A Correlation Based Pulse Detection Technique for Gamma/Neutron Detectors

Muhammad Faisal[1)], Randolph T. Schiffer[1)], Marek Flaska[2)], Sara A. Pozzi[2)], David D. Wentzloff[1)]

1) Department of Electrical Engineering and Computer Science
2) Department of Nuclear Engineering and Radiological Sciences
University of Michigan, Ann Arbor, Michigan 48109, USA

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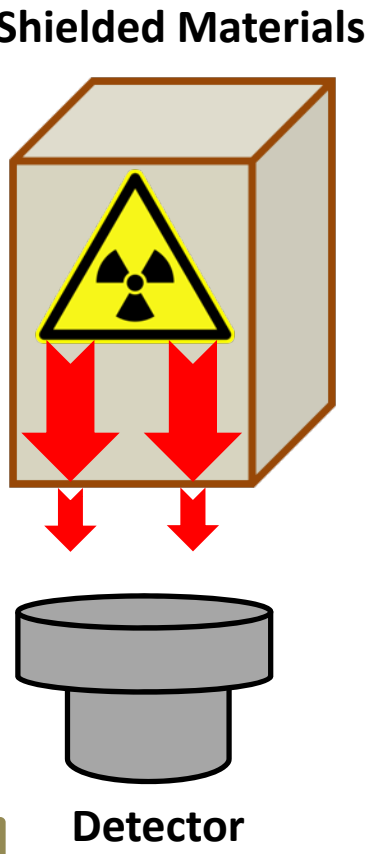
Motivation

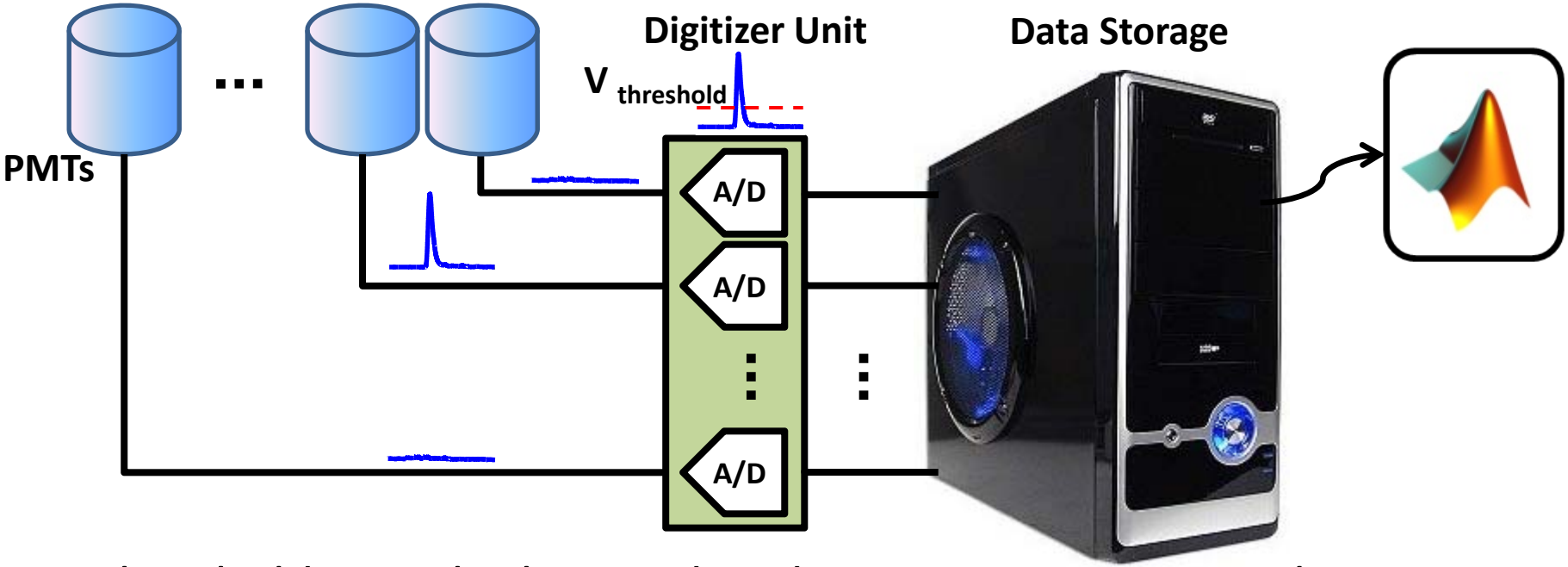
- Shielded radioactive materials
  - Low energy radiation
  - Difficult to detect
- Signal processing to detect these pulses
- Efficient online detection required (e.g. airports)



