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Latest MPPC development from Hamamatsu

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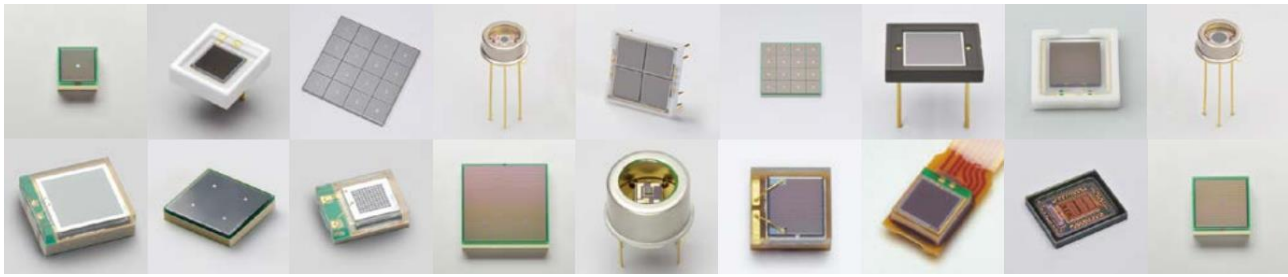
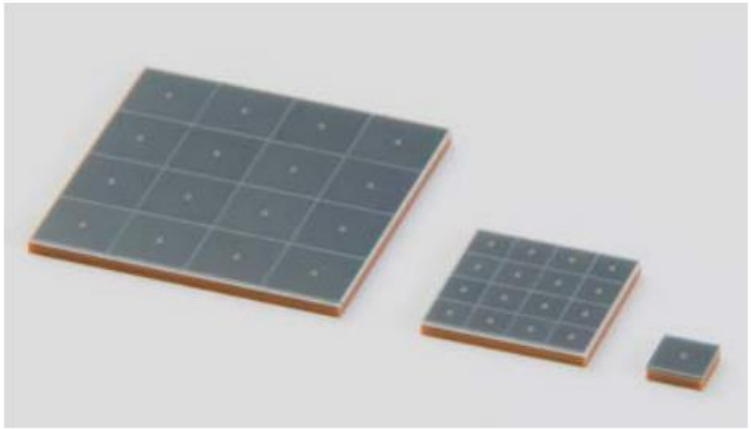
Development of VIS(Blue)-MPPC

