Software development and source test of the high-energy neutron detector for LAMPS at RAON

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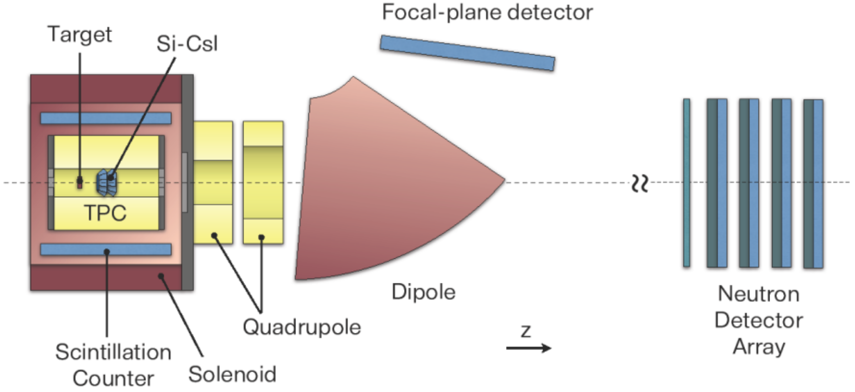
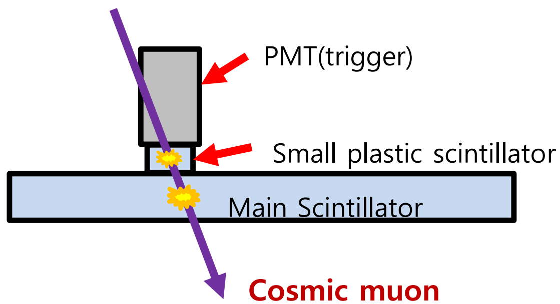
Introduction

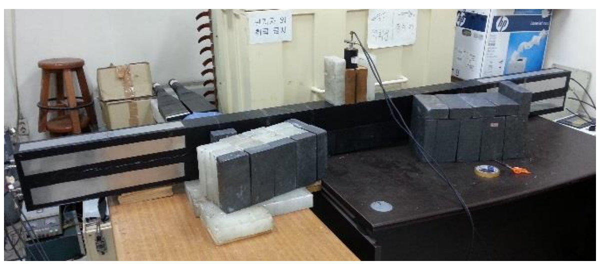


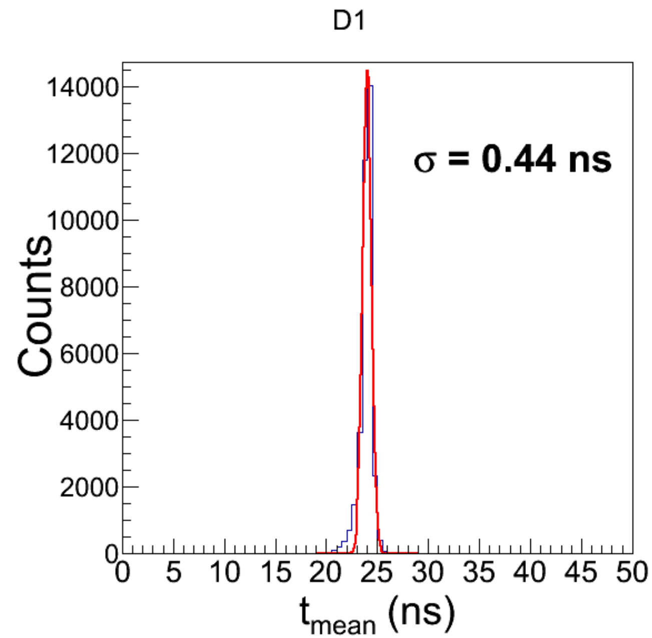
- "RAON" – Korea Rare Isotope Accelerator at RISP
  - ➢ A Future multipurpose accelerator for the basic & applied sciences.
- LAMPS(Large Acceptance Multi-Purpose Spectrometer)
  - ➢ Primary purpose : Nuclear symmetry energy
  - ➢ Also useful for nuclear structure & nuclear astrophysics.
- Neutron detector
  - ➢ Neutron measurement is important to understand the isospin dependence of nuclear symmetry energy.
  - ➢ Should cover from a few tens to a few hundreds MeV.

