DArT Data Analysis

Background and Alpha Study

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DArT Collaboration Meeting
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LSC Laboratorio Subterráneo de Canfranc
DARKSIDE
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
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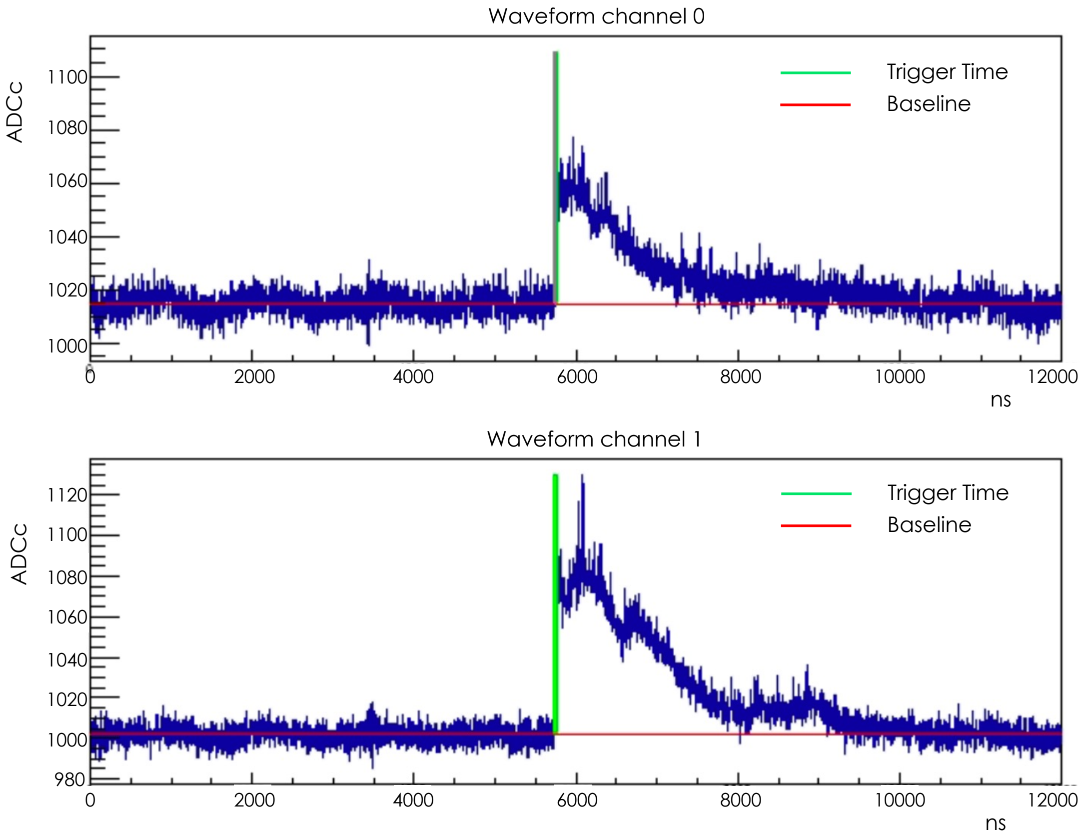
GOALS

- **Evaluation of continuous performance** of the detector
- Study of the **stability** of the setup
- **Determination** of feasible **operation conditions** of the DAQ and electronics
- Getting information about **acquisition rate**
- Understanding the possibility to perform a **calibration of the photoelectronics**
- Getting information about **purity of liquid argon**
- **Setting protocols** for operating the inner detector
- Getting information about **Rn emanation**

Background: Dataset

Run 180 (20/02/2022)

- Live time = $3.33 \cdot 10^5$ s (~ 90 h)
- Number of events = $7.16 \cdot 10^5$
- Average trigger rate = 2.15 Hz
- Trigger threshold = 40 ADCc (~ 5 mV)
- Coincidence between channels
- Acquisition Window = 12 μs (6000 samples)
- Post Trigger = 50% of window
- Bias board outside the chamber

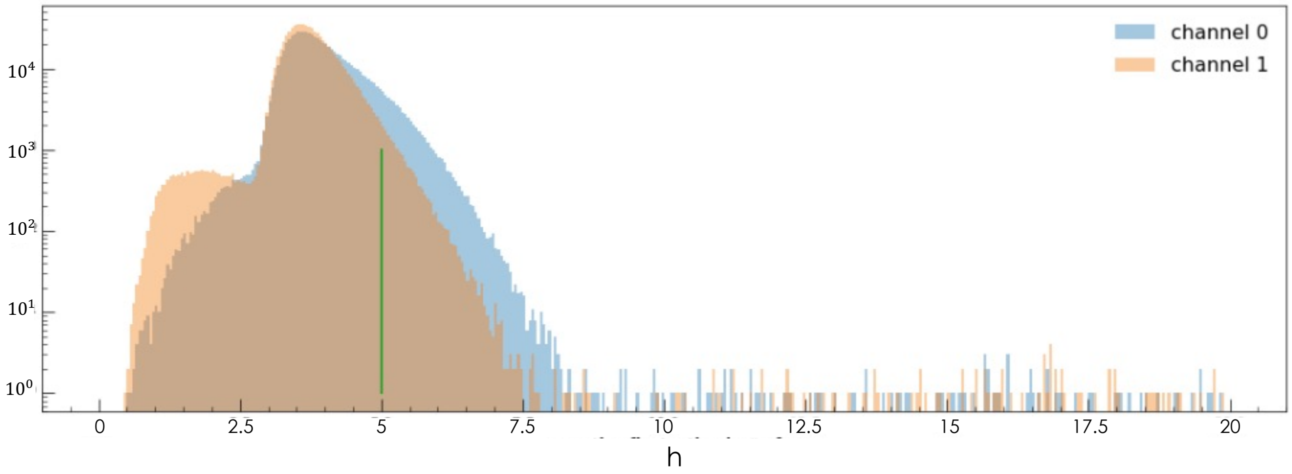


Background: Cut

- Cut applied to **reject noise events**
- Cut variable: **maximum negative fluctuation in number of RMS of the baseline**

