An improvement of performance in MTPC with waveform deconvolution technique

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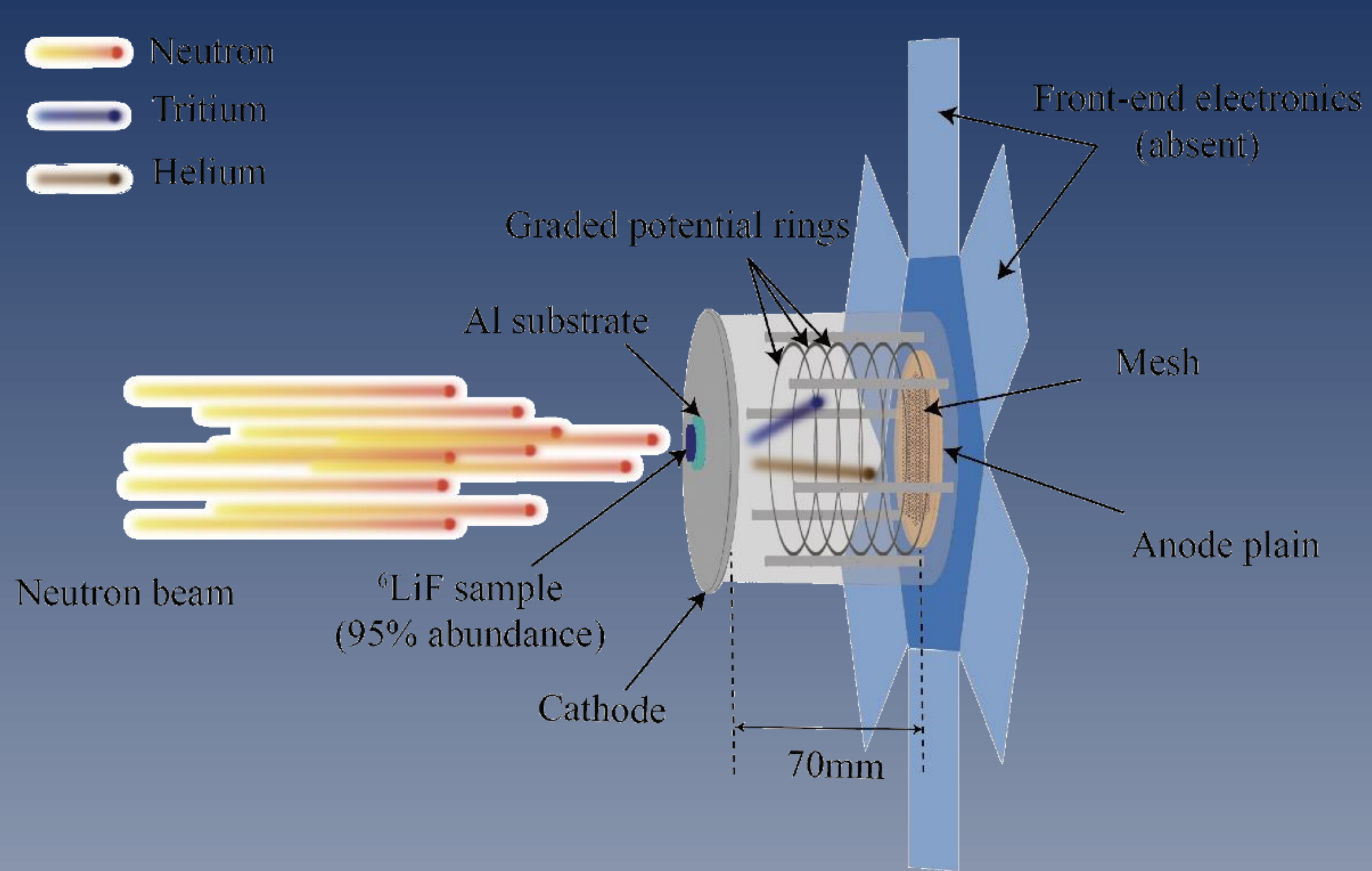
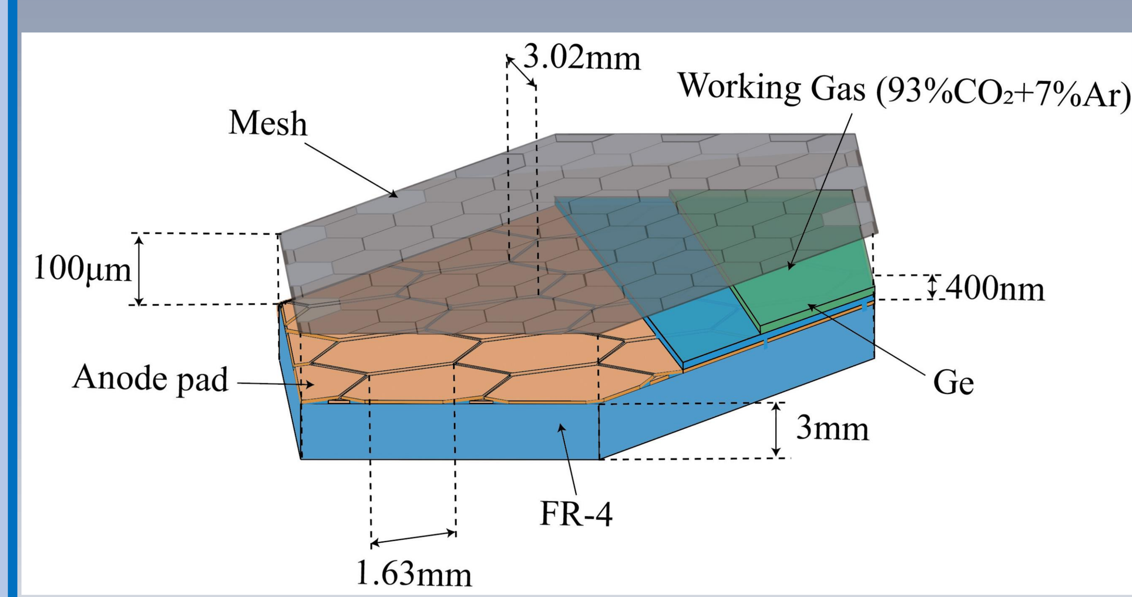
Abstract:

The multi-purpose time projection chamber (MTPC), which is designed for measuring neutron nuclear data of varied field, has been fabricated at China Spallation Neutron Source (CSNS). Its drift region is flexible, ranging from 70mm to 140mm. Ionization electrons are avalanched and collected via a resistive Micromegas detector with 1521 readout channels. As timing precision plays an important role in particle 3D track reconstruction as well as in time-of-flight method (for measuring neutron energy), we have developed deconvolution technique combined with waveform fitting for offline waveform analysis. We have modeled the anode signals which contains energy and space information of detected particles. Start time of signals are obtained by utilizing Fast Fourier Transformation (FFT) deconvolution technique. Data from ^{6}Li(n,t)α experiment is used to study the detector's enhanced performance. A simulation of MTPC signals and noises is applied to estimate the timing resolution and timing bias of our software. The result shows that the timing precision of analysis result is significantly improved.

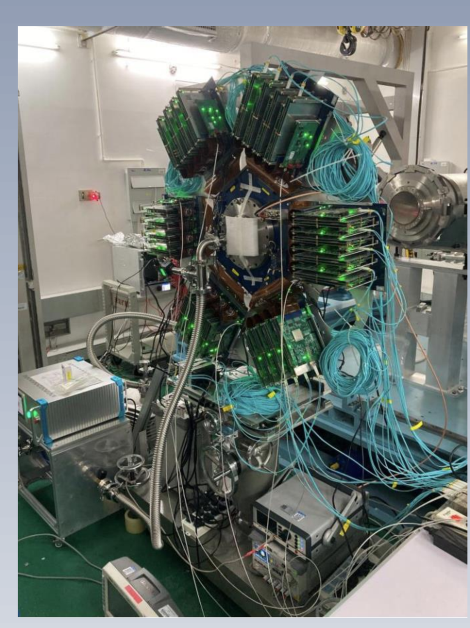
Introduction:



MTPC structure and ^{6}Li(n,t)α experiment



Resistive Micromegas detector



MTPC electronics and DAQ

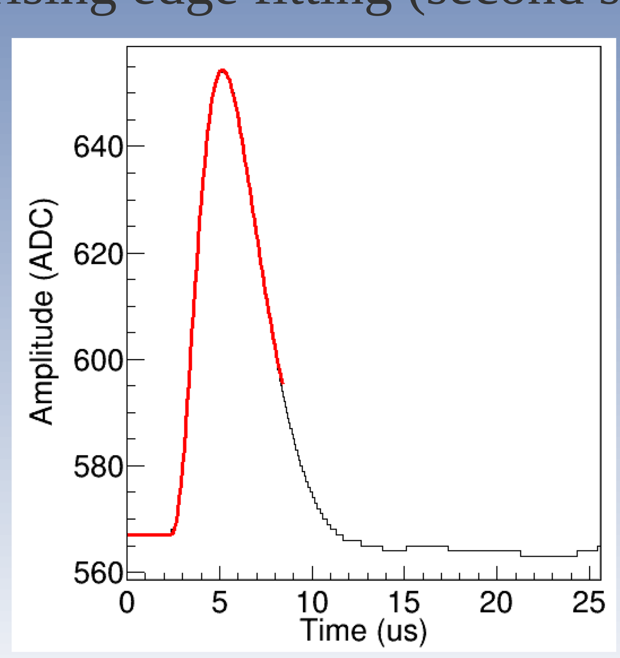
MTPC is designed for measuring neutron induced charged particle emission reaction in CSNS. Signals of MTPC are readout by resistive Micromegas detectors in anode. An experiment measuring ^{6}Li(n,t)α reaction has been conducted.

Waveform fitting:

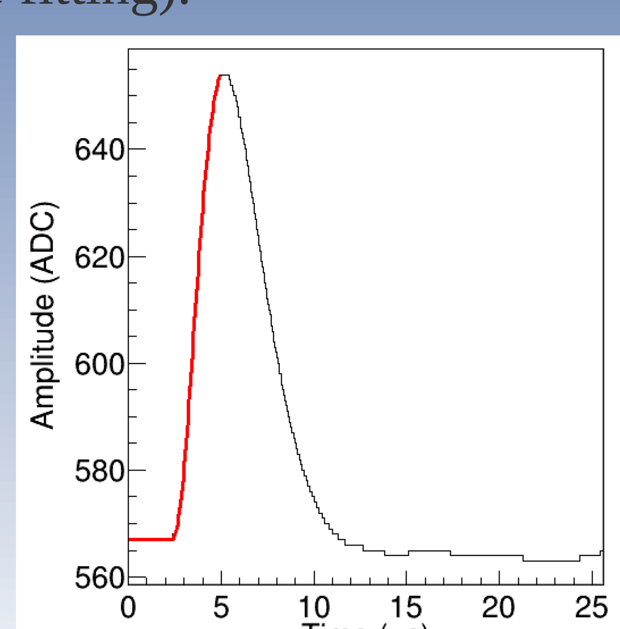
Measured signals are fitted by theoretical expression. The electronics response is given by:

$$h(t) = \alpha \cdot \left(\beta^3 e^{-\frac{t}{\tau_r}} - \beta^3 e^{-\frac{t}{\tau_1}} - \beta^2 t e^{-\frac{t}{\tau_1}} - \frac{\beta}{2} t^2 e^{-\frac{t}{\tau_1}}\right)$$

And signals are fitted via two steps: a full peak fitting (first stage fitting) and a rising edge fitting (second stage fitting).



First stage fitting



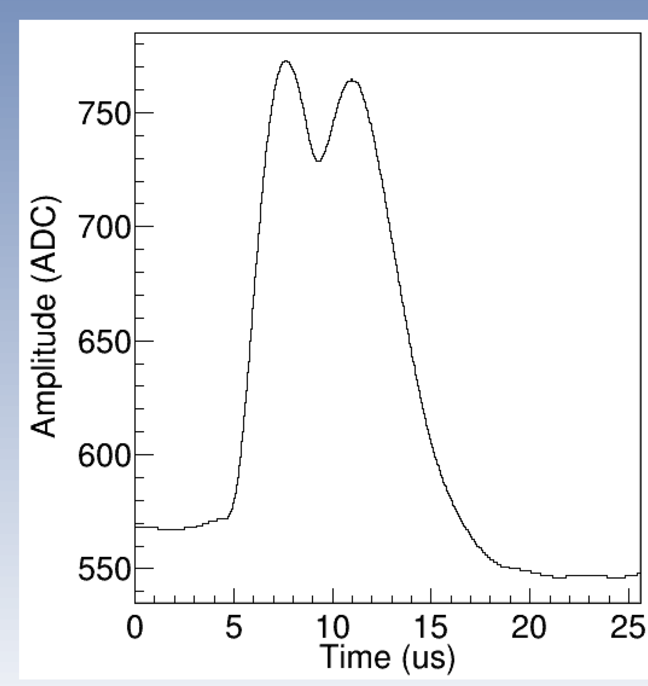
Second stage fitting

Waveform deconvolution:

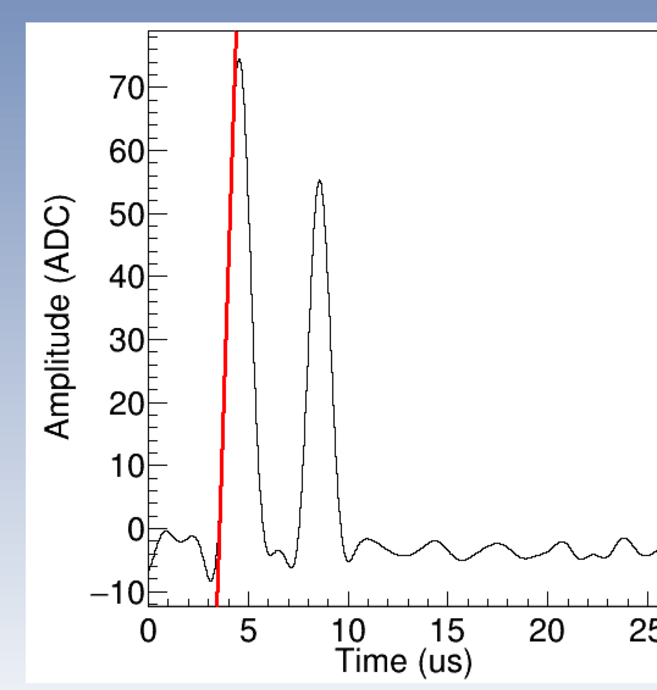
To improve the timing resolution and avoid timing bias, induced current is reconstructed by adding filter in frequency domain to signals:

$$S(\omega) = \frac{M(\omega)}{R(\omega)} \times F(\omega)$$

Timing is done by fitting rising edge. Piled-up signals can be solved.



