Radiation damage of Hamamatsu Si-PMs (MPPCs)

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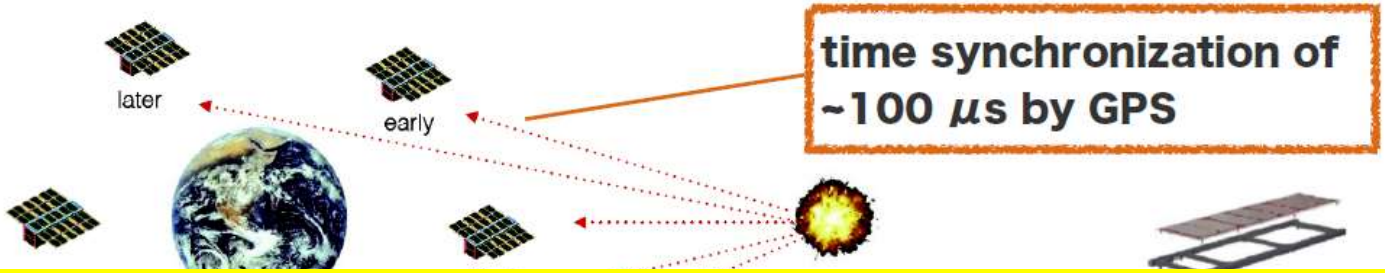
- CAMELOT mission needs lower threshold to detect more gamma-rays
- Experimental setup: 200 MeV protons
- MPPC sample: S13360, S14160 + 1 cm^3 CsI (Tl) scintillator
- Damage: dark current, energy spectrum
- Annealing:
- Suggestion: shielding, cooling

Hirade et al. (submitted)

"CAMELOT" : Cubesats Applied for MEasuring and Localizing Transients

Hungarian/Japanese collaboration project.

PI: Norbert Werner (Hungary MTA-Eotovos Lorand University)



For better localization,
cross correlation of light curves requires more gamma-rays

- Cubesats ··· Covering all sky
- Difference of arrival time ··· Decide the position of transient

CAMELOT will detect 10 GRBs/year (Prototype ver.)
~ 300 GRBs/year (Complete ver.)

