Drift Time Calculation of High Purity Germanium (HPGe) P-type Point Contact (PPC) Detectors

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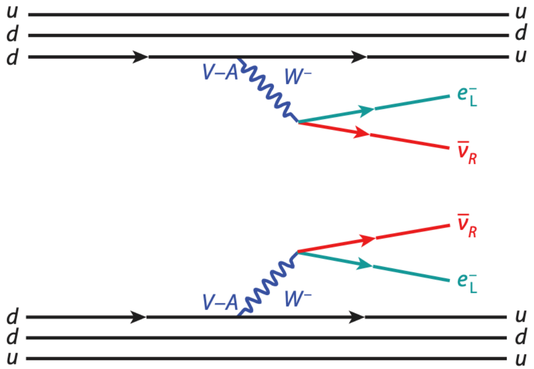
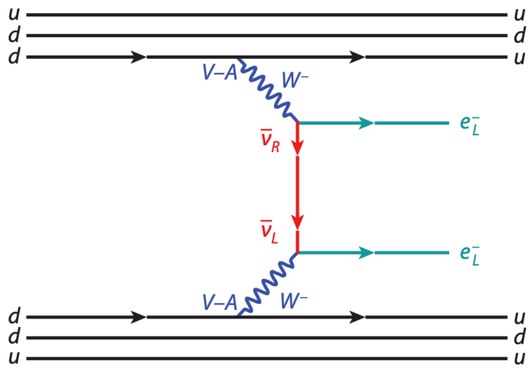
Neutrino, a Majorana particle?

Goeppert-Mayer: double beta decay first proposed → Majorana: For beta decay theory to remain the same, neutrino would have to be its own antiparticle (a **Majorana particle**) → Furry: If neutrino were a Majorana particle, then **neutrinoless double beta (0νββ) decay** can occur



2νββ decay

Rare but has been observed



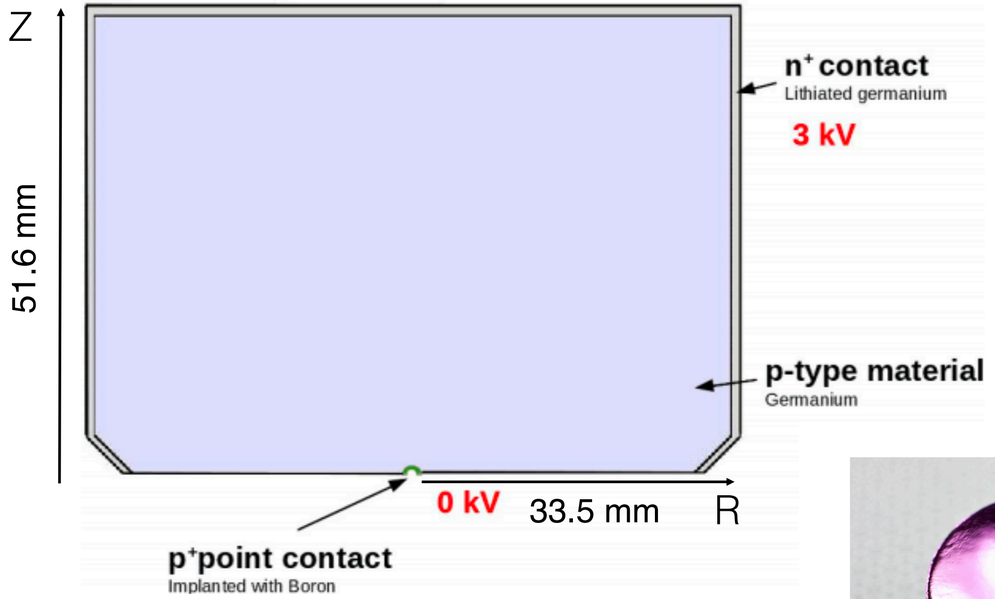
0νββ decay with light Majorana neutrino exchange

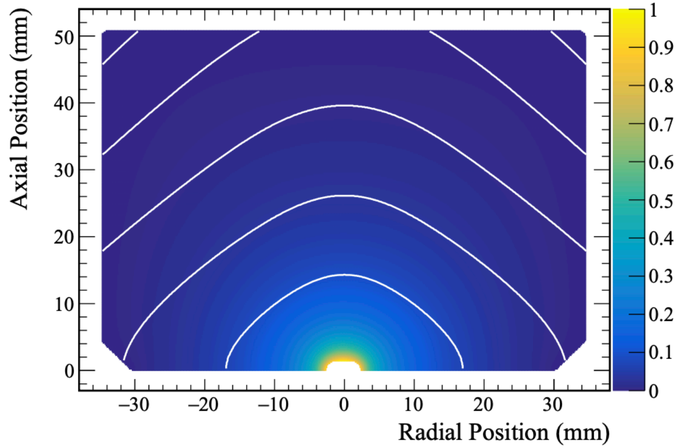
What we are searching for!

