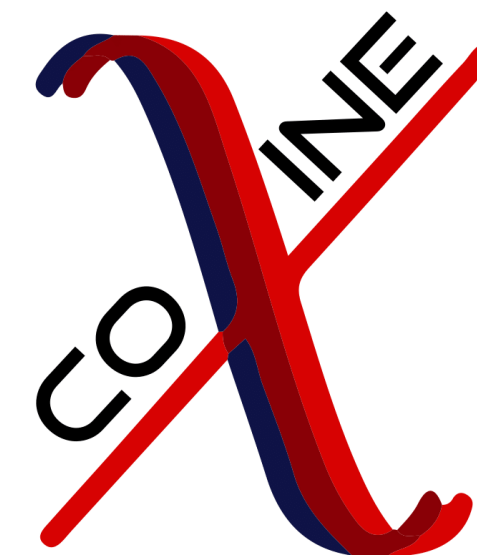# An alpha event analysis in the COSINE-100 NaI(Tl) detector

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On behalf of the COSINE-100 collaboration

1. Introduction

- COSINE-100 is a direct dark matter detection experiment using NaI(Tl) scintillation crystals. Understanding backgrounds in the NaI(Tl) crystals is important for the dark matter search experiment. Many alpha particles are produced in the alpha decays of daughter nuclei of the U-238 and Th-232 decay chains. The goals of alpha events analysis are to figure out quenching factors of alpha particles and to estimate contamination of U-238 and Th-232 in NaI crystals. An alpha event analysis using the two years of COSINE-100 data will be presented.

- COSINE-100 Detector

| Crystal	Mass (kg)	Size (inches diameter×length)	Powder	α Rate (mBq/kg)	^{40}K (ppb)	^{238}U (ppt)	^{232}Th (ppt)	Light yield (PEs/keV)
Crystal-1	8.3	5.0 × 7.0	AS-B	3.20 ± 0.08	34.7 ± 4.7	< 0.02	1.3 ± 0.4	14.9 ± 1.5
Crystal-2	9.2	4.2 × 11.0	AS-C	2.06 ± 0.06	60.6 ± 4.7	< 0.12	< 0.6	14.6 ± 1.5
Crystal-3	9.2	4.2 × 11.0	AS-WSII	0.76 ± 0.02	34.3 ± 3.1	< 0.04	0.4 ± 0.2	15.5 ± 1.6
Crystal-4	18.0	5.0 × 15.3	AS-WSII	0.74 ± 0.02	33.3 ± 3.5		< 0.3	14.9 ± 1.5
Crystal-5	18.3	5.0 × 15.5	AS-C	2.06 ± 0.05	82.3 ± 5.5		2.4 ± 0.3	7.3 ± 0.7
Crystal-6	12.5	4.8 × 11.8	AS-WSIII	1.52 ± 0.04	16.8 ± 2.5	< 0.02	0.6 ± 0.2	14.6 ± 1.5
Crystal-7	12.5	4.8 × 11.8	AS-WSIII	1.54 ± 0.04	18.7 ± 2.8		< 0.6	14.0 ± 1.4
Crystal-8	18.3	5.0 × 15.5	AS-C	2.05 ± 0.05	54.3 ± 3.8		< 1.4	3.5 ± 0.3
DAMA				< 0.5	< 20	0.7–10	0.5–7.5	5.5-7.5

- Motivation
  - We have data more than 2 years
  - To understand each alpha peak where they are from
  - To estimate contamination of U-238 and Th-232 in NaI crystal
  - To figure out quenching factor of alpha particles in NaI crystal

