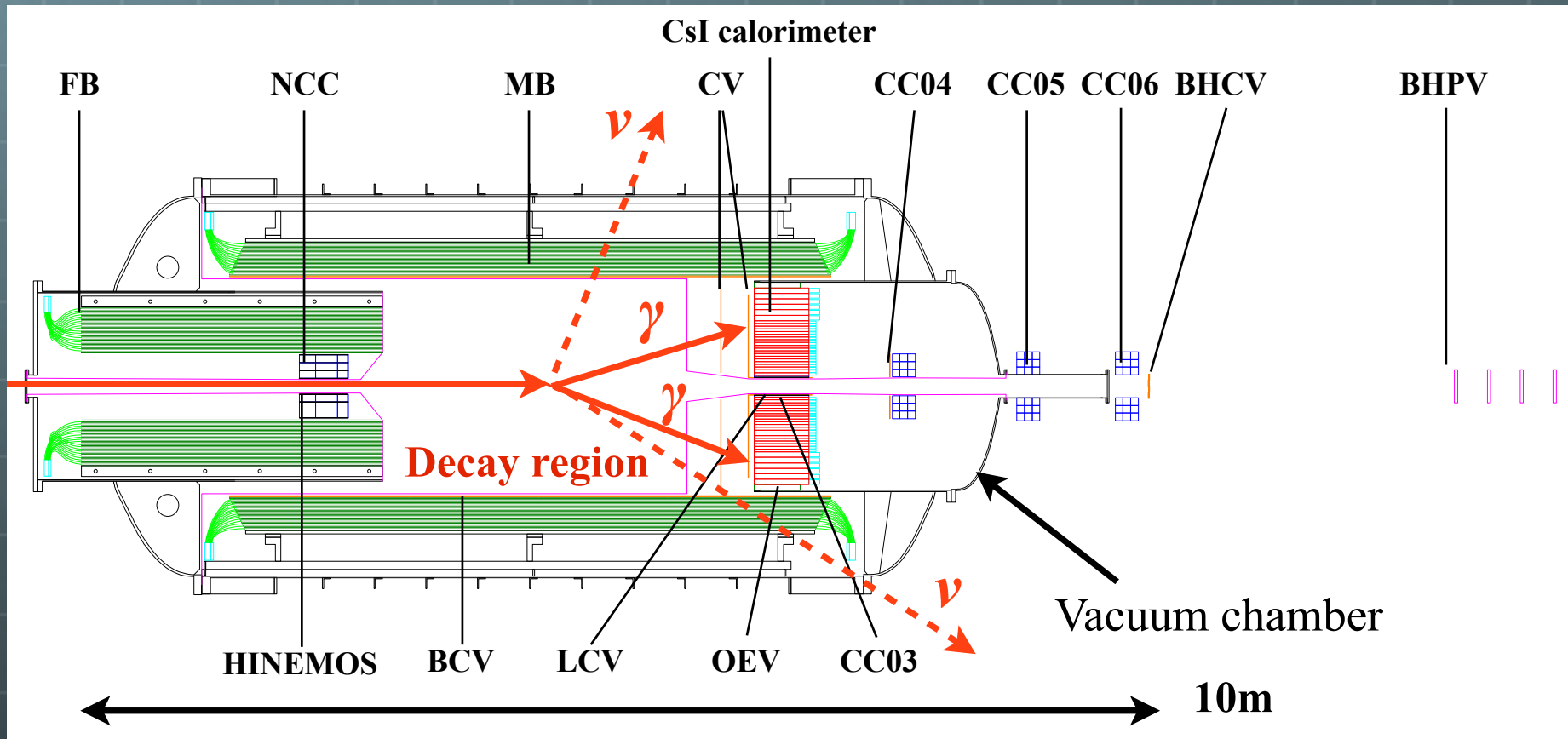


# New charged veto for KOTO

G.Y.Lim  
IPNS/KEK

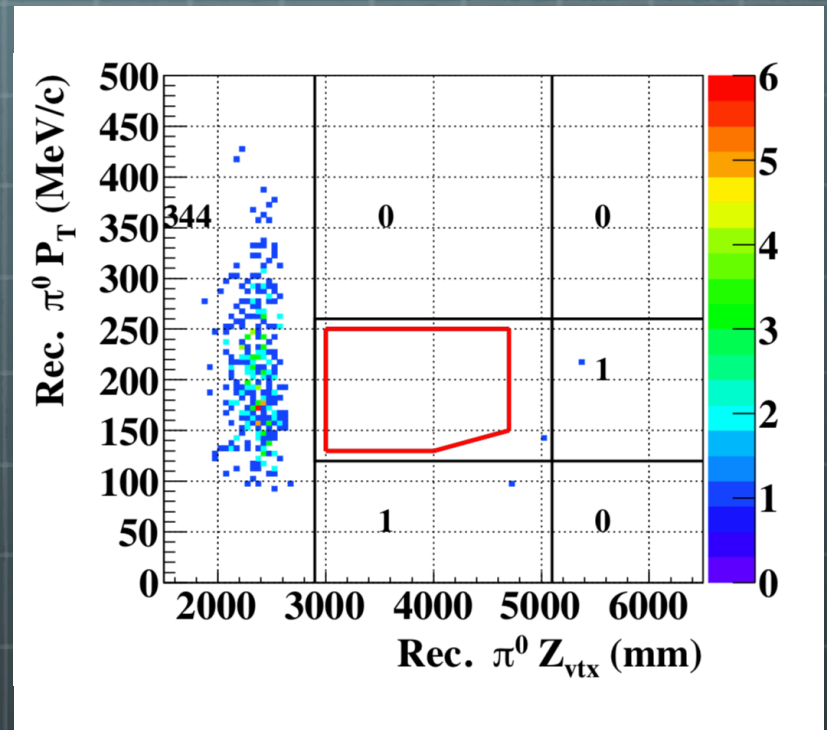
CBNU @ 17th Sep., 2018

# KOTO Detector



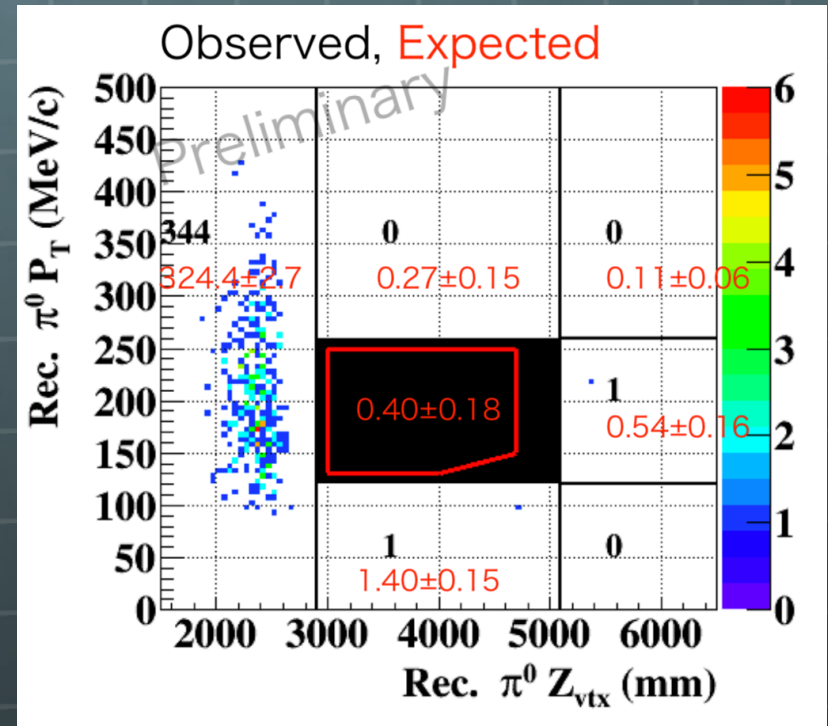
# Result of 2015 Run

- Several detector upgrades to reject background events observed the first physics run
- Background estimation with blinded signal region
- Opened Box in June 2018
- No signal candidate
- $BR < 3.0 \times 10^{-9}$  @90%C.L.



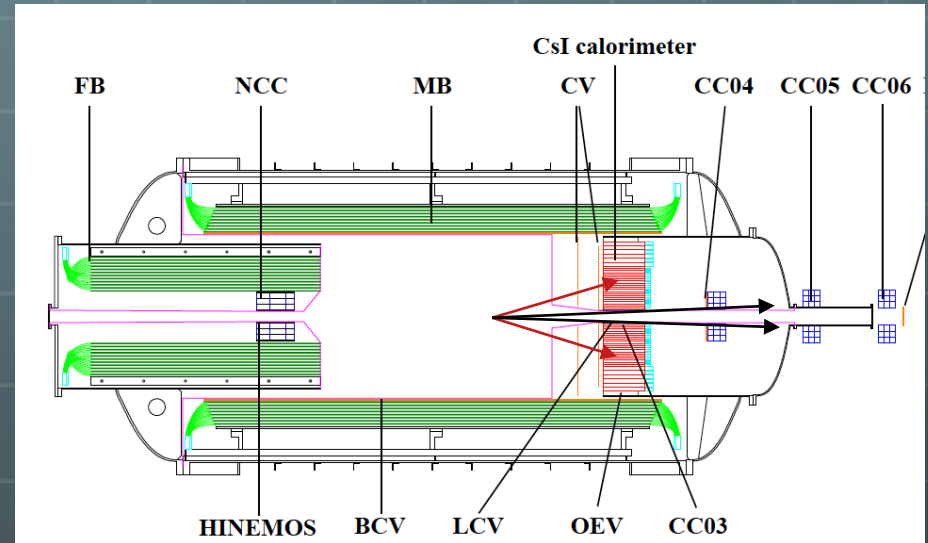
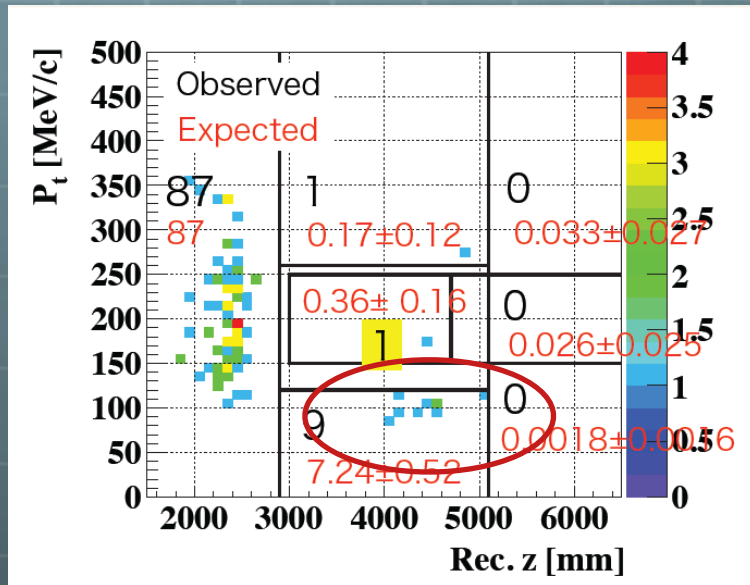
# Background budget

background source	#BG
Halo neutron hitting CSI	$0.24 \pm 0.17$
Halo neutron hitting upstream detectors	$0.04 \pm 0.03$
$\eta$ background	$0.03 \pm 0.02$
$KL \rightarrow \pi^+ \pi^- \pi^0$	$0.05 \pm 0.02$
$KL \rightarrow 2\pi^0$	$0.02 \pm 0.02$
other BG sources	$0.02 \pm 0.02$
Sum	$0.40 \pm 0.18$