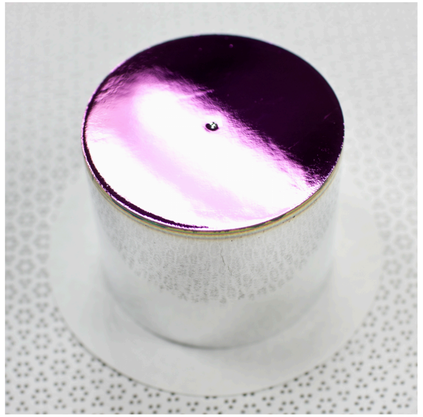
- Sheds light on the nature of neutrino mass
- Proof of physics beyond the Standard Model (total lepton number violation)

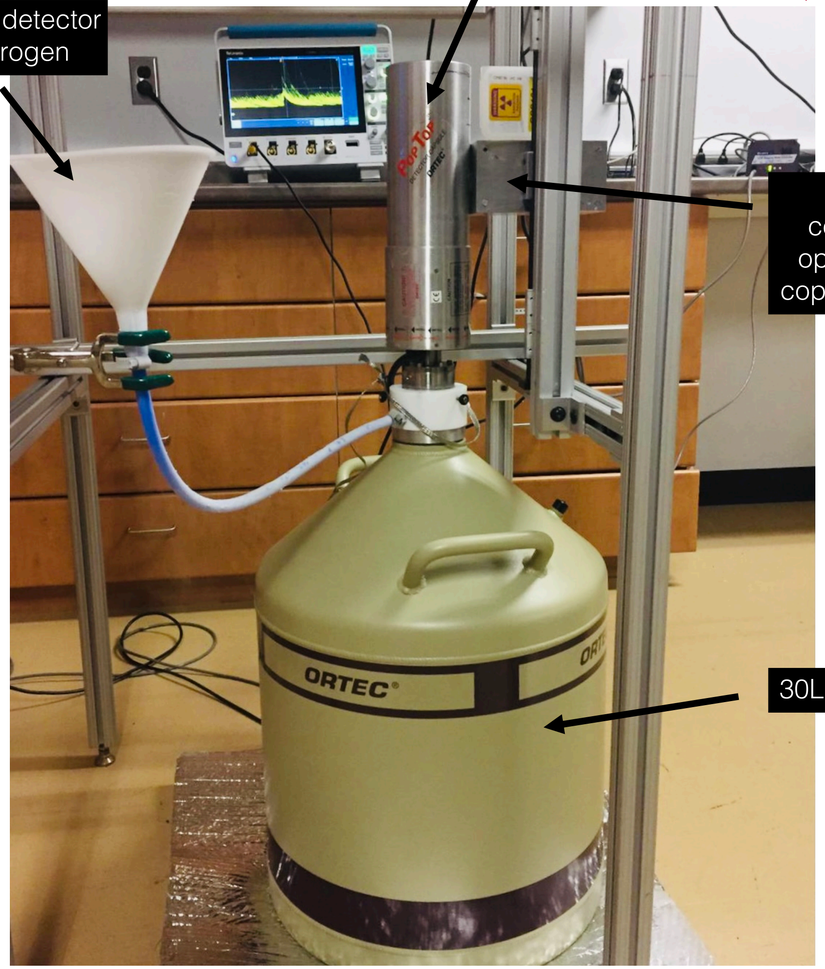
R. Saakyan. Two-neutrino double-beta decay. Annual Review of Nuclear and Particle Science, 63:503-529, 2013.

What is A HPGe PPC Detector?









