Test results of Cherenkov absorber for HCAL

8 March 2016

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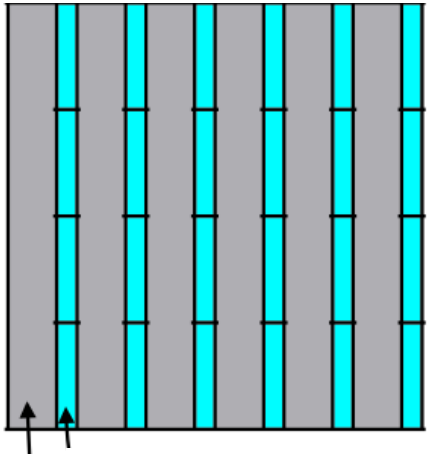
CALICE Collaboration meeting at Kyushu University

Cherenkov HCAL for PFA

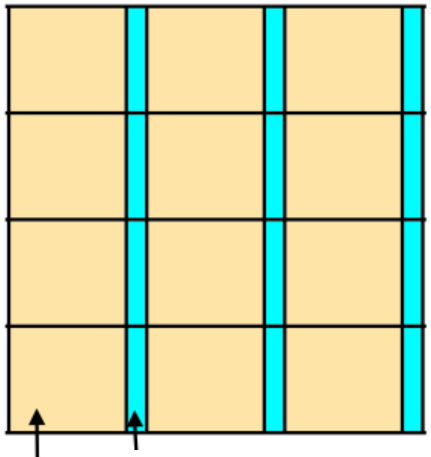
Current design of AHCAL



scintillator tile
readout with a thin PPD

Iron absorber
no information

Cherenkov PFA HCAL



scintillator tile
readout with a thin PPD

transparent heavy absorber
Typically a lead glass block
Each block is read
out with a PPD

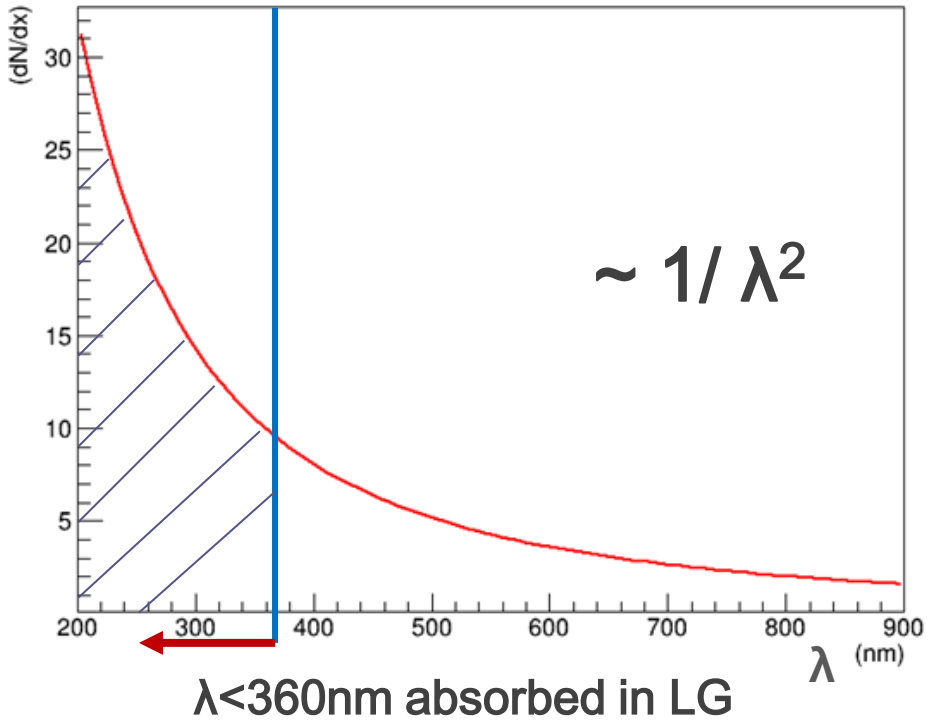
Dominant degradation of calorimetry comes from HCAL energy resolution affected by fluctuation of EM/hadron composition. ➡ Separate EM component by detecting Cherenkov.

Cherenkov light detection

- Cherenkov detector (Lead Glass and PPD)
- Detecting muon is a challenging issue with the lead glass.

Because :

- Extremely small number of photons than scintillation
- Number of photons ~ $1/\lambda^2$
- λ <360nm light absorbed in lead glass

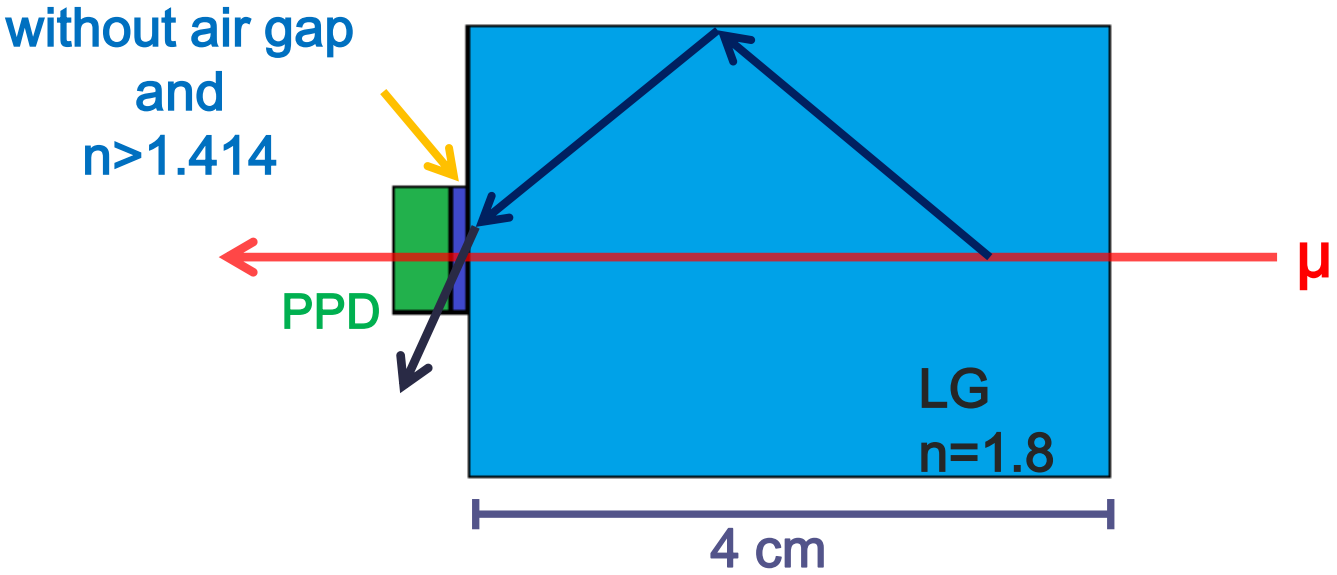


- Muon detection with this detector ensures ability of this detector also to measure EM/hadron showers.