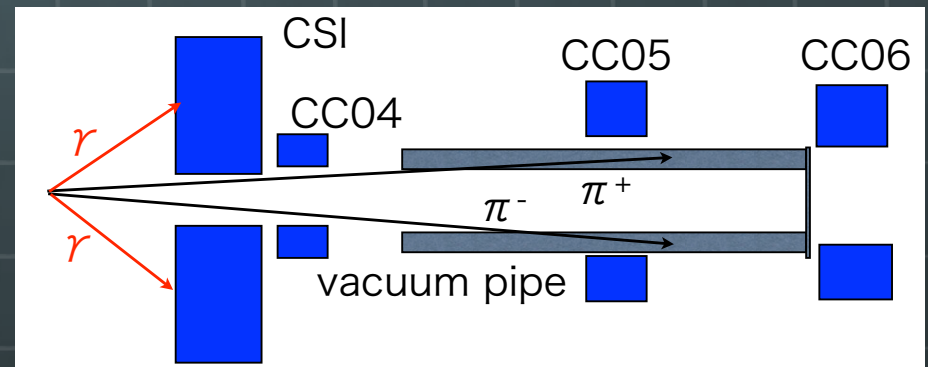




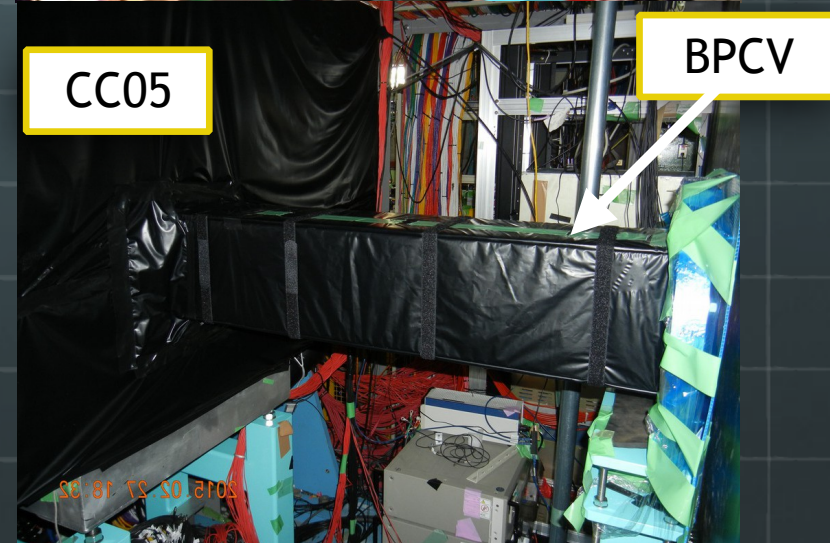
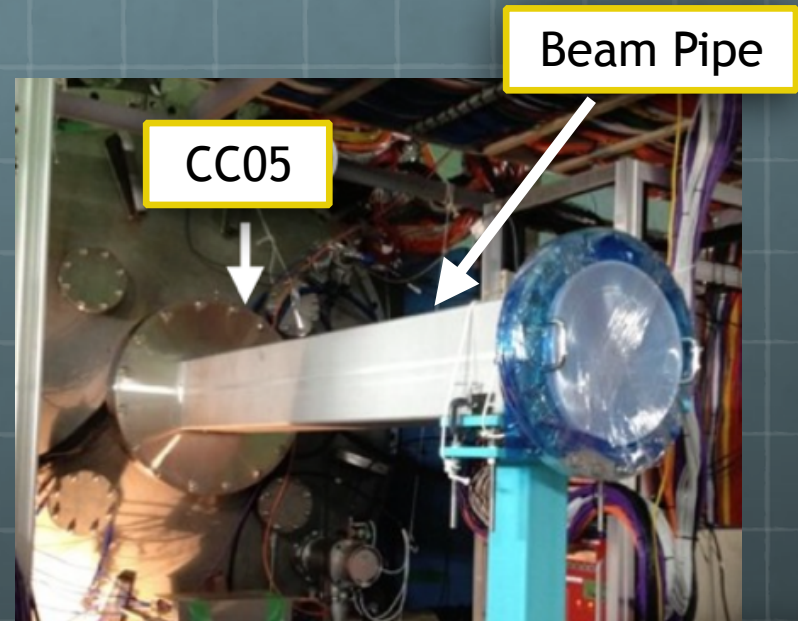
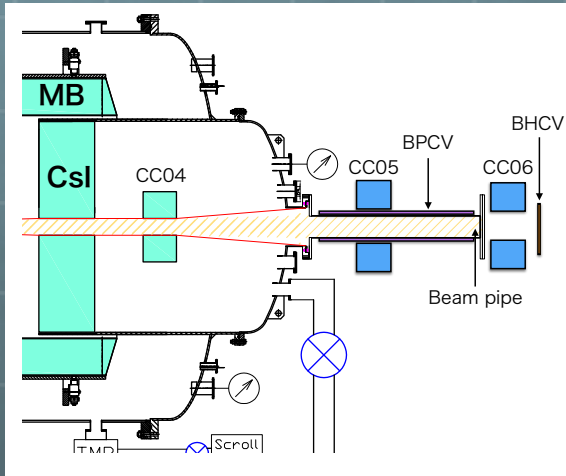
$$K_L \rightarrow \pi^+ \pi^- \pi^0$$



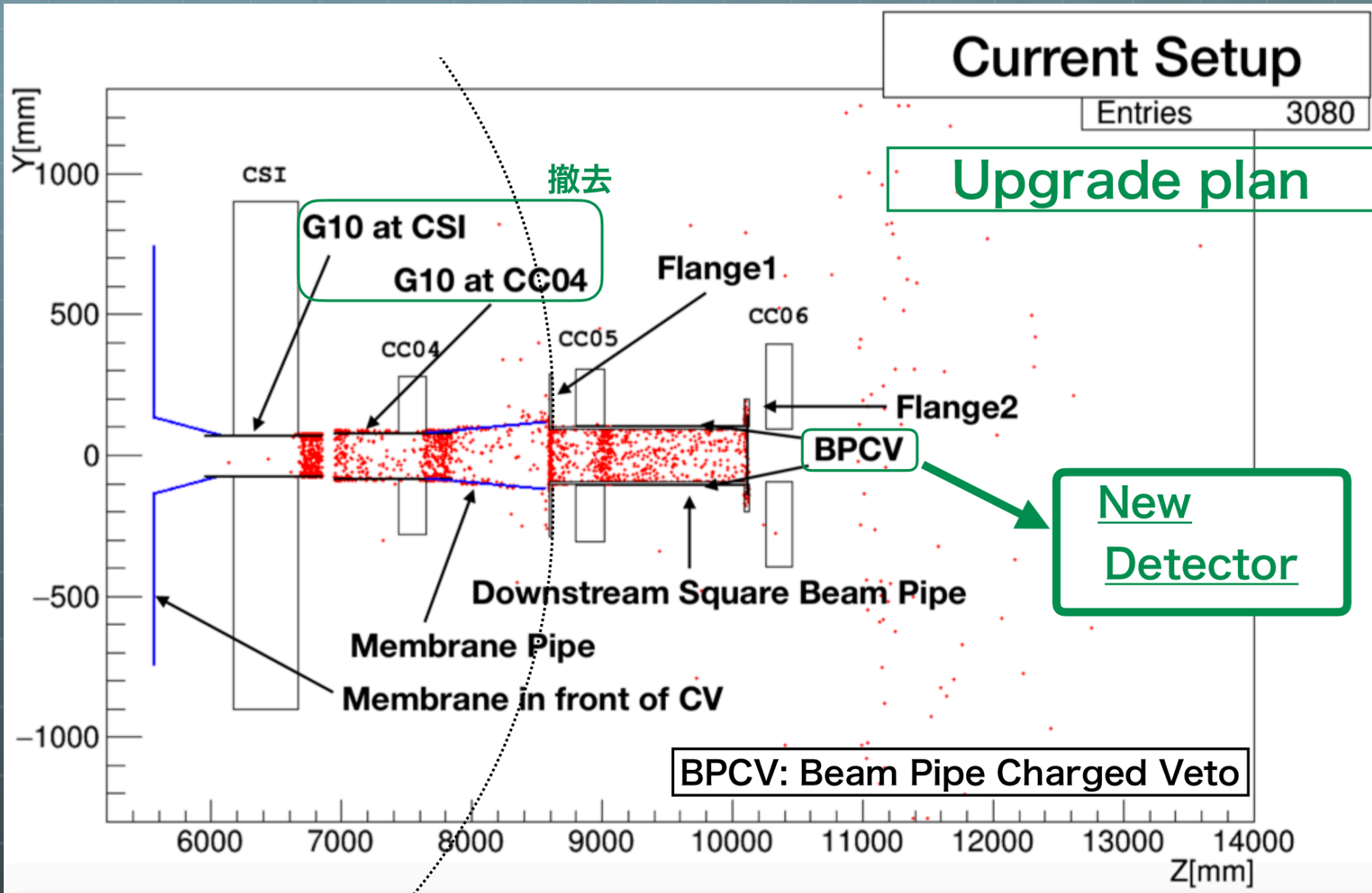
$\pi^+$  and/or  $\pi^-$  were not detected due to interaction with vacuum pipe



