Calibration for Liquid noble gas detector by 220Rn

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Content

Motivation

- For Dark Matter search, detector calibration at low energy is important

    - Detailed understanding of Energy scale, threshold, …

- In addition to them, accuracy of **vertex reconstruction** is also important for 1-phase detectors.

    - 1-phase detectors need to reconstruct events only by photons, and it become more difficult at low energy.

    - Current gas sources can provide uniform events, but no information on decay vertex.
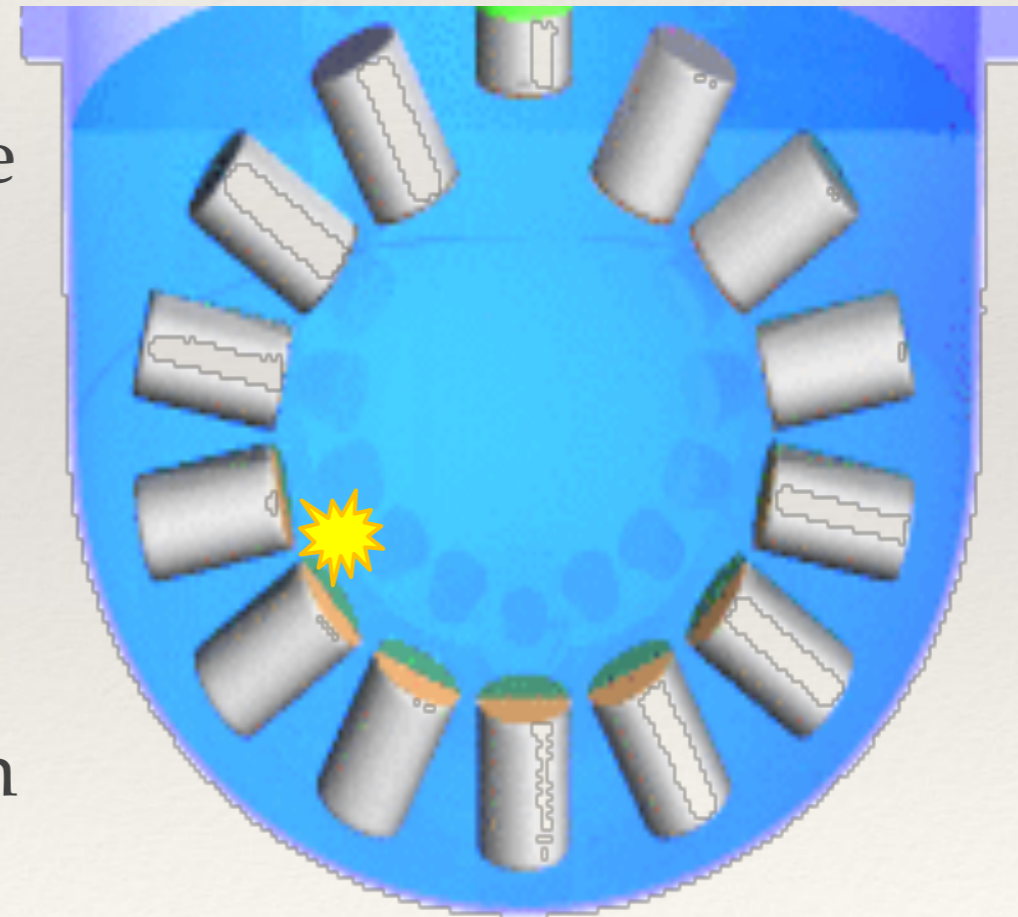
Bi-Po consecutive events

- The hint to realize this vertex calibration is in study for Rn: Bi-Po tagging.

  - β - α consecutive events in short time

- α has lot of photons, so it is possible to reconstruct events precisely.

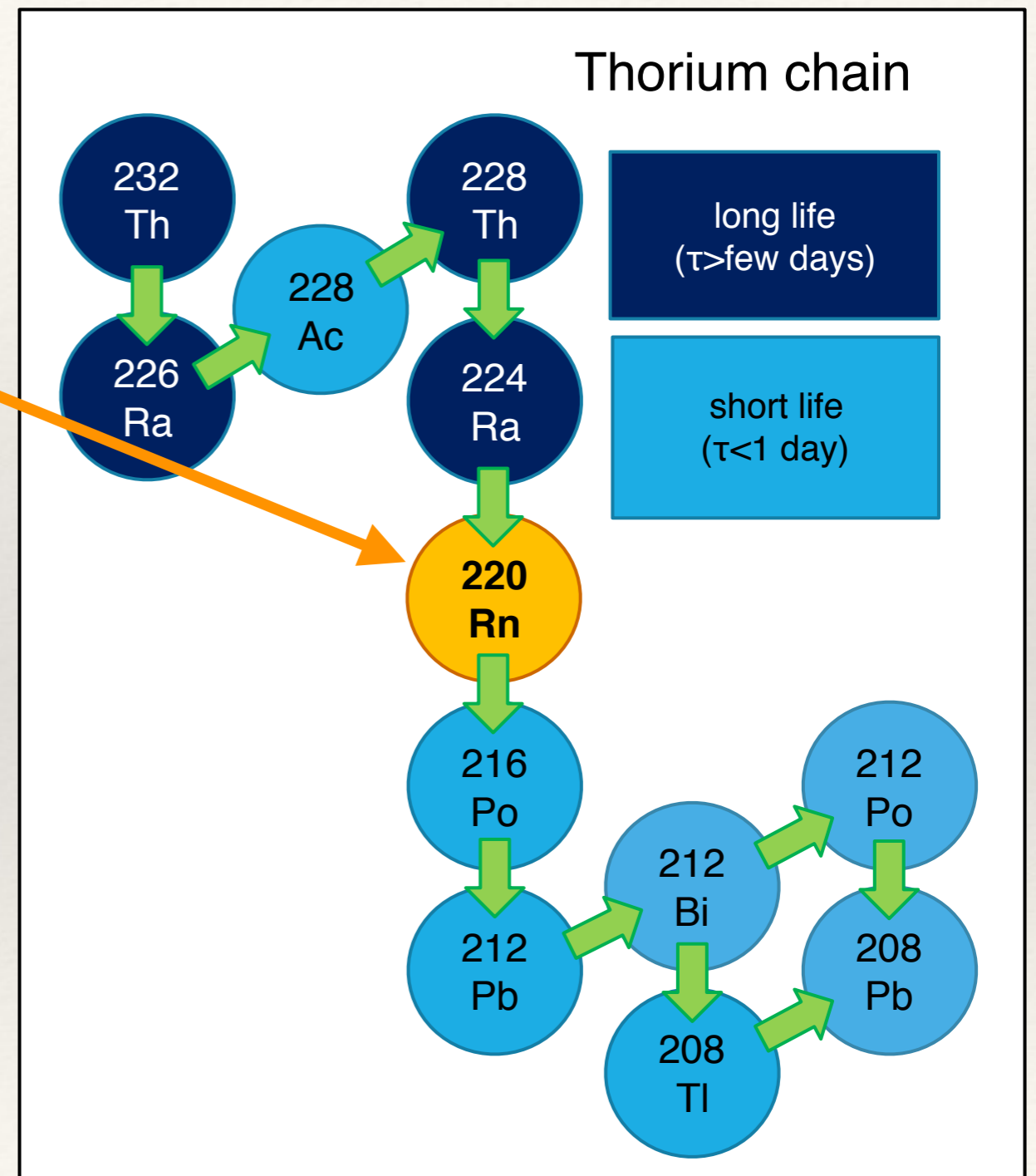- By comparing the vertex of α and low energy region of β, get performance of reconstruction.
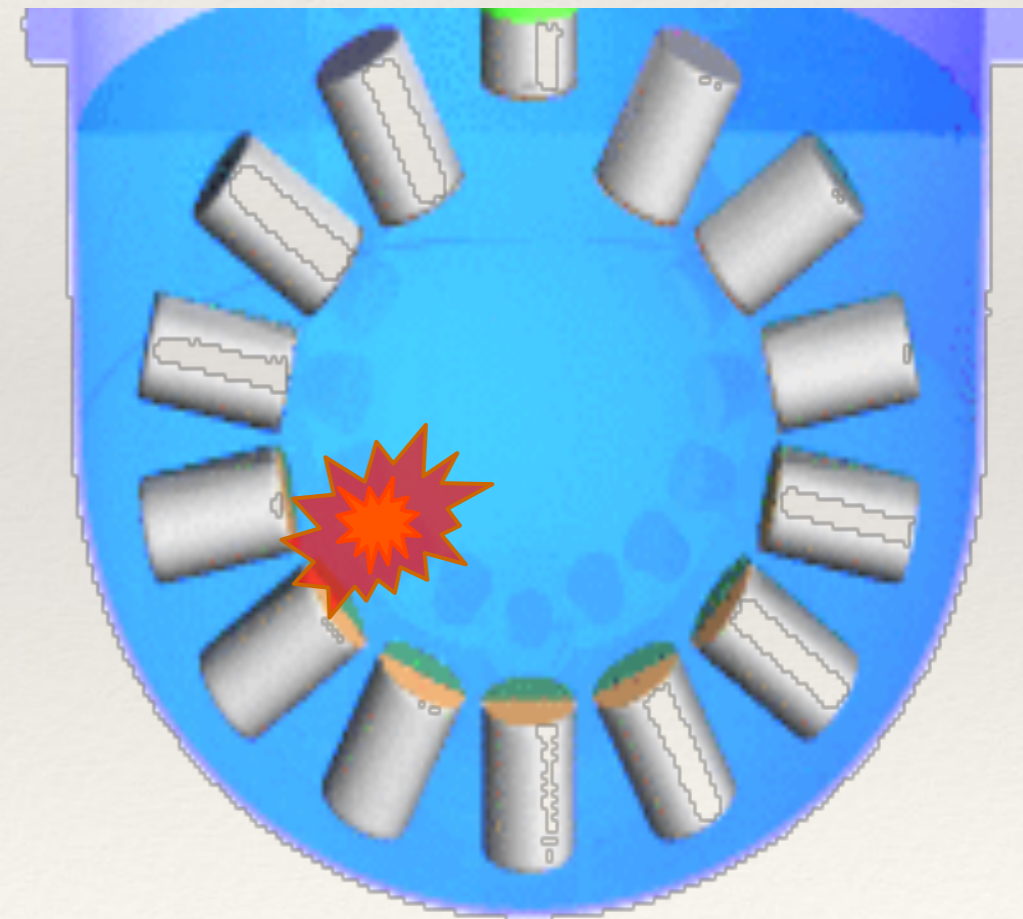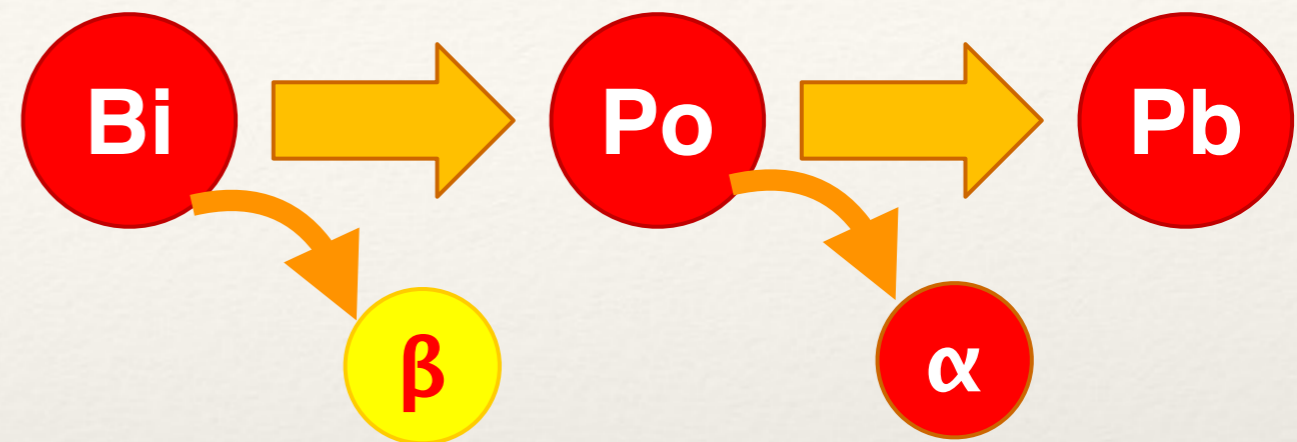
Bi-Po consecutive events

- In this work, I try to introduce 220Rn into the small liquid Xe detector, as the preparation for the calibration.