MPPC®

Multi-Pixel Photon Counter



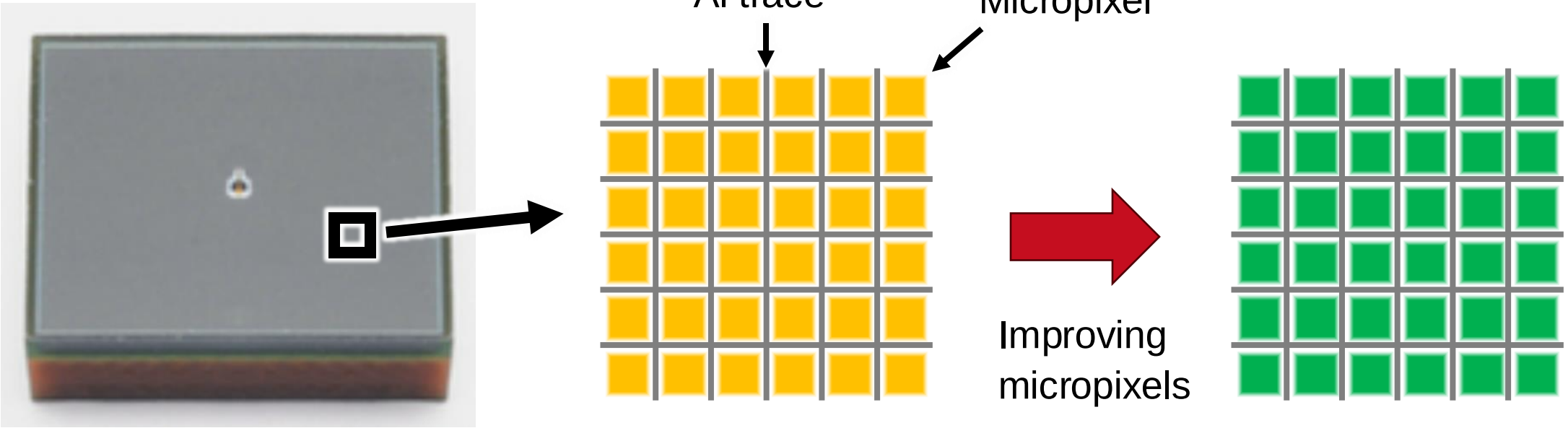
S14160 / S14161 series



Next generation MPPC

- ✓ Higher PDE
- ✓ Lower dark noise

The structure of the latest developed MPPC



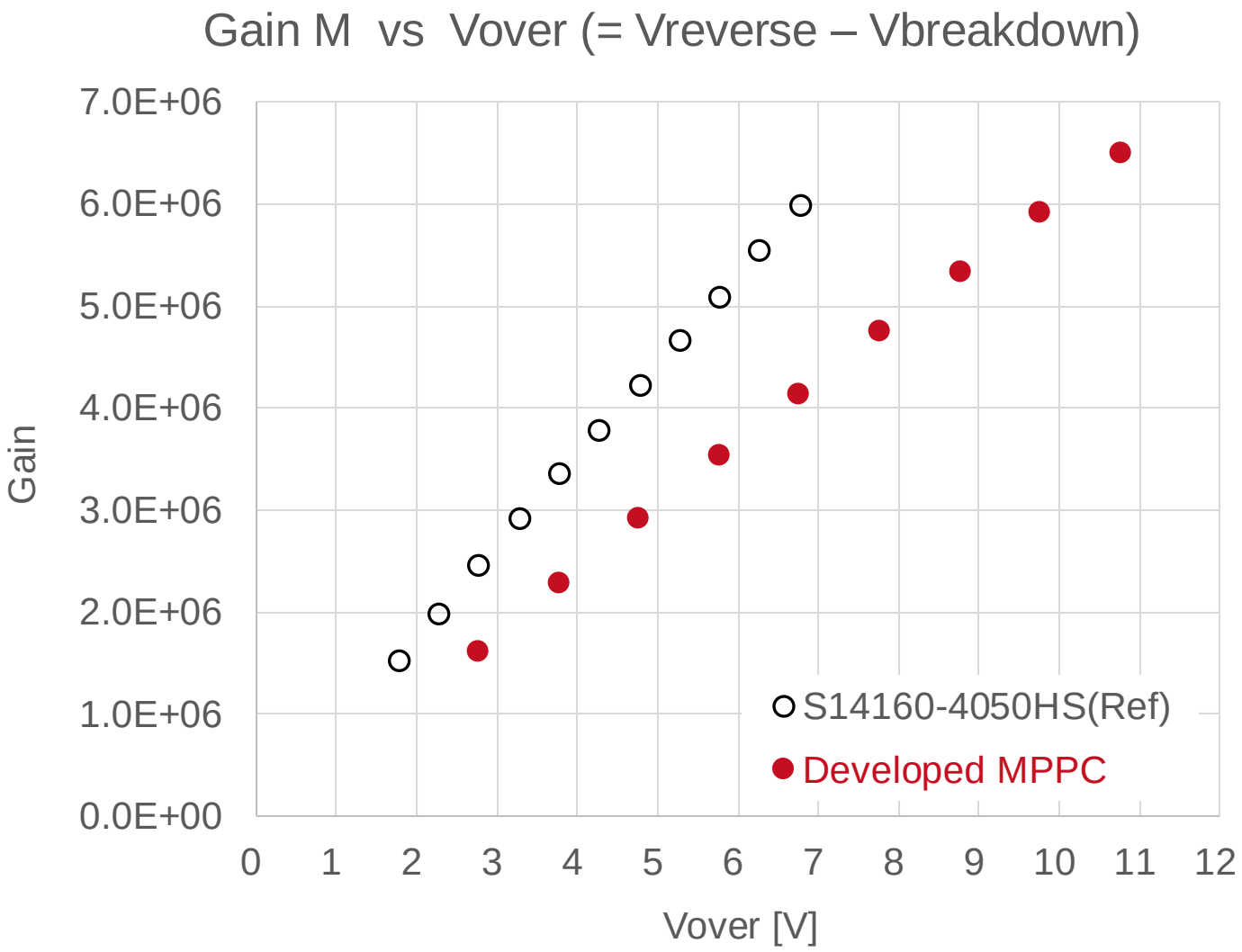
Samples used in this report

S14160-4050HS(Ref) : HWB-MPPC, Sensitive area 4mm sq., Pixel pitch 50μm

Developed MPPC : HWB-MPPC, Sensitive area 3.7mm sq., Pixel pitch 50μm

Characteristics of the developed MPPC (Ta = 25degC)

