SAPIENZA
UNIVERSITÀ DI ROMA

Background with mild shield: low energy spectrum with OFND

BULLKID analysis meeting
04/03/2026
Matteo Cappelli

Data: background with mild shield

Data with internal and external lead shield
290 hours for 2 clusters with 15 KIDs
19 Apr 22:00 – 5 May 8:00
Publication in preparation

		1	2	3	4	5	
13	12	11	10	8	7	9	6
14	15		16	17	18		19
27	26	25	24	23	22	21	20
29	28	30	31	32	33	34	35
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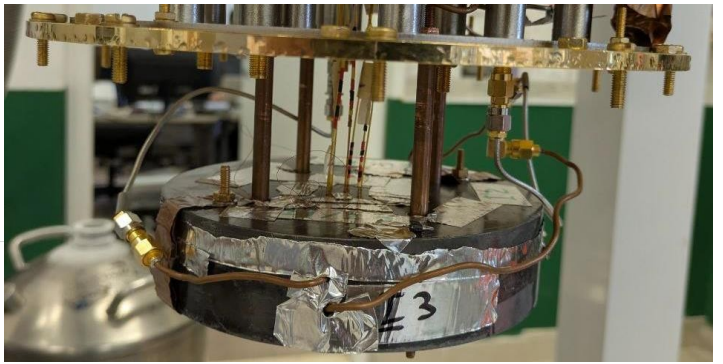
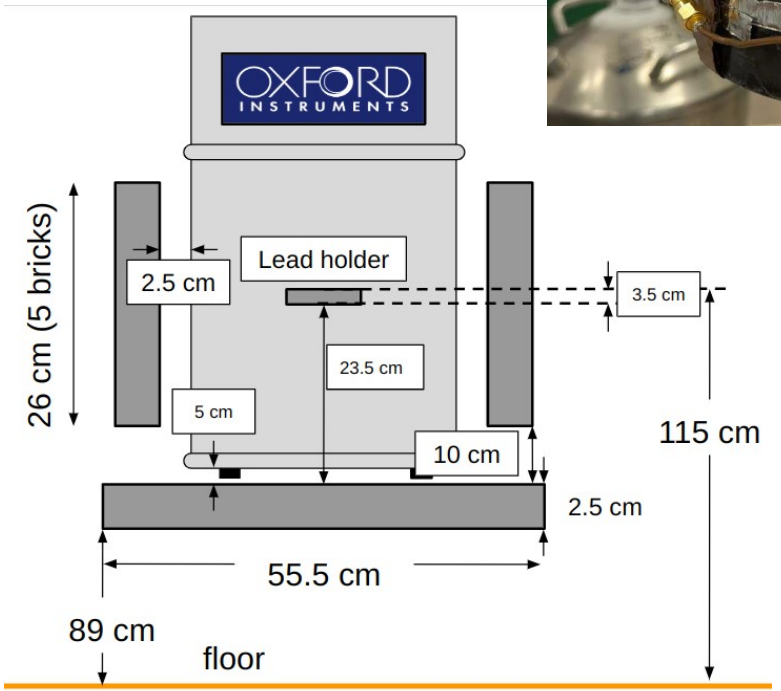
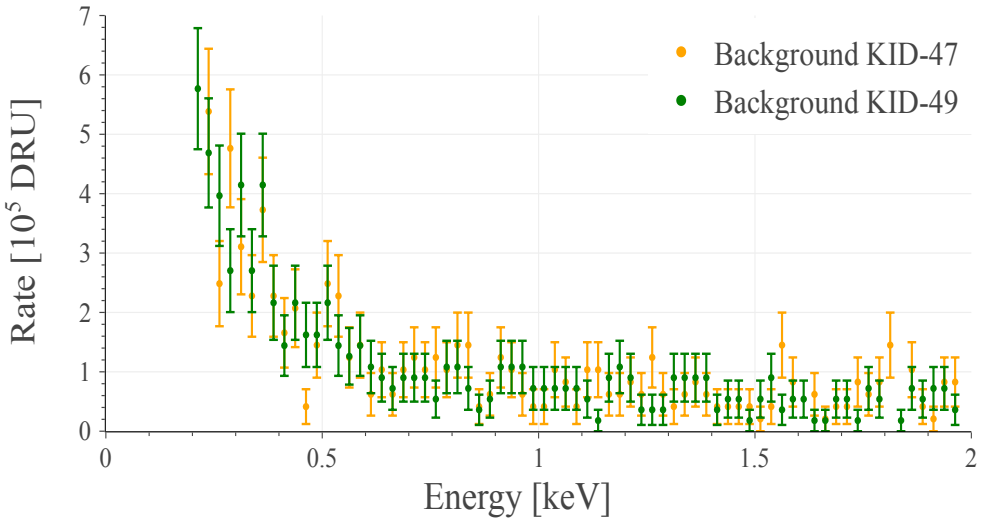
44	45	46	47	48	49	50	51
	57	56	55	54	53	52	