$$h = -\frac{min(ADCc\ -\ baseline)}{RMS_{baseline}} < 5$$

for each ADC value of each event, for both channels



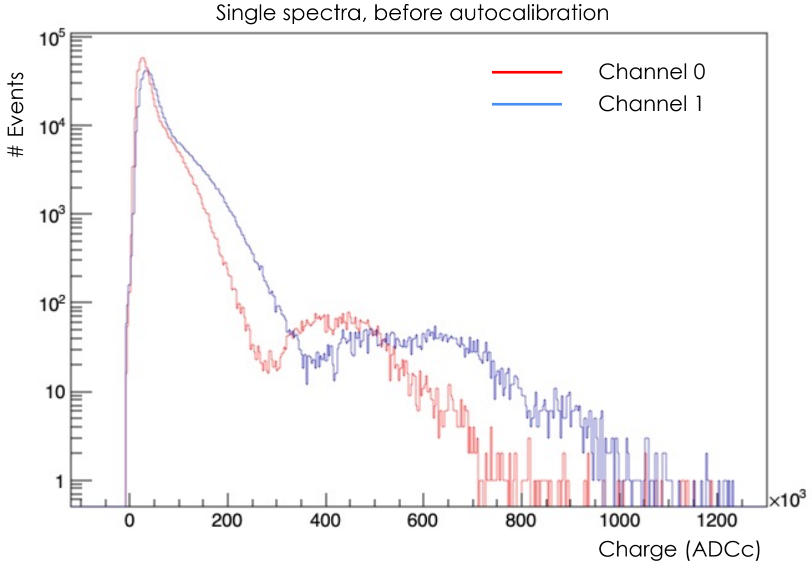
$6.42 \cdot 10^5$ events that survive the cut

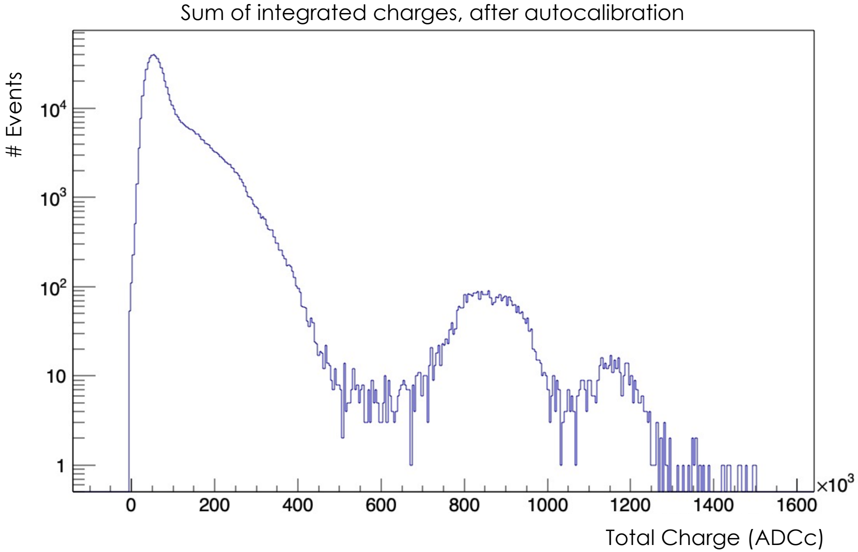
- **10% of total events rejected**

Background: Energy Spectrum

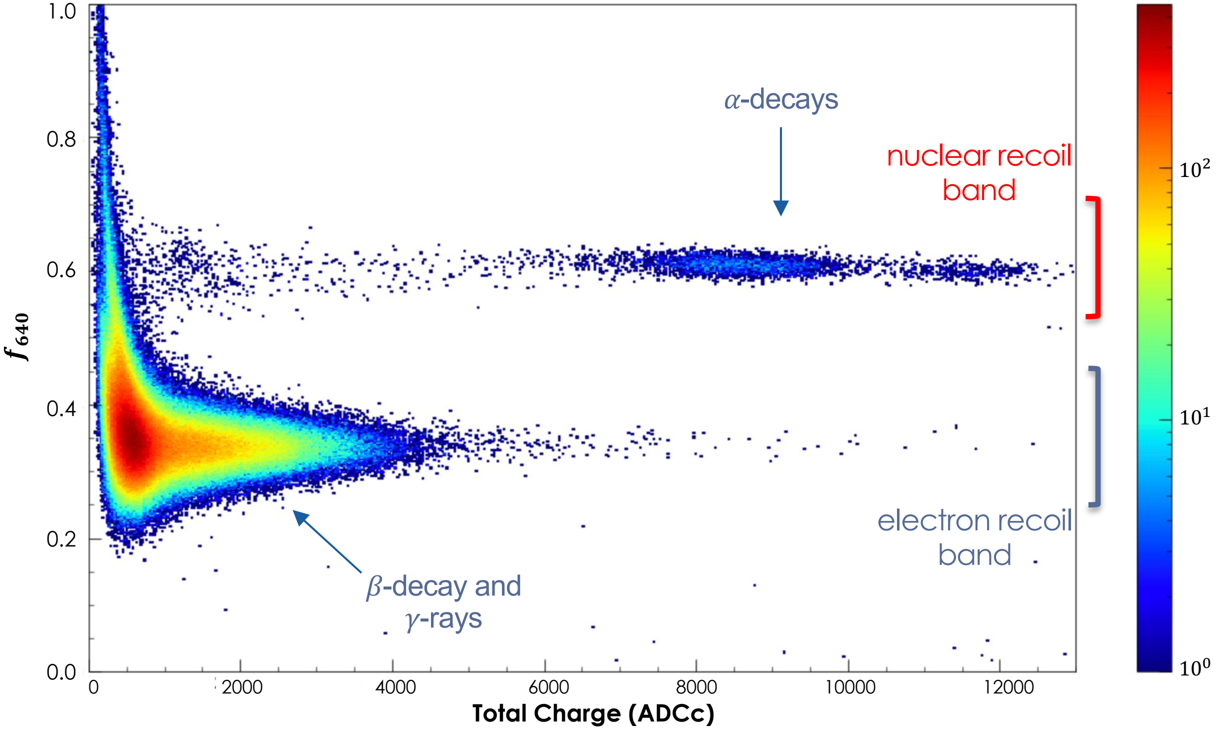
Integrated charge of the two channels considered

