Talk #23

SiPM Radiation: Quantifying Light for Nuclear, Space and Medical Instruments under Harsh Radiation Conditions

Proton irradiation on modified Hamamatsu MPPCs (Si-PMs)

Ryo Imazawa
(Hiroshima University)

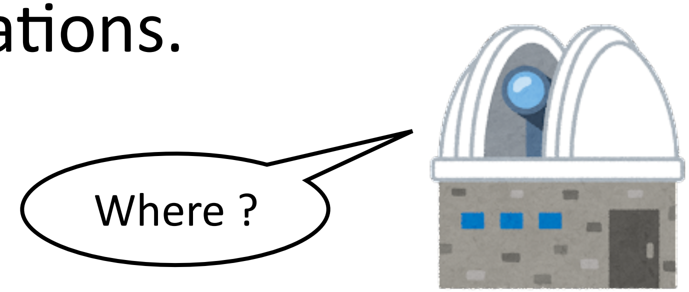
Why we use Si-PMs?

We want to study the origin of Gamma-Ray Bursts (GRBs).

Gamma-ray transient events in the space.
Cause of this is unknown.
(Super novae?, Neutron stars merger?...)

Multiwavelength observation is very important.
(follow up observation by ground-based telescopes)

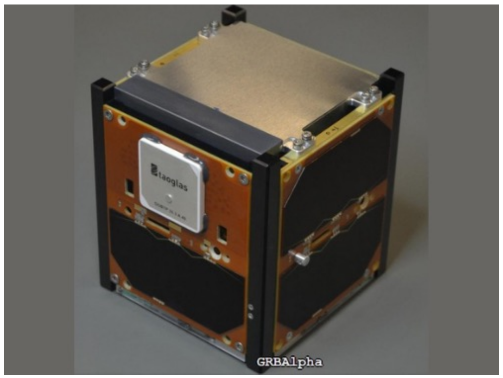
→ **Wide field of view and good localization accuracy** is important to follow up observations.



Why we use Si-PMs?

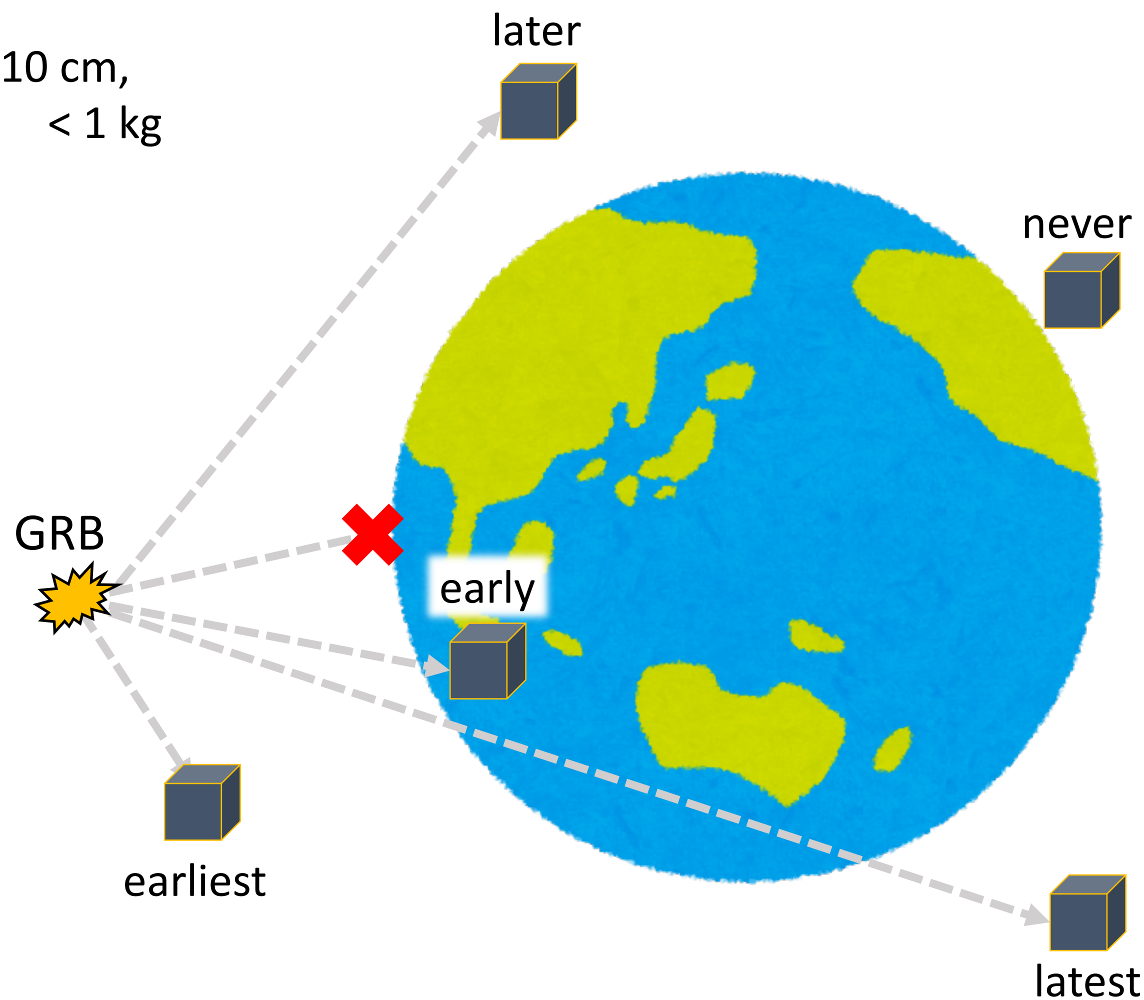
Wide field of view and good localization accuracy

→ How to ?



