Alpha-Beta Discrimination in LENA

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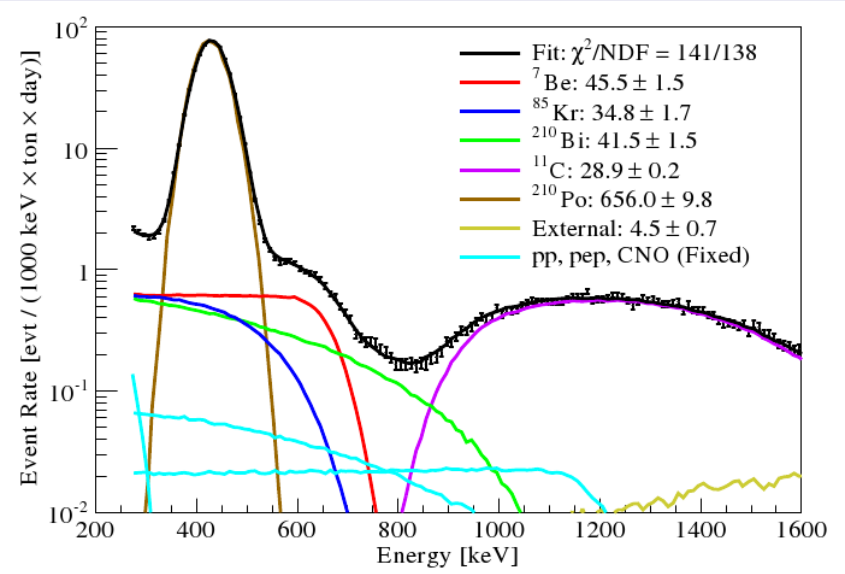
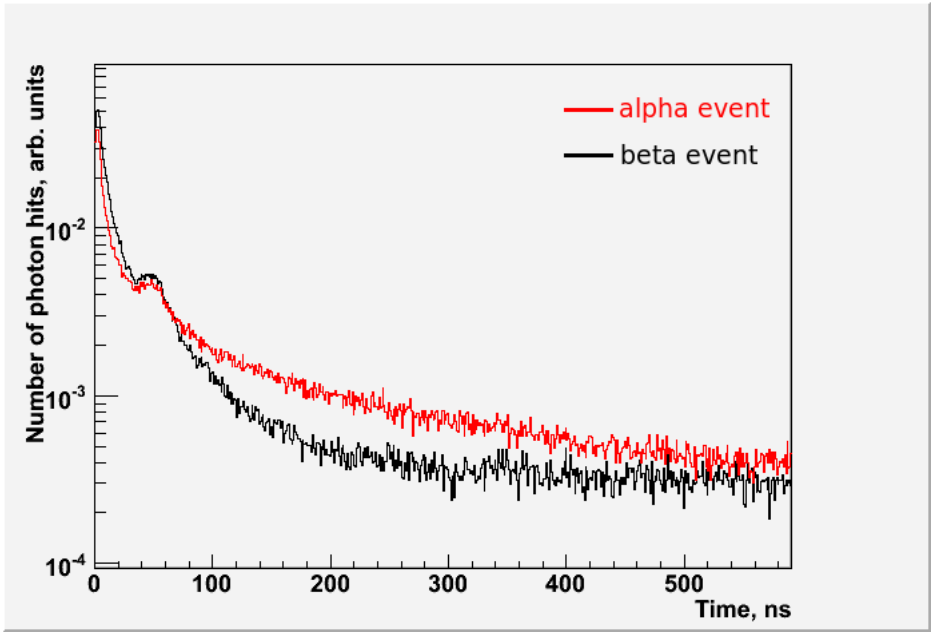
Energy spectrum in Borexino



