MPPC for calorimetry application

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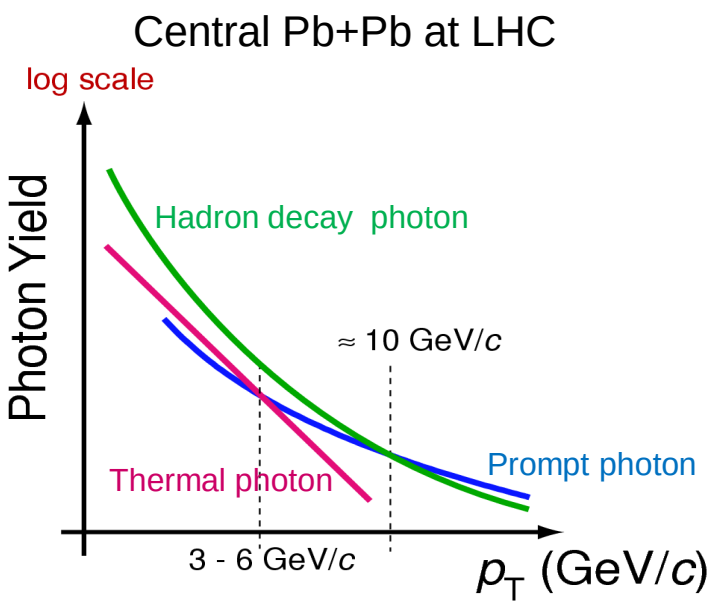
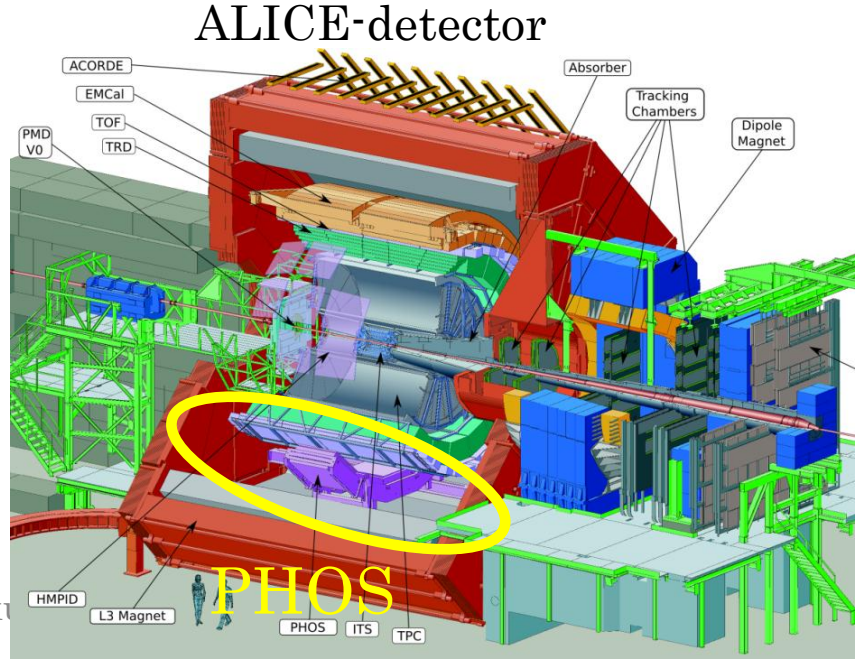
Photon measurement with Calorimeter

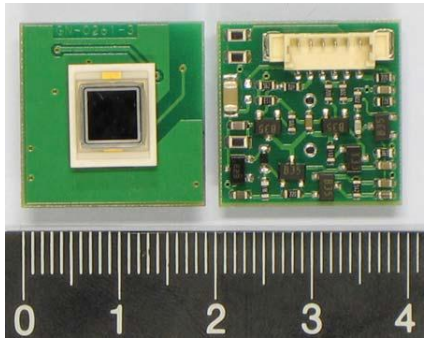
- Physics goal of photon measurement
  - Test of pQCD (Neutral meson @ high pT)
  - Temperature of QGP (Thermal photon @ low pT)
- Advantages of photon measurement
  - Direct probe (without strong interaction)
- Calorimeter for photon measurement
  - cf.) PHOS @ ALICE





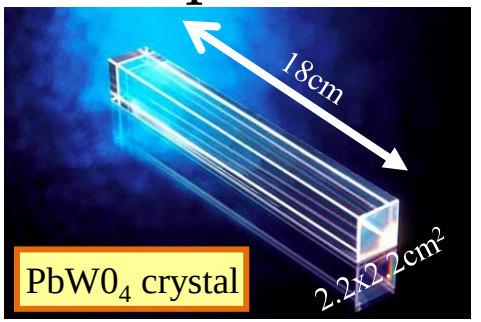
PHOS (PHOton Spectrometer)

- PHOS
  - $PbWO_4$ crystal and APD readout
  - Excellent energy resolution : 3%@1GeV
  - Best two-particles separation at LHC

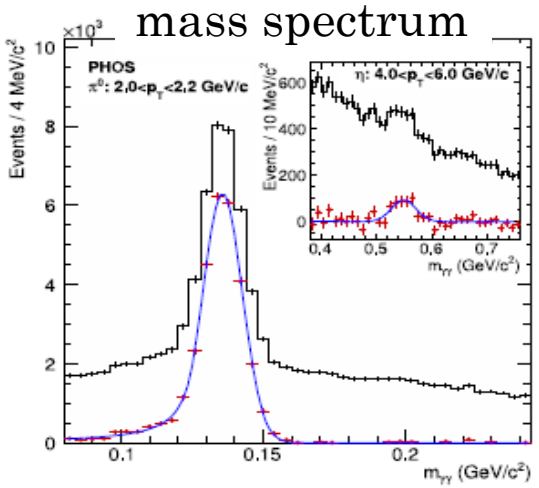


APD & preamplifier

- For precise photon measurement, especially at low pT
  - Hadron rejection (e.g. anti-neutron) is important.
  - Good timing resolution (σ < 1ns) is required.



→ <u>MPPC is a good candidate.</u>



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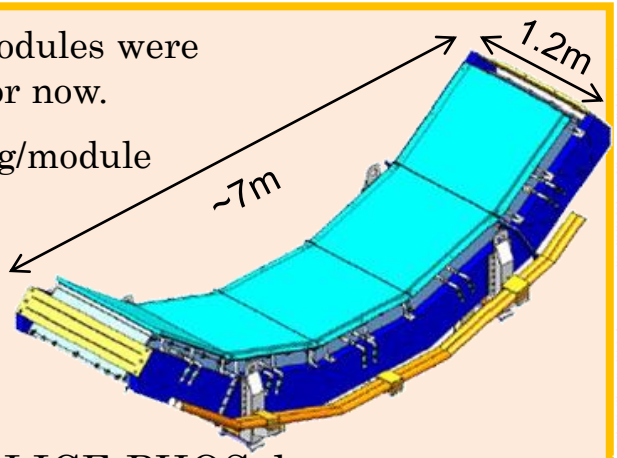
3 PHOS modules were installed for now.

$\Delta\varphi$ = 20 deg/module

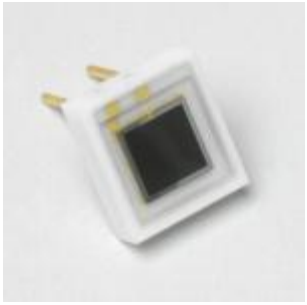
$|\eta| < 0.12$



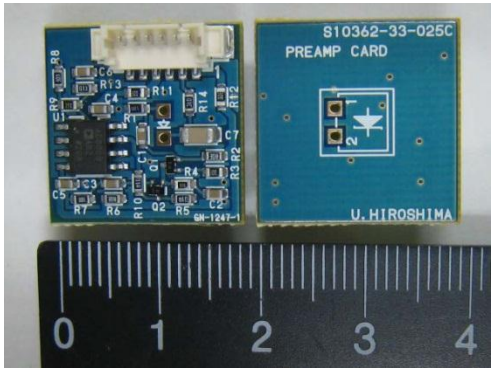
<u>ALICE-PHOS detector</u>

MPPC(Multi-Pixel Photon Counter)

- What's MPPC ?
  - Single photon sensitive device
  - A large number of Geiger-mode APDs
  - High gain of 10^5 – 10^6
  - High photon detection efficiency for blue and green lights
  - Operable in magnetic field



MPPC
Hamamatsu Photonics K.K.
model : S10362-33-025C
14400 pixels per 3 × 3 mm^2
1 pixel is 25 × 25 μm^2

