Short pulse processing in TES detectors (study case for ATHENA: IFU)

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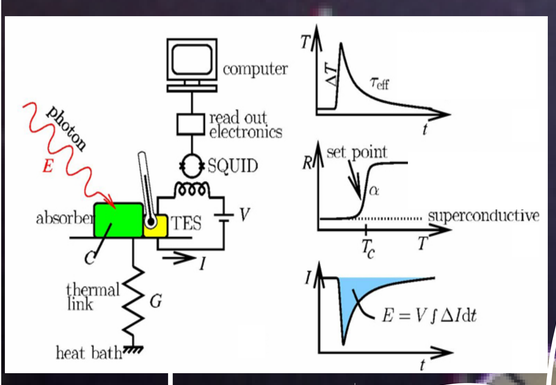
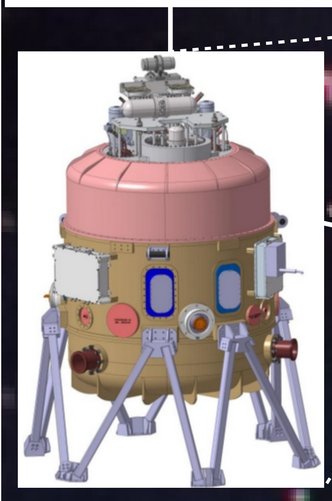
SIRENA is the software aimed at performing the on board event energy reconstruction for the *Athena* calorimeter X-IFU, in the Digital Readout Electronics unit. Processing will consist in an initial triggering of event pulses followed by an analysis (with SIRENA) to determine the energy content of events. Single Threshold Crossing and Optimal Filtering have been chosen as the baseline detection and reconstruction algorithms. To better improve the energy resolution results when reconstructing pulses shorter than those considered of high resolution, some variations to the standard optimal filter are being analyzed.





X-ray Integral Field Unit [1]

On-board data processing

SIRENA

http://sirena.readthedocs.io

Single Threshold Crossing [3]

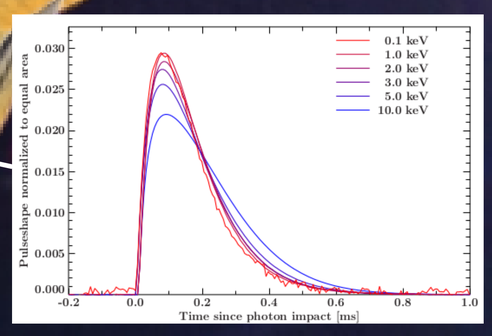
Optimal Filtering (Resistance Space) [4,5]

Transforming current into resistance the detector response is more linear with respect to the energy

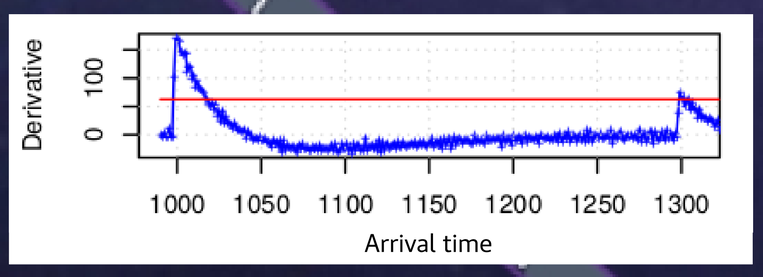
$$Data \quad D(t) = H \times Model(t)$$

$$Minimize \quad \chi^2 = \sum \frac{[D(f) - H \times Model(f)]^2}{NOISE^2(f)}$$

$$Energy \quad H = \sum D(t)\, OptFil(t)$$



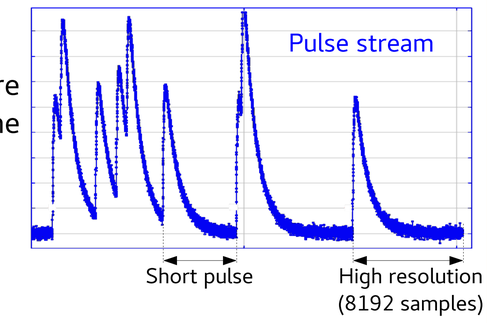
Response of X-IFU microcalorimeter to X-ray incoming photons are electrical pulses.



