Physics Laboratory
School of Science and Technology
Hellenic Open University

KM3NeT
Opens a new window on our universe

Characterization of KM3NeT photomultipliers in the Hellenic Open University

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Hellenic Open University

VLVnT13, Very Large Volume Neutrino Telescope Workshop 2013

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

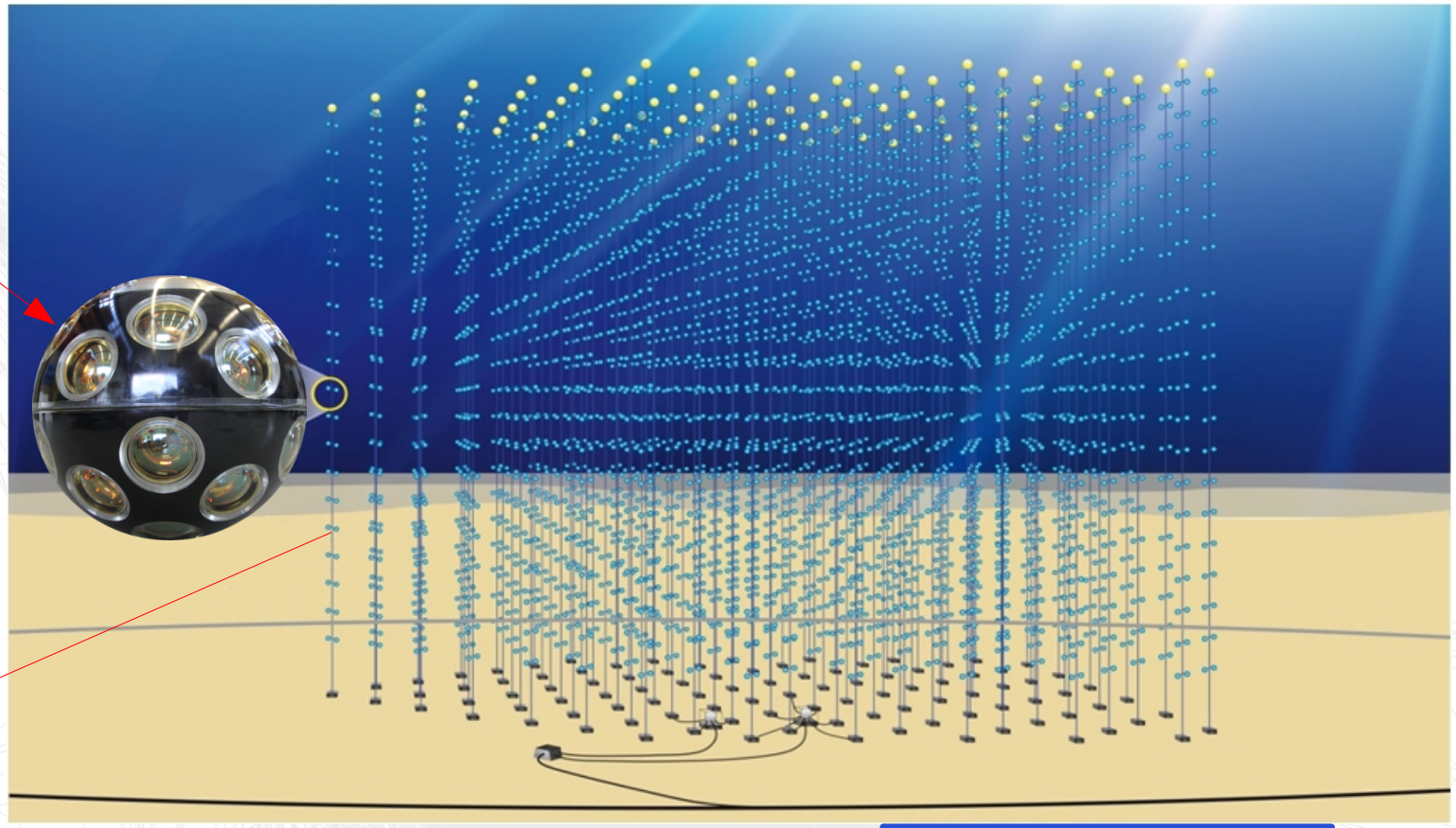
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

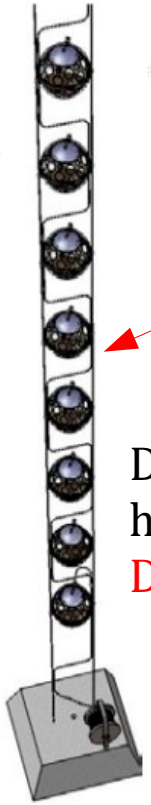
Outline

- The KM3NeT telescope
- The KM3NeT optical modules
- PMT characterization
  - Calibration setup
  - Gain slope and single pe characteristics
  - Peak-to-Valley
  - Transit Time Spread
  - Dark current rate
  - After pulses fraction and multiplicity
- Summary and outlook

The KM3NeT Telescope

Optical Module (OM): pressure resistant sphere cointaining photomultpliers



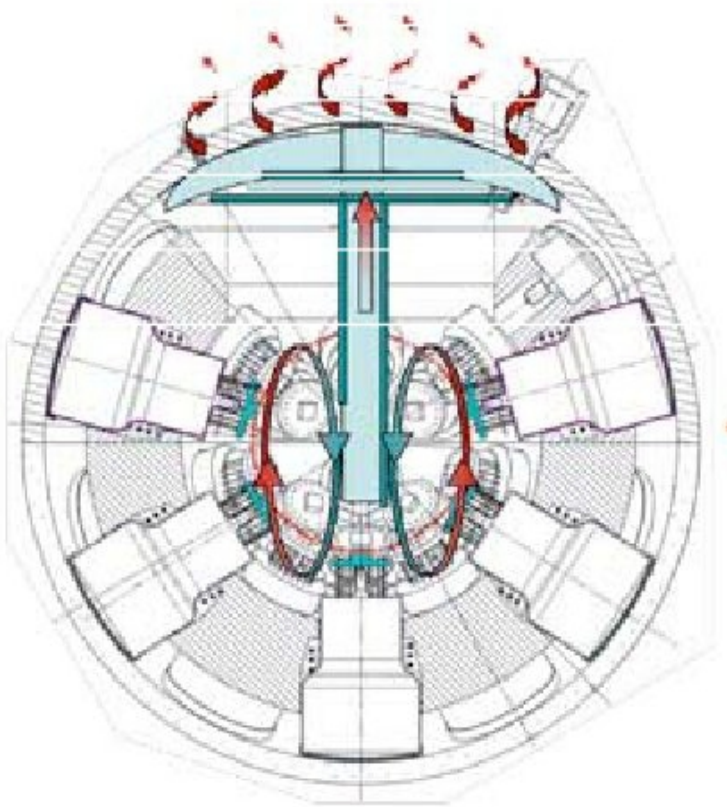


Detection Unit (DU): mechanical structure holding OMs, enviromental sensors, electronics,...
DU is the building block of the telescope

KM3NeT in numbers
- ~12200 DOMs
- ~620 DU
- ~20 DOM/DU
- ~40m DOM spacing
- ~1 km DU height
- ~100 DU distance
- ~4 km^3 volume

KM3NeT Optical Modules

- 31 3'' PMTs (~30% max QE) inside a 17'' glass sphere with 31 bases (total ~6.5W)
- Cooling shield and stem
- Full prototypes under testing
- Single vs multi-photon hit seperation
- Large (1260 cm^2) photocade area per OM



PMT Characterization

PMTs under testing (Nikhef, ECAP Erlangen, INFN Catania)

- 200 Hamamatsu R12199 PMTs (E. Leonora talk)
- 94 ETL PMTs
- 7 HZC PMTs (O. Kalekin talk)

