Analysis and identification of alpha events for NEWS-G

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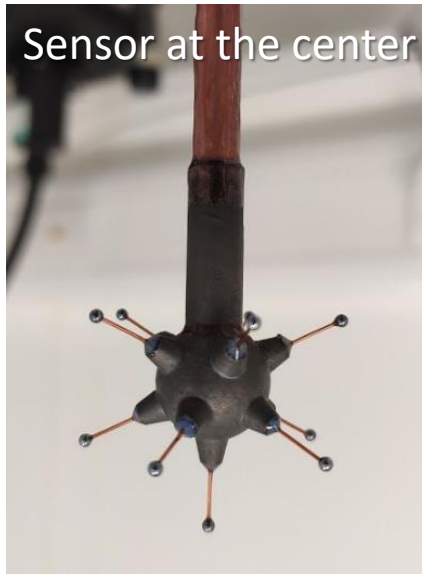
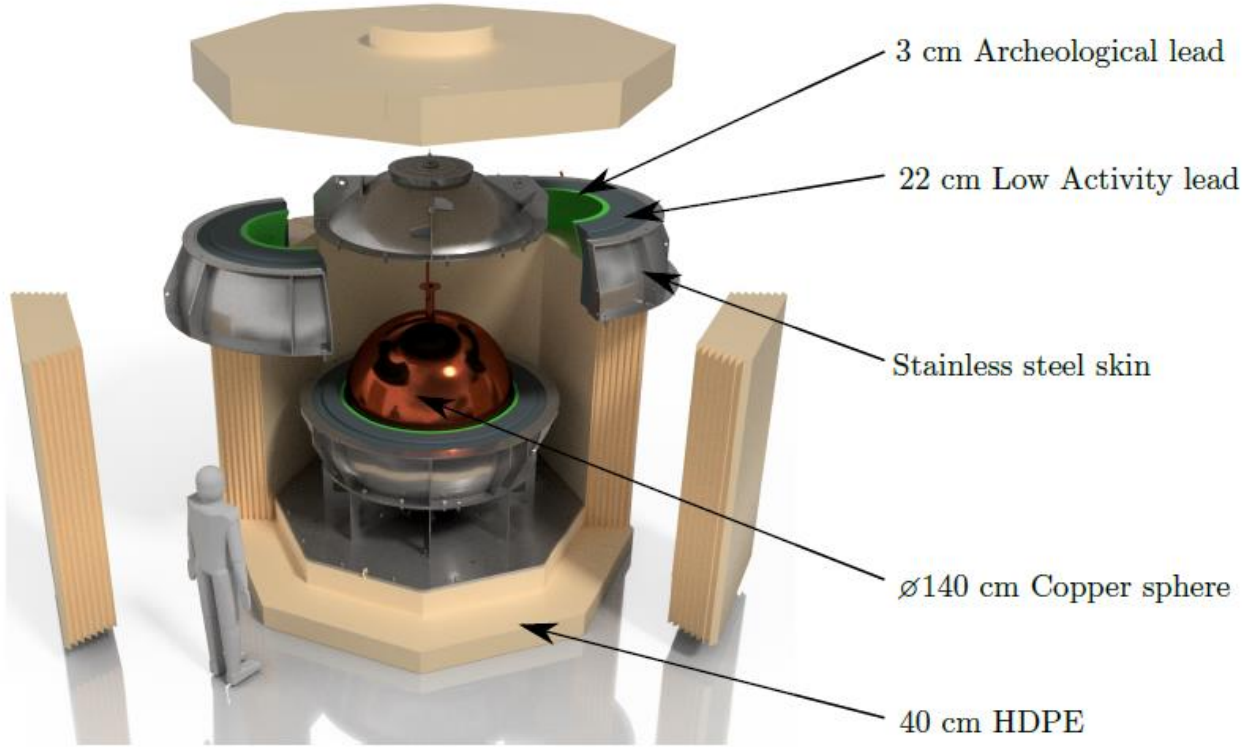
On behalf of the NEWS-G collaboration

