UVレーザーで励起したシンチレーション光を用いたMPPCの飽和現象の研究

Study on MPPC saturation using scintillation light excited by UV laser

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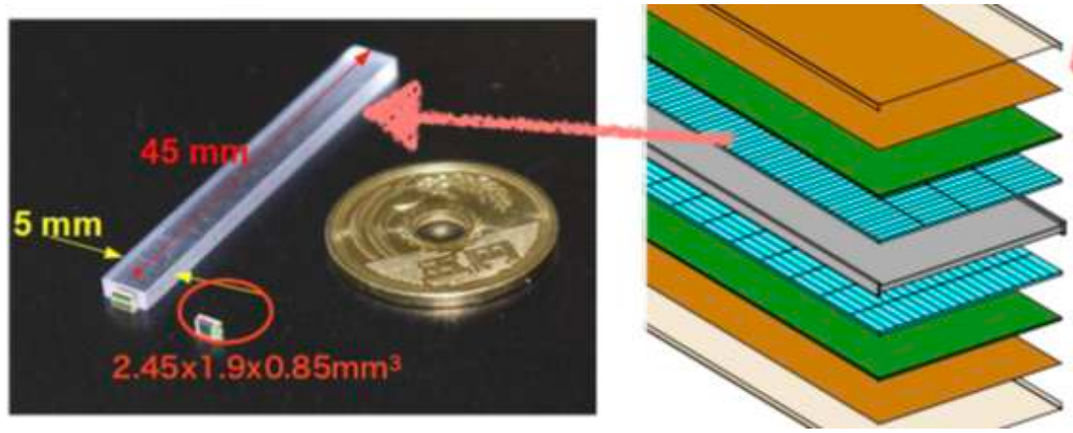
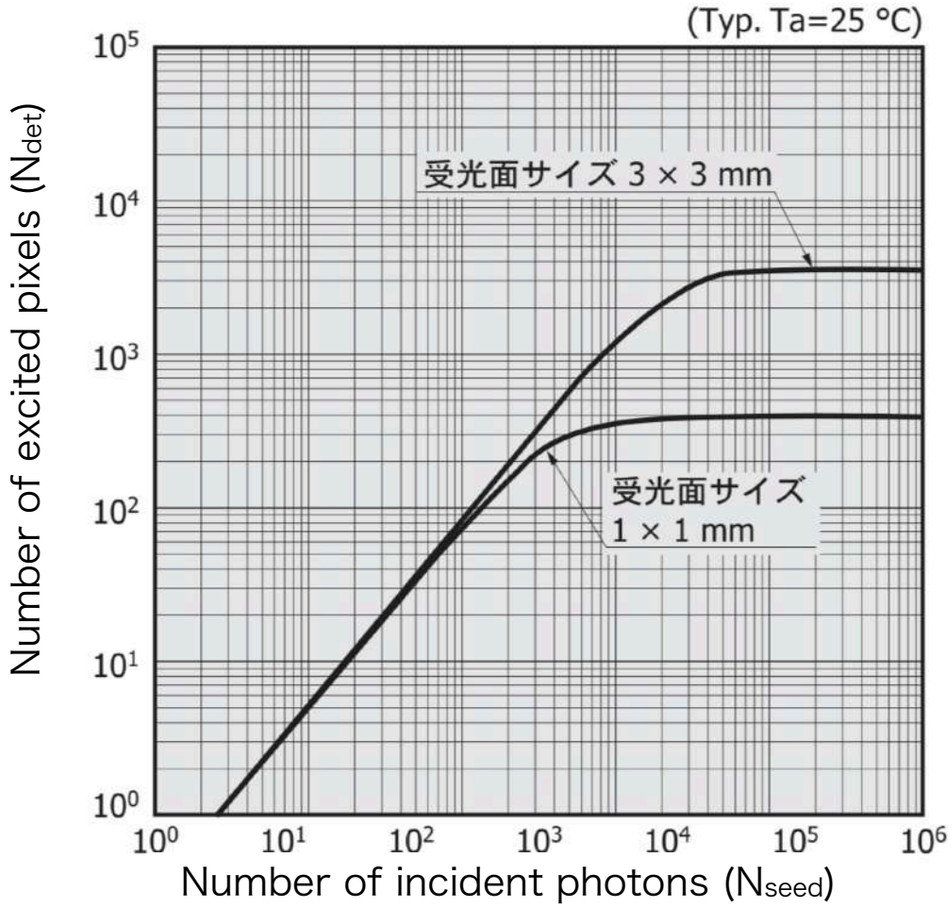
Small-pixel MPPC for Sc-ECAL

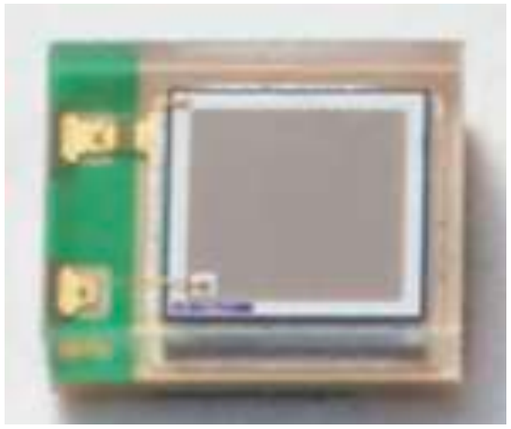
- Sc-ECAL
  - Based on scintillator strips readout by MPPC
  - Virtual segmentation : 5mm × 5mm with strips in x-y configuration
- MPPC saturation
  - When large number of photons inserted to MPPC, MPPC cannot detect whole of them and saturate.
  - Linearity (N_{seed} vs. N_{det}) becomes worse at the region of larger light yield
- Large dynamic range is required for MPPC
  - To measure small and dense EM shower
- Small-pixel MPPC is suggested
  - 10μm - 15μm pitch





Hamamatsu Photonics K.K.,
Opto-semiconductor Handbook

MPPCs for ECAL

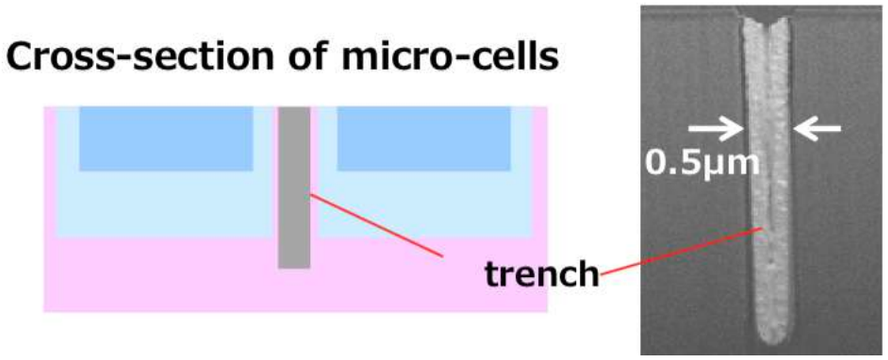


- Standard MPPC for Sc-ECAL : Hamamatsu MPPC S12571 series
  - Small pixel size : 10/15 μm
  - Breakdown voltage : 65 V
  - No Trench isolation
- New MPPC : Hamamatsu MPPC S14160 series
  - Small pixel size : 10/15 μm
  - Breakdown voltage : 38 V
  - 0.5 μm trench isolation
    - Low crosstalk

Crosstalk : The excited pixel may affect other pixels, making them produce pulses other than output pulses

