New Trends in Nuclear Physics Detectors (NTNPD-2021)

University of Warsaw, Warsaw, Poland
Monday 25 October 2021 - Wednesday 27 October 2021

Scintillation detectors for fast neutron/gamma discrimination using PSD technique on charge integration ratio

Author: Vo Hong **Hai**[1]

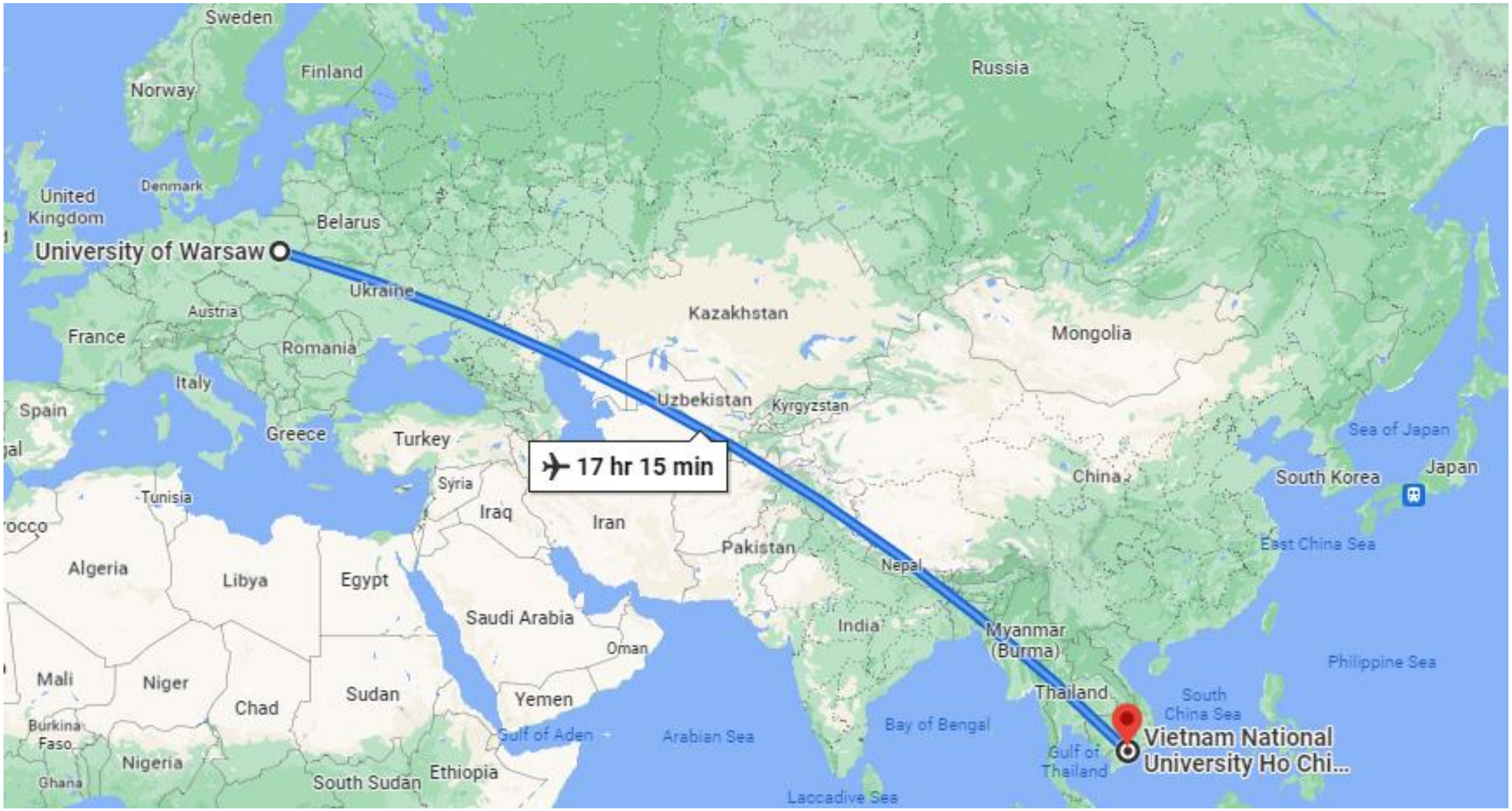
Co-authors: Tran Cong Thien[2], Phan Thanh Xuan[1], Tran Tien Phat[1], Masaharu Nomachi[3]

[1]University of Science, Vietnam National University-Ho Chi Minh, Vietnam

[2]Department of Physics, National Central University, Taiwan

[3]Osaka University, Japan

Email contact: vhhai@hcmus.edu.vn

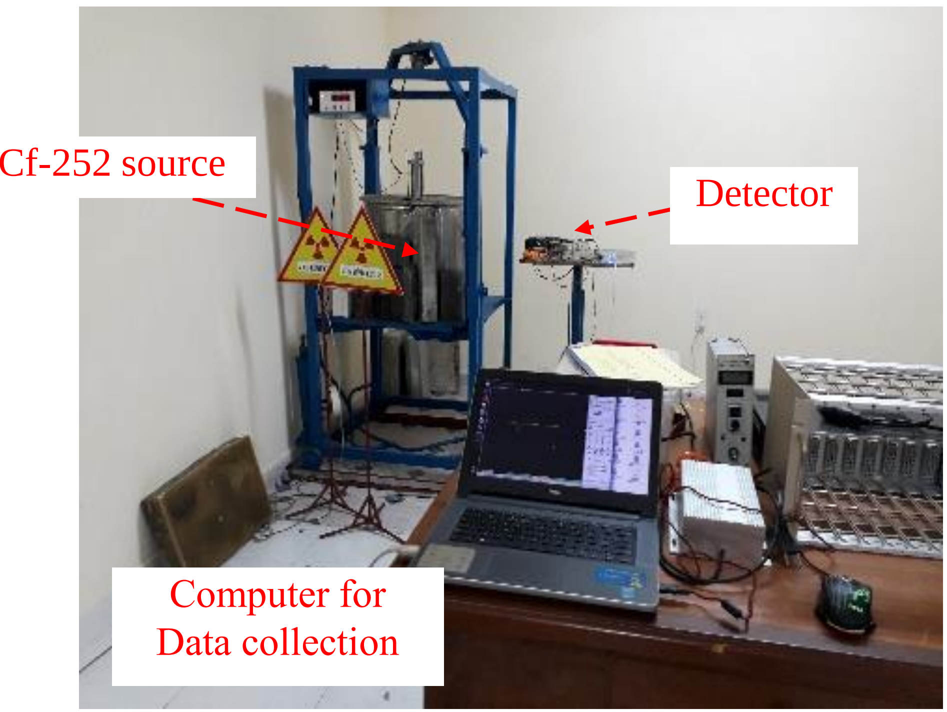

Sweden
Finland
Norway
Russia
Denmark
United Kingdom
Belarus
University of Warsaw
Ukraine
Austria
Kazakhstan
Mongolia
France
Romania
Italy
Uzbekistan
Kyrgyzstan
Spain
Greece
Turkey
Sea of Japan
17 hr 15 min
Syria
China
South Korea
Japan
Tunisia
Iraq
Iran
Pakistan
East China Sea
Algeria
Libya
Egypt
Nepal
Saudi Arabia
India
Myanmar (Burma)
Oman
Philippine Sea
Mali
Niger
Chad
Sudan
Yemen
Thailand
South China Sea
Burkina Faso
Gulf of Aden
Arabian Sea
Bay of Bengal
Vietnam National University Ho Chi...
Gulf of Thailand
Nigeria
Ghana
South Sudan
Ethiopia
Laccadive Sea

Outline

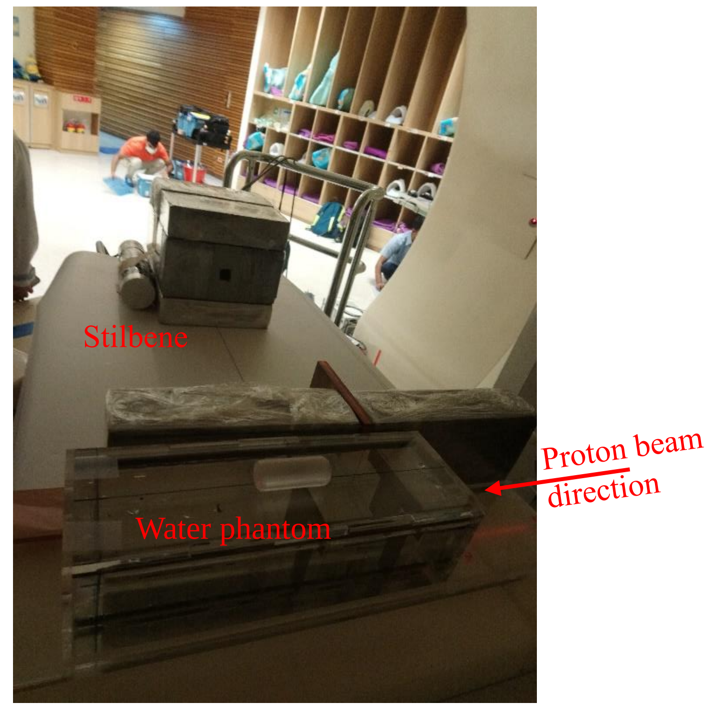
In this talk, I will present two experiments to study neutron/gamma discrimination.

