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Simulation studies for OF trigger

BULLKID analysis meeting

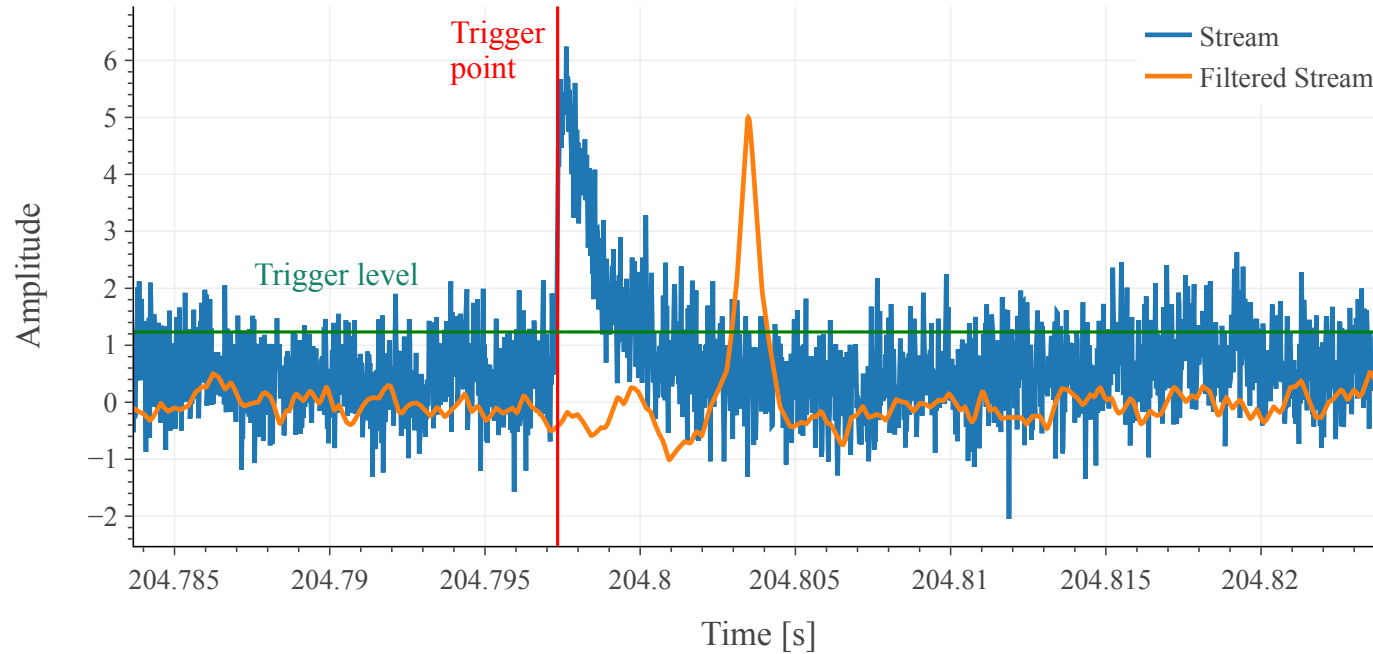
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OF trigger

We use a trigger based on the Optimum Filter to lower the **trigger threshold**

- Filter the stream with the OF
- Trigger on the filtered stream



Needs to be implemented as an hardware trigger also in the new BULLKID electronics

OF trigger

Filtering in the frequency domain

$$v_{\text{flt}}(t) = \int_{-\infty}^{\infty} df e^{i\omega t} H(f) \tilde{v}(f)$$

$$v_{\text{flt}}[k] = \sum_{j=0}^{N-1} e^{i\frac{2\pi}{N}k} H[j] \tilde{v}[j]$$



Convolution in the time domain

$$v_{\text{flt}}(t) = \int_{-\infty}^{\infty} dt' H(t - t') v(t')$$

$$v_{\text{flt}}[k] = \sum_{j=k}^{k-N+1} H[k - j] \tilde{v}[j]$$

The OF trigger in the new electronics will work on time domain data, we will need to do the **convolution** in the time domain.

