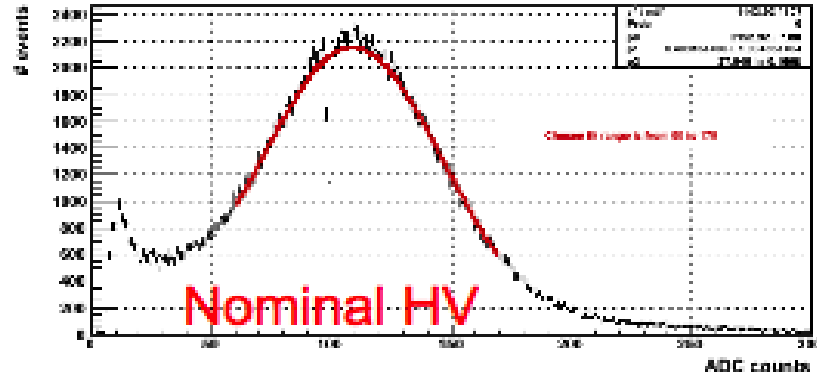
Gain measurement ZB 6092 (HV = 1425)



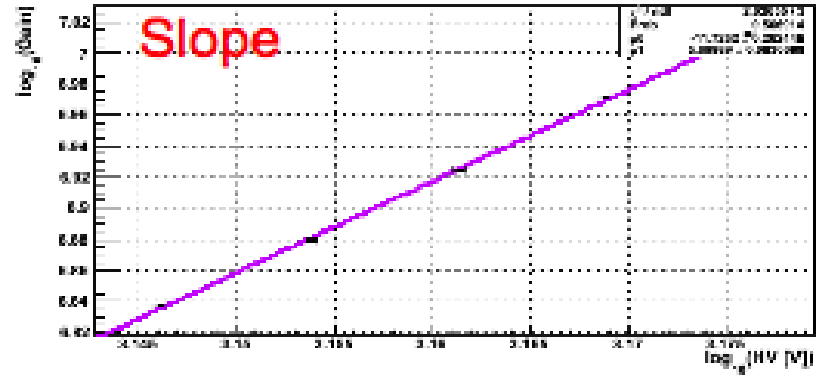
Gain measurement ZB 6092 (HV = 1500)



Gain measurement ZB 6092 (HV = 1450)

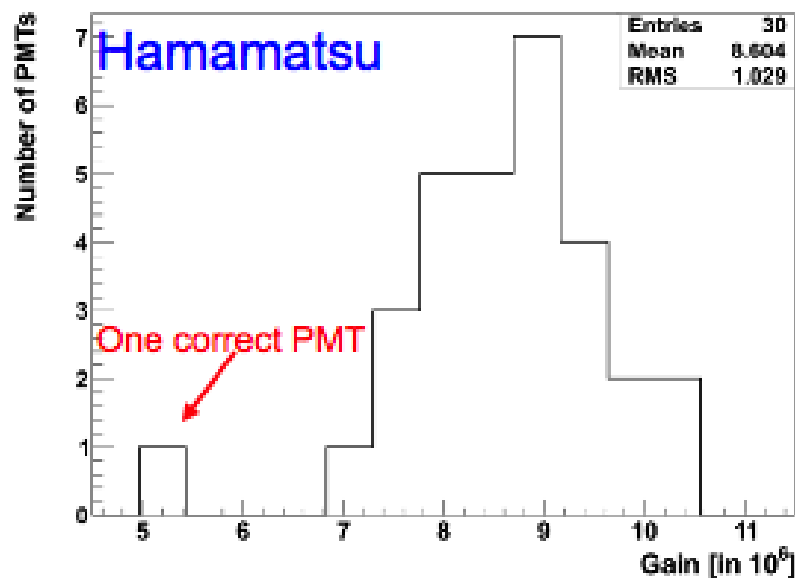


Gain of ZB 6092 versus HV

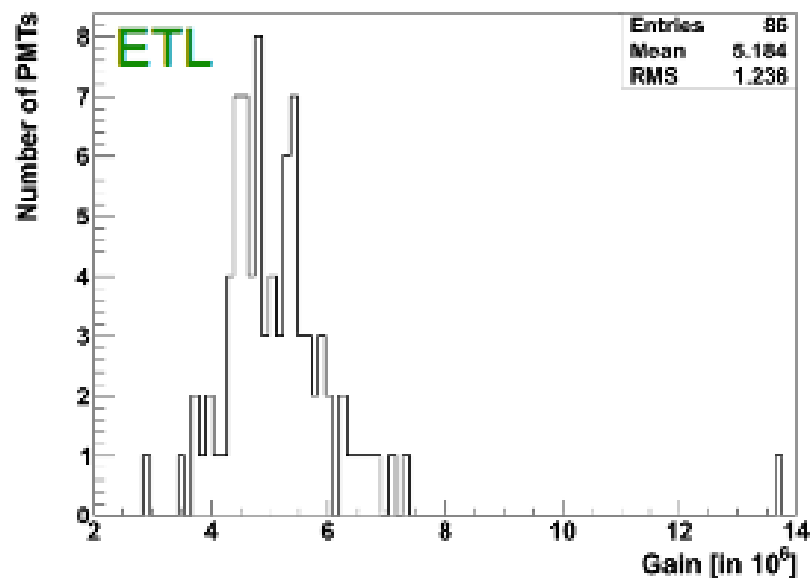
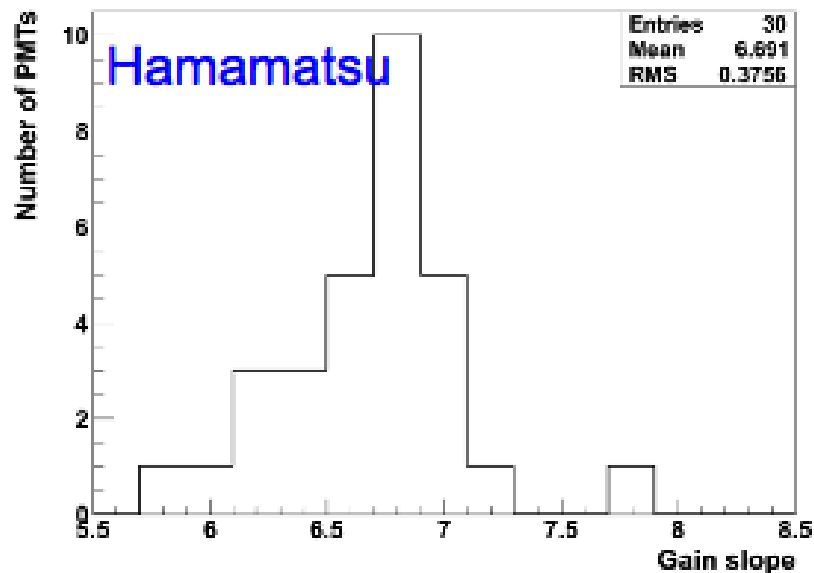
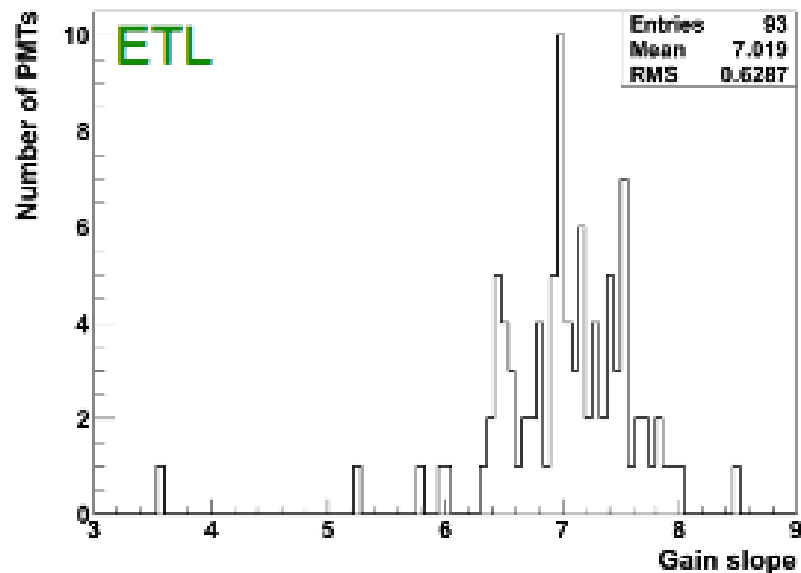


