

New Background Discrimination Methods for the NEWS-G Dark Matter Search Experiment

WNPPC 2022

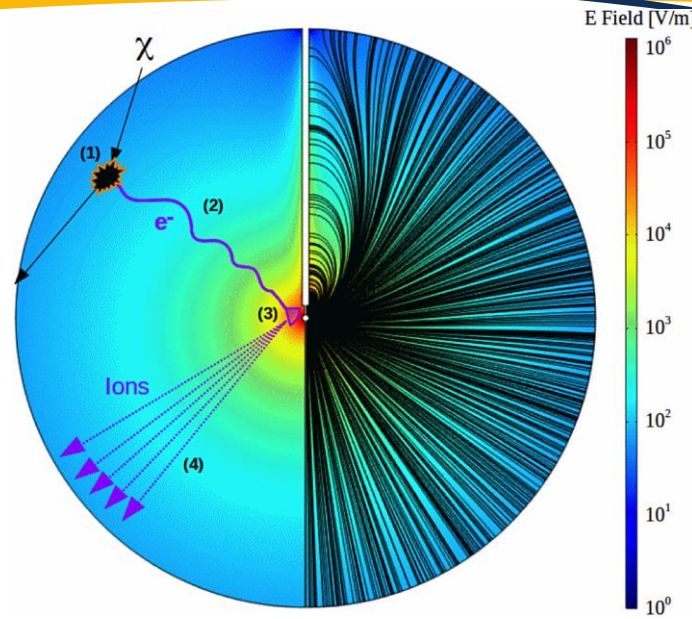
Jean-Marie Coquillat

February 16th, 2022

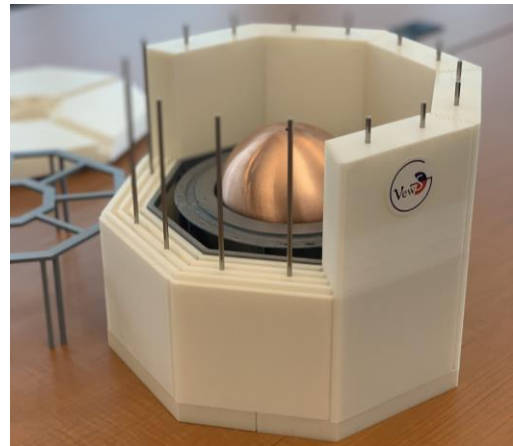
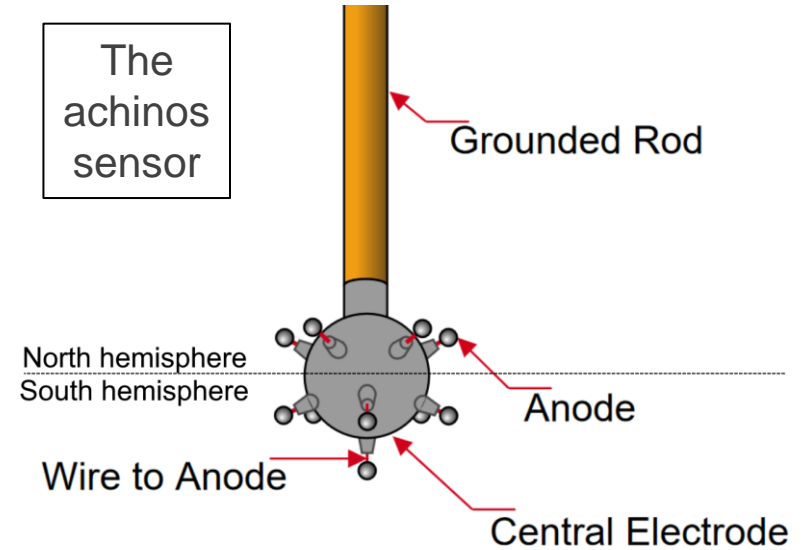


Electric field and calibration

NEWS-G uses a spherical proportional counter in order to search for low mass WIMPs. The latest detector, a 140 cm of diameter sphere, has taken data at the LSM (France) in Fall 2019 and is currently being commissioned at SNOLAB.

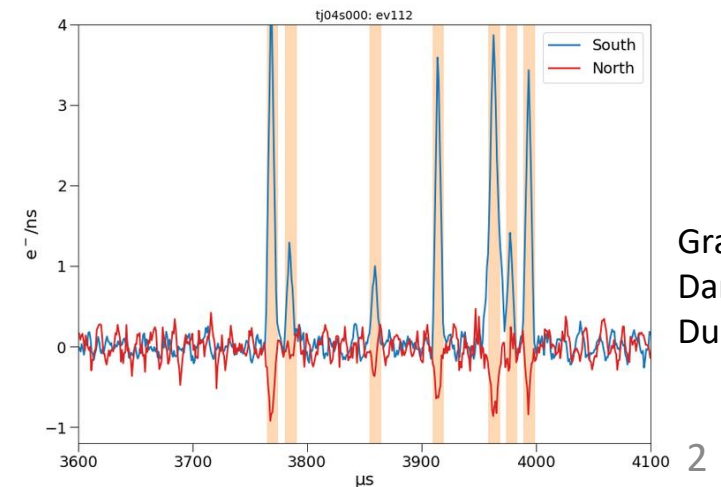


WIMP detection principle (left) and electric field inside an SPC (right)



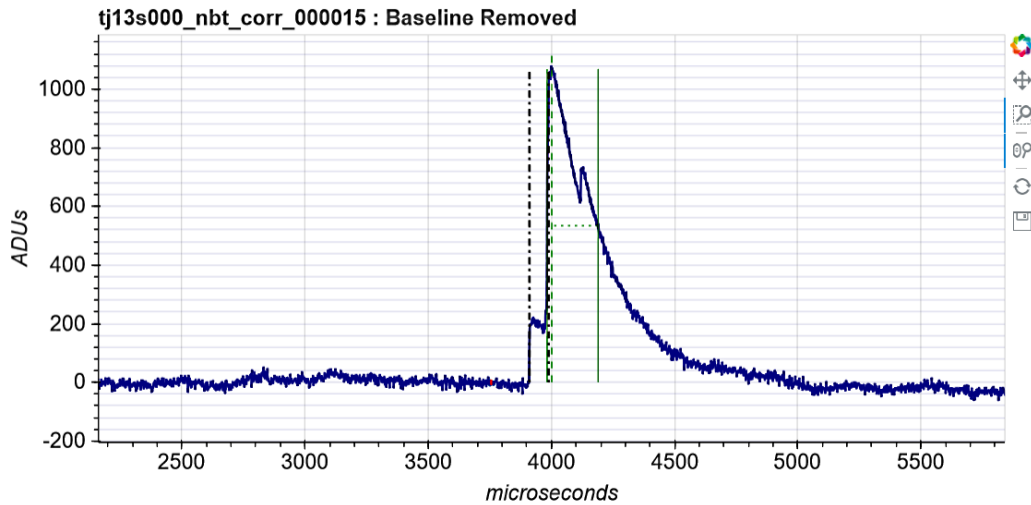
S-140 detector model

There is a crosstalk between the north and south hemispheres of the achinos. A positive signal in the south anodes creates a smaller negative signal in the north anodes, and vice-versa.