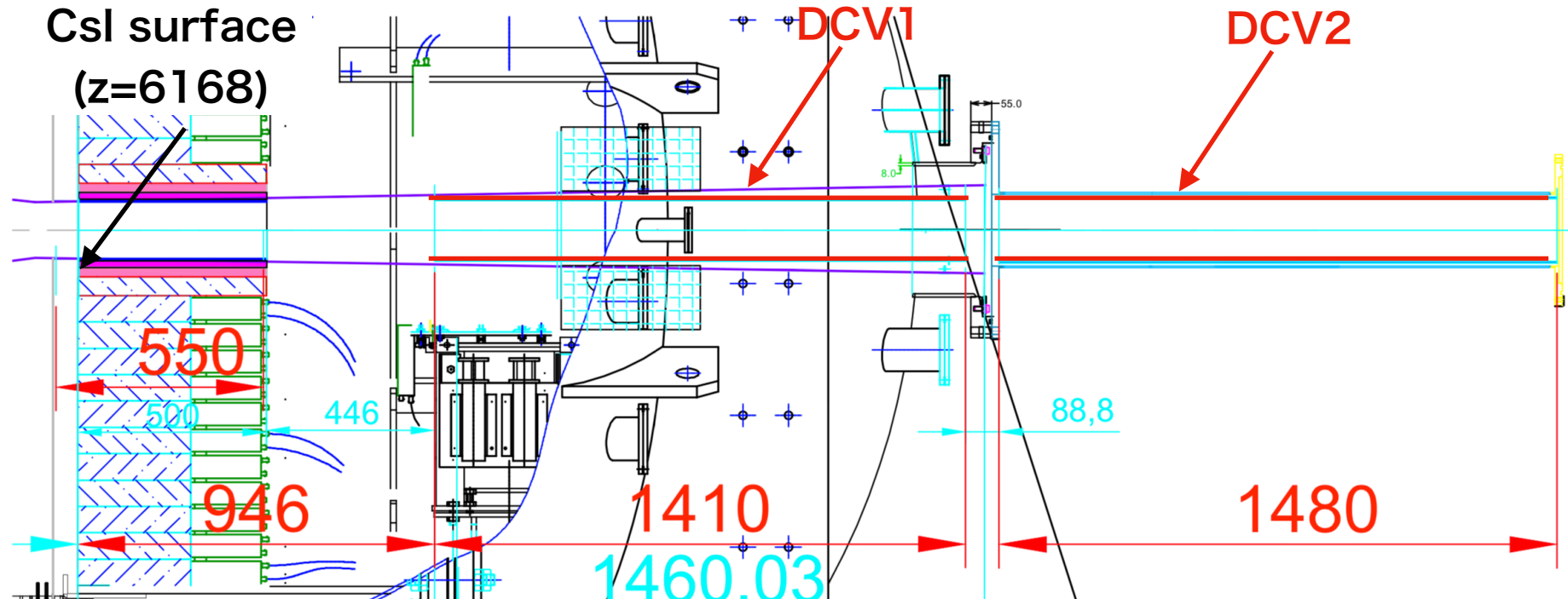
$$K_L \rightarrow \pi^+ \pi^- \pi^0$$



- Beam pipe with lighter material
- Stainless Steel -> Aluminum
- Beam Pipe Charged Veto
  - 5mm-thick Plastic Scintillator
  - Wavelength shifting fiber readout



# Downstream Charged Veto



1. Membrane doesn't be changed (using current one).
2. DCV1 start 946 downstream from the Csl surface.
  1. Cross section is 166mmX166mm and length of 1410mm
3. DCV2 start 89mm downstream from the DCV1 rare edge.
  1. Cross section is 176mmX176mm and length of 1480mm
4. Thickness of DCV1 and DCV2 is 5mm
5. Csl G-10 : change length 900 ->550
  1. start 50mm in front of the Csl



# Outgassing



## Chamber Evacuation

$$P(t) = P_0 \exp\left(\frac{-St}{V}\right) + \frac{Q}{S}$$

$P(t)$  : Chamber pressure at time  $t$

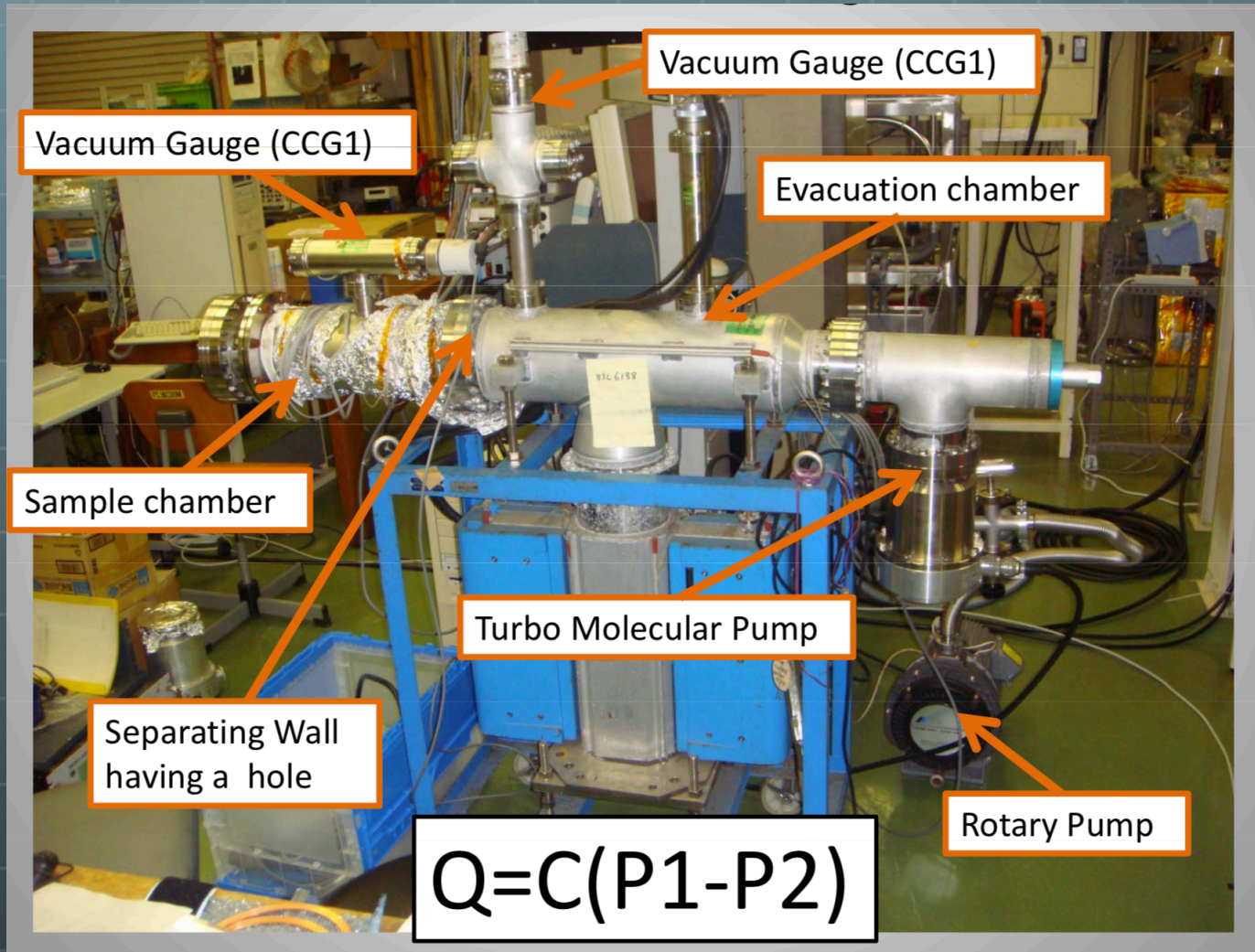
$P_0$  : Initial Pressure

$S$  : Pumping speed

$Q$  : Rate of outgassing

$V$  : Volume of chamber

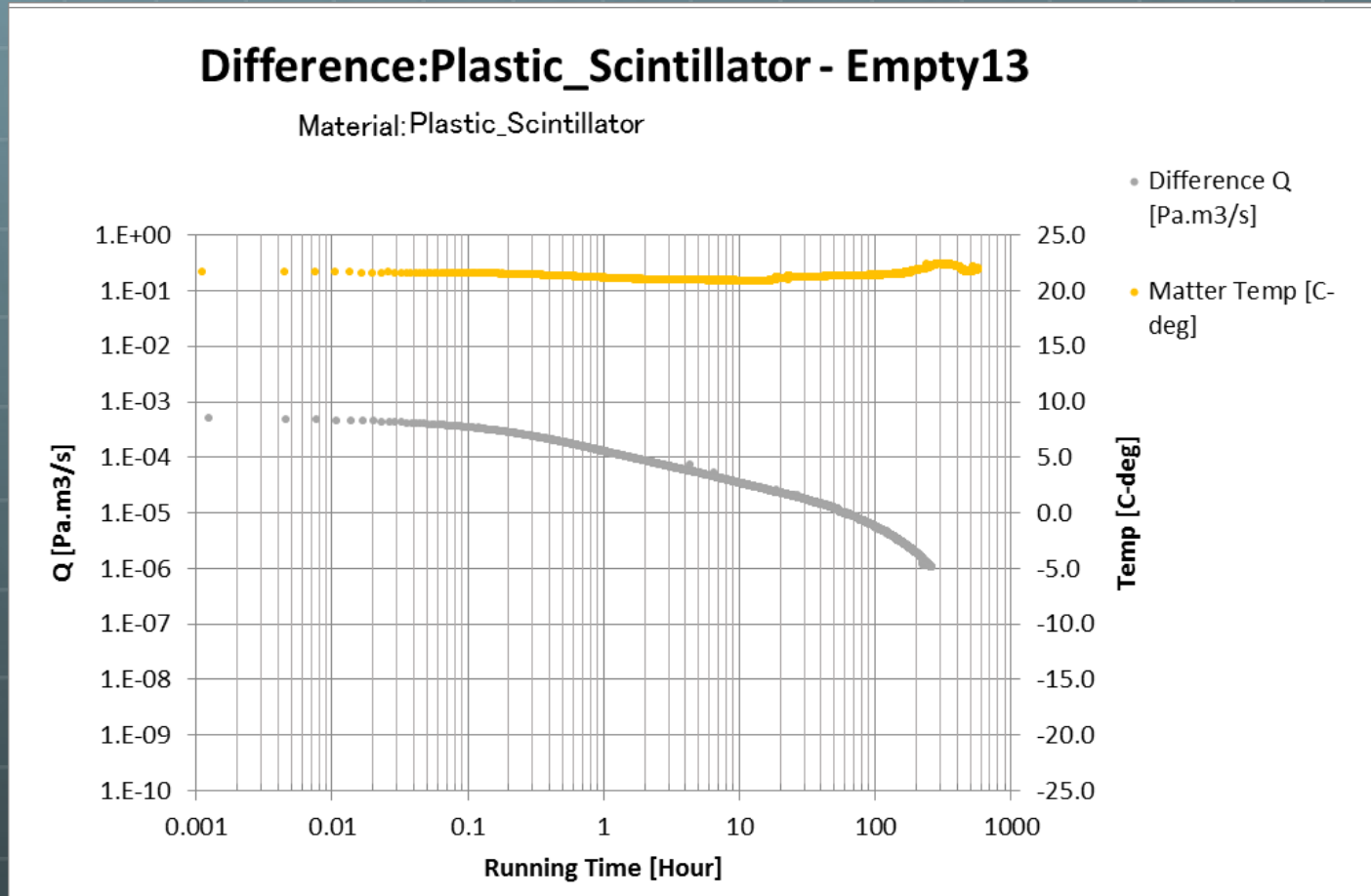
# Measurement on outgassing rate













# Outgassing rate of plastic scin.



$$Q = 1.0 \times 10^{-6} \text{ Pa} \cdot \text{m}^3 / \text{s} \text{ for } 2 \times 10^{-5} \text{m}^2$$

