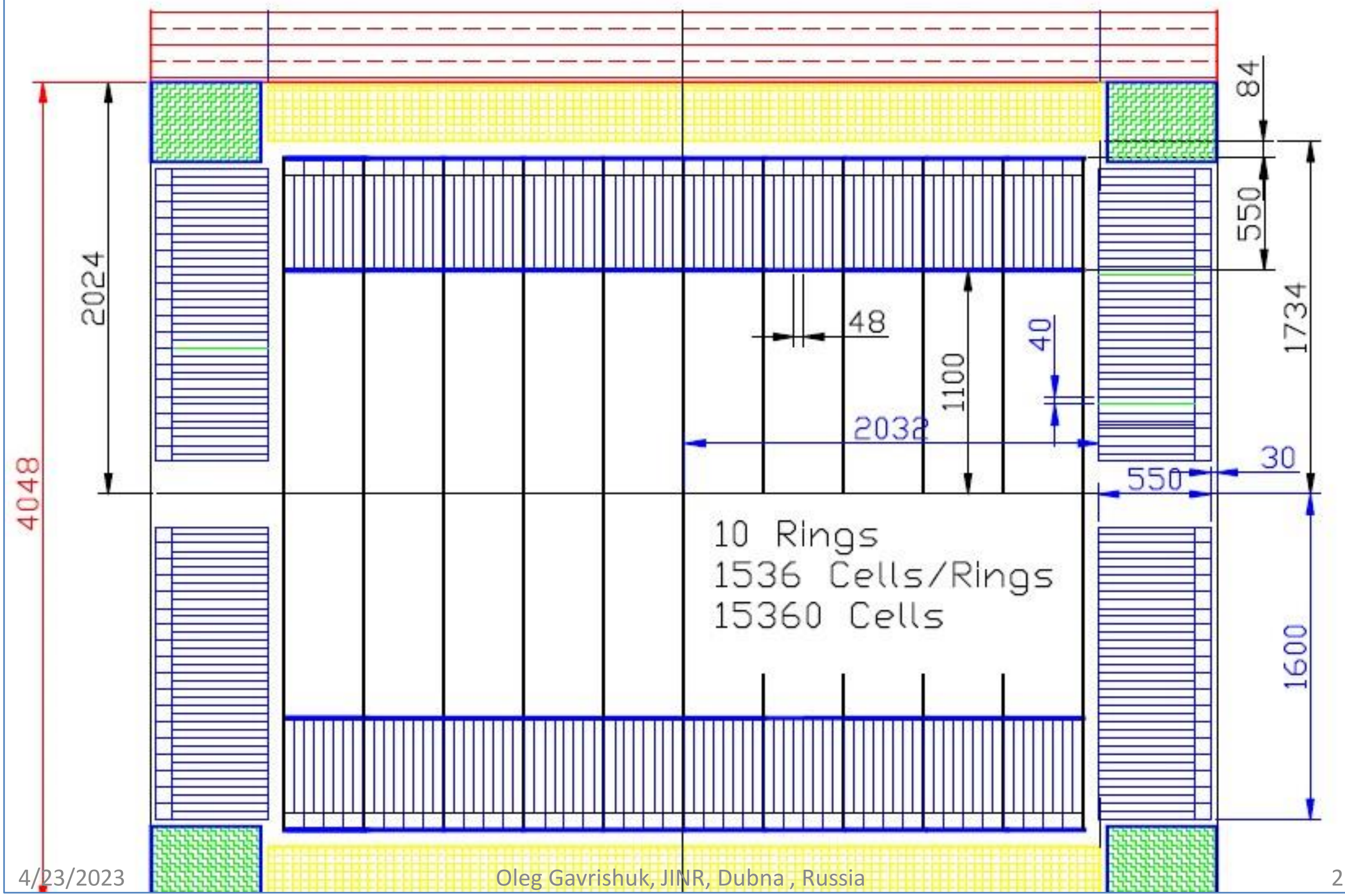
SPD ECAL , April 2023 Status Report

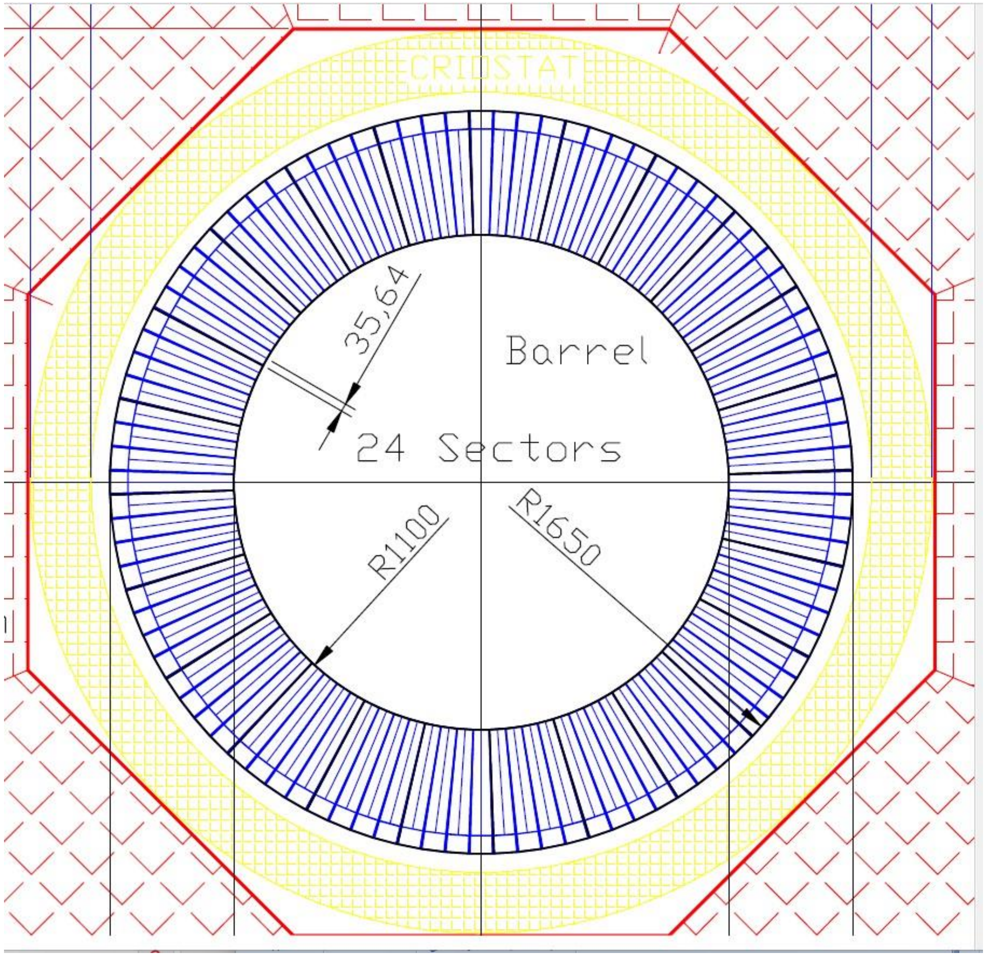
Oleg Gavrishuk, LVHE, Dubna, Russia

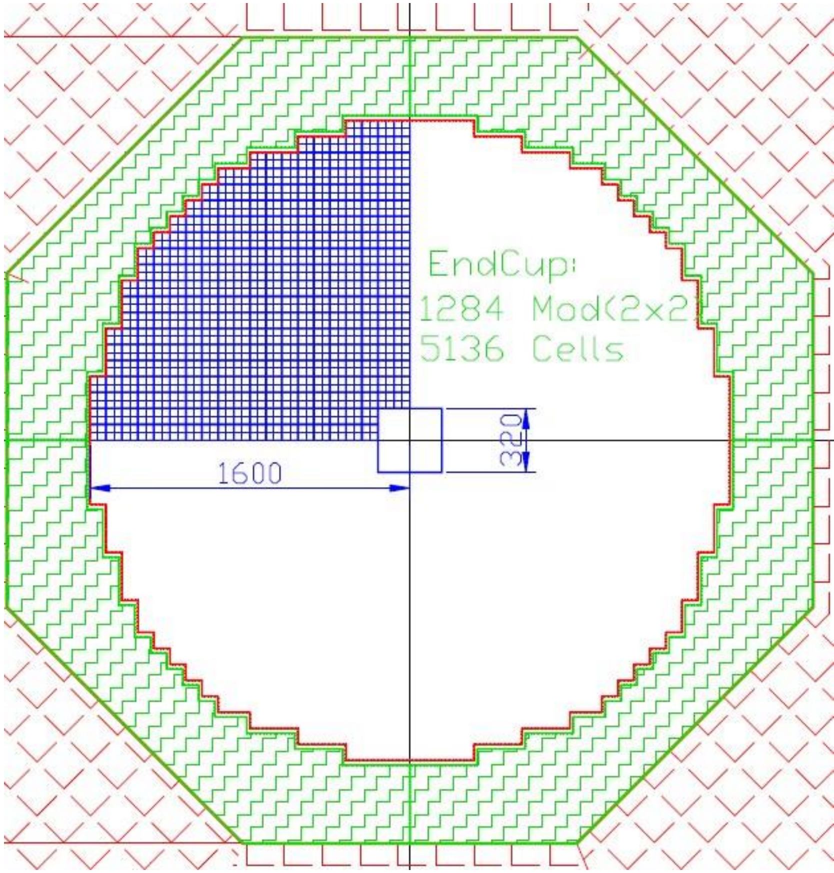
1. **ECAL position inside of Cryostat**
2. **ECAL New Sizes corrected in 2023**
3. **Test results with new SiPm EQR15 11-6060D-S**