Detector in our lab

S. I. Alvis et al. (Majorana), Phys. Rev. C 100, 025501 (2019)

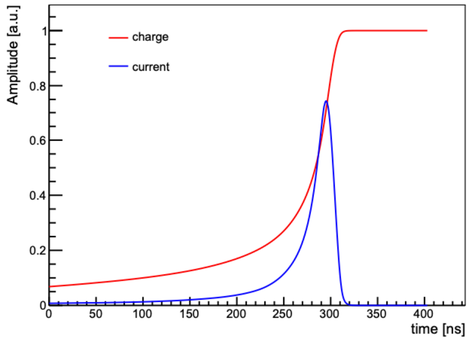
E. Aguayo et al. The Majorana Demonstrator. arXiv e-prints, page arXiv:1109.6913, September 2011

S. Mertens et al. Characterization of high purity germanium point contact detectors with low net impurity concentration. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 921:81-88, 2019

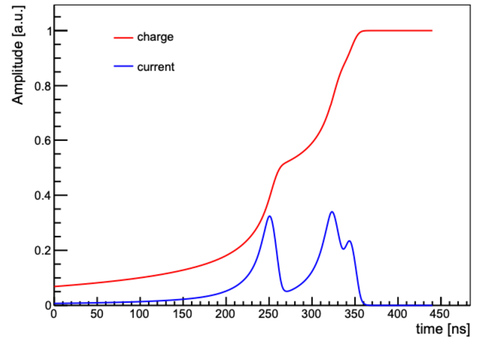
Why HPGe PPC Detectors?

- Low background - impurities are removed in the detector crystal-growing process
- Excellent energy resolution
- Source-as-detector configuration – enhances signal detection efficiency
- Distinguishes between single site and multi site events

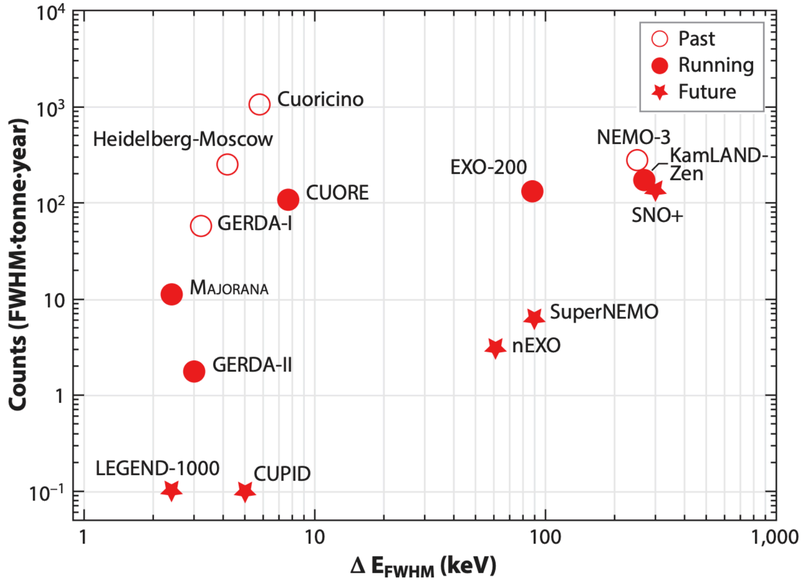
Also great for dark matter searches



Single site event



Multi site event

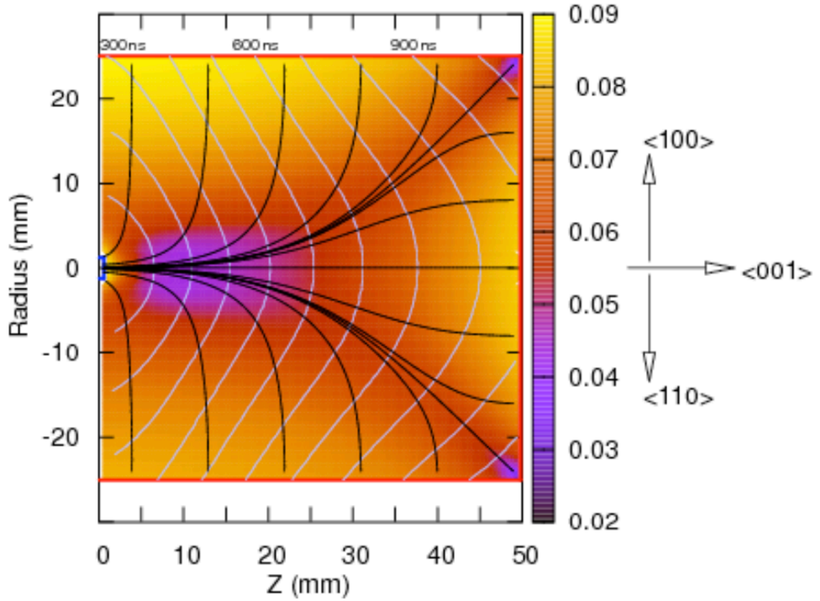


Majorana Demonstrator, GERDA, LEGEND-1000 - using HPGe PPC detectors.

