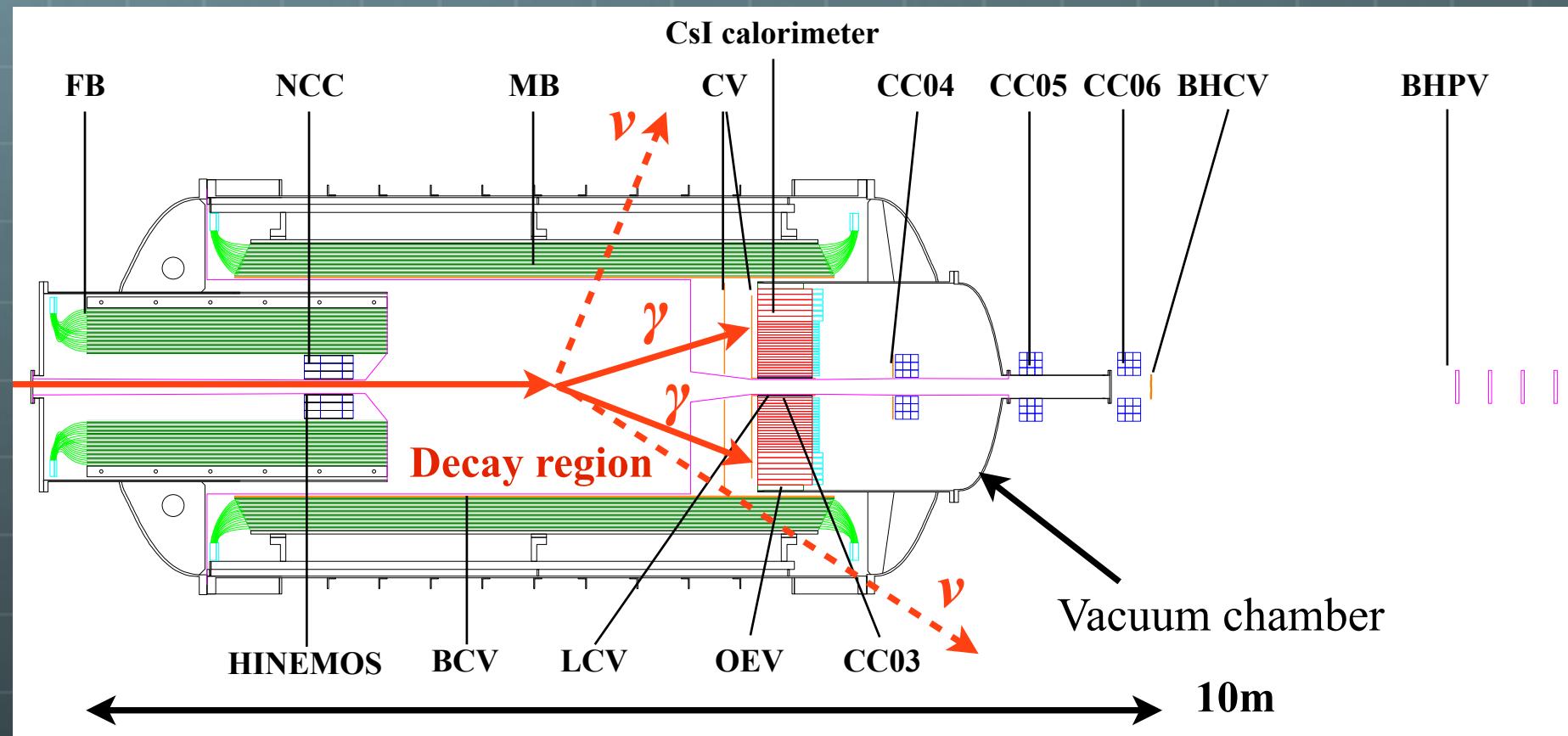


New charged veto for KOTO

G.Y.Lim
IPNS/KEK

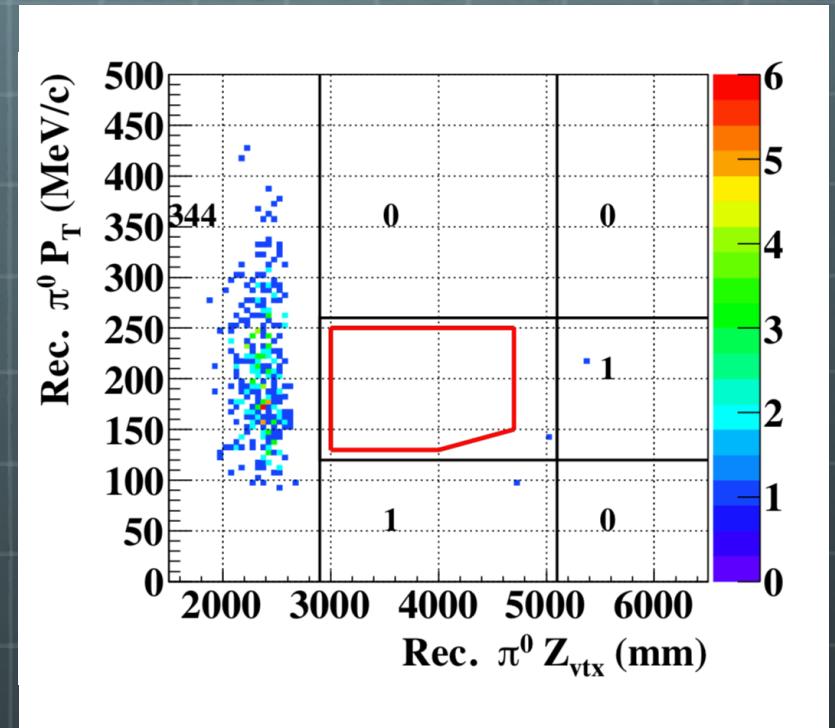
CBNU @ 17th Sep., 2018

KOTO Detector



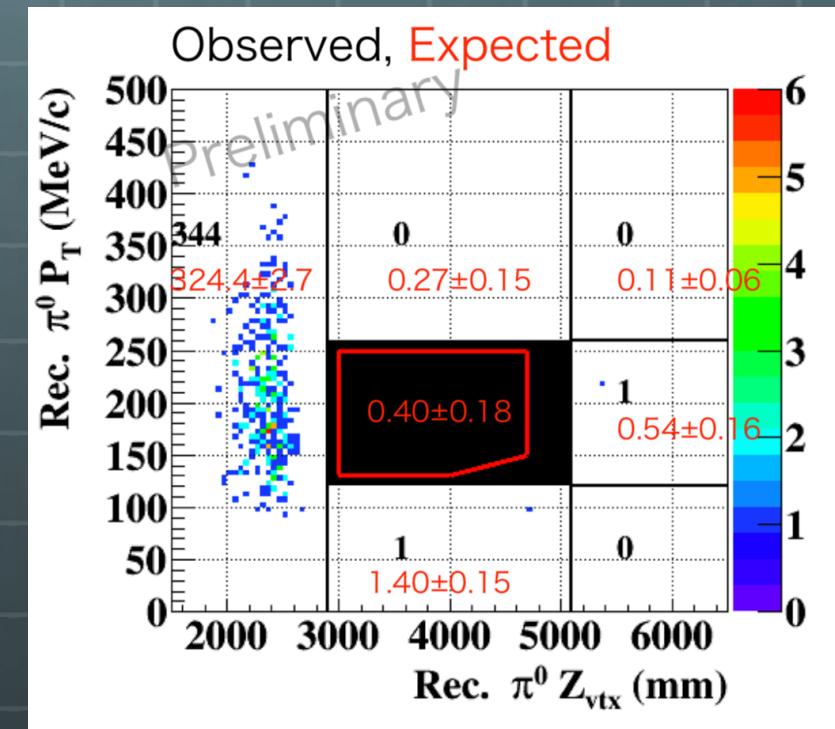
Result of 2015 Run

- 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.

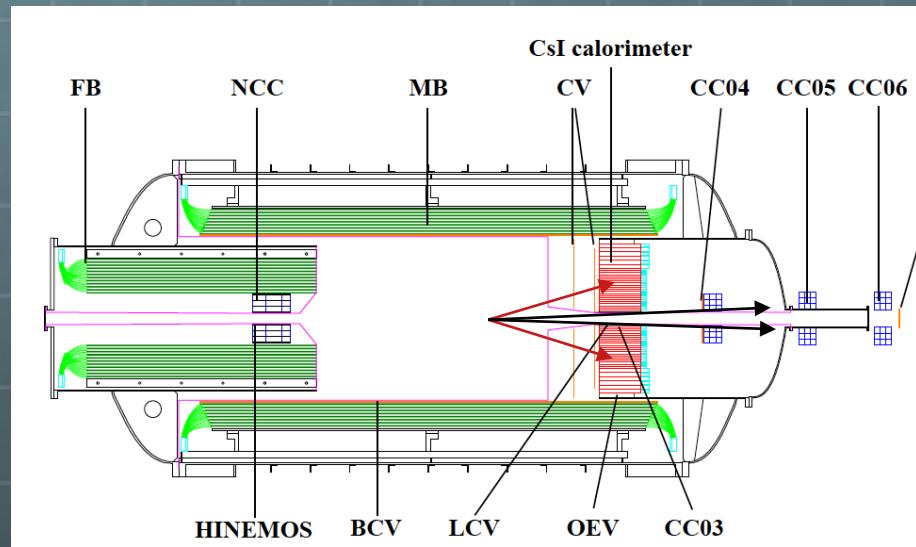
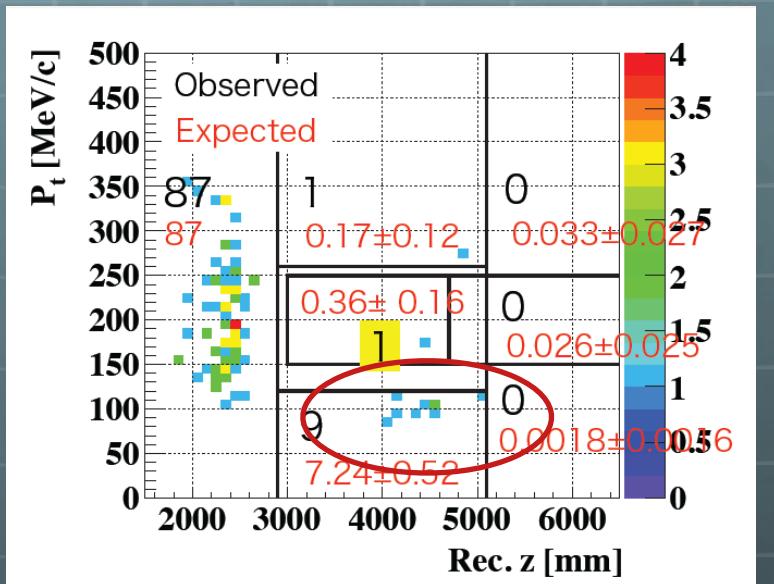