Autocalibration factor *K* = 0.73 ▶ Integrated charge of channel 1 multiplied by *K*





Background: Pulse Shape Discrimination (PSD)

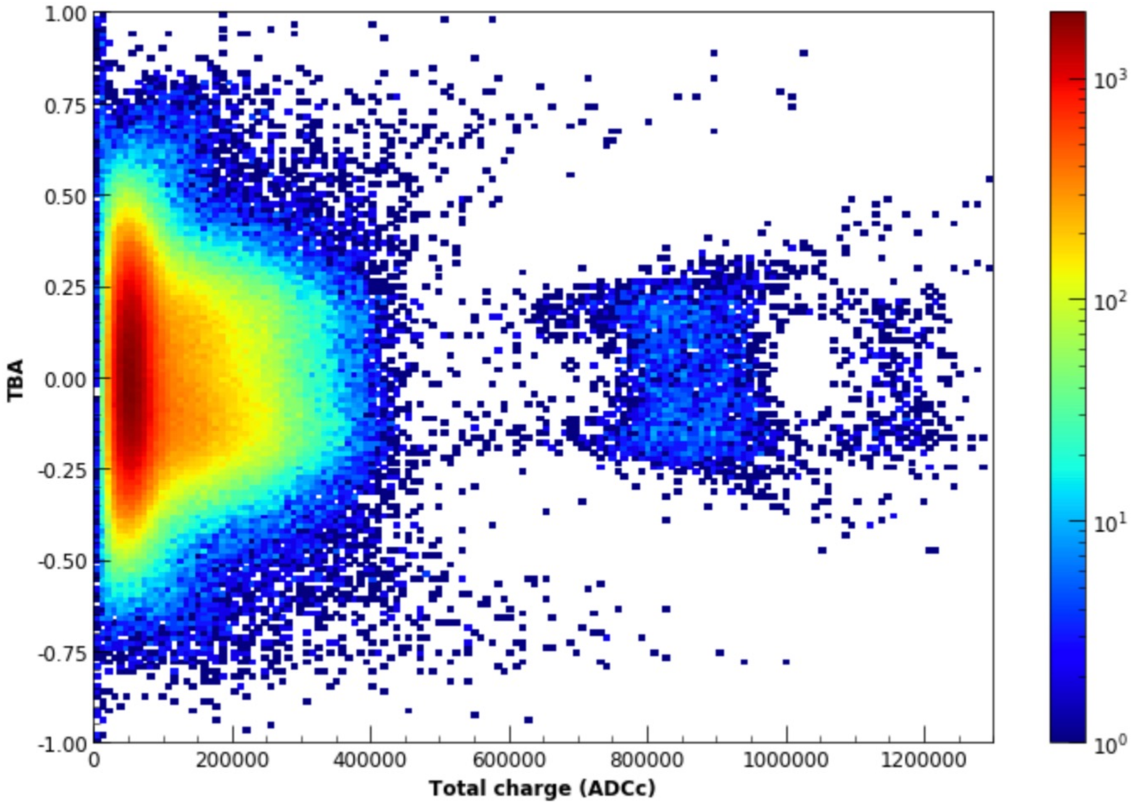


$$f_{640} = \frac{q_{640,0} + q_{640,1}}{q_{tot,0} + q_{tot,1}}$$

$q_{640,i}$ = integrated charge in the first 640 ns from trigger time of channel i

$q_{tot,i}$ = integrated charge in the ROI (5 μs after trigger time), of channel i

Background: Top – Bottom Asymmetry



$$\mathrm{TBA} = \frac{q_0 - q_1}{q_0 + q_1}$$

The **DArT chamber** is practically **symmetric**

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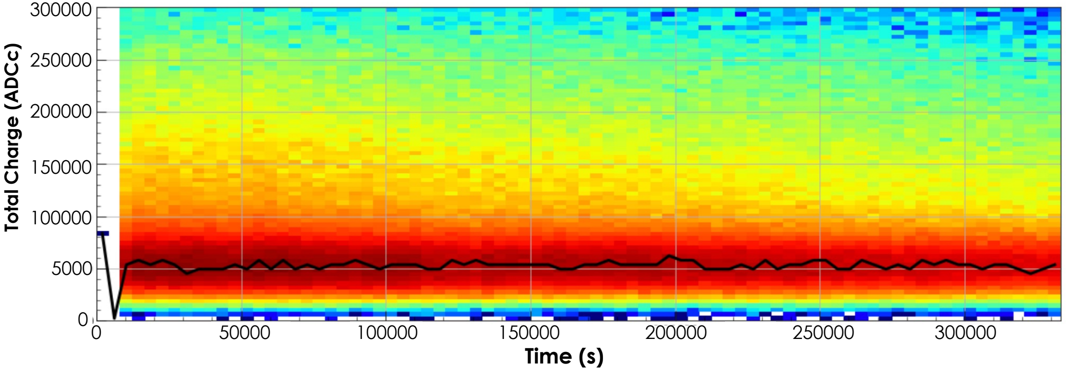
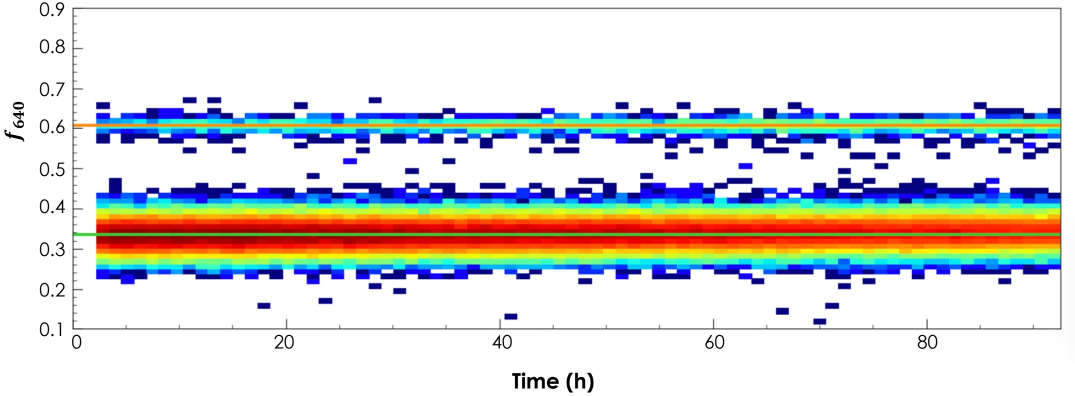
The **geometric effects** on light detection should cancel out in average