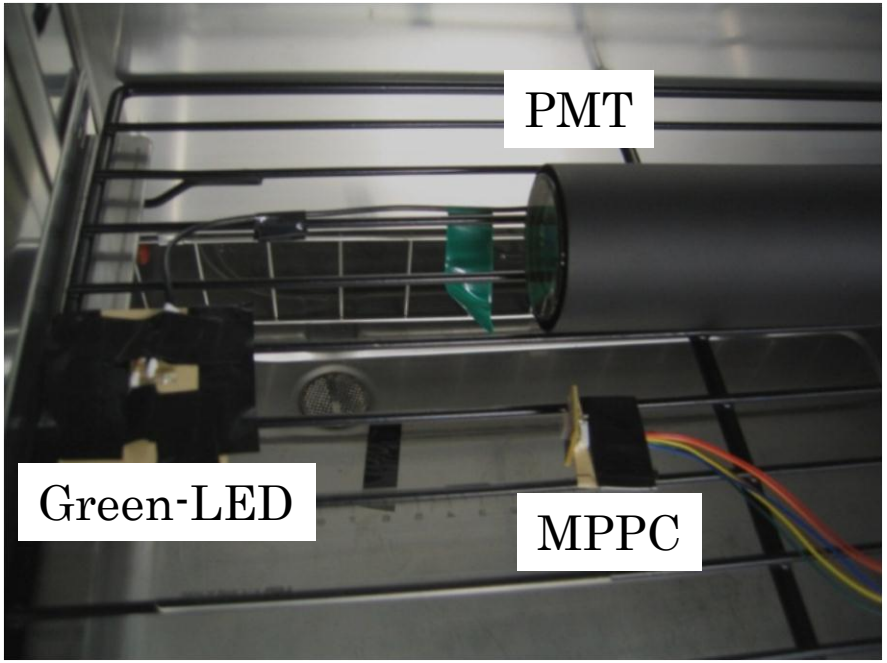


preamplifier

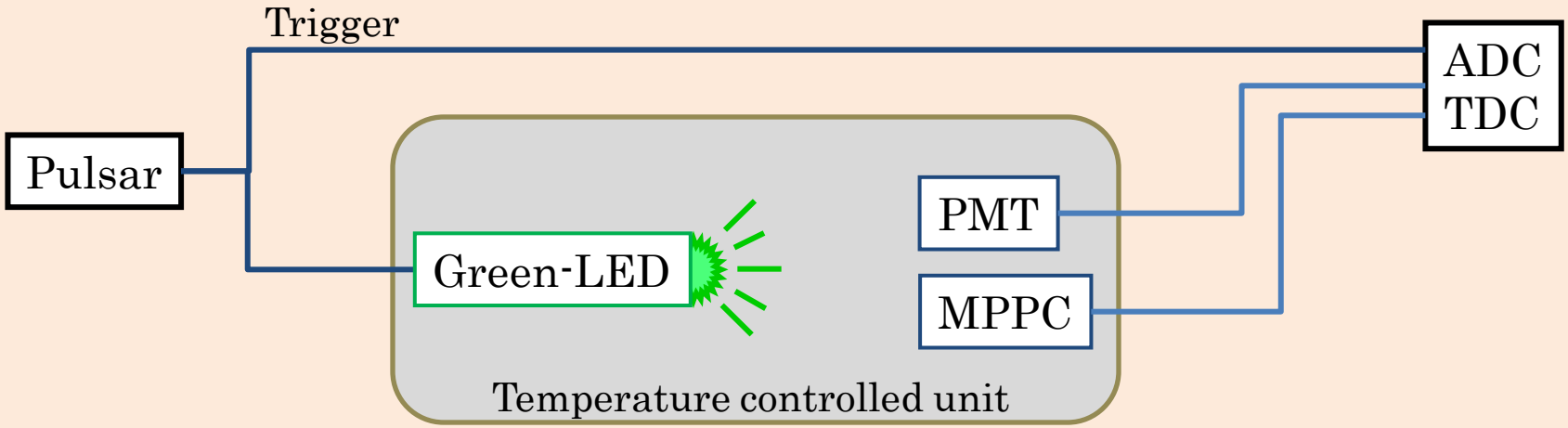
MPPC & preamplifier

Purpose & Setup

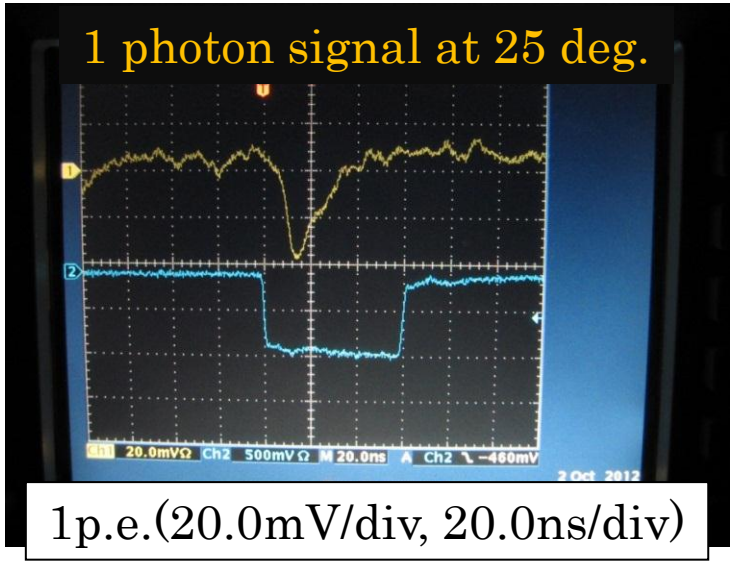
- Purpose
  - Gain and time response
  - Bias voltage dependence
  - Temperature dependence