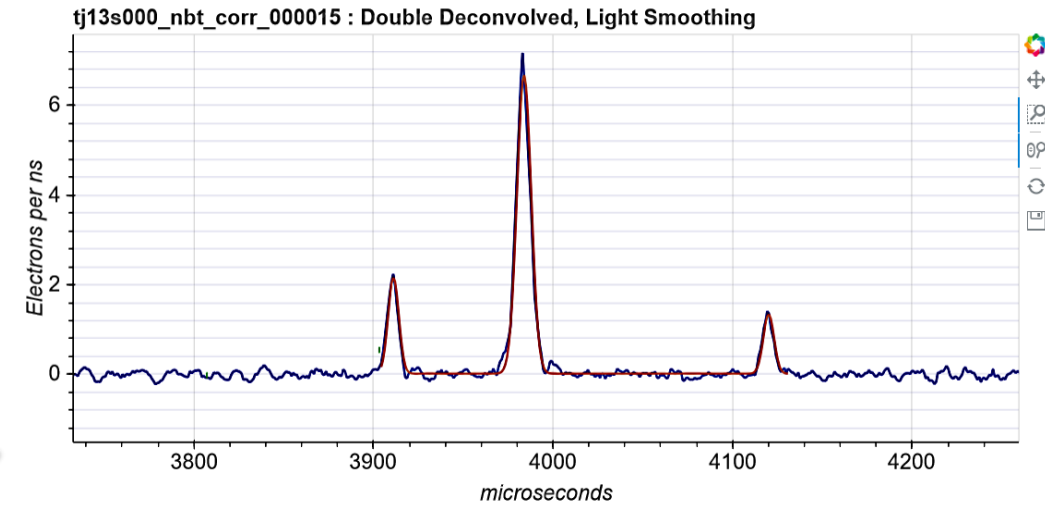


Graph from Daniel Durnford

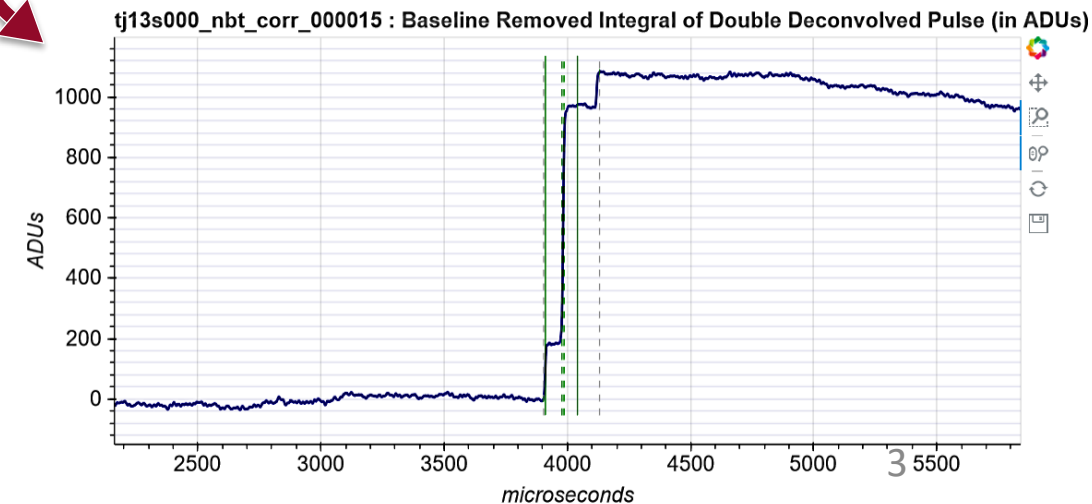
Double deconvolution



Double
deconvolution

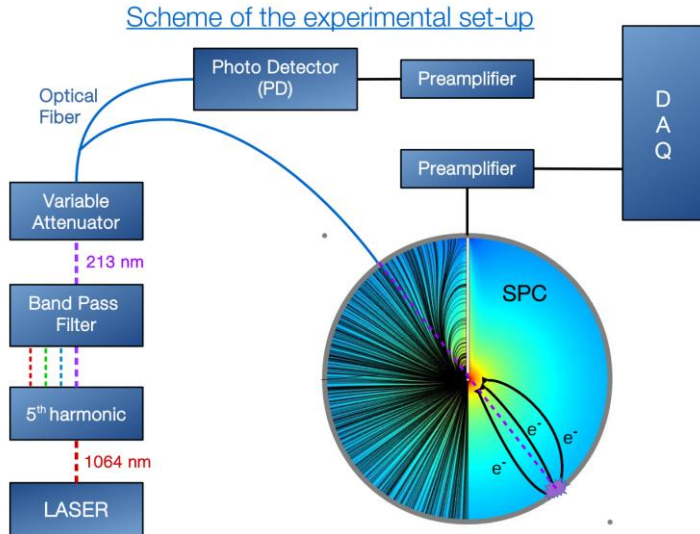


Integration

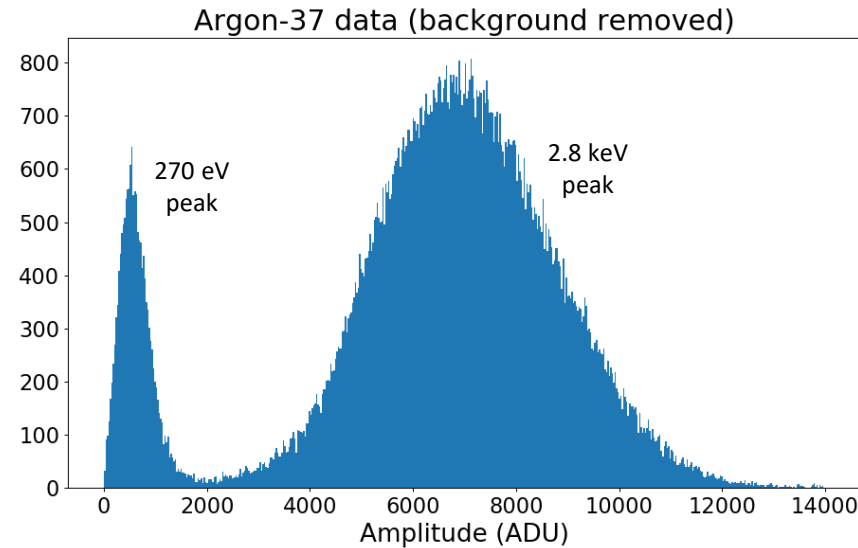


The ballistic deficit is the signal amplitude that gets underestimated due to the exponential decay of the preamplifier. The full amplitude (energy) is retrieved by doing a double deconvolution of the raw signal, and then integrating the pulses.

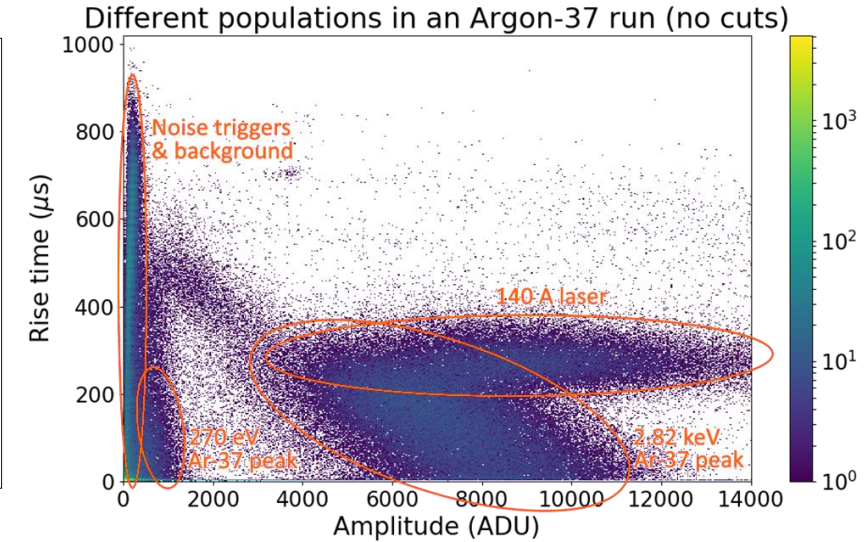
Calibration and spikes



Laser calibration [10]



³⁷Ar calibration



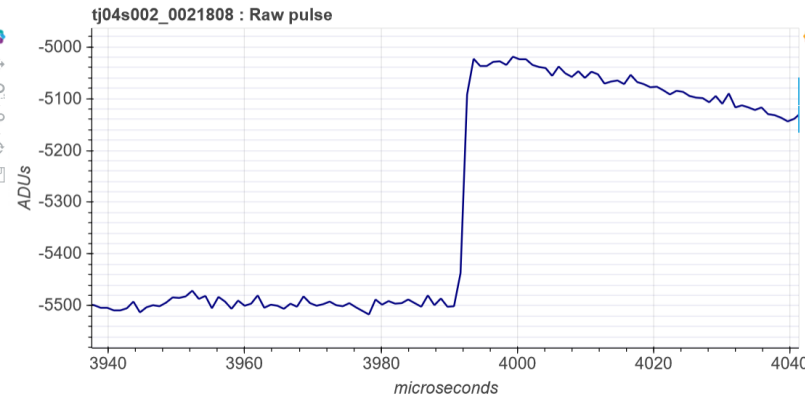
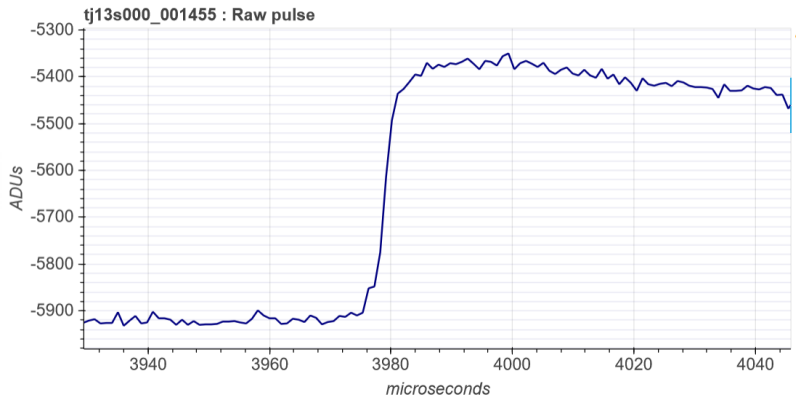
Selection of different kinds of events

A troublesome kind of events: **Spikes**

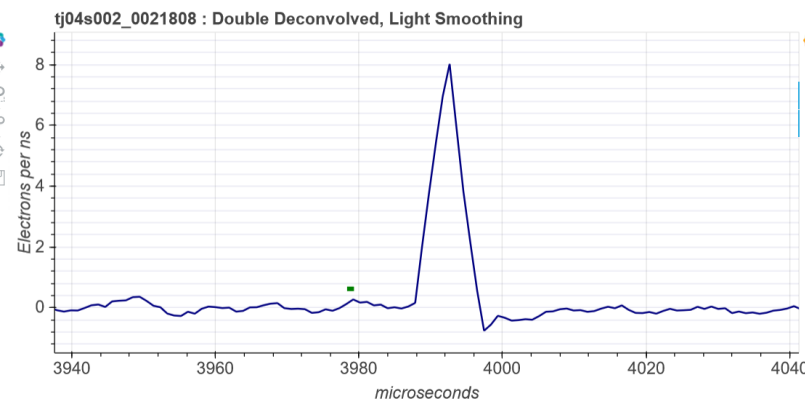
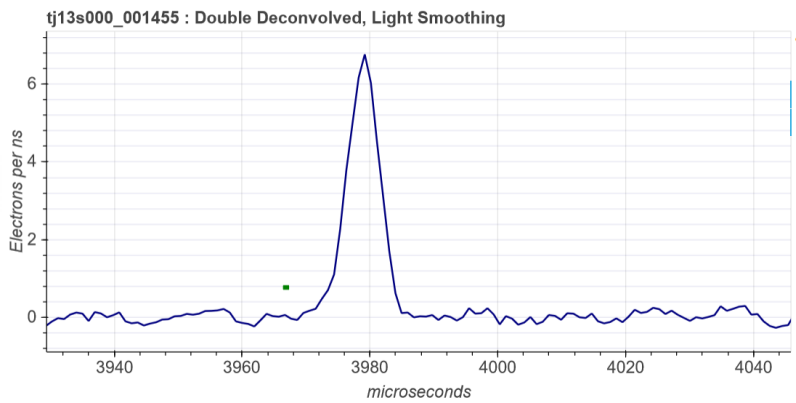
- They are non-physical sudden rises of the signal.
- They do not come from any primary electron, do not create a Townsend avalanche.
- They can be caused by irregularities in the voltage supply or internal discharges.