Problems:

- Resources: for each channel, O(2000) in the final experiment, we need **N weights** for the convolution, being N the **window length**
- Time: the filtered sample k needs $N/2$ points in the past and $N/2$ points in the future to be computed

Possible solutions:

- **Downsample** the stream to reduce N
- Use a **unique filter** to reduce the number of channels

Simulation

A first simulation has been performed to see how much we can downsample the stream.
Simulate pulses over a noise stream and then trigger with the OF trigger implemented in Diana

Simulation parameters:

Simulated time: 5324.80 s

Sampling frequency: 500 kHz

$\tau_r = 100 \mu\text{s}$ (rise time)

$\tau_d = 1 \text{ ms}$ (decay time)

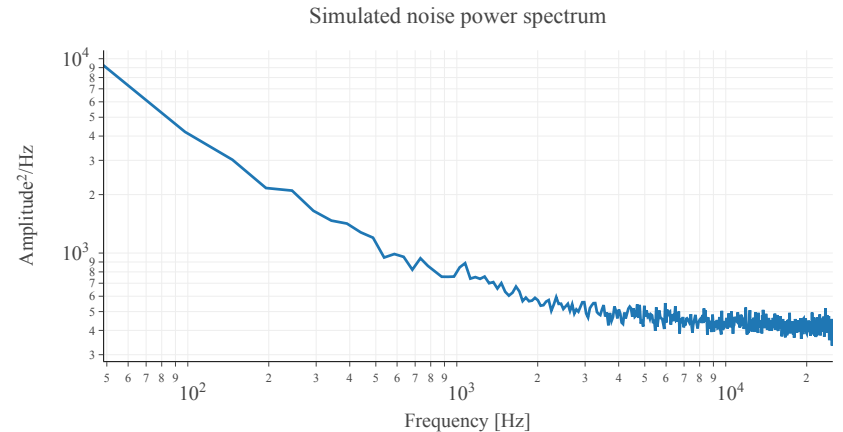
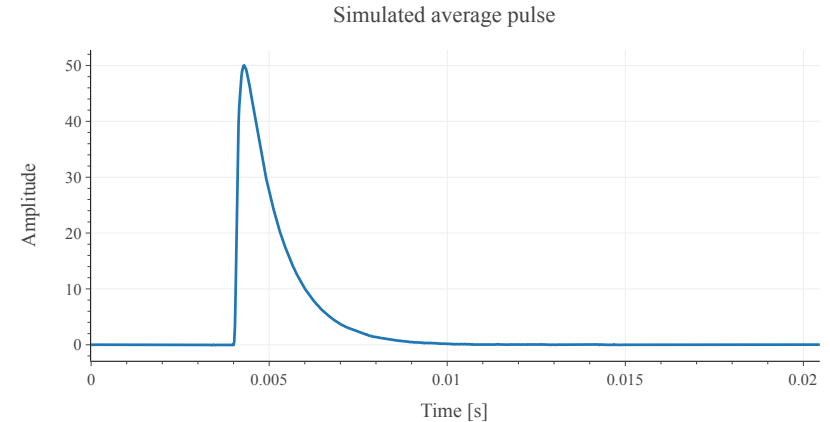
Window length = 1024 points (20.48 ms)

