Photon/Neutron discrimination with digital pulse shape analysis

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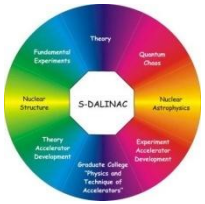

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Overview

- Goals
- Short Introduction to Pulse Shape Analysis
- Data Analysis
- Results
- Summary

Goals

- Goals of this work:

  1. Record digital signals to apply (n,γ) discrimination in the lab
  2. Application of numeric algorithm to perform discrimination
  3. Investigate the separation under variation of sampling rate and resolution

Introduction to Pulse Shape Discrimination

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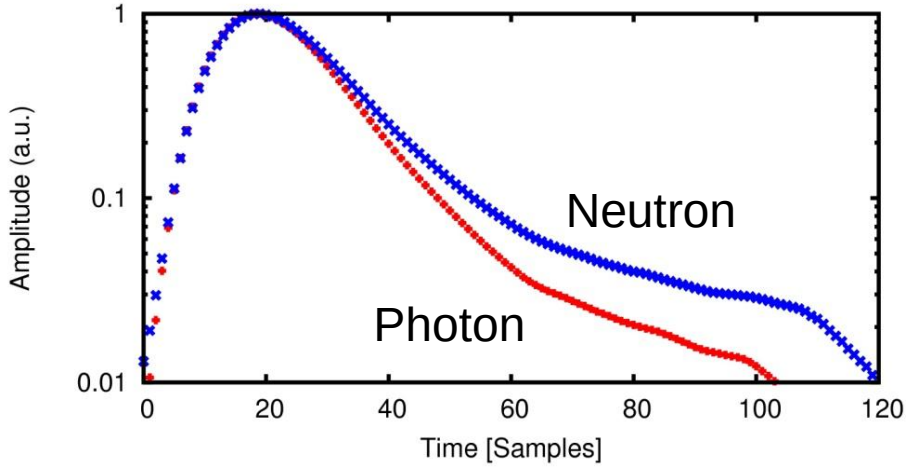
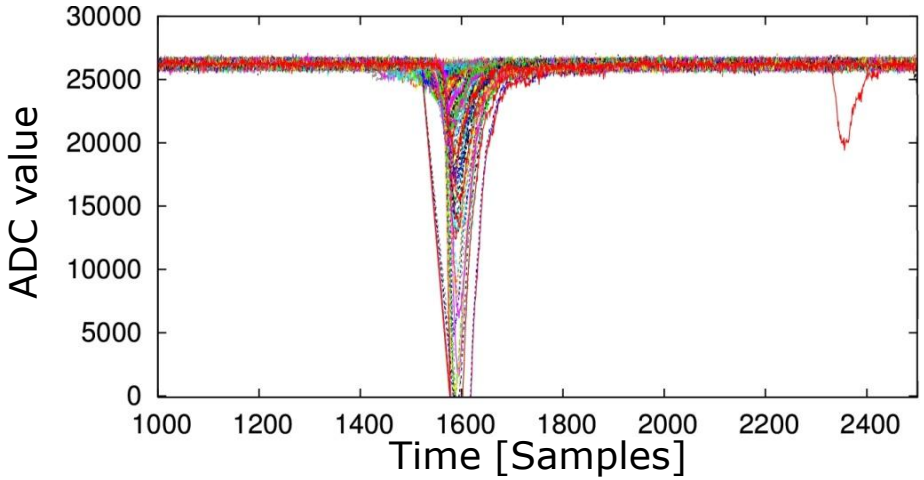
- Detector: Liquid scintillator BC501A with ^{252}Cf source
- Different pulse shapes result from different reaction processes
  - Neutrons: Recoil protons
  - Photons: Compton effect
- Neutron signal contains stronger slow component:



➡ Discrimination based on the pulse shape

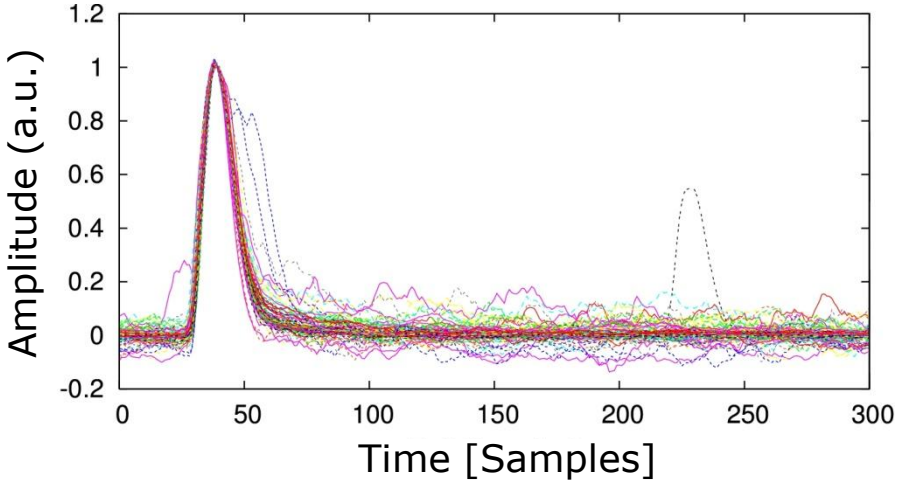
Data Analysis

- Raw data
  - No direct separation visible
  - Needs processing



- Filtered, scaled and time aligned data
  - Noise reduction
  - Only slow component important
  - Alignment on rising edge

  → Shape analysis



Pulse Shape Discrimination
Fuzzy C-Means Introduction

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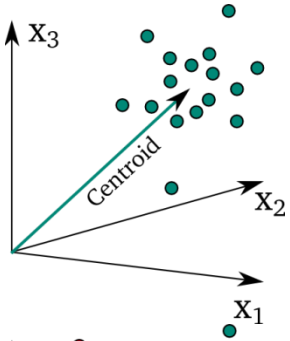
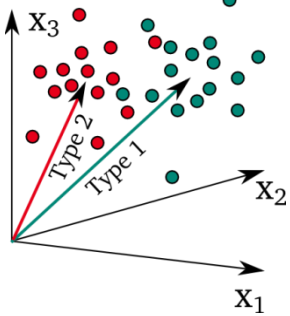
- Use of ISODATA **Fuzzy C-Means** algorithm to find signal classes [1]

- Signals represented by vectors in n-dimensional phase space

  - Similar signals have vectors close to each other with a statistical distribution