Lead Glass (LG) + MPPC

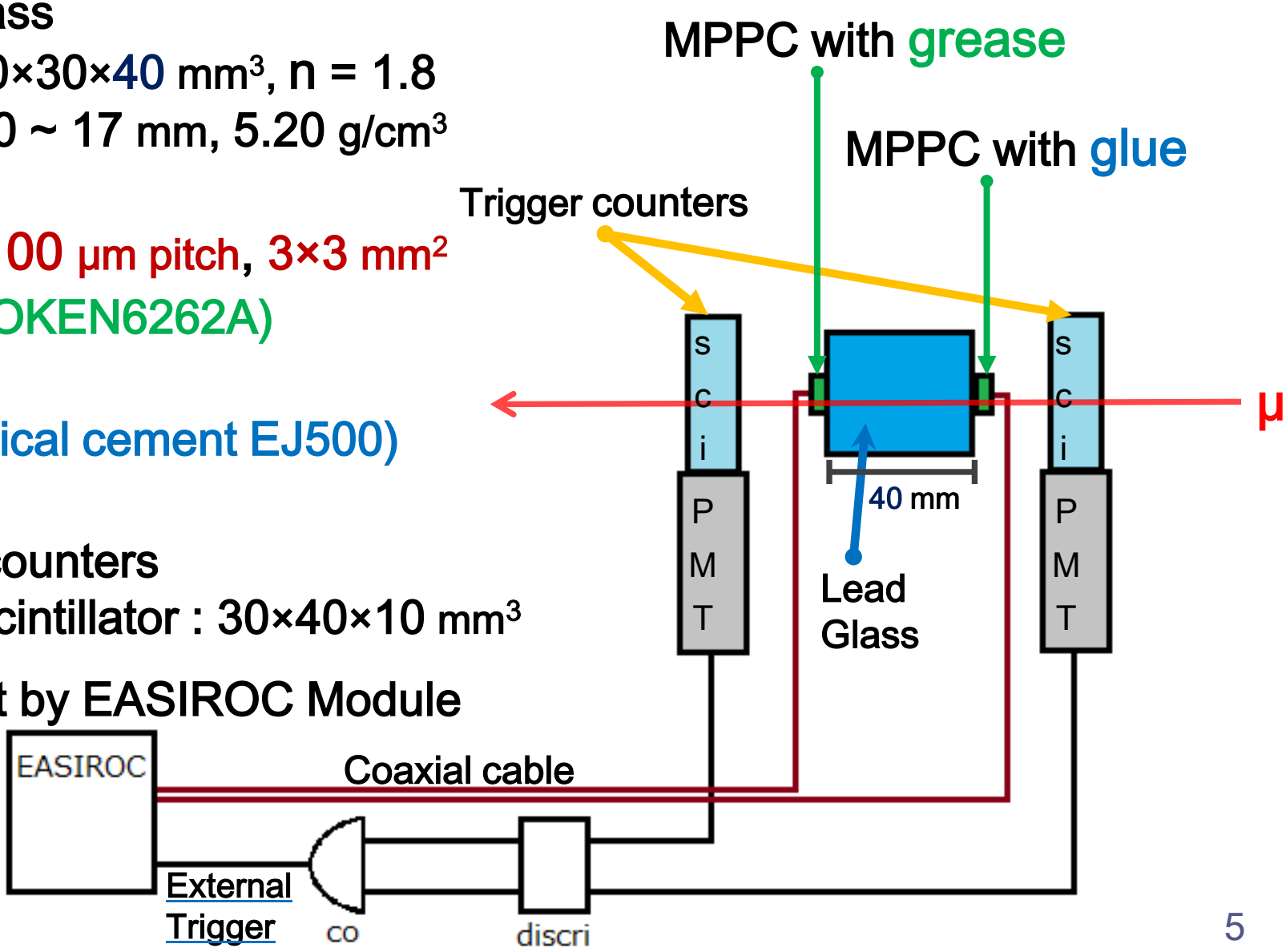
- Large refraction index of LG (n=1.8) makes total reflection angle larger
- It causes difficulty for light signal readout

- Need material with n>1.414 for readout
  - Optical grease or glue



Set up at H6 CERN

- Lead Glass
  DF6 : 30×30×40 mm^3, n = 1.8
  X0 ~ 17 mm, 5.20 g/cm^3
- PPD
  MPPC: 100 μm pitch, 3×3 mm^2
- grease (OKEN6262A)
  n = 1.45
- glue (optical cement EJ500)
  n = 1.57
- Trigger counters
  PMT + scintillator : 30×40×10 mm^3
- Read out by EASIROC Module



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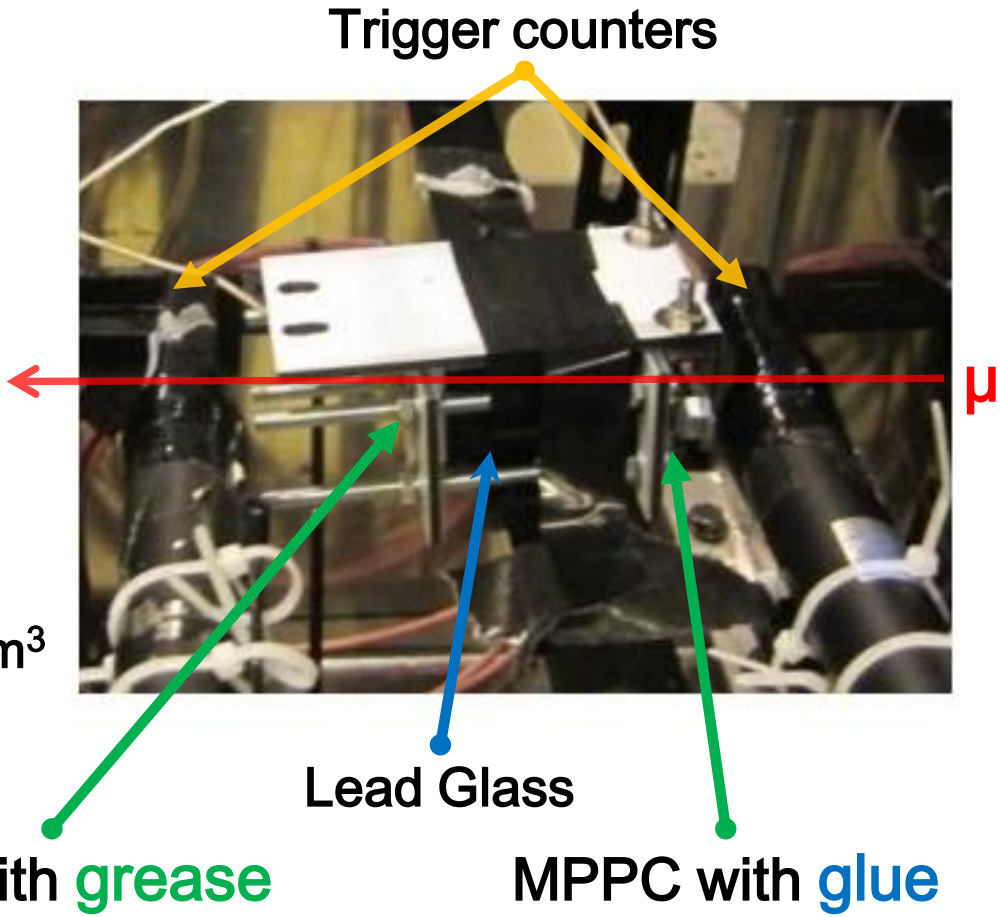
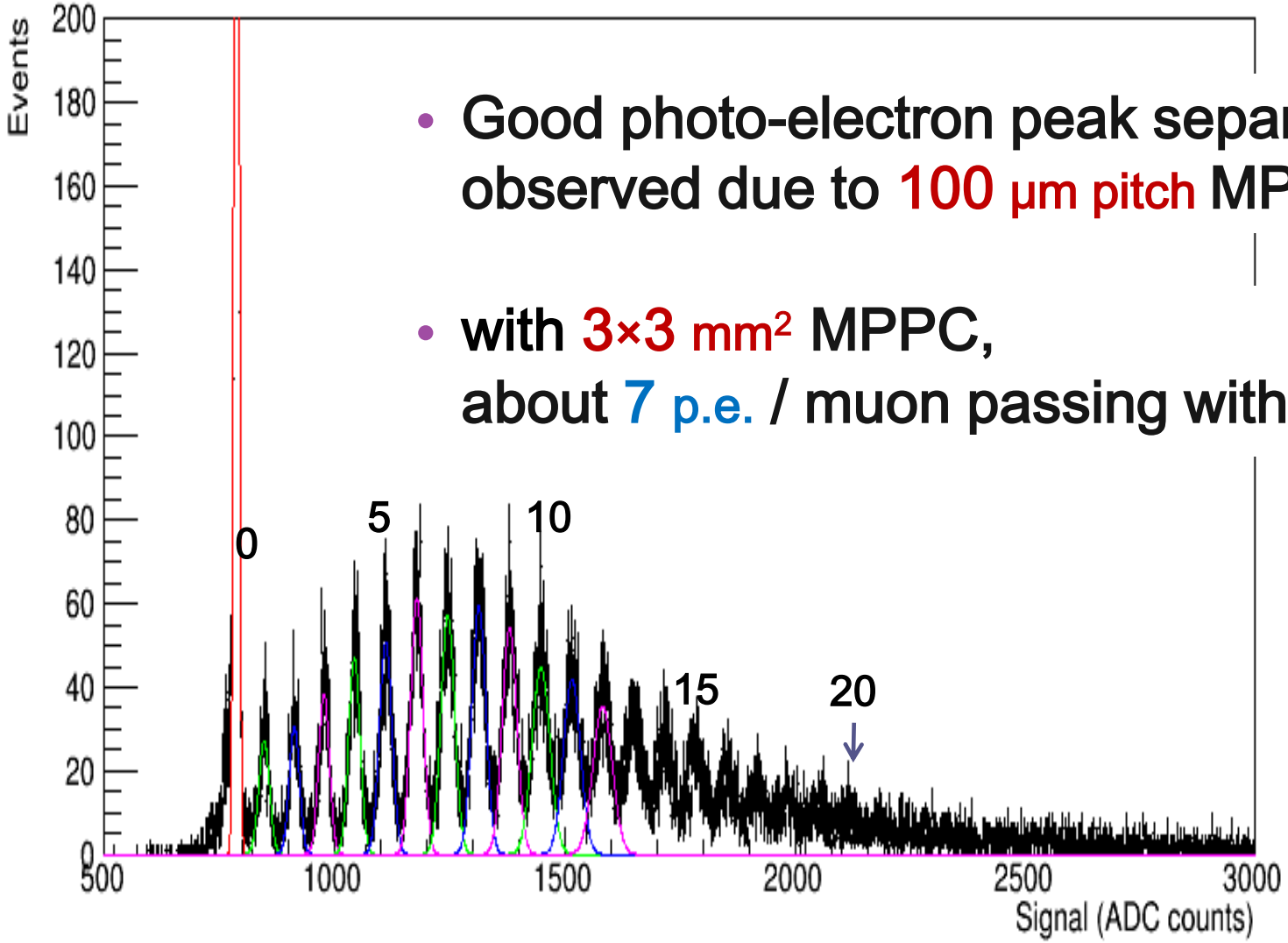