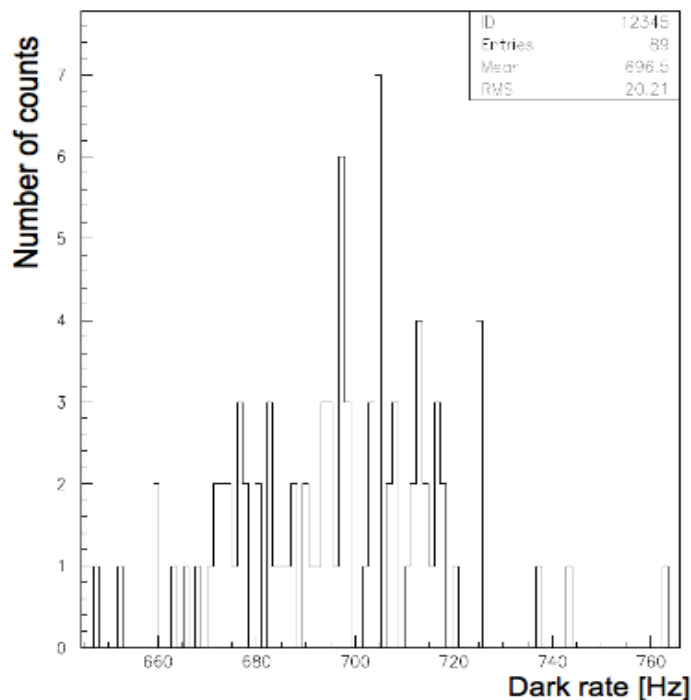
Gain

Gain @ nominal voltage



Gain @ nominal voltage

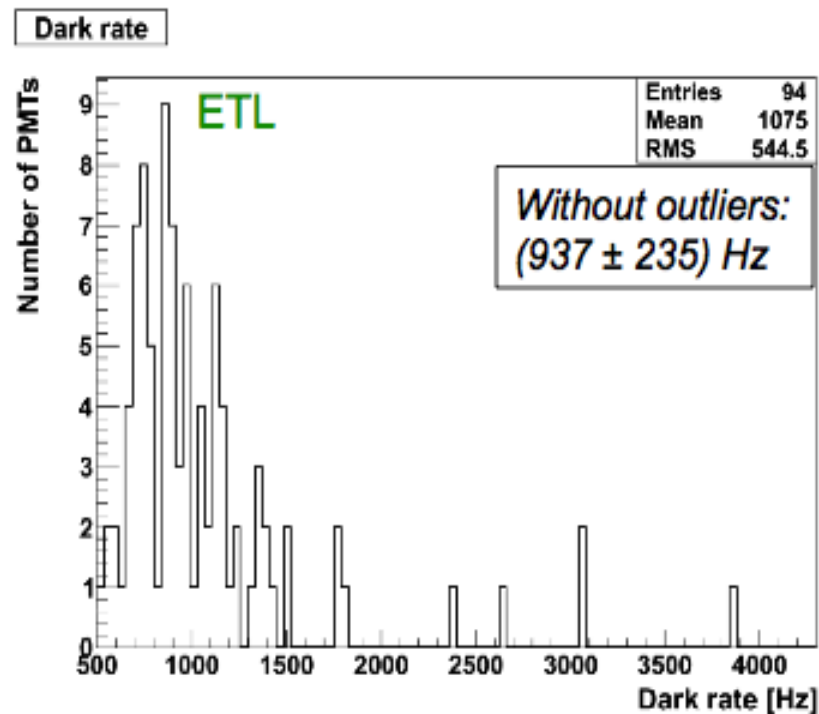
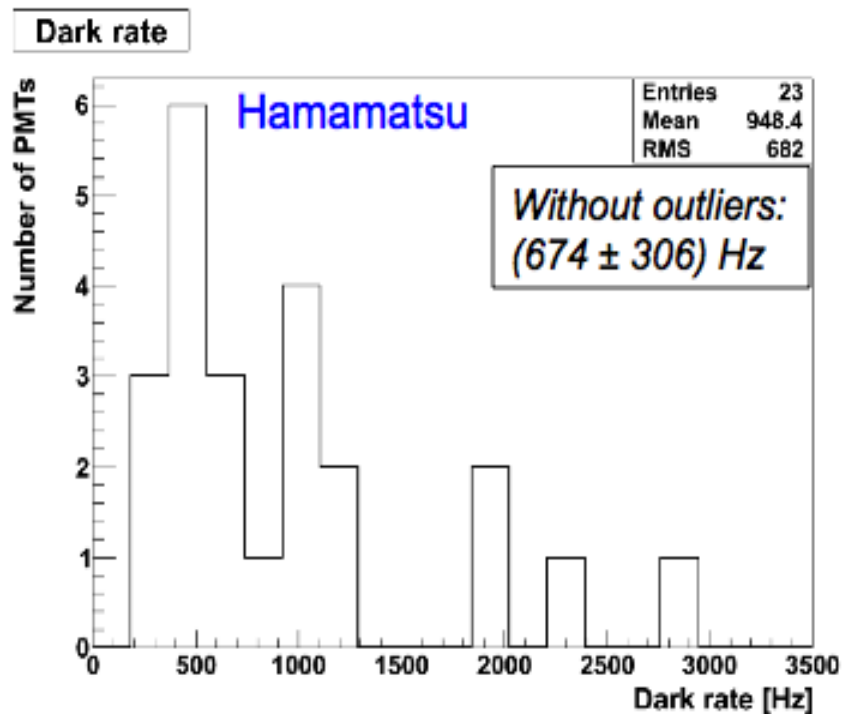
Gain slope ($\log_{10}(\text{gain})/\log_{10}(\text{HV})$)Gain slope ($\log_{10}(\text{gain})/\log_{10}(\text{HV})$)

