GP80 Trigger Efficiency Study

Marion Guelfand - Olivier Martineau

Hardware Session - Warsaw collaboration meeting - 04/06/2025

T1 trigger: objectives and logic

Objective: Optimize T1 parameters to achieve best balance between **efficiency** and **purity**

Efficiency: Maximize number of cosmic ray events passing trigger: test on **DC2 simulations**
Purity: Smallest fraction of background events: test on **MD (nominal trigger rate: 1 kHz)**

Adapted from Xishui

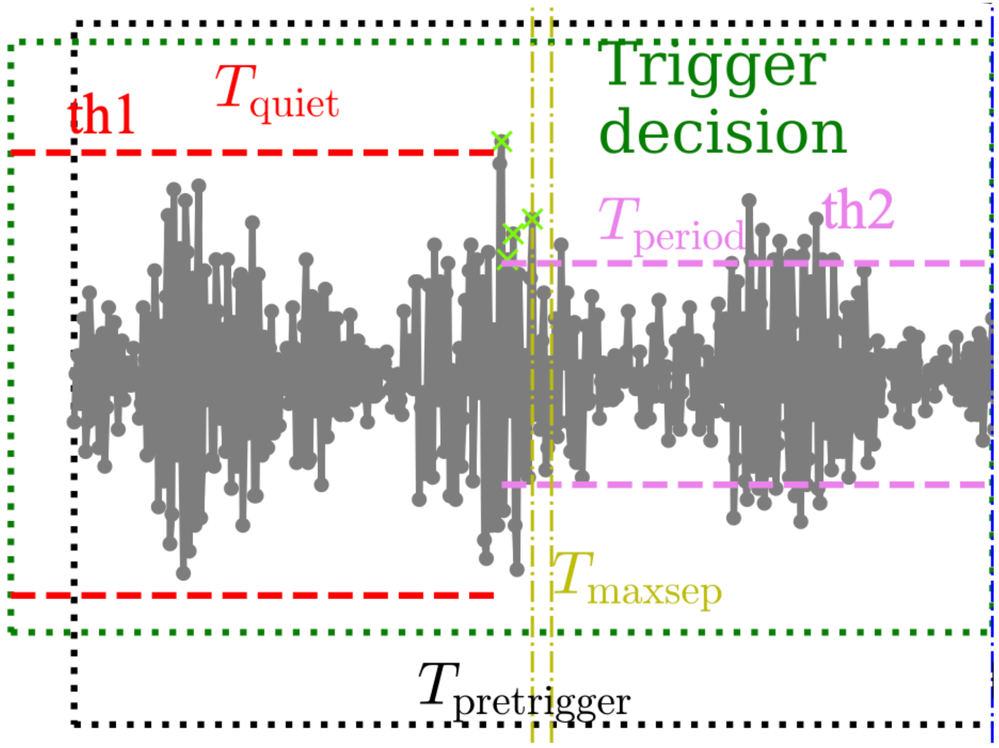
Realistic o**ffline T1 Trigger** applied on **channels X and Y simultaneously:**
tag X or Y or XY if both channels triggered

Trigger parameters:

Th1: first signal amplitude threshold
T_quiet (500ns): A time window preceding Th1, during which no other peak should exceed Th1
T_period (500ns): The time window during which the trace is analyzed after the first Th1

Th2: second threshold
T_sepmax: The maximum time period allowed for two consecutive peaks (both exceeding Th2)
NC: number of crossings that exceeds Th2 (**including Th1 peak**)

from Xishui



DC2 simulations: processing

DC2 simulations with **new RF chain**: /sps/grand/DC2.1rc2/ : **1000 events** *From Matias*

From Xu Xing

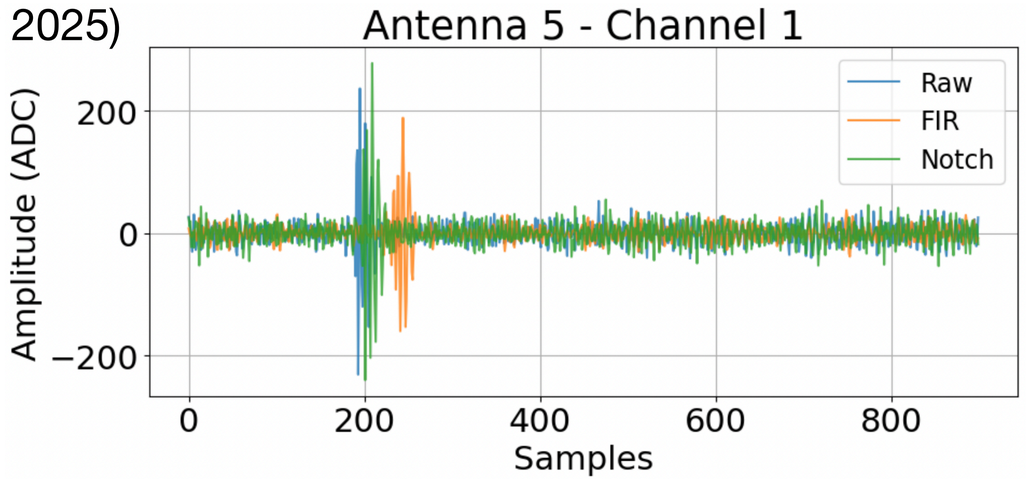
Select ZHAireS-AN: **experimental noise** added (MD from February 2025)

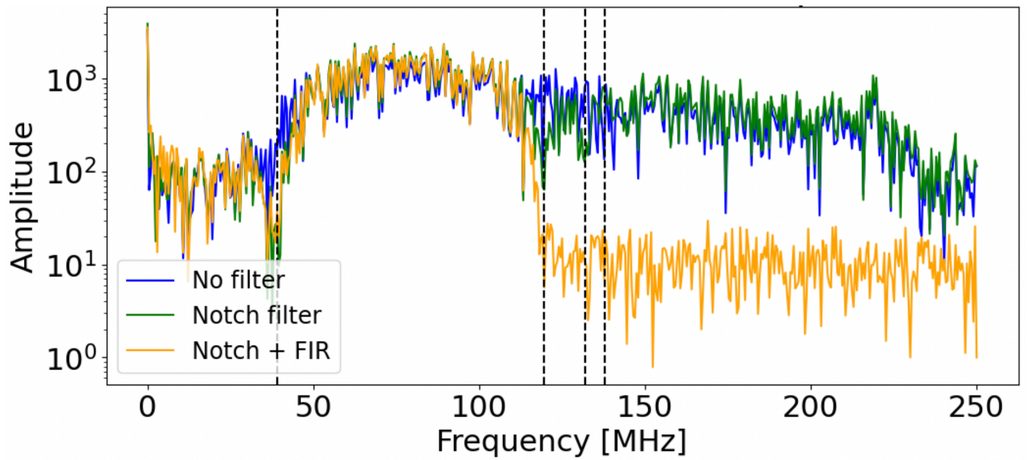
From Pablo

Comparison of Two Processing Configurations

Processing 1 – Simulated Notch Filters Only *From Sei*
Parameters (same as online):
Filter 1: f= 39MHz, r = 0.9
Filter 2: f= 119.4MHz, r = 0.94
Filter 3: f= 132MHz, r = 0.95
Filter 4: f= 137.8MHz, r = 0.98
Represents on-site configuration at the beginning of 2025

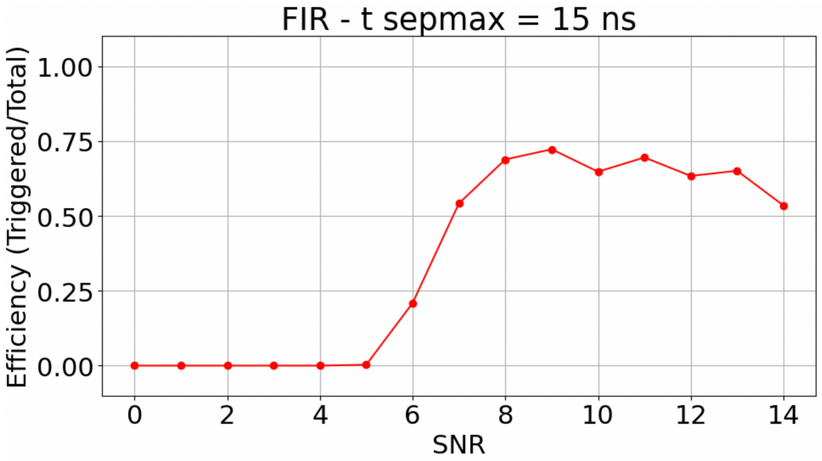
Processing 2 – One notch Filter + FIR filter *From Pablo*
Notch: f= 39MHz, r = 0.9
FIR: Cuts frequencies above 115 MHz
Represents current on-site configuration (since May 2025)

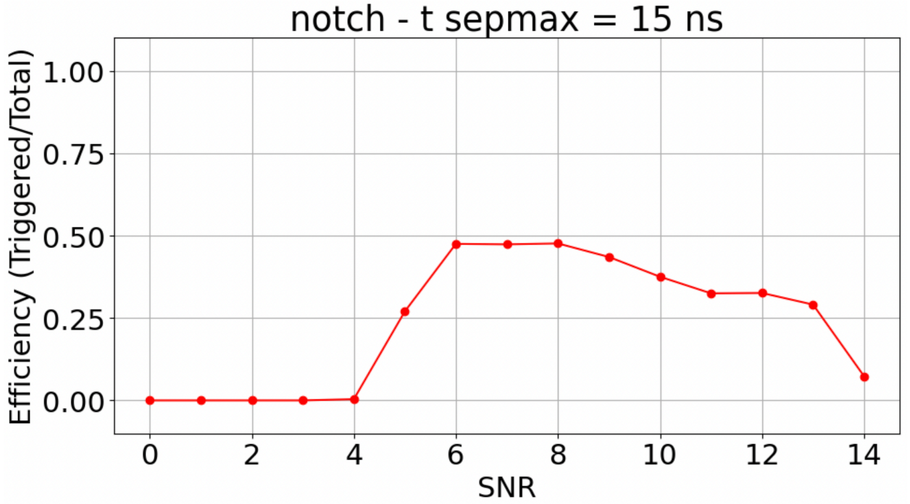


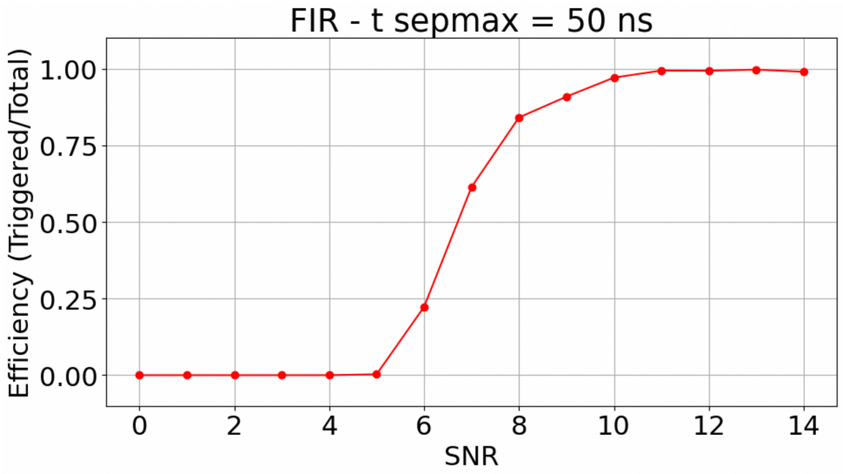


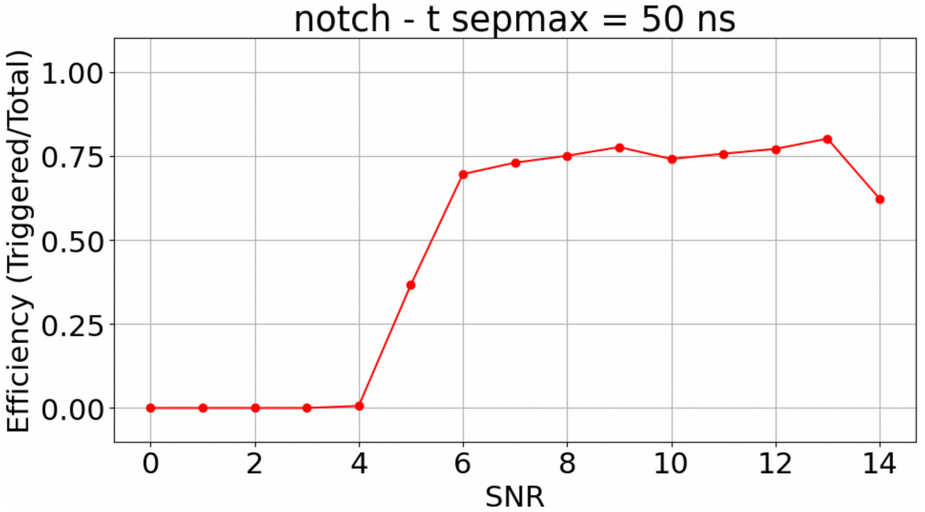
Test t_sepmax parameter

Parameters on site from May 2025 :
t_quiet = 500 ns, t_period : 500 ns th1 = 70 ADC th2 = 48 ADC
NC = [2-7]









Maximum time separation of 50 ns provides better efficiency than 15 ns.

