The Bessel Filter Simulation

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March 8, 2007

Abstract

We describe the simulation and pulse fitting result of the Bessel filter for the JParc E14 experiment. The performance of the filter is studied. Energy resolution is less than 2% , which is largely due to the asynchronous sampling of the shaped Gaussian pulse. Timing resolution is better than $0.5ns$ when energy deposited is above $10MeV$. And we can tell two pulses apart if they are more than $20ns$ away from each other and with energies above $40MeV$.

1 Introduction and Methods

The Bessel filter is a seven-pole filter consisting of 10 capacitors, 3 inductors and two resistors[1]. The electronics development group at the University of Chicago initially designed this shaper for the ATLAS tile calorimeter[1].

In our experiment, this passive filter can be placed right next to the PMT in the vacuum without dissipating heat. It makes the CsI PMT pulse into a quasi gaussian pulse with a fixed FWHM of $45ns$. This filtered output will be sampled by the $125MHz$ flash ADC. Then we can retrieve the information of the signal by fitting the sampling point with a gaussian function using the chisquare method. We use the fitted peak as the time of the hit, and the amplitude as the charge from PMT. One obvious advantage of this shaping-sampling scheme over the fast sampling of the original pulse is the less cost and smaller data size. In this article we study the uncertainty in the procedure.

The fitting results depend on where do we sample the pulse, or the sampling starting points. The global trigger determines this. And the global trigger is random relative to the timing of the pulse in each individual block of CsI. We call this asynchronous sampling. Different sampling starting point will give slightly different time and energy information. The effect of asynchronous sampling is also studied.

In a high rate experiment like E14, we need to tell two close pulses apart if they are in the same CsI block. The LC circuit of the shaper has a linear response. When there are two pulses coming in the same block closely, the output of the shaper will be two gaussian pulses. However the pulse is not a perfect gaussian. It is not always possible to tell if there are two or one pulses. We use the fitted time interval of the output as the figure of merit to tell two close pulses apart.

2 Simulation Setup

The input pulse from PMT is measured and approximated by a pulse wich has a rise time of 5ns and a falling edge composed of two exponential functions$(18.4 * e^{-t/23.6ns)} + e^{-t/(63.5ns)})$,which is shown as Figure 1.

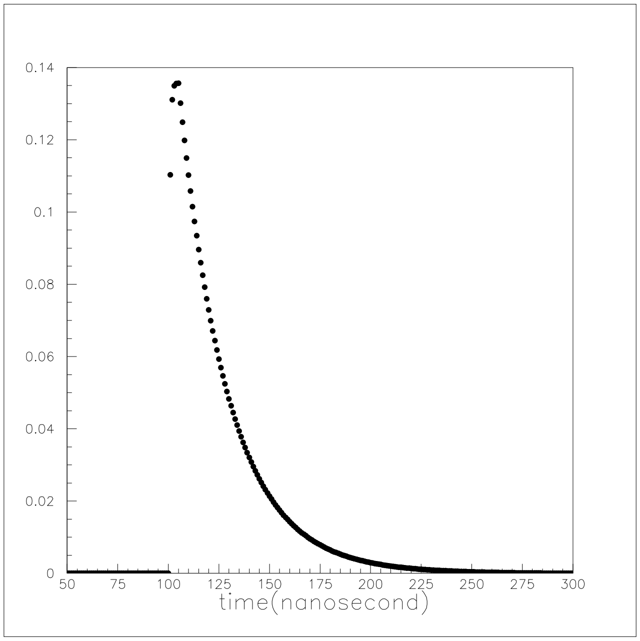

Figure 1: Approximated input pulse. y-axis is in arbitrary unit. This pulse is get from KTev measurement of the CsI pulse.

This pulse is fed to the bessel filter in the electronics simulation software, Accusim. Accusim has the same engine as SPICE. Figure 2 is one example of the output pulse.

Then the output at each point is smeared by the photo electron statistics at the PMT before fitting. The assumed photo electron yield here is $30 p.e./MeV$. From these smeared pulses we get the distribution of the fitted information and study the uncertainty.

