Pulse shape discrimination between neutrons and gamma rays with digital electronics

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0.1. Introduction

Goal

Digital n-gamma discrimination

Compare classical methods (digitalized)

Impact of ADC characteristics

Especially interested in low energy

Outline

0. Introduction

1. Setup

2. Analysis

3. Results (so far)

4. Outlook (to do)

5. Summary

1.1. Setup

Available equipment

NORDBALL BC501 detector

4ch 100 MHz 14 bit TNT2 FADC

BARTEK NDE202 PSD Unit

Cf-252 source

1.2. NORDBALL BC501 detector

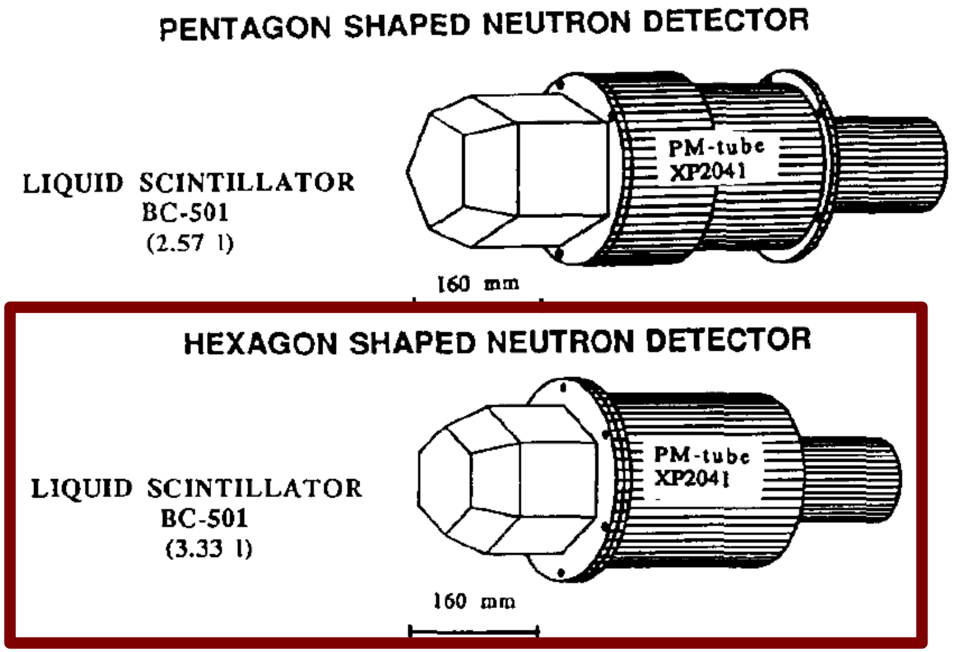

Fig. 1. Schematical drawings of the hexagon and pentagon shaped detectors.

Limited voltage of ADC

=>

Low HV: 1750 V

(Optimal 2200 V)

Still narrow range, but mainly small pulses of interest

S. E. Arnell, et. al, Nucl. Instr. and Meth. A 300 (1991) 303.

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1.3. BARTEK NDE202 PSD Unit

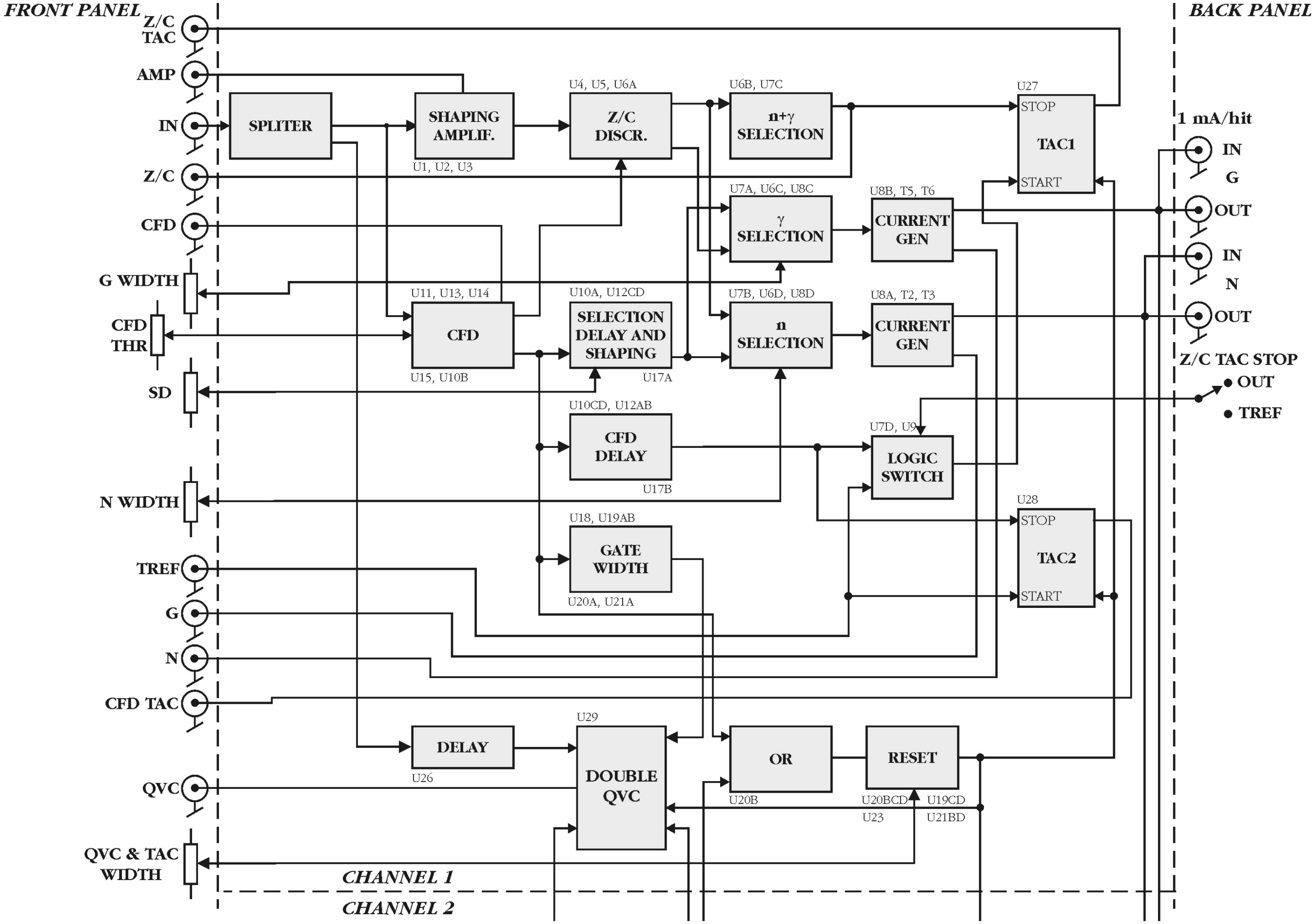
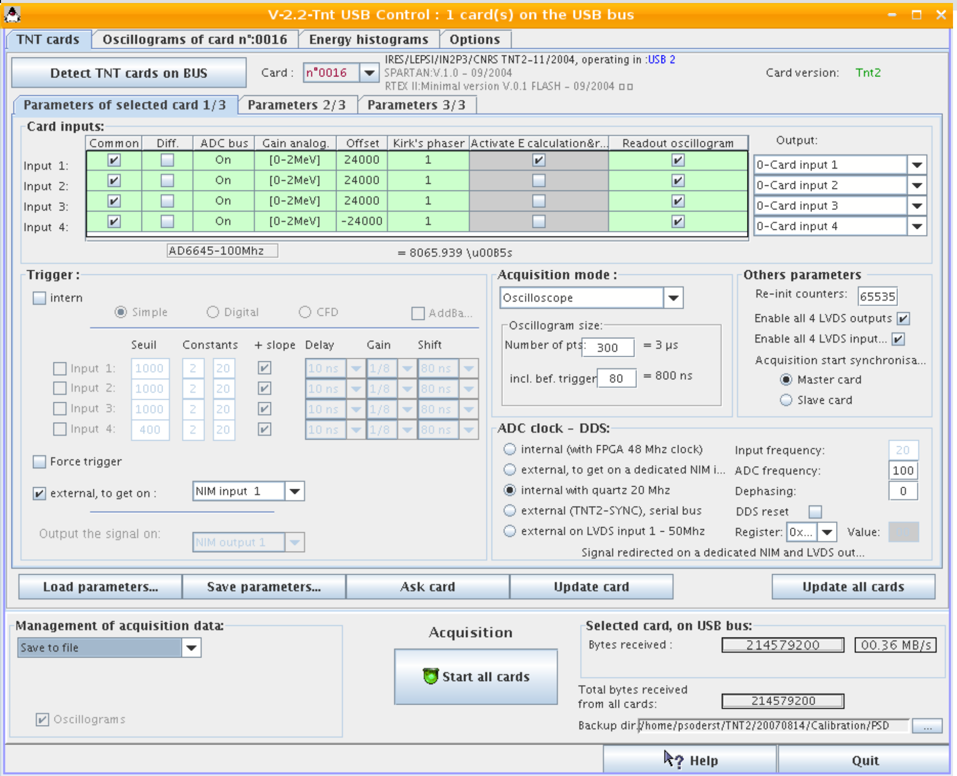