Cherenkov signal by muon (50 GeV)

- with grease
- dV = 1.1 [V]



- Good photo-electron peak separation observed due to 100 μm pitch MPPC.
- with 3×3 mm^2 MPPC, about 7 p.e. / muon passing with 4 cm long

Cherenkov signal by muon (50 GeV)

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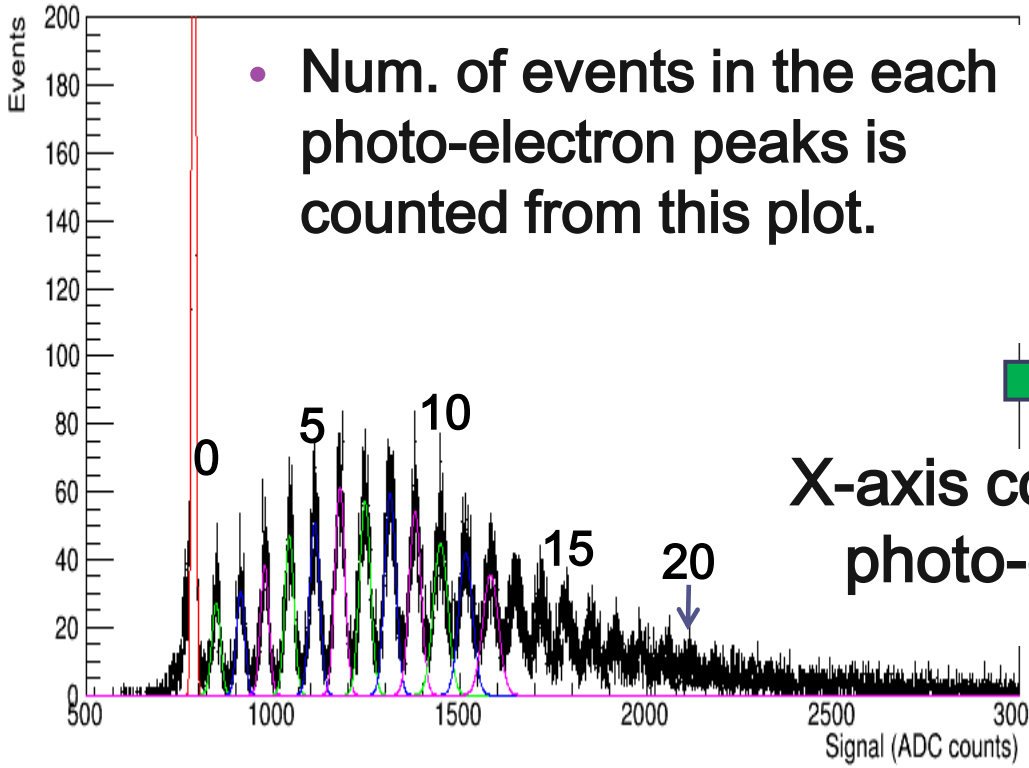
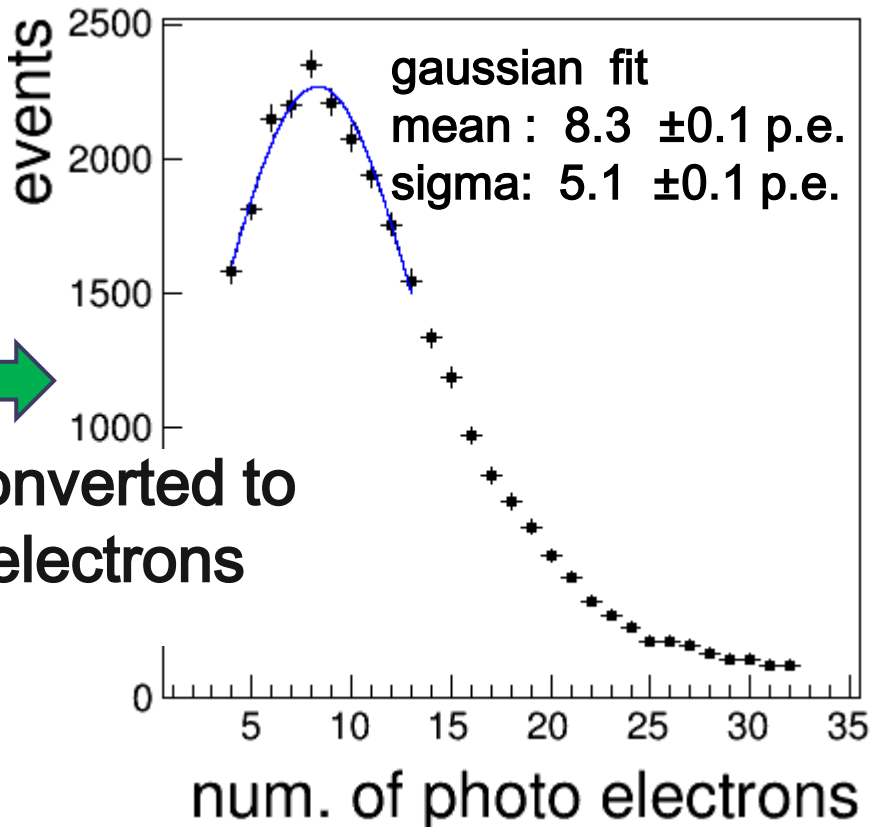
- dV = 1.1 [V]



- Num. of events in the each photo-electron peaks is counted from this plot.

