# Scintillation event energy measurement via a pulse model based iterative deconvolution method

## Introduction

Solid scintillation detector is one of the most commonly used devices for high energy photon and particle detection, due to its high detection efficiency, fast operation speed, low cost,production capability and radiation hardness.For scintillation detection systems, event energy measurement is a crucial task.In nuclear medical imaging equipments like positron emission tomography (PET) and single photon emission computer tomography,energy information is used to reject Compton scatters and events not generated by the isotopic tracer.Moreover, energy information is even utilized in Anger logic algorithm to localize an event's position in PET systems equipped with position-sensitive photomultiplier tubes (PMTs).

Scintillation detectors are usually considered as a linear system, which will produce a current signal with amplitude proportional to the energy of the detected photon. Many methods are designed to calculate the energy of single events. Their accuracy is severely affected when two or more pulses are piled up. Such piled-up events are usually caused by high source activities, long pulse duration and etc. Pileup processing is important in the energy measurement .

In this work, we proposed an iterative energy measurement method, which can process pileup without detection and is independent of signal pulse shape. Our method applies MLEM algorithm to deconvoluting the digital scintillation pulses and then integrates the voltages of the resulting spike signals to obtain energy information. The real world experiments showed that the proposed method provided encouraging performance in ER and count rate recovery.For singles data, measured energy using our pulse model based iterative deconvolution(PMID) method is equal to that of the digital gate integrator (DGI). For pileups data, the ER achieved by PMID at 511 keV is 12.88%, which is better than that of digital DLC (DDLC). It is even close to the ER produced by DGI for singles data. Meanwhile, the counts collected by PMID are 5.75 times to those collected by DGI with a 2% energy window.

## Methods and Materials

1. Characteristics of the scintillation pulse.

$$p(t) = f(t) * \varphi(t) + n(t)$$

$$\varphi(t) = K\left(1 - \exp\left(-\frac{t}{\tau_1}\right)\right)\exp\left(-\frac{t}{\tau}\right)u(t) \qquad \tilde{n}(t) = C \cdot \bar{p}(t)$$

