MPPC development

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Shinshu Univ. Hight Energy Physics Lab.

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Outline

- MPPC
- Motivation
- Measurements
  - Gain
  - IV
  - Noise
- Summary and Plan

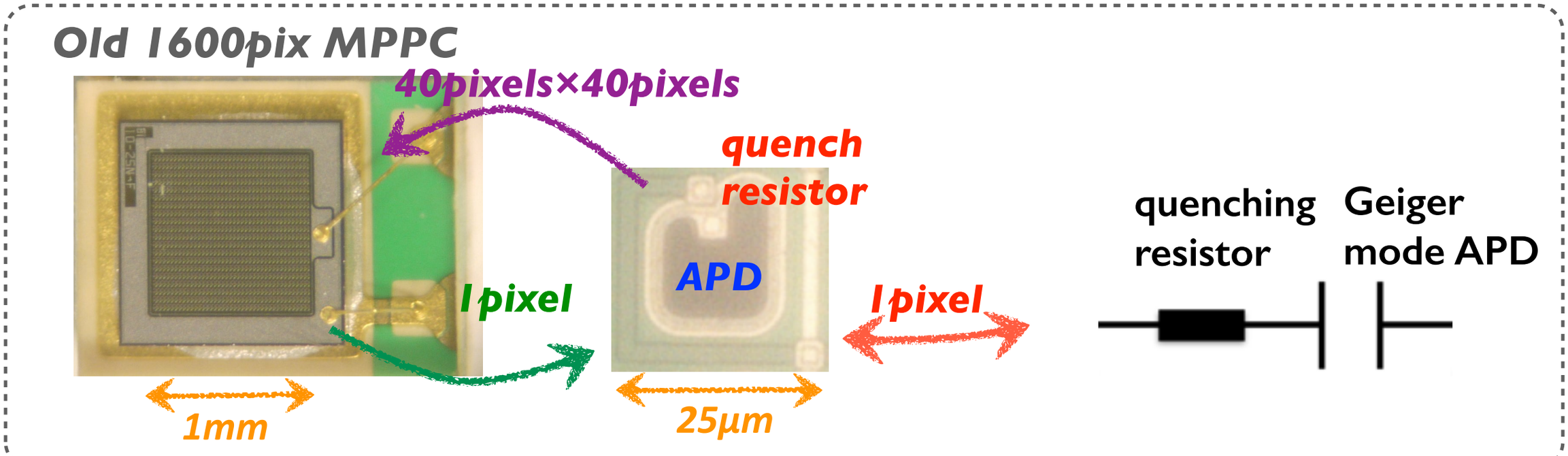
MPPC

The MPPC produced by Hamamatsu Photonics a is new type of photon-counting device made up of multiple APD(avalanche photodiode) pixels operated in Geiger mode.

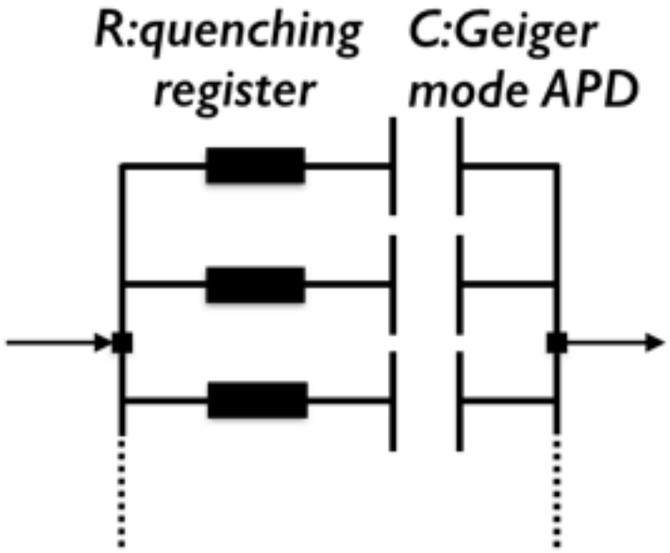
- Excellent photon-counting capability
- Low bias(~-70V) operation (cf. APD~-150V)
- High gain(10^5~10^6 cf. APD~10^2)
- Good photon detection efficiency
- Excellent timing resolution(~30ps)
- Insensitive to magnetic fields
- Room temperature operation
- Compact size(1mm×1mm)
- Low cost

So it delivers the high-performance level needed for photon counting.

MPPC structure

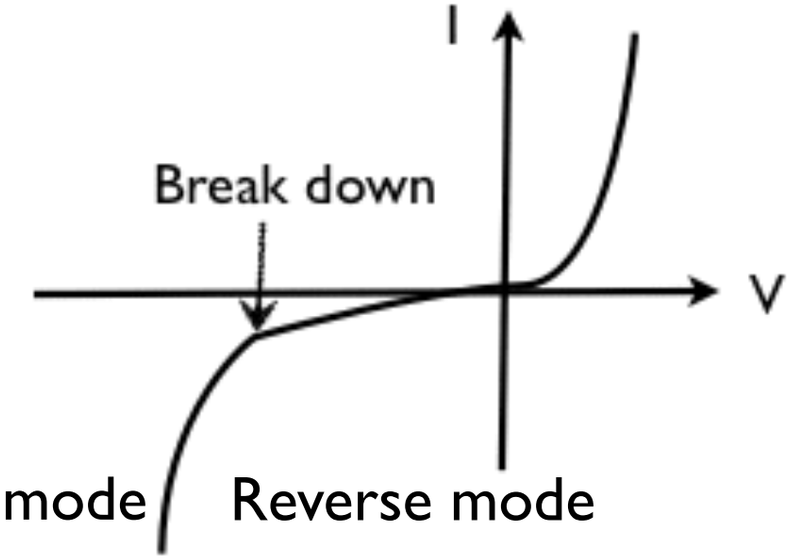


MPPC equivalent diagram



Geiger mode

-Operated slightly above breakdown voltage



Over Voltages = Operation Voltages - Break down Voltages

Motivation

- The MPPC has excellent performance for ILD Sc-ECAL
- The MPPC has some weak points for calorimetric use,

-Dynamic range

it is defined by number of pixels on a sensor.If the light yield is too strong comparing with the number of pixels, the response of MPPC is going to be saturated.

- We have required the developing for new types MPPC

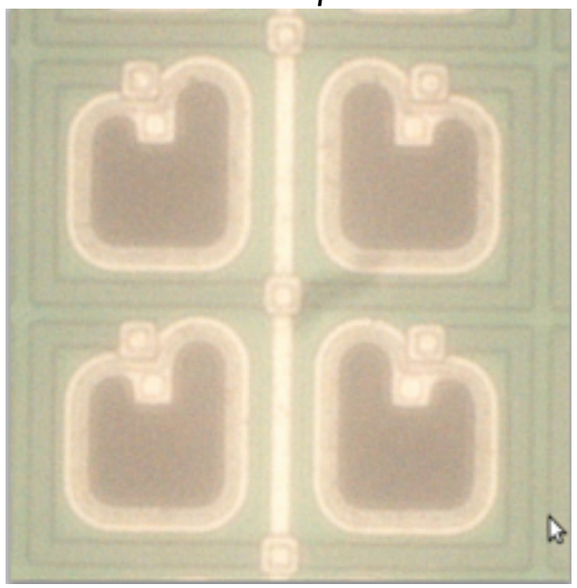
which has dynamic range since five years ago.

- using a metal quenching register
-10000 pixels in 1mm^2

MPPC developments for ILD ScECAL

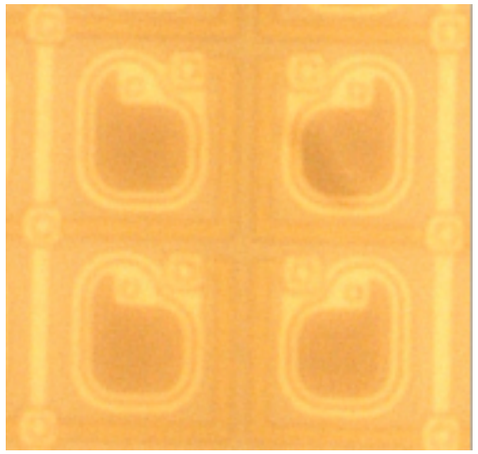
Previous MPPC produced by HPK

25um pitch



2007

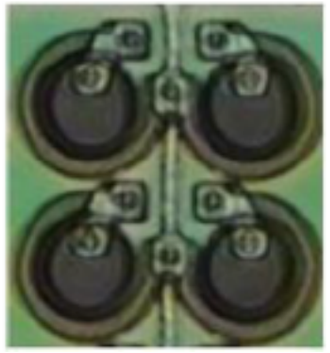
20um pitch



2010

Not Commercial

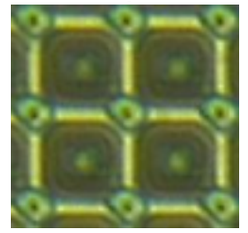
15um pitch



2010

New !

10um pitch



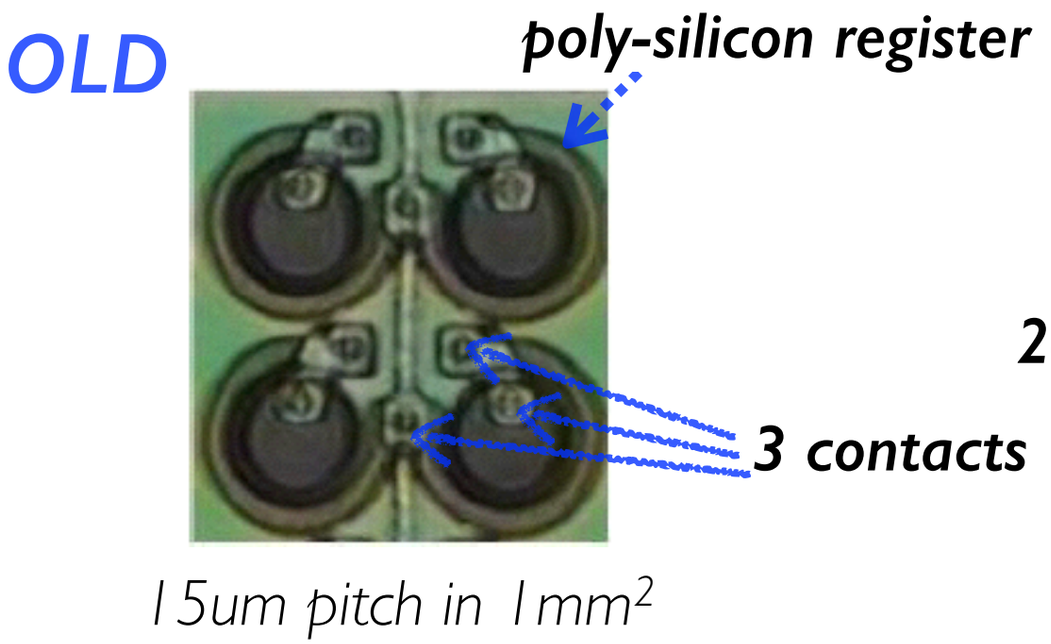
2013

Pixel size	**Large**		**Small**
Dynamic range	**Small**		**Large**
PDE	**Large**		**Small**
Gain	**Large**		**Small**

New type MPPCs

- HPK changed quenching register ***from poly-silicon to metal.***
- Aperture ratio is improved.
- Some MPPCs , Numbers of contacts decrease.

