NDL SiPm Series EQR15 11-6060D-S

1) Test results with 480 nm LED

2) Cosmic test

www.ndl-sipm.net/PDF/Datasheet-EQR15.pdf

NDL (Novel Device Laboratory, Beijing) http://www.ndl-sipm.net/indexeng.html

NDL SiPm Series EQR15
11-6060D-S

www.ndl-sipm.net/PDF/Datasheet-EQR15.pdf

- For a conventional SiPM, the quenching resistors are usually fabricated on the surface, and used to connect all APD cells to trace metal lines. In contrast, NDL SiPM employs intrinsic epitaxial layer as the quenching resistors (EQR), and uses a continuous silicon cap layer as an anode to connect all the APD cells**. As a result, the device has more compact structure and simpler fabrication technology, allows larger micro cell density (larger dynamic range) while retaining high photon detection efficiency (PDE).**
- Для обычного SiPM гасящие резисторы обычно изготавливаются на поверхности и используются для соединения всех ячеек APD с металлическими линиями. Напротив, NDL SiPM использует собственный эпитаксиальный слой в качестве гасящих резисторов (EQR) и использует непрерывный слой кремния в качестве анода для соединения всех ячеек APD. **В результате устройство имеет более компактную структуру и более простую технологию изготовления, позволяет увеличить плотность микроячеек (больший динамический диапазон) при сохранении высокой эффективности детектирования фотонов (PDE).**
- **NDL (Novel Device Laboratory, Beijing) http://www.ndl-sipm.net/indexeng.html**

EQR15 Series SiPMs

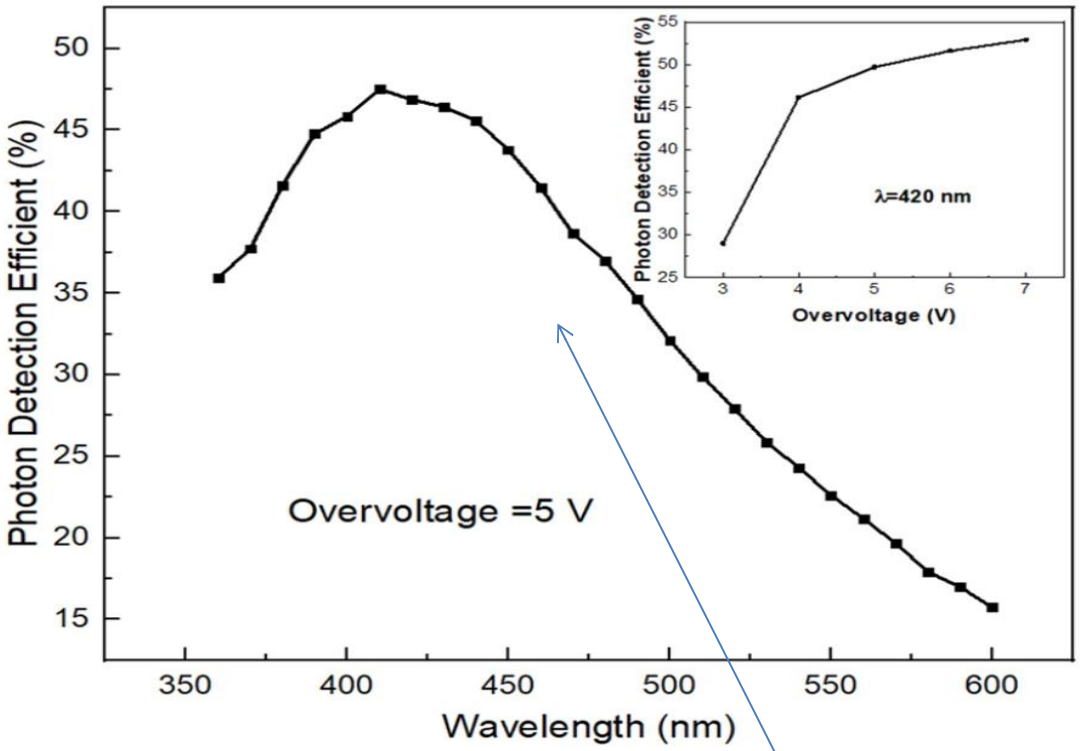
Specifications subject to change without notice

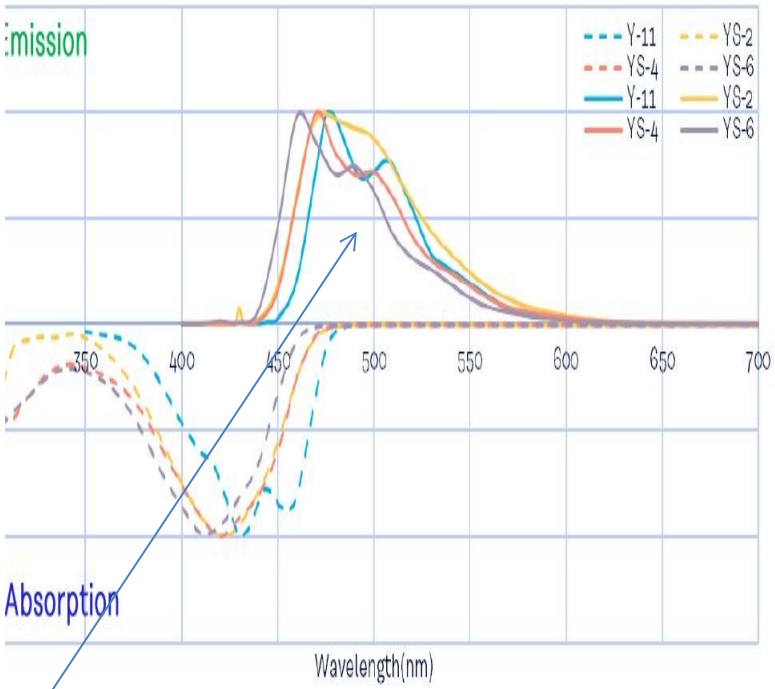
Type	EQR15 11-1010D-S	EQR15 11-3030D-S	EQR15 11-6060D-S	EQR15 22-1313D-S
Effective Pitch	15 μm			
Element Number	1×1			2×2
Active Area	1.0×1.0 mm^2	3.0×3.0 mm^2	6.0×6.0 mm^2	1.3×1.3 mm^2
Micro-cell Number	4444	40000	160000	7396
Typical Breakdown Voltage (V_B)	30 V			
Temperature Coefficient for V_B	28 mV/°C			
Recommended Operation Voltage	V_B + 8 V			
Peak PDE @ 420nm	45 %			
Gain	4.0×10^5			
Dark Count Rate (DCR)	250 kHz / mm^2			
Terminal Capacitance	5.6 pF / mm^2			

Above parameters is measured at their recommended operation voltage and 20 °C, and it can operate at 77 K.

EQR15 Series SiPMs

Specifications subject to change without notice



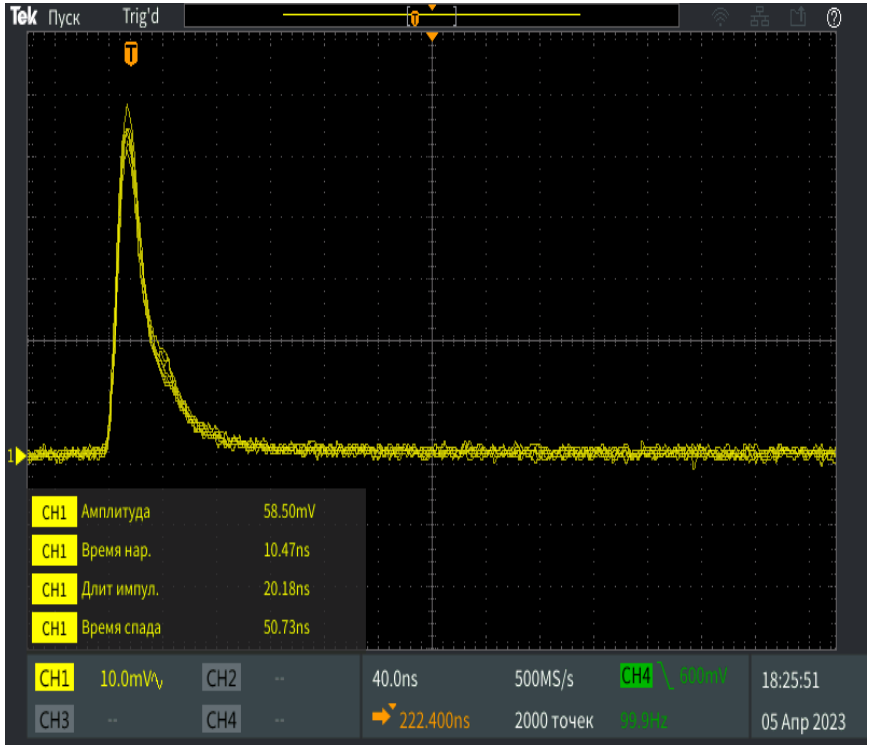


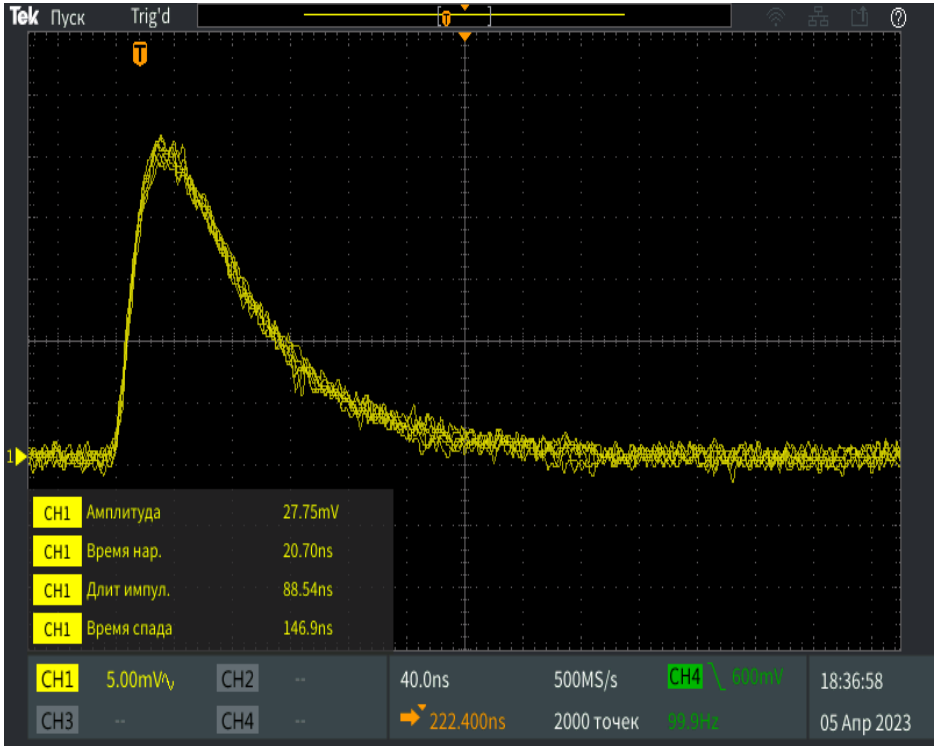
Photon Detection Efficient (PDE) correspond to WLS Emission spectra of Y11.
PDE close to flat maximum about 45% at 6-7 Overvoltage.

