

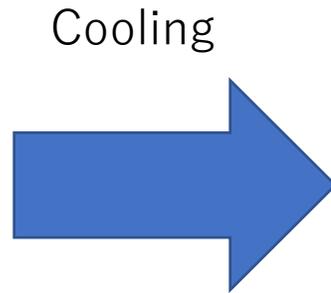
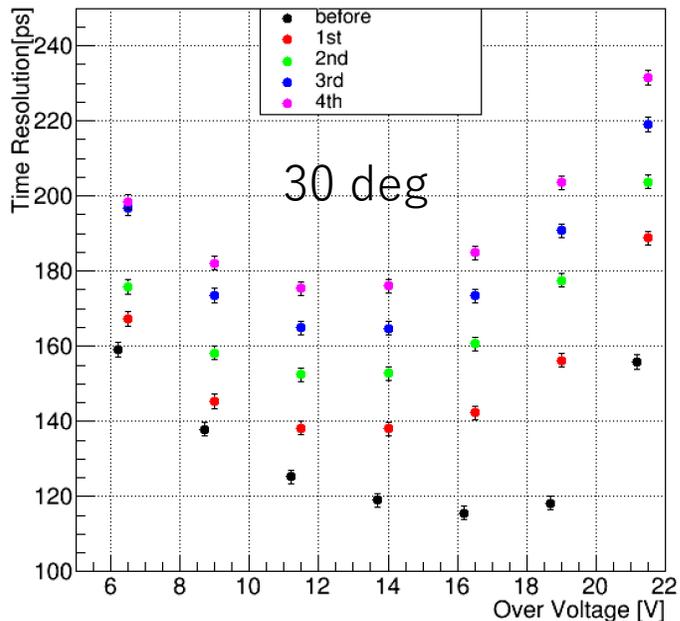
Study on the Effect of Ununiformed Radiation Damage among 6 SiPMs for Timing Counter

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Apr.5 2018, @Tokyo

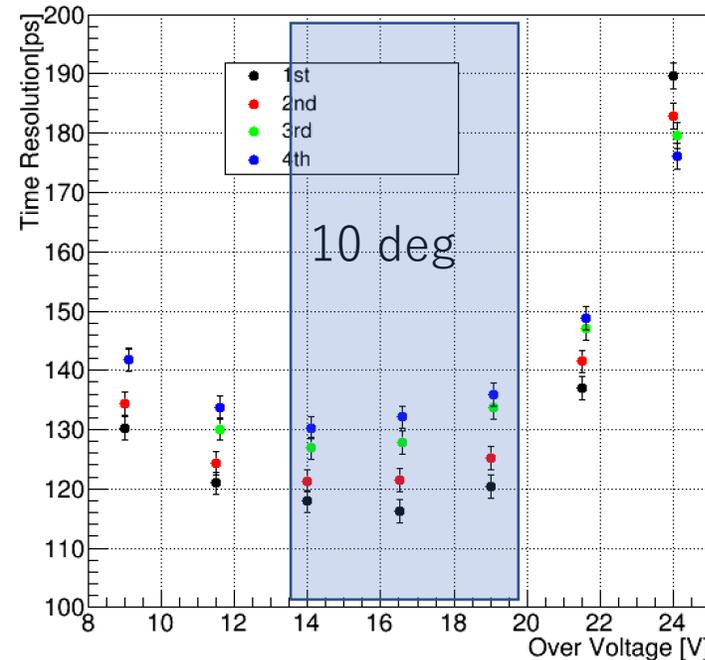
Radiation Damage Problems

- ★ Current increase due to radiation damage was observed
- ★ We investigated current increase & its effect on TC performance, and estimated **~5% deterioration @ 10 degree**
- ★ This is the case of **uniform damage among 6 SiPMs**

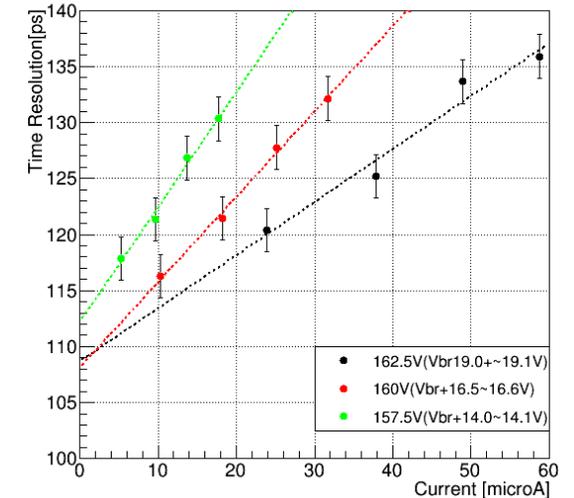
Time resolution plot



Time resolution plot

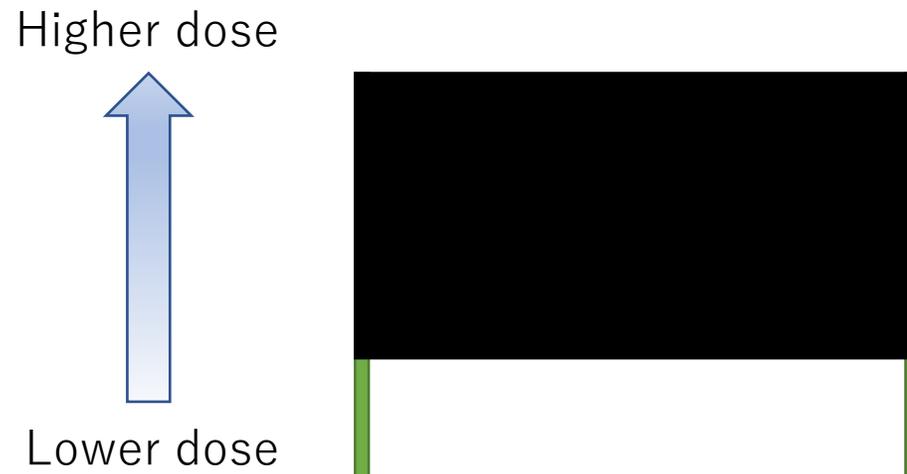


Time resolution vs. Current



Damage Unbalance

- ★ There is “Damage Unbalance” among 6 SiPMs
 - * SiPM (top) is exposed to much higher dose than SiPM (bottom)
- ★ What kind of effect is caused by unbalance?
 - * Is there position dependence of time center?
 - * Is that deteriorates the time resolution?
 - * IV curve shape?



