# ATHENA X-IFU event reconstruction: arrival time correction

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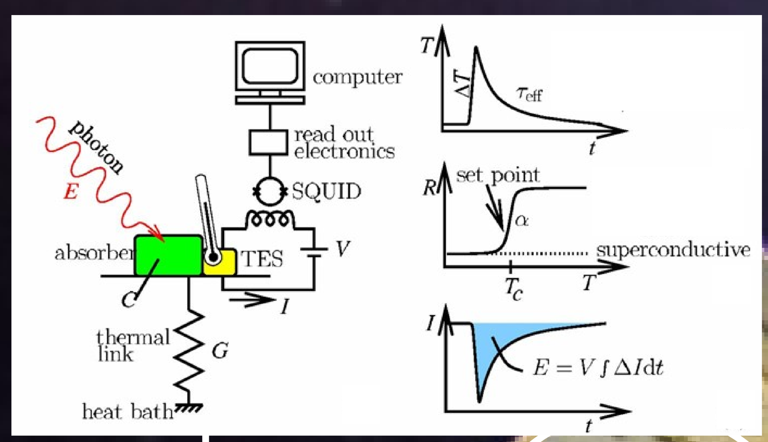
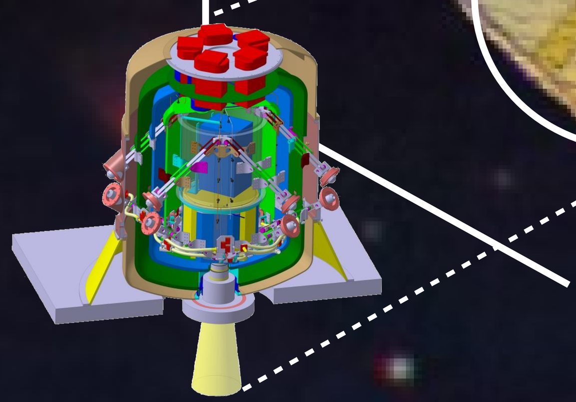
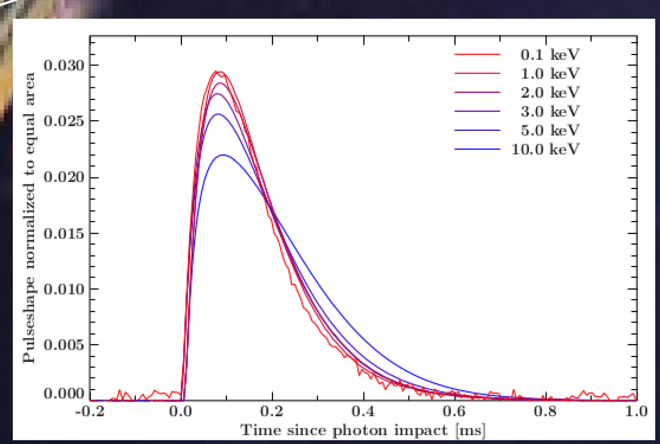
ADASS XXVIII

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, fine tuning in the arrival time estimation is required especially for the lowest sampling rates being considered.



X-ray Integral Field Unit [1]




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

SIRENA

**Pulse detection**
Triggering algorithm
STC [4]

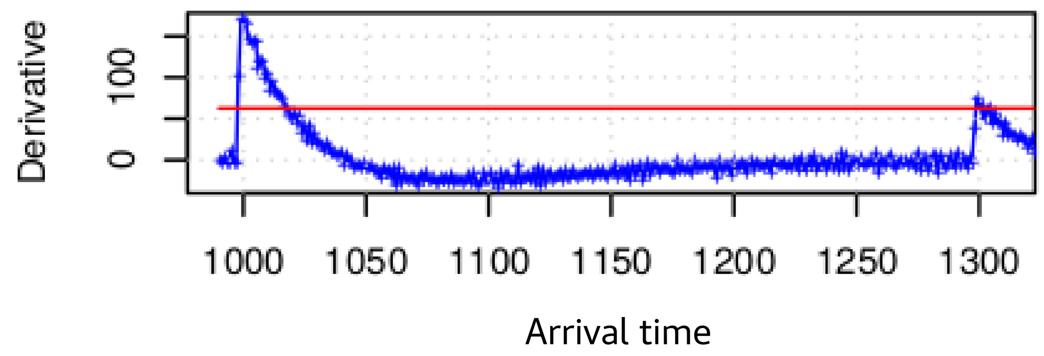
**Event Reconstruction**
(Energy & Energy resolution Determination)
OPTIMAL FILTER [7]

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

## Baseline definition for on-board data processing

(http://sirena.readthedocs.io)

Single Threshold Crossing [3] + Optimal Filtering (Resistance Space) [4,5]