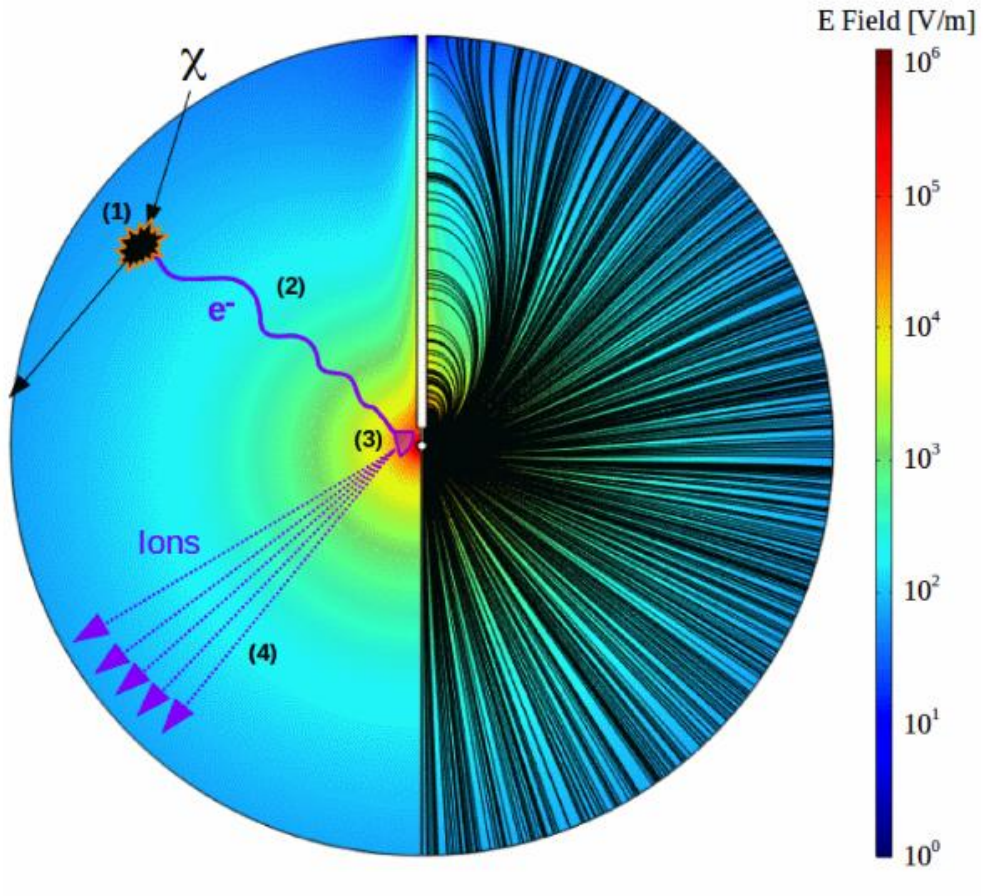
NEWS-G detector summary

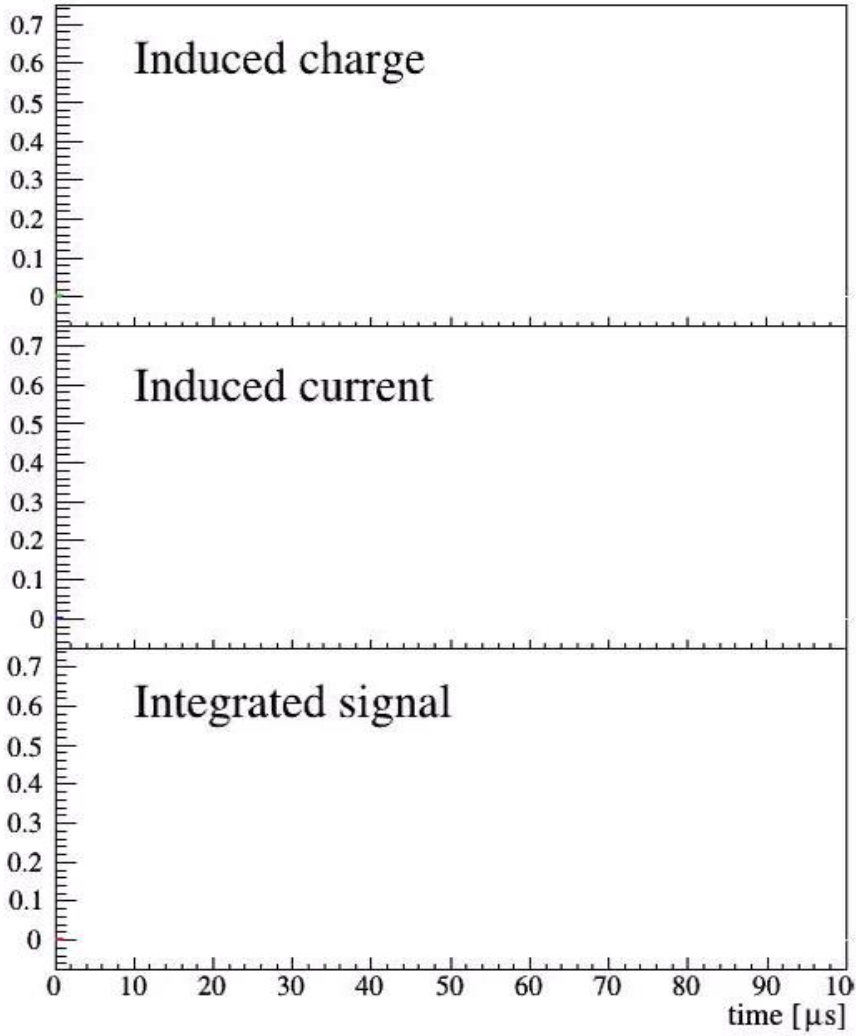
- Spherical proportional counter filled with gas
- Searching for low mass WIMPs (0.1 to few GeV)
- Current data analysis from LSM runs of Ne and CH_4
- Installation finishing at SNOLAB after COVID break





Event detection



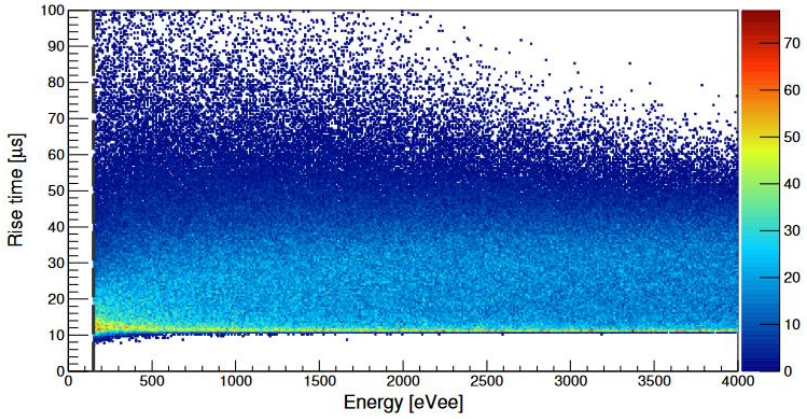


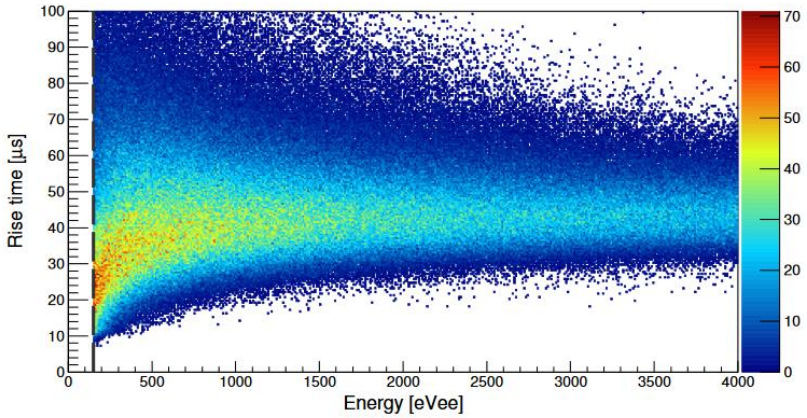
Animation by Philippe Gros

NEWS-G detection summary

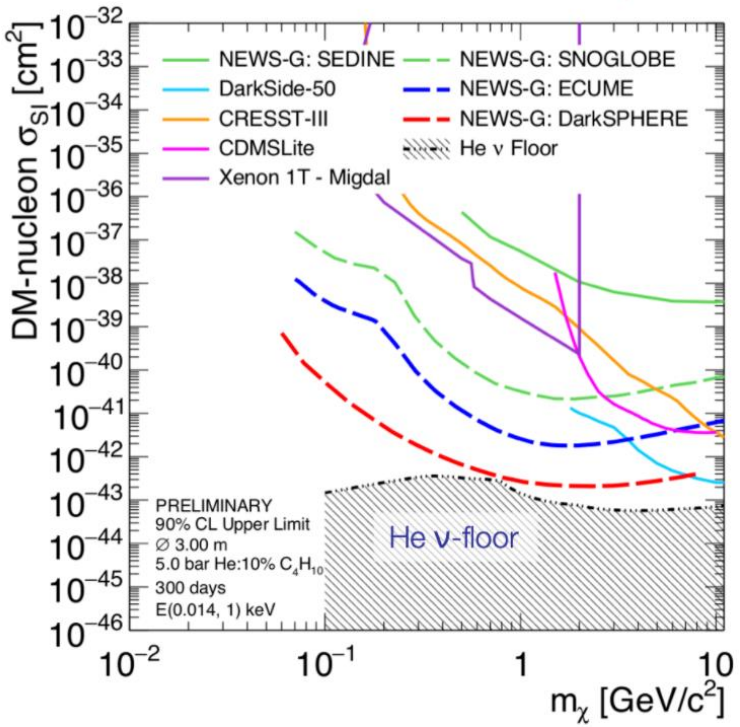
- Volume vs surface events discrimination by the rise time
- Sensitivity threshold as low as ½ an electron
- Possibility of counting and identifying individual electrons