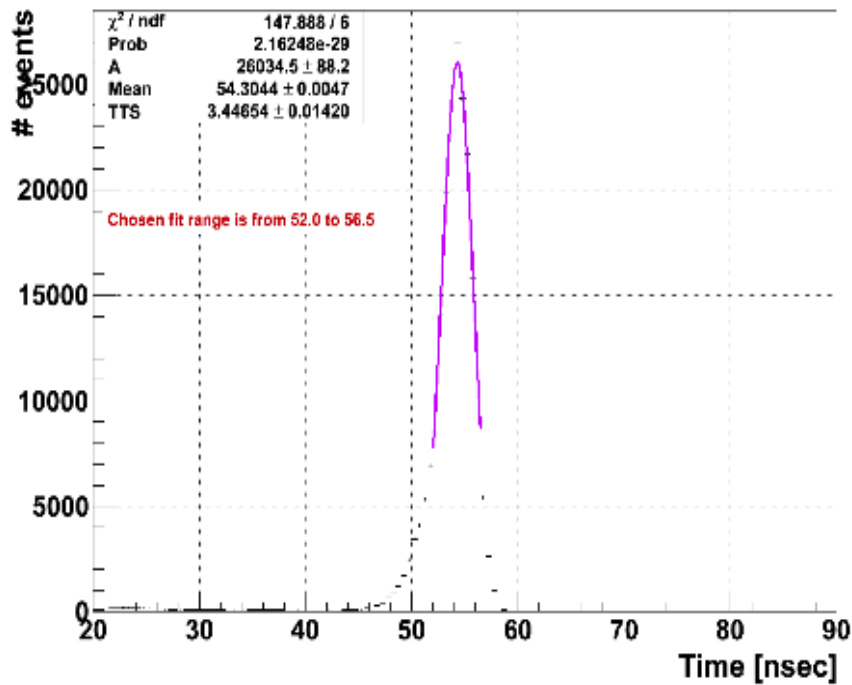


Dark rate

Count pulses in ~100 intervals
of 10 seconds each
=> dark rate = average

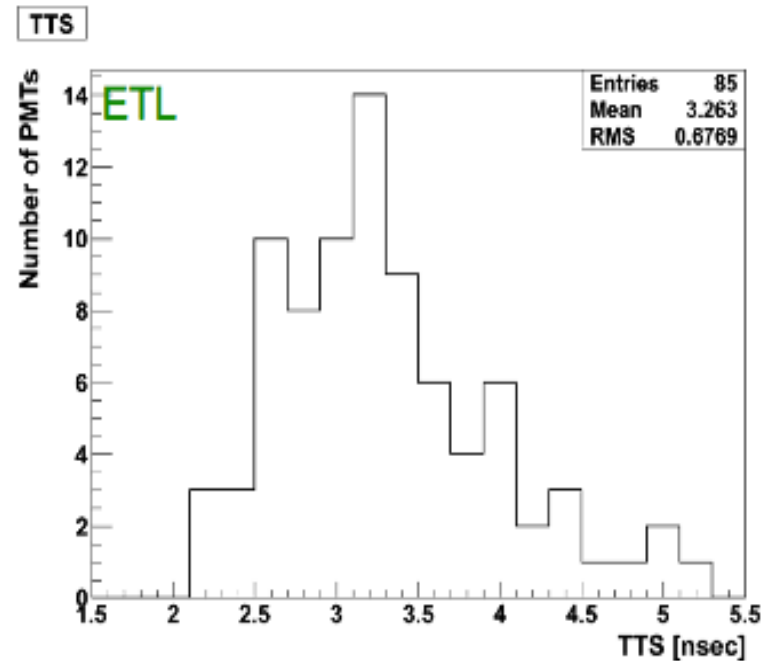
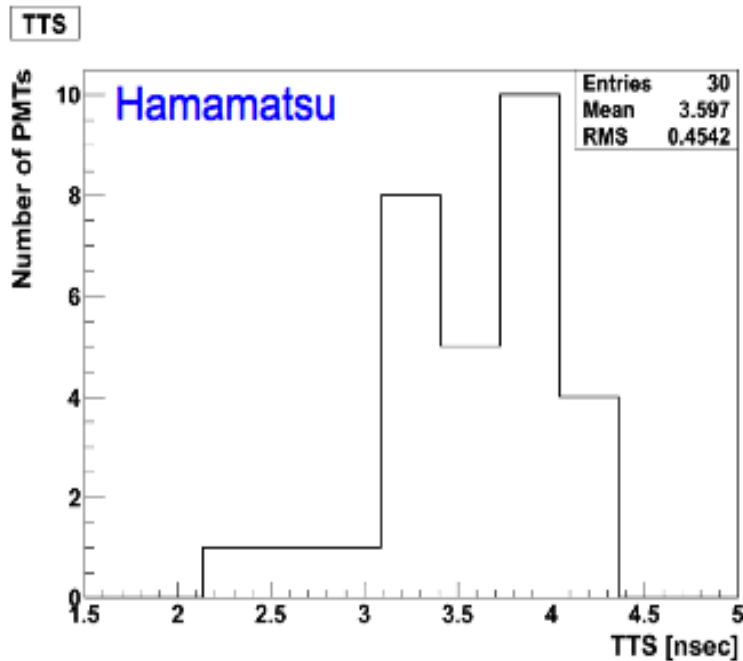
Specified: < 1500Hz