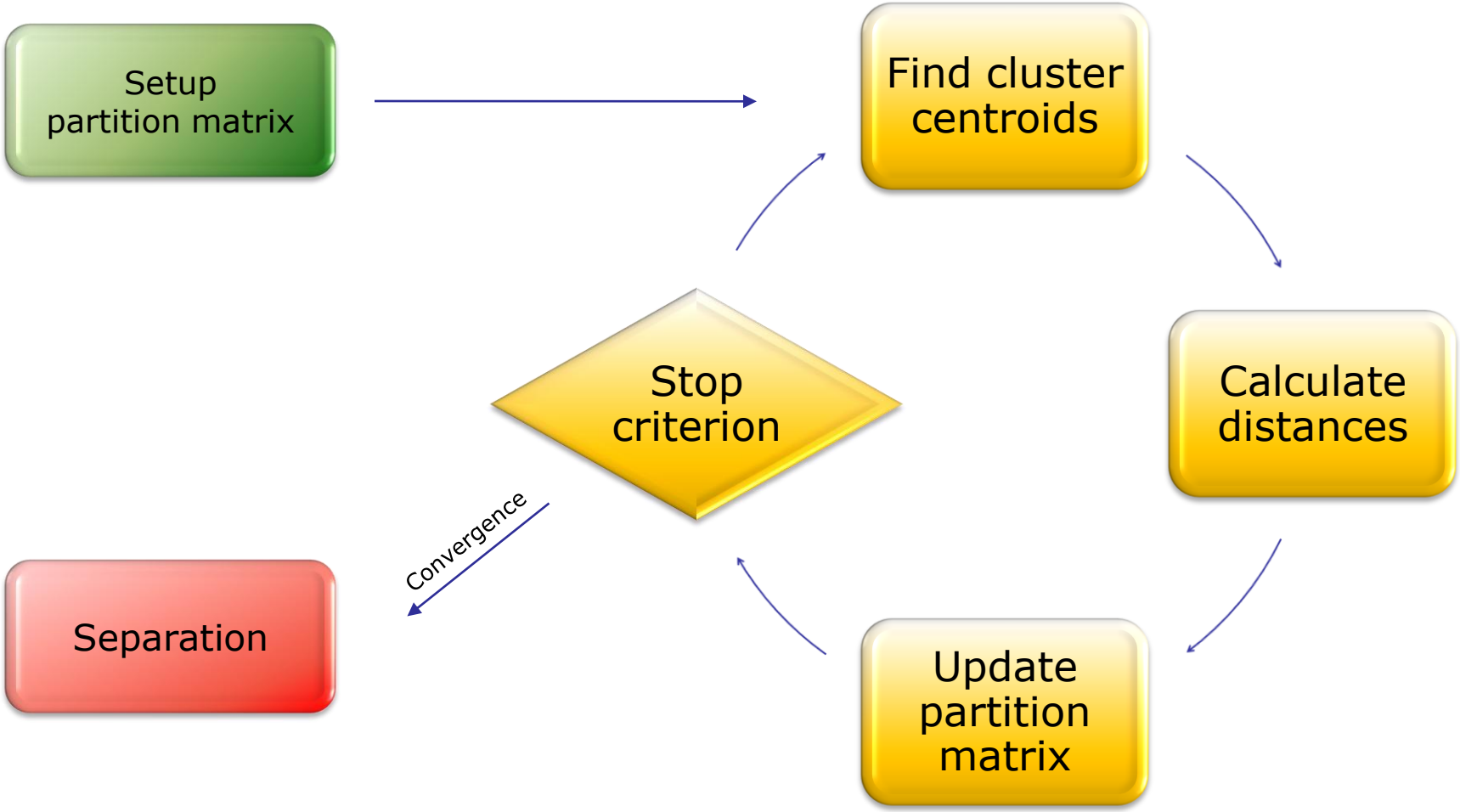


  - Different pulse shapes point to different areas in phase space
  - Centroid vector of each area is the class prototype



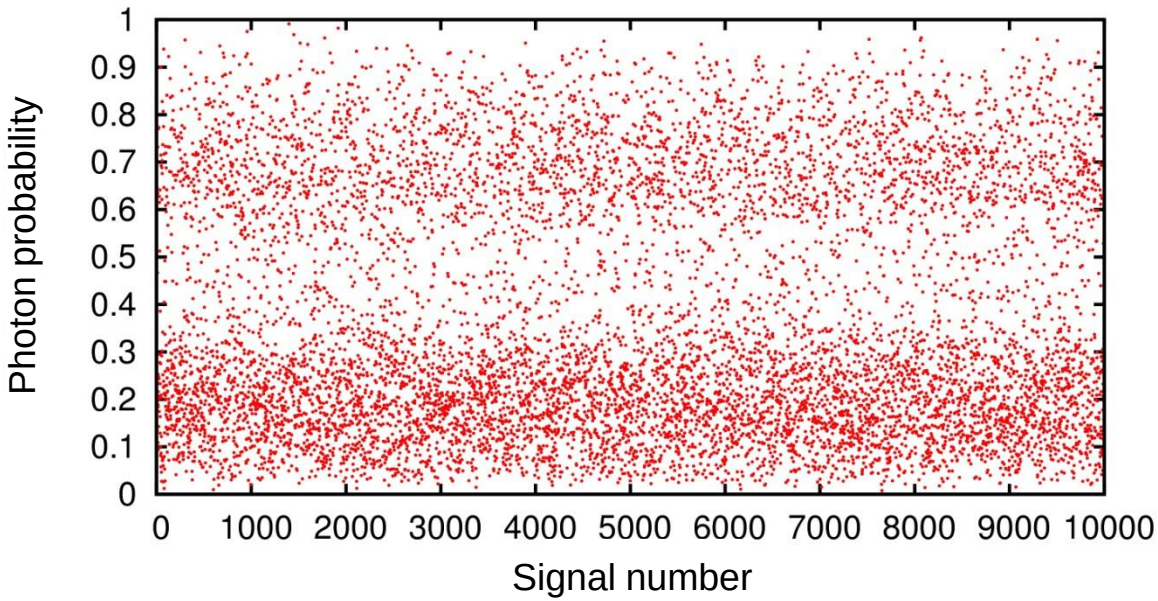
[1] R. O. Duda, P. E. Hart and D. G. Stork: Pattern Classification. John Wiley and Sons Inc., 2nd Ed., New York 2001