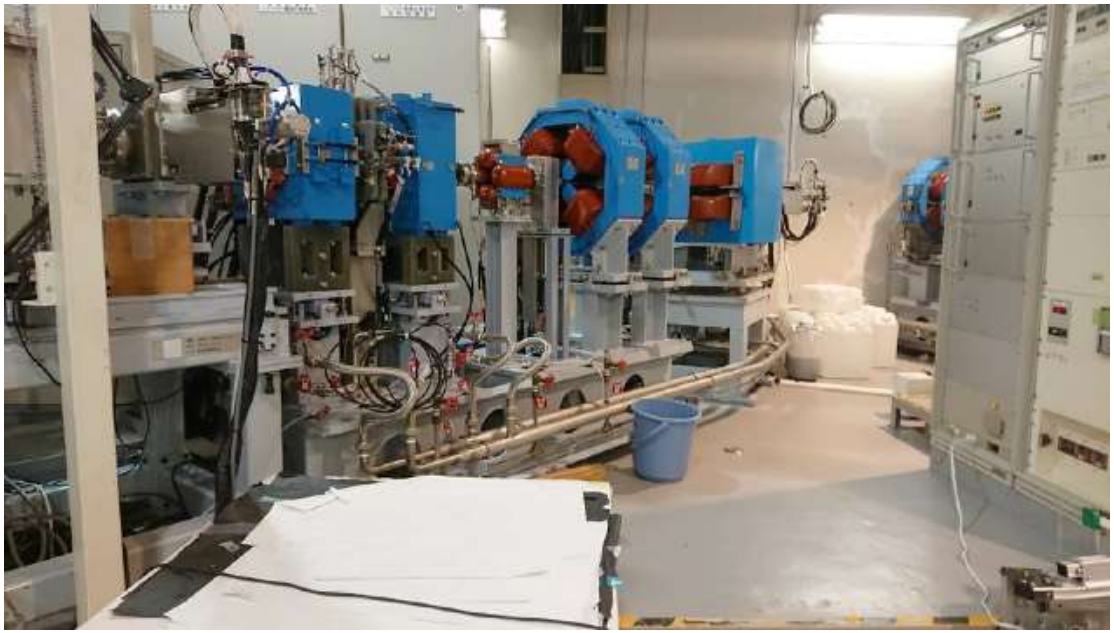
Required condition of Scintillator

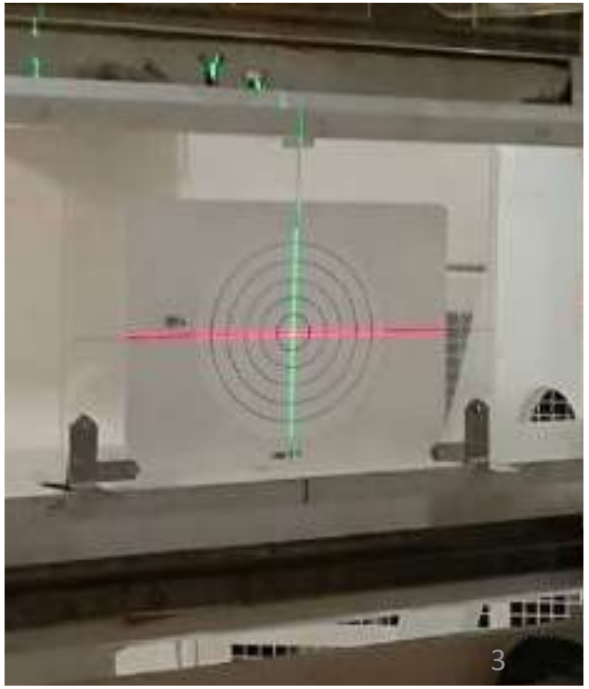
- Large effective area
- Lower energy threshold (~50 keV)

Experimental Setup of Proton irradiation

Experiments at **Wakasa-wan energy research center** (Japan)
200 MeV protons
1000 rad = 10 Gy corresponds to 1.71 x 10^{10} protons/cm2
(6×10^9 1 MeV n_{eq})

We are assuming 1000 rad /year without shields.
several 100 rad /year with 1-mm Pb shield.

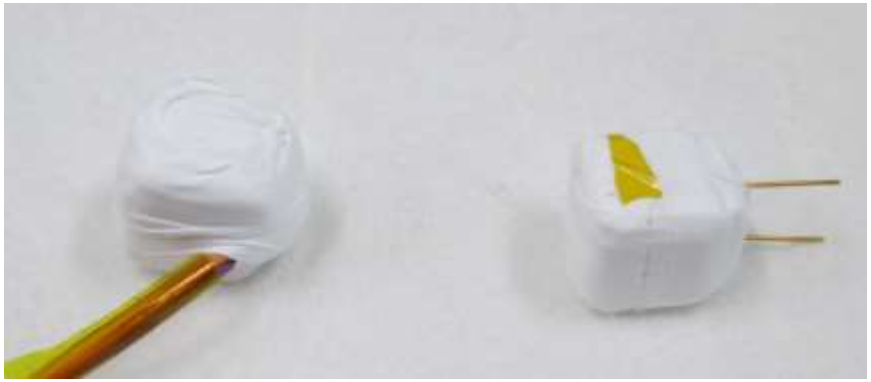




2 MPPC samples

with 1 cm^3 CsI (Tl) for energy spectra

Only MPPCs are irradiated.



Both have 6x6 mm^2 size
left … S13360-6050CS
(in black case => x1.7 better threshold with surface mount)
right … S14160-6050HS