～10 cm,
< 1 kg

Nanosatellite



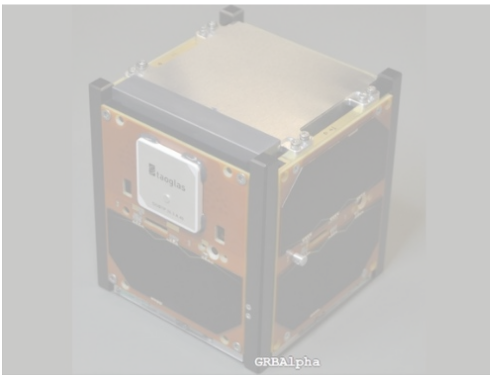
By using timing information (~ms), with many nanosatellite.

(Norbert et al. 2018 CAMELOT project)

Why we use Si-PMs?

Wide field of view and good localization accuracy

→ How to ?



Nanosatellite

By using ti
informatio
with many
nanosatellite.
(Norbert et al. 2018 CAMELOT project)

So, we need light and small detectors!!!

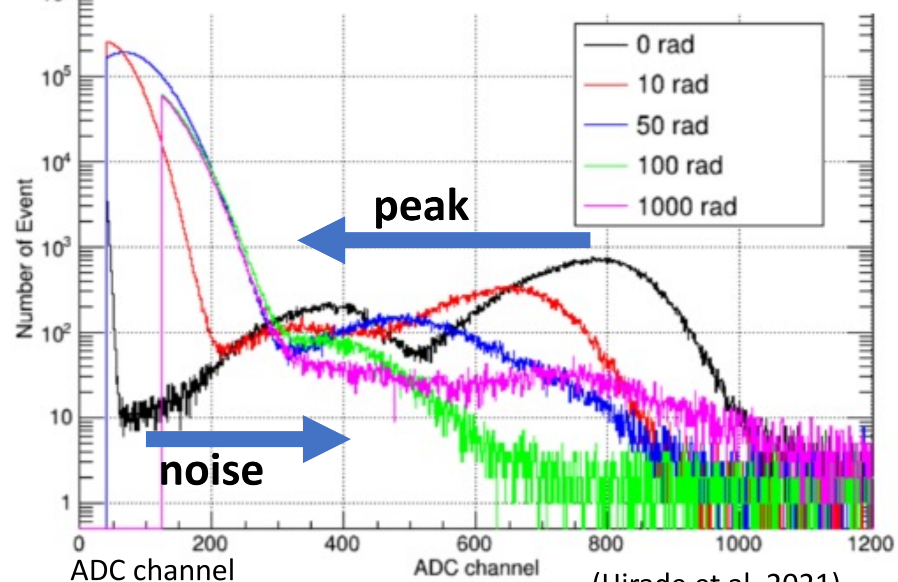
MPPC; Si-PMs by HAMAMATSU

Many advantages as gamma-ray detector onboard…

Low break voltage(~50 V), High gain(~10^6),
and small size(~mm).

Good element for Nanosatellite!

Spectrum per irradiation dose (^{241}Am,60 keV)



ADC channel

(Hirade et al. 2021)

But it has weak durability to radiation.

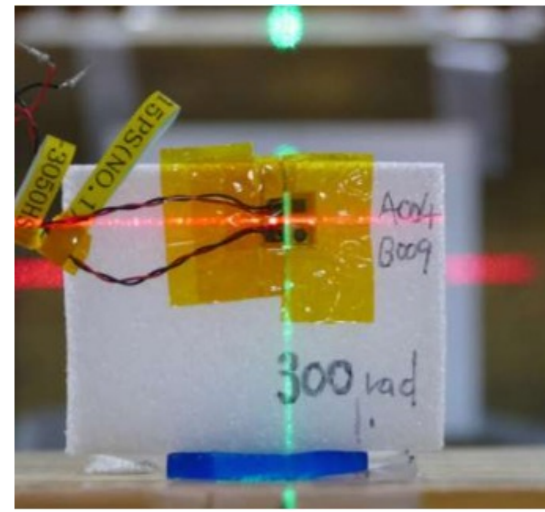
HAMAMATSU made modified version of MPPCs.

➡ **Purpose: compare the radiation tolerance of the current and modified MPPCs.**

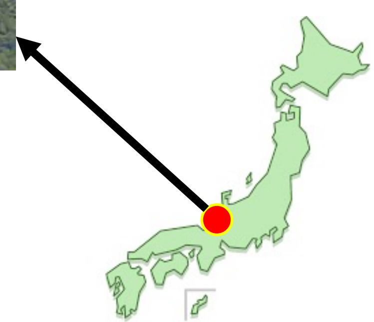
Proton radiation experiment (May 19, 2020)

We brought MPPCs to WERC, and radiated 200 MeV protons (≒1 MeV neutrons) to current/modified MPPCs, respectively.

Wakasa-wan Energy Research Center,
Fukui, Japan
(credit: S. Hatori)

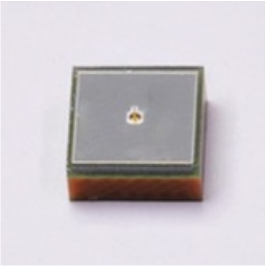


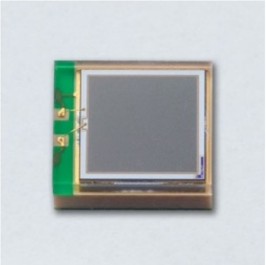
Setting in the beamline
(Set four MPPCs to hit equally.)