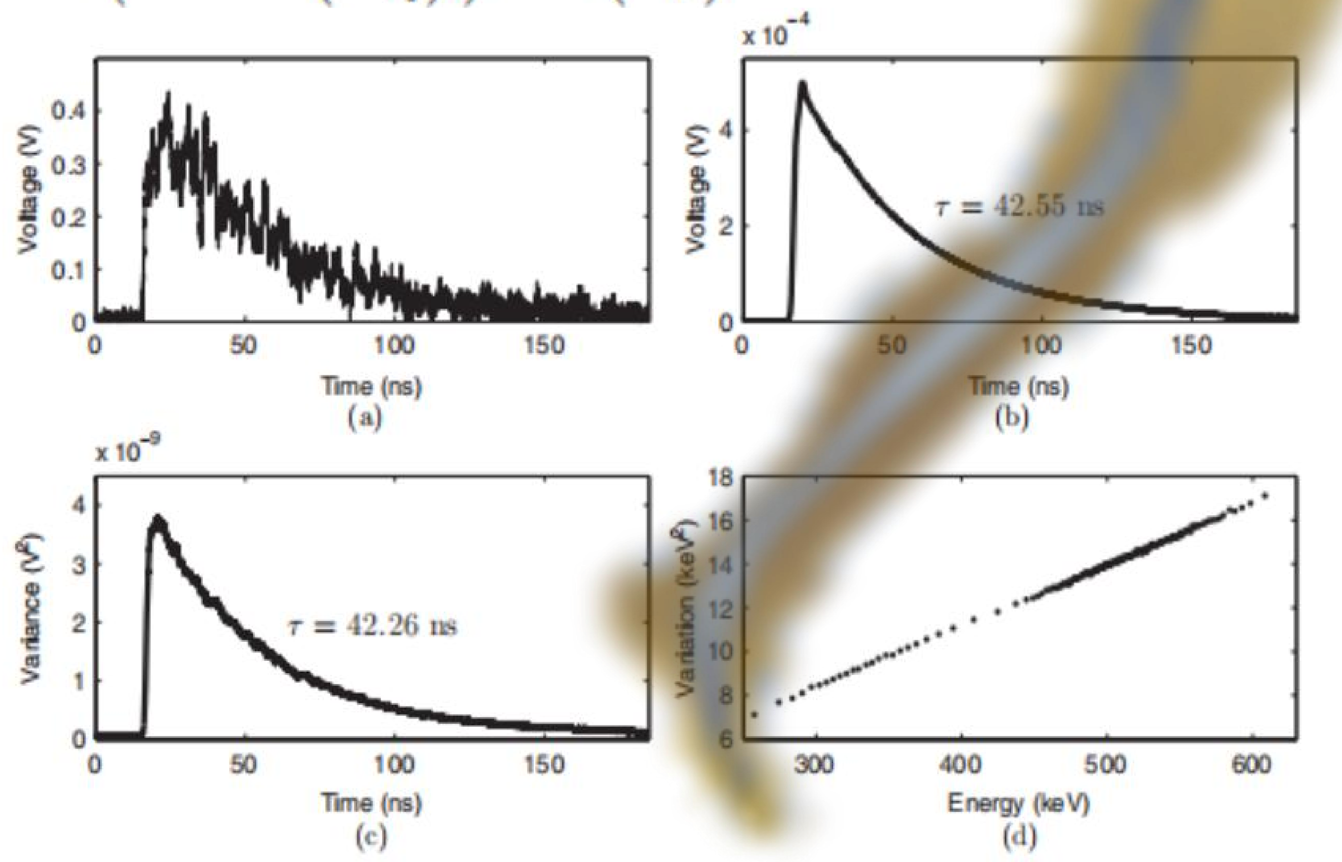
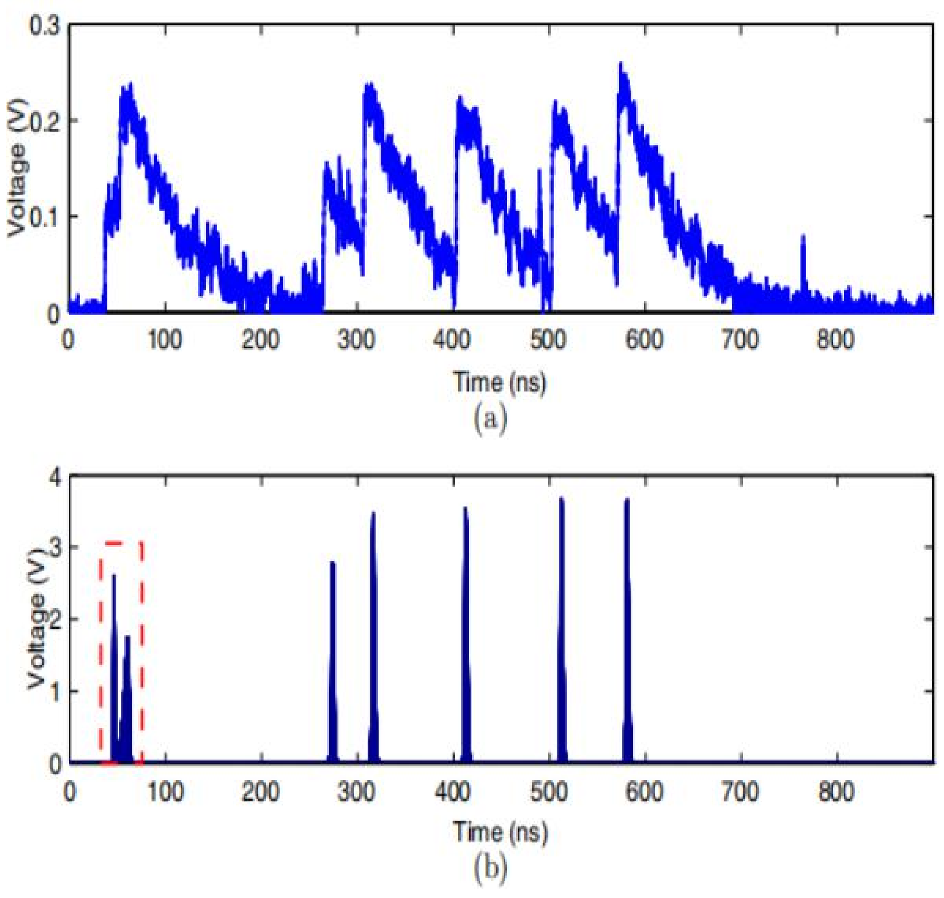



Figure 1. (a) A typical scintillation pulse sampled by a high speed oscilloscope. (b)Mean of the 5000 acquired pulses after normalization and alignment. The exponential fitting result shows the decay constant is 42.55 ns. (c) Variance of the 5000 acquired pulses after normalization and alignment. The exponential fitting result shows the decay constant is 42.26 ns. (d) Total varianceof pulses with different energy level.