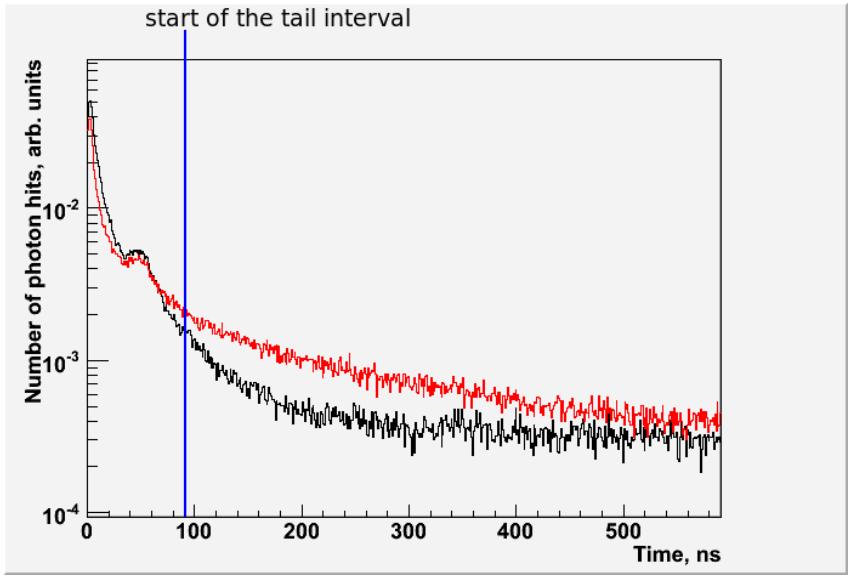
- Alpha decays from ^{210}Po is a background for the ^{7}Be detection
- Alpha events feature a different pulse shape than electron recoil (beta) events
- Possibility to identify alpha events

Typical Pulse Shape of Alpha and Beta Events



- The photon emission process can be described by the exp. decays of a fast and several slow components
- Alpha particles emit more light in the slow components than electrons

Tail-to-total Method



- The pulse is integrated in two different intervals:
  - The tail interval encompasses the last part of the pulse
  - The total interval includes the whole pulse
- Subsequently the ratio between these two intervals is calc.
- α events feature a higher tail-to-total ratio than beta events

Gatti Method

- The average pulse shapes from known α and β events are calculated
- A set of weights is calculated from those pulse shapes

$$\mathrm{P_i} = \frac{\alpha_\mathrm{i} - \beta_\mathrm{i}}{\alpha_\mathrm{i} + \beta_\mathrm{i}}$$

- The gatti parameter is calculated by the following formula:

$$\mathrm{G_S} = \sum_\mathrm{i} \mathrm{P_i S_i}$$

- The gatti parameter depends on the particle type

- The dimensions of LENA are larger than the attenuation lenght of the scintillator

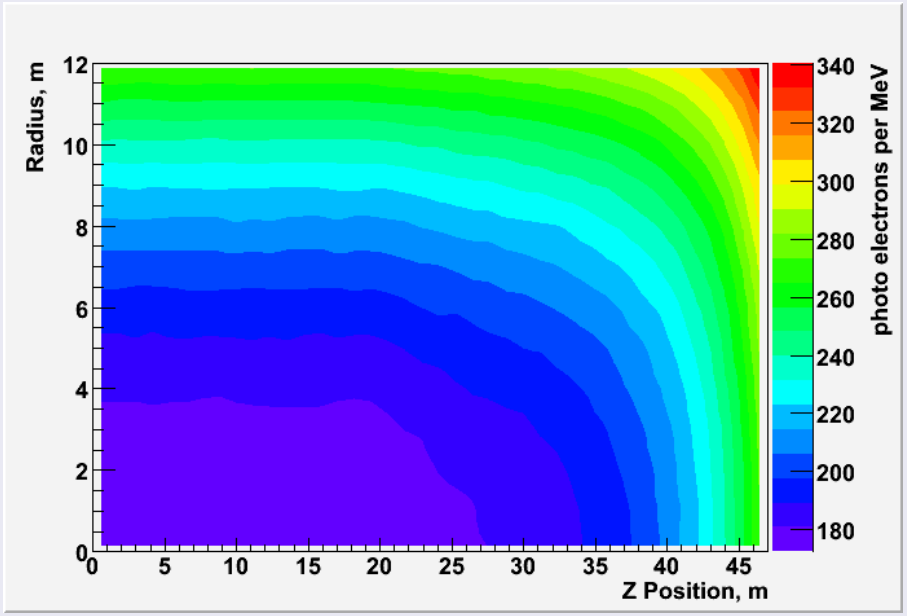
- Photoelectron yield and pulse shape depend on the event position
- Calibration of the simulated detector is necessary to get the position dependency of the photoelectron yield, the tail-to-total ratio and the gatti parameter

