

# Inter-University ICRR Joint program

Jeong Yeol Yang

**Light scattering measurement in the water  
using the Super-Kamiokande detector**

Members : Jeong Yeol Yang<sup>1</sup>, Soo-Bong Kim<sup>1</sup>, Intae Yu<sup>2</sup>

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<sup>2</sup> *Sungkyunkwan University*

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# 0. Introduction

- Research Purpose  
Through using regularly projected laser sources,
  - 1) Measure water transparency, which is necessary for MC tuning
  - 2) Monitoring water transparency in time variation
- Research Plan
  - 1) Operate and maintain laser injector system
  - 2) Do analysis in use of taken laser data and give report weekly in the calibration group
  - 3) Regularly attend meetings and visit the facility

# 1. 2019 Activity report

- Visit & Works (6 times, 151 days)
  - 2018/12/9~23 : Optical fiber installation
  - 2019
    - 1/12~2/28 : Top injector installation
    - 3/16~3/31 : Step motor maintenance
    - 5/10~5/26 : Analysis & Collaboration meeting
    - 7/17~8/14 : Shift works and Laser system maintenance
    - 10/29~11/27 : Analysis & Collaboration meeting
- Attend meeting
  - 5/23~5/25 : 2019 May collaboration meeting
    - : Report result between end of SK4 & start of SK5
  - 11/14~11/16 : 2019 Fall collaboration meeting
    - : Report result in SK5 data
  - Weekly calibration meeting (Online&Offline, 34 times)
    - : Report laser data taking status & analysis progress
- HW Contribution (slide 6)
  - Prepare spare parts for injector position control system



## 2. Water laser system

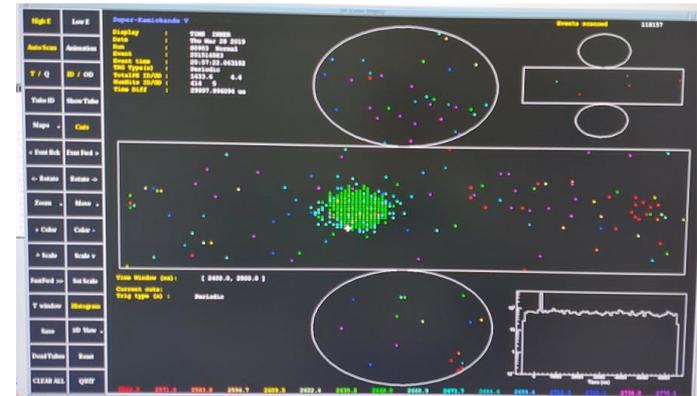
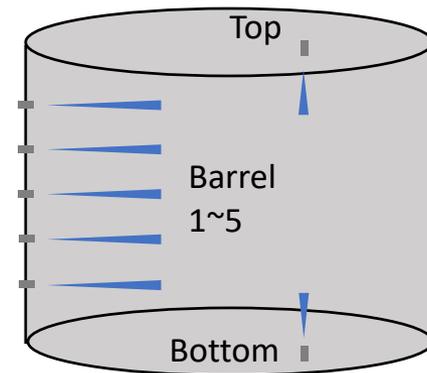
By using Laser, measures

To know how many photons are

**Absorbed or Scattered**

- 7 injector positions

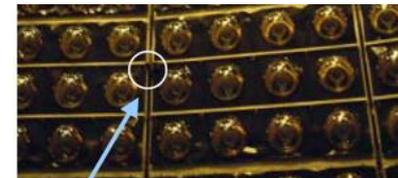
- 5 laser wave lengths



Measured **timing hit distribution of scattered photons**

→ Compare Data and MC template

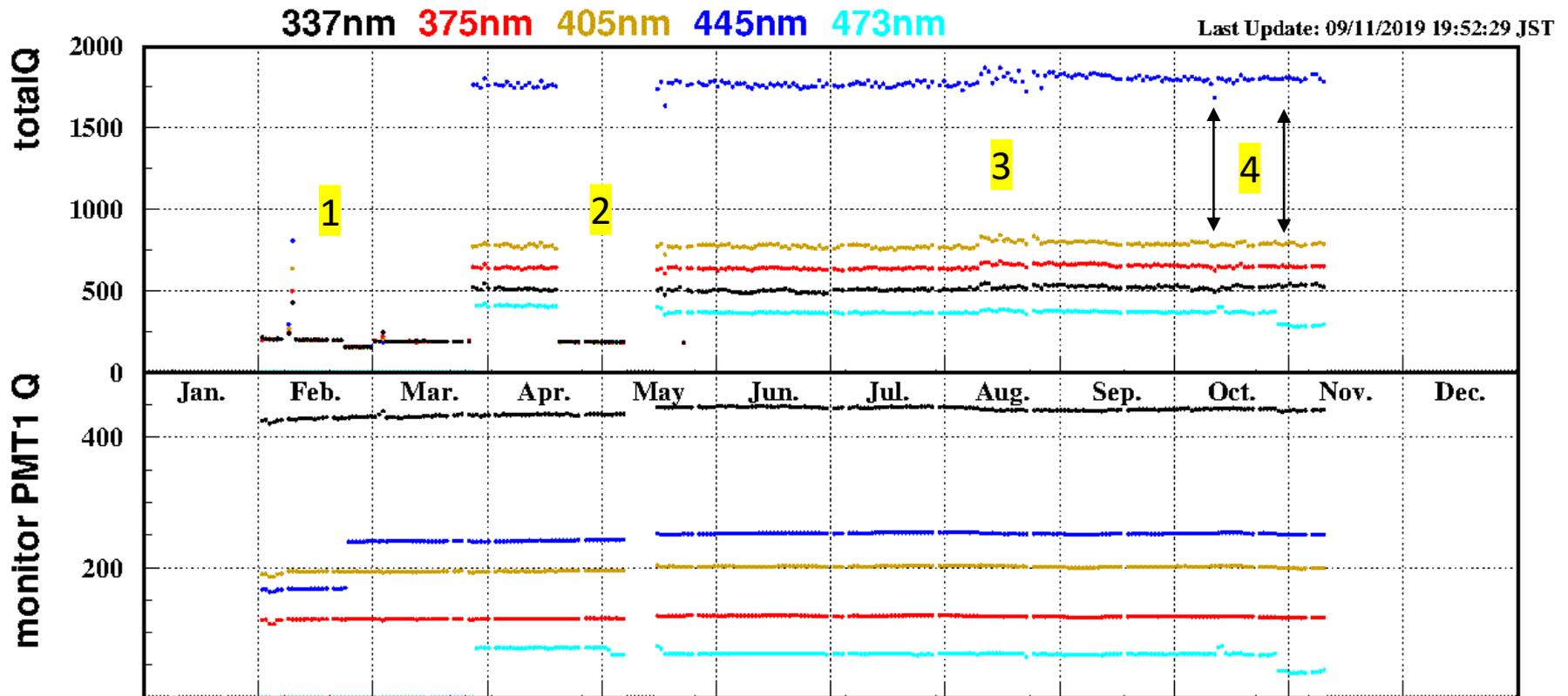
→ Finding input water parameter of MC



LASER  
Injection  
Position



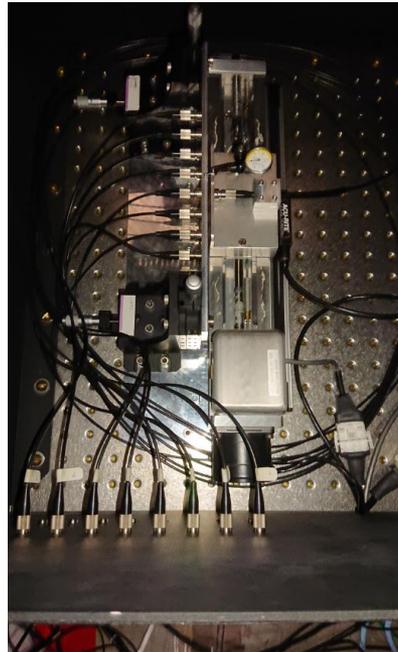
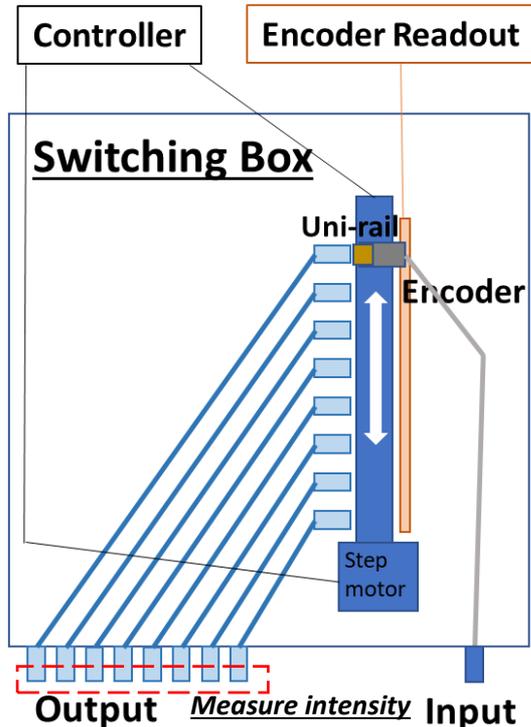
## 2. Water laser data-taking status



- 1 Computer storage break down
- 2 Step motor initialization problem
- 3 2019/8/7~28 LINAC calibration, fluctuation due to the small number of event.
- 4 2019/10/10, 10/30 LASERS used for other injector after reconnected, Intensity some of LASERS decreases.

# 3. Hardware maintenance<sup>[1]</sup>

1. Overhaul the switch box (2019/8/9-13) : apply lubricant & clean inside
2. Prepare spare parts (**Ready to use**)
  - HW: Spare computer, step motor & controller, position encoder & read-out
  - SW: Codes and scripts are set up on spare computer



3. Laser intensity test
  - In use of spare parts (expt. motor)
  - 405nm laser / 7 injector
  - 1" PMT(-900V) / Oscillo scope

Injector position	Pulse charge (pC) err = 3.2916%
New Top	0.357685
Barrel 1 / 2	0.347796 / 0.342431
Barrel 3 / 4	0.359253 / 0.336679
Barrel 5 / Bottom	0.380710 / 0.361466

## 4. Analysis and Result

- Now doing iteration for MC absorbance parameter.
  - 1) Update SKDetsim MC
  - 2) Compare Nhit timing dist. Of MC samples (before/after)
  - 3) Getting water parameter with new (or old) MC template
  - 4) Provide water parameter to MC group
  - 5) Repeat 1)
- Reference period for gain drift : 2019/8/20-9/19
- Reprocessed data-set with new calibration constants
- Also water laser data-reprocessing for SK5 is done<sup>[2]</sup>

*[2] More specific in the backup slides*

## 4. Analysis - MC sampling results

- Compare MC samples for SK4 and recent version(10/16) <sup>[3]</sup>
- Produce 2 par. fixed & 1 par. varying to end of range
- MC generation information (tba=0)
  - (**abs**, ray, mie) = (**0.2**, 1.0, 0.8), (**1.5**, 1.0, 0.8)
  - (abs, **ray**, mie) = (0.8, **0.9**, 0.8), (0.8, **1.1**, 0.8)
  - (abs, ray, **mie**) = (0.8, 1.0, **0.2**), (0.8, 1.0, **1.5**)
- Both MCs exclude HK pmts. (in analysis as well)
- Difference in calibration constants (such as TQ map)

*[3] More specific in the backup slides*

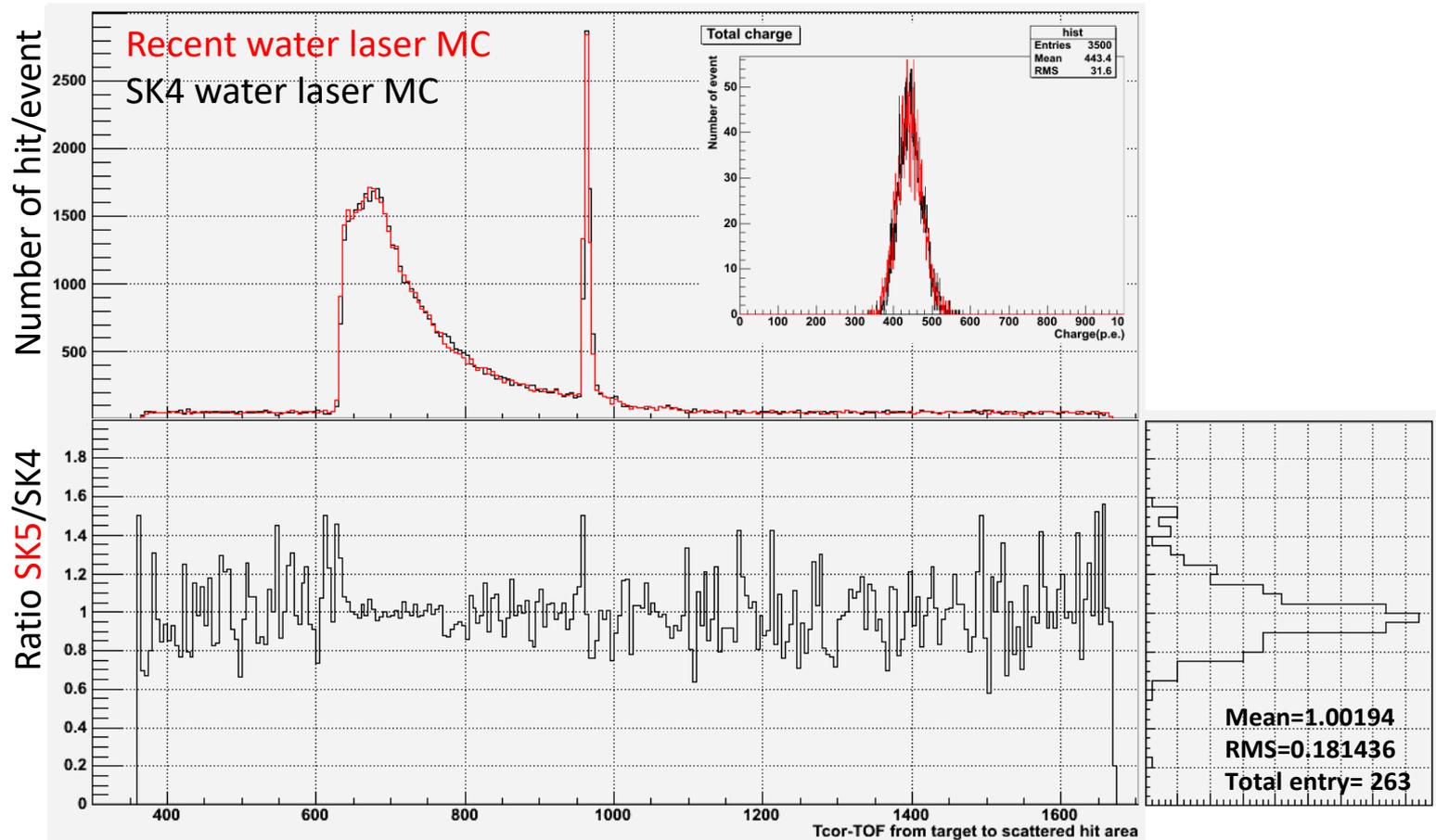
Example) Nhit timing dist.  
from target to scattered hit area  
& Charge distribution

MC generation information (tba=0)

(abs, ray, mie) = (0.2, 1.0, 0.8), (1.5, 1.0, 0.8)

(abs, ray, mie) = (0.8, 0.9, 0.8), (0.8, 1.1, 0.8)

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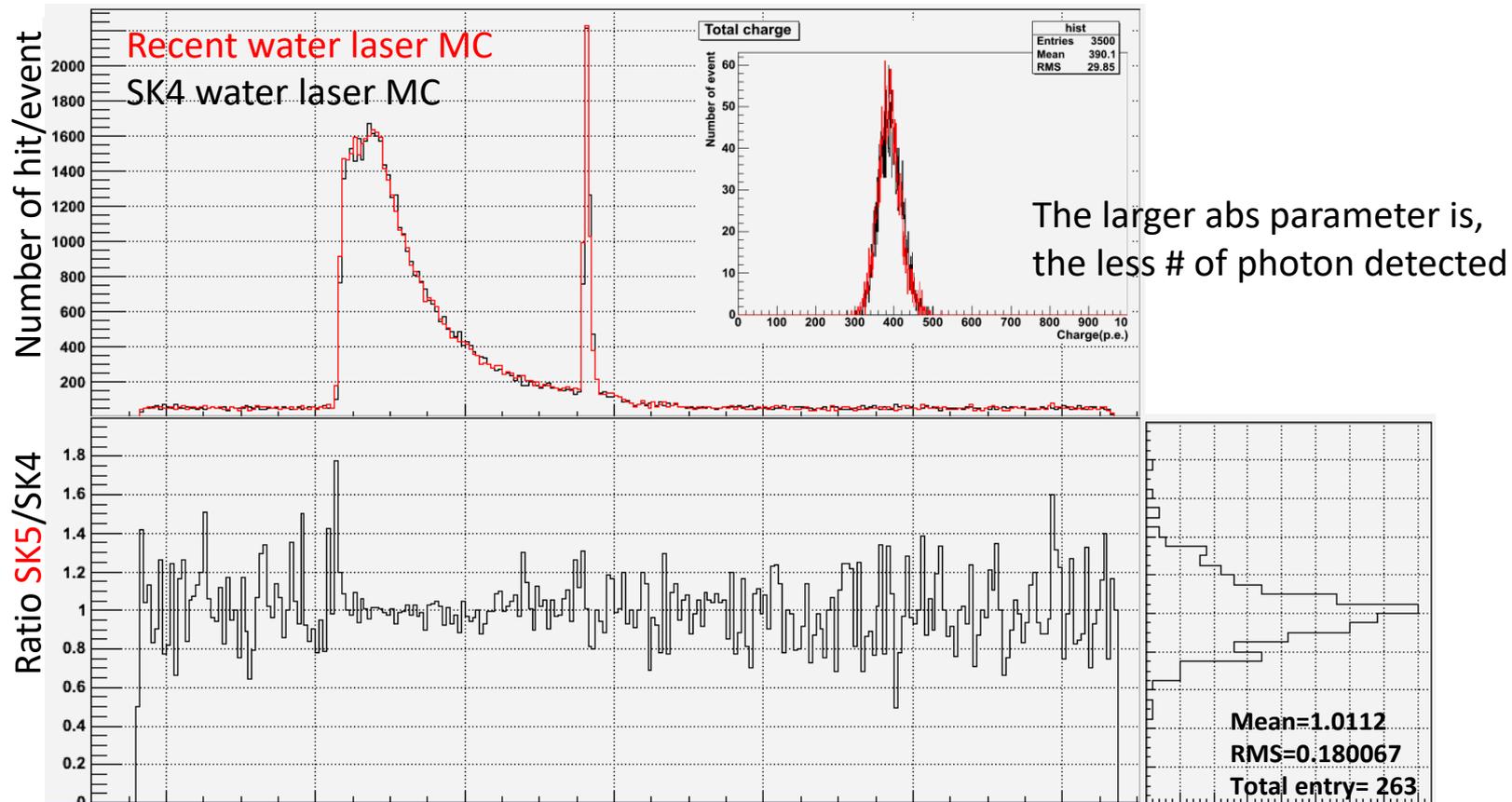
Example) Nhit timing dist.  
from target to scattered hit area  
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(abs, ray, mie) = (0.2, 1.0, 0.8), (1.5, 1.0, 0.8)

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(abs, ray, mie) = (0.8, 1.0, 0.2), (0.8, 1.0, 1.5)



The bottom line

: SK4 & SK5 results are the same so that just use the SK4 template, at least now.

# 4. Results

- Time variation for  $N/Q^*$   
 ((Total – dark hits) in scattered area) / Total charge
- Water Parameters <sup>[5]</sup>  
 : Last two month in SK4 / Ref. period for Gain in SK5
- Wavelength = 337, 365, 375, 400, 405, 420, 445, 473
- Injector position = Top, barrel1~5, Bottom
- For SK4/5 season (337/375/405/445/473)<sup>[4]</sup>

*\*N : total number of hits in scattered area, top region(>2m) with subtracting dark hits*

*Q : total charge in P.E. with subtracting dark charge*

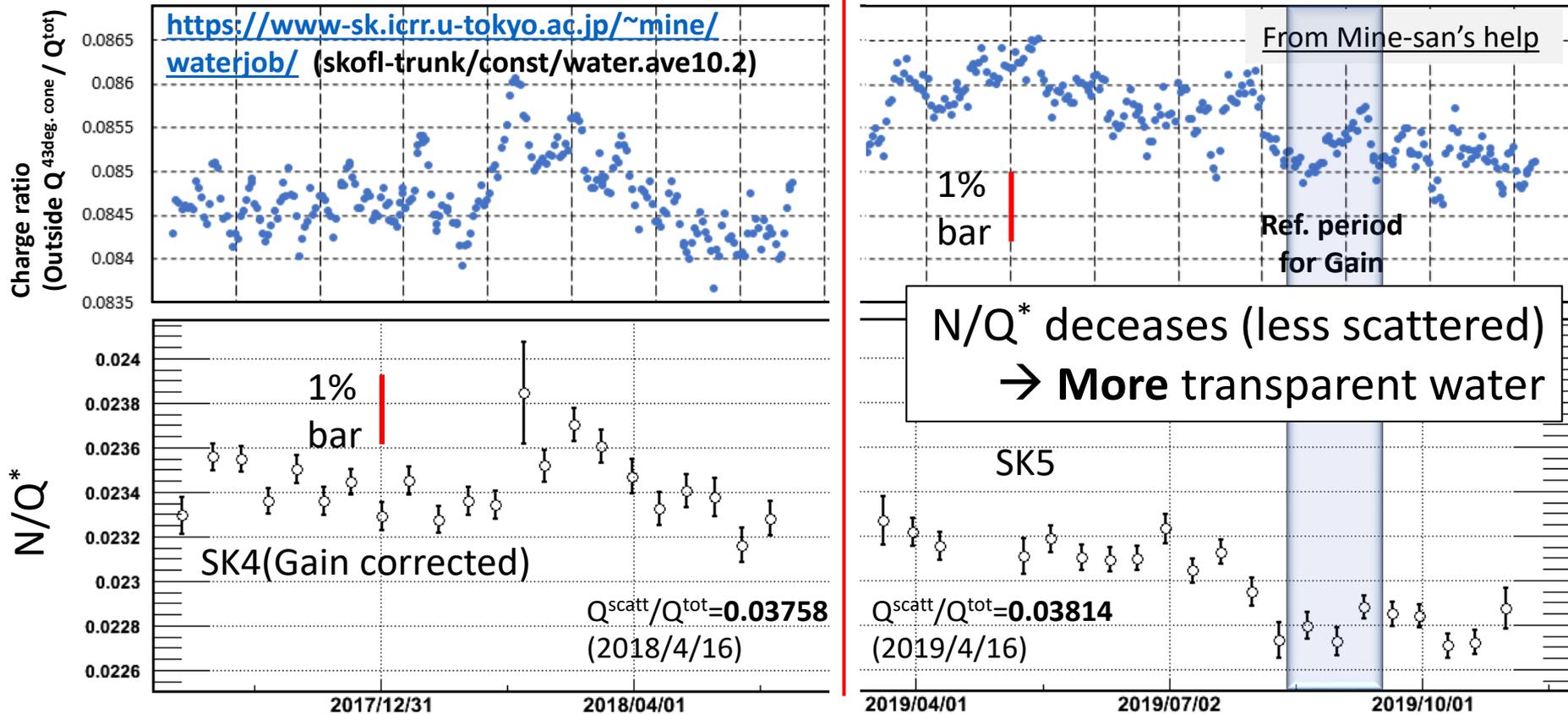
*[4] : Other injectors and wavelength results in the backup slides*

*[5] : More specific in the backup slides*

# 4. Result - $N/Q^*$

- Top injected / 405nm LASER : 3% decreasing

PRELIMINARY

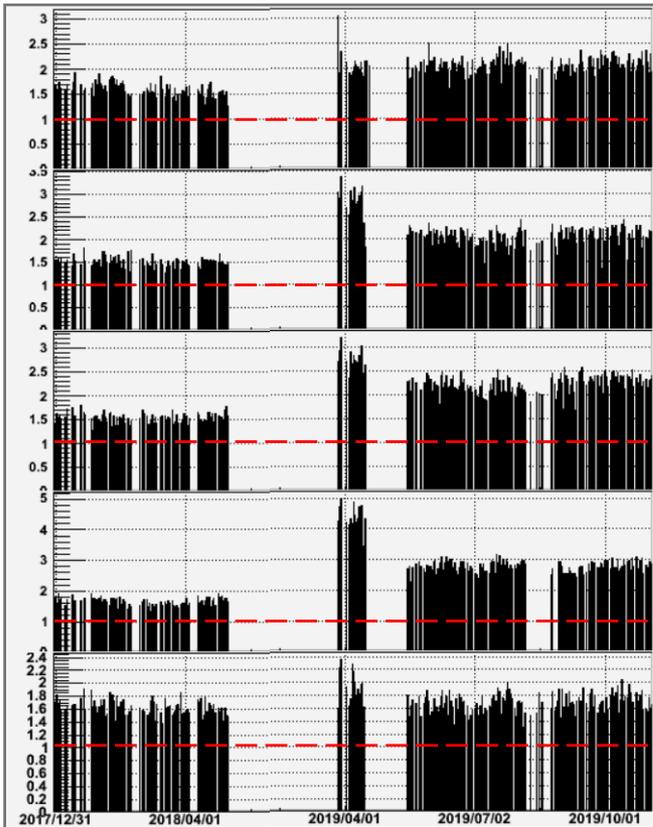


- \* N : total number of hits in scattered area, top region (>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 4. Result – Water parameters<sup>[5]</sup>

