Tests of Multi Pixelated Photon Counters (MPPC) with the cell sizes 15 and 20 microns

O. Gavrishchuk, N.Grafov, S. Golubykh ,O.Minko, I.Pudin – JINR, LHEP
https://lhep.jinr.ru/en/main-page/

NDL SiPm Series:
EQR15 11-6060D-S & EQR20 11-6060D-S

NDL (Novel Device Laboratory, Beijing) http://www.ndl-sipm.net/indexeng.html
http://www.ndl-sipm.net/PDF/Datasheet-EQR15.pdf
http://www.ndl-sipm.net/PDF/Datasheet-EQR20.pdf

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**

NDL SiPm Series EQR15
11-6060D-S

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

NDL (Novel Device Laboratory, Beijing) has been developing a unique SiPM technology (EQR-SiPM) that employs the resistor under each APD cell in the epitaxial layer as the quenching resistors. EQR-SiPM has the advantages of small microcell, high micro cell density (large dynamic range) while retaining high fill factor and high photon detection efficiency (PDE), low temperature coefficient for breakdown voltage, simple fabrication technology and radiation hardness. It is also easy to implement charge division in chip to realize a high resolving position-sensitive (PS) SiPM.

NDL (Лаборатория новых устройств, Пекин) разрабатывает уникальную технологию SiPM (EQR-SiPM), в которой резистор под каждой ячейкой APD в эпитаксиальном слое используется в качестве гасящего резистора. EQR-SiPM обладает преимуществами небольших микроячеек, высокой плотности микроячеек (большого динамического диапазона), сохраняя при этом высокий коэффициент заполнения и высокую эффективность обнаружения фотонов (PDE), низкий температурный коэффициент напряжения пробоя, простую технологию изготовления и радиационную стойкость. Также легко реализовать разделение заряда в кристалле для реализации позиционно-чувствительного (PS) SiPM с высоким разрешением.

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

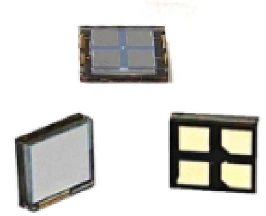
EQR15 Series SiPMs

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.

EQR20 Series SiPMs



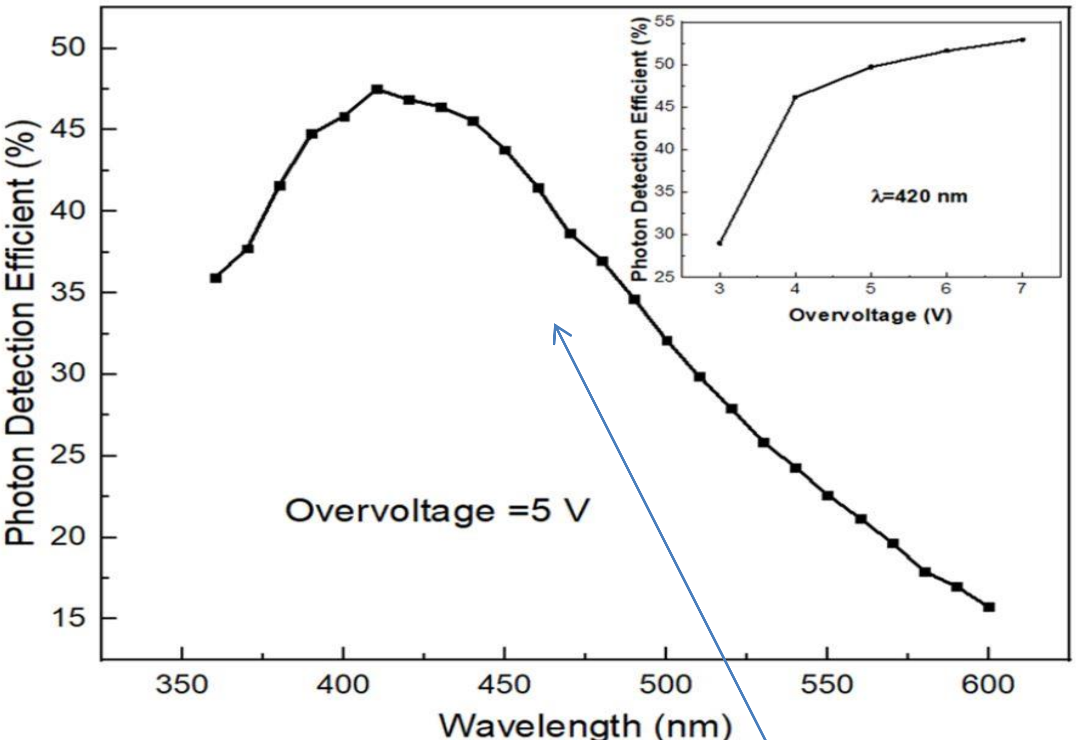
Specifications subject to change without notice

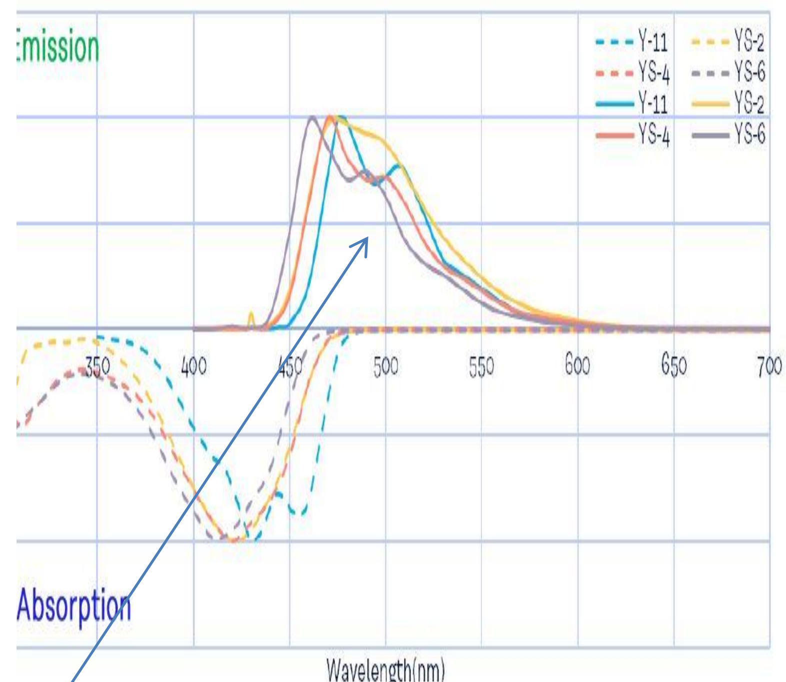
Type	EQR20 11-3030D-S	EQR20 11-6060D-S
Effective Pitch	20 μm	
Element Number	1×1	
Active Area	3.00×3.00 mm^2	6.24×6.24 mm^2
Micro-cell Number	2500 /mm^2	
Typical Breakdown Voltage (V_B)	27.5 V	
Recommended Operation Voltage	V_B + 5 V	
Peak PDE @ 420nm	46 %	
Gain	8.2×10^5	
Dark Count Rate（DCR）	150 kHz / mm^2	