↓ Volume events



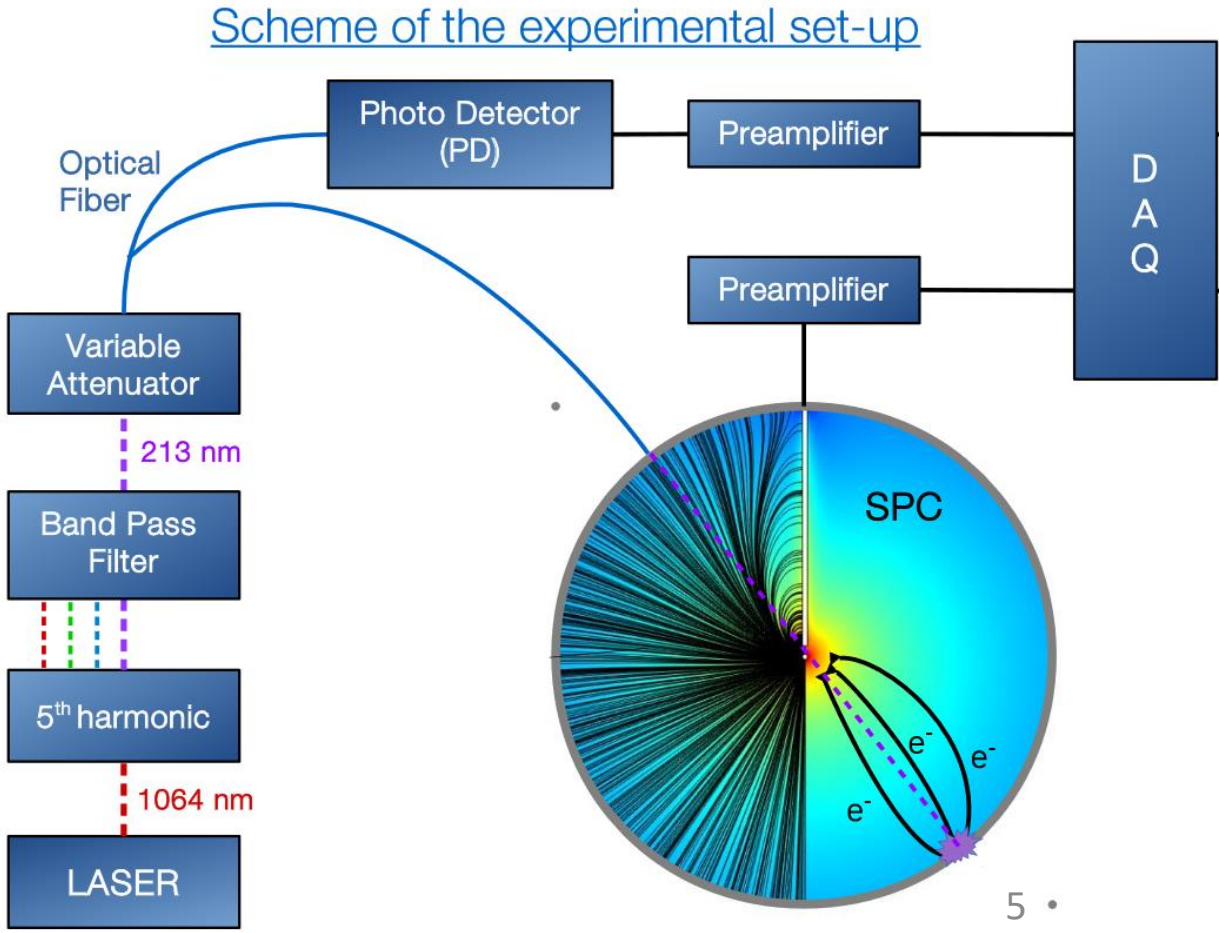


↑ Surface events



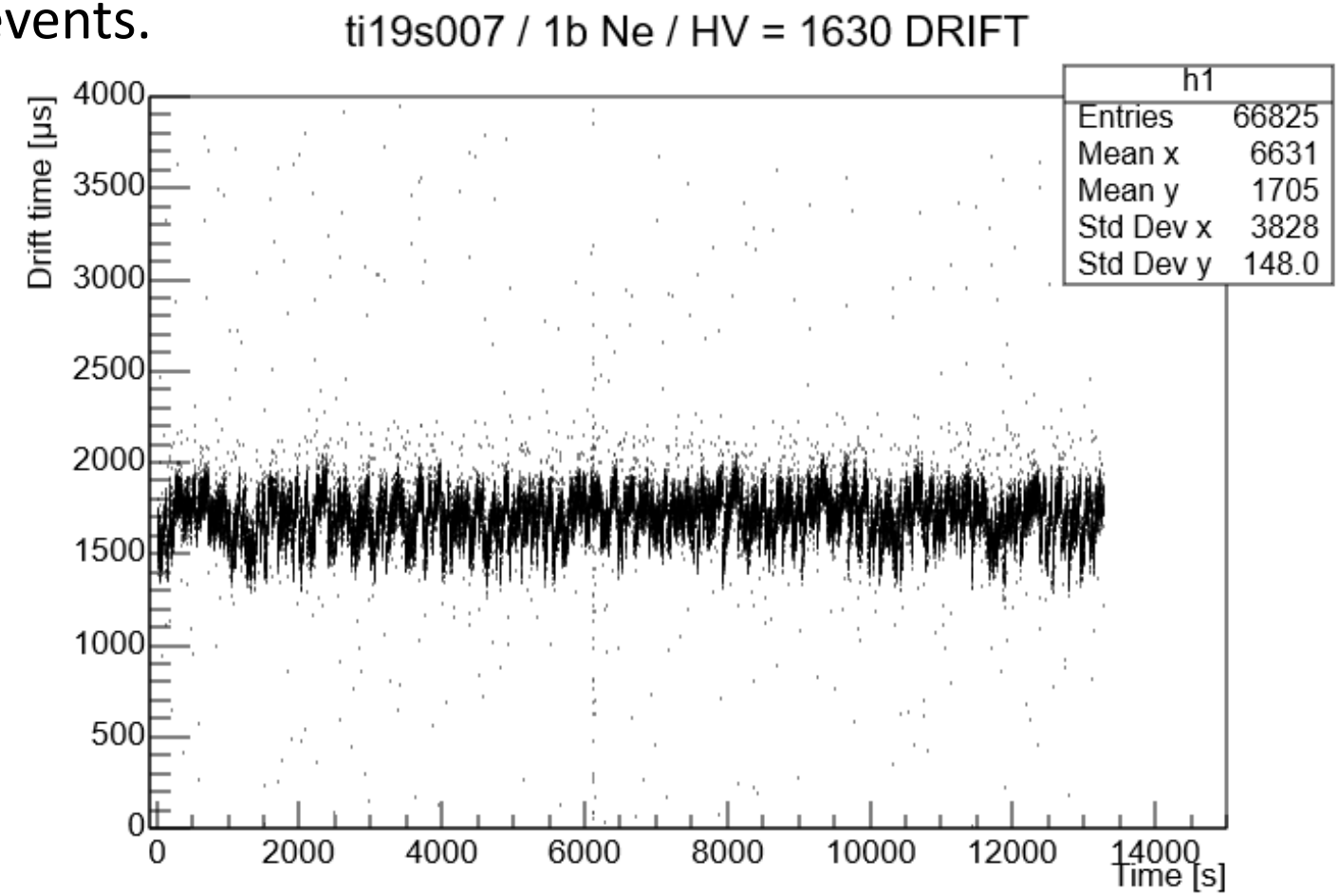
Drift time

- Drift time: Mean time for e^- to travel from surface of the sphere to the central anode
- Allows characterization of the detector, e.g. for simulations
- Measured with a laser using a photodetector and the photoelectric effect
- Laser used at 5 or 10Hz in all runs for more consistency