1. Build a Plastic Scintillator detector EJ276 to study neutron/gamma discrimination for Cf-252.

2. Using a Stilbene detector to measure neutron/gamma discrimination for medical proton therapy.



Dalat Nuclear Research Institute, Vietnam



Chang Gung Memorial Hospital, Taiwan.

Chang Gung Memorial
Hospital, Taiwan.
Kunming
昆明市
YUNNAN
GUANGXI
GUANGDONG
FUJIAN
Taipei
台北
Taiwan
Kaohsiung
City
Hong Kong
香港
Hanoi
Hanoi Capital
3-hour flight
Laos
HAINAN
Vientiane
Paracel
Islands
South
China Sea
Luzon
Thailand
Manila
Bangkok
กรุงเทพมหานคร
Vietnam
Pattaya City
Cambodia
Dalat Research Institute
Philippines
Viện Nghiên
Cứu Hạt Nhân
Vietnam National
University Ho Chi...
45-min. flight
Spratly
Islands
Panay
Cebu
I am here
Ho Chi Minh city
Gulf of
Thailand
Negros
Palawan

Materials

Scintillator Materials

EJ-276 (or EJ-299-33),
ELJEN TECHNOLOGY

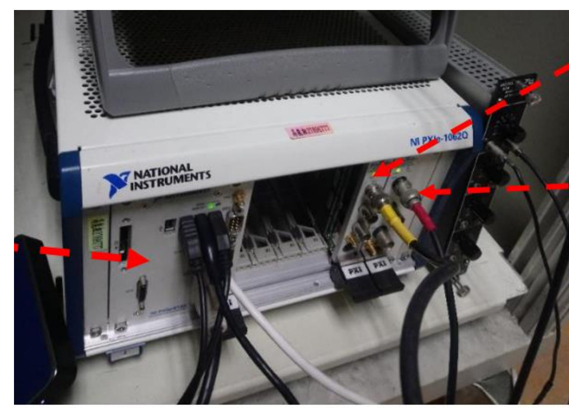
Photo detectors

PMT R6236-01,
Hamamatsu

Electronic readout

DRS-4 digitizer,
PSI Paul Scherrer Institut

Stilbene detector (aged)



Digitizer NI PXI-5152 (8bit ADC),
National Instrument, Corp.

1. Build a Plastic Scintillator detector EJ276 to study neutron/gamma discrimination for Cf-252.

Scintillator Materials

EJ-276 (or EJ-299-33),
ELJEN TECHNOLOGY

Photo detectors

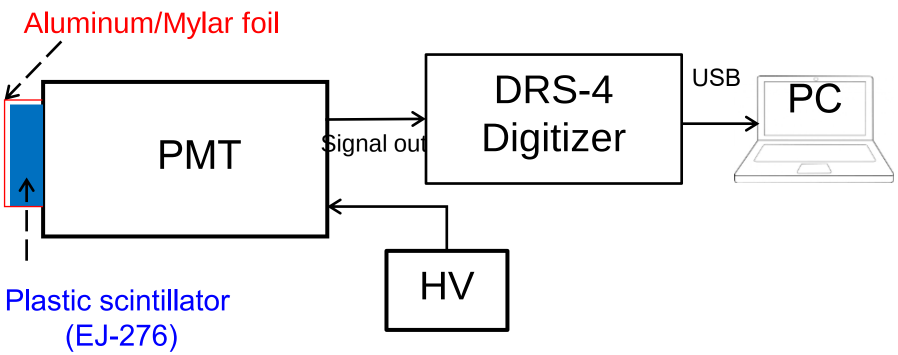
PMT R6236-01,
Hamamatsu

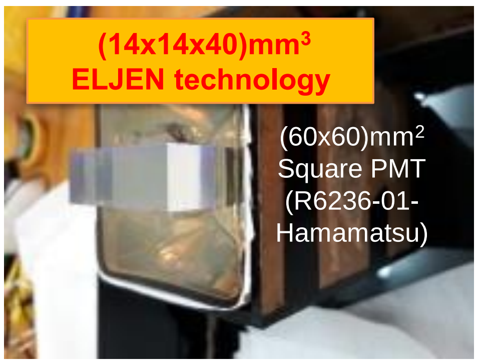
Electronic readout

DRS-4 digitizer,
PSI Paul Scherrer Institut

Experiment has been done at the Dalat Nuclear Research Institute, Vietnam

Plastic scintillation detector setup and DRS-4 digitizer





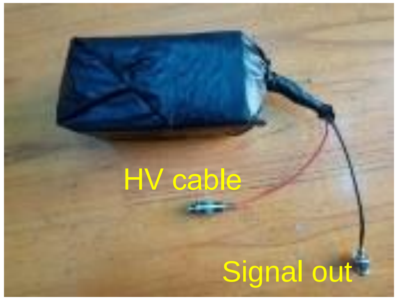
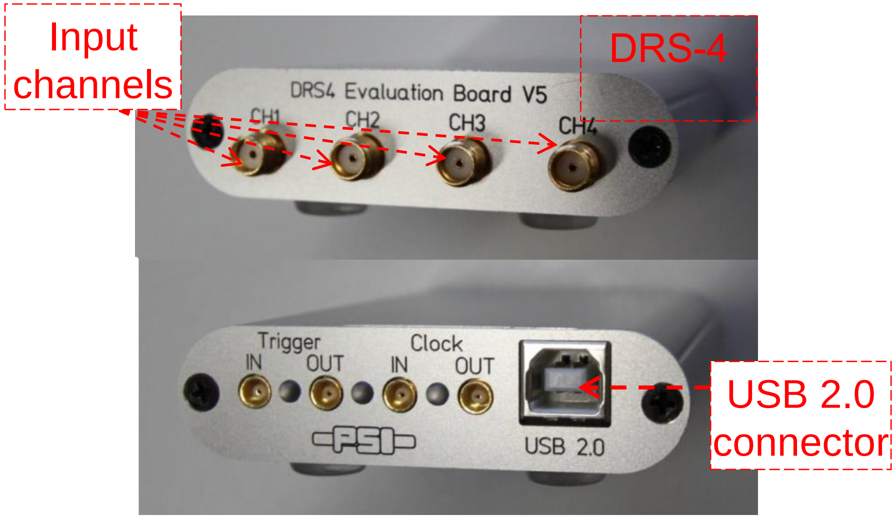
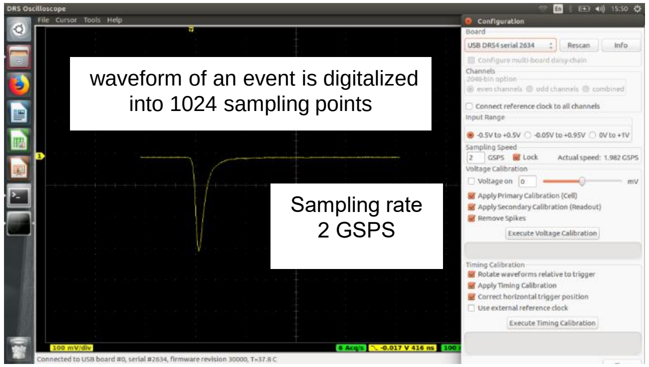


Table 3. Decay times (τ) and the light intensities (I) for all tested scintillators.

Scintillator	Particle	Fast component τ_1 (ns)	I_1 (%)	Medium component τ_2 (ns)	I_2 (%)	Slow component τ_3 (ns)	I_3 (%)	Background component τ_4 (ns)	I_4 (%)
~~EJ309 (from [18])~~	gammas	3.7 ± 0.4	**80**	31 ± 3	**10**	140 ± 10	**7**	790 ± 80	**3**
	neutrons	4.8 ± 0.5	**46**	32 ± 3	**24**	140 ± 10	**20**	620 ± 60	**11**
EJ299-34	gammas	4.3 ± 0.2	**74**	18 ± 2	**14**	140 ± 10	**12**	—	—
	neutrons	4.5 ± 0.2	**58**	20 ± 3	**18**	170 ± 15	**24**	—	—
EJ299-33	gammas	4.6 ± 0.3	**73**	19 ± 2	**16**	130 ± 10	**12**	—	—
	neutrons	5.0 ± 0.2	**54**	22 ± 3	**21**	180 ± 15	**25**	—	—
EJ299-34G	gammas	5.3 ± 0.3	**73**	19 ± 2	**15**	150 ± 10	**12**	—	—
	neutrons	5.5 ± 0.3	**60**	25 ± 3	**17**	180 ± 15	**23**	—	—
EJ299-33G	gammas	5.6 ± 0.3	**76**	22 ± 3	**13**	160 ± 15	**11**	—	—
	neutrons	5.8 ± 0.3	**61**	25 ± 3	**15**	180 ± 15	**24**	—	—



