Noise Study in ProtoDUNE DualPhase
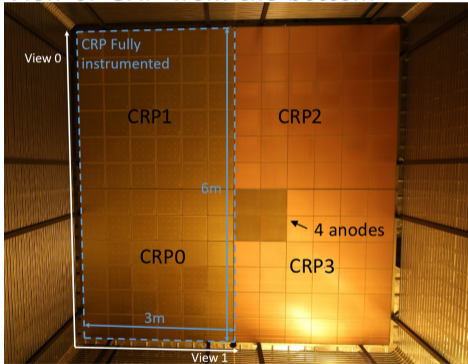
Pablo Kunzé

6 mai 2020
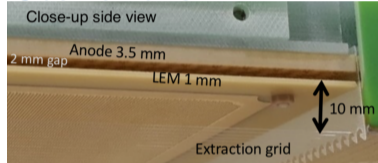
Charge Readout Planes (CRP)
Reminder

View of CRP from the bottom

View 0 — CRP Fully instrumented — CRP1 — CRP2 — 6m — 4 anodes — CRP0 — CRP3 — 3m — View 1

Side view of CRP

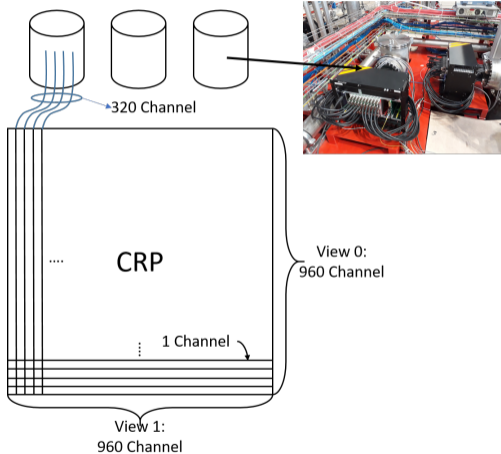Close-up side view — Anode 3.5 mm — 2 mm gap — LEM 1 mm — 10 mm — Extraction grid

Electric fields :
▶ Extraction
▶ Amplification
▶ Induction

▶ Detector $6 \times 6 \times 6 m^3$
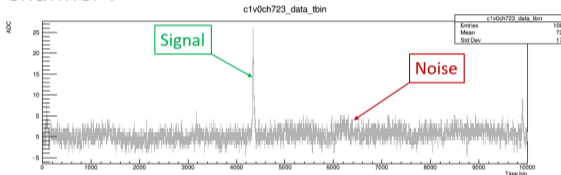▶ CRP : $3 \times 3 m^2$

Schematic view of CRP

- ▶ Schematic view of a CRP
- ▶ In each CRP : 2 views with 960 channels
- ▶ For each view : Channels grouped in 3 crates for acquisition (320 channels by crate)
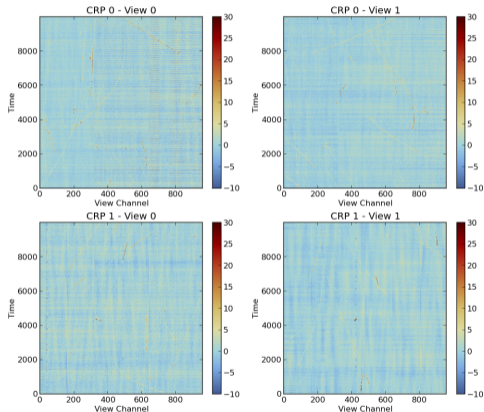
Example of charge signal

2D event display

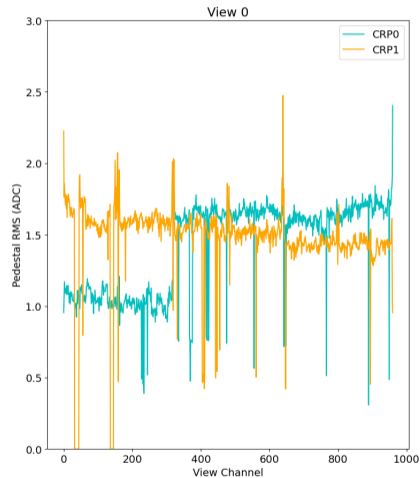1 channel :

