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# Real-time Lossless Data Compression Method Used in the Readout System for MPGD

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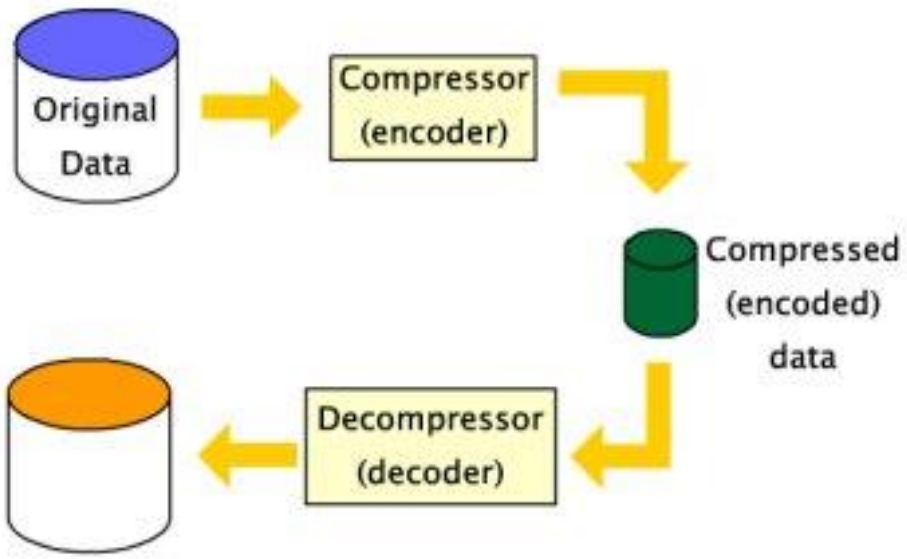
# Outline

- Data Compression & Physical experiments
- MPGD Readout System
- Situation1
- Situation2
- Summary

# Data Compression

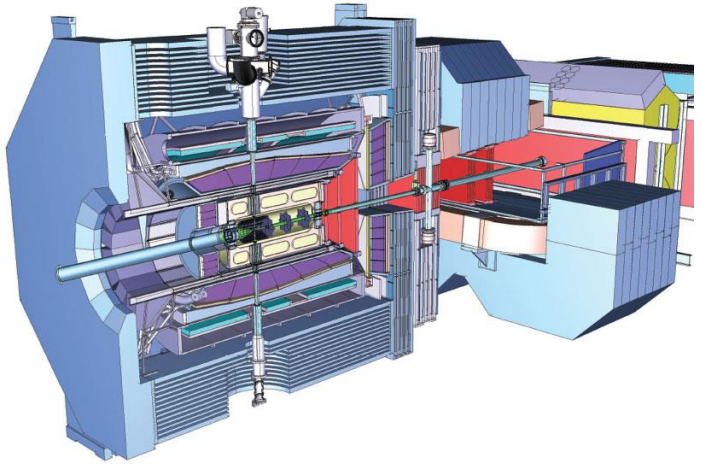
- Data Compression is about storing and sending a smaller number of bits
- See a lot of usage in the fields of audio, video etc




# Modern Physical Experiments

- More and more detector channels, higher and higher measure precision, higher and higher sample rate
  - Give high pressure on data transmission and storage
- Low entropy system
  - The physical process, the detectors and readout electronics feature the signals


LHC:
10~100Mchannels
~100Gbyte/s



PANDA:
~10GHz
40~200Gbyte/s

# Compression Strategy

- Loss Compression VS Lossless Compression
- Two Step
  - ◇Preprocessing
    - According to the characteristics of the data.
  - ◇Compression
    - Huffman coding
    - LZ coding
    - Run-length coding