# DCV contribution

-  Total surface of DCV :  $2 \text{ m}^2$ 
  -  90.1 times larger than test sample
-  Pumping speed of TMP :  $(800 \text{ l/s}) \times 4$
-  Outgassing rate :  $1.0 \times 10^{-6} \text{ Pa} \cdot \text{m}^3 / \text{s}$ 
  -  Total outgassing rate:  $9.0 \times 10^{-5} \text{ Pa} \cdot \text{m}^3 / \text{s}$
-  Reaching Pressure  $P = 2.8 \times 10^{-5} \text{ Pa}$



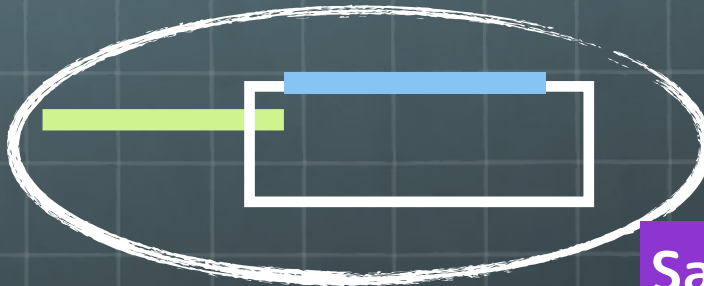
# R&D for light guide



Simple transparent light guide  
Matter of material selection  
refection sheet



Variation of light guide  
To change shape of light guide for  
better light collection



No light guide  
Insert fiber into reflecting box

Sample making

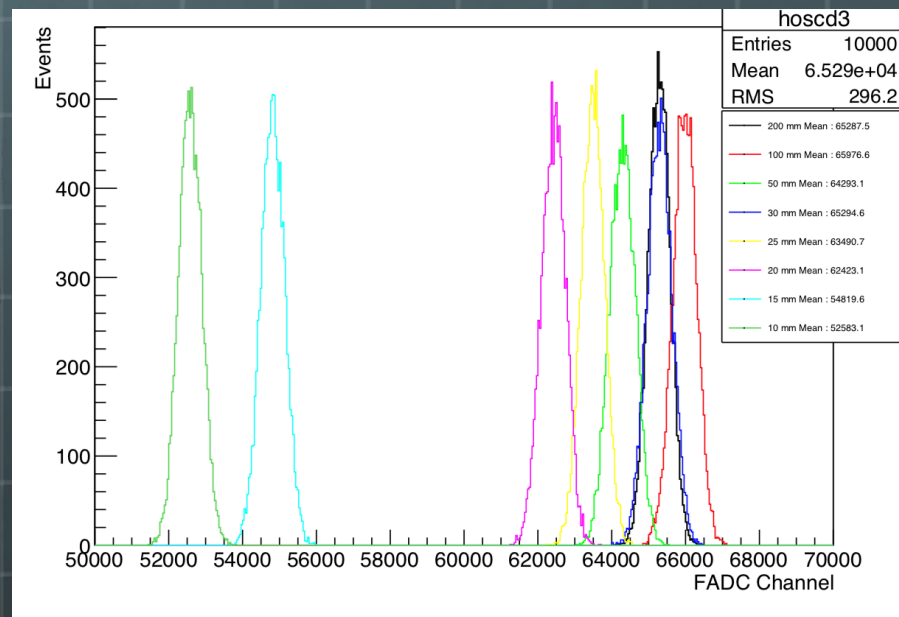
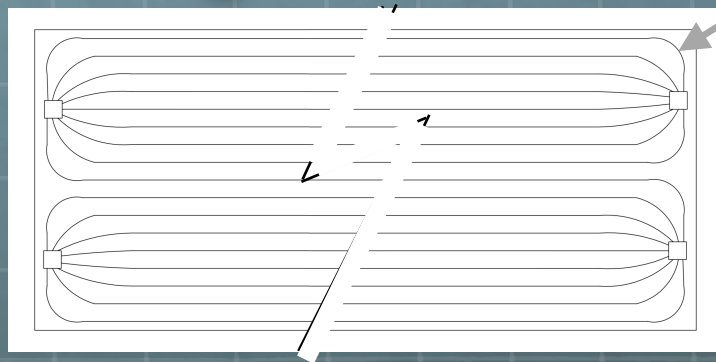


Variation of reflecting box  
Insert a reflecting cone in the box



# Bending Loss

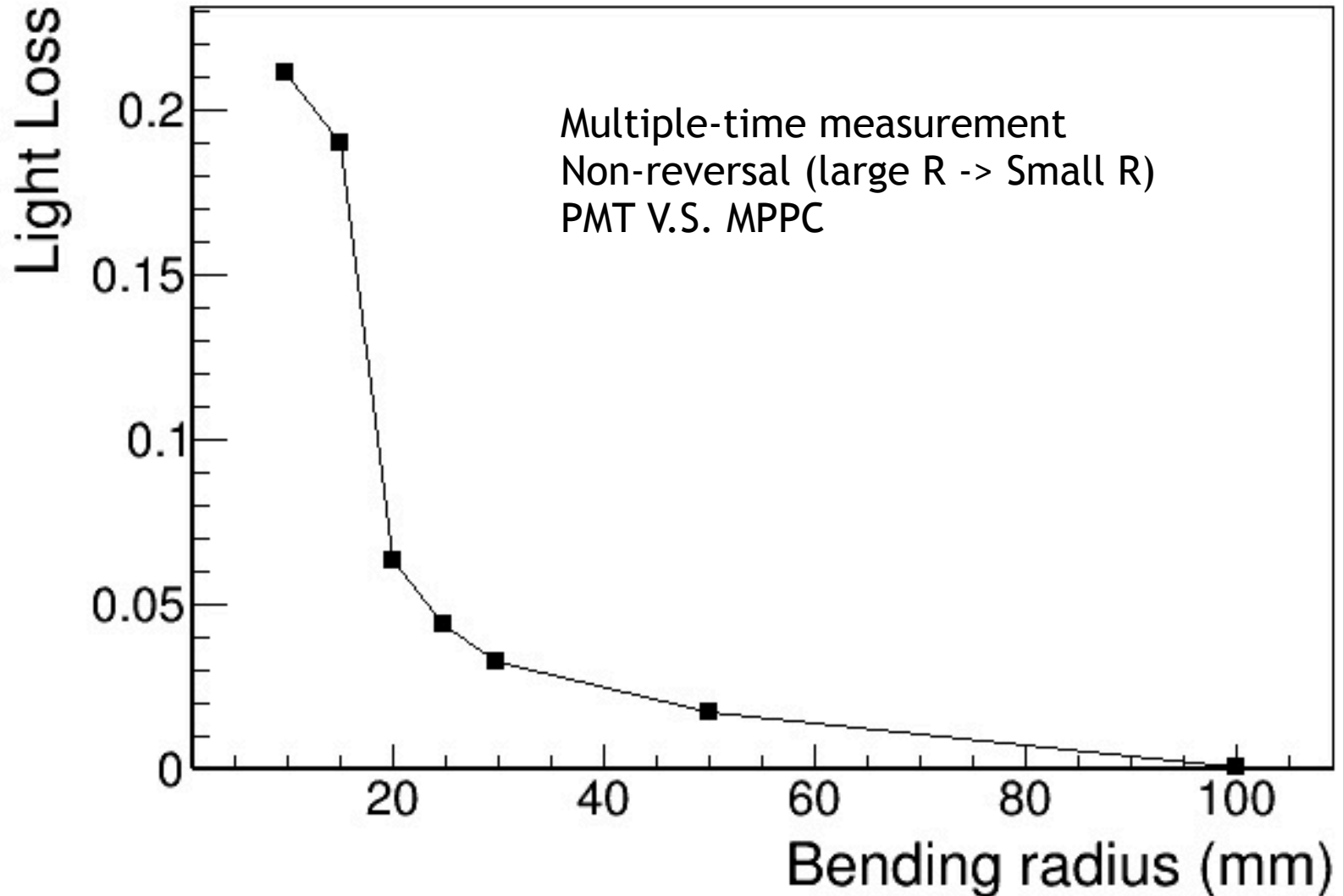
How to determine R ?





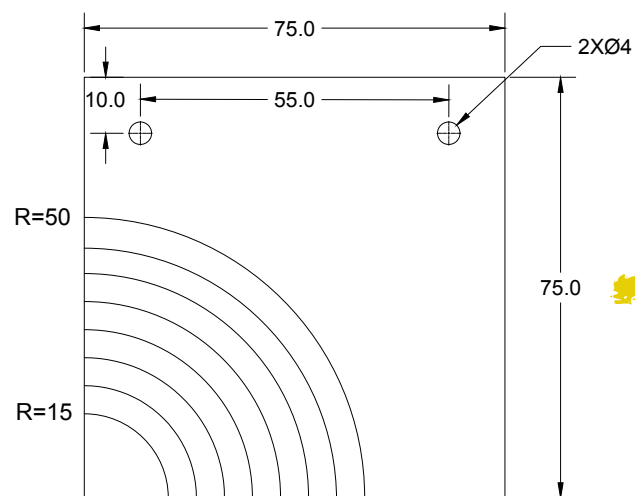
# Bending Loss

How to determine R ?