Cosmic Muon Test

1) Time Resolution



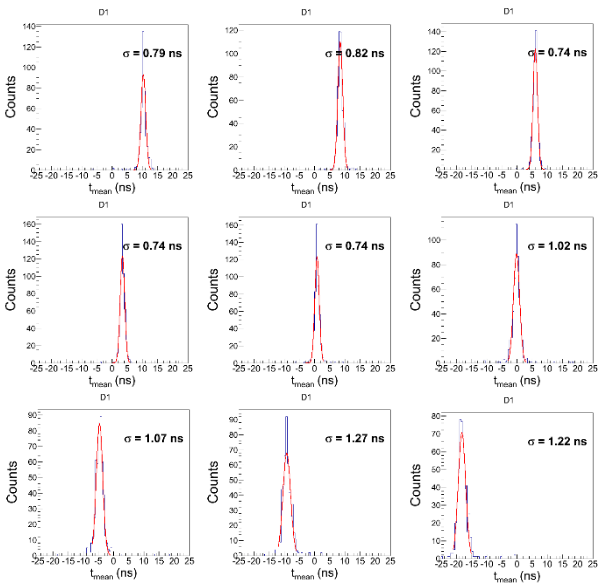


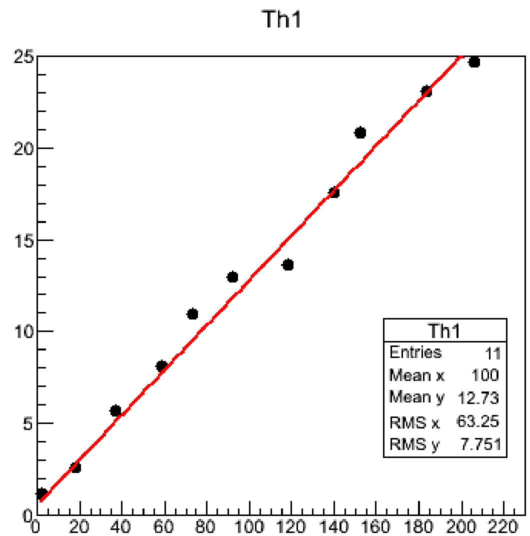


- Threshold : 150 mV
- Cosmic muon has high energy.
- We can get results similar to high energy neutron cases by using cosmic muons.
- Trigger time resolution $\sigma_{trigger}$ = 308 ps
- Measured time resolution $\sigma_{measured}$ = 440 ps
- Intrinsic time resolution $\sigma_{intrinsic} = \sqrt{\sigma_{measured}{}^2 - \sigma_{trigger}{}^2} = 314$ ps

Cosmic Muon Test

2) Position Resolution





$$\Delta t = ax + b$$

$$x = \acute{a}\Delta t + \acute{b}$$

$$\acute{a} = \frac{1}{a}, \ \acute{b} = -\frac{b}{a}$$

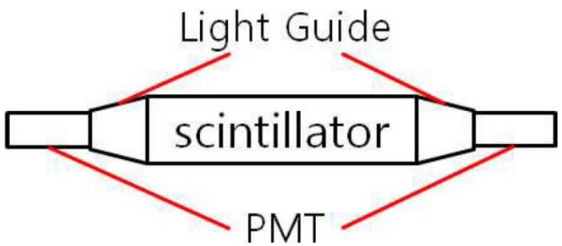
$$\sigma_{\acute{a}} = \sqrt{\left(\sigma_a \frac{\partial \acute{a}}{\partial a}\right)^2}, \ \sigma_{\acute{b}} = \sqrt{\left(\sigma_a \frac{\partial \acute{b}}{\partial a}\right)^2 + \left(\sigma_b \frac{\partial \acute{b}}{\partial b}\right)^2}$$

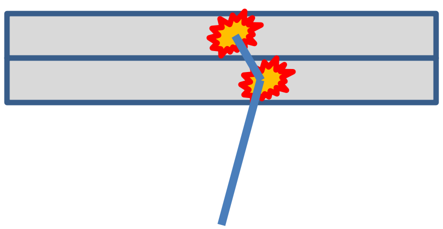
$$\sigma_x = \sqrt{\left(\sigma_{\Delta t} \frac{\partial x}{\partial \Delta t}\right)^2 + \left(\sigma_{\acute{a}} \frac{\partial x}{\partial \acute{a}}\right)^2 + \left(\sigma_{\acute{b}} \frac{\partial x}{\partial \acute{b}}\right)^2}$$

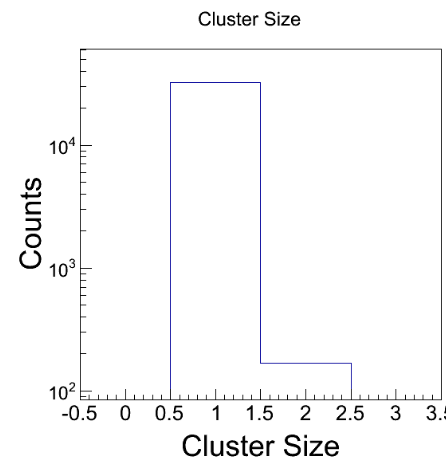
a′ (cm/ns)	b′ (cm)	σ_x (cm)
8.20 ± 0.03	-4.93 ± 4.69	7.62

^{252}Cf Test

1) Time of Flight with ^{252}Cf



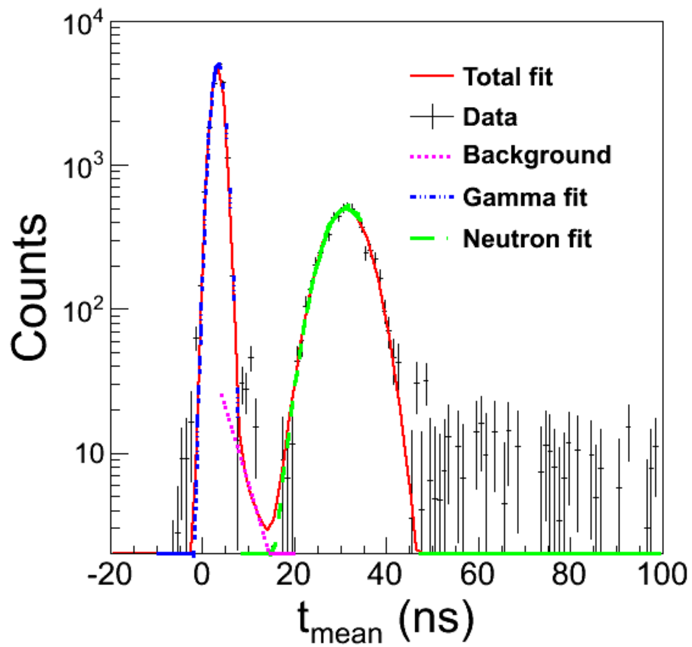




- Gamma & neutron are emitted by Californium 252.
- Gamma is used as reference of time.
- TOF method is used to calculate energy of neutron.
- Neutron can be detected in both detectors.
- Hit is ordered by its deposit timing in the each event.
- Only 1st hit will be used as real hit.