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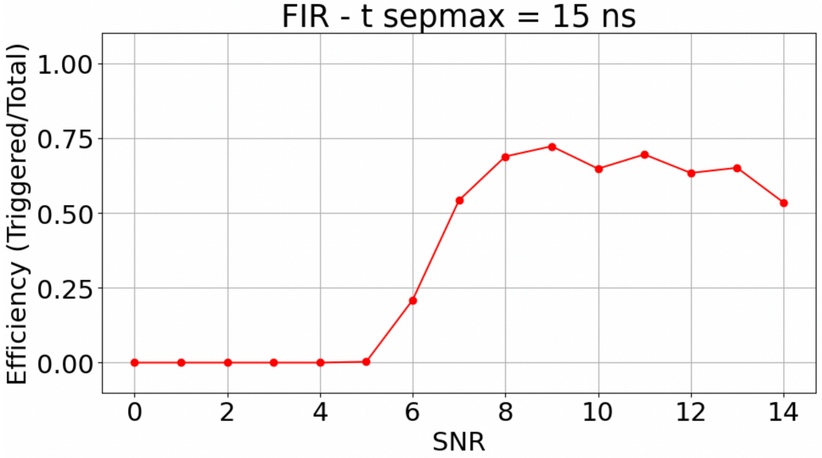
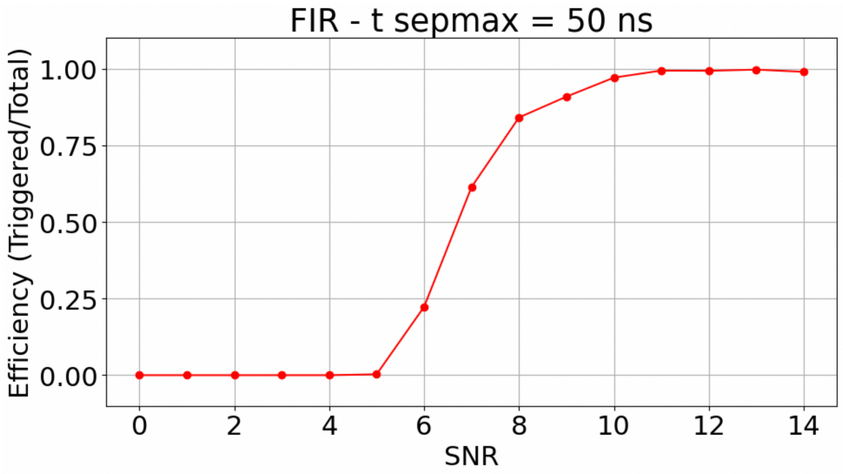
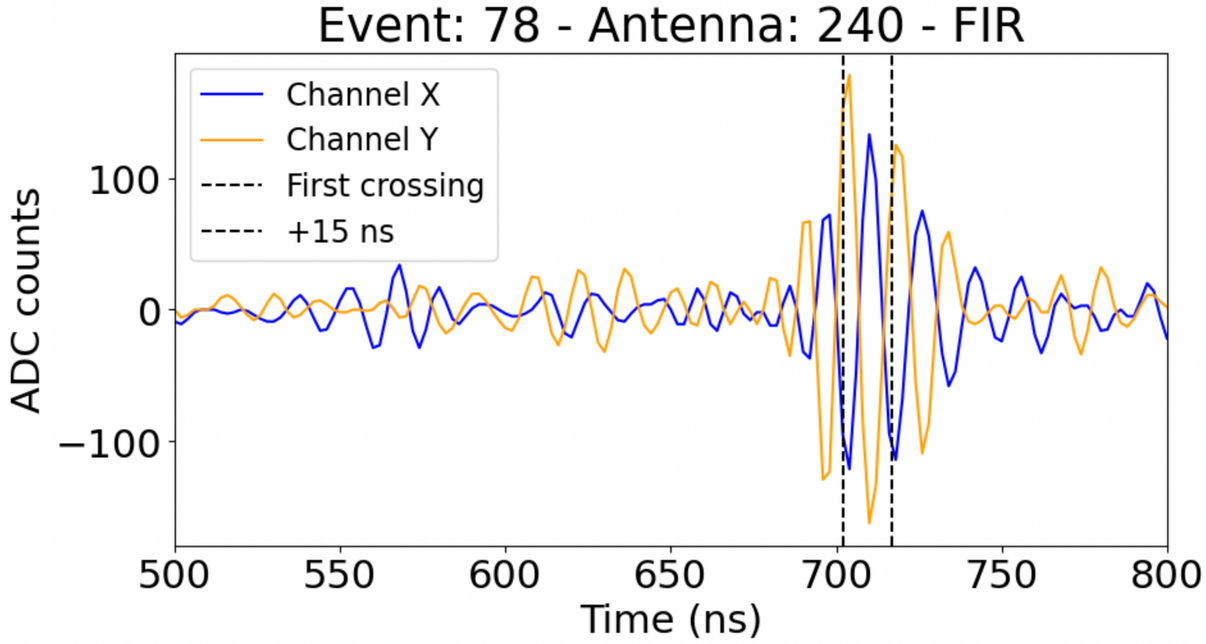


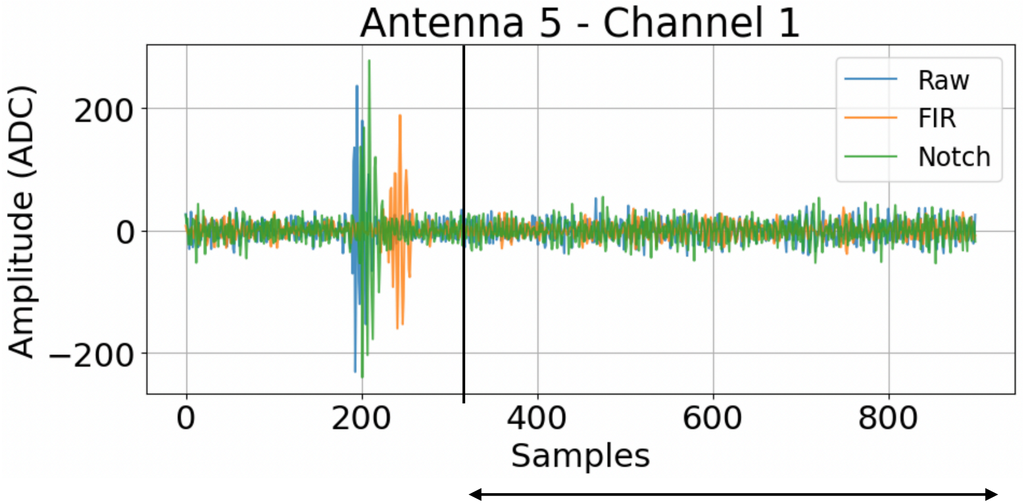




With t_sepmax = 15 ns, time window still overlaps with first pulse in some cases — too short to reach a second pulse

Need t_sepmax > 15 ns!

Test TH2 parameter

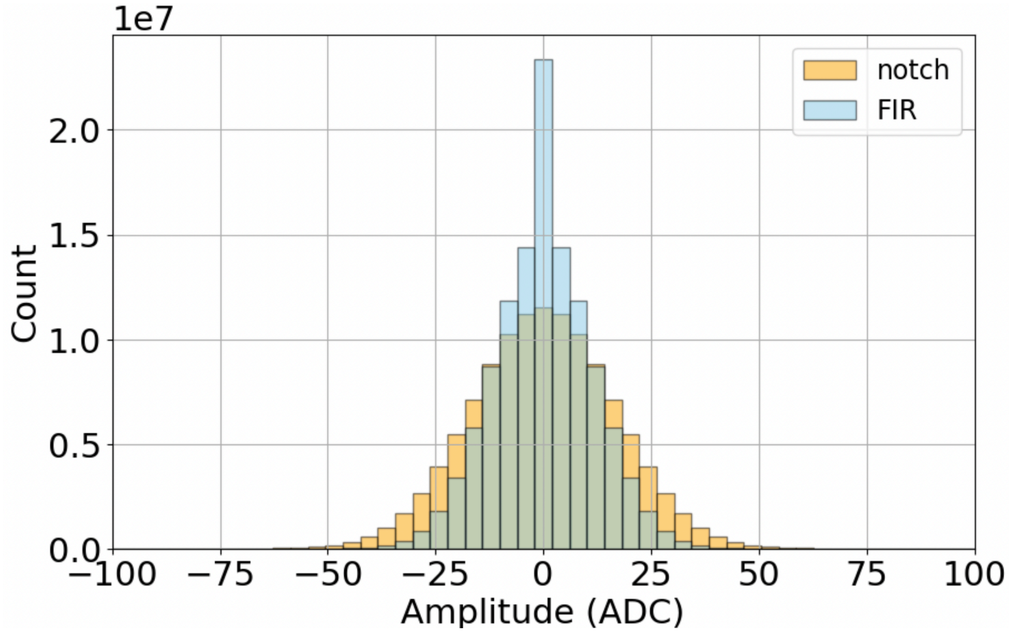


Mean standard deviation σ from the baseline (outside the pulse):

- FIR: $\sigma = 11{,}5$ ADC
- Notch: $\sigma = 16{,}5$ ADC

Distribution of all amplitudes in all traces in the baseline (outside the pulse): between 1000ns and 2048ns

FIR filter suppresses secondary pulses



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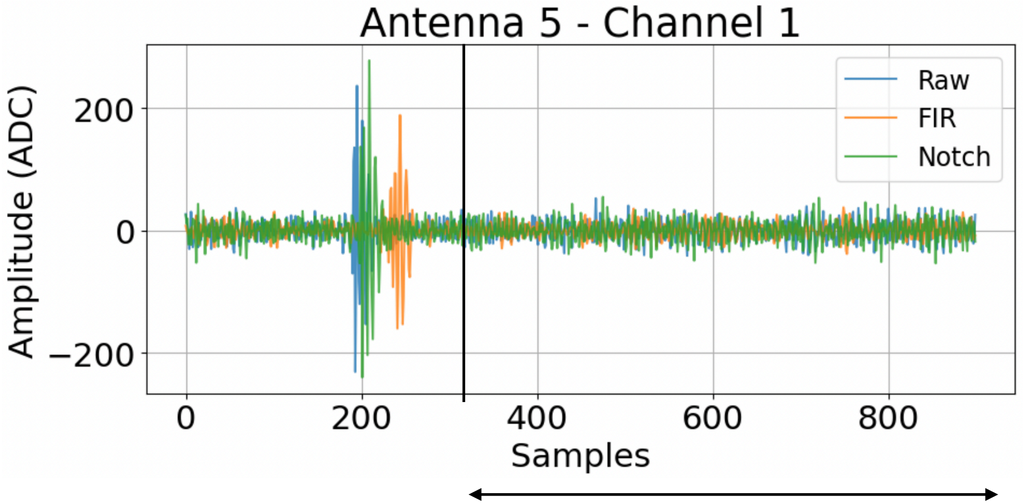

Mean standard deviation σ from the baseline (outside the pulse):

- FIR: $\sigma = 11{,}5$ ADC
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Instead of using fixed amplitude thresholds (e.g. TH2=48 ADC), TH2 now defined relative to the baseline noise level, expressed in multiples of its standard deviation σ.