Noise contributions: flat + $1/f$ + $1/f^2$

σ noise (non filtered) = 1

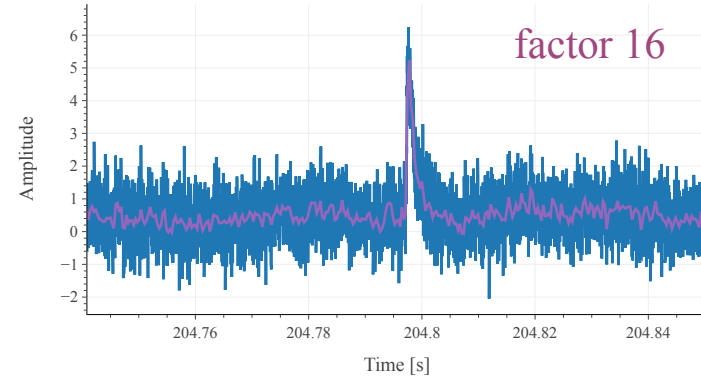
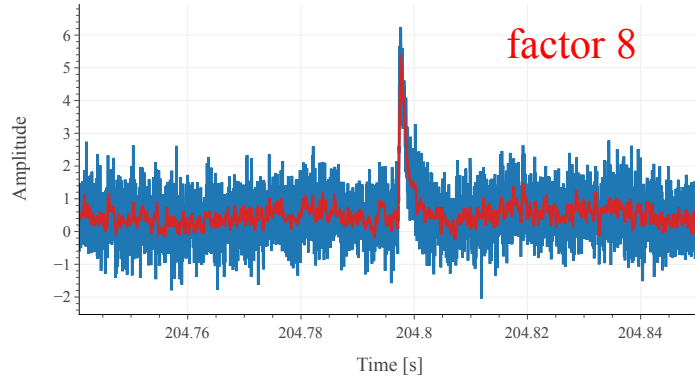
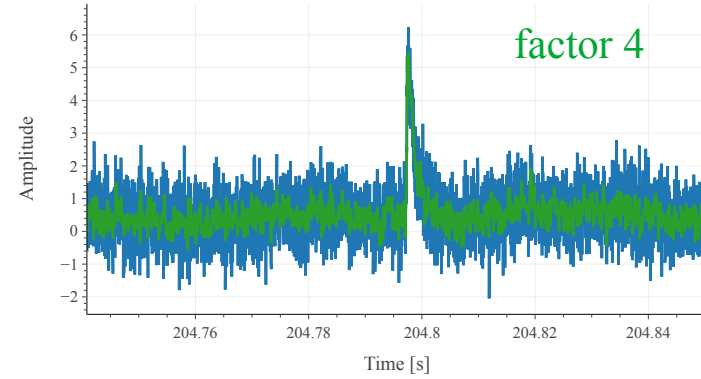
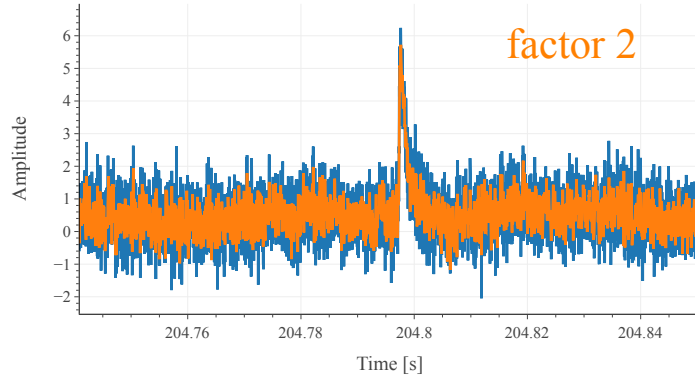
Pulse generated on a noisy stream with the following amplitudes:

[0.3, 0.6, 0.8, 1, 1.1, 1.2, 1.25, 1.5, 1.7, 1.9, 2, 2.5, 5]



Downsample streams

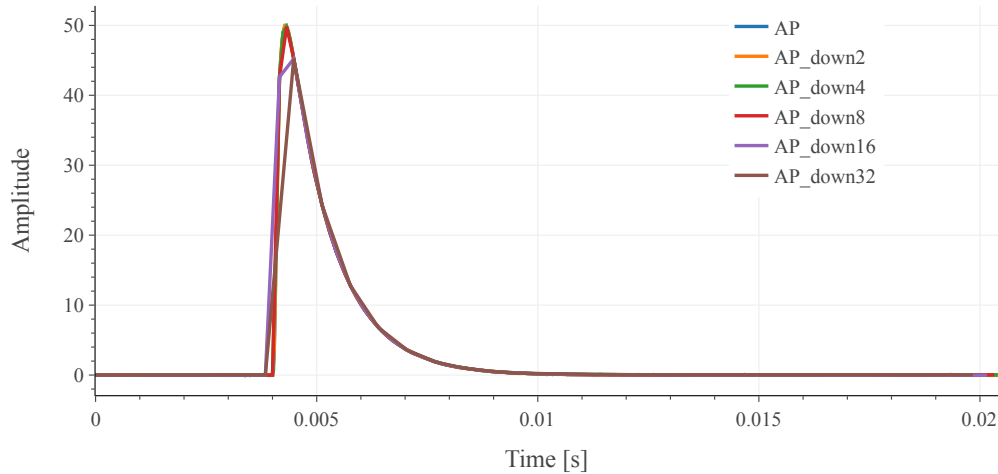
Downsample the stream at factors 2,4,8,16,32