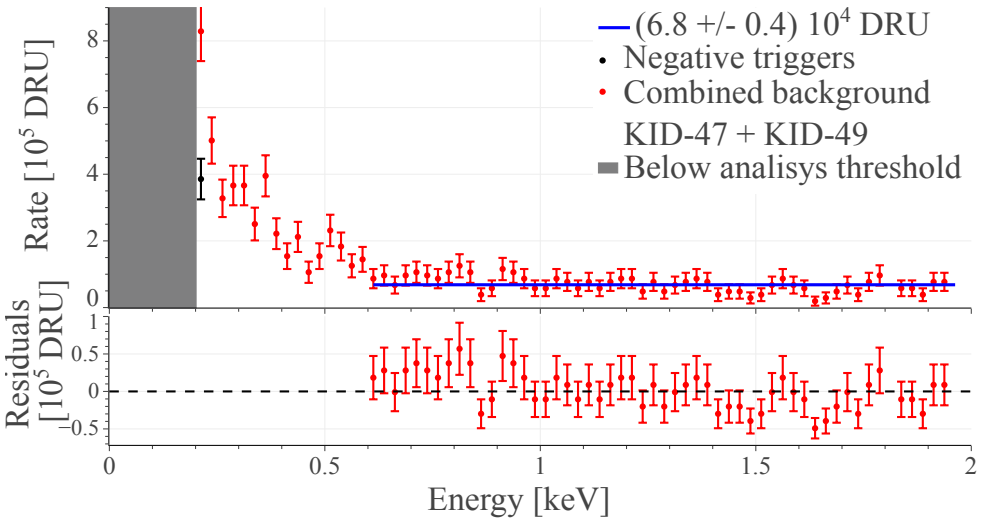




Low energy spectrum results

Low energy analysis in the range [0-2 keV]
Analysis threshold of 200 eV (~6σ)
Flat component + rise under 600 eV
Analysis with amplitude from OF, calibrated with lead peaks





Pulse shape and anti-coincidence cuts

New analysis with OFND

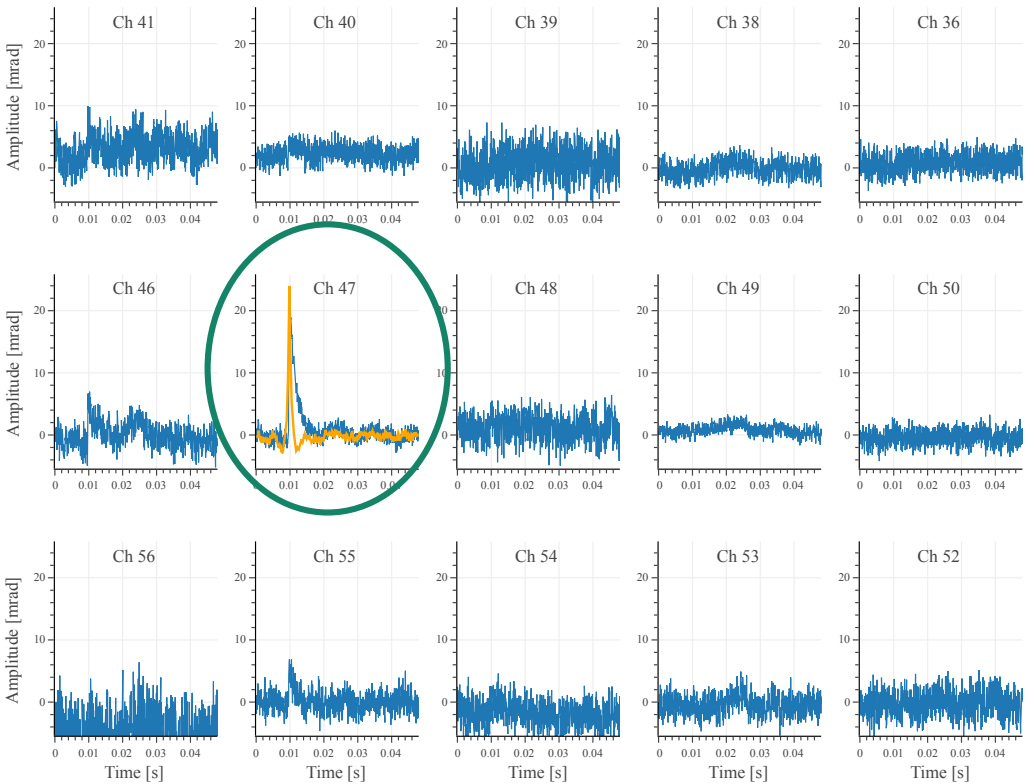
N-dimensional optimum filter (OFND) employed to **lower the baseline resolution** and **reduce the rate of negative triggers**

The filtered signal is:

$$\tilde{v}_{\mathrm{filt}}(f) = \frac{1}{K} \sum_{a,b=1}^{N} \tilde{s}_a^*(f) \hat{\sigma}_{ab}^{-1} \tilde{v}_b(f)$$

templates — noise covariance — waveforms

Combines the signals on different detectors to improve the amplitude resolution.



