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Performance of the prototype neutron detector for low-energy LAMPS at RAON

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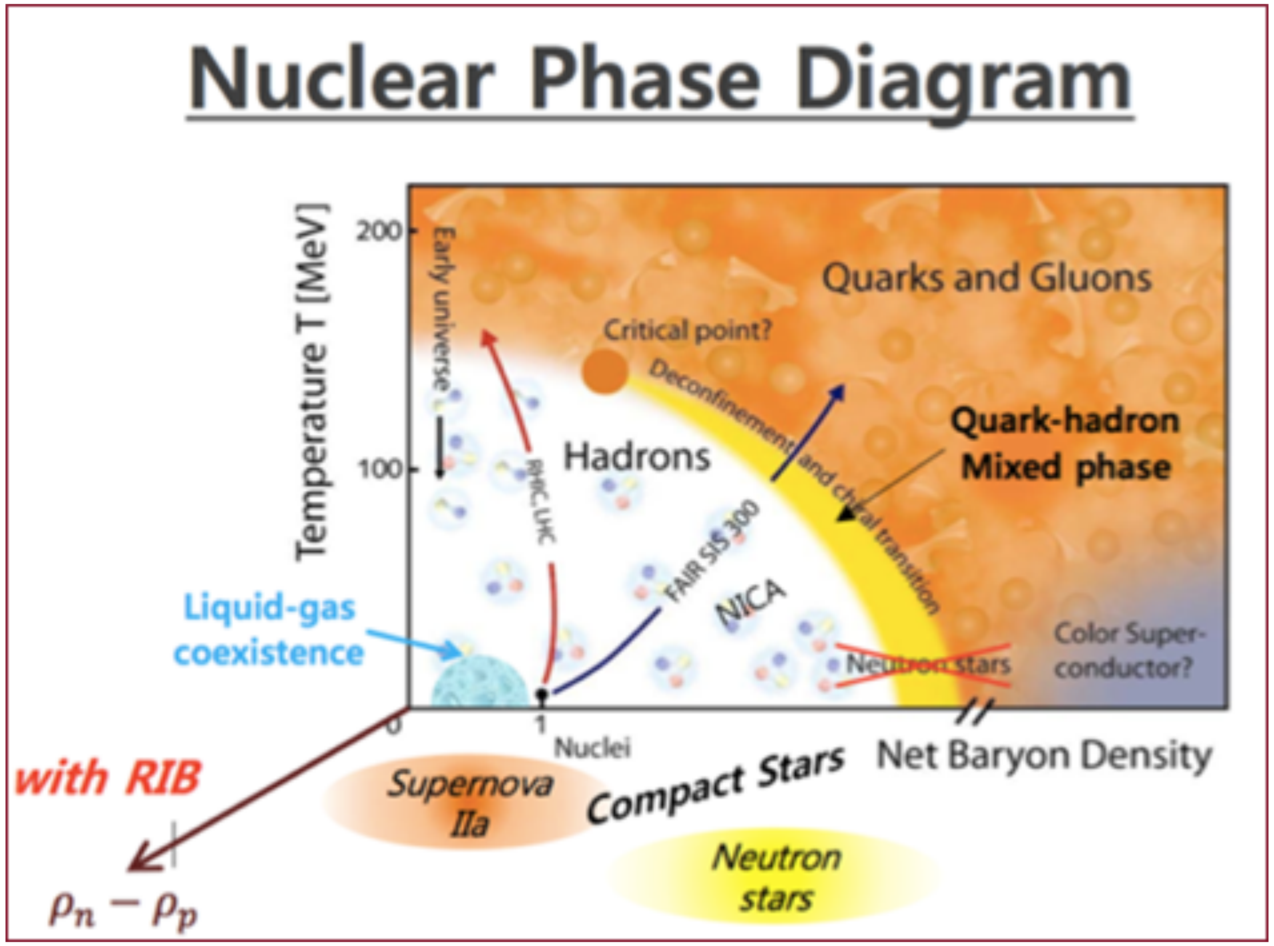
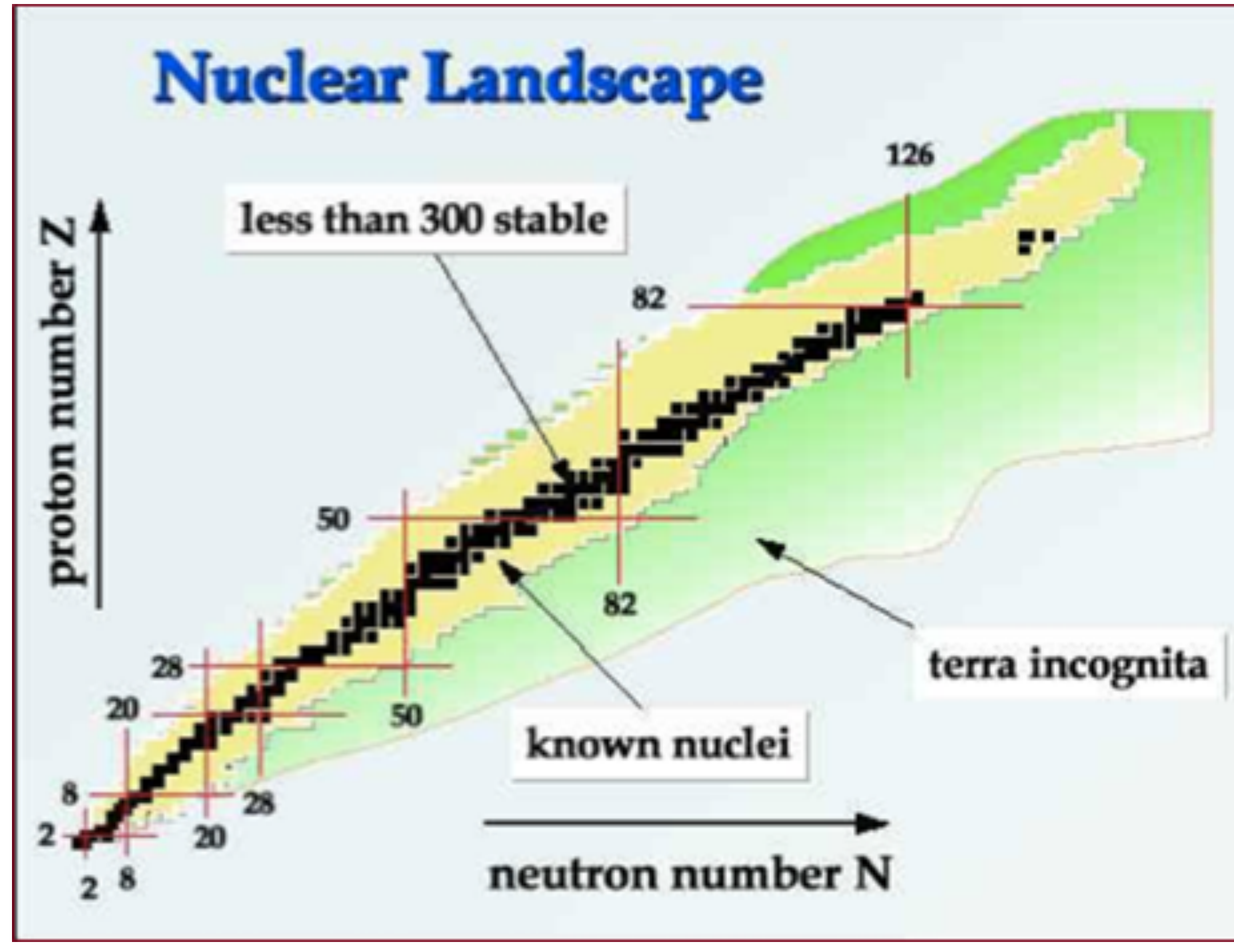
Introduction

Physical motivation





Understanding astronomical phenomena by the EOS of nuclear matter at low density.

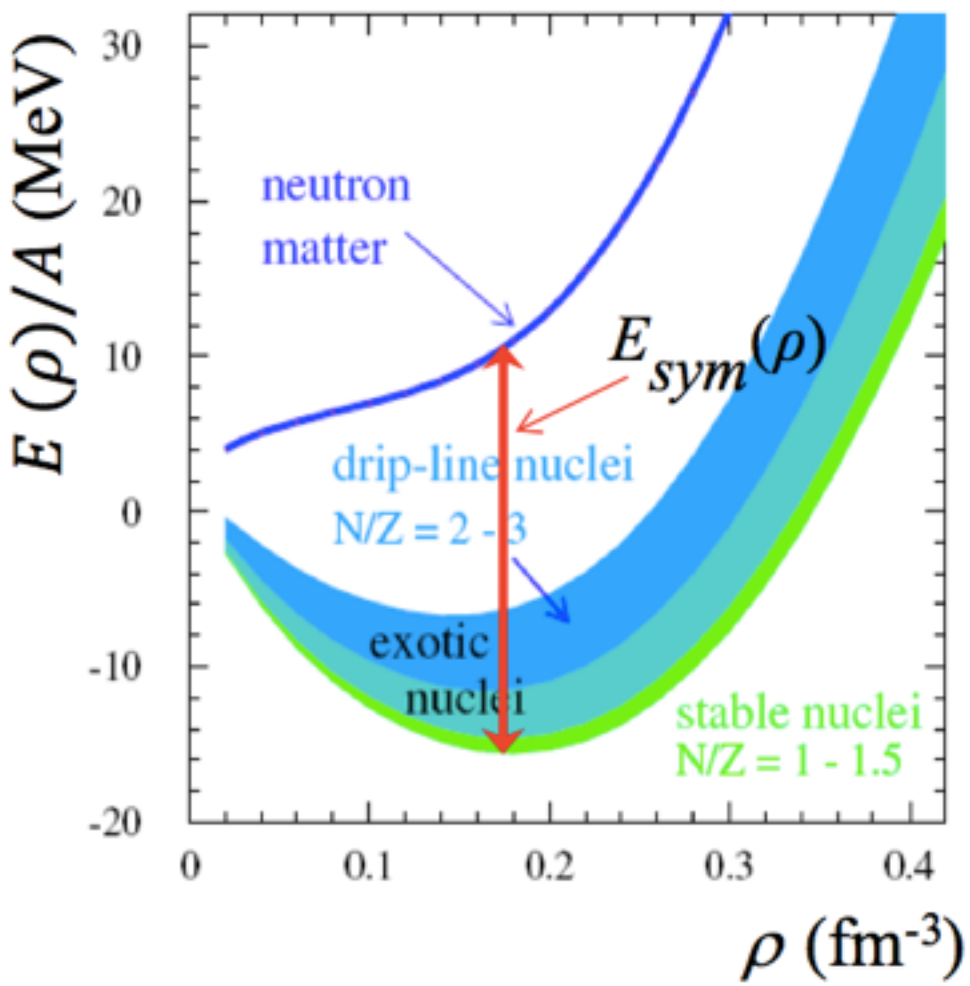
Understanding Exotic nuclei near the neutron drip line.

Large Acceptance Multi-Purpose Spectrometer(LAMPS) to study isospin-dependence of nuclear properties

