

Low Temperature R&D

19/05/14

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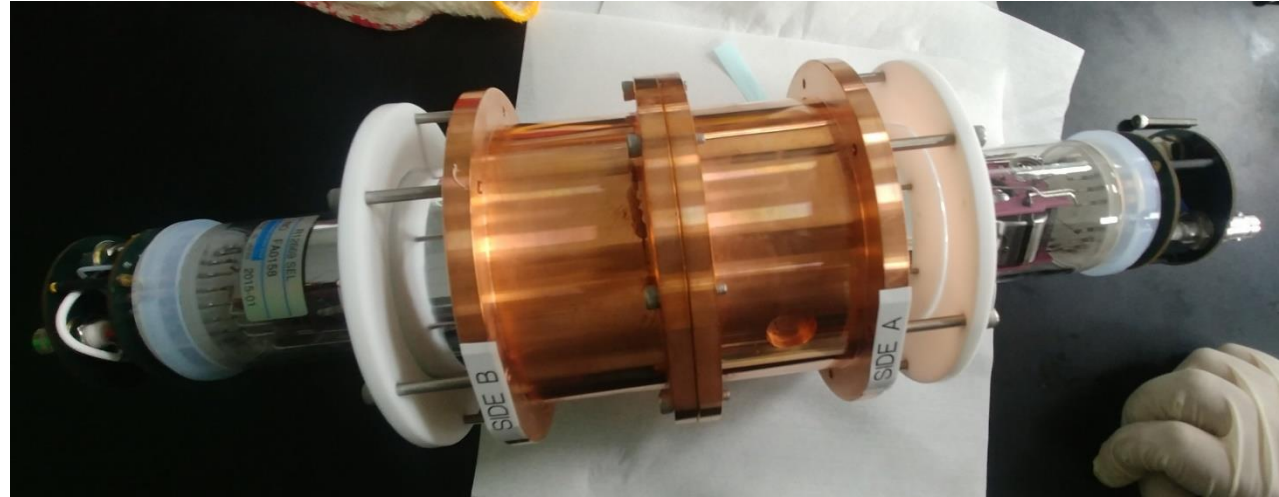
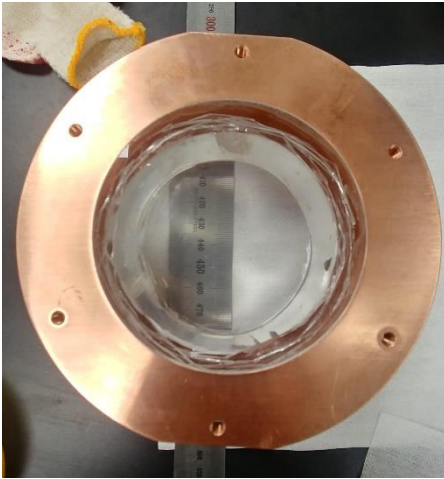
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- Experiment Setup
- PSD between alpha and gamma according to temperature change
- PSD between neutron and gamma according to temperature change

Purpose of Low Temperature Experiment

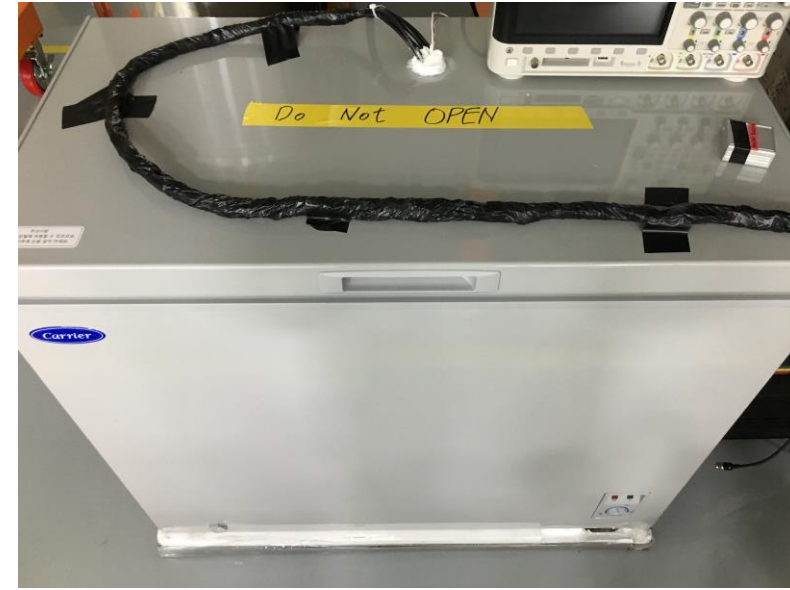
- To check light yield of NaI crystal according to temperature change
- To observe PSD(alpha, neutron, beta/gamma) when temperature goes down
- To measure PMT noise as a function of temperature

Low Temperature R&D NaI(Tl) Crystal(NaI-031)

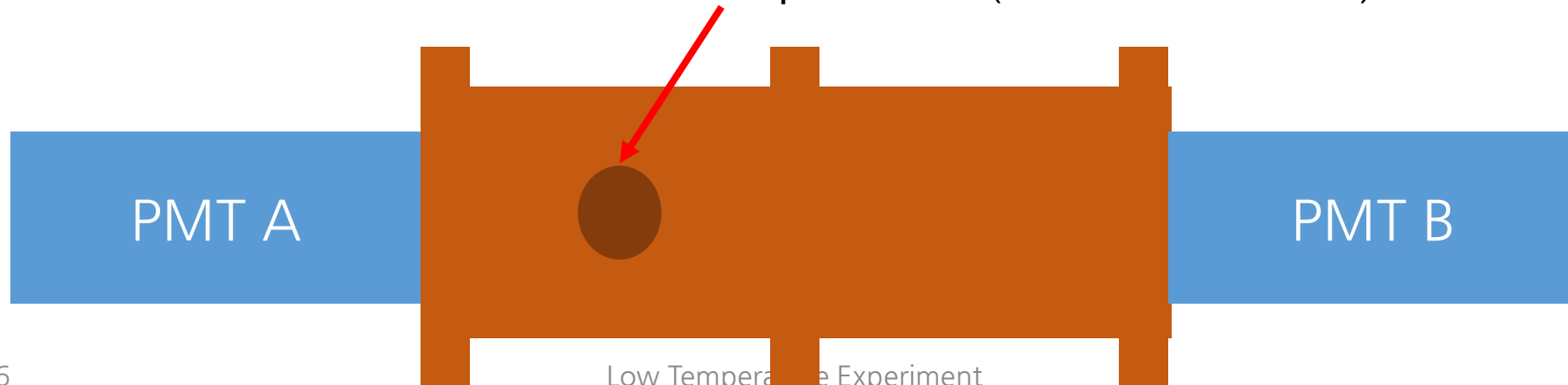


- NaI-031 (SICCAS)
 - diameter : 75mm, height : 75mm
 - Weight(expected) : 1.2 ± 0.12 kg
 - Alpha Activity : 0.73 ± 0.16 mBq/kg
- PMT(SIDE A) : FA0056
- PMT(SIDE B) : FA0158