2. Inversion of the Toeplitz matrix via MLEM iteration




$$\vec{p} = H\vec{f} + \vec{n}$$

$$f_j^k = \frac{f_j^{k-1}}{\sum_l h_{lj}} \sum_l h_{lj} \frac{p_l}{\sum_j h_{lj} f_j^{k-1}}$$

Figure 2.(a) The original scintillation pulses, containing pileups and singles.(b) The solution afterthe MLEM iteration in the PMID method.

## Experiment settings and results

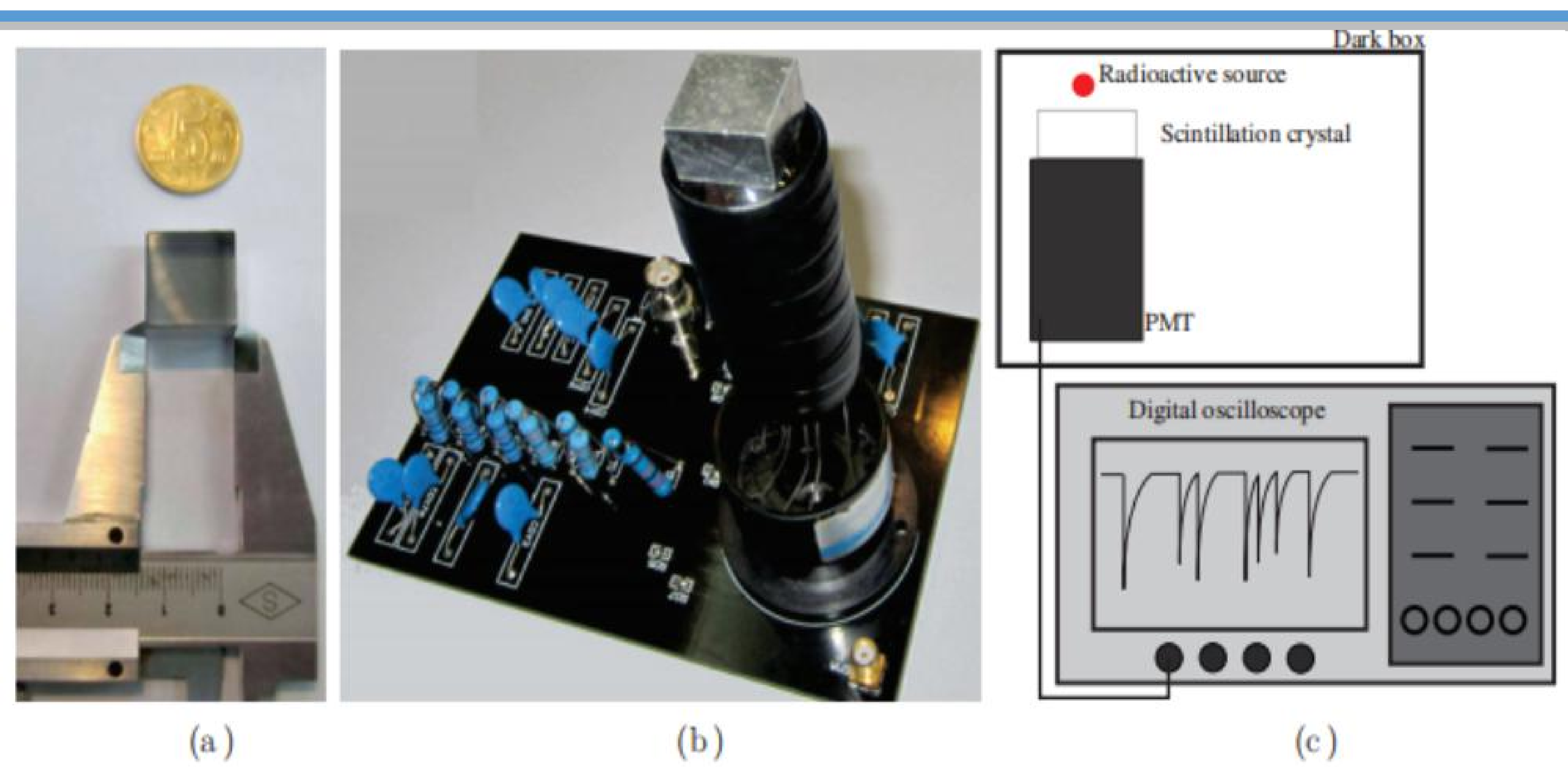