10000 data points for $4ms$
1 point each 400ns
Noise : pedestal RMS ~ 2 ADC
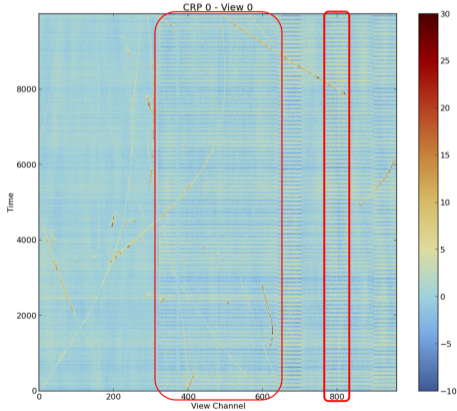

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Three main types of noise

▶ White
removed with a lowpass filter (0.09 MHz)

▶ Coherent
noise seen by a specific group of channels

▶ Microphonic
fluctuation of pedestal depending on time and channel

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Coherent Noise

Noise seen by a group of channels at the same time.
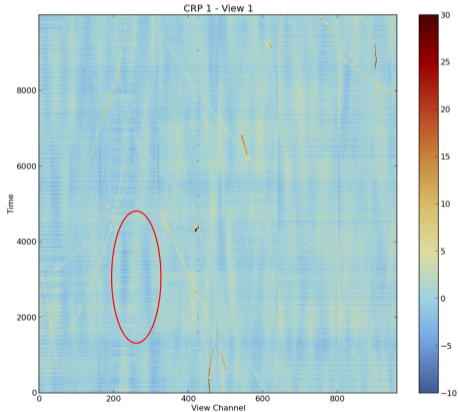

CRP 0 - View 0

- ▶ Coherent Noise on 64 and/or 320 channels in red box

Specific frequencies due to elements of the detector acting like antennas.

Microphonic Noise

Origin under investigation. One cause might be vibration creating a change in capacitance and inducing noise

▶ One event CRP 1 View 1
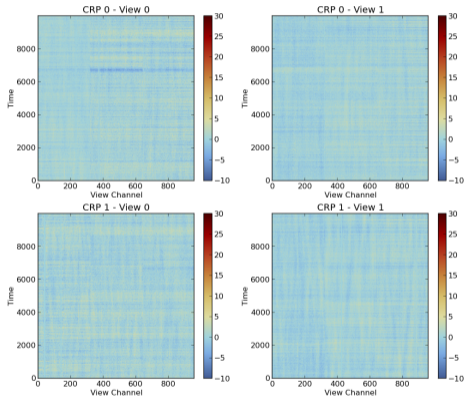
Run used for noise study

Run 1417 of 14th of January (from 18 :50 to 19 :42) made for the study of waves and noises with different voltage on Grid and LEMs.
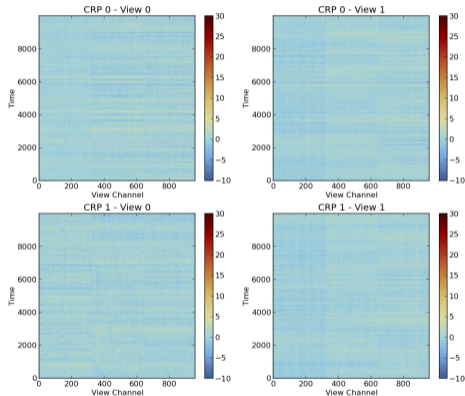
Mainly use two configurations :

▶ Grid and LEMs at 0V (19 :11)

▶ Grid at 2kV and LEMs at 2.5kV (18 :59)

Event display before noise removal for 2 configurations

Grid at 2kV and LEMs at 2.5kV

The three kinds of noise are present.

Grid and LEMs at 0V


Microphonic noise not present here.