2. Alpha two peak Analysis

- Alpha Pulse Shape Discrimination

preliminary
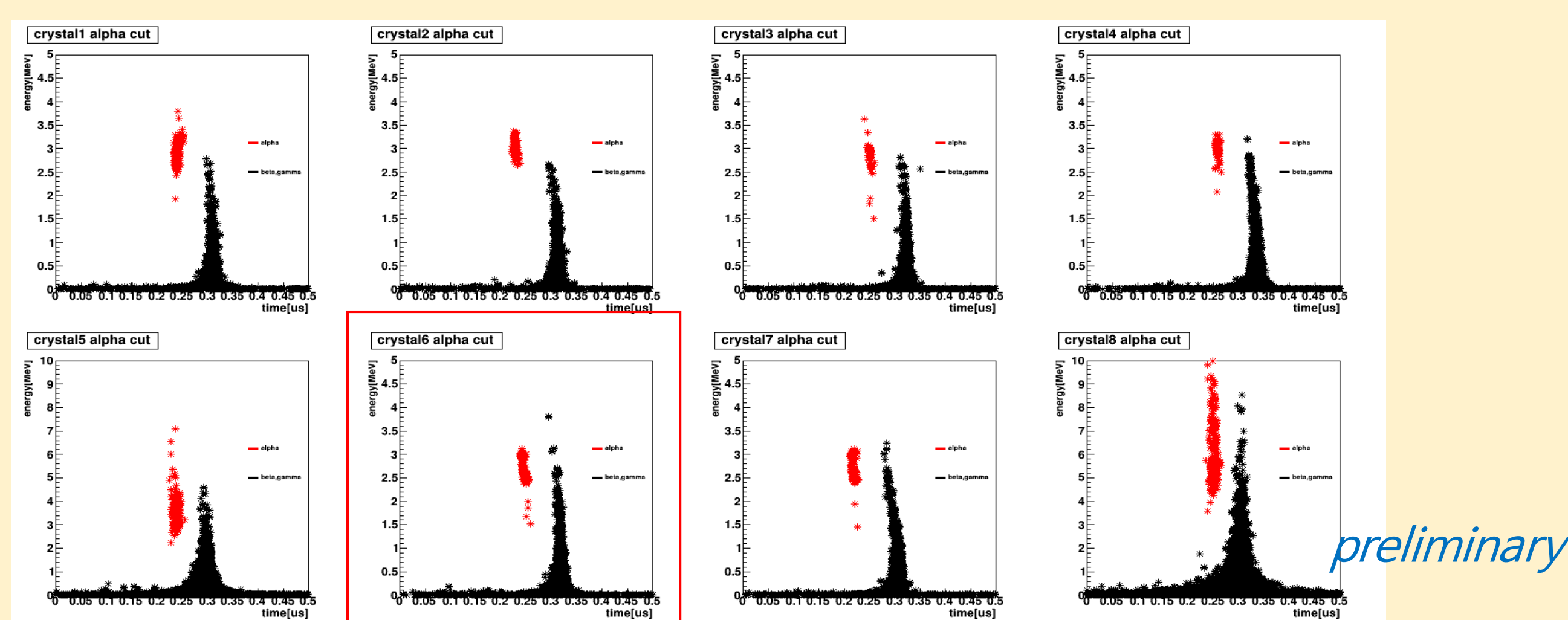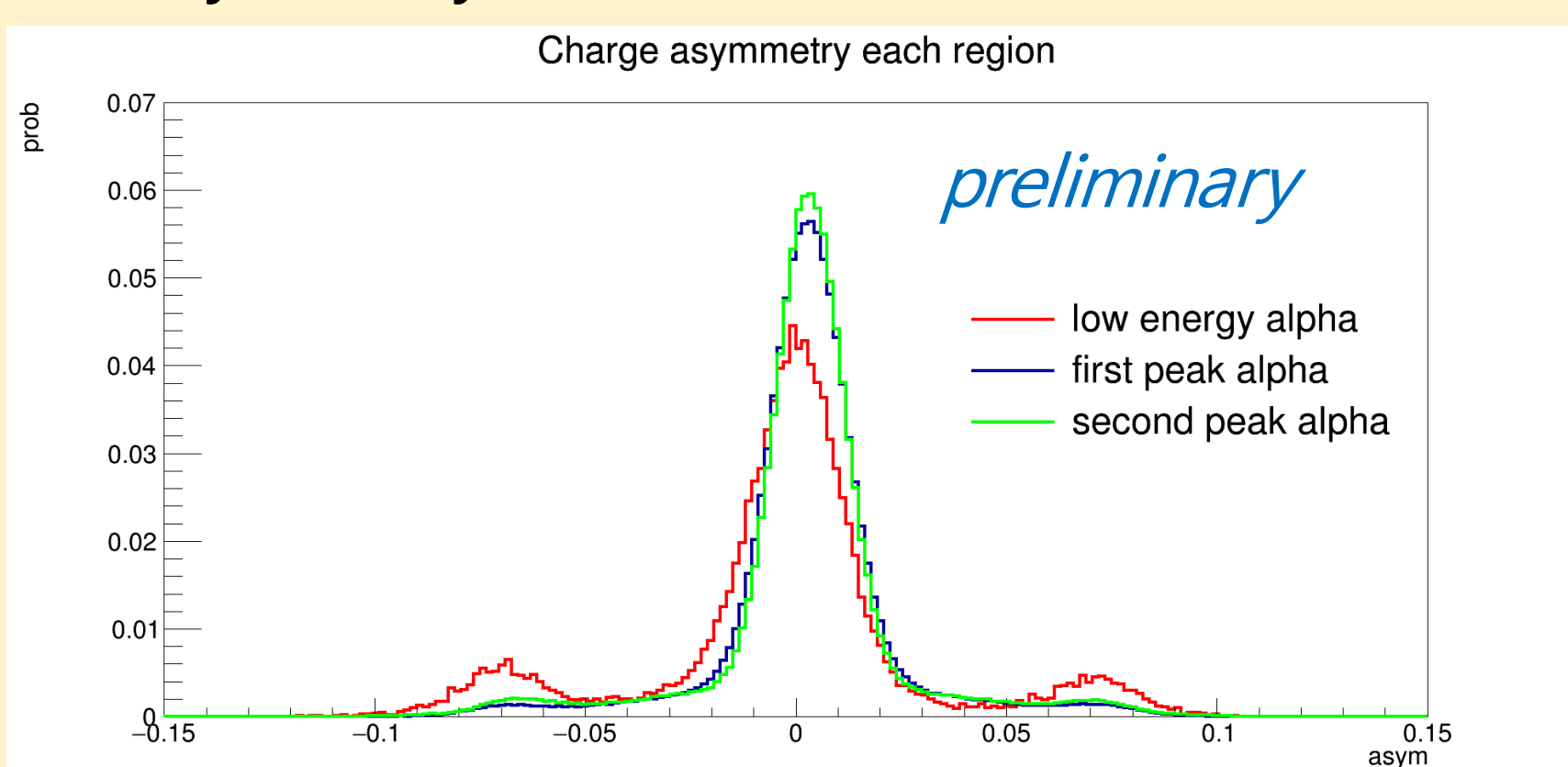