Test configuration 3σ and 4σ

For FIR: $3\sigma \sim 35$ ADC and $4\sigma \sim 48$ ADC

For notch: $3\sigma \sim 48$ ADC and $4\sigma \sim 60$ ADC

Distribution of all amplitudes in all traces in the baseline (outside the pulse): between 1000ns and 2048ns

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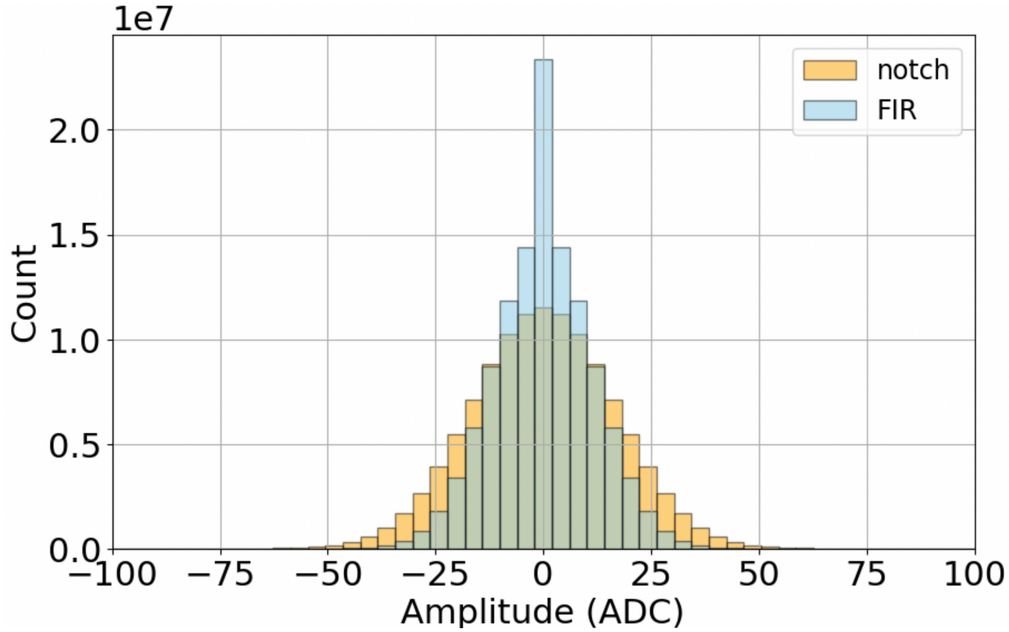

Test TH2 parameter

Parameters on site from May 2025 :
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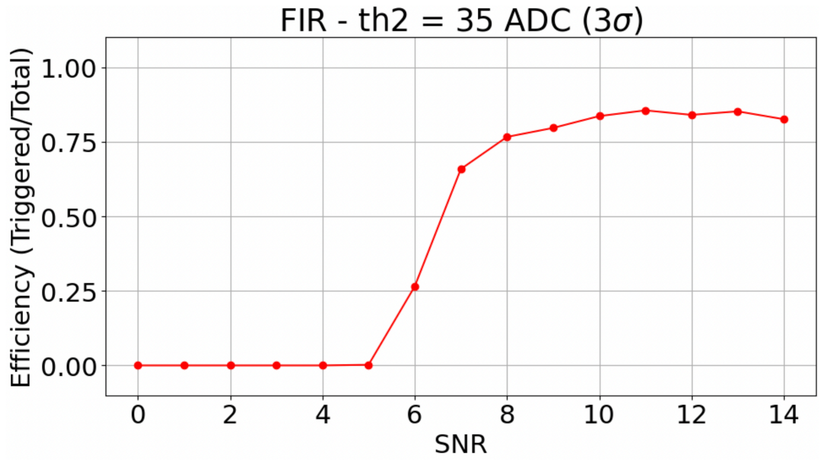

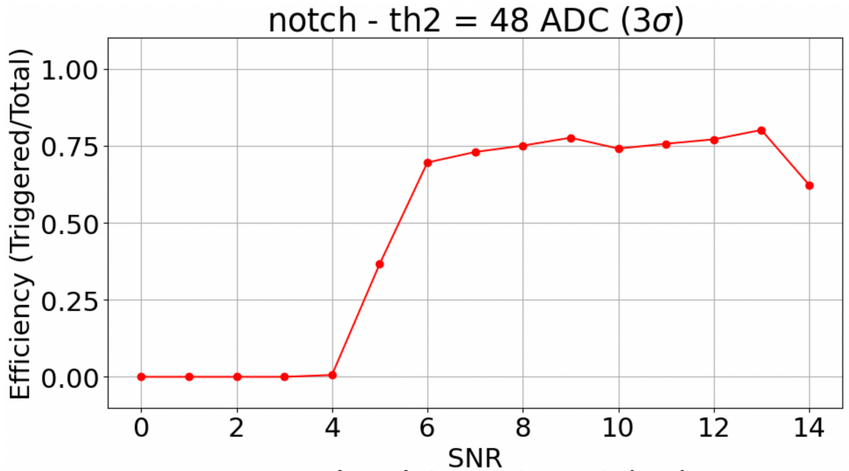

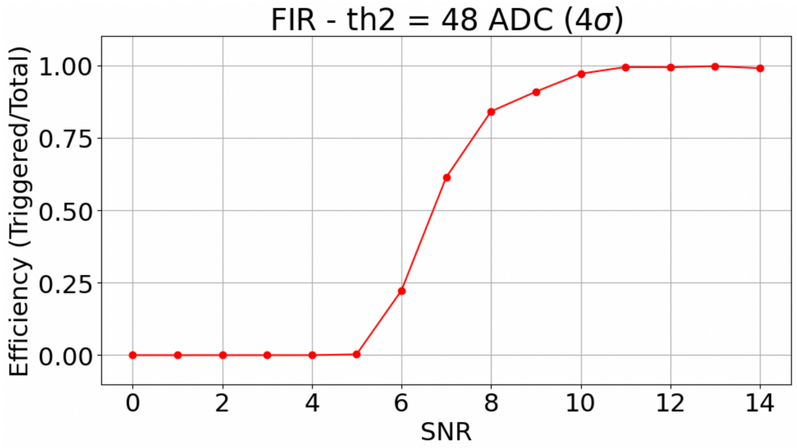

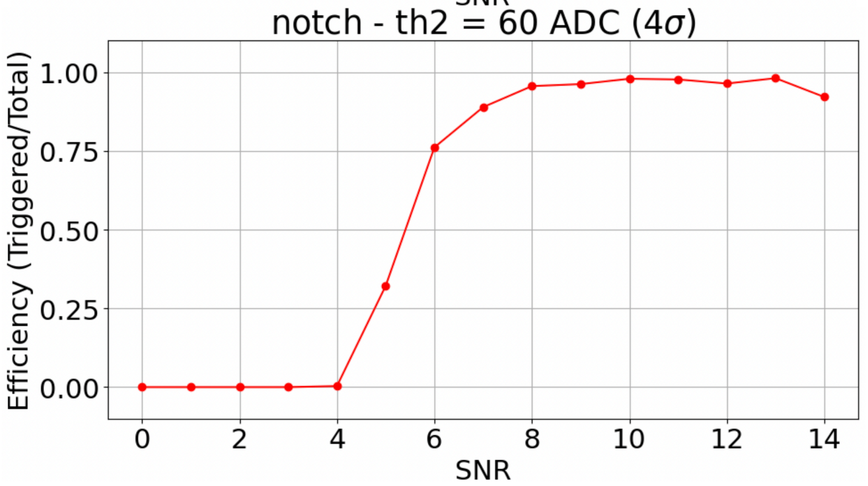

4σ is safer than 3σ, offering better detection efficiency.

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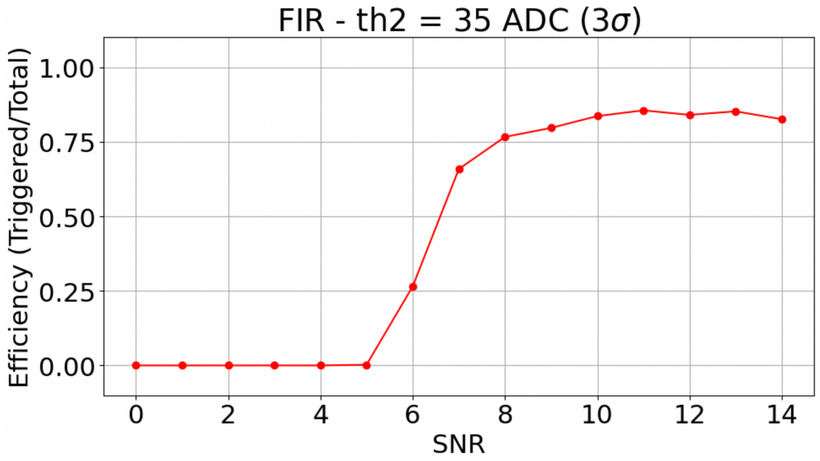
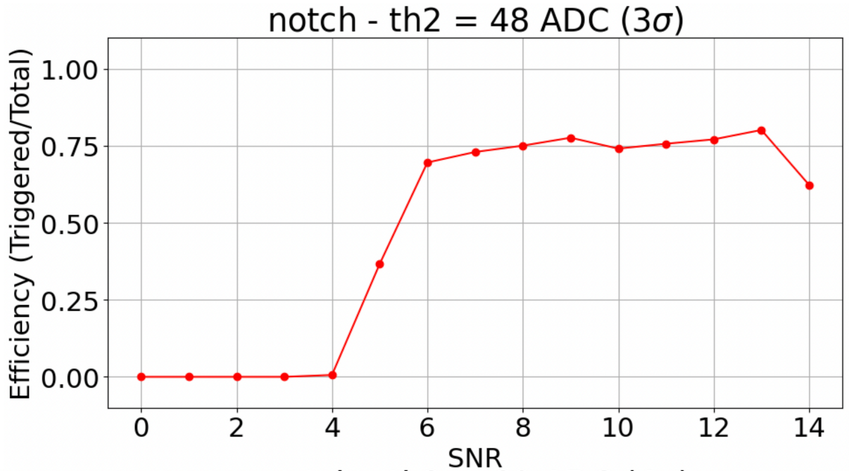
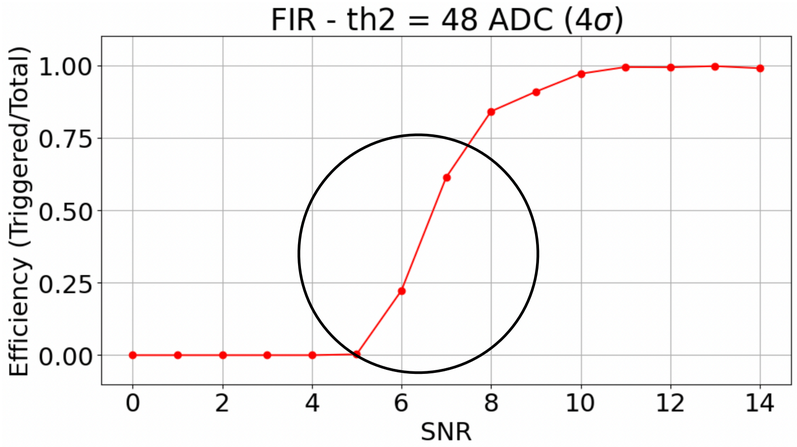
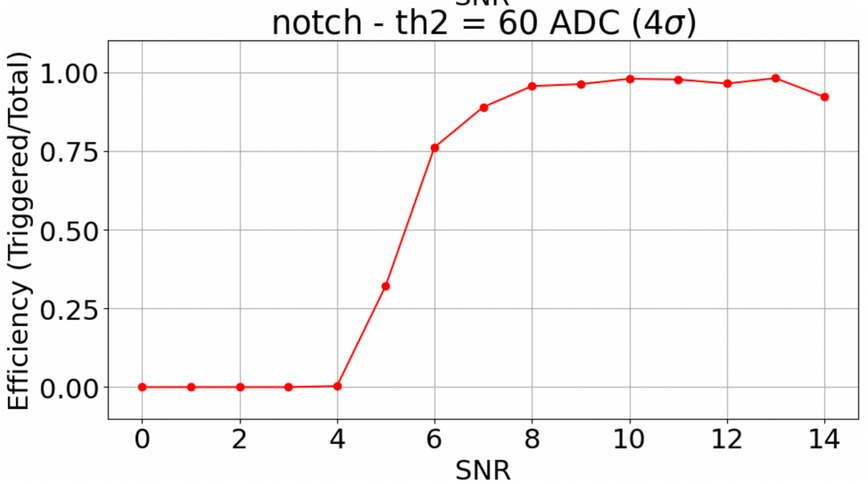