Damage Unbalance

- ★ With 3 configuration, we did measurement to see the damage unbalance effect
- ★ Neutron damaged & electron damaged SiPMs were used
 - * Important difference is not irradiated particle, but the current level of SiPMs

	No damage	Damaged by electron	Damaged by neutron
A	○○○○	○○	
B	○○	○○○○	
C		○○	○○○○

IV curves

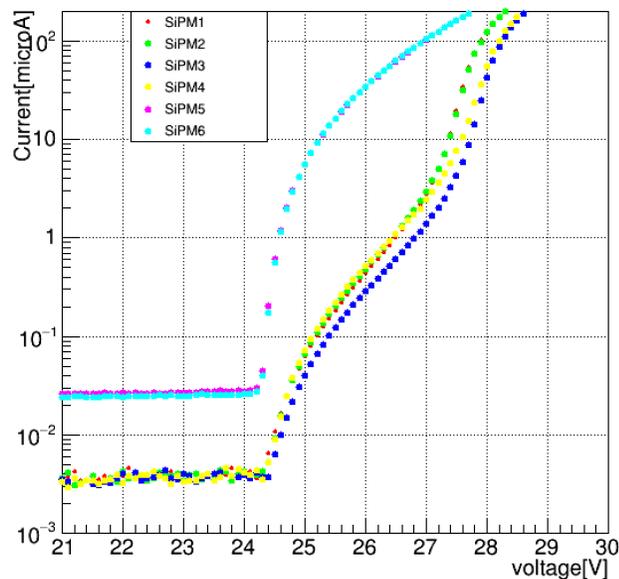
★ Configuration A and B has the extreme radiation damage unbalance

*A : 2 badly damaged & 4 no damaged

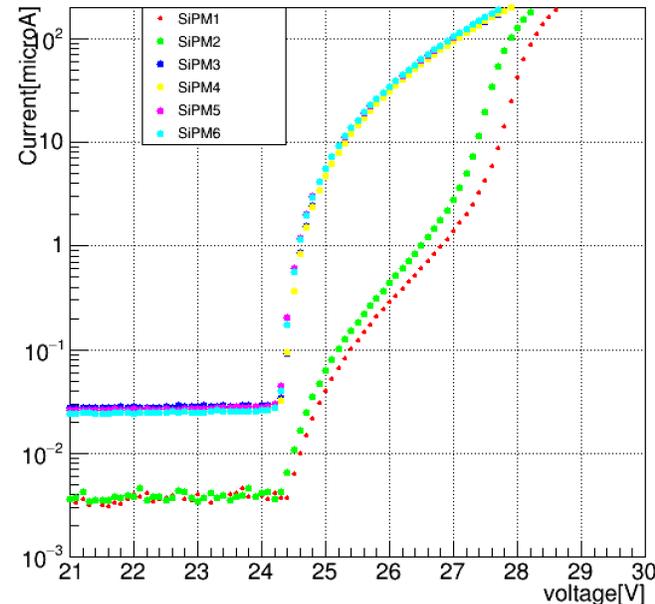
*B : 4 badly damaged & 2 no damaged

★ Configuration C is gradual radiation damage unbalance

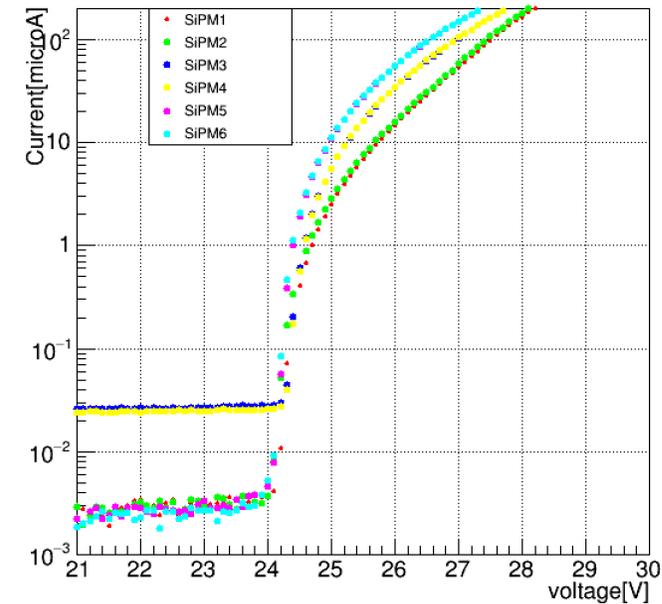
IV curves A. SiPMs



IV curves B. SiPMs



IV curves C. SiPMs

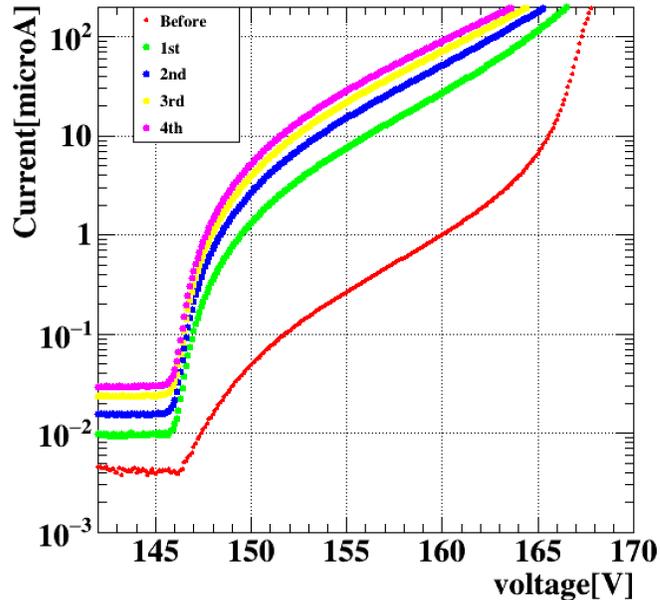


Breakdown voltage shift

- ★ We observed V_{br} shift due to leak current increase of each SiPM
- ★ Usually, $V_{br} = 6V_0$, but in case A, $V_{br} = 6V_0 + 4\delta V_0$