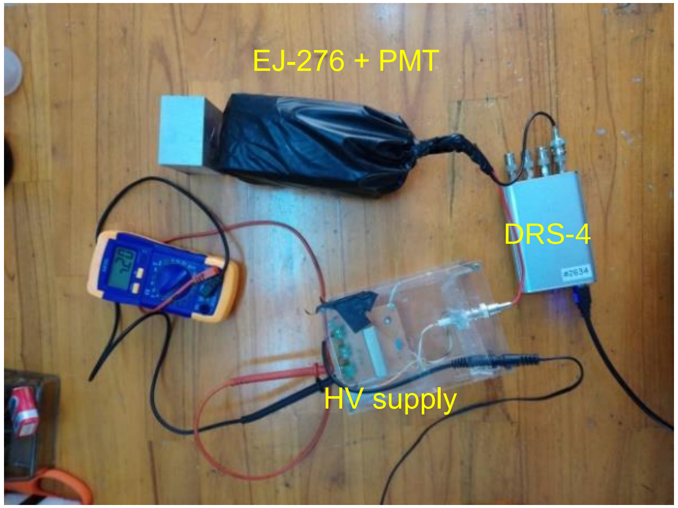


DRS-4 digitizer:

- 4 input channels.
- 0.7 GSPS to 5 GSPS with 1024 sampling points
- Maximum readout rate is about 500 events/sec.
- DRS4 Developer stefan.ritt@psi.ch

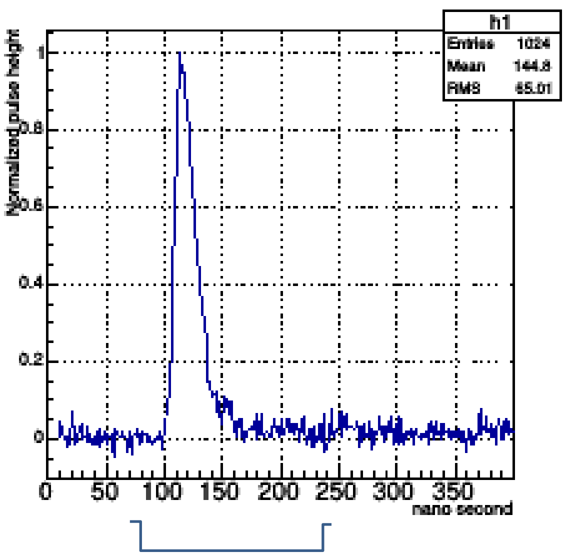
(https://www.psi.ch/en/drs/evaluation-board)

Gamma energy calibration

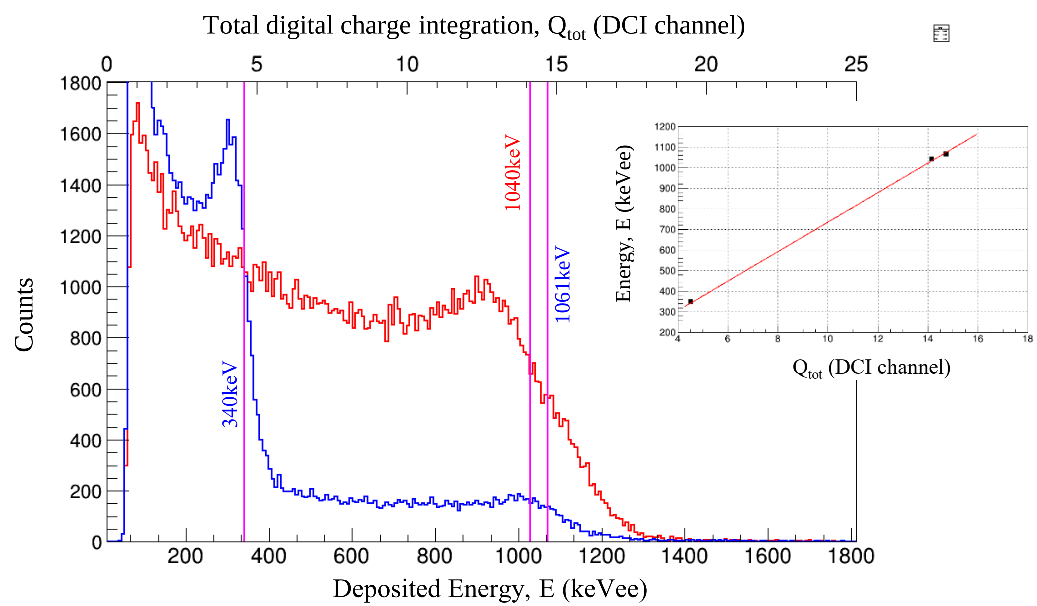


GAMMA SOURCES	GAMMA ENERGY (KEV)	COMPTON EDGE (KEV)
NA-22	511	340
	1274	1061
CO-60	1252.5 (EQUI.)	1040

Gamma energy calibration for the detector is based on Compton Edge.

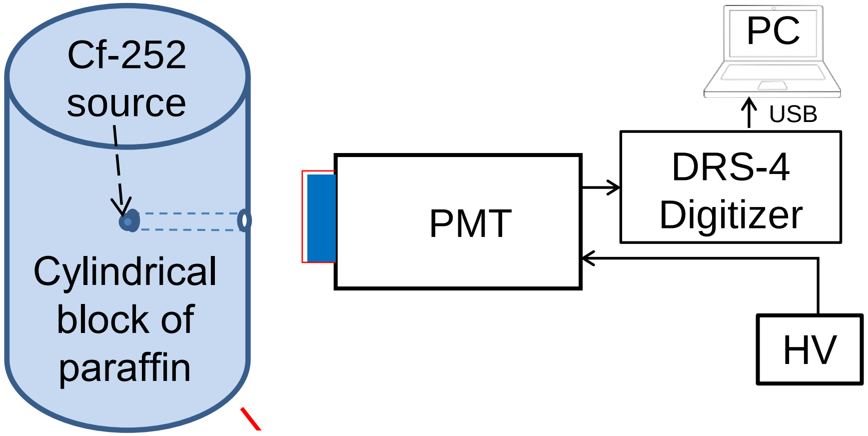


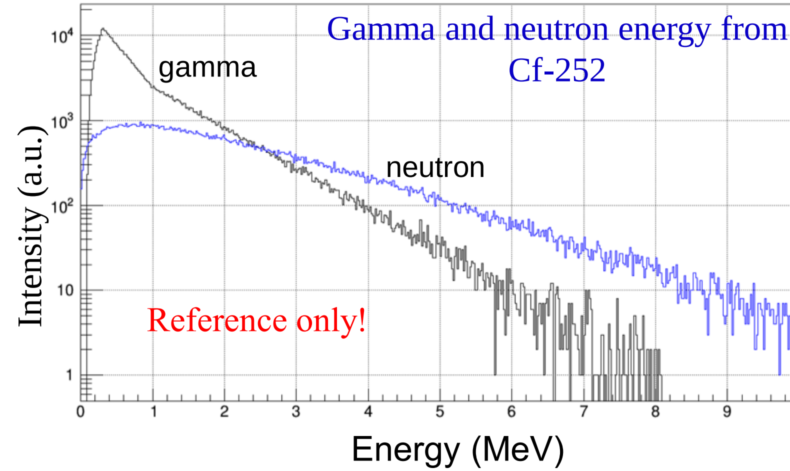
Total digital charge integration, Q_{tot} (DCI channel)