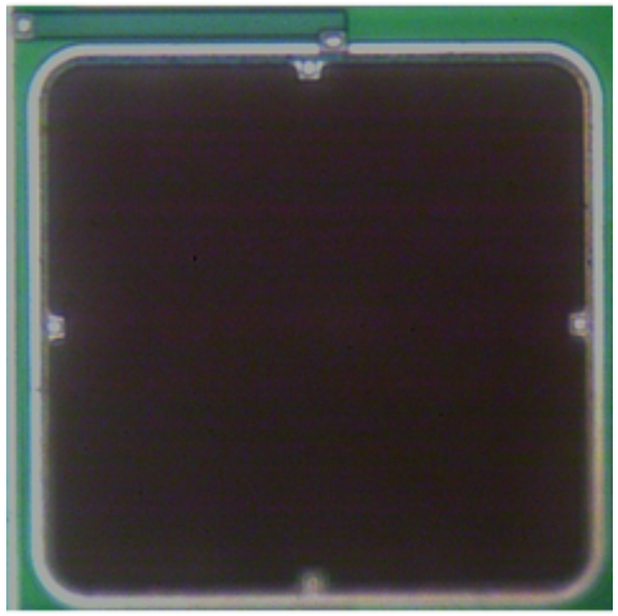
(Especially, new 25um,15um and 10um pitch MPPC have 2 contacts)

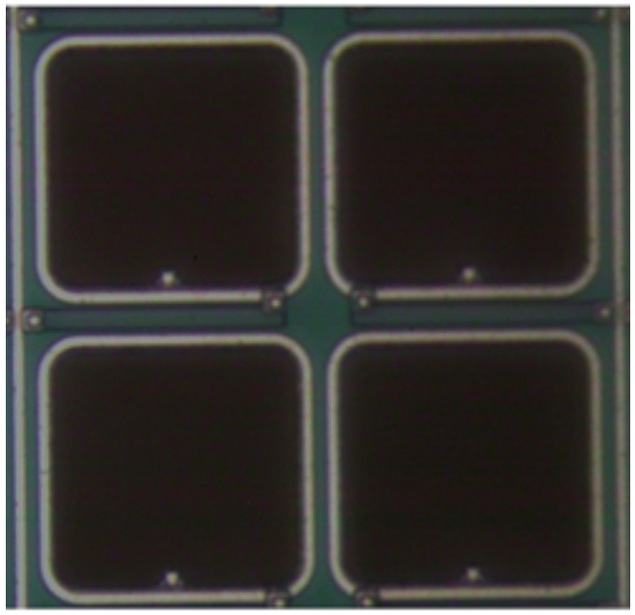


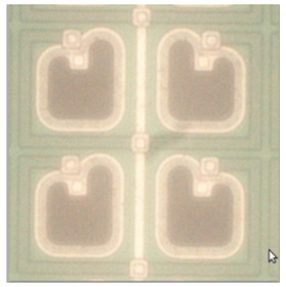
Samples of Old vs. New MPPCs

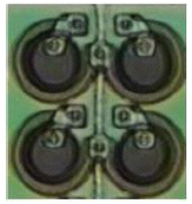
CALICE Calorimeter for ILC

OLD



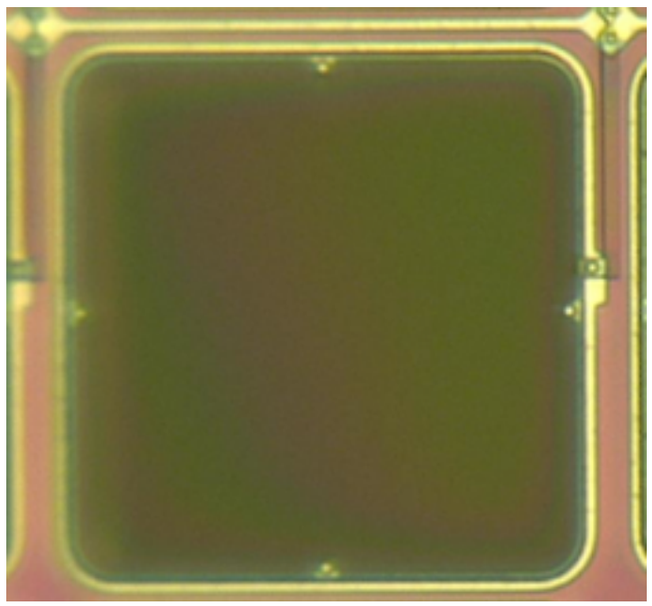




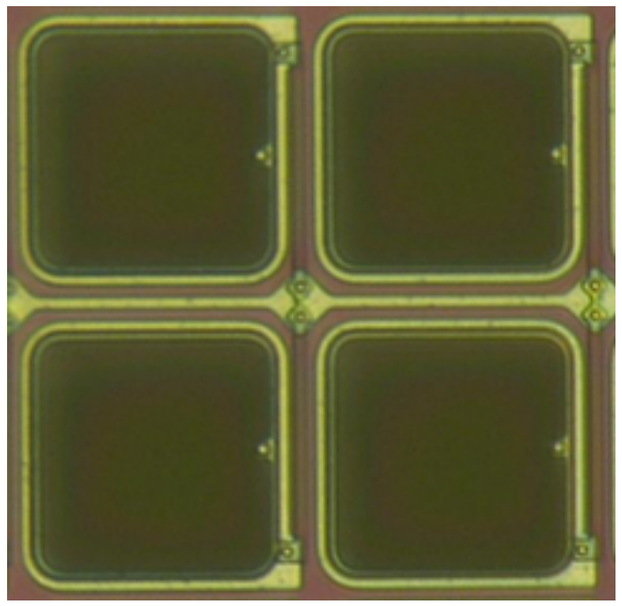


NEW

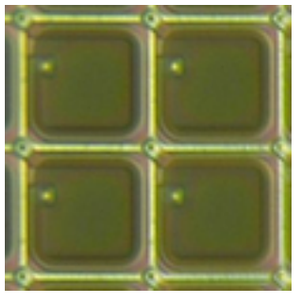
100um pitch



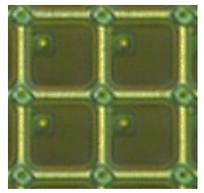
50um pitch



25um pitch



15um pitch

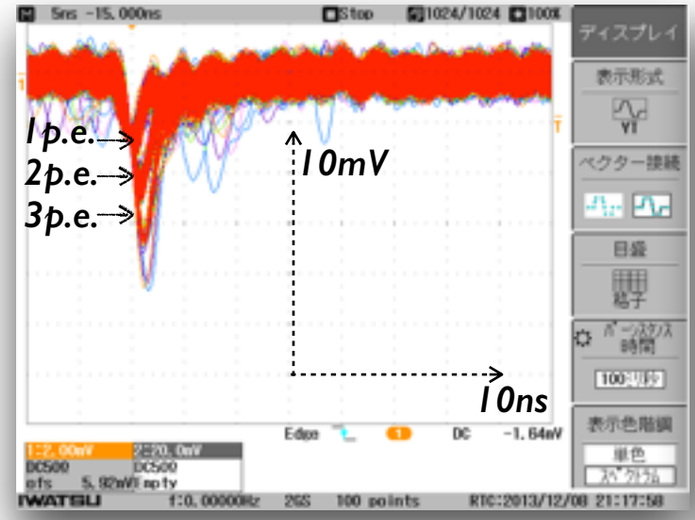


10um pitch

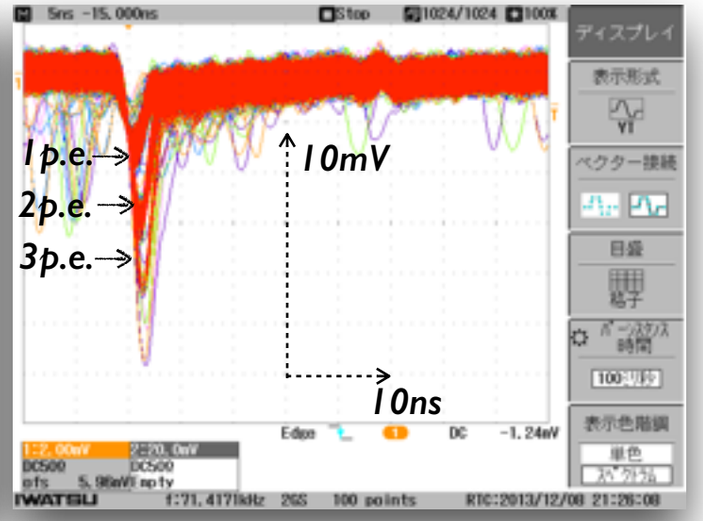
Signals of New MPPCs

These pictures show output signals of new type of MPPCs which are operated recommend operation bias from HPK.