Simulation Setup

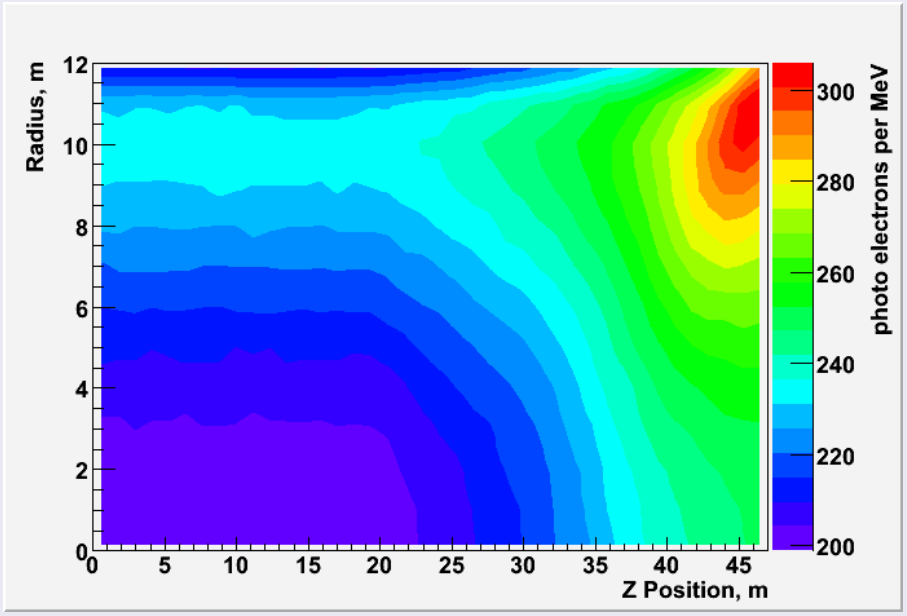
- Two calibration runs at 300 keV and 500 keV visible energy for electrons and alphas
- $1.56 \cdot 10^6$ events at 624 different positions in the fiducial volume (R<12 m, $|z|$<47 m)
- Calibration points homogeneously distributed with 1 m dist.
- Simulation was performed with and without Winston cones
- Tail interval was set to [90 ns, 600 ns]
- Only PMT hits with a distance to the event position of less than 30 m were saved to suppress dark counts (1% loss of photon hits, 63% dark count reduction)