Background budget

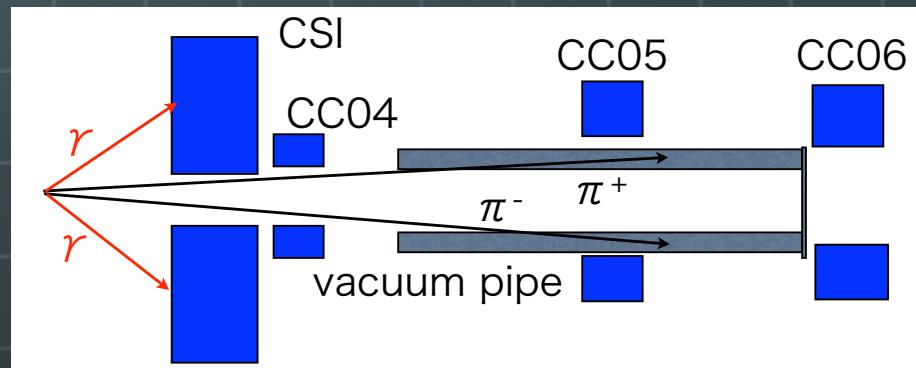
background source	#BG
Halo neutron hitting CSI	0.24±0.17
Halo neutron hitting upstream detectors	0.04±0.03
η background	0.03±0.02
KL- $\rightarrow\pi^+\pi^-\pi^0$	0.05±0.02
KL- $\rightarrow 2\pi^0$	0.02±0.02
other BG sources	0.02±0.02
Sum	0.40±0.18



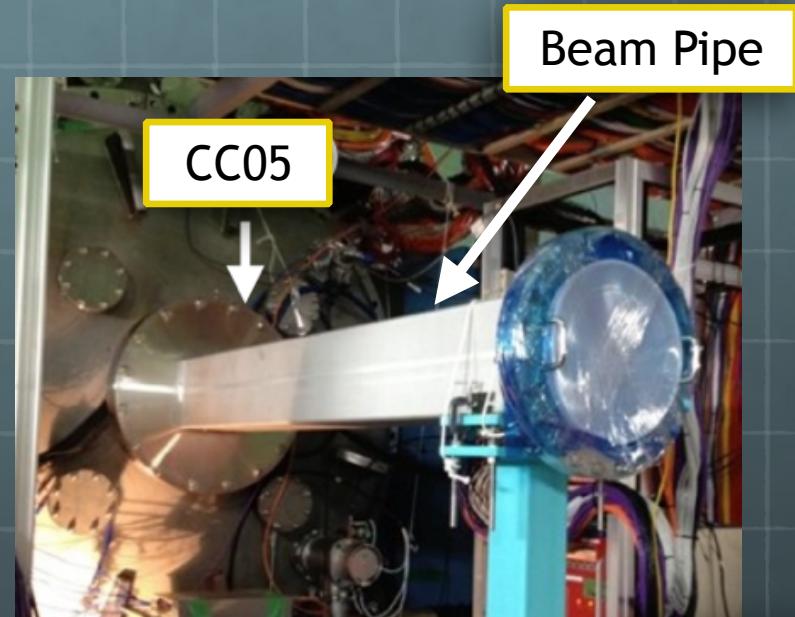
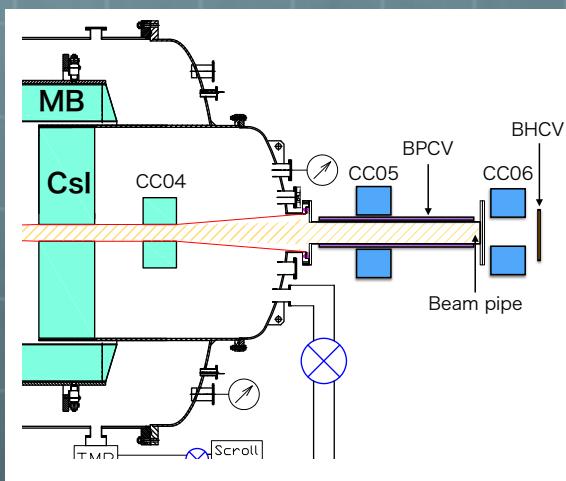
$K_L \rightarrow \pi^+ \pi^- \pi^0$



π^+ and/or π^- were not detected due to interaction with vacuum pipe



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

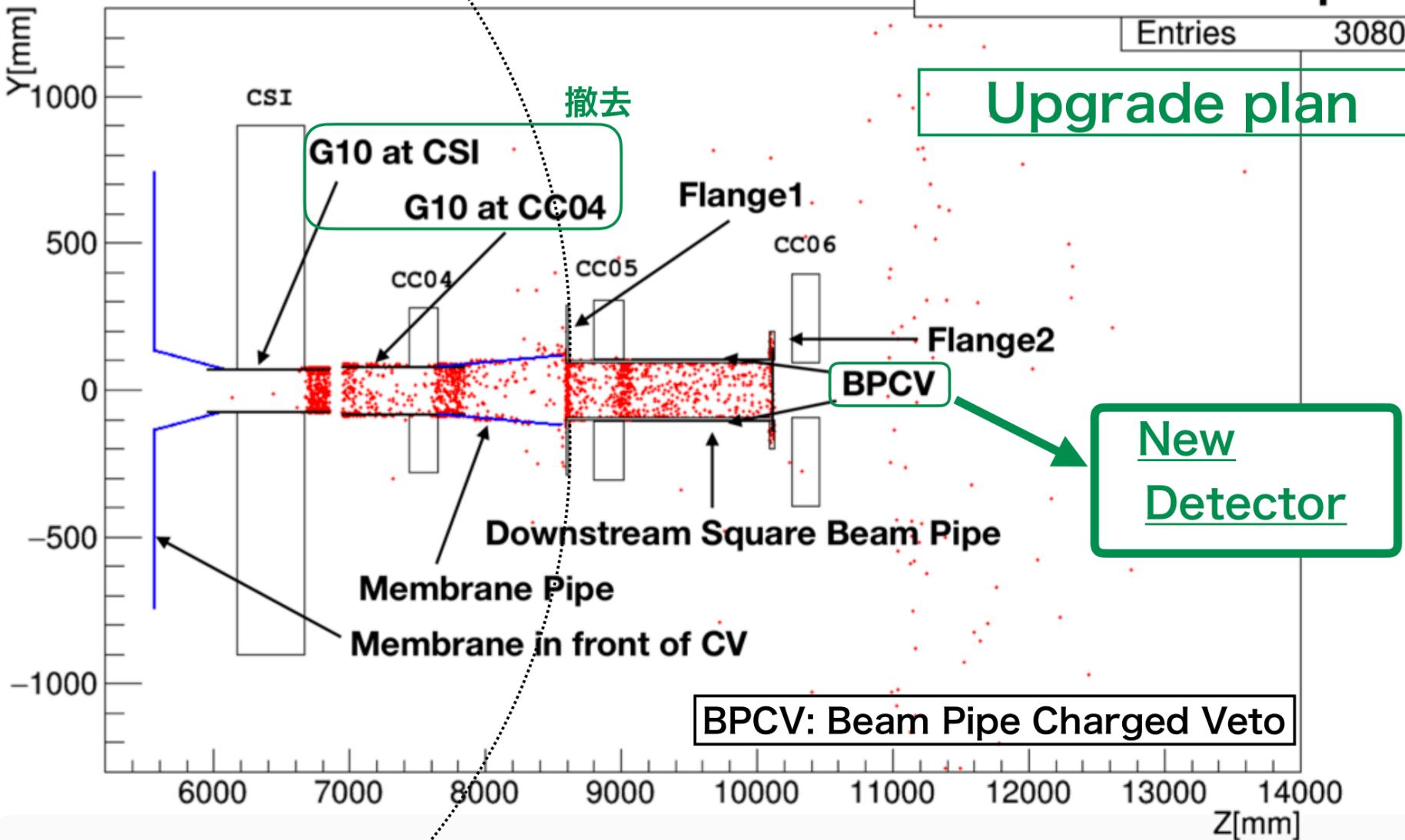


- Beam pipe with lighter material
- Stainless Steel -> Aluminum
- Beam Pipe Charged Veto
- 5mm-thick Plastic Scintillator
- Wavelength shifting fiber readout

Current Setup

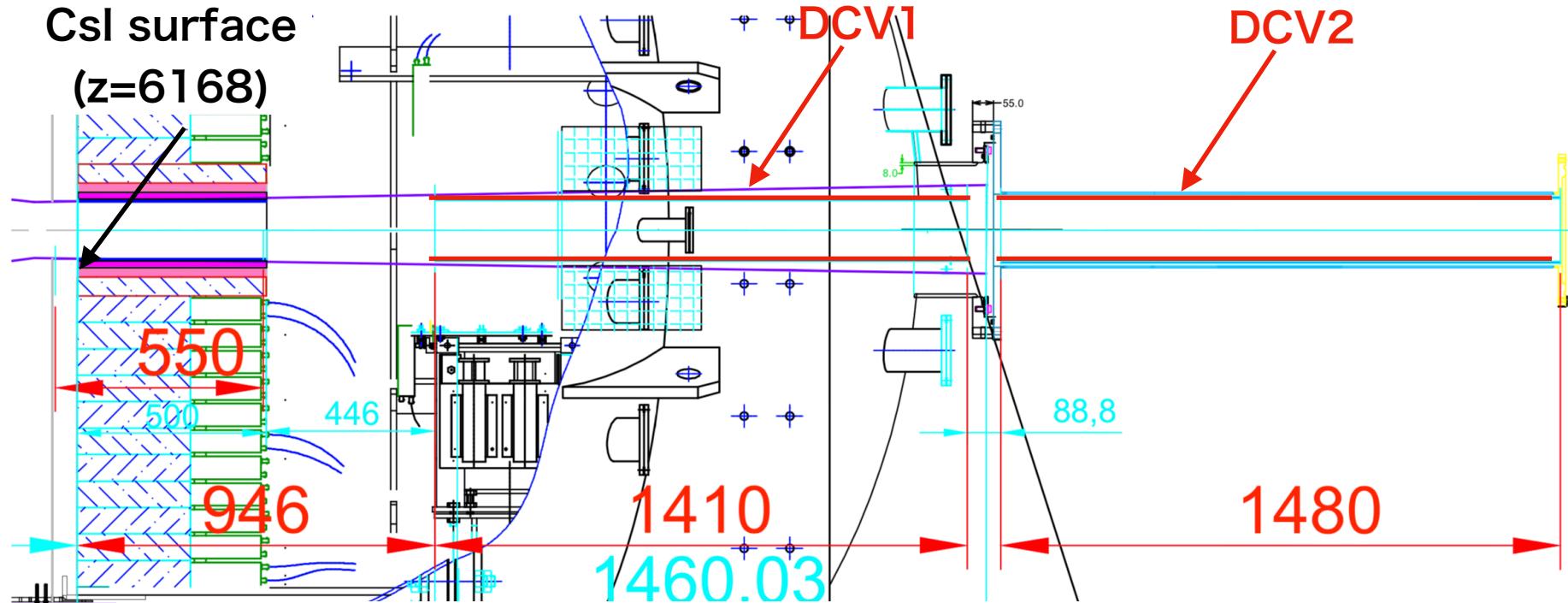
Entries 3080

Upgrade plan



Downstream Charged Veto

CsI surface
(z=6168)



