Pulse Shape Analysis

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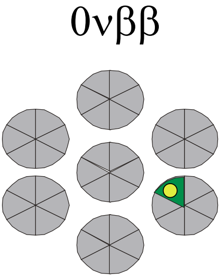
OUTLINE:

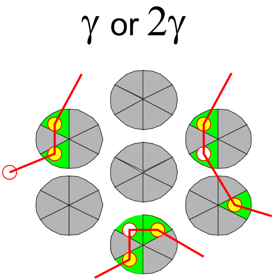
- motivation
- description of the procedure
- results

Motivation: background recognition

lower background → higher sensitivity



localized deposit
single site event

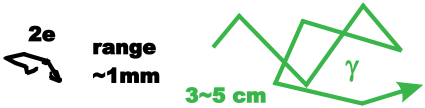


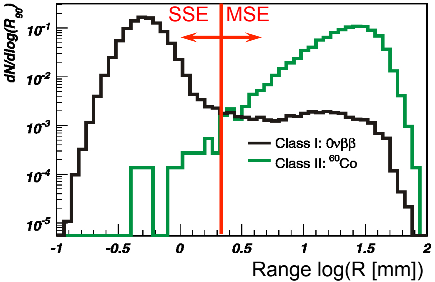
several deposits
multi site event

hardware discrimination: granularity → segmented HPGe detectors

Motivation: background recognition

study of pulse shape details → Pulse Shape Analysis (PSA)



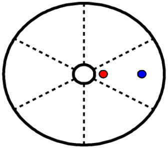


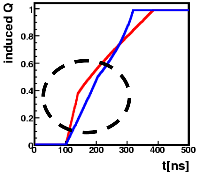
NIM A 570 (2007) 479-486

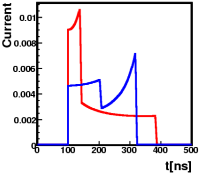
- R_{90}: radius within which 90% of the energy is deposited
- photons: Compton scattering → multiple energy deposits
- $0\nu\beta\beta$: energy deposit locally, within $\approx$ 1 mm

Pulse shape properties

Single site event (SSE):

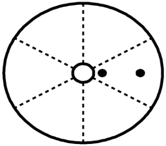


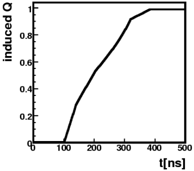


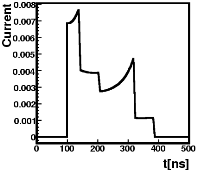


Knee indicates that one kind of charge carrier reaches electrode and stops drifting

Multiple site event (MSE):

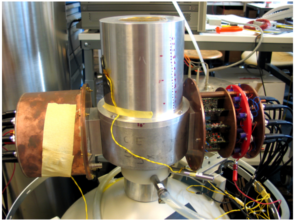


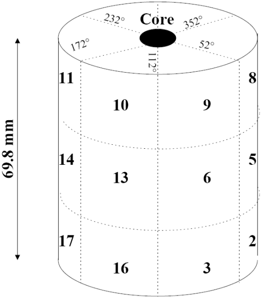




MSE tends to have more complicated pulse structures.

Pulse shape analysis procedure



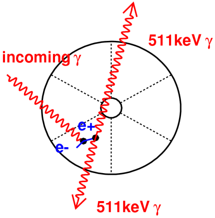


- 18-fold segmented detector
- 100 kBq ^{228}Th source facing the center of segment S
- trigger: $E_s > 1$ MeV

- collection of SSE and MSE samples
- study of PS differences and training of PSA methods
- application of methods to the data sample to identify photon-like and electron like events

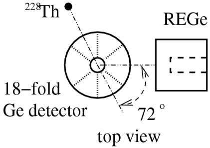
Determining SSE and MSE samples

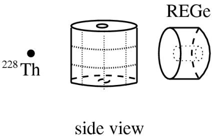
Double escape events (DEP)



- E_γ = 2615 keV (from ^{208}Tl)
- pair production, e^+ annihilation
- $E_{core} = (1593 \pm 5)$ keV
- energy deposit on a millimeter scale