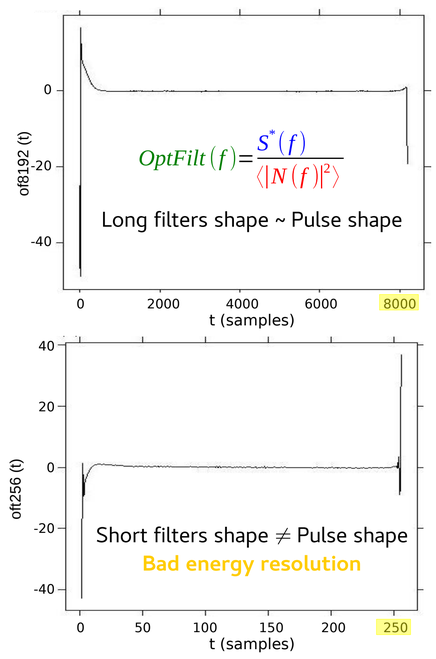
Pulses must be detected (triggered) and then its energy must be reconstructed on board by the Event Processor in the Digital Readout Electronics Unit [2] by the SIRENA software

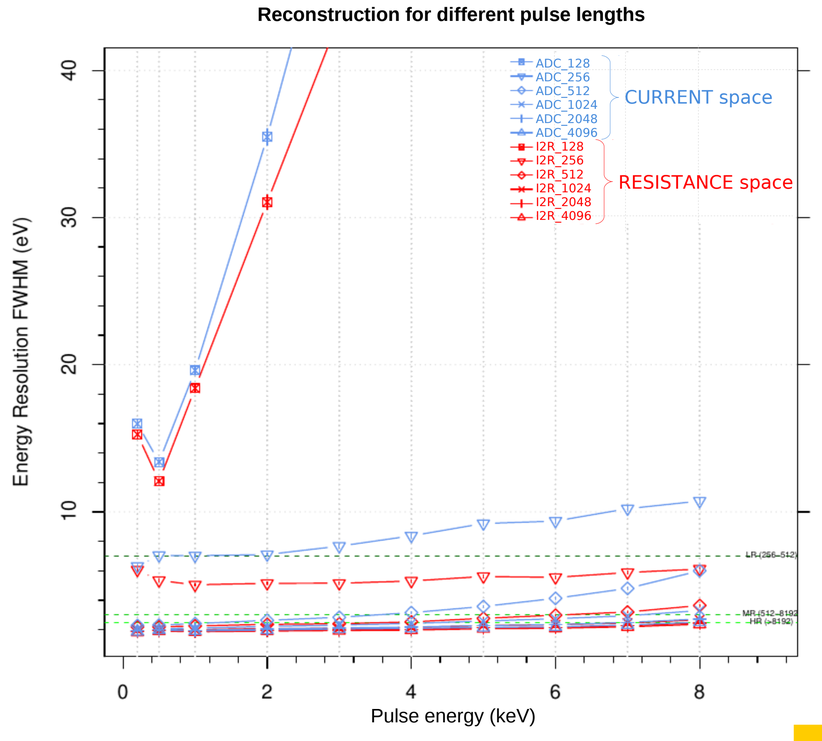
Short pulses reconstruction:

Energy resolution for optimal filter in the resistance space is slightly better than for optimal filter in the current space. However, when two pulses are close enough (being shorter than high resolution pulses) and short filters in current or resistance space must be used in their reconstruction, the energy resolution gets unaffordable values (X-IFU requirement 2.5eV@7keV).



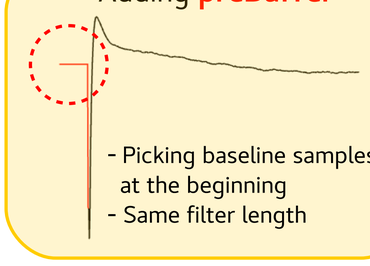
Sampling rate = 156.25 kHz
1 sample ↔ 6.4 μs