Experiment Setup

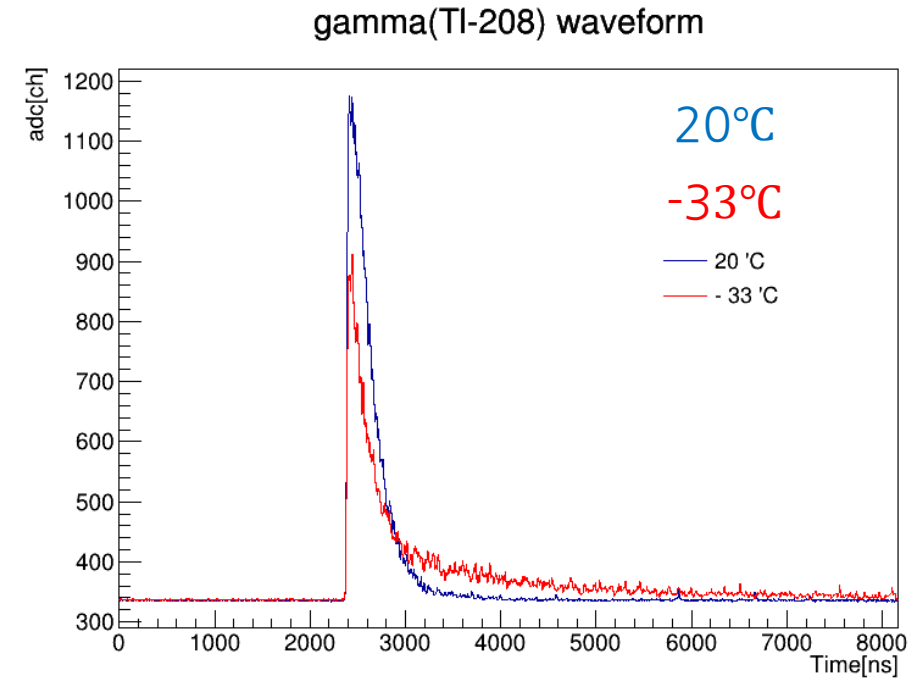
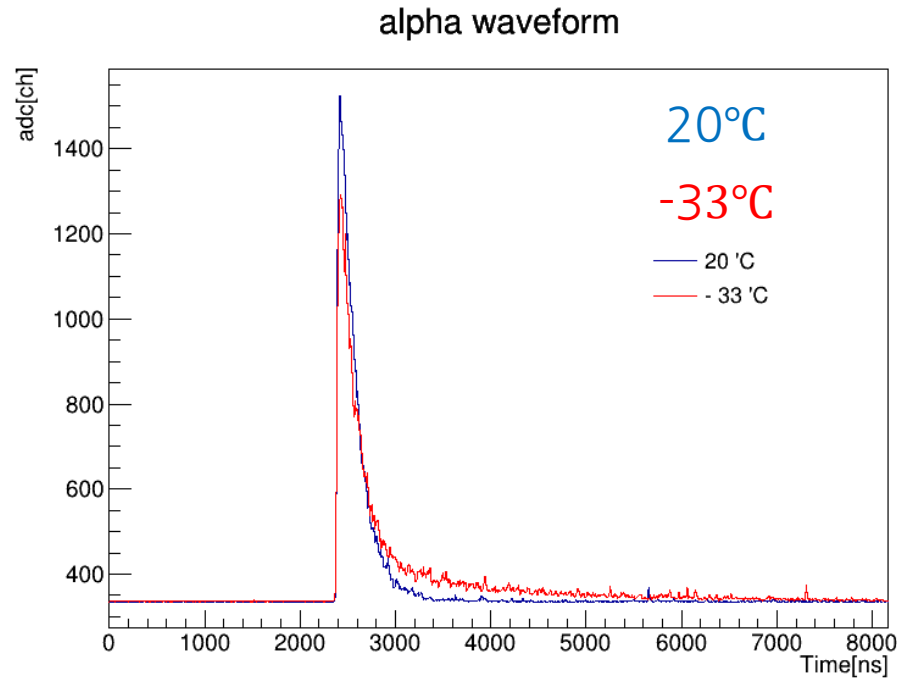


- We took data at 20 °C and -33 °C
 - Refrigerator(-33 °C)
- Source position(for calibration)



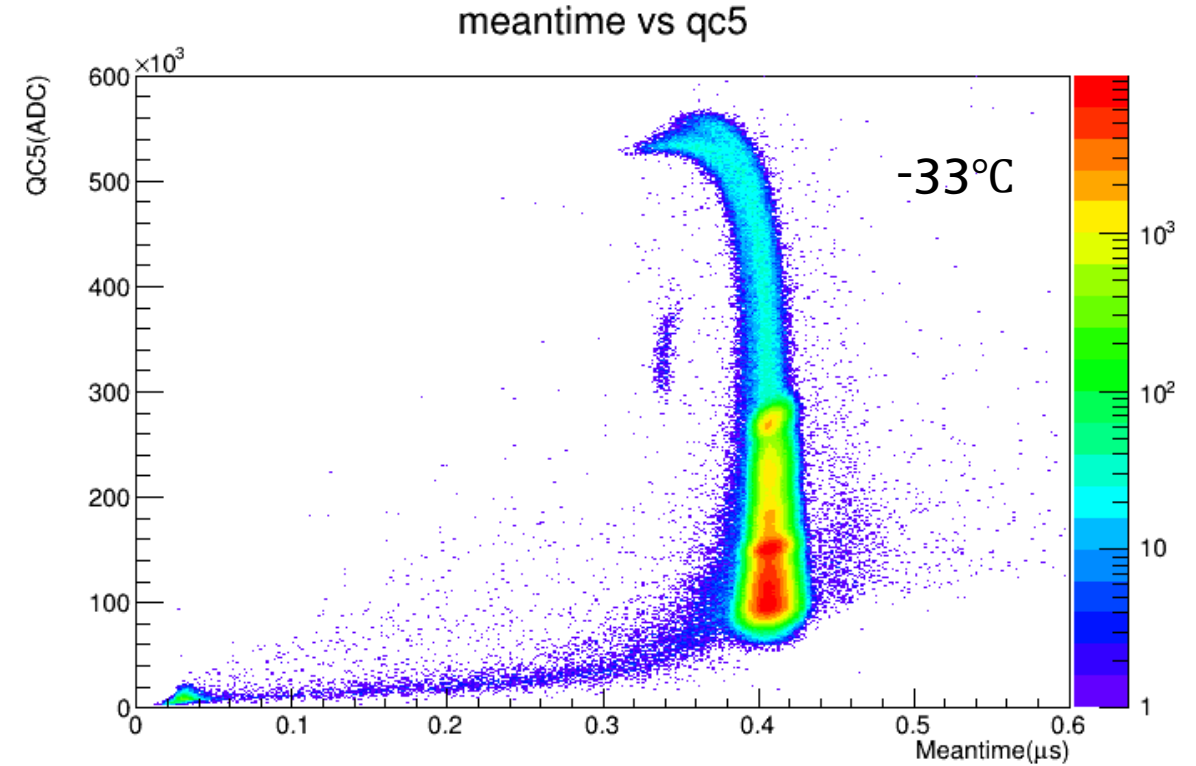
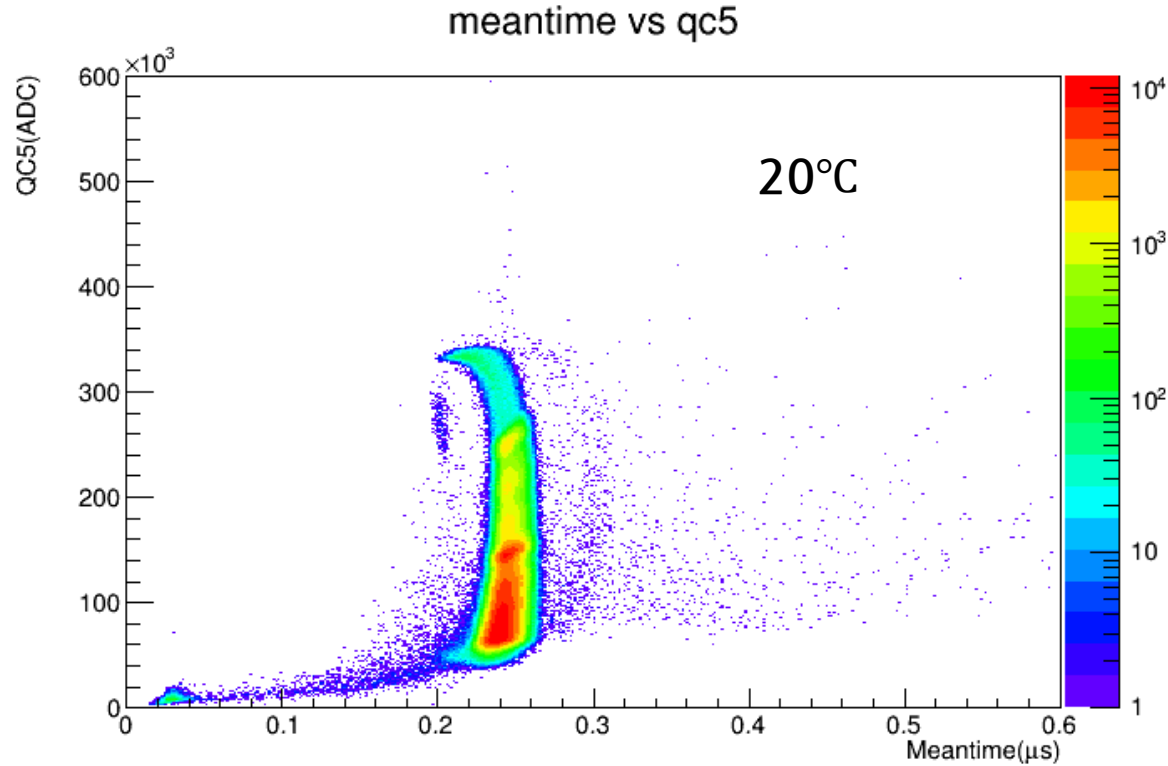
PSD(alpha, gamma)