  - Make system and count the number of atoms injected.

- 220Rn: isotope of Rn in middle of Th chain.
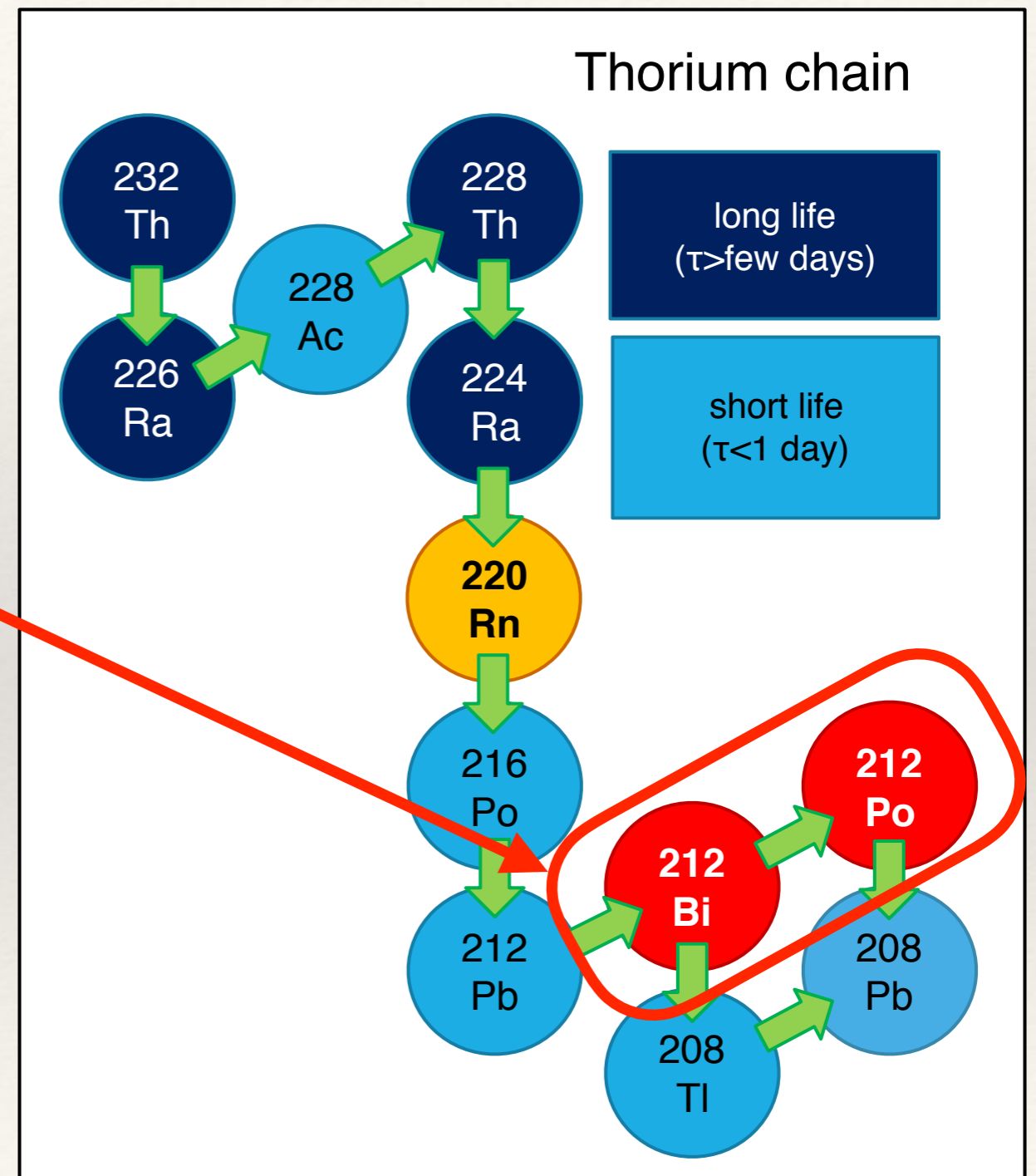
  - Later, I will explain why choose 220Rn for this test.

Characteristics of 220Rn

- 220Rn is the RI located in middle of thorium chain.
  - half life: 56.6s
- Advantage:
  - Bi-Po consecutive events
    - τ = 299ns
    - We can use this events for calibration
  - No long life RIs after 220Rn
    - All daughters of 220Rn are short life.
    - Maximum: 10.6h of 212Pb
- 220Rn is noble gas
  - we can use metal getter to remove contaminations.

Thorium chain

long life (τ>few days)

short life (τ<1 day)

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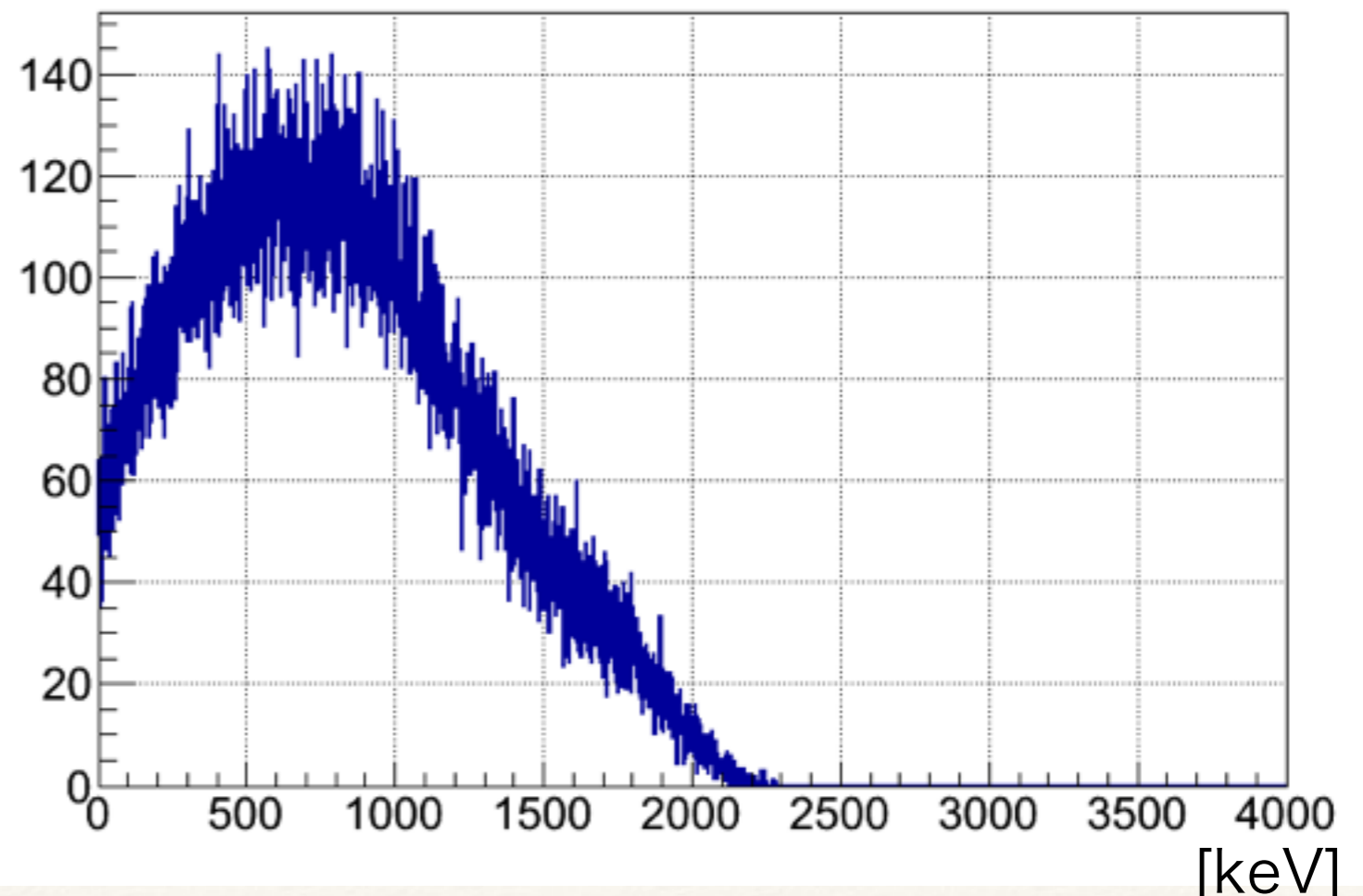 - No long life RIs after 220Rn

