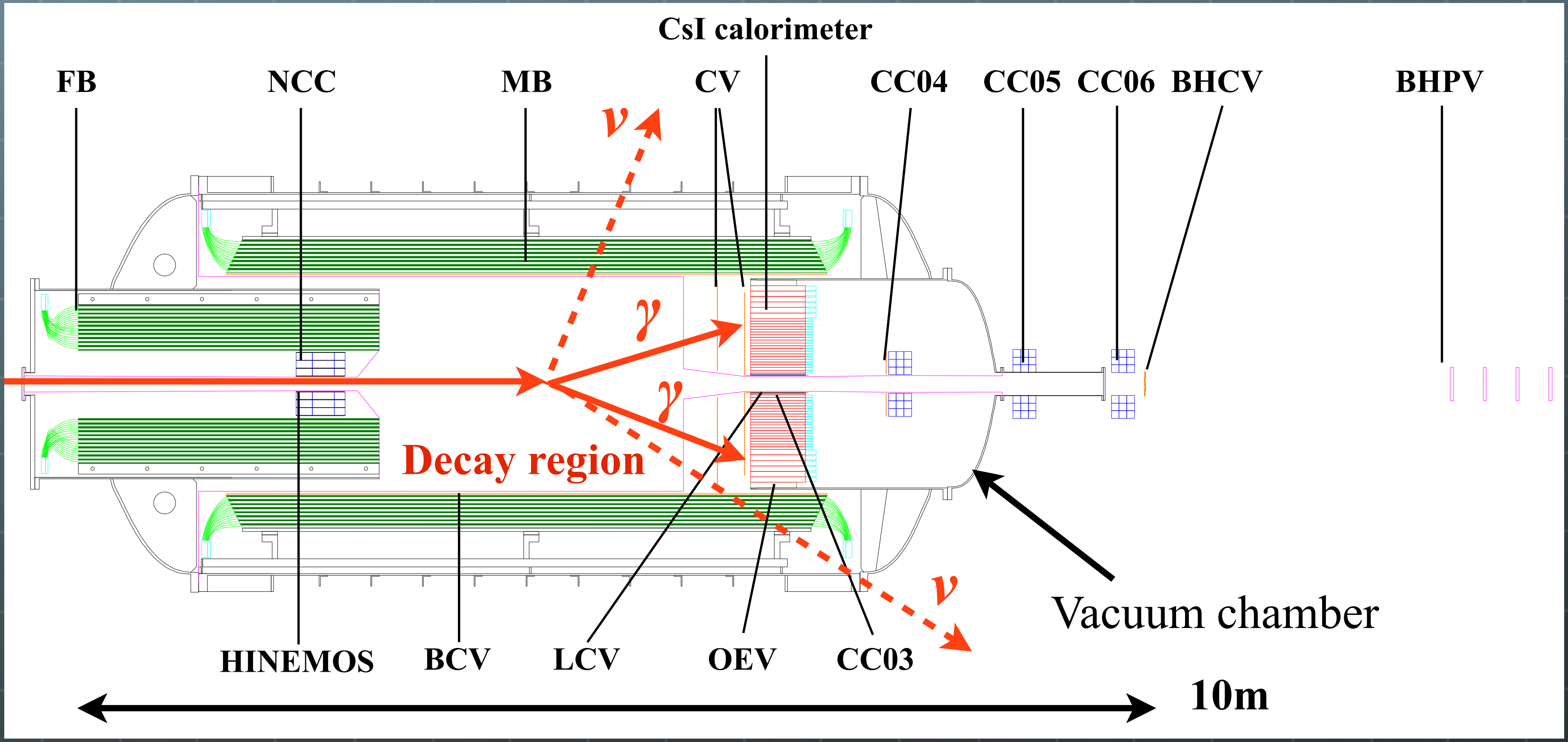
New charged veto for KOTO

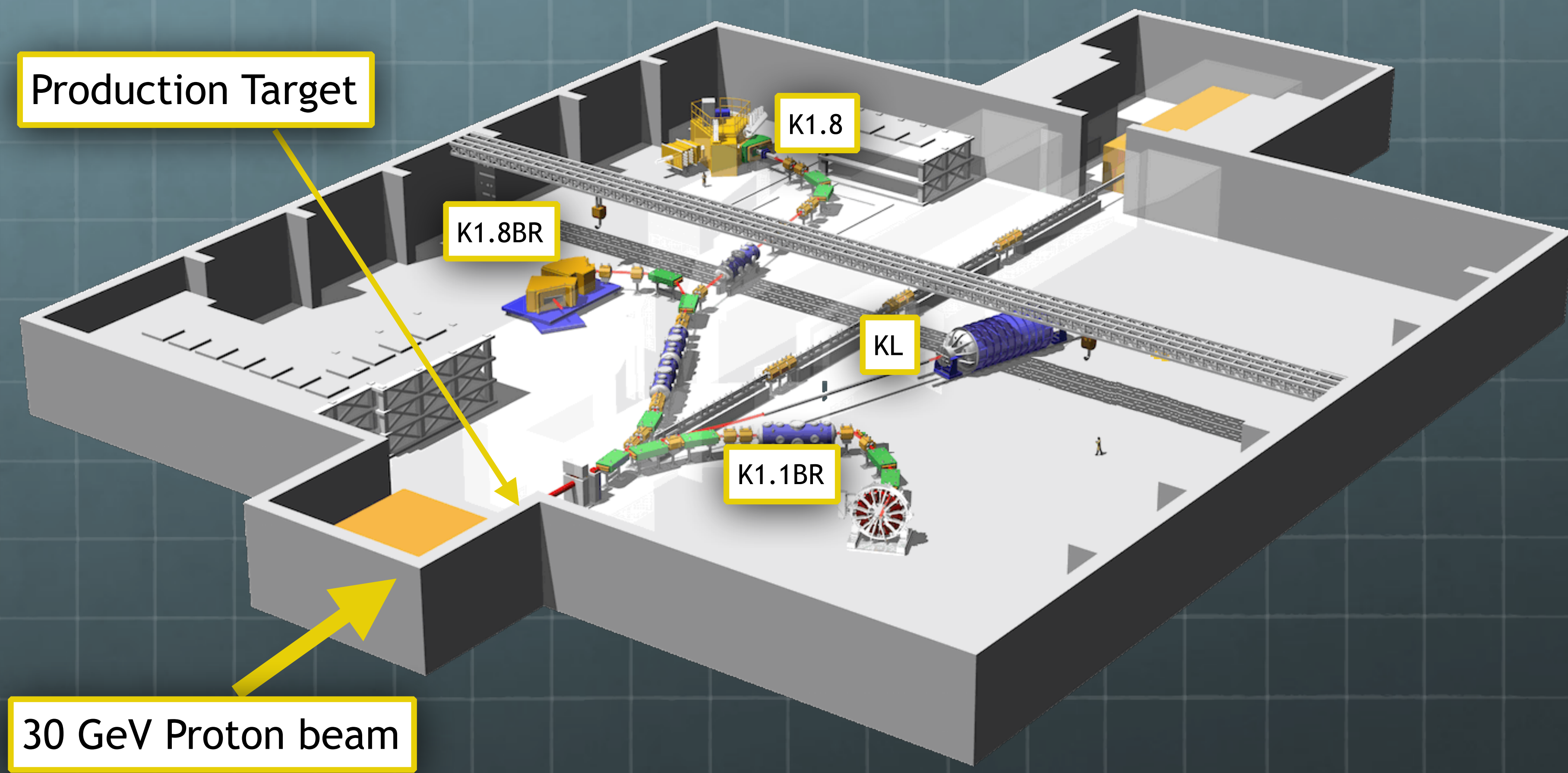
G.Y.Lim
IPNS/KEK

Korea Univ. @ 11th Oct., 2018

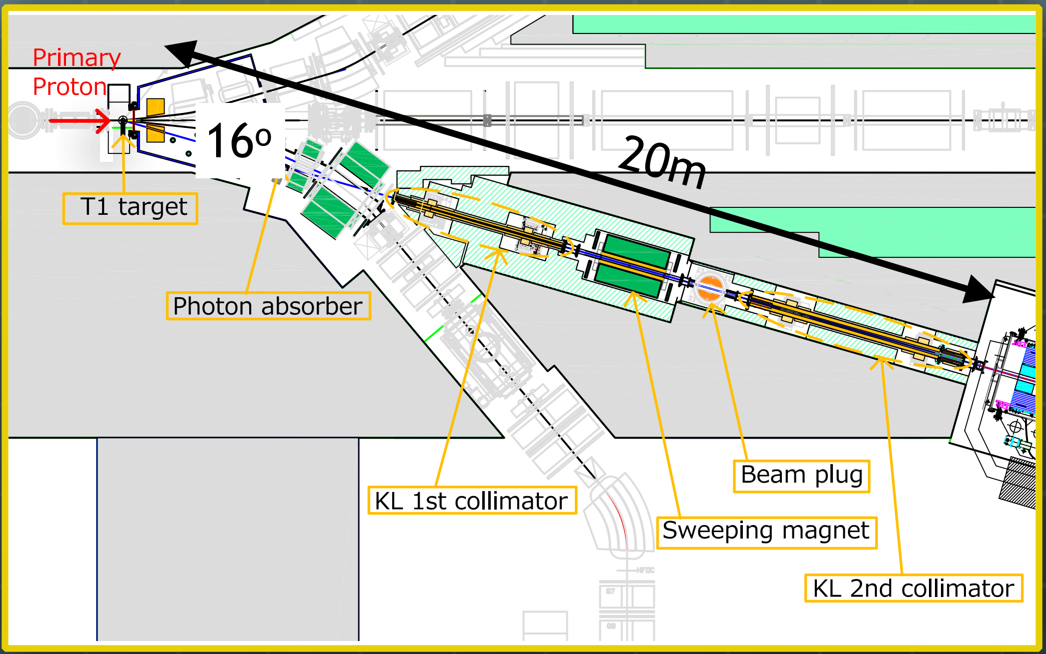
KOTO Detector

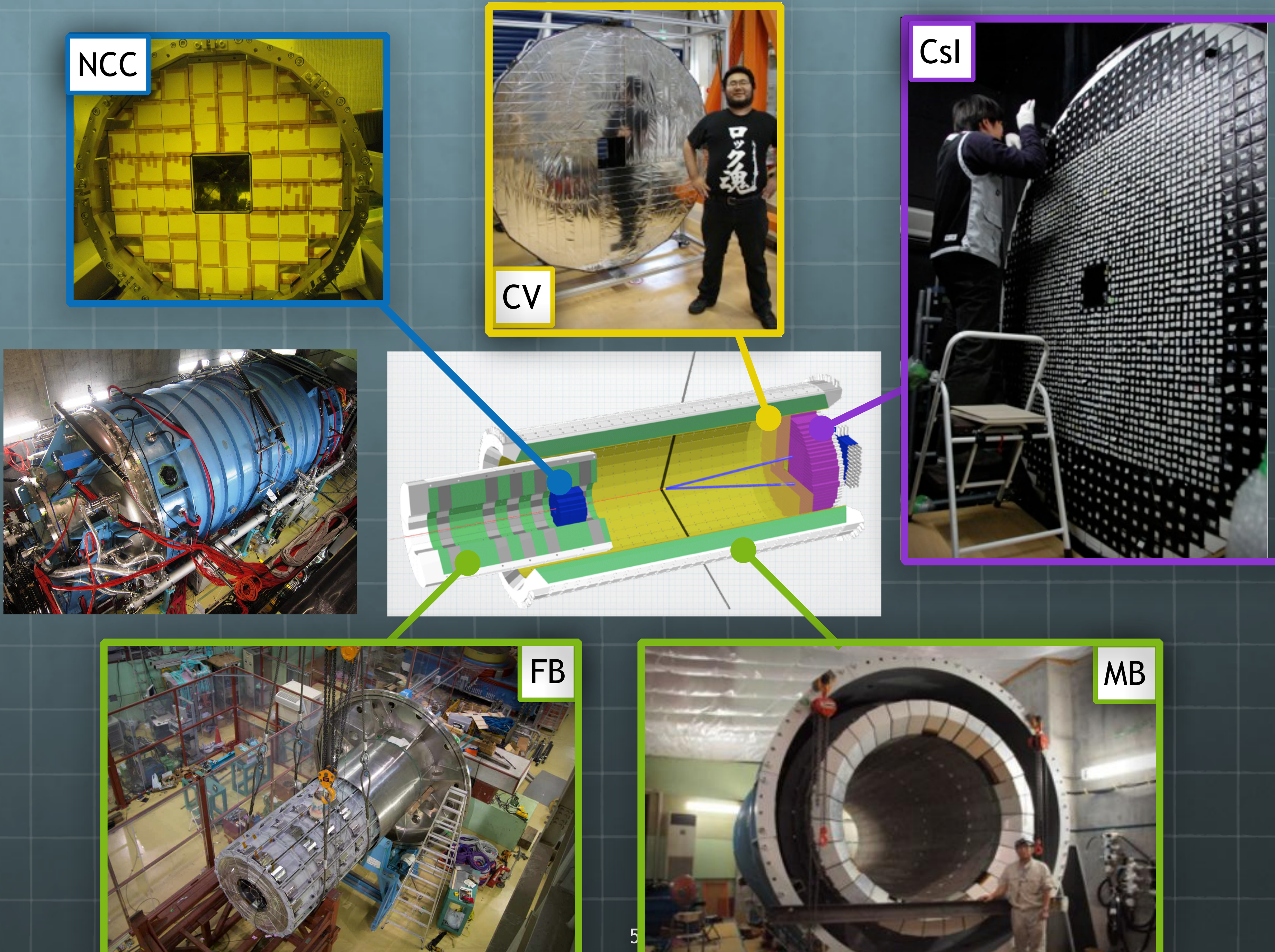


Hadron Hall so far



KL Beam Line


Primary
Proton
16o
20m
T1 target
Photon absorber
KL 1st collimator
Sweeping magnet
Beam plug
KL 2nd collimator


NCC
CV
CsI
FB
MB

Timeline of KOTO

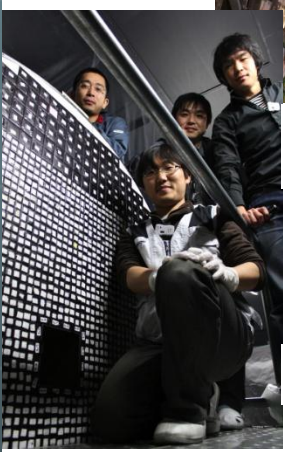
2009

Beamline construction finished (2009 Aug)

2010

Earthquake (2011.3.11)

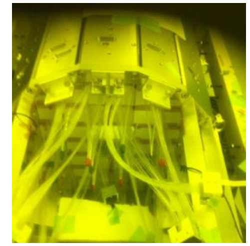
2011



CsI calorimeter stacking finished (2011 Feb)

Charged Veto installation (2012 June)

2012



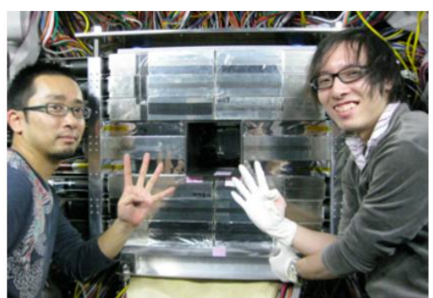
NCC installation (2012 Nov)

Main Barrel installation (2012 Dec)

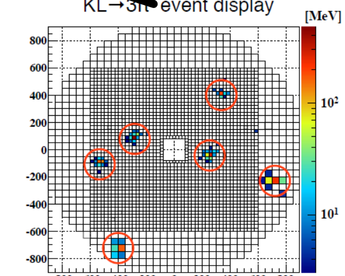
Closing vacuum chamber (2012 Dec)

FB installation (2012 Nov)

Sub detectors (CC04 etc.) Installation (2012 Dec)



