# Gas electron tracking detector for beta decay experiments

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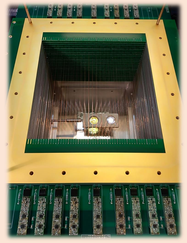
## INTRODUCTION

For 3D-tracking and identification of low-energy electrons a new type of gas-based detector was designed that minimizes scattering and energy loss. The current version of the detector is a combination of a plastic scintillator, serving as a main energy detector, event trigger and a hexagonally structured multi-wire drift chamber (MWDC), filled with a mixture of helium and isobutane gas. The drift time information is used to track particles in the plane perpendicular to the wires, while a charge division technique provides spatial information along the wires.

The gas tracker was successfully used in the miniBETA project as a beta spectrometer for the measurement of the weak magnetism form factor in nuclear beta decay. The precision of the three-dimensional electron tracking in combination with low-mass, low-Z materials and monitoring of backscattering from the electron energy detector, facilitated a reduction of the main systematics effects.

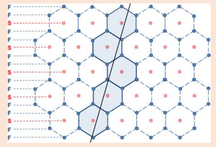
## Multi-Wire Drift Chamber (MWDC)

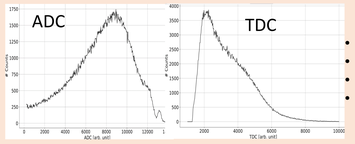
- **Recognize back-scattered** electrons as *V-tracks*
- **Reduce background** from *gamma's and cosmic muons*
- **Correct for gain non-uniformity** by reconstructing the scintillator hit position



### MWDC properties

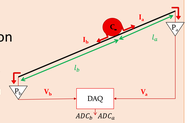
- Mixture of **Helium** and **Isobutane**
- **Low pressure** (*300-600mbar*)
- **Hexagonal shape** of the cells
- **Signal wires** at *~2000V*
- **Field wires** at *ground-level*

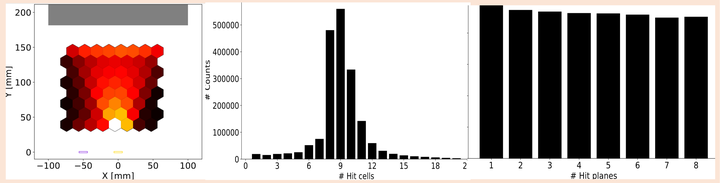


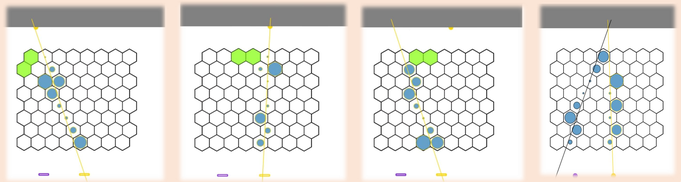



### Electron tracking

- Pattern recognition
- XY from drift time calculation
- ( x,y ~ 0,5 mm)
- Charge division method for vertex reconstruction in 3D ( z ~6 mm)



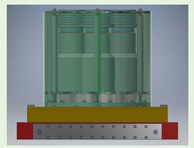
Pattern recognition eliminates the background

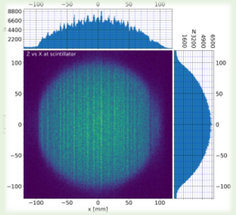
## Scintillator

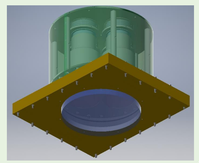
Plastic EJ-204 with cylinder shape: h=30mm, r=100mm attached to the lightguide with readout by 4 PMTs

### Advantages

- Low **backscattering coefficient** (~2–7%)
- Low amount of **brehmsstrahlung** (<10%)





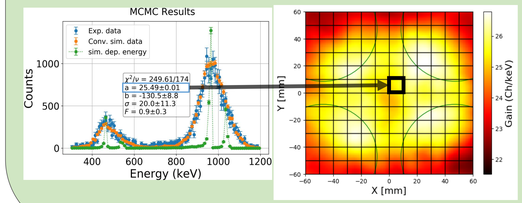



## 2D-gain map

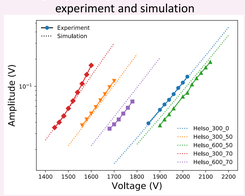
- Scintillator calibration with **Bizmuth-207**:
  → *2 e⁻ conversion peaks at ~500 keV and 2 peaks at ~1 MeV*
- Model of the detector response includes a **linear** term with **offset**, a **noise** resolution and a **Fano** factor:

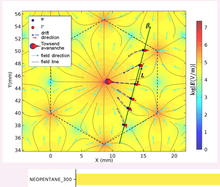
$$ADC = aE + b. \quad \& \quad \sigma_E = \sigma_n + F\sqrt{E}$$

- Divide scintillator surface in a **grid of squares**
- Fit experimental spectrum with simulated spectrum using a **Markov Chain Monte Carlo (MCMC)** method
- **Extract gain** for each location and **map** the detector surface



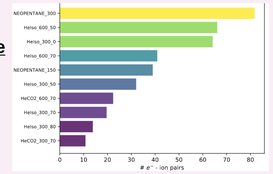

Average signal height: comparison between experiment and simulation

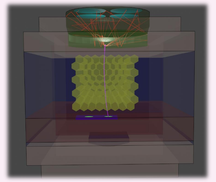



### Signal height versus voltage

- Average signal height from muonic data for:
  → *Different gas mixtures*
  → *Increasing Voltage*
- Very good agreement with simulation



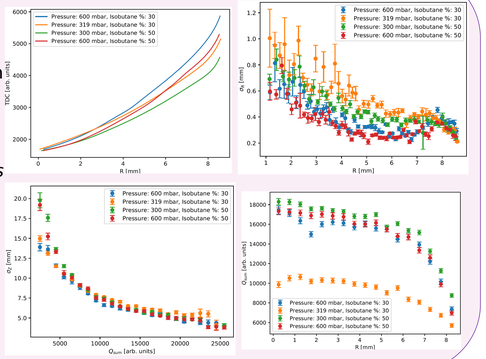



## Monte-carlo simulations

- **Geant4**: Detector geometry, particle tracking
- **Garfield++** Ionization and electron drift and signal readout

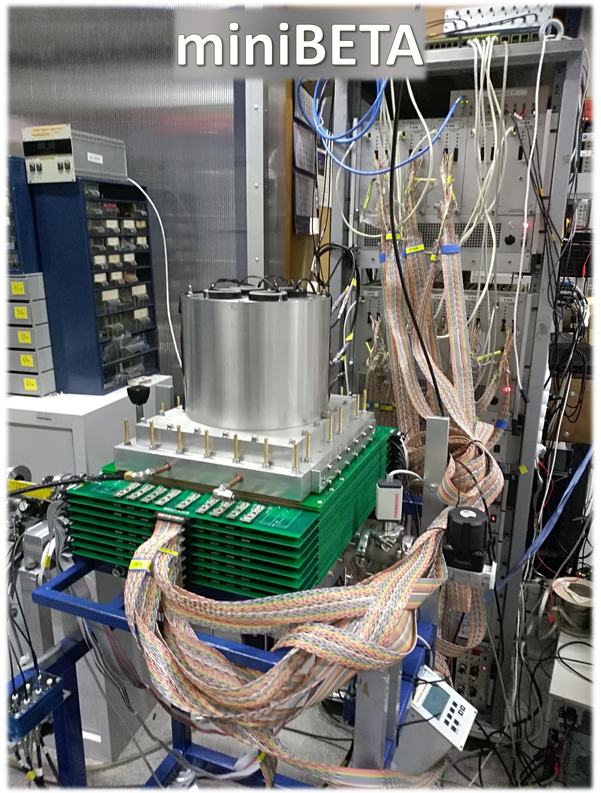
→*Goal: **Interface Geant4 and Garfield++** and fully simulate events in order to support the measurements*

## Properties of gas mixtures





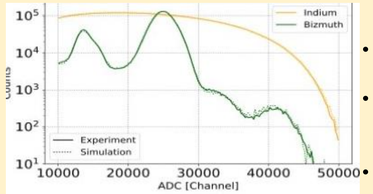


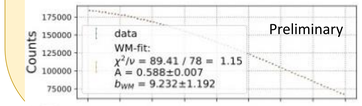



## Spectrum shape measurements

Spectrum comparison:

- Experiment vs MC
- Bi-207 and In-114 (b_WM=0)
- 600 mbar, 30% Isobutane
- %- level agreement




WM extraction:

- Theoretical beta spectrum and WM correction factor from Hayen et al.
- Detector response from MC and gain map calibration
- 2-parameter fit with normalization and b_WM
- Results depends on the energy window and included scintillator surface – work on this is in progress

## SUMMARY

The presented experimental technique is applied to the beta spectrum shape measurements in isotopes: 114In (preliminary results) and 32P (analysis is in progress).

This technique is also applied to the neutron beta decay correlation experiment for tracking of decay and mott scattering electrons (BRAND project).

References:

M.Perkowski, PhD Thesis (2020) ; L. De Keukeleere, PhD Thesis (2021)

K.Bodek et al., EPJ of Conf. 219, 04001 (2019)