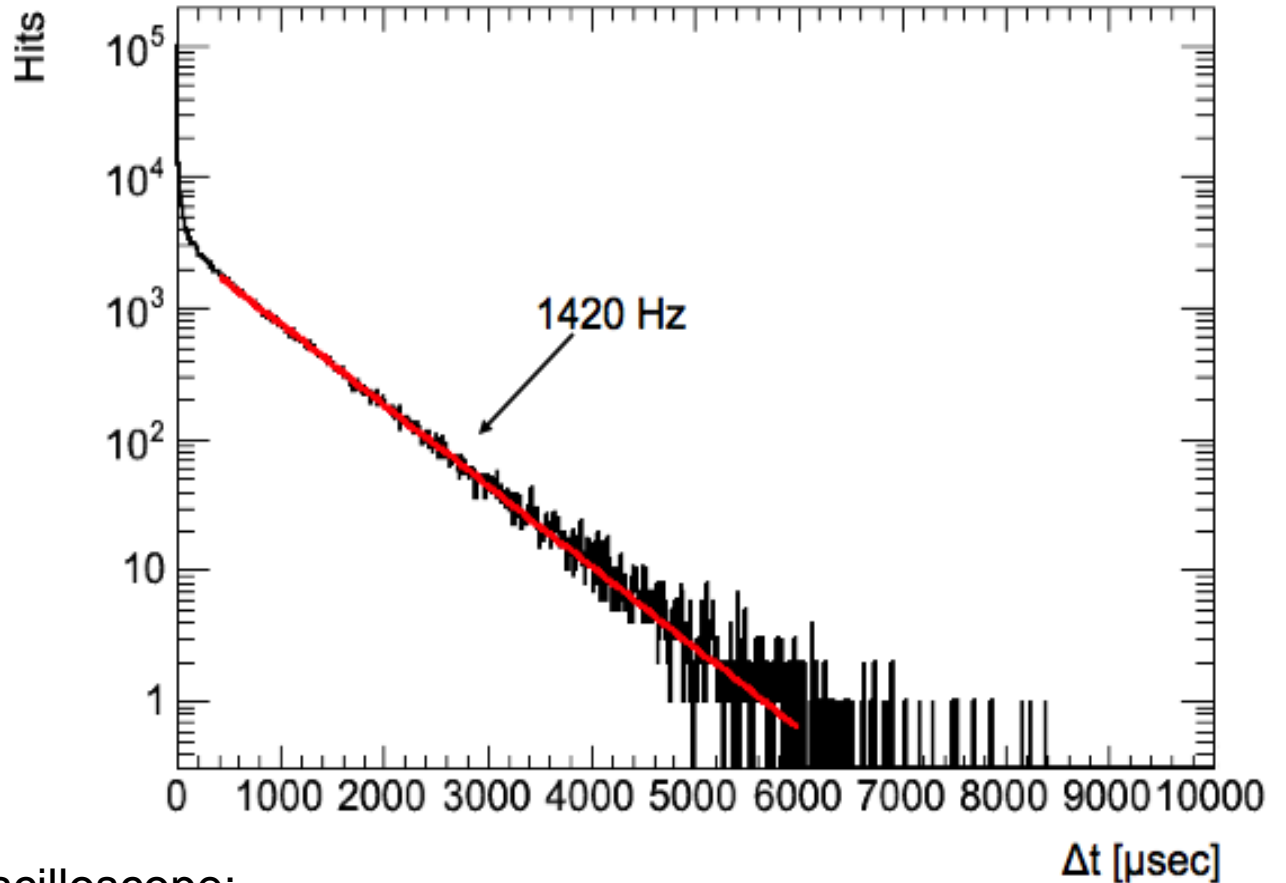


Transition Time Spread

- TTS \equiv FWHM
- Width of LED pulser: 800 ps
- TTS = $\sqrt{3.45^2 - 0.8^2}$ ns = 3.4 ns
- Specified: < 4.7ns



Afterpulse fraction

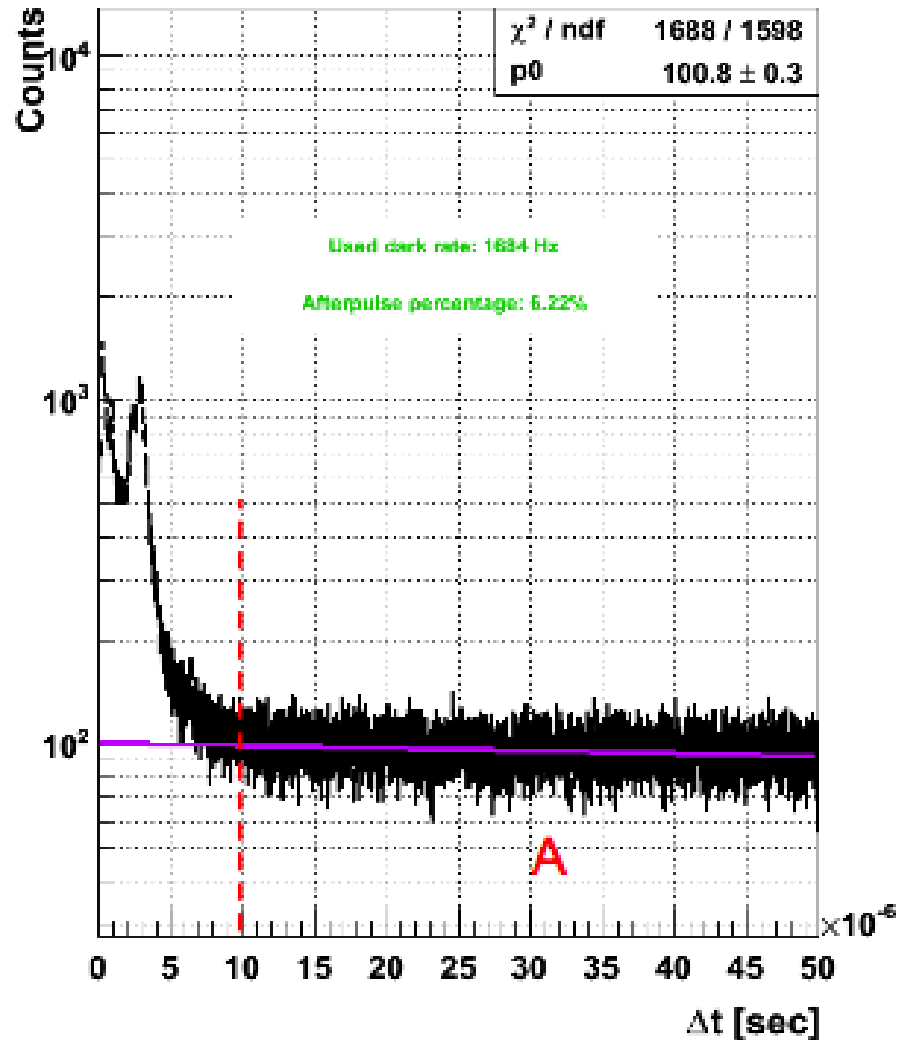


Afterpulses measured with oscilloscope:

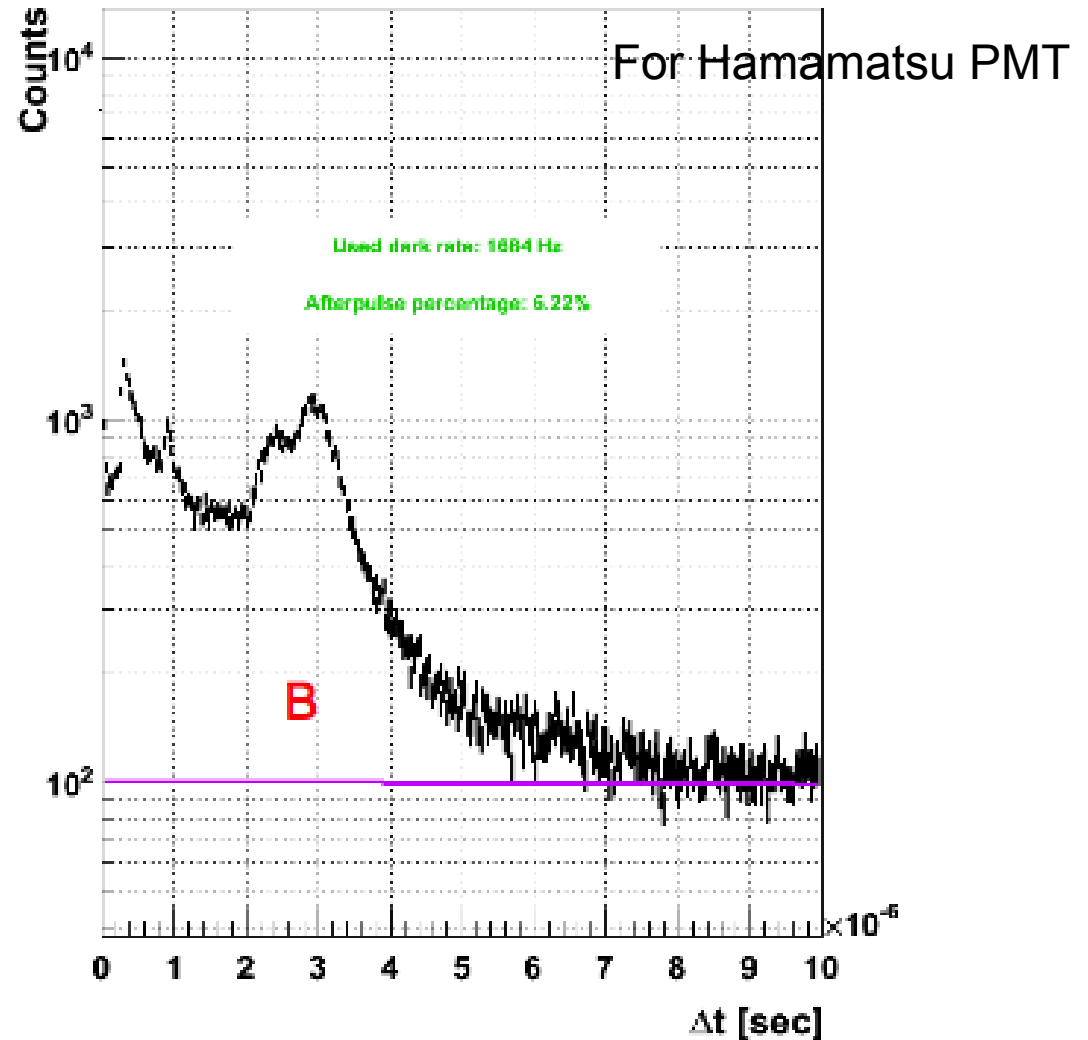
- storing in histogram distance between two pulses
- two options:
 - + triggering on any pulse
 - + triggering on laser

Afterpulses

Number of pulses versus time for ZB 6107 (HV = 1330)



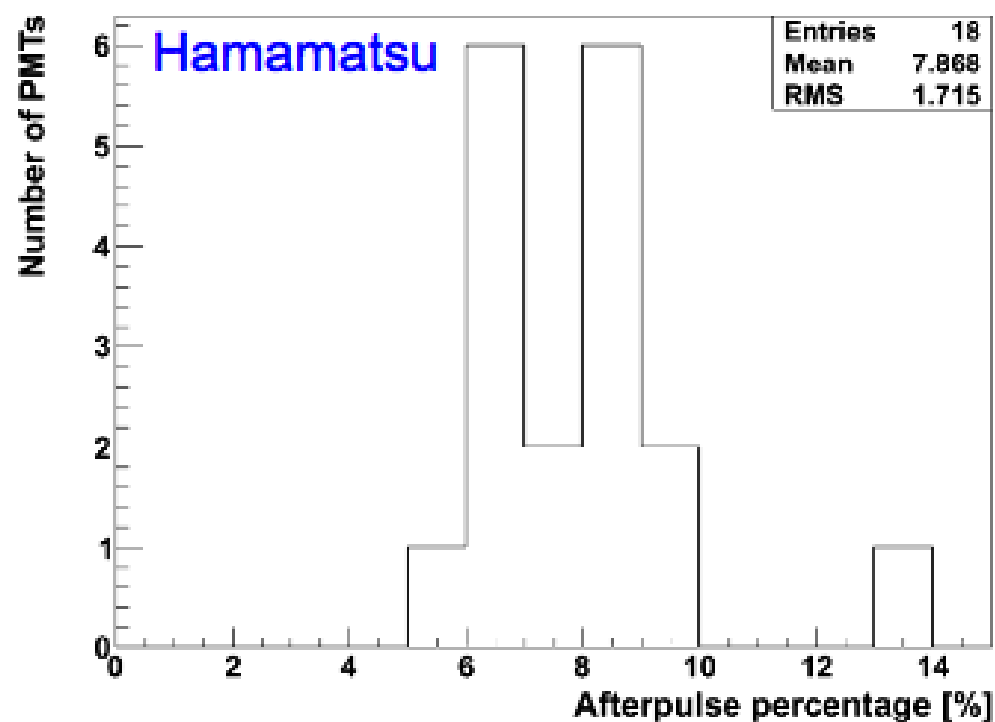
Number of pulses versus time for ZB 6107 (HV = 1330)