3 Timing Resolution

Figure 4 shows the chisquare fitted peak time at different energy. The absolute number is arbitrary but the input pulses all come at the same time. We can see the resolution at $200MeV$ is $0.25ns$. This means we can set a $(-2\sigma, +2\sigma)$ veto window of 1.5ns at this energy if we assume the veto detector has the same time resolution.

The distribution for $200MeV$ pulse is flat. This is due to the fact that asynchronous sampling effect dominates over the fluctuation in each sampling at higher energy.

The time resolution is worse at lower energy hit especially when the energy gets below $5MeV$. See the trend of time resolution in Figure 5.

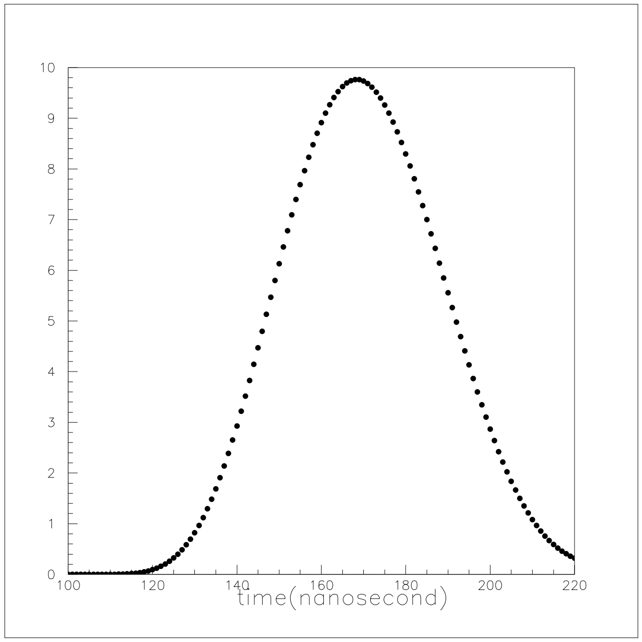

Figure 2: The Bessel filter shaped CsI pulse. The output of the filter is delayed by around $60ns$ from the input.

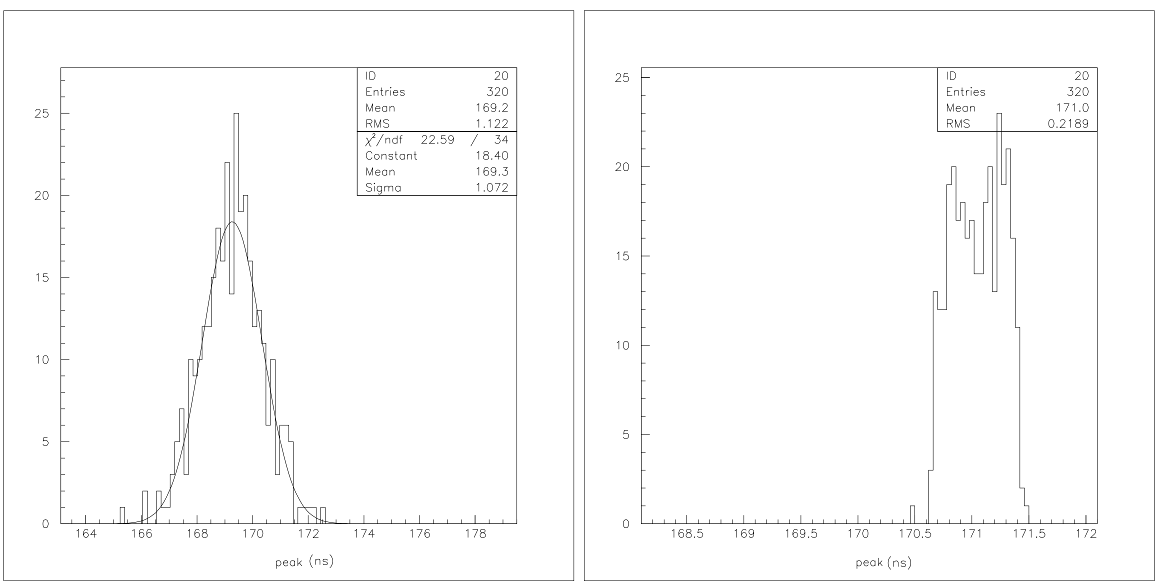

Figure 3: Distribution of peak time for $2MeV$ (left) and $200MeV$ (right) pulses