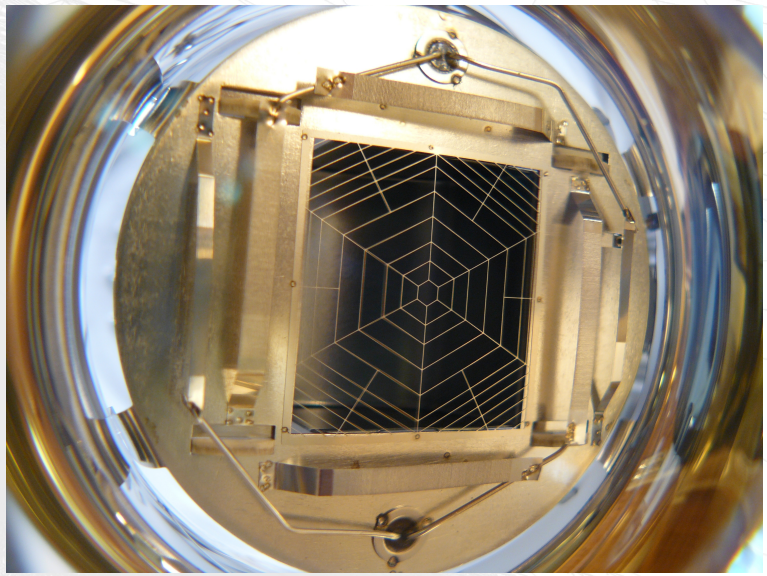
Tested for

- Quantum efficiency
- Gain slope
- Dark current rate
- Transit Time Spread (TTS)
- After pulse fraction
- Peak-to-valley ratio
- Effective area

KM3NeT specifications for PMTs:

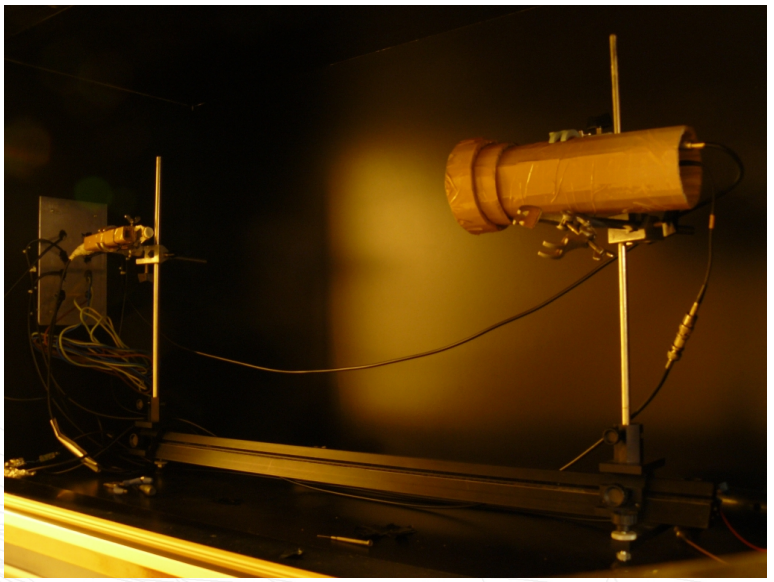
- QE @ 470nm > 20%
- HV for 5×10^6 gain 1000-1400V
- TTS <2ns sigma
- Dark current rate <1kHz
- Peak-to-valley ratio >3

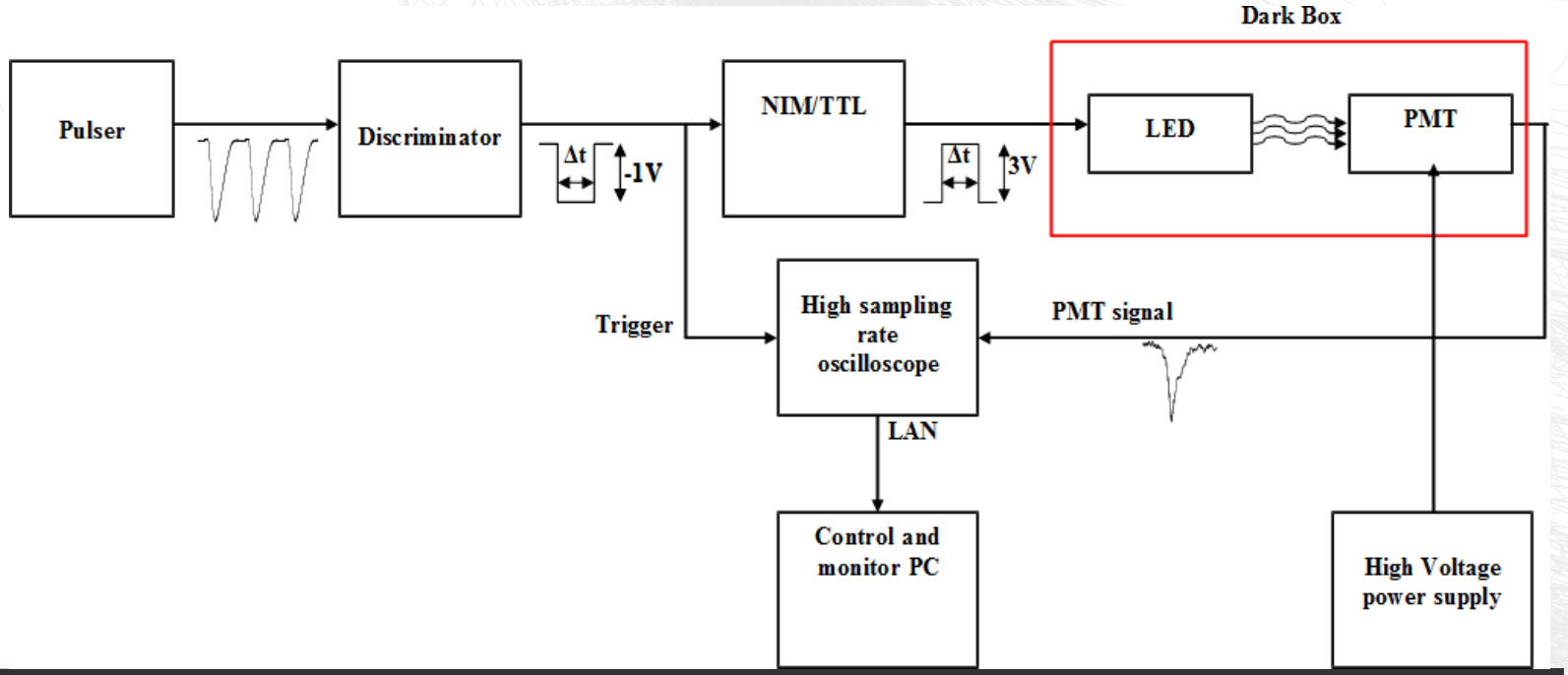
Hamamatsu R12199-02



HOU PMT Calibration Setup

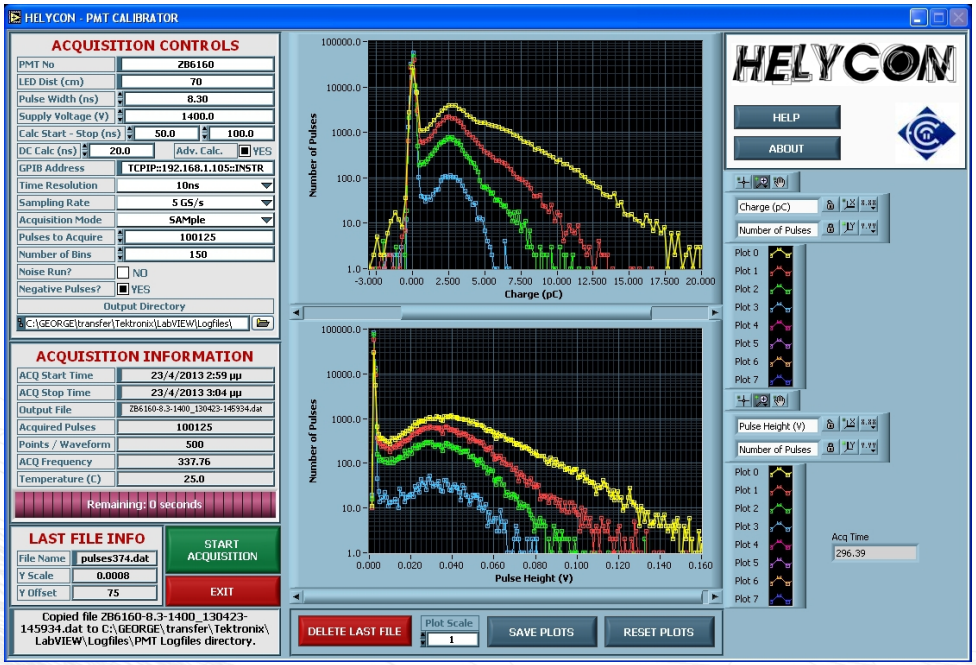
- Dark box hosting the PMT under calibration
- PMT power base provided by Erlangen
- HLMP-LB11-FJ000 LED (blue - 470nm) inside the dark box powered by a ~3V pulse with adjustable width
- NIM Pocket Pulser Model 417 (10kHz)
- NIM electronics: discriminator and NIM/TTL
- External high voltage power supply for the PMTs