    1. **New Sipm testing results**
    2. **EC prototype cells 40x40 Cosmic test**
    3. **Long time stability with new SiPm**

ECAL with New Sizes in 2023

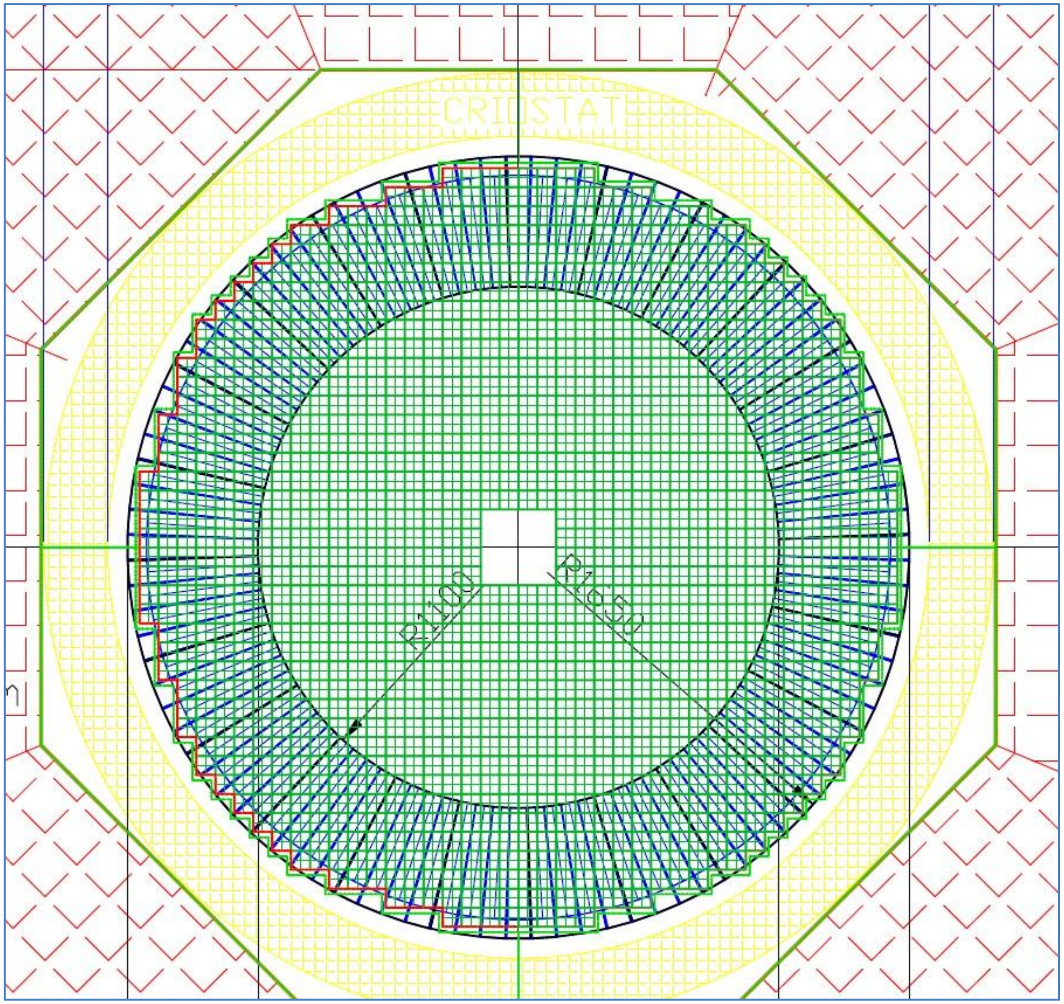


ECAL with New Sizes in 2023





ECAL composition with New Sizes in 2023



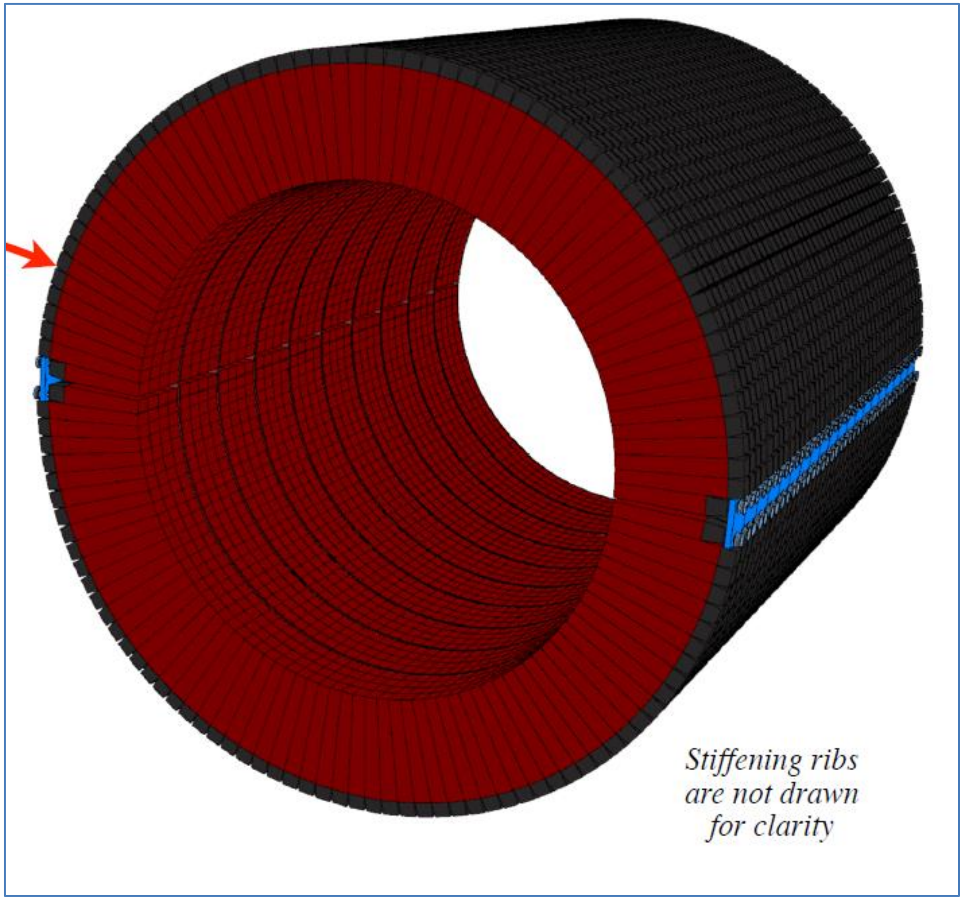
Barrel :