Meantime vs energy
Especially, Crystal 6 analysis
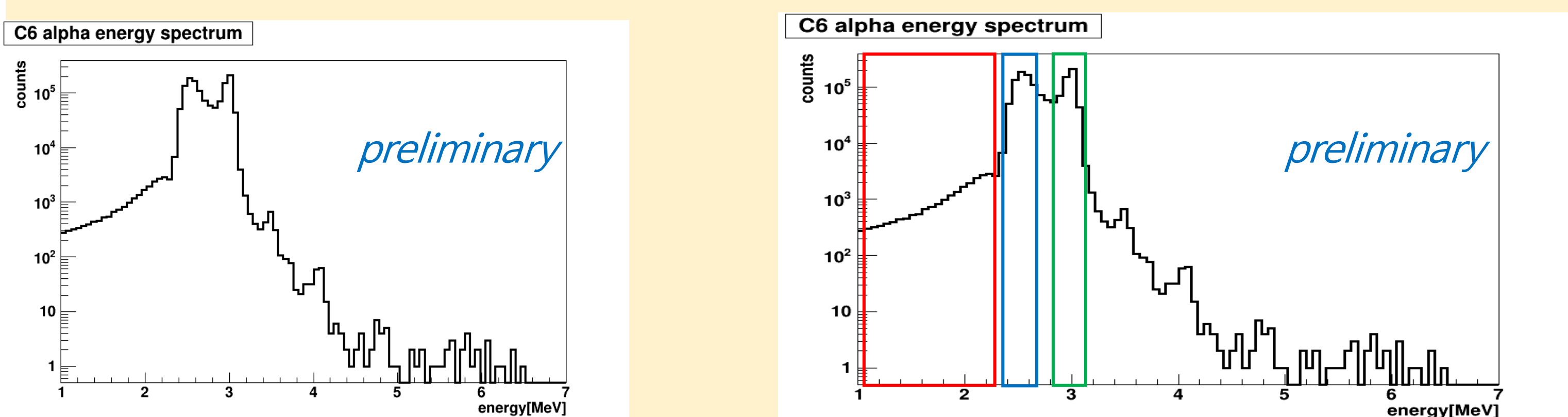
- Crystal 6 alpha energy spectrum