Absorbance [1/m]  
Asymmetry [1/m]  
Symmetry [1/m]

Goodness (1---)



JY Yang (SNU)

SK5 PRELIMINARY

Ref. period for gain drift



Inter-University ICRR (14 Dec 2019)

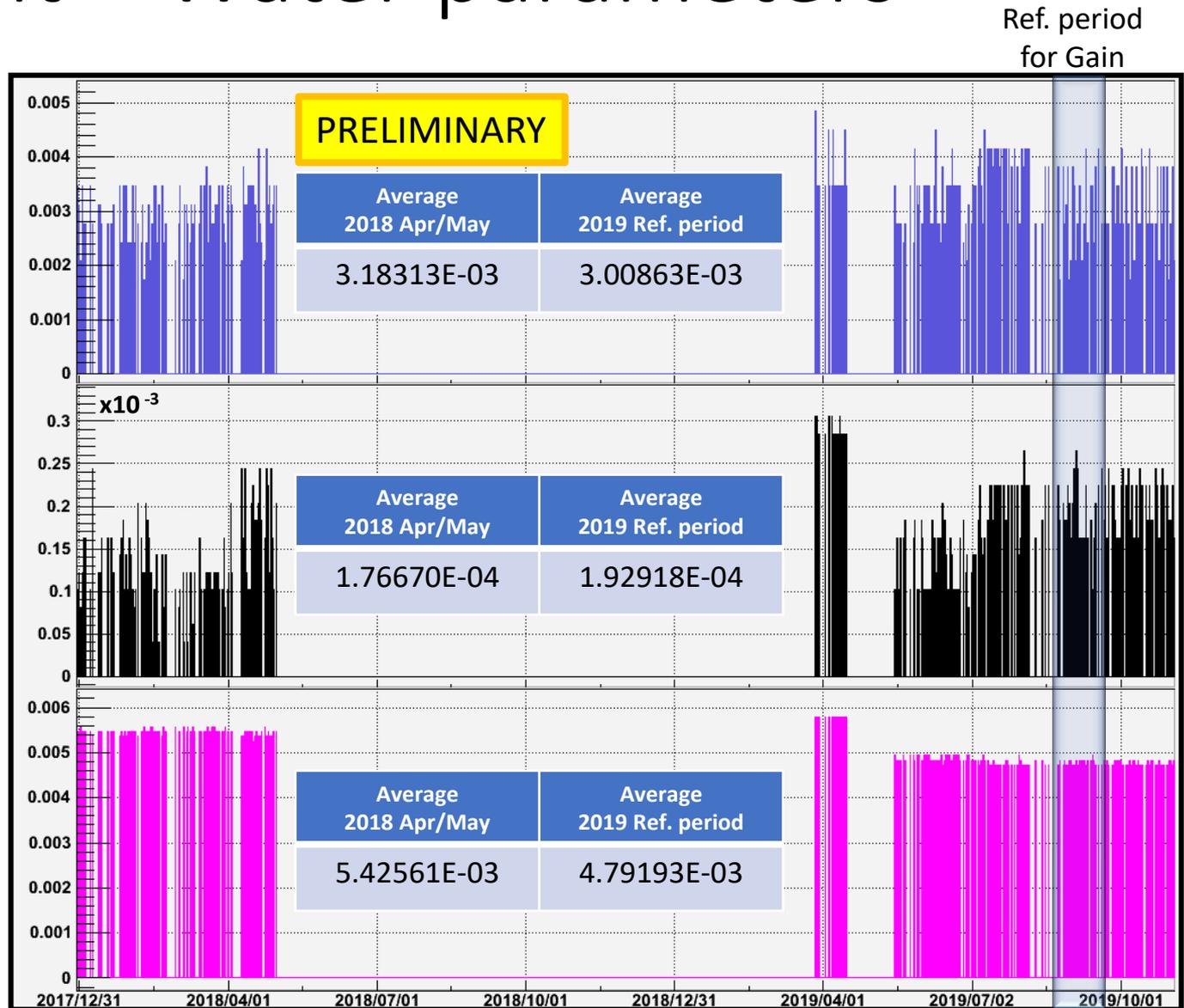
[5] : More specific in the backup slides

# Summary

- Water laser data is taken normally.
- Hard ware spare parts are ready to use.
- Water laser data processing done for analysis.
- Now decision of absorbance coefficient in MC is still under iteration.
  - Provide water parameter & update MC
  - Validate the absorbance parameter in MC

# 3. Result – Water parameters

Absorbance [1/m]  
Asymmetry [1/m]  
Symmetry [1/m]  
405nm



# 3. Result – Water parameters

Absorbance [1/m]<sup>17</sup>  
 Asymmetric [1/m]  
 Symmetric [1/m]

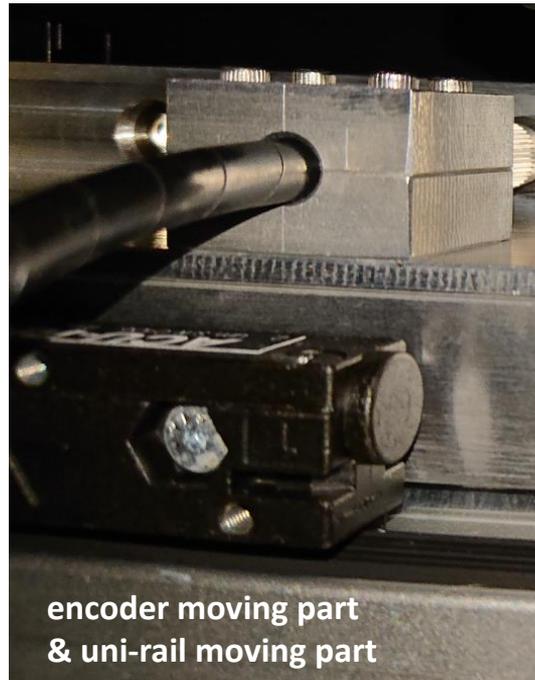
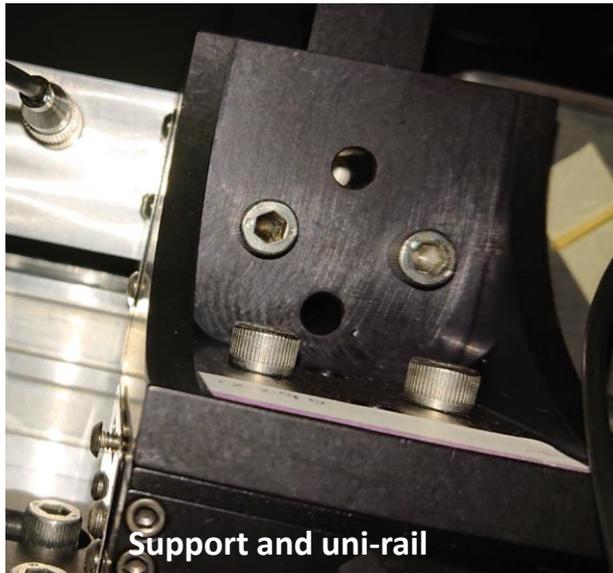
PRELIMINARY	SK4 (2018 Apr & May) / Transparency (m)		SK5 reference Period / Transparency (m)	
337nm	1.25325E-03	68.48	2.307913E-03	71.78
	3.14178E-04		4.097978E-04	
	1.30353E-02		1.121383E-02	
375nm	1.93473E-03	100.25	2.44251E-03	104.24
	1.38455E-04		2.54035E-04	
	7.90156E-03		6.89705E-03	
405nm	3.18313E-03	113.83	3.00863E-03	125.10
	1.76670E-04		1.92918E-04	
	5.42561E-03		4.79193E-03	
445nm	5.91931E-03	103.6	5.73884E-03	109.70
	1.70367E-04		2.01088E-04	
	3.56239E-03		3.17582E-03	
473nm	8.87292E-03	86.31	8.29087E-03	92.62
	7.65805E-05		1.10828E-04	
	2.63661E-03		2.39463E-03	

# Back-up

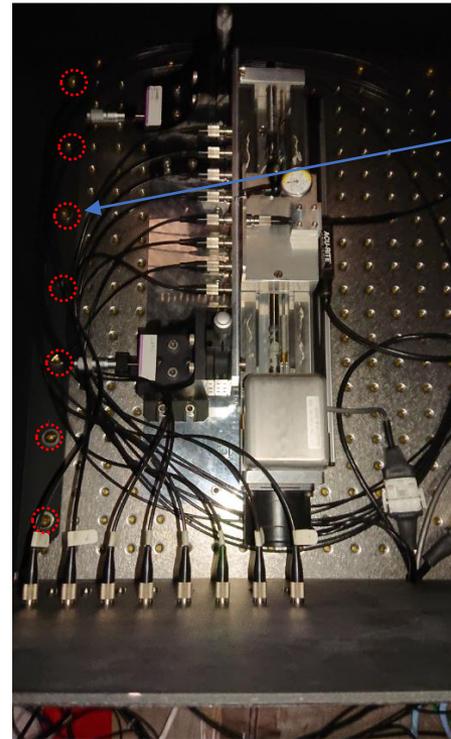
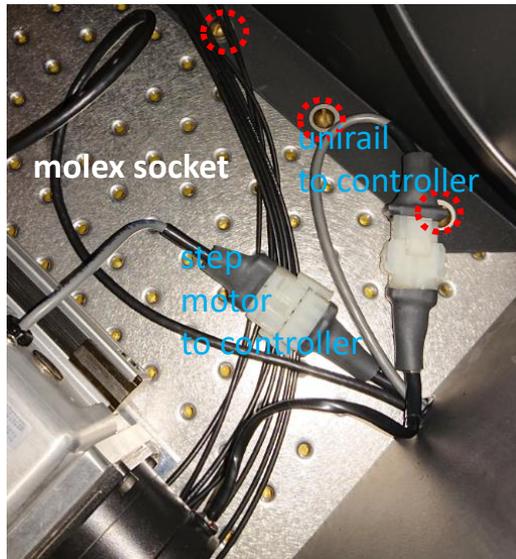
- [1] Hardware maintenance
- [2] Data reprocessing for water laser system
- [3] MC samples of SK4/5
- [4] N/Q for all injectors & wavelengths
- [5] Water parameter for each wavelength

# [1] Hardware maintenance

# [1] attachment between inside parts

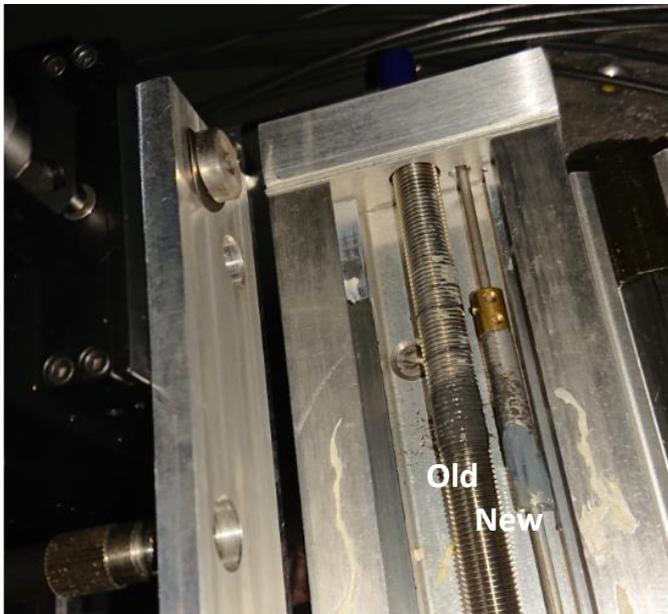


# 1) attachment between inside parts



If replacing any part,  
We should unscrew all bolts( )  around box

## 2) Overhaul switching box



**Wipe out & Apply the lubricant on the rail**

# 3) Test between recent and new part

Step Motor	--connected to--	Controller	--connected to--	Computer	--connected to--	Client
Current		Current		Current		sukcal
New		New		New		

Currently working system  
: C-C-C-sukcal

**Tested** combination

: C-C-**N**-sukcal

C-**N**-C-sukcal      C-**N**-**N**-sukcal

**N**-C-C-sukcal      **N**-C-**N**-sukcal

**N**-**N**-C-sukcal      **N**-**N**-**N**-sukcal

Confirm working



# Remark from trial and error

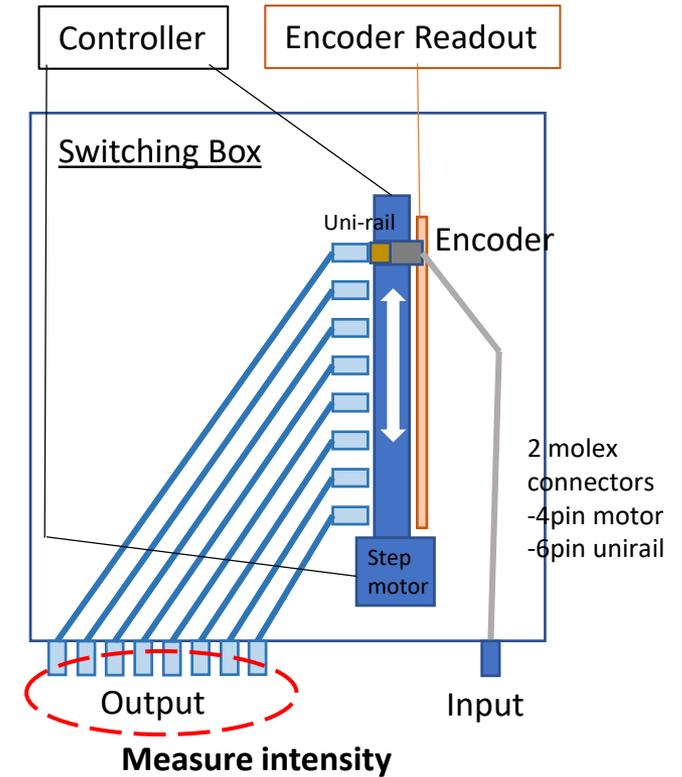
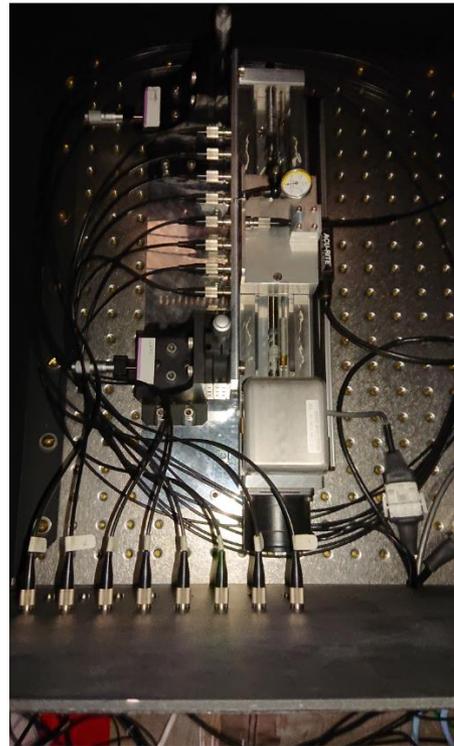
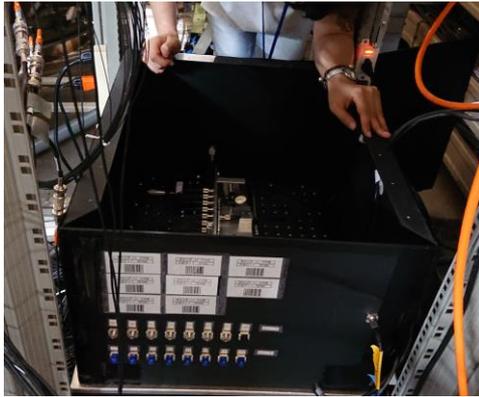
When using new step motor controller,

1. Step motor speed should be less than 3100(Max 6000) or every rotation should be less than 4 revolution.
2. Serial setting is different from recent one  
9600 8N1 – corresponding code name = xxx\_VMX  
(cf. recent 9600 7E2)
3. After changing any device, reset → power off → power on.

More specific, refer to below log file. (2019/8/8~2019/8/14)

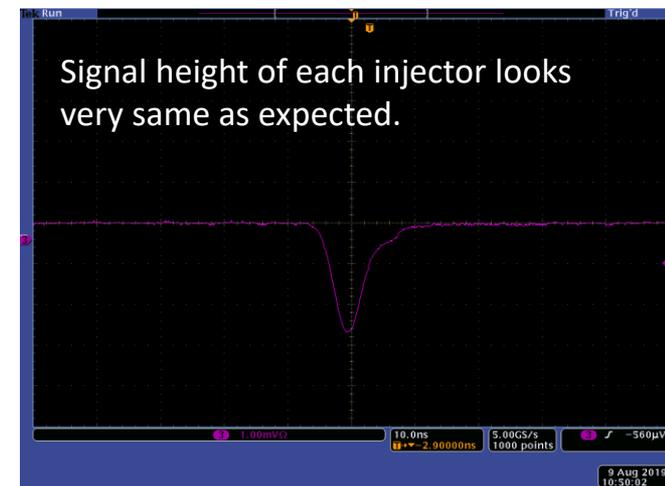
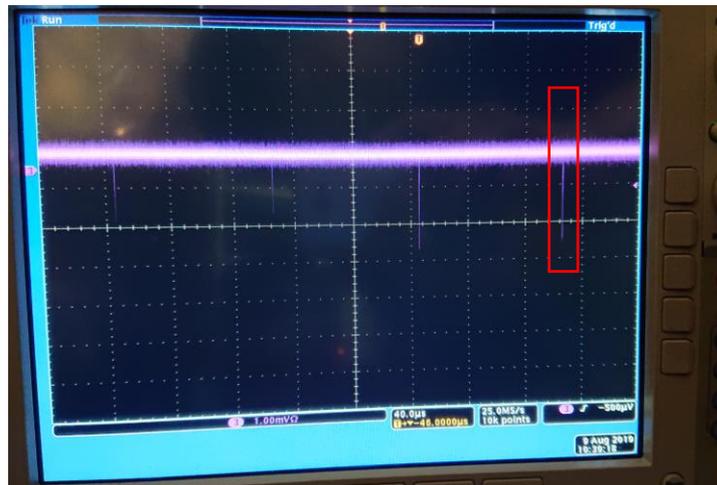
[https://www-sk.icrr.u-tokyo.ac.jp/~calib/water\\_scattering/WATER\\_HARDWARE.txt](https://www-sk.icrr.u-tokyo.ac.jp/~calib/water_scattering/WATER_HARDWARE.txt)

# Inside of switching box



# Measuring light intensity

- Measure the laser light from output by using 1" PMT (-900V)
- 405nm fixed, change in 7 injector positions
- Data is acquired and stored by using oscilloscope



## Laser intensity at the output of switching box

Repeat No.	Ped Charge	Charge in 200ns	Net pulse charge
New top_1	1.792436pC	1.424754pC	-0.3676820pC
New top_2	1.765165pC	1.406282pC	-0.3588836pC
New top_3	1.727311pC	1.383946pC	-0.3433649pC
New top_4	1.760419pC	1.393016pC	-0.3674035pC
New top_5	1.746805pC	1.394614pC	-0.3521902pC
New top_6	1.746023pC	1.383016pC	-0.3630071pC
New top_7	1.729759pC	1.381895pC	-0.3478636pC
New top_8	1.700873pC	1.357412pC	-0.3434608pC
New top_9	1.761879pC	1.401092pC	-0.3607871pC
New top_10	1.751435pC	1.379224pC	-0.3722102pC
<b>takes ~ 3x10min</b>		<b>Average (Error)</b>	<b>-0.357685pC (3.2916%)</b>

Number of sampling = 1024 → Statistical error could be 3.12%

Above error may come from the LASER module fluctuation(in 30min), systematic error

# Laser intensity at the output of sw. box

Repeat No.	Ped Charge	Charge in 200ns	Net pulse charge
New Top			-0.357685pC (3.2916%)
Barrel 1	1.709532pC	1.361736pC	-0.347796pC
Barrel 2	1.676332pC	1.333902pC	-0.342431pC
Barrel 3	1.704830pC	1.345577pC	-0.359253pC
Barrel 4	1.710800pC	1.374121pC	-0.336679pC
Barrel 5	1.725472pC	1.344763pC	-0.380710pC
Bottom	1.801243pC	1.439777pC	-0.361466pC

Shared same laser source (405nm)

but different optical cable and fitting position,

**Laser intensity is similar, other position error would be similar ~3.29%**

# [2] Data reprocessing for water laser system

# Water Laser data processing

data processed



Data format (Corrected)		Data contents for each run	MC template
Raw → Reformat		PMT#, T, $Q^{\text{ori}}$ , event #(all)	-
ZBS		PMT#, T, $Q^{\text{ori}}$ , event #(laser)	-
<b>corrected ZBS</b>		PMT#, T, $Q^{\text{cor}}$ , event #(laser)	PMT#, T, $Q^{\text{cor}}$ , event #(laser)
Histogram for Nhit <b>with weighted</b>		Timing Nhit <sup>cor</sup> distribution Total $Q^{\text{cor}}$	Timing Nhit <sup>cor</sup> distribution Total $Q^{\text{cor}}$
Log text files	N/Q	Nhit, Total $Q^{\text{cor}}$	-
	Chi2 fitting	water parameters <sup>cor</sup>	water parameters <sup>cor</sup>

# Data reprocessing & analysis status

- The results between SK4 & SK5 MC sample are consistent.  
→ Using the SK4 MC templates is fine at least now
- Analysis for water laser data is on processing  
Run # : 80891(Mar 27) ~ 82144 (Nov 5), 317 runs  
(Gain drift is not reflected yet)

Data re-processing : 2/2 steps Done

- ZBS file → Hbook (set of histogram)
- Hbook → Chi2Table (After comparing with MC template)

Data Analysis : 1/2 steps done

- Hbook analysis : Done
- Water parameter analysis : Done

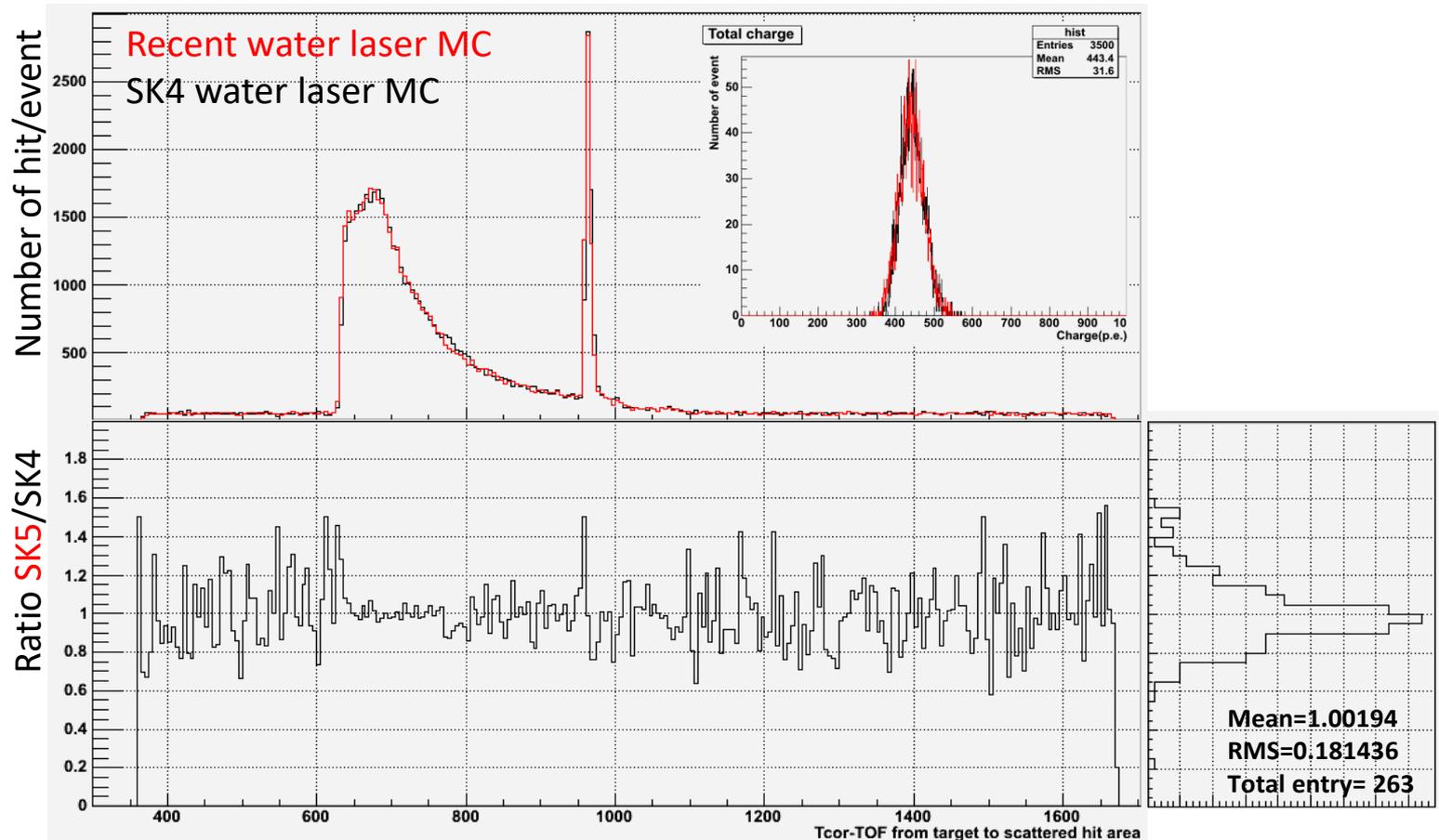
[3] MC samples of SK4/5

# Information of MC generation

- Top Injected 405nm laser light
- Number of event = 3500 / Number of photon per event = 6000
- SK4 MC : SKDETSIM which was used in SK4 analysis  
/home/jyyang/disk02/water\_calib/work\_MC/Gen-MC/detsim\_old
- SK5 MC : SKDETSIM updated at (16<sup>th</sup> Oct 2019)  
/home/jyyang/disk02/water\_calib/work\_MC/Gen-MC/detsim\_191016  
(svn co <https://kmcvs.icrr.u-tokyo.ac.jp/svn/rep/skdetsim/trunk>)
- Sim card info : /home/jyyang/disk02/water\_calib/work\_MC/Gen-MC/MC-gen/sk4\_laserMC\_gen.csh (For SK4/5, the same used)
- Results : /home/jyyang/disk02/water\_calib/work\_MC/MC\_template/  
SK4\_old\_191030\_6000\_2 *or* SK5\_191030\_6000\_2