1. Membrane doesn't be changed (using current one).
2. DCV1 start 946 downstream from the CsI 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. CsI G-10 : change length 900 ->550
 1. start 50mm in front of the CsI

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

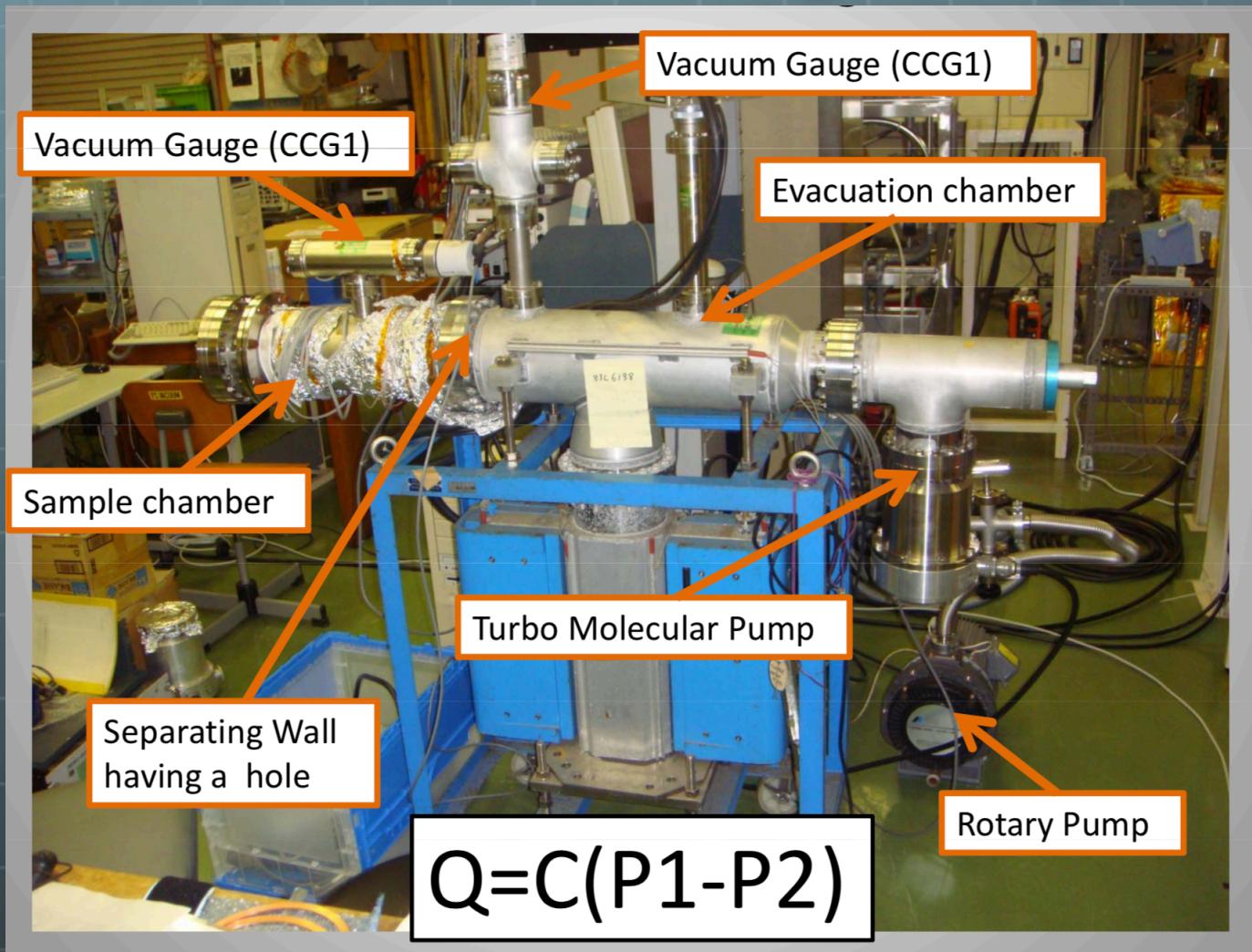
S : Pumping speed

Q : Rate of outgassing

V : Volume of chamber



Measurement on outgassing rate

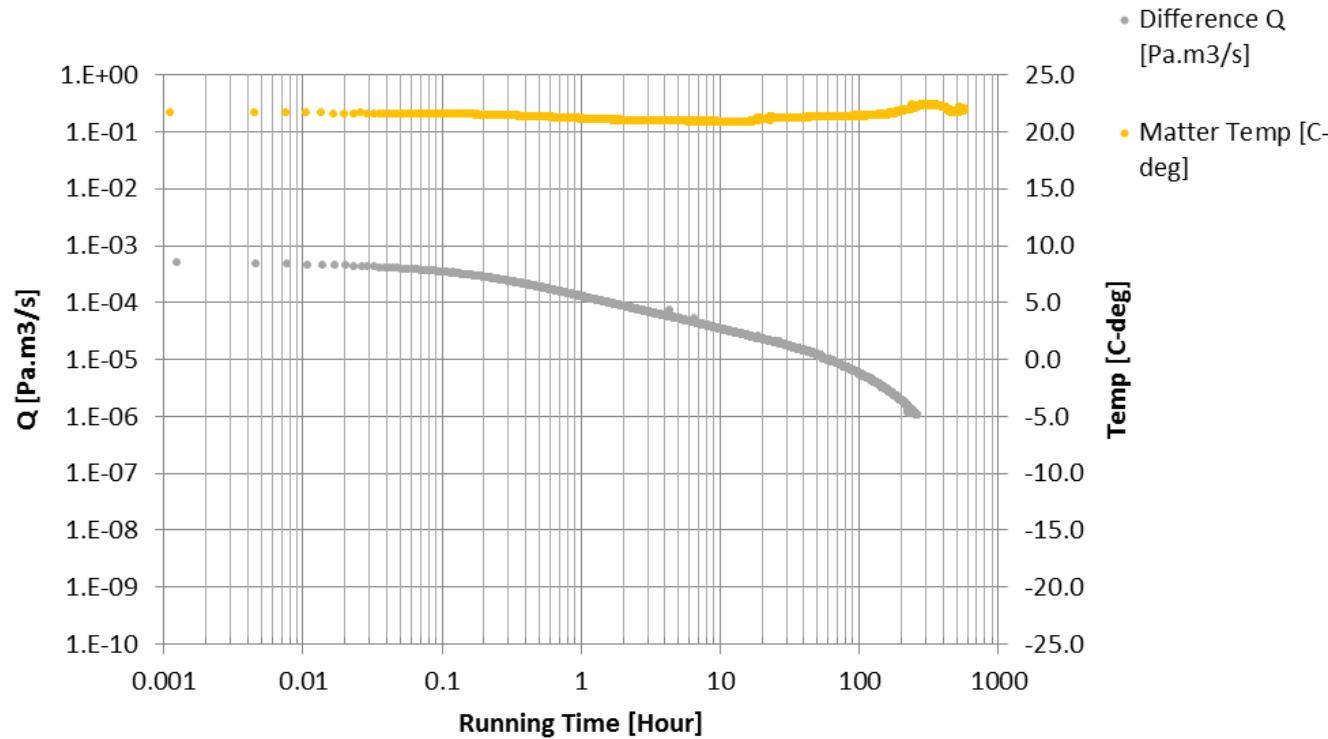




Outgassing rate of plastic scin.

Difference:Plastic_Scintillator - Empty13

Material: Plastic_Scintillator



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

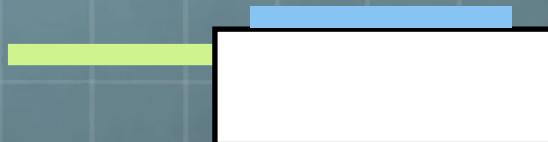


DCV contribution

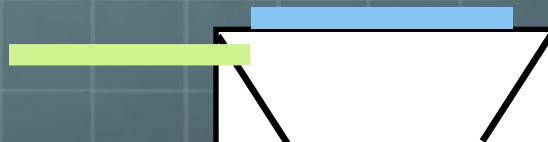
- Total surface of DCV : 2 m^2
- 90.1 times larger than test sample
- Pumping speed of TMP : $(800 \text{ l/s}) \times 4$
- Outgassing rate : $1.0 \times 10^{-6} \text{ Pa} \cdot \text{m}^3 / \text{s}$
- Total outgassing rate: $9.0 \times 10^{-5} \text{ Pa} \cdot \text{m}^3 / \text{s}$
- Reaching Pressure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



