Data Flow design for event detection and qualification in TES x-ray detectors

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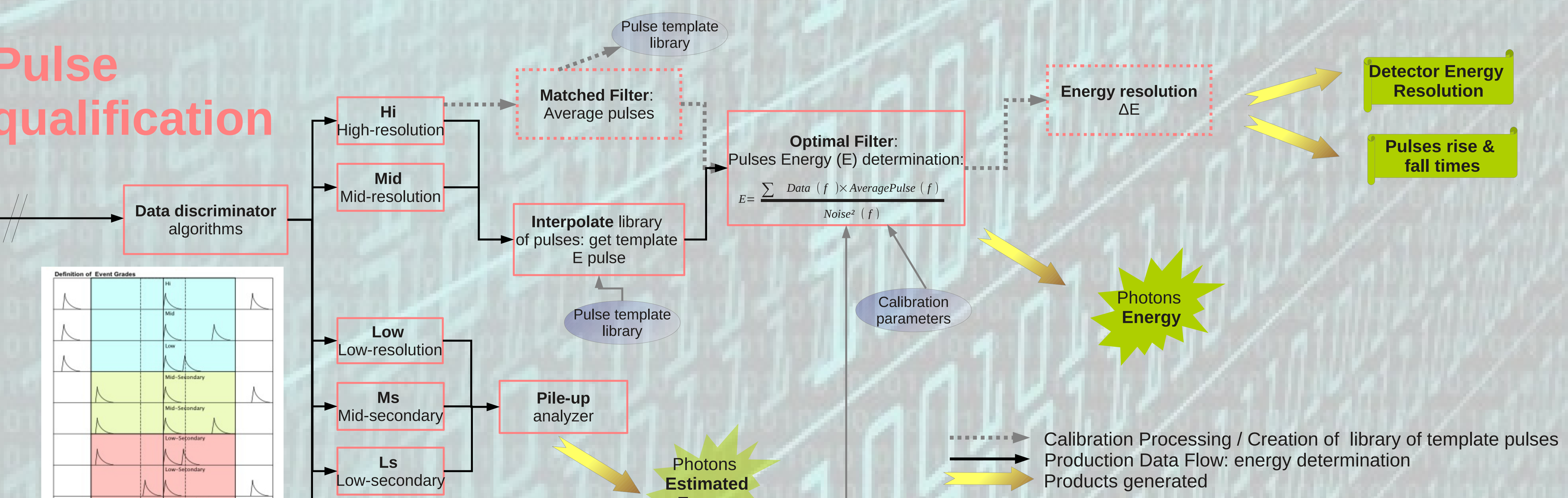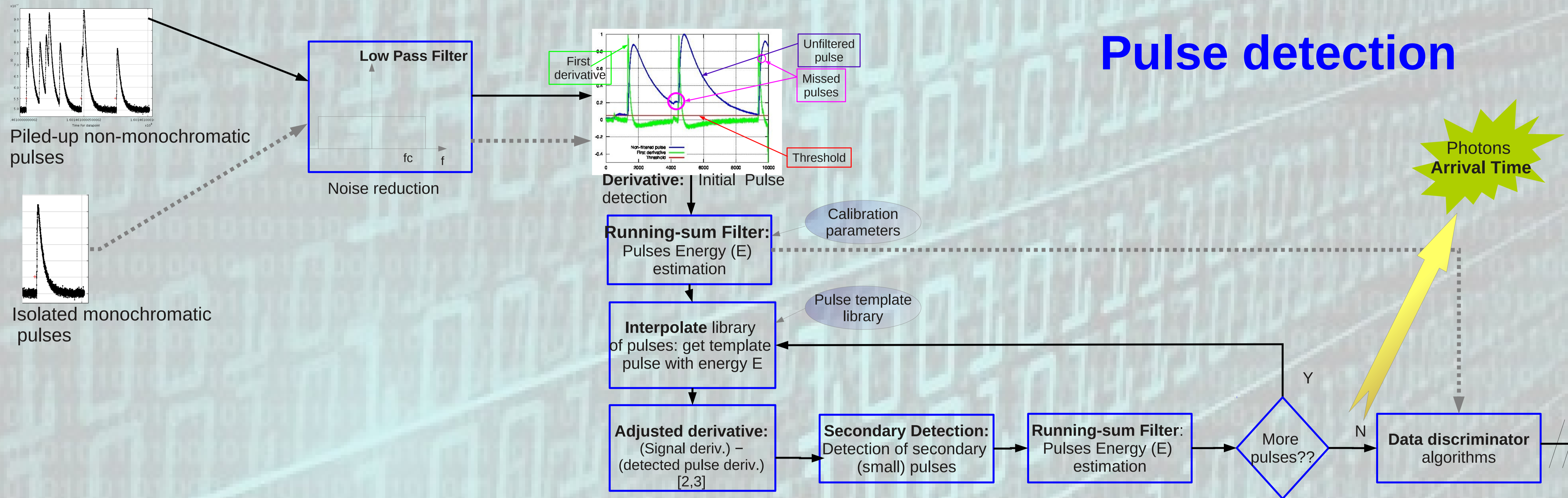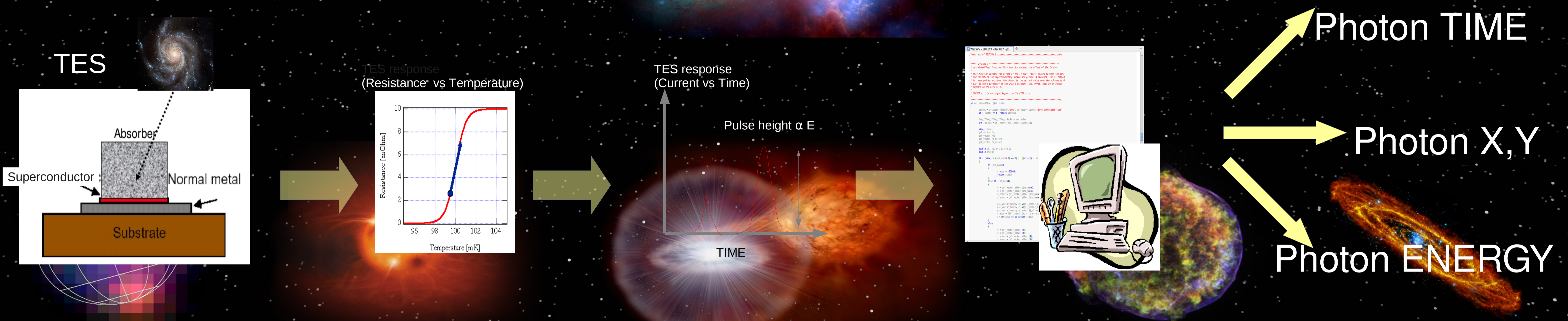
New Astronomy: The current and forthcoming research lines in X-ray astronomy (black holes, accretion physics, hot cosmic plasmas, large bound structures) will require unprecedented spectral resolution with imaging capabilities.
New Detectors: The most promising detectors able to provide these capabilities are the calorimeters based on Transition Edge Sensor (**TES**) technologies, like the one that has been under development for the proposed ATHENA x-ray space mission.
New processing: These new detectors require a different approach for the event detection: they must detect the electrical pulses that are the response to an abrupt change in resistance in the device, caused by the absorption of an X-ray photon.
Let's see how to process this...!