- To analyze two peak shape and the others, divided region

  - 🟥 Low energy alpha events (1 〈 energyD 〈 2.3 [MeV])
  - 🟦 First peak alpha events (2.4 〈 energyD 〈 2.7 [MeV])
  - 🟩 Second peak alpha events (2.9 〈 energyD 〈 3.1 [MeV])

- Two Peak Analysis
  - Asymmetry

preliminary
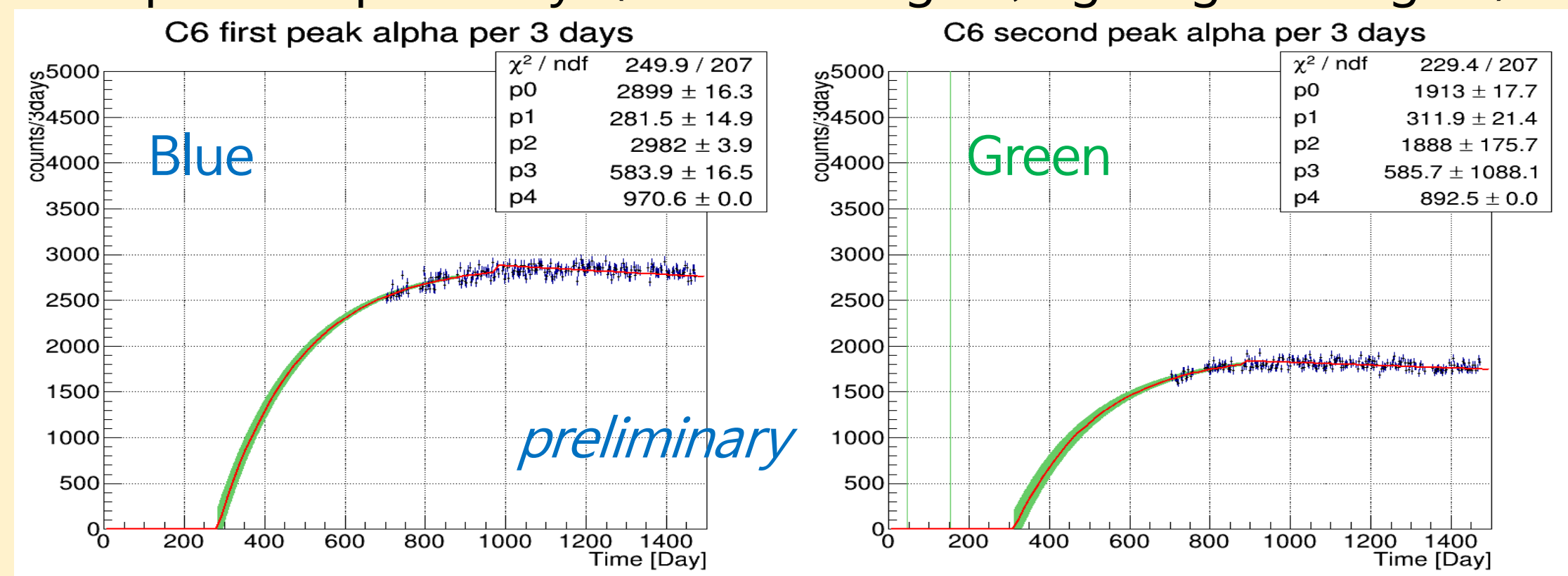
Red asymmetry distribution is similar to crystal surface (ratio of cylinder base and side)

-〉 red region is surface alpha events
-〉 blue and green region are bulk events

  - Alpha rate per 3 days (left : blue region, right : green region)