KL→3π0 event display



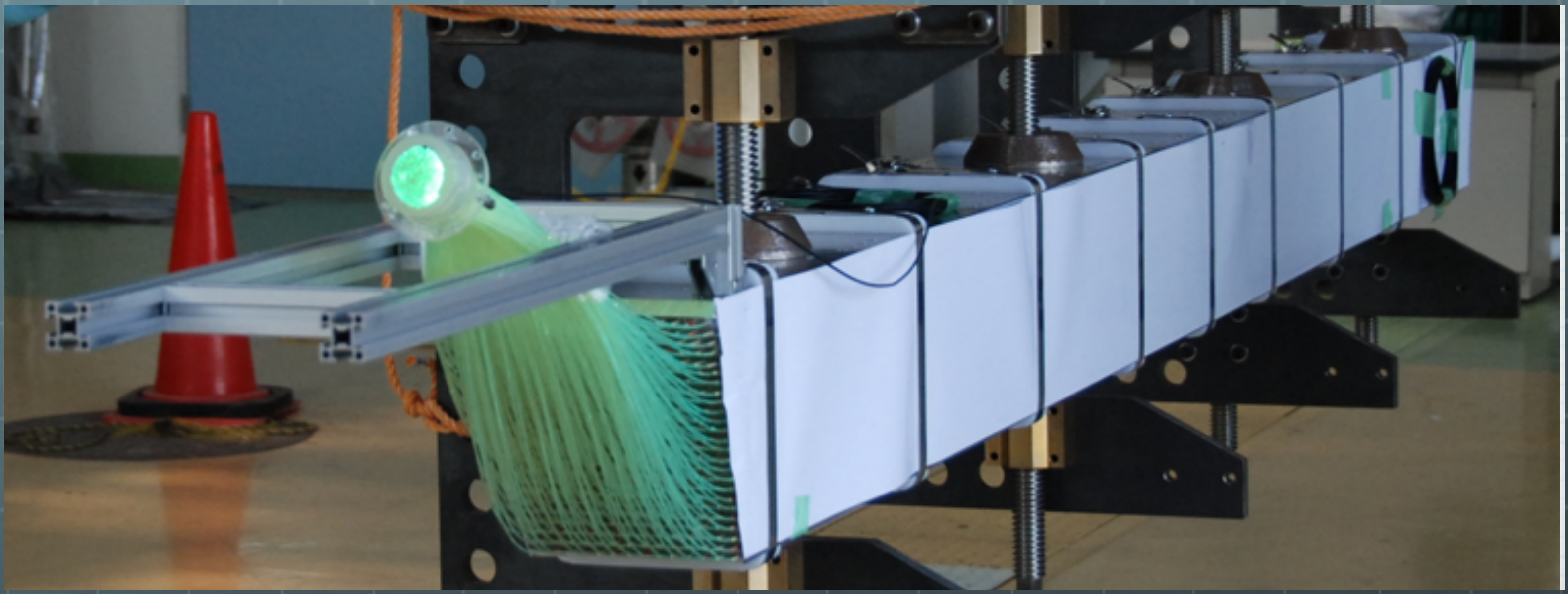
2013 Jan engineering run

2013

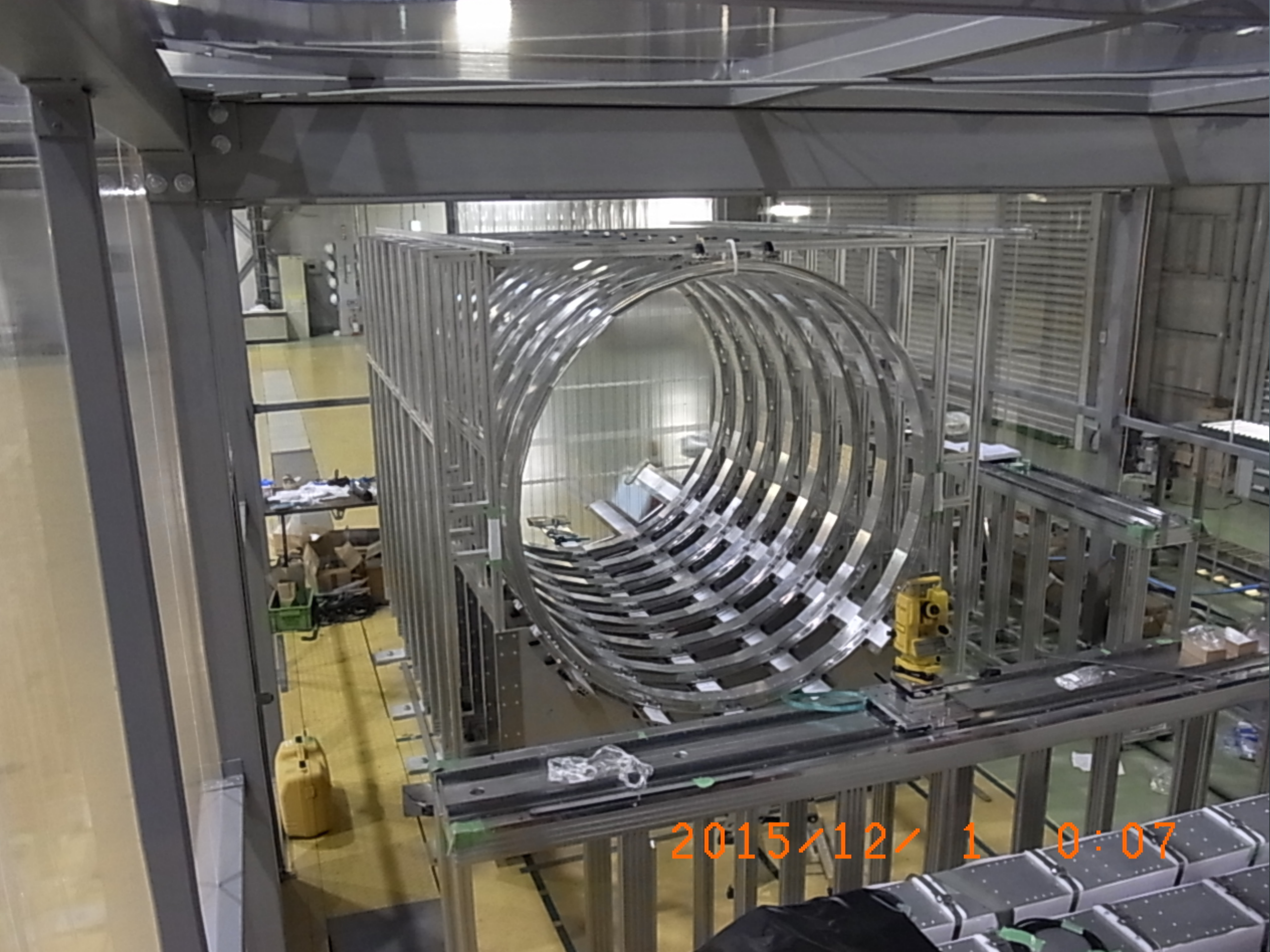
1st physics run 2013 May

2014

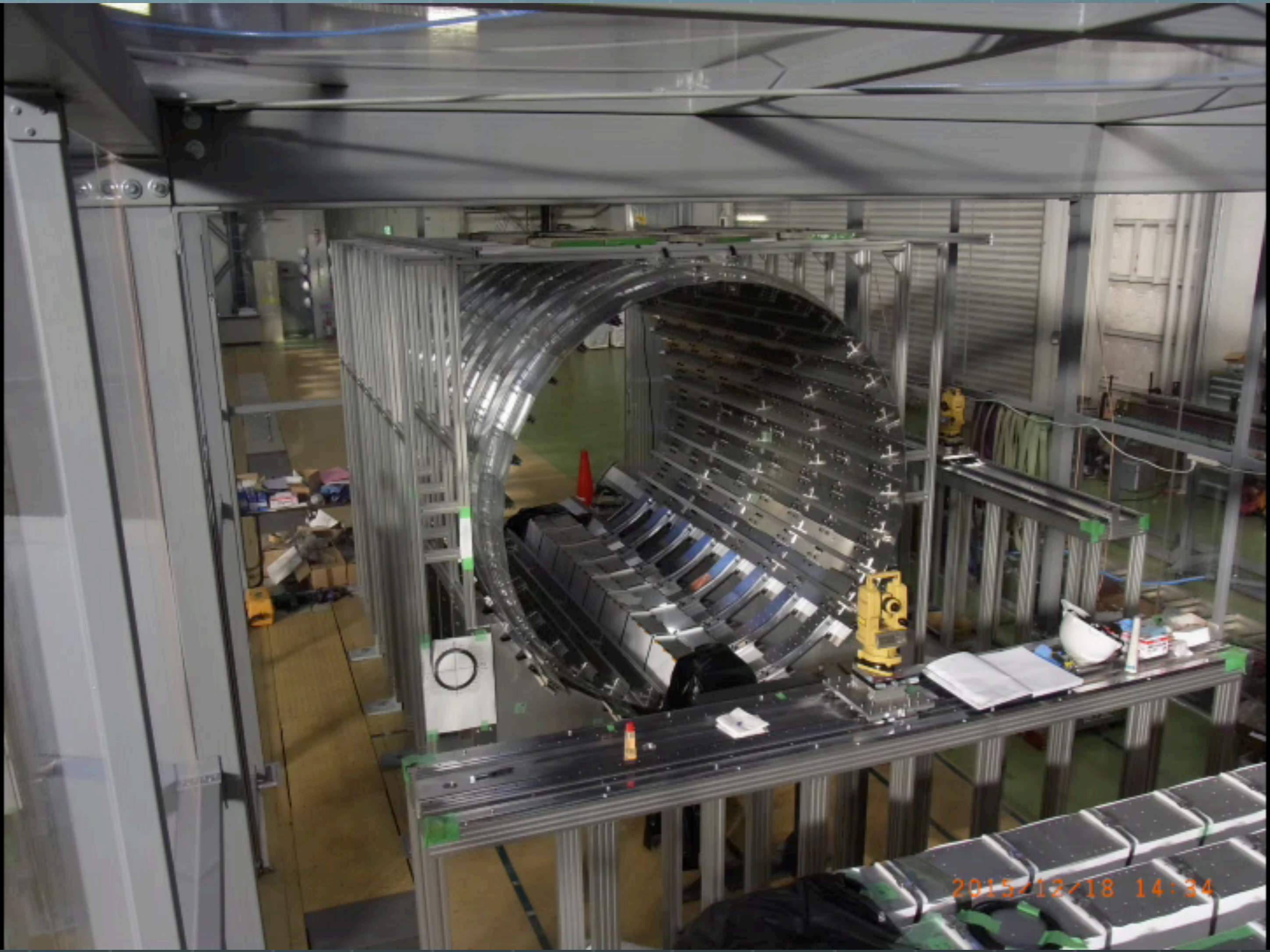
Inner Barrel



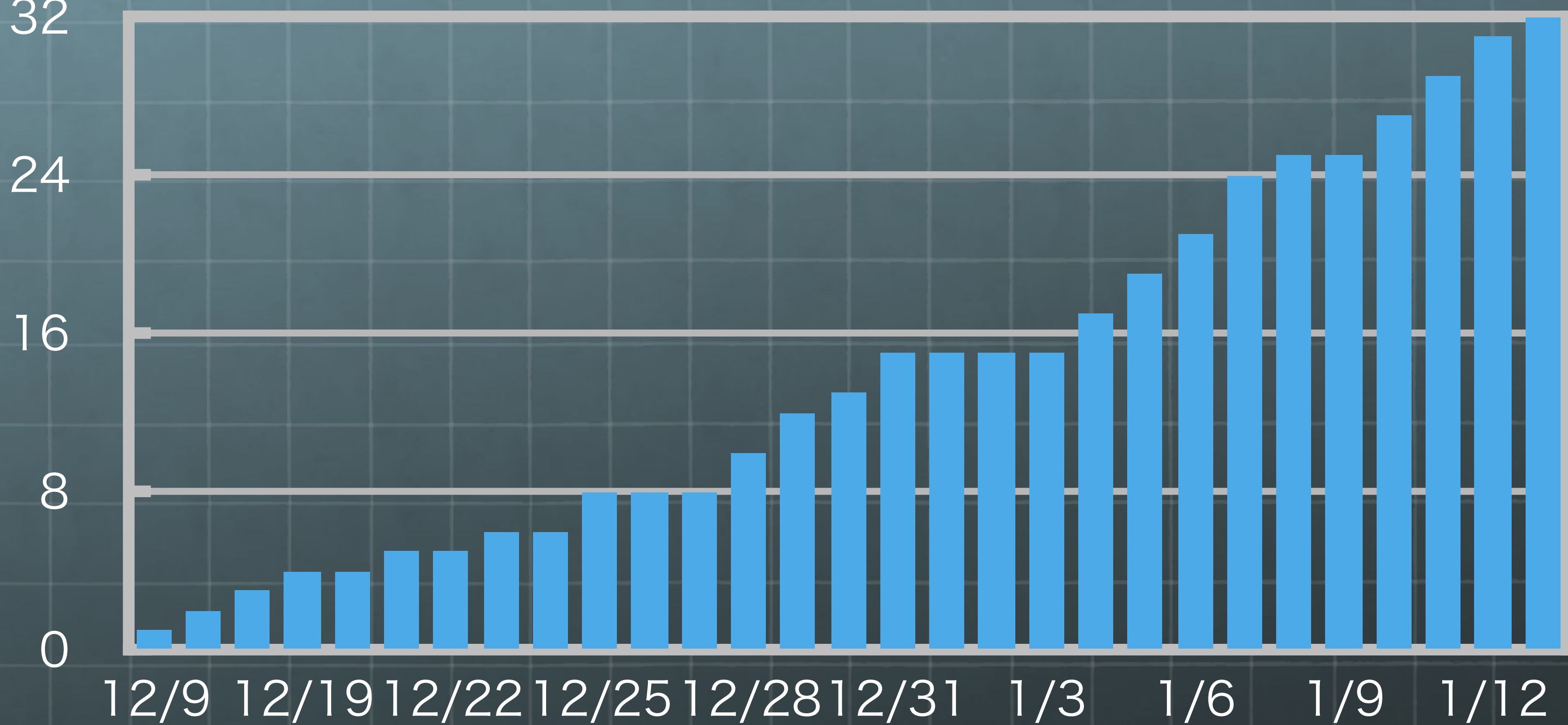
- Alternation lead sheet (1mm) and plastic scintillator(5mm)
- Wave length shifting fiber read-out (BCF-92, ϕ1.5mm)