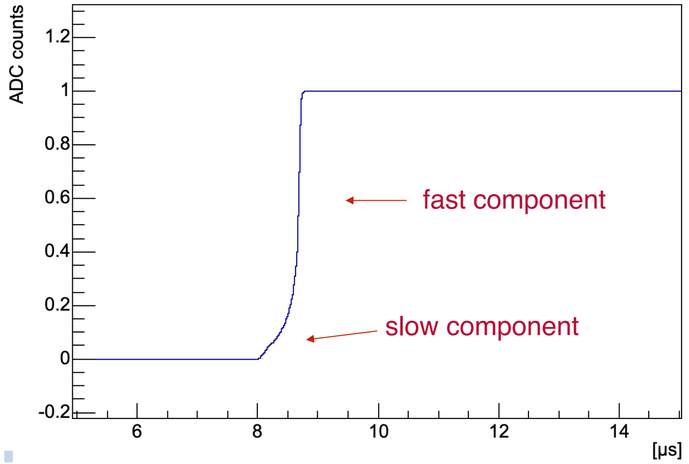
S. Mertens et al. Characterization of high purity germanium point contact detectors with low net impurity concentration. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 921:81-88, 2019

A.W.P. Poon M.J. Dolinski and W. Rodejohann. Neutrinoless double-beta decay: status and prospects. Annual Review of Nuclear and Particle Science, 69:219-251, 2019.

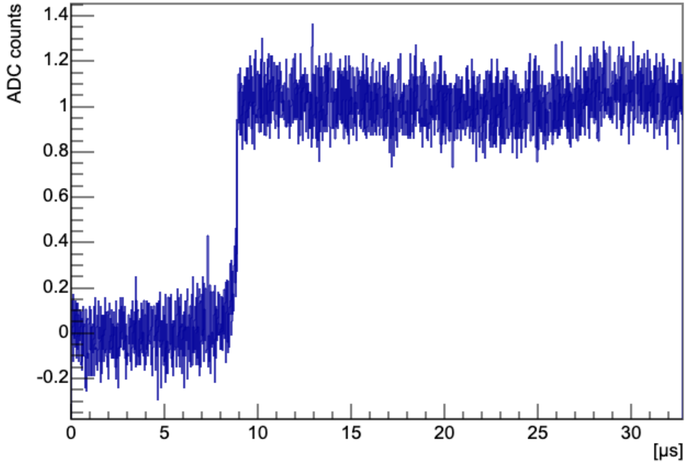
Drift Time



A diagram of a point-contact detector's electric field intensity (color pattern), drift trajectories (black lines), and surfaces of constant drift time(grey).