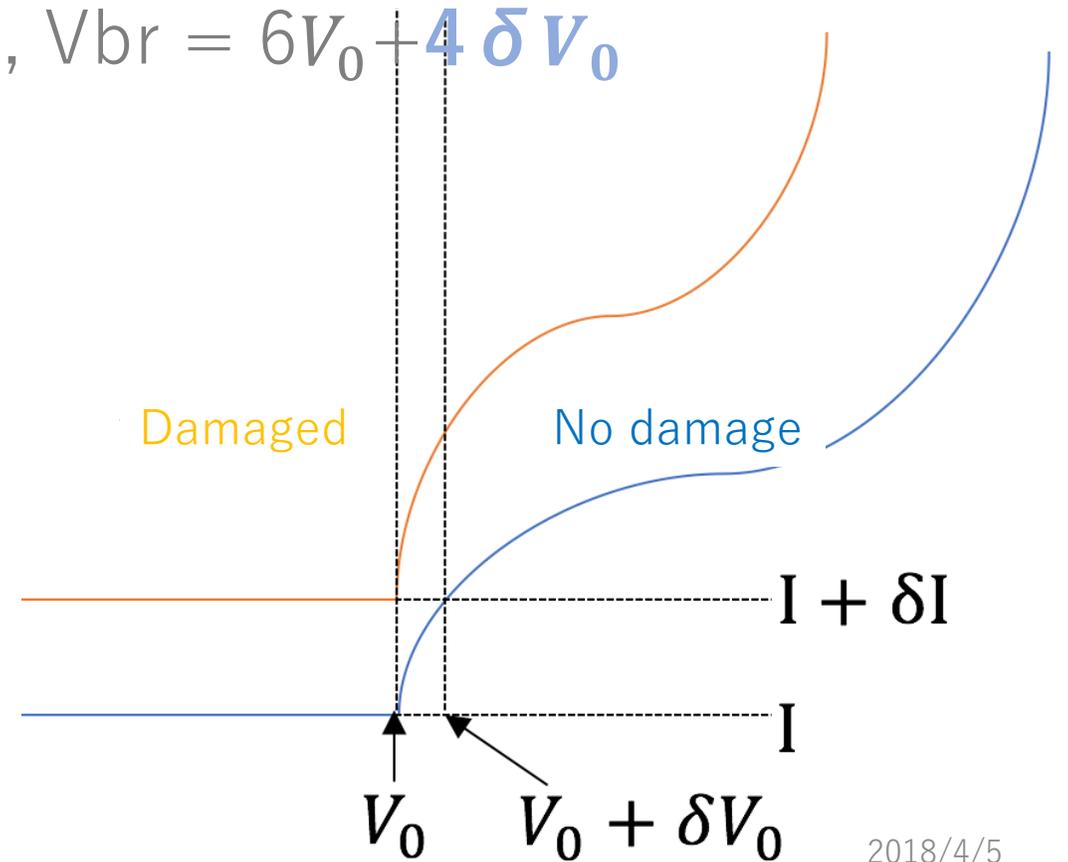
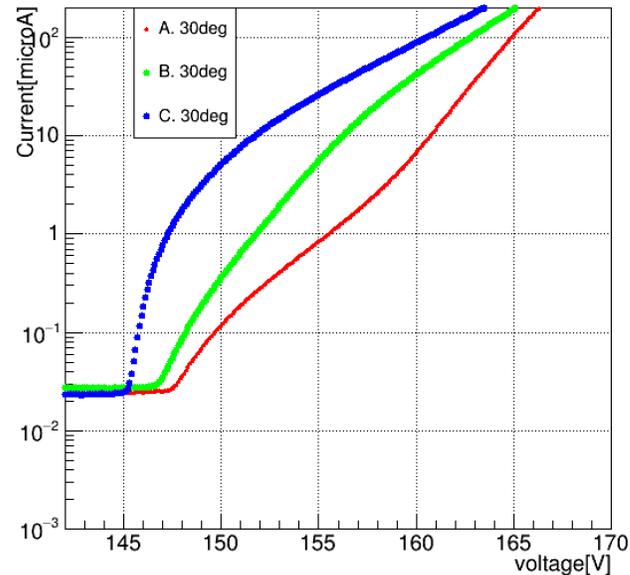
All damaged: $V_{br} \sim 146V$

6 series IV curves



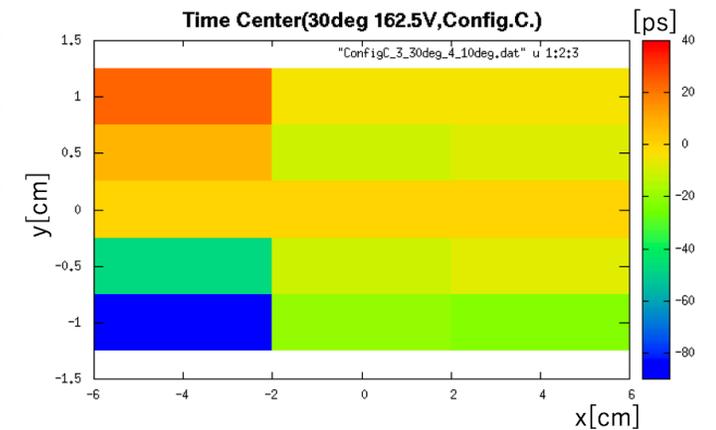
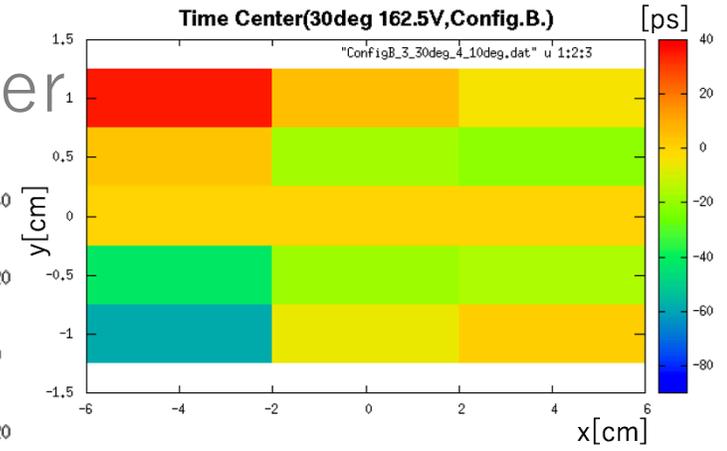
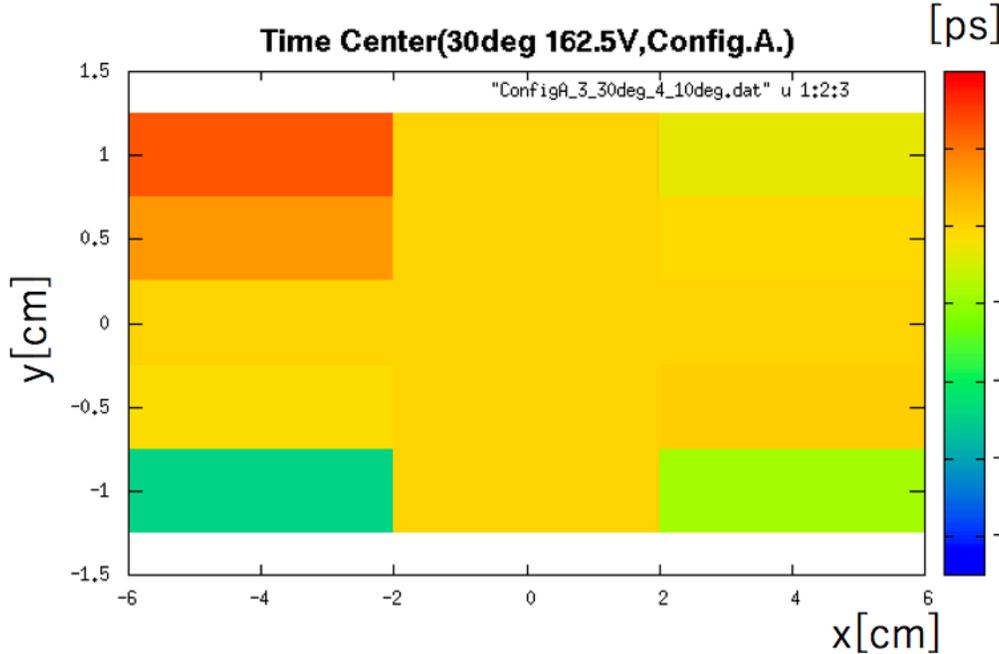
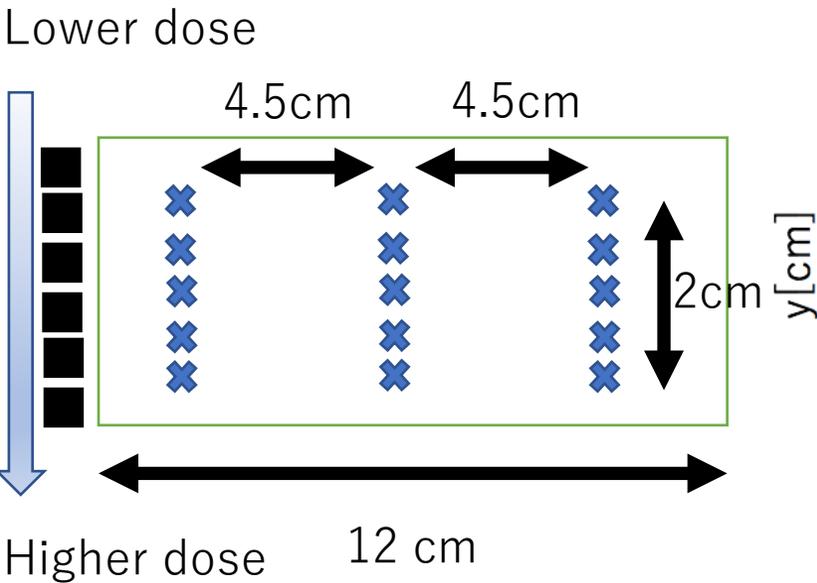
A: $V_{br} \sim 147-8V$