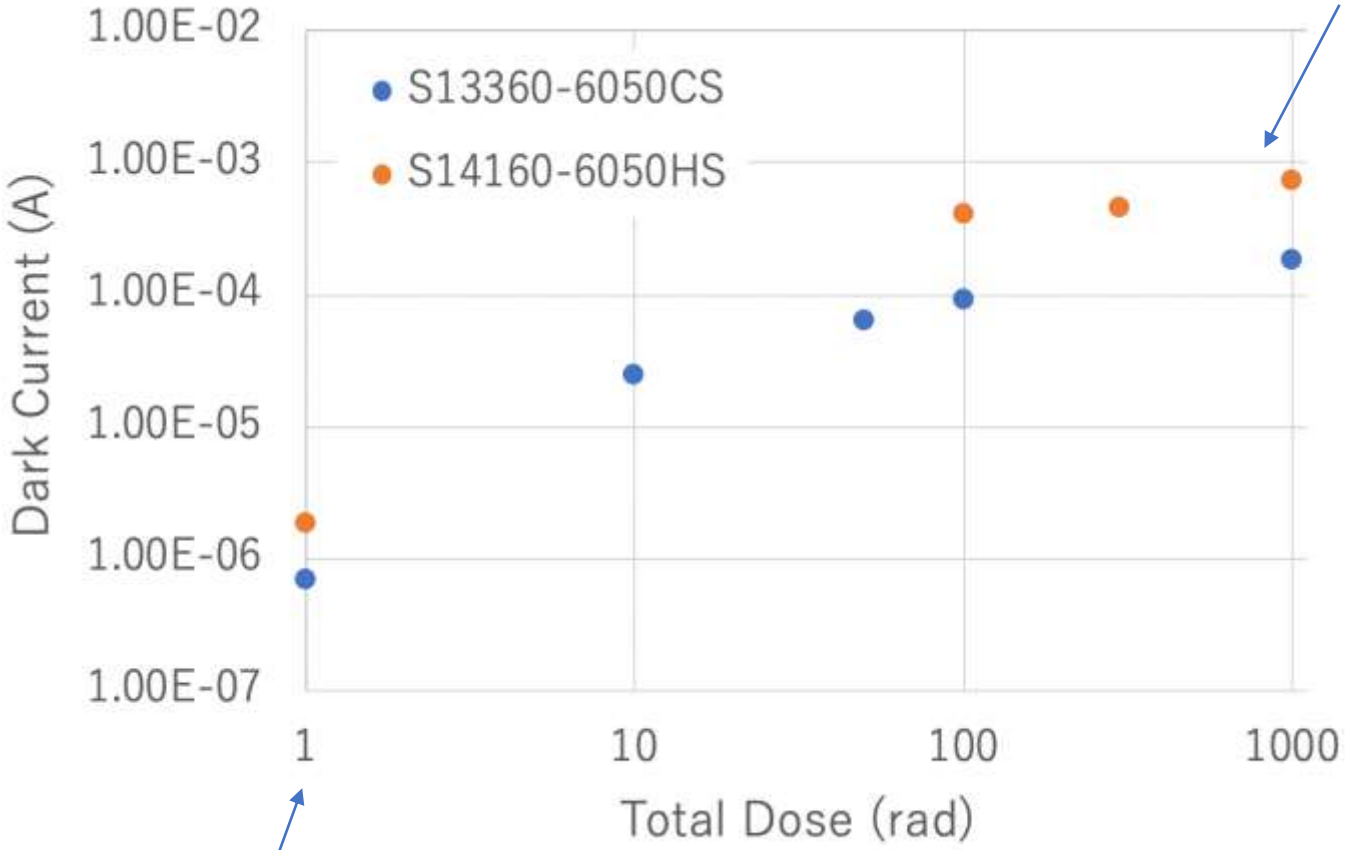
S14160 (newer one) has
- High PDE
- High gain
- Low operation voltage
- (but high dark current)

	PDE (%)	Gain (10^6)	Dark current (uA)	Operation voltage (V)
S13360-6050CS	40	1.7	0.388	54.4
S14160-6050HS	50	2.5	1.63	41.0

Dark current (same Vop @ room temperature)

Hirade et al. (submitted)

With 1 kΩ resister,
the actual voltage is decreased by ~1V.