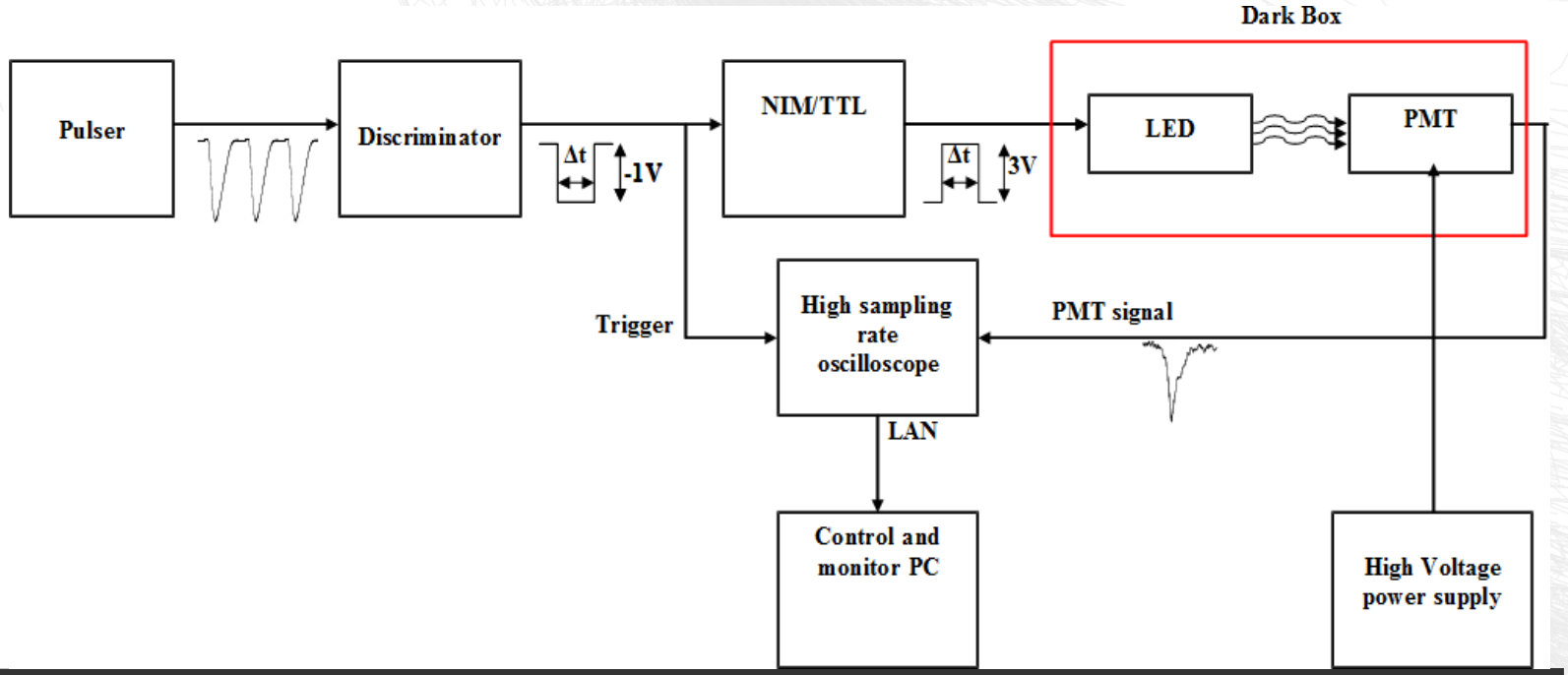




HOU PMT Calibration Setup

- 5GS/s high sampling rate oscilloscope (Tektronix 5052B) with LAN connectivity
- Custom software for data acquisition (LabVIEW and C++)
- Acquisition rate 350Hz if the full pulse waveforms are saved, >1kHz otherwise
- PMT stays in darkness without supply voltage for ~3h
- PMT powered with the typical voltage for ~1h before measurements begin





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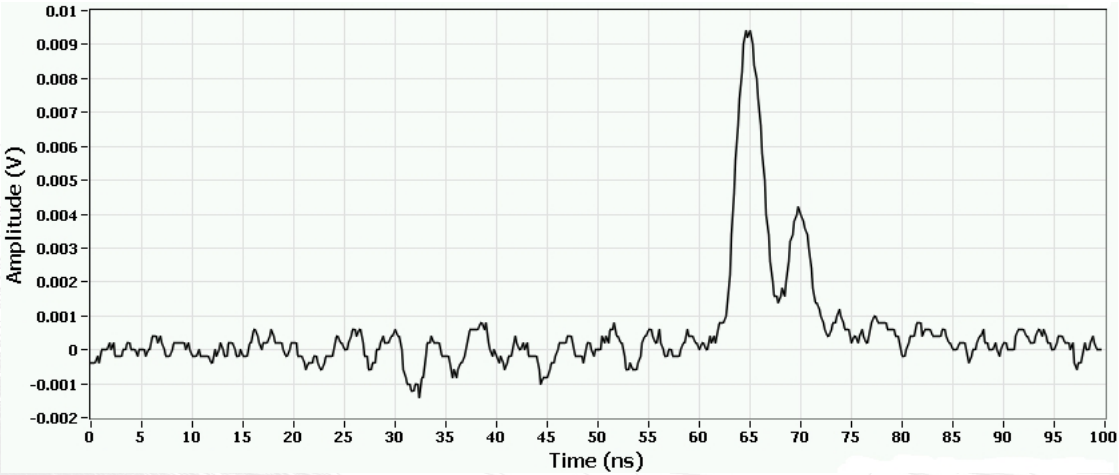
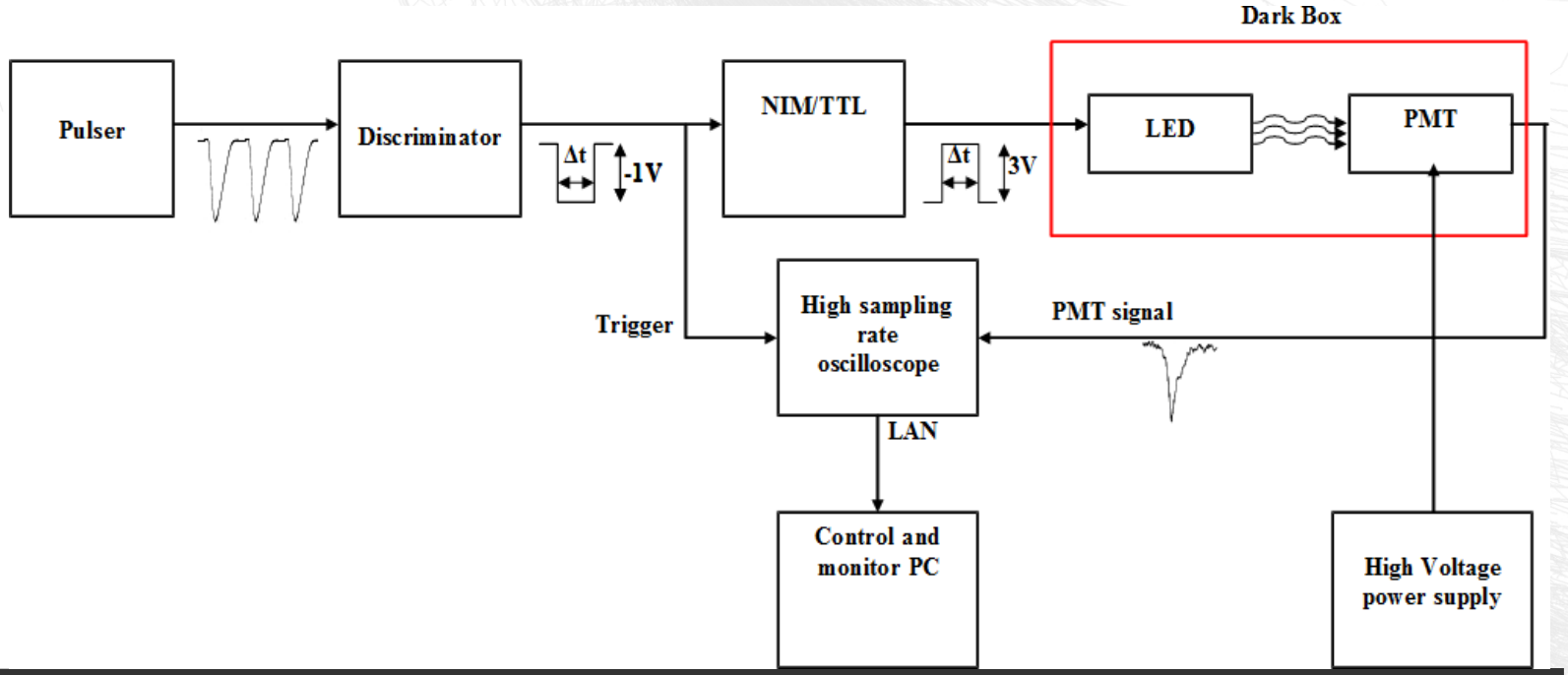
Gain slope & single pe characteristics Setup