TES

TES response
(Resistance vs Temperature)

TES response
(Current vs Time)

Pulse height α E

Photon TIME

Photon X,Y

Photon ENERGY

Pulse detection

Piled-up non-monochromatic pulses

Low Pass Filter

Noise reduction

Isolated monochromatic pulses

First derivative

Unfiltered pulse

Missed pulses

Threshold

Derivative: Initial Pulse detection

Calibration parameters

Running-sum Filter: Pulses Energy (E) estimation

Pulse template library

Interpolate library of pulses: get template pulse with energy E

Adjusted derivative: (Signal deriv.) − (detected pulse deriv.) [2,3]

Secondary Detection: Detection of secondary (small) pulses

Running-sum Filter: Pulses Energy (E) estimation

More pulses?? — Y

N — **Data discriminator** algorithms

Photons **Arrival Time**

Pulse qualification

Pulse template library

Data discriminator algorithms

Definition of Event Grades

Hi High-resolution

Mid Mid-resolution

Matched Filter: Average pulses

Interpolate library of pulses: get template E pulse

Pulse template library

Optimal Filter: Pulses Energy (E) determination:

$$E = \frac{\sum Data\,(f) \times AveragePulse\,(f)}{Noise^2\,(f)}$$

Calibration parameters

Energy resolution ΔE

Detector Energy Resolution

Pulses rise & fall times

Photons **Energy**

Low Low-resolution

Ms Mid-secondary

Ls Low-secondary

Pile-up analyzer

Photons **Estimated Energy**

Empty events for baseline

Noise spectrum

············> Calibration Processing / Creation of library of template pulses
———————> Production Data Flow: energy determination
⇒ Products generated

References & Acknowledgements

[1] Ceballos M.T. et al. 2011, ASP Conference Series, Vol 442, 335
[2] Ceballos M.T. et al. 2012, ASP Conference Series, Vol 461, 777
[3] Boyce K et al. 1999, Proc. SPIE 3765
[4] Background image credit: CSIC for ATHENA mission