Trench : Separation between each pixels in order to reduce crosstalk

	S12571	S14160 (Latest)
Breakdown voltage	65 V	38 V
Trench isolation	none	Yes
Trench width	-	~ 0.5 µm
Fill factor	10µm: 33% 15µm: 53%	10µm: 31% 15µm: 49%



Hamamatsu Photonics K. K., PD18

Trench technique of new MPPC

- MPPC S14160 series employ trench technique
  - Low crosstalk
  - Low operation voltage
  - No reduction of fill factor
- Longer tail due to larger cell capacitance
  - Longer recovery time
- Saturation is improved for new MPPC?
  - Low crosstalk → saturation ↓
  - Longer recovery → saturation ↑

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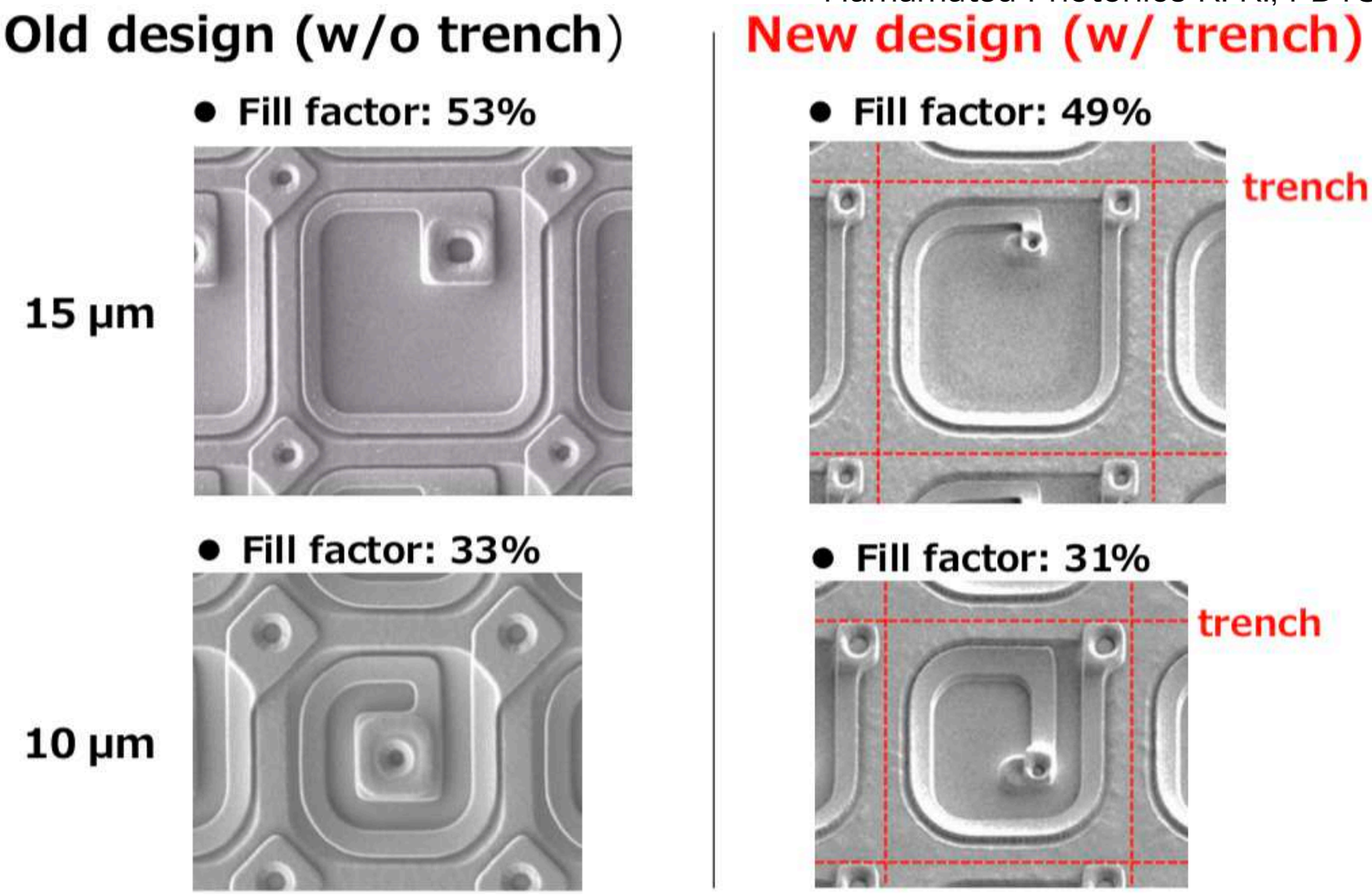
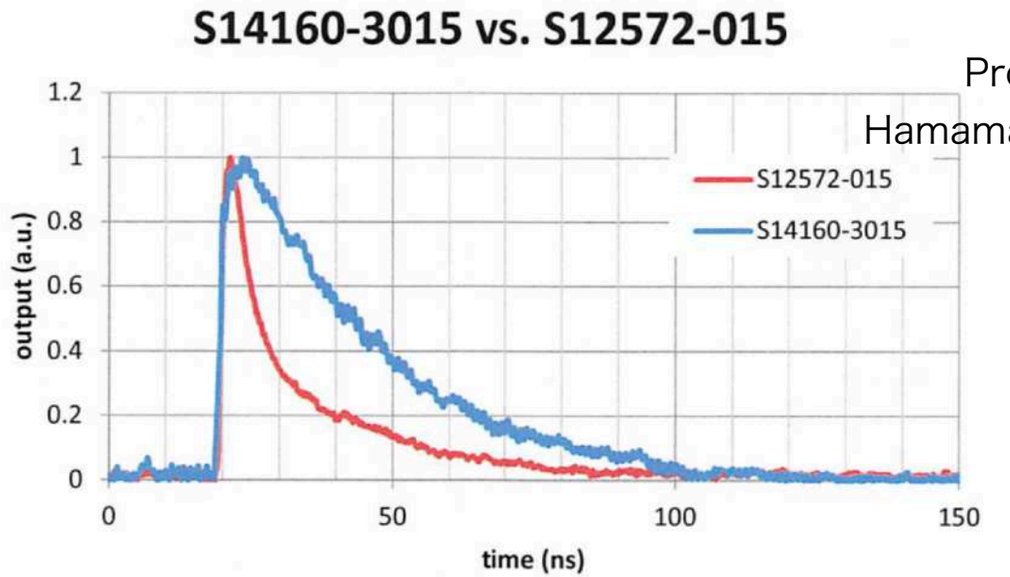