- Raw waveform



- height at room temperature is higher than height at low temperature
- wave decay time at room temperature is faster than wave decay time at low temperature

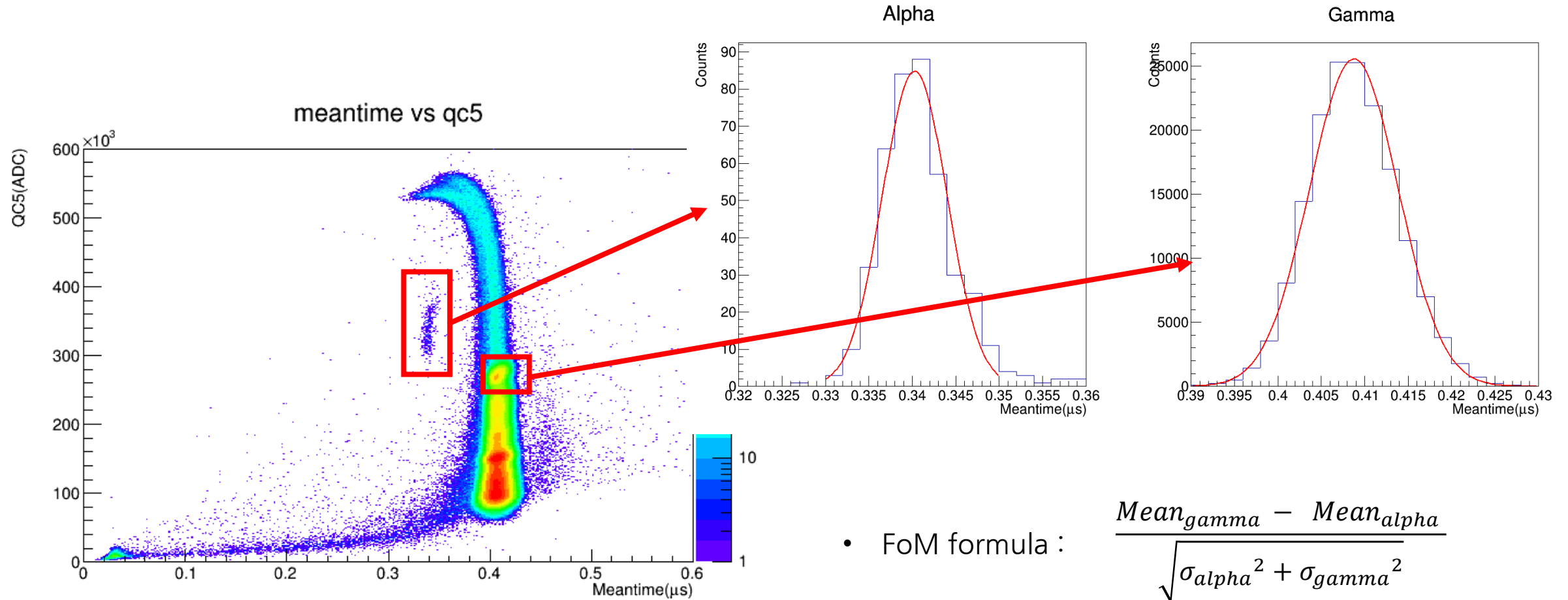
PSD(alpha, gamma)



- integration[start to 1.5us] meantime vs adc sum[start to 5us]

PSD(alpha, gamma)

- PSD from alpha events and gamma events using meantime variable



- FoM formula :

$$\frac{Mean_{gamma} - Mean_{alpha}}{\sqrt{\sigma_{alpha}^2 + \sigma_{gamma}^2}}$$

- Alpha events from Po-210
- Gamma peak from Tl-208 gamma decay(2614 keV)