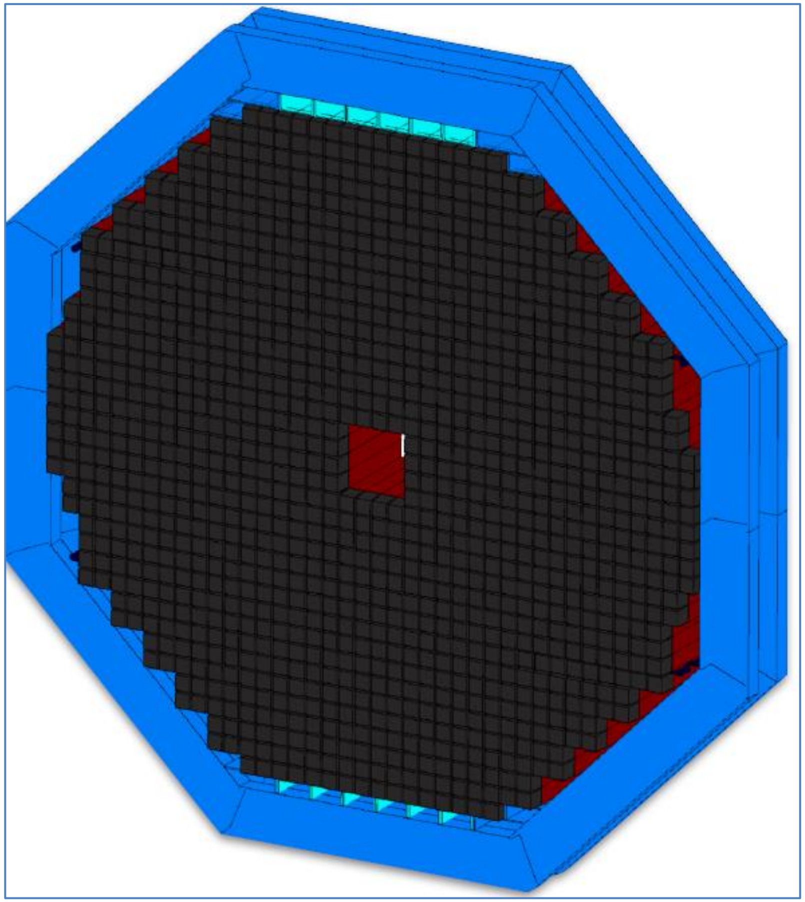
1. 10 Rings – 1536 cells/Ring
2. Total Cells – 15360
3. ADC64 – 240
4. 16ch Amplifiers – 960
5. Power units – 24
6. Weight – 38.4 tonn

ENDCUP:

1. Cells – 5136 / per EndCup
2. Total cells – 10272
3. ADC64 – 160
4. 16ch Amplifiers – 642
5. Power units – 20
6. Total Weight – 256 tonn

ECAL 3D View Barrel and Cup parts





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.

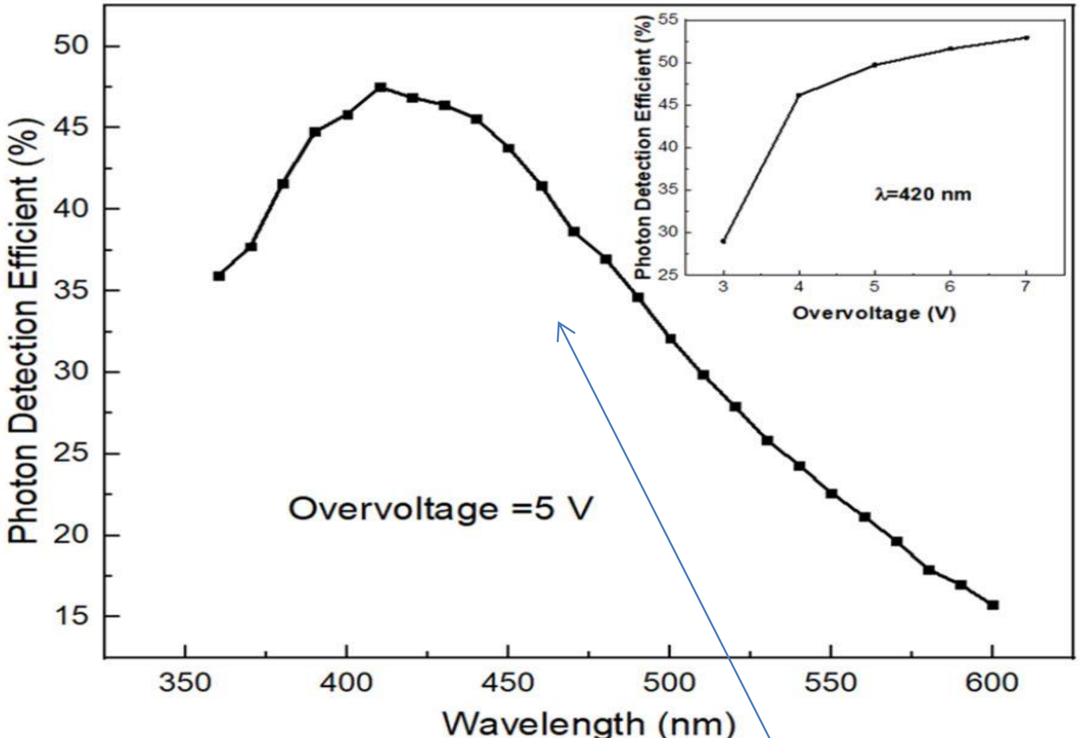
NDL SiPm Series EQR15
11-6060D-S

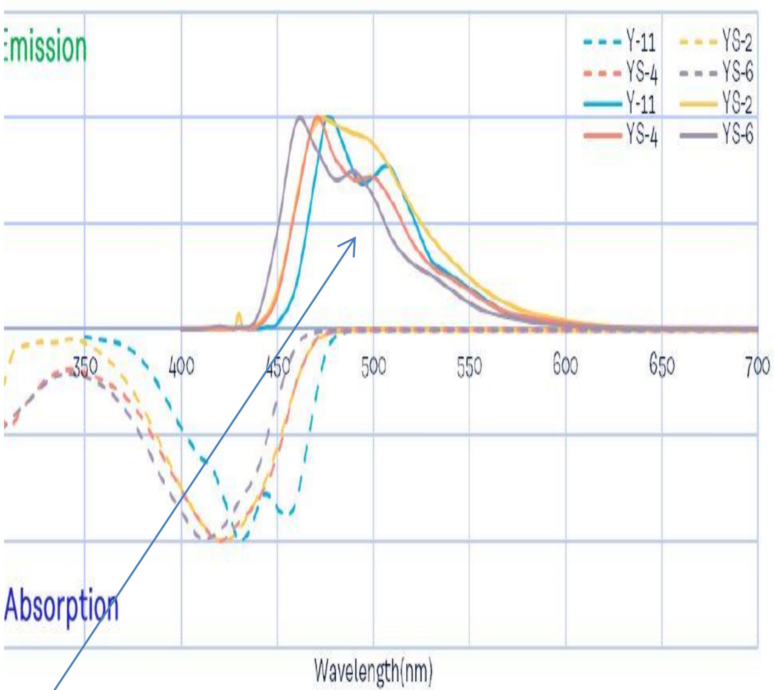
www.ndl-sipm.net/PDF/Datasheet-EQR15.pdf