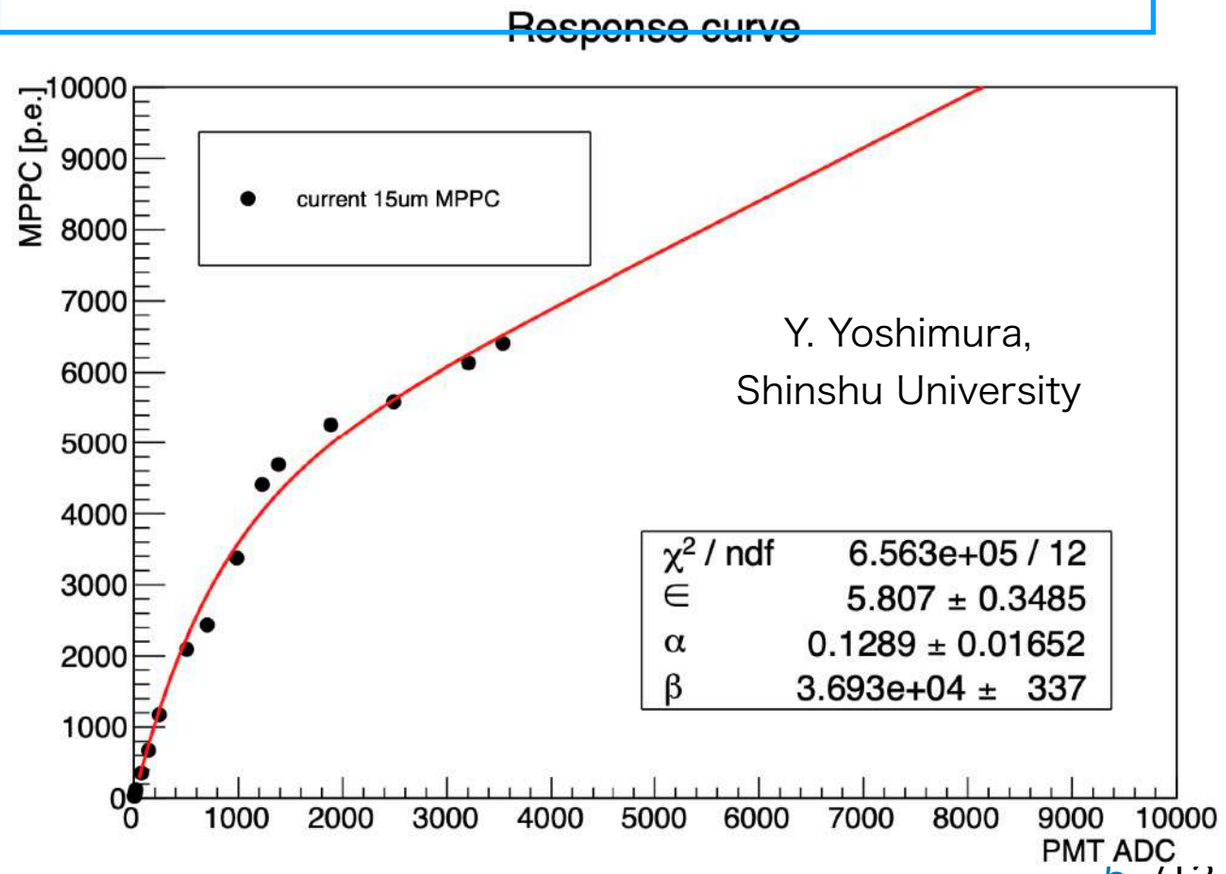
Provided by Hamamatsu Photonics

Saturation of MPPCs

- Standard MPPC : S12571-015P
  - Active area : 1.0 × 1.0 mm
  - Pixel pitch : 15 μm
  - 4489 pixels
- MPPC saturation for S12571-015P was measured in the previous study
  - Directly injecting ps laser with 407 nm wavelength (Y. Yoshimura, Shinshu University)

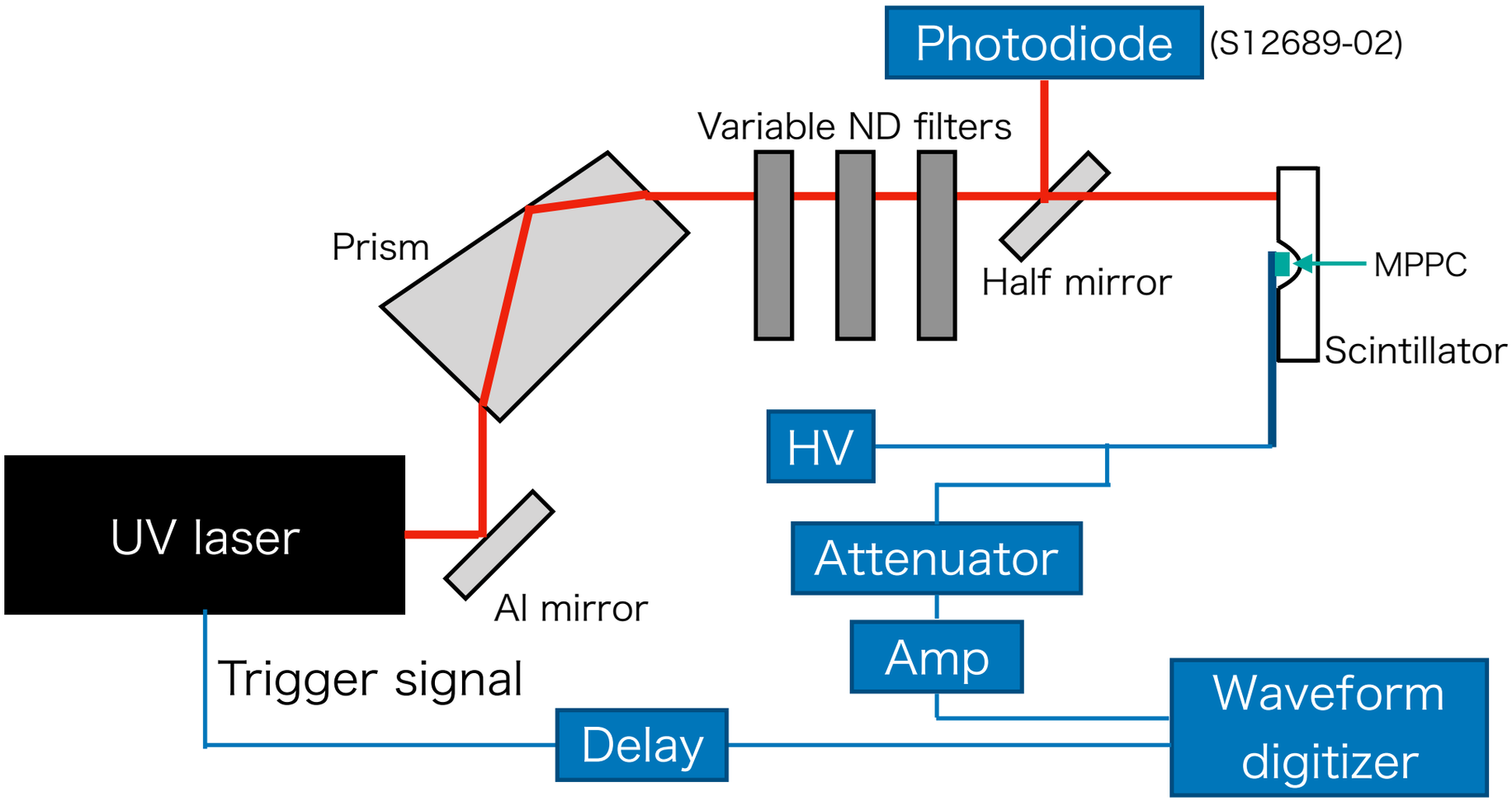
- New MPPC : S14160-1315PS
  - Active area : 1.3 × 1.3 mm
  - Pixel pitch : 15 μm
  - 7296 pixels
- MPPC saturation for S14160-1315PS has not been tested.