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

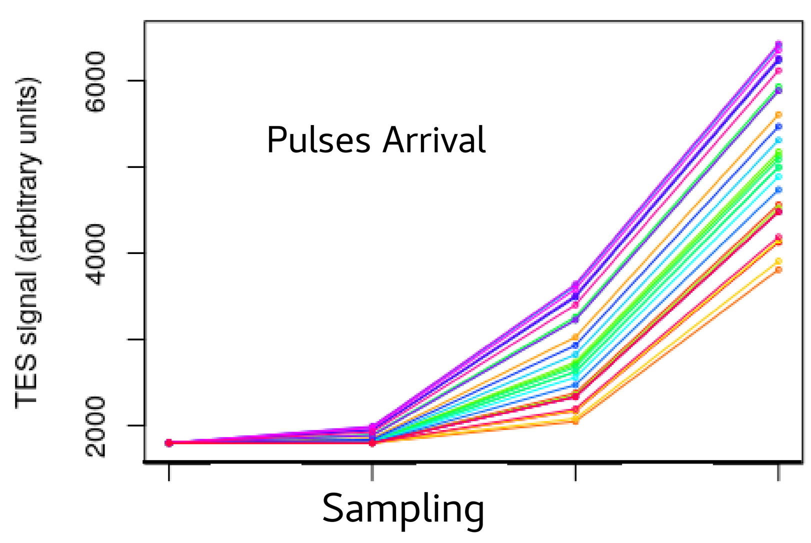
$$\text{Minimize} \quad \chi^2 = \sum \frac{[D(f) - H \times Model(f)]^2}{NOISE^2(f)}$$

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

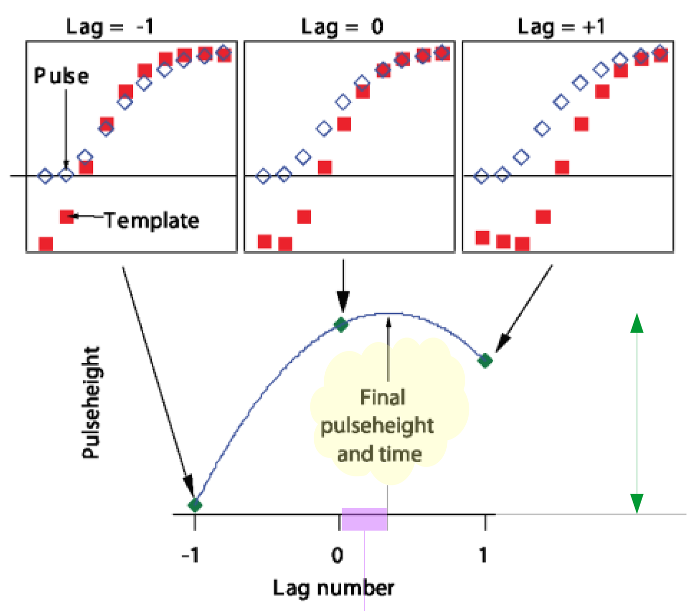
## Arrival Time correction:

STC algorithm establishes a Trigger Time (detection of the pulse) where the derivative of the signal crosses a pre-established threshold. Non perfect sampling of pulse rising edges causes random offset between the (real) arrival time and (STC) trigger time. Some initial correction can be done to better estimate the arrival time, but the offset affects the reconstructed (with the Optimal Filtering algorithm) energies, broadening the energy resolution to levels above the 2.5eV@7keV X-IFU requirement. An additional correction is needed.

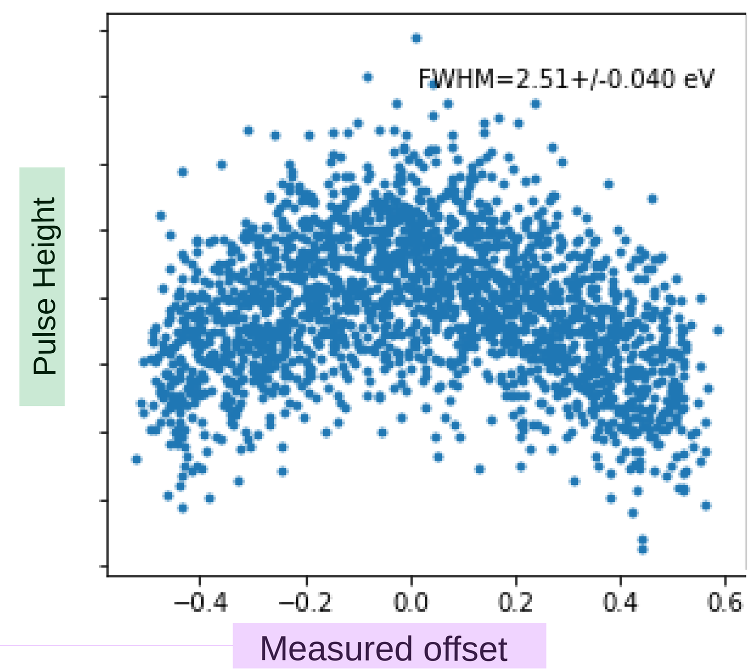
Pulses arrival not in phase with sampling