EQR15 Series SiPMs

Specifications subject to change without notice

Pulse shape of SiPm with 15 μ pitch and 6x6 mm^2 size – frm 10 ns LED

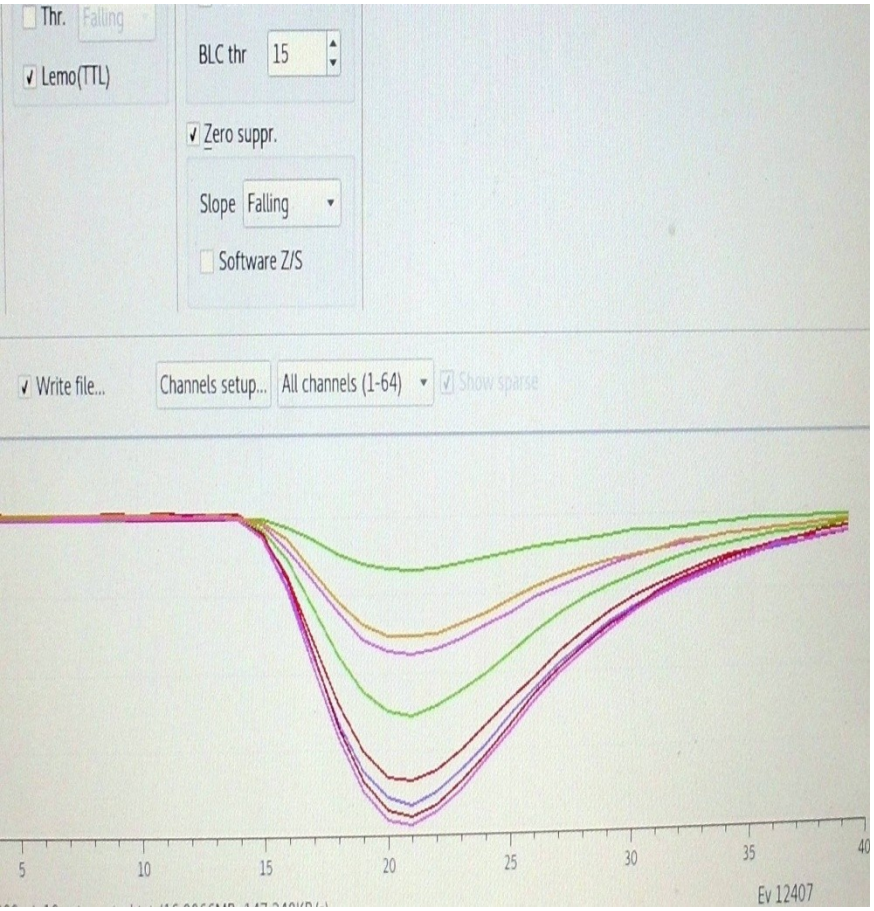


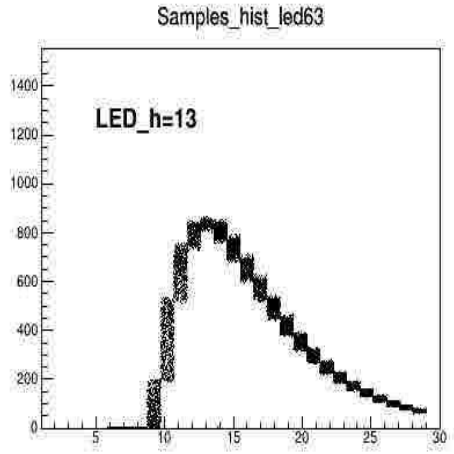


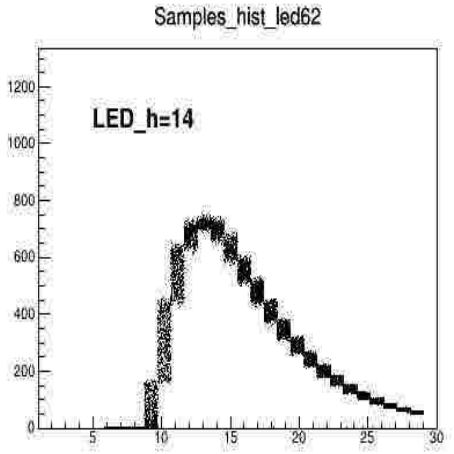
EQR11-15-6060-S
Front – 10 ns
Length – 20 ns

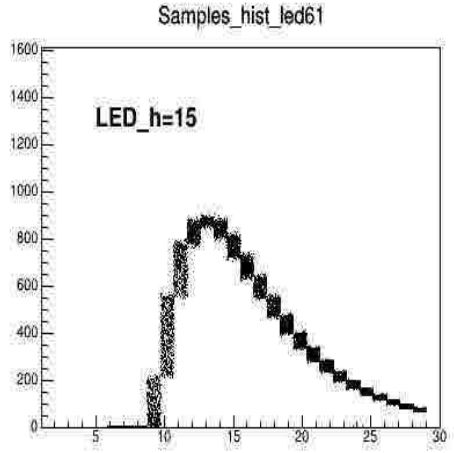
HAMAMATSU S14160-50
Front – 21 ns
Length – 89 ns

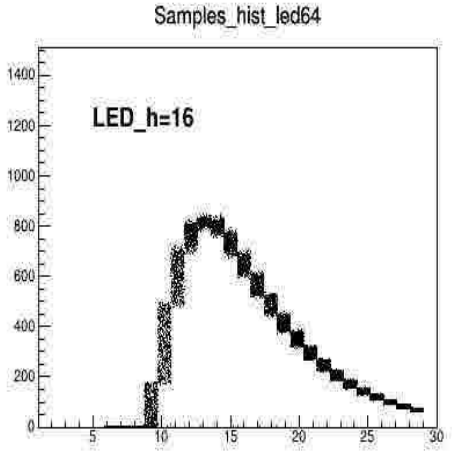
Wave form and digitizing



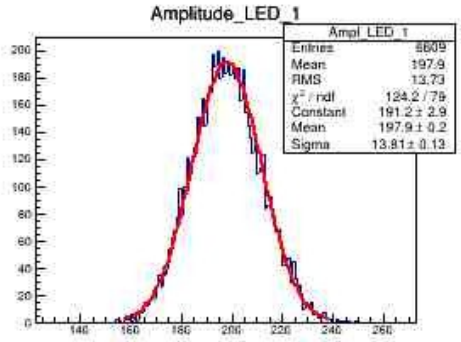


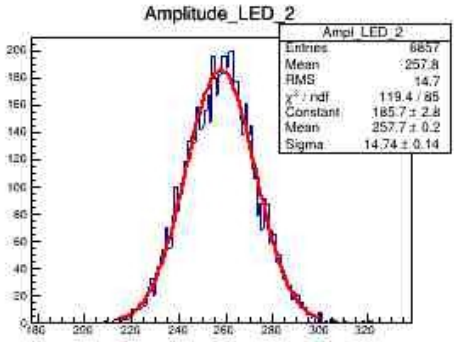


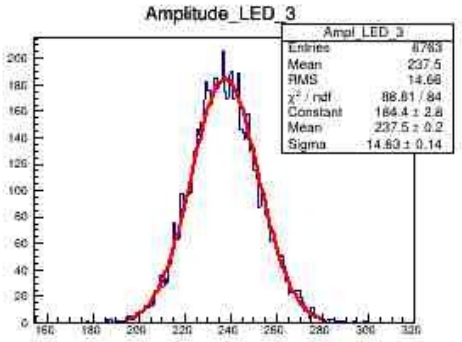


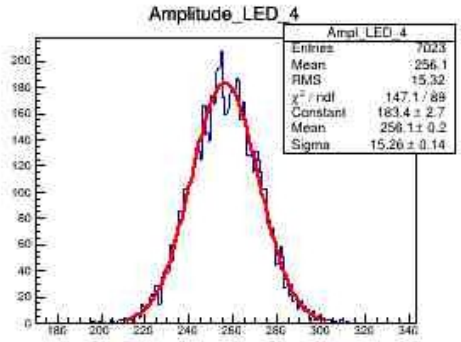


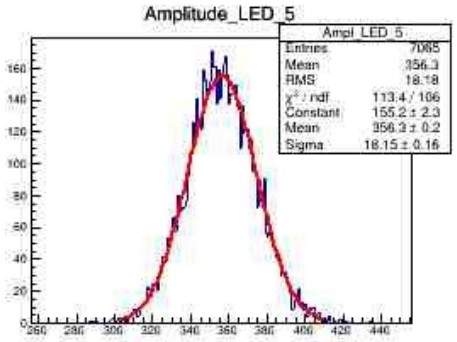
LED amplitudes to caclucte Number Pixel Fired = {Amean/sigma}**2