Fig. 1 Block scheme of one channel

1.3. TNT2 FADC



Card : n°0016
IRES/LEPSI/IN2P3/CNRS TNT2-11/2004, operating in :USB 2
SPARTAN:V.1.0 – 09/2004
RTEX II:Minimal version V.0.1 FLASH – 09/2004 □□
Card version: Tnt2

Card inputs:

	Common	Diff.	ADC bus	Gain analog.	Offset	Kirk's phaser	Activate E calculation&r...	Readout oscillogram	Output:
Input 1:	☑	☐	On	[0-2MeV]	24000	1	☑	☑	0-Card input 1
Input 2:	☑	☐	On	[0-2MeV]	24000	1	☐	☑	0-Card input 2
Input 3:	☑	☐	On	[0-2MeV]	24000	1	☐	☑	0-Card input 3
Input 4:	☑	☐	On	[0-2MeV]	-24000	1	☐	☑	0-Card input 4

AD6645-100Mhz
= 8065.939 \u00B5s

Trigger :
☐ intern
● Simple ○ Digital ○ CFD ☐ AddBa...

	Seuil	Constants		+ slope	Delay	Gain	Shift
☐ Input 1:	1000	2	20	☑	10 ns	1/8	80 ns
☐ Input 2:	1000	2	20	☑	10 ns	1/8	80 ns
☐ Input 3:	1000	2	20	☑	10 ns	1/8	80 ns
☐ Input 4:	400	2	20	☑	10 ns	1/8	80 ns

☐ Force trigger
☑ external, to get on : NIM input 1
Output the signal on: NIM output 1

Acquisition mode :
Oscilloscope
Oscillogram size:
Number of pts: 300 = 3 µs
incl. bef. trigger 80 = 800 ns

Others parameters
Re-init counters: 65535
Enable all 4 LVDS outputs ☑
Enable all 4 LVDS input... ☑
Acquisition start synchronisa...
● Master card
○ Slave card

ADC clock – DDS:
○ internal (with FPGA 48 Mhz clock)
○ external, to get on a dedicated NIM i...
● internal with quartz 20 Mhz
○ external (TNT2-SYNC), serial bus
○ external on LVDS input 1 – 50Mhz
Input frequency: 20
ADC frequency: 100
Dephasing: 0
DDS reset ☐
Register: 0x... Value:
Signal redirected on a dedicated NIM and LVDS out...

Management of acquisition data:
Save to file
☑ Oscillograms

Acquisition

Selected card, on USB bus:
Bytes received : 214579200 00.36 MB/s
Total bytes received from all cards: 214579200
Backup dir: /home/psoderst/TNT2/20070814/Calibration/PSD