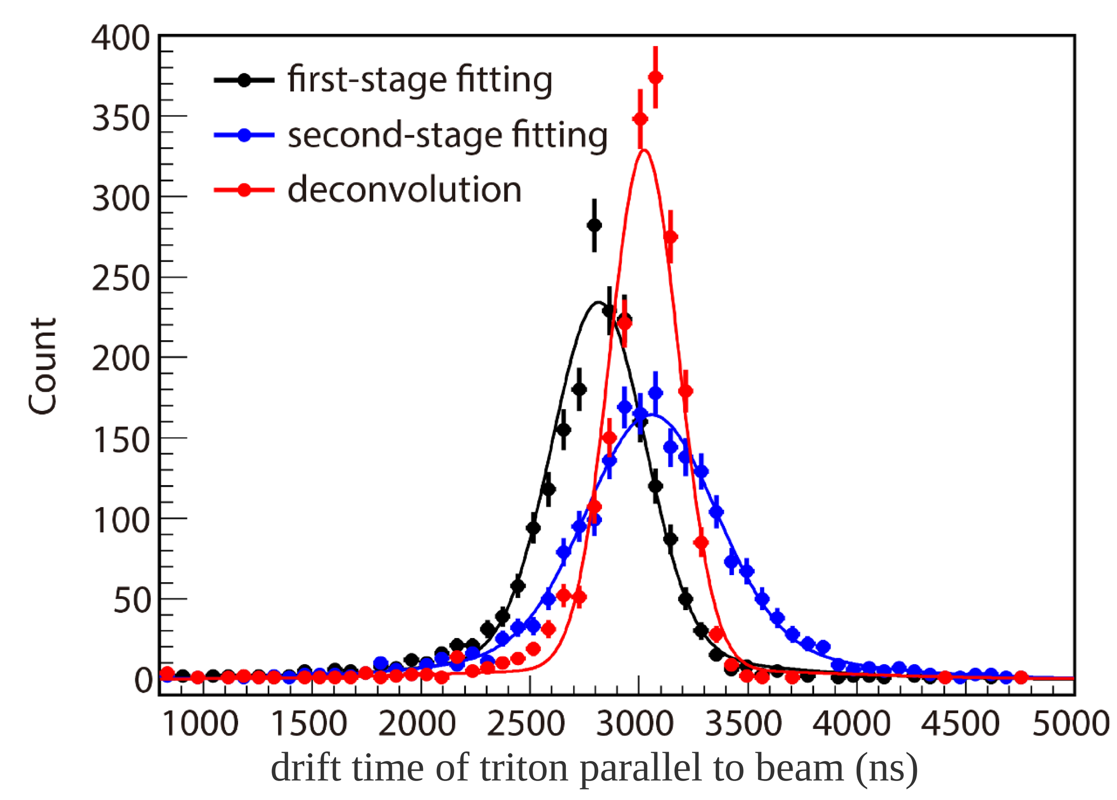
Measured signal

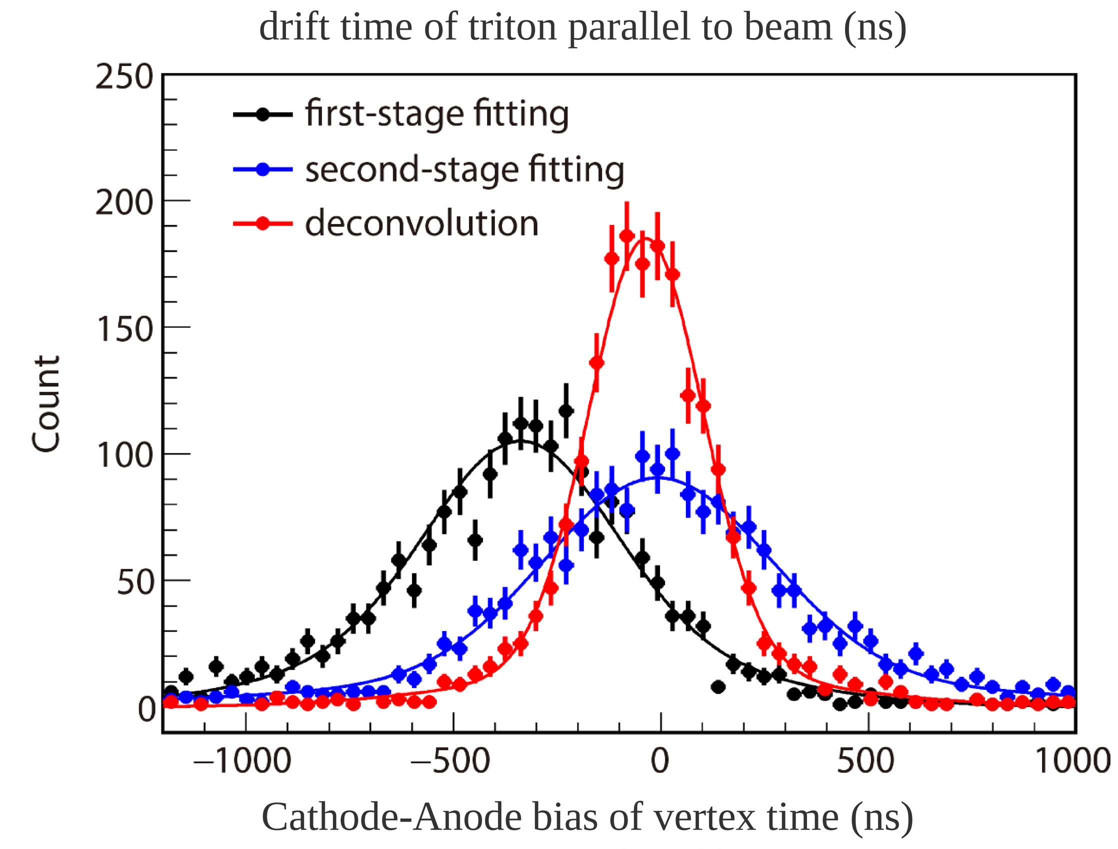


Reconstructed signal

Results:

Timing resolution and timing bias are significantly improved with waveform deconvolution technique. The result is calibrated by the simulation of Garfield++.





Timing properties of different method

Reference:

[1] W. Tang, et al. Data Unfolding with Wiener-SVD Method[J]. Journal of Instrumentation, 2017
[2] W. Jia, Y. Lv, et al. Gap uniformity study of a resistive Micromegas for the Multi-purpose Time Projection Chamber (MTPC) at Back-n white neutron source[J]. Nucl. Instrum. Meth. A, 2022
[3] Y. Li, et al. Performance study of the Multi-purpose Time Projection Chamber (MTPC) using a four-component alpha source[J]. Nucl. Instrum. Meth. A, 2024