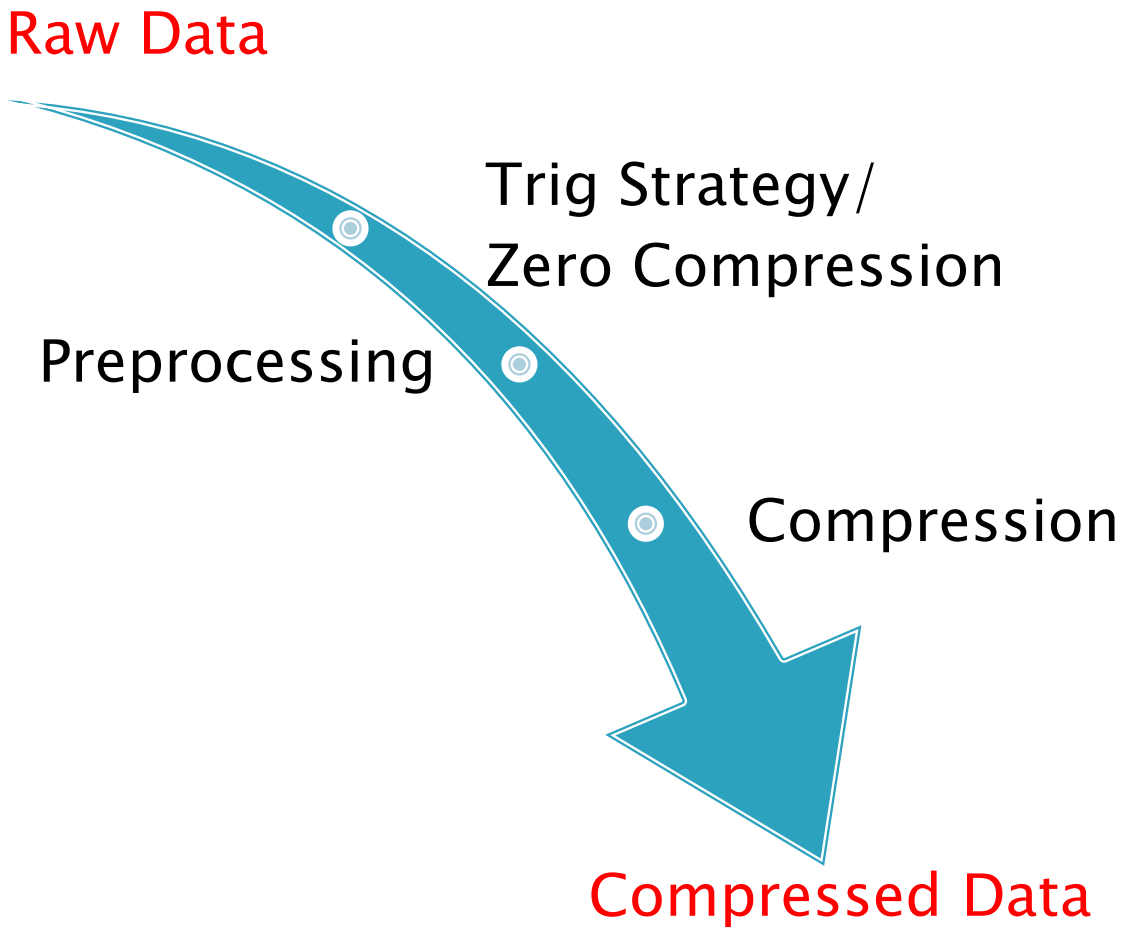
**Preprocessing example**

1, 2, 3, 5, 5, 6, 8, 7, 8, …

Y = X

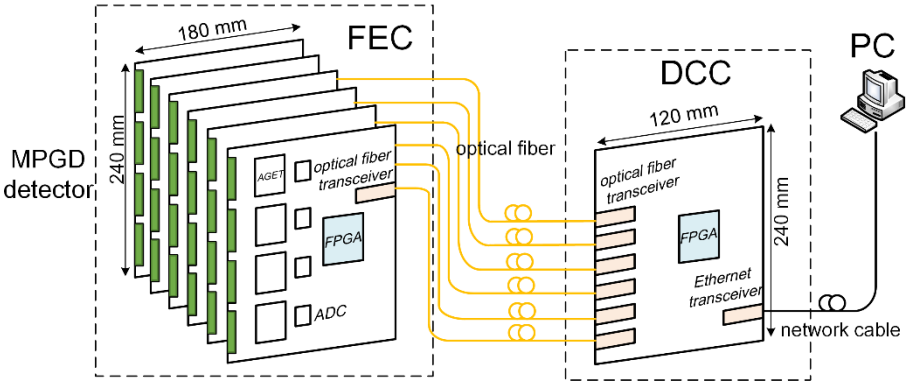
0, 0, 0, 1, 0, 0, 2, 0, 0, …

# Data Compression in physics

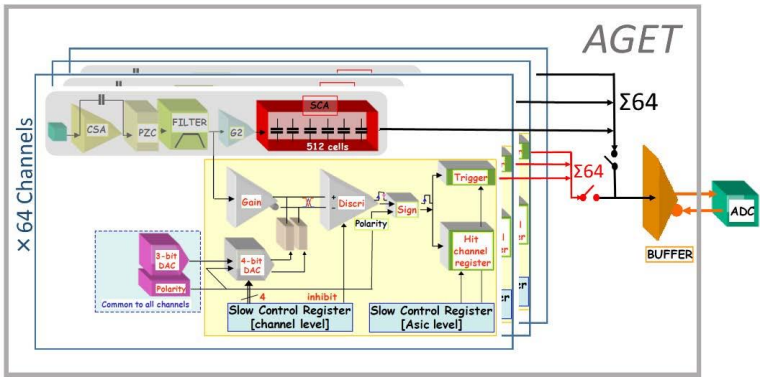


# MPGD Readout System

- Micro-pattern Gas Detectors (MPGD) Readout System
  - FEC & DCC
  - Scalable
- AGET Chip
  - Designed by GET collaboration for MPGD readout
  - 64 channels
  - CSA, Shaping, SCA (512 sample deep)



