Development of multifunctional digital pulse processing module for particle identification in liquid scintillator

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4. Summary

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Multifunctional digital pulse processing module (MDPPM)

NGT400 module was developed for fast neutron tagging using LSC. (H.J.Kim IEEE NSS/MIC 2008)

(Digital pulse shape analysis (DPSA) method is implemented by digital charge comparison (DCC) method in FPGA)

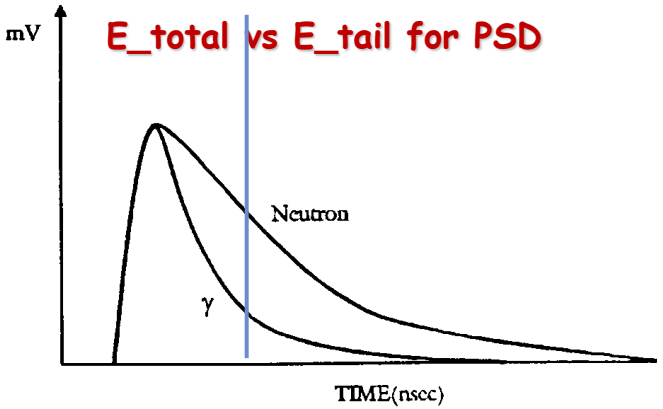
NGT400 : http://www.noticekorea.com/?p=2725

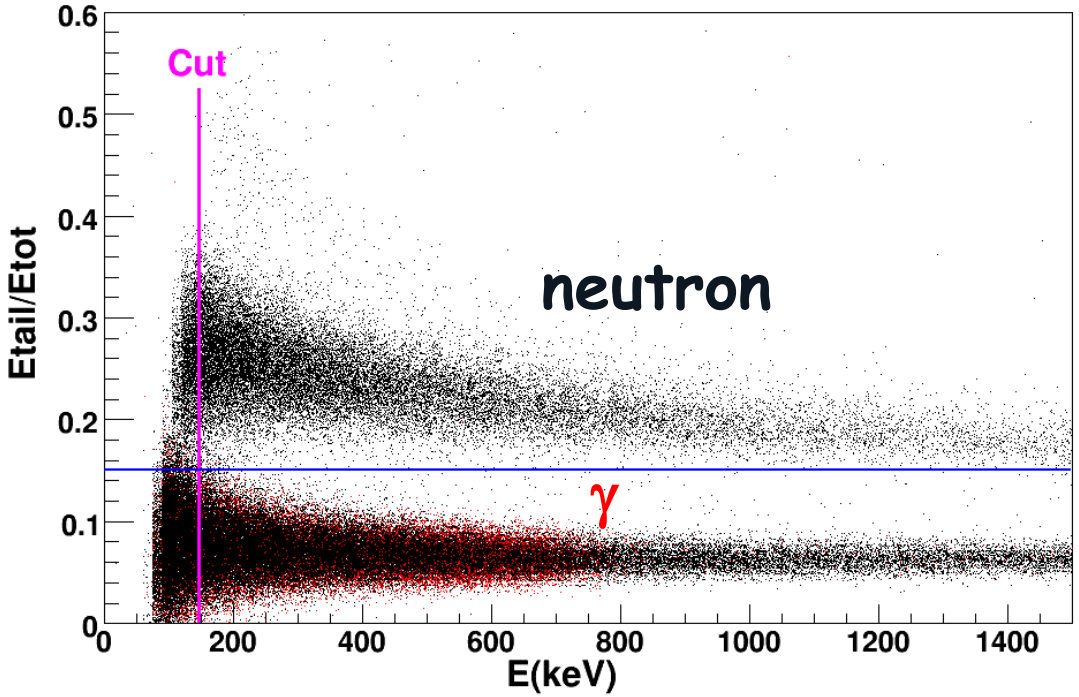
Time tagging information is added for delayed coincidence technique (DCT).