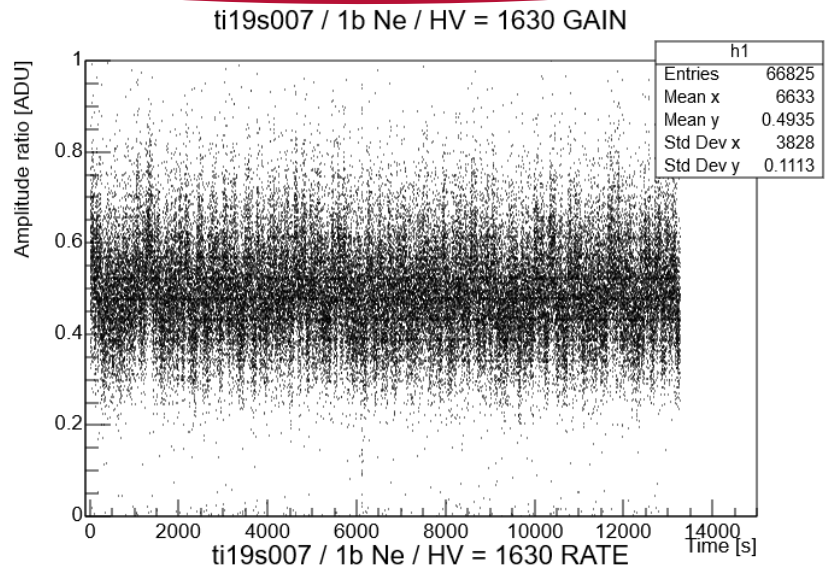


Fluctuations in the drift time

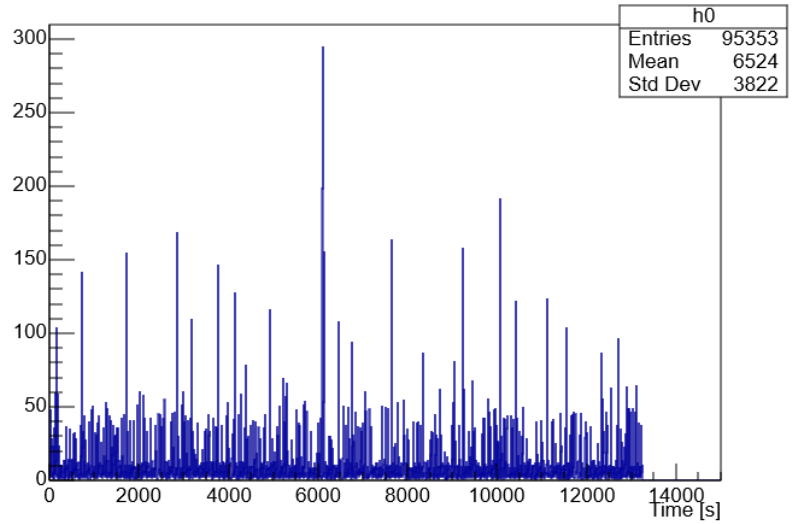
The drift time fluctuates a lot, suddenly falling every ~30-40s. Similar fluctuations are observed on the gain and total rate of events.



Gain

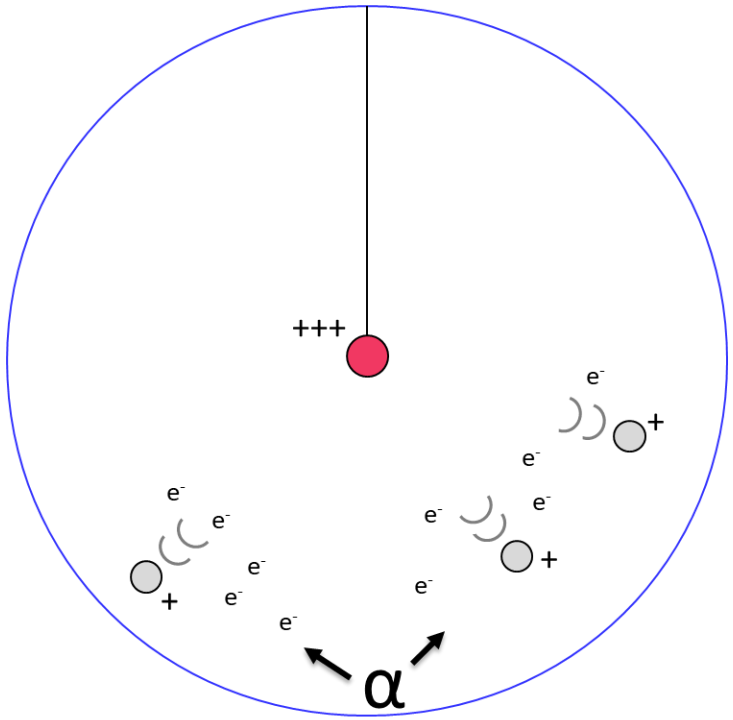


Rate



Alphas in the detector

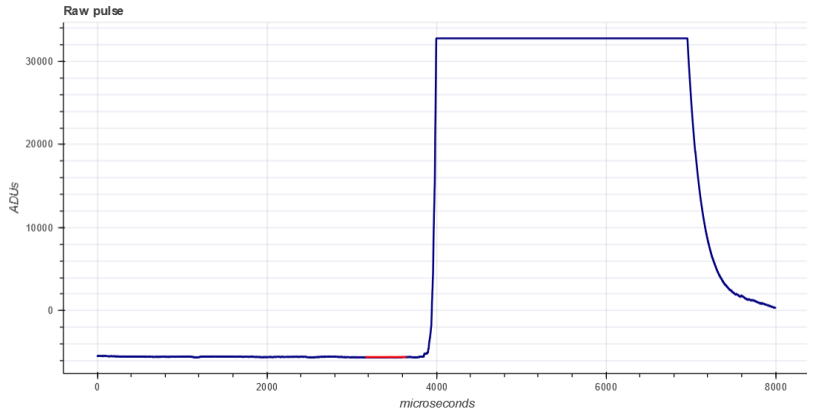
- Alpha particles are coming from the surface of the detector.
- Probable culprit: ^{210}Po contamination