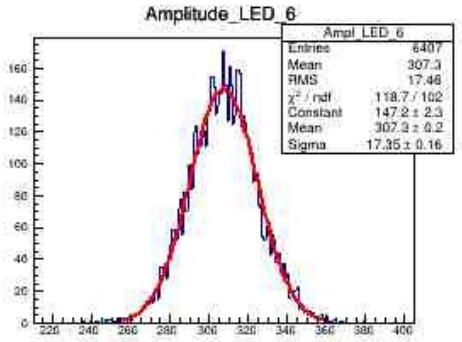


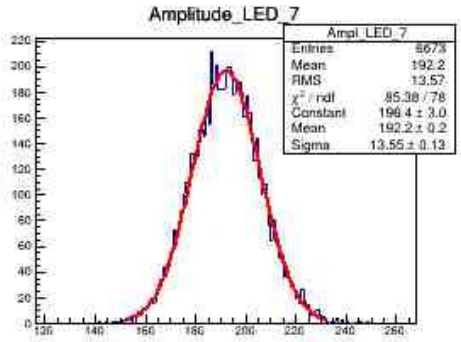


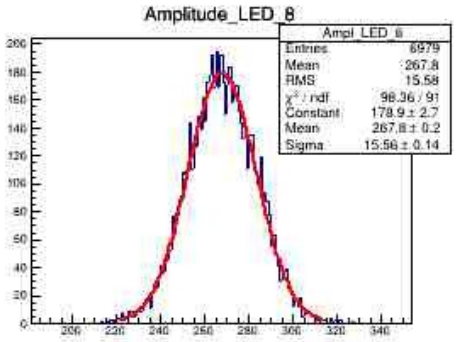


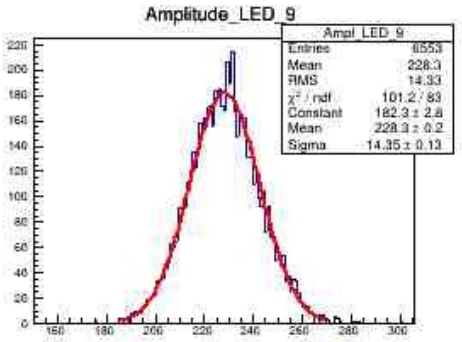






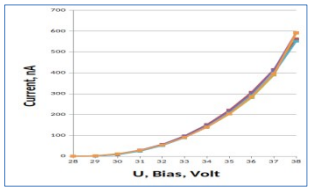


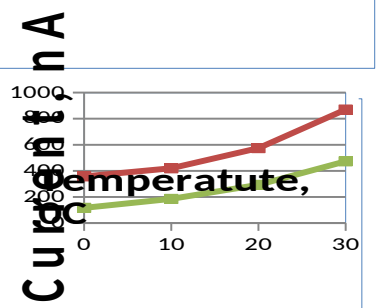


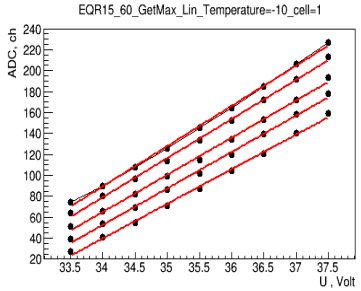


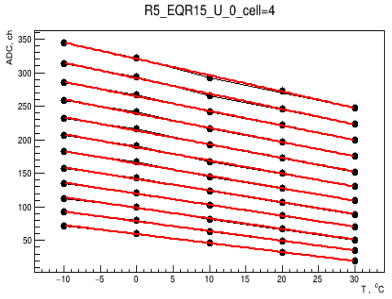
SiPm test Results

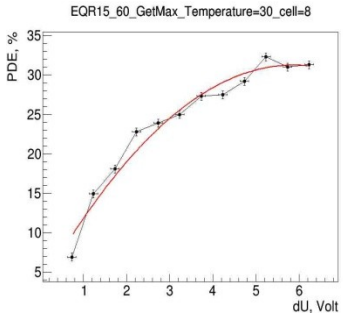
- Dark Current measurements
- Gain vs Overvoltage: dA/dU
- Gain vs Temperature: dA/dt
- PDE vs Overvoltage
- Operation Volt. how to select it ?
- Temperature stability studies

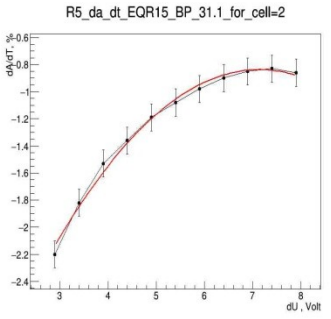




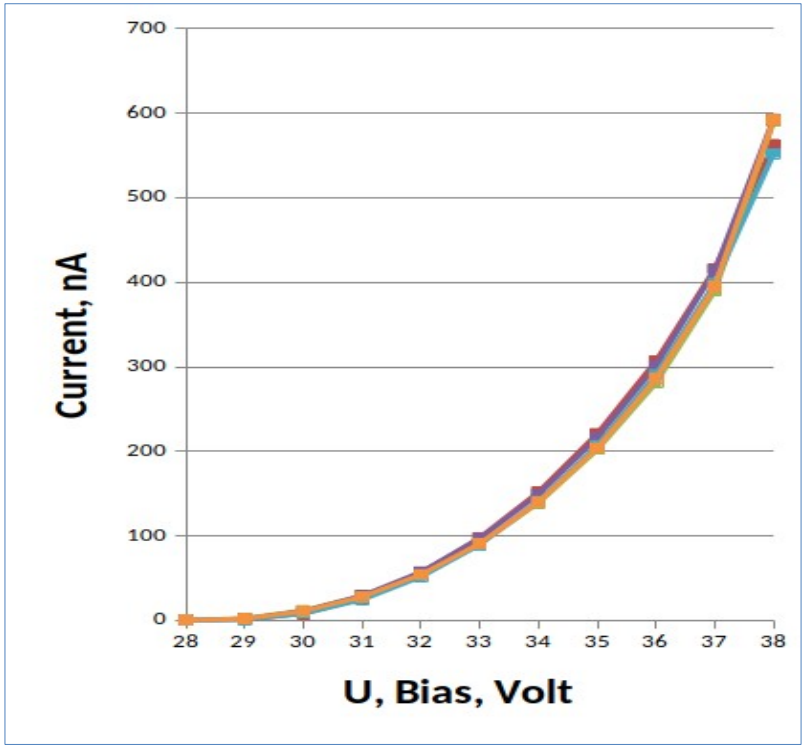


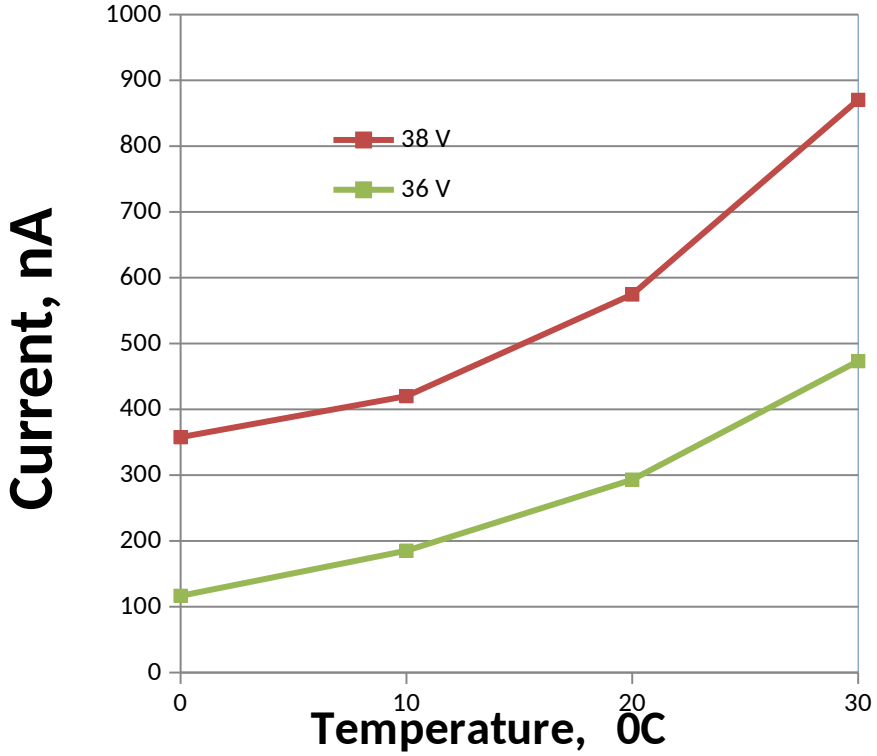






EQR15-60 Dark Current vs Bias voltage and its temperature dependences around operate Voltage