- PMT in spe conditions by narrowing the LED pulse width
- Oscilloscope triggered by the LED power pulse
- Around 100000 pulses acquired for each PMT voltage supply in the range 1000-1400V with 50V step
- Procedure may be repeated for higher light level





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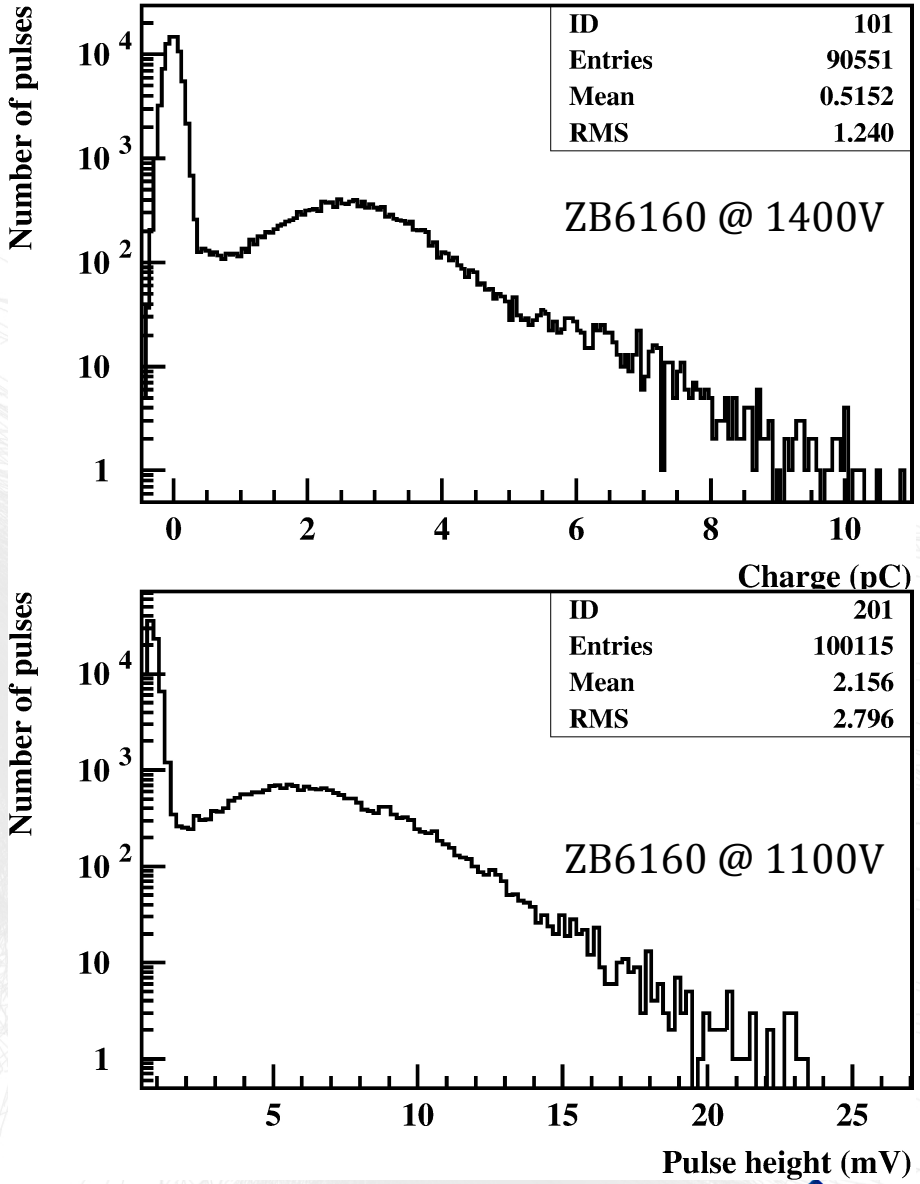
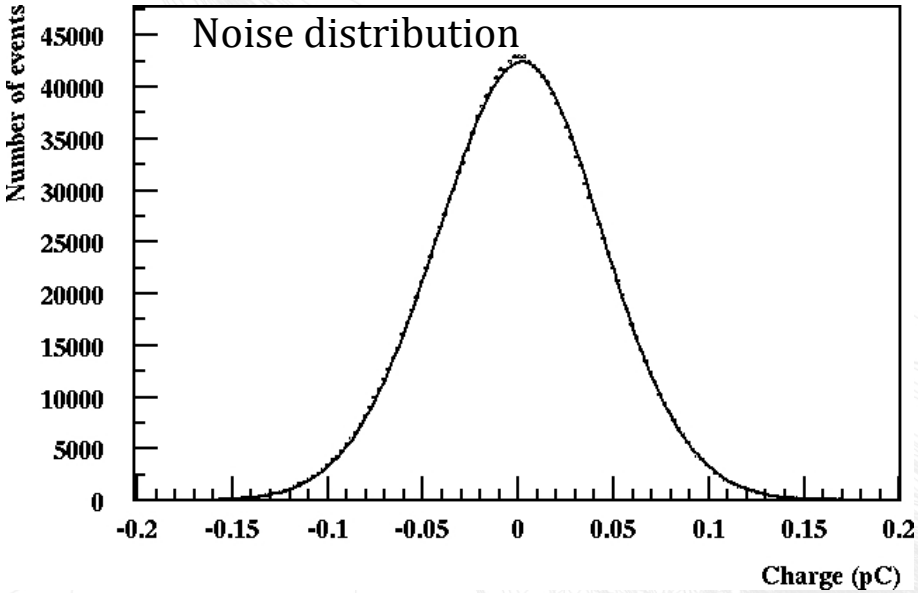
Gain slope & single pe characteristics
Results

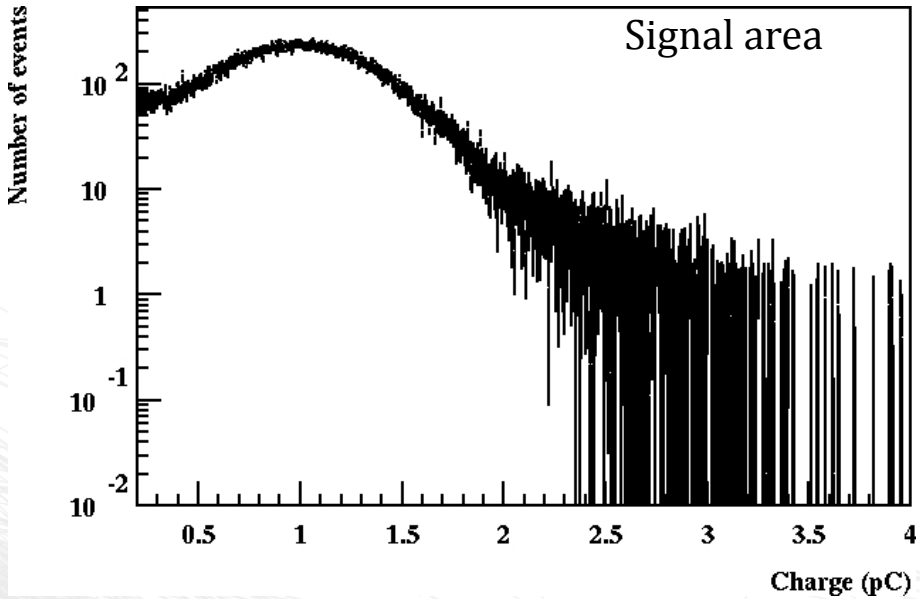
Data Analysis
→ Binary data converted to V=f(t)
→ Check data quality
→ Correct dc offset (if any) due to temperature changes
→ Noise reduction
→ Charge and pulse height distributions

PMT charge distributions:
- spe mean charge
- spe mean pulse height
for every PMT high voltage supply



Charge Distributions (single pe level)