Above parameters are measured at their recommended operation voltage and 20 °C

EQR15 Series SiPMs

Specifications subject to change without notice





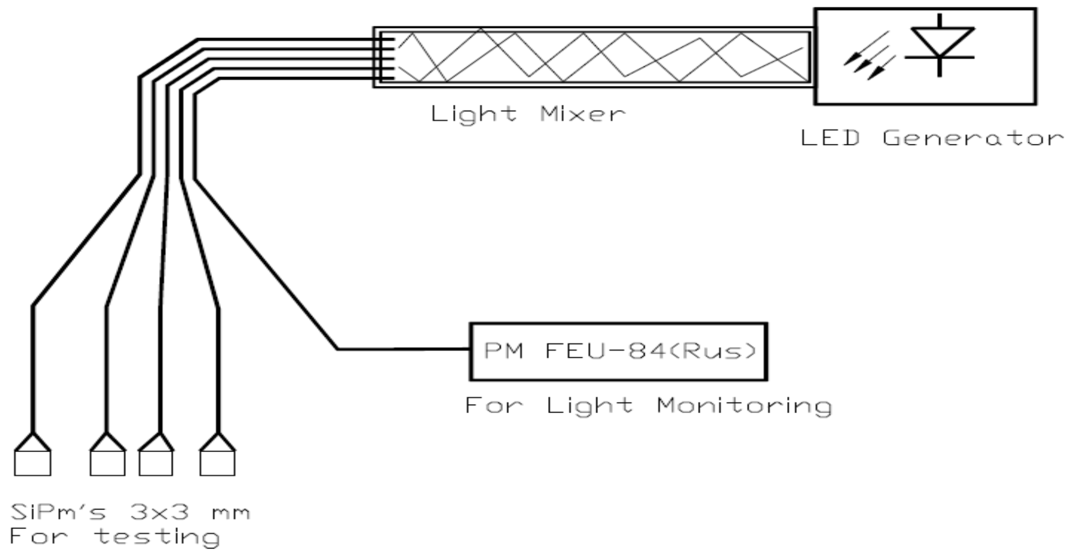
Photon Detection Efficient (PDE) correspond to WLS Emission spectra of Y11.
PDE close to flat maximum about 45% at 6-7 Overvoltage.

The tests of photon counters with a light flux that produces a response in the range of up to 50,000 photoelectrons was performed.

The signal of the calorimeter at an energy of 1 GeV is approximately 5000 photoelectrons.
Accordingly, this will be the range from 500 to 50,000 photoelectrons for 50 MeV and 10,000 MeV. We give the light flux not in the number of photons, but in the number of photoelectrons as this value is used for statistical accuracy, $1/N^{1/2}$.
Thus, for a minimum range of 50 MeV, the statistical measurement error will be 4.4%. This results in an increase in the measurement error by about 20%. That means it is undesirable to descend below this value of the light output.

A bright blue LED emitting light at a wavelength of 460 nm was used as a light source. A generator with a pulse duration of about 20 ns and a frequency of 200 Hz triggered the LED.

The measurement set-up is shown in Fig. 1. An optical mixer distributed the light from the LED to five plastic Plexiglas fibers, each having a diameter of 1 mm. Thus, the light from one LED was evenly distributed on five channels. The uniformity of the light fluxes in such a mixer is approximately 5%.



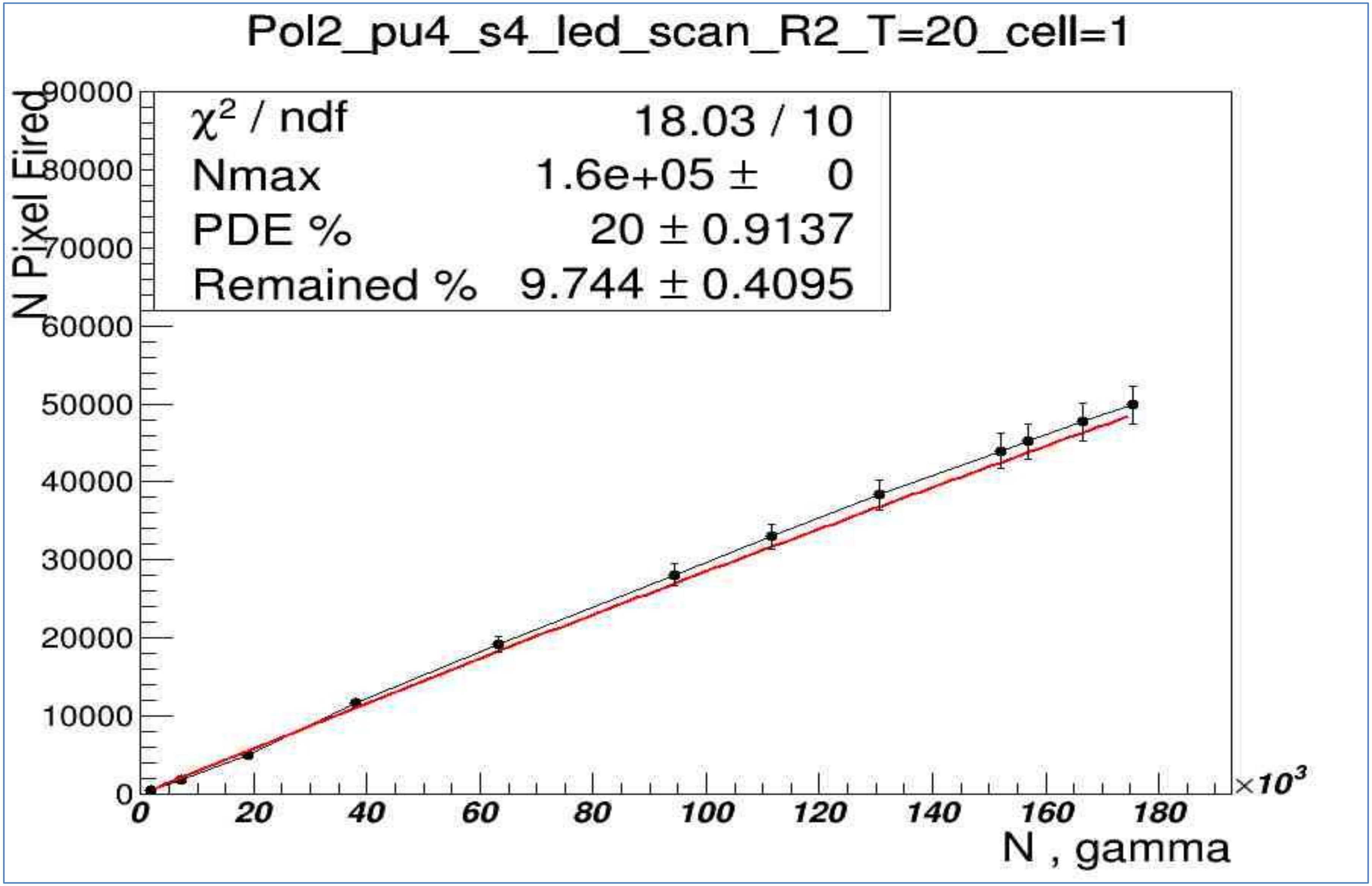
The measurements of the dependences of the fired pixel number on the photons incident on the diode were carried out as suggested below. The number of fired pixels is presented as the sum of the first order $\mathbf{N^{LO}_{fire}}$ fired pixels plus the number of pixels depending on the remaining non-fired $\mathbf{N_R}$s with a certain factor $\boldsymbol{\alpha}$.