X-axis converted to photo-electrons

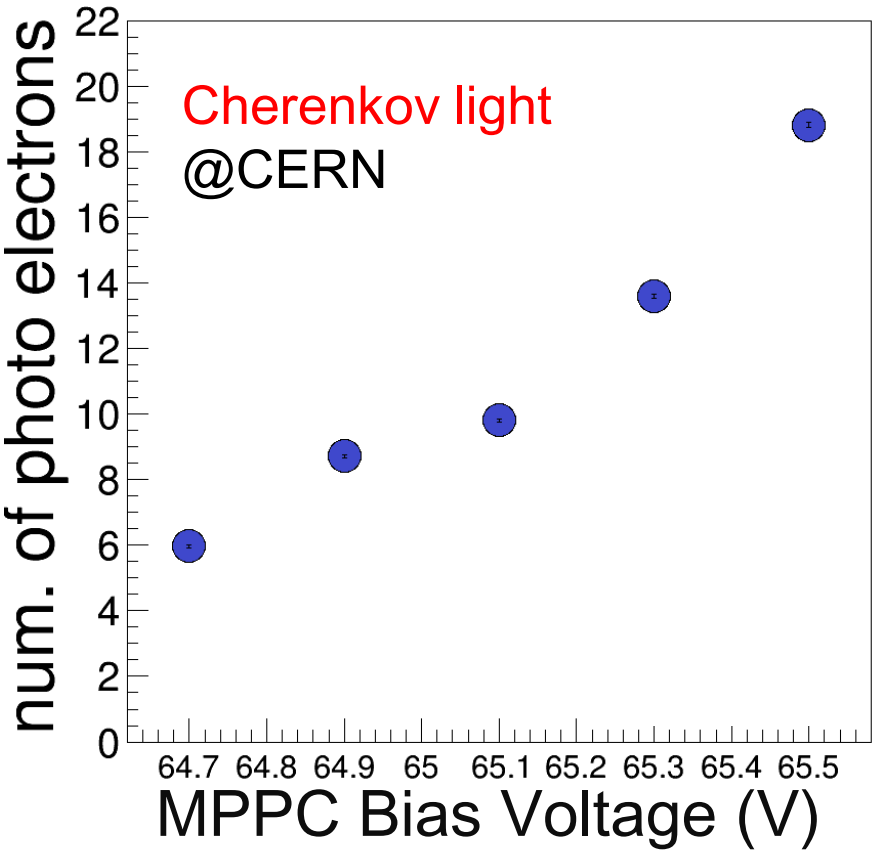


Cherenkov light with grease case :

- 8.3 ±0.1 p.e.