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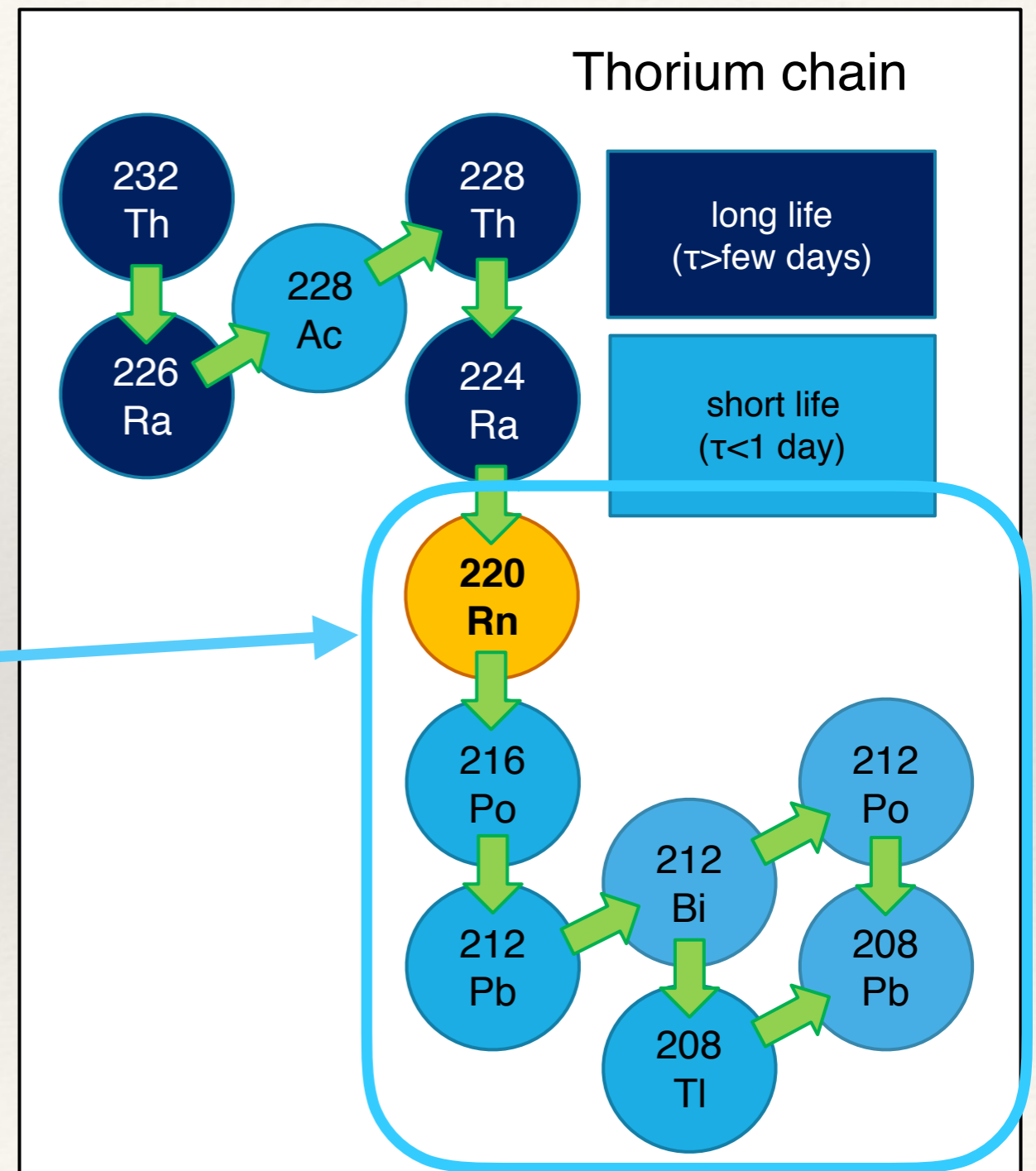
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Thorium chain

212Bi simulated spectrum in large LXe 1-phase detector

[keV]

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Thorium chain

232 Th	228 Th
228 Ac	
226 Ra	224 Ra

long life
(τ>few days)

short life
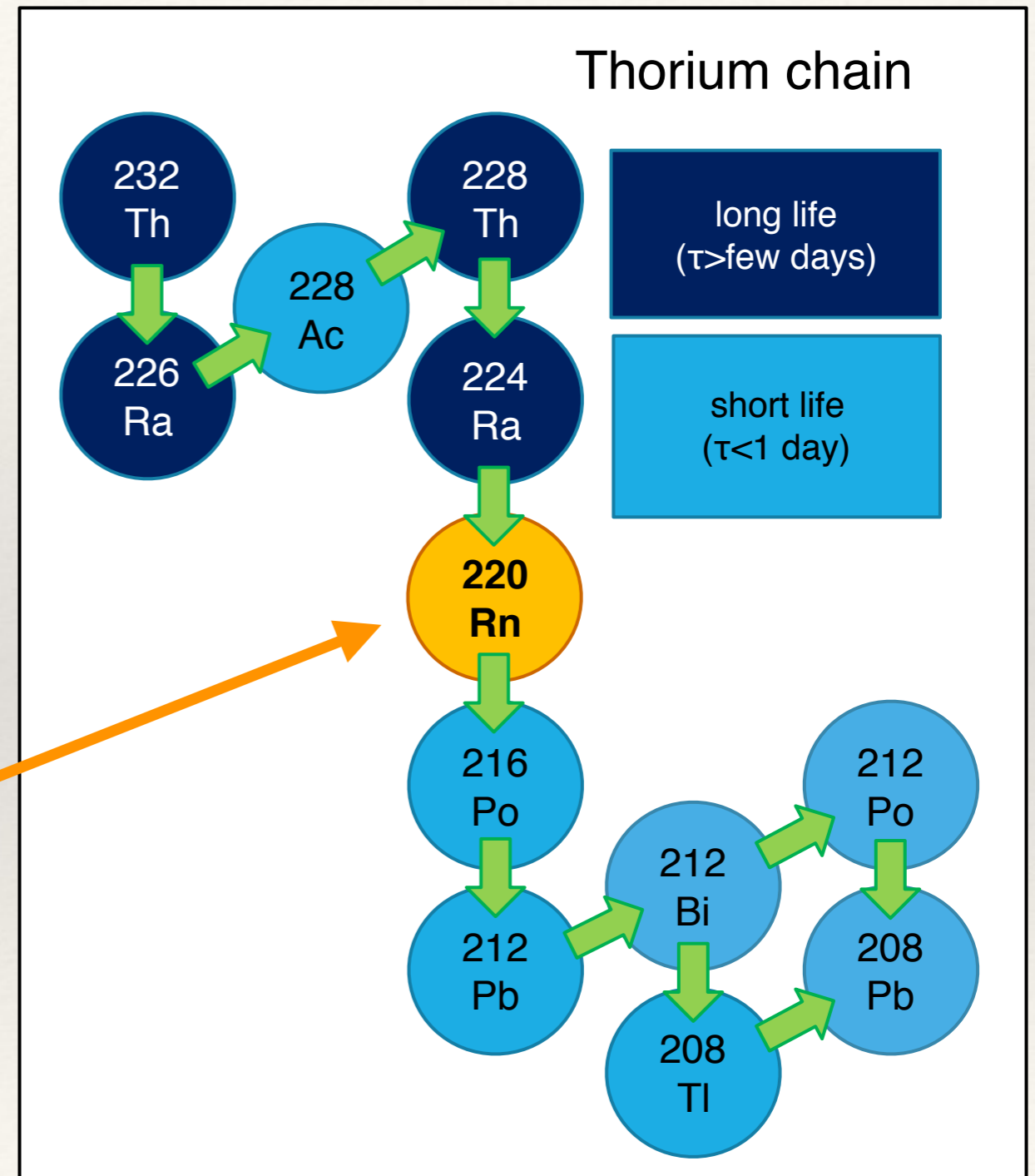(τ<1 day)

220 Rn

216 Po

212 Pb

212 Bi

212 Po

208 Pb

208 Tl

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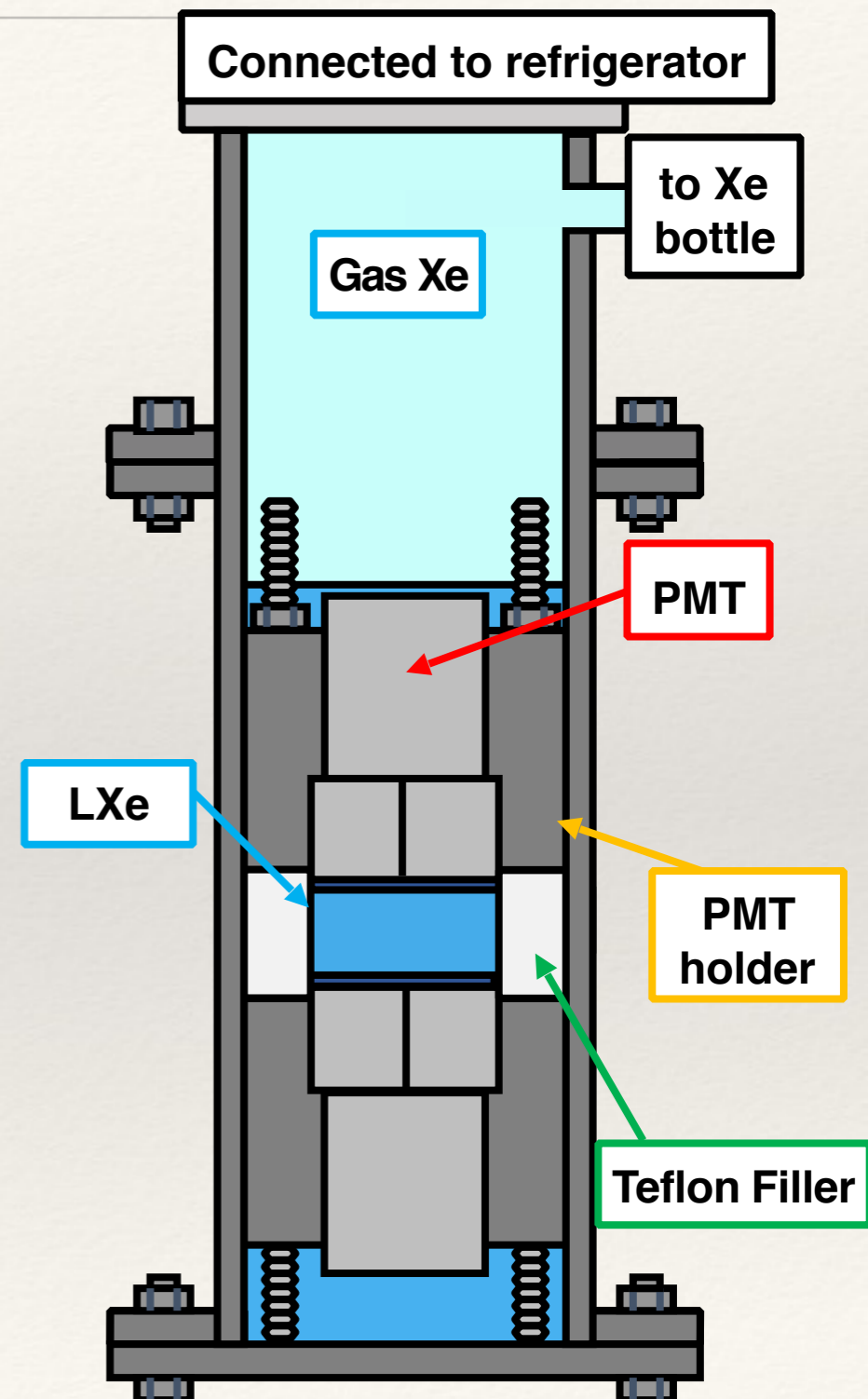
    - we can use metal getter to remove contaminations.