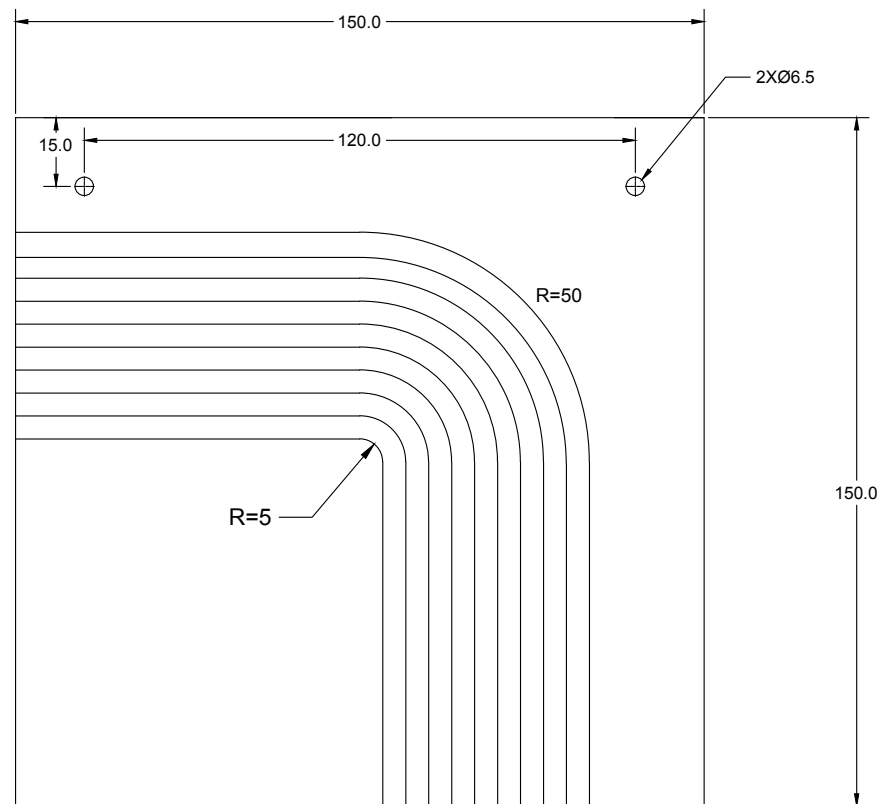




# For better measurement



R=15から50まで5mmステップで、溝の深さと幅は1.7mm

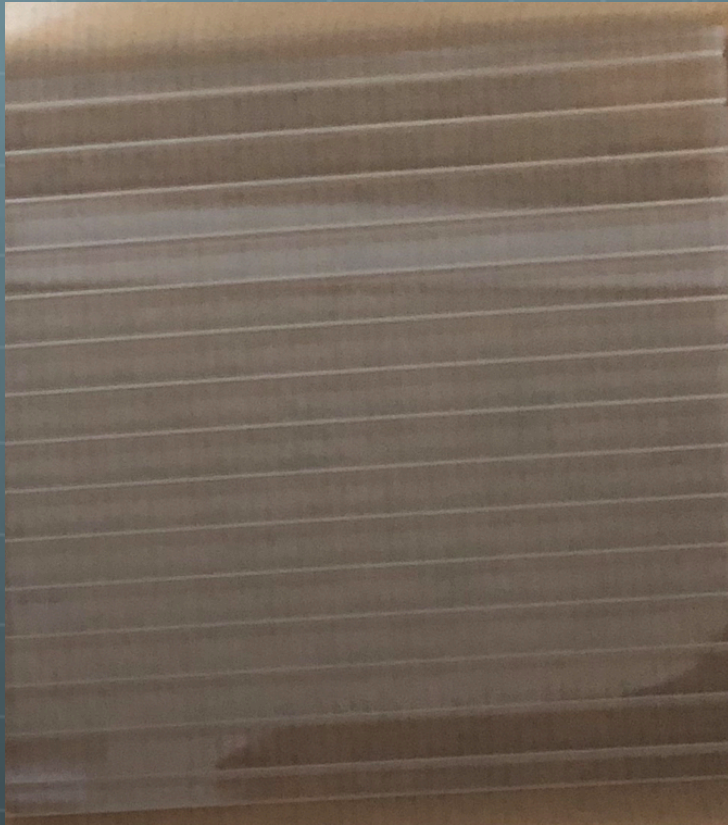


R=5から50まで5mmステップで、溝の深さと幅は1.7mm





# Pitch dependency ?

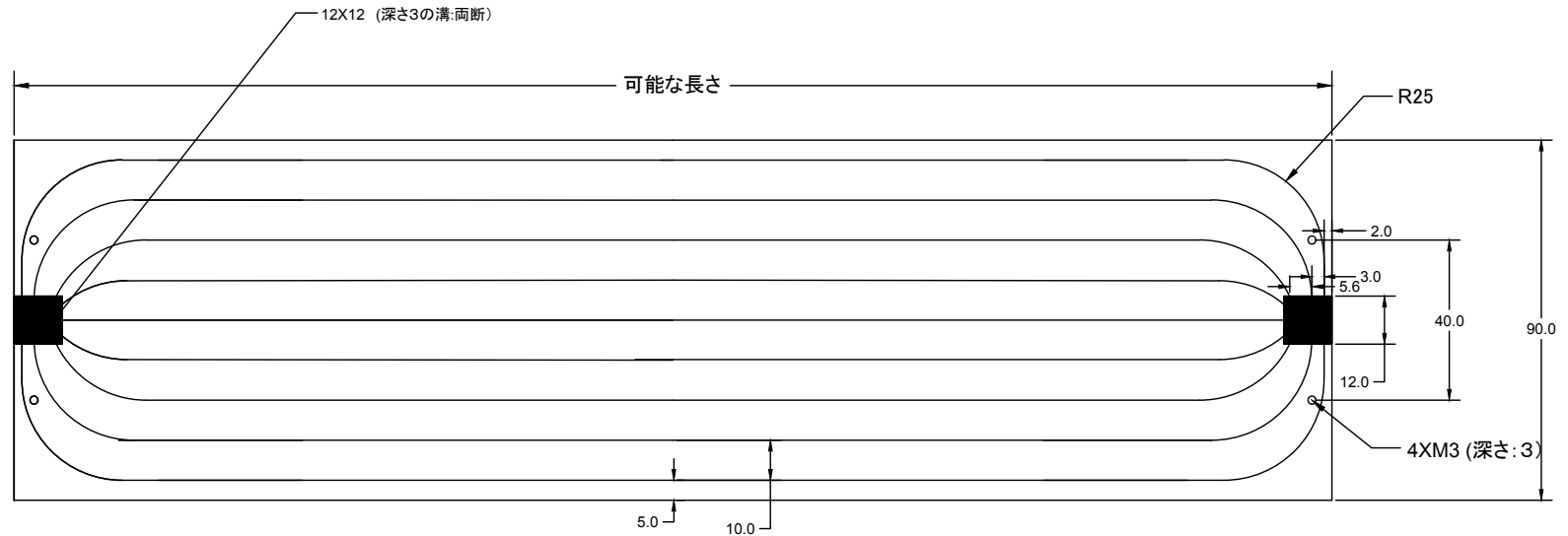


3 different pitches of groove  
10mm 6.6mm, 5mm  
2 different WLS fiber

- Best light yield !









# First trial



Will be delivered by the end of this month  
Overall configuration will be tested

# Things to do

-  Decision on pitch of groove
-  Selection of Reflector
-  Design of fiber attachment (lightguide)
-  Establishing gluing process
-  Read-out circuit
-  Feed-through

# Decision on pitch of groove

- Select one of the 6 different configuration.

- Best light yield.

Y11 : Bending loss  
Light Yield

- Position dependency

- Kye is the measurement on number of photo-electrons

  - By the end of this week ?

- Repeat same measurement with EJ-200

  - By the end of this month



# Selection of Reflector

- Large light yield
- As light as possible (~tens of micron ?)
- Operation inside vacuum
- No falling down into the beam line
- Alumilized mylar
- 1st week on October (including wrapping method)

Discussion : In reality, what kinds of things to do ?

# Design of fiber attachment (lightguide)

- Design & prototype making - by the end of Sep.
- Test & selection by the middle of Oct.
- Gluing process will be related.



# Read-out circuit & Feed-through

- Study at KEK

- 1st prototype by ~~middle of Oct.~~ → End of Oct.

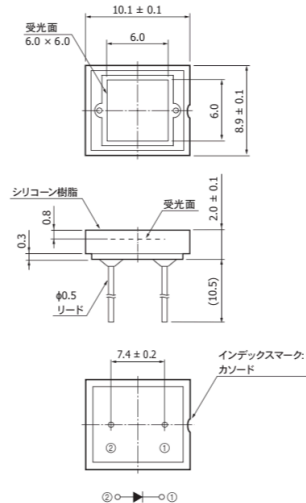
- Final design by the end of Oct.

- Production by the end of Nov.

Keep this schedule

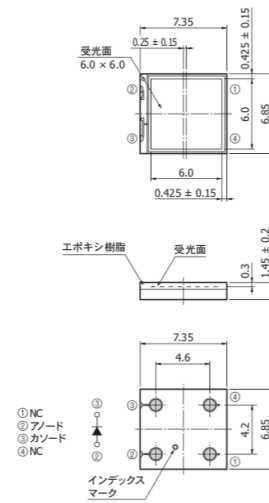
# MPPC selection

S13360-6025CS/-6050CS/-6075CS



KAPDA01571A

S13360-6025PE/-6050PE/-6075PE



KAPDA01531A

S13360-1350CS	50	1.3 × 1.3	667	セラミック 表面実装型	74
S13360-1350PE		3.0 × 3.0	3600	セラミック 表面実装型	
S13360-3050CS		6.0 × 6.0	14400	セラミック 表面実装型	
S13360-3050PE					
S13360-6050CS					
S13360-6050PE	75	1.3 × 1.3	285	セラミック 表面実装型	82
S13360-1375CS		3.0 × 3.0	1600	セラミック 表面実装型	
S13360-1375PE		6.0 × 6.0	6400	セラミック 表面実装型	
S13360-3075CS					
S13360-3075PE					
S13360-6075CS					
S13360-6075PE					

# MPPC selection

☐ 電気的および光学的特性 (指定のない場合はTyp. Ta=25 °C)

型名	測定条件	感度波長 範囲 λ  (nm)	最大感度 波長 λp  (nm)	検出効率 PDE*1 λ=λp  (%)	ダークカウント*2		端子間 容量 Ct  (pF)	増倍率 M	降伏 電圧 VBR  (V)	クロス トーク 確率  (%)	推奨動作 電圧 Vop  (V)	推奨動作 電圧の 温度係数 ΔTVop (mV/°C)	
					Typ.  (kcps)	Max.  (kcps)							
S13360-1325CS	Vover =5 V	270 ~ 900	450	25	70	210	60	7.0 × 10 <sup>5</sup>	53 ± 5	1	VBR + 5	54	
S13360-1325PE		320 ~ 900											
S13360-3025CS		270 ~ 900			400	1200	320						
S13360-3025PE		320 ~ 900											
S13360-6025CS		270 ~ 900			1600	5000	1280						
S13360-6025PE		320 ~ 900											
S13360-1350CS	Vover =3 V	270 ~ 900		40		90	270	60		1.7 × 10 <sup>6</sup>	3		VBR + 3
S13360-1350PE		320 ~ 900											
S13360-3050CS		270 ~ 900			500	1500	320						
S13360-3050PE		320 ~ 900											
S13360-6050CS		270 ~ 900			2000	6000	1280						
S13360-6050PE		320 ~ 900											
S13360-1375CS	Vover =3 V	270 ~ 900		50		90	270	60	4.0 × 10 <sup>6</sup>	7	VBR + 3		
S13360-1375PE		320 ~ 900											
S13360-3075CS		270 ~ 900			500	1500	320						
S13360-3075PE		320 ~ 900											
S13360-6075CS		270 ~ 900			2000	6000	1280						
S13360-6075PE		320 ~ 900											