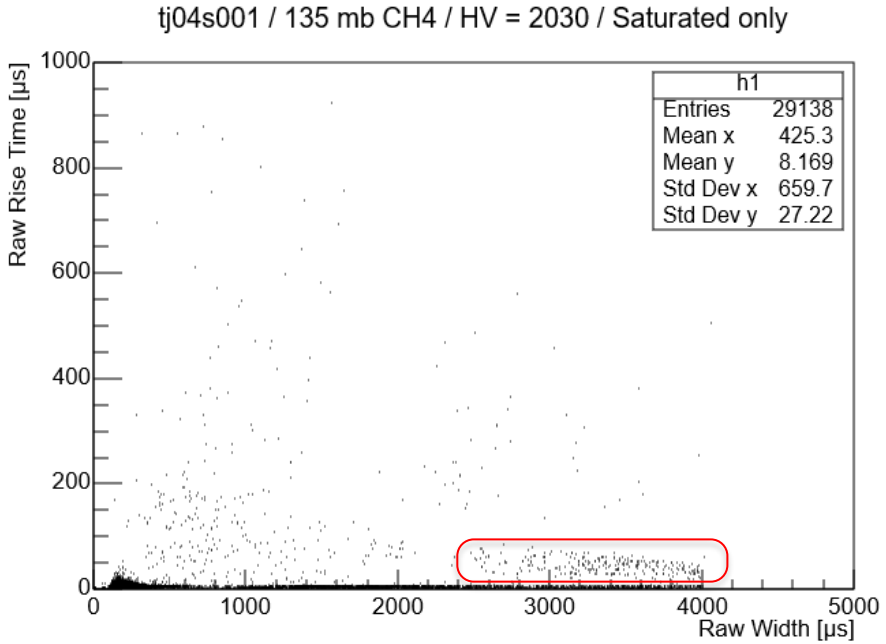


"Space charge effect": Slow drift of ions perturbate the electric field

Alpha event signal →

- Saturated
- Large width
- Low/medium rise time



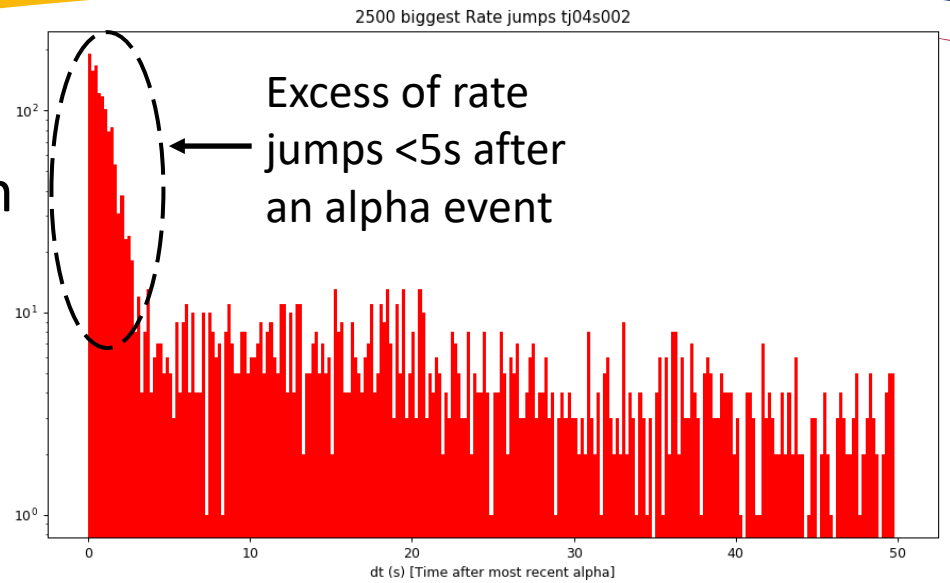


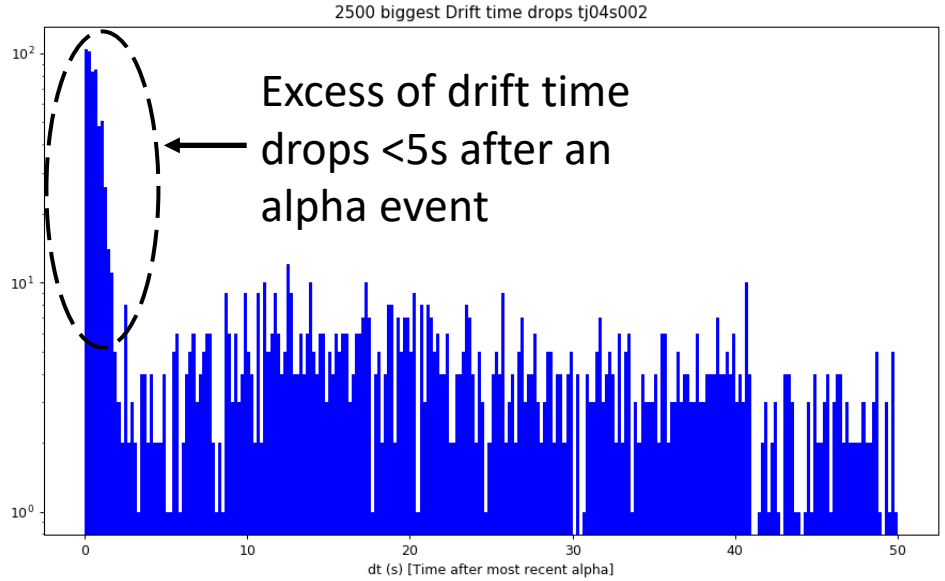
These alphas cause the fluctuations observed on drift time, gain and rate.

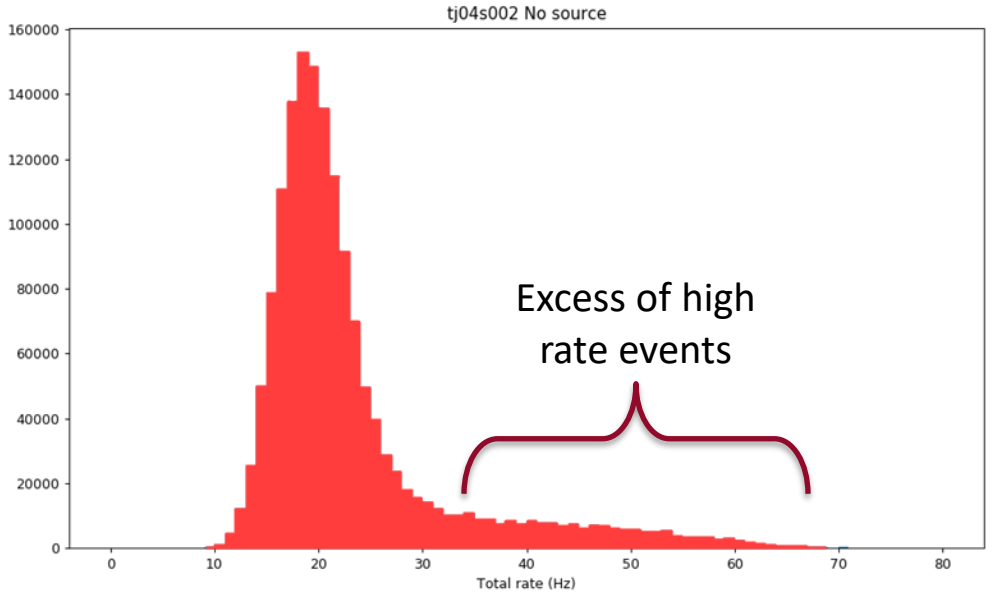
Fluctuations effects

Clear correlation between the different fluctuations

Here is the time difference between big rate jumps / drift time drops and the most recent preceding alpha.



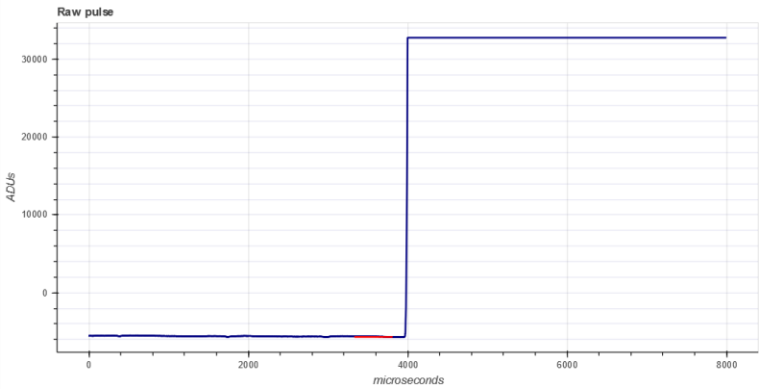




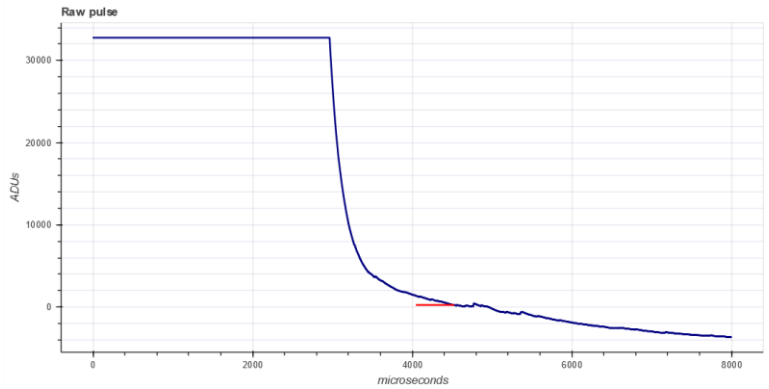
Problem: low energy background. A lot of seemingly "good events" are created because of this phenomenon, similar to a WIMP single-electron event.