=> Multifunctional digital pulse processing module (MDPPM)

Digital pulse shape analysis (DPSA)

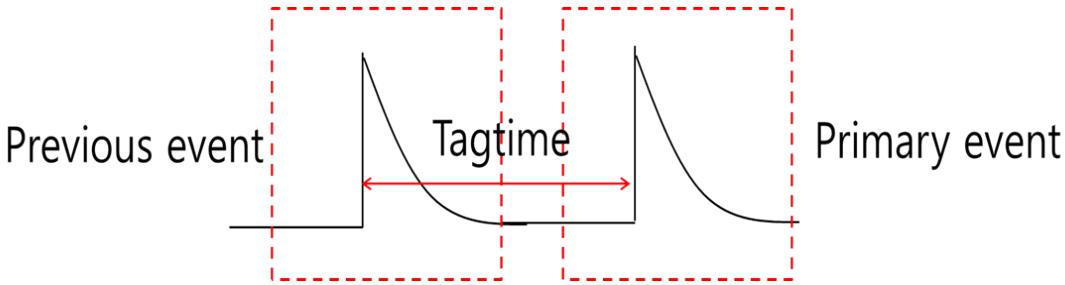
Digital charge comparison (DCC) method





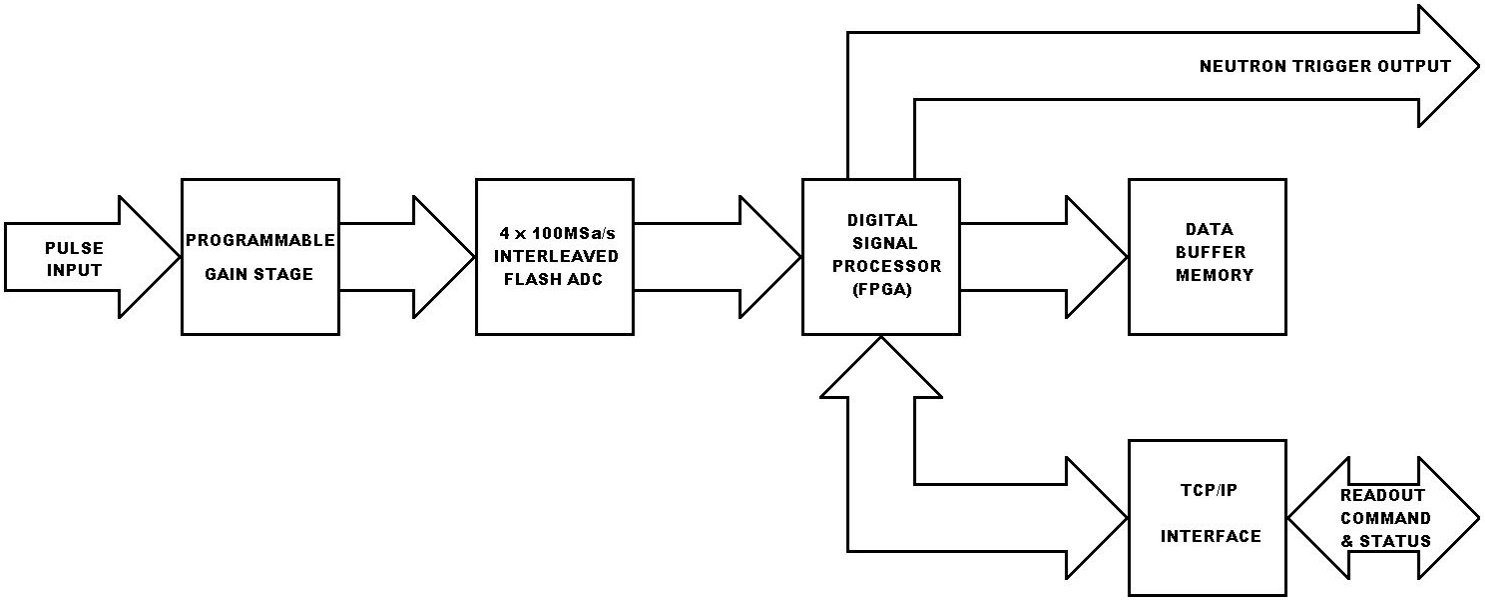
n/γ separation with ^{252}Cf source with BC523

Delayed coincidence technique (DCT)