CAEN

USB connection to PC

Java interface

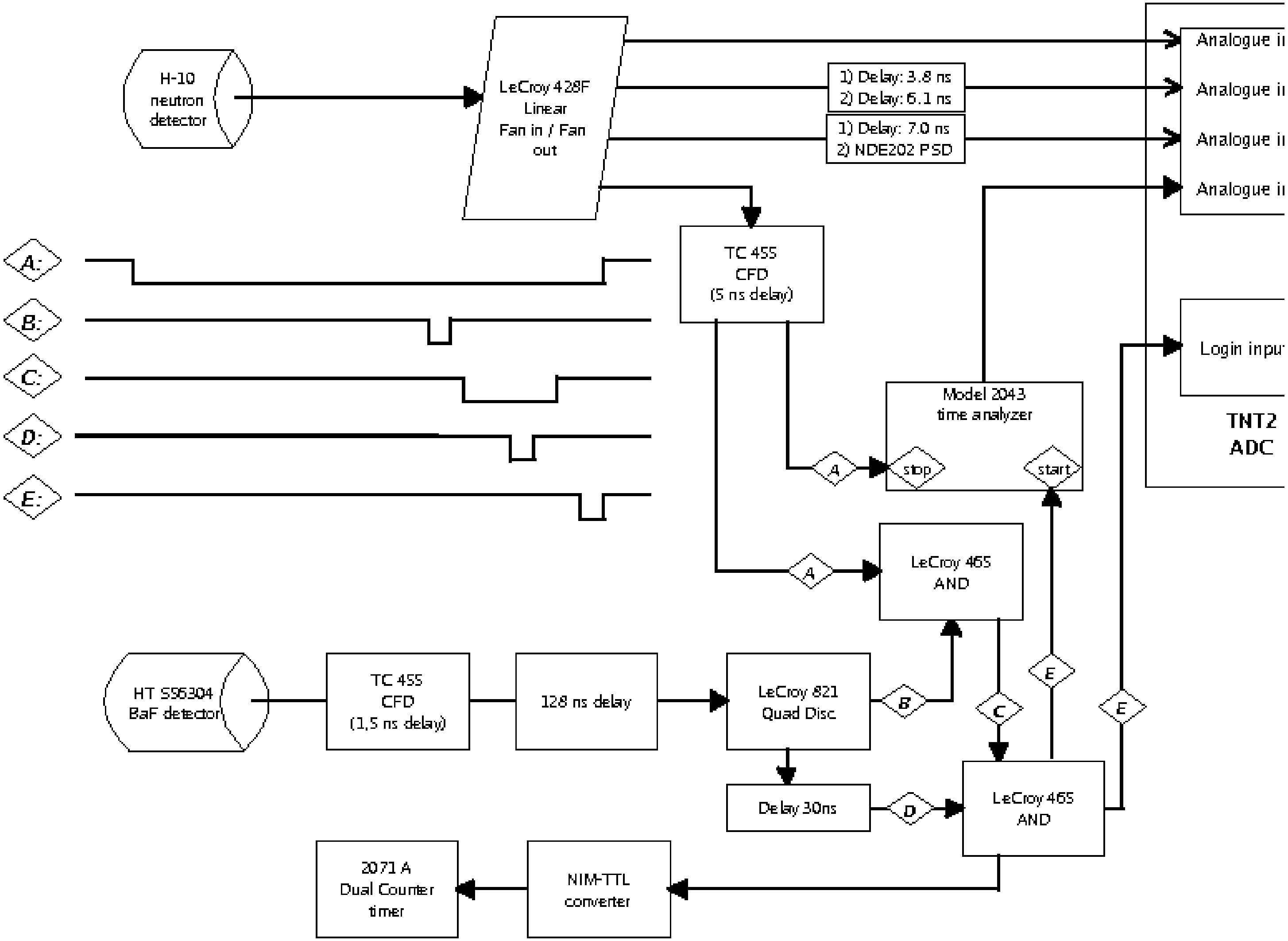
40 MHz analogue bandwidth

+/- 0.62 V @ 50 ohm

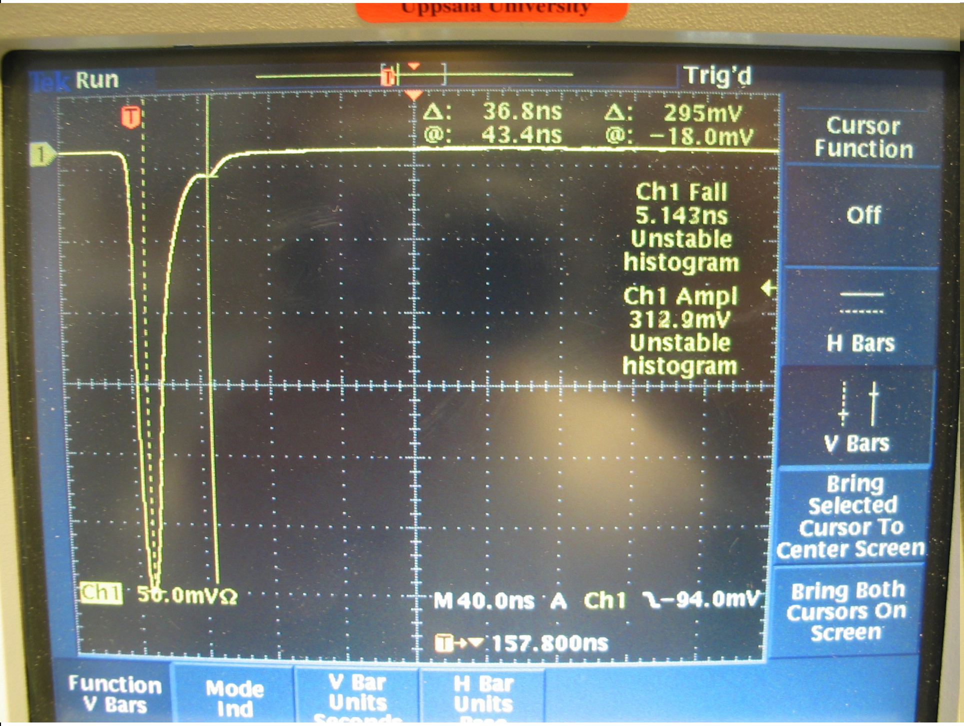
100 MHz & 14 bits

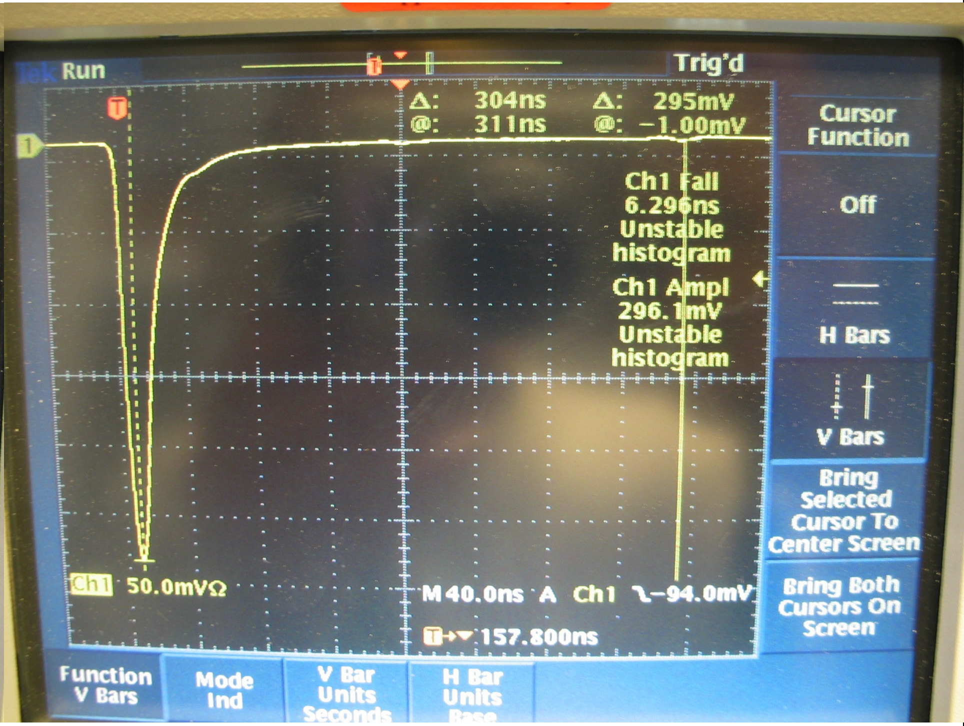
(In our experiment increased up to 300 MHz)