Badly reconstructed alpha events

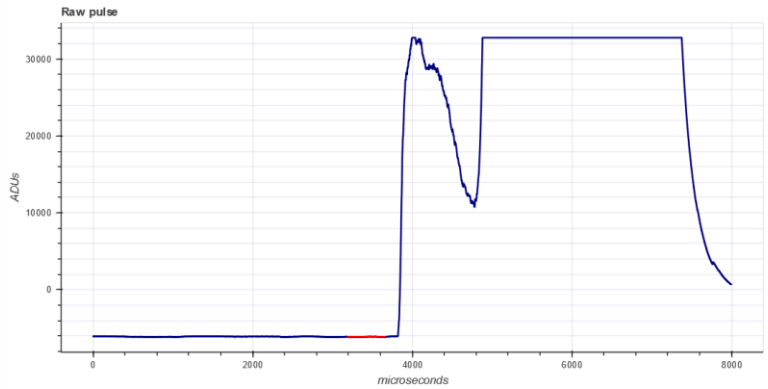
- An alpha cannot be found for all rate jumps and drift time drops.
- Many alpha events do not follow the signal selection conditions because they are not reconstructed correctly.
- Some are missing the start or the end of the event, and others have the signal broken up. Because of that, the processed width or rise time is completely wrong which makes them difficult to detect.



Event cut at the end



Event cut at the start

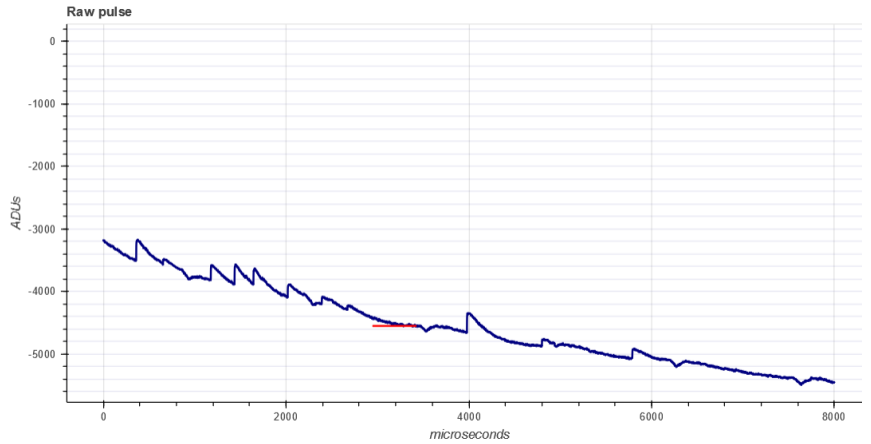


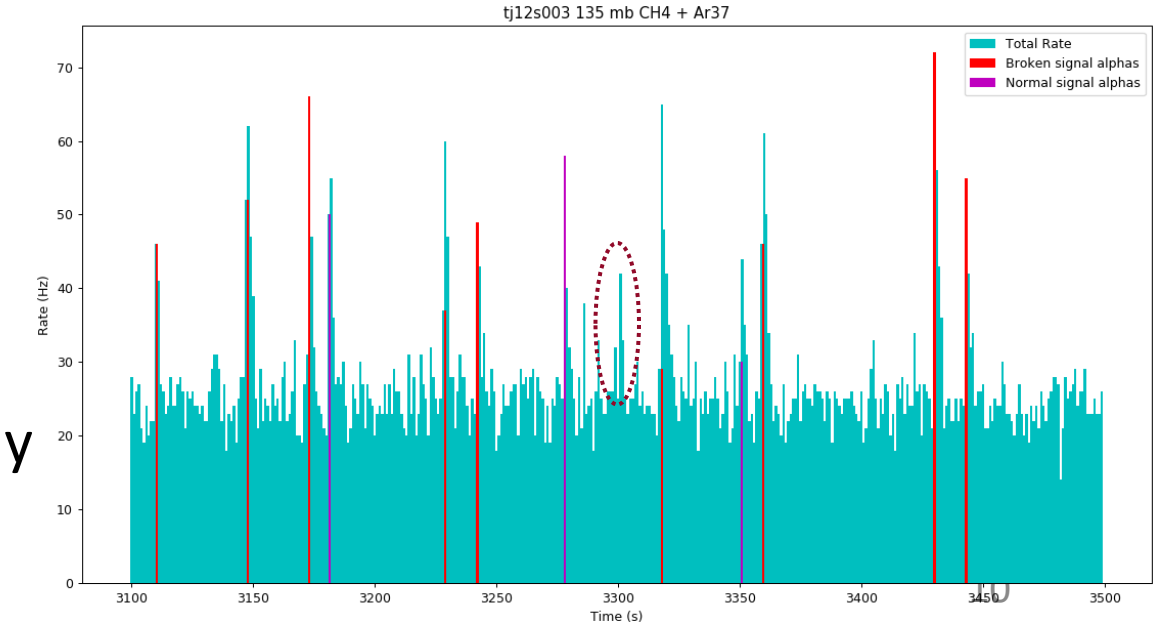
Event broken up

Finding the missing alpha events

- To find those events, more specific conditions were added, by looking at the tail following alpha events, that has a decreasing baseline between each of the subsequent events.
- With the additional alpha selection for badly reconstructed events, the number of missed alpha events is greatly reduced.
- An additional selection on the rate of events is there for the remaining alpha events that still were not caught by the function.
- A selection on drift time is used for runs that only triggered on laser events.