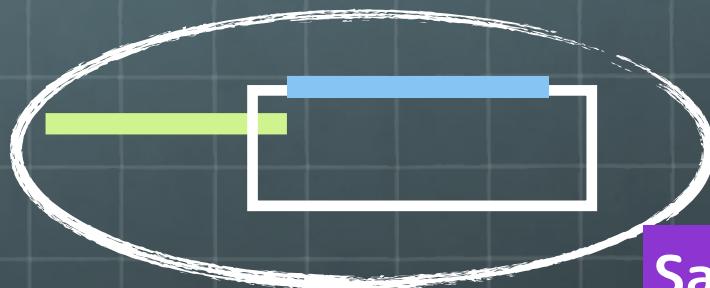
R&D for light guide



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

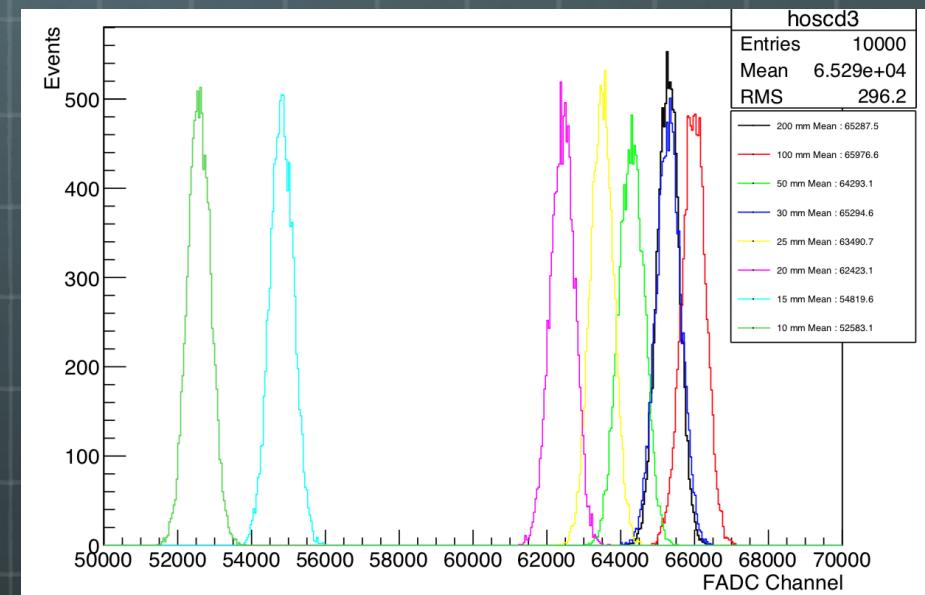
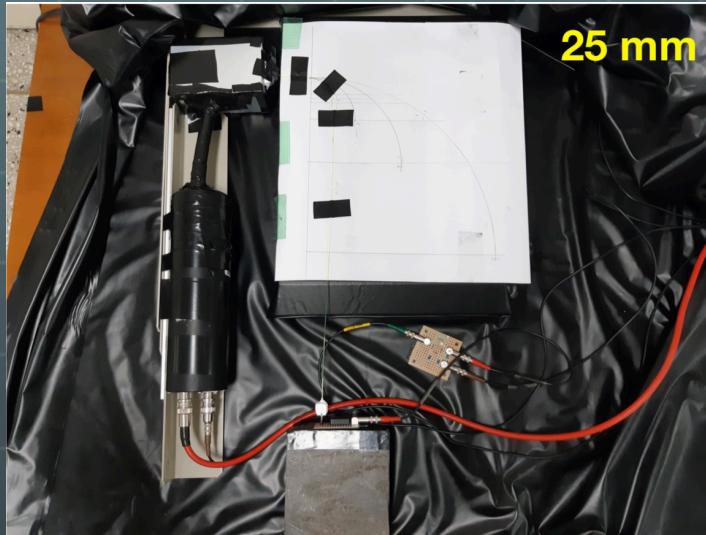
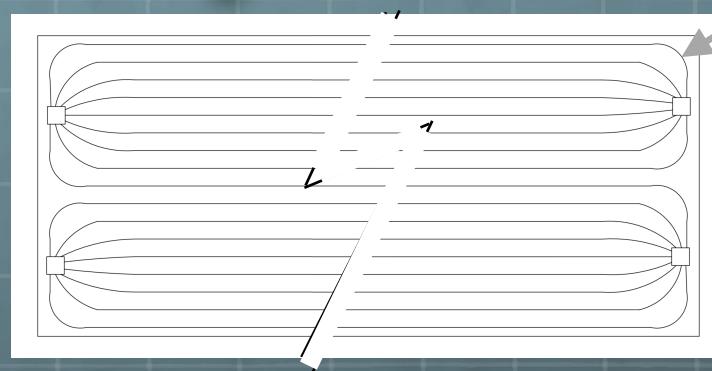


Variation of reflecting box
Insert a reflecting cone in the box



Bending Loss

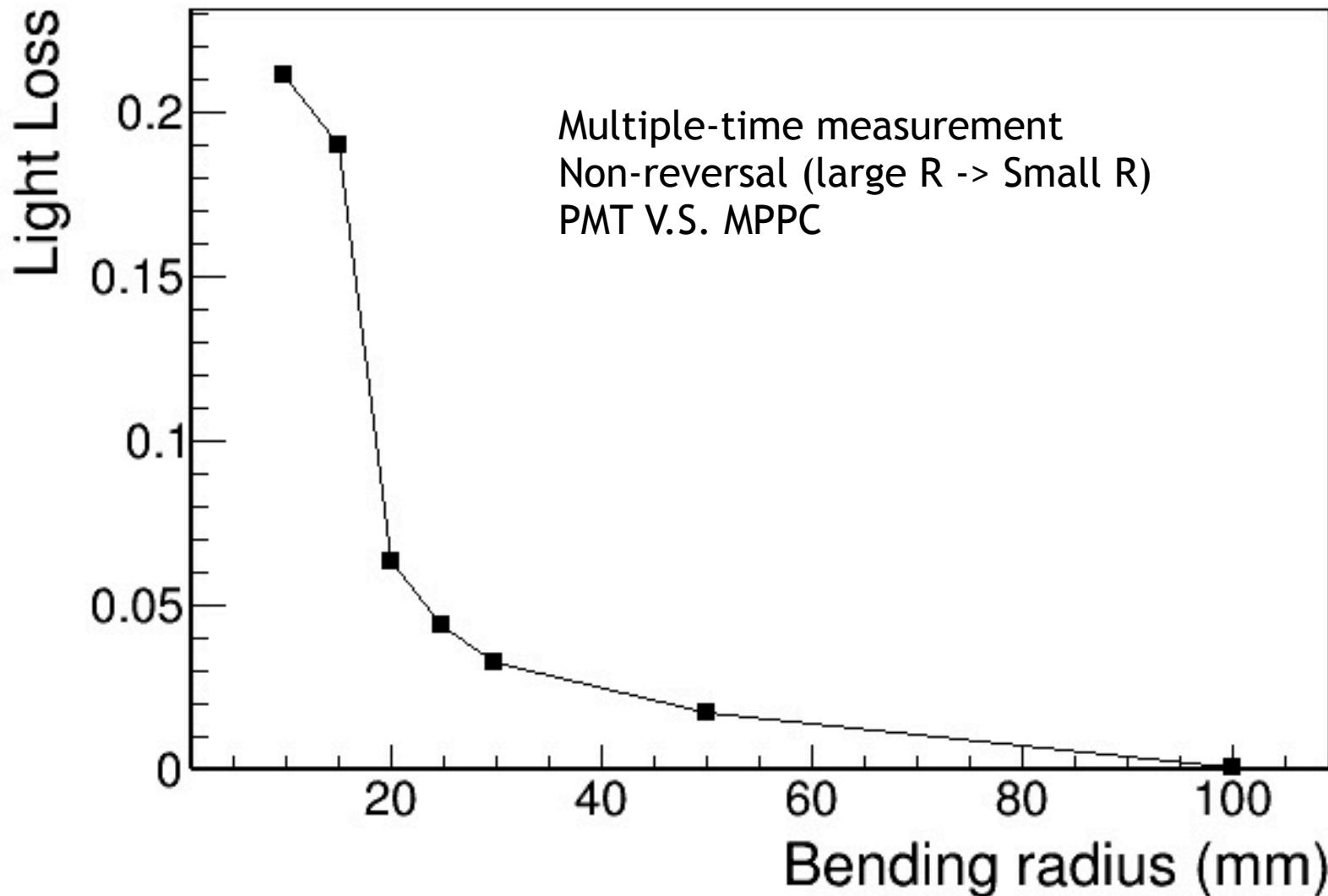
How to determine R ?





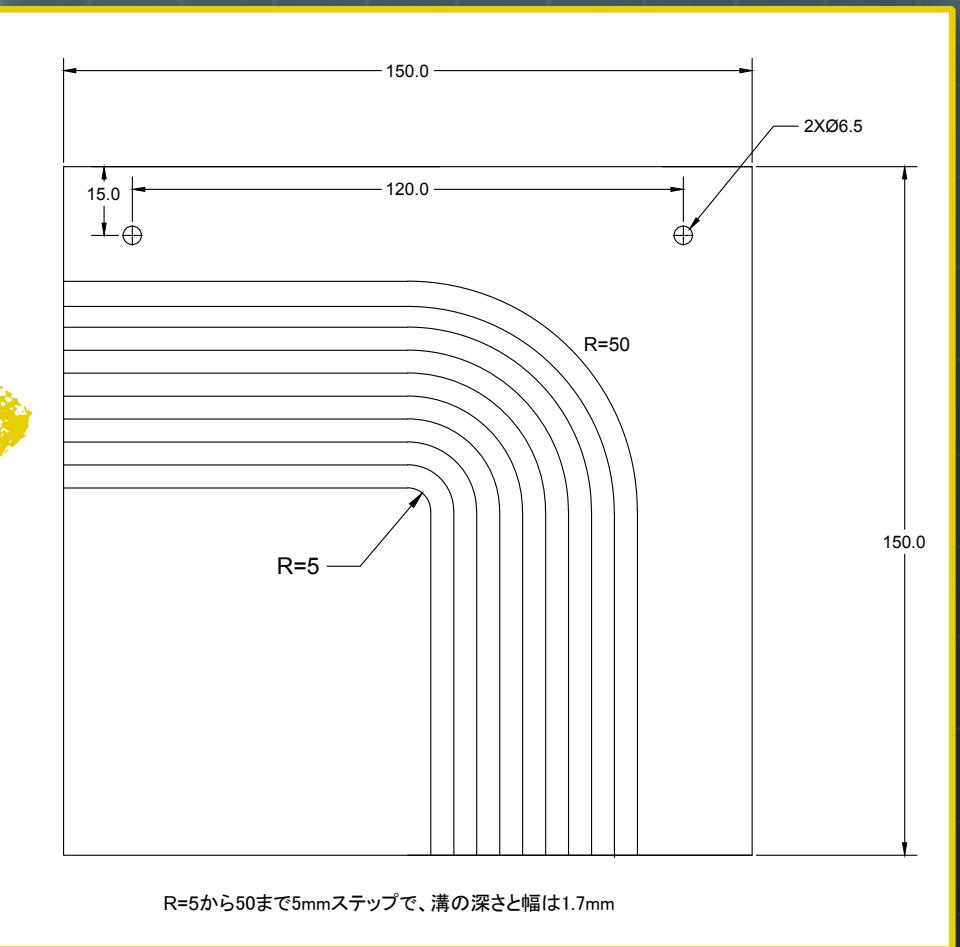
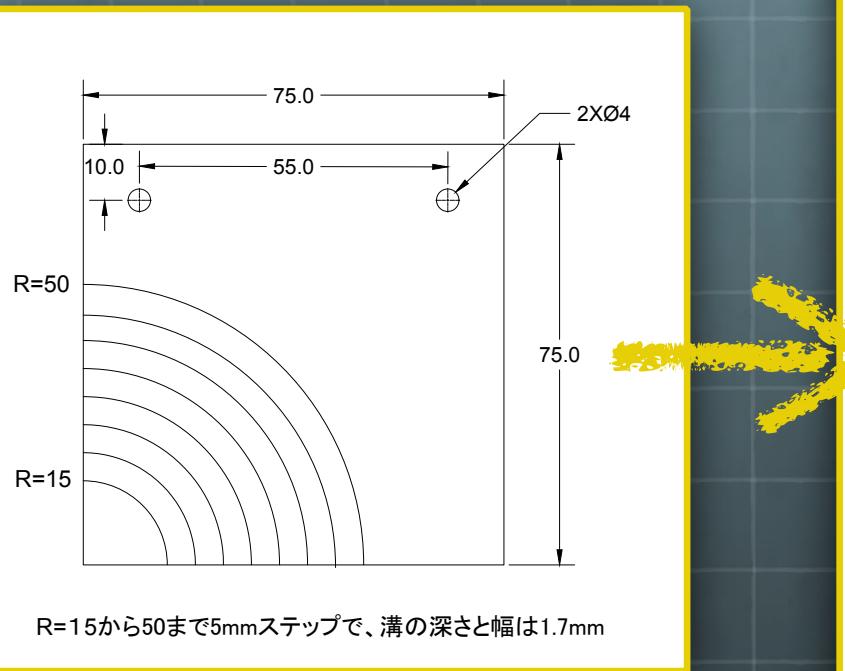
Bending Loss