1.4. Electronics

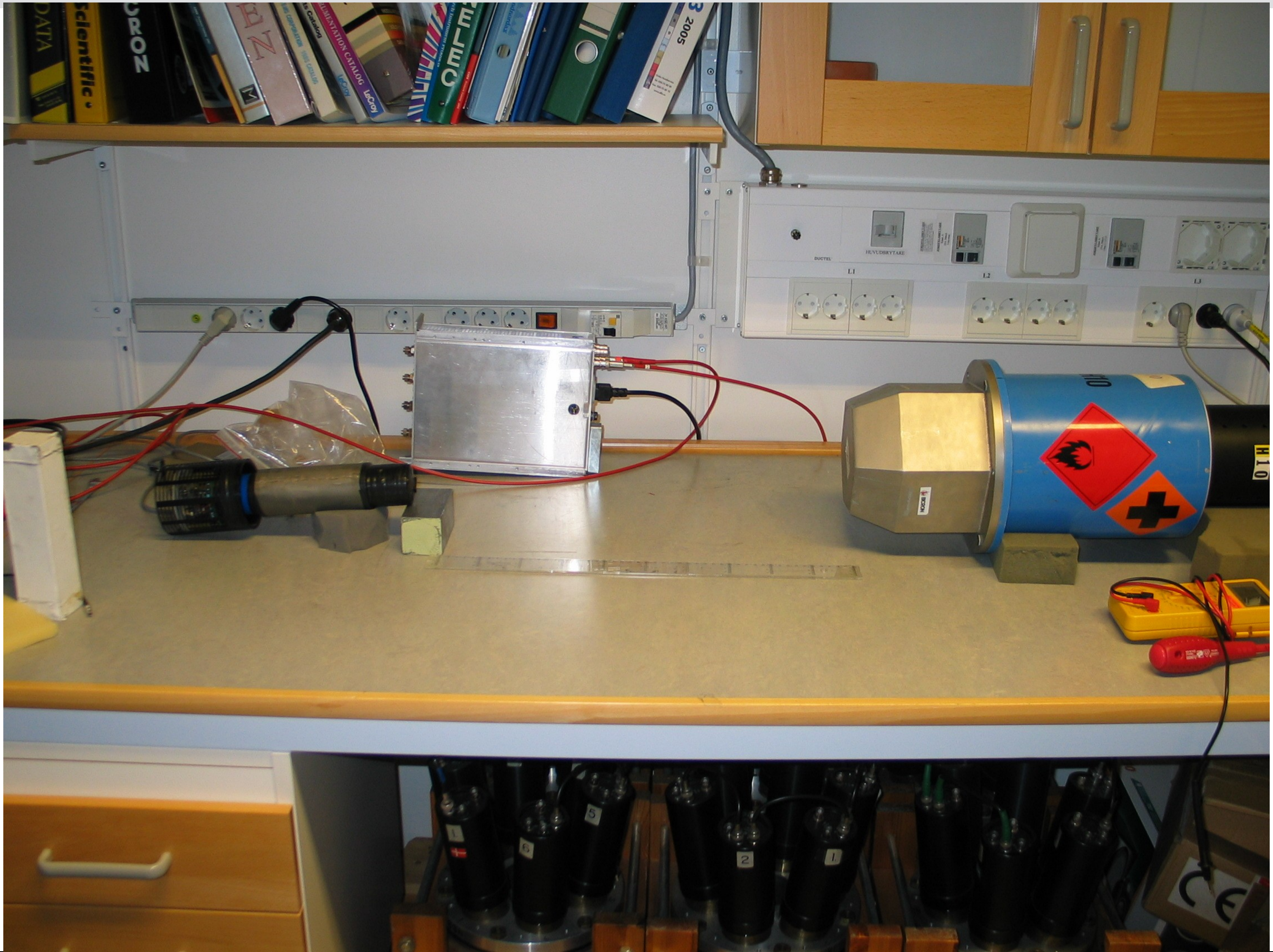


1.5. Reflections


Δ: 36.8ns Δ: 295mV
@: 43.4ns @: −18.0mV
Ch1 Fall
5.143ns
Unstable
histogram
Ch1 Ampl
312.9mV
Unstable
histogram
Ch1 50.0mVΩ M 40.0ns A Ch1 ⤥−94.0mV
157.800ns


Δ: 304ns Δ: 295mV
@: 311ns @: −1.00mV
Ch1 Fall
6.296ns
Unstable
histogram
Ch1 Ampl
296.1mV
Unstable
histogram
Ch1 50.0mVΩ M 40.0ns A Ch1 ⤥−94.0mV
157.800ns

1.6. Setup



2.1. Analysis

1. Base line fit separately for the three channels
2. Gain and time matching
3. Combining the graphs

	Analog	Semi-Digital	Digital
Z/C	NDE202	Folding	Int. rise time
Charge comp.	-	Slow	GDM integral

2.2. Folding

Digitally imitate the analogue Z/C discrimination method

Starts with leading edge on shaped pulse

$$f(t)=p(t)*h(t)=\Sigma\, p(\tau)h(t-\tau)$$

$$h(t)=h_s(t)*h_i(t)*h_d(t)$$

$$h_i(t)=\exp(-t/\tau_i)$$

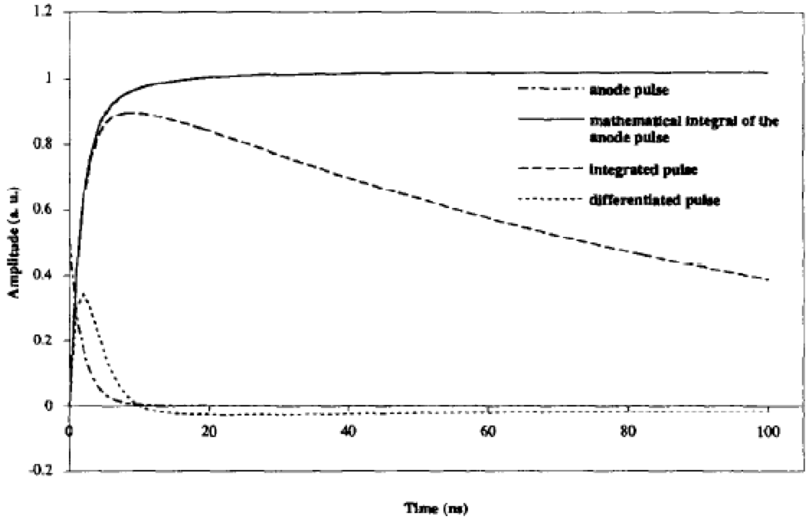


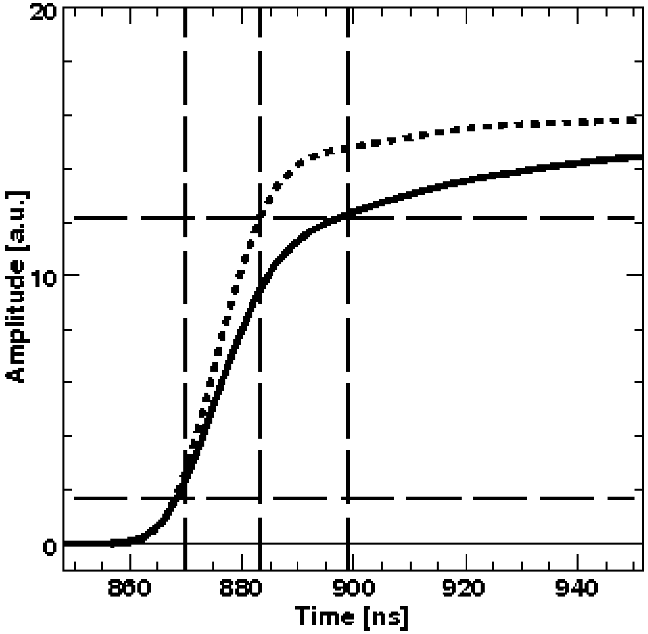
Fig. 9. The waveforms in the figure explain the principle of the zero crossing method, representing the scintillation pulse, its mathematical integral, the output after the RC integration and the result after the CR differentiator.