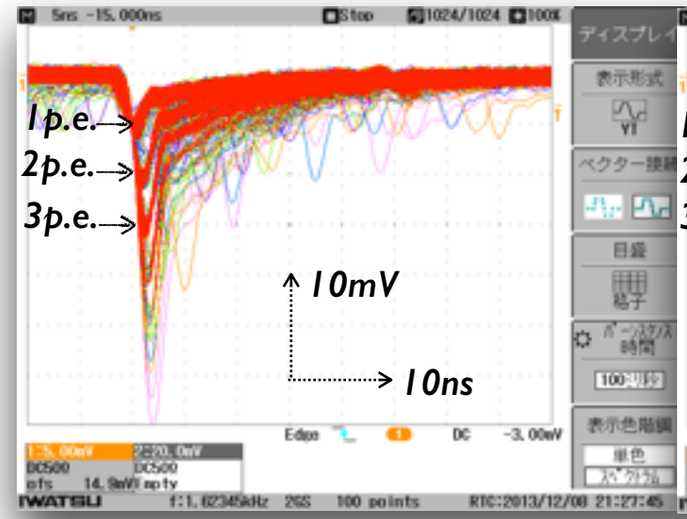
10um pitch



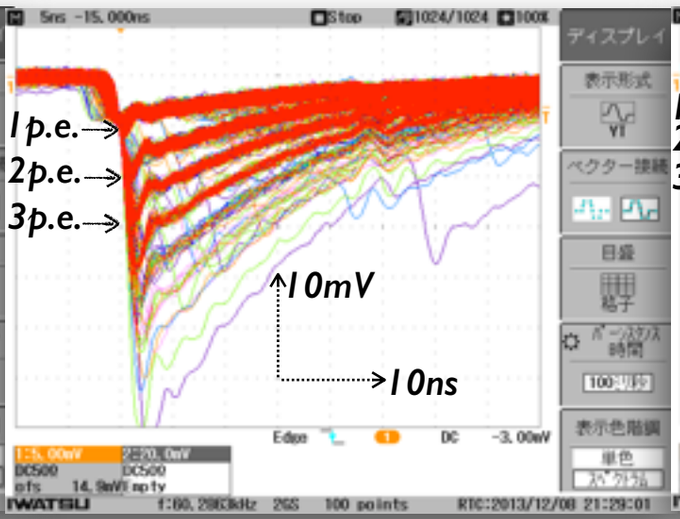
15um pitch



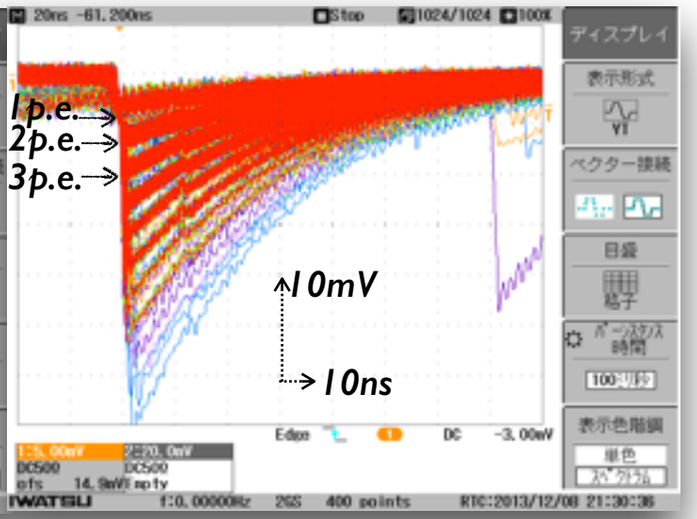
25um pitch



50um pitch

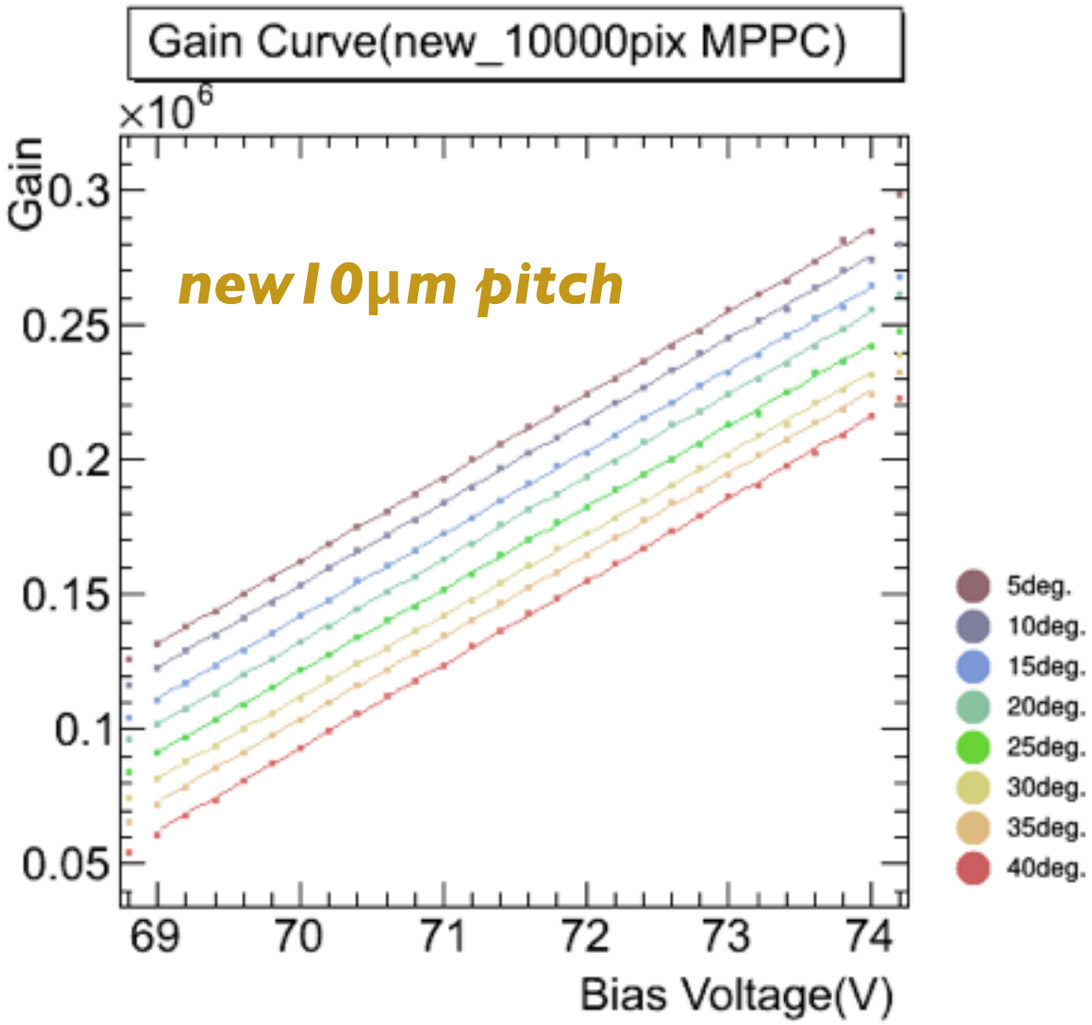


100um pitch

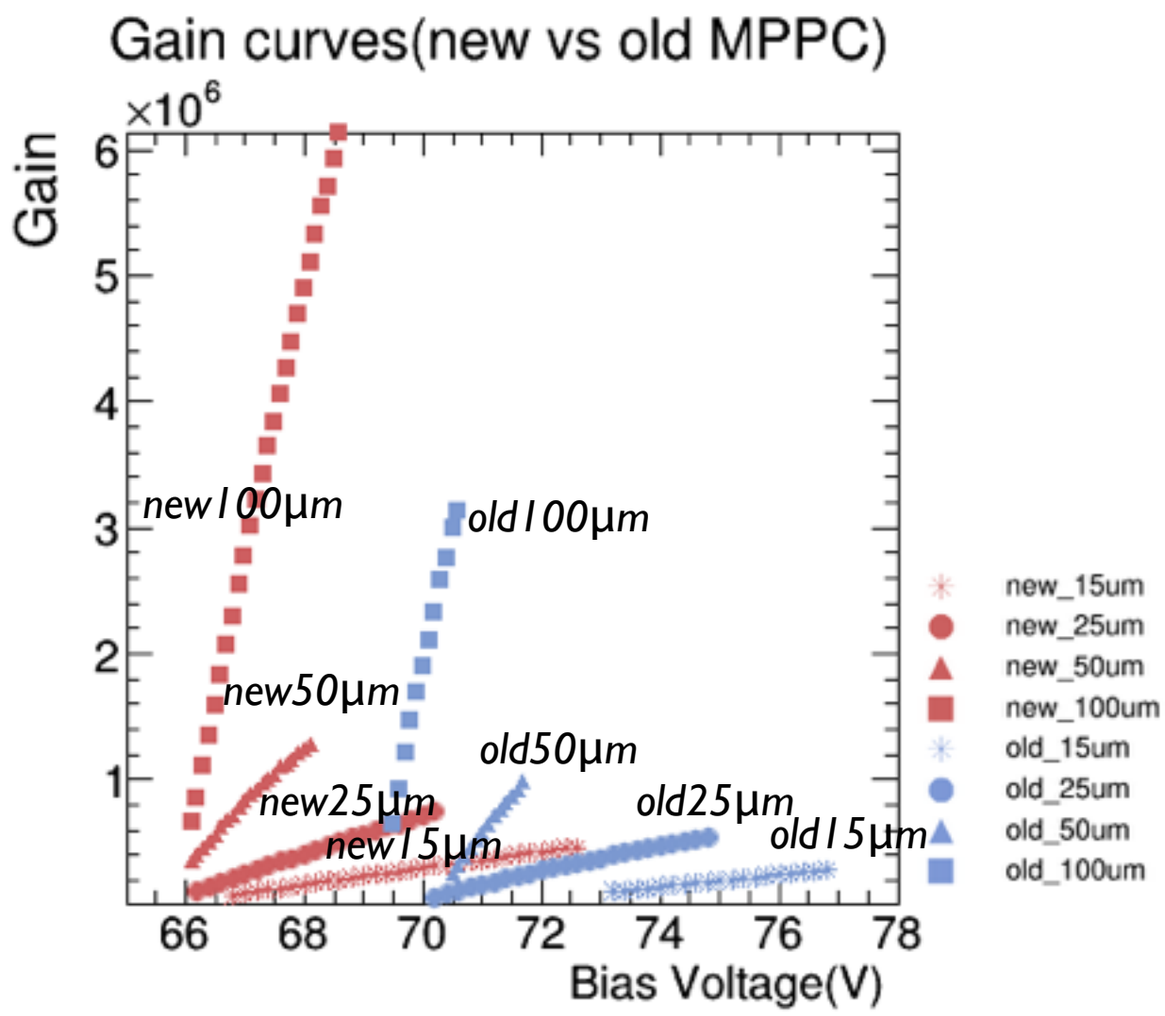


Single photon detection and good separation of few light yields peaks.
Excellent photon counting capability. Fast rise and fall time,especially 10um pitch.