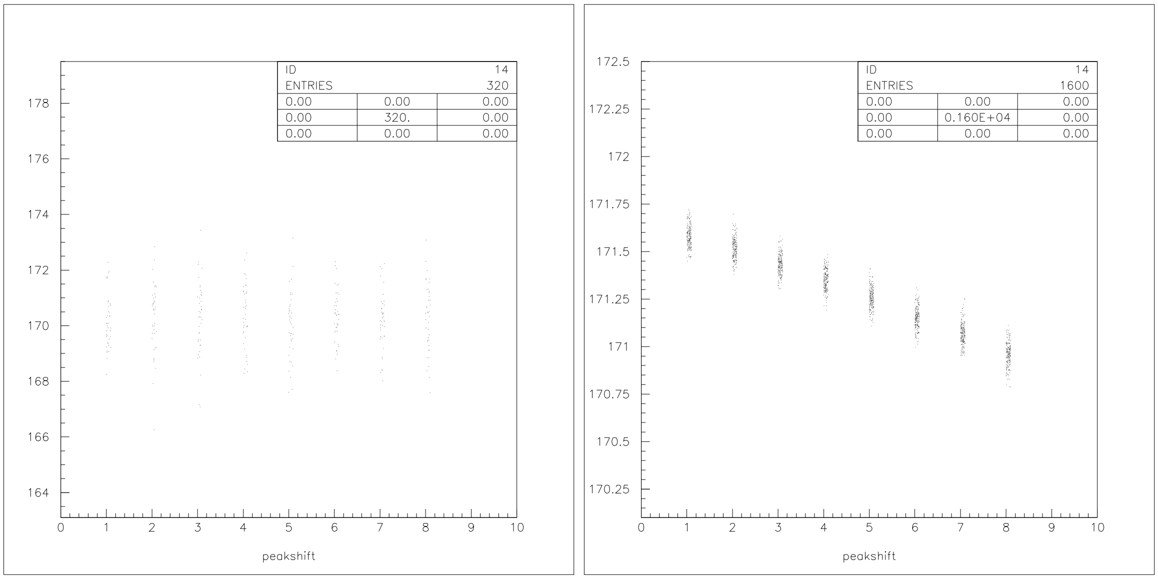

Figure 4: Asynchromous sampling effect. Fitted peak v.s. sampling shift for pulses with $2MeV$ (left) and $200MeV$ (right) pulses

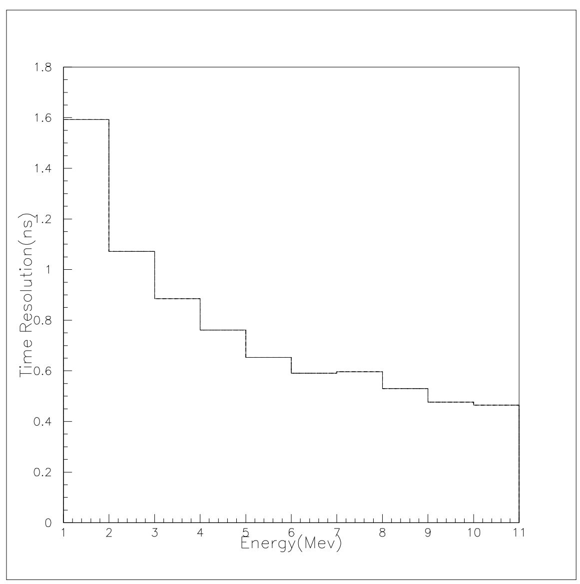

Figure 5: The Time resolution from fitting v.s. the energy of the hit in the low energy range.

4 Energy Resolution

In this section we look at the amplitude parameter in the same fitting as in the last section. We use the amplitude to measure the energy.