- Time constant of emission of scintillation light (few ns) is not negligible compared to recovery time of MPPC cell (dozens ns)
  - Expected smaller saturation
- **Our idea is to measure the MPPC saturation with scintillation light**
  - **The measured saturation curve can directly be used for saturation correction**



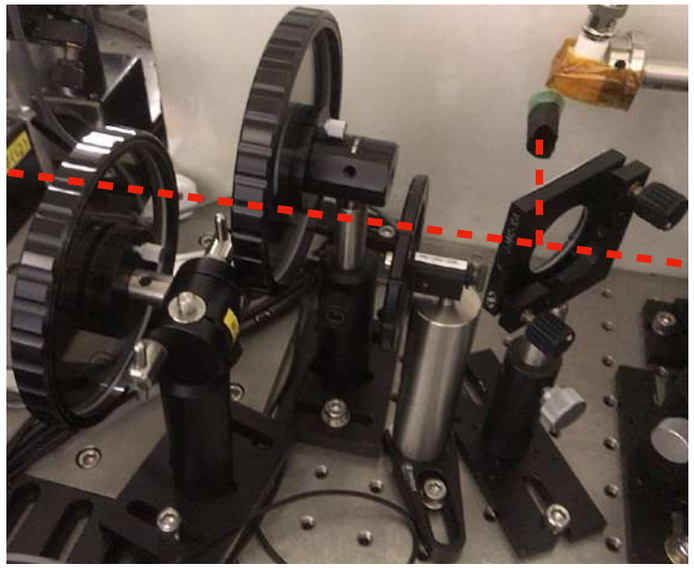
Saturation study with UV laser

- Excite scintillation light with fast fsec UV pulse laser
  - Standard 5 × 45 × 2 mm^3 scintillator strip (EJ-212) with center dimple
  - 190 nm wavelength → invisible to MPPC
  - Signal attenuations (10 - 40 dB) used to avoid saturation of electronics
  - MPPC S12571-015P with over voltage of +5 V (Recommended voltage by Hamamatsu)
  - MPPC S14160-1315PS with over voltage of +5 V (〃)
  - Incident light intensity is monitored with photodiode



