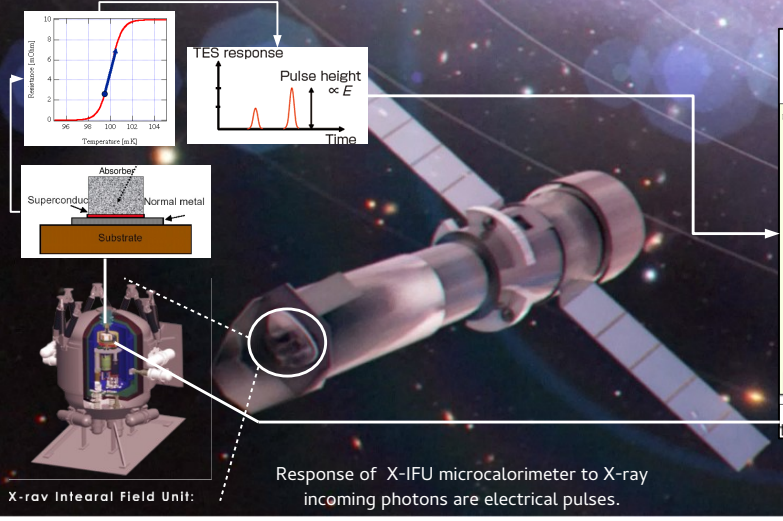
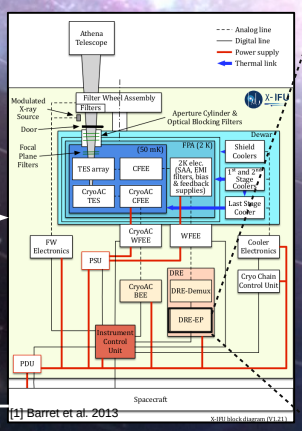
Athena X-IFU event reconstruction software: SIRENA

M.T.Ceballos[1], B. Cobo[1], P.Peille[2], J.Wilms[3] , T.Brand[3], T.Dauser[3], S.Bandler[4], S.Smith[4]
[1]IFCA, Spain; [2]IRAP, France; [3]Remeis Observatory & ECAP, Germany; [4]GSFC, USA

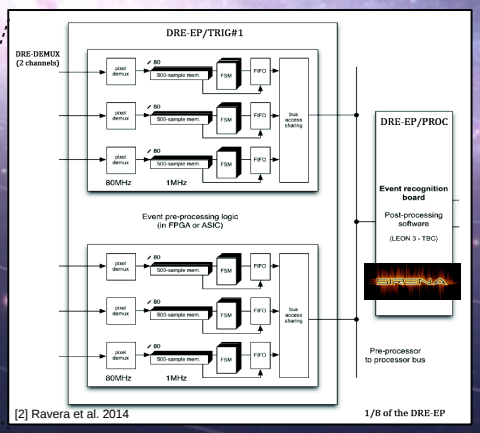
SIRENA is the software aimed at performing the on board event energy reconstruction for the *Athena* calorimeter X-IFU. This on board processing will be done in the X-IFU Digital Readout Electronics (DRE) unit and it will consist in an initial triggering of event pulses followed by an analysis (with the SIRENA package) to determine the energy content of such events.



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



[1] Barret et al. 2013



[2] Ravera et al. 2014 1/8 of the DRE-EP

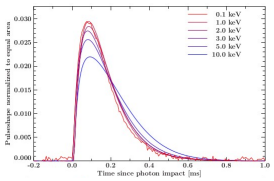
Pulses must be detected (triggered) and then its energy must be reconstructed on board by the Event Processor in the Digital Readout Electronics Unit by the SIRENA software

Development under **SIXTE** (P12.14) environment for end-to-end simulations

http://www.sternwarte.uni-erlangen.de/research/sixte/index.php

Simulation of X-IFU TES physics (tool: **tessim**)

Numerical solution of differential equations for T (t) , I(t)[3]



SIRENA

Triggering algorithm for Pulse detection (to be integrated in SIXTE) [4]

Event Reconstruction (Energy & Energy resolution determination by Opt. Filt., Covar. Mat, etc.)

RECONSTRUCTION METHODS (work in progress)

Optimal Filtering [5,6]

✗ Pulses are scaled versions of a single shape: Response of detector is linear (or energy-dependent filter interpolation)
✗ Noise is stationary

$$Data \quad D(t)=H\times S(t)$$
$$Minimize \quad \chi^2=\sum \frac{[D(f)-H\times S(f)]^2}{NOISE^2(f)}$$
$$H=k\sum D(t)\,OptFil(t)$$

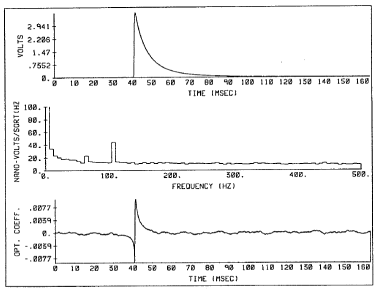
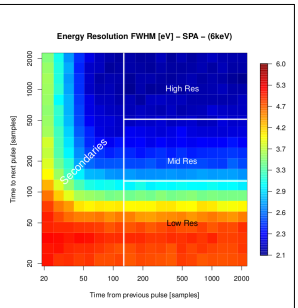


Fig. 1 Plots showing (top to bottom) average pulse shape, power spectrum of the noise, and the optimal filtering template.



Energy resolution map for 6 keV and one of the X-IFU configurations in study (see **P12.10**) done with SIRENA + OptFilt. Note: SIXTE simulated data. Optimal filter to the exact input energy (from simulations) has been used.

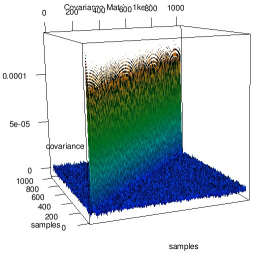
Covariance Matrices [7,8]

Least squares optimal filter varying with photon energy. Accounts for noise non-stationarity & detector non-linearity

Calibration:
- Densely spaced narrow lines for calibration
- Model template (M) + covariance matrix (deviations from model) + weight matrix (W) (inverse of covariance matrix)

$$Minimize \quad \chi^2=(Data-M)\,W\,(Data-M)$$
$$Energy=f(E_\alpha,E_\beta,U,M_\alpha,M_\beta,W_\alpha,W_\beta)$$

α,β: calibration points that straddle the unknown signal U

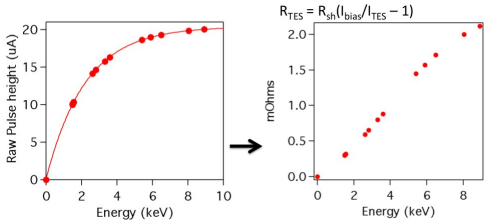


Resistance Space [9]

Optimal Filter after transforming signal I_{TES} to R_{TES}:
✓ Removes nonlinearity due to the bias circuit

PCA [10,11,12]

Others?...



References:
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