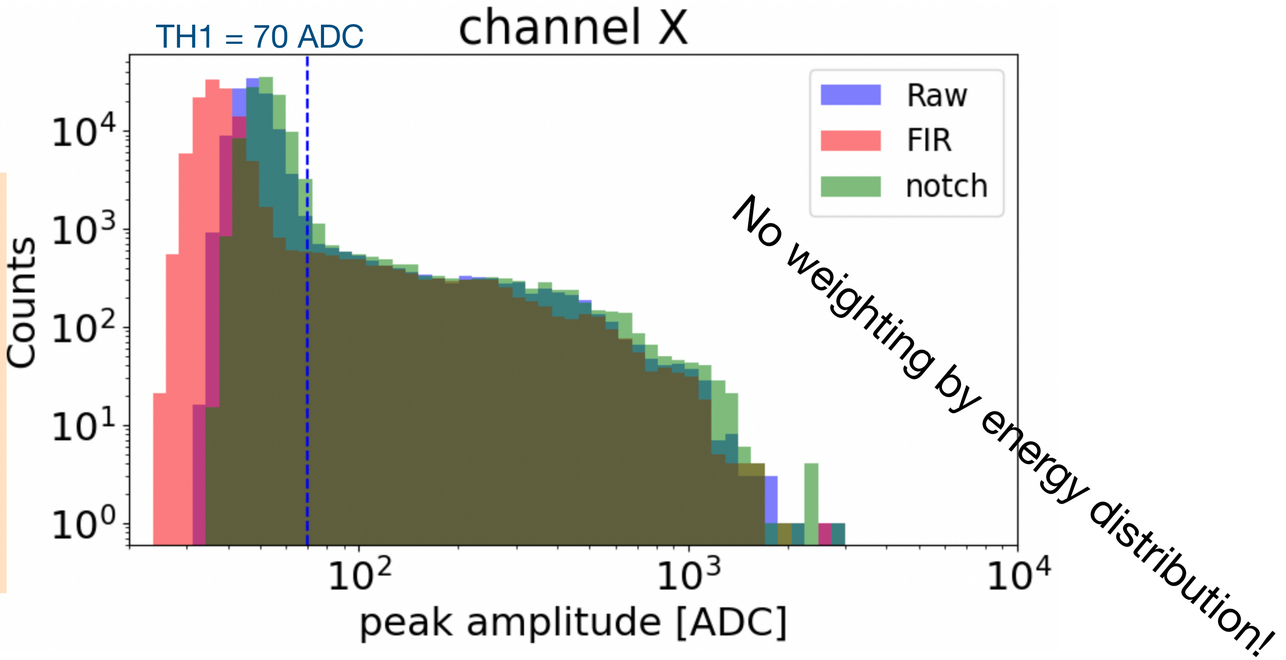


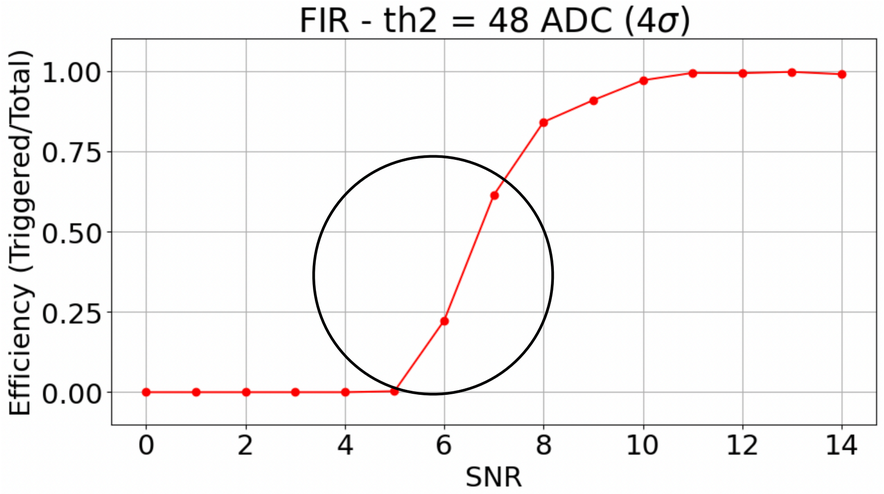
4σ is safer than 3σ, offering better detection efficiency.
For FIR filter, efficiency decreases significantly at an SNR of 6 and below: need to **adjust TH1 parameter**

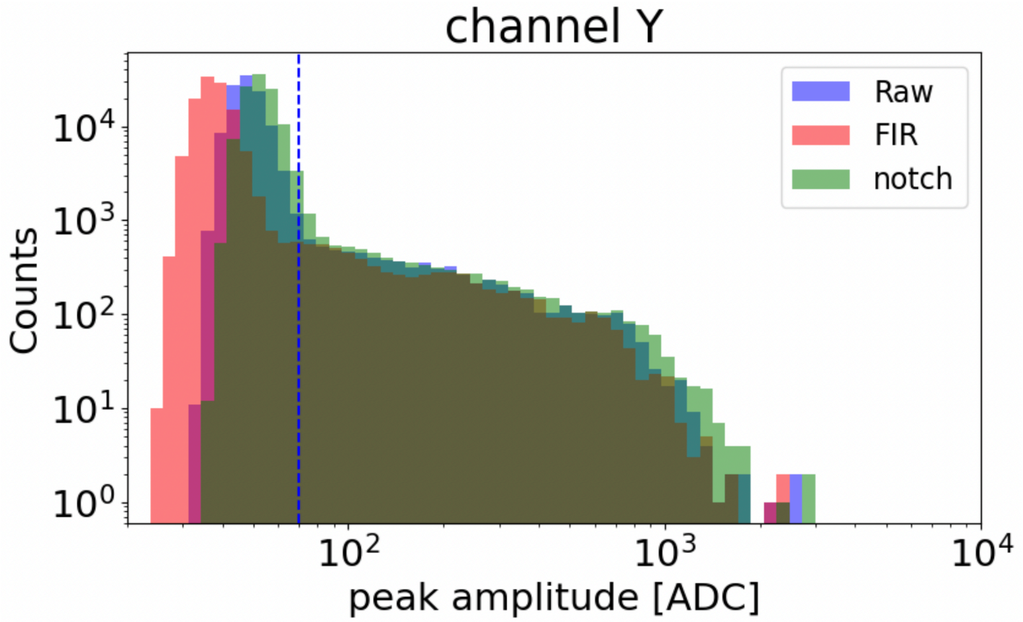
Test TH1 parameter

Peak Amplitude Distribution – DC2 Simulations (No Trigger Applied)

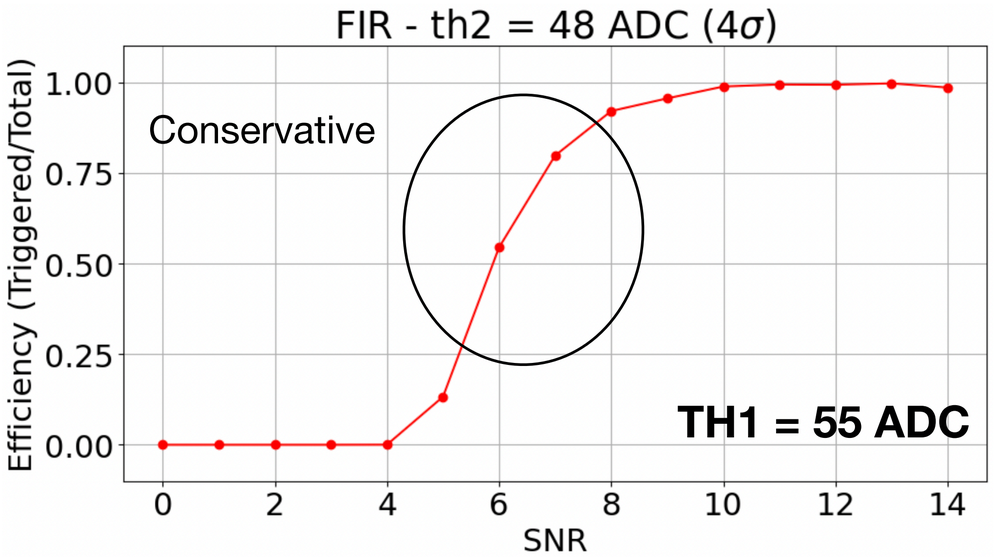
- Two distinct regimes observed:
  - Low ADC bump → noise-dominated region
  - Gradual decrease at higher ADC → signal peak distribution
- Effect of FIR filter:
  - Signal peaks are **shifted toward lower ADC values**
  - **➜ Lowering TH1 threshold** is necessary to trigger on **low-SNR events with FIR**