G. Ranucci, Nucl. Instr. and Meth. A 354 (1995) 389.

2.3. Integrated rise time

Digitally integrate the pulse and take the rise time

Start on 10 % of max



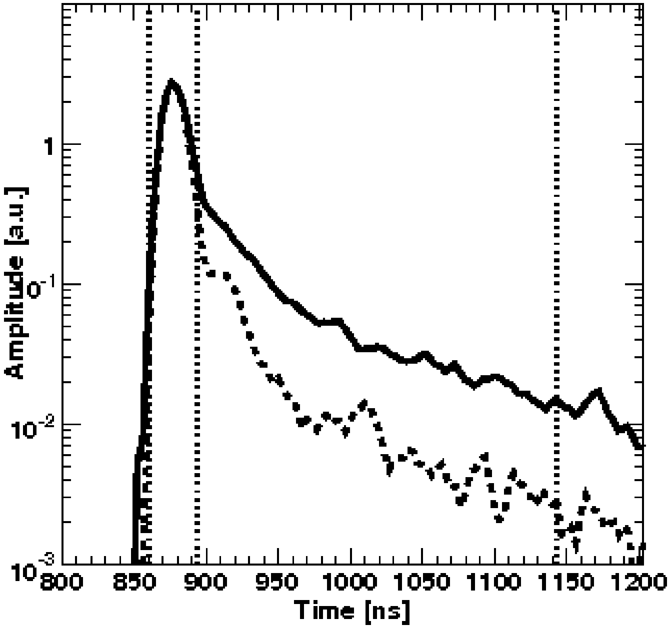
In this case the optimal is found to be about

10 % - 72 %.

2.4. Slow component

Locate the start of the slow decay component, and compare integrals

Starts by leading edge



In this case:

Fast = 0 - 33 ns

Slow = 33 – 283 ns

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2.5. Gatti and De Martini integral

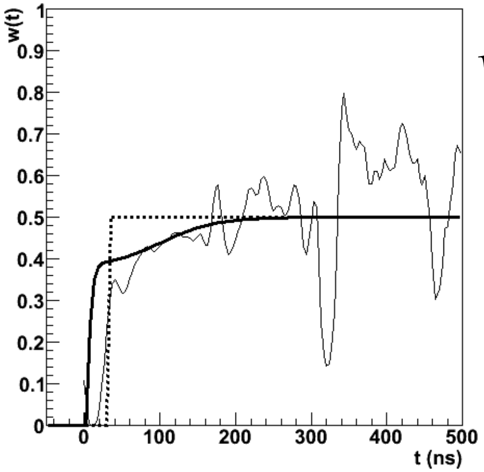
Starts by leading edge

Integrate the entire pulse with a suitable weight

$$S=\int_0^T p(t)w(t)dt$$

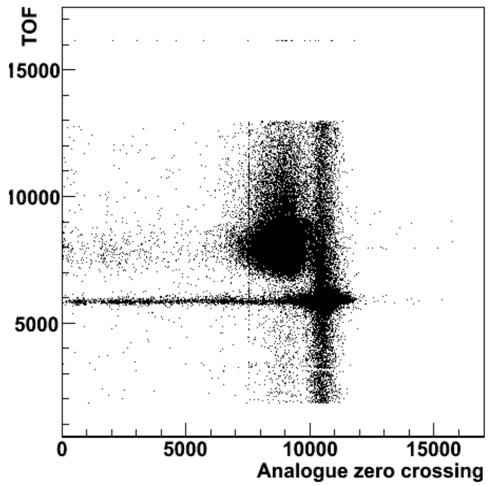
The optimal weight can be shown to be

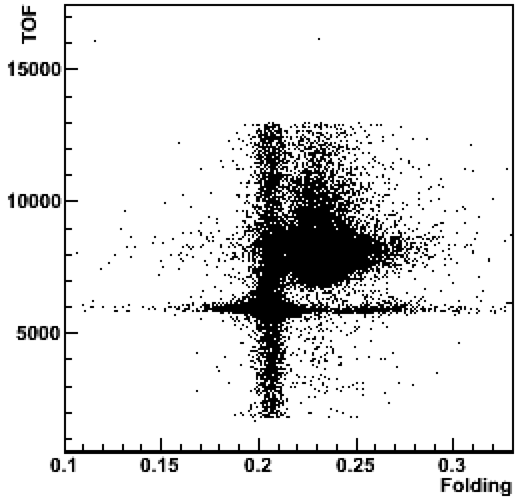
$$w(t)=(n(t)-\gamma(t))/(n(t)+\gamma(t))$$

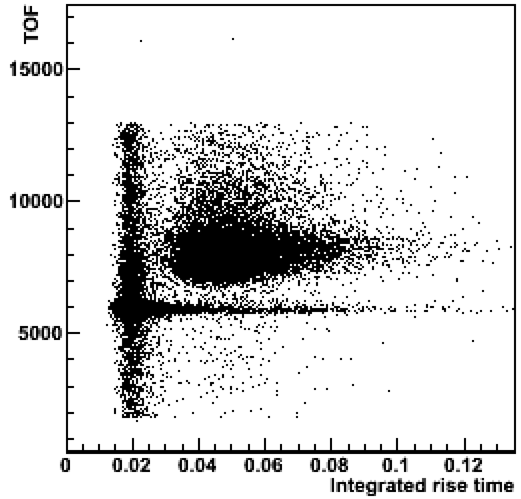


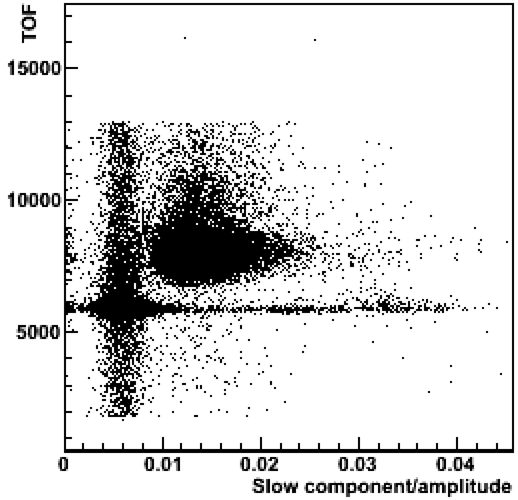
E. Gatti, F. de Martini, in: Nuclear Electronics, Proceedings of International Conference at Belgrade, Vol. II, IAEA, Vienna, 1962, p. 265.

