

COINCIDENCE MODULE FOR SPECTRAL- AND TIME-CORRELATED MULTI-PARTICLE DETECTION WITH FOUR PIXEL DETECTORS TIMEPIX

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Abstract

An integrated coincidence system for multi-particle detection has been built to validate the coincidence detection and synchronize the readout of several pixel detectors. A system of two and also four detectors was built for measurements of angular correlations of rare fragments in ternary and quaternary fission which are detected in coincidence with the binary fragments. The pixel detectors are operated with the readout interface FITPix which provide power, control and DAQ. FITPix provides in addition signal communication ports and extended operability for the pixel detectors and the Timepix device (such as widely adjustable internal clock, external clock, clock gating, etc.), enables advanced triggering and high frame rate (up to 40 fps). The whole measurement can be triggered by a single event. An integrated analog spectrometer based on the USB 1.1.2 readout interface equipped with devoted module is used to provide a trigger from the common sensor signal of one pixel detector. The coincidence unit then monitors, validates and synchronizes the readout of the digital data. All operation and DAQ are managed by the modular software package Pixelman. The whole system can operate in vacuum and can be configured and extended into more detectors for a wide range of particle coincidence physics experiments.

Introduction

Semiconductor pixel detectors of the Medipix type [1] show great potential for precise studies of fission [2]. These devices provide more complete spectrometric information on different types of particles such as the position of single particles with μm resolution. The Timepix device [3] allows registering in addition the deposited energy and the particle time of interaction per pixel. The physics aim of this program is the detection of rare fission fragments in coincidence with the binary fragments and the measurement of their angular spatial distributions [4].

The pixel detector Timepix

The Timepix detector [3] is composed of a semiconductor integrated chip and a sensor. The chip is divided into a matrix of 65.536 pixels (array of 256×256 pixels of $55 \mu\text{m}$ pitch). Sensors can be provided from different semiconductor material (Si, GaAs, CdTe) and also thickness of (300, 700, 1000 μm). The principle of detection of ionizing radiation is based on the PN junction, which is connected in reverse bias. Under the sensor is placed the ASIC integrated circuit by bump-bonds. The ASIC contains for each pixel an electronic circuit

composed of analog and digital parts. The analog section contains the amplifier and comparator. The comparator threshold can be set by a DAC in each pixel individually. When the energy deposited in the pixel is greater than the preset threshold value, the comparator generates a pulse in the digital part. The digital section includes a processing unit for pulse synchronization with unit clock signal and a 14-bit counter. The digital unit can operate in one of three modes. The first mode is the time over threshold (TOT) mode which measures the energy deposited in the pixel. The second mode is the time of arrival (Timepix) mode which measures the particle time of interaction (arrival time). The third mode is the counting (or Medipix) mode in which the counter counts the number of particles crossing the threshold in the given pixel within a period of time. The counter can also work as a shift register. This mode is used when reading data from the detector. In each column there are shift registers connected to a 3584-bit shift register which is connected to a Fast Shift Register (FSR). FSR is part of the digital interface used to configure the detector, data reading and control. Reading of the data is possible via a serial interface that uses the LVDS voltage standard. The second option is to use 32-bit gate, which uses the CMOS standard. The maximum reading frequency for the whole chipboard is 100MHz.

The FITPix readout interface

FITPix [5] is a new control and DAQ interface for the Medipix type pixel detectors. The interface is based on a FPGA which is located in the digital system. The firmware can be divided into two parts. The first part is responsible for communicating with the PC. The second part devotes to the full operation of pixel detector. The device and the illustration of the architecture are shown in Fig. 1. Currently there are several types of communication standards supported (USB 2.0, Spacewire, RS-232). FITPix reaches up to 90 frames per second which corresponds to a data flow of 90 Mbit/s. The interface can be synchronized via an external port with other devices. This allows coincidence measurements for multi-particle detection.

