# calpnalgo

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**Abstract**

Library of dedicated calibration algorithms for EPIC PN

# 1 Instruments/Modes

| Instrument | Mode |
|---|---|
| EPIC PN | IMAGING, TIMING, BURST |

# 2 Use

| | |
|---|---|
| pipeline processing | n.a. |
| interactive analysis | n.a. |

# 3 Description

## 3.1 General

This package is only called via the CAL and has no interface to the user.

## 3.2 CTI correction

In CCDs part of the charge released by an absorbed photon is lost during transfer to the readout node. This loss depends on several parameters, in particular on the position where the photon was detected, its energy, the temperature of the CCD, and the saturation of traps by charges preceding along the readout direction. In order to determine how these parameters affect the charge loss of the pn-CCD cameras, more than three billion events were recorded in extensive sets of calibration measurements from February 1998 to January 1999.

For deriving the CTI, each CCD column was split into macro pixels, which were determined by adaptive binning to contain a sufficient number of first singles around the line feature. The charge losses were then obtained, column by column, by cross-correlating a spectral template accumulated from all first singles of a column with spectra from the macro pixels of the same column, to yield a first estimate of the energy shifts. This value was then used to improve the template and the cross-correlation was repeated until convergence was achieved.

In order to obtain a general CTI correction code, a model based on the capture and emission process of electrons in deep level traps was developed. This model, described in detail in [**?**], considers the dependence of the CTI on energy and temperature, and takes the effect of precursors and the presence of noisy pixels into account. It was calibrated with the spatially resolved charge losses obtained with the technique described above, and makes it possible to calibrate not only the spectral response of each pixel, but also the mutual influence of pixels along the same CCD readout column.

### 3.3 Gain correction

In the pn-CCD, 768 individual amplifiers allow fast readout, but imply different gains for the different readout channels which all have to be determined and corrected for. The gains of the 768 readout nodes were derived by comparing the position of CTI corrected calibration lines (in adu) with their known energy. Since all gain values were found to be close to 5 adu, they were normalized to yield the constant conversion factor 1 adu = 5.00 eV at the nominal temperature, independent of energy, for $E > 3\,\mathrm{keV}$.

More details on the CTI and gain correction can be found in [**?**].

### 3.4 Response matrix

The model which is used to describe the energy response of the pn-CCD is the so-called partial event model (see [**?**]). The model accounts for the effects of incomplete charge collection close to the detector surface. An efficiency function CCE is defined that reflects the portion of charge collected if a photon is absorbed in a certain depth. This function is folded with the probability of absorption in that depth which is given by the absorption law. The resulting analytical function for the spectral shape is then folded with the Gaussian noise distribution given by the Fano noise and the system noise (electronic and transfer noise).

Different processes are responsible for different spectral features that are visible in the detected channel distribution of infalling monochromatic X-rays. Absorption in the oxide causes detection of very few electrons, resulting in a flat shelf that extends down to the detector noise peak. If the photon is absorbed in the silicon, but close to the silicon surface, only a part of the generated electrons will reach the readout node, causing a shoulder at the low-energy side of the main peak. The variation of this portion with absorption depth is described by the CCE. If the absorption takes place deep in the detector all generated electrons will be detected. The relative strength of the flat shelf, shoulder and main peak is dependent on energy.

Monochromatic synchrotron radiation at 15 different energies ranging from 0.150 keV to 15 keV was used to calibrate the energy response of the pn-CCD detector. The resulting channel spectra were fit with the partial event model and the model parameters derived as function of energy. The detector response matrix is then filled using the partial event model with the parameters derived from the ground calibrations.

## 4 Errors

This section documents warnings and errors generated by this task (if any). Note that warnings and errors can also be generated in the SAS infrastructure libraries, in which case they would not be documented here. Refer to the index of all errors and warnings available in the HTML version of the SAS documentation.

none issued by this package

# 5 Input Files

# 6 Output Files

# 7 Algorithm

```
subroutine calpnalgo
  ...
end subroutine  calpnalgo
```

# 8 Comments

# 9 Future developments

# References