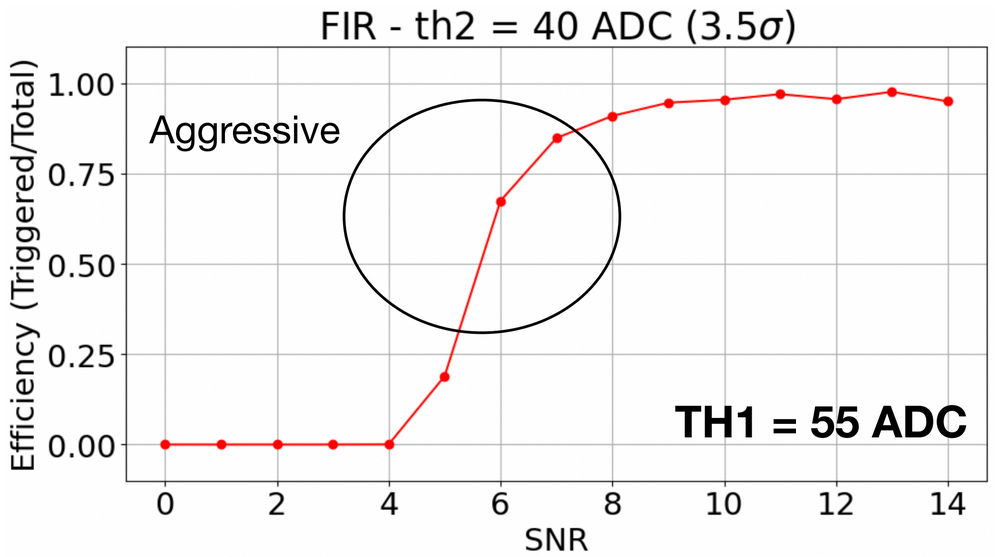


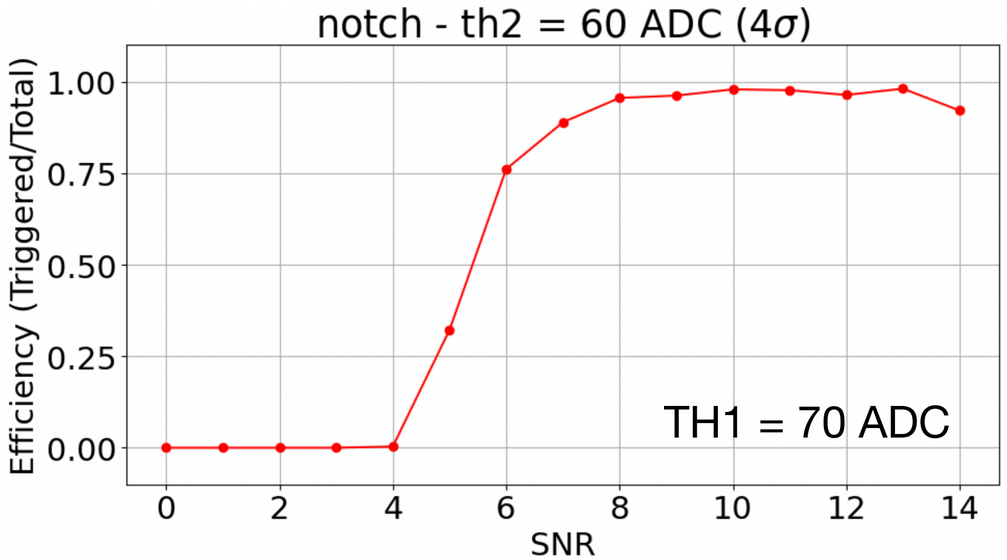




Optimal set of parameters for FIR and notch







Optimal parameters
t_quiet = 500 ns, t_period : 500 ns
NC = [2-7], t_sepmax = 50 ns

- For FIR: **TH1 = 55 ADC** and TH2 = 40 ADC (3.5σ) or 48 ADC (4σ)
- For notch: **TH1 = 70 ADC** and TH2 = 60 ADC (4σ)

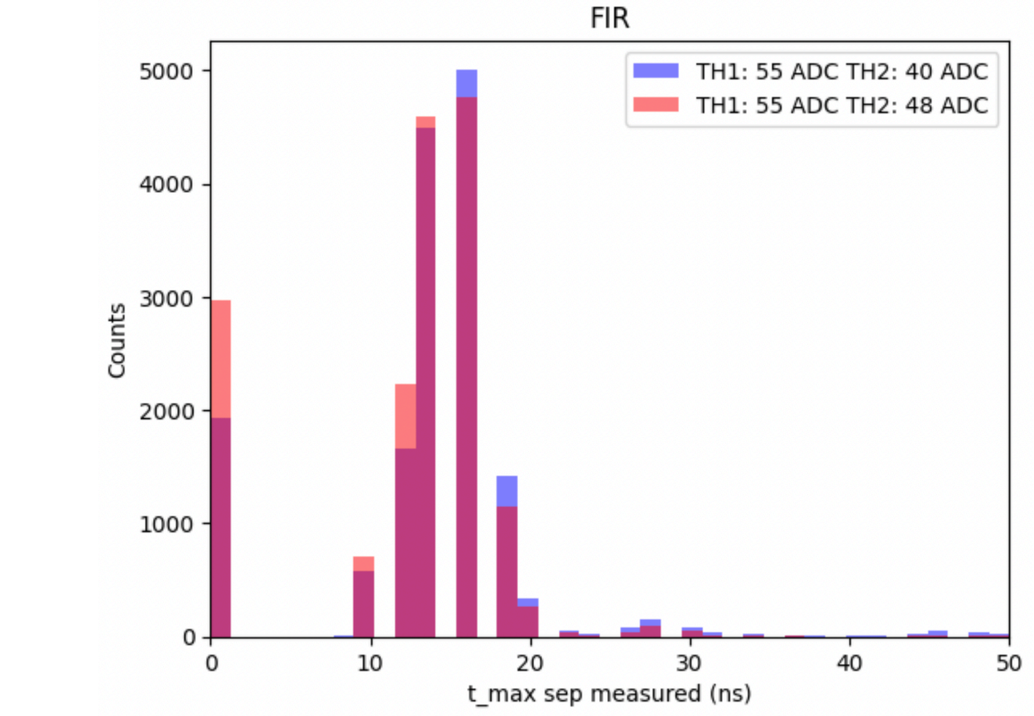
Distribution of NC and t_max sep measured on DC2 with FIR

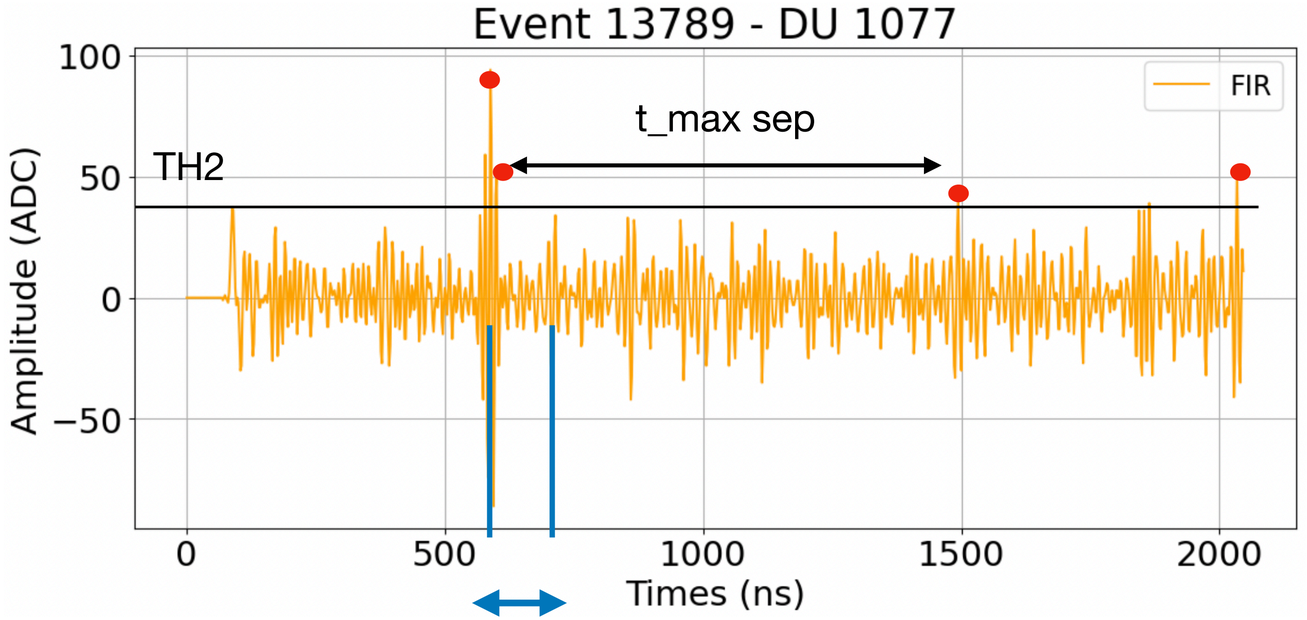
We have set the trigger parameters. Now, Systematic Validation of Trigger Parameters
Select only traces that exceed **TH1 = 55 ADC** to focus on significant signals

Analyze the distribution of:

- **Number of crossings (NC)**
- **Maximum separation time between consecutive peaks (t_max sep measured)** that pass **TH2 (TH2 = 3.5σ and TH2 = 4σ)**

Compare these distributions to the trigger parameter settings (t_sepmax = 50ns and NC [2-7]): **post validation of NC and t_sepmax settings**





T1 parameter: t_sepmax = 50ns

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If **t_sepmax < 20 ns**, significant signal loss occurs.

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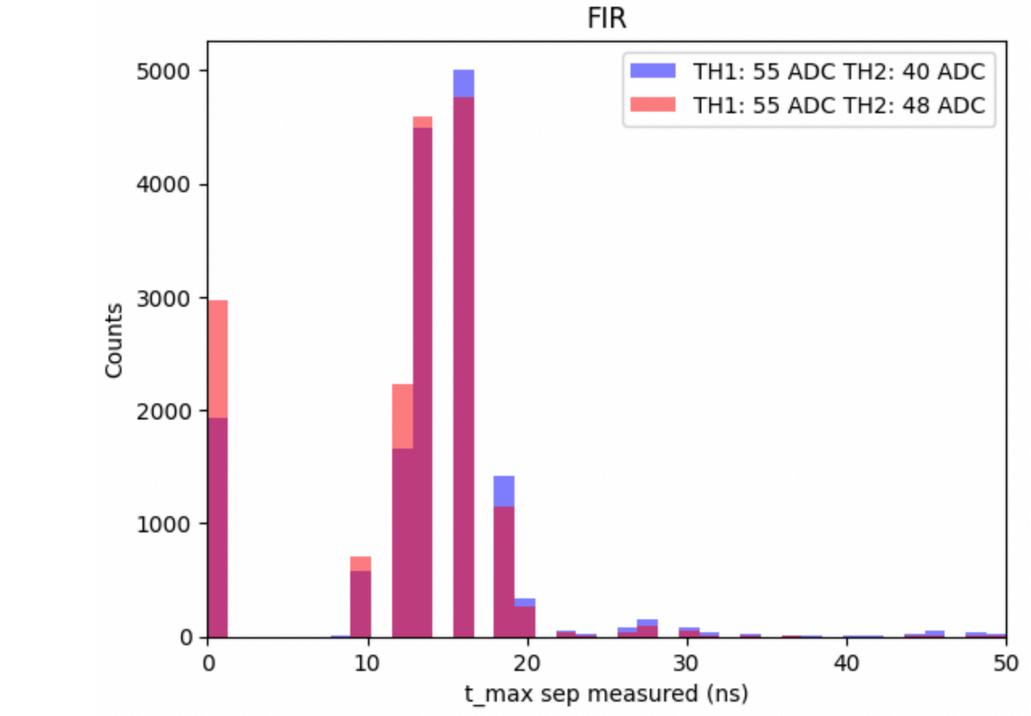