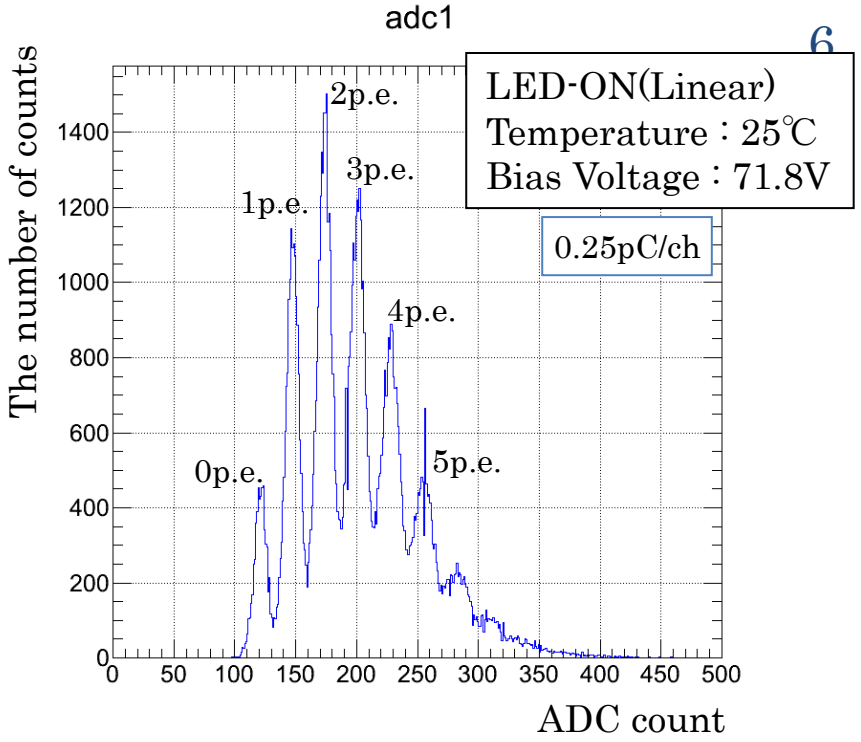
Experimental setup

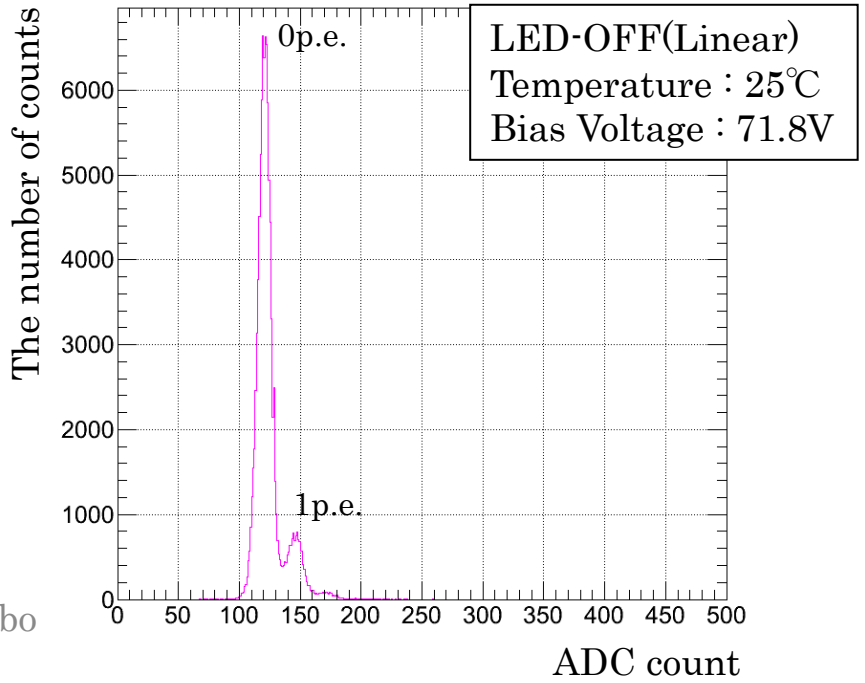


Single photon signal



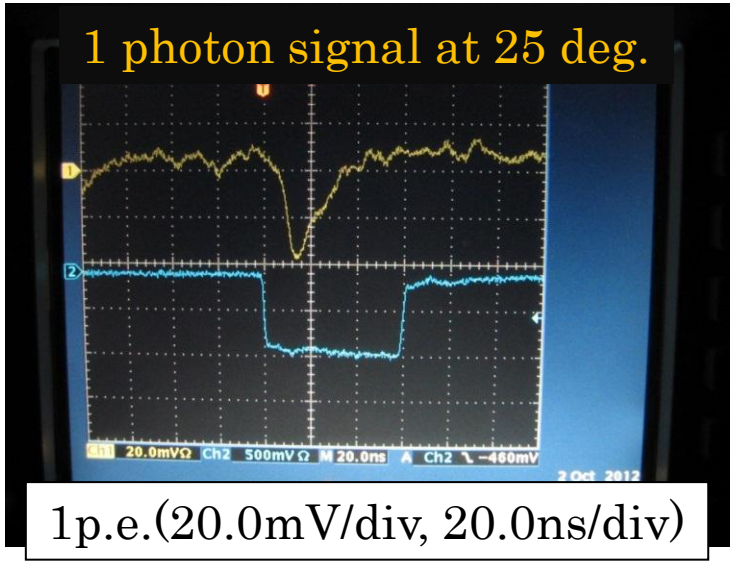
1p.e.(20.0mV/div, 20.0ns/div)



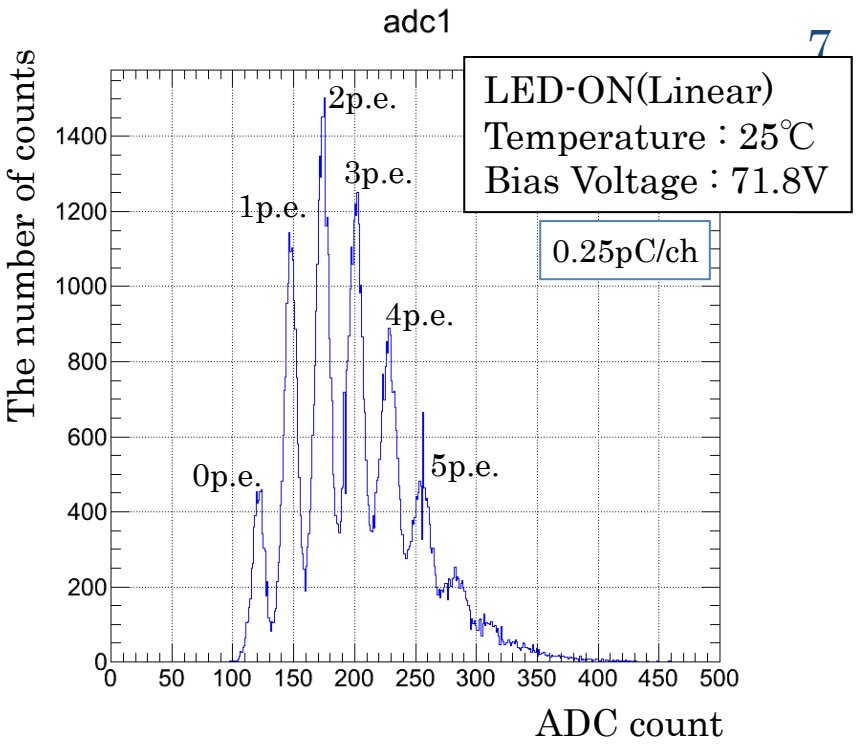


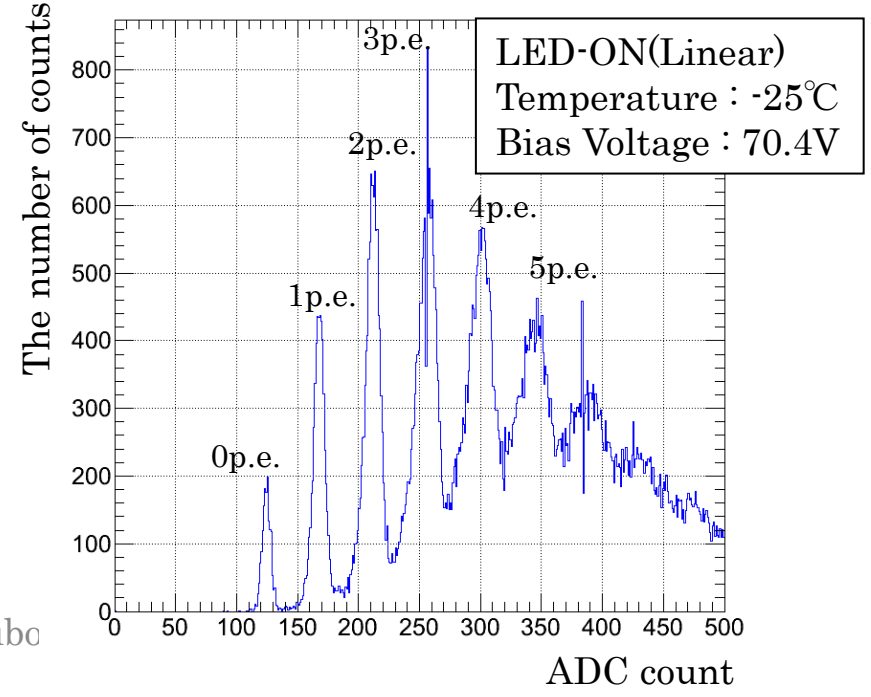
- LED-ON at 25 deg.
  - Single photon signal is clearly seen
  - Good separation of photon peaks.
- LED-OFF at 25 deg.
  - 0 p.e. peak is confirmed by LED-OFF data.
  - 1 p.e. peak is caused by dark count.

Single photon signal



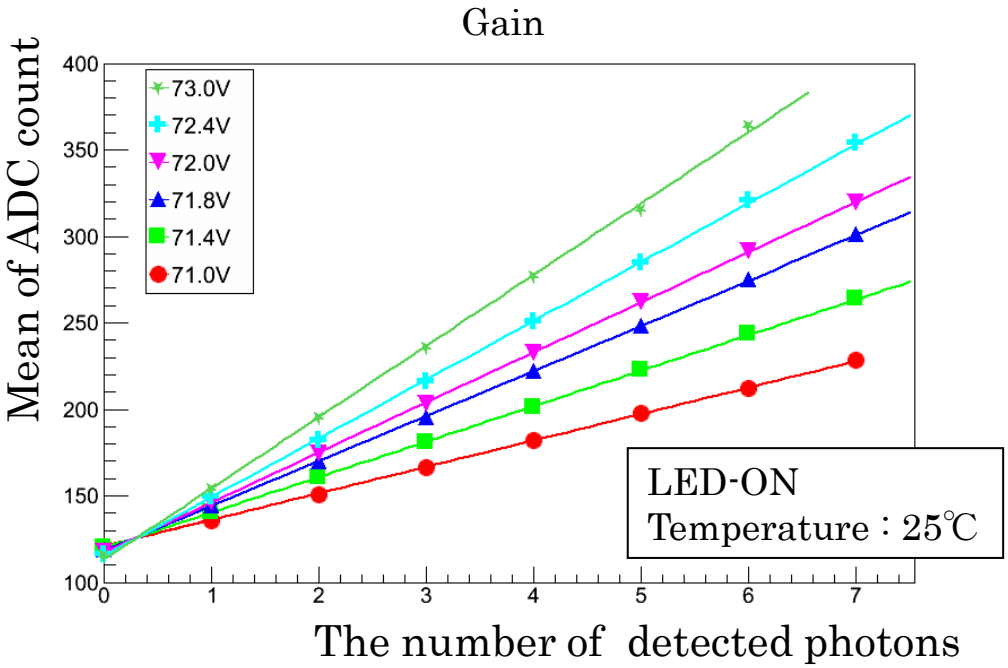
1p.e.(20.0mV/div, 20.0ns/div)