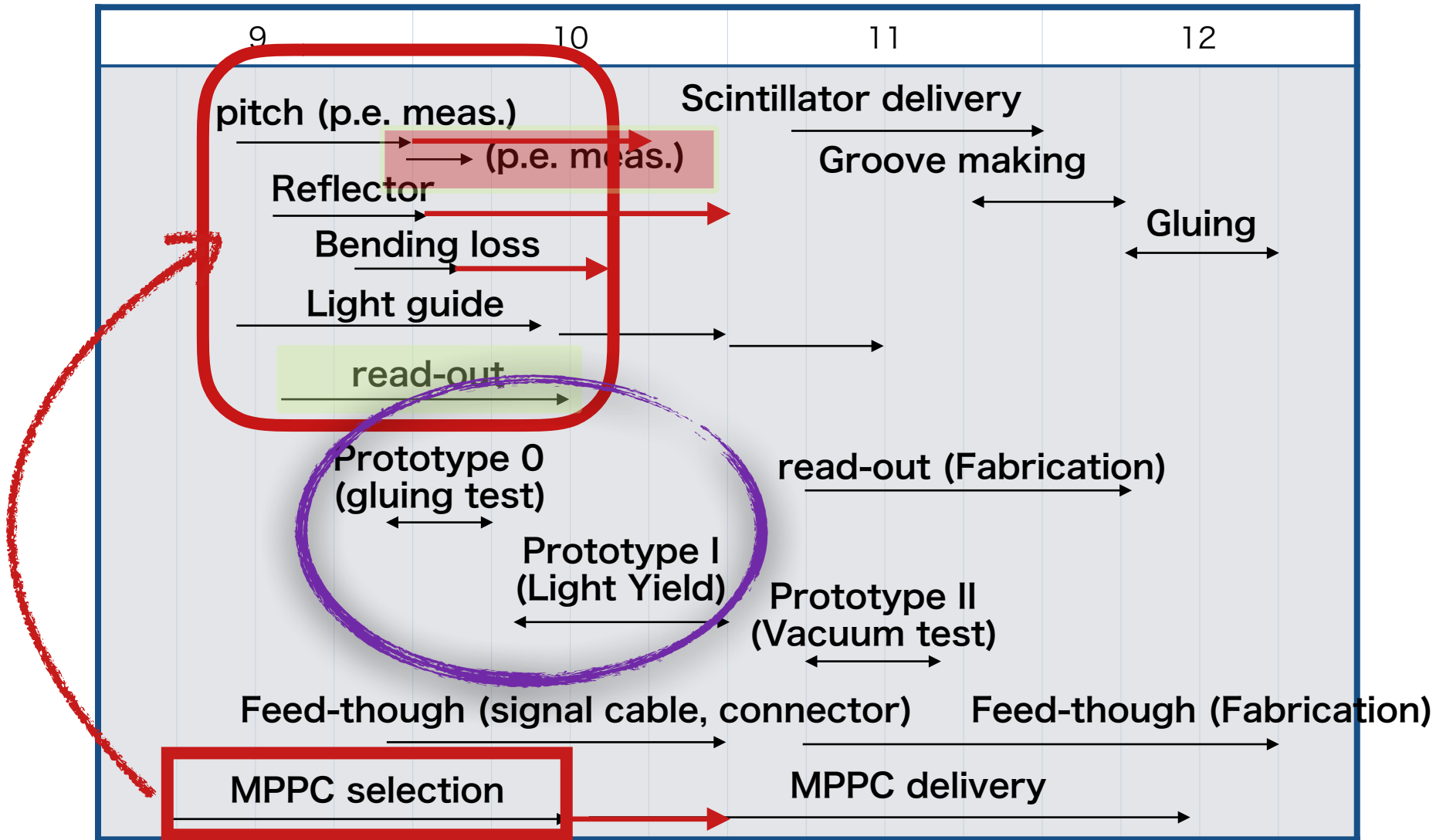
\*1: 検出効率は、クロストークレバレッジを考慮して算出されています。

\*2: 閾値=0.5 p.e.

注) 上記特性値は、表中の増倍率が適用された状態で算出されています。ご了承ください。

Ask estimate for 50 pcs (~4M Won)

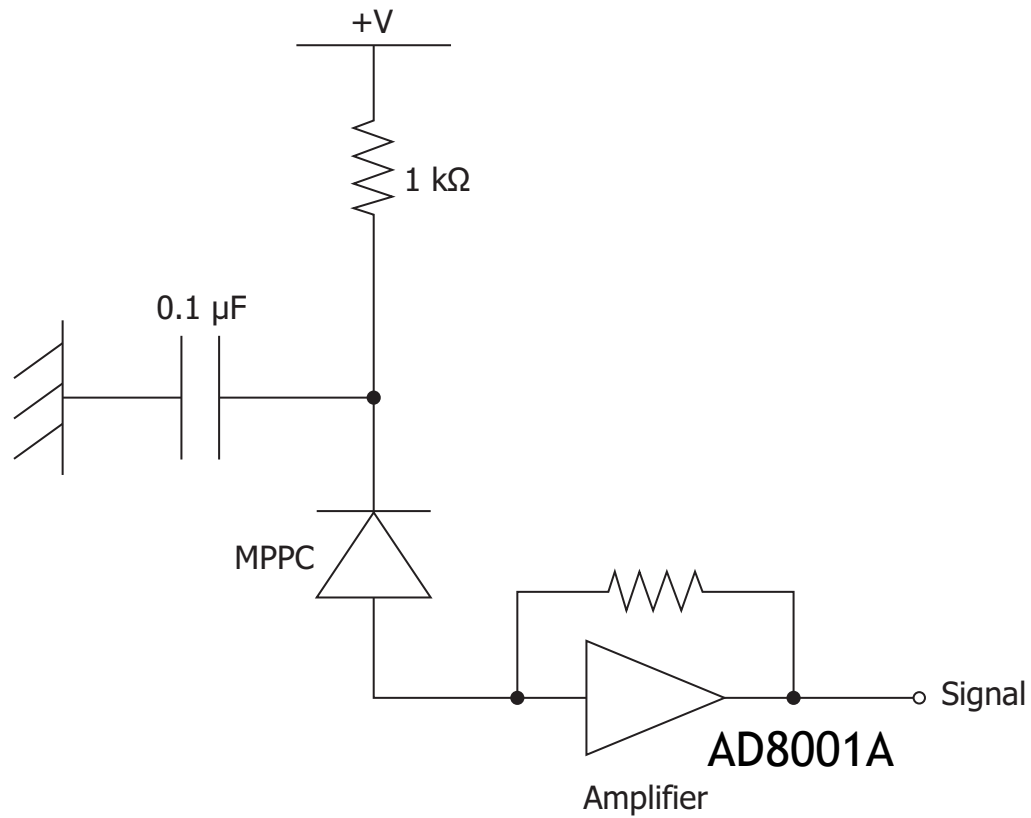
# Schedule



**No contingency plan. Keep schedule**

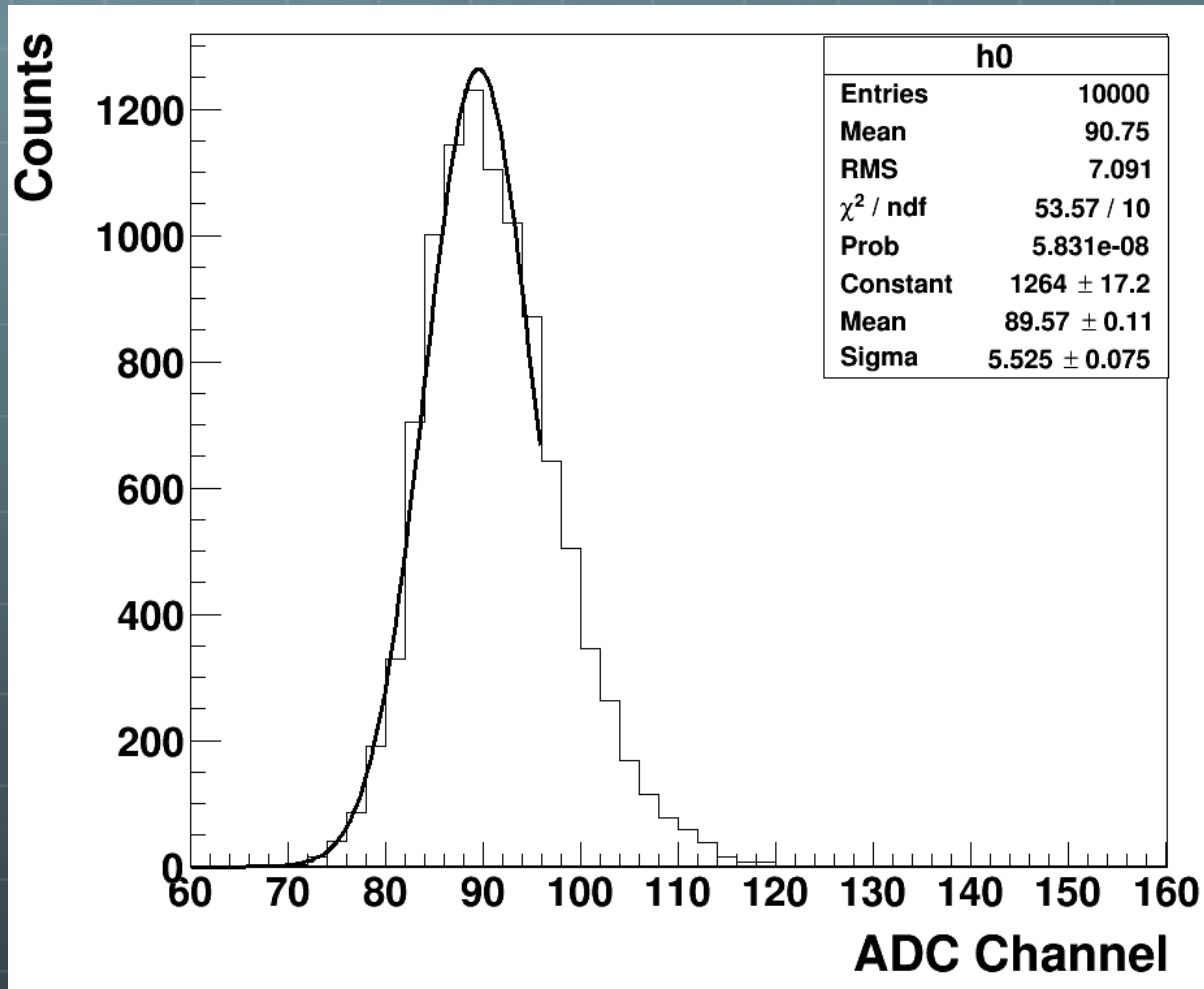
# p.e. Measurement ?