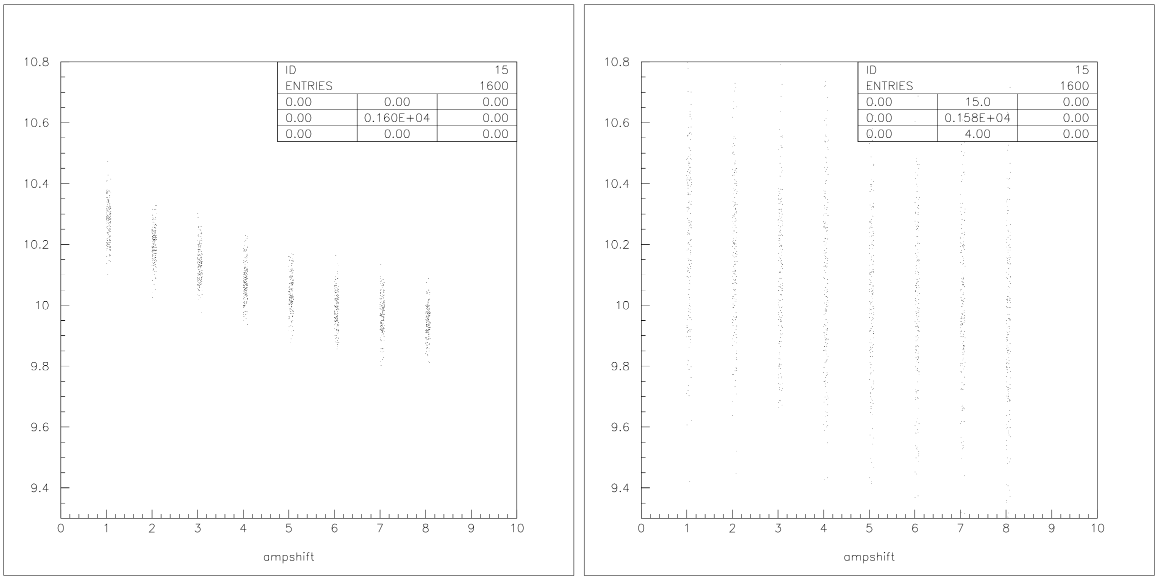

Figure 6: Fitted Amplitude v.s. the sampling starting point. The sampling starting point is swept through the $8ns$ separation by shifting $1ns$ each time. The hit of the one on the left has a energy of $200MeV$, and $10MeV$ for the one on the right

The energy resolution excluding the photo electron statistics is less than 2% from the calculation of the standard deviation. See Figure 6.

5 Two Pulse Separation

Figure 7 is an example of an two pulse simulation. The amplitude ratio of them in this study is 5 : 1. Two pulses are nicely separated and the linear response of the device is clearly seen.

We fix the width and float all the other four parameters of the two gaussian functios to fit the output, and plot fitted time interval against the input pulse time interval in Figure 8.

Even if there is only one pulse, we still can fit the output by two gaussians. The time interval get from this fitting is close to 0. To be able tell two pulses from one pulse, the fitted time interval has to be different from 0. By this judgement, we can say high energy pulses($200MeV : 40MeV$) are seperatable if they are $20ns$ apart. For low energy pulses($10MeV : 2MeV$), we can not tell them apart if they are less than $40ns$ apart.