→ Main purpose for **Symmetry-Energy research**

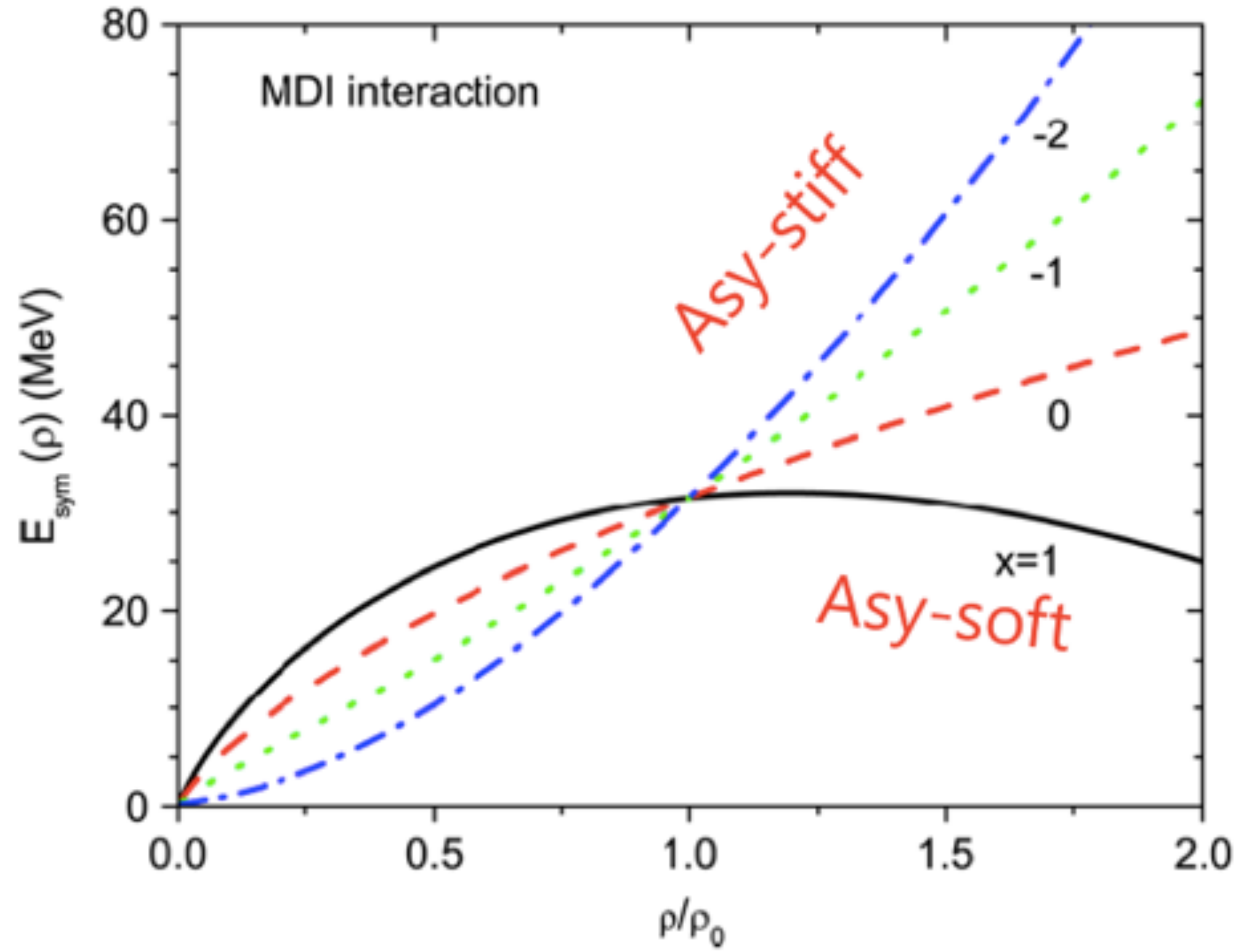
EOS & Symmetry energy

Nuclear energy for different n-p ratio and definition of symmetry energy.



Theoretical assumptions on the density dependence of symmetry energy.

L.W. Chen et al., PRL 94, 032701 (2005)



$$E(\boldsymbol{\rho}, \boldsymbol{\delta})/A = E(\boldsymbol{\rho}, \boldsymbol{\delta}=0)/A + E_{sym}(\rho)\boldsymbol{\delta}^2 + O(\boldsymbol{\delta}^4) + \cdots$$

$$[\ \boldsymbol{\rho} = \boldsymbol{\rho}_n + \boldsymbol{\rho}_p\ ,\ \boldsymbol{\delta} = (\boldsymbol{\rho}_n - \boldsymbol{\rho}_p)\ /\ (\boldsymbol{\rho}_n + \boldsymbol{\rho}_p)\ ]$$

Useful information

- n/p ratio
- Flow parameters for n and p

→ we want to detect neutrons accurately.

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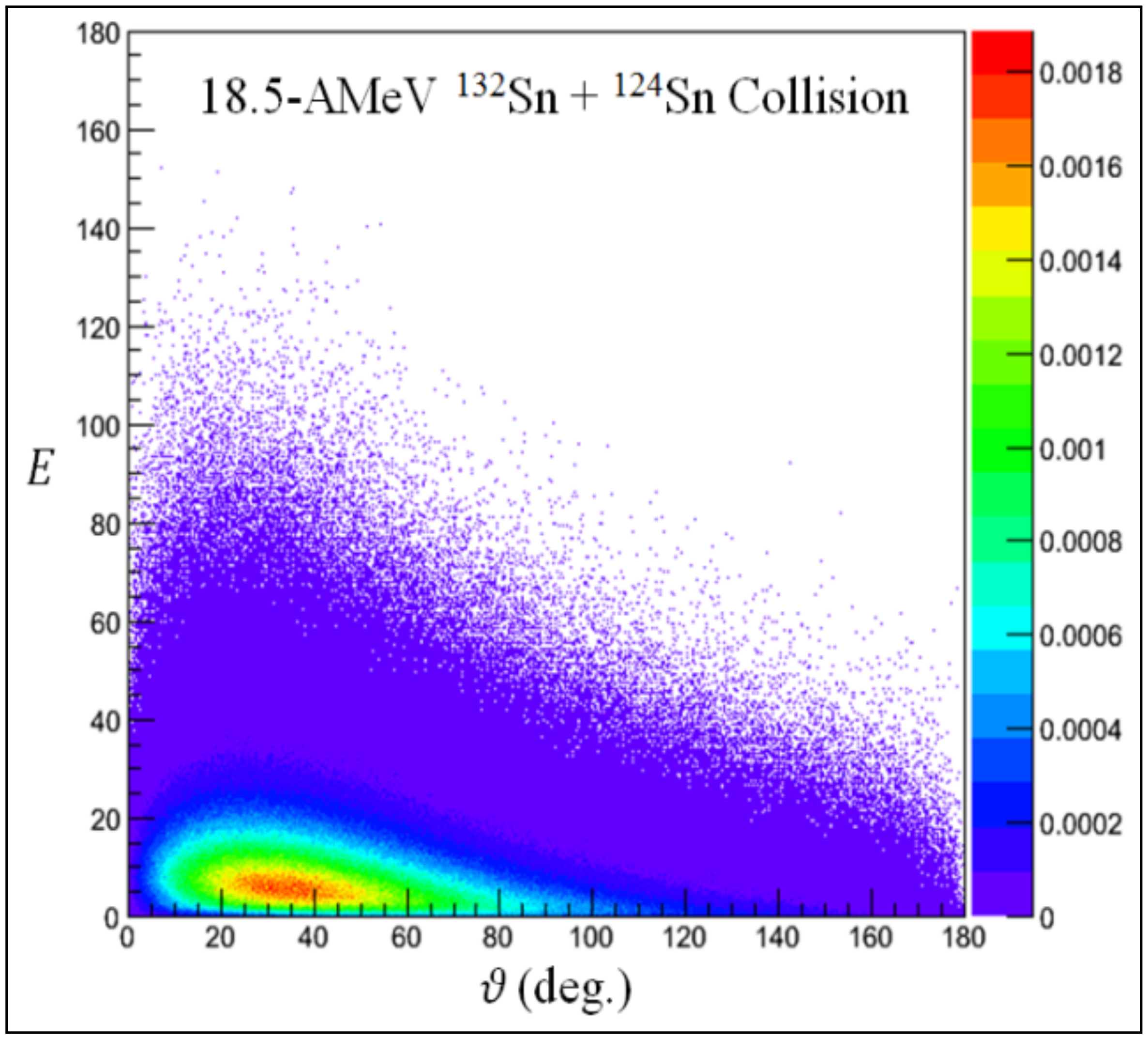
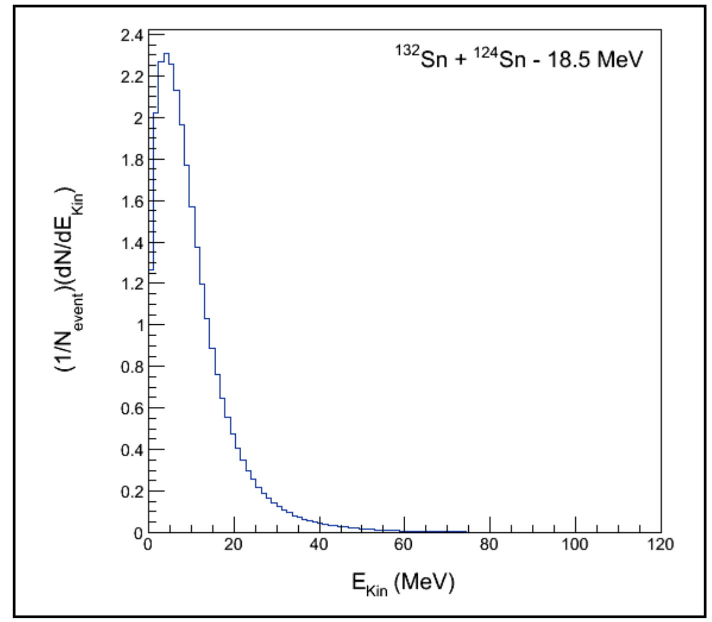
Simulation result and experimental design

Simulation in low energy Lamps

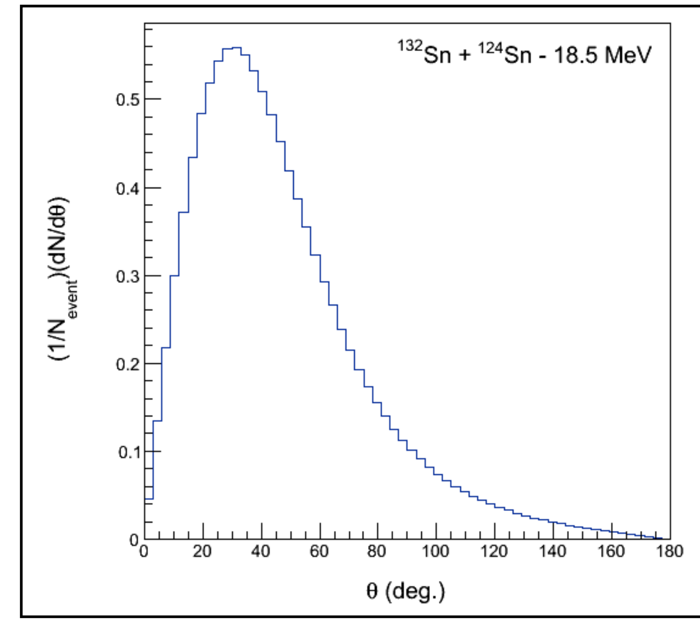
132Sn+124Sn at 18.5-AMeV from PHITS in low-energy LAMPS experiment (J. B. Park, KU)



Energy distribution for neutrons



Angular distribution for neutrons



- Depth of the scintillator detector blocks : 20 cm
- Neutron energy range : 4 ~ 80 MeV. (ε > 50%)
- The most probable and mean energies of the neutrons are 6.0 and 10.5 MeV, respectively.

Experimental Design of neutron detector

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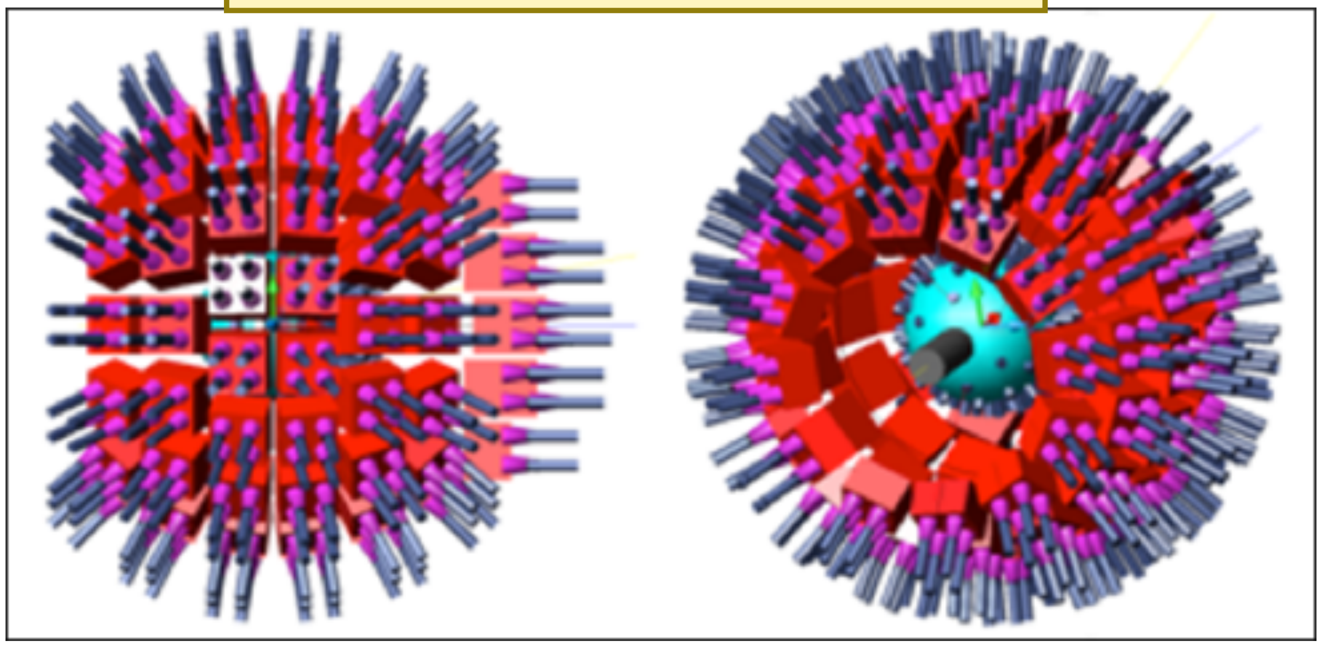
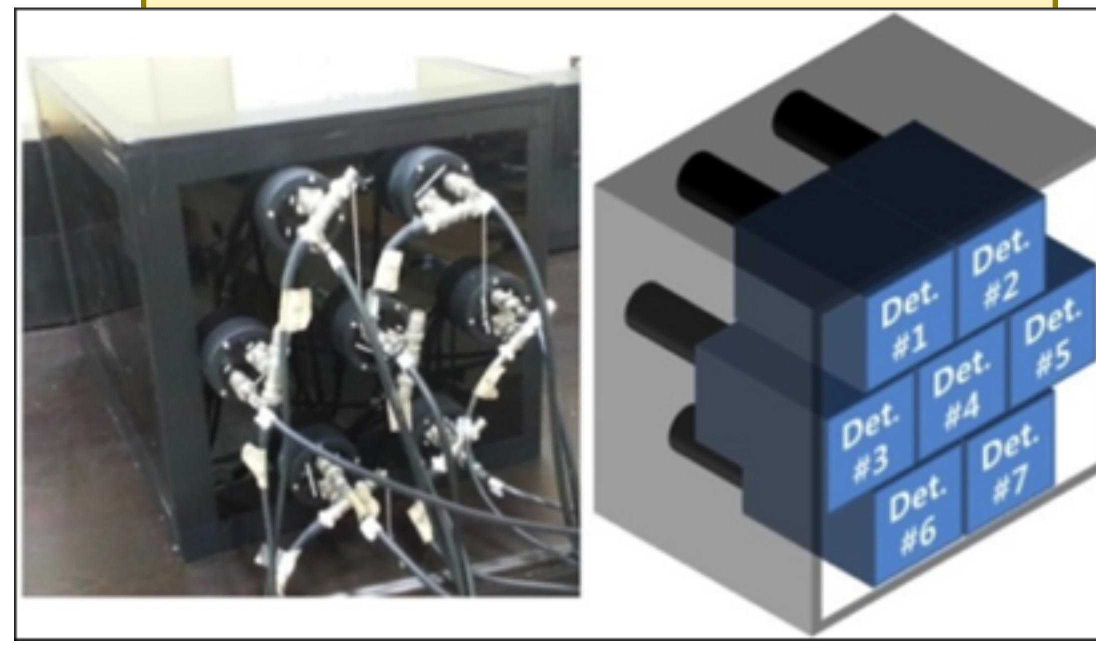
Preliminary Low-LAMPS design