How to determine R ?





For better measurement





Pitch dependency ?



3 different pitches of groove

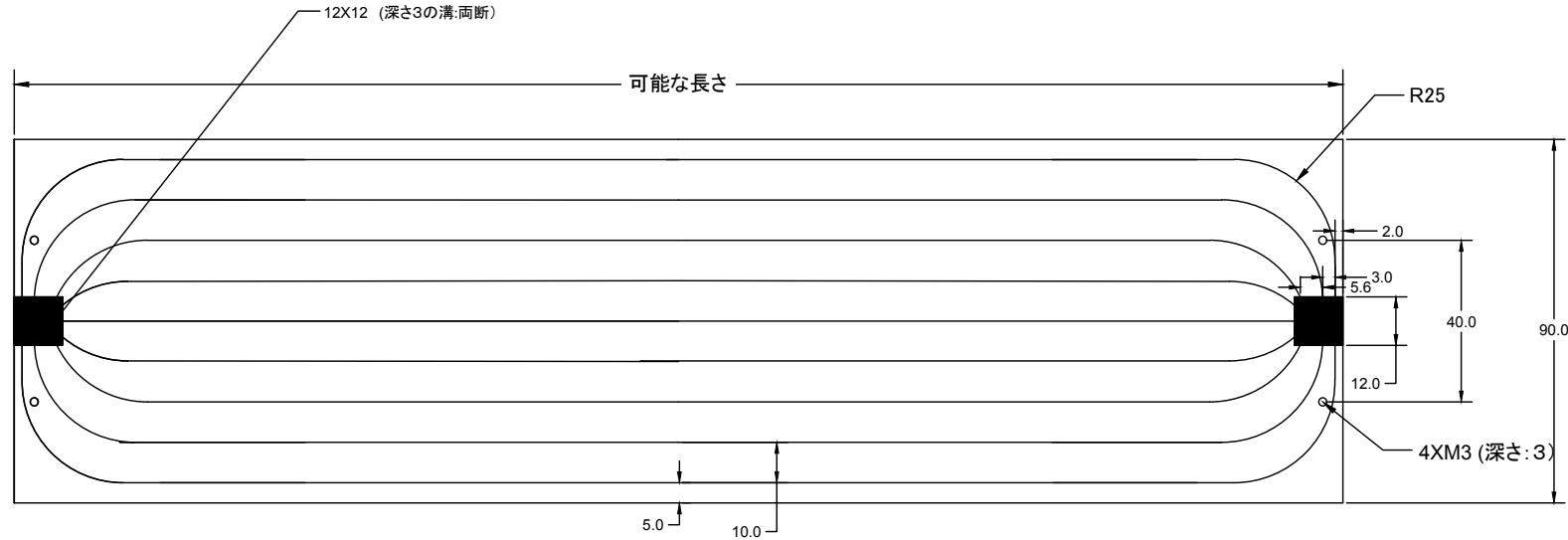
10mm 6.6mm, 5mm

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.
-  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

Y11 : Bending loss
Light Yield

Selection of Reflector

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

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

Design of fiber attachment (lightguide)

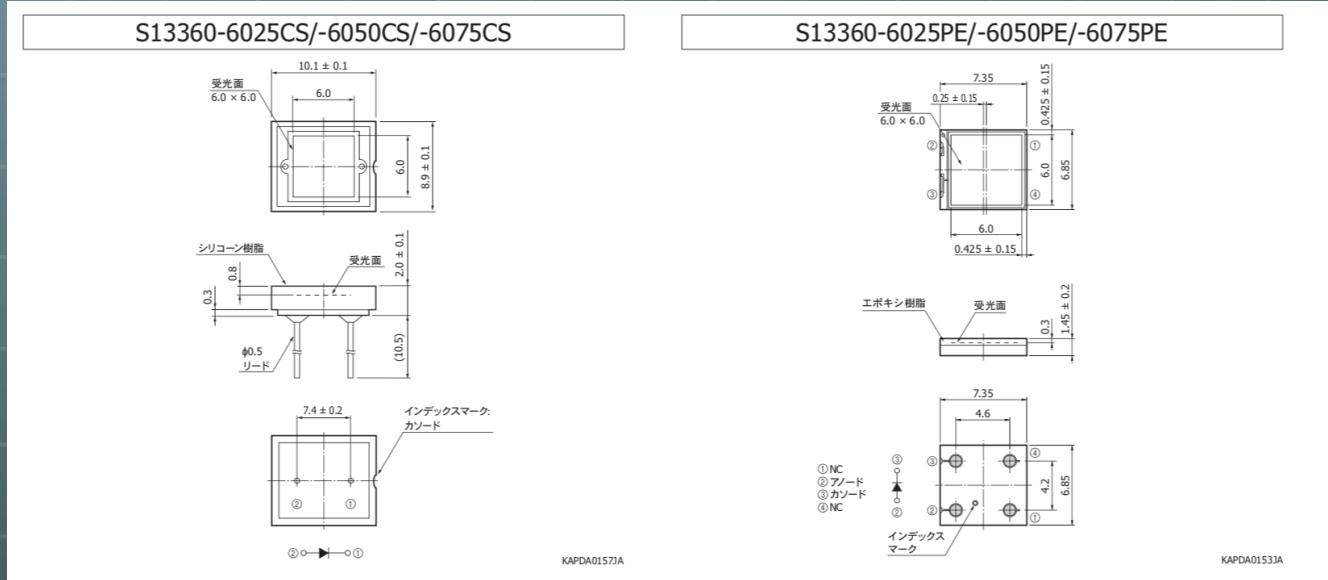
- Design & prototype making - by the end of Sep.
- Test & selection by the middle of Oct.
- Gluing process will be related.

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



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

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 λ_p (nm)	検出効率 PDE*1 $\lambda=\lambda_p$ (%)	ダークカウント*2		端子間 容量 Ct (kcps)	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 $\Delta TVop$ (mV/°C)
					Typ.	Max.						
S13360-1325CS	Vover =5 V	270 ~ 900	450	25	70	210	60	7.0 × 10 ⁵	1	VBR + 5	54	
S13360-1325PE		320 ~ 900			400	1200	320					
S13360-3025CS		270 ~ 900			1600	5000	1280					
S13360-3025PE		320 ~ 900		40	90	270	60	1.7 × 10 ⁶	3	VBR + 3		
S13360-6025CS		270 ~ 900			500	1500	320					
S13360-6025PE		320 ~ 900			2000	6000	1280					
S13360-1350CS	Vover =3 V	270 ~ 900	450	50	90	270	60	4.0 × 10 ⁶	7	VBR + 3		
S13360-1350PE		320 ~ 900			500	1500	320					
S13360-3050CS		270 ~ 900			2000	6000	1280					
S13360-3050PE		320 ~ 900			90	270	60					
S13360-6050CS		270 ~ 900			500	1500	320					
S13360-6050PE		320 ~ 900			2000	6000	1280					
S13360-1375CS	Vover =3 V	270 ~ 900	450	50	90	270	60	4.0 × 10 ⁶	7	VBR + 3		
S13360-1375PE		320 ~ 900			500	1500	320					
S13360-3075CS		270 ~ 900			2000	6000	1280					
S13360-3075PE		320 ~ 900		50	90	270	60					
S13360-6075CS		270 ~ 900			500	1500	320					
S13360-6075PE		320 ~ 900			2000	6000	1280					