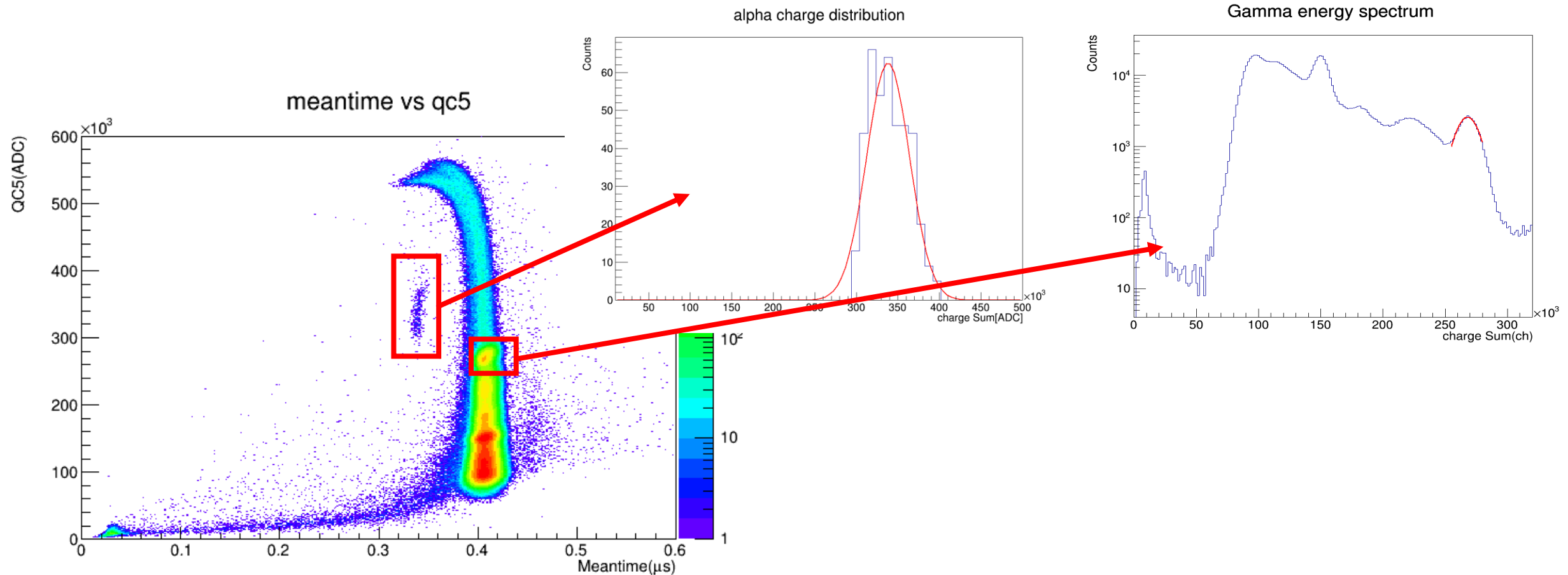
PSD(alpha, gamma) using FoM result

temp	FoM of PSD(alpha, gamma)		
	Integration meantime [start to 1us]	Integration meantime [start to 1.5us]	Integration meantime [start to 2us]
20°C	5.82±0.26	6.06±0.27	5.53±0.32
-33°C	6.03±0.25	7.76±0.36	6.92±0.34

- PSD power at low temperature is better than PSD power at room temperature
- Using integration[start to 1.5us] for PSD is better than using other variables
- FoM is 28 ± 0.01 % increased at -33°C(meantime 1.5us)

Light output(alpha, gamma)

- Alpha and gamma(Tl-208) energy spectrum



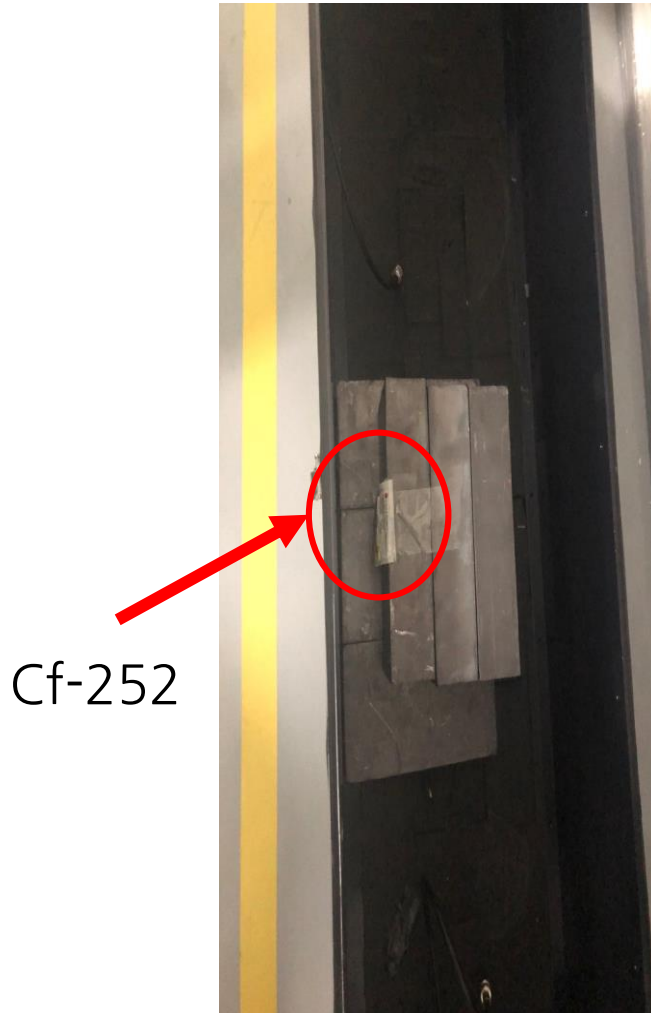
- Alpha events from Po-210
- Gamma peak from Tl-208 gamma decay(2614 keV)

Light output(alpha, gamma)

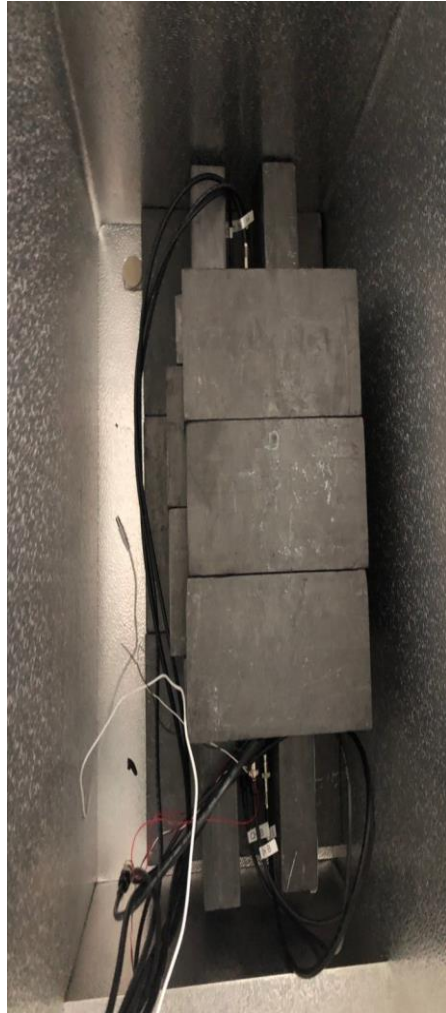
temp	Mean of Charge Sum(light output)		
	Alpha[adc sum]	Gamma(Tl-208) [adc sum]	Ratio(alpha/gamma)
20°C	$2.67e5 \pm 2.77e3$	$2.47e5 \pm 3.89e2$	1.08 ± 0.01
-33°C	$3.38e5 \pm 1.49e3$	$2.67e5 \pm 7.71e1$	1.26 ± 0.005

- Light output(charge sum) is increased at -33°C
- Ratio(alpha/gamma) at -33°C is higher than Ratio at 20°C

Experiment Setup(Neutron)