Spikiness

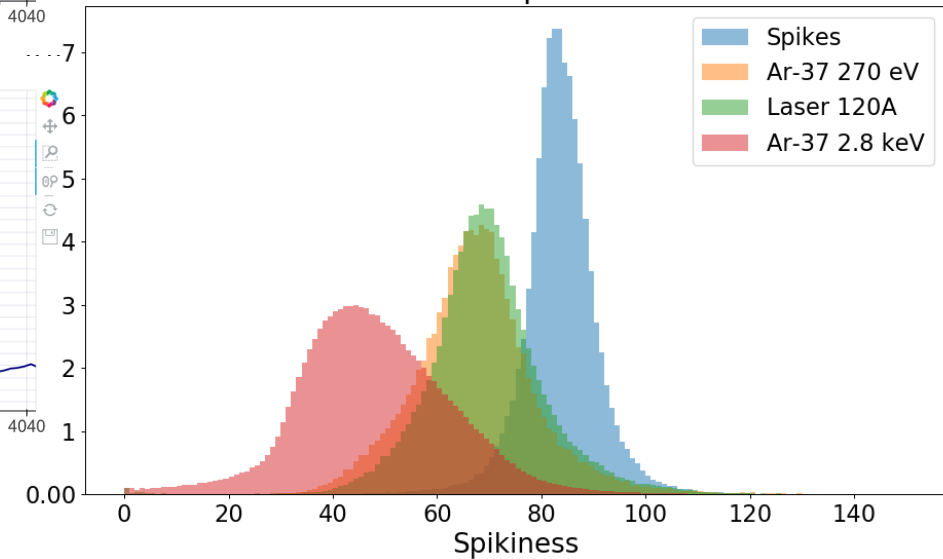
1st comparison method Spikiness



$$\text{Spk} = \frac{\text{Max signal derivative}}{\text{Peak height}}$$



Various spikiness



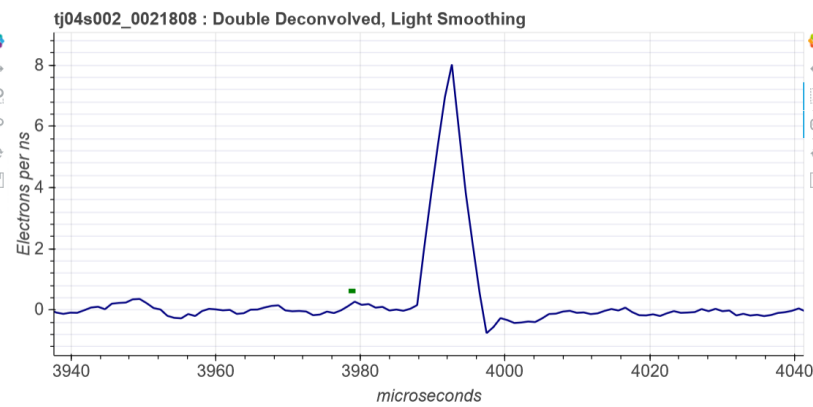
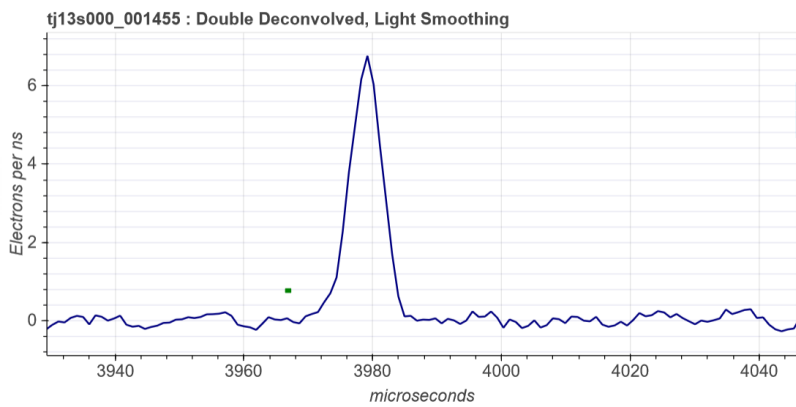
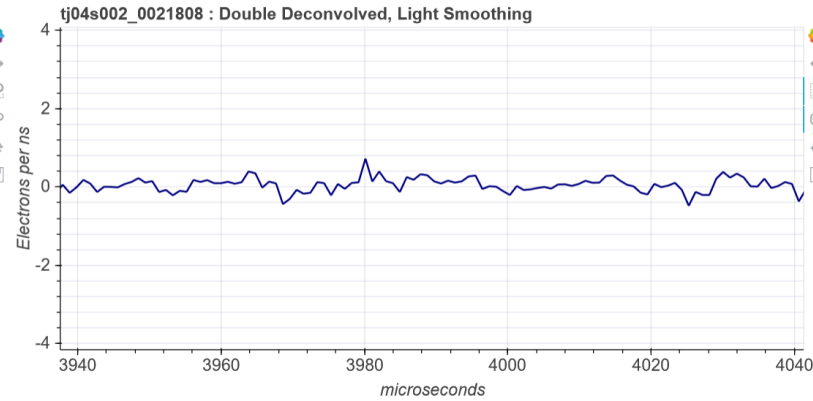
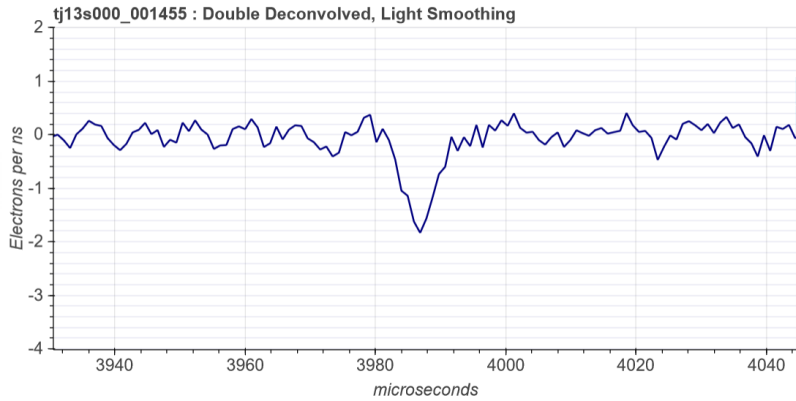
Probable
electron event

Probable spike
event

North/South integral ratio

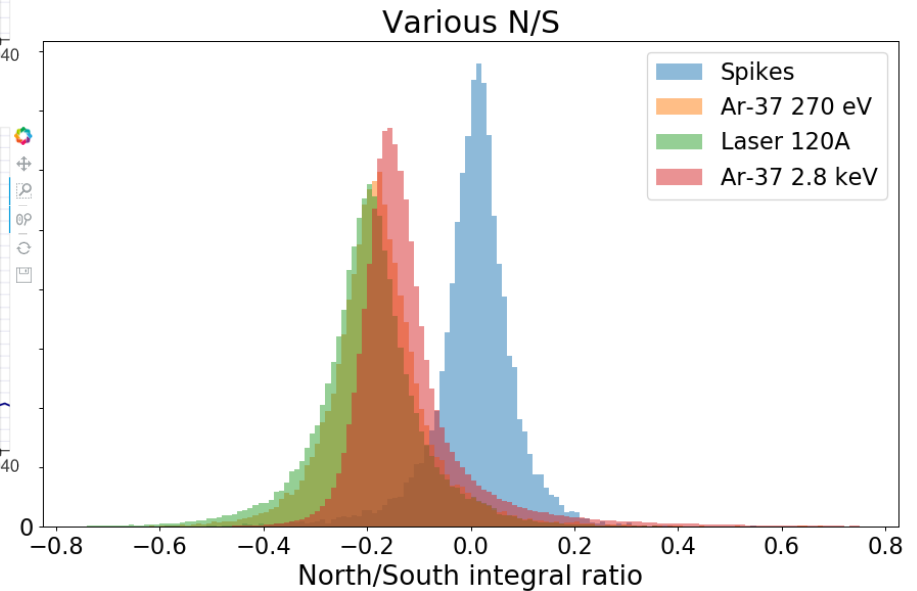
2nd comparison method
N/S ratio

$$N/S = \frac{\text{North DD2 integral}}{\text{South DD2 integral}}$$



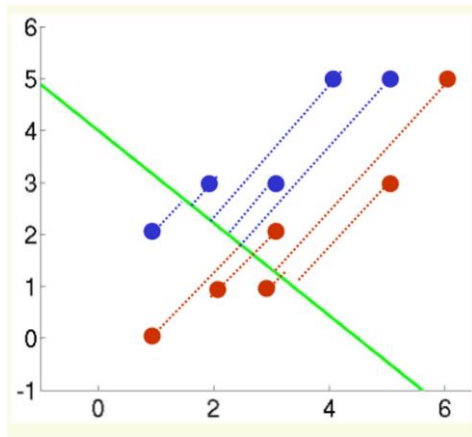
Probable
electron event

Probable spike
event



Linear Fisher discriminant

Optimal comparison:
Combining both methods



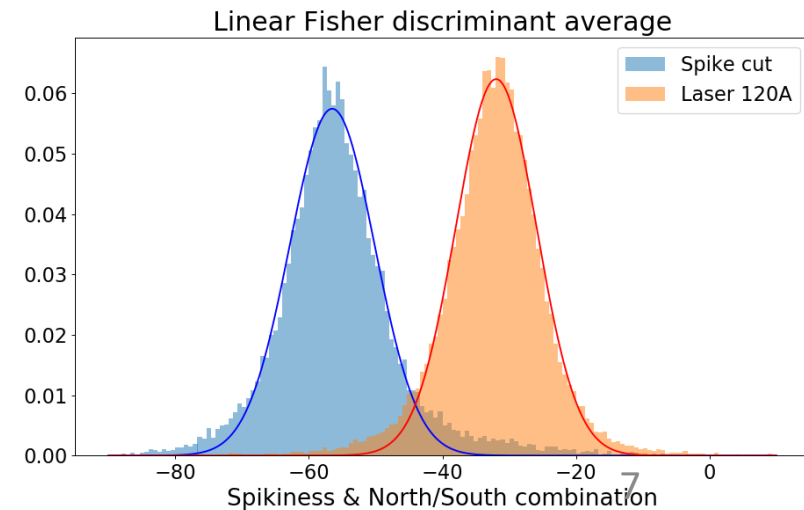
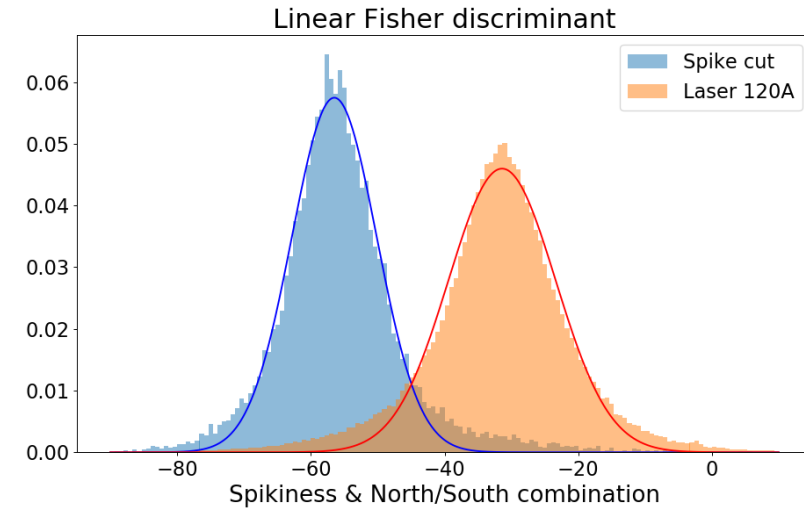
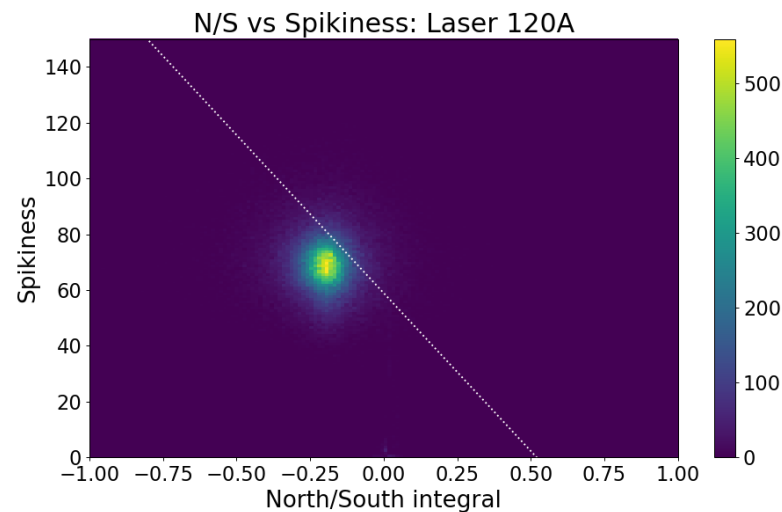
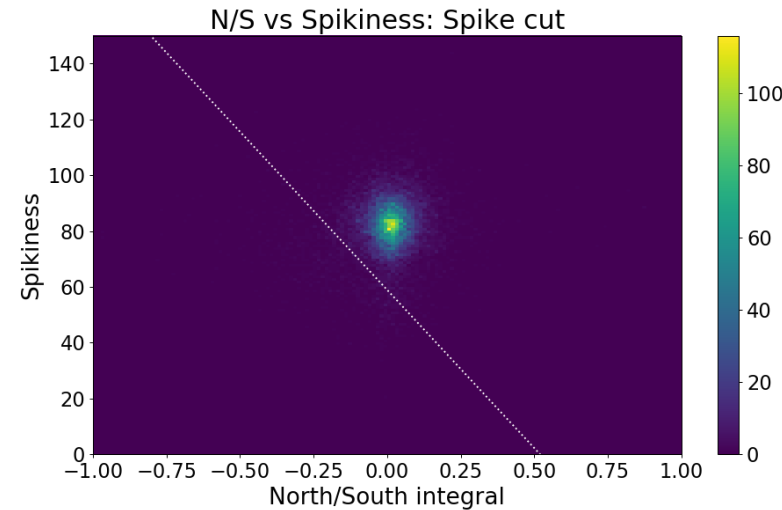
$$\text{Separation } J(\omega) = \frac{(\mu_1 - \mu_2)^2}{N_1(\sigma_1)^2 + N_2(\sigma_2)^2}$$

