# XMM-Newton CCF Release Note

## XMM-CCF-REL-265

## RAWY-dependent calibration of the PATTERN fraction in EPIC-pn Timing Mode

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# 1 CCF components

| Name of CCF | VALDATE | List of Blocks changed | Change in CAL HB |
|---|---|---|---|
| EPN_QUANTUMEFF_0017 | 2000-01-01T00:00:00 | FRACTION_CHANNEL | NO |

# 2 Changes

We have recalibrated the PATTERN fraction in EPIC-pn Timing Mode taking into account the significantly larger database of exposures available in the science archive (XSA). This allows us to perform a novel analysis of the PATTERN fraction dependency on the position of the source in the detector ("`RAWY`-dependence" hereafter). The new CCF explicitly includes this dependency. Moreover, and for the first time, the fraction of triples and quadruples events in EPIC-pn Timing Mode has been calculated.

The main driver for the change is summarised in Fig. 1, which shows the fraction of single events as a function of PI channel energy for different `RAWY` values. This plot makes use of all the 217 exposures in EPIC-pn Timing Mode for which data were available in the XSA as of January 1, 2010. We have, however, conservatively removed all exposures where the total count rate exceeds $400s^{-1}$ to avoid photon pile-up. The comparison with the function implemented in `EPN_QUANTUMEFF_0016` shows that the current calibration does not match well any of these curves, although it lays in between the `RAWY=190` and `RAWY=191` experimental curves.

Each of empirical distributions of singles, doubles, triples, and quadruples events for each of the `RAWY` values specified above was independently fit with a parabolic logarithmic function:

$$F = A + B \times \log(E_{PI}) + C \times \log(E_{PI})^2$$

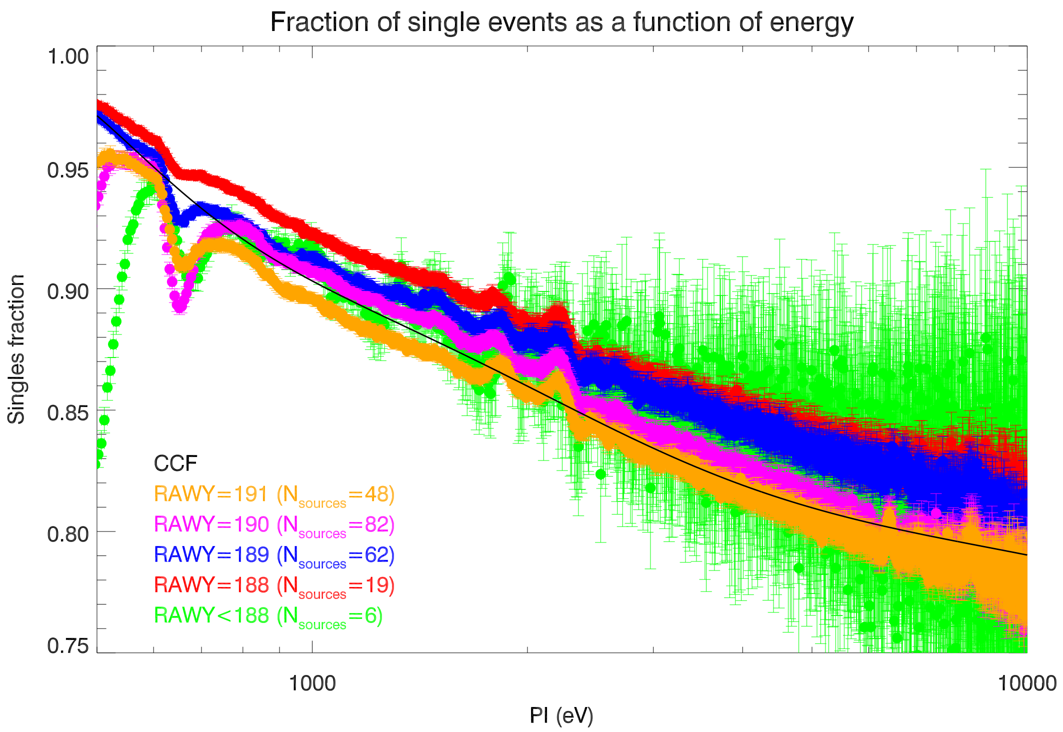


Figure 1: Fraction of single events (over the total number of events) as a function of PI channel energy for different values of the `RAWY` source position. The *black solid line* represents the function implemented in CCF `EPN_QUANTUMEFF_0016`.