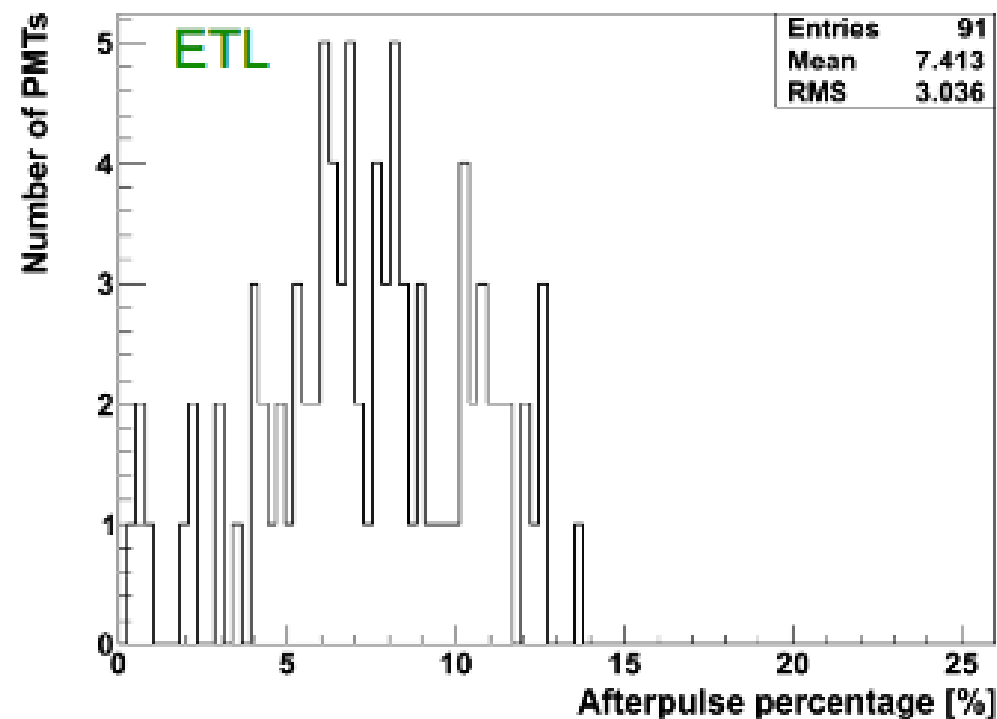
$$\text{Afterpulse \%} \equiv B / (A + B)$$

Afterpulses

Afterpulse percentages



Afterpulse percentages



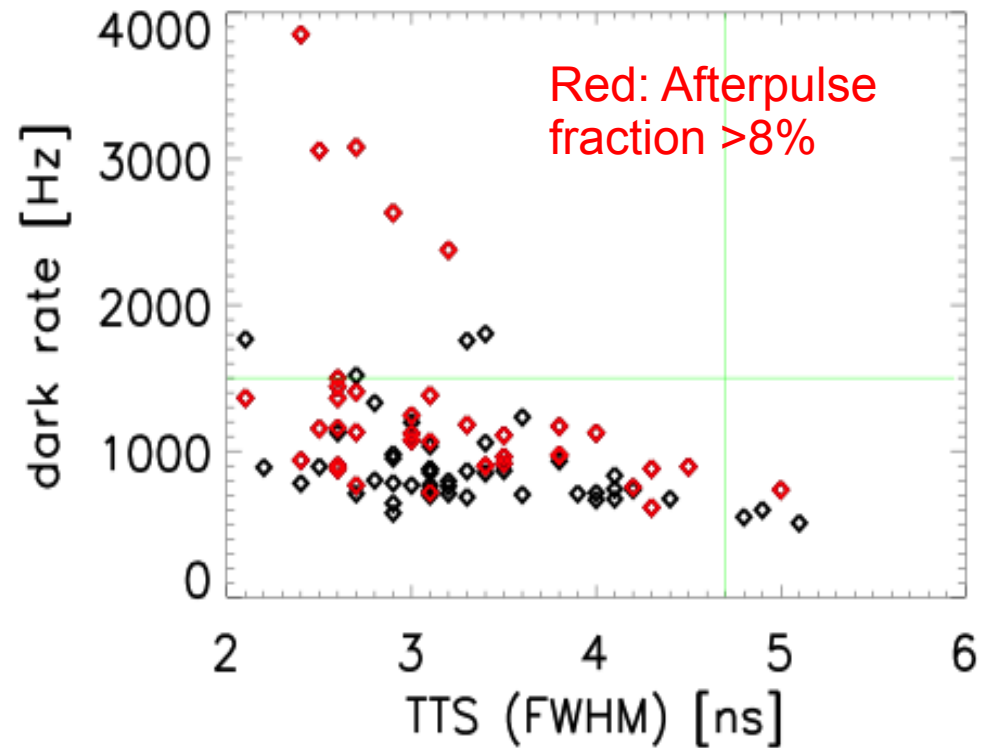
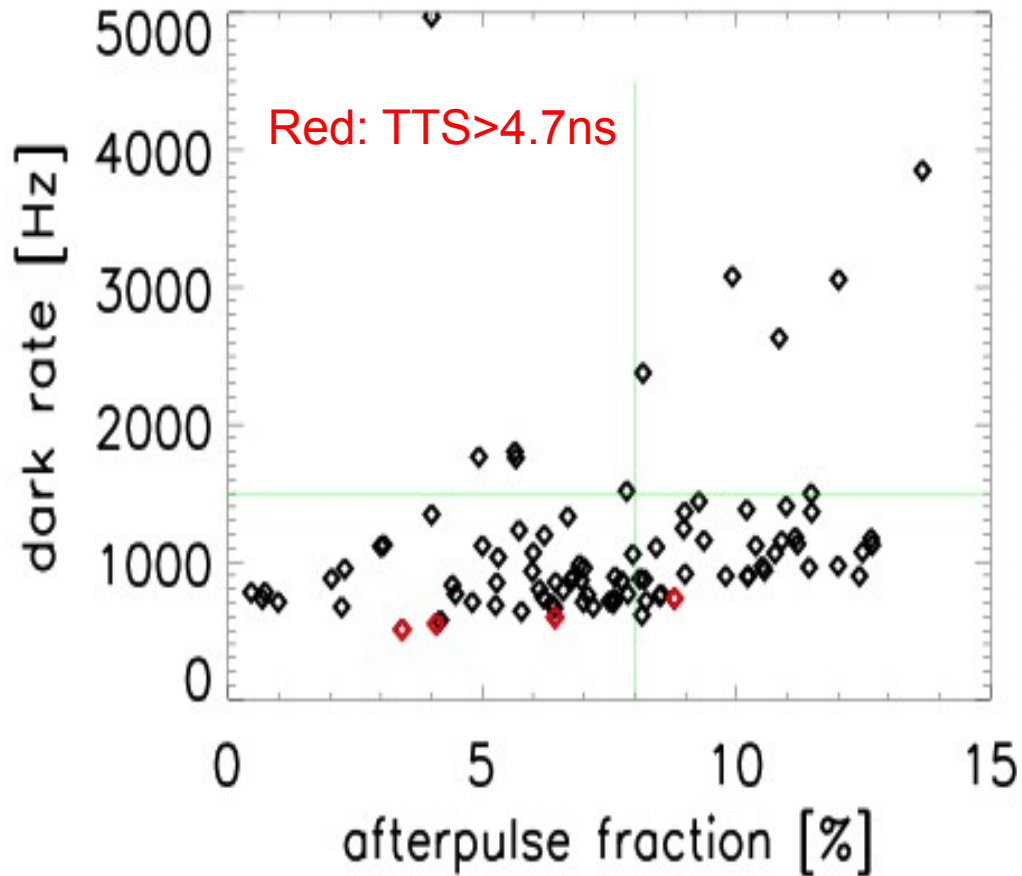
Requirements:

Dark rate < 1500 Hz

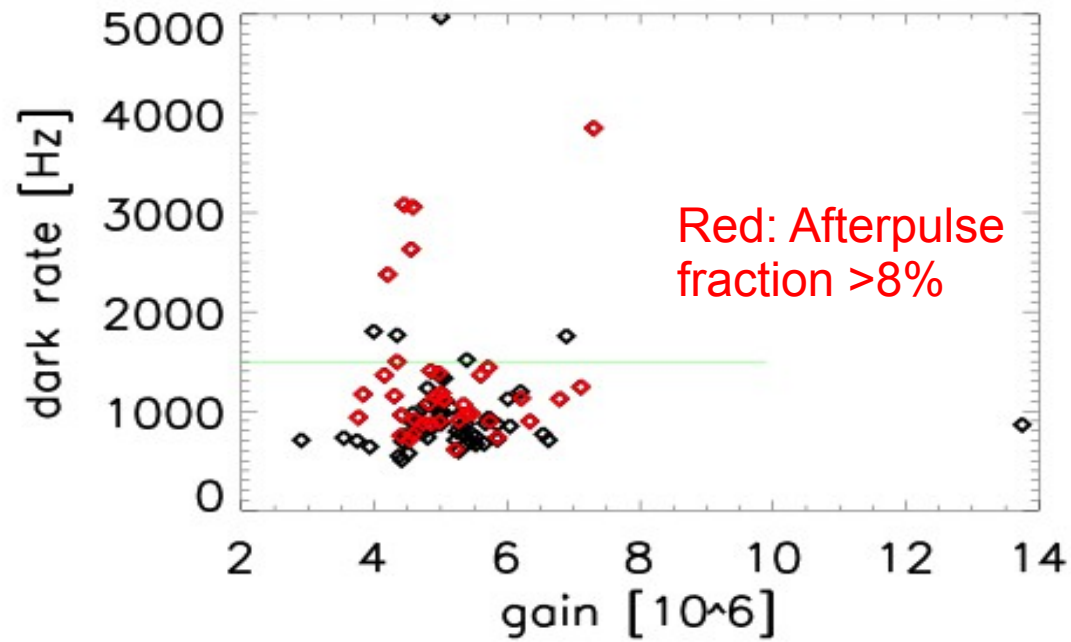
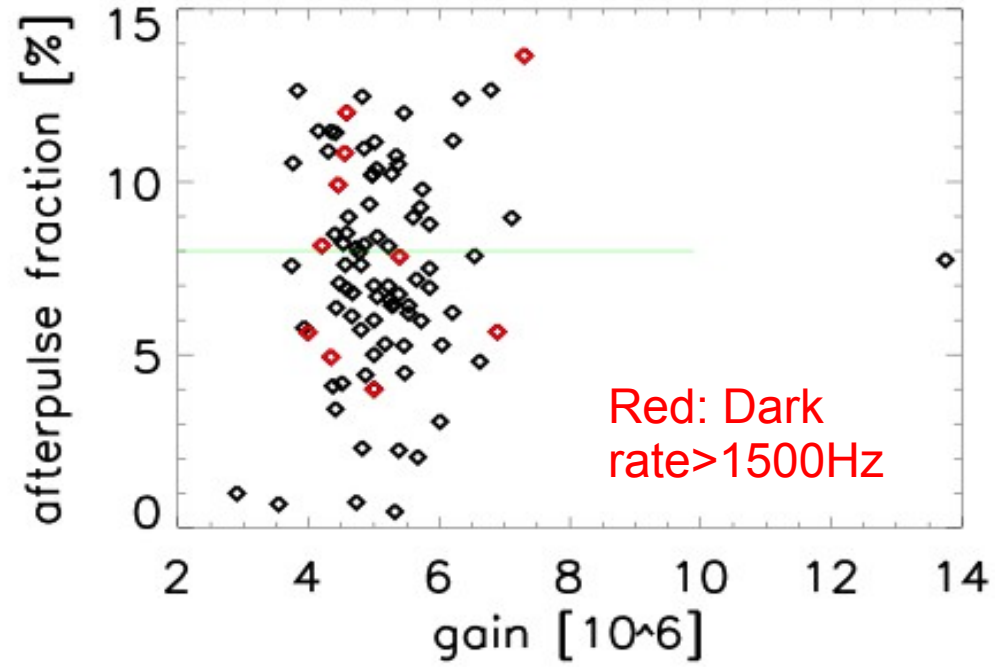
Afterpulse fraction < 8%

TTS < 4.7 ns

ETL



ETL



Comparison to specifications

| | ETL <small>[accepted] / [total measured]</small> | Hamamatsu <small>[accepted] / [total measured]</small> |
|--------------|--|--|
| Afterpulses | 53 / 91 | 10 / 18 |
| Dark count | 83 / 94 | 19 / 23 |
| Gain | 83 / 86 | 1 / 30* |
| TTS | 79 / 85 | 30 / 30 |
| Total | 37 / 85 (43.5%) | 8 / 18 (44.4%) |

* Gain can be tuned easily

HZC PMTs

Chinese manufacturer
Design based on Photonis expertise

Maarten de Jong/Els de Wolf visited in December
Prototype PMTs delivered in January

| PMT No. | HV [V] | Gain [1×10^6] | HV at gain 3×10^6 | TTS [ns] | dark current [per s] | Afterpulse to dark percent |
|---------|-----------|-----------------------------|-------------------------------|-------------|-------------------------|-------------------------------|
| 18 | 1453 | 5.6 | 1342 | 3.81 | 1678 | 12.02 |
| 22 | 1485 | 5.0 | 1377 | 2.76 | 2363 | 43.78 |
| 48 | 1414 | 5.15 | 1312 | 3.24 | 3238 | 18.55 |
| 54 | 1668 | 4.96 | 1531 | 2.66 | 1750 | 13.35 |
| 58 | 1543 | 5.26 | 1411 | 3.13 | 2497 | 13.98 |
| 59 | 1546 | 4.56 | 1449 | 3.42 | 1921 | 11.91 |
| 66 | 1438 | 4.14 | 1354 | 2.94 | 1851 | 18.98 |

HV higher than
requirements
(max 1300V)