Real-Time Detection

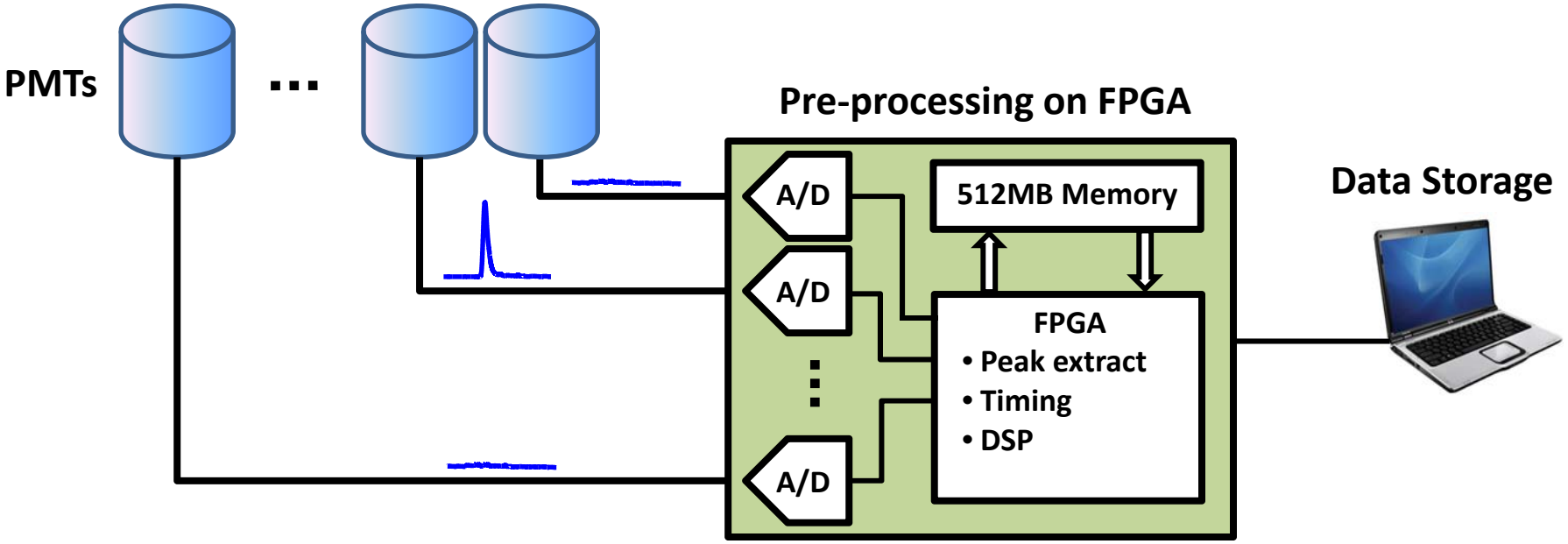
Current State-of-the-Art

- Analog : mostly counting pulses
- Digital : Data stored for post-processing



- Threshold must be lowered to detect lower energy pulses
  → false detections

This Approach

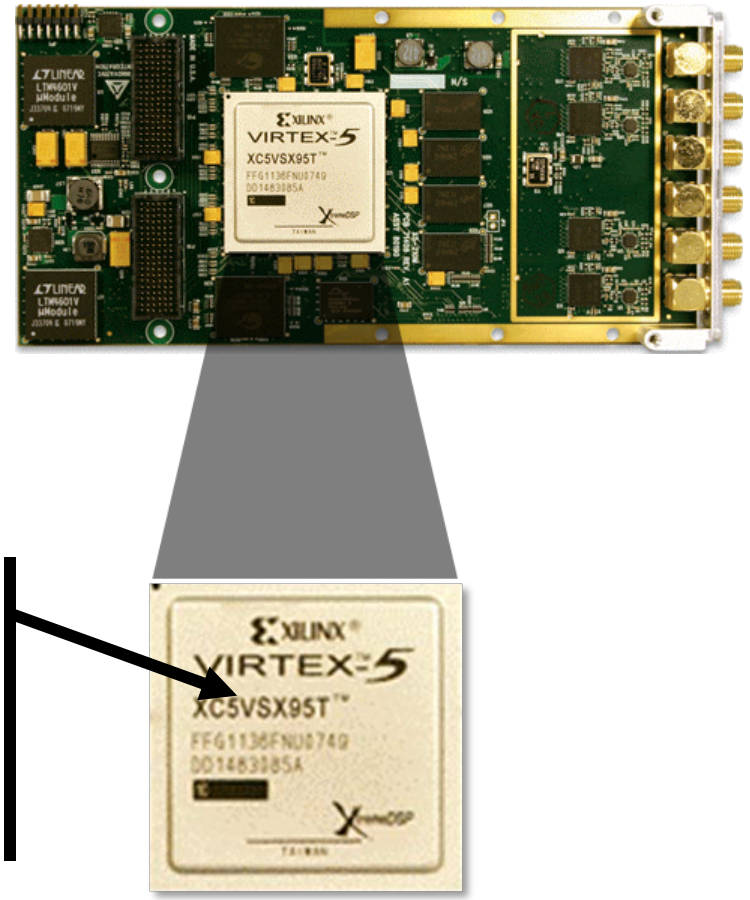


- Data is analyzed prior to storage
  - Significantly less amount of data is stored