6 series IV curves



Time Center @ 30 degree

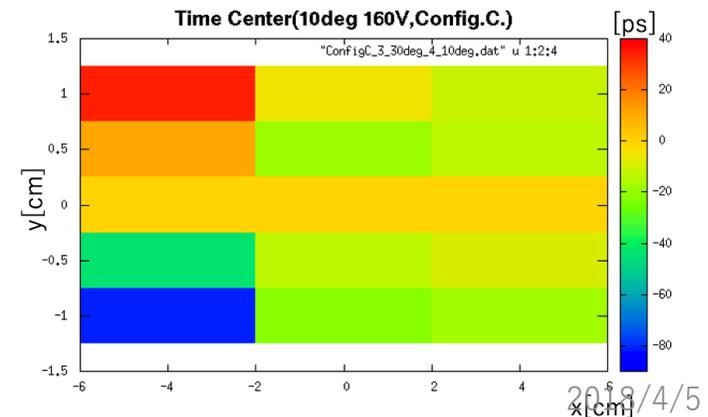
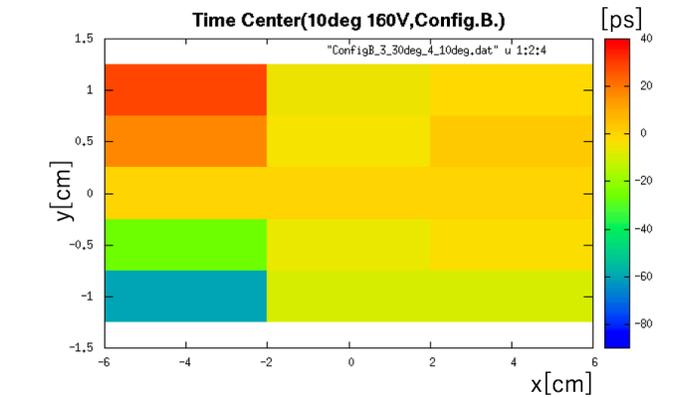
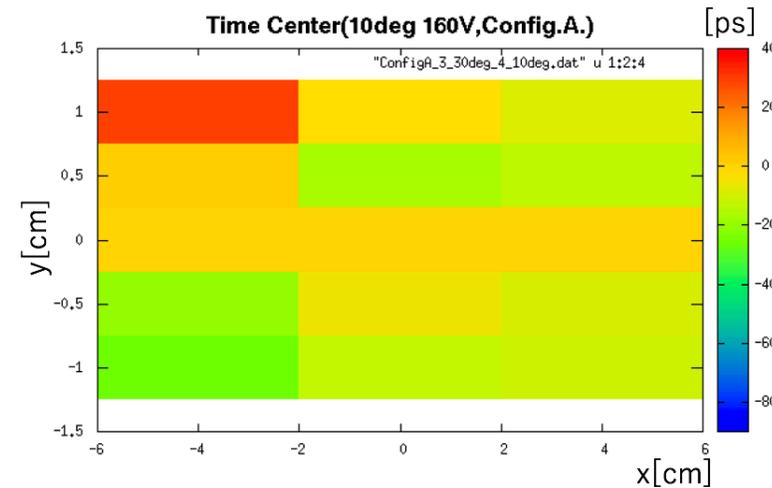
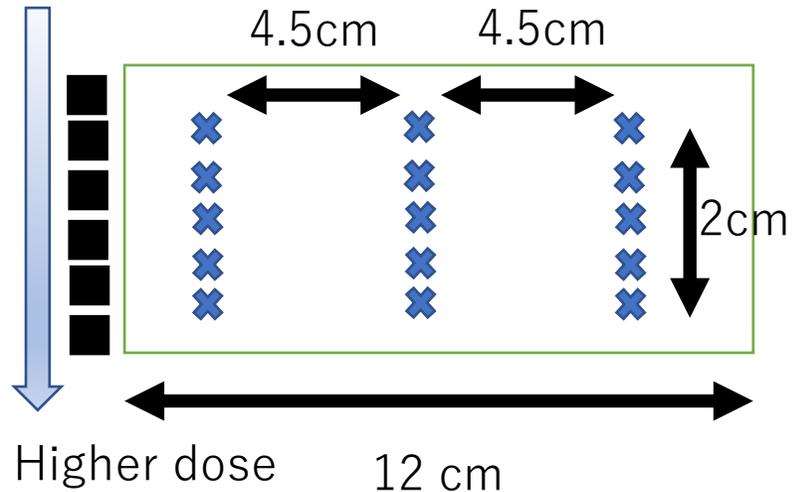
- ★ Measured the time center at each point
- ★ We can see the position dependence of time center



Time Center @ 10 degree

- ★ Measured the time center at each point
- ★ Seems smaller position dependence at far points