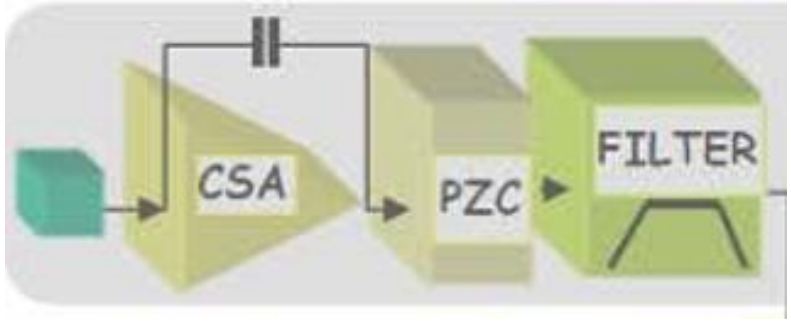

Structure of MPGD system

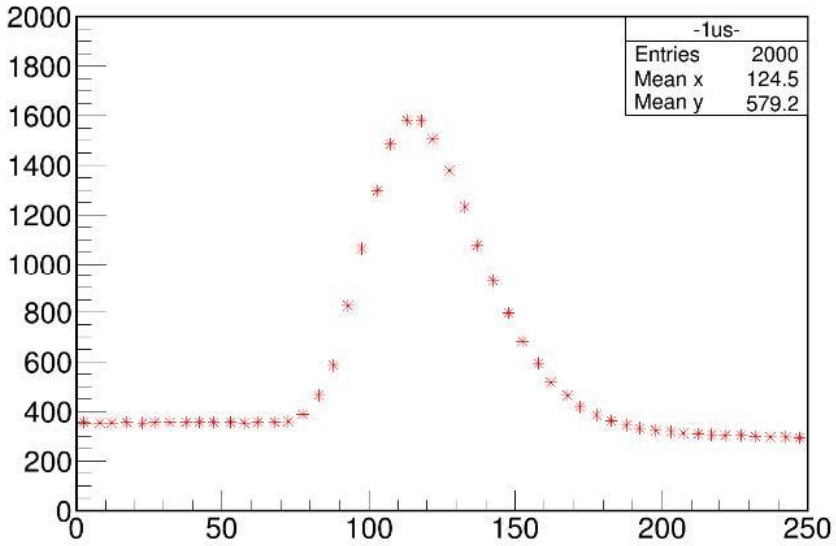



Analog part of AGET

# Situaton1

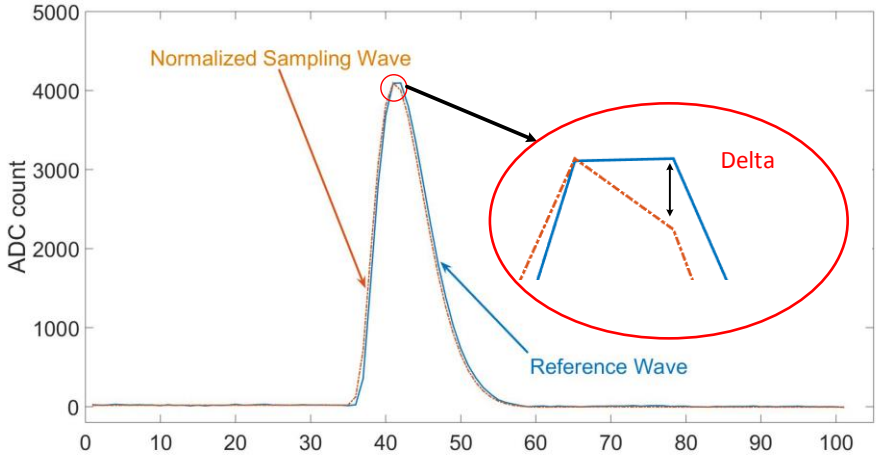
- Output wave of AGET
  - Gaussian waveform
  - Determined by the shaping circuit

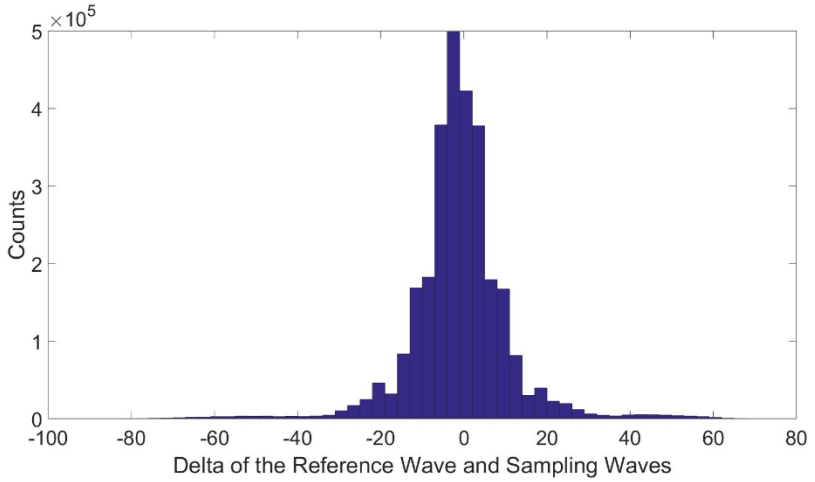