*1: 検出効率は、クロストークを考慮した値です。

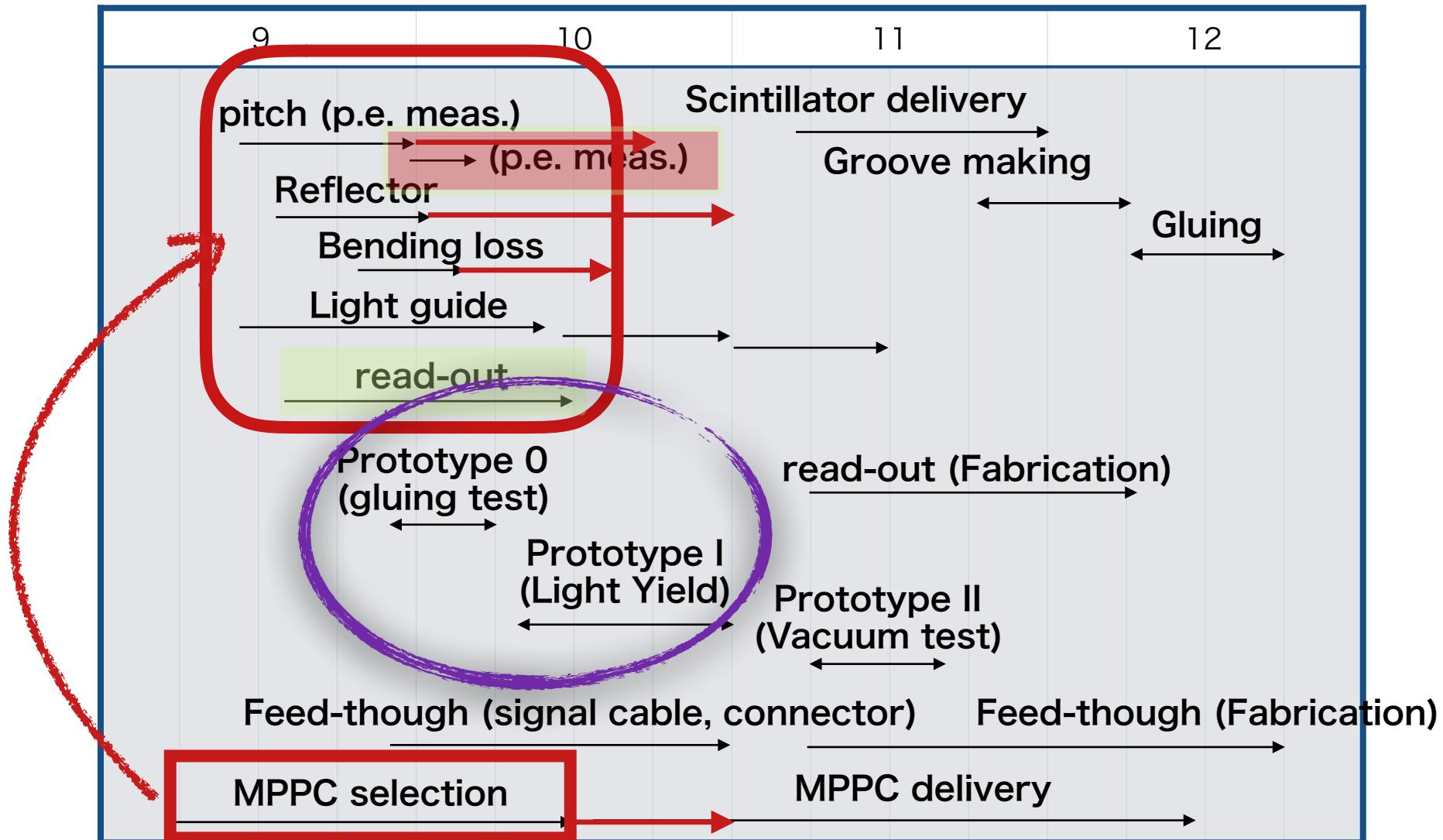
*2: 閾値=0.5 p.e.

注) 上記特性値は、表中の増倍率が

Ask estimate for 50 pcs (~4M Won)

ください。

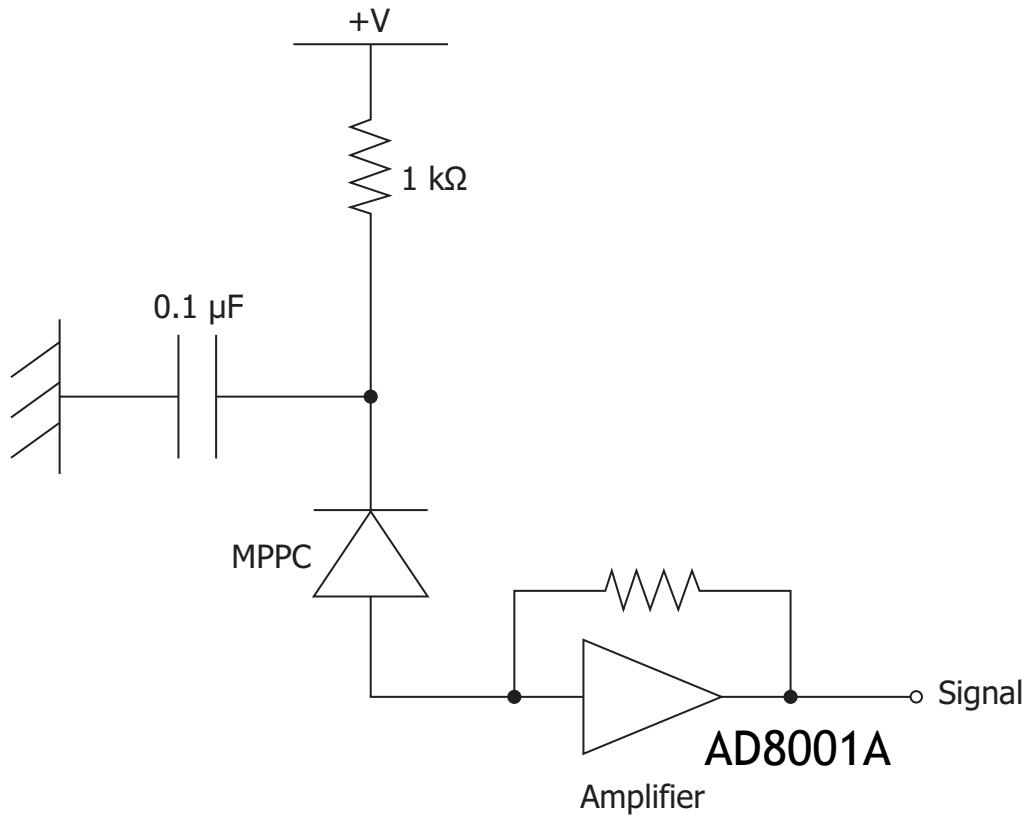
Schedule



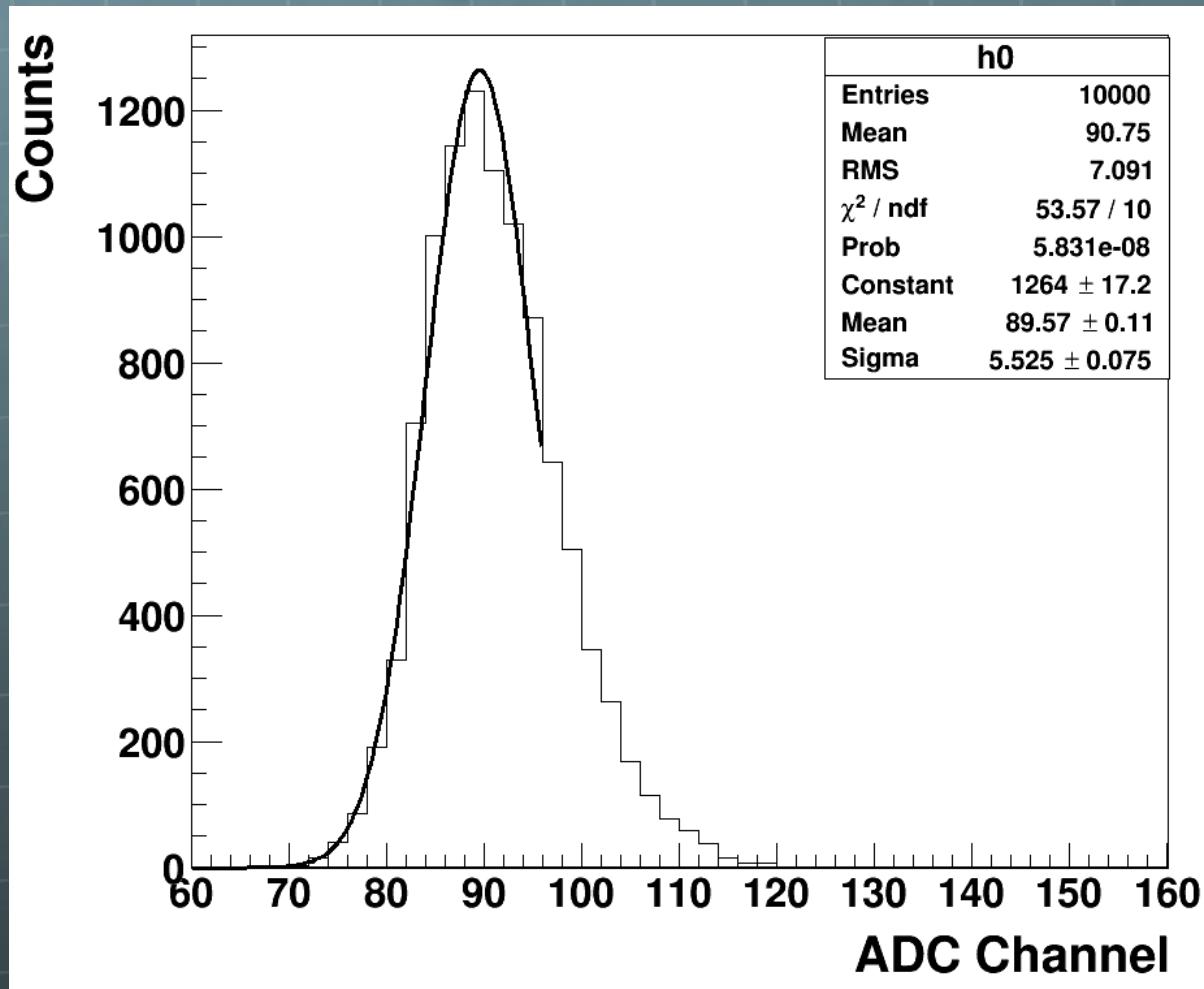
No contingency plan. Keep schedule

p.e. Measurement ?

S13360-6050CS



Wide pedestal ?