Lower dose

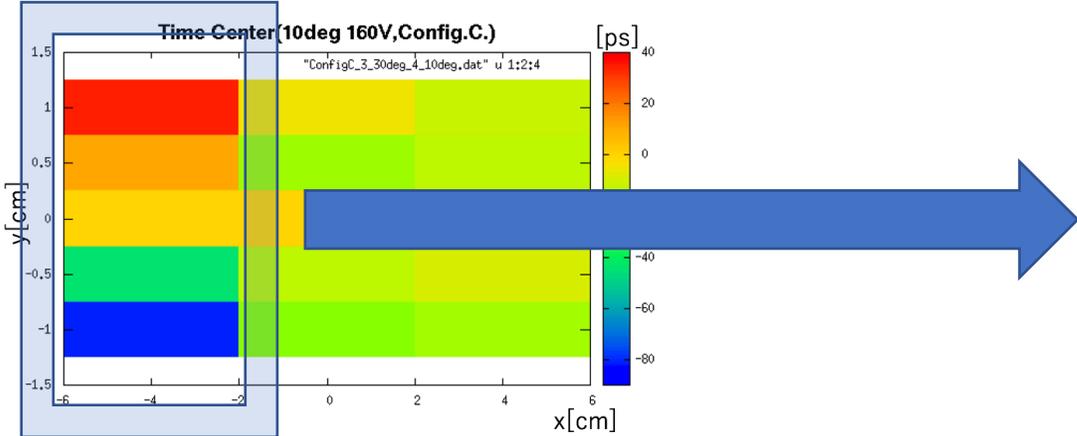


Effect on Time Resolution

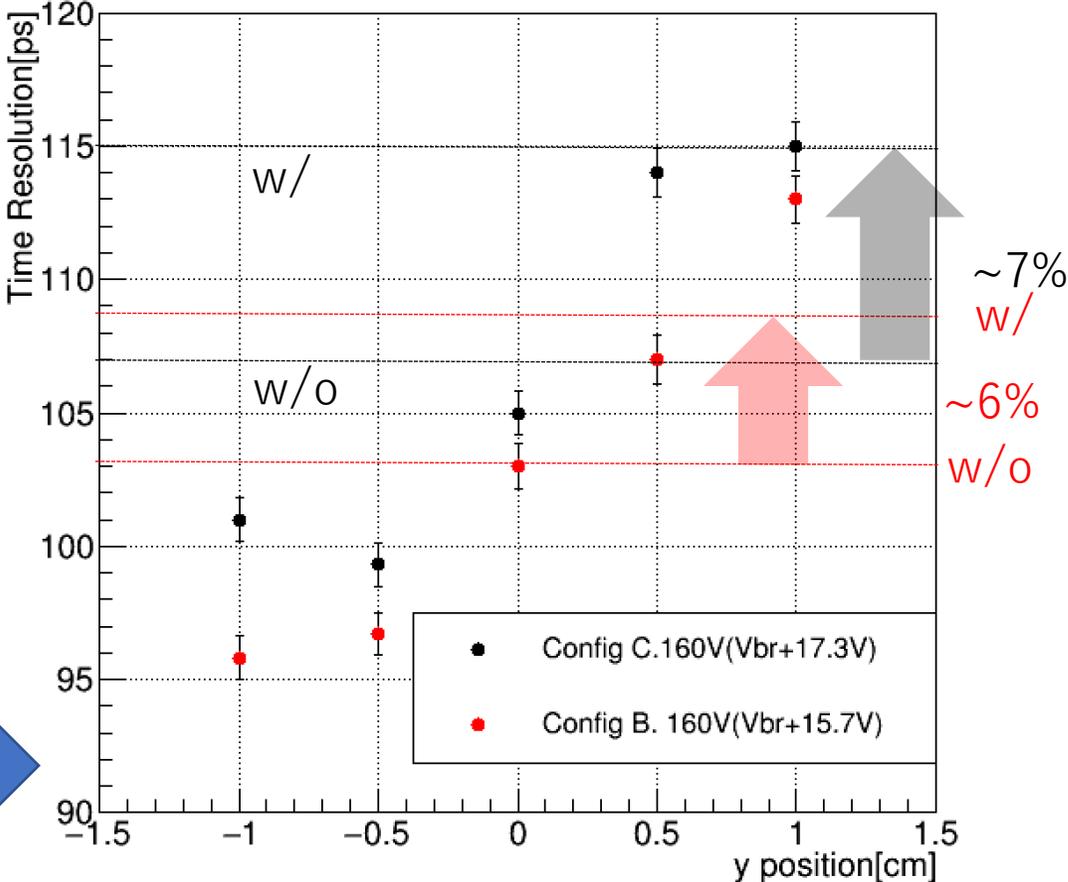
★ We estimated the effect on time resolution

★ Right plot shows case B. & C. @ 10 degree

★ Deterioration can be observed compared w/ time center difference & w/o time center difference



Resolution position dependence



Summary

- ★ We confirmed the behavior of ununiformed radiation damage effect on series connection
- ★ We confirmed
 - * **Breakdown voltage shift (~2V max)** due to leak current increase
 - * **Time center difference** on position -> **~7%** deterioration @ C.
- ★ Time center should be **compensated with track information** from DCH
 - * Since positron hit position may have correlation b/w counter, this deterioration **cannot be compensated by multi-hit**
- ★ We completed the measurement and understood on radiation damage effect on series connection last year
 - * Started to summarize the results on this topic for output

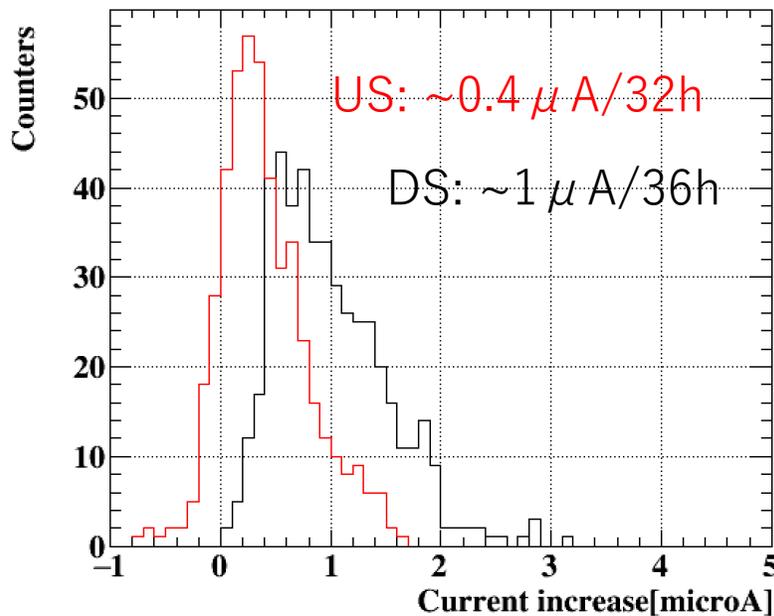
Pilot run 2017

- ★ I will briefly comment on some topics related to radiation damage
 - *Current Monitoring
 - *IV Monitoring
 - *Cooling Systems

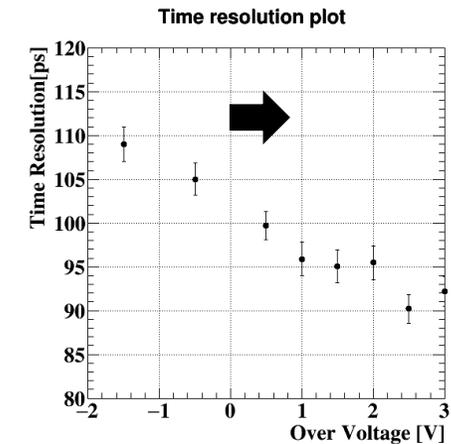
Current Monitor / Voltage Tuning

- ★ During beam test **obvious current increase** was observed due to radiation damage
- ★ Last year's operation voltage was **1V higher than previous year based on "laser bias scan"**
- ★ Operation voltage should be tuned based on current & resolution checked with laser signal