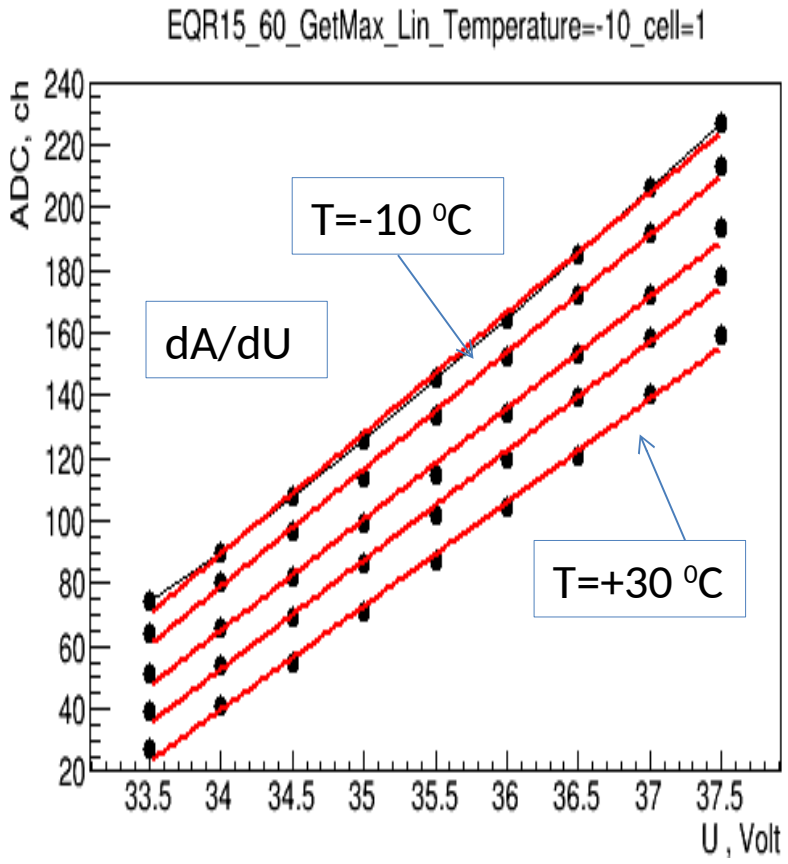


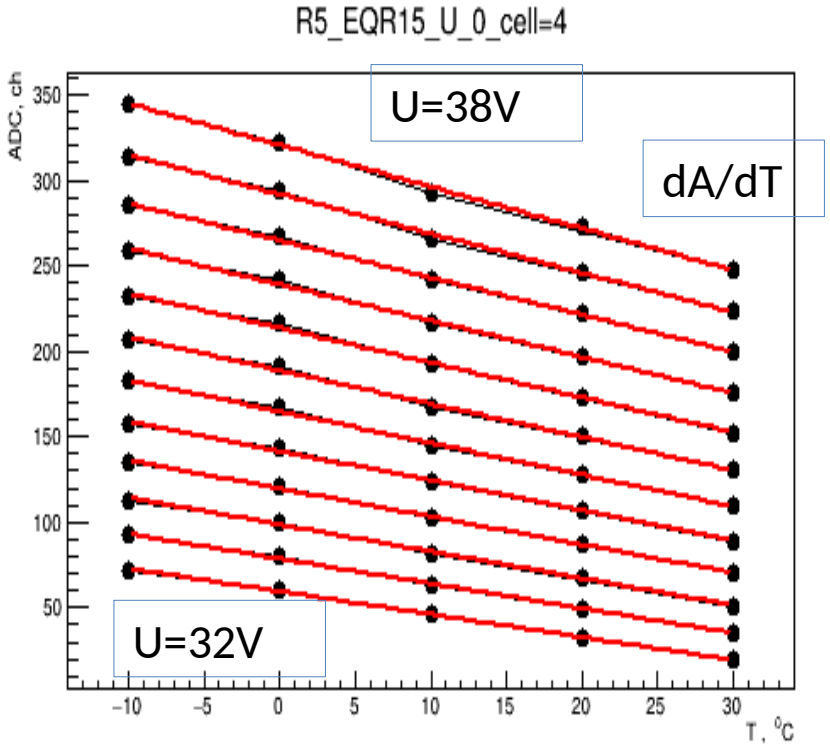


Dark Current vs Operation Bias (36-37 V) at room temperature (20 ^{0}C) is equal to 300-400 nA. Its are corresponded to the factory data and is similar HAMAMATSU too.

Gain vs Overvoltage allow obtain: slope=dA/dU vs U

Gain vs Temperature allow obtain: slope=dA/dT vs T



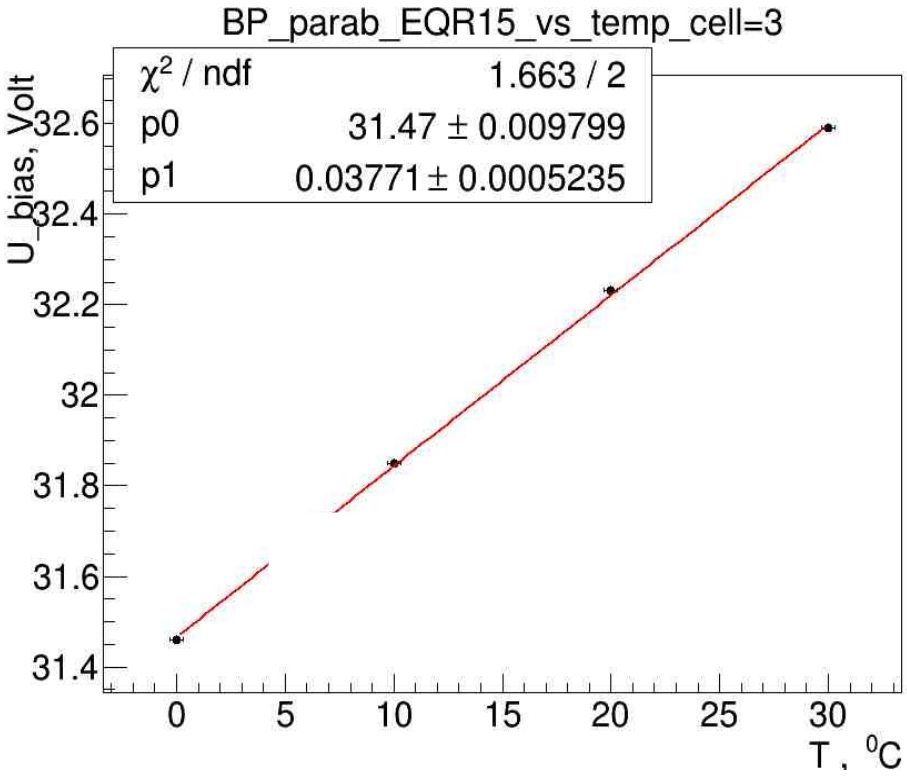


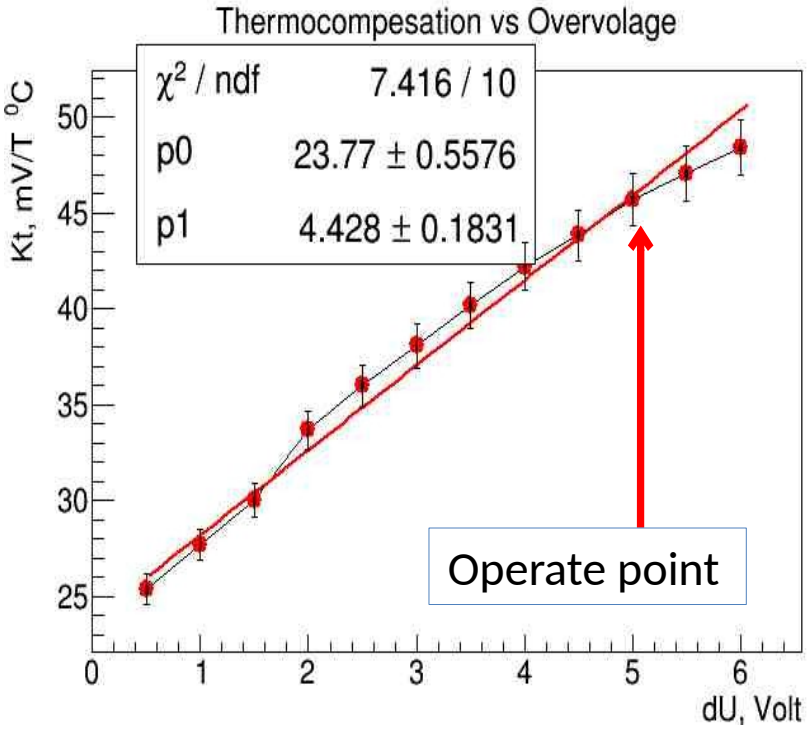
K_t=dU/dT=dA/dT/dA/dU

The thermal stabilization coefficient (K_t) was defined as the ratio of the slope dA/dT to the slope dA/dU depending on the applied bias.

Break Point (Bp) was defined as extrapolation point of dA/dU to zero. Take assumption his linear behavior from Temperature we find that Bp=32 V at 20 ^{0}C.

Kt=dU/dT=dA/dt/dA/dU fom previous slides we find that dependence from Overvoltage has linear behavior and equal to ~50 mv/^{0}C at Operation point 5.5 V.