Gain curves Bias voltage & temperature dependence



Gain increases with bias voltage.
Gain decreases with temperature.

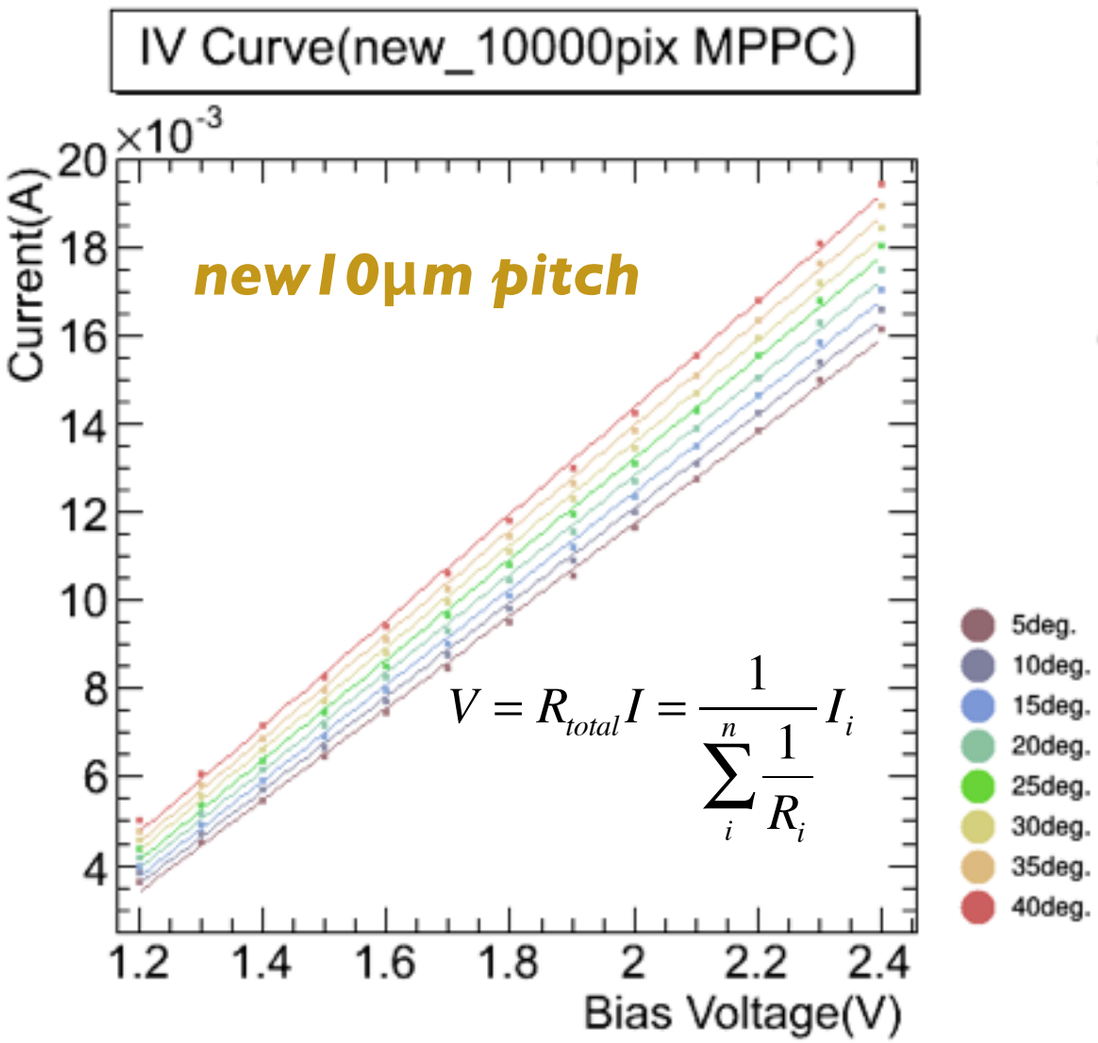


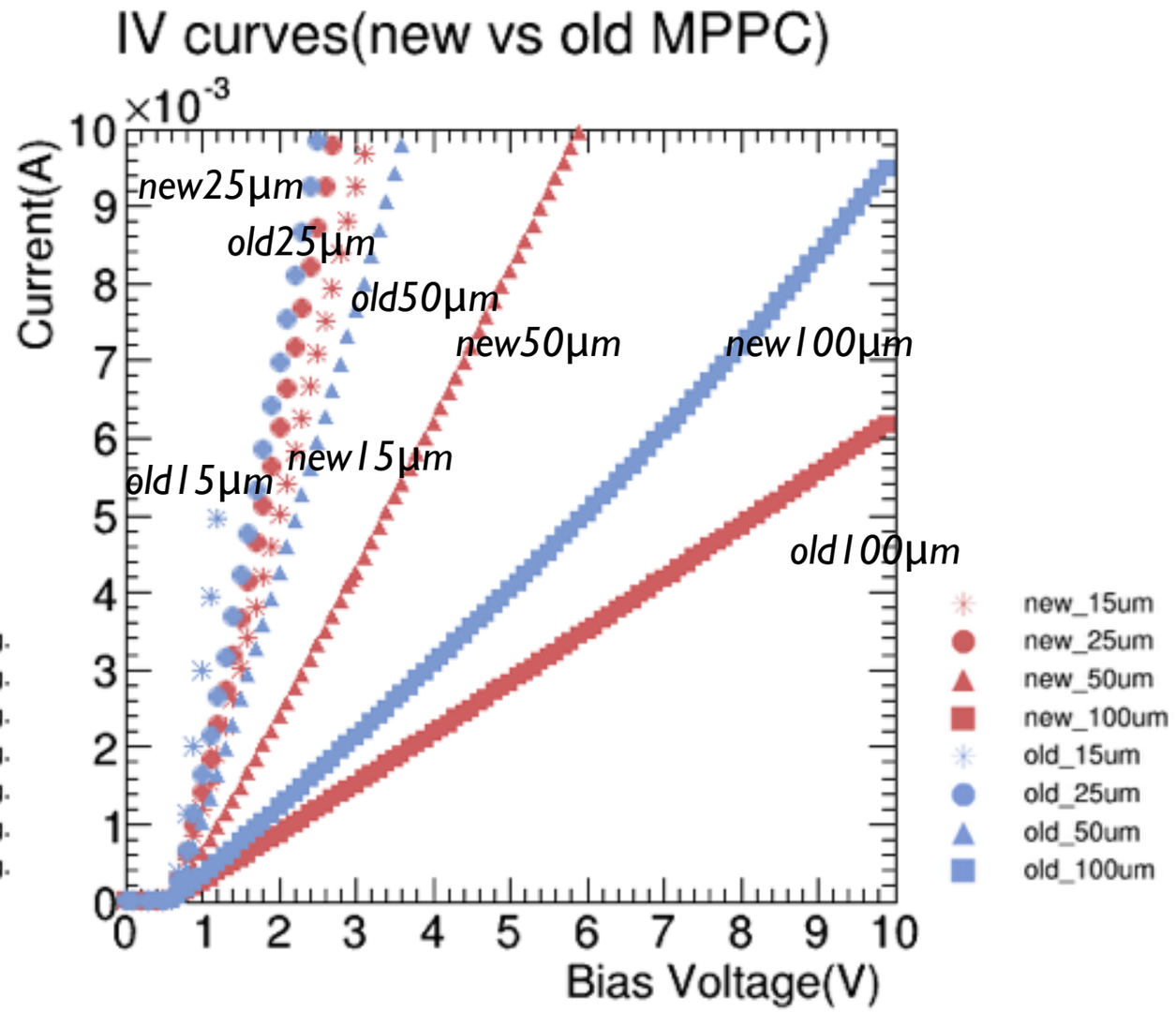
Gain increases with pixel size.

We tested gain curves for V_{break}, dG/dT, dG/dV on all samples.
Operation G(T,V) of MPPC is under control.

IV curves

Bias voltage & temperature dependence





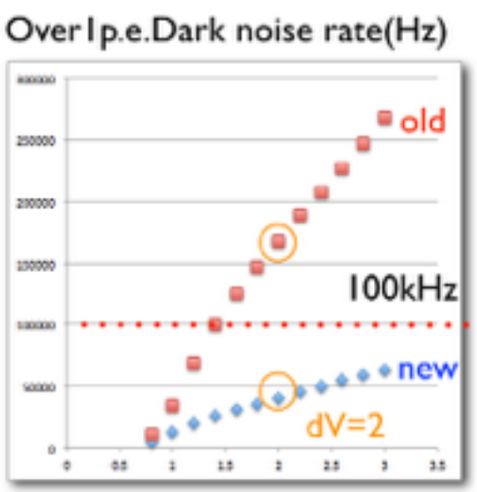
Current increases with temperature.
Current increases with bias voltage.

We tested IV curves for quenching resistance R and dR/dT on all samples.