Baseline resolutions with OFND

Calibration is performed, as before, with lead peaks

A ~ 9% gain in the baseline resolution is observed for the two master channels (baseline resolution of ~ 31 eV)

```
Resolution with OF : 34.29163668886203 eV
Resolution with OFND : 31.248781018117107 eV
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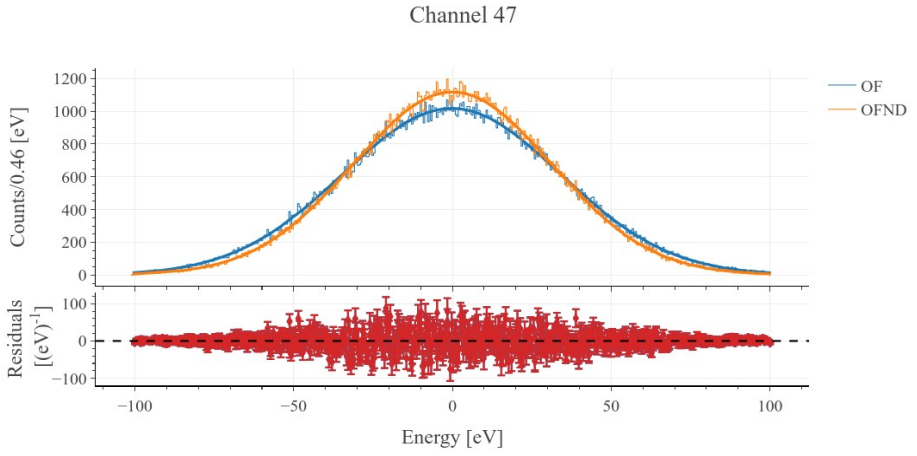


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Resolution with OF : 33.906748694976095 eV
Resolution with OFND : 30.955679852387817 eV
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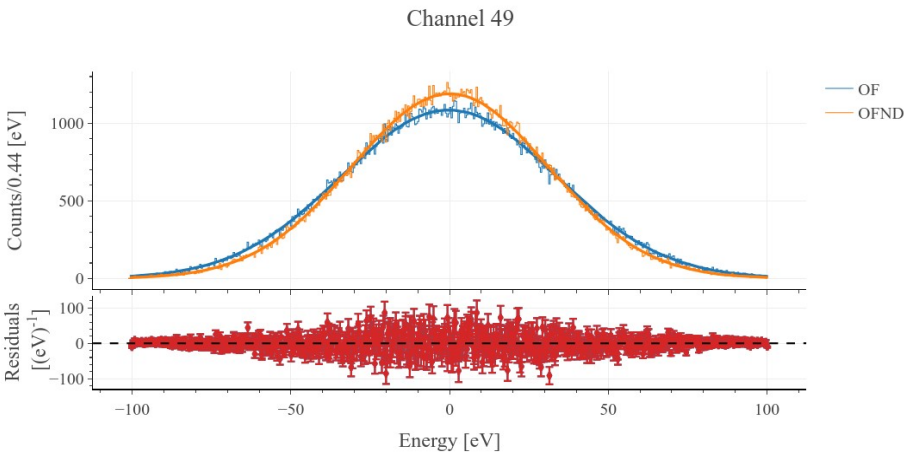