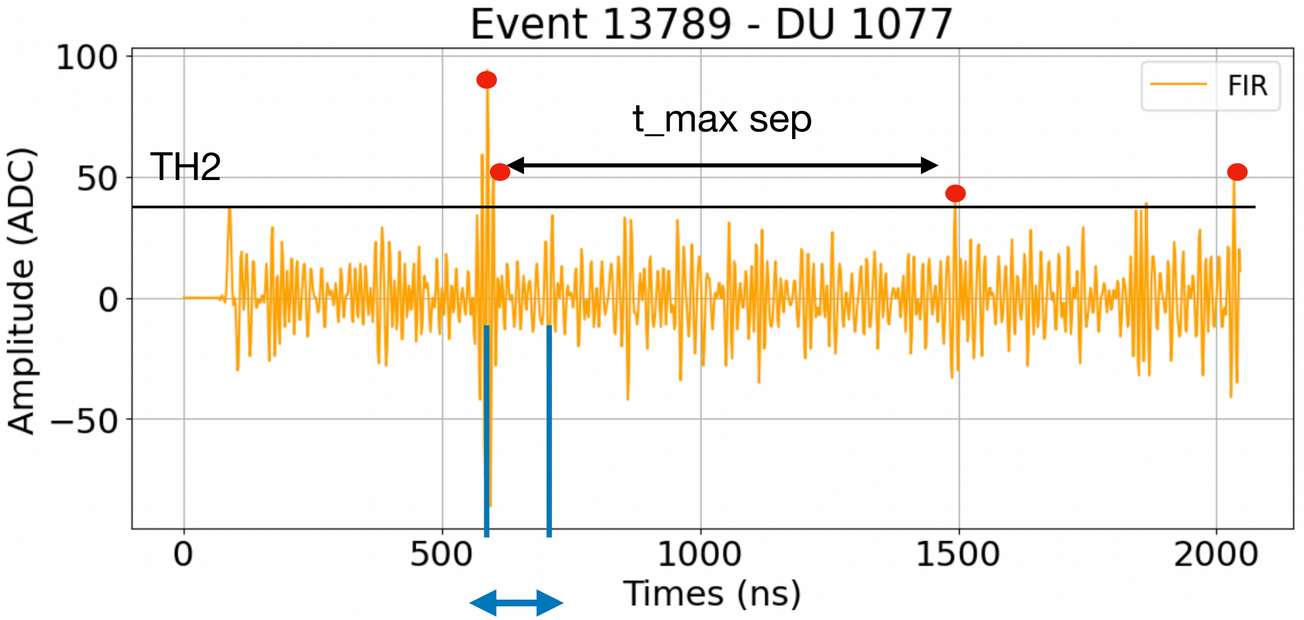

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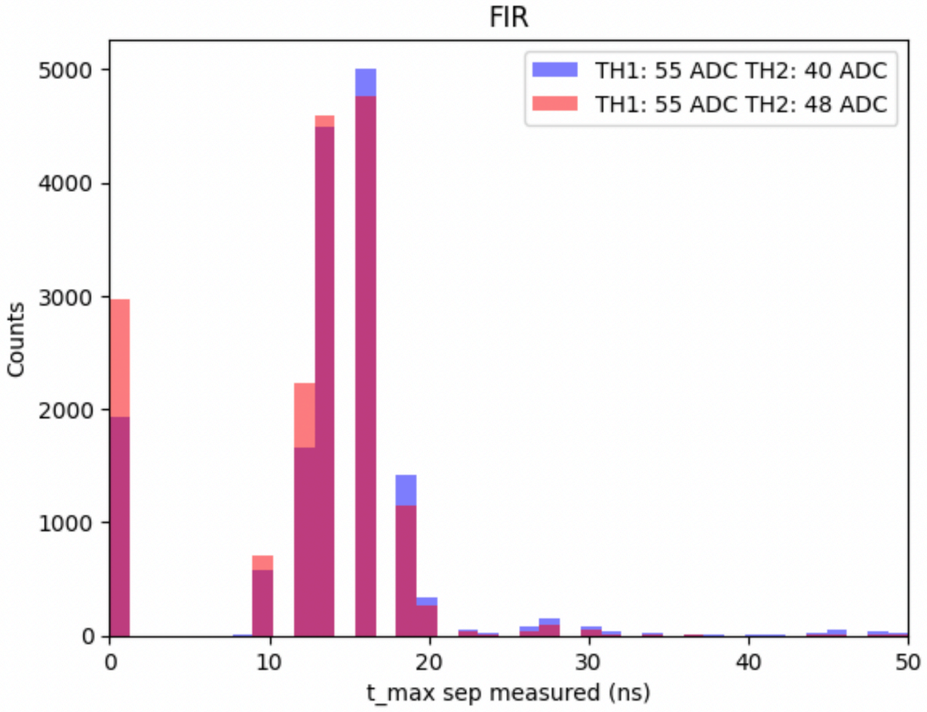
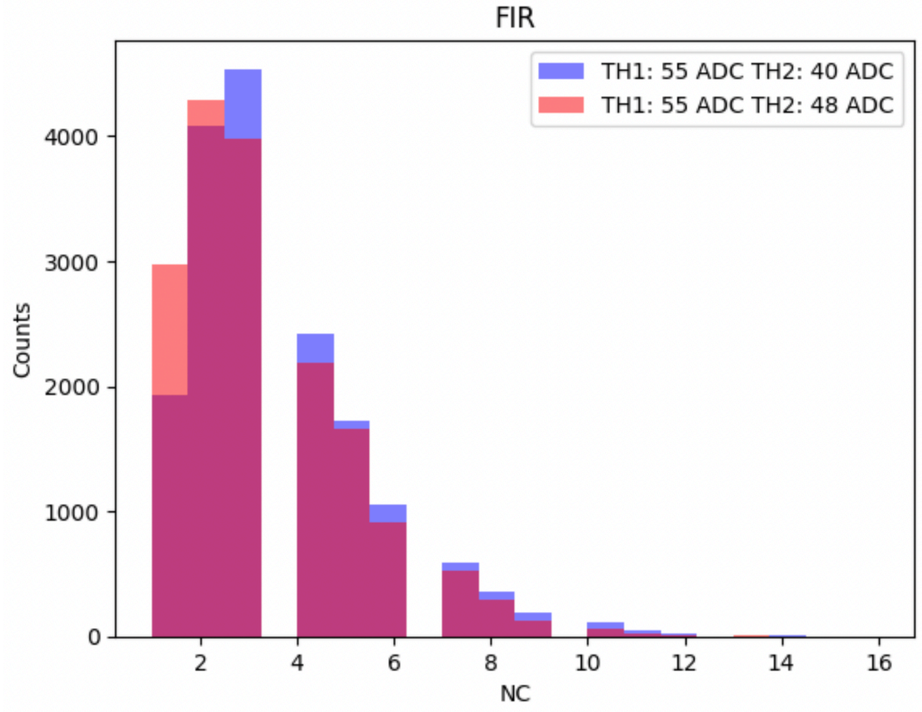
If **t_sepmax < 20 ns**, significant signal loss occurs.

If **NC < 7**, signals are also lost

Compare these distributions to the trigger parameter settings (t_sepmax = 50ns and NC [2-7]): **post validation of NC and t_sepmax settings**

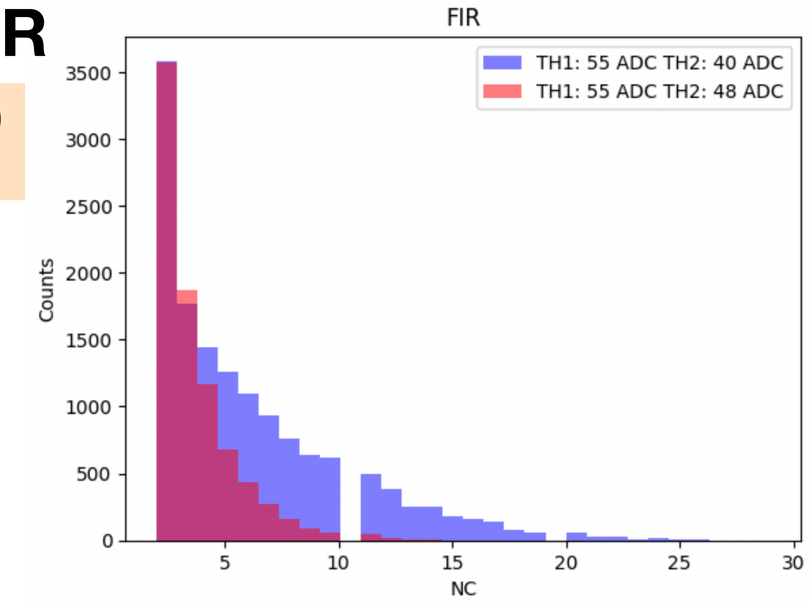


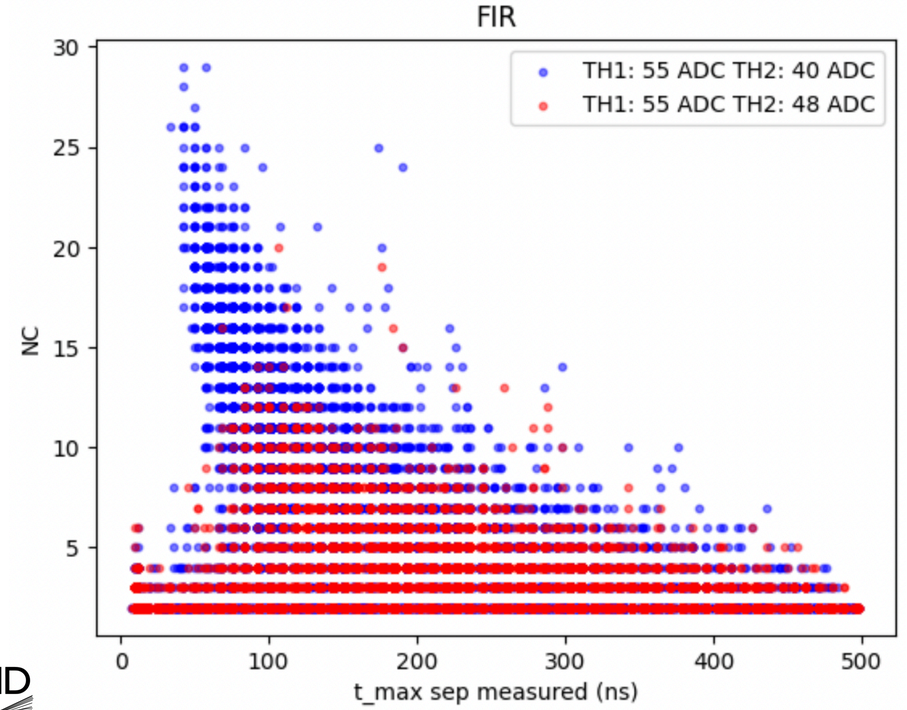


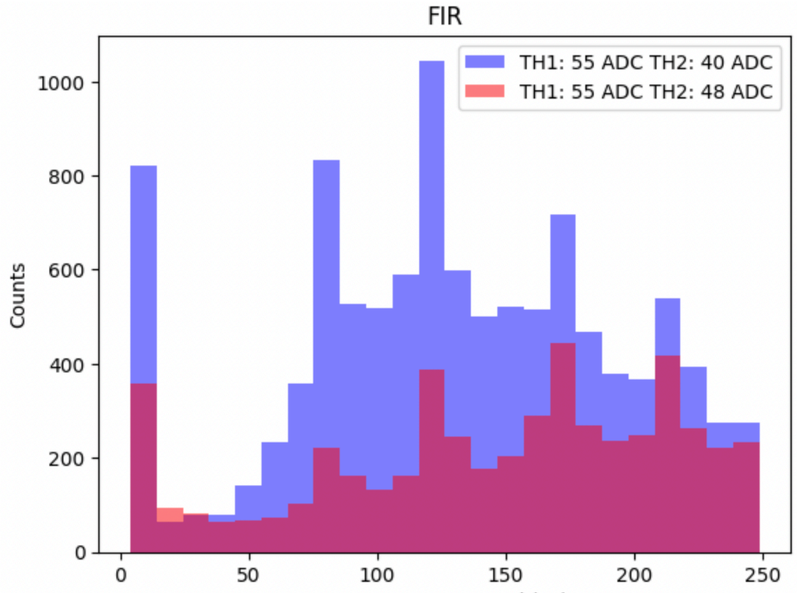
Distribution of NC and t_max sep on **MD data with FIR**

Select MD from February 19, 2025 (Effective time of data per antenna: 0.44s)
Processing 2 – One notch Filter + FIR filter