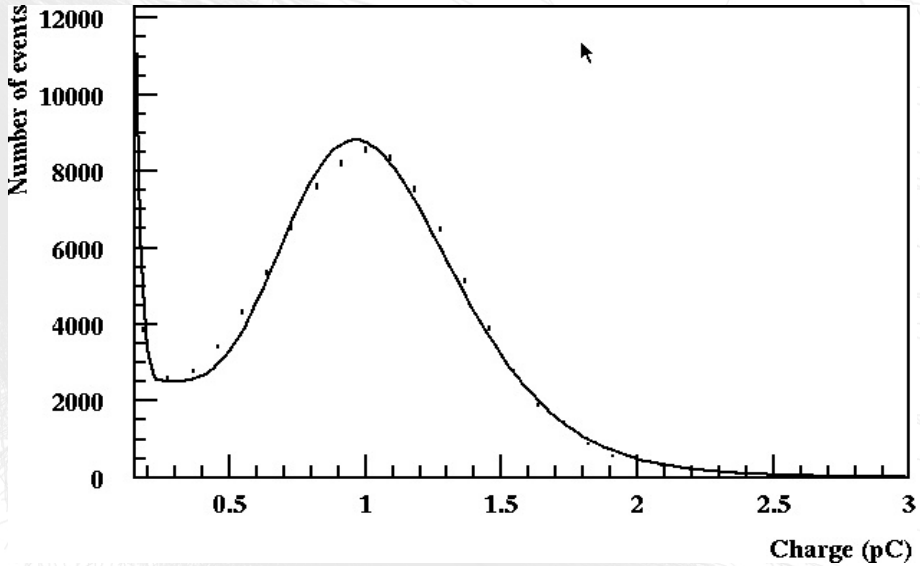
→ Gaussian distribution for the noise
→ Exponential distribution for the dark current

→ Polya functions used for the signal

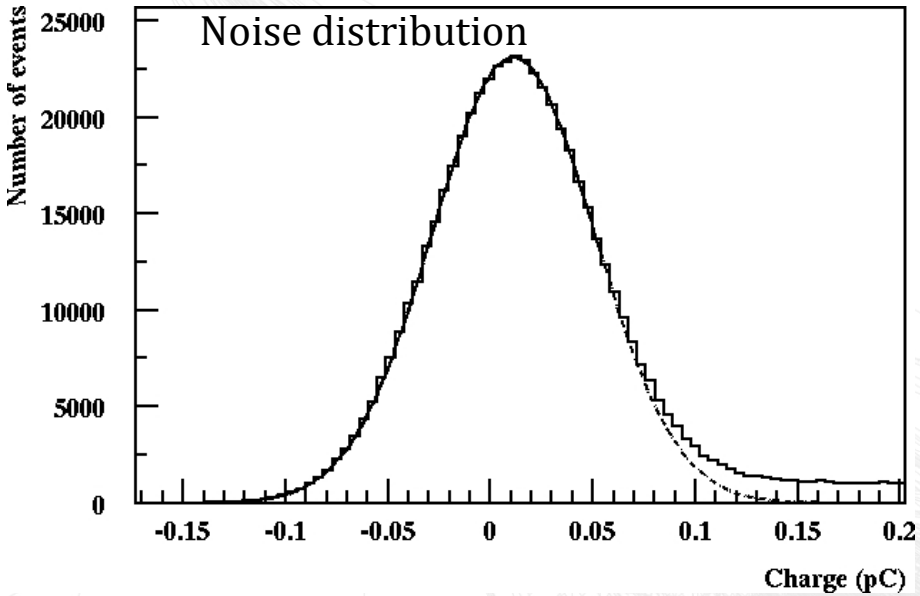
$$P(x) = \frac{(a \cdot x / M)^a}{x \cdot \Gamma(a)} \cdot e^{-a \cdot x / M}$$

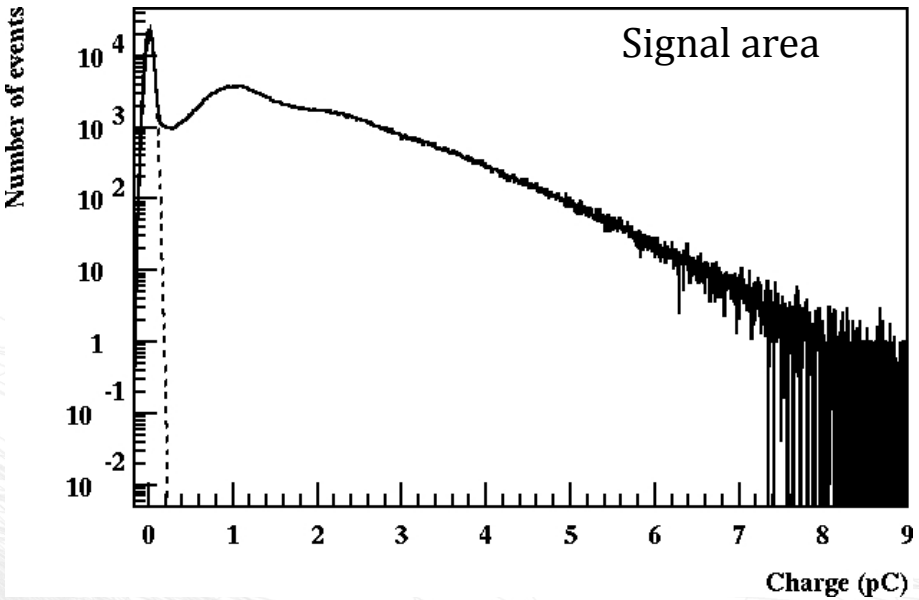
$$\bar{x} = M$$

$$\sigma_x = \frac{M}{\sqrt{a}}$$



Charge Distributions (more light)





→ Gaussian distribution for the noise
→ Exponential distribution for the dark current

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$$P(x) = \frac{(a \cdot x/M)^a}{x \cdot \Gamma(a)} \cdot e^{-a \cdot x/M}$$

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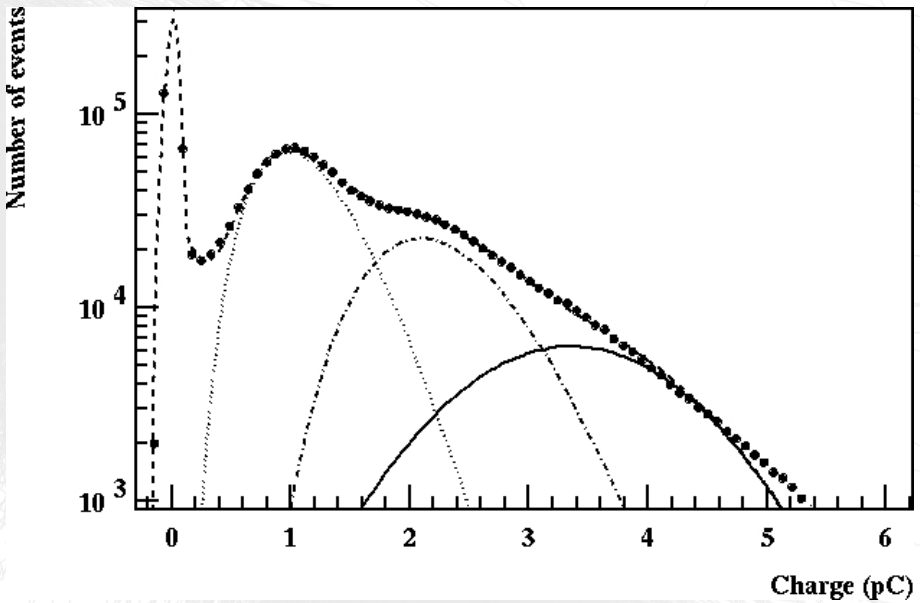