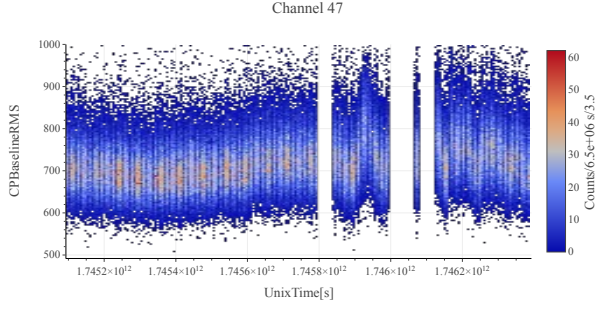
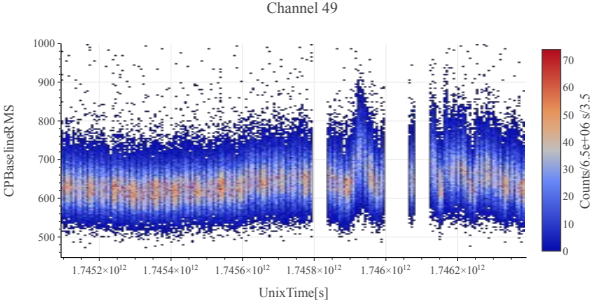


Stability of the baseline:





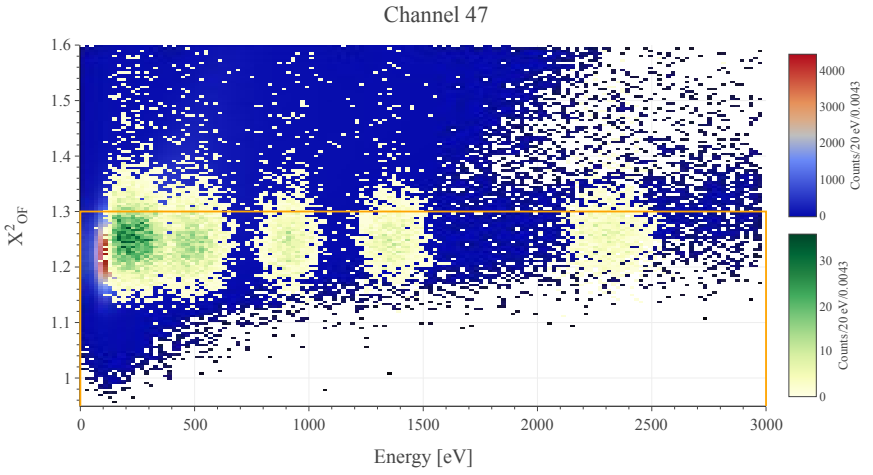
Cuts

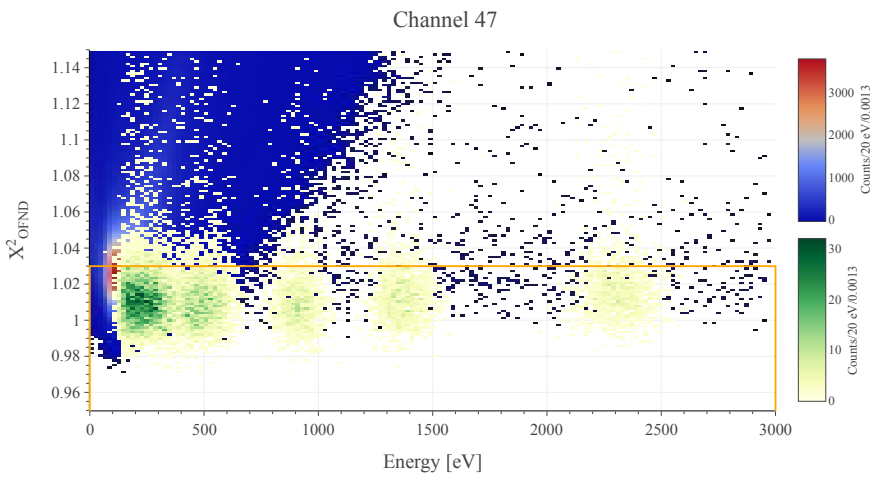
Cuts are based on usual pulse shape and cluster variables + χ^2 from the multidimensional OF
Analysis in the range [0-3 keV]

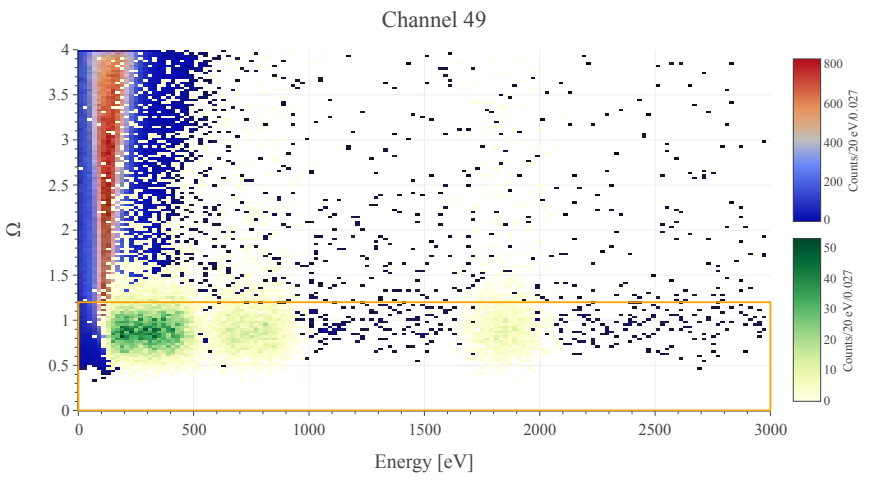
Cut variables:

- χ^2_{OF}
- χ^2_{OFND}
- Ψ_i
- Ω

Comparison of LED (used for efficiencies) and Background

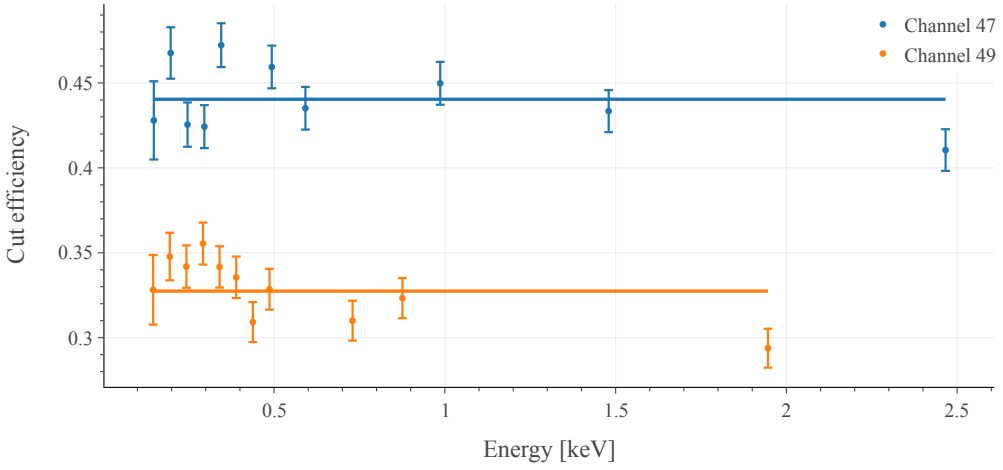


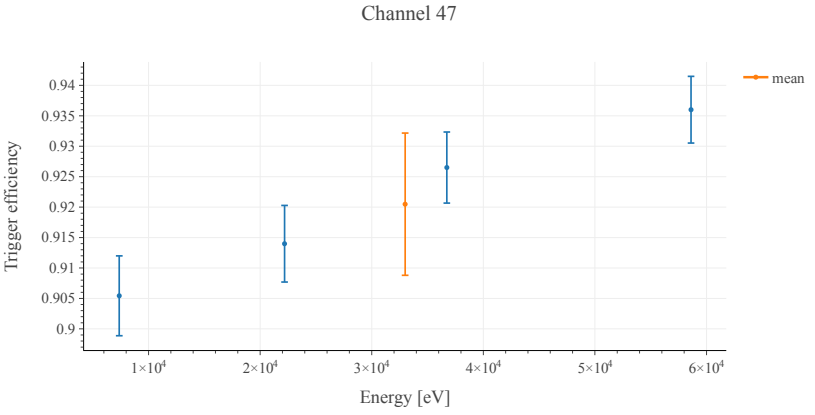