Background: Stability

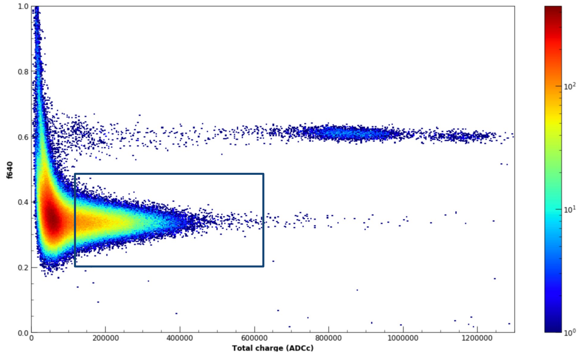




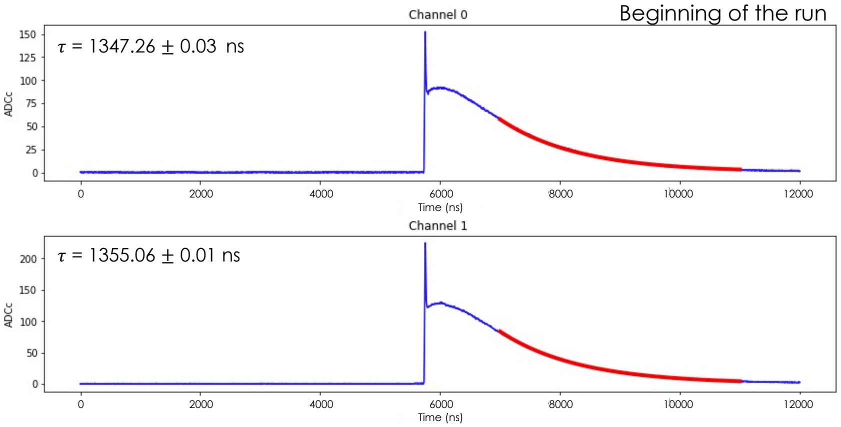
Total charge decreases a bit in time, but pretty stable anyway

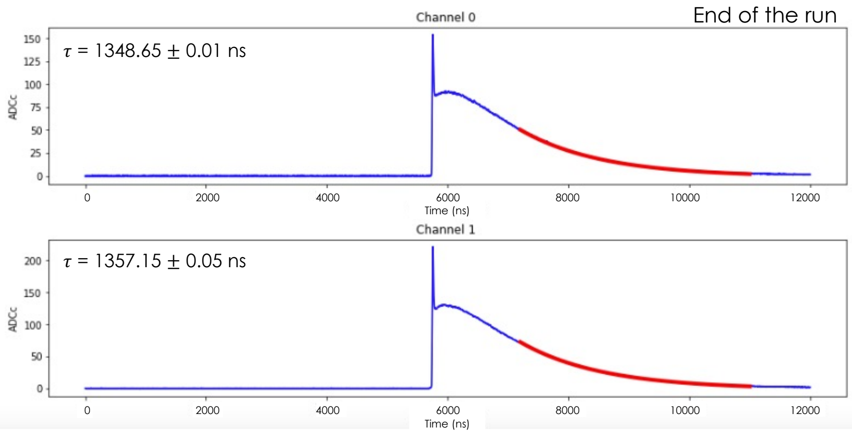
f_{640} stable in time, both for electron and nuclear recoil bands

Background: LAr Purity – Beta Decays

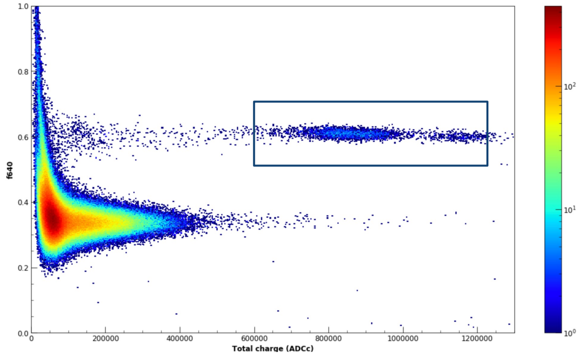


- Measurement of the decay time of the slow component of the signal, at the beginning and at the end of the run
- **Average** of 300 waveforms in the **electron recoil band**
- Fit function: **decreasing exponential** $f(x) = a \cdot e^{-x/\tau} + d$