The number of fired pixels of the first order - $\mathbf{N^{LO}_{fire}}$ is usually represented as:

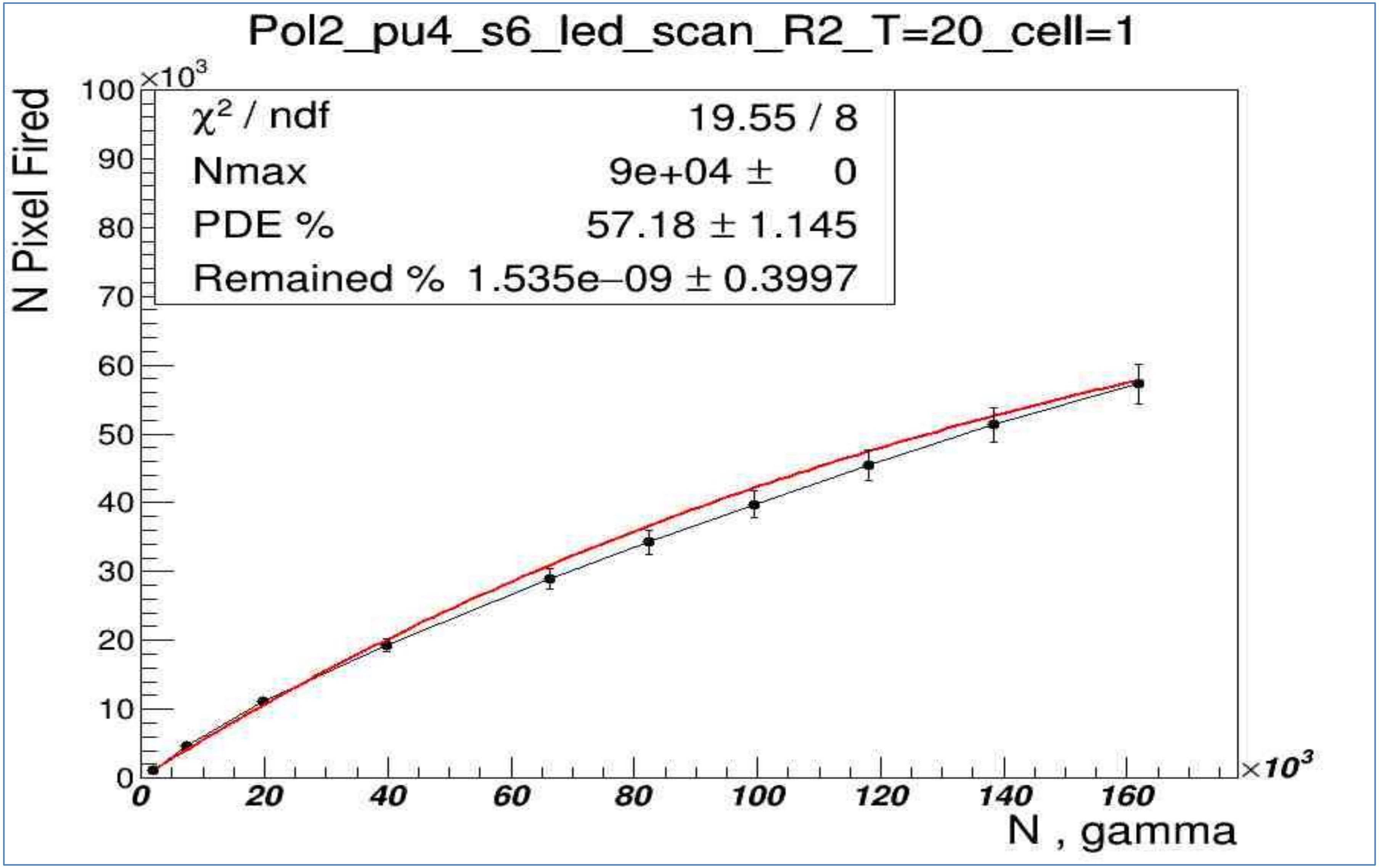
$\mathbf{N_{pix}}$ is the maximum number of pixels in the MPPC,
$\mathbf{N_{in}}$ is the number of photons arriving at the MPPC,
$\boldsymbol{\varepsilon}$ is the photon detection efficiency (PDE).

https://arxiv.org/pdf/1510.01102.pdf Describing the response of saturated SiPMs Katsushige Kotera ∗ , Weonseok Choi † , and Tohru Takeshita Department of Physics, Shinshu University, 3-1-1 Asahi, Matsumoto, Nagano 390-8621, Japan March 21, 2016