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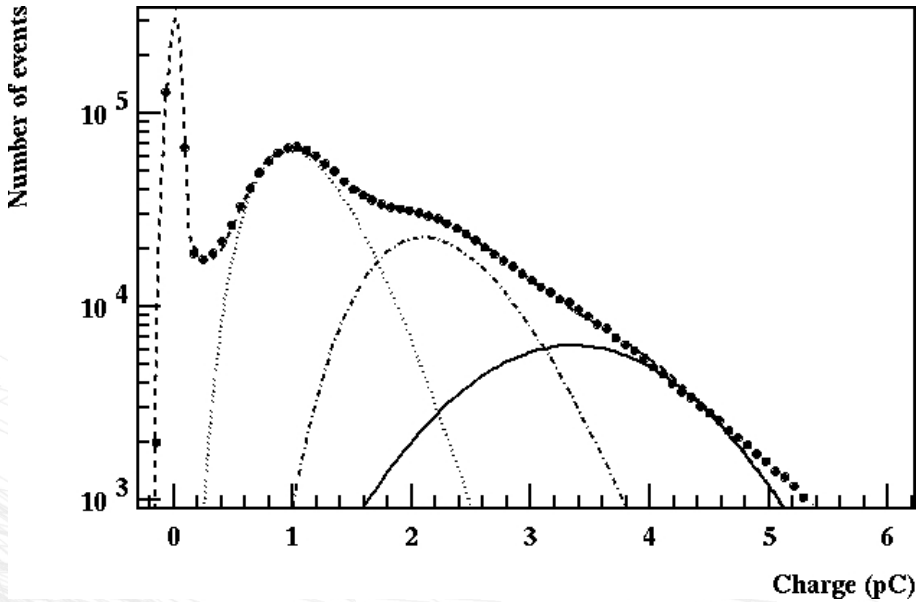
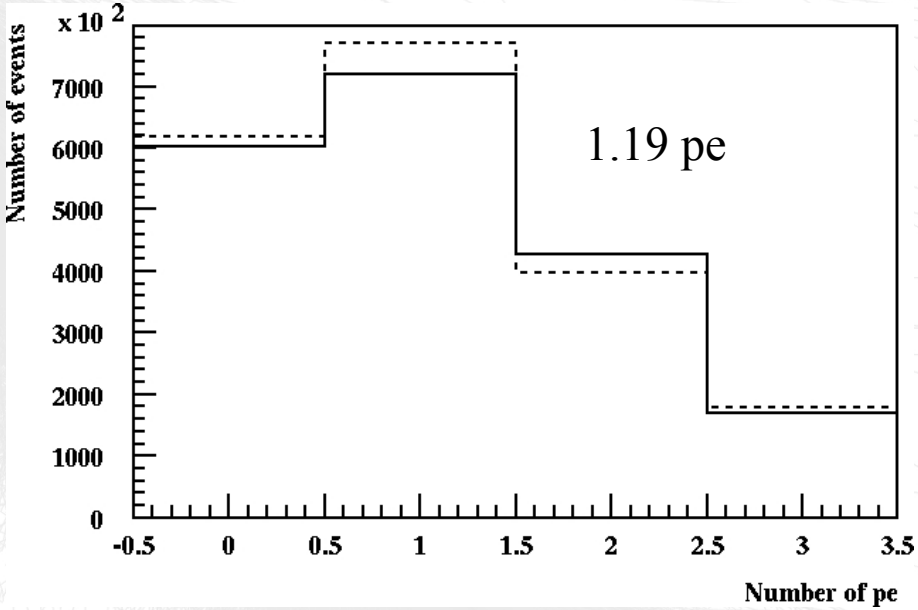
Charge Distributions (more light)

Using the charge distributions for each number of photoelectrons, we can estimate the number of events for 0, 1, 2, … photoelectrons

→ the mean number of photoelectrons is estimated assuming poissonian statistics and fitting the discrete distribution





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Gain slope & single pe characteristics Results

Gain as a function of supplied voltage

$$G_V = A \cdot V^{kn}$$

But

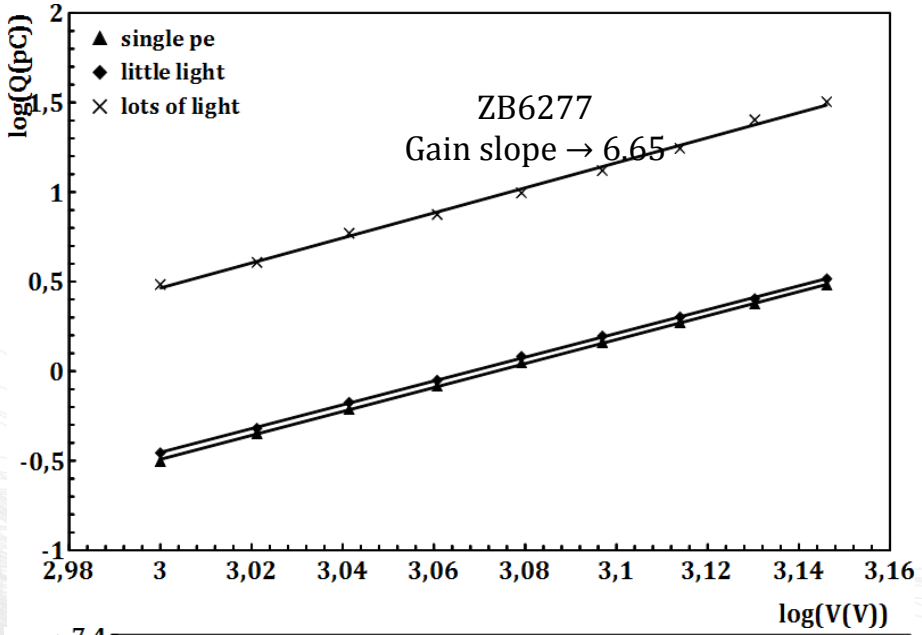
$$G_V = \frac{Q_V^{N_{pe}}}{N_{pe} \cdot e}$$

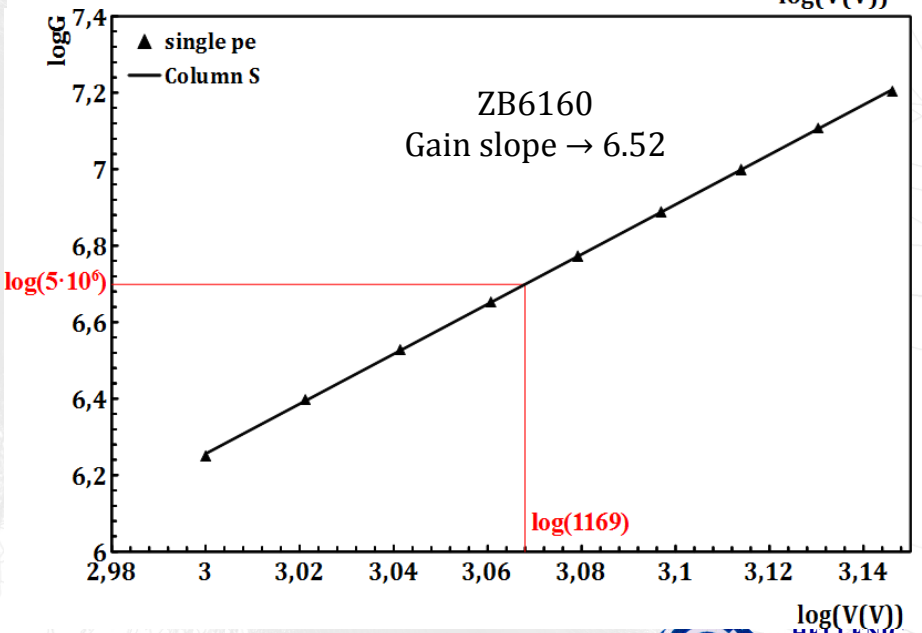
$$\log Q_V^{N_{pe}} = \log\left(N_{pe} \cdot e \cdot A\right) + kn \cdot \log V$$

Slope is calculated at every light level employed

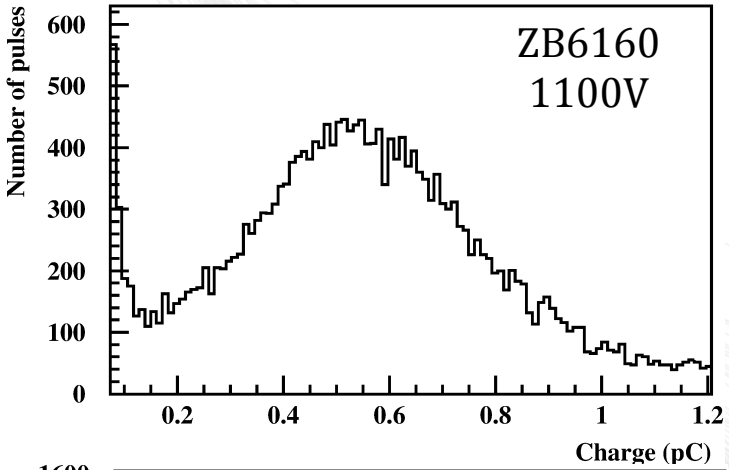
Calculation of the operational voltage for a specific gain of $5 \cdot 10^6$