^{252}Cf Test

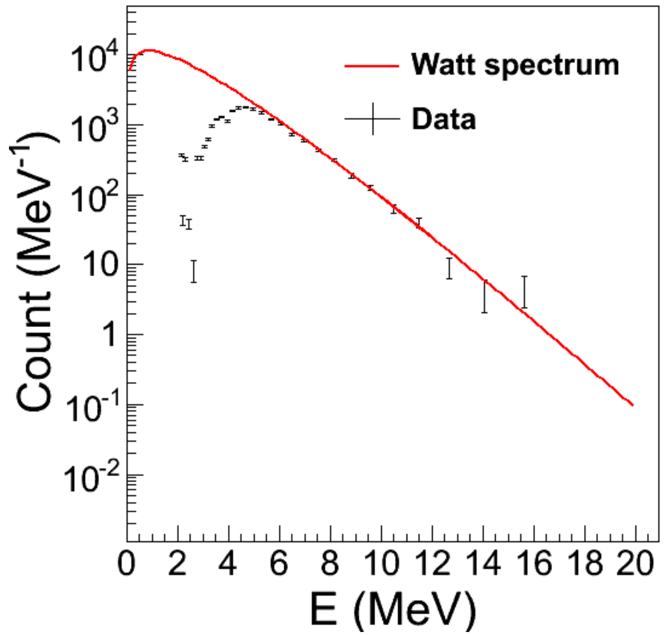
2) Time Distribution



- Accitental is the noise which electronics counts as signal when particle does not reaches to the detector.
- We must subtract this count of ratio.
- The plot is accidental subtracted time distribution when the hits are the first hit.

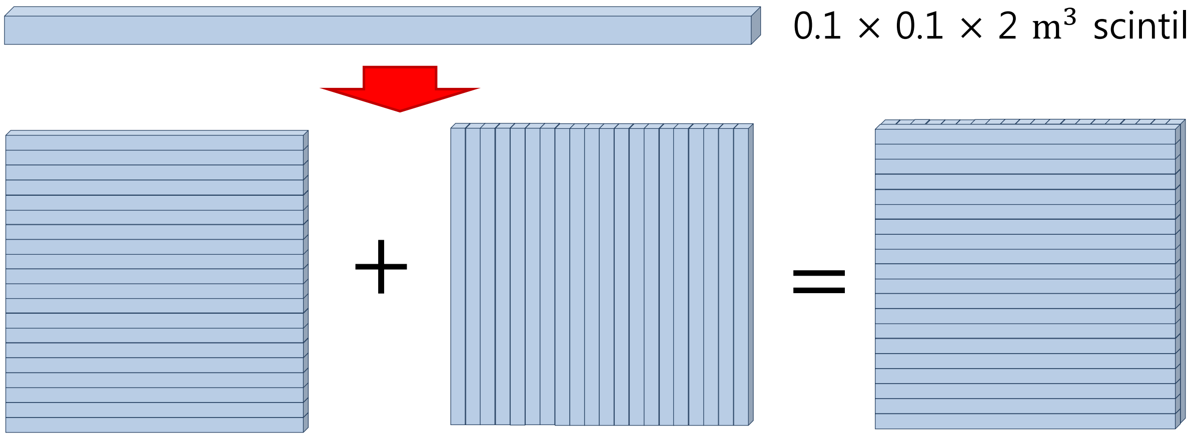
^{252}Cf Test

3) Watt Spectrum



- Using TOF method, neutron counts of each time can be converged to the counts of each energy.
- 2 m long bar-type detector can detect over than 5 MeV neutron.
- Watt spectrum : $y = 14067 \times e^{-0.88x} \times \sinh\sqrt{2x}$