# S13360-6050CS





# Wide pedestal ?



# Wide pedestal ?

Single electron  $1.6 \times 10^{-19}$

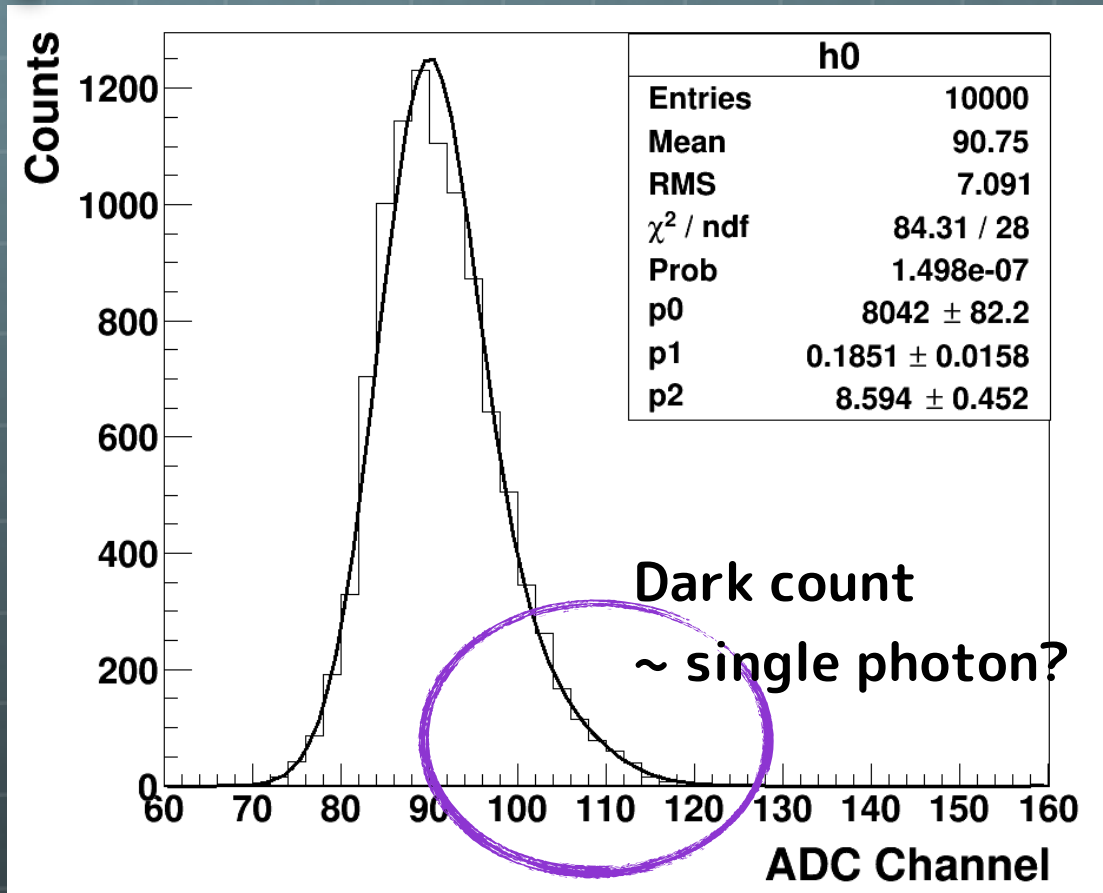
MPPC gain :  $1.6 \times 10^6$

Amp gain : 10

$\Rightarrow 2.6 \times 10^{-12} \text{ C} \sim 10 \text{ ch}$

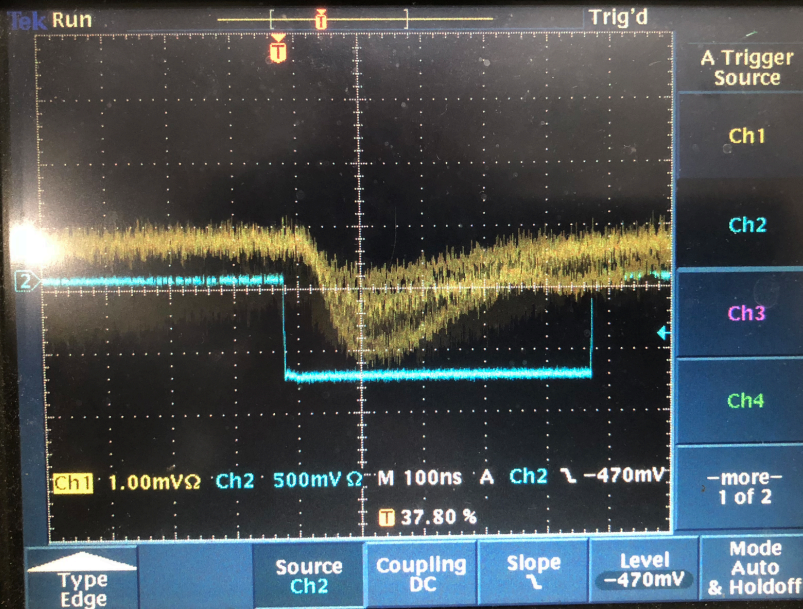
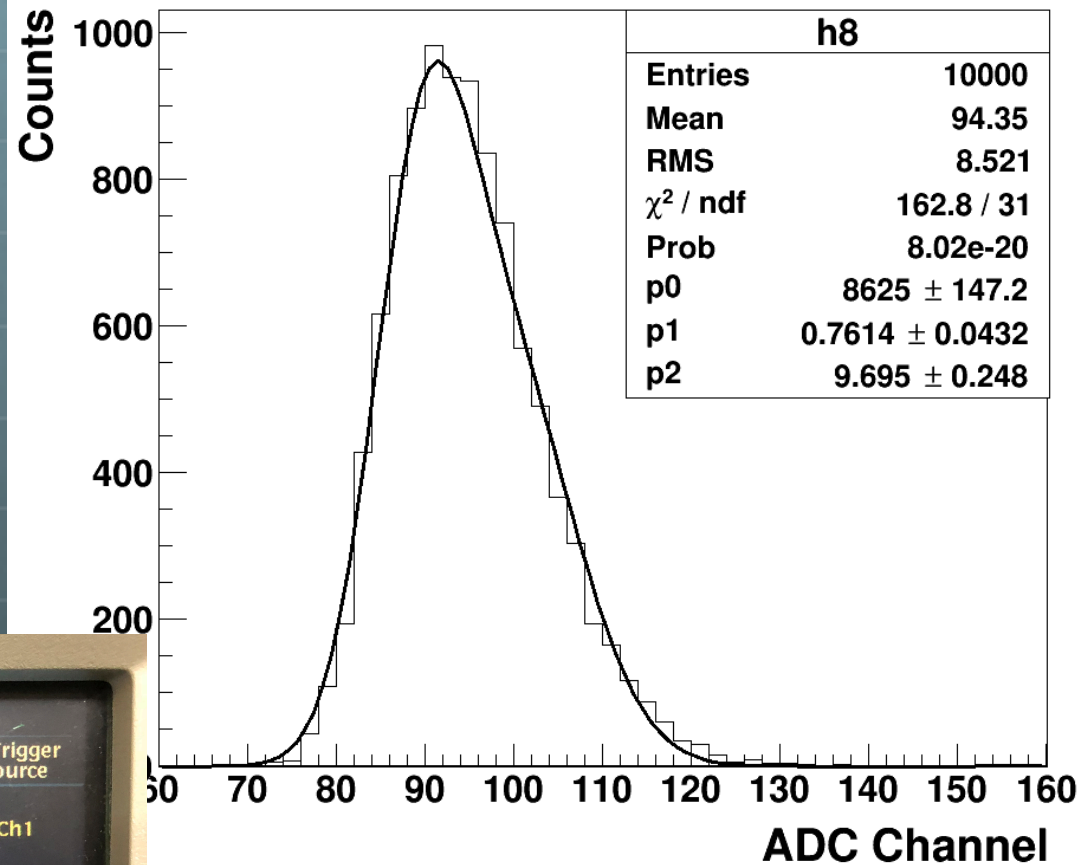
$x$  : ADC channel  
 $A(p1)$  : Normalization Factor **p0**  
 $\bar{N}(p2)$  : 平均光電子数 **p1**  
 $\sigma(p3)$  : 標準偏差  
 $p(p4)$  : 各ピーク間隔 **p2**  
 $q(p5)$  : ペデスタルピークの channel

$$R(x) = A \sum_{N=1}^{N_{max}} \frac{\exp^{-\bar{N}} \bar{N}^N}{N!} \frac{1}{\sqrt{2\pi N\sigma}} \exp \left\{ -\frac{(x - pN - q)^2}{2N\sigma^2} \right\}$$



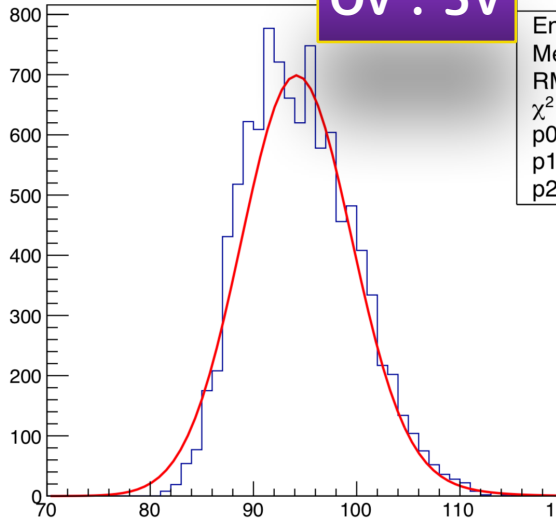
**0.25pC/ch**

# Weak LED Light



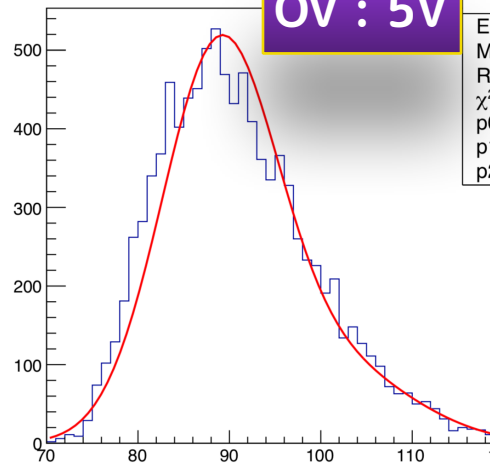
# Diff. Over Voltage

OV : 3V



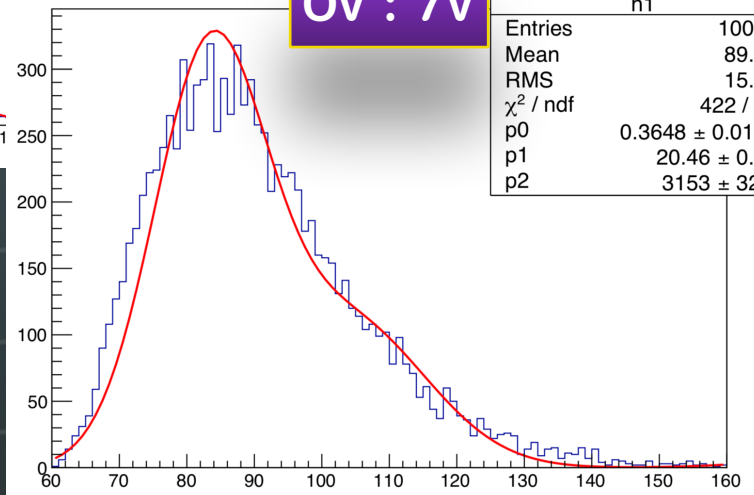
h1	
Entries	10000
Mean	94.1
RMS	5.311
$\chi^2 / \text{ndf}$	565.3 / 33
p0	$0.03318 \pm 0.00675$
p1	$5.779 \pm 0.690$
p2	$4071 \pm 43.0$