- Select only traces exceeding **TH1 = 55 ADC** to focus on significant signals
- Analyze the distributions for TH2 = 3.5σ and TH2 = 4σ of:
  - **Number of crossings (NC)**
  - **Maximum separation time (t_max_sep)** between consecutive peaks
- Compare these distributions with the current trigger parameter settings
- Compute **trigger rate** and evaluate **purity**







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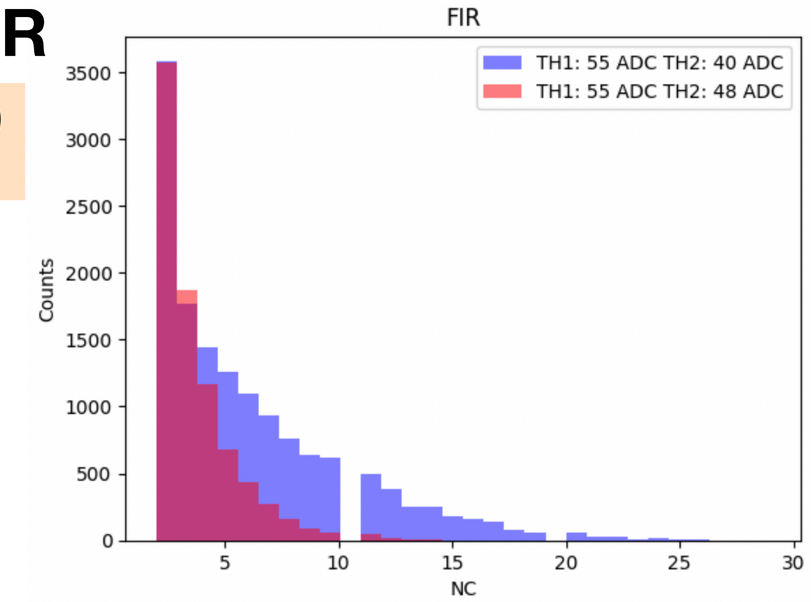

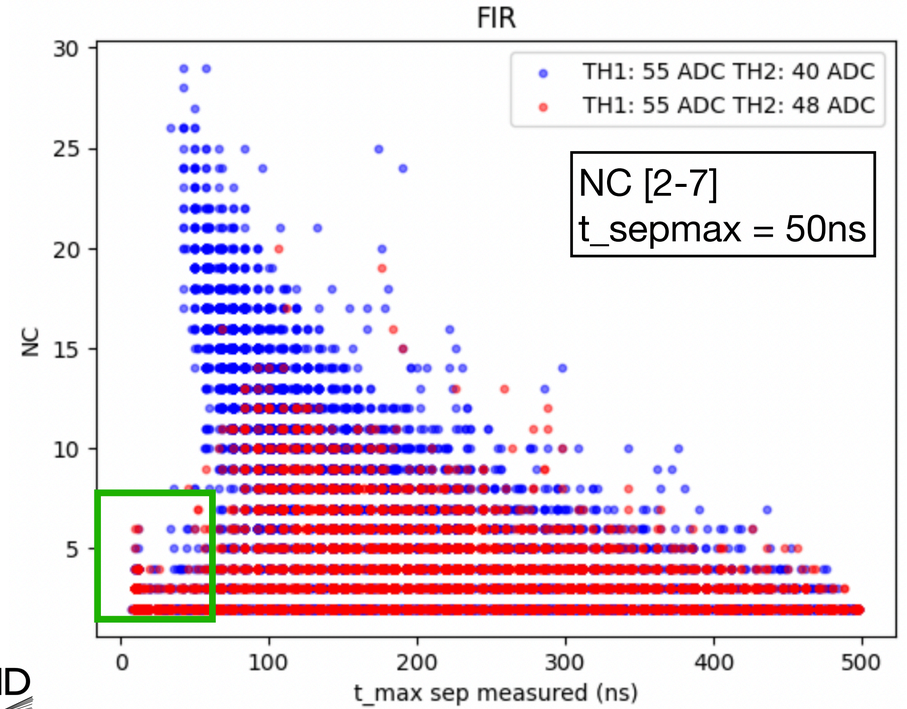

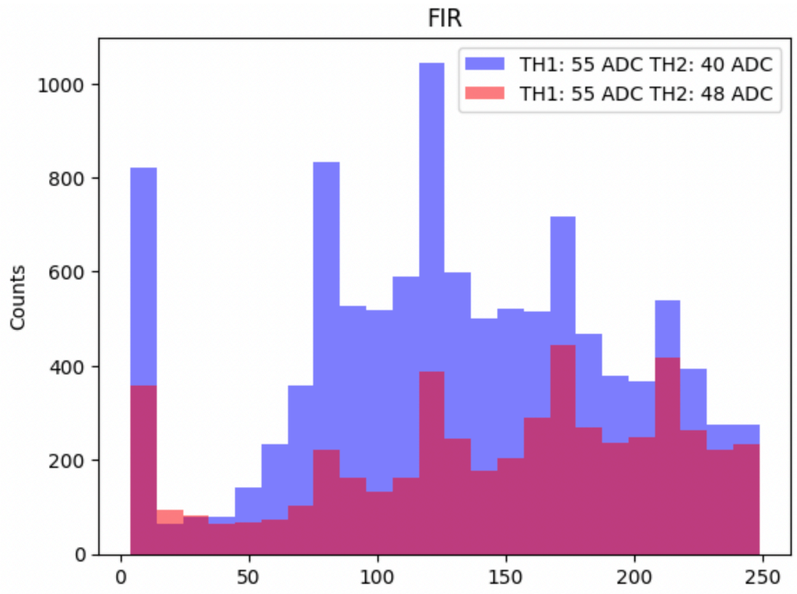

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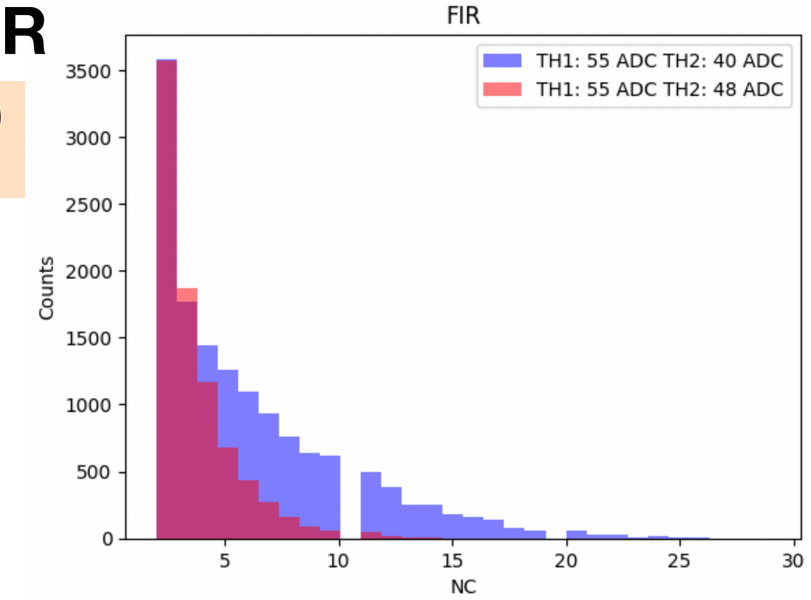
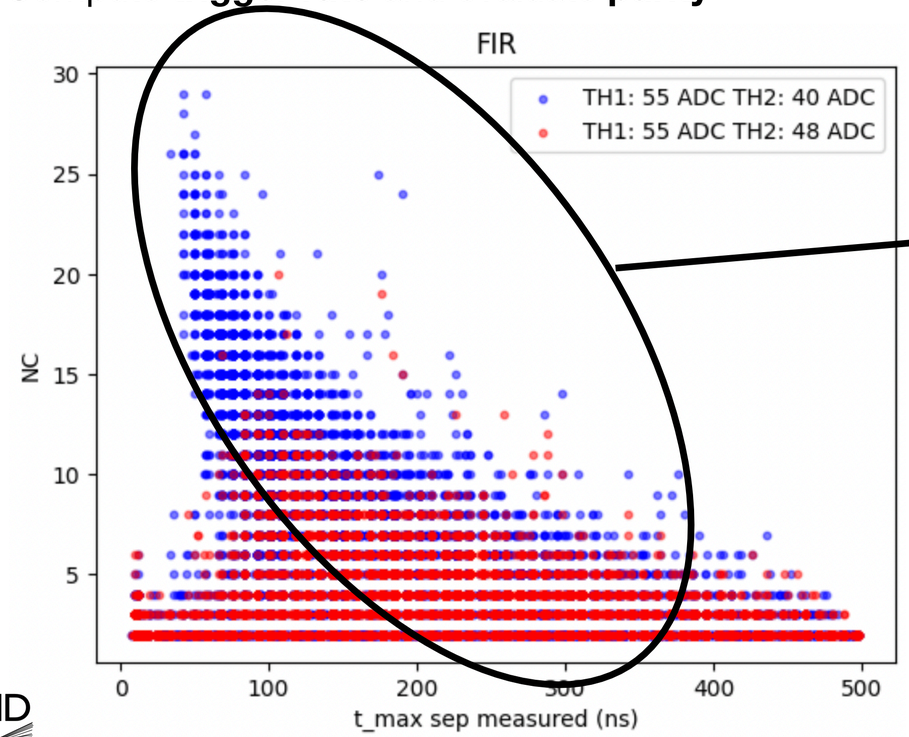
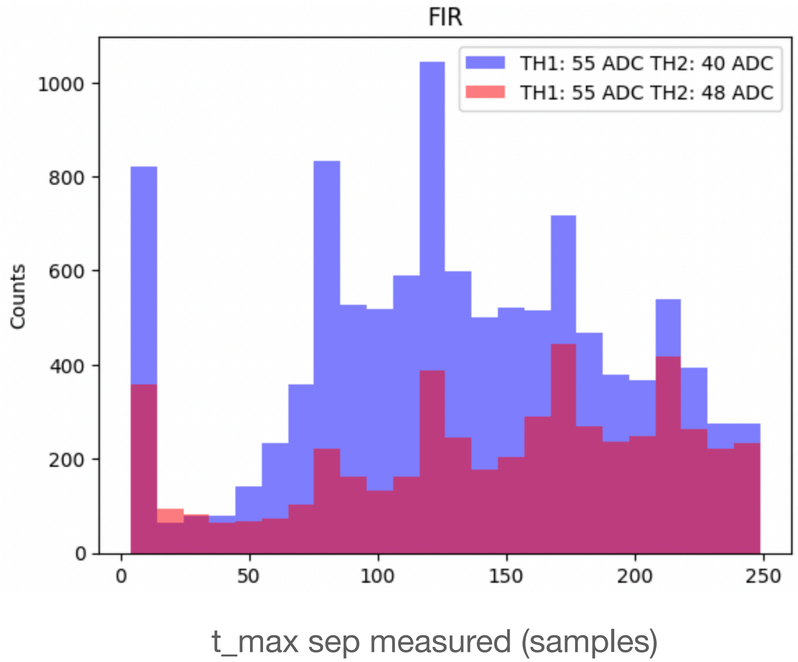