- Improve detector sensitivity
- Real-time pre-processing

Equipment

- Commercial board
  - 250MS/s, 14 bits, 4 channels
  - Connects directly to PC (e.g. laptop)
- On-board FPGA customizable for pre-processing of data

Innovative Integration's X5-210M



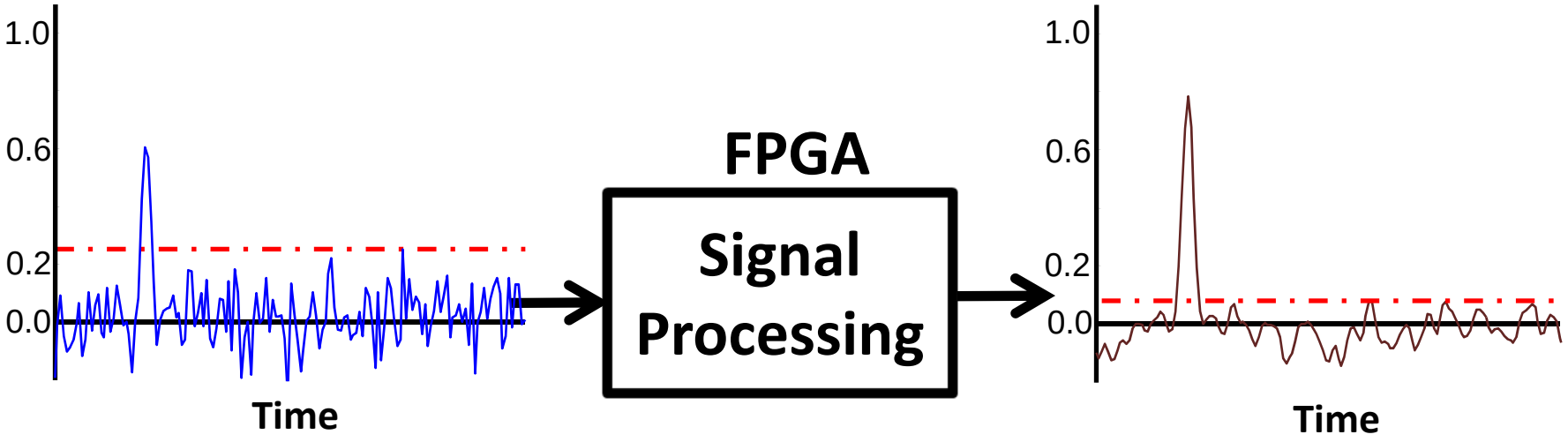
Real-time detection
Extract useful information from pulses (e.g. height, time)

Normalized Cross Correlation(1/2)