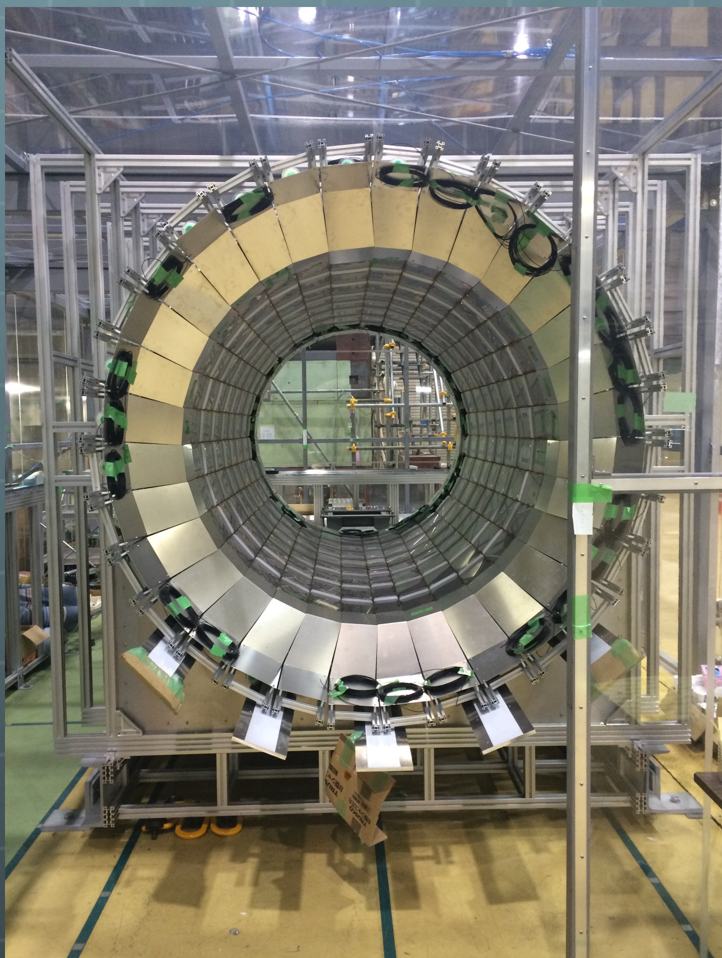

2015/12/ 1 0:07

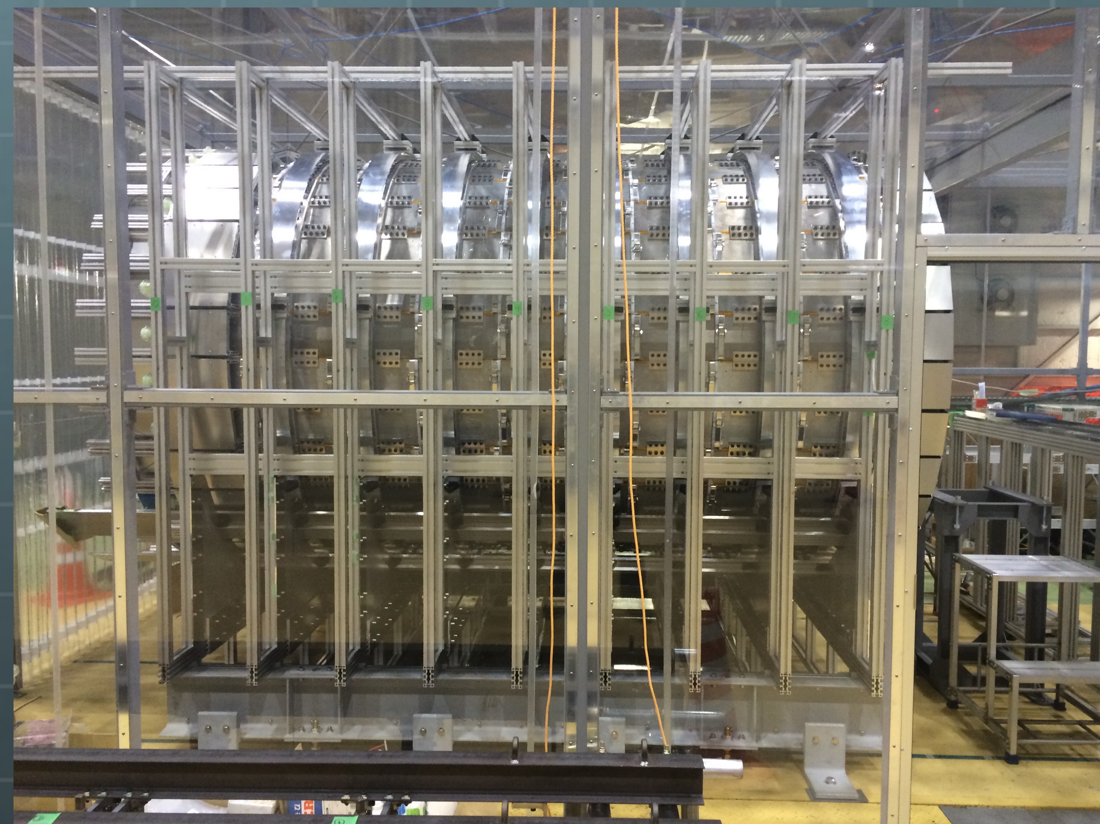

2015/12/18 16:24


2015/12/18 14:34

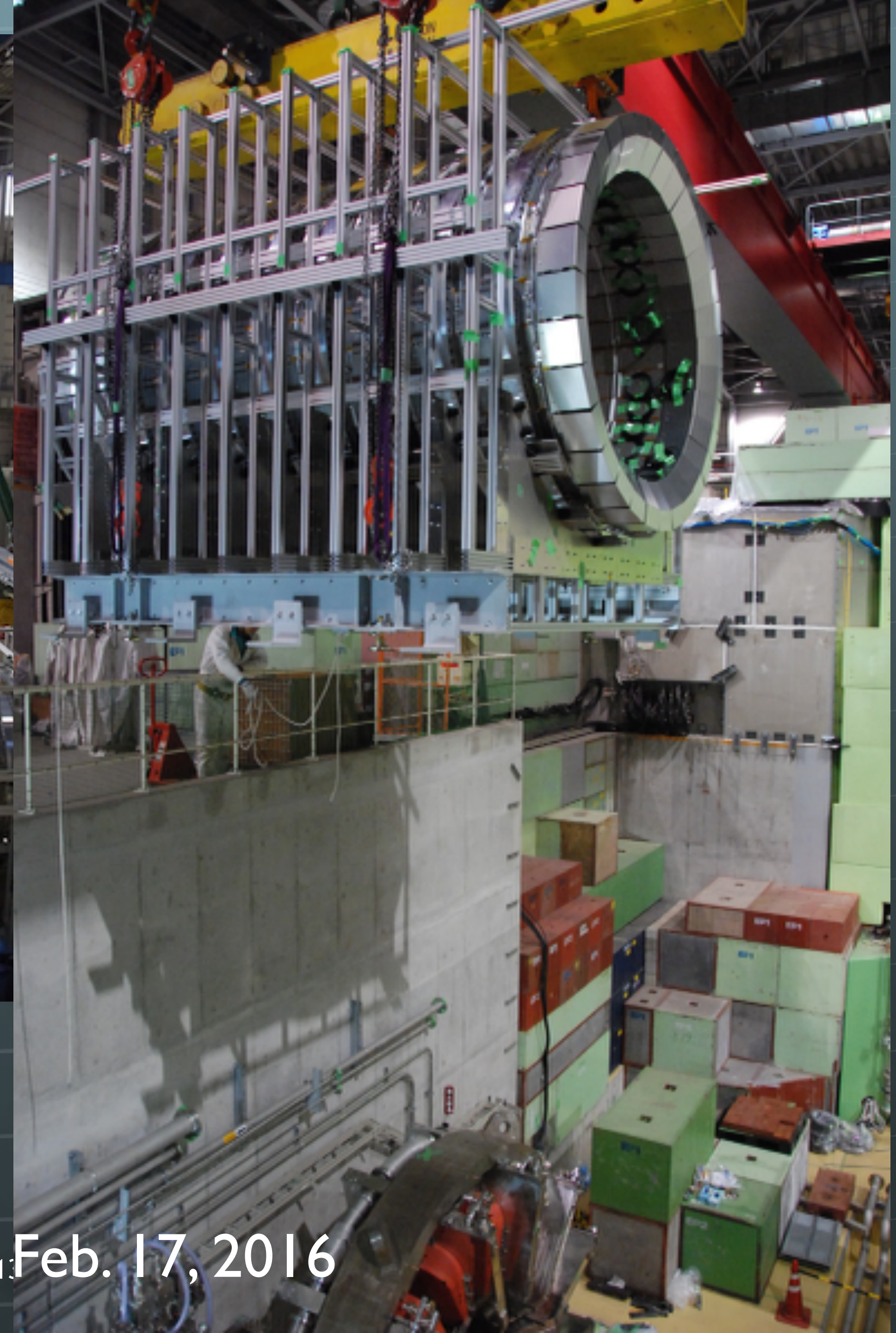
Assembling History



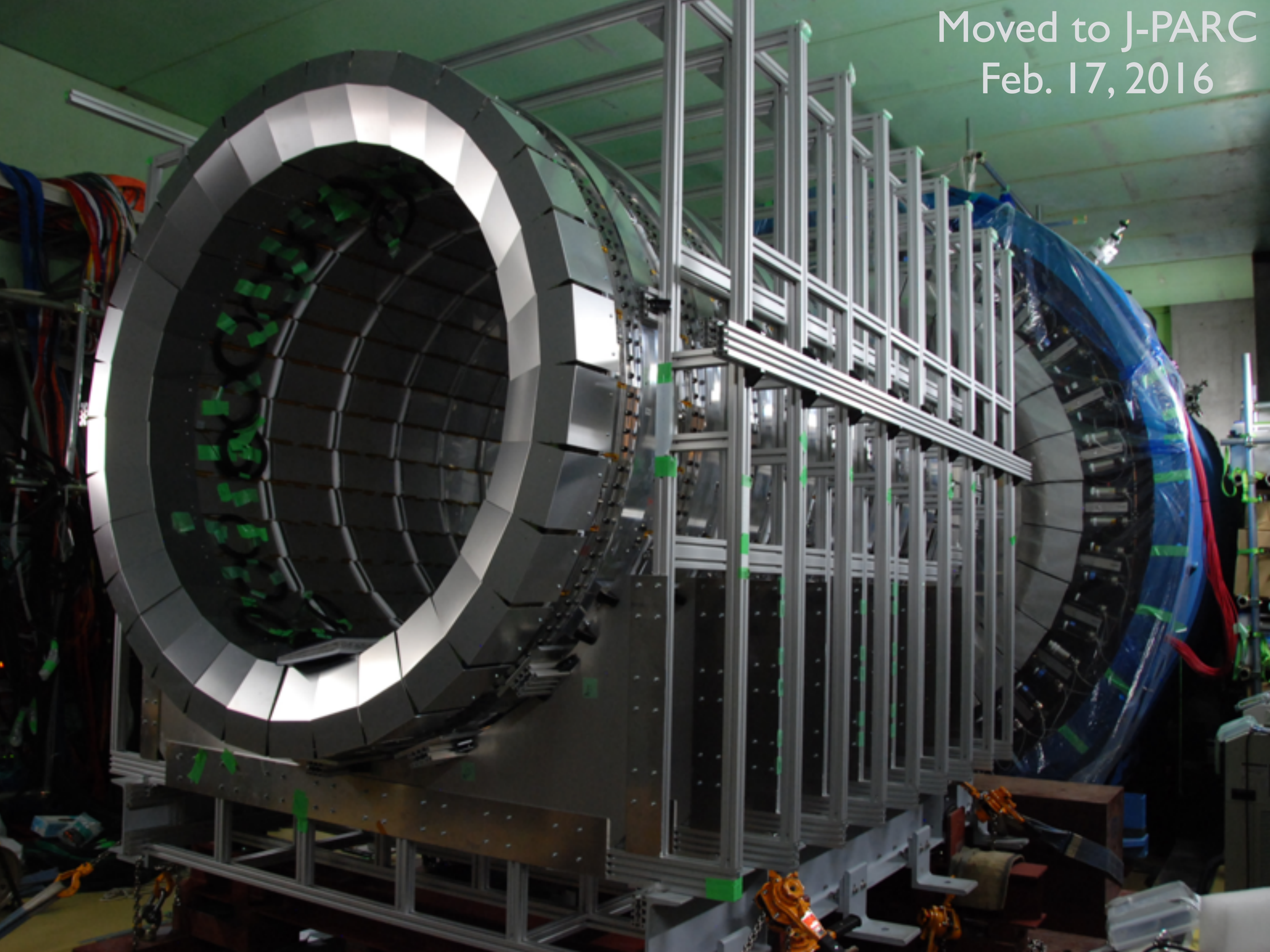




Jan. 13th, 2016



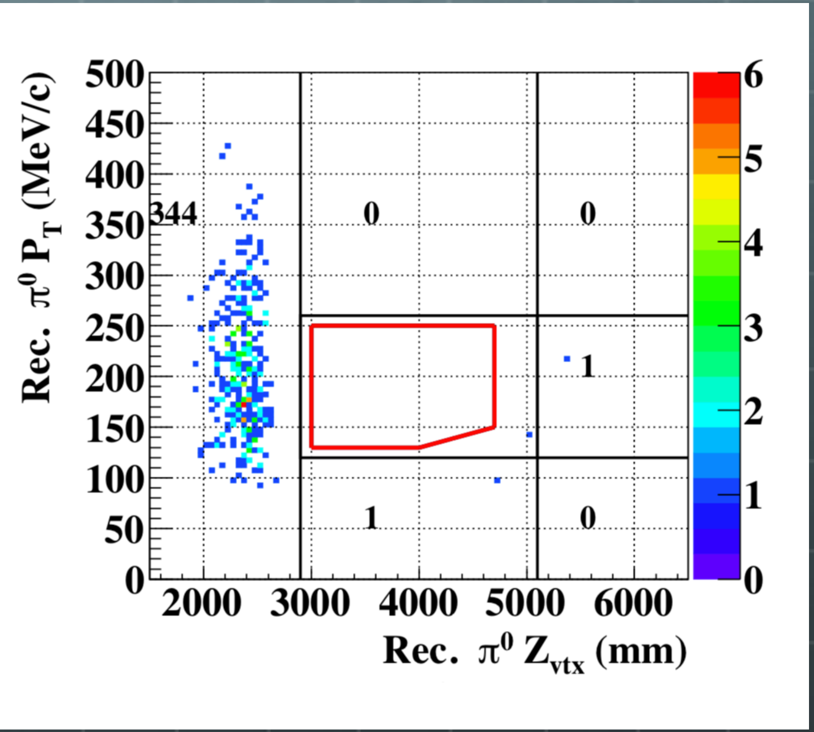
Feb. 17, 2016


Moved to J-PARC
Feb. 17, 2016


Installed
April 1, 2016

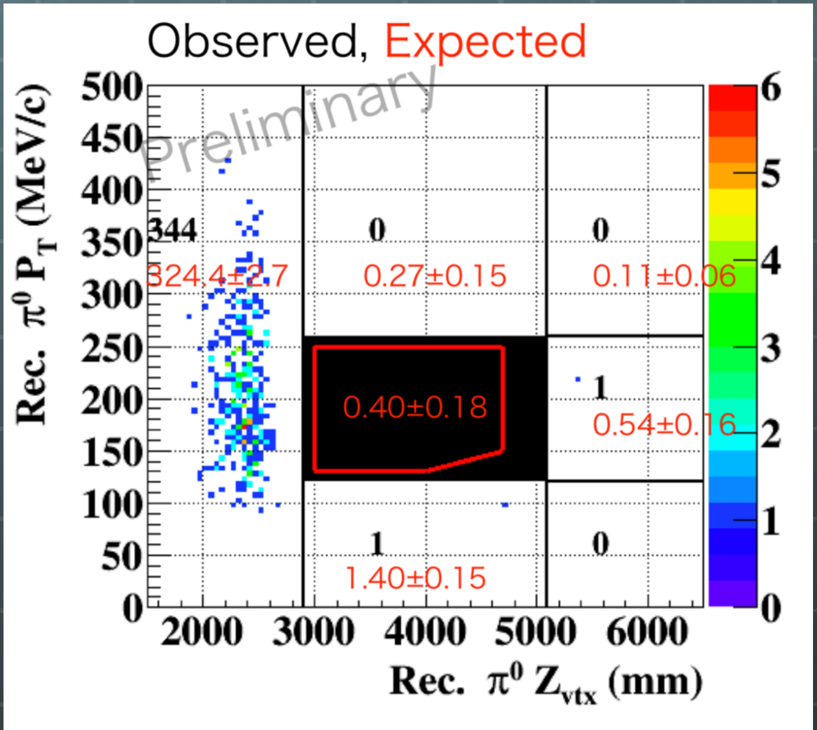
Result of 2015 Run

- 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<3.0×10-9 @90%C.L.

