Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
Świerk

Development of a digital method for neutron-gamma discrimination based on matched filtering

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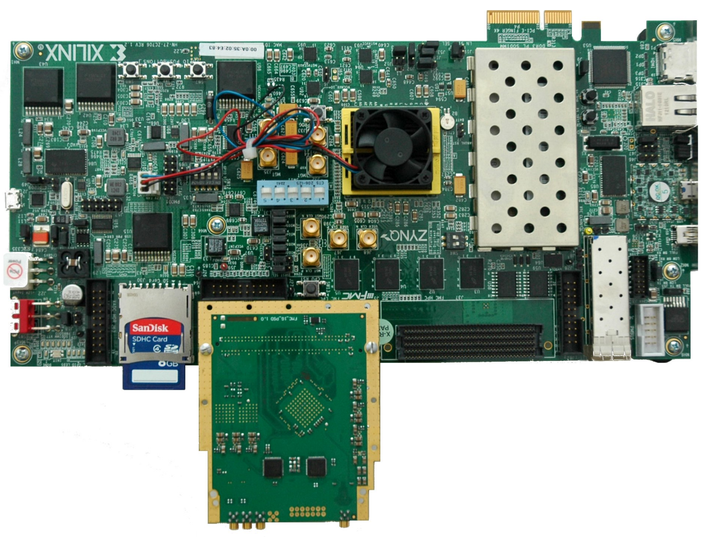
Neutron-gamma discrimination is crucial for measurements with detectors sensitive to neutron and gamma-ray radiation.

Different techniques to discriminate between neutrons and gamma-rays are widely used in many applications, e.g., homeland security, radiation dosimetry, environmental monitoring, fusion experiments, nuclear spectroscopy.

The most popular conventional methods used for neutron-gamma discrimination are charge comparison (CC), zero-crossover method (ZCO), rise-time inspection (RTI) and frequency gradient analysis methods.

Modern electronic components, such as high speed analog to digital converters and powerful programmable digital circuits for signal processing, allow us to develop a fully digital measurement system. With this solution it is possible to optimize digital signal processing (DSP) algorithms without changing any electronic components in an acquisition signal path.

We report on results obtained with a digital acquisition system DNG@NCBJ designed at the National Centre for Nuclear Research, Poland. A 2"x2" EJ309 liquid scintillator is used to register mixed neutron and gamma-ray radiation from both ^{137}Cs and PuBe source. A dedicated algorithm for DSP, based on matched filtering, was developed and compared with conventional methods.



Xilinx ZYNQ-7000 SoC ZC706 evaluation board with ADC

DIGITAL NEUTRON GAMMA DNG@NCBJ

DNG@NCBJ measurement system is based on a direct sampling of the input signal. Data acquisition is based on 12-bit/1GSPS analog to digital converter and signal processing operations are performed in the digital way by FPGA SoC with ARM9 processor on Xilinx ZC706 evaluation board.

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METHODOLOGY

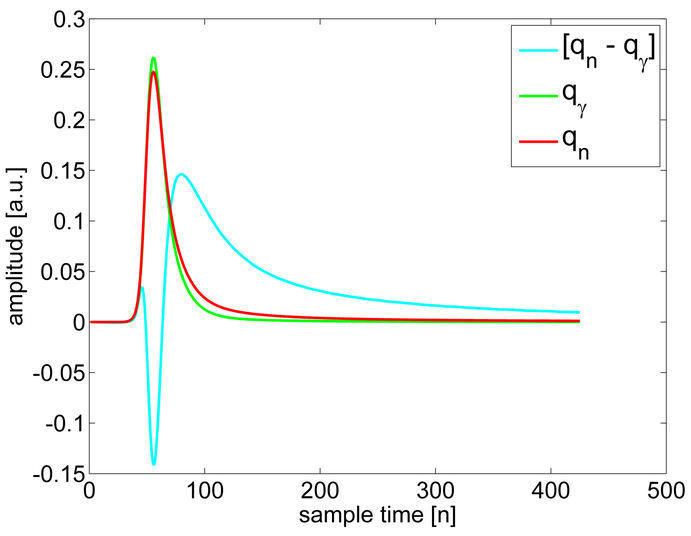
***Data pre-processing part of algorithm for n/γ discrimination*:**

1. **for starting point, well known methods are used to determine teaching sets of impulses for n and γ. Only impulses with very high probability of correct discrimination are used;**
2. **computation of autocorrelation matrices of n/γ signals from previously determined;**
3. **computation of decomposition of autocorrelation matrices. Eigenvectors are then an estimate for n and γ pulse shape;**
4. **optimal coefficients for used discrimination method are computed based on difference between eigenvectors q_n and q_γ computed in step 3.**