Single Compton Scattering events(SCS)





- tagging photon scattered at $72^\circ \rightarrow E_\gamma = 575$ keV
- electron recoil: $E_{core} \approx 2040$ keV

Determining SSE and MSE samples

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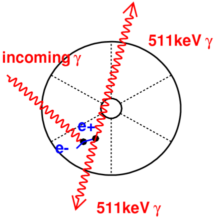


- $E_\gamma = 2615$ keV (from ^{208}Tl)
- pair production, e^+ annihilation
- $E_{\rm core} = (1593 \pm 5)$ keV
- energy deposit on a millimeter scale

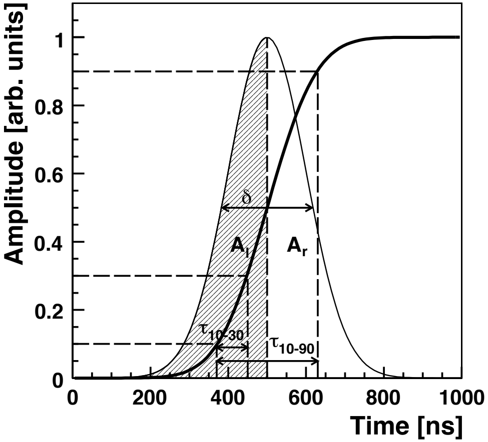
MSE

- photon from ^{212}Bi: 1620 keV, multiple scattering (Γ_1 sample)
- single escape peak: 2103 keV

Likelihood method

Input parameters:

- risetime τ_{10-30}
- risetime τ_{10-90}
- left-right asymmetry $\zeta = \frac{A_l - A_r}{A_l + A_r}$
- δ: FWHM of the current pulse



Likelihood method

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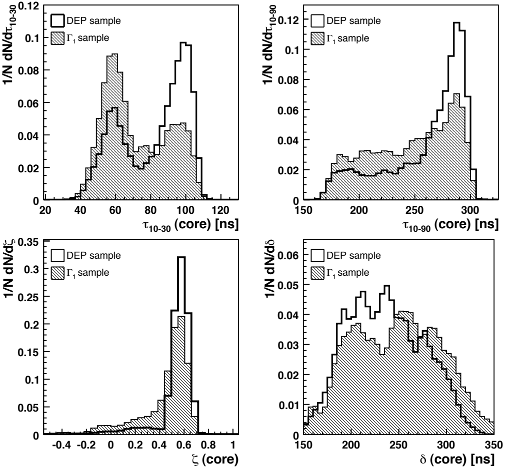
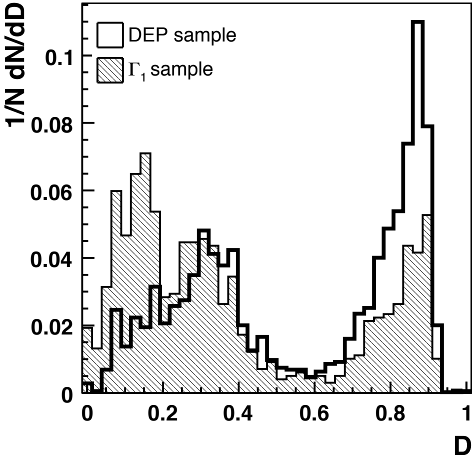


Likelihood method

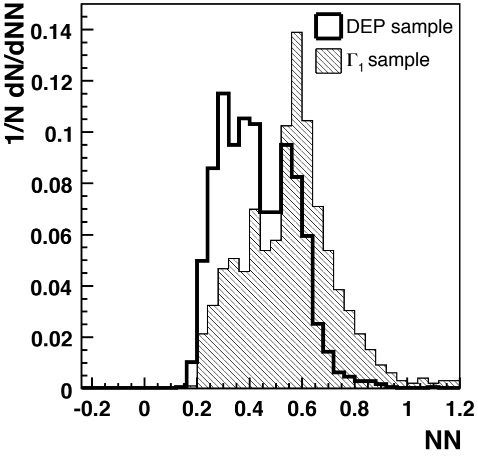
Input parameters:

- risetime τ_{10-30}
- risetime τ_{10-90}
- left-right asymmetry $\zeta = \frac{A_l - A_r}{A_l + A_r}$
- δ: FWHM of the current pulse
- construct likelihood discriminants (D)



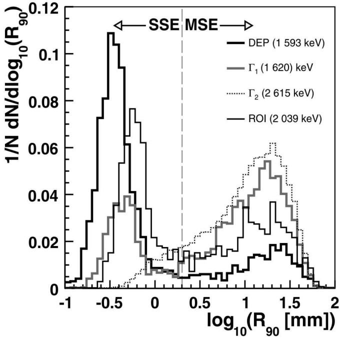
ANN method

- 40 bins of normalized pulses →40 input neurons
- 40 hidden neurons
- 1 output neuron (NN)
- network trained with DEP (NN=0) and Γ_1 (NN=1) samples
- 1000 iterations



Distinction between electron-like and photon-like events

- preselection of events by applying a single segment cut
- D^{cut} (likelihood method) and NN^{cut} (ANN method) chosen to keep 90% of the events in the DEP training samples
- DEP not pure: fraction of SSE event (X_{SSE})in DEP and Γ_1 samples estimated on MC sets by requiring R_{90} <2 mm



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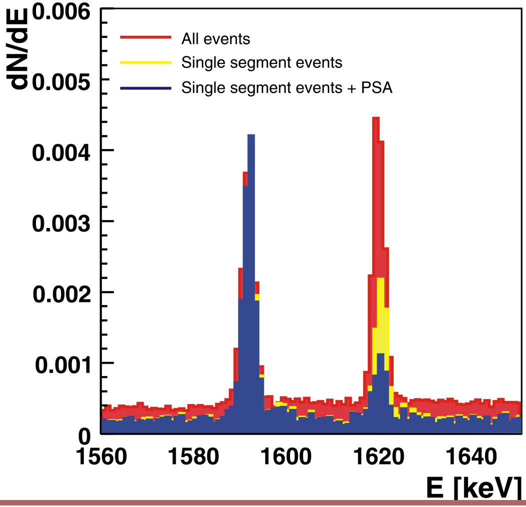
- DEP not pure: fraction of SSE event (X_{SSE})in DEP and Γ_1 samples estimated on MC sets by requiring $R_{90} < 2$ mm
- fraction of events identified as electron-like ($\pm 2\%$):

	SSE (%) - likelihood	SSE (%) - ANN	X_{SSE}
DEP (1593 keV)	89.3	89.3	89
Γ_1 (1620 keV)	67.1	54.1	55

Neural Network method has the best performance!

Distinction between electron-like and photon-like events

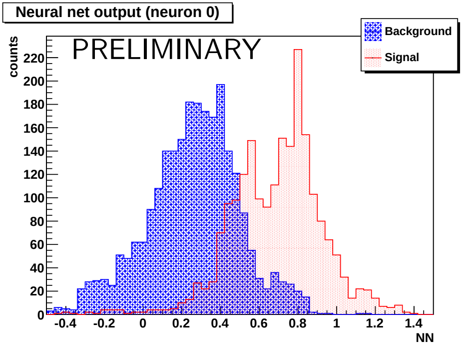
Spectrum from a ^{228}Th source, core electrode and ANN analysis:



- single segment cut suppress by a factor ≈ 3 the 1620 keV line
- further suppression by a factor 1.5 in the 1620 keV peak due to PS analysis

Training the method with SIMULATIONS

- analysis performed also with single Compton scattering data
- problem: obtaining a clean training and testing sample in data
- solution: pulse shape simulation!
- PS package now existing
- ANN analysis with clean simulated samples!
- analysis ongoing



Conclusions

- electrons and multiple scattered photons can be distinguished by the shapes of the induced pulses
- pulses read from the core electrode → in future more information through segment pulses and mirror charges
- PS analysis based on two different methods has been tested
- methods to be trained with SSE and MSE samples as pure and homogeneous as possible → simulations
- strong selection by the single segment cut
- Artificial Neural Network shows the best performance
- ANN suppresses by circa a factor 1.5 photon peaks surviving the single segment cut