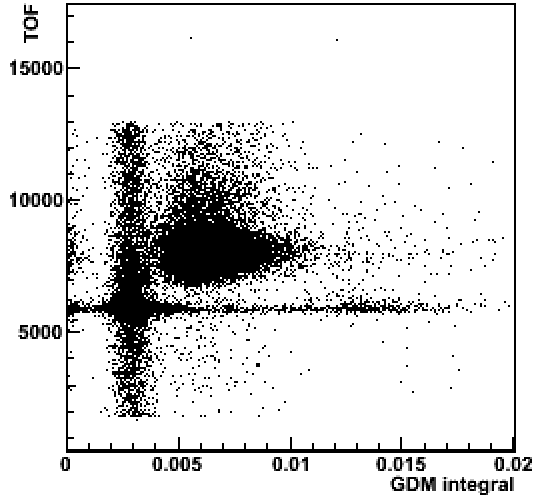
3.1. Results


TOF
15000
10000
5000
0
5000
10000
15000
Analogue zero crossing

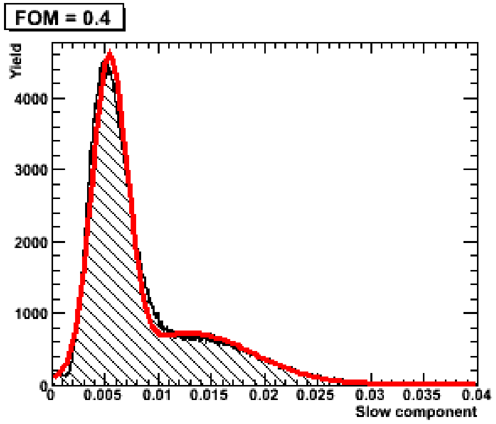

TOF
15000
10000
5000
0.1
0.15
0.2
0.25
0.3
Folding


TOF
15000
10000
5000
0
0.02
0.04
0.06
0.08
0.1
0.12
Integrated rise time

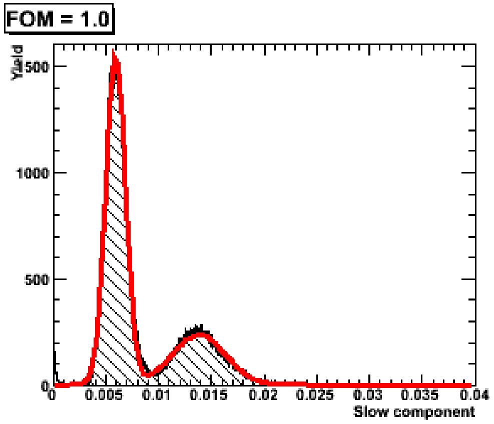

TOF
15000
10000
5000
0
0.01
0.02
0.03
0.04
Slow component/amplitude

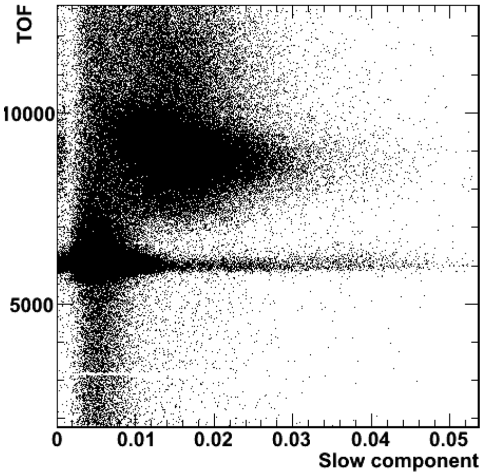

TOF
15000
10000
5000
0
0.005
0.01
0.015
0.02
GDM integral

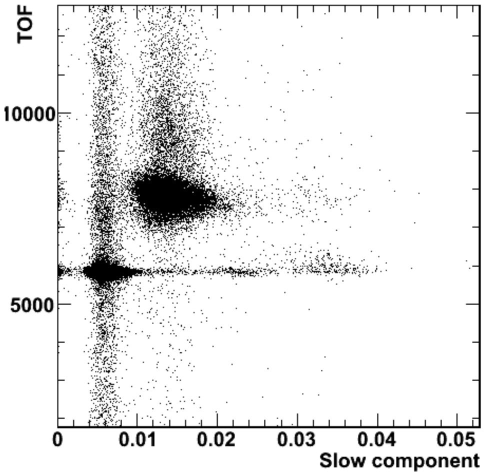
3.2. Figure of Merit


FOM = 0.4

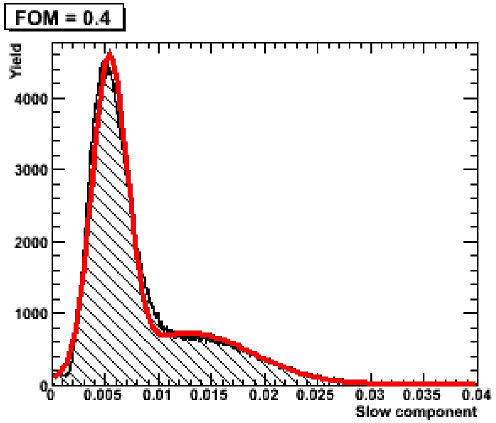
$$FOM = \frac{\left| X_\gamma - X_n \right|}{\left(W_\gamma + W_n \right)}$$


FOM = 1.0

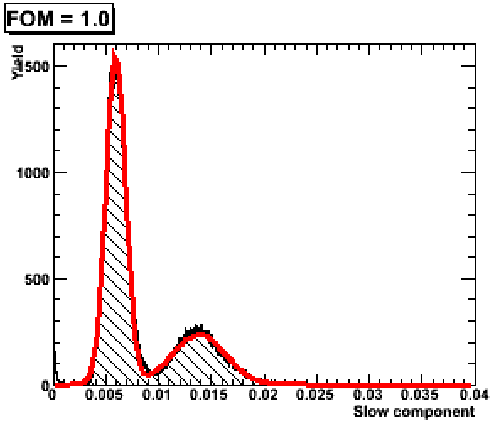


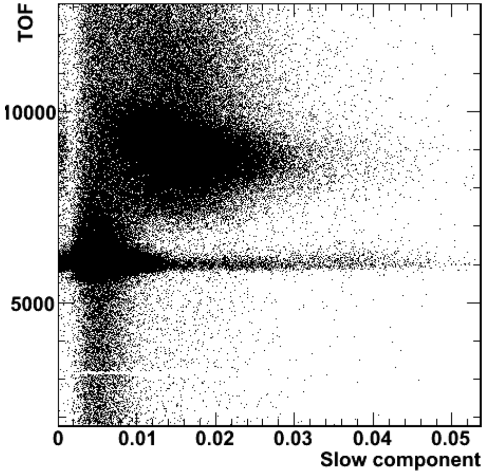


3.2. Figure of Merit



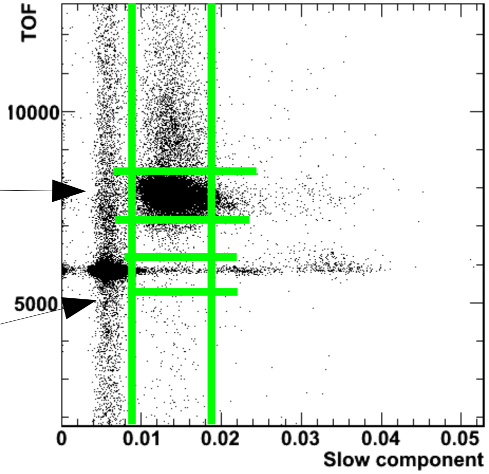
$$FOM = \frac{\left| X_\gamma - X_n \right|}{\left(W_\gamma + W_n \right)}$$



