A Counter/Discriminator of Neutrons and Gamma Rays

Moslem Amiri, Václav Přenosil

Embedded Systems Laboratory
Faculty of Informatics, Masaryk University
Brno, Czech Republic

amiri@mail.muni.cz

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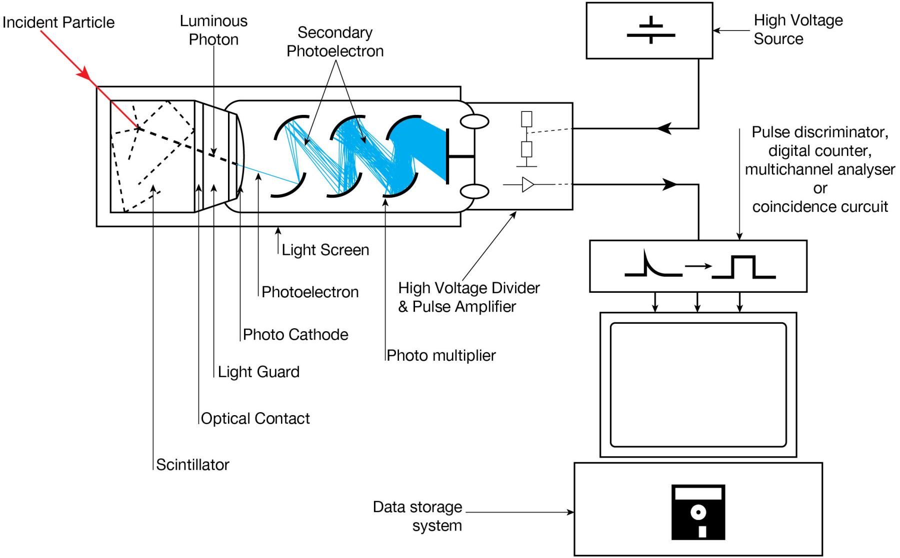
Outline

- Physical background
- Our introduced technique
- Comparison with another technique

Neutron Radiation

- Neutron radiation is produced during
  - Nuclear fusion
  - Nuclear fission
  - Or any kind of nuclear reaction
- Applications of neutron radiation
  - Identifying properties and structures of materials
  - Curing cancerous tumors
  - Neutron imaging
  - ...
- Usage in various branches of science
  - Nuclear physics
  - Biology
  - Geology
  - Medicine
  - ...
- Problem
  - Neutron fields coexist with γ-rays

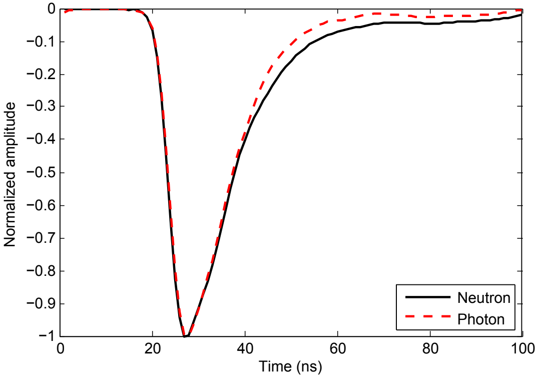
Radiation Detector



Digitizers

- The digitizers used
  - Acqiris DP210
    - 8-bit resolution
    - Set at 1 and 2 GS/s
  - Acqiris DC440
    - 12-bit resolution
    - Set at 250 and 420 MS/s

Neutron and Photon (γ-ray) Signals



Optimum Filter Implementation

A mathematical principle

Let $n(i)$ and $g(i)$ be discrete-time functions, normalized to unity:

$$\sum_i n(i) = \sum_i g(i) = 1 \tag{1}$$

If a weight sequence $p(i)$ is computed as:

$$p(i) = \frac{g(i) - n(i)}{g(i) + n(i)} \tag{2}$$

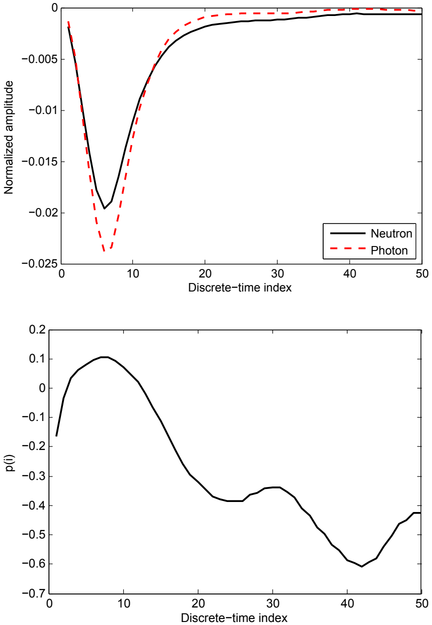
then an unknown function $u(i)$, close to either $n(i)$ or $g(i)$, can be identified as one of them by the sign of S defined as:

$$S = \sum_i p(i)u(i) \tag{3}$$

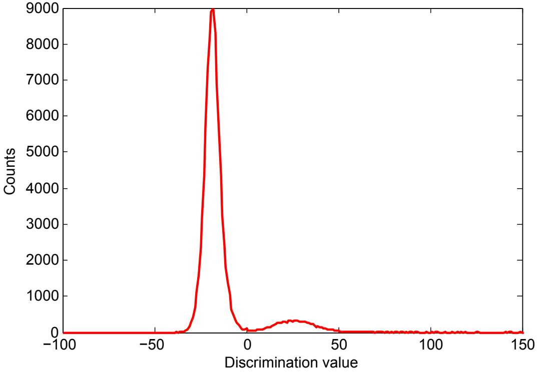
Pulse Identification

- In Eqs. 1, 2, and 3, if $n(i)$ and $g(i)$ are replaced with neutron and γ-ray pulses, respectively, then:
    - If $S < 0$, the particle is identified as γ-ray
    - If $S > 0$, the particle is identified as neutron
    - This can be used to count the number of neutrons and γ-rays
    - To find the efficiency of discrimination, an ideal factor is the amplitude of S for a pulse

Normalized Pulses – Weight Function



Experimental Distribution (12-bit res., 420 MS/s)



FoM

- For comparison, Figure of Merit (FoM) is used:

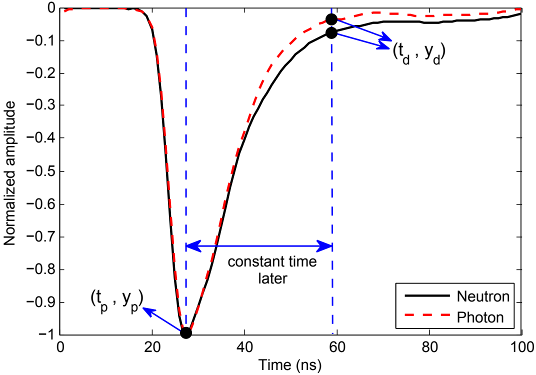
$$FoM = \frac{S}{FWHM_n + FWHM_\gamma}$$

  - S: separation between the peaks of the two events
  - $FWHM_\gamma$: full-width half-maximum (FWHM) of the spread of events classified as γ-rays
  - $FWHM_n$: FWHM of the spread in the neutron peak

Results

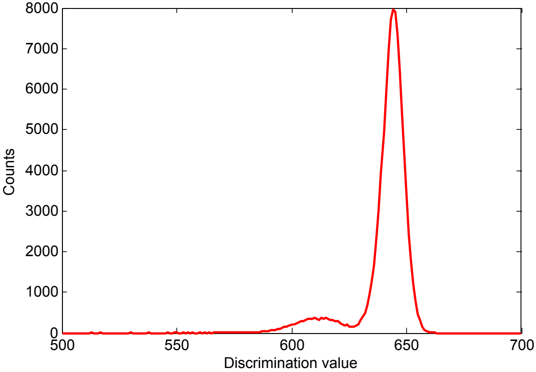
Data format	FoM	Neutron counts	Photon counts
12-bit, 250 MS/s	1.25	9032	90968
12-bit, 420 MS/s	1.21	9293	90707
8-bit, 1 GS/s	1.06	9558	90442
8-bit, 2 GS/s	1.05	9462	90538

PGA Method



$$m = \frac{\Delta y}{\Delta t} = \frac{(y_p - y_d)}{(t_p - t_d)} \quad (4)$$

PGA Method - Distribution Plot (12-bit, 420 MHz)



PGA Method – Results

Digitizer	8-bit, 1 GS	8-bit, 2 GS	12-bit, 250 MS	12-bit, 420 MS
FoM	0.88	0.91	0.94	1.00

Acknowledgment

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Thank you for your attention!