- 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



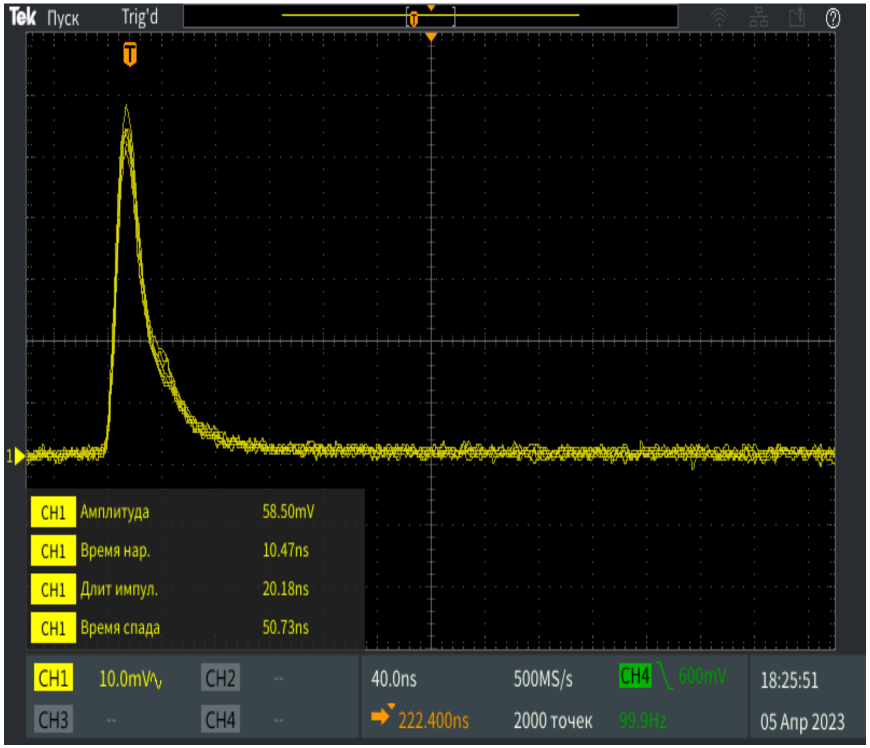


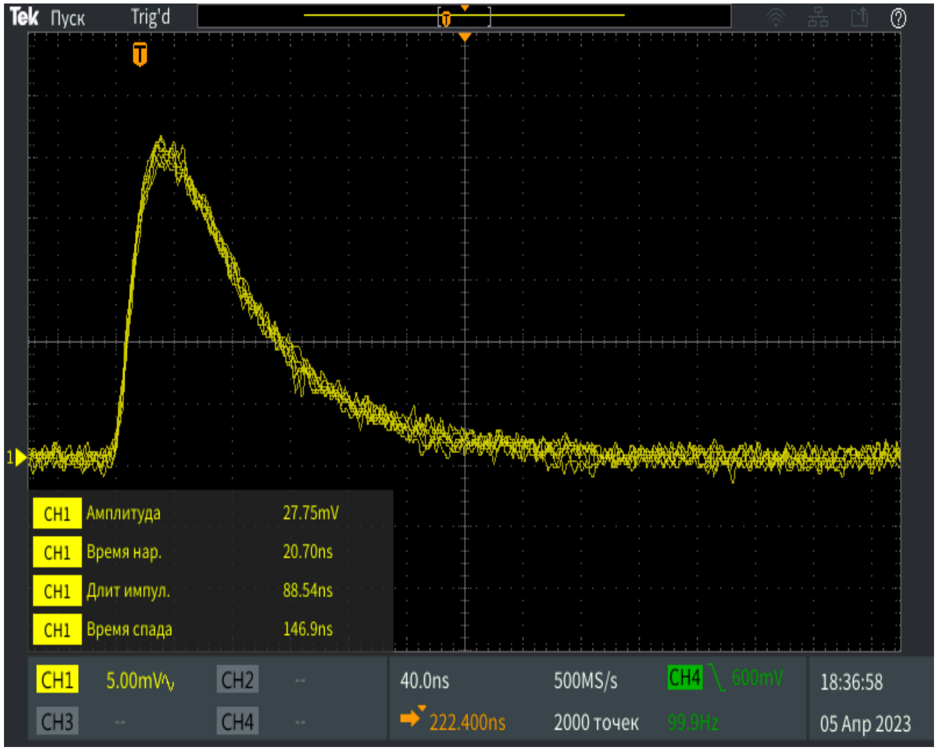
Photon Detection Efficient (PDE) correspond to WLS Emission spectra of Y11.
PDE close to flat maximum about 45% at 6-7 Overvoltage.

EQR15 Series SiPMs

Specifications subject to change without notice

Pulse shape of SiPm with 15 μ pitch and 6x6 mm^2 size



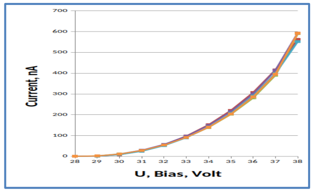


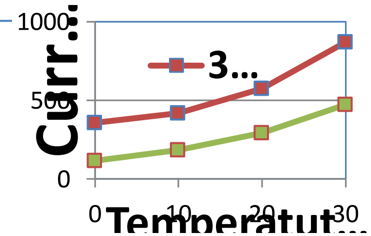
EQR-15-60
Front – 10 ns
Length – 20 ns

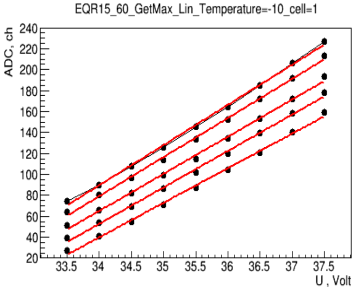
HAMAMATSU S14160-6015
Front – 21 ns
Length – 89 ns

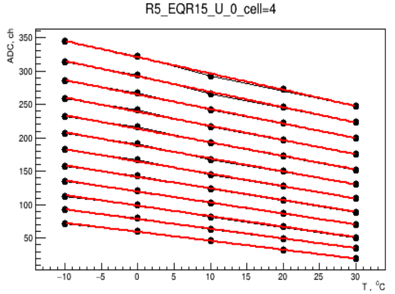
SiPm test Results

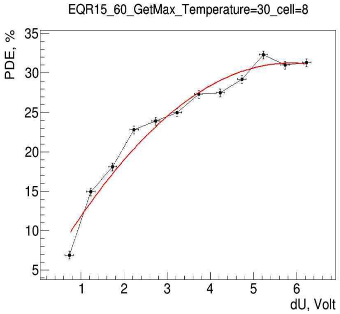
- **Dark Current measurements**
- **Gain vs Overvoltage: dA/dU**
- **Gain vs Temperature: dA/dt**
- **PDE vs Overvoltage**
- **Operation Volt. how to select it ?**
- **Temperature stability studies**