Proton radiation experiment (May 19, 2020)

S14160-3050HS
(current model B)





S14160-3015 MOD
(current model A)

Current versions / Modified versions

	S14160-3015PS (current model A)	S14160-3050HS (current model B)	S14420-3050 MOD (modified A)	S14160-3050 MOD (modified B)
break V	38	38	42	38
gain	3.6×10^5	2.5×10^6	3.6×10^6	2.5×10^6
efficiency	32 %	50 %	40 %	50 %

modified A: Designed to suppress potential changes on the chip surface due to charge-up of the protective layer

modified B: Designed so that carriers in the deep Si substrate layer do not reach to avalanche layer.

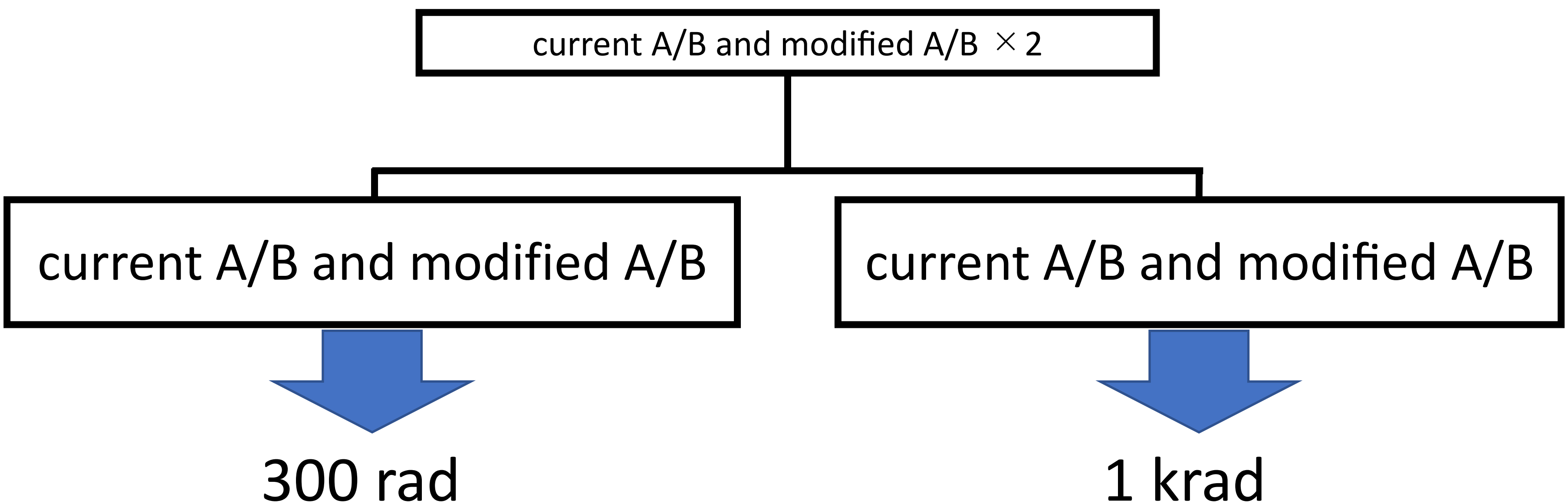
Proton radiation experiment (May 19, 2020)

We prepared two pairs of MPPCs
(Two each of current A/B and modified A/B are prepared).

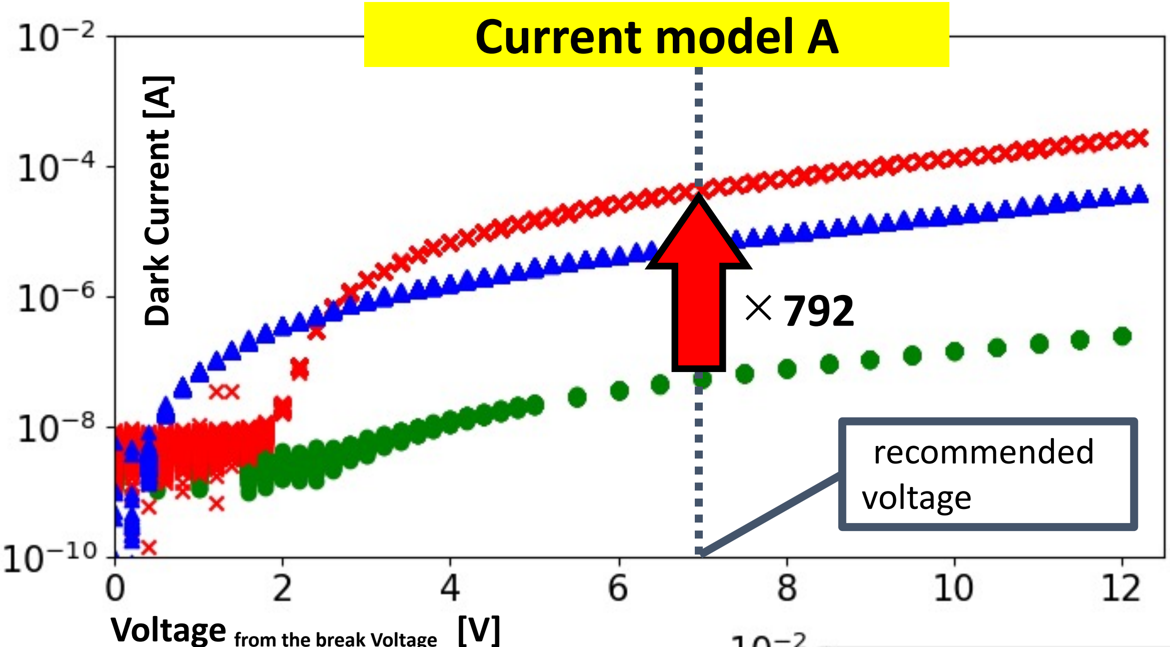
And radiated protons as below conditions.