Experiment setup

Incident light intensity controlled with three ND filters

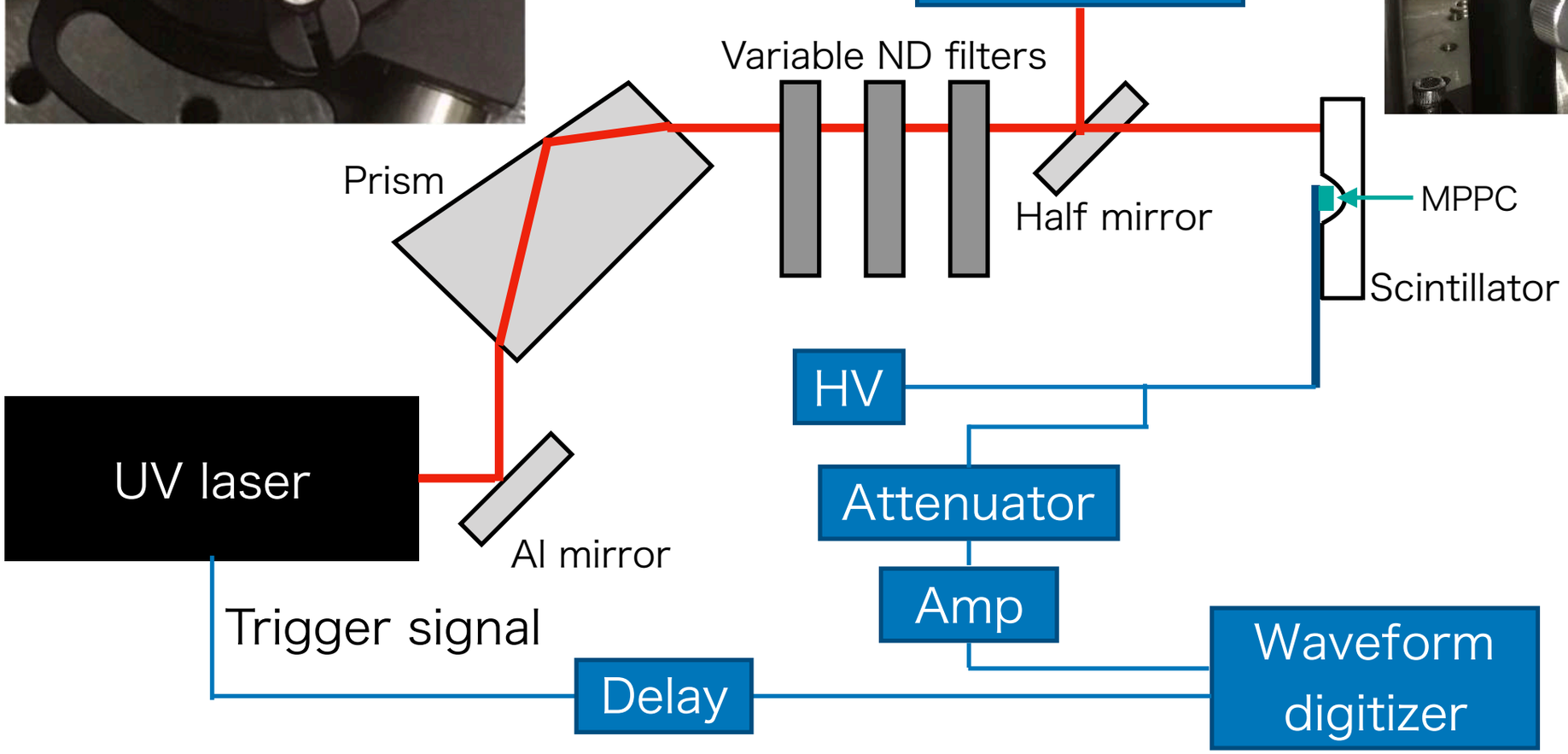


Cut off contamination
of other wavelength light

Laser Light is
split using
half mirror

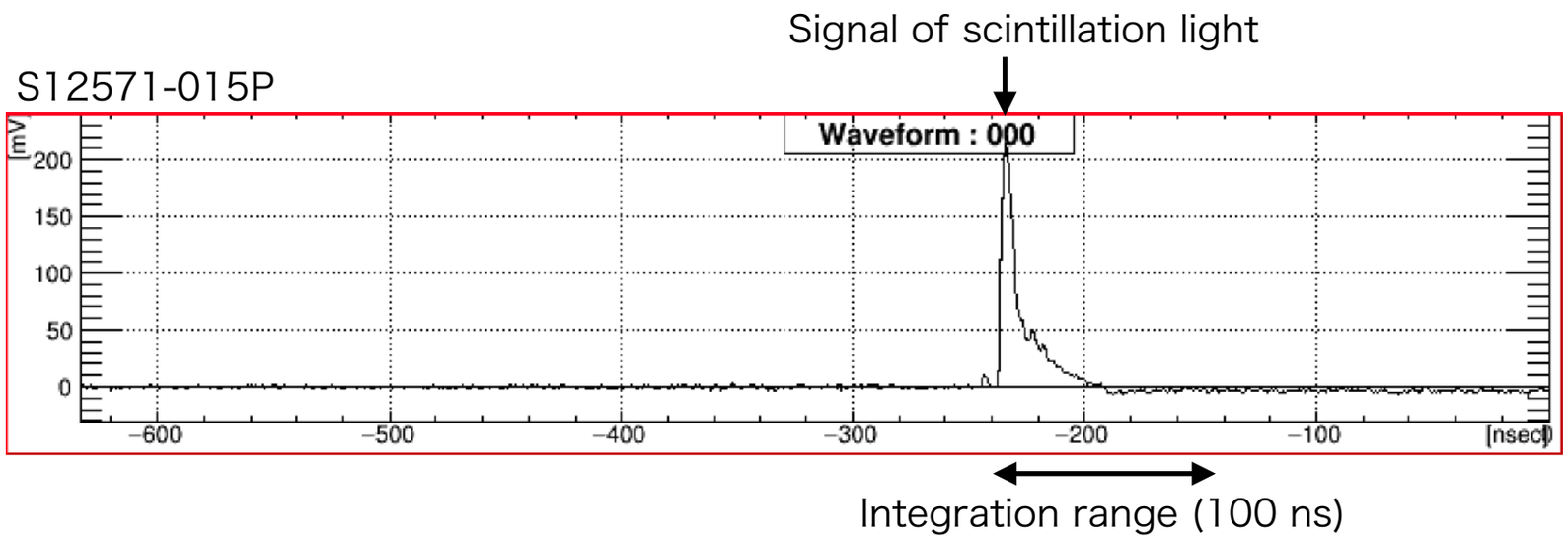
Photodiode

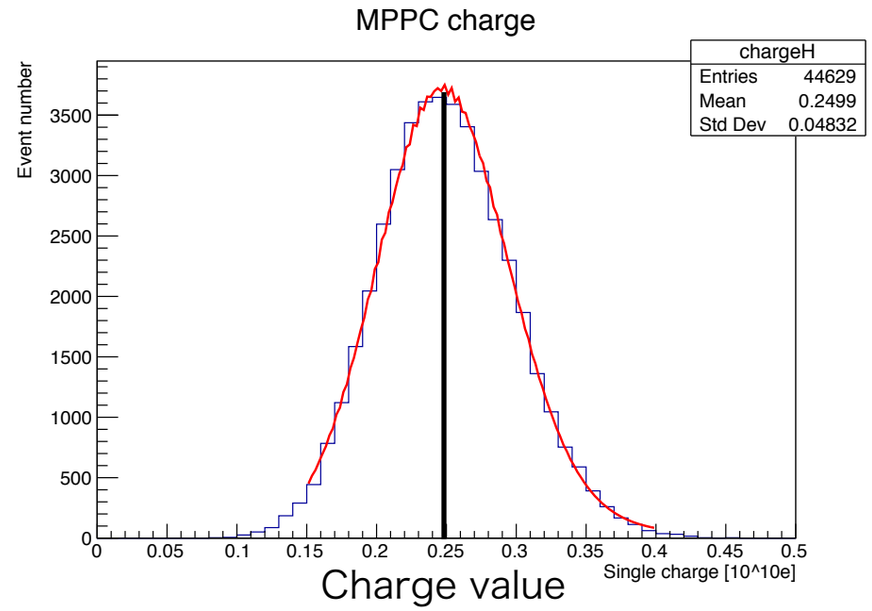
Scintillator
& PCB

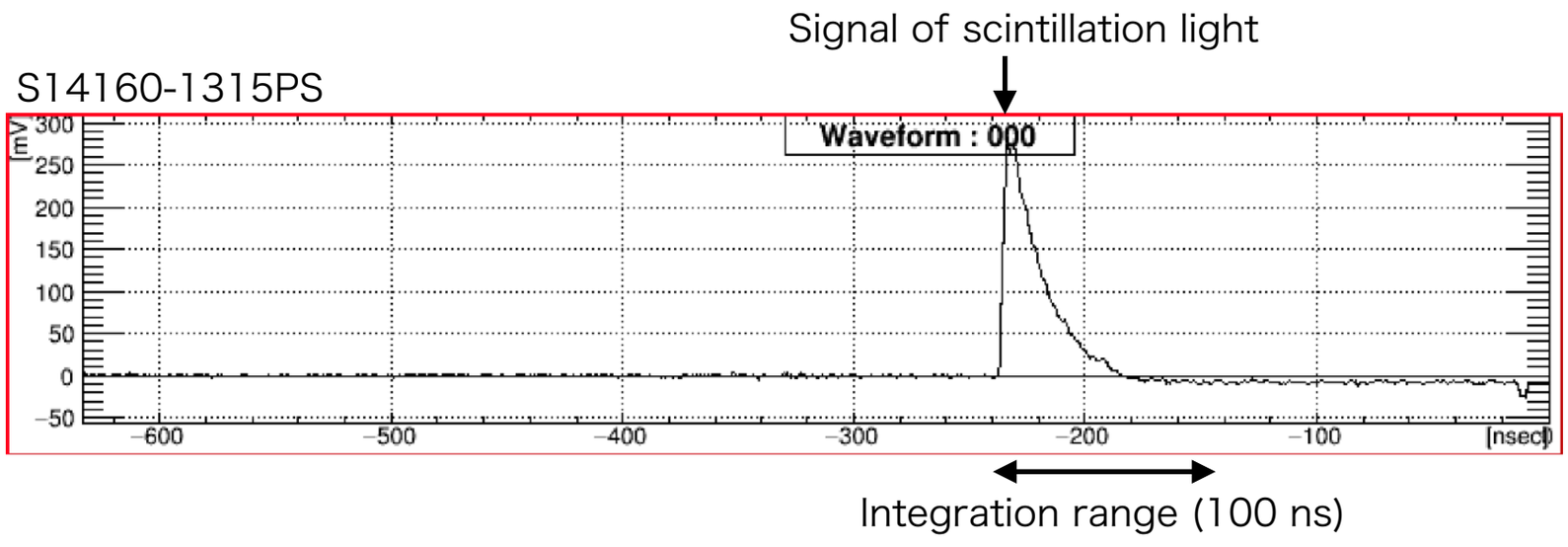


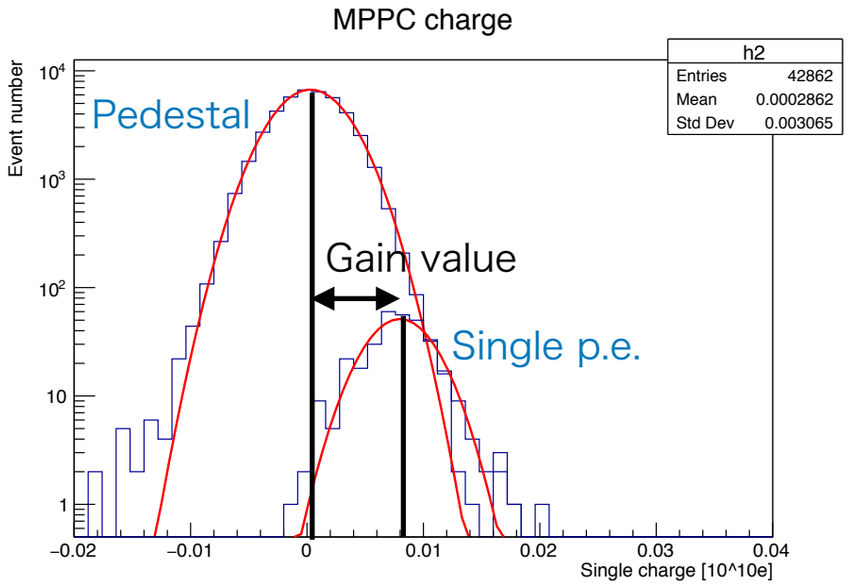
Analysis

- Digitized waveform is integrated to estimate charge.
- The charge is then converted into number of photoelectrons being divided by single photoelectron charge.
  - Single photoelectron charge is obtained by interval of pedestal and triggered dark signal.