**First correction**: data & model alignment [6]



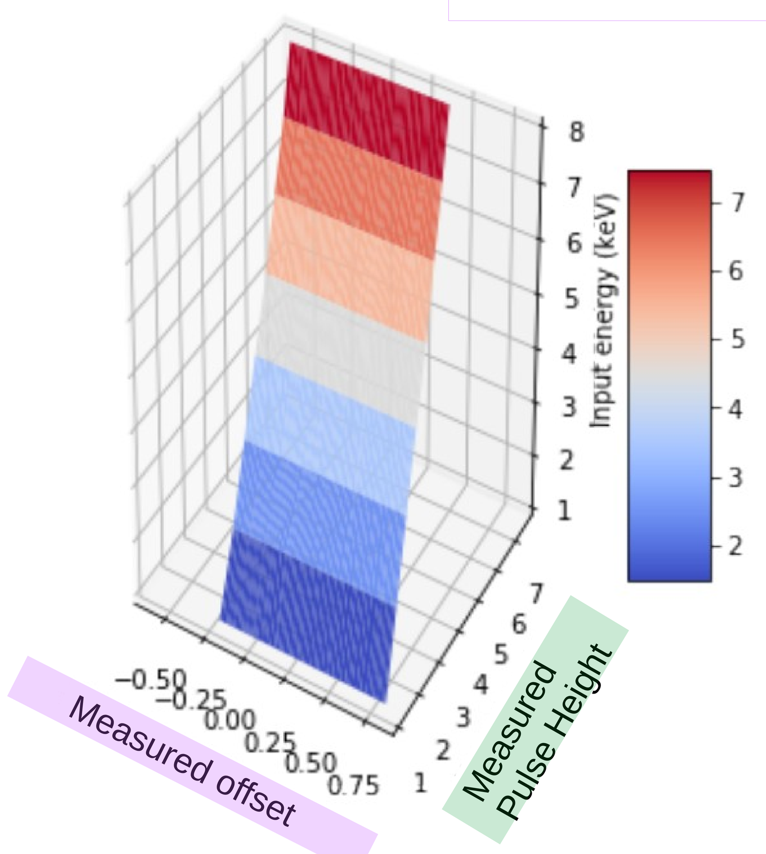

Estimated Pulse Height correlation with time offset

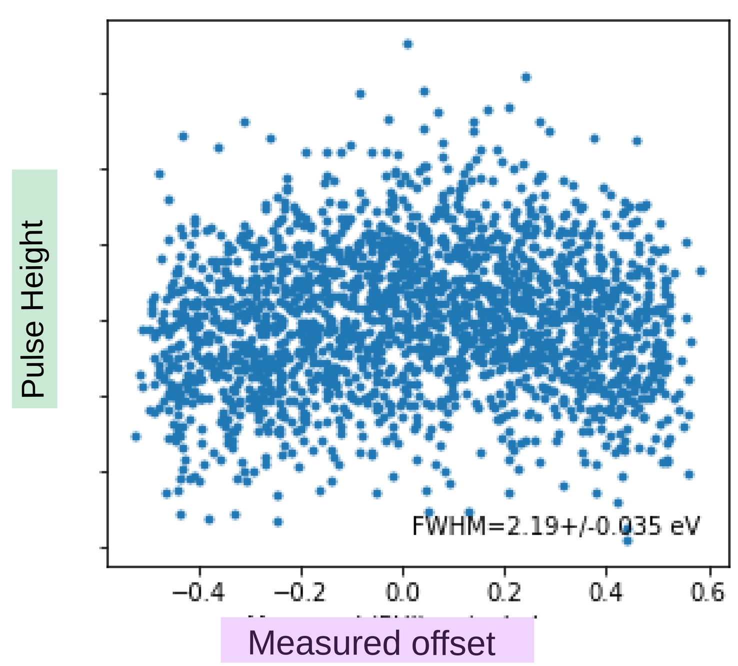



**Second correction**: using pulses of various offsets and energies (from the *xifusim* X-IFU simulator), fit a 2D polynomial gain function (6x6) to their reconstructed pulse heights and offsets f(PH, offset)

Then, when a pulse is reconstructed:

Energy = f(PulseHeight, Offset)




### Conclusion:

1) Effect is less important for nominal sampling rate (156.25kHz) but it is relevant for lower values of the sampling rate being considered in the instrument design (half or one quarter of nominal)
2) Polynomial fit does not fully correct the effect, leaving a residual dependence of the reconstructed energy with the arrival offset. Other additional corrections are being studied.[7]

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] Adams J.S. et al. 2009, LTD13, 1185,274
[7] Fowler J.W. et al., LTD16 proceedings

**Acknowledgments:** *This work has been funded by the Spanish Ministry MINECO under project ESP2016-76683-C3-1-R, co-funded by FEDER funds.*