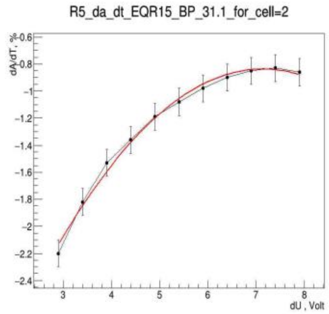




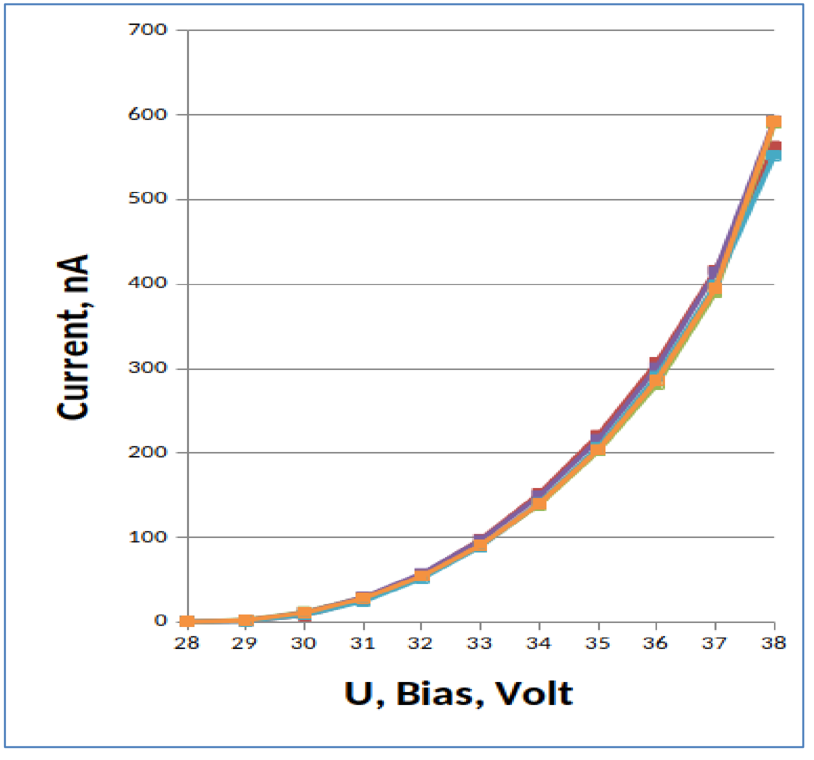


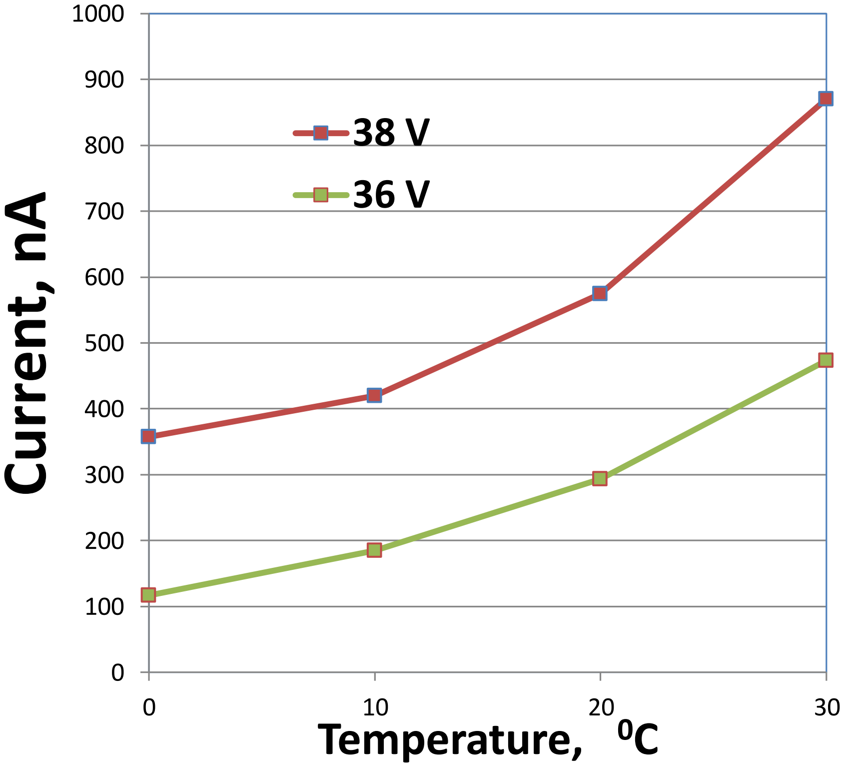






EQR15-60 Dark Current vs Bias voltage and its temperature dependences around operate Voltage

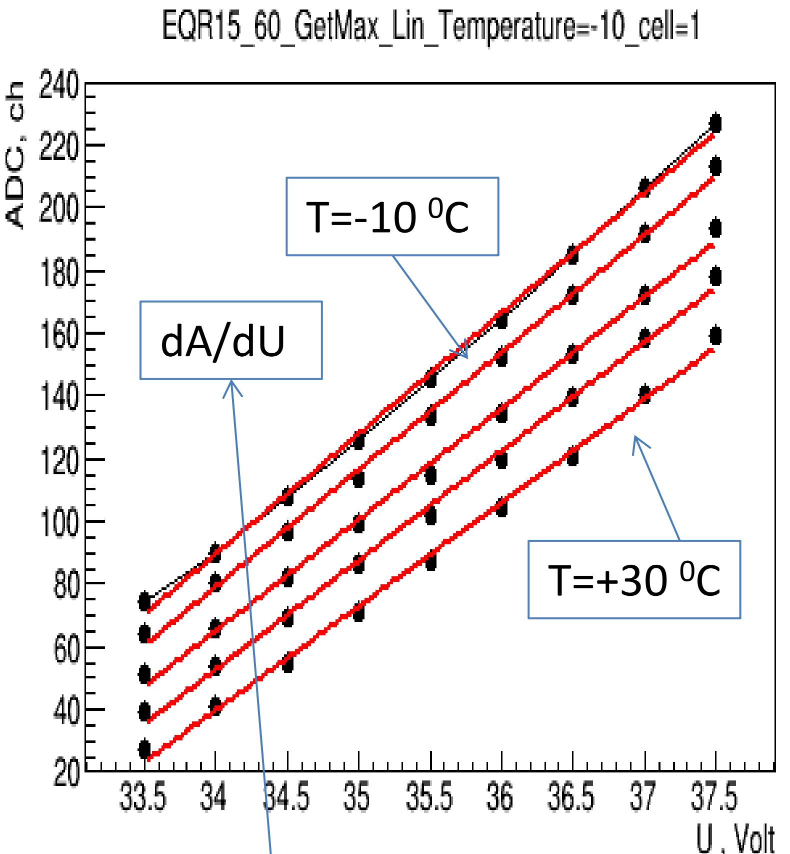


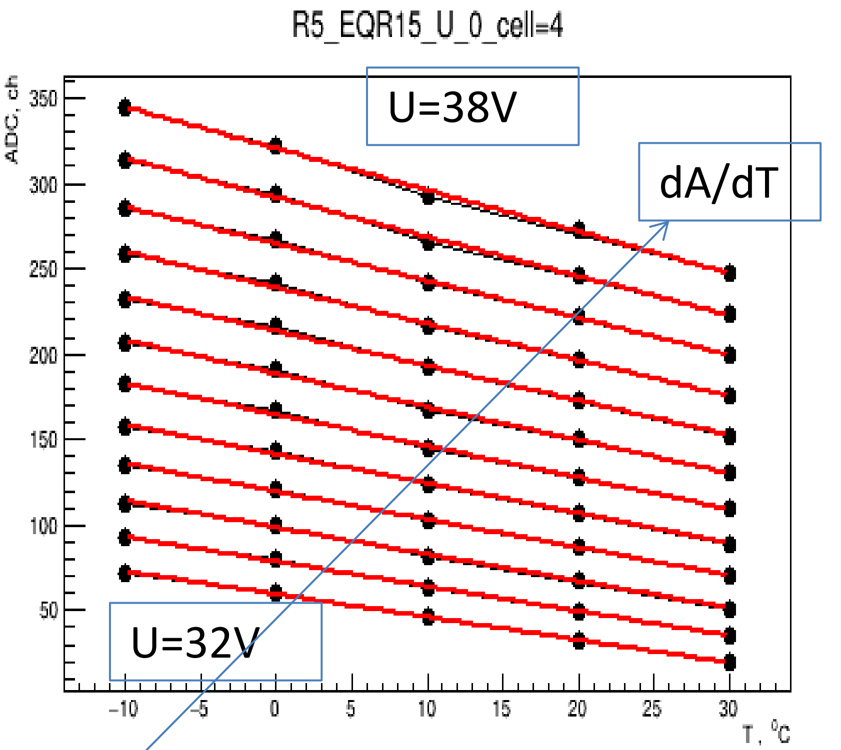


Dark Current vs Operation Bias (36-37 V) at room temperature (20 ^{0}C) is equal to 300-400 nA. Its are corresponded to the factory data and is similar HAMAMATSU too.