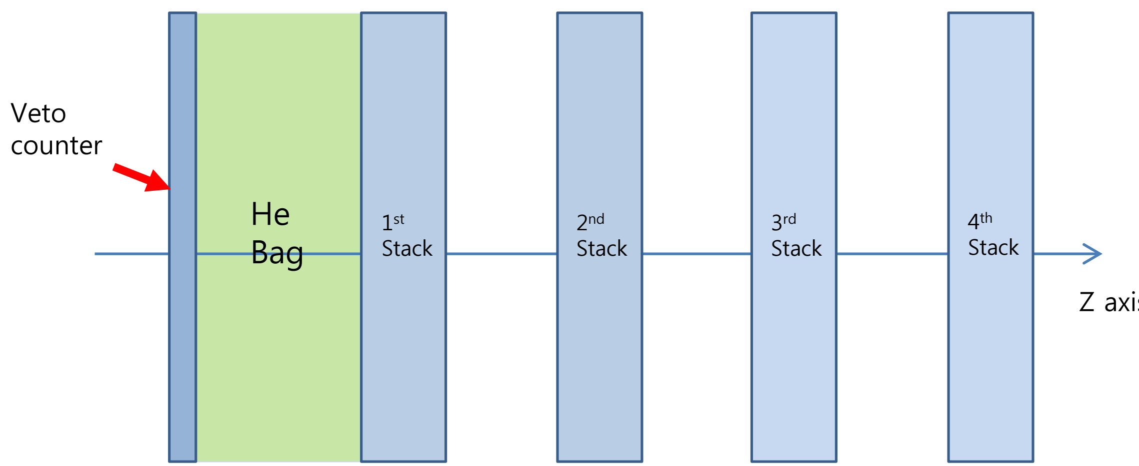
1) Structure



$0.1 \times 0.1 \times 2\ \mathrm{m}^3$ scintillator for 1 module

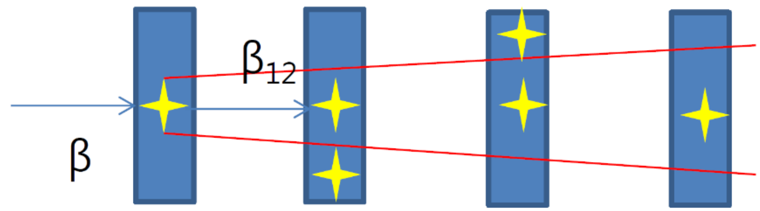
× 20 : Horizontal layer   × 20 : Vertical layer   × 40 : 1 Stack

- 4 Stacks (8 layers)
- 40 cm gap between stacks
- 20 module for 1 layer
- Veto counter & Helium bag
in front of neutron detector



2) Algorithm

$$\beta = \frac{v}{c}$$



① Beta Condition

- As neutron goes through layers, it deposits energy on scintillator.
- Neutron losses its energy.
- Velocity of neutron decreases.
- $\beta > \beta_{12} > \beta_{23} > \beta_{34}$ (β_{ij} : Beta between i-th stack & j-th stack)

② Geometic Condition

- 1st stack : Hits within 30 cm from 1st hit position,
- 2nd stack : within 40 cm from 1st hit position,
- 3rd stack & 4th stack : within 60 cm from 1st hit position,
  are considered as hits remained by same neutron.

③ Back Scattering

- Particle can be bounce off the next stack.

3) Efficiency

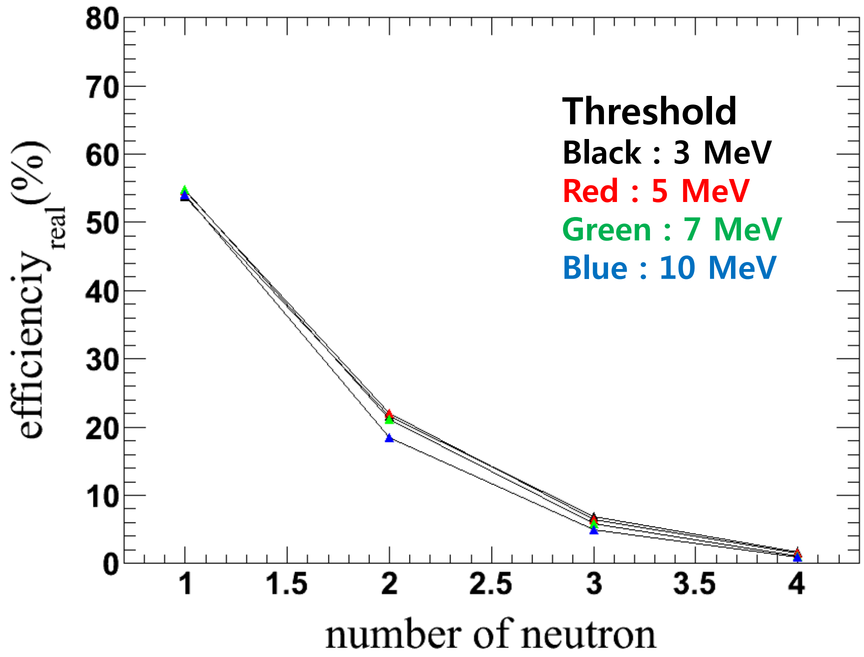
I. Generate events(10000 events)

II. Randomly select (1, 2, 3, 4) event(s) among the generated events, and collect hits of that(those) event(s).
   - **Real incident neutrons**

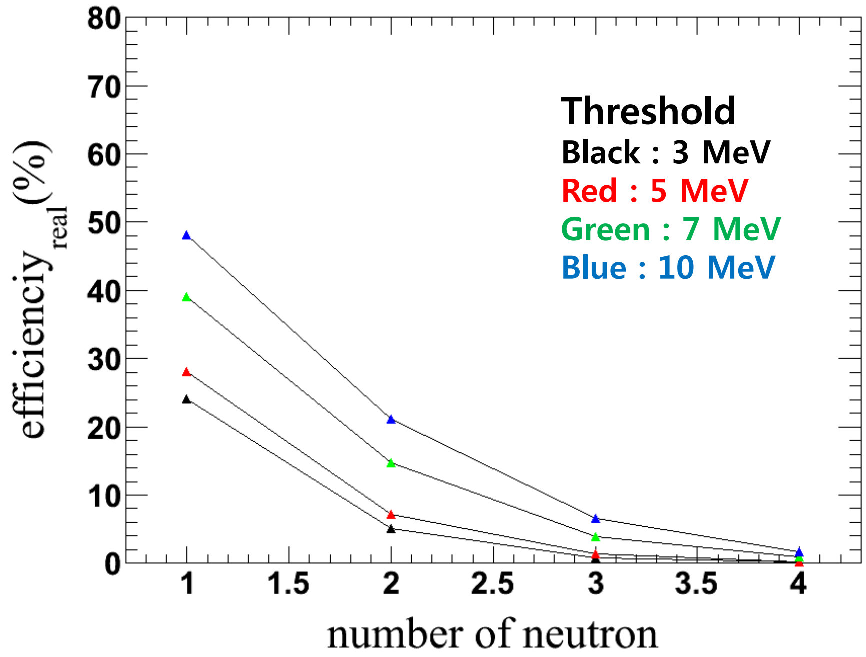
III. Using 3 conditions(Beta condn., Geometric condn., Back Scattering), classify the hits into groups that is expected to be the hits by same neutron.