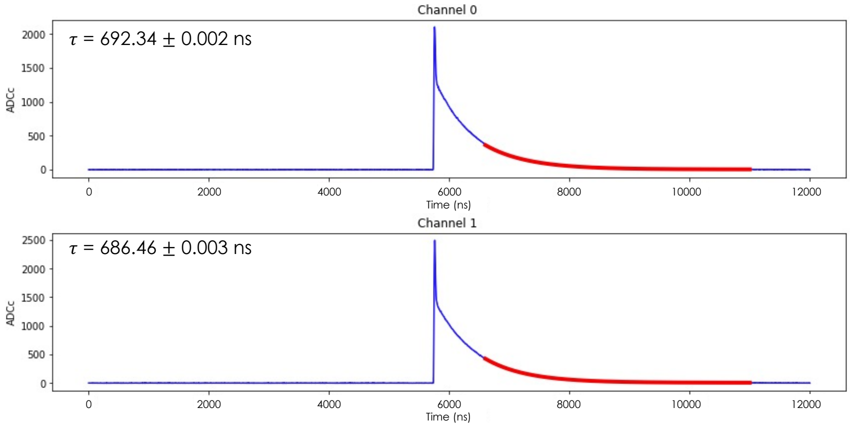




Background: LAr Purity – Alpha Decays



- Measurement of the decay time of the slow component of the signal, at the beginning and at the end of the run
- **Average** of 300 waveforms in the **nuclear recoil band**
- Fit function: **decreasing exponential** $f(x) = a \cdot e^{-x/\tau} + d$



A shorter decay time is measured

For the alpha the waveforms are **dominated by the response of the SiMP** with respect to the physics

▼

we **cannot perform a measure** of the triplet lifetime in this case

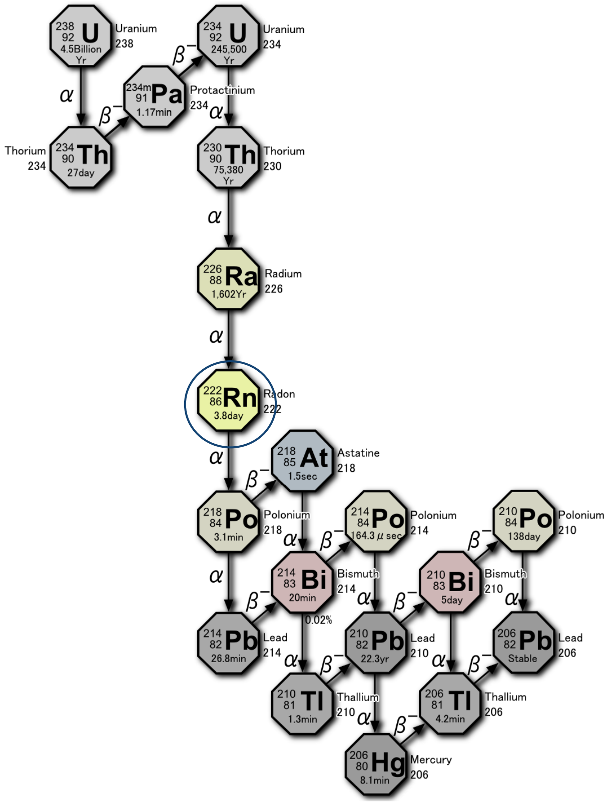
Background: LAr Purity

- While for beta decays we are able to perform a measure of the triplet lifetime obtaining consistent results, because the slow components dominates with respect to the fast one, the same is not possible for alpha decays: a deconvolution of the signal is needed to separate the argon signal from the response of the SiPM and proceed in this way with the measure of the triplet decay time. We expect to obtain the same result as the beta case

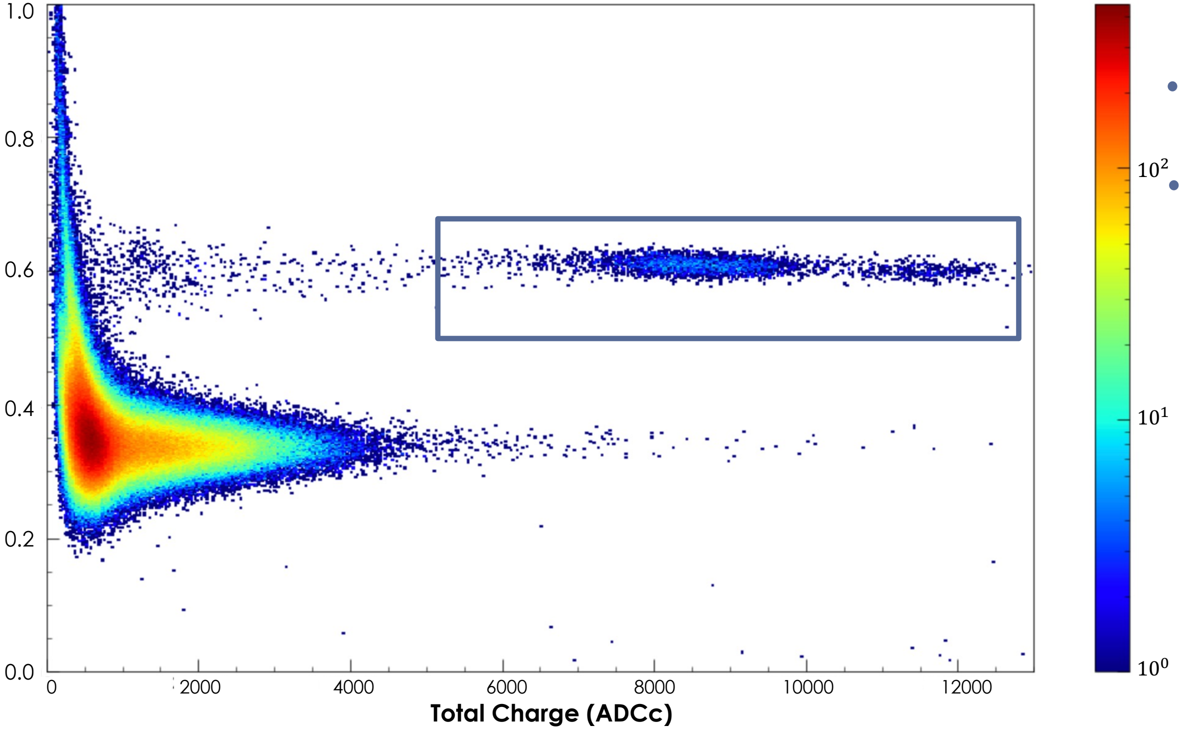
- Since the decay time measured for the slow component of the signal in the electron bands remains constant, we can conclude that the purity of liquid argon within the chamber doesn't get worse in time, excluding in this way the presence of a leak in the system and confirming a great airtightness of our setup