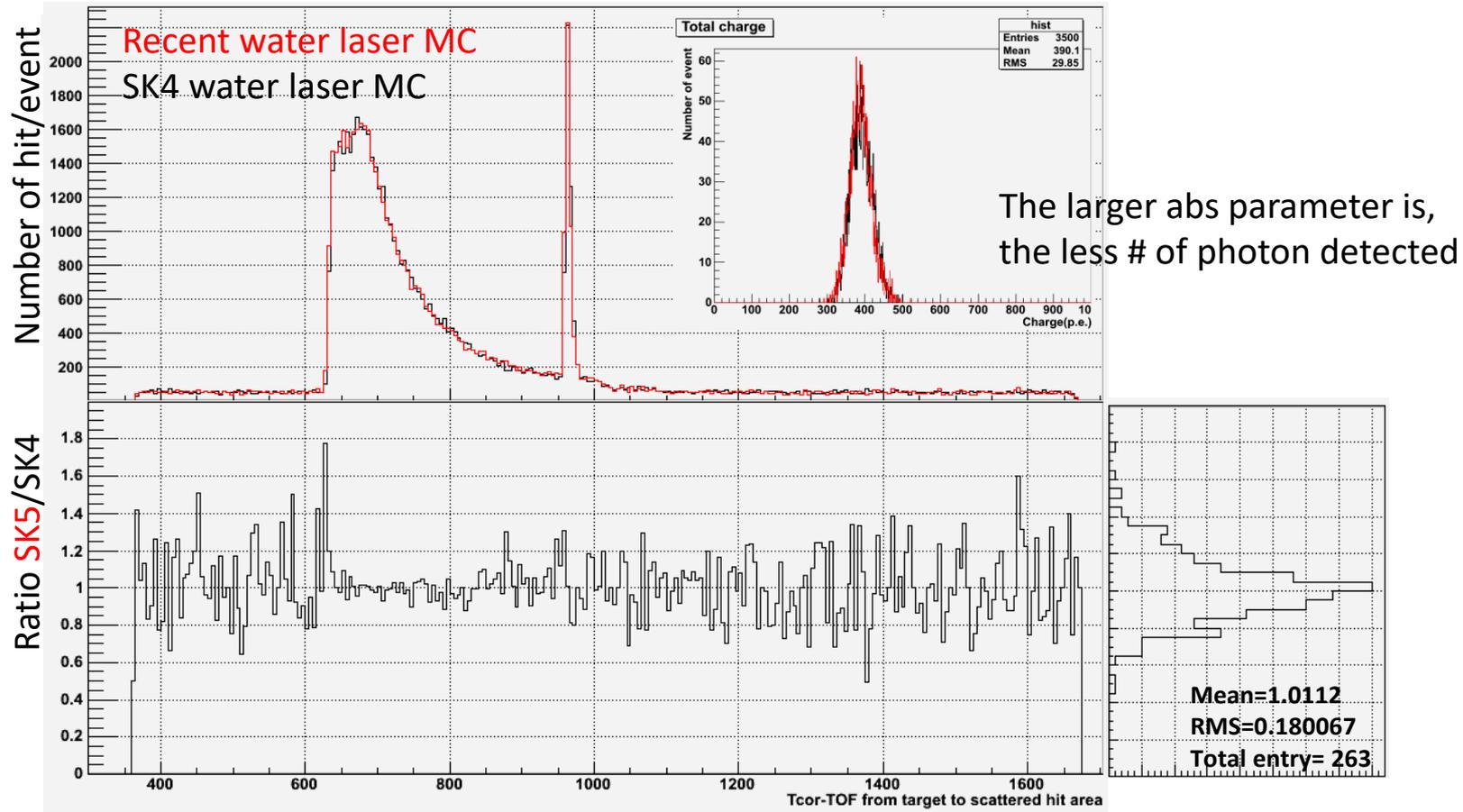
# Nhit timing dist. from target to scattered hit area & Charge distribution

MC generation information (tba=0)  
 (abs, ray, mie) = **(0.2, 1.0, 0.8)**, (1.5, 1.0, 0.8)  
 (abs, ray, mie) = (0.8, **0.9**, 0.8), (0.8, **1.1**, 0.8)  
 (abs, ray, mie) = (0.8, 1.0, **0.2**), (0.8, 1.0, **1.5**)



# Nhit timing dist. from target to scattered hit area & Charge distribution

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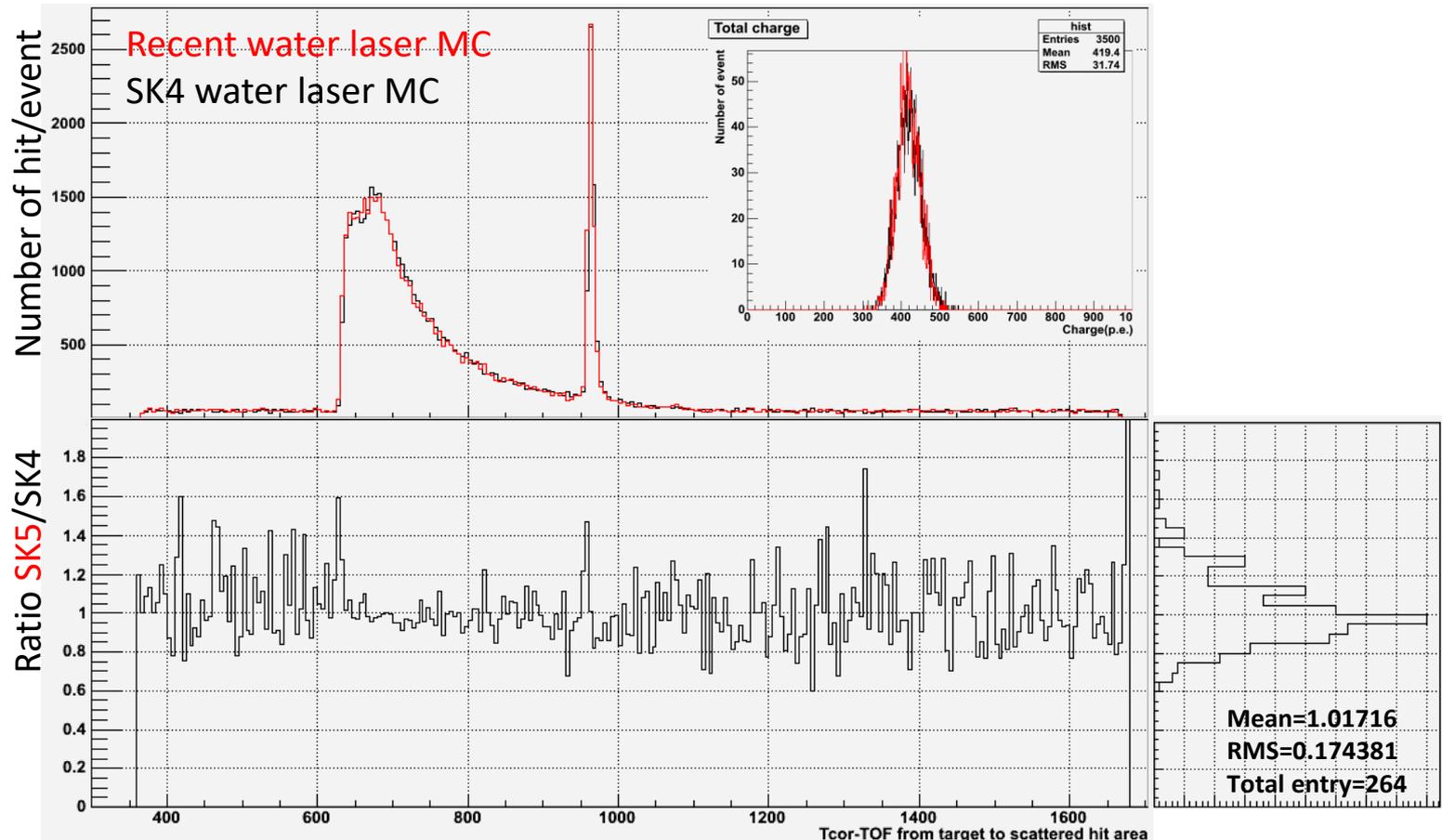
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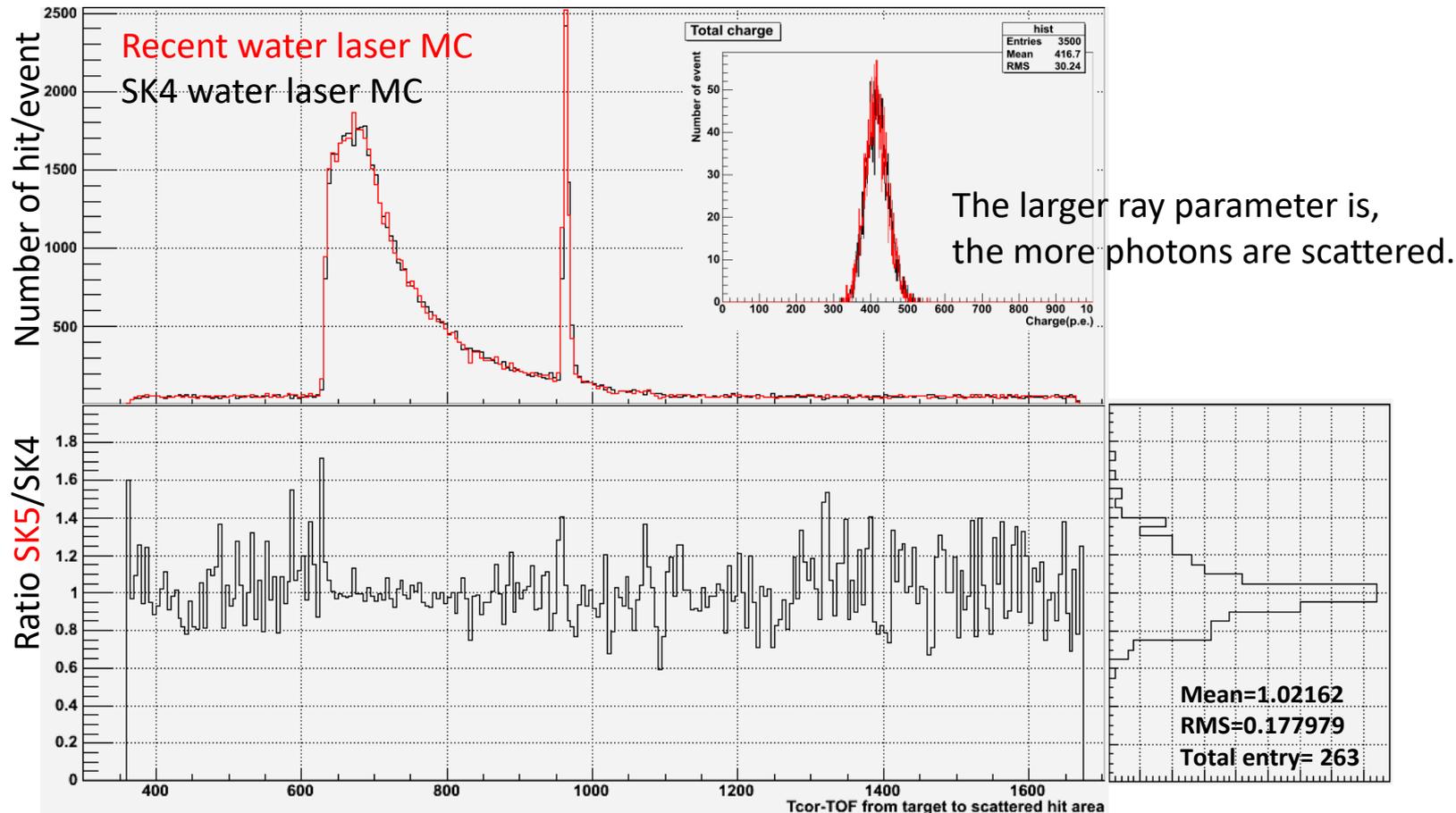
(abs, **ray**, mie) = (**0.8**, **0.9**, **0.8**), (0.8, **1.1**, 0.8)

(abs, ray, **mie**) = (0.8, 1.0, **0.2**), (0.8, 1.0, **1.5**)



# Nhit timing dist. from target to scattered hit area & Charge distribution

MC generation information (tba=0)  
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 (abs, ray, mie) = (0.8, 1.0, 0.2), (0.8, 1.0, 1.5)



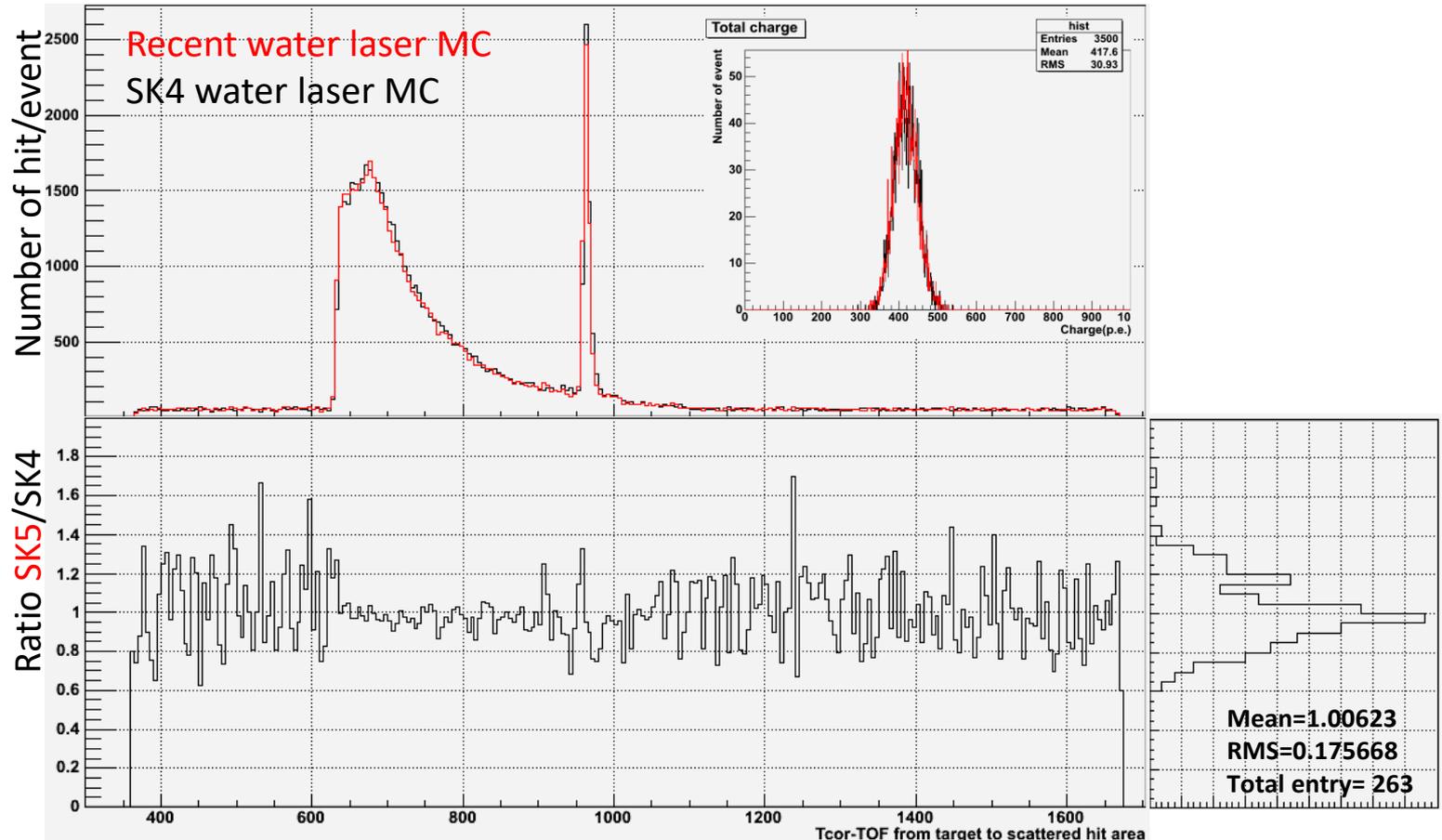
# Nhit timing dist. from target to scattered hit area & Charge distribution

MC generation information (tba=0)

(**abs**, ray, mie) = (**0.2**, 1.0, 0.8), (**1.5**, 1.0, 0.8)

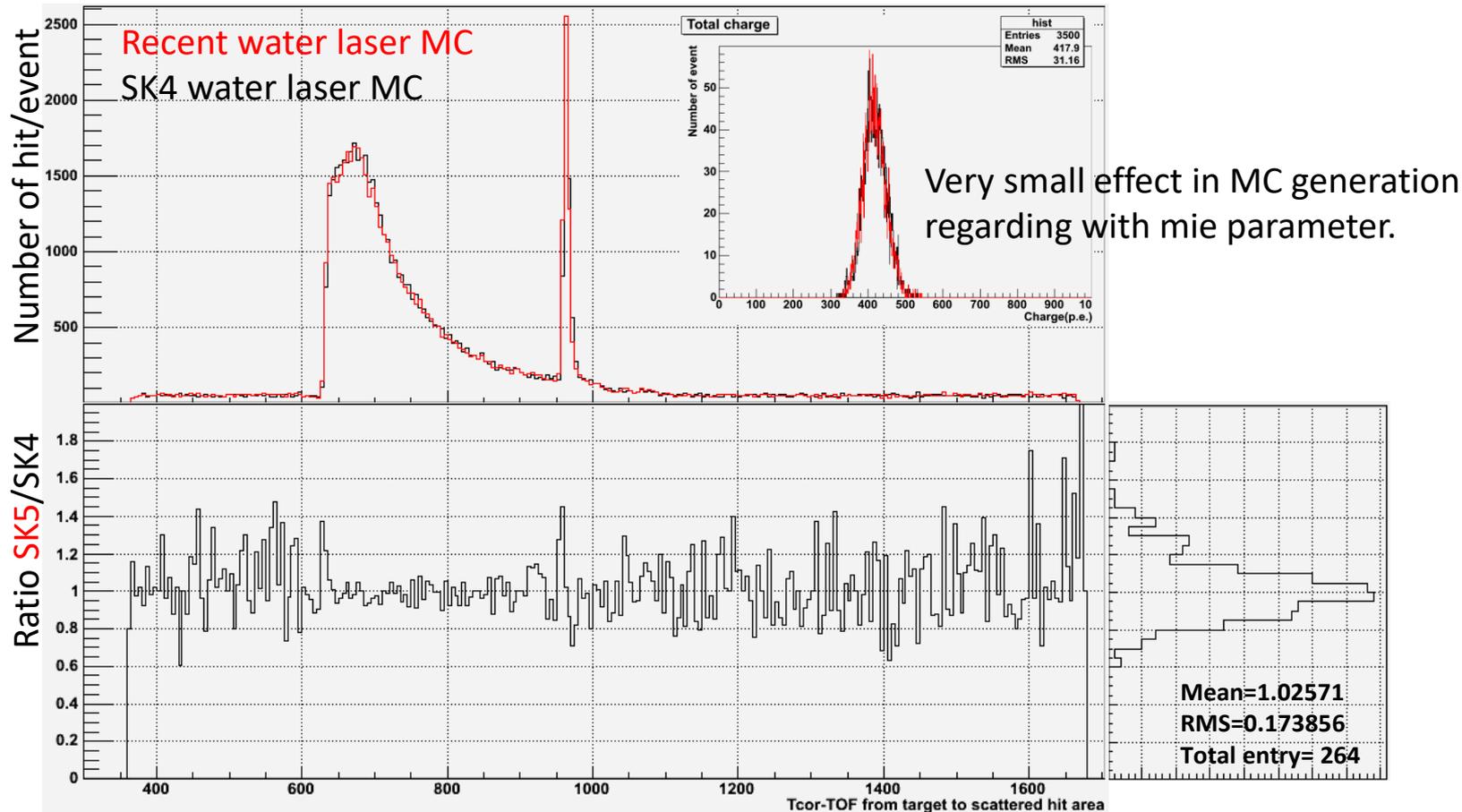
(abs, **ray**, mie) = (0.8, **0.9**, 0.8), (0.8, **1.1**, 0.8)

(abs, ray, **mie**) = (**0.8**, 1.0, **0.2**), (0.8, 1.0, **1.5**)



# Nhit timing dist. from target to scattered hit area & Charge distribution

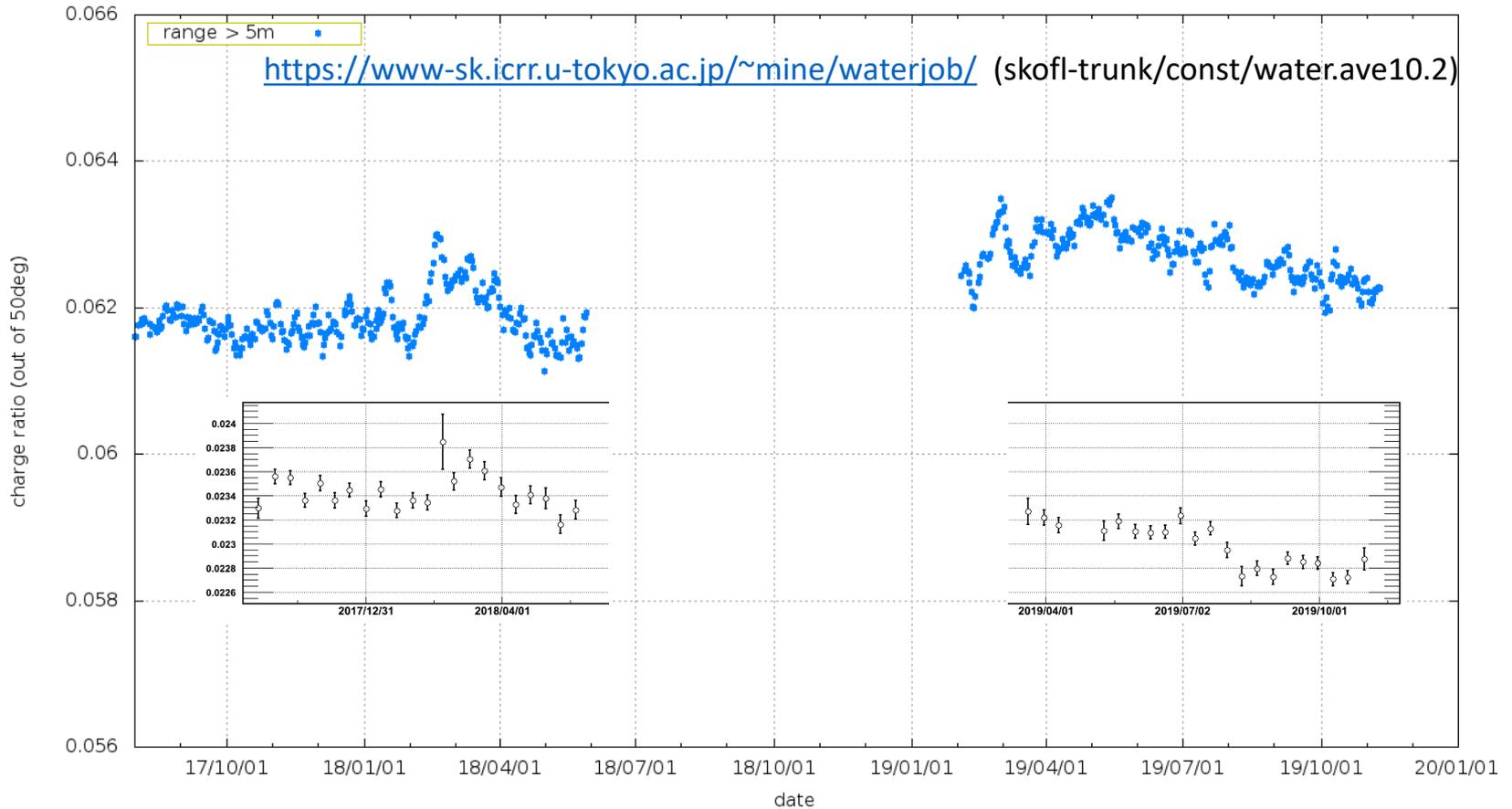
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 (abs, **ray**, mie) = (0.8, **0.9**, 0.8), (0.8, **1.1**, 0.8)  
 (abs, ray, **mie) = (0.8, 1.0, 0.2), (0.8, 1.0, 1.5)**