Pulse Shape Discrimination
Fuzzy C-Means Overview



Pulse Shape Discrimination
Fuzzy C-Means Result

- Partition matrix after convergence



- Histogram plot reveals separation quality

Pulse Shape Discrimination Figure of Merit

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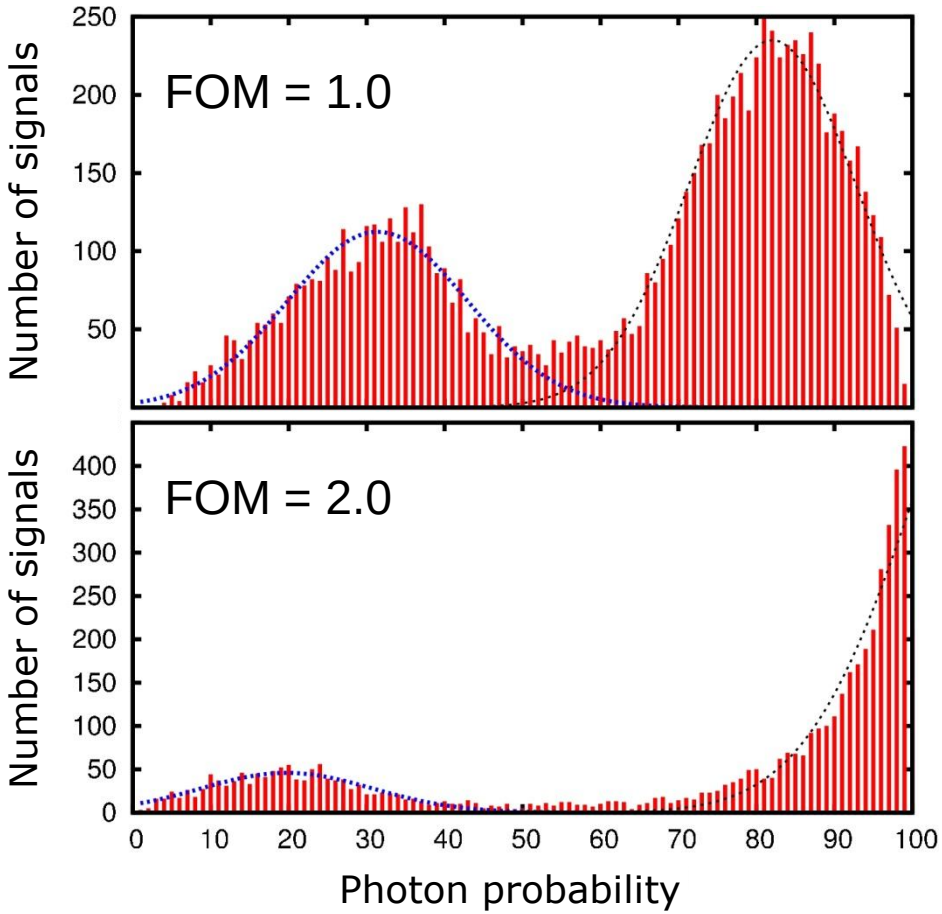
- Separation quality
  - Define Figure of Merit (FOM)

$$\mathrm{FOM} = \frac{d(\mathrm{n},\gamma)}{\sum_i \mathrm{FWHM}_i}$$



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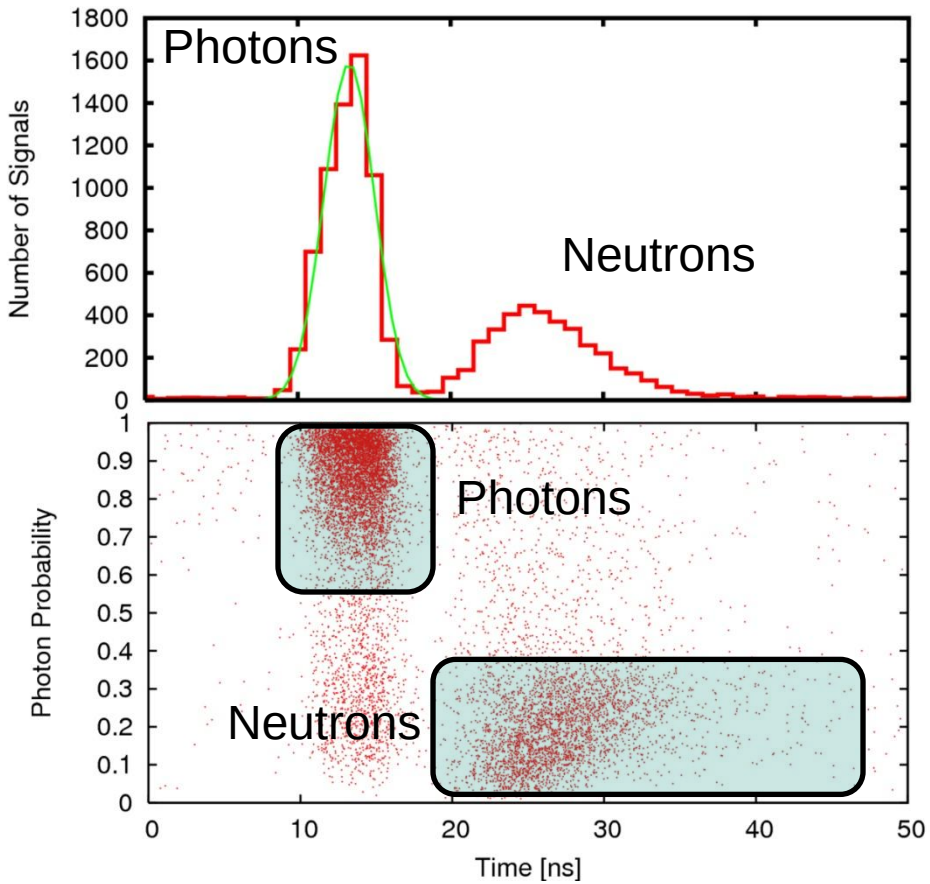
Pulse Shape Discrimination Time of Flight