Noise curves

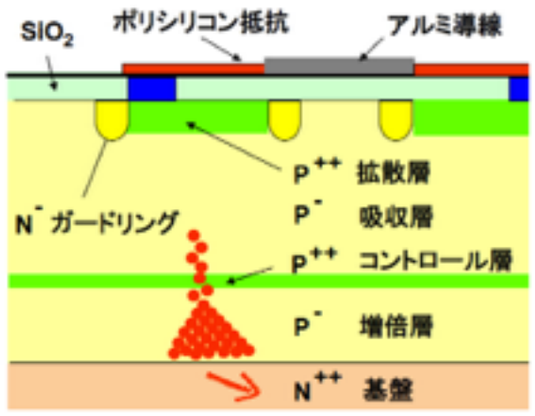
three types of noise

New vs. Old 25um MPPC

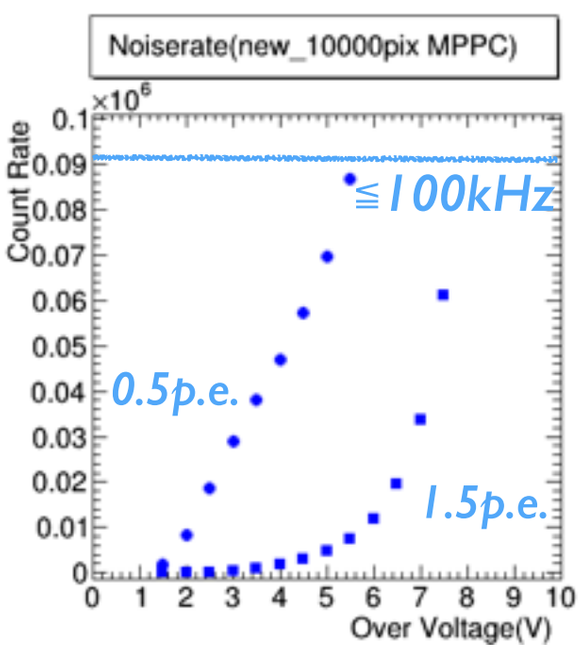


dV=2 →41kHz(new)
→167kHz(old)

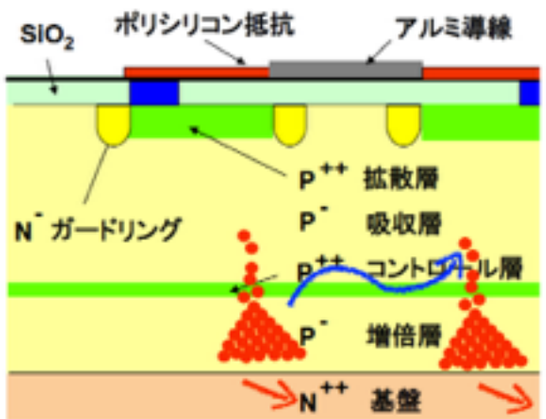
Dark noise



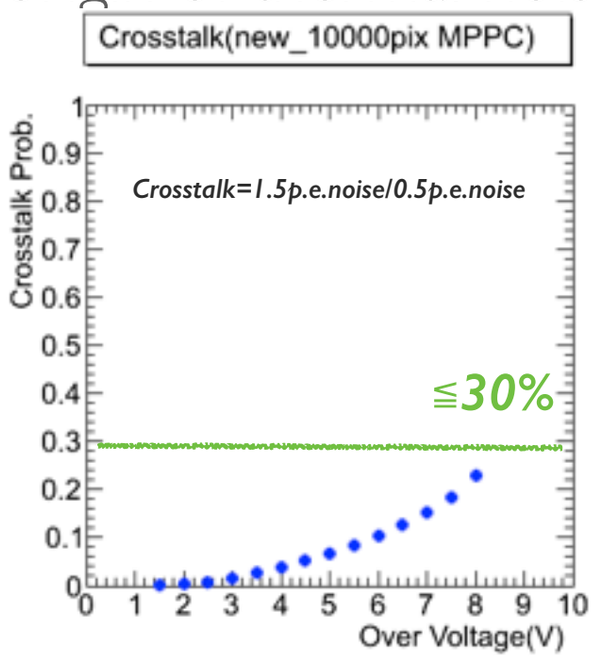
thermal noise



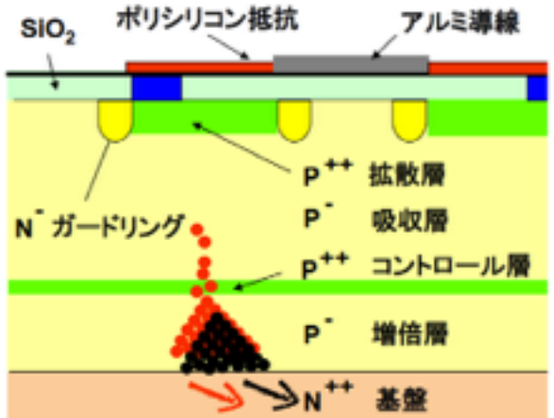
Crosstalk



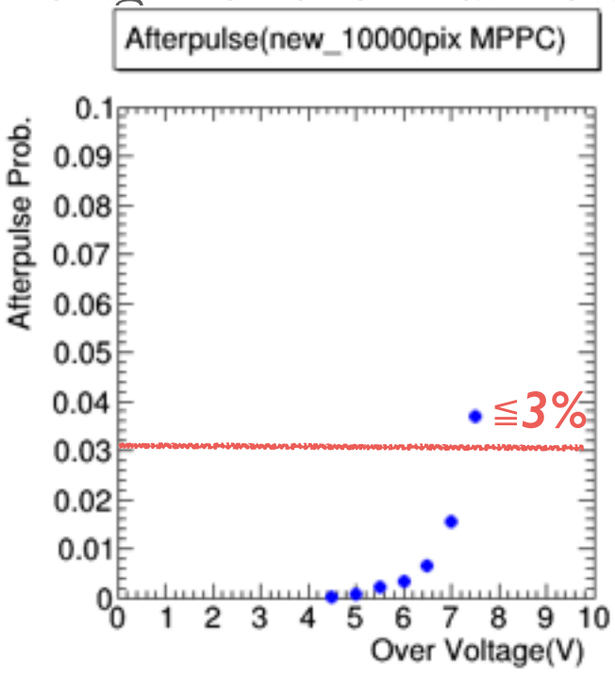
origin of thermal noise



After pulse



origin of thermal noise



We tested dark noise with new vs old 25um pitch MPPC,decreased to quarter of dV=2.
We tested dark noise,crosstalk and after pulse (new 10um pitch MPPC).

Summary and Plan

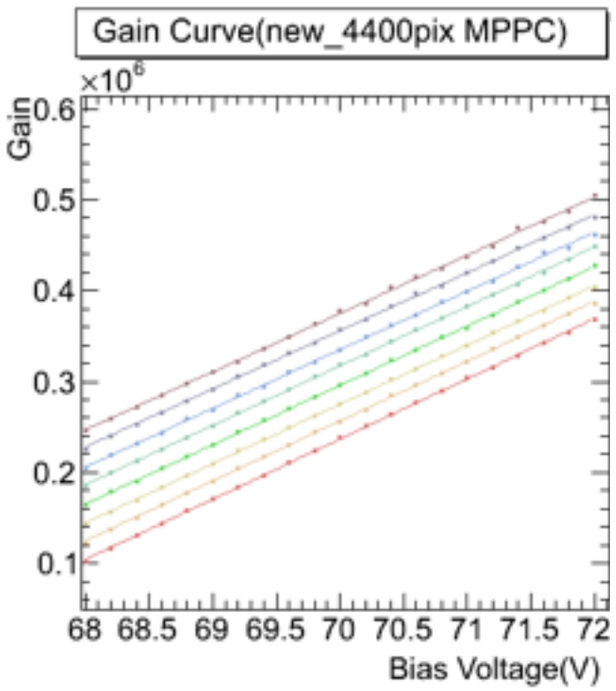
❑ Summary

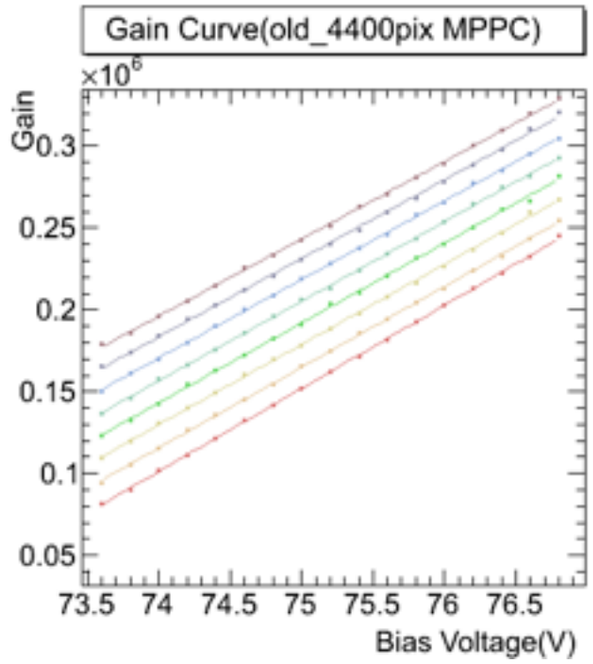
- *HPK released New types of MPPC on November.*
- *HPK changed quenching register from poly-silicon to metal.*
- *Tested basic performance, Gain curve, IV curve and Noise curve.*
- *Aperture ratio, Gain and Noise rate is improved.*
- *Operation of MPPC is under control.*

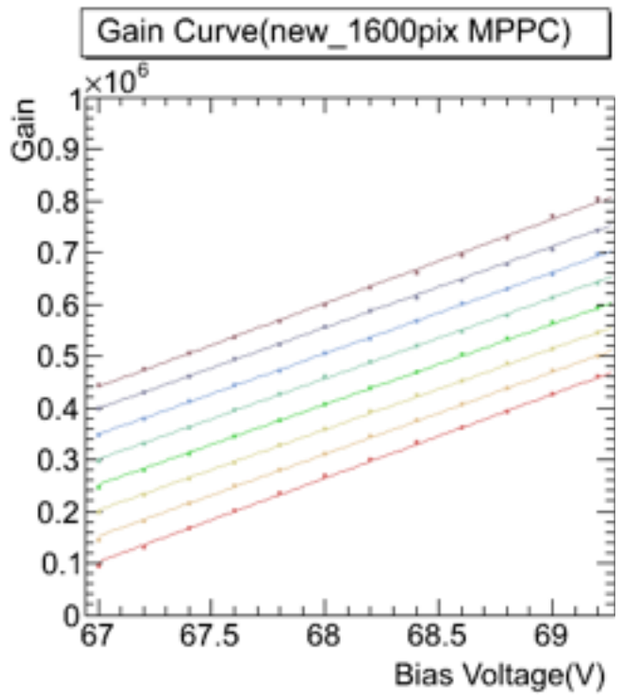
❑ Plan

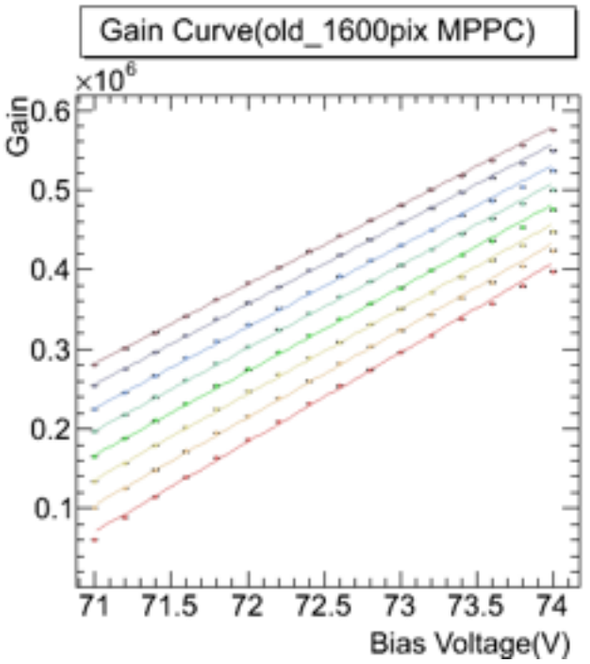
- *Test more basic performance,especially dynamics range (ongoing by tukuba groups)*
- *Test dead volumes effects and PDE for uniformity inside a pixel.*