Cf-252

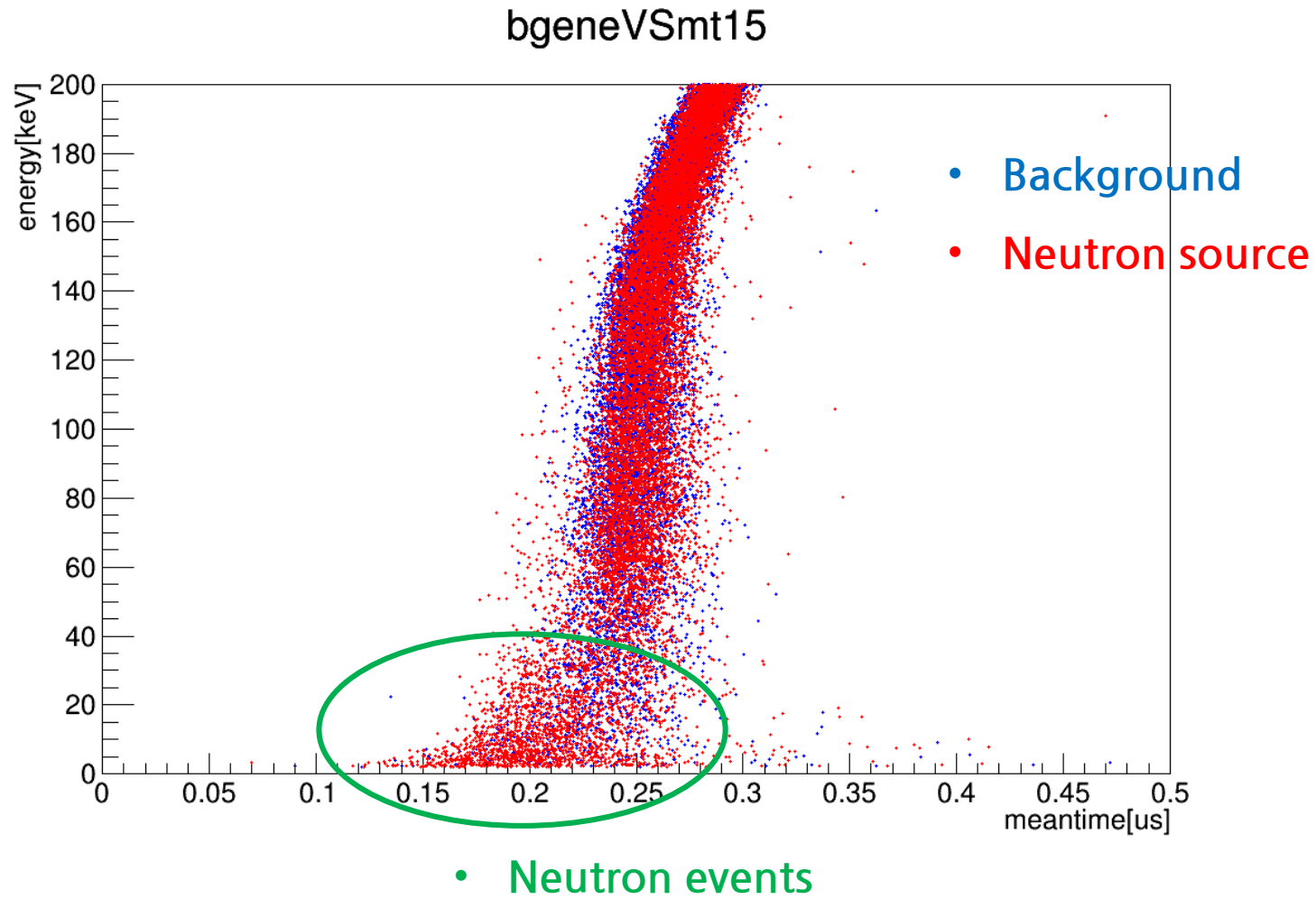


- Neutron source : Cf-252
- Shielding thickness : Pb 20cm
- We took data at 20 °C and -33 °C
- Comparing neutron source with background

• Outside(in dark box)

• Refrigerator(-33 °C)

PSD(neutron, gamma)

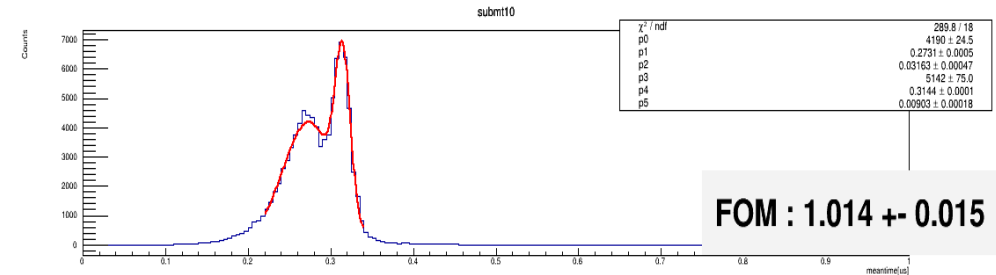
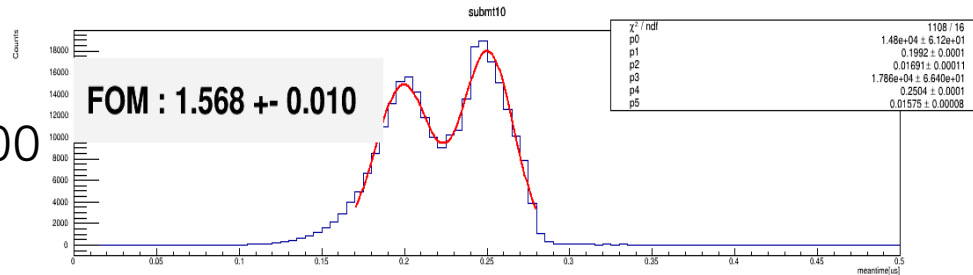


- Comparing neutron source data with background data

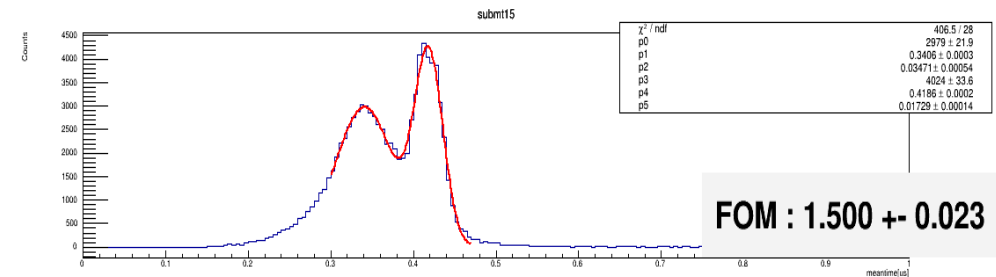
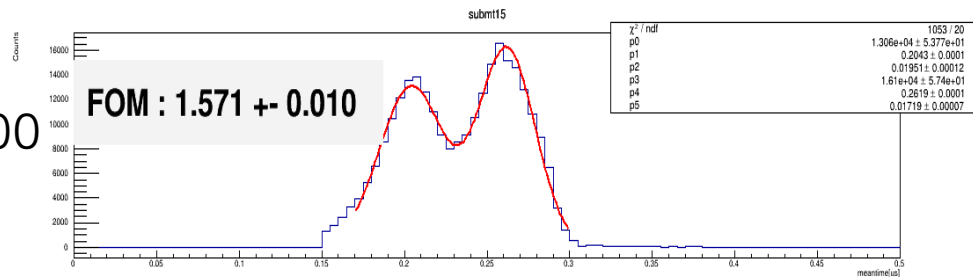
PSD(neutron, gamma)

- Subtract background data from Cf-252 source data (energy cut(2keV< energy <200 keV))

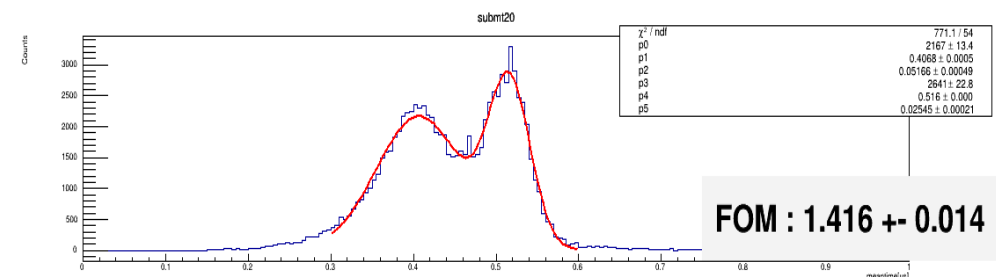
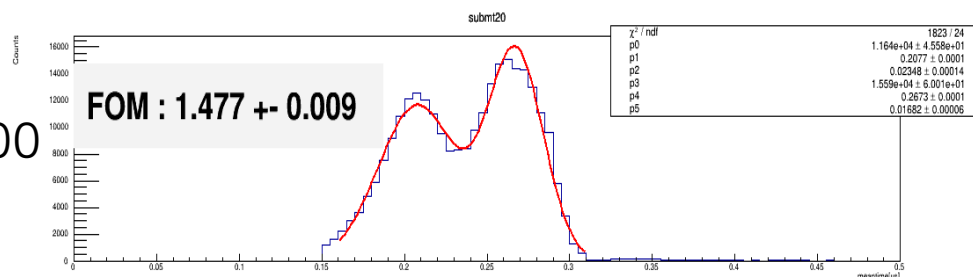
- nmt1000