	^{238}U family	^{235}U family	^{232}Th family
Mother isotope	^{214}Bi Q_β = 3.27 MeV $T_{1/2}$= 20 min.	^{219}Rn Q_α = 6.95 MeV $T_{1/2}$= 3.97 s	^{212}Bi Q_β= 2.25 MeV $T_{1/2}$= 55.6 s
Daughter	^{214}Po Q_α= 7.83 MeV $T_{1/2}$= 164 μs	^{215}Po Q_α = 7.53 MeV $T_{1/2}$= 1.78 ms	^{212}Po Q_α= 8.95 MeV $T_{1/2}$= 0.299 μs
Grand daughter	^{210}Pb	^{211}Pb	^{208}Pb

MDPPM schematics



44 x 20 x 4cm
19" rack mount

Command input : total and tail pulse width, gain, polarity, threshold, particle tag

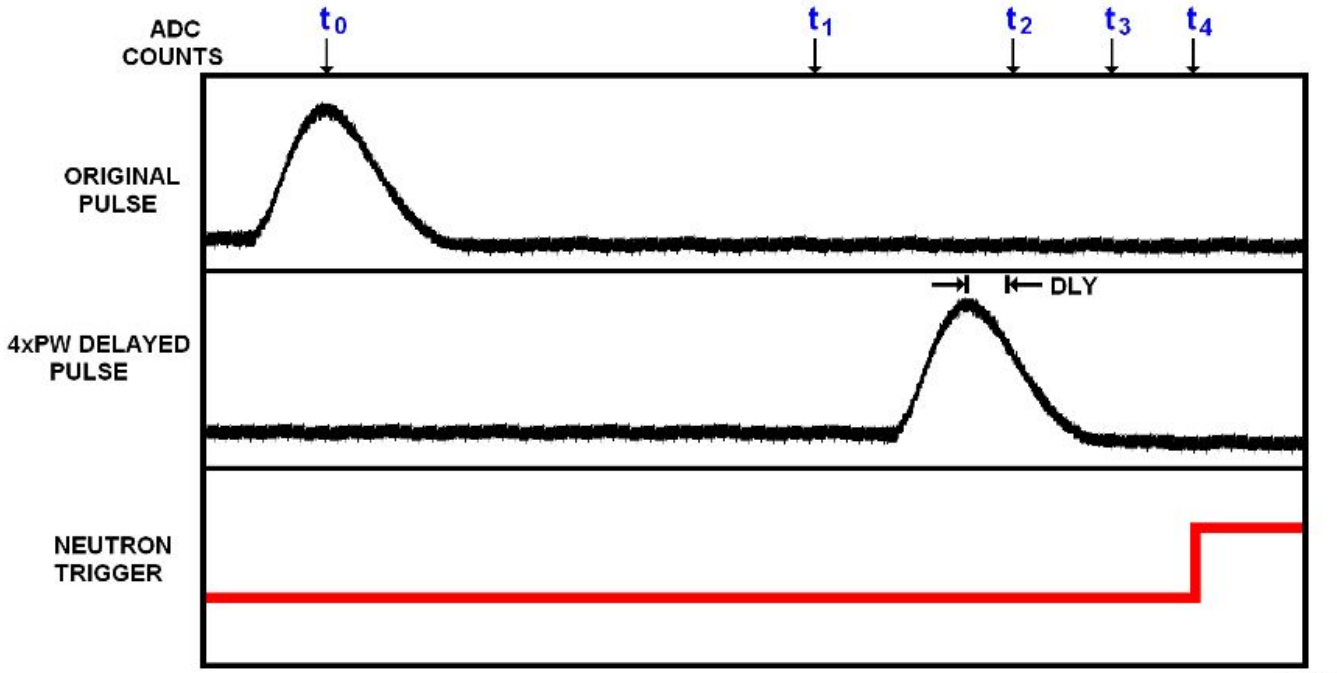
Output : total and tail integration charge and particle flag + tagging time

MDPPM Characteristics

- 400 Msa/s FADC with 10 bit
- FPGA Logic for charge comparison algorithm
- TCP/IP interface (maximum 3 Mbyte/sec)
- Particle trigger out (neutron, alpha)
- Time tagger (10 ns)
- Software setting in DAQ system:

1. Pulse width for charge integration : 20 <T< 1270 ns
2. Pulse tail integration width : 0 < T_{tail} < 1000 ns
3. Gain adjustment : 0.7 – 10
4. Threshold setting for self triggering
5. Negative or positive polarity setting
6. Particle tagging with tail to total charge ratio setting

FPGA algorithm in MDPPM



* ALL SUMMINGS ARE DONE WITH PEDESTAL SUBTRACTED

PW = PROGRAMMED PULSE WIDTH

DLY = PROGRAMMED TIME DELAY FROM PEAK TO START OF TAIL

Tpd = ADC PIPELINE DELAY + PROCESSING LOGIC LATENCY = 300 ns

t_0 : PEAK POSITION

t_1 (= t_0 + 3 x PW) : START OF BODY SUM

t_2 (= t_0 + 4 x PW + DLY) : START OF TAIL SUM

t_3 (= t_0 + 5 x PW) : END OF SUM

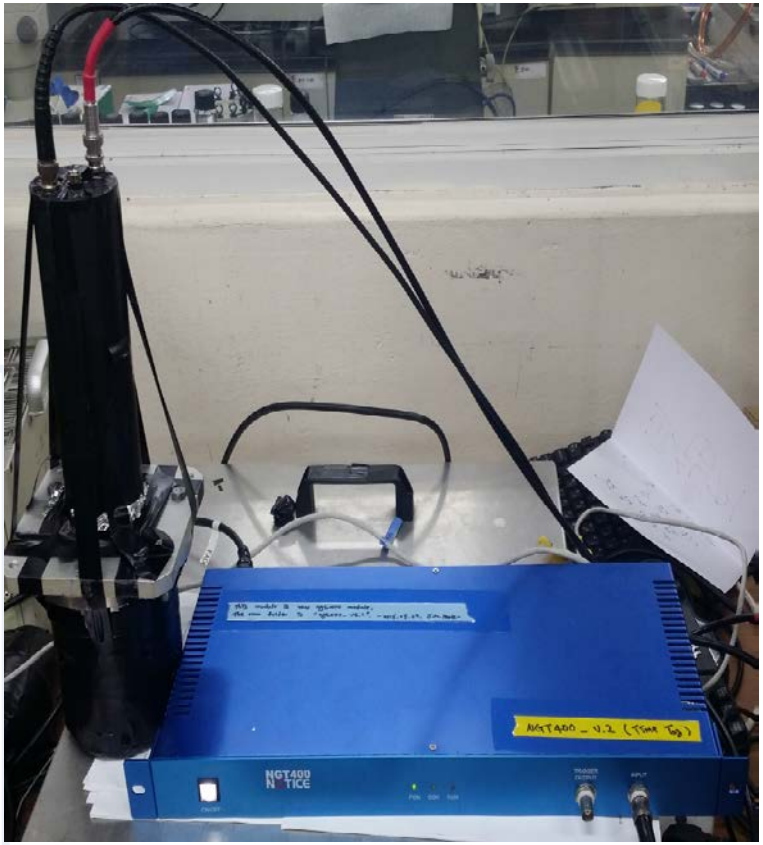
t_4 (= t_0 + 5 x PW + Tpd) : NEUTRON TRIGGER SIGNAL GENERATION