-〉 Most blue and green region events are from Po-210

-〉 there are two peak

701 day : 2016/10/20
p1 : fit function start day
300 day : around 2015/09

Crystal 6 production
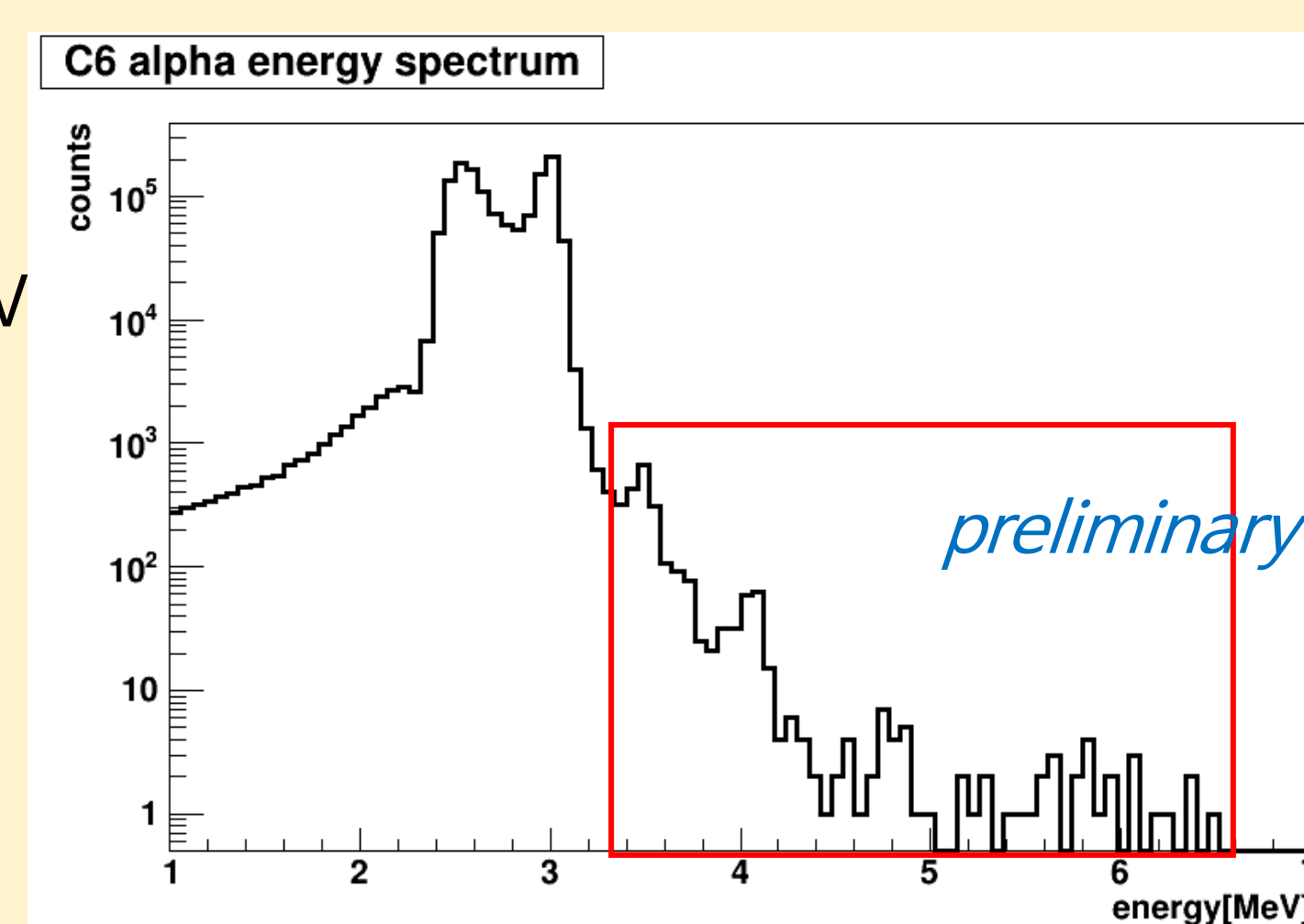Production powder : 2015/08/06
Growth : 2015/10/02