- nmt1500



- nmt2000



20°C(100 hour data)

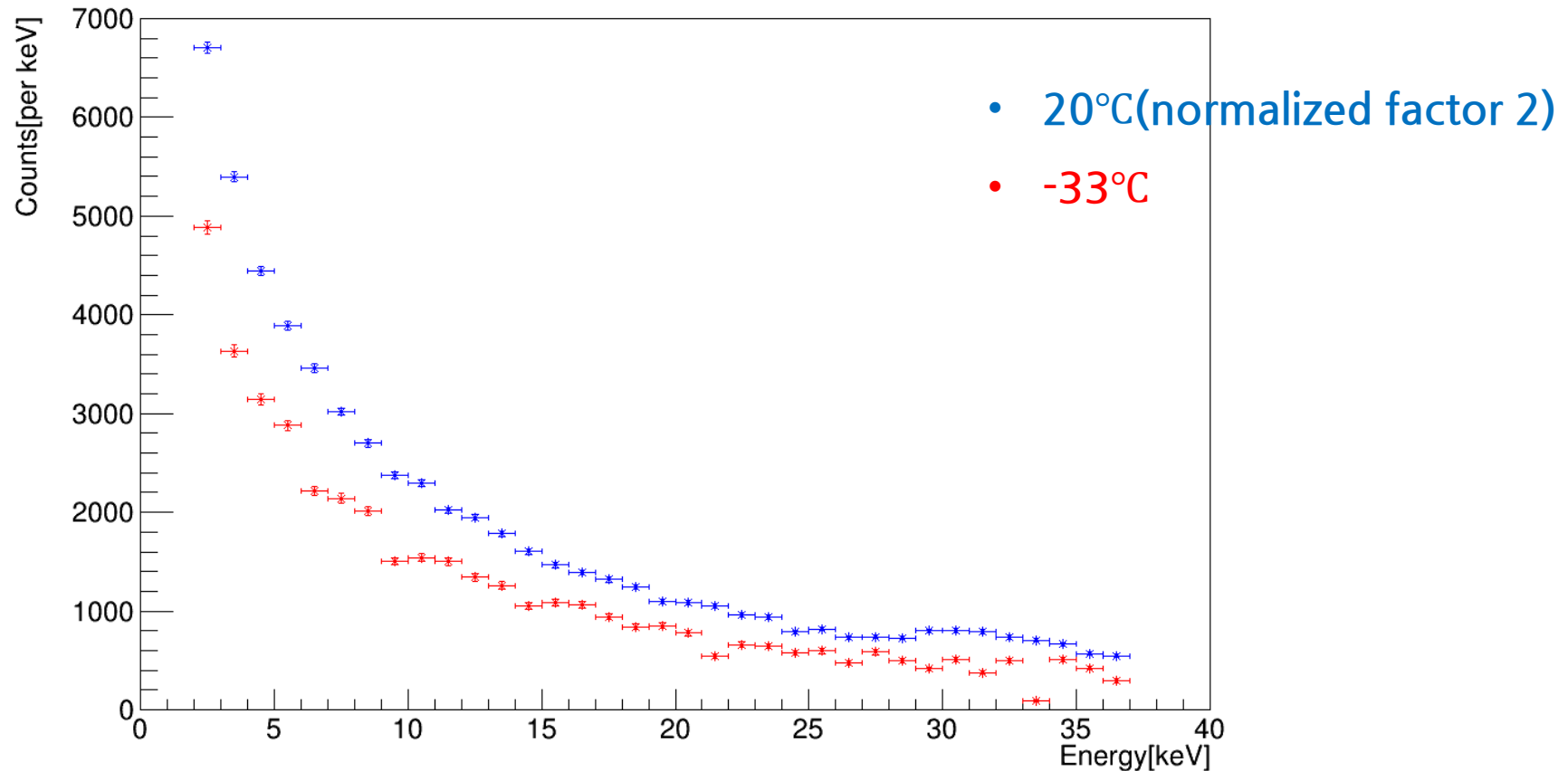
1D meantime

-33°C(50 hour data)

- PSD power at room temperature looks better than PSD power at low temperature (when energy range is 2 keV to 200 keV)

PSD(neutron, gamma)

neutron energy spectrum



50 hour data

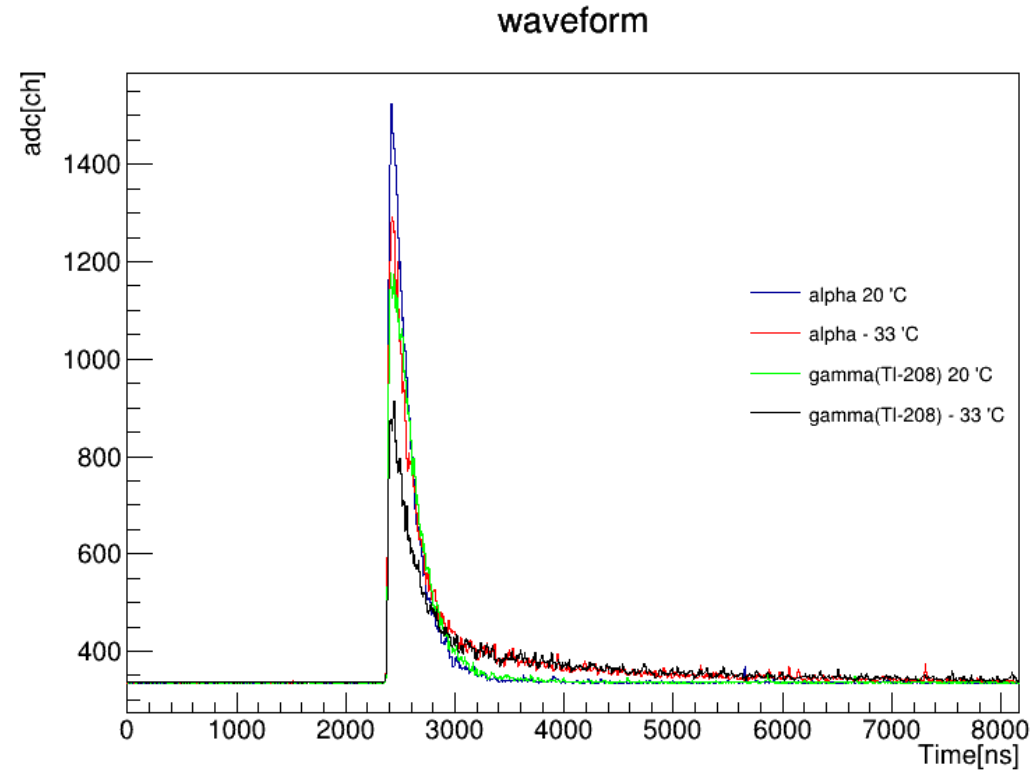
- Using Gaussian fitting, estimating the number of neutron events each energy region(1 keV division)
- Quenching factor of low temperature neutron events could be larger than room temperature neutron events