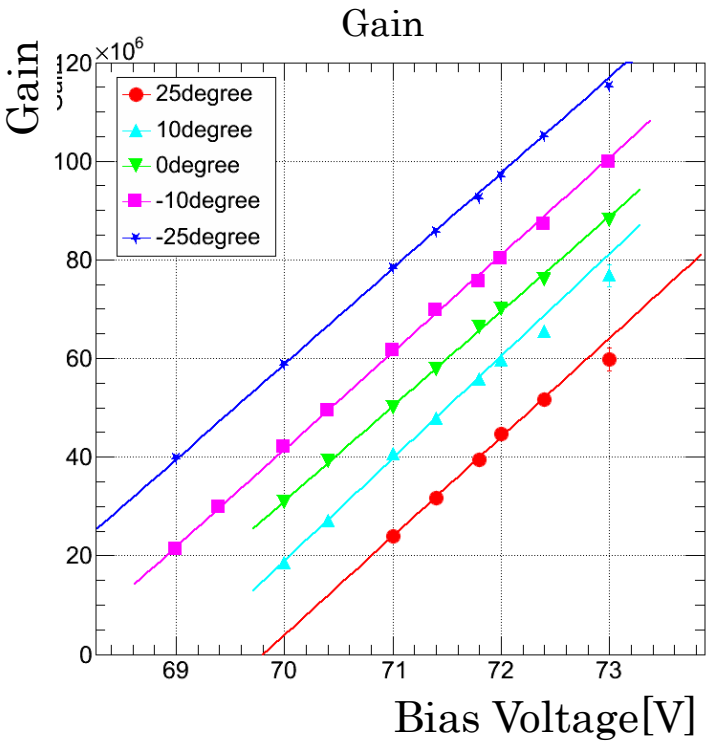




Single photon detection and good separation of photon peaks are successful between –25 and 25 degrees Celsius.

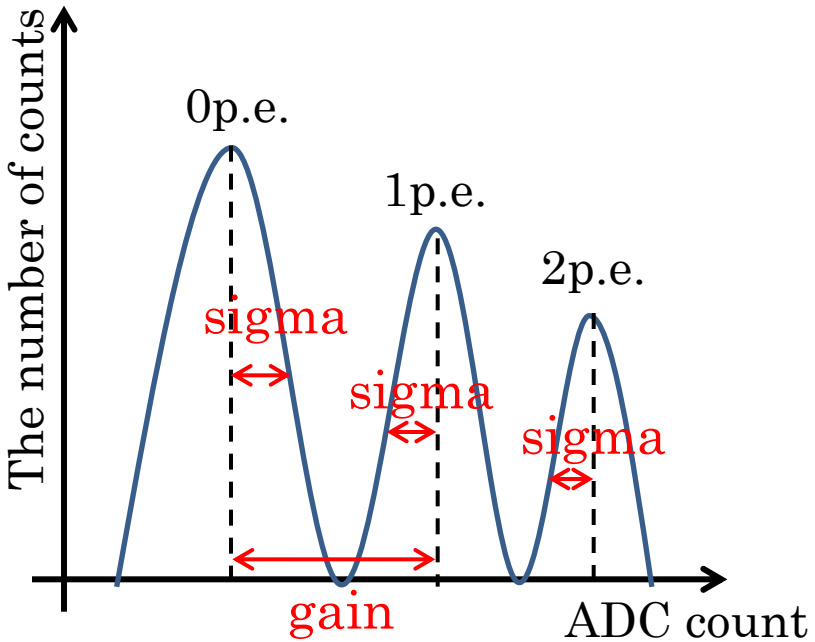
Gain ~Bias voltage & Temperature dependence~



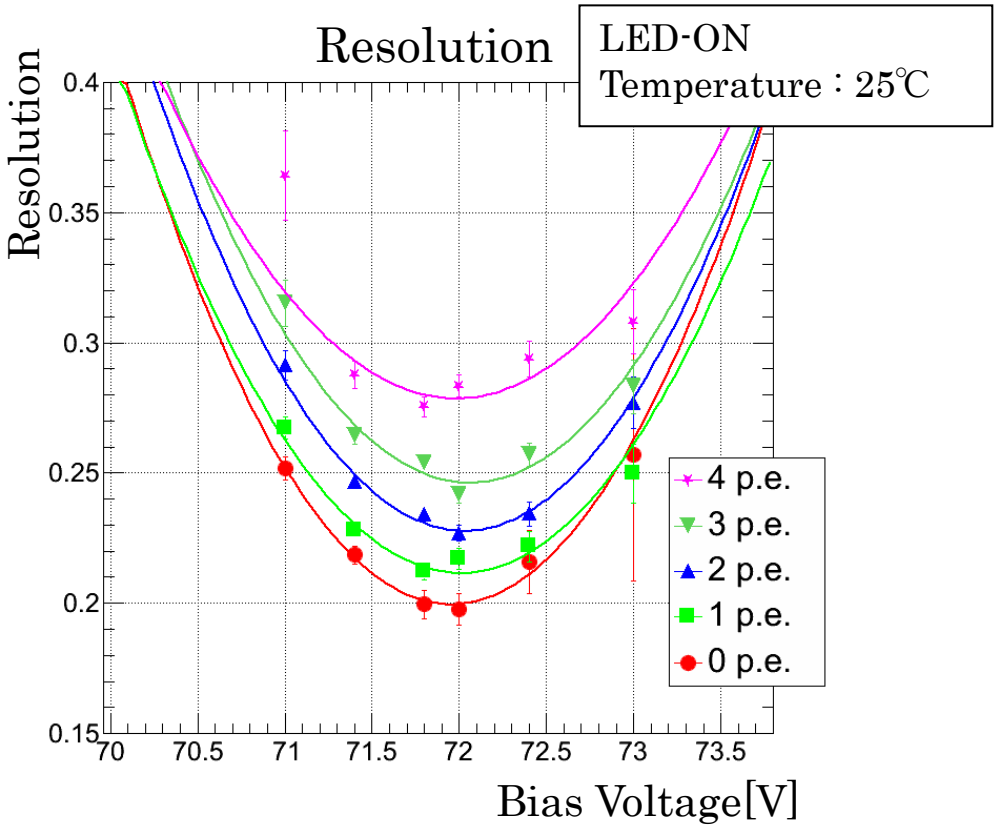


- Operation of MPPC is under control.
  - Output signals proportional to number of photons
  - Larger gain coefficients as higher bias voltage
  - Gain becomes higher as temperature goes down.

Resolution



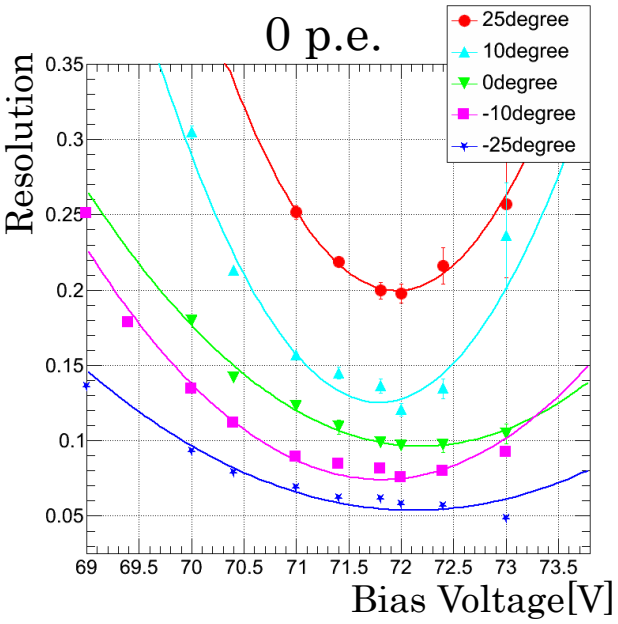
$$\text{Resolution} \equiv \frac{\text{sigma}}{\text{gain}} \text{ [p.e.]}$$



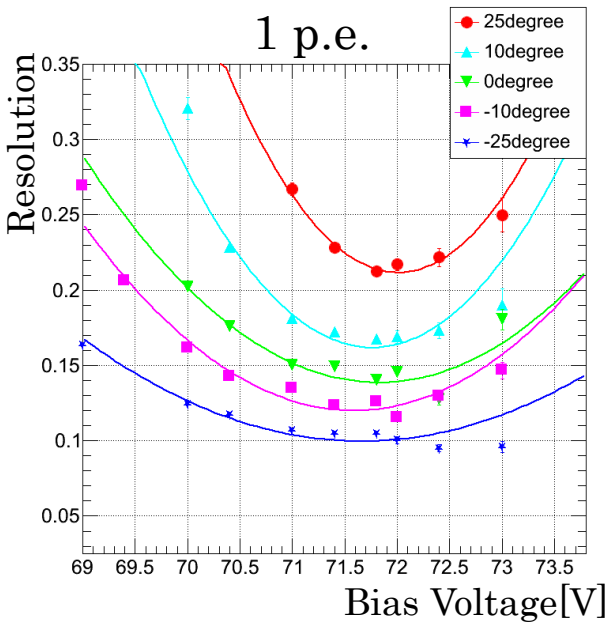
- Resolutions are derived from each photon peak.
- The optimized voltage is at the local minimal value of resolution.