Gain



Cd+Cq of a micropixel

S14160-4050HS : 142.2fF

Developed MPPC : 97.6fF

dM / dV

S14160-4050HS : 8.9 x10^5

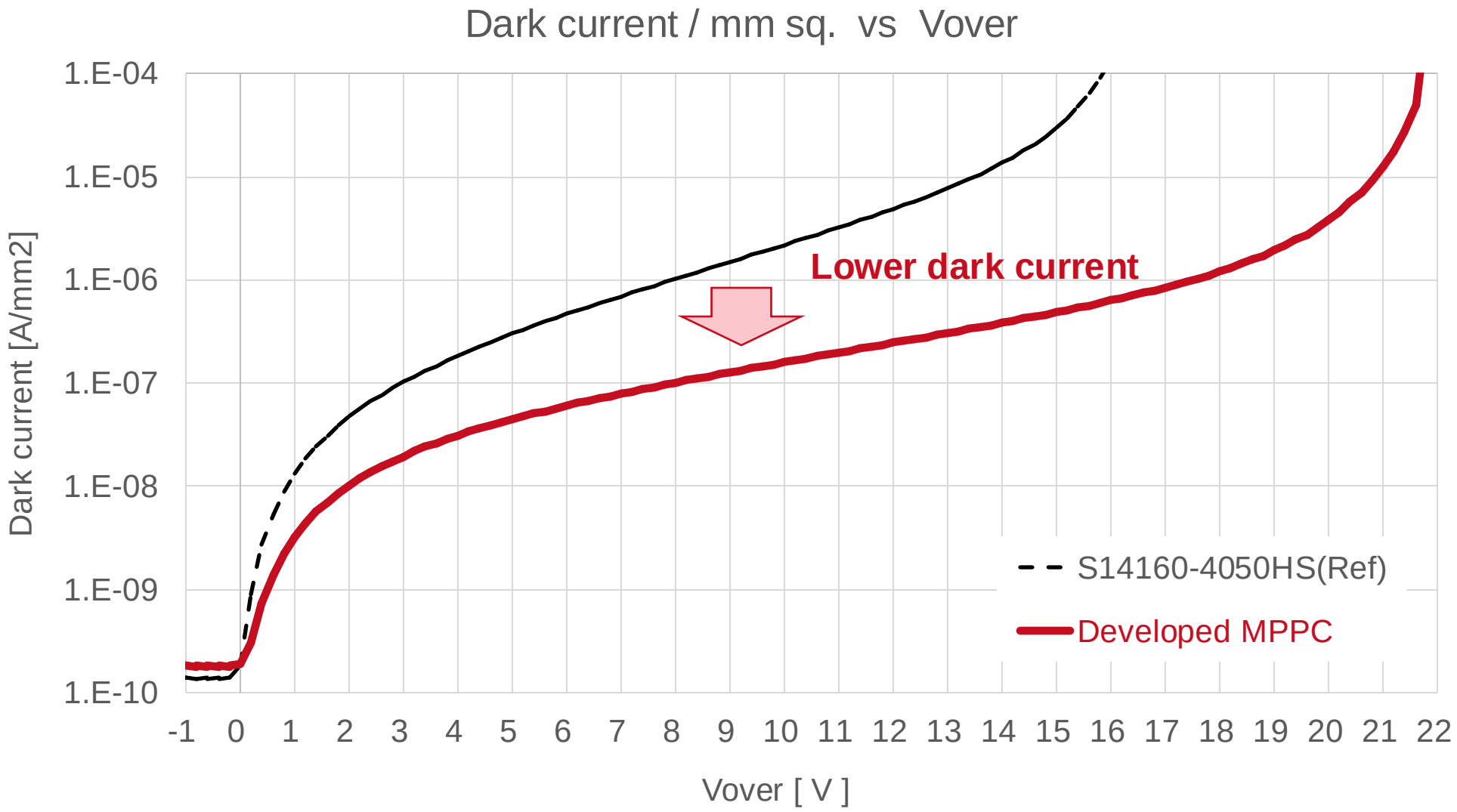
Developed MPPC : 6.1 x10^5

Vbreakdown

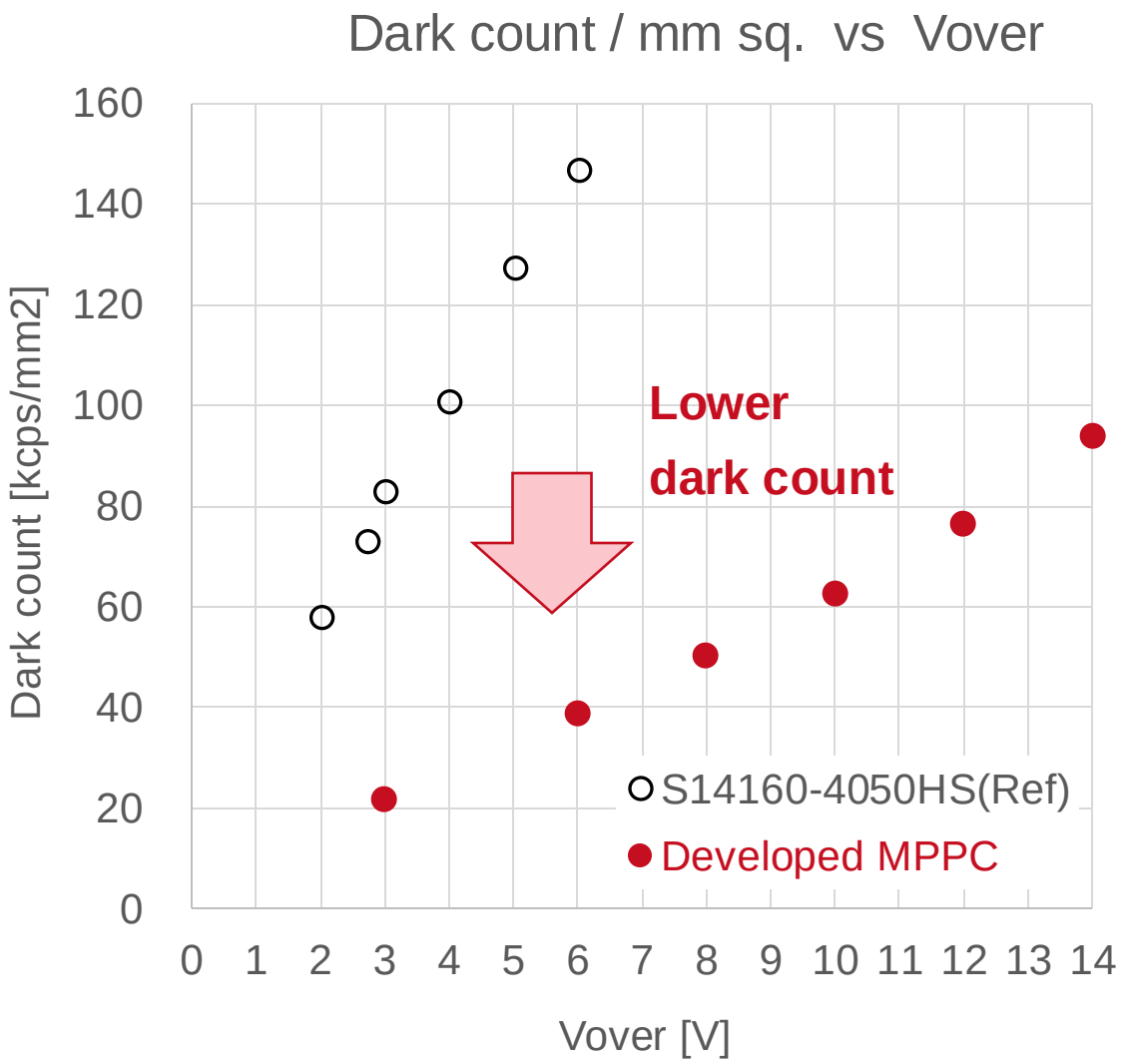
S14160-4050HS : 38.4V

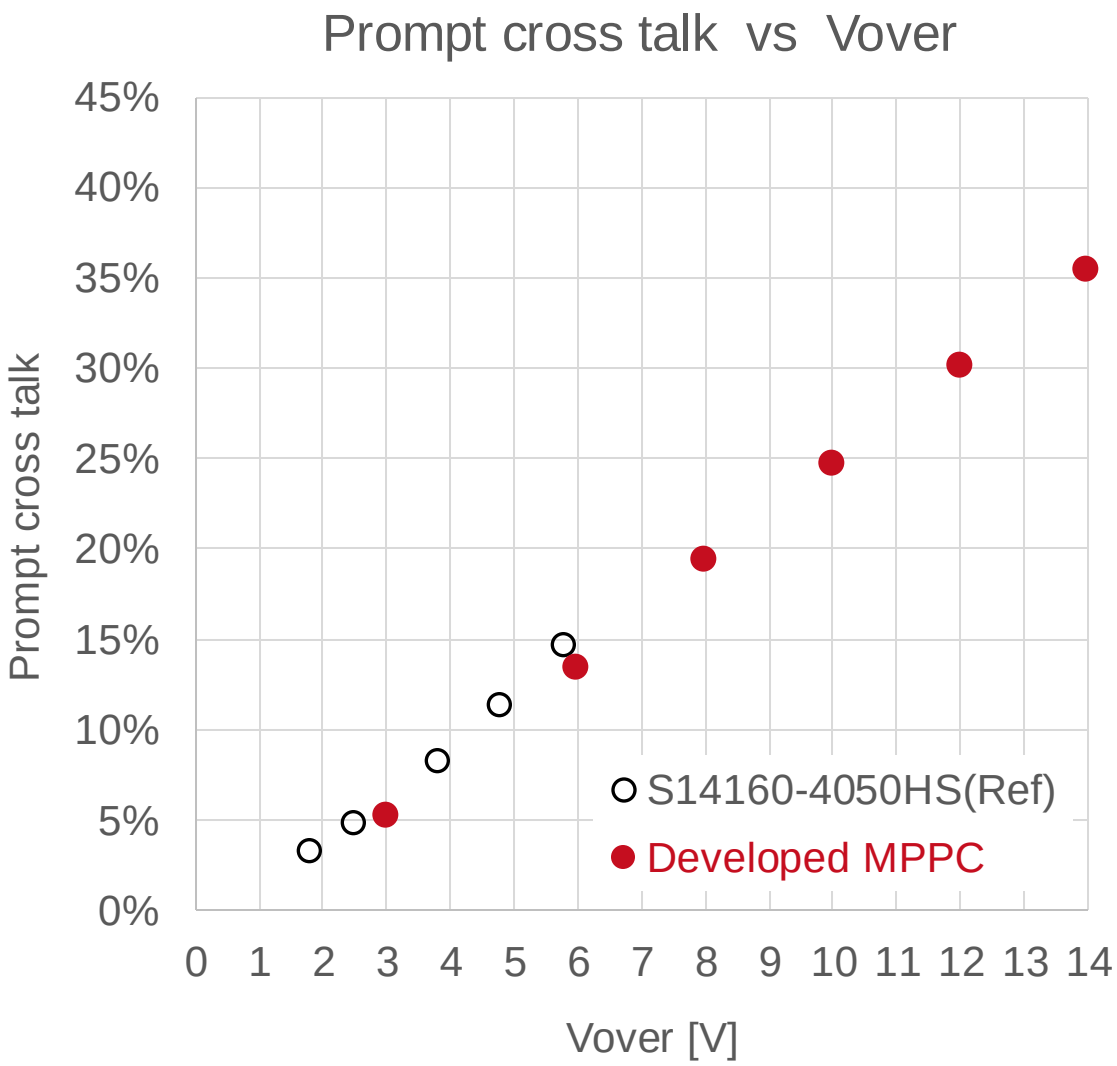
Developed MPPC : 51.3V

Dark current

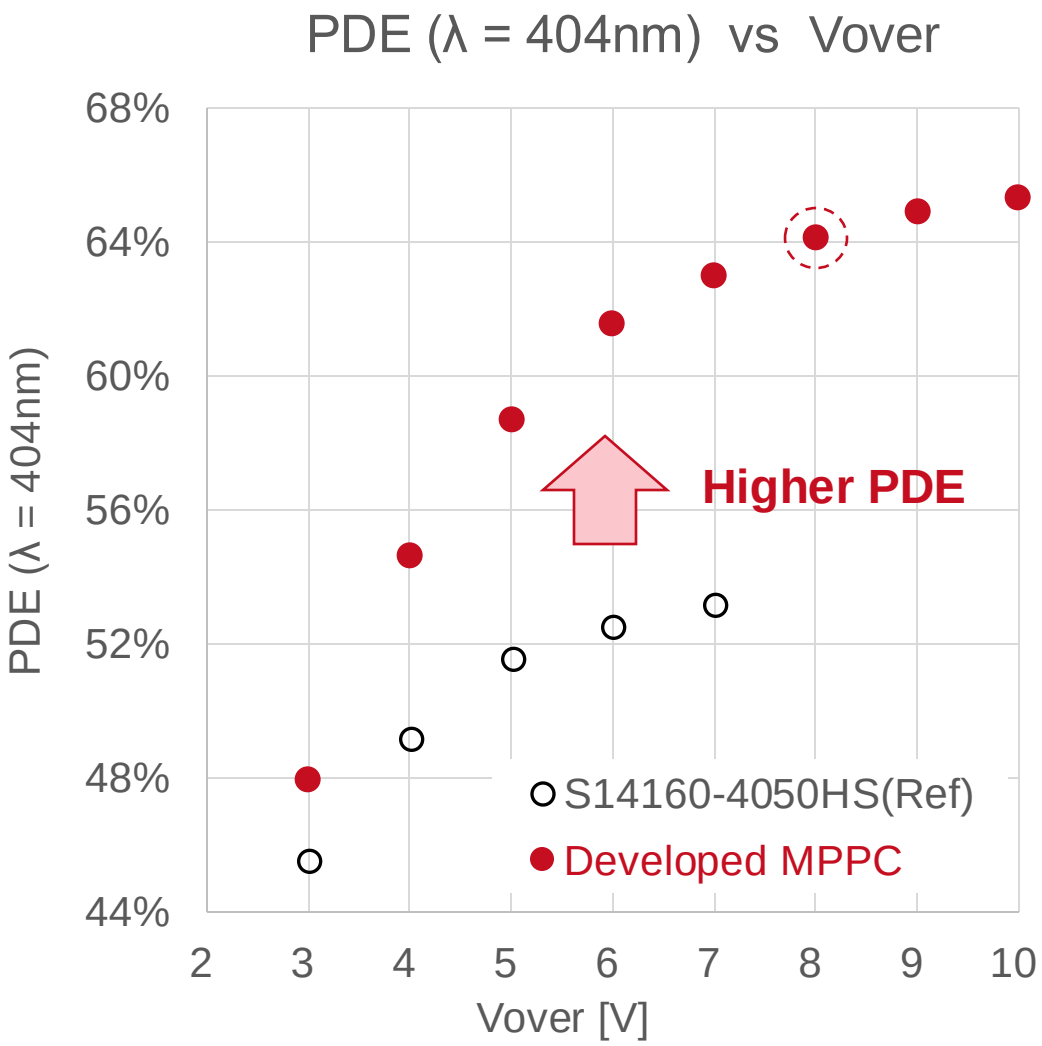


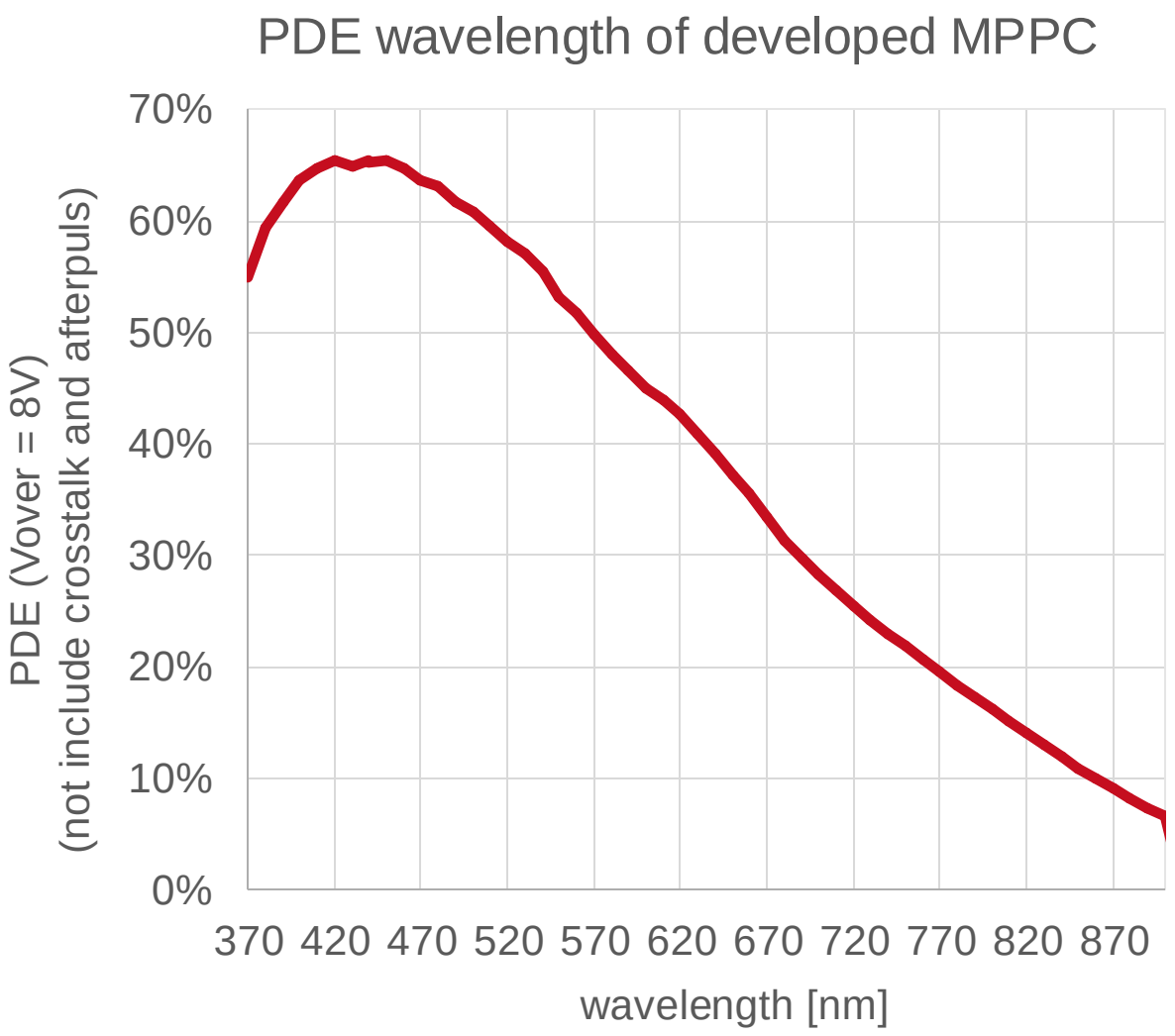
Dark count and Cross talk