Thorium chain

232 Th · 228 Ac · 228 Th · 226 Ra · 224 Ra · **220 Rn** · 216 Po · 212 Pb · 212 Bi · 212 Po · 208 Pb · 208 Tl

long life (τ>few days)

short life (τ<1 day)

Source / Detector

- I used Lantern mantle as Th source.

  - maker: CAPTAIN STAG (Japanese company)

      - Activity of Th: 1.2kBq/piece

      - Emanation of 220Rn: ~30Bq/piece

          - Measured by Ge detector

      - 50 pieces are used.

- I use small Liquid Xe detector in Kamioka mine.

  - 2 PMTs are located face to face

  - ~ 0.6 kg of LXe at the center

Connected to refrigerator

Gas Xe

to Xe bottle

PMT

LXe

PMT holder

Teflon Filler

Developed System

→ : 220Rn gas was introduced into detector with Gas Xe.

- To introduce 220Rn in the detector, I used gas Xe as carrier.

- Th source is put at middle of the flow pipe.

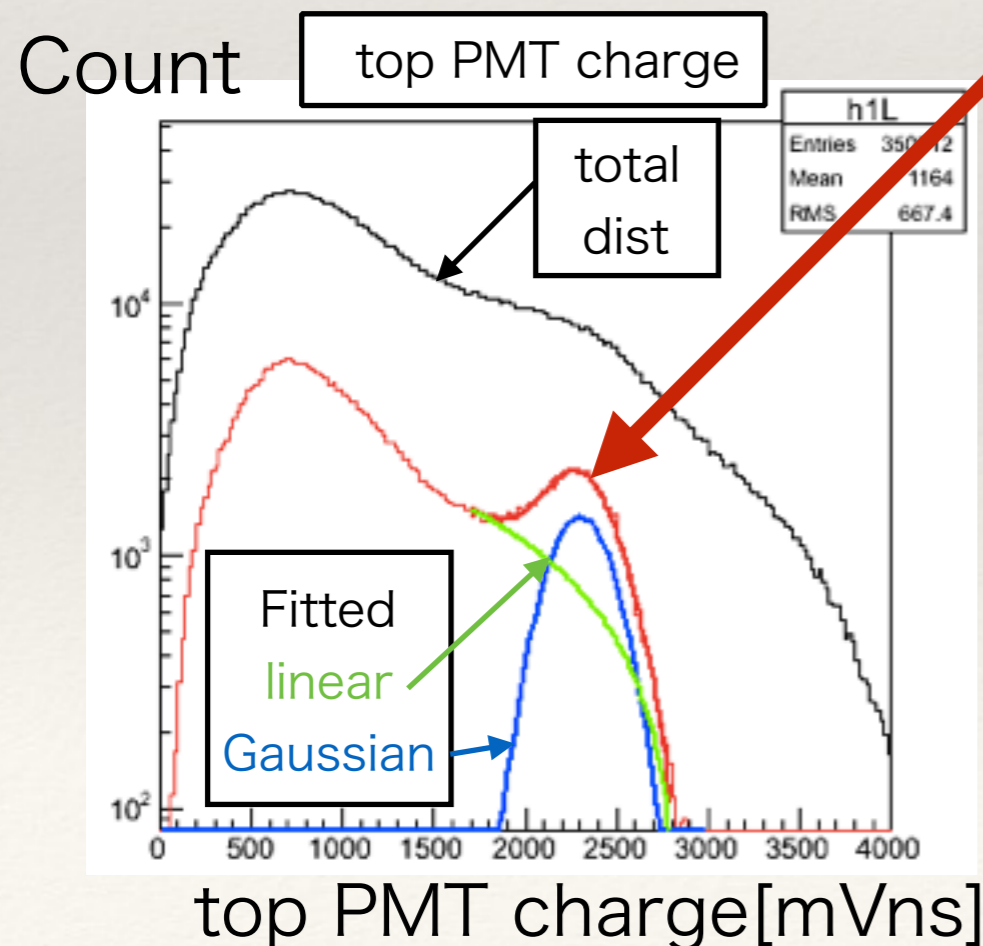- Xe gas from bottle flush 220Rn and they go to detector with purified by metal getter.
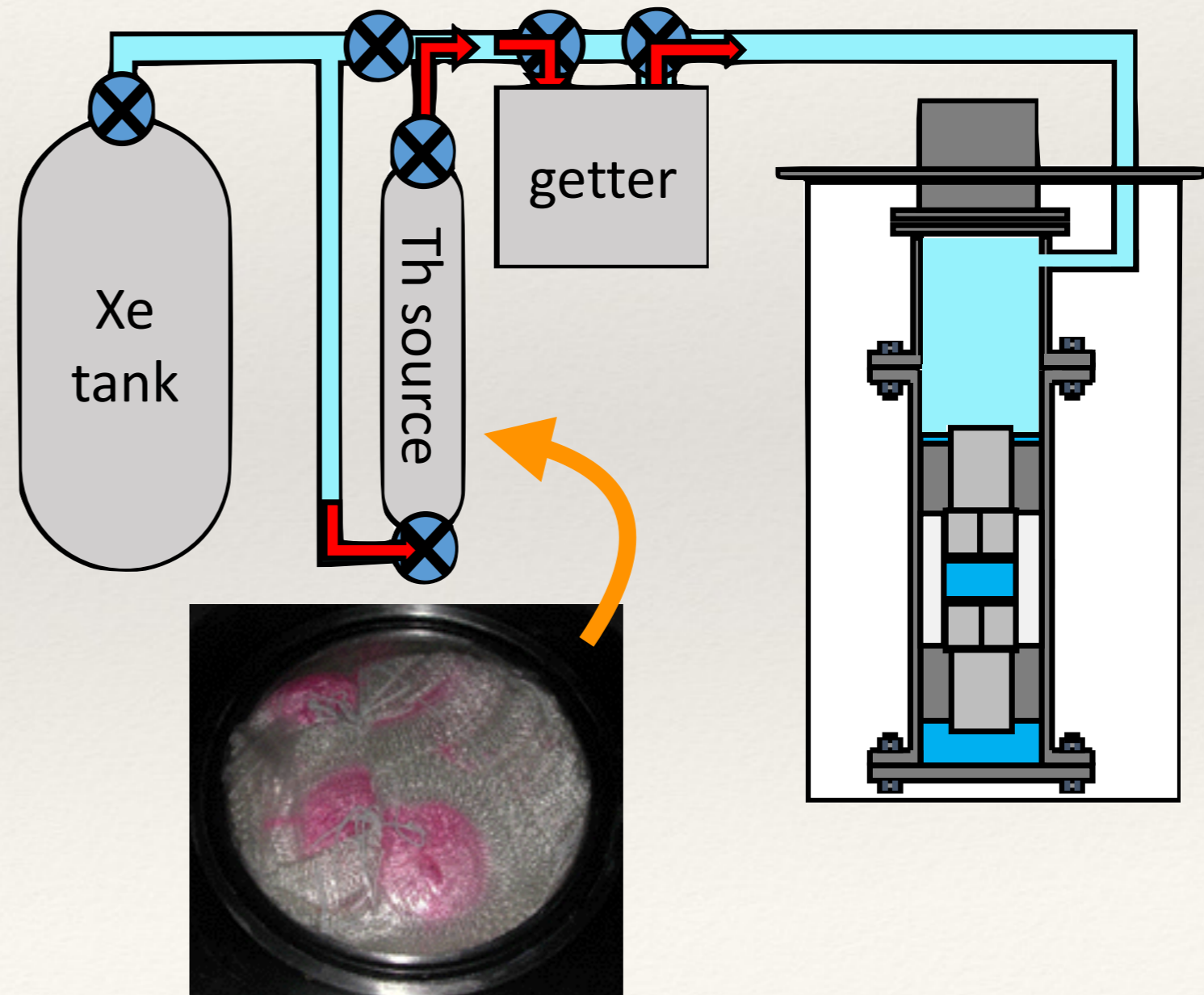
Gas introducing
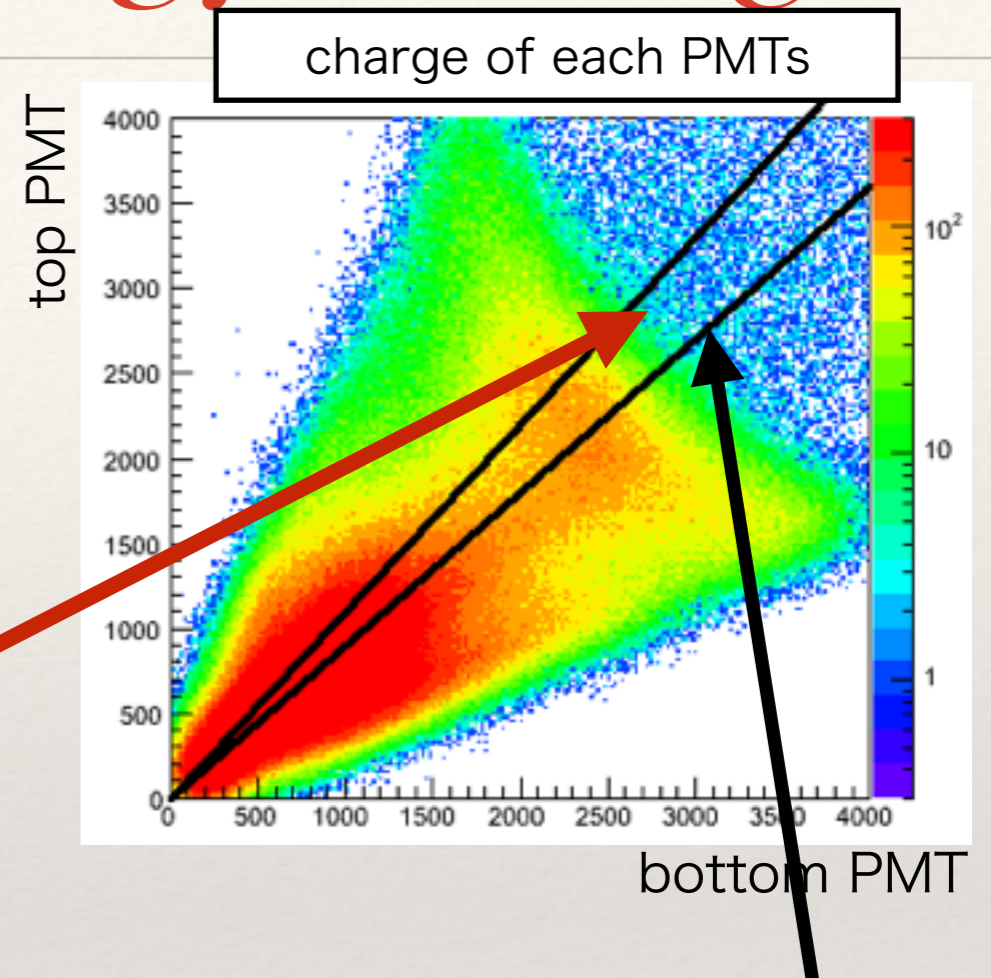
* Introduce of 220Rn was operated by changing the flow of Xe carrier gas.