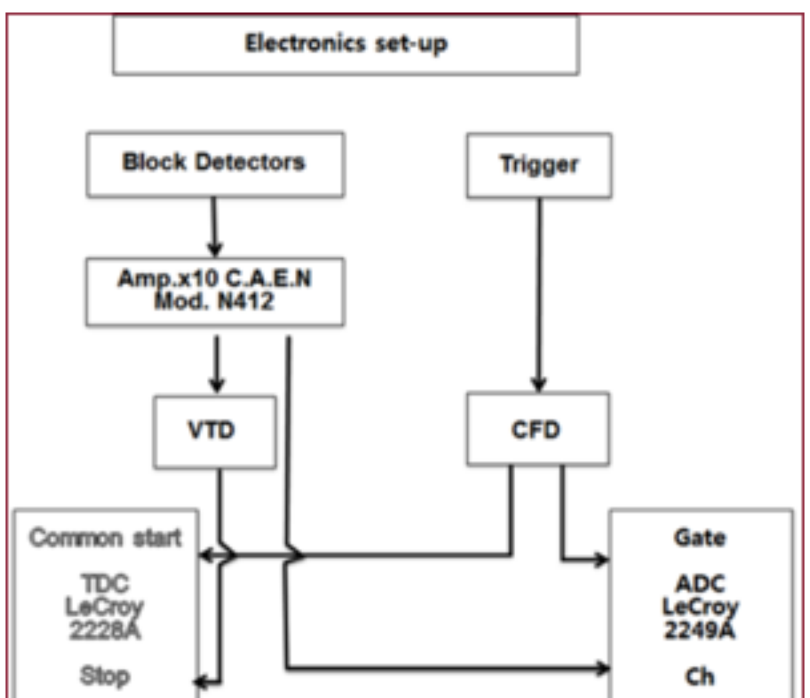


- Basic structure of unit detector module : 3 x 3 array
- Size of unit detectors : 10 x 10 x 20 cm^3

Prototype neutron detector design



- Prototype detector module : Composed of 7 block detectors
- Size of unit detectors : 10 x 10 x 20 cm^3



Experiment equipment	
Detector matter	Plastic-scintillator (Bicron model BC408)
Neutron source	^{252}
Time of flight distance	1.5 m
Discriminator	VTD, CAEN model N844
PMT	VTD, CAEN model N844
TDC	LeCroy model 2228A
ADC	LeCroy model 2249A

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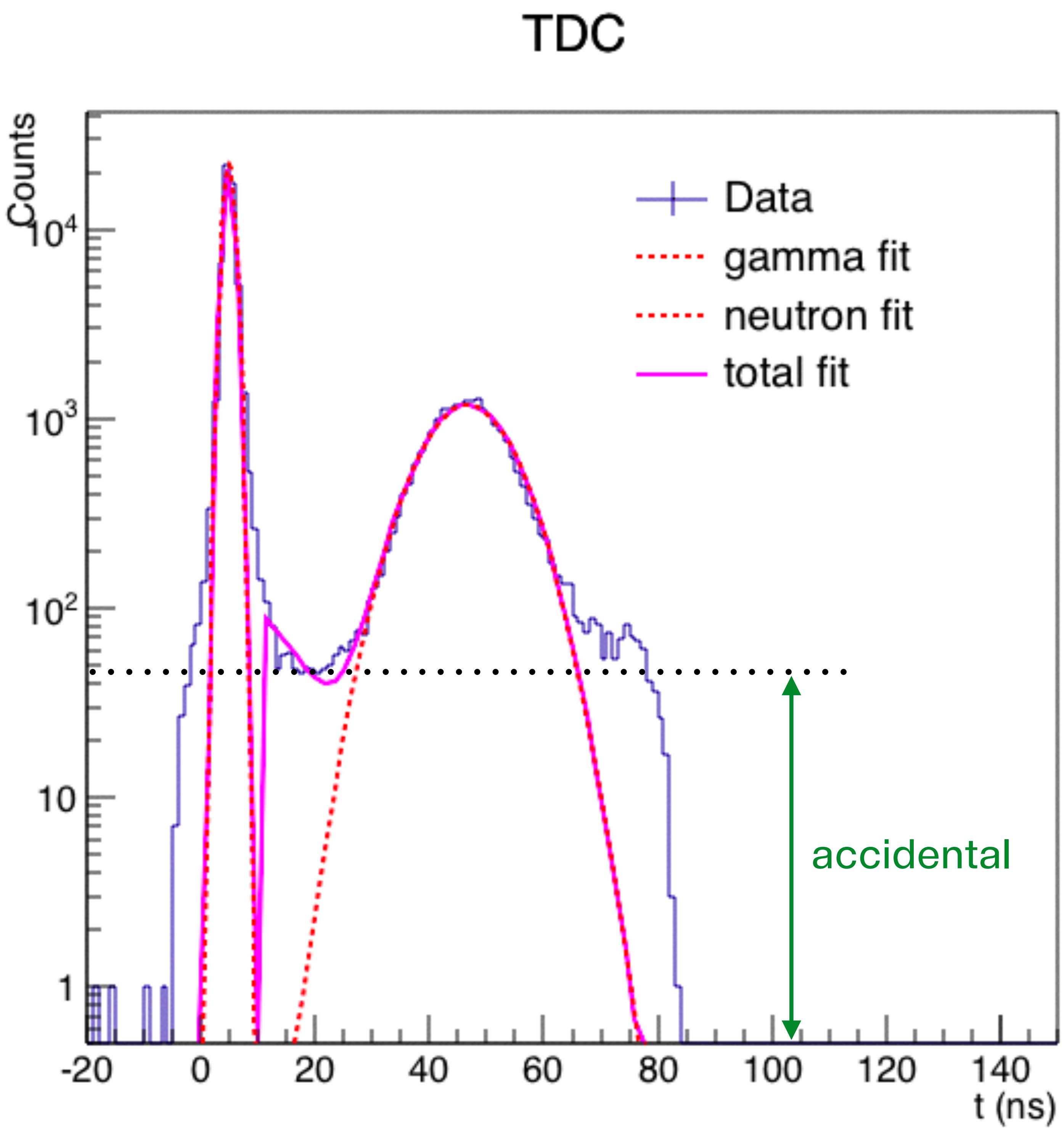
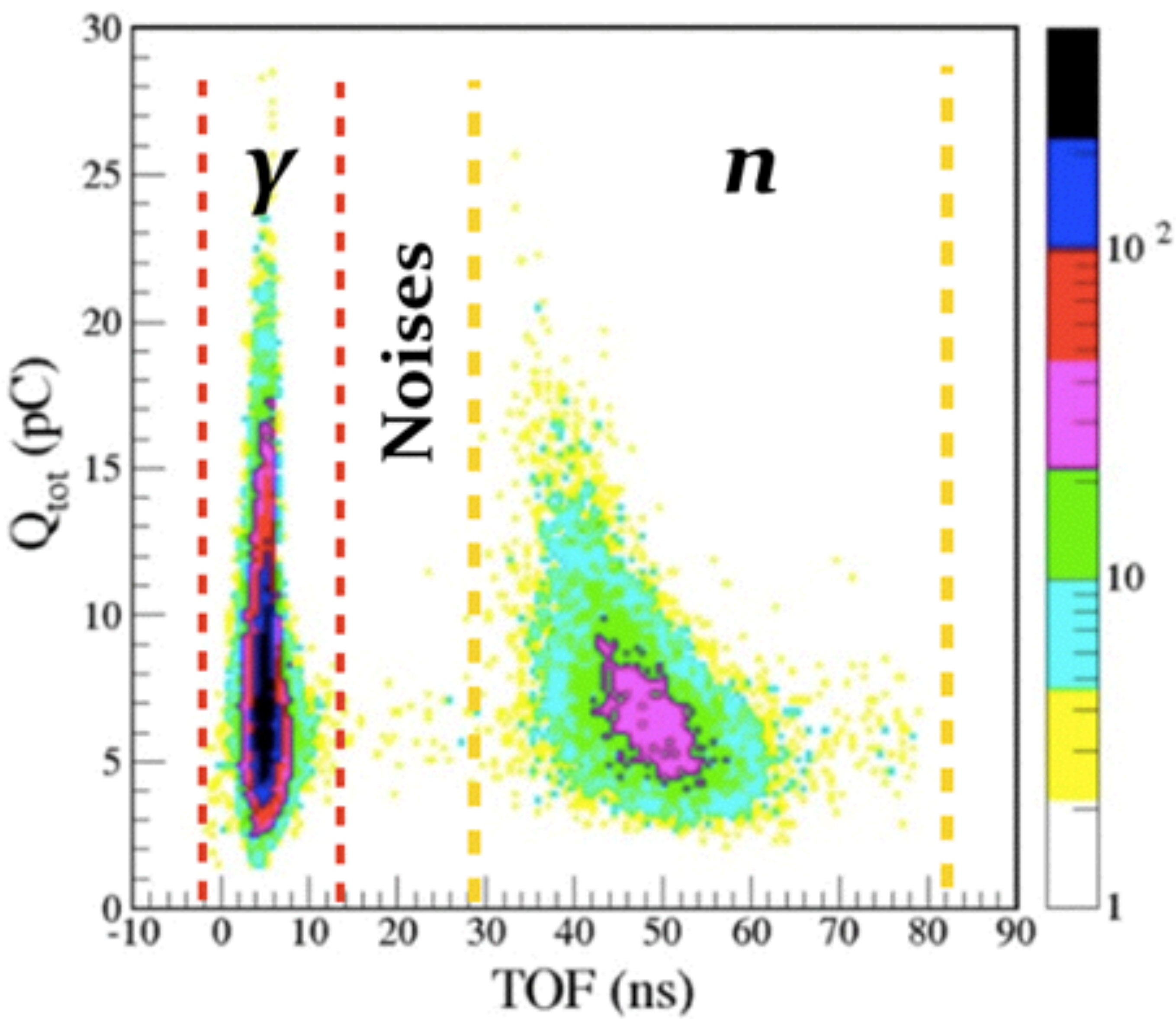
Data analysis

TOF with 252Cf



- Gamma and neutron are emit by californium 252 at fission decay.
- Gamma is used as reference of time.
- TOF method is used to calculate energy of neutron