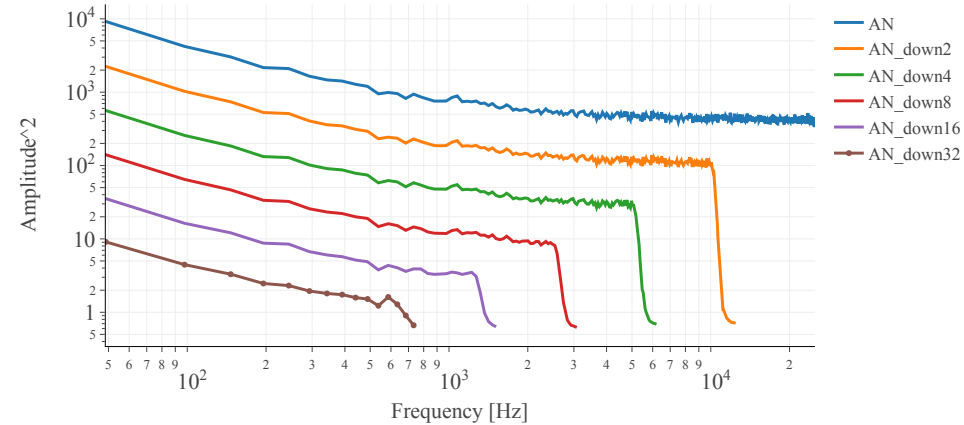
Filters

For each downsampling factor, we build a different optimum filter used for triggering

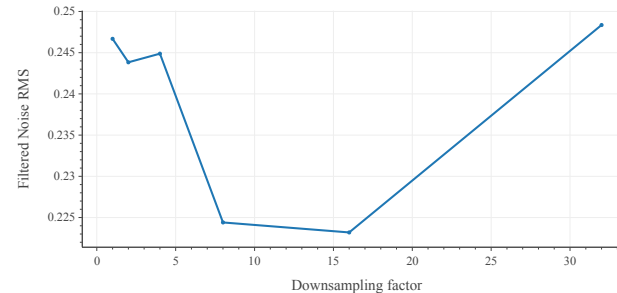
The template pulses are downsampled taking less points on the original template pulse



The NPS are re-computed from the downsampled noise traces

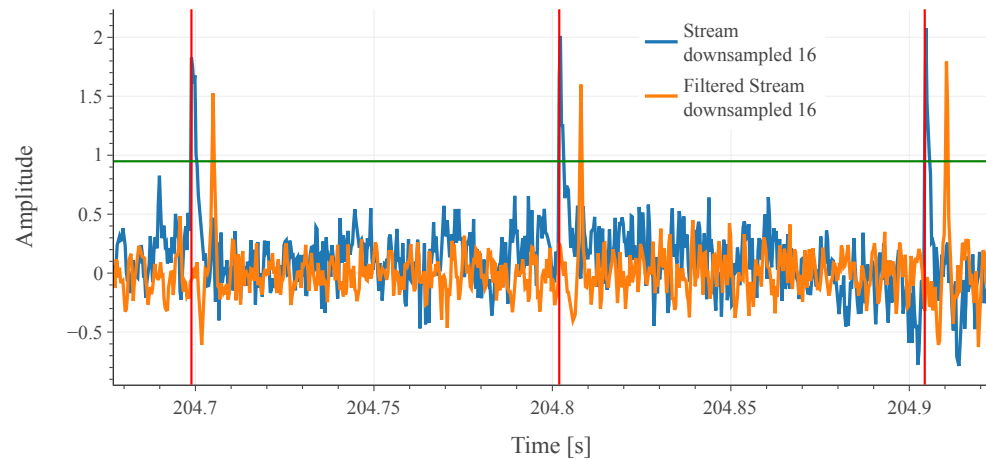
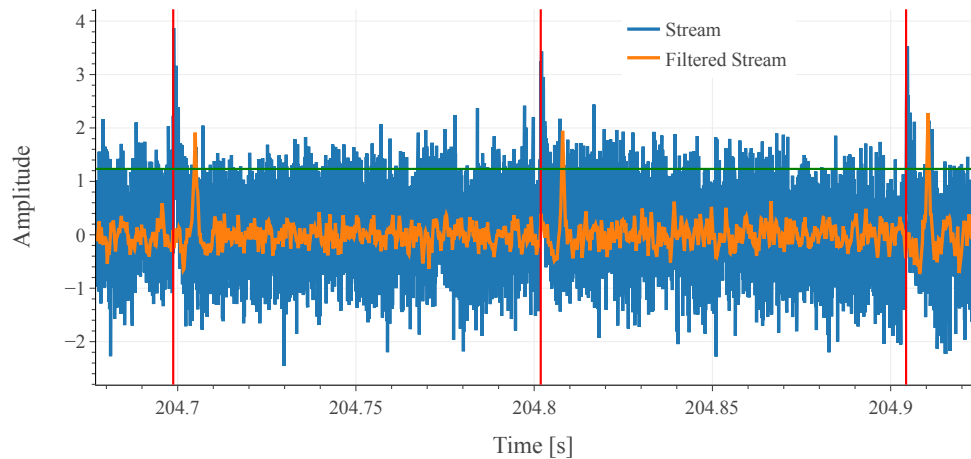