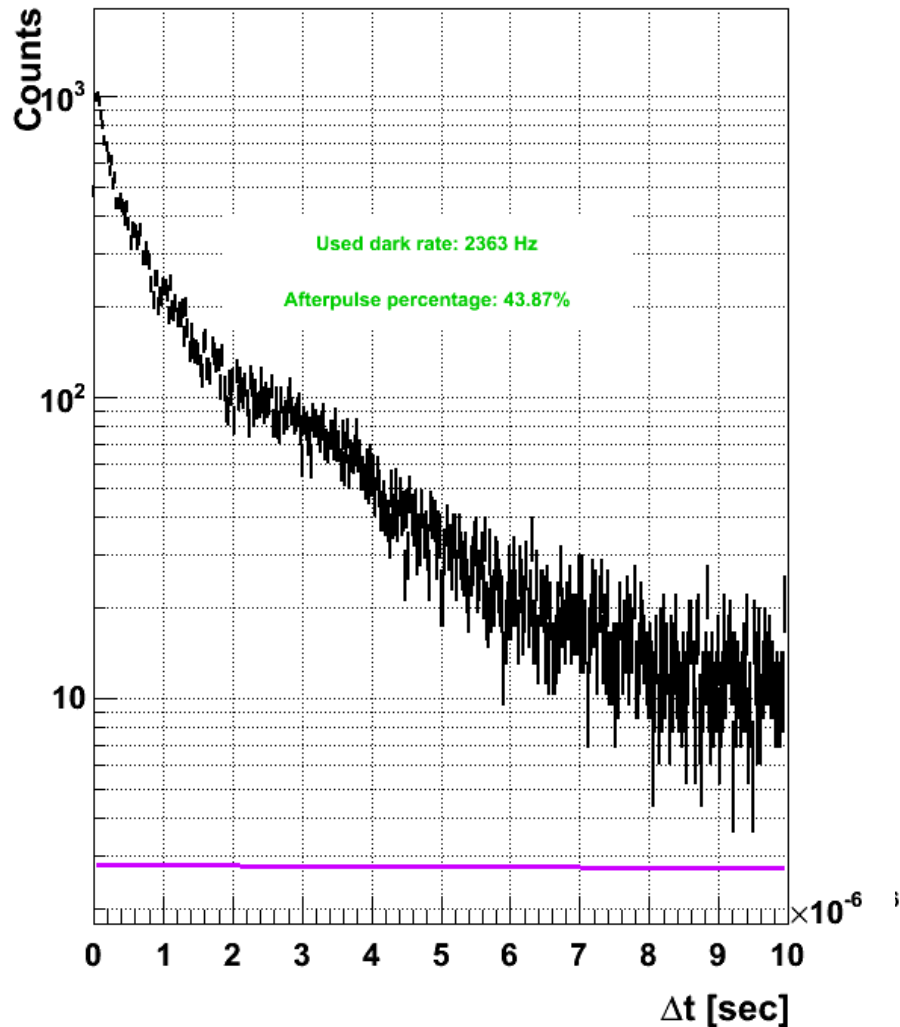
HV can be tuned,
TTS marginally larger (~0.2ns on 100V)

High dark current
(max allowed 1500 Hz)

Very high afterpulse
fractions
(in total max 8%
allowed)

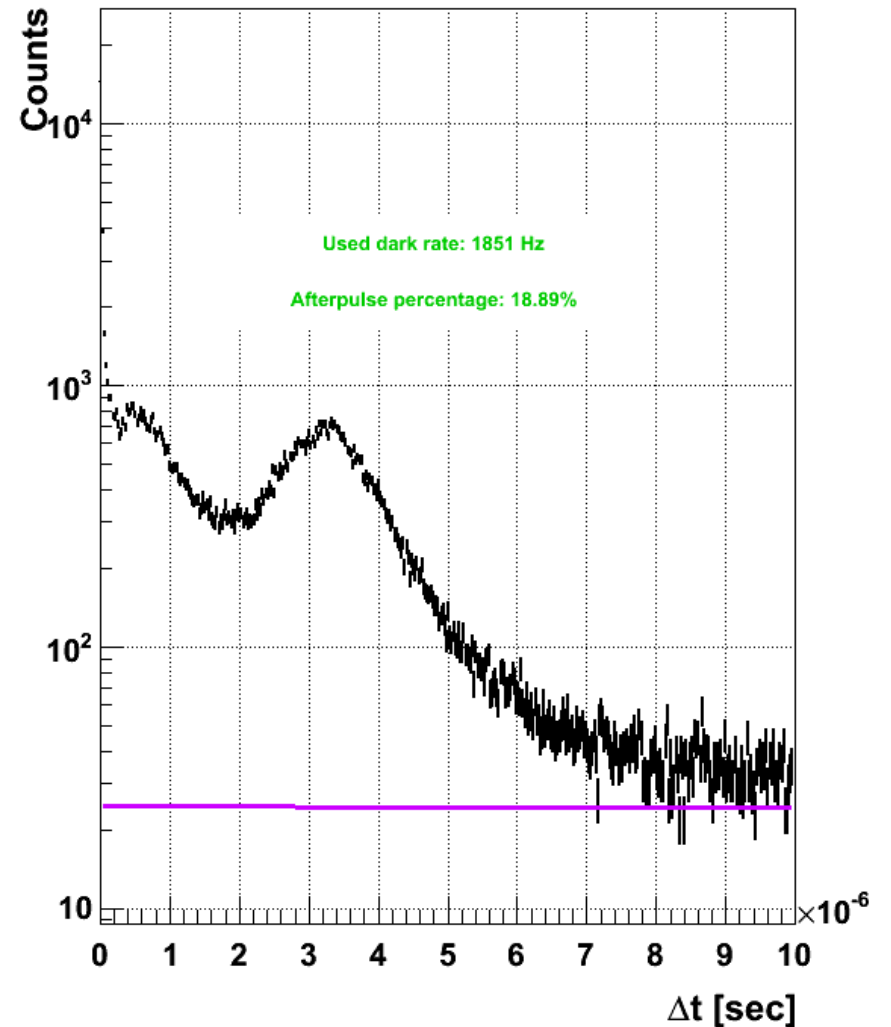
Trigger on any pulse

Number of pulses versus time for PMT 22 (HV = 1485)



Trigger on Laser signal

Number of pulses versus time for PMT 66 (HV = 1438)



Here measurements of 2 different PMTs, but tendency the same for same PMT
High afterpulsing and structure under investigation

Summary

- Measurements can be routinely made on single PMTs, upgrade for automatization and multi-PMTs required for mass production
- ETL PMTs fail specifications mostly due to high afterpulse fraction
- HZC tubes require HV beyond specification and show far too high afterpulse fraction
- Systematic of afterpulse measurement needs to be investigated