Current Increase



Using laser, we searched new Vop
 -> 1V shifted from last year



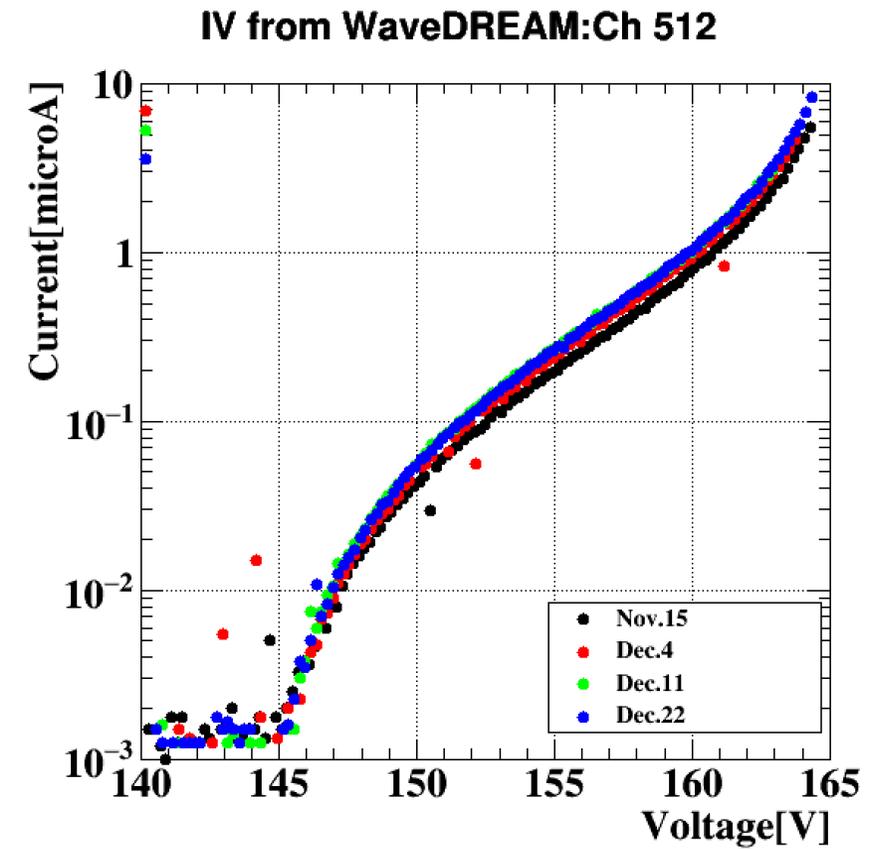
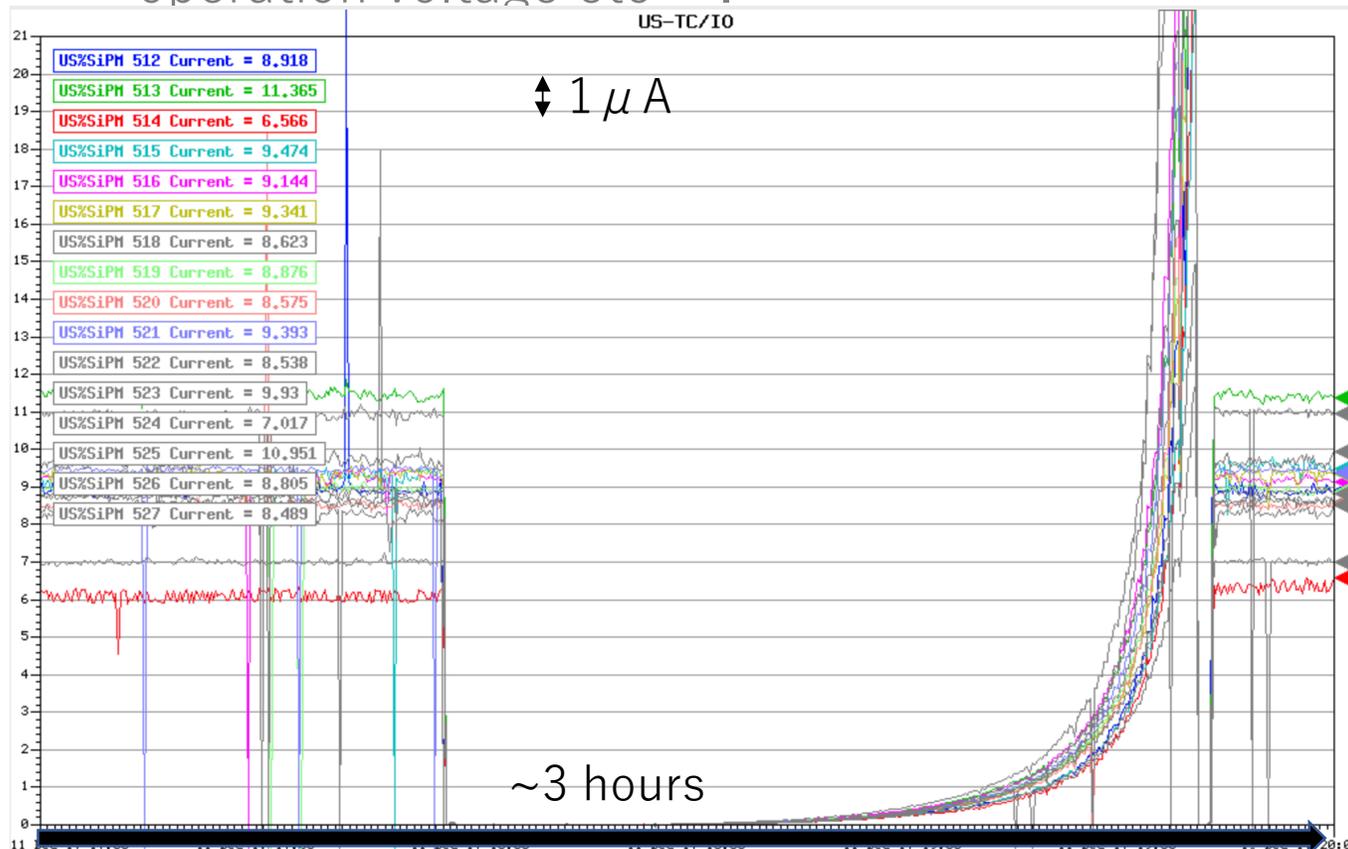
	Observed increase	Expected ~ 3 years
US counters	$\sim 0.4 \mu\text{A}/32 \text{ hours}$	$\sim 158 \mu\text{A}$
DS counters	$\sim 1 \mu\text{A}/36 \text{ hours}$	$\sim 394 \mu\text{A}$
2016 commissioning	$\sim 0.24 \mu\text{A}/32 \text{ hours}$	$\sim 94 \mu\text{A}$

Vop+1V

$\sim 30\%$ deterioration around $100 \mu\text{A}$

IV Monitoring

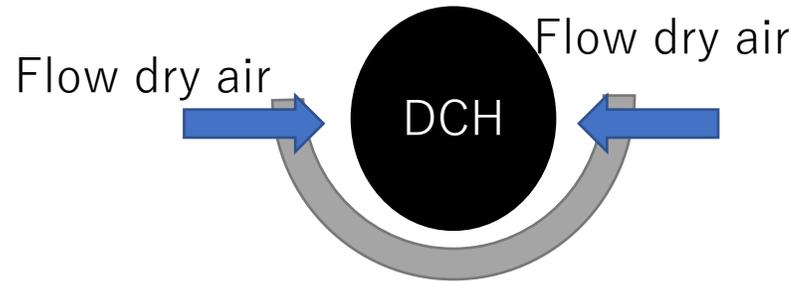
- ★ With the DAQ setup, we succeeded in **continuously taking IV characteristic data of all US counters at once**
- ★ Monitor as sensor to radiation damage, temperature and useful to determine the operation voltage etc ...