Remove Noise

Classic way :

1. Low pass filter with FFT
2. Substract the mean ADC for a group of channels for each time bin
   ▶ Remove white and coherent quite well but not the microphonic

Alternative way :

1. Low pass filter and remove frequencies with FFT2D
   ▶ Goal : Remove microphonic in addition of white and coherent

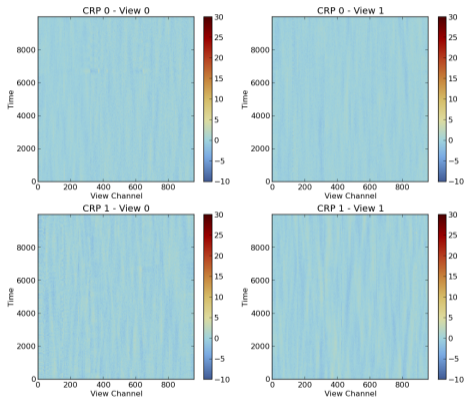Pablo Kunzé | Noise Study in ProtoDUNE DualPhase
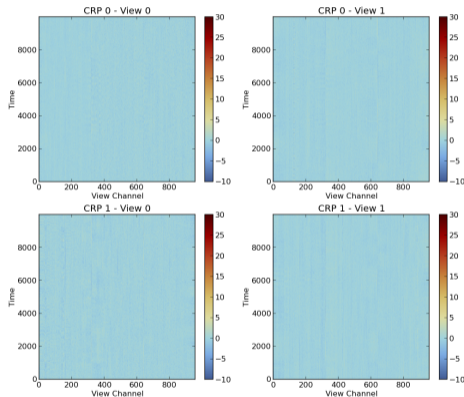
Example of 2D Frequency Space
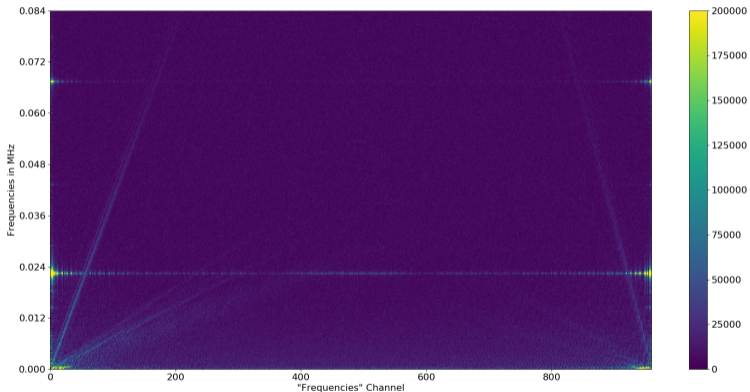
- ▶ FFT2D for View 0, CRP 0 of one event
- ▶ Can see horizontal specific frequencies
- ▶ Diagonal lines are linked to signal
- ▶ Frequencies to remove in MHz : 0.0144, 0.0185, 0.0225, 0.0288, 0.0432, 0.06, 0.0673

Event display after application of low pass and FFT2D

Grid at 2kV and LEMs at 2.5kV

Grid and LEMs at 0V

Coherent and white noise are filtered for both configurations.

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Compare Microphonic between CRP0 and CRP1

1. Remove Coherent Noise
   - ▶ Apply FFT2D Filter
2. Plot the pedestal RMS of CRP0 and CRP1 and compare them

Pedestal RMS after FFT2D filter for 30 events
(Grid at 2kV and LEMs at 2.5kV)
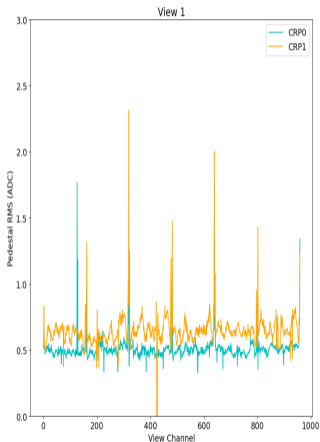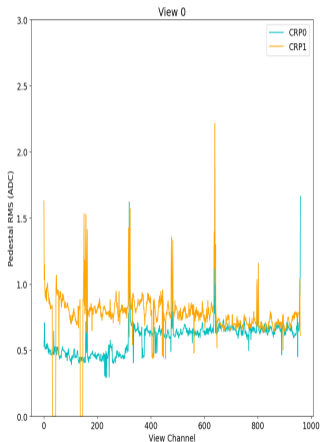
- ▶ Microphonic noise → Fluctuation of Pedestal RMS
- ▶ Ped RMS higher for CRP1 than CRP0
- ▶ Microphonic noise more present in CRP1 than 0
- ▶ Peaks due to LEM borders and some by noisy/temporary dead channels
- ▶ Ped RMS already below 1 ADC just by removing coherent and white noise