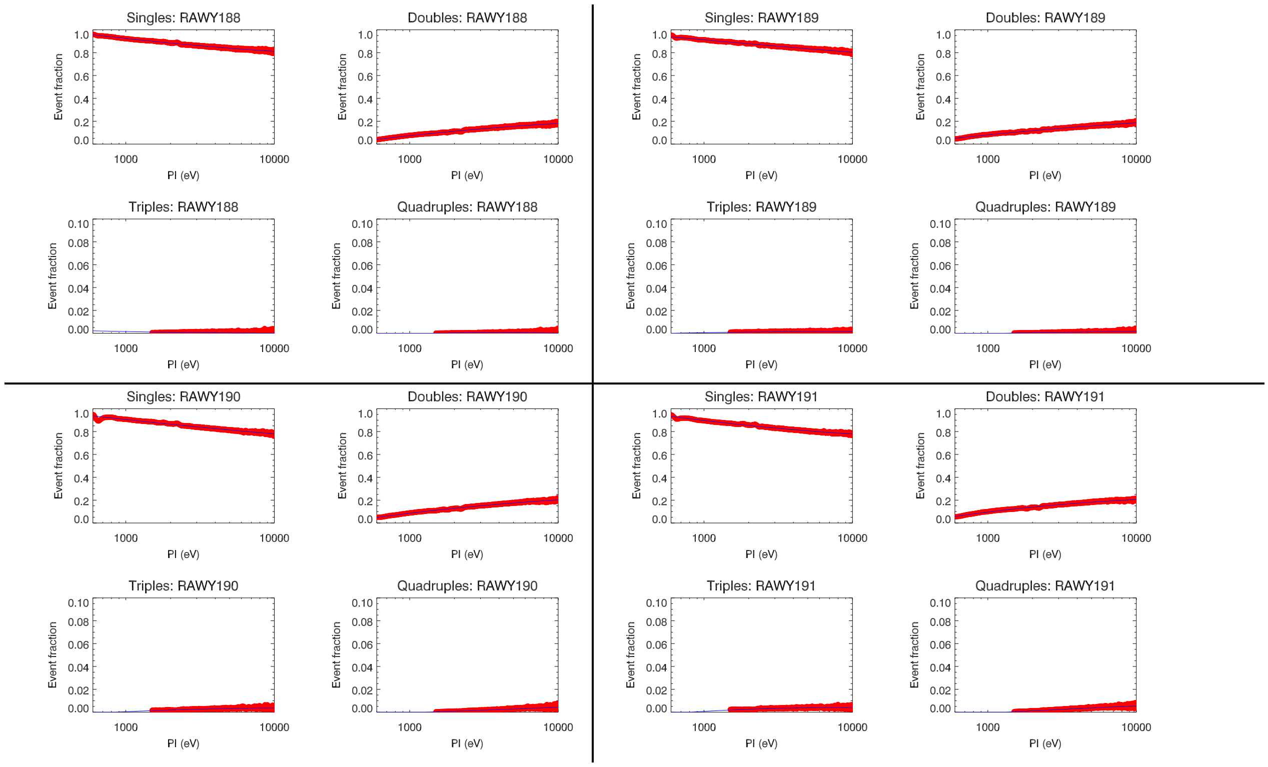


Figure 2: Fraction of singles, doubles, triples and quadruples events as function of energy for different position of the source on the detector. The four quadrants in this plot contains refer to, from *top left* to *bottom right clockwise*: `RAWY=188`, `RAWY=189`, `RAWY=190`, `RAWY=191`, respectively. The *solid lines* are the best fits.

where $F$ is the event fraction and $A$, $B$, and $C$ are fitting parameters. The whole exposure sample has been divided in five sub-sets, corresponding to `RAWY=191` (48 exposures; it includes also one exposure with `RAWY=193`), `RAWY=190` (82 exposures), `RAWY=189` (62 exposures), `RAWY=188` (19 exposures), and `RAWY<188` (labelled `RAW_small`; 6 exposures). The value of `RAWY` was extracted from the event list header. The fits were performed in the 0.7–10 keV energy range, to avoid low-energy electronic noise which distorts the pattern fraction distribution. Such a restriction does not have any impact on the scientific quality of this update, because users are recommended to analyse EPIC-pn spectra in Timing Mode in this energy range. The corresponding distributions as a function of energy, together with the best-fit curves are shown in Fig. 2.