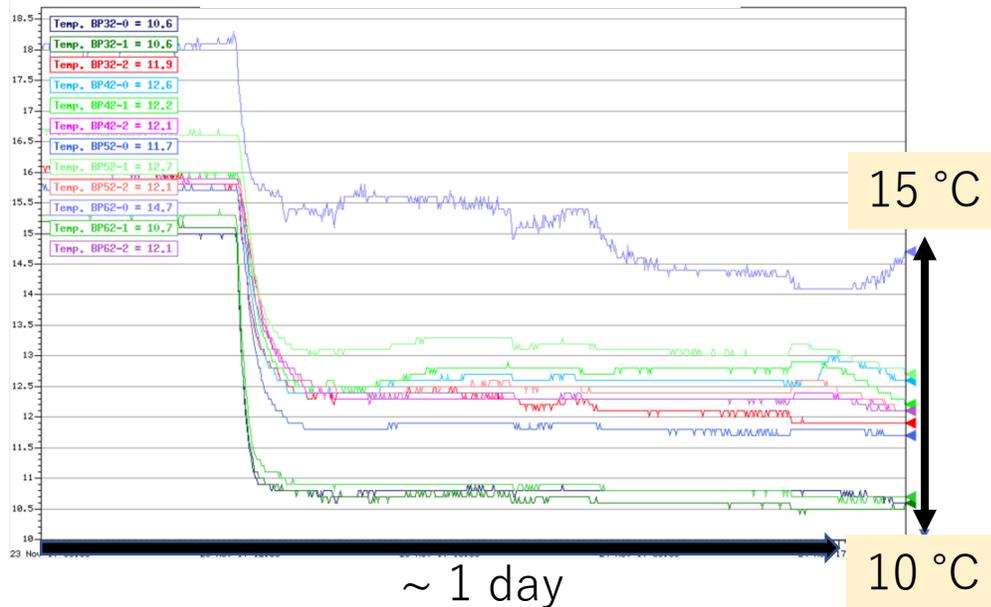
Leak current cannot be measured, so we added some offset
 Temperature is a bit unstable@Nov.15 compared with the other data

Cooling systems: chiller test 10°C

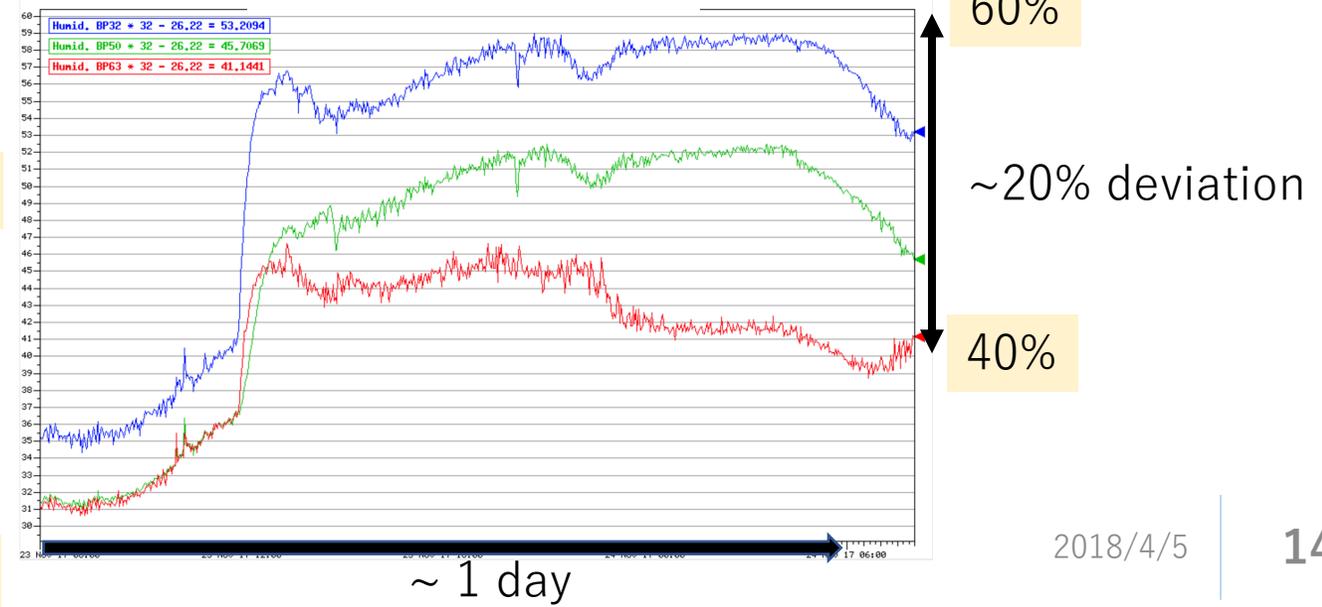
- ★ 10 degree operation test was conducted
- ★ To avoid water due, we flowed dry air
 - * By dry air, we confirmed ~10% humidity suppression @ 20 degree
- ★ But dry air is room temperature, so temperature did not become stable
 - * Cool dry air system is needed