[4] N/Q for all injectors & wavelengths

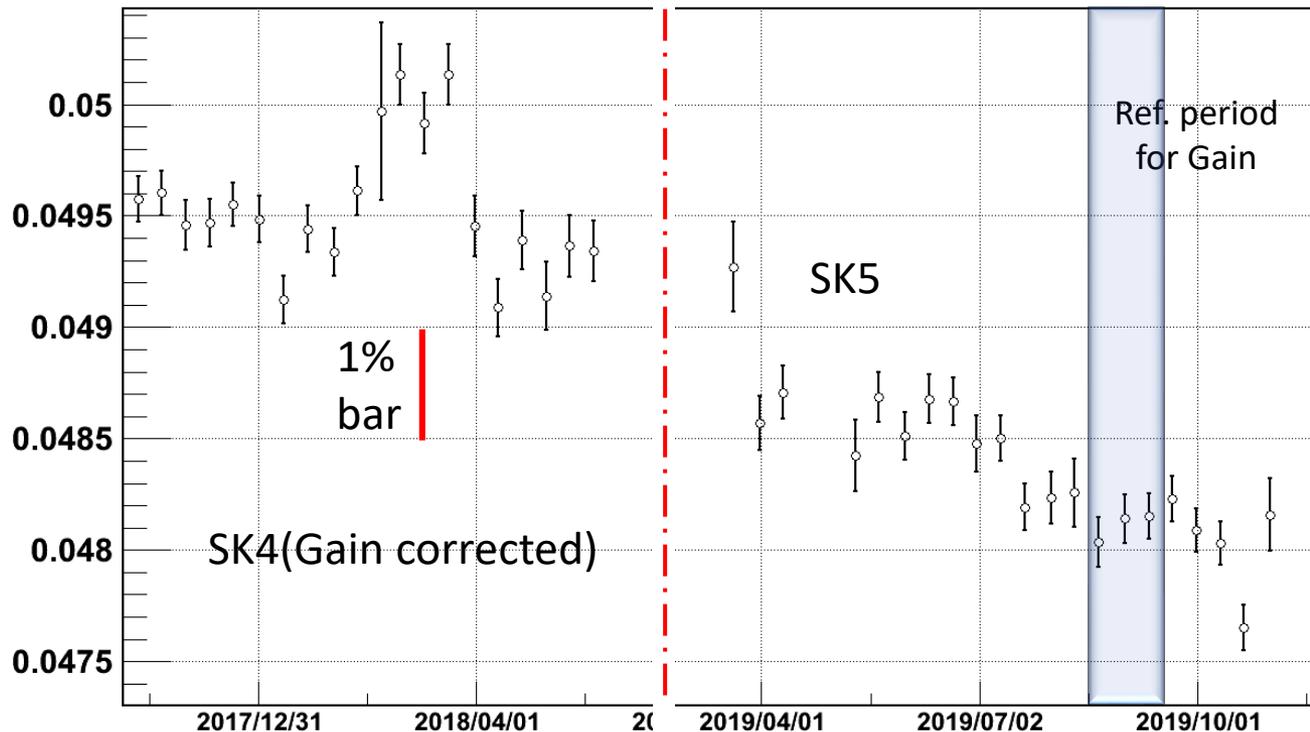
# OD-measurement for water transparency

From Mine-san's help



# 3. Result - $N/Q^*$

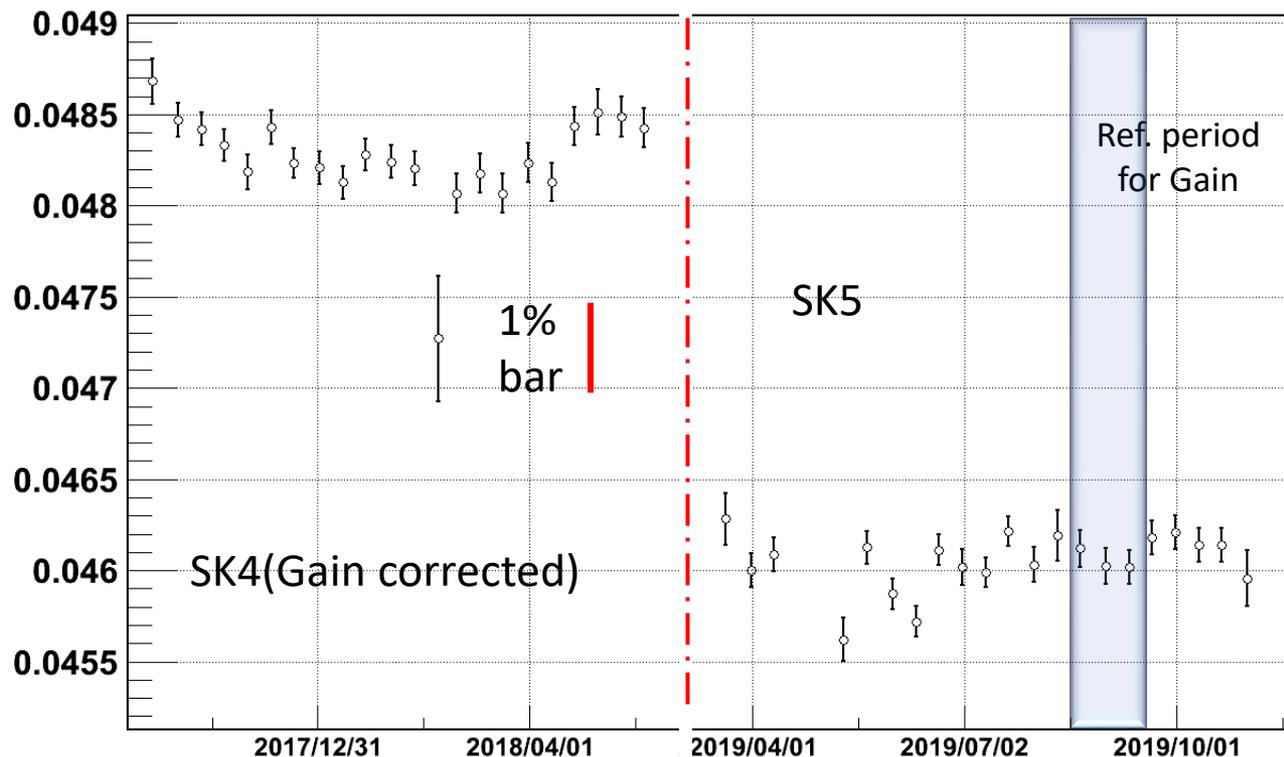
- Top injected / 337nm LASER : 2.8% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

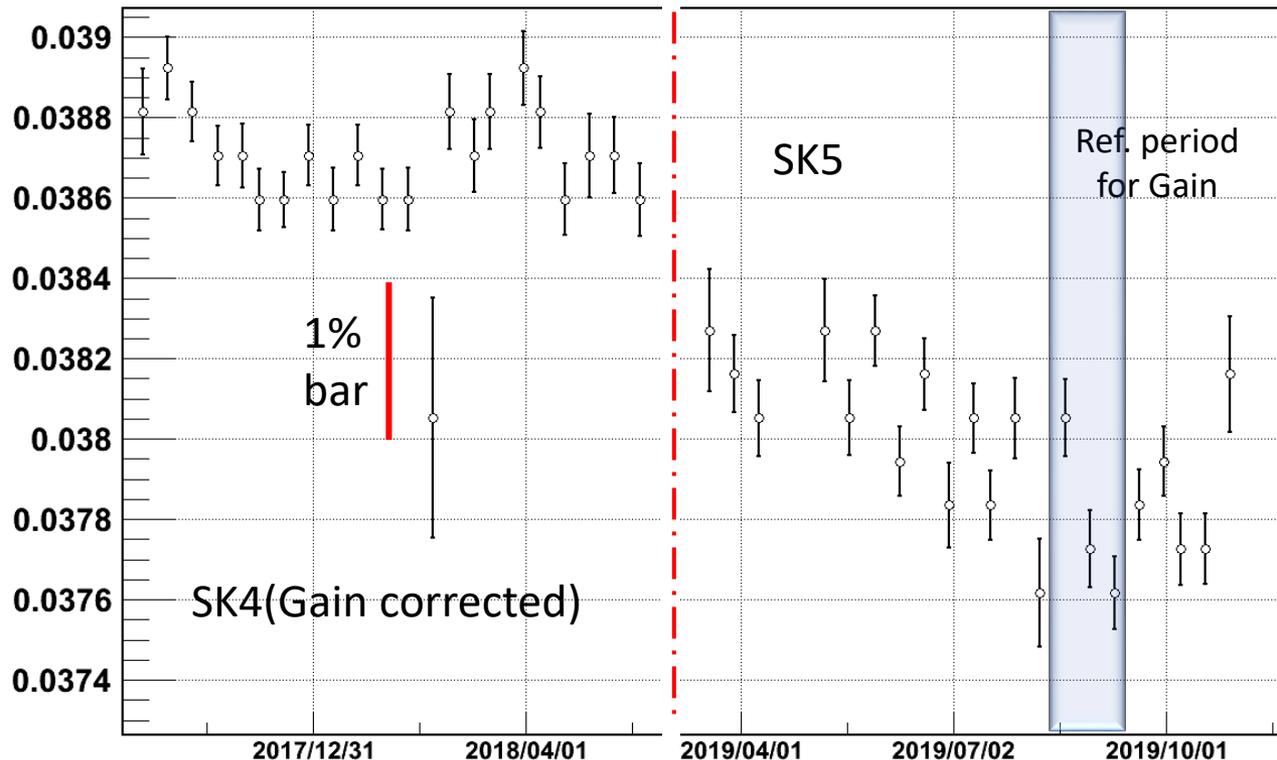
- B1 injected / 337nm LASER : 4.5% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

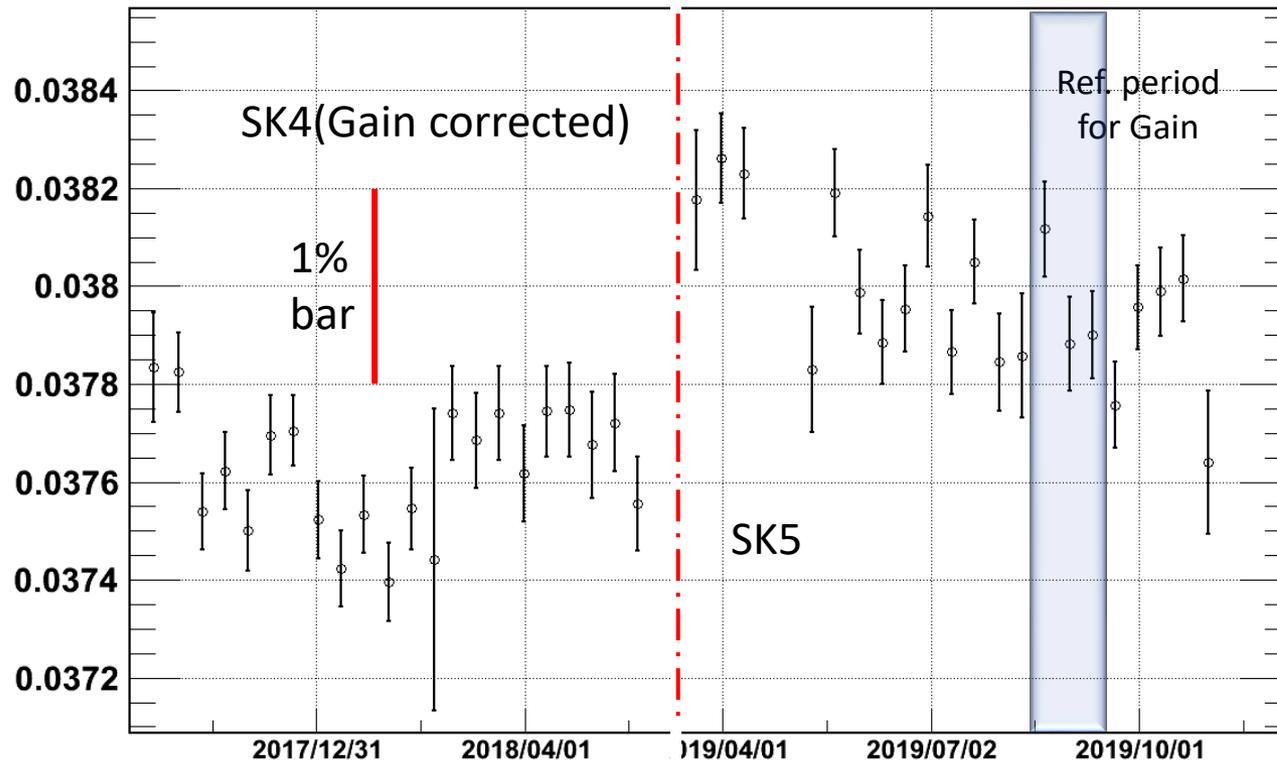
- B2 injected / 337nm LASER : 2.6% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

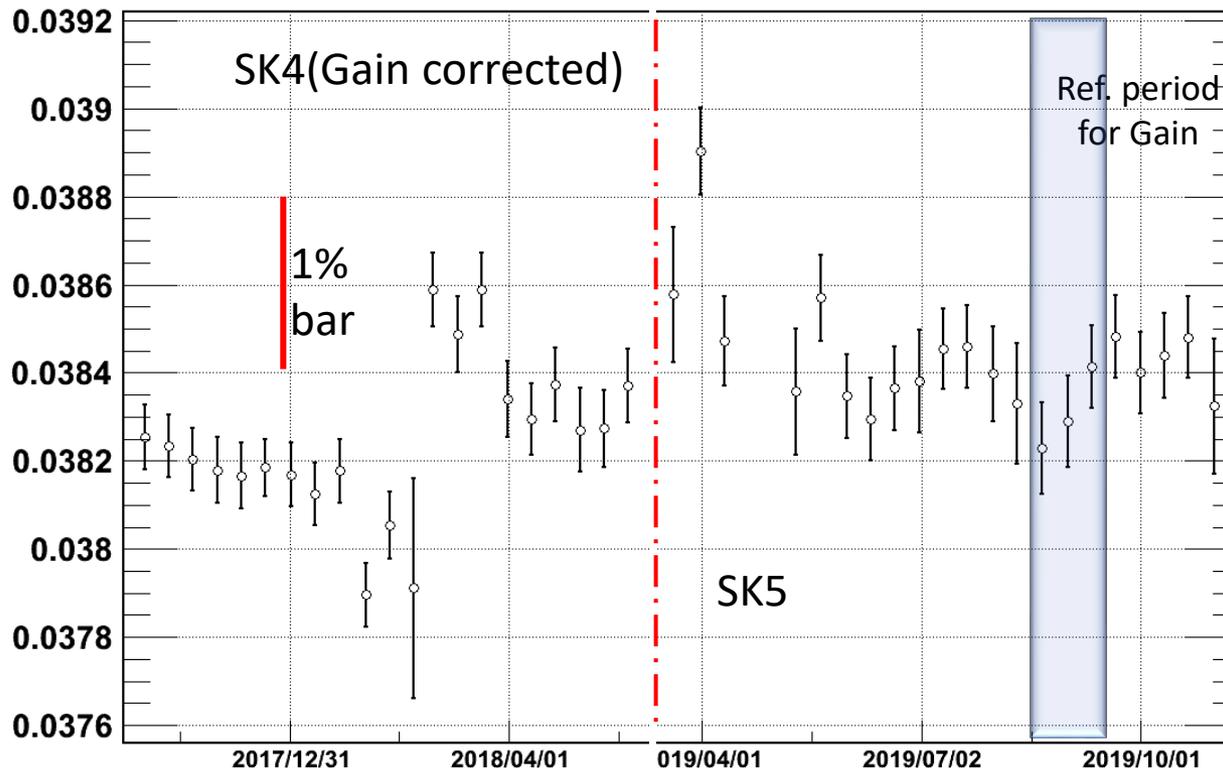
- B3 injected / 337nm LASER : 0.8% increasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

- B4 injected / 337nm LASER : 0.5% increasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

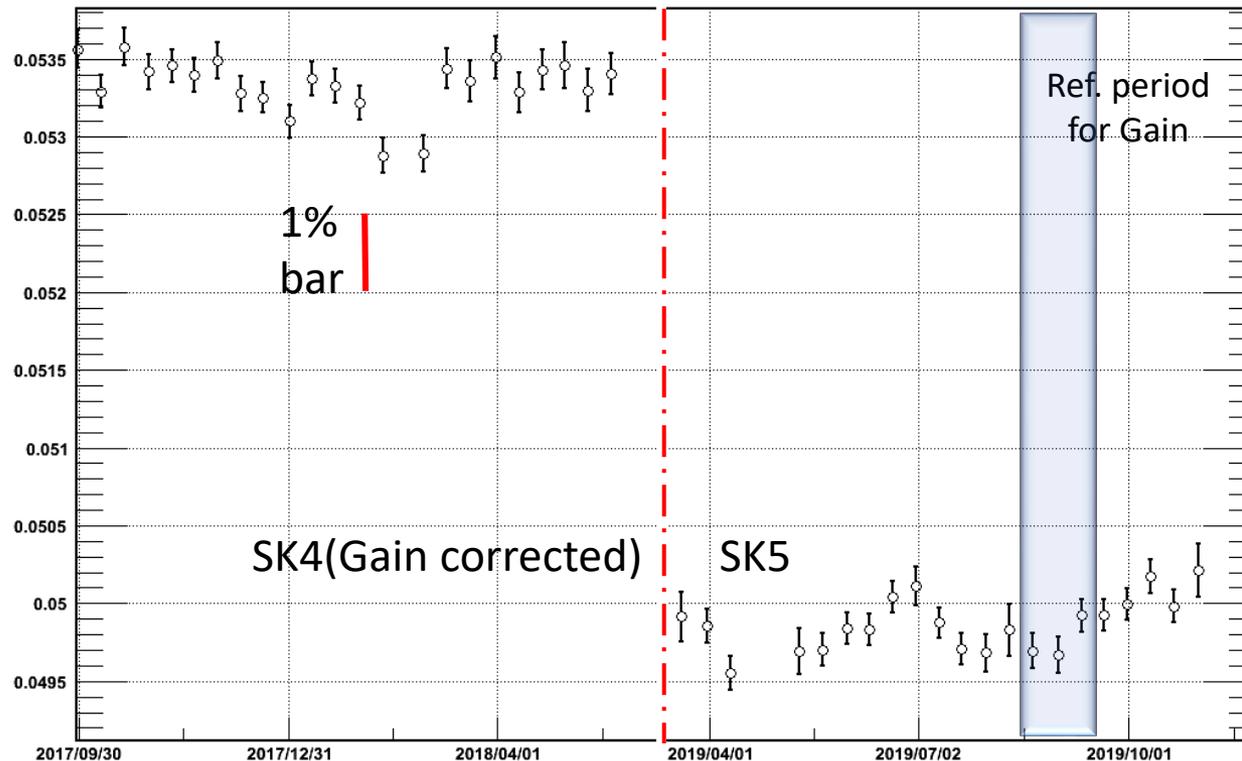
- B5 injected / 337nm LASER : 3.9% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

- Bottom injected / 337nm LASER : 7% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

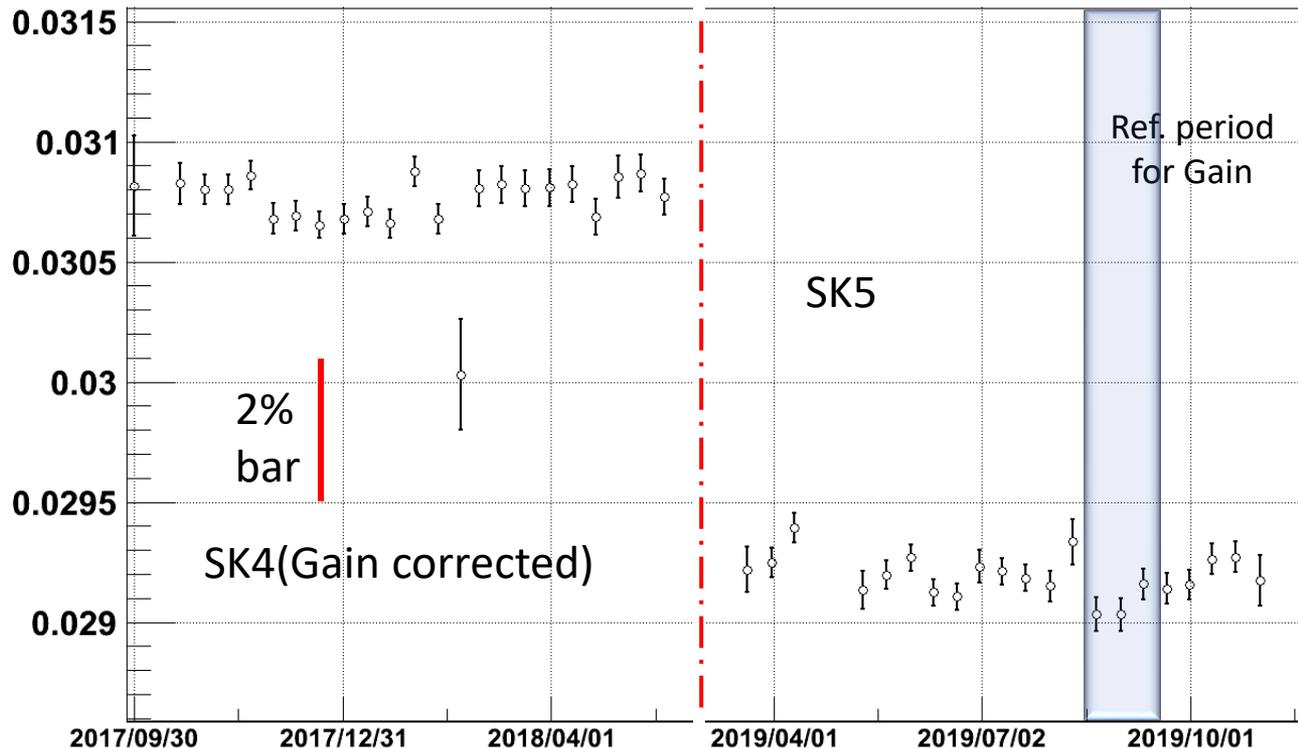
- Top injected / 375nm LASER : 3.3% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

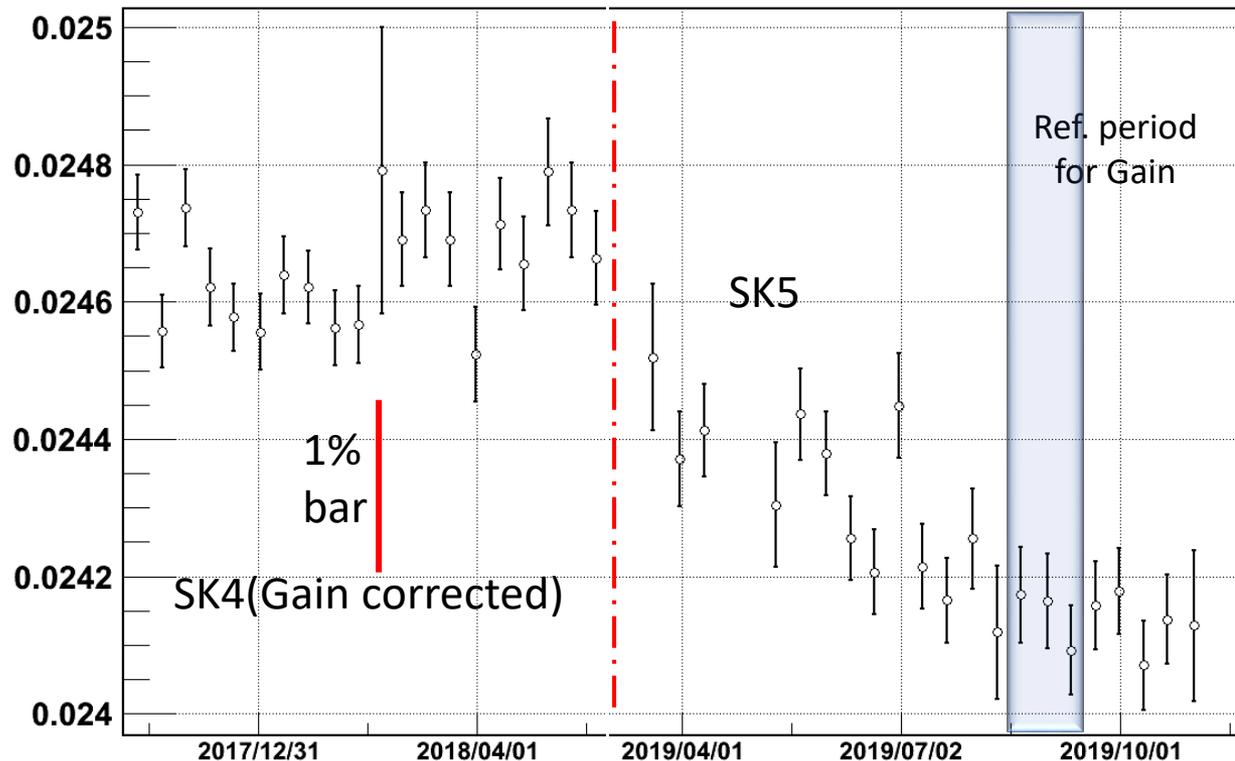
- B1 injected / 375nm LASER : 7.8% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