# Compression Method

- Preprocessing
  - Compared with the reference wave
- Compression
  - Huffman coding



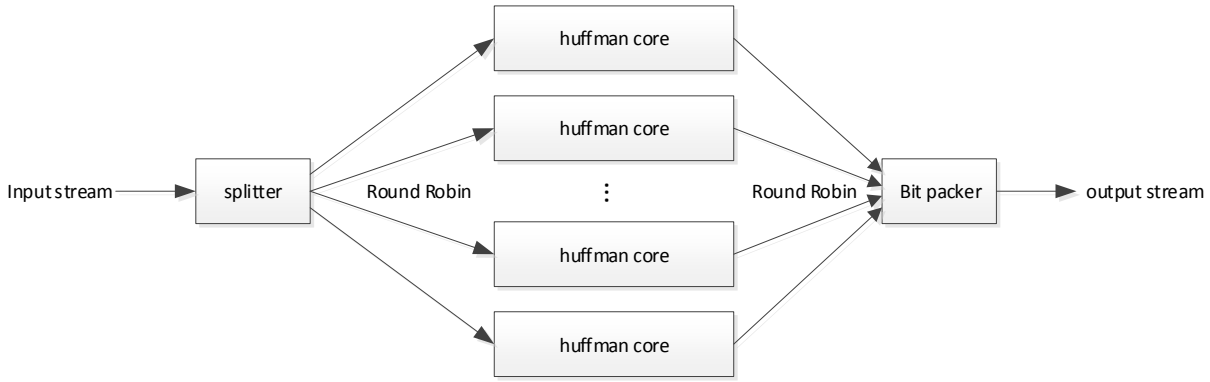
# Huffman Coding

- Coding according to the frequency
  - Higher frequency, shorter code
- Dynamic table VS Static table
- Parallel Huffman core in FPGA to improve the speed