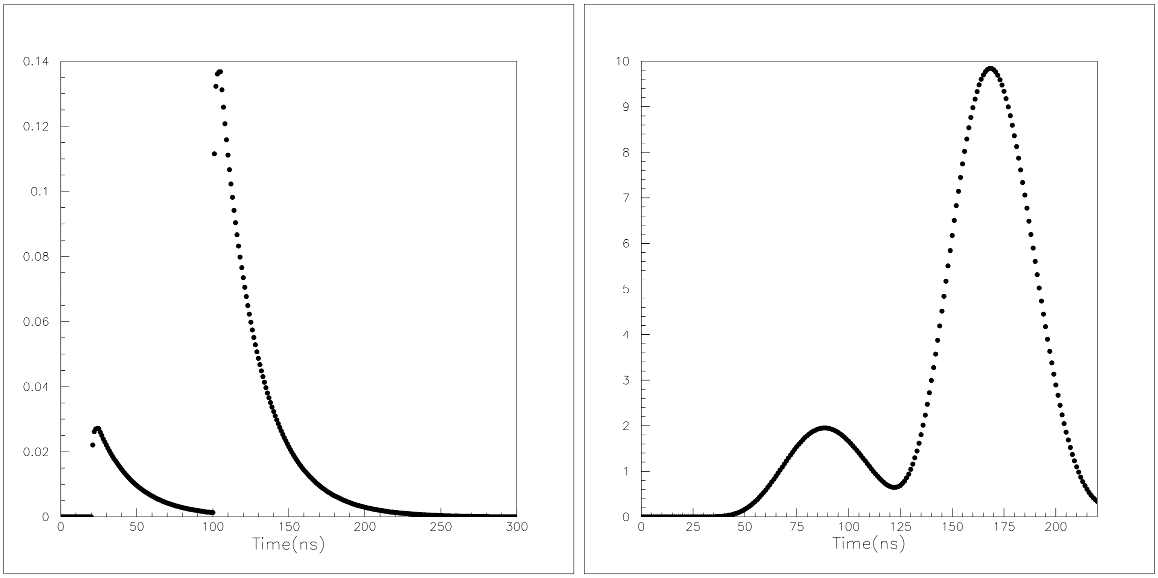

Figure 7: Two pulse simulation example. The input is on the left and the output is on the right. There is a $80ns$ separation between the inputs in this example.

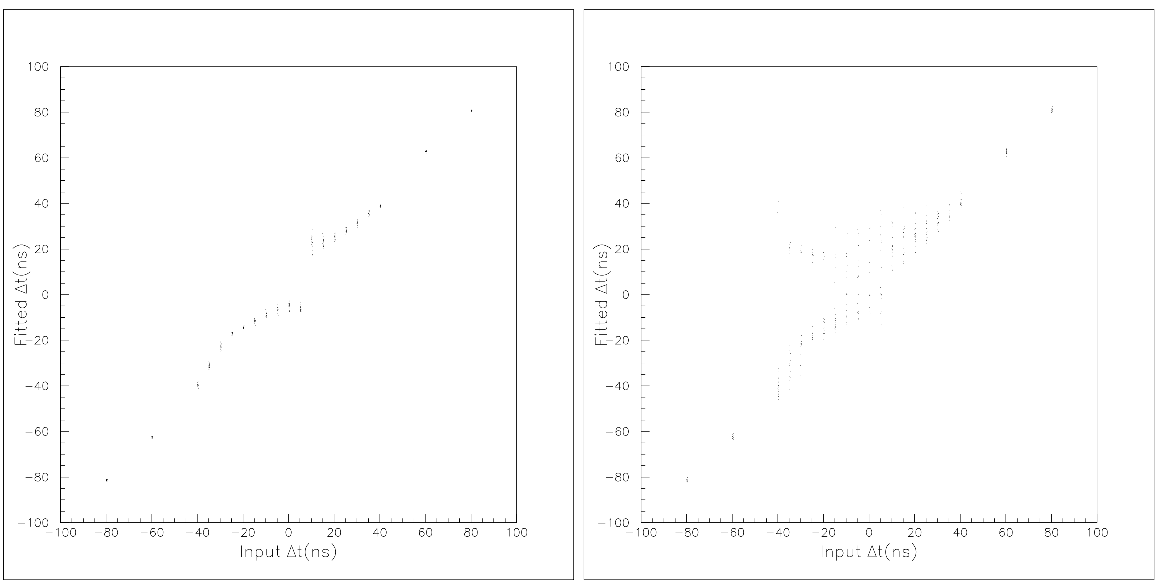

Figure 8: Fitted time interval for different input pulse separation. On the left the energies of big pulse:small pulse is $200MeV : 40MeV$. On the right the energies of big pulse:small pulse is $10MeV : 2MeV$.

6 Comments

The electronics components used in the electronics simulation have exact numbers. In reality there is a variation of 1-2% for the component values of different channels. This effect can be calibrated, and will be modest[1].

If there is pulse shape variation, One can use the pulse width to make correction for peak timing. Before correction, the measured time(peak timing) shift is 1.5ns for 20% variation in the fall time constant.

References

[1] K. Anderson, et al., Nucl. Instr. and Meth. A 551(2005) 469.