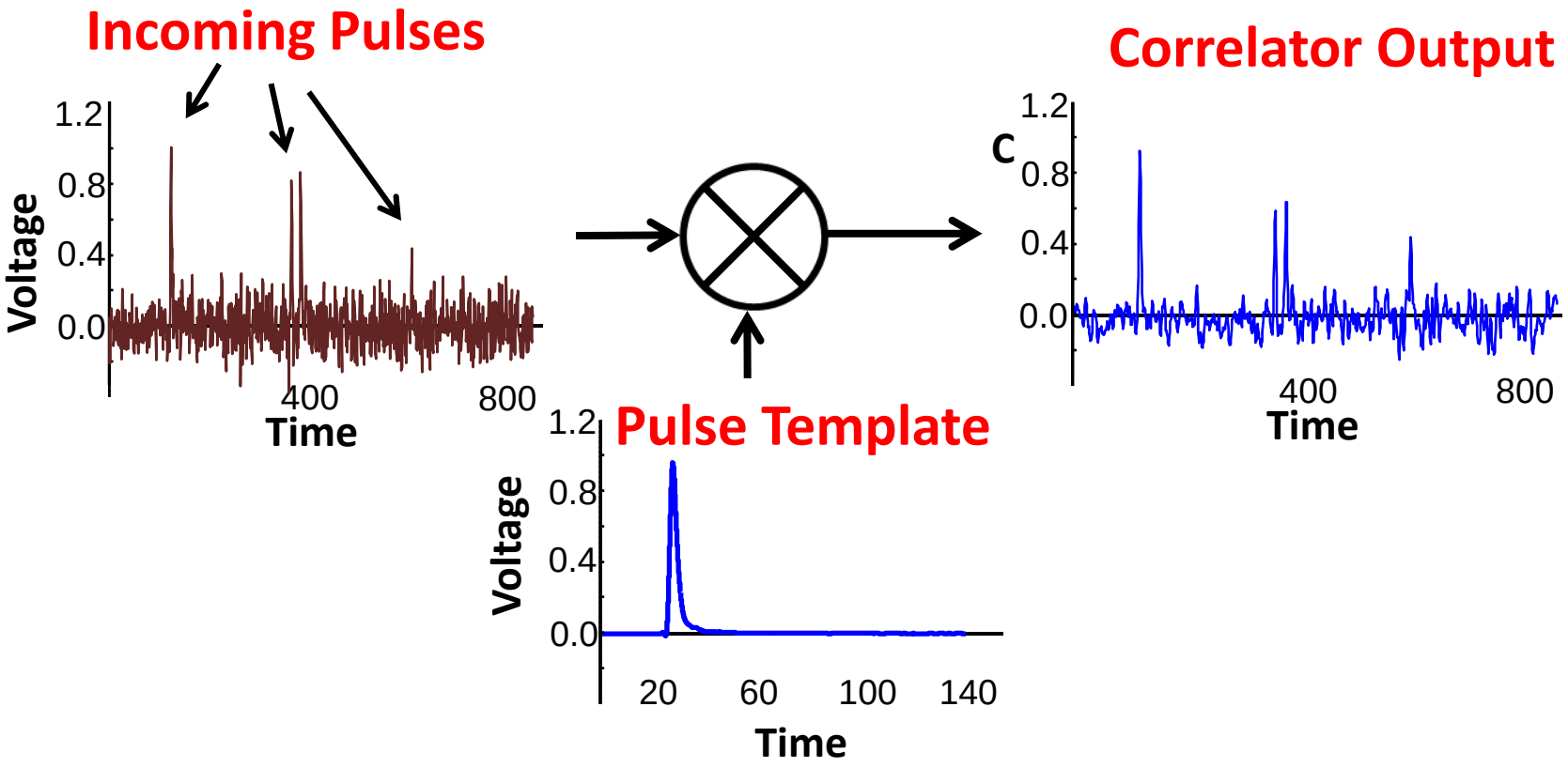
- Pre-processing in real time on an FPGA
- Measure of similarity between two signals

$$C(u)=\frac{\sum_x\left[f(x)-\bar{f}_u\right]\left[t(x-u)-\bar{t}\right]}{\sqrt{\sum_x\left[f(x)-\bar{f}_u\right]^2\sum_x\left[t(x-u)-\bar{t}\right]^2}}$$