1. 200MeV proton 300 rad (correspond to ~2×10^9 neutrons[1 MeV])
2. 200MeV proton 1 krad

100 rad → 0.1 years in the space
(100 rad → 1 gray)



Dark current measurement of 300 rad radiated MPPCs

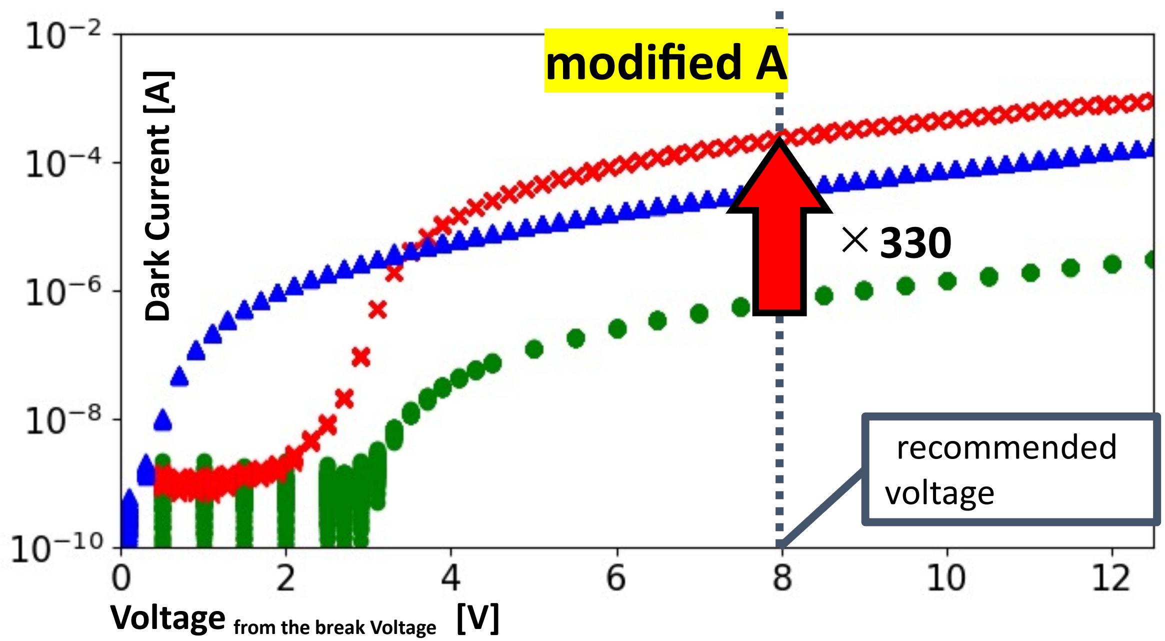


● before radiation (+20°C)

× after (+20°C)

▲ after (-30°C)

Current model shows ~800 times higher dark current after the radiation.

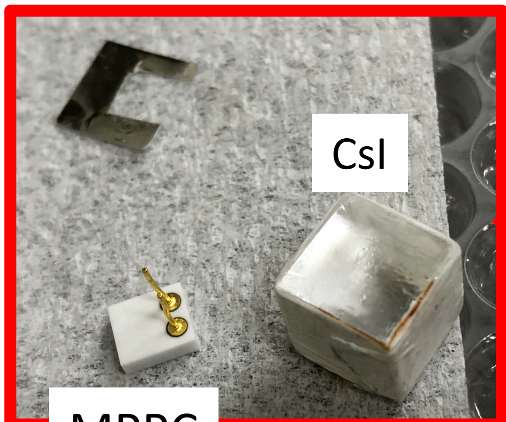


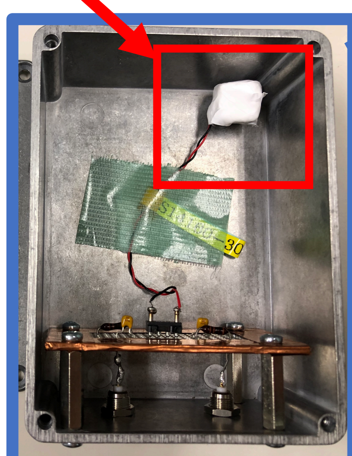
Modified version may be less aggravated by irradiation.