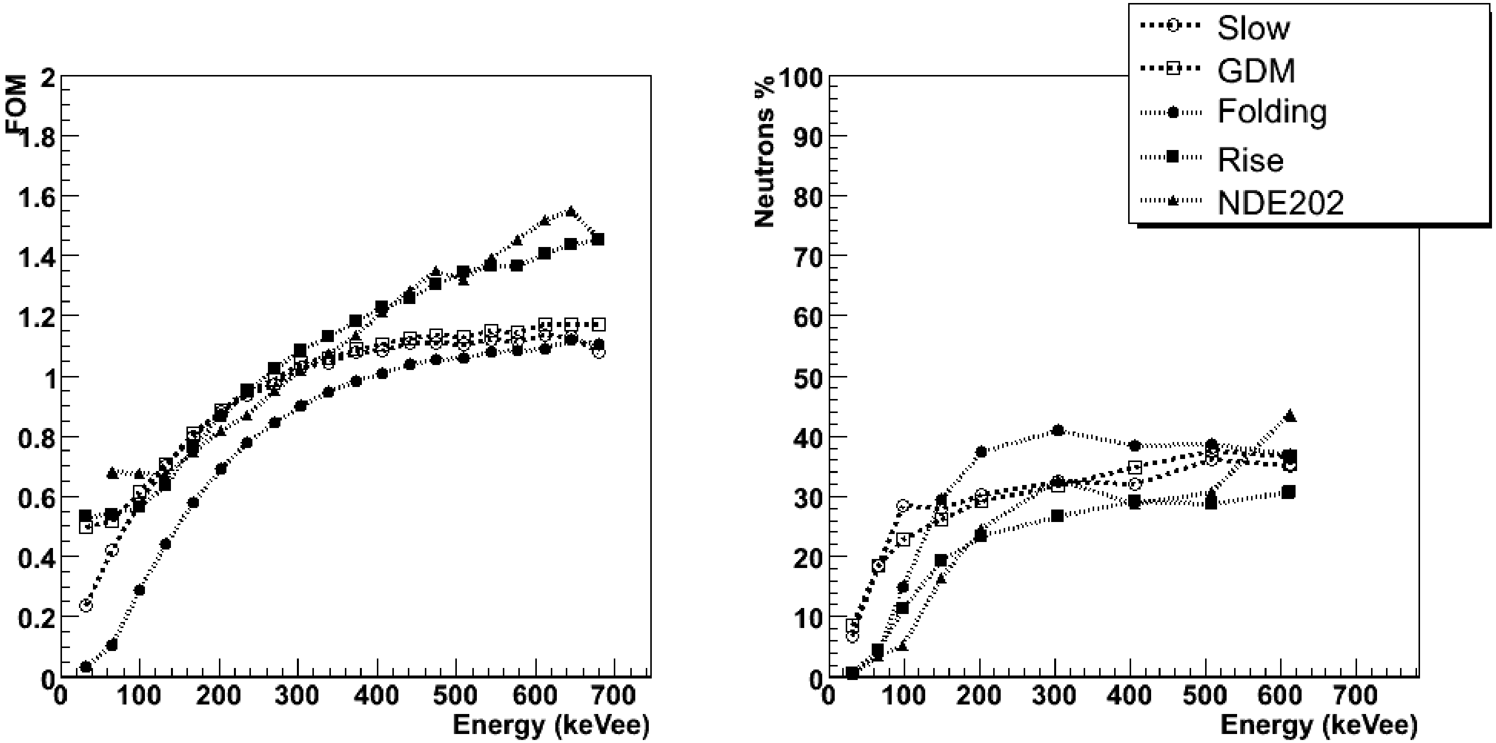


n %

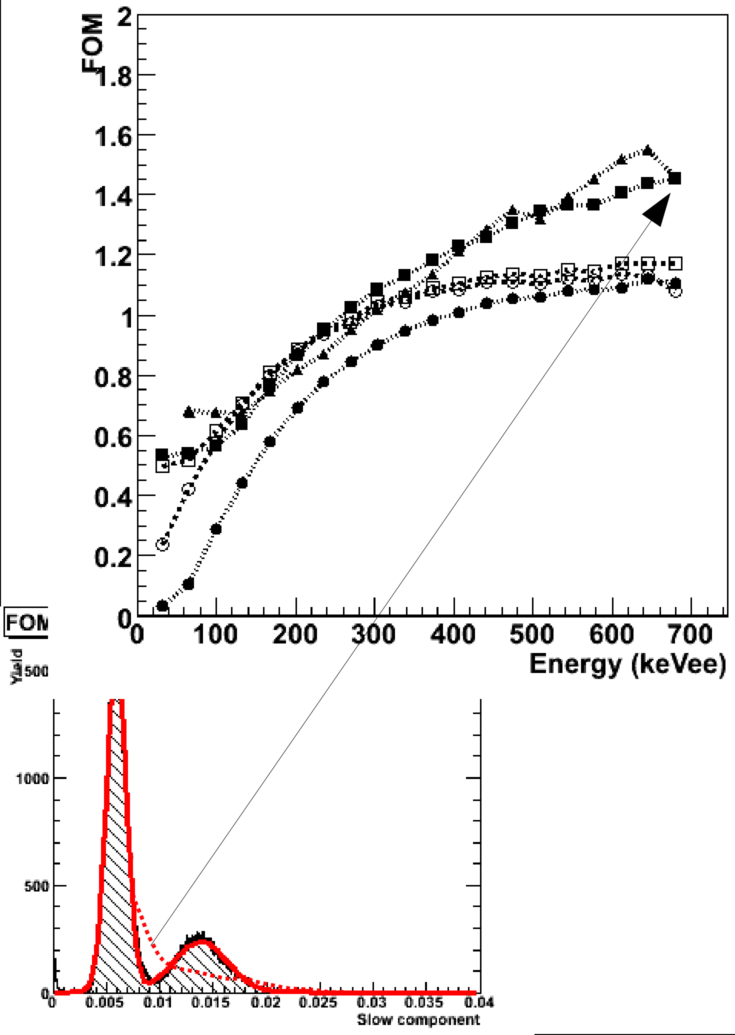
0.1 %

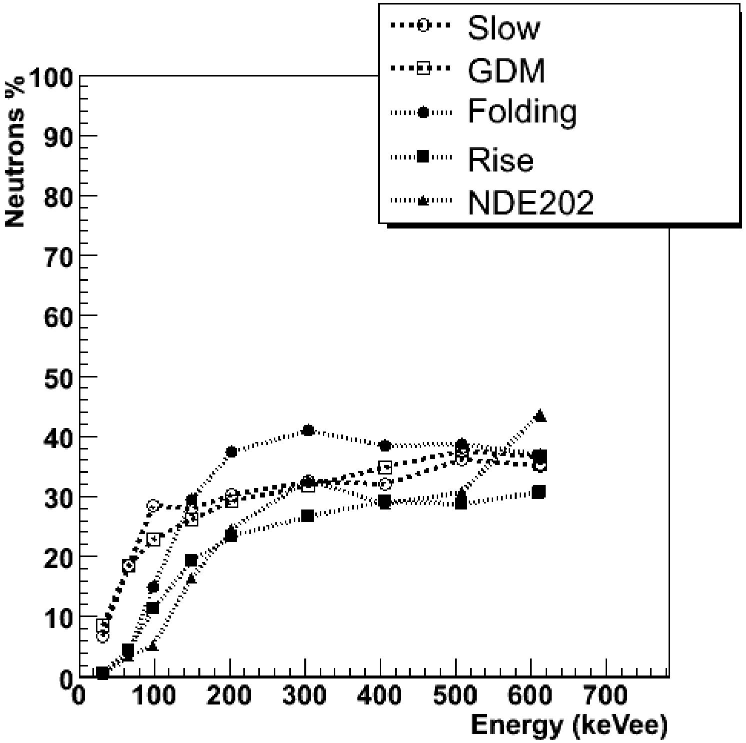


3.3. Different methods



3.3. Different methods





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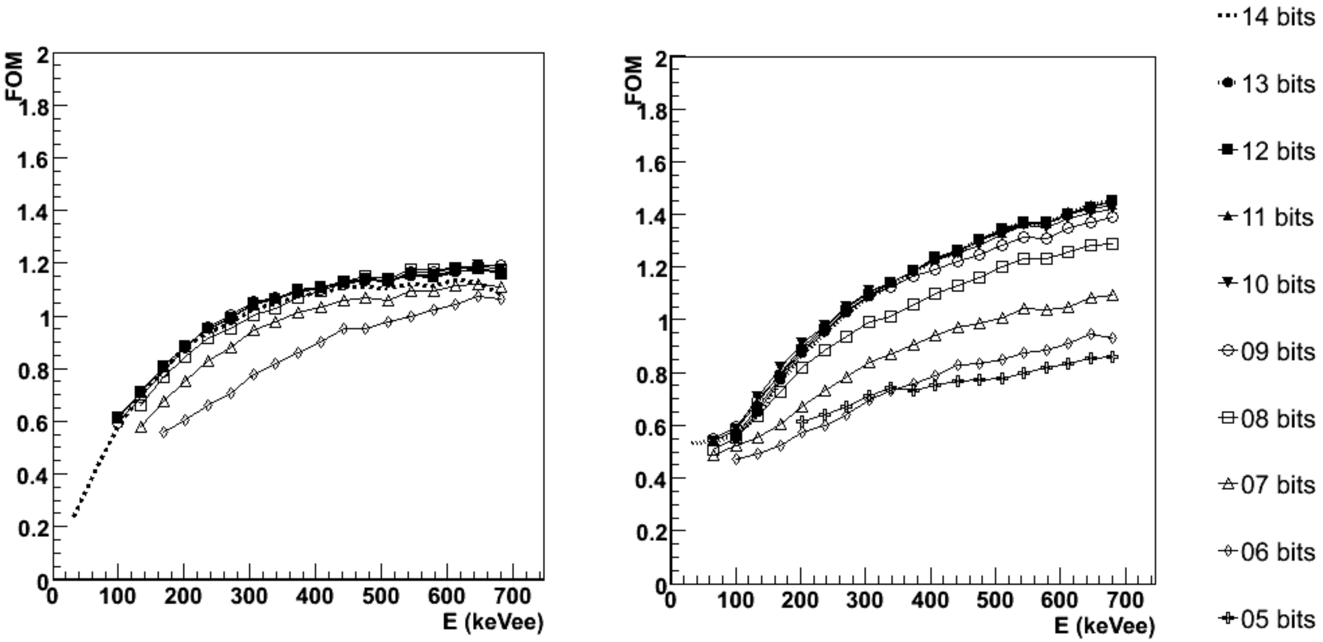
3.4. Reducing bits and frequencies

- Reducing number of bits 14 -> ... -> 5
  - Integer division on the datasets
- Reducing frequencies 300 -> ... -> 75
  - Keeping every other, third, forth, point in the dataset

3.5. Reducing the bits

GDM less sensitive to reduction in bits

9 bits enough for the range up to 700 keV



GDM

Rise

3.6. Reducing the bits

	keV	
Bits	Electron E	Proton E
9	700	1650
10	1400	3200
11	2800	6600
12	5600	13200
13	11200	26200
14	22400	52500

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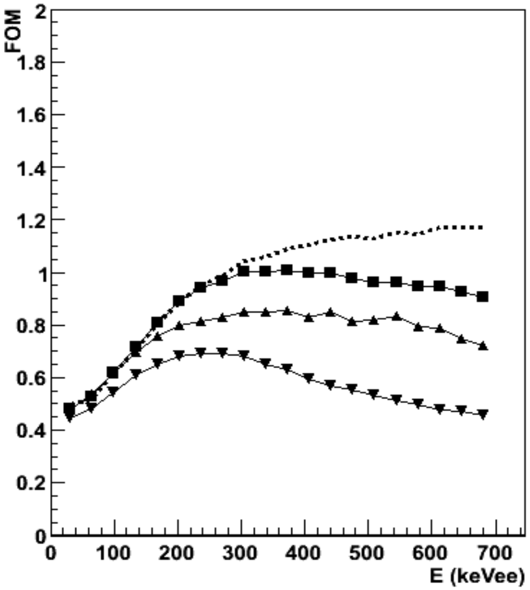