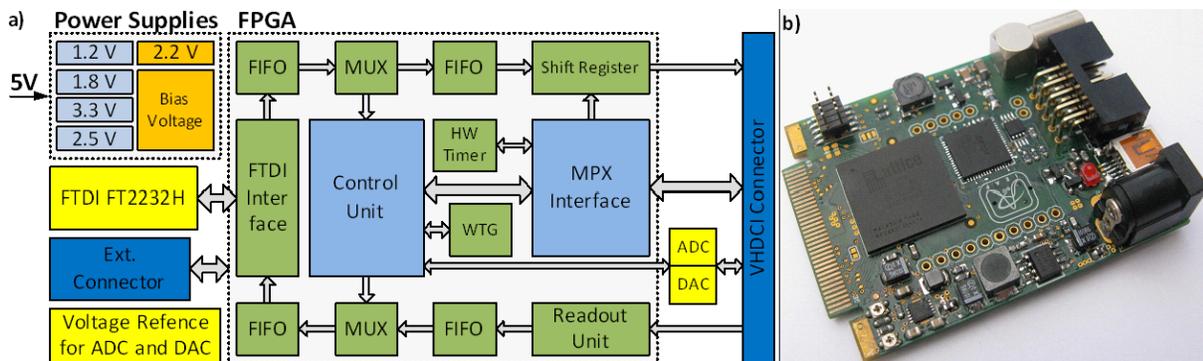


Figure 1: Architecture of FITPix (a) and the assembled interface (b) with dimensions 45 mm × 60 mm. Power consumption is 2.5 W. The interface can operate in vacuum. Figure taken from Ref. [5]

Coincidence module: multi-detector DAQ validation and synchronization

In order to monitor and validate the operation as well as synchronize the data readout of several detectors run in coincidence, an integrated synchronization master unit (coincidence module) was constructed. The layout of the module architecture is shown in Fig. 2.

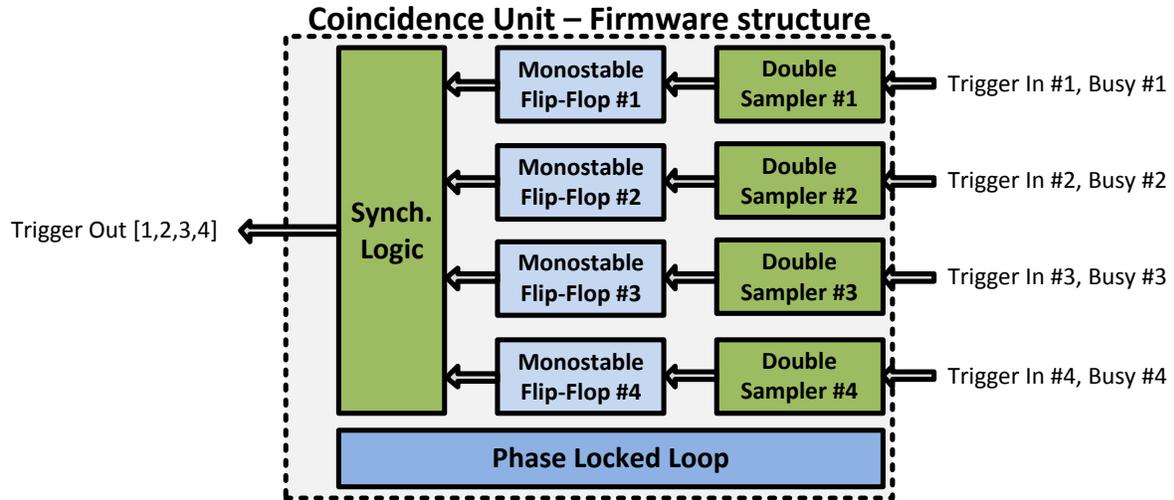


Figure 2: Architecture layout and firmware structure of the coincidence module.