Conclusion

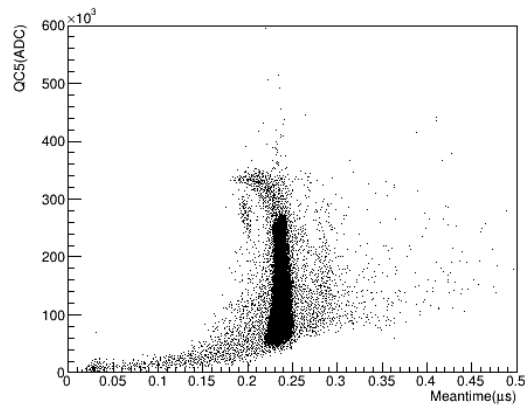
- Alpha PSD power improves by 28% at -33°C compared to the PSD power at 20°C
- Quenching factor of alpha events is higher than that of gamma at -33°C
- Light output is increase at low temperature
- Neutron study is ongoing

Back up

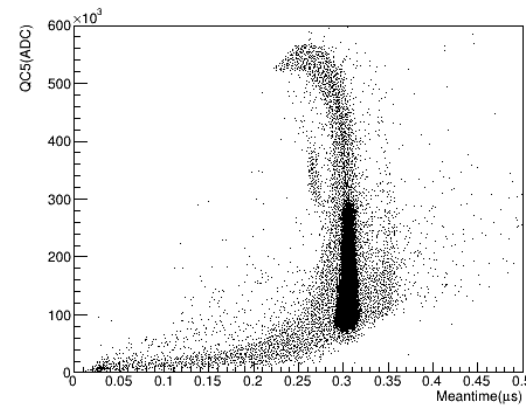
PSD(alpha, gamma)



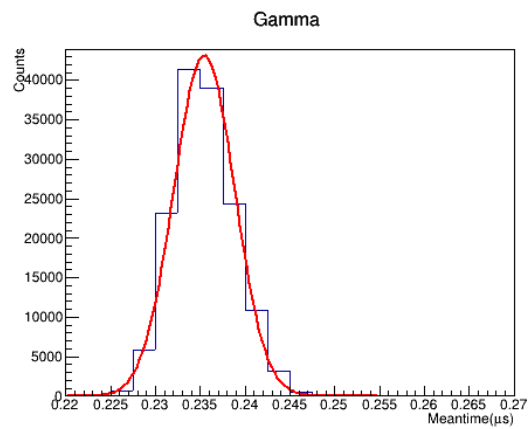
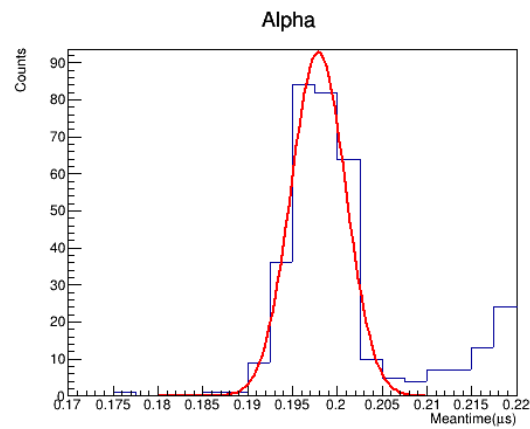
PSD(alpha, gamma) using FoM(nmt1000)



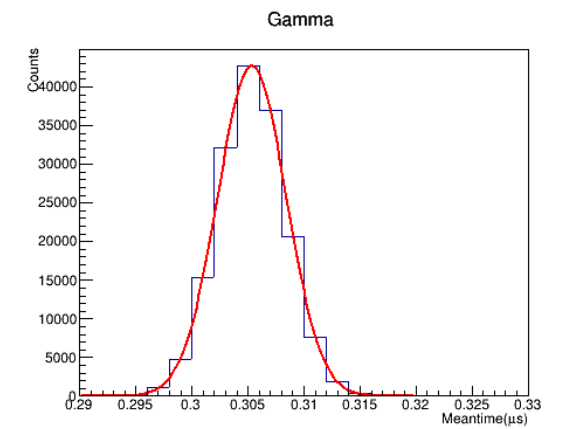
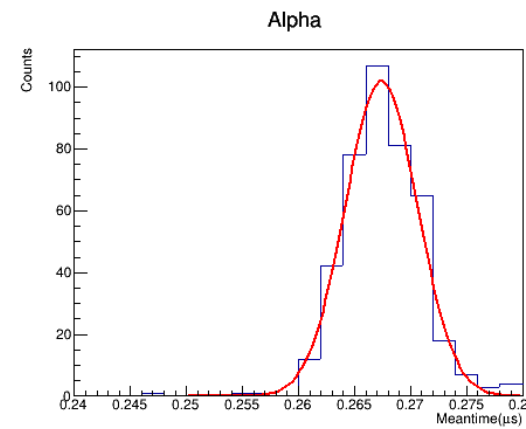
alph mean : 0.197879 +- 0.000181
alph sig : 0.003046 +- 0.000136
gamma mean : 0.235417 +- 0.000009
gamma sig : 0.003398 +- 0.000006
FOM : 5.826073+-0.260485



alph mean : 0.267395 +- 0.000164
alph sig : 0.003222 +- 0.000136
gamma mean : 0.305341 +- 0.000008
gamma sig : 0.003061 +- 0.000006
FOM : 6.038887 +- 0.254002