Alphas: ^{222}Rn Contamination

- ^{238}U is present in detector materials
- ^{222}**Rn** is formed as intermediate step in the chain
- Since ^{222}Rn is an **inert gas**, the small contamination of ^{238}U in the detector materials is expected to produce a **continuous emanation** of ^{222}Rn gas within the DArT chamber, producing **background alpha particles** originated from natural decays



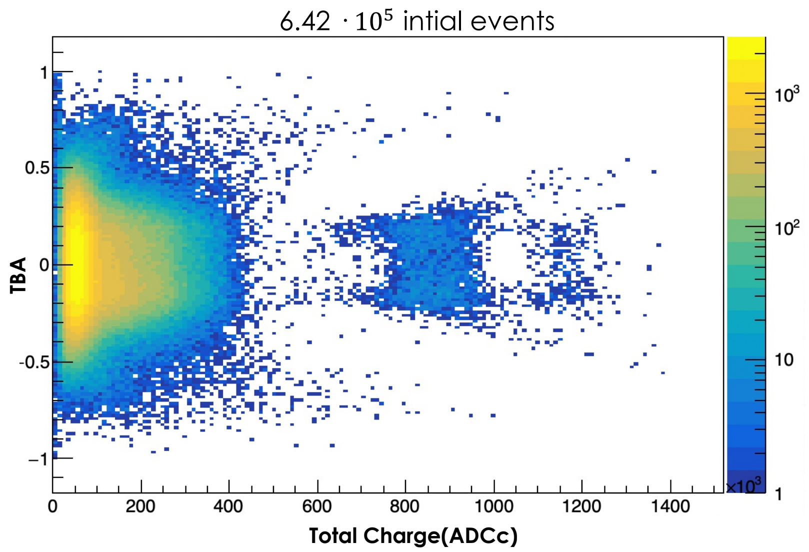
Alphas: Alpha Selection

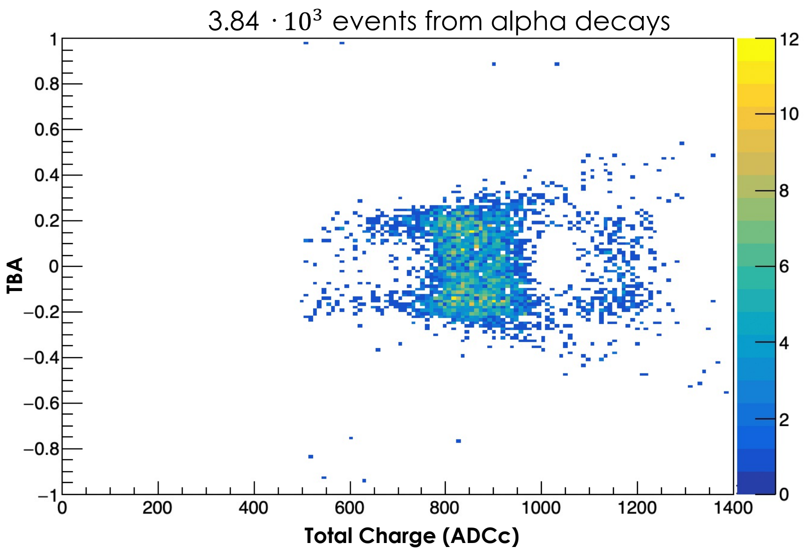


- $6.42 \cdot 10^5$ intial events
- $3.84 \cdot 10^3$ events from alpha decays

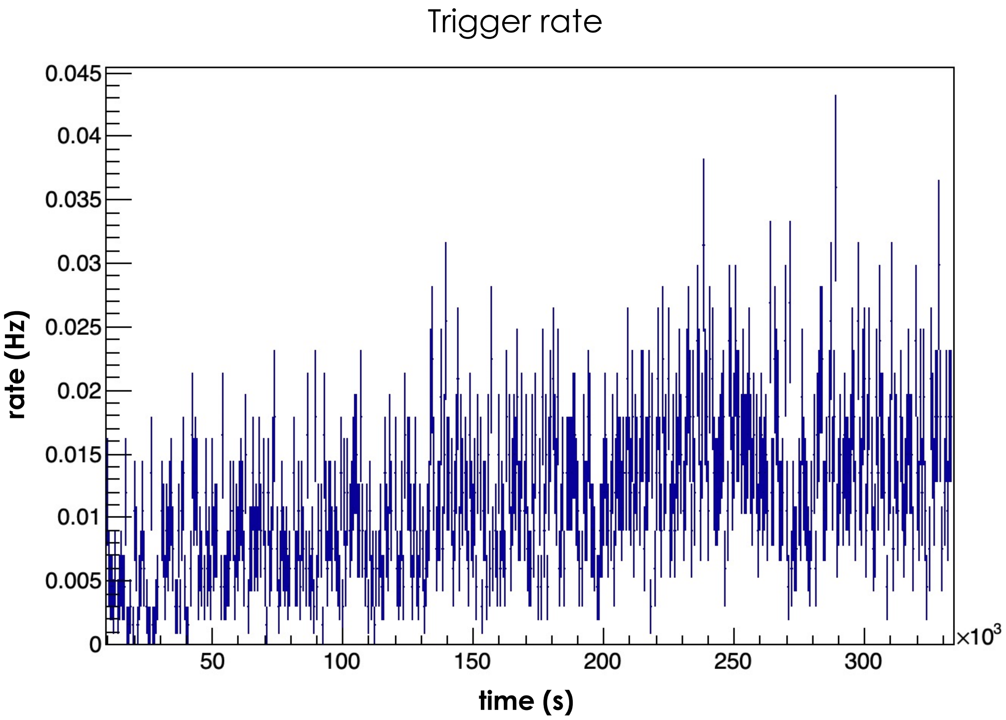
0.6% of total amount of events

Alphas: Alpha Selection





Alphas: Alpha selection



Rate of alpha events **increases** in time

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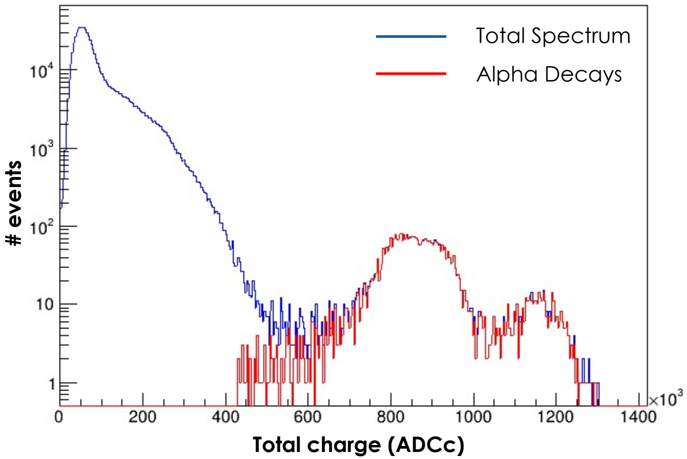
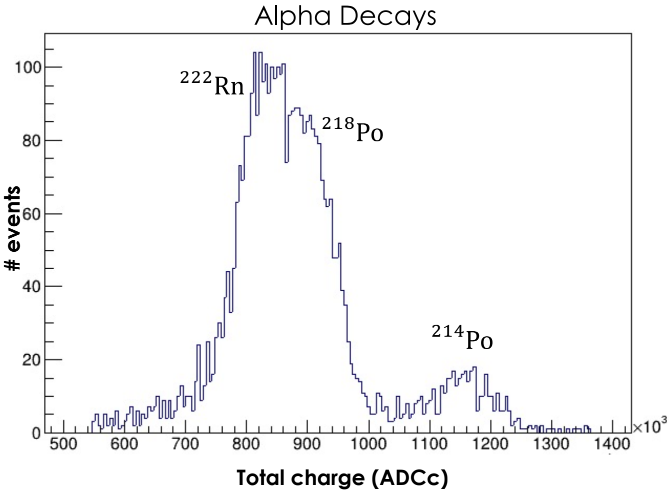