Position Dependent Photoelectron Yield

Simple detection mode

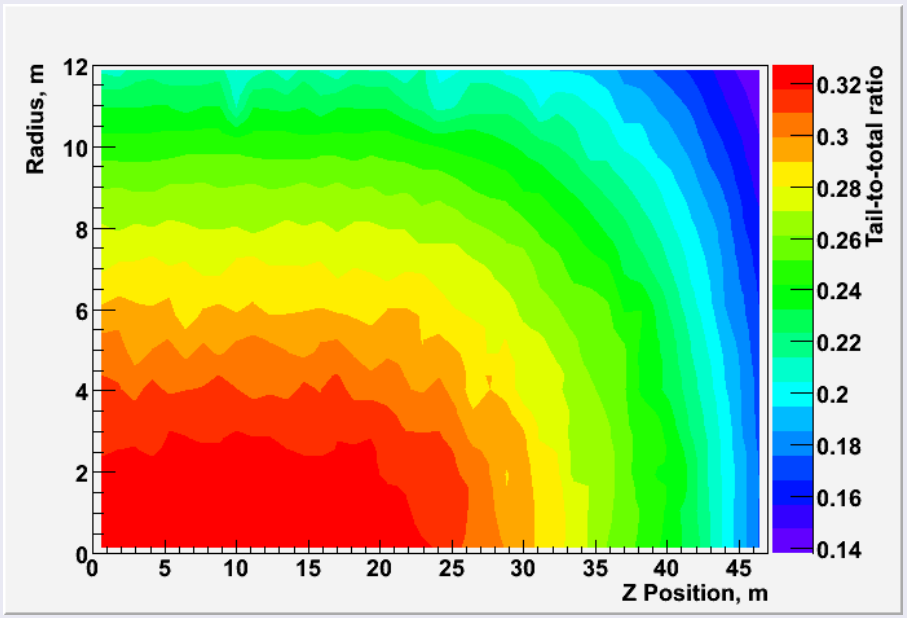


Winston cones mode

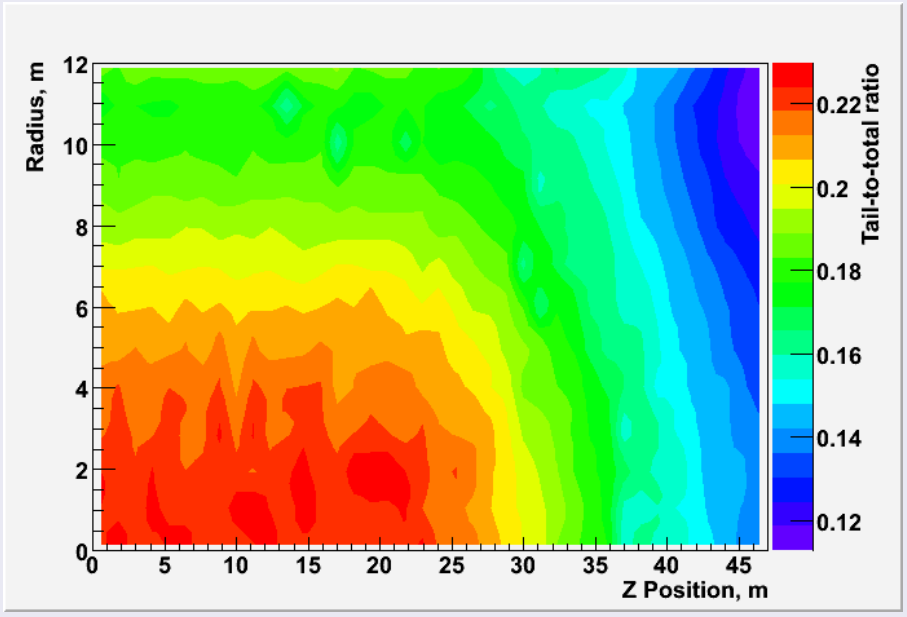


Position Dependent Tail-to-total Ratio

Simple detection mode



Winston cones mode



Energy Reconstruction and Pulse-Shape Discrimination

- Determine the average photoelectron yield at each calibration point by fitting a gaussian
- Determine the tail-to-total and gatti parameter cut values at each calibration position, so that 95% or 99% of all beta events are accepted
- Calculate the photoelectron yield, the tail-to-total and the gatti parameter cut values by a linear fit of the expected values at the adjacent calibration points

Simulation Setup

- $5 \cdot 10^5$ 5.3 MeV alpha events (^{210}Po) were simulated
- Events were homogenously distributed over the fiducial volume (R$<$12 m, $|z|<$47 m)
- For each event, the tail-to-total ratio and the gatti parameter were calculated, and compared with the cut values
- LAB, oxygenated LAB ($\mathrm{LAB_{oxy.}}$), PXE and unpurified PXE ($\mathrm{PXE_{unpur.}}$) were used as scintillators

Discrimination Efficiency for LAB

Tail-to-total method

β-acceptance	discrimination eff. simple det. mode	discrimination eff. winston cones mode
95.0 %	95.3 %	98.3 %
99.0 %	85.9 %	93.1 %