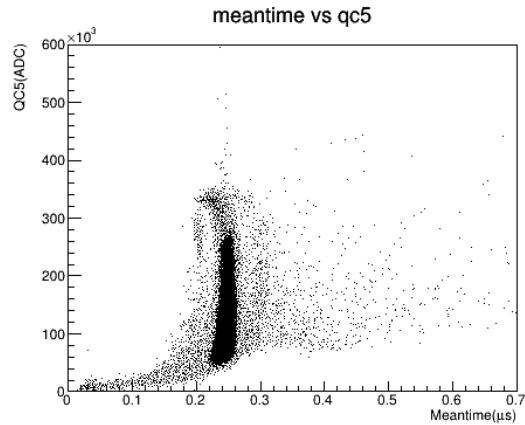


20°C

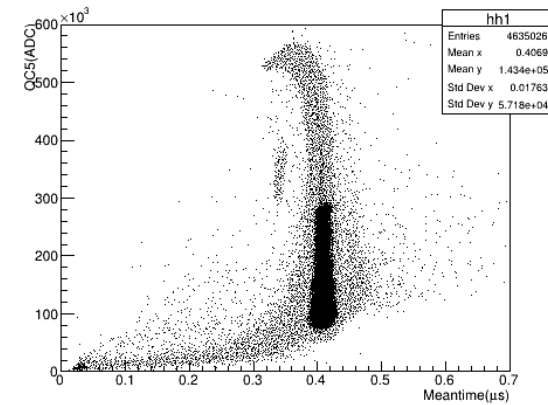


-33°C

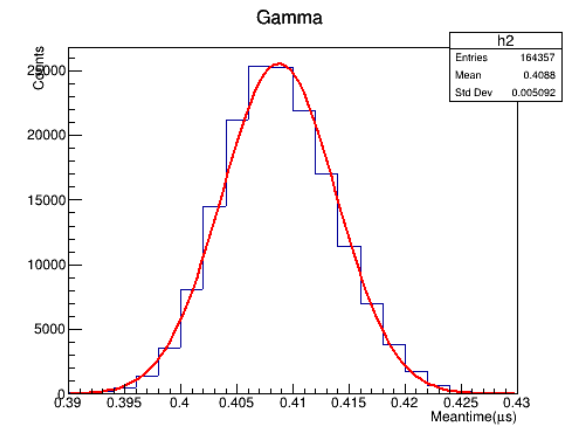
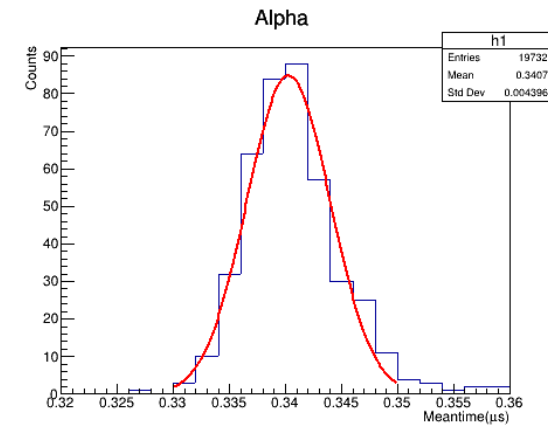
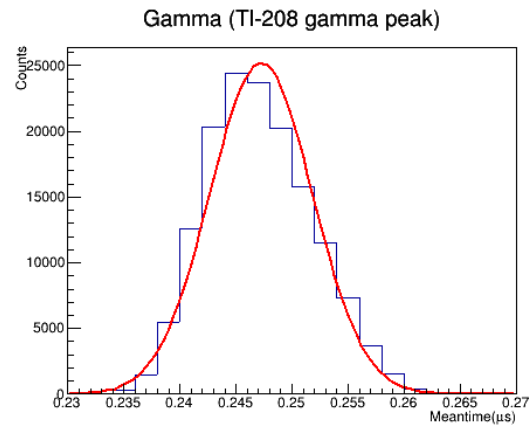
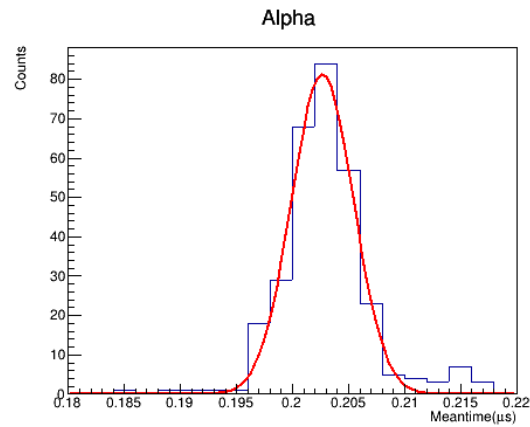
PSD(alpha, gamma) using FoM(nmt1500)



alph mean : 0.202668 +- 0.000127
alph sig : 0.002770 +- 0.000127
gamma mean : 0.247244 +- 0.000013
gamma sig : 0.004581 +- 0.000008
FOM : 6.064244 +- 0.278469



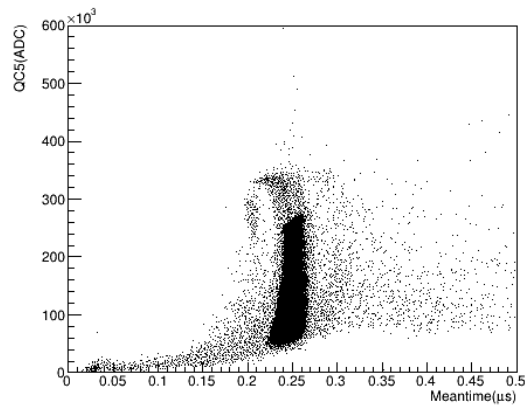
alph mean : 0.340270 +- 0.000174
alph sig : 0.003725 +- 0.000174
gamma mean : 0.408756 +- 0.000013
gamma sig : 0.005090 +- 0.000009
FOM : 7.769529 +- 0.363386



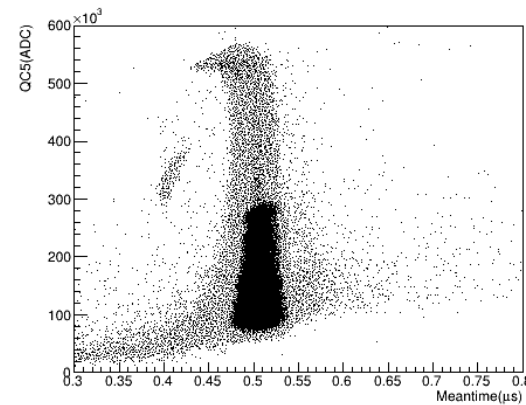
20°C

-33°C

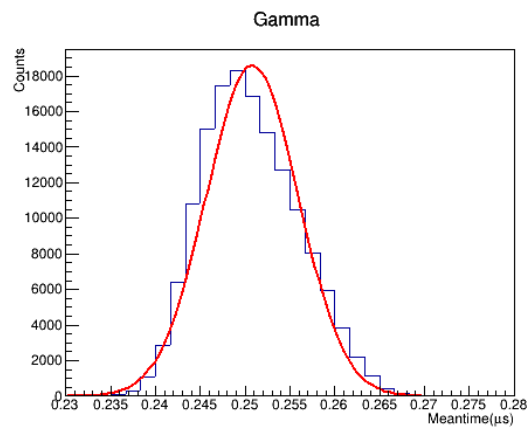
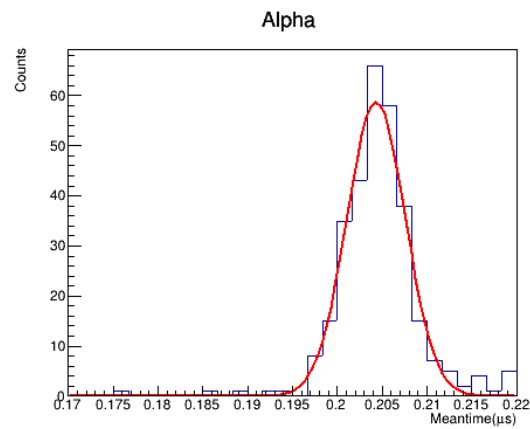
PSD(alpha, gamma) using FoM(nmt2000)



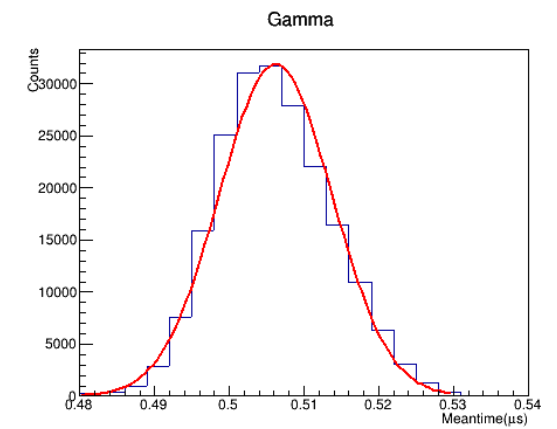
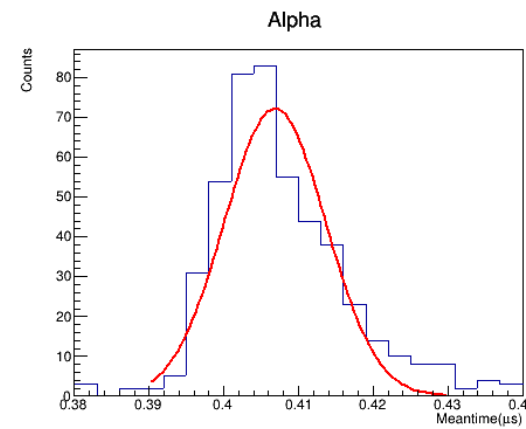
alph mean : 0.204319 +- 0.000199
alph sig : 0.003272 +- 0.000193
gamma mean : 0.250776 +- 0.000016
gamma sig : 0.005129 +- 0.000009
FOM : 5.530450 +- 0.325797



alph mean : 0.406847 +- 0.000454
alph sig : 0.006778 +- 0.000338
gamma mean : 0.506186 +- 0.000018
gamma sig : 0.007562 +- 0.000012
FOM : 6.927470 +- 0.345396



20°C



-33°C