* In this test, gas flow was kept as

  * Rate: 2 liter/min

  * Time: 2 min

* ~1500Bq of 220Rn is expected by 50 pieces of mantle.

  * It means 1.2×10^5 220Rn atoms in the source holder.

Calibration For Energy Scaling

charge of each PMTs

top PMT

bottom PMT

* 137Cs source (662keV γ) was located at the bottom of detector for Energy Scaling.

center selected

Count

top PMT charge

total dist

h1L
Entries 350?12
Mean 1164
RMS 667.4

Fitted
linear
Gaussian

top PMT charge[mVns]

* By selecting events between black lines, events happened around central part are selected.

* Then fit peak by Gaus + linear

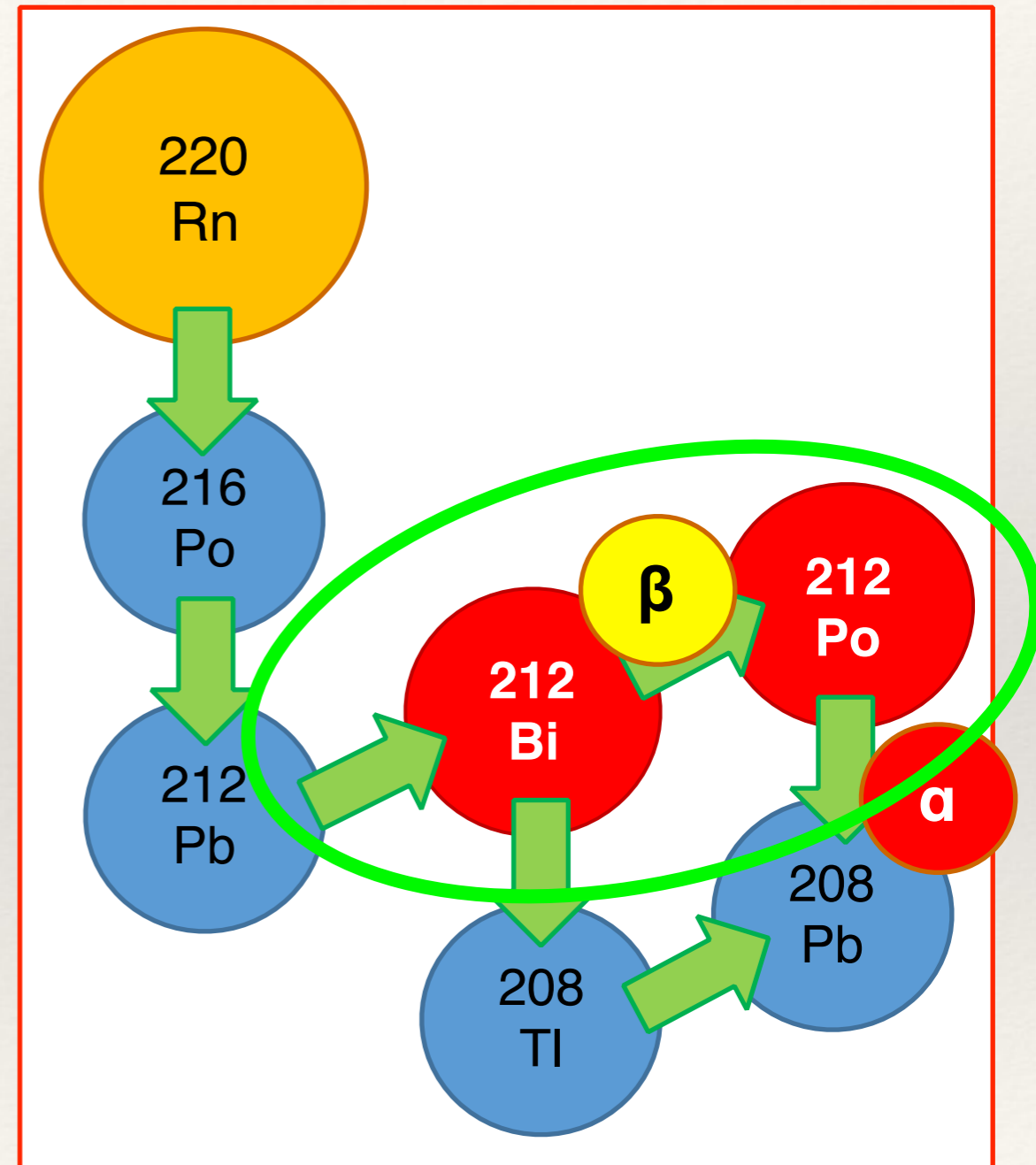# Method to count injected 220Rn atoms (1)

- After the injection, there are 2 methods to count number of 220Rn atoms.

- Method (1): use decay of 220Rn and 216Po
  - 220Rn: $\tau = 55.6$s
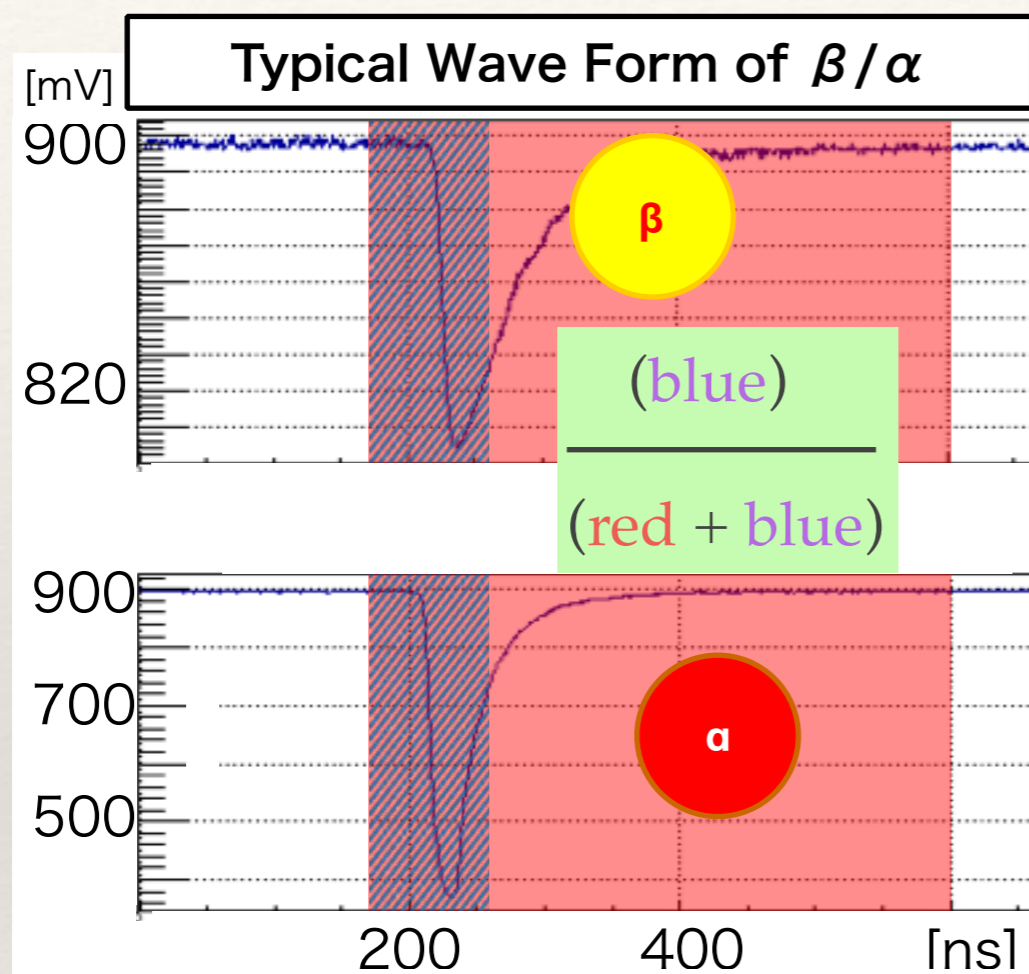 - 216Po: $\tau = 0.164$s

- Limited by 220Rn decay.

- After this, they stay as 212Pb.
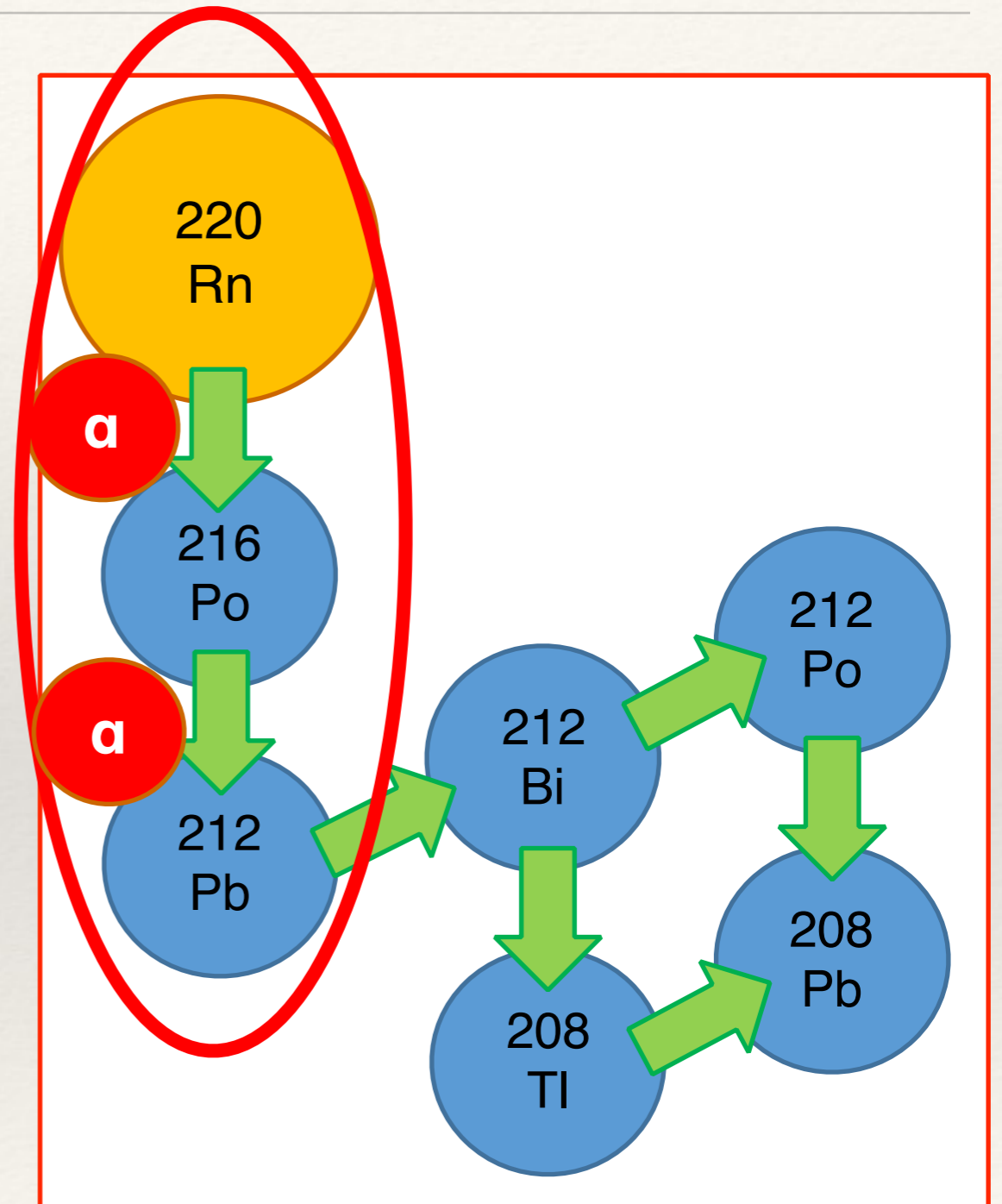
Method to count injected 220Rn atoms