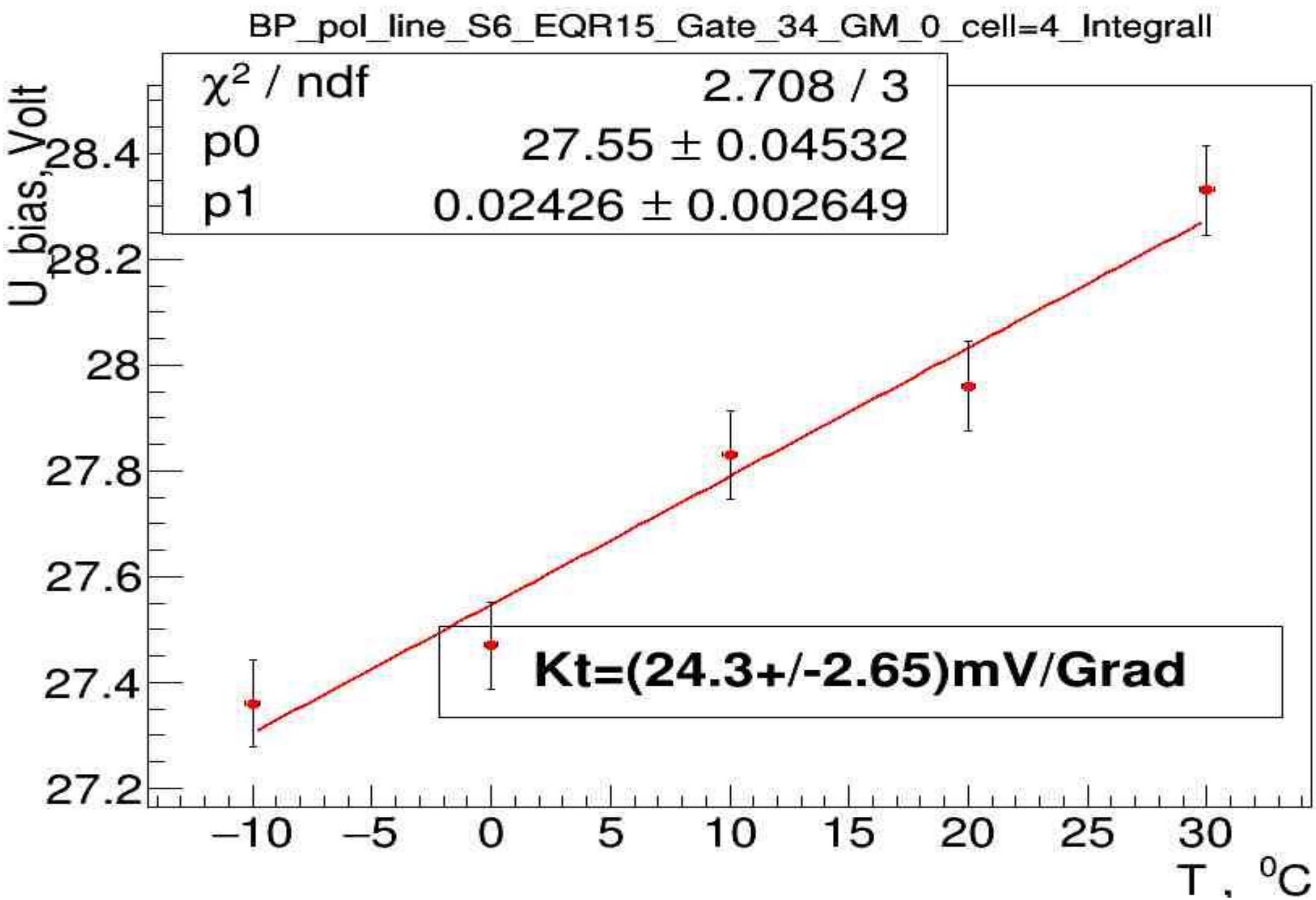
EQR15-11 6060 scan



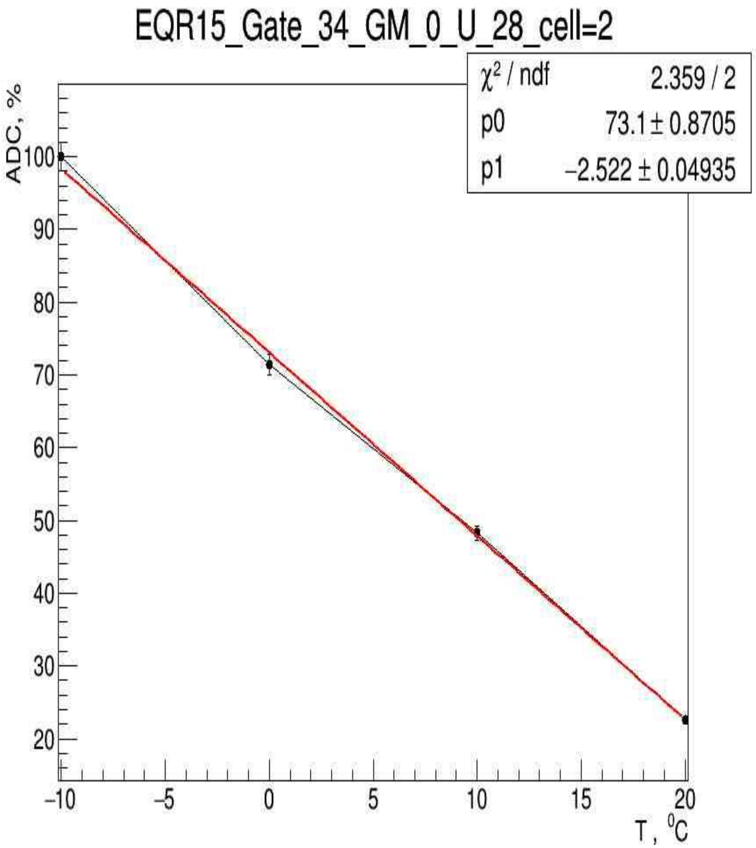
EQR20-11 6060 scan

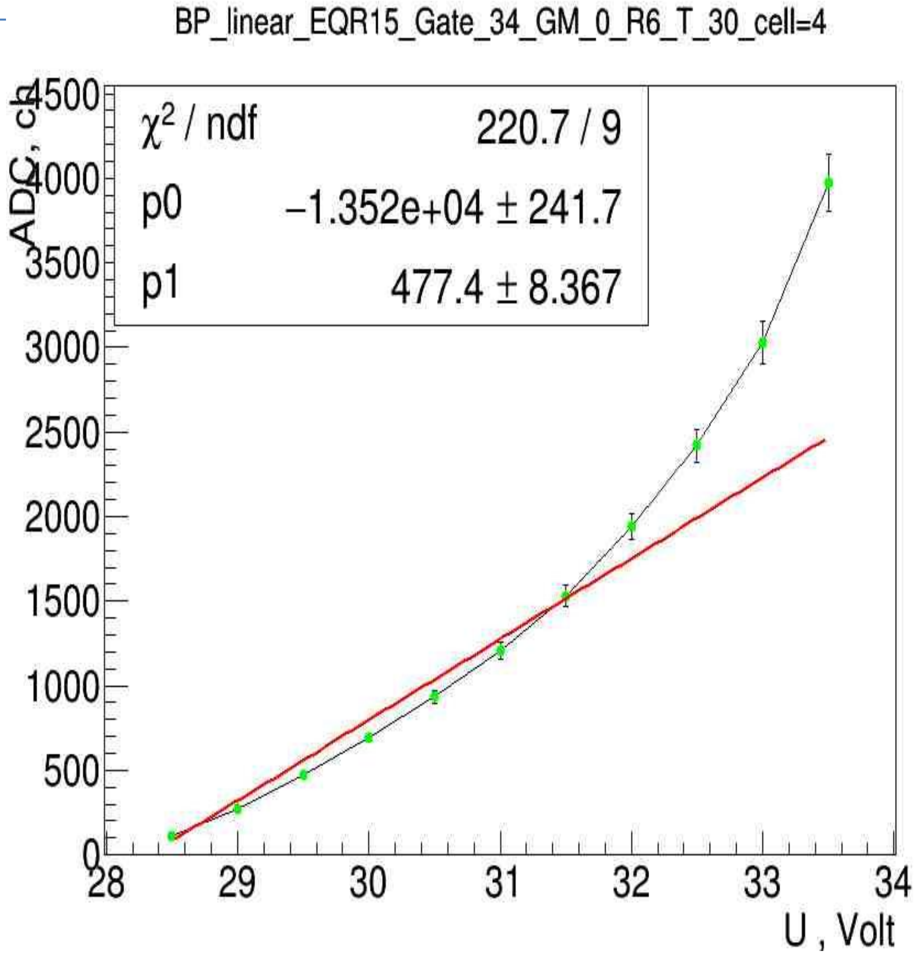