## 3 Estimated scientific quality

SAS response generators `arfgen` and `rmfgen` use only the combination of singles+doubles events. Since the main impact of this recalibration is a change of the relative fraction of single and double events, with the additional determination of the $< 1\%$ fraction of triples and quadruples, the impact on the spectral quality is expected to be negligible. Nonetheless, this recalibration could be crucial if at some point in the future spectra of single events only will be calibrated. Moreover, the response generator must be able to read the source position (keyword `SRCPOS`) in the header of an event list

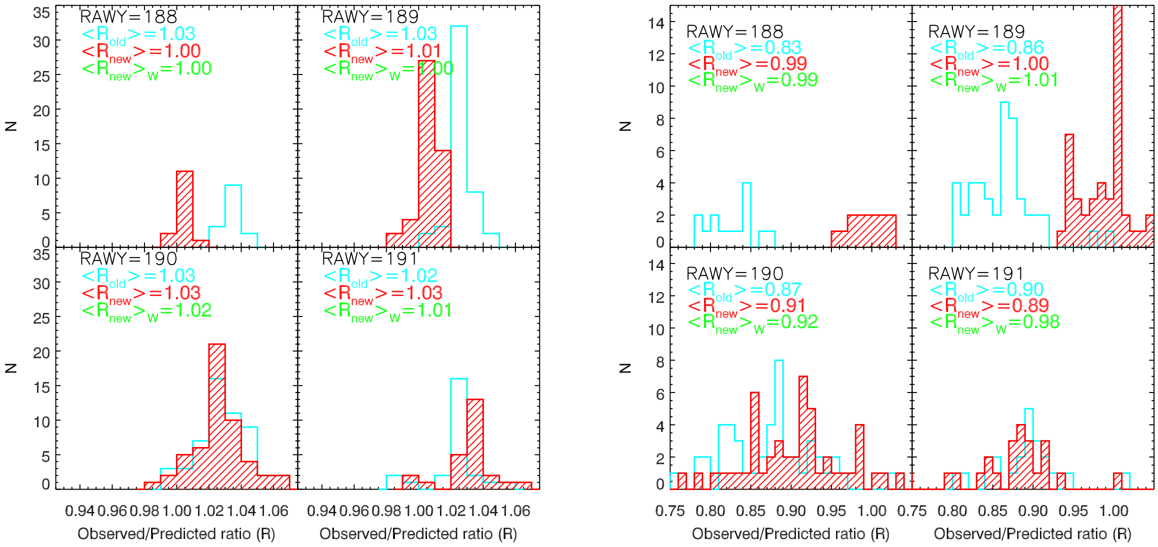


Figure 3: Histograms of the ratios between the observed and the `epatplot`-produced predicted singles (*left*) and doubles (*right*) fractions in the 1–10 keV energy band. This figure is based on SASv9.0. The numbers indicate the mean with the 0016 (*blue*) and 0017 (*red*) CCF, and the weighted mean with 0017 (*green*), where the weigth was defined as the number of counts in each observation.

or spectral file) to apply the correct pattern fraction. If a decision is taken to implement it, this functionality will be supported in SAS versions later than 10.0 (May 2010).

On the other hand, this recalibration makes the usage of `epatplot` as a pile-up estimator in EPIC-pn Timing Mode much more robust and reliable. The systematic offset between predicted and observed PATTERN distributions present with previous versions of this CCF almost entirely disappear if `EPN_QUANTUMEFF_0017` is used (cf. Sect. 4).

## 4 Test procedure and results

We have reduced the whole sample of 217 EPIC-pn Timing Mode exposures with SASv9.0 and the `EPN_QUANTUMEFF_0017` CCF, and compared the predicted 1–10 keV PATTERN fraction calculated by `epatplot` to the observed ones. The improvement in the agreement is almost always significant (Fig. 3). However, for `RAWY=191` the mean of the distributions show a marginal worsening of the agreement between predictions and data.

### 4.1 Dependency of the PATTERN fraction on the count rate

This unexpected behaviour has been traced to be due to a newly discovered energy-dependent dependency of the PATTERN fraction on count rate for `RAWY=191` and, less strongly, `RAWY=190`

(Fig. 4). Similar trends are observed in the triple- (Fig. 5; *left panel*) and quadruple-to-singles ratios, whereas an opposite trend is seen in the unrecognised-to-singles (Fig. 5; *right panel*) ratio. The origin of this phenomenon is still unknown. Once the mean of the observed versus predicted fraction ratio is weighted in the number of total counts in each observation (just one of the many possible weights that human ingenuity could conceive), the agreement improves significantly.