ACAIEEIEAHIIECICIEEICCEEH

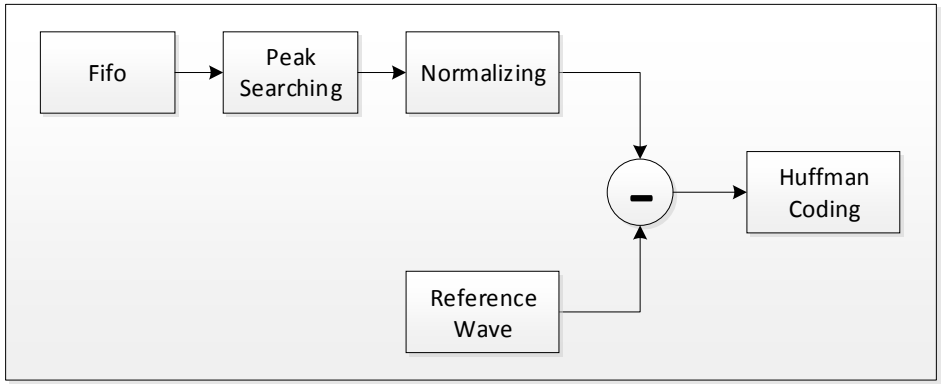
**E = 01**
**I = 00**
**C = 10**
**A = 111**
**H = 110**

| Before | After |
|---|---|
| 75bits | 55bits |



# FPGA Implementation

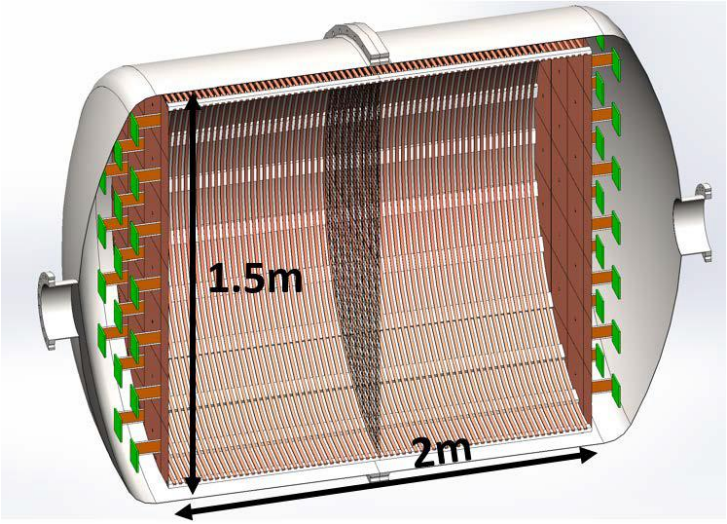
- Xlinx Zynq-7000 (xc7z045ffg676-2)
- Runs well under the clock of 100MHz
- Compression Delay: 150~450 clock cycles (1.5us ~ 4.5us)