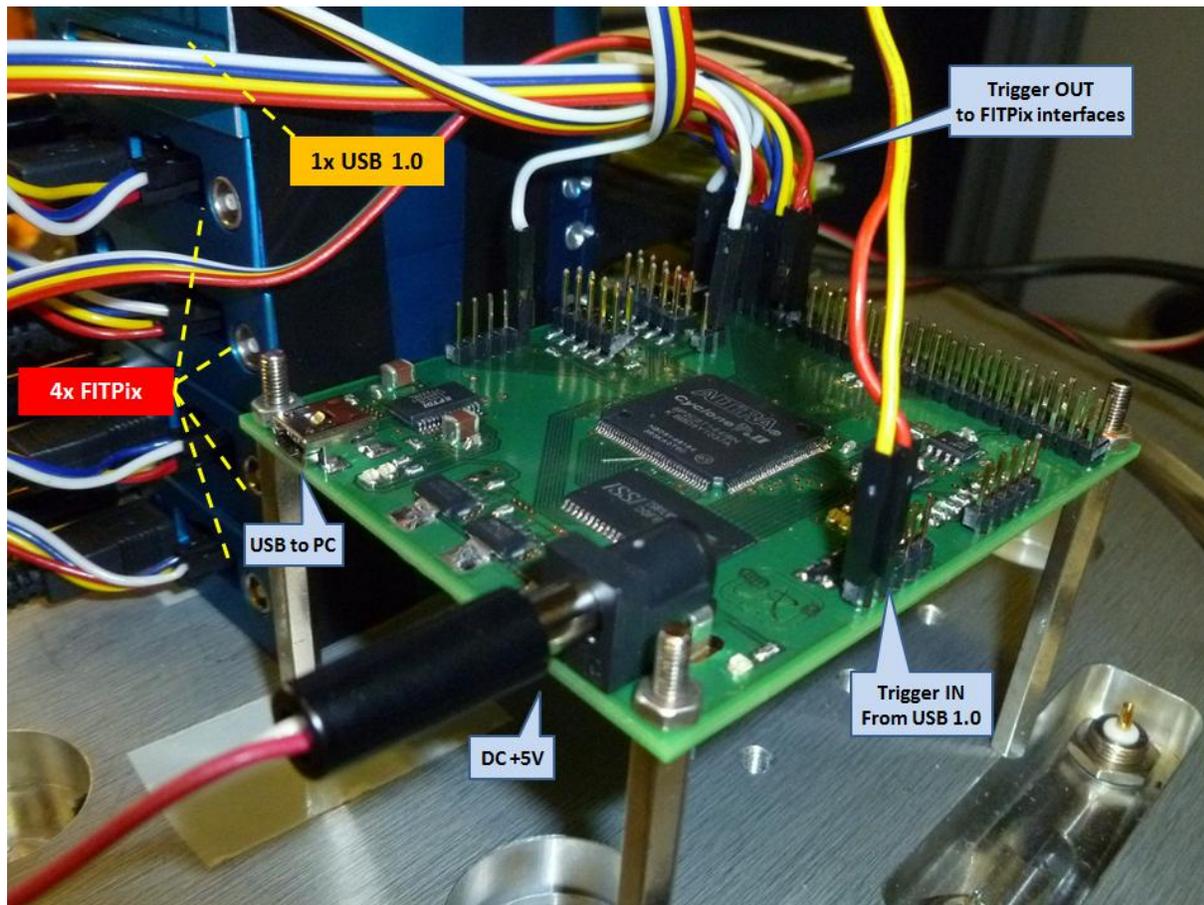


Figure 3: Coincidence module connected to one USB 1.0 interface (provides trigger) and four FITPix interfaces (take trigger). The readout interfaces appear in the background partially hidden.

The module connected to one USB 1.0 interface, which produces the trigger in signal, and four FITPix interfaces, which receive the trigger start signal, is shown in Fig. 3. The block diagram of the assembled coincidence system for multi-particle detection is shown in Fig. 4.