Figure 3. (a) The LYSO scintillation crystal is in the size of 16.5×16.5×10 mm3. (b) The detector consists of an LYSO crystal coupled to a Hamamatsu R9800 photomultiplier tube. (c) The pileups data experiment setup. Only one channel of oscilloscope was used.

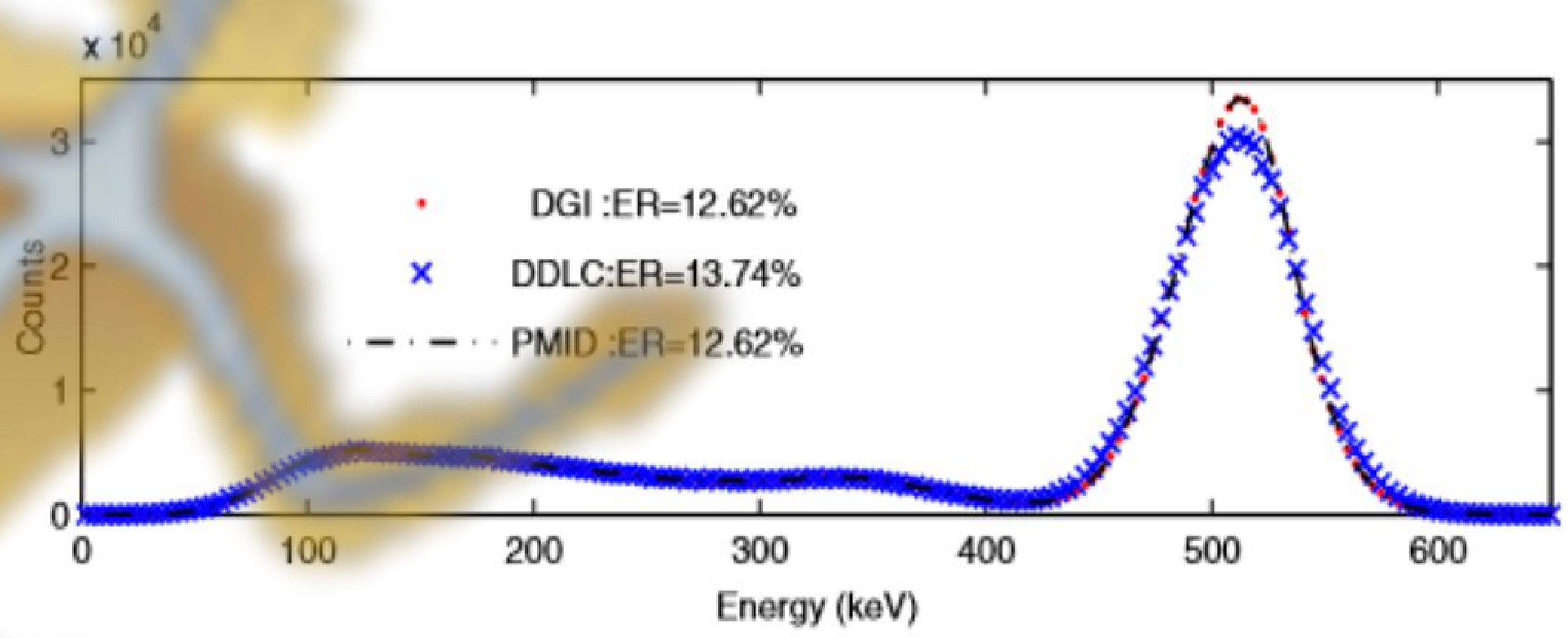



Figure 4. The energy histogram obtained from 900 000 single events. Results based on events acquired at channel 1 of the digital scope is displayed here.