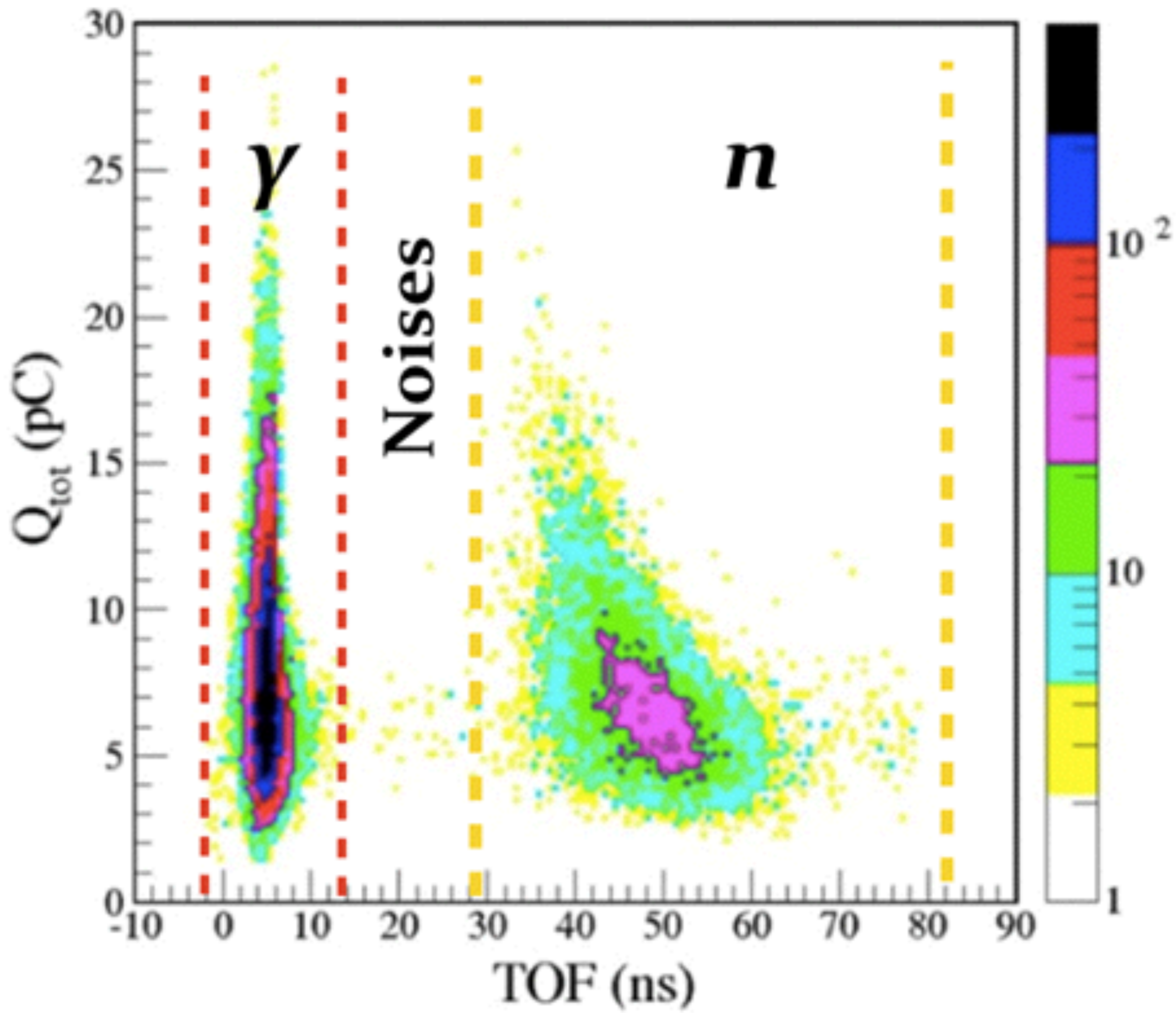
Gamma, Neutron, Noise information

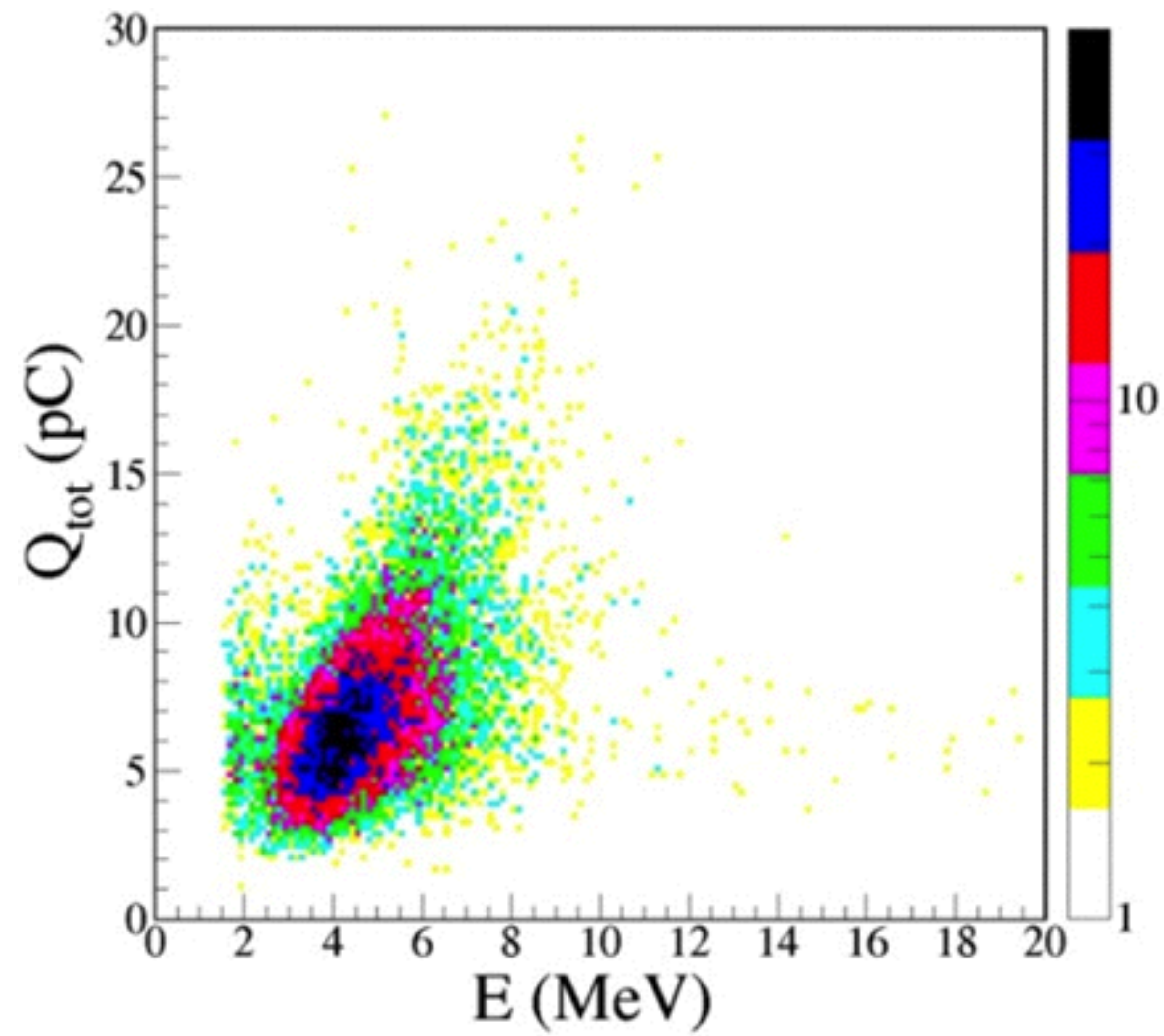


Q_{tot} = total detector response of the radiation.

- Gamma peak centered at **5.05 ns**
- Neutron time zone: **24 ~ 80 ns**
- Mean noise rate per detector = **51.4 Hz**
- Noise accidental hits in the neutron time zone in the broad band with a width of Qtot ranging from **1 to about 12 pC**
- The ratio of the accidentals in the neutron time zone = **0.089±0.005**.