Simulated pulse



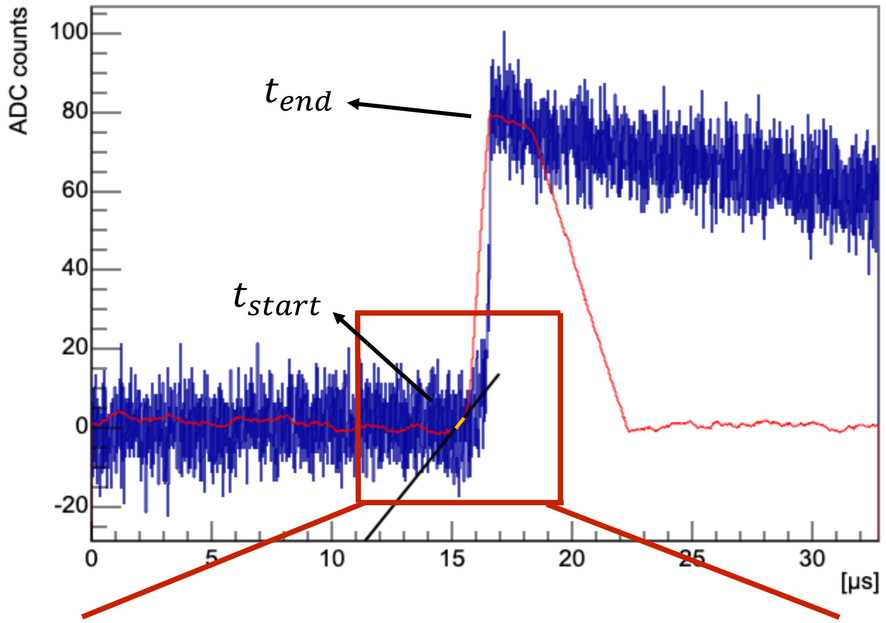
Simulated pulse with added noise

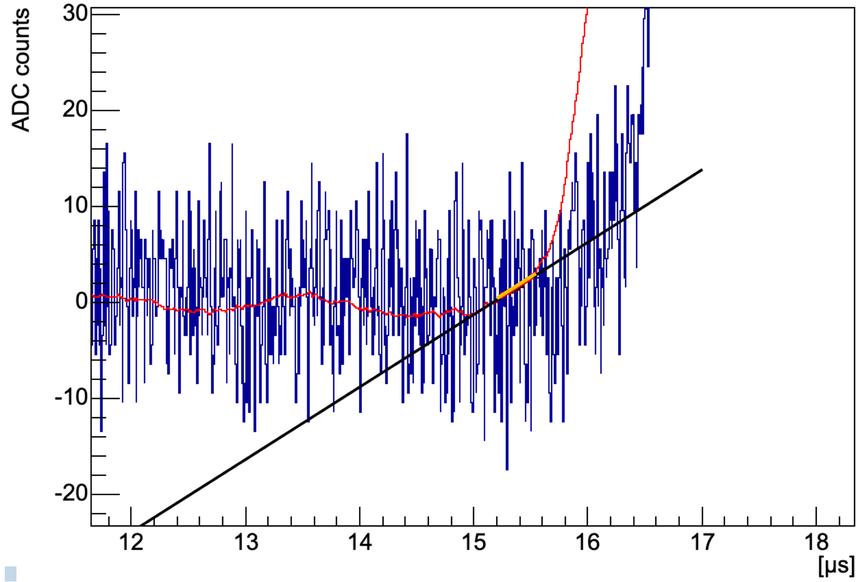
Motivation:

- Position sensitivity
- Charge trapping - improve energy resolution

E. Aguayo et al. The Majorana Demonstrator. arXiv e-prints, page arXiv:1109.6913, September 2011

Drift Time Calculation

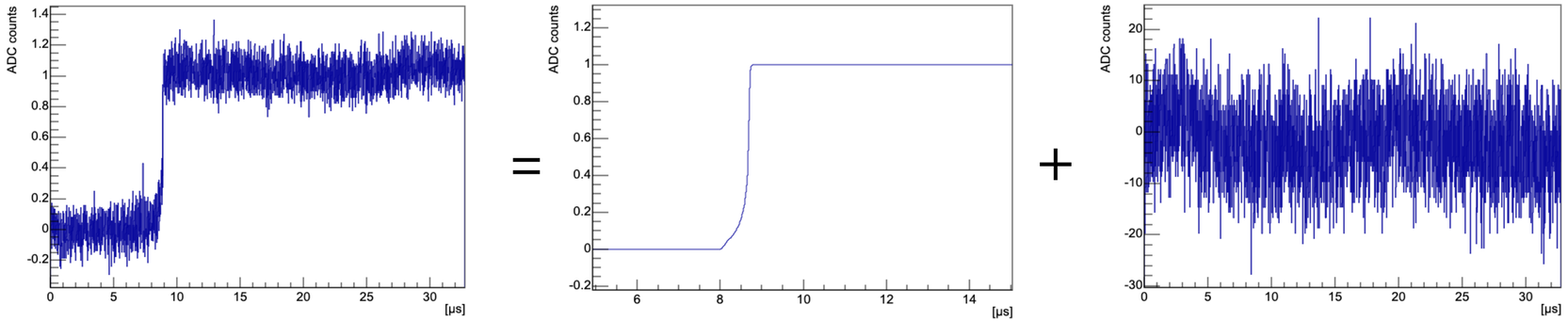




- Drift time = $t_{end} - t_{start}$
- t_{end} = pulse sample at maximum value of trapezoidal pulse
- t_{start} is defined by the intercept of slope and trapezoidal baseline (plus a constant offset due to the trapezoidal filter)

Testing with Data

- Simulated data for OPPC detector.
- Noisy simulated data: simulated data + detector background noise.