Resolution ~Temperature dependence~

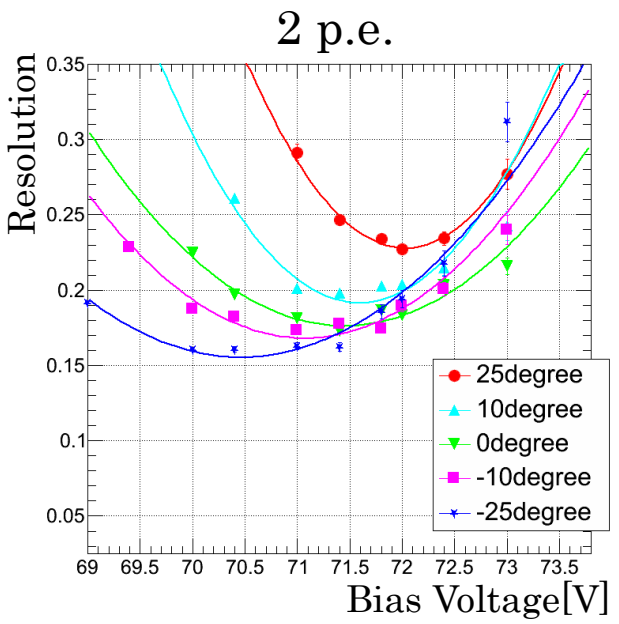
Noise
0 p.e.



Signal & dark count
1 p.e.

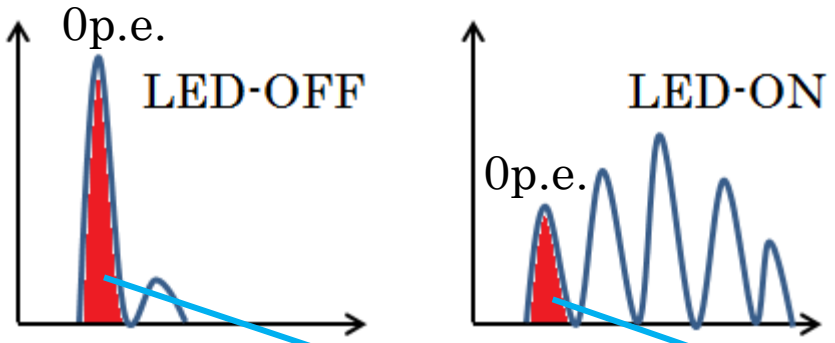


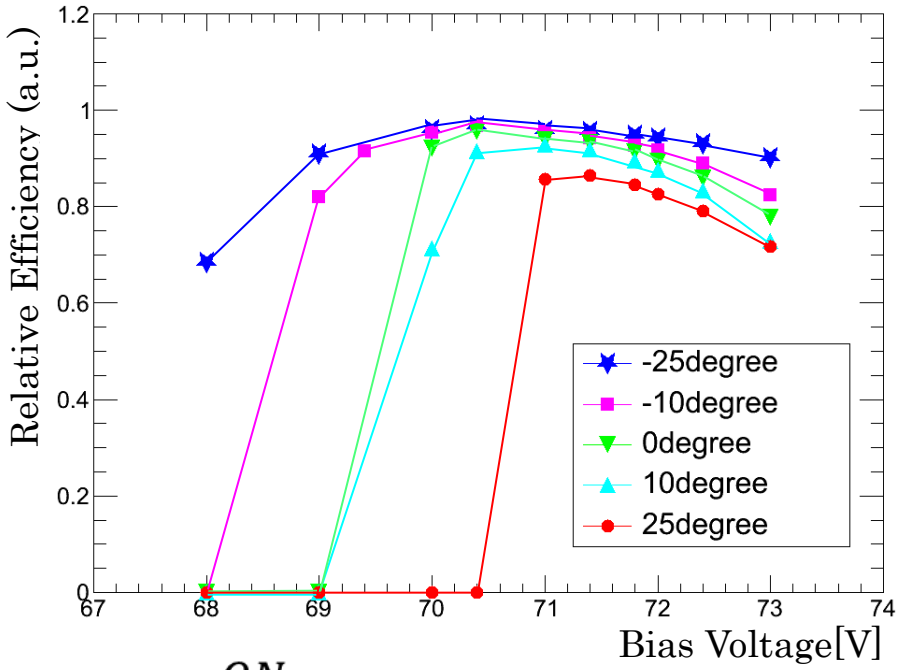
Signal & a few dark count
2 p.e.



- Better resolution at lower temperature.
- The best operational voltage goes down with decreasing temperature.

Relative efficiency



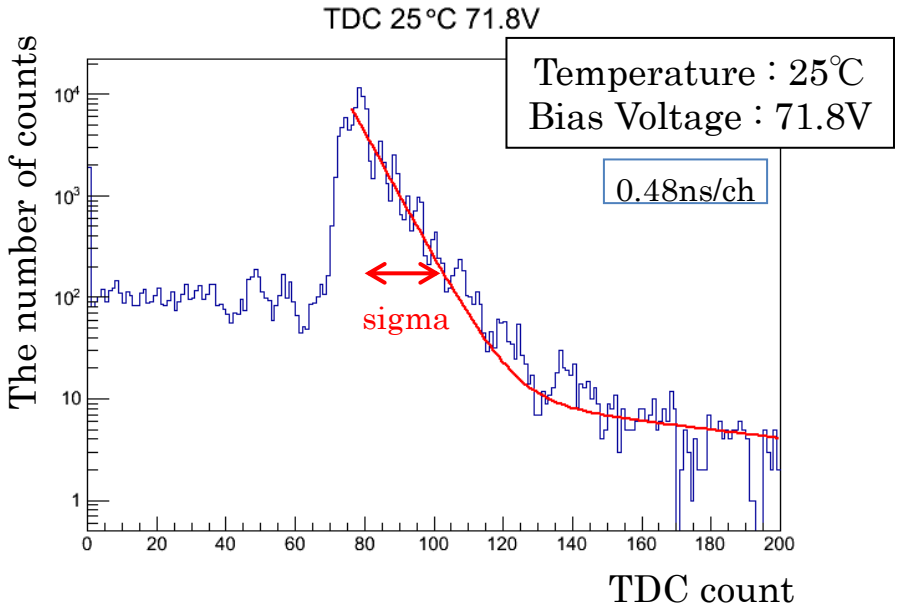


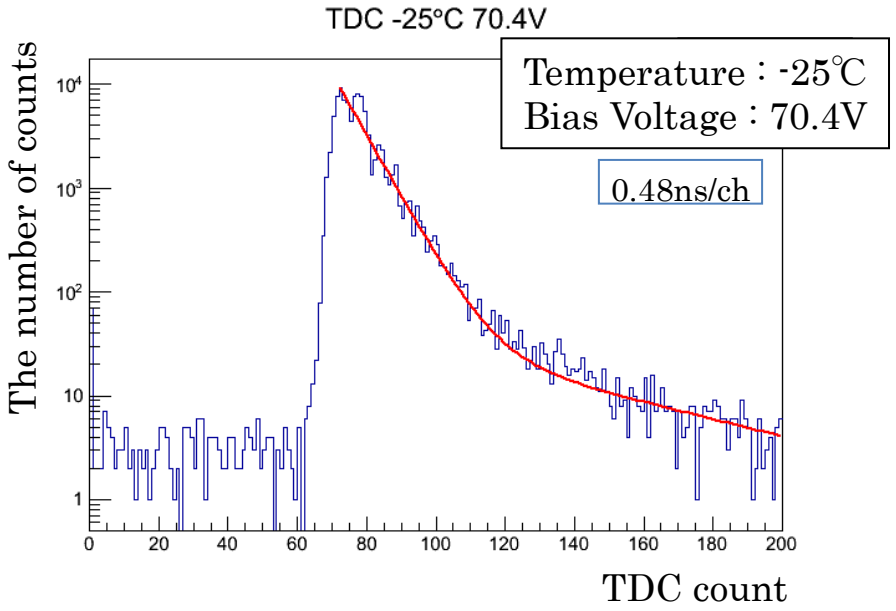
$$\text{Relative Efficiency} \equiv \frac{0p.e.yield^{OFF} - 0p.e.yield^{ON}}{all\ entries}$$

- MPPC detects photons at above a threshold bias voltage.
- The threshold voltages are lower at lower temperatures.
- The relative efficiencies are higher at lower temperatures.
- The relative efficiencies drop at over-voltages.