Neutron Separation



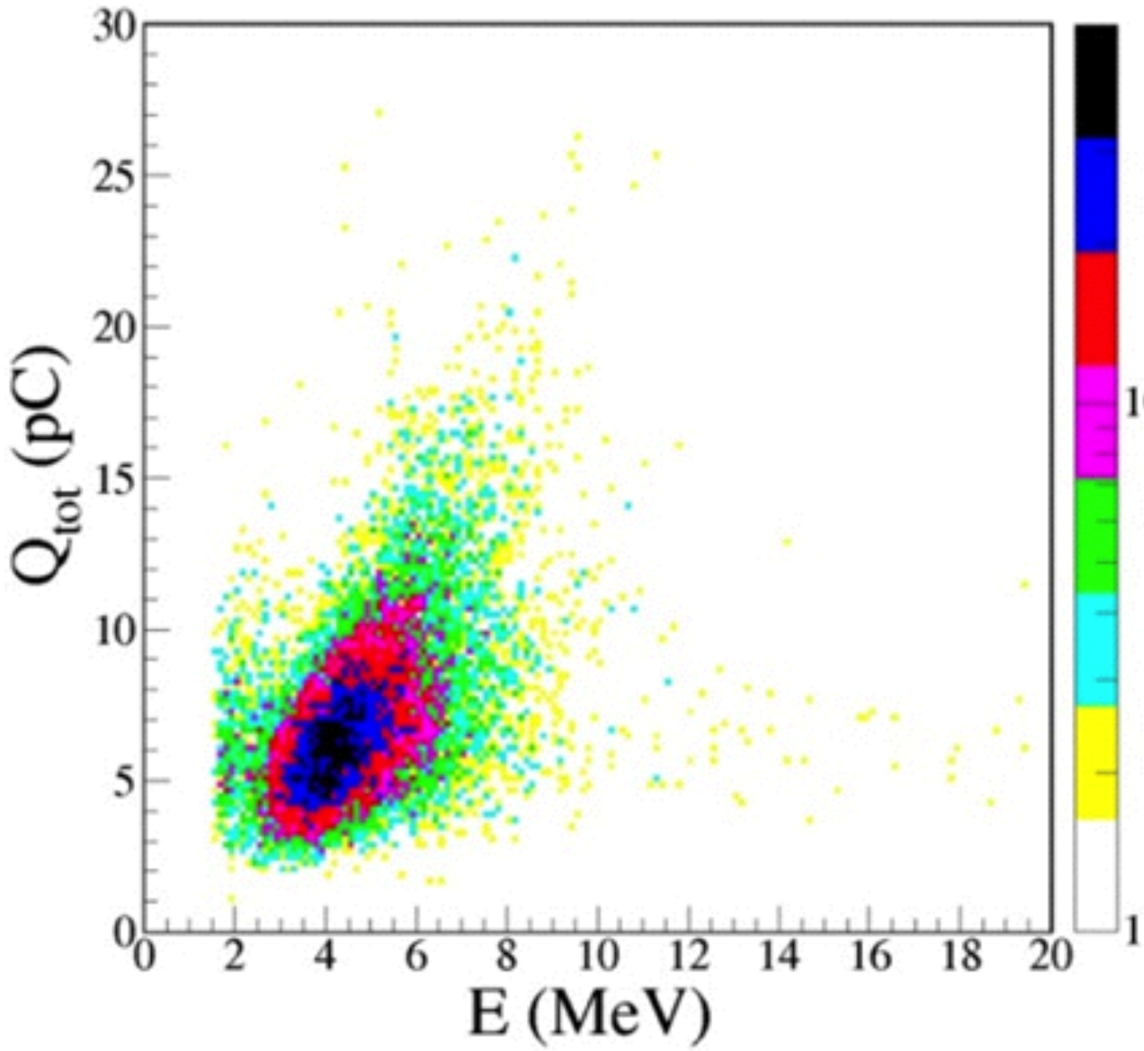


Gamma + Neutron + accidental

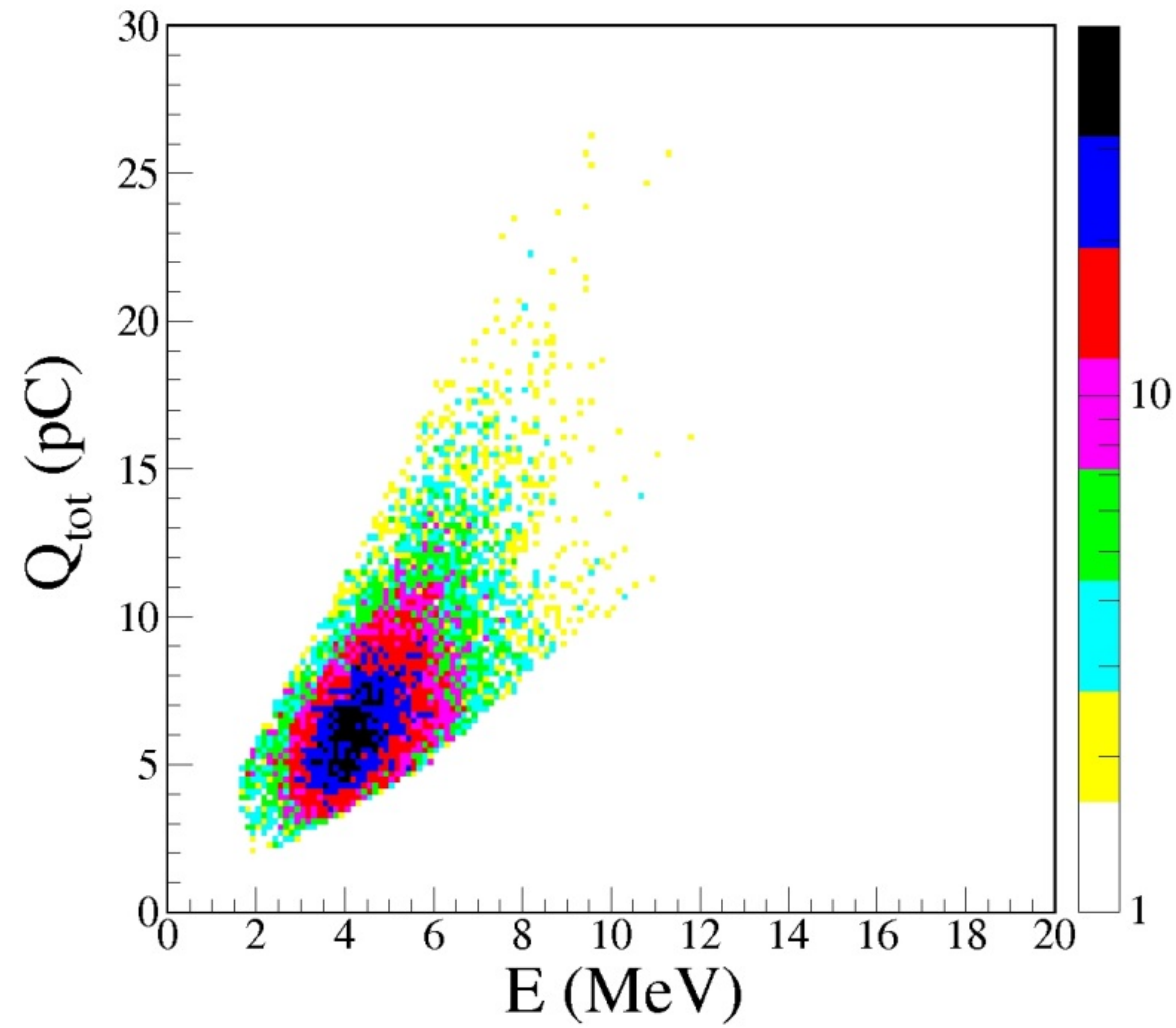
Neutron + accidental

24 ns < TOF < 80 ns

Noise filtering



Neutron + accidental

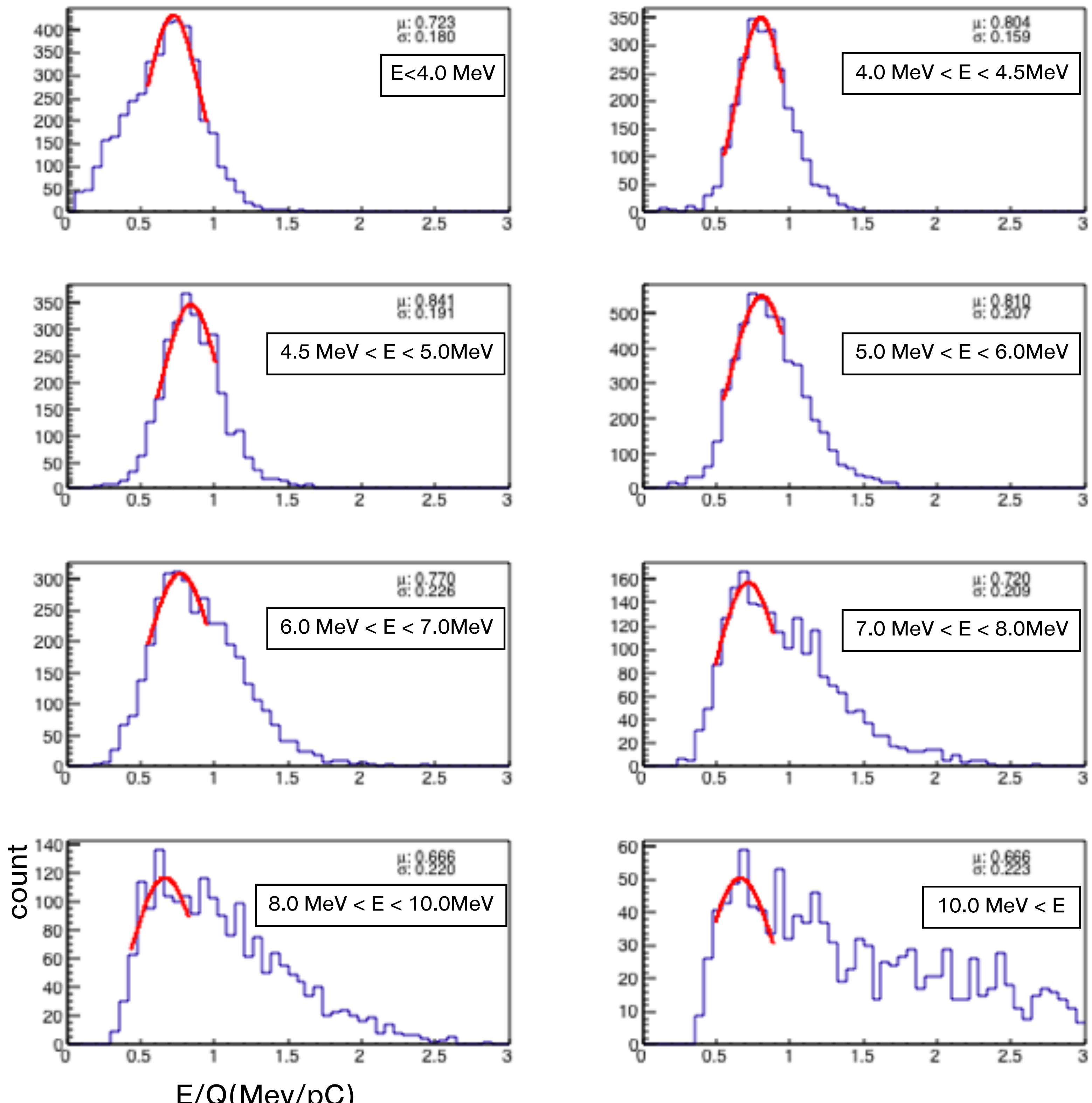


Neutron

Noise filtering

true neutrons ε = 94.5 % with 75 % background rejection

Noise filtering



➜ *E/Q*$_{tot}$ the data in lower energy ranges is well identified by the high statistics of the **true neutrons**.

1) **Divide E/Q graph** into 8 energy ranges.

2) Get sigma using gaussian fitting at **4.5 ~ 5 MeV**.

3) We asymmetrically selected the hits lying within **-2 σ and 4 σ ranges.**

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Test results

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Kinetic Energy spectrum

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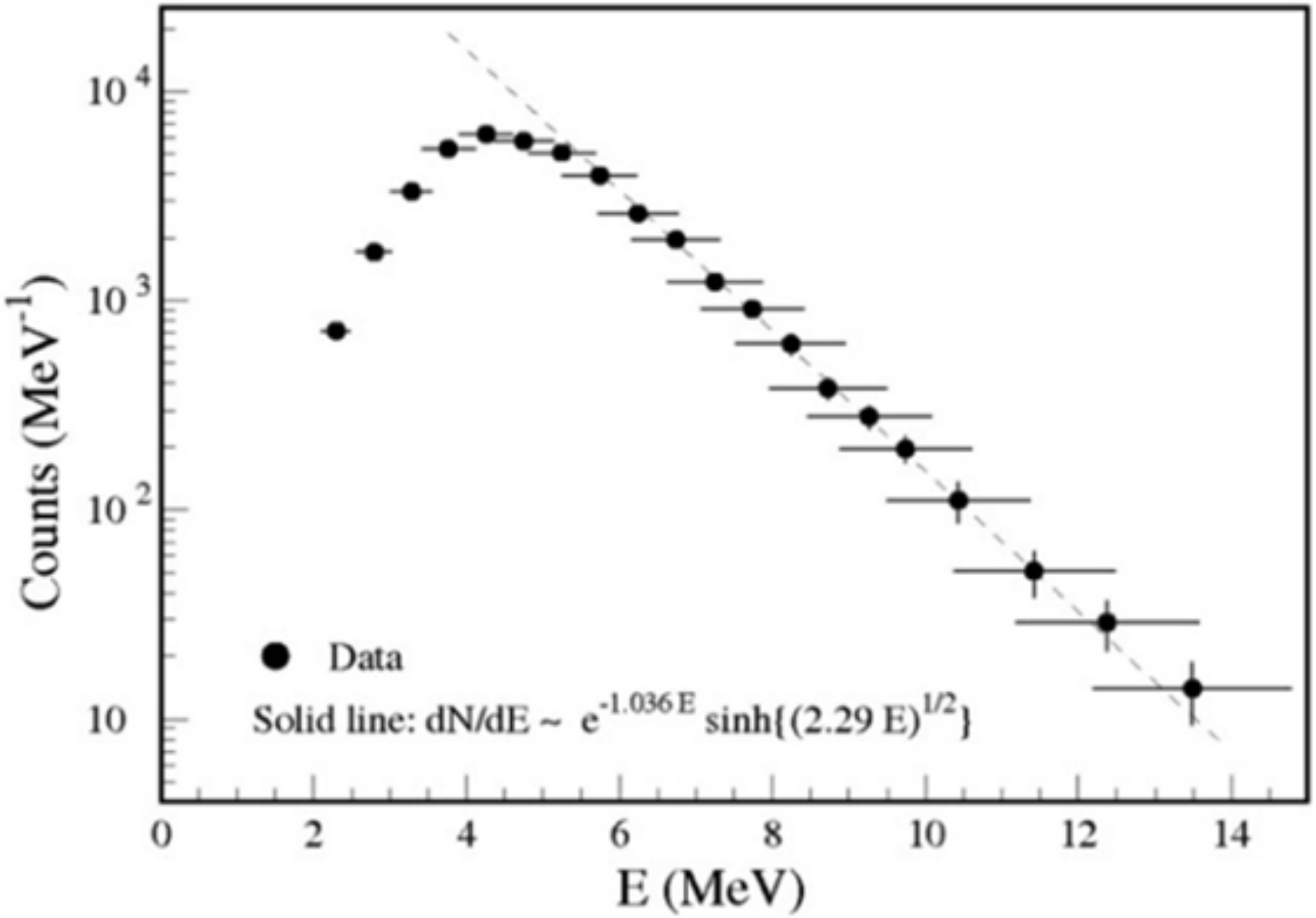
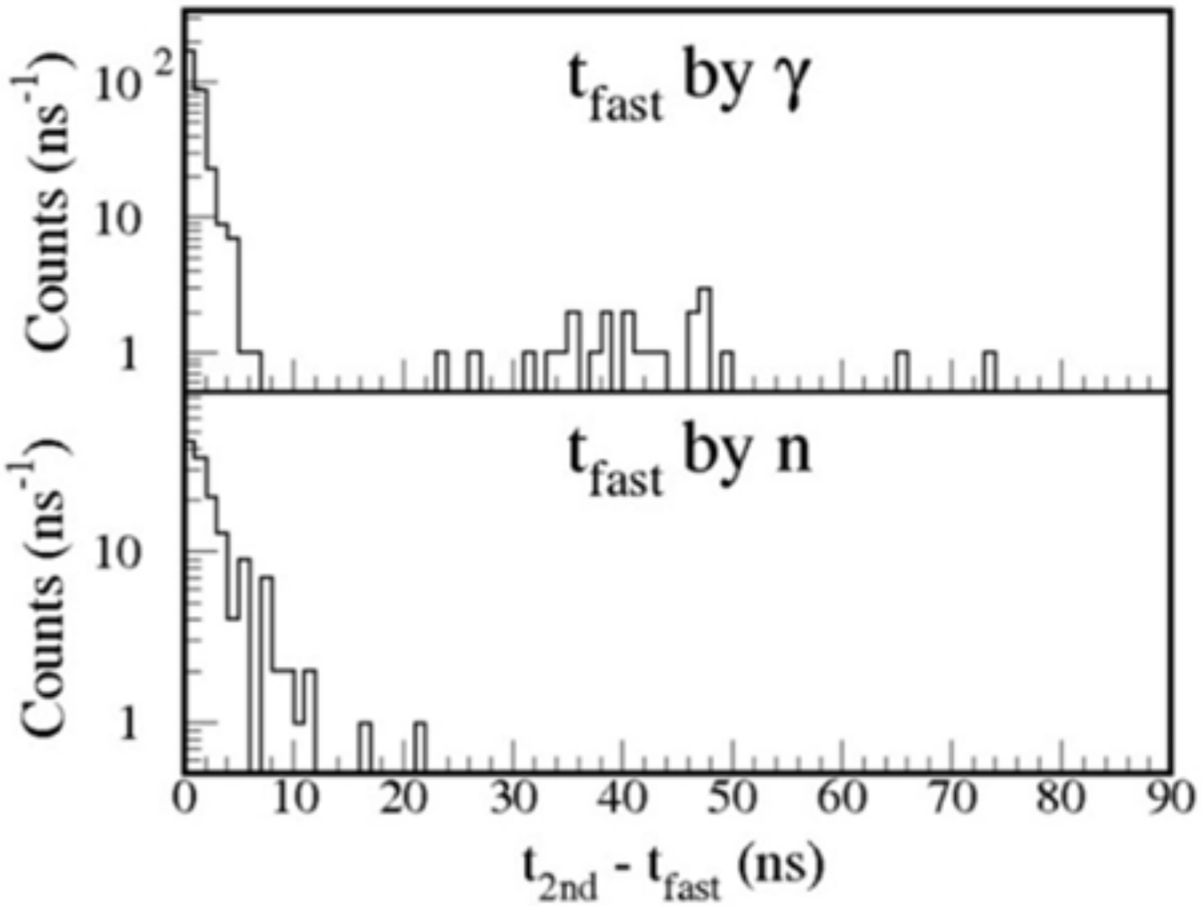


Neutron-energy spectrum of ^{252}Cf measured by the present prototype neutron-detector module.