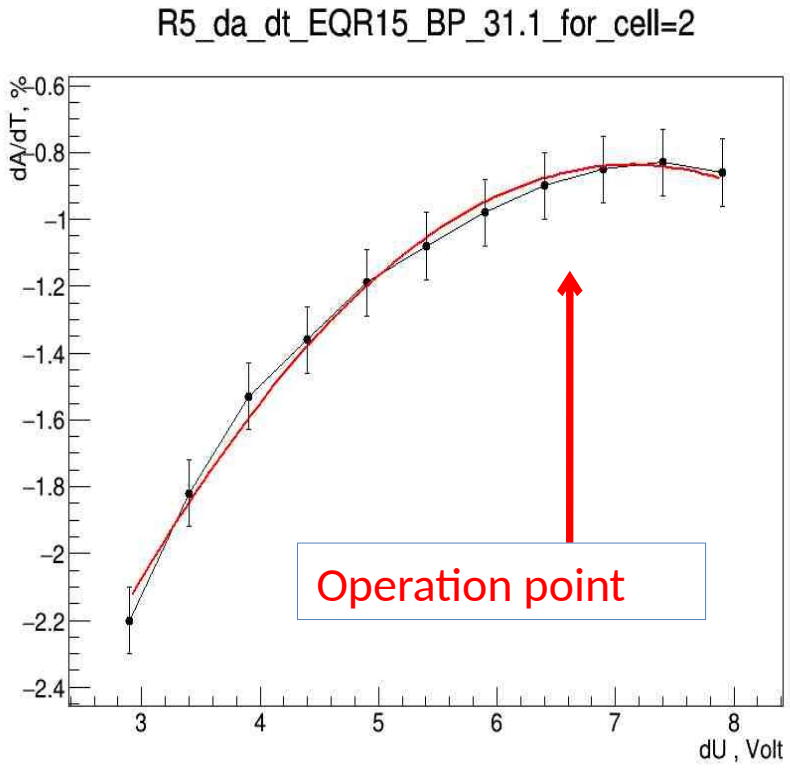




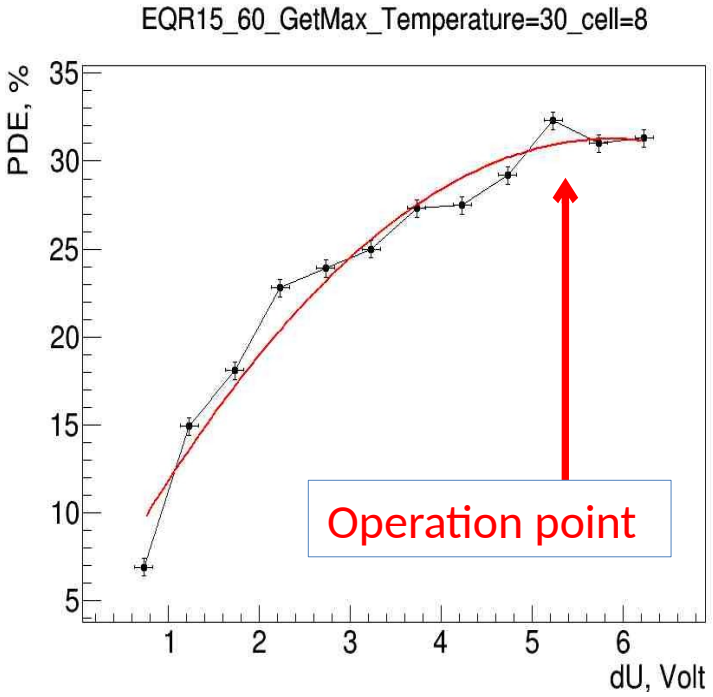
Temperature sensitivity vs dU

Photon Detection Efficient vs dU

dA/dT vs dU



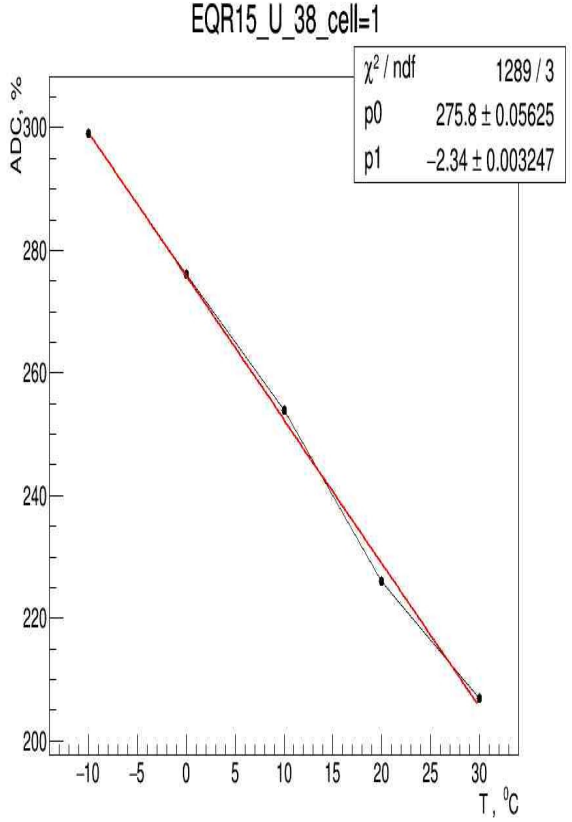
PDE vs dU

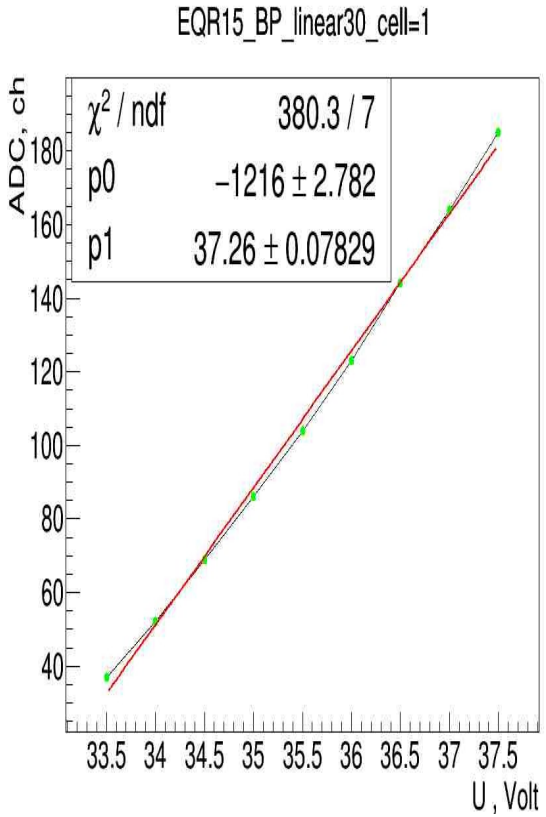


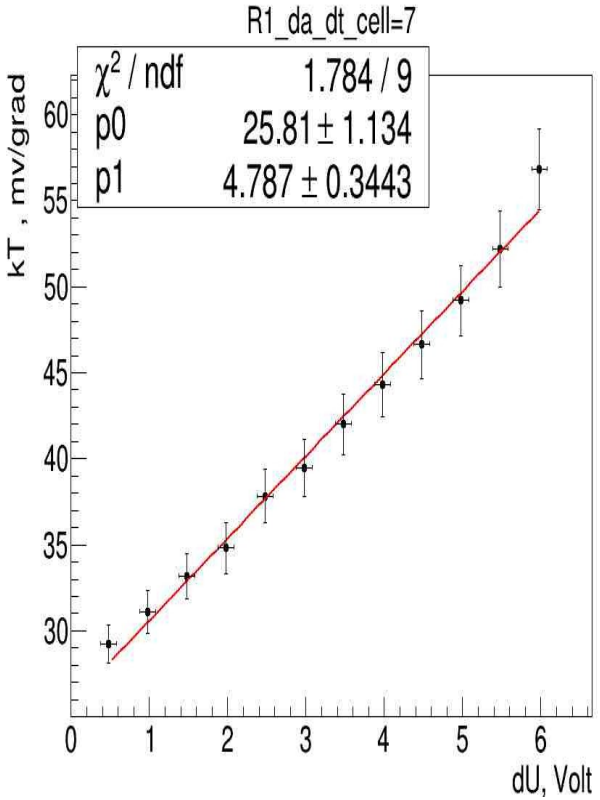
Operation point was found at **dU=6.5 V** take in account that:

1. dA/dT and PDE – has Plato in dU.
2. dA/dT has minimal value ~ 1%/^{0}C , PDE close to maximal value ~ 32%.