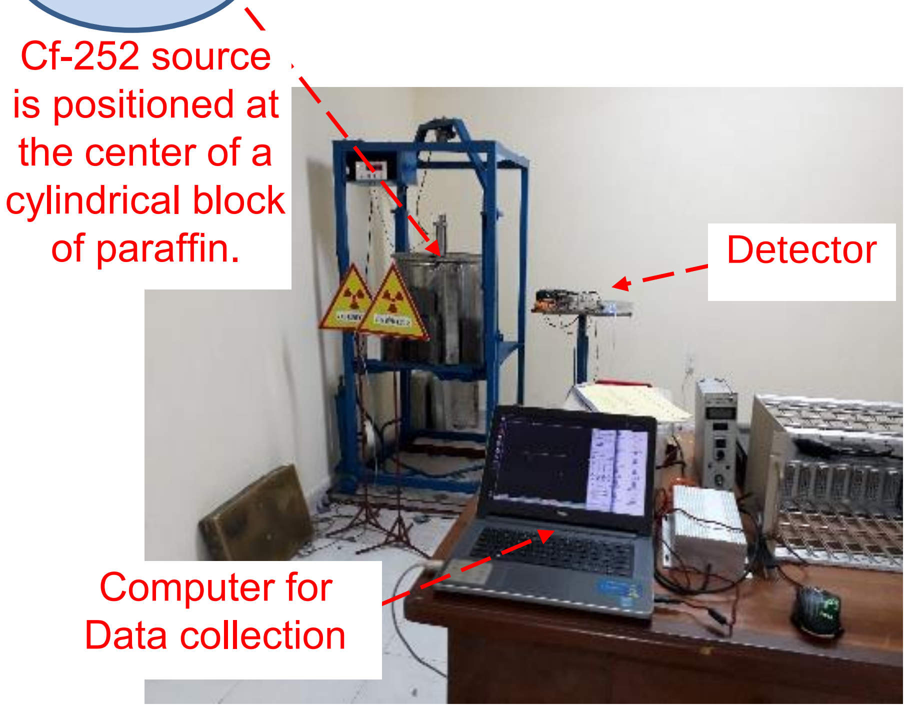


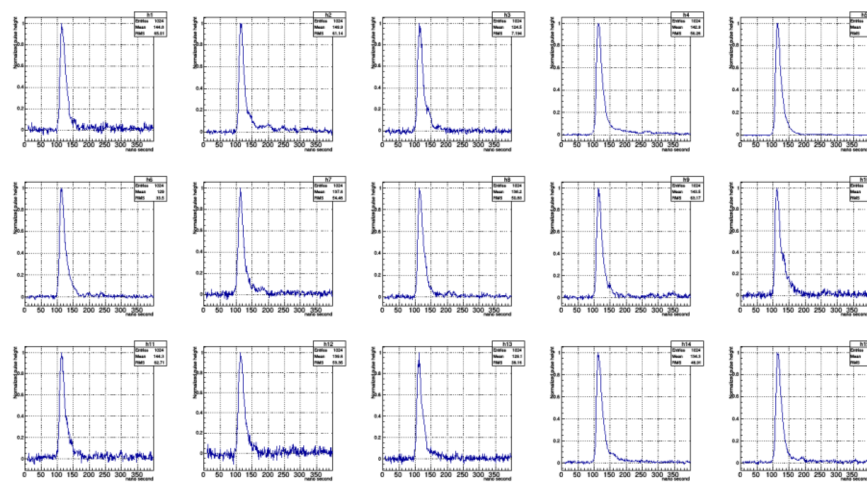
Experiment for Cf-252 source

Experiment set-up



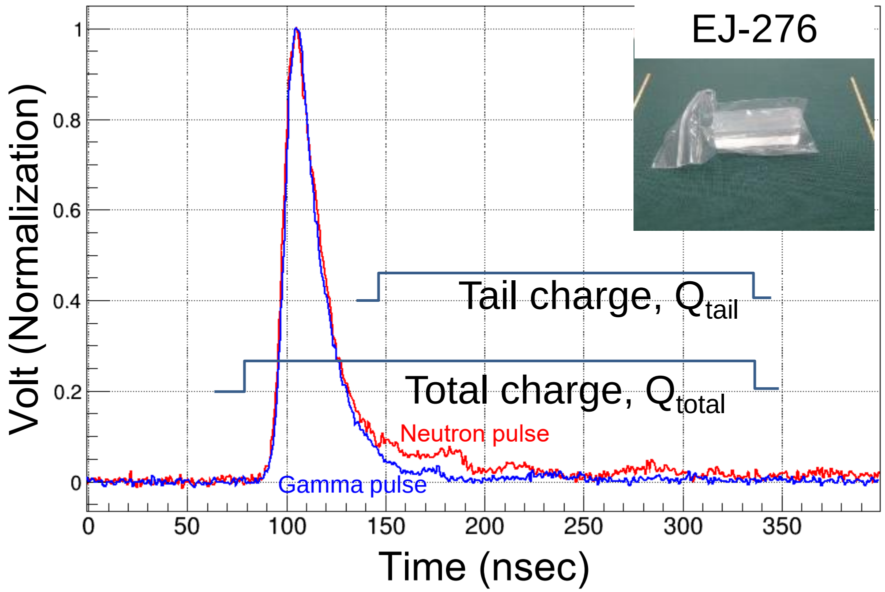






Pulse shape discrimination (PSD) technique on Charge Ratio Q_{ratio}

Pulse shape discrimination (PSD) technique



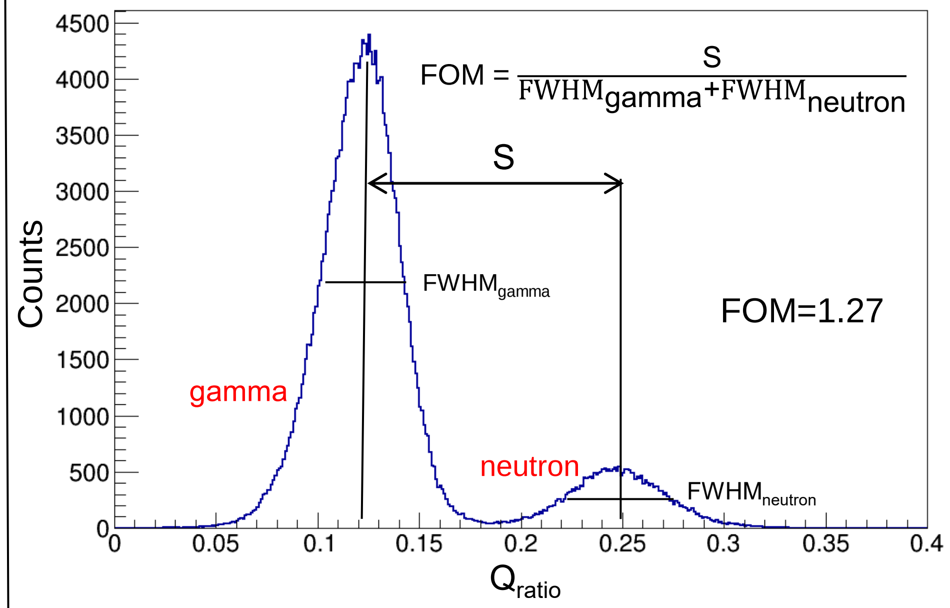
Tail-to-Total Charge Ratio (Q_{ratio}) method in PSD Technique

$$Q_{ratio} = \frac{Q_{tail}}{Q_{total}}$$

Q_{tail}: Charge calculated within Tail gate

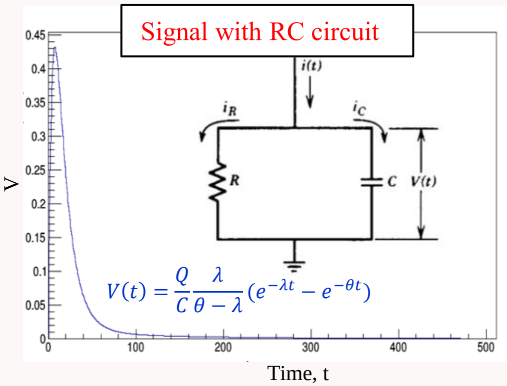
Q_{total}: Charge calculated within Total gate

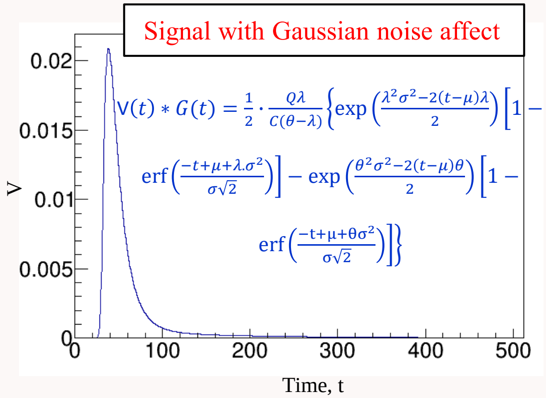
Figure of merit (FOM)

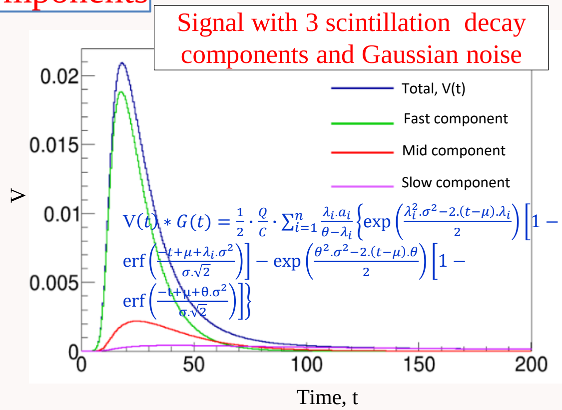


$$FOM = \frac{S}{FWHM_{gamma}+FWHM_{neutron}}$$

Calculation of signal response of a scintillation detector with 3 decay components