## 5 Expected Updates

Once the origin of the pattern-fraction dependency on count rate for large `RAWY` is understood, a possible update of the CCF (and associated CAL) may be envisaged. Otherwise, this CCF will be updated as soon as a significant enlargement of the EPIC-pn Timing Mode exposure sample is achieved.

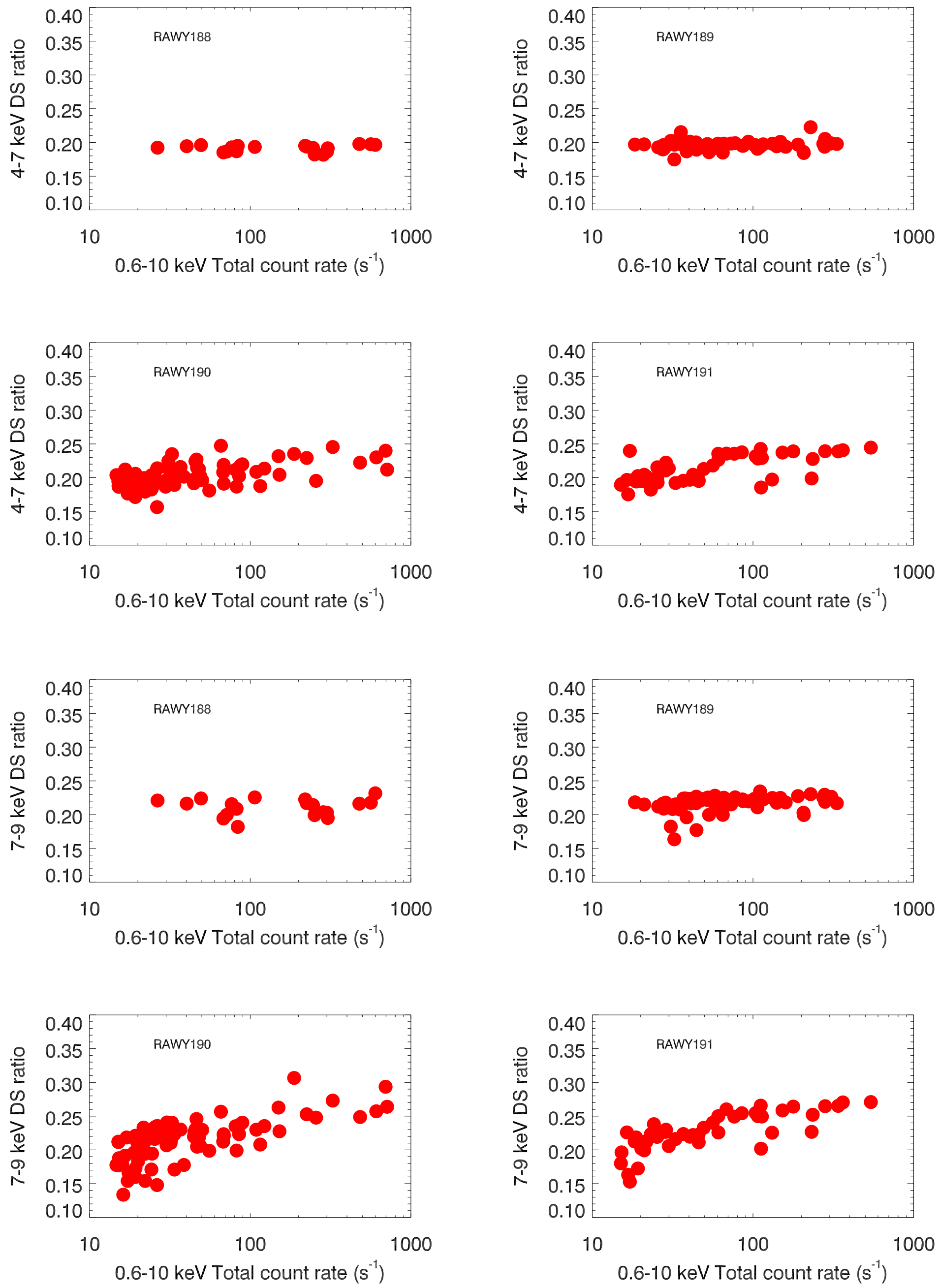


Figure 4: 4–7 keV (*upper panels*) and 7–9 keV (*lower panels*) double-to-single event ratio as a function of the total 0.6–10 keV count rate for different positions of the source on the detector.