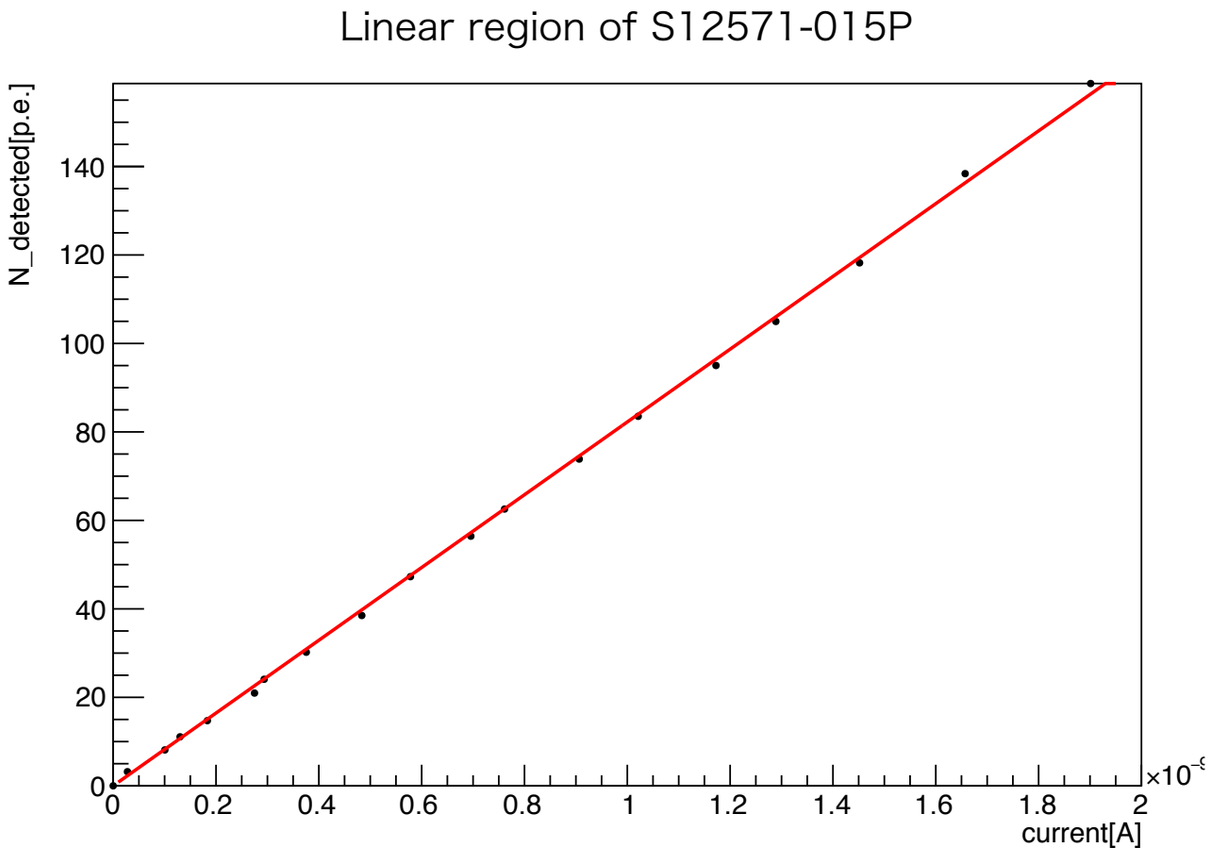


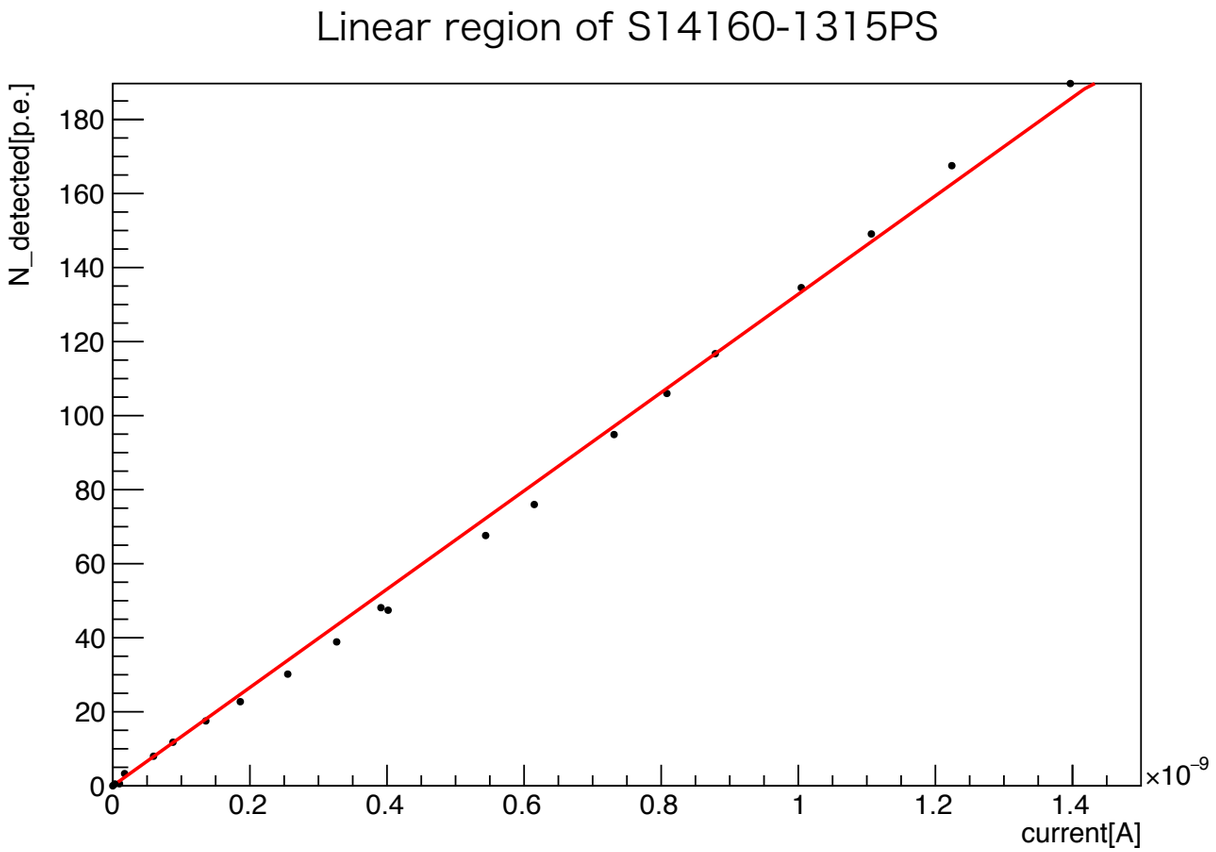




Laser intensity

- Incident light intensity is monitored with photodiode
  - Laser light is split using half mirror
- Relation between number of photoelectron (Npe) and photodiode current is calibrated at small Npe (e.g. linear) region
- Effect of crosstalk and after-pulse is not corrected yet