$$\text{New axis } \tau_i = \omega^t x_i^t$$

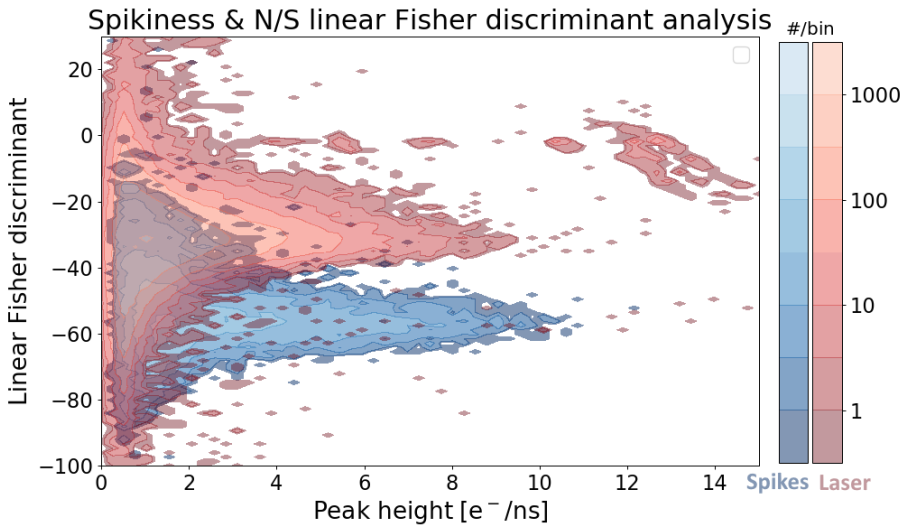
$$\omega = [-0.678619815, -76.8674863]$$

Spk

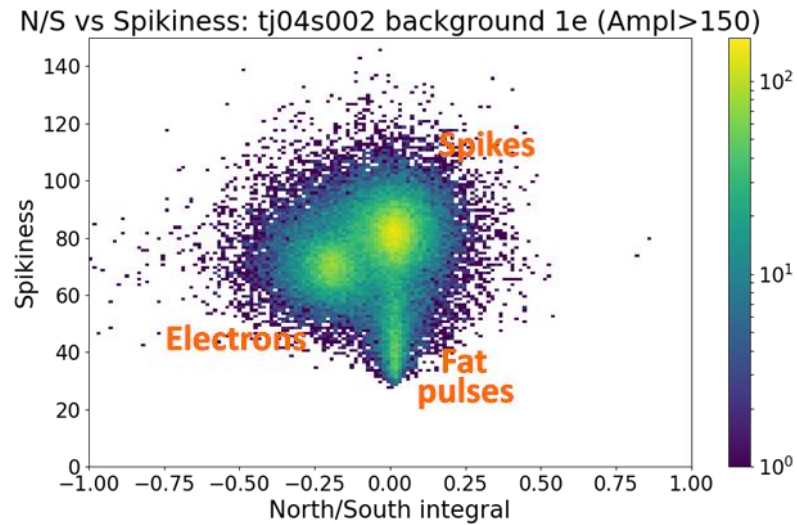
NS



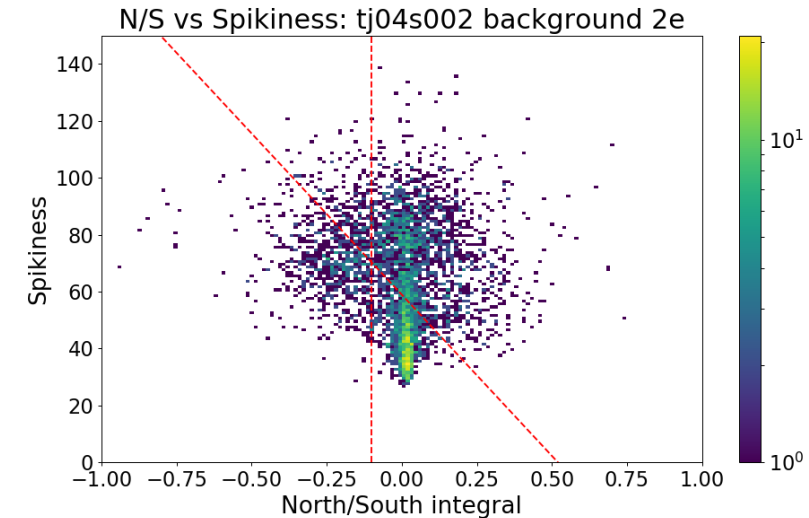
Fits to the physics data



The separation between electron and spike events is weaker at lower energies.

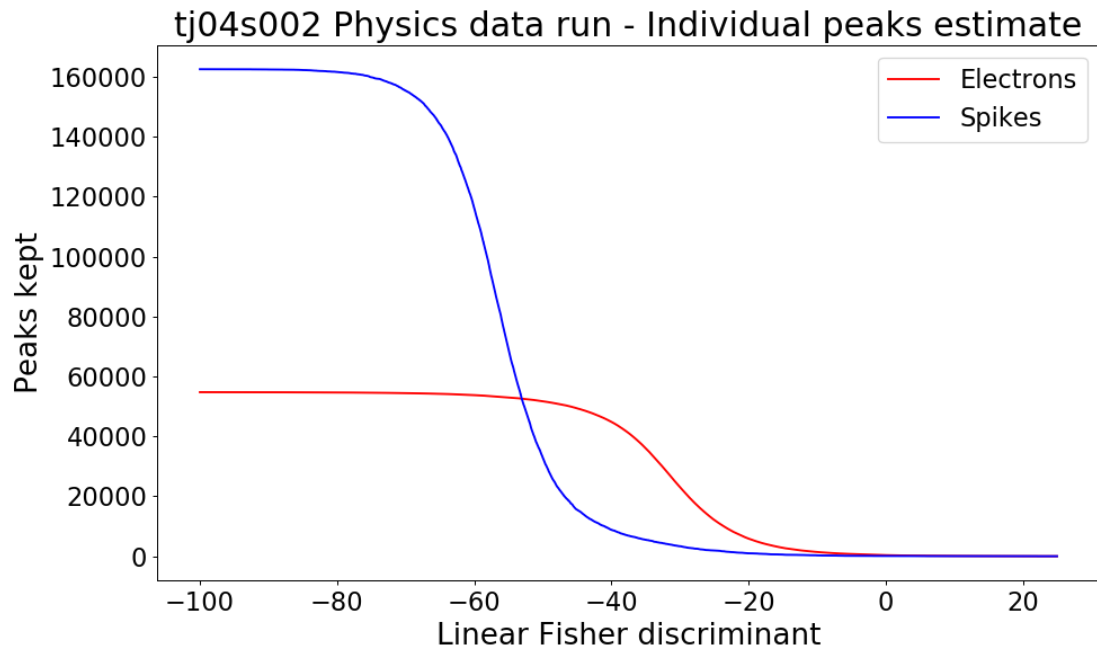


Wide pulses are another dominant background of unknown origin in the data.



A cut on N/S removes fat pulses (dominant in 2-peak data) and a Fisher discriminant cut removes spikes.

Cut optimization



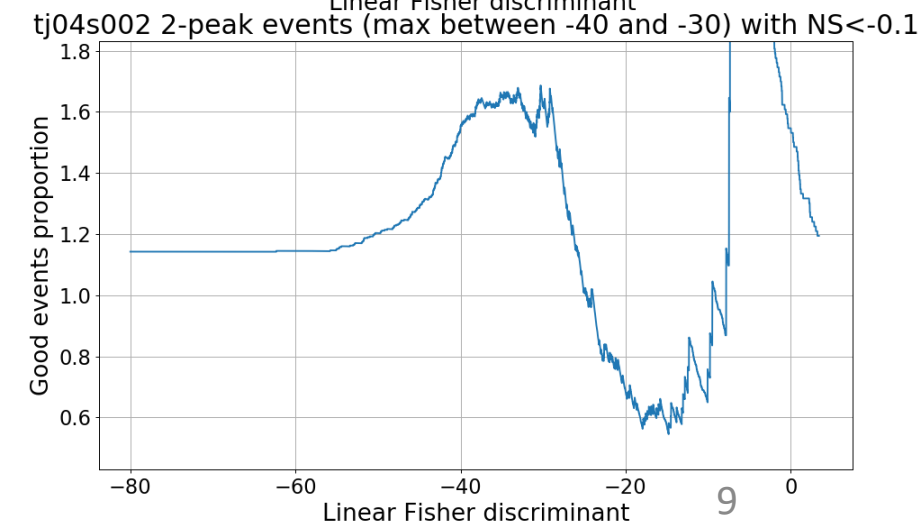
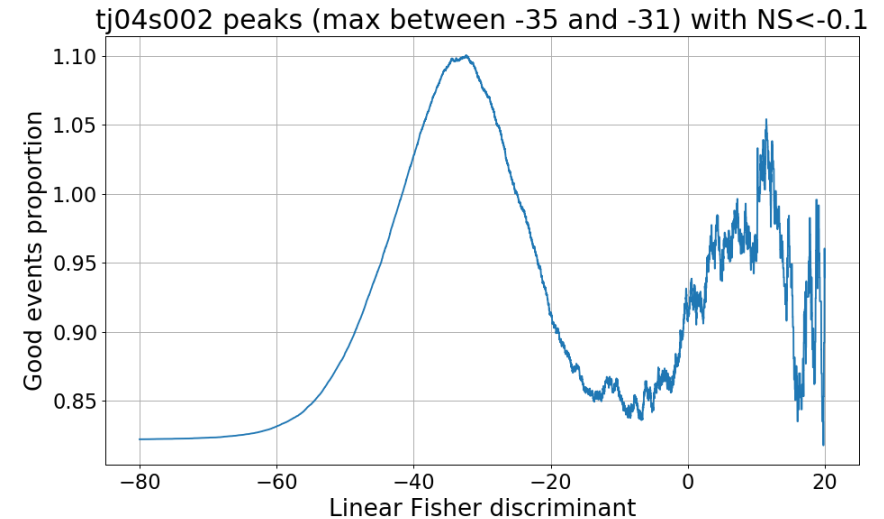
Cut too weak:
Not enough
spikes are
removed