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

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



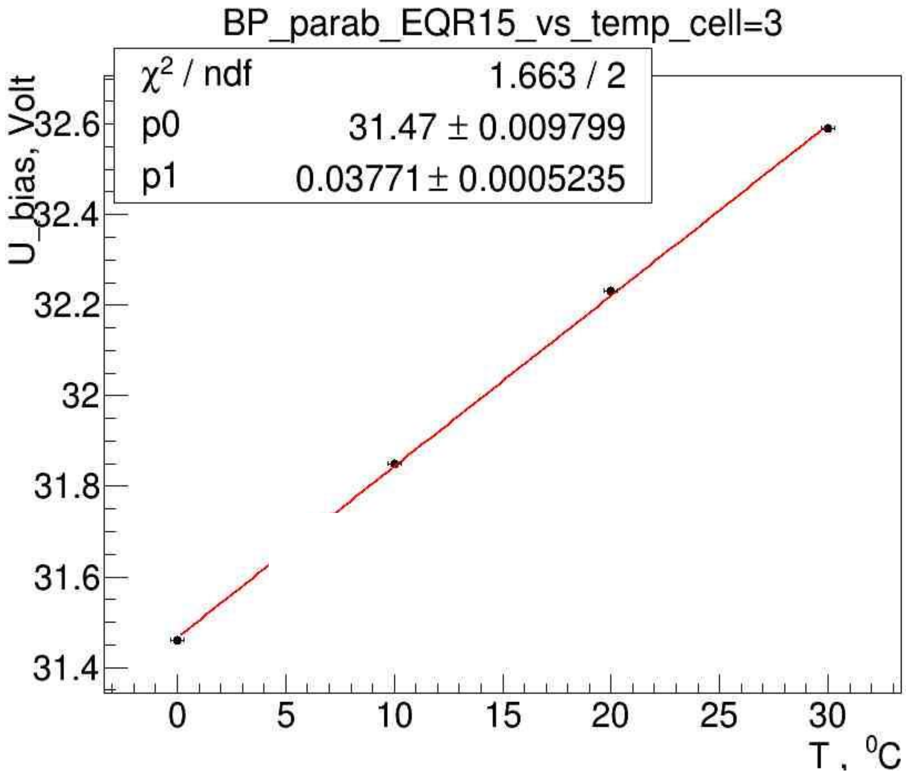


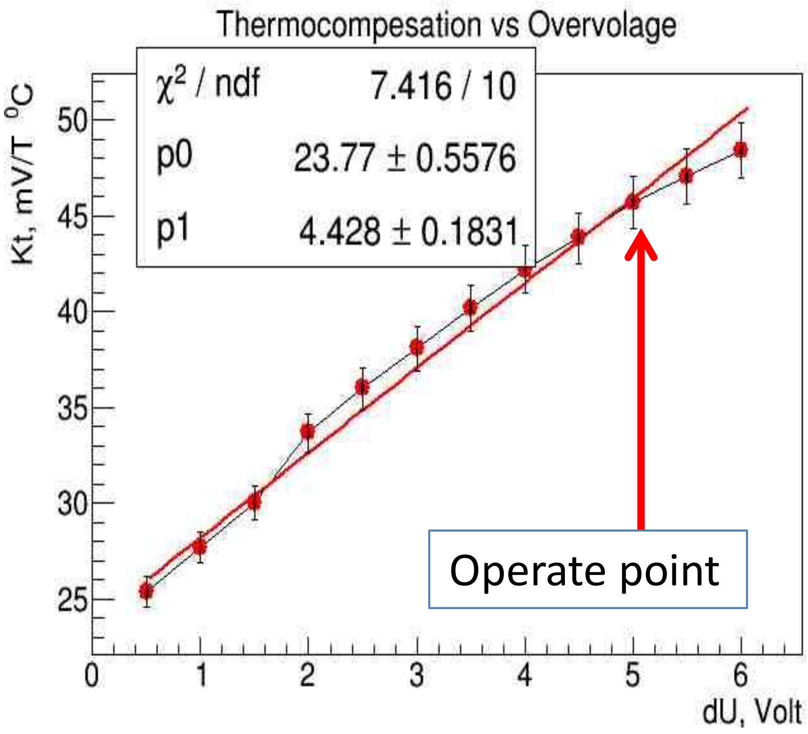
K_t=dU/dT=dA/dT/dA/dU

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.

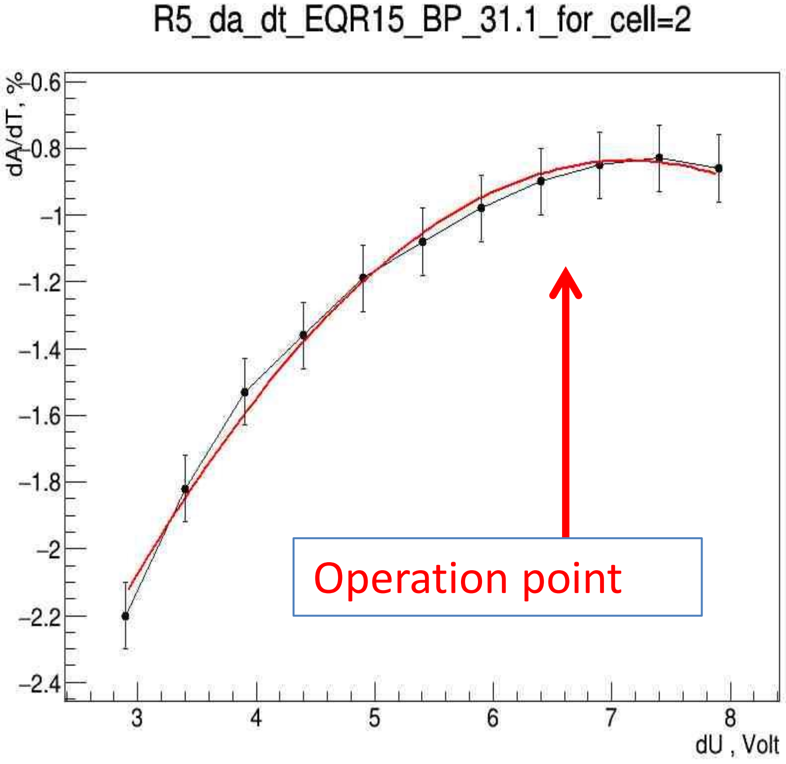




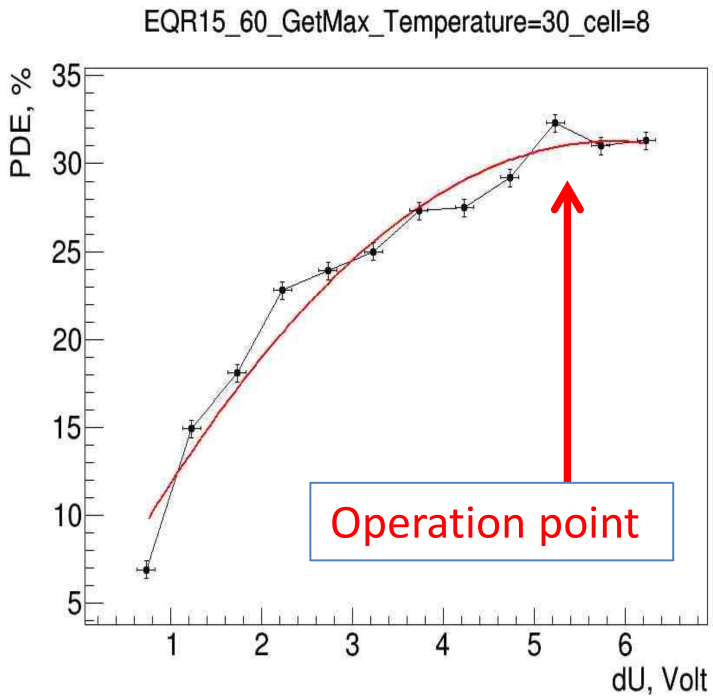
Temperature sensitivity vs dU

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%.

Test results with cosmic particles

Cosmic Rays

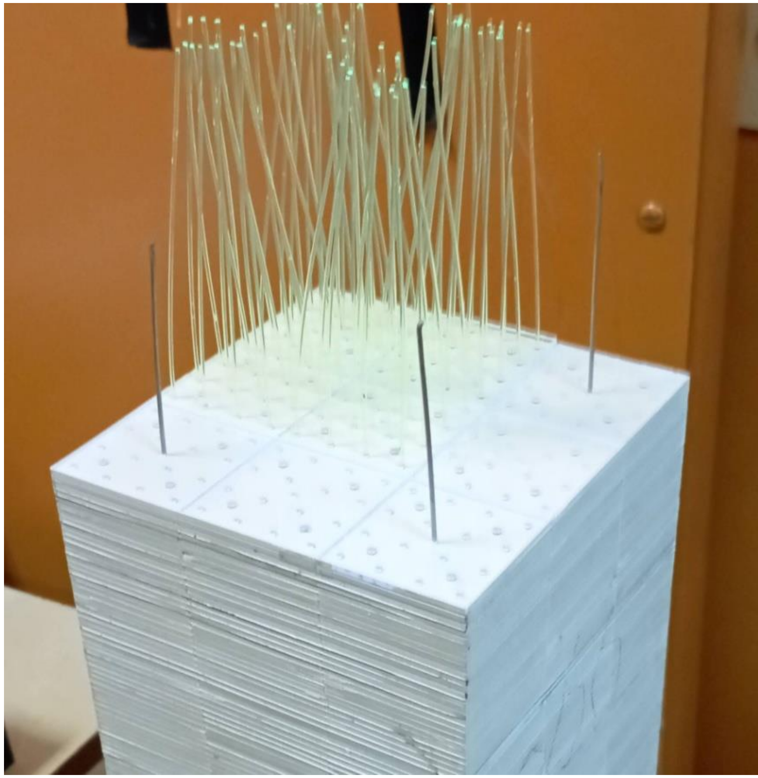
Setup of 4 modules.
Each module consist from 9 cells of 4x4 cm^2. Totally tested 36 cells.