IV. Count the number of groups.
   - **Reconstructed incident neutrons**

V. Efficiency (%) = {(real_good) / (event_number)} × 100
   - **Real_good : the number of events satisfying both Beta condn & Geometric condn, and also satisfying (Real incident neutrons) = (Reconstructed incident neutrons)**
   - **Event_number : 10000 events**



Neutron energy : 100 MeV



Neutron energy : 300 MeV

Conclusions & Next Step

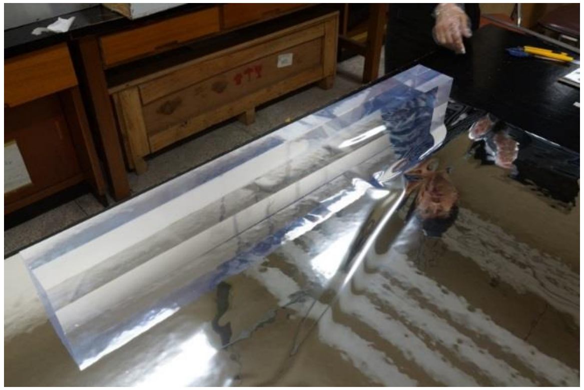
- Time resolution of bar-type detector with cosmic muon : 314 ps
- Position resolution of bar-type detector with cosmic muon : 7.62 cm
- 2 m long bar-type detector can detect over than $5\ \mathrm{MeV}$ neutron.
- Next step
  - ➢ Need to test the “Beta condition” using 2 m long bar-type detectors.
  - ➢ Improve high-energy neutron detector simulation continuously.

Back Up

Back Up

Components

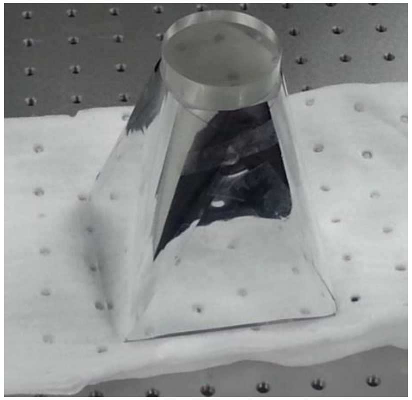
Scintillator



Bicron BC-408

Decay constant: 2.1 ns
Bulk light attenuation length: 380 cm
Refractive index: 1.58
H:C ratio: 1.104
Density: 1.032 $\mathrm{g/cm^3}$
Softening point: 70 ℃

Light guide



Arcrylic

Density: 1.18 $\mathrm{g/cm^3}$
Refractive index: 1.4914

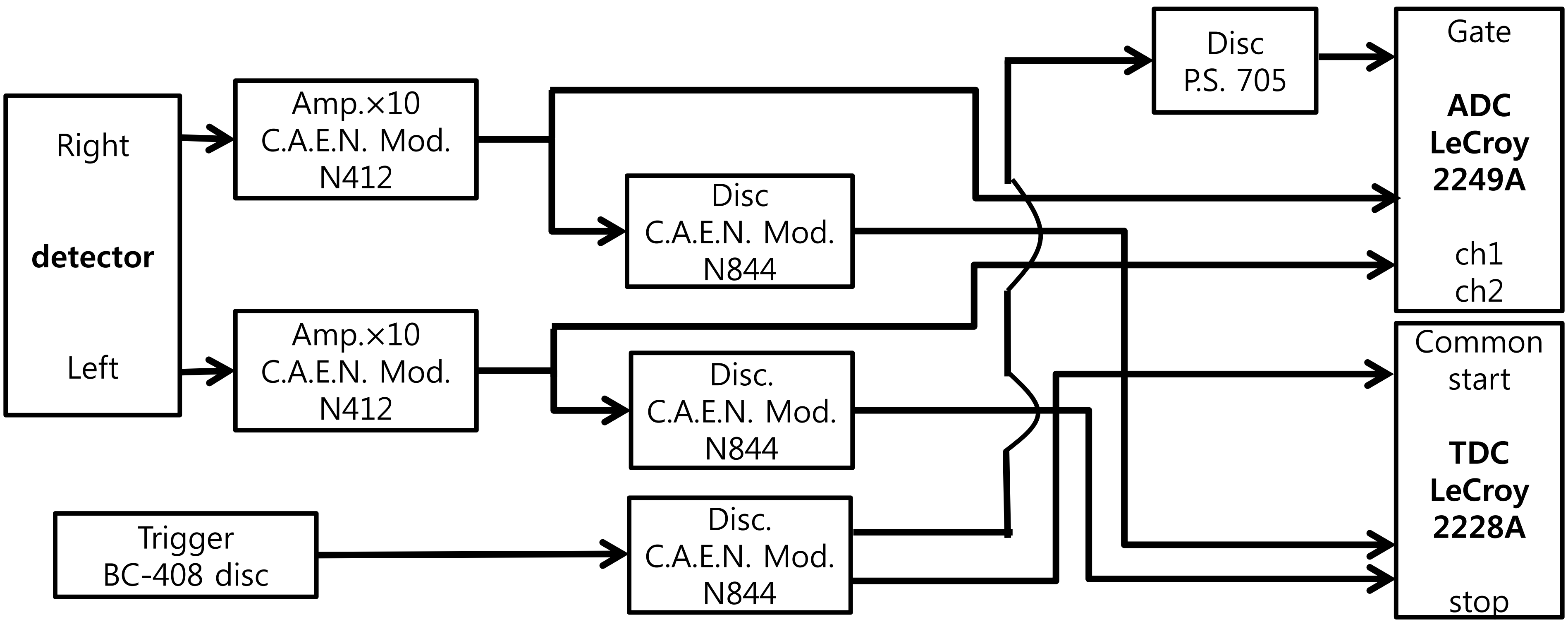
PMT

H2431-50

Wavelength short: 300 nm
Wavelength long: 650 nm
Transit time: 16 ns
Gain: 2.5×10^6