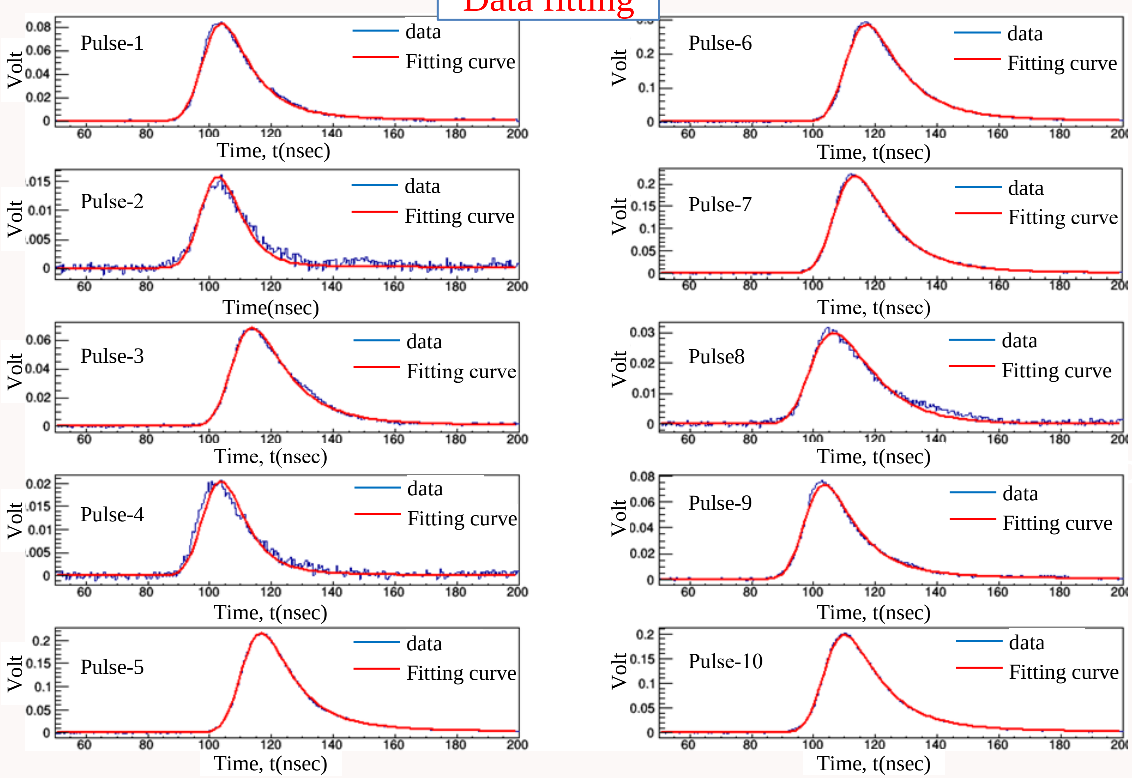
λ: Decay constant

$$G(t) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(t-\mu)^2}{2\sigma^2}}$$

$$\theta = \frac{1}{RC}$$

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-u^2}du$$

Data fitting



Fitting formula:

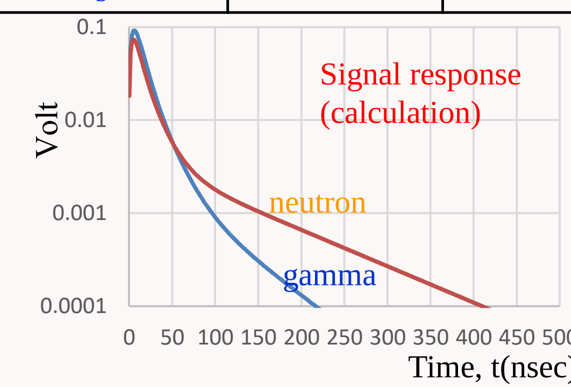
$$V(t)= \sum_{i=1}^{3} A_i\left\{\exp\left(\frac{\lambda_i^2\sigma^2-2(t-\mu)\lambda_i}{2}\right)\left[1-\mathrm{erf}\left(\frac{-t+\mu+\lambda_i\sigma^2}{\sigma\sqrt{2}}\right)\right]-\exp\left(\frac{\theta^2\sigma^2-2(t-\mu)\theta}{2}\right)\left[1-\mathrm{erf}\left(\frac{-t+\mu+\theta\sigma^2}{\sigma\sqrt{2}}\right)\right]\right\}$$

Fitting parameters: A_1, A_2, A_3, θ, λ_1, λ_2, λ_3, σ, μ.

From measurement data for Co-60 and Cf-252

Fitting

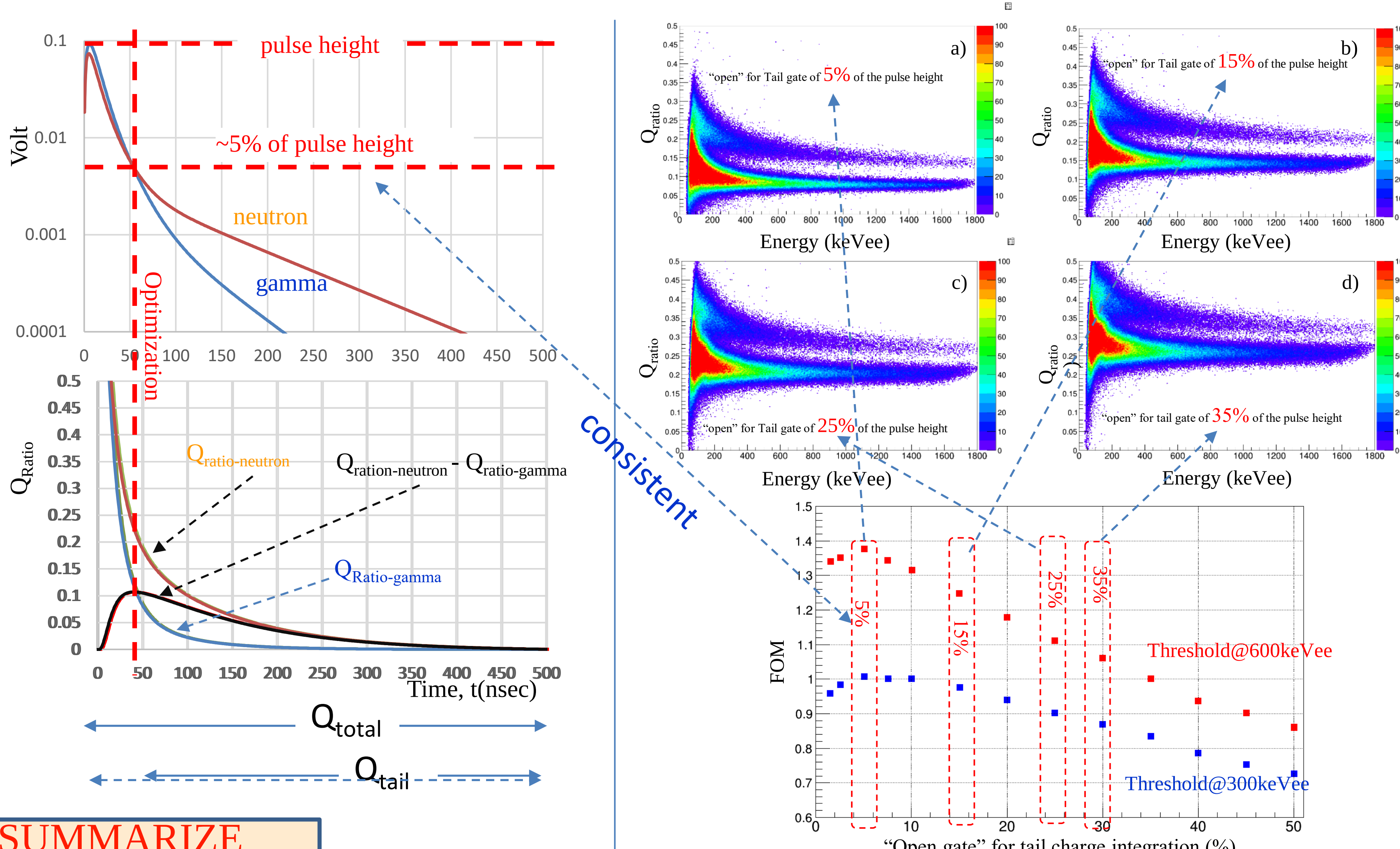
Fitting parameters	Gamma	Neutron
θ	0.124 ± 0.034	0.142 ± 0.048
λ_1	0.266 ± 0.075	0.328 ± 0.073
λ_2	0.055 ± 0.019	0.059 ± 0.019
λ_3	0.016 ± 0.010	0.009 ± 0.005



Data analysis

This work

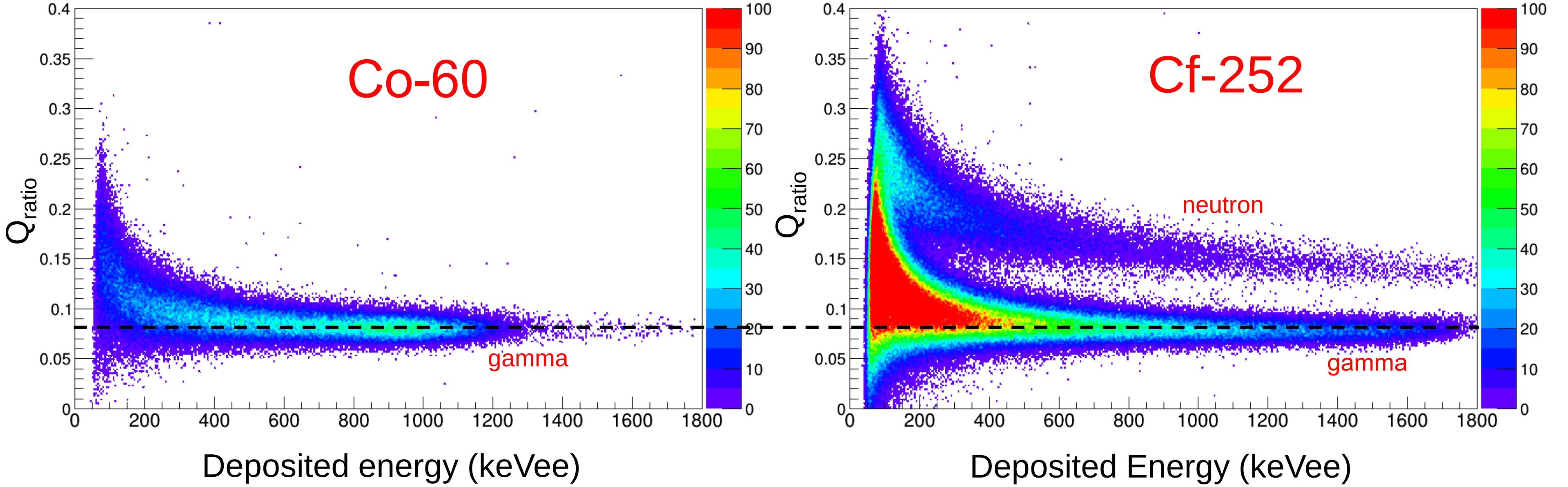
Previous work [#717, RT Conf. 2018]