Timing distribution

LED time jitter : 0.8ns





- Timing distribution between LED start and MPPC signal
- Resolution: 1.48 ± 0.02ns @ 25 deg.
  1.550 ± 0.002ns @ –25 deg.
- Temperature independent at a few photons

Outlook

- For calorimetry application
  - Assure linearity of MPPC for a large amount of photons
  - Measure timing resolution under realistic conditions
- In parallel…
  - Ongoing study by plastic scintillator with MPPC
  - Study with cosmic ray and RI source
- Next Step in January
  - MPPC with $PbWO_4$ crystal
  - Pico-second pulse laser as a input to crystal.

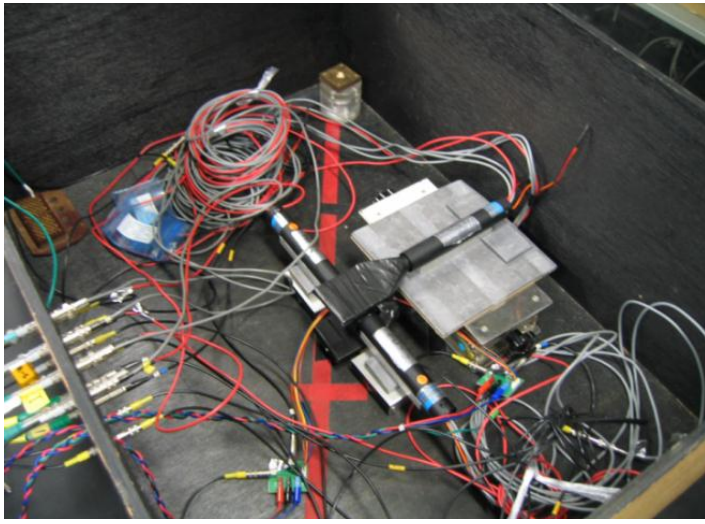
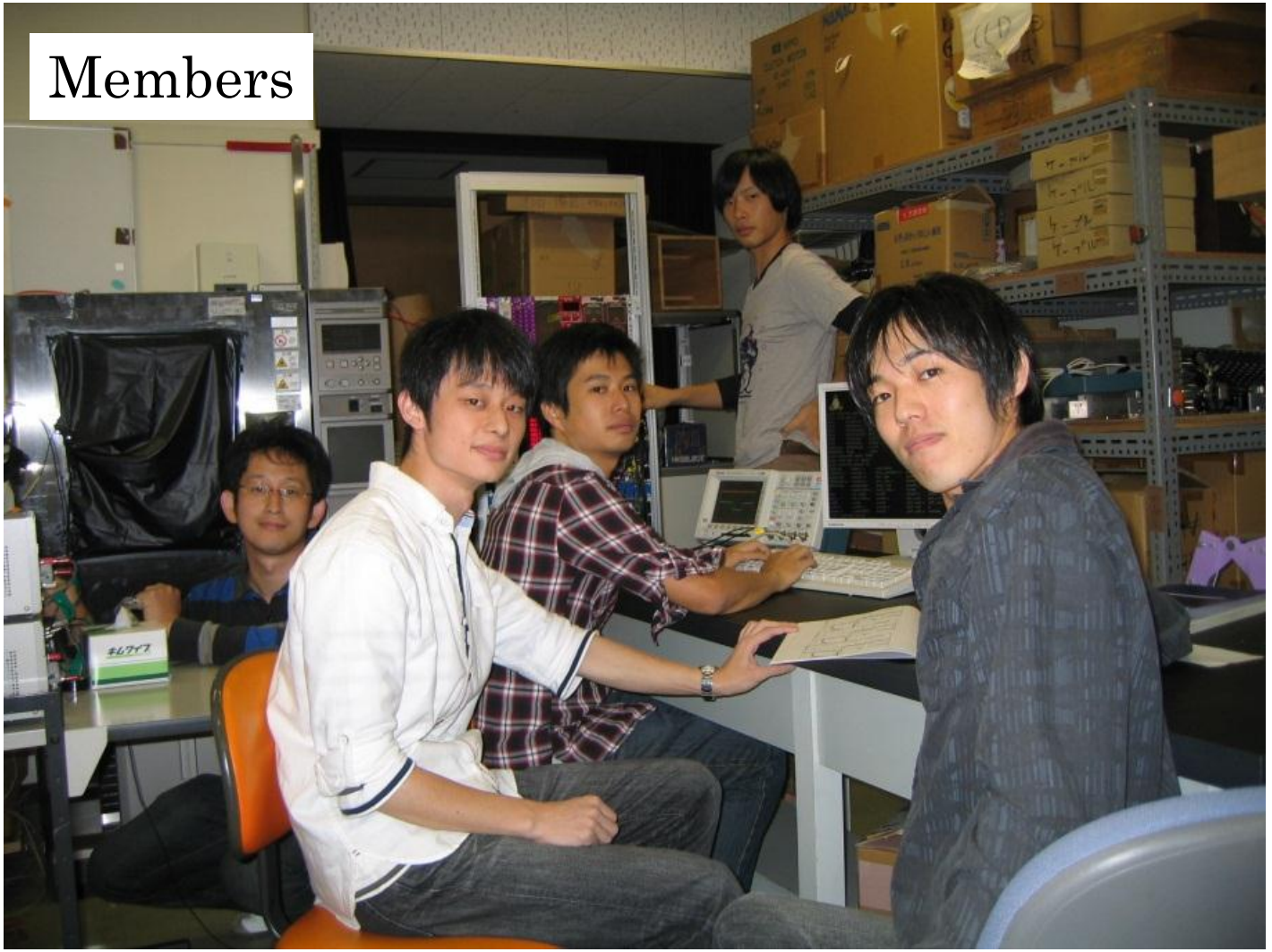