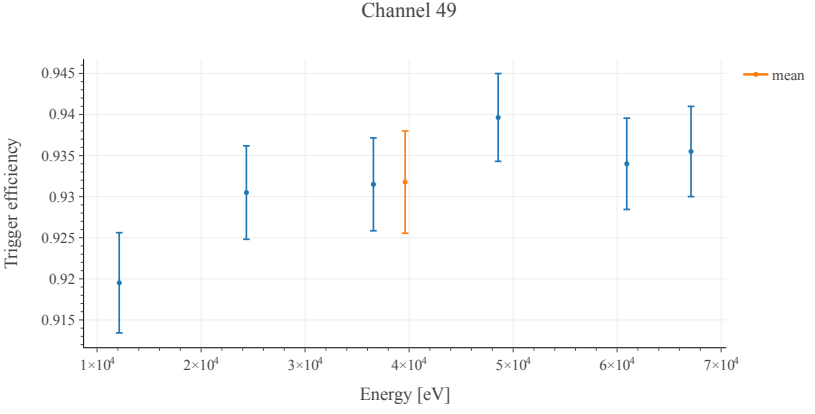


Efficiency

The cut efficiency is evaluated on LED events from threshold to 2 keV.
The trigger efficiency (plateau) is evaluated at high energy averaging over LED events



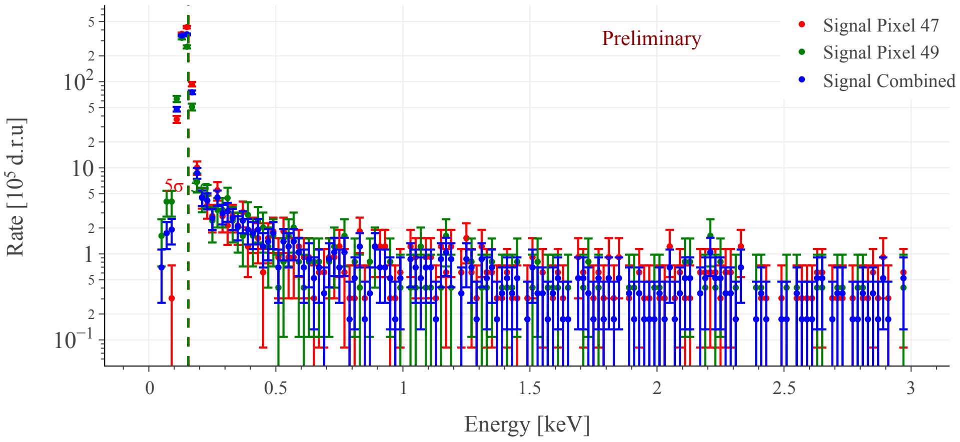


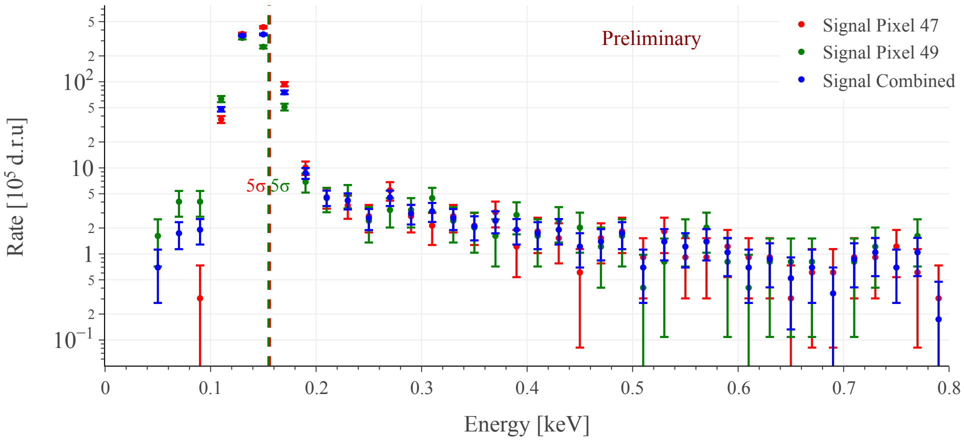


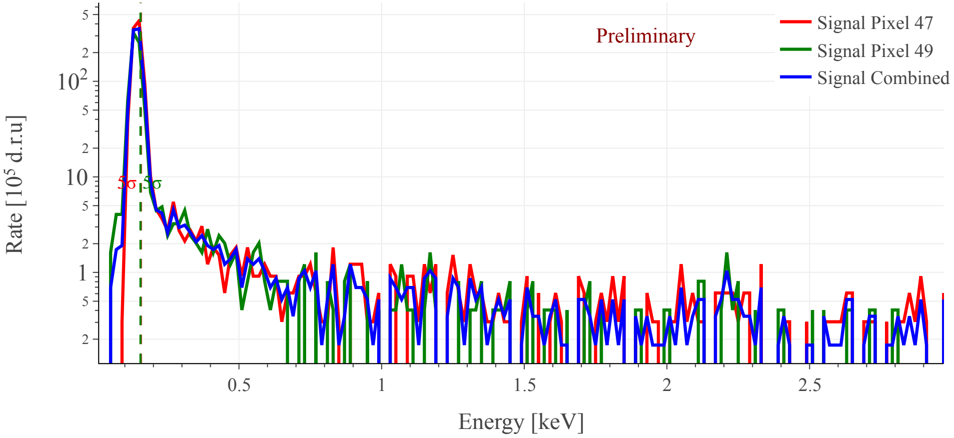
Trigger efficiency is around 90%
Cut efficiency is around 35-45 % (needs to be improved to have a better exposure)

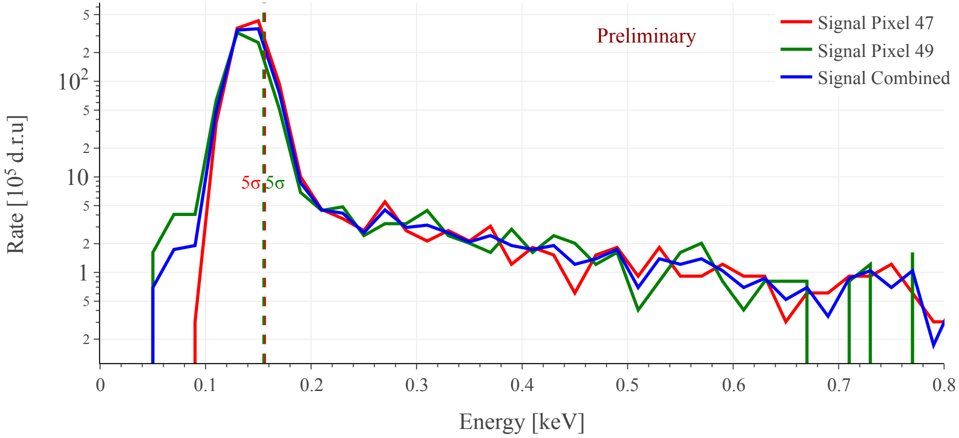
Energy spectra (signal)