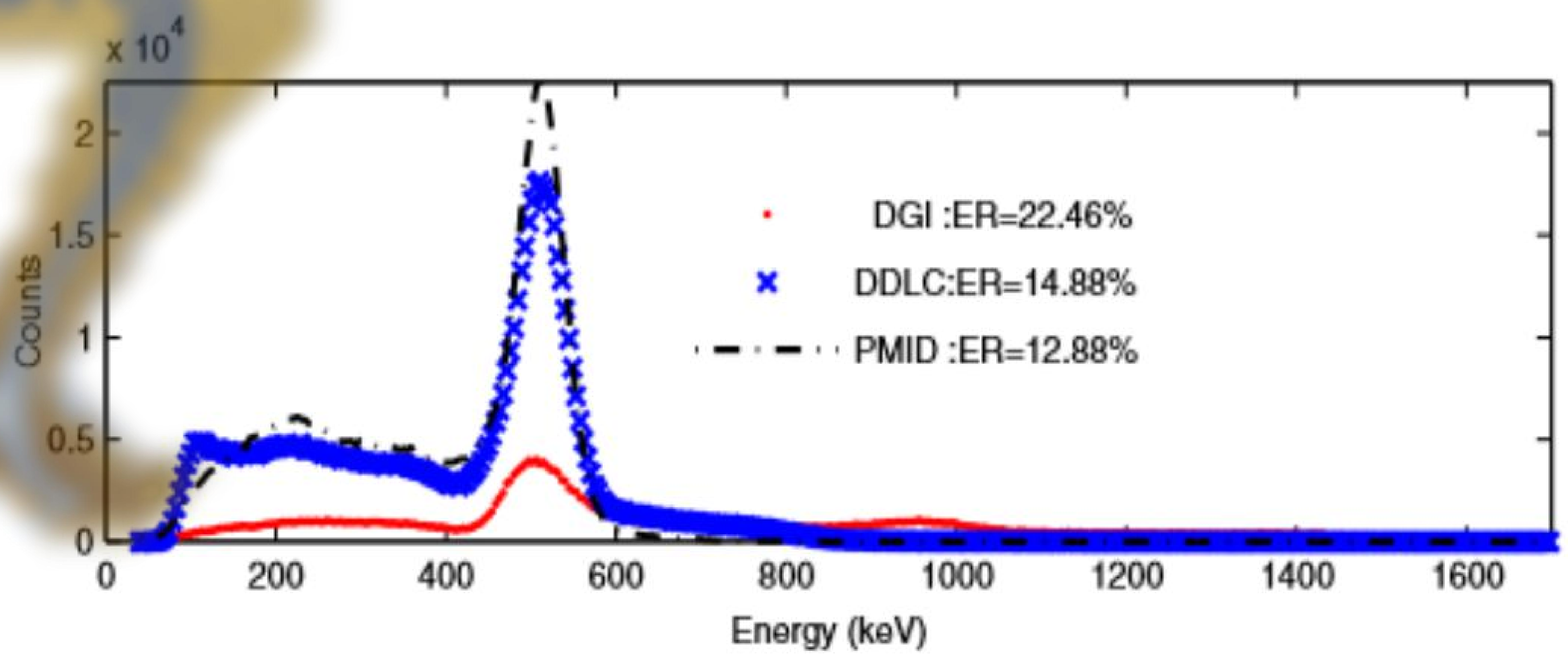



Figure 5. The energy histogram obtained from pileups data.

## Discussion and Conclusion

Based on the mean pulse of scintillation signals, we constructed a linear model for scintillation detection systems and thus transferred the measurement of event energy to a deconvolution problem. We proposed a pulse model based iterative deconvolution (PMID) method, which can process pileup events without detection and is adaptive fordifferent signal pulse shapes.The proposed method was compared with digital gated integrator (DGI) and digital delay-line clipping (DDLC) using real world experimental data. For singles data, the energy resolution (ER) produced by PMID matched that of DGI. For pileups, the PMID method outperformed both DGI and DDLC in ER and counts recovery. The encouraging results suggest that the PMID method has great potentials in applications like photon-counting systems and pulse height spectrometers, in which multiple-event pileups are common.

## Acknowledge

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