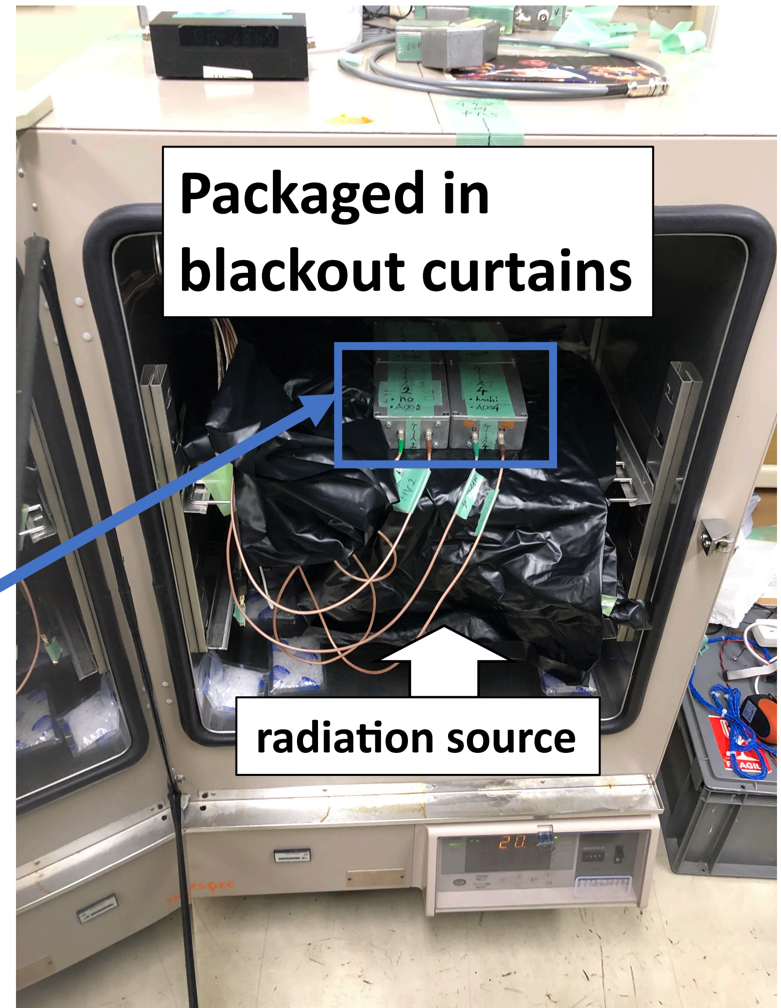
→ However, this may be due to the high dark current before irradiation of the modified one.

After the proton radiation experiment

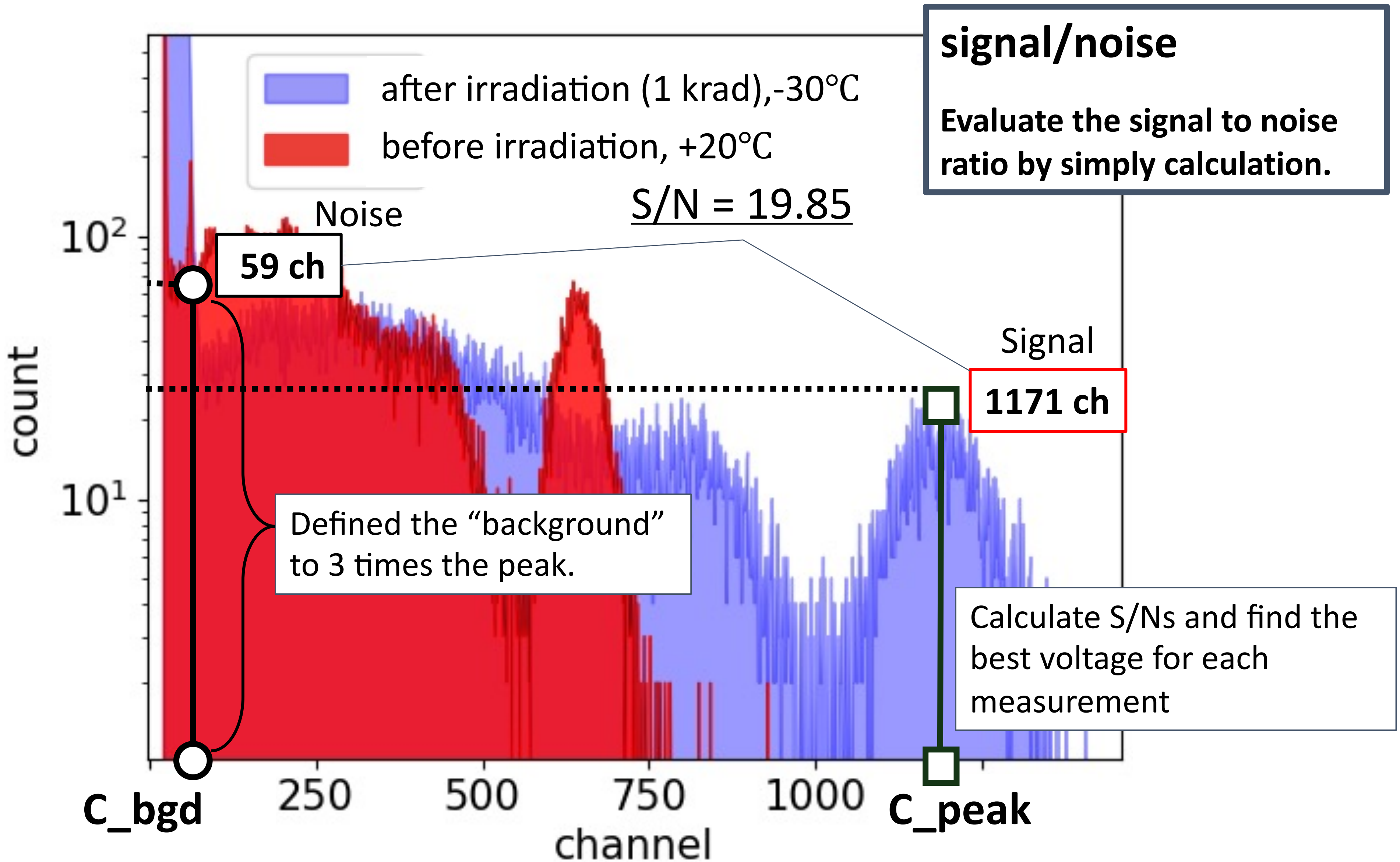
Put in thermostatic layer and measured at each temperature.
(room temperature +20°C and low temperature -30°C)
(Source: ^{137}Cs, ^{109}Cd, ^{241}Am)
↑ topic in this talk