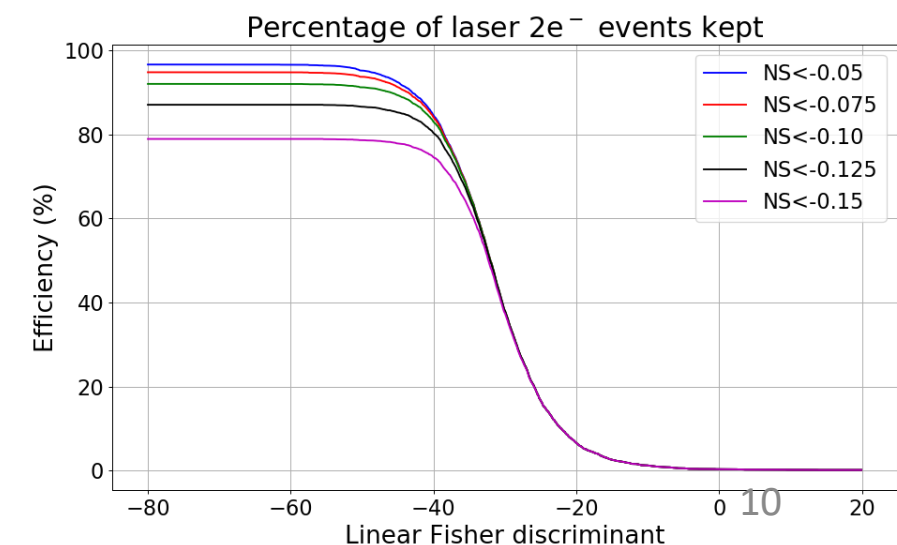
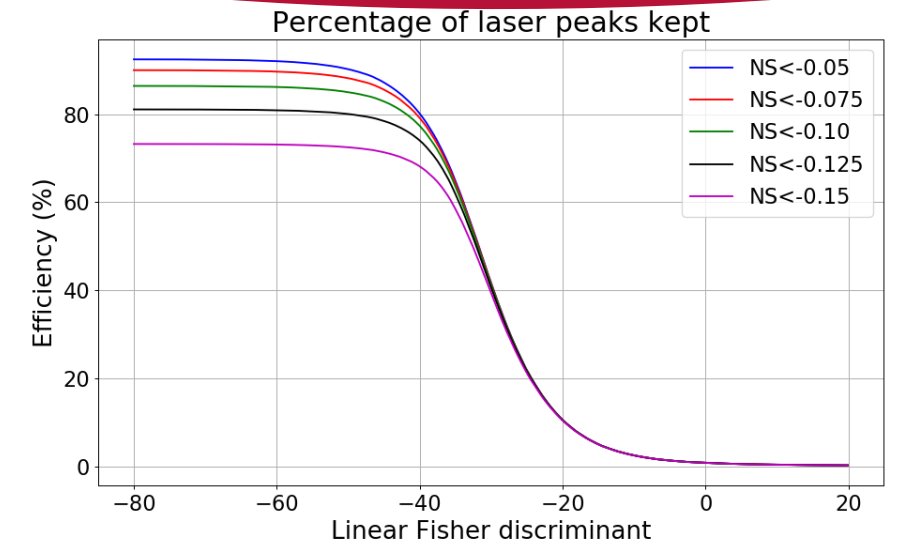
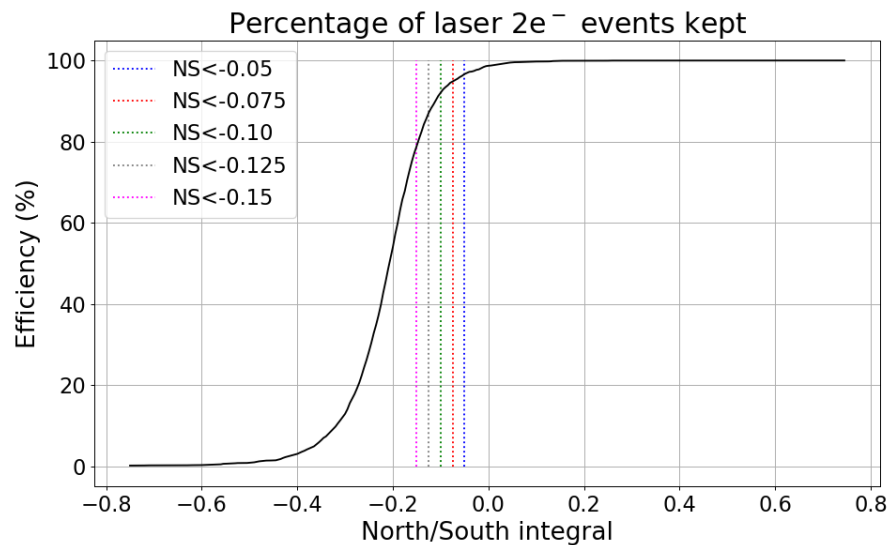
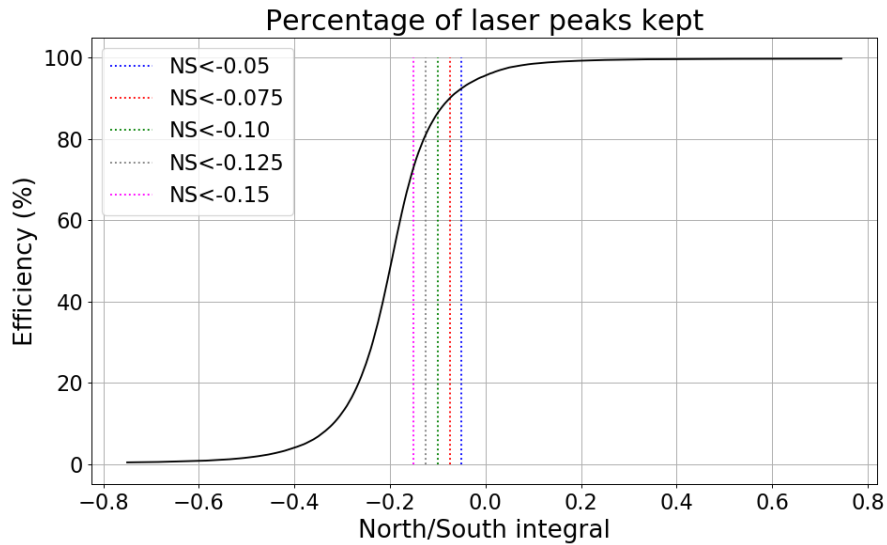
Cut too strong:
Too many good
electron events
are removed



Optimization
of cut on the
Fisher
discriminant



Cut efficiencies



Efficiency
of cut on
N/S

Efficiency
of cut on
Fisher
discrim.

Conclusion

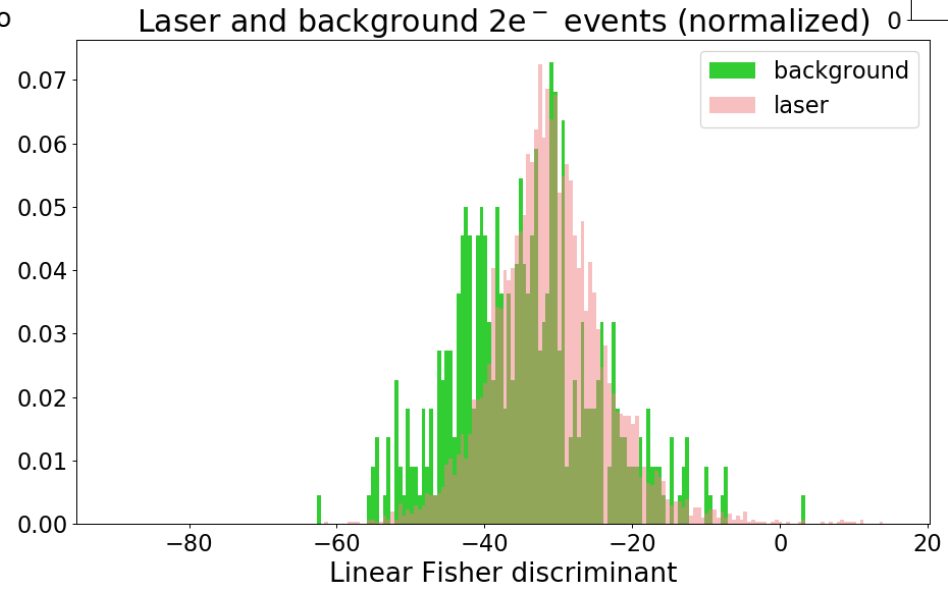
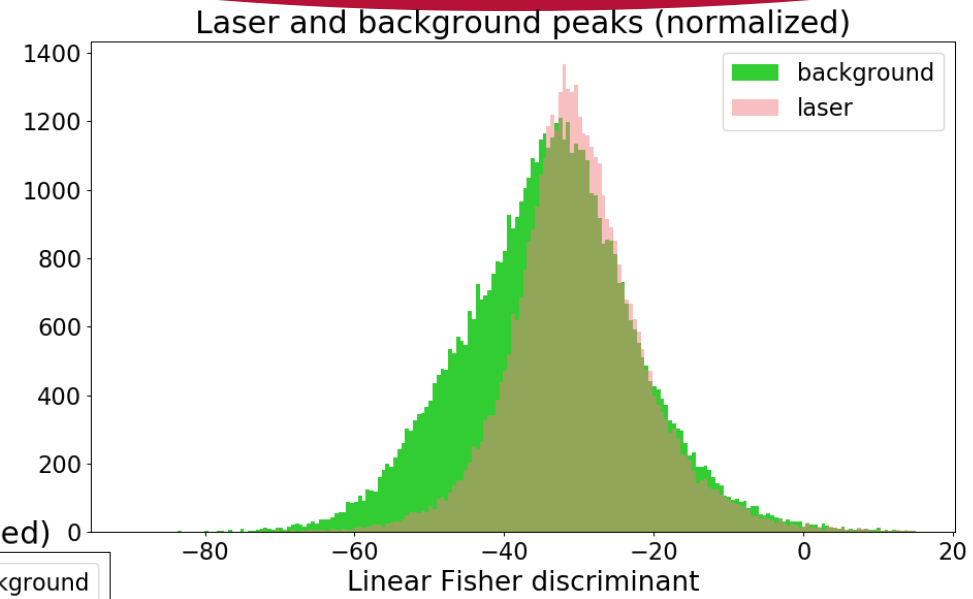
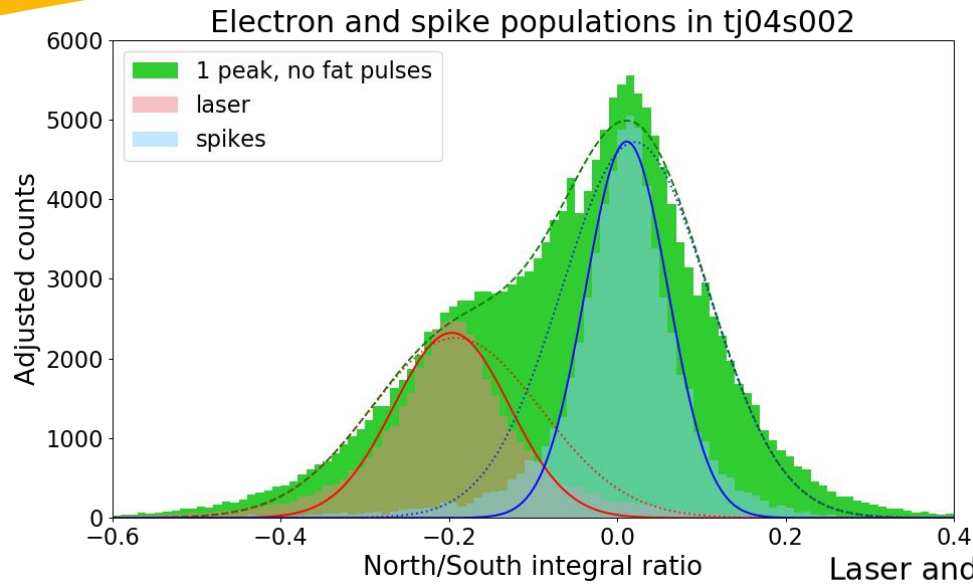