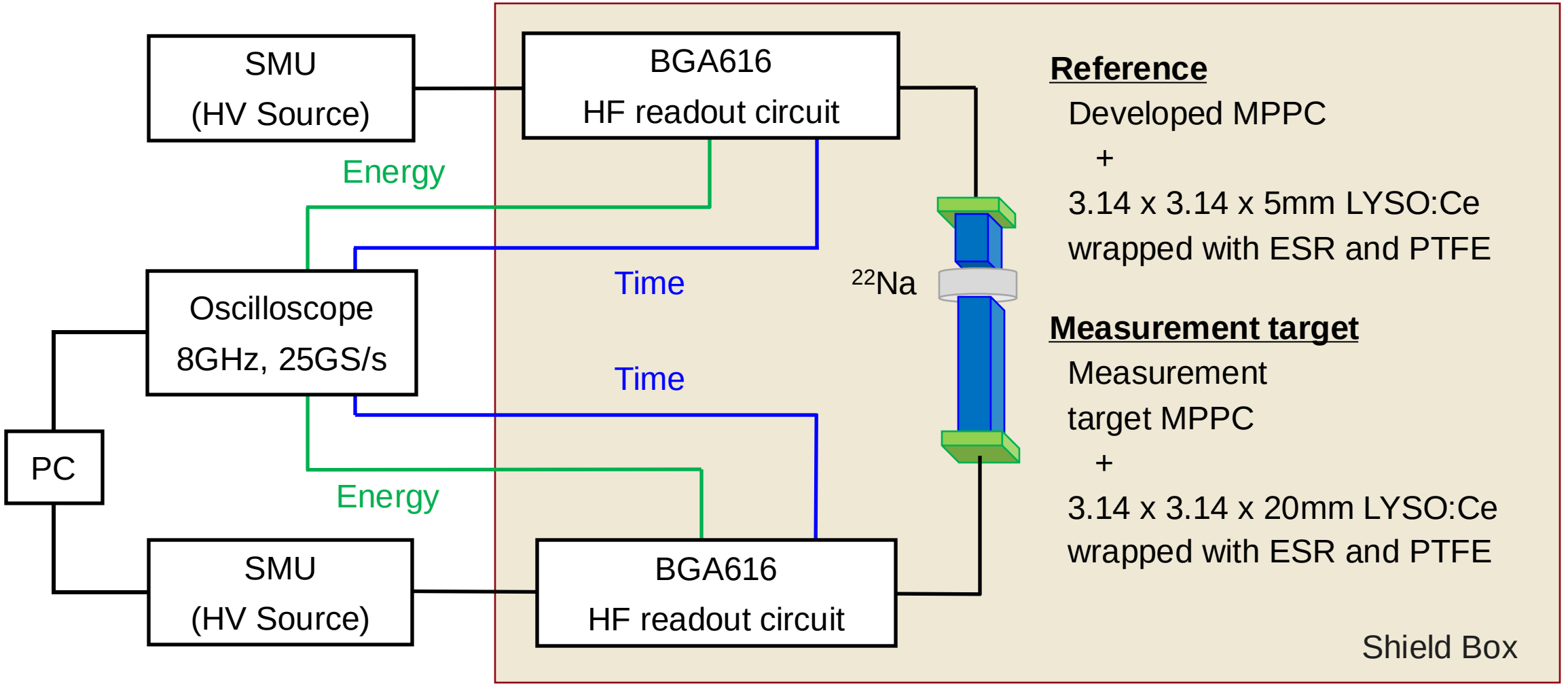
PDE at λ = 404nm , PDE wavelength



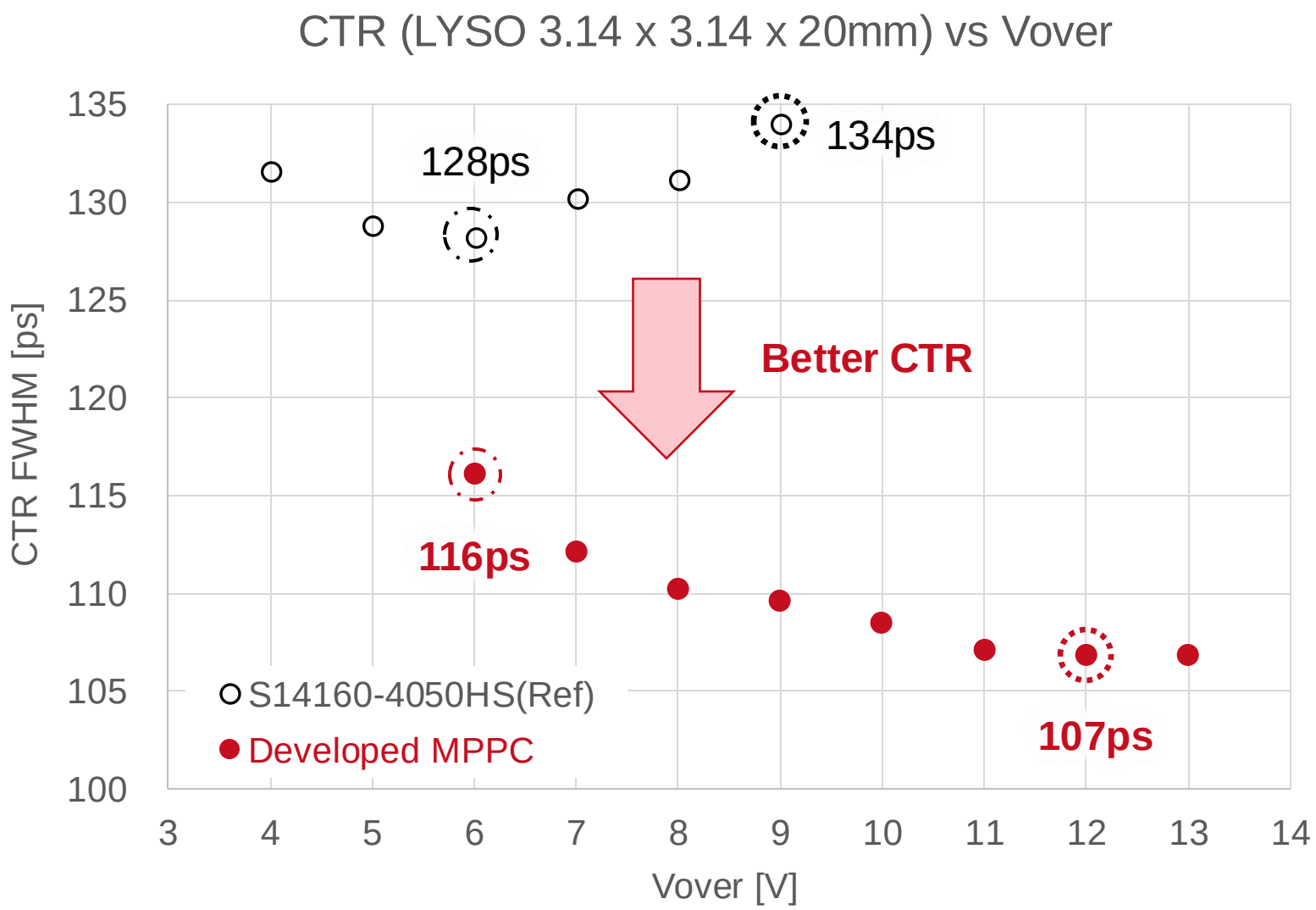


CTR of the developed MPPC (Ta = 25degC)

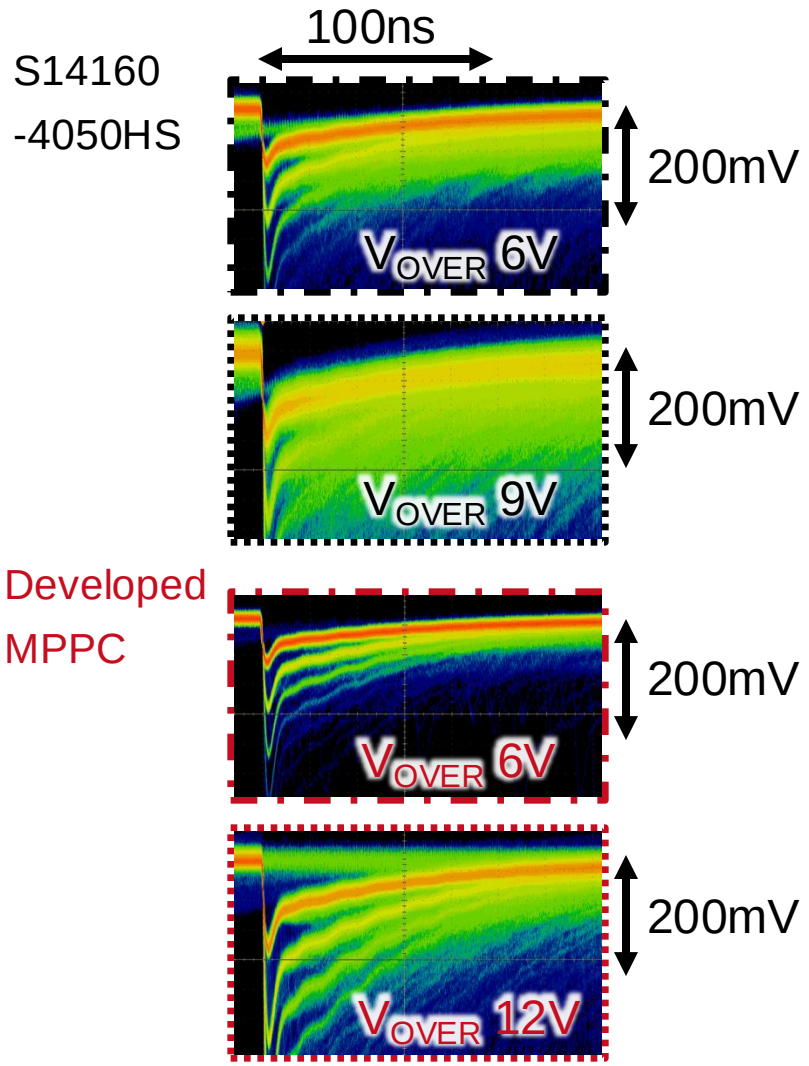
CTR measurement setup



CTR



Superimposed dark pulse



PDE, DCR and Timing charactaristics

(Ta = 25degC, n = 1)

Sample type	**S14160 -4050HS**	**Latest developed MPPC**	
Vover [V]	**6**	**6**	**12**
Cd+Cq [fF]	142.2	97.6	
dM / dV	8.9 x10^5	6.1 x10^5	