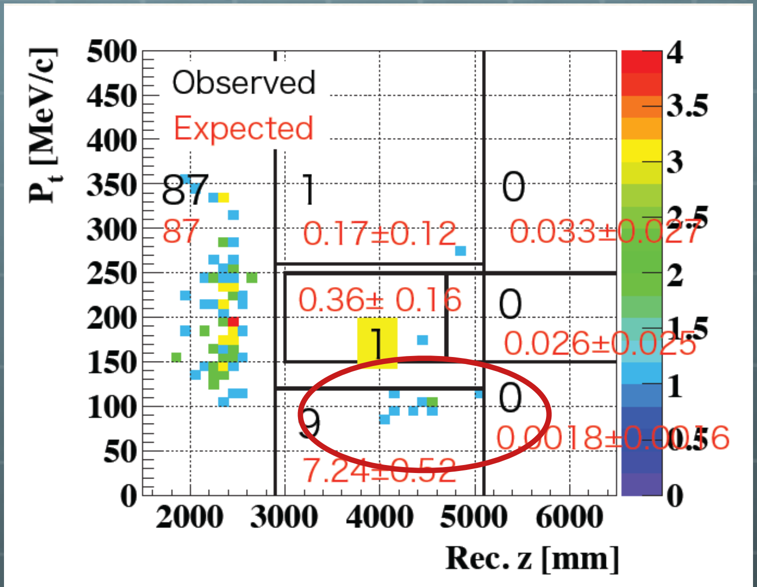


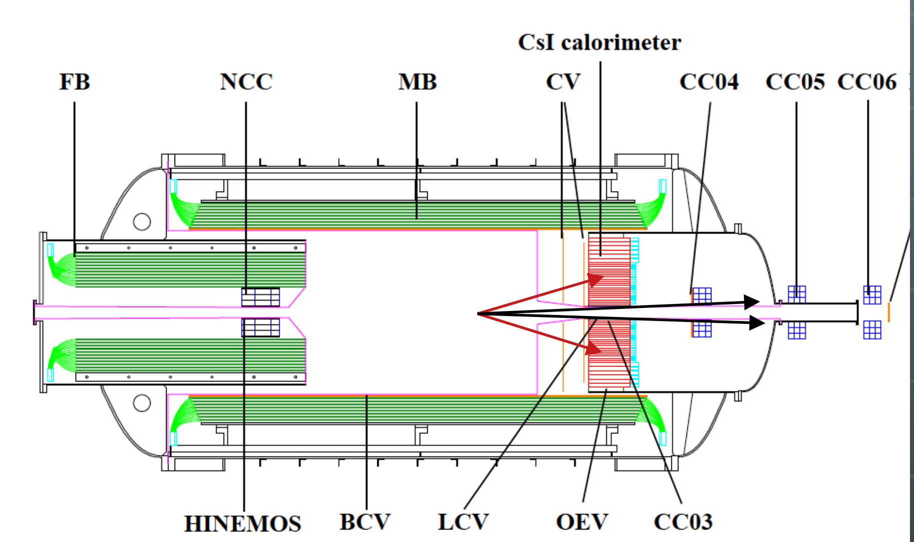
Background budget

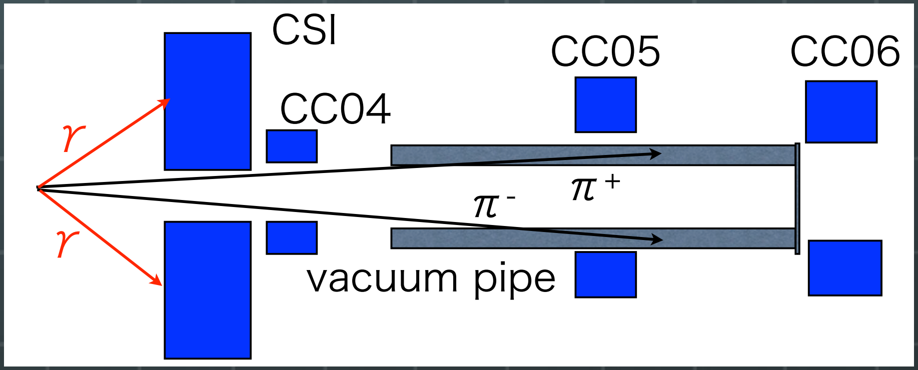
background source	#BG
Halo neutron hitting CSI	0.24±0.17
Halo neutron hitting upstream detectors	0.04±0.03
η background	0.03±0.02
KL->$\pi+\pi-\pi0$	0.05±0.02
KL->2π0	0.02±0.02
other BG sources	0.02±0.02
Sum	0.40±0.18



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

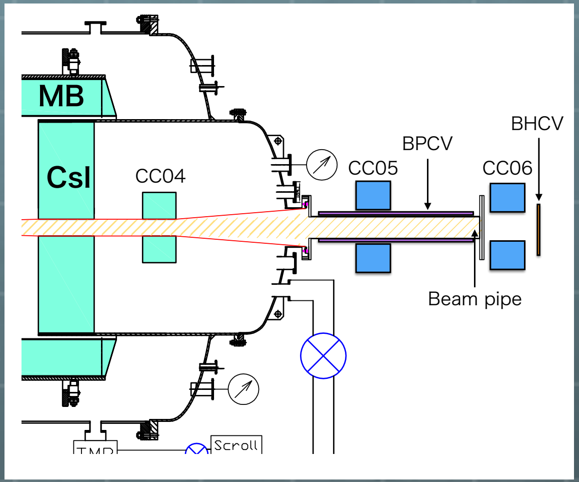


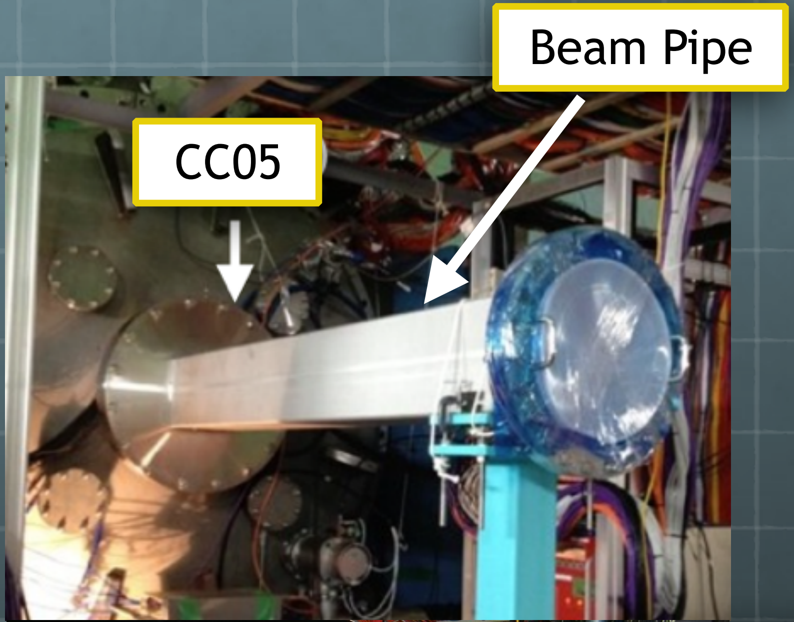


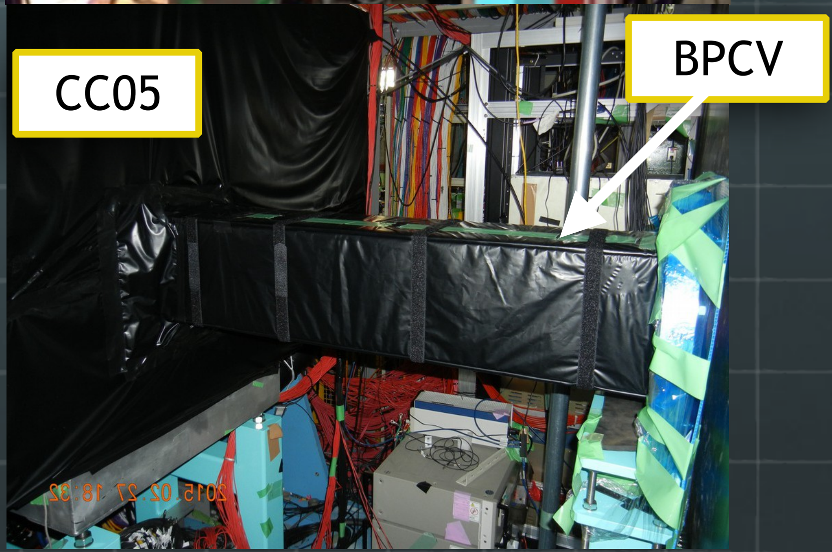


π^+ and/or π^- were not detected due to interaction with vacuum pipe

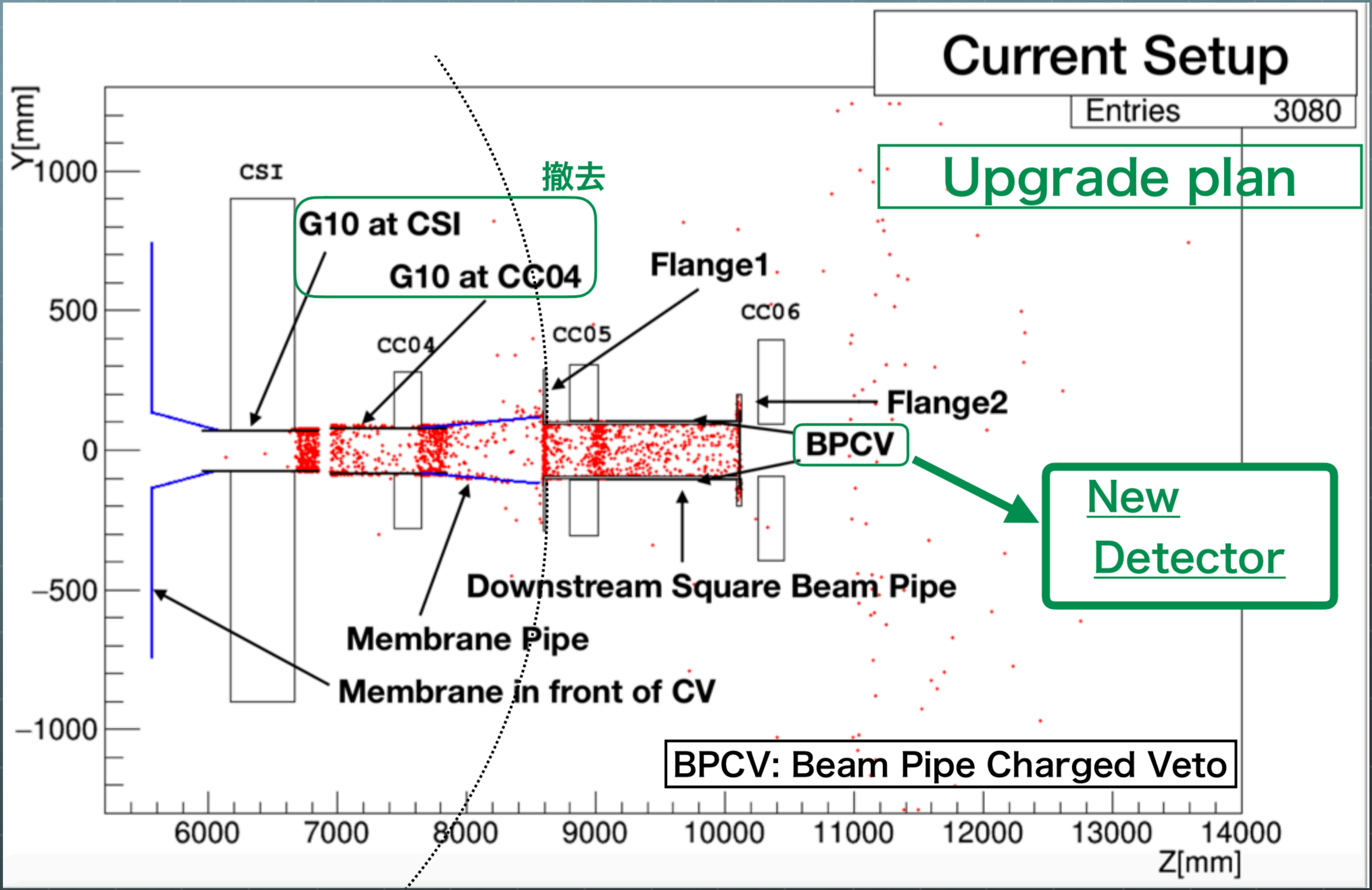
$K_L \rightarrow \pi^+\pi^-\pi^0$



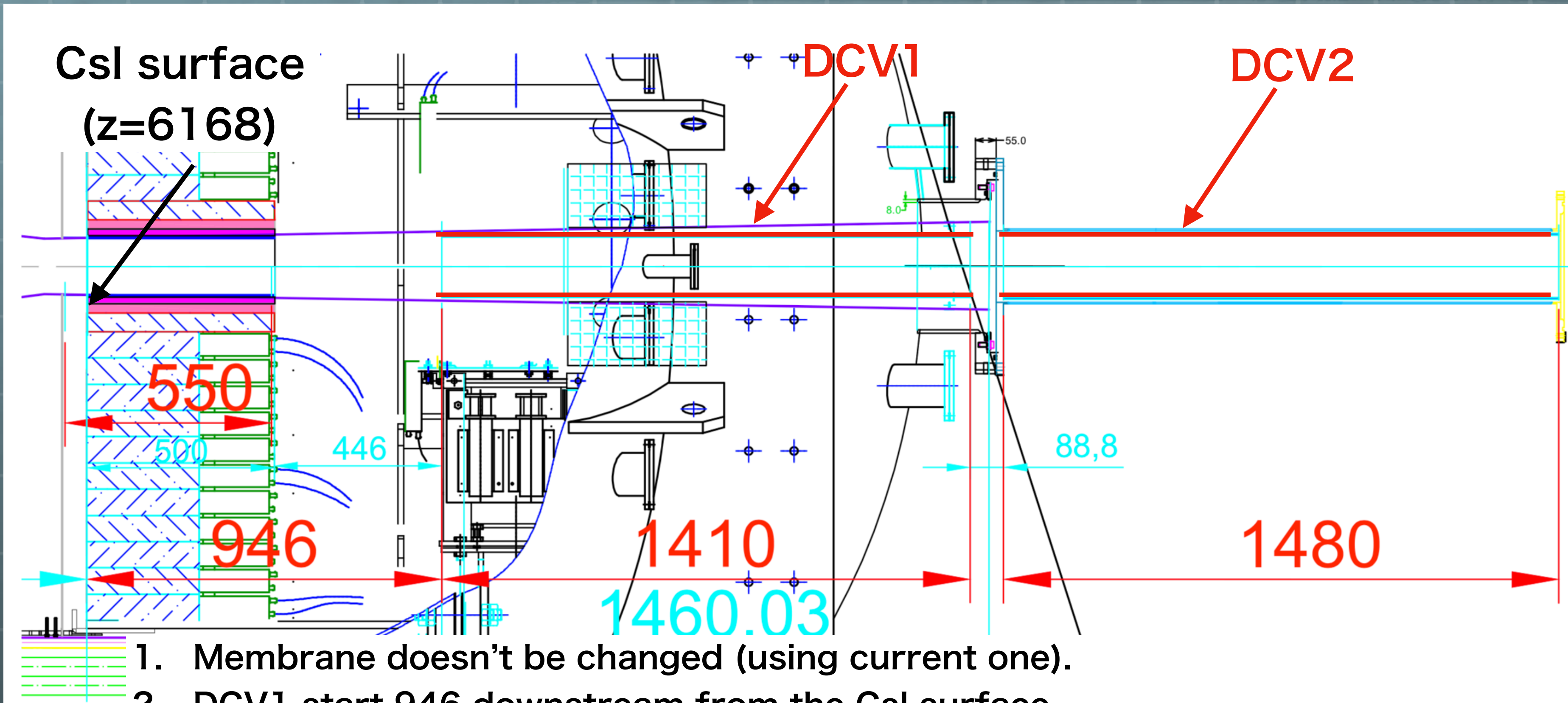




- Beam pipe with lighter material
  - Stainless Steel -> Aluminum
- Beam Pipe Charged Veto
  - 5mm-thick Plastic Scintillator
  - Wavelength shifting fiber readout


Current Setup
Entries 3080
Upgrade plan
Y[mm]
1000
500
0
−500
−1000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Z[mm]
CSI
撤去
G10 at CSI
G10 at CC04
Flange1
CC04
CC05
CC06
Flange2
BPCV
New
Detector
Downstream Square Beam Pipe
Membrane Pipe
Membrane in front of CV
BPCV: Beam Pipe Charged Veto