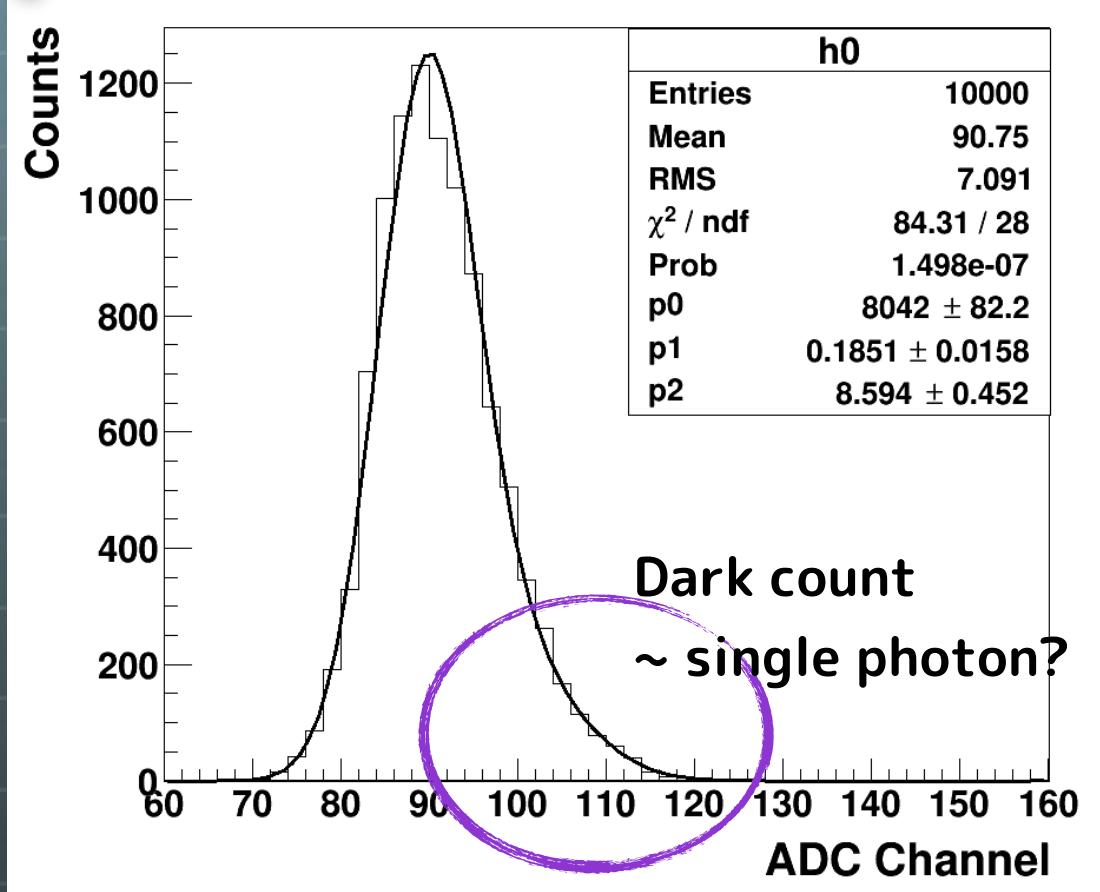


Wide pedestal ?

Single electron 1.6×10^{-19}
 MPPC gain : 1.6×10^6
 Amp gain : 10
 $\Rightarrow 2.6 \times 10^{-12} \text{ C} \sim 10 \text{ ch}$

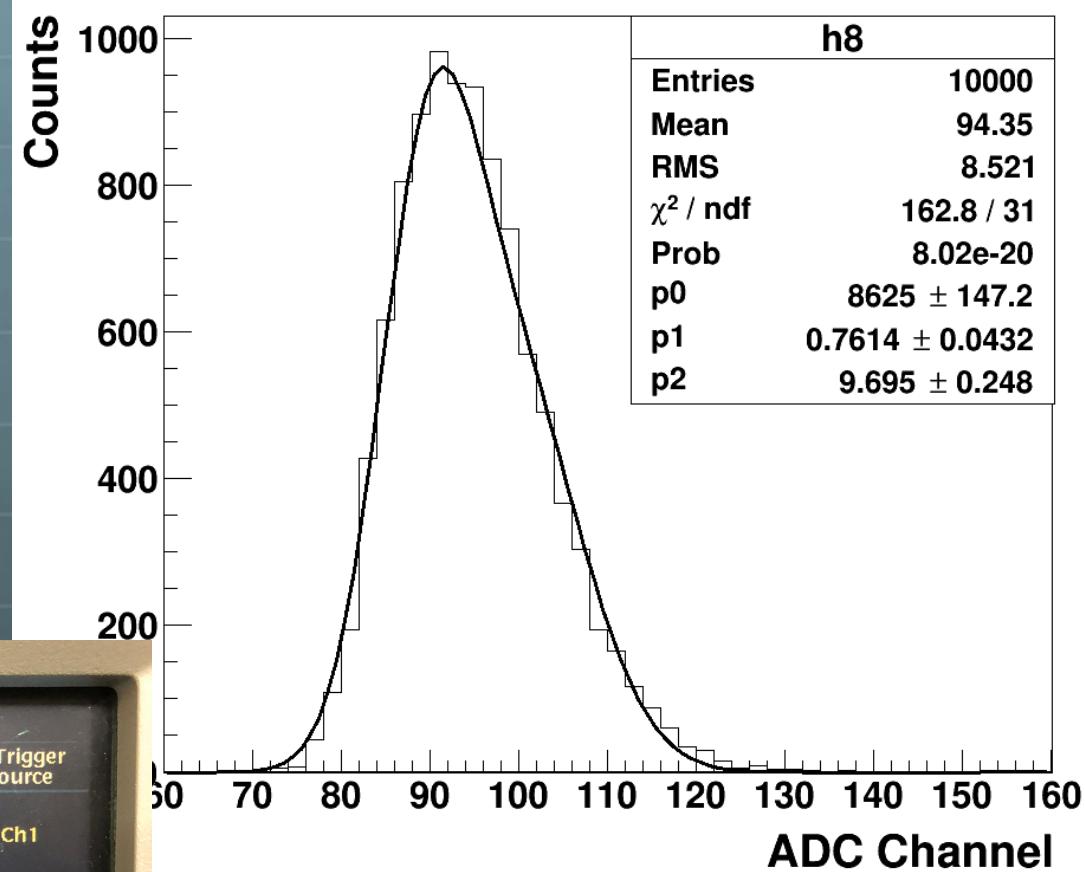
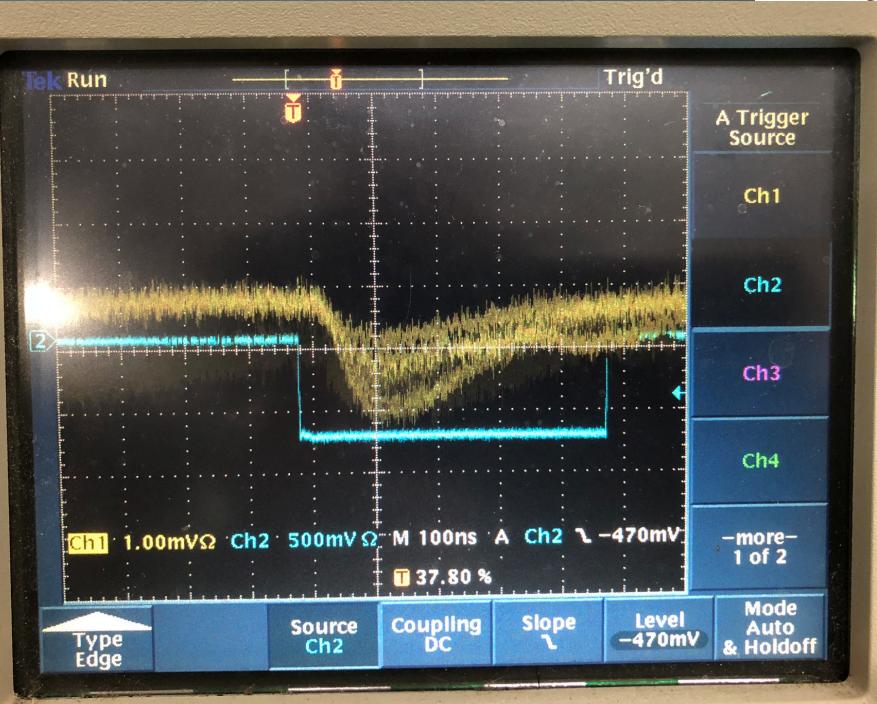
x	:	ADC channel
A(p1)	:	Normalization Factor p0
\bar{N} (p2)	:	平均光電子数 p1
σ (p3)	:	標準偏差 p2
p(p4)	:	各ピーク間隔
q(p5)	:	ペデスタルピークの channel