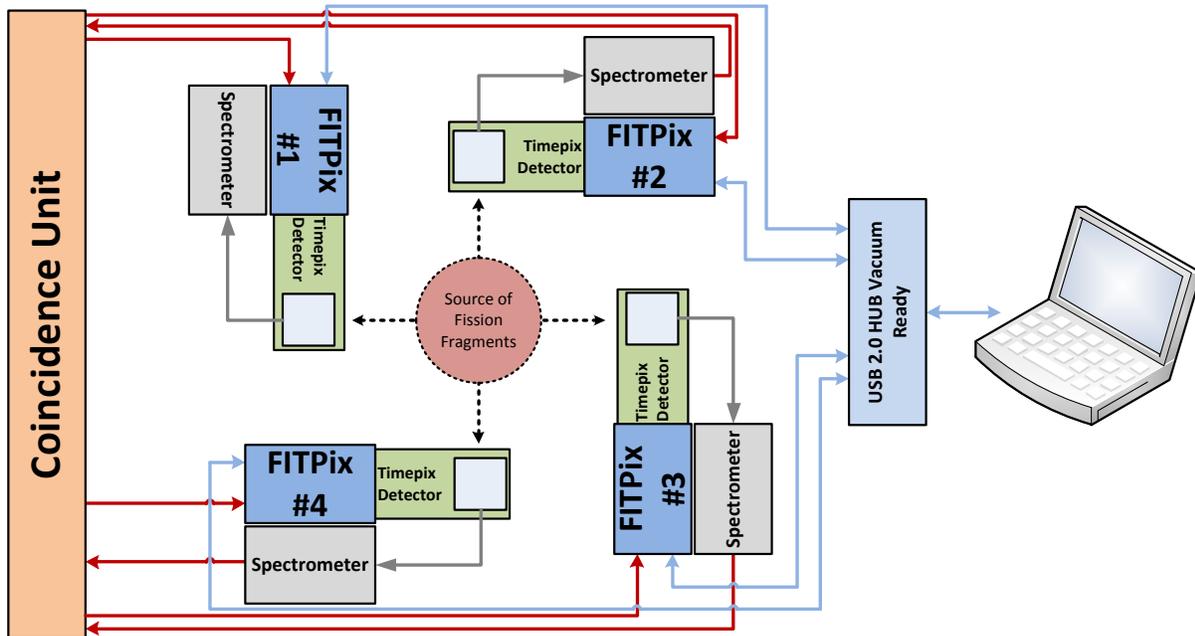


Figure 4: Block diagram of coincidence system for multi-particle detection validated and synchronized by the constructed coincidence module. In the figure all detectors are equipped with devoted analog spectrometric modules.

Each FITPix is assigned with a sync port equipped with several signals: trigger in, busy, out trigger. The coincidence module picks up for example the busy signal from all the interfaces. As long as there remains at least one busy signal classified as active, the coincidence unit ignores the trigger signal from the analog spectrometer (trigger) and the data frames are not readout. The scheme of the signal flow in the coincidence module is shown in Fig. 5.

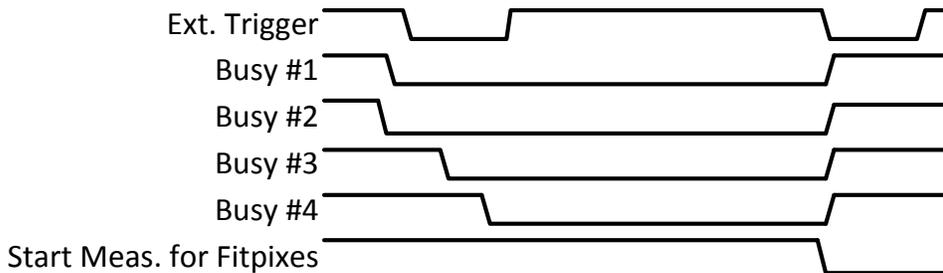


Figure 5: Scheme of signal flow in the coincidence module for the setup in Fig. 4.

Signals from the coincidence unit are linked to the FITPix interfaces via external digital port which is designed to synchronize multiple devices. A busy signal indicates that the given interface is ready and able to handle/receive the external trigger. The unit verifies that all devices are ready in which case passes on any external trigger signal coming and the

measurement can start. A trigger out signal is fed into the interfaces and validates the measurements. The maximum inaccuracy, given by two periods in the dual sampling, is 20 ns (for a 100 MHz frequency is the coincidence unit). Thanks to the structural design of gate array firmware it is easy to add more channels into the coincidence unit and precisely synchronize an arbitrary number of FITPix interfaces (limited only by the number of pins in the FPGA).