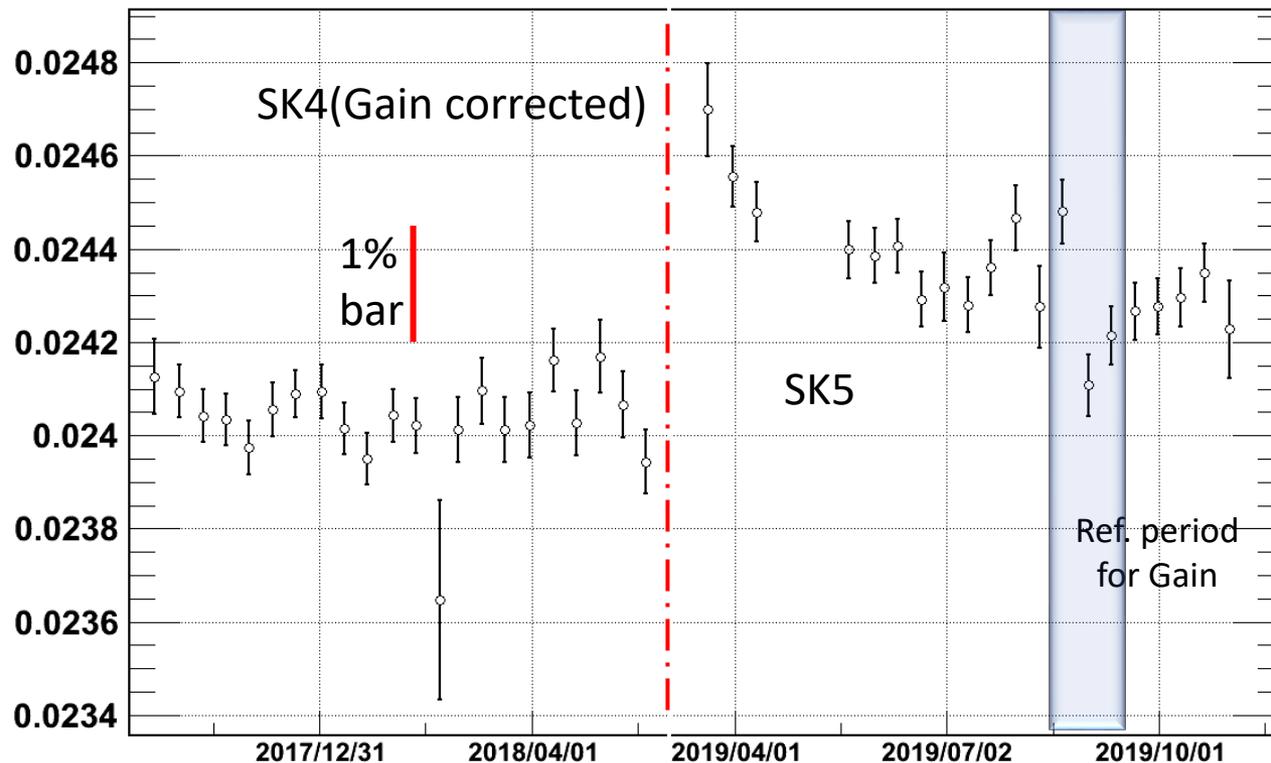
- B2 injected / 375nm LASER : 2.2% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

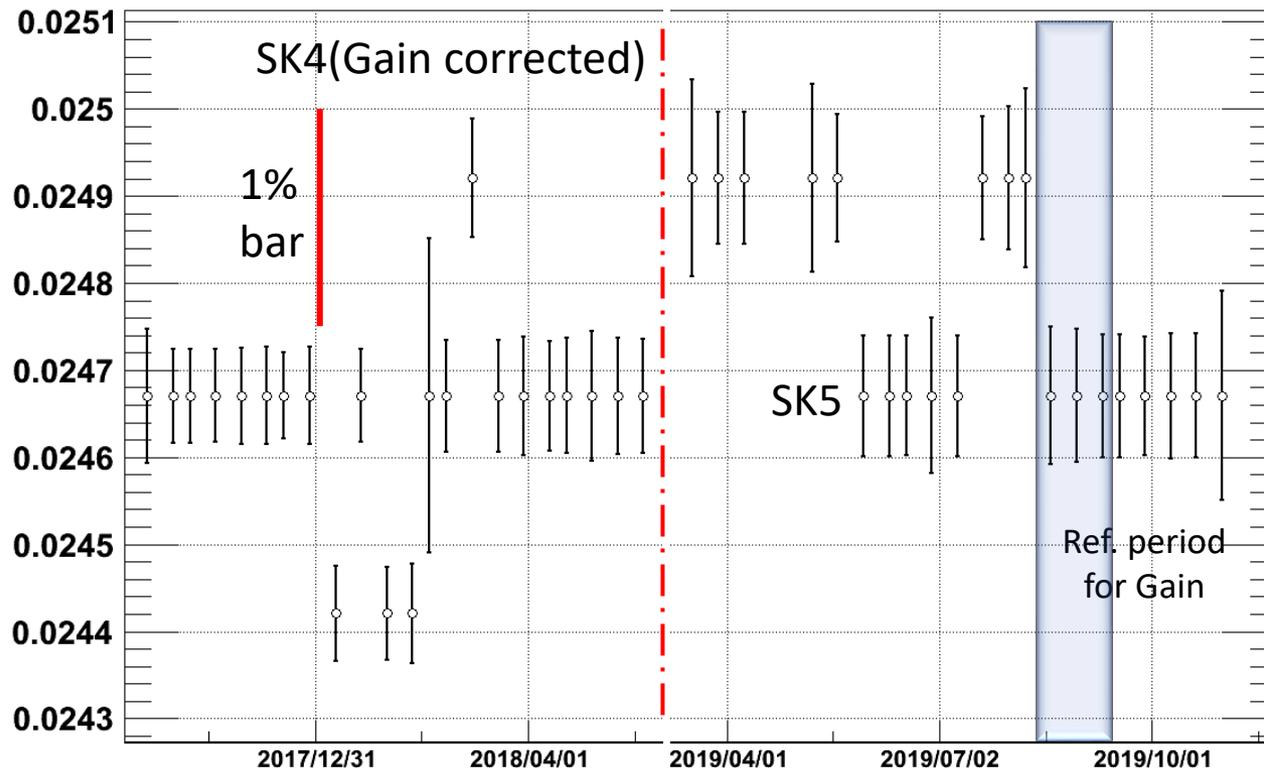
- B3 injected / 375nm LASER : 0.8% increasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

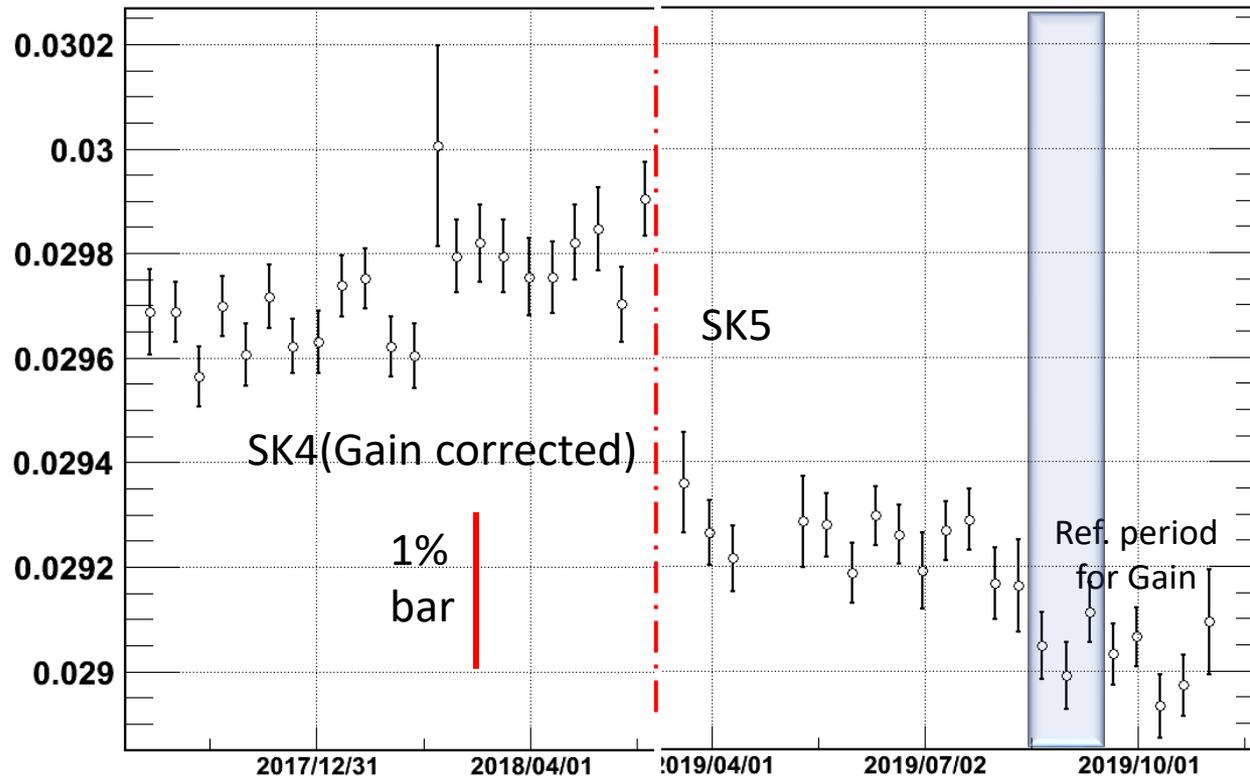
- B4 injected / 375nm LASER : 0.1% increasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

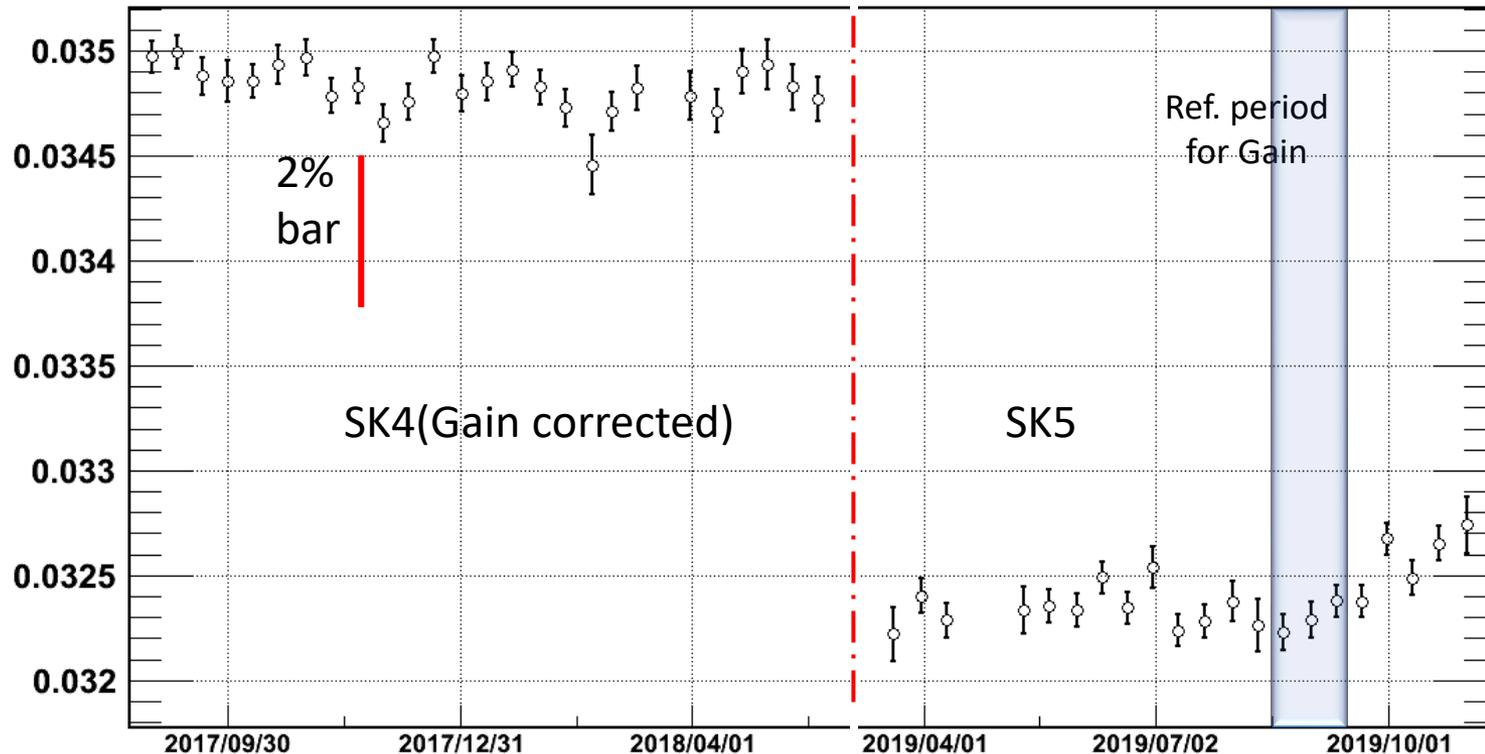
- B5 injected / 375nm LASER : 2.3% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

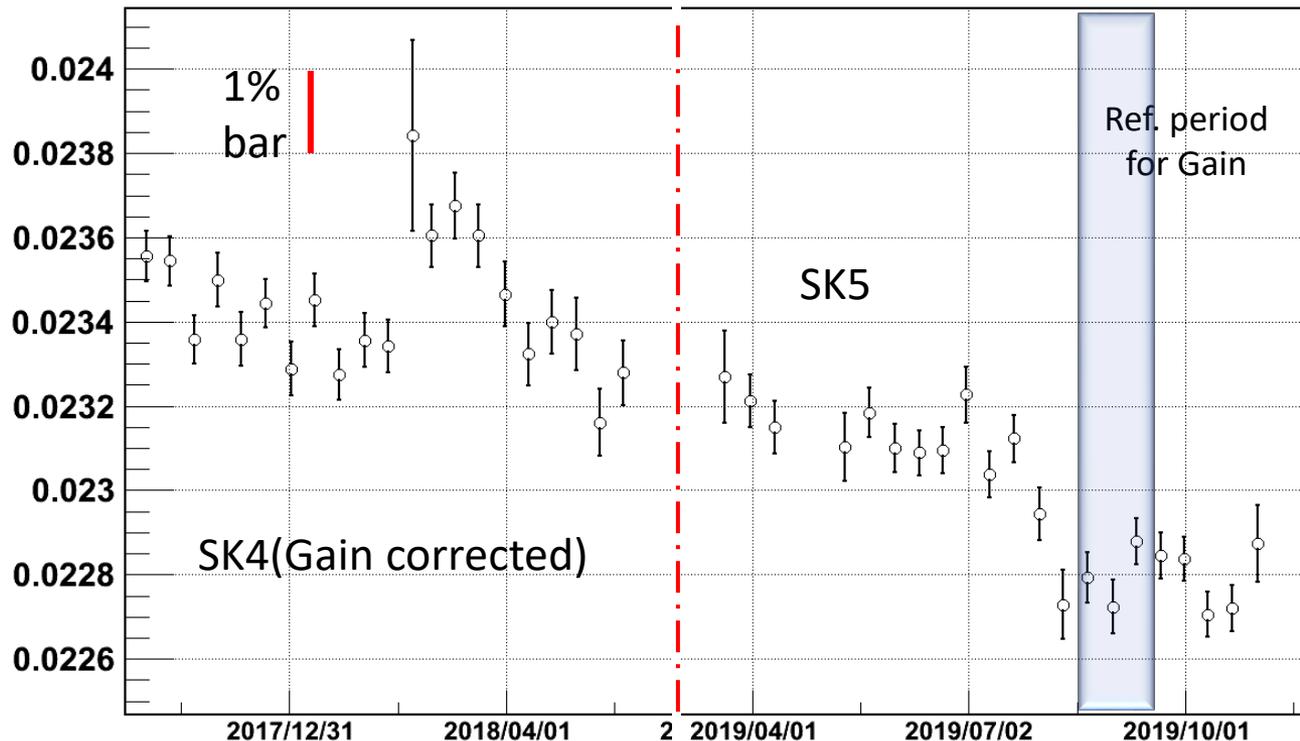
- Bottom injected / 375nm LASER : 6.8% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

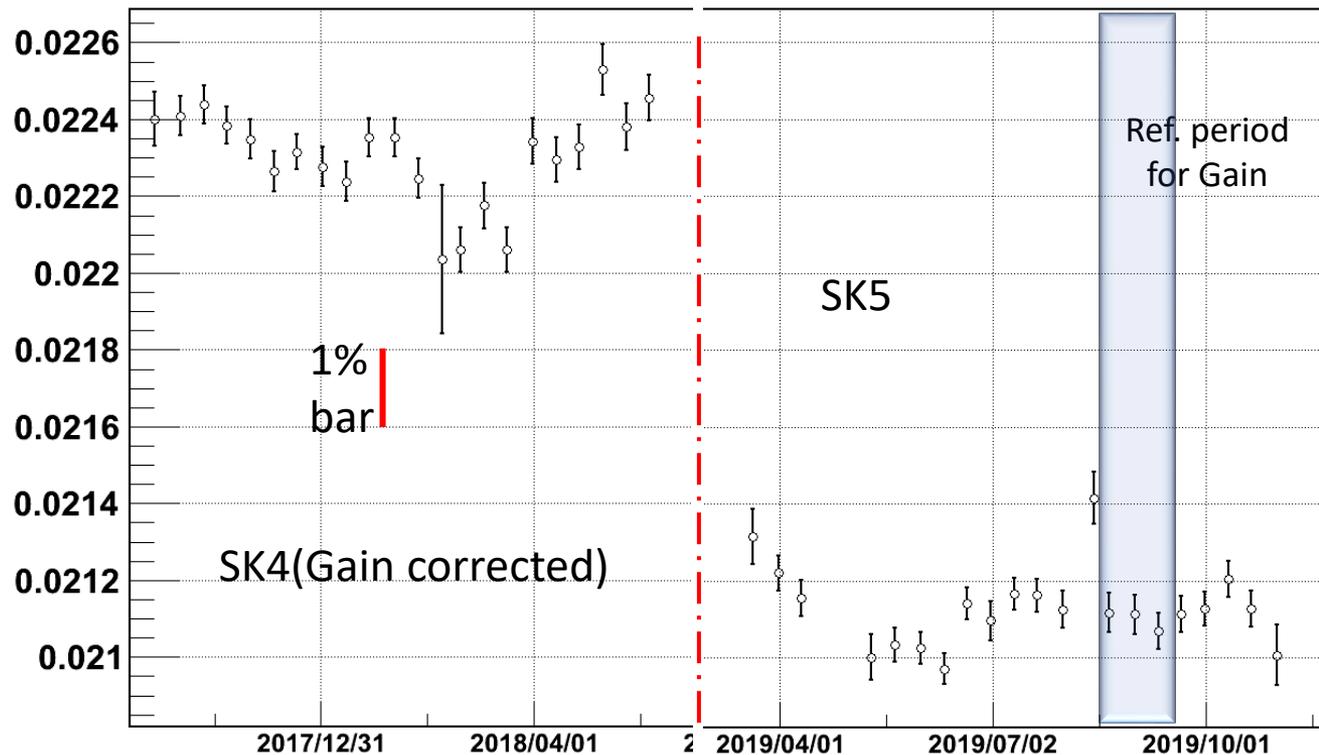
- Top injected / 405nm LASER : 3% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

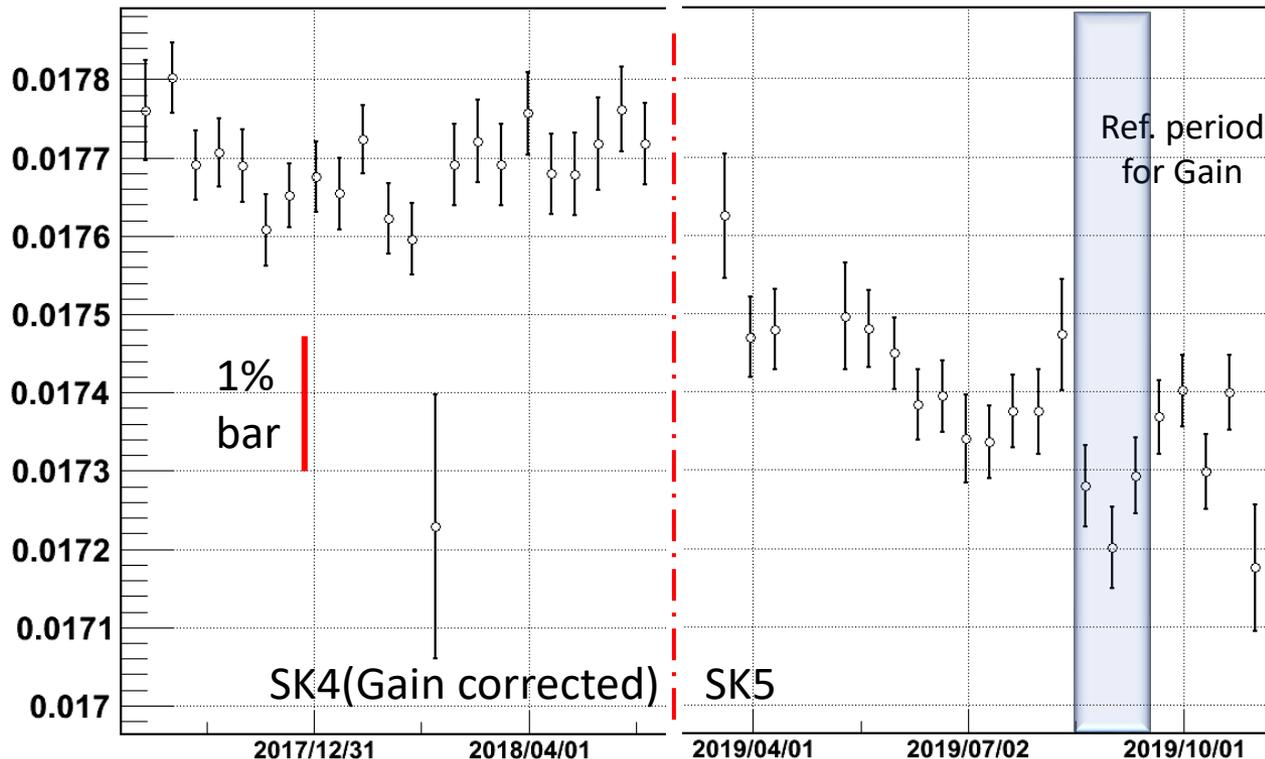
- B1 injected / 405nm LASER : 5.8% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

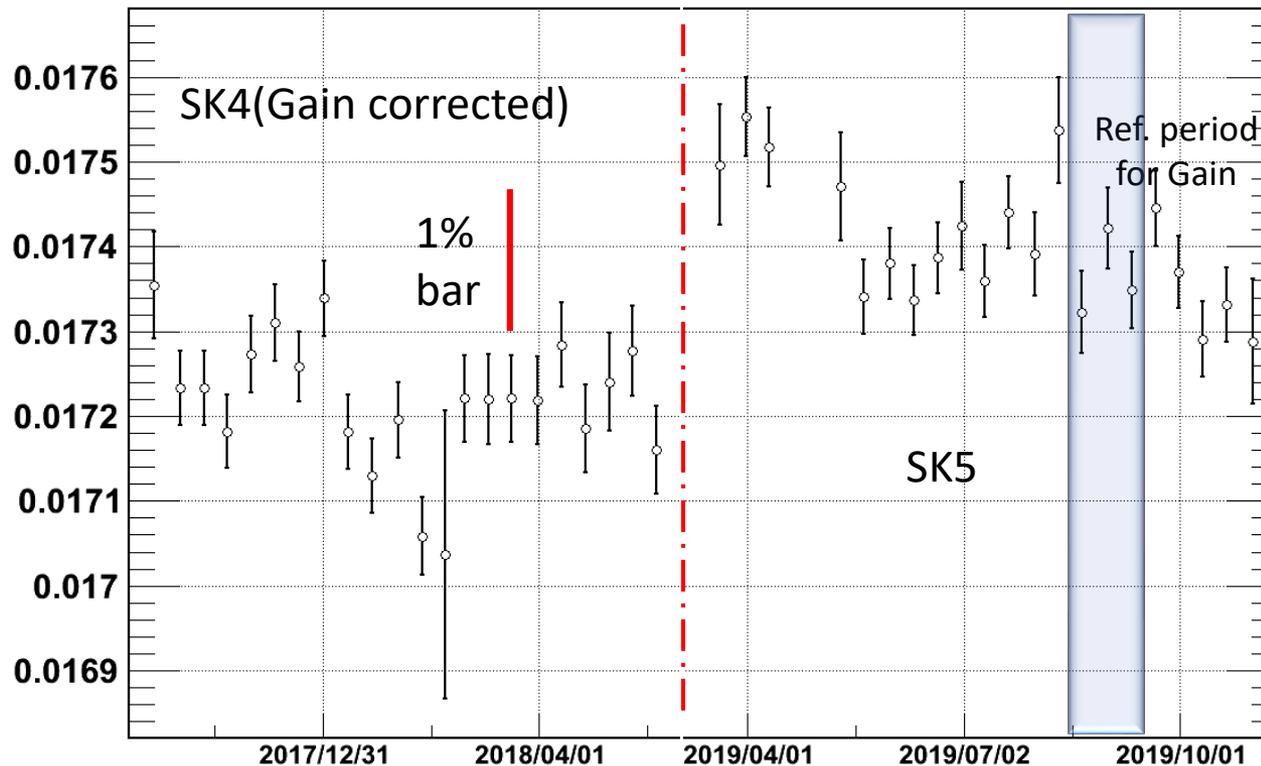
- B2 injected / 405nm LASER : 2.8% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