- Spike events and wide pulses can be discriminated with the combined use of the spikiness and North/South integral ratio variable.
- This event selection will serve in the LSM data paper that should be published in the next months, using CH_4 gas.
- This data analysis will continue to be useful in the next WIMP search in SNOLAB and other future SPCs.

- Main source:
 - Jean-Marie Coquillat. *Calibration and background data analysis in the scope of the NEWS-G dark matter experiment*. Master's thesis, Queen's University, 2021.
- Image sources:
 - Slide 2: A. Giganon, I. Giomataris, M. Gros, I. Katsioulas, and X.F. et al. Navick. *A multiball read-out for the spherical proportional counter*. *Journal of Instrumentation*, 12(12):P12031–P12031, Dec 2017.
 - Slide 4: Giomataris, I., Gros, M., Katsioulas, I., Knights, P., Mols & et al. (2020). *A resistive ACHINOS multi-anode structure with DLC coating for spherical proportional counters*. *Journal of Instrumentation*, 15(11), P11023–P11023.
 - Slide 4: Q. Arnaud, J.-P. Bard, A. Brossard, M. Chapellier, and M. et al. Clark. *Precision laser-based measurements of the single electron response of spherical proportional counters for the NEWS-G light dark matter search experiment*. *Physical Review D*, 99(10), May 2019
 - Slide 7: Olga Veskler. *Cs434a/541a: Pattern recognition*, October 2004.

Extra slides

N/S vs Fisher fit to data



$$\frac{\# \text{ of laser event with } \tau > -25}{\# \text{ of total laser events}} = \frac{\# \text{ of physics data events with } \tau > -25}{\# \text{ of total good electron physics data events}}$$

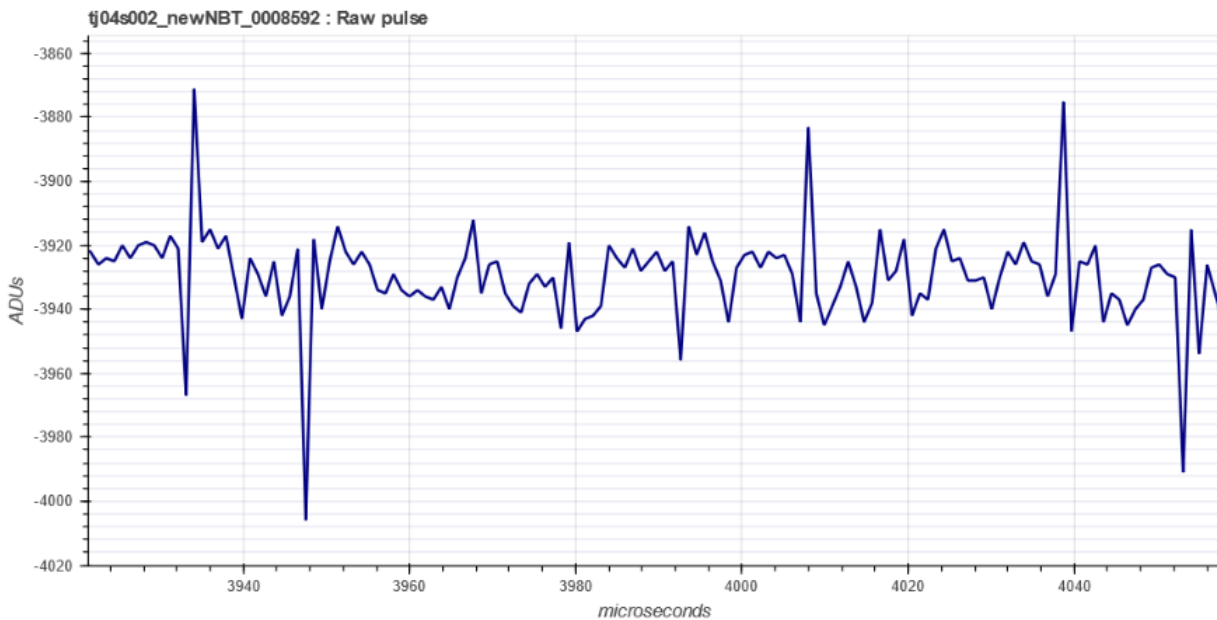
North channel

Wide pulse
Spk: 38.5 N/S: 0.036

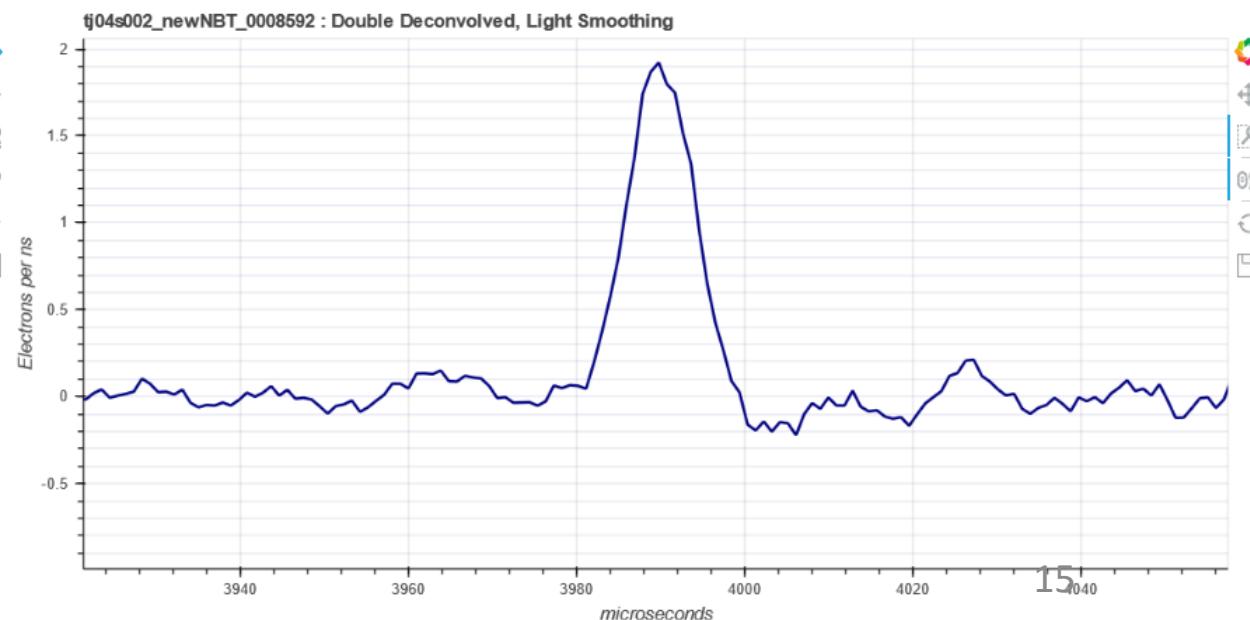
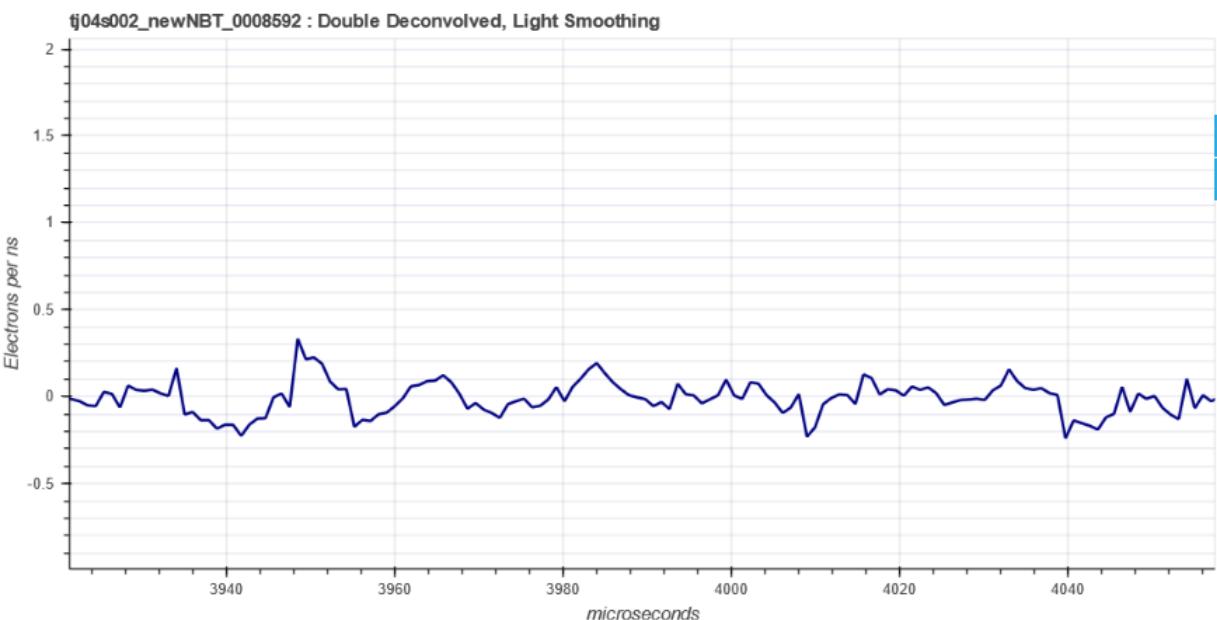
South channel