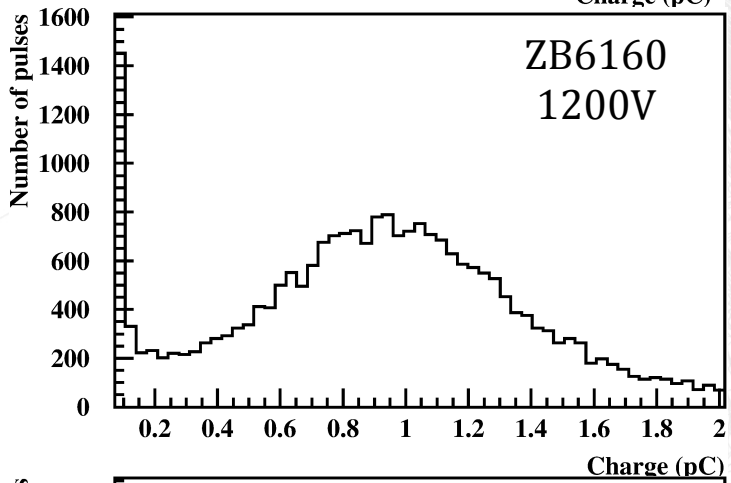
$$G_V = G_{V_0} \cdot \left(\frac{V}{V_0}\right)^{kn}$$

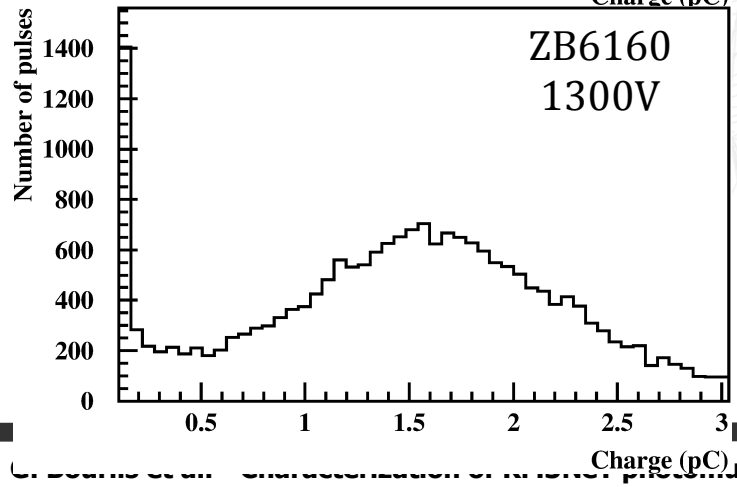


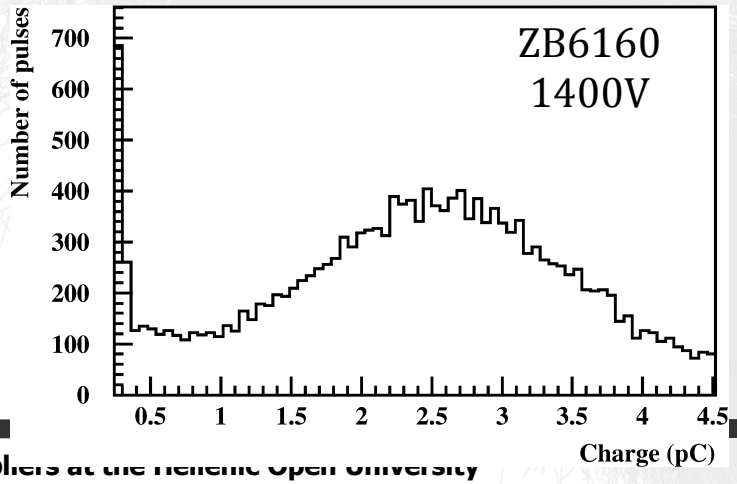


Peak-to-Valley measurements









Peak-to Valley preliminary results for ZB6160

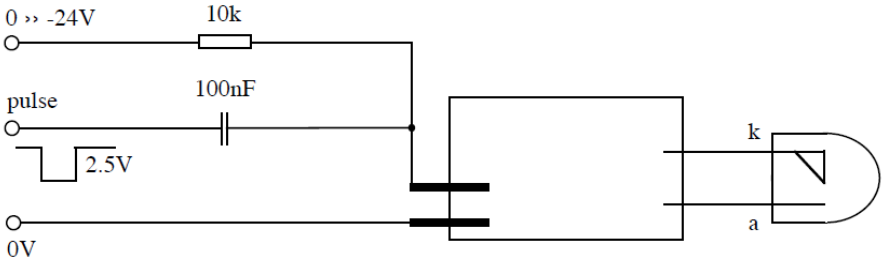
High Voltage (V)	Peak-to-valley
1100	3,3±0,1
1200	3,5±0,1
1300	3,6±0,2
1400	3.4±0,1

Transit Time Spread (TTS) measurements

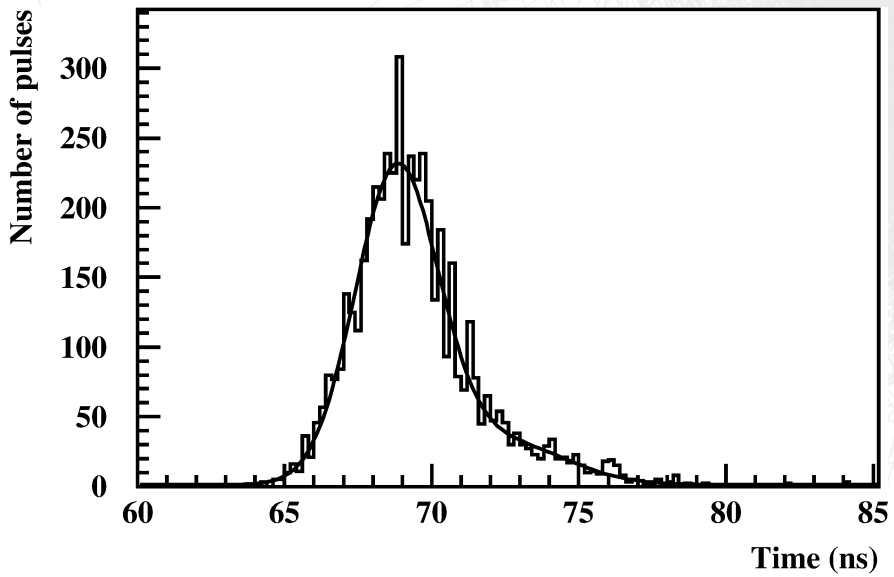
Sheffield Pulser for the LED with a ~0.5ns light output width

- PMT at spe conditions
- Acquisition of 100000 waveforms
- Distribution of the arrival time of the pulse (measured at a threshold equal to 1/3 of the spe mean pulse height)

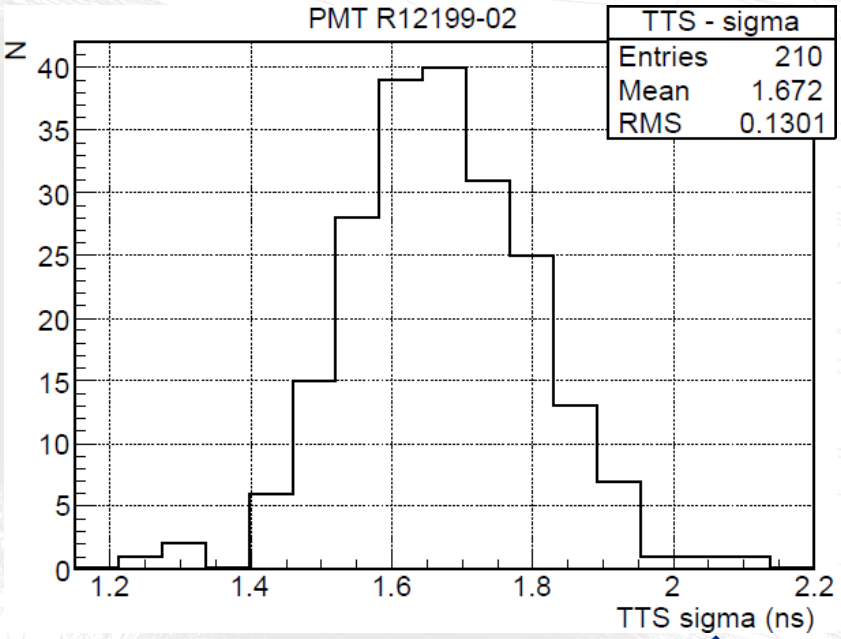
J. E. McMillan, Using the Sheffield Pulser, Sheffield, 2001