Downstream Charged Veto



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

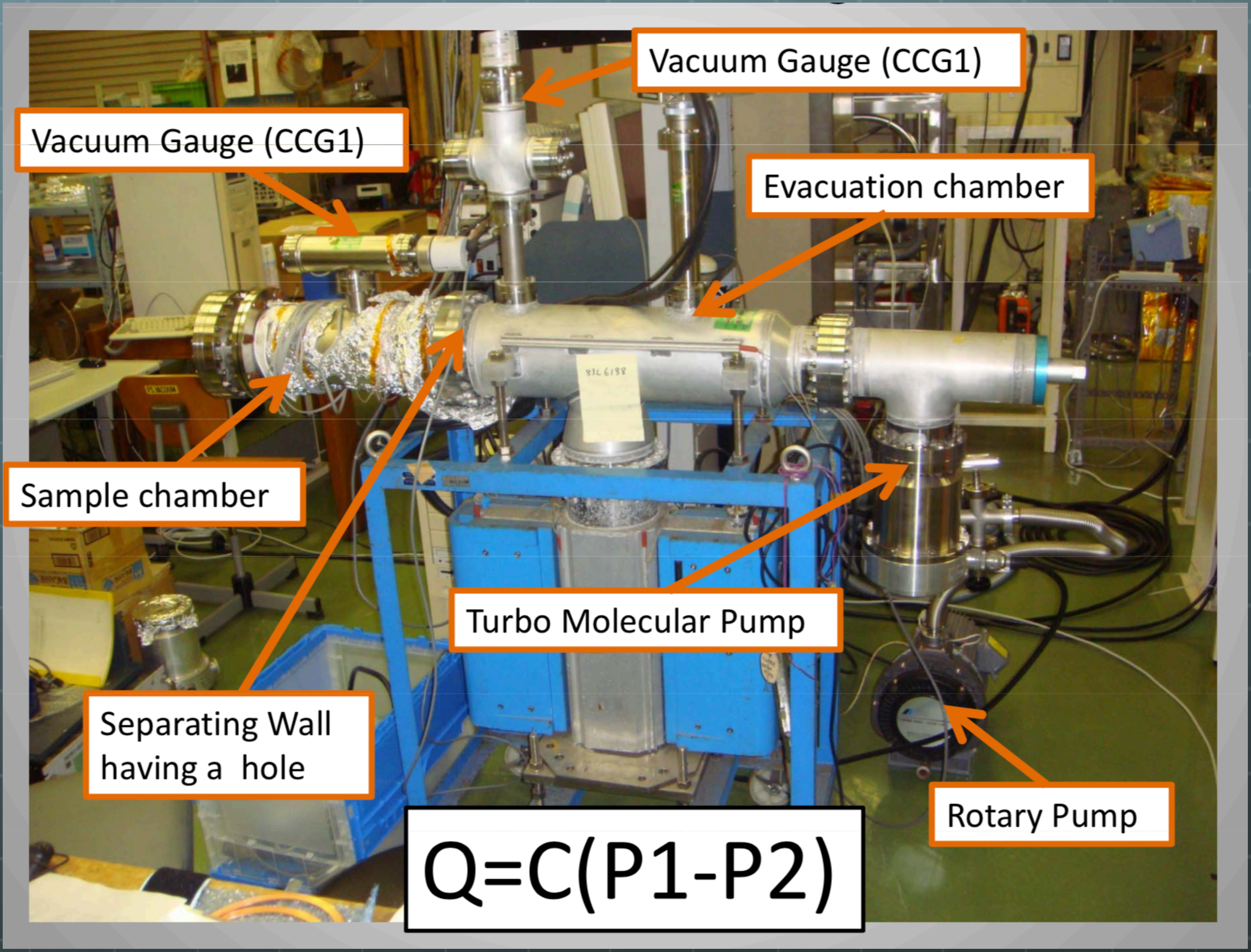
P0 : Initial Pressure

S : Pumping speed

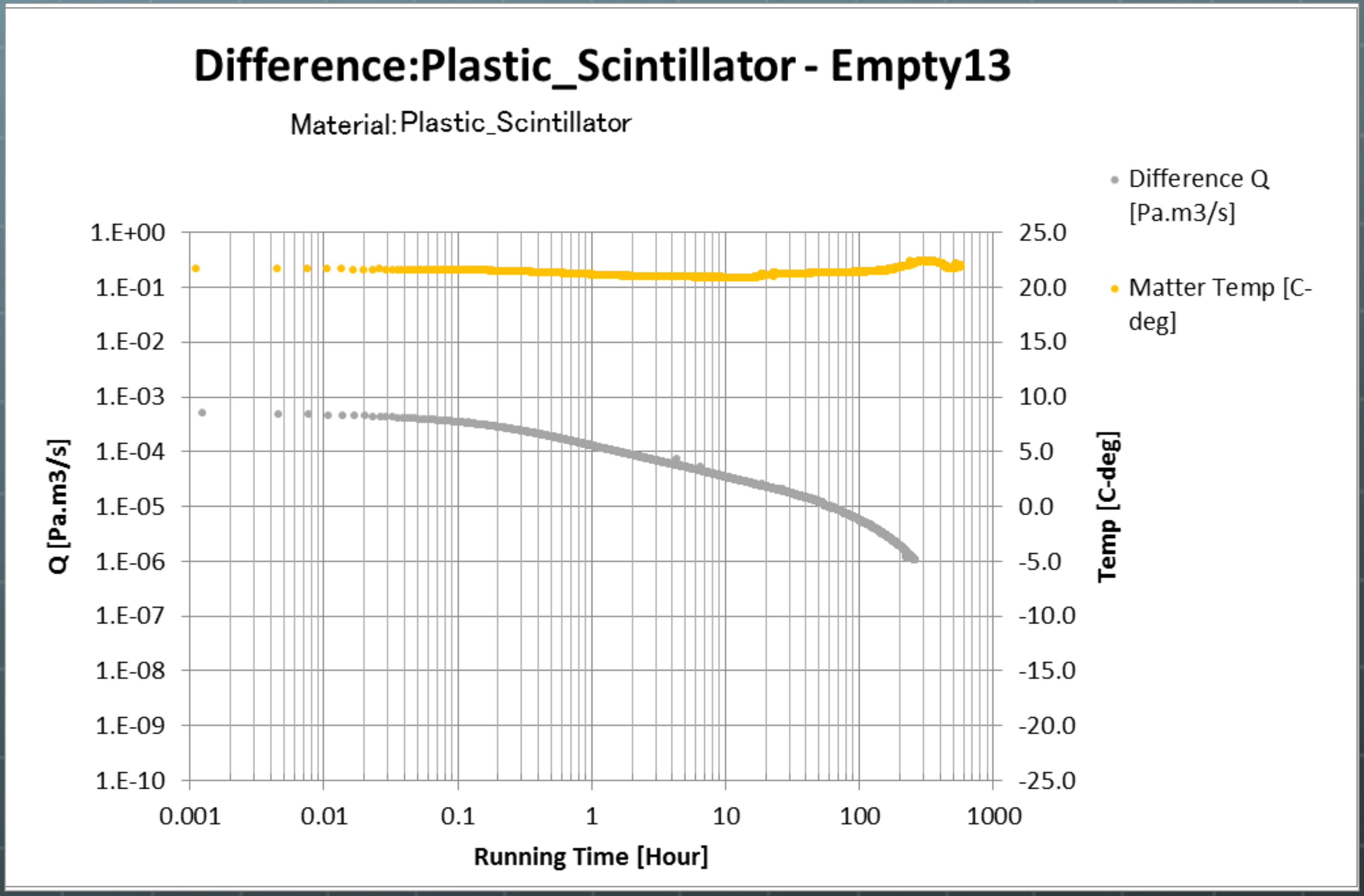
Q : Rate of outgassing

V : Volume of chamber

Measurement on outgassing rate



Outgassing rate of plastic scin.



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

DCV contribution

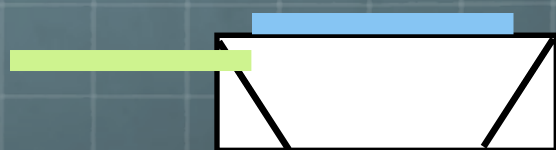
- Total surface of DCV : 2 m^2
  - 90.1 times larger than test sample
- Pumping speed of TMP : (800 l/s)X4
- Outgassing rate :$1.0X10^{-6}$ Pa・m^3／s
  - Total outgassing rate:$9.0X10^{-5}$ Pa・m^3／s
- Reaching Pressure P = 2.8 X 10^{-5} Pa

R&D for light guide

Simple transparent light guide

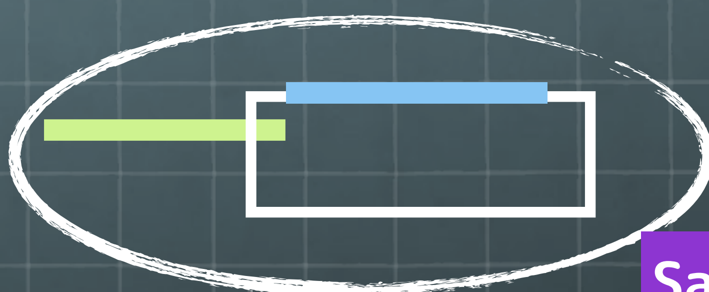
Matter of material selection

refection sheet



Variation of light guide

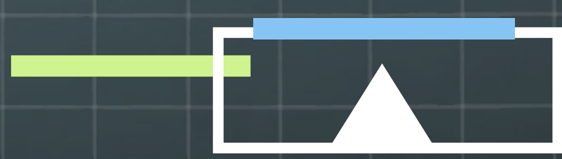
To change shape of light guide for better light collection



No light guide

Insert fiber into reflecting box

Sample making

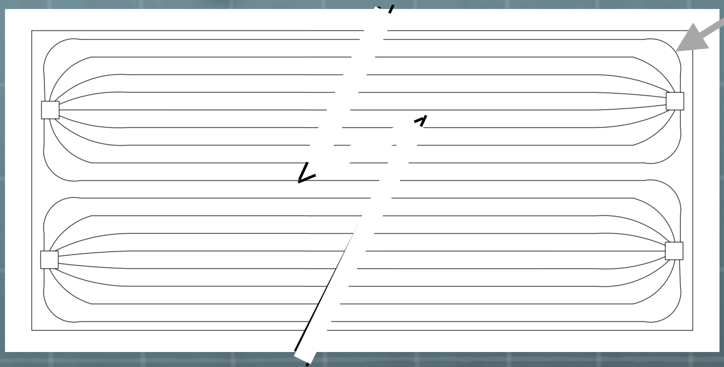


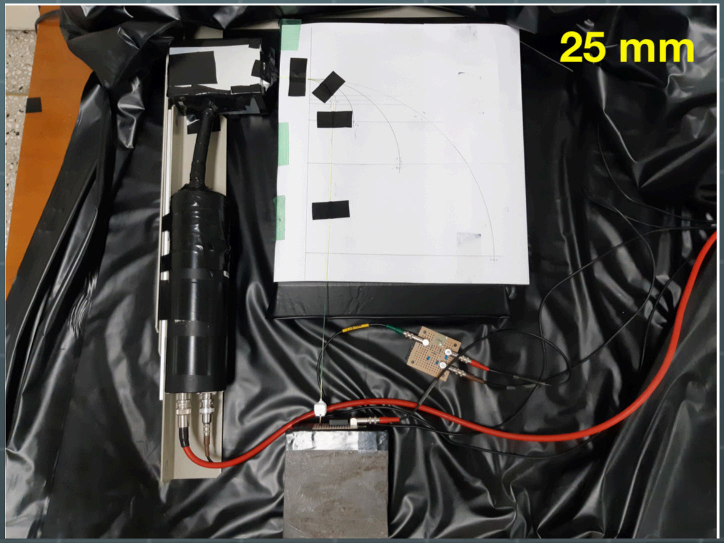
Variation of reflecting box

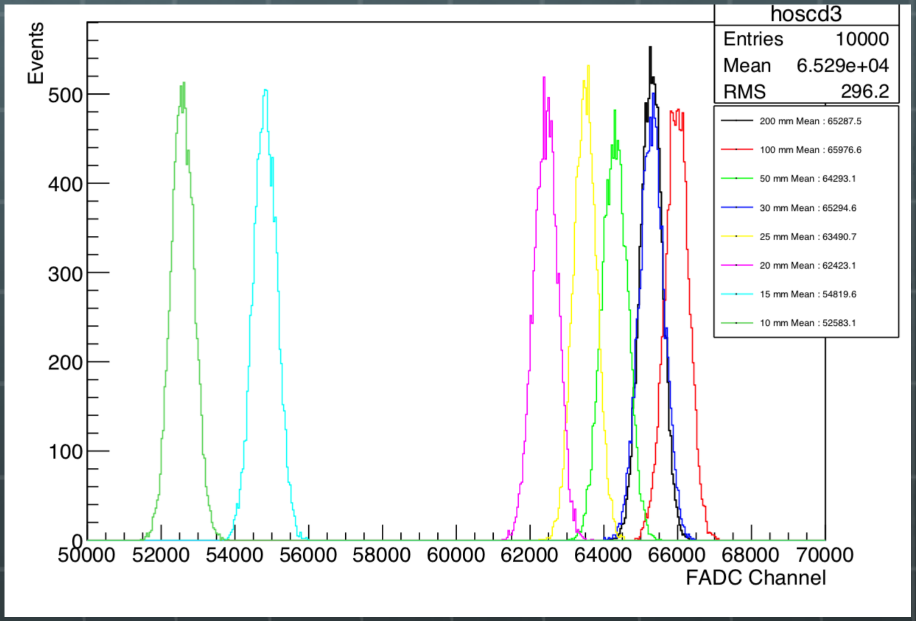
Insert a reflecting cone in the box

Bending Loss

How to determine R ?