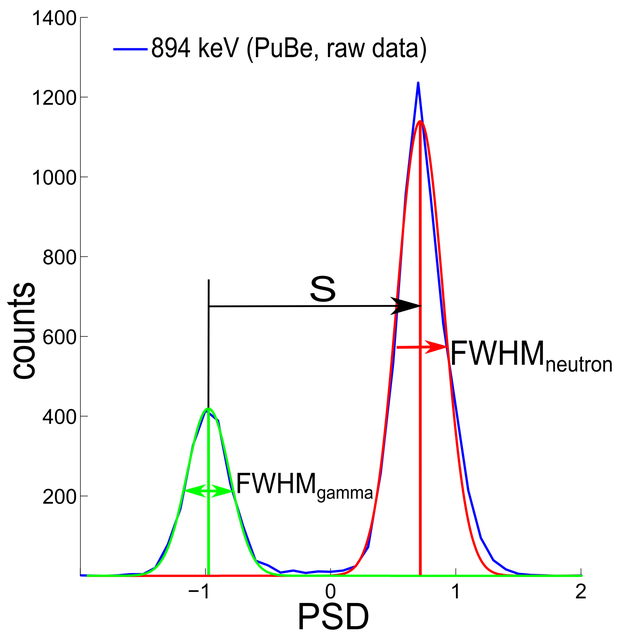
***Final data processing* is based on finite impulse response filtering and the pulse shape discrimination is calculated according to the formula:**

$$PSD = \sum_{i=1}^{M} y(i) \cdot [q_n(i) - q_\gamma(i)]$$

M - number of pulse sample ; y - input signal;



The $[q_n - q_\gamma]$ difference (arbitrary) calculated from Eigen vectors q_n and q_γ

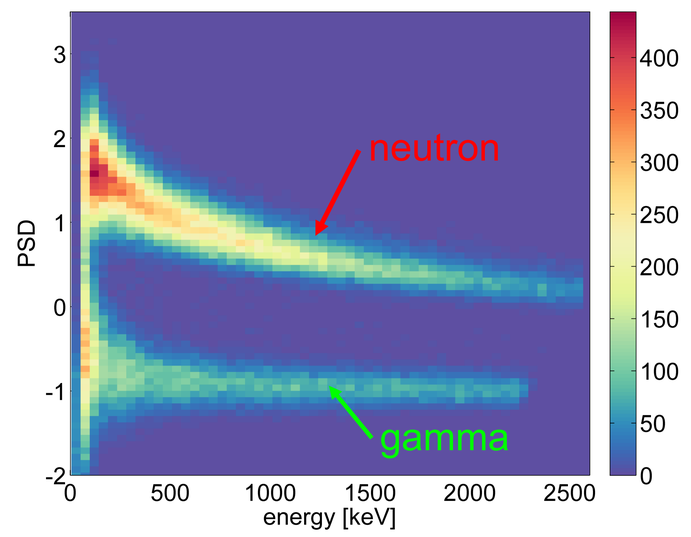


Definition of figure of merit (FOM)

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

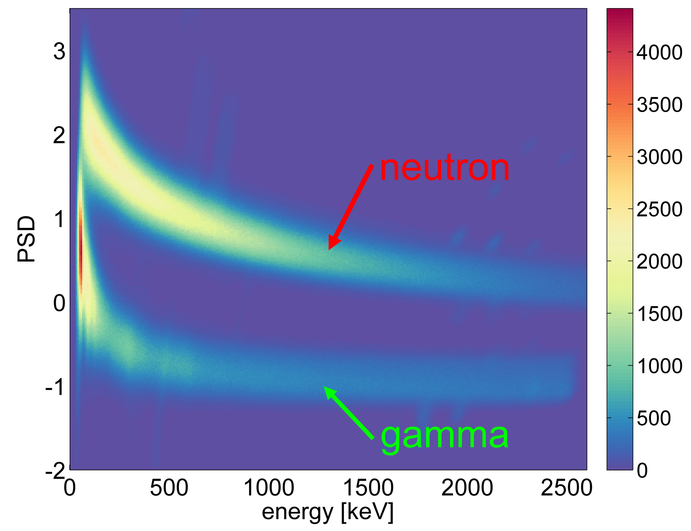
S – the distance between gamma-ray and neutron peaks
FWHM – the full width at half maximum

Pre-processing signal (PuBe, raw data)



Energy	56 keV	112 keV	224 keV	447 keV	897 keV
FOM	—	0.92	1.37	1.78	2.01

Signal processing (PuBe, list-mode data)



Energy	56 keV	112 keV	224 keV	447 keV	897 keV
FOM	0.64	1.04	1.46	1.62	1.62

CONCLUSIONS

- **Digital discrimination technique in organic scintillators are being developed as an alternative to traditional analogue methods .**
- **Method is based on pre-processing advanced pulse shape analysis and real time hardware implementation.**
- **Both raw and list-mode data are available.**
- **Filter coefficients can be further optimized for better discrimination, especially in the low energy range.**

Acknowledgement

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