$$-1\le C(u)\le +1$$

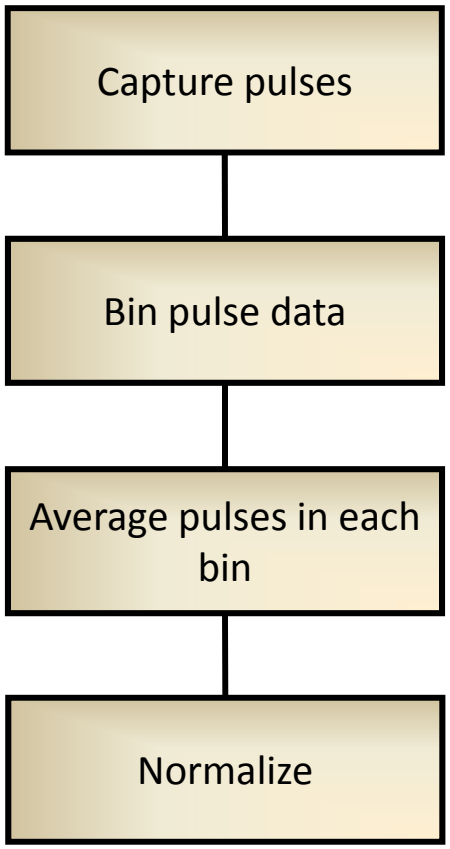


Normalized Cross Correlation(2/2)



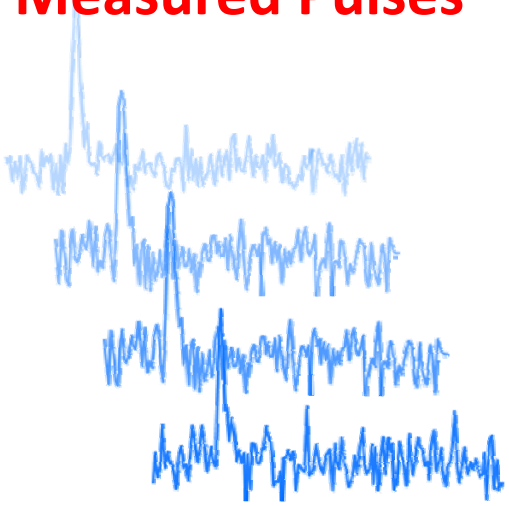
Amplify Signal & Attenuate Noise

Template



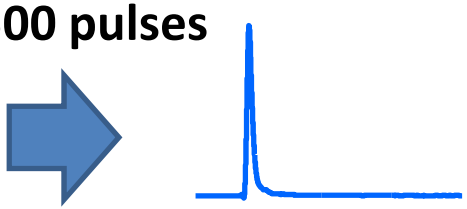
- Template used in the correlator to recognize pulses

Measured Pulses



Template

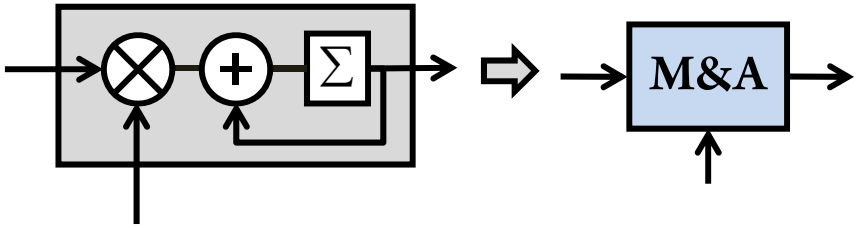
Average 1500 pulses



Hardware Implementation(1/2)