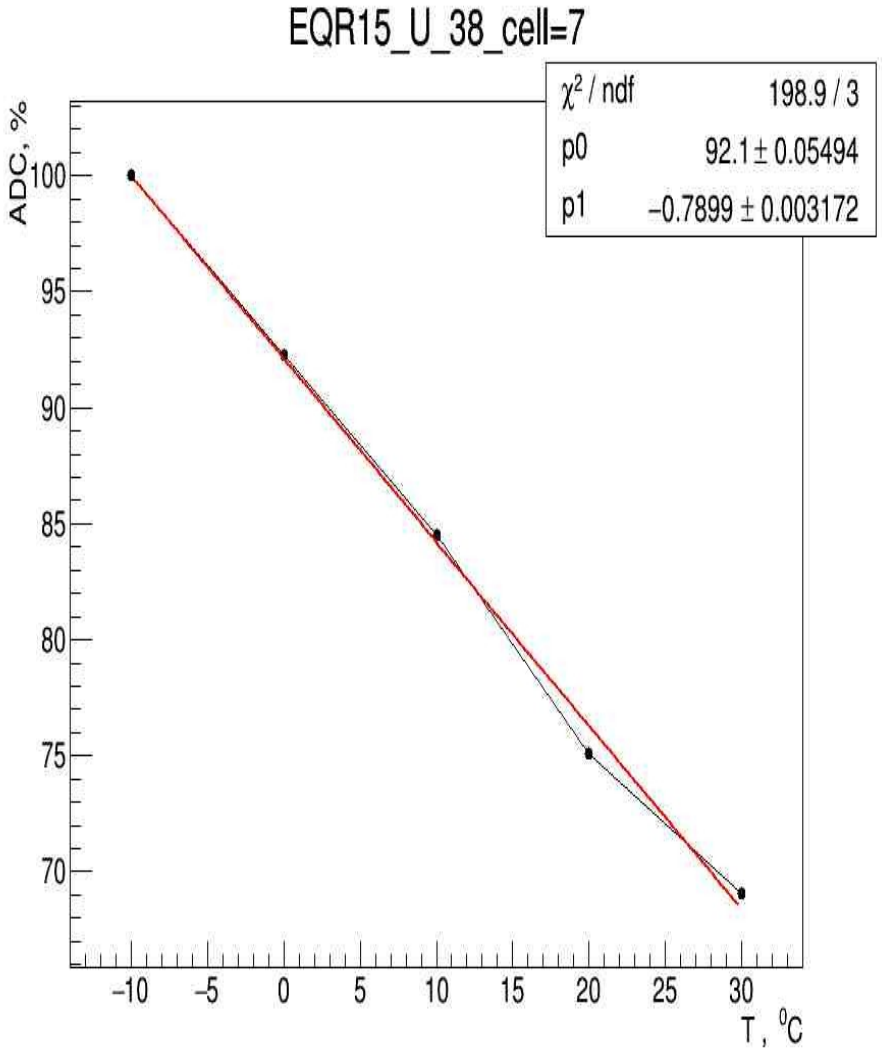
Kt=dA/dT / dA/dU

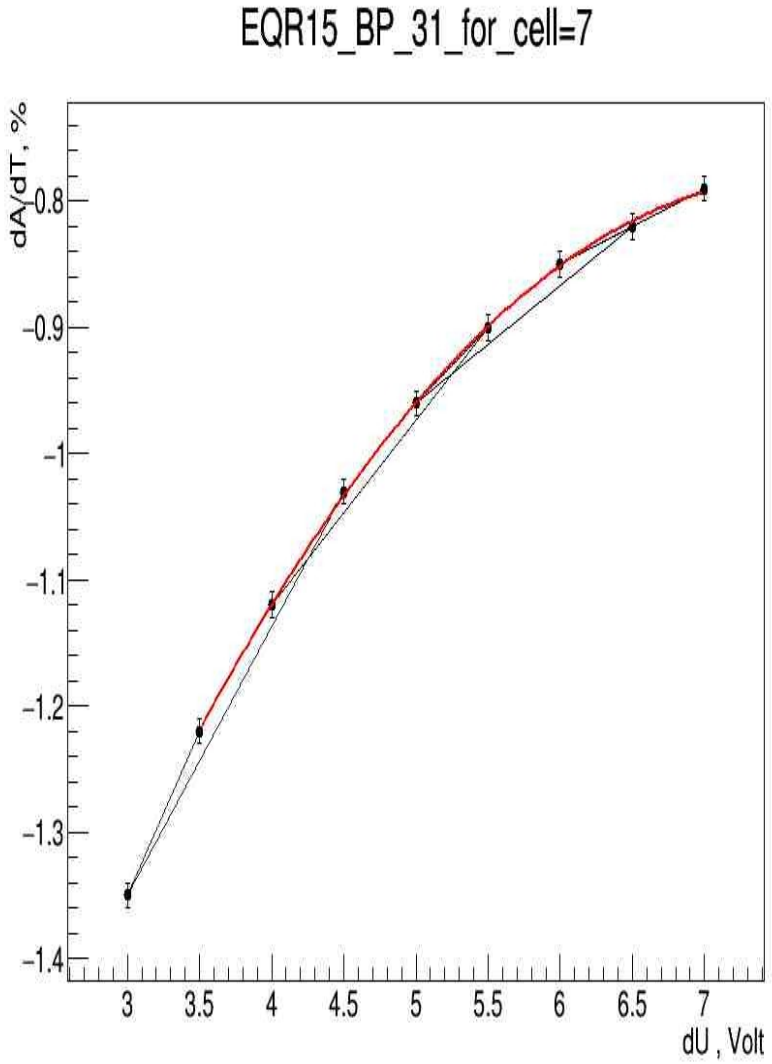

EQR15_U_38_cell=1
χ² / ndf 1289 / 3
p0 275.8 ± 0.05625
p1 −2.34 ± 0.003247
ADC, %
T, °C


EQR15_BP_linear30_cell=1
χ² / ndf 380.3 / 7
p0 −1216 ± 2.782
p1 37.26 ± 0.07829
ADC, ch
U, Volt


R1_da_dt_cell=7
χ² / ndf 1.784 / 9
p0 25.81 ± 1.134
p1 4.787 ± 0.3443
kT, mv/grad
dU, Volt

dA/dT % vs Overvotage





Test results with cosmic particles

1. 4 Module 3x3 cell wit sixes 40x40 mm – MPD option 2012
2. Cosmic beam
3. Event selection = only One cell – one hit events
4. LED monitoring – 1 Hz permanently
5. Kt = 20,30,40,50 mv/Grag for different modules
6. Mip resolutin = 9.7 %
7. Long time stabilyti at Kt=50 mv/Grad

Test results with cosmic particles

Cosmic Rays

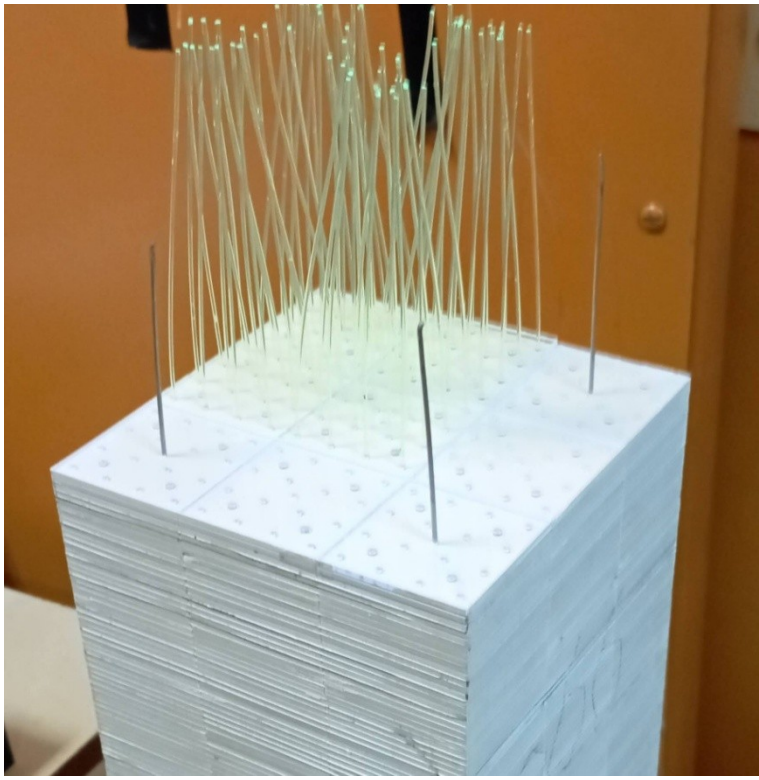
Setup of 4 modules. Each module consist from 9 cells of 4x4 cm^2. Totally tested 36 cells.

Sampling:

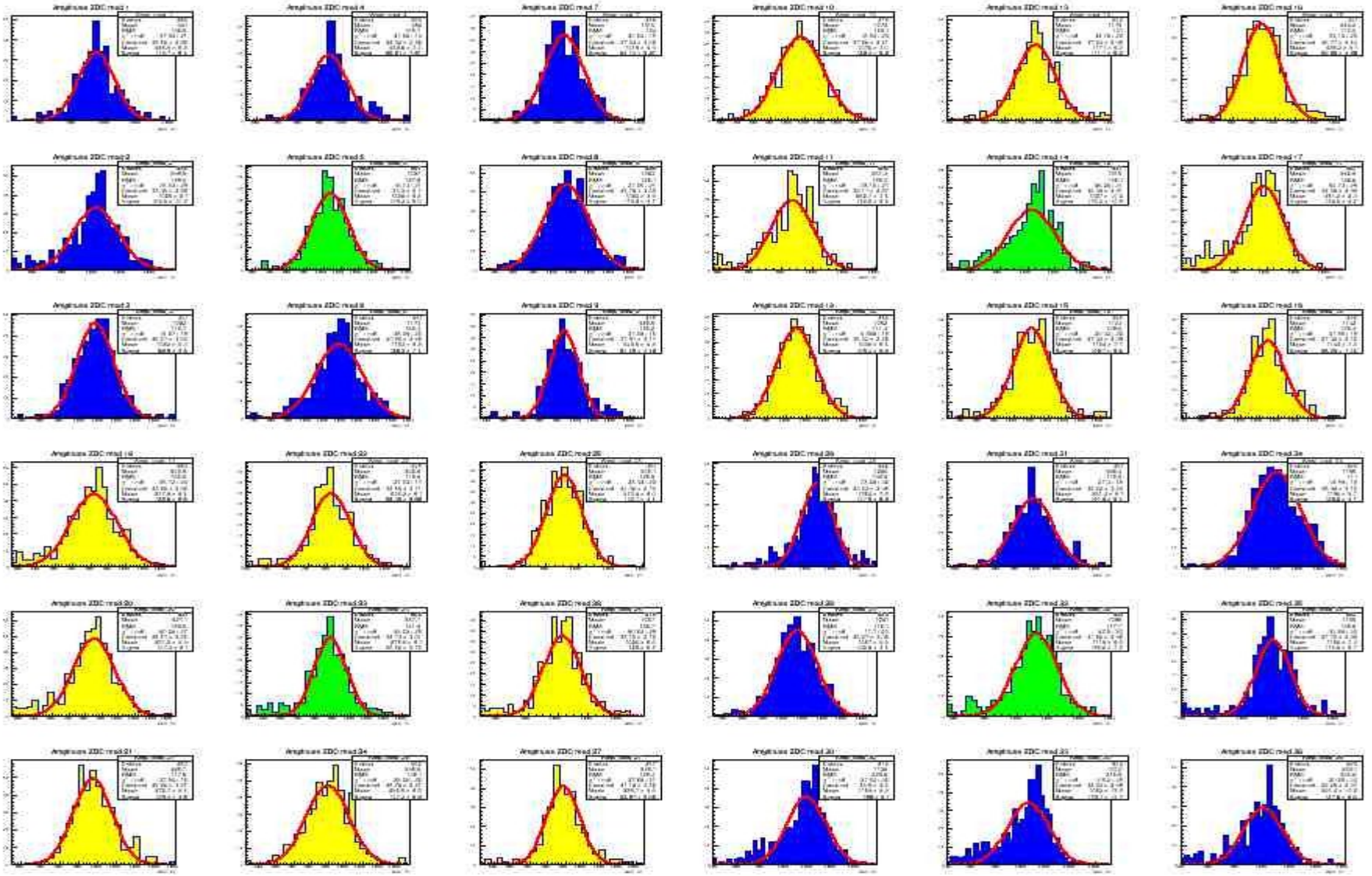
- 1.5 mm Scintillator
- 0.3 mm Lead
- 200 layers

Scintillator composition:

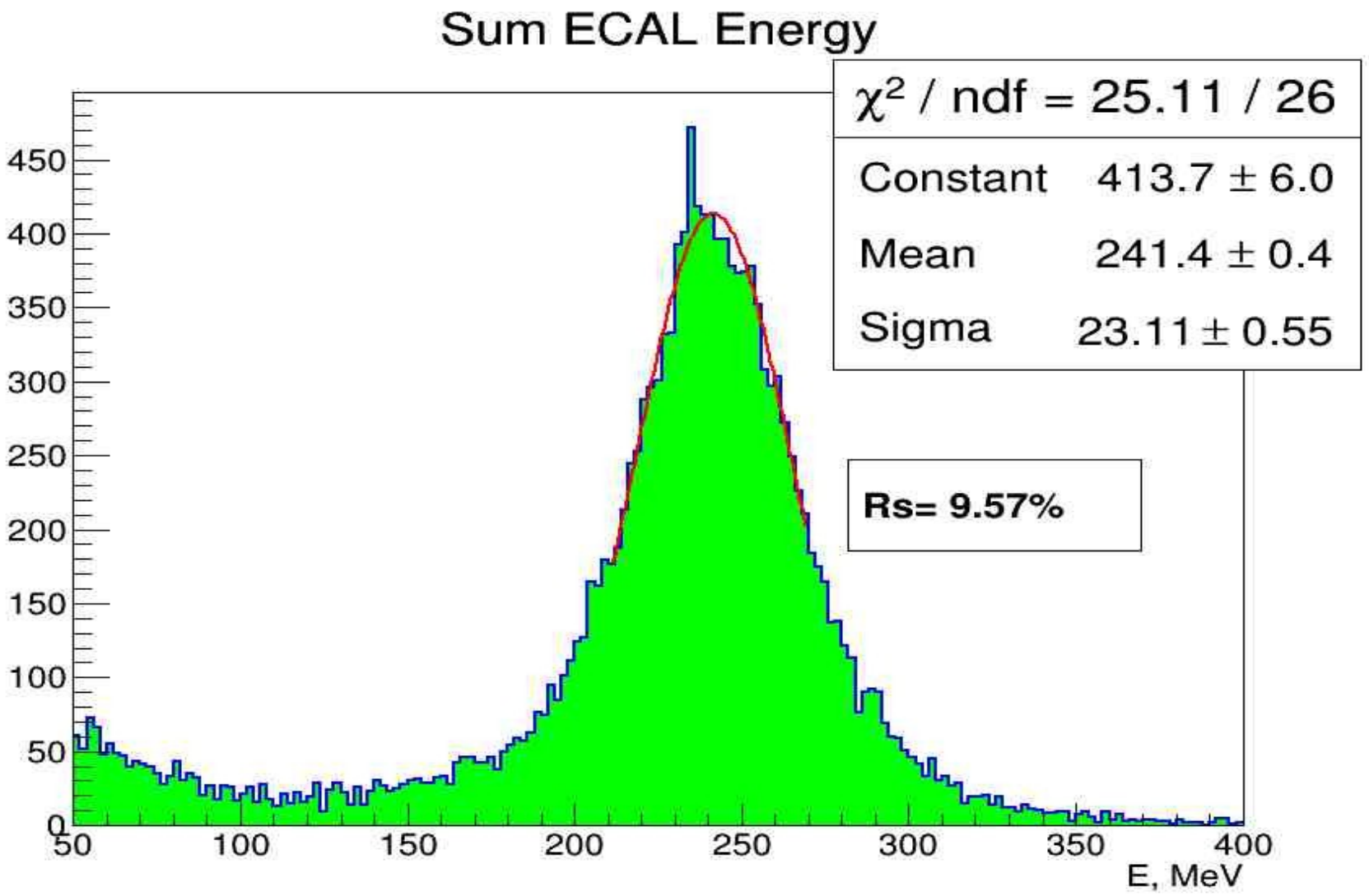
- Polysterene
- 1.5% Paterphenyle
- 0.04% POPOP



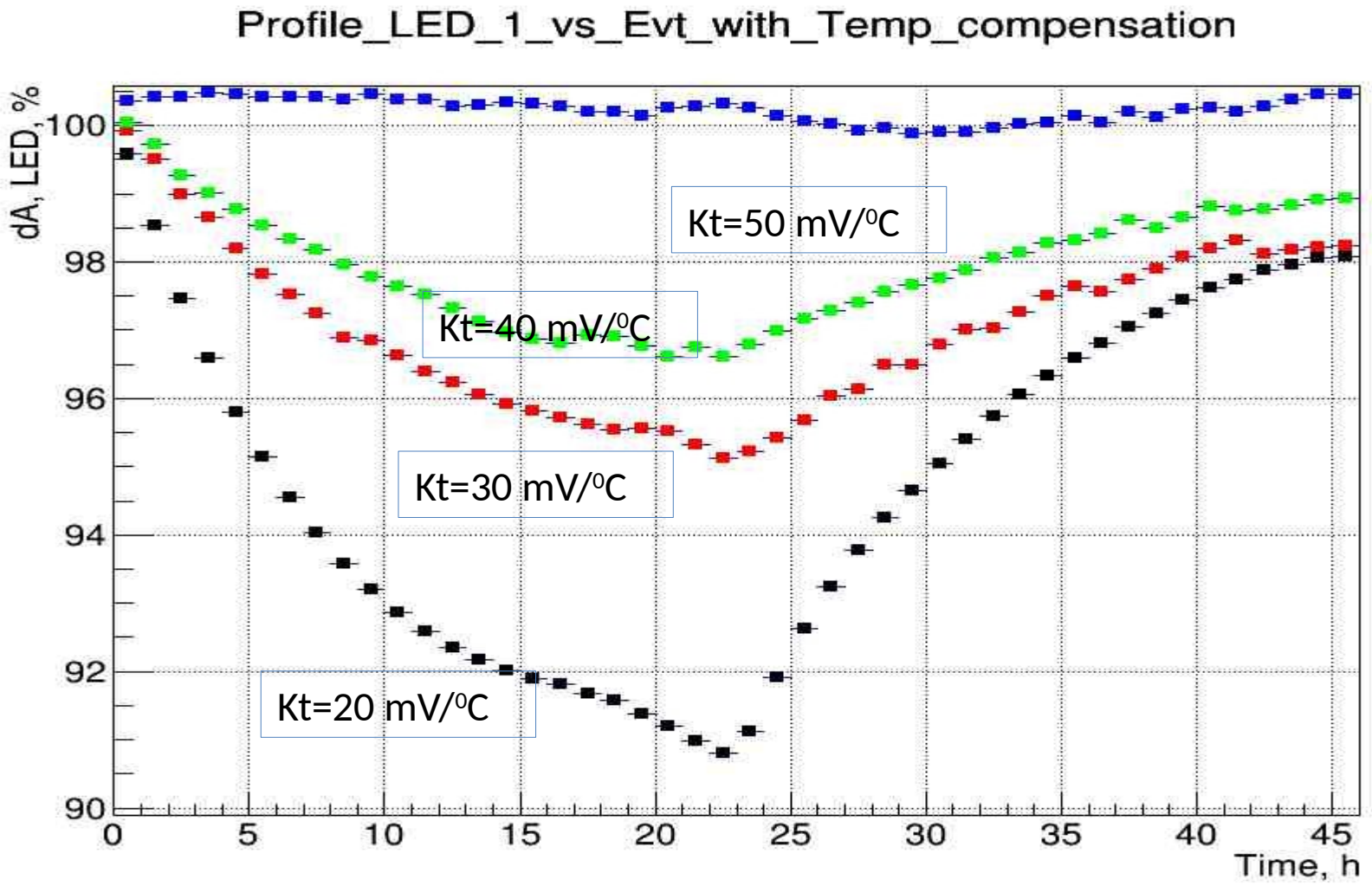
Single Ecal module shown in assembling stage.
It is visible 9 cells as 3x3 matrix with WLS fibers (16 per cell). Y11(200) diameter 1.0 mm was used.



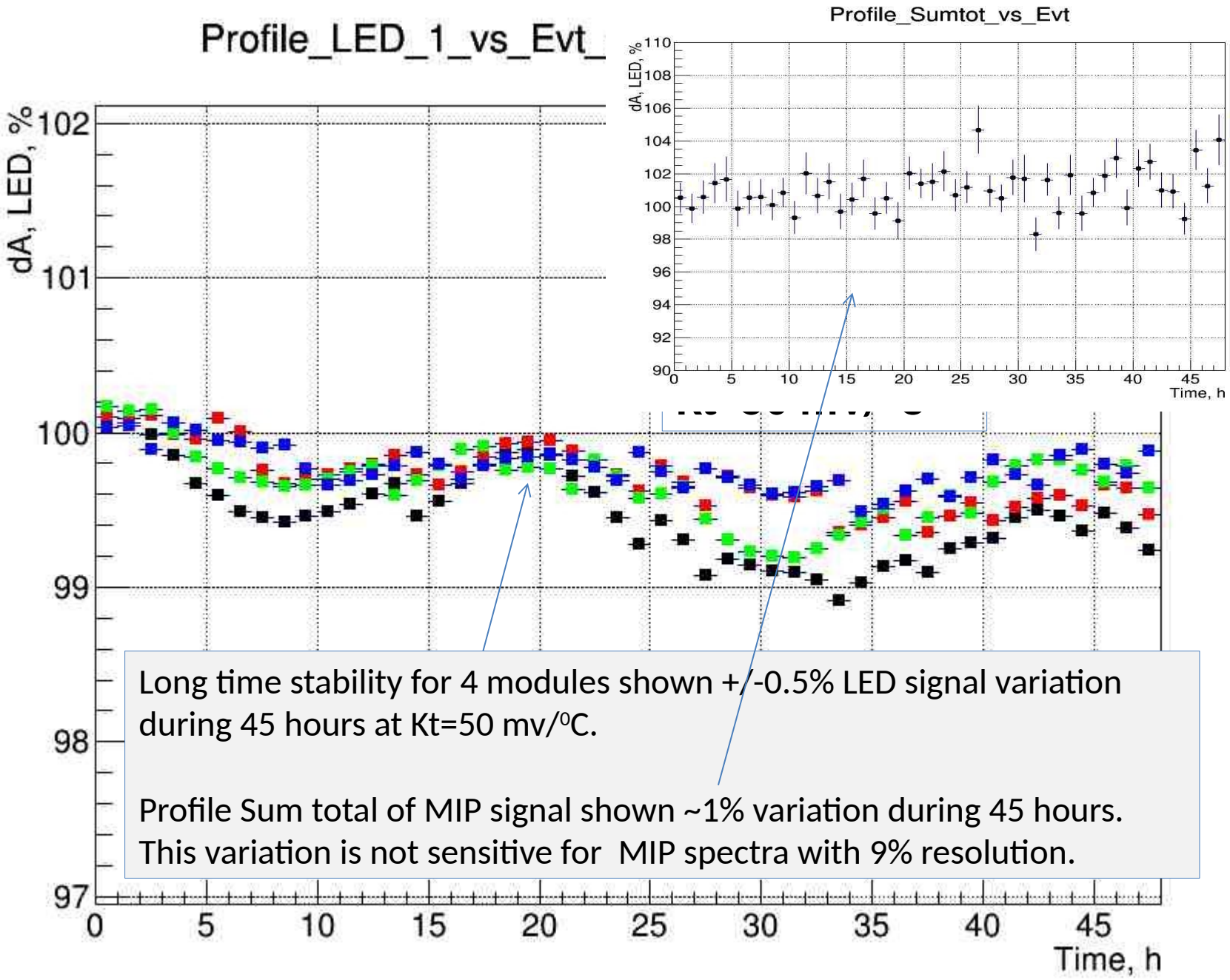
MIP spectra from 36 Cells. Top view shown on picture Above. One hit/event – applied selection criteria during analysis.
Calibration coefficients were found and normalized to 240 MeV.