Photo : plastic scintillator with MPPC

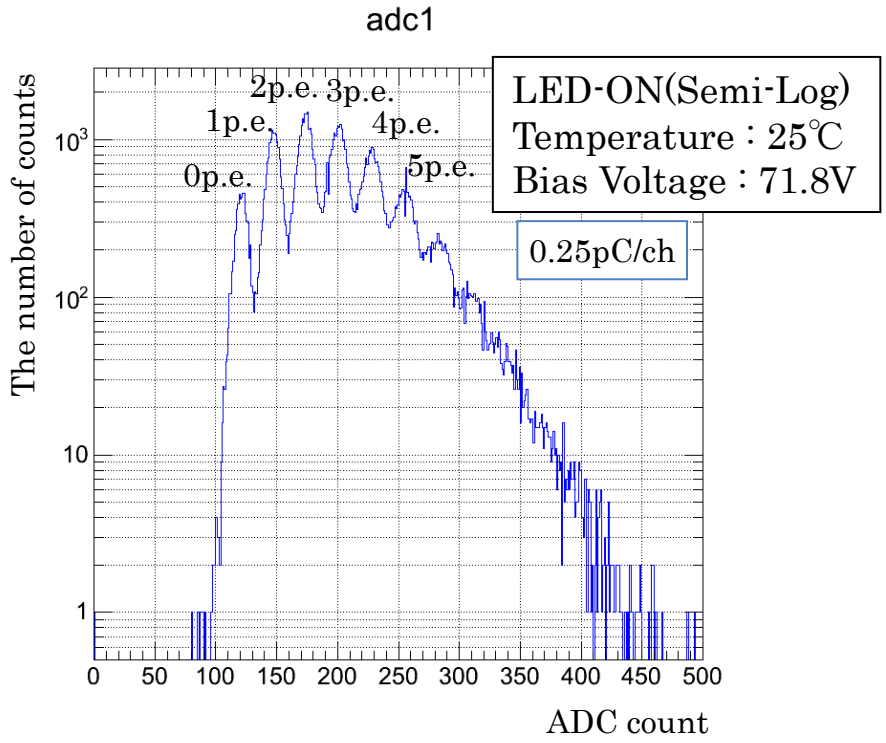
Summary & Conclusion

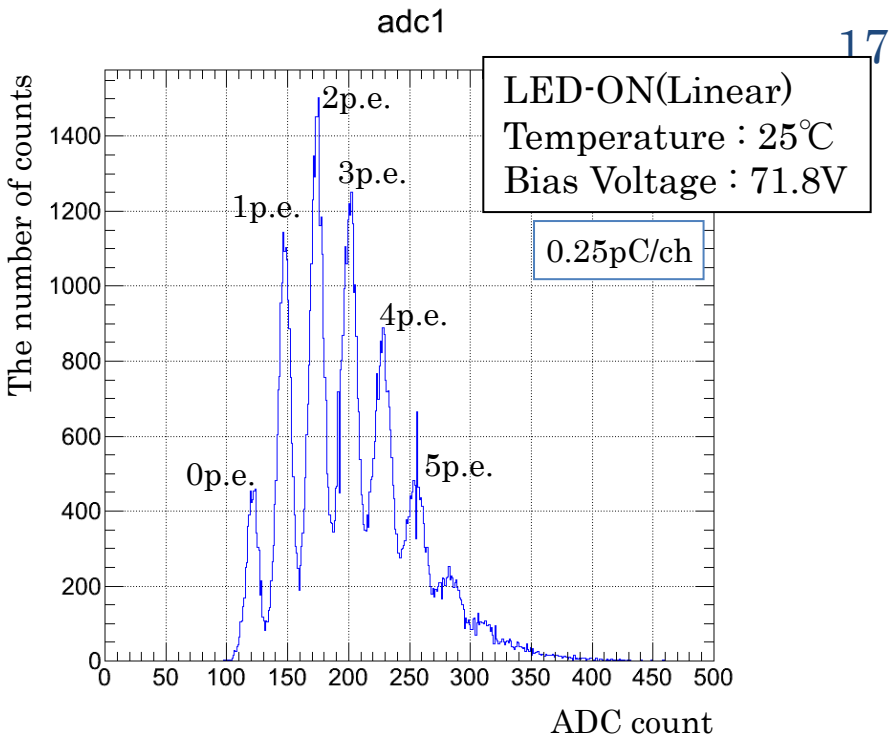
- MPPC is under control.
- Procedure to optimize bias voltage at a given temperature is established.
- Single photon detection and excellent separation of photon peaks are observed.
- Relative efficiency as a function of bias voltage and temperature are discussed.
- Timing response is under study at a few photons level.
- Study of MPPC with $PbWO_4$ crystal is planned in this January.

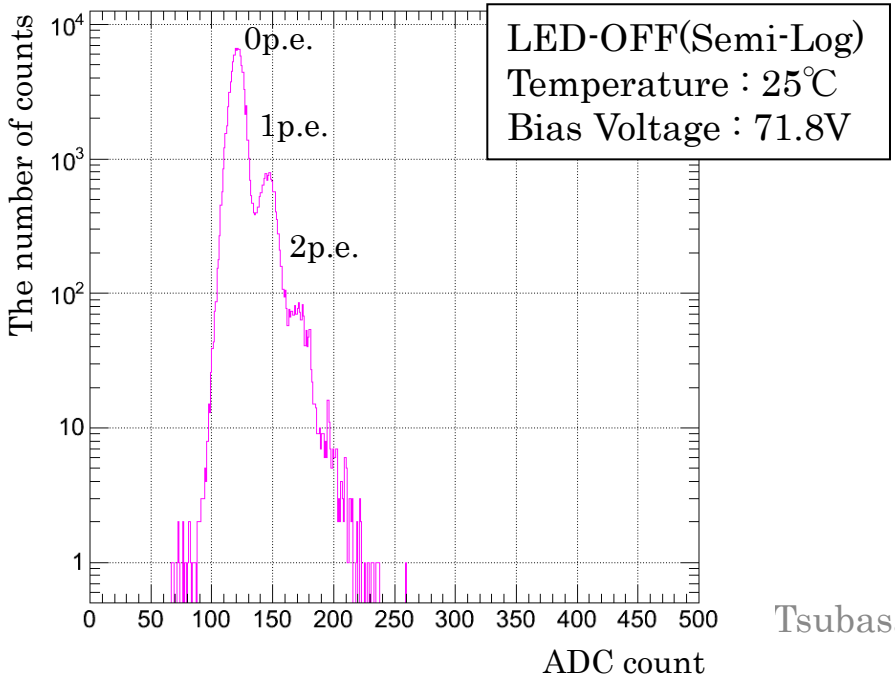


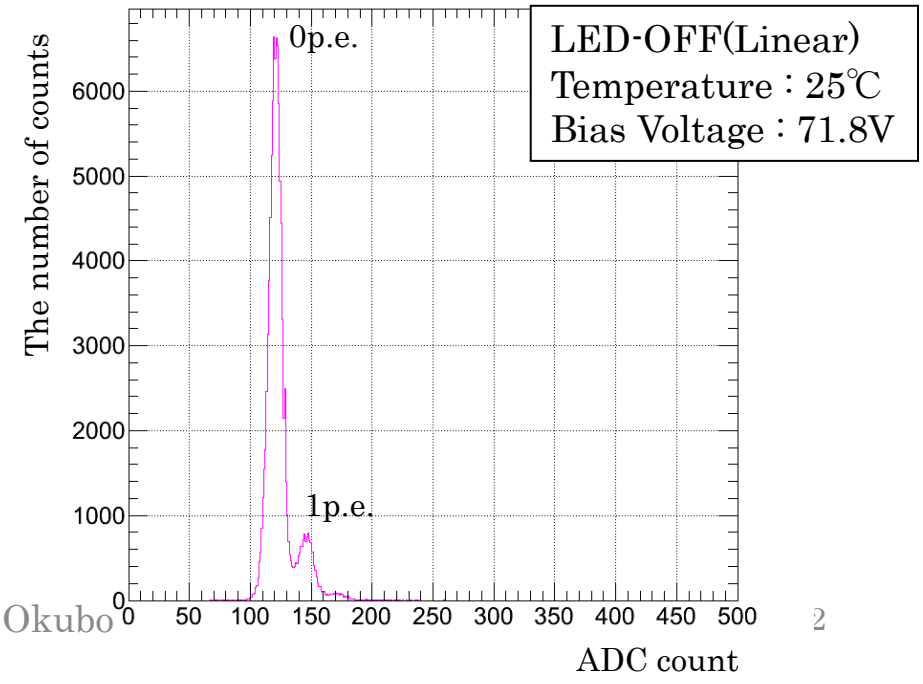
Thank you for your attention.