1300 ns delay in trigger out with 200 ns pulse width

LSC detector with 5cm Pb shielding

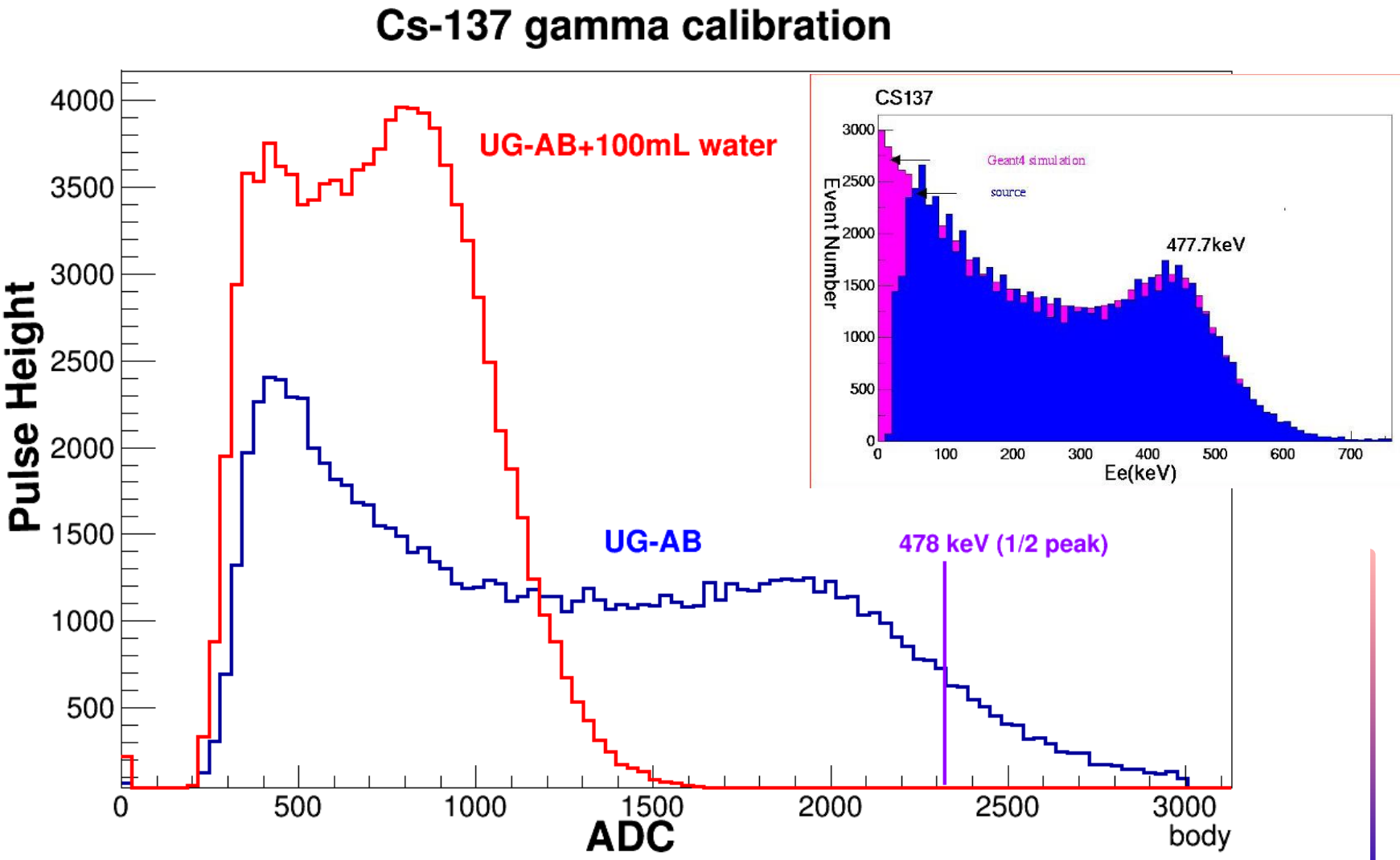
SUS container
v = 1.0 L
d = 2 mm Teflon
+ 2 mm SUS outside
5 mm glass window
Test with
700 mL UltimaGold AB
+100mL Tap water