Sampling:

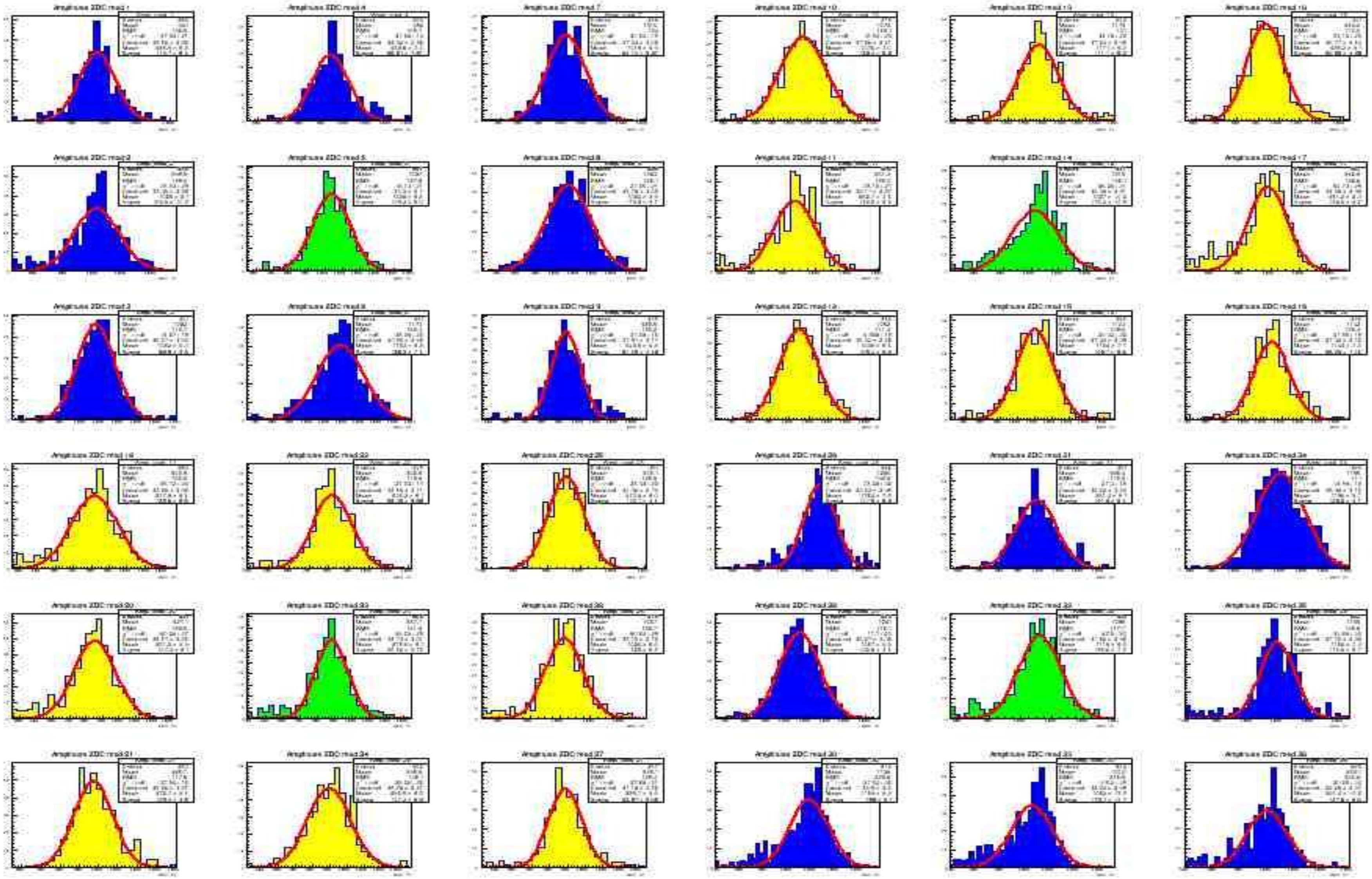
- 1.5 mm Scintillator
- 0.3 mm Lead
- 200 layers

Scintillator composition:

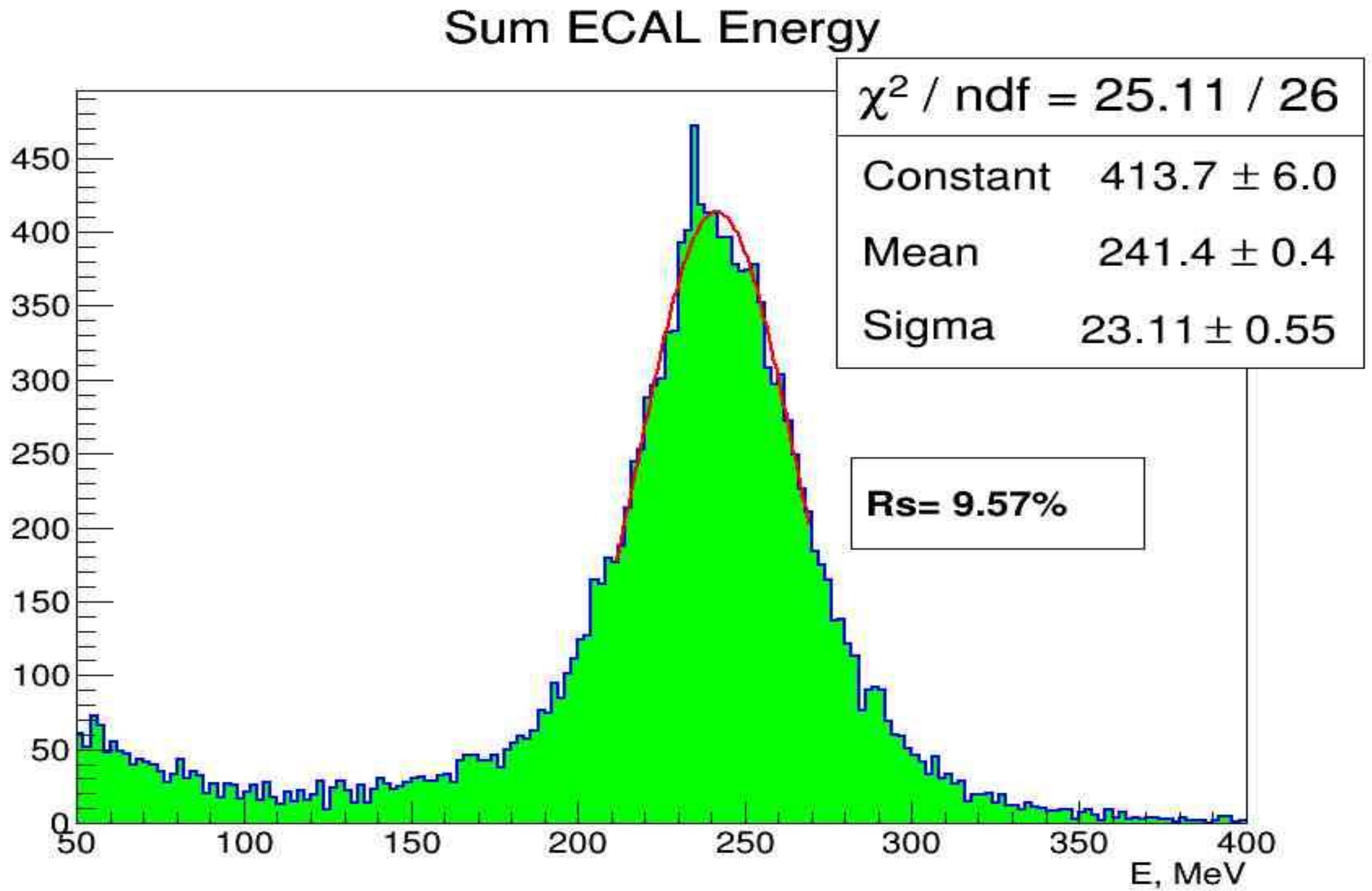
- Polysterene
- 1.5% Paterphenyle
- 0.04% POPOP