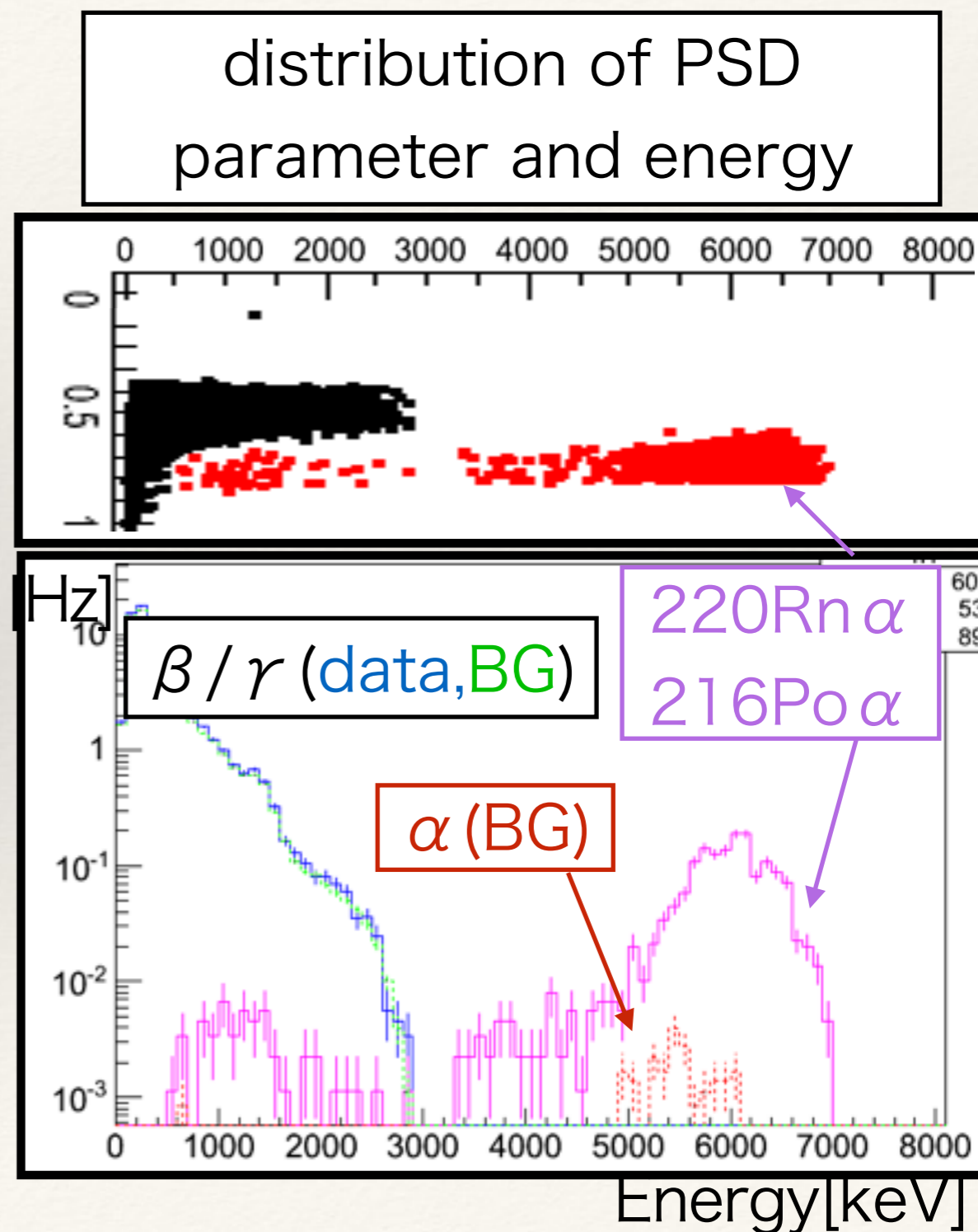- Method (2): use decay of 212Bi and 212Po, after 212Pb

  - 212Bi: $\tau = 1.1$h

  - 212Po: $\tau = 299$ns

- Limited by 212Pb decay, $\tau = 10.64$h

Method (1): Counting for 220Rn and 216Po

Typical Wave Form of β / α

$$\frac{\text{(blue)}}{\text{(red + blue)}}$$

β

α

distribution of PSD parameter and energy

β / γ (data, BG)

220Rn α
216Po α

α (BG)

Energy[keV]

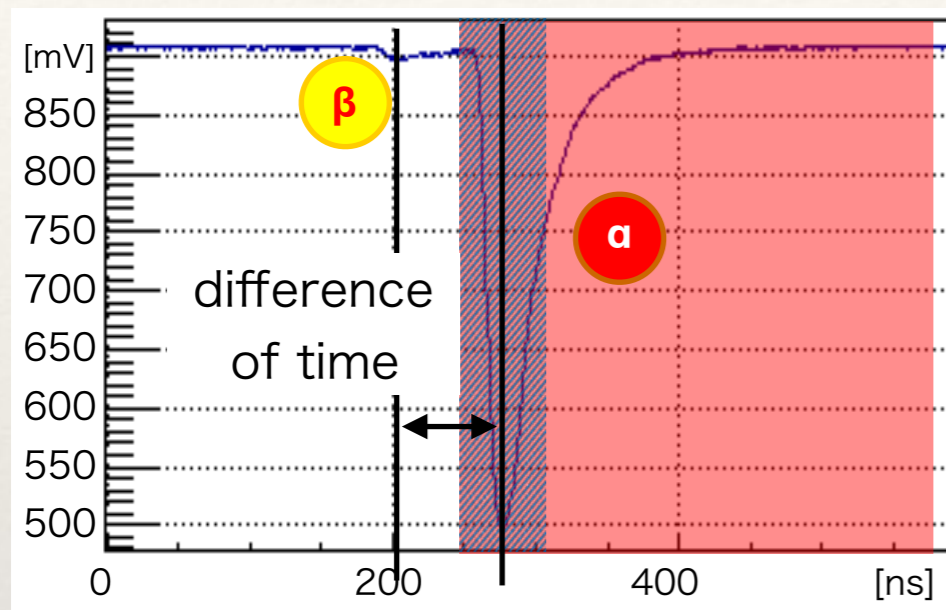❖ To distinguish α from β/γ, difference of scintillation time was used .
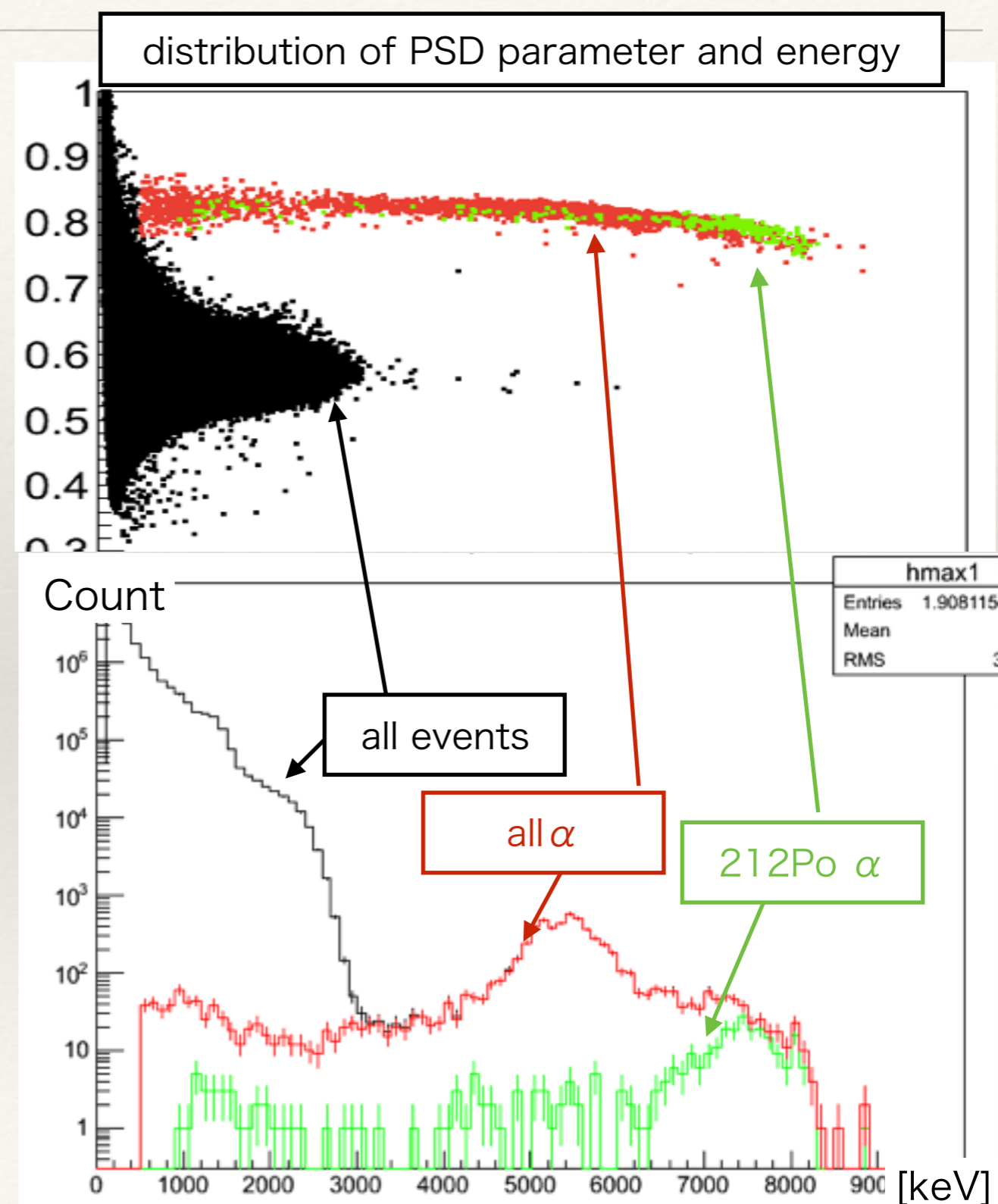
Method (1): Counting for 220Rn and 216Po

- We observed 1401.0±37.9 α events in 15min after injection, with BG subtraction.