EQR-20-11-6060 Ubp vs T

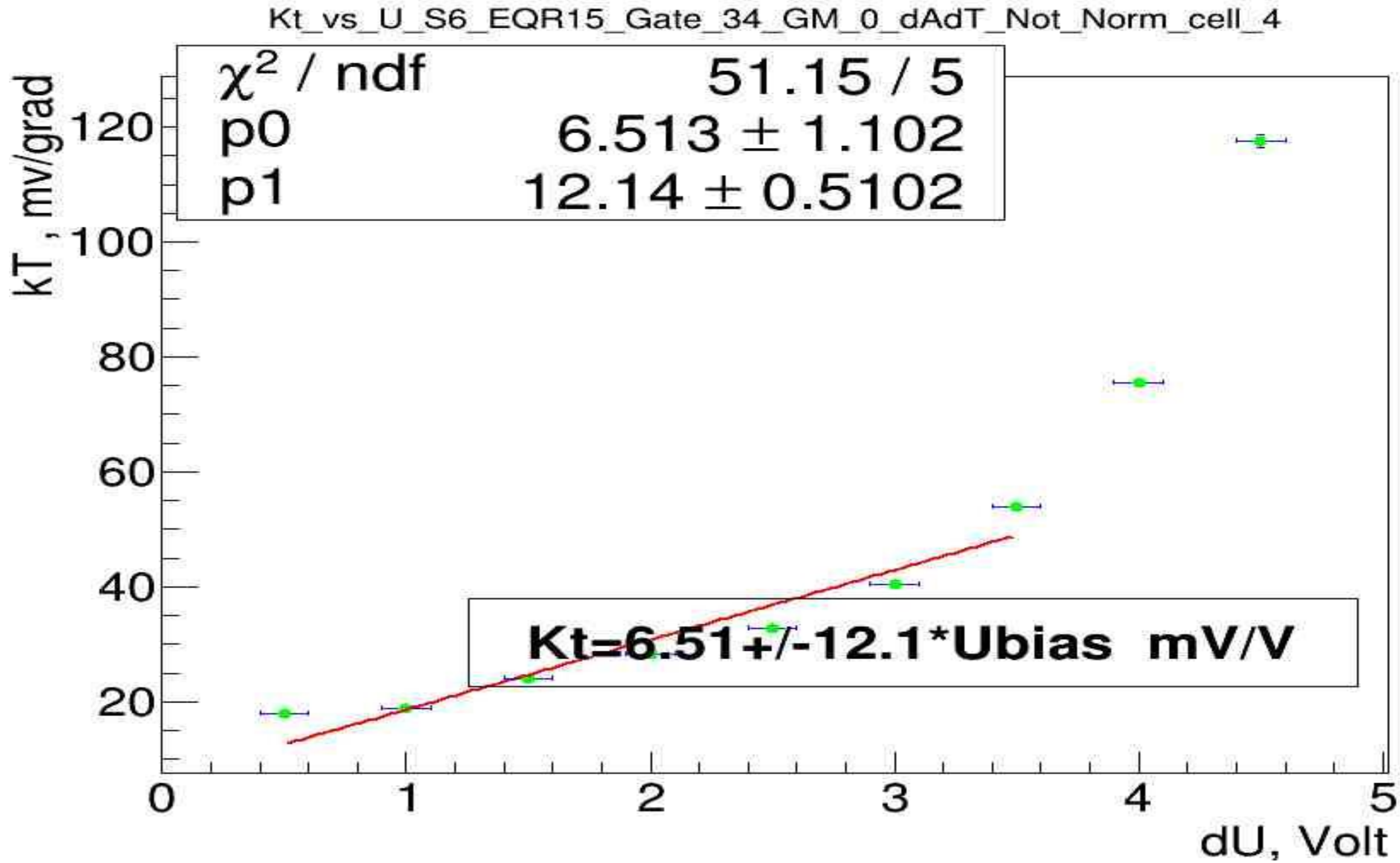


EQR-20-11-6060 dA/dT and dA/dU

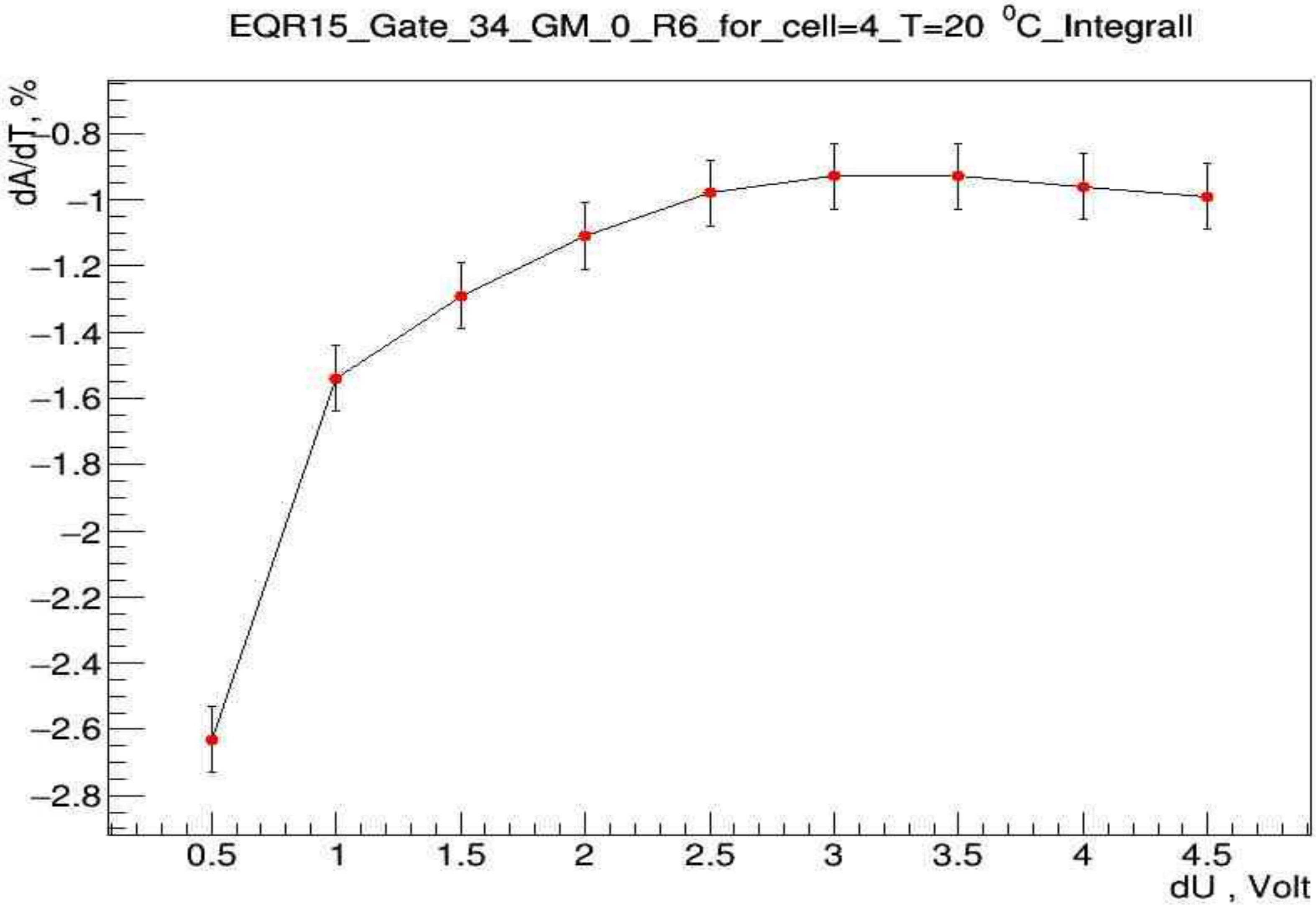