The RMS of the filtered noise is practically unchanged with the downsampling factor



Filter and trigger streams

For each downsampling factor, filter and trigger the streams with the corresponding filter



Trigger efficiency

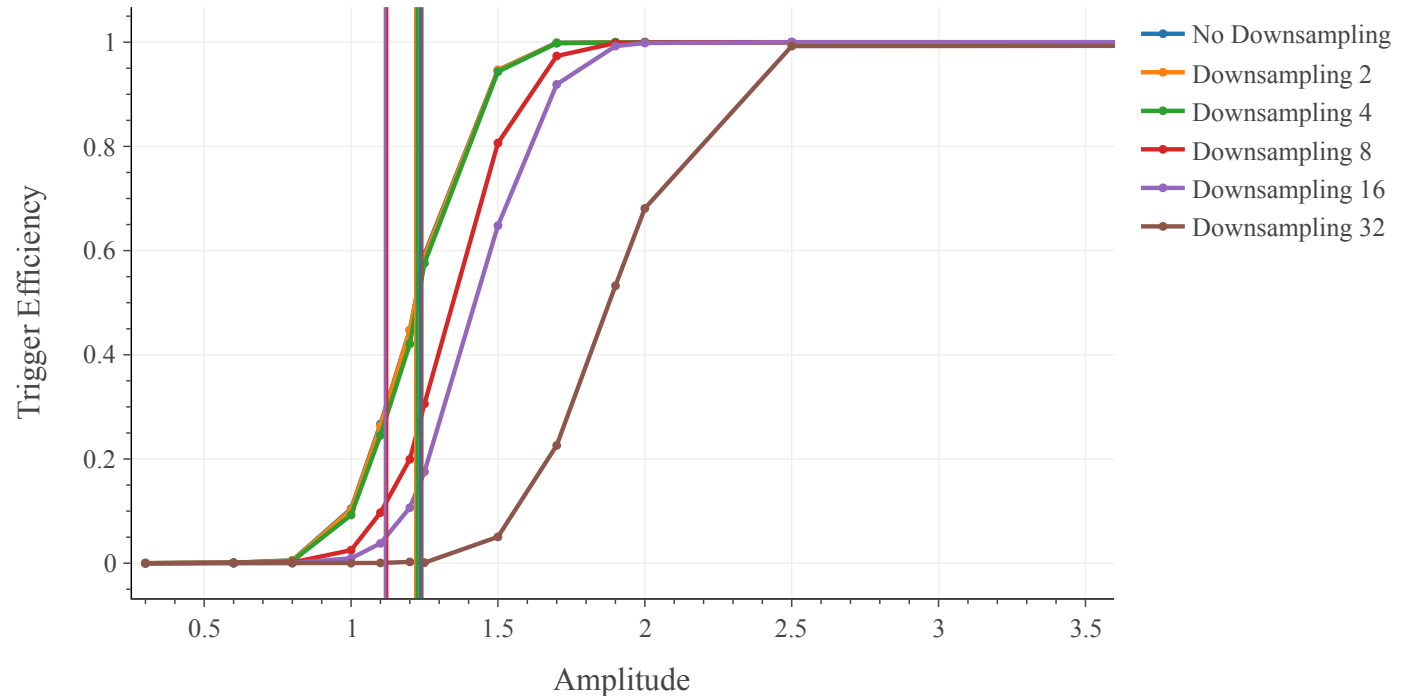
Evaluate the trigger efficiency (number of triggers found / number of injected triggers) as a function of the injected pulse amplitude for every downsampling factor.