3. Th-232 contamination

- Th-232 decay chain
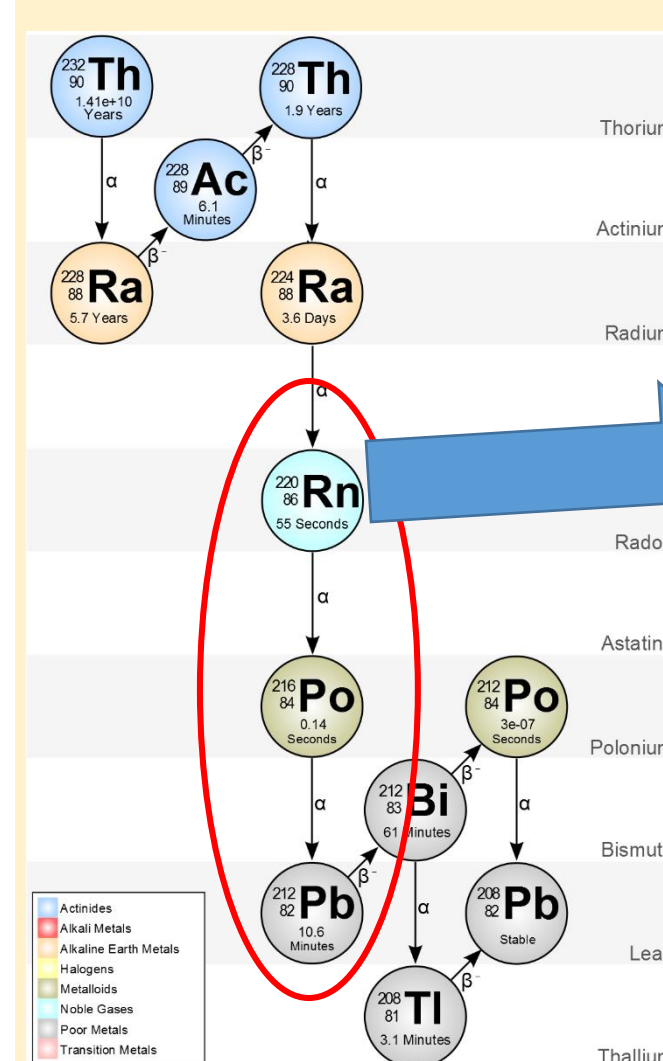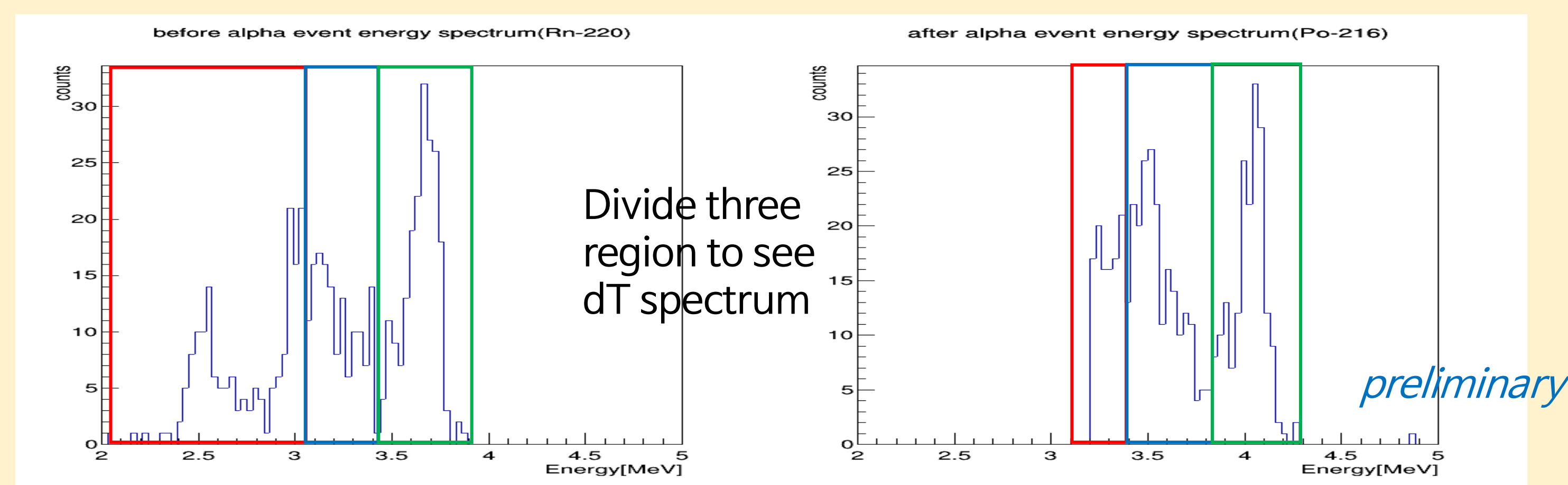

- Rn-220 : 55.6s , 6.405MeV
- Po-216 : **0.145s** , 6.906MeV

-〉 we can select alpha-alpha coincidence events

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Analysis high energy events to select alpha-alpha coincidence events
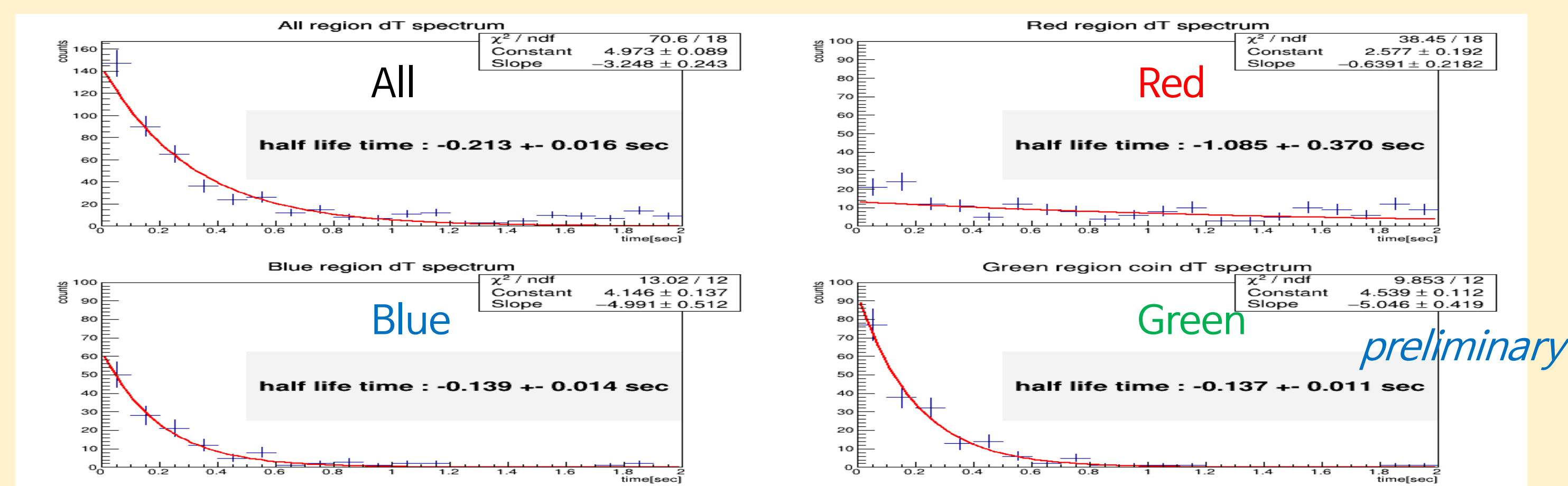Because Q value of Po-210 is 5.4 MeV