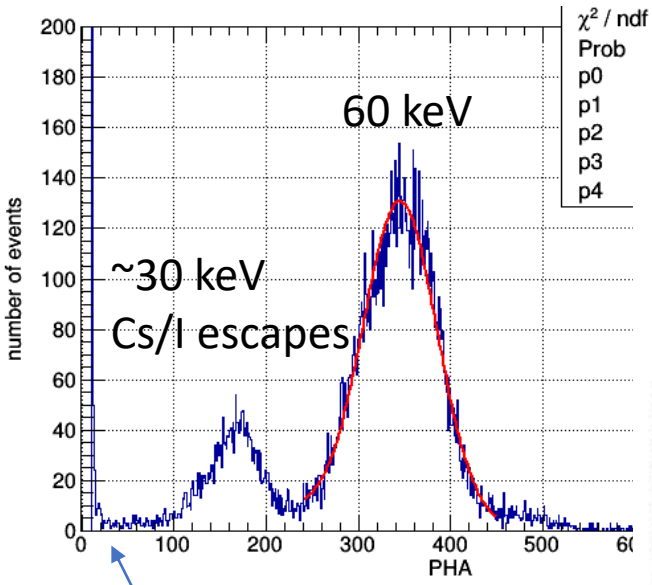


No damage

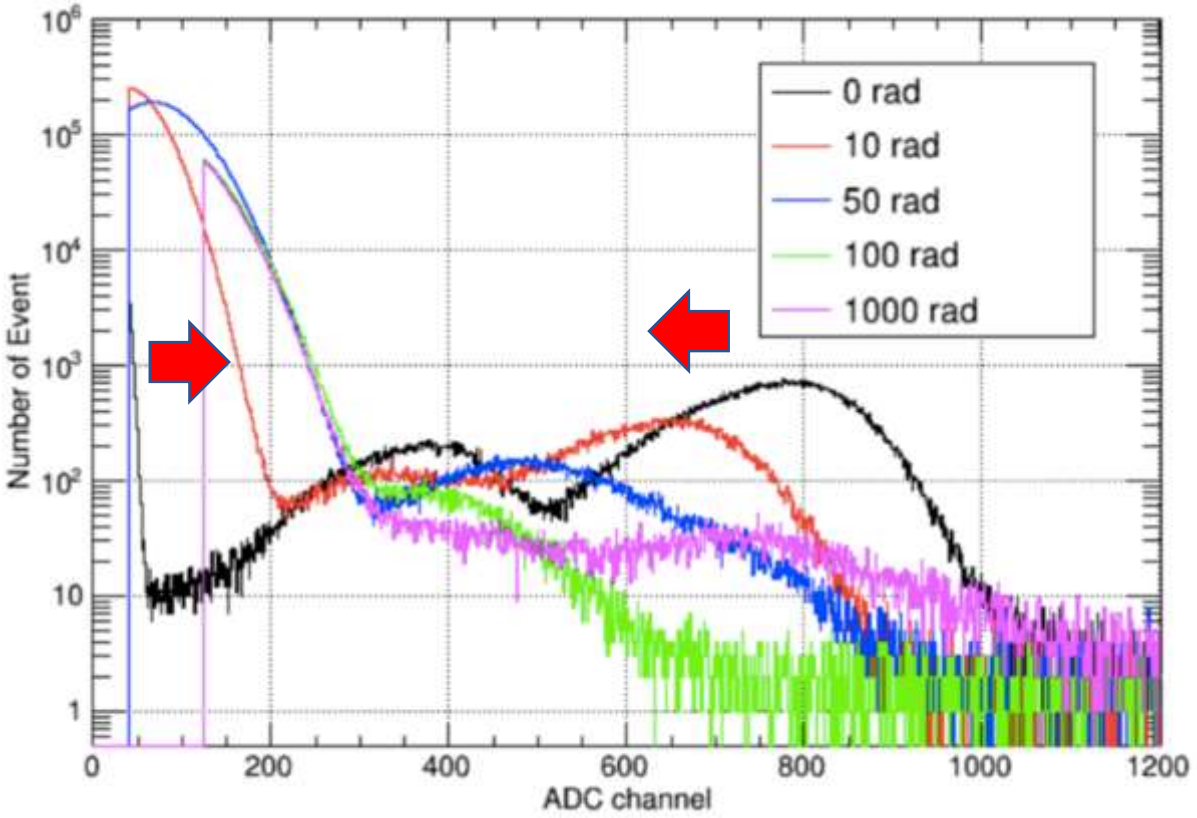
Energy spectra (same Vop @ room temperature)

Hirade et al. (submitted)

^{241}Am with CsI (Tl) (no damage)



Noise threshold: a few keV



Even with 10 rad irradiation, noise threshold increase & gain decreases.