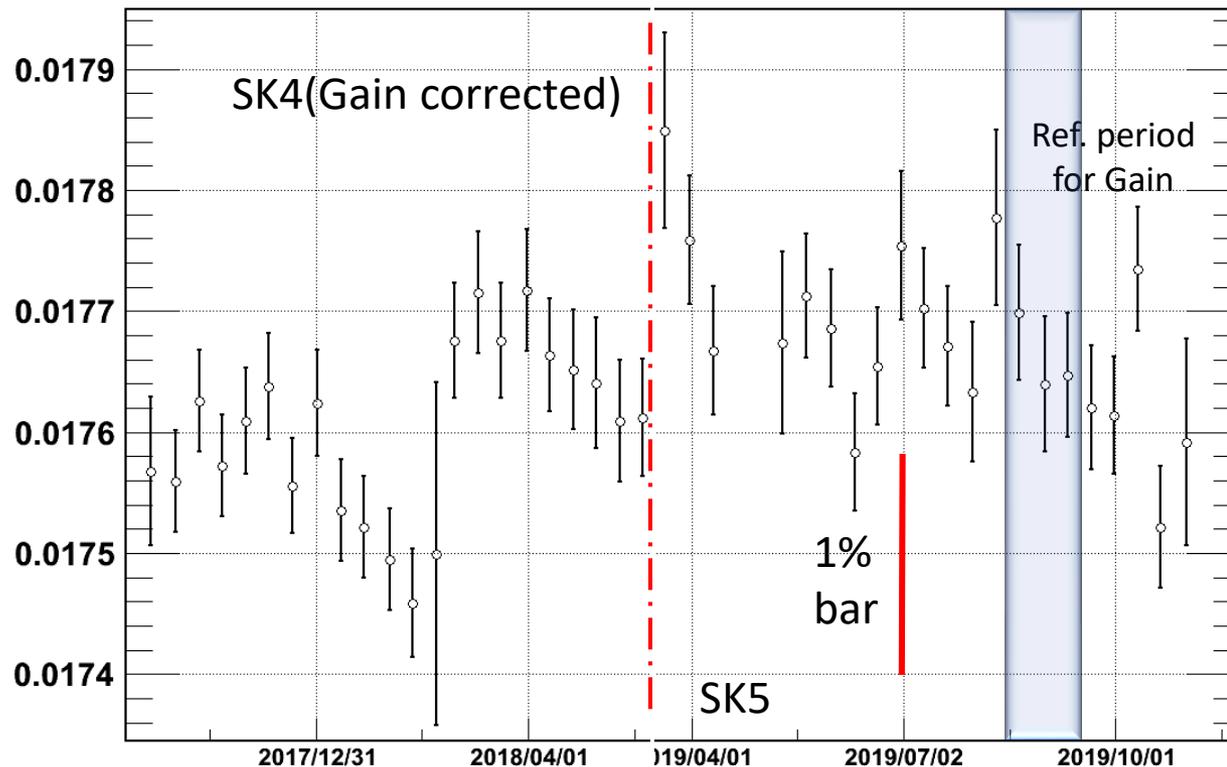
- B3 injected / 405nm LASER : 0.2% increasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

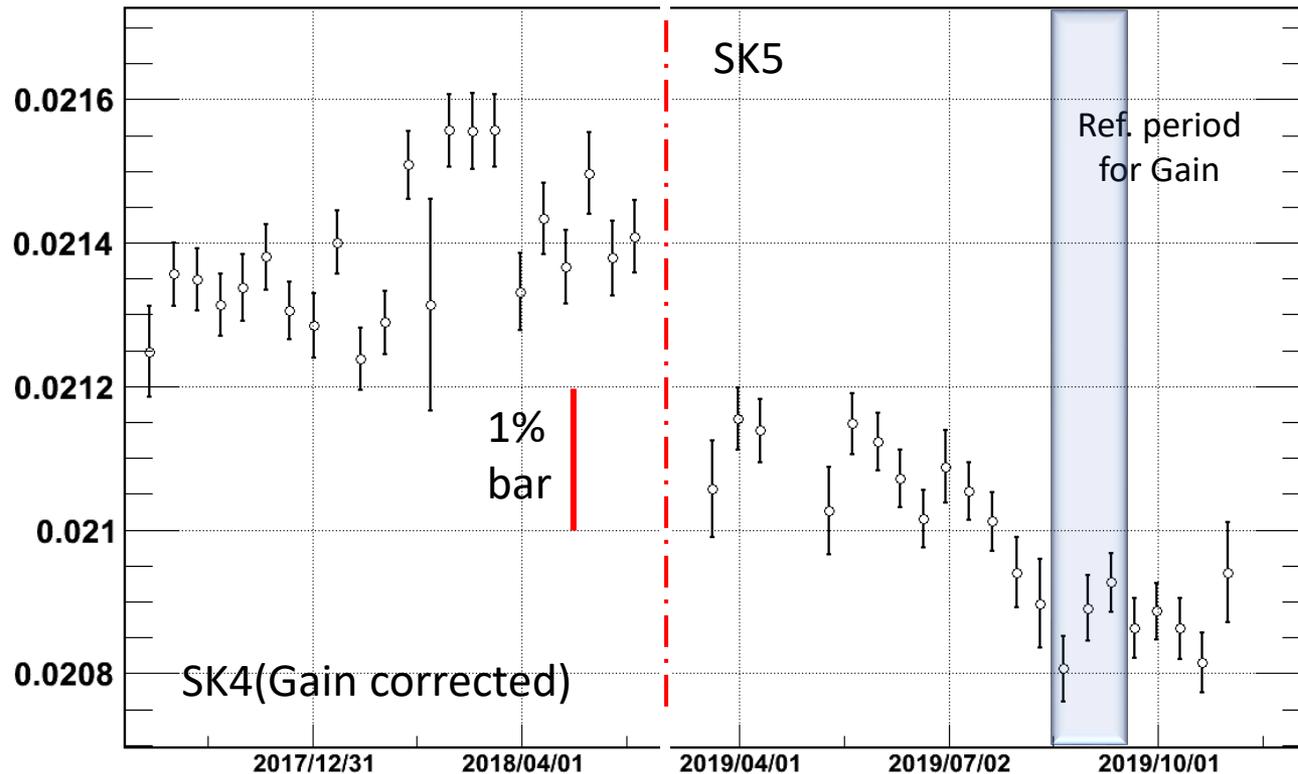
- B4 injected / 405nm LASER : % decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

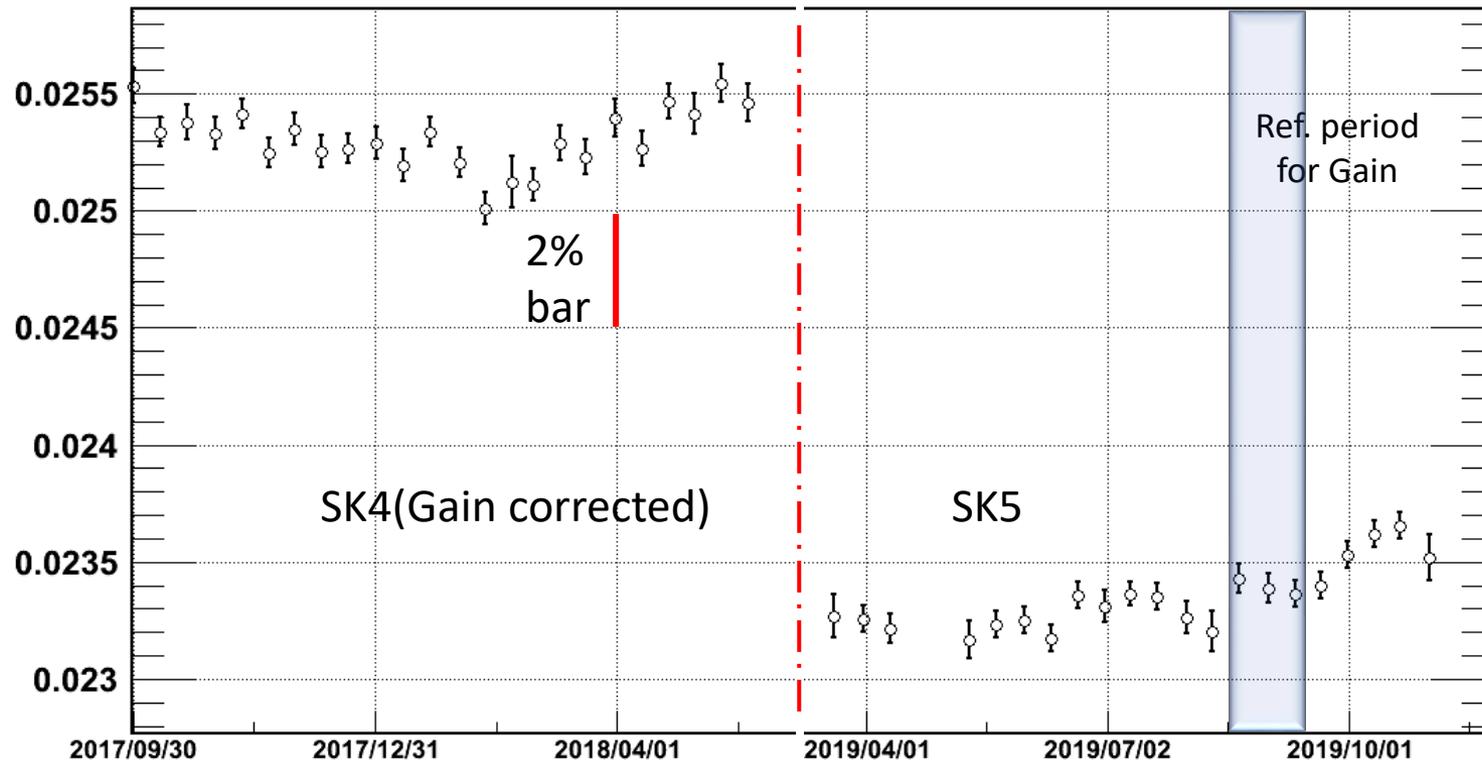
- B5 injected / 405nm LASER : 2.5% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

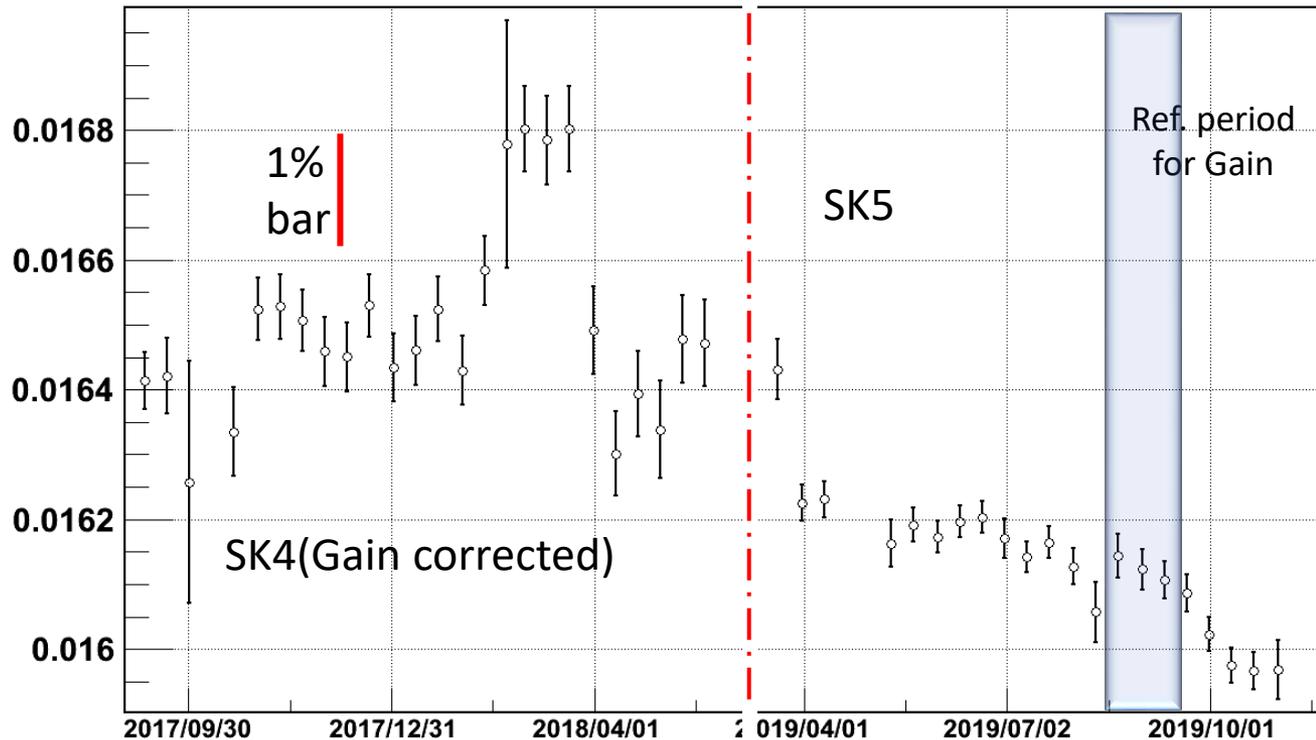
- Bottom injected / 405nm LASER : 8% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

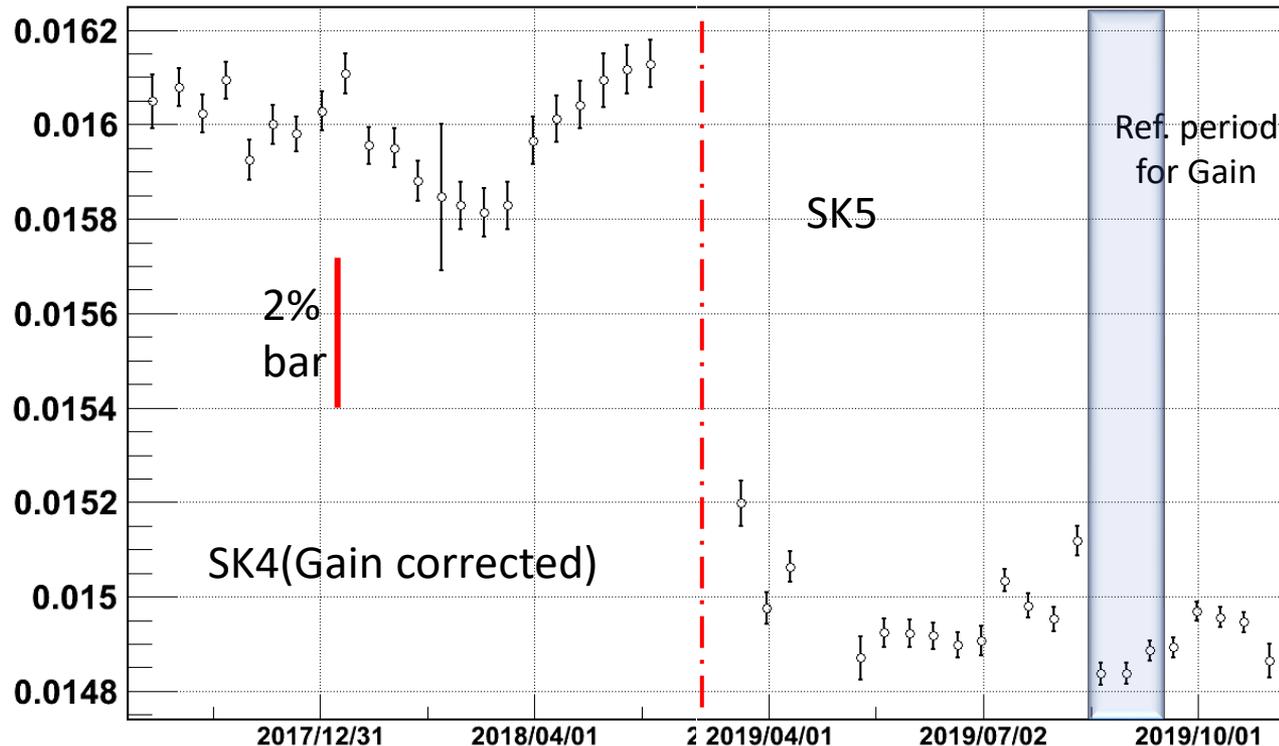
- Top injected / 445nm LASER : 3.1% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

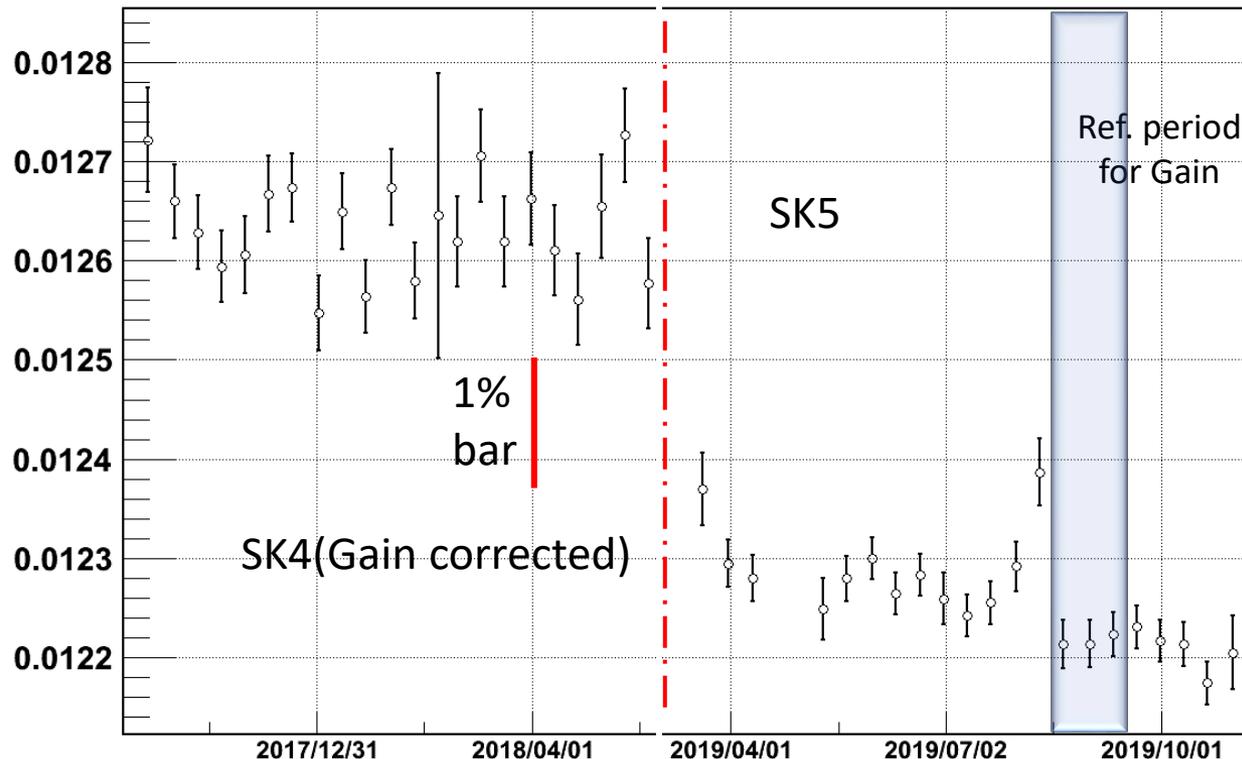
- B1 injected / 445nm LASER : 7.5% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

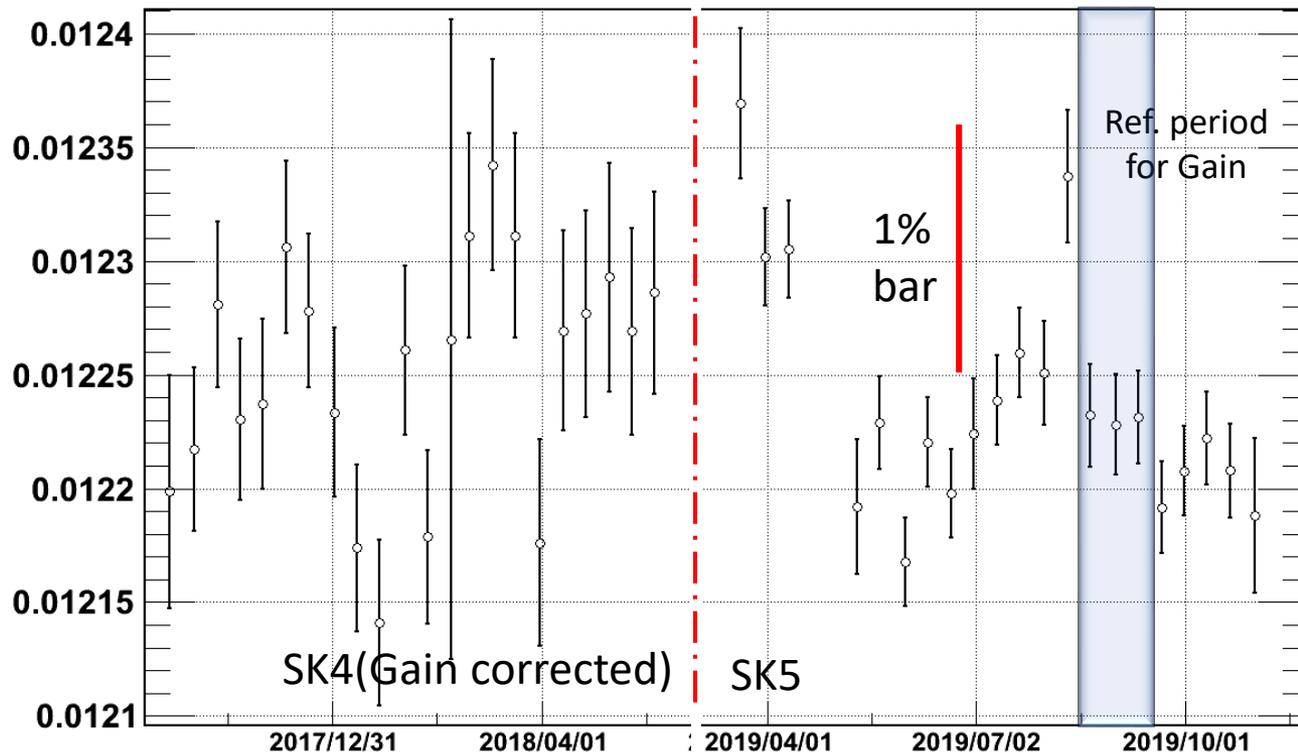
- B2 injected / 445nm LASER : 3.4% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

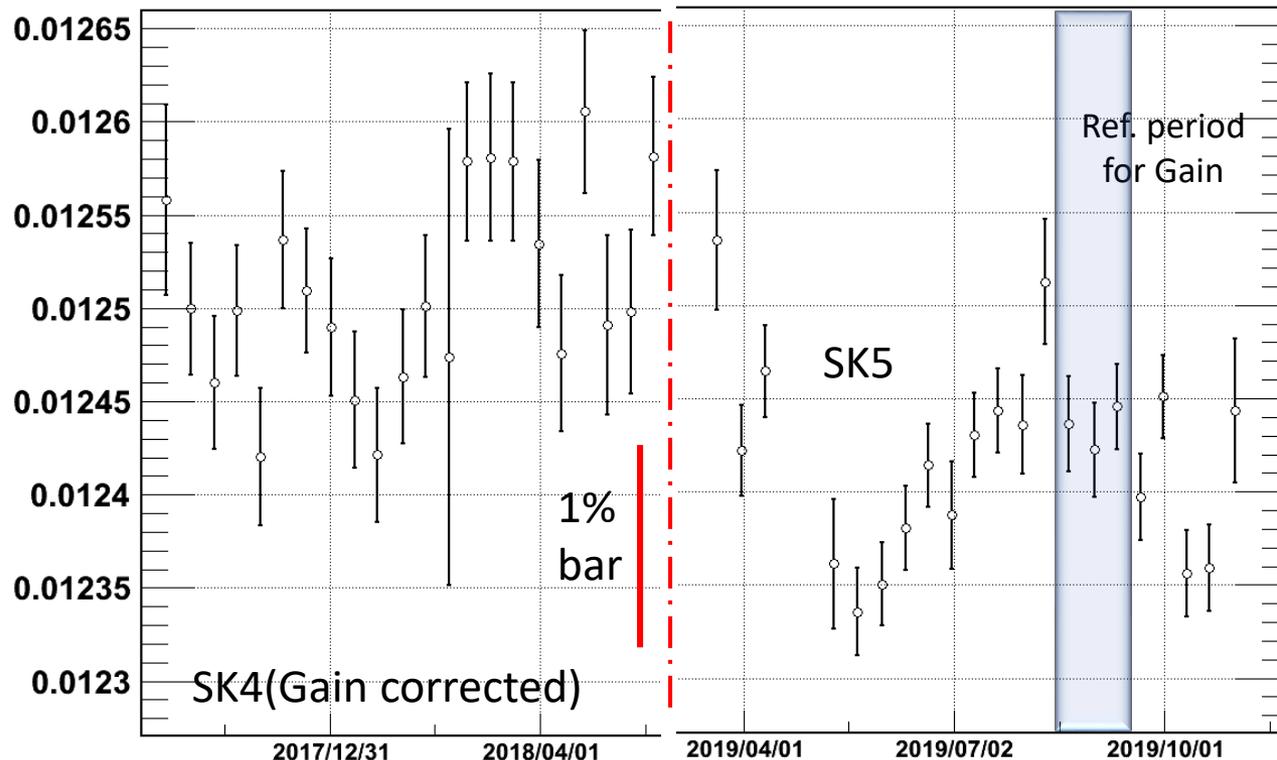
- B3 injected / 445nm LASER : 0.25% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