(The dashed line stands for the systematic trend of the neutron yield.)

- Digitization threshold
  : **300 keV**
- 7 module block detector can detect over than 2 MeV neutron and detect **exactly over 4.5 MeV neutron.**
- Neutron energy confirmed with **ε > 50 % over 4 MeV.**

Δt between 2hits



Time difference between the **1**st and **2**nd hits for the events by the **γ**(top) and by the **n**(bottom) emitted from the ^{252}Cf decays.

- **Case of the fastest gamma hits**

  The second hits in the neutron time-region (20 ~ 80 ns) were produced by
  1. One of the **fissile neutrons**
  2. The **fastest gamma hit**.

- **Case of the fastest neutron hits**

  The maximum time difference between the two hits created by a single neutron was about **20 ns**.

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Summary

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1. We **design the neutron detector array** for the low-energy LAMPS experiment **using PHITS** for **^{132}Sn + ^{124}Sn at 18.5-AMeV**.

2. Detector resolution function E/Q asymmetric cuts (-2σ to 4σ) for **selecting true neutrons**.
(**ε = 94.5 %** with **75 % background rejection**)

3. Neutron energy confirmed with **ε > 50 % over 4 MeV.**

4. The **maximum time difference** between the two hits created by a single neutron was about **20 ns.**

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THANK YOU.

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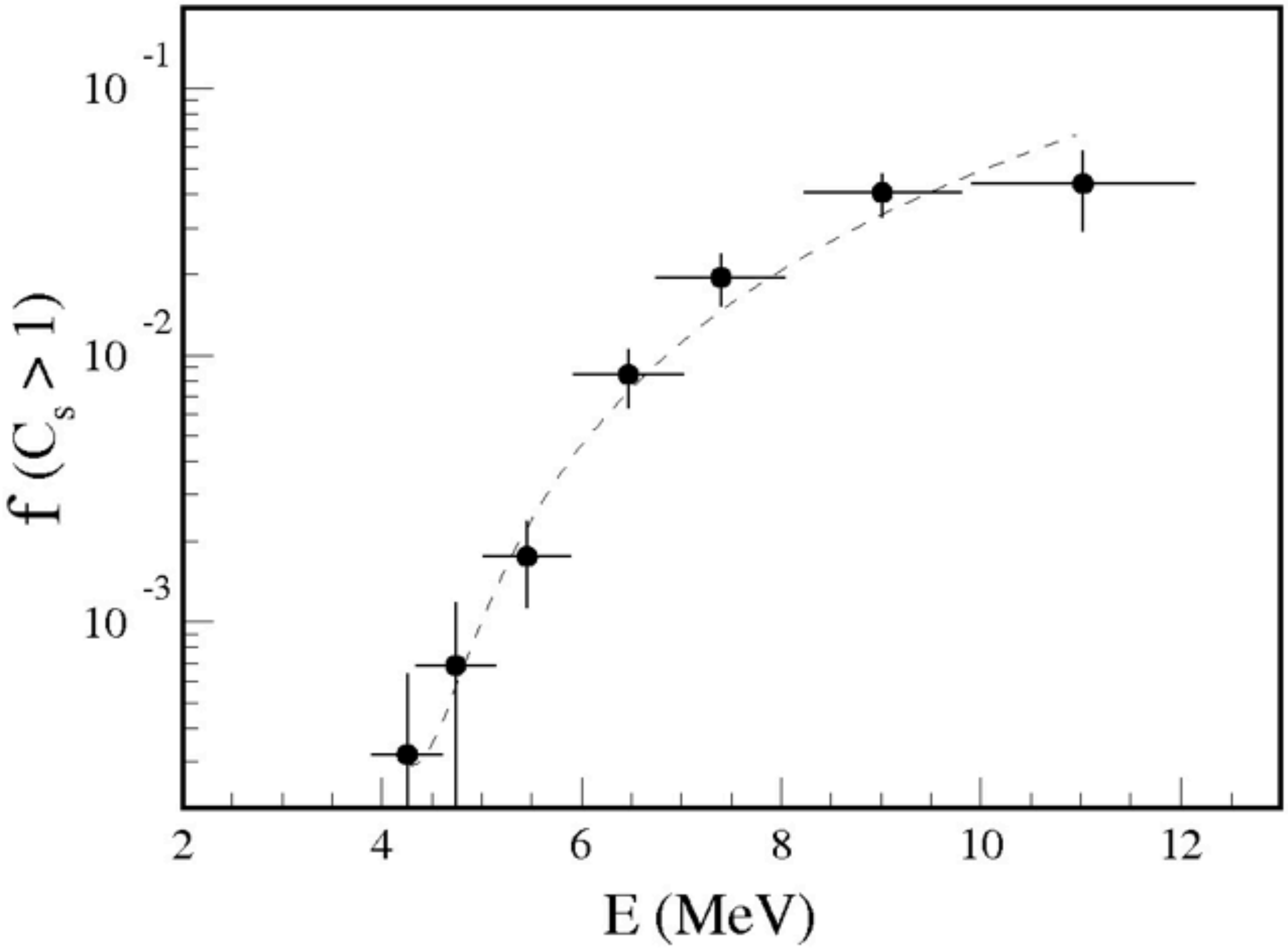
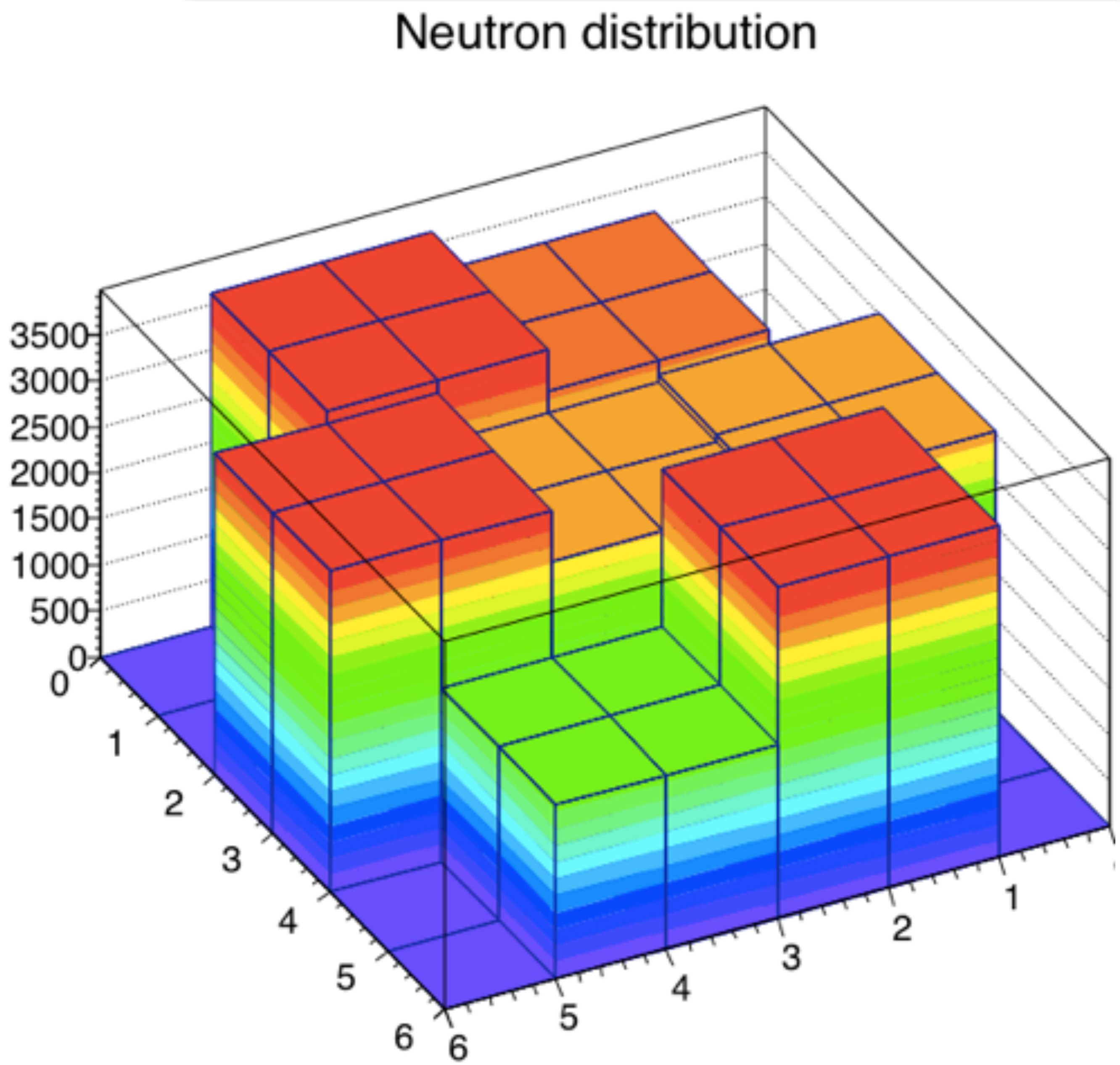
BACK-UP