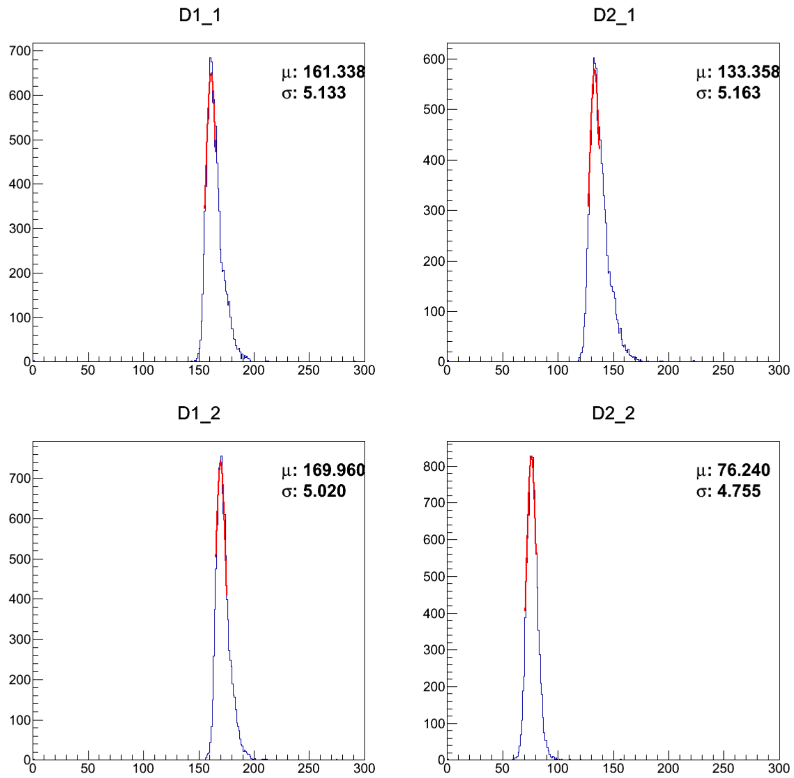
Circuit

- Threshold : 180 mV
- Trigger threshold : 40 mV



^{252}Cf Test

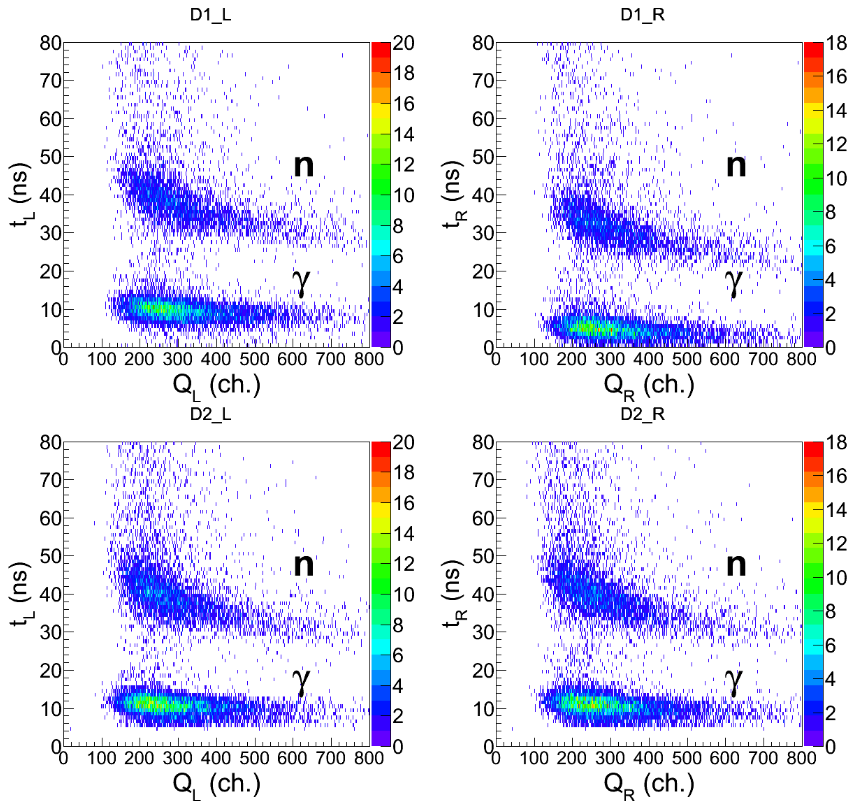
2) Pedestal Subtraction



- The electronics have basic charge value.
- This is called as “pedestal” and it must be subtracted to get real integrated charge value.