- alpha-alpha coincidence events selection

Divide three region to see dT spectrum

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- Cut condition : time difference(dT) 〉 2 sec (99% alpha coin events would be existed in a second)

After alpha deposited energy 〉 3.3MeV (Po-216 : 6.9 MeV)

- alpha-alpha time difference spectrum

All — half life time : -0.213 +- 0.016 sec
Red — half life time : -1.085 +- 0.370 sec
Blue — half life time : -0.139 +- 0.014 sec
Green — half life time : -0.137 +- 0.011 sec

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Blue & green : alpha-alpha coincidence (there are also two peak like Po-210 events)

4. Quenching factor of alpha

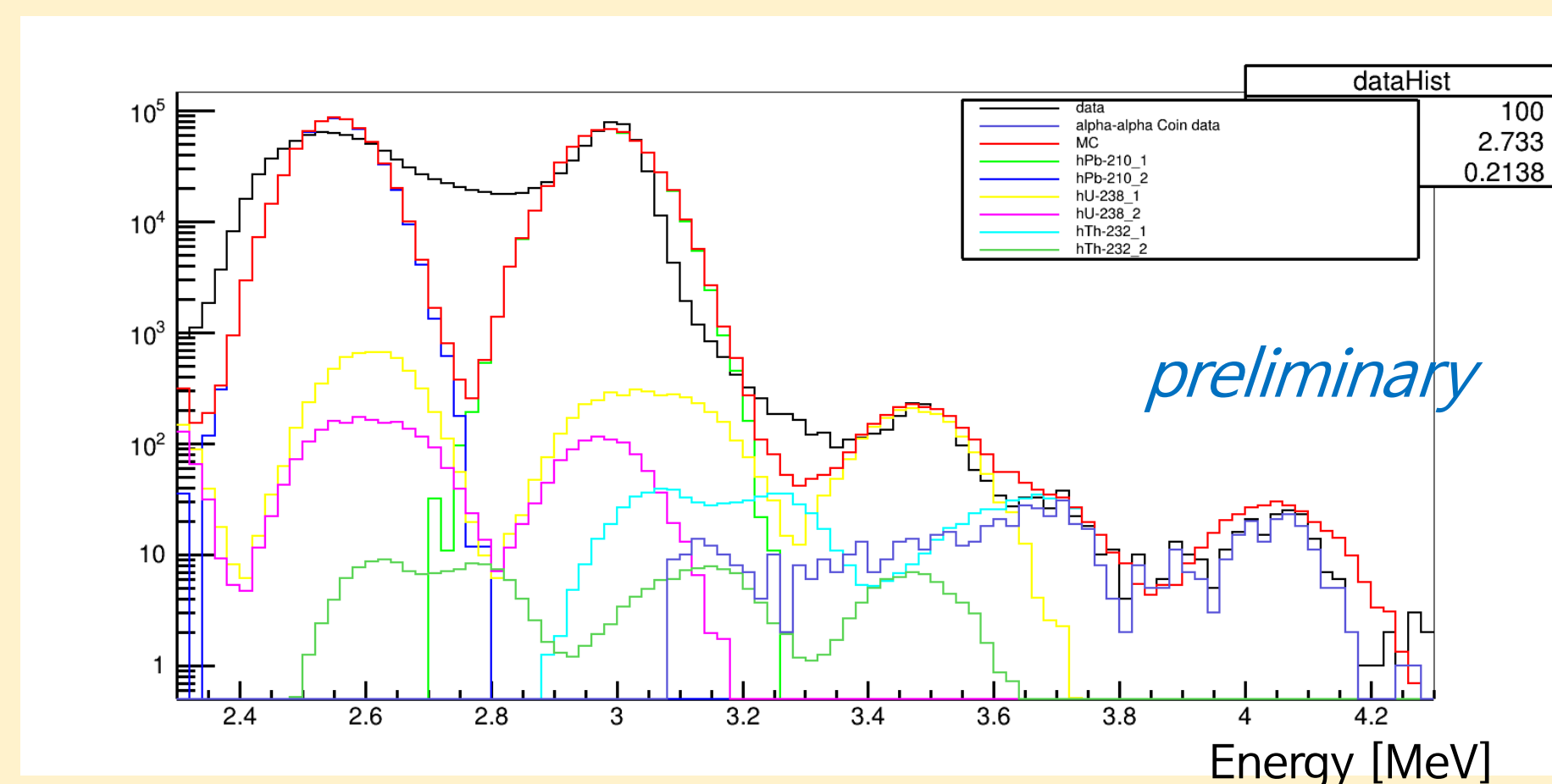- Quenching factor = deposited energy/alpha decay Q value