Bias Voltage dependence with muon beam

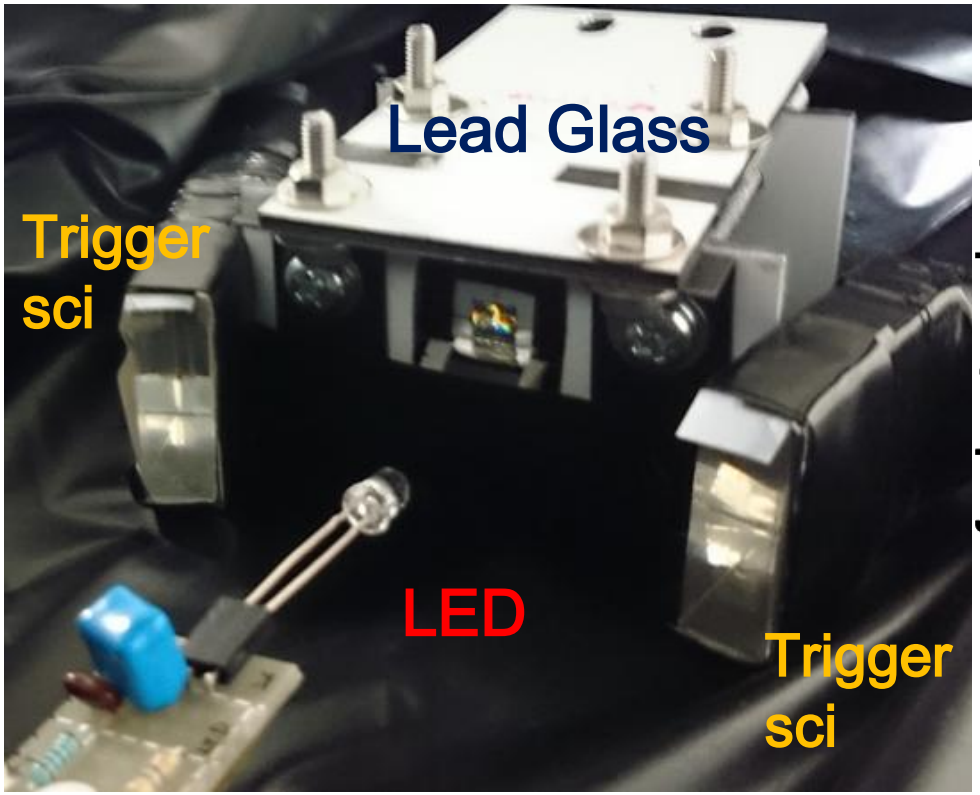
From the MPPC with grease data at CERN

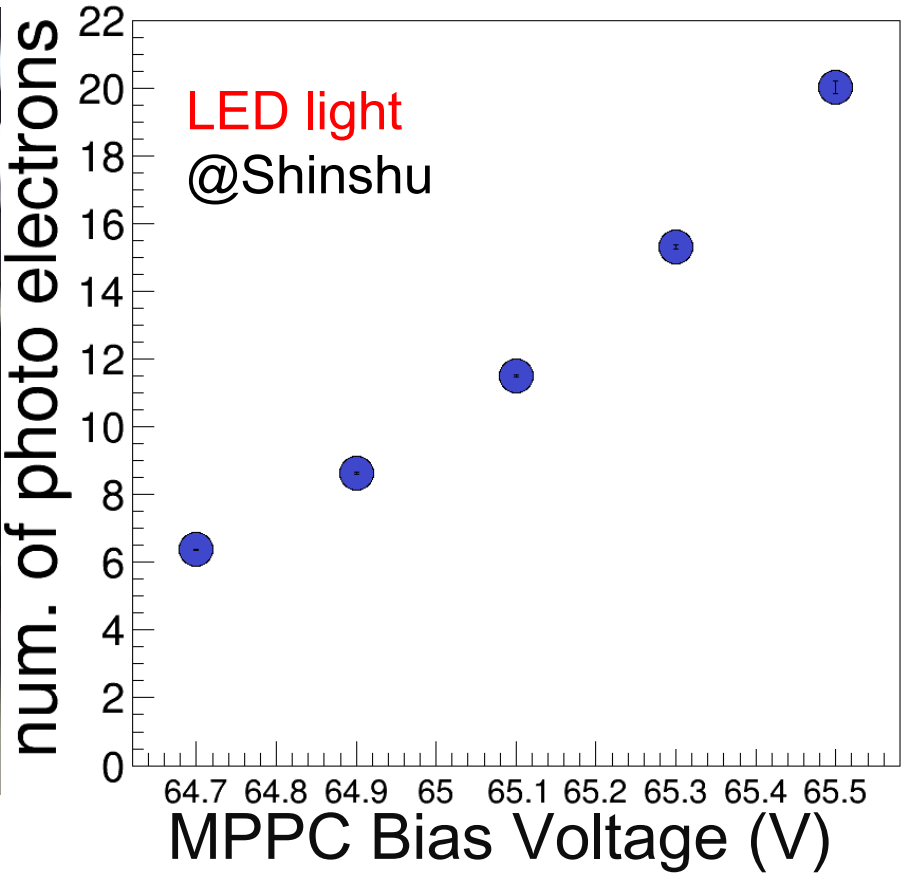


Observed number of photo-electrons largely depends on bias voltage of the MPPC

Bias Voltage dependence test with LED system

From the MPPC with grease data at shinshu

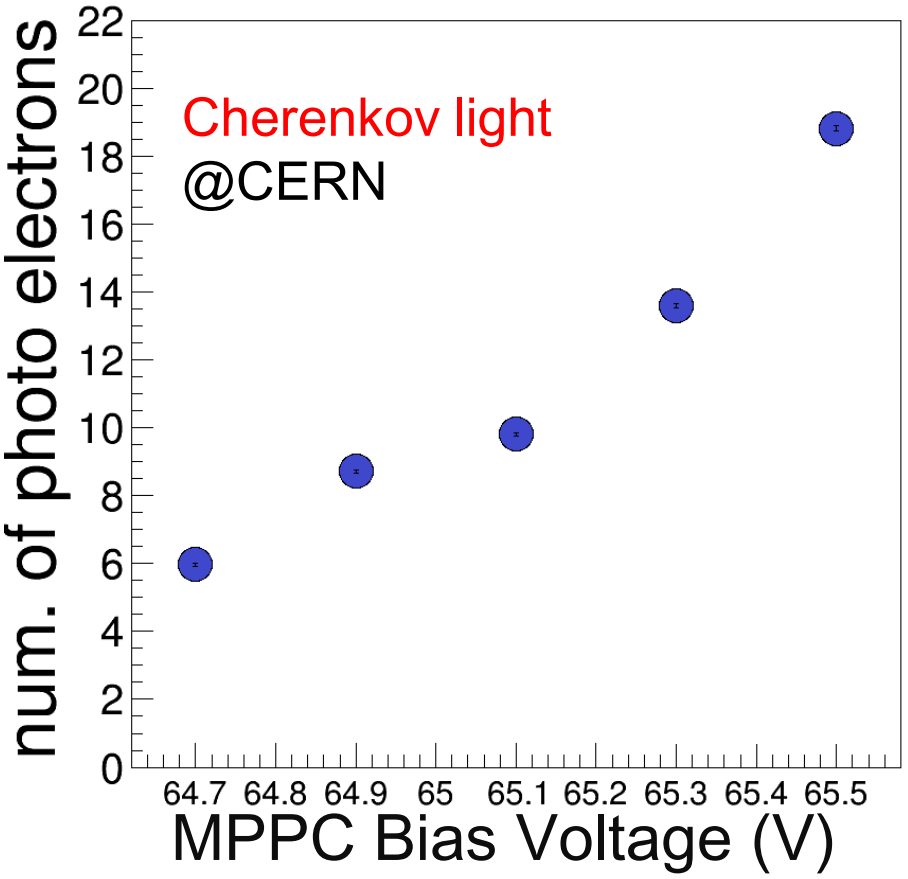


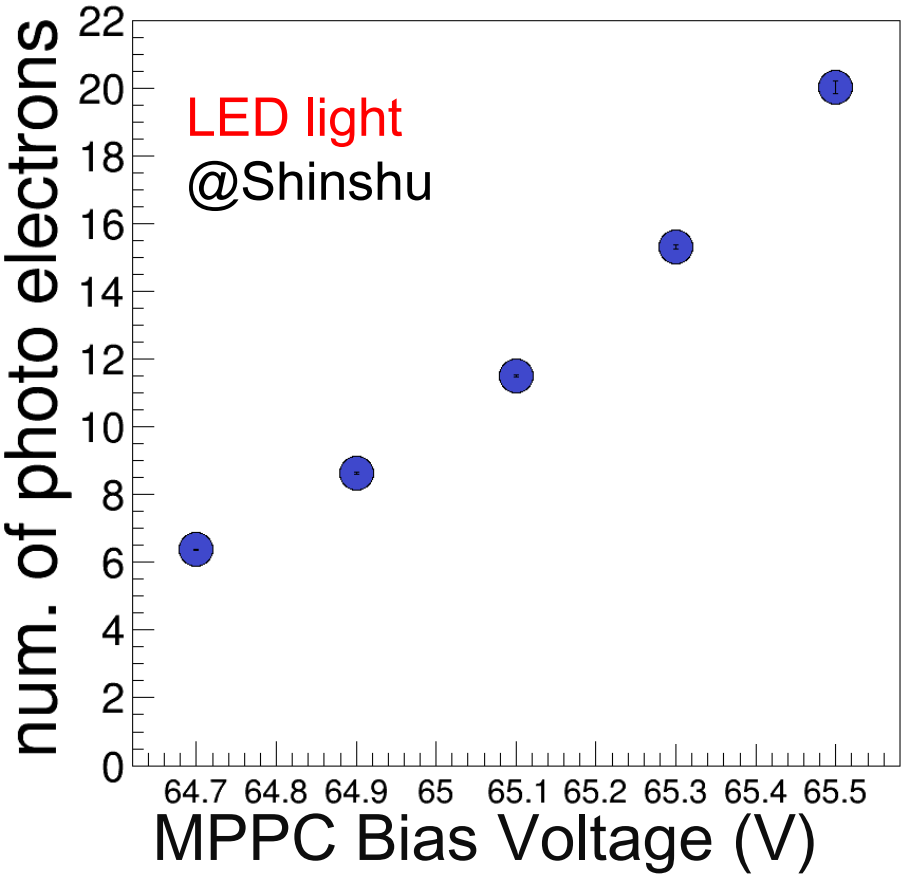


V_{bias} dependence of light yield is confirmed by LED system.

Bias Voltage dependence

Again comparison of Vbias dependence with grease





V_{bias} dependence of the observed light yield
Comes from change of MPPC property on V_{bias}
(Photon Detection Efficiency, Xtalk)