ZB6277 FWHM = 3.55ns
TTS = 1.4ns



O. Kalekin, DE. Leonora, D. Samtleben, Test Report, 200
Hamamatsu PMTs of type R12199-02, 1-4-2013



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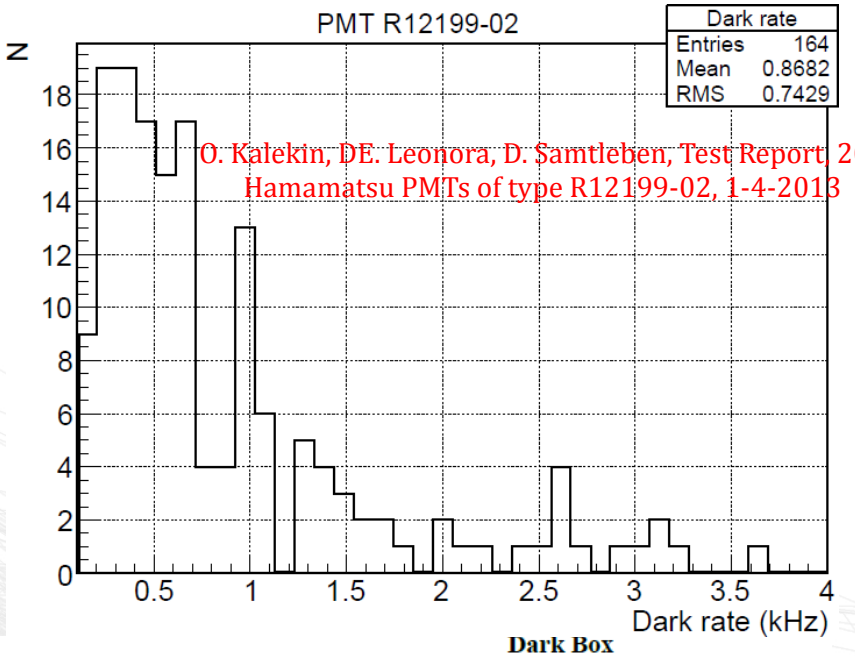
Dark current measurements

- PMT signal input to the CAEN Mod. N844 Low Threshold Discriminator
- PMT voltage set for a gain of $5 \cdot 10^6$
- Discriminator threshold set to 1/3 of the spe average pulse height
- Discriminator output fed to ORTEC 871 TIMER AND COUNTER and the dark current rate is measured

ZB6277 ~2.5kHz

ZB6160 ~1.4kHz

Measured at a room temperature of ~25°C



O. Kalekin, DE. Leonora, D. Samtleben, Test Report, 200
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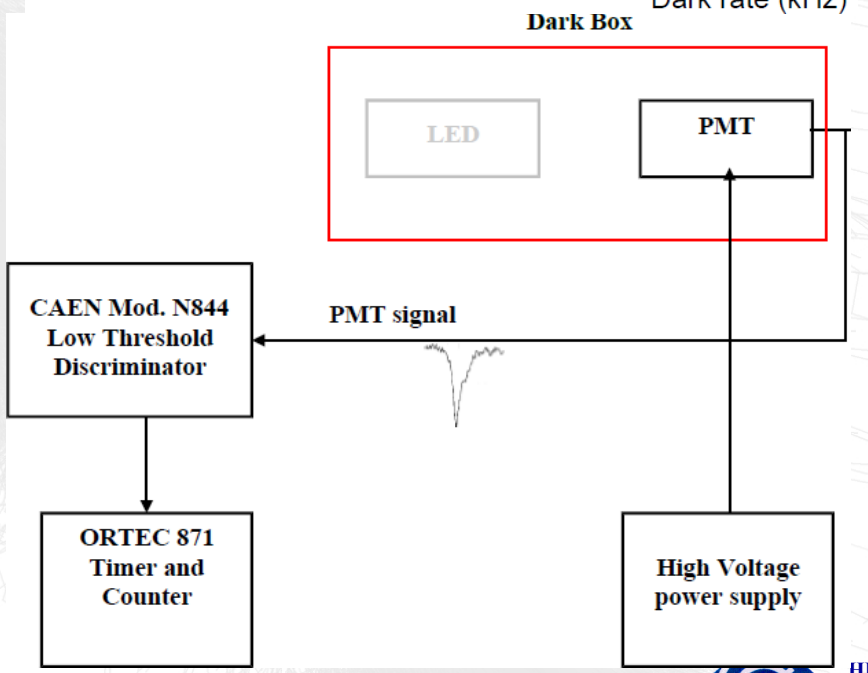

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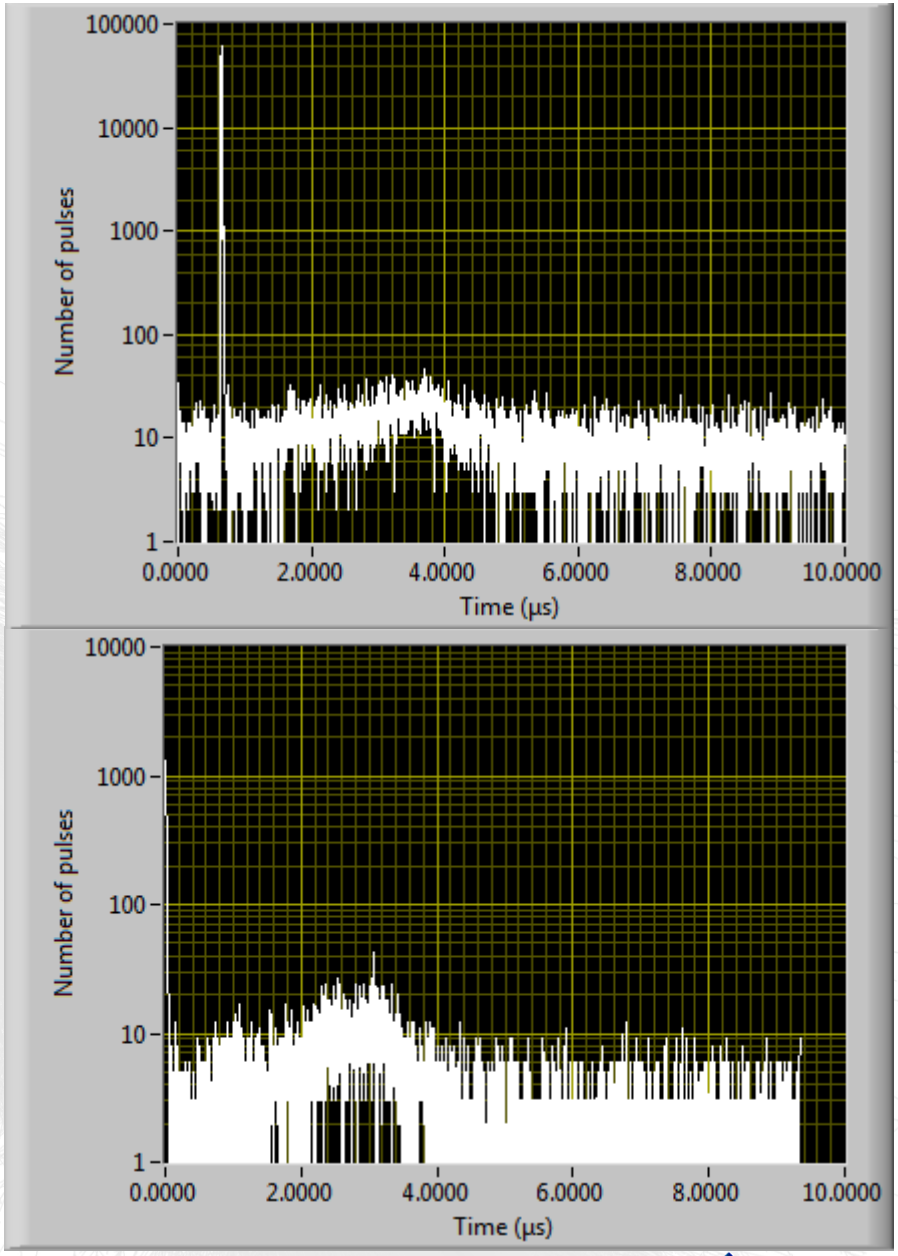
After pulses

Work for after pulses fraction is underway

- Same setup as for gain slope
- 10μs or 100μs window recorded
- Pulses registered if higher than 1/3 of the spe mean pulse height
- Time distribution of the pulses following the main pulse
- Multiplicity of after pulses is also measured



Summary and Outlook

HOU 3'' PMT Calibration

spe characteristics, gain slope, TTS, peak-to-valley

- Acquisition of ~100000 pulses at 8-10 power supply values up to 1400V (around 1h)

Dark current rate measurements at various room temperatures measured instantly

After pulses fraction and multiplicity

- 3-4M waveforms (around 1h)

Outlook

- Automation of the measurements and analysis procedures
- Development of the first DOM construction center of the KM3NeT-Gr