Binwidth set at 20 eV. 5σ is taken from the noise gaussian. First bin center above 5σ is at 170 eV (160 eV is threshold). Signal spectrum for the two pixels and combined.



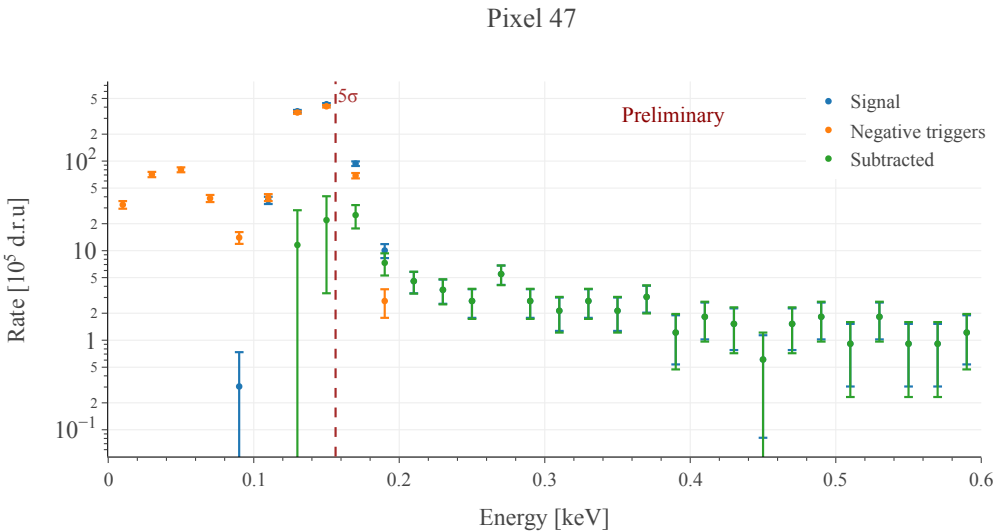


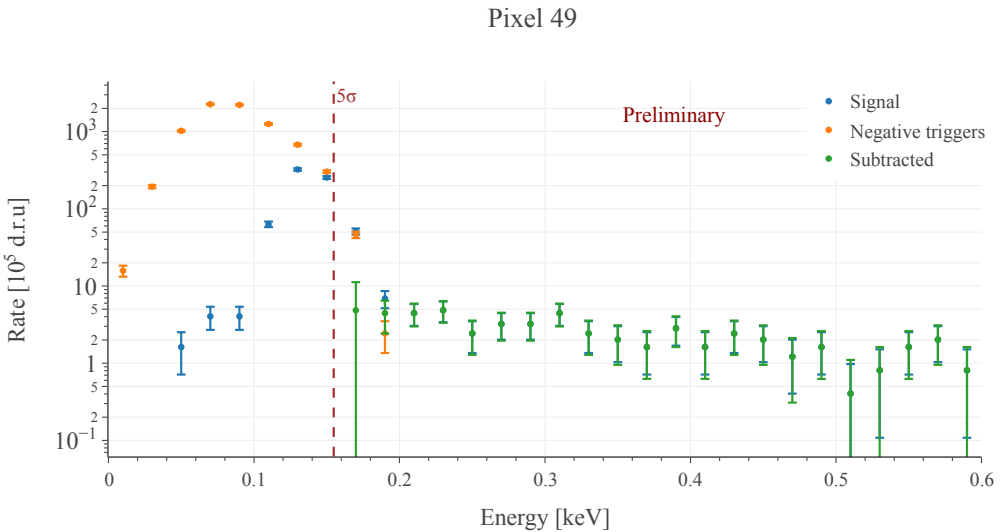




Energy spectra (signal - negatives)

Since we know the rate of negative triggers, we can perform a **statistical subtraction**

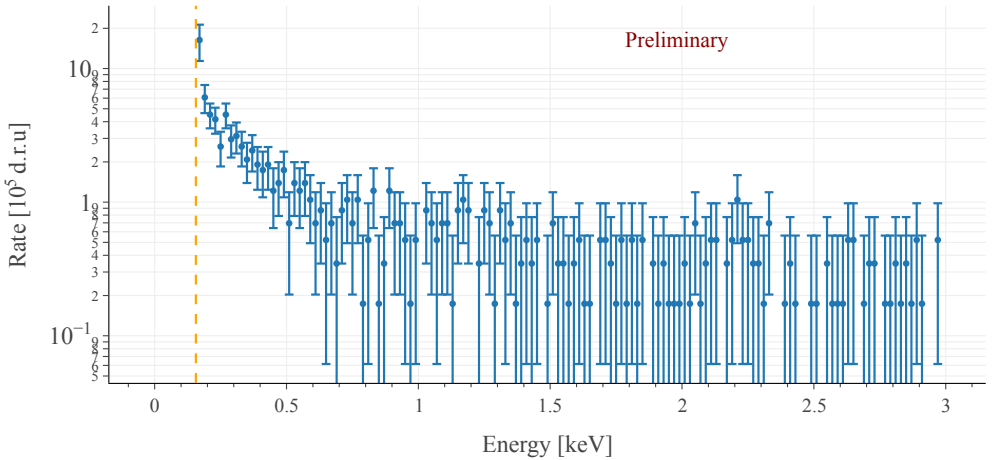


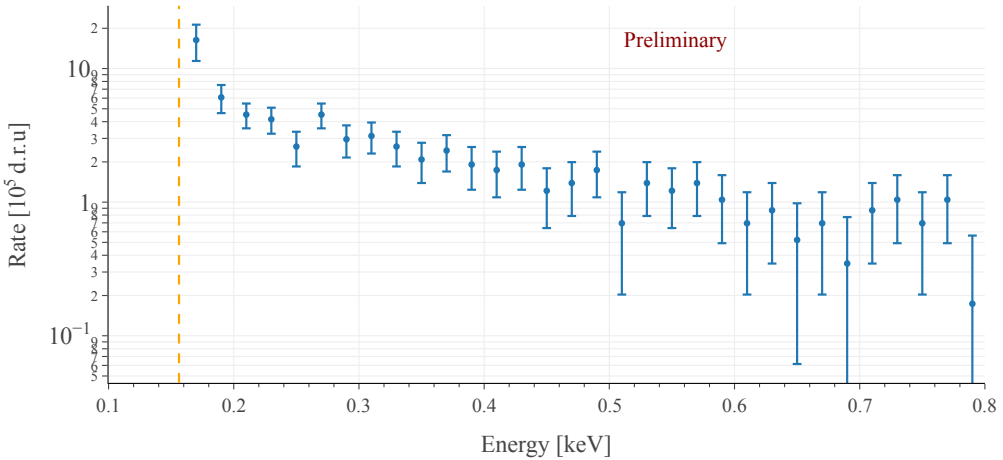


In this way the statistically remove the contribution of noise false positives, remaining **only with physical signals**

Final spectra (subtraction + combination)

