Development of a 256-channel Time-of-flight Electronics System For Neutron Beam Profiling

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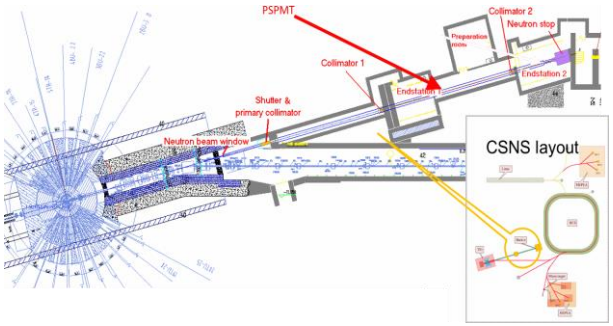
MODERN PHYSICS DEPARTMENT

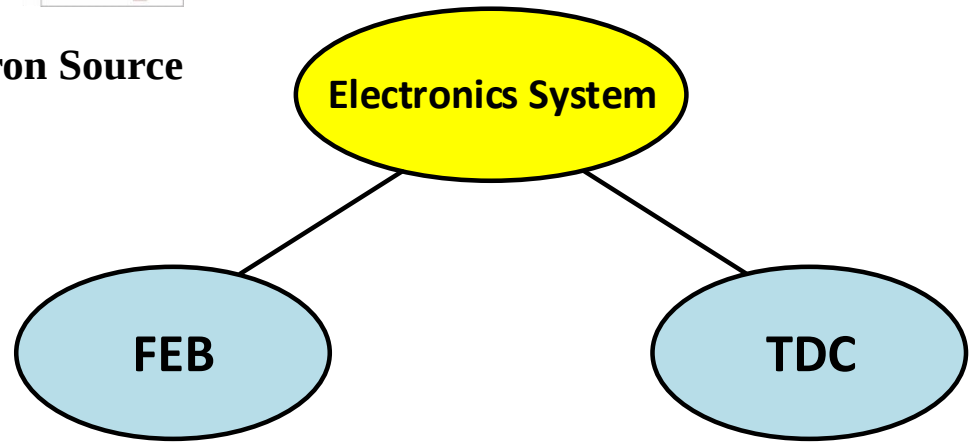
Brief Introduction

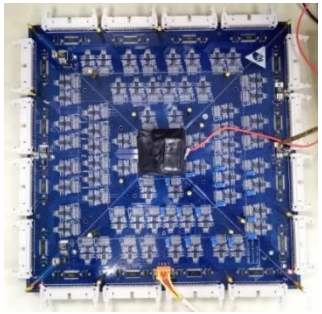


China Spallation Neutron Source

Energy resolution <1% @1MeV

$\Longrightarrow$ Time precision < 28ns

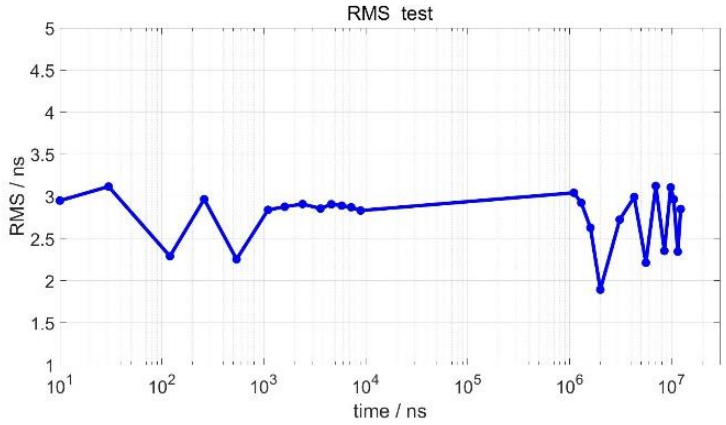




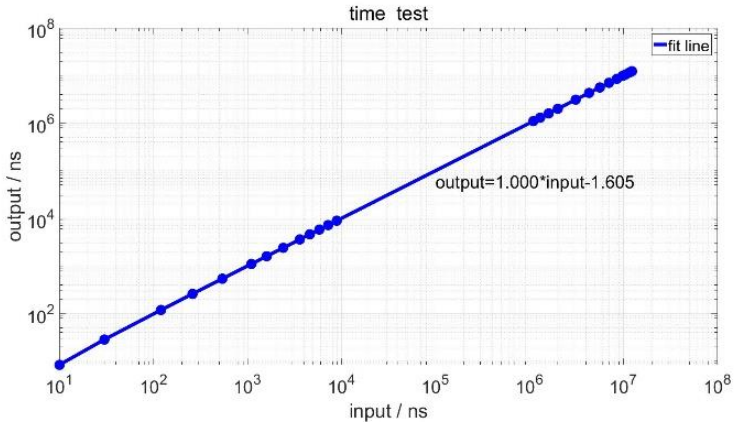
Front-end board

Time-to-digital converter

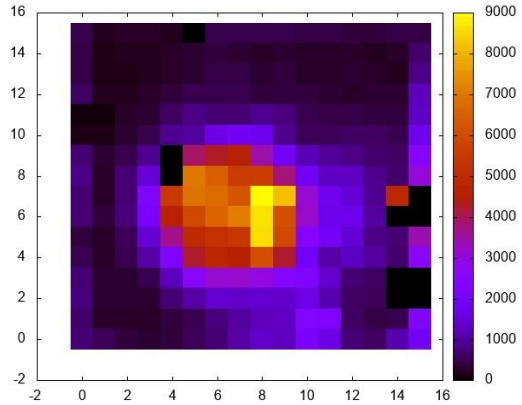
Test Result



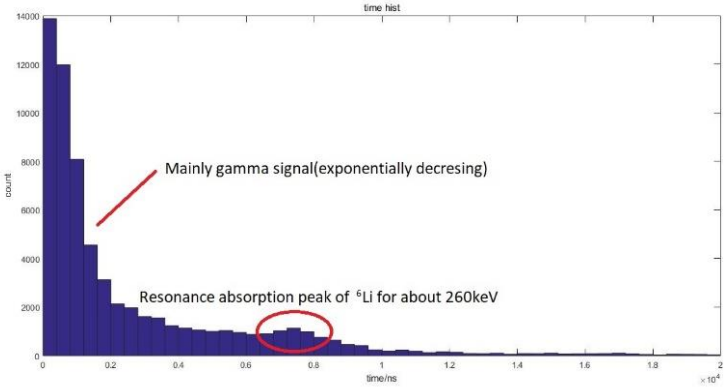
Time precision < 3.5ns



Dynamic range : 0-10ms



30mm spot

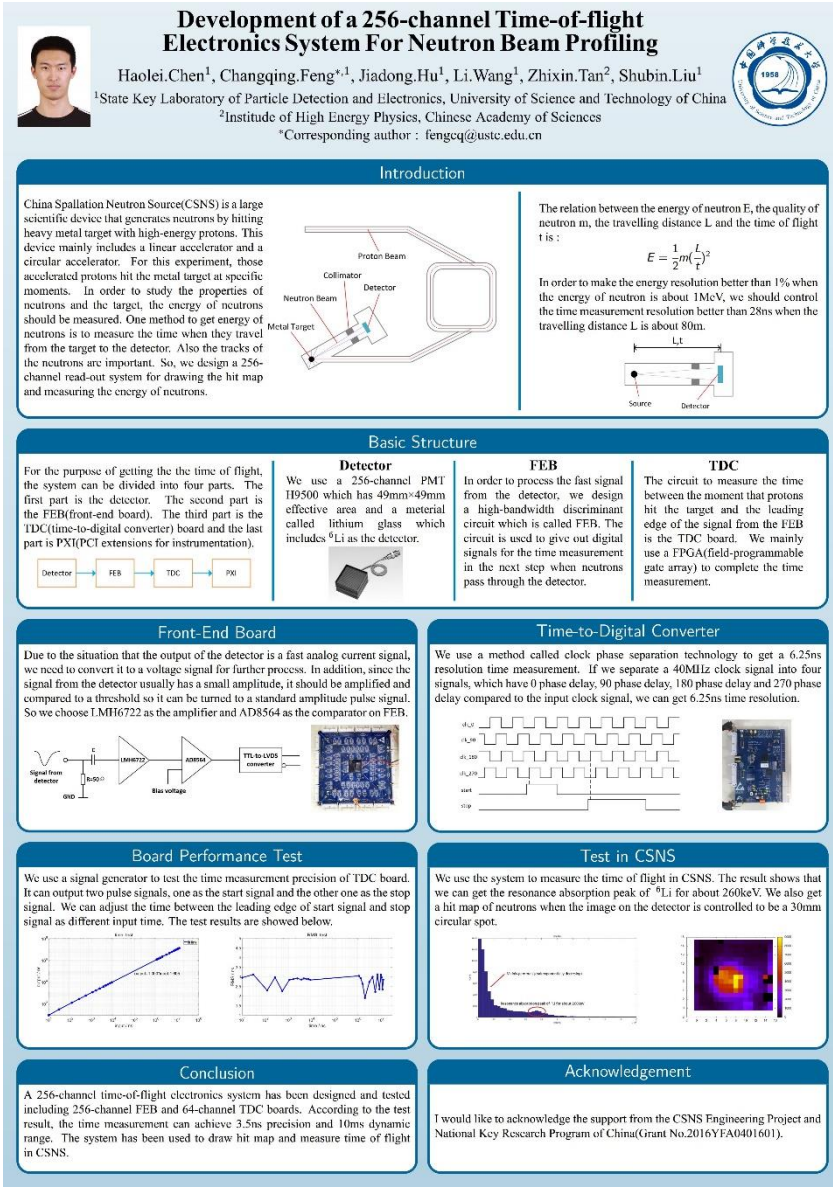


Time spectrum

Poster

Overview of the experiment

Detail of FEB and TDC



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Introduction

China Spallation Neutron Source(CSNS) is a large scientific device that generates neutrons by hitting heavy metal target with high-energy protons. This device mainly includes a linear accelerator and a circular accelerator. For this experiment, those accelerated protons hit the metal target at specific moments. In order to study the properties of neutrons and the target, the energy of neutrons should be measured. One method to get energy of neutrons is to measure the time when they travel from the target to the detector. Also the tracks of the neutrons are important. So, we design a 256-channel read-out system for drawing the hit map and measuring the energy of neutrons.

Proton Beam, Collimator, Detector, Neutron Beam, Metal Target