Measurement of fission fragments in coincidence

The module was tested on a setup consisting of four pixel detectors, each controlled by separate FITPix interface, and one USB 1.0 interface, housing the analog spectrometric module connected to one sensor for common trigger (setup shown in Fig. 6). The detection of three particles in coincidence is shown in Fig. 7. The setup equipped with the module run continuously for several days providing full synchronization of DAQ readout for all devices.

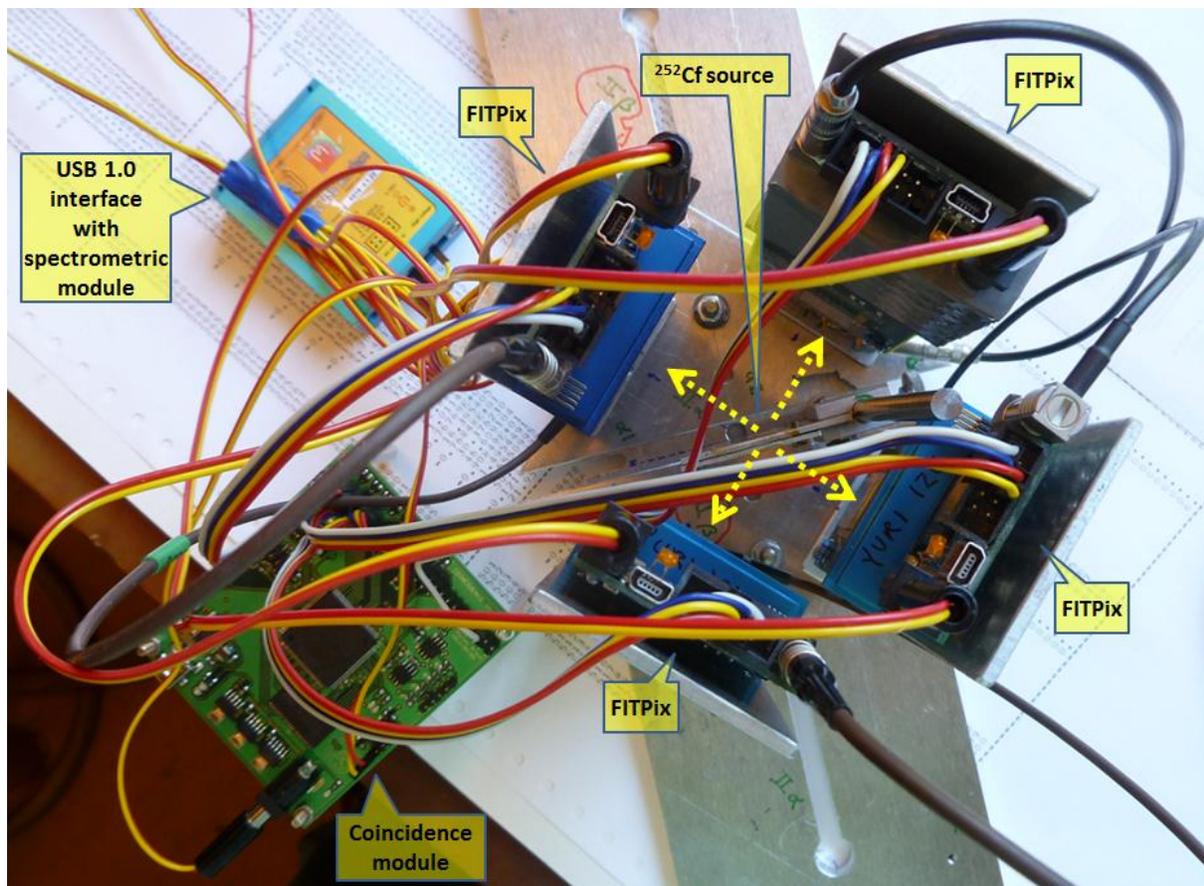


Figure 6: Experimental setup for coincidence detection of fission fragments consisting of four pixel detectors (two Timepix and two Medipix2) devices each controlled by separate FITPix interface. See block layout in Fig. 4.