Rn from detector materials **accumulates** inside the chamber with a following collection of alphas due to it

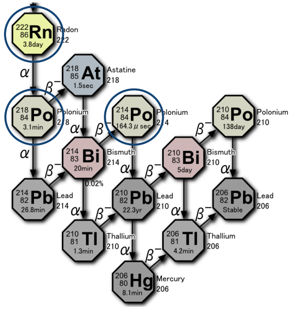
It is consistent with what we expect, since the rate has to increase for a few days until it becomes stable because of the Rn decay (τ = 3.8 days)

Alphas: Energy Spectrum



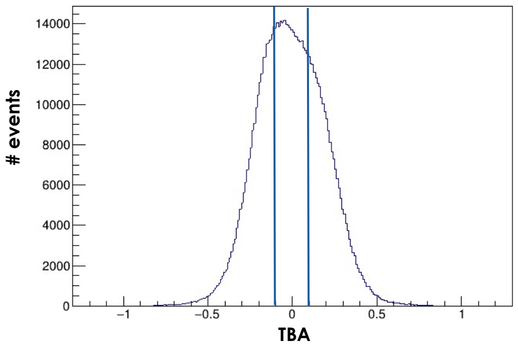


Three different peaks observed, that we could associate with **three isotopes** of ^{238}U the chain:

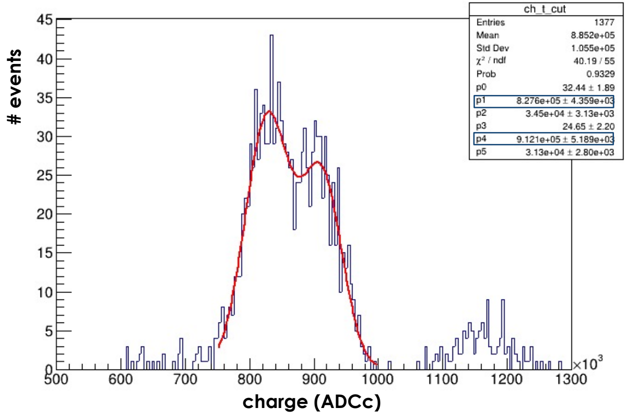


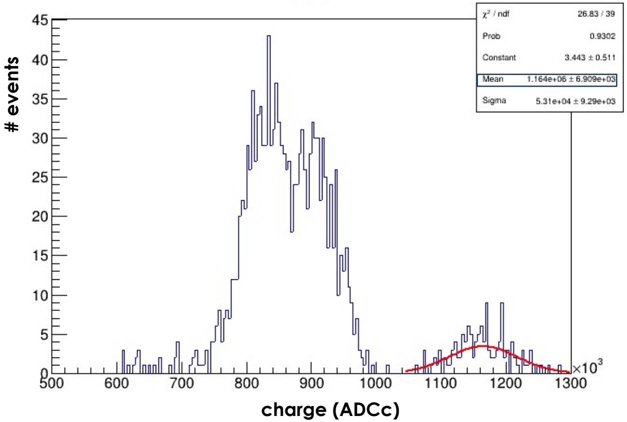
- ^{222}Rn (Q-value = 5590.3 keV)
- ^{218}Po (Q-value = 6114.68 keV)
- ^{214}Po (Q-value = 7833.46 keV)

Alphas: Measurement of alpha energy



~ 32% of events





- Cut in top-bottom asymmetry to increase the resolution (left)
- Fit of first 2 peaks (middle): **sum of gaussian functions** with 3 parameters each