Annealing: Dark current (same Vop @ +20 degC)

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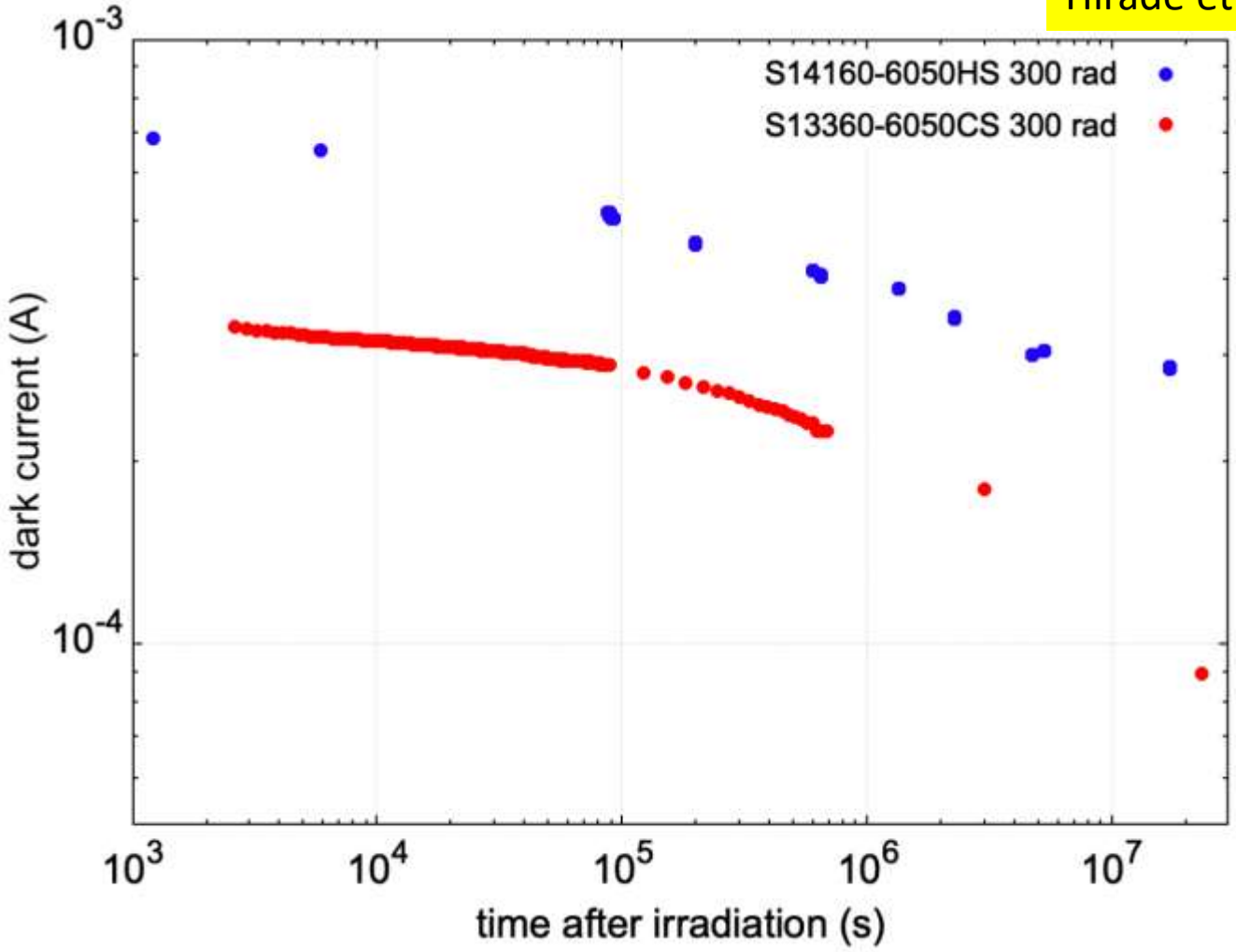
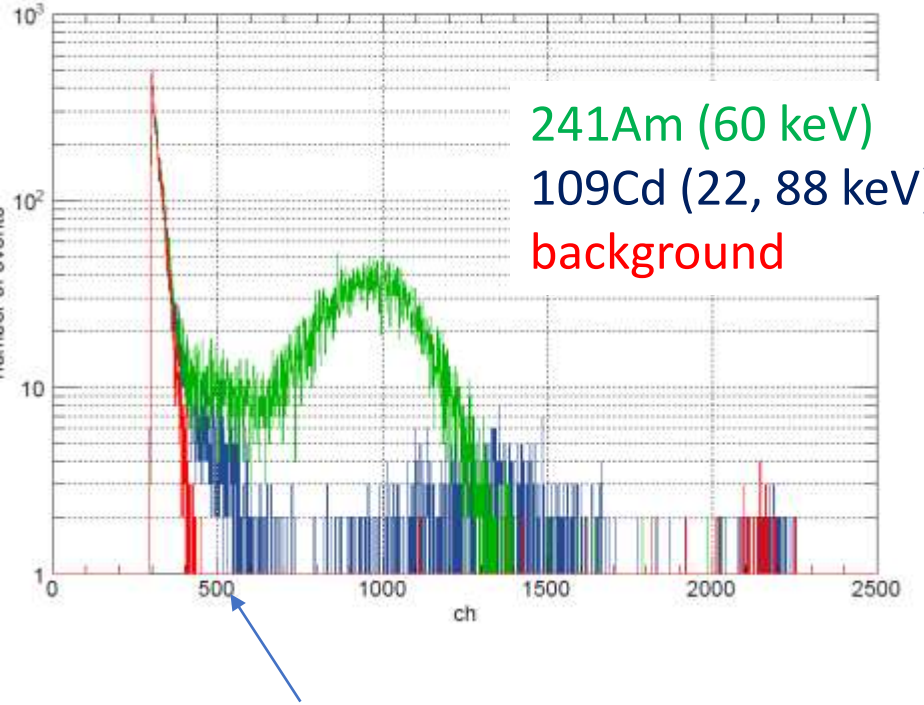