Pedestal RMS after FFT2D filter for 30 events
Without microphonic (Grid and LEMs at 0V)
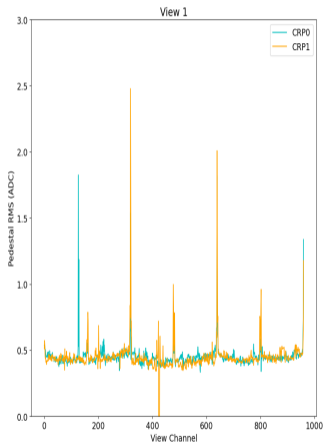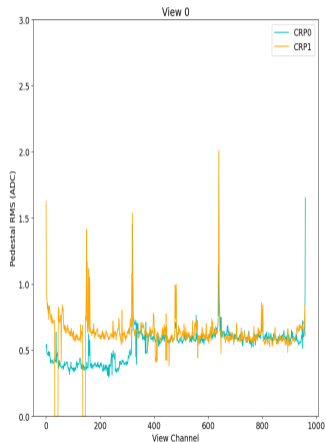
► No difference between CRP0 and CRP1 (except for the 320 first channels of view 0)
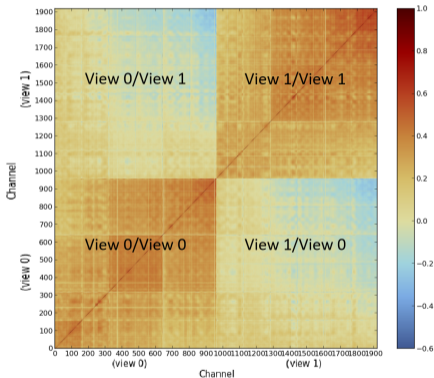
Study of Correlation between channels

Taking a look at the correlation coefficient between channel to better identify noises. Done for the same two configurations of Grid and LEMs voltage, before and after FFT2D filter.
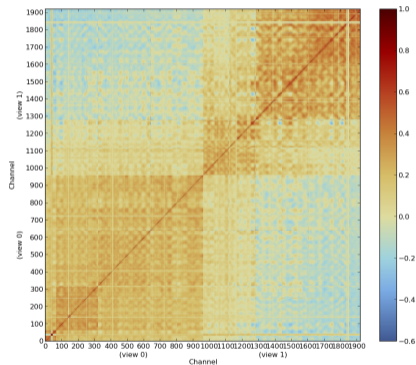
Study of Correlation between channels
Correlation between channels for an event without noise filtering (Grid 2kV LEMS 2.5kV)
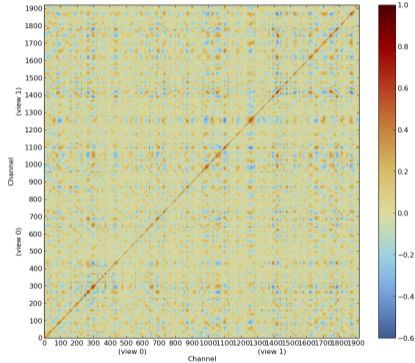
CRP 0

CRP1

Two structures : Correlation similar for group of channels (coherent noise) and local
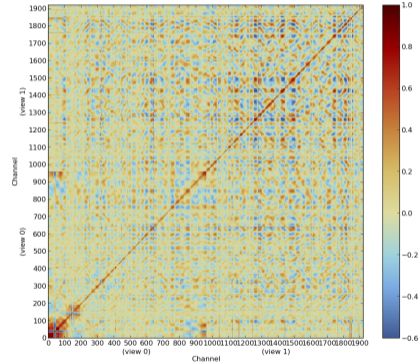fluctuation of correlation (microphonic noise)