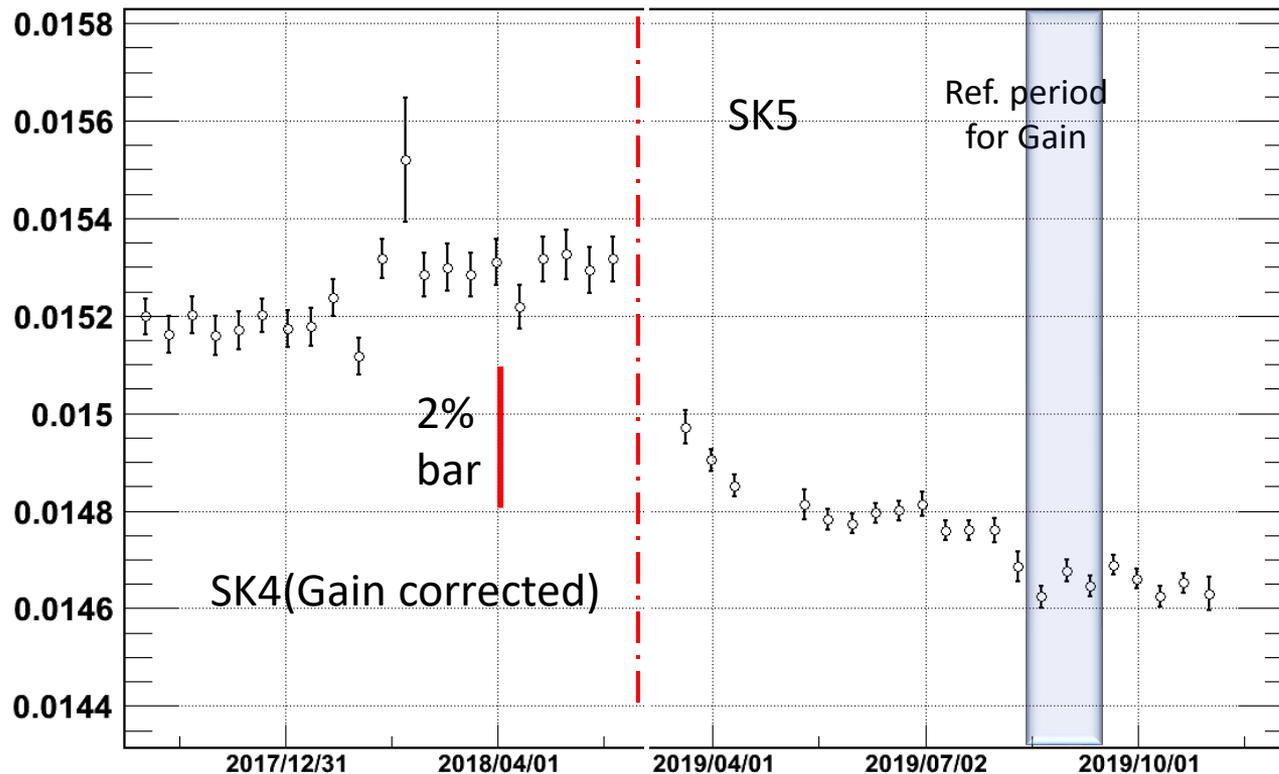
- B4 injected / 445nm LASER : 0.64% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

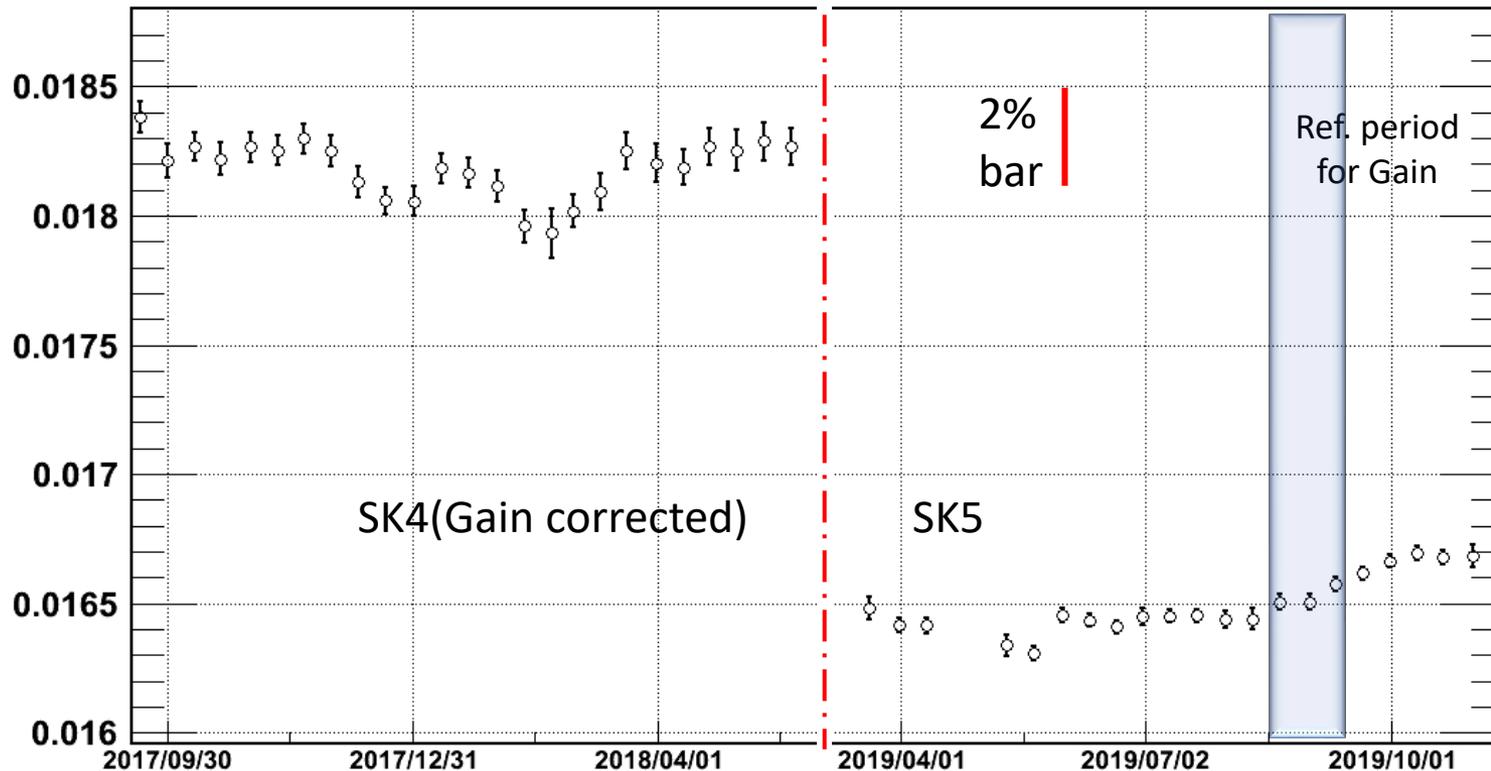
- B5 injected / 445nm LASER : 3.6% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

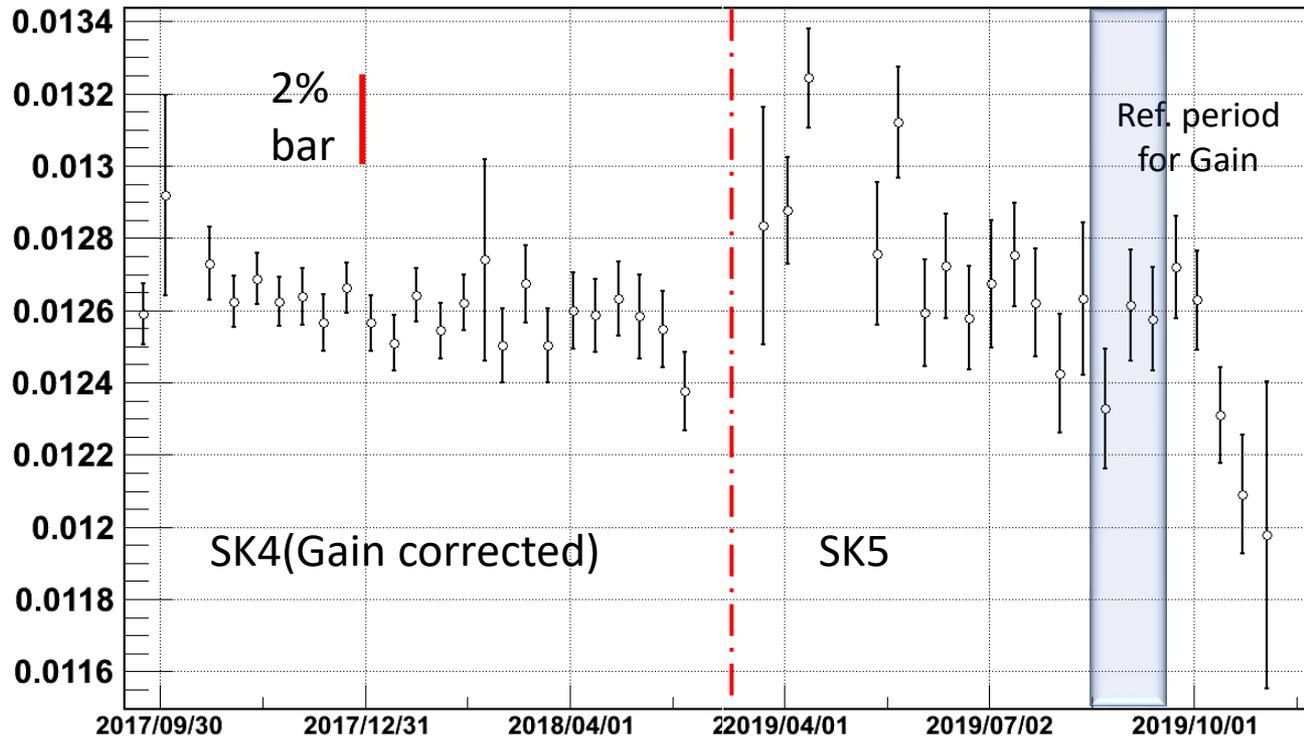
- Bottom injected / 445nm LASER : 8.2% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

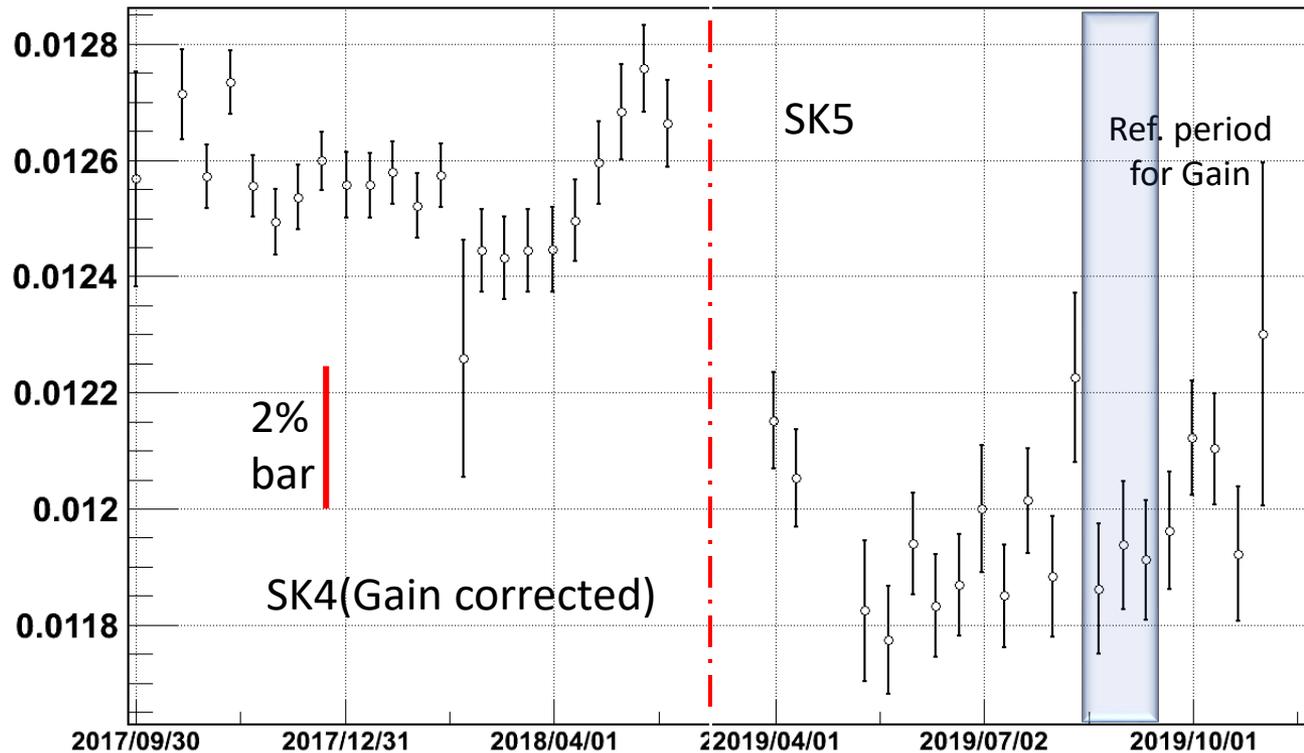
- Top injected / 473nm LASER : 4.8% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

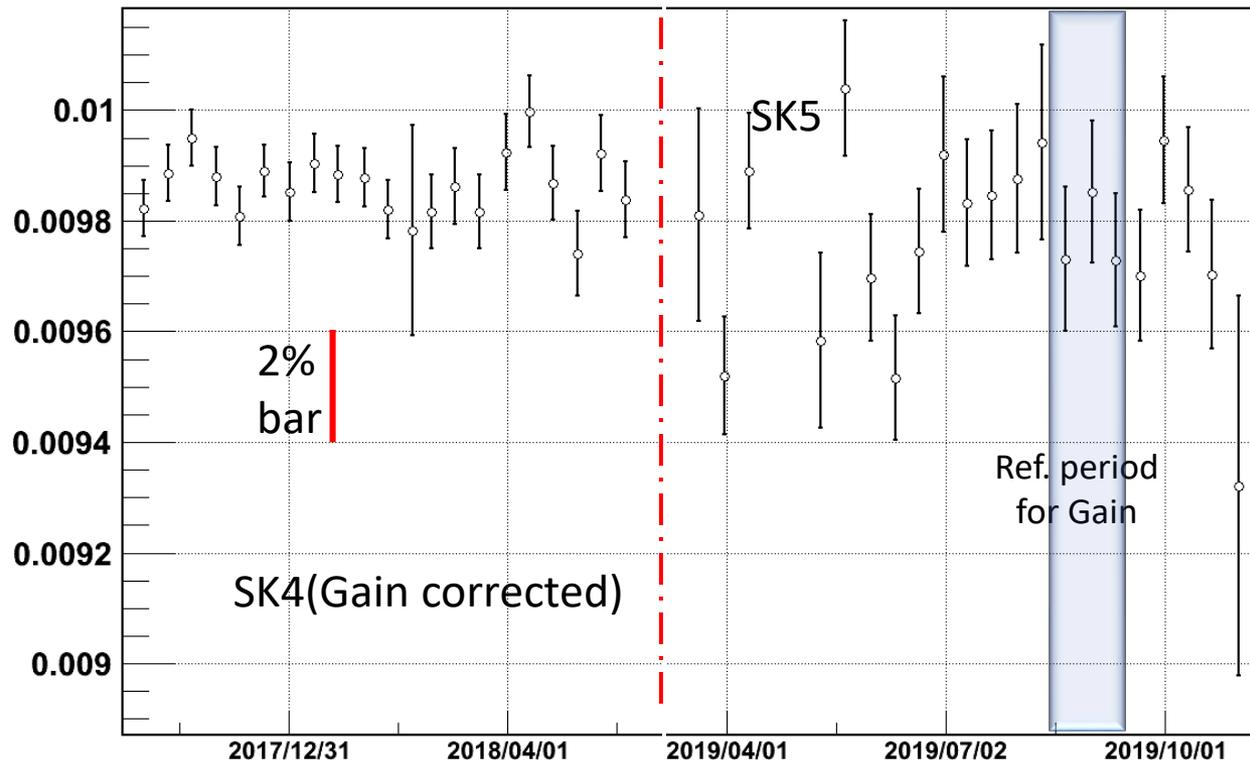
- B1 injected / 473nm LASER : 5% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

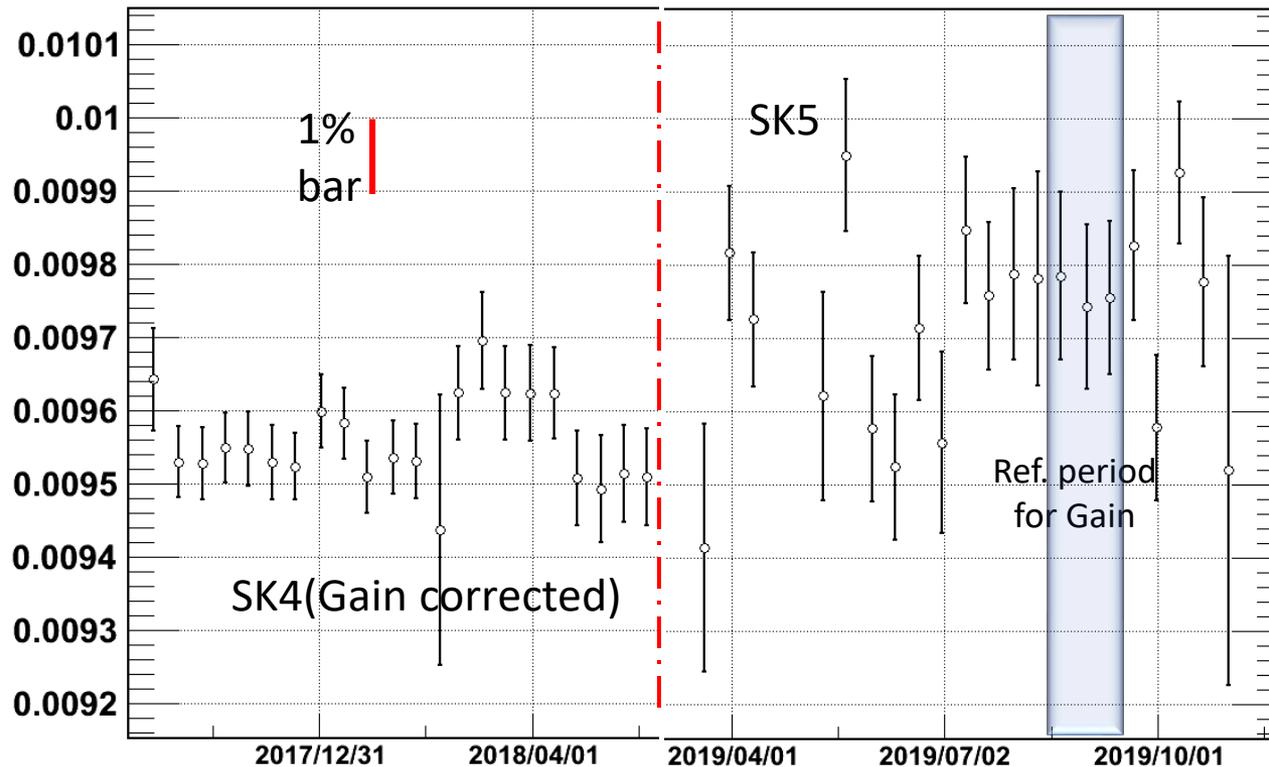
- B2 injected / 473nm LASER : 2.3% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

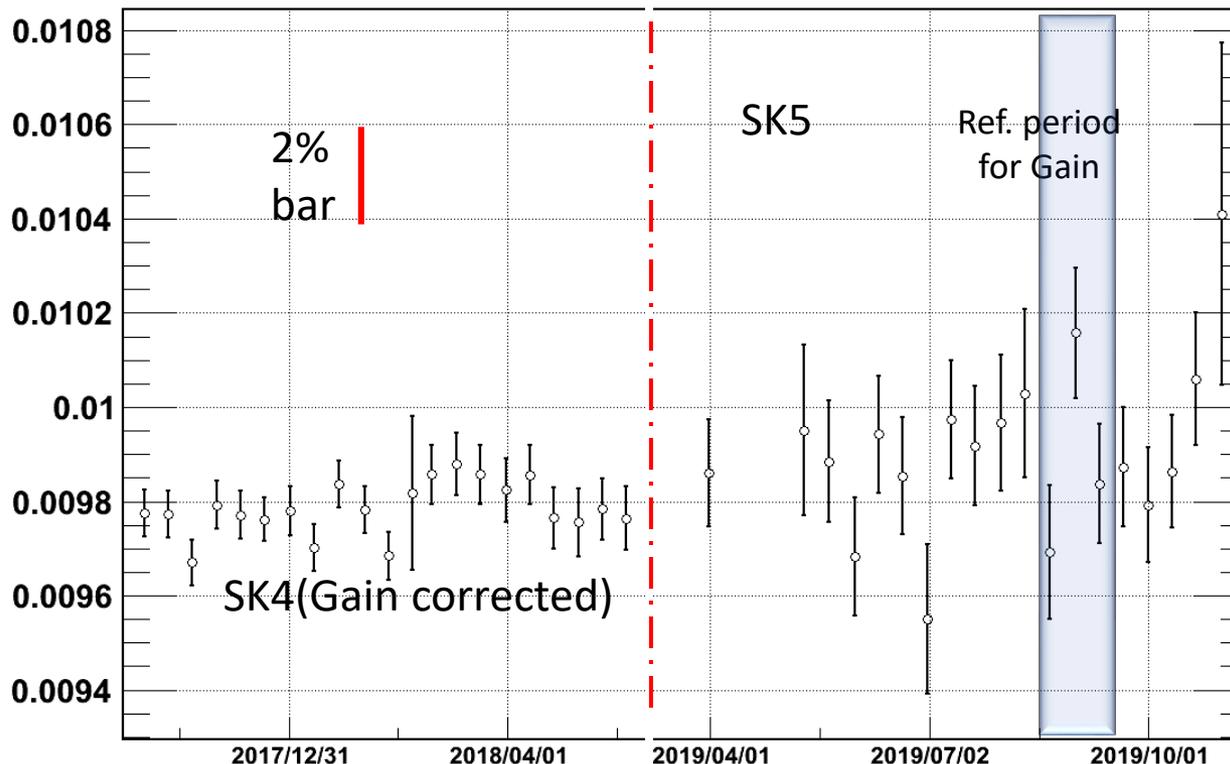
- B3 injected / 473nm LASER : 1.2 % increasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

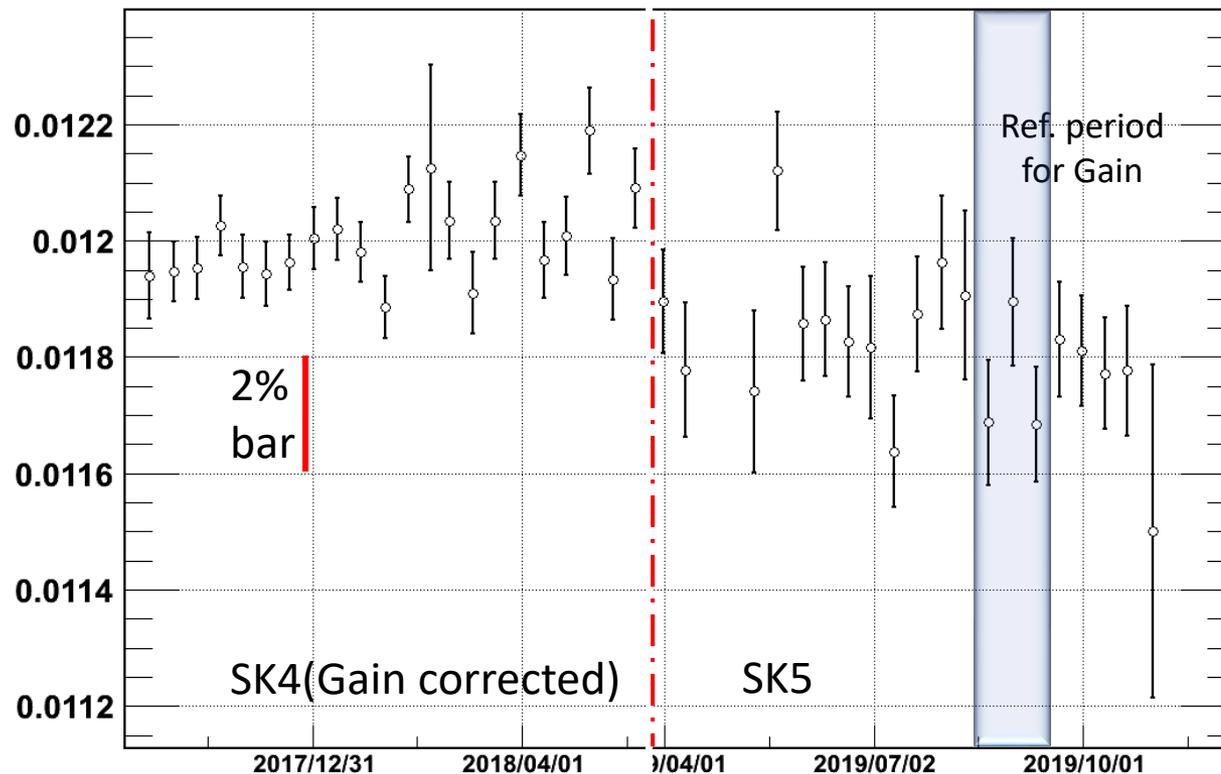
- B4 injected / 473nm LASER : 2% increasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