Background



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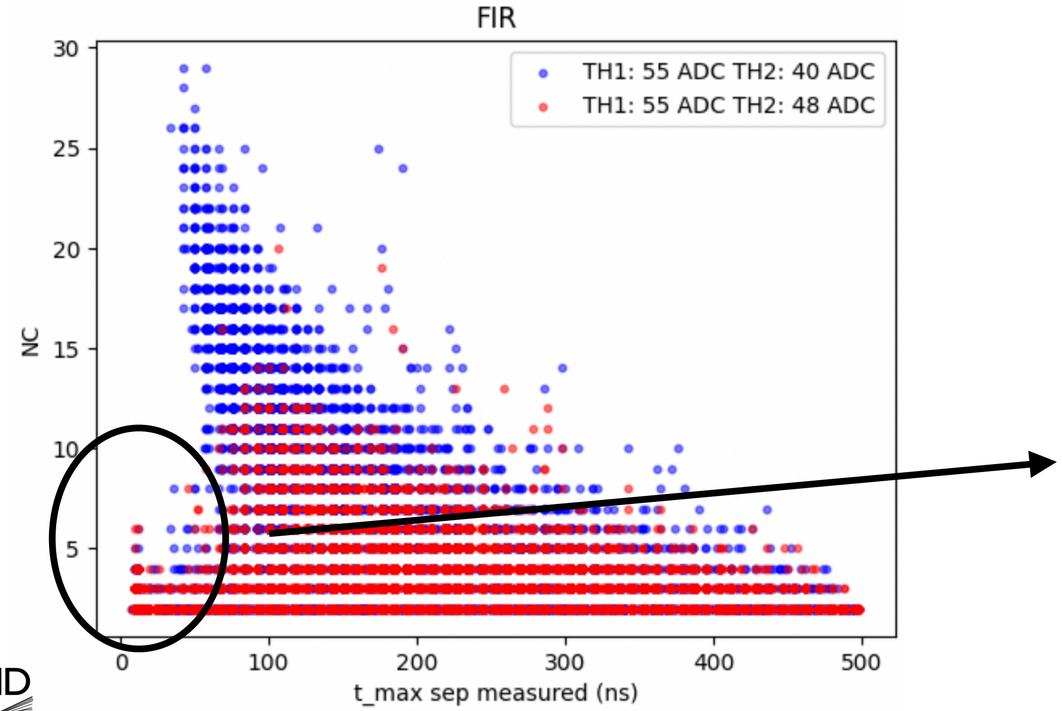
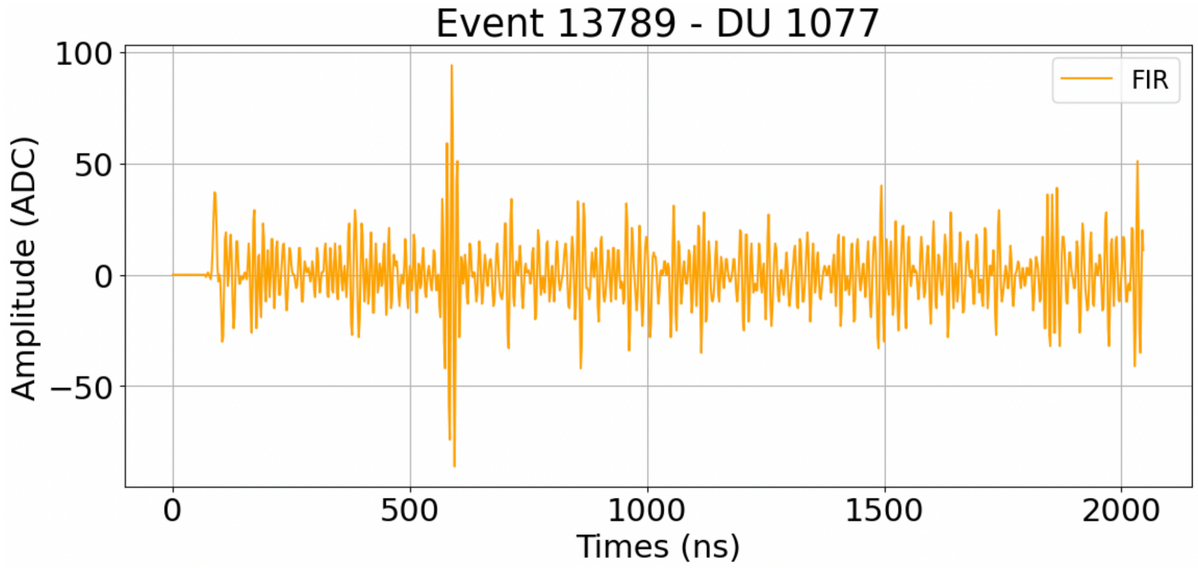


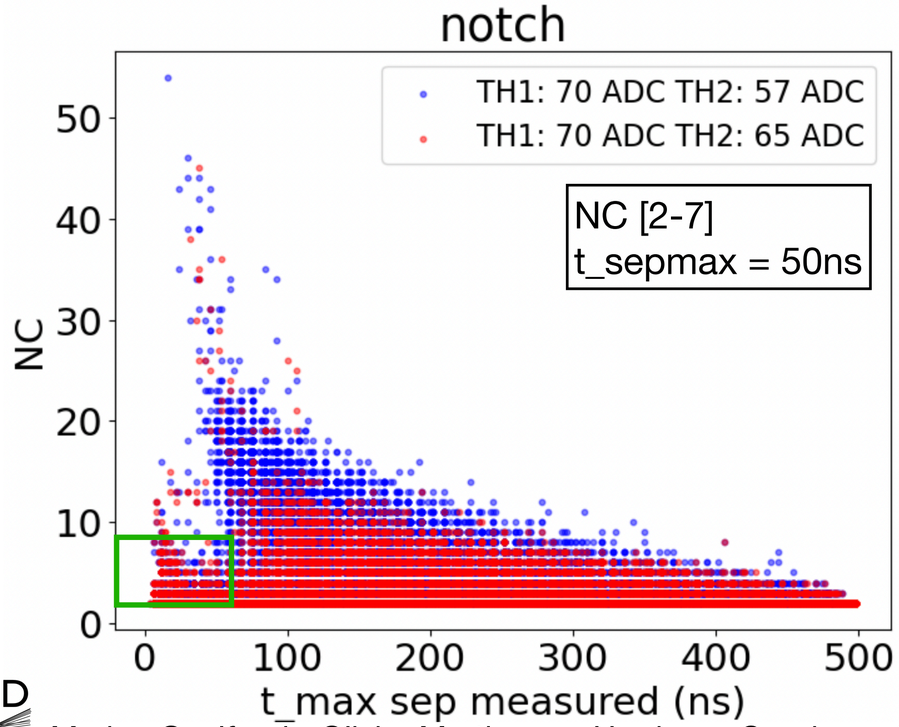
Clean pulse in MD

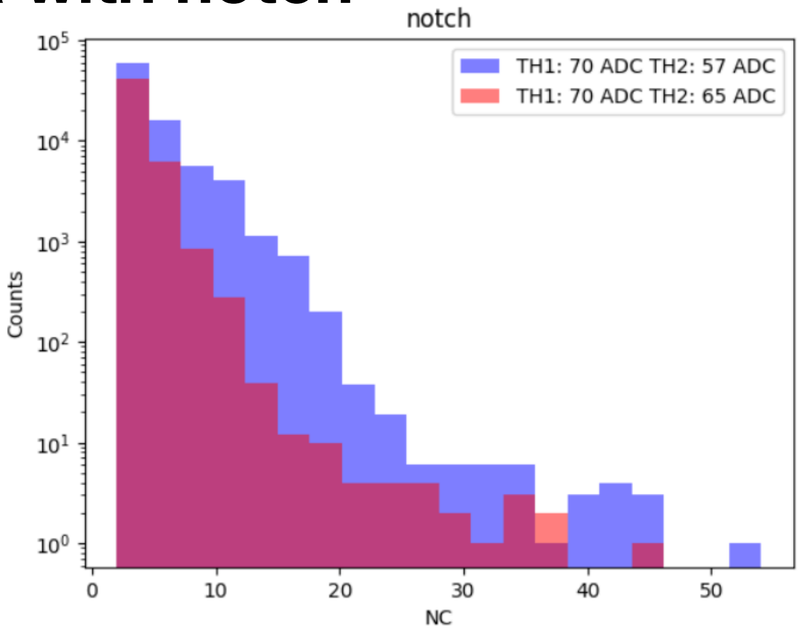


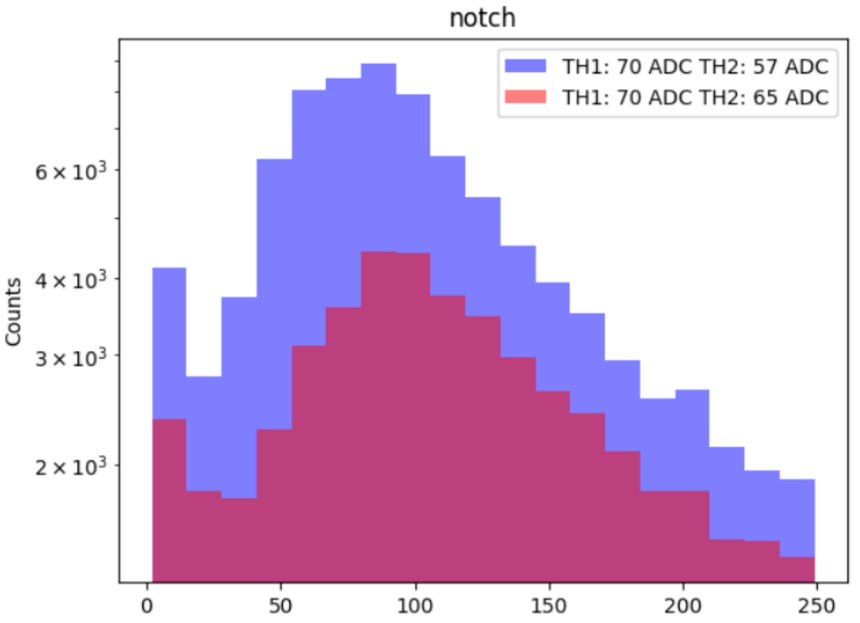
Distribution of NC and t_max sep on **MD data with notch**

Select MD from February 19, 2025
Processing 1 – Simulated Notch Filters Only

- Select only traces exceeding **TH1 = 70 ADC** to focus on significant signals
- Analyze the distributions for TH2 = 3.5σ and TH2 = 4σ of:
  - **Number of crossings (NC)**
  - **Maximum separation time (t_max_sep)** between consecutive peaks
- Compare these distributions with the current trigger parameter settings
- Compute **trigger rate** and evaluate **purity**







Tests optimized parameters on MD data - Trigger rate

Optimal parameters
t_quiet = 500 ns, t_period : 500 ns
NC = [2-7], t_sepmax = 50 ns

MD data from February 19:
26 DUs running:
total of 215916 events per DU + 1 DU with 14378 events

Warning: **just a snapshot**
Channel X and Y studied **independently** here

Trigger rate: Number of triggered events / (2*Number of traces) / 2048 ns

FIR: TH1 = 55 ADC and TH2 = 3.5σ: Number of triggered events on channels X and Y: 1692
Trigger rate: 73 Hz
FIR: TH1 = 55 ADC and TH2 = 4σ: Number of triggered events on channels X and Y: 1227
Trigger rate: 53 Hz

FIR: TH1 = 70 ADC and TH2=4σ: Number of triggered events on channels X and Y: 116
Trigger rate: 5 Hz

Notch: TH1 = 70 ADC and TH2 = 3.5σ: Number of triggered events on channels X and Y: 11896
Trigger rate: 516 Hz
Notch: TH1 = 70 ADC and TH2 = 4σ: Number of triggered events on channels X and Y: 7477
Trigger rate: 324 Hz

Conclusion

Thorough study leads to optimal T1 parameters (EAS T1 efficiency > 70% at SNR 6-7 and > 90% above):

For FIR: TH1 = 55 ADC, TH2 = 3.5σ or 4σ

For notch: TH1 = 70 ADC, TH2= 4σ

T_sepmax = 50ns

NC [2-7]

Leads to nominal trigger rate (< 100 Hz for FIR and < 400 Hz for notch)

Very positive effect of FIR