MIP spectra from 36 Cells as Total Sum take in account the Calibration coefficients normalized to 240 MeV. These Energy resolution corresponded to MC



Test of long time Stability was done with different Kt for individual module.
The temperature variation from 20 to 30 ^{0}C per day was applied.

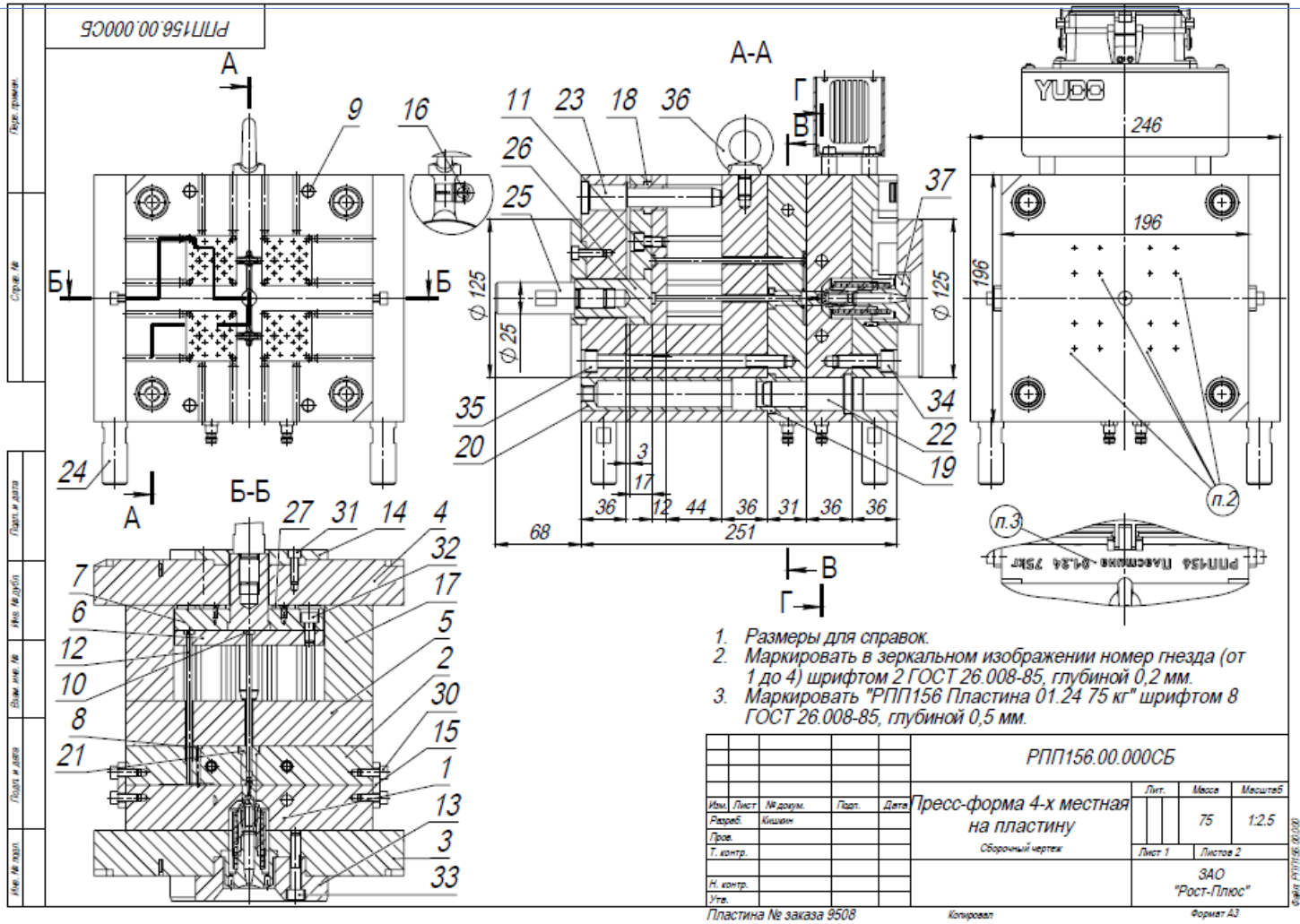


Long time stability for 4 modules shown +/-0.5% LED signal variation during 45 hours at Kt=50 mv/^{0}C.

Profile Sum total of MIP signal shown ~1% variation during 45 hours. This variation is not sensitive for MIP spectra with 9% resolution.

Matrix form for new scintillator production (40x40x1.5 mm^3) should be ready in end of 2023

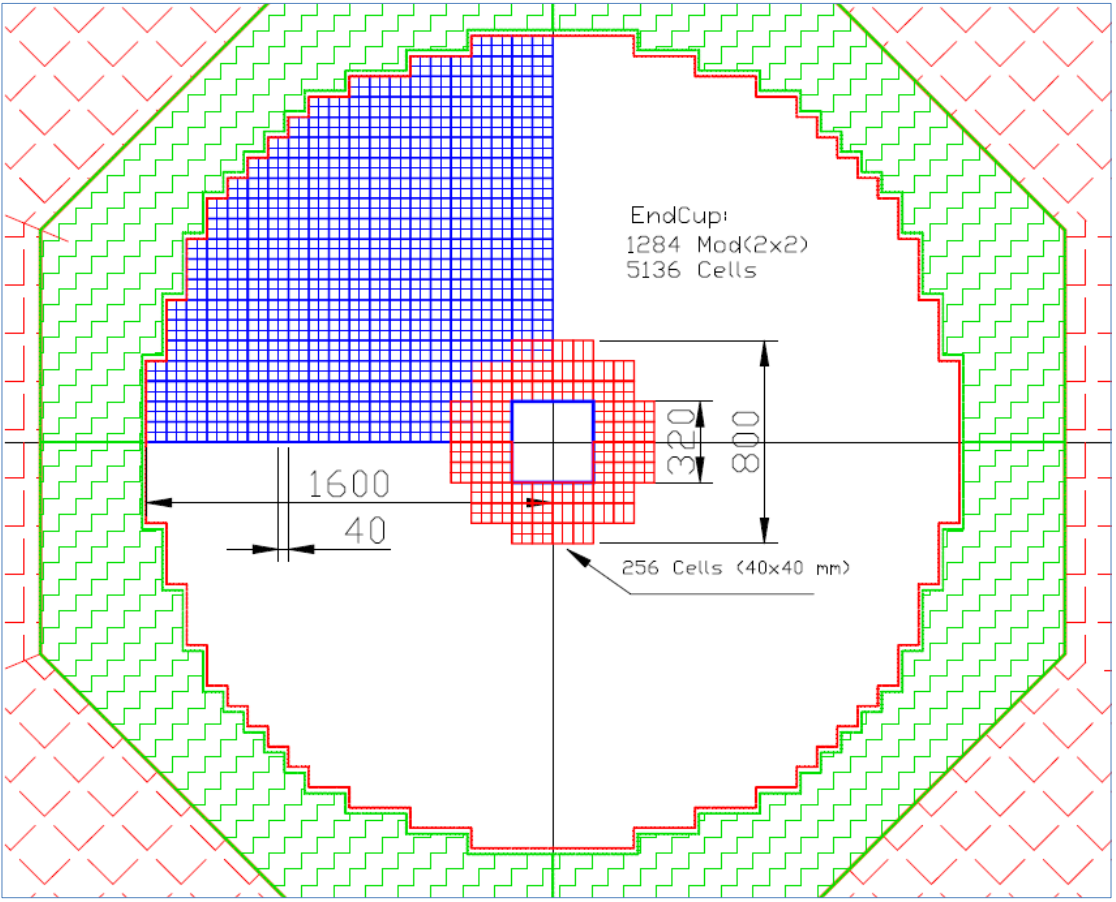
Matrix firm is special setup for molding by pressure technology
It allow produce scintillator from granulated polystyrene with doppands
4 set form produce 4 scintillator plate per 1 minute



Plan for 2024:

End Cup for SPD with new scintillator to be produced in February-March of2024

256 cells of 40x40 mm^2 = 64 modules of 4 cells=2x2



This Figure shows in red 64 modules, consisting of 4 cells each. The weight of this assembly is 597 kg. This will require 130 kg of polystyrene, 465 kg of lead, as well as additives: 1.95 kg of P-terphenyl and 65 g. POPOP, and 2000 meters WLS fiber type Y-11. **It is 1/20 part of End Cup and taken time of 36 Days to prepared 51200 Stint. plates.** To read this setup, we need four ADC64 - 64-channel amplitude encoders, as well as 16 boards of 16-channel amplifiers and bias voltage regulators.