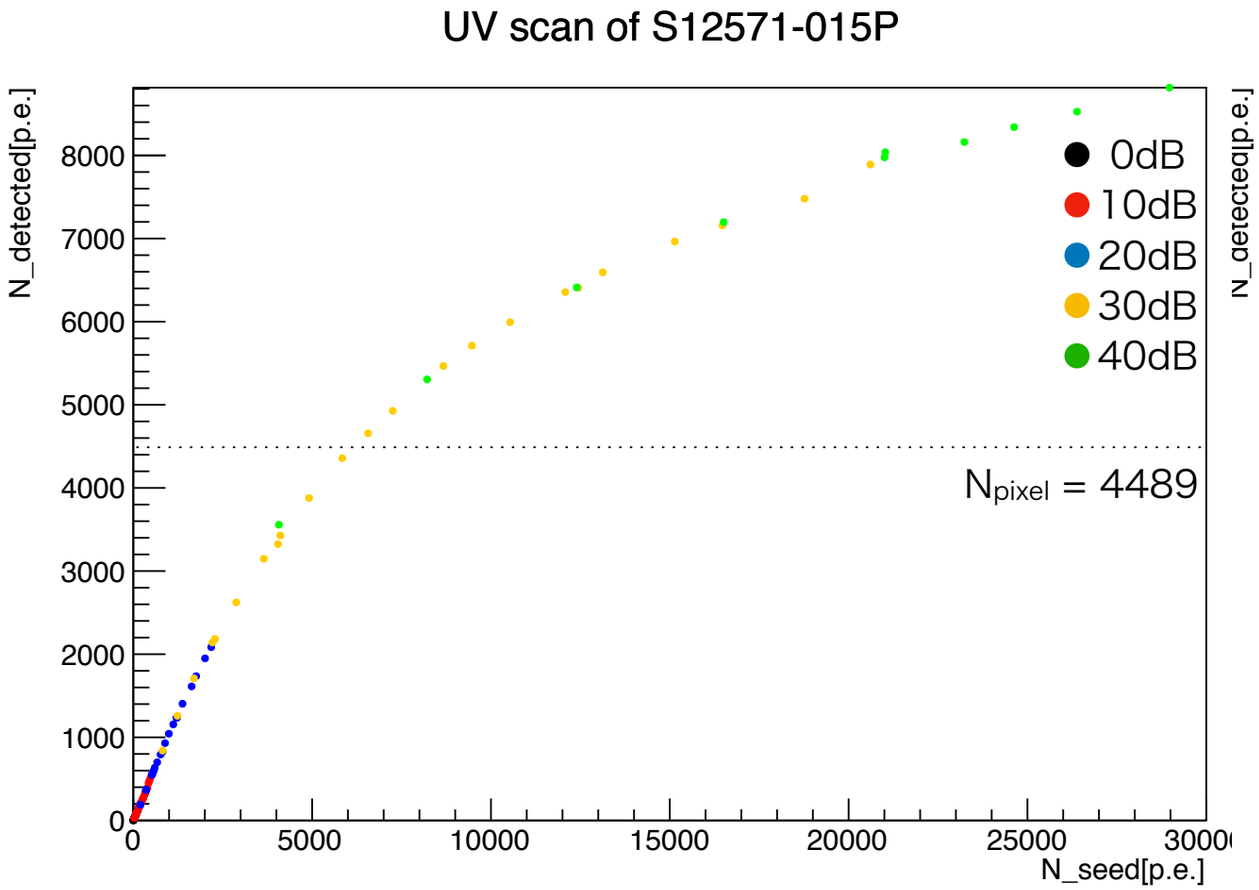


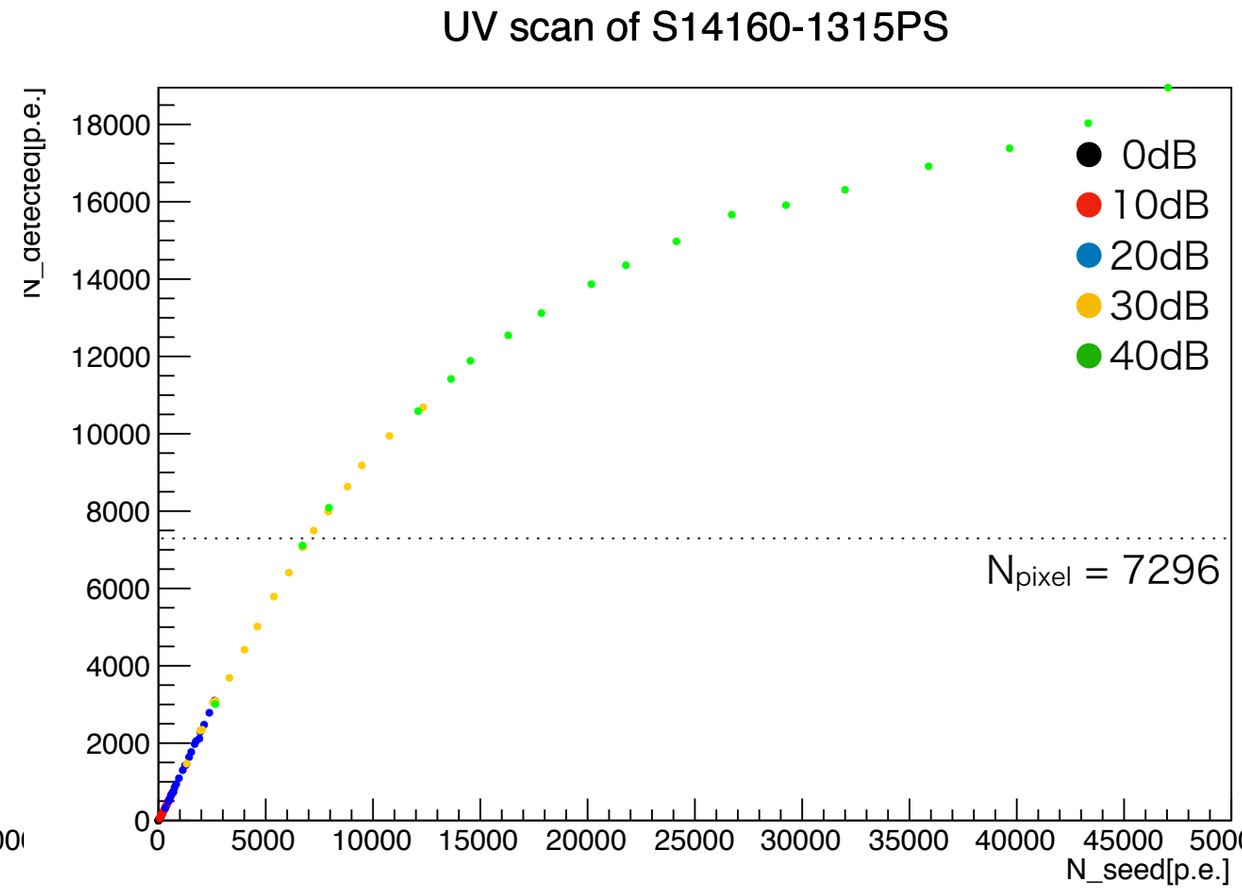


MPPC saturation

- Saturation curves are obtained for wide range of Npe
- Over-saturation is observed for both MPPCs