^{252}Cf Test

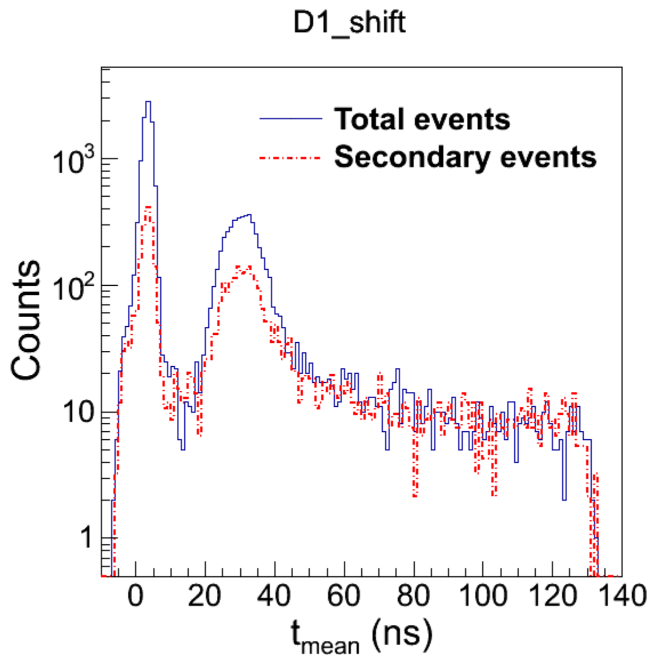
3) 2-D Plot

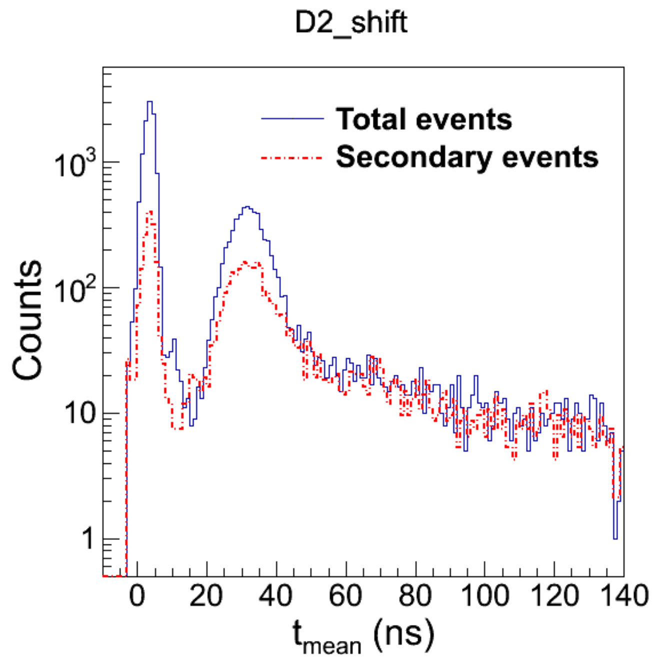


- Pedestal is subtracted.
- Neutron & gamma are well separated.
- There is ADC dependence of neutron energy.

^{252}Cf Test

4) Time Distribution



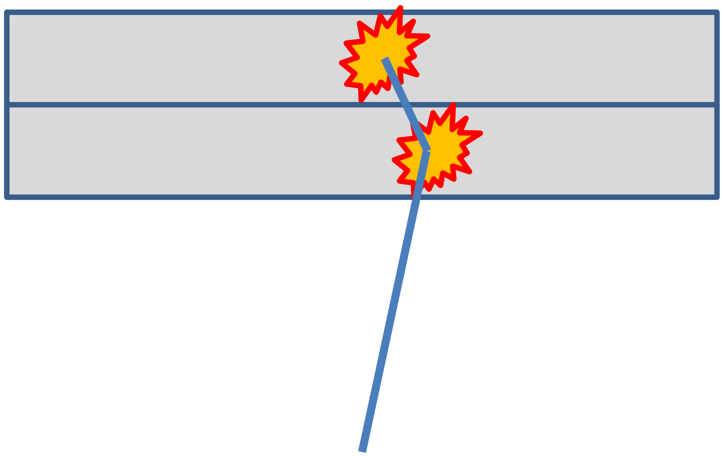


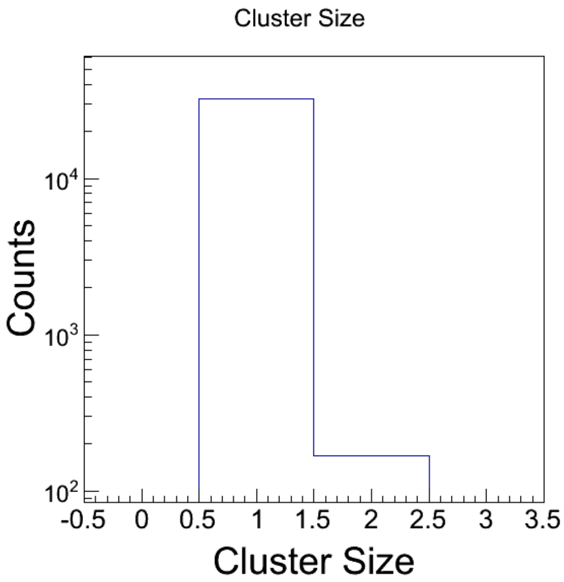
- For each detector, time is the mean time of both side.
- Every points shifted to gamma value as 3.33 ns.