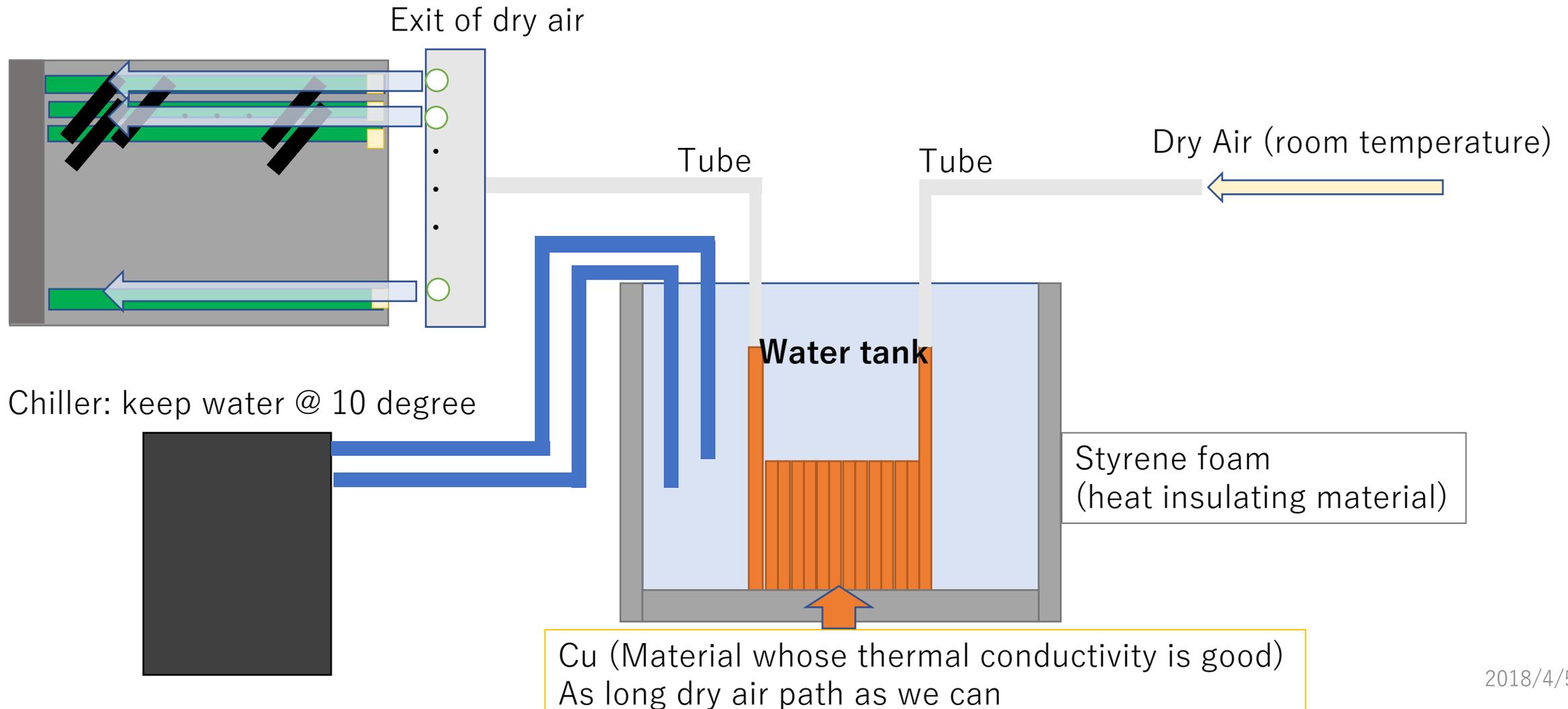
Temperature of US TC



Humidity of US TC



Cooling Dry Air System (Plan)



Cooling Dry Air System

★Costs

- *Much lower, simpler than ready-made goods

- What we need is some **air tubes, water tank and long copper tube**

★Performance & safety

- *Should be checked in practice

- *Test will be conducted during in summer?

- *Safety should be checked since **water can be the source of problems**

★Area

- *We do not know how much water & copper tube length is enough for making stable 10 degree dry air, but we need area to put this in $\pi E5$
Area

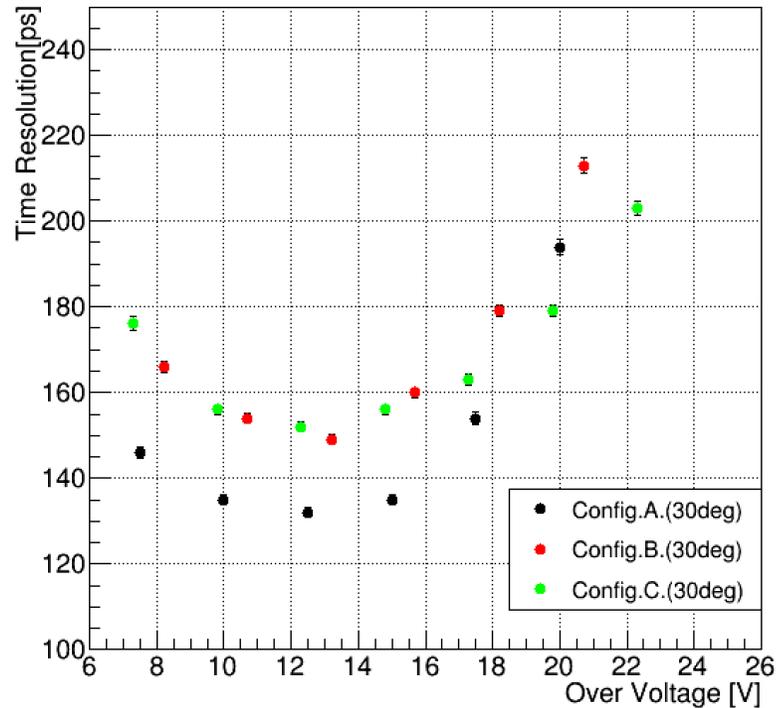
Summary

- ★ We **completed the measurement for understanding radiation damage effect** on timing counter
 - *30% deterioration @ 30degree, 5% deterioration @ 10 degree
 - *Breakdown shift & time center difference on position
- ★ We **prepared method to suppress and optimize the counter operation under radiation**
 - *IV monitoring
 - *Laser bias scan
 - *Cool dry air system
- ★ We assure that **“Though radiation damage will deteriorate the TC performance, we can suppress and its deterioration level will be almost negligible to the final sensitivity.”**

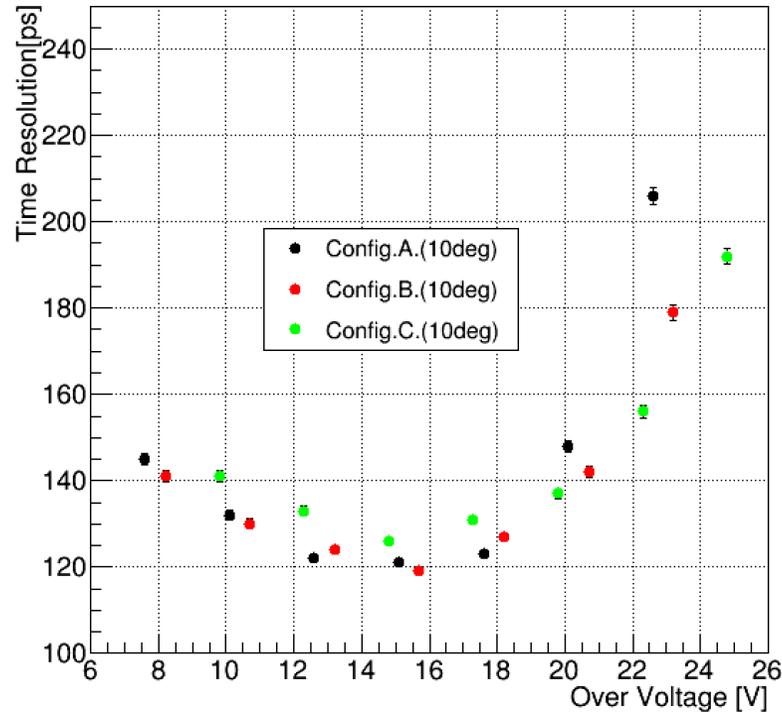
Effect on Time Resolution

★ We estimated the effect on time resolution

Time resolution plot(30deg)



Time resolution plot(10deg)



TC Maintenance & Prospect

- ★ Some bad counters were found @ Maintenance work, but we succeeded to operate most of counters properly
- ★ Minor problems (Problem # / All #)
 - * Laser fiber broken (~11/512 fibers)
 - * Temperature sensor broken (~6/192 sensors)
 - * SiPM broken (~**1/1024 channels**)
 - * Chiller broken (when shutdown)
- ★ **In 2018 autumn** DCH will be installed
 - * TC will be installed and operated in **best condition**
 - * With full detector, **engineering run** will start

Summary

- ★ Commissioning for TC in 2017 was **successfully finished**
 - * ~2 weeks data taking, only **1 ch / 1024 ch** broken
 - * Systems tested & worked well during commissioning
- ★ Cooling systems
 - * Chiller test was done for low temperature & stable operation
 - * **20 degree operation was stable** within ~1 degree, more dedicated system is needed for 10 degree operation
- ★ Current monitoring / Voltage optimization
 - * **Obvious current increase due to radiation damage**, higher than 2016
 - * **Voltage tuning method with laser** was developed
 - * **Continuous IV data** is sensitive sensor to radiation damage
- ★ **In 2018 autumn, engineering run** will start
 - * TC will be **in best condition** by maintenance work