OV : 5V



h1	
Entries	10000
Mean	90.57
RMS	8.829
$\chi^2 / \text{ndf}$	308.9 / 61
p0	$0.2059 \pm 0.0128$
p1	$11.86 \pm 0.41$
p2	$3684 \pm 37.7$

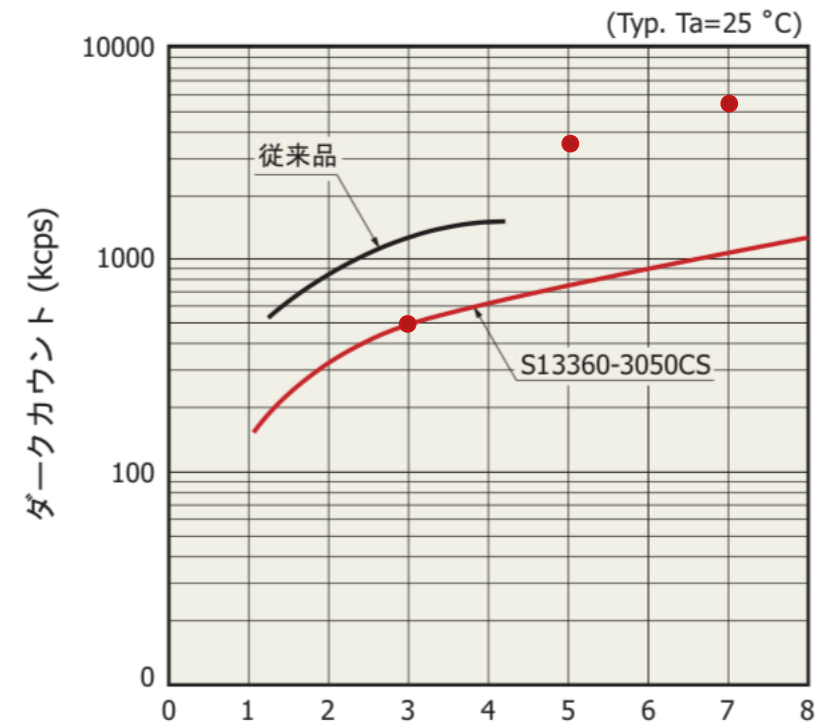
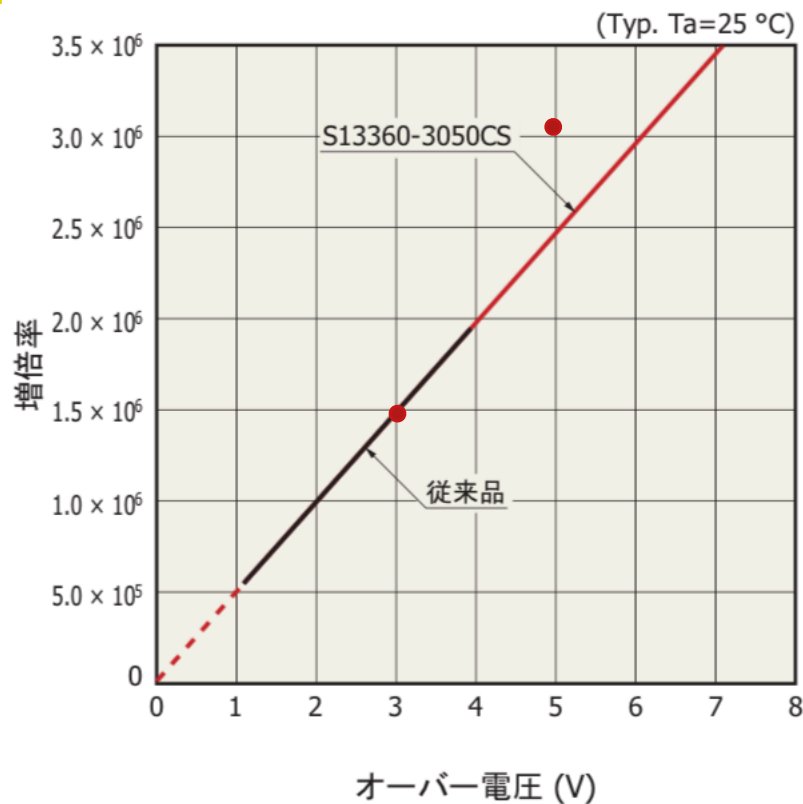
OV : 7V



h1	
Entries	10000
Mean	89.97
RMS	15.26
$\chi^2 / \text{ndf}$	422 / 96
p0	$0.3648 \pm 0.0137$
p1	$20.46 \pm 0.40$
p2	$3153 \pm 32.3$

With this fitting performance,  
it is hard to mention about  
single photon

Reconsider fitting function



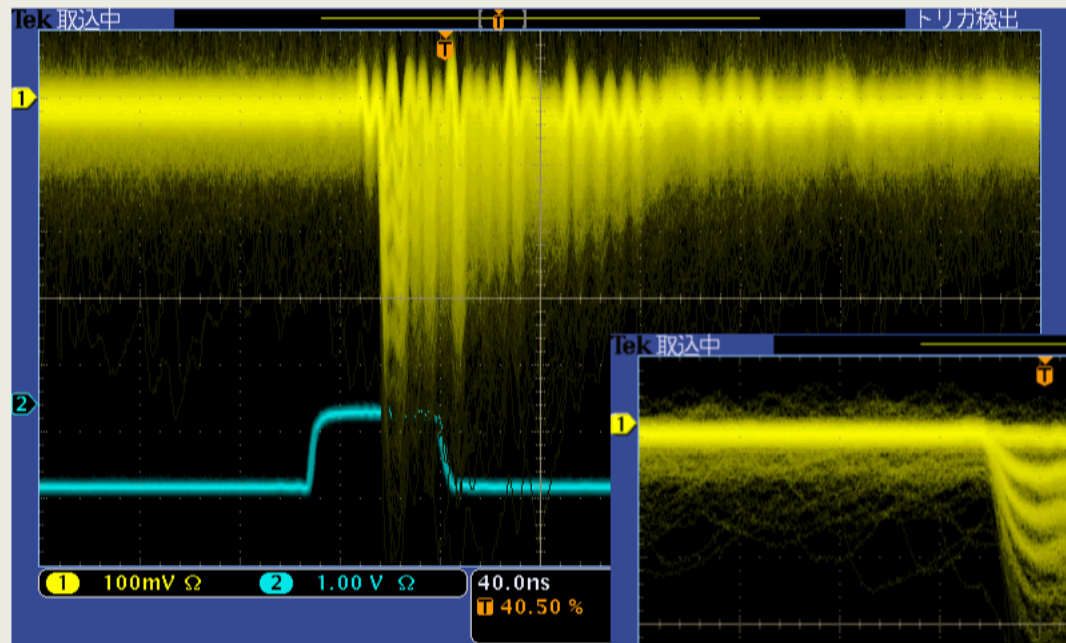


# Two issues

- To understand Noise.
  - clear peak
    - Removing high frequency components ?
    - Just cancellation out for charge integration ?
- Higher gain amplifier

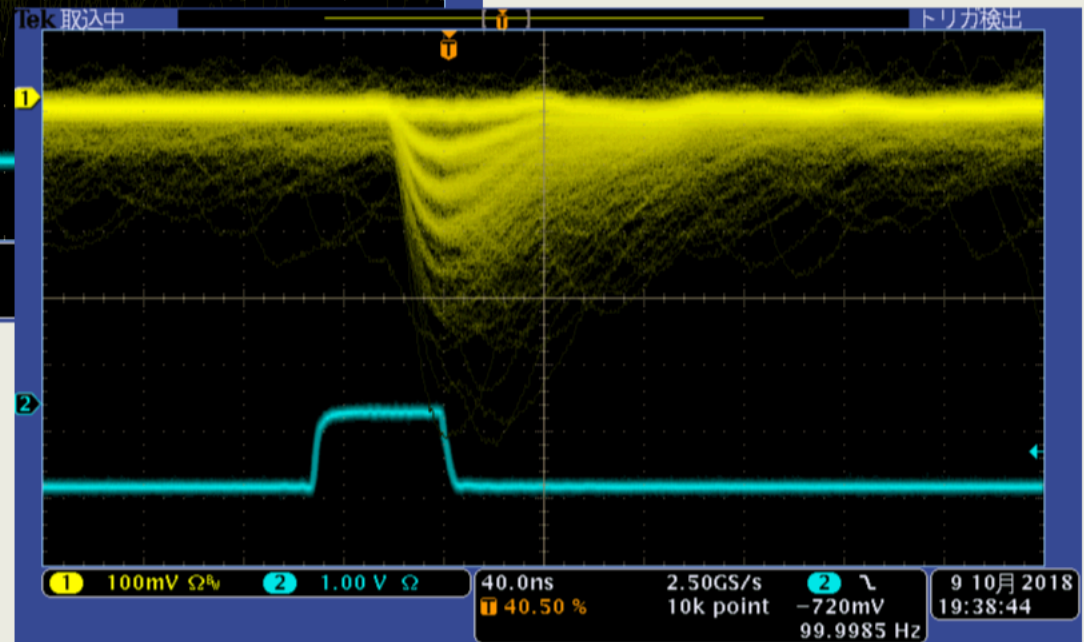
MPPC:  $V_+ = V_{op} + 3V$

Amplifier x100 (100mV/Div.)



Bandwidth  
300MHz

Bandwidth  
20MHz



# Two issues

- To understand Noise.

- clear peak

- Charge sensitive

- Higher gain amplifier