LSC + PMT + DMPPC



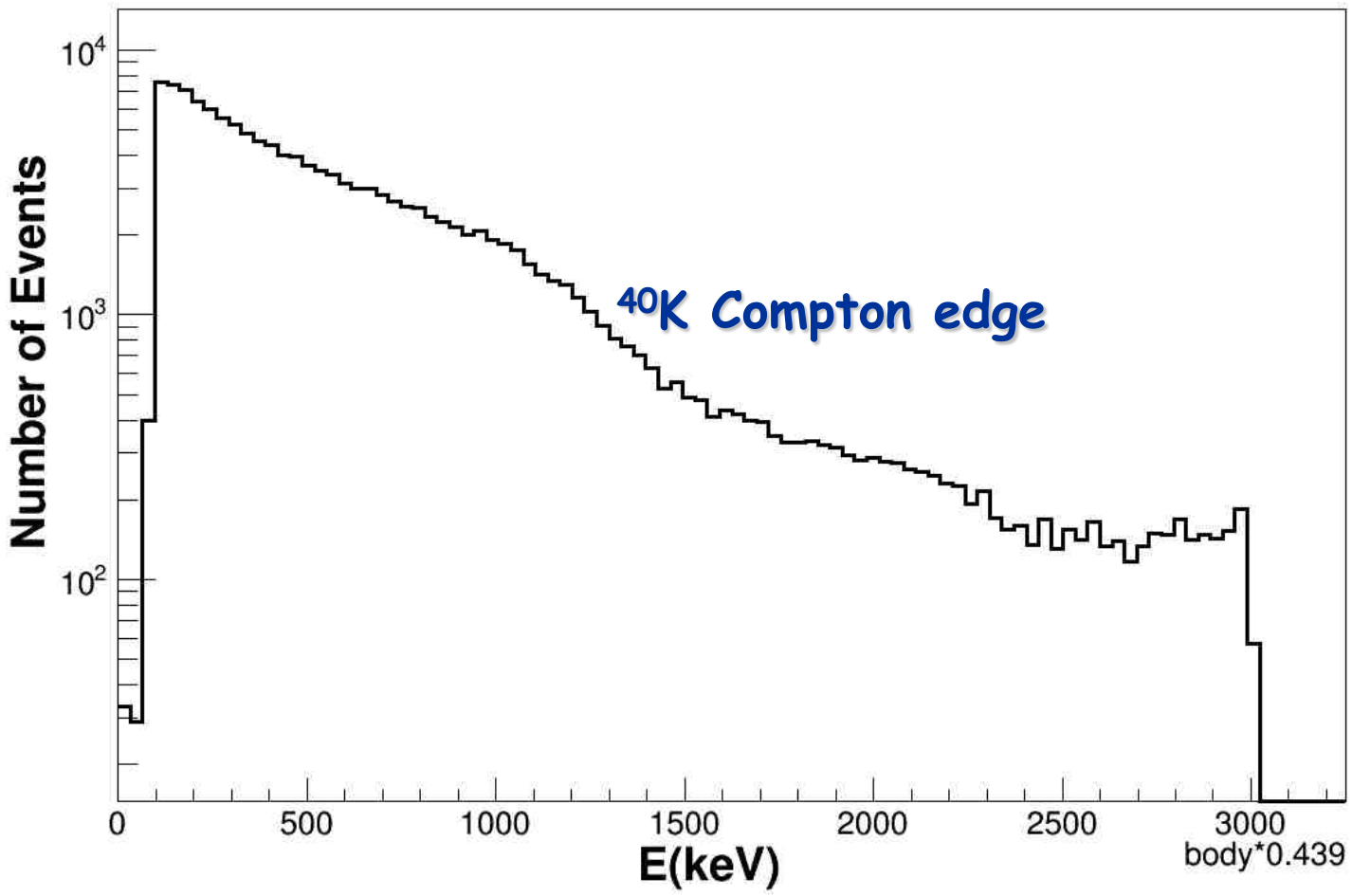
Detector + 5cm Pb

Energy Calibration with ^{137}Cs γ source



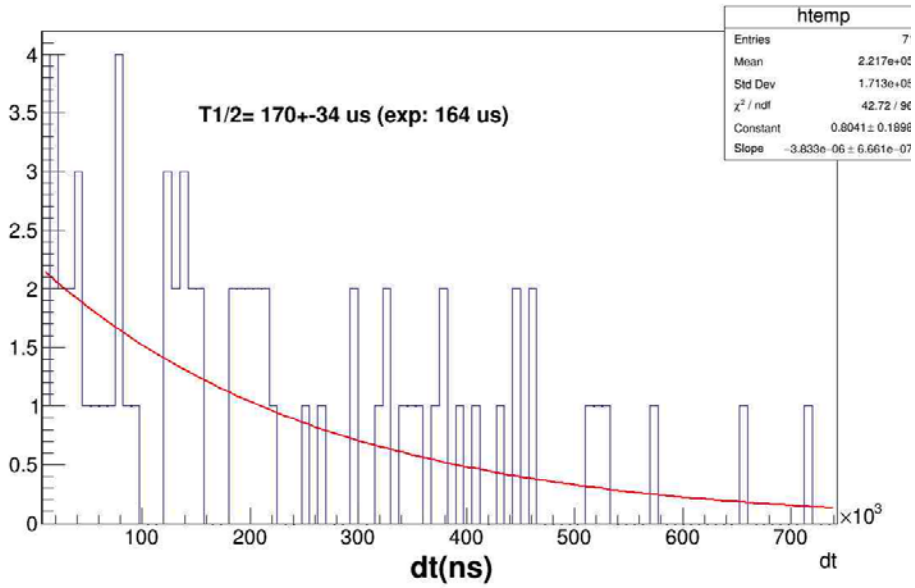
Background spectrum with water sample