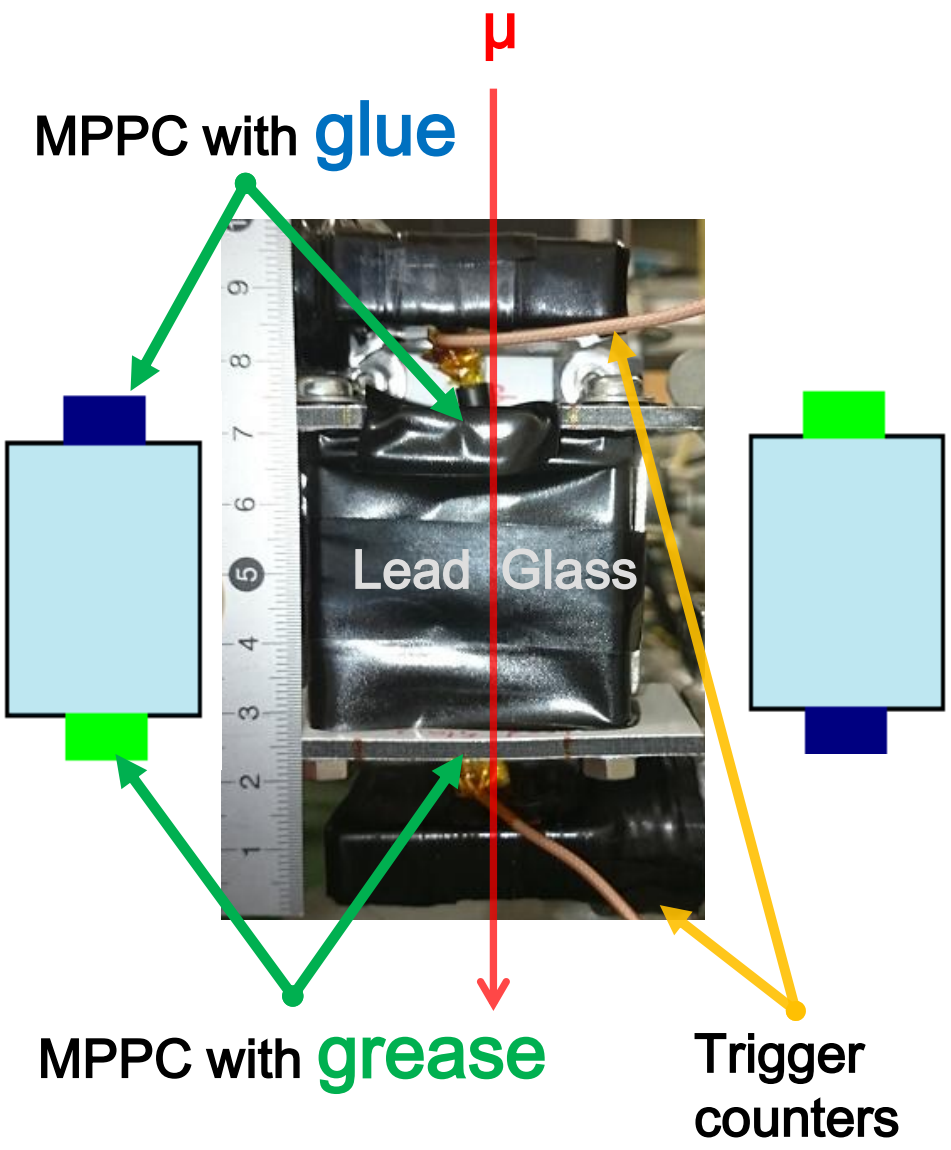
Summary

- Result of Cherenkov light detection at H6 CERN

	dV	p. e.
grease	+1.1	8.3 ±0.1
glue	+1.3	14.3 ±0.1

- Good enough for muon detection … this detector can work for shower measurement !
- Observed num. of photo-electrons depends on MPPC bias voltage. … need to be careful, “p.e.” is affected by MPPC condition.
- For fair comparison about grease and glue case, cosmic ray test is going.
- Measure the EM shower

On going cosmic ray test



- For fair comparison about grease and glue case
- using cosmic ray

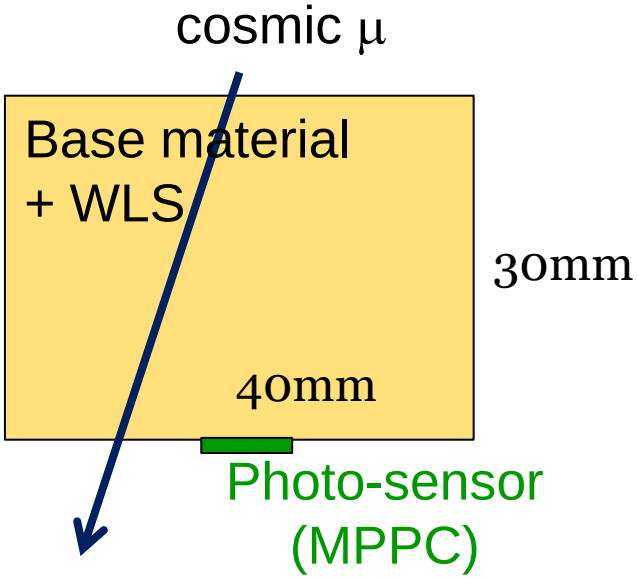
4 cm

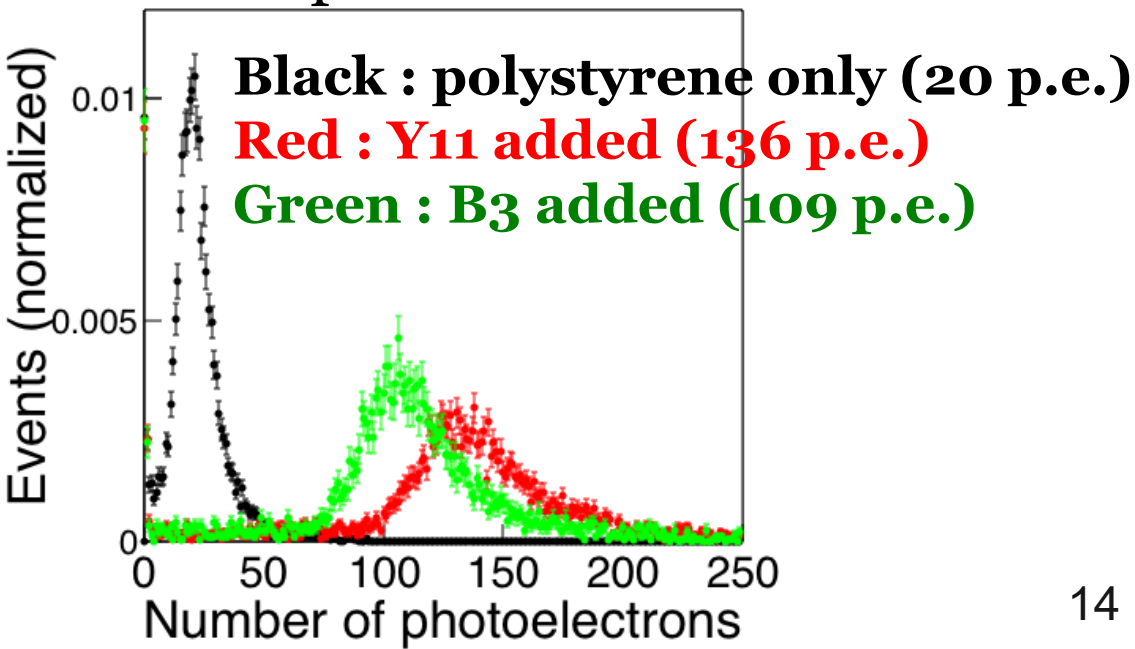
- MPPC with grease and MPPC with glue attached to upper part and under part of Lead glass.

Possible Further improvement

- Cerenkov light tends to have short wavelength ($dN/d\lambda \sim 1/\lambda^2$).
- Almost of glasses/plastics are not transparent for short wavelength photon.

- Idea to detect more Cerenkov photon -
  Shift wavelength longer by putting WLS material !
  - Candidate WLS : organic (Kuraray Y11, B3), inorganic quantum-dots (CdTl, etc)
- Polystyrene + organic WLS have proven this idea!

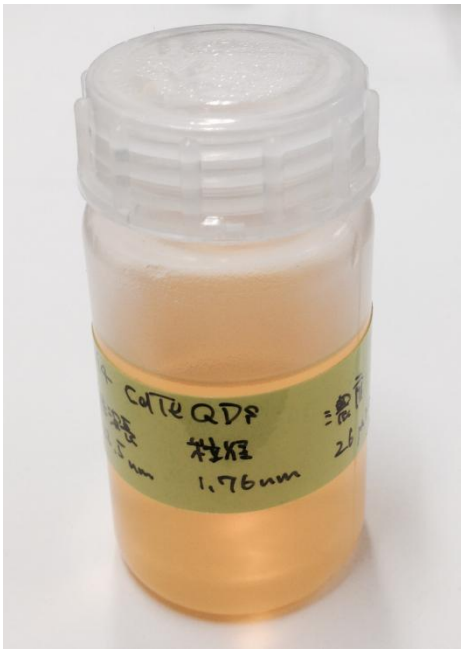


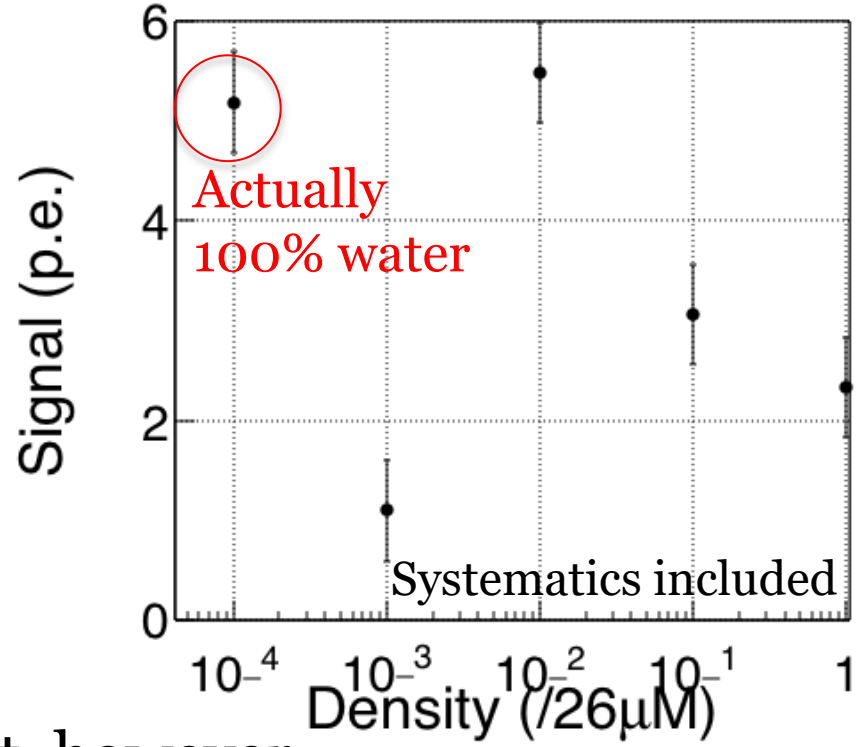


Possible Further improvement

However for total measurement HCAL, we need heavy base material + inorganic WLS.