Vbreakdown [V]	38.4	51.3	
Gain	5.3 x10^6	3.7 x10^6	7.3 x10^6
Dark current [nA/mm sq.]	467	**61**	**246**
Dark count [kcps/mm sq.]	147	**39**	**77**
Prompt cross talk [%]	14.8	13.5	30.2
PDE at 404nm [%]	53	**61.5**	**65.3**
CTR FWHM w/ LYSO 3.14x3.14x20mm [ps]	128	**116**	**107**

- We successfully developed MPPC with **lower dark noise** and **higher PDE**.
- This new MPPC achieved **nearly 100ps CTR** with the high-speed scintillator.

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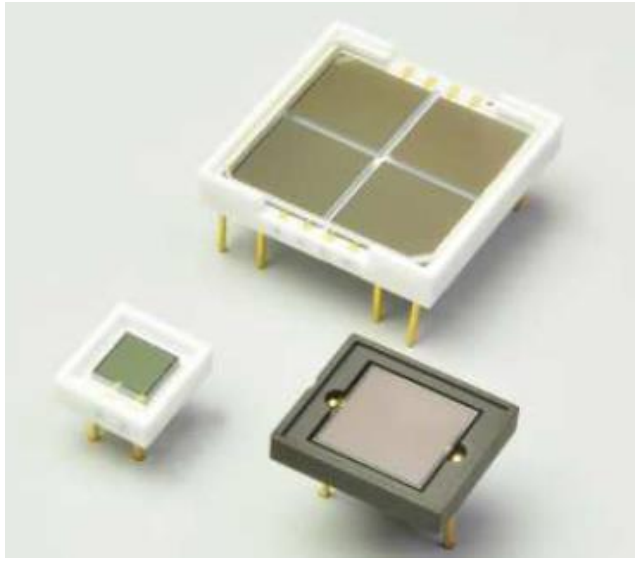
Development of VUV-MPPC (VUV5)

Strategy for VUV5 development

VUV4 (S13370 series) → Next generation: VUV5



Strategies for characteristic improvement

- 1st step: DCR suppression
- 2nd step: PDE improvement

- Initially, a structure is developed to reduce the DCR.
  Significant structure changes are required for DCR suppression.
- The next step is optimization to improve sensitivity.