The energy spectrum **combined and subtracted** is the one that will be used to put limits

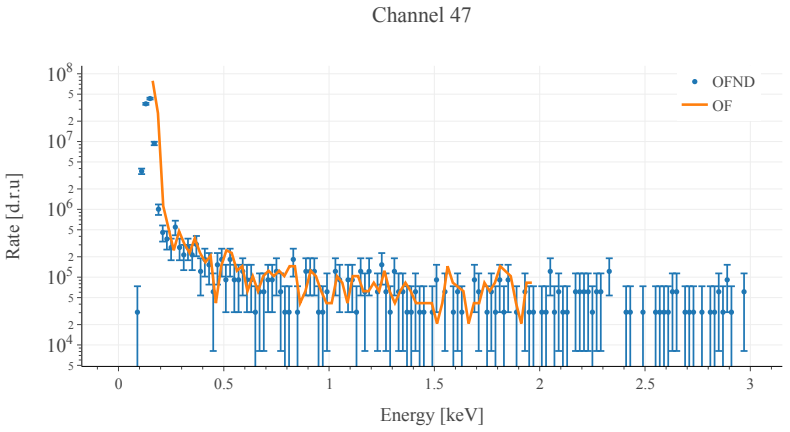


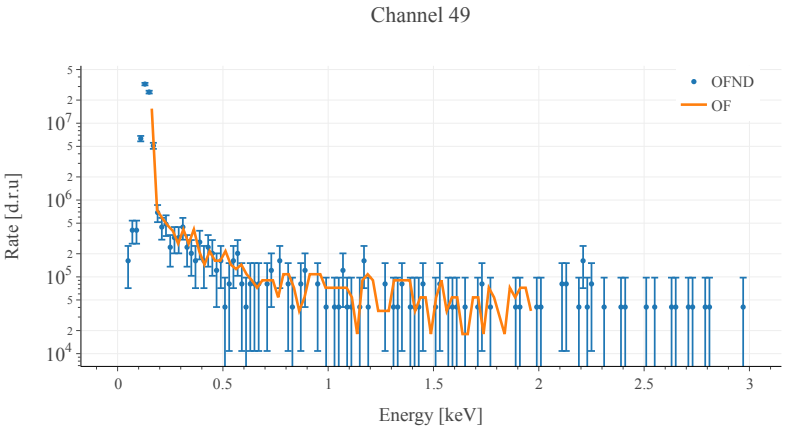


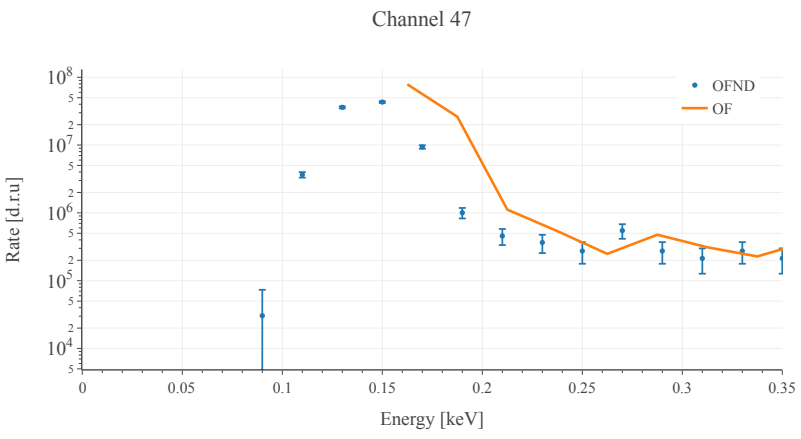
Limits on DM electromagnetic properties from this energy spectrum

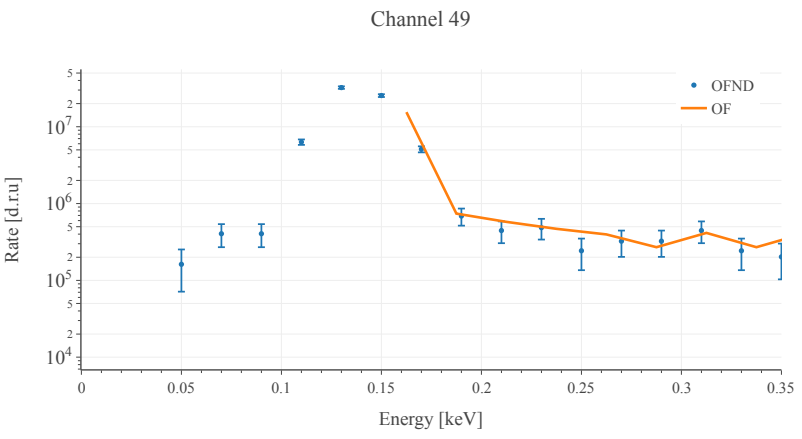
Comparison with previous analysis

In a channel-by-channel comparison, the gain in using the OFND is evident only on channel 47
Probably due to the different cuts implementation in the two analysis



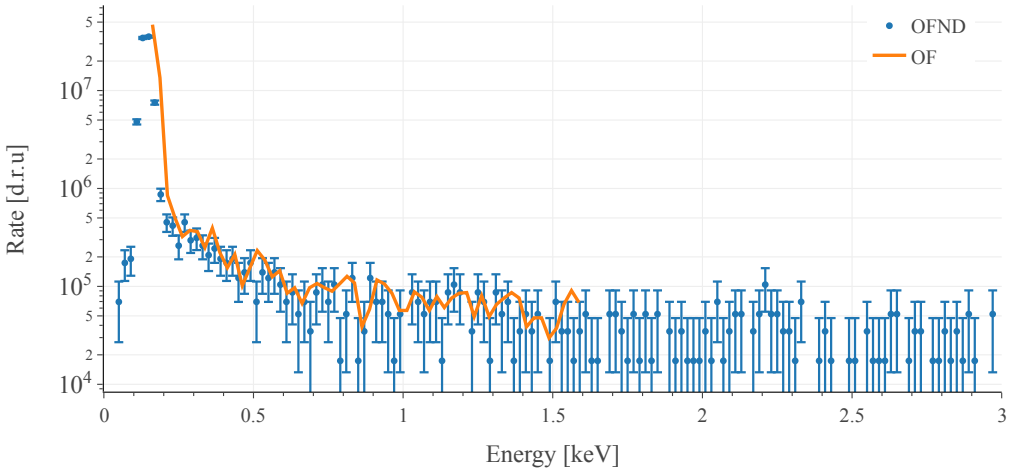


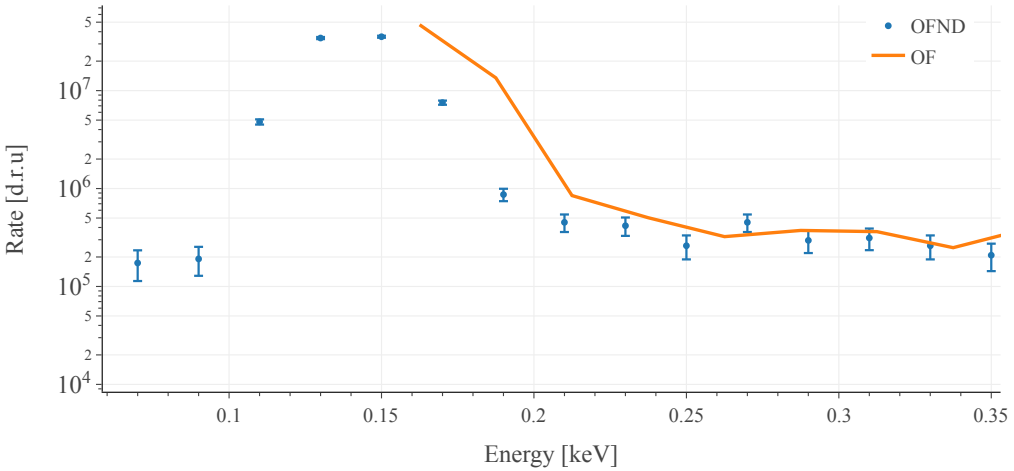




Comparison with previous analysis

However, when we combine the pixel, the gain with OFND is clear





Conclusions

Analysis results:

- Improved baseline resolution of about ~9 %
- Analysis threshold improved from 200 eV to 160 eV
- OFND and statistical subtraction used to lower the rate at threshold

To do:

- Investigate other variables (Aspect filter)
- Try to further reduce the negative trigger rate
- Try to increase the efficiencies to have more exposure
- Put limits on electromagnetic properties (work from Eric and Alberto)

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thanks for the attention