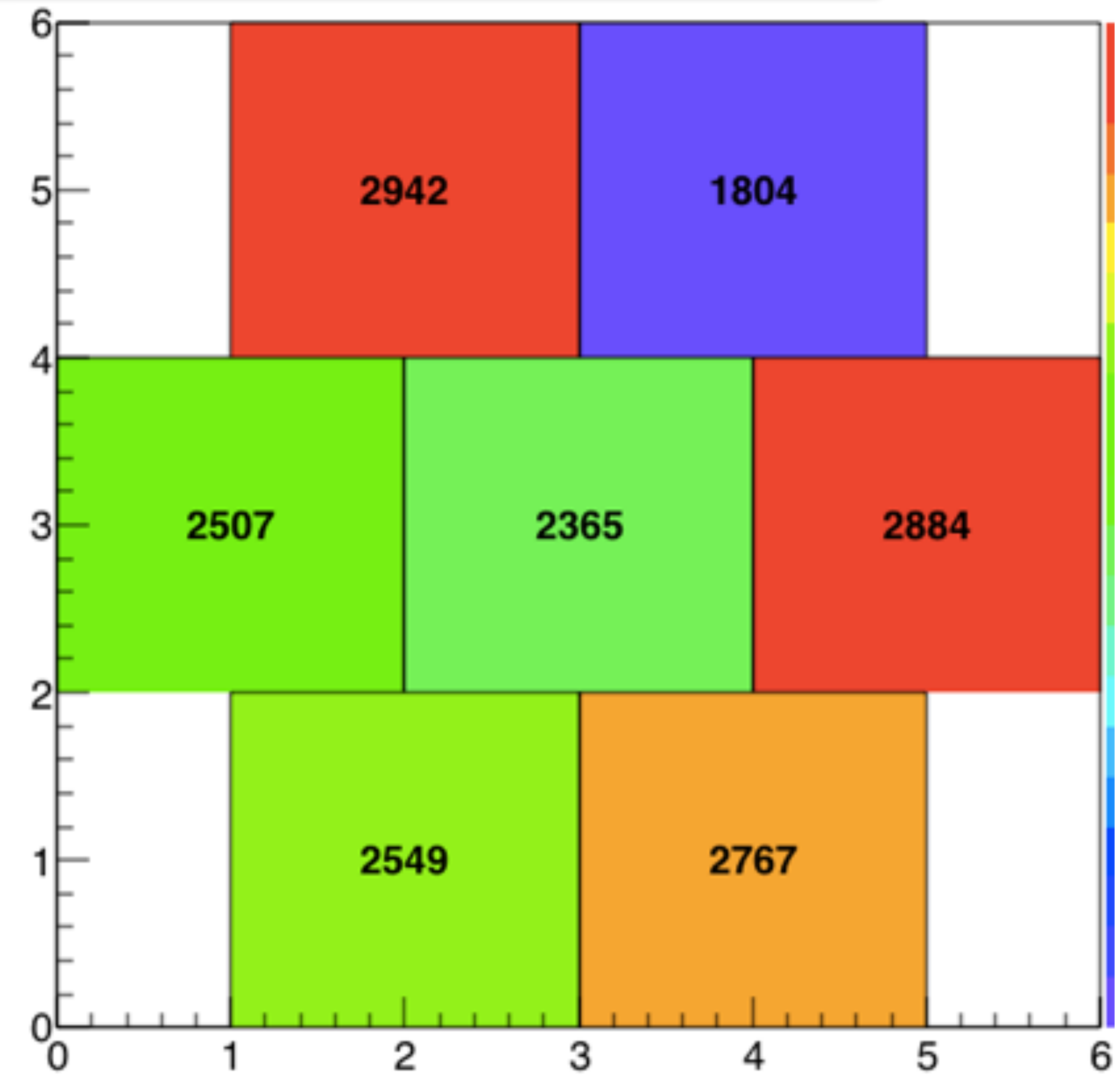
Energy vs Cs

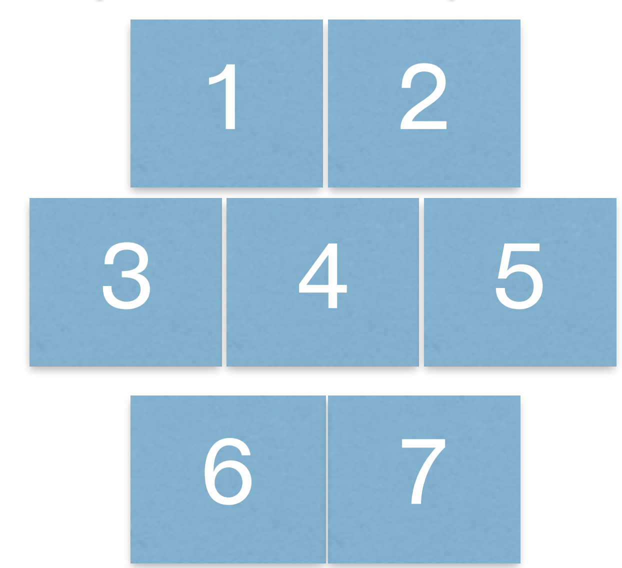


Fractions of events producing more than one detector hit (Cs > 1) as a function of the neutron energy.

Neutron Hit Distribution

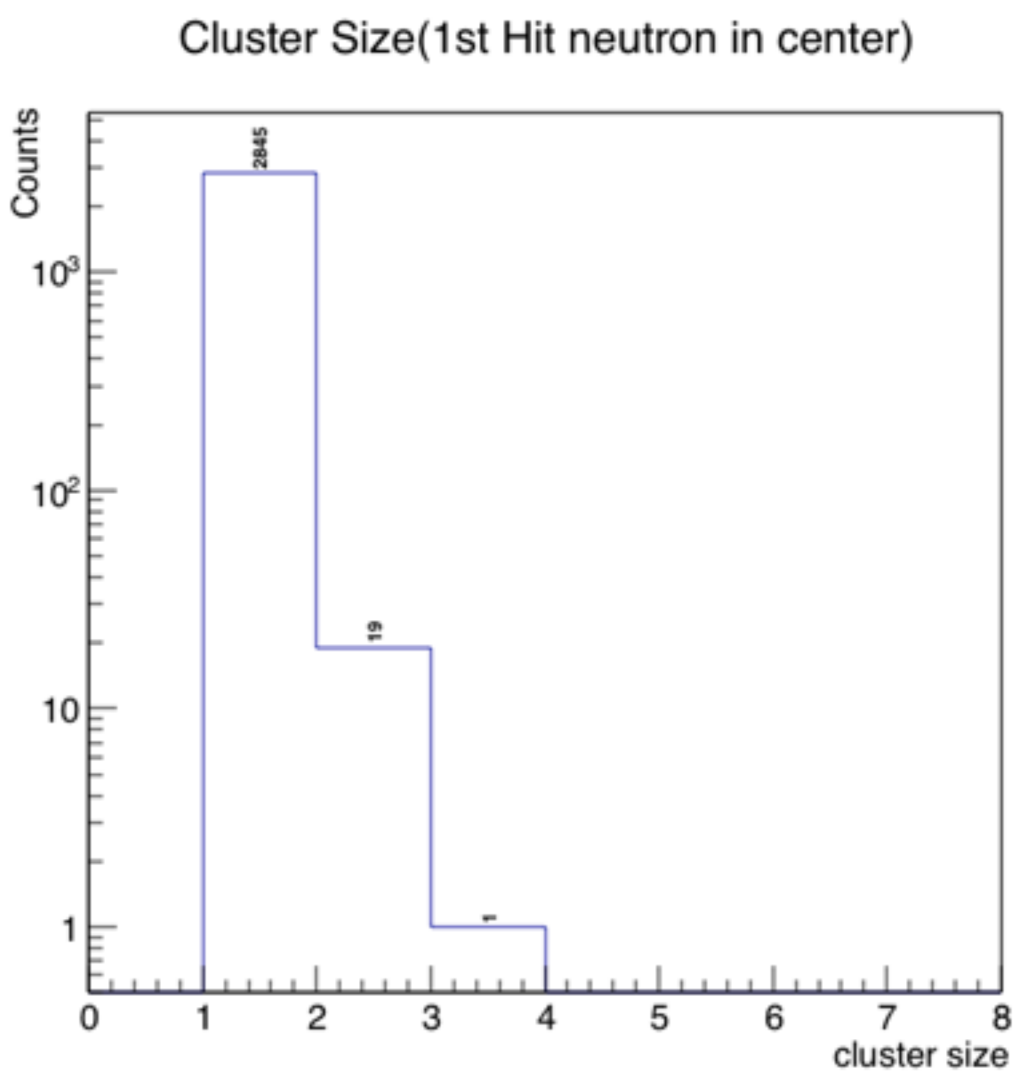


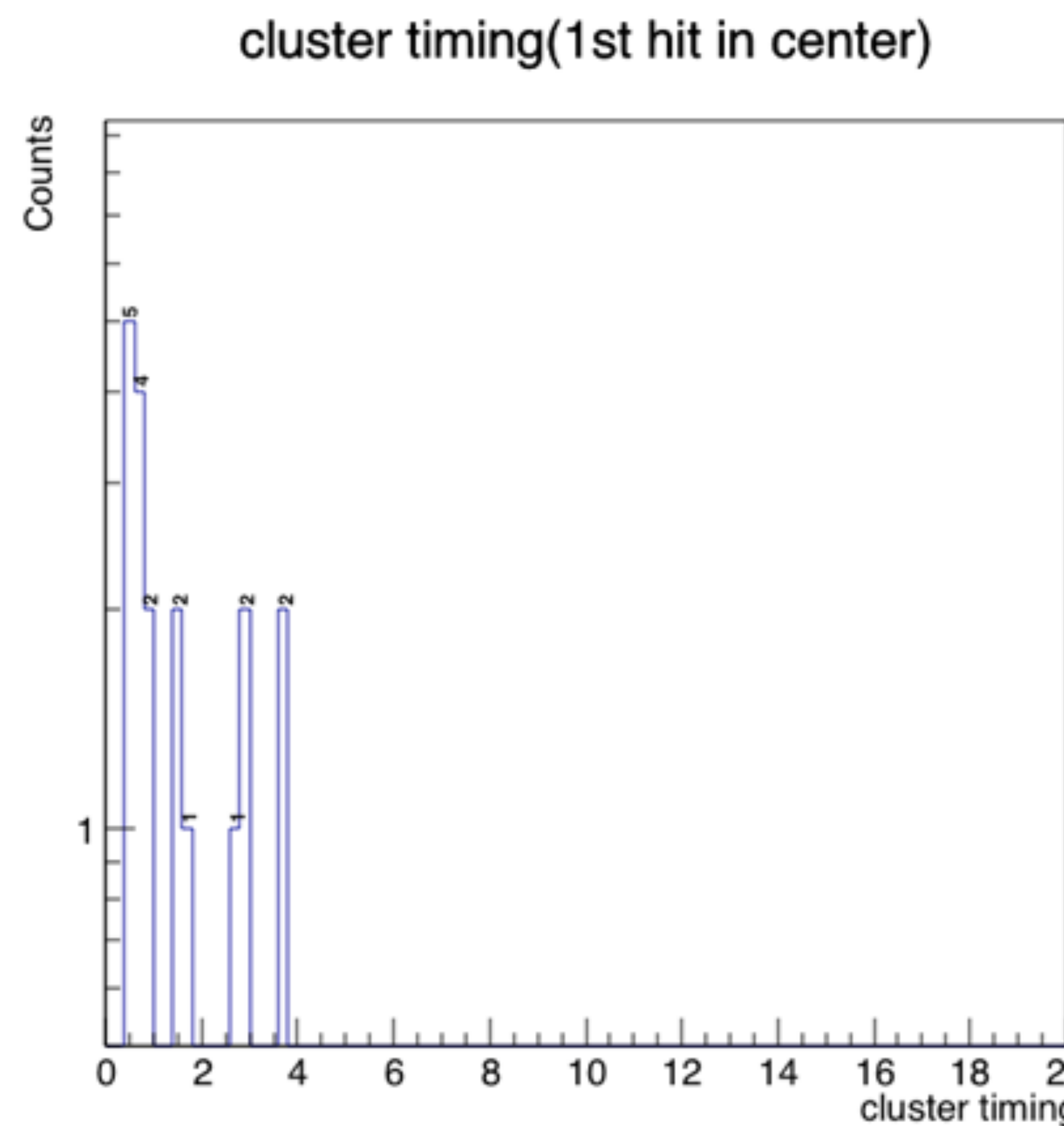




- Each detector's acceptance is pretty similar except for detector2.