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

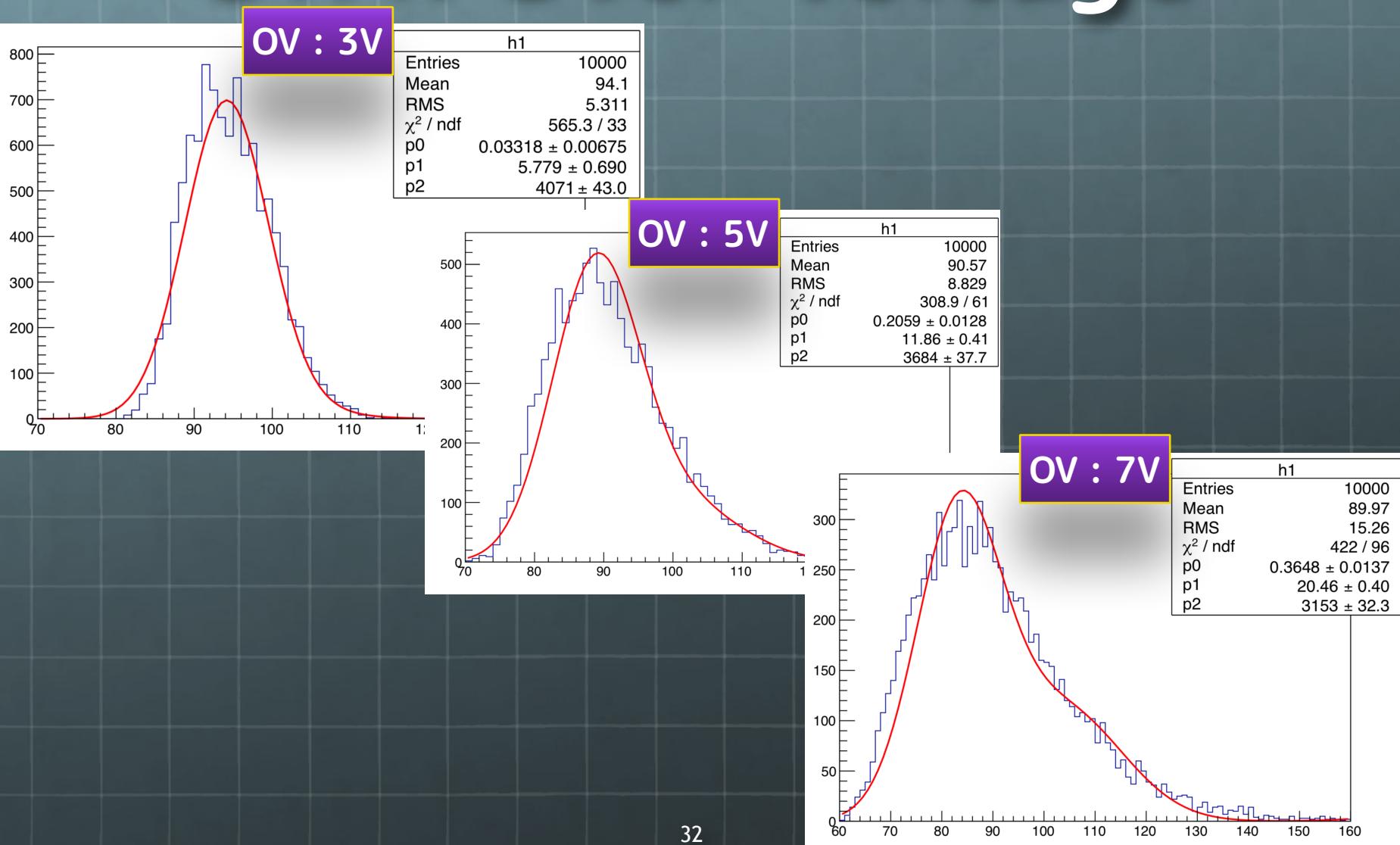


0.25pC/ch

Weak LED Light

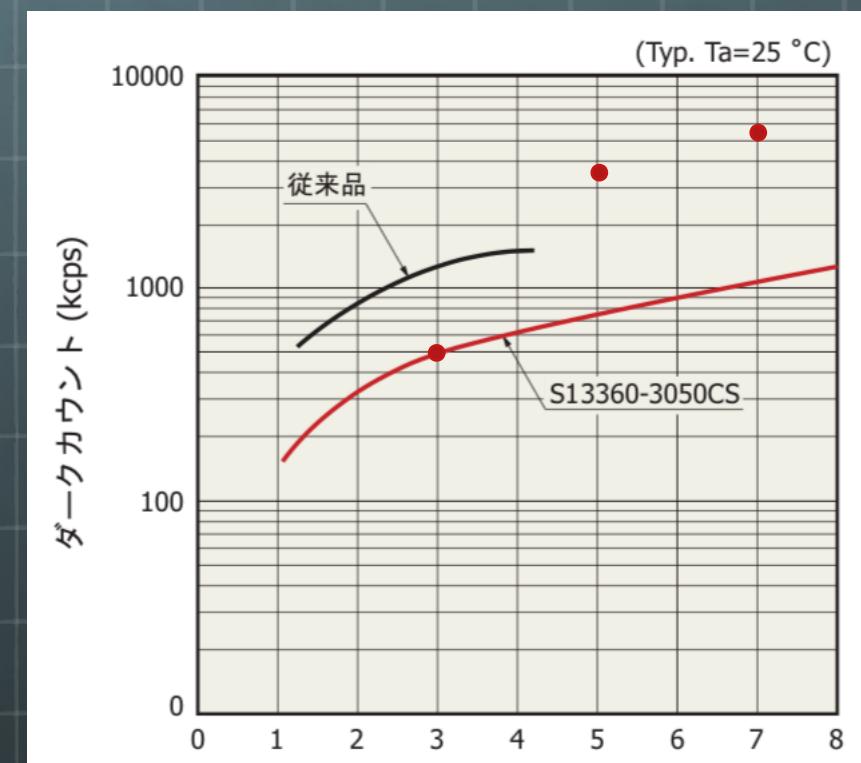
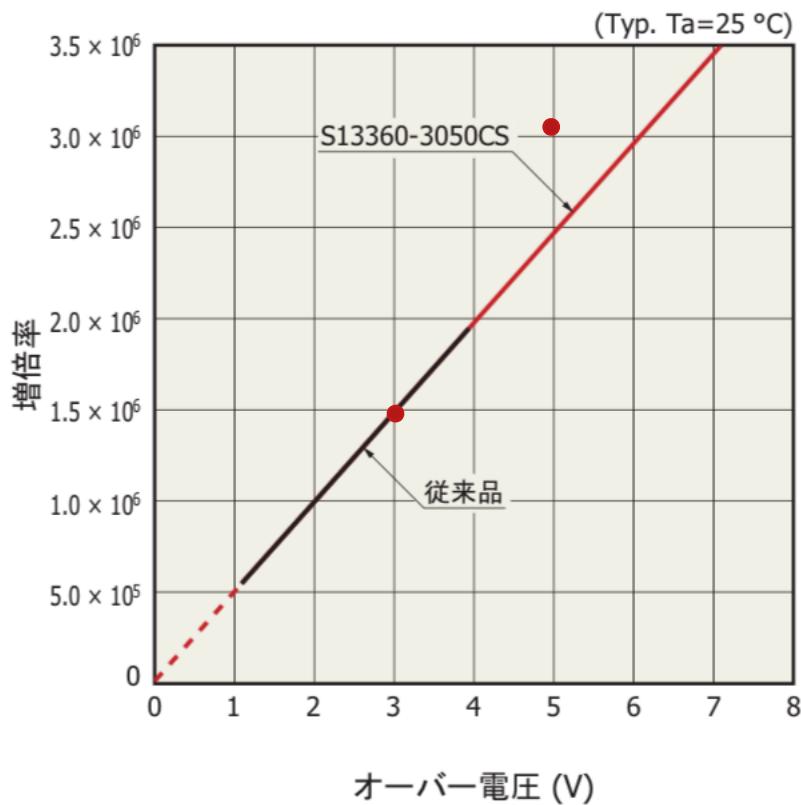


Diff. Over Voltage



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

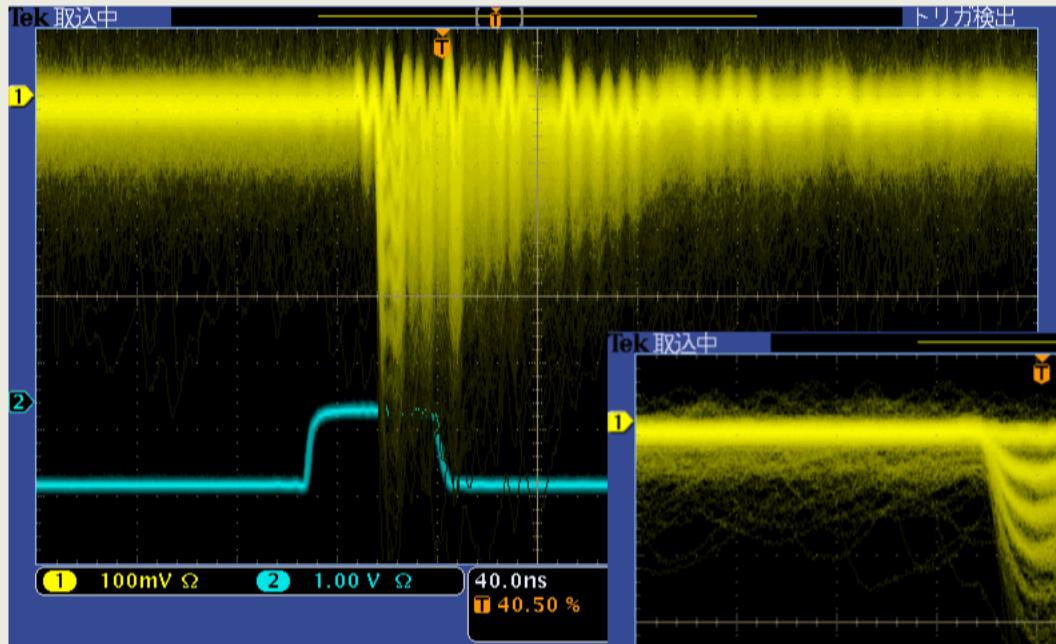
Reconsider fitting function



Two issues

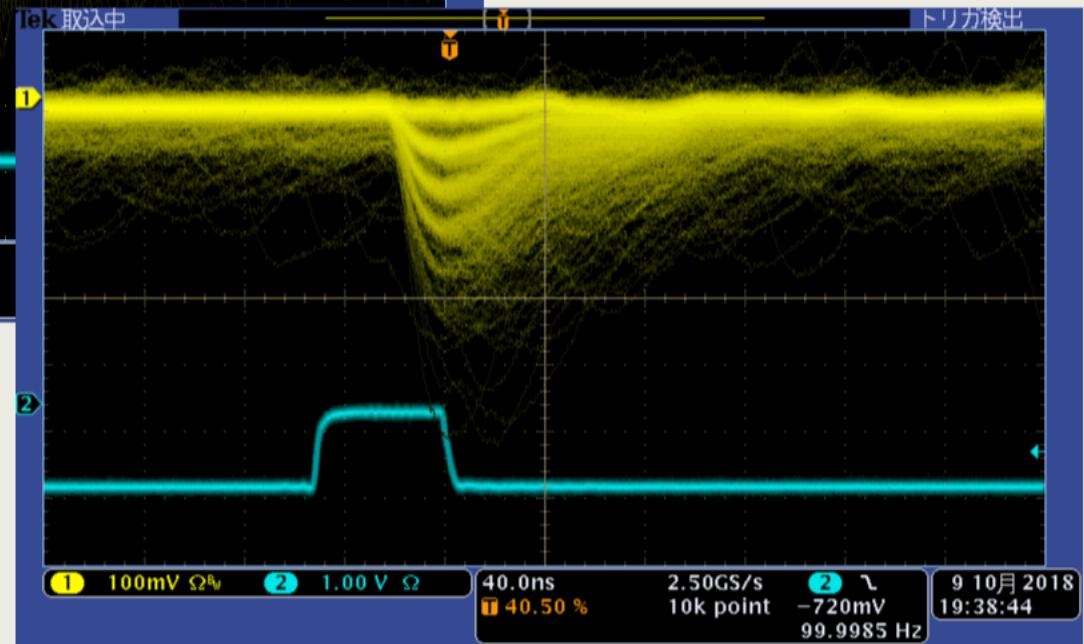
- ➊ To understand Noise.
 - ➊ clear peak
 - ➋ Removing high frequency components ?
 - ➋ Just cancellation out for charge integration ?
- ➋ Higher gain amplifier

MPPC: $V_+ = V_{op} + 3V$
Amplifier x100 (100mV/Div.)



Bandwidth
300MHz

Bandwidth
20MHz



Two issues

- ➊ To understand Noise.
 - ➊ clear peak
 - ➋ Charge sensitive
 - ➋ Higher gain amplifier