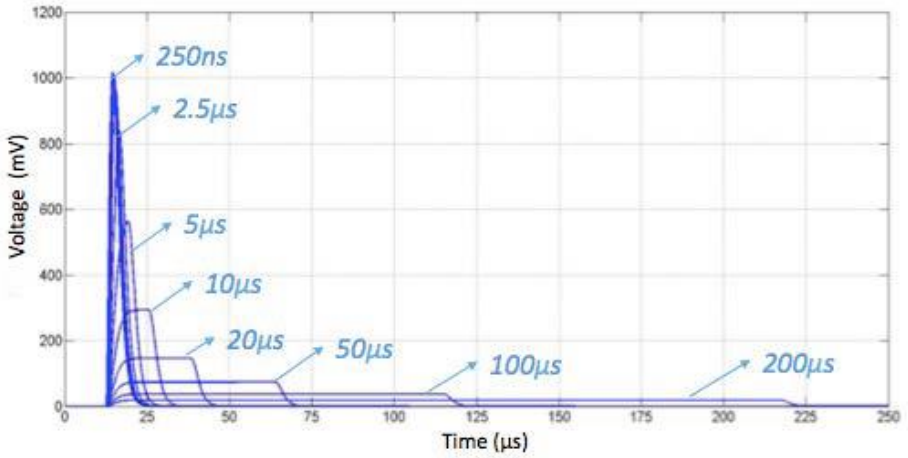




| Slice LUTS (218600) | Slice Registers (437200) | Block RAM Tile (545) | DSP |
|---|---|---|---|
| 438 | 372 | 5 | 0 |
| 0.20% | 0.09% | 0.92% | 0 |

# Situation2

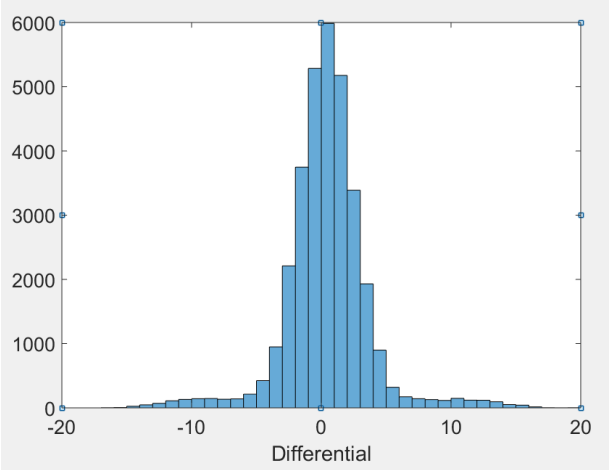
- PandaX-III
  - Searching for neutrinoless double β decay
  - $^{136}$Xe TPC, Micromegas
- Signal
  - May be as long as 100us
  - Get the signal information by integrating the waveform

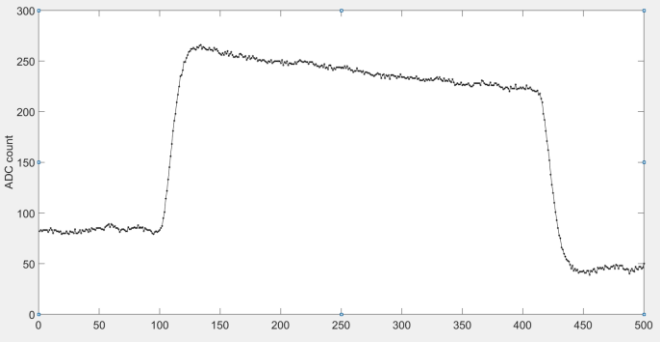


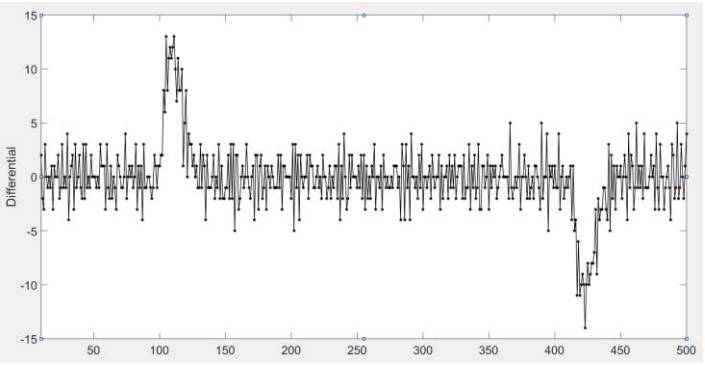



# Compression

- Preprocessing
  - Calculation the differential of the wave
  - Results are centred around zero
- Compression
  - Huffman coding