Raw pulse



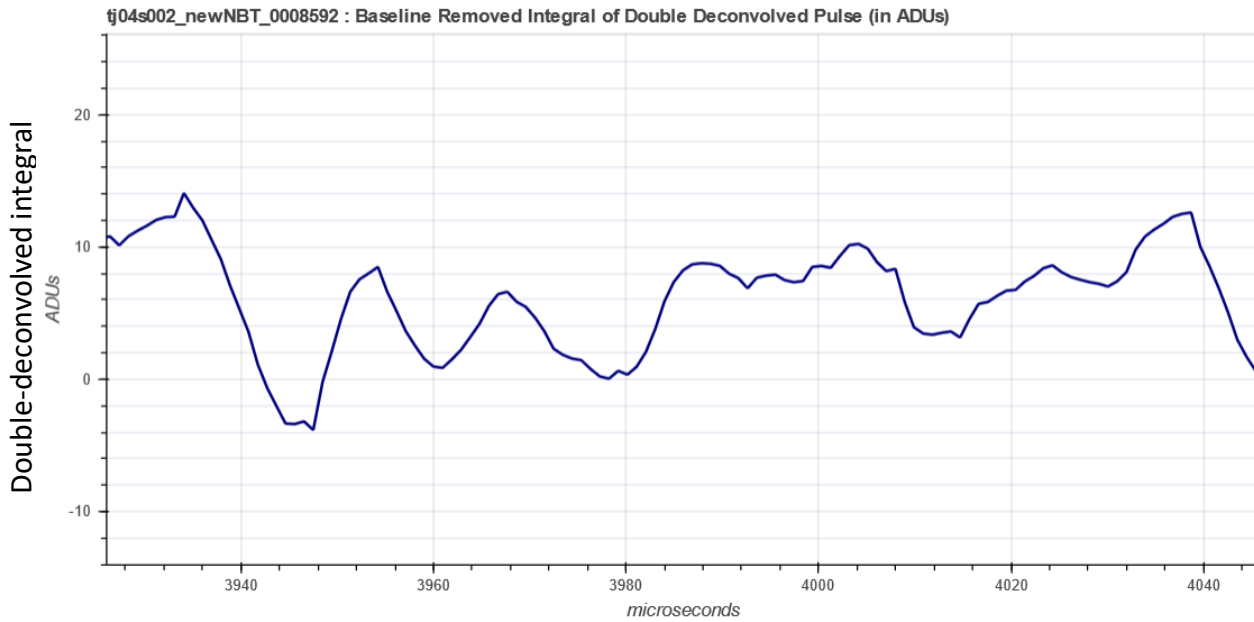
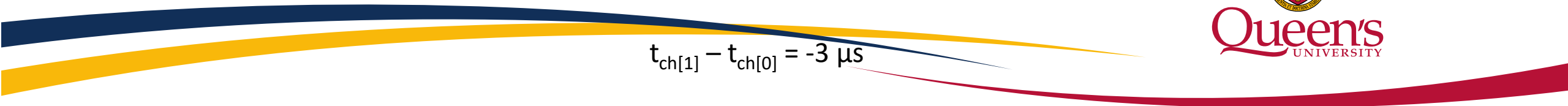
Double-deconvolved