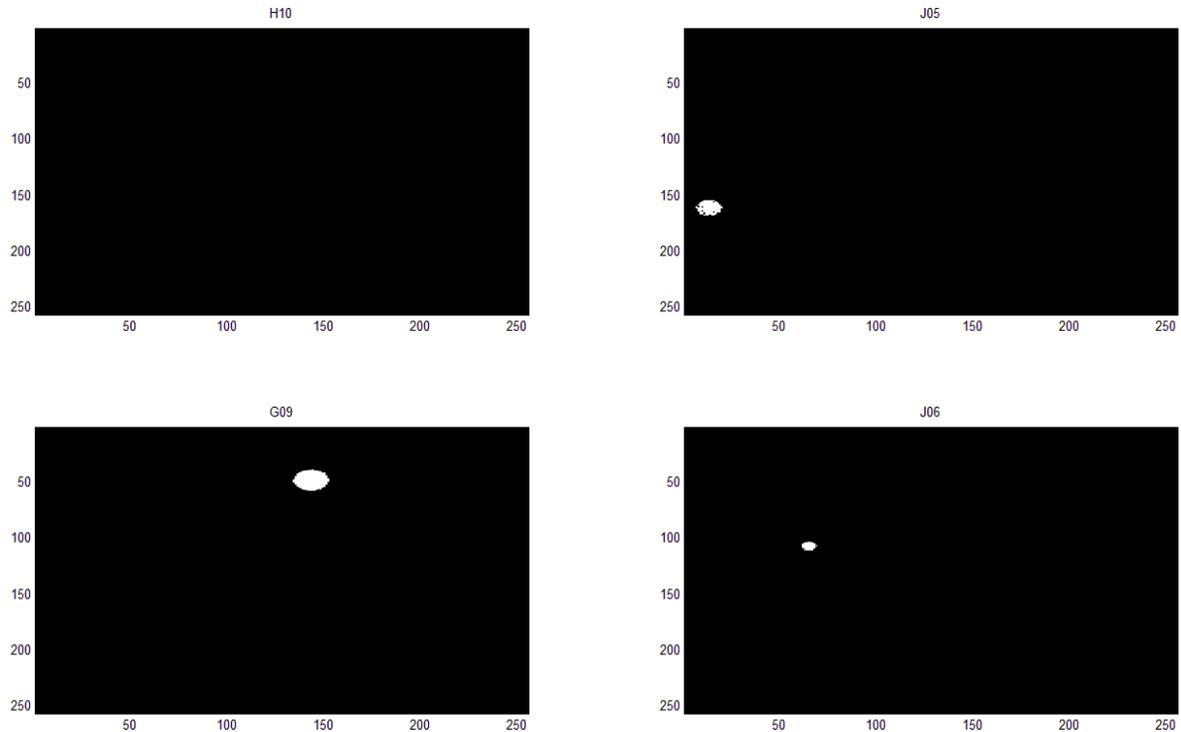


Figure 7: Detection of three particles in coincidence for the setup shown in Fig. 6. Frame acquisition started by trigger (generated by detector TPX J06) and frame exposure time 100 μ s.

Conclusions

The coincidence module was developed for precise synchronization of four FITPix-run pixel detectors for the purpose of experiments on correlated detection of fission fragments. While the FITPix interfaces are controlled by the software package Pixelman, which controls the data acquisition, but cannot guarantee a smooth and fully synchronized readout for all detectors. The constructed coincidence module enables accurate synchronization and maximizes the number of data readout rate reaching up to frames per second for four pixel detectors. This gain significantly reduces dead time and eases the offline data evaluation. Successful operation of the module was demonstrated with measurements on a spontaneous fission source. Nearly forty million data frames were readout from up to four detectors during two weeks with full synchronization.

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