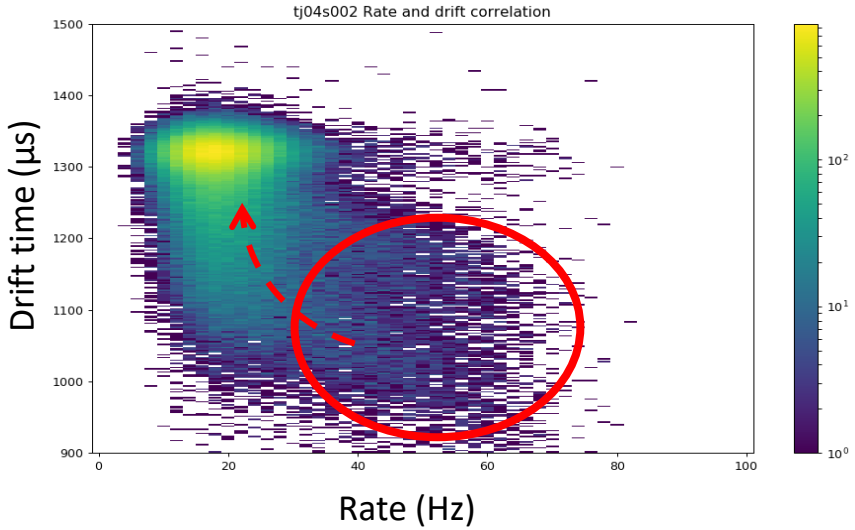
Tail of events following an alpha

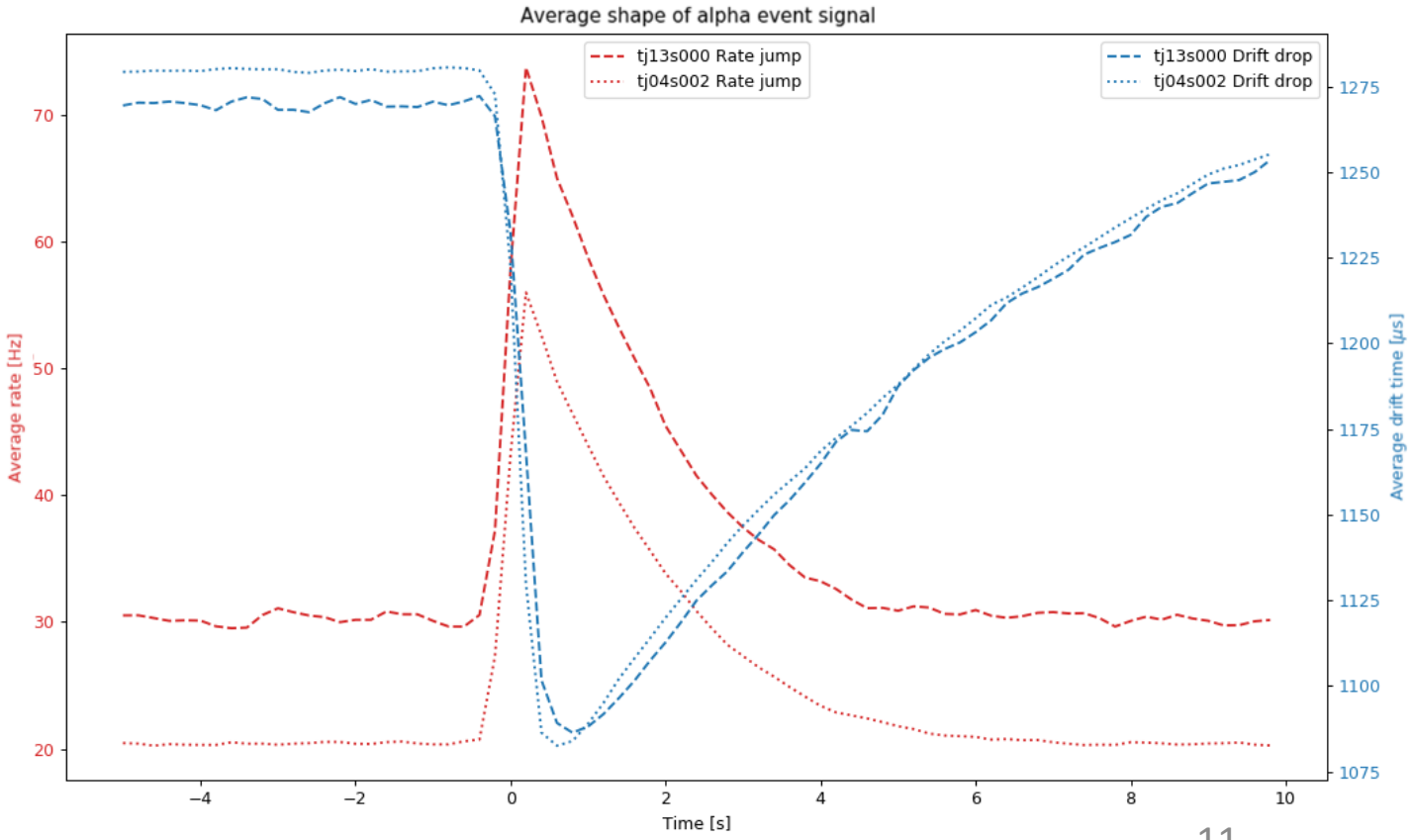




Fluctuation shape

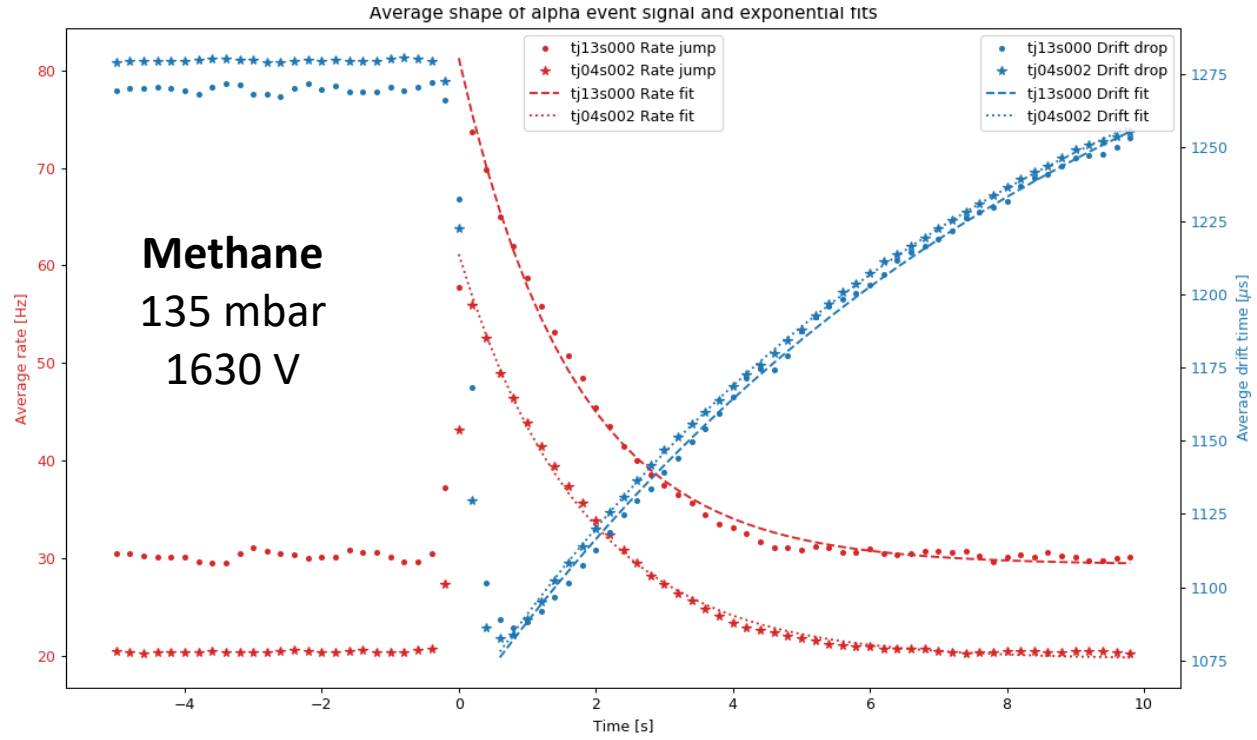
- Averaging all alpha events shows the shape of the fluctuations in rate and drift time.
- Sudden drop of the drift time after an alpha, followed by a slow (>10s) exponential return to baseline
- Similar effect with the rate of events, but with a much faster return to baseline