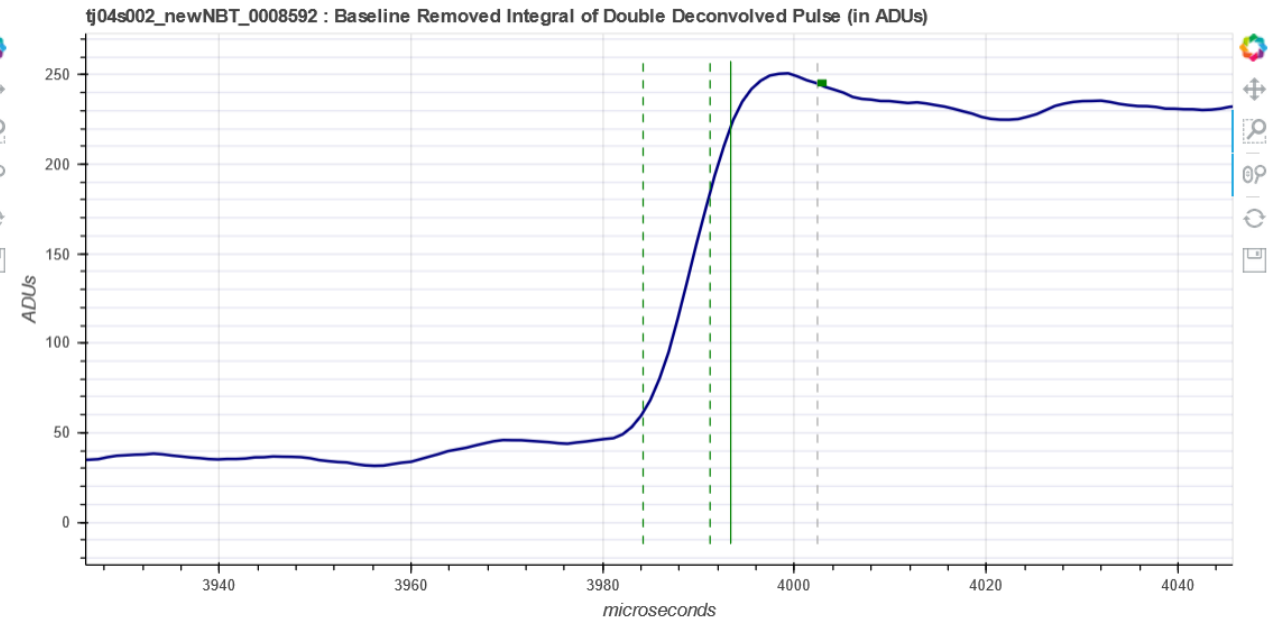
Wide pulse
Spk: 38.5 N/S: 0.036



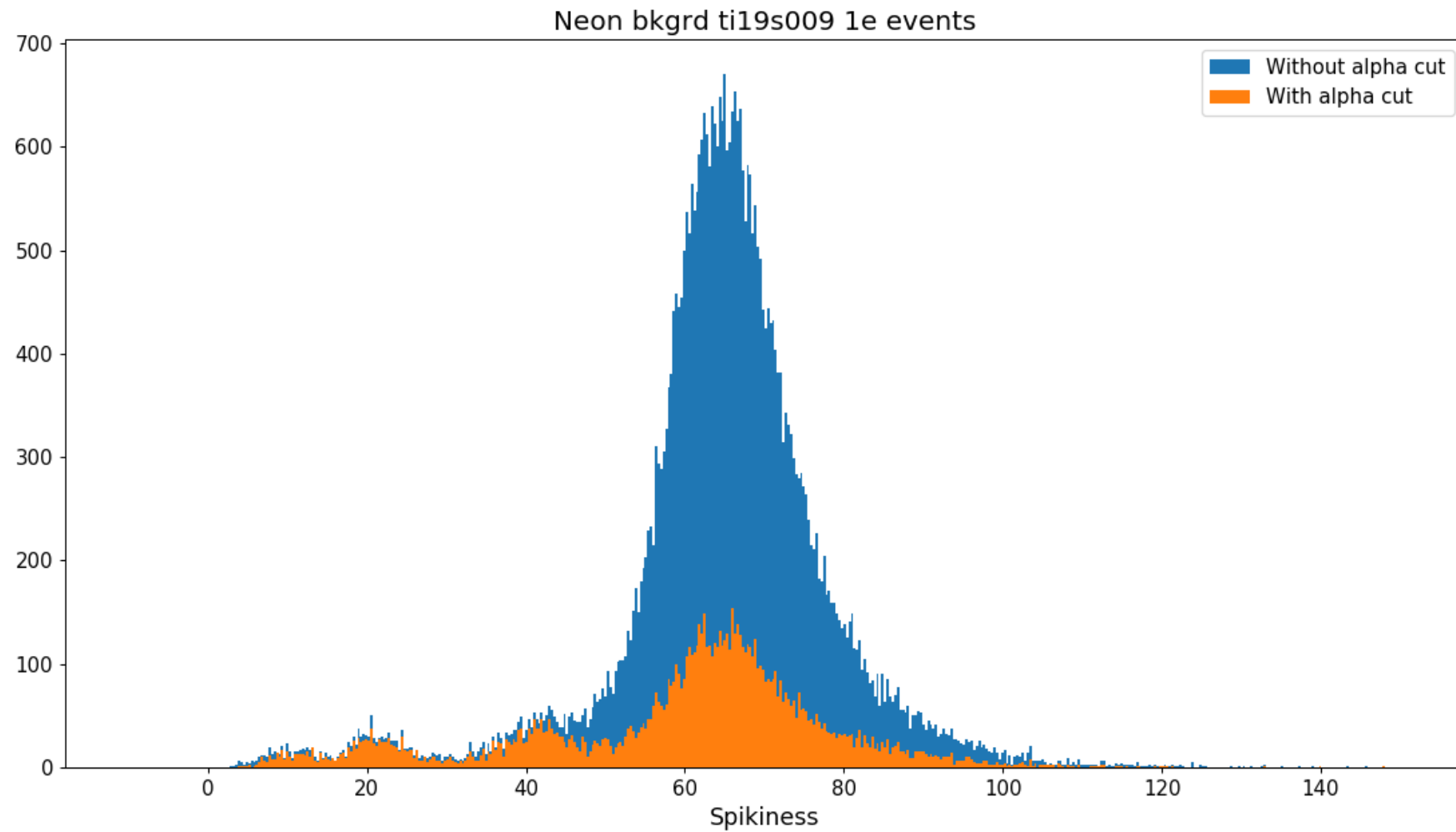
$$t_{ch[1]} - t_{ch[0]} = -3 \mu s$$



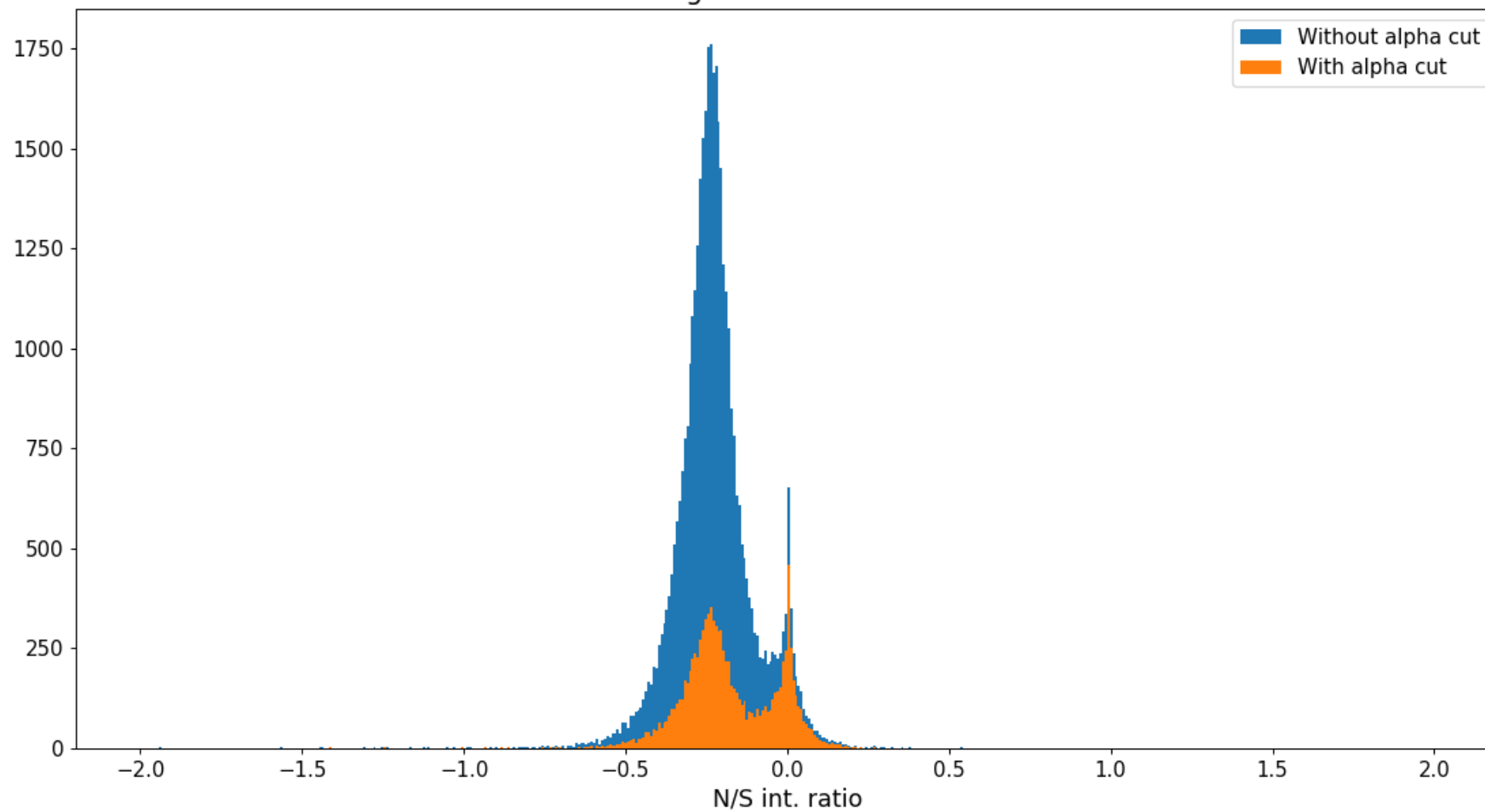
North channel

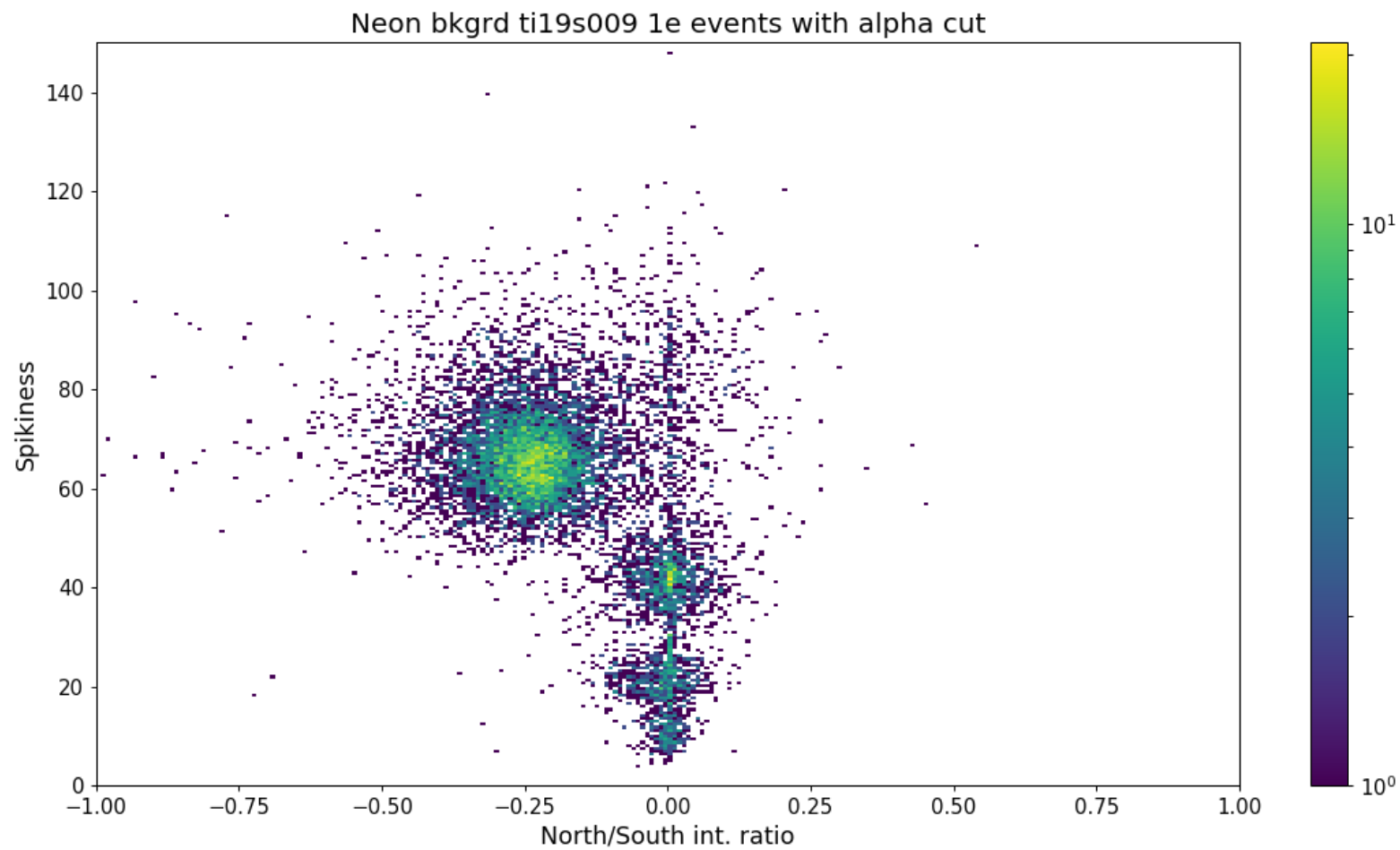


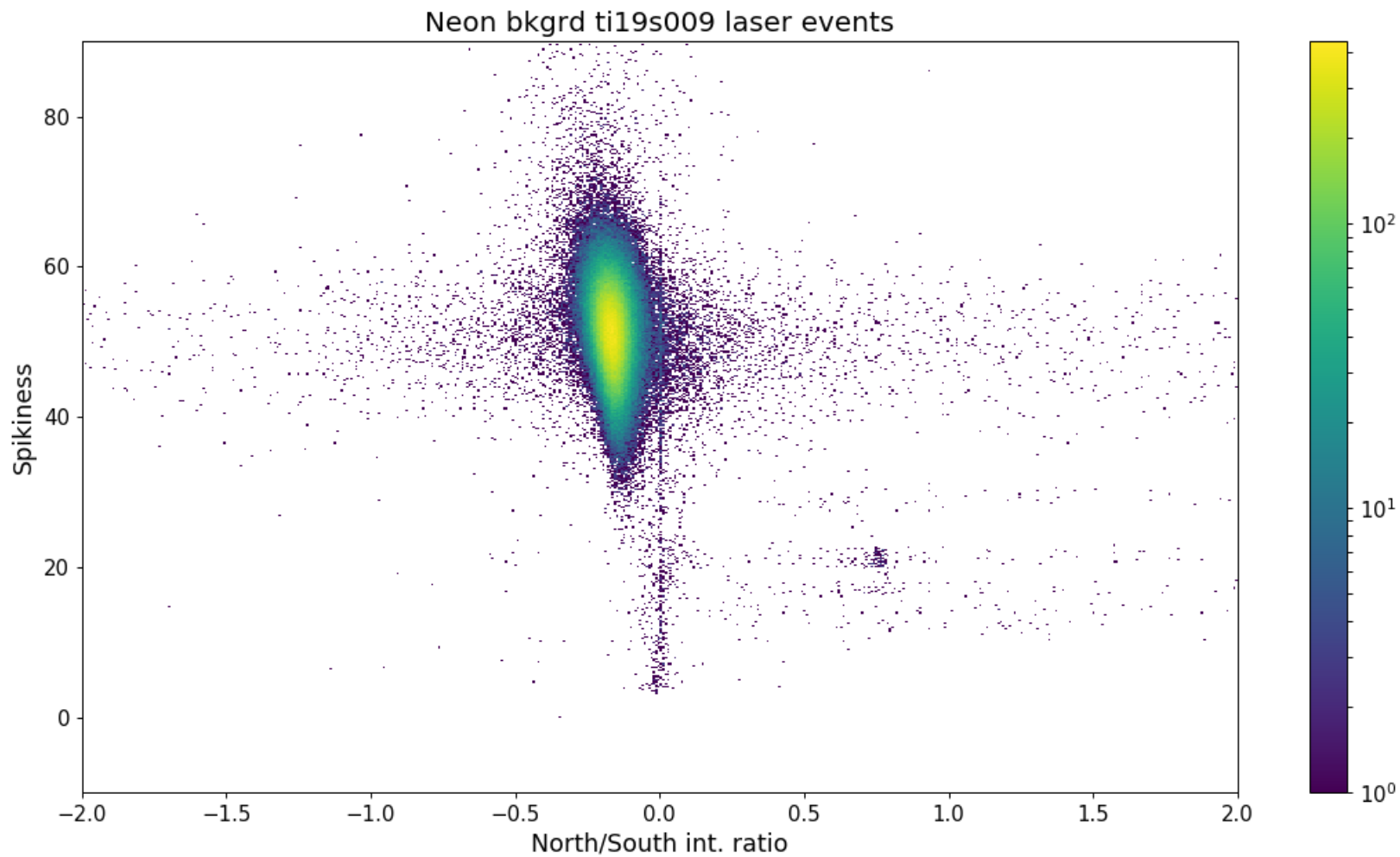
South channel



Neon bkgd ti19s009 1e events







Neon bkgd ti19s009 2e events without alpha cut