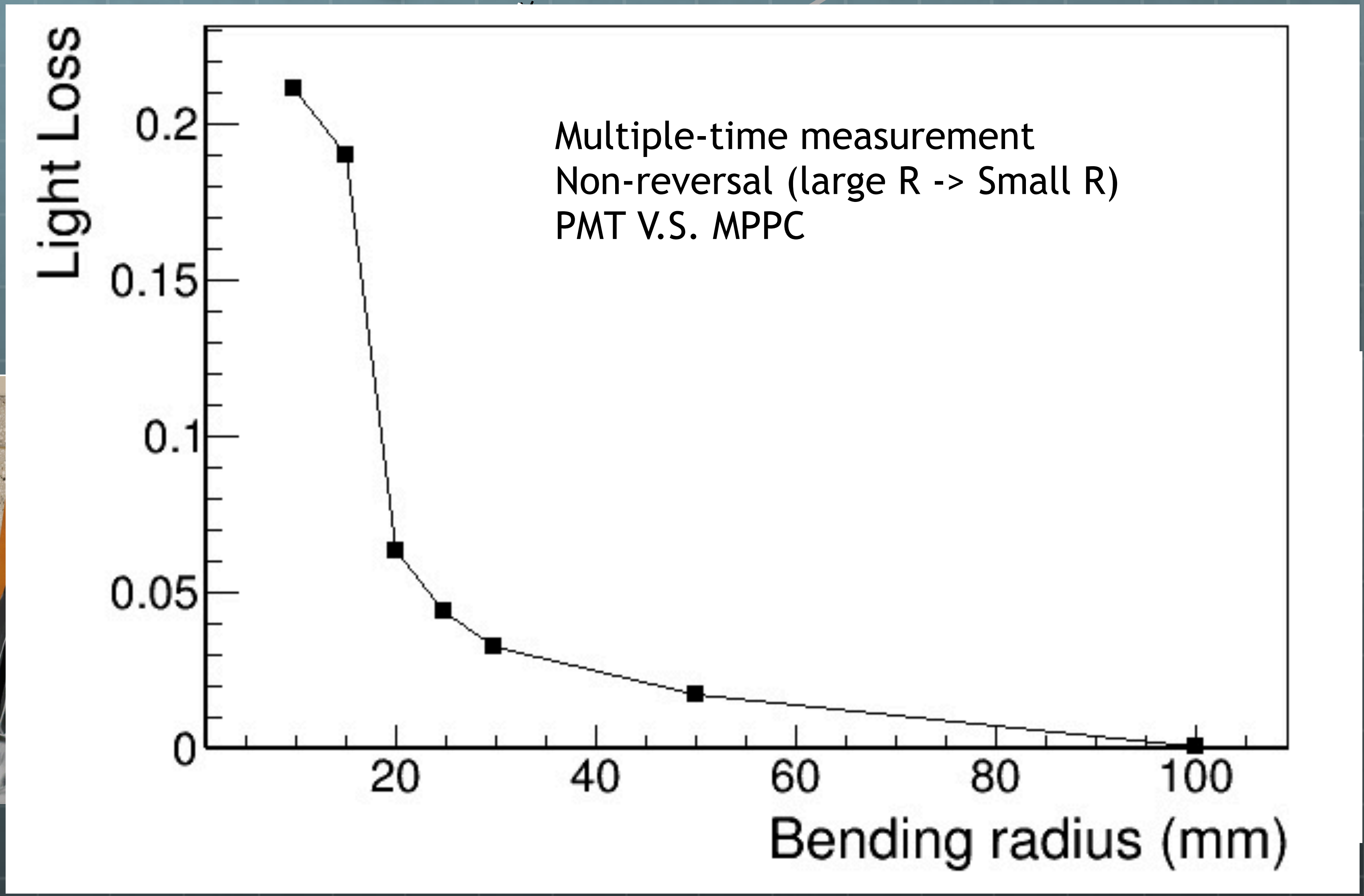




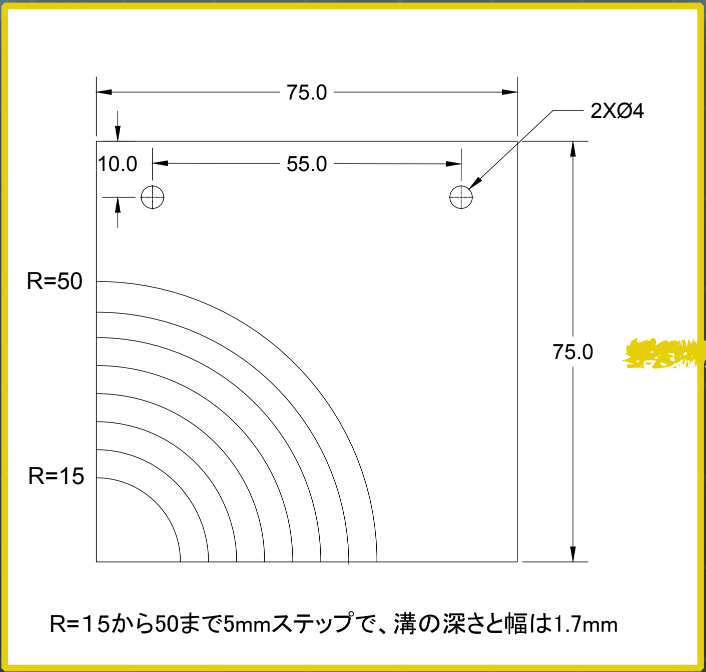


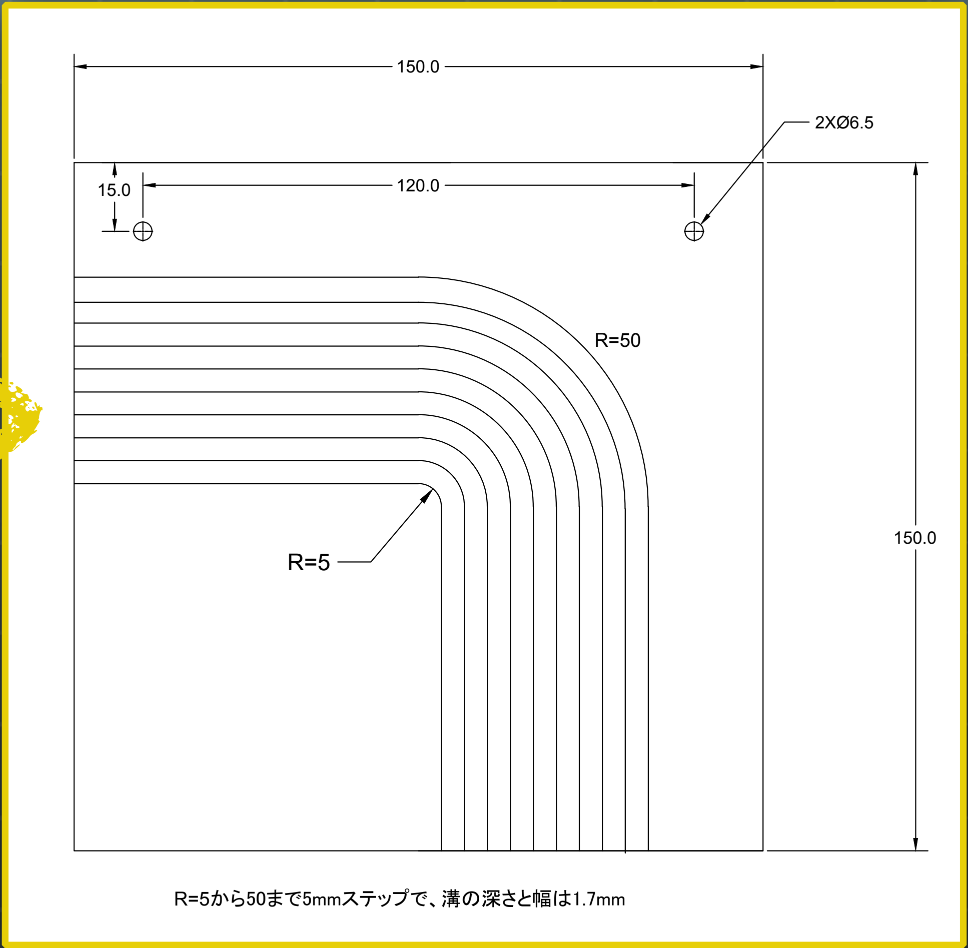
Bending Loss

How to determine R ?

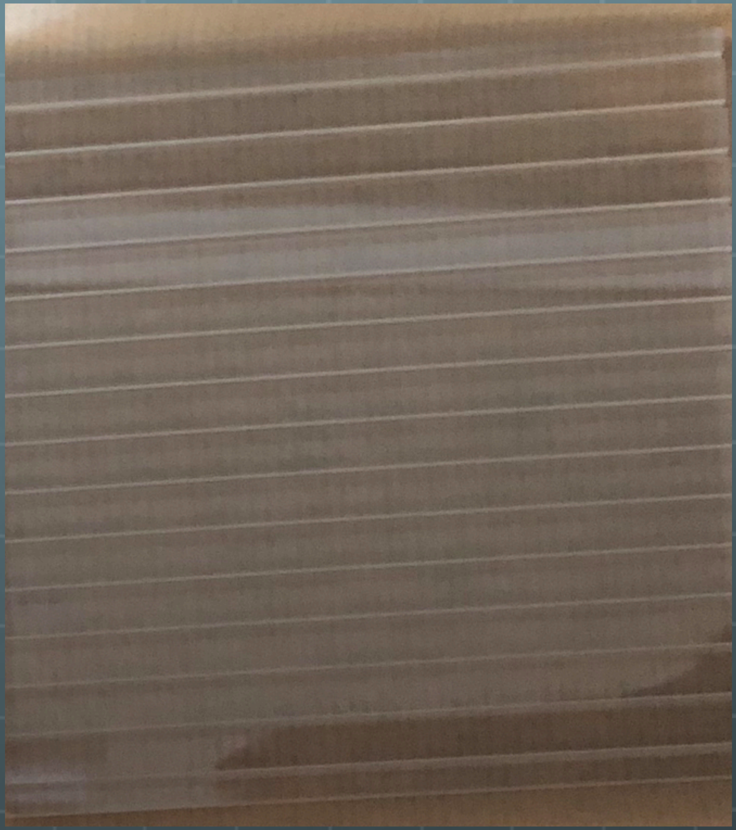


For better measurement





Pitch dependency ?



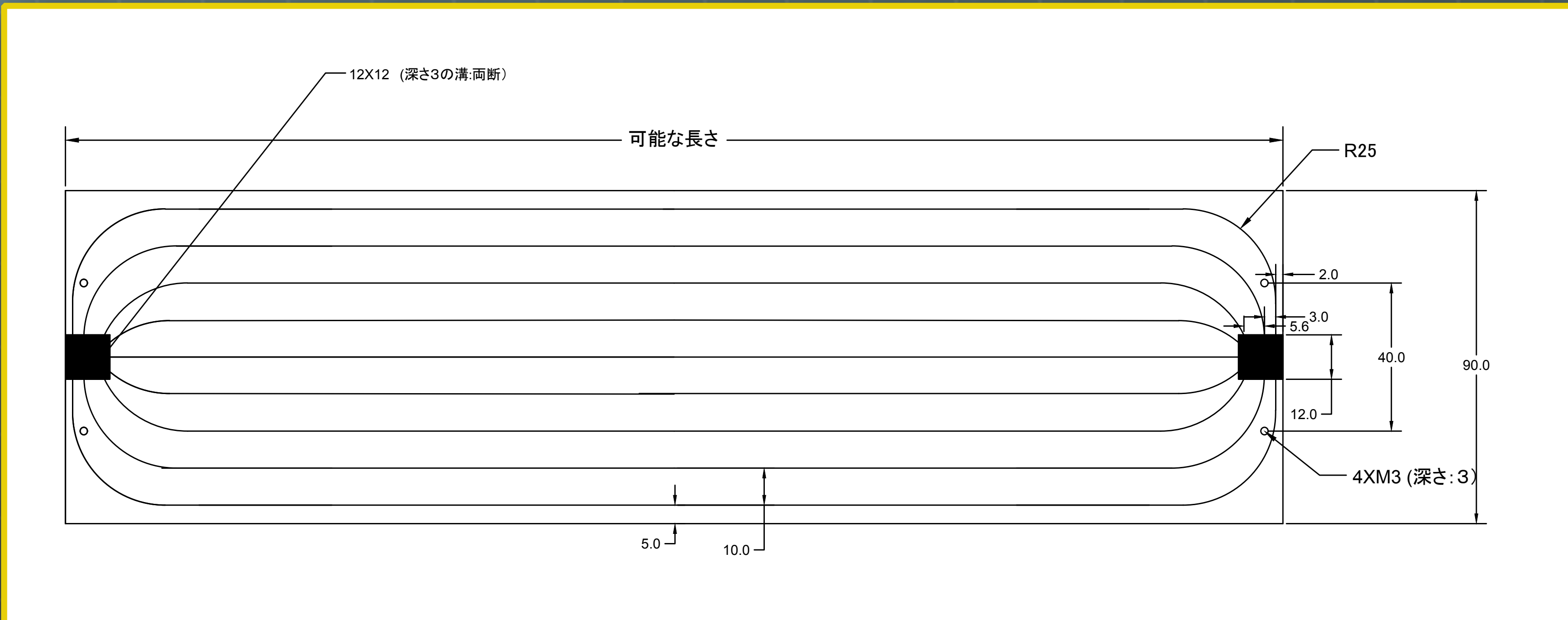
3 different pitches of groove

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-electorns

    - 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)

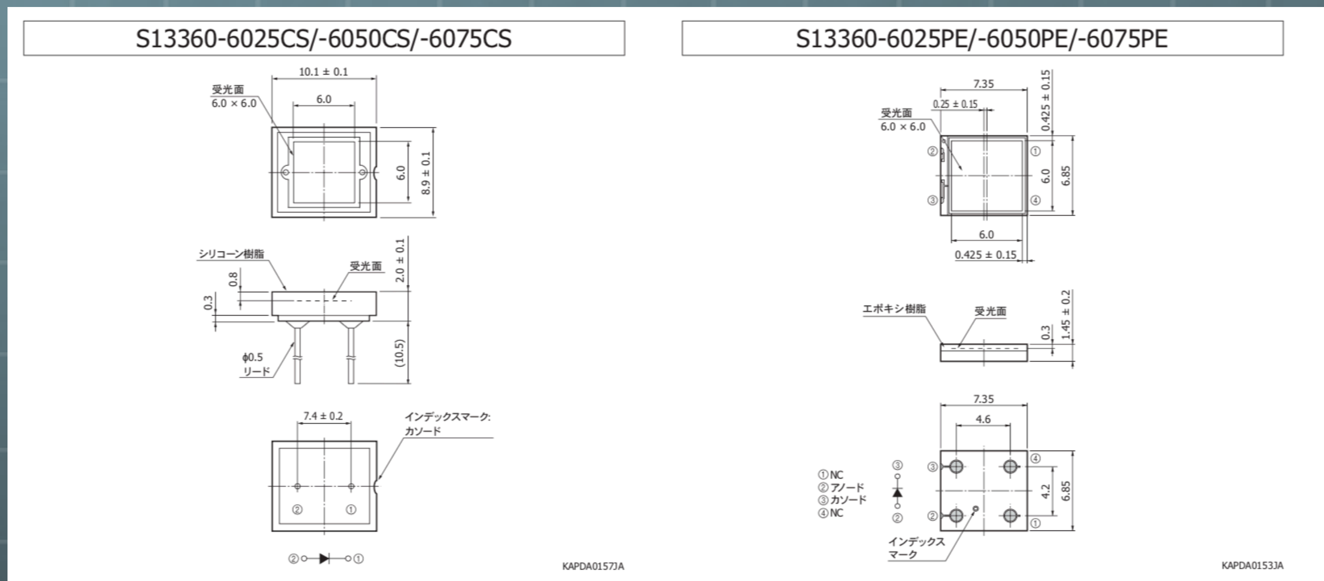
Design of fiber attachment (lightguide)

- 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.
- Final design by the end of Oct.
- Production by the end of Nov.

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				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 ℃)

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/℃)
					Typ. (kcps)	Max. (kcps)						
S13360-1325CS	Vover =5 V	270 ~ 900	450	25	70	210	60	7.0 × 10^5	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 × 10^6		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 × 10^6		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										

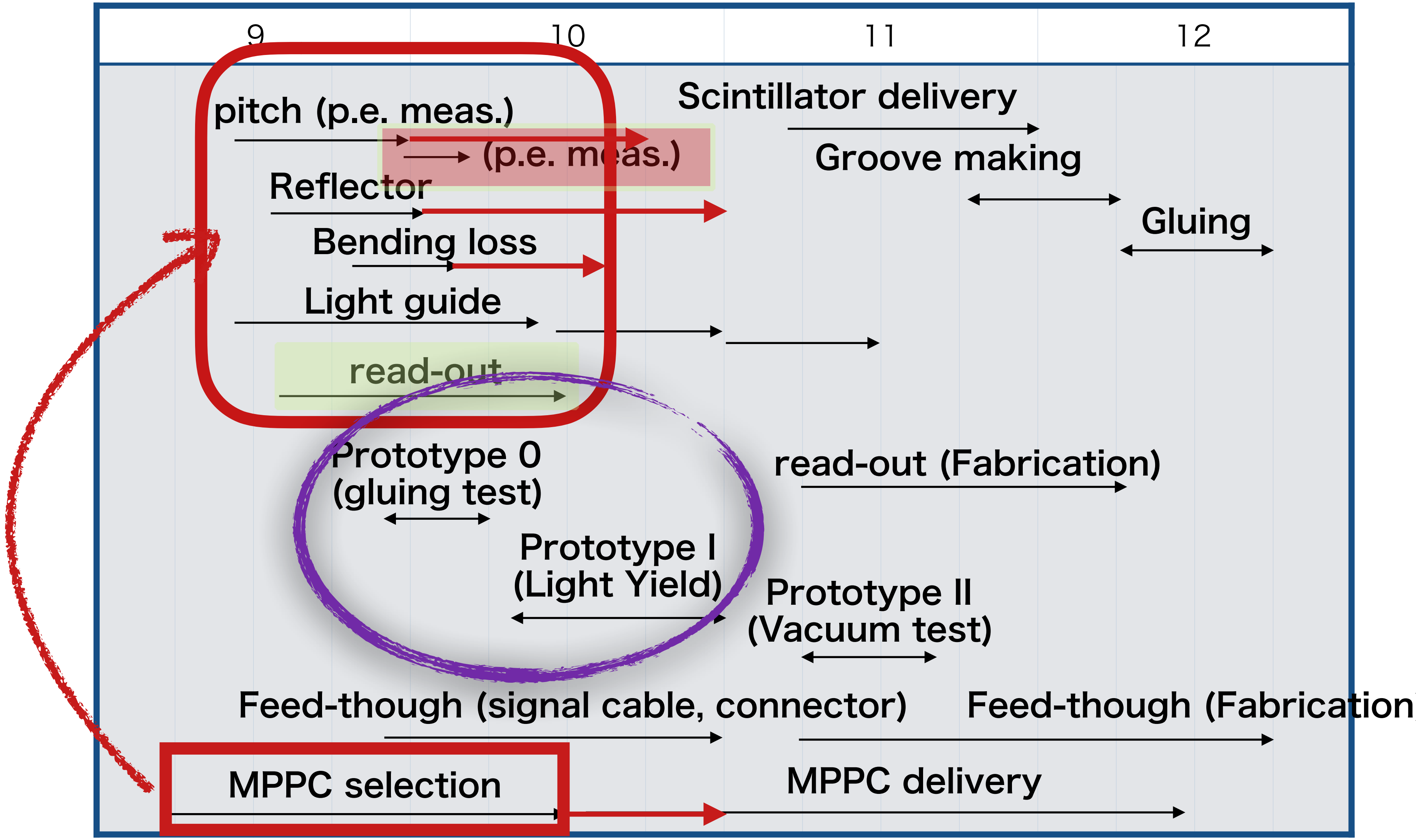
*1: 検出効率は、クロストークと

*2: 閾値=0.5 p.e.