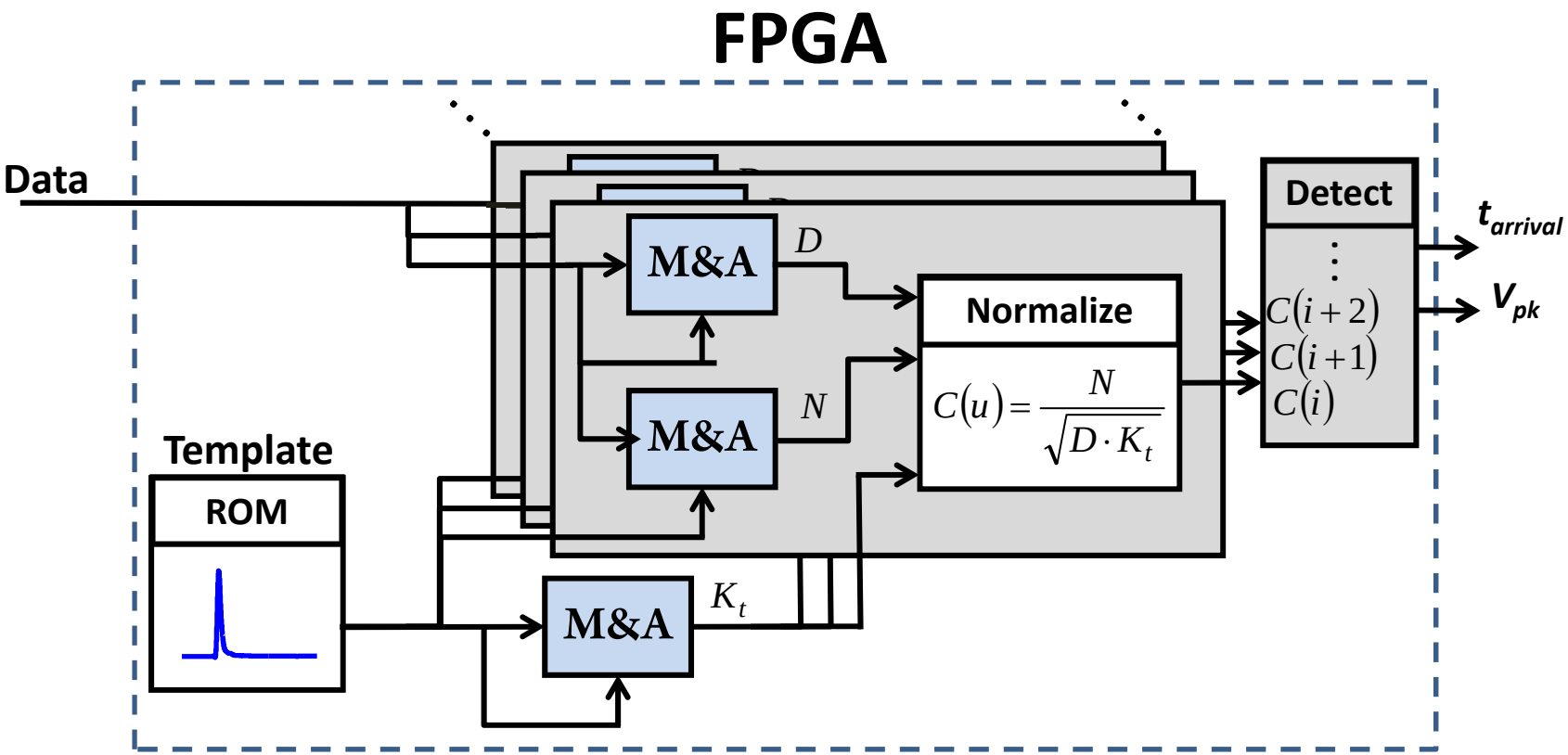
$$C(u) = \frac{\sum_x [Incoming\ Data] \times [Template]}{\sqrt{\sum_x [Incoming\ Data]^2 \sum_x [Template]^2}}$$