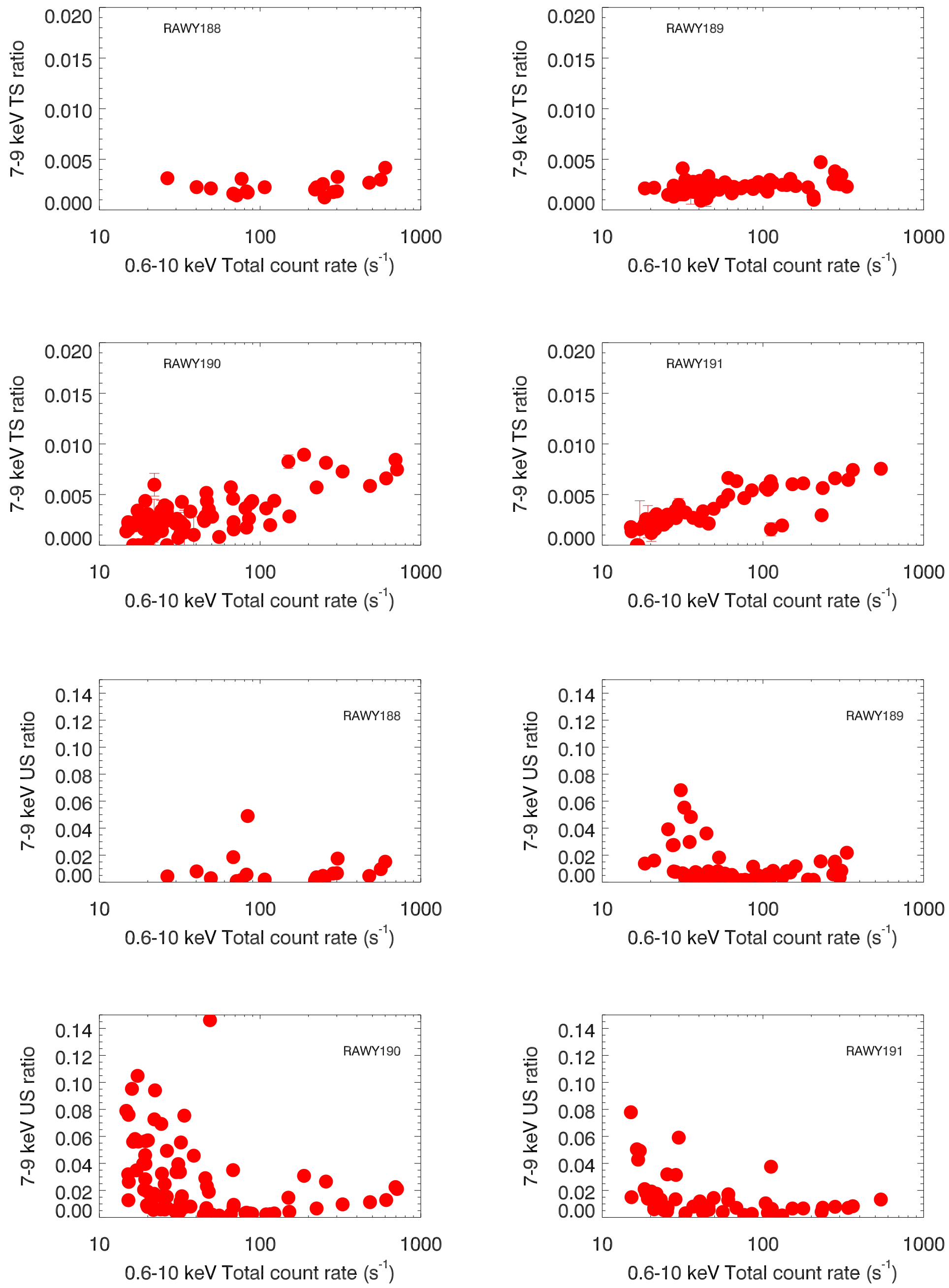


Figure 5: Triple-to-single (*upper panels*) and unrecognised-to-singles (*lower panels*) event ratios as a function of the total 0.6–10 keV count rate for different positions of the source on the detector.