  (3.33 ns = Gamma travel time of 1 m)

^{252}Cf Test

6) Clusterization

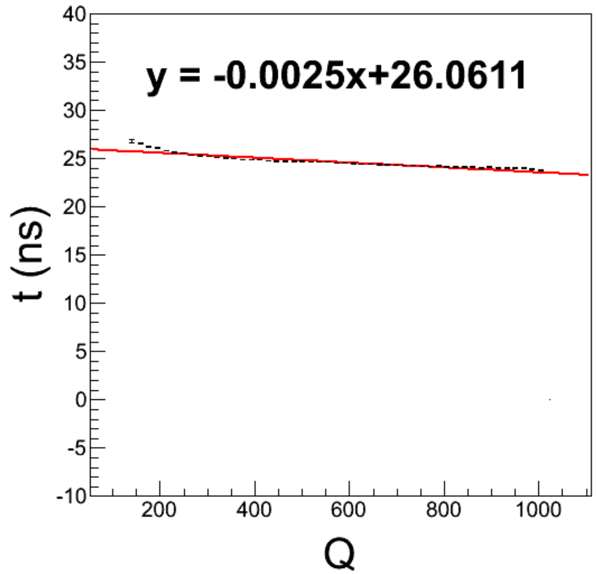




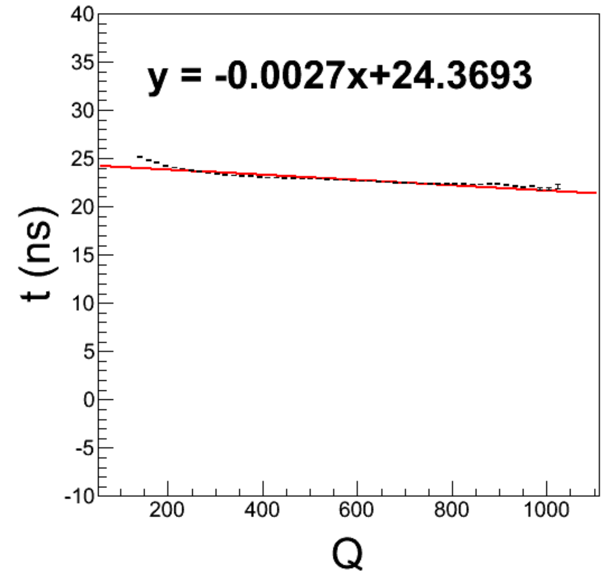
- Neutron can be detected in both detectors.
- Hit is ordered by its deposit timing in the each event.
- Only 1st hit will be used as real hit.

Cosmic Muon Test

1) Time Walk Correction



Left



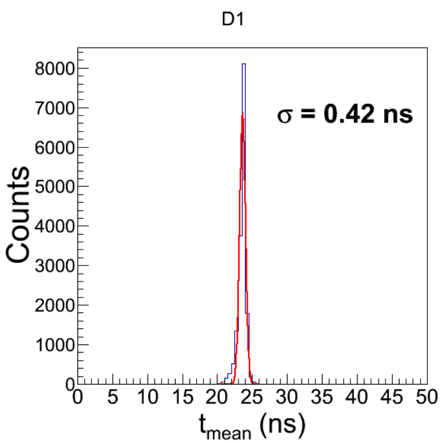
Right

- In this experiment, we have used VTD(Voltage Threshold Discriminator).
- So, When ADC value is high, TDC value(time) is low,
  ADC value is low, TDC value(time) is high.
- Therefore, TDC value should be corrected with Time Walk Correction.

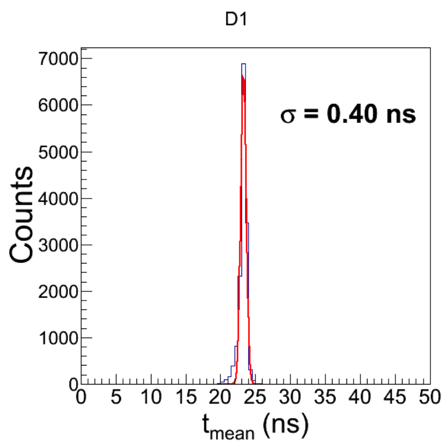
Cosmic Muon Test

3) Time resolution at higher PMT voltage

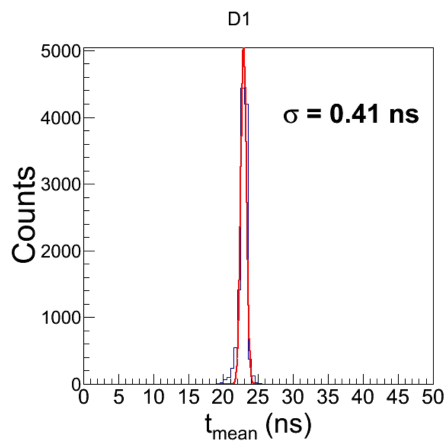
- Increasing both PMT voltages 50 V per 20000 events



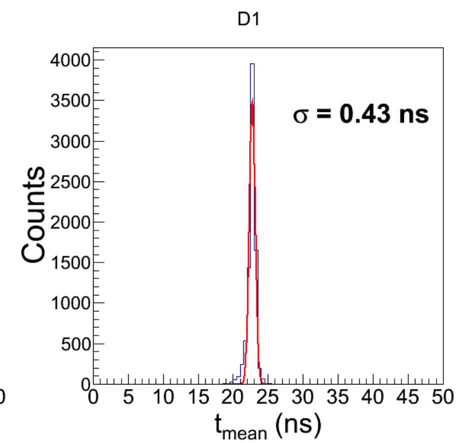
σ_t=0.288139 ns



σ_t=0.260032 ns



σ_t=0.264455 ns



σ_t=0.296315 ns

Increasing voltage