- Correlator building block: Multiply and Accumulate



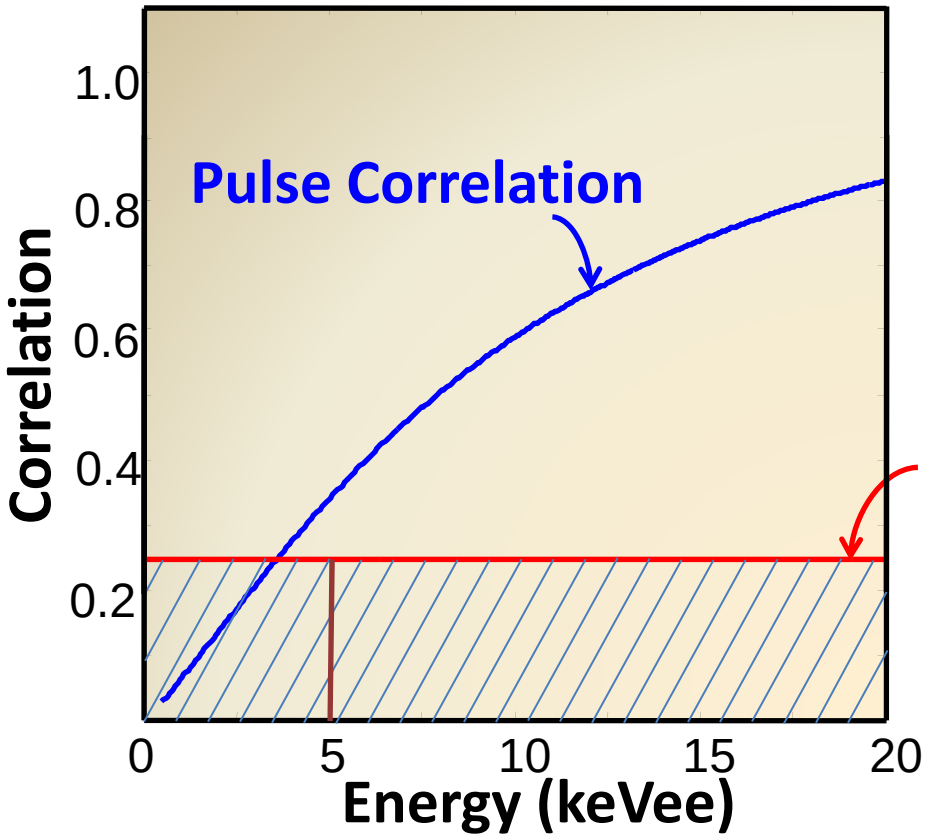
- Available on FPGA as hardware accelerators

Hardware Implementation(2/2)



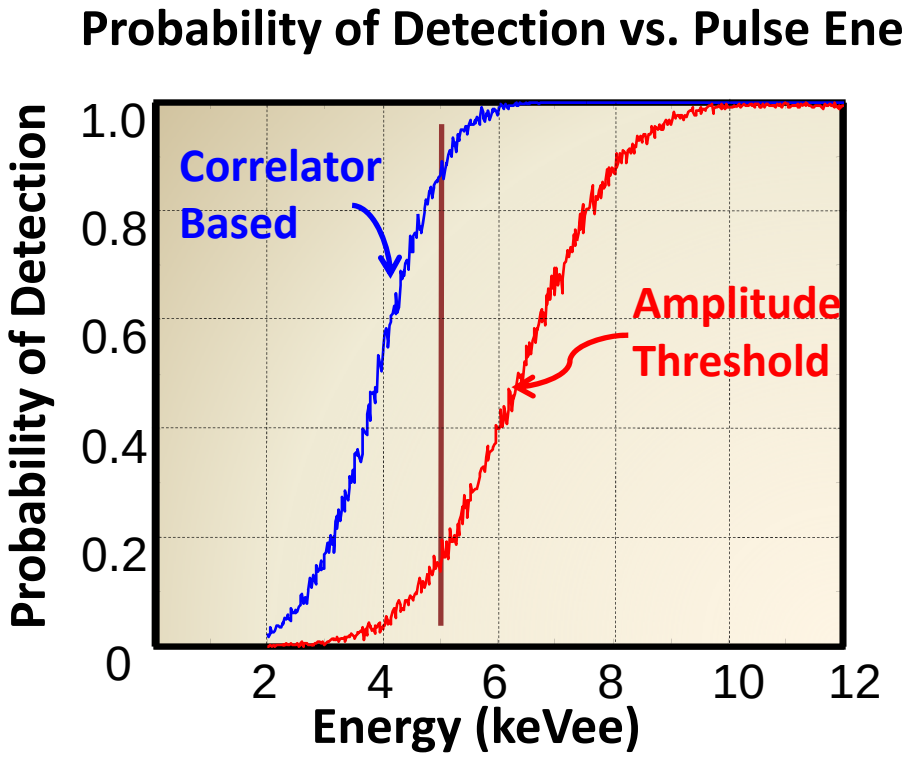
Simulation Results (1/2)

Noise Level
5 keVee



- Pulses detected in presence of noise
- E.g. A 5 keVee pulse in 5 keVee noise

Simulation Results (2/2)



- A 5 keVee pulse in presence of 5 keVee noise
- Probability of detection: 18% to 86%

Conclusion

- Proposing an FPGA-based approach for pulse detection
  - Real-time data processing
  - Improved sensitivity (≈ 4x @ 5keVee)
  - Reduced data storage

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