The dark current decreased by 2-3 times over ~half a year.

Annealing: energy spectra

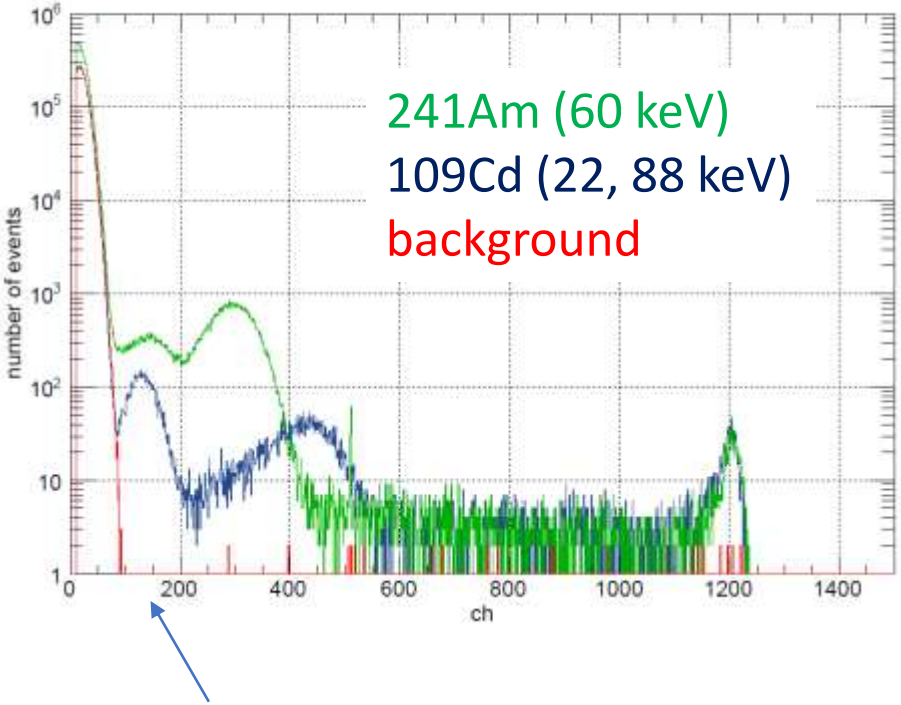
Hirade et al. (submitted)