注) 上記特性値は、表中の増倍率が … ください)。

Ask estimate for 50 pcs (~4M Won)

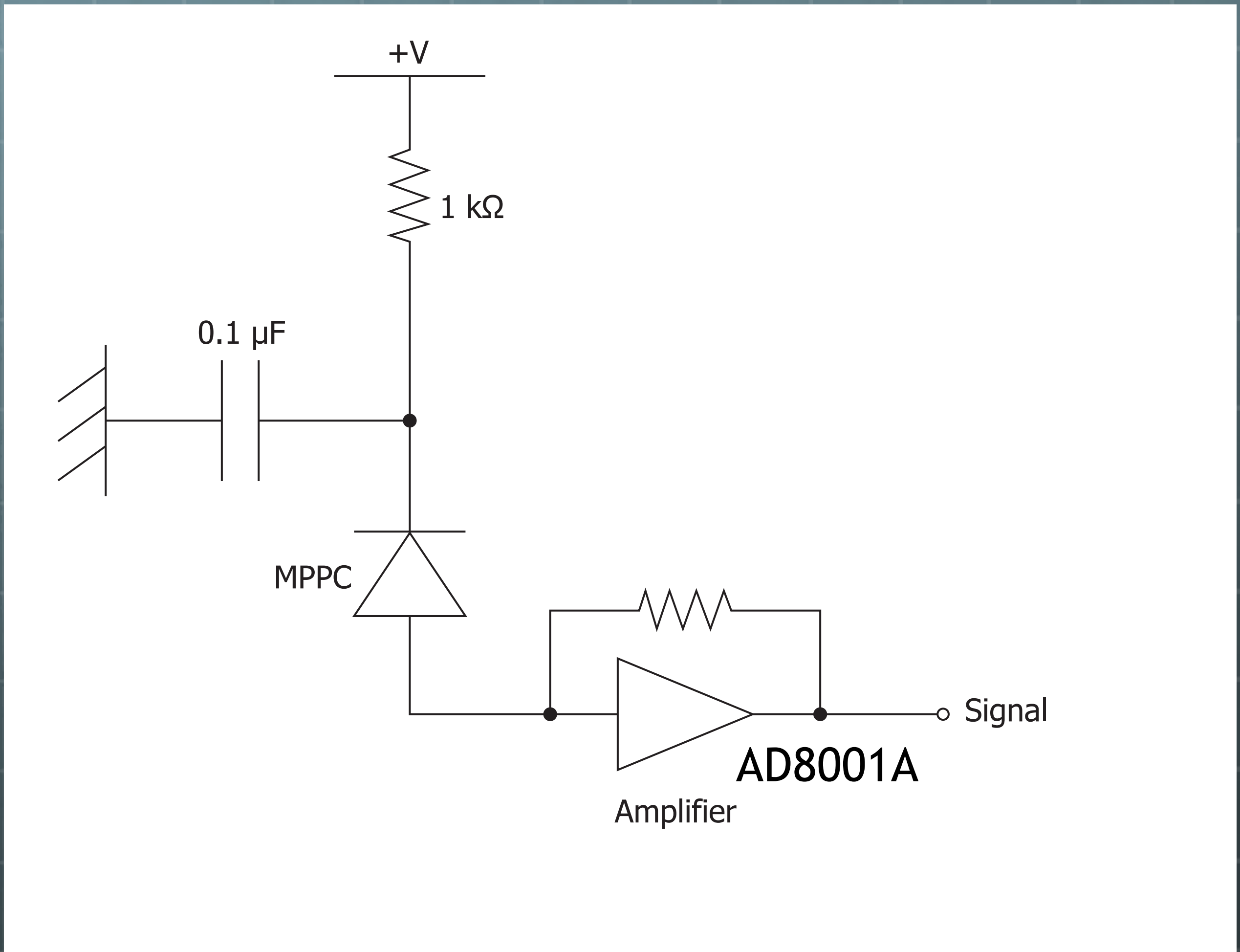
Schedule



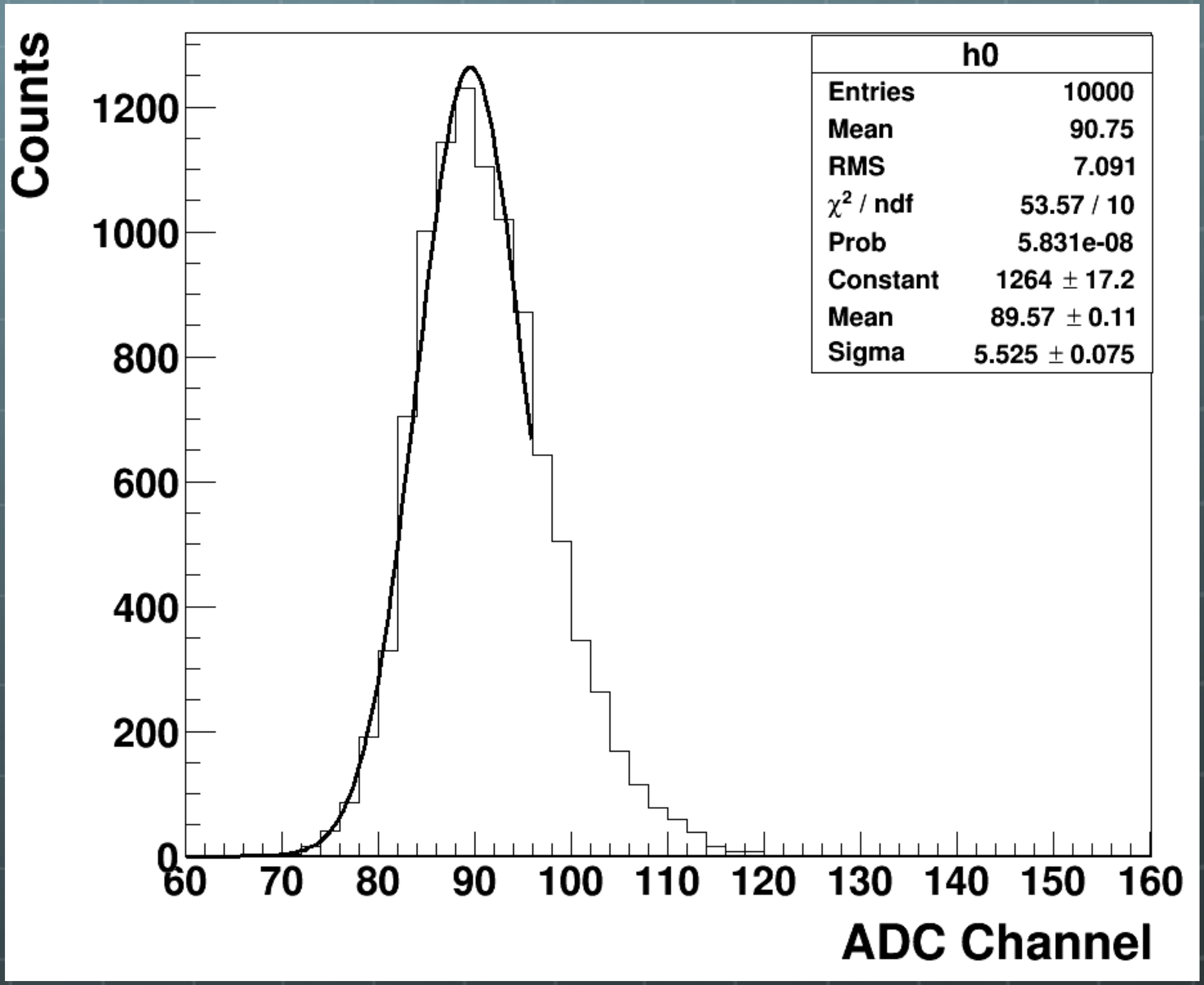
No contingency plan. Keep schedule

p.e. Measurement ?

S13360-6050CS



Wide pedestal ?



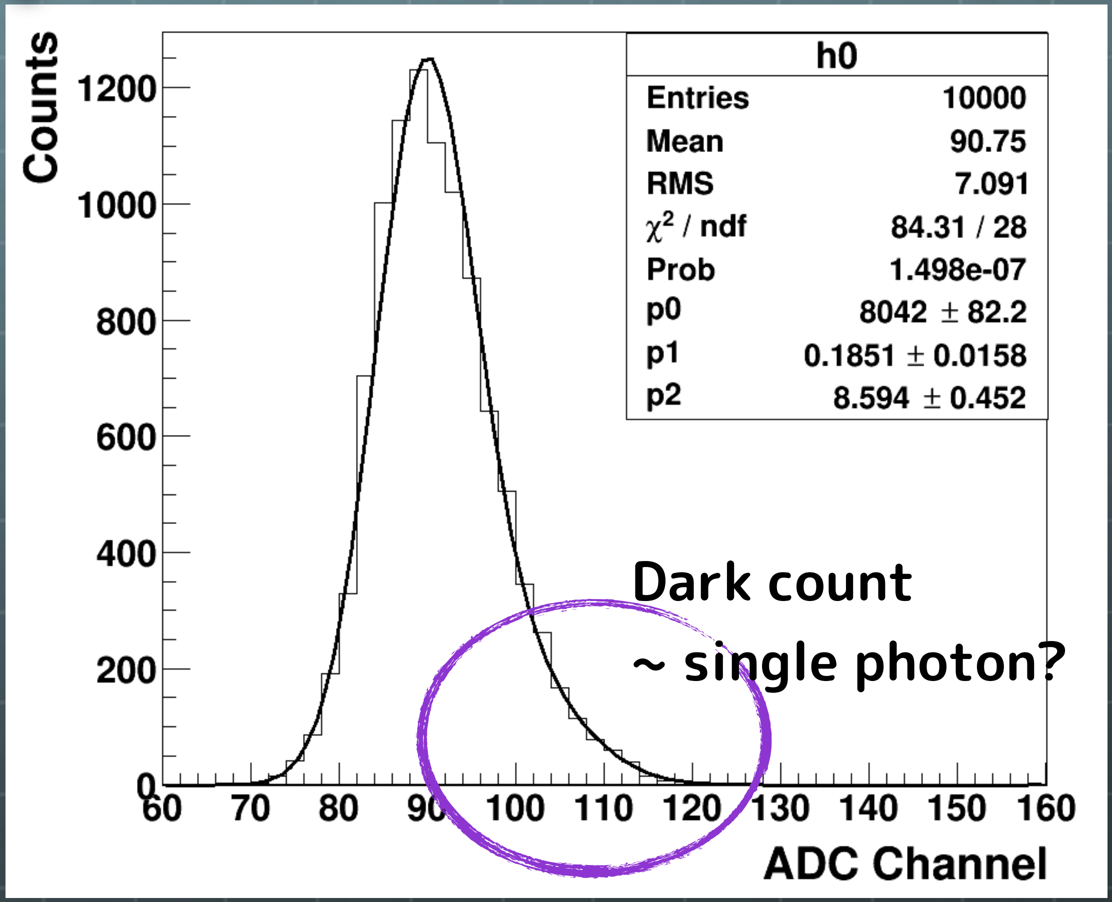
Wide pedestal ?