SUMMARIZE

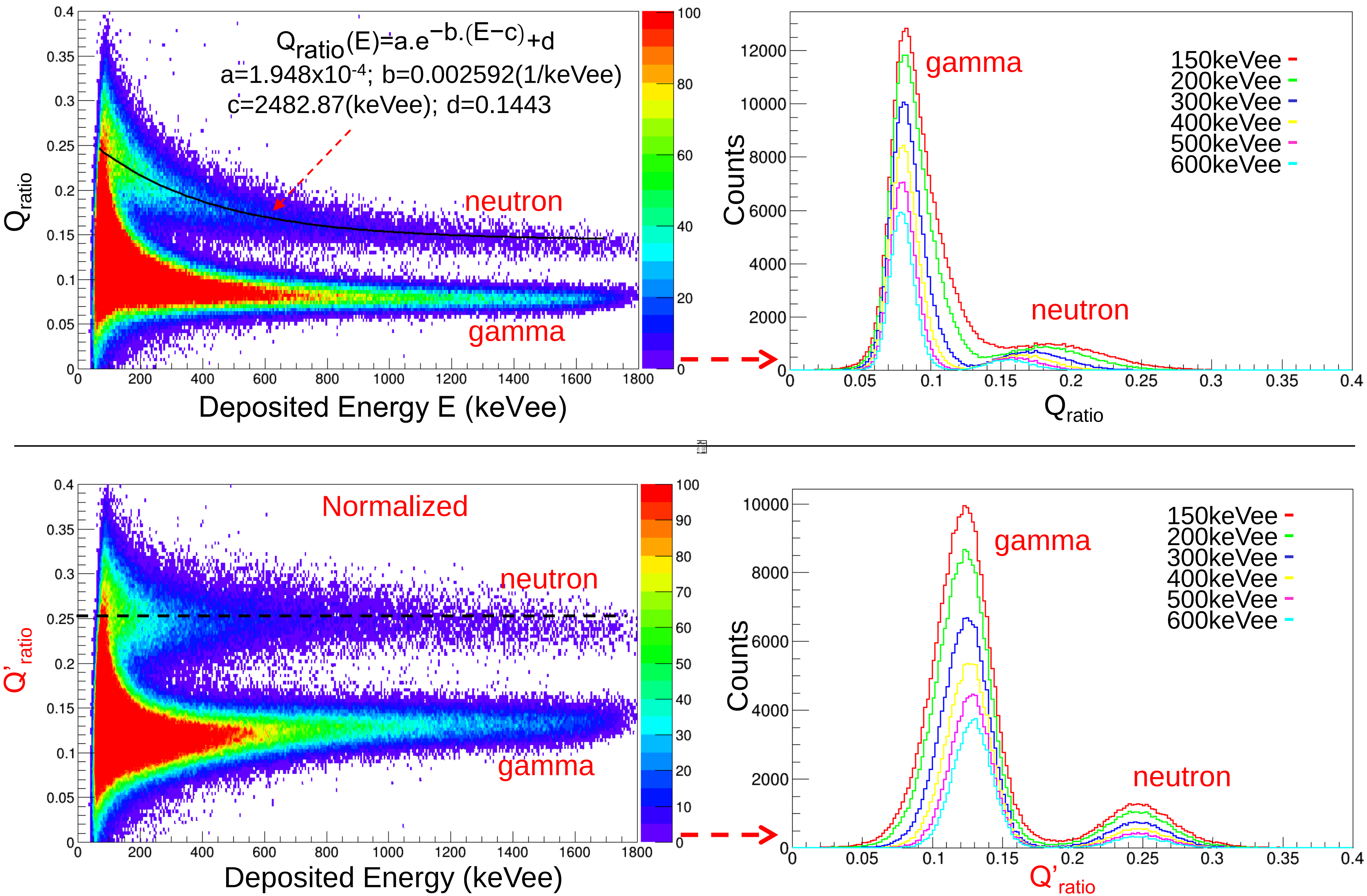
- Equation to describe the pulse response for the EJ-276 scintillation detector with 3-decay components and gaussian noise.
- Determine characteristic parameters OF scintillation detector from measured data.
- Optimization of Q_{ratio} technique for neutron/gamma discrimination.

Q_{ratio} method for Co-60 and Cf-252

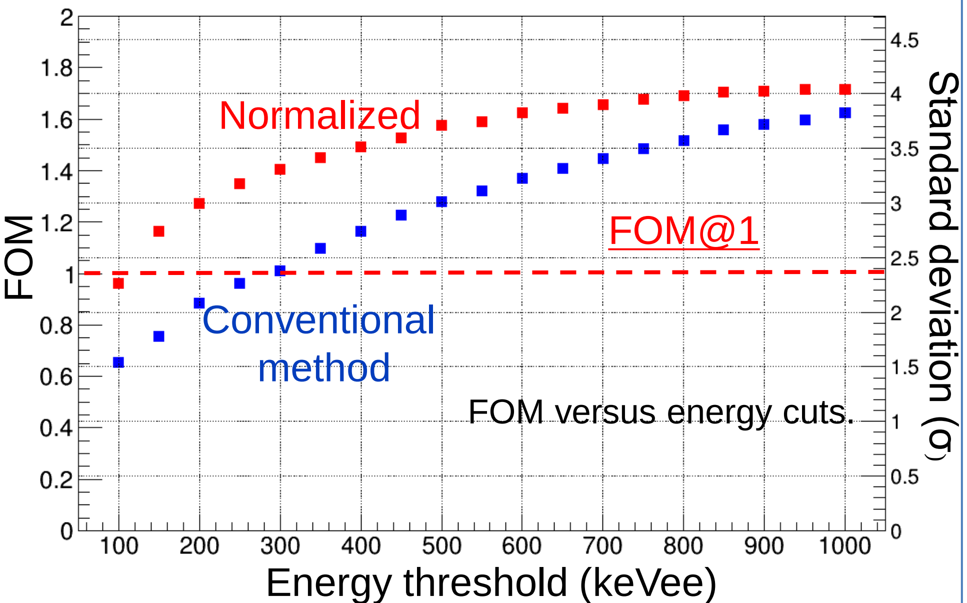


Note: keVee (keV electron equivalent)

Analysis FOM for neutron/gamma discrimination of Cf-252 measurement



Comparisons

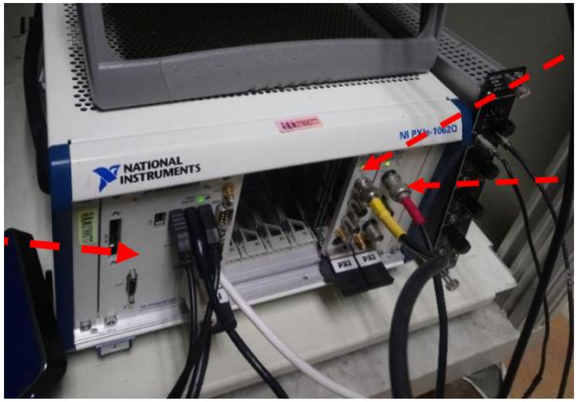


Energy threshold (keVee)	FOM from other work	This work (new method)
100	0.84 J.Iwanowska-Hanke (2014) IOP Science [5]	0.96±0.01
180	0.96 S.A. Pozzi (2013) NIMA [6]	1.24±0.01
200	0.93 Pauline Blanc (2014) NIMA [7]	1.27±0.01
200	0.76 S. Nyiblue (2013) NIMA [8]	1.27±0.01
300	1.01 A.Jancar (2015) Radiation Physics and Chemistry [9]	1.40±0.02

- The FOM quantities calculated from this work show better FOM quantities in comparison with other works.