Test result of CdTl quantum-dot solvent





No improvement observed yet, however
we will test more different types of inorganic WLS materials for dream of the total measurement HCAL !!

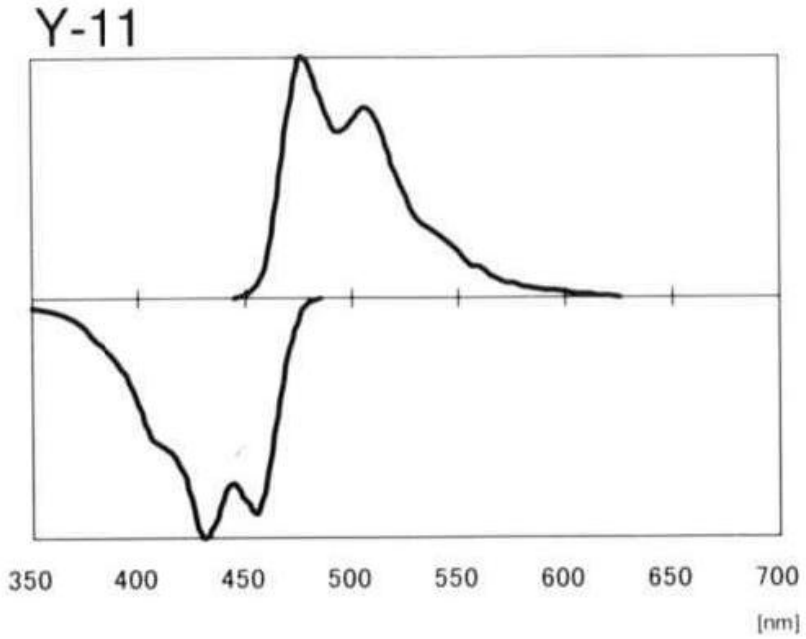
Back up

Kuraray WLS absorption & emission spectra

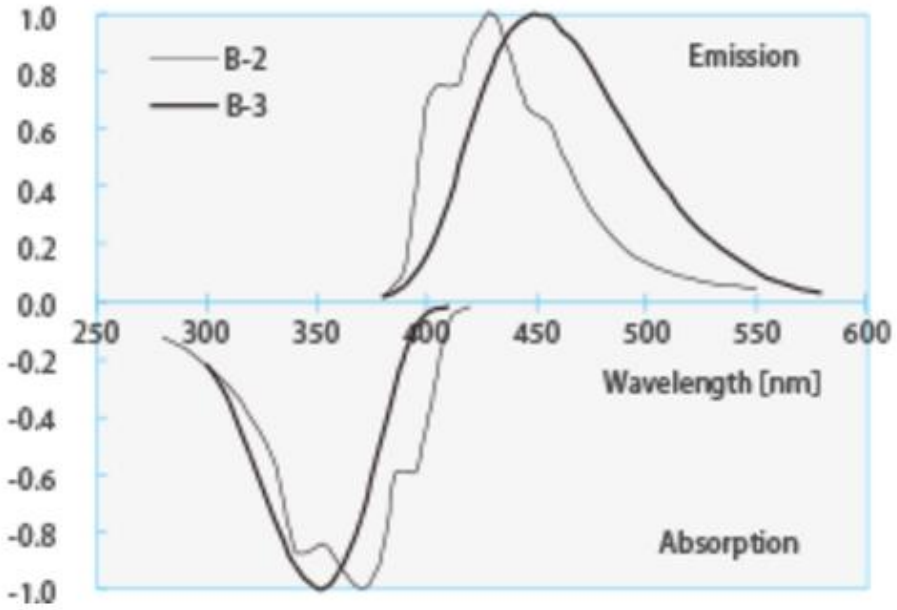
http://kuraraypsf.jp/psf/ws.html

Absorption/Emission (arbitrary unit)

Blue to Green shifter



B-2, B-3 UV to green shifter



Wavelength [nm]