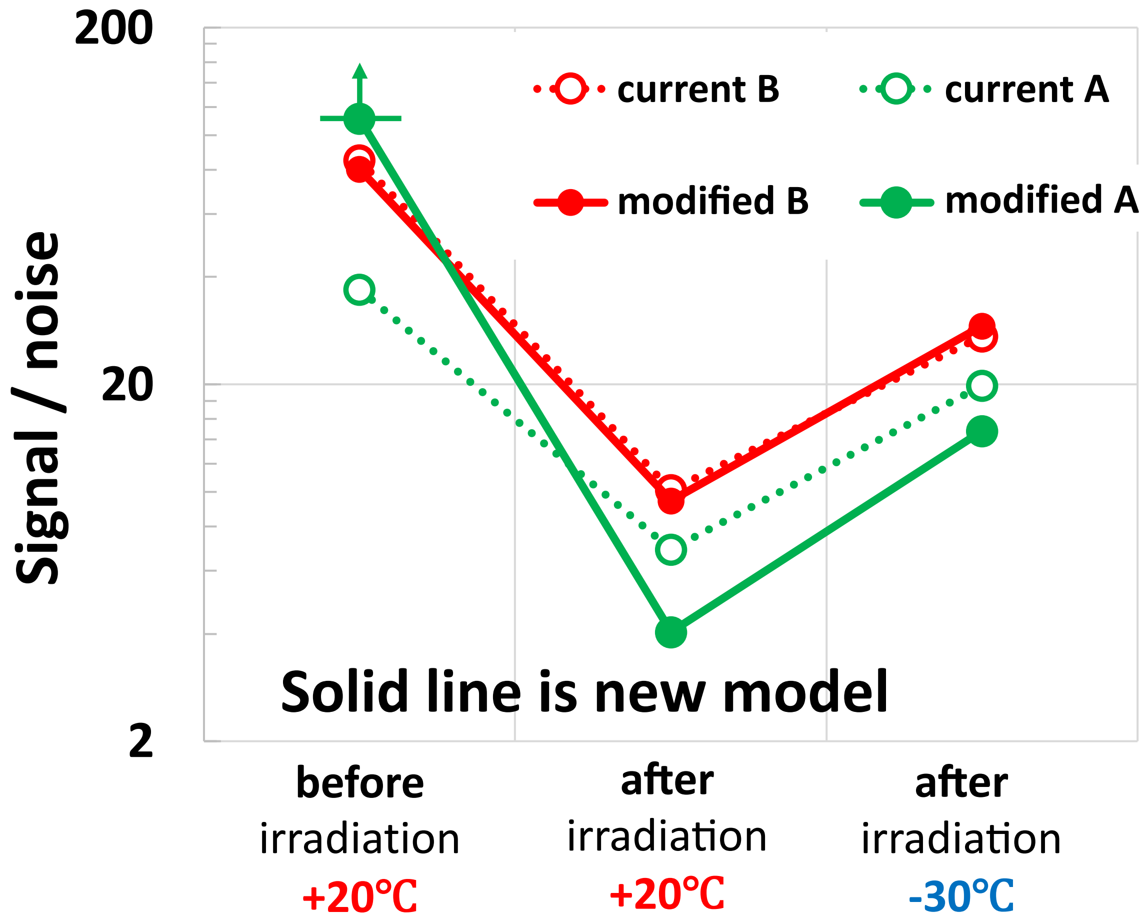




histogram (^{137}Cs), current model A, before(＋20℃) and after(-30℃)



Signal/noise in each temperature, each version of MPPCs



Modified A had good performance before irradiation, but damage by irradiation was significant. Modified B has the same performance as current B by cooling to -30℃ after irradiation.

Summary

- What we did

The modified MPPC and the current model were tested for space applications. Proton irradiation experiments were conducted.

- As a result,

Modified B showed no improvement, and modified A showed good dark current before irradiation, but radiation resistance was not so good.

From the present results alone, it cannot be said that modified version is superior in radiation tolerance.

- In the next work,

Lower temperature experiments will be investigated to see if the noise goes down.