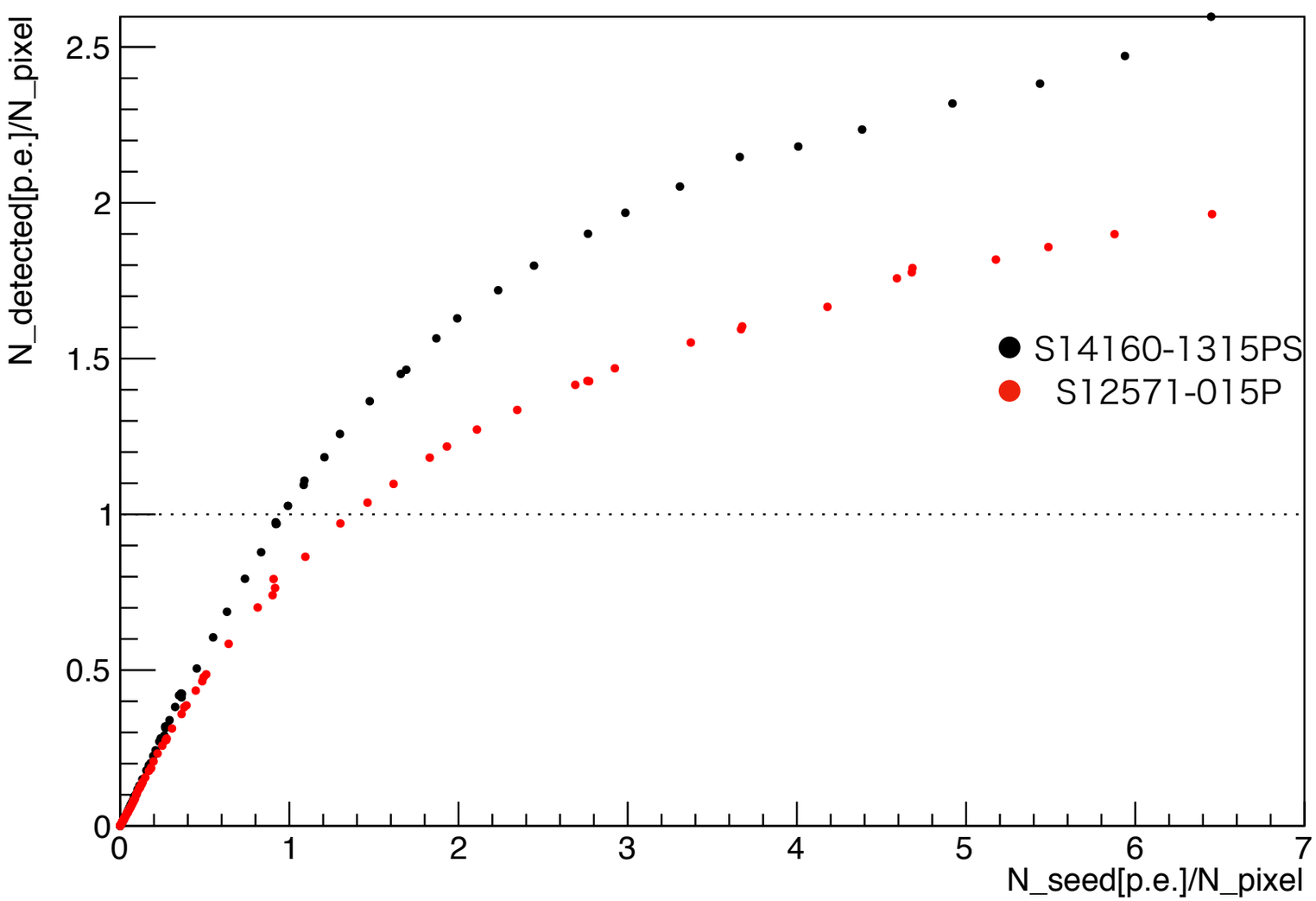
- Still some systematics in correction for signal attenuation factor
  - We observed that the attenuation factor depends on light intensity
  - Probably due to change in signal shape caused by MPPC saturation





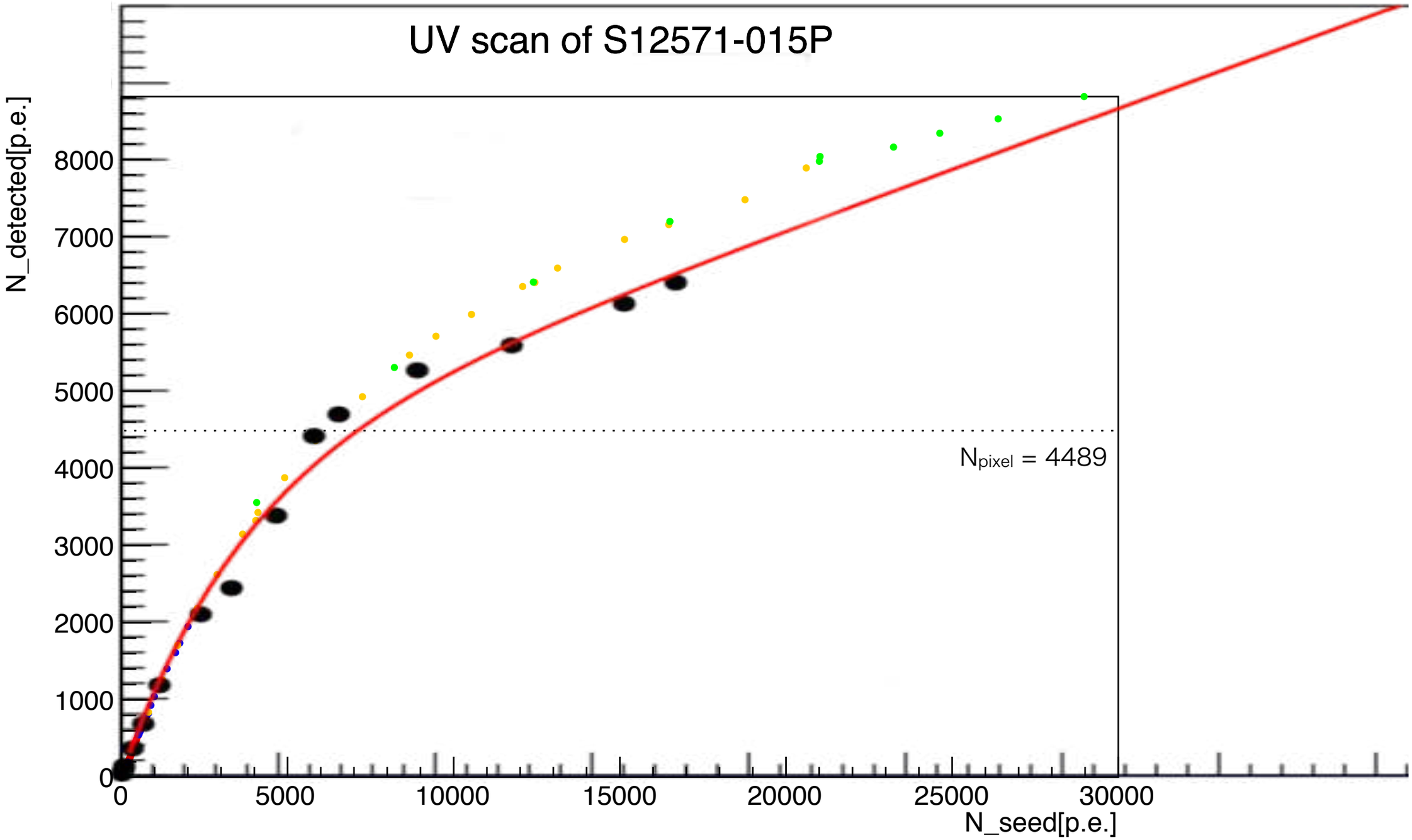
Comparison with two types of MPPCs

- Normalized by number of pixels
- S14160-1315PS is less saturated compared with S12571-015P
  - Effect of longer tail of S14160 cannot be disentangled from this measurement
  - Need further verification
    - We plan to do the same measurement with fast 400 nm laser



Comparison with previous study

- Comparing the measured saturation of S12571-015P with the previous study
- Saturation recovery observed



To do

- Investigation light intensity dependence of attenuation factor
- Measurement with fs 400 nm laser
  - To compare with UV-laser measurements
  - To investigate the effect of the longer tail of S14160
- Comparison with theoretical model of saturation

Summary

- Saturation of MPPC can ce a crucial issue for Sc-ECAL.
- Saturation curves for candidate MPPCs were measured using scintillation light excited by fast UV-laser
- It was found that the saturation was improved for the new MPPC (S14160)
- Further studies such as theoretical modeling and 400 nm laser measurement are necessary

Backup