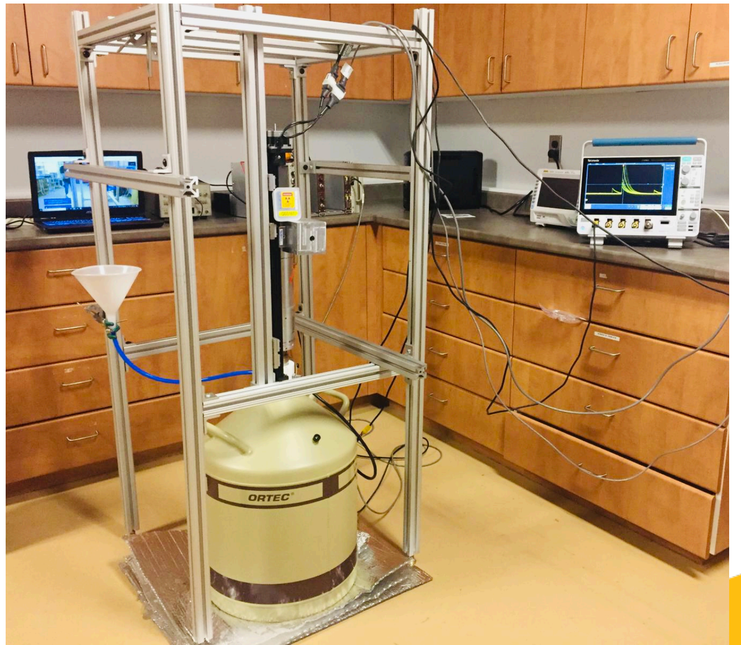


One simulated pulse was combined with 1000 different noise to make 1000 different fake pulses