- Rate of α increased up to ~10Hz.

[Hz]

α rate after injection

1bin=5s

data α

BG α

time after injection[s]
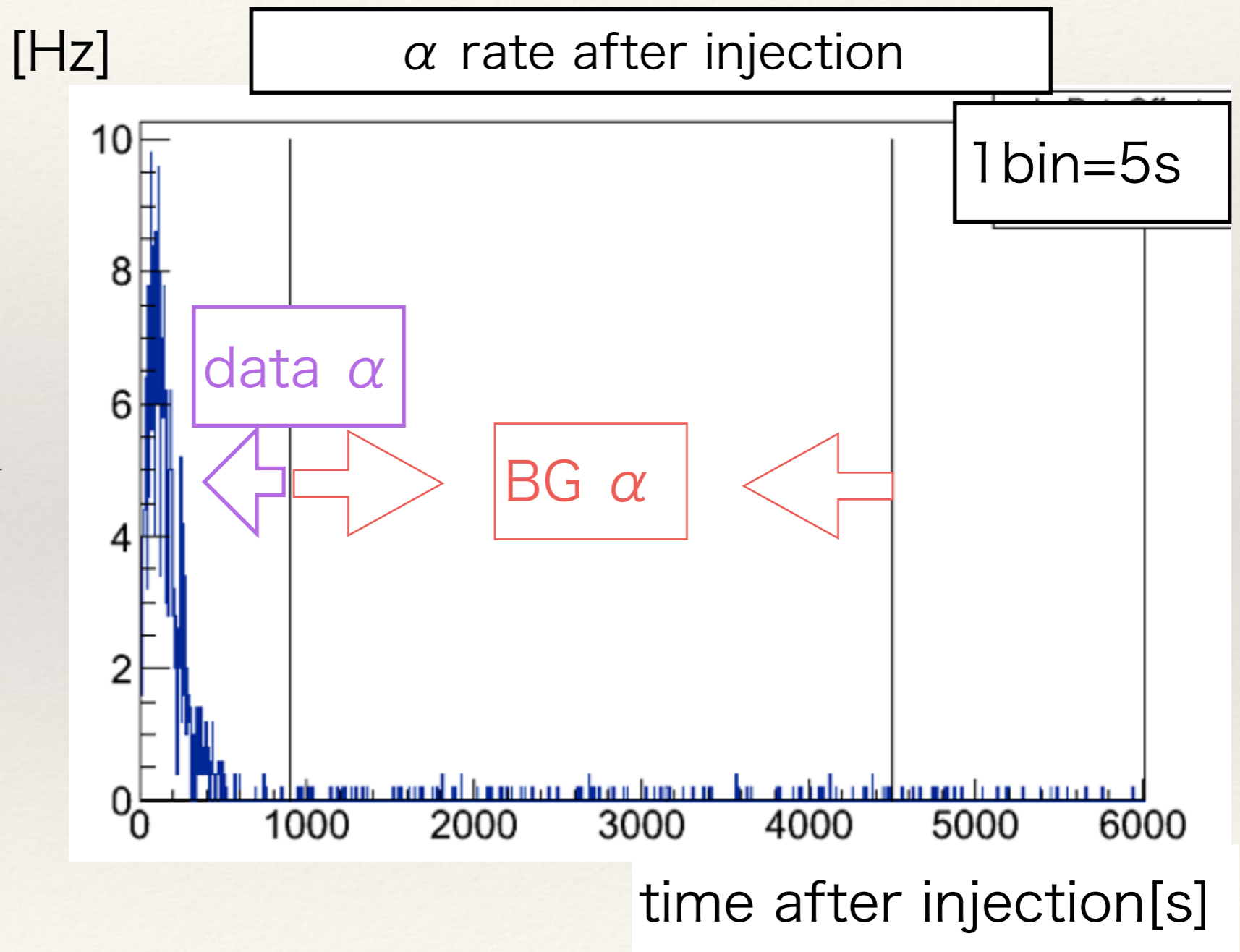
# Method (2) Counting for 212Bi and 212Po

- 212Bi-212Po (half life 299ns) decay consecutively.

    - Use scintillation decay time

    - Require timing of α from trigger

        - α is in [30, 900]ns after trigger

- We observed 292±17.1 212Bi-212Po events in 61h.

distribution of PSD parameter and energy

all events

all α

212Po α

Count

hmax1
Entries 1.908115
Mean
RMS

[keV]

Method (2) Counting for 212Bi and 212Po

- ❖ Fitted half life is consistent with an expectation(299 ns).

- ❖ Result of fit : 297±34 ns

212Po Decay timing
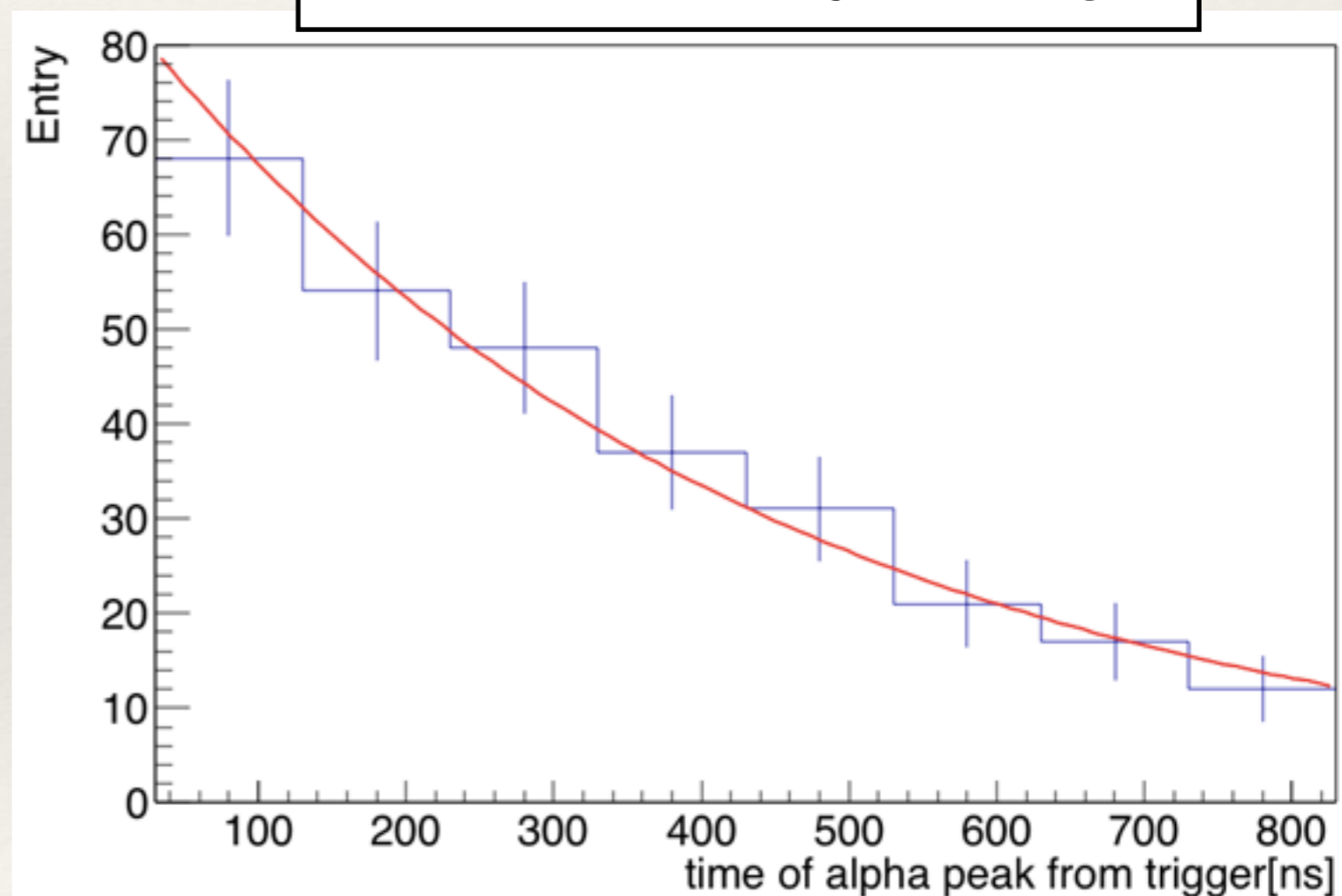
Results – Estimation for number of atoms

- Method(1): There are 2 α in the decay process.
  - Number of 220Rn atoms is evaluated as **1401.0/2 = 700.5 ±19.0**.
- Method (2): we have to consider
  - Branching ratio(BR)
  - Efficiencies (ex. window of FADC)
  - Number of 220Rn atoms is evaluated as **292/0.64(BR)/0.75(eff) = 608.3±35.6.**
- Difference between both method is under study.

- In this test, I injected 220Rn gas for 2min.
  - 220Rn emanates with ~1min, so we can increase the number of events with increasing the loading time.

Number of 220Rn atoms

| method	count	220Rn atoms
1:220Rn,216Po	*1401*	*700.5±19.0*
2:Bi-Po	*292*	*608.8±35.6*

Summary

- We developed the 220Rn calibration system for liquid noble gas detector as the preparation for vertex reconstruction calibration.

  - We could introduce 600-700 220Rn atoms.

- We can increase number of 220Rn atoms by using more mantles and increasing injection time.

- Note:

  - In this slide I focused on the vertex reconstruction for 1-phase detector, but there are some other studies of 220Rn for 2-phase detectors.