EQR-20-11-6060   kT vs dU = dA/dT / dA/dU

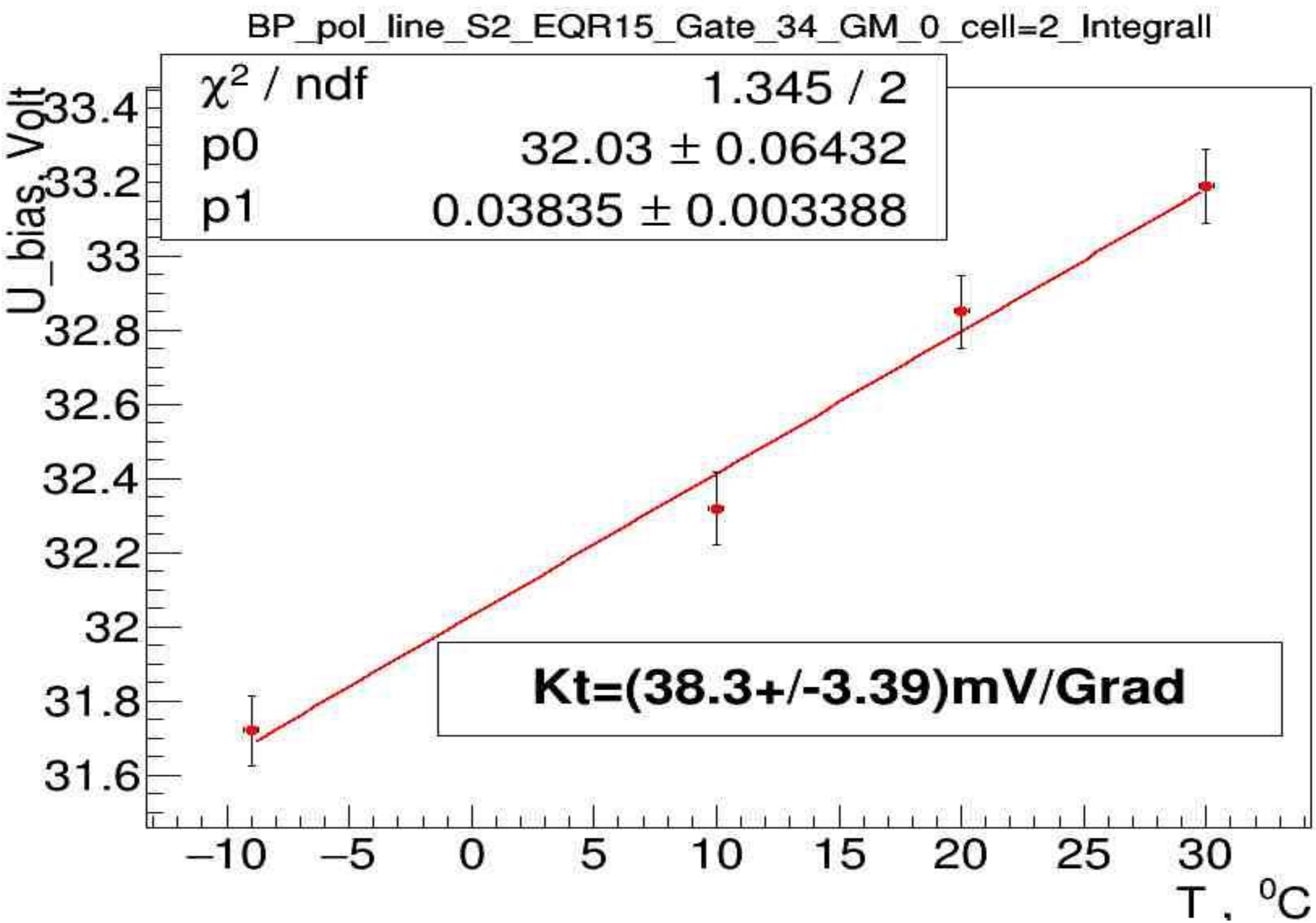


EQR-20-11-6060 dA/dT % vd dU

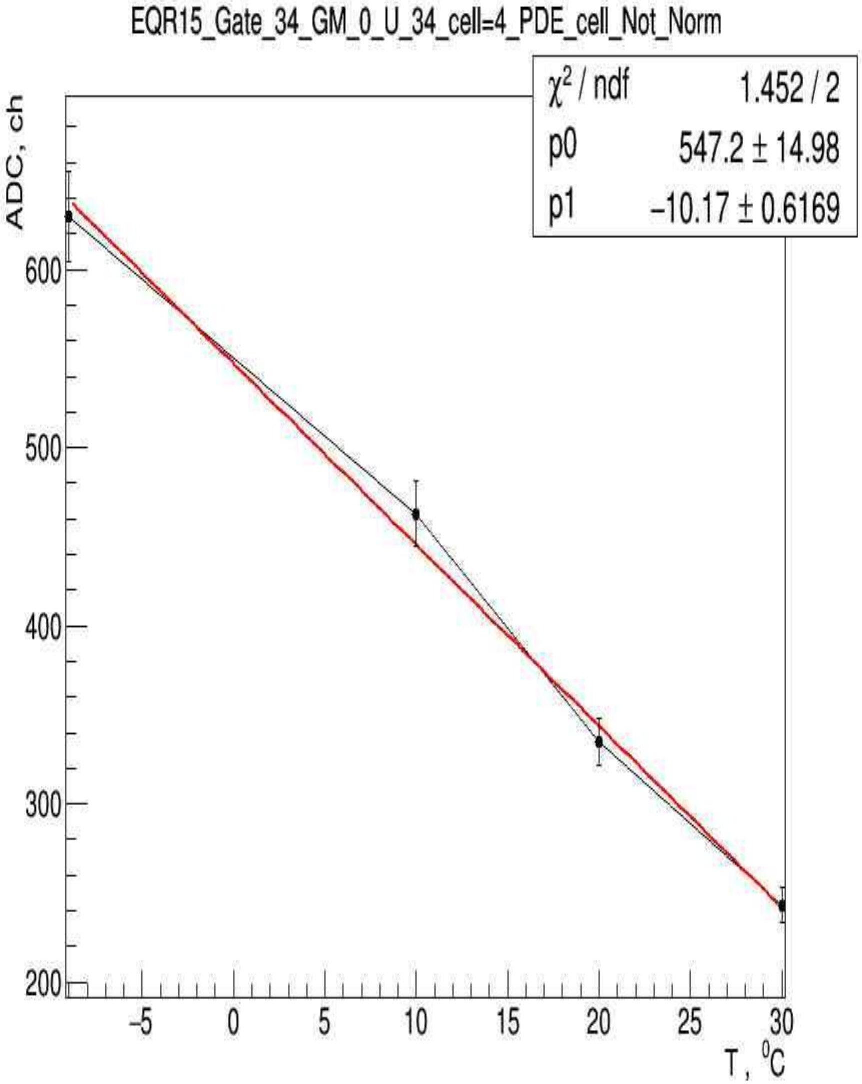