Just after the irradiation@-30 degC



22 keV is not easy to see…

7 months later@-30 degC

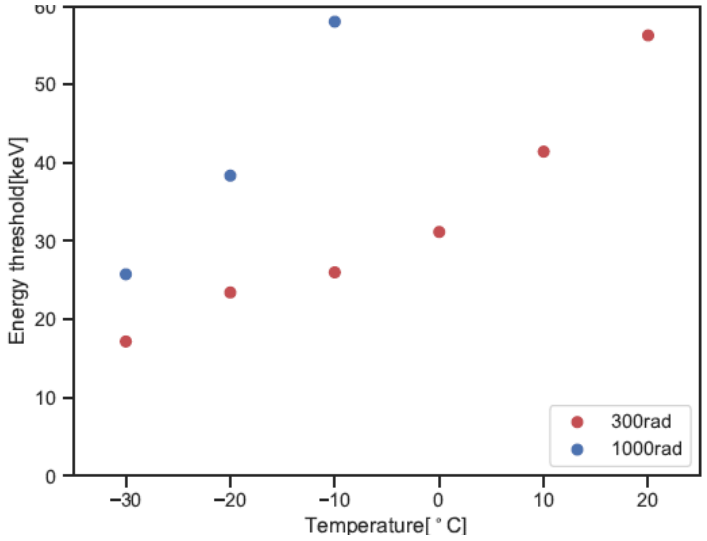


22 keV is easy to detect.

Energy threshold (S13360)

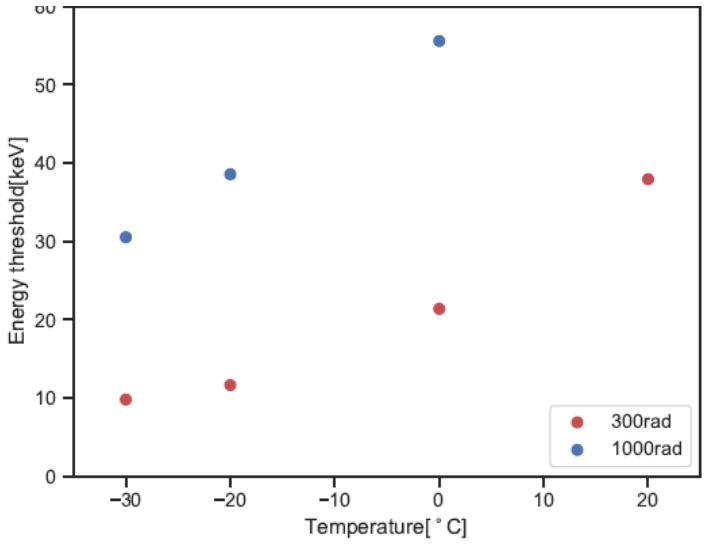
Just after the irradiation at suggested Vop

Hirade et al. (submitted)

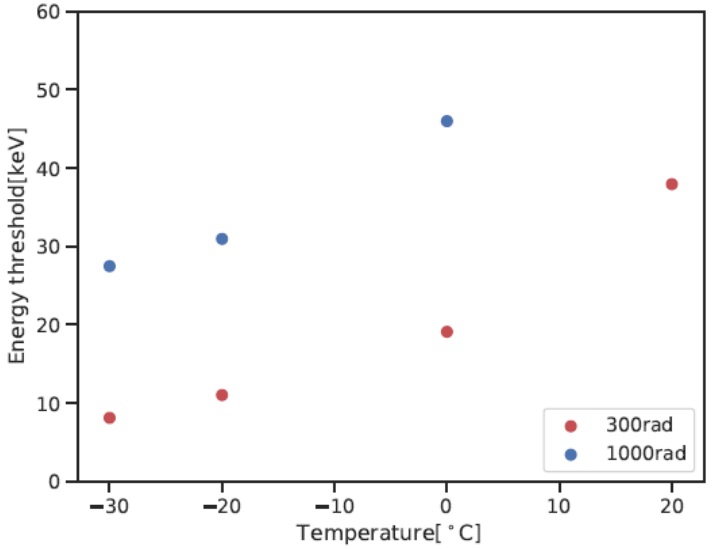


(in black case
=> x1.7 better threshold
with surface mount)