Gatti method

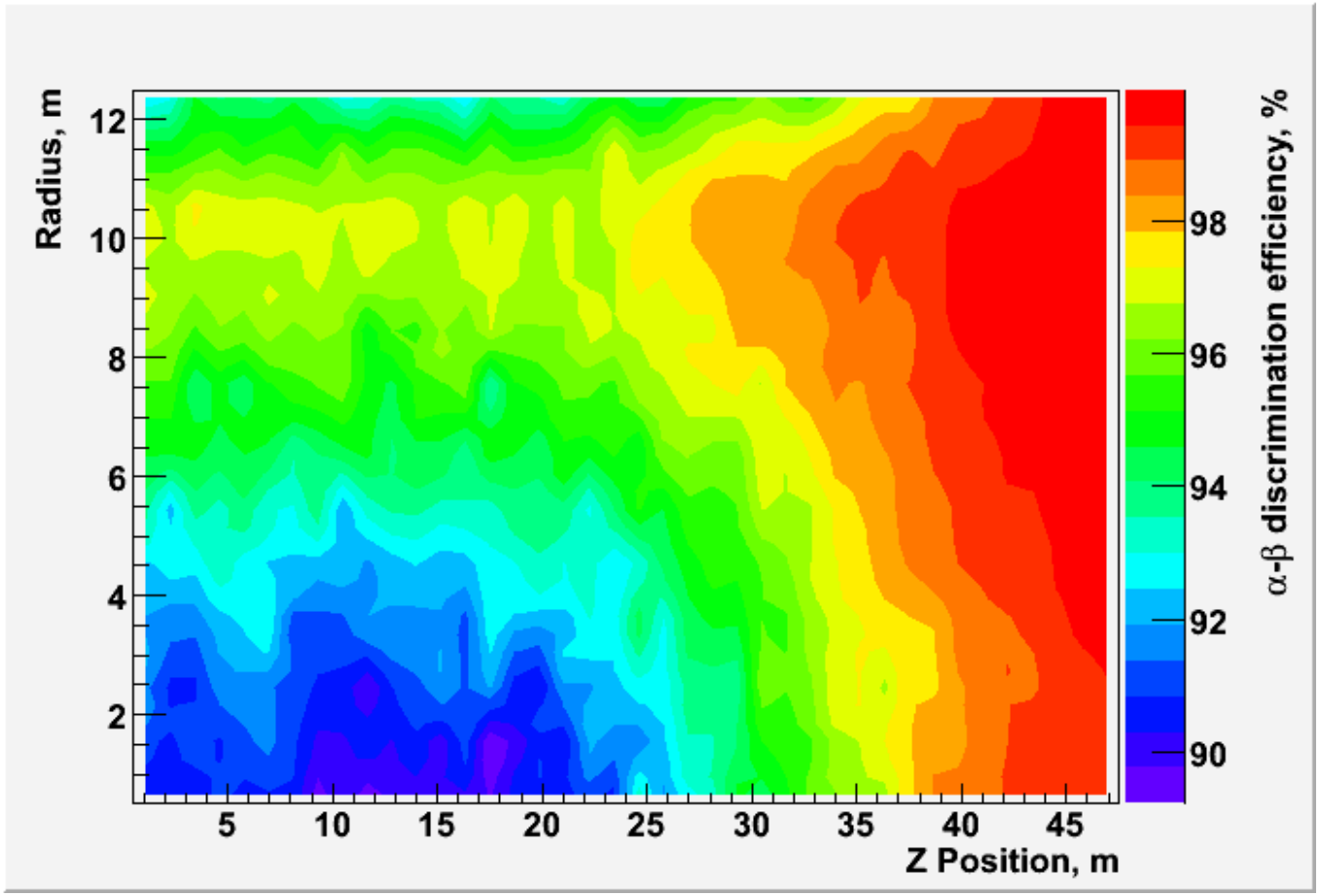
β-acceptance	discrimination eff. simple det. mode	discrimination eff. winston cones mode
95.0 %	97.5 %	99.3 %
99.0 %	90.7 %	96.6 %

Dependency of the Disc. Eff. on the Dark Noise Rate (LAB)

Dark noise rate per 8″ PMT	β-acceptance	discrimination eff.
0.5 kHz	99.0 %	98.8 %
1.0 kHz	99.0 %	97.2 %
2.5 kHz	99.0 %	88.0 %
5.0 kHz	99.0 %	74.1 %

- The discrimination efficiency is strongly dependent on the dark noise rate
- The rate of latepulses and afterpulses have only a minor effect

Position Dependency of the Discrimination Eff. (LAB)



Comparison between the Disc. Eff. of LAB and PXE

Scintillator	β-acceptance	discrimination efficiency
LAB	99.0 %	96.6 %
$\mathrm{LAB_{oxy.}}$	99.0 %	53.7 %
PXE	99.0 %	18.1 %
$\mathrm{PXE_{unpur.}}$	99.0 %	14.1 %

- The discrimination efficiency of LAB is much better
- Oxygen contamination severely affects the discrimination eff.

- Alpha events from ^{210}Po decays can be rejected with 96.6% efficiency at 99.0% beta acceptance if LAB is used
- If LAB is contaminated with oxygen, the discrimination efficiency drops to 53.7%
- If PXE is used, the discrimination efficiency drops to 18.1%
- The discrimination efficiency depends strongly on the dark noise rate
- The effects of latepulses and afterpulses are negligible

Backup slides