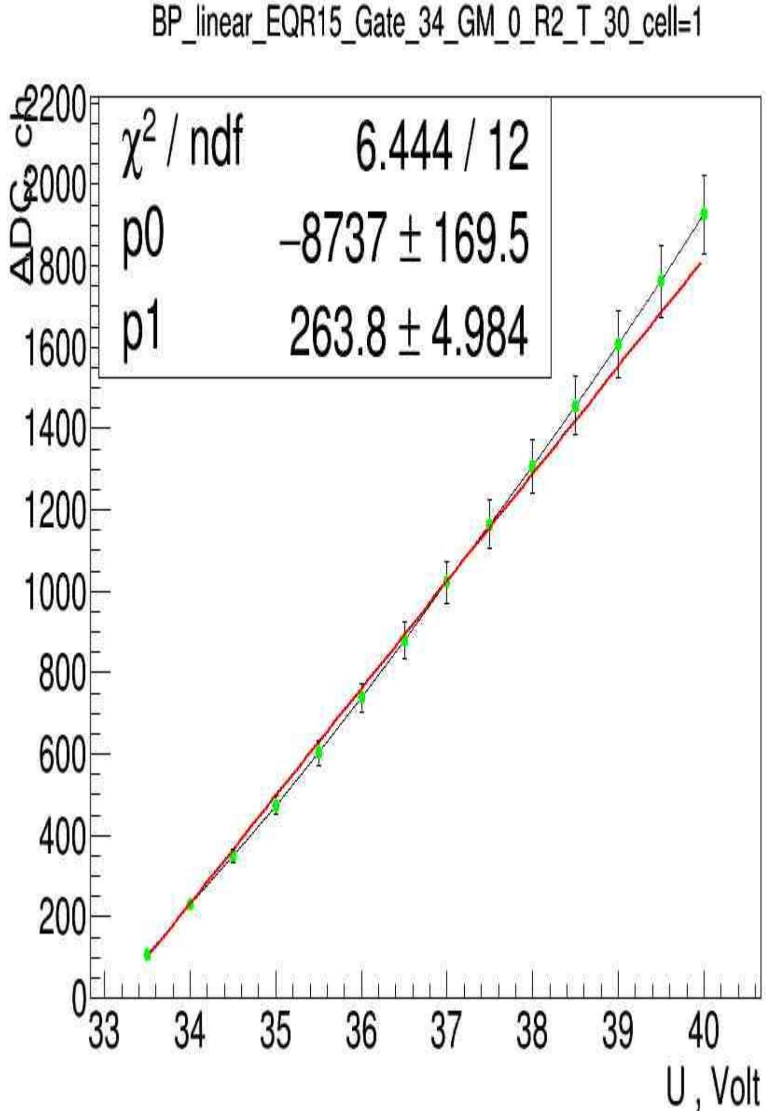
EQR15

EQR-15-11-6060 Ubp vs T

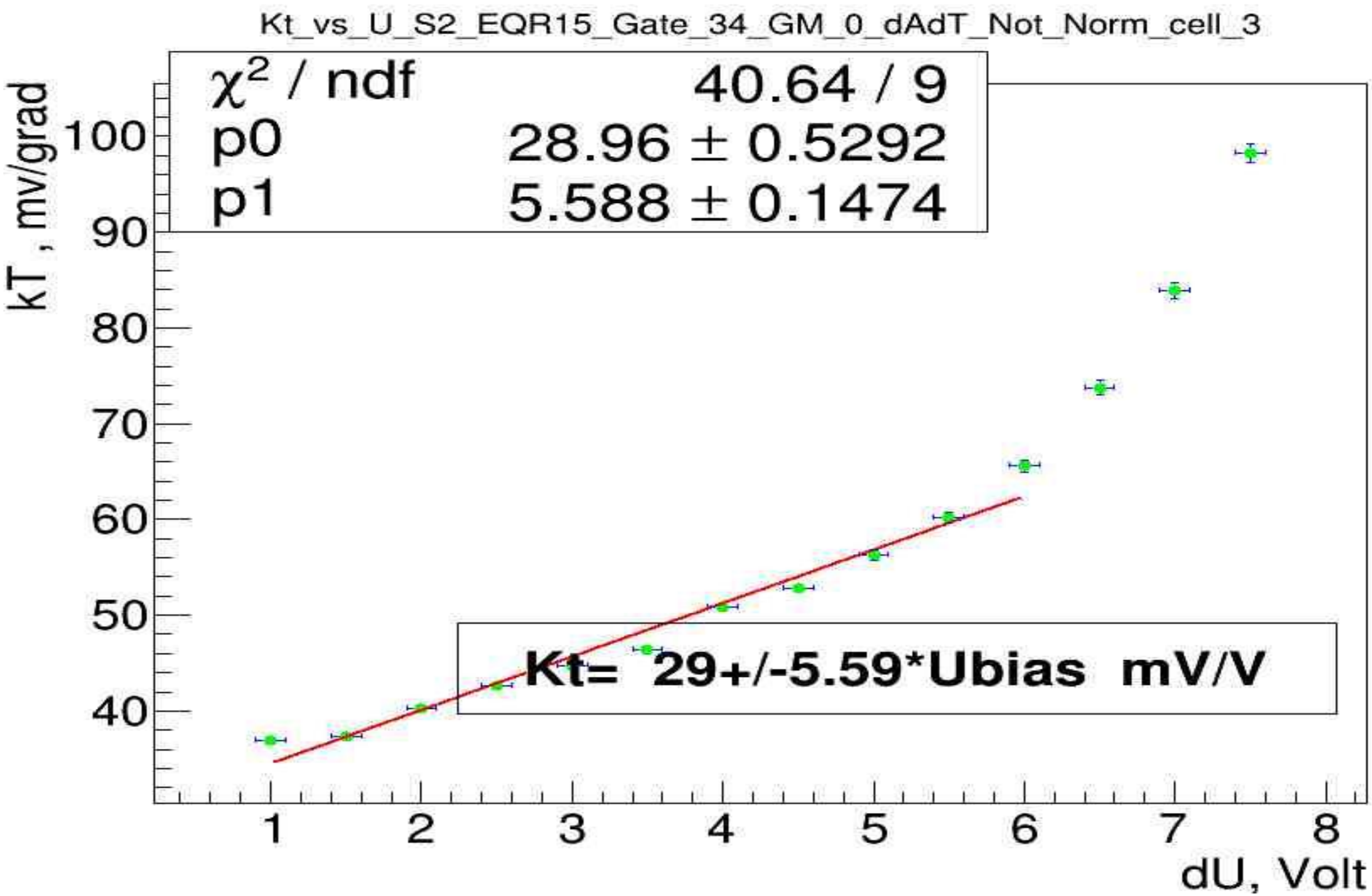


EQR-15-11-6060 dA/dT and dA/dU