2. Using a Stilbene detector to measure neutron/gamma discrimination for medical proton therapy.

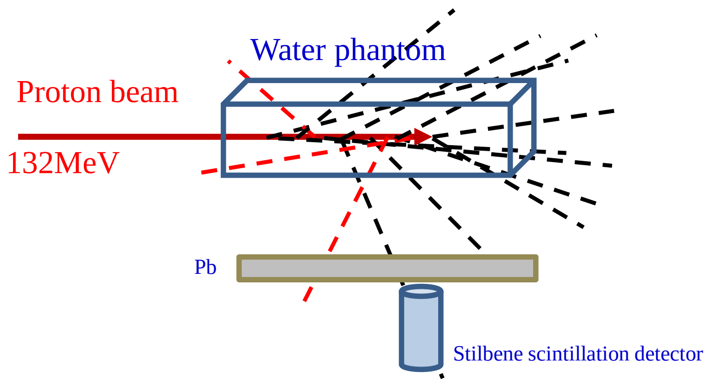
Stilbene scintillation detector (aged) (2in. x 2in.)

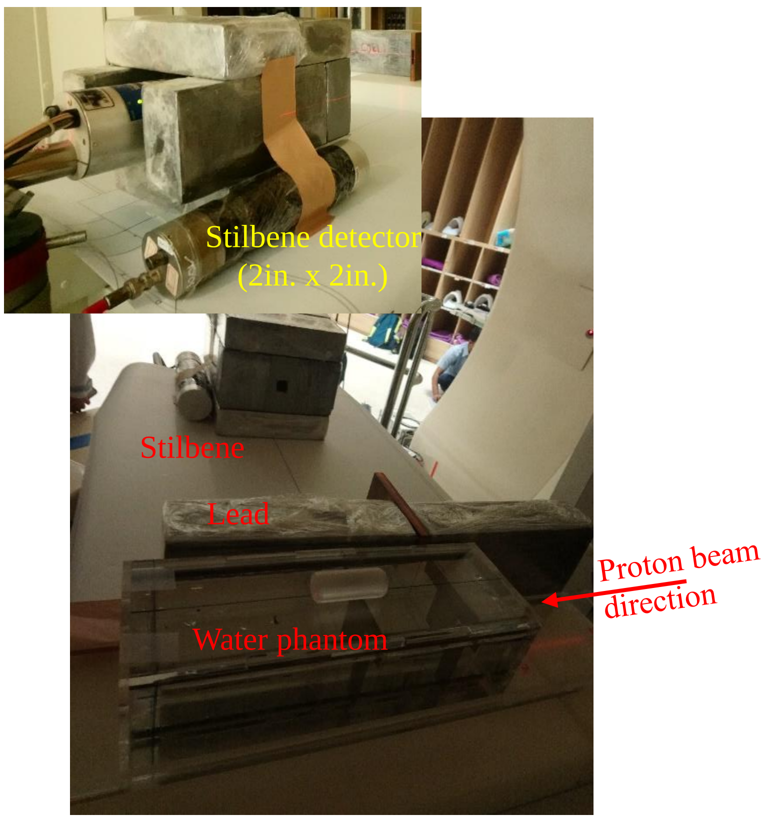


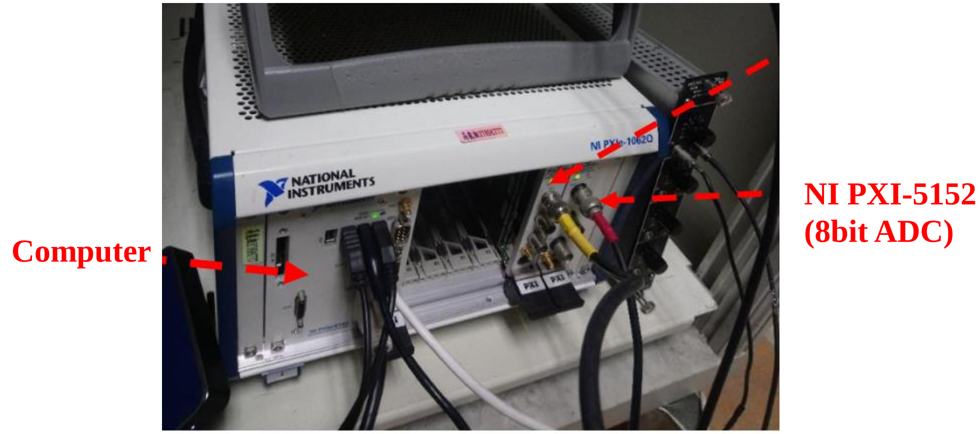
Digitizer NI PXI-5152 (8bit ADC), National Instrument, Corp.

Experiment has been done at Chang Gung Memorial Hospital, Taiwan.

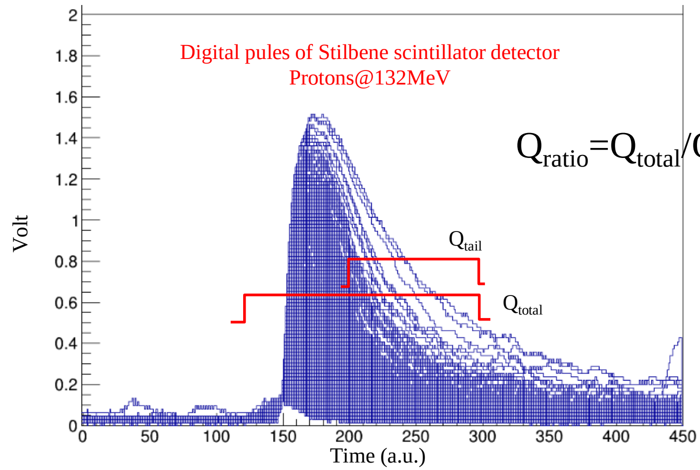
Experiment set-up for neutron/gamma measurement



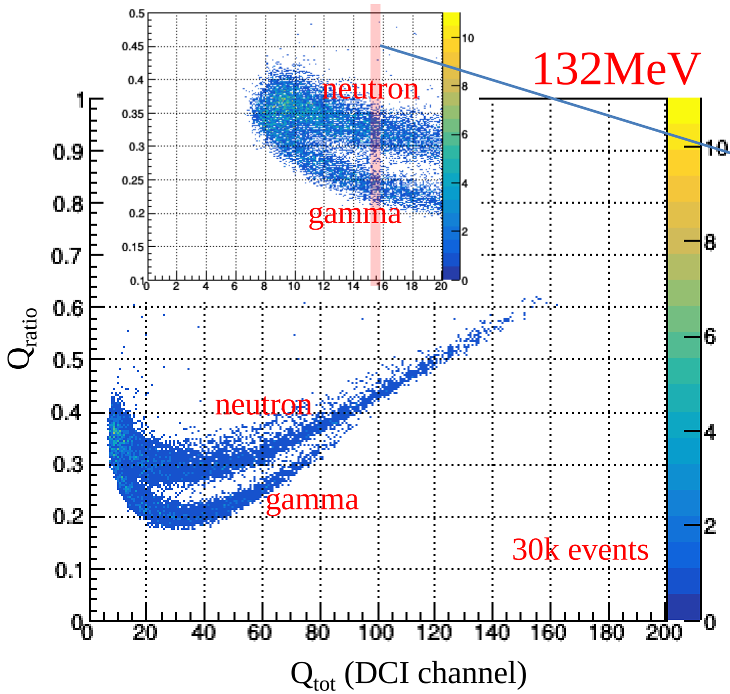


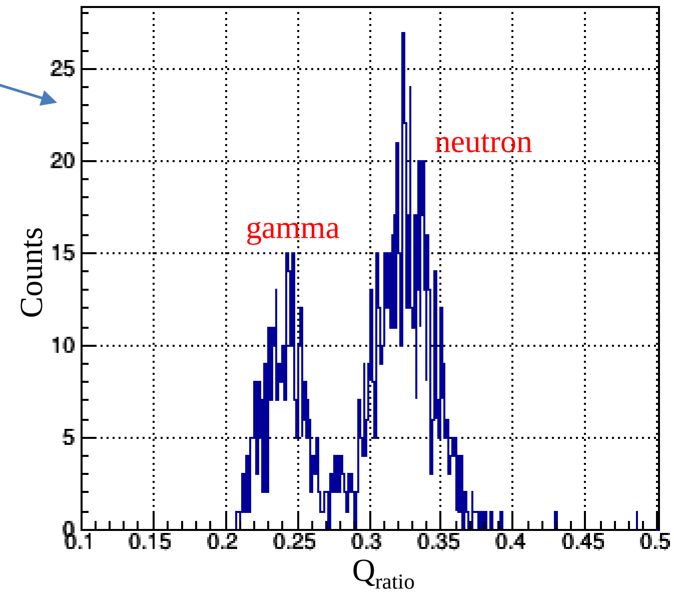


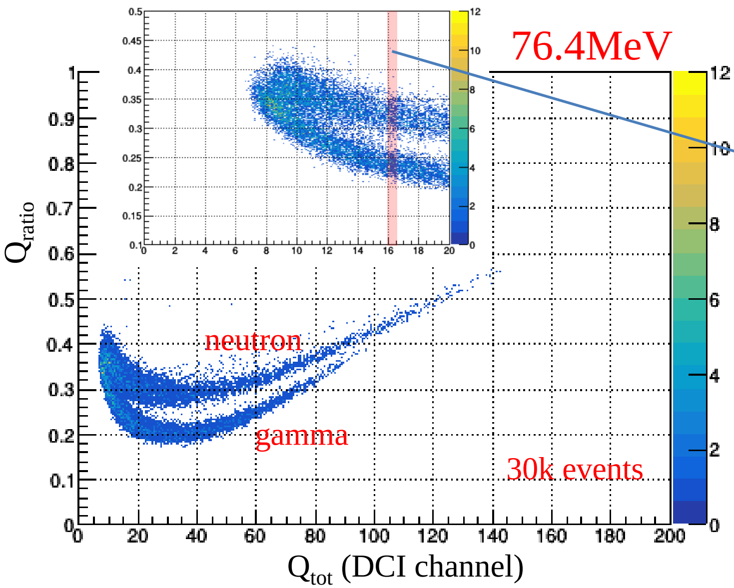
Digitizer NI PXI-5152 (8bit ADC), National Instrument.
- 2 input channels
- 2 GS/s, 300 MHz
- 8-Bit/ 4Volt-range (~20mV resolution)
- https://www.ni.com/pdf/manuals/374443j.pdf