Single electron 1.6×10^{-19}

MPPC gain : 1.6×10^{6}

Amp gain : 10

=> 2.6×10^{-12} C ~ 10 ch

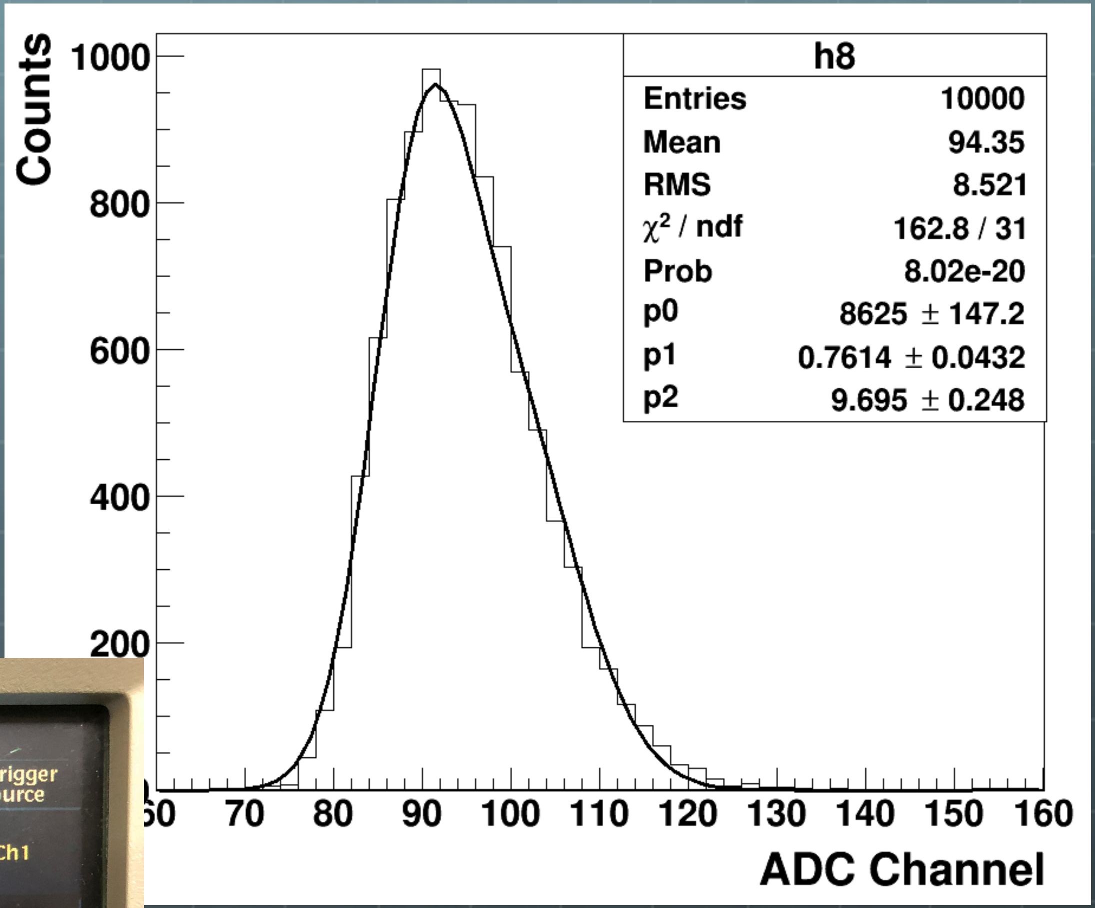


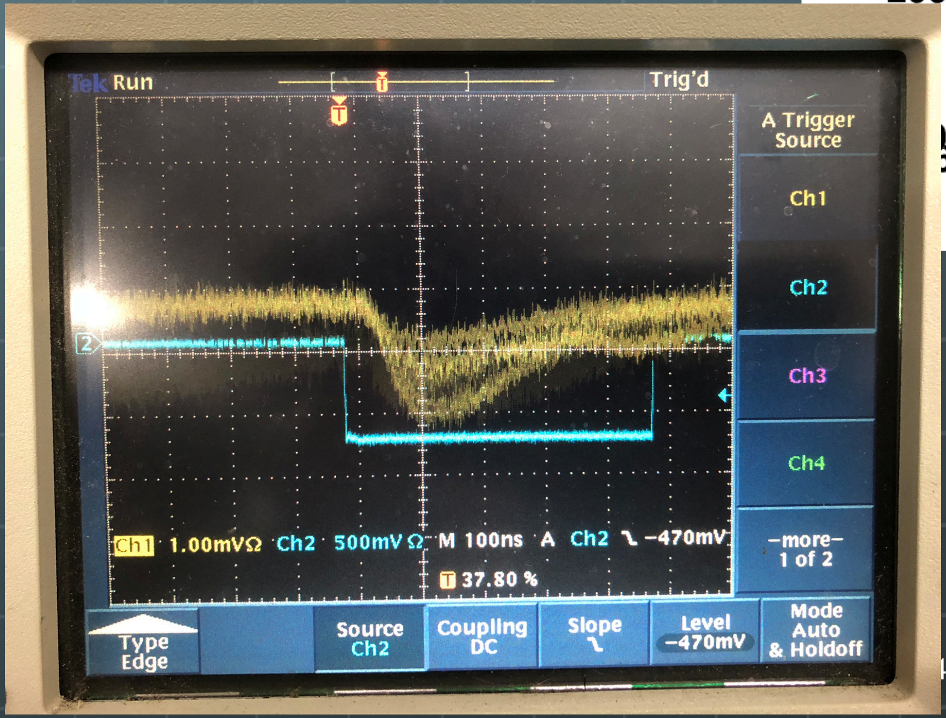
0.25pC/ch

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

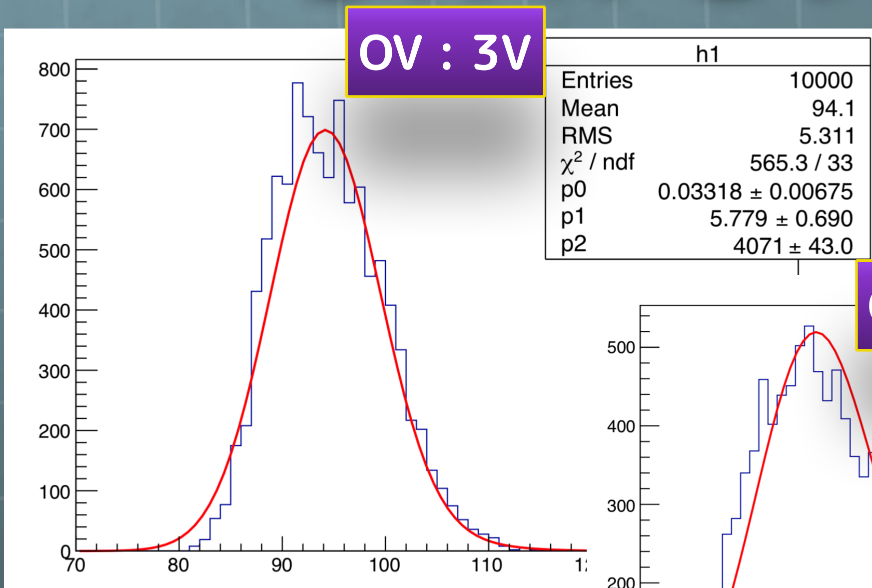
$$R(x) = A \sum_{N=1}^{N_{max}} \frac{\exp^{-\bar{N}} \bar{N}^N}{N!} \frac{1}{\sqrt{2\pi N}\sigma} \exp\left\{ -\frac{(x - pN - q)^2}{2N\sigma^2} \right\}$$

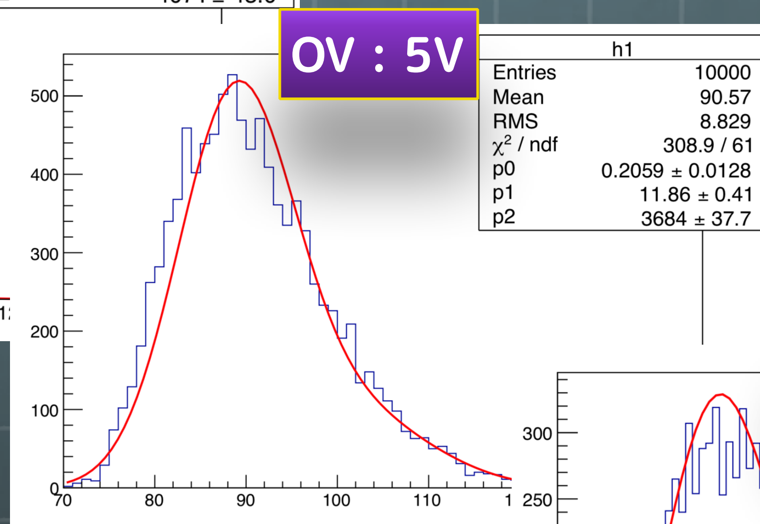
Weak LED Light

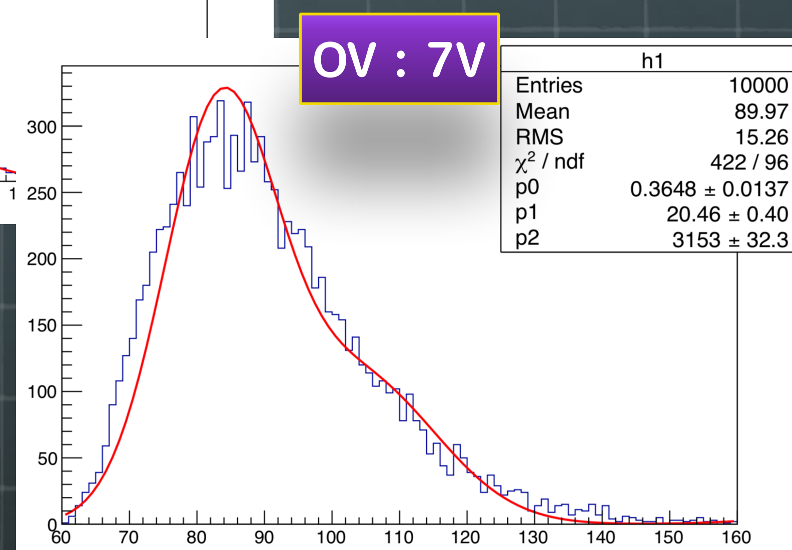




Diff. Over Voltage

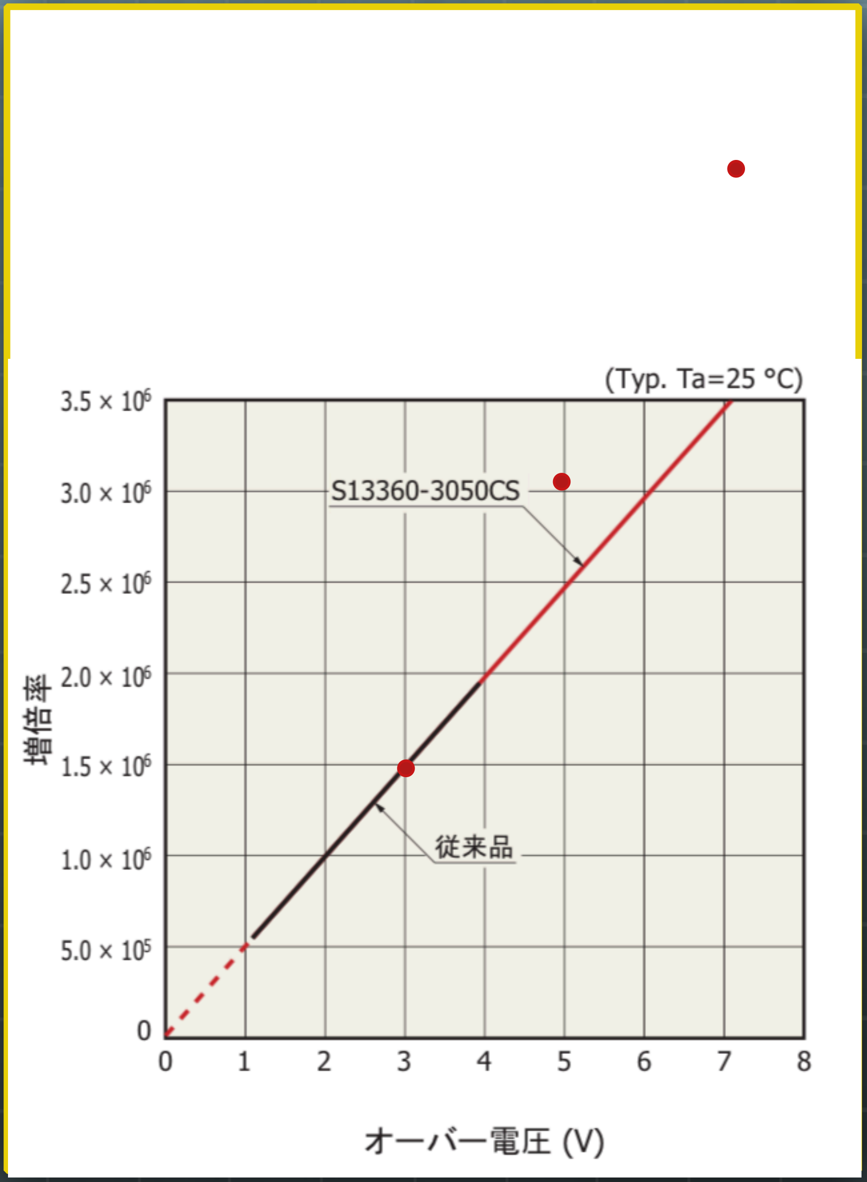


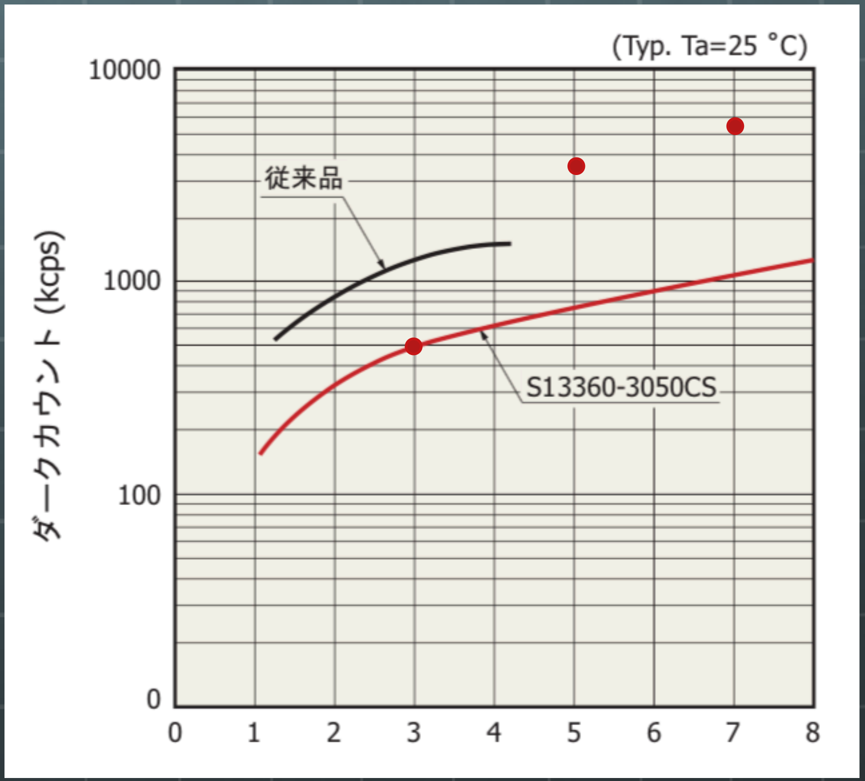




With this fitting performance, it is hard to mention about single photon

Reconsider fittine function

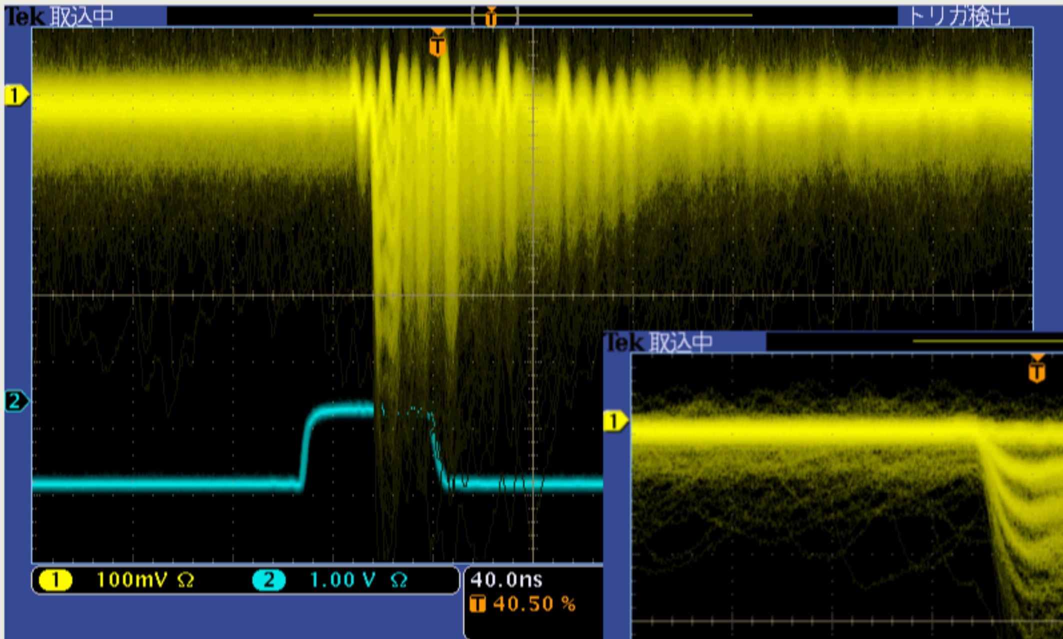




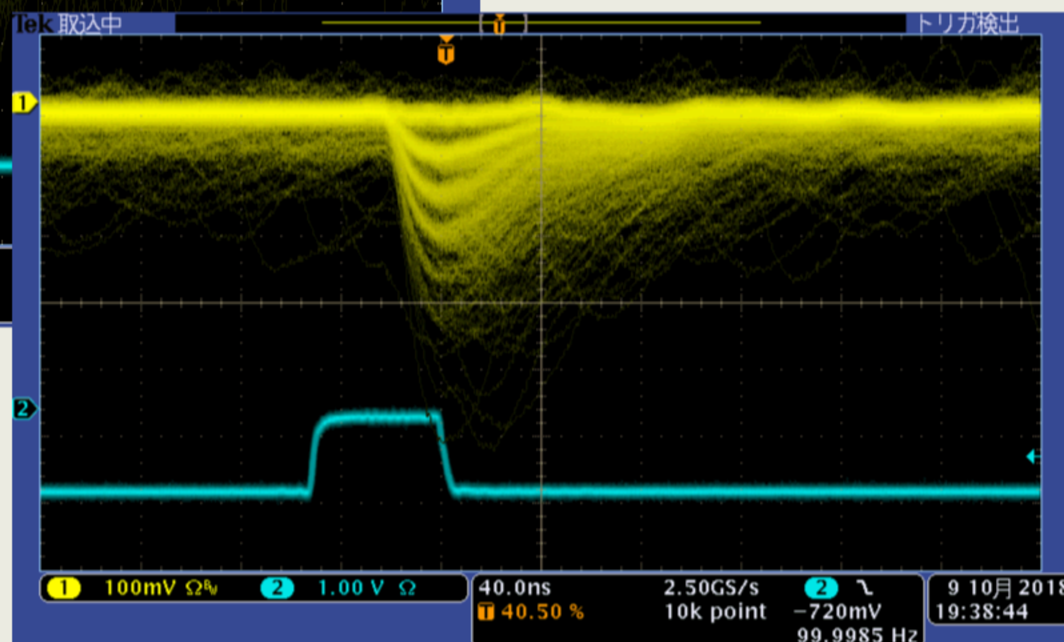
Two issues

- 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

Summary

- New type of charged particle detector.
- There are lots of R&D items.
- We will fabricate the detector by the end of this year.
- It will be good candidate for trigger counter for LAMPS.