1st step: DCR suppression

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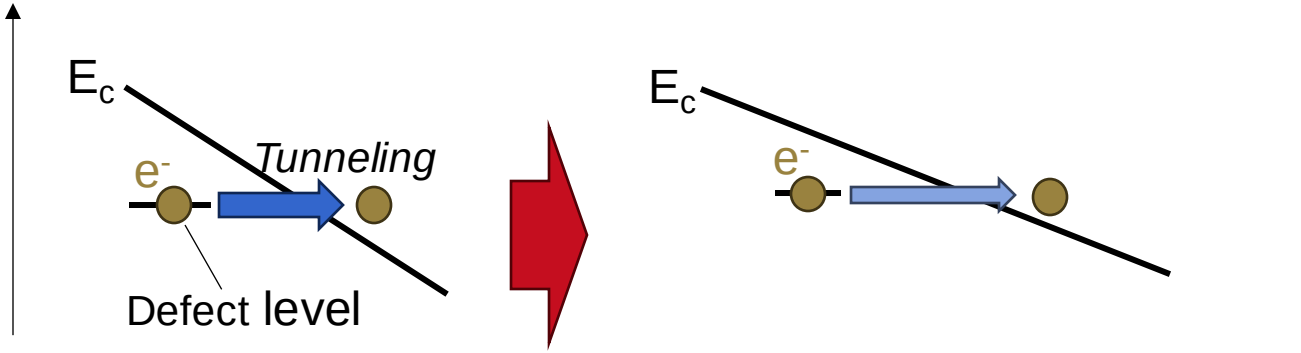
Target of Dark Count Rate (DCR): below 0.01 cps/mm^2 at LXe temp.
(comparable to Photomultiplier Tube's DCR)

- DCR is related to the electrical field in the avalanche layer, especially at lower temperature.

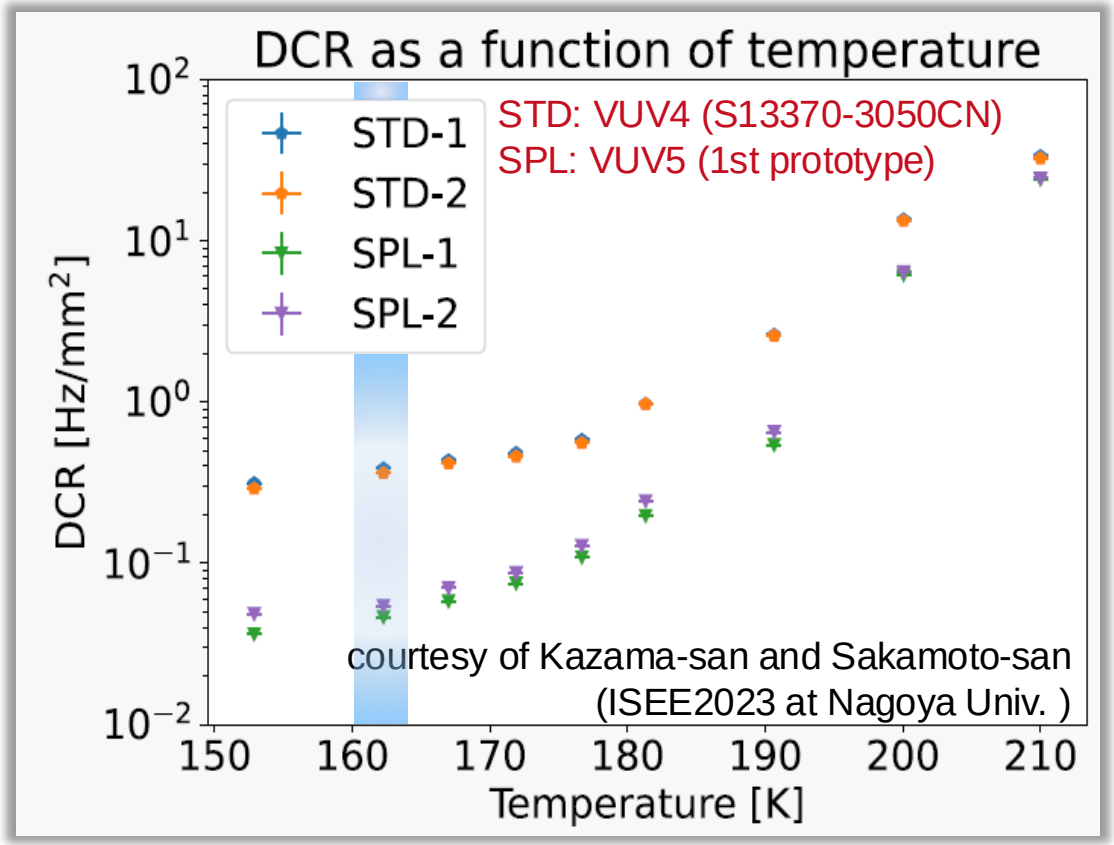
  = The lower electrical field, the lower DCR.

- DCR of VUV5 (1st prototype) is reduced to 1/10 from VUV4 LXe temperature.(About 0.05cps/mm^2)
- The 2nd prototyping is on going for more improvement.



Standard structure

Lower electric field structure
= Smaller tunnelling probability

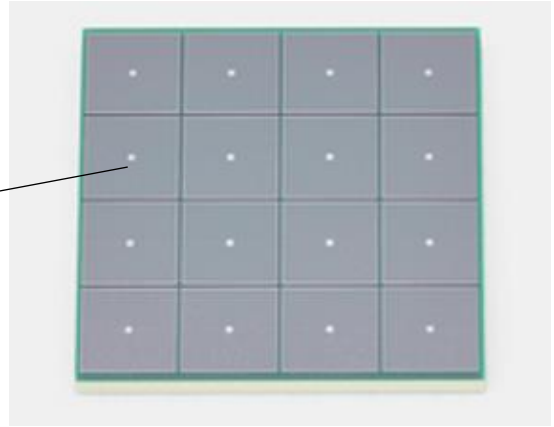


2nd step: PDE improvement

- It is expected to improve characteristics using the same method as VIS-MPPC.

- Target of PDE(*75um cell size, Typ. value*):
  λ = 125 nm : **30 %** *(ref. VUV4: 25 %)*
  λ = 175 nm : **35 %** *(ref. VUV4: 30 %)*

- TSV(Through Silicon Via) structure can improve the geometrical fill-factor.
  (VUV-MPPC with TSV technology has been developed.)