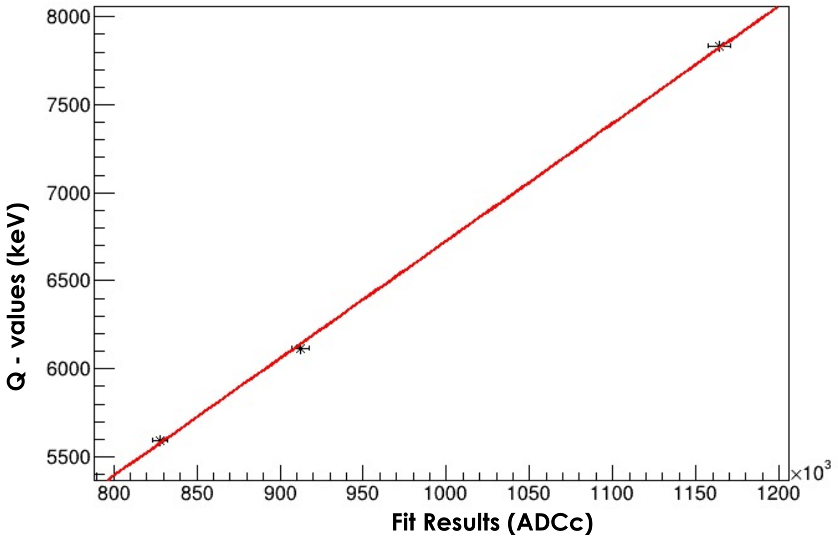
$$f(x) = p_0 e^{-\frac{1}{2}\left(\frac{x-p_1}{p_2}\right)^2} + p_3 e^{-\frac{1}{2}\left(\frac{x-p_4}{p_5}\right)^2}$$

- Fit of third peak (right): **gaussian function** with 3 parameters

$$f(x) = p_0 e^{-\frac{1}{2}\left(\frac{x-p_1}{p_2}\right)^2}$$

Alphas: Measurement of alpha energy

- **Linear fit:** $f(x) = kx + C$
- **Fit Result:** **k** = $(6.68 \pm 0.16) \cdot 10^{-3}$ keV/ADCc, **C** = 49.7 ± 150.3 keV
- **Error propagation:** $(\Delta E)^2 = (k \cdot \Delta x)^2 + (x \cdot \Delta k)^2 + (\Delta C)^2$



$$E_{^{222}Rn} = x_{^{222}Rn} \cdot k + C \pm \Delta E = (5576 \pm 305)\ \text{keV} \cong Q_{^{222}Rn}$$

$$E_{^{218}Po} = x_{^{218}Po} \cdot k + C \pm \Delta E = (6140 \pm 297)\ \text{keV} \cong Q_{^{218}Po}$$

$$E_{^{214}Po} = x_{^{214}Po} \cdot k + C \pm \Delta E = (7822 \pm 428)\ \text{keV} \cong Q_{^{214}Po}$$

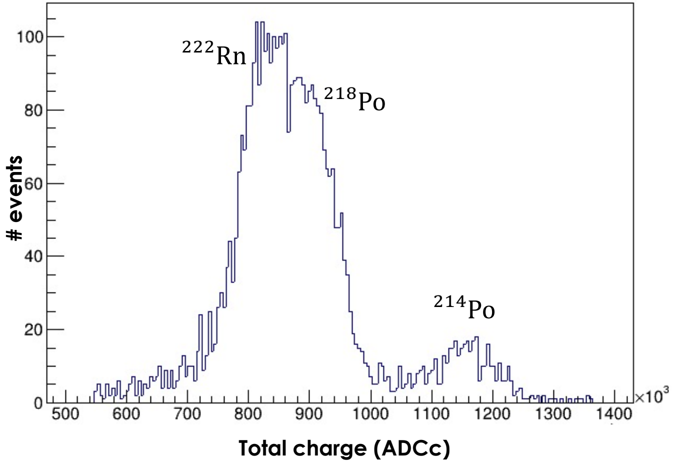
- Confirmation that those peaks are the ones of isotopes ^{222}Rn, ^{218}Po, ^{214}Po from ^{238}U decay chain

Alphas: Measurement of alpha energy - Comments

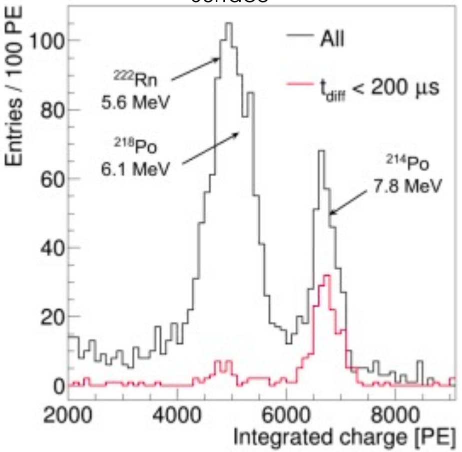
From the comparison of our analysis with the one made on surface, we observe that the $^{214}\mathrm{Po}$ peak has very few events: we are losing all the subsequent events that are separated in time less than 200 μs.

Problems with the event definition in MIDAS for the existing data induced an artificially high dead-time of the detector (> 420 μs), deninig us the possibility to performed consistent BiPo coincidence studies

Underground



Surface



Conclusions and Next Steps

- With the current setup underground:
  - we are able to apply an **efficient cut** in the way to reject most of the noise
  - we perform an **excellent Pulse Shape Discrimination** (PSD), distinguishing very well alpha from beta decays
  - we can monitor the **stability in time of the electronics** tracking the stability in time of the charge and f_{640} variables
  - we are able to **evaluate the purity of liquid argon** used and we proved a great airtightness of the chamber
  - thanks to the PSD, we could select very well the events due to alpha decays inside the chamber and we used them to perform a **first calibration** keV/ADCc of the system

Next Steps

- A new filter box, with **less electronic noise** than the one used for these results, will be used from now onwards, allowing for **cleaner background studies**
- Perform a **calibration KeV/PE**, taking data in the appropriate conditions for this aim (long dark current run, specific LED, etc.)
- Problems with the event definition in MIDAS for the existing data induced an artificially high dead-time of the detector, preventing consistent BiPo coincidence studies. This issue is fixed now and the **BiPo analysis** will be redone

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