CdTl quantum dots abs/emission spectra

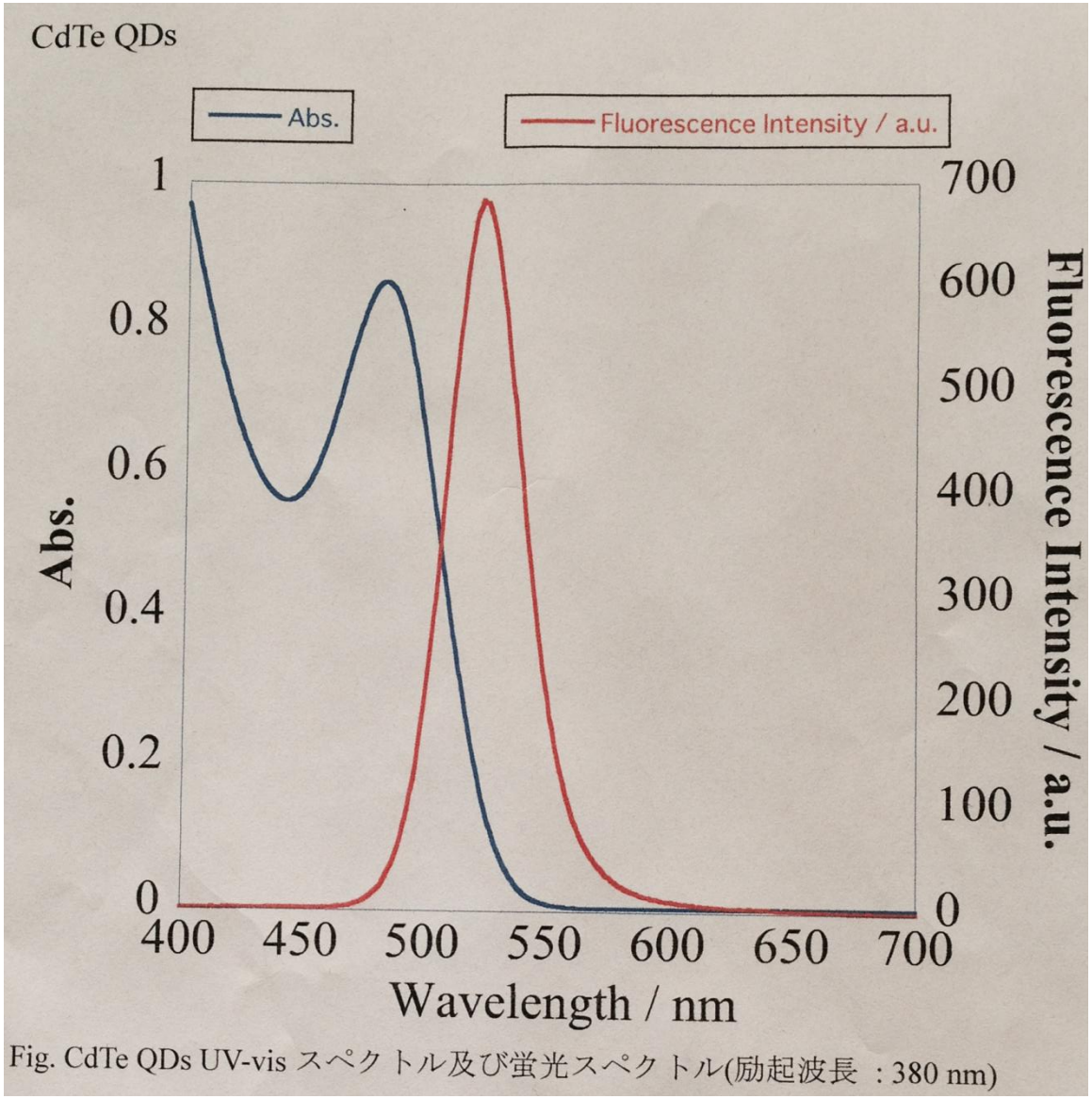
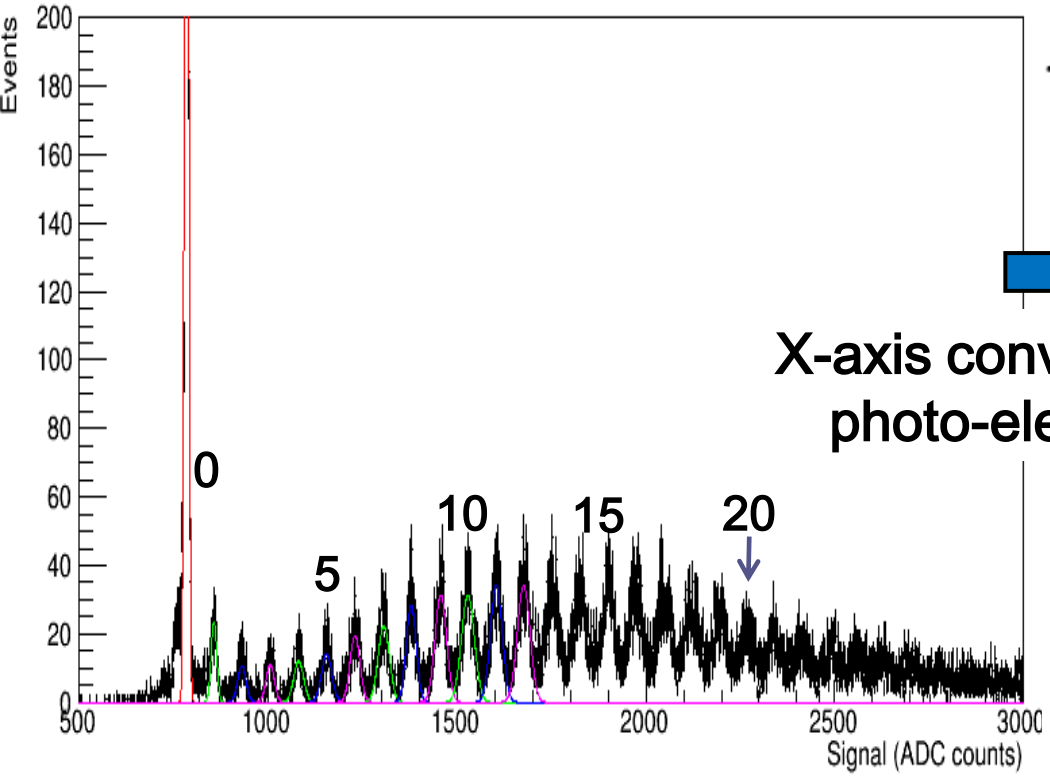


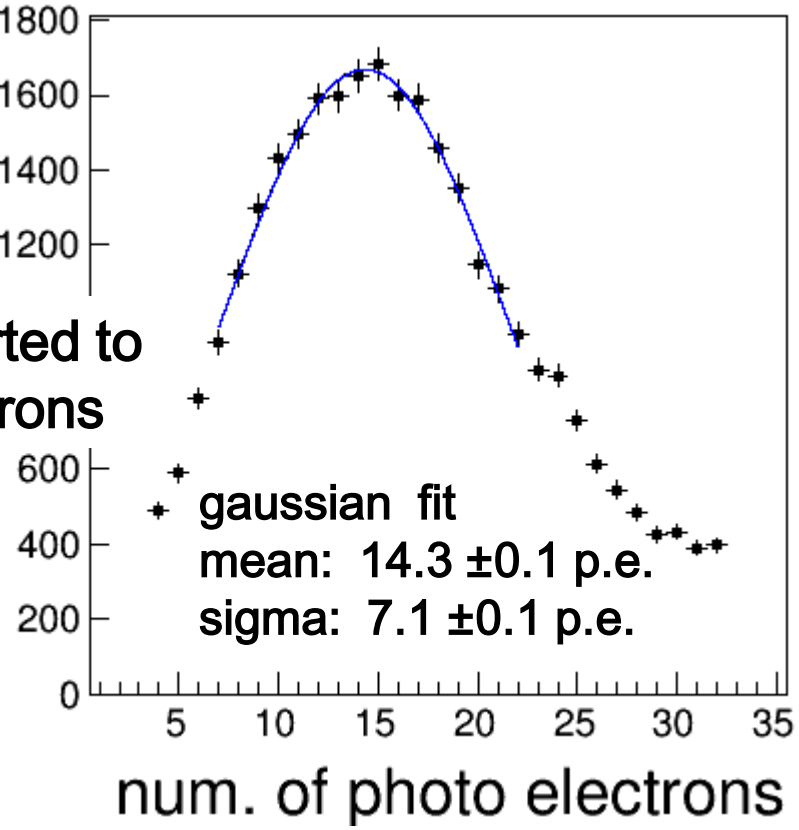
Fig. CdTe QDs UV-vis スペクトル及び蛍光スペクトル(励起波長 : 380 nm)

Cherenkov signal by muon (50 GeV)

- with glue
- dV = 1.3 [V]



X-axis converted to photo-electrons



Cherenkov light with glue case :

- 14.3 ±0.1 p.e.

MPPC, grease, glue

- S12572 - 100C[ch0 : 4B000280, ch1 : 4B000278]
  Effective photosensitive area : 3mm×3mm
  Pixel pitch : 100μm
  Number of pixels : 900
  Window refractive index : 1.59

- OKEN6262A
  Refractive index : 1.453

- EJ500
  Refractive index : 1.57

EASIROC and delay for external trigger

EASIROC()

- Set HV : 69.26 [V]
- UDP biasV : 68.26 [V]
- InputDAC ch0 : 330, ch1 : 330
  (ch0 : dV = 1.1 [V], ch1 : dV = 1.3 [V])
- Shaping time : 25 [ns]
- Amp : 100 [fF]

DELAY

- DELAY module : 40 [ns]
- Lemo cable : 8 [ns]

Trigger signal

- width : 60 [ns]

MPPC dV at H6 CERN

- V– ref V + (DAC - 255) × 0.02
- V : setHV – 1.3
- ref V : 2.5 or 4.5 [V]
- DAC : 256 ~ 511, ch0 : 330, ch1 : 330, 1bit = 0.02 [V]

- (69.26-1.3) – 4.5 + (330 - 255) × 0.02

by the result of DAC test at shinshu
ch0 : 1.52 [V]
ch1 : 1.59 [V]

- ch0 : MPPC with grease (V_{bd} : 63.85 ±0.08 [V])
  (69.26 - 1.3) - 4.5 + 1.52 = 64.98 [V]
  dV = 1.1 [V]

- ch1 : MPPC with glue (V_{bd} : 63.73 ±0.07 [V])
  (69.26 - 1.3) - 4.5 + 1.59 = 65.05 [V]
  dV = 1.3 [V]

Lead glass

- DF6
- n = 1.8
- X0~17mm
- I nuclear interaction length = 17cm
- Density 5.20 g/cm3

  from
  performance of the VENUS lead-glass calorimeter at TRISTAN
- Radiation length 1.69 cm
- Critical energy 12.6 MeV
- Refractive index (rid) 1.805