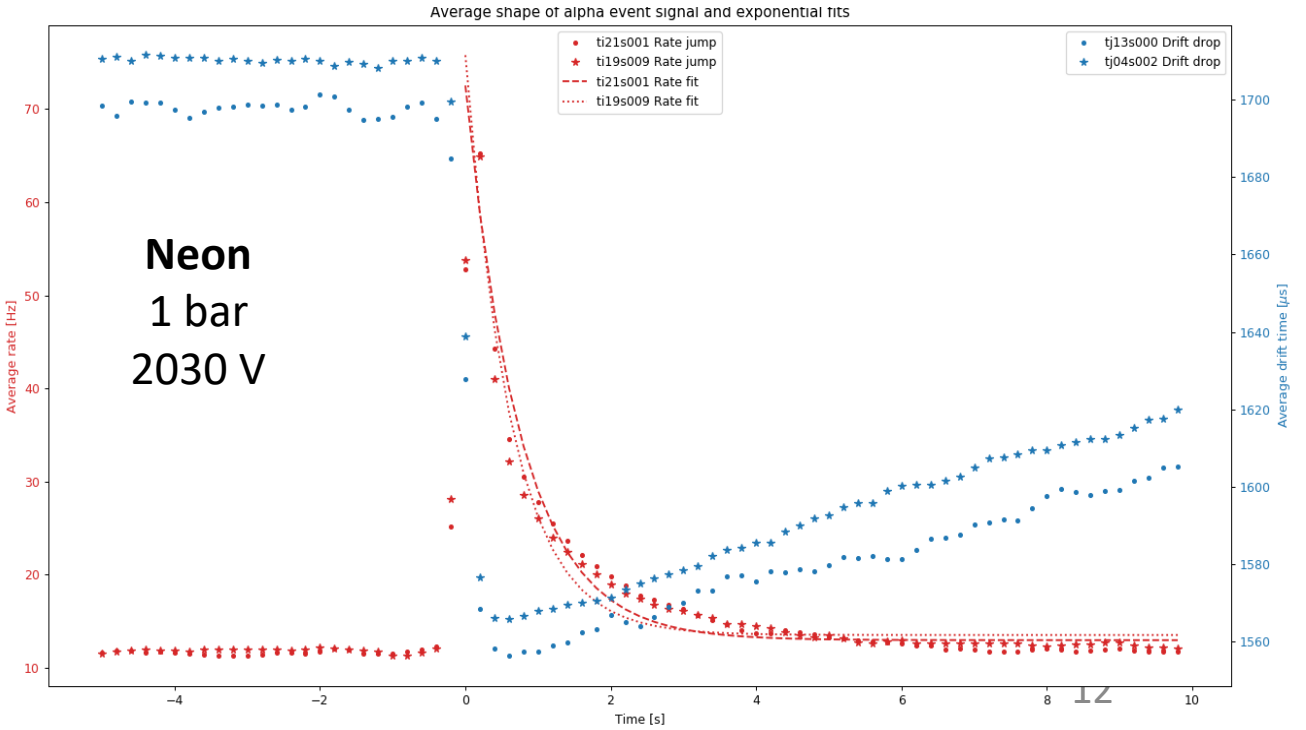




Evolution of rate and drift time after an alpha

- The fluctuation shapes differ slightly when comparing the runs taken in methane (135 mbar, 1630 V) and in neon (1 bar, 2030 V).
- Drift time stays low a lot longer in the neon run than in the methane run after an alpha, but it is the opposite when looking at the rate.

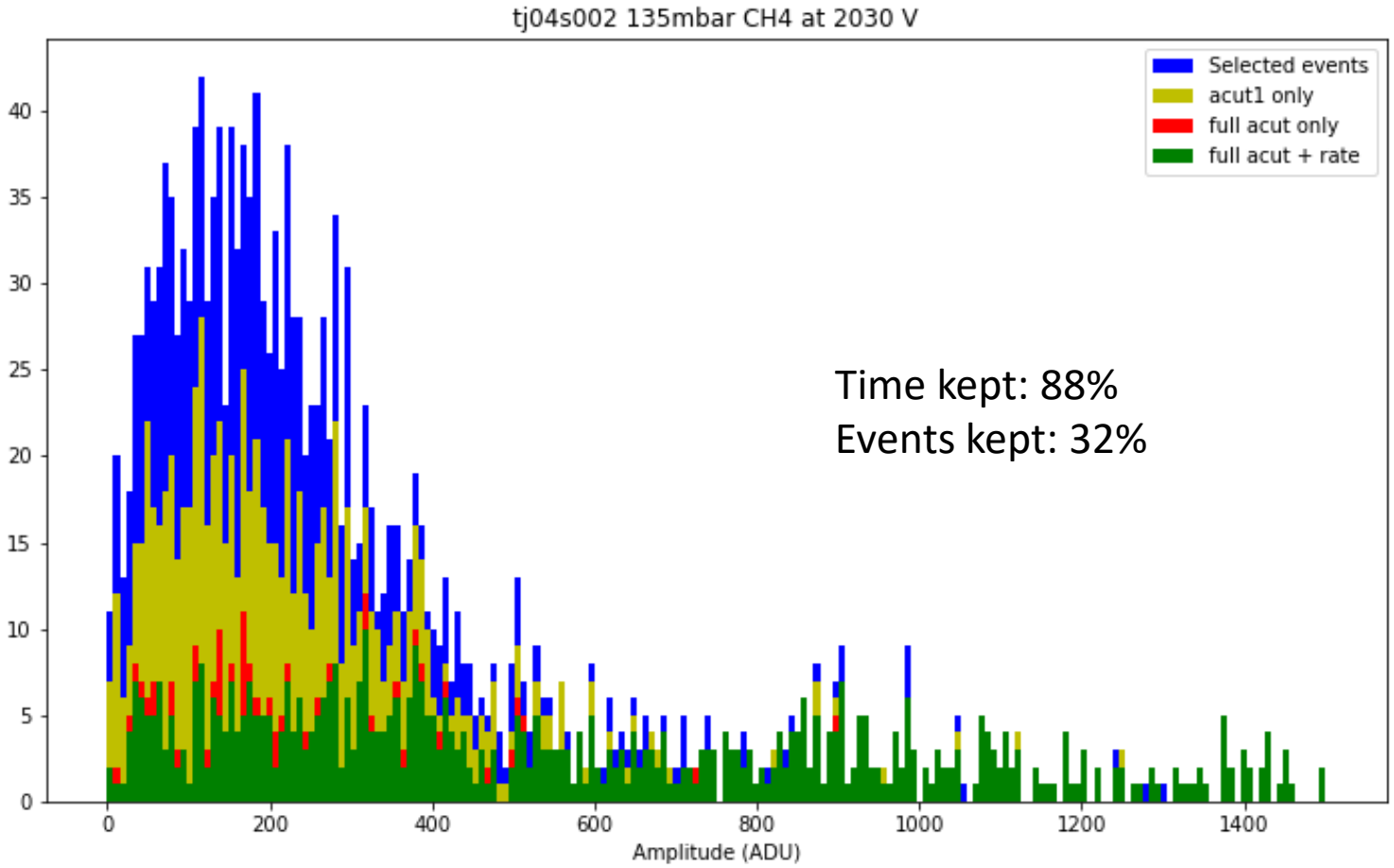




Current amplitude histogram

- A cut of 5 seconds is made after each detected alpha to remove all alpha correlated events.

- With the full alpha cut and the rate cut, 68% of the low energy background is removed, while only cutting 12% of the total run time.



What's next for SNOLAB

- Removing the alpha source
  - Etching of inner surface

- Direct detection of alpha events
  - Low gain channel on detector so alpha signals do not saturate

References

Thank you!

- Q. Arnaud et al., First results from the NEWS-G direct dark matter search experiment at the LSM, Astroparticle Physics97(2018) 54-52.
- Q. Arnaud et al., Precision laser-based measurements of the single electron response of SPCs for the NEWS-G light dark matter search experiment, arXiv:1902.08960
- A. Dastgheibi-Fard & G. Gerbier, Development of Spherical Proportional Counter for light WIMP search within NEWS-G collaboration, arXiv:1904.01944