23,000 sec data, 8.7 Hz background

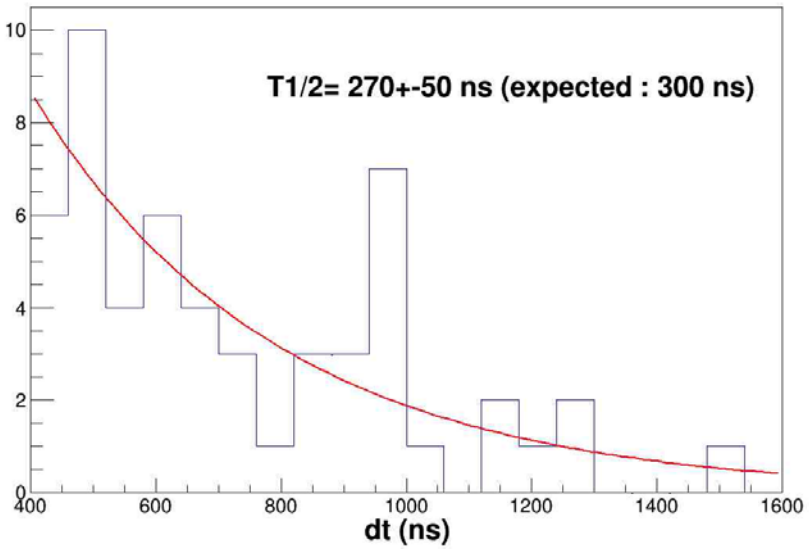


Half life of Bi-Po events

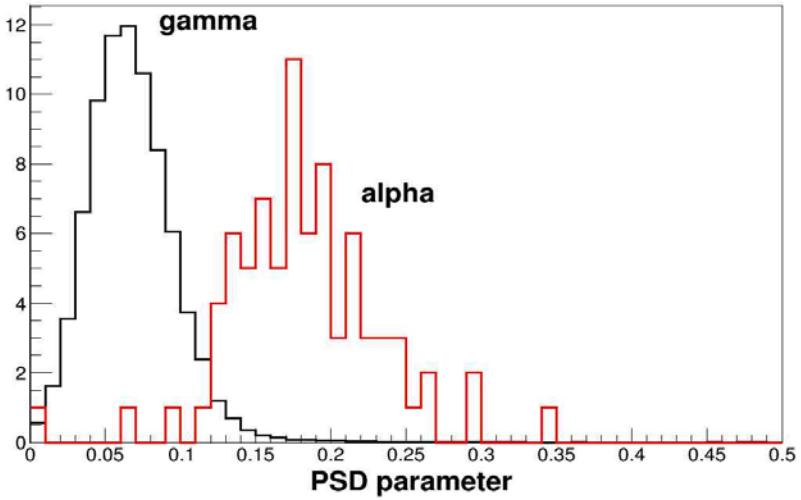
$^{214}Bi \rightarrow ^{214}Po \rightarrow ^{210}Pb$ (^{238}U)