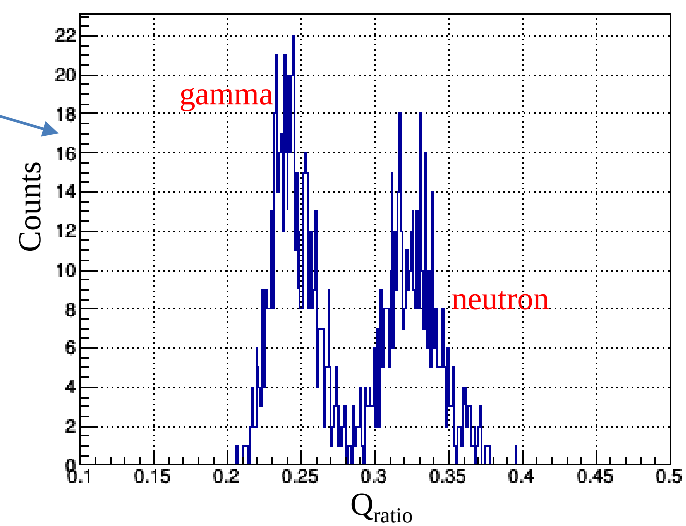


Analysis of Q_{ratio}



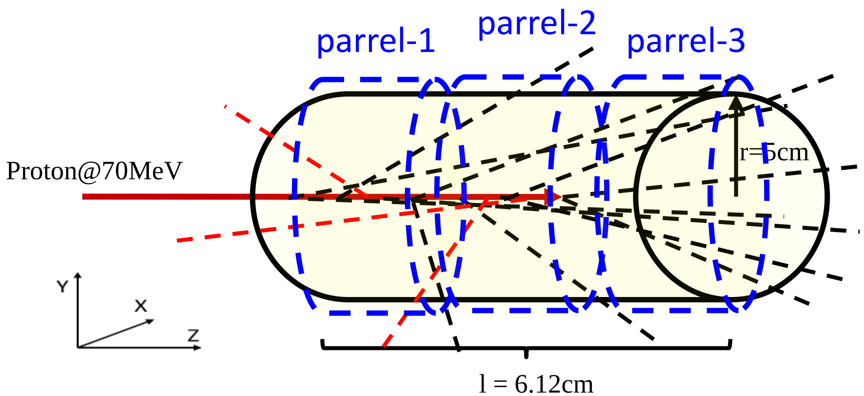


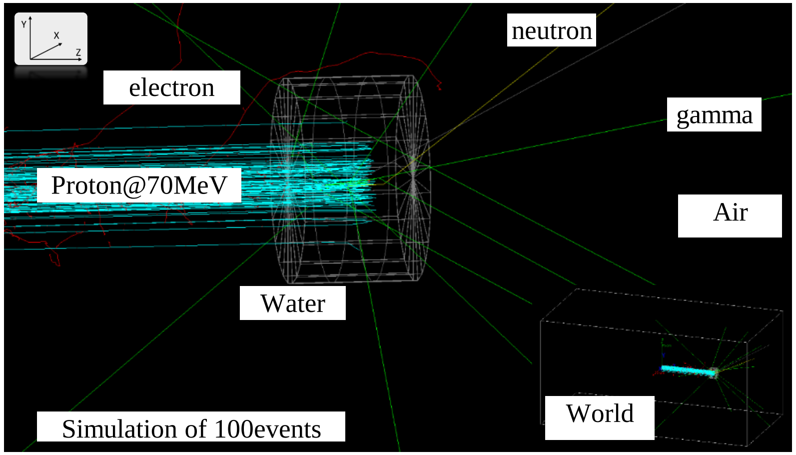




Neutron studies using Gate/Geant4 simulation toolkit

Using Gate/Geant4 Monte-Carlo simulation toolkit to study secondary neutron and gamma from a water phantom irradiated by proton beam.

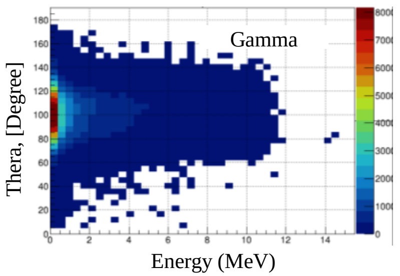




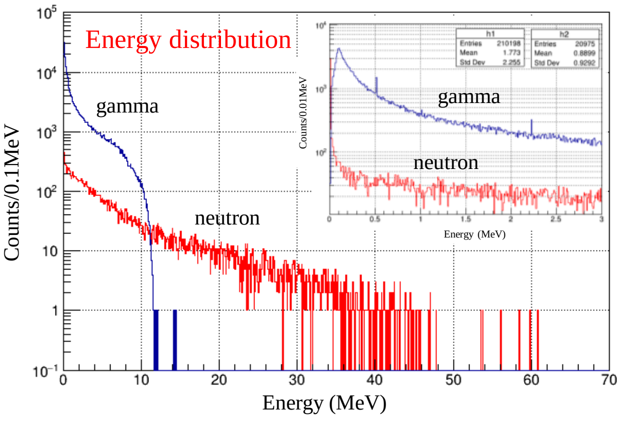
Number of events is 10.4×10^6.

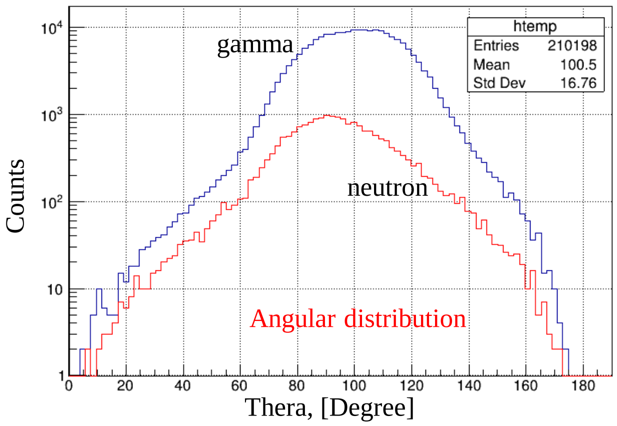
Proton energy: 70MeV

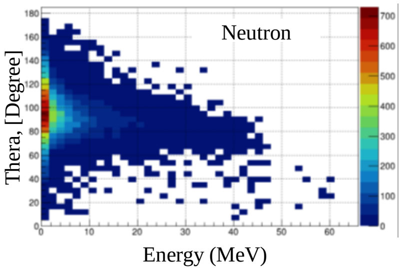
Gate 9.0 and Geant4.10.6.



Analysis of parrel-1







Summaries

- There are several types of scintillator materials can be used to separate neutron/gamma background.
- Traditionally, PMT has been good or suitable for scintillator materials. Recently, SiPM or MPPC becomes more attractive to replace PMT.
- Fast Digitizer with high resolution of time and voltage is perfect for PSD technique.
- For neutron studies in Medical radiotherapy, high-energy secondary neutron is very interesting to study. This technique might be useful for that.

Thank you very much for your attention!

Full name: Vo Hong Hai
Academic title: lecturer
Administration title: Deputy head,
External Relation Office Contacts:
Email: vhhai@hcmus.edu.vn Website:
https://sites.google.com/hcmus.edu.vn/rewes/ IEEE member: 93983296

1. Research Areas:

(1)-High-Tech electronic readout for radiation detectors,

(2)- Geant4/Gate simulations for radiation studies,

(3)-Environmental radiation studies,

(4)-Neutron production from Medical Linear Accelerator.

2. Faculty/Department/Laboratory/Office

- Dept. of Nuclear Physics, Faculty of Physics & Engineering Physics

- External Relation Office (Deputy head)

3. Research Activities

(1)- Online real-time radiation monitoring systems

(2)- FPGA trigger system for coincidence detector.

(3)- plastic scintillation detector for neutron/gamma discrimination

(4)- Studies on neutron production in Medical Linear Accelerator

(5)- Geant4/Gate simulation for radiation detector and LINAC.

4. Research projects:

(1)-Collaboration project of advanced electronic development (with Prof. Nomachi's group, Osaka University, Japan).

(2)-Collaboration project (E36) of advance electronic development (KEK, Japan).

(3)-Study on Cosmic-ray induced background on HPGe detector, National Nafosted foundation.