Baking experiments performed, H. Matake will present later. (talk #24)

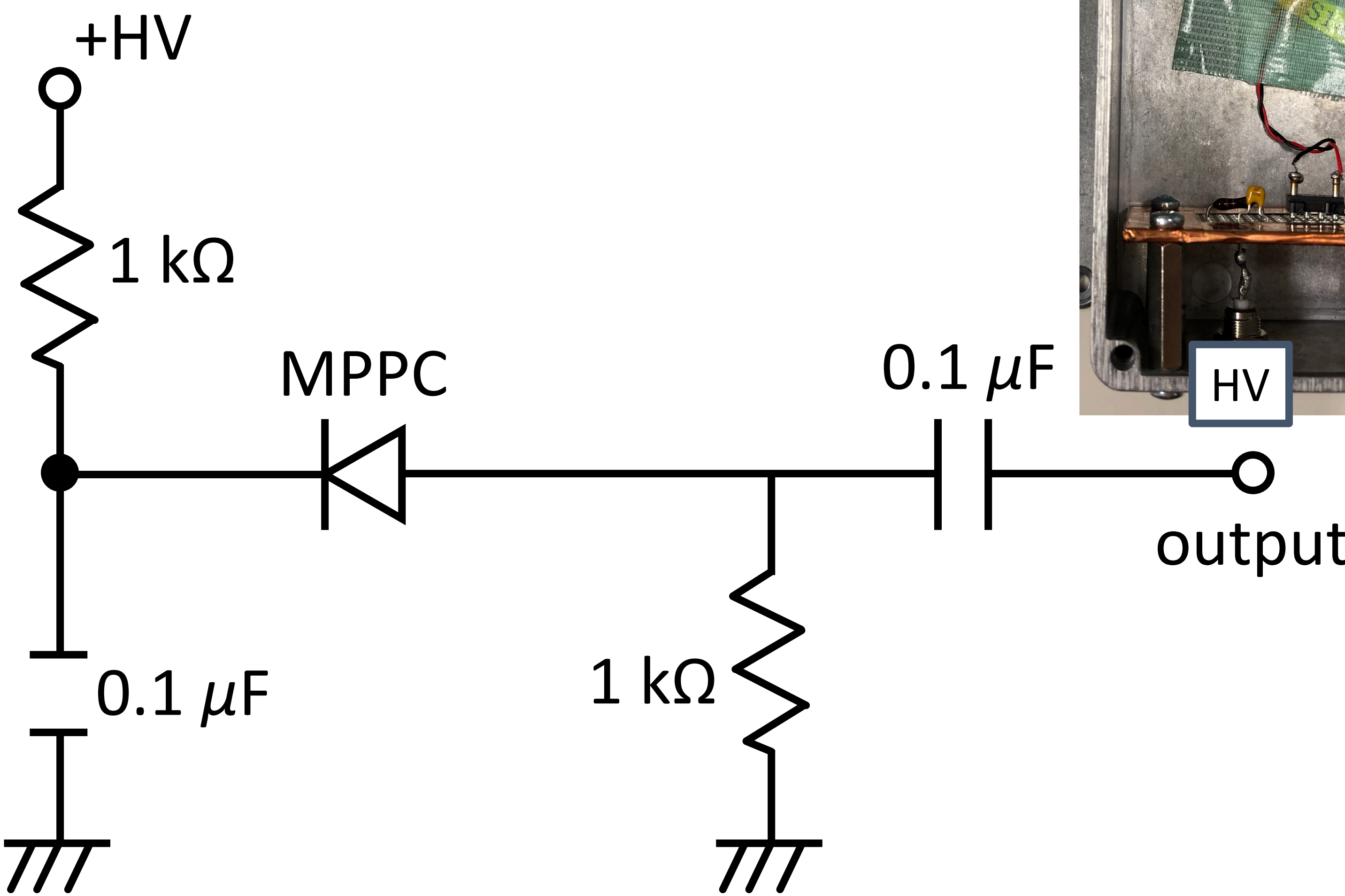
Backup

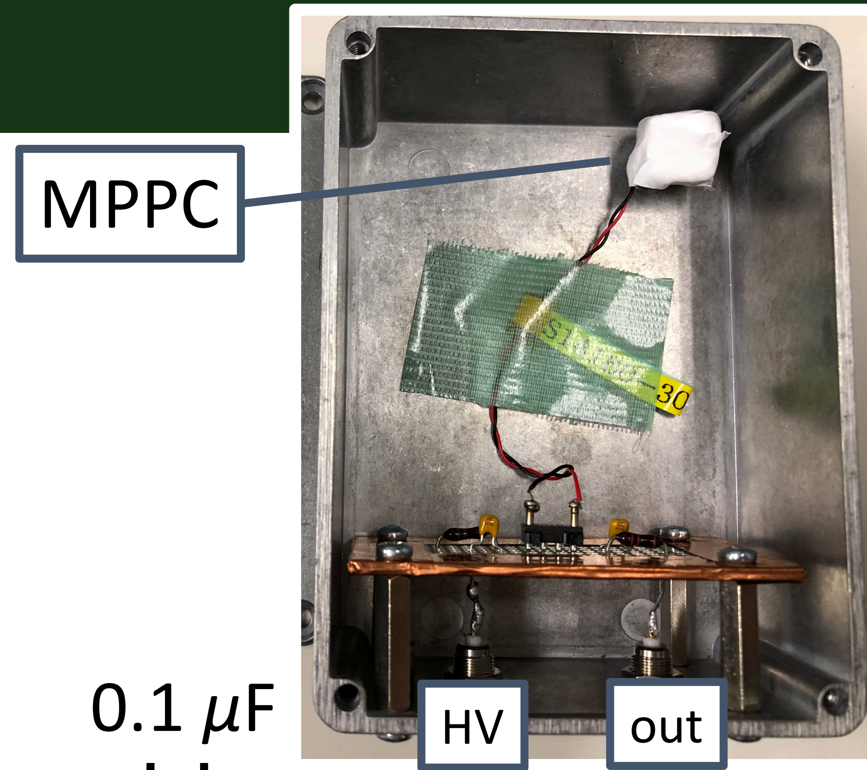
Recommended voltage per MPPC and best voltage after irradiation