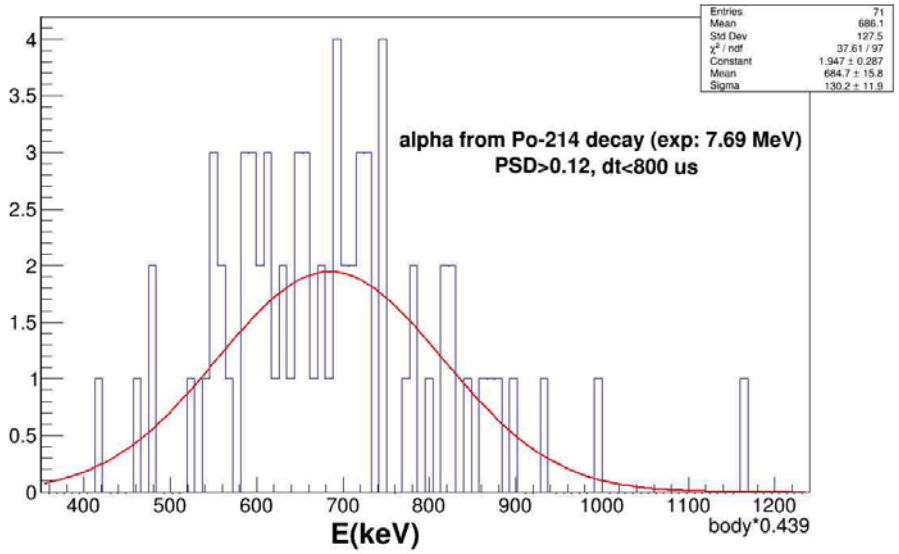


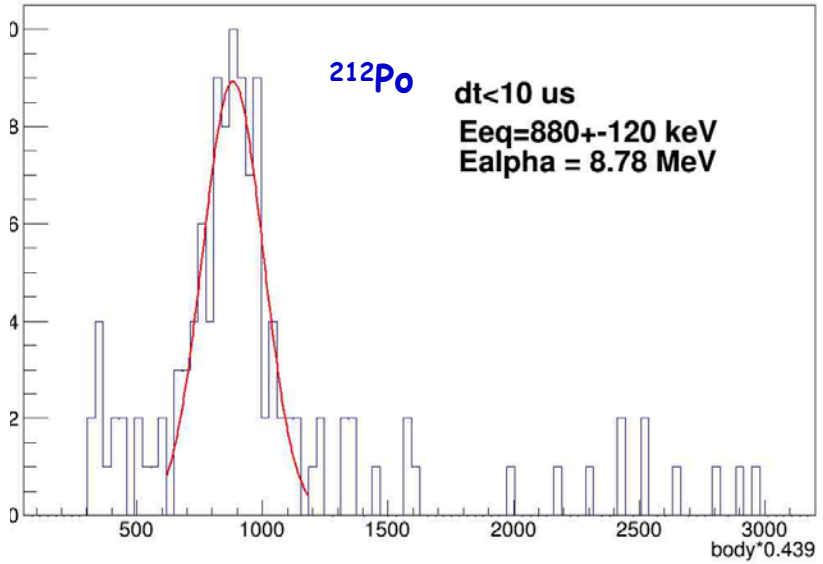
$^{212}Bi \rightarrow ^{212}Po \rightarrow ^{208}Pb$ (^{232}Th)



PSD and alpha energy of Radon product







Summary and prospect

- Multipurpose Digital Pulse Processing Module was developed using both DPSA between alpha and beta particles and delayed coincidence technique (DCT) of short-lived decay product.

- Ultima Gold AB (700 mL) was used for the detection of radium and radon decay product in Tab water (100 mL) and we measured 0.03±0.004 Bq/L of ^{222}Rn (^{238}U decay chain) and 0.09±0.01 Bq/L of ^{220}Rn (^{232}Th decay chain).

- No noticeable background was detected with pure UG-AB, <0.01 Bq/L level of sensitivity can be easily achieved and <0.001 Bq/L is possible with optimization.

- We will work on optimization of DPSA and background reduction with better shielding at deep underground lab.

- Various water soluble samples can be used to determine low radioactivity of radium and radon level.

Thank you

^{238}U, ^{235}U, and ^{232}Th decay chain