7 months later at suggested Vop



7 months later at best Vop

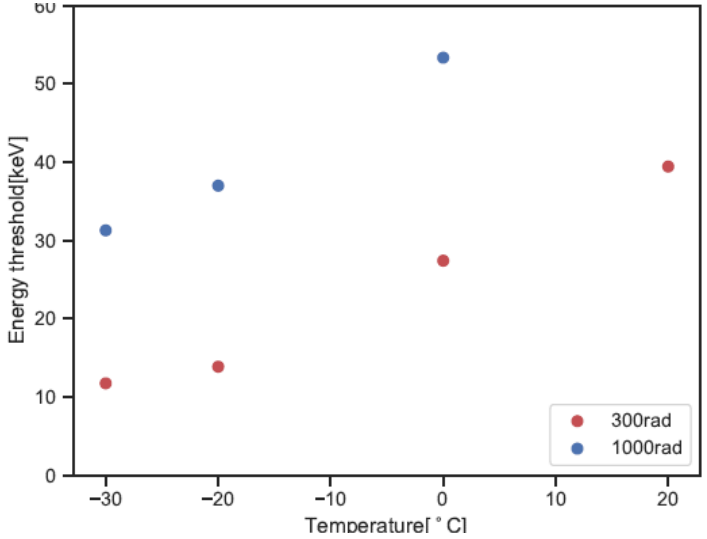


Typically, lower Vop is better to reduce too much dark currents.

Energy threshold (S14160)

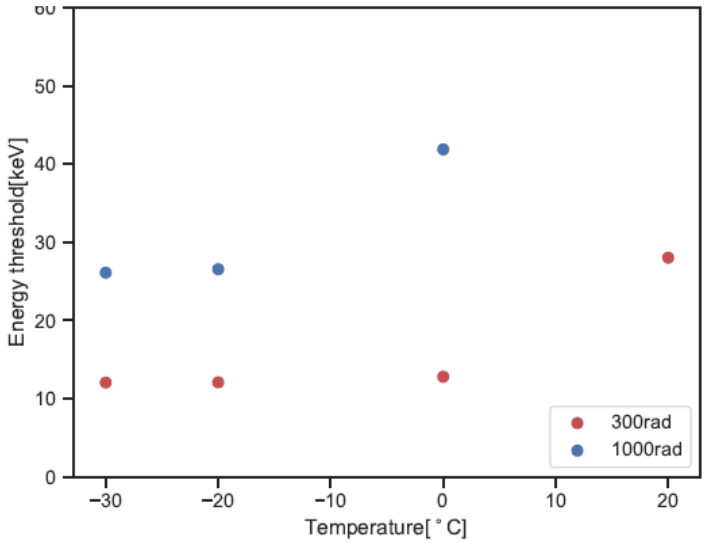
Just after the irradiation at suggested Vop

Hirade et al. (submitted)

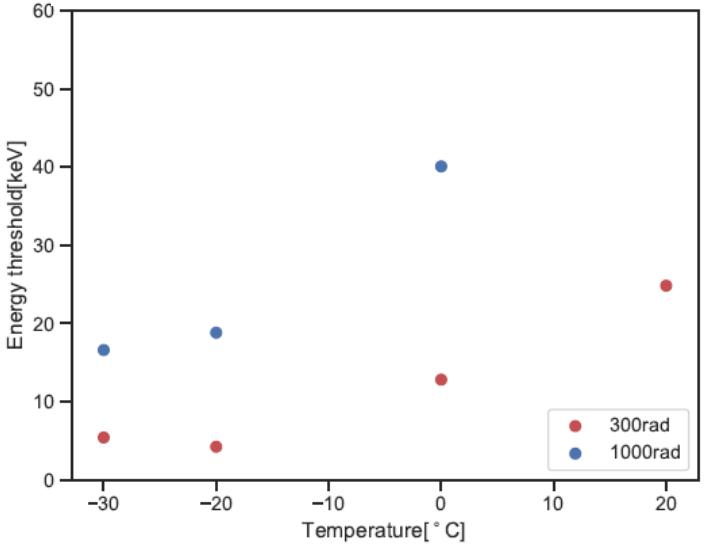


Comparable thresholds for both MPPCs with surface mounting.

7 months later at suggested Vop



7 months later at best Vop



Typically, lower Vop is better to reduce too much dark currents.

Suggestion for satellites

- MPPC size should be just enough to correct scintillation photons, while not too large (for less dark current).

- Shielding: One side is already ok with scintillators.
  The other side needs Pb etc. (even with a thin layer)

- Cooling: it can be ok for large satellites.
  For CubeSats, it can be difficult…

- Better scintillators:
  - Higher light yield
  - Faster decay