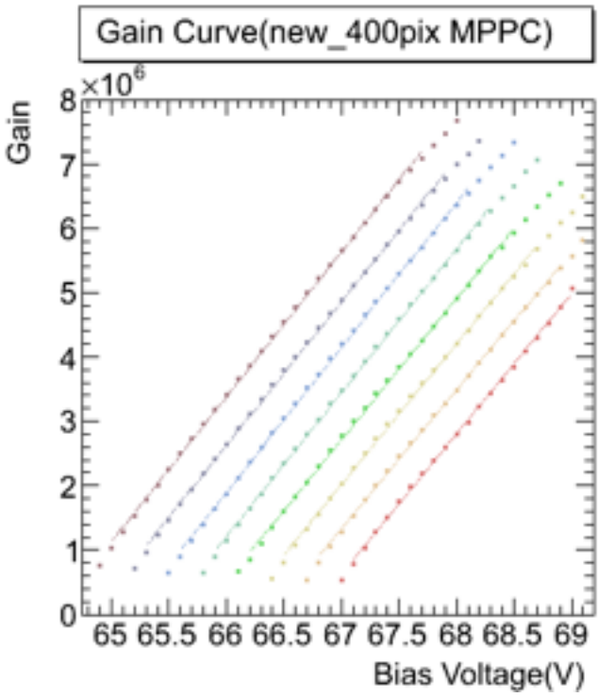
Back up

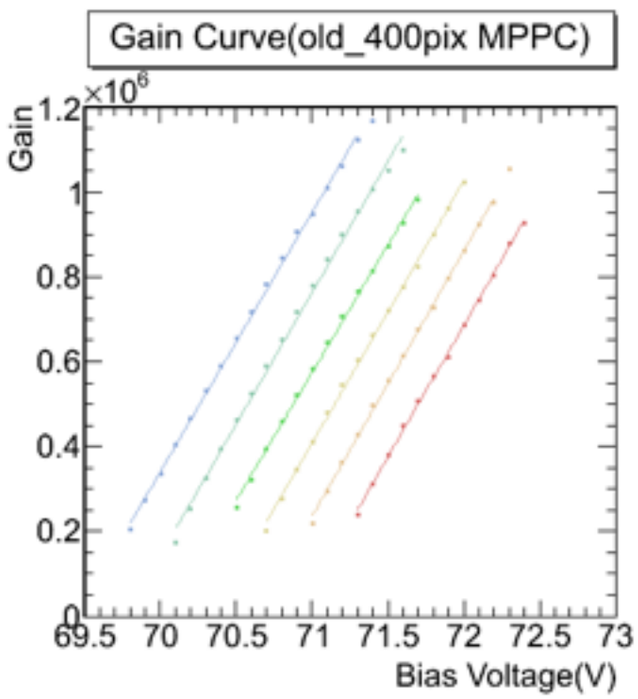

Gain Curve(new_4400pix MPPC)
×10^6
Gain
0.6
0.5
0.4
0.3
0.2
0.1
68 68.5 69 69.5 70 70.5 71 71.5 72
Bias Voltage(V)

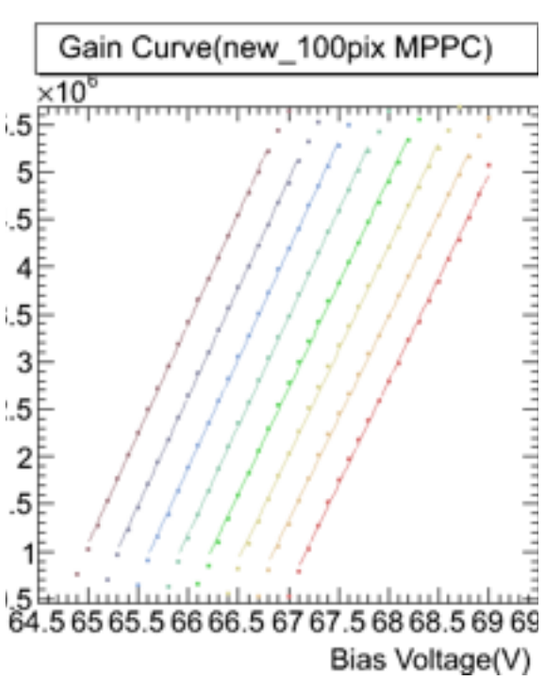

Gain Curve(old_4400pix MPPC)
×10^6
Gain
0.3
0.25
0.2
0.15
0.1
0.05
73.5 74 74.5 75 75.5 76 76.5
Bias Voltage(V)

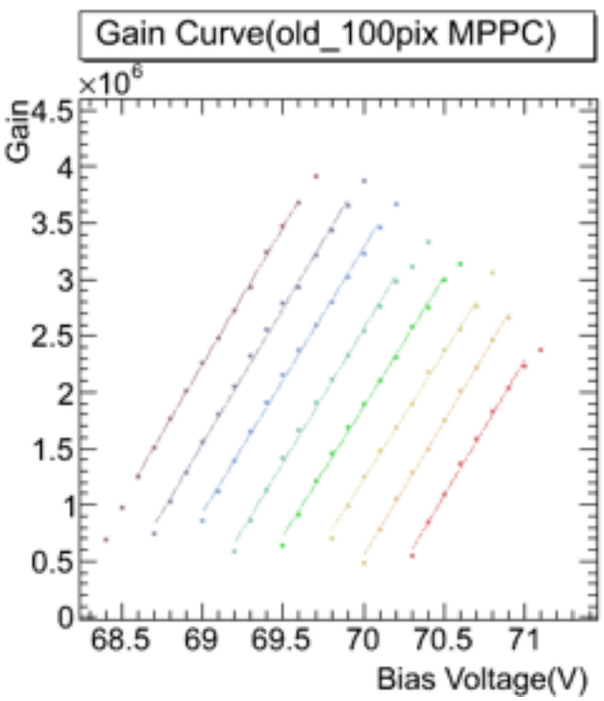

Gain Curve(new_1600pix MPPC)
×10^6
Gain
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
67 67.5 68 68.5 69
Bias Voltage(V)

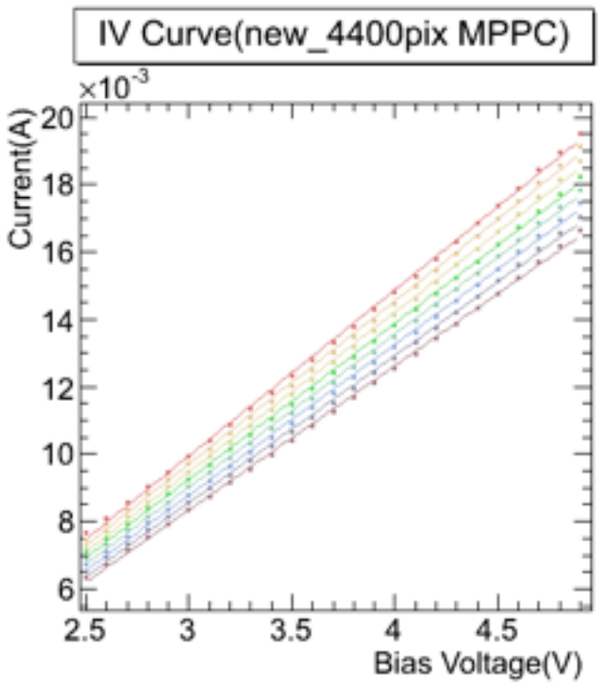

Gain Curve(old_1600pix MPPC)
×10^6
Gain
0.6
0.5
0.4
0.3
0.2
0.1
71 71.5 72 72.5 73 73.5 74
Bias Voltage(V)

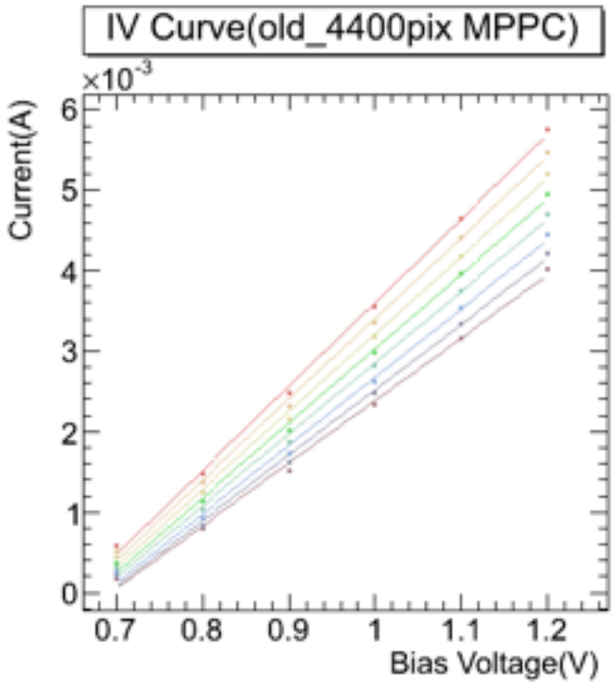

Gain Curve(new_400pix MPPC)
×10^6
Gain
8
7
6
5
4
3
2
1
0
65 65.5 66 66.5 67 67.5 68 68.5 69
Bias Voltage(V)