	Recommended	best voltage after 1k irraditation (+20℃)	best voltage after 1k irraditation (-30℃)
current A	43.0 V	40.0 V	38.5 V
current B	41.0 V	40.0 V	38.5 V
modified A	47.5 V	45.0 V	42.0 V
modified B	42.5 V	41.0 V	39.5 V

Backup

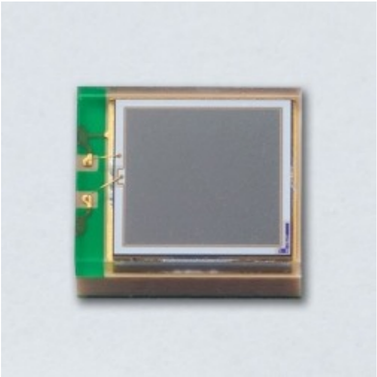
circuit diagram



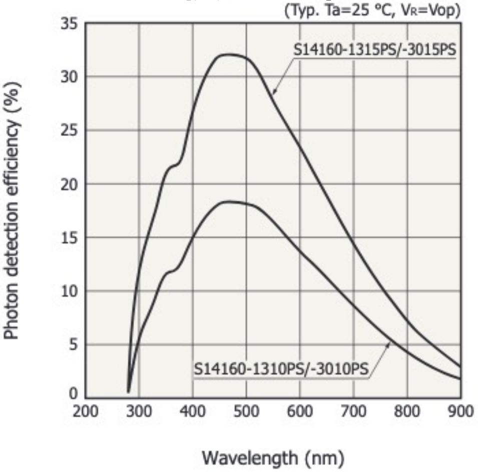


Backup

14160-3015HS (current model A)



検出効率

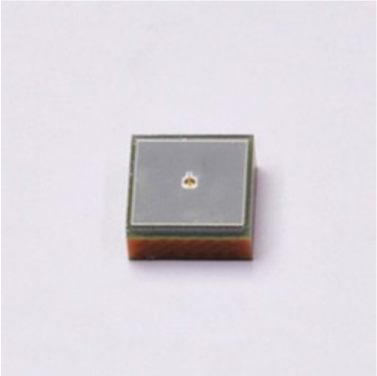


パッケージタイプ	表面実装型
チャンネル数	1 ch
有効受光面サイズ/ch	3 × 3 mm
ピクセル数/ch	89984
ピクセルサイズ	10 μm
感度波長範囲	290～900 nm
最大感度波長 typ.	460 nm
ダークカウント/ch typ.	700 kcps
端子間容量/ch typ.	530 pF
増倍率 typ.	1.8×10^5
測定条件	Ta=25 ℃

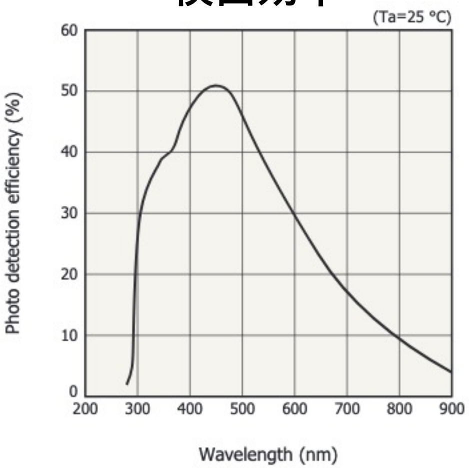
浜松ホトニクス: 製品情報
https://www.hamamatsu.com/jp/ja/product/type/S14160-3015HS/index.html

Backup

14160-3050HS (current B)



検出効率



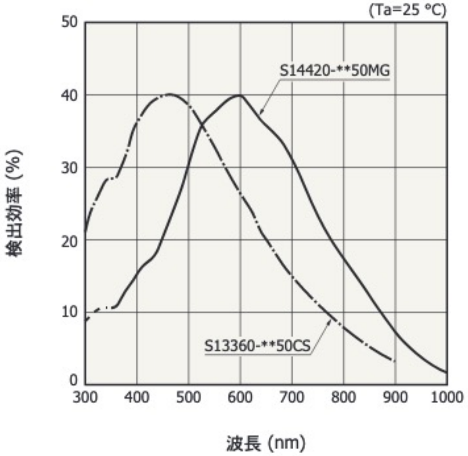
パッケージタイプ	表面実装型
チャンネル数	1 ch
有効受光面サイズ/ch	3 × 3 mm
ピクセル数/ch	3531
ピクセルサイズ	50 μm
感度波長範囲	270～900 nm
最大感度波長 typ.	450 nm
端子間容量/ch typ.	900 pF
増倍率 typ.	2.5×10^{6}
測定条件	Ta=25 ℃

浜松ホトニクス: 製品情報
https://www.hamamatsu.com/jp/ja/product/type/S14160-3050PS/index.html

Backup

14420-3050MG (新型 Aの改良前)

検出効率



パッケージタイプ	メタル (TO-5)
チャンネル数	1 ch
有効受光面サイズ/ch	ϕ 3.0 mm
ピクセル数/ch	2836
ピクセルサイズ	50 μm
感度波長範囲	350～1000 nm
最大感度波長 typ.	600 nm
ダークカウント/ch typ.	1600 kcps
端子間容量/ch typ.	350 pF
増倍率 typ.	3.6×10^6
測定条件	Ta=25 ℃

浜松ホトニクス: 製品情報
https://www.hamamatsu.com/jp/ja/product/type/S14420-3050MG/index.html