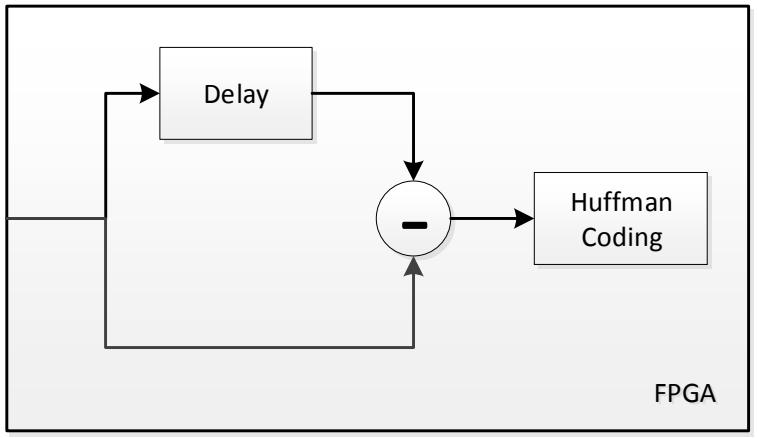


# FPGA Implementation

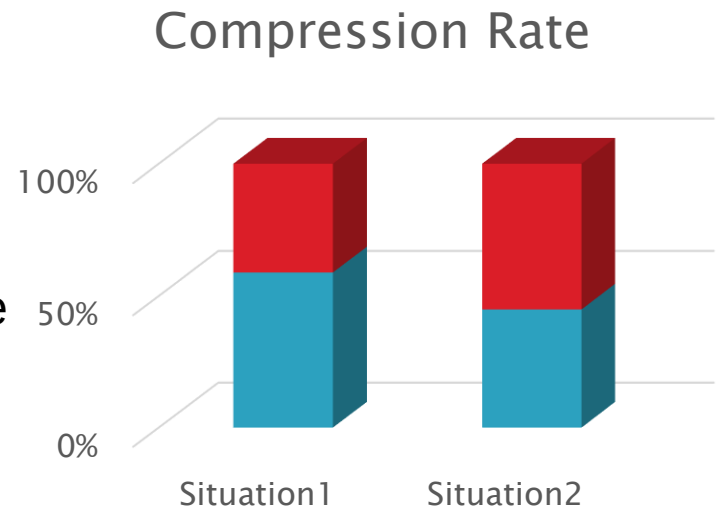
- Xlinx Zynq-7000 (xc7z045ffg676-2)
- Runs well under the clock of 100MHz
- Compression Delay: <10 clock cycles (100ns)

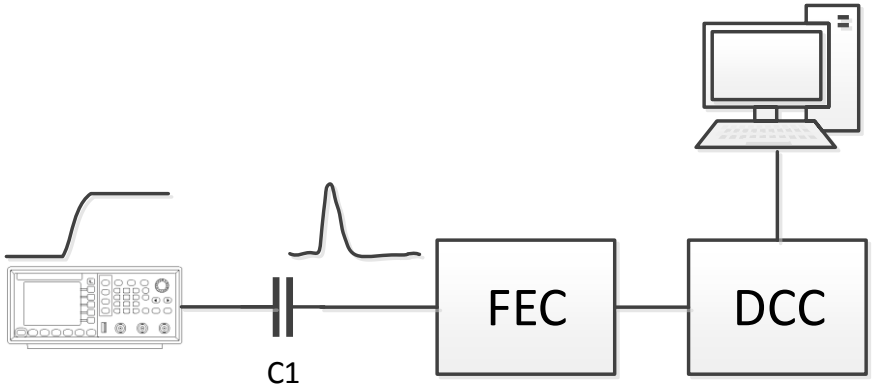




| Slice LUTS (218600) | Slice Registers (437200) | Block RAM Tile (545) | DSP |
|---|---|---|---|
| 394 | 293 | 1 | 0 |
| 0.18% | 0.07% | 0.18% | 0 |

# Test

- Test with signal generator
  - A step signal is generated
  - A charge signal is generated after C1
  - Width of charge signal is decided by the rising edge of the step signal
- Compression rate
  - Situation1: 43%
  - Situation2: 30%



# Summary

- Considering using data compression in physical experiments
- Based on a MPGD readout system, for two different situations, implementation two different real-time compression algorithms
- More than MPGD