Back up

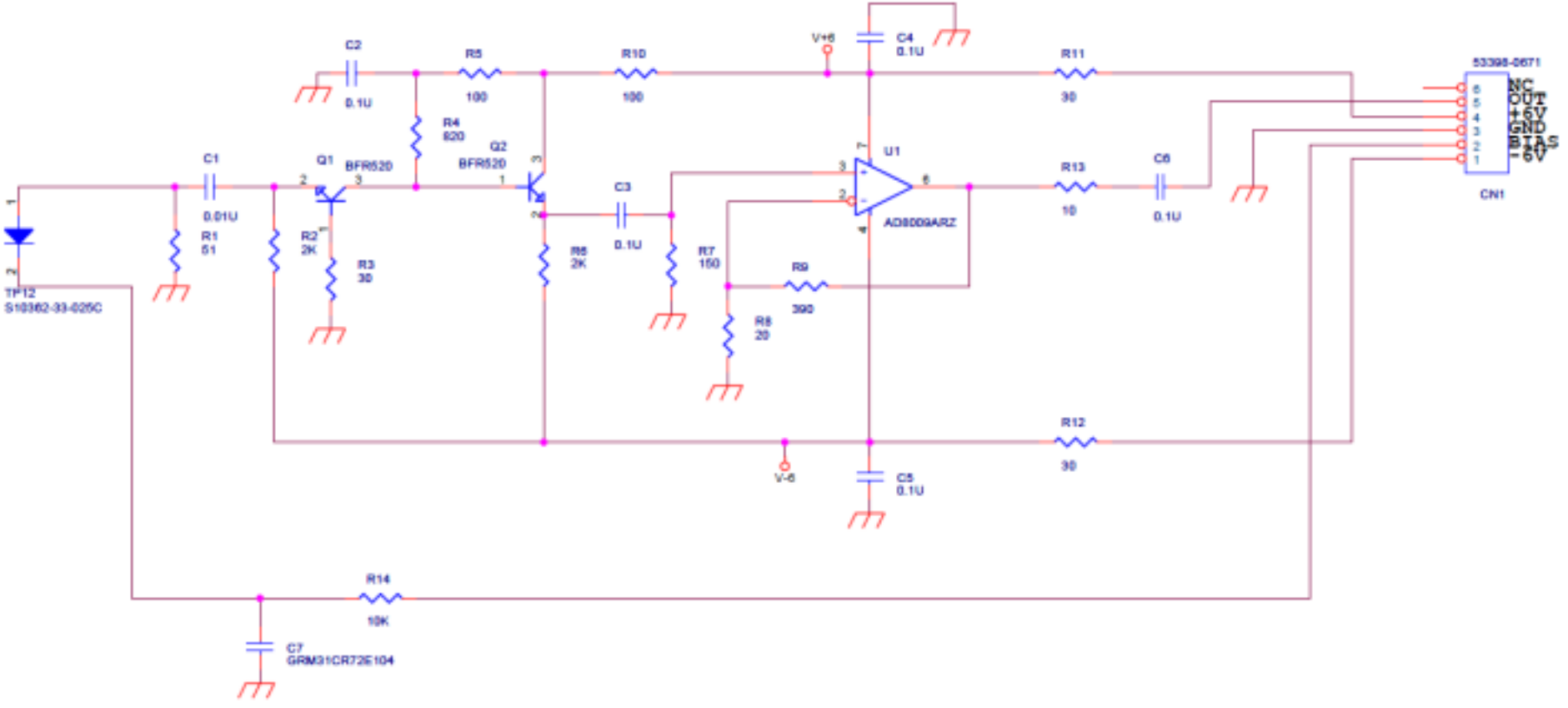

adc1
LED-ON(Semi-Log)
Temperature : 25℃
Bias Voltage : 71.8V
0.25pC/ch
0p.e.
1p.e.
2p.e.
3p.e.
4p.e.
5p.e.
The number of counts
ADC count


adc1
LED-ON(Linear)
Temperature : 25℃
Bias Voltage : 71.8V
0.25pC/ch
0p.e.
1p.e.
2p.e.
3p.e.
4p.e.
5p.e.
The number of counts
ADC count


LED-OFF(Semi-Log)
Temperature : 25℃
Bias Voltage : 71.8V
0p.e.
1p.e.
2p.e.
The number of counts
ADC count


LED-OFF(Linear)
Temperature : 25℃
Bias Voltage : 71.8V
0p.e.
1p.e.
The number of counts
ADC count

The circuit diagram of preamplifier



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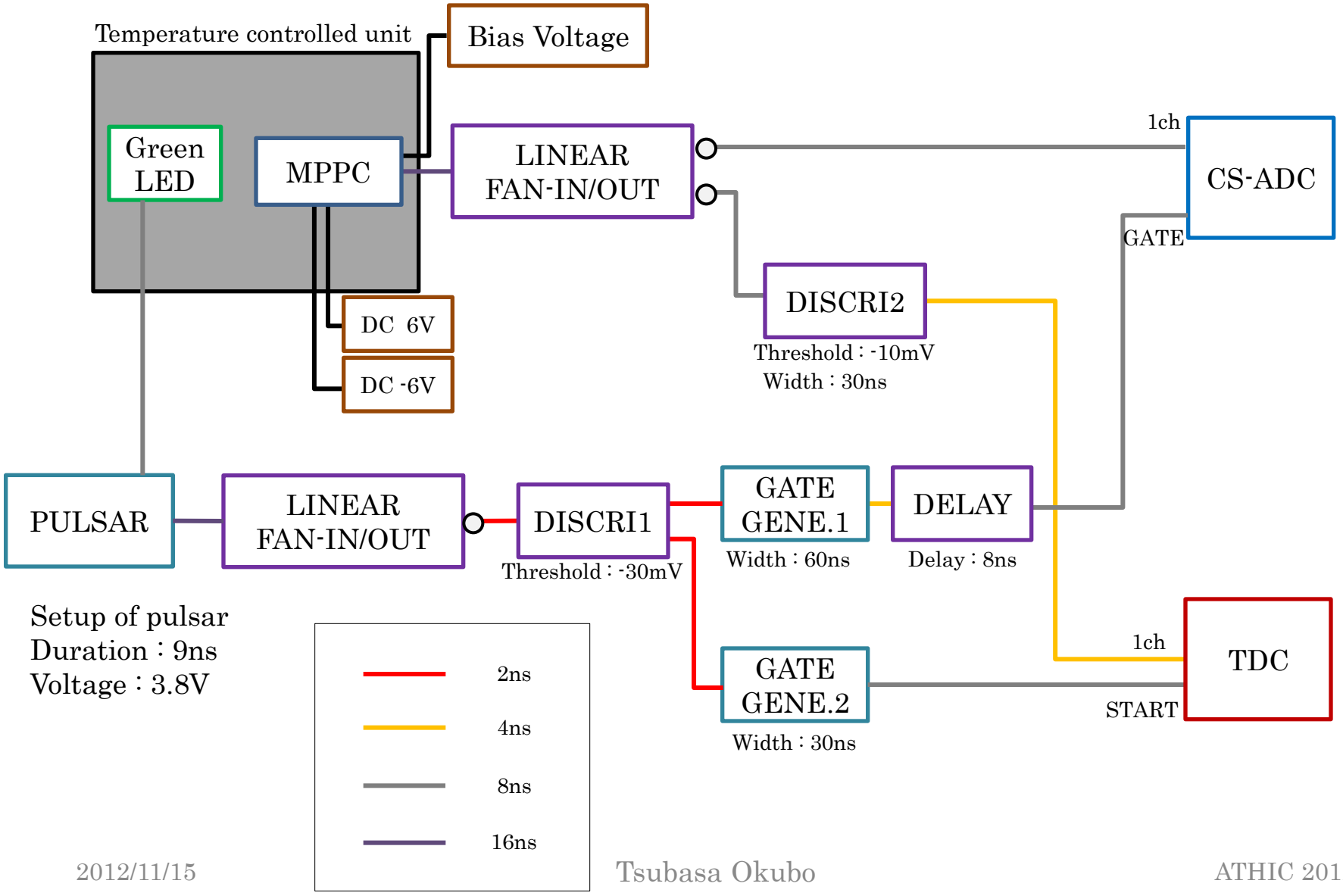
Title: MPPC Preamp		
Size: A4	Document Number: <Doc>	Rev: <RevCode>
Date: Wednesday, May 16, 2012	Sheet 1 of 1	

Readout diagram



MPPC spec

仕様 (指定のない場合はTyp. Ta=25 °C)

項目	記号	S10362-33シリーズ			S10931シリーズ			単位
		-025C	-050C	-100C	-025P	-050P	-100P	
有効受光面	-		3 × 3			3 × 3		mm
ピクセル数	-	14400	3600	900	14400	3600	900	-
ピクセルサイズ	-	25 × 25	50 × 50	100 × 100	25 × 25	50 × 50	100 × 100	μm
開口率 *1	-	30.8	61.5	78.5	30.8	61.5	78.5	%
感度波長範囲	λ		320 ～ 900			320 ～ 900		nm
最大感度波長	λp		440			440		nm
動作電圧範囲	-		70 ± 10 *2			70 ± 10 *2		V
ダークカウント *3	-	4	6	8	4	6	8	Mcps
ダークカウント Max. *3	-	8	10	12	8	10	12	Mcps
端子間容量	Ct		320			320		pF
時間分解能 (FWHM) *4	-		500 ～ 600			500 ～ 600		ps
逆電圧の温度係数	-		56			56		mV/°C
増倍率	M	2.75×10^5	7.5×10^5	2.4×10^6	2.75×10^5	7.5×10^5	2.4×10^6	-

*1: 1ピクセルの中で受光部の占める割合。
*2: それぞれの製品の推奨動作電圧については、製品に添付されたデータを参照してください。
*3: 0.5 p.e. (閾値レベル)
*4: シングルフォトンレベル
注) 各値は推奨動作電圧時における値です (製品に添付されたデータを参照してください)。
型名の最後の記号は、パッケージを表します (C: セラミック, P: SMD)。

LED intensity ~temperature dependence~