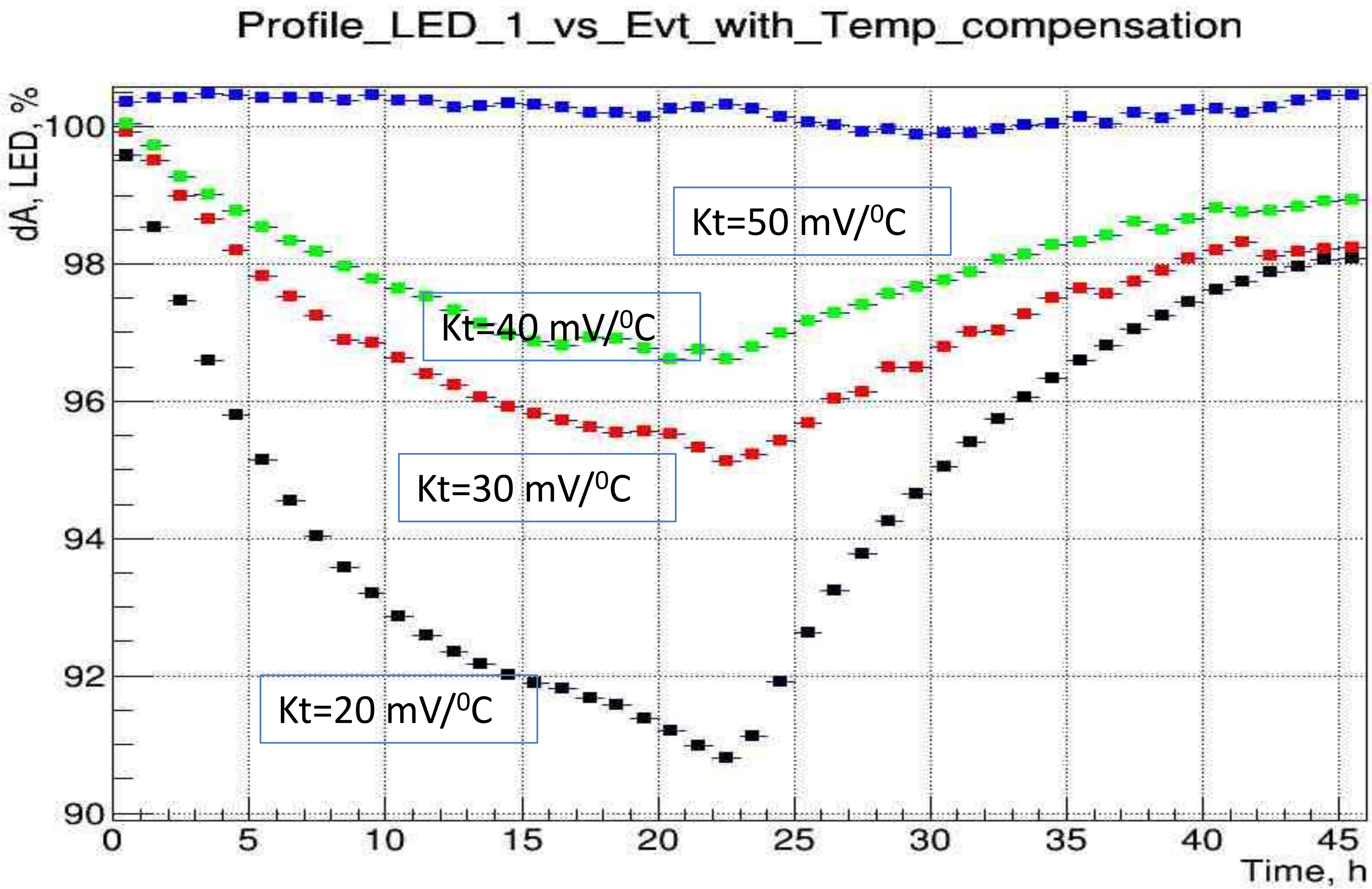
Single Ecal module shown in assembling stage.
It is visible 9 cells as 3x3 matrix with WLS fibers (16 per cell). Y11(200) diameter 1.0 mm was used.



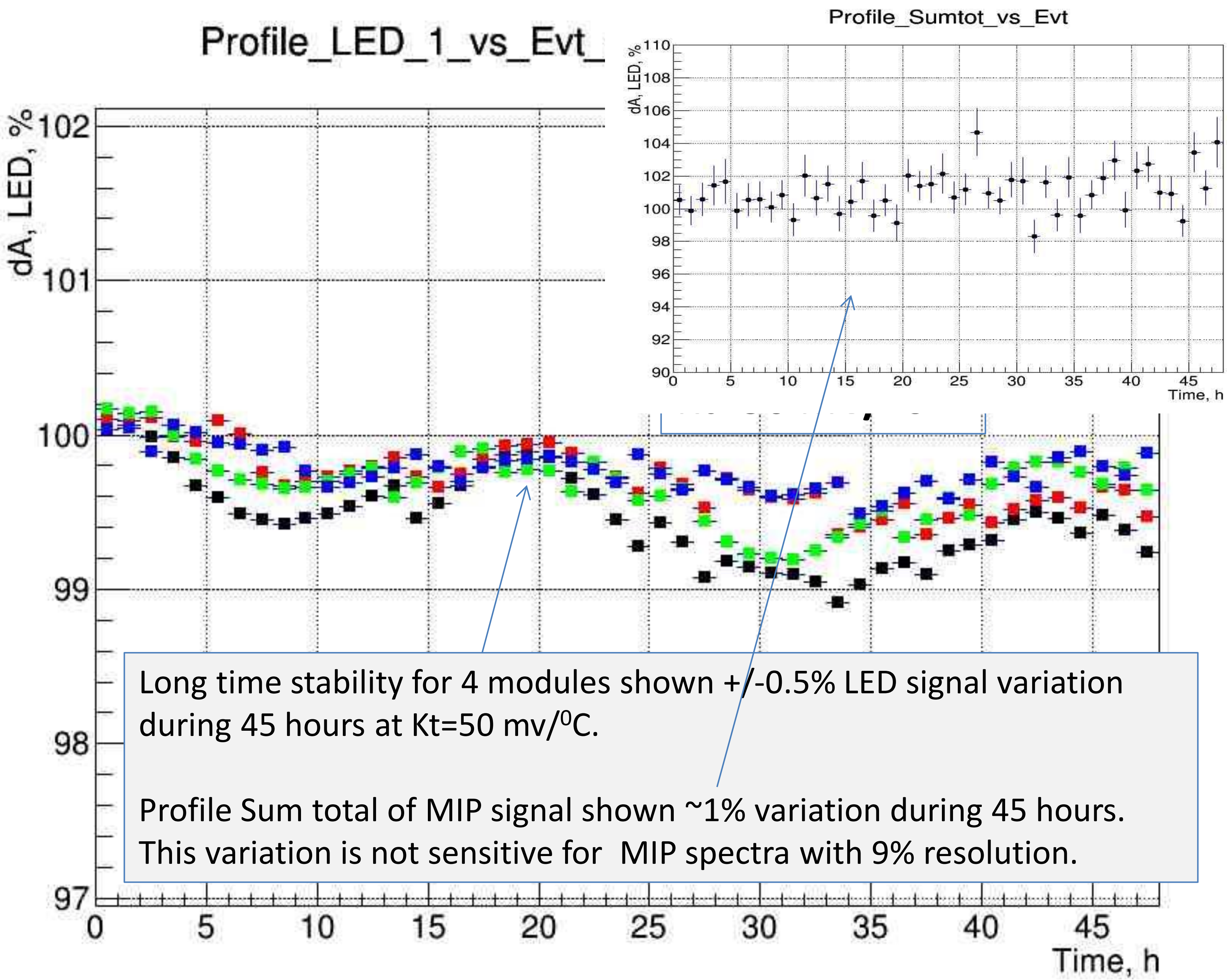
MIP spectra from 36 Cells. Top view shown on picture Above. One hit/event – applied selection criteria during analysis.
Calibration coefficients were found and normalized to 240 MeV.



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.

Conclusions

1. New ECAL geometry was designed in 2023
2. SiPm EQR15-60 China production were studied
3. New ECAL setup with cell size 4x4 cm^2 assembled
4. ECAL test in cosmic rays was done for:
    1. Energy resolution estimation
    2. Long time stability measurement

End of Report

Thanks for attention to All