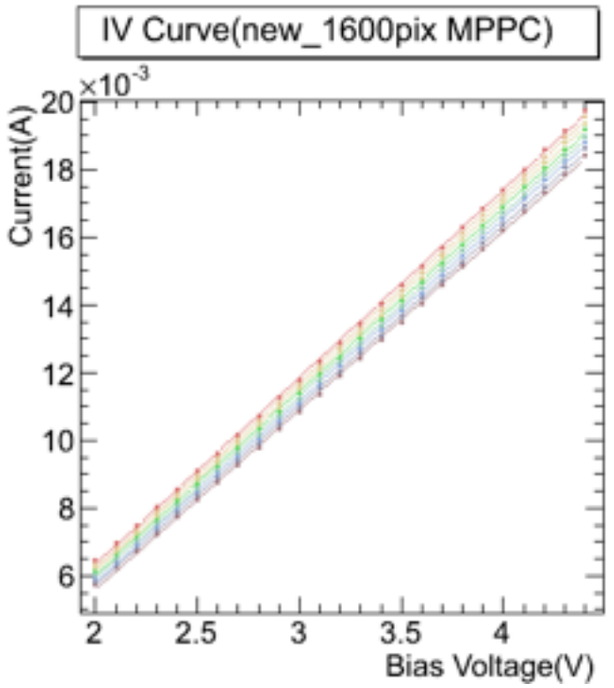

Gain Curve(old_400pix MPPC)
×10^6
Gain
1.2
1
0.8
0.6
0.4
0.2
0
69.5 70 70.5 71 71.5 72 72.5 73
Bias Voltage(V)

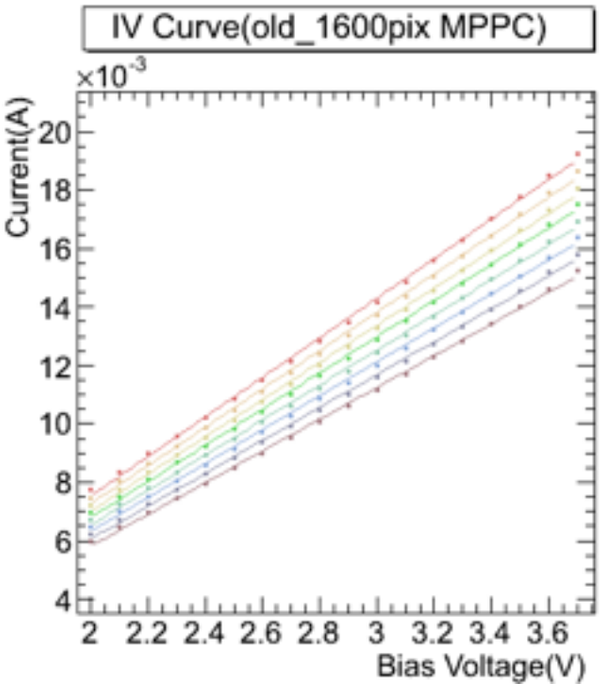

Gain Curve(new_100pix MPPC)
×10^6
Gain
64.5 65 65.5 66 66.5 67 67.5 68 68.5 69
Bias Voltage(V)

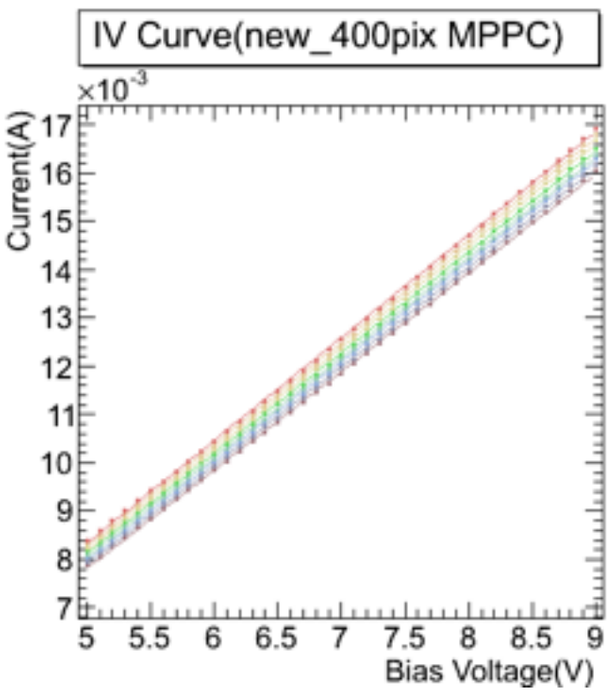

Gain Curve(old_100pix MPPC)
×10^6
Gain
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
68.5 69 69.5 70 70.5 71
Bias Voltage(V)

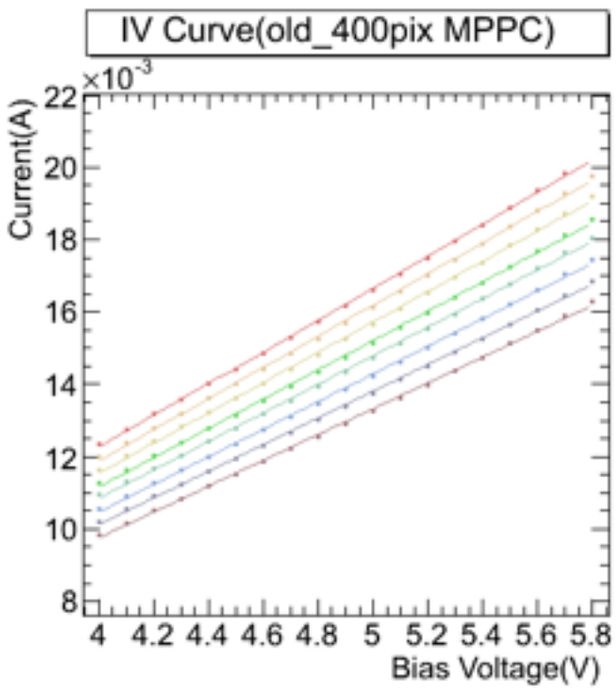

IV Curve(new_4400pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)

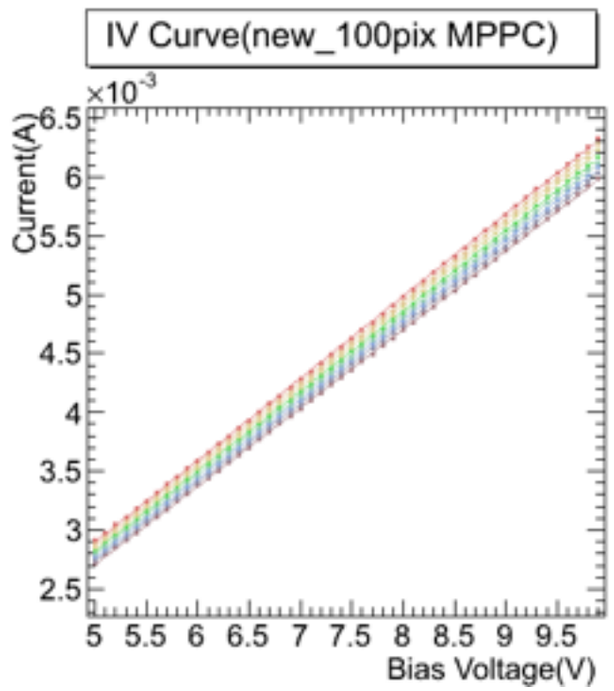

IV Curve(old_4400pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)

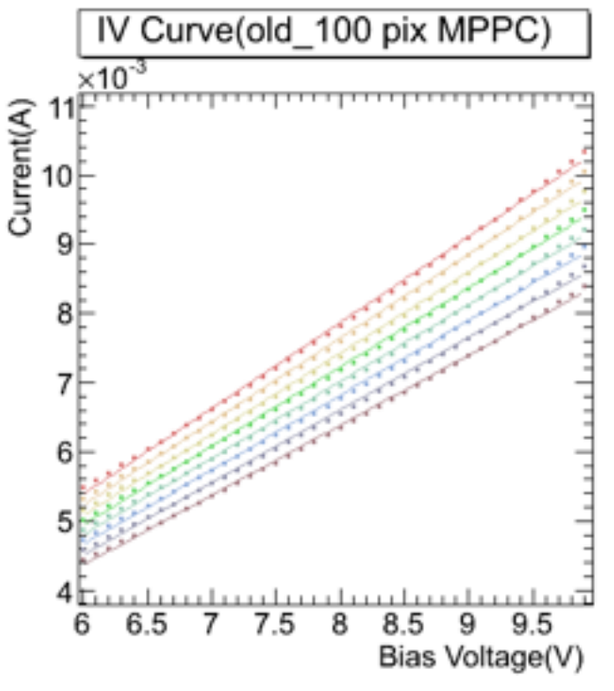

IV Curve(new_1600pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)


IV Curve(old_1600pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)

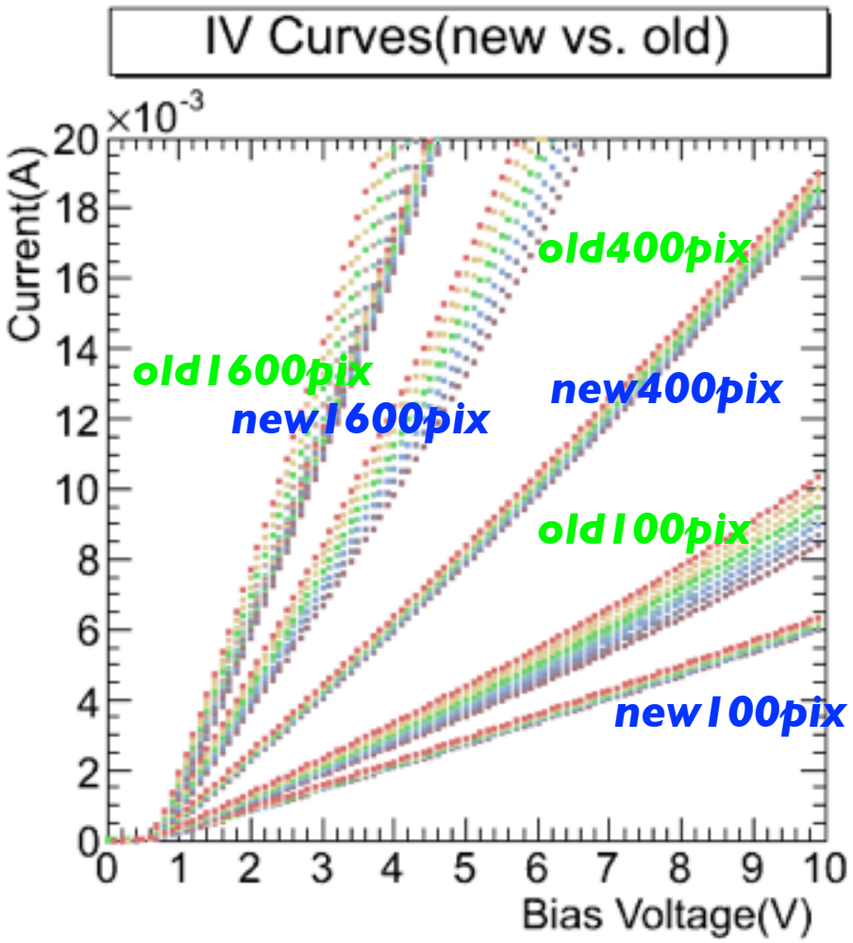

IV Curve(new_400pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)