Second peak matched   First peak matched

preliminary
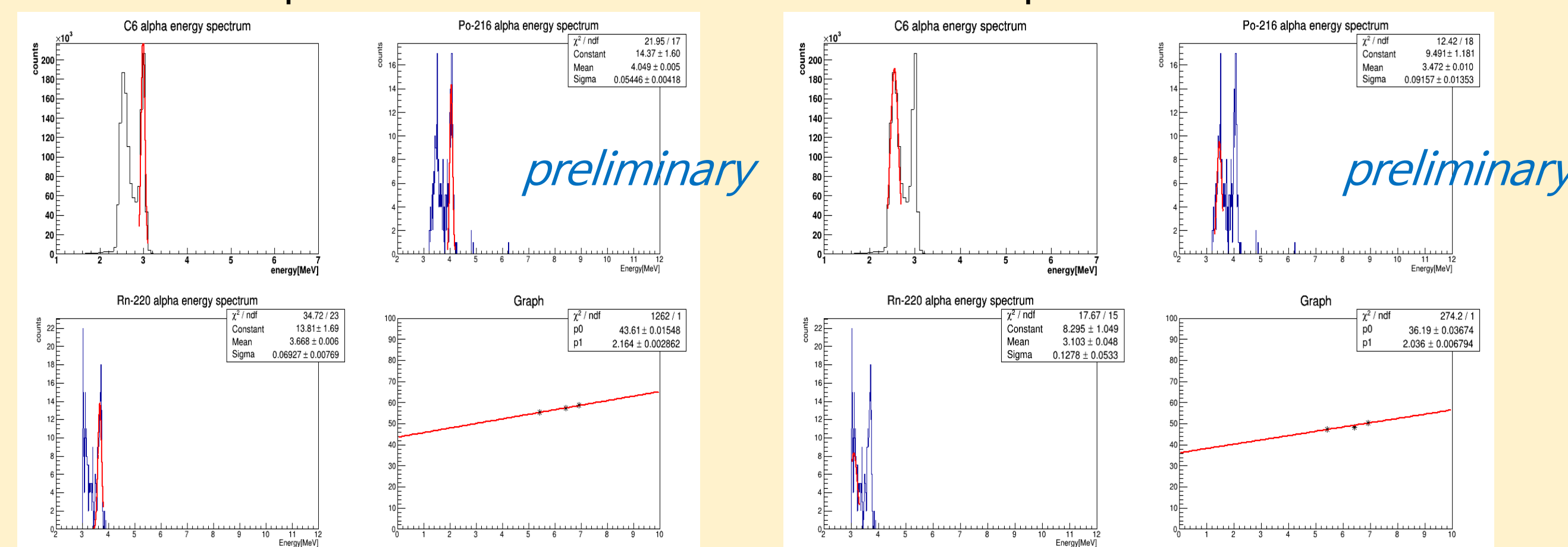
Get quenching factor using Po-210, Rn-220, Po-216 (first linear polynomial)

- Monte Carlo fitting

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5. Summary

- There are two peak from alpha events
- Get quenching factor from two peak
- Two peak issue is still question
- MC fit need to be more exquisitely