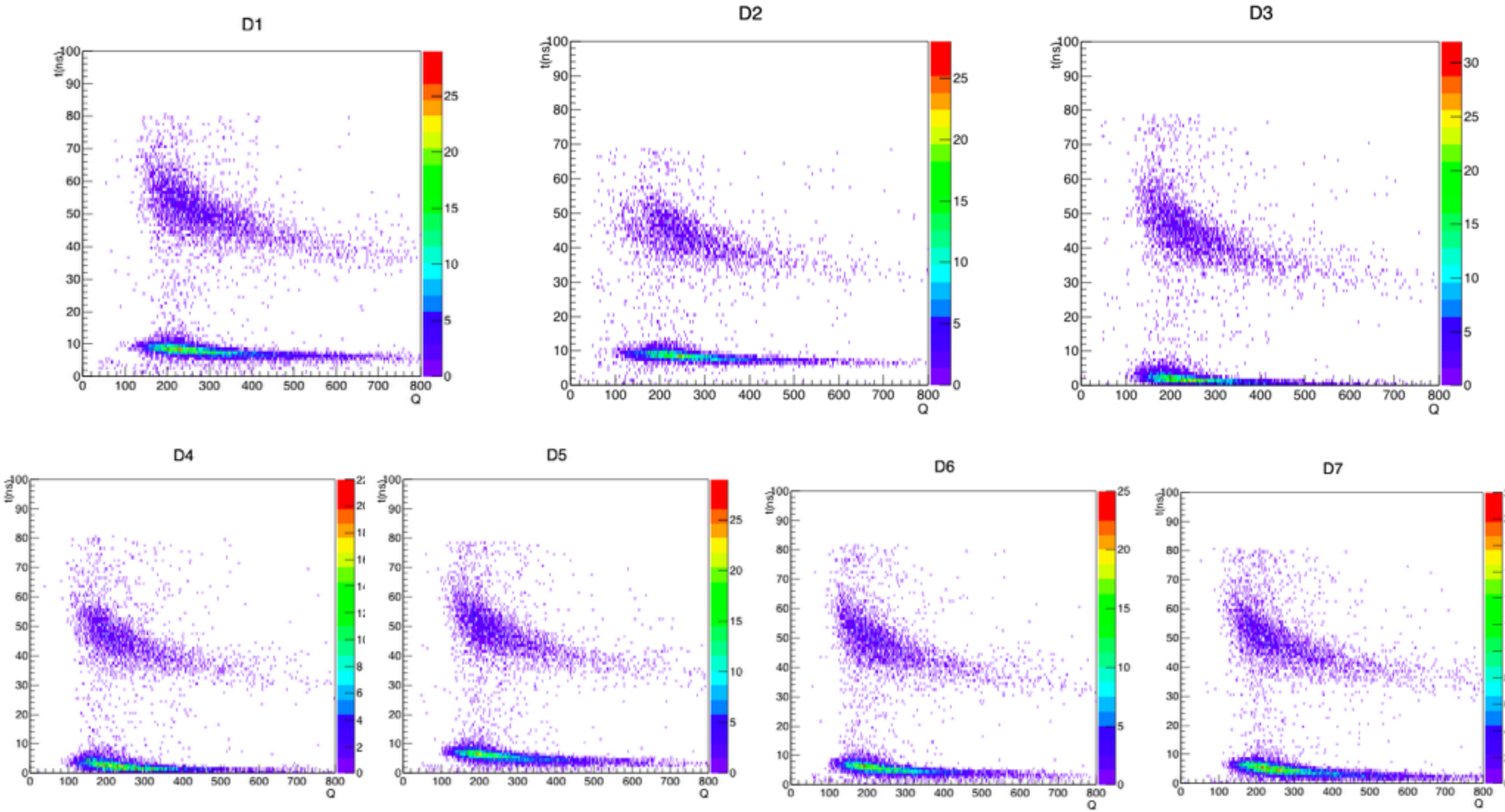
Cluster Size



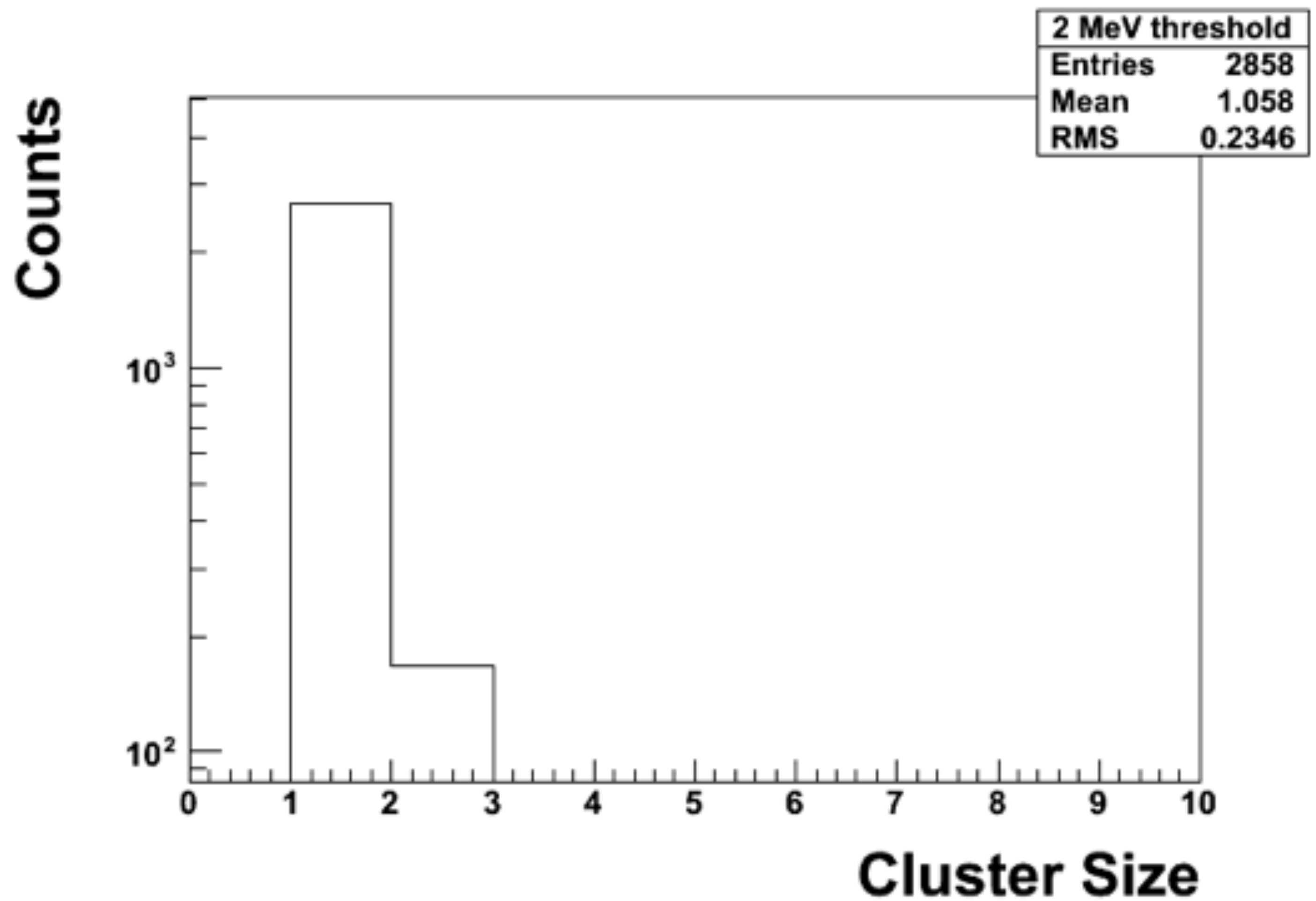


- (Cs > 1) Probability : 0.698%
- There is no data which Ct>4ns

before TWC

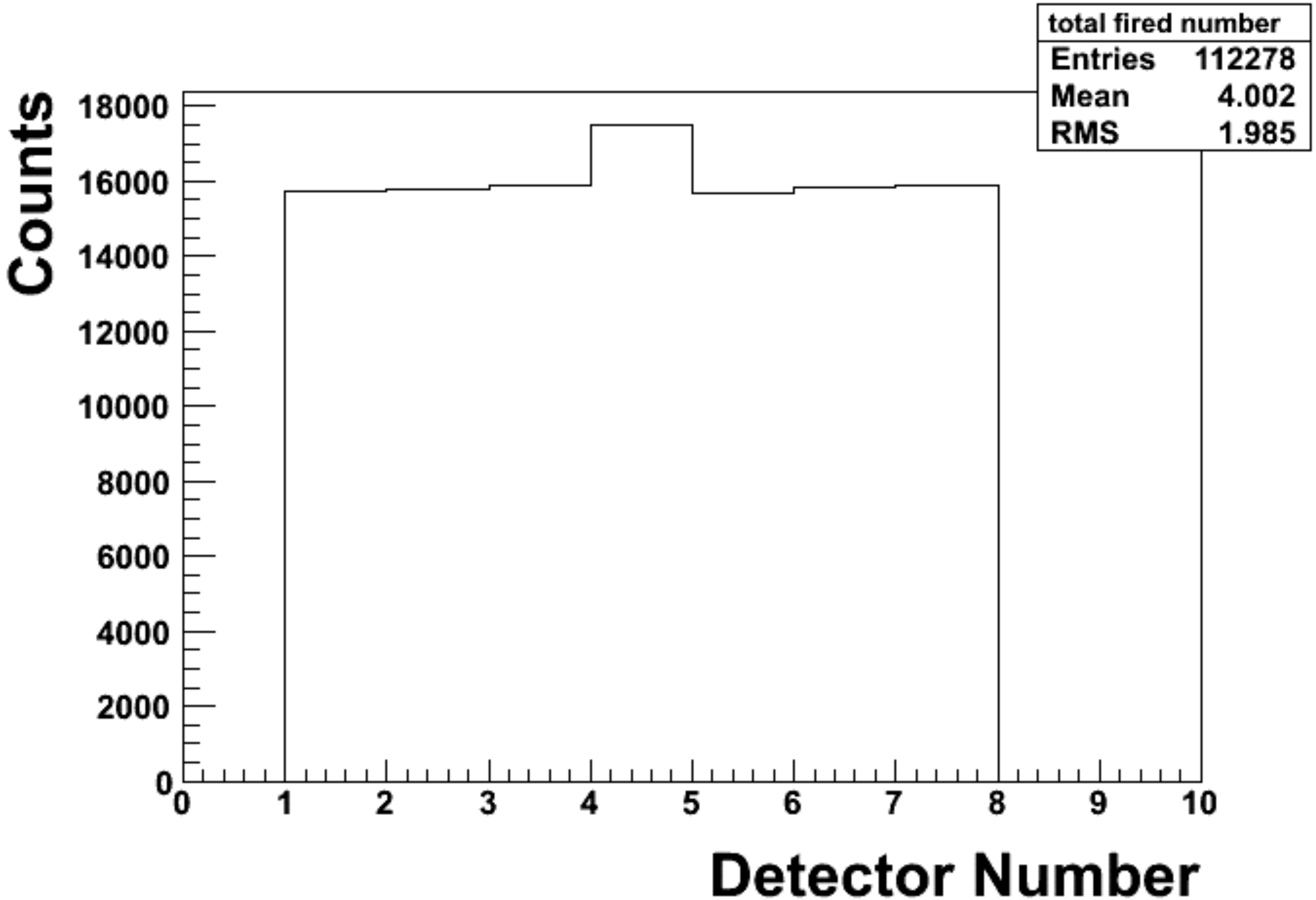


Cluster Size(Simulation)



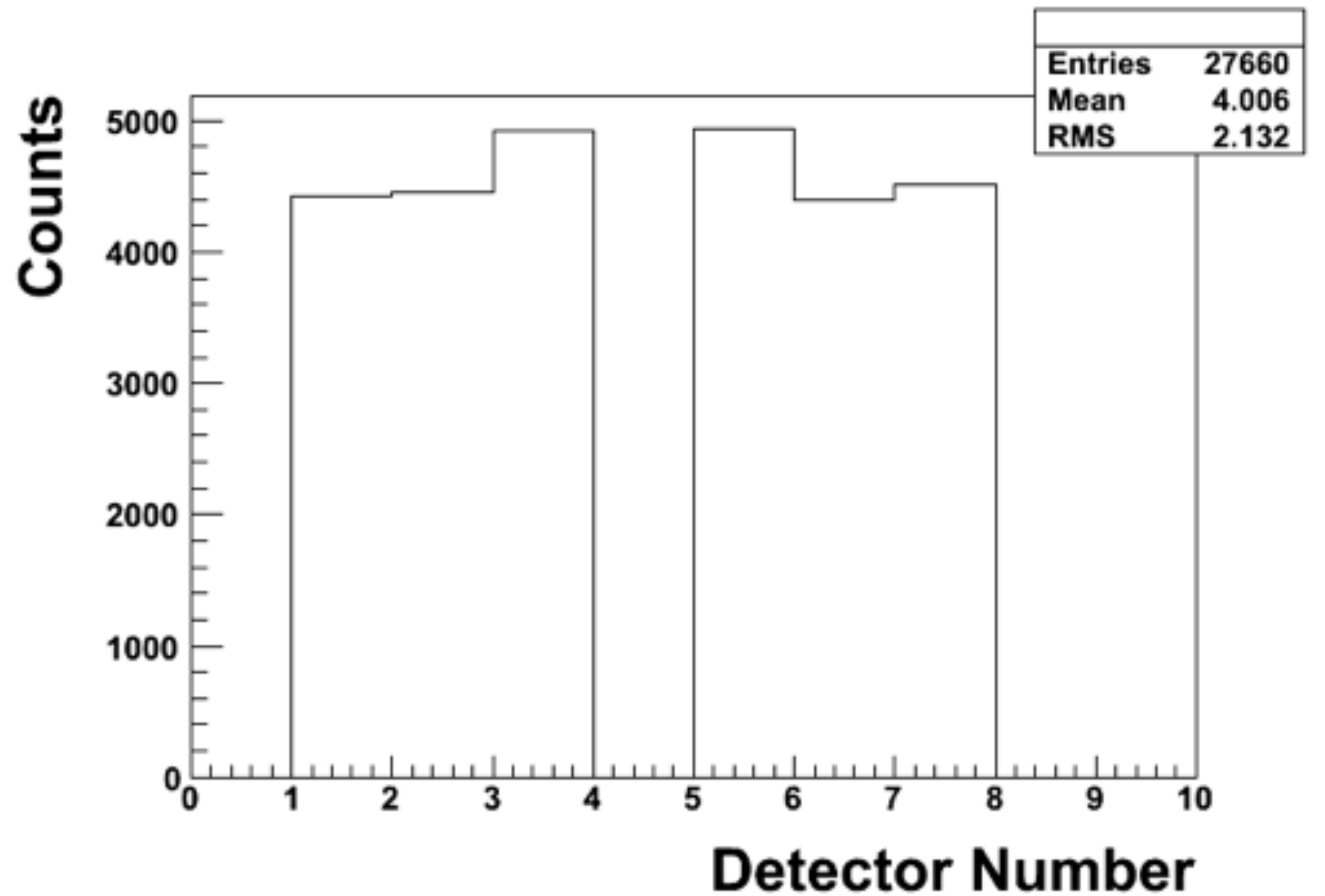
cs	ratio between cs=1)
1	1
2	0.06296
3	0
Simulation	

1st Hit distribution(Simulation)



Simulation

2nd Hit distribution(Simulation)



Simulation

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- 23865 neutron + accidental
- 20865 real neutron
- 21508 accidental cutting value
- 97.02% acceptance