Study of Correlation between channels
Correlation between channel for an event after FFT2D filter (Grid 2kV LEMS 2.5kV)
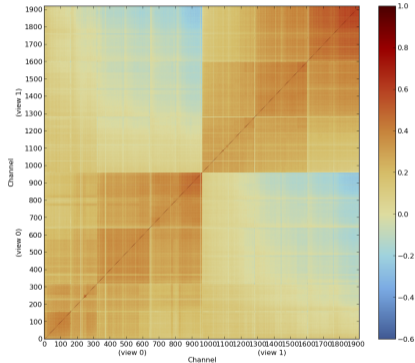
CRP 0

CRP1

The structure from group of channels disappeared (coherent noise), only local fluctuations are visible (microphonic noise)
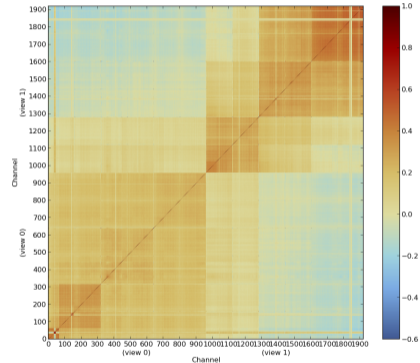
Study of Correlation between channels
Correlation between channel for an event without noise filtering (Grid 0V LEMS 0V)
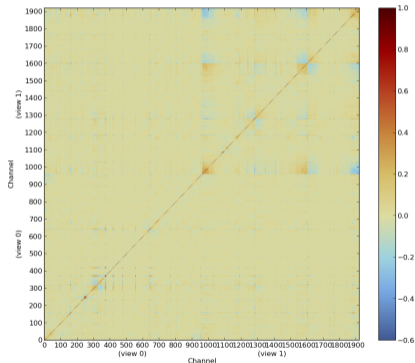
CRP 0

CRP1

Only structure associated to group of channels so coherent noise is present here, no microphonic.
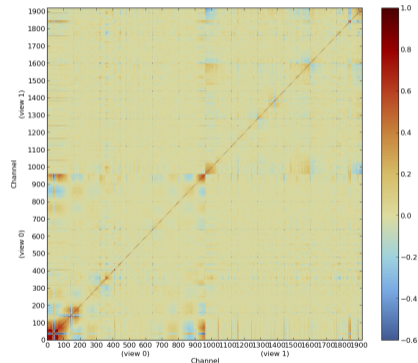
Study of Correlation between channels
Correlation between channel for an event after FFT2D filter (Grid 0V LEMS 0V)

CRP 0

CRP1

None of the two kind of noises. Only the problematic channels create correlations.

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Conclusion and perspective

▶ For run 1417 (January 2020) : CRP1 has more microphonic noise than CRP0

▶ Check if it is also the case for other runs

▶ Microphonic noise is linked to LEMs and grid voltage while coherent is not

▶ Will quantify the effect of LEMs and grid voltage on micriophonic noise

▶ Correlation between channels allows to see structure of noise but doesn't bring additionnal informations for understanding of microphonic

▶ Look at correlation also between channels of CRP0 and CRP1

▶ Do the 2D spectra for other runs as well to see if the frequencies are the same

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Concerning the FFT2D filter

Remove well coherent and white noise but for now, it has no effect on the microphonic. Maybe in the diagonal lines?

Drawbacks : creates artefacts around tracks.
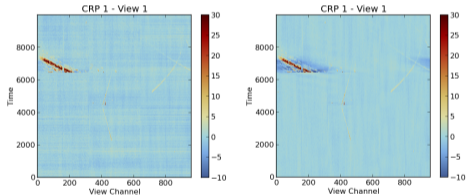
Working on supress or reduce this effect to use it for track reconstruction.