IV Curve(old_400pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)

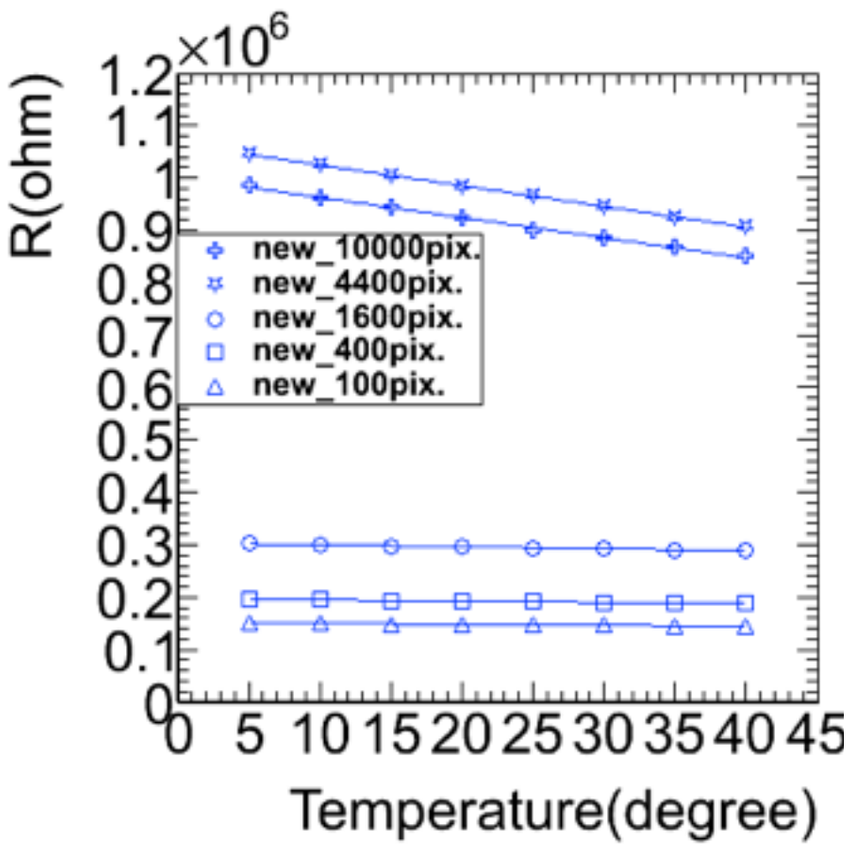

IV Curve(new_100pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)


IV Curve(old_100 pix MPPC)
×10^-3
Current(A)
Bias Voltage(V)

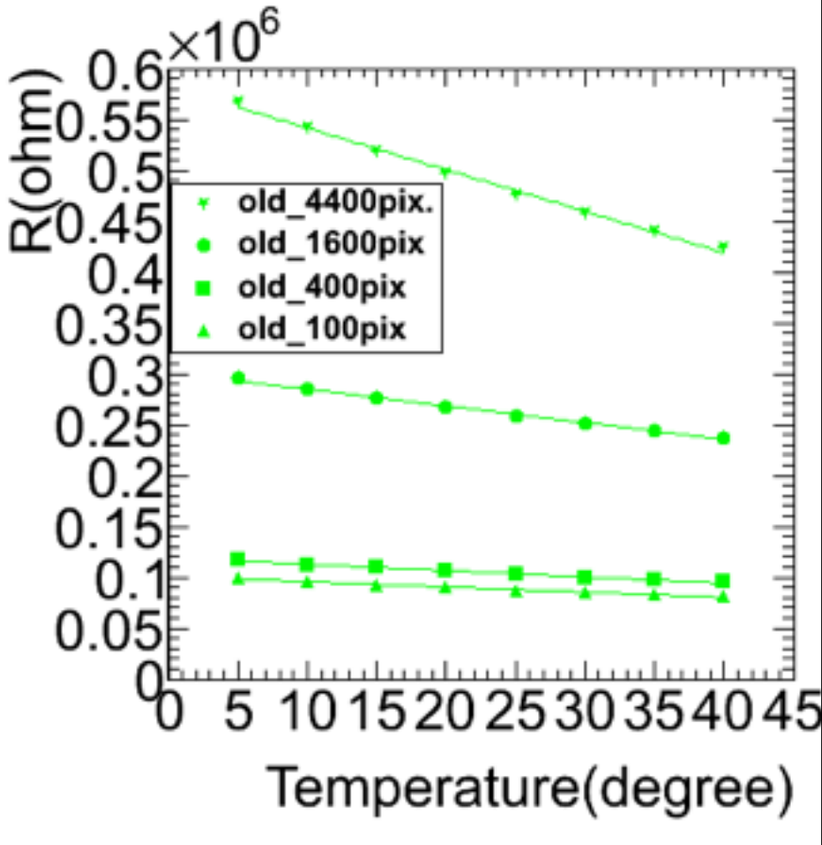
IV curve (new types & old types MPPC)



Resistance vs. temp(new)



Resistance vs. temp(old)



R(10000pix)~878kΩ
R(4400pix) ~949kΩ
R(1600pix) ~295kΩ
R(400pix) ~194kΩ
R(100pix) ~148kΩ

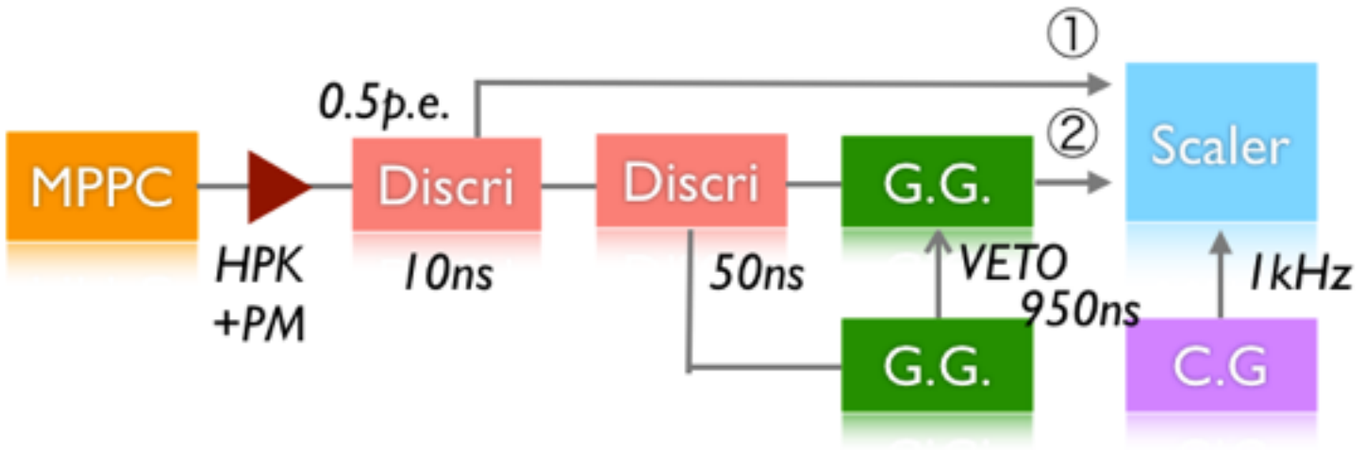
new @25deg.

R(4400pix) ~476kΩ
R(1600pix) ~258kΩ
R(400pix) ~103kΩ
R(100pix) ~87kΩ

old @25deg.

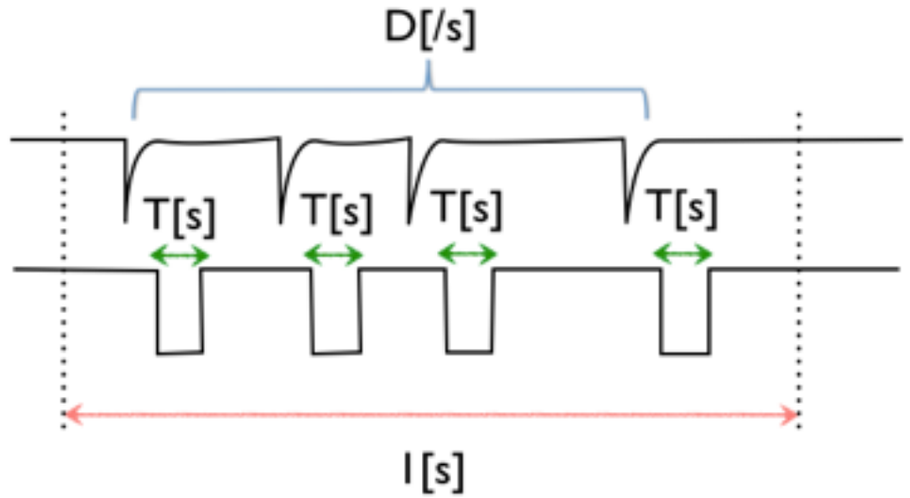
Measurement of dark noise rate

scalar① : number of dark noise including after pulse + crosstalk
scalar② : number of dark noise including crosstalk



system to exclude afterpulse

Dark noise rate correction



D : fake dark noise
Dc:correct dark noise Dc(1-DT)=D ∴ Dc=D/(1-DT)

Setup of after pulse rate & after pulse prob.