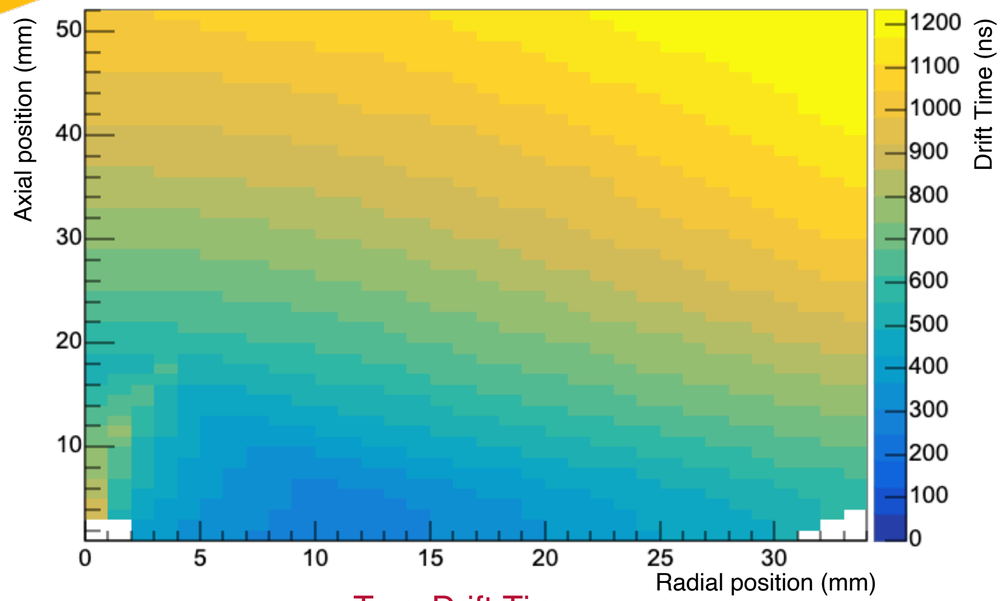
- Experimental data

60 different Z positions, 1mm apart, each taken for ~4 minutes

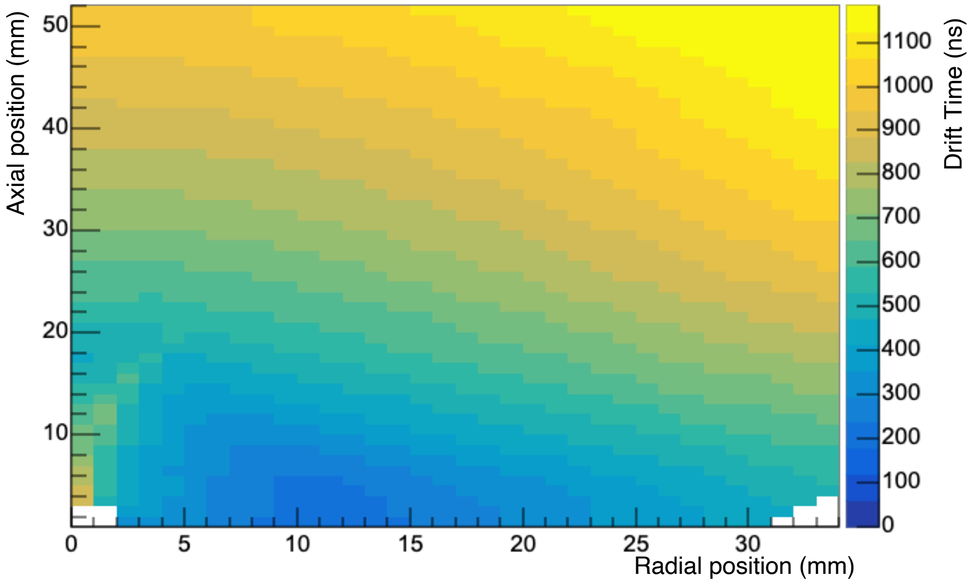
Source: 100uCi Am241



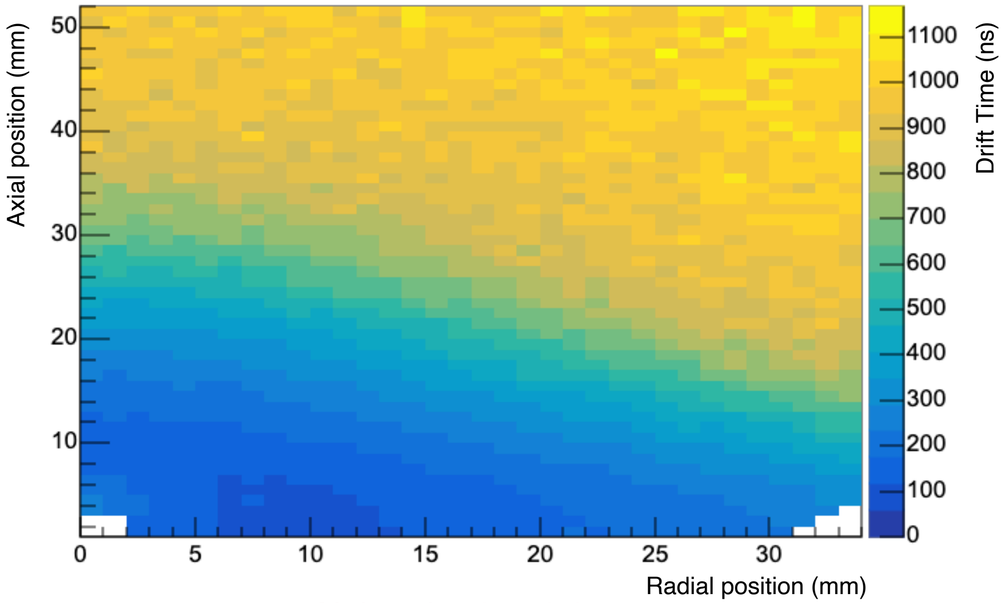
Simulation Results



True Drift Time



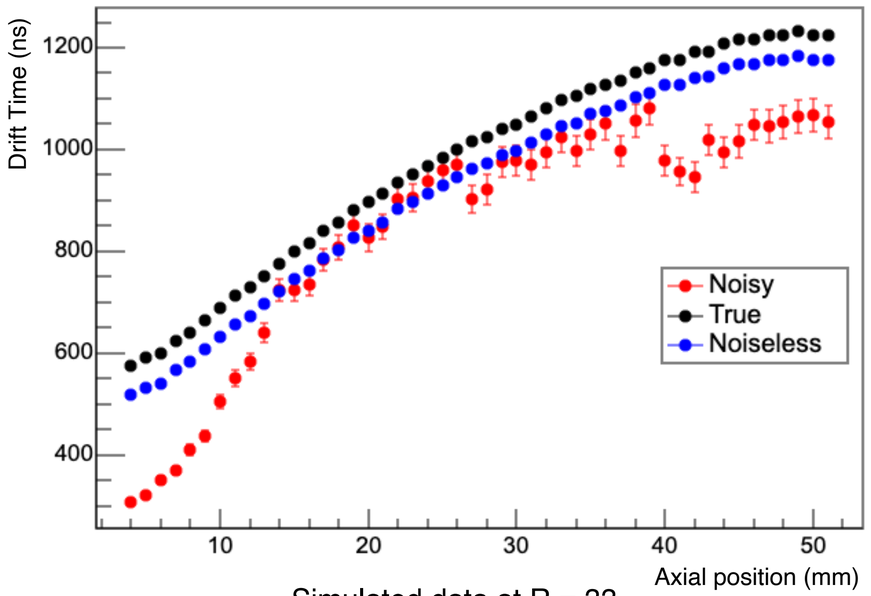