Setting the threshold at 5σ , where σ is the filtered noise RMS (vertical lines):

The real trigger threshold differs from the one that has been set at high values of downsampling



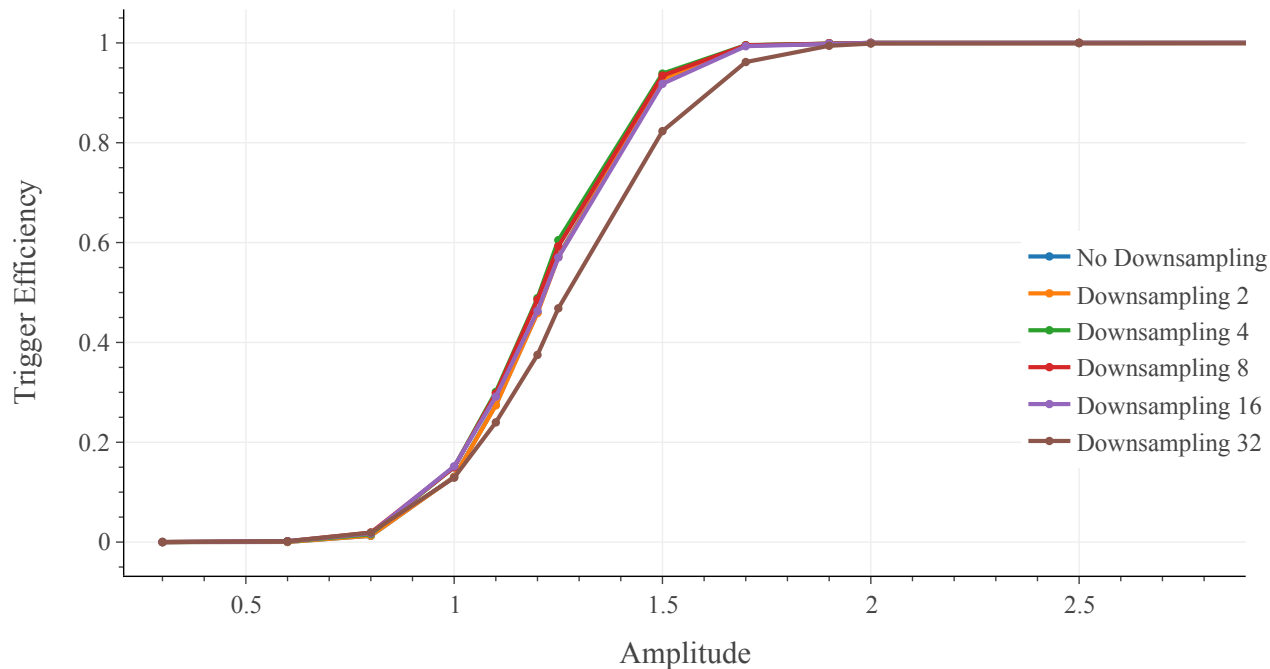
We will loose events if the only operation is downsampling



Reset the trigger threshold

In order not to lose events, we need to decrease the **trigger threshold** the more we downsample

Downsampling factor	Threshold [σ]
1	5
2	5
4	4.9
8	4.5
16	4.25
32	3.4



The efficiency curves are now aligned to have the **same trigger efficiency** for every downsampling factor.

What about false positives?

Conclusions and outlook

Preliminary conclusions:

- We can for sure **downsample until a factor 16/32** lowering the trigger threshold without losing events
- The procedure seems to **not increase the rate of false triggers**
- In this way we can save resources up to a factor 32

To do:

- **Push the procedure** until a factor 64 and more
- See if we can use a **single trigger** to trigger all the channels



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thanks for the attention