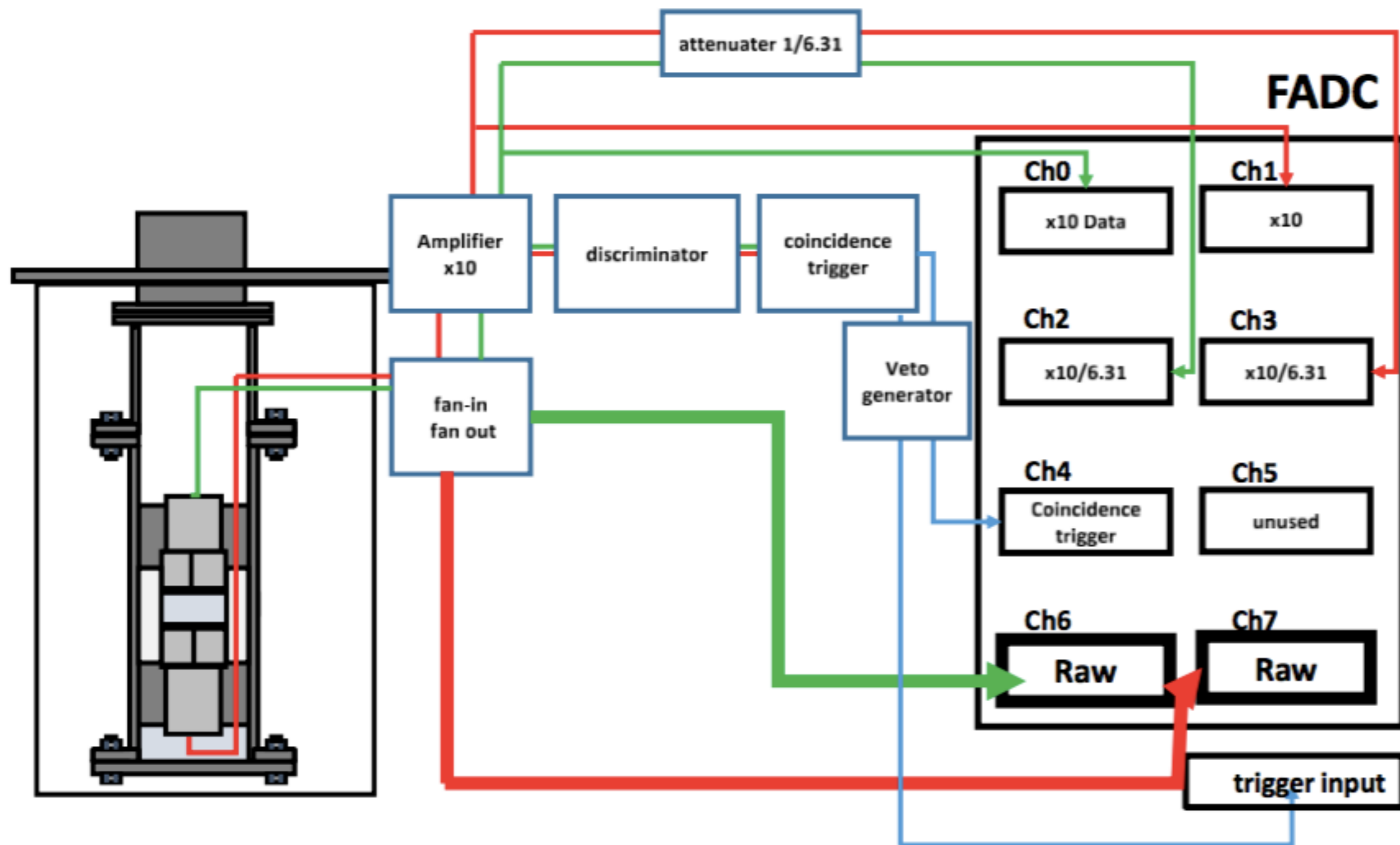   - Ref: Rafael F. Lang et al, Journal of Instrumentation, Volume 11, P04004 (April 2016)

back up

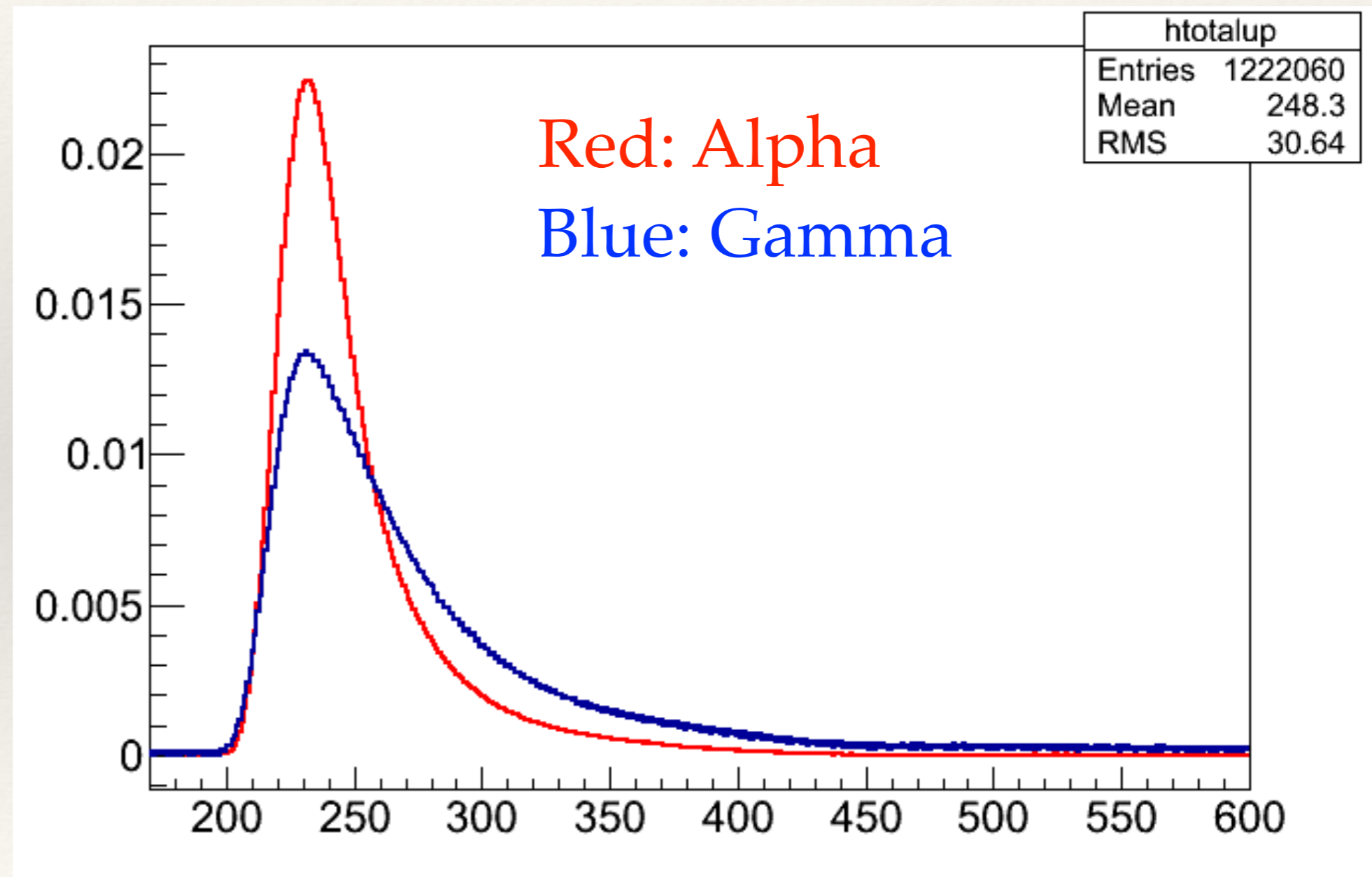# Method (2) Counting for 212Bi and 212Po

❖ Decay of 212Bi-212Po events

10.75±0.86 h

<=> 10.64 h (expected)
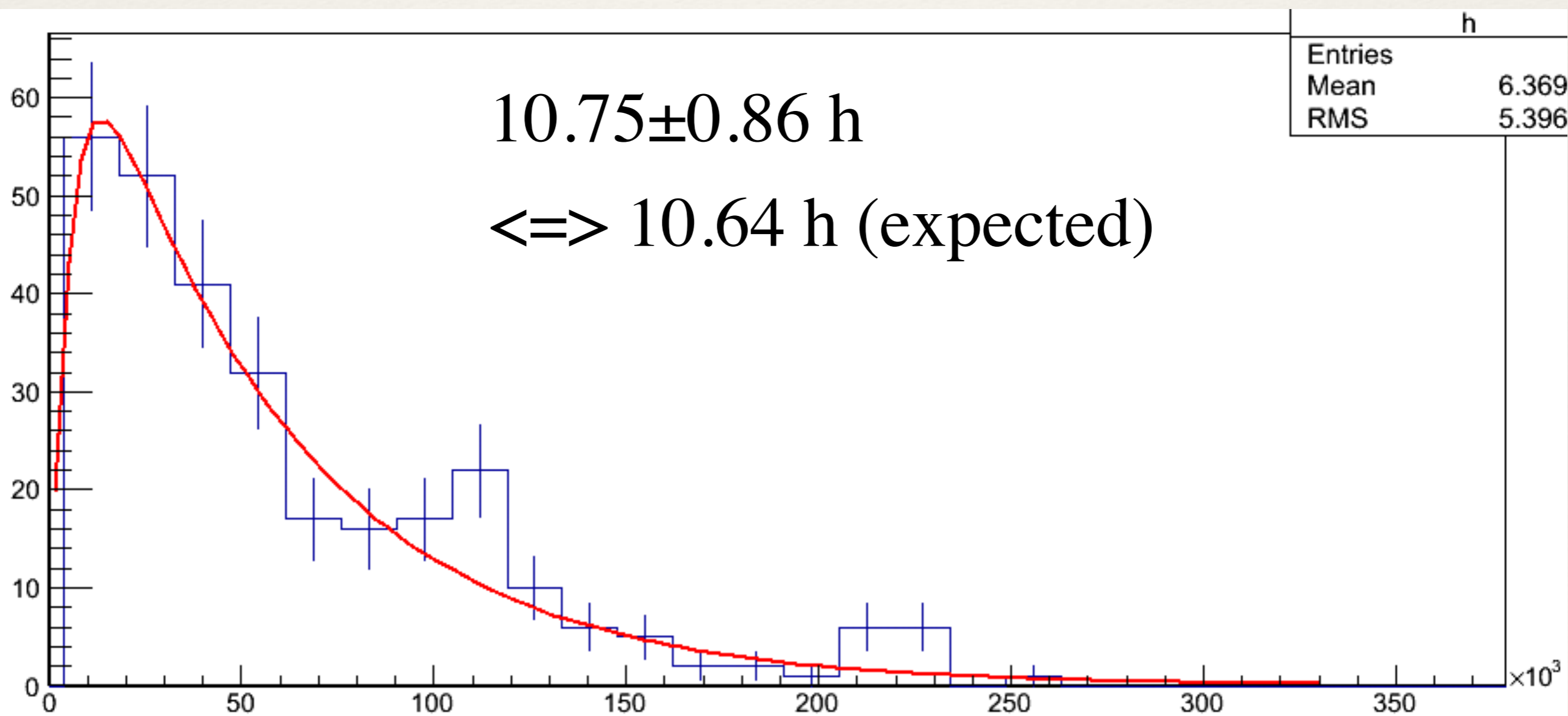
DAQ for test chamber

Normalized Wave form template

* Normaliz ed Wavefor m

* cross at t = 257ns

Red: Alpha
Blue: Gamma

htotalup
Entries	1222060
Mean	248.3
RMS	30.64

Method (1): Counting for 220Rn and 216Po

$$\frac{\text{(blue)}}{\text{(red + blue)}}$$

❖ To distinguish α from β/γ, difference of scintillation time was used .

Typical Wave Form of β/α

[mV]

900

87ns

β

343ns

820

900

700

α

500

200   400   600 [ns]