Noiseless simulated data



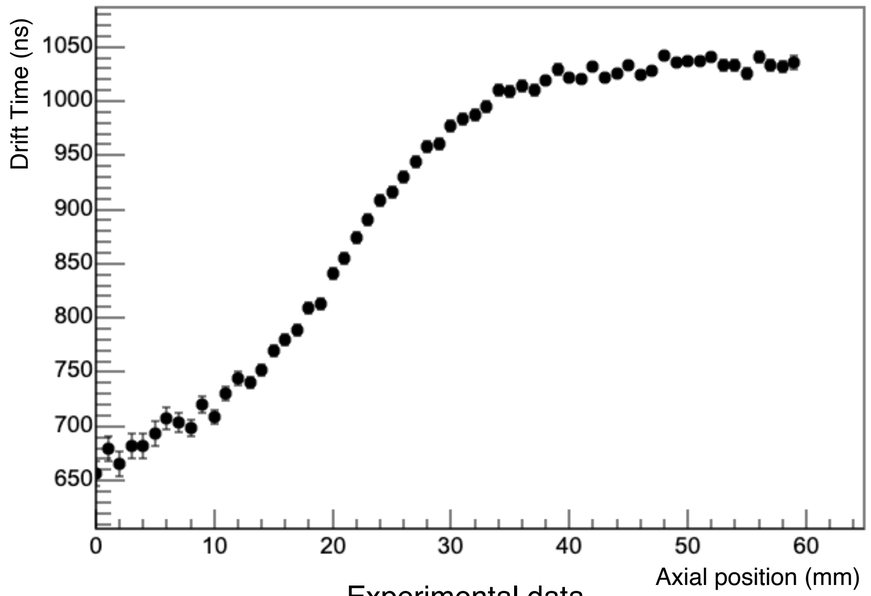
Noisy simulated data

Noise amplitude factor = 0.013

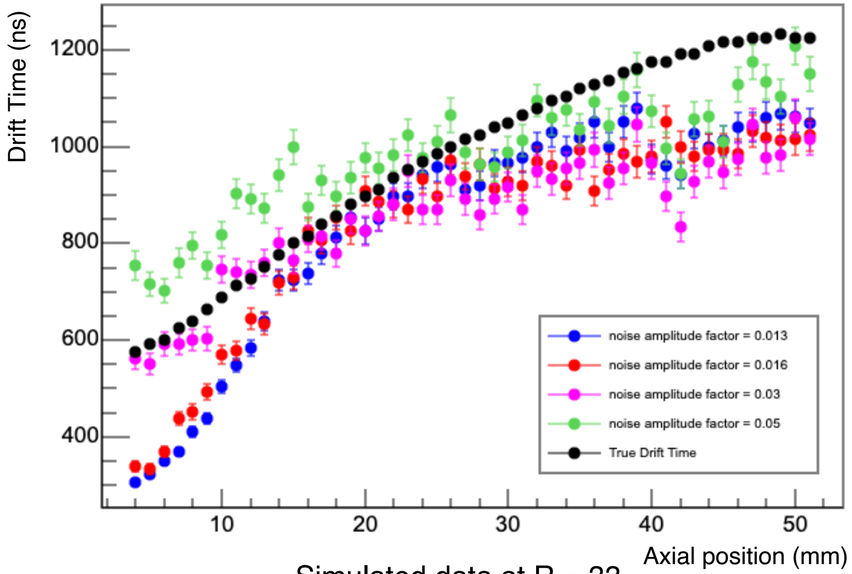
Results



Simulated data at R = 33



Experimental data



Simulated data at R = 33

Effect of background noise on drift time

Thank You!