The relation between the energy of neutron E, the quality of neutron m, the travelling distance L and the time of flight t is :

$$E = \frac{1}{2}m(\frac{L}{t})^2$$

In order to make the energy resolution better than 1% when the energy of neutron is about 1MeV, we should control the time measurement resolution better than 28ns when the travelling distance L is about 80m.

L,t, Source, Detector

Basic Structure

For the purpose of getting the the time of flight, the system can be divided into four parts. The first part is the detector. The second part is the FEB(front-end board). The third part is the TDC(time-to-digital converter) board and the last part is PXI(PCI extensions for instrumentation).

Detector → FEB → TDC → PXI

Detector

We use a 256-channel PMT H9500 which has 49mm×49mm effective area and a meterial called lithium glass which includes ^{6}Li as the detector.

FEB

In order to process the fast signal from the detector, we design a high-bandwidth discriminant circuit which is called FEB. The circuit is used to give out digital signals for the time measurement in the next step when neutrons pass through the detector.

TDC

The circuit to measure the time between the moment that protons hit the target and the leading edge of the signal from the FEB is the TDC board. We mainly use a FPGA(field-programmable gate array) to complete the time measurement.

Front-End Board

Due to the situation that the output of the detector is a fast analog current signal, we need to convert it to a voltage signal for further process. In addition, since the signal from the detector usually has a small amplitude, it should be amplified and compared to a threshold so it can be turned to a standard amplitude pulse signal. So we choose LMH6722 as the amplifier and AD8564 as the comparator on FEB.

Signal from detector, LMH6722, AD8564, TTL-to-LVDS converter, Bias voltage, GND

Time-to-Digital Converter

We use a method called clock phase separation technology to get a 6.25ns resolution time measurement. If we separate a 40MHz clock signal into four signals, which have 0 phase delay, 90 phase delay, 180 phase delay and 270 phase delay compared to the input clock signal, we can get 6.25ns time resolution.

clk_0, clk_90, clk_180, clk_270, start, stop

Board Performance Test

We use a signal generator to test the time measurement precision of TDC board. It can output two pulse signals, one as the start signal and the other one as the stop signal. We can adjust the time between the leading edge of start signal and stop signal as different input time. The test results are showed below.

Test in CSNS

We use the system to measure the time of flight in CSNS. The result shows that we can get the resonance absorption peak of ^{6}Li for about 260keV. We also get a hit map of neutrons when the image on the detector is controlled to be a 30mm circular spot.

Conclusion

A 256-channel time-of-flight electronics system has been designed and tested including 256-channel FEB and 64-channel TDC boards. According to the test result, the time measurement can achieve 3.5ns precision and 10ms dynamic range. The system has been used to draw hit map and measure time of flight in CSNS.

Acknowledgement

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Measurement system structure

Test result

Poster session 2

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