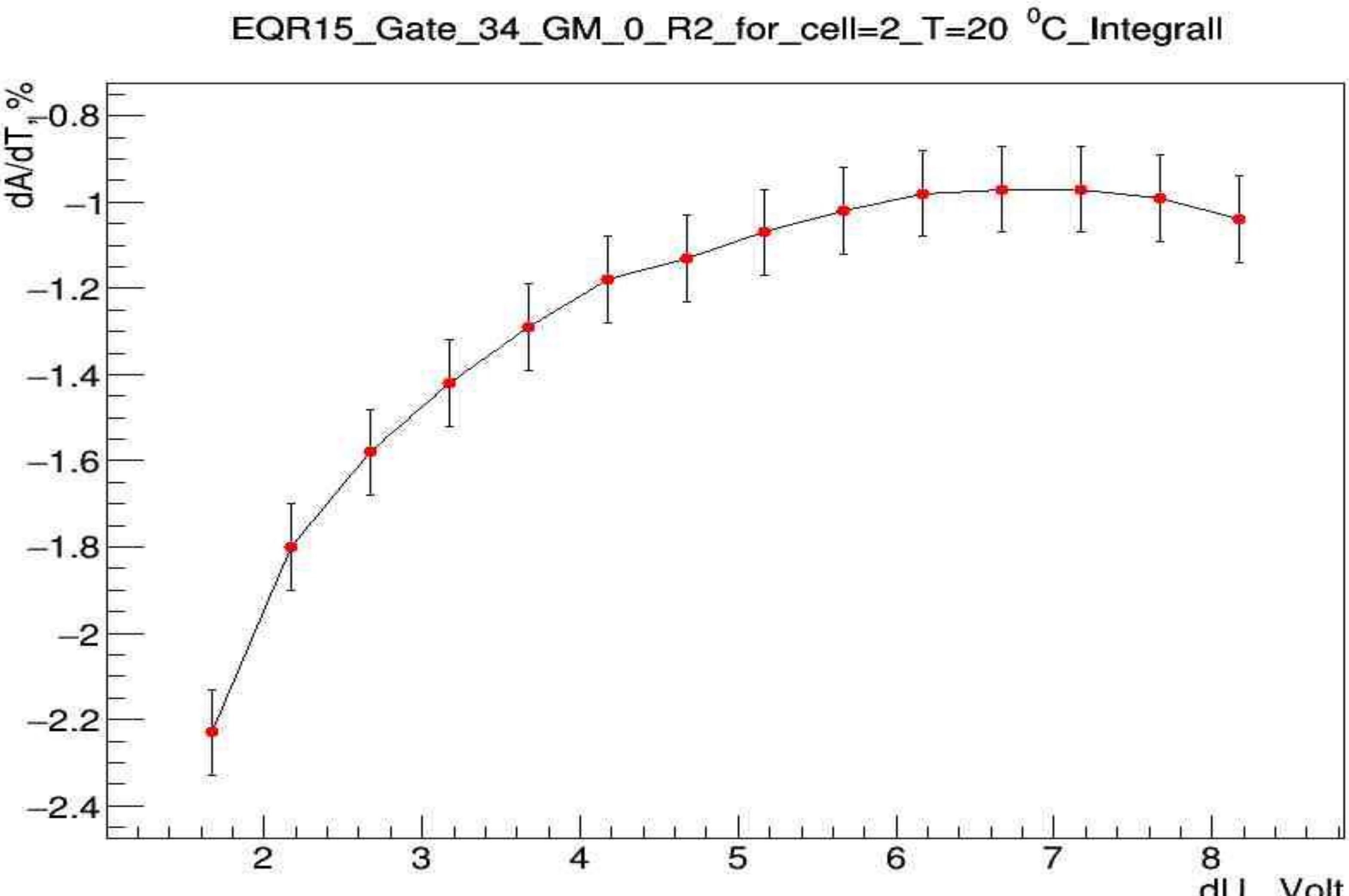




EQR-15-11-6060 kT vs dU = dA/dT / dA/dU



EQR-15-11-6060 dA/dT % vd dU



And of report
Thanks All for attention