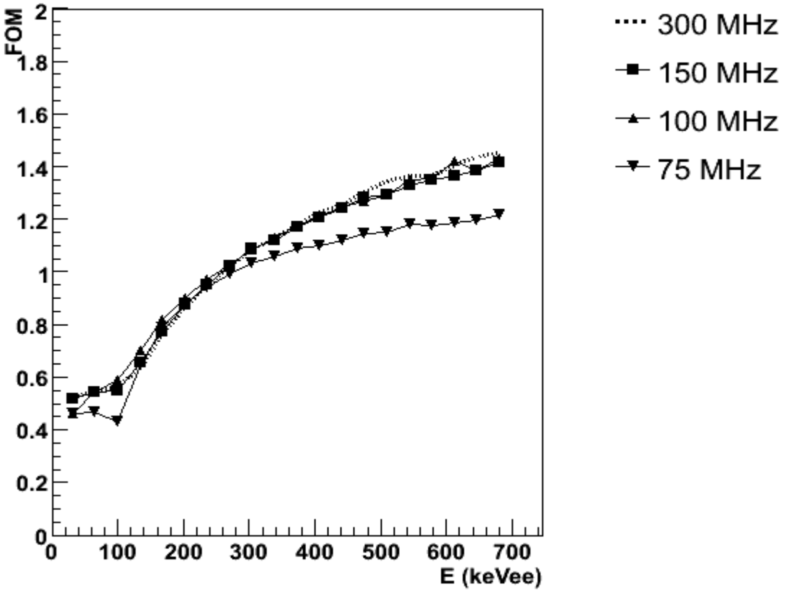
3.7. Reducing the frequencies

Rise less sensitive to reduction in frequencies

GDM not converged?



GDM



Rise

4.1. Outlook

GDM not converged for frequency reduction

Increase the frequencies somehow.

Simulations? (Probably possible/needed only for Charge Comparison)

5.1. Summary

- Methods for PSD in BC501 scintillator
  - 2 x Charge comparison
  - 3 x Zero Cross Over
- Impact of ACD properties on PSD
  - 5-14 bits
  - 75-300 MHz

5.1. Conclusions

- Quite low sampling frequencies can be tolerated if integrated rise time is used
  - Still an open question at which frequency and to what value the GDM converges. Simulations?
- Down to 9 bits can be used for a range of up to 700 (~1700) keV electron (proton) energy. 13 bits for up to 10 (~23) MeV. GDM is less sensitive .