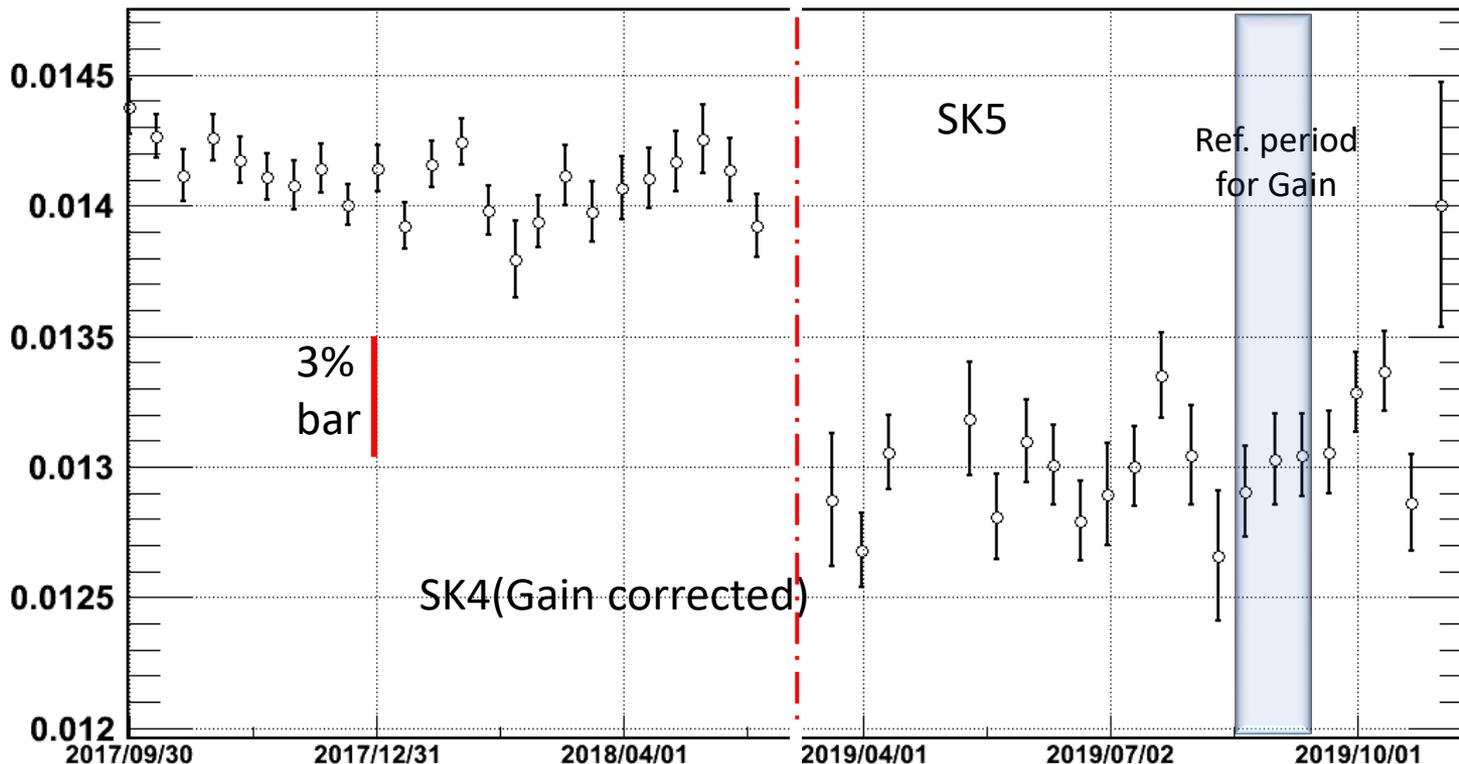
- B5 injected / 473nm LASER : 1.3% decreasing



- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits
- Q : total charge in P.E. with subtracting dark charge

# 3. Result - $N/Q^*$

- Bottom injected / 473nm LASER : 8.4% decreasing

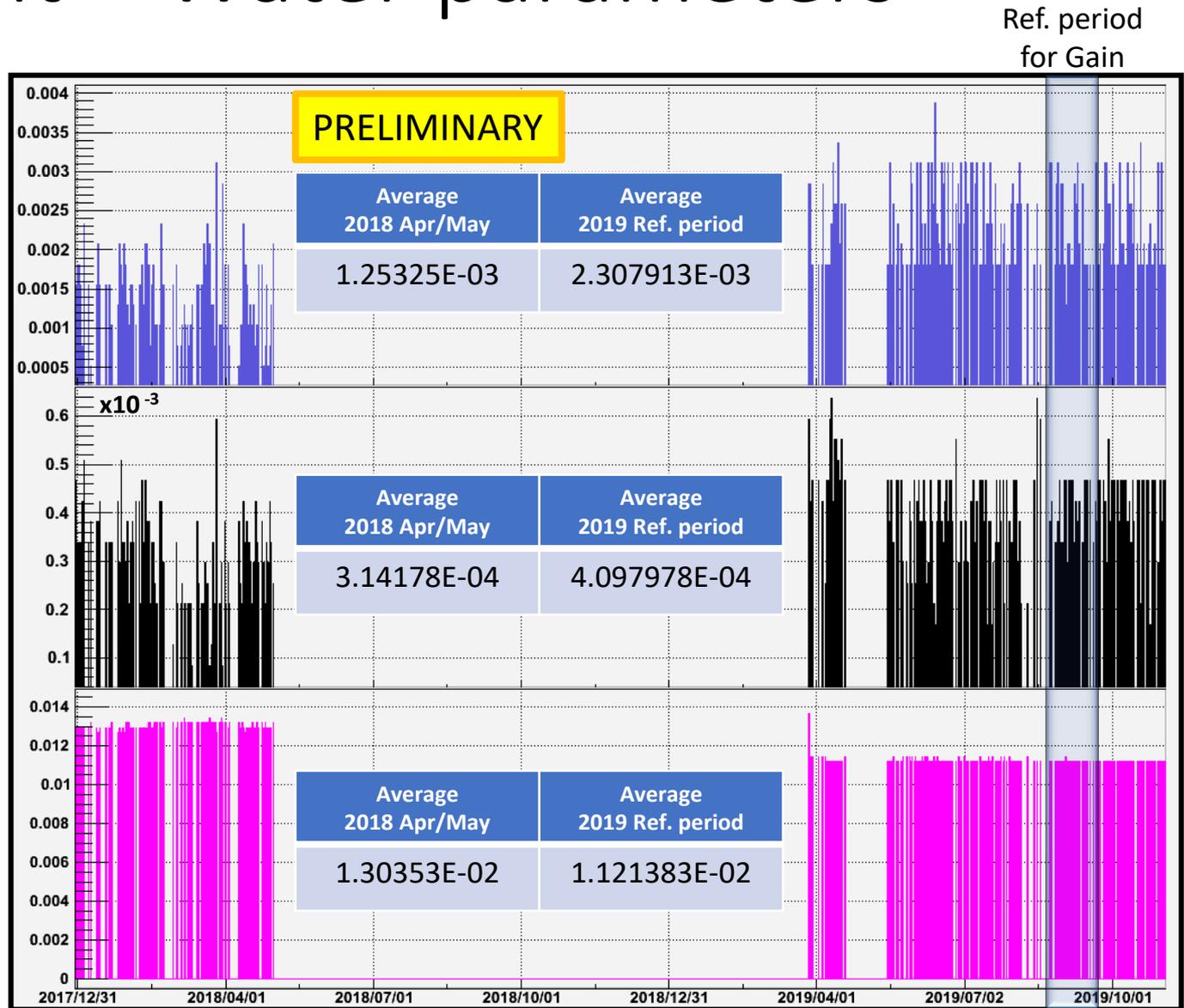


- \* N : total number of hits in scattered area, top region(>2m) with subtracting dark hits  
 Q : total charge in P.E. with subtracting dark charge

[5] Water parameter for each wavelength

# 3. Result – Water parameters

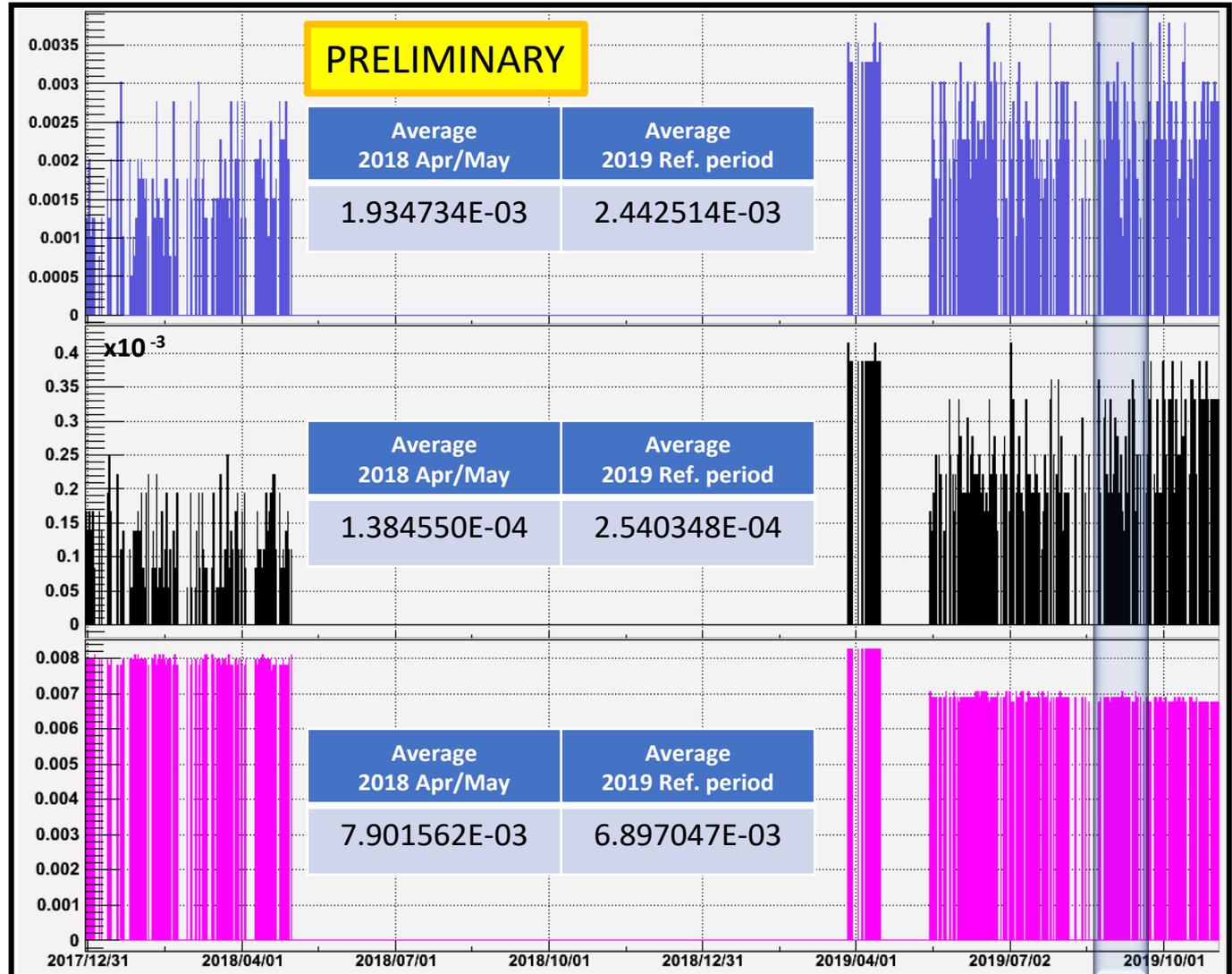
Absorbance [1/m]  
Asymmetry [1/m]  
Symmetry [1/m]  
337nm



# 3. Result – Water parameters

Absorbance [1/m]  
 Asymmetry [1/m]  
 Symmetry [1/m]  
 375nm

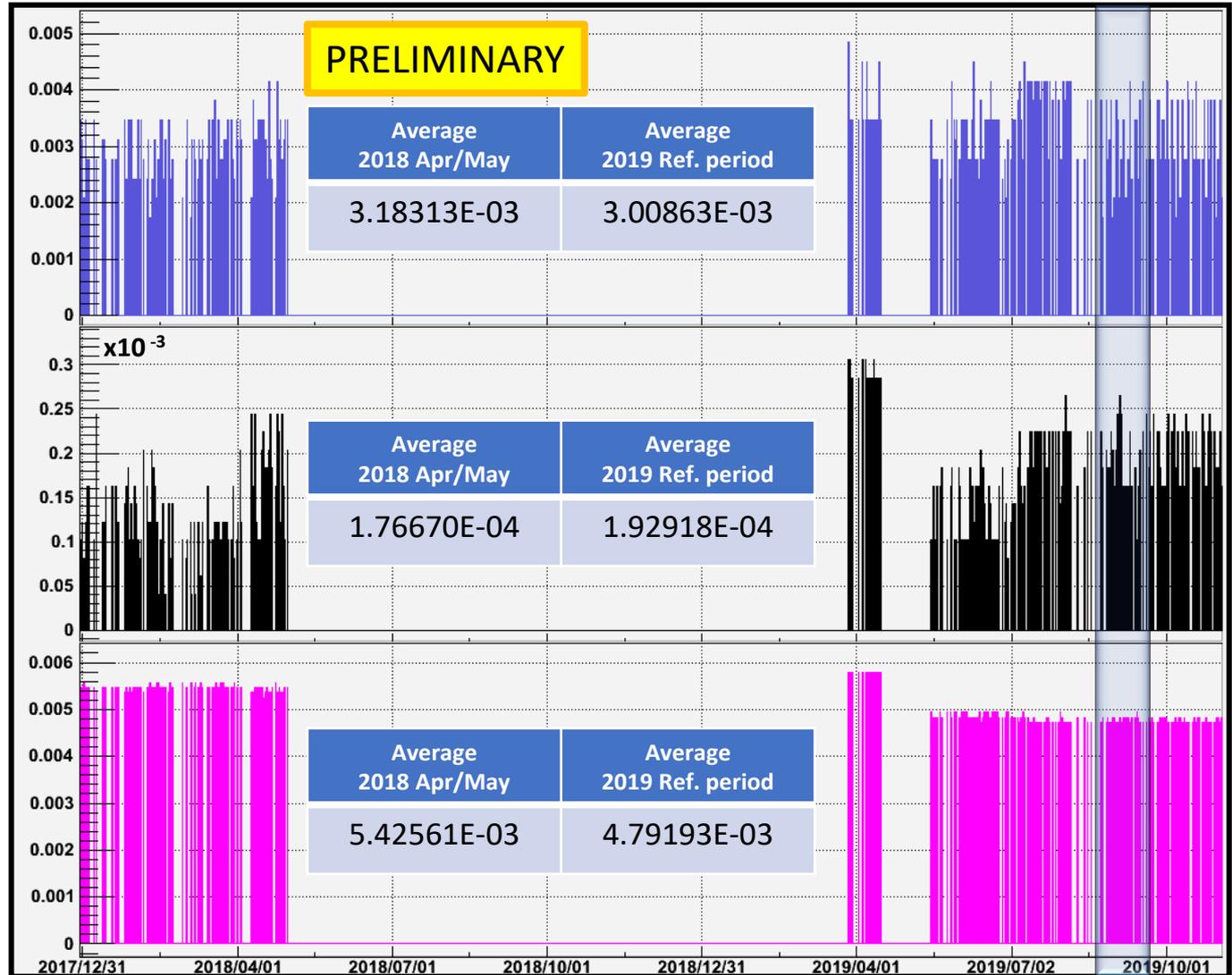
Ref. period  
 for Gain



# 3. Result – Water parameters

Absorbance [1/m]  
 Asymmetry [1/m]  
 Symmetry [1/m]  
 405nm

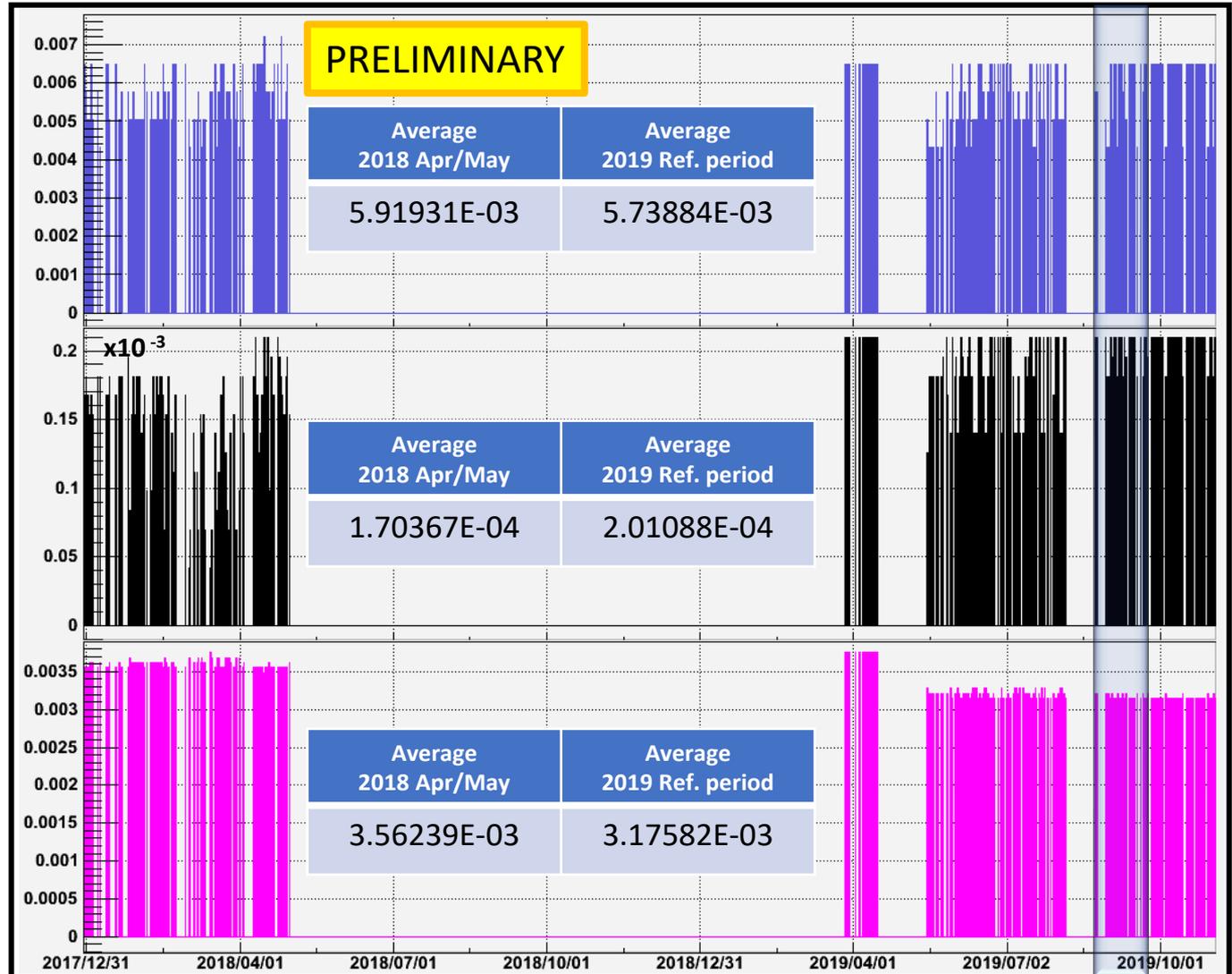
Ref. period  
 for Gain



# 3. Result – Water parameters

Absorbance [1/m]  
 Asymmetry [1/m]  
 Symmetry [1/m]  
 445nm

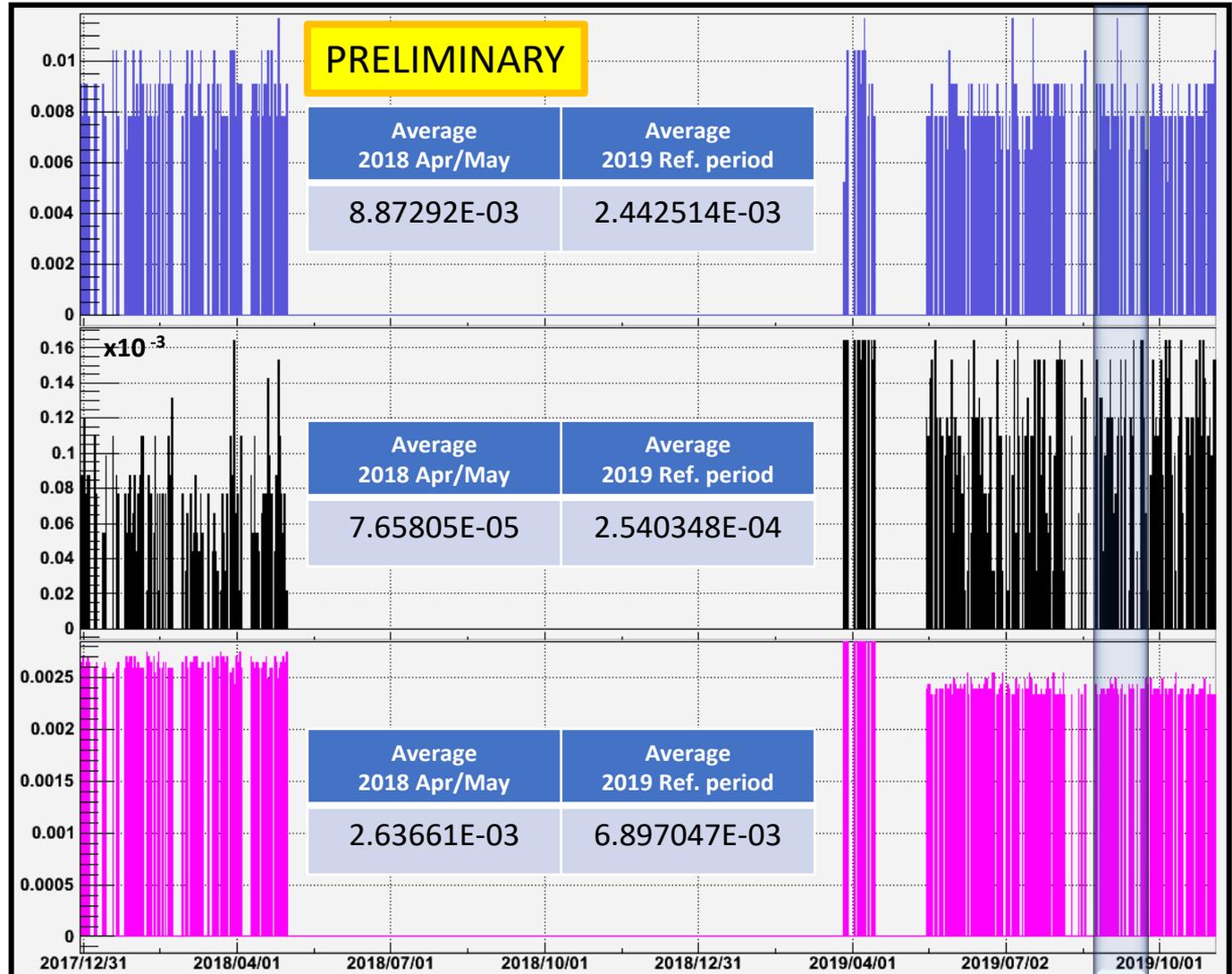
Ref. period  
 for Gain



# 3. Result – Water parameters

Absorbance [1/m]  
 Asymmetry [1/m]  
 Symmetry [1/m]  
 473nm

Ref. period  
 for Gain



Absorbance [1/m]  
 Asymmetric [1/m]  
 Symmetric [1/m]

# 3. Result – Water parameters

PRELIMINARY	SK4 (2018 Apr & May) / Transparency (m)		SK5 reference Period / Transparency (m)	
337nm	1.25325E-03	68.48	2.307913E-03	71.78
	3.14178E-04		4.097978E-04	
	1.30353E-02		1.121383E-02	
375nm	1.93473E-03	100.25	2.44251E-03	104.24
	1.38455E-04		2.54035E-04	
	7.90156E-03		6.89705E-03	
405nm	3.18313E-03	113.83	3.00863E-03	125.10
	1.76670E-04		1.92918E-04	
	5.42561E-03		4.79193E-03	
445nm	5.91931E-03	103.6	5.73884E-03	109.70
	1.70367E-04		2.01088E-04	
	3.56239E-03		3.17582E-03	
473nm	8.87292E-03	86.31	8.29087E-03	92.62
	7.65805E-05		1.10828E-04	
	2.63661E-03		2.39463E-03	



JY Yang (SNU)

FIN.