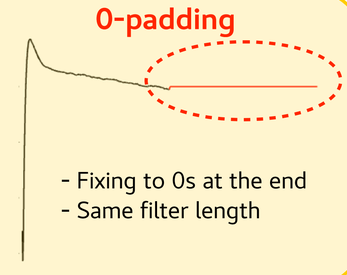
ALTERNATIVES TO STANDARD OPTIMAL FILTER

Adding preBuffer

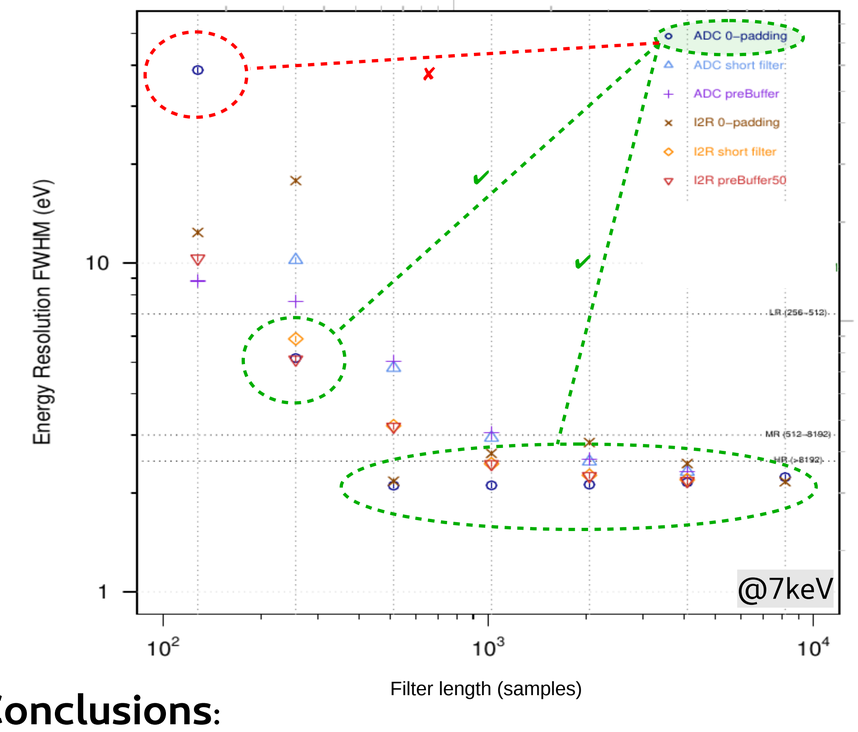


- Picking baseline samples at the beginning
- Same filter length

0-padding



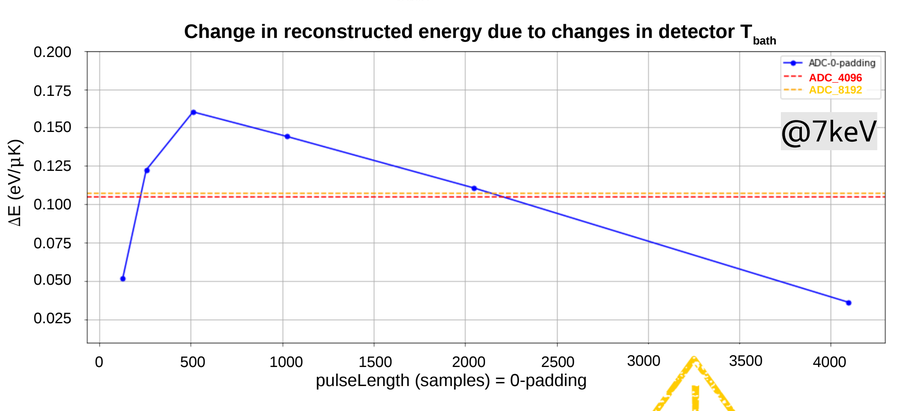
- Fixing to 0s at the end
- Same filter length



POSSIBLE 0-PADDING DISADVANTAGES

BASELINE SENSITIVITY

Standard optimal filter is sensitive to the change in the pulse shape. 0-padding could be sensitive to changes in the pulse shape and in the baseline level (due to variations of the TES detector T_{bath}).



Requirement: < 0.15 eV/μK

Conclusions:

1) Best option with pulses ⩾ 256 samples (High, Medium and Limited resolution) ⟹ 0-padding
2) 0-padding option could provide a reduction of the computational resources needs to get high energy resolutions, changing the 8192-samples length filters (High resolution) to 1024-samples length 0-padding filters
3) More analysis of 0-padding required; how to proceed with shortest pulses still pending

Data simulated using SIXTE simulator [6]

References:
[1] Barret D. et al, 2018, SPIE 2018 Conference Proceedings, 10699
[2] Ravera L. et al. 2018, SPIE 2018 Conference Proceedings, 10699
[3] Cobo B. et al. 2018, SPIE 2018 Conference Proceedings, 10699
[4] Szymkowiak, R.L., 1993, JLTP, 93,281
[5] Boyce K. et al. 1999, Proc. SPIE 3765
[6] Dauser T. et al. 2019, A&A, 630, A66

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