- TOF Measurement to confirm separation
  - Width of photon peak: 3.9 ns
- Combined TOF and FCM
  - Separation visible in both dimensions

  → FCM provides correct separation



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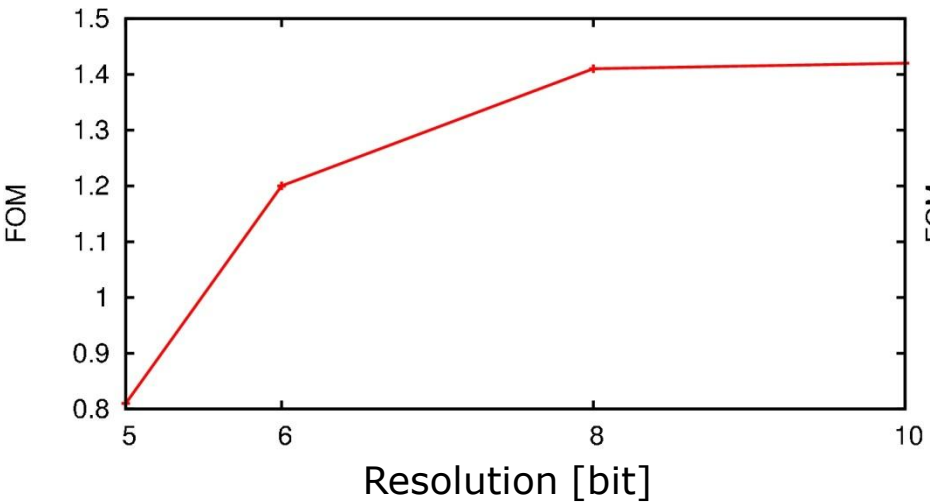
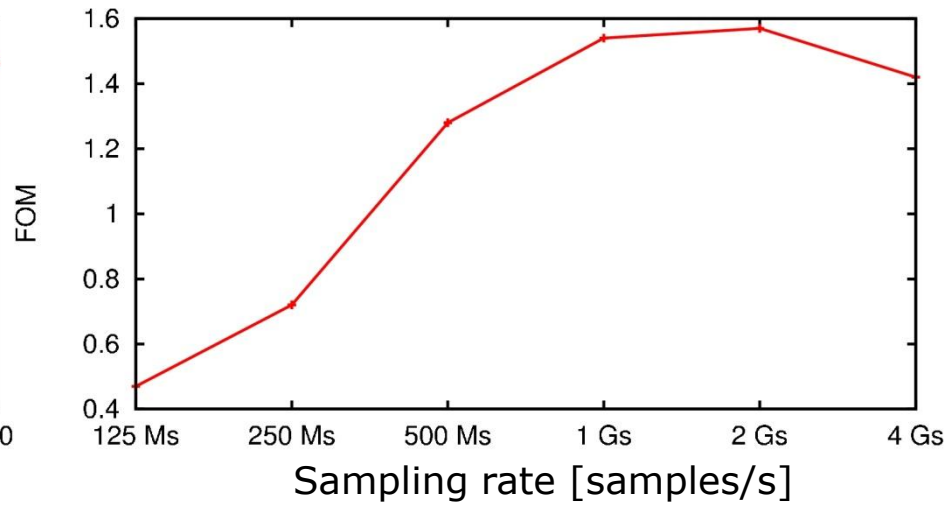
Results
Bit- and sampling rates

- Bitrate variation from 4 to 10 bit and sampling rates from 75 Ms/s to 4 Gs/s





- Saturation: more than 8 bit or higher than 500 Ms/s
- Bitrates below 5 bit and sampling rates below 125 Ms/s not feasible
  - Lower sampling rates only with phase correction

Summary

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- Application of Fuzzy-C Means algorithm to handle signal analysis
- Dependence of FOM on sampling rate and resolution
  - Flash ADC with 500 Ms/s at 10 bit resolution suitable
- Confirmed FCM-Method as a fine tool for discrimination

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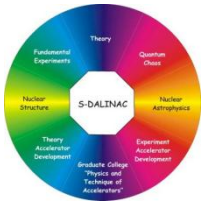

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