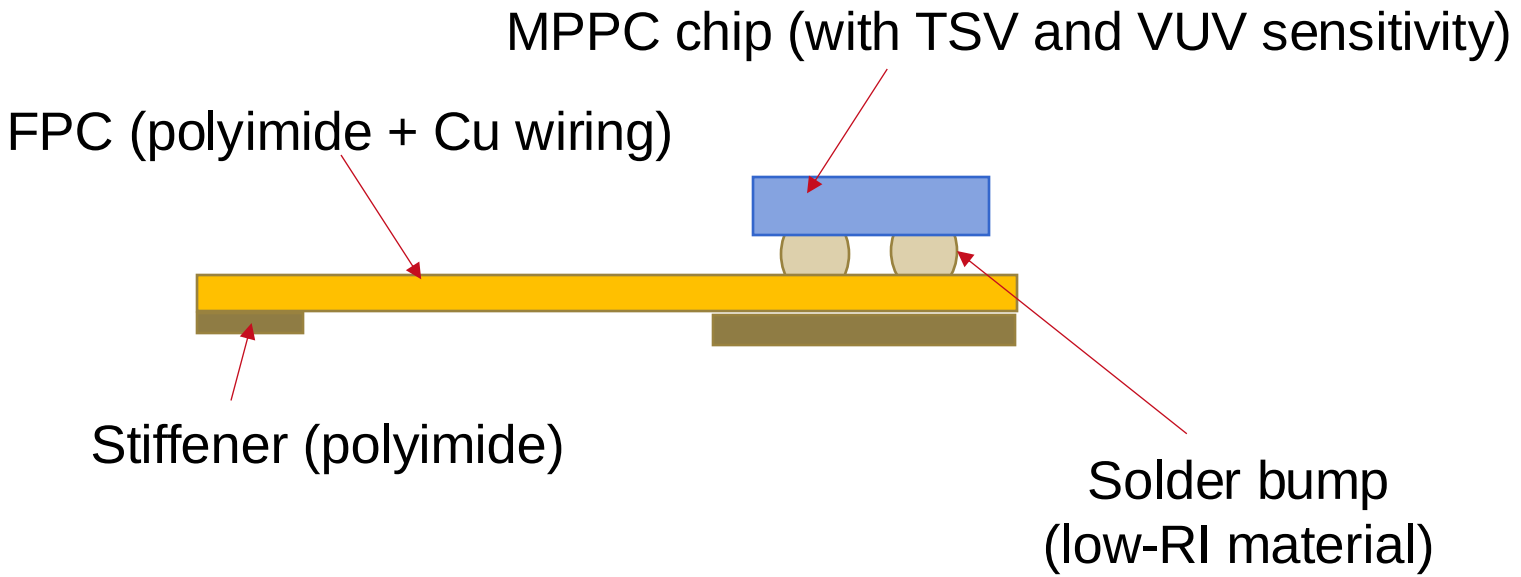


MPPC array with TSV structure

Low-RI MPPC

- MPPC for Dark matter search and neutrino(0vββ) experiments need limited radioisotope content of material mass.
- We are developing Chip on Film(CoF) MPPCs that are lightweight and can be made by low radioisotope materials(mainly polyimide).
- Suitable for mass production because of using print circuit technology.

Prototype : Single channel



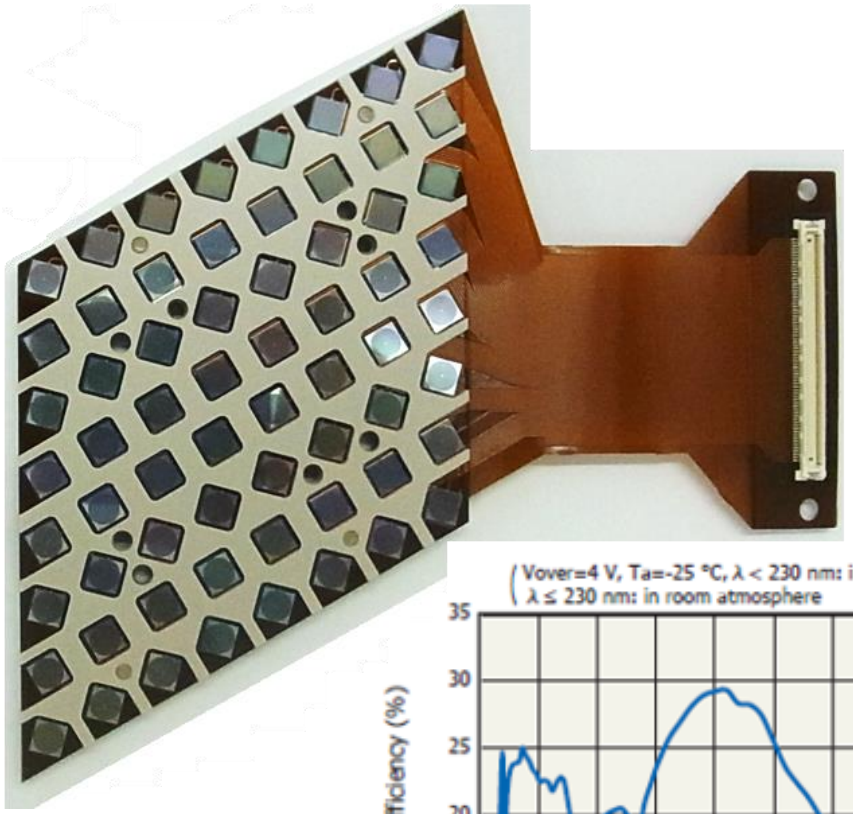
Low-RI MPPC array

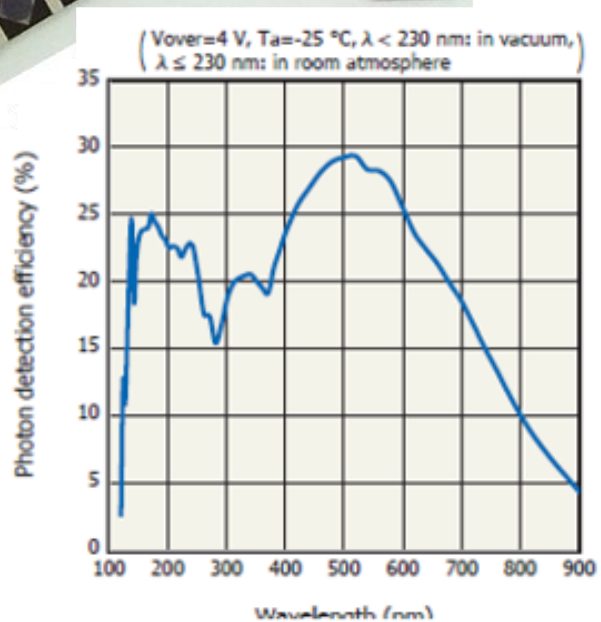
Customized VUV-MPPC array for the AXEL group

- AXEL : Neutrinoless double beta decay search with high pressure Xenon gas TPC.
- Customized MPPC chip based on the S13370 series (cell pitch 50μm, TSV type, 64 ch.)
- Low RI materials used in the package of this MPPC array (FPC substrate: Polyimide, Stiffener: PEEK)

- *RI-level is not measured.*
- FPC material and process do not care about the RI. We need to optimize the material and process.
- A reference work on FPC RI:

  *Arnquist, I.J. et al., EPJ Techn Instrum **10**, 17 (2023).*





Summary

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- Next generation MPPCs are under development. (VIS and VUV).
- For VIS-MPPC, significant improvements of the PDE, DCR and timing characteristics are achieved. Reproducibility and reliability verification is ongoing.
- For VUV-MPPC, prototyping is ongoing for more DCR suppression, and ways to improve PDE are being investigated. Development of low-RI package is ongoing.

➢ ***Hamamatsu continues MPPC's enhancement for physics experiments!***

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